Trend Report 2005

RFID – Leveraging Global Commerce
With Tracking & Tracing Technologies

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Trend Report 2005: RFID – Leveraging Global Commerce With Tracking & Tracing Technologies
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Preface

Emerging tracking & tracing and ubiquitous computing technologies, most notably RFID, promise to change today's business and society in various ways. These new technologies hold powerful potentials to boost process efficiency in logistics, security, health and many other areas by reducing errors and counterfeiting, superseding media breaks and accelerating processing speed, going far beyond the boundaries of existing barcode based applications. The gap between the real world of physical objects and the virtual information space is more and more diminished, the flow of goods and the flow of data approach parallelism, enabling companies to get a more precise view of their internal assets to better control and manage their processes. The connection between a physical good and its manufacturer through the whole product life cycle enables enterprises to sell interlocked services and solutions, increase customer lock in and follow new business models. Value added services provide vast benefits for consumers and make life easier and more secure. The standardization of product related data facilitates the exchange of information between companies all along the supply chain.

This trend report shows the work and visions of 20 students of the Class of 2007 of the Center for Digital Technology and Management. Their work represents a starting point in understanding where tracking and tracing is today and where students envision its further development. The book is split into two parts: Part one presents six research reports looking at the state of the art of tracking and tracing technologies from several perspectives. First, you will find an outline about the social and legal framework, followed by an overview of the current RFID market and existing applications. Then the technical aspects are described, starting from ERP applications over the EPCGlobal standard to hardware aspects.

Part two is visionary. Five student teams present tracking and tracing applications that in their opinion will reshape the future. RFID will impact the flow of goods and data in the smart supply chain and change manufacturing processes in the factory of the future. The discussion around RFID certainly leads to privacy questions but also raises the question what's in for the consumer. The next team envisions the application of smart RFID road signs for more efficient and safe traffic. The chapter ends with a discussion how public safety can be improved by using RFID.

Please enjoy reading this interesting booklet, maybe some ideas will inspire you to future activities in the field of tracking & tracing.

Dietrich Schmitt — Munich, February 2006
Vice President and Managing Director Germany

Howard Barrett
Vice President and Managing Partner
Global Commercial Industries UKEMEIA

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PART I:

Research Report

Social and Legal Framework

Laura Dietze and Rebecca Ermecke

1 Introduction

In current discussions RFID is often seen as a risk in the fields of health, ecology and above all privacy. In the following, some commonly feared scenarios are listed. They are then examined concerning their credibility and possible solutions are indicated. The second part deals with standardization and regulation issues arising with the introduction of RFID.

After discussing the importance of industry standards on product development, a closer look on the currently existing standards will take place. Then, these standards will be evaluated and their estimated future impact discussed. Furthermore, other regulations affecting RFID will be presented.

2 Barriers and Implications on Society

2.1 Introduction

Although RFID is not a new technology -the first publication dates back to 1948- it is only recently, that the public really gets aware of it (Fleisch and Thiesse 2005, p. 3). With prices of tags decreasing, more and more applications seem feasible and visions of a world emerge where every single item is RFID tagged. In this context the question arises how this is going to affect peoples' day to day life and the subsequent barriers and implications on society.

2.2 Positive Implications

First of all, there are certain positive effects for consumers. By using RFID, companies expect significant cuts of costs which will possibly result in cheaper products. Moreover, RFID technology allows to introduce better service, also in the after-sales field. Tagging high-prize items could facilitate warranty tracking and the realization of recalls (Sheffi 2004, p. 8). Theft prevention could be carried out more effectively and in general the tracking and tracing of products along the supply chain could lead to more security. For example RFID could help to prevent drug counterfeiting, which is quite significant, considering that about 30 % of drugs exported to third world countries are plagiarisms or even placebos (Schmid 2004, p. 6). In addition, RFID is likely to become directly part of the consumer's experience: personalized services and products, as well as mass customization, will make products more convenient.

Nevertheless, there is a vivid discussion about the possible risks the introduction of RFID brings about and the resulting implications on society.

2.3 Negative Implications

2.3.1 Privacy Issues

The debate about RFID has become quite emotional in the past few years. It is feared that the introduction of RFID will lead to massive privacy infringements.

The success of books such as Orwells "1984" or the film "enemy of the state" suggest that privacy invasion culminating in constant surveillance is a fear that is deeply rooted in the hearts of people.

First, one should have a look at what privacy is and why it is important. In 1890 Warren and Brandeis defined privacy as the "right to be left alone" related to the physical accessibility of a person (Bohn et al. 2003, p. 4 citing Warren & Brandeis 1890). Nowadays, the so-called "information privacy" gets into the focus, which Westin defined as "the claim of individuals […] to determine for themselves when, how, and to what extent information about them is communicated to others" (Bohn et al 2003, p. 4 citing Westin 1967).

The right of privacy is directly linked to freedom, which is a necessary basis of a democratic society (Bohn et al. 2003, p. 4).

Typical Fears

In current discussions about RFID the following problems concerning privacy are often mentioned.

An important issue is the violation of the so-called "location privacy". This involves the long-term tracking of individuals carrying RFID tagged items (Weis et al. 2004, p. 202). In a world with a pervasive infrastructure of networked readers it might be possible to scan people and to evaluate the current position of the items. If the data available on the tags, i. e. a product code, is linked to personal data, such as the name or payment data, it could be possible to monitor a person constantly.

This surveillance is suspected to be carried out secretly, as RFID tags are really small and there is no human sense detecting radio waves. This could be misused by companies, the government and also criminals. The latter might find it useful to scan people and their bags or even whole houses in order to decide what and whom to rob. The so-called promiscuousness of RFID tags describes the feature that interrogated tags reveal the information stored upon them to anyone (Fusaro 2004, p. 41).

When monitoring is realized by companies, surveillance can be divided in out-store and in-store monitoring. In the out-store area companies could obtain all sorts of data, knowing exactly how a person spends a day. When combined with sensors, RFID tags could gather a lot of sensitive and intimate data (Mattern 2003, p. 6). Concerning in-store measures, RFID widens the already existing possibilities of tracking people. Today there are cameras installed in most of the shops but it is quite an effort to collect relevant data for consumer profiles. This could then all be done automatically. Combining in-store and out-store collected data allows to create detailed consumer profiles and could lead to intrusive marketing going far beyond the bombardment of spam mails we are already used to. When entering stores one is greeted by name and ads will be directly aimed at one's -believed to be- individual needs (Fusaro 2004, p. 37).

Another common apprehension is that the introduction of RFID tags might lead to a violation of the principle of equality. Consumers could be separated into different classes corresponding to their income or purchasing power and thus receive more or less service in banks, shops etc. (Lace 2004, p. 4). Another criteria for social sorting might be the willingness of consumers to have their items tagged or to get them "killed" at the point of sale, with possible results for the service received or the enforcement of warranty claims (Privacy Rights Clearinghouse 2003, p. 6).

Credibility of Nightmare Scenarios

Given these fears and nightmare scenarios, it is important to examine whether these are actually justified and whether the level of surveillance is actually feasible. Moreover, one should consider the motivation of different groups concerning the collection and use of the data provided. If there is nobody interested in the data, it is unlikely that is going to be used against consumers.

Looking at the technical possibilities constant surveillance and positioning of people hardly seem to be feasible. Technical features depend on the type of RFID tags. In the following it will be assumed that there will be low-cost, passive tags used on consumer items. Passive tags do not have an own source of energy. They are "asleep" until passing close to a networked reader that provides them with energy of electromagnetic fields (Fusaro 2004, p. 40). The range of these tags is rather small and depends on various factors, low-frequency tags can be read from one foot (0,33 m) or less (RFID Journal FAQs, no.1).

To implement an accurate surveillance, a pervasive infrastructure of readers would be necessary, which does not seem to be realistic.

In order to track and monitor individuals, the data from the tag – usually product code – has to be linked with personal information. Although the tag tells its content to everyone, not everyone can use this information or relate it to a person. A lot will therefore depend on the security and access control of the relevant databases.

Sticking to the example of thieves scanning whole houses from the street, RFID journal states, that the power output had to be that high that popcorn stored in the house would start popping. Moreover, the thief would have to know which product code is linked to which object. It seems that it is still easier just to have a look into the windows of the respective house (RFID Journal FAQs, no.2).

It is also important to note that a secret surveillance can hardly be carried out since it is very easy to detect radio waves with suitable devices (Garfinkel 2002, p. 5).

Concerning the motivation of companies to track individuals it is useful to have a look at how companies used the data at hand in the past. The bar-code technology already allowed for evaluating the combination of products purchased and linking them to payment data obtained from credit cards. Apparently, this was no big deal in the past and the data obtained was not usually used against consumers. Customer cards seem to be more suitable to track consumer habits in detail but nobody is forced to have one.

Solutions

There are several approaches to how to solve the issues surrounding RFID and privacy:

Concerning technical aspects, encryption could be used to ensure privacy. However, the dissemination of RFID tags mostly depends on the costs of these tags. A critical line is set on 0.05 $ per piece right now. These tags have very limited capabilities of encryption (Weis et al. 2004, p. 204).

Another proposed solution is the so-called kill-command by which the tag is going to be deactivated after purchasing an item. A problem is that consumers cannot usually verify whether this deactivation has really been done. Most of the tags on consumer items, however, would be put on the packaging and could be disposed of, right after the purchase. Still, there remain concerns about in-store surveillance (Privacy Rights Clearinghouse 2003, p. 5).

Even with encryption and kill-commands, possibilities of gathering data and misusing it, still exist. It is therefore important to assure that companies deal with this data in an ethical way. The question is how this can be ensured.

In a free market environment consumers have the power to punish those companies which do not act accordingly by not buying any products anymore. So there is to some degree a regulation by the market itself which suggests a proper and ethical use of customer data.

To some extent, however, there have to be also regulation and legislation posed by governments, also on an international level. In the next section regulation issues will be discussed in more detail.

2.3.2 Health Issues

Another field of risks associated with RFID is health. When RFID tags are used near or on food it has to be assured that they are not accidentally eaten. It is commonly feared that the “bombardment with electromagnetic energy”[1] Will have serious implications. Unfortunately, the health risks relating to electromagnetic radiation are not yet fully understood. Yet, the amount of electromagnetic radiation will be significantly weaker than for today’s cellular phones (Bohn et al. 2003, p. 14). National legislation comprises critical values, which will be discussed in the next section.

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1 http://www.spychips.com/what-is-rfid.html

There might also be the risk of RFID affecting people with pacemakers for their hearts and other medical devices therefore ICNIRP (the International Commission on Non-Ionizing Radiation Protection) recommends a close cooperation between the medical device and security system industries (ICNIRP statement 2004, p. 195).

2.3.3 Ecological Implications

Ecological implications might result from pollution in tag production and RFID waste. On the other hand, there are applications planned in the field of waste management. RFID tags on items could help to sort material more efficiently and improve recycling. For example, tags on batteries could facilitate their proper disposal. RFID also allows incentives for good waste management (Saar & Thomas 2003, p. 135) although privacy issues might arise when interrogated bins reveal their content (see above).

2.4 Conclusion

All in all, it seems that there are risks but they can be dealt with in reasonable ways. As is has already been stated, the current debate about the introduction of RFID is marked by hysteria and often wrong information. Organizations and pressure groups such as CASPIAN (Consumers Against Supermarket Privacy Invasion and Numbering) have called for a boycott of companies as Benetton or Gilette, who planned to introduce tagged products. These groups take an active role in shaping the public opinion and establishing fears of the implication of RFID in areas as health, environment and above all privacy. Companies and producers of RFID, however, remained rather defensive and reluctant in spreading information and then mostly pointing at technical details. (Fleisch and Thiesse 2005, p. 2)

This could lead to serious problems for companies if not even a crisis. In this context, a foresighted risk analysis and management are necessary (Fusaro 2004, p. 44). Companies have to adopt an open and offensive communication culture and consumers need to be shown the advantages and possibilities of this new technology (Fleisch and Thiesse 2005, p. 13). The media and the government might also play an important role in consumer education. It is crucial to deal with customer data in an ethical way, companies have to obey rules and communicate them (Fusaro 2004, p. 40).

EPCglobal has issued guidelines concerning RFID and privacy. These require companies to clearly indicate the presence of RFID tags on products or their packaging and to leave consumers the choice of getting rid of them. Moreover, they state the importance of consumer education, i. e. familiarize customers with the technology and help them to understand the benefits. Finally, the guidelines prohibit collecting or storing personal data (EPCglobal guidelines[2]).

When introducing RFID on consumer goods, it is crucial to watch out for possible risks, which mostly depend on the respective technical implementation.

[2] http://www.epcglobalinc.org/public_policy/public_policy_guidelines.html

These risks have to be dealt with responsibly in order to maintain the “delicate balance of freedom and security” (Mattern 2003, p. 6) in the future.

3 Why Are Standards Necessary?

3.1 Standards as the Motor for Development

In the early phase of RFID standards barely existed. If existent, they were four wall applications at best, which means that standards only existed within one facility or organization (Ferguson 2002 p. 142). Experts believe that the lack of universal standards, which made interoperability impossible, have slowed down the development of RFID severely. Many organizations considered the adaptation of RFID too expensive and too risky in this case (RFID Protagonisten ringen um Standards 2005).

Standards are necessary to fully take advantage of what RFID has to offer. Within a four wall application RFID is helpful but cannot unfold its full potential. Standards can be established by a market leader whose products become widely accepted before the issue of standards even emerges. This effect is often being pushed through aggressive marketing which aims at placing one particular product as the only option early on (Schulenburg 2005). If there is no market leader that defines the norm, agreed on standards can help the development of a product like RFID. Sometimes standards are defined by laws.

3.2 The Current Situation

Currently standards are on the way. By far not all problems have been solved yet but standards are slowly catching up with the development. There are two major developments in terms of standards and regulations that will be opening doors for the further development of RFID applications. One important development towards open systems are the industry standards by EPCglobal. The non-profit joint venture between the EAN International and the Uniform Code Council (UCC) originated from the MIT Auto ID Center. It is a private/academic consortium backed by leading retailers, manufacturers and technology companies which is thriving for a global standard to make universal adoption and effective implementation possible (Symbol 2005).

Their newest developed standard generation 2 is bridging major gaps between different existing standards scattered around therefore moving a big step towards a universal standard. (EPCglobal 2005)

The other major issue to be solved are the radio frequencies available in the respective countries for RFID usage. A new European guideline has provided Europe with similar possibilities as the US but not all problems are solved yet (Roberti 2004).

Generally spoken the development is on a good way but certainly not all issues are solved currently.

4 Existing Standards and Regulations

4.1 EPC

The main organization thriving for a universal standard is EPCglobal. Their newest standard generation 2 is regulating the number system, the tag, the readers, and reference implementations on many software components (RFID-Protagonisten ringen um Standards 2005). They classify their tag standards into classes where the new generation 2 standard now includes class 0, 1 and 2.

But EPC has not only defined standards for the tags.

Table 1. All EPC Tag Classes defined by rewriteablility

EPC Tag Class	Tag Class Capabilities
Class 0	Read only → EPC number encoded onto the tag during manufacture and can be read by a reader
Class 1	Read, write once → tags manufactured without EPC number which can be encoded onto the tag later
Class 2	Read and write
Class 3	Class 2 plus power source (advanced features or larger read range become possible)
Class 4	Class 3 plus active communication
Class 5	Class 4 plus the option to communicate with passive tags

(Source own according to EPC global)

EPC Tag Data Specification Version 1.1 specifies specific encoding schemes for a serialized version of different codes.[3] Apart from the encoding schemes EPCglobal has also identified interface specifications and protocols for certain bands including radio frequency and tag requirements (EPCglobal 2005).

RFID is currently used on different bands e. g. 13.56 MHz. Epcglobal has also developed EPCIS (EPC Information System) a networked database to register event information and attribute data (Harrison 2004). Currently EPCglobal is also working on an application programming interface (API) for issuing ONS queries and an operational guidelines document that outlines industry best practices for the operation of DNS infrastructure (EPCglobal 2005).

[3] E. g. EAN.UCC Global Trade Item Number (GTIN®), the EAN.UCC Serial Shipping Container Code (SSCC®), the EAN.UCC Global Location Number (GLN®), the EAN.UCC Global Returnable Asset Identifier (GRAI®), the EAN.UCC Global Individual Asset Identifier (GIAI®), and a General Identifier (GID).

Even though not all areas are fully developed and accepted yet EPCglobal has set the pace towards an overall RFID standard.

EPCglobal standards are available royalty free to support the EPC Network development. But problems persist as several companies are holding patents out of earlier phases of development that overlap with parts of the new standards. Intellectual property rights have not been solved yet (EPCglobal Intellectual Property Policy). Therefore, it is not guaranteed that the standard will be accessible for free for everybody which could be a large drawback for the global development of RFID applications. Another problem is that not-standardized tags and readers are already being used right now and it will take time to replace them if the will to do so is there at all. Companies like Texas Instruments are confident that they can deliver tags according to the new standard by summer 2005 (Logistik Inside 2005).

ISO Norms

Some of these standards have already been conveyed into ISO norms (Gliden 2004).

The 18000 series includes the most up to date ISO norms concerning RFID applications. Currently six ISO norms mainly define the parameters for air interface communications.[4] (Ident Jahrbuch 2005 p. 50).

ISO/IEC DTR 24710 is currently under development and will be defining elementary tag license plate functions for ISO/IEC 18000 air interface definitions in the future. (International Organization for Standardization 2005)

Not only industry standards are influencing the development of RFID also existing laws and regulations that interfere with certain areas of RFID have to be considered e. g. regulations for the use of Radio Frequencies.

4.2 Frequency Regulations

Frequencies available for RFID use differ from country to country. Especially within Europe where a lot of available frequencies are blocked for e. g. mobile phone service providers, a frequency shortage exists. With the new ETSI 302-208 regulation forthcoming new frequencies came available within Europe. In general the following frequencies are being used for RFID applications: below 135 kHz, 13.56 MHz and according to the new standard between 865 – 868 MHz within Europe and up to 915 MHz in the US. Another possibility currently only available in the US is the frequency range around 2.45 GHz. These frequencies differ in read range and data transfer speed. The most commonly used frequency at the moment is the one between 865 and 868 MHz as it allows the biggest distance

[4] 18000-1:2004 sets the parameters to be determined in any Standardized Air Interface Definition in the ISO/IEC 18000 series. Whereas 18000-2:2004, 18000-3:2004, 18000-4:2004, 18000-6:2004 and 18000-7:2004 define the parameters for air interface communications in the area of radio frequency identification for item management on certain frequencies.

between tag and reader. With the new ETSI 302-208 regulation in place it is now possible within Europe to achieve similar reading distances as in the US. ETSI 302-208 increases the spectrum band from 250 kHz to 3 MHz through an additional frequency range and now allows a maximum effective radiated power (ERP) of 2.00 watts. This increase from 0.5 watts ERP to 2.00 watts ERP now allows similar read ranges as in the US where the ERP currently lies at 4.00 watts ERP. The increase in read range allows the use of RFID within e. g. logistics as a read range of about 5 meters becomes possible (Roberti 2004).

One drawback of the new standard is the fact that to make the limited number of channels fit everybody's needs only one channel can be used at a time and a so called spectral mask has to be used to avoid bleeding into other channels. This limits the data transfer rate to about 30% of the US standard. Therefore the new standard has not only brought about improvements but also disclosed new problems. Experts still consider the new standard an important step to universal usage of RFID across borders and are positive that the disadvantages Europe still faces can be compensated by advanced radio engineering or alternations of the standard at a later point in time (Roberti 2004).

5 Other Regulations Affecting the Development of RFID

5.1 RFID Specific Regulations in Germany and in the US

Another big issue that has to be solved concerning RFID usage is the question of data privacy. As mentioned above there are several critical issues about the data being gathered through RFID. In terms of regulations there have not been passed special laws within Germany so far. Therefore general laws for data security apply. An inquiry by the opposition to the Bundestag has resulted in a paper where the Bundestag explains that they are not especially concerned about the issue. Therefore no action is to be expected in the near future. The only issue they see is the storage and access to personalized data which is in their opinion covered by § 4 Abs. 1 Bundesdatenschutzgestz (Bundesdatenschutzgesetz BDSG) according to which the storage of personal data is only allowed if there is a special law requiring this storage or the person has agreed on its data being stored (Antwort der Bundesregierung 2004). Even though the Bundestag seemed unconcerned in 2004 there has been a study brought on the way in 2005 by the assembly of data security officials and the ministry of education and science to evaluate the possible consequences of RFID applications. (Bundesministerium für Bildung und Forschung 2005)

The study is being conducted by an independent center for data security. Results are expected mid year 2005 (TAUCIS 2005 Unabhängiges Landeszentrum für Datenschutz Schleswig-Holstein).

All these developments have to be assessed carefully as a topic so crucial to public opinion tends to be used politically. Therefore it is hard to tell if there will be any action towards special regulation by the Bundestag any time soon as the will to take action shifts as quick as the public opinion on the topic.

Another development is emerging in the US where already a Senate Bill No. 1834 is on the way in California. It has passed senate easily and is now awaiting parliament approval. It contains general regulations on storing personal data and some special restraints considering library usage of RFID tags (Senate Bill No. 1834).

5.2 Critical Values for Electromagnetic Fields

Another issue emerging once again around RFID is the question of electromagnetic fields being generated through RFID usage. Currently it is still difficult to define critical values as RFID applications operate on many different frequencies in distinct areas. Therefore it is on the one hand side hard to define what values are actually being achieved and on the other hand side who is exposed to it for how long. Usually different critical values apply for people working around electromagnetic fields and the general public. The critical values further depend on which parts of the human body are affected. (Information zu Elekromagnetischen Felder, Bundesamt für Strahlenschutz)

6 Summary

Concerning privacy invasion there are certainly some issues surrounding RFID that have not been solved yet. Therefore, upcoming risks have to be carefully evaluated and measures have to be taken against hysteria in public opinion. In general, discussions about technology have become quite emotional in the last decades. Once a technology has been positioned as a threat it is really difficult to convey any rational arguments anymore. Hence, it is important to thoroughly inform customers early about the risks and chances of RFID. This is mainly a task of companies and producers of RFID, but the media and the government should also play an important role in consumer education e. g. in schools. Companies should obey strict rules when using RFID on consumer items and consumers should always have the possibility to opt out. Generally, it can be assumed that companies operating in a competitive environment take an interest in satisfying customers and being a good corporate citizen, and therefore have a certain motivation to deal with consumer data in an acceptable way.

In the legislative sector a thorough review of existing laws is necessary to determine if alterations are necessary.

A similar picture emerges concerning standards. Even though the development towards general standards is well on the way, several issues remain unsolved. EPCglobal is planning to offer their standard royalty free to encourage the development of RFID. The free spreading of standardized applications is blocked for two reasons. First because of older patents held by different firms and second simply due to the fact that other tags and applications are already used.

Concerning the crucial necessity of radio frequencies a good step has been made especially within Europe but the result certainly is not perfect yet. The growth of the sector will probably lead to difficulties again due to a frequency shortage.

An increased level of electromagnetic radiation will open discussions on health concerns again. Detailed measurement procedures for electromagnetic fields around RFID applications have to be determined before critical values can be set. Only then health concerns can be properly evaluated.

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RFID Market

Susann Grämer, David Holzmann, and Jakob Keller

1 Introduction

This paper is intended to provide a general insight into the global market for radio frequency identification (RFID) technology. We first state the current market relevance of the different fields of application of RFID and conclude that supply chain management scenarios are predominant today. Drug counterfeiting and baggage handling are considered to have above-average potential in the future. Significantly declining prices for RFID tags and related equipment as well as the impact of compliance standards set by major retailers are the key drivers for RFID adoption. The lack of user acceptance, increased costs compared to today's barcode systems and technical and regulatory uncertainties are preventing a more rapid adoption in the business world.

We then shift the focus on key players and their influence on the RFID market. The supply side consists of companies which provide hardware, software and services. All important vendors active in those areas are named and categorized by their contribution to the market landscape.

On the demand side, supply chain applications are identified as the key drivers. Particularly large players such as Wal-Mart, Metro and the Department of Defense dominate and their policies in favor of RFID are expected to accelerate RFID adoption. Factors such as compliance requirements, acceptance of standards, network externalities and in particular lower prices due to ramp ups of production capacities will lead to substantial growth of demand.

2 Overview

The commercial success of any new technology depends on whether an appropriate market for the innovation can be found or created. The new features and impressive capabilities exhibited by RFID technology are, at least to some extend, revolutionary and make it very difficult to define the right market or find the most suitable application for it. At the moment companies are still in a trial and error process and try to figure out what RFID's killer application could be. As the search continues, some implementations are already successful today and new markets are established.

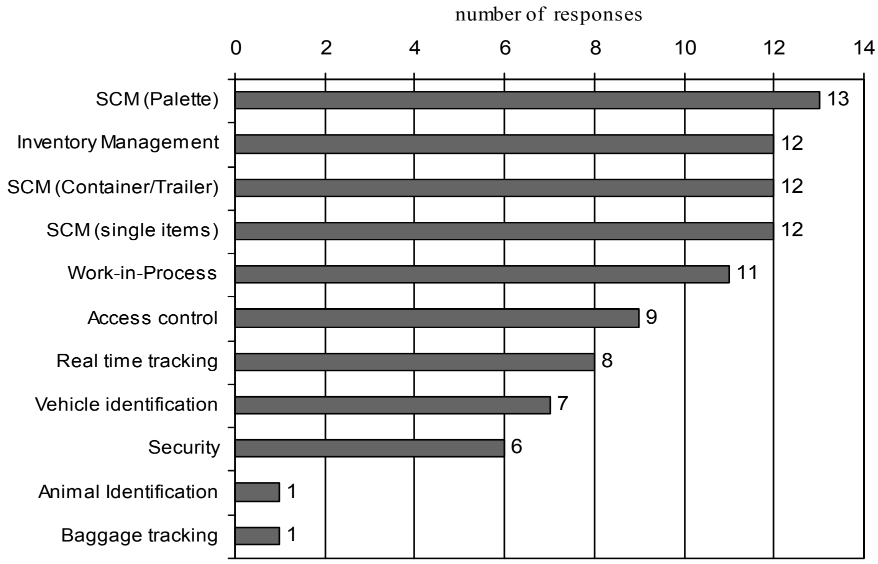

Fig. 1. Market relevance of different RFID applications – number of mentions in survey with 246 companies (AbiResearch 2004)

In this paper, we try to cover all relevant aspects of the markets for RFID technology as well as give an overview of the key players and developments on both the supply and demand side.

3 Market Segmentation

3.1 RFID Applications and Their Market Relevance

There are lots of applications for RFID systems – some already used today, some in development, some are even just an idea.

The largest application for RFID systems today is the field of track & trace. Track and trace means that an item is tagged with a RFID tag and than can be followed and identified electronically by RFID readers. There are several concrete applications existing today – in the figure above they are assorted according to their market relevance. The most important ones are Supply Chain Management applications (SCM).

3.2 Market Potentials

There are lots of RFID applications in use or at least planned – the question is if there is a potential for a company to create benefits by using RFID applications for a special task. For some of the above mentioned RFID applications there is a huge potential:

1. Drug counterfeiting costs the worldwide pharmaceutical industry up to $30 billion a year, which means that there is a huge potential to increase benefits by using RFID systems against counterfeiting (AbiResearch)
2. Airline companies (e. g. Delta Airlines) spend up to $100 million a year locating and returning lost baggage. Using RFID systems instead of barcodes improves the rate of properly returned baggage items from 89 % to 99.7 % (Heise 2004).

3.3 Drivers and Restraints for RFID Usage

There are several reasons driving companies to use RFID systems. First of all there are requirements by large retailers forcing their suppliers to use RFID in the same way the retailer does. Secondly decreasing costs for RFID systems – especially tags – and an increasing number of applications and therefore increasing benefits drive firms to install a RFID system. Another point is cost savings – baggage tracking in the airline industry for example reduces costs for locating baggage.

On the other hand there are still restraints causing that a company does not want to use RFID. One problem is the partially missing end-user acceptance; another point is the RFID tag price being still higher than the price for a barcode. In addition there exist different incompatible RFID systems from different producers and different regions.

Sectors That Drive the RFID Market

Given that supply chain management is a main application for RFID systems this sector is also the largest and fast-growing RFID market. According to the applications mentioned above there are three other large sectors using RFID on a grand

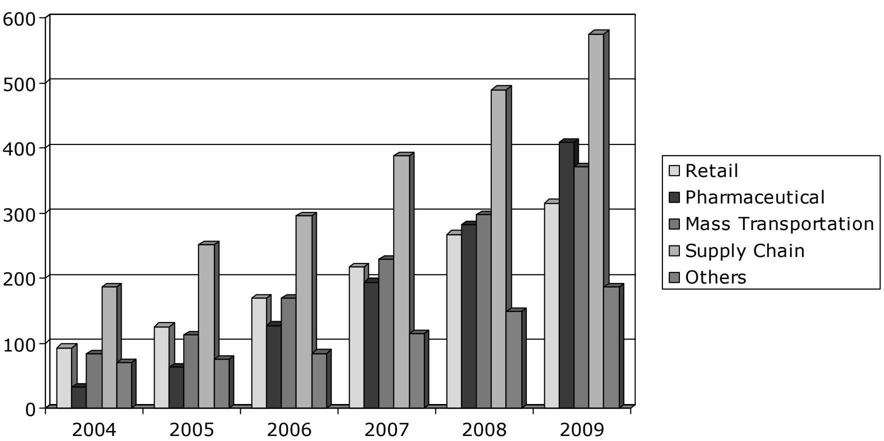

Fig. 2. RFID revenues according to sectors for Western Europe, 2004 to 2009 (Juniper Research 2005)

scale: First there is the retail sector where RFID is implemented for stock and inventory management as well as anti-theft control. This sector is today the second largest market for RFID in Western Europe, but it has not the growth potential that other sectors have. The pharmaceutical sector that uses RFID against counterfeiting is for example today one of the smaller RFID markets but will grow and be the second largest one by 2009. Last there is the mass transportation sector that wants to establish e. g. transportation without tickets through RFID systems.

3.4 The RFID Market – Revenues and Sales

The RFID market includes the global shipment of transponders, readers, software as well as RFID services like consulting or implementation.

In the past this market grew from $965 million in 2002 to $1.1 billion in 2003 and $1.5 billion in 2004 (VDC 2003). Forecasts expect a market volume of $3.6 billion in 2006 and a year to year growth rate of 37% (Bauer 2005, VCD 2003).

Out of the $1.1 billion spend for RFID technologies in 2004, $550 million were spend for RFID transponders, $272 million for RFID readers and $301 million for software and service (Liard 2004; VDC 2004).

Fig. 4 shows that the spending for RFID software and services is rising with the growing number of implementations, while tag revenues decrease due to the decreasing costs of tags.

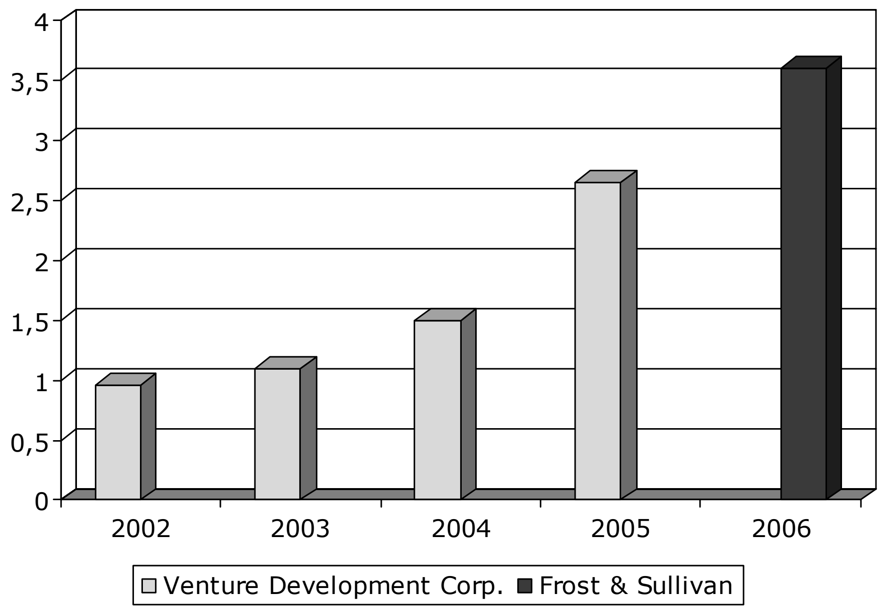

Fig. 3. Global RFID revenues 2002 to 2006 in billion Dollars (VDC 2003; VDC 2004; Bauer 2005)

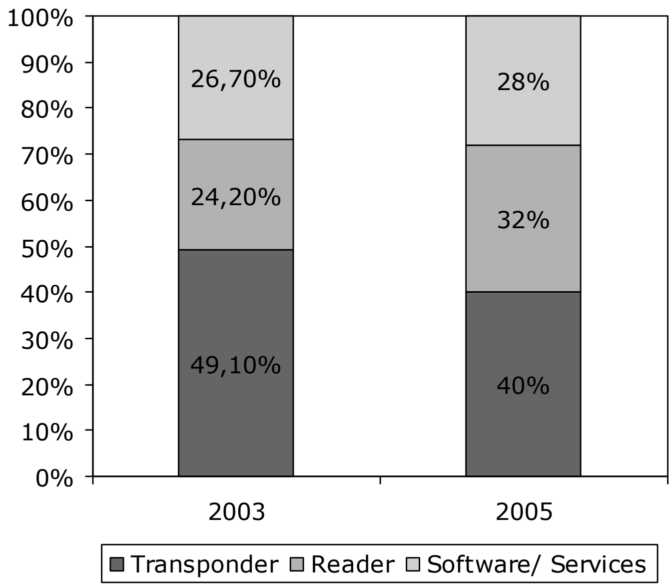

Fig. 4. Proportion of RFID transponders, readers and software/services on total RFID revenues in 2003 and 2005 (Liard 2004)

4 RFID Market Players

4.1 RFID Vendors

The market for radio frequency identification (RFID) is very fragmented, which means that there are many niches. This has its reason in the numerous applications of RFID, such as supply chain management, animal tracking or theft prevention in retail stores. Consequently many vendors entered the market from different industries. Among these there have been many small companies (Holzman et al. 2003, p. 3). Today many companies, especially in the software market, begin to cooperate and establish partnerships, for example Sun Microsystems and SeeBeyond. But as in all growing markets, it can be seen that big player develop and the market concentrates. For that reason it is likely that these partnerships are just a current development, in the long term the RFID market will consolidate as larger companies will integrate RFID in their product portfolios and as they have higher synergies with other products that way (ABI Research 2005 as cited by RFIDGazette 2005). So it is the case that merger and acquisitions take already place, such as the acquisition of Matrics by Symbol Technologies.

As shown in Fig. 5 the RFID vendors can be divided into hardware, software and services. Furthermore Fig. 5 gives some examples of the key players of every category.

4.1.1 RFID Hardware Vendors

The RFID hardware market can be categorized by the different products, which are offered. These are tags, readers and printers. The market for RFID tags and readers is the most important segment of the RFID hardware market and is rapidly growing. Deloitte & Touche (2004 as cited by IT Facts 2005) expects that more than 10 billion tags have been sold by the end of 2005.

In order to produce tags and readers in huge, cost-effective volumes high investments in big production lines are necessary. Consequently the market is characterized by large, well-known companies, such as Texas Instruments, and some pure RFID vendors which have reached the critical size. Furthermore the market for RFID commodities is already very competitive, which will lead to consolidation. For these reasons a market entry in the RFID hardware market for commodities is not recommended. However, as the market is fragmented, there are still possibilities to cover small niches with very specific products, such as tags with special features. In contrast to the RFID tag and reader market the market for RFID printers[1] is already highly concentrated, i. e. there are only a few players, such as Zebra, Toshiba or Sato (PIMS Canada 2004).

The key players of the RFID hardware market are described below.

Alien Technology

Alien Technology is a leading supplier of RFID readers, standardized tags and services (Computerwoche 2004). At the moment they can assemble 2 million tags a month. They plan to increase their production in order to be able to produce 20 billion tags a year in 2006. Furthermore Alien Technology believes that the prices for the best customers will decrease from today 20 cent to almost 5 cent with the new production line in 2006 (Economist 2004).

Texas Instruments

Texas Instruments is a key player concerning radio frequency identification (RFID) technology and the world’s largest integrated manufacturer of RFID tags, smart labels and reader systems (PR Newswire 2004). They offer a wide range of applications, such as EPC supply chain, logistics, automotive, animal tracking, airline baggage ID, product authentication or wireless commerce (Texas Instruments 2005). In 2004 Texas Instruments sold around 178 million RFID tags, which generated revenues of about $ 300 million (Fuquay 2005).

Royal Philips Electronics

Philips is one of the leading manufacturers of RFID tags and readers. Their RFID ICs are “specifically designed for high volume logistics applications such as parcel

[1] RFID printers are used to digitally encode data in smart labels and RFID tags (Zebra 2005b).

RFID VENDORS	HARDWARE	Tags & Readers	• Alien Technology • Texas Instruments • Royal Philips Electronics • Infineon Technologies • EM Microelectronic • Symbol Technologies
		Printers	• Zebra • Intermec
	SOFTWARE	RFID pure play vendors	• ConnecTerra • RF Code • Savi Technology • Globeranger • OAT Systems
		Application vendors	• SAP • RedPraire • Manhattan Associates • IBM • SeeBeyond • OAT Systems
		Platforms	• IBM • Microsoft • Sun Microsystems • Oracle • SAP
		Integration specialists	• Webmethods • SeeBeyond • Tibco
	SERVICES	• IBM • Hewlett Packard • Sun Microsystems • Accenture • RedPraire	

Fig. 5. RFID vendors

Source: Forrester Research, own analysis

and airline baggage handling, rental, and retail supply chain management" (Royal Philips Electronics 2005).

Further leading producers of RFID tags and readers are

1. Infineon Technologies: RFID tags with strong security algorithms for data protection
2. EM Microelectronic: Passive single chip RFID circuits and readers IC's
3. Symbol Technologies (acquisition of Matrics): Fixed and mobile RFID readers, tags

(Infineon Technologies 2005; EM Microelectronic 2005; Symbol Technologies 2004, p. 4).

Zebra

Zebra is an international operating company with 2200 employees. It is listed at the NASDAQ and has a market capitalization of around $ 3.5 billion (Zebra 2005a). Zebra offers printers for high-frequency (13.56 MHz) and ultra-high-frequency (UHF) EPC-compatible RFID smart label printers (Zebra 2005c).

4.1.2 RFID Software Vendors

The RFID middleware market has very high growth rates. It is estimated that this market reached $ 16.4 million in 2004 and about $ 43 million in 2005, which means a growth rate of over 160%. In addition to that it is estimated that the middleware market will make up 3% of the total RFID systems revenues (IT Facts 2004). Because of these high growth rates, many companies from the following software segments RFID pure play vendors, application vendors, platform giants and integration specialists (Fig. 5) entered the market (Forrester Research 2004, as cited by Computerwoche 2004). The platform vendors often cooperate with other companies of the RFID market (Computerwoche 2004) in order to integrate their partner's software into their own platforms. One example therefore is the cooperation between Sun Microsystems and SeeBeyond (Jacqueline Emigh 2004). Furthermore the well-known software companies, such as Microsoft, IBM, Oracle or Sun Microsystems, drive the market in the direction of complete RFID solutions as they see demand for complete, simple and well-functioning RFID software (RFIDGazette 2004). Because of the variety of the RFID software supply, the RFID software market can be regarded as competitive. For that reason a market entry can only be recommended for a specific niche.

4.1.3 RFID Service Vendors

As the RFID market is just developing and complex concerning the integration in existing processes and systems, there is need for RFID consultancy and services. As a result of this Hewlett Packard, IBM, Sun Microsystems or Accenture offer RFID services, which support companies in making use of RFID and integrating it into their existing infrastructure. Especially RFID software companies and consultancies specialized in software or information technology offer RFID services. Because of the various application possibilities of RFID and as most of the RFID service vendors are concentrated on supply chain management, warehouse management or the integration of RFID in manufacturing processes, there are still many niches, which have not been covered by a market player. That is why a market entry can be recommended, especially in services for small and mid-size companies, as the described players mainly concentrate on big companies.

4.2 Demand for RFID Technology

Today's demand for RFID products comes from diverse existing applications, such as toll collection, animal tracking and access control solutions as well as from the rapidly growing segment of supply chain management solutions. This is expected to shift even more during the next couple of years, when new industry standards and sinking costs enable the broad adoption of RFID technology in supply chain management (Krebs 2004). Because of its crucial relevance for the future success of RFID, the focus of the following section lies in pointing out the effects supply chain management has on the RFID market.

4.2.1 Demand by Major Retailers

The world's leading retailers rely heavily upon the efficiency of their logistics and supply chain management systems. Having implemented an appropriate RFID strategy early on, could therefore turn out to be a key competitive advantage. This is why companies such as Wal-Mart, METRO Group and many others started experimenting with potential applications of this technology in their supply chains. Given the enormous amounts of goods to be tracked, their use of passive tags and matching equipment could soon account for a large share of the RFID market. In order to better understand how this market is going to develop, one should analyze how these key players intend to make use of these new technologies.

Wal-Mart has been one of the first major retail companies to announce the introduction of RFID technology in its supply-chains. On April 30, 2004, one of its regional distribution centers and several connected retail stores started accepting cases and pallets equipped with RFID tags by eight different suppliers. By January 1, 2005, all shipments to these locations coming from Wal-Mart's top-suppliers were required to be electronically tagged. The goal of this initiative is to accelerate and simplify the handling of shipments as well as reduce costs and increase availability of products in stores (Roberti 2004).

Similar to Wal-Mart's efforts, METRO Group has asked some of its suppliers to attach RFID tags on pallets and equipped several warehouses and stores with the necessary infrastructure to read these tags. The results of those experiments showed that storage costs, out-of-stock situations and loss were reduced significantly. METRO Group's RFID rollout plan demands carton-level tagging using EPC standard compliant smart chips by the end of 2005 (Collins 2004a; Collins 2004b; Collins 2005a).

Both retail giants have recognized the benefits that can potentially be realized by using RFID solutions to improve their supply chains:

1. Reduction or elimination of labor intensive manual shipment handling processes reduces costs, error rates and delays.
2. Additional inventory information prevents out-of-stock situations while at the same time reduces costs of capital lockup by allowing the reduction of safety stock.
3. The ability to track and trace items within the supply chain enables very effective supply chain optimizations and helps to reduce the loss of goods during transport and storage.

These benefits can only be achieved if RFID tags are used consistently for all shipments. This is why Wal-Mart and Metro use their influence on suppliers to mandate certain RFID compliance standards. Initially the scope of these requirements is limited to certain key suppliers, products, logistics centers and shipment types. Once the results of this experimental phase are evaluated and possible problems are solved, a broad rollout is planned and all shipments will be tagged on carton-level. Item-level tagging is not likely in the foreseeable future because the additional costs are not justified by the marginal gains in information.

4.2.2 Demand by the U.S. Department of Defense

The United States Department of Defense (DoD) is in charge of operating one of the largest and most complex supply chain networks. Huge quantities of diverse goods ranging from perishable food to aircraft parts and explosives have to be distributed to varying locations around the globe, often on a tight schedule. The DoD has an interest in improving the efficiency of its supply chains and has conducted experiments with RFID technologies in this field. Some of these applications are similar to the projects conducted by private companies described above. For example, RFID technologies have been used to track containers filled with explosives in Iraq. Suppliers are also required to tag their shipments in the future. Because of the extend of its operations and the size of its budget, the DoD's decision on RFID implementations have a major effect on the development of the RFID market. Of particular interest is a recently signed contract framework allowing the different branches of the U.S. military to buy standard compliant tags from a group of five suppliers. The agreement includes delivery dates, depending on volume and type of tags ordered, and ensures that all branches of the military use compatible technologies (Collins 2005). These are signs that indicate that the DoD is serious about its RFID plans which will ultimately lead to significant growth of demand for RFID equipment.

4.2.3 Expected Development of Demand for RFID Equipment

Businesses are more likely to invest in technologies which promise to also create value in future applications and improve integration with their partners. Complying with industry standards is therefore one of the most important criteria when choosing the specific form of implementation. However, there has not been a commonly accepted standard for RFID equipment, resulting in a very fragmented market. Important investments were delayed in order to prevent costly mistakes.

All of the organizations mentioned in the previous sections are today supporting the standards issued by EPCglobal Inc. This is particularly true for "EPC Class 1/Generation 2", a standard for passive RFID equipment to be used in a variety of applications all over the world. Due to the reduction of uncertainty, demand for transponders and matching readers compliant to this specification is expected to increase.

Only a few examples of influential organizations that enforce the use of RFID tags by their suppliers could be described above. The effect of these policies is clear: As RFID compliance requirements are applied to an increasing number of companies of all sizes from many industries, demand for RFID technology will grow rapidly.

Once a company has invested in making its infrastructure RFID compliant and has gained some experience in mastering the technology, it is more likely to also use it in other areas. This is another source of growth for the RFID market.

A particular RFID implementation is usually more useful once it is connected to or integrated with other systems, both internal and external ones. As soon as RFID becomes more widespread, the ability to create such networks increases. These network externalities will further accelerate the commercial adoption of RFID.

All these factors will lead to an enormous increase in demand for RFID products in the next couple of years and will attract new investments in RFID manufacturing capacities. This increases output and leads to lower prices of tags and readers due to economies of scale (Capone et al. 2004, p. 8). Lower prices will further remove barriers for large scale RFID rollouts.

5 Outlook

RFID is a new technology with high growth rates. As already described, it is estimated that the RFID market is growing by 37 percent a year, which means that the RFID market will have a considerable size in the next years. The key driver for this growth is the application of RFID in the supply chain management, which is also the main market for RFID. Further drivers with high growth rates are pharmaceuticals, mass transportation and the retail sector. As large players are involved and production capabilities are expanded, prices will come down to a level that makes new applications profitable. Consequently new markets for RFID will arise, which will increase the demand for RFID hardware, software and services. On the supply side it can be seen that the market begins to consolidate. At the moment many cooperations and partnerships take place. In the long run, however, the market will consolidate, so that some key players will develop.

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Current Track and Trace Applications

Sophie Ahrens, Tobias Assmann, Julia Gebele, and Andrea Socher

1 Introduction

In the quest for efficiency and productivity operational effectiveness is a key success factor (Porter 1996, p. 61-78). To reach this goal not only single action has to be taken but the "total value chain" needs to be optimized. Processes regarding inbound and outbound logistics as well as operations and customer service need to be reconsidered. Being able to identify goods along the value chain is a key success factor in terms of time, quality process optimization and cost. Automatic identification plays a major role in today's supply chain management. Systems in this context are solutions that do not require manual data entry of product identification codes[1]. Auto-ID systems have revolutionized the field of logistics since the early seventies and are used not only for business to business but also for business to consumer applications. The latest auto-ID technique, Radio frequency identification (RFID), is about to revolutionize the complete value chain and the way business is done in the near future.

The aim of this paper is to identify the status quo of this new technology and the fields of application today. It will pay close attention to the benefits and problems going along with auto-ID systems.

There will be a brief introduction to logistics and supply chain management. Moving on, well-established auto-ID systems such as barcodes, magnetic stripes and biometrical characteristics and their fields of application are described. The second part ends with an analysis of the benefits and problems of these systems. The focus of the third part lies on RFID applications, including a discussion of their benefits and problems.

2 Supply Chain Management

Supply chain can be defined as "a network of facilities and distribution options that performs the functions of procurement of materials; transformation of these materials into intermediate and finished products; and distribution of these finished

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[1] As explained by Kevin Ashton in an interview conducted by Quinn for the Supply Chain Management Review in 2003.

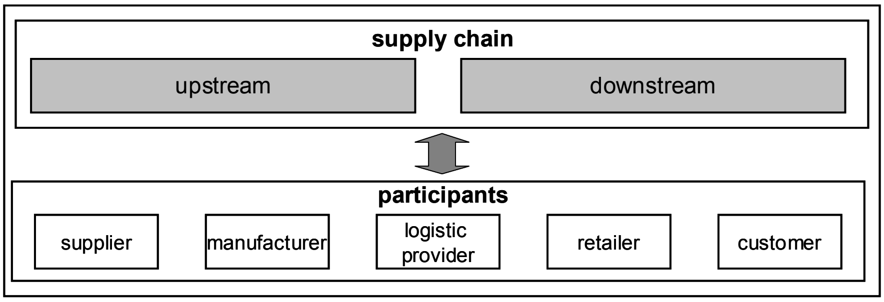

Fig. 1. Supply chain participants

Source: Own source

products to customers" (Ganeshan & Harrison – Introduction to Supply Chain Management on http://en.wikipedia.org/wiki/Supply_chain). Supply chain management deals with intercompany ordering processes. The Fraunhofer Institut also coins the phrase "flow management" to describe supply chain Management (www.supply-chain.de/german/arbfeld/Index.htm).

Being able to identify every product throughout this process is essential for smoothly working logistics. This is significantly simplified by the implementation of automatic identification systems. Supply chains are essential for production and distribution of goods. Commonly the supply chain is differentiated in upstream and downstream supply chains. Whereas the upstream value chain is the supply stream in order to produce a good, the downstream is characterized by the physical distribution of the good.

Throughout the supply chain there are different participants involved as shown in the figure above. They will be briefly discussed now.

Supplier is the first participant in a supply chain. In order to coordinate delivery processes a lot of information has to be administrated. To allow just-in-time delivery real-time information is vital.

Manufacturers need accurate information about their stocks to align their production and make sure that material shortages will be discovered in advance.

Logistic Providers take over the goods from manufacturers. It is considerably important to them to locate these goods. Any additional information about the goods can help to minimize cycle time and offer higher service, for example quality control.

Retailer's most important task is to ensure the availability of products. The possibility of real-time access to available inventory, order status, tracking information and other logistics data will lead to improved customer satisfaction, reduced complexity and improved performance.

Customers are indirectly participating in the supply chain. As all previous steps are targeted at the customer as he is the key success factor. An excellent working supply chain will allow availability of products anytime anywhere with additional service at reasonable cost.

Since all the steps to be taken are largely done by different businesses supply chains are commonly open cycle systems. This has several implications. Not only does every downstream stage have to rely on the proper delivery of the needed goods by the upstream stage. On time production and customization also demand flexible manufacturing. To make it even more difficult, within this process there are different auto-ID systems with different standards in use on each stage. These systems require different IT solutions that often are proprietary solutions of the single businesses. Tracking and tracing of goods throughout the total supply chain can therefore constitute an insolvable obstacle with the current systems in use. A generic IT solution that every member of the supply chain can integrate in their IT-system is not common at all. The ideal case allows all divisions and systems that encounter the product to use a shared data pool. Therefore a generic product lifecycle management has to be developed which stores, governs and retrieves all data that is generated during production, storage and distribution of a product (Johnson and Whang 2002).

Not only for applications but also to prevent the Bullwhip Effect, a seamless supply chain is necessary. The bullwhip effect describes the slow building up of demand of a product in its supply chain due to a lack of information of the suppliers. In order to prevent stock from falling short, wholesalers order safety stocks. The next supplier up the value chain does the same and eventually this adds up to a huge oversupply of the particular good, which causes unnecessary, costs (Kim et al 2005).

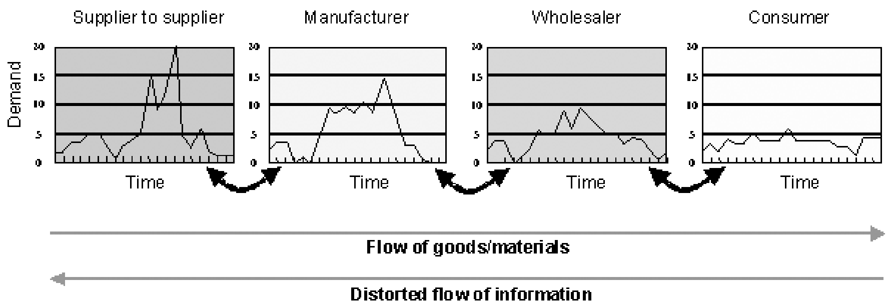

Fig. 2. The Bullwhip effect

Source: Busch, A.: Wide ranging differences in functionality and technology, SAP Info, 2002

3 Status Quo: Auto-ID Systems

The term auto-ID was introduced by IBM in 1998 (http://www.adlexikon.de/E-Business.shtml). Automatic identification (auto-ID) systems have the purpose to automate the registration and identification of objects (Haller and Hodges 2002, p. 3). The object to be recognized contains encoded information. Identification is accomplished by decoding the scanned information (Saar and Thomas 2003, pp. 133–139; Strassner and Schoch, p. 3). In the following paragraphs the currently used technologies will be introduced. Afterwards their fields of application followed by their benefits and problems are discussed.

3.1 Traditional Technologies

A lot of different technologies are included in the automatic identification family. See Agarwal for a detailed list (Agarwal 2001, p. 9). The following techniques are widespread and exemplary.

3.1.1 Barcodes

The most common and widespread system that is used in businesses is the barcode. The first code formats were developed in the 1940s. On April 3, 1973, the most popular and important version of the technology was adopted: the Universal Product Code (UPC). This standardization made it worth for manufacturers and companies to invest in the further development of the barcode and its adoption. The first barcode system ever implemented was by General Motors in 1969. It was used in a plant in Pontiac, Michigan, to monitor the production and distribution of automobile axle units (Hagey 1998).

The barcode is a font, readable by special machines. It consists of various broader and thinner bars and spaces which can be optically identified by so called bar code readers (in colloquial terms usually known as “scanners”) to be electronically processed by computers.

3.1.2 Magnetic Stripes

Another well known technology for automatic identification today is the magnetic stripe. It is a stripe, 0.9525 centimeters wide, made up of tiny iron-based magnetic particles.

Initially they were used in accounting departments at the beginning of the 1970s. Therefore, magnetic stripes, containing certain data were applied on accounting cards. The information could additionally be read in plaintext on those cards. The operation to read out the data is called Magnetic Ink Character Recognition (MICR). It is done by physical contact and swiping the card past a reading head (http://de.wikipedia.org/wiki/Magnetstreifen).

Today, magnetic stripes are commonly used in credit cards, certain passports, identification cards, etc. The magnetic stripe can mostly be found on the backside of a card, especially if it is designed to be read out electronically. This technology is very inexpensive and adaptable to many functions. As Terry Sumner, Arthur Blank & Company from ICMA put it:

“Magnetic stripe cards continue to serve customers and merchants as a sophisticated information tool. With backing from many markets and industries, mag stripe cards support increasingly complex IT infrastructures with ease and a high degree of functionality.”

3.1.3 Biometrical Characteristics

Biometrics-based authentication is more and more used for automatic personal identification instead of traditional technologies. It is proved that this kind of authentication is outstandingly reliable and can overcome some of the limitations of traditional systems. This is especially important as the need for highly secure identification of a person is rapidly increasing. Automated biometrics typically deal with the analysis of fingerprints, retinas, voices, faces or hand measurements, as these features are as unique as one's DNA. Compared to the data and information of previous scans, a person can be clearly and definitely identified.

It is of course not the actual fingerprints or iris scans that are stored in databases, but scans are by complex mathematical algorithms reduced to digital keys which can be saved and later be used for comparison (http://www.barcode.ro/tutorials/barcodes/autoid.html).

3.2 Fields of Auto-ID Application

After having introduced common auto-ID systems in the previous section it is now discussed where in the value chain they are used and by whom. Another way to differentiate the two is by the types of parties involved. For e-business it is common to speak of Business2Business (B2B) regarding business connections and about Business2Consumer (B2C) relating to end customers (http://de.wikipedia.org/wiki/E-Business#Literatur).

3.2.1 Track and Trace

Track and trace is elucidated as shipment trace and retrieval or position reckoning by the logistic dictionary (www.lexikon-logistik.de).

Barcodes are commonly used in supply chains for tracking and tracing, electronic cargo handling, product handshaking, enhancing product lifecycle development, as well as in the retail market for automatic registration of the products at the cash desk. Furthermore they are used to collect data for marketing purposes (Wilding and Delgado 2004, pp. 42–47). Because of their well-established infrastructure they can be found throughout the complete supply chain and are established in B2B (Saar and Thomas 2003, pp. 133–139).

3.2.2 Financial Transactions

Magnetic stripes are commonly used as a medium for identification or financial transactions as stated in subsection 2.1.2. Both business and consumers take advantage of this auto-ID technology and therefore magnetic stripes are highly accepted. This technology allows one interface between consumer and retailers of products and services. Having only one card to pay at different points has several advantages. Higher service standards can be reached and payments are secured due to coding applied to the cards. For most transactions access is secured through a personal code in order to reach higher security levels.

3.2.3 Access Control

Although less common, biometric identification is used, whenever a precise identification of a (human) being is needed. These systems are widely accepted in a business context as long as the necessity is obvious to the user.

After all, the areas of usage are not limited to certain steps within the logistics process and more specifically within the supply chains. Due to widespread acceptance in B2B and B2C there are no limits concerning user group acceptance.

As stated in the following paragraphs, due to the benefits and problems lying within the technology, a self selection of these technologies took place in the past.

3.3 Benefits of Auto-ID Systems

Auto-ID systems can be a great help in many fields of business. It is more important to take a closer look at barcode technologies than at magnetic stripes and biometrics, because they are mostly used within supply chains.

It is obvious that the barcode technology has made life easier for manufacturers and retailers as well as for customers. Barcodes do not only help to get more quickly through certain processes, but it also helps businesses with their sometimes very complex organization. Most apparent is of course, that by the use of barcode technology the quantity of manual work can be decreased by enormous rates. And this is not the only benefit. Retailers and manufacturers can save a lot of time, costs and personnel by using barcodes.

3.3.1 Time Savings

First of all, there is the time aspect. One application where significant time savings can be achieved is the inventories. The number of needed employees for the accomplishment of a regular inventory in a retailing store can be immensely reduced if barcode technology is implemented (http://www.mecsw.com/info/benefit.html). Therefore costs for labor force will decrease, too.

With barcode technology involved, manual work is almost eliminated. Writing down serial numbers and checking them manually, takes a lot more time than scanning an item with a barcode reader to extract the relevant information. These time savings result again in diminished labor costs for the retailer (http://www.mecsw.com/ info/benefit.html).

3.3.2 Error Reduction

To go without manual notes also means to reduce errors. The risk of delivering goods to the wrong person is present in the shipping business. Especially in pharmaceutical cases e. g. blood transfusion accuracy is a fundamental requirement. “The typical error rate for human data entry is 1 error per 300 characters. Barcode scanners are much more accurate; the error rate can be as good as 1 error in 36 trillion characters depending on the type of barcode used.” (http://www.mecsw.com/info/benefit.html).

3.3.3 Stock Accuracy

Stock shortage is also a serious problem for retailers. This problem can also be tackled by barcode technology.

Very often, the responsible person does not immediately know when stock is falling short. Many times this results in empty shelves and as an inevitable consequence to decreasing volumes of sales. When barcodes are implemented, information will be forwarded to a computer by scanning the code of an item when purchased. The system will then automatically know the time when shelves need to be refilled so that they never run out of items (Seppala 2003).

As one can easily discern, using barcode technology can result in drastic cost-cuttings by eliminating the Bullwhip effect.

3.4 Problems

Although technologies for the automatic identification of goods and also persons are quite sophisticated these days, there are still some problems and restrictions occurring while they are in use. As it has already been said above, for supply chain management especially the barcode is relevant. Although the barcode technology is so ubiquitous in the world, there are still some challenges that are difficult to handle with the explicit use of barcodes.

3.4.1 Information Storage

The black and white stripes which are read out by special machines contain certain information, generally about the type of the item, the identity of its manufacturer, and its price. As the length of a barcode (usually 12 digits) is limited in practical usage, and has a predefined amount of information, it can not include individual information about an item, but rather identify a class of a product (Agarwal 2001, p. 10).

This is, of course a great disadvantage for consumers as well as for manufacturers or retailers. There are many cases in which it could be vitally important to get particular information about a certain item, like the time when and the place where it has been sold, e. g. if a good has been stolen or gone off in a supermarket. In fact, this is not possible by using simply barcodes.

It is also impossible to update barcodes because the contained information is static. The whole code would have to be reprinted, which undoubtedly leads to higher costs and additional work for manufacturers or retailers (Agarwal 2001, p. 11).

3.4.2 Visibility

Another problem, especially for manufacturers, is the required line of sight between the reader and the barcode. There are two possibilities to scan the codes. The first one is mostly used in shops and supermarkets; therefore a staff member has to scan every product's code one at a time by a handheld machine. Simultaneous processing is not possible. As maybe almost everyone has experienced in the lines of the checkouts at supermarkets, very often this procedure takes a lot of time. The second one is primarily implemented when assembly belt production is possible. High powered scanning machines are installed, and barcodes can be automatically read when passing by. This system only works smoothly, provided that the line of sight is never disturbed and the products are precisely arranged on the assembly line (Agarwal 2001, p. 11).

3.4.3 Code Damage

Barcodes simply do not work if they become damaged. As they are just printed symbols, they can be easily destroyed when they get into contact with water, chemicals or even dirt (Agarwal 2001, p. 11). It is also possible that the code gets partly or wholly ripped off a product, which again makes it unreadable. Some codes even fade away when they are printed in low quality, e. g. when the product is exposed to the sun.

These problems can lead to increasing costs and higher amounts of work as the codes have to be replaced in case of damage or loss.

4 RFID Technology

RFID technology provides solutions for the problems and limitations given by the barcode. But RFID technology offers more then that. This technology gives rise to considerable benefits and spans a wide range of application areas.

4.1 Differences Between RFID and Barcode

The comparison of the parameters show up the distinctive characteristics of RFID technology and the barcode system (c.f. Table 1).

4.2 Solving the Problems with Barcodes

4.2.1 Information Storage

The amount of information, which can be stored on a single tag, is much higher than on a barcode. Every object receives a unique identification number. The possibility to write various data on one tag enables item-level information which is not possible with barcodes. For example a barcode only contains information about an item class but not about the single item. Therefore the received information through RFID is much more detailed and accurate than with barcode. A wide range of applications and additional features is possible, because RFID tags are multifunctional.

Table 1. RFID vs. Barcode

Parameter	Barcode	RFID
Data volume (byte)	1-1000	16-64 k
Reading speed	up to 4s	up to 0,5s
Read-write capacity	impossible	possible
Purchase Price	very low	about 40 cent
Requirements for line of sight	yes	no
Transmission method	laser	electro magnetic waves
Multifunctional capability	no	yes
Legibility through persons	conditional	impossible
Unauthorized copying	easy	difficult
Influence of optical cover	complete losses	no influence
Influence of direction and location	low	no influence
Influence of dirt and wetness	very strong	no influence
Signs of wear	conditional	no influence

Source: Strassner and Schoch, p. 3; BSI 2004, p. 80; Wilding and Delgado 2004a, p. 28

The information on the tag is read by specific readers and gets stored by the computer system. Due to the increased amount of data space available, security adjustments can be added. This will make unauthorized copying of codes impossible, leading to higher security standards. (Sheffi 2004, p. 1).

4.2.2 Visibility

Barcodes can only be scanned at one discrete point in combination with humans and readers. RFID tags offer the possibility to give continuous information at different points without manual scanning. This means that line of sight reading is not required any more and many tags can be read simultaneously into the computer system. The possibility to record different products in bulk without sorting enables higher reading speed. Trailers, cases and pallets do not have to be opened to identify the content. The RFID technology increases the "volume of throughput" and reduces manual labor because electronic portals will do the check-in.

4.2.3 Code Damage

Additionally the usage reliability is increased because the information gets stored directly in the computer system. Errors occurring in documents of e. g. shipping actions will decrease. If the RFID tag gets in contact with dirt, moisture or chemicals it has no influence on the RFID functionality. It is still readable in harsh environments (Sheffi 2004, p. 1; Angeles 2005; Wilding and Delgado 2004a,b,c; Anonymus3).

4.3 RFID Applications and Benefits

Since several decades the RFID technology is used experimentally for various purposes. In some specific sub-areas RFID could already prove itself and is widely used. New potential applications get tested in various pilot projects.

"(…) RFID systems help companies to cut costs, improve customer service, reduce labor, increase accuracy and improve supply-chain throughput. RFID systems applications can be used by different sectors such as the military, retail, industrial, life sciences, logistics and financial. The military and the life sciences sectors have been the first to use the technology." (Das et al, 2002, Harrop et al, 2003; IDTechEx Ltd, 2003a as cited by Wilding and Delgado2004b).

4.3.1 Logistic and Supply Chain Management

One important field of application for RFID is supply chain management. In times of storage reduction and the importance of the "just in time" concept, the supervision of the supply chain is of greatest importance. RFID technology enables real time item-level tracking through the whole logistical network. RFID closes the information gaps in the supply chain creating high transparency and leading to more efficient control of logistical processes (Angeles 2005; BSI 2004, pp. 86-90).

4.3.2 Production and Manufacturing

Asset and Product Management

Asset and product tracking allows to monitor and manage the movement of goods. Each product gets tagged with an RFID chip right from the start of the manufacturing process that leads to an efficient and accurate routing during the production process. There are different levels of tagging: pallet, case and item level tagging. Benefits will increase the more item-level tagging is implemented. Especially in the highly individualized production of cars this aspect plays an important role. The big challenge is to get the right item to the right place in the right time. Due to the ability to track single items and their location throughout the whole process RFID makes this more reliable and efficient (Wilding and Delgado 2004b; Alexander et al. 2002, p. 7).

The **Ford Motor Company** annually produces 300,000 – 400,000 cars and trucks in its Cuautitlan/Mexico factory, using an automated production process.

They installed 40 antennas on the floor of their factory, 25 in the area of body production, 12 in the painting area and 3 in the final assembly area. The car moves from one area to the next and every time a particular part of the 20-plus-digit serial number on the tag is prompted by a reader. The referenced information indicates the automated manufacturing line the next specific assembly operation which has to be executed. Through this highly automated production process the production costs get optimized (Zhekun et al. 2004; Angeles 2005, p. 54).

To identify the compound parts in the complex process of manufacturing different car types is of highest importance. To solve this issue **Opel Belgium** marked the work piece porter and also the pick up with transponders.

The benefits are enormous, because Opel can avoid the manufacturing of wrong parts. Product handshaking makes sure that correct association is guaranteed since every part gets authenticated and is rejected if incorrect (Wilding and Delgado 2004b, p. 42; BSI 2004, p. 87).

4.3.3 Distribution and Transportation

The whole distribution process can be split up into several stages.

Receiving and Check in

RFID portals are installed at strategic points to read the item tags and record the new inventory quantities to the computer system when cases and pallets arrive. The correct stock amount will be calculated by updating the purchase order and the incoming products and inconsistencies will show up immediately.

Putaway and Replenishment

Barcodes do not have to be scanned manually any more when the putaway driver picks up the product. The depot of the products is automatically scanned each time a movement of products takes place and the achieved information gets stored in the inventory location system. Alerts will be given by the system if products end up in wrong locations.

Order Filling

The pickers get the exact information from the system where to pick up the right items. The time effort to locate specific items decreases and therefore the productivity of assets can be increased. After the order is fulfilled the system alerts that these quantities have been removed. At the same time the inventory files will be updated with the changes in the inventory.

Picking and Shipping

Loaders can transfer the products right away on the trailers because there is no need of line of sight reading anymore. Due to this the whole shipping process will take less time and the conveyors will run at higher speeds.

Yard Management

A precise yard management plays an important role in the whole distribution process. It is much more visible if the trailers and tractors do have RFID tags. Readers have to be installed at the entrance and exit doors and throughout the whole yard. Tracing these assets gives the opportunity to locate the position and monitor the movements. Exact information can be retrieved about the content of the trailers. The productivity of assets is increased, but this application requires expensive hardware.

Kitchens, Inc. USA is a retailer in home furnishings with 500 stores national wide getting serviced by three distribution centers. They had been facing several problems in the past like slow check-in processes and high shrinkage due to errors. To counter these problems the supplier has to tag the cases. Installed reader portals in inbound doors, on material-handling equipment and on vehicles e. g. pickers could record the exact location of the products. They spent $7.8 million installing the hardware, software and for the integration of the case-level tracking system in the distribution centers. Another benefit was the saving of $16.7 million in labor expense and the losses due shrinkage reduction (Angeles 2005, p. 57–58; Alexander et al. 2002, p. 13).

Transportation

Product and asset tracking in the transportation process of the supply chain is realized by implementing readers at strategic important positions. Before the tagged assets and products leave the supplier each tag will be identified by readers. During the transportation the tracking system will be updated when products and assets pass readers. The retailer can observe the movement until the load gets delivered to the retailers receiving area. If shipments take longer than expected the computer system gives an alert. Transportation manager get in contact with the responsible company to avoid delayed delivery. Manual labor costs will decrease because there is no need of manual scanning and inspection. The visibility of the transportation process generates the possibility to handle problematic cases more efficient.

An interesting application for managing the transportation process with RFID technology is the **Port of Singapore**. (Angeles 2005, p. 54) The Port of Singapore has to organize the arrival and departure of approximately 50 ships with containers a day. They installed thousands of RFID tags on the asphalt road of the shipyard. Thousands of containers had to be tracked with smart tags. The Electronic Data Interchange (EDI) system working with X, Y and Z coordinates places and locates the containers on the port.

Condition Monitoring

By adding sensor functions to specially designed RFID tags, these can be enabled to measure e. g. temperature or humidity. For example the United States military section used these RFID tags to monitor the condition of ammunition (Wilding and Delgado 2004, p. 45).

4.3.4 Retail

One very interesting area for RFID applications is the retail sector. The global trailblazers of RFID technology in the retail sector are Metro, Tesco and Wal-Mart. The usage of the new technology has the potential to offer many benefits.

Wal-Mart, the big player in the retail sector carried out a trial with the RFID technology in the district of Dallas, USA. They worked together with 8 suppliers.

They tracked the goods "(…) from when they leave suppliers, through its warehouses, docking doors and supercenter stock rooms, to when they leave the back rooms for the supermarket shelves"(Anonymus3, 2004, p. 3).

The suppliers tagged the pallets and cases of 21 products with RFID tags. When they arrived at the Wal-Mart distribution center they passed doors and got scanned and identified by the readers. From the distribution center they got delivered to the "Super Centers". The pallet and case-level tracking system worked well and Wal-Mart could reduce their labor cost and the inventory accuracy went up. Wal-Mart finished their pilot project and wants to roll-out with the RFID technology.

Starting in January 2005 Wal-Mart wanted to cooperate with 100 suppliers to fully implement the tracking and tracing of their products with RFID technology. But facing the problems of a lack of knowledge concerning the processes and a technology still very unstable they had to announce to roll-out only in Texas (BSI 2004, p. 86; Wilding and Delgado 2004c, p. 38, Sheffi 2004, p. 7; www.walmart.com).

Product Tracking

Tesco, the biggest retailer in the UK realized in June 2004 the project "the intelligent shelf". They worked together with Mead Westvaco, which are an American packaging company and Entertainment UK. They wanted to test the functionality of smart shelves. They tagged DVDs in Sandhorst and Leicester stores and installed readers at the shelf units and also in the backroom of the Tesco store. The employees see through a secure web site the current stock close to real time. The inventory accuracy went up because the system records every movement of a product. The goods can be replaced much faster because the refilling information is automatically tied to the purchases of the consumer "On-shelf availability" could be improved. The work of sorting DVDs titles was cut down as a consequence of the electronic product code (Wilding and Delgado 2004c, p. 33; Anonymus2, 2003, p. 2).

Merchandising Support Functions

The **Metro** Group Germany started an initiative to develop solutions facing the problems of retailer shops and customer satisfaction. The idea was to combine many different innovative technologies including RFID and testing them under real conditions. The project is called "Advanced retailing". Therefore they founded the Metro Future Store in Rheinberg/Germany in April 2003.

RFID technology can also overtake Marketing Functions and one example is the merchandising support functions realized by the Metro Future Store. They tagged Pantene Shampoo. If the customer lifts a bottle from the shelf the screen play above starts a commercial and information is given to this product.

The Metro Group started in November 2004 to implement the RFID technology in their supply chain. In the first phase 20 suppliers tagged their pallets shipping to

Metro stores. This year their supply partners start to tag cases and parcels, monitoring the whole supply chain (Wilding and Delgado 2004b, p. 46; www.metro-group.de; BSI 2004, p. 85).

Customer Monitoring

Gillette is one of the important companies that drive the development of RFID technology and is a supplier of Tesco and Wal-Mart retail stores. Gillette USA and UK started “the shelf that takes your photo” trial. In the first trial they tagged Gillette razors in a Tesco supermarket in Cambridge. When the customer took a razor out of the shelf it was taken a picture from this person automatically. Also when leaving the store they got photographed once more in order to avoid thefts. But there came up privacy concerns so Gillette decided to stop tagging individual products (Wilding and Delgado 2004c, p. 32–33).

Customer Experience

There are RFID applications focused on the customer experience and satisfaction. **Prada** opened a conceptual store “the space age dressing room” in New York City in December 2001 to satisfy the customer to the maximum. Every high-value merchandise product got traced with an RFID tag. If this tag is detected by readers which are installed in the shop you get access to a database which has a lot of information about this particular product of merchandise e. g. sketches and videos. In the dressing rooms readers and a touch screen are installed, giving the customer information about the product (Wilding and Delgado 2004c, p. 40).

4.4 Other Applications

4.4.1 Safety and Security Functions

Access and Route Control

Auto-ID cards, such as magnetic stripe cards, contact smart cards or infrared scan of barcode cards are nowadays common to verify automatically the access status of individuals. Usually these cards require direct contact with a terminal that is connected to the used IT services. RFID applications make contactless access systems possible and thus enhance the features of traditional data cards as well as reduce their costs: the readers are well protected from detrimental environmental effects and vandalism. The transponder is usually integrated in a smart card, key rings or wrist bands. In addition to identification, writing capabilities allow data updates and support other multifunctional applications. Contactless RFID access systems have already prevailed on the market, as operators that need fast identification of individuals or groups want to avoid long checking procedures. The most prominent examples are tickets for the **soccer world championship 2006**. As soon as someone has to pass access points several times, these systems become especially interesting. Therefore they are widely used in holiday resorts or as access cards to ski lifts (BSI 2004, pp. 76-81; Wilding and Delgado 2004b).

The possibility to identify persons and record their attendance time at specific locations can be used for tracing systems. In the context of increasing outsourcing of public services to private companies RFID allows an indirect control of the performed tasks and thus an adequate remuneration. The **city of Dresden** equipped selected areas that need maintenance like bus stations or playgrounds with RFID tags. Thereby contractors using mobile reading devices have the possibility to locally record their work. This data helps the city to improve the planning and execution of its outsourced services. The capability characteristics of these RFID systems are just like the ones used for contactless access systems. Another RFID tracing systems is used in a **Taiwanese hospital** in its struggle against SARS. Everyone inside the clinic has to wear RFID tags that correspond with readings devices at doors and other important locations. In case of emergency the spread of infections can easily be traced (BSI 2004, pp. 76-81).

Electronic Payment Devices

RFID technology also provides the same security as common contact smart cards for financial transactions, while having the benefit of being contactless. Thereby customers can enjoy faster service at cashiers and smart cards that, unlike traditional magnetic strip cards do not wear out. This technology is applied in road toll payment systems where vehicles are automatically identified and resulting fares are directly debited from the owner's bank account. In a pilot study in **South Africa** the advantages were particularly obvious. The tags could be read up to a distance of six meters, a driving speed of 250 km/h and resisted a temperature between –40 and +85 Celsius. Today, such a system is used at **Portuguese Via Verde** for its toll-fee transactions (BSI 04, pp. 76-81; Wilding and Delgado 2004b).

Authenticity Checks of Documents

Due to the large data storage capacity of RFID tags they are used to implement electronic forgery protection systems and therefore improve authenticity checks. The **Dutch ministry of the interior** – responsible for the issuing of passports – launched the „2B or not 2B"-project, to test the integration of biometric data in passports. In accordance with the guidelines of the International Civil Aviation Organization, facial characteristics or fingerprints are used as recognition features (BSI 2004, pp.72-74).

4.4.2 Object Tracking

Baggage Handling

RFID tags are used in the airline industry to label baggage in order to reduce the number of misplaced items. "Of the 1.5 billion bags carried on commercial flights each year, around 0.7% go astray. Dealing with each lost bag costs airlines an average of $100, or around $1 billion a year for the industry as a whole, not to mention the loss of customer goodwill. A big part of the problem is that crumpled or torn barcode labels are misread by the machines that process baggage as it travels between passenger and plane: the accuracy of printed barcodes can be as low as 80%. RFID tags, in contrast, have accuracy rates exceeding 95%. "(Anonymus5, 2005). At the moment trials are limited to selected airports and airlines, e. g. to **KLM** and **Japan Airlines** or the **Montreal airport** (Anonymus5, 2005).

Animal Tagging

Electronic identification systems for farm animals have been used for twenty years. There are three kinds of RFID tags used: The first kind is injected, the next group is placed in the stomach of ruminant animals and the last ones are electronic earmarks. The main benefit is the possibility to consistently track animals from birth until the point of sales of their meat. **The European Commission** successfully tested the electronic identification of about one million farm animals between March 1998 and December 2002. Supported by this study the EC released a regulation, that from 2008 on all of its member states with more than 600,000 sheep and goat have to use RFID tags. Comparable ambitions can be seen in **Canada**, where the electronic identification has been required since January 2005. Another example is a law of **Nordrhein-Westfalen** in January 2003 that prescribes injected RFID tags for all dogs above a weight of 20 kg or a height of 40 cm. Thereby officers can easily check legal concerns of the specific dog, such as tax numbers and muzzle or leash obligations (BSI 2004, pp. 67-72).

Container Tagging

In the area of electronic container identification especially for **gas** and **chemicals** RFID technology has been used for years. The high storage capacity of RFID tags allows the storage of additional data, like ownership, TÜV dates, content, volume or the maximal filling pressure. These tags can also resist extreme temperatures, dirt, moisture, radiation and acids (BSI 2004, pp.67-72).

Waste Management

In the context of raising direct and indirect disposal costs the use of RFID in the area of waste management is spreading. In many municipalities in Germany – e. g. in the Bavarian county of **Hof, Erlangen-Höchstadt, Kehlheim** or **Heiligenstadt** – RFID tags for garbage cans were introduced to optimize the process of waste management and to allow a price according to use. These tags allow the municipality to improve their control of external contractors, to optimize the routing of garbage trucks and to prevent fraudulent use of garbage cans (BSI 2004, pp. 76-81).

Maintenance

RFID tags are used for tool identification and maintenance management, to ensure all tools are used in the right place and serviced according to regulations. By recording the place, time and objective of the use of every tool, maintenance companies can retain their warranty rights by proofing the manufacturer proper handling. The **Flugzeug AG** tested a RFID tagged tool box, with RFID tagged tools. The system automatically informs the mechanic, if tools need to be serviced or replaced. **Airbus** also uses a similar system (BSI 2004, pp.74-76; Wilding and Delgado 2004b).

4.5 Problems of RFID

Technical Shortcomings

The interference of electromagnetic signals can cause low reading speeds and problems with the reading of many tags at a time. Additional issues are problems with scanning RFID tags close to metals and liquids in specific ranges. These technical shortcomings need to be solved before a wide implementation of this technology is possible.

Costs

The most important barrier is nevertheless the cost of the tags. By early 2003 the cost of chip smart labels was around 40 cent, but for most companies the prices have to fall below 10 cent a piece to become interesting. To make full scale item-level tagging possible the price of a RFID tag must be below one cent. In addition to these acquisition costs significant investments in the background infrastructure of the RFID system are required for new hardware, software and system integration.

Standardization

Even though the international standardization of RFID is progressing, globally accepted standards are missing which complicates the implementation of industry-wide applications. Global standards are essential to create a stable framework that companies can rely on and allow the interoperability of components of different manufactures.

Privacy Issues

The increasing use of RFID systems attracts public attention and raises discussion about privacy issues. Civil rights unions published a collective position paper covering RFID and the resulting privacy issues. The signing organizations recognize the legitimate interest of corporations to use RFID, but they call upon the industry to avoid the use of this technology due to unknown risks and consequently missing appropriate counter strategies.

Environmental Concerns

Another challenge is related to environmental concerns about non-biodegradable, sometimes poisonous materials in the tags, which complicates their disposal and raises the question of their presence near food. In anticipation of these problems, technological developments that use environmental friendly materials have always been focused on (BSI 2004; Wilding and Delgado 2004a).

4.6 Solutions

EPCglobal

The development of global standards for RFID technology is particularly important due to the use of RFID in open systems with supply chains involving hundreds of international companies. The most important organization in this field is EPCglobal Inc., which develops and oversees standards for the EPCglobal Network™. For review and ratification of submitted technical standards EPCglobal Inc cooperates with the International Organization for Standardization (ISO).

The EPCglobal UHF Generation 2 protocol, a consensus standard built by more than 60 of the world's leading technology companies, will be used as a base platform upon which standards-based products and future improvements will be built.

An EPCglobal standard ensures interoperability and sets minimum operational expectations for various components in the EPCglobal Network™, including hardware components. While EPCglobal oversees interoperability and conformance testing of standards-based products, the actual development of these products comes from leading solution providers around the globe.

Following the outcome of this work group, EPCglobal plans to submit the Generation 2 standard to the International Organization for Standardization (Anonymus5, 2005).

Regulation

The regulatory requirements for frequency bands are also an important issue. There was not a single frequency that could globally be used for RFID. This area improved a lot, however, when the Japanese government decided to allocate 950 to 956 MHz for RFID, thus allowing the possibility of global adoption of UHF tags for supply-chain tracking since this frequency can now globally be used exclusively for RFID (Wilding and Delgado 2004a).

5 Conclusion

As seen in the previous sections, a lot has been done in the field of auto-ID within the last years. Looking at the current constraints to a wide application of RFID technology there are signs that revolutionary applications will be developed once these obstacles are overcome. This paper also pointed out, that this new technology will develop along the whole value chain. Once successfully established in business to business processes it will then move on to business to customer applications. But the main problem is that RFID tagging is not yet as accepted as other auto-ID systems. While no customer minds having a barcode attached to his package of crisps, people seem to mind when RFID is involved, mainly because of privacy concerns. Of course also cost and technology problems have to be considered, but these obstacles will be more easily overcome than reservations of customers. Consequently the only one to stop RFID from causing a revolution, especially in retailing, is the global consumer.

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RFID Integration into ERP Systems

Veronika Gamper, Sebastian Kraiker, Jing Li, Johannes Wust

1 Introduction

With the adoption of RFID-tags in inventories, manufacturing or sales a flood of real-time data is produced has to be processed and analyzed. The following section covers the impact of the usage of RFID tags on enterprise software systems. The first section gives a general overview of enterprise resource planning systems, the core software systems of enterprise information systems. Then, requirements for software systems that handle the data sent by RFID readers are discussed and in the last section solutions of several software vendors are presented.

2 ERP Systems

2.1 Overview

An Enterprise Resource Planning (ERP) system denotes an information system that supports the effective planning and control of companywide resources. ERP systems are "designed to address the problem of fragmentation of information in business organizations" (Muscatello 2002). This fragmentation results in the usage of different, sometimes proprietary, so-called legacy systems. These systems were designed to support one specific business function. Many heterogeneous systems lead to potentially inconsistent data and redundant storage of data.

To meet the goal of integrated, companywide available data, ERP systems have the following characteristics (O'Leary 2000 p. 27):

1. ERP systems integrate most of a company's processes and process most of its transactions.
2. They have a client-server architecture with one enterprise-wide database.
3. Data can be accessed on-line and in real time.
4. ERP systems provide an integration of transaction processing and planning activities like production planning.

Business functions supported by common ERP systems include Financials, Human Resources, Operations and Logistics and Sales and Marketing.

After a Consolidation on the market, there rest two important vendors of ERP: SAP and Oracle. JD Edwards was bought in 2003 by Peoplesoft and at the beginning of 2005, Peoplesoft became part of Oracle (Gartner 2005).

2.2 Example Process

To illustrate how an ERP system supports a company's business processes, an example is presented. The example is given in O'Leary (2000 p. 36 – 37) and generalized for ERP systems.

International Sneaker Company (ISC) is a hypothetical U.S. company that sells shoes worldwide. The manufacturing takes place in Taiwan.

1. Ordering: A sales representative from ISC enters the data for an order from a Brazilian retailer in the company's ERP system. The system automatically checks the price, the discount for the retailer and his credit history.
2. Availability: The ERP system checks the inventory. It finds that half of the order is available from a warehouse in Brazil and the other half has to be delivered from ISC's factory.
3. Production: The ERP system informs the warehouse to ship the part of the order that is in stock to the retailer. The manufacturing module schedules the production of the remaining portion of the order in Taiwan. Additionally, an invoice in Portuguese is printed out.
4. Manpower: The ERP system notes that there is a shortage of workers to handle the order. It alerts the personnel manager.
5. Purchasing: The purchase manager gets a notice that new raw materials to a certain amount have to be ordered.
6. Order Tracking and More Ordering: Via Internet, the Brazilian retailer notices, that a portion of the order has been completed. He also places another order via ISC's web shop.

2.3 Example ERP System: SAP R/3

To show the architecture of an ERP system, the widely adopted system SAP's R/3 is presented roughly.

SAP's R/3 has a three-tier architecture which consists of a single database, an application layer and a presentation layer. Usually the R/3 installation is executed on one database server, several application servers and the hardware of the presentation layer are the workstations of the users. Depending on the size of the installation, the complete system can be executed on one server or there can be also more than one database server executing the database transactions of the single database. The client-server approach leads to a great flexibility in choosing the hardware. The database can be any of the common relational database systems.

The data in the database consists of the R/3 software and client data. The whole program code for applications and screens is stored in the R/3-repository. Client data includes the customizing and control data of the installation. Customizing data is for example the business units of a company and the customization of R/3's predefined standard processes. Client data includes master data, like contact information of customers and all operational data. Several mandators can be defined to hide data from unauthorized users or to use one R/3 system for several companies. (Metzger and Röhrs, 2000, p. 25-36)

SAP provides several modules to support business functions. The core modules are the following:

Financials (FI), Controlling (CO), Materials Management (MM), Production Planning (PP), Sales and Distribution (SD) and Plant Management (PM). The next generation ERP system of SAP will be called mySAP and be based on the SAP's new technology platform NetWeaver (Kagermann 2004).

2.4 Issues on Implementing an ERP System

There are several reasons why companies implement ERP systems. Ross and Vitale (2000) identified six main motivations during their research study:

1. need for a common platform
2. process improvement
3. data visibility
4. operating cost reductions
5. increased customer responsiveness
6. improved strategy decision making

The assets of ERP systems for a company manifest themselves in several operational figures like decreased inventory, personnel reductions or speeding up the financial close process. Besides, the adoption of an ERP system can create value through its influence on the organization of a company (O'Leary 2000 p. 7-9): ERP systems are shipped with many "best practice" business processes. A company that implements an ERP system has to adapt its processes to these best practices and can improve its way of doing business. Bringing all processes in line, leads to organizational standardization across different locations. This can yield to higher efficiency and better manageability. Additionally, a single image of a company can be presented to the outside world as documents have the same layout and interfaces to customers and suppliers are companywide consistent. With a companywide database, an ERP system provides on-line and real-time information for controlling and operational planning. This data is also an important source for Data Warehousing and Data Mining and can thus support strategic controlling and decision making.

Besides these expected advantages the implementation of an ERP system could yield to several drawbacks apart from the costs resulting from the implementation and operation (Davenport, 1998). Companies whose competitive advantage lies in the flexibility of its processes might loose this advantage with the introduction of an ERP system as ERP systems are based on best practices that are open to competitors as well. Another consequence of the enterprise-wide standardization of processes for global companies is that regional or national units cannot align their processes with the needs of local customers anymore. As a solution, only a part of the processes might become standardized. Finally, implementing an ERP system is a huge project fraught. While several projects have met their goals (Brown and Vessey, 2001) the introduction of a company-wide ERP system always carries a high risk and numerous projects failed. One common problem is that the implementation is considered as a purely technical project. An ERP system heavily influences all business processes that are supported by the system and thus, the management of a company has to be involved in the project to eventually redesign the business processes. Wagle names measures that have to be adopted to successfully introduce an ERP system (Wagle 1998).

2.5 Integration of Different ERP Systems

Ideally an ERP system should process all business transaction within a company. Besides, there is a great demand for automated transactions that cross organizational boundaries, especially since the growth of eBussines during the last decade. But the need for Electronic Data interchange (EDI) for business-to-business commerce existed long time before the emergence of the internet. X12 EDI (X12 2005), a widely adopted standard for data exchange, celebrates this year its 25th anniversary. Dayal et al. 2001 gives an overview of the historical development of business integration as well as state of the art standards.

Besides open standards for automated business-to-business (B2B) communication, like international EDI standards UN/EDIFACT (UN/EDIFACT 2005) and the above mentioned standard of X12 (X12 2005) or newer XML-based approaches like ebXML (ebXML 2005) and RosettaNet (RosettaNet 2005), there exist also integration frameworks from several vendors. The open standards mainly provide common data dictionaries and structures for data interchange. Integration Frameworks were developed by the major vendors of ERP systems SAP and Oracle as well as of Microsoft and several specialized service providers.

Despite the existence of standards, electronic data interchange is still considered as a problem in inter-organizational communication. Damsgaard and Truex (2000) analyzed the standards EDI and UN/EDIFACT and ascribed this fact to a substantial difference between standards for data interchange and purely technical standards like VHS for video recorders. As a consequence of the diverse needs in different branches of business it is almost impossible to define a universal and complete grammar for data interchange. Therefore, EDI standards are understood as “emergent languages” that have to be considered on two different levels: an institutional level that gives a guideline for enterprise data interchange. On the local organizational level this guideline should be flexibly interpreted and applied to specific needs.

3 Integrating RFID Data into ERP Systems

3.1 RFID Offers New Potentiality to Improve Effectiveness of ERP System

To control companywide resources effectively, managers make a lot of business decisions based on data provided by ERP systems. Without a consistent and high quality data input, business decisions cannot be really effective: "… much more effective business decision making based on the rational analysis of data rather than pure conjecture" (Edmund W. Schuster, et al. 2004 p. 13).

To get always correct data input in real time is difficult. Actually, in supply chain management, bar code as Auto ID is widely used. This is not the best way to get data input: "Despite the heavy use of data capturing (bar code) and data transmission technologies (EDI), data quality in the retail supply chain is still far from perfect. Some of the data quality problems are caused by a lack of integration between the physical and the virtual world." (Christian Tellkamp et al. 2004 p19).

Radio frequency identification (RFID), as an alternative approach, offers automatic product identification, can improve Data Accuracy, Objectivity, Timeliness and Completeness. "The biggest drawback affecting ERP is timeliness of inputs because of the difficulty in configuring true high-speed, fully automatic data collection points. In contrast, Auto-ID technology offers the potential to increase by an order of magnitude the amount, accuracy, and timeliness of data within businesses and supply chains. With Auto-ID, real-time streaming data, filtering, processing, and response are possible." (Edmund W. Schuster, et al. 2004 p. 14)

3.2 Technical Requirements and Application Integration Structure

3.2.1 New Technical Requirements

There are some new technical system requirements for RFID software infrastructures. The following requirements show that the development of RFID systems is a complex task:

1. Open system architecture: features of RFID technology include open standards and protocols for IT infrastructure interfaces, tags and readers, data codes and formats. "… the architecture should be based on existing communication protocols like TCP/IP and HTTP, as well as syntax and semantics standards like XML, PML and EPC … " (Christof Bornhövd, et al 2005). This means that all components, whether hardware or software, should interoperate regardless of the vendor.

2. Filtering and Aggregation of data: Plenty of RFID tags have to be read simultaneously. This potentially leads to some false or redundant reading of RFID tags or sensor devices. A powerful filter should be flexible and configurable so that next processes get only relevant information in different situations. Relevant information should be reorganized based on related events: “The infrastructure needs to support the composition of multiple related events to more complex events for further processing.” (Christof Bornhövd, et al 2005).
3. New features need new Applications: RFID systems offer a lot of new features such as: access control, condition monitoring, Transactions support, positioning/locating functions and so on. Every new feature/function like that must be developed and integrated in ERP systems.
4. Flexibility: Different business scenarios and different systems should be supported: “… the infrastructure needs to provide flexible means at the business logic layer to respond to abnormal situations, like the missing of expected goods or company-internal rerouting of goods. To avoid redundant implementations of the same business rules in different enterprise applications… ” (Christof Bornhövd, et al 2005).
5. Distribution of System Functionality: some business logic is spread over companies or across countries. RFID software system designer have to consider that: “… the Auto-ID infrastructure supports the distribution of message pre-processing functionality (for example, filtering and aggregating) and, to some degree, business logic across multiple nodes to better map to existing company and cross-company structures.” (Christof Bornhövd, et al 2005).
6. System scalability and administration: It is clear that RFID adoption will produce a lot of data and RFID should make these data clear, scalable and reliable. All infrastructures should be monitored, controlled and able to be tested.

To fulfill these requirements, the structure presented in the following section is necessary.

3.2.2 Application Integration Structure

“Many early RFID middleware solutions focus on features like reader integration and coordination, EPC track-and-trace tools, and baseline filtering capabilities. But these are just a subset of the many features that complete RFID middleware platforms must provide.” (Leaver 2004, p. 4) RFID system must have a balanced combination of some capabilities in the architecture. The architecture of RFID system is shown in Fig. 1.

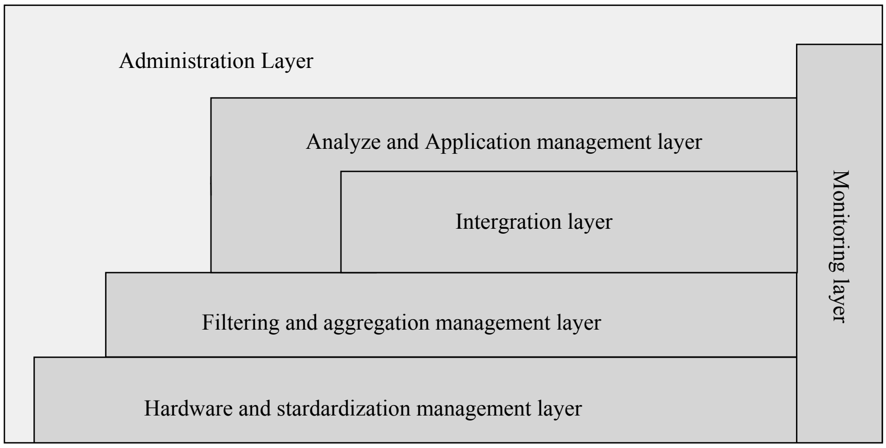

Fig. 1. RFID System Architecture
Source: Own Figure

This architecture consists of six layers:

1. Hardware and Standardization management layer: In this layer, a wide array of hardware platforms, including all sorts of readers and sensors should be configured, monitored, and integrated with applications and other technologies like barcode: "…For example, users should be able to tell a reader to "turn off" if needed. (…) Integration with other auto-ID or X-Internet technologies, like sensors and biometrics, is also important" (Leaver 2004, p. 4). Base information should be standardized, for example in PML (Finoerkemeier, C. et al 2003) format.

2. Filtering and aggregation management layer: This layer creates a consistent "image" of RFID data, so that these data source is scalable, reliable and based on a flexible data model. This means EPC or PML data from the low layer should be filtered, eventually routed or reorganized and saved. "… This capability should include both low-level logic like filtering out duplicate reads and more complex algorithms like content-based routing. Comprehensive solutions will also offer tools for aggregating and managing EPC data in either a federated or central data source. "(Leaver 2004, p. 4)

3. Integration layer: Incoming data should be made available and compatible throughout the supply network in this layer. This includes providing information to all relevant ERP applications, business partners and customers. "…It should also provide a library of adapters to popular WMS and SCM applications like SAP or Manhattan Associates, as well as APIs and adapters for using standard technologies like JMS, XML, and SOAP to integrate with other third-party apps. (…) RFID middleware must provide B2B inte-

gration features like partner profile management, support for B2B transport protocols, and integration with the EPCglobal Network, much of which is operated by VeriSign." (Leaver 2004, p. 4)

4. Analyze and Application management layer: In this layer data should be analyzed – ideally in real time – and applications should use this data to provide support for business intelligence. For example, Events manager have to support the "just in time" concept: "Instead of just routing RFID data to business applications, sophisticated RFID middleware platforms will actually orchestrate RFID-related end-to-end processes that touch multiple applications and/or enterprises, like inventory replenishment. Key process management and composite application development features include workflow, role management, process automation, and UI development tools." (Leaver 2004, p. 4-5)
5. Monitoring layer: There is no question that an RFID system is a complex platform that includes packaged routing logic, filtering, and integration with typical RFID-related applications and processes like receiving, shipping, and asset tracking and so on. All of them have to be monitored.
6. Administration layer: In this layer, the whole system should be managed. It provides exception handling and responses as well as testing of subsystems: "…RFID middleware platforms must include features for dynamically balancing processing loads across multiple servers and automatically rerouting data upon server failure. These features should span all tiers of the architecture — even the edge devices."(Leaver 2004, p. 5)

SAP research (Christof Bornhövd, et al 2005) has gathered some experience with RFID systems after designing the four-tier architecture of RFID systems and finishing some pilots with it. The experiences are about lessons learned such as "100% RFID Reading Accuracy cannot be Expected" or "Deploying an Auto-ID Solution is a Long Term Task." (Christof Bornhövd, et al 2005 p. 6). Besides, open issues were identified: "Different Qualities of Service", "Distributed Smart Items Infrastructure", "Networked Embedded Systems" (Christof Bornhövd, et al 2005 p. 7). This shows that RFID software systems still have a long way until reaching perfectness.

4 Software Vendor's Current Approaches Towards RFID Integration

4.1 Vendors' Profiles

According to a research by Forrester (Leaver 2004, pp. 1-2), RFID middleware has to combine both core infrastructure and packaged application features. Forrester divides the numerous vendors into four segments:

1. RFID pure plays that emerged from pilots by the Auto-ID center, which can make use of their valuable experience in the early days of development of standards (e. g. ConnecTerra, OATSystems)
2. Application vendors offering products from RFID-enabled applications for warehouse and asset management to RFID middleware with reader management, data filtering and business logic (e. g. Manhattan Associates, SAP)
3. Platform giants that extend their existing applications to integrate RFID to leverage their product (e. g. Oracle, IBM, Microsoft, Sun Microsystems)
4. Integrations specialists adding features to their existing integration software to handle RFID (e. g. webMethods, Seeburger)

While early adopters of RFID technology might make the best choice with smaller vendors, Forrester expects platform giants such as Oracle, Sun Microsystems, IBM; Microsoft and SAP to become more dominant once companies build broader RFID infrastructures.

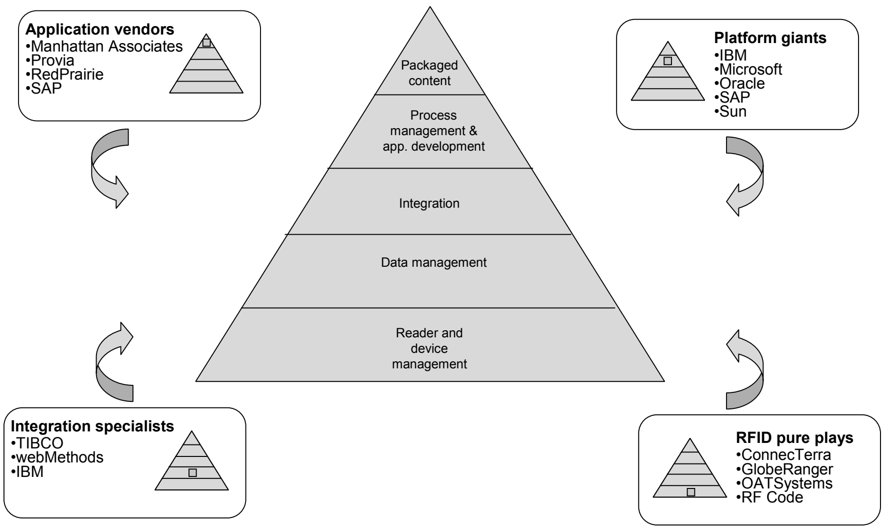

Fig. 2. Vendors' profiles

Source: Forrester Research, Inc.

4.2 Implications of the Early Market

As the Forrester Research paper from August 2004 puts it: The state of the market is "early, really early" (Leaver 2004, p. 5). This means that many products are still in development or testing phase and there certainly have not been made long-term experiences with them. This in turn means that there are very few independent researches on this topic and most information has yet to be compiled from the companies' own press releases and technical white papers. These of course don't offer architectural details which are valuable property of the companies, however they give a sufficient overview on different concepts, of which a few will be depicted here.

4.3 Oracle

Oracle, being one of the largest vendors for enterprise software, clearly belongs to the category of platform giants.

In April 2004 Oracle announced its Sensor-Based Services strategy (Collins 2004), which consists of supporting RFID and other sensors in its core database and application products. It also announced the release of two packages—the Oracle Compliance Assistance Package and the Oracle Pilot Kit. The Oracle Compliance Assistance Package is intended to help companies to fulfill RFID requirements from large retailers such as Wal-Mart, Target and Metro as well as from the Department of Defense. The second package, the Oracle Pilot Kit, includes drivers for leading RFID readers and tools to give these companies immediate insight into business processes. The drivers facilitate prototype testing and pilots.

Oracle Sensor-Based Services are features to capture, analyze and respond to data from different sensors, RFID being one of them (Oracle Press Release 2004).

Intel and Oracle cooperate on sensor-based computing to obtain the best performance and compatibility between their products.

Oracle Sensor-Based Services turn data from sensors into valuable information. Capturing, managing, analyzing and accessing data, acting on information and events – these are the key issues that Oracle identified in integrating RFID and other sensor-data into its current business solutions. In the white paper "Intel, Oracle and Sensor-Based Computing – Laying the Foundation for Maximum Business Value" (Oracle 2004, pp. 4-6), these key issues are being defined and related to the various software solutions offered by Oracle (Table 1):

Table 1. Oracle Software Solutions

Tasks	**Oracle Software Solutions**
Capture information	Oracle® Application Server 10g
Manage information	Oracle Database 10g
Analyze information	Oracle Business Intelligence Oracle E-Business Suite
Access information	Oracle Application Server Portal Oracle Wireless
Act on information and events	Oracle Application Server 10g

1. **Capturing Information:**
   Oracle Application Server 10g integrates and manages sensor readers. It captures and filters data before handing it over to a common data store that makes the data available to other applications and analyzes it.

2. **Managing information:**
   The large amounts of sensor data have to be stored and managed efficiently, a task met by Oracle Database 10g.

3. **Analyzing information:**
   The software package that deals with this aspect is Oracle Business Intelligence. In the event of changing business requirements it supports the process of taking decisions in matters that need to be settled fast but also have to be well-founded on the information that is available. The embedded analytical tools enable organizations to identify trends based on statistical evaluations and plan accordingly. Other useful tools are time stamping and version control. Oracle Business Intelligence covers areas as widespread as data access, analysis and warehousing, collaboration within the company and application development tools for customizing the software.

4. **Accessing information:**
   Oracle Application Server Portal and Wireless enables people in different locations to collaborate in real-time, providing them with data from online and mobile devices, creating a virtual single workplace.

5. **Acting on information and events:**
   Oracle Application Server 10g integrates systems, automates business-processes while enabling people to react on events and collaborate in real time.

The flexibility of Oracle concerning the adoption stage of a company is well worth mentioning. Depending on the stage of adoption, different deployment options are available. Also, an EPC compliance enabler ensures compliance with current mandates from large retailers.

Also other Oracle offerings, like the E-Business Suite and Oracle Warehouse Management include RFID capabilities to improve the process by sensor-based information.

In the research conducted by Forrester (Leaver 2004, p. 9), Oracle is mentioned as one of the key players in RFID deployment because of its flexible and multitiered architectures in RFID middleware. Forrester expects Oracle to have its strengths in data management and application development, because of its product strategy and experience in these areas.

4.4 SAP

According to Forrester (Leaver 2004, p. 4), SAP falls into the category of application vendors, specializing in offering packaged content, as well as into the group of the platform giants focusing on process management and application development.

SAP's NetWeaver is intended for companies to be able to design, build, implement, and execute fast new business strategies and processes (SAP 2005a). In short, NetWeaver component Master Data Management, supporting the management of master data and related rich content in a central repository, ensures data consistency across systems. NetWeaver component Exchange Infrastructure supports process-centered collaboration between SAP and non-SAP components, even between different locations. Another component of SAP NetWeaver is SAP Auto-ID Infrastructure (SAP 2005b), which enables the company to integrate RFID readers and printers. This component helps companies to comply with RFID mandates from the Department of Defense, the U.S. Food and Drug Administration and the main large retailers pushing RFID integration.

Integration of RFID into SAP offerings is aimed at two core processes:

1. Supply chain execution: features to improve the visibility of inventory, replenishments and returns and to manage claims
2. Enterprise asset management: features to improve identification of equipment, maintenance and inspection, and obtain up-to-date information on assets

SAP promotes easy integration of SAP RFID into the existing IT infrastructure and handling of large amounts of data through:

1. Connectivity with readers, tags and other devices
2. RFID data integration, filtering and management
3. Encoding and rewriting of RFID tags
4. Integration of large amounts of RFID data with back-end business processes

Currently, SAP plans other RFID solution packages to address business problems such as predictive maintenance and adaptive manufacturing.

Forrester (Leaver 2004, p. 9) identified SAP as the leading vendor for supporting RFID deployment because of its long experience on the edge between applications and infrastructure. Forrester also suggests decoupling the RFID middleware functionality, which is not the case so far, to keep ahead of others. To ease integration of RFID data across various applications and to ease data exchange within different companies, another suggestion made is that SAP should focus on SAP NetWeaver components like Exchange Infrastructure (XI) and Master Data Management (MDM) in its RFID middleware offering.

4.5 Microsoft

Microsoft certainly fits into the category of platform giants. Its enormous presence on the market for software in general and operating systems in particular alone makes it necessary to look at this player's current status and its future plans regarding EAI (Enterprise Application Integration), ERP and RFID.

Microsoft's best known solution for business integration is the BizTalk server. According to the BizTalk roadmap (Microsoft Corporation 2005) Microsoft is not planning to expand this platform in order to handle RFID data in the future.

On the application level Microsoft offers its own ERP Systems that cover different company sizes and needs. This is where RFID integration will take place in Microsoft products. In a press release from September 2004 (Microsoft Corporation Press Release 2004) it says: "Microsoft Business Solutions will provide a full range of RFID capabilities, from RFID reader management to the functionality needed to translate reader events into information relevant to business processes. (…) Microsoft Business Solutions plans to include RFID technology in upcoming ERP releases including Microsoft Business Solutions–Axapta® 4.0, Microsoft Navision 5.0 and the next major release of Microsoft Business Solutions--Great Plains®"

From a technical point of view this is surprising in the way that it is common sense that a first handling of the RFID raw data has to take place before it enters the ERP application. So either Microsoft has decided to build a special solution or their plans aren't as advanced yet. If it boils down to a special solution with proprietary elements there is the risk that it will suffer from the same lack of connectivity as the BizTalk Server did.

So Microsoft itself is not a competitor at the RFID software market at this time. However, Forrester Research put the company in the middle category of "Strong Performers" concerning "Future Scalable Deployments". (Leaver 2004, p. 11)

4.6 Sun Microsystems

The following statement from Forrester Research clearly shows the outstanding position of Sun Microsystems on the RFID software market: This company "is the first large platform vendor to introduce a generally available RFID middleware solution" (Leaver 2004, p. 14). It is called "Java System RFID Software Architecture" based on well-known Java standards.

This architecture is made up of two components: The "RFID Event Manager" and the "RFID Information Server" (Sun Microsystems 2005a, p. 3). They now will be introduced with respect to the layers of the application integration structure described in subsection 3.2.2.

The hardware and standardization management layer and the filtering and aggregation management layers are made up by Sun's Event Manager: The Event Manager is meant to receive data directly from the RFID tag readers and to process and transfer it in real time. So it is equipped with a "general-purpose event routing, collating, and filtering system" (Sun Microsystems 2005a, p. 5) that can be adapted to specific requirements by extending the basic functionality with user-defined processing modules. It also provides the capability to connect to the EPCglobal Network. So these features adhere to the EPCglobal standards.

In addition to the vertical extensibility in terms of provided functions the Event Manager is also scalable horizontally. It is designed for a distributed architecture that – according to Sun – provides "self-organizing, and network-centric capabilities" and makes it "highly scalable" (Sun Microsystems 2005a, p. 5). It is proposed that every "geographically remote site, such as a store, distribution center, or warehouse" (Sun Microsystems 2005a, p. 3) has its own Event Manager in order to localize data traffic and therefore reduce the overall traffic.

To avoid complex communication connections between numerous Event Managers on the one side and ERP systems or other applications on the other side the Java System RFID Information Server was introduced. It acts as a central integration layer as well as an analyzing and application management layer. Here all detailed data about the tagged objects is stored, possibly matched and enriched with other information sources from within the enterprise, and made available to higher-level applications, such as ERP systems. Also business-to-business (B2B) integration is possible (Sun Microsystems 2005b, p. 3).

However, no comment is made by Sun on where exactly the raw tag data should be enriched with the product details available from the global net services. Both, Event Manager and Information Server have these capabilities. According to the specific situation of the enterprise best practices will have to develop.

After Forrester Research has pointed out that "the product is missing graphical configuration and management tools, so buyers must have Java developers on hand – or must add graphical tools from third-party partners" (Leaver 2004, p. 14), Sun has developed a Web based GUI to provide a powerful and easy-to-use monitoring and administration layer (Sun Microsystems 2005c).

All in all Sun has already developed a promising architecture for RFID integration. This opinion is shared by Forrester Research. Sun therefore strengthens its position as a provider of comprehensive software solutions.

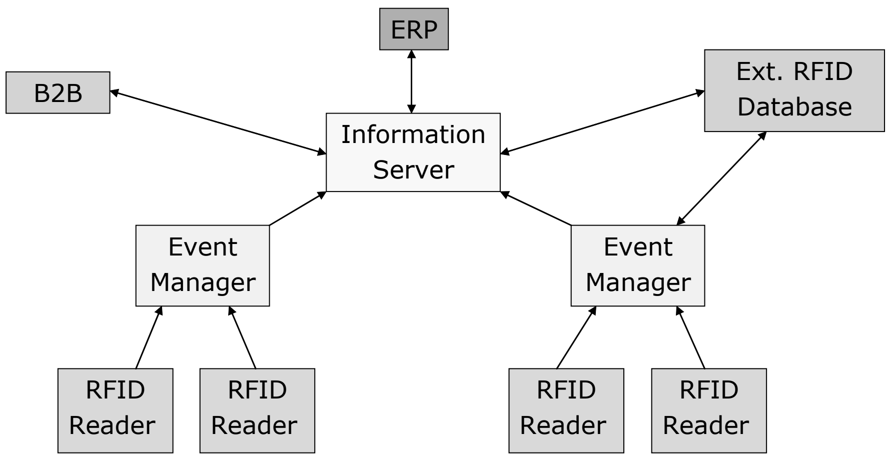

Fig. 3. Sun's Java RFID Architecture

Source: Own figure

4.7 Seeburger

Seeburger AG, founded 1986 in Bretten, Germany, is as the company itself puts it, “the sole provider to realize total partner integration” (Seeburger AG 2005). This means, in addition to integrating business data in a vertical way into ERP systems and other applications within an enterprise, their strength is the horizontal business-to-business connectivity between a wide variety of so called standards for business information interchange. This has made the company a recognized leader within the category of integration specialists and certainly puts it into a good position at the emerging RFID integration market.

Seeburger currently offers an RFID integration solution called “IDnet”, developed for logistics. This central platform is hosted from the Seeburger’s data centers and thus is clearly separated from the customer’s existing IT-infrastructure. It is meant to collect data coming from different RFID readers in different companies via internet and exchange certain data between companies. . This means that from the hardware and standardization management layer up to the analyzing and application management layer everything can be hosted by Seeburger, including even the filtering and aggregation management layer.

However, the RFID readers within a company, the central IDnet system and the company’s ERP system could be connected using Seeburger’s Business Integration Server “BIS” (Seeburger AG 2004, p. 1) which then could take over the tasks of certain layers to an extent that is not clearly defined.

The hosting concept was chosen to minimize changes in the customer’s existing infrastructure and therefore minimizing investment costs (Niemann 2004, p. 16). In addition Seeburger provides their customers with transponder chips free of charge, so the companies only need to buy RFID reader hardware at the beginning. The charges for renting the hosted infrastructure are “calculated on the number of requests of information”. (Seeburger AG 2004, p. 2)

According to Seeburger’s integration experience this solution probably won’t have many restrictions in terms of connectivity at the integration layer. However, from a technical point of view it remains unclear where in the architecture the RFID data is being filtered, enriched and processed. On the one hand the RFID readers’ data traffic will have to be localized reaching a certain amount of traffic, but on the other hand this would need changes in the companies’ IT systems again and will therefore reduce the advantage of the hosting concept.

A strength of Seeburger’s solution, however, seems to be the monitoring and administration layers which are made up by powerful graphical tools. They include easy-to-use visualization of material flows and comprehensive simulation functions.

With this offered package Seeburger has come out of the corner of the highly specialized integration business and taken a step towards a more comprehensive service provider embracing all required layers introduced in subsection 3.2.2. By this they certainly gain reputation as designers of the latest technological developments; however, they also face new competitors in this area. So it is questionable if they can be as successful as they have been within the pure integration business in the past.

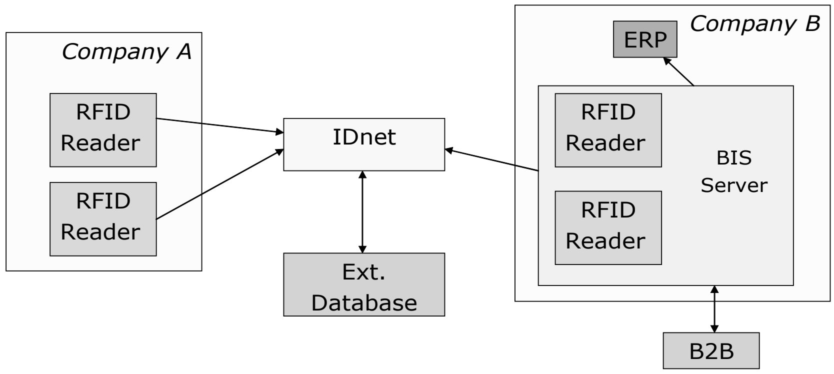

Fig. 4. Seeburger's IDnet
Source: Own figure

4.8 Other Vendors

These have been examples of different approaches that are taken by the industry towards RFID integration into existing IT infrastructure today. However, there are several vendors that were not depicted here but should be mentioned due to the fact that in this early stage of the market the players' positions are not fixed. Among these vendors especially IBM, Savi Technology and Manhattan Associates seem to be of importance.

There are some companies that are also heavily involved in developing relevant technology on a lower level, however not offering ERP integration. According to the mentioned categories one could refer to them as "RFID pure plays". Among them are OATSystems, ConnecTerra and RF Code, whose products merely offer integration tools. (Leaver 2004, p. 12)

On the other hand it was already showed that there are vendors that focus on integration rather than on providing the low-level infrastructure, like TIBCO Software and webMethods.

Combined with each other these two specialized kinds of products could serve as a complete solution for integrating RFID data into ERP systems (Leaver p. 15).

However, the hope of big players like SAP is that a complete solution delivered and maintained by one single company is more attractive in terms of complexity and convenience for the customers. The development of the market will show which of the different concepts will take hold.

5 Conclusion

ERP Systems are an essential element in today's business life. As processes become more complex they allow companies to manage their resources effectively. RFID technology can help to build more accurate models of the business processes; however, this increases the complexity of data processing.

Thus requirements for RFID software systems are complicated and chameleonic. RFID systems should be flexible, multitiered architectures. These systems have to be able to deal with high-volume data and support the integration with different ERP systems as well as the communication with trading Partners and customers

In this rising market several vendors with different approaches and focuses are starting to compete for providing the most sensible integration systems. Platform giants such as SAP as well as integration specialists like Seeburger have started to offer or are planning to offer individual concepts like hierarchical structures or hosted platforms, with each of them having their own advantages and disadvantages. In order to analyze these systems thoroughly costly evaluation methods have to be performed.

However, as the market grows more experience will be made with these systems by customer companies and the most sensible solutions will have the chance to become highly demanded products all over the world.

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The EPCglobal Network™

Stefan Hudelmaier, Dominik Schmidt, Philipp Torka, and Nino Ulsamer

1 Introduction

This paper introduces the EPCglobal Network, a standard proposed by EPCglobal. The network combines the benefits of modern RFID technology with those of globally accessible information systems in order to allow all entities along and beyond the supply chain to recall data about an arbitrary individual product. The products are identified by RFID and the data is directly provided by the manufacturing company.

The first section will provide a general overview on the EPCglobal Network. Hereupon, the subsequent sections will discuss the different components as well as the interactions between them. Finally, a conclusion will point out possible applications, chances and limitations of the standard.

2 Overview

2.1 Motivation

Prior to the development of the EPCglobal Network, there was no global standard for collecting and communicating product-related information. (EPCglobal 2004a, p. 4) In fast moving times of international, highly connected collaboration raising needs for reliable track and trace applications, product specific online information and just in time deliveries, this proves essential however.

The EPCglobal Network enables generic product identification in real time and thus supports supply chain processes considerably. It ensures a consistent, reliable and always up to date data supply. Finally, it achieves major time savings due to the removal of the line of sight requirement by using RFID. Thanks to the radio frequency technology, products do not need to be moved or unpacked for identification anymore. (EPCglobal 2004a, p. 8)

2.2 Status

The implementation progress of the EPCglobal Network is still in an early phase (Grasso 2004, p. 9). In September 2003, version 1.0 specifications were released at the EPC Symposium in Chicago. Meanwhile, large parts of the network are being redefined whereas focus shifts from defining components towards defining interfaces (Harrison 2004b, p. 22; Harrison 2004a, p. 1).

2.3 Network Structure and Components

The following figure shows the standard architecture of an EPCglobal conforming network.

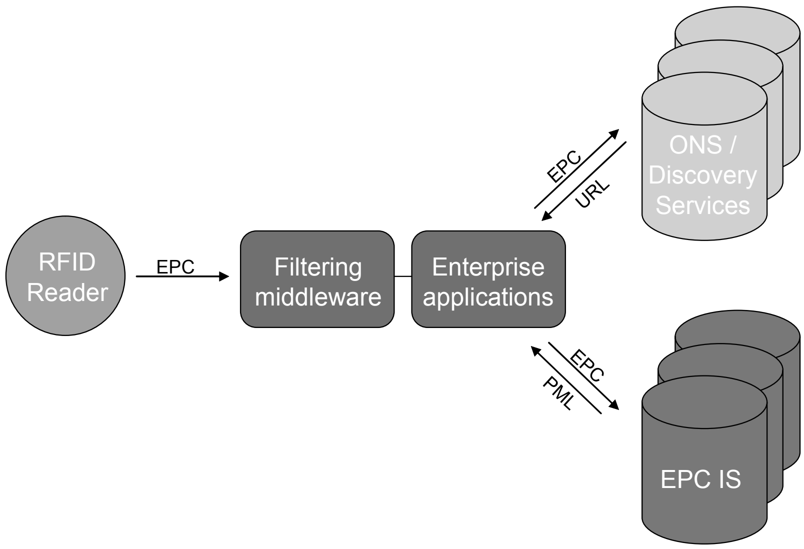

Fig. 1. Architecture of the EPCglobal Network

Source: EPCglobal 2004a et al.

The Electronic Product Code (EPC) is the globally agreed standard for product identification and is designed to assign a unique identification number to every single product worldwide.

The middleware and the enterprise applications occupy a central position within the whole structure. Firstly, they are connected to the physical RFID reader device. Secondly, they establish connections to the information providers on the Internet and therefore serve as a gateway.

The ONS system provides naming services helping the middleware component to contact the appropriate information hosts which form the so called EPC information service (EPC IS). These servers are usually operated by manufacturing companies. The actual product-related data is stored in the EPC IS and can be queried by the enterprise applications. The EPC IS servers take advantage of the Product Markup Language (PML) and encode the requested information using this standard.

2.4 Taking Advantage of Distributed Applications

During the past couple of years, a trend emerged leading from centralized systems to distributed applications. The EPCglobal Network can be considered as one example for this.

Distributed applications are executed in networked environments and share the workload between different computers. The single machines communicate using the message passing or shared memory paradigm and often specialize in a certain task. (Coulouris et al. 2001) For instance, the ONS servers are solely responsible for resolving EPC numbers into server addresses.

This is for several reasons. Firstly, a decentralized network increases the overall performance considerably. Secondly, critical services can set up redundantly on different systems in order to maintain a high level of resilience. Finally, different tasks can be controlled by different institutions, which allows a reasonable and necessary division of work.

For example, the middleware component might be operated by a retailer, whereas the EPC IS server is run by the manufacturing company. This enables the retailer to query the manufacturer's database for a particular piece of information.

3 Electronic Product Code

3.1 Characteristics

The two main characteristics of the Electronic Product Code (EPC) can be summed up with its universal scope and its uniqueness. Indeed, the EPC is intended to assign a distinct number to any individual object making it uniquely identifiable (EPCglobal 2004b, pp. 8-9).

This assignment establishes the basis for a reliable global tracking and tracing. However, the EPC does never contain additional data such as object properties. All advanced product-related information has to be obtained from the EPC IS.

Several predefined EPC classes facilitate the integration of legacy standards like the Global Trade Identification Number (GTIN). At present, GTIN numbers can be found on almost every retail product, mostly in conjunction with a barcode (Brock 2001a, p. 13). Since most of these standards do not distinguish products on item level, they have to be serialized though. In addition to the standard classes, the EPC definition also permits user-defined extensions.

Furthermore, the EPC specification differentiates between pure identities and tag encodings. The latter ones allow different encodings of the same EPC identification number in order to meet certain hardware requirements. In contrary, pure identities abstract from the actual application.

3.2 Components

3.2.1 Overview

As already mentioned, the EPC specification comprises several classes for compatibility reasons. Basically, there is just one new class, the other currently existing classes are based on legacy standards like GTIN. This section will cover the components of the new general identifier (GID) as well as of the SGTIN class, a serialized version of the GTIN system. Other legacy standards are represented accordingly.

Every EPC encoding starts with a header which determines the class and the length of the code. The remaining digits depend on the chosen class.

3.2.2 GID

A GID conforming pure identity contains three fields: a general manager number, an object class and a serial number. The general manager number is the unique identification of the organizational entity which "is responsible for maintaining the numbers in subsequent fields" (EPCglobal 2004b, p. 11). The object class number is intended to describe the product, for example a certain book, the serial number finally refers to a single item and has to be unique within the object class.

The GID-96 encoding simply combines these numbers with an appropriate header creating a code with a total length of 96 bits:

Table 1. GID-96 specification

Field	**Header**	**General manager**	**Object class**	**Serial number**
Length	8 bits	28 bits	24 bits	36 bits
Value	0011 0101 (binary value)	*[268,435,456 possible values]*	*[16,777,216 possible values]*	*[68,719,476,736 possible values]*

Source: EPCglobal 2004b, p. 19

3.2.3 SGTIN

An ordinary GTIN is composed of an indicator digit, a company prefix, an item reference and a check digit. The company prefix can be compared to the general manager number of the GID. The indicator digit and the item reference are combined to one number and form a rough equivalent to the object class of the GID. The check digit becomes redundant with RFID technology and is thus omitted.

Since GTIN identifies entire object classes only, a unique serial number has to be added during the conversion. There are two encodings of SGTIN (SGTIN-64 and SGTIN-96) which are equivalent in terms of representing a pure identity. The following table shows the 64-bit variant.

Table 2. SGTIN-64 specification

Field	**Header**	**Filter value**	**Company prefix**	**Item reference**	**Serial number**
Length	2 bits	3 bits	14 bits	20 bits	25 bits
Value	10 (binary value)	*[8 possible values]*	*[16,383 possible values]*	*[9-1,048,575 pos. values]*	*[33,554,431 pos. values]*

Source: EPCglobal 2004b, pp. 20-21

The additional filter value allows further categorization for efficient filtering operations and is not part of the pure identity. The number of possible values for the item reference depends on the company prefix.

4 EPC Middleware

4.1 Terminology

The term "middleware" is used to describe a software component acting as an intermediary between two systems. On the one hand it facilitates communication by providing a convenient interface for the connected systems to use for exchanging data. On the other it may perform certain computations in order to decrease the number of information interchanges needed between the communication partners, thus improving efficiency.

In the context of RFID the software component that directly communicates with the readers is called middleware. Its paramount functions are to be compatible with readers from as many manufacturers as possible and to provide a uniform interface to programs wanting to access those readers or rather the information the readers have gathered. It also has to include filters for the information received, such as noticing and resolving ambiguities, i. e. when two readers have scanned the same RFID-tag.

4.2 The EPC Middleware Component

The middleware component of EPC as envisioned by the Auto-ID and EPCglobal groups has undergone a rather drastic change in the course of the development of the overall system. As per the specifications developed by the Auto-ID group in 2003, the middleware component was to be called 'Savant' and very strict requirements were imposed on the inner workings of any program wanting to bear that name and fulfill that function in the EPCglobal Network. In the 2004 specifications created by EPCglobal, the Savant was replaced by the so called Application Layer Events (ALE), which have a slightly different role. The requirements mostly focus on homogeneous interfaces and event handling (Harrison 2004b, p. 29). Unfortunately the exact specifications of ALE are not yet available as they are scheduled to be released in Q4 of 2005, so this document will have to remain sketchy in this regard.

4.3 The Savant

Version 1.0 of the specifications developed by the Auto-ID group, the predecessor of EPCglobal, contained a system named ‘Savant’ to act as the intermediary between the RFID Readers and Enterprise Applications. It was also to be able to directly communicate with the local EPC Information Service and update its database with information newly acquired by the readers. One of Savant’s most important features was its modular layout to allow for as much flexibility as possible, since the Auto-ID group realized that the uses of EPC would be very diverse indeed (Clark et al. 2003, p. 12). It is important to note that the term Savant doesn’t refer to a single implementation of a program, but is rather a description for any program fulfilling the requirements stated in the Savant specification. External applications were to communicate with Savant using remote procedure calls (RPC), using either XML or SOAP (Clark et al. 2003).

4.4 Application Layer Events (ALE)

As has already been mentioned, the detailed specifications for ALE have not yet been published, so this section will focus on what is currently known.

4.4.1 Differences to Savant

In 2004 EPCglobal revised the layout of the EPCglobal Network. One of the most prominent changes was the replacement of Savant by the so called Application Layer Events. The borders between hardware and software and between the different software components respectively have become less strict, allowing them to expand on their roles, such as a Smart Reader doing some filtering itself. Also fewer requirements are placed on an implementation of the middleware component, with most of the specifications focusing on the nature of the interfaces. The reader device management is not a part of ALE as it was with Savant. It is rather set up on top of another layer in direct connection with the readers. A model for the reader management layer is currently also being developed by EPCglobal.

4.4.2 Structure

The following figure will provide an overview on ALE.

As shown in Fig. 2, the readers are transmitting the EPC numbers they have scanned to ALE, where they are digitally represented in an abstraction layer either as single logical readers or locations, which can encompass numerous physical

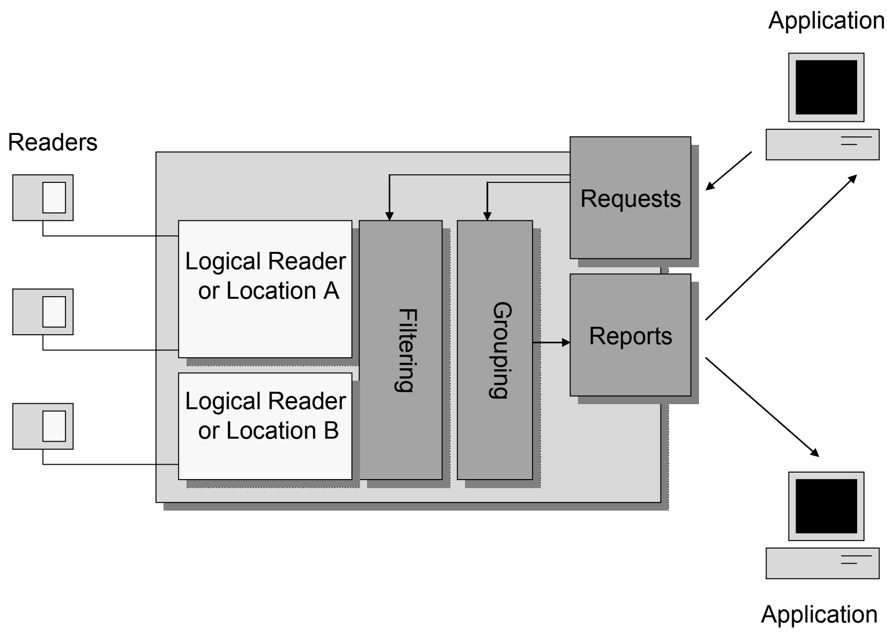

Fig. 2. Application Layer Events schematic view
Source: Auto-ID labs, Cambridge 2004

readers (Traub 2005). The data received is then filtered, to extract the important events out of the huge amounts of data collected by the readers. This is necessary as the readers continuously scan their surroundings for tags. Without filtering capabilities of their own, they constantly transmit the EPC numbers – and possibly other data from sensors etc – they have read to the application layer. So as to not overwhelm external applications that are connected to ALE, the above mentioned filtering has to take place. For example an external application should only be notified once, when an item has been scanned for the first time and not be informed continuously of its presence each time a certain reader extracts its EPC number.

4.4.3 Communication with External Applications

Applications can request information either singularly (e. g. "Where is item XY now?") or request a report to be delivered in certain intervals (e. g. "Tell me the whereabouts of item XY every 5 minutes!"). It is also possible for the requestor and the recipient of a certain report to be different. ALE has grouping capabilities, like treating every item belonging to the same product group alike. A report sent to an external application may contain the following information (Harrison 2004b, p. 29; Traub 2005):

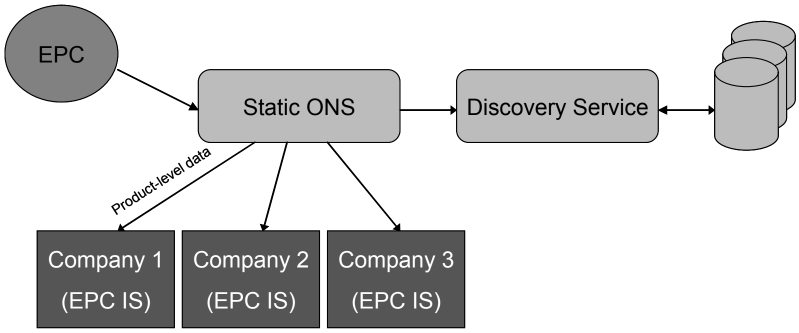

Fig. 3. Name services
Source: Harrison 2004b, p. 28

1. Timestamp
2. Responsible Logical Reader or location
3. List of EPC numbers (either all that have been read or only those that have either appeared or disappeared)
4. Number of tags of a certain group (certain company, product class etc.)

The format of the requests is specified using WSDL (Web Services Description Language). Describing the interfaces in such a way makes it easier to formally check if certain programs completely comply with the specifications, which is important for certifications (Harrison 2004b, p. 22).

5 Name Services

According to Fig. 3 a typical request for data on an EPC involves three parts. First, there is the (Static) Object Name Service which provides services to get information about a product directly from the manufacturer. Second, there is the EPC Information Services (EPC IS) managed by the manufactures which hold all data on the relating products. Third, there is the EPC Discovery Service. This part is still under development and yet not strictly defined but will offer services to manage track and trace operations on a certain product (Mealling 2003, p. 5; Harrison 2004b, p. 27). In older literature discovery services are often referred to as the dynamic part of the ONS.

5.1 Object Name Service

The Static Object Name Service (ONS) builds a connection between a certain product and all information about this product gathered during a RFID tracking process. The necessity for this connection is due to the distributed design of the

EPCglobal Network. The following sections will provide a detailed look at the architecture of the service, compare it to the established Domain Name System (DNS) and describe an approach to build the ONS service upon the existing DNS.

5.1.1 Underlying Principles

The main issue for the ONS is the number of queries that will have to be handled. According to VeriSign (2004a, p. 8) this number could be more than 100 billion queries per day in the future. Therefore scalability is a major requirement for the ONS which means additional hardware can be provided in order to improve the performance of the system and not limit its size.

Another requirement for the system is the ability of caching (Auto-ID Center 2002, p. 5). Caching allows storing information received from a former query and using this stored information in order to speed up the lookup process for the next query.

For the purpose of model close to reality the ONS service should be managed hierarchically (Auto-ID Center 2002, p. 5). A query is sent to the topmost member of the ONS which redirects the request to a lower level that might be the manufacturer level, then down to the product level and so on. This kind of management allows the before mentioned caching strategies and scalability to be implemented easily.

A system which has the same requirements and already exists is the Domain Name System (DNS) as mentioned above. The following section will exemplary describe a DNS query and compare the system to the ONS.

5.1.2 Domain Name System

The process starts when a user enters a domain name (Uniform Resource Identifier, URI), for example “www.cdtm.de”, in his web browser. As a result he wants to see the homepage of CDTM. The browser itself therefore has to find out the IP address of the CDTM web server, send an HTTP query to this server and retrieve the corresponding HTML code. The first step for the browser is to find out the IP address of the entered domain name. For this purpose it sends a query to the local DNS resolver which is usually implemented by the operating system. The DNS resolver itself forwards the query to a preset recursive DNS server which could be hosted by the user’s internet service provider. This recursive DNS server now contacts one of the root authoritative DNS servers. From this point on there are two possibilities. The first one is that the authoritative server has an entry in its database pointing to the IP address of www.cdtm.de. This is unlikely to be the case because there are billions of domain names and the scalability principle would be violated if every domain name in the world had an entry in the authoritative servers. It is more likely that the authoritative server holds an entry for the “de” domain. It returns this entry to the recursive DNS server which takes this address and retries its query for www.cdtm.de. Again, this query can be either the wished result or be another redirection to an authoritative server which holds in

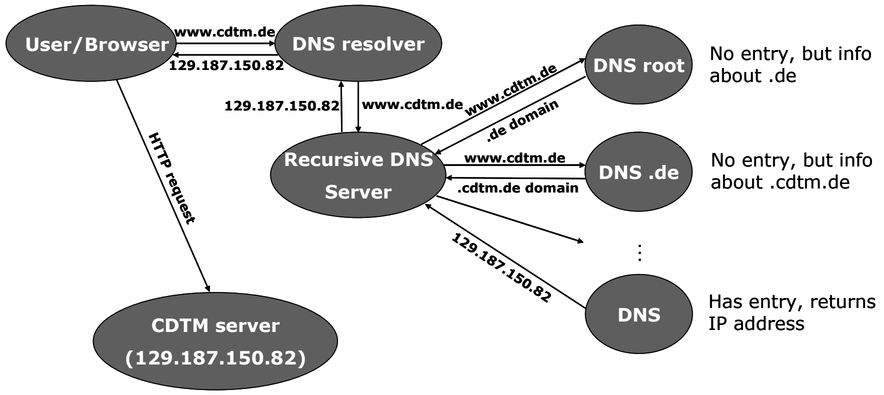

Fig. 4. DNS lookup of www.cdtm.de

Source: Own illustration

formation about the "cdtm.de" domain. This process is recursively repeated until the IP address of www.cdtm.de is found (Larisch 2002 pp. 229-244).

The DNS fits to the requirements from section 5.1.1. As already mentioned the system is scalable. With the division into name spaces the data is both organized in a hierarchical matter and divided into smaller parts that can be handled by different servers. To make the lookup faster caches can be added at every step of the procedure. That makes the whole system quite inflexible at short notice because old data is being held in caches and can't be updated within minutes.

The following section describes the implementation of the ONS using the existing DNS infrastructure.

5.1.3 Implementation of ONS

Since the structure of the ONS is very similar to that of DNS one way to implement the ONS is to use the existing DNS and set up another layer on top of it. This layer uses the functionality beneath and therefore shares all advantages and disadvantages of DNS.

When a program wants to communicate to a PML server of a given product it first has to transform the product code into a format that it can pass on to the DNS, i. e. an URI. Details on that operation can be obtained from Mealling (2003, p. 8).

Due to performance reasons the current implementation of the ONS only resolves the EPC up to the product level, so the serial level is being left out. The advantage of implementing the ONS on a serial level would be consistency. If the ONS is only used to look up products on a product level, but information on a serial level should be obtained, another protocol has to be defined to bridge that gap. But the load on the ONS would increase dramatically as every single entity would have to be looked up making caching quite difficult (Uo et al. 2004, p. 6).

5.2 EPC Discovery Service

5.2.1 Classification

The ONS system as specified in version 1.0 is not capable of providing an automatic track & trace mechanism (Flörkemeier 2004, p. 13). Especially if it comes to a serial-level view that changes very dynamically DNS technologies may not be appropriate (Harrison 2004b, p. 27). The EPC Discovery Service registry being currently under development is intended to enable "efficient track-and-trace capabilities through the EPC Network" (VeriSign 2004a, p. 2).

5.2.2 Mode of Operation

As the client is in charge of contacting different EPC Information Services (EPC IS) while performing a complex query it is necessary to implement "real-time dynamically updateable directions" that provide information about which ECP IS holds data connected to a specific product – usually being identified by an EPC (Harrison et al. 2003, p. 11). Harrison et al. (2003, p. 12) propose a "secure registry" that implements the functionality of keeping track of all sources of information related to a specific EPC. The registry mechanism of the EPC Discovery Service was formerly referred to as "Dynamic ONS" (Harrison 2004a, p. 9). It may also hold associated timestamps or even indication flags.

A mechanism for each custodian to update a registry is being provided by the EPC Discovery Service registry (Harrison 2004a, p. 9). Whenever an EPC IS stores data related to a specific EPC it updates the EPC Discovery Service registry. This scenario usually occurs when a handover from one custodian to another custodian takes place (Harrison 2004b, p. 28).

6 EPC Information Service

6.1 Classification

Harrison (2003, p. 3) defines the EPC Information Service (EPC IS) as a service which "provides a standard interface for access and persistent storage of EPC-related data, for read and write access by authorized parties." In a different definition VeriSign (2004a, p. 1) proposes that the EPC IS "stores and retrieves serial-number-specific product information about products as they move through the supply chain" – focusing more on the nature and purpose of data.

As the actual information about a specific product is not stored on its tag the remaining description data moves to networked databases: the EPC IS at which the Electronic Product Code (EPC) is generally being used as a database key (Brock 2001b, p. 2; Harrison et al. 2003, p. 4). In this context it is important to realize that the EPC IS stores event data at an instance-level granularity which will naturally result in large amounts of data (Harrison 2003, p. 4).

6.2 Architecture

6.2.1 Mode of Operation

The EPC IS layer is the lowest level in the EPC Network architecture where business logic is combined with raw data coming from the sensoring framework (Chawathe et al. 2004, p. 1192; Harrison 2004a, p. 7). Harrison (2003, p. 4) identifies several key requirements to be implemented by an EPC IS such as “access to a long-term repository of low-level Auto-ID event data” as well as “access to higher-level time-stamped data”, see also Harrison 2004a, p. 7.

There is no standard on how the product data have to be stored inside the server. Brock et al. (2001, p. 7) point out that companies can maintain data in existing formats with current procedures: EPC-related data can be stored in information systems of different types (Harrison 2004a, p. 5). Fig. 5 illustrates a setup where the data are held in different systems but can be accessed using the EPC IS in a transparent way. The Physical Markup Language (see below) otherwise is intended to be an exchange format.

One key aspect of the EPC IS architecture is that the data about a specific object is not necessarily stored on a single server – EPC IS (and especially the instance-level data) will be fragmented across the supply chain (Harrison et al. 2003, p. 4). Furthermore the external EPC IS provided by a company will usually only provide data that is held locally (Harrison 2004a, p. 6). That way the client is in charge of accessing multiple ECP IS in order to receive further data; see Fig. 5 (Harrison et al. 2003, p. 9; Harrison 2004a, p. 5). The way the client manages to get to know where additional information can be found is being discussed in the EPC Discovery Service paragraph (see above).

Types of Data

EPC IS stores two general types of information: On the one hand EPC IS holds event information including a timestamp and on the other hand it stores (static) attribute data (Harrison 2004a, p. 4; Harrison 2004b, p. 16). Time-stamped data can consist of either

1. Observations (“Who? When? By Whom?”),
2. Transactions (“Why? Which ones?”),
3. Measurements (“How?”) or
4. Containment/ Symbolic Locations (“Where?”)

(Harrison 2003, pp. 5-6), whereas static data can contain a much wider range of attributes (Harrison 2003, p. 8). Static data can be subdivided into class-level (standard properties that are the same for all instances of the same product type) and serial-level (instance-specific) data (Harrison et al. 2003, p. 5; Harrison 2004a, p. 4). For the time-stamped data it is necessary to get information on the current state as well as to trace the data history (Harrison 2004a, p. 4).

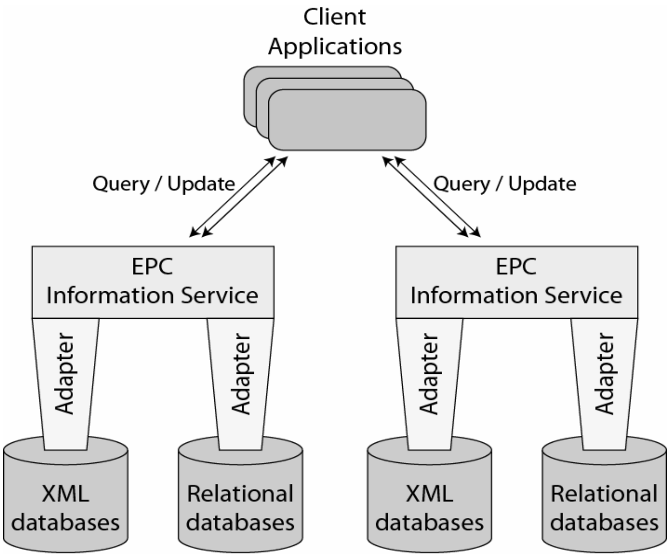

Fig. 5. EPC IS usage by client applications
Source: Harrison 2004a, p. 5

6.3 Security

EPC IS is the entity being responsible for the actual access to information. Thus each company can control access to data associated with its EPCs as the EPC IS is managed at the local level. As already mentioned above the EPC IS will be fragmented. Therefore, it is possible that each company providing an EPC IS can define in detail which data can be accessed by whom (Harrison et al. 2003, p. 4).

Complex queries may need to get access to data from different servers in order to come to a result (Harrison et al. 2003, p. 4). As contacting other servers has to be done by the client there is no security risk which could otherwise arise if an EPC IS which may have more rights than a client contacts other servers itself and delivers the results to the client.

As EPC IS is going to provide web services XML Digital Signatures are considered as a solution for authentication (Harrison 2004a, p. 6).

6.4 State of Development

The EPC IS was formerly known as PML Server/Service (Harrison 2004b, p. 31; Harrison 2004a, p. 1). It is still in a rudimental state of design according to Flörkemeier (2004, p. 12).

Recently a modular design has been proposed: The client can trigger the server to provide an interface description for each method or capability it offers (Harrison 2004b, p. 32) – but the EPC IS standards are still under development (Harrison 2004b, p. 34).

7 Physical Markup Language

7.1 Classification

The Physical Markup Language (PML) is designed to provide a universal standard (also referred to as a "common 'language'" (Brock et al. 2001, p. 4)) in order to describe physical objects, processes and environments for use in IT systems (Brock 2001b, p. 1).

Although there is much more information in the physical world than can be represented in a markup language there are common characteristics of physical objects (for example volume or mass). The intention of the PML core components is to adequately describe those basic physical properties (Brock et al. 2001, p. 4).

According to Harrison (2004a, p. 3) PML was refocused to "concentrate on a well defined PML Core" (see below) that can describe low-level event data coming from the EPC sensoring framework. In general PML enables the distribution of EPCglobal Network objects related information by providing "common, standardized vocabularies" (Flörkemeier et al. 2003, p. 6).

7.2 Basic Principles

It was chosen not to invent a new syntax for PML but to use the Extensible Markup Language (XML) as it is already widespread and a multiplicity of applications exists (Brock 2001b, pp. 4-5, Brock et al. 2001, p. 5). As XML is a metalanguage that is intended to describe the form and structure of other languages PML is essentially a specific schema of XML (Brock et al. 2001, p. 5). Brock et al. (2001b, p. 6) emphasize that "the intention of PML is [to] capture and describe the real-time state of the physical environment." Furthermore PML should not store any data that can be inferred from other data (Brock 2001b, p. 4).

PML is designed to support the unambiguous description of hierarchies such as compositions of objects (Brock 2001b, pp. 5-6). But there is no need to use the PML format in order to store the actual data. In fact, it is a method to demark information for distribution. That is, companies do not have to change their existing storage formats – "a PML 'file' may only exist during transmission" (Brock et al. 2001, pp. 6-7). PML only specifies in which way the data should be communicated (Harrison et al. 2003, p. 4).

7.3 The PML Core

The description capacities of the PML Core as specified by Flörkemeier et al. (2003) are focused on observables, i. e. physical objects that can be observed or data that can be measured by sensors. The underlying model consists of sensors, observations and observables: "An observer or sensor makes certain observations of certain observables" (Flörkemeier et al. 2003, p. 26).

In order to represent those entities a set of different elements can be specified:

1. The Sensor Element which can contain one or more
2. Observation Elements consisting of elements to describe the observed parameters (such as DateTime, Tag or Data Element).

Fig. 6 shows a simple PML document containing the observation data of one sensor. In addition it is also possible to represent tags with onboard sensors by using a recursive structure of elements.

```
<pmlcore:Sensor>
    <pmluid:ID>urn:epc:1:124.162.37</pmluid:ID>
    <pmlcore:Observation>
        <pmlcore:DateTime>2002-11-06T13:04:34-06:00</pmlcore:DateTime>
        <pmlcore:Data>
            <pmlcore:Text>temp=22,24,25,22,22,23,22</pmlcore:Text>
        </pmlcore:Data>
    </pmlcore:Observation>
</pmlcore:Sensor>
```

Fig. 6. Sample PML document

Source: Flörkemeier et al. 2003, p. 32

According to Harrison (2004b, p. 31), there is currently no further work on PML in progress.

8 Conclusion

If one has a look at the progress of the EPCglobal Network over the last few years, one can see that there is a very active development going on. In order to profit from all the benefits such an imaginary network of products would offer, standardization is a big issue. The EPC is almost accepted as a standard even though companies might come up with their own individual solutions to maximize their benefit. The middleware component, ONS and Discovery Service are still under development but standards are tried to be found as well.

EPCglobal is currently forming such a standard by introducing the EPCglobal Network. It instructed one of the big players in internet technology, VeriSign, to implement the ONS and Discovery Service (VeriSign FAQ). It set up task forces to work on open topics and find standards there. The consensus here is to define interfaces rather than strictly defining what each single component should do (Harrison 2004a, p. 1).

The internet is a living example of a network that grew on its own and could form standards that are now accepted by everybody. The EPC network still has to make this step in order to fully evolve its power.

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Physical Layer of RFID Systems

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1 Introduction

This report focuses on the physical layer of radio frequency identification (RFID) systems. The purpose of this report is to describe the basic principles of RFID technology as well as its problems and possible solutions for these problems. First the components and the basic principles of such systems will be described. Then the characteristics and performance of the most important frequency ranges will be discussed. Afterwards the communication between readers and tags will be explained. At the end different tags, their manufacturing process and different readers are described.

2 Components and Basic Principles of RFID Systems

2.1 Components of RFID Systems

A RFID implementation consists of 3 different components:

1. Transponders, also known as tags
2. Readers
3. Data processing system

A tag can be seen as the data medium. It consists of a microchip, some kind of coil or antenna and is attached to an object which should be traced or identified.

The reader is able to retrieve the data stored on tags in its range and has to validate it. The retrieved data is passed on to the data processing system.

There are a couple of significant differentiators for RFID systems. Most of those differentiating factors are tag specific but there are also differences in the communication between the reader and a tag and the reader itself.

The tags can be supplied with power in 2 different ways: Passive tags are operating without a battery and therefore use the power transmitted by the reader, active tags need a battery to work.

Most tags have a static memory and a static functionality (state machines). This means the data and also the functionality is defined at the time of chip production.

For simple applications those tags are sufficient, but there are also chips available which use different types of writeable memory. In some rare cases even microprocessors are used on tags. With microprocessors it is possible to change the functionality of a tag in its life cycle. These more advanced tags are necessary if additional data (for example from a connected sensor) has to be written to the memory or if security features have to be implemented.

The communication of reader and tag can also work in different ways. The data can be transferred via different frequency bands and with different techniques. Another differentiator is the mode of operation, which defines if reader and tag are sending data/energy simultaneously or one after the other.

Readers can be static or mobile (Peoplesoft 2004, pp. 3-4), (Finkenzeller 2000, pp. 11-14).

2.2 Three Possible Principles to Transfer Data Through the "Air Interface"

To understand the wireless data transfer it has to be clear that every data transfer is an energy transfer of some form. Electric, magnetic or electromagnetic alternating fields are used to perform the wireless transfer. The difference between data and energy transfer in the following section is the power which is transmitted by those fields. To transfer data, relatively small fields are sufficient, as against strong fields are needed to transfer power which is enough to operate e. g. a microchip.

In this section the different possibilities of wireless data transfer will be described. The used frequency bands will be discussed in a later section.

There are 3 possible ways to transfer data from the tag to the reader. The used principle and the matching frequency band define the range of the specific RFID system. Most widely spread is remote coupling which is used for short range data transport (up to 1 m). Backscatter coupling is used for long range data transport. Close coupling systems are used for very small ranges (up to 1cm) and are relatively rare (Finkenzeller 2000, pp. 23-25).

2.2.1 Remote Coupling

Remote coupling uses inductive coupling (Fig. 1) as its basic principle. It is the most common RFID coupling and is used for short range systems. Full duplex and also sequential systems can be used for this coupling method (Finkenzeller 2000, p. 29).

Power Supply

Remote coupling tags are usually passive and therefore consist only of a microchip and a coil. The power to operate the tag and to send a response has to be provided by the reader. It is transported through a magnetic field which induces a current at the coil of the transponder. This current is used to operate the transponder. The efficiency of power transport via a magnetic field through the air is very low. Therefore only low power circuits can operate far away from a reader (Finkenzeller 2000, pp. 40-43).

Data Transfer

The data transfer from the tag to the reader is done by performing changes to the magnetic field with the tag. These changes can be measured by the reader. As the data drives the changes of the magnetic field in the tag, the data is transported to the reader.

With a little more complicated circuit in the tag, it is possible to send on 2 frequency bands which are symmetric to the band used by the reader.

The second possibility makes it easier for the reader to extract the data sent by the tag as it is simpler to differentiate between 2 different frequency bands than measuring a small change in the magnetic field (Finkenzeller 2000, pp. 43-45).

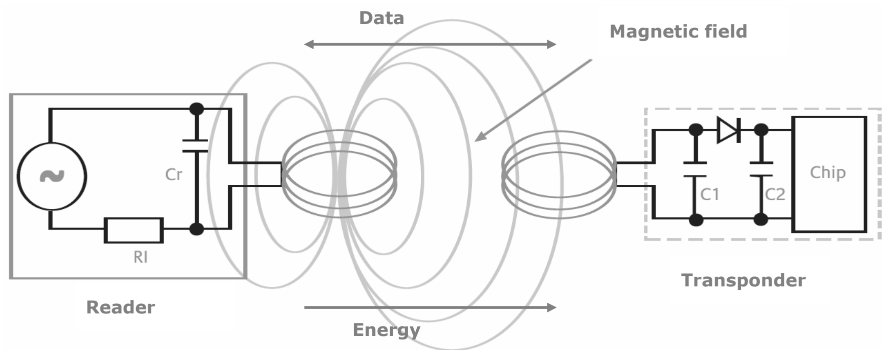

Fig. 1. Inductive coupling

Source: Bundesamt für Sicherheit in der Informationstechnik (2004), p. 33

2.2.2 Backscatter Coupling

Backscatter coupling is widely used for long range systems and uses the full duplex method (Finkenzeller 2000, p. 29).

Power Supply

Due to the fact that backscatter coupling is used for long range systems, the power which is transmitted by the reader is not sufficient to operate the microchip on the tag. Therefore the tags have to have their own battery. To improve the battery life, the energy transmitted by the reader is used to switch the microchip from standby mode to working mode and vice versa (Finkenzeller 2000, pp. 47-48).

Data Transfer

RADAR technology is used to transfer data from the tag to the reader. Every electromagnetic wave is reflected by objects which are sufficiently big compared to the electromagnetic wave (Fig. 2). The efficiency of the reflection is dependent on the object and is termed reflection cross-section. Objects which are in resonance

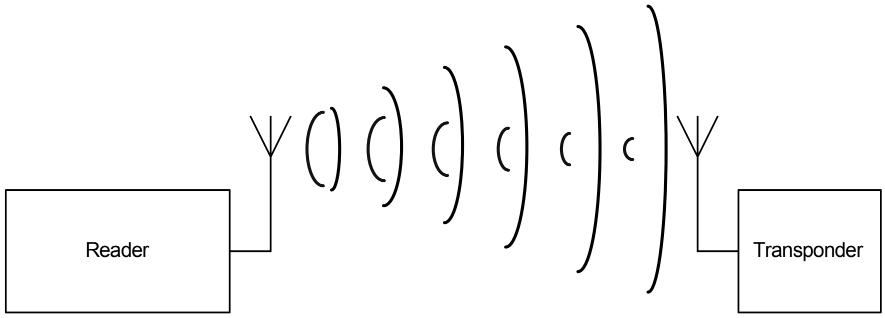

Fig. 2. Backscatter coupling

with the arriving wave fronts have a very high reflection cross-section. The antennas of the tags are tuned to the frequency of the reader and therefore are in resonance. Their reflection cross-section can be changed by varying the load which is connected to the antenna of the tag. Data driven changes of the load again makes it possible to transfer data from the tag to the reader (Finkenzeller 2000, pp. 48-49).

2.2.3 Close Coupling

Close coupling uses the full duplex operation mode (Finkenzeller 2000, p. 29).

Power Supply

The power supply is very similar to the inductive coupling but due to the very short distance (0.1 to 1 cm) the efficiency is much higher. With close coupling it is possible to have passive tags with microprocessors and indeed all the available close coupling tags use microprocessors (Finkenzeller 2000, pp. 50-51).

Data Transfer

The data transfer of close coupling systems is the same as the second method described for remote coupling.

A second possible way for the data transfer is a capacitive coupling which is based on an electric field. This technology is not widely spread and therefore not discussed here (Finkenzeller 2000, p. 51).

3 Frequency Ranges and Working Environment

3.1 Introduction

RFID systems generate and radiate electronic magnetic waves, so they are legally classified as radio systems. The function of other radio services must under no circumstances be disrupted or impaired by the operation of RFID systems. It is particularly important to ensure that RFID systems do not interfere with nearby radio and television, and mobile radio services etc. The need to exercise care with regard to other radio services significantly restricts the range of suitable operating frequencies available to an RFID system. For this reason, it is usually only possible to use frequency ranges that have been reserved specifically for industrial, scientific or medical applications. In this section RFID systems will be presented, which operate in the most important frequency ranges respectively.

The most important frequency ranges for RFID systems are 0-135 kHz, 13.56 MHz, 868/915 MHz, and 2.45 GHz (Finkenzeller 2003, p. 167-169). Fig. 3 shows the estimated distribution of RFID transponders at the various frequency ranges. The estimation is only for 2000-2005, but it can be expected that the distribution of the global market for transponders will be monotonously increasing in the following 5-10 years. On the other hand, it is obvious that high frequency will still play the most important role in the RFID systems.

3.2 13.56 MHz RFID Systems

From Fig. 3 it can be seen, that RFID systems working in the frequency 13.56MHz are most popular. The vast majority of 13.56 MHz systems operate "passive", i. e. without the need of an integrated battery. This has positive implications on cost, lifetime and environmental situation. The range 13.553–13.567 MHz

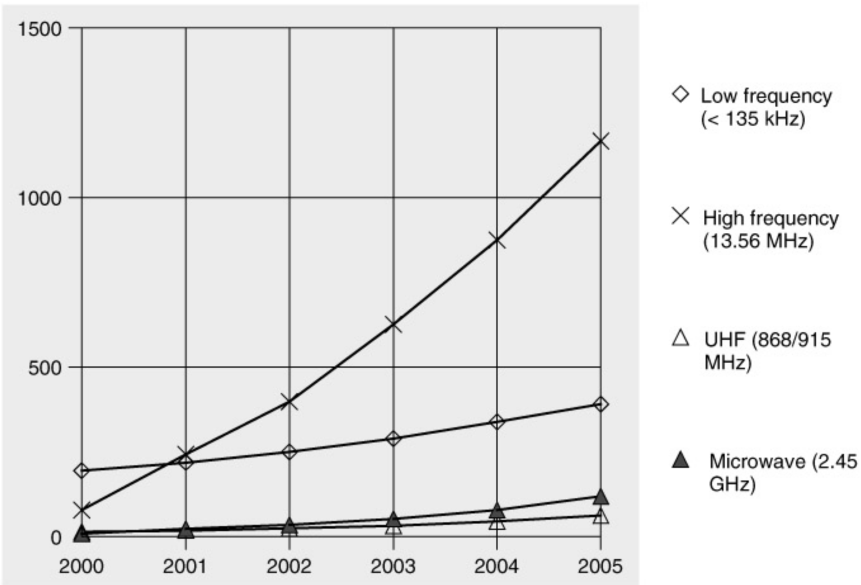

Fig. 3. The estimated distribution of the global market for transponders over the various frequency ranges in million transponder units

Source: RFID Handbook Figure 5.2

is located in the middle of the short wavelength range. The propagation conditions in this frequency range permit transcontinental connections throughout the day.

3.2.1 Basic Operating Principle

The basis operating principle of passive 13.56 MHz RFID systems is energy and data transmission using inductive coupling. This is exactly the same principle as used in transformers. An antenna of the reader generates a magnetic field, which induces a voltage in the coil of the tag and supplies the tag with energy. Data transmission from the reader to the tag is done by changing one parameter of the transmitting field (amplitude, frequency or phase). The return transmission of the tag is done by changing the load of the field (amplitude and/or phase).

Differing from UHF systems and Microwave systems, the operating zone of passive inductive RFID systems (13.56 MHz and also <135 kHz) is in the "near field" of the reader transmission antenna, which results in achievable operating distance of approximately the diameter of the transmission antenna. Moreover, the RF filed at 13.56 MHz is not absorbed by water or human tissue, which allows operation through water or human beings. Due to shielding or reflection effects RFID systems are sensitive against metal parts in the operating zone. The impact of this orientation-sensitiveness can be solved by using more complex transmission antennas.

3.2.2 System Integration and Performance

Professional system integration is of the same importance to make best use of RFID products. The "heart" of every reader/writer is an RF-module which takes care of the communications between tag and reader/writer. Typically, two or three RF-module types can be found (AIM Frequency Forum 2000, p. 6):

1. RF module for "proximity" applications (up to approx. 100mm), especially used in handheld devices, printers and terminals.
2. RF module for "vicinity" (long range) applications (range limited by technology and regulations; today for leading 13.56 MHz technology typically up to 1.5m). Typically more complex than "proximity" modules, higher power consumption.
3. Sometimes a third class of "medium range" can be found (range up to approx. 400mm)

Typically, smaller operating distances allow higher operating speed ("proximity" systems operate at approx. 100kBaud), whereas longest operating ranges can only be achieved with slower baud rates (25 to 70kBaud). This has an impact on system integration and optimization. However, there is evidence that 13.56MHz RFID systems can reliably achieve operating distances of approx. 1,5 m in "gate" applications or cover a "window" of 1x1m in a tunnel reader and solve the requirements of key item management applications in terms of data size and object movement.

3.3 868/915 MHz UHF RFID Systems

3.3.1 Basic Operating Principle

RFID systems operating in the UHF frequency range make use of conventional electromagnetic wave propagation to communicate their data and commands, and in the case of battery-less tags also to power the RFID transponders. This is contrast to low frequency RFID systems, which operate on the induction principle, much like a transformer. In order for passive RFID technology to be properly exploited, the reader must produce an adequate energy field to power tags at a usable distance. The received power of tags is dependent on antenna size which in turn is dependent on frequency.

3.3.2 Performance

Since UHF RFID systems make use of conventional electromagnetic wave propagation, some of the electromagnetic energy is absorbed and converted into heat when passing through any substance other than a vacuum. On the other hand, UHF EM waves are related to light and behave in a similar manner. They can be reflected off radio conductive reflective surfaces, they can be refracted as they pass across the barrier between dissimilar dielectric media or they can be diffracted around a sharp edge. Moreover, radio Waves will penetrate into different liquids depending on the electrical conductivity of the liquid.

Concerning the read range in UHF RFID systems, it is dependent on the transmitter power output and in the case of passive tags, on the energizing requirements of the tags. Tag size also plays a major role in determining read range. The smaller the tag is, the smaller is the energy capture area and therefore the shorter is the reading range.

The nature of UHF radio allows the use of relatively small directional antennas. This permits the reader beam to be directed towards a particular area and so selectively read a group of tags or discriminate against other tags. This directional capability has an additional benefit, in that it allows the reader to discriminate against potential interference from other readers or transmitter sources.

3.4 2450 MHz RFID Systems

3.4.1 Basic Operating Principle

RFID systems that operate at 2450 MHz can be called microwave RFID systems. It has been widely used for over 10 years in transportation applications. Systems operating in microwave regions are divided between “active power” and “passive power” tags (AIM Frequency Forum 2000, p. 17). Operational range and functionality can be extended with active power (a battery in the tag), and passive power provides extended life and lower costs. The basic operating principle of 2450 MHz RFID systems is energy and data transmission using propagating radio signals. This is exactly the same principle as used in long-range radio communication systems. An antenna of the reader generates a propagating radio wave, which is received by the antenna in the tag. A passive power tag converts the signal to DC voltage to supply the tag with energy.

3.4.2 Performance

Differing from inductive RFID systems (13.56 MHz and also <135 kHz), microwave RFID systems operate in the "far field" of the reader transmission antenna. Achievable operating distances 0.5 to 12 meters is possible for passive power tags and beyond 30 meters for active power tags. For active systems data transmission rates are not greatly influenced by operating range for microwave RFID systems, whereas for passive systems the low chip power consumption dictates lower data rates. Long range systems (greater than 15 meters) are operating at data rates up to 1 Mbit/s. Passive or active microwave article tagging RFID systems operate typically at data rates of 10 to 50 kbits/s. The symbol-rate (the modulation frequencies) is higher since the user data is encoded. Ranges of 1 to 10 meters from a single antenna are typical for passive power microwave RFID systems (Surfbest 2001).

Compared to the low frequency inductive systems, the Microwave systems can have longer range, higher data rates, smaller antennas, and more flexibility in form factors and antenna designs. On the other hand object penetration and reading range under no line-of-site conditions can be more robust with inductive systems (AIM Frequency Forum 2000, p. 22). Date Rates with active Microwave systems are higher than inductive systems whereas with passive systems the difference might not be significant.

3.5 Short Summary

Based on what is discussed above, on the one hand by deploying RFID systems operating on different frequency ranges so many requirements in different fields can be fulfilled. On the other hand it can be seen that due to the characteristic of different frequency ranges it may also raise some challenges. RFID systems are sensitive against metal parts in the operating zone due to shielding or reflection effects. This applies more or less to all RFID systems, although the physical reasons are different. It results that especially in supply chain extra money needs to be invested to solve this problem. Radio waves are absorbed or penetrated by water at ultra-high frequencies and microwaves. That makes tracking goods containing water problematic, but good system designs and engineering can overcome this shortcoming. It often happens that some other radio services may under some circumstances be disrupted or impaired by the operation of RFID systems. For example, RFID systems working at UHF may be interfered by the mobile network. That's why UHF is not so widely used, though it is very effective from the technical point of view. The following table shows different frequency ranges which are deployed for the different applications and their working range and tag cost. It gives a basic overview how the RFID systems operating at different frequency ranges look like in the real life.

Table 1. Summary frequency ranges

Frequency	Range	Tag Cost	Applications
Low-frequency 0-135 KHz	3 feet	\$ 1+	Pet and ranch animal identification; car key-locks
High-frequency 13.56 MHz	3 feet	\$ 0.5	Library book identification; clothing identification; smart cards
Ultra-high freq. 868/915 MHz	25 feet	\$ 0.5	Supply chain tracking: Box, pallet, container, trailer tracking
Microwave 2.45 GHz	100 feet	\$ 25+	Highway toll collection; vehicle fleet identification

Source: www.node-net.com

Interface Between Network and Hardware

Each RFID system needs to be adapted application dependent, since its functionality and complexity vary a lot with the specific implementation. On the other hand, to enable multi-vendor implementation, i. e. the usage of hardware from different manufacturers, and/or multi-user implementation, e. g. to provide the usage of tags through several RFID systems in a supply chain, a standardization of the communication interfaces is required.

In the following, an insight in the technological basics of RFID interfaces will be given combined with a review of current standards and future standardization efforts. Starting with an overview of the components within a RFID system, a closer look on the interface between the tags and the readers will follow in 3.7. The interface between readers and the network will be addressed in 3.8

3.6 System Components

Independent of its specific application, a RFID system can be always structured as seen in Fig. 4. The network communicates, e. g. it sends a data request, with a reader over the network – reader interface. The reader obtains the requested data from the tags over the wireless reader – tag interface and forwards it to the network.

3.7 Reader – Tag Interface

The performance of the reader – tag interface is crucial for a RFID system. Since it uses a wireless channel it is exposed to signal disturbance and the data rate is significantly lower than for the network – reader interface. On account of this, when developing a RFID system, the attention has to be concentrated on the communication performance between tags and readers.

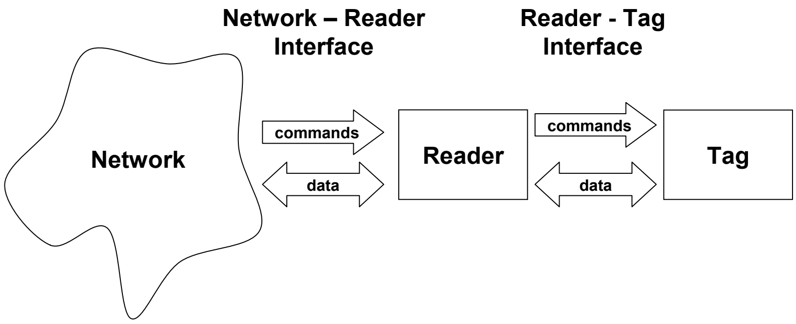

Fig. 4. Interfaces within a RFID system

3.7.1 Modes of Operation

There are 3 different modes of operation. Those modes specify at what time energy is transported from the reader to the tag and at what time the reader communicates with the tag and vice versa. The modes are shown in Fig. 5. The full duplex procedure (FDX) allows that energy and data transfer in both directions happens at the same time. This mode requires the tag to send its information on a different frequency as the reader does. The reason is that the tag is sending its data with less transmitting power than the reader does. The field of the reader is that dominant, that it is not possible to extract the data sent by the tag on the same frequency. Therefore the tag sends with a frequency which is usually half of the frequency used by the reader but can also be another subharmonic or even inharmonic frequency.

A half duplex system (HDX) transports power from the reader to the tag at all times, but the data transfer between reader and tag alternates. The advantage of this procedure is that reader and tag may use the same frequency to share their data.

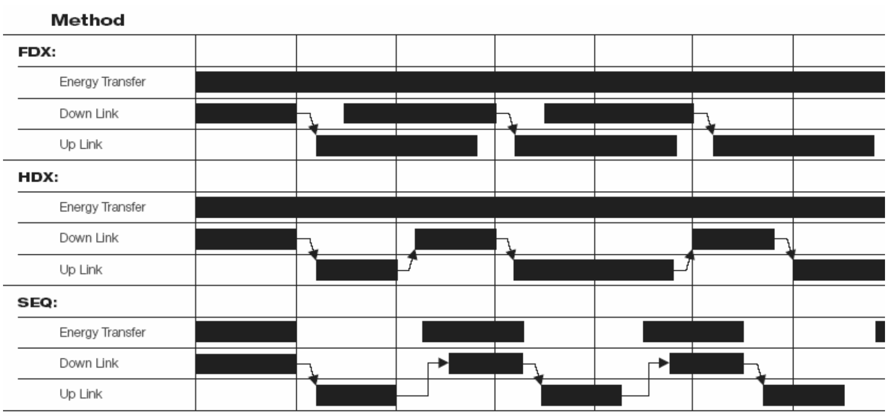

Fig. 5. Modes of operation
Source: Tektronix 2004, p. 6

The sequential procedure (SEQ) uses a very different approach. The reader doesn't constantly supply the tag with power and the reader only sends data to the tag while it is sending power. In the gaps between the power transport slots the tag is sending data to the reader. The energy which is needed by the tag to operate in its active period has to be stored temporarily (Finkenzeller 2000, pp. 39-40).

3.7.2 Components of a Digital Communication System

Fig. 6 illustrates the composition of a typical digital communication system. In a first signal coding step the signal is adapted optimally to the channel characteristics. This involves protection against channel noise, symbol interference and collision. The signal processing takes place in the so-called baseband, a lower frequency band than the final transmission band.

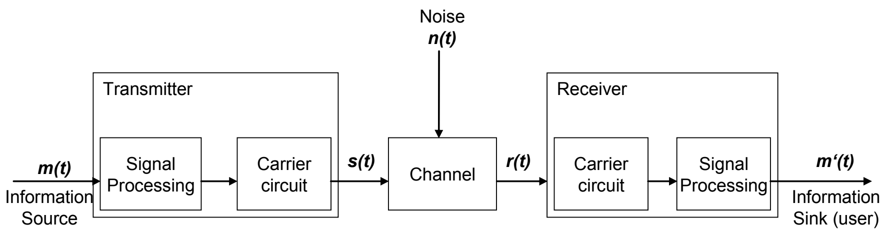

Fig. 6. Components of a digital communication system

Source: Finkenzeller 2000, p. 153

In the next step the signal is modulated on a carrier frequency (carrier circuit), i. e. the amplitude, phase and frequency of the baseband signal is impressed upon the actual transmission frequency. The resulting signal can now be sent over the channel to the receiver. For RFID primarily magnetic fields (inductive coupling) and electromagnetic waves (microwaves) are used as transmission media (Finkenzeller 2000, p. 153). Since the transmission occurs over a wireless channel the signal is overlaid by noise.

At the receiver side, the signal needs to be demodulated, i. e. the retrieval of the baseband signal. In a final step (signal processing) the information is recaptured by decoding the signal, combined with error detection and correction.

Coding in the Baseband

There are several coding procedures which are appropriate to be used in RFID systems (Finkenzeller 2000, pp. 154 – 156), e. g. Manchester code or pulse-pause coding. When choosing a coding procedure it has to be done with respect to the signal and its susceptibility to transmission errors. For passive tags continuous power supply has to be assured additionally.

Modulation Procedures

Since the transmitted data in RFID is always binary, it can be presented by only two states, one for "0" and one for "1". There are three modulation procedures used in RFID systems, amplitude shift keying (ASK), frequency shift keying (FSK) and phase shift keying (PSK), see Finkenzeller (2000, pp. 156 – 162).

1. In amplitude shift keying the amplitude of the carrier signal is switched between two values, e. g. high amplitude corresponds to "0" and low amplitude corresponds to "1".
2. In frequency shift keying the carrier frequency is switched between two frequencies respectively.
3. In phase shift keying the phase of the signal is switched between 0 and 180 .

At the receiver side, the coding and modulation procedures are applied in a reverse way. Since the data was transmitted over a wireless channel, it is very likely that noise or interference (mutual symbol distortion) leads to receiver errors. To detect or even correct errors, the procedures discussed in 3.7.3 can be used.

3.7.3 Data Integrity

Error Detection

It is of importance to know, whether the received signal is identical with the transmitted one or if some bits were wrongly detected. A very popular way to figure this out is the usage of a checksum procedure, like the parity check, XOR sum or cyclic redundancy check.

In these procedures additional bits are added to the data bits. The transmitter calculates a sum according to a given algorithm and stores the result in the additional bits. The receiver evaluates the sum again by following the same algorithm and compares it with the stored result.

A problem with check sums is that multiple errors might nullify each other. The cyclic redundancy check, handles this problem very well, even for large amounts of data, in using all previous sum results when calculating a new value.

Anti Collision Procedures

Many situations and applications require a detection of a large number of items (tags) at the same time. To provide the tags simultaneous channel access, the channel capacity needs to be segmented by using multi-access procedures. Since for tags, the service capability is limited and their production needs to be low priced, the most suitable procedure for RFID systems is time division multiple access (TDMA), in some cases frequency division multiple access (FDMA), see Lampe, Flörkemeier and Haller (2005, p. 8) and BSI (2004, p. 35). TDMA allows several tags to share the same frequency by assigning each tag an individual time slot.

The implementation of TDMA can be done with anti collision procedures which can be divided into transponder driven (probabilistic) and interrogator (deterministic) driven procedures.

Among the transponder driven procedures the most commonly used is the Aloha algorithm. The reader transmits several times a request command to all tags to identify themselves. When receiving the command, each tag starts after an individual random delay to transmit its EPC. Since the time interval between two reader commands is large compared to the response time of a tag, it is likely that a tag transmits its EPC without collision. To decrease the collision probability in the next time interval, the reader may set the already registered tags silent. The disadvantage of transponder driven algorithms is, it can not be guaranteed that after a certain time all tags could be identified.

The tree-walking algorithm is the most frequently used interrogator driven procedure. The reader addresses only a limited group of EPC numbers and permanently decreases the size of the group until only one tag responds. The reader reads the EPC, sets the tag to silent mode and repeats the whole proceeding until the complete set of EPC numbers has been covered. This algorithm guarantees the identification of all tags, but its performance depends highly on the data rate, which is only sufficient for the UHF band.

Data Security

More and more new RFID applications transfer security relevant information. For this reason security mechanisms are required to protect the information against potential attackers. A very simple but useful way is the usage of keys. An item can verify itself by proving the knowledge of a key. In calculating always an individual key, e. g. by using the serial number of the specific tag, with an algorithm, the security can be further increased. Another expedient way is to cipher the data when transmitting it. However, since the implementation of such security mechanisms increases the costs they should only be implemented appropriately (Finkenzeller 2000, pp. 193 – 200).

3.7.4 Standards

Up to now the Auto-ID Center/EPC global developed the following standards for the reader – tag interface:

1. HF class 1 (Auto-ID Center 2003a)
2. UHF class 0 (Auto-ID Center 2002)
3. UHF class 1 (Auto-ID Center 2003b)
4. UHF class 1 generation 2 (Auto-ID Center 2004)

The HF class 1 standardization for the 13,56MHz band, is a so-called reader talks first protocol and uses the Aloha algorithm.

The UHF class 0 and class 1 standards are also reader talks first protocols. They both use half duplex procedures and a version of the tree-walking algorithm, but the tags from class 0 standard need to be programmed by the manufacturer while the class 1 tags can be programmed at the place of installation. Due to different coding and modulation procedures these two standards are incompatible, what leaded to the demand for a new specification with a strong anti collision algorithm and which works in any country.

In the end of 2004 the UHF class 1 generation 2 standardization has been adopted. When developing class 1 generation 2, the reader to tag link was evaluated in regard of tag powering, while the tag to reader link was developed with perspective of link quality (Mitsugi, Yumoto, Hada and Murai 2004). This leads to larger distance and less sensitivity to errors. The challenging task for this standardization was to enable "global service requirement in a frequency band, which is not allocated globally." (Mitsugi, Yumoto, Hada and Murai 2004).

3.8 Network – Reader Interface

The network – reader interface handles the communication from the readers to the servers. This interface is user driven and the configuration, monitoring and alarm notification of the reader – tag system are processed through it as well as the provisioning and inventory control.

EPC global is currently developing the Reader Protocol version 1.0 to standardize the application interface and the data exchange (Walk 2005).

4 RFID Hardware

As described in the sections before, a RFID-system is usually made up of two parts. On the one hand the tag, which is also called transponder. On the other hand the reader or interrogator. Due to the great amount of diverse application of RFID-systems the hardware for the tag and the reader can be very different. The following sections will show an overview of the most common existing hardware and will give a short introduction into the manufacture of RFIG-tags.

4.1 Tags

Tags are made up of the following components:

1. microchip containing the memory and the control system
2. coil or antenna
3. housing
4. Active Tags also contain of battery or a capacitor to store energy.

4.1.1 Construction Formats

Depending of the use of the tag, the tags can be split up in two groups.

The first group of tags is used for identification and positioning of an item. These tags are attached or even injected into the item. They should father be small in comparison to the item and they should not interfere with the function of the item. The most common construction formats of these tags are:

1. smart labels
2. tubes (glass housing)
3. disk, coins and other plastic housing tags
4. special tags for tool and gas bottle identification

The second group of tags work in someway independent on their own. The tags have a more complex purpose like smart cards for paying systems or door and car keys. The most common construction types of these tags are:

1. smart cards
2. disk, coins and other plastic housing tags

4.1.2 Smart Labels

A common construction format for RFID tags is the so called smart label. The transponder is thin and flexible and can be produced in a wide range of formats. It can easily be converted into paper or plastic labels or integrated into a product. The actual list price for silicon based smart labels ranges from 0.50 $ to 1.60 $. (Finkenzeller, 2000), (Texas Instruments, 2005)

But actually there are great efforts to lower the prices for smart labels. Start up companies like Alien Technology or Matrics expect the price to fall to five cents per tags if the production volume is high enough. (Economist, 2003)

OrganicID, a start up company from Colorado Springs estimates, that by developing new technology for printing organic tags, the price could reach even one cent per tag. (Dimmler, 2004)

Fig. 7 shows a range of silicon based smart labels produced by Texas Instruments.

4.1.3 ID-1 Smart Cards

The so called "smart card" is one of the most known formats of RFID tags. They are produced in familiar ID-1 format (85.7 mm x 54.0 mm x 0.76 mm). The format is known from credit cards or telephone cards.

They are based on the same technology as the smart labels. The inlay contains the microchip and the antenna. The inlay is laid between 4 layers of PVC foils. The foils and the inlay are baked under pressure to form a permanent body. The list price for smart cards as shown in Fig. 8 is around 3 to 6 $. (Finkenzeller, 2000), (Texas Instruments, 2005)

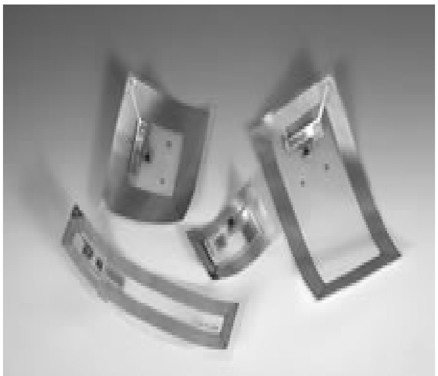

Fig. 7. Smart Labels
Source: Texas Instruments

Fig. 8. Smart Cards
Source: Texas Instruments

4.1.4 Disk, Coins and Other Plastic Housing Tags

Tags in plastic housing are used for application with higher mechanical demands. The microchip and the antenna or the coil are encapsulated within a plastic compound. The so called disk is a very common construction format for this kind of tags. The transponder is set up in a round housing with diameters ranging from a few millimeters up to 10 centimeters. There is often a hole in the middle of the disk for fastening the tag to an object. The price for this tags are listed 5 to 16 $. (Finkenzeller, 2000), (Texas Instruments, 2005)

4.1.5 Glass Housing

Tags in glass tubes have been developed for the identification of animals. They are injected under the skin of the animal. The tubes have a length of 12 to 32 mm and a diameter of about 4 mm. The glass tube contains a microchip and a capacitor to smooth the energy supply. The coil is a thin wire which is wounded on a ferrite core. The list price depends on the size of the tube and ranges between 5 and 7 $. (Finkenzeller, 2000), (Texas Instruments, 2005)

Fig. 9. Tag in plastic compound
Source: Texas Instruments

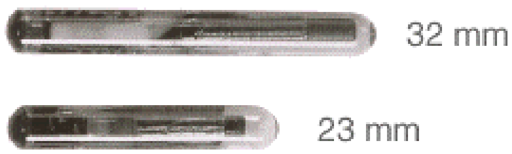

Fig. 10. Tag in glass housing
Source: Texas Instruments

4.1.6 Other Construction Formats

Due to high number of possible applications of RFID tags several special formats have been developed in the last years. There are tags integrated into car or door keys. Also available are clocks with integrated tags which can be used as ski passes.

E. g. for the special application of tool and gas bottle identification the tag has to couple into the metal surface of the object. The coil is a wire wound in a ferrite pot core. The microchip is mounted on the reverse of the core. For the protection of the tag, the antenna and chip are cast into a plastic shell. (Finkenzeller, 2000).

4.2 Manufacture

As shown in the figure the production of a tag can be split up in three main steps:

1. production of the microchip
2. production of the coil/antenna and the connection to the chip
3. and finally the fitting into the housing

In the next sections the steps will be explained more detailed.

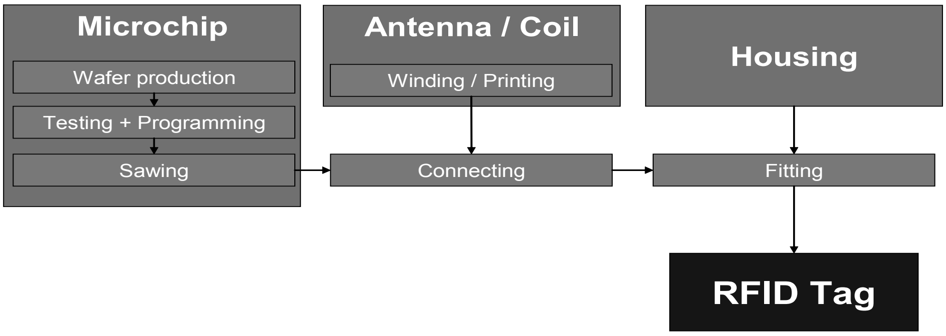

Fig. 11. Manufacturing of a tag
Source: RFID Handbuch 2000

4.2.1 Microchip

The production of an RFID microchip goes in accordance with the manufacture of normal semiconductors. The microchip is produced on wafers. A wafer is a slice of very clean silicon and has a diameter of about 20 cm. In a repeated procedure of doping, exposure, etching and washing the electronic circuits and elements are created on the wafer.

In a next step the microchips are tested and programmed. For this operation additional contact fields are used. It is a great advantage, that there is a direct contact to the microchip. This permits unlimited direct access without the limitation of the HF-communication. Depending on the later use of the tag a serial number can be programmed in this stage. For simple read only tags the serial number is programmed by cutting through connecting lines using a laser beam. Defective chips are marked at this stage so they can be easily sorted out at a later point. After completing the testing and programming the direct access is deactivated for ever by breaking certain connections with strong currents. The last step is the sawing of the wafer into single chips, which are called dice. (Finkenzeller, 2000)

4.2.2 Antenna / Coil

The coil is usually produced by winding a thin wire. During the winding the tool is heated to the melting point of enamel. When the winding is finished, the coil cools down, causing the enamel to harden fast and to fix the wires in their position.

Newer technologies use embedding or printing principles to produce the coil or the antenna. Embedding means, that the wire is laid down by a plotter into its exact position and then fixed by heating. Printing technology uses special copper, which can be printed directly on PVC foil.

The antenna or coil is connected to the microchip by welding or mechanical connections (Finkenzeller, 2000).

4.2.3 Housing

Finally the microchip and the antenna/coil are inserted in a housing. As seen before the housing can be PVC foils for smart labels, glass tubes or any plastic housing.

The production of the tag is fished by a final functional test.

4.3 Reader

The Readers are second part of a RFID system. Just like the tags, there are many different kinds of readers available. The main classes of readers are the mobile readers on the one hand and stationary readers on the other hand. The list prize for start around 200 $ and go up several thousands Dollars. Following pictures show a mobile and stationary reader (Finkenzeller, 2000) .

4.4 Outlook

There are a great number of different kinds of RFID tags. They were developed in the last years to match special application. These tags are not very cheap. Today's market is asking for cheap RFID labels to tag items in logistic processes. The requirements for these tags are not very high compared to most of the ones used today.

Fig. 12. Mobile RFID reader
Source: Tagsys

Fig. 13. Stationary RFID reader
Source: Tagsys

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PART II:

Trend Reports

The Smart Supply Chain

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1 Introduction

Concerning supply chain Management and the pilot testing of RFID technology, the great efforts of retailers like Metro, Walmart or Tesco resound throughout the world. But also in other branches of industry the adoption of RFID in the supply chain plays a significant role. As goods become traceable and data about products currently on delivery is available, products can even be traded while already on the way to the original purchaser. Based on this possibility, this report describes the emergence of a new market in supply chain Management as the cause of the widely implementation of RFID technology.

The outcomes in this report are based on an extensive analysis of current supply chain Management and the development of RFID technology. Trends in supply chain Management were identified and carried on beyond already existing solutions. It starts with a concrete scenario looking at the market of perishable goods. Followed up with the current state of several problematic facets of supply chain Management, assumptions about the evolution of these fields are made. Based on that, the possibility of the emergence of the new market and its characteristics are explained. In section 5 and 6, technological aspects that enable the emergence of the market and others which might be disablers for the existence of such a market are covered. section 7 discusses possible market drivers and sections 8 and 9 conclude with the economic and financial aspects of the emergence of the new market.

2 Scenarios

2.1 In-Transit Routing of Perishable Goods

In the following scenario the emphasis is focused on perishable goods and in particular exotic fruits, because the need of a fast and flexible reactive supply chain is very high due to the short endurance of perishable goods because of their active metabolism. The importance of short storage and fast transports are indispensable.

Imagine a common retailer store in Berlin, Germany in the year 2015. If these days a customer purchases a product at a retailer store the process takes place highly automatically. Implemented readers at the inbound and outbound doors read out the unique number of the RFID chip tagged on the product. To get the information which product has been sold at which amount is no long lasting process anymore. The retailer has only to check the data belonging to the RFID chip number on the Product Information Service (PIS) Server supported by the owner of the codes. In this scenario the logistic provider "Exotics_in_transit" will be the owner of the product codes. The retailer shop "2015" in Berlin checks his stock amount on a Thursday evening in January 2015. The exact information is given immediately due to the RFID tags on the fruit pallets. In the retail business it is essential that products are tagged otherwise the ware control system of the retailer will not work efficiently. But in the case of fruits & vegetables it is still not possible to tag single mangos, leeches or pineapples. In that case the pallets are tagged. The purchasing process takes place and the data belonging to the purchased products are updated in real-time. There is no time lag between these two processes as it was in former times. Real-time information gives the retailer the possibility to react immediately to stock changes.

It is still Thursday evening at the retailer shop "2015" in Berlin. He had received a couple of orders regarding mangos for tomorrow Friday for a couple of banquets taking place at the weekend in different hotels due to the World Conference in Berlin 2015. The mangos will be delivered on Friday morning with other fruits & vegetables from the distribution center of "Exotics_in_transit" situated in Hamburg. The mangos from the producer "Manga Inc."situated in Mexico get picked and stored on pallets that had been tagged with RFID tags. "Manga Inc." stores the product data on the PIS server and transports the charge to the harbor of Acapulco in Mexico. The harbor is the first transshipment center of the mango transport to Europe. A transshipment center is defined as a location where transport vehicles of products are changed or even the products change their designated destination. At the harbor the first plausibility check takes place. The RFID readers implemented at the "inbound doors" of the harbor read out the unique RFID tag number on the pallets. Based on this code the software system of the harbor sends a location update request to the PIS server. This request contains the information that the product has arrived at the harbor. The location of the product is therefore updated automatically driven by the harbor of Acapulco. The pallets get loaded on the cargo ship with destination Europe, Hamburg harbor. The RFID readers at the inbound doors of the cargo ship read out again the RFID tag number of the pallets and another plausibility check takes place announcing that the pallets have left the harbor. The journey takes about three weeks crossing the Atlantic Ocean. Due to the long travel time the mangos get stored in freezers with specific temperature. The temperature will be controlled by RFID readers. Checking real-time the temperature every anomaly can be ascertained. But the capacities on cargo ships containing freezing infrastructure for perishable goods are restricted. The "Manga Inc." company has quantity contracts with the operator of the chatter. These long-term contracts keep the transaction costs marginal. The contract defines the agreed capacity on every cargo ship. If the capacity is less due to demand variations at the end of the month the two companies reckon up the unused capacities. This eventuality foresees their common contract conditions. But the capacity of one company can sometimes even be higher if a third company will not fill up their capacities. The capacities will be available to another company sending goods on the cargo ship. The cargo ship company “Cross Atlantic” organizes this trade-off. “Cross Atlantic” sets the exact detail plan of the cargo ships online onto their intranet. Every contract company will log in and announce their planned amount of freight going to be loaded on the specific cargo ship. Up to the maximum sum of their contract regulated capacity. If it’s less the other companies stock up the amount not utilized by the original capacity holder. So if one company has a greater amount than agreed in the contract, they even can take over the capacities off other companies. A win-win situation for every company arises. The cargo ship achieves in best case a 100 % capacity load and companies can trade-off their freight amount between each other. Information technologies enable that the different companies communicate in real-time achieving trade-offs concerning their transactions with small transaction costs and also increasing their welfare.

The cargo ship with the mangos arrives in Hamburg. The Hamburg harbor is the next transshipment center where the next plausibility checks take place. The cargo ship docks and gets reloaded. RFID readers are implemented on the asphalt at every strategic point within the harbor area. Here the first plausibility check takes place, because the pallets are arrived at the next transshipment center, the Hamburg harbor. Routing the pallets of products to their right storage location, where they get picked up in-time by the responsible logistic provider “Exotics_in_transit”. The area of the harbor is organized by dividing the “storage area” into location coordinates. If products arrive at the harbor they get uploaded and brought to the right location by assigning the coordinates driven by automatic vehicles. First the RFID tag numbers of the pallets are red out by RFID readers and then the freight is coordinated within the harbor area to the coordinates X/Y. The next step is to load the pallets of mangos on the transport vehicle of the logistic provider. At the doors of the freight vehicle RFID readers are implemented and read in the pallets being uploaded. Here the second plausibility check takes place as the mango pallets leave the transshipment center. At the logistic provider’s distribution center, the next transshipment center, the mangos are stored with other exotic fruits arriving from all over the world. Here the extensive step of commissioning and conditioning takes place. Every day more than 200 freight vehicles arrive to get the conditioned freight consisting out of different sorts of fruits brought in the right amount ready for delivering to the retailers. The logistic provider of the future will still be responsible for the transport organization, conditioning and picking of the products the retailer is supplied with.

Coming back to the retailer store “2015” in Berlin:

Late on Thursday evening in the year 2015 the retailer receives another couple of orders from restaurants in Berlin. “2015” tries to order this extra amount from their logistic provider “Exotics_in_transit” who checks their orders and capacities for the next day. But they cannot execute the order because their stock of mangos is due to the short lead-time not enough. The retailer “2015“ is participant of the online platform for fruit & vegetables. All retailers and suppliers trading with fruit & vegetables can get registered at the “f&v_platform”. The investing costs of joining are the transaction costs and 1% of the platform traded ware amount. But the benefits for every participant exceed in tremendous way the investment. Every member gets registered online, creates a profile and receives a personal login account to be able to enter the platform. The retailer just logs in and gets access to the information announced on the platform which is driven by an independent commercial service provider. The retailer sets an announcement online on the platform and releases the price he would pay for. The goal of the online platform is to match the supply and demand by bargain or by auction. In this scenario the retailer has announced a realistic tender for the mangos on Thursday evening. The retailer receives an alert because the retailer “Flexible” in Munich has given a supply belonging to the demand. Due to the urgent situation the principle first come, first served is realized. If the retailer accepts the supply he transfers the demanded price online. Looking at the situation of the retailer “Flexible” in Munich: he recovers that his amount of mangos did not decrease the last two days. The last regular order arrived three days ago. The next order is expected for tomorrow, Friday morning. But the demand hadn’t been that high the last days. For Friday an extra order for mangos was given due to a national vegetarian meeting in Munich. But the event was planned outside and due to the bad weather forecast they cancelled the extra order on Thursday morning. The retailer cancels the order. The logistic provider “Exotics_in_transit” guaranties 24 hours right of withdrawal before accomplishing the order. In case the order by the vegetarian association is cancelled on Thursday evening, the retailer could not rely on the 24 hours right. “Flexible” informs his logistic provider to reroute the sold amount of mangos to Berlin. The pallets can be for example on the ship coming from Mexico, arriving at Hamburg harbor, on the way to the distribution centers, stored at the distribution centers or already sent in-transit to the retailer. Implemented RFID readers at every transshipment centers enable to update the exact location of the tagged products in-transit by sending a plausibility check to the PIS Server. The logistic provider is able to find out the delivery in-transit to reroute. The mangos with destination Munich are already in-transit. The logistic provider updates the new destination and the address of the new recipient, the retailer “2015” in Berlin of the certain amount of mangos on the data belonging to the unique RFID number on the PIS Server. When the freight arrives at the next transshipment center the product location gets updated and the information of changing the route to the new destination is given. The new route to Berlin is the fastest and cheapest way for the charge transport. At the rail station in Hannover the charge of mangos is uploaded and put on the train to Berlin. The RFID reader at the inbound doors of the train reads out the number of the token pallets. Another plausibility check takes place that the pallets have left. Every transshipment center gives advice for the plausibility check when the products arrive and leave. This process happens dynamically every time a product comes up.

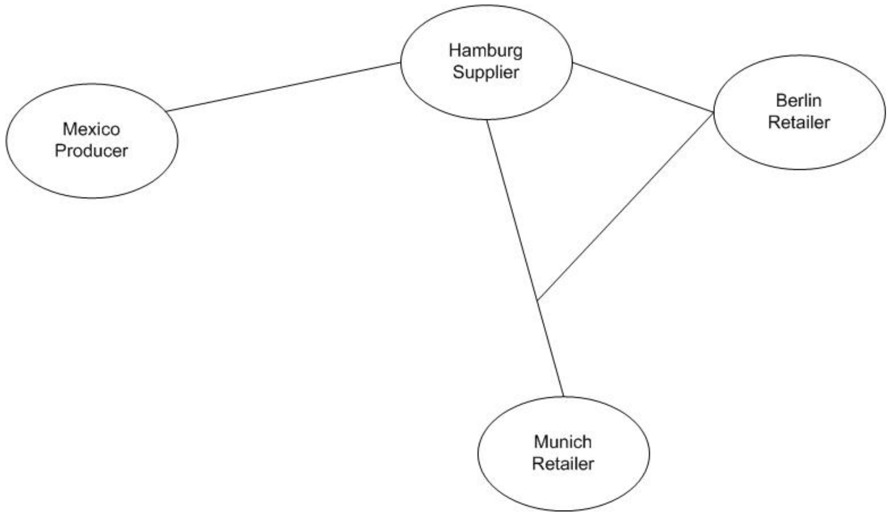

Fig. 1. Connection of trading partners

Source: Own design

Arriving in Berlin in the early morning the retailer can pick up the pallets or let them supply by a local transport company. The mangos are in time, early on Friday morning arriving at the retail store in Berlin and can be sold to the hotels.

Within less than one day perishable goods had changed in a simple manner the owner and the goods have not been discarded. Perishable good waste will decrease and the profit of enterprises will go up due to this enhanced flexibility to react to changed or cancelled orders.

2.2 Selling Perishable Goods In-Transit

Another scenario would be when the mangos are still on the cargo ship from Mexico to Hamburg. This would mean that "Manga Inc." had loaded more mangos on the ship as already ordered from retailers. But they hadn't fulfilled the contract regulated maximum capacity on the "Cross Atlantic" cargo ship. 20% of the transport capacity is still available. They just stock it up with mangos and during the three weeks of shipping any retailer can order these goods in-transit. The process is quite simple because the new destination and the address of the recipient will be written on the PIS Server. So the pallets arriving in Hamburg will check in and give the logistic provider the exact destination address without paper written delivery receipt. This scenario is imaginable for all kinds of goods and branches. The platform is the synonym for one great market place trading goods managed by the logistic provider. This is only an extract of the trading possibilities arising through the high potential of flexibility through RFID technology.

3 A New Market

3.1 Risks in Supply Chain Management

Supply chain management has to assure that products are delivered in time, to the right place, in the right quantities and qualities and in a cost-effective manner. As a supply chain consists of different participants with different and sometimes mutual exclusive objectives, it is a great challenge for the individual company to meet the mentioned objectives of supply chain management.

Chopra and Sodhi (2004) describe several risks for companies and point out common strategies to minimize each of these risks. A selection of the risks is presented in the following passage:

Delays in the delivery of ordered goods often result in the inability of a supplier to respond to the demands of the purchaser. Reasons that lead to this situation can be insufficient output of the supplier’s plant, or delays on the transport way caused by customs or accidents. A way to be prepared for delays is the maintenance of inventories. Inventories bear the risks of obsolescence of products and high inventory costs. But due to an uncertain knowledge about demand and supply and to be prepared for possible delays inventories remain indispensable. A related problem is the problem of capacity: Excess capacity assures the service of large orders but increases the risk of high costs in times of lower demand.

Two important reasons can be identified for the risks mentioned above: a lack of cooperation between suppliers and retailers and inflexibility due to technological barriers.

The key technology to redesign way more flexible supply chain is the RFID technology. To exploit the whole potential of RFID, companies have to cooperate and build systems that cross organizational boundaries. The next section briefly describes the current adoption of RFID and starting from that point the trend towards the integration of RFID technology in the whole supply chain process. Based on that observation the potential for a new market is explained.

3.2 The Trend Towards RFID in the Supply Chain

During the last years, several companies launched pilot projects with RFID technology. Wilding and Degaldo (2004) list companies of different branches of business, namely Mark & Spencer (UK), Gillette (USA, UK), The GAP (USA), Tesco (UK), Woolworth (UK), Allied Domecq (UK), Argos (UK), Figleaves.com (UK), Benetton (Italy), Walmart together with the Auto-ID center (UK), Exxon Speedpass (USA) and Prada (USA). Additionally numerous other companies of the retail business or the automotive industry have started projects to evaluate RFID technology. Results of these test runs are reduced lead-time, reduced shrinkage, increased shelf-availability, decreased picking errors or higher quality of data capture. Wilding and Degaldo (2004) state that the adoption of RFID has proved as highly successful when adopted in internal processes or processes that involve a small number of trading partners. For the application in larger supply-chain networks common standards and data models have to be developed. Another barrier is still the costs of tags. These costs restrict the usage of RFID to high value products on item or case level.

Bacheldor (2005) presents an empirical study about the adoption of RFID. 114 business-technology professionals were asked if they currently adopt RFID technology. 18% affirmed, 25% answered that they are currently pilot testing it and 57% do not use RFID or currently do not plan to use it. Of the professionals using or pilot testing RFID, 14% are very satisfied, 68% somewhat satisfied and 18% state that they are not satisfied with the adoption of RFID. Based on the survey Bacheldor (2005) concludes that "there's no stopping to RFID now".

Kinsella (2005) describes several early adoptions of RFID technology and compares RFID to bar codes and the impact bar codes had on the supply chain. Kinsella (2005) states: "whether RFID will be adopted is no longer question".

A constant trend towards the adoption of RFID in the supply chain can be constituted. The Advisory Group forecasts a great increase of the total market in the manufacturing supply chain (Fig. 2). Tag costs will no longer be a barrier in the future as tags are probably sold for 5 Cent or even 1 Cent in the future (Dunlap et al. 2003).

A reason for the adoption of RFID technology in the supply chain is more transparency. The objective is the possibility to trace goods throughout the whole supply chain. This possibility could reduce the risks pointed out in subsection 3.1 as more accurate data is available. For example, delays can be forecasted more precisely as manufacturers can inform customers about problems on the transport route.

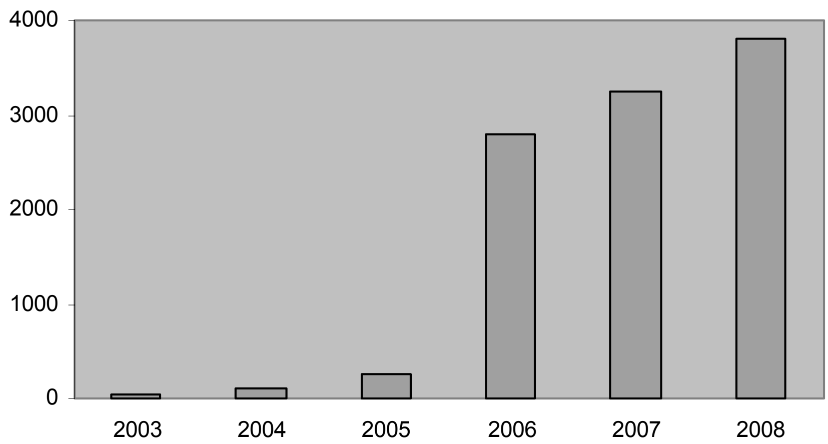

Fig. 2. Total market for RFID systems in the manufacturing supply chain in $Millions

Source: Polsonetti 2004

Based on the studies mentioned above and the benefits for supply chain management, it can be assumed that in ten to fifteen years the infrastructure of the supply chain has developed so far that items or at least cases can be traced throughout the whole supply chain. Ports, airports, distribution centers and good stations will be equipped with readers for RFID tags. Every company whose goods pass such a reader-equipped point in the supply chain may have access to the data as the transshipment centers will provide the therefore necessary services. Hence, companies can monitor the route of in-transit goods and thus have the possibility to intervene promptly in case of any problems.

Besides the purely technical and cost issues, there is also a trend towards standardization of data structures. The most popular standard is the EPC standard. It is a specification for the bit string stored on a tack. This bit string is the key to product-related data stored on a database. Standardized data structures are indispensable when supply chain activities cross organizational boundaries. In the following it is assumed that with the implementation of the infrastructure required for in-transit visibility of goods, a global standard for data structures concerning tag code and product information is fully developed and accepted by the majority of companies.

3.3 The New Market

With the full implementation of RFID throughout the supply chain, companies get the position of their goods from logistic providers or transshipment centers through standardized interfaces. Logistic providers, transshipment centers and customers can make use of the standard identification scheme for goods. Hence, companies have now the knowledge about the position of their goods and due to common standard for identification of goods every other company can pick the freight if it gets access to product related data. As a consequence is the possibility for trading goods that are actually in-transit. On the one hand, a manufacturer can sell goods that were sent to wrong destinations to customers located at that destination. This is extremely interesting when perishable goods are transported and a return transport would take too long. The other interesting scenario is that a customer resells ordered goods while the order is on its way to him. This could be interesting in case of a miscalculation of material consumption or of a varying need of resources that have a long transportation route.

But how can the demand for goods at one place meet the supply for these goods? One possibility is similar to a commodity exchange. In contrast to a common exchange, the traded goods have another attribute besides the price: the location. Potential buyers designate a maximum price that they would pay for a certain product at a certain place. Analogously, a vendor states a minimum price he wants to get paid for his goods at a certain place. As a matter of the required flexibility this is only thinkable in an internet-based form. Another restriction of this kind of market place is that it is only possible for bulk goods that do not differ in quality and that are turned over in huge amounts. Thinkable goods would be hardware for computers like chips or memory of a certain vendor, or perishable goods like food or flowers.

Another market place to trade these goods would be an online platform where vendors can place their offers. Potential buyers can scan all offers online and buy if they are interested. It is also thinkable that vendors offer their products in online auctions. This kind of market place allows any kind of offers, as no market price is calculated for a special good.

In case a vendor sells some products, the buyer gets the tag codes of the bought products and can therefore easily identify them. When picking the products he can access a database where product-related data is stored and gets all the information about the product.

4 The Evolution of the Market

In this section it will be described how the requirements considering the supply chain are going to change within the next ten to fifteen years. These changes are also basic for the possibility of the emergence of a new market like it is described in the previous passage. The first part is about the tagging of products. As a consequence of the products being tagged, it will be possible to have a synchronous flow of material and information. To use this tremendous advantage, a data network will be required in order to share the product related data, which is described in section 3.3. The last part displays the possibilities that are offered by the full visibility of the supply chain.

4.1 Product Tagging

In the current situation, the supplying of goods with RFID tags is quite limited. One of the reasons why most items cases or pallets are not yet tagged is costs. As RFID tags are not produced in high numbers, their fabrication is quite expensive these days. Nevertheless researchers assume that due to the fact that more and more enterprises plan to implement RFID technology in the future, it is very likely that costs per tag will decrease in the next decade because of mass production. Metro and Wal-Mart can already buy tags at prices of about 5ct as they order large numbers. To extend the tagging of products to item level, case level or pallet level, prices will have to drop to 5ct or even below.

Only if products can be identified in the supply chain, such a revolution of the supply chain will be possible. The trading of in-transit goods, no matter if it is perishable food or manufacturing parts, for example for cars, will only work if the participants of the market can clearly recognize which good they are dealing with. Therefore product tagging is a basic pre-requisition. The level of tagging depends on the kind of goods which are traded. In case of food, container or pallet tagging will be sufficient, but if parts of material are the subject of the deal, it might be important that items are supplied with an RFID tag. The various advantages of product tagging, especially the cost reduction that will result from implementing RFID technology, will persuade many firms to go with this unstoppable trend. This development justifies the assumption that within the next ten years, prices of tags will sink to a level where the tagging of even single items will pay off.

For the development of a market for goods which are already on the way to their primary destination, the condition can be seen as fulfilled that all products will be tagged within the next decade.

The following argument for the emerging of such a new market is the possibility that with the use of RFID technology material and information flow synchronously.

4.2 Synchronous Flow of Material and Information

By using RFID technology it is possible to track and trace the route of a product, or of parts of material, even when they are already in-transit, in real time. One can say that material and information now flow synchronously. The concerning information about items can either be stored on the tag, or saved at a database, as will be described later on.

While using barcode technology real-time information was not available. Most data is being collected by different means. It can be done manually, by tags or barcodes. Without using RFID data is collected at different stations of a supply chain, by different people at different times and is thus entered in a database. This database is of course updated from time to time, but the intervals might last from hours to days. During this time, the information is only “pseudo-real time”. Participants of the supply chain might backup their decisions on the information provided by the database; if this information is inaccurate or overage, wrong decisions could be an inevitable consequence (Joshi 2000).

With idea of trading goods while on their way, it is also assumed that decisions concerning supply and demand are made near-term; hence it is critical that information retrieved from the database by participants is accurate and always up to date. Switching over to the implementation of RFID technology offers great new opportunities for firms. One example where the synchronous flow of material and information is vitally important is the automated manufacturing processes. Only if the data about current whereabouts of certain components of a product is highly correct, changes on short notice regarding supply and demand are possible; thus a smooth production process can be warranted. The idea of real-time is not brand-new, it is just becoming more and more commonplace, with many firms discovering the advantages of driving revenues, cutting costs and improving efficiency. There are various other fields in which the real-time based applications are valuable:

Logistics: Logistics environments requiring rapid handling of large numbers of inventory items can use real-time location information to drive efficiency, cutting millions of dollars from the costs of managing valuable assets and searching for lost equipment.

Manufacturing: Capital and operating costs can be cut by creatively utilizing instant knowledge of the location of equipment, high-value inventory, and people.

Automotive: Rapid vehicle location and identification can benefit all segments of the automotive value chain, including manufacturers, distributors, and retailers.

Retail: Visibility data provides retailers with opportunities to optimize store layouts, improve customer service, streamline operations, and ensure store security" (Sybase 2004).

It can easily be seen that the aspect of the synchronous flow of goods and information is vitally important when looking at the arising of such a new market where routes and destinations of products or items are part and parcel.

In the next section it is explained why a data network is required to make use of the product relevant data.

4.3 Data on Network

With the possibility to give each item a unique identification number, which can also be provided on a tag, the information combined with such a number could also be stored in a database network.

When a tag is attached on an item, it is also provided with a number by which it can be explicitly identified. Every bit of information concerning the specific item can be stored, organized and administrated in a special database network.

Anyone who wants to get access to the database to look up information has to authorize himself by a password or a similar access code. For further actions like changing information, adding or deleting it, different authorization regulations are implemented. Along the way can be ensured that only participants with certain rights enter the database and no misuse will occur.

Concerning the different authorization rights the following scenario can be imagined. The manufacturer produces an item and supplies it with a RFID tag. Additionally, he puts an identification number on the tag. The number is also stored in a special database. The manufacturer has an authorization code for his own products; thus he can deposit information about his product, for example material, location of the plant where it has been produced, time of production, etc. When the product leaves the manufacturer, the recipient will receive the identification number; with another password, he can follow the delivery process by looking up current whereabouts and condition of the shipment. By the visibility of the supply chain he will be provided with data about any costly delays or other problems occurring. Actions can then be taken to resolve these exceptions. However, the recipient is not enabled to change any of the data.

When products have to be re-routed, because destinations have changed at short notice, the information could either be modified by the logistics provider or the manufacturer himself.

The data storage in a network makes data storage on tags unnecessary and information processes more convenient for every participant. The network solution also ensures that no data inconsistencies occur.

To administrate the huge amounts of data, sophisticated network architecture will be needed. To avoid information overload, a distributed network is an ideal solution. The implementation of this architecture delivers other important benefits. The availability of data increases as it is possible for many participants to get access to data at the same time. Another important point is that with many working machines, bottlenecks are avoided; data is transferred more efficiently in real-time.

With all these developments concerning the supply chain, a full visibility of the supply chain can be achieved. The advantages are described in the next passage.

4.4 Visibility of Supply Chains

The rapid rising of globalization throughout the last years has lead to increased competition on the worldwide market. The optimization of processes becomes more and more important to gain specific advantages in competition to win the struggle with other rivals in the market. The collaboration among a number of trading partners can thus be critical for an effective supply chain management. It is important to share information between companies to be able to react to unforeseen events in the supply chain. Such events can be: production bottlenecks, fulfillment delays, or supplier shortages. On the other hand it is possible that customer orders are higher than expected or changes of already existing orders are made. Here, the aspect of visibility comes into action. Visibility means, that critical supply chain information can be viewed and shared by all trading partners, as the information is centralized. According to Unisys, there are 6 important types of supply chain information:

1. Location: For participants it is crucial to know exactly where a product is at the moment. This enables firms to calculate exact amounts of existing and receiving stocks.

2. Specificity: What kind is a product? Which material is it made of, of which color is it, when does it expire, etc. If there are changes in demand, products can quickly be replaced as their exact specifity is known.

3. State: Has a product been in appropriate environment during transport? This is especially important if perishable goods are shipped. Quality at the end of a transporting process depends mainly on the conditions during shipment. With RFID technology, the whole process can be controlled.

4. Compliance: Have all regulation and documentation regulations been maintained? This plays especially an important role if goods are traded cross-borders.

Mainly concerning food, there are different rules and regulations in different countries. In order to ensure smooth transporting processes it is important to meet all different regulations.

5. Integrity: Has the product been breached or compromised in any way? Integrity is mainly about security and theft protection during a transporting process.

6. Authenticity: Is the received product exactly the product that was ordered? Counterfeiting is a serious problem in shipment processes. With the use of RFID this problem can easily be tackled and thus lead to immense cost reductions (Unisys 2005).

If one is able to anticipate all kinds of disruptions in the supply chain because the respective information is provided, it is possible to react in real-time. This would enable him, for example, to change destinations of goods, to give detailed information about the current whereabouts of his products or to track and trace goods if they seem to have gotten lost. And this is exactly what is meant to happen on a new market as it was described above. If trading partners have full insight in the supply chain processes, they are also able to make significant modifications, just like reselling for example a container of fruit to a different buyer. This might be necessary when due to any delays on the transport, the fruit would not arrive before perish. In this case it could be sold to a buyer in a nearer location.

To use the services just mentioned, a lot of detailed information has to be provided. Here the RFID tag comes into action again. On the one hand, there is the possibility of storing information directly on the tag. In comparison to barcodes, large amounts of data can be stored on a tag. But there is another, even smarter alternative.

The next passage deals with the participants of a supply chain. Their function will be shortly described, but also the effect of a new market like it was introduced in the beginning on them. Why would they take part in such a market and what benefits do they get out of it.

4.5 Participants

To define a market and its structures it is important to know who plays which role in it. As it has already been mentioned, there is potential that through the RFID technology new market structures or even completely new markets may arise. To explain why this could happen, not only technology and data issues are to be listed, but also the players in a market. To discuss them, it is quite convenient to describe a classic supply chain with its participants. “A supply chain is a network of facilities and distribution options that performs the functions of procurement of materials; transformation of these materials into intermediate and finished products; and distribution of these finished products to customers” (Ganeshan & Harrison).

The following chart gives a short overview about how a supply chain is composed:

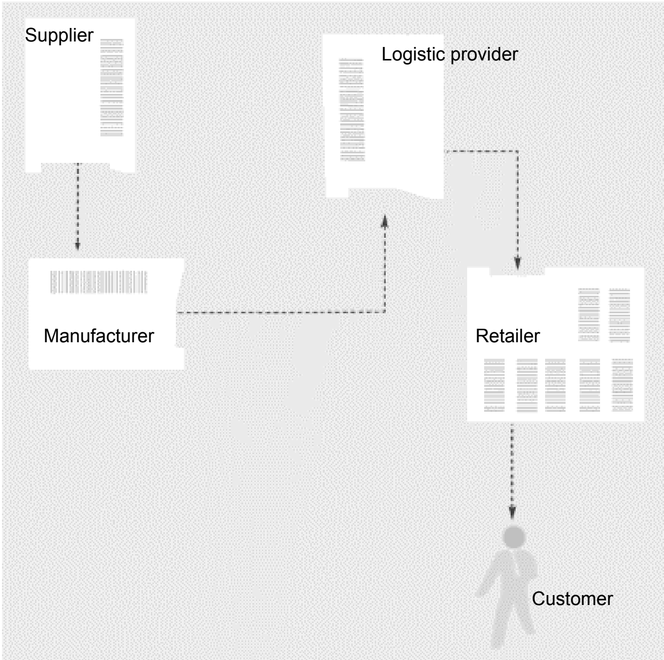

Fig. 3. The supply chain
Source: Own design

Supplier

In a classic supply chain, the supplier comes first. He supplies the manufacturer with material for production processes. A supplier has a lot of data and information to administrate. Orders have to be fulfilled; warehouses to be operated and administrated, delivery processes have to be coordinated. As just-in-time operation has become an ordinary form of production, it is critical for the success of a supplier to deliver the right parts of material or products to the right customers in time. RFID improves data management as has been displayed above; this is why distributors can benefit from the implementation of RFID technology. The aspect of changing directions and destinations at short notice of goods or items because of changed requirement is also highly interesting for distributors. Surpluses and shortages could easily be balanced by rerouting goods that are already on their way. The possibility of sharing of information and the visibility of the supply chain are essential aspects in the case of such a new market.

Manufacturer

The next participant of a supply chain is the manufacturer. The automatic recording of data of goods or items by the use of RFID saves a lot of money. With every item tagged, there is no longer need for personnel; the inventory can be done automatically by RFID readers. But it is not only efficiency that increases, it is also the error rate that decreases and thus costs are saved again. The manufacturer can also be interested in the possibility to change material requirement on short notice. Broken down machines or the loss of a shipment could make changes in the material resource planning necessary. With the chance to be a player in a market of in-transit goods, he is able to cancel orders due to unforeseen events in the production process, whereby the manufacturer could easily avoid storage costs. By placing additional orders for extra material he can avoid working at low capacity rates and thereby prevent additional costs.

Logistic Provider

The third part of a supply chain is the logistic provider. Once a product leaves the factory, or in case of vegetables plantations, it is handed over to a logistics provider. For such a provider it is considerably valuable to be able to track and trace where the goods and shipments are at the moment. With the idea to change destinations of orders at short notice because of any arisen capacity problems or other difficulties, the logistics provider is eventually the instance to take action. He has to check which transport capacities are available and where are capacity problems occurring. With the help of certain computer systems he must be able to decide whether an item has to go on by plain, ship or truck, depending on time pressure and the nature of the product. With the use of RFID technology it is more convenient for him to organize the shipments in order to ensure that they arrive at the right destinations in time. Locations of goods and products can be identified, but also nature, destination, place of manufacturing or expiry dates. The possibility to get a fast overview enables the logistics provider to act very quickly.

Retailer

The next station in a supply chain is the retailer. For retailers, things like customer convenience, stock availability, theft control and price control play a major role. Most important is of course the case of the availability of products. If shelves are empty, no volume of sales will be achieved. The possibility of real-time access to available inventory, order status, tracking information and other logistics data will lead to improved customer satisfaction, reduced complexity and improved performance. Here, the possibility of ad hoc orders also comes into consideration again. If surprisingly und unforeseen high numbers of items are purchased and no stock is available at the warehouses, the retailer can order additional shipments by this special service that balances demand and supply of goods. The service ensures that he will not run out of stock and maximum volumes of sales are gained. If demand is lower than expected and already ordered shipments are not required, a retailer can resell the shipment even before it arrives at his warehouse via this new market.

Customer

The final part of the supply chain is the customer. It is obvious that the customer is not directly involved in any of these processes in connection with the particular new service that may arise because of RFID. The customer is of course the one who profits from a development like this. The retailer can ensure that every product is ever available for purchase. Furthermore costs can be reduced in manufacturing as has already been explained above; this can lead to the decrease of prices of products, which is again an advantage for customers.

5 Technology Enablers

The following section describes technological issues that enable the formation of the new market described in subsection 3.3.

5.1 Standardized Data Structures and Interfaces

A crucial point for the interchange of data is a standardized communication between all members of the new market. Standardized data structures and interfaces enable the interchange of data between all participants of the market.

A data structure that has to be adopted by all participants is the structure of the bit string that is assigned to each product and that forms the key to the product-related data in the database. The first reason why all participating companies have to adopt the standard is that the bit strings have to be unique. Besides, every company's information system has to be able to interpret every possible bit string. This is not feasible with different or even proprietary codes.

Standardized codes for items drive the acceptance for item-level tagging, as the same codes can be used by all participants in the supply chain. The manufacturer can use the code internally during production or in his inventory. During the shipment of the goods to the buyer, logistic providers can identify the goods using the same code. And, as all codes are unique, the buyer is able to use the code for example during the picking process or for identification in his own enterprise software system.

Besides the identification codes for products, participants of the new market have to interchange product-related data. As sellers offer their products to virtually every other company the software systems of all these companies have to be able to communicate with each other in a standardized way. Therefore all participants have to build their systems upon equal data structures or at least communicate over a standardized protocol that is integrated in each company's enterprise software system.

There is a need for a data description language with which all companies can describe relevant product information, like expiry date, weight, size or current location. Additionally there is a need for a query language to request precise information about a product.

One existing standard that meets all the requirements is the Electronic Product Code (EPC) that was originally developed by the auto-id center. EPC was defined "to provide unique identification of physical objects" (Brock 2001). Together with EPC the Physical Markup Language (PML), a XML-based language, can be used as a description language for data interchange. The EPC Information Service (EPCIS) (Harrison 2003) provides an interface to access information about some codes. Queries can be formulated and the EPCIS returns the information as a PML package.

5.2 RFID Technology

The most important technology enabler is the RFID technology. Due to RFID, the unique identification code for every item can be stored on a tag attached to each item. The tags are small, robust, can be easily read and are relatively cheap. This section explains how RFID enables the formation of the new market. The explanation compares the existing bar code technology to RFID and shows that the advantages of the adoption of RFID are a crucial factor that leads to the potential for the new market.

The RFID technology appears as enabler for unique identification, because an RFID tag provides enough space to store a unique identification key for virtually every item.

An advantage of tagging items with RFID tags instead of printing bar codes on the items is the fact, that the tags can be affixed on potentially every product. To tag an item, there is no need for a plain surface.

A tremendous strength of RFID is that the reading process does not require a line of sight between the tag and the reader. As a consequence, whole pallets can be picked without unpacking the items. This leads to an immense increase of the throughput of the picking process. As a consequence items can be read more often on their way through the supply chain without extremely slowing down the whole process. Detecting items with bar code identification would require unpacking and reading of all items. Then all items have to be packed again. This approach is way too inflexible to be practically adopted to achieve more visibility throughout the supply chain. With RFID, items can be read several times during their way through the supply chain and the collected data leads to accurate and precise information about the location of products.

As reading of RFID tags can be easily automated, picking of items is less error-prone than the manual reading of bar codes. In a test phase Metro achieved a reading-rate accuracy of 99% (Manufacturing Business Technology 2005). Figleaves.com has reduced picking errors down to 0.1% with the usage of RFID (Wilding and Delgado 2005). So when the technology is fully developed in a few years, it is very likely that sufficiently high reading-rates can be achieved.

The points mentioned above account for RFID as the main technology enabler for the formation of the new market. The key issues in comparison to bar codes are that RFID provides the possibility to identify items uniquely and the flexibility to trace items throughout the whole supply chain.

5.3 An Internet of Products

Due to RFID technology the unique code can be tagged on the products. With standardized, unique identification codes for products and a protocol for data interchange, software systems of participants of the new market can communicate. But who tells a company or a transshipment center that knows the code for a product, where to get the product information related to that code?

5.3.1 Requirements for a Network of Product Information

For the formation of the new market, a service that resolves the identification codes of products to product-related information is indispensable. On the one hand, some participants only want to get the information to a certain code, like buyers of goods, and on the other hand, there are those that need update or provide additional information, like transshipment points that may have to update the current location of a product.

Companies have to be networked to interchange product data. A common distributed database of product information has to be set up. A network that enables the supply chain visibility that is indispensable for the formation of the new market has to fulfill the following criteria:

1. Given a product code, any participant of the system has to have the possibility to find the product-related data without any further knowledge about the product.
2. The data assigned to a product code stored on the network has to be controlled by the company that owns the code.
3. Companies should have the possibility to restrict the access to their product data.
4. A mechanism for updating information has to be implemented.
5. Communication has to be sufficiently secure.
6. The network architecture should be scalable.

A mechanism for updating information is needed in case of product movements as the location of a product has to be updated in that case. The network architecture should allow scaling the system to a level where item-tagging is possible.

EPCglobal Inc. defines with its EPCglobal Network (EPCglobal 2004) a standard that meets almost all requirements mentioned above. The EPCglobal network uses the EPC as an identification code for products. Every company has its own server providing the EPC Information Service (EPCIS). Several so-called “Discovery Services” enable user to find data and control the access to data. The Service that helps to find product-relevant data to a certain product code is the Object Name Service (ONS) (Oat Systems & Auto-ID Center 2002). It is based on the internet Domain Name Service (DNS) and returns the address of the server that provides the EPCIS for a given EPC. As supply chain partners communicate over the internet several established techniques for secure communication like secure socket layer (SSL) or other virtual private network (VPN) protocols can be applied to reach a satisfying level of security. As the whole data set is distributed over several servers that are in control of the participating companies the architecture itself is sufficiently scalable, assumed that network capacity or hardware power is sufficient.

The only requirement, which is not adequately covered, is the mechanism for updating product information. In the following section a mechanism for updating the location of a product is presented.

5.3.2 Update of Product Location

To show all the components required for the update mechanism, a network model similar to the EPCglobal Network is introduced. Fig. 4 gives an overview over the network. A manufacturer ships some tagged products to a buyer and the buyer wants to retrieve the information related to the products.

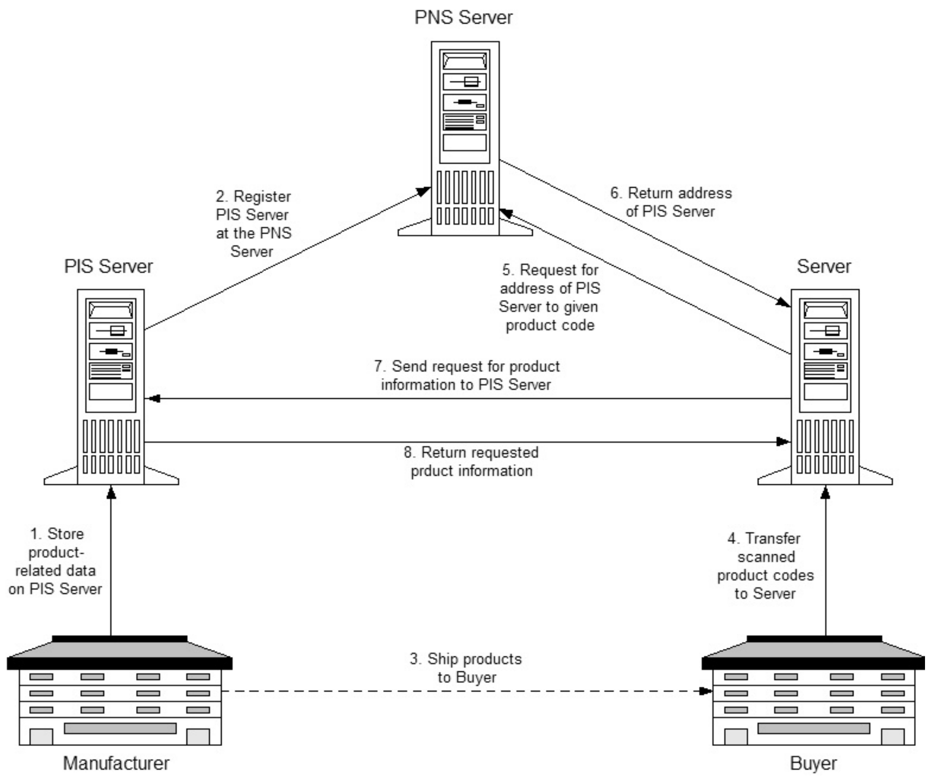

Fig. 4. General network for product data interchange

Source: Own design

In the presented network, the manufacturer tags the produced products and stores the data related to a product on his Product Information Service (PIS) Server. The Product Information Service provides the data related to the codes of the product of the manufacturer. The manufacturer has to register his PIS Server at the Product Name Service (PNS) Server, so that every other supply chain partner can find the address of the PIS Server of the manufacturer. The Product Name Service can be seen as a service, similar to the ONS (Oat Systems & Auto-ID Center 2002) that resolves, based on the Domain Name Service (DNS), product codes to internet addresses. For reasons of illustration only one PNS Server is presented. Actually, there is hierarchical network of PNS Server just like the distributed database of the DNS. Then the manufacturer ships the products to his customer. During the picking process the buyer reads the product codes tagged on the products and transfers them to a server. The server has to find the data corresponding to the product codes in the network that forms a distributed database. Therefore the server sends a request to PNS Server to get the address of the PIS Server that provides the PIS for the products arrived at the buyer. When the PNS Server has returned the corresponding address, the server of the buyer queries the PIS Server to retrieve the product information stored on that PIS Server for a given product code. In case the buyer is authorized to access these data, the PIS Server sends the requested data back to the buyer.

For the new market described in section 3.3 the owner of a product needs full information about the location of its products. Therefore, ideally every time a product moves to another location, the information concerning the location of the product has to be updated. Practically, the points where readers are placed are the in- and outbound of transshipment centers like harbors or distribution centers and of the supply chain partners in a supply chain. There exist two communication models how the update of the data can be triggered.

One possibility is the "push model": A participant in the network receives some products that were shipped to him. So he has the information that the products changed their current location to the place where the participant is situated. In the push model the participant that received the products contacts the PIS Server of the owner of the product code that the products arrived at his location. One can say that the participant that received the products pushes the information to the owner of the codes.

The other possible model is a "pull model". Here the owner of the product codes polls the participants of the supply chain constantly if products tagged with a certain product code have arrived at the place of the participant. If they get a positive response they know that the location has changed. In a way, the owner of the codes pulls the information.

During its way through a supply chain, a product could arrive potentially at every participant of supply chains in the whole world, like every harbor or airport and virtually every company. As a manufacturer usually knows the route a product takes throughout the supply chain, some participants are extremely more likely to be the next recipient of a product as others. So in the pull model the owner of the codes would not have to poll all companies and transshipment centers in the world. Nevertheless to know promptly when a product arrives or if a product was delivered to a wrong destination a lot of messages have to be sent to achieve supply chain visibility in real time. When applying the pull model only one message has to be sent between the supply chain participant that received the product and the owner of the codes. Therefore the push model is adopted in this mechanism.

A problem that occurs in both models is that the owner of the codes is completely dependent on the participant of the supply chain where the products arrived in regard to the quality of the data and the point of time when the data about the new location is sent. This is obvious for the push model as the participant in supply chain that receives the products of an owner triggers the communication and determines the data about the new location he sends. In the pull model it is indeed the owner that triggers the communication and no information about the location has to be delivered as the owner of the codes knows whom he asked if the products have been received. But it is up to the participant that received the products how fast he reads the tags and transfers them into his software system and additionally there is no guarantee for the owner of the codes that in case of a positive response the product is really there.

No problem can be seen for other companies participating in the supply chain. For transshipment centers it is assumed that if there is a real demand for such a service, harbors or distribution centers will rapidly adopt the technology and provide the services for noticing when a product has arrived due to a competitive advantage.

Fig. 5 shows the scenario when the tagged products of a manufacturer arrive at a harbor. The manufacturer has tagged his products and the product-related information is stored on his PIS Server, which he has registered at the PNS Server. When the products arrive at the harbor the tags are read and the codes transferred to a server of the harbor. Then the PNS is contacted to get the address of the PIS of the owner of the product codes. The server of the harbor contacts the PIS Server of the owner and sends him a location update request.

As the owner of the product codes wants to have high quality data about the movement of his products and eventually wants to provide this information for other he checks the new location for plausibility. In case of a plausible location the location data is updated on the PIS Server of the manufacturer.

5.3.3 Automated Plausibility Checks

In the example process illustrated in Fig. 2 the manufacturer as the owner of the codes checks the new location for plausibility before updating the location of the product. Checking the plausibility manually for each update request would be very costly so an automated solution has to be found.

As the manufacturer knows the destination of its products, he also knows the most likely routes to the destination. If he organizes the transport himself he even knows the exact route.

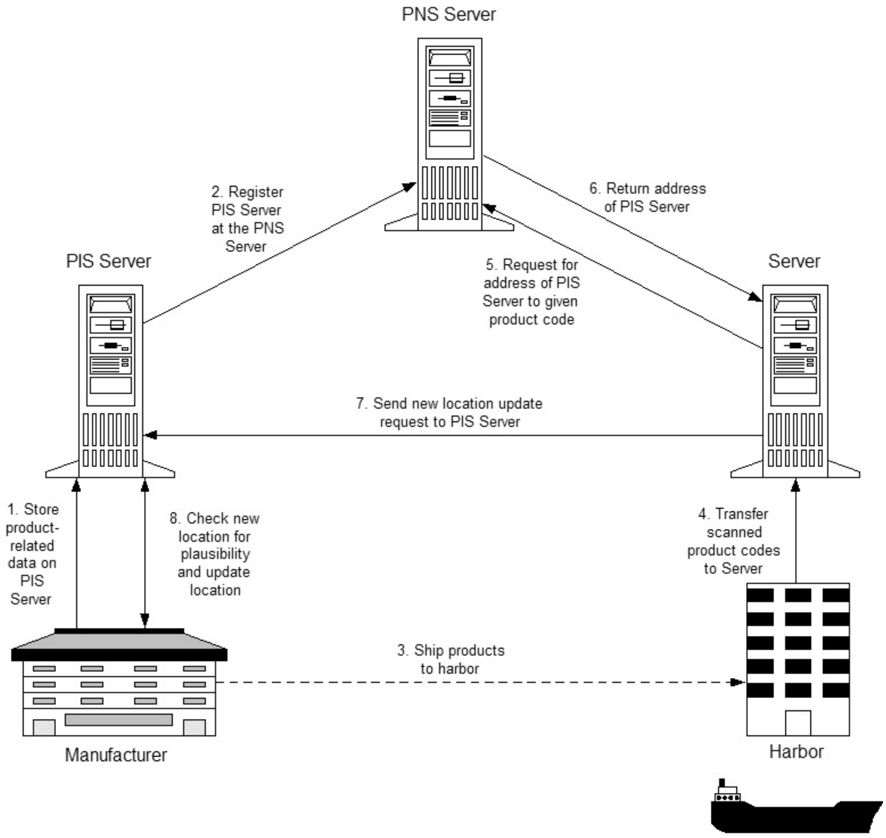

Fig. 5. Update of the location information of a product

Source: Own design

The network of participants of suppliers and the possible routes of products can be interpreted as a directed graph. All participants in the supply chain form the set of vertices and the possible movements from on participant to another the set of directed edges of the graph. A route from the manufacturer to a buyer can be interpreted as a directed path in the graph.

Based on that graph an automated plausibility check can be performed. If the new location of a product is the next vertex on the path to the destination, the new location is plausible and automatically accepted as the new location of the product. If the new location is not a vertex of the path the manufacturer is alerted.

An example is given in Fig. 6. In the example a supplier from Munich wants to ship products to Hamburg. Depending on the exact date of shipment his products take two different routes: From Munich over Stuttgart and Mainz to Hamburg and from Munich over Erfurt to Hamburg. Hence, the resulting graph consists of the

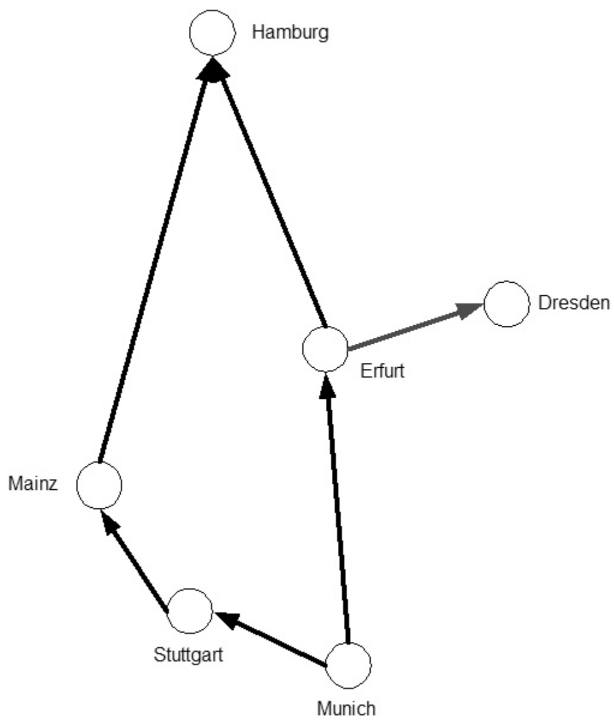

Fig. 6. Plausibility check for location updates
Source: Own design

five vertices Munich, Stuttgart, Mainz, Erfurt and Hamburg and the directed edges representing plausible movements as shown in Fig. 6.

When a product leaves the outbound of the inventory of the supplier in Munich its current location status would contain the information that the product has left the inventory of the supplier in Munich with a certain truck to Erfurt. Then the product takes one of the two routes. The next two plausible location update request would contain as new location Stuttgart or Erfurt. Assumed that the product takes the route across Erfurt and in Erfurt it would be reloaded from a truck on a train. After unloading from the truck the tag of the product is read at the goods station of Erfurt. Based on the code read from the tag, the software system of the goods station sends a location update request to the PIS server of the supplier in Munich. This request contains the information that the product has arrived at the goods station in Erfurt. As this location is a succeeding vertex of the vertex Munich in a plausible path from Munich to Hamburg the update of the product location is plausible and automatically performed. Before the products are loaded on the train, the tags are read again and another location update request is send to the PIS server of the supplier in Munich. This time the location status contains the information that the product leaves Erfurt with a certain train to Hamburg. If the products are wrongly sent to another city, for example Dresden, the supplier is alerted and knows in real-time that the products are transported to the wrong destination.

With the reservation of the right to update the data for the locations an owner of codes ensures that no impossible locations are stored in the location status of the product-related information. If, for any reason, in the example presented in Fig. 6 an update request with the new location of New York in the USA would be send to the PIS of the supplier in Munich after the products have left Munich, he knows that the new location is impossible and can ignore the location update request.

6 Technology Challenges

In the previous part, it has already been talked about the technology enablers which make the trading of in-transit goods possible with RFID technology. In the following part the challenges from the technical point of view will be discussed.

6.1 Challenges in RFID Technology

As it is known, RFID systems generate and radiate electronic magnetic waves, so they are legally classified as radio systems. Usually it is only possible to use frequency ranges that have been reserved specifically for industrial, scientific or medical applications. When designing network with RFID, it may meet some challenges due to the features of different frequency ranges. Moreover, characteristic of RFID tags and readers may also cause some problems.

- Due to shielding or reflection effects RFID systems are sensitive against metal parts in the operating zone (AIM Frequency Forum 2000, p. 6). This applies more or less to all RFID systems, although the physical reasons are different. Since in the described transit network the goods are wrapped with metal materials in many cases. This feature in RFID systems might be very crucial which causes problems when reading the tags especially in automotive industry. Current techniques for reading passive smart labels on metal are relatively expensive and cumbersome. However there are some solutions based on active transponders and novel passive tag designs that show promise. One possible solution is to deploy microwave RFID systems, because it is possible to design tags that work flat on metallic objects in the systems. But costs will be increased.
- Radio waves are absorbed or penetrated by water at ultra-high frequencies and microwaves. That makes tracking goods containing water problematic, but good system designs and engineering can overcome this shortcoming. For example, low frequencies work better on products with water. Certainly the read range is not wide enough, thus the scope of application is limited.

- One problem encountered with RFID is the signal from one reader can interfere with the signal from another where coverage overlaps. This is called reader collision (RFID Journal 2002). One way to avoid the problem is to use a technique called time division multiple access, or TDMA. In simple terms, the readers are instructed to read at different times, rather than both trying to read at the same time. This ensures that they don't interfere with each other. But it means any RFID tag in an area where two readers overlap will be read twice. So the system has to be set up so that if one reader reads a tag another reader does not read it again.
- Another problem readers have is reading a lot of chips in the same field. Tag collision occurs when more than one chip reflects back a signal at the same time, confusing the reader. Different vendors have developed different systems for having the tags responding to the reader one at a time (RFID Journal 2002). Since they can be read in milliseconds, it appears that all the tags are being read simultaneously.
- It often happens that some other radio services may under some circumstances be disrupted or impaired by the operation of RFID systems. For example, RFID systems working at UHF may be interfered by the GSM mobile network. So how to ensure RFID systems properly work at such frequencies is very important. From the technical and cost point of view, UHF is the most effective frequency range. But many other devices use the UHF spectrum, so it will take years for all governments to agree on a single UHF band for RFID.
- Environmental impact of all those transmitters, antennas and readers plays also important roles in RFID systems. For example, in automobile industry some process are executed at such a high temperature like 240 C or in food industry some goods must be kept at an extreme low temperature. It means some tags are needed to be designed to survive up to 240 C, in addition to extreme low sub-freezing level. Thus, extra investment is required to cover the cost for providing the solutions of low- and high-temperature applications.
- It turns out that tag read accuracy is not exactly the 100% we had expected it to be, although we are assured that the number is fairly close to that. However, compared to barcode the read accuracy in RFID systems is already increased by 10%-20%. The error rates of reading items are fairly low, but any error rate has the potential to insult the customer, and that's obviously not a good public relations exercise.
- As the magnetic field has vector characteristics, there exists an influence of tag orientation performance. This impact of this orientation-sensitiveness can be solved by the usage more complex transmission antennas. Thus it is possible to operate tags in a certain operating zone independently from their orientation.

- In addition, the RFID vendor landscape is still evolving. Many mid-size and small vendors are likely to consolidate in the next few years or simply go out of business. Big technology players have recently purchased some small, but visible, RFID vendors in an effort to dominate this evolving technology. This behavior will likely continue to increase until a few key players remain (Higginbottom 2005, p. 9). Companies will need to carefully select their technology partners to ensure ongoing capabilities for the future. This means that companies will need to objectively perform due diligence, examining vendors' financial viability as well as their technological strengths. As market consolidation occurs, companies must reassess their vendor and technology selections to ensure extendibility of their RFID architectures.

6.2 Challenges in Data Network

As shown in the previous section, the in-transit network involves getting information flow of goods i. e. data, data stores and management, software, service servers, security and etc.

Industry analysts have predicted that RFID will produce 30 times more data than companies have today. To ensure that data doesn't overwhelm current systems and is instead used for smarter, better, faster performance, companies should leverage several other critical IT components, including data stores, OLAP applications, business rules engines and distributed services (Unisys 2004, p. 8). These components are necessary to build an effective RFID architecture and, ultimately, to integrate with existing enterprise infrastructure.

Data stores are required to house and manage the massive amounts of data that RFID technology will produce. EPC tag stores will contain the tag identification numbers associated with specific items (containers, pallets, cases, individual items, orders, etc.). Online transaction processing (OLTP) data contains the key elements of the electronic pedigree. In particular, it contains the mass serialization and chain-of-custody data that ensure all of a tagged item's movements and modes of transport can be tracked. As it includes data on all levels of physical containment, mass serialization can be thought of as a file explorer for the world of physical items. Chain-of-custody data, including information about condition changes and time in and out of custody, is required to determine that the normal and expected custody chain has not been impaired in any way. It may also contain chain-of-integrity data related to physical devices, such as container seals, packaging techniques, holograms, etc. Since the amount of data is extremely huge, data stores turn out to be heavy burden on servers. Proper maintenance and periodically check of servers are quite important.

Data management is another issue. As mentioned above industry observers suggest EPCs and other RFID data will increase current stores of enterprise information by a factor of 30. Even companies that avoid drowning in data may struggle to derive value from it. Data can be an asset, provided it is put to work in support of core business goals, rather than locked up in data stores. Huge amount of data may be continuously inter-exchanged between all the participants. Traffic may happen any time. Carefully network design and implementation is needed to address those challenges.

Distributed services represent another key layer of the RFID-based networks. These software pieces are executed to work with RFID readers or data stores, and sometimes come bundled with various readers as value-added services. RFID configurable reader applications typically run on a centralized basis and provide interfaces with readers and portal or mobile dashboards. These maybe used to augment and integrate with ERP, CRM and other enterprise applications, so executives can track key performance indicators across the entire business. This level of integrated visibility gives executives advance notice before minor bottlenecks cause inventory or stocking problems for customers. Enterprise application integration is necessary to connect ERP, CRM and other systems with the RFID network, including centralized RFID applications, distributed services and the data stores.

However, there is still little integration of RFID technology in standard software. A middleware tool used for connecting RFID (called "Savant") is under development by several associations. A Savant based infrastructure could be very useful for different industries. Software vendors like SAP are working on providing interfaces to Savant and on integrating RFID support directly into their mainstream products. They still have a lot of problems to solve.

Much of the implementation complexity arises because RFID generates substantial volumes of data requiring filtering, aggregation and analysis. In addition to the challenges of synchronizing data with existing systems, the participants will eventually demand access to this information. All participants such as manufacturers, retailers will need to redesign their information-sharing and data management processes and policies. They will also need to further integrate their systems to facilitate data exchange.

7 Market Drivers

What are the possible market drivers for deploying such a network with RFID? In this section the answer to these questions will be given. In section 7.1, the market drivers from the manufacturers' point of view will be described. Several different situations encountered with manufacturers will be analyzed. In section 7.2, market drivers for retail business will be discussed in general. Afterwards, the drivers for automotive industry as a trailblazer will be given.

7.1 Manufacturers

RFID technology promises to profoundly improve key operational areas for manufacturers in so many industries (RFID Journal 2002). By deploying in-transit trade network, it helps manufacturers answer fundamental questions that they have always struggled with: What quantity of goods should we produce? When should these products be made? Where do they need to be shipped? Where in the vast supply chain is that shipment right now? How can we react if goods are sent to wrong destinations? How to deal with the product returning problems in advance? With timely and accurate answers, manufacturers can run much more efficient forecasting, production and distribution operations. In fact, just-in-time manufacturing can give way to exact just-in-time or real-time manufacturing.

The basic working process with RFID for manufacturing is like this. As goods travel down the production line, RFID tags are physically applied and a unique ID is written and then validated for quality assurance purposes. The unique ID is automatically associated to the product/order details to facilitate further tracking and exception management. During the pallet build process, goods are automatically identified to aid with customer order configurations. Finally, pallets are identified and tracked as they are delivered to the staging area ready for shipment. For example, as features are added to a personal computer assembly, they could be recorded on the tag. In this case, the tag would keep a current “inventory” of the PC’s contents. The tag information could later be read to produce a shipping list and invoice. The tag could also remain with the item for later use by field personnel during installation and maintenance.

Here several situations will be given which the manufacturers will meet with high possibilities in the supply chain and how the whole procedure works in the network and what the manufacturers can benefit by deploying in-transit network with RFID.

Some industry analysts show us that global shrinkage in the Consumer Package Goods (CPG) supply chain is \$60Billion yearly (Hewlett Packard 2004, p. 7). Shrinkage means theft, expiry, loss, and damage before reaching the customers. Customers here can be end-customers, logistic providers, retailers or OEMs. One of the main reasons causing the shrinkage is that the goods are very often sent to wrong destinations. On one hand, by increasing the visibilities of the whole supply chain the probability of sending goods to the wrong destinations can be reduced. On the other hand, a manufacturer can sell goods that were already sent to wrong destinations to customers located at that destination. This is extremely interesting when perishable goods are transported and a return transport would take too long.

Product returning in the supply chain is another very big problem. It occurs not only in B2C field but also in B2B scenarios. As far as managing the returns are concerned companies re-use them, re-sell them, leave them to a third party or destroy them. But companies are more likely to benefit if they can also make use of the information that comes back with returned merchandise. Managing the collection and acquisition of used or returned products potentially accounts for a significant part of the total costs of any supply chain (Rakesh Verma and Vinayak Vhatkar 2005, p. 5). To design the network for collection a company can install several drop points for customers to hand in used products, integrate the reverse flow of used products with other transportation flows. RFID-based network will make the operations more effective and responsive, thus reducing the cost. It is also relatively easy and efficient for companies to deal with reusing, re-selling, or leaving them to a third party by deploying in-transit network with RFID. For example, a computer retailer has ordered a lot of different computer components including CPU, mainboard, sound card and DVD ROM from different manufacturers. But after all the components arrive, because of some reasons the retailer wants to return part of the products. The traditional way is that the retailer just sends those unwanted parts back to the manufacturers and let them deal with those products. But now for the retailer, he can sell the products to other retailers who also share the network and are in demand of those products. For manufacturers, they can re-sell them to other local retailers or even other manufacturers through the network. Even when the products are already on the returning way, it also works. Obviously, it is a win-win situation for both manufacturers and retailers.

Temperature control and observation is also a very critical factor in the supply chain for manufacturers, especially in food industry. Up to 20% of foods are discarded due to spoilage in the supply chain (US FDA). RFID-based in-transit network can address this problem or at least improve the performance by monitoring shipments of temperature sensitive products. The ability to have a permanent, incontrovertible record of the temperature history of a product enhances the safety of the consumer, lowers insurance costs and reduces the possibility of legal disputes over the liability for a particular loss. Since data on network are accessible to all participants, the manufacturers can observe the status of their goods wherever they are. If they found some unexpected situation occurs during transportation. For example, because of temperature increasing the expiring date of some perishable goods has been shortened. The manufacturers can sell their goods before reaching the destinations. The possible way to sell them is to ask the customers who also participate the shared network and immediately need those goods. So one can conclude that an economical, accurate method of recording the temperature variables of a product once it leaves the processing plant would be a terrific asset to the entire temperature sensitive and perishable products industry.

7.2 Retail Business

The key strategy for retail is managing product availability of goods that customers want to purchase whilst minimizing inventory stock on hand and maximizing speed to shelf, a fine balance to say the least. The challenge is being able to obtain both real-time demand and supply chain product visibility using cost effective and efficient approaches.

Today, when a retailer receives products shipped from its distribution center or directly from manufacturers, it will do one of two things: it will either conduct a time consuming and manually intensive process to verify that the product matches the ship list before accepting receipt of the product and adding it to the store’s on-hand inventory record, or it will skip this process and automatically receive the shipment “as is” (Alexander et al. 2002, p. 17). The more time-consuming approach helps to keep inventory accurate and addresses mis-ship problems immediately. So the retailers must take a trade-off between cost and accuracy. The RFID system essentially eliminates the need to make this difficult trade-off decision; you get accuracy at virtually no cost. For the vast majority of products received, case-level tagging is sufficient to ensure accuracy. This process will work as follows (Alexander et al. 2002, p. 17):

As pallets are unloaded from the truck and brought into the back of the store, the RFID reader located at the store's back door reads the pallet tag and all the individual case tags for the cases loaded on that pallet. By reading both the pallet and the case tags, the system automatically verifies that all the cases that should have been loaded on that pallet are indeed there, and that there are no discrepancies due to theft, mis-picks or mis-shipments.

At the same time that the product is scanned and received, the received product quantities are automatically added into the backroom storage on-hand inventory based on what was scanned by the reader, not on what the shipping list indicates. Any discrepancy between the shipping list and what was actually scanned at the back of the store will generate an immediate exception error notification that the store could then act upon and resolve immediately with the distribution center. Discrepancies could be categorized and tracked for root-cause analysis and preventative planning. Product theft, for example, could be quickly identified and addressed.

Once the product has been received into the back of the store, the next big challenge that retailers face is maintaining visibility of backroom inventory so that when restocking becomes necessary, it can be performed quickly and effectively. Using the RFID system for case-level tagging will give retailers the ability to track, in real time, product availability in the backroom and temperature controlled areas.

Many retailers still rely on at least one or two complete physical inventories annually. This inventory process has an impact on retail out of stocks to varying degrees. As retailers shift their focus from consumer service, production and restocking to preparing for inventory, out of stocks do increase. Moreover, the labor constraints at retail often require management to shift tasks that maintain in-stock levels to tasks such as inventory preparation and counting. This shift in labor resources also contributes to out of stocks before, during and right after the inventory. Item level RFID systems will allow the readers to instantly read the entire store. Reading the inventory real-time will enable a retailer to capture existing inventory levels without manually counting.

Fig. 7 shows us the growth expectation for the retail shareholder if deploying RFID-based network.

7.3 Automotive Industry

Compared to other industries, automotive supply chain has the reputation of being well organized compared to other industries, supply chain visibility and information accuracy are still far from perfect. Automotive manufacturers, referred to as original equipment manufacturers (OEM) are dependent on their suppliers for a large number parts, components or modules. Because of this dependency supply chain visibility is more crucial. The following features of automotive industry may drive itself to enter into the new market.

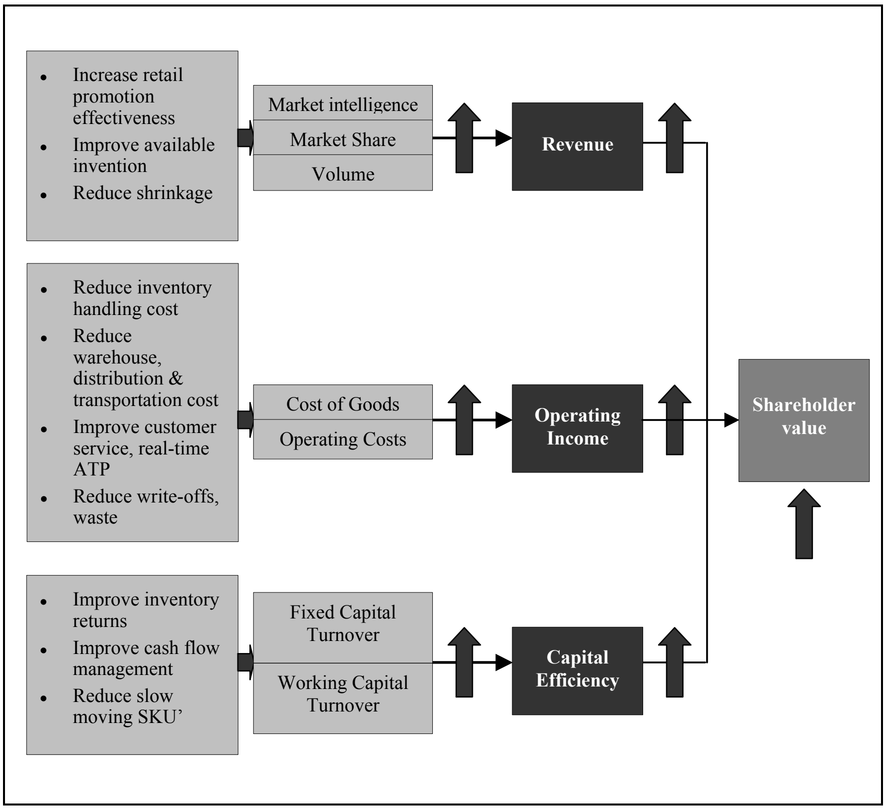

Fig. 7. Growth expectations for retail shareholder
Source: Auto-ID Center

1. Electronic data interchange is a vital business
2. Real-time manufacturing requires real-time data exchange
3. Success of standard
4. Complex products and assembling process
5. Numerous suppliers and different components
6. Open for new technical innovations
7. Proven ability to implement new systems
8. High grade of automation
9. Necessary economies of scales

In the automotive industry, electronic data interchange (EDI) is a vital business (Supply&Demanding-Chain Executive 2004). Operating in a strict just-in-time (JIT) environment means coordinating production schedules, orders and delivery processes – and all their associated details – with a long list of vendors in an efficient and cost effective manner. Standardized data structures and interfaces enable the interchange of electronic data between all participants of the network. All participants are accessible to the real time data and can upload or update their own data. Thus data interchange is becoming easy and efficient.

The automotive industry comprises relatively few market players that participate in associations like AIAG, ODETTE, JAMA/JAPIA, and VDA (Strassner/ Fleisch 2003). Standards are discussed in those groups. The AIAG has monitored the development of RFID for several years and is the initiator of the B-11 tire label spec. The success of this standard may be the driver of smart supply chain with RFID in the automotive industry.

The supply chain of an automotive manufacturer handles approx. 200,000 different parts (Martin Strassner and Elgar Fleisch 2003, p. 20). How to manage those different parts efficiently in supply chain is very demanding. Identification technology is necessary for keeping track of parts in stock or in-transit, for preventing misrouting and for minimizing safety stock requirements. Full automation is the only way to keep identification free of errors. A highly JIT-optimized supply chain can easily be jeopardized if errors occur. As it is known in automotive industry there are numerous suppliers, cooperating with hundreds of suppliers is a very demanding and annoying thing. Now since all participants can share the database and can post online announcements, the cooperation is becoming easier and more efficient. OEM can just post their orders online. The related suppliers can ship the goods immediately according to the online orders. The RFID-based in-transit network makes all the goods visible. Both OEM and suppliers can track the goods anytime through the network. They know where exactly they are and what the status of the products is now. They are able to react in advance if some problems occur during transportation.

The automotive industry has always been an early adopter of new technologies to streamline logistics and manufacturing. They have a proven ability to implement new systems, even those of high complexity. The assembling line that was firstly deployed in automotive industry has been improved to be a big success and has been widely used in other industries. From the acceptance point of view, it is possible for automotive industry to enter into this new market. Because of the high grade of automation in automobile, compared to other industries, it's relatively easy to adopt new RFID systems. Some investigations show that 50 million cars are produced in one year. So from the economical point of view, the market in automobile industry is big enough to set up this kind of network. Based on what has just been discussed, it can be seen that automotive industry could be a trailblazer for this new market.

8 Emergence of the New Market

RFID technology will change the supply chain. The current market structures will be redesigned even on the economic point of view. The current supply chain will turn into a “supply chain net”. The following section will be an economical analysis of the emergence of the new market. The institutions of the supply chain, the existing property rights and the hybrid organizational form will be described. The change of transaction costs, their environment parameters and their determinants will also be covered.

8.1 Supply Chain Institutions

The new market consists of institutions on which the theory of an economic market is based on. Considering institutions the central question is which costs arise by creating, using and assimilation of the existing institutions, which institutions favor specific types of transactions and to which extend institutions differ through of allocation neutrality. The term institution is defined as constitution in the sense of an organization. These organizations consist out of a bundle of single, coordinated rules. The rules forbid, commit and allow certain behavior in recurrent situations. Institutions make the interaction of human beings easier. They constrict the scopes in recurrent situations and make the human actions predictable. This reduces the uncertainty about the behavior of other individuals. Institutions rise accidental, which is called the invisible hand or intended. The stable equilibrium evolves through the cooperation of self-interest orientated actors: the supplier, the manufacturer, the logistic provider and the retailer considering the B2B supply chain participants. They act with limited rationality and under the norm to maximize their individual utility and their profit. The human intellect is restricted in the capacity of information processing (Furubotn and Richter 2003, pp.1). But the new information and communication technologies enable the participants to communicate almost synchronously overcoming national borders and thereby able to manage a global supply chain. Having the opportunity to monitor and send goods real-time to every distinction which is acquired. RFID technology will give institutions kind of third dimension, because it will be possible to organize the good streams within the supply chain in an automated way. It will reduce the uncertainty of the exact location of the product and the behavior of the individual.

8.2 Consolidated Property Rights

The supply chain consists out of individuals, companies and rules accordingly norms, e. g. contracts between the companies of the supply chain. These norms allocate the individual property rights and regulate the transactions between the companies. Property rights can be divided into absolute and relative rights. Absolute property rights are existent with the possession of a product. Relative property rights arise of contracts between the companies. Looking at companies property rights are preconditioned. Otherwise would be no exchange possible. The exchange of products is equated with the exchange of property rights. One simple change of property rights is called transaction. They are also the reason for existing enterprises in their current form. Enterprises exist because they can solve the coordination and motivation problems associated with transactions rendered possible by having lower transaction costs than the market. They perform better than markets could. “A firm … consists of the system of relationships which comes into existence when the direction of resources is dependent on an entrepreneur.”(Coase 1988, pp. 41). But costs do arise through bargaining contracts between the enterprises to manage the product stream, the supply chain. To relieve this, rules or institutions had been settled to create transparency, e. g. norms of quality (Marteinsen 2000, pp.11). Looking at the RFID supply chain the EPC global standard is an example for setting norms to create transparency. If RFID technology is implemented the management and organization of the supply chain will be taken over by a logistic provider. The logistic provider will consolidate thereby property rights. In former times the logistic provider only dealt with the issues of organizing the product transport from location “A” to “B”. Transactions of products are going to be under his control and under his foresight. The exchange of information between companies will not decrease but will change. Plausibility checks will take over the information function. Information relating to the product are bundled efficiently and handled by the logistic provider. The producer or the manufacturer of the products will still have the absolute property rights. The owner of the codes can be the logistic provider or still the manufacturer. But if the logistic provider is the owner of the codes he will consolidate the relative property rights. Being the owner of the codes of the RFID tag number will enable him to organize the whole product flow. If the product arrives at the retailer, the retailer will become the absolute property right of the product, but the relative property right of the codes will stay in the hands of the logistic provider.

8.3 Transaction Costs

When the property rights are allocated between the companies transaction costs arise. The theory of transaction costs is an analysis model to acquire the cost of all organization forms and to give advices for every activity managing the product flow. The analysis starts with the detection of the attributes of every activity having influence on the transaction costs. The aim is to detect frictional losses and minimize them to achieve an optimal coordination form. Transaction costs are based on the exchanging relationships between the specialized companies of the supply chain. Companies appear in manifold exchange relationships of trade-offs and coordination. The occurring problems in organizing all the relationship matters have to be solved by organization, which solves the organization problem. The current supply chain relations are long termed and are determined on trust based relationships between the supply chain participants. Long-term contracts are essential to keep the transaction costs small (Schary/Skjott-Larsen 2001, p. 73). But the arising future market transactions instead are short and occur largely anonymous. The intensity is rather small in contrast to the coordination of the supply chain.

RFID technology enables that the exchange of information gets automated. Information and products flow synchronously between the enterprises. There will be a higher frequency of information exchange transactions which evoke higher transaction costs. But the information are way more bundled, up to date and exchange processes are much more efficient in comparison to former times. These issues will reduce the transaction costs determined by the new information and communication technologies, e. g. the ability of having automated plausibility checks. Transaction costs will decrease through creating total transparency through new ways of exchanging product related information. The coordination of the product stream would be fulfilled in the most efficient way if no transaction costs arise. But transaction costs avert that the market mechanism is an efficient solution and the theory of market failure comes into account. They arise through incomplete foresight and sideward through asymmetrical sectored information and are the costs of the production factor “Organization” (Picot 1982, p. 270). Transaction costs combine all costs of information and communication for the companies involved to the exchange process. Every company gets informed in the best achievable way through RFID technology in the future. The companies have access to the same information regarding the product therefore the asymmetrical information situation gets reduced. Identifying the single activities of the supply chain and combine them optimal into the supply chain process is the main challenge of managing the supply chain. Every company, generating transactions has to adjust with the others to achieve small transaction costs. The logistic provider will coordinate and organize the routing of the products. The goal is to turn the exchange relationships between the companies into efficient ones. All important information are bundled to handle the product flow and to overcome the great challenge organizing the product flow efficiently all along through the supply chain. The whole process must be coordinated factual and temporal. The organization makes sure that the bearer not fails due to the restricted rationality and the opportunistic behavior (Picot 1982, p. 269). Opportunism means that individuals realize their self-interest as well as to the disadvantage of other individuals. Transaction costs can be allocated to the detailed phases of the conclusion of the contract. The different phases exist out of:

Initiation	Communication between the supply chain participants
Convention	Negotiation of contracts, getting legal advice, determine the owner of the product codes and the absolute and the relative property rights
Managing	Leading the process/coordination of the product flow laid into the hands of the logistic provider
Controlling	Product quality and date delivery control is assured
Accommodation	Ex post quantitative and scheduled changes will become close to zero

Environment Parameters

The most important parameter onto the transaction costs are the environment parameters as described further:

- **Uncertainty**

  Is the measure for the predictable and the number of necessary changes during transactions. If the unsureness is high it means that transaction costs are rising. If the product stream stops for any reason the company is forced to keep products in stock. But the new market will reduce uncertainty, because products will be observed and monitored much more accurately. The ability arises to react much faster to changes during transactions. The location of the product is given real-time and the route of products can be changed even the product is already in-transit. The uncertainty about the location of the product is almost eliminated.

- **Specificity and strategic importance**

  The specificity of a product determines the value difference between the planned application of the product and the second best application. The greater the difference the higher is the specificity of the transaction (Picot et al 2005, p. 59). Companies investing in the RFID technology want to ensure the stability of the technology because they have to make long lasting commitments. But having invested into RFID infrastructure connotes that they do have cost advantages and differentiation benefits compared to market actors not using RFID technology and therefore not being a player in the new market. There are different aspects designating the specificity of the RFID infrastructure in context with the RFID technology. Increasing forms of specifity considering the site and the physical asset specifity:

Site	RFID readers at strategic points (transshipment centers) within the supply chain. Investments in localized facilities.
Physical asset	RFID tagged products turn into high specific items

- **Frequency**

  Frequency comes first into account when the exchange procedures are specific and strategically important. Concerning the supply chain the exchange procedures frequency is high. If the frequency is high, initiation und agreement costs are distributed onto the single transactions. Thereby the average costs fall and it comes to a fixed cost digression (Picot 1982, p. 272). The investment in RFID infrastructure will come to a return of investment in a long foresight and amortize themselves.

Determinants of Transaction Costs

New information and communication technologies are the cost determinants of the organization of the future supply chain. They enhance the human information converting and the capability to communicate. The phases of the contract closing get alleviated. The RFID technology will enable to convince enterprises borders and to coordinate the single achievement processes over the whole supply chain. New information and communication technologies will reduce transaction costs.

The more efficient the coordination between the participants along the supply chain is, storage will get redundant. The optimal storage capacity has to be defined looking at the whole supply chain because storage means capital commitment and costs. This refers to the just-in-time principle, which eliminates stock amount because the production starts directly after matching the order. To deliver just-in-time means to deliver at the right moment, the right quantity and quality at the right place to fulfill the actual demand. The aim is to adjust the activities of the supply chain close to the market demand. But one important condition is the economic efficiency of transport networks, which is defined as follows (Dyckhoff et al 2004, p. 1):

$$\text{Economic Efficiency (W)} = \frac{\text{Assessed performance (e.g. proceeds)}}{\text{Cost}} = \frac{L}{K}$$

But it has to be taken into account that product life cycles get shorter and products get more individualized and complex. The just-in-time principle and a high performance in relation to the costs strengthens the innovation grade of the products in short life cycle times. The supply chain is turning into the storage in an abstract sense.

8.4 The Supply Chain Network

For the supply chain it has to be found a coordination model with the smallest transaction costs. The assignment takes place on a contractual basis, so transaction costs determine which organizational form is realized. The organization and configuration of the supply chain is a dynamic process, which has to react to features of performance allocation. Tagging all products with RFID chips will be a fundamental transformation. The existing organizational models are: market, hierarchy and forms in between which are aggregated as hybrid structures. It depends on the situation and the surrounding which differs in every specific challenge. The supply chain consists out of the hierarchy form within the companies and the market form to organize the product flow on its way to the customer. Combining these two forms the supply chain is a hybrid form of organization (Picot 1991, p. 351). Interfaces within the supply chain get mostly free of frictions and the building networks are offering a huge potential. New organization forms are going to develop through the new technologies of information and communication. Combined with the RFID technology the supply chain will get revolutionized. In former times companies relayed on long product cycles, stable markets and a countable number of competitors. But this has changed and the borders of the firms become blurred. Internationality, short product cycles, increasing numbers of competitors from different countries and developing networks have changed the competition situation. The changing conditions constitute a pressure to optimize their original challenge. The competitor environment and the product variety have changed. Also the surrounding has changed and companies have to concentrate on their core competencies. Their strategic core is the know-how of their employment, the technological and organizational abilities, because only these competences can significantly contribute to the expectants of the end customer. Markets get customer driven. Already Byrne had 1993 a vision of the future market "The virtual corporation is a temporary network of independent companies – suppliers, customers, … – linked by information technology to share skills, costs, and access to one another's markets." (Hofmann 2001, p. 144). Due to the high network of the supply chain participants they have to consider their whole supply chain. The "supply chain net" is not a sequential consideration anymore. It is a whole network of ability with different options of the material and information flow. "Supply chain net" points out an organizational form, which in a special way shows the complexity of the exchanged relationships. Networks are the outstanding organization form of the future, because they enable a fast adoption to changes of the company's environment. The supply chain members have to overcome the national boarders regarding their communication and their transactions. The transactions have to develop faster, more flexible and have to save costs. Delivery time and deadline constancy are important factors along the supply chain. Companies have to break-through borders. The more common the coordination between the companies will be their benefits regarding time, cost and even quality will increase. Time, quality and costs are the three key factors of the success of a company. The goal of every single company is to maximize their profit. Working close together with the other partners in the supply chain develops a supply chain network, which common goal is to maximize the common success. Companies have to be able to react to changes more effective and reactive. This flexibility is based on the management of the logistic process. Therefore the power for the logistic process is laid in the hand of the logistic provider. Due to the new organization form of the supply chain the data related to the product will be in the hand of the responsible company. The logistic provider will be seen as the playing role in this context. The PIS Server will be in authorization of the handling logistic provider. The logistic provider will match the orders of the supply chain participants within the supply chain. Being the owner of the codes will give him a new art of empowerment managing the stream of products. Demand and supply in former times not being matched will now be able to get matched. And they will not only be matched. This process will be handled faster, more effective and efficient.

The globalization brings along great chances but also high risks. Markets get bigger and competition harder. But the motivation to act globally is clear: open up new markets, achieve economies of scale and produce in countries with cost structures at a reduced rate e. g. in China. The companies have to build up a global network. Globalization brings along that the distances are getting longer between productions and consume. For example products are manufactured in Asia and have to arrive in Oslo as fast and as cheap as possible. Companies start to use the network of companies to manage the steadily arising amount of products. Cross border transactions und intercontinental ware streams are rising up. The new software possibilities make the data streams transparent, this construction enables a fast and cost convenient availability of data for all companies in the supply chain. This enables value added services as specified in the scenarios in section 2.

9 Financial Analysis

In this passage a short overview about annual losses in the food supply chain will be given. Each year, tremendous amounts of food make their way though worldwide supply chains. Because of unfavorable climatic structures in many countries, most fruit and vegetables have to be imported. Other countries have favorable conditions for the cultivation of these goods; they have immense export rates. These circumstances lead to the matter of fact that just at this moment huge quantities of fruit, vegetables, meat and fish are being transported to almost every country in this world.

It is said that "*15%* of the worldwide air cargo flows are perishables with a further expected growth of *7.1%* (…)" (Merge Global 2003). Especially in South Africa and South America the export of perishables goods plays an important role. Lufthansa states that "up to *80%* of total export airfreight is perishables (…). Another significant example is Brazil; according to Lufthansa, its exports of food and vegetables make up *42%*, bringing in revenues of about *$ 30.64Billion*. But as the following tables show, other countries also have large export rates, concerning perishable food like fruit and vegetables (Lufthansa Consulting).

Another important sector of perishables is fish. The FAO estimates that each year the worldwide production of fish averages *90Million* tons. It is estimated by the FAO that these numbers will still slightly grow within the next years. Fig. 8 shows the development of the production of the past 10 years (FAO 2004).

It is not difficult to realize that there is high potential concerning improvements in the supply chain. Hewlett Packard states that *20%* of food deliveries have to be

Table 1. Fruit export rates

Fruit Export Flows in kg		Export Value in US$	
Argentinia	153.463.532	Argentinia	11.914.510
Spain	50.899.972	Spain	23.690.287
Uruguay	43.679.459	Uruguay	4.749.363
Italy	41.810.353	Italy	19.270.954
Germany	36.801.090	Germany	18.681.850
Portugal	26.317.433	Portugal	15.838.974
Canada	15.474.015	Canada	21.823.385
France	9.200.572	France	8.294.941
Russia	5.767.673	Russia	5.117.168
Belgium	6.514.357	Belgium	3.994.008
Switzerland	12.286.442	Switzerland	5.773.180

Source: Lufthansa Consulting

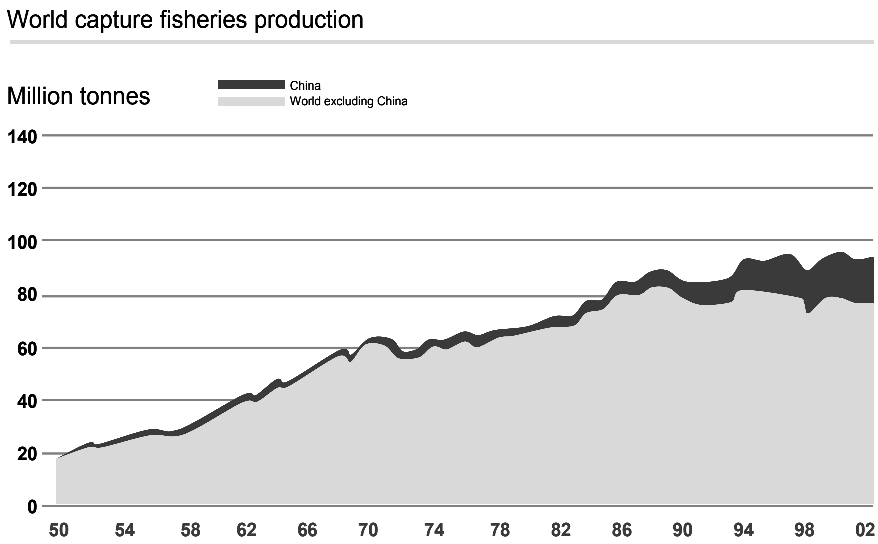

Fig. 8. Fish world production

Source: Food and Agriculture Organization

discarded because of spoilage. This is quite obvious, considering that a lot of difficulties can occur in a supply chain. One reason for the perish of large quantities of food are delays in the supply chain. If a container is for example forgotten or lost, it will miss its ship or plane. The shipment has to wait an average of 1-3 days to get on the next ship, an average of 0.5-1 day to get on the next flight (Moore 2004). In cases of perishable goods these are quite long periods. Assuming that long distances have to be covered, it might then already be too late to reach the destination before the shipment has to be discarded. Especially in the case of fruit and vegetables it is critical for the producers to be able to sell high amounts of their harvests as they are produced seasonable. Great losses in volume of sales would be realized if parts of the harvest perish and spoil in case of transport and logistical problems and inefficiencies.

Losses because of spoilage add up to *$60Billon* per year. Producers and suppliers loose large amounts of money and might in some cases even have to cover the costs for the disposal of the damaged goods. This points out again that there is still room for optimizations in the supply chain.

At this point one can come back to the idea of the emergence of a new market for goods, as it has been described above. In order to illustrate the advantages a producer can gain from the participation in such a market platform, a scenario about an exporter of mango in Mexico will be described in the next passage as Mexico is the world largest exporter of mango.

First of all, it has to be mentioned that the name and the company of the exporter who is described in the next passage are completely imaginary. The main purpose of describing that kind of an agricultural company is way of a simple illustration of the economic effects of the development of a new market.

"Manga, Inc.", which is the name of the company, is dealing exclusively with fresh mango. Mango is a "(…) typical example of an important horticultural export product for developing countries. In fact, mango makes up *50%* of all tropical fruits produced worldwide (…) ". The existence of many producers depends on the successful selling of their harvests. Therefore a producer of mango has been chosen to display the advantages a company has from participating in this new market.

Mango is produced in huge numbers; the worldwide yearly production is estimated to be about *23 million tons*. As the demand of mango is presently increasing, in this case it is assumed that the worldwide production will rise to *30Million tons* until 2015. *2%* of the yearly production are exported, the main part by Mexico. This makes up an amount of *600000 tons* yearly.

The next assumption is that "Manga Inc.", being the biggest mango exporter in Mexico, is exporting *150000 tons* every year. The average demand price for one ton of mango is about *$600*. For "Mango Inc.", this means yearly volumes of sales of about *$90Million*. Because of spoilage and wastage within the supply chain, "Manga Inc." will loose about *20%* of his shipments as was stated earlier, an amount of *30000 tons* each year. These add up to a yearly loss in volumes of sales of *$18 Million*.

It is easy to see that there is potential for optimization. Participating in the new market could provide these improvements and reduce the money that is lost every year, due to the perish of large amounts of fruit in the supply chain. Two cases will therefore be described. In the first "Manga Inc." will be able to reduce wastage of shipments of *5%*, and in the second case a reduction of *12%* will be achieved.

Worst-Case

Assuming that such a market exists, a kind of provider will be offering a platform for all participants to coordinate supply and demand. This provider will not offer services for free, so the assumption is made that trading partners are charged when they want to profit from this service. Costs will only be coming up when a transaction is made. This will be *1%* of the price negotiated between the trading partners for the subject they are dealing with.

In this scenario it is predicted that "Manga Inc." will be able to sell additional *5%* via the platform. Of course it is not able to gain the full price of the shipments. Presuming that the average price is *80%* of the usual price per ton, Mango inc. can demand *$480*. This brings extra volumes of sales of *$3.6Million*, because of additional *7500 tons* sold. Subtracting the *$36000* for the transactions, in this worst case scenario a net profit of *$3.56Million* can be achieved.

Best Case

In the best case, it is assumed that “Manga Inc.” will sell additional *12%*. This means that he only looses *8%* of his shipments, instead of *20%*. It is again presumed that he can negotiate a price which is 80% of the original price. So the price per ton mango is *$480*. His additional income via the platform will be *$8.6Million*; the will be able to sell extra *18000 tons*. In this case he has to pay *$86000* to the provider of the platform; finally his extra profits add up to *$8.15Million*.

These calculations show that no matter if the worst case or the best case occur, any firm will have the possibilities not only to cut losses because of spoiled goods, but it will even be in the position to make large amounts of additional volumes of sales. This is why it is assumed that there will be huge interest to become a participant of such a new market.

10 Conclusion

The new information and communication technologies have changed the possibilities of people getting in contact with each other. Markets being formerly separated due to the distance assimilate and borders decrease. The market will become one global market because distances aren’t an obstacle anymore. Competition will arise because markets being manageable face nowadays themselves new competitors’ opponent. They have completely different start conditions. Countries like China will become a strong competitor on the future world market. Due to these changes the market will develop much more unpredictable, turbulent and dynamic than ever before. Supply chains will be international and globally dispersed, as they are now already but this development will get much stronger in the near future.

Firms are forced to react to these changes unless they want to stay a strong competitor on the market. They have to overcome the borders of their companies as well. The opportunities, which offer the RFID technology is tremendous. RFID brings real-time into the whole supply chain. The potential, which arises through tagging the products and having readers as routing points, will change the market into an effective, efficient and flexible reactable to the changing circumstances given to the companies. Costs will reduce because information about the product will be exactly given in real-time. This enables the companies as mentioned above to re-route, identify wrong products on transport at every routing point and can avoid counterfeiting due to the unique identification through RFID technology. Another aspect is that products get more individualized to the needs of the customers. Customers want to contribute to the attributes of products. The market develops steadily from a seller market into a customer market. The customer of the future has higher expectations regarding product choice, availability and price (Picot et al, 2003, p. 3). The new possibilities given through the RFID technology will be able to face these issues and create value added services. The supply chain is going to turn into a freeway of goods being able to solve problems in a smart way.

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The Factory of the Future

Zoltan Elek, Susann Grämer, Jakob Keller, and Nino Ulsamer

1 Introduction

This paper shapes the vision of a "Factory of the Future" with respect to the current development of the RFID technology. It tries to analyze the situation today and shows a couple of possibilities to profit from RFID technology.

The first part of the paper describes current facts and trends that have to be taken into consideration when forming the vision of a factory in a timeframe of five to ten years. That vision is described in detail in the second part of the paper.

The first part starts with an introduction of the main advantages of RFID technology, especially regarding innovations, compared to the technology used in factories today. It continues with a detailed description of the factory as a complex composition of processes showing possible optimizations and extensions by RFID technology. After that currently important ongoing trends in the field of manufacturing are explained – again including the influences of RFID technology on them.

As a result of the previous analysis the second part then focuses on describing a possible factory of the future by exemplarily showing the daily routine of an expert working at this factory.

The vision is followed by a validation regarding legal and technical limitations and other challenges.

2 Overview

At the very moment a lot of companies try to integrate RFID technology into their manufacturing process. This task showed to be quite difficult because there is no "killer"-application of RFID that guarantees positive return on investment. A big number of smaller improvements have to be done to replace the established and satisfactorily working barcode technology. RFID has to be applied throughout the whole manufacturing process to create a consistent harmonically interacting system.

Therefore single processes have to be defined and analyzed regarding possible advantages RFID technology might offer. To simplify this approach the actual advantages of RFID will be pointed out in the next section by briefly describing the technology itself, already referring to potential applications in the manufacturing process or in the factory itself.

3 Advantages of RFID

RFID technology can be split up into four different parts: identification, localization, sensor networks and smart tags. Each of those characteristics offers advantages when using RFID in manufacturing. Those will be explained in the following sections.

3.1 Identification Advantages

One advantage of RFID that can be of interest in a factory is that each tag has a unique code that guarantees a fast and secure identification. This code – the Electronic Product Code (EPC) – is universal and valid on a global scale. It codes the producing company, object class (e. g. milk, 1 liter bottle) and serial number, so that even products of the same object class (there are usually lots of products belonging to one class due to the nature of a factory) can be distinguished easily. Furthermore product details (e. g. special modifications of a product) can be saved on most kinds of RFID tags. A tag can be identified by scanners within a range from one up to 15 meters. In a factory these features support fast identification and localization of a product as well as provide information on special treatments needed to perform product modifications.

3.2 Localization Advantages

In a complex environment such as a factory it is often difficult to find certain items. With the help of RFID technology objects can be located easily. The advantages of RFID regarding localization issues can be divided into two major groups: the local and the global advantages. Local advantages affect the tagged object and the localization process itself whereas global advantages can be found in a more abstract layer.

Local Advantages

The main local benefit lies in the technique used for the RFID scanning process. The data transfer is completely wireless without need for intervisibility and happens within split seconds. This is a great improvement compared to barcodes where a line-of-sight has to be established due to the optical reading process. Closely linked to this optical reading process is another problem of barcodes: they can get soiled resulting in an imprecise or even wrong read code. Especially when exposed to a harsh working environment the risk of bad identification is very high. RFID solves this problem by not working through an optical channel but using electromagnetic waves to transmit data.

The distance from which RFID tags therefore can be read is currently several meters even through nontransparent objects which allows scanning tags without opening any surrounding box or container.

3.2.1 Global Advantages

This leads to the global advantages of RFID. Because of the easier and faster reading process more readers can be placed along the way of a product moving in a factory or along the supply chain. These readers collect a lot of data and together with information about their location build the basis for a sophisticated localization of objects.

Even today readers have to be put to specific locations of objects manually or objects have to be arranged in a special way; using the RFID technique automates this process – objects can be scanned by just moving through an electronic gate.

3.3 Smart Sensors and Smart Sensor Networks

One possible future application of RFID technology lies in the field of smart sensor networks (Haller and Hodges 2002). These networks are made up of numerous nodes, so called smart sensors, which show two important characteristics: They know some information about themselves or their environment and they are able to communicate this information. Even simple RFID tags, that hold data related to the object they are attached to, can therefore be classified as smart sensors. However, one can think of far more advanced sensors: They may measure temperature, vibration, humidity or other physical parameters of their environment and communicate this data for use in numerous applications. Smart sensors could also be equipped with memory allowing them to store certain information such as sensor readings with appropriate timestamps. This feature is useful whenever important sensor data needs to be processed by a system that does not have access to the sensor all the time. The data stored in memory can be transmitted once the connection is successfully re-established.

Smart sensor networks are formed if for example a number of smart sensors are communicating with a reader that acts as a coordinator. This reader might then take actions as a result of the information it receives from the smart sensors. Another possibility of forming a smart sensor network is derived from peer-to-peer networking: The sensors could have the ability to communicate directly with each other and autonomously make decisions based on that information.

Smart sensor technologies can possibly be used in countless applications. In the area of industrial production one can think of the following examples.

Monitoring of Equipment

Tiny sensors built into machinery and tools constantly keep track of the usage and the level of wear. Provided with this data the item itself is able to predict failure or need for maintenance and communicates this information to the network in real-time. This helps to reduce downtimes and lowers the cost for manual inspections.

The manufacturer of such equipment benefits from that data as well: Detailed information on usage and environmental factors help to understand which features are used most often, where common sources for defect lie and a lot more. This leads to improvements in the product design of future versions and reduces the cost caused by acquiring such information by other means.

Handling and Storage of Sensitive Materials and Goods

Materials and goods that are sensitive to certain environmental conditions (temperature, humidity, exposure to light or vibrations) are input factors for manufacturing processes in many different industries, such as pharmaceuticals, chemicals, electronics and food processing. It is therefore important to know whether these goods have been properly handled and stored and can thus be safely used in production or have to be disposed. Smart sensors attached to or embedded in these goods can help to quickly and reliably identify their current state and their past exposure to certain environmental influences. This saves costs by eliminating the need for manual checks and by helping to reduce errors in production due to defective input factors.

Sensors in Production Processes

In manufacturing processes involving industrial furnaces it is often difficult to adjust the intensity and duration of heat-exposure to the processed object. This problem occurs in many other manufacturing processes as well and is often a result of long feedback-cycles: The period of time from an adjustment to the point when results are observable and can be considered for further adjustments is too long. Smart sensors attached to or embedded in the processed objects could help to reduce this delay by making precise item-level sensor data available in real-time. The results of shorter feedback-cycles are improvements in quality and reduction of waste.

All these potential applications benefit from one or more key advantages of smart sensor technology, which are:

1. automatic reading from a distance without line-of-sight,
2. location of sensor very close to or even embedded in the object to be observed,
3. flexibility of self-configuring sensor networks,
4. avoidance of manual readings and lower error-rates, and
5. item-level sensor data in real-time or stored in memory.

Even though the sensors described above are not commercially available yet, first prototype applications are already being tested or are going to be implemented in the next few years (Economist 2004). Once international standards for smart sensors are established and demand increases, lower prices are likely to accelerate the adoption of this promising technology.

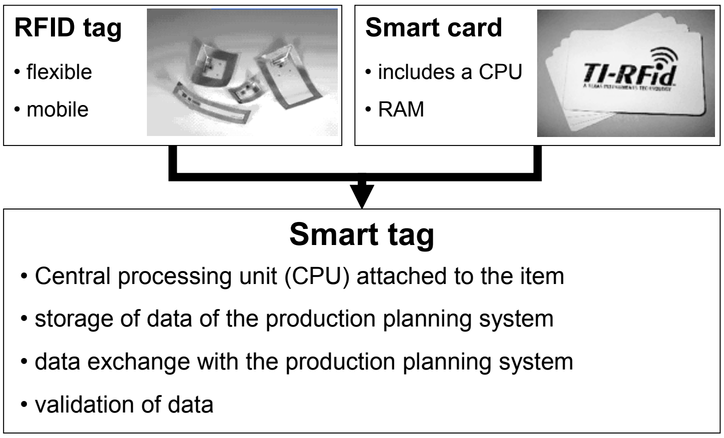

Fig. 1. Smart tags
Source: Overmeyer and Höhn 2004

3.4 Smart Tags

More advanced tags can turn the items into so called smart items. As shown in the following figure smart tags combine different advantages of RFID tags and RFID smart cards.

Today's RFID labels are easy to produce and very flexible. They are available in different kind of shapes and sizes. Using a frequency of 15.56 MHZ they have a reading range of about 1.5 meter. Operating as passive tags, they don't need a power supply. But their disadvantage is that they normally just contain a read-only-memory (ROM) with very limited storage capacity.

Smart cards are used in paying systems for example. They already contain a central processing unit and can be seen as a small and simple computer. The smart cards are not just able to store data but the can also change it, delete it or process it. Today's smart cards are just available in card form. Due to security reasons smart cards have a very limited reading range of around one centimeter.

Smart tags combine the advantages of both systems. They could be attached on items in a production line and communicate with the machines. The information for the production of each item could be stored on the tag before item enters a production line. The tag could communicate with the machine and central production planning system. This could lead to less data exchange with the central system and more data processing on a decentralized level.

Another advantage is that not every machine has to be connected to the central network.

The tags could also store information about the manufacturing process like the quality of a certain process or the time needed for it.

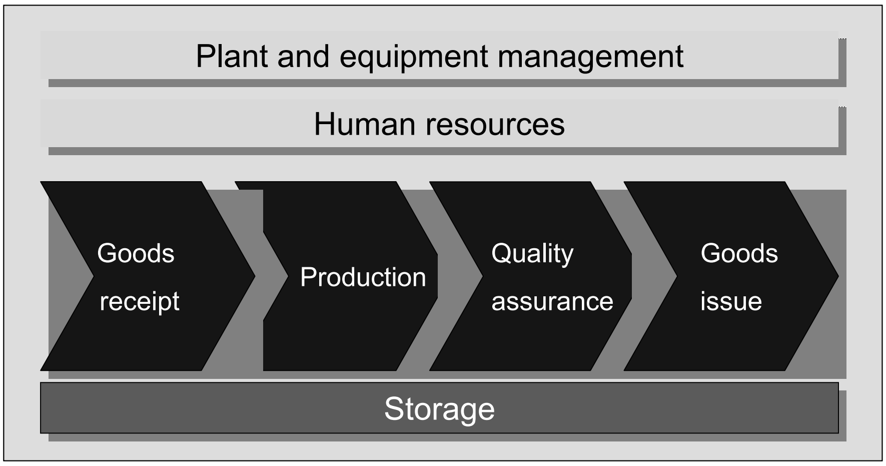

Fig. 2. Divisions of a factory
Source: Authors' illustration

3.5 Divisions of a Factory

This section will describe the divisions and processes of a factory that have been defined as follows: goods receipt and issue, storage, production, quality assurance, plant and equipment management and human resources. The problems faced in these divisions are quickly analyzed and possible solutions using RFID technology are proposed.

3.6 Goods Receipt and Goods Issue

The main goal of a factory is to efficiently transform input factors into the desired finished products. This requires systems that deal with the interfaces between a factory and its environment. One of the most important issues in this field is the handling of incoming and outgoing shipments: Raw materials and preliminary products need to be checked and accepted when they enter the factory. Finished goods need to be prepared and sent out to their destination once the production process is complete.

Traditionally goods receipt is a manual job: Somebody had to physically check the contents of shipments and compare them to the delivery note and a list of what the factory expected to receive from its suppliers. This was obviously a very time-consuming and costly process with high error rates. The growing complexity and integration of manufacturing companies with respect to their supply chains required new approaches and technologies to efficiently manage the exchange of goods.

Today most companies assign an unique International Article Number (EAN) to each class of their products. Barcodes containing a machine-readable representation of this code are attached to each individual item or each case of items. This helps to quickly and easily identify shipments and avoids human error. The information generated by reading the barcodes is transferred to and processed by the company's enterprise resource planning system (ERP). This includes for example a comparison to the delivery note transmitted earlier by the supplier via electronic data interchange (EDI). Companies benefit from these automated business processes because less human interaction is required. The results are reduced costs, improved quality, faster execution and lower error rates.

New methods of production, such as just-in-time manufacturing, would not be possible without these technologies. But they also constantly demand improvements and new solutions to further optimize the handling of goods. RFID technology plays an important role here, because it allows companies to further automate many tasks associated with goods receipt and issue. Within the next couple of years, the following scenario is likely to become reality (Capone et al. 2004):

All shipments of goods moving from one production facility to another are equipped with RFID tags. They store a globally unique Electronic Product Code (EPC) which can be automatically read and used for easy identification in various stages of the supply chain as well as the manufacturing process. Tags are built into the products during manufacturing or are attached, either to each single item or to cases and pallets, before they leave the manufacturer's site.

All the gates at the facilities are equipped with RFID readers, which automatically scan each inbound and outbound shipment. These readers receive the EPC identifiers transmitted by the tags and pass them on to the network and eventually to the ERP system which processes this information: Orders and shipments are matched, the level of stock is increased or decreased and appropriate documents (e. g. delivery notes) are generated.

If the delivery contains goods that are sensitive to certain environmental factors, the memory of the smart sensors embedded in the shipment is retrieved and analyzed. Only if this log shows that the goods were handled properly, they are accepted and cleared for processing or storage. Otherwise, the supplier is notified of the incident and further information, such as cause and time of the event, is sent to him to help avoid similar events in the future. All this is done very quickly and does not require any manual steps.

A few of the features of such a system are already in use today. In the retail sector, which potentially benefits the most from RFID-enabled supply chains, RFID solutions have been tested in real-life scenarios (Collins 2004a, 2004b, 2005, Roberti 2004). Large retailers were early adopters and put their suppliers under pressure to attach RFID tags on all shipments. Lower prices and international standards are expected to turn RFID into a technology that is economically attractive for manufacturers as well. The application described above is likely to become reality in the medium term.

3.7 Storage

Factories are required to manufacture the desired amount of products without unintended interruptions. This is only possible if the production lines are supplied with all the required resources at all times and if build-ups of finished products are prevented. Warehouses serve the purpose of dealing with these issues. The level of stock acts as a security against unexpected variations in demand for input factors during production or helps to balance changes in market demand for finished products. By increasing the amount of items in stock, the probability of having to interrupt production due to missing preliminary products is reduced (Tempelmeier 1998, pp. 254-257). Nevertheless, businesses are always trying to reduce the level of stock. This is a result of the cost of capital lockup associated with high stocks. Companies, which are able to lower their stock of inventory, benefit immediately, because they reduce the need for financing working capital. The amount of required storage space is also reduced and can result in lower costs as well. The task of the storage division of a manufacturer is thus to minimize storage costs while making sure that the continuity of production is not risked. RFID technologies can possibly be used to support this goal in several ways (Capone et al. 2004, p. 11).

Smart Shelves Provide Real-Time Inventory

In order to manage storage efficiently, information on the present inventory, such as type and quantity of goods, is essential. Acquiring this information manually is very costly, slow and error prone, which is why, in general, it is done only once a year in connection with the annual report. However, if all items are tagged and readers are installed throughout the warehouse, a very detailed and constantly updating real-time inventory can be created easily. This information can be used to optimize the level of stock and potentially lowers costs. Procurement decisions can also be based on such precise and timely inventory information: Purchase orders can be issued immediately once the available stock is lower than a specific level.

Most of the required data comes from RFID readers built into the shelves of the warehouse. Simple models of these so called “smart shelves” are already available today and used in retail applications. In a few years, this technology can make it into the warehouses as well.

Tags Help Workers to Locate Items

Locating a specific item within a large storehouse can be quite challenging. Passive RFID tags address this issue: They are used as labels and are attached to all the items in a warehouse. Workers, who are collecting a list of items, are equipped with RFID-enabled handhelds. This device guides them through the warehouse by calculating the quickest routes, and it verifies that the correct items were picked. Companies benefit from lower error rates and faster retrieval of items from stock which reduces required manpower and lowers costs.

Automatically Operated Warehouse

Today's warehouses are at least to some extent operated by humans. This has a strong influence on their structure since workers have to be able to reach all areas of the building. Automation has not yet rendered manual labor obsolete, because machines were not able to reliably identify certain objects. RFID technology removes that barrier and allows for automatically operated warehouses to be set up. These could be structured more efficiently, because they are not limited to human restrictions anymore: There is no need for broad ways in between the shelves and proper illumination is not necessary.

Sensor Networks Protect Sensible Items

In some cases, the content of warehouses has to be carefully monitored to prevent spoilage or even dangerous situations. This is true for example in the food processing industry or in factories that require hazardous materials, such as chemicals. Meat, which has been stored above a certain temperature, is not suitable for consumption by humans anymore and has to be disposed somehow. Photosensitive materials (e. g. film, chemicals, milk) must not be exposed to sunlight. Some chemicals are even at risk of exploding if they are not kept at certain environmental conditions. These variables have to be measured on a regular basis and actions (e. g. adjusting cooling, covering items) have to be taken to prevent undesirable events. This can be a very costly task when not done efficiently. Smart sensor networks implemented with RFID technology could help managing the type of warehouse described above. Sensors measuring the relevant factors are attached to the goods and are read frequently. The data is analyzed either centrally or by nearby nodes and the necessary steps to prevent damage to the sensitive materials are automatically performed. The effects of these changes can be sensed immediately and further corrections may be initiated. Ideally the sensors have logging capabilities and were attached to the goods at the point of their production. This way the full history of environmental conditions can be used to determine the state of an item and might even be used to calculate an accurate expiration date.

All these possible applications of RFID in storage management will take some time to become reality. But once all products are tagged as a result of supply chain improvements, these tags are likely going to be used in storage applications as well and help companies to handle their warehouses more efficiently. Even today, there are examples of companies which benefit from RFID-enabled warehouses (Albright 2003).

3.8 Production

Production is the creation of products within a factory. There are different forms of production depending on the product and its technical aspects. The aim of optimization of production is to improve the relationship between input and output.

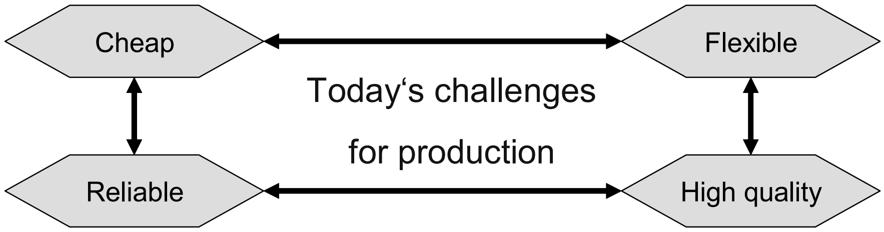

Fig. 3. Today's challenges for production
Source: Authors' illustration

Faster changing markets, the principle to fulfill the wishes of the customers and concepts like just-in-time production and supply chain management are challenges for today's production. As shown in Fig. 3 there is a need for cheap and high quality production on the one hand and flexibility and reliability on the other hand.

To manage these challenges, a better networking of all parts of production is needed. This networking ranges from the order, the overview of the storage area and the performance of productions sites. The data within a factory has to be linked to optimize production. The data has to be precise and actual. Today's production and planning systems (PPS) often relay on manual data input. But this is cost intensive and not always reliable. If the data is not up-to-date, it might have no use anymore. The PPS needs to know the actual numbers of item in the production line and the actual status of the storage to control machines.

To meet the challenge of providing actual and reliable data for the production and planning system RFID has been used already. The advantages of RFID in identification, localization and tracking of single items can be utilized. A common application of RFID in today's production is to track and trace item.

For this application the item is attached with an RFID tag and there are readers at main point of the production line. When an item passes by a reader, the production and planning system gets a message. The PPS can then update its virtual map of the production and optimize it.

But this form of track and trace is limited: RFID tags cannot be used on every production line. At some points of a production for example the items get heated or reshaped. This would destroy the RFID tag.

Another problem is the high amount of data which has to be analyzed by the PPS. There are messages of hundreds of readers to tell the system that everything is just in plan.

Smart RFID tags can be used in the production to communicate with the machine. A possible scenario is that a mayor part of the car like the chassis receives a smart RFID tag. In the next steps of the production, when other parts of the car get added, the RFID tag could tell the machine what to do and what happened already before.

3.9 Plant and Equipment Management

In a factory, a high number of machines, tools and other equipment can be found. There's a need to administrate and manage those tools and machines – to have an inventory of everything, to control abrasion and replace old tools, to guarantee usage restrictions or just to locate tools. This whole field can be summarized by the term equipment management.

In the future, equipment management can be supported by RFID: an RFID tag with identification number, description of tool, supplier, production date and other characteristics will be attached to or integrated in each tool and machine.

Management of Tool Usage

First of all, in factories time is often wasted by workers to look for tools. Tools are used by several workers and sometimes even in several parts of the factory, so they are carried around and searched for every day. RFID could help to locate and find tools and save time. Starting with a simple solution, an RFID reader could just scan for a specific ID in a specific area and state if a tool is or is not there. Moreover, a network of readers could be connected to a computer system and show the exact position of a tool on a virtual map of the factory.

Next, there is a need to prevent that tools are misplaced and taken out of the part of the factory they are intended to be in. Often tools seem to be lost while just being transported to another section, or they are stolen without being recognized. RFID readers at doors and section borders could prevent the transport of tools out of the section and theft, for example by raising an alarm.

An alarm could also be raised when tools have been forgotten near to or within machines (that are equipped with an RFID reader) and pose a security risk. Using RFID technology, damage can be prevented, and inspections are much faster and cheaper via RFID readers than manually.

Management of Tool Maintenance and Repair

Most tools and machines are used up over time. The abrasion can not always be seen from the outside, and often used up tools are dangerous or don't produce the wanted effect anymore. That's why tools and machines have to be controlled from time to time, which is quite time-consuming and expensive in larger factories. Expiring dates have to be checked regularly to replace or repair tools on time. RFID tags reporting the tools' production date and date of expiry as well as RFID smart tags with sensors provide a simple, automatic and (in the long run) cheaper management of tool maintenance.

Management of Tool Inventory

Tools, even more than products, have to be available permanently. One kind of tools being not usable for several hours or a day may stop the whole production process. On the other hand, due to their value, storing tools is often more expensive than storing products. That's why an optimal tool inventory has to be achieved – enough tools to keep production running, but not too much tools to limit fixed capital.

RFID helps to determine the tool inventory, to count removed and used up tools and to notice when new tools have to be ordered.

3.10 Human Resources

Human resources "refers to the individuals within the firm, and to the portion of the firm's organization that deals with the hiring, firing, training, and other personnel issues" (Wikipedia). In a factory there are several human resources issues:

1. Training
2. Time recording
3. Security (e. g. recording time in dangerous areas)
4. Access controls
5. Hiring/ Firing

Hiring and firing employees is an office job that is done with the help of computers – technology like RFID is not directly needed in this field. Same is for the field of staff training.

Time Recording records the working hours of all employees, e. g. by collecting access and exit times of the employees as well as breaks. It is mainly used for payment purposes. Normally, employees write their working hours manually into lists or computer programs, or they use magnetic swipe cards at the entrance that transmit working hours to a computer system. Studies showed that the more time-consuming and complicated time recording is, the more inaccurate information will be, and the more productivity of employees will decrease. Worktech (2004), for example, states as first rule for time-recording systems the ease of data entry. The whole time recording process can be simplified through usage of RFID: with RFID, times are recorded and collected automatically by a computer program. At every entrance an RFID reader has to be installed, every worker has to be equipped with an RFID tag (e. g. on a card, wristband or implanted), and access/ exit times are recorded contact-free and without human intervention. With the same system times spend in a smoking area or in a canteen can be traced to get an extensive time record. Altogether, a minute-by-minute time record will be achieved by the computer system.

Access controls can be implemented as soon as RFID readers are installed in the factory. These controls are important for high security areas, for rooms with machines operated only by specially trained workers or for rooms that can only be entered when machines are off. Given that every worker wears an RFID tag with unique identification code, RFID readers on doors can be programmed to open those doors only for special codes. Normal entrance into the factory can also be controlled, for example by a photo appearing at the reception when an employee wearing his ID passes by.

On the one hand, security means access controls. On the other hand, there are several other security issues in a factory. Examples are time limits for the stay or work in dangerous areas (e. g. in very loud or hot places, in radioactive areas) or for very monotone work. These time limits have to be controlled – and RFID combined with sensors are a perfect solution. Sensors can measure time, volume or temperature and transfer these date to active RFID tags, which then can trigger an alarm when reaching to high values.

3.11 Quality Assurance

Quality assurance is obligatory for all steps of the manufacturing process, starting from the goods receipt, continuing through the actual production and storage areas until the final product leaves the factory. The intention of quality assurance is to obtain and improve the quality of the products (Günther and Tempelmeier 2005, p. 129).

With the growing complexity of products it is impossible to guarantee the products' quality by checking them when they leave the factory; instead all parts of the product have to pass a quality check before they are put together in order to minimize the dimension of each instance of quality checks (Stauss 1994, p. 31).

3.11.1 Methods of Quality Assurance

Statistical control procedures are one common method of measuring the quality of products. Total control, i. e. checking the quality of every single item, is too expensive for mass production at the moment, so partial controls are used to reduce the costs of quality control. Partial control means taking samples out of all items and concluding the overall quality by those randomly chosen pieces using statistical methods (Günther and Tempelmeier 2005, p. 134).

3.11.2 Advantages of RFID

The question arises what improvements RFID can bring into play. The following sections will form an answer to this question by having a closer look at the identification and localization advantages and the sensor capabilities of RFID tags.

Advantages of Identification

The main advantage of RFID tags in the field of identification is the unique number code (Electronic Product Code, EPC) which can be assigned to products on an item level. This leads in general to more detailed data about what is happening in the factory.

According to Stauss (1994, p. 227), data collection is the most important factor of quality management. The collected data forms the basis on which decisions for product acceptance and improvement are made. An automatic identification method like RFID makes it possible to gain more data about the products in the plant, make the data collection more efficient and reliable and therefore improve the data collecting process.

In section 3.11.1 it was stated that partial control is the only applicable method of quality control in mass production because of missing methods to control and handle the data of each product. RFID technology provides ways to overcome those issues.

The quality of the collected information leads to the next advantages of RFID: the advantages of localization.

Advantages of Localization

The best data is worthless without context information. Context information enriches the actual information, for example a product code identifying a certain item, with some other information. In the case of RFID this is the information about the position of the reader which reads the RFID tag. Considering the factory as a whole this enables efficient real-time tracking applications and quality management systems always knowing where a certain product is at the moment.

Up to this point the actual quality of the product is still unknown. This is where the smart tags come into play.

Advantages of Smart Tags

In order to automatically measure the quality of the products in the factory, sensors are needed. They can be attached either to the product itself which is again not suitable for mass production with the price of sensors being quite high. The much more sophisticated method is to put a sensor at a certain point of production which is able to communicate with the RFID tags around it and provides those tags with the data it measures.

An application like this was implemented by Pierrel-Ospedali, an Italian pharmaceutical company. They controlled the sterilization process of their medical products using temperature sensors; the process also had to be saved in a database for documentation due to legal issues. Unlike barcodes, RFID tags are not destroyed in hot surroundings. Therefore, the whole process could be automated and is less error-prone (d'Hont 2004, p. 7).

4 Trends

After the description of the RFID technology and the divisions of a factory this section will take a look at what is already going on in the real business world. Several trends will be identified and the influences of RFID technology will be analyzed.

4.1 Automation

Automation is one of the oldest ongoing trends in production. The core of automation is the transition of work from human beings to machines. This is mainly achieved by technological innovation.

Ancient windmills can be regarded as one of the first milestones in automation. With the start of the industrial revolution automation began to spread. Energy was available for a wide variety of machines. Steam and later electricity could be easily converted into mechanical power.

With the use of assembly lines, automation reached a point of perfection at the beginning of the last century. Human work was still used predominantly at the first assembly lines. But Taylorism reduced meaning of human work by applying the principle “match the worker to the job” (Wikipedia.com 2005)

The second break-through in automation arrived in the middle of the last century when computers were integrated into production. In former times machines were just able to do simple operations. But with the use of computers, machines got much more flexible. Today’s industrial robots move fast and powerful and can be used for a vast number of tasks.

Computers used in combination with machines can automate human work not only in production. Today they are also used in quality assurance and identification. This combination led to the first factories where humans were not needed for production (Dudenverlag 2001)

Today’s trend of automation is changing. In the past mass production asked for more productivity and cheap products. Today mass customization and globalization ask for quality and flexibility in production. In this context the advantages of RFID technology come into play.

The trend of using RFID technology in today’s production can be divided into two parts. On the one hand RFID enables a very effective and reliable way of identification. Products and their parts can be tracked within production. This information is very valuable in numerous processes of manufacturing. On the other hand so called smart tags take over control of production and can lead to a more flexible and decentralized production.

4.2 Mass Customization

Global market are characterized by fast changing market conditions – customer needs as well as product trends are changing fast, demand is heterogeneous and people ask more and more for individual products. Manufacturers need to react flexibly to those changes and cannot be profitable by only producing large volumes of standard products. They need individual products to differentiate themselves from their competitors. That’s why mass customization is one great trend today and for the future (Anderson 2004). It combines mass production with product variety. The advantage of mass production is economies of scale – thousands of products are produced the same way which makes each product very cheap. But

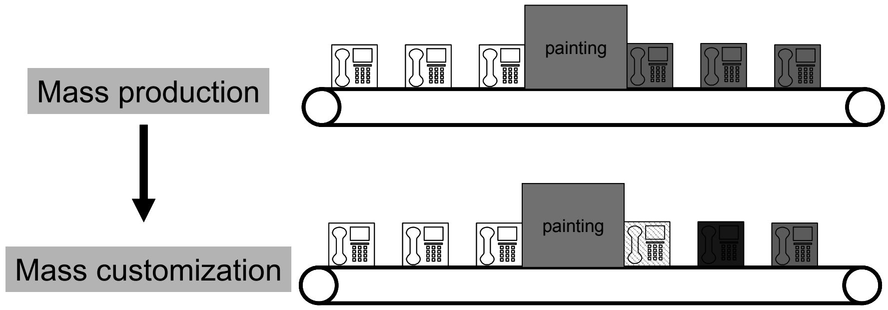

Fig. 4. Mass production ⇔ mass customization
Own illustration

mass production offers only standard products, no product variants. Through mass customization, different variants of one product can be produced, starting from very simple variations, e. g. in color, to very individualized products (Zipkin 2001, p. 82).

While for example in mass production products are painted uniformly, mass customization allows consumers to choose their color without limitations as can be seen in Fig. 4.

Main Elements of Mass Customization

There are three main elements of mass customization: elicitation, process flexibility and logistics. Elicitation means "a mechanism for interacting with the customer and obtaining specific information" (Zipkin 2001, p. 82). The customers' data and their choices (e. g. product measurements) have to be elicited, today mainly through computers and internet applications.

Process flexibility means that production must be flexible enough to fabricate products according to the elicited product information. While flexible production of immaterial goods (such as news services) is very easy and cheap due to information technologies, flexible production in other industries is expensive, is still in development or just not existing yet. Digitally controlled cutting systems for example, that can cut lots of different patterns but work only in one dimension, have been existing for several years. Robots that form three-dimensional objects are very expensive, high-level software and programming languages to operate them are only in development. So today, only certain production steps are flexible enough to customize mass products, other steps (and therefore other product features) have to be the same for all products.

Logistics have to ensure that the identity of customized products is maintained throughout the production and delivering processes. In contrast to mass production, where hundreds of products can be shipped to the same place (e. g. a supermarket), customized products have to reach the right customer.

Demand for Mass Customization

Customization is said to be a big trend of the future. Today, customization is used for products that have to meet physical dimensions – for example, clothes have to fit different people's shapes or windows are built for particular houses. There are also products where the problem is not the physical dimension but the customers taste. 19% of cars in Europe are customized, 60% of cars produced in Germany are built-to-order which shows a large potential for mass customization in this sector. While today an average customized car needs 50 to 60 days to be finished, the goal of several car makers is to do the same in less than 14 days through efficient mass customization (The Economist 2001).

Mass customization offers not only benefits for customers, but also for manufacturers – it offers, for example, the potential to increase customer loyalty. While today even satisfied customers tend to change vendors, customers that buy mass customized products are very loyal. They made a specific investment to design their own product, e. g. because they transmitted lots of personal data which can't be easily transferred to other manufacturers. Therefore these investments can be regarded as a type of switching costs that stop customers from changing their vendor (Stotko 2002).

Flexible Manufacturing Systems to Cope with Mass Customization

Mass customization manufacturing systems require "a high level of adaptability and flexibility in production" (Blecker and Graf 2004).

Modularized production*,* where typical manufacturing capabilities are grouped into functional modules, provides such a flexible manufacturing system (Qiao et al.). These modules are flexibly combined to meet the requirements of customized production. At each module one production step is done, and this one step can be done in various ways. For example, fabrics can be cut in different sizes, or a machine can insert one of several CD players in a car dashboard. This leads to another strategy to cope with mass customization: the modularization of a product itself. One particularly good example is Dell, which sells customized computers. It has a warehouse of modules available and on order just assembles the requested components. Through working with such modules economies of scale arise when modules are produced – actually those modules can be produced in mass production. The customization is reached through the specific combination of modules.

How RFID Could Improve Mass Customization

For mass customization a production in small modules is very effective. Modularized manufacturing requires very good coordination: The required raw materials or parts have to be at the right place at the right time. RFID tags could help to automatically identify the kind of customization of a product and the needed parts, so that each system calls for parts from other systems. After that it uses possible spare time to work on other tasks and finishes the product as soon as all parts are available.

Especially when producing modularized products, RFID should be used for inventory and logistics coordination. The inventory may contain lots of different modules, and for each product the right module has to be brought to the assembly line. The unfinished products carry RFID tags, while readers at production modules recognize the desired customization and send this information to the inventory management. There, again via RFID tags, the fitting product module can be found and transported to the right manufacturing line. In case active (or smart) tags are used, readers at the inventory can save the destination of a module on its tag and transportation systems can be coordinated automatically.

4.3 Virtualization and Simulation

Two trends that can't be overlooked in manufacturing are virtualization, i. e. mapping of process or product data to software, and simulation which is an enhancement of virtualization and allows simulating processes to analyze and optimize them.

4.3.1 Virtualization

As mentioned above virtualization means creating a computer model of a factory or a manufacturing process using data obtained from observing this process in reality. The following sections will take a closer look at the trend "virtualization", show the advantages that RFID can bring and finally give some examples where RFID is currently being used to improve virtualization.

Introduction

Virtualization is a powerful tool to present data for other systems from a logical view rather than providing the physical data as you can see in Fig. 5. Logical presentation means the data is put into a semantic context, for example some position of a product in the workflow, instead of being interpreted as the absolute position

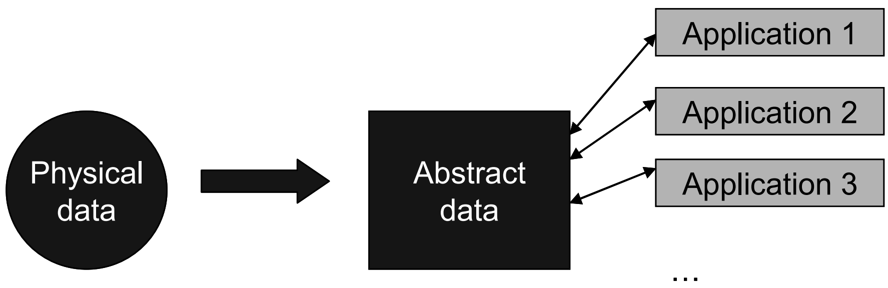

Fig. 5. Virtualization model

Source: Authors' illustration

within the building. The advantage of adding such an abstraction layer is that calculations and pre-processing of data is done once when the data is received and every application using the data benefits from the pre-processed data.

Moreover the data can be put into Enterprise Resource Planning (ERP) systems which allow control and visualization of all processes in a company, including manufacturing.

Virtualization can be done at many points in manufacturing. It can be used to control storage areas by monitoring goods moving in and out and therefore knowing the exact number of goods at this site at every point of time. It also can be used to monitor items, i. e. goods, products or tools, moving in the factory which in case of monitoring products leads to simulation. The topic of simulation will be discussed in section 4.3.2.

Advantages of RFID

Virtualization can benefit from RFID technology a lot. The most critical point of virtualization is the data collection process. This data collection can be improved using RFID by means of automatic reading processes without the need of an established line of sight.

Readers can be positioned at strategic points in the factory, for example the entry and exit point of a storage area. Machines used in the assembly line could also have RFID readers installed. All items moving around in the factory would be tagged with passive RFID tags that can be read by the installed readers and therefore produce reading events when reaching the range of an RFID reader. Those reading events would forward the readout unique product code to the software layer of the factory, which could be an ERP system.

But not only location information could be mapped in such a manner. It would also be possible to get data from sensors which are either attached to an active RFID tag or positioned at a fixed location. This enriches the location data of the passive RFID tags read at this place, with temperature information for instance.

Because of the elimination of any manual process like typing in values from some automatically produced printout, there is almost no delay in the track and trace process, so the data gathered in the database is actually real-time data. Only real-time data has the power to allow real-time applications; an example is to realize the need for a reaction and to trigger quick responses on demand changes. Flexible manufacturing systems make real-time data more and more important.

After having discussed the advantages of RFID for virtualization, this section will show some applications of RFID in the virtualization process of manufacturing.

Automated Guided Vehicles (AGV)

Kennedy Space Center operates Automated Guided Vehicles (AGV) which carry goods or products from A to B. An AGV system consists of moving vehicles without a human driver that get their directions from a central computer that keeps control over all of them and coordinates their movements. Such AGVs have some advantages compared to a vehicle with a human driver: first of all they don't cause any accidents. A human can make a mistake – a computer (if correctly programmed) usually does not. Another advantage is that they can carry goods that would harm humans, for instance Plutonium. And they work as precise as no human ever could.

In order to keep track of their AGVs and to guide them through the factory, Kennedy Space Center uses RFID tags embedded in the floor and readers on the vehicles (LogisticsToday 2005). The vehicle can update its current position reading the RFID tags passing by and handing their data over to a connected central computer. This system therefore knows the position of all its vehicles and leads them to their destinations.

Real-Time Production Adoption

Another possible application that Bellini (2005) proposes is real-time production adoption. Given the huge amount of RFID based production data gained in the factory and the demand for the product, the system can automatically adjust the amount of products that has to be produced. This application can react in real-time because its data basis is provided in real-time. So the manufacturing process gets very flexible and easy to adapt to the current market situation and development.

Equipment Management

As another part of virtualization, the equipment, i. e. machines, tools and repair materials, can be tracked and visualized in the virtual view of a factory. According to Raymond (2003, p. 2) it is essential for a manufacturer to have all equipment organized and located at its correct place all the time as this yard management processes are time critical. Active RFID tags could be put on tools and connect to the factory's central server in a short time interval to inform it about their current position. So the system knows where all its tagged equipment is and can give an alert if anything is misplaced. At the beginning this could be used only for expensive tools to help prevent theft. With RFID tags getting cheaper and cheaper it then can be expanded for every tool in the factory. This enables automatic assistance systems for workers in the factory to guide them to tools they need and remind them of returning the tools to their origin.

4.3.2 Simulation

A trend based on virtualization is simulation. The following sections will illustrate the technique of simulation and show how to use RFID to improve the process of simulation.

Introduction

As explained in the previous section, virtualization builds a model upon data collected from the real production environment. If the data is detailed enough a simulation can be run on top of it, i. e. the software can predict what happens if some parameters are changed. Such predictions can be used to analyze processes, detect possible bottlenecks and try to find a solution to the problem by optimizing processes. Besides that, simulation can also be used to visualize a new or already existing system design in action in order to simplify the understanding of how it works (Carson 2004, p. 2).

But simulation also has got some drawbacks. In order to guarantee the consistency of the model, the data on which the model is build upon must be of high quality. The process of getting data is very time-consuming and error-prone since data is often entered manually (Robertson and Perera 2001, p. 1). Even when the data is collected it can be quite difficult to "validate and cleanse the data" (Carson 2004, p. 5), i. e. analyze it, detect possible conflicts and fix them.

As the simulation model is only as reliable as the data it uses the next section will connect data collection with RFID technology and show the advantages of such a system.

Data Source

The benefits of an automated data collection process for simulation models are quite obvious: the data would contain fewer errors, and even more as well as more detailed data would be available. Since the reading process of RFID tags is automated they could be used to automatically recognize items when moving through the factory. Readers for virtualization purposes are already installed throughout strategic locations in the factory. Important for optimization are the readers installed at machines to collect information about events – when do products arrive at a machine, how long does it take to process them and when do they leave the machine again? This data could then be stored in the factory's virtualization software and used as data input for the simulation application as illustrated in Fig. 6.

The figure shows the information handling with RFID data that is gathered by virtualization software, i. e. an ERP system or some other system that uses the real-time data produced by RFID tags to build up a virtual model of the factory. This data

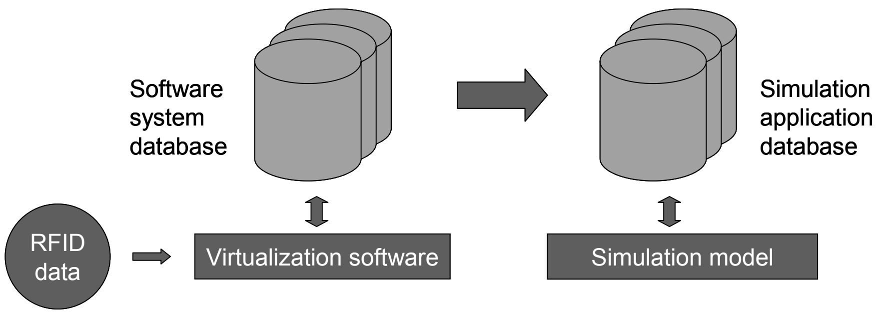

Fig. 6. Database model

Source: Randell and Bolmsjö 2001, p. 2 is stored in the system's database and automatically updates another database which in turn is then being used as the data basis for the simulation software.

Using this technique manual data input is no longer necessary and the high quality data of the RFID tags can be used. Not only the pure location data but also data of sensors combined with passive or active RFID tags can be accessed.

The next advantage of RFID tags is the creation of serial level data. Until now most simulation models are stochastic models, i. e. not all items are taken into consideration but a few randomly chosen items represent all others (Carson 2004, p. 1). Of course, within this process there is a mathematically founded error rate that has to be taken into consideration. With the use of serial level data every single item moving through the factory can produce data for the simulation model making it much more accurate.

Optimization

As mentioned before the main use of simulation is to detect bottlenecks by analyzing data and removing those bottlenecks, i. e. optimizing processes.

There are different methods of detecting bottlenecks: Roser et al. (2003, pp. 2-5) exemplarily show three methods for detecting bottlenecks in Automated Guided Vehicle (AGV) systems (that can be used for other systems as well): utilization, waiting time and shifting bottleneck. Utilization calculates the percentage a vehicle is active and treats the most active one as a bottleneck. The waiting time method calculates the waiting times for items before the beginning of each process. The process with the highest waiting time is considered as a bottleneck. The third and most sophisticated method uses the same data input as the utilization method but tries to detect the longest not interrupted utilization time of the machines.

After identifying the bottleneck, this step of the process has to be improved. There are no general methods to do that because it is highly dependent on the bottleneck itself. The increased bottleneck's performance will positively affect the overall system's performance.

As soon as the optimization process is finished the changes can be implemented in the factory itself. The advantage of the real-time RFID data is that the effects of the modifications can be seen at once – a modification which decreases the systems performance could be rolled back immediately stopping possible losses. Positive effects can be noticed as well, proving the simulators' work.

4.4 Networking, Outsourcing and off-Shoring

Every company that requires certain input factors to generate output, and that is the case for basically all companies, is facing so called make-or-buy decisions. This means that the management has to decide whether goods or services are provided internally or are bought from other companies or the market (Tempelmeier 1998, p. 248).

In the early days of industrialization, the share of value created internally was very high. This proved to be efficient for manufacturers of products that are characterized by low complexity, low specificity and constant demand over a long period of time. Today, however, most markets have turned from sellers markets to buyers markets that have to react to the individual needs of the customer and require increasingly flexible forms of organization (Picot et al. 2003, p. 272). For this reason companies shift activities that are not part of their core competences out of the organization and obtain those goods and services externally. As a result of this development, flexible networks of companies have emerged. The decision to contract other entities for parts of the value chain is called outsourcing. Some companies even try to benefit from the differences in labor costs throughout the world by looking for contractors abroad. This is often referred to as off-shoring.

In order to understand how RFID technologies might impact these networks of companies, a few aspects of transaction cost theory are briefly described. Transaction costs are costs that emerge from initiation, agreement, handling, supervision and adjustment of contracts that form the basis of an economy characterized by division of labor and specialization. These costs depend on the characteristics of goods or services as well as the form of organization chosen by the company. Ideally, companies choose the form of organization that causes the minimum amount of transaction costs. Depending on factors like specificity, strategic importance and uncertainty, hierarchical forms of organization or market structures are preferred. For example, goods or services with high strategic importance to a company (e. g. development and production of car engines for a car manufacturer), should be handled internally. Whereas functions characterized by low strategic importance (e. g. production of standard screws, facility management) should be obtained from the market. In between these extremes, various degrees of cooperation of companies are located which further complicate the search for an optimal solution (Williamson 1990, Picot et al. 2003, pp. 49-53).

Improvements of information and communication systems have important implications on trans-action costs. In general, such developments lower transaction costs. But the extent to which this is valid is not uniform for all forms of organization. As a result, companies are required to reevaluate their form of organization under the new conditions and possibly make changes accordingly. It is not clear, however, whether improvements in technology make hierarchical structures or markets more favorable for accomplishing the organization’s tasks. Possibly more important is the fact that the reduction of absolute transaction costs makes new transactions possible and expands markets (Picot et al. 2003, pp. 70 – 74). For example, the invention of e-mail had a tremendous effect on the economy: It clearly lowered transaction costs by substituting other channels of communication, e. g. conventional mail, fax and telephone. This allowed many companies to outsource various processes, such as customer support, transforming them from very hierarchical forms of organization towards a market structure. At the same time e-mail expanded the range of available communication channels and lowered absolute transaction costs which made new transactions (e. g. personalized mass-advertisement) possible.

RFID technology can have similar effects on the economy, especially on manufacturing. Many aspects of RFID technology and its applications can be regarded as new information and communication systems and therefore lower transaction costs. This can already be sensed in supply chain management applications, where currently most of the momentum of RFID deployment is observed. Since flexible and efficient supply chains are essential for outsourcing in manufacturing, it is likely that improvements in this field make cooperation and networks of companies more attractive. This would accelerate the trend towards structures which are organized as markets. The effects on factories would therefore be further specialization and even stronger focus on core competencies.

In contrast new technologies also tend to improve the efficiency of hierarchical organizations. They allow companies to grow further in size, while still keeping them manageable using the improved methods of communication and coordination. That way the advantages of economies of scale can be further exploited (Picot et al. 2003, pp.74 – 75).

RFID could therefore help producers to manage the manufacturing process of complex products more efficiently by reintegrating certain aspects of the value chain into the hierarchical organization of the company. The following examples illustrate this: Sophisticated RFID-based access control systems could reduce the need for security personnel, which is in many cases outsourced to external companies focusing on security services. In this application, RFID technology improves the efficiency of hierarchical forms of organization stronger than market structures can benefit (unless security companies adapt the technology and offer new services based on it). Similar developments can be imagined in quality assurance tasks. Many manufacturers have contracted third parties which specialize on quality assurance. RFID has the potential to simplify and improve the process of quality assurance. This could convince the manufacturer to do the task internally again.

The impact of RFID technology on the level of cooperation in-between businesses, namely the effects on networks of companies, outsourcing and off-shoring, is likely going to be considerable. As of today, it is unclear how strong and in which direction the decision for a form of organization will be influenced by RFID. A likely scenario is believed to be a combination of both aspects described above, leading to numerous changes, but not revolutionizing the distribution of the value chain between manufacturers and suppliers.

4.5 Virtual Factory

Some years ago, in Switzerland, near the German border, a pilot project brought a research done by St. Gallen University to reality. A virtual factory was installed. Today several virtual factories exist and the systems seem to be a trend for the future (Crowsten 2000).

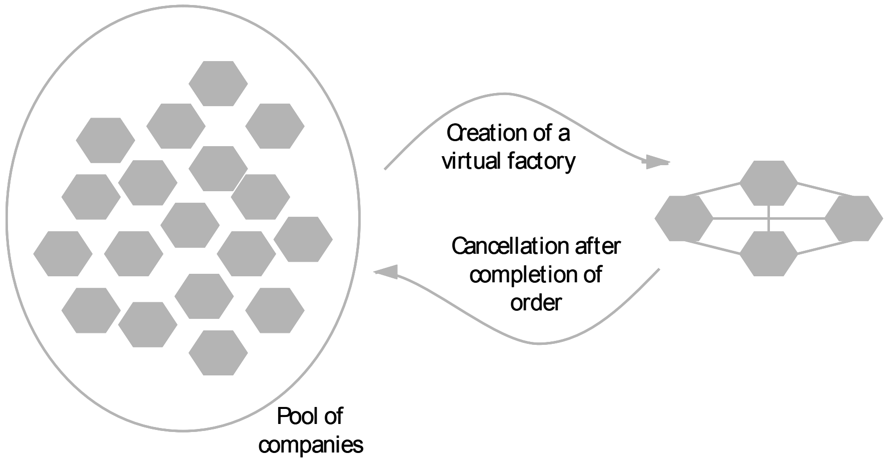

Fig. 7. Construction of a virtual factory
Source: Authors' illustration

4.5.1 Definition

According to the definition of St. Gallen University, a virtual factory is a temporary cooperation of several independent factories with the aim to produce a specific product or service. Each firm within this cooperation concentrates on its core competencies and deals with all activities that it can handle the best.

Each virtual factory is formed according to a customer's order – companies that have (out of a pool of corporations) suitable competencies perform as one factory until the order is completed. By using the companies' core competencies each company fulfils specific tasks.

Therefore virtual factories require a high level of communication and coordination. Usually, all companies use one common computer system to exchange data and information.

4.5.2 Usage of RFID in Virtual Factories

RFID usage in a virtual factory can improve coordination a lot: all products and preliminary products are tagged and can be identified easily; therefore the exchange of such products is much faster and easier. Readers register which product is at which place, and what needs to be done to finish the product is saved on its active tag. Since all partners use one central computer system everyone can access such data, can plan their resources and reduce manufacturing time. One manufacturing partner can, for example, see where a product he needs to work on is at the moment in another factory, and he can estimate when the product will arrive at his plant – production planning is therefore based on more accurate and on-time data, capacity overload or production stops are avoided in favor of a continuous production.

5 Vision

After introducing RFID technology, its impacts on manufacturing and currently ongoing trends in the previous sections, this section will now draw a vision of the factory of the future. This vision is a combination of the presented trends and develops a coherent idea of how a factory could look like in the future.

Entrance

Just like every day, Bob, an expert technician working in a state of the art car manufacturing plant in 2012, enters the factory building and simply walks through the entrance. The gate is equipped with RFID readers as well as other sensors which detect motion, and each person is scanned for an ID card provided by the company. These ID cards act as passive RFID tags and contain a unique number which is associated with the employee's account. The information collected at the entrance gates is used for security reasons since it allows only those persons to pass, that carry a valid card with them. But it also automatically provides data to the timekeeping system, which generates very precise payroll information. At the moment Bob passes the RFID reader, he hears a sound and red lights start to flash. Security personnel ask for his ID card and he quickly recalls that he left his purse in the car. The guards reject his offer to return to the parking lot in order to get it, but simply issue a temporary ID after having checked and verified Bob's biometric information. The company's information systems instantaneously associate the new card with Bob's account so that he does not even notice a difference for the rest of the day.

Bob's PDA vibrates. It reminds him of an appointment he made for the inspection of a production machine. On his way to the machine, Bob takes a short brake and gets himself a cup of coffee from one of the RFID-enabled vending machines. Even though he is using the temporary ID card to pay, the price is automatically charged to his account. While enjoying the drink, he reads the check list for today's inspections. He remembers his first internship in a production factory. He assisted his boss at the inspections. His job as an intern was to carry all the papers needed for inspection. Now his PDA replaces these papers – and also the intern.

Tool and Machine Wastage

Bob continues his walk through the factory when he sees a big room with a label that says "Tools repository". He takes a look inside. This is the place where all kind of tools are stored for later use. There is also a special area which stores more advanced tools – tools that are expensive and that exist maybe only a few times within the whole factory. Some of those tools are used up over time. That is why the administration department decided to put active RFID tags on those tools for which the current status of wastage could be determined by sensors. So the administration software always knows the status of these tools and can order new ones when they cannot be used any more. For tools where the wastage status cannot be detected via sensors automatically the tags record how often they were used and the wastage status is estimated by comparison to standard values.

The same system is used not only for tools but also for machines in the production line. As they use up as well it is equally important to measure the current status of wastage for them. The system automatically detects which parts of the machine do not work properly any more, orders replacement parts and sends a technician to the machine to substitute the particular part.

Maintenance efforts could be reduced a lot using this system. First of all no one had to control tools and machines all the time. And when a defect or a need for replacement is detected the technician is instructed by the computer system which part he has to repair, where to find this part etc. That makes their assignment much more efficient.

Repair Situation

After arriving at the machine he scans all the RFID smart tags for data stored upon them. Charts and numbers appear on the screen of his PDA. It takes him only seconds to get an overview of the production performance of the last weeks.

The system realizes that the electric engine 21C is getting weaker. Bob activated the notes view on his PDA. Now he can see the machine in front of him on his screen and a lot of virtual post-its appear. These notes were placed there during production, installation, usage or inspection of the machine. To get an overview of the notes, he filters them. Now only the notes concerning engine 21C appear. Engine 21C was a trouble maker last year. Then changes were made and its functionality was restored, but the life time of the engine was reduced. Since few weeks from now it would have to be replaced anyway, Bob decides to do it now.

It is the right time because the machine will not be in use before next morning. He starts a tutorial program on his PDA how to exchange the engine. The reference to the program is stored on the RFID tag which is attached to the machine.

The program shows him a list of tools needed and starts a search of available tools in his surrounding. The PDA shows a map of the factory and the point where the needed tools are right now. This localization of the tools is possible, because all items including machines and tools are equipped with an RFID tag.

The program asks Bob if he wants to get the tools himself. The alternative option would be to ask one of the team assistants to do this job for him. Bob decides to call an assistant. It is much easier to change the parts in a team. And the team assistant, an intern who has been around for a week, could learn something new.

Just few seconds after Bob's decision the intern Steve gets a message on his PDA. He confirms the job and starts to collect the tools. He is very happy, that the PDA shows him his way, because it is his first assignment in this part of the factory. The PDA determines its own position by reading RFID tags which are built into the floor – the same system is used by the automatic guided vehicles. After a few minutes of walking and with some tools and spare-parts in his hands the intern Steve arrives at Bob's machine. Bob already finished the rest of the inspection.

Now they can change the trouble-making part. While doing so, Bob tells Steve how his days as an intern were. With "those were some hard days" Bob starts his story and by the time they finish their job, he is still in the middle of it. Steve appears to be very interested and they decide to have a short break and smoke a cigarette. The smoking area is on the way to Bob's office anyway. The company has a policy of discouraging smoking and has put a couple of measures into place to support this. While lighting his cigarette, Bob reads a sign on the wall that says: "Due to our non-smoking policy, RFID-readers will detect your presence in this area. Please be advised that your monthly payroll will be reduced by the amount of time you spend here." He is once again resolved to quit smoking. After saying goodbye to Steve, Bob heads for his office.

Self-Coordinating Decentralized Manufacturing

On his way Bob walks by the research laboratory. This is the place where the production of the future is tested. There are no workers around, the researchers are the only real persons in the huge lab – but there are several robots working and producing. Bob reads the sign at the door; it says "Self-coordinating robotic manufacturing". One of the researchers is going to explain and show the whole installation to him.

The manufacturing is set up to produce a product from the idea to its completion. Each product will be unique, with specific features and an extra design. There is no central planning needed, no central coordination of machines – and no worker, which makes Bob feel frightened. Self-coordinating robotic manufacturing can be implemented in a car factory as well as in companies producing furniture or computers.

As the figure below shows, the manufacturing system consists of a large production hall and several small production facilities that perform extra production steps, e. g. coloring. Each product makes its way through the factor independently.

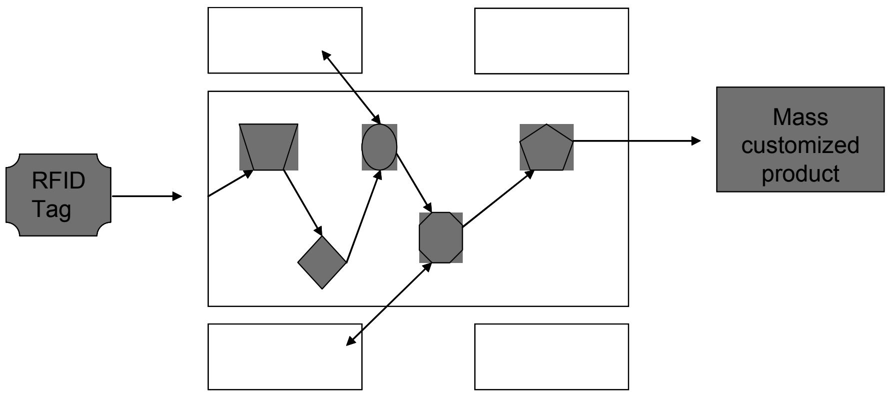

Fig. 8. Self-coordinating robotic manufacturing

Source: Own illustration

At the beginning of the system there is a monitor. Here (or at home at their own monitor) customers can design and plan the product. Let's take a car: they can design an individual shape, make design and equipment components, choose a color and specify all other features. After a reassurance and verification of product safety and stability all data is sent to a central server and printed on a rewritable RFID tag. Now the RFID tag enters the manufacturing system that consists of several robots placed in a large factory floor, with other robots in connected or nearby factories. Each robot is equipped with an RFID reader, and all systems are connected via wireless network. The first idle robot reads the new RFID tag and starts to produce the car according to the data on the tag. Via the network it sends orders to other robots or systems (and writes the transmission on the tag in order to track all orders) so that all needed systems cooperate as a virtual factory. While for example the first robot requests the production of the car frame, a second robot has finished its previous task, reads the new tag as well and starts to form the customized dashboard. Therefore it requests a navigation system from another manufacturing partner of the virtual factory and integrates it into the dashboard. After finishing the dashboard the robot deletes the order "dashboard" from the RFID tag and reads this or another tag looking for a new task. The robots are self-coordinating because they start a new job after they finished one, read what is already done and begin the next task that has to be done. The different production elements are saved on the tag in chronological order, so that each task is done at the right time. Complex tasks and tasks that require special machines can be delegated to special systems. When rewriting the tag new orders can be placed as well, e. g. "Do nothing for this product, the system waits for required parts".

At the Office

After his stop at the research laboratory Bob arrives at his office. While having a coffee his PDA vibrates. He fetches it out of his pocket and looks at the flashing message on the display. "Guided student tour starting in half an hour" – today he has to lead a guided tour for interested students through the factory showing them the different production stations and processes, he remembers.

He leaves his office and heads directly to the visitors' entrance. There the first students are already waiting for him. They passed the security gate at the entrance after they were equipped with a temporary RFID chip that provided very limited access. They are only allowed to open certain doors, and moving around without escort of their registered supervisor will set off an alarm. RFID readers monitor their movements and check that close to each visitor's tag a supervisor is detected.

Bob talks to the students while they are waiting for some late-comers and starts the tour as soon as they are complete. For security reasons he instructs them to keep together as a group.

He again takes a look at his PDA which automatically shows a floor plan of the factory building with a red path that marks the route they should follow. Their first stop is the drying hall.

Access Control

When the group arrives at the door of the drying hall, Bob uses the opportunity to explain the RFID-based access control system to his visitors: “Every one of you received a guest ID card today and you were instructed to carry it along with you at all times. This is mandatory for all people within this factory for a number of reasons. First of all, there are many hazardous and confidential areas and most people, like you for example, are not supposed to enter those. This is why all doors read every RFID tag of the ID cards and check the person’s permission. Our access control system knows where each person is allowed to enter and uses this information to decide whether the person is allowed to open a specific door or not. Why don’t you try to open the door over there?” One of the students walks to a door labeled “Server Room”. She is not able to open it, but the small display on the door tells her that guests are not allowed in this area and she needs to be in company of a system administrator to enter. Bob continues his explanations: “Please be careful: Without your ID card you won’t even be able to use the bathrooms! Besides access control, these cards are also an important safety feature. All machines, that could be dangerous to humans, including our cranes, lifts and automated guided vehicles, have to make sure that they do not put people at risk. They are therefore programmed to stop operating whenever they sense somebody too close to them. This information is gathered by all sorts of sensors, including motion detectors and light barriers, but also RFID readers which search for ID cards. By the way, if somebody accidentally leaves a tool within a machine, which happens to me all the time, these readers will notice that as well and prevent damage by blocking the machine. This saves us a lot of money and reduces downtime of machines.” One of the students raises his hand and asks: “If our location can be determined all the time, is this information used to track us throughout the building?” Bob responds: “In general, it is not. But locating items and persons in this facility can be very helpful to us. This way one can easily check whether a special tool or an expert who is required for a certain task is nearby. And if somebody gets lost, he or she can always rely on the guidance provided by his PDA. But now let us see what is going on in the drying hall.”

The Drying Hall

Bob and his students enter a big hall where they can see freshly varnished cars in all colors – the drying area. Before further processing the lacquer has to dry and harden to avoid damages like little scratches in the new car. “But when is this process finished? How does the system know when it can go on?” the students ask. Bob isn’t quite sure himself so they go on until they see a worker heading for the drying hall. Willing to satisfy the students’ curiosity Bob goes ahead to the worker and asks him: “How does the system know when the lacquer is dry?”

“A new system”, the worker answers. “Like almost everything here.” Bob is not surprised. “There are electrical sensors all over the cars that register whether the lacquer is cured.” “Electrical sensors measuring current flow and determining the viscosity of the lacquer – that's easy", Bob thinks. "And the data is mapped into the software layer via RFID?" Bob asks the worker. He nods his head.

Now Bob has a rough imagination how the system worked: the measured data from the electrical sensors is continuously read out by readers installed at strategic places in the drying area which are connected to the central computer. They read the sensor data and forward it to the computer together with the IDs of the cars that they read out from the RFID tags on them. The central computer controls this data and notices when the drying process is finished according to the changing measured resistance of the lacquer. Afterwards it sends out a signal to the drying hall that the car is ready to proceed and shortly later it is transported to its next pass.

Due to this automatic recognition and processing the time the cars have to wait in the drying hall could be reduced and the workflow optimized.

"Amazing what can be done with those RFID tags in combination with a powerful computer system." Bob thinks, turns to his group again and guides them to their next stop.

Kanban

While the group crosses another manufacturing hall Bob thinks of what he has learned about traditional manufacturing systems and compares that to the systems today. Basically, over several years the production processes weren't changed. But they were improved by the usage of new technologies; they were made more efficient, faster and cheaper. In the hall they cross there is a Kanban system used: Kanban coordinates the production flow through a Call-for-parts principle. Kanban is usually a card that signalizes what is produced when and in which amount, so that the needed parts are provided on time. The Kanban system therefore can reduce the circulating inventory and increase availability of parts, which are important advantages compared to a central planning system. Years ago, Kanban cards were collected with boxes and brought to the first production step, from where later the needed parts were brought back to the requester. While this system helped to make manufacturing processes faster and more efficient, it was kind of inefficient to collect the cards with boxes and transport them to another place.

The RFID Kanban system now installed at the factory offers lots of improvements. There were two development steps for the RFID Kanban. First, all Kanban cards were tagged with RFID tags. Readers scanned those tags and tracked the exact movement of each Kanban through the factory – therefore real time information on what is actually happening on the shop floor could be collected and used, for example, for virtualization and simulation matters (Factory Logic 2005).

One problem of traditional Kanban systems is (or was) that someone or somewhat has to issue the pull signal as soon as new parts are needed. In the second development step all parts are tagged, scanned regularly by readers and gathered in an information system (e. g. in a virtualization system) so that the Kanban can be issued automatically. One solution is here the installation of RFID reader barriers (which are similar to light barriers) at the supply line: as soon as the readers can't find tagged material in the supply line anymore a virtual kanban (i. e. a signal) is issued to the preliminary system (Baudin and Rao 2005).

Quality Assurance

The group goes on and passes by a rack of stacked metal boxes. Looking at the boxes Bob notices a small green item attached to each box. “That must be the motional sensor Robert told me about last week”, he says to the students. Robert is responsible for quality assurance of transportation of goods to and within the factory. He tries to remember how this sensor works. He can’t recall the exact technical functionality that Robert explained him but he still knows the sensor responds to movements and shocks. Those movements are stored in an active RFID tag connected to the sensor. At certain quality assurance check point those tags send their data to a reader that passes the information on to the central computer. The computer compares the measured values to standard values and tries to identify possible transportation damages. The sensor can measure its rotation and can therefore determine if the box ever stood upside-down with a potential damage of the material inside.

The sensors can also recognize shocks; that means they notice when the box falls down on the floor or is crashed to another box or wall. Since those things can happen very easily during transportation it is important to have a reliable checking and assure the integrity of the contents of the box.

Of course not every container is tagged with this quite expensive technology. Only products that can easily get damaged like glass or electronic equipment have to be observed that carefully.

It is needless to say that this kind of system doesn’t prevent damage; but at least it detects it at an early point where the problem can be handled easier.

AGV

The next stop for the group is the storage area. They see huge racks filled with boxes, small containers, single pieces of plastic and metal, everything mixed-up, without any recognizable order. “Only a computer can manage a mess like this”, he tells the students and remembers three years ago, when the new software system for storage control was introduced.

Up to this point all items moving around in the factory were tagged with passive RFID tags. Every supplier was forced to tag their products, too, and data exchange was made possible by the established EPCglobal network that provides a standard for communication between enterprises. It was then possible to have a complete abstract software view of the factory with its components and items in it. By keeping track of the store’s contents and logging all requests for pieces in the store from every point in the factory the arrangement in the area could be optimized using a mathematical algorithm. Of course, this new order was no longer suitable for humans who have to find a certain item in the mass of racks. So concurrently a new transport system was installed in the factory. All human drivers steering vehicles for transportation within the factory were replaced by computer controlled vehicles, so called AGVs (Automated Guided Vehicles). In order to be guided through the factory the floor was tagged with passive RFID tags and readers were installed on the vehicles so they can update their current position and therefore be navigated by the central computer system.

But the reader is not only used for guidance it also identifies the items within the storage area.

All items within the store are also tagged with passive RFID tags. Every item is therefore registered in the storage software system and has its own place in a certain rack. When an item is requested from some part of the factory an AGV moves to the rack associated with the item, automatically pulls it off the rack and brings it to the desired location. The readers on the vehicle are being used to identify the item in the short distance, to avoid errors by items that are very close to each other.

When an item should be stored in the storage area a storing request is sent to the storage system. It calculates the correct place for the item according to the estimated probability where and when the item will be used again, the current filling level and so forth and sends an AGV to the current location of the item which will carry it to the store and unload it in the calculated rack.

By automating all those processes on the one hand the error rate of transportation within the factory could be reduced. On the other hand the transportation was also accelerated because the AGVs can drive at a faster speed than humans; as all of them are organized centrally they know the position of other vehicles and avoid crashes. The flexibility of the whole transportation within the factory could be increased a lot.

"BEEP, BEEP, BEEP" – suddenly a loud noise behind him disturbs Bob in his deep thoughts. He turns around quickly to see a huge vehicle that sends out this bothering sound only one meter away from a shocked student. "Wow, thank god he's tagged!" Bob thinks and recalls the small passive RFID tag that every person in the factory had to wear. Those tags can be read by the readers on the computer guided vehicles and are recognized as belonging to human beings within milliseconds by looking up the transmitted ID in a database. When the computer detects such a tag in front of a moving vehicle it is stopped at once to prevent physical injury and an acoustical alarm signals the person that he blocks the vehicle.

Still startled the student steps aside and watches the big vehicle without a driver accelerating and moving around the next corner.

6 Evaluation of Vision

Business Requirements

Above, we described several possible applications for the usage of RFID in manufacturing. Now the question is when these solutions will become reality and what needs to happen that manufacturers install RFID on their factory floor?

One important point is the connection of production and supply chain: in supply chains, more and more RFID solutions are installed. Let's take Walmart that forces all its suppliers to provide all products with RFID tags. The more RFID spreads around in supply chains, the more realistic becomes RFID in manufacturing:

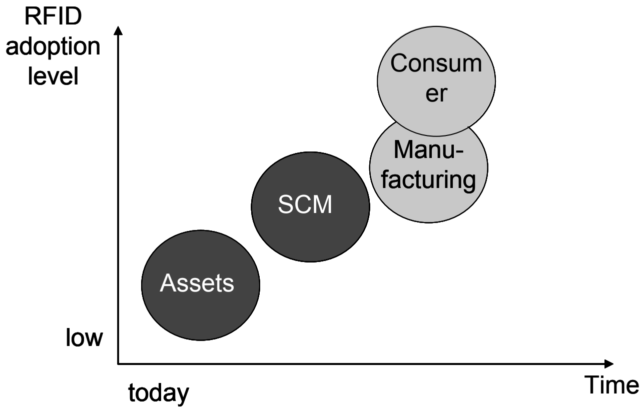

Fig. 9. The adoption of RFID technology

Source: Bapat and Tinell 2004

if all products from the goods issue of a factory have to wear a tag, why don't start tagging one step earlier, that is on the factory floor? If factories are forced to install RFID technology at least at the goods issue it's reasonable to install the same technology all over the factory. Therefore mandates on manufacturers are crucial drivers for RFID adoption – or as Datamonitor states: "The impact of exogenous factors such as mandates on manufacturers will continue to drive the greater RFID market to a point where not complying with mandates becomes less expensive than compliance." (Datamonitor, 2005) The potential for cost savings and increasing efficiency raises a lot when RFID can be used over the whole production and supply process.

As can be seen above in the installation of RFID in factories will follow the installation at supply chains – and this adoption has just started, which means that a broad adoption in manufacturing will not happen until some years in the future.

A barrier for the implementation of RFID technology is the existing high degree of automation. Barcodes are a standard for track and tracing, and lots of production systems are supported by computer systems and therefore very automated even today (Fleisch and Stroh 2004). This high degree of automation makes it harder to convince manufacturers to change stable processes and make a large investment.

Technological Requirements

One big problem in factories is that metal interferes with RFID transmissions – especially high frequency transmissions – and in manufacturing halls lots of metal can be found. So one requirement is that tags with other frequencies than HF are used or RFID systems that are not disturbed by metal are developed. Same is for machines or products that contain a high amount of liquid.

Secondly, common standards have to be achieved. RFID in manufacturing is only reasonable when the same ID can be used through the whole supply chain. Therefore there has to be used a unique coding system (like EPC), a tag frequency that is readable around the world and a technology that is worldwide compatible. Besides, all companies within one supply chain have to have access to a common database.

Legal Issues and Privacy Concerns

There are several legal and privacy issues that have to be solved before some of the proposed applications can become reality.

The control of employees is (at least in Germany) not always legal. Basic legal principles that regulate also RFID usage are the "Bildschirmarbeitsplatzverordnung", that prohibits employee efficiency control, and the "Betriebsverfassungsgesetz" that prohibits the company to use control technologies and techniques without asking the workers' council for authorization (Lischka 2000). The "Bundesdatenschutzgesetz" requires the agreement of everyone involved or observed, too. The "Telekommunikationsgesetz" (RFID tag and reader can be seen as telecommunication devices) regulates that only specific appointed institutions are allowed to intercept the transported data (Bitkom 2004).

These regulations mean for example in the case of RFID access control that employees have to be informed about this control, the identity of the controlling instance, about the operation mode and the kind of data collected as well as about the right to ask for the collected information and for deletion (Bitkom 2004).

In the UK a codex for data security is published by the Information Commissioner. This codex allows surveillance of employees only if there's justified reason, no alternative and the reason excuses the negative impact on the employees (Information Commissioner).

In the US, the Electronic Communications Privacy Act from 1986 prohibits the interception of electronic communications (and again RFID data can be seen as electronic communications) – but companies may still read electronic data if they are service provider for this electronic communication, or if employees give consent (which is usually part of the labor contract) (Kizza and Ssanyu 2005).

7 Conclusion

After intensively reviewing the impacts of RFID technology on manufacturing the authors come to the following conclusion.

There is no single "killer" application for RFID in manufacturing – otherwise it would already exist, since RFID technology is not that new. A lot of companies have been analyzing the use of RFID; the result is mostly the same: the technology could help to improve some processes but is still to expensive to be used on a large scale. So at the moment RFID is only set up in sub-sections of the factory.

If RFID technology shall completely evolve its potential, it has to be used in a more interconnected manner. That means the different applications of the technology that are not profitable on their own have to be combined and work closely together. In that way RFID can help to control the complex system of a factory with software systems that react more properly and faster than any human person.

This is, however, a big step that has to be carefully prepared. Companies therefore should actually start to introduce RFID technology in smaller, single processes. But then they have to overcome the first starting difficulties and try to realize the benefits that a combination of their implemented application and another small application in another part of the factory or process might bring.

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Leveraging Global Commerce – What's in for the Consumer?

Sophie Ahrens, Rebecca Ermecke, Karl Janker, and Philipp Torka

1 Introduction

At the moment, everybody is talking about RFID. Chances and risks are evaluated and analysts forecast different scenarios. And although there are still unsolved issues, it seems as if RFID has the potential to revolutionize supply chains and the business world.

The effects on consumers are, however, rarely taken into account. Applications in the consumer sector are considered fancy but are believed not to be of any economic relevance. As costs seem to be exorbitant they are usually just shrugged off. But RFID in the consumer sector is already reality. Payment in the cafeteria, tickets for the soccer world championship 2006 and toll-collection systems in the US work via RFID, and these are only examples. Apparently there are some exceptions to the rule that RFID applications in the consumer sector do not pay. This was the incentive for a trend report covering the general impact of RFID on consumers and investigating possible application scenarios.

In the course of the paper a scenario of the future world is presented; a world where RFID is accepted and widely adopted in everyday life. Subsequently, necessary premises for such a scenario are laid down and then, in the section "Adoption and Diffusion" assumptions will be made about where and how a diffusion and adoption of RFID applications is likely to occur. Before integrated applications are examined in detail concerning their characteristics and the feasibility of their implementation, an overview of possible applications in the consumer sector is given. Finally, general advantages and disadvantages RFID could bring about for consumers are discussed.

2 Vision

… Good morning Held! Wake-up! It's a beautiful day, 25 C; slightly cloudy, though. You are meeting Mr. Scrooge at 9 o'clock in his office. Time for some serious fund raising! Don't be late!" Held sighs and can't help thinking what would happen if he just kept his eyes closed for a little longer. Some diffuse memories of last night's party come back to his mind. "Held, it is getting late. Now there is no time for breakfast anymore" The voice in his headset seems to be really annoyed with him. Held figures that there is no way but getting up.

[In the scenario described above, the alarm clock gets the information from the organizer/smart phone lying next to it. The device is recognized via RFID, the information about the personal schedule can then be inferred from an online database. Here, the smart alarm clock also identifies the persons lying in the bed by RFID. Thus, it can send the information directly to the headset of the respective person who has to get up, so that other persons are not disturbed. As wearing headphones at night is not very comfortable one could also imagine that the alarm clock contains speakers.]

Held picks up his organizer that lies next to the alarm clock and drags himself towards the wardrobe. Considering his appointment with Mr. Scrooge it proposes a rather formal outfit. Held presses "yes" on the touch screen. The wardrobe offers the choice between a black and a brown suit. Held wonders whether his white one must still be in the laundry. He chooses the tie his ex-girlfriend gave him for his last birthday. The combination doesn't look too good on the screen, so he finally goes for a red one which perfectly matches with his new trench coat. With regard to the weather the latter is, however, not necessary as his wardrobe points out correctly.

[The smart wardrobe communicates with the user via a touch screen interface. The wardrobe recognizes the clothes that are stored in it via RFID, as well as the organizer of the user. It has access to a database containing pictures of all the clothes that can be seen and combined on the screen. There is also other data stored about the respective clothes that could be entered by the manufacturer and by the user, i. e. whether the piece is to be put in the category formal or whether there are any buttons missing etc. The wardrobe is also linked to a database containing weather information and the schedule of the person. It can, therefore, give some sophisticated advice about what to put on, but still allows full flexibility and adapts to the wishes and needs of the user. With this application one will not forget about clothes anymore, just because they happened to have vanished to some remote corner of one's wardrobe.]

After choosing his tennis outfit for this afternoon, Held gets showered and dressed. He rushes towards the door – gosh he is really late. Maybe he should reprogram the alarm clock and allow some extra time in the morning …"What about your racket? "asks a voice. Right! Tennis this afternoon! How could he forget? He puts his racket into his sports bag. This time the door lets him pass without any further comment.

[Memo machines could be installed at doors. The device is linked to the RFID home center, where all the information is stored that is obtained by the network of RFID readers in the house. Therefore, the memo machine is fully aware of all the

items in the house. It also has a reader itself that checks whether the person leaving the house (recognition by RFID: GlobalID or organizer) has all the relevant items on him/her. In order to do that it can access one's personal schedule, data about the weather etc. It could also memorize which persons brought which objects or other persons to the house, which do not belong there and make respective remarks if they do not take these things / persons out again when they leave]

"It was horrible you can't believe it. I couldn't do anything anymore, I lost my identity … Basically I stopped existing!" His neighbor Cassandra offered Held to take him in her car. He accepted but it turns out to be a really bad decision. She had had a nightmare and would not stop talking until he has heard every detail. She dreamt the government had mistaken her for a terrorist and somehow managed to deactivate her personal ID card completely. So she was not able to enter a building, or to drive her car, she could not pay anymore or simply log on to her computer. "Well, they could not do that. And if they really managed to get all the data from your ID card they could have been tracking you all the time and would have seen that you haven't been where the crime happened. You see, I really don't think this is realistic." He thinks Cassandra is definitely exaggerating. People have feared a total surveillance for a long time, just think about all these old books like "The Pelican Brief" by John Grisham or even "1984". However, he has never heard about something like this actually happening.

[RFID technology can be used for payment, access control and authentication. In an extreme case one could imagine having just one card for everything, instead of dozens of plastic cards, keys, passwords and logins. This could bring about a lot of advantages but there might also be risks. The idea of a GlobalID card will be discussed in more detail in a later section]

But as he has expected Cassandra just goes on telling him how naive he is and that the government already knows a lot about every citizen. "Just imagine, last week the garbage collection refused to empty my bin, just because of one yogurt cup, which was wrong. They have a nerve …" "Listen Cassandra, you certainly got more wrong than just one yogurt cap. How did that happen? Haven't you seen the red light on the bin? Sorting garbage really isn't that big a deal anymore …" "I don't know; maybe there was something wrong with the system. Anyway, we are so dependent on the technology nowadays! Last week something happened with the traffic signs and there was a huge car accident. Just imagine what happened if …" Held stifles a yawn and thinks that his neighbor has a funny talent for deriving apocalyptic scenarios from a yogurt cup. How could someone be that pessimistic about everything? "Listen; just drop me off here; thank you anyways!"

[Assuming every product is tagged and remains to be that after the point of sale, RFID could bring about a lot of advantages for waste management. The smart bin in the application mentioned above reads the tags of the things to be disposed and signals where to put it. On the other hand, the whole bin could be scanned by the

garbage collection and in case of any irregularities just refuse to take it away. Furthermore RFID could be used to replace traditional traffic signs.[1]]

When Held approaches the Office building he reads the letters on top of it. “Scrooge Games Incorporate”. He works in the R&D department being responsible for testing prototypes of new games and could not imagine any better job. It is 10 to nine. In the elevator, Held meets a colleague, Robin, who was at the same party the other day. He is complaining that the elevator would not let him out at the first floor so he cannot meet the beautiful team assistant he got to know at the same event. Held smirks.

[Companies already use automated systems of access control to determine which employee can go where. In the scenario described above, the elevator is equipped with RFID readers checking the GlobalID cards of the people entering it. The elevator is linked to a database and therefore knows which ID is associated with which access rights. So employees might not have access to certain floors where they are supposed not to work.]

When he gets into his office his organizer tells him that Mr. Scrooge will be late, he has just entered the train, so it will take him another half an hour. Held sits down on his chair, his computer logs on automatically but asks him to identify himself by fingerprint. He presses the house button. The RFID home center tells him that everything is where it should be.

[As mentioned above, the GlobalID card could also be used to log on to computers, sometimes there might be additional security measures used in combination with RFID, i. e. biometric data. RFID might also be used for localization, as long as the tags are close to a reader. In the scene mentioned above, one could imagine that Mr. Scrooge just presses a button on his own PDA and thereby authorizes Held to keep track of his location for a certain period of time.]

The meeting with Mr. Scrooge is rather disappointing. He does not really seem to be enthusiastic about the Star Wars game that Held has developed in the past year. It is basically a computer game but it can only be played properly when one has bought original figures and placed them somewhere near. Mr. Scrooge, however, does not really like the idea and will probably not approve the necessary budget. He thinks Star Wars games are really a bit backward and points out that the 9th and 10th movies were not really successful. However, they agree on another meeting to discuss further possibilities of the basic idea of the game. Mr. Scrooge likes the idea of a revival of the Sims. Real objects of the player’s environment could be implemented in the game. Sims- as if this was not a bit backward. They agree to have another meeting the next week – maybe even with some representatives of IKEA who might be willing to sponsor the project. The organizers lying on the table automatically agree on a time that fits into the respective schedules.

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[1] Please see chapter A new world of products and services for more details

[RFID allows many interesting possibilities to link the real world and the virtual world. This could be a basis for computer games where one needs to buy certain equipment in order to have it ready in the virtual world. In this example the user would have to buy Star Wars figures with RFID tags on them and place them in front of the computer. The latter needs to be equipped with an RFID reader just as for the way of log-on described above. When the tags of the figures are read, they work like a key to unlock certain playing options. In the example of the Sims game the computer does not only use the tags that are directly read by the reader it contains but is linked to the data gathered from all the readers in the house. So when one starts building a virtual world, one begins with items that one disposes of in the real world. Of course, depending on the game, there might be room for improvement and to alter one's own possibilities. Nevertheless, such applications could add a lot of authenticity and fun aspects to many different games. It is important to notice, that a pre-requisite of such games is that for each of the respective real-world objects, a counterpart in the virtual world has to be been designed. Finally the mutual agreement on an appointment works if both smart phones contain both: an RFID reader and a tag. They recognize the other smart phone and then log-on to a database where both schedules are compared (WLAN, UMTS, GPRS). A similar task is already operable in Microsoft Outlook but could then be just carried out with more comfort and without the necessity of having to sit in front of a computer.]

When Held goes back to his office he sees that his team members already have arrived. Julius is sitting in front of his computer wearing Roman clothes. Just as the virtual figure he is playing. Held thinks that all these role play geeks will probably love that game. In contrast, his colleague Steve is hardly wearing anything. He is testing an update of the blockbuster 'Virtual Strip poker 5000'. Held decides to go on working on an RFID version of the twister game. He puts on his gloves and socks with tags on them and plays a little round. There are still some problems with the readers, because sometimes they do not localize it precisely. Held thinks that this does not really make sense as an RFID application, it is better to play it with other persons directly. That's the fun really, the contact to other people. He thinks about what he is going to do tonight. He really likes the idea of having a little party.

[A virtual Twister game could be implemented if under every colored field there was a short range reader and the person playing the game had RFID tags on feet and hands, i. e. by wearing tagged gloves and socks. The information where the hands and feet are could then be transmitted to another player somewhere else. However, playing Twister on your own, without really experiencing the closeness and body contact to other persons is probably not the same fun than it used to be. The role play game, where real costumes are required to play the respective virtual figures works on the same principle as the Star Wars game. The user has to dress just like the character he is playing, because it is only unlocked if the computer can read a certain combination of RFID tags put on the clothes. The virtual

strip poker works the other way round. Here the person is first scanned for the clothes he/she is wearing and then a picture, i. e. of a dummy (maybe what you see depends on your age, that can be derived from your GlobalID card) is created, which wears the same things. As the game goes on the user has to throw away clothes, so that they disappear from the read range and the computer is paying attention, that no new things, that are tagged in a way, they are recognized as clothes, comes close. In the way described above, the fun of the game would depend a lot one's own imagination but it could be a lot of fun]

Held notices that he has received some letters, no sender is written on it, he holds the letter close to a reader to check whether it is actually his. No it is for Julius, the guy in the Roman dress. The sender is his soon-to-be ex-wife. Poor guy, this woman really gave him a hard time since she found out that he had cheated on her with a friend of hers. Really bad mistake not to check the house for any unusual items before she came back …

[Instead of printing the address on letters, one could use RFID tags to label them.]

It's lunch time. The guy he was going to play tennis with this afternoon has cancelled the appointment. He did not even call himself; just send a cancellation via his organizer. What happened to all these people today? Held wonders whether he should have lunch in the cafeteria. Just check who is in there … nobody interesting as he infers from the screen at the entrance. He decides to eat at home. Again, he presses the house button on this computer. His fridge seems to be pretty filled and several proposals for recipes pop up. There is everything he needs. No need to go shopping. Excellent!

[The RFID readers identify the products stored in the fridge and the pantry and save this data. Based on this information the computer can propose recipes that can be cooked with the available ingredients. This information can be accessed from everywhere]

He walks down to the parking lot and wonders where he has parked his car. This happens to him every day, he consults his organizer but it tells him, that it is still at his house … right, Cassandra gave him a lift. His PDA indicates that the next train is leaving in three minutes and Held rushes towards the station.

[Here again, RFID is used to localize an object, of course this only works under the condition that it is situated somewhere close to a reader]

The screens on the outside of the first two wagons show that there are no free seats available anymore. Held keeps running until he has reached the third wagon. With the third one he is more successful; there is still a seat left. Going by train is really annoying sometimes. Nevertheless he likes the idea that he is going to get some more kilometers on his bonus record: Maybe he will get enough bonus miles for a small trip to Barcelona this summer. After all, the parties there are just great. He sits down, feeling really exhausted. Still tired of the other day, he tries to sleep but the two elderly ladies next to him would not stop talking. They are stuck in an argument whether all these RFID applications would interfere with pacemakers or not. One of them insisted that this was, what caused a friend of them to die, but the other one thinks that it was just a problem with the battery. Held wonders why old people always had to talk about depressing things like death or illnesses.

[It could be useful to use RFID in trains in order to identify people. The readers on the doors of the train would automatically recognize when someone gets on and off the trains. This would enable tariffs on the basis of the actual distances one has made by train. The payment could be effectuated via the GlobalID card based on a frame contract, so that one would just have to pay a certain amount of money at the end of the month. Given the exact personal 'consumption' of train miles, all sorts of bonus systems could be based on that; similar to the ones that are already used by airlines. To go even further one could imagine that there are RFID readers integrated into every seat of the train. Then it would be possible to know exactly who is sitting where. The screens at the outside could therefore tell you which seats are already taken and which are free. Readers on the doors, however, would be sufficient to count people and then calculate the number of seats available without exactly knowing who is sitting where. Concerning the conversation of the two ladies: There are concerns, that the frequencies used by RFID might interfere with medical devices such as pacemakers, but this could not be proven until now.]

He remembers a conversation with his grandmother the other day. She was, however, quite happy with her new medicine cabinet that automatically checks whether she takes the right doses of everything. Furthermore it makes sure, that she does not mistake her husband's drugs with her own. And then, his gran added an encomium about the fridge they had given her for Christmas. Whenever she cooks something and has spent for example all the noodles in her package, she just has to hold the empty package in front of the fridge and press new on the screen. The order is then just added to the daily delivery to her house. She really appreciates the new device, as going shopping and finding the brands she is looking for really exhausts her. Yesterday however, it did not work for some reason; maybe she had accidentally cut out the tag. So she made Held promise to bring her another packet next time he visited her. Held thinks that she could also have called the delivery man but he is willing to do her that favor. Some minutes later, they reach the station where Held lives. "What about your sports bag?" asks the voice in his ear … When is he ever going to learn it?

[RFID could be used to enable high reliability systems, also in the consumer sector. An example is the medicine cabinet described above. The respective persons have to be identified, i. e. by wearing a bracelet with a smart label on it. The medicine packages are also identified via the tags they carry. Somewhere the data has to be stored which medicines goes together with which person. Furthermore RFID

RFID also allows to go back to the use of objects where purely virtual applications have been used in the past, i. e. online shopping. These haptic versions of existing applications could be very useful, for example for elderly people who are very insecure when it comes to dealing with computers and purely visual interfaces. With the application described above online shopping would be as easy as just holding an empty package in front of a reader and order a new one. The Memo Machine on the doors of the train works exactly the same than the described above.]

First place to go when he arrives at home is the kitchen. All the thoughts about empty noodle packages have made him really hungry. He grabs some things from the fridge and puts them onto the counter. “Apparently you would like to have pancakes! Would you like some help? Held decides to accept. “You are still lacking some sugar” He adds the sugar and stirs everything. The plate where he put the pan heats automatically to the correct degree. The kitchen tells him how long it will usually take until the pancakes are ready but he still has to pay some attention himself. After having lunch he starts to think in more detail about his evening plans.

[The reader under the counter reads the tags of the items, which have been laid down. The data about the combination of ingredients is then compared to saved recipes. If the computer has guessed correctly it can then give further advice and assist with the cooking. The location of the pan is also recognized by readers in the plates of the oven ...]

The “Brain-Machine 4000” turned out to be a blockbuster for Scrooge Games Incorporate. The demand was even greater than expected and contributed significantly to the annual turnover. Held owned an older model but often downloaded updates from the Internet. He relied on it very often when he was lacking a creative idea. “Theme Party” he typed in. “Price category: cheap”. On a scale from “ceremonial” to “freaky” he chooses “unconventional” “Hello Held, how about having a Hawaii party tonight?” Not bad, he thinks. He presses ‘Accept’. “You got a Hawaii shirt in your wardrobe and you could use your plastic plant for decoration. The creativity machine makes further suggestions including the right background music like for example some of the CDs he has just bought yesterday.

[RFID allows being more aware of the objects around us. In a house full of readers, no items will disappear in dark corners anymore. Given these entire data one could think of applications, such as the Brain Machine described above, which use the available data and combine them in new ways in order to meet the needs specified by the user. The machine would have to be linked to the other applications in the household, such as the pantry, the fridge, etc. to make useful and integrated recommendations.]

There is also a proposal for a guest list. The criteria of choosing people is one the one hand the chosen style of the party so classified snobs as well as rather formal business contacts are automatically excluded. Held really does not feel like seeing Mr Scrooge tonight. On the other hand there are also some mechanisms implemented to check the compatibility of the people, for example Robin just hates Cassandra, therefore these two are never invited together. Held does some minor changes on the guest lists and then invitations are sent to the organizers of all of his friends. When the guest list is fixed, the creativity machine presents the shopping list. "You just need to buy: coconuts, soft drinks, plastic cups …" Held holds his PDA close to the machine and uploads the list. "And we suggest, you clean up first!"

[The machine relies on the information in the database, some of which the user might have entered himself Furthermore it relies on the data gathered on the last parties, especially the spatial clustering of people. After all, RFID can not only be used to locate objects but also people. Sometimes this information is no use as for example smokers were basically forced to spend a lot of time in proximity on the balcony. Sometimes, however, one could also derive very interesting information from the clusters. Who has been with whom for what time and from that derives who likes whom and which persons should be invited together. The objects in the house can also be localized and if everything is lying on the floor, the machine can conclude, that it is time to tidy up.]

Held looks around. Well, there are definitely a lot of things lying around. Time for Carsten Cleaner! This was a present of another ex-girlfriend and a really useful one for a change. Held sets the robot on the floor and it starts hovering the living room. But although the machine is relatively sophisticated it is by far not able to do the work alone. Thus, there remains a lot to do for Held until tonight. He starts off with the laundry. He puts some things into the washing machine but then it refuses to work. It tells him to take out his wool pullover again. He obeys and the washing machine automatically chooses the correct program. He remembers Cassandra having trouble with her machine the other day. Apparently her Prada t-shirt refused to get washed with some no name trousers. Held found that rather amusing but his neighbor got really annoyed with it. She planned to sue the company but calmed down a bit when Held proposed to download an update for her that managed to circumvent the problem. With regard to the state of his CD rack he decides he should also clean some dust. "And one, two, three, go …" he rushes towards the first rack, he needs some seconds to clean it, "the wardrobe" says a voice in his ear and he hurries towards the other side of the room. A colleague of him developed the "PUTZ-game" and he offered to test it in his own four walls. The prototype still suffers some minor errors but Held is pretty optimistic that they will soon be able to start off at the market. Cleaning is definitely more fun that way … Half an hour later, he is really exhausted. The game is directly linked to his personal fitness schedule. "Mediocre" judges the voice in his ear and recommends a work-out in the morning. Held chooses "ignore", he really doesn't feel like getting up early the next day. He is really satisfied with his result though. His flat definitely looks much more inviting now, than it used to an hour ago. He sets off Carsten Cleaner, which is still hovering the floor.

[Robots might be improved by using RFID. The possibility of identifying things via RFID tags could reduce the requirements concerning image recognition. The smart washing machine also uses RFID readers in order to read the tags on the clothes and to decide whether the combination of identified clothes should be washed together or not and how. This is a very useful application for consumers but theoretically one could imagine a kind of abuse such as mentioned above, where the branded items start bitching when being put together with no name clothes. Another RFID based application that could be used in the household is the CleaningGame. It basically localizes where one is with the glove, which carries an RFID item and measures the time to get from one cupboard to another and dust off the furniture. This application could be linked to the organizer containing a personal fitness plan and then automatically reserves additional time slots to be spent in a fitness center.]

Held decides to go shopping. When coming to his car, he is a bit puzzled, everything is somehow wrong, someone has readjusted the seat, mirrors and everything … he checks the database and finds out that a friend of him, John, is the one to blame. Yeah, right, he remembers, he was going to buy some furniture and asked Held to lend him his car. He agreed, but as Held was away that weekend, reprogrammed the car, so that it would accept John's ID. When Held sits down everything moves back to its usual position and the car asks him to authenticate by fingerprint in order to start.

[The GlobalID that has already been discussed could also be used as a car key. As it allows to recognize the individual on the driving seat there might be the possibility to have access to data such as the size of the person etc. Consequently the position of seats, mirrors etc. could be automatically adjusted.]

In the newspaper, Held has read, that the Future Store chain has managed to become a market leader in retail and that it kept continually expanding all over the world. The store in his town was inaugurated half a year ago and Held often goes there. When he enters the store, his shopping list appears on the screen on his shopping cart. He notices that the quantities of many things have changed. Apparently some more people have accepted to come to the party. After some seconds the list is substituted by a map, indicating the most efficient way through the supermarket in order to get all these things. Held starts of with the fruits, he has planned to buy some pine apples and passion fruits. The screen on his cart, suggests buying some papayas as well, as they are a special offer this week. Held thinks, that this is really a good idea and also adds some mangos to his shopping cart, he wonders whether all these actually grow in Hawaii and decides to use on of the information terminals across the supermarket. When he holds the mango close to the reader, he learns all about its way to the supermarket. His very specimen is actually from Kenya but he figures that this will not make any difference to his guests.

He buys the candles and plastic caps that the creativity machine put on the shopping list and also some things its cart recommends to him in addition. Held is, however, a bit annoyed when it keeps presenting some table-cloths with palms trees on them. They are really kitschy and do not even look Hawaiian at all, so he presses the small "ignore" button on the bar end of his shopping cart and the add disappears from the screen. In another aisle, Held spontaneously decides to put a cake in his cart but quickly puts it back to the shelf when the screen on his cart starts flashing in a red light, indicating that the product contains nuts and that Held is highly allergic to them. Held remembers having trouble to breathe because of these mean little things as a child, in the last few years he had managed to avoid eating them.

After all he ends up with many more things than he has intended to buy – just as most of the times but he thinks that they are all very useful. He checks out at the counter. The content of his cart is scanned and the amount indicated on a small screen. In order to pay, he just needs his GlobalID card and a further identification by fingerprint. He thinks back of the times when you still had cashiers scanning all the single items. This really took ages. Cassandra used to work as cashier when she was a teenager and often talks about how many of her colleagues had got unemployed when they were made dispensable. However, most of them were still needed to restock the shelves and so on. When Held walks out of the Future Store he also remembers all the beggars hanging around supermarkets, asking for the coins you used to carry around these days …

[In the RFID age, shopping might work just as described above. The shopping cart contains a PSA (Personal shopping assistant) that interacts with the user via a touch screen. An RFID reader is integrated in the PSA. The PSA could get the shopping list from the smart phone and accordingly calculate the most convenient way through the supermarket and map this on the screen. When things are put into the shopping cart, the PSA scans the items, puts it on a list, which could indicate for example the sum of prices of all items in the cart. It can also tell about product characteristics, expiration dates etc. Alternatively one could also imagine having extra terminals for that purpose. On the basis of the individual data and the combination of items already in the cart and on the shopping list, the PSA could make recommendations about products and carry individualized adds with special offers. The checkout could also be facilitated by using RFID capabilities of bulk reading. This might make cashiers redundant. As mentioned in the story, also beggars might vanish from the streets due to the cease of existence of cash in the age of a GlobalID card and fully automated payment (which does of course not mean, that there has to be less poverty.]

He starts putting the things in his car and notices a very good-locking woman parking just next to him. Secretly he scans her with is organizer. Has she made any data available? His organizer indicates that she possesses a wading-pool which would be just a brilliant fridge for drinks at a Hawaii party as his PDA points out. Apparently she also has the same creativity machine than him and has also downloaded the 'Go exotic' update. Held starts talking to her. She is called Suzie and seems to be quite nice. They start a conversation about how much fun the creativity machines brought about and Held invites her to come around tonight and bring along her wading pool. “Oh, great idea. I’d love to …” But she points out, that she still has to make sure that someone is looking after her three-year old son. Held sighs inwardly. He really could have anticipated that. People possessing wading pools were bound to have children.

[As the smart phone contains an RFID reader, Held can scan the woman for RFID tags. However, he will only obtain the information that she has chosen to make publicly available. As she also owns the creativity machine and has decided to share the relevant data with this community, Held gets to know, that she owns something which might be relevant to his theme party.]

She starts thinking loud that she could ask her neighbor who is usually really friendly to look a bit after him. Anyways, he would not have to do that much. Only recently she has bought a computer program that could entertain her son for hours. She tells that it includes a lot of games and exercises where the child was to bring along all sorts of things for example his teddy Baer or building bricks. “Go get your teddy” and then the toddler just goes off, and comes back with the toy that is recognized by the computer and then he receives some more instructions and incentives to play with the things and to use his toys in new combinations. He really liked it and it was just so cute! Held smiles politely but cannot help thinking why she thinks he would be really interested in every detail of her child’s game. Anyway, he knows all these things already. One floor above his office all the people are working on these kinds of things. But he does not tell her that. He notices that she seems to have finished her monologue. “So,” she concludes “I think my neighbor can do that. See you later on then!

[Combining the virtual and the real world could lead to computer based games that also have haptic elements which could be very useful for small children. In the application described above, the computer basically entertains the child but also involves real objects. It can therefore also pay attention hat the child does not leave the room, by only demanding things that can be located in the room.]

On the way back home he wonders whether it is any use to date mothers. Even if they were single there were always problems to arise. He thinks that there should be a way of somehow recognizing whether the girl is single or not and whether she has any children. Theoretically, would of course be possible. After all he was also told about her possessing a wading pool. It all depended just on the sort of data that you chose to make public. Some people were really concerned about all sorts of privacy stuff and he figures that many girls afraid that they would be lacking an excuse if they could not just pretend to have a boyfriend. However, it would make flirting much more efficient. “Brave new world”, he thinks.

Back home Held starts decorating his house. Everything looks really good. The door bell rings. There they are- his guests. Cassandra, Julius, Steve, John, Suzie and some other people. They are having a really traditional round of twister. The atmosphere is great. Looks like another long night …

3 Assumptions

In order to make the developed applications possible in the future, some assumptions had to be made. These assumptions will also impact the diffusion and adoption discussed in theoretical concepts about diffusion and adoption

3.1.1 Technological

From the technological point of view, it is necessary that existing problems of the RFID technology have to be solved.

For a complete substitution of the barcode it has to be possible to scan every kind of object which has an attached RFID tag. Right now it is only possible to scan items which consist either of metal or water or of different materials. It is not yet possible to read the tags of items which contain water and metal. In order to be able to use only one identification technology in the supply chain it has to be possible to also scan soda cans and tinned food.

For a big rollout of RFID the reliability of RFID tags has to improve. As soon as bulk scanning is used it is not acceptable that single products are not scanned because of faulty tags or other technology related problems.

To be able to use the same hardware and software for all different kinds of applications, standards like EPCglobal have to be adopted by every company. It is also necessary that the information about the products is available also for the consumer and not only for businesses.

3.2 Economic

For most RFID applications in the consumer sector it is important that RFID is widely spread in the business sector. Some proposed applications are based on tagged products. It is necessary that nearly all goods are tagged in order to get reasonable working applications. For the consumer it is very important that the needed hardware is affordable for home use and that it is possible to integrate it into already existing home networks. A first approach to prove the customer that he or she can gain value by the usage of RFID is to use mobile phones which are RFID equipped.

As only a serial number is stored on the tags all needed information about the object has to be obtained from online databases. In order to get this information everywhere the world of the future has to be a networked world. It is necessary that the rates for mobile internet connection are dropping in order o allow the suggested applications to become a success.

3.3 Legal

It is supposed that in the future RFID applications are not widely forbidden because of privacy concerns. It is most important that the RFID tags of products do not have to be destroyed at the point of sale to the end consumer. On the other hand it is vital that the safety and privacy of consumers will be protected by law in order to minimize risks for the consumer.

3.4 Social

A majority of consumers have to accept RFID as a technology which is not only used in the B2B sector but also by them. The fear to be a more transparent customer has to be outplayed by the positive effects which are possible with the RFID technology.

4 Adoption and Diffusion

Most of the applications for consumers require a certain amount of users in order to be beneficial both to the user and to the business providing the application. This section describes diffusion and adoption concepts and exemplarily links them to different applications identified in the vision. Pre-requisites are identified that applications have to fulfill in order to reach successful adoption and diffusion.

The second part of this section considers the impact of the suggested applications on decision-making and control. Psychological concepts are used to systematically analyze their impact on adoption. Furthermore, possible resistance against innovation is taken into account. Finally, some assumptions about consumer needs are discussed as possible fields of application. Based on these findings one can form a view on the feasibility and likelihood of a Held-like life and decide whether the vision is a dream to come true or not.

4.1 Diffusion

Diffusion is the process of communication of an idea through different channels over time within a community (social unit).

Adoption and diffusion are two concepts of the diffusion theory.

Both are equally important for the success of new products. Without communication nobody would even know about a perfectly personalized alarm clock thanks to RFID and thus even the best innovation might never be sold!

Several theories and models have been derived in order to explain and visualize these processes. In the following an attempt is made to briefly explain prominent and/or significant concepts that help to evaluate the feasibility of the derived applications in the consumer sector. Pre-requisites for diffusion that have to be fulfilled by the applications are also pointed out as well as forces that can accelerate or inhibit diffusion.

4.1.1 Diffusion Stages

The diffusion of innovations is first of all a process of adaptation and understanding that takes place in several stages. Concerning a “face-to-face” situation as illustrated in Fig. 1 one distinguishes the following phases: say, hear, understand and do. Analogous to verbal diffusion one can think of innovation diffusion stages as: technically possible (innovation), marketable, diffusion, confirmation/use.

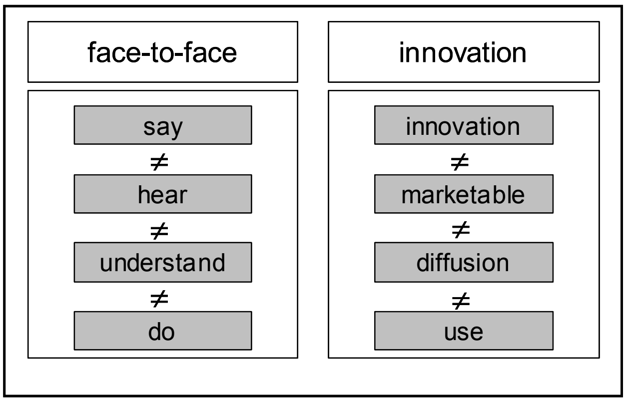

Fig. 1. Diffusion Stages of Information and Innovation

Source: modified from Scharpe, K. (2001)

The conversation between Held and Cassandra on the way to work is an exemplary "face-to-face"-situation. While she is trying to share her worries the information selected and heard by Held is her incapability to operate the garbage system properly. Based on this information he understands that Cassandra needs some advice to avoid such hoodoos in the future. After having told her about the red control light on the garbage bin he considers his work done and puts an end to the conversation. Ergo Cassandra's message didn't come across as intended. Concurrent to diffusion stages in conversation the spread of innovations can be modeled. An idea becomes an innovation as soon as it is technically feasible. As the spoken word it becomes reality. An innovation is marketable if potential consumers hear about the innovation. The new product can be communicated to target groups. Diffusion kicks in if the innovation is understood, a touchstone for its readiness to marketing. Finally the innovation will be used if it "does" as understood by the consumer.

As pointed out above, it is important to take into account that one stage does not equal the next, nor does every technology by law of nature go through all stages. This has several implications for an innovation targeted at an end customer. The more difficult it is to explain the utility, usage or potential benefits, the harder it will be to reach a fast and thorough adoption in the sense of the fourth stage. Furthermore, the perception differs among individuals, which has to be taken into consideration for the communication strategy of new technologies.

A similar approach is undertaken in the Technology Acceptance Model (TAM) by F.D. Davis (1989, pp. 319-340), which tries to explain how users come to accept and use a technology. The two fundamental dimensions are perceived usefulness (PU) and perceived ease-of-use (EOU). PU is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance" (Davis 1989, pp. 319-340). EOU on the other hand is "the degree to which a person believes that using a particular system would be free from effort" (Davis 1989, pp. 319-340).

The feasibility of smart kitchen and cooking applications perfectly demonstrate the gap between technical possible and adopted applications. The gap between a marketable application and its adoption can only be overcome if PU and EOU top the additional cost in time and money. Automation of time-consuming unimportant processes can significantly enhance the PU. An automatically generated shopping list or automated order of basic comestibles are exemplary applications. The EOU on the other hand can be suggested if applications are accessed through well-established interfaces such as touch screens, smart phones and the like. Recipes and inventory lists administrated and accessed via touch screen allow the user to manage the new application intuitively which significantly boosts the perceived EOU. As pointed out in the vision a high EOU allows even Helds's grandmother to keep up to date with technology! Only if PU and EOU coincide crossing the gap is possible; an application is accepted and used by the consumer.

4.1.2 Adopter Typologies

Held and Cassandra are like two sides to a coin. While Held is pushing RFID innovations, Cassandra on the other hand tries to withdraw from any modern product, if possible. The classic diffusion model by Rogers (1983, pp. 243+) depicted in Fig. 2 differentiates five types of adopters within a society (cluster) who take over an innovation at a particular time. Hereby the additional number of adopters depends on the size of the group adopting.

Innovators, such as Held, make up the smallest group of adopters namely 2.5% and are commonly described as venturesome and educated with access to multiple information sources. Early adopters, even though they make up only 13.5% of total adopters, are said to be social leaders as they are popular and educated. The majority can be divided into early and late majority who account for 34% each. Whereas the early majority is characterized as deliberate with many informal social contacts the late majority can be described as skeptical and traditional with

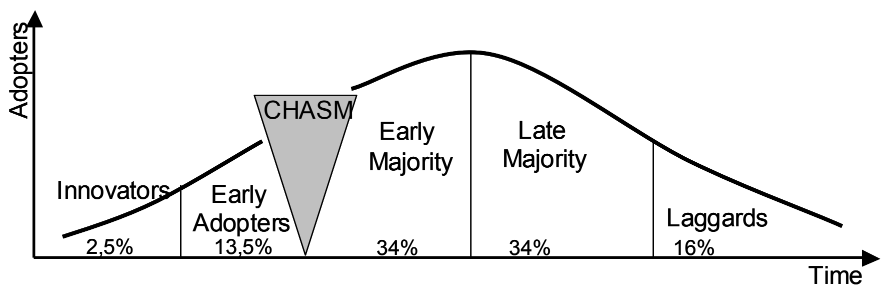

Fig. 2. Adopter Typologies

Source: modified from Rogers (1983)

a lower socio-economic status. 16% of the overall adopters pool the laggard group. Just like Cassandra, they are afraid of debt and use their friends and neighbors as a main information source.

The idea of the diffusion curve helps to understand who promotes innovations and how the diffusion takes place within a society or community. On the other hand this model shows the significant role of early adopters for the successful overall diffusion. Only if early adopters are seen as opinion leaders they trigger demand and it is of high interest if any such group can be identified and convinced for the different applications to guarantee an overall success.

Geoffrey Moore (1991) brings out the underlying motive for adoption. Whereas innovators and early adopters are visionaries the other adopter typologies comprise pragmatists. He postulates that a chasm is created by the two different orientations. This chasm can inhibit an innovation to become widely accepted and economically valuable. In order to cross this chasm he proposes different marketing strategies. From the consumer perspective the TAM model which was introduced earlier in subsection 4.1.1 tackles the dimensions of key issues to be communicated to pragmatists.

The timeframe of adoption depends largely on the type of good monitored. If the innovation takes place for capital expenditure goods, the diffusion will take much longer as opposed to diffusion times in the consumer goods sector. This is due to the time the product is generally in use. The realization of an RFID equipped kitchen as an example for capital expenditure goods might have very gently inclined diffusion curve due to the reluctance of consumers to buy a new kitchen as soon as there is a technologically better one. On the other hand the diffusion of internet took place about ten times as fast as the diffusion of radio, partially because computers at that time had already become consumers goods (Schumann M., Hess T. 2002). The same can be expected for online games with RFID technology since online gaming is a fast growing market[2] due to the fact that most people play PC games and use the internet already. The spread within society will be discussed in the next section along with network externalities.

For example the games Held and his colleagues design will be consumer goods and probably subject to fashion and have short diffusion times.

4.1.3 Phases of Adoption and Influencing Factors

Having talked about diffusion more from a macroeconomic perspective above, the phases of and environmental influences on decision making in individuals are also to be analyzed for further understanding of adoption.

Fig. 3 models the interaction between communicated features of the innovation and the adoption process. As seen above adoption takes place in two phases. The first phase is focused on gaining knowledge about the innovation. The knowledge

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[2] The market volume in 2000 of $ 81 million grew to estimated $ 3758 million in 2005 according to Spiegel Magazine 27/2005, p. 87

about the innovation is derived in different ways depending on the type of adopter. Whereas the innovators and early adopters consider the technical features of the application and base their decision upon them, the later decide upon perceived characteristics of opinion leaders who are members of the early adopter segment. This behavior could be a result of missing technological knowledge. The retrieved information and knowledge subsequently effects persuasion. With persuasion the information/opinion-building phase ends. The different ways of decision making can eventually create a chasm between adopter typologies and force an application out of the market as discussed in subsection 4.1.2. Decision-making, implementation and confirmation take place in the second or adoption phase. Decision and persuasion for any adopter are largely dependent on the TAM-model discussed in subsection 4.1.1. Confirmation is defined as the continued adoption of a technology. A memo machine for example is not really adopted unless it is constantly in use. In case Held would shut off this application it would connote that according to the TAM model the technology does not offer a high PU or is difficult to handle.

During the whole process of decision making the environment influences the process. The four dimensions are as follows social environment, technical environment, legal environment and economic environment. These environmental factors trigger or inhibit the promotion of innovation as outlined in the section 3.

Especially concerning applications that stand for or are integrated into status symbols this model shows how important lead users are in the opinion-building phase. Therefore when looking at the consumer side of applications it is important that an innovation is not only technically highly interesting, it also needs to have a high social value or needs to be attributed to people with a desirable lifestyle in order to enhance adoption. Last but not least it also has to be observable by other people. For example the use of smart phones equipped with an RFID reader in

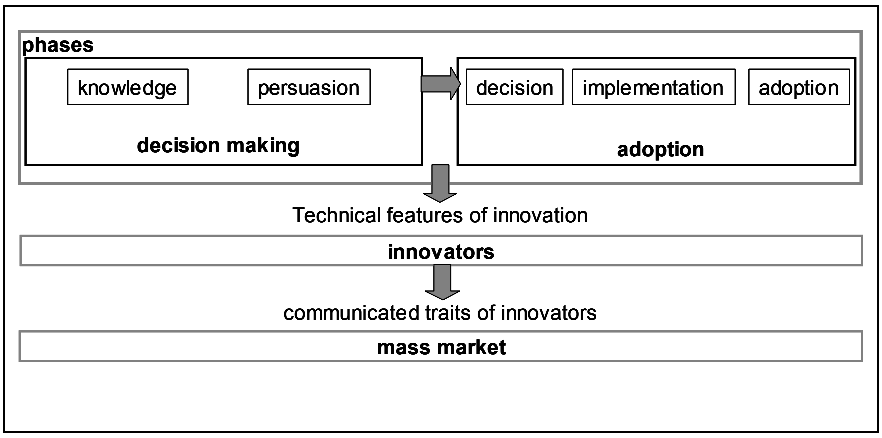

Fig. 3. Phases of Adoption

Source: modified from Schenk, M. (2002)

order to phase schedules or to retrieve information about other people is highly dependent on their social standing. One can also imagine children on a school yard showing off the latest and hottest game pawns for their online games, who, in the role of opinion leaders, promote and market an application. A second aspect that can be indirectly retrieved from this model is that most goods can only be valued by experience. The information asymmetry (not knowing what you get before you use it) can be partially undone by lead users that serve as testimonials. This has to be especially taken into account for applications that promote automation such as cleaning robots or automated paying in transportation systems with GlobalID. Applications of this kind force the user to give up control over certain processes and will be only willing to do so if the innovation is trustworthy and manageable. This will be further investigated under the topic 4.2 in this section. The third implication from this model is that an innovation itself can be perfect, the environment on the other hand might inhibit its diffusion. This plays an important role for the practicability of many of the applications identified in this report, such as GlobalID, especially concerning law issues.

4.1.4 Emergence and Diffusion of Innovation Through Communities

Beliefs and interests are shared within a community and differ between communities. Each community is a cluster of shared assumptions, beliefs and culture [Lebenswelt (Habermas, J. 1981)]. (Kirsch 2001) The dissemination of innovation is effected on the basis of interaction. Interaction functions as a connection between and a creator of communities. (Zippel, K. 2005, pp. 58-75) Interaction is enabled by vicinity only. This can either be a shared physical or conceptual "space". Long-lasting interaction is established through socially-emerged or formal structures. Free interaction on the other hand originates from so-called "tags". These tags can be individuals such as opinion leaders or topics. They serve as a signpost for possible interaction. The subject matter of garbage collection as Cassandra depicted could be such a topic around which a community of interests emerges. Held on the other side, as an early adopter of the creativity machine, might very well be a lead user of RFID applications in his community (tag) and attract other potential user groups. Interesting with regard to innovation is that interaction is the vehicle of diffusion which can be reinforced either way mentioned above. The emerged communities are self-enforcing due to the auto-catalytic effect of signposting through interaction cycles.

Concerning RFID applications an analysis of potential user communities regarding their size and ability to draw attention (serve for signposting) can be of great value for market entry strategies and the prediction of diffusion. For example functional applications such as RFID equipped kitchen shelves might not find such a strong community of supporters who would be able to serve as signposts in the public eye. Applications integrated in cell phones or other status symbols on the other hand might find a strong innovative and technology-oriented community that has great potential as a "tag" to attract new users.

4.1.5 Network Externalities

Positive network externalities exist when "the utility (…) a user derives from consumption of the good increases with the number of other agents consuming the good" (Katz, M., Shapiro C. 1985, pp. 424-440).

Network externalities can be divided into direct and indirect effects. Direct effects lie within the product itself. Online-games for example are only fun if there are not only a lot of people playing them but also at the same time. Indirect effects are described according to Varian as follows. "Another more indirect effect for network externalities arises with complementary goods. There is no reason for a video store to locate in a community where no one owns a video player, but then again, there is little reason to buy a video player unless you have access to prerecorded video tapes to play in the machine. In this case the demand for video tapes depends on the number of VCRs, and the demand for VCRs depends on the number of video tapes available, resulting in a slightly more general form of network externalities." (Varian, H., p. 631)

Applied to the areas of application in the consumer sector almost all of the identified innovations build on indirect network externalities such as the washing machine, wardrobe, ticketing and gaming. It would not be of any use to buy a washing machine that can automatically select the appropriate program according to the information stored on RFID tags if clothes were not be equipped with such tags. On the other hand there is no point in storing cleaning instructions in a database and link it to tagged clothing if there is no washing machine in the market that can make use of such information.

Taking the identification of people and their various forms of application as an example the need for a sufficient user group is obvious. Without a big number of users most of the applications are useless.

As a result there is a certain amount of adopters necessary in order for the innovation to be valuable and trigger an acceleration of growth. Rogers (1983, pp. 243+) has modeled the spread of an innovation within society as an S-shaped curve as shown in Fig. 4.

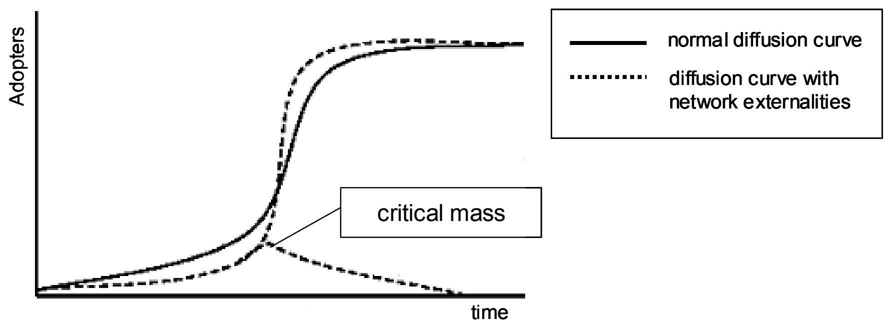

Fig. 4. Diffusion curves

Source: Petermann, T. (2000, p. 32)

Due to the unequal size of the different adopter typologies the overall diffusion takes a non-linear course. Network externalities can accelerate this process which is reflected in a steeper slope of the S-shaped diffusion curve. If the critical masses cannot be reached applications are forced out of the market. Another fact to be pointed out is that in order to trigger indirect network externalities standard-setting is fundamental. Referring to the example above, until VHS reached a critical mass Betamax and Video 2000 as technically superior technologies hindered diffusion of VCRs. After VHS became the standard adoption took place at a much faster rate. (Schoder, D. 1995, p. 24) Especially concerning innovations in the payment sector such as GlobalID standardization will be a prerequisite for success. Attempts for standard-setting of RFID applications are already pushed by organizations such as EPCglobal.

4.2 Decision Making and Control

As most RFID applications are aimed at automation of processes or support of some sort questions of control over processes arise. Their impact depends largely on the different decision styles. Cassandra for example seems to be some kind of control freak and therefore rejects many convenient RFID applications. Furthermore most innovations seem to challenge existing competence. Both issues are important as variables in the diffusion process. Their influence on diffusion and adoption of applications will be discussed in the following paragraphs.

4.2.1 Control

Behavior patterns largely depend on the type of decision process. Decision-making requires information about the subject to decide upon. Depending on the decision process four different styles can be identified. Extensive, limited, by habit, and impulsive decision processes. Every Held or Cassandra disposes over all four styles. Depending on the subject matter a certain style will be triggered. The amount of cognitive effort put in depends on the style of the decision as shown in Fig. 5.

Extensive decision processes are characterized by high involvement and sufficient time to search for alternatives due to missing prior experience. (Engel et al. 1990, p. 29)

Additionally, the result is usually socially visible. As this style requires the consideration and processing of a lot of information it is likely to reach a point of information overload. RFID applications could serve the information processing. Taking the creativity machine as an example, because of the bounded rationality one might not be able to keep in mind and link everything that one possesses in order to derive a theme for a party. This application helps the individual to correlate and cluster items to support decision making and therefore enhances the decision process. As long as the control over the decision remains in the user's power and the derivation of solutions is transparent such applications are likely to be adopted.

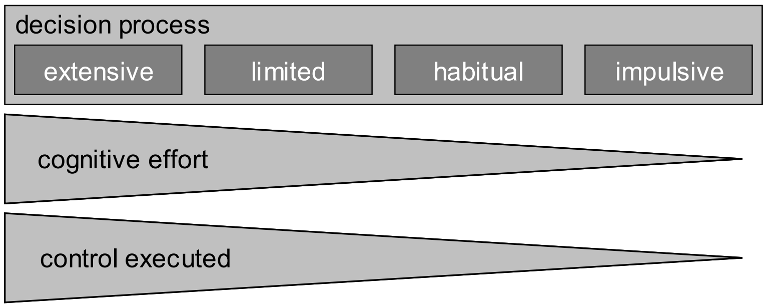

Fig. 5. Decision Styles
Source: Own scheme

Limited decisions can resort to former experience. Only if internal information is not sufficient a search for external information is triggered. (Weinberg, p. 1981, p. 94)

This advancement allows reducing the demand for cognitive effort in decision making. Key information such as opinions from early adopters, are often the basis for decisions. Therefore the decision involves less control than the extensive style. Thinking about smart shopping applications such as the PSA, certain types of RFID-based advertisement using testimonials based on user profiles might suit this decision style. They could trick the user to buy more items than desired, since the application suggests to the user that he is in control of the decisions made.

Decisions by habit are repeated decisions which are characterized by a declining cognitive effort. Searching for and screening of different alternatives do not take place. Usually this style is derived from the extensive style or the impulsive style that were over time converted into decisions by habit. (Rüttinger et al. 1974, p. 141)

The automated ordering application Held's grandmother embraced so enthusiastically is an application that allows the automated action of decisions by habit. The acceptance of such an application is possible because this decision style does not involve a lot of cognitive effort. Therefore, users are not reluctant to outsource these decisions as long as they can program the single decisions previously and the processes executed are made transparent to the user.

Impulsive decision processes are spontaneous, not considered decisions made at an instant. (Kroeber-Riel, W. 1990, p. 368) The results are bounded to the situation. The cognitive effort put in is lower than for any other decision style. Consequently it is unlikely that a consumer actively decides to adopt an application that will trigger impulsive decisions. Nevertheless it is very likely that some applications will enhance this decision style as a side effect.

The smart wardrobe could for example be connected to a database of selected stores. When selecting an outfit the wardrobe could propose new items that would suit a certain occasion or would fit with already existing clothes. If Held is in the mood for something new or disappointed with his looks derived from the pictures on the screen it is very likely that such applications enforce impulsive decisions. New possibilities for marketing will be spawned.

4.2.2 Competence

Schumpeter coined the phrase ''creative destruction'' referring to innovation. When an innovation is introduced it usually substitutes old products and removes established ways of doing things despite of the fact that many of these things might have worked very well in the past. Therefore, innovation often causes resistance. Formerly useful knowledge is devaluated and human capital destroyed.

Thus, when looking at possible future applications for a new technology it is crucial to evaluate whose competencies are made obsolete by the respective innovation. When introducing applications affecting private areas such as the smart kitchen etc., there are above all house-wives who might be reluctant to these innovations, as they seem to destroy their competencies.

4.3 Assumptions About the Consumer

The success of a product after all depends on the willingness of the consumers to buy the product at a given price. In the following some consumer motives and needs are discussed that are on the one hand areas where RFID applications could be introduces and on the other where an especially high willingness to pay is assumed.

4.3.1 High Reliability

As RFID allows a more accurate tracking and tracing, and an easier constant surveillance of persons and objects as well as an improved authentication and identification it is useful to be implemented in fields where high-reliability is crucial. For example RFID could help to identify blood conserves. When concentrating on consumers the medicine cabinet Held's grandmother uses can serve as an example. The GlobalID card could possibly prevent catastrophes like the assassination in the London subway system because everybody on board can be exactly identified and tracked. This topic is further investigated in the Homeland Security trend report.

Other parts of our lives where high reliability counts, is everything that is related to children. A waterslide park in California has introduced a system that uses RFID to monitor children. A package can be rented at the entrance that helps to keep track of the movements of children. This business model has turned to be successful, the profits made by the park with this application actually exceed income from entrance fees.[3]

In general it seems that people are willing to pay a certain amount of money in areas where high reliability is crucial. One should therefore systematically analyze in what other areas high reliability is necessary and how the technical advantages RFID brings about could be used there in order to create useful and successful applications.

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[3] This example was provided by Patrick Riley, Berkeley, during a video lecture at CDTM.

4.3.2 Security

The motive of security is closely linked to that of high reliability. RFID allows identifying and tracking items and can be applied to prevent counterfeiting.

It could be used to improve access control, to avoid food scandals and the like. Depending on the culture of the consumer group they will be willing to pay for extra information. Especially Japanese consumers are very concerned about aliment and disburse additional security.

4.3.3 Fun

It does not always have to be pragmatic! RFID can be used to personalize products. It allows to link the real world with the virtual world and to combine given objects in a new context. All this could be a source of many games and more personalized fun products. If applications address social standing, the need for entertainment or social contact consumers are most likely be willing to pay for the application. Taking online games as an example people will receive respect for their successful play if it can be made explicit. RFID can help to make success visible through game pawns existing in real life, who can gain additional features according to their performance in the online game. At the same time playing is fun and allows interaction with different people.

4.3.4 Social Standing and Prestige

Who would have imagined the success of ring tones and SMS? Especially young people and children are happy to pay a lot of money for applications as long as they might allow a bit more respect from others in school etc. As a result the use of applications might disengage from the intended purpose. Initially thought of as basically useless, applications might get ahead because of attributes that do not lie within the innovation itself.

In order to successfully position a product in such a way, a lot of marketing is usually necessary as well as widely accepted and admired lead users who can serve as testimonials. Any application that can be executed in a social surrounding or whose results allow a better standing for the user fall potentially into this category. Smart phones with extra features, the hottest game pawns the coolest party thanks to the latest creativity machine are possible examples.

4.3.5 Product Involvement

RFID allows creating strong linkages between the real world and the virtual world. Therefore, real objects can be used instead of virtual interfaces. This might allow sophisticated information based solutions expand to groups of customers who cannot or do not want to deal with virtual products only. This is especially true for old people and young children. RFID allows generating applications where the advantages of information technology can be used in a context of real, touchable objects.

Examples mentioned in the vision such as the Virtual Babysitter who can play games such as "Bring along your teddy" or smart kitchen applications allowing to hold empty packages in front of the interface installed at the fridge instead of filling out online forms on a PC when ordering food via the Internet are such applications. They allow real product involvement for the user and might have huge economic potential embedded.

4.3.6 Comfort

People are lazy. They might want to invest something in order to make their lives more comfortable and effortless. Applications that support or automate decision making for example can make life more comfortable. Automatic check out in supermarket, GlobalID cards for everything, automatic recognition and personal adjustments for car drivers are comfortable on the one hand side and allow the user to remain in control over the processes on the other hand.

5 RFID Applications

In this section possible RFID applications are described. In the first part the applications are structured and links to applications which are already described in the vision are made. Later some more complex applications are described in more detail.

5.1 Analysis of Consumer Applications

The consumer sector is a very wide sector. Consumers interact among each other, companies and the government which allows a lot of different RFID applications. In order to cover this sector, the different RFID applications have to be structured and sorted into bins. There are different possibilities of structuring the consumer

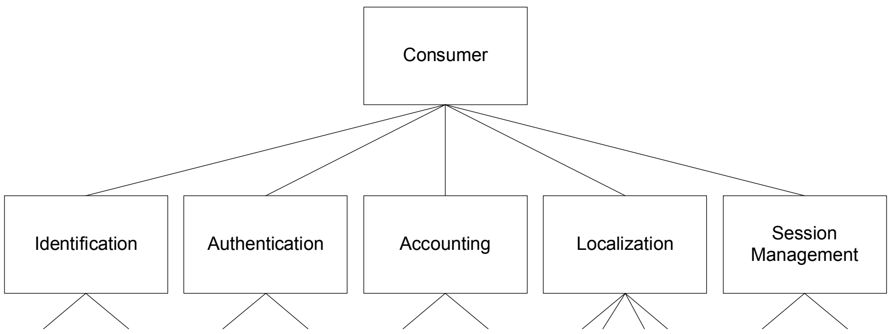

Fig. 6. Structure of possible application areas in the consumer sector

Source: Own scheme

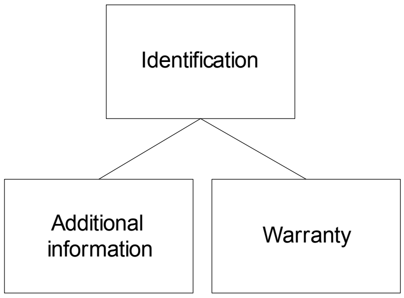

Fig. 7. Applications in the identification sector

Source: Own scheme

applications but none of those allow a really exclusive structuring. The following structure makes a systematization of areas of applications possible.

As shown in the tree structure in Fig. 6 RFID applications in the consumer sector can be split into the areas of authentication, localization, accounting, session management and identification. Small applications of each sector will be discussed shortly in this section bigger applications will be discussed in more detail later.

5.1.1 Identification

The easiest application of RFID is object identification as seen in Fig. 7. For this scenario a tag is read by an RFID reader and additional information about the scanned object is transferred from the Internet. A special object name service is introduced to get this information efficiently[4]. With RFID it is not only possible to know which kind of object is scanned but RFID-tagged products can be identified uniquely.

This means that every object has a singular number which is similar to a serial number of valuable goods today. A singular number makes it possible for the consumer to check whether products in his shopping cart are expired or if an item contains ingredients which cause allergies for a family member. Even factory recalls or warranty issues can be managed more efficiently. The needed data, for example information about the date and the point of sale, is stored centrally and no receipts are needed anymore.

Identifying electronic objects makes it possible to get the right updates for products without being an expert in this specific field.

Another possible application is RFID assisted garbage sorting. RFID readers at trash cans or at garbage trucks make this possible.

RFID technology can also help to get better image recognition results. With the knowledge which objects are near a camera and what those objects look like, it is

[4] See chapter “The EPCglobal Network” in this book, p. 73 ff.

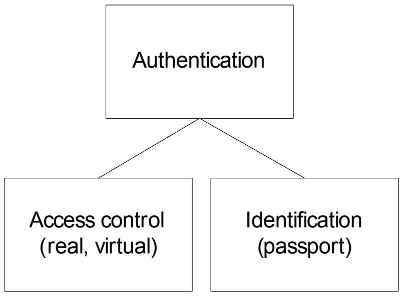

Fig. 8. Applications in the authentication sector

Source: Own scheme

easier to get reasonable recognition results. When a computer system is very aware of the exact location of objects in certain areas, it is possible to create cleaning robots which are able to at least tidy up all tagged items.

5.1.2 Authentication

Talking about RFID in public in Germany usually means talking about the new RFID-passport which is included in the authentication branch of the suggested tree as seen in Fig. 8. Passports will include an RFID chip which contains biometrical features of the owner.

Another possible application of RFID for authentication is access control. In this area a lot of different isolated RFID applications are already existent as shown in the introduction but no broad approach is done until now. This means that an average customer already uses RFID for authentication but the systems are usually not compatible.

Access control can be split up in the two branches of access control on regular basis and entering an event.

Access control on regular basis right now is usually being done by keys and passwords or in few cases by tickets e. g. public transportation. An average consumer has to deal with a big amount of keys and passwords.

Admission for events is usually enforced only by tickets right now. In most of the cases, it is still necessary to have a paper ticket even if the process of ordering the ticket was done completely online.

It would be much more convenient for the consumer to have an ID card which allows him to enter all the locations and log on to all computers. This scenario is described later in the GlobalID section.

5.1.3 Accounting

Another possible sector which will be affected by the usage of RFID technology is the accounting sector (Fig. 9). The payment type in the last years changed rapidly form cash payments to cashless payment methods like credit or debit cards. It is

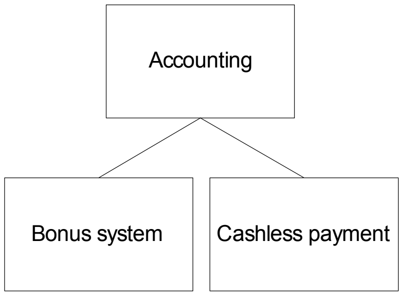

Fig. 9. Applications in the accounting sector
Source: Own scheme

convenient and safe for both parties to transfer money cashless. But as there are many different service providers which offer cashless payments (banks, credit card companies and isolated solutions inside companies to pay for food) the convenience is still improvable. All different cards can be substituted by one payment card.

Similar to the methods which are already existent, it is possible to introduce different levels of security dependent on the amount to be paid. For small payments it is sufficient to place the RFID card near the reader. For accepting the payment for bigger amounts of money, it is necessary to authenticate a person either by a PIN-number or even by biometric features.

A possible enhancement of the system is to even integrate the different bonus systems of supermarkets and department stores.

An even more integrated scenario will be shown later. Accounting and Authentication will be combined into one GlobalID card.

5.1.4 Localization

Localization of objects is a key feature of the RFID technology. Different applications with very different levels of complexity can use this feature of RFID as shown in Fig. 10. For this application most objects have to be tagged. The easiest application is an inventory list where all objects inside a specific area are localized and identified. In households it would for example make sense to place RFID readers at locations where many goods are located (pantry, wardrobe) or and at locations where goods have to pass in order to have a significant different location. With permanent RFID readers in the pantry, wardrobe and at most doors the location of goods is already possible to locate tagged objects quite well. With mobile RFID readers it is then very easy to find the object inside a specific area.

The local database then can help the people to find specific objects (car key, CDs,…) and knows when which object was removed by whom from which place. The chances of remembering who borrowed what would rise with this application.

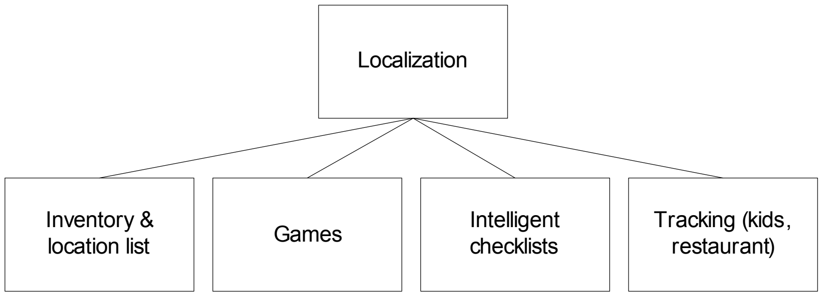

Fig. 10. Applications in the localization sector

Source: Own scheme

Slightly more complicated applications can be washing machines which are able to automatically select the washing program because of the knowledge which pieces of clothing are inside. Such a washing machine is also able to detect whether it is ok to wash the inserted articles of clothing or if some pieces have to be removed because of parameters like color or material. An RFID reader with network connection at the door of the washing machine and a database with all parameters for every piece of clothing make this application possible. A similar application is an RFID packing list for holiday of business trips. The lists are created by the consumer and the computer can assist during this task. Later it is possible to check if the whole packing list is really inside the suitcases by just scanning the suitcases with an RFID reader.

Combining external knowledge like weather forecast or appointments with RFID applications makes it possible to design very effective reminders which where not possible earlier. A bad weather forecast can lead to a reminder to take an umbrella or rain coat to work or a scheduled tennis match will result in a notice that the person is about to forget his tennis racket in the closet. A person leaving a flat can be identified clearly by his GlobalID card (described later). A reminder will be activated if the person is about to forget something. It is also possible to set off an alarm if a person is taking something with him which doesn't belong to him.

Another possible application is to track kids or elderly people inside certain areas. With RFID readers near staircases or at doors it is possible to alarm the parents of a toddler that the kid is not where it is supposed to be.

The different games introduced in the vision are also based on localization tasks. Most games check wide areas for tagged things and activate certain parts of the game only if specific objects are in the range of the reader. This might be a very interesting new aspect of online role-playing games. The user then plays these games in a more realistic environment. For the proposed Twister and Strip Poker application, the localization has to be more precise in order to make those games realistic. Depending on the field of usage one or more RFID readers which are connected to the computer are needed (Twister).

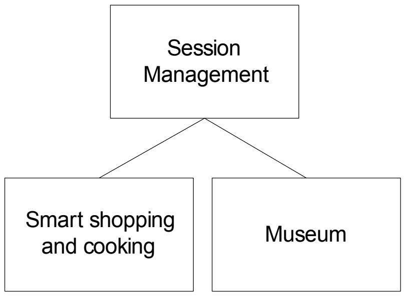

Fig. 11. Applications in the session management sector

Source: Own scheme

More futuristic applications can make suggestions to the consumer what he can do with items belonging to him. This can start with recipes which are able to be cooked with the available ingredients or even end up with the suggestion to have a Hawaii Party at ones place because he has most of the needed things at home. Such a system is not absurd as there are already intelligent and self adapting programs around (20Q 2005). The smart shopping and cooking application can include such a creativity machine.

5.1.5 Session Management

Session Management means that different tasks are integrated into one workflow (Fig. 11). An RFID equipped system assists the customer during work routines which are not necessarily at one location. Based on information gained in early steps of the workflow subsequent decisions will be made by the system. Smart shopping and cooking as well as personalized museum tours are possible examples for session management applications. Some of these examples will be described later. For part of these applications it makes sense to store the gathered data a long time. In case of the personalized museum tour one might want to get more information about a certain painting in a museum he visited last year.

5.2 Global Identification (GlobalID)

5.2.1 Overview

Nowadays, an average person has to carry dozens of different keys, cards, passes and other means of identification about with one. This is space lavishing, rather inefficient and quite often also confusing. Accordingly, a lot of people tend to restrict the number of identification items taken around to a minimum level, resulting in particular cases in which they cannot identify themselves.

A person for example has registered with the local library and has received a library card. Since the person's wallet is already packed with all kinds of bank, health and insurance cards as well as the driver's license and the general ID card, the person decides to leave the card at home and only take it along when intending to borrow a book. What happens if the person spontaneously makes up his/her mind to pick up a book on the way back from work?

Likewise, lots of people are struggling with oversized bunches of keys containing many very similar looking keys. Although accepted by most of them, this turns out to be a very time consumptive issue for persons like janitors who have to open several doors day after day.

RFID as a generic identification technology in conjunction with a respective standard could considerably contribute to solving this problem. The GlobalID card aims to serve as one universal identifier capable of replacing single keys, cards, passes and other means of identification.

5.2.2 Scope

The GlobalID card allows a unique identification of persons in every imaginable scenario and for various purposes.

It is, however, limited to persons as object identification implies modified assumptions and different use cases. Object identification will be covered by the following section about smart shopping.

5.2.3 Benefits and Threats

The vision has already provided an outlook on GlobalID based applications. Held's GlobalID card was used for payment on public transport, access control in the elevator of his office and finally for user authentication at his workstation which was performed due to an RFID reader next to the computer.

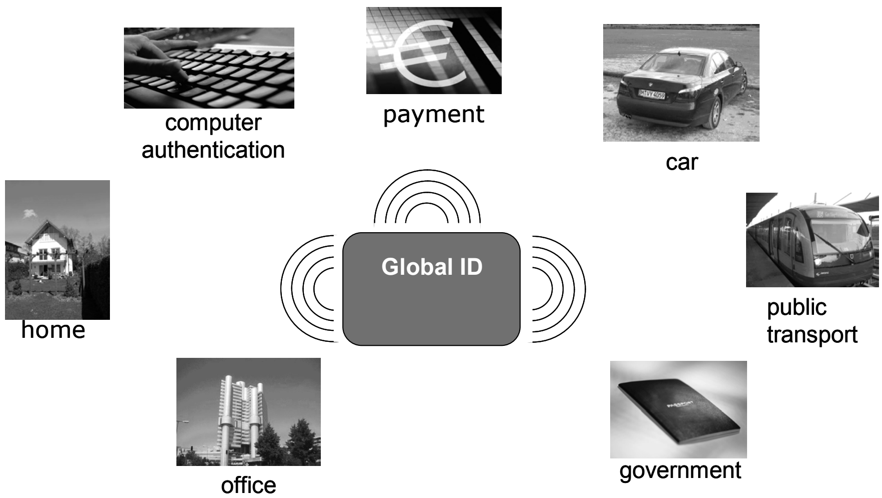

Fig. 12. Possible GlobalID applications

Source: Own scheme

These particular examples can be easily generalized to more complex and comprehensive applications. The GlobalID could serve as a universal way of access control, no matter if in the office, at home or for example at the sports club.

It would be possible that any door unlocks automatically by simply approaching it, provided that the one is eligible to open it. All payment transactions could be performed by using the GlobalID superseding cash and conventional credit cards. Access to any computer worldwide could simply rely on authenticating persons via their GlobalID. This would be a great relief to all people struggling with dozens of different user names and passwords.

Furthermore, the combination of GlobalID with professional session management yields promising outlooks. A museum could for example provide personalized comments which depend on the person itself as well as the showrooms of the museum the person has already visited. Finally, the GlobalID card could support electronic government projects by incorporating e-passport features.

All these application have a huge potential to considerably ease everyday life. People would not have to spend time on identifying or authenticating them anymore, but this would be done in a completely automated manner. In terms of the smart elevator which chooses the proper floor for a certain person, GlobalID does not only simplify current processes, but also provides opportunities for enhancements thanks to more precise and personalized information.

From the providers' point of view, GlobalID cards simplify customer administration. All personal data of a client is transferred from a central authority for GlobalIDs in the future which means that the company does not have to care about updating customer records anymore. In case the client loses his GlobalID card, he cancels his old one and obtains a replacement card from the central authority in stead of applying for new cards at all participating companies.

Obviously, the introduction of a GlobalID requires a major initial effort and cooperation of all institutions involved. Global standards have to be defined and even more adopted by the companies which is certainly not trivial. EPCglobal has shown that this can prove successful as long as all parties concerned act jointly.

Finally, a GlobalID system will probably raise privacy concerns and other worries. Once a personal ID is stored centrally, mechanisms which ensure differentiated and generally very restricted access to these data become essential. Tackling this will prove crucial for the overall success of the concept. The following sections will provide a closer insight into the GlobalID application from the technical, economic, social and legal point of view.

5.2.4 Technical Feasibility

GlobalID Technology at a Glance

A GlobalID scenario implicates different questions: First, where is the personal information going to be stored, second, how does identification work in practice and third, how are unauthorized persons prevented from obtaining and abusing private data. The following paragraphs will research into this and discuss various solutions.

Methods of Data Storage

Currently, a lot of identification systems are based on local data. The most intuitive approach envisions storing all ID related data directly on the identifying medium, for example a magnetic card or an RFID based smart card. This is very convenient concerning the implementation, but can turn into a nightmare in terms of efficient administration.

Following a more sophisticated approach, one would certainly store personal data on a central server and therefore making it available to several applications. The purpose of the identifying medium is thus downgraded to establishing the link to the central record, not providing the actual data itself anymore. This scheme is implemented in most major companies as well as, for example, hotels with electronic key systems.

A GlobalID solution relies on universal identification requiring that one and the same identification procedure needs to be globally available. Based on local data, this would raise need for a permanent reliable synchronization in real-time which turns out to be a huge realization issue. But the central storage solution is certainly not trivial either in this case.

Since a lot of very different companies and institutions need to get involved, centralized data warehousing beyond company scope is crucial. Finally, central storage systems imply typical server issues such as load balancing and reliability. The next section will provide a closer insight into these topics.

Identification Procedure

The first step of identification, which is retrieving the GlobalID related information from a respective RFID tag, proved to be rather simple and is already realized in a lot of different productive environments. Depending on the actual application, ranges of RFID readers can be varied in order to achieve a trade-off of convenience and safety[5].

The whole process becomes more challenging once the actual identity has to be determined from the raw data received from the tag. Once again, the raw data could simply contain the GlobalID, but this would bring about major problems in case a GlobalID card has to be replaced. Replacing a GlobalID card would mean replacing the GlobalID itself which would require all the vendors referring to this ID to change it as well and thus outweighing the advantages of any GlobalID solution.

Due to that, the card should only contain a unique reference to the GlobalID which has to be stored in a central database. This database might be also extended by further personal information. Obviously, the interfaces to this database need to be well defined and access has to be restricted accordingly. Therefore, a neutral, non-profit oriented organization should be preferably selected for the administration of GlobalID. The governments would be possible candidates as they are generally considered trustworthy, already experienced in ID administration and fur-

[5] See chapter "Physical layer of RFID systems" in this book, p. 91 ff.

thermore in many cases interested in electronic ID systems anyway. Alternatively, major credit card companies could deal with this task as they have a lot of expertise in administrating large customer bases though not being perfectly neutral.

After having decided on a global standard, these authorities need to build up IT infrastructure in order to manage the GlobalIDs. Since permanent and stable access to these resources is crucial for the whole application, infrastructure needs to meet highest standards concerning reliability and fault-proofness. A cooperation with organizations like the Network Information Centers (NIC), which are responsible for the Internet DNS system and therefore face similar requirements, could prove reasonable. Finally, smart caching solutions would ease load issues. Once again, caching strategies could be deducted from the DNS system since the underlying procedures show a lot of similarities.

Privacy

An application like GlobalID, which deals with highly confidential personalized information, raises a lot of privacy concerns. The following two aspects are especially critical: First, persons should be only identified by vendors which are eligible to do so and second, which is even more important, absolutely nobody should be able to hijack another person's identity.

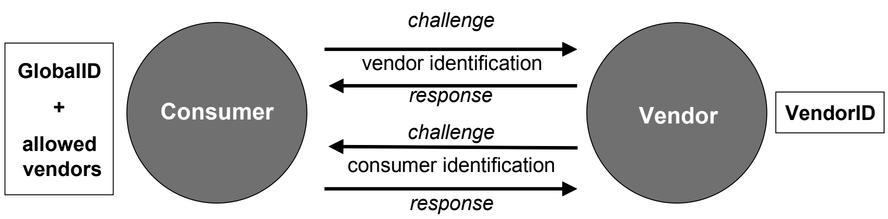

Fig. 13. Secure message exchange

Source: Own scheme

The first problem can be solved by applying a two step authentication process. This means that before any consumer identification takes place, the vendor has to authenticate himself. The GlobalID record in the central database of one person contains a list of allowed vendors and only these are allowed to access personal data. Furthermore, this list can be transferred to the GlobalID card ensuring that the smart chip on the card only responds to readers of allowed vendors.

The second problem can be simply tackled by applying challenge/response authentication methods. Challenge/response methods allow verifying that somebody is in possession of a secret without transferring and thus revealing this secret piece of information. (Menezes et al. 2001) In terms of GlobalID, this means that vendors can identify their customers, provided they are eligible to do so, but the customer does not need to transfer his GlobalID reference which consequently cannot be stolen and abused.

5.2.5 *Economic Feasibility*

Overview

From the economic point of view, the launch of GlobalID comprises two steps. At first, the infrastructure needs to be set up, GlobalIDs need to be assigned and the respective have to be rolled out. Afterwards, the vendors can gradually adapt their business process in order to support previously issued GlobalIDs.

Infrastructure and GlobalID Rollout

The most cost-intensive part of GlobalID is the build-up of infrastructure for the centralized ID administration. A powerful, highly reliable and redundantly available data center has to be installed in order to deal with the considerable amounts of personal data. This will be solely profitable if enough vendors join the GlobalID system willing to pay for global identification services. There are several reasons why vendors should do so.

Firstly, GlobalID will completely release vendors of administrating client related basic data and highly time consuming issues in customer management like issuing or replacing customer cards. Secondly, vendors do not need to worry about faked information anymore, GlobalID information is supposed to be reliable. Thirdly, customers are more likely to accept electronic means of identification, authentication and payment, if they are issued by central trustworthy authorities.

The standardization process will require additional resource allocation but it could be incorporated into related e-government projects which are already underway. The GlobalID assignment and the actual rollout could be linked to regular renewal cycles, for example ID or credit card renewals.

Possible Players

The GlobalID rollout has to be carried out by authorities which meet certain criteria. Firstly, they need to be financially able to cover the considerable initial costs. Secondly, they have to be considered trustworthy by potential customers since they will be in charge of those digital IDs. The administration of GlobalID is a highly security-related task implicating an enormous responsibility. Thirdly, they are obviously supposed to show some expertise in the field of professional ID management.

As already mentioned in the subsection "Identification Procedure", the government and major credit card companies would be possible candidates for this. Both of them have a reasonable financial background, a universal reputation and an extensive expertise in identity administration.

Alternatively, a dedicated neutral organization could take over responsibility which is backed by vendors and possibly the government. GlobalID administration shows clear similarities to other naming service systems like DNS. The dedicated organization would be an equivalent to existing neutral bodies responsible for name service administration like the Network Information Centers (NICs) which are in charge of top level Internet domains. The concepts of these Internet centers haven proven successful and NICs have been established for almost every top level domain in the meantime, for example DENIC[6] for the German de domain.

Gradual Adoption

For those vendors which run a working RFID infrastructure, the introduction of GlobalID implicates adopting the respective business processes in order to comply with standardized interfaces. Although this is mostly not trivial, the previous section has pointed out several reasons why this finally pays off.

Companies which do not make use of RFID technology so far will benefit from considerable efficiency increases. In addition to the advantages, already described above, GlobalID helps automating routine jobs like access controls and thus provides a huge potential for a high return on investment.

In both cases, RFID can be gradually adopted thanks to the fact that GlobalID technology has been made available by the central authority and companies are encouraged to join in subsequently.

5.2.6 Social Implications and Rollout Strategies

Consumer Behavior

There is no doubt that the launch of a GlobalID system affects everyday life sustainably. GlobalID brings about a lot of advantages and convenience but it will certainly also raise concerns and objections.

One crucial factor for the success of the whole concept is trust. Understandably, consumers will not accept GlobalID unless they are convinced that their electronic identity is safe. Thus, the above mentioned administrative authorities need to be neutral, non-profit oriented and universally accepted institutions.

Finally, the security and privacy issues described above have to be taken seriously. Identification based on GlobalID means dealing with highly confidential information and requires sticking to strict policies. Consumer reactions to security holes in this very special area are supposed to be very sensitive.

Rollout Principle

In order to achieve a high level of acceptance, the preferable rollout strategy should be an incremental one. First, the GlobalID have to be assigned and respective cards need to be distributed by the responsible authorities. Second, vendors can join the system gradually. This gradual enhancement is a desirable effect which will allow consumers to steadily familiarize with the new opportunities of GlobalID.

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6 See www.denic.de for further reference

5.3 Smart Shopping and Cooking

5.3.1 Scope

A possible workflow which can be made more convenient by the usage of RFID is the process of shopping and cooking. First the most integrated scenario will be described and later the feasibility of the different applications in this scenario will be discussed.

After choosing a recipe and the numbers of persons which attend the meal the RFID home center checks the availability of the ingredients in the pantry. The interface of an RFID home center might look like the fridge seen in Fig. 14. Automatically a shopping list is created and transferred to an RFID reader equipped smart phone of the person. Dependent on the needs of the person brand products or cheap products are chosen and the optimal supermarket is selected. If a supermarket is out of stock of some specific products the smart phone will warn the customer before going there. As an RFID reader is included in the smart phone

Fig. 14. Smart fridge

Source: Lexicle (2005)

Fig. 15. Personal Shopping Assistant
Source: Wincor-Nixdorf (2005)

the person can walk through the supermarket and find the right products. Another possibility is to integrate a Personal Shopping Assistant (PSA) in the shopping cart (Fig. 15). The PSA is a device mounted on the shopping cart and is similar to Tablet PC. It knows exactly where each product is located and guides the customer through the supermarket. The route can either be optimized for the shortest way or can pass some items which the customer might want to buy. By the usage of either the PSA or a smart phone it is also possible to check the whole bundle for expiration dates and possible allergies of persons in the household or tell the consumer how much money he is already going to spend. It might also be possible to get the information about the supply chain of each product.

The checkout can be as easy as walking with the cart by the cashier station and accepting the payment by authenticating yourself by the usage of the GlobalID card which was described in the last section. Automatically bonus points of the supermarket chain are earned. At home all the goods bought will be added to the inventory list of the pantry and the RFID home center is able to assist the customer in further processes.

As shown in the vision it might be possible for the RFID home center to guess what the consumer wants to cook and assist him e. g. by giving hints about missing ingredients.

As an alternative to this scenario it is also possible to create the shopping list as described above and then send this list to an online shop which delivers the wanted ingredients.

It might be integrated in the smart shopping and cooking application that only designated people are allowed to remove certain thing from the pantry or from somewhere else, otherwise an alarm will go off. Possible cases where this might be of use are alarms when kids try to get alcoholic beverages or too much chocolate from the pantry or if one person is accidentally grabbing the medicine of another person.

5.3.2 Benefits and Threats

The main benefit of the smart shopping and cooking application is that the tasks of shopping and cooking are made more efficient. For many people those two tasks are among the most annoying tasks they have to do. The whole process of smart shopping and cooking is as much integrated into the normal life of the individuals as possible. Well known user interfaces and devices like mobile phones and computers can be utilized to participate in the advantages of the RFID technology. The process is only an assisting process and is not dominating the user. The user gets suggestions during the whole process but can do whatever he likes the whole time. Smart shopping and cooking can therefore be compared to a navigation system. The system is able to assist the consumer but does not force one to do something.

Based on the inventory of the pantry, experience of past shopping and particular wishes of a consumer a shopping list can be created automatically. The wishes of the consumer can be as precise as a recipe and as inexact as a wish to have a party. The risk of forgetting to put e. g. some ingredients of a special recipe on the shopping list is therefore reduced. The consumer also doesn't have to take care about the things which are used continuously and thus often forgotten (milk, butter, coffee and toilet paper). Based on a central database or on the knowledge of the last supermarket visits and the particular needs of the person, the best supermarket for the items on the shopping list is chosen. For a short shopping list it does not make that much sense to drive to a very cheap shopping center far away but for a lot of items it pays to go there. It is also possible to check the inventory of a supermarket and only go there if all needed articles are in stock. The virtual shopping list can be stored on some central database or on the RFID equipped smart phone.

As the consumer arrives at the supermarket he is able to use the generated shopping list to get the best route through the convenience store. For example he could see a map on the screen of his PSA attached to the shopping cart. This is be more convenient than going zigzag through the store until all things of a paper shopping list are finally in the shopping cart. As the user also has his GlobalID with him the shopping cart can know about the consumer's allergies and can check each chosen article for its ingredients. In case of an item which might cause allergic reactions the consumer will be warned.

Another big advantage of RFID in supermarkets is that it makes a second generation self checkout possible. It is not anymore necessary to scan each item individually but instead the content of the shopping cart will be bulk scanned. The payment will be authorized by the usage of the GlobalID card. The lines at checkouts will disappear.

At home the bought items will be automatically added to the inventory list and cooking can begin. It is also possible that the RFID home center assists the consumer during the cooking process. The computer can find out if the salt is moved while the customer cooks the meal. If salt is needed for the recipe but is not moved near the stove the computer can remind the person to use it.

The main threat of the shopping process is that a consumer might get a more transparent human than he already is. The suggested routes through the supermarket might be adapted to each individual as he is identified at the beginning of the shopping. Depending on the past shopping behavior of the individual customer some convenience stores might choose to guide the customers to their most expensive products or to shelf warmers.

5.3.3 Technical Feasibility

In order to make the described process possible the assumptions made for the future world have to be fulfilled. Furthermore a back end system has to be set up. This system has the task to make all information available which is necessary for the purchase because it is not sufficient for the suggested application to only identify a product. This system has to be highly reliable as it is the core of the whole application.

As the system is widely spread and many different parties are involved it is necessary to standardize all interfaces.

Back End System

The back end system has to provide the following pieces of information which can be made public by different organizations.

In order that computers are able to process the data automatically all products have to be categorized. This categorization can be done similar to online shops (Amazon 2005). One category might be e. g. “noodles – 500g package”. This categorization is necessary for the computer to be able to search for similar products from different brands in different shops.

The information about prices of different products in different shops has to be available. This is necessary to perform the search for the cheapest super market for a given shopping list.

Another piece of information which might go with the prices of products in different supermarkets is information about their stock. The consumer knows already before going to the supermarket which products are out of stock and could (probably automatically) adapt to this problem.

Finally the ingredients and the expiration date for each individual product have to be stored as well.

The information about ingredients and expiration dates has to be provided by the supermarket itself or the manufacturer of the product[7]. The supermarket also has to provide the consumers with the information about its stock.

[7] See chapter “The EPCglobal Network” in this book, p. 73 ff.

All other information about categorization and prices can either be provided again by the supermarkets or by the individual consumer. It would be possible to upload the prices which one paid for a product at a specific shop to a central database (Hardwareschotte 2005). Also the categorization could be improved by each individual.

Local Systems at the Consumer's Home

There is also a need for local databases at each home. The ingredients of the pantry have to be stored there as well as individual recipes. The clients which use these databases are smart kitchen devices, smart phones and smart shopping carts. The information has to be available everywhere but due to a more and more networked world this is not a major problem.

Based on the knowledge stored in the databases and the wishes of the consumer the system is able to propose recipes or can even suggest which kind of party makes most sense for the upcoming evening. A lot of knowledge has to be incorporated to make the system able to give reasonable suggestions. In order to make this possible advanced methods of machine learning have to be used. In the consumer sector it is necessary that such a system is delivered with a predefined setting which later adapts to the behavior in the individual household.

One occurring problem is that RFID makes it possible to locate a package but is normally not able to know how much of the content is still there. This is very important for goods which are not used at once like salt or coffee. It is either possible to guess how much salt is left by counting the times it was used or to count only full (not opened) products as items in the inventory. As soon as a product is opened it would then be deleted from the inventory list and therefore would be added to the shopping list. A third possible scenario is that those items are added to the shopping list manually by scanning that item and adding it to the shopping list. This can be done by the consumer as soon as one finds out that the product will soon be used up.

5.3.4 Economic Feasibility

The proposed scenario is only economically feasible if RFID is widely used in B2B applications and therefore is also the preferred method of identification in nearly all shops. The RFID tags can then be used for consumer applications free of charge.

The prices for the RFID readers have to be low and the system has to be integrated in the every day life of a normal consumer. A possible approach is a mobile phone which is equipped with an RFID reader. Such phones are already available (Nokia 2005). For the full functionality of the system the kitchen and the pantry have to be fully RFID equipped and connected to a local computer. This integrated scenario is more expensive but with dropping prices of hardware and more and more computers at home still feasible.

In order to get the relevant data (information about the stock and the prices of each individual product) from the supermarkets it has to pay for the supermarkets to use RFID and to make the data public. RFID has the potential to increase the efficiency in the supermarkets so it is highly possible that every product is tagged one day. If one competitor makes all the data available for the public others will have to join in.

5.3.5 Social Implications

People have to accept the usage of RFID in the consumer world for the proposed application. Therefore it is crucial to guarantee data security. If data security is not assured the suggested system would make a transparent human out of each customer. Every purchase could be assigned to an individual. It would also be possible to get the information about items that are locked in a trunk or are carried around by an individual.

Some people are very concerned about privacy issues of the RFID technology. On the other hand consumer use customer cards a lot. With customer cards it is also possible to assign purchases to individuals[8].

5.3.6 Rollout Strategies

The implementation of smart shopping and cooking will be a step by step implementation. It is dependent on the usage of RFID in supermarkets. The different branches and the different supermarket chains will most probably not start the usage of RFID simultaneously everywhere. Mobile phones will not be RFID reader equipped at once as they are usually used for two or more years. The technical equipment which is needed at each home will probably very slowly make its way there as described in the section 4.

5.4 Personal Fashion Adviser

5.4.1 Overview

It is astonishing how much time people spend in front of their wardrobes every morning, day-to-day. This is obviously due to a mixture of tiredness as well as typical human indecisiveness and actually a task which could be perfectly supported by computers. The innovative solution of a personal fashion adviser (PFA) monitors the contents of a wardrobe and submits personal proposals based on user-defined preferences, environmental parameters like the weather and even records in the electronic diary.

A PFA system consists of a small display with a touch screen and some RFID readers which can be easily mounted in every wardrobe. Using PFA is very intuitive and simple thanks to an outstanding usability as well as easy menu prompts and a high level of automation.

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[8] See chapter “Social and legal framework” in this book, p. 3 ff.

5.4.2 Scope

The personal fashion adviser is a consumer-oriented RFID application based on reliable object identification. The application currently focuses on management and selection of clothes, although generalizations are still possible.

PFA relies on the assumption that all wardrobe items are equipped with RFID tags allowing a reliable identification of those.

5.4.3 Benefits and Threats

On closer examination, PFA turns out to be a very convenient and especially time-saving solution. A lot of wardrobes are very packed so that it is almost impossible for a person to retain an overview on all contained clothes. This leads quite often to a simplified human selection process based on a smaller range of preferred clothes resulting in some clothes being untouched for a long time.

The PFA in contrast maintains a full database of the wardrobe contents and is capable of finding an optimal solution out of the whole range within a fraction of second. It applies very sophisticated selection algorithms which rate all the essential characteristics of clothes appropriately.

Even more important, PFA also considers external factors since PFA can be easily connected to the Internet. Having this done, it queries online weather forecast services automatically and adapts its proposals according to the expected weather conditions. Furthermore, PFA is capable of connecting to online diaries stored on groupware servers which proves essential for well clothing. Therefore, it can distinguish between business and leisure schedules properly.

Nevertheless, PFA will face its limitations if consumers are not willed to accept proposals. The section about social implications will provide closer insights into this problem.

The fashion market is finally a very fast moving business segment which means that keeping selecting algorithms up to date is not a trivial issue. Therefore, this could turn into a resource consuming problem.

5.4.4 Technical Feasibility

Identification of Wardrobe Contents

The underlying premise for every fashion proposal is a comprehensive inventory of the wardrobe. This can be done by several RFID readers installed in different compartments of the wardrobe.

Since RFID tags contain unique identification numbers, the so-called electronic product code (EPC)[9], only, resolving these numbers into real product identifiers becomes mandatory. Online databases or alternatively offline copies of these databases will process the corresponding queries.

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[9] See chapter "The EPCglobal Network" in this book, p. 73 ff.

Selection Algorithms

Designing smart selection algorithms for fashion proposals is a complex task. In order to obtain high quality results, it proves essential to introduce a fine-grained rating scheme. Every piece of clothing needs to be rated carefully in terms of different criteria, for example usability for certain occasions. These ratings should be stored in online databases as well making them accessible for all PFA users.

The selection algorithms itself needs to create a ranking of these criteria based on user preferences, environmental parameters and information from the diary. After this, the weighted criteria have to be matched with the actual score of the inventory. This complex computation can be efficiently solved by creating and applying neural networks.

The networks have to be trained to deal with all kinds of different occasions, for example business meetings, leisure activities, parties and so on. Since complete training takes a long time on the one hand, but a good training needs to be specifically tailored to one person on the other hand, it seems reasonable to ship new PFAs with a basic training and encourage users to customize the advisers depending on their very personal preferences. The PFA supports adapting to user specific selection patterns automatically.

Once the selection algorithms work smoothly, the remaining task is to create a user-friendly menu prompts which is manageable problem.

5.4.5 Economic Feasibility

The total price for a single PFA mainly depends on two factors, the costs for the hardware as well as costs for providing fashion information in online database. The former costs are quite well calculable and have to be borne by the customer.

Since creating an appropriate online database implicates a major effort, costs for this are certainly not negligible. Keeping them as low as possible however turns out to be a crucial factor for the overall success of the product.

A possible solution for this issue might be to involve fashion suppliers. They have an active interest in a proper rating of their products making their fashion suitable for new PFA technology. On the other hand the information could influence ratings and thus bias the supplied information.

Furthermore, these databases could be built up by the customer themselves and shared mutually with the entire community according to the Wikipedia concept.

5.4.6 Social Implications and Rollout Strategies

Once again, PFA is a completely new, very innovative concept which will certainly affect everyday life. The acceptance of this solution depends very much on a person's willingness to adapt the own dress style to a fashion proposed by a computer. The quality of the PFA proposals plays obviously an important role in this context emphasizing the essential role of very well designed and trained neuronal networks.

One general limitation of automatically created proposals is the fact that results are always deterministic and thus predictable in some way even though individual neural networks are applied. This might boost mainstream and diminish individual dress styles which might result in not desirable social implications.

Similar to other products, the general rollout can be carried out incrementally. This allows customer to familiarize with the new opportunities of PFA.

5.4.7 Global Availability of RFID Applications

The world of the future will be a networked world. Therefore many of the suggested applications can be used completely or partly from remote locations. As seen in the vision it is possible to remotely monitor ones home and even check for the ingredients for a special meal. It is possible to make important information not only locally but globally available.

6 General Advantages and Disadvantages for Consumers

6.1 Advantages

Up to now, various RFID applications in the consumer sector have been discussed. Although all these applications are very different and aim at different parts of our lives some general tendencies can be extracted.

RFID creates many new ways of linking the real world with the virtual world which means that new applications can combine advantages of both spheres. Applications using smart solutions based on profound information but simultaneously offering a haptic dimension would be especially useful for small children and elderly people. As already pointed out previously, RFID also enables high reliability systems in the consumer sector and could make our lives more secure.

When RFID technology is combined with sophisticated systems of information processing, it allows enhancing our knowledge about objects, supporting complex decisions and reducing the information overload encountered by individuals.

The dissemination of RFID is also likely to bring about more personalized and convenient products and services. More data can be collected about consumer habits and preferences increasing personalization. This can lead to products and services which really fit individual needs. Applications like games as well as several opportunities of automating boring routine processes could make lives more fun.

6.2 Disadvantages

On the other hand there are ways of using detailed customer profiles to the disadvantage of consumers. Personalized advertising might be really nice and interesting but it can also be extremely intrusive and annoying. People fear infringement of their personal privacy[10] or even feel manipulated and restricted in their decisions and actions.

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[10] See chapter "Social and legal framework" in this book, p. 3 ff.

Furthermore, information about consumer habits and preferences could be used to implement highly sophisticated pricing policies which do not have to be beneficial for customers. The practice of charging different prices for different groups of customers is called price discrimination. This can be done under two premises: the company has to have information about the respective reservation price of the group and it has to be possible to prevent arbitrage. Price discrimination can be either directly (i. e. student discounts) or indirectly using means of self selection (differing prices in business class and economy). In the extreme case of perfect price discrimination each individual has to pay a different price corresponding to the individual willingness to pay. Then all of the consumers' surplus can be skimmed off by the seller.

If companies want to introduce RFID, they have to make huge investments to build up the infrastructure and fix costs will increase. On the other hand processes in the supply chain can be made much more efficient which decreases variable costs. As the RFID applications accumulate a lot of highly personal data, products can be better tailored to user needs. This will allow a higher turnover for respective companies. There is the possibility that there will be a huge gap in the industry between the "haves" and "not-haves". A cycle of higher revenues can emerge and build up entrance barriers. These enormous investments will probably not be stemmed by small and medium sized companies. Therefore a wide spread introduction of RFID into the business is likely to cause an industry shake-out leading to reduced competition if not even (natural) monopolies. Returning to the issue of benefits and threats to the consumer brought about by RFID, this is rather bad for consumers as such an industry structure will weaken their position and allows for exploitation.

7 Conclusion

After a close analysis of the possible RFID scenarios in the consumer sector it can be concluded that the consumer could indeed profit from this new technology. With many different possible applications the life of consumers can be made more convenient and fun. Processes can be made more efficient and the dataflow can be made more consumers centered. RFID can contribute to the networked world the consumer lives in.

However, until now, a common belief is that consumer applications are very nice and interesting but that they just do not pay and do not make sense from an economic point of view. Indeed, given the current situation this seems to be true. Nevertheless this might change in the future if certain criteria are fulfilled. First of all, prices for readers and tags will have to decrease dramatically, just as stated in the assumptions made above. Second, applications like the supermarket scenario will not make any sense in the consumer sector, as long as RFID has not spread in the B2B sector and the supply chain. On the other hand, RFID applications in the consumer sector, especially if they involve fun, could help RFID to get more acceptance in the B2C sector. Acceptance of RFID by consumers has been identified as a third crucial factor for the success of the technology. Whether or not, applications will prevail also depends on the consumers' willingness to pay for the additional benefits.

Drastically decreasing prices for tags are commonly predicted, as soon as mass production is going to start. This will also depend on the decision of companies to introduce RFID. There are already some pilot projects and first moves by leading companies in retail. Whether RFID will really be used on a large scale and with the use of common standards will be seen in a few years.

Concerning the acceptance of consumers, there are many lobbies and consumer initiatives at the moment which are opposed to RFID and try to influence the public opinion as well as politics. There are, however, always concerns about new technologies or new systems before they are adopted, but later on everybody uses the system as they make life better and easier. Examples for this behavior are online shops or bonus systems of major department store chains or in the RFID sector the toll collect systems in the USA. There are a lot of different small applications possible but only bigger packages of applications will significantly increase the customer benefit. Some possible packages have been described earlier. With reasonable application packages it will be easy to enter the consumer sector. RFID technology could be combined with other forms of home automation technology. Due to network effects the combination of both systems could improve their acceptance. Not all described applications are likely to be true in the nearer future, but as seen in the last decades the innovation cycle gets faster and faster and so some unrealistic scenarios might make it earlier to the market than everybody believes.

Consumers' willingness to adopt the proposed applications has already been discussed in the section 4. Certain fields and motives for which RFID could be reasonably used and a high willingness to pay is assumed. Possible examples are high reliability and security systems, fun applications and applications making life more comfortable and effortless.

One can always see positive and negative effects of the new technology. It depends only on oneself whether one prefers to take the perspective of Held or of Cassandra.

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Smart RFID Road Signs

Tobias Assmann, Laura Dietze, Sebastian Kraiker, Jing Li, and Dominik Schmidt

1 Introduction

According to the ADAC (about 20 million traffic signs exist on Germany's roads. That is one traffic sign every 28 meters (ADAC 2005a). Handling all this information can be very difficult. Cars, trucks, bad weather condition, darkness, trees and other obstacles often impede visibility of road signs. Advertising panels – especially in the cities – additionally distract the driver. A further problem is to remember which road signs apply in the current situation. Different road signs have different areas of validity and there are varying rules how to cancel the validity of a specific road sign.

This problem is aggravated by the demographic trend in Germany, which shows on the one hand increasing life expectancy and on the other hand a drop of the birthrate. Recognizing and remembering a traffic sign is particularly difficult for the growing number of elderly people. It would be desirable to have a system that approaches the situation in two ways. First of all it should be capable of reliably recognizing every road sign independent of the current situation. Secondly it should provide a mechanism that keeps track of which road signs are currently valid, by memorizing recognized road signs and processing information about their scope.

The idea is basically to attach RFID tags to road signs and to install RFID readers in cars. Such a system fulfills the above identified requirements: Road signs can be recognized regardless of the current situation and the information about their scope can then be presented to the driver. The infrastructure on the user side is provided by the automobile industry, consisting of RFID readers and attached information technology systems. In return, SRRS improves the safety and the convenience for the driver and the passengers.

There are three kinds of Smart RFID Road Signs (SRRS) in this system. Static SRRS, Dynamic SRRS and Advanced SRRS. Static SRRS are the least complex ones and are for tagging usual traffic signs. Dynamic SRRS are a more sophisticated and they are able to transmit dynamic information, for example of traffic management systems or sensor data. The last group are Advanced SRRS, which have the capability to store additional information, enabling more complex information systems and even commercials. Not only RFID will be needed to make this system work. A lot of partners have to cooperate to integrate the rapid technological developments. While changing some of today's processes on and along the road, it is very important to keep the focus on the customer.

If these issues are overcome, the prospects of the market are great. The market volume of in-vehicle active safety systems will rise from 2.9 billion Euro to 11.6 billion Euro in 2010. In a second phase until 2015 the market volume will reach saturation with 15 billion Euro. Getting only a small percentage of this number would still be a huge opportunity. Car manufacturers have to pay a license fee per car for integrating the readers for the RFID signs into their vehicles. The second stream of income are also license payments, but of a very different kind. They come from companies using RFID signs to target commercials at passing drivers. In conclusion the revenue adds up to 240 million Euro per year in the best case, which will come two thirds from the automobile industry and one third from the advertising companies.

The other important part of the investment decision is its costs. The first roll out of the system will cost about 265 million Euro. The maintenance and the construction site signs cause a yearly expense of about 28 million Euro. Adding up these numbers, it is a great investment in the best case with a NPV of close to 650 million Euro.

2 Smart RFID Road Signs

2.1 General Idea

Road signs play an essential role in today's road traffic regulation. It would be impossible to handle complex traffic situations without them. Road signs assure safety by setting clear rules. Therefore, it is the personal responsibility of every road user to respect them (StVO 2004, §39).

In return, the location for road signs has to be chosen carefully. Only if there are urgent circumstances a new road sign shall be installed. Unfortunately, the situation in reality often differs from this principle.

In the following, the main issues concerning road signs are presented and the need for an improvement of the situation is shown. Afterwards, the principle of the proposed solution is explained followed by an introduction to the different players that are involved.

According to ADAC (2005d), about 20 million traffic signs exist along Germany's roads. That is one traffic sign each 28 meters on an average. A third of all traffic signs is dispensable. It becomes difficult to perceive them all, not just because of the sheer mass, but also because of bad environmental conditions. The steadily increasing traffic makes it even harder to concentrate on the whole information a driver has to deal with nowadays.

Cars, trucks, bad weather condition, darkness, trees, and other obstacles often impede visibility of road signs. Advertising panels – especially in the cities – distract the driver from perceiving them. A further problem is to remember which road signs count in the current situation, but this information is crucial. Different road signs have different area of validity and there exist different rules how to cancel the validity of a specific road sign.

If the demographic trend in Germany is included in the consideration which shows on the one hand an increasing expectation of life and on the other hand a drop of the birthrate, one can see that the group of the elderly will gain in size. According to B&D Forecast (2005), the critical speed up of aging of the German population will begin in 2010. The share of car purchaser aged above 60 will increase from 26 to 34 percent. This age group particularly relies on driver assistance systems to compensate for the decrease of their cognitive capabilities.

It is obvious that the current situation described above is not satisfactory at all and certainly improvable. A lot of accidents can probably be avoided if solutions for these problems can be found. It would be desirable to have a system that approaches the situation in two ways. Such a system should be capable of

1. reliably recognizing every road sign independent of the current situation and
2. providing a mechanism that keeps track of which road signs are currently valid, that is memorizing recognized road signs and having information about their scope.

As a result the driver could concentrate better on the actual traffic and the safety increases on the one hand. On the other hand the system provides more comfort as the information can be presented in different ways e. g. as images or as audio messages.

To accomplish this task the system has to be capable of reading the road signs reliably. At the moment there exists no suitable system: Traffic signs are not machine readable in a quality being sufficient for the previously defined requirements. Optical systems that are currently under development have the same problems as the human vision system as the use of light has its limitations. Other kinds of systems that rely for example on internet databases are highly error-prone. For further details please see section 4.3.

Therefore, an automatic road sign recognition system has to use a different technology. Radio frequency technology is much better qualified for the given tasks than the above described technologies. It can transmit information contact less thus no line of sight is required. It works under environmental extremes and provides a long read range at which multiple tags can be read at once in realtime as the identification rate is very fast. The RFID technology consists of two functional parts: reader and tags.

RFID tags store information; they can carry a sufficient amount of data needed for the requirements of automatically readable road signs. In addition they are rather cheap as well as robust as they do not contain any moving part and can be easily mounted on various objects and surfaces. Most tags do not even need a power supply and they are difficult to counterfeit.

RFID readers on the other side read out the information stored on RFID tags. They are cost-efficient (see the subsection “Tag Installation”) and comparatively space-saving. It is straightforward to connect them to an information processing infrastructure that can work with and interpret the detected data (see subsection 3.2.3).

The idea in principle is to equip road signs with RFID tags and to install RFID readers in cars. A combination of attached hardware and software takes care of processing the incoming road sign data that are formatted and presented in an appropriate way to the driver. Such a system can solve the above identified requirements: Road signs can be recognized regardless of the current situation and information about their scope can be presented to the driver using rather simple algorithms combined with a road sign database (see section 3).

2.2 Players

2.2.1 Introduction

Several players are involved in the Smart RFID Road Signs settings. There is always an entity that provides the content as well as an entity that uses the content. This report discusses different scenarios with two basic constellations of players. The content user is in both cases the same, namely the car (co-)driver, but there exist different content providers: On the one hand

1. the public authorities and, on the other hand,
2. private companies.

The mentioned scenarios are going to be introduced in detail in section 3. Closely connected to the content user is the automobile industry and its suppliers that have to provide the technical infrastructure in the cars. The setup of the road sign infrastructure involving the RFID tag installation is taken over by a company that is hereby responsible for an important part of the technical infrastructure. The following paragraphs provide a more in-depth view of the player's needs and prospects on the basis of the just introduced categorization, as can be seen in Table 1.

2.2.2 Provider

Infrastructure Level

The entity responsible for the main technical infrastructure on the provider side – that is the installation of RFID tags – is the operating company. The public authorities cooperate closely in terms of authorizing the intervention traffic infrastructure which is public area and providing information about changes of road signs. Benefits resulting from this cooperation are described in the next section.

Considering the number of road signs that have to be equipped with RFID tags one can get an idea of this undertaking's dimension, but this basic infrastructure is without question necessary to actually generate a benefit for the users and thus make the system work. If there would be huge holes in the RFID road sign coverage no one would be able to use the system efficiently as no one could rely on the

Table 1. Players of the SRRS scenarios

	Provider	User
Infrastructure level	Operating company	Automobile industry
Content level	Public authorities	Driver
	Private companies	

information availability and therefore would rather resign using the system as a whole. So the initial rollout process is of prime importance and hence has to be organized very well. Later changes are more likely small consisting of adding or removing single road signs. By making available the system's basic structure the operating company can offer attractive services to the content providers and charge them for usage in return.

Content Level

As described above there are two types of content providers. The major content provider is thereby the public authorities which provide content in the form of road sign data that consists in most cases of the same information that is currently available by traditional road signs.

Public authorities are responsible for the traffic on a federal state level. Their scope of duties covers among others the increase of traffic safety (HSW 2005). The entity responsible in Bavaria for example develops an own program that deals with traffic safety improvements (BSWVT 2002, p. 40). A further task is the optimization of existing traffic systems (BSWVT 2005).

With the introduction of SRRS the public authorities can improve safety on streets on the one hand and can use the system for traffic management optimization (see the subsection "Traffic Management Support") on the other hand. As the system will play an important role in traffic related issues it has to be highly reliable or rather failsafe and easily maintainable.

The second type of content providers consists of private companies that can use RFID enabled signs as advertising panels giving them the possibility to selectively address their target customer groups. Therefore, from companies' point of view the SRRS system provides additional benefits because higher revenues realized by accessing relevant customers. Furthermore, it is important that the advertising companies can influence the information that is stored on the tag and the associated presentation as well as different forms of interaction such as direct web links which can provide additional functionality.

2.2.3 User

Infrastructure Level

The infrastructure on the user side consisting of RFID readers and attached information technology systems is provided by the automobile industry. This branch is very innovation driven in its search for ways to attract new and keep existing customers. As the brand image is more important than in other areas when it comes to emotionally accentuated buying decisions of cars it is a plus if added values can be provided by the car manufacturer to the end customer.

The number of electronic components grows constantly as well as the total market for vehicle safety. Especially active safety systems will play a significant role (Business + Innovation Center 2004, pp. 7 – 8). It is likely that the SRRS system will be introduced mainly in upper class cars at the beginning as the additional charge is relatively small in comparison to the overall purchase price. A similar later diffusion as it can be observed with car navigation systems is probable as the technology becomes widely known and attractive to other car classes as well.

Moreover, the commercial truck segment is worth to be considered, too, because safety is a big issue there as well and truck drivers spend a lot of time on the road. Assisting the truck driver at her work place would improve the safety for the same reasons as mentioned beforehand.

Content Level

The driver respectively co-drivers are positioned on the content level of the user side. They receive the information provided by the SRRS system in their cars. Therefore, the user acceptance is a necessary precondition which is influenced by several factors. Reliability is crucial but also the user interface will play an important role: The user hast to trust in the system. In return, SRRS improve the safety and the convenience for the driver and the passengers.

3 Application Scenarios

3.1 Introduction and Differentiation

In this section general technology of this system and different application scenarios will be described. There are three different types of signs within this system:

1. Static RFID Signs
2. Dynamic RFID Signs
3. Advanced RFID Signs.

Static RFID Signs are read only RFID Signs. The reader receives the ID from the tag on the sign and each ID represents a class of signs. One 96 bit content of one tag could mean for example “No right turn”.

Dynamic RFID Signs are almost like Static RFID Sign from the user’s perspective. They display traffic information. But Dynamic RFID Sign are writeable; data on them can be changed depending on different events.

Advanced RFID Signs have different functions, structured text/information and links in RFID Tags can be stored. Advanced SRRS is not used as traffic information signs, but can be used for advertisement.

RFID signs in the SRRS system are not tagged by item level in order to simplify the installation of the signs. The RFID sign's ID represents a sign class, the installing worker does not need to care about which item fits which place and so on. If the worker sees the traffic sign, he only selects the right kind of RFID sign and installs it (see subsection 3.3).

Each kind of signs has one or more application scenarios with different user benefits. Static and Dynamic SRRS have the same user interface, Advanced SRRS has its own user interface.

3.2 General Technology

A RFID system consists of 3 different components:

1. Tags, also to be called Transponders
2. Readers
3. Data processing systems including software systems

The detailed application of the system has different demands concerning technology. What kind of tags or readers? What are the special requirements of the data processing systems? The answer of these questions is presented in the subsections 3.3 to 3.5.

3.2.1 Tags

Tag as the data medium has two types:

1. Passive tag
2. Active tag

Passive tags get power transmitted by the reader. It doesn't need power support and therefore it is a lot cheaper than an active tag. Active tags need power support, the battery is normally used. But for the tags used on road signs solar energy is a reasonable power source.

Generally because of their own power support active tags have a larger read range than passive tag. Active tags have a larger range than passive tags. The exact range of tags is dependent on the frequency range, which will be described in the subsection 3.2.4.

For financial reasons, in these systems passive tags are much more used than active tags.

These tags are writeable, that means within their life cycle data on them can be changed by microprocessors. Security features are possible to be implemented in some types of tags.

The SRRS passive tags due to their short operating range will be mostly installed in the road whereas tags with long operation range (active tag) could be installed next to the roads depending on operating range and function demands. The detailed description of reason and place of installation will be point out in following.

3.2.2 Readers

In this system the readers, which can send electronic magnetic waves and get information back from the tags, should be installed in the cars.

Stationary readers will be installed in the cars. The reader should be installed at the bottom of car, so that reader can get information waves directly and the necessary read range is decreased.

Because the system has three types of tags: static, dynamic and advanced sign tag. Each of them needs different functions, data handling und data format. That means readers should be connected with the application system, in order for the data to be handled.

3.2.3 Data Processing System

The RFID data processing system includes data transfer by "air interface", data receiving by the RFID reader and data handling by the application. The reader transforms "energy waves" into a data stream.

The Contents of Static RFID Signs and Dynamic RFID Signs are just one ID. Each ID has own meaning. The contents of advanced RFID signs are not only IDs but also real information. For example formatted text (see subsection 3.5.5).

The application must know the meaning of the ID (or the formatted content see subsection 3.5.5), filter out unusable information, show data in right format and have some advanced functions like forwarding, ability to connect to the internet or get current state information from the car e. g. gas level.

3.2.4 Basic Technical Feasibility

The following argument points out that with today's technology the SRRS system is in general feasible. This sign tagging system operates at 868 MHz frequency range. In this frequency range the achievable operating distance is 3 m for passive tags and 100 m for active tags (identecsolutions 2005). Passive or active RFID systems transport information normally at data rates of 10 to 50 kbit/s (Finkenzeller 2003, p. 172). Therefore, in the 868 MHz frequency range cars can read the information from signs in high speed situation. Furthermore, a RFID system in Europe has to respect the European radio regulations, especially the regulations for SRD's (short-range device). This means it has to operate only at special frequencies and bands (ISM band: Industrial, Scientific, and Medical Band). The solution for the SRRS is the 868 MHz ISM band (Europe).

Basic idea: The time of data transport from the tag to the reader is X seconds and the speed of the car is Y meters per second. If the distance the car is within operating range of the tag is D, D must be larger than $X \cdot Y$ meters, and then the system works. If the distance (D) is shorter than $X \cdot Y$, the system does not work.

If the car rides with 200 km/h equals 55.5 m/s. 96 bits data need 0.0096 s with 10 kbit/s to be transported.

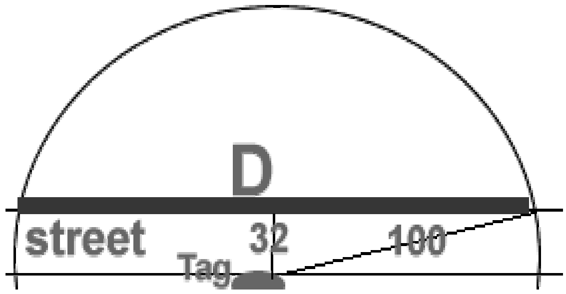

Fig. 1. Calculation of active RFID sign

Source: Own illustration

The time of data transport is 0.0096 s (X), the speed is 55.5 m/s (Y): X · Y = 55.5m/s · 0.0096 s = 0.5328 m. A passive tag that is installed in the streets has normally an operating range of 3 m (D). D = 3 m > 0.5328 m. Thereby this type of tags in the streets works fine with the SRRS.

Advanced RFID signs need 10 kbit memory because of the necessary functions and therefore use active tags (see subsection 3.5). With 50 kbit/s 1 kbit data needs 0.2 s. The time of transport is 0.2 s (X). The speed of the car is still 55.5 m/s (Y). X · Y = 55.5 m/s · 0.2 s = 11.1 m.

An active tag has 100 m operating range. A road with 8 lanes is approximately 32 m wide. That means distance (D) for the car within the operating range of the tag is approximately 189 m; $D = ((100^2 - 32^2) \cdot 2)$ m = 189 m (see Fig. 1).

This is much larger than 11.1 m. D = 189 m > X · Y = 11.1 m. Therefore advanced RFID sings work fine with the SRRS system too.

3.3 Static Smart RFID Road Signs

3.3.1 Introduction

The simplest scenario in terms of functional as well as of technical complexity is the basic scenario of static Smart RFID Road Signs introduced in the following. It is an adequate introduction that helps to understand the fundamental principles of such an automatic road sign system as there are no additional features involved that would go far beyond the porting of common visible road signs to an infrastructure that can be read and processed by machines in order to achieve above described advantages of constant visibility and supporting interpretation.

The (static) information represented by road signs is encoded digitally in an appropriate way (see subsection 3.3.5) and is stored on a RFID tag. On the other side, the RFID reader system installed in the car receives the encoded information, decodes it and processes it. In order to decide which data needs to be stored to represent road signs unambiguously, the different existing categories of road signs have to be analyzed. By all means, the desired coverage includes urban environments as well as roads outside of cities. As there are a couple of different requirements for those two settings – considering for example concentration or variety of installed road signs – the specifications have to be chosen carefully in order to fulfill all necessary conditions.

3.3.2 Road Sign Categories

Taking a look at the German road traffic regulations ("Straßenverkehrsordnung") it reveals that there exist more road signs and related regulations than one would actually think of. The primary question is for which road signs is the RFID tagging reasonable? After having solved this question the required data structure can be discussed. Yet another important aspect for the system is the scope of the particular road signs.

Germany's road traffic regulations differentiate three basic categories of road signs (StVO 2004, §40 – 42):

1. warning signs ("Gefahrenzeichen"),
2. regulation signs ("Vorschriftzeichen") and
3. guidance signs ("Richtzeichen").

Additional information can be added to those types of road signs using add on signs ("Zusatzzeichen") which can restrict or widen the area of validity of the related road sign. The further listed traffic installations ("Verkehrseinrichtungen", StVO 2004, §43) are mostly a combination of road signs already introduced in the other categories or consist of objects that are intended to support the course of street through their actual physical shape and position (for example arrows or cones) and are therefore not suitable for being tagged. In general, road signs that contribute to the regulation of the traffic flow or are of importance to safety should definitely be tagged. An overview on which roads sign are equipped with tags is given in Fig. 3 and is explained in detail in the following paragraphs.

Warning signs are intended to prepare the driver for the announced danger and are thus inherently of major importance. They are installed about 150m to 250m in front of the actual site of danger outside of urban areas and almost at the side of danger within urban areas if not otherwise identified by add on signs (StVO 2004, §40). As an implication the system has to be aware of the current context in order to correctly display the valid road signs (see also discussion of guidance signs).

Arriving at a conclusion the danger road signs numbered in StVO (2004) from #101 (which is a general warning sign at which a danger can be specified using an add on sign) up to #151 (warning signs caution against a specific danger) can be easily represented by RFID tags without further problems. A bit more thought has to be put into the reasonable representation of the beacons (signs #153 through #162) which prepare the driver for railroad crossing by showing different remaining distances while driving towards the danger side. In this case it is not necessary

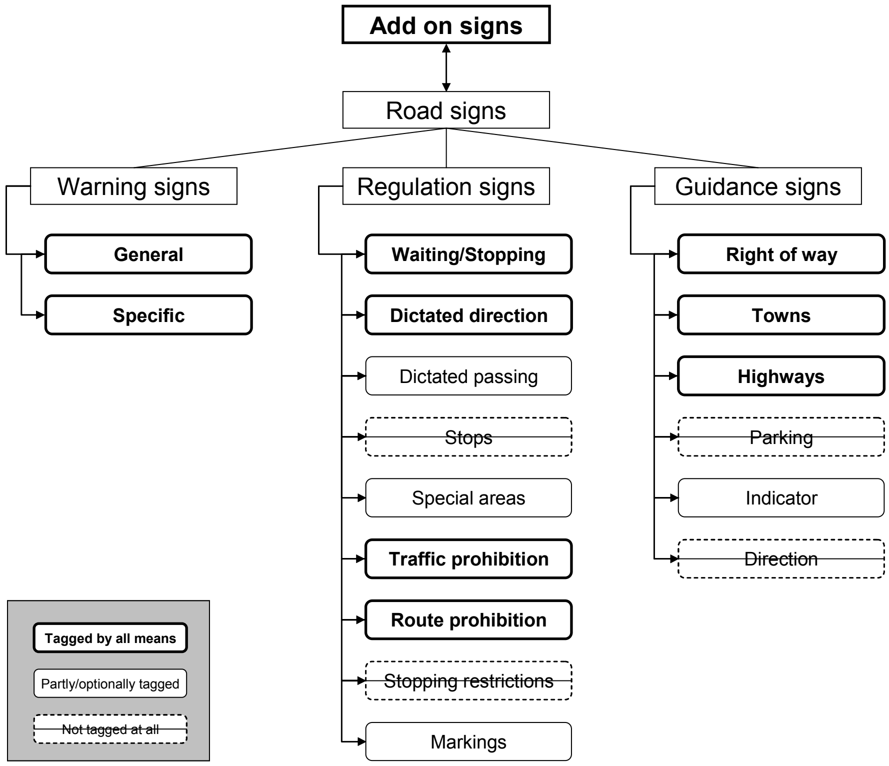

Fig. 2. Road sign categories and their integration into SRRS

Source: Own analysis

to implement a one-to-one mapping as one initial information containing the overall distance would be sufficient. The system then can calculate the remaining distances and display them appropriately to the driver. As can be seen later, standard add on signs are suitable for fulfilling this task.

The second group of road signs consists of **regulation signs** which is a more inhomogeneous group. Therefore, the individual road signs have to be reviewed in regard to their suitability for integration in the SRRS system. The following regulation signs (**waiting and stopping commandments**) have to be adapted at any rate as they are crucial for regulating the traffic: St. Andrew's Cross sign (#201), yield sign (#205), stop sign (#206) and give way to oncoming traffic sign (#208). Road signs covering the **dictated direction of traffic** – like arrows showing the prescribed course of the road (sign #209 to #215) or the one-way road sign (#220) – can be implemented without obstacles as well.

Dictated passing signs are not that important to be implemented by all means as the information provided for example by sign number 222 cannot be used easily in a reasonable way. The car would have to know on which side it passes the sign in order to provide a warning message if applicable. The road signs that present the information that the emergency lane can also be used for regular traffic (#223.x) could be tagged more easily.

Road signs covering **stops** of busses etc. are not going to be equipped with RFID tags as they do not contribute to the actual flow of traffic. **Special area signs** indicating for example bike paths can be tagged in order to provide a warning message in case of accidental passage. **Traffic prohibition signs** would serve the same purpose. They can trigger a warning message if a prohibited area is entered. As there exist road signs that prohibit cars with specific characteristics such as length or weight they do not apply to all traffic participants. In order to display such road signs only if applicable a filter function is needed which will be discussed in detail below when the add on signs are introduced. Furthermore, it may be useful to receive a warning about a prohibited area in advance. In this case the road signs can be equipped with add on signs that indicate a distance.

Route prohibitions signs can limit the speed (#274) or prohibit passing (#276 and #277). Their scope ends where it is explicitly indicated or it ends when a condition stored on an add on sign is fulfilled. The road sign group of **stopping restrictions** will not be equipped with RFID tags as they do not contribute to the flow of traffic. **Markings** (especially arrows directly printed on the streets) can optionally be tagged to increase the convenience for the driver as it can be sometimes hard to identify in which direction the currently occupied lane is leading if there are a lot of other cars standing on the lane.

The last group of road signs defined in the road traffic regulations consists of **guidance signs**. Road signs indicating the **right of way** (#301 and #306) are mandatory to be tagged. **Town signs** have to be equipped with RFID tags to distinguish between urban and non-urban areas which is crucial as there exist different types of rules. The same applies to signs indicating the beginning respectively the ending of **highways**. Highway exits can also be tagged to enhance the driver's convenience. **Parking signs** (indicating parking lots) will be tagged just as little as stopping restrictions signs (prohibiting parking in designated areas) for the same reasons.

Indicator signs as described in StVO (2004) can optionally be tagged to serve as an additional source of information but most of them do not contribute essentially to the flow of traffic. An exception is the road sign which indicates a recommended speed (#380). **Directions signs** often contain complex information especially on highway with multiple lanes and sophisticated exit structures. Therefore, they are not going to be equipped with RFID tags in general. Navigation systems are the better choice for giving directions.

Add on signs can be attached to other road signs in order to alter their scope. They can set a distance in which the associated road sign becomes valid or they can limit the range of validity. Furthermore, add on signs are used to specify several types of danger or to illustrate special right of way constellations. Weather or time restrictions and exceptions for specific vehicles such as bikes can be expressed using add on signs as well. Some more miscellaneous add on signs exist, for example to indicate a bad state of the shoulder.

3.3.3 Filter Functions

As previously mentioned, a filter function is necessary for several types of signs if only those road signs should be displayed that really apply to the current context. Basically there are two possible solutions to implement a filter function: The filtering can take place either in the RFID system integrated in the car (internal filter) or in the road sign itself which requires a dynamic SRRS (external filter), see also the subsection "Filtering Function".

Not every filter can be implemented in both possible locations; it depends on the filter's requirements. Time constraints can easily be processed in the car's system as they only require an exactly working clock. It would make no sense to move such a filter function into the sign as dynamic road signs are a lot more expensive. Filters that require information about the vehicle such as type, weight, or other kinds of specific measurements can only be implemented as internal filter, as opposed to weather condition related filter functions: Although it would theoretically be possible to build the necessary sensor into the car, it is more reliable to have them attached to the sign; also to ensure that every driver receives the exact same information.

The benefits of a filter – may it be internal or external – are:

1. Reduction of the number of actually displayed traffic signs
2. Abolishment of add on signs setting up condition rules
3. Exclusion from misunderstanding concerning the application of the conditions

The former two points result in a decrease of cognitive effort for the driver to perceive and process the signs and their prerequisite conditions. So she can keep her concentration on the actual traffic situation which can save lives and thus increases safety. The last point means that there is no possibility anymore for different interpretations of the conveyed rules by different drivers. For example, it can be hard to determine whether the surface of a road is wet enough that a reduced speed limit applies. Different interpretations could result in accidents. This is avoided by the clear statement of the dynamic sign.

3.3.4 Implementation Issues

Having identified the road signs that will be equipped with RFID tags the next challenge is to decide on the method of installing the physical tags on the roads. The most apparent solution is to attach the RFID tag to the actual pole of a traffic sign but it is necessary to consider the following matters.

As there are highways that consist of four or even more lanes the range of such a RFID tag would have to be adjusted accordingly. It is not guaranteed that passive tags as they are used in this static road sign scenario fulfill the necessary range requirements. Even if they do the RFID tags can be easily blocked if trucks are driving between the car and the road sign. Such a disadvantage is not acceptable. Furthermore, a long transmission range would mean that cars that are driving on the opposite lanes would read road signs that are probably not valid for them, especially when road signs are considered that are installed directly in between of two driving directions as it is common on highways or road signs within cities where the density of signs is very high.

An imaginable way out would be to block tags on the back side using metal plates or similar appropriate objects. This solution would only work outside of urban areas if at all because surfaces of buildings would reflect the radio waves making the blocking objects useless.

Therefore, only a per-lane installation of RFID tags is suitable, meaning to have multiple tags for one single road sign if there is more than one lane in a driving direction. The tag is mounted into the street surface by drilling a hole, inserting the tag and finally sealing the hole using an appropriate material that is capable of letting radio waves pass through such as commonly used asphalt or concrete. It has to be ensured that the reading range is limited to the width of one lane so that cars driving on a different lane cannot read tags that are not meant for them. Furthermore, with this architecture it becomes possible to have different signs on different lanes which is especially useful if one thinks of arrows directly placed on the streets. The readers are going to be installed underneath the car in order to ensure a high reading quality and to limit the reading to one lane only. Fig. 3 illustrates an example road setup with installed RFID tags. There are two tags per road sign installed on the street. One can see that cars cannot read tags that are not on the same lane. A road sign is only recognized by the system if the order ("1", then

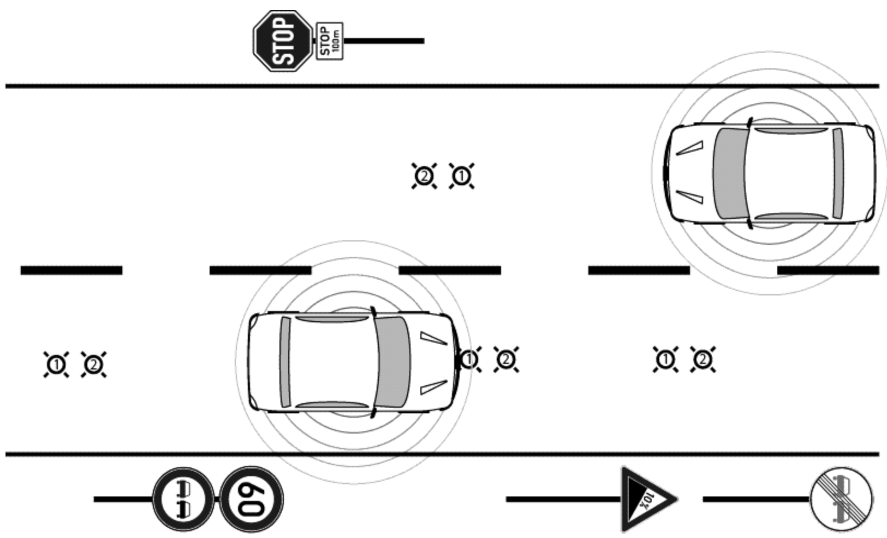

Fig. 3. Installation principle

Source: Own illustration

"2") is correct. Therefore, the right car would ignore for example the speed limit of 60 kilometers per hour and the passing prohibition installed in one location if it would drive on the opposite lane.

If construction areas are taken into consideration, drilling a hole in the road is not appropriate as the according road signs have to be removed when the constructions are finished. A different procedure is worthwhile: The tags are built into markers that are commonly used to reroute lanes. Furthermore, this solution simplifies the process from the view of the construction workers. They know exactly where road signs have been installed as they can see the physical objects, and it becomes easier to move construction areas.

Another circumstance has to be thought of: What if a car has for some reason to drive on the opposite lane because it is passing or avoiding a barricade? It could happen that it reads a road sign that it is not intended to be read and presents as a result misleading information to the driver. A possible solution would be to store additional information about the direction of the sign which could – in combination with the car's direction – be interpreted, but such a system would be very complex and error-prone in the setup process as well as in the technical processing. It is definitely better to keep a system as simple as possible.

Thus, an installation of two tags per road sign is more favorable. Both of the tags are mounted relatively close together, representing one single road sign. One of the tags holds the information that it represents the first element of a series of two, the second tag accordingly. Only if both tags are read by the car in the correct order the according road sign is recognized; the information is ignored otherwise.

The position of the RFID tags in relation to the road sign has to be considered carefully as well. Should the tags be installed in front of, at the same position as or maybe even behind the road sign? The answer clearly depends on the type of sign. In general the best practice is to install the RFID tags parallel to the road sign. If a prior annunciation is desired a tag equipped with an add on sign that holds data about the distance to the actual tag can be installed in advance. For some road signs it may even be suitable to install the according tags behind. If a no entry sign standing at an intersection is considered, a tag parallel tag installation

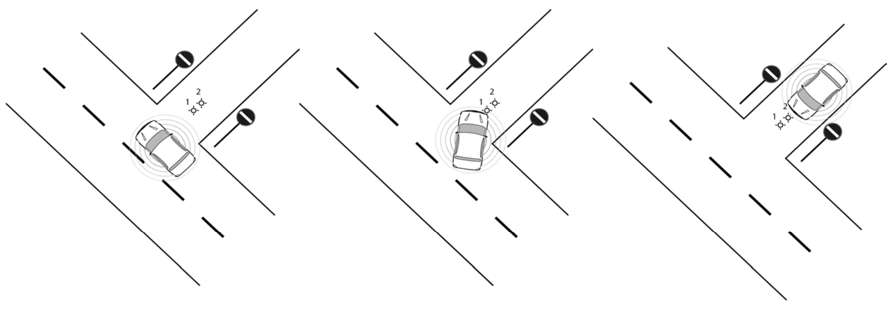

Fig. 4. Example junction

Source: Own illustration

would possibly mean that cars driving on the main road could also read the information. Therefore, the best position would be shortly behind the actual road sign which is still sufficient to alert the driver in case of accidentally entering a prohibited traffic area.

Fig. 4 shows a junction with a no entry sign that is equipped with RFID tags behind the actual road sign. As can be seen, the sign is only going to be displayed if a car is entering the street in the wrong direction. A car passing by will not recognize the tags as they are positioned out of the car's reading range (left illustration). If a car enters the one way street it reads the two tags in the correct order and thus a warning can be displayed to the driver (middle illustration). A car driving the one way street in the right direction reads the tags but in the wrong order: No sign is displayed (right illustration).

3.3.5 Data Representation

As there is a predefined quantity of possible road signs that is not likely to change very much in the future it is expedient to represent each road sign type by a unique ID. If there are minor changes or additions they can easily be integrated into the system by a simple software update. Only the ID is stored on the tag; all additional data is held in a database within the car's RFID system.

Furthermore, the RFID tag has to have to store the IDs of add on signs in addition that are hereby bound to the road sign they refer to. An area to store variant data in addition to the ID is needed as well as a lot of road signs require additional information, especially add on signs. It is advisable to develop a suitable data format to save the information in a structured way. Different types of data are possible: Distances, speeds, names of towns, etc.

3.3.6 User Interface

The user interface is the only part of the system that the user actually can see and interact with. Therefore, an elaborate design is indispensable. As safety relevant information is shown, the screen has to be placed in the driver's field of vision. This can be accomplished either by integrating a display into the console in front of the driver or by using a head-up display (HUD) that augments the reality.

In any case, the display has to be capable of showing different road signs at the same time as shown in Fig. 5. It is preferable to have different areas for showing different types of signs simultaneously in a way that a single sign type is always displayed at the same position, thus minimizing the driver's cognitive effort. One area emphasizes the most recent or most important sign by displaying it bigger than the other signs. Another significant feature is the indication of the distance between car and sign if add on signs are used. It is also possible to integrate the speed indicator in the system by directly showing a potential speed limit. Clear error messages have to be displayed if signs cannot be recognized to point out that a sign exists but was not correctly recognized by the system.

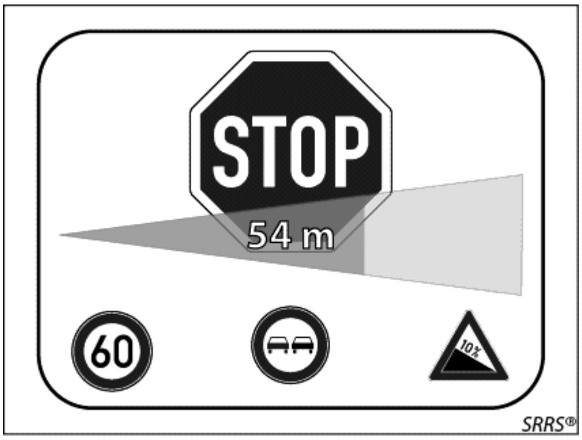

Fig. 5. Graphical user interface
Source: Own illustration

In addition to the visual presentation of information, optional audio messages can be enabled as well at which it can be configured which types of signs shall be read out loud.

3.4 Dynamic Smart RFID Road Signs

3.4.1 The Need for Dynamic SRRS

As seen above most of the existing road signs can be augmented by Static SRRS ("augmented" in these paragraphs means supplied with an according RFID tag). However, "most signs" are not enough and it would be a critical mistake to stop at this stage of thoughts.

For example traffic management measures that include changing speed limits can not be realized by Static SRRS. However, as all conventional signs of this type will be augmented by RFID tags a certain adoption of the drivers has to be reckoned. This means that a driver gets used to having the current speed limitation on the display within her car. Practically speaking it can not be expected from drivers to continuously scan for speed limitations derived from non-augmented signs. Thus, with only having Static SRRS, the existence of such traffic management measures alone would damage the 100% reliability of the whole system and therefore would make it obsolete. In fact it will be seen in the analysis of other concepts (subsection 4.3) that similar concepts fail just because such measures were not taken into account.

The solution to this problem is the introduction of the Dynamic SRRS. Its principle will be explained first. Then its fields of application will be discussed, including a comprehensive analysis of traffic management measures in order to show that no critical issues can be found that damage the concept of SRRS.

3.4.2 General Principle

As the title suggests the content of Dynamic SRRS can be changed by remote instructions. Their range of possible values is basically the same as that of the static signs. This means that all signs according to the StVO can be encoded. However, it is possible to accumulate multiple signs on one tag due to cost reduction reasons as dynamic signs have to contain active components (which also need power supply) and thus are more expensive than static signs.

The RFID-reader attached to the vehicles can not distinguish a static sign from a dynamic one unless explicit meta information on the tag is provided.

On the one hand Dynamic SRRS are to be applied where ever regulations for a road can be easily changed by public authorities. This for example would be the case with traffic management systems. On the other hand especially signs of warning ("Gefahrenzeichen") are often dependent from environmental conditions like wet road surfaces. The compliance of these conditions could be determined by either manual input again by public authorities or their authorized representatives or by local sensors that apply changes to the tags automatically.

So benefits derived from Dynamic SRRS come either from the support of traffic management systems or from their ability to act as an intelligent filter to reduce the amount of signs for the individual driver.

3.4.3 Fields of Application

Traffic Management Support

Traffic management systems provide benefits for public authorities as well as drivers in the form of maximizing capacities of existing roads, minimizing travel time and reducing accidents.

Existing systems are based upon dynamic modification of regulations and providing additional information, many of them conveyed by traffic signs along the road.

In order to provide an evaluation of necessities and benefits and to put the application into context the possibilities and limitations of Dynamic SRRS need further examination according to different types of traffic management.

Prognos and Keller (2001, p. 51) distinguish eight categories of traffic management measures on behalf of the German federal ministry of transport. Another paper by the German federal ministry of transport additionally mentions three more measures (BMVBW 2003a, pp. 3 – 4). These categories will now be shortly introduced and sometimes summarized with respect to a possible support by Dynamic SRRS.

Road Traffic Information and Dynamic Destination Guidance

"Road traffic information" refers to the supply of information about traffic states which can lead to optimized route planning by the individual driver (Prognos and Keller 2001, p. 57). This information could be transmitted by either conventional radio broadcast or by means of the Traffic Message Channel (TMC) which provides digital data about traffic disturbances via radio frequency signals covering wide areas (BMVBW 2004, p. 56). As messages of this kind are not tied locally but rather are of importance some distance ahead, and as this results in high data volume SRRS are not suitable for providing this kind information.

"Dynamic destination guidance" refers to dynamic route generation which is performed automatically by navigation systems within the car (Prognos and Keller 2001, p. 59). Basically the same information like for "Road traffic information" systems is needed, however in machine readable format in any case. As this again includes information about traffic events within a great radius it will result in data volumes RFID technology is not capable of transmitting in such short periods of time the introduced system allows.

Traffic Adaptive Lights

"Traffic adaptive lights operation" refers to the ability of traffic lights to change according to an automated analysis of the traffic conditions around the corresponding crossing or sometimes even wider areas of the traffic net (pp. 62 – 63). This is applied mostly at crossings that carry heavy loads of traffic within cities.

A study performed for a crossing near the city of Karlsruhe suggests an average decrease of travel time around the crossing of about 8% (p. 62). At first glance this is a benefit for the users but on second glance this could also have impacts from the point of view of national economics. The authors point out that the decrease of travel time varies according to local differences between crossings.

SRRS seem not capable of improving the impact of traffic adaptive lights as such. However, they can add to the convenience of the driver by means that could be implemented with conventional traffic lights, too (see the subsection "Support of Conventional Dynamic Signs").

"Adaptive lights operation giving priority to public transportation" also refers to "intelligent" traffic lights; however, the underlying algorithms take into account special needs of public transportation vehicles (e. g. buses) that result from their effect of self-increasing delays. As mentioned above the algorithms do not have to be taken into account when discussing the application of SRRS, so the same benefits as for conventional traffic lights discussed in the former paragraph apply here as well.

Dynamic Parking Information and Guidance

Dynamic parking information and guidance systems basically boil down to providing information about the current amount of free parking lots in public parking garages nearby. As an example for an existing system see the city of Zurich (Dienstabteilung Verkehr Zürich 2005). Signs throughout the city show the names and directions of parking garages nearby (statically) and the number of free parking lots for every garage (dynamically). An empiric study for the city of Aachen showed a reduction of the traffic caused by the search for free parking lots by 14%. This is a benefit for the drivers as well as the public authorities. The measure also increased the average utilization of the garages from 62% to 82%. This increases the income for the operators of the garages and therefore decreases the costs for the users.

As seen later on Dynamic SRRS implementing measures like this would be referred to as "Advanced SRRS".

Track Influence on Arterial Roads

"Track influence on arterial roads" refers to the change of regulations concerning distinct parts of highway tracks with high traffic load (BMVBW 2003a, pp. 2 – 3). These regulations are derived from certain conditions of environment and traffic and set up manually by the local authorities that are responsible for the concerning road. Typically they are shown on LED displays mounted on artificial bridges above the road.

These displays have the function of harmonizing the traffic flow by showing conventional signs like (Prognos and Keller 2001, p. 68, and BMVBW 2003a, p. 3):

1. speed limits
2. warnings (traffic queues ahead, road works, bad sight)
3. no overtaking

The impacts of such systems on roads with high traffic load are according to Prognos/Keller (2001, p. 69):

1. increase of capacity by up to 20%
2. decrease of accidents by 30%
3. increase of average vehicle speed by 10%

These figures reveal high potential in this technology, especially in future scenarios with increased traffic loads. Thus a support by SRRS is essential, also due to the effect of adoption to SRRS of drivers mentioned above.

The benefits of SRRS in particular are basically the same as with static signs, which means increased ease of perception and recall and therefore leads to increased safety for the drivers (see section 2).

In the wake of this advantage there also comes a cost saving impact for public authorities: As the recall of current traffic signs is supported by the individual vehicle there is less need to set up multiple display systems that have the function to recall the currently valid signs for the drivers. Assuming that the harmonization of traffic flow does not require high geographic resolution and therefore local accuracy of dynamic traffic signs does not need to be high either, one display system after every entry point of a highway basically would be enough. This could save part of the costs of setting up these systems which cross highways like bridges and therefore cost 100,000 Euro to 300,000 Euro on average per kilometer and sometimes even up to 500,000 Euro (BMVBW 2003a, p. 3).

Net Influence on Arterial Roads

Net influence on arterial roads refers to direction signs that can be changed remotely in order to suggest alternative routes to certain destinations that avoid overloaded roads. Currently these signs are implemented by multiple so called prisms showing the names of different destinations on different sides (BMVBW 2003a, p. 3). These prisms are built into a direction sign that only shows arrows according to the ways of the tracks. The denomination of these arrows can be achieved dynamically by letting the prisms rotate until they show the desired destination.

So basically it boils down to the augmentation of direction signs like the signs number 438 to 449 in the StVO (§ 42). However, as described in the context of Static SRRS (see subsection 3.3.2) this kind of information is not appropriate for transmission via SRRS. Especially if considering their decreasing importance due to the increase of individual route computing by navigation systems, also taking into account current road overloads (see dynamic destination guidance).

Node Influence Systems

Node influence systems are mounted above roads consisting of multiple lanes, very much like track influence systems (BMVBW 2003a, p. 3). However, their possible shown signs are (StVO § 37, number (3)):

1. a diagonal red cross, meaning the lane beneath is not cleared for usage
2. a green arrow pointing downwards, meaning this lane is cleared for usage
3. a yellow blinking arrow pointing diagonally downwards, meaning the lane has to be changed following the shown direction.

Systems like this are used in order to disable the right lane temporarily where big traffic streams are likely to join into the highway coming from a drive-up on the right. They are also sometimes used in tunnels in order to disable one lane which is temporarily used for maintenance works (BMVBW 2003a, p. 3).

RFID support in this area seems to make sense, however the benefits derived are limited to the basic benefits of static signs. A cost saving factor for public authorities is not likely here as one tag only provides information for its specific lane. Information concerning all available lanes is useless as long as the vehicles can't match their position to a specific lane automatically. That means the recall of signs can not be provided by the vehicle as drivers are likely to change lanes. Thus the recall task has to be fulfilled by exterior signs repeated in certain distances.

But as the recall functionality is excluded from the RFID benefits in this specific case there only remains the benefit of ease of reception. Assuming that light signals like this can be read even during the worst weather conditions it seems to be sufficient to provide only a static tag that makes the driver aware of an existing node influence system not supported by SRRS.

Temporary Emergency Lane Clearance

To temporarily allow the usage of the emergency lane on highways is possible in Germany since a modification of the StVO in 2002 (BMVBW 2003a, p. 4). The current regulation currently is conveyed by dynamic signs numbered 223.1 to 223.3 of the StVO (§ 41). This system has proven to provide high benefits according to safety and traffic flow if certain conditions apply to the traffic situation of this area. In addition a dynamic assignment of emergency road clearance has proven to be superior to a static clearance of the emergency lane (BMVBW 2003a, p. 4).

So this calls for the use of Dynamic SRRS in order to apply all basic benefits for the driver. In addition here a cost saving effect can also be assumed. In contrast to node influence systems the regulation conveyed is the same for all lanes although or just because it aims exclusively on the emergency lane. That means that with the spread of RFID Readers in vehicles exterior recall of the current regulation becomes less important and therefore fewer signs are needed.

Conclusion

Additionally mentioned measures like "Traffic jam management on freeways" (Prognos/Keller 2001, p. 72) and "Traffic inflow regulation" (BMVBW 2003a, p. 4) do not have any special consequences according to SRRS.

Thus it can bee seen that the concept of SRRS is sufficient to support all traffic management systems. This means that there will not be any situations concerning regulation systems on roads where the SRRS system can not be implemented or only be implemented insufficiently.

However, beyond the proven implementability there are also some distinct advantages concerning especially traffic management.

The major advantage the SRRS system offers in this area is the reduction of human error. A lot of processes that now involve a fast decision made by a traffic controller could also be automated. For example if there is sudden rain tagged digital signs could immediately react whereas nowadays a traffic controller who sees the weather change maybe through a camera has to react and make adjustment manually. These manual adjustments can cost valuable time during which a crowded road in a sudden downpour can be very dangerous. With the automation in place traffic controllers will have to take fewer responsibilities and processes in traffic control will become more easy. Instead of deciding from time to time procedures will evolve that allow ever consistent decisions to be made automatically.

It is important to mention, however, that this kind of support is not aimed towards an extension of existing traffic management measures as long as they can not be automated. This means it will not create new processes but the system will completely rely on existing processes which, however, may be simplified in the wake of an SRRS introduction.

Filtering Function

Another aspect where Dynamic SRRS can provide benefit for the drivers and indirectly also for public authorities is their use as an exterior filter. That means traffic regulations that are tied to certain external conditions will be conveyed only if the given conditions apply.

However, in contrast to some aspects of traffic management support there is no absolute need to augment suitable warning signs by Dynamic SRRS. They still can be equipped solely with static tags which, however, would leave the cognitive processing to the drivers. The decision about the applied technology is in the hand of the road operator.

A description of signs suited for filtering by Dynamic SRRS follows.

1. The sign “Traffic queues likely ahead” (#124 according to StVO § 40) provides a general warning that this track is likely to be affected by traffic jams. It could be replaced by dynamic signs that only occur when an actual jam is fact. This could be combined with the set up of a traffic management system including expensive display systems. However, as this sign is a warning sign and thus is not essential for traffic flow it could be provided solely by RFID where the sign would have more the character of providing information than giving orders. In this case it seems sufficient if only SRRS participating drivers get the information and by their reaction influence also other drivers, for example according to their speed. This would save the costs of setting up physical displays while still having an advanced structure of warning.
2. The sign “Traffic signals” (#131) warns of lights where they would not be expected. These, however, sometimes operate only during certain hours of the day (e. g. while road works actually take place during day). So a dynamic sign could be tied to the actual operation of the lights, either by electric signal or by a given time code processed by the vehicle’s system.
3. The signs “Risk of ice” (#113), “Slippery road” (#114), “Side winds” (#117) and “No vehicles during smog” (#270) could be tied to the actual weather conditions which could be provided by the SWIS system (see the subsection “Tag Connection”). This also applies for the sign “maximum speed” (#274) in combination with the add on sign “when wet”.

Support of Conventional Dynamic Signs

There have been official road signs that periodically change for decades before traffic management and telematics were introduced. Their possible support by Dynamic SRRS of course has to be evaluated as well.

Traffic Lights

As traffic lights are relevant signs according to the StVO (§ 37) and as implementation is possible from a technical point of view it would be an option to supply all traffic lights with Dynamic SRRS. This applies for adaptive lights as well as traffic lights in general. The difference is only that the electric signal triggering lights changes comes from different sources: One from a timer and the other from more or less complex algorithms. As this technology already exists and is not interfering with the display components the benefits for the driver as well public authorities are the same.

Basically the benefits would be:

1. Enabling audio messages about changes of the lights within the car. This would enable the driver to put his concentration somewhere else than the traffic lights while they show red. She could for example change the radio program, prepare a phone call by dialing or browse her navigation system.
2. Enabling audiovisual warnings when passing red lights. As 23% of accidents in Germany with more than one involved party include the disregard of the right of way this could have an impact especially when considering the reduced ability to see of elderly people (BMVBW 2003b, p. 31).

Thus an implementing company has to deliberate about whether it supplies traffic lights with Dynamic SRRS on their own expense. Due to its costs the implementation will probably not happen until a late stage when the adoption has advanced throughout nearly all vehicles.

Barriers

Barriers of level crossings have a similar meaning as traffic lights, thus the same considerations apply here. However, as barriers are physical objects it does not seem to be necessary to provide an additional audiovisual warning when passing a closed barrier. So the benefits of SRRS here are less than with traffic lights and therefore they will not be implemented sine die. However, signs that warn of the approach to a barrier are not affected by this, so they can be regarded as implemented and give the driver a clue to be prepared.

3.4.4 Technical Considerations

Due to the fact that different applications shall be run on the same basic system some technical considerations are necessary.

RFID Reader and Tags

Due to cost saving reasons the RFID reader attached to the vehicles should be the same as for Static SRRS.

Thus the RFID tags have to operate in the same frequency range. In fact they also need the same read range and should therefore only respond in a passive way. This is in order to allow the precise determination of their position when they are read out. A read range of several meters would blur the automatic position determination which can be a problem at certain geographic locations. As a consequence Dynamic SRRS containing traffic signs need to be attached to the road like Static SRRS.

However, the tags need to be reprogrammed from time to time and thus need an active component capable of this. This has important consequences: The programming device needs power supply and connection to a digital data source. Therefore not only the tags themselves become more expensive but also their installation and the set up of the according infrastructure.

To keep the costs as low as possible one Dynamic SRRS has to be able to simulate multiple traffic signs by serial data transmission of the according IDs.

Tag Connection

The difficulty to provide the active component of a tag with electrical power depends on its geographical position. If a Dynamic SRRS is used in combination with existing traffic management systems the existing power supply can be used. Also, there are already about 4,000 sensors along German freeways collecting traffic data, which are run solely by solar power panels (DDG 2005; Roth 2001, p. 6). So this source of electricity always seems to be an option for Dynamic SRRS, except for tunnels, which, however, are equipped with an electricity network anyway.

The data for the Dynamic SRRS can either come from local sensors or remote control centers. For Dynamic SRRS that depend on weather conditions and the like local sensors may be used. In context of telematics there is already a wide range of sensors in use, which for example can detect temperature, wind speed, fog, frost and glaze (Roth 2001, p. 6). Many sensors of this kind can be found along German freeways and belong to a system called SWIS ("Straßenzustands- und Wetterinformationssystem"). In context of this system public authorities like the German road administration offices and the German meteorological service (DWD) cooperate in order to provide precise information and prediction of dangerous road conditions derived from adverse weather (Landesbetrieb Straßenbau und Verkehr Schleswig-Holstein 2004). The data of this network could be used as well for Dynamic SRRS. The data for telematics applications always comes from the according regulation centers (BMVBW 2003a, p. 5).

The transmission of data in order to run remote telematics displays often takes place by using wires along the freeway (BMVBW 2003a, p. 5) or is achieved by using existing mobile networks like GSM (Roth 2001, p. 6). This gives sufficient freedom for the placement of any Dynamic SRRS. Where telematics displays are wired, this information carrier can be used; otherwise, mobile networks come into play.

3.5 Advanced Smart RFID Road Signs

3.5.1 Introduction

The advanced functions of advanced RFID signs offer a great alternative for car drivers and Service providers along roads. For example companies could use the additive texts to be advertisement for them. The possibility to additionally provide internet hyperlinks not only allows even more multimedia information for customers, but also the interaction between driver/co-driver and companies. Because of the safety aspect the interaction is only allowed for co-driver. The driver should only participate in the interaction, if the car is not active in traffic.

The following describes a couple of example scenarios for using advanced RFID signs.

Scenario One: Restaurant

Main focus: Restaurants send advertisement through active tags to the driver at e. g. diner time and use RFID signs as digital alternative instead of traditional signs.

Around diner time on the highway, if the driver and/or co-driver are hungry they may be looking for restaurants. If they do not know the environment very well, it is difficult to find a suitable restaurant and it is also dangerous if the driver gets distracted by searching. The SRRS offers restaurants the possibility to save advertisements on advanced RFID signs, through active RFID tags the information is sent to the car, in order for the driver or co-driver to get range of products at the right time. Also in a big city it is normal that there are traffic jams at after work time. The driver has to wait anyway, so this is a good time to send advertising information from locations like restaurants or bars along the way to the driver. The driver would read the information when passing the location and can find out more about it if he wants to. SRRS allows the linking to the Web page of the location. The Web page could be dynamic, that means a booking system is included and the driver could book a service online for example to reserve a table for dinner in a restaurant which may contributes to her convenience or simply saves time.

Scenario Two: Gas Station and Repair Work Shops

Main focus: Intelligent cars' IT systems know the current state of the car, depending on these state information, on-board computer can get information from the RFID signs automatically and can combine it and pass it on to the driver.

Cars in the future have advanced automatic observation systems, in order to know the state of a car in real time, for example if the windscreen wipers on the car are broken, this observation system realizes it. The car internal IT system then works together with the RFID reader to check the repair work shops along the way for the required service. And then it shows the driver that the windscreen wiper on the car is broken, in 1,000 meters there is repair work and ask if the driver wants to repair the wiper in that work shop. One more interesting example is actions depending on gas state. The in-car IT system knows that the gas in car is running low, it checks gas stations close-by with help of the RFID sign system. The driver can get proposals for refueling. At the same time he gets detailed information on the next gas station, such as gas pricing, special supply or payback program.

Scenarios Three: Tourist Features and Hotels

Main focus: The interaction between drivers/co-drivers and hotels, tourist companies.

The tourist company should present its special features for tourists at all times. Now web technology offers the alternative to do that by internet. The information is thereby always reachable, but the user can not see these tourist features with her own eyes. On the other hand if the user drives to this tourist feature, he can see it with his own eyes, but he can not get additive information (like history or traffic information) quickly and easily. Advanced RFID signs offer not only this additional information, but also the possibility of interaction with providers (hotels, tourist companies and so on). For example: The driver and his co-driver are riding along the highway. The co-driver is watching out of window of car and sees a beautiful palace. The co-driver knows nothing about it and neither does the driver. The co driver looks at the RFID reader display and selects all touristy information. In a second the co -driver knows more about the history about this palace, it is so interesting for him that they decide to visit this palace at once. In the next step they can select all hotel information on the screen and through provided links they can book rooms close to the palace.

3.5.2 Necessary Process Changes

Roadside businesses are being given new excellent, very exactly aimed advertising opportunities. The interaction with a passing driver does not only allow aimed advertising but also creates a greater service need. Roadside businesses who want to take the chance to actually capture a driver when he is in need for a certain service have to develop to be able to offer this service at any given time. The most attractive offers for the driver are certainly velocity and convenience. He wants to be able to decide how long he wants to break, not the queue at the food counter. A driver who is being hit by an advertisement for e. g. a rest stop when he is hungry and already orders his food from the road expects to find it ready and hot when he gets in. The roadside businesses need to change their processes to make that possible maybe even separate kitchens will be necessary to cater for the different needs of regular stopping guests and guests passing through who pre-ordered.

3.5.3 Filter Functions

A filter function is eminently important for advanced RFID sign scenarios. Because the driver must not be obstructed by advertisements (see subsection 4.1.3). There are two types of filtering for signs: one type of them takes place in the car. The other type takes place outside on the road signs and can be managed by e. g. advertising companies.

On the one hand advertising companies want to reach their customers' needs as effective as possible. They could use time constraints to change the sign content. For example: restaurants may change their RFID content between breakfast, lunch and dinner depending on the time of the day. Some companies have to exchange their sign content depending on the available offers. For example: hotels should update their free room information dynamically. If a hotel has no free room, the RFID signs need not be activated. The same is true for parking garages.

On the other hand the RFID system in the car should have a couple of filtering layers. First the RFID reader could demand only information from sign important in the current situation. For example: the reader could demand only parking information. If the reader gets the information, it has to filter it again, in order to inhibit wrong information and redundant information. The reader then forwards the result to the suitable application. The application should filter this information depending on its configuration, which can be changed by the user (the driver/codiver). For example if the user wants to participate in interaction and get as much information as possible, applications could connect to the internet and use linking information received from tags to get the website, so that multimedia information such as company logos and interaction links could be displayed. If the user wants to get only simplest information, like how many park spots are available, the application can filter out all links and display only text information from the tag.

3.5.4 Implementation Issues

Advanced RFID signs can be used by many different companies at different times. Therefore it is very important that the sign can be repaired, replaced and updated easily. To be installed in the road is not a reasonable solution for that. Therefore the advanced RFID sign should be installed next to the road. Because the reader is installed at the bottom of car, altitude of installation of the advanced sign should be very low, that means it should be close by of the ground.

Active RFID tags are necessary for advanced RFID, because active RFID has much larger range than passive tag so that advertisement's companies can reach customer early and customer stays in operating range for a long time in order to possibly receive more data. Active tags need power support. The combination of solar energy and power supply line are suggested power supplies for SRRS. Batteries are not an option because even though long life cycles are possible exchanging batteries of thousands of signs along e. g. a highway is not an option. In the cities power support of SRRS can be combined with power supply lines. Along highways SRRS uses solar energy. Along a highway there is sufficient space to install solar panels and a set of assets of solar energy is able to support several advanced RFID tags.

In order to reduce costs advanced RFID boxes could be built, so that a couple of advanced RFID tags could be installed in these RFID boxes and a RFID box has a power supply from asset of solar energy or power supply line. The advantage of the box is that on one hand a couple of signs can share one power supply thereby save installation cost and simplify installation of signs, one the other hand it simplifies servicing of signs.

The installation of this system is complex. Firstly the power supply has to be installed. The asset of solar energy should be able to support a couple of RFID boxes, and the energy should be able to be saved in batteries in order to ensure functionality at night and bad weather conditions like snow and rain. Secondly the RFID boxes have to be set up. Therefore power supply is available and the box should be "plug and play" so that the advanced RFID signs can be installed easily. That means the worker just needs to know which box with which sign, and put the sign into the box and it works.

There is still one question open: How can one define the position of the RFID boxes? The answer clearly depends on geographical allocation of the companies. In general the boxes should be set up close to a bunch of companies. But it could be changed depending on the different needs, for example if a restaurant wants to invest into their own RFID box that will be possible as well.

Depending on the filter functions microprocessors on the tags are necessary. This microprocessor can filter and change information on the tags. There is two ways to filter and change information: a clock/calendar can be implemented in the microprocessor so that the information on the tag can be changed depending on the time of day or day of week. This is very suitable for restaurants, they need not to change numbers of availability on a daily basis, and therefore the logic clock does all updates and changes automatically. Of course this way the possibilities to change information are limited. For more detailed changes another set up is necessary, information can be changed by the electro magnetic wave. That means electro magnetic wave can manage the microprocessor on the tags, the microprocessor gets a command and can change or filter the information on the tags. This way has the advantage that all the s can be changed centrally. As this feature could be misused a security problem arises. Therefore the security feature on the microprocessor is very important, so that only identified user can change the information.

Active tags have a larger operating range. It is possible to read the information from the other side of the road; in a few cases the information is unusable. In order to fix this problem, the signs could have two senders: one of them is on the left side of tag; other is on the right side of the tag. The left sender transmits a first signal to the cars and then the right sender gives the signal. The reader is expecting the whole information, only if the reader gets the signals in right way the information will be passed on. This two signal event costs only a couple of milliseconds; because the two signal need to be only 1bit long. Of course this method should be not used, if the information is welcome for both sides.

The cost of installation of advanced signs will be financed by the advertising companies. The power supply should be built up by a company centrally, and the RFID box could be built up centrally or decentrally. The advertising companies should pay for SRRS package including the power supply, license and tags.

3.5.5 Data Representation

There is not a predefined quantity of possible advertising signs as they change all the time depending on changing providers, the time of day, current availability of the day. The content with only one ID will not sufficient. Structured information is essential, because only if structured the information can be handled flexibly by the reader and further applications.

Because of the limited memory on the tags e. g. company logos can not be saved on the tag. And the interaction like food booking is also not possible to be done by RFID. Therefore an internet connection in the car is necessary for the linking function. This linking function means that if the reader gets linking information, it can connect with the internet and with this linking information the suitable Web page or image will be downloaded and displayed.

The most important question is, which information should be saved on the tag itself. In order to answer this question, taking a close look at the user is useful. First the reader gets the whole information and e. g. a logo should be displayed, if the internet connecting works and the logo's location is correct. If it does not work a text should be displayed that represents the information. Therefore two types of data are needed: **logo location** and **display text**. The short information about availability within an advertising road side business is useful for the customer to know what kinds of product are provided by that company. The field **supply** is needed to save the availability information of company. The application needs to know the term of validity from this particular information. As SRRS is a very location dependent system, the sign is out of the area of validity after a given distance. The information shall be deleted after that distance. The field **validity** is needed to save term of validity on the tag. If the internet connecting exists, getting more information online is possible. The field **linking** is needed to locate the Web page that gives further information about the company. A nice feature for the driver not having to look at the display all the time is voice messages. In the field **sound** this voice message could be saved or the link to an online sound file. The online sound has the advantages that the sound message can be combined with music as background or the sound could be changed depending on availability. In these application scenarios of advanced RFID signs the interaction between user and companies are described. These interactions are only possible if and in car internet connection exists. Therefore in the field **interaction** a link to an interaction Web page is saved. In the field **address** a map is saved, so that the user can find the location easily. The categories of the different businesses are also important for the application to know how to deal with the data. The field **category** is needed to save different categories: **hotel**, **restaurant**, **tourist information**, **gas/repair station**, **parking** and many more. These categories are also fields on the tags. They have their own substructure: e. g. hotel has subfields for free rooms: to show how many free rooms they have and what kinds of rooms these are. The **free room** field again has a subfield room price. Restaurant has subfields as well: **breakfast**, **lunch**, **dinner** and **specialties**. Each of them has subfields for prices and so on. A company that is not part of any of the above categories can save its information as free text. This substructure of these fields enables the application that is connected with reader, to point out the information individually depending on context of information. For example in the case of a hotel, the information can be displayed as follows: We have a free room: one large room for two persons, 5 still available. Price: 50 Euro per night. In the case of a gas station, the information can be displayed like this: We have gas for you. Costs: 1.3 Euro/liter. Furthermore we a cleaning service offer today, just for you: 5 Euro.

Following figure shows example of the information in a structured way.

```xml
<displaytext>littel chinese great food</displaytext>
<logolocation>http://www.logologologo.com/logo1.gif</logolocation>
<address>muster streete 76</address>
<supply></supply>
<interaction> http://bestellenichwas.de/bookingforcar.jsp</interaction>
<validity>1500meters</validity>
<linking> httP://www.kleine-chinese.de/carview.do</linking>
<sound> http://www.</sound>
<category>restaurant</category>
<restaurant>
  <breakfast>
    <name> milk</name>
    <price>2 Euro</price>
  </breakfast>
  <lunch>
    <name> big milk</name>
    <price>3 Euro</price>
  </lunch>
  <dinner>
    <name> Hot chicken</name>
    <price>10 Euro</price>
  </dinner>
  <speciality>
    <name> hot large chicken</name>
    <price>20 Euro</price>
  </speciality>
</restaurant>
```


Fig. 6. Example of the information in a structured way

Source: Own illustration

The internet access is no problem for the users in the future. On one hand in the future most new cars have internet access and the user have flat-rate packages. This means that the user does not need to pay additionally for advanced sign information only because it uses the bandwidth of the car. On the other hand if the user does not want to get additional multimedia information and the like from internet, he can cut the internet access, so that just the basic text information (that means displaytext and address) will be displayed.

3.5.6 User Interface

The advanced RFID signs have a different content as static and dynamic RFID signs. Therefore it needs a completely new user interface. An independent screen is necessary. The reason is that on one hand different content should be displayed and on the other hand other function like interaction should be allowed, so that a different design is needed. Of course for safety aspects the traffic information and advertising information shall be displayed separately.

The co-driver or the driver when stopping can see all the information of the signs on this screen. The customer then can use navigation controls to select information. Ok/apply to say “yes” to a request. Internet linking is needed to get more information about the company online. If interaction is clicked, a dynamic Web page should be called for interaction. Category buttons are for selecting category’s contents. Cancel button is for saying “no” to a request and for terminating the internet access.

The following part points out what shall be shown and how to select the information.

The car arrives in the operating range of advanced RFID signs and gets information structured as described before from right side of the road. The information will be filtered, forwarded to the application and then the application displays all the logos at the navigation’s list, if they are accessible on the internet. The first company’s information will be shown on the display. On the left top corner of the display the logo should be shown if logo’s location is accessible on the internet, otherwise plain text should be displayed. On the right side of display the availability information from the field supply on the tag will be shown and the detailed information will be shown depending on time of day or the state of the car. For example if food information is requested after 5 pm the dinner offers with prices should be displayed. The gas stations should display the particular gas needed for the car including price. The location is also displayed. The location information will be changed depending on the validity and the distance traveled in the mean time. On the lower half of the screen the display text should be shown. As the information is read by the application, the period of validity is saved in the application. Depending on this period the company information can be deleted after a given time period.

To select information the user needs move up and down on the menu list and select whatever interests him by his navigation controls. Each selection changes the information on the screen.

The following shows how to select information within one category and start interaction through input and submit functions.

If the user wants only some information, the category buttons can be used. After clicking on a category buttons (such as hotel for hotel information or p for parking information) only the information of the selected category will be shown in the navigation list.

In the categories of content: hotel, parking, restaurant and repair station an interaction menu for reserving and booking is available. To start the interaction the user needs to click the interaction button, if the suitable information is active on screen. The link that is saved in the field interaction is called; the dynamic page can be downloaded and be displayed. The dynamic page should be especially designed for this application. There are only booking links on this page, in order for the user to select the links with his navigation controls. To submit the booking request the OK button should be clicked.

If the sound button is clicked, the active information in the field sound will be read out by the application, or the multimedia sound data could be played by accessing the stored link.

4 Market and Competition

4.1 Legal Framework

4.1.1 Liability

Setting up a high reliability system creates some problematic legal issues. Among the most important are probably the liability claims for incorrectly read or omitted tags. To come up with a solution it is necessary to look at similar problems experienced with conventional traffic signs. There might also occur difficulties reading them, in case they are covered with snow, branches or other vehicles, they are rotated (BGH III ZR 167/68) or even completely destroyed (Köln SS 6/66). In these cases only the signs that can be identified by their form (OLG Oldenburg 1 U 87/67) or otherwise quickly understood with reasonable diligence are still valid. Of course, no one has to dig out snow covered signs. Locals however are expected to know signs and to act accordingly even if they cannot read them. Other drivers are not entitled to speed on either. They are required to be especially attentive and ready to brake after passing a sign they could not read. However, if there are still accidents caused by invalid signs, the public road traffic authorities are liable (OLG Koblenz AZ 12 U 1121/97) (sicherestrassen.de 2005).

So what principles can be derived from these court decisions? First of all, the driver always has to act sensibly and apply common sense. Only if he is unable to understand the situation, the authority that set up the sign becomes responsible. Secondly, as always, there are ways to pass on the blame. If there was a technical problem, the manufacturer of the product is fully liable under product liability law (§ 241/2 BGB until § 280/1 BGB). If the sign or tag was improperly installed, the construction company can be held responsible. Only if there is nobody else to be found, the road traffic authorities have to pay. Therefore if a company takes on the responsibility to tag the road signs, there should be hardly any cases, where they are liable.

4.1.2 Outsourcing of Public Responsibilities

Another difficulty might be the transfer of a public function to a private company. Even if entrepreneurs are providing a public “good”, they should be acting on their own risk and costs. The incentive to do so is the opportunity to financially profit from its later public use. Such contracts have specific clauses concerning on the one hand the quality of the products, control of prices and the continuity of the service. On the other hand they cover competition privileges enforced by public authorization and exclusive licenses.

In connection with sewage treatment plants, that already work with such contracts, and roads, that are financed with private funds under the “Fernstraßenbauprivatfinanzierungsgesetz”, the term “Betreibermodell” was established. The expression is of particular importance for private road financing, where it can be distinguished from the “Konzessionsmodell”. There are legal as well as economic differences: Using a “Betreibermodell” the private investor refinances by directly collecting fees from the users. Such a model requires legal provisions, to allow the public authority to lend its right to collect dues to a private entity. At all times, the project remains sole property of the private constructor, while the public authority takes a back seat as a kind of inspector. With a “Konzessionsmodell” the investor only receives a temporary right to use the public facility, which is after the construction immediately for remunerations transferred back to the state. The public authority collects fees from the end user and compensates the private investor only internally, who never really faces his customers. This way the realization of major projects speed up, but the associated costs and incomes are not permanently outsourced from the public domain. Thus if there are major risks related to user acceptance and therefore the revenues of a project, the “Betreibermodell” is particularly suitable (Konzelmann 2005).

4.1.3 Traffic Interference

The third issue that needs to be addressed is the distraction of the driver by the additional information presented. That is a problem inherent in any in-vehicle information and communication system and therefore the European Commission published official guidelines (European Commission 2000) that need to be followed regarding the human machine interface. First of all these guidelines give an overall design principle: “The system should be designed in such a way so that the allocation of driver attention to the system displays or controls remain compatible with the attentional demand of the driving situation.” (European Commission 2000) Furthermore there are two principles, regarding the installation of such a system. No part of the system should obstruct the driver’s view, but nevertheless visual displays should be positioned as close as practicable to the driver’s normal line of sight. Other important aspects are the information presentation principles. The driver should be able assimilate visually displayed information with a few glances which are brief enough not to adversely affect driving. The fourth important problem is the interaction with displays and controls. The driver should be able to control the pace of interaction with the system. Additionally systems providing non-safety-related dynamic visual information should be capable of being switched into a mode where that information is not provided to the driver. Finally there are some basic system behavior principles; visual information not related to driving that is likely to distract the driver significantly (e. g. TV, video and automatically scrolling images and text) should be disabled or should only be presented in such a way that the driver cannot see it while the vehicle is in motion. In conclusion some basic principles become evident which have to be obeyed especially concerning the tags used for ads. As seen in subsection 3.5.6 the system offers three different ways of interaction. It can either be used by the co-driver, by the driver while the vehicle is not in motion or by the driver while the vehicle is in motion via audio control.

To additionally reduce this problem, there are at the moment two research projects running. The first big group tests a system called Communicar and is supported by DaimlerChrysler and Volvo. It monitors the driver's actions, adapts its dynamic dashboard display to the situation and tries in this way to screen out unwelcome distractions. The second project has a different approach and is sponsored by BMW and Robert Bosch. It gets its information from a database that shows the complexity of a junction. This system therefore requires GPS and a previous rating of every intersection. This information is then used to asses the workload of the driver and to adjust the level of information presented to her (Economist 2004).

4.2 Market Size

According to a recent study by B&D-Forecast (2005), the market volume of in-vehicle active safety systems will rise from 2.9 billion Euro to 11.6 billion Euro in 2010. Based on today's market penetration of system like ABS, ESP or braking assistance the market share of second generation systems (track keeper, fog sensors, accident and object identifying) estimated to rise to 30 percent. Simultaneously due to cost reductions first generation driving assistance systems will increase their market share to 80 percent. In a third phase until 2015 the market volume will reach saturation with 15 billion Euro Second generation systems will then have reached a market penetration of 75 percent. This huge number is of course the whole safety system market and RFID traffic signs can reach even in the best case only a tiny proportion of this amount. But as described later on a mere one percent would be more than enough revenues.

Most of the increase in demand is caused by the consumer's preference of vehicle security and the demographic development of car purchasers. A recent ADAC survey found security to be the most important purchase criteria, even more important than quality or cost/performance ratios. This tendency will be boosted from 2010, when the critical speed up of aging of the German population will begin. Old people particularly rely on driver assistance systems to compensate for the decrease of their cognitive capabilities.

4.3 Analysis of Similar Concepts

4.3.1 Introduction

There exist similar concepts to that of SRRS, which on the one hand may be a threat in terms of competition. But on the other hand this shows that research in this direction is taken seriously, also by big players of the automobile industry, and thus the SRRS concept has a realistic chance to become implemented in the future.

In the following three concepts are discussed which aim to provide the same function as SRRS, that means the permanent display of traffic signs within the car from which the known benefits are derived.

4.3.2 Digital Traffic Signs

An interesting concept comes from CDTM (2004). The authors suggest replacing physical traffic signs by a central database which is permanently sent by means of Digital Audio Broadcast DAB. Alternatively mobile internet technology could be used in order to access the database of traffic signs. The position of the car is determined by GPS.

The benefit of this approach would be that public authorities could save setup and maintenance costs for the physical signs, which are enormous when considering that setting up a single and simple sign, according to the authors, costs about 150 Euro.

Like with the SRRS solution an expensive effort has to be made in order to provide the infrastructure, which in this case means, building up the database of all traffic signs. Such databases are not existent at this time (p. 168).

However, there are several clear disadvantages:

1. A central database creates a single point of failure. First, this means extremely high requirements for hardware and software components regarding total breakdowns. Second, human mistake is never avoidable and in this case could wipe out the signs of an entire freeway within seconds. Third and most dangerous, however, seem to be hostile activities such as terrorist attacks aiming at the destruction of the system. It is questionable if – just to give one example – denial of service attacks could be prevented in the case of internet transmission.

2. Assuming transmission of traffic sign updates via internet it is also questionable if the transmission can be guaranteed. Many parameters can prevent a successful transmission, such as net overload, atmospheric disturbances and dead spots. Due to the lack of reliability the authors clearly suggest DAB as information carrier (CDTM 2004, p. 174).

3. Assuming transmission via DAB one faces another problem. Each channel of DAB has a transmission rate of 128 kbit/s (TKLM 2005, p. 5). Assuming that one channel would be exclusively occupied by the continuous broadcast of traffic sign data, that there are 15 million traffic signs that have to be transmitted (see the subsection "Tag Installation") and that every sign needs 50 bytes (including positioning and transmission meta data) one could calculate that a complete broadcast would need more than twelve hours. This means that dynamic traffic management measures – however important they are – could not be supported. The localization of transmission data by breaking down the covered area into 240,000 segments as suggested by the authors (CDTM 2004, p. 176) is theoretically possible; however, it would need an infrastructure and content distribution system that comes close to the complexity of the internet system with all its disadvantages (TKLM 2004, p. 8). Additionally the coverage of DAB in Germany currently is only 80% of the population (TKLM 2004, p. 1).

4. Due to global standards, pedestrians and cyclists a replacement of the physical signs would actually not be possible (CDTM 2004, p. 178) which makes the great advantage obsolete.

To sum it up, the benefit and roll out effort would be comparable to the SRRS system; however, it would be based on a far more complex technology, which decreases reliability.

4.3.3 Traffic Sign Reminder

The idea behind the Traffic Sign Reminder developed in Saarland, Germany, is similar to that of SRRS. Also a decentralized system should be used to make vehicles aware of traffic signs. However, the inventors propose an active sender attached to every sign, powered by solar panels, which can be read by receivers attached to the inside of the windshield of a car (TSR 2005).

The strength of the system is the possibility of some additional applications the authors mention vaguely. One example is the announcement of traffic jams. This, however, seems not to be elaborated carefully. According to the article (TSR 2005, "Staumeldesystem") the proposed system functionality would mean the moment you are stuck in a traffic jam you get the message that there is a traffic jam. In order to further transport and manage according traffic messages additional infrastructure and sender capabilities would be needed.

However, the disadvantages are quite obvious. As a piece of hi-tech is installed on almost every sign very high roll out costs as have to be reckoned. In addition it is likely that the proposed senders do not have the maturity yet to work reliable. Therefore also high maintenance costs have to be taken into account. Finally the need for continuous power supply adds to the complexity of the system and increases the costs another time.

Thus the TSR system seems to be much more expensive than the SRRS system while providing no clearly defined additional benefit. This makes its implementation rather unrealistic.

4.3.4 Optical Recognition

Another approach to transfer Traffic Signs into the car is optical recognition: A digital camera continuously scans the outside of the car and sends its images to a processing unit. There all traffic signs in sight are extracted and identified by means of computer vision algorithms. A prominent example for research towards this direction is part of the invent project, whose partners include many well-known German companies from automobile and technology industries, such as BMW, DaimlerChrysler and Siemens (invent 2005).

The strength of this approach is that no additional infrastructure is needed along the roads but all needed technical devices are installed within the car. This of course would save roll out costs of several hundred million Euro.

However, this technology is not only error-prone but errors are common when it encounters bad weather conditions, adverse lighting, soiled signs and other optical distortions. And the harder sign recognition becomes the more processing is needed in order to cope with this. According to Hook and Borras (2005, p. 35) it is not possible to perform according image processing in realtime. Additionally there's no guarantee for intervisibility between the traffic sign and the camera. The line of sight may be interrupted completely by obstacles like trees or other vehicles, especially trucks. In this case the best image processing algorithm will not be able to recognize the sign.

To sum it up this basically means that optical recognition suffers from much of the same limitations like human sight. Therefore it loses on reliability which in turn means that the system can not be realized.

4.3.5 Conclusion

After all it seems that only a system based on local RFID read outs is able to provide enough reliability in order to act as a helpful driver assistant system. This of course is based on the assumption that the increasing technical maturity of RFID technology will be able to exclude almost every read out error in the future.

4.4 User Acceptance

4.4.1 By Public Authority and Automobile Industry

A critical success factor for any new system is its user acceptance. As the RFID system does not require direct interaction with the end customer, the driver of a vehicle using this system, there are two levels of customer acceptance. The first hurdle is the public authority and the automobile industry. Only if these groups can be convinced of the benefits of RFID signs, the second level is reached and the end customer can decide upon the system.

Criteria for the approval by the public authority are most of all reliability, transparency and some kind of public benefit. The reliability of the system is strongly supported by its decentralization. There is no central data base or anything comparable and therefore a complete breakdown of the entire system is not possible. In case of problems associated with the radio communication signs will not be displayed incorrectly but in fact not at all. Therefore the user has a clear indication of the occurrence of a problem. The next issue is transparency. The technology is so simple, that it will probably be used on every product to replace barcodes. There is also no danger of an abuse by the operating company, because every user has access to all the data and there are no “secret databases”. The last important aspect is a clear public benefit. The purpose of the system is partly to increase driver safety, which easily meets the last criteria.

The automobile industry not only takes into account those aspects mentioned for the public authority but is also concerned with the following characteristics.

Most important is the integration with existing systems. This could easily be arranged and would even enable additional functions like the possibility to create some form of adaptive cruise control. Another focus of this industry is customer convenience, which will not pose any problems as it is one of the main benefits of the RFID tags. The last but surely not least important topic is the costs. As evident in the analysis of the other players in the market, RFID signs are by far the cheapest and at the same time most reliable system compared to other developments.

4.4.2 By Individual Drivers

If this first hurdle gets passed, the system still has to face its critical inspection by the end user. Consumers are looking for convenience and safety, but they also dislike changing their habits or dealing with RFID system that might intrude their privacy. The first two topics have already been covered, thus inertia and privacy are left. As most people do not like to change an innovation might fail, just because it requires its user to adapt. In this respect RFID signs are no problem, because the old way of looking at signs does not get replaced, but the new information is added. Therefore the user simply gets additional warnings, but he can stick to his old ways and adapt slowly.

As soon as someone talks about RFID, users start to think about privacy issues. They are afraid of being watched or even tracked and thus usually display certain mistrust. On that account the transparency of the system is again very important. The users themselves are the active part in such a system and they never provide any information but just receive it. With the user being the only one getting additional information, the privacy discussion should easily be solved. In conclusion all user acceptance issues are not very problematic and the business aspects of the systems come to the fore.

5 Marketing

In the following part an insight into the overall marketing strategy shall be given. At first the main target groups will be identified. Then a short introduction into the main goals and the therefore applicable strategies will follow.

5.1 The Product

The product is a combination of services and licensing. The basic infrastructure provided makes the system worthwhile. By tagging all major signs the system becomes interesting. Only with this infrastructure in place the product becomes interesting e. g. to the automotive industry. Therefore the infrastructure is important part of the product. The product furthermore consists of licenses offered and services provided through diverse co-operations. Licenses are sold to the automotive industry so they can offer the service to their end customer. In the future direct selling of licenses to end customers might become relevant. Apart from the infrastructure and the licenses the product comes with a range of service options. The cooperation is provided with partnerships with construction companies who are tagging the essential traffic signs as well as additional informative signs or advertisements for the public authority and for private customers. Close cooperation also exists with reader manufacturers to ensure compatibility and provide ideal hardware for the automotive industry. The same has to be true for software providers at least as far as the basic requirements go to ensure compatibility and safety.

Service packages will be offered for advertisers. They have the possibility to have a sign including a tag installed by us. The process will be as easy as placing an ad in the local paper.

5.2 Target Groups

As seen above our product is aimed at several different groups and needs collaboration with varying partners. There is not one single clearly defined target group. Target groups are diverse and change over time. There are groups that have to be targeted first as their cooperation is crucial for the whole project. Only once the link to them is established a market for the next target group is created.

First of all the development of a cooperation with the state will be the number one priority. Therefore the focus will lie on governmental decision makers. After this group has been convinced other partners will be targeted. The next B2B customer of importance is the automotive industry. Once a reasonable amount of players in this industry is on board a new interesting market for the advertising industry will emerge. Potential advertisers will therefore be the next target group. Additionally to these three main target groups several partnerships have to be formed along the way. Hardware, software and service providers are the starting point but also have to be involved continuously to reach the best possible product.

5.3 Marketing Goals

The marketing goals are as well as the target groups diverse. The first goal concerning the government as a partner can not be fractionated into little steps. It is one big goal with one acceptable outcome. A “yes” to a cooperation that allows SRRS to tag road signs and furthermore sell licenses to partners using them. After achieving this first goal all other goals are more scalable and designed to improve through time.

Winning step by step the big players in the automotive industry and using their cooperation as a basis to conquer possible advertisers. Here the first goal will be to convince at least two big players in the automotive industry to offer the service to their luxury class customers. In the advertising sector step one will be to get businesses along the highway to advertise with SRRS.

5.4 Strategy: Long-Term Versus Short-Term

As pointed out above strategic steps have to follow one after the other to succeed. One target group is offering the basis for the next. Therefore the strategy has to be fairly flexible as the customers and co operational partners change over time. So there is no one long term strategy but several short term strategies aimed at the target group relevant at each point of time. If one milestone has been reached and a certain acceptance and or market share within one group has been achieved the next level group can be conquered. E. g. once the government has been convinced to co-operate the automotive industry has to be tackled but at the same time advertisers have to be approached. Not only do the advertisers depend on a certain market penetration but also the additional information and services provided by the potential advertisers to the automotive industry's end customers are relevant for the automotive industry's interest in the product. Therefore the different phases are not self contained – they overlap or more clearly put, have to overlap to ensure success.

So there are different strategies due to the fact that there is more than one target group right from the beginning.

All groups have one thing in common they are B2B or B2G customers, end customers will not be approached directly in the first phase but their needs and interests will nevertheless be in the focus of argumentation. Due to the fact that there will not be end consumer communication strategic instruments are limited. In the following these instrument shall be defined for our three main target groups. Before an appointment of instruments can take place the unique selling proposition for each of the groups has to be explained.

The Government

What advantages of interest does our product provide for the state? Through tagging all major signs along highways, radial highway, motorways and big arterial roads a more effective traffic management becomes possible. Flexible speed limits and no passing restrictions allow a better, more controlled flow of traffic especially during peak times and on highly frequented roads. Speed limits can not only be changed according to volume of traffic but also due to weather conditions this not only offers complex traffic management but also increases safety. Safety increase is provided through secure, reliable broadcasting of information (e. g. speed limits) inside the car even if weather conditions reduce visibility of signs. Furthermore warnings like "slippery when wet" will only be shown when sensors actually detect water and therefore make the warning necessary. Therefore the general information overload for the driver through conditional signs will be reduced. The same applies to signs which are time constrained like speed limits that only apply at night. Additional to increased safety and better traffic management road construction costs can be reduced. Tagging is quick and easy and only needs a road or lane to be closed for minutes. Setting up construction site can be made a lot easier and faster as well. One further continuative advantage deriving from better traffic management and optimized road closing times is better flowing traffic. Less stop and go means less impact on the environment. All these additional advantages will only fall into place after SRRS have reached a certain coverage and it becomes possible to not only augment existing road signs but give additional information to with SRRS equipped drivers through tags only.

Therefore we have three key arguments to convince the government safety, easy traffic management and environmental protection. These three keys advantages indirectly lead to cost reduction in the long run. There for cost reduction is our best argument backed by several issues ranked high public opinion.

Instruments to put across these arguments will be intense lobbying activity. Aiming at the public interest of the issue interest for our project will be risen. Bringing across the rational arguments is another instrument used within the B2G communication. Closed presentation and one on one negotiation with decision makers will be the next step. A further important piece in the marketing mix will be the proposition of training on one hand side to all involved parties in road construction on the other hand side to traffic managers.

The Automotive Industry

What is in for the automotive industry? They get the possibility to offer an additional feature to their end customers. They can provide their customers with extra safety and additional services brought right into the car. No sign can be missed again. Dated back signs can be accessed any time. The driver will be helped through the information overload currently existent through complex traffic signposting. Signs of relevance will be provided to the driver in the right order at the appropriate point of time. The driver can request additional information according to his needs. These special benefits will be arguments to convince the big players within the automotive industry to adapt the new technology early on. Strategic instruments to convince them to be first will be several measures within B2B communication. Communications activities are similar to the B2G communication used to convince the government whereas arguments differ. Stress will be put onto the concrete advantages for the end customer. The unique selling proposition has to be shown to the automotive industry as reasonable benefit for their customers. Here the needs of the end customers play an important role even though they are not being addressed directly.

The Advertisers

The advertisers are the third group in the big picture. The first group targeted will be businesses along the road e. g. service stations, restaurant and hotels. Any business that targets drivers will be relevant in the long run. The product offers the possibility to target a driving audience at a certain point of time. Advertising will hit the target audience at the time where it already is in need for a certain product and therefore more open to listen. For example a driver that has been covering a longer distance on a highway and is in need for a stop anyway will be far more open to listen and react to a certain advertisement promoting a special rest stop offering him exactly what he needs.

Classical direct marketing will be used to reach the advertising customers. A sales force will be offering customized contracts to each individual roadside advertiser. A service pack will include a certain amount of signs, tag space and the actual tagging. Traffic statistics for certain roads will be the basis for these packages. Questions like, are the typical drivers passing a certain spot driving business related or on private trips, are they only traveling short distances or will they be on the roads for longer will be answered. Therefore not only appropriate into the car advertising at the perfect point of time becomes possible but also certain driver groups can be addressed according to their needs.

Conclusion

Several short term strategies aimed at certain target groups, using diverse instruments for a long term strategy building upon each other. In general B2B instruments will be used but the needs of the end customer shall never be forgotten. In the long run an introductory awareness campaign in cooperation with the automotive industry is conceivable. As the system is interrupting the drivers in car space awareness and acceptance by the end consumer has to be created. This is only possible by showing him the advantages for his own safety and convenience.

6 Business Model and Economic Success

6.1 Business Processes

6.1.1 Initial Roll Out

The business model consists of two phases, which start simultaneously. The first one is the initial roll out of the infrastructure and the second one is its maintenance. Both have several processes that have to be managed. The role out phase begins with a clear definition of the kind of signs that will be tagged. As described above in subsection 3.3.2, not all kinds of signs are equally suitable for tagging. This first phase focuses in the beginning on the static signs and then moves on to dynamic signs. The referencing signs will be installed by the company or institution presenting itself on the tag. Therefore this process does not need to be described. To properly coordinate the installation a database of all the roads has to be created including the companies responsible for tagging the specific road. Thereby a particular company is assigned to every road, in the best case the one that is anyway already responsible for the normal traffic signs of this road. These companies then cover their roads, tagging all the signs and marking these signs on a map. This map enables the contractors to proof their work and to be paid accordingly. The tagging itself is actually quite easy. It involves two people: the first worker blocks the road with a suitable vehicle and is the driver. The second one drills the hole, puts in the RFID tag, fills the hole and checks its function with a reader. The installation of dynamic tags would be a little more difficult, if they need a connection to a traffic management system. It should be possible to use the connection of the existing traditional traffic sign.

The complete roll out will take five years. Each year about a fifth of all signs will be tagged, starting with the signs of the most important and biggest highways and gradually going down to the minor roads.

6.1.2 Continuous Maintenance

A different problem is the permanent maintenance of the infrastructure and its adaptation to changes of traffic signs. The authority responsible for the sign notifies the company running the RFID infrastructure and this company coordinates the installation of the new tag or the destruction of an old one with a construction company. As far as possible that should be the company anyway responsible for putting up or tearing down the traditional traffic sign. The same process is basically true for the maintenance of the sign, just the initiation is different. Noticing broken tags works just like noticing missing or broken traffic signs. Either attentive citizens or the police notify the operating company which triggers the replacement.

In co operation with experienced construction companies it will then be possible to offer "service packages" to ad customers. They just provide the necessary information and funds, while getting all the actual work done in exchange. The price of these packages includes the costs for setting up the required advanced SRRS.

6.2 Business Model

6.2.1 Cost Structure

Administration

The first group of expenses are required to set up the firm running the whole project. The most important professional that needs to be hired is a combined CEO and CFO. She is on the one hand responsible for the coordination of all the other employees and on the other hand in charge of the communication with the outside investors and of the management of the raised funds. The next fundamental position is a lawyer. Due to all the legal issues mentioned in subsection 4.1 and the fact that all the actual construction work is outsourced, a lawyer is truly essential. She does the contract design, the coordination with the government and deals with possible liability issues. Another important aspect is the coordination and teaching of the contractors. Construction companies will not be familiar with our system and therefore need advice on the installation, even though the process should be quite simple. These people do the coordination of all the involved construction companies that work on the initial roll out of the infrastructure as well as the permanent maintenance of the whole system. The last two members of the team share the function of marketing and sales. They do the communication and coordination with the automobile industry as well as with the marketing agencies that work on the commercials. All the 14 professionals mentioned above are estimated to earn on average 100,000 Euro a year. They also each need about 30 m² of office space that comes including running cost at some 150 Euro per m² a year. On top there is office equipment that needs to be leased at about 1,000 Euro a year per employee and additional IT that will cost another 5,000 Euro a year. Another small group of expenses are the marketing campaigns that are available at about 100,000 Euro a year. These entire administrative expenses sum up to a yearly 1.5 million Euro.

Tag Installation

Looking at costs, the tag infrastructure naturally has the biggest impact. Its two drivers are the expenses for the installation of a tag and the number of tags deployed. The expenses for installation of one tag consist of three factors. The salary of the workers, the tag itself and the machinery needed to install it. The salary of the workers can be easily calculated by multiplying the time they need with their wage and the number of workers. The task should take two guys about half an hour including the time needed for transportation and coordination. The usual wage at construction sites is between 10 Euro and 16 Euro (Bauindustrie Sachsen 2005), therefore 15 Euro per hour is a conservative guess. The two passive tags usually used will be very cheap in five years and their price will be below 1 euro. The machinery required boils down to a good drill and a RFID reader to check functionality and will not cost more than 5,000 Euro. It can also be used many times and an average use should be 5 times a day in 300 days for 5 years. Summing up an installation will cost about 18 Euro per traffic sign. That is at least the amount that will be paid to the construction company, which will probably need less time for the actual work, but has to cover additional costs.

Even more difficult to estimate is the number of tags that will be installed. In this case, three separate numbers have to be considered. The number of fixed traffic signs, of signs at construction sites and the replacement frequency of tags. The problem with the number of fixed road signs is that there is not one single entity responsible for the administration of these signs. It is always the authority that is also responsible for the road it belongs to. Therefore there are signs that are managed on federal, state or municipal level and thus there are only estimations for the number of overall traffic signs. According to the ADAC (2005a) there are some 20 million signs along German roads. Considering that about three quarters of all sings will be tagged, since certain kinds of sings are irrelevant for the project, the total number of signs is about 15 million. The first roll out of the system will for this reason cost about 265 million Euro.

There is also no secured number of overall construction sites, but there are about 150 sites at freeways (ADAC 2005b). Since there is 90 times the amount of signs overall compared to freeways, there is probably also about 90 times the number of construction sites. If there are about 10 signs at each site, there should be some 100,000 signs overall.

The last factor is the replacement frequency of tags. Since they are well protected from the environment, they should last about 10 years. This continuous replacement and the construction site signs cause a yearly expense of about 28 million Euro.

6.2.2 Revenue Structure

Licenses

After considering the costs the next point that needs to be considered are the potential sources of revenue. The first important income comes from the automobile industry. The car manufacturers have to pay a license fee per car for integrating the readers for the RFID signs into their vehicles. The amount they are willing to pay strongly depends on the maturity, reliability and acceptance of the system. Therefore the price for one license will gradually rise from 20 Euro in the first year to 100 Euro after five years. To estimate the number of cars equipped with such a reader, it is most convenient to look at the introduction of other innovations in the automobile industry. Successful innovations usually reach a long term market share of above 90 percent (VDA 2004). Since this is only true for successful ones, three scenarios can be differentiated with a final market share ranging from 20 percent in the worst case to 80 percent in the best case. The detailed market shares in each year can be found in the appendix. Innovative customers will start buying reader equipped cars in the first year – even though there are hardly any signs tagged yet – to be properly prepared for the future. Even though most innovations are used even in cheap cars in the end, the target market of the RFID system would only be 2 million of the 3.3 million newly registered cars and the 200,000 newly registered trucks (KBA 2004). The main reason is the price of one license of 100 Euro which might be very high compared to the price of the cheaper third of the automobile market. In conclusion the revenue from licenses adds up to 160 million Euro per year in the best case, which is still only about one percent of the market for in-vehicle active safety systems described above. Taking all these numbers into consideration, the revenue calculation is still very conservative and the best case is not that unlikely.

Ads

The second stream of income are also license payments, but of a very different kind. They come from companies using RFID signs to target “infomercials” at passing drivers. The price these would be willing to pay depends on the maturity, acceptance and reliability of the system as well as the price of substitutes and the kind of information that can be stored on the tag. Since the utility of really specifically targeting potential customers as well as the price of substitutes is quite high, prices will start at a yearly rate of 200 Euro in the first year and gradually rise to 1,000 Euro in the last year. Figuring out the number of companies interested in such a system is very difficult due to the diversity of the potentially interested companies. Nevertheless rough estimations can be made. Gas stations, (fast food) restaurants and hotels are among the most likely customers. There are about 15,000 gas stations in Germany (ADAC 2005c) and about 8,500 fast food (McDonalds 2004; Wikipedia 2005b) restaurants. These should make up about half of the potential customers and the total number should therefore be around 50,000. Concerning the market share that can be reached, three different scenarios are once again the best solution. In the worst case only about 20 percent of our customers will be willing to pay, while in the best case 80 percent might be convinced. Summing up these numbers revenues will come two thirds from the automobile industry and one third from the advertising companies.

6.2.3 Profit Scenario

A potential investor will of course add up these numbers and look for the net present value this investment will generate. Thinking about the financing of the project, four distinct characteristics show up: A high risk, a long period of high negative cash flows, hardly any tangible assets and all the revenues from licenses for a special kind of intellectual property. Therefore a complete equity financing of the first five years is most appropriate with costs of equity of about 20 percent. The required funds would be raised in several financing rounds, starting in the year before the project. The amount of money that would have to be raised depends on the success scenario and ranges from 460 million Euro in the worst to 260 million Euro in the best case. After this start-up phase, the roll out of the infrastructure is completed, customer acceptance will have been figured out and positive cash flows will even in the worst case begin. In this second phase the cost of capital will drop to 10 percent due to the lower risk and the beginning of debt financing. That will thus be the perfect timing for a sale of the company and the refinancing of the investors. To calculate the sale price it is common to discount the expected earnings with cost of capital based on the formula of the perpetuity. Due to the difference in the market share the sale price will be 370 million Euro in the worst case and close to 2 billion Euro in the best case. Discounting all these cash flows the investor comes to the net present value, the basis for his investment decision. It is a lousy investment in the worst case with a negative NPV of 93 million Euro, but a great one in best case with a NPV of close to 650 million Euro. Assigning equal probabilities to each scenario the average NPV would be about 235 million Euro and therefore be a great opportunity.

7 Vision

Imagine sitting in your car driving down the highway trying to find your new customers remote office in the country side. It’s pouring down raining, getting dark already and you are pretty sure you missed the exit while overtaking a truck. Right in front of you is the next construction site coming into sight. 20 different signs announce ever changing speed limits, ending lanes and exits at the same time, barely visible in the weather conditions. You are hungry, in need for a coffee and not quite sure if your gas is actually going to last to the next service station. While trying to figure out how far to the next service station on your navigation system you miss a speed limit and look up just in time to see the flash of the speed camera announcing a painfully expensive ticket.

Now imagine the following situation. You are sitting all relaxed in your own car doing almost nothing but trying to decide what to eat at the next rest stop which is exactly 17 kilometers ahead and will be reached within 6 minutes at the current speed that the car is keeping on its own. Your board computer is displaying the menu of the two restaurants at the next service station right into your car. One click later you made a reservation and your diner will be waiting exactly at the right time so you won't lose any time by waiting in line or for the waitress to bring your food. The car has now changed lanes to prepare the exit off the highway while you have not even spotted the sign yet due to the bad weather conditions. The car is now slowing down early enough to take a safe right turn at the end of the exit lane. It is taking into account the bad weather conditions as well as the traffic around to ensure a smooth and safe exit for you and the traffic around. You are taking over the wheel now being guided by light arrows outside and a voice to a parking spot right in front of the restaurant that has been reserved for your after making the order earlier on. Therefore you only have to walk a couple of steps until you reach the warm and dry restaurant where your diner is being served that very second.

Back on the highway only shortly later you set the car onto autopilot after entering the final destination you receive estimation on how long it will be until exiting the highway and reaching the destination. A couple of minutes a soft voice wakes you out of your day dreams triggered by the constant announcements and stories around the country site and the villages passing outside.

The first imagination could be titled today whereas the second one might be called a dream. A dream that can come true due to RFID technology. Backed by other technical developments these applications can be realized. A lot of partners have to cooperate to integrate rapid technical developments, make the necessary changes in today's processes on and along the road and to ensure the customer isn't being left behind on the way.

Different co-operations, developments and campaigns necessary shall be introduced in the following paragraph.

7.1 Co-Operations

Co-operations will be necessary among several industrial partners to merge diverse technical developments within and outside the RFID sector. Not only teamwork in the technical field will be necessary but also constant communication with the legislation making traffic rules and safety experts will be necessary. The driver of the future shall be provided with as much convenience and additional information as possible without taking any chances regarding his safety. None of the applications mentioned above will be allowed to distract the driver from his main task – the safe steering of the vehicle. Imagining the system not only to be applicable within one country political, multinational negotiations to set standards have to take place Europe-wide.

7.1.1 Companies

Co-operations will be needed amongst the RFID industry – reader and tag producing industry – and first and most importantly the automotive industry. Readers have to be developed that fulfill a wide range of abilities. They have to be able to read all different kinds of tags at a high velocity and the readouts have to be fed to the cars board computer to be processed and displayed. Standards and flexibility are necessary at the same time. The readers have to be able to read all tags and be integrated into different board computers and systems at the same time. In the area of tags the range lasts from very simple passive tags to highly complex, active, networked tags. Tags have to be easy to handle for all different kinds of users. To ensure compatibility for the whole system but also make the best possible result in all the concerned areas possible, intensive co operation amongst the different developing parties will be necessary. Apart from close teamwork within the developing sector co-operations in the implementing sector will be crucial for success. Extensive training for everybody concerned with the new system could be part of that co operation. This involves training amongst others the construction worker who installs the tag as well as the traffic manager receiving and dispatching information differently.

7.1.2 Political

Very different co-operations will be needed outside the industrial sector. Close communication maybe in the form of round tables with the legislative will be needed for two reasons. One important area is road traffic regulations that have to be adapted for sign tagging to become possible. Not only has the law to allow and support the tagging but also regulations have to be passed on how, when and by whom signs can be tagged to allow safe implementation. Issues like how far in advance signs have to be tagged and who makes decisions on tagging have to be negotiated. Most importantly a central point has to be found where detailed information on each tagging action will be stored. These mainly organizational co-operations have more reasons apart from making all tagging transparent and traceable which is most importantly safety. Defining cognizance is only the first step in reaching the common goal of all involved parties – more safety on our roads. Here fore the experience of road safety experts concerned with traditional traffic sign posting has to be integrated and merged with the new technology.

Apart from safety issues the system gains value by being applicable worldwide. In a first step diffusion within Europe would be desirable. Here problems of compatibility have to be solved in a joint effort. A first step would be consistent sign posting within Europe. That would solve the issue of special, national signs not in the SRRS database. Even closer co-operations will be necessary with the legislative body once international operations shall become an option. Another step that could be taken to enable SRRS for different countries are individual user interfaces according to national specialties.

Concluding can be said that the common goal on the not industrial side has to be safer roads through RFID signs in a greater area.

7.2 Technical Development

Above co-operations inside and outside the industrial sector have been described. Now a few examples will be given which areas of technical development might be influenced. After considering the basic technologies driving the system in the above sections these part is looking at technologies indirectly influenced or being influenced by the SRRS.

7.2.1 Sound Engineering

A field that will be become increasingly important in the automotive sector will be sound engineering. With RFID entering the car even more information shall be provided for the driver. As the best way to do so without distracting the driver too much is still sound, sound engineers have to constantly develop distinctive sounds for all kinds of applications. The difficulty here is the drivers already being used to a lot of characteristically sounds that tell them a certain things. They for example will immediately recognize the sound of the indicator. New unique signals have to be established for new information. Drivers have to get used to theses alternations. Becomes the information too complex to pass on through sounds voice becomes the only option. As directing voices are already in extensive use more or less successful in navigation systems today the question remains how to distinguish information coming from the navigation system from those coming from SRRS. As the information coming from road signs can be more crucial e. g. for safety reasons they should be distinguishable from those coming from the navigation system. The same is true for advertisements that will be considered less important than information from the navigation system.

7.2.2 Automated Driving

SRRS could support developments like adaptive cruise control. Adaptive cruise control unlike simple speed control not only sticks to a given velocity but also reacts to vehicles ahead through RADAR that recognizes the distance to the car in front. With SRRS there would not be the need anymore to adjust the speed manually the car simply will pick up the allowed speed and use it as far as possible. The biggest problem still unsolved in the area of automated driving is vicinity recognition. The car can stick to a certain speed and stay away from obstacles in front but can not recognize suddenly approaching obstacles from behind or the side. RFID readers within each car open up new options within vicinity recognition and therefore can support the process towards real automated driving.

7.2.3 Safety

Additional features are imaginable. One possible scenario reducing costs immensely and increasing safety would be virtual speed bumps. These speed bumps would be simulated by the buffers triggered through a tag in the road. The bump being caused through the tag would be adjusted in intensity according to the speed of the car. Is a driver speeding the bump in the car would be felt stronger. As the bump is being caused electronically by the car itself it would remain safe no matter how fast the car is running over a virtual speed bump. Another option for a similar scenario would be an automatic aid to keep the car in the right lane. Today lines between lanes are often marked not only by color but also grooved to alert the driver when leaving the lane. A signal triggered by RFID which sends an alarm inside the car would be much cheaper to implement and safer. These sort of applications have one common advantage they increase safety as they are controlled from the board computer and can not turn out too strong and potentially dangerous. The second main advantage is in the costs. Any form of road constructions is immensely expensive especially if roads need to be closed for the duration. With the new system only RFID tags have to be installed which is fast and easy. The bumps or grooves are not actually there anymore but still fulfill their purpose.

7.3 Different Possible Applications

In the following part some more possible applications shall be described. They incorporate different technologies with the SRRS system and therefore open up new possibilities in addition to the main scenarios described in the sections above.

7.3.1 Incorporation with the Navigation System

Parking Guidance

Another possibility to create new features is to incorporate the navigation system and the information received from tags outside. If looking for a parking spot within a city center the driver needs two bits of information: where is the next parking garage situated and are there free spots available at the present time. The first information can be easily provided by the navigation system. In comparison the information about free spots changes continually and needs to be updated on a regular bases, in the ideal case the information should be available in real time. Dynamic RFID tags signs giving directions towards a parking garage allow this information to be send into the car up to date and at the right time. The combination of the of the ever changing but short information being provided on the sign and the consistent, more detailed information coming from the navigation system allows an ideal combination of the two technologies to the advantage of the driver. No more reading maps and driving at the same time only to arrive at the garage to find out it is full.

7.3.2 Interaction with Other Systems Within the Car

Additional advantages are created by interaction with several other instruments, sensors and applications within the car. A combination of information coming from the RFID tags outside and the sensors within the car enable more defined applications. E. g. a RFID tag signals from outside that the next service station is 20 kilometers ahead from inside the car the information about the amount of gas still in the tank is available, these two bits of information are now connected and delivered to the driver who only receives the needed information: exit to fill up gas or continue driving. He doesn't have to make any estimations himself, only receives the information he actually needs and is therefore able to focus on his main task the driving.

7.3.3 Interaction of Different Vehicles

In the far future with more developed readers that serve as transmitters as well other applications are thinkable. Communicating directly with cars in your close vicinity. You could finally tell the driver in front of you what you really think about him, word for word not only through honking. A more friendly approach would be the mysterious blond girl in the car next to you at the traffic light or having a spontaneous chat while sitting in the endless traffic jam. Or simply being alerted if a friend's car is close by. Possible communication between cars opens a lot of options either with friends or with random drivers in the same situation. A form of tracking friend's cars would be one option. Receiving a signal if a good friend is close by or keeping in touch while driving long distances together.

Slightly different is the interaction with other drivers. They can be used to vent one's anger, to flirt or even once again for safety purposes. Ever been driving behind someone whose door was about to open, desperately trying to get him to understand your gestures? Tell him in simple words within seconds.

7.3.4 Entertainment

If flirting and communication is not enough entertaining there are other options. Assuming that read out speeds have improved and it is possible to transfer bigger amount of data into a speeding car all kinds of entertaining information could be presented inside the car. In the meantime and with internet connection present in the cars within the near future these applications could be realized through internet referencing as described in subsection 3.5. Information about cities and the countryside being passed, traffic statistics when sitting in the next traffic jam at these new construction site in your town. Not only information also songs and sound files could be transferred. Imagine passing the local soccer stadium suddenly listening to the soccer club song and the live recording of last weekends match. It's like your radio suddenly knows where you are and in what situation and broadcasts accordingly. Sightseeing in you own car would be possible, drive through a foreign city listening to all kind of interesting facts while passing the sights. Pass by a restaurant that is recommended by the virtual travel guide and make a reservation without even stopping the car or picking up the phone.

8 Conclusion

In one sentence, Smart RFID Road Signs bring the information from road signs into the car. This is not only convenient for the driver who can check with one simple glance what the speed limit is or which sign she just missed overtaking the truck but also improves road safety immensely. Safety is not only improved through unmistakable sign recognition at any time and under any weather condition but also through reduction of information overload for the driver. Filters allow the driver to only receive the signs relevant for her at the given time.

The development of SRRS is interesting for three parties. Public authorities have advantages in several issues very vulnerable in the public eye like traffic safety and convenience on the roads. In contrast to all other relevant proposed systems, SRRS is capable of supporting and even slightly improving dynamic traffic management measures. The automotive industry can offer an extra service to its customers. Combinations with already existent on board systems allow interesting additional applications. The third party gaining an advantage through SRRS are advertisers targeting drivers. The customer can be approached in exactly the situation in which he might be interested in the specific product or service.

Altogether the system will become very interesting and valuable after it has reached certain coverage as only then certain applications like improvements in traffic management can become possible. In the long run, more and more applications – through technical improvements, higher coverage and combinations with different technologies – allow even more than the simple safety improvement the system can guarantee right from the beginning.

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Appendix: Financial Calculations

Table 2. Costs

costs		
		per year
marketing and sales	HR	200.000
	campaigns	100.000
finance	HR	100.000
infrastructure	facilities	50.400
	equipment	19.000
legal department	HR	100.000
coordination and teaching	HR	1.000.000
tag installation and maintenance	traffic signs	53.000.000
	temporary signs	1.766.667
	maintenance	26.500.000
sum		82.836.067

Table 3. Revenues

worst case					
market share	1%	5%	10%	15%	20%
year	1	2	3	4	5
licenses	400000	4000000	12000000	24000000	40000000
ads	100000	1000000	3000000	6000000	10000000
revenue	500000	5000000	15000000	30000000	50000000
base case					
market share	2%	10%	20%	30%	40%
year	1	2	3	4	5
licenses	800000	8000000	24000000	48000000	80000000
ads	200000	2000000	6000000	12000000	20000000
revenue	1000000	10000000	30000000	60000000	100000000
best case					
market share	4%	20%	40%	60%	80%
year	1	2	3	4	5
licenses	1600000	16000000	48000000	96000000	160000000
ads	400000	4000000	12000000	24000000	40000000
revenue	2000000	20000000	60000000	120000000	200000000

Table 4. P&L Statement

worst case					
year	1	2	3	4	5
revenues					
licenses	400.000	4.000.000	12.000.000	24.000.000	40.000.000
ads	100.000	1.000.000	3.000.000	6.000.000	10.000.000
expenses					
marketing and dales	300.000	300.000	300.000	300.000	300.000
finance	100.000	100.000	100.000	100.000	100.000
infrastructure	69.400	69.400	69.400	69.400	69.400
legal department	100.000	100.000	100.000	100.000	100.000
coordination and teaching	1.000.000	1.000.000	1.000.000	1.000.000	1.000.000
tag installation and maintenance					
traffic signs depreciation	5.300.000	10.600.000	15.900.000	21.200.000	26.500.000
temporary signs	1.766.667	1.766.667	1.766.667	1.766.667	1.766.667
maintenance	5.300.000	10.600.000	15.900.000	21.200.000	26.500.000
EBIT	-13.436.067	-19.536.067	-20.136.067	-15.736.067	-6.336.067
tax	-5.374.427	-7.814.427	-8.054.427	-6.294.427	-2.534.427
net profit	**-8.061.640**	**-11.721.640**	**-12.081.640**	**-9.441.640**	**-3.801.640**
base case					
year	1	2	3	4	5
revenues					
licenses	800.000	8.000.000	24.000.000	48.000.000	80.000.000
ads	200.000	2.000.000	6.000.000	12.000.000	20.000.000
expenses					
marketing and dales	300.000	300.000	300.000	300.000	300.000
finance	100.000	100.000	100.000	100.000	100.000
infrastructure	69.400	69.400	69.400	69.400	69.400
legal department	100.000	100.000	100.000	100.000	100.000
coordination and teaching	1.000.000	1.000.000	1.000.000	1.000.000	1.000.000

Table 4 (continued)

tag installation and maintenance					
traffic signs depreciation	5.300.000	10.600.000	15.900.000	21.200.000	26.500.000
temporary signs	1.766.667	1.766.667	1.766.667	1.766.667	1.766.667
maintenance	5.300.000	10.600.000	15.900.000	21.200.000	26.500.000
EBIT	-12.936.067	-14.536.067	-5.136.067	14.263.933	43.663.933
tax	-5.174.427	-5.814.427	-2.054.427	5.705.573	17.465.573
net profit	**-7.761.640**	**-8.721.640**	**-3.081.640**	**8.558.360**	**26.198.360**
best case					
year	1	2	3	4	5
revenues					
licenses	1.600.000	16.000.000	48.000.000	96.000.000	160.000.000
ads	400.000	4.000.000	12.000.000	24.000.000	40.000.000
expenses					
marketing and dales	300.000	300.000	300.000	300.000	300.000
finance	100.000	100.000	100.000	100.000	100.000
infrastructure	69.400	69.400	69.400	69.400	69.400
legal department	100.000	100.000	100.000	100.000	100.000
coordination and teaching	1.000.000	1.000.000	1.000.000	1.000.000	1.000.000
tag installation and maintenance					
traffic signs depreciation	5.300.000	10.600.000	15.900.000	21.200.000	26.500.000
temporary signs	1.766.667	1.766.667	1.766.667	1.766.667	1.766.667
maintenance	5.300.000	10.600.000	15.900.000	21.200.000	26.500.000
EBIT	-11.936.067	-4.536.067	24.863.933	74.263.933	143.663.933
tax	-4.774.427	-1.814.427	9.945.573	29.705.573	57.465.573
net profit	**-7.161.640**	**-2.721.640**	**14.918.360**	**44.558.360**	**86.198.360**
tax	0,4				

Table 5. Cashflow Statement

high risk WACC	0,2					
low risk WACC	0,1					
year	0	1	2	3	4	5
worst case						
revenue	0	500.000	5.000.000	15.000.000	30.000.000	50.000.000
costs	0	8.636.067	13.936.067	19.236.067	24.536.067	29.836.067
operating cash flow	0	-8.136.067	-8.936.067	-4.236.067	5.463.933	20.163.933
investments	0	53.000.000	53.000.000	53.000.000	53.000.000	53.000.000
free cash flow	0	-61.136.067	-61.936.067	-57.236.067	-47.536.067	-32.836.067
cash flow to equity	-20.000.000	-60.000.000	-60.000.000	-60.000.000	-50.000.000	-30.000.000
cash at the end	20.000.000	18.863.933	16.927.867	19.691.800	22.155.733	19.319.667
selling price	220.959.000					
NPV	**-93.759.404**					
base case						
revenue	0	1.000.000	10.000.000	30.000.000	60.000.000	100.000.000
costs	0	8.636.067	13.936.067	19.236.067	24.536.067	29.836.067
operating cash flow	0	-7.636.067	-3.936.067	10.763.933	35.463.933	70.163.933
investments	0	53.000.000	53.000.000	53.000.000	53.000.000	53.000.000
free cash flow	0	-60.636.067	-56.936.067	-42.236.067	-17.536.067	17.163.933
cash flow to equity	-20.000.000	-60.000.000	-60.000.000	-40.000.000	-20.000.000	
cash at the end	20.000.000	19.363.933	22.427.867	20.191.800	22.655.733	39.819.667
selling price	741.459.000					
NPV	**153.515.866**					
best case						
revenue	0	2.000.000	20.000.000	60.000.000	120.000.000	200.000.000
costs	0	8.636.067	13.936.067	19.236.067	24.536.067	29.836.067
operating cash flow	0	-6.636.067	6.063.933	40.763.933	95.463.933	170.163.933
investments	0	53.000.000	53.000.000	53.000.000	53.000.000	53.000.000
free cash flow	0	-59.636.067	-46.936.067	-12.236.067	42.463.933	117.163.933
cash flow to equity	-20.000.000	-60.000.000	-50.000.000	-10.000.000		0
cash at the end	20.000.000	20.363.933	23.427.867	21.191.800	63.655.733	180.819.667
selling price	1.882.459.000					
NPV	**646.008.793**					

Improving Public Safety by Using RFID

Veronika Gamper, Florian Rohrmüller, David Holzmann, and Stefan Hudelmaier

1 Introduction

When switching on the TV and watching the news, one is hard pressed to find one uplifting piece of information. Although this is surely in part due to the fact that "only bad news is good news" is the first thing you learn as an editor in the staff of a news program, one cannot help but get the impression that the world is becoming more and more insecure. At the time of writing of this report the images from the terrorist attacks on London are still fresh in the collective mind, for a short while overshadowing the constant news-flashes of abductions and suicide bombings in Iraq and reports of rising domestic criminality. However, the downward spiral of violence, crime and terrorism is not unavoidable. Emerging technologies, among them RFID, have the potential of making a difference and in the course of the next decades making the world considerably safer to live in. Although you can be sure that the guys in the news program won't admit that.

This part of the Trendreport is focusing at various possible applications for RFID in the field of homeland security and fraud protection. For most it has quickly become evident that the use of RFID is not serviceable, often because of one reason: For the benefits of RFID to really pay off, cooperation is necessary: In a B2B application the buyer has to be able to trust the supplier that the information on the RFID tags is up to date. If the former has to check each article for consistency between the information on the tag and the real thing, the gain in effectiveness that RFID promises is lost completely. If the technology is to be used to protect public safety, one must always consider that there might be numerous ways to fool an RFID system.

One of theses applications was for example using RFID for weapon control: In this scenario weapon manufacturers would have to include an RFID tag somewhere inside their guns and make sure that without a working tag inside, the weapon cannot be fired. RFID readers would then be able to ascertain if there were weapons somewhere in the vicinity, making it easy to make sure that schools for example are weapon free. However, it soon became clear that there were huge problems with this plan which were impossible to overcome: Old weapons would still function without broadcasting radio waves which would be warning nearby readers about their presence. People could also tinker with new guns to overcome the security mechanism requiring a working tag inside. Jamming devices could be used. In the end, the public would probably be less safe, because it would rely on ostensible security measures that could be overcome with reasonable ease by a determined villain.

However, three areas could be isolated in which the use of RFID can benefit public safety. The first area concerns the safeguarding of the food supply chain, making sure that the things everyone eats are neither contaminated with natural diseases nor poisoned by terrorists. The second covers the problem of rising domestic crime, more specifically preventing the theft of cars and software piracy. The third and last part is about measures that can be taken to better monitor criminals on parole and to prevent abductions by using RFID to keep track of personal movement. For each of the areas, first, the current situation is analyzed, then the RFID solution will be presented, with a description of a scenario and a further analysis of the market, the costs, legal and social aspects.

2 Food Safety

2.1 Introduction

In recent years there have been several food crises that have had a perceivable effect and posed a real threat for the consumer. Among them has been the outbreak of mad cow disease in 2000 that is not yet completely contained and resulted in a number of people, mainly in the UK, to be infected with Creutzfeldt Jakob Disease. Another crisis has been the dioxin scandal in Belgium during which a quantity of dioxin affected the food supply through contaminated animal feed.

On a more global scale the outbreak of the avian influenza in China has been seen as a major threat by specialists everywhere. It is feared that a similar occurrence may lead to a so called pandemic, the development of highly contagious bacteria or viruses that affects people everywhere on the globe causing millions of deaths (like the Spanish flu in the late 1910s that killed more than 25 million people).

In the future, terrorists may try to cripple a country by actively contaminating food in order to poison the people who consume it or even introduce and spread diseases through this channel in order to affect an even greater range of people. Next to the loss of life and health this may lead to, the damage dealt to the economy of the affected country and the whole world would be grave indeed. Consumer confidence and the general morale would be dealt a severe blow and would likely not recover for years to come, possibly dwarfing the results the 9/11 attack had on the economy in comparison.

These examples, several of which will be elaborated on below, serve to demonstrate that the food supply is both essential to the well-being of the population and also very vulnerable. Even small irregularities in this area can have very serious effects on the psychological state of the society. Although less common, crisis that cause massive loss of life, are also not out of the question. No matter what the extent: Crises in the area of food supply should be prevented if possible and if they occur despite the best efforts, they have to be contained effectively and their effects have to be kept at a minimum.

In this context, RFID may be able to make a decisive difference. Due to its ability to quickly and efficiently scan large numbers of articles, it can be used to monitor the movement of livestock, plant material and food products and build up a comprehensive database about the whereabouts, the origins and the interrelations between the various goods. If it is moreover coupled with advanced and partly automatic integrity checks, so as to eliminate the possibility of tinkering with the used RFID tags, it is a mighty weapon indeed, both against natural and artificial threats to the food supply.

2.2 Current Situation

According to the United Nations World Health Organization (WHO) currently food-borne diseased are killing about 1.8 million people each year, a majority of them children (AP-Foodtechnology 2004). Most of those fatalities occur in third world countries. While it can be argued that improved hygiene regulations for example would be considerably more effective than the measures that can be taken using RFID, this new technology should not be disregarded even for helping developing countries improve the quality and integrity of their food supply. Should the industrial nations be able to implement a system similar to the one proposed in this report and should the prices for this technology, especially for the RFID tags, drop further – which is to be expected – the implementation of such a system might be interesting for third world countries as well. There, it would not only improve the crisis prevention and reaction capabilities, but also boost the general state of health of the population.

In the developed countries, food safety is perceived to be very important as seen in the following survey conducted by a British food safety agency in 2002 (Food Standards Agency 2002). When asked if they were concerned about food safety people answered like this:

This means that both governments and companies have an interest in assuring that their population and the customers have reason to believe that the food is safe and that everything is done to prevent harm.

2.2.1 Mad Cow Disease

Five years ago, the situation was as follows: There had been a huge number of mad cow disease cases in Great Britain, which caused the rest of the world to ban exports from the British isles as far as meat and livestock are concerned. And yet the mad cow disease was able to spread to continental Europe (and other parts of the world, including Canada).

This shows that in spite of the ban on imports from the UK and the screening methods that were in place, a number of cows bred in Great Britain and infected with the mad cow disease where shipped to continental Europe, where they infected other livestock with their illness. This shows that the old system of checks and track & trace leaves much to be desired.

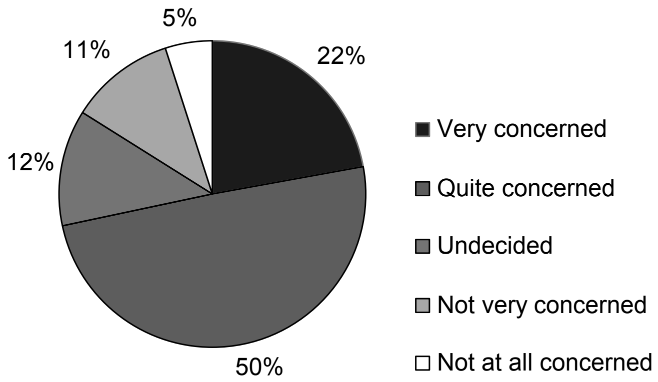

Fig. 1. Concerned about food safety?
Source: Food Safety Agency 2002

2.2.2 Danger of Bio-Terrorism

A then member of the US government Tommy Thompson, Secretary for Health and Human Services, said in a speech in 2004 that he was worried every single night that terrorists might attack the food supply chain. He added: "For the life of me, I cannot understand why the terrorists have not attacked our food supply, because it is so easy to do." (Globalpolicy.org 2004)

In the world after 9/11 the danger of bio-terrorism has been a much discussed issue. Although there have been no major attempts of using Bio-terrorism against the western world, it would be a mistake to dismiss the probability of the occurrence of such an attack as small, much in the same way as it was wrong not to consider the threat of using airliners as bombs before the attacks on Washington and New York in 2001.

Bio-terrorism will not be viewed in complete generality, but rather the possibility of an attack on the food chain. Thus, the "bio" in "bio-terrorism" is used here more in the sense of targeting the biological resources of society than in the usual sense of using biological pathogens. For an attack on the food supply can also be made using chemical materials like, for example dioxin or even using radioactive materials.

The notion that the danger of this sort of attack on the food supply chain may be a very immediate and devastating one has been backed by a recent analysis by Stanford University[1]. There, a scenario is created that involves the release of botulinum toxin – also known as botox – somewhere along the supply chain from the farms where the milk is produced to the consumer. A statistical model of the effects of the attack has been created that allows to vary the amount of toxin that

[1] Wein, Lawrence / Lui, Yifan (2005): "Analyzing a bioteror attack on the food supply: The case of bolulinom toxin in milk", Graduate School of Business and Institute for Computational and Mathematical Engineering, Stanford University.

has been used, the point at which it has been introduced, the time that was needed until the threat was detected and so on. Judging from this model, if such an attack would occur in the United States, even small quantities of botulinum toxin would suffice to kill a staggering amount of people. If – for example – 1 g was used by the terrorists, 100,000 of the affected 568,000 people would be likely to die. If they were to use one order of magnitude more, it would result in the majority of the effected people of just over half a million to die.

2.2.3 Current Monitoring and Legal Situation

The monitoring of the food supply chain is of course different from country to country and is currently developing at different paces and moves in slightly different directions. The situation in three different regions of jurisdiction (US, EU, Australia) will be explained in all brevity. These regions have been chosen because the EU and US have a huge amount of food products moving inside their borders and Australia uses a very modern system that even includes the use of RFID.

In the European Union numerous actions have been taken in response to the deficiencies that have become evident. In the course of this regulations are currently becoming more stringent and yet track & trace is still largely based on traditional paper-based approaches (Dairy Reporter 2004). With the release of Regulation No 178/2002[2] the European Food Safety Authority has been created to provide scientific counseling in the area of food safety. Along with it a program called "TRAde Control and Expert System" or TRACES for short has been set up to move away from the traditional paper based and country specific tracking of livestock by creating a central database for the movements of 50,000 cattle per day across the EU. Although also focused on the movement of animals, a system similar to or even built upon TRACES could be used as part of the proposed system that is to protect all of the food supply chain and not only the one concerned with live animals.

Australia's so called National Livestock Identification is one of the most modern systems for track & trace of live animals in the world. It requires cattle to be marked with an RFID tag located either in the ear or the rumen, which allows to trace back the movements of any cattle to its place of birth.

The system currently planned in the USA being called "National Animal Identification System" is "technology neutral", which means that some states in the US may choose RFID as the identification method while others decide to use retinal scans. This has several disadvantages the most prominent one is that it makes it harder for the system to be coherent on a national level.

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[2] Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January2002: "Laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety."

These efforts have to be recognized as steps in the right direction, but they are certainly not as far reaching as would be technologically possible. They are focused on the traceability of meat because of being mainly motivated by the BSE scare. A more all-encompassing approach is proposed in this report.

2.3 RFID Solution

2.3.1 Description of the Food Supply Chain

Before the setup of the system can be described, some attention has to be paid on the nature of the food supply chain. Crops, milk and the like are produced at farms, are collected by trucks, are transported to silos and are later shipped to processing plants. After the product has been finished and is packaged, it is transported to distributors who in turn send it to retailers. There the consumer buys the product and – most likely – consumes it. It is very similar with meat products, with the heightened complexity of animal transports before they are slaughtered in the abattoir.

2.3.2 RFID Enabled Seals

In all but the last mile of the food supply chain – from the farm to the distributor – food is transported in large homogeneous quantities, which is to say that a single truck carries about 5,500 gallons of milk and nothing else (Wein 2005, p. 1). This opens up the possibility of using RFID enabled seals to safeguard the integrity of the transported goods. These are active tags that are attached to sensors that can detect an opening of the container or tank that the food is transported in. The main advantage is that, should an illegitimate opening of the container or tank – including a possible tampering with the contents – have occurred, the RFID tag can raise an alarm at the destination, notifying the system of the danger. In the context of the Botox scenario that has already been mentioned this would rule out or greatly diminish the danger of terrorists contaminating the milk during the insecure transport between the different facilities.

An advantage of protecting these large quantities of goods is the ratio between the value of the goods transported and the money required for the RFID seal. Even the just mentioned truckload of milk, a very cheap product, is worth more than four thousand Euro[3], while the RFID tag including sensors will be available for less than € 100 and can be reused.

A feature that could be added to the seals are additional sensors that measure the temperature. RFID is already used for this purpose for example in a system from Syscan International. This feature can mainly be used to ensure that perishable goods that have to be kept cool, i. e. most foodstuff, is kept at the required level of

[3] Based on the assumptions that one litre of milk is worth .27 Euro (Wikipedia, Milch) and that one truck carries 5,500 gallons (Wein 2005)

temperature. If this is not the case, the quality and innocuousness of the food is no longer guaranteed and the RFID tag can give the appropriate signal to the system at the receiving facility.

Those systems at the receiving end of transportation have to be integrated in a central database that is preferably operated by a public organization, so as to ensure that warnings that are deployed by RFID enabled seals are in fact registered and not “swept under the carpet”.

2.3.3 Centralized Track & Trace System for Transport of Food

The current architectures using RFID in the context of food safety concentrate on tracking the movements of live animals until they are slaughtered. This makes it possible to find out where an infected animal is originating from and – if the system is flexible enough – which other animals it might have infected during its travels from place of birth to abattoir. With dropping costs for RFID tags and growing usage of RFID along the supply chain in general, it is feasible to also trace the movements of smaller quantities of products after they have been processed.

2.3.4 Fraud Prevention

Especially in the area of food, there seems to be a tendency of certain participants in the supply chain to try to act contrary to existing safety regulations. Had everyone followed regulations, BSE would not have spread to continental Europe to the extend that it did. The proposed system must therefore be fitted with good checking capabilities so that the produced data is as reliable as possible. It has to be made sure that the RFID tags are valid, i. e. that the goods they are physically located on are in fact what is described by the data they have encoded. To retain the advantage of automation that RFID promises, a validation system is needed that can in part also automate with little human help.

2.3.5 Upholding the Integrity of the Information

If the system is to gain trust among the consumers and the population in general, it has to work reliably and be fraud resistant. Measures have to be taken to guarantee that the information gathered by RFID are in fact valid. To this end different procedures can be used: When transporting larger quantities and active tags are used, they can be fitted with a program that allows them to be identified reliably, using asynchronous authentification[4]. Verifying the validity of passive tags is harder but also manageable. External characteristics of the tagged product can be stored in the database, in order to enable an inspection to cross check the information. A low tech approach for this is the use of scales, a more high tech and very promising one is the use of artificial peptides or dna-samples used as biological barcodes (Vernede 2003, p. 14)

[4] More information on this approach can be found in the "Consumer" section of this Trendreport

2.4 Scenario – The Cheeseburger

In the course of this scenario, the way the beef on a McDonald's cheeseburger takes from farm to fork is considered. Furthermore, the actions resulting from an infection of the cheese on the aforementioned burger are explained.

The meat from the special cheeseburger comes from a cow that lived in Bavaria, Germany. It was originally born in Beaupreau, France. There, immediately after birth it was provided with a RFID tag in a rumen bolus[5] by a veterinarian. When it was transported at the age of two years first to a market near Munich, then to a farm near Landsberg, Lech, Germany. At each stages of its travel (departure from farm, arrival at market, departure from market, arrival at farm) its RFID tag was read and its whereabouts were submitted to a central database run by the European Union. When it was slaughtered in an abattoir, this was also registered. The quarters of the cow were then also tagged using RFID and transported to a cold storage house. For the transport, an RFID enabled seal was located on the inside of the door of the refrigerated truck in order to notice any illegitimate opening of the door and any dangerous rise in temperature. After a short stay in the cold storage house the quarters were transported to a processing factory near Landsberg, where the typical hamburger pieces of beef were created. Those were put into a cardboard box, that was of course also equipped with an RFID tag. This box was then transported to the McDonald's restaurant in Oberschleissheim near Munich, where the tag was scanned and the data was sent to the McDonald's owned database.

Enter Peter, who is hungry. He orders the cheeseburger and gets one with the respective piece of beef. The beef is fine, but despite best efforts the cheese is contaminated with salmonellae. Peter cannot help but realize that something is wrong. He goes to a hospital, where the reason for his illness is found. The authorities are alarmed – in Germany that has to be done in case of an infection with Salmonellae[6] – upon which a query to the central database is made. It in turn queries the company database of McDonald's that specifies exactly where other slices of cheese that might also have been infected are transported to. Those are held back, are systematically tested and are destroyed. Since the information gathered by the RFID tags shows that the cooling has been continuous, the processing factory is isolated as the cause of the problem and improved hygienic measures are taken to prevent a recurrence of such an infection.

[5] A rumen bolus is a pill that is placed in one of the stomachs of a cow.

[6] Gesetz zu Verhütung und Bekämpfung von Infektionskrankheiten beim Menschen vom 20. Juli 2000 §7.

2.5 Applicability & Market

2.5.1 Impact of the Legal Framework

Usually the legal framework is considered a possible disabler for RFID based technologies because the regulatory bodies are slow to adapt to the new technology because of concerns about privacy for example. As far as food safety is concerned however, legislation is definitely an enabler for RFID technology. Fearing the costs of new a food crisis and the unrest they would cause in the population, both the United States and the European Union have recently passed laws setting the standards for traceability and transparency even higher.

2.5.2 Costs of the System

According to the Statistisches Bundesamt, the German state payed € 633 in 2000 for security per inhabitant. This includes expenses for the military, the police etc. This figure makes it clear that adding RFID tags to all food items solely for security reasons is not possible: In 2003 the German consumer used roughly 10% of his overall spendings on food and beverages (destatis 2003). For a person with expenses of € 10,000 per year this amounts to € 1,000, resulting from the purchase of an estimated 1,000 articles of food an beverages. Should an RFID tag be used for each of those articles, and if it is assumed (optimistically) that € 0.1 are needed for the physical tag and the facilities needed for tagging and tracking, the costs for food and beverages would rise by 10%[7], if the consumer had to leverage the additional costs. Should the state pay for the improved security, it would amount to over € 4 billion per year, which is a rise of 8% of the security budget.

These figures show that using RFID tags for track & trace at the last mile for security reasons only is very expensive, probably prohibitively so. However, since it is to be expected that the retailers will themselves introduce RFID tags for the articles they offer for sale in order to increase effectiveness, the possibility will arise to include those tags into the security infrastructure. It is therefore necessary to timely introduce regulations guaranteeing the interoperability of the retailers' RFID tagging scheme and the databases monitoring to movement of goods in the food sector. If this is achieved, the improved traceability on the last mile is achieved practically for free, comparatively speaking.

As far as tagging cattle with RFID is concerned, the US Animal Identification Plan (USAIP) is expected to cost $500 – $600 million to implement (Jones 2004). In Germany in 2003 there were about 15 million cows, 26 million pigs and 3 million sheep (Landwirtschaft in Zahlen 2003). If only the costs for tagging all of these are considered, it would amount to € 4.4 million – at a tag cost of € 0.1. Since only 4 million of the cows are dairy cows, the majority of these animals is used as a source for meat. Thus, the annual costs for tagging the newborn animals,

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[7] This is due to the additional cost of 100 Euro for the tags in relation to the overall spendings of 1,000 Euro.

replacing the slaughtered ones is not considerably smaller than the € 4 million needed to tag the initial farm animal population.

The cost for the overall system would of course be much higher than the cost of the actual tags. In order to ascertain the dimension of the cost, one can look over the Atlantic at the system currently planned in the US, the already mentioned USAIP. Although the persons in charge are still vague about the costs, it is estimated that $500 million to $600 million will be needed. TRACES, the European database for cattle movement will probably cost about € 138 million. Since only a very limited amount of goods is tracked with this system, the resources required to monitor all foodstuffs down to the box of Cornflakes, would be staggeringly high. This can be easily evaded however if the companies themselves are forced to track their products and provide the authorities with full access to them, in a time of crises or for inspection purposes.

2.5.3 Cost Reduction

Since it is impossible to foresee the magnitude of coming crises in the food supply chain, the costs of past ones can be evaluated and it can be considered if and to what extend an RFID based system might have helped to decrease those costs. It is also an option to imagine a scenario of a future crisis, perhaps involving a terrorist attack, and doing a similar check of the benefits and overall performance of such a system as far as the potential for cost reduction is concerned.

While setting up the proposed system will cost a large amount of money, the sum would be dwarfed by the costs future crisis are causing and certainly also by amount of money that would be saved as compared to having to deal with a crisis without the help of RFID.

When the foot & mouth disease broke out in the United Kingdom in 2001, 4,047,000 cattle had to be killed (Food Quality News 2005) , costing the British food industry about £2.4 billion (€3.5 billion). According to an inquiry by the US government, if a similar outbreak would happen in the United States of America, it might cause costs somewhere in the order of magnitude of US$ 30 billion (€25 billion).

The costs of crises such as the just mentioned outbreak of foot & mouth disease or of BSE is not only caused by the huge numbers of animals that have to be killed in order to contain the disease. Costs have also increased – to no small extent – by the loss of consumer confidence in general and especially in agricultural products. If the uncertainty is great enough, the former can even have an impact on the economy of the whole nation, and – should a country as influential as the US be affected – the global economy as well.

Should a terrorists introduce the disease or chemical agent, the destructive effect might be even greater since the terrorists would be behaving in a strategic manner in order to maximize the effect his tampering has.

In the case of such an attack on the food chain or in the event of a pandemic that spreads through this channel, a lot of people will be directly affected. In the scenario from Stanford half a million people are estimated. Even in the more optimistic sub-scenarios, where the amount of poison is low, half a million people are affected (Wein 2005). Considering that the number of hospital beds in Germany is currently at 553,000 (Wikipedia, Krankenhaus), one gets an impression of the difficulty and the cost such a large number of affected people would result in.

2.6 Spin-off Applications

In supermarkets in Japan it is already possible to use the camera of a mobile phone to scan the code of a product, submit it to a database and receive various information about the product, like origin, date of fabrication etc. With a system like the proposed one in place, the consumer can be very sure that the information he has received is correct due to the high fraud-resistance. Also the data quality can be higher, so that additional information like whether a vegetable product has been in contact with pesticides are available. The use of RFID readers that are likely to be deployed in mobile phones in the foreseeable future, makes it possible to scan the contents of the whole shopping cart all at once and for example check it if every item in it has been produced ecologically.

2.7 Conclusion

The appropriate use of RFID in the context of safeguarding the food supply chain is by any means an important step. Both companies and governments have to take additional steps to improve the integrity of the food supply chain. In order to combine higher security and greater effectiveness, RFID or a similar technology is inevitable in this area. With its bulk reading capabilities the net of checks and controls can be made much tighter. If, at the same time, the system itself is checked for possible fraud, it can really make a difference to mitigate the effects of crises or even prevent them from happening altogether.

3 Theft Prevention

3.1 Introduction

Theft is one of the most important issues, societies have to deal with, as it causes dramatic economic damages and endangers public safety. When talking about theft, one can differentiate between theft in companies and theft in private households. It is estimated that the theft of intellectual property alone accounted for $250 billion of damage in 2004, an alarming figure with tremendous economic impact (Fiutak 2004). John Ashcroft, the former *federal attorney general* of the United States of America, even calls for the “strongest, most aggressive legal assault against intellectual property crime” (Fiutak 2004), a statement that underlines how crucial the topic is. Furthermore, the German Federal Ministry of the Interior mentions 3 million thefts in Germany in 2004.

Because of the huge dimensions of theft, this report analyses to what extent RFID can be used in order to tackle theft. In doing so, it is focused on two fields with considerable economic impact, software piracy and car theft, which are described and analyzed in the following.

3.2 Software Copy Protection

3.2.1 Introduction

Today, one cannot imagine a world without computers. Some years ago, hardware was in the center of attention, as it was the key driver and the critical element for many applications. During that stage, software was often just an add-on to hardware and sometimes people did not even have to pay for it. The situation has changed dramatically since that time, so that hardware is not the critical point for many applications anymore. Furthermore, the hardware market has become extremely competitive, a fact that has let to small margins (Die Welt 2005). At the same time, software has become a very valuable good. Commercially packaged software had a total market size of $90 billion in 2004. Because of its high value and the fact that information is easily duplicated, software is very often illegally copied. Today, software piracy has a tremendous impact on economy. In 2004, 35 percent of software was illegally copied, which means in total figures that losses due to piracy increased from $29 billion in 2003 to $33 billion in 2004 (Business Software Alliance 2005, p. 9). The highest piracy rates occur in newly emerging markets such as China, with a piracy rate of 90 percent. Still, although the United States of America have the lowest piracy rate with 21 percent, this still implies losses of $6.65 billion a year (Business Software Alliance 2005, p. 5).

There are already numerous mechanisms on the market trying to prevent the copying of software, such as dongles or secret URLs, which could not effectively reduce software piracy.

For that reason a new technology which enhances software copy protection is needed. This section analyzes whether RFID is an appropriate technology able to reduce software piracy. The analysis will be done from a technical, legal and economic point of view.

3.2.2 Current Situation

Currently, all kinds of software, from business applications, operating systems to consumer software, are illegally copied. In numbers, this means that over one third or $33 billion of the software market were illegal copies in 2004 (Business Software Alliance 2005, p. 9). An alarming example is that there are more illegal copies of Microsoft products than open-source-software products on the market (heise Security 2004).

As the software market is growing, it is unlikely that the absolute figures of software piracy will decrease. On the contrary, forecasts project that software piracy will rise to $40 billion a year over the next five years (Business Software Alliance 2005, p. 4).

Today, most of the computer software is distributed in form of CDs or DVDs. One reason is that many applications and especially computer games need a lot of memory. As for many games the memory of a CD with a capacity of 700 MB is not sufficient anymore, DVDs are used instead. But even the memory of a current DVD is not big enough for all the data, leading to the development of new DVDs with a capacity up to 45 GB (Pilzweger 2005). As computer games become more and more realistic, this trend continues, meaning that additional data has to be stored. Today bandwidth is not big enough to transfer the data over the internet and even the memory of a usual hard disk is too small to store the data of several games.

For that reason computer games and other computer software with a high data volume will also be stored and distributed on DVDs in the future. As bandwidth is growing, it is likely that more and more software that does not need so much data will be downloaded directly over the internet by the user. However distribution over retail stores or supermarkets is very effective and customers are used to buy their software that way. In addition, many customers do not trust internet stores if they do not know the internet store or the software brand. This is not the case when software is bought physically. Beyond users often do not know what happens if they buy a new computer or have a complete system breakdown and fear their bought software is lost. This means that the market for direct downloads is growing, but only to a certain extent. The distribution of software on discs via stores will continue to dominate the market in the next decade.

Because of the high value of software, there are already many software protection mechanisms, but they have not been able to significantly reduce software piracy. Most of them are based on the licensing process of the software. Microsoft, for example, uses a product key for Windows XP, which has to be entered for the installation. After entering the product key, the user gets a hash code, called installation code, consisting of fifty numbers, which he then sends to Microsoft via internet or telephone to receive a confirmation code, also consisting of 50 digits (PC Welt.de). It is evident that this system is far from optimal regarding customer satisfaction. Additionally, the Windows user is allowed to register up to 100 times and after sending a copy of his license to Windows, he will be able to register again, which makes the procedure very ineffective as the user can install the software on many computers.

Besides licensing, serial numbers or CD-keys are used to prevent software piracy. When the user wants to install the software, he has to enter a valid serial number or the CD-key in order to be able to install the program on the computer. The serial number is verified by a special algorithm to avoid counterfeiting of keys. This approach is often cracked by warez communities[8], which publish valid serial numbers on the internet, so that basically everyone with access to the internet can use them for illegally copied software. Therefore serial numbers or CD-keys are not an effective software copy protection tool (DevGuy 2001).

[8] These communities breach the copyright often using the internet and illegally copy software.

Security Device

Security devices or dongles, as they are called colloquially, are a kind of software piracy prevention, which are commonly used for expensive software. As the RFID copy protection solution can be compared to a security device, the latter is described in more detail below.

A dongle is a small hardware device which must be connected to the computer when installing or using the software and is used like an authentication key. Today, dongles have a non-volatile memory, so that information, such as the license code, can be stored. Furthermore, key parts of the software are not on the CD or DVD anymore but on the dongle, which means that a dongle must be plugged in in order to use the software properly. This mechanism makes it much harder to copy software, as it is not sufficient to copy the CD or DVD anymore, but also the dongle has to be replaced, which is almost impossible. For that reason, cracks try to manipulate the operating system or the software. In order to prevent this, strong encryption mechanisms are built-in, which make it very difficult to manipulate the system (Wikipedia, Dongle).

Thus, security devices are very effective and it is unlikely that private users are able to crack it. However, security devices are actually not widely spread and that for a good reason. Firstly, the dongle might be lost. In that case, the software does not work or cannot be installed anymore on computers, which has the same effect like losing the CD or DVD. Because of this, customers disapprove to this technique. Secondly, in order to plug in the dongle a port is needed. This problem has been solved to some extent with the introduction of USB ports. The problem is that notebooks often have less than four USB ports and these few are already used for the PC mouse, a printer and other devices, which means that it is very uncomfortable to have a dongle occupying one USB port (Wikipedia, Dongle). The third, last and most important reason is the price. Security devices are only used for expensive software, not for the mainstream software market, because of the high price of dongles such as USB sticks. The security device vendor Matrix, for example, sells dongles for 9 Euro when over 10,000 pieces are bought.

Concluding one can say that security devices are a very effective technology, but costs are and will remain too high for a large part of the software on the market.

3.2.3 RFID Solution

Description

The RFID solution is based on a reader installed in the computer and a tag attached directly to the CD or DVD. This implies that, in order to copy a disc, not only the disc, but also the additional hardware has to be copied, making it much more difficult. The RFID copy protection acts like a security device, i. e. it is based on the CD or DVD and an additional hardware device. The big advantage of the RFID solution is that the hardware device is a small tag which is placed directly on the disc and cannot be lost. Furthermore, costs of that technology are very low so that it can be widely used even for very inexpensive software.

In order to use this technology, it is necessary that RFID readers are installed in computers. The question is whether there are any key drivers in favor of RFID, so that computers will be equipped with RFID readers. Today, the RFID technology is mainly used for business solutions, such as supply chain management or inventory management. As RFID is a very strong growing technology, it is likely that RFID will play a bigger role in private households in the near future. Companies in the telecommunication sector, for example, are already working on cell phones with an integrated RFID reader. This clearly shows the trend to employ RFID technology and that it is possible to integrate RFID readers in mobile devices from a technical point of view. As there are many possible new applications arising with RFID, there will also be demand for RFID readers in computers. Therefore it is very likely that future computers will already be equipped with an RFID reader, so that the RFID software copy protection can utilize these. If this should not be the case, the copy protection based on RFID can be regarded itself as a key driver for RFID readers, as software piracy will decrease sharply.

Unique Selling Proposition

As already mentioned, the software piracy rate was over one third in 2004 (Business Software Alliance 2004, p. 9), clearly proving that there is no really effective solution on the market which software companies all over the world could use in order to tackle that problem. The RFID software protection solution will not be able to reduce software piracy to zero, but it will make it much more difficult to copy software, leading to a decrease of piracy rates. Certainly, especially companies selling computer games will take advantage from that technology as games will be distributed physically on DVDs because of their need for large memory capacities and because of limited bandwidth. In addition to that, computer games are often illegally copied by teenagers that will not be able to overcome RFID based copy protection.

Additionally, the RFID solution is less expensive than a security device, so that companies distributing their software with dongles can cut costs. A dongle, when over 10,000 pieces are bought, costs approximately 9 Euro, a tag on the other hand costs less than 50 cent, resulting in a cost reduction of over 95 percent.

Beyond the RFID technology has advantages not only for software companies. Compared to other software protection mechanisms it also brings along more comfort for software users, as no product keys or serial numbers are needed anymore. The process of installing and registering Windows XP – typing in a product code, getting a hash code, contacting Microsoft in order to get the installation code- is superfluous. Furthermore, no security device is needed, what means that the user does not have to use additional hardware, that has to be taken care of. This is a big advantage as security devices can be lost, with the result that users cannot use or reinstall the software anymore. As the RFID tag is directly mounted on the CD or DVD, it is impossible to lose it.

Technical Aspects

In this section the technical aspects of the RFID software copy protection are described. First, the interaction of the tag and software, i. e. which information is transferred, is explained. Then the technical specifications are presented. After that the transformation phase, i. e. the phase of coexistence of old computers without RFID readers and new computers with RFID readers, is described.

Interaction of Hardware and Software

When the software disc is inserted into the CD-ROM drive, a signal containing the information that the disc is tagged, is sent out so that the system recognizes that information from the tag is needed in order to use the software. If this is the case, the RFID reader checks if the disc is tagged. If it is not, it is quite clear that the disc is an illegal copy and the user will not be able to use the software. As a key part of the software is stored on the tag, cracks cannot just manipulate the operating system or the software. Furthermore, strong encryption algorithms are used which prevent that information is read from the tag in order to copy it. In the next step, the authentication key is read from the tag and compared with the software key. If they do not match, the installation process and the game are interrupted respectively. If the keys match, the copyright management is initiated. The tag stores the type of license that the user bought, i. e. how many installations are allowed on how many systems and how many of installations have already been done. The system can then check if an installation is allowed on the computer, according to the license. Next to the installation of the program, the information, i. e. computer identification key and number of installations, is encoded on the tag. A user has, for example, just a license for installing the program on one computer. After installing it on his home computer, the computer identification key, and the number of installations is stored on the tag, so that he cannot install the software on a friend's computer, too. If the user wants to install the software on a new computer, he has to uninstall the software on his old computer first. The copyright settings will be changed, so that the software can be installed on a different computer.

Tag

The tag is directly placed on the disc or even integrated in the disc, so that it cannot be removed. In the latter case, the user will even not visibly notice the tag. For this application a passive tag is used, requiring no energy source, so that there are no energy restrictions. Furthermore, the tag must be programmable in order to modify the settings, such as the computer authentication key. As data is transferred, it is crucial that the data is encrypted. Therefore strong security algorithms are used, which prevent that someone can read out the tag and manipulate the system or copy the tag.

Different information has to be retained on the tag. First of all, a unique authentication code has to be stored, which is necessary in order to check if it is the right tag for the disc and the software, so that it is not possible to place the tag on other discs. In addition to that, an essential software part, which is necessary for the software installation and for playing the game respectively, is stored on the tag. This mechanism makes it impossible to use a copy of the software just by copying the disc and then by manipulating the authentication code. To manage the copyright issue, the license and therefore the number of installations allowed is stored on the tag. That way software companies have the control over how often the user can install a program, according to the license he bought. In order to increase this number the user has to uninstall the program. In that case the number is increased by one. If the computer software is bought by a company which wants to install the software on its network, the information about the license is sufficient. For private use, a unique computer identification key is created, based on the computer hardware, which clearly identifies the computer. This identification key is stored on the tag, so that the user can reinstall the software if the hard disk is deleted or the operating system reinstalled.

Reader

In order to use the RFID software copy protection it is necessary to integrate an RFID reader into the computer. This RFID reader has to fulfill some requirements, otherwise the technology will not be successful.

As the RFID reader will be integrated into the computer, which can be a notebook, size is a critical factor. However, there already exist very small RFID readers. One reader from Texas Instruments, for example, has the following size specifications: 3.8cm x 2.8cm x 1.3cm. Furthermore, it can be assumed that the size of RFID readers will decrease over the next five years, so that integration in computers will be unproblematic. For the purpose of software copy protection, a short reading range of up to 20cm is sufficient. Still, it is likely that RFID readers with a wider range will be used in order to use the reader for other applications as well. Another important characteristic is the energy consumption of the reader, which must be very low. Producers of RFID readers are well aware of this fact and are constructing readers with low consumption rates. In the next years this trend will even be enforced, as RFID readers will be more and more integrated in mobile devices.

Beyond this, it is crucial that RFID readers are inexpensive, as users are not willing to pay for software protection. Today, there are already readers for approximately $110, for example from Texas Instruments. Buying these in big volumes will lead to decreasing prices. In addition to that, using RFID for software protection will lead to high volumes which bring about scale effects and learning effects, with impact on prices. Assuming that prices decrease by 25 percent a year, RFID readers will cost $10 in eight years.

Transformation Phase

The RFID software protection solution is based on a tag and a reader that interact. Without one of these two components, the new software protection will not work. Integrating tags in discs or simply tagging discs is not the critical factor. This is rather the integration of RFID readers in computers as the RFID solution does not work without them. The transformation phase is the time slide when computers with and without RFID readers coexist. First, most computers will not have RFID readers built in. The amount of computers with an RFID reader will increase steadily until every computer is able of handling RFID technology. Therefore, two scenarios are possible, depending on the decisions of software companies. On the on hand, they could wait until every computer is equipped with an RFID reader, which would solve the problem. On the other hand, software companies might introduce the RFID software protection technology at an earlier stage. This is the more likely scenario, as the technology is already available and software piracy is a huge issue. In that case, software companies will not want to sell their software on tagged discs only, as many customers would not be able to use it. For that reason, software companies are recommended to sell standard products, such as MS Office, with the old and new copy protection, i. e. when using the software, the systems check if the computer has an RFID reader. If not, the current software protection is used. Otherwise the new RFID based solution is applied. Innovative products, such as new operating systems or software games should be sold only with the RFID protection solution in order to push that technology.

Legal Aspects

Every country has its own laws and regulations. However, it can be seen that, because of globalization, most countries, especially industrialized, passed similar copyright laws. This let to resembling laws in Europe for example. In contrast to this, there are still huge problems in emerging markets, where copyright is just developing. Thus, the German legislation concerning the copyright law is described in more detail first. Afterwards, the copyright in emerging markets is shortly analyzed.

One has to state that under the terms of §1 patent law software programs cannot be patented, as they are not based on technical cognition (Wikipedia, Softwarepatent). In order to protect software against piracy, the copyright law is used, which copyrights computer programs.[9] The copyright law protects the copyright holder's interests, i. e. the interests of the software companies, by securing them the exploitation right and the right of use.[10] This means that the copyright holder must agree to a copy. Thus, it is not allowed to copy software without prior agreement of the software company. The only exceptions are, if a copy is needed in the main memory for conventional use, a copy for observation or tests. Furthermore the user may generate one single backup.[11]

[9] According to §2 para. 1 Copyright law.

[10] §§ 15 et seqq., 31 et seqq. Copyright law.

[11] Under the terms of §69 d para. 3 Copyright law.

In addition to that, the software companies are allowed to determine the scope, the content and the duration of the right of use.[12] By this law, companies have the right to license their software, i. e. they may sell limited rights of use. Today, this method is quite common. Users are allowed, for example, to install the software on one computer only. They may not use the software on another computer, such as a notebook, even if the user is the same person.

When changing hardware and that also means the whole computer, the user must still be able to use the acquired software on the new computer.[13] With existing software protection solutions it is not possible to handle this from a legal point of view, because software companies cannot check if the user uninstalled the program on his former computer. With the RFID based solution this will be possible, as the necessary information is stored on the tag.

The next question is whether the user is allowed to evade the RFID software copy protection. §95 a et seqq. Copr. clearly states that it is forbidden to evade any technical measures, such as security devices, which copyright the software. Any action taken against the RFID solution is therefore antinomian. When implementing technical measures against software piracy, the software company has just to ensure that an allowed use of the software is not barred.

This clearly states that companies are allowed to protect their software from a legal perspective. In contrast to industrialized countries others do not ensure the implementation of copyright. Especially in emerging markets, where software piracy is around 90 percent and the demand for software growing above-average, there is need for law and regulations. Some of these countries pass new laws concerning copyright, but legislation is still vague (IT Vietnam 2002). This implies that software companies cannot protect their products by law, but they have to develop technical barriers. It is questionable if the RFID software protection can handle this, as there are many IT specialists in these countries. However, the RFID technology makes it much more difficult to copy software because of its complexity, which will at least prevent people with an average knowledge in information technology from copying software

Business Implications

When talking about the market, one has to consider whether the RFID based technology can be realized from an economic point of view. At the moment, no computers have RFID readers and discs are not equipped with tags. In order to be able to integrate these two essential components, computer and disc manufacturers would have to invest in their production facilities and to integrate the RFID components. The question is who will pay for this technology, what kind of drivers exist and if a win-win-situation for all involved parties is achievable.

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[12] §§31 et seqq. Copyright law.

[13] OLG Frankfurt (CR 2000, 146).

Cost and Benefit Analysis

First, the costs and benefits of the RFID software solution are calculated for the German market in Table 1 in order to get a feeling for the dimensions. Some assumptions, as described below, had to be made.

In 2004, Germany had a piracy rate of 30 percent, in terms of losses $1.899 billion. It is assumed that software piracy will also increase in Germany from today $1,899 billion to $2,279 billion over next five years. [14]

Furthermore, it is assumed that the RFID software protection will decrease software piracy by 13 percent in the first year after its introduction. Because of the short life cycle of computers and software, the reduction curve has bounded growth with an upper limit of 20 percent, i. e. the marginal rate of reduction is decreasing. As it is not likely that software sales will increase by the same amount as software piracy decreases, it is assumed that software sales will increase by $0.2 for a $1-decrease of software piracy. In 2003, 36.5 million software products and 3.24 million personal computers for private households have been sold in Germany (GfK Panel Services Consumer Research GmbH 2004, p. 2). This study estimates an increase of up to 40 million software products sold in 2010, as the market is growing at a rate of less than 5 percent in developed countries (Business Software Alliance 2004, p. 4) and then keeps personal computer sales constant.

In order to calculate the total costs, the costs are split into two categories, tags and readers. The costs for tags compromise the costs for the tags themselves, the costs for tagging discs and the conversion of the disc production. Analogous to this, the costs for readers compromise the costs for the readers themselves, the costs for integrating readers in computers and the conversion of the computer production. Today, a passive non-programmable tag costs just about 20 cent. Alien Technology, a tag manufacturer, believes that the prices for the best customers will decrease from today 20 cent to almost 5 cent with new production lines (Economist 2004). However, the prices for programmable tags are higher and the RFID software copy protection solution needs memory in order to store the information. For this reason, the costs for the needed tags are much higher than for non-programmable tags. It is estimated that these tags will cost 50 cent in 2008 and then continuously decrease to 20 cent per tag in 2012. After that, prices are kept constant for the calculations. Furthermore it is assumed that tagging discs costs 1 cent, as discs cost around 20 cent in a retail store. The costs for building a new disc factory are about € 100 million (Heise News 2004), so that for both conversion of the disc and computer production $5 million are calculated. These figures are very high compared to the total costs of building up a disc factory, as this report does not want to influence the calculations in favor of the RFID based software protection. RFID readers are already sold for $110 by Texas Instruments. As RFID readers are a commodity, it is estimated that because of market power and a

[14] Software piracy made up $33 billion in total in 2004 and will even increase to $40 billion until 2010 (Business Software Alliance 2004, p. 4).

yearly price reduction of 25 percent, common for computer hardware, prices will decrease to $10 over eight years. As integrating RFID readers in computers is not a difficult process, it is assumed that costs for this process are $1 per computer. Based on these assumptions, one can calculate the cash flow for the RFID solution, as shown in Table 1. With these cash flows and the weighted average cost of capital (WACC) of 11 percent, which is the average of the software sector (Rohde 2002), it is possible to calculate the net present value for the RFID software protection. As can be seen in Table 1, costs are still too high in the next 4 years, which results in a negative net present value. However, costs will decrease considerably, leading to a positive net present value by the year 2010 (Table 1). This means that an investment into the RFID-based solution would create value for the companies and should therefore be undertaken.

Table 1. Calculations of costs and returns of the RFID software copy protection solution for the German market

Calculation for Germany	2008	2009	2010	2011	2012
Losses due to piracy in $mln	2145.00	2210.00	2279.00	2279.00	2279.00
Decrease of piracy in%	13.00%	17.00%	18.00%	19.00%	20.00%
Decrease of piracy $mln	278.85	375.70	410.22	433.01	455.80
Purchase of new products in $mln	55.77	75.14	82.04	86.60	91.16
Purchased products in mln pieces	38.00	39.00	40.00	40.00	40.00
Costs for one tag in $	0.40	0.30	0.23	0.20	0.20
Costs for tags in $mln	19.00	11.70	9.00	8.00	8.00
Costs for tagging discs in $mln	0.38	0.39	0.40	0.40	0.40
Sold computers in mln pieces	5.00	5.00	5.00	5.00	5.00
Costs for one reader in $	34.00	25.00	19.00	14.00	10.00
Costs for readers in $mln	170.00	125.00	95.00	70.00	50.00
Costs for integrating readers in $mln	5.00	5.00	5.00	5.00	5.00
Costs for conversion of disc production in $mln	5.00	0.00	0.00	0.00	0.00
Costs for conversion of computer production in $mln	5.00	0.00	0.00	0.00	0.00
Total savings in $mln	-148.61	-66.95	-27.36	3.20	27.76

Source: Own analysis

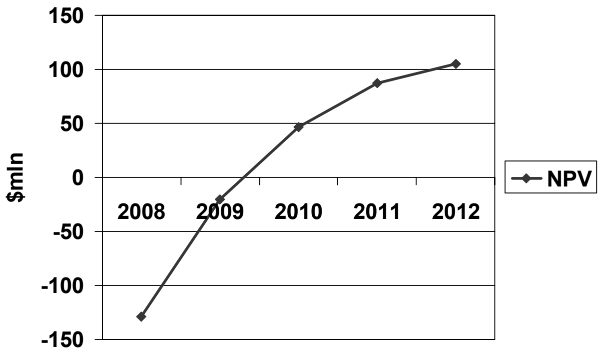

Fig. 2. Net present value of the RFID software copy protection solution for the German market[15]

Source: Own analysis

Market Drivers

In order to convince disc manufacturers to integrate tags on their discs, a software company would need a lot of market power and have to set up contracts to sell their software on these discs only. Otherwise, disc manufacturers would probably not invest. The question whether it is necessary for software companies to build up their own software protection tools would have to be settled, which has not been done at this moment. As companies cannot differentiate by software protection it is not a core competence. Furthermore, no companies have considerably higher competences in the field of software protection in comparison to other companies, so that outsourcing is a possible option. For that reason, a joint venture of well established software companies which concentrates on software protection is recommended. This would have a lot of advantages which are described below.

A joint venture has much more market power than one single software company, thus it could negotiate with disc manufacturers to integrate RFID tags on or even inside discs. These disc manufacturers would be much more willing to tag discs when they identify a larger market and a stable demand. Furthermore, RFID software protection could become a standard if several companies agree on this solution, so that it can be used on every computer. A standard also implies high volumes and therefore scale effects, which lead to decreasing costs in software protection. Software companies can save on expenditures since costs for buying the RFID software protection will be less than the costs for an in-house development.

The next question is whether there is a possible win-win situation for all companies concerned, i. e. software companies, disc and computer manufacturers and RFID vendors.

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[15] Every net present value is calculated for a time period of ten years.

The RFID-based software protection solution will lead to a decrease in software piracy and therefore software sales will increase. Software companies will have higher returns and for that reason more profits. On the other hand, the question arises on who bears the costs for this solution and whether there are any further benefits for the involved players. The key for this is if the customer, i. e. the buyer of a computer, wants RFID equipped computers and if he is willing to pay for it. As there will be many applications based on RFID for private households in the future, such as a kind of private inventory management, it is likely that there will be demand for computers with RFID inside. One indication for this is that companies are already developing cell phones equipped with RFID readers. If customers themselves demand for RFID, this would enhance the RFID software protection dramatically as the main cost factor would drop out. In that scenario it would be the case that at the beginning RFID equipped computers would be sold more than computers without RFID technology, at higher prices. Consequently, not only software companies gain profit from RFID, but also computer manufacturers, as they can differentiate by RFID, which can imply higher returns or higher margins. This will not be long-lasting because of the relatively small investment for the conversion of production.

The RFID-based software protection would be a key driver for the RFID hardware market, i. e. tags and readers, and lead to a sharp increase in RFID sales. For that reason, RFID vendors could sell more RFID hardware and returns would increase. Thus, RFID hardware vendors can be regarded as clear winners of an RFID software protection. It is presumed that it is problematic to differentiate for disc manufacturers by RFID, as they only tag discs and have no further functions in the value chain. One can see that a situation where the customer demands for RFID- equipped computers would be best for all companies concerned. It is therefore recommended that companies should market RFID positively and try to push the technology.

If the end customer is not interested in RFID, other drivers for the RFID software protection are necessary. As the calculations clearly showed that software companies will benefit from the RFID solution even if they pay for the RFID readers, software companies should be eager to push RFID. For that reason, it is recommended that the above mentioned joint venture or one powerful market player should cooperate with computer manufacturers in order to convince them to integrate RFID readers. One possible scenario could be that software companies sell special versions of software on tagged discs only, so that end customers are motivated to ask for RFID-equipped computers. So it can be said that in the case that end customers do not demand themselves for RFID in computers, software companies, in the form of a joint venture for example, have to actively promote and boost RFID equipped computers.

To summarize, it can be said that a win-win situation can arise for software companies and RFID vendors. Computer manufactures can definitely benefit at the beginning. When RFID readers become a standard in computer equipment, computer manufacturers will not benefit anymore by implementing RFID. Disc manufacturers will neither win nor lose by implementing RFID.

3.2.4 Conclusion

There are already many existing solutions on the market which try to prevent software piracy more or less successfully. If there were no software protection mechanisms at all, one can imagine that the effect of software piracy would be much worse and some companies could even not exist because of missing returns. However, it seems that current solutions cannot handle software piracy in terms of reducing it dramatically. According to the Business Software Alliance, the damage caused by software piracy will even grow over the next years. In this context it could be shown that RFID is an enabler for a new software protection solution consisting of the two hardware components tag and reader. The tag is essentially needed for the copyright management, as all the information concerning copyright is stored on it using strong encryption algorithms. It is therefore much more difficult to crack the software protection and to copy software illegally. Even if an RFID-based solution will not stop software piracy, the calculations revealed that a decrease of 20 percent in software piracy in connection with a simultaneous increase in software sales by 20 percent would already be sufficient to justify an investment in the RFID-based solution as the net present value would be positive. Nevertheless this investment should not be undertaken before 2010, as convenient tags do not exist at present and costs for RFID are still too high. When prices decrease, software companies should promote the technology and invest in it as they will be the main beneficiaries.

3.3 Car Tracking

3.3.1 Introduction

Car theft is nearly as old as the car itself and assumed alarming proportions with the emergence of organized car theft criminality. Simultaneously with the technical development of the vehicles, the security mechanisms for cars improved, leading to a permanent decrease of the theft rate in the last ten years. Nevertheless, since the total number of registered cars has increased every year, the actual number of stolen cars still remains high.

In 2004 there were 58,937 cars stolen in Germany (BMI 2005). In 2003, more than 280,000 cars were purloined in the UK (The Home Office 2005). In 2002 the total number of stolen cars in the US exceeded 1.2 million; statistically there happens one theft every 27 seconds. With a damage of \$8.6 billion, car theft became the most harmful crime on personal property in the US (FBI 2003).

Most of the cars are stolen in cities with more than 500,000 residents and during the night hours. Also fact, the thieves do not only aim for exclusive upper class cars, middle and even lower class cars appear in the statistics as well (MDR 2005). The actual number of stolen VW for example, was twice the amount of stolen BMW and around three times of stolen Mercedes in the German theft statistic of 2003 (GDV 2004). Admittedly, there exist a lot more VW on the streets than

BMW or Mercedes. It also showed up that eight year old cars are stolen more likely than new ones.

If the vehicle does not appear within the next days the chances to get it back drop dramatically. Especially in Europe with its open borders, the cars can be brought to other countries within hours. Once the car left the country its recovery is very hard. This also is confirmed by the fact that only in about 40% of the cases in Germany the cars can be retrieved (BKA 2004) while the rate in the US is at 65% (FBI 2003). In Russia for example, the police detects many stolen cars from Germany and also reports this via Interpol. Due to legal conflicts between criminal and civil law the official channel is blocked and the car owners wait vainly (Köhler and Staubach 2002).

There are several systems – using different technologies – on the market, which try more or less successfully to address this problem. In the following will be analyzed, how a RFID solution could look like, where its strengths and weaknesses are and under which circumstances an implementation would be expedient from the economical point of view.

3.3.2 Current Situation

RFID in Car Alarm Systems

There exist numberless alarm systems on today's market. Most of them aim for theft prevention like the steering wheel lock, the ignition protection or the glass breakage detector. Mainly the electronic immobilizer system stood the test of time. The number of vehicle thefts decreased in Germany by three-fourths compared to 1993 (BMI 2005), what experts ascribe basically to the launch of the electronic immobilizer.

Especially some of the newer systems rely on RFID technique. Very popular is the usage of a Digital Signature Transponder (DST). Developed by Texas Instruments, more than 150 million vehicle immobilizer keys are already in use worldwide. These passive low-frequency RFID transponders use a 40 bit cryptographic key, to authenticate themselves to the corresponding reader in the car. The ignition system will only work after a successful authentication of the correct transponder (Bono et al. 2005).

C-Chip Technologies for example developed Theftstopper1, where three RFID readers are connected to different units of the car. The car will only start if each reader verified the key, what makes it three times harder for thieves to override the system (Swedberg 2005).

However, a team from the Johns Hopkins University and the RSA Laboratories in the USA found a method, to easily hack a DST system. They achieved to crack five customary DST keys within only 2 hours (Bono et al. 2005).

The biggest disadvantage of all these alarm systems is, once they have been overridden the car is lost. Especially for professional thieves this does not raise any problems. Systematically they burgle garages, inside they are the whole night undisturbed and can hack the alarm system. Even more mean are the cases, were thieves first broke into the house to steal the car key. With the original key there was no further need to hack any alarm system. To improve the chances of retrieving a car once it has been stolen, the application of car tracking systems is suitable.

Review of Car Tracking Systems on the Market

Car tracking systems can be seen as kind of post-theft protection systems, complementary to the theft-prevention systems. There are already several solutions for car tracking systems available on the market. A significant characteristic of all of them is, similar to a mobile phone, these car tracking systems consist always of two parts. One part is the hardware implemented within the car. The other part is the surveillance and tracking network of a security provider.

In Austria, A1 and the ÖAMTC offer a system called A1 Carfinder. A unit with a sim card is installed within the car. In activating the system when leaving the car, the vehicle can be monitored over the mobile network. Via cell positioning the system can detect whenever the car starts to move. In this case, the ÖAMTC control center as well as the car owner will be alerted and can take appropriate actions, for example a remote controlled engine blockade. With an emergence button, the ÖAMTC could be also called in case of a breakdown, mugging or an accident. An upgrade with a GPS unit enables also the localization of the automobile in a foreign European country (ÖAMTC 2003).

There are several systems using the GPS system like Onstar, ResQ or NetworkCar. Actually the Global Positioning System, abbreviated with GPS, was developed to get one's own position but not to locate remote objects. First it requires a huge onboard unit which is hard to hide and second, objects are invisible for the system when they are hidden behind thick walls of concrete, for example in a underground parking lot. Moreover the units are quite expensive. Due to these reasons GPS is not really practical as a tracking system.

Another system using the cellular telecommunication network is Boomerang2, the advanced version of Boomerang. Provided by Boomerang Tracking Inc. in Montreal, this system covers North America and can locate a car even "in underground parking lots and shipping containers" (BoT).

One problem all these systems have in common, it might be possible for a thief to bypass them if he is undisturbed long enough. Of course, when the system is shut down, the car will be invisible and the surveillance network will give alarm, but until someone would reach the car's last location it might be already miles away.

The only way to detect a car with an off-state alarm system is to check whether it has a proper running onboard system. This requires on the other side that each licensed car is equipped with such a system.

The United Arab Emirates plan to establish a total traffic monitoring system. They commissioned IBM to develop a telematics system using GPS, GPRS, GSM, Bluetooth and RFID features. In the first instance the government hopes to decrease the high death rate in the traffic. Their idea will be barely put through in other countries since it represents the total surveillance of the motorists. Starting with a driver verification via a RFID tagged driver license, the car will be permanently speed controlled. The data from the vehicles will be stored and analyzed by the public authorities (Heise 2005). Especially the latter issue would scare up privacy activists in most other countries. Therefore it might be already hard to find a legal platform to track a local car in a foreign country. Moreover the system would be too expensive to supply a larger range of coverage. As a result of this it would not be interesting for bigger countries.

A lot cheaper would be the concept proposed from the Bavarian ministry for the interior. A video based auto recognition system identifies the license plate number of the vehicle and verifies it with a database. Indeed, first tests with the system lead already to achievements in the fight against crime (BSTMI 2002, BSTMI 2003 and BSTMI 2004). The grave disadvantage of the system, it simply can be bypassed by changing the license plate of the car.

To summarize, all the above presented systems have their positive and negative aspects. However, none of them is consummate. In order to really improve the car theft situation, a system is required what comprehends those advantages and at least minimizes the disadvantages.

3.3.3 RFID Solution

Description

In contrast to the existing theft prevention applications, RFID is here considered to be used in a post-theft protection system. The car tracking solution described in the following has to fulfill three main issues. First, it must be possible to detect a deactivation of the system; therefore it needs to be implemented in every vehicle on the road. In this case every automobile without working system would be suspicious. Second, for the first point to be feasible, the costs drawn on every car owner have to be low. Finally it has to handle the privacy issues, that means the risk of data abuse has to be minimized.

In order to ensure that every registered car is visible for the system, it needs to be forced by law that every owner has to equip his automobile with the according devices. Furthermore, check points will be installed throughout the road network and especially near borders. Whenever a car passes such a check point, its vehicle identification number (VIN) will be read out and matched with a central car-tracing database. This database contains all reported cases, including stolen and suppressed vehicles and cars from suspicious persons. If there is a matching with the car at the check point and an entry in the database, an alarm will pop up in the police control center from where the actions needed can be taken. If a suspicious car has been located on a freeway for example, the next police patrol a few kilometers further has just to watch for it and to stop it. The car driver himself will not realize anything of the whole process, until he sees the red stop signal in front of him.

Technical Implementation

As already mentioned, the system is based on RFID technology. The idea is to equip every registered vehicle with a RFID tag, on which its VIN number is stored. Every year around 225,000 stolen cars get a fake VIN (FBI 2003), this is a lot more complicated when the tag has to be counterfeited as well. In order to read out the VINs, readers are installed at the check points. These readers permanently read the VIN from each passing car and transmit it over a mobile network (GSM) to the next police control center, where it will be matched with the central database. From the technical view, the system can be partitioned into two parts. First the RFID part, which comprises the reader – tag system and second the network part, which controls the transmission and the processing of the VINs.

2,450 MHz RFID

For this application the 2,450 MHz frequency (microwave) RFID is excellently qualified. First of all this frequency band is licensed for RFID use in all industrial nations throughout America, Europe and Asia. So it can be used in all these markets. From the technical side, there are several attributes militating for its implementation.

Most important are reading range and passage speed, since the system has to cover multilane freeways with fast passing cars. Microwave systems can operate at a passage speed of up to 400 km/h, what would be even enough to track a formula 1 car. Passive tags have a reading range up to 12 meters, active tags could go even beyond 30 meters (AIM 2000). The disadvantages of active tags are their costs and their economic life-time. Since they require an onboard battery, their durability is receding every time they are read out. The reading range for passive tags can not cover a whole freeway, but by multi reader installations on both sides and additionally on the central reserve this problem can be solved easily. The additional reader costs pay off very quickly due to the cheaper tags.

The system does not require a direct line of sight and it is able to read out tags independently from their orientation. This makes it possible to install the tag with arbitrary alignment at any place within the car. In using procedures to handle multiple access, it is no problem to read 20 or even more tags simultaneously (AIM 2000). Another feature is the directional reading capability of the readers which has two positive aspects. First it avoids interference problems with other readers, second it allows a well-defined observation area. The latter enables for example the monitoring of only one driving direction at a freeway. This would provide the additional information of the moving direction of the car, besides its location.

Further positive aspects of a 2.45GHz system is its good resistance against dirt and moreover its excellent behavior in a metallic environment.

The small size of the tags is also a favorable feature, so they can be hidden within the car very well. The antenna is the most spacious part of the tag, but it only requires space in one dimension. Therefore the tags can be very thin with a length of 2 to 10 cm.

Another issue concerns the read-write characteristic of the tags. Rewritable tags are of course out of question to circumvent any manipulation of the system. Thus remain two possibilities for read-only solutions. One is, to implement factory programmed tags. That means, the tags would already be written with the data at the RFID manufacturer. From there, the tags have to be carried to the car manufacturer where they are installed in the corresponding vehicle. The other option is to use one time field programmable (OTP) tags, which can be uniquely recorded at the car manufacturer. Their advantage is that they require less logistical effort, since factory programmed tags have the constraint, to have the right tag at the right time at the right place.

No problems occur concerning limitations on electromagnetic fields or radiation power. All actual standards and regulations have no influence on the system performance, since its values are below the limits.

Since the memory size is huge (some tags can already store 256 byte) compared to some low frequency tags, more complex cryptographic procedures can be used. Instead of using a key length of only 40 bit (like the DST system), a key length of 512 or 1024 bit could be used for example. The only constraint is given by the reading time, since a longer key would also need more time to be read out. This has to be considered with respect to the passage speed.

Network

After reading out a VIN, the reader will transmit it over the GSM network to the next police control center. The data is transmitted secure, since the GSM system uses good protection mechanisms. An alarm software will transmit the VIN over the internet to the central car-tracing database. This database contains comprehensive information about all suspect vehicles involved in any registered crime. It is important to point out, that this database is not identical with the central vehicle register, where all nationwide licensed automobiles are listed. This is very significant when considering the legal aspects of the system.

A search algorithm looks for matching entries within the database, and sends the resulting information back to the alarm software. In the case, no matching entry to the VIN could be found, the alarm software will immediately delete the VIN. On the other hand, if an entry has been detected, an alarm will pop up in the surveillance center. This alarm contains besides the complete case information, also the reader ID from where the VIN has been received. The current location of the vehicle can be determined via this ID and the operator in the surveillance center can take the appropriate actions.

In order to detect also those cars where the tag has been removed or destroyed, two proceedings are applicable. First, readers will be installed next to monitoring cameras. The camera can identify passing cars in using object tracking video technologies. A permanent matching between reader and camera reveals, whenever a car is passing without a working RFID tag. In this case the camera data will be sent to the police center where a manual check of the license plate number can be done. In order to really know which car is affected, the directional reading characteristic of the reader is used and the field of vision of the camera will be limited respectively. The other proceeding is to equip the police patrols with hand-held readers. By pointing with the reader towards the car, the tag can be checked and also read out. This could be combined with common speed controls.

Admittedly, this still leaves a small chance for thieves since they might be lucky and do not pass one of these check points. Nevertheless it is a significant improvement compared to the other systems. A manipulated car can not be used within the covered area – in general a country – since it might be detected every moment. Therefore it has to be brought to a foreign state what can be antagonized by stronger controls throughout the borderland. Since a tag can also be broken due to technical reasons, the owner of a car where the suspicion has not been confirmed would be informed and get a time limit to fix the tag. To ensure the latter, the VIN of the car is stored in the database and will be deleted the next time when it has been located by a reader. However, due to tag life-times of about 10 years this will be rather an exception.

Legal and Social Aspects

Legal Aspects

The presented car tracking system has a crucial aspect. It affects every car owner, no matter if he is involved in any crime or if he is unsuspicious. This results in a lot of explosive issues concerning social and legal matters. The underlying problem is, whether the protection of the rights of uninvolved individuals is assured or not. The permanent technical progress continuously offers new opportunities to face given problems, but there is a need to clarify thoroughly the impact on human and individual rights.

Already the required matching of the car number with the vehicle database yields an intrusion into the right of informational self-determination.[16] Since the system is hidden and the readers are disguised, the individual can not realize when and where he has been inspected. On the one hand this fact is essential to make a circumvention of the system harder. On the other hand, it is not possible for the checked person to verify afterwards the legitimacy of the procedure. This intrusion is inevitable and is one of the concessions which are implied with an increase in public safety.

Another problem is the construction of a movement profile, by connecting all the points where an object has been tracked. It is desirable for criminals but a horror scenario for innocent persons. Such a movement profile would be a massive intrusion into the basic rights of physical and spatial liberty of action and

[16] The right of informational self-determination states the right of each individual person, to determine the processing and the usage of his own data.

freedom.[17] This would not be acceptable for Germany and also not in comparable democracies in the world. As a consequence, it has to be ensured that the VINs of unsuspicious vehicles are deleted immediately after the examination. Due to technical issues, *immediately* would mean in this case within a few minutes. However, as long as the information is deleted before the car passes the next reader, a reconstruction of its route is impossible. In the extreme case of 5 minutes deletion delay and a car speed of 240 km/h, it would be sufficient if the readers are installed at a mutual distance of 20 km. This is definitely enough to still enable an in-depth coverage of the road network.

The fact that the locations of the readers would not be limited to criminal affected areas but can be anywhere at every street, generates an offence against the certainty percept (Weichert 2005).[18] There is no explicit demand for an offence and the car owner can not identify where and under which circumstances he might be tracked. This issue can not be avoided for reasons of system circumvention as already mentioned above. Therefore it would be necessary to find a legal solution which permits this offence for the given exception.

Another point is to determine which forms of crimes should be registered in the car-tracing database. Besides stolen cars it would be also applicable to register cars which were involved in raids or any other delict. More problematic is an inclusion of administrative offences like overstepping of speed limits. The recording of such a bagatelle delict is for example designated in the planned video recognition system of the Bavarian ministry for the interior (Weichert 2005).[19] This brings up various contentious issues and encounters strong resistance, especially because it could affect half of all car drivers.

However, even when all national aspects and legal problems are solved there is still a demand to rule international data transfer. To antagonize international criminality it is essential to track vehicles beyond borders. Problematic is, when the other country does not fulfill the same privacy standards which apply at home. Therefore, carefully agreements have to be made, which define the exposure of the data to another country. Furthermore, the own police officers need explicit instructions in which cases a data forwarding is permitted and when not.

Even between the western democratic countries in the EU exist a lot of differences concerning protection of privacy and personal data. Since the EU is the most collaborative community of states in the world, it is supposable that it is the first place where such an international tracking system will be established. The joint combat of international criminality belongs to the fundamental basis of the EU and has been established in article 30 of the EU-treaty. However, to create the legal framework for such a tracking system, the EU parliament has to be concerned with this topic at an early stage to be able to find a common policy.

[17] Art. 2 Abs.2 and Art. 11 GG.

[18] Art. 103 Abs. 2 GG.

[19] According to the bill concerning the amendment of the PAG: Art. 38 Abs. 3 PAG-E.

Social Aspects

What also has to be taken into account is how the society reacts on such a project. Especially in privacy and data concerns, the public opinion varies a lot between different countries. One extreme example is the USA. Afraid of terror and crime most Americans accept deep restrictions on their privacy rights. Just by reading out a driver license, every police officer has already access to a mass of detailed personal data. Even retailers are collecting data about the habits of their customers.

These are nightmares for many Germans, even though they become real more and more for them as well. Sometimes it seems the Germans are more afraid of loosing their informational self-determination than becoming victims of international terrorism. They prove it for example a few years ago, when the permission of the bugging operation has been discussed heatedly in publicity. Another example is the current dispute concerning biometric passports. Also the video recognition system is heavily discussed in politics and several federal states have already manifested their denial.

Another example is the video monitoring at public places. While the Germans get more the feeling to be haunted, most people in the UK have the feeling of being protected. The people in the UK rather welcome surveillance systems and are generally more open-minded to new technological solutions.

These examples point out how different societies think about data security and protection of privacy. Therefore it might be easier to establish this car tracking system in one country while it will be harder to establish it in another one.

However, in general there is no huge public interest on small steps. While most people will protest against intensive abrupt changes, they might accept them if they are launched piece by piece. As a consequence, to implement such a nationwide or even nation comprehensive tracking system, it is of importance to start the legal and social framework at an early stage. It definitely will need time to find familiarization and acceptance in the public.

Business Implication

Players

Since its implementation should get standard practice and due to its objective to increase nationwide public safety, this RFID tracking system is specific to be utilized and applied by a state and not a company. Especially the European countries within the Schengen area are suited for its implementation, since they are very susceptible for international organized car theft due to their open borders.

For the network provision every local GSM provider would be qualified and the software solutions can be commissioned to any competent company. There are several companies like node-net[20] for example, which specialized on the incorporation of RFID systems with databases. It is getting more complicated when looking

[20] http://www.node-net.com/.

for a suited RFID vendor. Since the market for microwave RFID is right at the beginning, the number of vendors is small and the range of products is limited. Companies like Aeroscout, IDMICO or Asseon-electronic offer already some solutions. Admittedly, these products fulfill only partially the special features and system requirements of the car tracking solution. As a result of this, a company has to be commissioned to develop a microwave RFID solution which is exactly adapted to this problem. The technical knowledge is already existent, only its realization is missing which can be assumed to be accomplishable until 2008.

Costs and Benefit

Implementation Costs

One advantageous issue of the RFID solution is its implementation costs are comparatively low. The hardware module of the A1 carfinder for example, would already cost 329 EURO. An additional GPS upgrade at least another 199 EURO (ÖAMTC 2003). Actually this is still quite cheap for a GPS device since other providers charge over $1000 per unit. However, there is still more to it than that. These private system providers have only a small clientele, nevertheless they have to monitor the whole road network. This results in a high surveillance effort per customer what results in monthly fees of 5 – 20 EURO.

The RFID solution is far below these expenses. Assuming that the system would be established by a state, the expenses are spread between several parties.

The tag costs would be drawn on the car owners. The present market price of a microwave tag is about 20 – 150 EURO, depending on its specific features like the reading range for example. The tag costs for low frequency tags are currently about 30 cent and are expected to be around 5 cent in a few years, this would be a reduction of over 80% within a short time. Since the current market for microwave tags is extremely low, most vendors still do only offer low or high frequency tags. An implementation of the RFID tracking system would create a great demand, even when the market would not be as high as in the moment for low frequency tags. With respect to this, a similar development for microwave RFID can be expected. Price reduction and market development will cut the price for microwave tags. The cheapest tags are assumed to be available for around 5 EURO by 2008. This is a justifiable price. Assuming additional 20 – 30 EURO installation cost[21] would result in less than 35 EURO one-time charge for each car owner. That is less than one tank of petrol.

The next part concerns the reader costs. The current market price is around 1,500 – 2,100 EURO. Similar to the tag cost this price can be assumed to drop as well. A price of 500 – 1,000 EURO by 2008 can be expected. Readers will be ordered by the state (stationary readers), which will be installed throughout the road network. The latter comprises in total 231,000 km, in which 12,044 km account for freeways with 2,200 interchanges (BMVBW 2005). Installing a reader

[21] applies only to old cars; new cars would be already tagged at the manufacturer.

every 20 kilometers, additionally two at each interchange, 500 more around the most frequent border crossings and finally duplicating the amount to cover both directions, results in 11,000 readers at the freeways. Since one third of the traffic volume occurs there (BMVBW 2005), the system would already cover a big part. Further readers should be installed within big cities and at significant highway intersections, especially in areas with high theft rates like in the newly-formed German states. Assuming 5,000 additional readers would finally result in 16 million EURO for the readers.[22] Since the system is expandable, the reader network can be improved step by step.

Additionally 5,000 readers[23] would be ordered by the test centers of the technical inspection agency for their maintenance purposes and further 5,000 initial pieces by the police.[23] Sooner or later all police patrol cars will be equipped with a reader.

To summarize the situation for the German market, a one-time demand of 47.6 million tags for all registered vehicles plus a permanent demand of 3.2 million tags per year for the new registered cars would arise (DESTATIS 2005). Additionally a one-time reader demand of 26,000 plus a demand for several thousand supplementary readers within the first years would emerge.

Finally there are the costs for the GSM utilization, the creation of the database and the software development. These expenses are hard to estimate and depend on bargaining power and the given market situation. Nevertheless, these costs can be assumed to be similar for the comparable systems. The A1 carfinder, the video recognition system, the GPS systems or the RFID solution, all have similar requirements concerning these issues.

Damage Prevention by the System

The number of car thefts in Germany is permanently decreasing since about 1993. Table 2 presents the development of the vehicle theft situation in the past five years. The annual reduction compared to the previous year fluctuated between 6% – 12%. In considering the damage for cars which had a physical damage insurance and the respective number of thefts, it can be shown that the average damage per car increased every year.

In order to get an estimation, how much damage can be prevented in implementing the presented RFID tracking solution, the results from a test of the video tracking system have been considered. According to the criminal statistics by the police for 2003 (BKA 2004), there were 3,320 cars stolen in total in Bavaria. Since the test covered only a part of the Bavarian road network, it is assumed that only half of the stolen cars were located within the test area. In further considering that the test period was only half a year, finally about one fourth of the car thefts were covered by the test. The application of the video system, lead to 282 hits during this period. From the 282 hits, 114 were related to theft or fraud delinquencies

[22] Assuming an unit price of 1000 EURO.

[23] In these cases: hand-held readers.

Table 2. Number of car thefts and caused damage for cars with physical damage insurance in Germany during the last five years

	2000	2001	2002	2003	2004
Vehicle thefts overall[24]	83,063	75,408	70,617	63,240	58,937
Reduction on last year in %	11,40%	9,22%	6,35%	10,45%	6,80%
Clarification rate[25]	26,2%	25,8%	26,8%	26,4%	27%
Thefts of cars with physical damage insurance[26]	42,560	37,549	34,775	31,707	
Damage in million EURO[26]	316,2	307,5	300,9	293,5	
Average damage per car	7,430 €	8,189 €	8,653 €	9,257 €	
Increase of damage per car	8,8%	10,2%	5,7%	7,0%	
Interpolated damage for all stolen cars in million EURO	617,1	617,5	611,0	585,4	

Source: BKA (2004), BMI (2005) and GDV (2004)

Table 3. Calculation of the damage prevention after an implementation of the RFID tracking solution in Germany

	2008	2009	2010	2011	2012
Car thefts overall	40,773	37,185	33,912	30,928	28,206
Average damage per car	13,538 €	14,608 €	15,762 €	17,007 €	18,350 €
Damage in million EURO	552,0	543,2	534,5	526,0	517,6
Damage prevention in million EURO by using the RFID tracking system	75,6	74,4	73,2	72,1	70,9

Source: Own calculations

[24] see: (BKA 2004) and (BMI 2005).

[25] see: (BMI 2005); the portion of cases wich could be solved.

[26] see: (GDV 2004).

(BSTMI, 2004). Consequently, the supposed number of 830 thefts and an amount of 114 hits result in a final hit rate of 13.7%.

In order to extrapolate the annual damage, an average increase of the damage per stolen car by 7.9%[27] per year has been assumed. Furthermore, a yearly reduction of the theft rate by 8.8%[28] has been taken. As earliest possible date for the system launch has been chosen the year 2008, since the further required technical developments and the establishment of a legal and social platform can be realistically accomplished within this period.

The achievable damage prevention for the years 2008 – 2012 with respect to the previous assumptions is depicted in Table 1. The RFID solution would prevent about 70 million EURO of damage per year. As a result of this, more than 360 million EURO of damage could be prevented alone within the first five years.

Benefit Compared to Other Systems

When comparing the presented tracking systems with respect to making them a nationwide standard, the GPS systems and the A1 carfinder can already be excluded due to their high unit costs. Remain the video and the RFID solution. The costs for a surveillance camera can be considered comparable to the reader costs. The only grave cost difference between these systems arises by the tags. While the RFID solution has the disadvantage of the additional tag costs, the video solution comes with the negative aspect to be easier to circumvent, what finally would result in a lower hit rate and therefore in less damage prevention as the RFID system.[29]

Chart in Fig. 3 illustrates the cost-effectiveness of the RFID system compared to the video system for several hit-differences.[30] The curves depict the minimum required run-time depending on the tag price of the RFID system, until the lower damage has amortized the additional tag costs. For a hit-difference of 40% and a tag price of 4 EURO for example, it would take 11 years. Especially with respect to new technologies, 11 years are a very long time and the actual hit-difference might be rather lower.

As a result of this, an implementation of the RFID car tracking system would be feasible, when the tag price drops below 2 EURO. For the system to be really reasonable and beneficial it should be actually around 1 EURO. However, when observing the drifting down of prices for low-frequency tags, this bench mark can be expected to be reached in a few years.

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[27] This is the average increase of the damage per car during the years 2000 – 2004.

[28] This is the average reduction of the theft rate during the years 2000 – 2004.

[29] The hit rate during the test of the video system has been considered to be similar to the potential results during a respective test of the RFID system, since the test was not generally known. Therefore, an adaptive behavior of the car thefts has not been assumed.

[30] The hit-difference states the performance difference between the RFID and the video system. A hit-difference of 40% for example: %(video) = 0.6 * %(RFID).

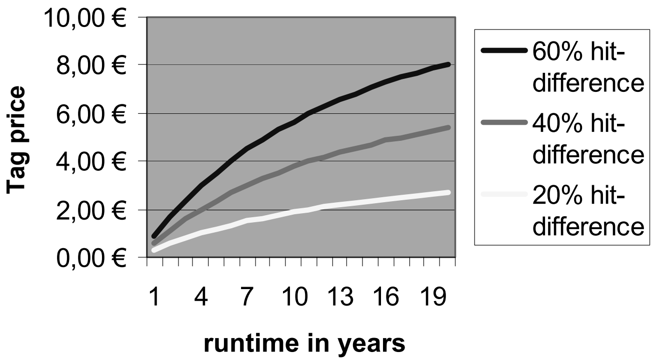

Fig. 3. Correlation between tag price and the minimum run-time for the system to be cost-effective; the calculation[31] has been done for three hit-differences compared to the video system.

Source: Own analysis

3.4 Conclusion

Obviously, a lot of effort is necessary to remedy all these technical, legal and social problems and finally the cost issues. Therefore, before considering an implementation, it is required to previously verify the usefulness of the system. Regarding this aspect, there are three constraints to satisfy. Can it effectively combat the threat? Are the possibilities to bypass the system inhibited reliably? However, the most important question to ask, is the system inevitable?

How successful new technologies can reduce crime has been demonstrated with the implementation of the electronic immobilizer system. Moreover, it is striking out while the number of thefts is permanently decreasing, the clarification rate of the cases remains nearly constant as seen in Table 2. An improvement in the criminological investigation methods would further enhance the situation. That a tracking system like the introduced RFID solution is suited to enhance the situation, could be verified by the results from the test of the video based recognition system. With respect to the small coverage of this test, its result demonstrates a criminological success and proves the effectiveness of such a system.

With respect to the second question, another argument for the RFID car tracking is its advanced by-pass prevention. No other system can achieve such a high protection. Those systems which are not implemented in every car can be easily overridden by destroying them, since the lack of these systems would not be suspicious. The video recognition system can simply be circumvented, by changing the license plate as already mentioned above, while an exchange of the RFID system is a lot more demanding.

[31] (47.6 million registered cars + 3.2 million annual new cars * years) * tag cost = annual prevented damage * years.

The last of the three constraints, has to be regarded with respect to the benefit and the alternatives of the system. In order to combat the crime effectively and nationwide, the video recognition system is the only alternative which comes into question. Considering the legal and social aspects, both systems are confronted with the same issues. However, the high theft rates and the international organized criminality necessitate such drastic actions. Some concessions have to be done in order to increase public safety.

The systems distinguish when considering their benefit, which is simply the gain in public safety compared to the related implementation costs. The results from the previous section pointed out, the market is not ready to provide the required RFID equipment for an economically reasonable price. Indeed, the RFID system has the highest reliability, but with respect to the related costs it can not compete with the video solution.

To sum up, an implementation of this RFID solution would definitely improve the current theft situation and enhance public safety. Besides the tracking of stolen cars it would be also suited to track bandits or terrorists who are on the run. The police could just launch a hunt for the getaway car to cover the whole area.

However, since its costs are not negligible, an implementation at the moment can not be recommended. The fast development in the technical market may change the situation in a few years. Then, the RFID system should be reanalyzed, especially with regard to new potential technologies.

4 Tracking of Criminals and Surveillance of People in Danger

4.1 Introduction

Tracking of criminals has always been a public concern, but it is becoming a more prominent issue than ever. Every year, 20,000 children in Germany are victims of sexual assaults, with experts claiming that the actual number is much higher, as many cases are never reported (Mielke 2005). In 2003, 2400 people have been convicted of sexual abuse of children and 2000 have been convicted of sexual abuse or rape (destatis 2005). There have been a lot of discussions on how to protect children from pedophiles. After a loud discussion in the media last year, with Marc H. being arrested and accused of child murder and abuse in two cases, recently these discussions have restarted with his conviction (FAZ 2005). After having spent his time in prison, he will still be detained. Nevertheless, detention after imprisonment is a rather rare case. Who can ensure that a criminal will not commit the same crime again? Too often has the media reported about ex-convicts that, after spending their time in prison, again committed a serious crime. Especially pedophilia, which seems to be non-curable, is in the center of attention. Politicians all over the world are discussing the correct and effective handling of the issue. The only effective solution to ensure that criminals, be it pedophiles, murderers or any other criminals to be watched, do not commit the same crime, seems to be their surveillance, life-long for pedophiles, limited to a shorter period of time for others. Certainly, personal surveillance is not feasible.

After a thorough analysis of the topic, two different applications, based on the same technology that might tackle the problem from two different approaches, were identified:

1. Tracking of prisoners on leave or suspects that are not allowed to leave the country as well as tracking of people not allowed to approach certain areas, such as pedophiles not allowed to get near to schools or nurseries (implantation of RFID tag)
2. Surveillance of people in danger of being kidnapped; surveillance of children for parents fearing they might get lost or kidnapped (RFID tag is inserted into not easily removable accessory such as a watch or belt)

4.2 Current Situation

4.2.1 Surveillance of Criminals

Currently, criminals on leave as well as suspects obliged to stay within a certain region have to report to a representative of an authority at constant time intervals such as once a day or they are being watched by members of the police force. Clearly, it is costly to have a person assigned to watching a prisoner or suspect. Also, having a prisoner report to an authority once a day or even several times, is not very effective considering the means of transport that are at disposition at present. Even a limited time interval of four hours can transport a person from Chicago to Mexico City and therefore possibly out of reach for the forces of order of the United States.

In some prisons, the detained are put in foot chains that set off an alarm when the detained leave the area where they are allowed.

Surveillance of Pedophiles

In New York, electronic foot chains have now also been applied for determining the movements of pedophiles and whether they approach schools or nurseries. This extension of the system has been accomplished by using mobile phones for the transmission of the position. The signal of the foot chain always has to be within reach of the mobile phone to ensure the correct functioning of the system. In Kansas, the system is not only used to determine the position of a pedophile, but an alarm is set off as soon as he leaves the city.

4.3 Surveillance of People in Need for Protection

People in danger of being kidnapped are monitored by the police or have been assigned bodyguards to their protection. This is certainly a great expenditure.

For parents seeking to watch their children's every move because of preoccupation, be it justified or not, or simply for the wish to control them, there are solutions already on the market. Software for specially designed mobile phones has been developed giving people the possibility to determine the exact position of the carrier of the phone. Controversies have arisen regarding privacy issues, but they have not been able to prevent the deployment of the systems.

4.4 RFID Solution

In the following section a solution using RFID will be proposed and the benefits will be explained. The two possible applications will be introduced by giving a general description of the concept. Then, the technical details for the applications will be given, describing the tags and the necessary infrastructure for the readers. Furthermore, the range of the system will be examined. After having clarified the technical part, the focus will be on legal aspects and the public opinion, as this is one of the key factors concerning the deployment of RFID, not only in the area of crime prevention. A short estimation of the costs and benefits compared to alternatives without RFID will be done, followed by an examination of the possible market size.

4.4.1 Description

Basically, two applications that satisfy the requirements to be accepted by the public opinion were found. First, the tracking of prisoners on leave or pedophiles will be analyzed. Then, the application of RFID will be analyzed from another point of view of crime protection, the protection of people in possible danger. For both systems, mobile phones are used to transmit the signals that the RFID tag is still within reach.

Tracking of Prisoners on Leave or Pedophiles

For this application, there is the need to ensure that the RFID tag is not removed from the person which should be tracked, since this is the main principle the idea is based on. Currently, there is a similar system to track pedophiles used in the USA that utilizes electronic foot chains and mobile phones transmitting the information of their presence and location. There also are pilot projects in Germany and Switzerland involving electronic foot chains and the surveillance of criminals.

Implantation of the RFID tag with additional sensors that sense the removal of the implant would satisfy this requirement that the RFID tag must not be removable and the technology will probably be available within the next ten years. One idea is to add sensors that act on electric impulses of nerve chains and would set off an alarm if these nerve chains are cut.

For pedophiles, the proposed system can be extended to include long-range tags identifiable at a distance of several meters. This could be implemented by a second tag in the mobile phone, to minimize the exposure of the person to the rays (freed of wearing the phone when inside a controlled building), and readers at several checkpoints. Checkpoints would then be installed at nurseries, schools and any other buildings for children.

Scenario

The criminal gets a tag implantation. The tag, a glass transponder, is resistant to liquid and its size of 22 mm makes it invisible on the exterior of the body. The people the criminal interacts with do not find out about the tag. The criminal is carrying the mobile phone with him, except for some short periods of time, when he is taking a bath or any other situation where it is impossible to carry a mobile phone. He is fully aware of the fact that he is being tracked and his every movement is being monitored in a central system. The mobile phone, carrying a reader able to identify the tag in the implant, checks the presence of the tag at constant intervals and transmits the information about the current location to the central database. The criminal will not dare to leave the area that he is allowed to stay in, as an alarm will be set off in that occasion and the police will be there within minutes, since the current location is known.

With the extension of the system, the mobile phone is equipped with a second tag, an active tag with a high frequency, detectable at larger distances, such as 10-12 meters. Schools and nurseries are then equipped with long-range readers and, if approached by a pedophile, the tag will be read and an alarm will be sent to the pedophile, informing him of the proximity of a school or nursery and telling him to leave the area immediately if he does not want to be in trouble. The event is noted and the pedophile may get questioned.

Surveillance of People in Danger of Being Kidnapped or Getting Lost

In contrast to the previous case, people using this system shall be able to remove the item containing the RFID tag from their body. Depending on the situation, the item should be removable, e. g. when the person is at a safe place (e. g. children at home, in the kindergarten). On the other hand it should not be too easily removable. Therefore, a tag in a watch or belt or not easily removable wristband would be a good place for carrying the tag. As in the other solution, a mobile phone is used for transmitting the information of the presence of the tag and the location of the person.

It is already possible today to locate the area of a mobile phone through the provider of the network. Using GPS or TV-signals can further improve the exact determination of the mobile phone, allowing to also detect the position of a mobile phone within buildings with poor or no reception.

Scenario

Tags are available in different versions: watches, belts, wristbands. The tag cannot be identified by merely looking at the item carrying the tag. The person carrying the tag also carries the mobile phone equipped with a tag reader. It checks the presence of the tag at constant intervals, transmits the information about the location and gives alarm if the tag is not present anymore.

The carrier of the tag can remove the mobile phone or set it on “sleep” mode when he/she is in a secure location (like in custody or at school/nursery, possibly the system then is switched off automatically for children).

If the tag is not present anymore, an alarm is given to either the authorities in charge of guarding the person in danger or the parents if they introduced the system to keep an eye on their children. If the case is to be taken serious, since the location is known, the person can be found within a very short period of time. If the forces of order start looking for the person immediately, the person should be found within a few minutes.

4.4.2 Technical Implementation

Currently, there are already tags in the most diverse forms. Corresponding to required features, one can already purchase an RFID wristband transponder for € 4.80 to € 7.50, depending on the material (barcode-shop 2005).

Glass transponders are the most suitable form of transponder for implantations. They are currently available for € 6 to € 8. At a frequency of 134.2 or 123.2 kHz they usually are readable up to a range of 100 cm. Hermetically sealed, they are resistant to liquids (TI 2005).

Companies such as ChildLocate (ChildLocate 2005) already offer software allowing the detailed description of the location of the mobile phone carried by the children, very much comparable to a navigation system for a car. After paying for the service, the parent needs to request the authorization for checking the location of the mobile phone. The child has to give the permission by replying with a sms to ChildLocate. Cooperating with a company offering this service or the development of a comparable system would be the perfect combination to the RFID technology.

Transmission of the signal can also occur using GPS. The CIA is currently investing in a company called Rosum, developing a system that uses TV-signals to replace GPS, which is not working under some conditions, such as in thick woods or strong walls of concrete. TV-signals promise very accurate information even in such circumstances (Spiegel 2005).

A central database stores the data associated with the person that is uniquely identifiable by the unique tag number. An alarm is set off on two occasions:

1. The system gets the information about the location, which is out of range of the allowed range.
2. The system is notified that the tag is out of reach for the reader.

To avoid false alarms, a process of double-checking is started. According to the situation and the possible consequences, a message can be sent automatically to the person being checked, giving him or her the possibility to reply with a code and cancel the alarm (e. g. for children being checked by their parents). Another option is to have an operator or authority calling and checking upon the person. The third option is to send an authority to make sure in person whether the alarm was a false alarm or not. Either of the options can and has to possibly lead to a fast intervention in the respective area to find the person.

4.4.3 Legal and Social Aspects

The key conditions to be met for RFID solutions to be successful on the market have been identified: free will and/or limited time of exposure to RFID readers. For both applications the requirements for successful marketing that were just mentioned stand:

In the case of implants as well as of the necessary accessory to be worn, it is the free choice of the person to wear the implant or accessory, implants are not forced onto. Even if the government would at some point decide to force every prisoner on leave to wear an implant to be controlled more effectively, this would be only for a limited period of time and therefore morally defendable.

Basically, the proposed solutions all have equivalent existing solutions that are already in use. Pedophiles are already monitored in New York and Kansas, using electronic foot chains and mobile phones transmitting the position. Electronic foot chains are also used for determining whether the prisoners are in theirs cells or where they are within the prison. The company Applied Digital Solutions (or ADS) was heavily criticized at first, scenarios as in George Orwell's "1984" were projected. Nevertheless, ADS has put its "VeriChip" on the market. It has not been very successful so far, the current applications seem not to show the benefit required to outweigh public concern about privacy. Questionable applications such as the implantation of the VeriChip to 50 customers of the Baja Beach Club in Barcelona are drawing more attention than probably more widely accepted applications such as the injection of the chips to AIDS patients unable to tell their medical history, as occurred in a hospital in Rome (Schmidt 2005).

Any legal aspects with tracking the position of children have been considered and settled when systems like ChildLocate were introduced. With ChildLocate, all data is collected lawfully[32]. The privacy procedures were developed in accordance with the Privacy Code of Practice approved by the four major mobile operators. Credit card details are used to verify the correct address of the customer. At any time the child can see who is able to locate it and is informed about how to withdraw from the system. Also, in order for the service to be activated, the customer has to send a message from the child's phone (ChildLocate 2005). Similar actions would have to be taken to ensure that the privacy of the persons watched by the RFID system is not harmed in any unlawful and unwanted way.

One has to take account of the fact though, that after September 11th the USA are far more open towards limitations of privacy for the purpose of better protection against criminal acts or terrorism. Europe, especially Germany, was very successfully insisting on laws defending privacy. On the other hand, there have been changes and restrictions also in Europe. Flight information is stored for up to three months and allows a limited tracking of the passenger. Everyone is now awaiting the changes that the recent terrorist attacks in London might change in the defense of

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[32] In accordance with the UK Data Protection Act 1998 Notification Registration Number PZ8277048.

privacy. Passengers on international trains to Germany are currently being controlled by the German Police. Given these facts, monitoring through RFID will be accepted more broadly after the recent terrorist attacks, especially when monitoring does not involve the average citizen and is solely used to reduce crime.

From another perspective, the foot chains identify criminals to the general public. The implantation of a tag, e. g. after a prisoner has left the prison, would ease the process of reintegration.

Disapproval from the public can be encountered with the argument that the users of the proposed systems are volunteers or use the system only for a short term. For prisoners that would use the system long-term, it could be a free choice between using this system and therefore benefiting of more freedom or staying in prison/being surveilled.

4.4.4 Business Implications

Players

For the two proposed systems, different players driving the implementation of the system were identified: For criminals and for the protection of witnesses or other people in danger to get kidnapped, the main driving force behind the implementation of the system will be the state or, more precisely, the forces of order. For the surveillance of children, parents will buy single systems. Large adoption of the system by a single player, as in the case of enforcement through a law, will result in low prices for the single system.

Depending on the competitors on the market, in the case of protection of children and other people that might be in danger, the buyers will probably base their buying decision on the features of the system, its reliability and detailed information about the location rather than on the lowest price. Also, for this application, vendors that are already on the market, such as ChildLocate, will be main players on the market offering an RFID solution, either as an extension of their current products or replacing their product line and therefore establishing themselves as cutting-edge technology leaders.

Cost and Benefit

For both solutions the main driving factor behind their implementation is not so much the costs as the additional benefit they offer.

Implementation Costs

For the purposes stated, the costs of the tags do not contribute greatly to the adoption of the system, as costs of this amount are negligible compared to the savings from different solutions such as surveillance through persons. If one wants to look at costs, one has to look at the costs of the readers, the costs of implanting a tag and the costs of transmitting the position through GPS or tv-signals (if the latter is implemented).

A reader for tags of the frequency 134.2 kHz can be purchased for approximately € 800 (SecureOrderProcess 2005).

Short-range glass transponders are available for € 6 to € 8, short-range wristband transponders for € 4.80 to € 7.50.

The costs of the service charge for determining the location currently ranges at € 100 including 25 location requests, additional service requests are available for about 50 cents. With more companies competing on the price level these costs are expected to decrease. Since the implementation for criminals and people in danger would require constant checking, a fixed fee would have to be introduced (ChildLocate 2005).

Applied Digital Solutions (ADS) already offers the service of implanting small glass transponders of 12 mm, with a frequency of 134 kHz and 128 Bytes of storage, for \$200 (approx. € 150), including chip ("VeriChip") and injection. For \$9.95 a month (approx. € 8), ADS offers the management of the data (Schmidt 2005).

Benefits Compared to Other Systems

a) Criminals

Provided that the system can be implemented in a way that it is reliable enough to ensure that prisoners will not escape, the costs of the system can be compared to the costs of keeping them in prison. In Bavaria, a day in prison for one person, after detracting all revenues from working, still costs € 69 (BSJ 2005). Therefore, already after a two-week detention in prison, the costs of an RFID reader and transponder and its injection would be exceeded. The costs of the handling of the data as well as the costs of the sensor to be added to the chip would have to be added.

A pilot project in Switzerland on electronic foot chains as an alternative to detention in prison showed that costs can be cut by half replacing part time detention; replacing full time detention in prison even results in a quarter of the costs. Another important fact worth to be mentioned is the social integration of the persons when they can spend the time outside the prison (NZZ 2003).

The RFID system could replace the electronic foot chains currently employed for pedophiles in some states in the USA. After their names had been made public in the internet in Great Britain, many pedophiles suffered attacks from their neighboring population. Replacing electronic foot chains by an implant would allow them and other criminals not to be identified due to the foot chain.

b) Surveillance of People in Danger (Real or Feared Danger)

Existing systems based on the localization of mobile phone have one drawback: there is no guarantee that the mobile phone is still with the person. Especially when thinking about kidnapping, the chances of the person taking the mobile phone along are small. The RFID solution overcomes this drawback, justifying the higher costs.

4.5 Conclusion

From the point of view of the costs, one can say that the proposed RFID solutions certainly offer a much cheaper alternative to personal surveillance or the costs of imprisonment.

They improve existing solutions for locating people, such as software locating mobile phones, by offering the additional information that the person that is being monitored is within reach of the mobile phone. The control function is therefore directly related to the person and not a device. The additional benefits should justify the higher costs of the products.

Public concern on privacy for the surveillance of criminals does not seem to be a critical problem, since similar solutions have already been deployed and they do not apply to the average person. Also, people are becoming more open towards security measures after terrorist acts.

For the surveillance of children or other people that might get lost or kidnapped, existing solutions have already proven to be ready for the market.

As long as the system is implemented for criminals that would otherwise have to report to an authority at certain intervals, the consequences of a failure in the system are not as grave as for criminals that would usually spend their time in prison. The system would therefore need to be checked for absolute fault tolerance, which can never be guaranteed. The application of the system would therefore probably not be possible on a very large scale, but could only be applied to a limited number of people. It can, on the other hand, be an effective means for improving the control on some people, such as pedophiles, criminals on leave or suspects not allowed to leave the country.

5 Conclusion: Can RFID Improve Public Safety?

All of the above applications have one thing in common. The usage of RFID would improve the reliability and accuracy for all of them. Existing solutions, for example food protection systems in Australia or comparable solutions, like the video based car tracking system, verify the usefulness from the technical point of view. The characteristic features and the significant qualities of RFID lead to exceptional advantages compared to currently employed systems.

Nevertheless, the previous analysis also pointed out that the applicability of RFID depends on more than just the technical factor. Also of fundamental importance are the legal aspects, the influence of which varies between both extremes. In one case they act as a promoter and in another they represent a handicap. With regard to the food supply chain safety, the demand for the RFID solution has been predominantly been created by legal and social implications. The massive piracy and the consequential non-compliance of the law in the software market, brought along the request for better protection. Legal problems, on the other hand, occur whenever individuals or personal data plays a role. Privacy issues and potential intrusions into the individuals' rights, pose problems. Whether innocuous car owners, or – more or less willingly – tracked criminals, a certain restriction to the rights of the individual has to be accepted in order to increase the level of public safety.

Another, unfortunately very crucial, factor is the economic point of view. Safety is not always cheap and it always has to be considered whether the actual safety improvement outweighs the respective costs or not. This is hard to decide when it comes to the prevention of pedophilia for example, or terror attacks where hundreds of people could die. Keeping the cost-effectiveness of RFID in perspective, the expenses were in general economically justifiable for the addressed applications. While in the food supply chain safety the prevented damage approximately compensates the costs of the RFID solution, there could even arise a win – win situation when it comes to the software protection. With respect to the area of personal safety, the gain in reliability and security definitely justifies its slightly higher costs. The car tracking solution serves in the first instance as prevention of property damage. Here a businesslike cost benefit calculation is rather possible. The result has pointed out that the RFID solution is in general appropriate to be employed, but the market still needs to make more progress, until the prices for the RFID hardware drop to a reasonable value.

All the outcomes and findings of the preceding sections lead to the overall result that RFID is not the magic bullet when it comes to security systems and fraud protection. While for some applications it is almost a must, it can improve the reliability for others compared to actual systems. Especially the drifting down of prices in the hardware market will turn the attention in these areas more and more to RFID solutions. However, as the examples in the first section have shown, RFID does not make sense in every case. Especially due to the mentioned non-cooperation, RFID is only suitable for a very few specific applications.

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