

CONNECTING MOBILE PHONES TO THE INTERNET OF THINGS

A DISCUSSION OF COMPATIBILITY ISSUES BETWEEN EPC TECHNOLOGY AND NFC TECHNOLOGY

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ABSTRACT

Near Field Communication devices and Electronic Product Code tags are two important RFID based solutions which have matured to market-readiness within the last years. Though both standards are based on the same technological foundation, there are some significant differences as to the goals that their developers intend to achieve through their use. Mobile phones are the most popular personal devices world-wide, with roughly three billion units in operation as of 2006. Market researchers are anticipating that by 2012 20% of all sold phones will be NFC enabled. With 300 million NFC phones sold in 2012, mobile phones would become the largest infrastructure of RFID readers world wide. On the other side, EPC tags will steadily become more available on logistical units and consumer products. The fact that more than a billion consumers might be equipped with NFC enabled mobile phones by 2015 raises the question whether the compatibility of EPC item level tags to these devices would not offer significant benefits. Against this background, this contribution investigates the drivers and barriers of a fusion of NFC and EPC technology, and discusses the resulting potential from a business perspective.

1. Introduction

1.1. Practical Relevance

The technologies of Radio Frequency Identification (RFID) enjoy an enormous interest at the current time, not only from the standpoint of research, but also from corporate practice. Companies from diverse branches are hoping for solutions to a wide range of management problems through RFID. The goals range from simple increases in processing efficiency for the receipt and dispatch of goods in distribution centers through to improvements in goods availability on the shelves and on to the struggle against shrinkage and product counterfeiting. The reason for the recent rapid and escalating use of RFID lies primarily in advanced miniaturization, the constant price decline which makes the use of RFID economically viable in ever more areas of application, and the establishment of widely accepted standards. Maybe the most influential standardization initiative so far has been the Auto-ID Center, which was transformed into the non-profit organization EPCglobal in 2003. The results of the Auto-ID Center's research activities became known as the "EPC Network", a collection of hardware and software standards for the use of RFID in various industries.

In parallel, a second RFID-related standard has emerged from the telecommunication industry. Near Field Communication (NFC) denotes a technology which enables the integration of RFID functionality into personal devices, such as mobile phones, thus making them both a RFID transponder and a RFID reader device. At the time of writing, the number of NFC phones available on the market was still very limited. If ABI Research's predictions are realistic, this will change in 2012 for when the company predicts a NFC phone market share of 20% (Card Technology, 2007). On the other hand, the presence of EPC tags on logistical units and consumer products will increase steadily. However, the two standards have not been developed to be compatible with each other. As a consequence, the companies who drive both technologies take the risk of overlooking a vast field of applications that is based on the combination of mobile phones with services that are linked to arbitrary physical objects.

1.2. Research Question and Structure

Against this background, it is the aim of this contribution to analyze and discuss the business potentials resulting from a common standard (cf. figure 1). For this purpose, we identify technical and managerial influence factors that could pace or foster the fusion of both technologies. We first consider the technical similarities and differences of NFC and EPC technology. Second, we investigate the organizations and the industries that have developed the two standards. The following section compares NFC applications to EPC network

applications in order to find possible intersections. Fourth, we discuss the economic benefits of individual companies, i.e. the logic of revenue models that rely on NFC and/or EPC technology. The paper closes with a summary and conclusions.

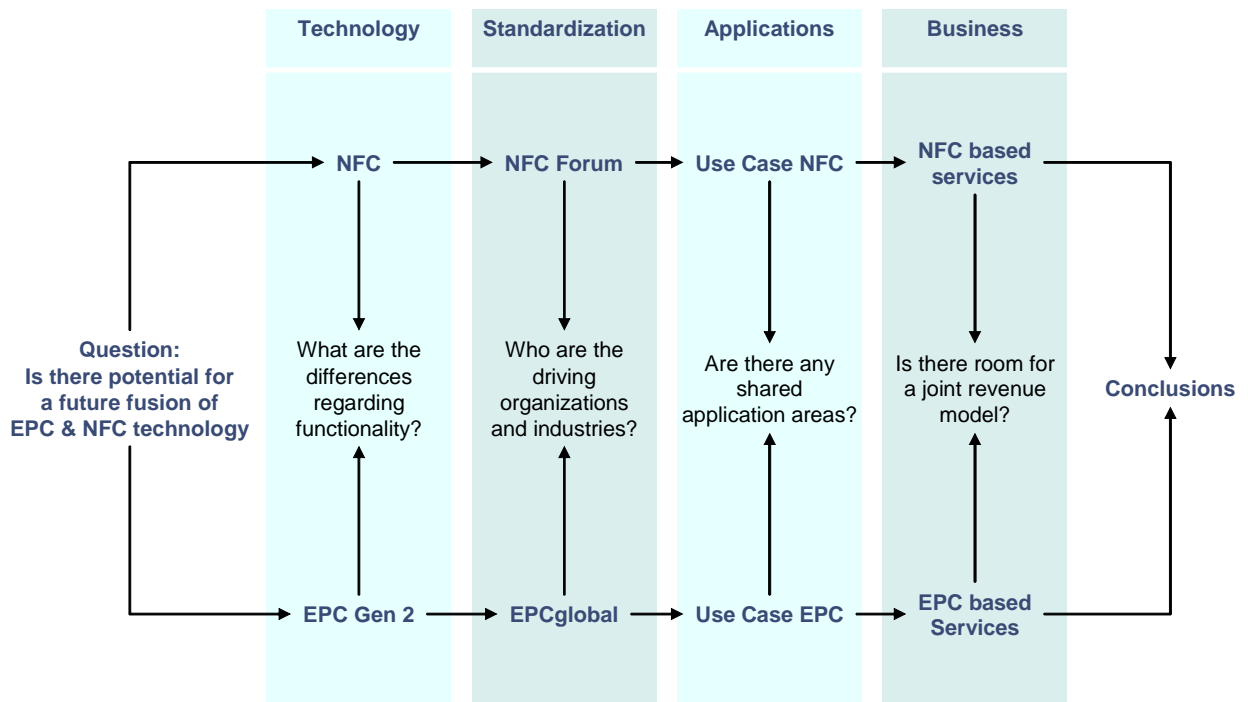


Figure 1: Research question and paper structure

2. Technology

2.1. Near Field Communication

NFC technology combines the functionality of a RFID reader device and a RFID transponder into one integrated circuit. As an integral part of mobile devices (e.g. mobile phones or PDAs), the NFC components can be accessed by software to either act as a reading/writing device or to emulate a RFID tag. NFC operates at 13.56 MHz (High frequency band) and is compatible to the following international standards:

- ISO/IEC 18092 (also referred to as NFCIP-1),
- ISO/IEC 14443 (smart card technology, “proximity coupling devices”), and
- ISO/IEC 15693 (“vicinity coupling devices”).

These three distinct standards are tied together by a selection algorithm – referred to as NFCIP-2 and defined by ISO/IEC 21481 – that determines which one of the three aforementioned communication standards is going to be used at the beginning of a communication session. The development of ISO/IEC 21481 compliant devices allows for the interaction with a large number of already deployed application infrastructures with security and RFID applications running on ISO/IEC 14443, 15693, or 18092.

Contactless-payment applications using Sony's FeliCa™ technology are widespread in parts of Asia, while contactless payment applications using the MIFARE® platform (ISO/IEC 14443-A) are more common in Europe. Until the end of 2006, an estimated 1.2 billion MIFARE® chips have been sold which can be read by 7 million MIFARE®-compliant reader modules (O'Connor, 2006c). 170 million FeliCa™ chips have been sold, of which 30 million are in use in Japanese mobile phones (O'Connor, 2006c). Moreover, ISO/IEC 15693 is the standard air-interface for many RFID HF applications across the world.

NFC devices feature three modes of operation:

- **Smart Card Emulation.** When using the card-emulation mode, an NFC enabled device emulates an ISO/IEC 14443 or FeliCa compatible smart card. Among others, this mode enables the use of the NFC device as contactless credit card or electronic ticket.
- **Peer-to-Peer.** NFC devices can use the peer-to-peer mode defined in ISO/IEC 18092 to transfer data such as electronic business cards between two NFC enabled devices.
- **Read/Write.** The read/write mode allows NFC devices to access data from an object with an embedded RFID tag. It enables the user to initiate data services such as the retrieval of information or rich content (e.g. trailers and ring tones).

2.2. EPC Technology

One trigger for the recent rapid and escalating use of RFID has been the activities of the Auto-ID Center, a project founded in 1999 at the Massachusetts Institute of Technology (MIT), in cooperation with numerous industrial sponsors, with the aim of developing worldwide RFID standards. The main result of the Auto-ID Center was the Electronic Product Code (EPC), an unambiguous numbering scheme for the designation of arbitrary physical goods which should ensure the interoperability of the technology in supply chain wide applications (Sarma, 2005). In the following years EPC became the technical foundation for the multiple RFID initiatives of large retailers such as Wal-Mart and Metro.

The EPC Identifier is a meta-coding scheme designed to support the needs of various industries by accommodating both existing coding schemes where possible and defining new schemes where necessary. In contrast to the well known EAN/UCC barcode structure, the new schemes encoded in EPC identifiers are supplemented by a serial number identifying a single product instance instead of the product category. On top of this numbering scheme, the standardization organization EPCglobal has defined protocols and middleware APIs, known

as the EPC Network which allows for the exchange of that data in a standardized way among supply chain partners.

The Auto-ID Center initially developed three protocols for both High Frequency (HF) and Ultra High Frequency (UHF) bands:

- “860MHz–960MHz Class I Radio Frequency Identification Tag Radio Frequency & Logical Communication Interface Specification Recommended Standard” (Auto-ID Center, 2002),
- “13.56 MHz ISM Band Class 1 Radio Frequency Identification Tag Interface Specification: Recommended Standard” (Auto-ID Center, 2003a), and
- “Draft protocol specification for a 900 MHz Class 0 Radio Frequency Identification Tag” (Auto-ID Center, 2003b).

However, by the end of 2003, in the course of the transformation of the Auto-ID Center into EPCglobal and the Auto-ID Labs, the development of the HF standard has been ceased. Due to its larger read range, the UHF band seemed more appropriate for the tagging of logistical units. In the following years, EPCglobal led on the development of the EPC Class 1 Generation 2 UHF protocol (EPC Gen2) which was approved by the International Standards Organization as ISO/IEC 18000-6C in July 2006 (O'Connor, 2006b). At the time of writing, a comparable standard for EPC tags operating in the HF band has not been adopted. However, due to different application requirements EPCglobal subscribers are currently reviving the initial efforts of the Auto-ID Center in the HF area. EPCglobal's goal is to have a ratified HF standard by mid 2007 (Roberti, 2007).

2.3. Comparison

Table 1 gives an overview of NFC and EPC technology and the respective standards. While NFC represents an approach to integrate competing smartcard standards for end-consumer applications, EPC technology was developed to more efficiently handle logistical units. The EPC air-interface is standardized in its UHF version and will in all likelihood become available in an HF version later this year. In contrast to that, NFC is only available as HF technology. Whereas UHF and HF are incompatible by nature due to the different physical coupling principles (inductive vs. electro-magnetic), an HF EPC standard could be compatible to NFC devices. Particularly, if the emerging HF EPC standard will build upon ISO 15693, firmware updates might be sufficient to make NFC devices compatible with EPC tags.

ISO/IEC Standard	UHF EPC Gen 2 ISO 18000-6C	ISO 21481 ¹ (NFCIP-2/ECMA-352)		
		ISO18092	ISO 14443 A/B	ISO 15693

¹ ISO 21481 is the mode selection procedure for 18092, 14443, 15693.

		(NFCIP-1/ECMA 340)		
Frequency	UHF	HF	HF	HF
Principle of coupling	Electro-Magnetic	Inductive	Inductive	Inductive
Read Range	7m	4-5cm	4-5cm	70cm
Access operations	Read/write	Read/write	Read/write	Read/write
Data transfer rate	up to 640 kb/s (passive communication)	up to 400kb/s (passive communication)	106kb/s	6.62 kb/s
Kill-command	Yes	No	No	No
Identifier	EPC code variable in length, up to 96bit	4, 7, or 10 bytes random	4 (Type, 7, or 10 bytes random or fixed)	64bit factory-programmed
Tag data memory	8kb	1 kb lockable for read-only	96 bytes lockable for read-only	Up to 8 kb lockable for read-only

Table 1: Overview of EPCglobal & NFC standards

3. Standardization

3.1. Near Field Communication

The NFC Forum was founded by Nokia, Philips, and Sony in March 2004 to promote the use of Near Field Communication technology. By February 2007, the organization had 104 members (NFC Forum, 2007). The NFC Forum focuses on promoting possible uses of NFC enabled devices including contactless payment, mobile ticketing, the intuitive pairing of devices, and the download of data such as movie trailers and ring tones by touching so-called “smart posters” with NFC devices (Brown, 2004; Deffree, 2005; McGrath, 2006; Norton and Hall, 2006).

Industry	Number of Members	Percentage
Hardware Manufacturers	38	37%
Research & Academia	15	14%
Mobile Network Operators	14	13%

Solution Providers	9	9%
Mobile Phone Producers	8	8%
Financial - Credit Card	4	4%
Mobile Service Providers	4	4%
Organizations	4	4%
Public Transportation	4	4%
Software Companies	2	2%
Bank	1	1%
Retailer	1	1%

Table 2: NFC-Forum Members by Industries

The NFC Forum's members are largely made up of hardware manufacturers, mobile network operators, mobile phone producers, credit card companies, and public transportation operators. Together, these companies constitute 66% of its members. Table 2 contains a summary of the NFC Forum's members by industry. NFC is largely driven by companies producing, selling, and operating mobile phones and the required infrastructure. Providers of payment and ticketing services constitute a second important group. The majority of the companies driving NFC are based in Europe (49%), followed by Asian and North American companies (24% each).

3.2. EPC Technology

EPCglobal's mission is to lead the development of industry-driven standards for the EPC, so as to support the adoption of RFID (EPCglobal, 2007). It is part of GS1, the organization which has been managing the barcode numbering scheme for many years. By December 2006, EPCglobal had 1068 members (cf. table 3). The largest member groups are (a) consumer goods manufacturers (40.6%) and (b) solution providers (35.4%). Retailers, which have been among the most prominent advocates of RFID technology only make up 2.2% of the EPCglobal members. However, these numbers do not reflect the fact that many consumer products manufacturers joined the organization because they needed to fulfill a retailer's RFID tagging mandate.

Industry	Number of Members	Percentage
Consumer Goods Producers	434	40.6%
Solution Providers	378	35.4%

B2B Companies	60	5.6%
Healthcare & Life Sciences	44	4.1%
RFID Hardware Manufacturers	43	4.0%
Research & Academia	32	3.0%
Transport & Logistics	32	3.0%
Retailers	23	2.2%
Aerospace & Defense	10	1.0%
Mobile Network Operators	7	0.7%
Automotive	5	0.5%

Table 3: EPCglobal Members by Industries

60.6% of EPCglobal's members are North American companies. Asian (18.2%) and European (17.6%) companies are far less represented. The number of Latin American (2.6%), Middle Eastern, and African (1%) companies are smaller yet. These numbers indicate that EPCglobal is being driven by different industries than the NFC Forum. While the NFC Forum is focused on mobile phones, financial transactions, and public transportation, EPCglobal's members are rather focused on consumer products, trade, and logistics. Furthermore, while the NFC Forum has a rather large share of European companies, more than half of EPCglobal's members are North American. Again, this might explain some extent of the different benefit perceptions, as North American companies seem to see more benefits in supply chain applications of EPC technology, whereas Europe has a stronger focus on item level tagging and possible consumer services (Collins, 2005; Wasserman, 2006).

3.3. Common Members

Industry	Number of Members	Percentage
Hardware Manufacturers	11	44%
Mobile Phone Producers	5	20%
Research & Academia	3	12%
Solution Providers	3	12%
Software Companies	1	4%
Consultants	1	4%

Mobile Network Operators	1	4%
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Table 4: Common Members by Industries

The NFC Forum and EPCglobal had 25 common members as of December 2006 (cf. table 4). This means, that 23.8% of all NFC Forum members are also members of EPCglobal while only 2% of the EPCglobal members have a stake in the NFC Forum. A large share of these common members is made up of hardware manufacturers (44%) and mobile phone producers (20%). The majority of companies with stakes in both organizations are based in Asia (52%), the remainder are evenly based in Europe and North America.

4. Applications

4.1. Near Field Communication

The benefits of NFC mentioned most in industry publications are: mobile payment, mobile ticketing, the transfer of data from one device to another, the easy pairing of devices, such as mobile phone and Bluetooth headsets, and the download of information, such as trailers and ring tones from so called smart posters. (ecma international, 2005; innovision, 2006; NFC-Forum, 2006; GSM Association, 2007). Many NFC applications have already been deployed in the context of pilot projects, e.g. NFC based ticketing in Xiamen, China and Hanau near Frankfurt, Germany. Two further pilots are planned with the New York public transportation system and the London Tube (Hargrave, 2006). However, the barrier to widespread adoption and rollouts is still the lack of appropriate NFC devices in the hand of consumers and of the underlying infrastructure. If ABI Research's newest predictions are realistic this will change in 2012 at the latest, for when the company has predicted a NFC phone market share of 20% (Card Technology, 2007).

Another important development is the implementation of contactless payment services by Visa ("VisaWave"), MasterCard ("PayPass"), and American Express ("express pay"). By the end of 2006, credit card companies had shipped 20 million contactless cards (compatible to ISO/IEC 14443) which could be used with 205,000 readers at 45,000 locations (Mullagh, 2006).

4.2. Item-level tagging in supply chains

The most stated benefits of the EPC network are: more accurate inventories, improved product quality and safety, realtime track and tracing, and business processes efficiency gains, such as the automatic receiving of deliveries. (Global Commerce Initiative and IBM,

2005; Kurt Salmon Associates, Voluntary Interindustry Commerce Standards (VICS) et al., 2005; acatech, 2006; IBM and Grocery Manufacturers Association, 2006). On the other hand, the benefits of RFID most sought for by consumers are improved car anti-theft capabilities, faster recoveries of stolen items due to unambiguous identification, the improved safety and quality of prescription drugs and food, potential consumer savings due to lower operation cost, and faster, more reliable recalls of defective products (Capgemini, 2005).

The most important rollouts of EPC technology can be observed in the supply chain operations of the global retail industry's biggest and 4th biggest players Wal-Mart and Metro (Deloitte, 2006). In 2004 Wal-Mart and Metro both issued mandates that required their largest suppliers to tag all pallets and cases shipped to their distribution centers with EPC tags. In January 2007 the number of suppliers that ship tagged cases to Wal-Mart has exceeded 600 (Wal-Mart, 2006). By October 2006, 40 suppliers were tagging part of their deliveries to the Metro Group (Metro Future Store Initiative, 2006). However, the usefulness of the applied EPC tags stops at the retailers back-rooms. The tags are not intended for use by consumers, but to improve the retailers' supply chain efficiency (Hardgrave, Waller et al., 2005; Hardgrave, Waller et al., 2006).

More relevant in the context of this paper are the item level rollouts that have taken place, e.g. at the Dutch book retailer Boekhandelsgroep, who opened the first fully EPC tag enabled book store in 2006. Every book in the store contains an EPC Gen 2 Class 1 UHF tag which can be used for stock management, product information and check-out purposes (van der Lely, 2006). Another example is the Japanese department store chain Mitsukoshi which has been using RFID to serve customers more efficiently in its shoe departments, and has recently expanded its solution to include designer clothes. Mitsukoshi uses HF RFID tags compatible to ISO 15693 (PingMag, 2006). Pfizer is also using ISO 15693 compatible HF tags to authenticate all bottles of Viagra shipped to the United States while GlaxoSmithKline is using HF tags to tag the bottles containing its Trizivir HIV drug (Roberti, 2007).

As these examples indicate, current item level tagging activities do not show a clear course in the direction of HF or UHF technology. While the before-mentioned companies have rolled out RFID technology on the item level for at least part of their product range, the item level tagging plans of the two most prominent EPC technology advocates in the retail industry, (i.e. Wal-Mart and Metro) remain vague. While Wal-Mart is seen to be a strong supporter of using UHF at the item level (O'Connor, 2006a), Metro hasn't taken an active role in the discussion lately.

4.3. Synergies of NFC and EPC Applications

The overview of the referred to literature in table 5 draws a clear picture of NFC and EPC technology being two different technologies with a different set of application areas. NFC is perceived to be a solution for the implementation of consumer applications such as mobile payment and mobile ticketing. EPC technology on the other hand is seen to be a solution for the support of supply chain applications.

	NFC Use				RFID/EPC Use				
	Industry Publications			Company Whitepaper	Industry Publications				Consumer Survey
	1	2	3		4	5	6	7	
Mobile Payment	x		x	x					
Mobile Ticketing	x		x	x					
Physical Access Control	x								
Logical Access Control	x								
Contactless Loyalty Cards	x			x					
Health Care File Storage	x								
Car Ignition Key Storage	x								x
Electronic Rebate Coupons	x								
Data Transfer		x	x	x					
Easy Device Pairing		x	x	x					
Product Information				x	x	x			x
Field Force Solution				x					
Support of Children and Elders				x					
Information Download	x		x	x					
Improved Product Quality and Security					x	x	x	x	x
Track & Tracing					x		x	x	
More Accurate Inventories					x	x	x	x	x
Product Lifecycle Management					x				
Rapid Check-Out at POS						x			x
Automated Receiving						x	x	x	

Pick Lists Replenishment						x	x		
Better Service Quality (Accurate Deliveries)						x	x		
Asset Management							x		
Promotion & Event Execution							x	x	
Recovery of stolen items									x
Lower Consumer Prices									x
Reduced unsaleables								x	

(1) (GSM Association, 2007), (2) (ecma international, 2005), (3) (NFC-Forum, 2006), (4) (innovision, 2006), (5) (acatech, 2006), (6) (Kurt Salmon Associates, Voluntary Interindustry Commerce Standards (VICS) et al., 2005), (7) (Global Commerce Initiative and IBM, 2005), (8) (IBM and Grocery Manufacturers Association, 2006), (9) (Capgemini, 2005)

Table 5: Studies on the benefits of EPC technology and NFC technology

However, one common application of both technologies is the retrieval of additional product information, be it about the ingredients, the authenticity, the history of a product, or the easy access to data concerning its availability in a store (Capgemini, 2005; Kurt Salmon Associates, Voluntary Interindustry Commerce Standards (VICS) et al., 2005; acatech, 2006; innovision, 2006). Assuring the compatibility of NFC enabled mobile phones to EPC tags would, for example, enable their owners to access the EPC Network by simply “touching” an EPC tagged product with their mobile phone.

5. Business

5.1. Near Field Communication

The companies that seek to generate additional revenues with the deployment of NFC technology are retailers, credit card companies, mobile network operators, mobile phone manufacturers, and public transportation operators. In the following, we give an overview of their underlying motivation to concern themselves with NFC.

75% of retailers view the check-out process as the most important factor for improving the customer shopping experience (Chu and Morrison, 2003). Therefore, the most promising NFC application for retailers is likely to be contactless payment, since it can speed up the payment related part of the check-out process by 25% to 63% when compared to cash payments according to studies conducted by Visa and American Express (Norton and Hall,

2006; Turner, 2006). Furthermore, retailers could offer additional services to consumers, such as the retrieval of product-related information.

Credit card companies and credit card issuers could benefit from NFC because the technology will prevent them from having to produce physical cards and to ship them to their customers. Cards could instead be sent to NFC mobile phones over the air and be available within seconds from the approval of a customer's credit rating. This would significantly lower the cost of delivery. Also, credit cards on stolen or lost NFC phones could be deactivated over the air thus reducing the likelihood of fraudulent use (NFC-Forum, 2006). In addition, credit card companies hope to increase their transaction volumes by replacing cash payments with fast contactless payments without the need for PIN based authentication. In the US, these micropayment transactions without PIN can be made up to an amount of US\$ 20; in the UK, this option is offered up to an amount of £10 (mobile payments, 2007). The credit card issuers hope to increase their total amount of transaction fees this way.

MNOs are planning to earn money with NFC mainly by controlling the devices' smart card emulation mode which offers other companies a secure platform for the accommodation of their smart card profiles such as credit cards and electronic tickets. This source of income is guaranteed by making the MNO owned SIM card the only possible storage for such profiles (Balaban, 2006). Whenever a company wishes to enable a customer to use a smart card based service on his NFC phone or to delete a corresponding profile, it would be required to pay the customer's MNO for the download of the profile into the secure element or for its deletion. Additional potentials for the realization of revenues are the clearing of smaller monetary transactions through customers' phone bills and the involved transaction fees. Furthermore, the use of NFC could result in higher uses of the MNOs data services. Consumers could either be billed directly for the data transfers such as the download of trailers initiated by NFC tags, or be encouraged to subscribe to data packages or flat rates in higher numbers.

The mobile phone producers' benefit in NFC is mainly the possibility to add another module into their phones and to charge MNOs or consumers an additional US\$5 for their phones (Balaban, 2006). NFC also enables them to add yet another function to the phone, thus strengthening its role as the most important and most sold personal device world wide.

NFC's benefit for the providers of public transports is the potential of cheaper ticket delivery. This cost reduction is based on rendering paper tickets unnecessary and on the reduction of cash handling costs. Also, the quicker transactions based on contactless technologies would help to shorten waiting queues.

5.2. EPC Technology

The companies who seek to generate additional revenues with the deployment of EPC technology are retailers, CPG manufacturers, and logistic service providers. In the following, we give an overview of their underlying motivation to concern themselves with EPC technology.

Retailers are most likely to benefit from the use of EPC technology because of better information exchange with their suppliers and new event-driven business processes enabled by data captured through the use of EPC tags. When looking at the potentials of EPC tagging on the item level, retailers will once more stand to benefit from the possibility to implement new processes especially at the store level, such as pick list based replenishment made possible by recording the movement of goods from the backroom to the sales floor or even the installation of so called smart shelves. This could help retailers lower personnel cost, and to assure better product availability (Wong and McFarlane, 2003).

Furthermore, EPC tags on the item-level could help retailers to detect products misplaced by customers that had a look at them but decided not to buy them after all, e.g. apparel, books, CDs, and DVDs. Item-level tagging could also enable retailers to offer their customers additional services, such as the supply of additional product information at information terminals throughout the store floor. Information in this case could mean a list of ingredients, handling advice, recipe suggestions, a proof of authenticity, or the availability of the product in the retailer's front and backroom. While this information seems to be sought by consumers (Cag Gemini, 2005), the revenue model for the retailers remains vague. Moreover, the supply of EPC technology enabled terminals on store floors would require a significant investment on the part of the retailers.

Using EPC tags on the case or the pallet level does not seem to yield too many benefits to CPG producers. Item-level tagging, however, could provide the consumer goods producers with a new channel of communication with the consumers. Scanning the EPC tags on products with an adequate device could enable consumers to benefit from product related services, that the producer would supply them with. This way, the producer could directly communicate the benefits of the product to the consumer and highlight its advantages. This could especially be interesting for the promotion of high quality products. The cost could be partially reimbursed by saving on advertisement on other communication channels.

Logistic service providers will have to be able to provide their customers (i.e. manufacturers and retailers) with EPC based services, such as tracking & tracing. It remains to be seen whether this will become a service that logistic service providers will be able to charge for, or whether it will just become a must-have differentiation criterion when working for companies that use EPC tags in their own supply chains.

5.3. Revenue Models combining NFC and EPC

Against the background of our previous overview of the different business perspectives on NFC and EPC technology, respectively, this section discusses potential benefits that could be drawn from a combination of both technologies. NFC compatible EPC tags on individual items in retail would allow for linking additional services to consumer products that are being accessed by the owners of NFC phones.

As mentioned before, the deployment of EPC tag enabled information terminals on sales floors would require a significant investment on the part of the retailers. The ROI for these investments can hardly be predicted as it is not possible to determine their influence on a

retailer's sales without a pilot. The compatibility of NFC phones with item-level EPC tags, however, could enable consumers to benefit from additional product information on the sales floor using their own mobile phones. As a consequence, retailers could offer an improved level of service quality without having to invest into an extensive hardware infrastructure in its stores.

The compatibility of NFC and EPC item level tags could provide the MNOs with the opportunity to offer content or portal services to the suppliers and the users of product-related data. Portals which integrate manufacturer-supplied information and services with related services offered by retailers or third parties would be necessary for consumers to easily access the information they wish to procure. Again, the compatibility of EPC tags with NFC phones could raise the likeliness of consumers to access data on the net with their mobile devices and thus increase the data traffic that the MNOs will be able to bill consumers for.

CPG manufacturers might be the party that could benefit most from the compatibility of EPC with NFC phones. If consumers were able to read tagged products with their mobile phones, manufacturers could make manifold use of this direct means of communication to potential and actual consumers. Information about the product could influence a shopper's buying decision, while product related services could increase the customer's satisfaction with the product and make him a long time customer. The possibility of cross-selling by pointing customers to complementary products manufactured by the same producer or affiliated companies is a further benefit.

6. Conclusions

This paper gave an overview of NFC and EPC technology, the organizations driving standardization, the different areas of application, and the options for generating revenues with both technologies. Although NFC and EPC tags are both RF technologies, they operate on different frequency bands and cannot yet be used together. While a porting of EPC onto the HF frequency band is planned by EPCglobal, the companies driving NFC have no reason to implement a UHF version, as it would not be compatible to the existing smart card infrastructures.

Our analysis of the membership data of EPCglobal and the NFC-Forum have shown, that there were 25 members common to both organizations as of December 2006. This constitutes 23.8% of the NFC-Forum's members and 2% of the EPCglobal members. With Nokia joining EPCglobal and the Auto-ID Lab St. Gallen joining the NFC-Forum after our study in early 2007, the number of common members has grown to 27. This shows, that a growing number of companies have stakes in both technologies, which should help to drive the compatibility of both technologies.

As our literature analysis has shown, the potential for a fusion of the two standards lies in product-related services that are linked to RFID transponders on the item-level. In this scenario, a product's EPC would be read by a mobile phone in order to access information

and services on the net. However, various issues need to be solved before this vision becomes economically feasible.

First of all, technical incompatibilities have to be taken into account in the process of standardizing transponders for item-level tagging. This would require EPCglobal to develop an EPC protocol class for the HF frequency band that is compatible with existing NFC protocols. Out of the three NFC air-interfaces ISO 18092, ISO 14443A/B, and ISO15693, the latter appears to be most appealing: because of its read range of up to meter (in contrast to the centimeter range of the other two) it has proven successful in quite a of item-level tagging pilots. Thus, if EPCglobal would go ISO 15693 for item-level tagging, mobile phone users could also access these tags through NFC-enabled mobile phones. Companies that wish to provide their customers with EPC based product related services will have to tag their products with these HF based tags so that consumers can access these services with their mobile phones. If products are tagged with UHF tags, as has been done in some trials, consumers would have to use reader devices supplied by the retailers on their shop floors or separately sold UHF readers that they could attach to their mobile phones or personal computers. Interviews with different European retailers have shown that their willingness to invest into an infrastructure to supply product information is rather low, since it is rather difficult to predict a sufficient return on investment. While we do not have the necessary data to determine whether consumers would be willing to buy a separate device just to be able to access product related services, we believe it rather doubtful.

In contrast to the development of a HF EPC standard, the integration of UHF readers into mobile phones for the consumer market seems very improbable, since there is no significant business case for the MNOs who control which technologies eventually make it to the market. NFC promises to pay off because of its smart card emulation mode and the revenues it will generate for the MNOs, while UHF readers have no comparable ROI to offer.

From a managerial perspective, we have seen that the intersection of NFC and EPC-related application areas is rather limited. However, NFC/EPC-based services might become a crucial influence factor to the acceptance and the success of both technologies. Further research will be necessary in order to investigate the impact of such services to sales volume, customer binding, etc. Furthermore, pricing strategies and the design of revenue models that generate benefits for all affected parties are a second issue that should be given attention.

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