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Chapter 12

Commercial Utilization of Mobile RFID

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Additional information is available at the end of the chapter

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1. Introduction

The basic functionalities of mobile devices (e.g. phone calls, text messages, browsing the internet) are extended to the interaction with physical objects from the real world as a result of the establishment of mobile devices as ubiquitous and personal computing platforms [1]. In this context, mobile interaction with the physical world, the use of mobile devices as mediators for the interaction with the physical world, become more and more popular [2]. Radio Frequency Identification (RFID) technology is one of the enabling technologies that turn mobile devices – commonly mobile phones – into readers of RFID tags attached to physical objects [3]. RFID technology that is used in the context of physical mobile interaction is mobile RFID. This technology enables mobile devices with embedded micro RFID readers to read RFID tags [4]. Via mobile RFID people can contact RFID tagged objects anywhere [5]. The studies in the relevant literature (see Section 2.1) focus mostly on the realization techniques, architecture of the physical mobile interaction and its perception by users and the consequences of this perception. Advantages gained by physical mobile interaction – realized especially by mobile RFID - have not been discussed comprehensively. This study aims to provide an analysis to address this gap and provide a comprehensive discussion. There are indeed a few studies (see Section 3.2.1) in which advantages of using RFID technology in mobile devices are discussed. However, they are discussed briefly while discussing applications of RFID enabled mobile phones and how to use RFID technology in mobile phones.

This study has the characteristics of a review paper. It investigates the studies about physical mobile interaction, mobile tagging and mobile RFID as well as applications of mobile RFID in the relevant literature with the intention of revealing the competitive advantages gained by using mobile RFID.

The study is organized as follows: The next section provides an overview of different studies concerning the physical mobile interaction, illustrates the techniques and the supporting

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technologies to realize physical mobile interaction. In section 3, mobile RFID is defined. Afterwards commercial applications in the relevant literature are categorized, in order to define the possible B2C applications enabled by mobile RFID. In section 4, commercial advantages gained by application of mobile RFID are illustrated. Section 5 concludes the study.

2. Physical mobile ınteraction

2.1. Related work

The explanations below, which are related to the physical mobile interaction and the techniques as well as supporting technologies for the realization of physical mobile interaction, are outlined based on the explanations of the studies about the physical mobile interaction in the literature. The literature review revealed that studies about the advantages of physical mobile interaction – realized especially by mobile RFID - are limited. This limitation provides an opportunity for the execution of this study.

Various points concerned with physical mobile interaction, have been discussed until now. Reference [2] develops a framework called Physical Mobile Interaction Framework (PMIF) and shows an example of the implementation of mobile interaction with the PMIF. Reference [6] describes a generic architecture that supports mobile interaction, discusses techniques for physical mobile interaction and their integration in their architecture. Reference [7] presents an experimental comparison of four physical mobile interaction techniques: touching, pointing, scanning and user-mediated object interaction. It describes the advantages and disadvantages of these techniques based on the executed comparisons. Context-specific preferences for the techniques are also described. These preferences help application designers and developers to decide the integration technique. Based on a user-study, techniques pointing, touching and direct input for mobile interaction are evaluated in the study of reference [1]. In the study of reference [8] the techniques of pointing, scanning and touching are described. Furthermore, several use-cases concerning the techniques are illustrated. In the study, the touching technique is examined closer, and it is described how it can be realized via RFID or NFC (Near Field Communication). Reference [9] investigates user perceptions on mobile interaction with visual and RFID tags and potential usability risks that are due to the limited or erroneous understanding of the interaction technique. Reference [10] presents an analysis, implementation and evaluation of the physical mobile interaction techniques of touching, pointing and scanning. Reference [11] describes a conceptual system that enables the usage of physical posters as gateways to mobile services and a generic architecture for such a system. The services are related to advertisements and information presented on the posters. In the study, two scenarios are described to illustrate the usage of the developed system. Furthermore, places where posters can be found and behavior of people at stops where posters are observable are analyzed. Additionally, expectations of potential users in mobile and context-aware services are described. In order to prove the developed concept, a prototype is also illustrated. Reference [12] investigates mobile interaction with

tagged, everyday objects and associated information that is based on the Internet of Things and its technologies. The study focuses on the implementation, design and usability of physical mobile interactions and applications.

2.2. Definition

"Physical mobile interaction (PMI) describes such interaction styles in which the user interacts with a mobile device (e.g. smart phone, PDA) and the mobile device interacts with objects in the real world [7]." PMI enables mobile devices to interact physically with smart objects (tagged objects) and consequently with associated information as well as services [7], [12]. Smart objects can be things, people or locations. Figure 1 visualizes how the physical mobile interaction functions.

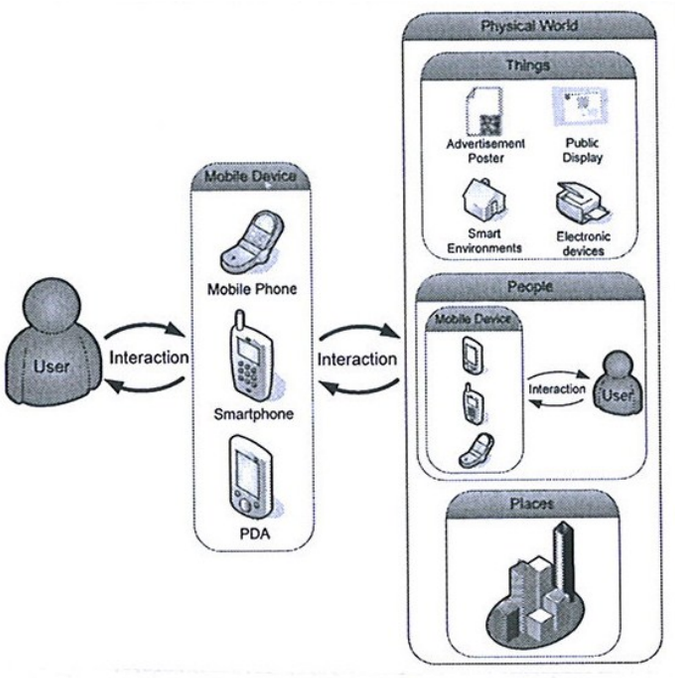

Figure 1. Physical Mobile Interaction [2]

2.3. Techniques for physical mobile ınteraction

Touching, pointing, scanning and user-mediated object interaction are the techniques that are commonly used for the physical mobile interaction [7], [8]. Based on the following determining factors, application designers and developers select the most appropriate technique to integrate into their applications [7], [10]:

- application context,
- location of the object,
- distance between object and user,

- service related to the object,
- capabilities of the mobile device,
- preferences of the user.

Pointing: By means of this technique, user can select or control a smart object by pointing at it with the mobile device [7]. Users of camera-equipped mobile devices point onto visual markers (e.g. QR-Codes (Quick-Response Codes)) on physical objects. In order to access the stored information on markers, visual markers are interpreted by recognition algorithms [13].

Scanning: According to this technique, mobile device scans the environment for nearby objects. Scanning can be triggered by a user, or the environment is scanned permanently by a mobile device. As a result of scanning, nearby smart objects are listed [7]. User is then free to choose the object with which he wants to connect. After the establishment of the connection, direct input from the user is required [8].

Touching: By means of this technique, user touches a smart object with a mobile device or brings them close together (e.g. 0 to 10 cm) [7], [8]. RFID and NFC are the common technologies for touching interaction [10]. Reference [14] is one of the first to present a prototype for touching interaction via RFID. The prototype uses RFID tags and a RFID reader connected to a tablet computer. It enables an interaction with augmented books, documents and business cards, in order to access links to the corresponding services like ordering a book or picking up an e-mail address [7], [10]. This interaction type is relevant for this study. In this context, it is discussed below how this technique is realized.

User-mediated object interaction: By means of this technique the user types in information provided by the object to establish a link between the object and the mobile device. As user is responsible for the establishment of the link, no special technology is needed for linking. Portable museum guides are good examples for the application of this technique. A visitor using portable museum guide has to type in a number to get information about a desired exhibit or a URL printed on an advertisement poster to get access to the corresponding services [7].

2.4. Supporting technologies for physical mobile ınteraction

Typical technologies that support physical mobile interactions are RFID, NFC and 2D Barcodes [15], [16].

2D barcodes and QR-codes: A traditional linear (1D/1-dimensional) code contains data in one direction only. 2D barcode is a graphical image that stores information both horizontally and vertically. That is why it can represent more data per unit area than a linear code. Additionally, it can encode several types of data such as symbols, control codes, binary data and multimedia data [15].

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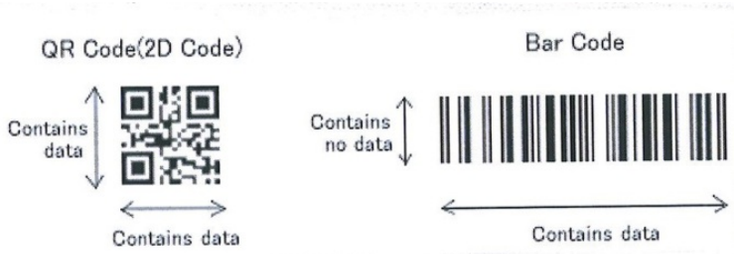

Figure 2. QR-Code vs. linear code [15]

Figure 3 includes some examples of 2D codes.

Figure 3. Examples of 2D barcodes [16]

Among barcodes, 2D barcodes are commonly used for mobile applications. QR-Codes were developed by the Japanese Company Denso Wave Corporation in 1994. It is faster than other 2D codes, because it contains three square position patterns that are used for position detection. These patterns are also used to detect the size, the angle and the outer shape of the symbol. When a reader scans a symbol, it first detects these patterns. Once they have been detected, the inside code can be read rapidly by the scanner. Decoding speed of QR-Codes is 20 times faster than that of other 2D codes [15]. These advantages of QR-Codes are the motives for preferring them for mobile applications.

In order to use barcodes for physical mobile interaction, mobile devices have to be equipped with cameras and image recognition algorithms. Using cameras of mobile devices and applying image recognition algorithms, barcodes – thereby products – are identified [3].

RFID: RFID is an Auto-ID technology that enables to identify tagged items by means of radio waves. Main components of a RFID system are:

- *Tag (Transponder):* It consists of an antenna and a microchip. Microchip stores data about the tagged item. Antenna transmits the data about the tagged item to the reader by means of radio waves [17].
- *Reader (Transceiver):* It is a device that communicates with tags through radio waves and reads data on them [18].
- *RFID Middleware:* It is a type of software that is used to consolidate, aggregate, process and filter raw RFID data, which are received from multiple readers, in order to generate useful information for end-users. It transmits also the processed data to backend enterprise applications [19].
- *RFID System Software:* It is software for the communication between tags and readers in order to read tags, write on tags, detect and fix erroneous data as well as to realize authentication for security [20].
- *Backend Enterprise Service:* This service helps to receive filtered RFID data from the middleware and integrate these with existing applications such as ERP, SCM or CRM systems through Application Programming Interfaces (APIs) [19].

NFC: This technology can be seen as an evolution of RFID technology [15]. It is a combination of RFID and interconnection technologies [21]. NFC is compatible with RFID. Both of them use the same working standards and radio frequencies for communication [15]. The differences between these technologies can be listed as follows:

- RFID operates in a long distance range compared to NFC. There is an eavesdropping risk for data exchange. NFC has a short transmission range. That is why NFC-based transactions are inherently secure and there is almost no risk of eavesdropping [8], [15].
- RFID allows only one mobile interaction method, according to which a reader reads or writes a predefined tag. NFC enabled devices allow three different mobile interaction methods. According to the first alternative, NFC enabled mobile device initiates the data transfer by sending a RFID signal to the tag. The tag responds and sends the information it contains back to the mobile device. This type of interaction is congruent with the interaction in RFID systems. According to the second type of interaction, the NFC enabled device acts as a tag (or a smart card). Information on the device can be read by a reader at an interaction point. According to the last type of interaction, direct communication between two NFC enabled mobile devices is possible [8].

NFC has two basic elements: Initiator (called reader in RFID) and target (called tag in RFID). Initiator begins and controls the information exchange. Target responds to the requirements of the initiator. Two modes of operation exist for NFC: active and passive. In the active operation, initiator and target generate their own field of radio frequency to transmit data. In the passive operation, only one of these devices generates the radio frequency field. The other device is used to load modulation for data transfer [21].

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3. Mobile RFID

3.1. Definition

Two main ways exist to integrate RFID with a mobile phone, which is a commonly used mobile device for physical mobile interaction: a mobile phone with RFID tags and a mobile phone with a RFID reader [10].

A mobile phone with a RFID tag is a mobile device that includes a RFID chip with some identification information programmed on it. Besides a cell phone antenna used for connection to the network operator, the phone contains a RF antenna for communication with RFID readers. When RF tag equipped phone and reader are within an appropriate range for interaction, the tag information is sent to the reader, and the reader can write some information back to the phone's RFID tag [22].

A mobile phone with a RFID reader is a mobile device that includes a RFID reader. This reader collects data from fixed or mobile RFID tags. The phone also includes an antenna. The phone should have an appropriate reader software for reading and writing tags [22]. The rest of this study focuses on mobile devices that are integrated with RFID readers.

A mobile RFID system works as follows [8], [23]:

- User brings the mobile device equipped with a reader and the object with a tag (smart object) close to each other.
- Reader software in the mobile device activates and decodes tag info, which can be a list of services (e.g. getting more information via an online user manual, changing the state of a smart object such as playing music from the smart phone on your home stereo by simply placing the phone on top of the home stereo) offered by smart object, e-mail address, telephone number, web address, preformatted short message, short text, electronic business card.
- Displaying the decoded info on mobile device.

Below an artificial scenario, that was developed in the context of PERCI-project (PERvasive ServiCE Interaction)[1], is illustrated, in order to highlight how mobile RFID functions. The scenario supports mobile ticketing and payment services. Two posters are used in the scenario that are associated with Web services for mobile ticketing. The first poster allows users to purchase movie tickets for appropriate options like movie title, cinema name, number of tickets and preferred timeslots. The second poster enables to ticket purchases for a public transportation system and offers options like station to start the journey, destination, number of passengers, duration of journey to suggest appropriate tickets. Each option on the posters has a NFC tag and a visual marker. Tags and markers contain or reference the information that the option represents (e.g. name of a cinema) [1], [12]. On the posters action and

1 PERCI-project is a project of the collaboration between University of Munich and NTT DoCoMo Euro-Labs [1] and is funded by the latter. The goal of the project is to investigate and develop new methods for mobile interactions with the Internet of Things [24].

parameter tags are used. Action tags contain URLs of different services. Parameter tags provide parameter-values for the invocation of service. In order to determine the service that is to be used (e.g. ordering a movie ticket), an action tag has to be selected first. Then the corresponding parameter tag has to be selected for the invocation of the previously selected service (e.g. movie title or time slot) [1]. Users interact with the posters with their NFC enabled mobile phones that support interaction techniques pointing, touching and direct input [1], [6]. A user can buy a movie and a transportation ticket by pointing and touching his NFC enabled mobile phone on the posters. His mobile phone displays his selections and presents him a payment form. The user enters his credit card details on his phone to proceed and receives an electronic confirmation. The user shows the electronic confirmation on his phone to the transport controller and cinema officer [6].[2]

3.2. Mobile RFID applications

3.2.1. Related work

Applications of mobile RFID span across multiple areas including enterprises, consumer markets, public sector and even private lives. Among the reviewed references, which studied the application possibilities of mobile RFID, some references have a general classification of all possible application areas and some concentrate on a few, special application areas. In order to analyze the references, the reviewed applications are grouped into a classification framework for mobile RFID that considers three main application groups: *Public*, *Business* and *Private* (see Figure 4). *Public* applications include non-commercial applications for public use such as applications for education and health. *Private* applications are also non-commercial applications of RFID based appliances and focus on using RFID in connection with mobile devices in houses or in offices (e.g. RFID tagged food items in smart refrigerators). *Business* applications cover all commercial and non-commercial applications in a business organization such as applications for Supply Chain Management, Customer Relationship Management or Workflow Management.

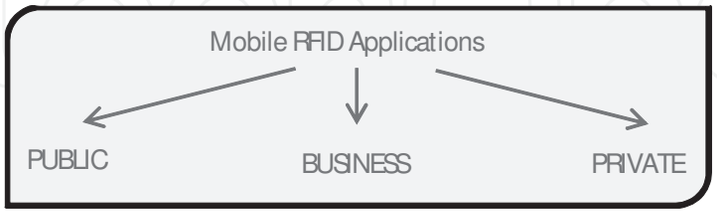

Figure 4. Classification framework for mobile RFID applications

2 As mentioned in Section 2.4, NFC technology is an evolution of RFID technology and besides two additional mobile interaction methods, it uses an interaction method that is also used by RFID technology. According to this method, a reader reads or writes a predefined tag. NFC tags of the illustrated scenario of PERCI-project use the mentioned method. In this context, it can be denoted that NFC tags of the scenario do not differ from RFID tags and the scenario of PERCI-project can be used as an example to highlight how mobile RFID functions.

Applications from thirteen references are reviewed in this study, in order to determine the possibilities concerning commercial utilization of mobile RFID. Below, each work is summarized briefly.

Study of reference [15] is one of the few studies that considers directly the use of mobile RFID and proposes four application categories:

1. Applications for education: RFID tags are used to enable learner to access learning content of an object according to the surrounding context.
2. Applications for health: Using mobile RFID for tagged medicines, RFID based patient smartcards, medical RFID patches enable easy access to patient's information and to monitor the health of patients.
3. Applications for entertainment and culture: Mobile RFID is used to enhance visits to museums and art galleries, particularly for guided visits.
4. Commercial applications: Using mobile RFID for any commercial activity such as ticketing, banking or purchasing goods and services.

Reference [25] groups mobile RFID applications into the following zones:

1. Applications for location based services zone: Services related to customer's current location are provided. Service providers deploy RFID tagged items/devices in a location that provide instant real-time information about services available at that location. Downloading bus routes by scanning RFID tagged buses, downloading prices of RFID tagged goods at stores, downloading movie information, trailers, show timings and the nearest theater locations by scanning RFID tagged movie posters, downloading current menu being served at a restaurant by scanning its RFID tag are some examples for applications concerning location based services.
2. Applications for enterprise zone: Mobile RFID applications support company's mobile staff like inventory checkers, field engineers, maintenance and repair staff, and security guards. It supports them in terms of inventory management in real-time, work attendance log, instructions on how to operate tagged items and demonstrating of staff presence at certain locations etc.
3. Applications for private zone: Mobile RFID assists users in their private spaces like home, garden, garage etc. For example, it helps users to make an instant call or send an instant message by scanning RFID tagged photographs and business cards. By scanning RFID tagged household items with a mobile phone, information (e.g. information about the expiration date of milk in the refrigerator or about the last watering time of a RFID tagged plant) can be obtained quickly.

Report of reference [22] focuses mainly on the enterprise market. However, a few consumer applications are presented to show the potential of the technology in the consumer market. Mobile RFID applications are categorized in five groups:

1. Applications for getting real time product information: For example, a service technician touches the machine to service with his smartphone, and up-to-date service information (for example last service date, instructions for additional service) is downloaded at his device.
2. Applications for collecting real-time information: For example, sending specific time and location information about a position or status for some calculations like meter measurement for pricing (measurement is sent for pricing by touching a tag attached on a meter with the mobile device) or like recording travel expenses (a tag attached on the car dashboard sends the starting and ending mileage for an expense report).
3. Applications for automatic asset tracking: Instead of counting devices manually on remote sites, mobile phone can collect info from RFID tags on equipment (PCs, desks, chairs etc.) and send this information to the centralized tracking application.
4. Applications for consumer marketing: Pointing onto a poster enables buying a video, a song etc.
5. Applications to initiate a call: A tag attached on a person's photo can be used to make an automatic call.

Reference [5] analyses commercial applications based on mobile RFID technology and defines three areas for it:

1. Product ordering: RFID tags are used for getting the latest information about products and for ordering them in case of a positive buying decision.
2. Transportation management: RFID tags are used to provide basic information of transported products and to record exception information.
3. Products receiving: RFID tags are used for checking the expected quality of the received products.

Reference [26] examines the utilization of RFID in mobile supply chain management and groups the application areas as follows:

1. Transport and logistics: toll management, tracking of goods.
2. Security and access control: tracking people, controlling access to restricted areas.
3. Supply chain management: item tagging, theft-prevention etc.
4. Medical and pharmaceutical applications: identification and determining the location of staff and patients, asset tracking, counterfeit protection for drugs.
5. Manufacturing and processing: streamlining assembly line processes etc.
6. Agriculture: tracking animals, quality control etc.
7. Public sector: passports, driver's licenses, counterfeit protection for bank notes, library systems etc.
8. Sports and leisure: tracking runners etc.

9. Shopping: facilitating checkout procedures etc.

Reference [27] defines seven scenarios for mobile RFID applications, which are partly inspired by Nokia:

1. Information retrieval: Mobile device helps to receive information on tagged items. Information would be stored in a database, which is accessed via mobile network. For example, a mobile phone user sees an advertisement on a poster and wants to get more information about the advertised product.
2. Data transmission: Means data transfer, for example for reading of electricity meters via a mobile phone.
3. Automated messaging: Messages will be transmitted when the tags are read (e.g. for reporting presence in the office).
4. Voice services: Through tagged items making phone calls simplifies.
5. Device integration: Information retrieved from tags in the environment can indicate to the mobile phone, which could then activate certain functions. For example, when a mobile phone is placed in a car, support for hands-free can be activated or when the mobile phone is in a hospital, it will be blocked.
6. Presence indication: RFID tag on the phone enables readers in the environment to identify the phone. For example, the location data of a person in a building can be used to provide automatic login to a system.
7. Mobile payment: RFID tags in the mobile device store information for payment.

In reference [8] two scenarios for physical interaction are introduced. The first one is a Smart Environment, according to which the user at home can interact with his personal electronic devices. The second one is about Information Heavy Situations, which can be applied for museum visits and guided tours. Transactions in supermarkets and fashion stores, buying car parking tickets, getting tourist information and using active posters are defined as possible utilization of mobile RFID in this study.

In reference [28], literature on mobile commerce (m-commerce) applications are reviewed. The result of this review reveals that location based services, mobile advertising, mobile entertainment services and games, mobile financial applications, product locating and searching, m-commerce in individual companies or industries are the possible m-commerce applications.

Reference [4] defines mobile RFID as a service using mobile devices to download information from RFID tags containing information of a specific area like stores, restaurants and tour sites.

Reference [29] executes a wide study about the utilization of mobile RFID. It describes many applications for RFID (e.g. buying electronic tickets, mobile payment, getting data about products, transportation, stock-trading, services like car rental, bike rental, car parking, taxi

ordering, admissions to museums, musical and sports events, automatic call of a technical service hotline) and demonstrates them with case studies.

Using mobile RFID in B2B sector is considered in references [30], [31], [32]. Reference [30] provides information about a B2B case study in the retail industry supported through RFID technology and demonstrates that the RFID network can improve all relevant supply chain processes. In reference [31], mobile RFID technology is used to track and trace a product during supply chain activities (e.g. mobile product authentication service for consumers or an alert service for manufacturers). In reference [32], mobile RFID is used to manage product arrival inspection and loading in the context of transport management.

In Table 1, all applications found in the reviewed references are categorized according to the framework for mobile RFID applications.

Application Areas	Application Types
Public	**Voice Services** [22, 27], **Identity Management** [29], **City Information** (bus routes, train schedules, restaurants, stores) [4, 8, 15, 25, 29], **Mobile Learning** [15], **Health Services and Information** [15, 26], **Mobile Entertainment Services** [25, 28],**Agriculture Management** [26]
Business	**Mobile Commerce**: *Mobile Advertising* [4, 27, 28] via active posters [8, 22, 27, 29], *Product Ordering* [5, 15, 26, 28, 29] (e.g. electronic tickets for buses, car parking, museums, events, [8, 15, 29]), *Service Ordering* (e.g. taxi, technical service, hotel reservation, ski area acess [29], renting a car, bike etc. [29]), *Mobile Payment* [8, 15, 27, 28, 29], **Asset Management** (inventory control) [5, 8, 22,26], **Transportation Management** (arrival inspection, loading, locating, searching, alert service) [5, 26, 29, 30, 31, 32], **Location Based Services** (data transmission for meter readings/pricing, progress reports, work attendance logs) [22, 25, 27, 28, 29]
Private	**Smart Living Environment** (presence indication, device integration, appliance monitoring) [8, 25, 27, 29], **Asset Tracking** [22], **Voice/Messaging Services** [22, 25], **Sports and Leisure** (tracking runners) [26]

Table 1. Mobile RFID applications in categories

3.2.2. Commercial use of mobile RFID

Public and *Private* applications of the mobile RFID classification framework are out of the scope of this study. In order to define commercial applications and the advantages of mobile RFID, this study focuses on *Business* applications. *Business* applications differentiate among *in-house*-applications, *B2B* and *B2C* applications. *In-house*-applications deal with the execution of internal, non-commercial processes in enterprises. *B2B* applications comprise mainly commercial applications in supply chain management with business partners as well as applications for logistic processes. *B2C* processes aim to sell goods to end-consumers. Figure 5 includes an extended classification framework for mobile RFID applications.

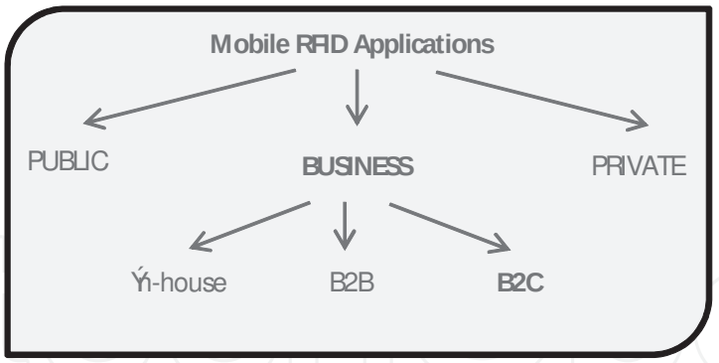

Figure 5. Extended classification framework for mobile RFID applications

As it is seen in Table 1, mobile RFID makes an important contribution to the execution of mobile commerce [5]. M-commerce is a subset of e-commerce and is defined *"as any transaction with monetary value that is conducted via a mobile network"* [33]. Through m-commerce, interaction between supplier and customer is facilitated not only by a mobile network, but also by a mobile customer device. Possible mobile networks for m-commerce are conventional mobile carrier networks, WiFi networks or networks of local frequency technologies for unique identification capabilities for goods (e.g. RFID) (see Figure 6). That is to say, mobile RFID is one of the possible supporting technologies for m-commerce. According to m-commerce supported by mobile RFID, commercial interaction and transaction between suppliers and customers are realized through physical mobile interaction as described above.

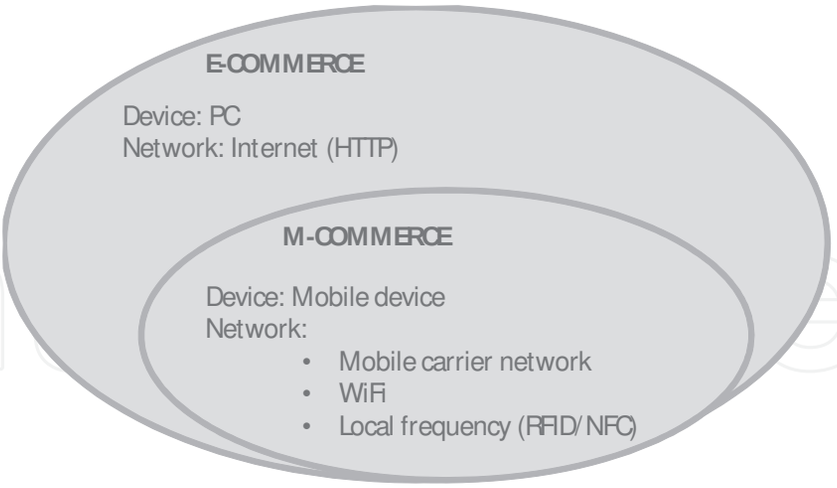

Figure 6. E-commerce vs. M-commerce

This study focuses on B2C m-commerce applications enabled by mobile RFID. As a result of this the m-commerce applications concerning B2C in Table 1 are defined closer:

- **Mobile marketing:** Mobile marketing is a sales approach that helps manufacturers, shopping malls, and service agencies to promote their products and services through interac-

tion with customers via their mobile devices [34]. Kotler [35] defines two basic marketing communications strategies: push and pull strategies. Push-based mobile marketing refers to any content sent by marketers to a mobile device, whether the consumer requests it or not and includes audio, short message service (SMS), e-mail, multimedia messages, or any other pushed advertising content [36]. While push marketing is marketer-initiated, pull marketing is consumer-initiated. Pull-based mobile marketing is defined as any content sent to the mobile consumer upon request [37]. Consumer requests information about products and services that interest him. For classical m-commerce applications enabled by mobile device's Internet or Wifi, both of the mobile marketing communications strategies are applicable. Sending a SMS advertisement to consumer's mobile phone is an example for push mobile marketing. Searching the Internet for a product via a mobile phone is an example for pull mobile marketing. For m-commerce applications enabled by mobile RFID pull marketing strategy is viable. Only if the consumer wants to get more information about a product or a service, or if consumer wants to buy a product or get a service of the RFID tagged item, he can request it. Furthermore, the pull marketing strategy of RFID supported m-commerce is more effective than by classical m-commerce. Because in classical m-commerce, getting information via mobile device's Internet service takes a lot of time and energy of consumer, while through RFID tags information gathering is very quick and convenient [5]. Advertising is an important method for the marketing mix element "communication" (see Section 4). Mobile RFID enables mobile advertising. Through active posters augmented with RFID tags, which advertise a product or a service, or through the tagged items themselves, marketers try to catch consumers' attention. If desired, information about goods is "pulled" very easily via a mobile device. In case of interest, the designated products and/or services can be ordered. Active posters can also be used for location-based mobile advertisements. By using their mobile devices equipped with RFID readers, consumers can read RFID tags, which are placed on boards, and get information about nearby services or products such as restaurants, cinemas [4].

- **Product and service ordering:** Activities concerning product/service ordering do not differ from classical mobile commerce applications. In the context of mobile commerce enabled by mobile RFID, ordering is carried out via a mobile device on Internet or on a product specific network as is done in the classical mobile commerce.
- **Mobile payment:** Payment for product or service ordering occurs also via a mobile device like in classical m-commerce.

4. Advantages gained by mobile RFID

Advantages of using mobile RFID for B2C applications can be grouped as in Figure 7. Mobile RFID is a RFID-based mobile IT application. That is why, the advantages resulted from its characteristics of being an IT system, a mobile solution and a RFID-based technology have to be considered initially.

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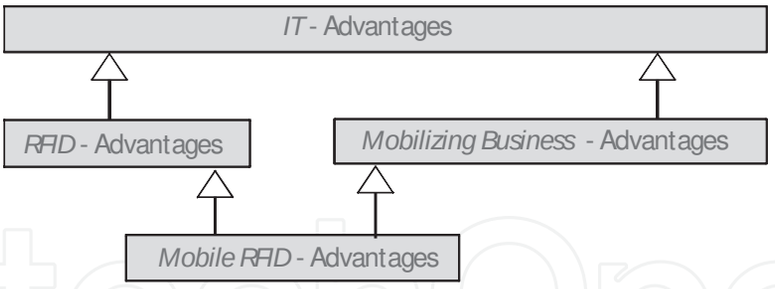

Figure 7. Inheritance classification for mobile RFID advantages

IT-adoption enables organizations to increase efficiency through the automation of processes and information management. As a special IT system, mobile RFID inherits this advantage. RFID technology is a radical innovation in terms of business processes. It does not only automate business processes more efficiently, but it also changes them radically [37]. In addition, it reduces inaccuracy of information caused by transaction errors (e.g. shipment errors, delivery errors etc.) [38], [39]. Substitution of expensive human work through a fully automatic identification system like RFID leads to an increase in information quality, higher data availability and higher speed of process execution, thereby to higher productivity, performance and cost savings [37], [38], [39], [40]. All of these advantages of RFID technology belong also to mobile RFID, which is a RFID-based technology. Mobile business solutions give users the flexibility to operate in a wireless computing environment anywhere [41] and anytime. Users can take advantage of information systems linking business processes among different departments within a company and among companies at remote locations [41]. Ability of accessing a corporate network anywhere and anytime is the primary motive for adopting mobile enterprise solutions [42], [43].

There are also some specific advantages of using mobile RFID in B2C applications. These can be listed as follows:

- **Advantages concerning Marketing Mix:** "*The marketing mix is a combination of tactical marketing tools that a firm uses to satisfy the target market* [44]". Four Cs marketing mix model, which is adopted in this study,[3] groups the marketing tools into four categories: customer needs and wants, cost to customer, convenience and communication. According to the four Cs marketing mix model firms should sell only products that customers need and want. Consumers are more concerned with total costs of ownership of a product rather than its price. Convenience means the ease of buying and finding the product as well as finding information about the product. Consumers should be provided with the most convenient way possible for purchasing. Under communication, any form of communication (e.g. advertising, public relations, personal selling, viral advertising) between a firm and its consumers is understood [45]. Using mobile RFID has a positive impact on the following elements of four Cs marketing mix model:

3 Today's firms tend to execute their activities customer-oriented. Thus, the study adopts customer-focused marketing mix model four Cs instead of product-oriented four Ps marketing mix model.

- *Customer Needs and Wants*: It is essential to offer products that meet customer needs and wants. In order to determine needs and wants of customers, marketers need a good customer database. They may use mobile tags to provide links to specific mobile sites in which through various tools (e.g. questionnaires, voting) information about the needs and wants of customers are collected. The captured information are then analyzed and used to determine offerings for the target customer [46].
- *Convenience*: As mentioned above, ease of finding information about a product is an essential aspect of convenience. Through mobile RFID tags, marketers can provide additional information about their products (e.g. the nutrient content in packaged foods) or events (e.g. concerts, parties, conferences etc.) and facilitate direct downloads (e.g. branded mobile content) [47].
- *Communication*: Advertising is a powerful form of communication and mobile devices are effective communication tools. Consumers use their mobile devices to get tag info that can be an advertisement of a product or a link to a mobile commerce enabled web site. For example, by pointing his/her cell phone onto a poster of a new single, a consumer can get info about the singer, watch the video clip and even buy the song [22]. Mobile RFID enables also location-based mobile advertisements. By using their mobile devices equipped with RFID readers, consumers can read RFID tags, which are placed on boards, and get information about nearby services or products such as restaurants, cinemas [4]. Reference [48] defines using mobile tags within a location-based mobile advertisement publishing system as a convenient way for vendors to create and edit advertisements that include the vendor's location as well as discount coupons stored on a tag.
- **Seamless B2C process:** Mobile RFID enables seamless process flow from advertising to product/service ordering and following to mobile payment with only one mobile device. Thereby, it contributes to solve the media break problem. Off-line products with RFID tags contain information pointers represented as URLs that enable users to access associated on-line contents. For example, a movie poster on a billboard, which is an off-line marketing instrument, can have a RFID tag. This tag enables the user with RFID reader equipped mobile phone to access online information associated with the movie poster (e.g. a short summary about the subject of the movie, comments of movie reviewers), which forms an important online-marketing instrument [49].
- **Ease of information access:** Information access is possible from anywhere to anytime. Information about products or services, which seems interesting for users, can be received immediately via mobile devices [50], [51].
- **Enhanced CRM:** With RFID tagged items and their ordering via mobile devices customer-oriented direct pull marketing strategy is followed. Customers are always able to retrieve valuable product/service information. This customer-oriented characteristic of mobile RFID can increase customer loyalty and lead to repeat purchasing [52].
- **New business models:** Mobile RFID technology leads to new business opportunities for services and products (e.g. the company Flexcar exists only because of its remote vehicle-usage-monitoring system) [22]. Companies that use this technology profile as innovative companies on the market. This is an important competitive advantage for companies [16].

All of the listed advantages have positive impacts on the increase of customer satisfaction, keeping existing customers and thereby increasing customer loyalty as well as on gaining new customers. As customer satisfaction, customer loyalty and an increase in the number of new customers impact directly the revenue of a company, it is not wrong to conclude that mobile RFID has an essential impact on the revenue increase of a company.

5. Conclusion

Although RFID is not a new technology, mobile RFID applications are still in their infancy and their business impact is still unproven. Most of the studies about mobile RFID in the relevant literature are limited to the realization techniques, application possibilities or to case studies. Commercial advantages gained by mobile RFID have not been discussed comprehensively. In this study, based on a literature review B2C applications of mobile RFID are analyzed and commercial advantages of using mobile RFID for B2C applications are illustrated. In this context, first physical mobile interaction concept was defined. Following, mobile RFID was introduced as a supporting technology for physical mobile interaction. After the categorization of mobile RFID applications in the relevant literature, the possible B2C applications enabled by mobile RFID were defined. Finally, commercial advantages of using mobile RFID were illustrated.

This study sheds an insight into the business value of mobile RFID from a commercial viewpoint. Certainly, findings of this theoretical study have to be concretized and validated through case studies in future research.

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