Current Benefits and Future Directions of NFC Services

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***Abstract*— Near Field Communication (NFC), as an emerging and promising technology, is an integration of Radio Frequency Identification (RFID) technology with mobile devices. NFC-enabled mobile devices can act as contactless smart cards and are also capable to read and write data from/to those cards. Research endeavours concerning NFC appear to focus mainly on development of NFC enabled services and applications. On the other hand, benefits and underlying values associated with different NFC applications' service is not yet well elaborated. In this paper we examined existing NFC applications, prototypes and studies from both academia and industry. We analyzed these applications by classifying them into NFC operating modes to surface the nature of underlying value-added services and benefits that they provide. Moreover we emphasized possible future usage scenarios together with directions and questions for future research based on the identified benefits.**

Keywords- Near Field Communication, Mobile Applications, Emerging Technologies

I. INTRODUCTION

Near Field Communication is a short range wireless communication technology which is evolved from Radio Frequency Identification (RFID). It enables communication between two NFC enabled devices within few centimeters.

Recently many business scenarios are implemented using NFC technology such as payment, ticketing, supply chain management systems, and also new NFC specific scenarios are arisen such as smart posters. NFC's three different operating modes, which are described later, and increasing capabilities of mobile devices enabled many NFC scenarios to be implemented.

In NFC, the communication occurs when two NFC compatible devices are brought together less than four centimeters, or simply by touching themselves. It operates at 13.56 MHz and can transfer data up to 424 Kbits per second [1]. In an NFC model two devices are involved in the communication, which are called initiator and target. Initiator is an active NFC device which is responsible for starting the communication. Also it has an embedded energy component whereas target can be either a tag, RFID card or an NFC device which responses the initiator's requests [2].

The devices in the communication share a single RF band in which the communication is half-duplex [2]. When one device is transmitting, the other one has to listen first and should start to transmit after the first one finishes.

One of the advantages of NFC technology is that mobile devices can be used both as an information storage or an NFC reader. They can read information from NFC tags and display that information on the screen with an ability to make additional processing. Also they can be used as a digital storage e.g. storing credit card information.

Other most important advantages of NFC technology include;

- The technology is compatible with existing RFID structures, existing RFID tags and contactless smart cards [1].
- It is easy to use and familiar to people because users don't need to have any knowledge about the technology. All a user has to do is to start communication by bringing two devices together [3].
- The transmission range is so short that, when the user separates two devices, the communication is cut. This brings inherent security. If there isn't any other device close, there is no other communication.

Since NFC technology is invented, various real-life applications have been evolved. An NFC literature review study in [4] revealed that, about 40% of the NFC literature concentrated on developing new NFC applications. However we realized that benefits and values of these applications are not studied. To demonstrate the value of an NFC application, consider the following example, which is *an automated check-in system for hotels* [5]. When a guest books a room from hotel, room's information and digital key are sent to the guest's mobile phone. As the guest arrives at the hotel, she does not need to wait in check-in queue, instead she directly goes to her room, and opens the door with her NFC-enabled mobile phone. Also checkout process is accomplished either through NFC-enabled TV in the room or through NFC enabled kiosk in the reception. As seen in the demonstration example, combination of NFC with other existing mobile technologies provided new benefits. Customers do not need to wait in the check-in and check-out queue and also they don't need to carry the hotel key with them.

In this paper, after examining all relevant projects and research endeavors, we aim to answer the following research questions:

- What are the benefits of currently developed NFC applications?
- Which possible applications can be implemented in the future, and what benefits can we expect from them?

In order to find answers to these research questions, we conducted literature review of NFC applications, application prototypes, and studies from both academia and industry. After the review, applications' characteristics and features are identified. Also an application list that contains all necessary information of applications is created. Several rounds are performed to create the list to make sure that all of the information is accurate. After creating the list we planned roundtable discussions, in which several academicians who are working on mobile technologies, NFC and management attended. After discussions, we decided to investigate applications' benefits and impacts to our life by classifying them based on NFC operating modes which are described in the next section. The reason to classify applications based on operating modes is that, they differentiate how NFC devices communicate with each other. Also as the communication mode changes in an NFC application, usage and benefit of the application change as well. So every mode has its own benefits and usage areas. After analyzing benefits of those applications, possible future scenarios that NFC can influence are discussed.

The remainder of this paper is organized as follows. Since NFC's operating modes are important for this research, section 2 includes the operating modes of NFC in detail. In section 3, we present overview of investigated applications by giving a summarized table. In section 4, we discuss the applications' benefits and future scenarios and propose new research questions. Finally we present our conclusion in section 5.

II. NFC MODES OF OPERATION

As stated above, we classified NFC applications based on NFC operating modes. As shall seen later operating modes are vital to characterize applications.

NFC has three operating modes; *Peer-to-Peer*, *Reader/Writer*, and *Card Emulation*. These operating modes are defined by NFC forum [1], which was formed to advance and standardize the use of Near Field Communication technology. In card-emulation mode the data is transferred from mobile-device to NFC-Reader; in reader/writer mode data is transferred is from NFC tag to mobile device or mobile device to NFC tag; and in peer-to-peer mode data is transferred between two NFC compatible devices.

Reader/Writer mode: In the reader/writer mode, NFC devices can read and write data from/to NFC tags and smart cards. NFC device acts as an initiator and passive tag is the target. Passive tag does not need any source of power. Active NFC device creates magnetic inductive coupling and transfers energy to smart card when it gets close enough. After the smart card is powered, communication starts. In this mode of communication the data speed can increase up to 106 Kbit/sec.

Card Emulation mode: In the card emulation mode, NFC device acts as an RFID card and other NFC devices can read data from this NFC device [1]. The advantage of this mode is that there is not any need for NFC tag or a RFID card, and stored information in the NFC device is used for further operations.

Peer-to-Peer mode: In the peer-to-peer mode, two devices can exchange data at link-level. This mode is standardized on the ISO/IEC 18092 standard, and allows data speed up to 424 Kbit/sec [1].

III. OVERVIEW ON APPLICATIONS

Table 1 presents the applications examined in this paper. The first column indicates which *NFC Mode* underpins the application (CE=Card Emulation Mode, R/W=Reader/Writer Mode, P2P=Peer-to-peer Mode). For the convenience of application survey in this paper, we give a short name to each application (the *application name column).* Finally the *source* column is to reference of the application.

TABLE I. NFC APPLICATIONS SURVEYED

NFC Mode*	**Application Name**	**Source**
CE, R/W, P2P	Automotive Environment	[6]
CE, R/W	Smart Universities Ambient	[7, 8]
CE, R/W	Ticketing	[9]
CE, R/W	Mobile Coupon	[10]
R/W,P2P	Hot in the City (Mobile Social Network)	[11, 12]
CE	Payment	[13, 14]
CE	Tapango E-ticketing	[15]
CE	Electronic Key	[5]
CE	Health Monitoring System	[16]
CE	Context-aware smart spaces	[17]
R/W	Attendance Control	[18]
R/W	Electronic Check	[19]
R/W	Meal Ordering for Elderly People	[20]
R/W	Meal Services for Elderly People	[21]
R/W	Services for Home Patients	[22, 23]
R/W	Medication Care in Hospitals	[24]
R/W	Mobile medical patient tracking and diagnosis system	[25]
R/W	Supporting Alzheimer patient's daily activities	[26]
R/W	Mobile Prescription	[27]
R/W	NFC based drug ADR detecting	[28]
R/W	Sales Data Management System	[29]
R/W	Mobile Sales Assistant	[30, 31]
R/W	Remote Grocery Shopping	[32]
R/W	Smart Poster	[33]
R/W	Smart Poster-Web Service	[34]
R/W	Smart Poster-Newspaper	[35]
R/W	Remote Electronic Voting	[36]
R/W	Pervasive Services	[37]
R/W	Touch & Interact	[38, 39]
R/W	Multimedia Controller	[40, 41]
R/W	AmI Environment	[42]
R/W	Pick & Drop	[43]

R/W	Cross-media Smart Postal System	[44]
R/W	Document Copying Control	[45]
R/W	Social Networking	[46]
		[47]
R/W	LocaTag	[48]
R/W	Encouragement of Outdoor Physical Activities	[49]
R/W	Location-based Wiki	[50]
R/W	Mobile Museum Guide	[51]
R/W	Tourist Map	[52]
P2P	Contact Information Management	[53]
P2P	File Transfer	[2]

*: CE=Card Emulation Mode, R/W= Read/Write Mode, P2P =Peer to Peer Mode

IV. BENEFITS OF NFC APPLICATIONS BASED ON THEIR NFC OPERATING MODES

In this section we discuss the benefits of investigated applications and future scenarios by classifying them into NFC operating modes. As described earlier, the reason to classify applications into NFC mode is that the communication way is different in each NFC mode and these differences make change in benefits and usage areas.

A. Benefits

1) Card Emulation Mode

After analyzing those applications using card emulation mode, the pertaining characteristic of the mode is concerned with eliminating the need for a physical object. Few examples may illuminate this characteristic. If we investigate payment applications [13, 14], the usage of mobile phone eliminates carrying contactless credit, smart cards, or cash. Instead, a user makes payment with her mobile phone. In electronic key application [5], NFC usage eliminated carrying physical key and contactless smart key. As it is used to enter rooms instead of electronic keys, it provides access control. We can also conclude that attendance control [7] also provides access control; in which students must be authenticated to prove attendance to the class. Moreover in ticketing application [9] and mobile coupon application [10], card emulation mode is used while cashing in ticket and mobile coupon. Actually these two processes also gained physical object elimination by eliminating paper-based tickets and coupons. In [15], in addition to ticketing, users are able to buy foods, drinks with their credits. This application also provided elimination of tickets and cash. As a result, most important features of card emulation mode are discovered as elimination of physical objects and providing access control.

2) Reader/Writer Mode

In reader/writer mode, data stored in an NFC tag is read by an NFC-enabled mobile phone and then that data is used to process further operations. Transferred data can be any type of text, such as a web address, data of an event, or some other data. After transfer operation, the data can be used for many purposes. In the most basic usage, transferred data can be displayed on the screen until user closes the application. Let us discuss by giving some examples. In smart poster application [33], a scenario in a university is developed. In this scenario, smart posters are used to give information to people. In an example scenario, when user touches his NFC-enabled mobile device to NFC-tag on the poster, department staff information is transferred from the tag to the mobile device. Then student can easily find staff's room with eliminating the need to remember room number which is still displayed at mobile device's screen. These processes provide mobility to user, as user can move or find her way, while the needed information still can be read from the screen.

Much more applications using reader/writer mode are developed than other modes. The most important reason for such development is found out that, there are so much interesting and easy to implement use case scenarios that can be developed in reader/writer mode. Also developments and implementations of reader/writer mode applications are relatively easier to implement than others.

As described above, in this mode mobile device has the ability to make additional processing after receiving data from NFC tag. In electronic voting application [36], users voted for student council voting with their NFC-enabled devices upon reading the candidate's data from an NFC tag. In [43], users downloaded multimedia content to their mobile phones upon receiving the corresponding URI from NFC tag.

Moreover, based on the design of the application, this mode is able to provide mobility and to decrease physical effort. Increasing processing power and wireless Internet access of mobile devices also helped on this issue and made this mode more attractive. In [22, 23], patients uploaded their medical information using NFC technology from their homes. In [20], elderly people ordered their meals from their homes. In remote grocery shopping application [32], clients shopped from home by touching their mobile devices to NFC tags that are placed onto items. Before throwing the garbage of food's packet, users touched their mobile devices to tags that are on the item's packet and ordered foods from market.

3) Peer-to-Peer Mode

Peer-to-peer mode is rare when compared to other modes, though it is studied for device pairing, networking and file transfer operations. In [6], bluetooth pairing is achieved between the mobile phone and the car's hands-free equipment. In [53] users exchanged their business cards by touching their NFC-enabled mobile phones to each other. Also in [11, 12], users can make new friends by touching their mobile devices to other users' devices. It can be said that peer-to-peer mode provides easy data exchange between two devices, however not much work is done in this mode, hence this outcome will not reflect clear findings.

Based on our findings, we think that the prominent mode of NFC is *Card Emulation Mode*, because NFC brings up two big improvements in this mode; *elimination of a physical object* and *providing access control* from mobile device.

When investigating commercially available and in-test applications, we have found that all of the commercial applications are using card emulation mode. These commercially available applications are payment [54, 55], electronic key [5], and ticketing [56]. We can say that currently card emulation mode is the most promising mode of NFC technology, and the fate of the NFC technology is based on how much acceptance those applications will get from users as well as partners such as financial institutions, mobile network operators, and academicians.

Table 2 summarizes discovered benefits of NFC operating modes together with future usage scenarios which will be also discussed next.

B. Future Usage

Until now, each NFC mode's benefits are discussed based on the developed applications. In this section we want to discuss possible future scenarios using NFC technology. To find out possible future scenarios we categorize future usage areas in terms of operating modes.

1) Card Emulation Mode

Mobile phones provide mobility to users, however when we investigate card emulation mode, we found out that this mode does not support mobility, instead its aim is to make mobile phone tightly coupled with its users. This can be considered as a challenge to mobile phones' mobility property, but people carry mobile phones with them most of the time, and the coupling of mobile phones with human body actually fits with the usage of mobile phones. One can expect that in near future, there will be the opportunity that people will carry NFC-enabled mobile phones not because of gaining mobility, but performing daily functions. Credit cards, keys, tickets will be embedded into mobile phones. So there will be more opportunities to integrate daily objects into NFC-enabled mobile phones.

Moreover we will be able to eliminate carrying physical objects by embedding that information into NFC-enabled mobile phones and also will be able to use them by mobile phones. Nowadays credit cards, tickets, keys, coupons can be used with NFC-enabled mobile phones, but thinking the possible usage areas excite us. We will be able to store so many objects such as id-cards, passports, finger-prints, driver-licenses. Most of these future developments have issues to solve and need to be researched, but they are able to provide physical object elimination and to increase the integration of mobile phones with human.

As mobile phone becomes a part of human, other opportunities will also arise. Most important opportunity will be using NFC-enabled mobile phones as a memory area for users' data. One of the most concrete examples to this usage is the scenario which stores user's patient info into NFC-enabled mobile phone. Most of the people do not want to share their health information with hospitals or any type of organizations to prevent insurance companies to access that data. So storing patient's information in mobile phone can be a critical issue in that manner. Patients then can give permission to doctors or other people that which information they can access. This would be a potential research matter which brings up research questions such as how to store those patients' disease data at mobile phones, and how users decide about permission to access for health records.

We expect that various scenarios related to storing human-related data will be under investigation. One needs to study underlying privacy and ethical factors for these scenarios.

TABLE II. BENEFITS AND POSSIBLE FUTURE SCENARIOS BASED ON OPERATING MODES.

	Card Emulation Mode	**Reader/Writer Mode**	**Peer-to-Peer Mode**
Benefits	1. Physical Object Elimination 2. Access Control	1. Increases mobility 2. Decreases physical effort 3. Ability to be adapted by many scenarios 4. Easy to implement	1. Easy data exchange between devices 2. Device pairing
Future Scenarios	1. Integration of id-cards, passports, finger-prints, driver-license 2. Storage area for critical information to provide user's privacy and authorizing people to access those information	Many real-life scenarios can be adapted to NFC in this mode. In all of the scenarios, some data need to be read from an NFC tag, and additional jobs need to be done by NFC-enabled mobile phone.	1. Secure exchange of critical data 2. Gossiping

2) Reader/Writer Mode

Notice that main benefits of the reader/writer mode are increasing mobility and decreasing physical efforts. Actually these benefits are in accordance mobile phone's mobility properties. As mobile phone and its applications provide mobility and this in turn generally decreases physical efforts. As an example, calling someone from any location provides mobility and eliminates the need to communicate by face to face. So it results in increasing mobility and decreasing physical effort. Moreover with the mobile services usage, e-mail applications are developed for mobile phones and these e-mail applications enable users to read and write e-mails without any geographical restriction. This also has the same effect on mobility and physical effort.

We can see that reader/writer mode supports mobility property of mobile phones. This mode is able to increase mobile phone usage. But we think that it cannot be an actor at NFC technology's future, because it does not add a special property to mobile phone usage.

Another benefit would be that most of the real-life scenarios can be adapted to this mode. It includes transferring data to NFC-enabled mobile phone from a tag and displaying it to user. Moreover mobile phones can make additional

processing with transferred data, can store it with increased storage capacity of mobile phones, or can transfer this data to any server on the Internet. These wide properties provide so many scenarios to be adapted easily.

3) Peer-to-Peer Mode

Main benefit of the peer-to-peer mode is exchanging data easily. When the two users touch their mobile phones each-other, communication starts with their permission. Data exchange between two NFC-compatible devices provides the possibility of secure exchange of critical data and social interaction. Because NFC devices can transfer data in 4 cm, exchanging critical data can be one of the key future applications of this mode. Also people would prefer to exchange critical digital information in such a short distance, but psychological effects of this scenario still need to be studied.

Exchanging critical data using NFC technology seems very secure to end users, this is a psychological advantage. But the security issues need to be considered. For example can communication be hacked from third-party from long distance? What are the privacy issues considering the exchange of critical information? Can one party reach and steal other party's data without permission? These are all research questions and bring new opportunities to researchers.

Social interaction is our currently researched topic about this mode, in which two people can transfer data each other, which is similar to gossiping. People can share desired data with others and again it can be used for many purposes.

V. CONCLUSION

This paper explores the very nature of underlying benefits and future usage scenarios of NFC applications. We consider NFC modes as essential characteristics for examining NFC applications. We contend that each NFC operating mode provides different benefits to users and all have different future usage scenarios.

We articulate that card emulation mode eliminates physical objects such as paper-based tickets or magnetic cash and credit cards. This mode is also able to provide an access control mechanism. Moreover this mode integrates mobile phone with human, thus in the future human-related data such as id-cards, passports, and patience data can be integrated into mobile phones, and an authentication mechanism for third parties can be implemented. Also we think that this mode may promote NFC to become an important technology by enabling to store personal private data into mobile phones. By this way, users will not share any private information with third parties; instead they will store that private information in their mobile phones, and authorize people to access it. So users will have the chance to increase their privacy.

NFC's another operating mode, reader/writer mode, provides various benefits to users based on usage scenarios. This mode's applications are easy to implement and most important benefits of this mode's applications are they can increase mobility and decrease physical effort spent by users.

The third operating mode, peer-to-peer mode, is not sufficiently investigated and it appears that this mode is primarily used for exchanging data easily between two compatible NFC devices. Future usage scenarios of this mode may be exchanging critical data between mobile devices, because exchanging digital information by touching two devices feel secure for users.

Our study provides an overview on the benefits of currently developed NFC applications by classifying them into NFC modes. Future scenarios are derived from the benefits of these applications and introduced new research questions. We believe that this study will guide for future research areas of NFC and future developments of NFC applications.

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The comprehensive list of all reviewed papers that corresponds to NFC applications surveyed can be found at http://it.isikun.edu.tr/icemt2010/references.htm

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REFERENCES

[1] NFC-Forum, Available: http://www.nfc-forum.org.

[2] Ecma International, "Near Field Communication - White Paper", 2005, Ecma/TC32-TG19/2005/012, Available: http://www.ecma international.org/

[3] M. Csapodi, A. Nagy, "New applications for NFC devices", Proc. 16th IST Mobile and Wireless Communications, Budapest, HUNGARY, IEEE, 2007, pp. 245-249.

[4] B. Ozdenizci, M. N. Aydin, V. Coskun, K. Ok, "NFC Research Framework: A Literature Review And Future Research Directions", Proc. 14th IBIMA International Business Information Management Conf., Istanbul, TURKEY, 2010, pp. 2672-2685.

[5] Assa Abloy AB. (2008). Vingcard [Online]. Available: http://www.vingcard.com/binary?id=66705