

Exploring Underlying Values of NFC Applications

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Abstract. Near Field Communication (NFC) is an integration of contactless smart card communication technology into mobile devices, such as mobile phones. NFC technology provides three operating modes and each mode differs from each other in terms of communication and data processing model. Each mode has distinguishable properties, advantages, and disadvantages; so that each one provides different possible business opportunities and different value-added perspectives. In this paper we survey currently available NFC applications as well as application prototypes. Afterwards, we analyzed those applications in order to find out which benefits they provide.

Keywords: Near Field Communication, Mobile Applications, NFC Communication Modes

1. Introduction

NFC is a short range radio technology that enables communication between two NFC enabled devices. Communication occurs when two NFC compatible devices are brought together less than four centimetres, 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 communication, two devices are involved. First device is called initiator which is an active device and responsible for starting the communication, whereas second device is called target and responses the initiator's requests. The communication starts when the active device gets close to the target and generates a 13.56 MHz magnetic field and powers the target device [1, 2].

NFC technology has brought many advantages and one of them is that NFC technology can be integrated into mobile phones and thus benefit from mobile phones' capabilities. Another key feature of NFC is that NFC enabled mobile devices can both read/write data from/to NFC tags and also can be used as a digital storage for NFC readers. NFC's three operating modes which are; *Reader/Writer*, *Card Emulation*, and *Peer-to-Peer* provided these properties. Each NFC application need to use one of these operating modes in the NFC communication.

Reader/Writer mode: Reader/Writer mode enables NFC devices to read/write data from/to NFC compatible tags [1].

Card Emulation mode: In this mode NFC enabled device acts as an emulated card and external NFC readers read the data that resides in NFC enabled device [1].

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].

Since NFC technology's invention, many applications and prototypes have been developed from both academia and industry. It is pointed out in [3] that, the type and number of NFC applications increased dramatically in the last five years. Based on the design of scenario, application and data model, one of the

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operating modes is used in each application. Each operating mode determines how NFC devices communicate with each other. Also as the operating mode changes in NFC, the process and benefit changes as well. So every mode has its own benefits and usage areas. In this paper, we examined those developed NFC applications and application prototypes from both academia and industry. After reviewing those applications we classified those applications based on NFC operating modes and investigated those modes' benefits by analyzing these applications.

The remainder of this paper is organized as follows. In section 2, we present overview of investigated applications. In section 3, we discuss the applications' benefits by classifying them into NFC operating modes. Finally we present our conclusion in section 4.

2. Applications Survey

In this section we present our reference applications by classifying them into operating modes. There are 35 applications examined and these applications are from 39 sources. Some applications have more than one reference; this is why there are 39 references while there are 35 applications. Also two applications use both card emulation mode and reader/writer mode.

Table 1. NFC Applications

	Application References	Count	Percentage
Card Emulation Mode	[4, 5, 6, 7, 8, 9, 10, 11]	6	16,22
Reader / Writer Mode	[8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40]	29	78,38
Peer to Peer Mode	[2, 41]	2	5,40
	Total	35	100,00

3. Identifying Benefits of Operating Modes

In this section we discuss benefits of NFC applications. In our survey, we classified NFC applications based on their NFC operating modes. The reason to classify from such a perspective is that, we identified that each operating mode provides different communication way. In card emulation mode, the data resides in an NFC enabled mobile phone and external NFC devices access this data. In reader/writer mode, data resides in NFC tags or compatible RFID tags. NFC mobile phones or NFC readers are able to write data to these tags as well as reading data from those tags. On the other hand, in peer-to-peer mode, two NFC-enabled mobile devices pair with each other.

3.1. Card Emulation Mode

After analyzing the applications that uses card emulation mode, the most important benefit of the mode is identified as elimination of carrying a physical object. Consider *payment application* [5] and *electronic key application* [4] as examples. In payment case; user is able to pay with her mobile phone while others should pay using cash or credit card in older methods. So NFC-payment is able to eliminate carrying cash or credit and debit cards. In e-key case; user can enter her hotel's room by opening the door with her e-key which is installed to her mobile device by SMS before arrival. Also she can check-out using NFC technology. NFC electronic key application is able to eliminate a physical object such as physical key, but also is able to provide access control, since it provides an authentication mechanism. Another example that provides access control is *attendance control* [6], which authenticates students while attending to class. We can say that identified benefits of this mode are elimination of carrying a physical object and obtainment of access control.

3.2. Reader/Writer Mode

So many applications are developed in Reader/Writer mode than others. The reason for such a difference is discovered that so many scenarios can be adapted to NFC applications by using reader/writer mode.

Smart poster applications are one of the most important applications of this mode and in [12] a university smart poster application is presented. In this application users are able to read data from NFC-enabled posters using their NFC-enabled mobile devices. Upon receiving a data to mobile device (e.g. a department staff information), she can walk away from the poster but she can still read data from mobile device. She doesn't need to write down the data to a paper neither she doesn't have to remember it which can still be read at the screen. As described above, user gained mobility from this process as she can get the required data to mobile device and leave the location.

In *shopping from home application* [16], clients shopped from home using market's NFC-tag equipped shopping binder and their mobile phones. In [14, 15], patients uploaded their medical information using NFC technology from their homes. In [30], elderly people ordered their meals from their homes. As described above, NFC provided less physical effort usage in these scenarios.

3.3. Peer-to-Peer Mode

Peer-to-peer mode applications are developed fewer than other modes' applications. It is generally studied for data transfer operations. In [41] users exchanged their business cards by touching their NFC-enabled mobile phones. Also in [2], file transfer is performed between an NFC-enabled mobile phone and an NFC-equipped computer. It can be said that peer-to-peer mode is able to provide easy data exchange between devices. After analyzing all of the applications, the following table is created which reflects the findings of operating modes' benefits.

Table 2. Benefits of NFC Operating Modes Identified

	Card Emulation Mode	Reader/Writer Mode	Peer-to-Peer Mode
Benefits	<ul style="list-style-type: none"> • Elimination of carrying a physical object • Access Control 	<ul style="list-style-type: none"> • Increases mobility • Decreases physical effort • Ability to be adapted by many scenarios • Easy to implement 	Easy data exchange between devices

4. Conclusion

We reviewed prior NFC application studies and analyzed those applications' benefits based on their NFC operating modes. It is found that card emulation mode eliminates carrying extra physical objects such as credit cards, cash and physical keys and also it is subject to provide access control. Another mode of NFC, Reader/Writer Mode, can provide different benefits based on the usage scenario. This mode's applications' most important benefit is found that they can decrease physical effort spent by users and provide mobility. On the other hand peer-to-peer mode is not deeply studied currently but it is subject to exchange data easily between two compatible NFC devices.

Our study clearly reflected the benefits of currently developed NFC applications by classifying them into NFC operating modes. We believe that underlying each operating modes' benefit by analyzing already developed applications will guide future developments of NFC-based applications.

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