TAMPERE UNIVERSITY OF TECHNOLOGY

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EXTENDING MOBILE WALLET THAT UTILIZES NFC

Master of Science Thesis

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Preface

I have written this Master's thesis while I was an employee of Sasken Finland Oy. I want to thank my employer Sasken Finland Oy for being flexible and allowing me to pursue the Master's degree while I was working full time.

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Tampere, 02.Aug.2016

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Abstract

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In recent years, the purpose of a mobile phone has been redefined. Mobile users are expecting that one day they can get away with their physical wallet. Mobile phone can virtually store all the content of the physical wallet like transit cards, identity cards including the credit/debit cards so that payments can be made easily, quickly, and securely with a mobile phone.

Mobile payments have been in use for the past couple of years and gaining momentum as more mobile phones are shipped with Near Field Communication (NFC) support. NFC-enabled mobile phones could play a key role in day-to-day life, serving as wallet, loyalty cards, access cards, and travel cards.

This thesis first explains Mobile Wallet concepts and different mobile payment types, while focusing on payments using Near Field Communication. Second, this thesis discusses the current leading Mobile Wallet solutions. Finally, the Star Bonus service is introduced by which users can see their past transactions and summary of their accrued bonus points.

Star Bonus service is a value-added service to the Mobile Wallet user. It was presented in Mobile World Congress-2014, 2015 and received good feedback. By integrating the loyalty card into the Mobile Wallet payment use case, Star Bonus makes payments easier and quicker. The positive response it garnered highlights the importance of adding value-added services to Mobile Wallet.

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ABBREVIATIONS

ADB	Android Debug Bridge
ATM	Automated Teller Machine
CPU	Central Processing Unit
CSS	Cascading Style Sheet
EMV	Europay, MasterCard, Visa
G&D	Giesecke & Devrient
GSM	Global System for Mobile Communications
HCE	Host-based Card Emulation
HTML	Hyper Text Markup Language
JAR	Java Archive
JSON	JavaScript Object Notation
MNO	Mobile Network Operator
MWC	Mobile World Congress
NFC	Near Field Communication
OS	Operating System
P2P	Person-to-Person
PC	Personal Computer
PHP	PHP Hypertext Preprocessor
PIN	Personal Identification Number
PNG	Portable Network Graphics
POS	Point of Sales
PSP	Payment Service Provider
QR	Quick Response
RFID	Radio-frequency identification
SDK	Software Development Kit
SE	Secure Element
SIM	Subscriber Identity Module
SMS	Short Message Service
SVG	Scalable Vector Graphics
TSM	Trusted Service Manager
UI	User Interface
UICC	Universal Integrated Circuit Card
USB	Universal Serial Bus

1. Introduction

In recent years, there has been a Near Field Communication (NFC) revolution with new contactless projects starting all over the world. According to Giesecke & Devrient (G&D), retail payment transactions made using NFC across the globe will exceed $ 180 billion by 2017, nearly eight times more than in 2012. Mobile Wallet applications on top of mobile phones with NFC will play a major role in day-to-day life activities by serving as virtual wallets, which contain virtual payment cards, mass transit tickets, loyalty cards, access cards and more. [1]

In spite of all the hype about Mobile Wallets and obvious advances in Smartphone technology in the last few years, payments through mobile are yet to be widely accepted. This has been largely due to the complexity of the payment ecosystem and all the involved players failing to agree on the common terms.

The second reason is like a chicken and egg problem; consumers do not know about the Mobile Wallet payments because merchants do not offer it, and merchants do not see any demand because consumers do not ask if it is available.

The goal of this thesis is to introduce the concepts of the Mobile Wallet utilizing NFC and to elaborate on the current major Mobile Wallet solutions, as well as implementation of a Star Bonus service on top of an existing Mobile Wallet application. The Star Bonus service integrates payment card with loyalty card into the payment system and shows the bonus points accrued and the history of payment transactions.

This thesis includes five chapters. Chapter 2 defines important concepts such as Mobile Wallets and different application areas of Mobile Wallets. Chapter 3 discusses NFC based mobile payments and players involved in the ecosystem. Chapter 4 discusses some of the existing Mobile Wallet solutions. Chapter 5 discusses the implementation of the Star Bonus service. Chapter 6 concludes the thesis.

2. Mobile Wallet

Mobile Wallet can be described as an electronic purse. Although Mobile Wallets have been around for the last ten years, in the beginning, they were more focused on coupon deployment and managing loyalty cards. In recent times, Mobile Wallet has penetrated into financial services such as banking and payments. Today, the value perception of the Mobile Wallet has significantly changed, from being just an alternative tool for payments to that of a robust customer engagement tool.

The motivation for Mobile Wallet comes from the user's desire to have convenience, security and value-added services during the payment. While mobile phones and other smart devices have become smaller over the years, most physical wallets have not. The growing number of credit and debit cards, along with identity cards, transit cards, driver's licenses, and a range of membership and loyalty cards has added more panels to the standard wallet over the years. Moving all or most of these cards to a mobile device would free up precious pocket space and give the user the option to carry all of his/her cards at all times. [2]

On the other hand, security is an important feature for the users. With the global increase in credit card fraud, it is imperative to use advanced technologies to minimize the fraud. This is in the interest of both the financial industry and the customers. [2]

At the same time, value-added services are also important, because a simple one-to-one migration from a physical wallet to Mobile Wallet would not contribute greatly to the potential success of Mobile Wallet. It has to integrate other services like ticketing, loyalty cards, and identity cards. [2]

A smartphone with a Mobile Wallet can be used to make the payments with virtual cards present in Mobile Wallet. It can also store coupons, loyalty cards, ticketing, and identity cards. Mobile Wallets make it possible to execute payments at merchant's point of sales (POS) by just tapping the mobile phone on the card reader. However, unlike with a plastic card, using these digital wallets to pay introduces the consumer to a whole new payment experience by managing all the payment-related services from one single mobile app.

Mobile Wallet may reside on a smartphone or on a remote network running on secure servers. It may be only accessed via mobile device, but it can also be managed and used with it. Most importantly, it is controlled by the user of the wallet. [2]

Mobey Forum defines Mobile Wallet as "Functionality on a mobile device that can securely interact with digitized valuables" [2]. Table 1 lists some common terms related to Mobile Wallet.

Table 1. Terms related to Mobile Wallet.

Term	**Definition**
Mobile Wallet	A Mobile Wallet is an application installed on the end user's phone that can make payments, store credit cards, debit cards, bonus cards and identity cards.
Mobile Wallet user	The Mobile Wallet user uses services provided by Mobile Wallet.
Mobile Wallet apps	These enable Mobile Wallet services on a smartphone.
Mobile payment	This is new and an alternate mode of payments using mobile phones, instead of using traditional methods like cash, credit cards, or cheques.
NFC payment	Paying with mobile payment application present in Near Field Communication (NFC) enabled phone just by tapping the phone to the terminal at the point of sale (POS).
Virtual Wallet	This refers to wallets that are offered in a "software as a service" model and operate in the 'cloud service' [2].
Mobile Money	The use of a mobile phone for financial transactions, to transfer funds between banks or accounts, to deposit or withdraw funds, to purchase goods, or pay bills [2].
Micro payment	A transaction where a very small amount of money is paid for exchange of goods.

2.1. History

Two decades ago, the idea of paying for something with a mobile device seemed outlandish, nothing more than a pipe dream. Yet today, the use of a mobile device for payments is not only accepted but becoming the norm in our society. [3]

A brief look at its history tells how mobile payments become what it is today. Year 1997, Coca Cola introduced a small number of vending machines in Helsinki that would allow customers to purchase their drink via text message. This small but innovative use case is considered the first example of mobile payments, and introduced the idea of using mobile features for transactions. That same year, Merita Bank used text messaging for bank account transactions, again bringing the ability to conduct transactions via phone to the forefront [3]

As time went on, we saw mobile phones used to buy movie tickets by Ericsson & Telenor Mobil in the year 1999, and even order pizza for delivery from Domino's Pizza, in the year 2001. By 2003, 95 million cell phone users worldwide had made a purchase via their mobile device. And the market only grew from there. [3]

2.2. Application areas

A mobile device can have one or more Mobile Wallets, and they can coexist and provide different services all together. Different application areas of Mobile Wallets can be seen from Figure 1. [2].

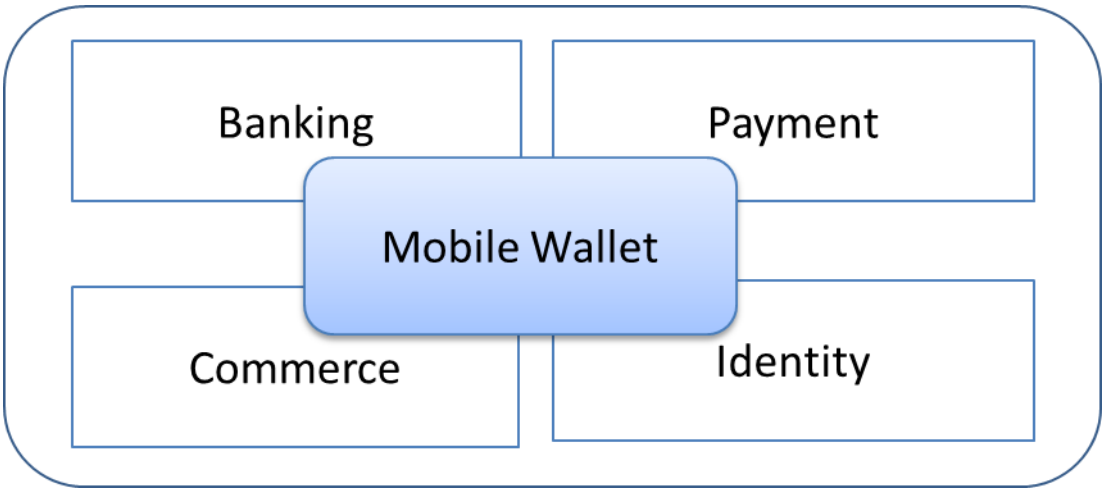

Figure 1. Different application areas of the Mobile Wallet. [2]

Banking. A Mobile Wallet can be used for different purposes like money transfer, bill payments, storing account information, to see transaction history, and for investments and wealth management. Typically, things that can be done by visiting a bank or by using website of the bank can be made using the Mobile Wallet.

Payment. Mobile Wallet can also be used for both proximity payment and remote payment. Proximity payment is used, for example, to buy grocery from the neighborhood store; remote payments can be used for buying digital goods or fashion apparel remotely. A Mobile Wallet can have different debit/credit virtual cards issued

by different vendors such as Visa, MasterCard, and American Express. These cards are then used for the payment.

Identity. Mobile Wallet can have an access control to restricted areas, for example as a key to enter the office shop floor. It can also contain membership cards, boarding passes, driving license card, insurance cards. In a way, Mobile Wallet can be used for digital identification.

Commerce. Mobile Wallet can store coupons, loyalty cards, and movie tickets. A Mobile Wallet can also be used in public transport if the travel tickets can be stored in the wallet as virtual tickets.

In addition, Mobile Wallets enable service providers to provide location based value-added services to users such as sending details about the special discount information to all the users who are near a store. Another example could be sending a discounted entry ticket to wallet users who are near a museum or concert hall. Out of these different application areas, this thesis focuses mainly on the mobile payments area.

2.3. Mobile payments

Mobile payments are one of the application areas of Mobile Wallets. Mobile payment is a transfer of funds in return for goods or services where a mobile device is functionally involved in executing and confirming payment. The goods and services can include digital content such as movies, songs, mobile applications, online subscriptions or regular purchases at the grocery store. As shown in Figure 2, mobile payments are characterized by the technology used, payment size, the location of a buyer in relation to a merchant, and the funding mechanism. [4]

The technology used to complete the payment transaction can be a mobile Short Message Service (SMS), a mobile browser, mobile application, Radio Frequency Identifier (RFID) tags or an advanced technology like NFC enabled Mobile Wallet application. The payment size matters while choosing the technology. Payments of less than USD $10 are considered as Micro Payments. Paying for car parking, transit, or for coffee are examples of Micro Payment. Payments above USD $25 are considered as Macro payments. Mobile recharge, bill payments, and the grocery at the retail shop are examples of Macro payments. [4]

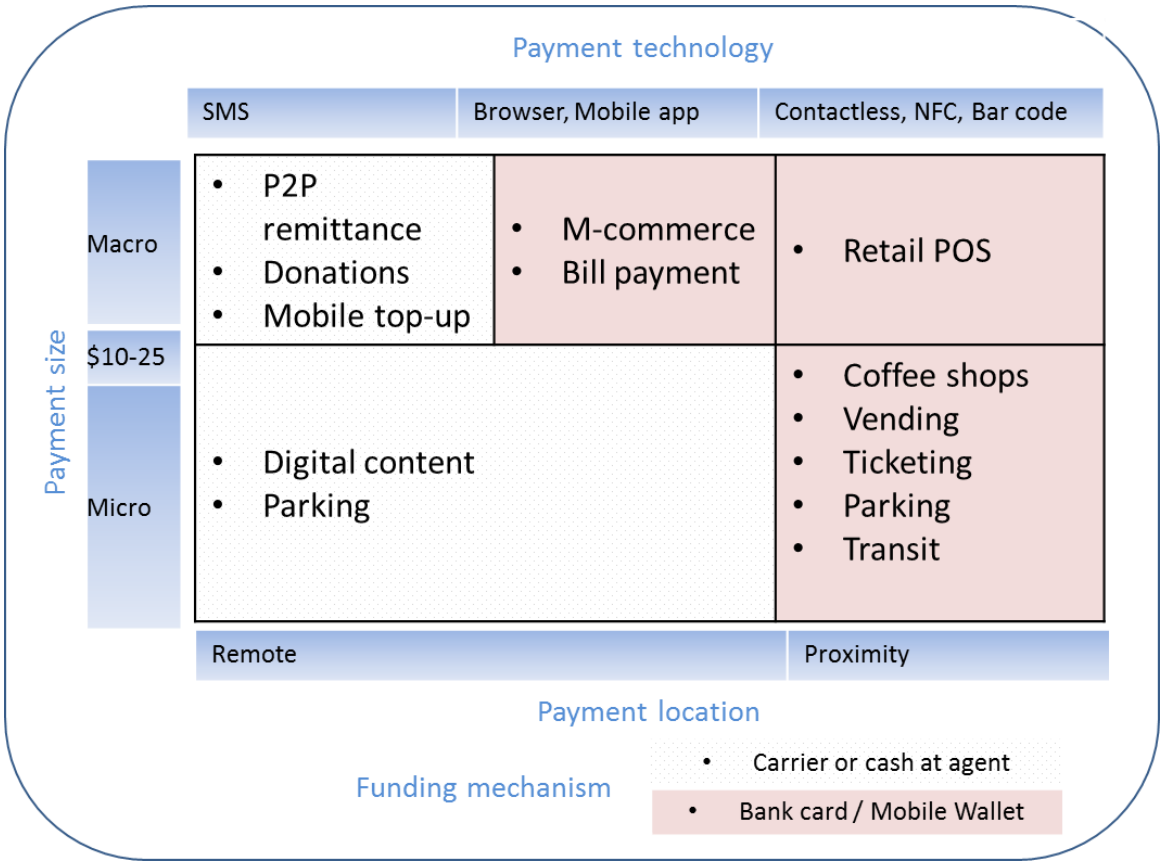

Figure 2. Mobile payment characteristics. [4]

Considering the buyer location, the payment can be a remote mobile payment or proximity mobile payment; in the latter case the buyer is physically present at the store. The funding for a transaction can be pre-paid mobile money or post-paid mobile bill or alternatively, the bank credit or debit card which is virtually stored in Mobile Wallet can be a source of funding. [4]

2.3.1. Remote mobile payment

In remote mobile payment transactions, the buyer uses a mobile phone to pay for the transactions without being physically present at a merchant store. For transactions of this type, POS (Point of Sale) device is not necessary for the merchant. An example of remote mobile payment is paying for digital goods such as online movie subscription by premium rate SMS or physical goods by paying for a merchant website through a secure web transaction. Some of the remote payment schemes are mobile phone bill, premium rate SMS, mobile web payment, Person-to-Person payment, and Smartphone apps.

Paying through mobile phone bill is the simplest method, where user pays by sending SMS and payment appears as part of the mobile bill. This is usually common for micro-payments. In mobile payment method using premium rate SMS, the buyer makes the payment by sending an SMS. The user is charged a premium rate for each SMS of this type. Merchant and the mobile operator share profit. Premium rate SMS payments got popularity for voting contestants on TV as it is simple to use and there is no need to download any web applications onto the phone. [4]

Mobile web payment is an online payment method that enables merchants, or retailers to bill goods and services from a website. The buyer can pay through a variety of payment mechanisms, like net banking or entering debit/credit card details. Another payment type is a person-to-person (P2P) payment where users can transfer funds from their bank accounts or credit card to another individual account using a mobile phone. The transaction gets completed using transferred funds. P2P is often seen as social money payment mechanism, for example to share payment for dinner among friends.

Use of Smartphone apps for payment has been increasing as more advanced mobile phones are released in recent years. Due to the growth of Smartphones and mobile web applications, many companies are making their e-commerce applications for different Smartphone platforms like iOS, Android, and Windows Phone.

2.3.2. Proximity mobile payment

In proximity mobile payment, the buyer is physically present at the merchant store and the payment is made at close distance without making any physical contact such as showing a mobile device to the POS terminal. Payments of this kind can be used at both attended POS location, such as a grocery store or an unattended location like vending machine and parking fees. The technology used by a merchant to implement proximity mobile payments can be any barcode technology or more advanced NFC technology. [4]

To complete payment using barcode technology, a barcode can be displayed on mobile phone screen, which is then read by a scanner at POS terminals. This barcode is unique to that user and the same is used to complete the payment. The other option is that mobile camera functioning as optical scanner is used to read a barcode displayed by the POS terminal to complete the payment.

During January 2011, Starbucks coffee company rolled out a mobile payment using 2-D barcode technology across the United States in their 6800 company owned stores. Users who already have the Starbucks card can download an application for iPhones, BlackBerry. The application displays the 2-D barcode of the Starbucks card to make purchases. A user can pay for the purchase by showing this barcode at the POS terminal. The same application allows the user to track balances and the history of purchases. [5]

The advanced technology to implement proximity mobile payment is NFC technology, also referred to as mobile contactless payment. Over NFC enabled mobile phone, payment application is installed and configured with the payment options. When user touches or waves the mobile device over the POS terminal during payment, the user account information is sent in the secured manner using NFC technology. Numerous pilots and projects are launched which use this technology. Chapter 4

introduces some of the current mobile payment solutions, which use NFC technology for mobile payments.

2.4. Wallet approaches

Mobile Wallets of great variety have been released to the market recently and these wallets have different approaches in their implementations. Depending on the stakeholders of the wallet, two broad approaches to wallet implementation are "vertical" and "horizontal". [6]

In a vertical wallet approach, the service provider itself provides the wallet to the users, and also controls and manages the services of the wallet. Although this is a closed approach with limited players, this has an advantage that time to market is short and there are fewer issues related to interoperability. Wallets of this type will usually have preloaded services. An example is the wallet from Starbucks. [6]

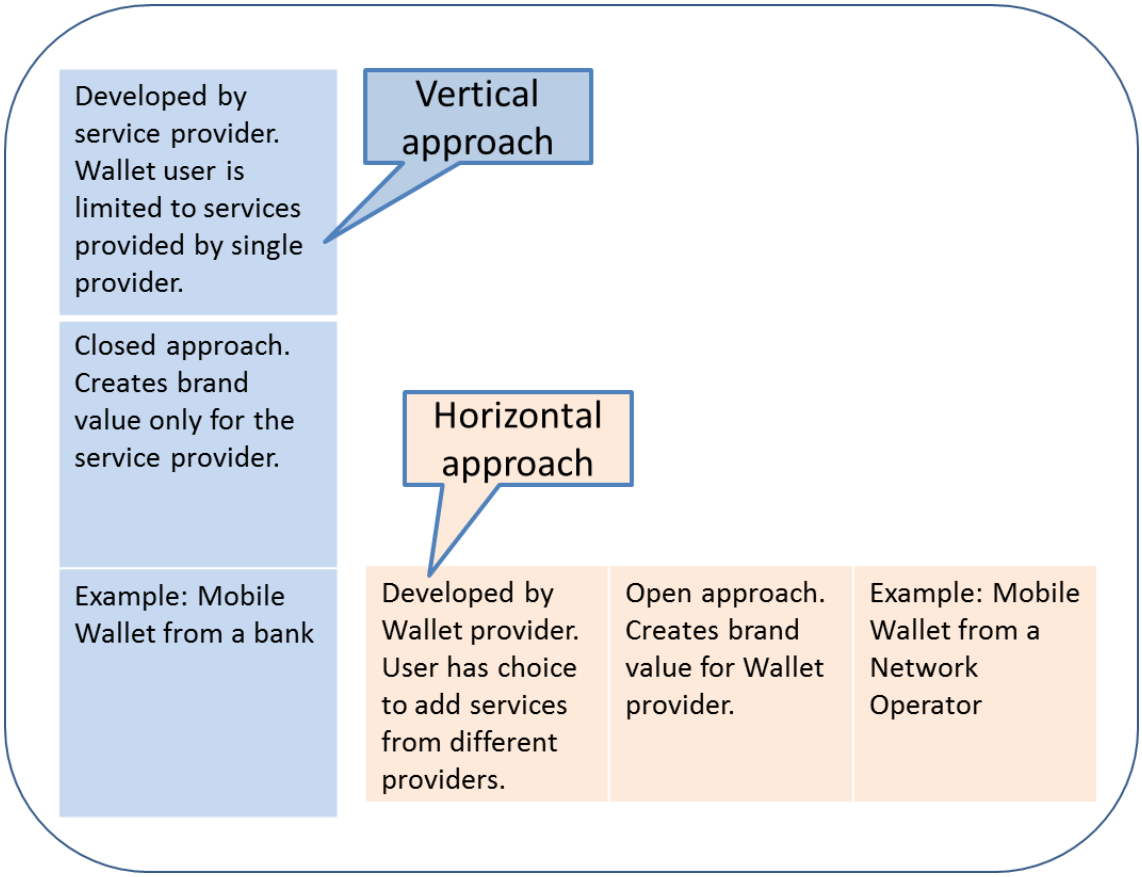

Figure 3. Vertical versus horizontal Mobile Wallet. [7]

In a horizontal wallet approach, the aim of a wallet provider is to reach a mass market with the capabilities of integrating services from different service providers. This is more like an open approach and allows users to organize the services they need from different service providers. An example is the wallet from Elisa. [6]

Figure 3 illustrates these two approaches from the mobile payment point of view. In the early days of Mobile Wallet, the vertical approach prevailed where the single payment service provider (PSP) controlled the entire life cycle of a wallet containing its payment services. With the advancement of technology offerings in security, horizontal type wallets have now released and users are allowed to choose the PSP themselves.

2.5. Different perspectives

Understanding the perspectives of different players involved in Mobile Wallet is important. The most important stakeholders of Mobile Wallet are the consumer, merchant and Mobile Wallet provider. The perspective of these stakeholders helps to understand why consumers are not warming up to the mobile payment service.

2.5.1. Consumer perspective

Mobile Wallet should be able to process metadata and show it to the user, about how user is spending, when, etc. summarized in a nicer way. This is something that consumer might desire. This would be easy to achieve in case if Mobile Wallet is developed and distributed by the bank.

Consumers perceive Mobile Wallets as more than just a payment alternative to cash and card. They expect the brand to provide marketing content such as coupons, loyalty programs, and product information in Mobile Wallets to help them with the shopping process. However, there is a large Mobile Wallet disconnect with brands and retailers failing to meet consumer demand for marketing content aimed at Mobile Wallets. [8]

Consumers expect mobile to not only be a better payment method but a better shopping companion that enables them to store shopping lists, offers, coupons, and product information. In fact, Mobile Wallets such as Apple's Passbook and Google Wallet not only offer those features but also loyalty cards that integrate with marketing campaigns. [8]

All four shopping activities: 1. Price comparison, 2. Product research, 3. Coupon lookup, and 4. Loyalty point collection, happen in separate applications on a smartphone today. Mobile Wallets can bring it all together in one place, making it convenient for the shopper to focus on their shopping instead of finding the right applications. [8]

Consumers are using mobile payments for a wide range of purposes – to pay their bills, make online purchases, pay for products at a store, and send or receive money between two parties. Paying regular utility bills is the top scenario where mobile payment is being used. Besides online and retail store shopping, consumers use mobile payments for peer-to-peer transfer. Most transfers occur between trusted members of a person's social network such as the local corner shop owner, friends, and family. [8]

The key reason behind consumer's reluctance in adopting mobile payment is they can not find a benefit when comparing it with cash and card, which are perceived as familiar, convenient and more secure. The familiarity with cash and card makes consumer believe they are more convenient even if they have to fish around for change when paying with cash or enter Personal Identification Number (PIN) numbers and sign during card purchases. [8]

Security with mobile payments is also a key concern among mobile payment non-users. Consumers are, however, interested in mobile payment if it becomes part of the shopping process by integrating coupons and loyalty programs via a Mobile Wallet. [8]

Consumers trust Mobile Wallet issued by banks above all other institutions and organizations. Both banks and credit card networks are transitional financial organizations to which people have entrusted their wealth, so it is natural for consumers to trust them with Mobile Wallets ahead of retailers and other brands. A key reason behind a greater trust in banks for Mobile Wallet rollout is largely due to significant exposure and usage of mobile banking via apps and mobile websites. [8]

Pivo Mobile Wallet from Finnish bank OP-Pohjola is one of the example Mobile Wallets issued by a bank. This Wallet does much more than just paying through NFC technology. The K-Plussa Loyalty card is integrated, which allows users to see past transactions and allows the user to track user spending with budgeting functionality. This wallet allows user to make a shopping list and shows the details of the stores and services near the user's current location. [9]

2.5.2. Merchant perspective

For Mobile Wallet to succeed, it is essential to consider the concerns of all stakeholders within the ecosystem. However, merchants are particularly important, as they will ultimately determine the payment type supported from a merchant's perspective and the payment type that is selected by the consumer when presented with a choice. Three questions are central in their decision-making processes: 1. Is it convenient? 2. Is it beneficial? 3. Is it secure? [10]

Convenience is a key criterion for both merchants and consumers. For example, merchants with limited physical space may prefer an acceptance terminal that fits into their counter space and can process multiple types of payments. Consumers may prefer mobile payments if they are easy to use and add value to their shopping experience. [10]

Hana SK in Korea is a good example of addressing convenience from both angles. Its POS terminals are easy for merchants to use and can accept all types of payments – including credit/debit/prepaid across brands and schemes. At the same time, its mobile payment solution allows customers to scan Quick Response (QR) code or NFC tag in-store, compare prices online instantly with other stores, complete the purchase online, and save customers the effort of carrying the goods home. [10]

Merchants often compare mobile payment terminal costs and fees with other forms of electronic payments. However, mobile payments are often used as a substitute for cash, which is a more expensive medium of exchange. Meanwhile, consumers often require an additional incentive to form a new habit and adopt a new means of payment. JR-EAST, a railway operator in Japan, achieved a positive benefit using mobile payments. While it invested USD 130 million over five years to introduce its prepaid card and mobile payment solution, the company reduced the operational costs associated with producing paper tickets, deploying ticketing machines, and maintaining gate machines. At the same time, customers were incentivized with high reward points. [10]

Security is critical to adoption of mobile payments. Merchants and consumers need to feel confident that the opportunity for fraud or other operational losses is kept to a minimum. The process of returning goods should be easy. Ability to integrate their bonus cards into the payment system so that user does not need to take out the loyalty cards from the physical wallet along with the Mobile. [10]

Merchants see Mobiles Wallets as an opportunity to: 1. Gain competitive advantage 2. Distinguish themselves as technologically-savvy and innovative to their customers 3. Migrate customers from cash to electronic or mobile payments. However, merchants recognize that Mobile Wallets are in its infancy and would benefit from integrating loyalty cards into the Mobile Wallets.

2.5.3. Wallet provider perspective

While it takes some time before Mobile Wallets become ubiquitous, in the meantime the consumers will be swiping magnetic strip cards, dipping Europay, MasterCard, Visa (EMV) cards, and tapping contactless cards and mobile phones for payments. These different payment methods lead to confusion among the consumers. [10]

The Mobile Wallet provider has to consider following. What is consumer’s appetite and capacity to grasp all the different mobile payment models? How many wallets does a consumer need and how many should a merchant offer? What are the different value propositions offered by the various solutions?

2.6. Extensibility

One common perspective between the user and merchant is the extensibility of the Mobile Wallet. It is important that the Mobile Wallet provide a framework to extend the Mobile Wallet functionality. The Mobile Wallet framework should allow adding individual components to the Wallet without compromising the security features. Mobile Wallet users should have the flexibility to decide what additional services they want.

These individual components, known as Widgets, will be used to add support for adding the identity cards, mass transit cards, loyalty cards, and any other value-added services like coupons and offers. With the help of these widgets, the Mobile Wallet can do a lot more than just storing credit cards.

Mobile Wallet providers should consider the extensibility feature in the design phase of the Mobile Wallet. This way, the effort required to implement and integrate the extensions into the Mobile Wallet ecosystem is reduced.

3. NFC-based mobile payments

After years of hype and uncertainty, NFC is finally here. Countries where plastic card use is the norm have witnessed a recent explosion in NFC-based mobile payments ecosystem. The emergence of Apple Pay, Samsung Pay and Host Card Emulation (HCE) all indicate that, this time, NFC is here to stay. [11]

The real credit for revolutionizing NFC-based mobile payments arena would have to go to Google's HCE support announcement at the end of 2013. This was when NFC-based mobile payments really cut loose. [11]

3.1. NFC technology

Developed jointly by Philips (now NXP Semiconductors) and Sony, NFC is a set of short-range wireless technologies, usually operating over a short distance, typically less than 4 cm. NFC is a standard for short-range wireless communications based on RFID technology. It is useful in applications where a physical touch, or close to it, is required to maintain security.

NFC harmonizes different contactless technologies in areas such as Access control, Consumer Electronics, Healthcare, information collection and exchange, Loyalty and coupons, Payments, Transport [12]. NFC applications can be built upon the existing RFID infrastructure and can therefore achieve cheap and fast acceptance and marketability and offer great usability.

NFC Communication happens when NFC-compatible devices are brought within four centimeters of one another. NFC operates at 13.56 MHz and transfers data at up to 424 Kbits/second. NFC-enabled transactions are inherently secure due to short transmission range [13]. NFC is used in mobile phones for payments in conjunction with an electronic wallet, and for setting up connections between Bluetooth devices. Unlike Bluetooth, no pairing code is needed, and because it is very low power, no battery in the device being read. NFC technology is promoted by NFC Forum.

NFC Forum was formed in 2004 to advance the use of NFC technology by developing specifications, ensuring interoperability between devices and services, and educating the market about NFC technology. Currently, the forum has 170+ members. Manufacturers, applications developers, financial service institutions, and more all work together to promote the use of NFC technology in consumer electronics, mobile devices, and Personal Computers (PC) [12]. The goals of NFC Forum are encouraging

the development of products using NFC Forum specifications and to ensure that products claiming NFC capabilities comply with them.

NFC-enabled devices can operate in three modes. These are [14]:

- **Reader/writer mode**, where information is read to or written from a passive NFC-enabled target. NFC targets are usually packaged in simple form factors, such as tags or key fobs, which do not require batteries.

- **Peer-to-Peer mode**, which allows NFC devices to exchange data in both directions.

- **Card Emulation mode**, which allows an NFC-enabled mobile device to emulate a traditional contactless smart card, thus enabling contactless payments and ticketing by NFC devices without changing the existing infrastructure.

NFC offers great capabilities for various and comprehensive use cases. The technology is convenient, easy to use and intuitively familiar to the users. They do not need to have any knowledge about the underlying technology as the communication starts automatically by simply bringing two devices, or a device and a tag respectively, physically together. Therefore, NFC is perfectly suited for mobile payment and ticketing scenarios.

3.2. Contactless payment using NFC

NFC payment primarily leads to faster and easier payment at the POS when compared with a traditional way of paying using cash or credit/debit card. When paying with cash, the transaction involves manual currency notes counting while paying and taking change back, all of which takes extra time.

Paying with credit/debit card is lot simpler in comparison with paying by cash; however, the user has to pick the right card from the wallet, insert it into the POS terminal and type the PIN code. With NFC mobile payment, this should be a lot simpler, just by waving the mobile to the POS device. Along with credit/debit cards, NFC mobile phone can as well store coupons and bonus cards. NFC enabled mobile devices can make a physical wallet redundant.

According to Juniper Research, there will be 516 million mobile users of NFC payment services by the end of 2019. As of September 2014 there were 101 million users. Juniper Research argues that Apple’s introduction of an NFC-based payment mechanism, Apple Pay, would stimulate the wider marketplace. It is also estimated that by end of decade three-quarters of smartphones worldwide will have NFC support. [15]

NFC-based mobile payments are bringing in a great deal of interest to NFC chip makers, smartphone manufacturers, mobile telecom carriers, payment network processors, as well as merchants. The interest among players is not just because of payments, but also because of the other opportunity areas like secured access, identity, e-tickets, and others for which NFC is best suited for communication due to its short range and secure nature.

3.3. Contactless payment use case

The steps involved in NFC-based mobile payment using Mobile Wallet are shown in Table 2. The pre-requisite is that the consumer should have an NFC enabled mobile and the Mobile Wallet application should be installed. Similarly, the Merchant should have the POS device that supports NFC-based payments. [7]

Table 2. Steps involved in NFC-based payment.

Steps	Description
Step 1	• After the consumer selects the items to buy and while at the payment counter, the consumer with an NFC-enabled mobile phone selects the Mobile Wallet whereby he wants to make payment. • The merchant has found the values of the purchased goods and enters the amount in to the payment terminal
Step 2	• The amount is displayed at payment terminal and visible to the consumer. • The Merchant selects contactless technology as the payment option and requests for the payment.
Step 3	• The consumer taps NFC-enabled mobile device to the payment terminal • Merchant selects the payment application to proceed • After receiving an audio/visual cue that the communication between the mobile device and payment terminal is over, the consumer can take the mobile device away from payment terminal. • Further authentication is made about the credit or debit card details from the virtual card used by a consumer, and then the payment will be approved or declined.

	• Optionally, information about the transaction is shown on the mobile device.
Step 4	• The merchant gets information about the result of a payment • The merchant in turn informs the consumer about the payment result • Depending on the nature of payment and on the wish of the consumer, the printed transaction slip would be given to the consumer

3.4. Ecosystem

As per Smart Card alliance payments council white paper, NFC-based mobile payments introduce new stakeholders in the mobile payments ecosystem. These stakeholders co-operate to deploy NFC-based mobile payment system. Figure 4 shows the major stakeholders who are involved in this ecosystem. [4]

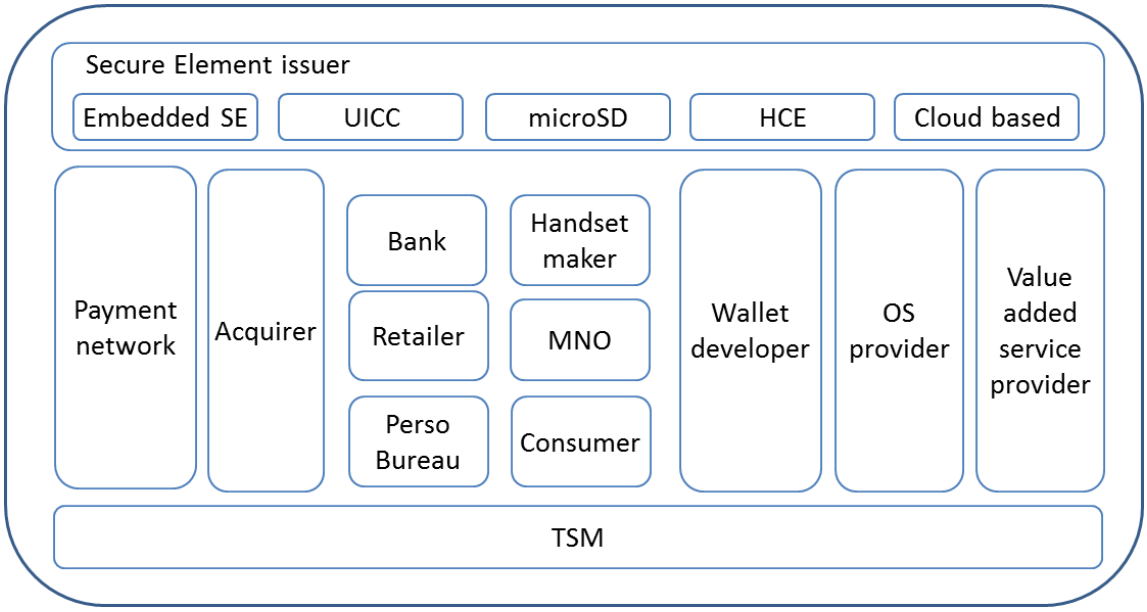

Figure 4. NFC-based mobile payments ecosystem. [4]

Secure Element Issuer. The secure element (SE) contains both secure memory to store credentials, and provides an execution environment for applications to run in a secured environment. Major technical SE solutions are based on one or more of these technologies: microSD, Embedded SE, Universal Integrated Circuit Card (UICC), HCE and cloud based.

One option is to embed the SE in the phone during phone manufacturing. The second option is to provide SE through removable UICC or subscriber identity module

(SIM) card, which is a natural way as all the phones which use Global System for Mobile Communications (GSM) technology are already using SIM cards. The third option is to use microSD cards as a SE. Many phones in the market have a microSD card slot so this can be adopted easily.

The fourth option is to use the HCE where Central Processing Unit (CPU) of the mobile is used to emulate the SE. No additional hardware is required in this case. HCE is available on Android version 4.4 and later. The fifth option is to use the cloud based approach where SE is located remotely.

According to NXP Mobile, transactions using HCE have limitations compared with hardware SE. HCE is not suitable for high value transactions (e.g. more than 15 €), nor for offline POS infrastructure. Also HCE is not suitable for international POS transactions. [16]

Discussions on SE always raise the question: who owns the physical SE, given that the stakeholder who owns the SE controls the resultant payment service? In the SIM/UICC-based model, the mobile network operator (MNO) is usually the owner of the SE which resides on the UICC. In this case, the MNO controls over the business conditions, together with the prevailing wallet solution. This allows them to set constraints on the design, branding, and other elements of the wallet. In Apple Pay, Apple has complete control over the service as SE is embedded in the handset (commonly referred to as ‘eSE’). [11]

Payment network. Transactions are authorized and processed by the payment network like Visa and MasterCard. The payment networks handle the communication between the bank that issued the card to the consumer and the bank of the merchant. Payment networks play a key role in the ecosystem when it comes to acceptance and expansion of mobile payment services. Additionally, in some cases payment networks perform certification of the Mobile Wallet applications after testing them for compliance [11]

Bank. Like in the standard payment model, also in NFC-based mobile payments, banks will continue to be the source of funds for consumers. The banks issue the debit/credit to consumers; in this case, it will be virtual cards, which will be present in the Mobile Wallet application [11]

If a bank wants to weigh in on deploying NFC-based mobile payment service, then the type of SE element matters most. At first glance SIM/UICCC-based solution looks suitable since all Smartphones contain a SIM. However, it is important to consider the fact that not all SIM cards have NFC capabilities. Also, the banks need to establish commercial agreements with all the MNOs operating in that area to reach the wider user base. Since different MNOs involved may require different branding and wallets, this can lead to different customer experience between MNOs for a single bank service. [11]

In case of HCE model, although there is no SE owner, there are different complications to address. Either the bank has to build the HCE solution in-house or pay a solution provider to deploy it. Developing it in-house requires time, skills and significant investment. When HCE model is used, the bank has control over the wallet, branding and marketing; which enables consistent experience among all users of the single bank. [11]

Retailer/Merchant. For the consumer to be able to pay by NFC-based mobile payment, the retailers should have the certified POS terminal that supports NFC. Retailers will be in favor of the payment system that takes the minimum time for each transaction. Retailers also like to integrate their membership cards into the payment system so that user does not have to take the membership card out separately during the payment.

Personalization bureau. The secure element in the mobile is configured as the identity of the specific user by the personalization bureau. Traditionally, the credit/debit cards are sent to consumers by personalization bureau department. In NFC based payment, they should be able to send the secure element along with the card.

Handset manufacturer. It is the decision of the handset maker that results in the presence of NFC support in the mobile device. In certain cases, mobiles are released into market with built-in secure element like in the case of Apple phones.

Mobile network operator. A mobile network operator (MNO) provides and maintains the services of the handset. Additionally in most cases the consumers get the mobile device directly from the mobile network operator. MNOs have a growing base of mobile consumers as more people subscribe to their services. This growing customer base offers them the strength and opportunity to partner with banks and financial institutions. If SE is part of UICC chip, then the mobile network operator decides the SE.

Consumer. The consumer is a payments application user. The application will be available on their NFC enabled handsets. The consumer generates the revenue for the remaining players of the ecosystem directly or indirectly.

Wallet developer. A Mobile Wallet is a value-added service provided by the mobile device. Banks, payment networks, handset manufacturers, MNO or merchants can develop the wallet. The wallets developed by merchants are of vertical type, which provide only the services of the merchant. The wallet developed by handset manufacturers and MNO are of horizontal type where the consumer is allowed to choose the desired services from the available list.

OS provider. The mobile operating system provides the required platform to be able to develop the wallets by different stakeholders. The Operating System (OS) provider may pre-install the horizontal type of wallet application on the device.

Value-added service provider. Apart from paying, Mobile Wallets can do a lot more with value-added services like coupons, loyalty cards, transit cards, access to restricted areas and location-based services. The value-added service provider provides these services.

Trusted Service Manager (TSM). TSM provides over the air (OTA) services to Mobile Wallet issuers and SE providers. These play a key role in getting the wallet application onto the handset, and usually the entire lifecycle of the wallet is managed by TSM. This role can be played by different entities, including MNO, personalization bureau, and payment network. In the SIM/UICC-based solution, the TSM's role is vital in safeguarding access to the SE.

4. Current Mobile Wallet solutions

Three major Mobile Wallet solutions discussed here are Apple Pay, Google Mobile Wallet, and Elisa wallet. The interesting fact is that leaders of different areas released each of these Mobile Wallets. Apple Pay is a service from Apple. Google wallet is released and controlled by Google, which specializes in internet related services and products. Finnish telecom operator Elisa released the Elisa Wallet. [17]

4.1. Apple Pay

Apple Pay is a mobile payment and digital wallet service from Apple. Apple Pay allows the users to pay using iPhone6, iPhone 6 Plus or Apple Watch. During October 2014, Apple Pay service started in the United States. [17]

Setting up Apple Pay is simple with the help of Apple Passbook. Apple Passbook already store users' boarding passes, tickets, coupons, and more. Now it can store credit and debit cards too. To get started, users can add the credit or debit card from iTunes account to Passbook by simply entering the card security code. Figure 5 shows the screen capture related to adding card to Apple Pay. The card can be added simply by pressing the plus sign. The second screen capture in Figure 5 also shows the list of all added cards to Apple Pay. [17]

Figure 5. Apple Pay Wallet card management. [17]

When a user adds a credit or debit card with Apple Pay, unique device account number is used instead of actual credit and debit card information. The device account number is stored securely in the secure element of the Apple device. These numbers are never stored on Apple servers. When a user makes a purchase, the payment is processed with the device account number, along with a transaction-specific dynamic security code. This way, Apple will never share or transmit credit or debit card numbers with merchants. [17]

Apple has also added additional security to the payments by using the Touch ID and made the payment very simple. There is no need to open an app or even wake up the display. To make a payment, all a user has to do is to hold their iPhone near the contactless reader with a finger on the Touch ID as shown in Figure 6. A subtle vibration and beep alert the user about the successful payment. [17]

If the Apple device is lost or stolen, "Find My iPhone" service helps to put the device in Lost Mode. This suspends the Apple Pay service. The user can also wipe the device clean completely using the "Find my iPhone" service. The other feature of Apple Pay is that it is easy for users to find nearby local stores that accept Apple Pay as the Maps feature of iPhone displays the Apple Pay symbol. [17]

Figure 6. Apple Pay Wallet payment using Touch ID. [17]

Apple Watch will also enable iPhone 5 devices to execute Apple Pay NFC payments, although the required authentication method will be different as the device does not feature Apple's Touch ID. [11]

4.2. Google Wallet

Google Wallet is a free mobile application to store credit cards, debit cards, gift cards, loyalty cards, and more. With Google Wallet a user can shop in stores, buy online and send money [18].

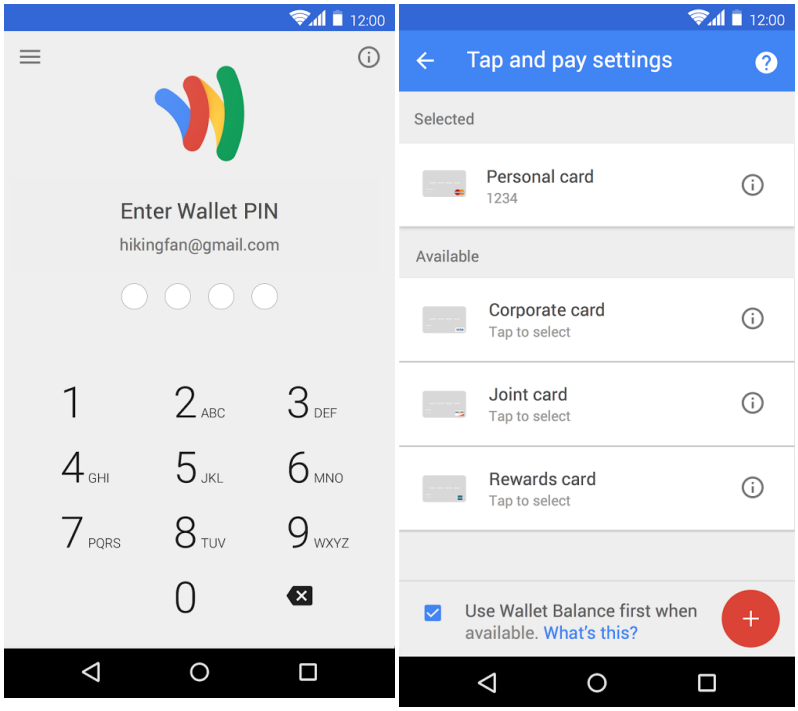

Figure 7. Google Wallet Screen captures. [19] .

As shown in Figure 7, the Google Wallet is protected by a PIN which needs to be entered every time the Google Wallet is opened. Once the Google Wallet is opened user could add new cards and see the list of already added cards. [18]

Google Wallet first demonstrated in May 2011 in New York, USA to purchase goods by tapping mobile phone using NFC technology [20]. Initially, the payment cards supported were MasterCard issued by Citibank and Google Prepaid Card, and the wallet application was available for subscribers of Sprint telecom across the United States using Sprint for the Nexus S 4G. [18]

Google has later collaborated with many banks, payment networks, POS systems, mobile handset manufacturers, mobile operators, and merchants. Google Wallet is supporting major credit and signature cards from VISA, MasterCard, American Express and Discover. [18]

Google Wallet uses NFC technology for tap and pay so the consumers require NFC enabled phone with the secure element in it. In addition, credit and debit cards are stored using cloud technology. The linked credit and debit card credentials are not stored on the secure element; instead, a virtual prepaid card created during wallet setup is stored in the secure element. While paying only the virtual prepaid card credentials are passed to merchants. [18]

Google Wallet provides numerous benefits for consumers and merchants. Consumers can use Google Wallet for both in-store and online purchase. Google Wallet enables customers to pay securely with just a single tap of an NFC enabled phone and provides value-added services like Google offers, featured offers and nearby offers. Nearby offers are the offers and discounts offered by local businesses that are close to the current user location. Figure 7 shows screen captures of Google Wallet. [18]

Google Wallet Card is a debit card that lets you spend your Wallet Balance everywhere Debit MasterCard® is accepted within the U.S., or withdraw cash at an ATM. User can add money to Google Wallet Card through a linked bank account, credit/debit card or when a friend or family member transfers money to user via Google Wallet. They can check their Wallet balance any time using Google Wallet application or by visiting wallet.google.com. [18]

4.3. Elisa Lompakko (Elisa Wallet)

Elisa Wallet (in Finnish it is Elisa Lompakko) is a smartphone application released by telecom operator Elisa [21]. The Finnish word for the Wallet is Lompakko. This wallet allows users to make secure purchases with a Smartphone. It is a mobile operator independent service: users of any other domestic telecom operator, not just by Elisa users, can use the wallet. The application can be installed on Android devices, Windows phones and on iPhones, as this wallet is operating system independent.

Elisa Wallet has a concept wherein registered users get a sticker, which can be attached behind the phone. With this, even those Smartphones that are not NFC enabled can be used for NFC based payments. The sticker acts as an NFC device and accepted at the payment terminals that have a MasterCard PayPass® logo.

The screen captures shown in Figure 8 are taken from Elisa Wallet for Windows phones. The first screen capture in this figure shows the list of accounts and the second screen capture in the same Figure 8 shows the summary of the account.

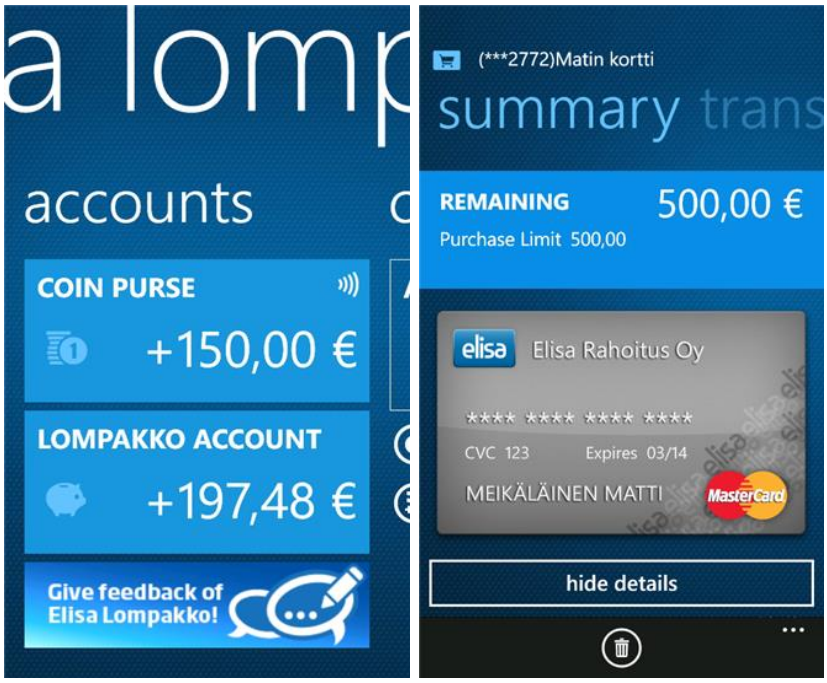

Figure 8. Elisa Wallet summary screen captures. [21]

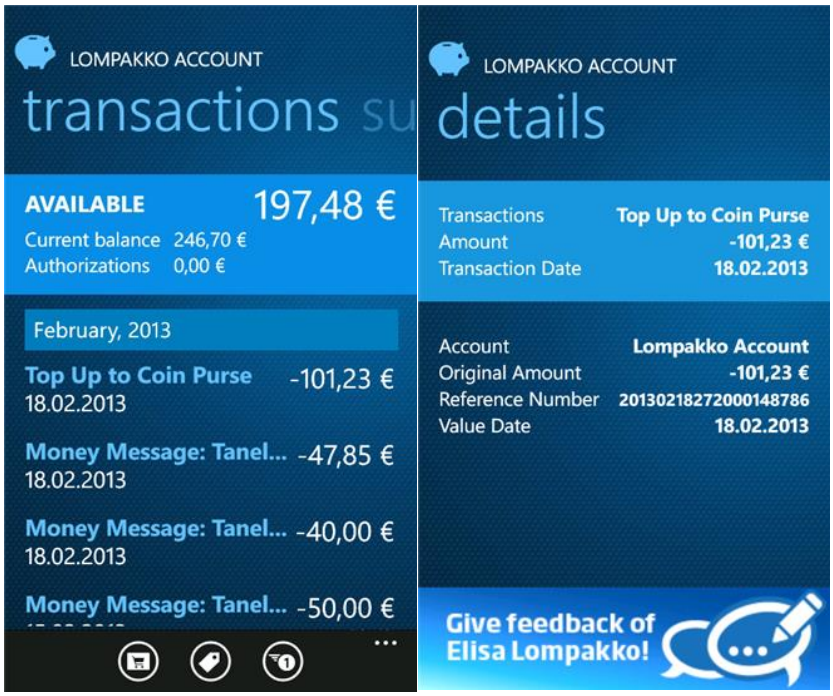

Figure 9. Elisa Wallet screen captures of transactions history. [21]

To enable the service, users have to register for the service through the Elisa web service or the Smartphone app, download the Elisa Mobile Wallet application and subscribe for the sticker. As shown in Figure 9, this wallet application also allows the users to see all the transactions history along with the account details.

4.4. Challenges for these wallet solutions

Implementing Mobile Wallet is not easy since it involves different stakeholders and agreeing on who controls what is the most difficult part [22]. From the end user's perspective, most of them have one physical wallet. Users have the complete choice regarding what they put in their physical wallet. Users can put the competing brands together without any issue. In addition, users have their choice selecting the look and feel of the physical wallet.

In the case of Mobile Wallet, users might have to use multiple virtual wallet solutions as Mobile Wallet solutions are released by different stakeholders. All stakeholders like mobile operators, merchants, banks, mobile operating system makers are trying to make their own Mobile Wallet solutions as it gives an opportunity to retain and gain more customer base. This situation is leading to competing Mobile Wallet solutions and the market is becoming fragmented with everyone trying to get their piece of the cake.

5. Star Bonus service implementation

The Star Bonus service is developed to show how the Mobile Wallet functionality can be extended by using additional services. It was also made with an intention to show the technical capabilities by demonstrating the developed application in the Mobile World Congress (MWC) 2014 and 2015 events. It also helped to understand the overall Mobile Wallet architecture.

Star Bonus service is developed on top of the Mobile Wallet framework. The Star Bonus service contains a client which is present and running on the mobile device. The server part which acts as persistent storage is running as a web server.

5.1. Environment

The Star Bonus service also referred to as the Star Bonus widget, is made on top of the Mobile Wallet framework. This framework allows adding the extensions, and the Star Bonus service is added as an extension to act as a virtual card for the loyalty card. A Samsung Galaxy S3 device with Android operating system version 4.3 is used for implementing and testing the Star Bonus service.

The Mobile Wallet framework developed by G&D is used to develop the Star Bonus service. The framework provides the software development kit for developing the extensions to their Mobile Wallet framework. The G&D framework provides the emulator to test the extensions. The emulator is used to test the Start Bonus service for different screen sizes.

Git is used as a version control system. It is a free, open source, distributed version control system designed to handle everything from small to very large projects with speed and efficiency [23]. Git also works very well in smaller one-man projects like this one as no central repository is required.

Chrome web browser is used to test the Star Bonus service before pushing the service onto the device. This is possible for the Star Bonus service, as it runs on the web side and the Android platform WebView component is WebKit-based. The desktop Chrome is a WebKit-based browser.

The Star Bonus service is packed using the jar command, and jarsigner is used for signing the service. The Star Bonus service is deployed on the device using the Android Debug Bridge (ADB). Windows operating system and Java version 1.6 are used.

As the Star Bonus service is implemented using standard web technologies, namely Hyper Text Markup Language (HTML), Cascading Style Sheet (CSS) and JavaScript – any tools capable of working with them can be used for the development. The simplest development environment is Text editor. Eclipse Web Tools Platform is recommended for those who are familiar with Eclipse.

5.2. General requirements

The primary requirement of the Star Bonus service is to keep it simple and easy for demoing it during the MWC. At the same time, the service should be able to integrate the loyalty card into the payment system and display the summary of bonus points and history of transactions.

The secondary requirement is to support different screen sizes. The Star Bonus service user interface should be fluid enough to support different smart phones having different screen sizes.

5.3. Functional specification

The Star Bonus service has three use cases as shown in Figure 10. The only actor for this widget is the end user of the Mobile Wallet application. The first use case is viewing the summary of bonus points accrued so far. These details are stored in Star Bonus web server. The Star Bonus service fetches the details from the server using the JavaScript Object Notation (JSON) object.

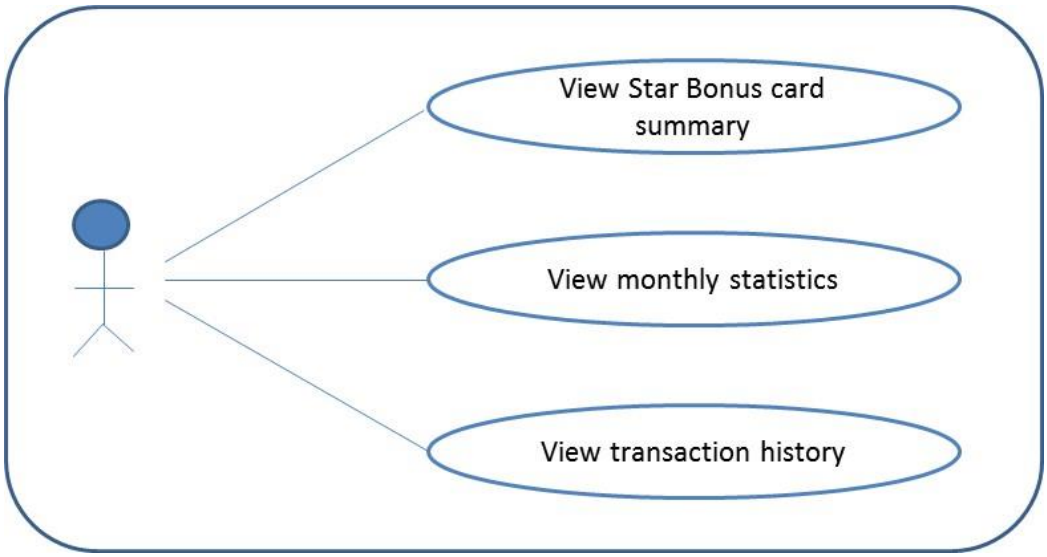

Figure 10. Star Bonus service use case diagram.

The second use case is viewing the monthly statistics of the transactions. The Star Bonus service extension calculates the monthly statistics after fetching all the transaction details from the web server. The third use case is showing the transaction

details sorted by date. Payment date, amount, and merchant details are shown for each transaction.

5.4. Architecture overview

Architecture overview of the entire system is shown in Figure 11. The block named Mobile device shows all the components that are either present or running on the Mobile device. Each block of the architecture diagram is explained below starting from lower layers.

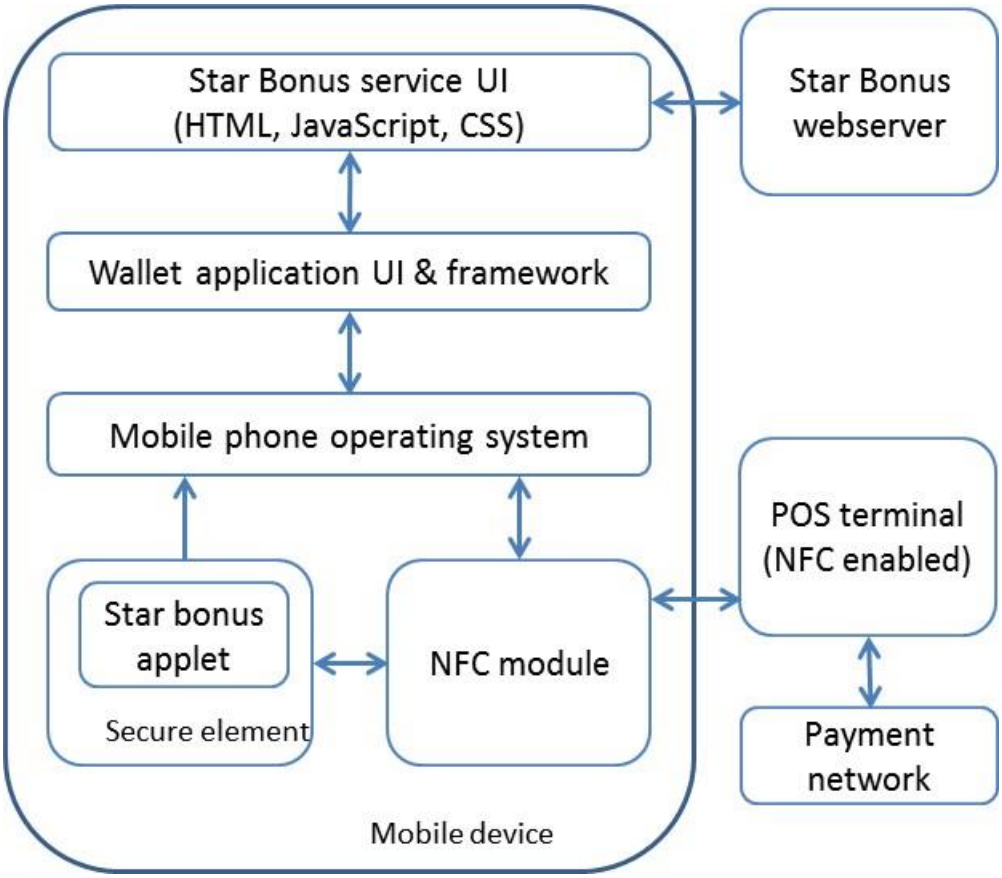

Figure 11. Overview of Mobile Wallet and Star Bonus service.

Secure Element. This module plays an important role in making trustworthy mobile payment solutions. Details about secure element and the different options for a secure element are discussed in detail in Section 3.4. The secure element used for the Star Bonus service implementation is UICC SIM. The UICC SIM contains the applets. In this case, the Star Bonus applet is used by Star Bonus service extension. The ID used by this applet should match with the ID defined for the Star Bonus service. This way, the security remains in place and only those extensions that have the applets in the secure element can have access to NFC module.

NFC module. This module handles NFC communication in secured manner. During the payment, NFC module communicates with POS terminal to exchange the

transaction amount and other details. NFC forum works on NFC Controller Interface. For paying with Mobile, NFC is used in the card emulation mode. In this mode, a mobile device can emulate any contactless smart card.

Mobile phone operating system. This part provides the framework for the development of the applications. The operating system communicates with the secure element and NFC module. Android operating system version 4.0 was used to test the Star Bonus service along with the Mobile Wallet. The Samsung Galaxy S3 device was used for the development purpose.

Wallet application User Interface (UI) and framework. This module shows the generic Mobile Wallet application running on the mobile device. The framework provides all the basic functionality of the Mobile Wallet, as well as the functionality to add services to the wallet. This includes giving access to file system, raising notifications on key press, and providing APIs to communicate with applets. Framework also includes the utility library and provides functionality to install and uninstall additional services.

Star Bonus service UI. This part is an extension added to the Mobile Wallet application. The extension is developed using HTML, JavaScript, and CSS. The detailed implementation of Star Bonus service is discussed in Section 5.5.

Star Bonus web server. The Star Bonus service requires storing of transaction details in a persistent manner. For this reason, the Star Bonus web server is used to store the transaction details. Star Bonus service extension can access the details from the web server using the JSON. At the same time, whenever the payment is made using Mobile Wallet, the Star Bonus service extension running on Mobile sends the details to the web server. The detailed implementation of Star Bonus web server is discussed in the Section 5.6.

POS terminal. The POS terminal in this case will have NFC capability. During the payment, the Merchant enters the transaction amount and the user pays the amount by the first opening the Mobile Wallet application and shows the Mobile to the POS terminal. NFC module in the device communicates with POS terminal in a secure manner with the help of secure element.

Payment network. The payment network validates Virtual card details stored in the Mobile Wallet. The virtual card is the same as the credit/debit, except that the card details are stored virtually in the Mobile Wallet application. The validation process in this case is the same as in the case of the physical card.

5.5. Star Bonus service

The Star Bonus service is developed using HTML, JavaScript and CSS. The Star Bonus service is paired with Secure Element applet whereby it communicates. The Applet ID of the paired applet must be specified in Star Bonus service manifest file. The Star Bonus service is first packed into BAR files. The format of the BAR files is shown below in Listing 1.

Listing 1. Folder structure of Star Bonus service.

```
META-INF - Contains the application manifest file
HTML - Contains the widget specific HTML files
CSS - Contains the widget specific style sheet files
JS - Contains the widget specific JavaScript files
LANGUAGES - Contains the widget specific translation files
Resources - Contains widget resources (images, etc.)More about the
structure of the widget
```

There cannot be any files under the root folder. The MANIFEST.MF file under the `META-INF` folder contains attributes describing the Star Bonus service. The `HTML` folder contains widget.html file. The resources folder contains an image file named icon.png and background.png. The `CSS` folder contains styles.css file. The `JS` folder contains widget.js file. The content of MANIFEST.MF file is shown below in Listing 2.

Listing 2. MANIFEST.MF file contents.

```
WidgetId: c153dfb9-4cdc-4467-8b77-d5a2bc4108a2
DisplayName: StarBonus
AssociatedAid: STANDALONE
Version: 1.9.0
ADDServiceProviderName:
ADDSeApplicationName:
NetworkAccessAllowed: true
```

Star Bonus service is packaged for distribution with the type suffix "bar". The files are simply renamed to Java Archive (JAR) packages with specific locations for the contained files. Running the command shown in Listing 3 at the root of the widget directory will produce a suitable package file.

Listing 3. Command for making bar file.

```
jar cmf META-INF\MANIFEST.MF StarBonus.bar *
```

The Mobile Wallet framework provides keystore along with the Software Development Kit (SDK) that must be used to sign the Star Bonus service “BAR-file” before deploying it to the mobile device. The wallet does not install unsigned widget “BAR-files”. The widget is signed with the below command shown in Listing 4. The keystore file and widget “BAR-file” need to be in the same folder.

Listing 4. Command for signing.

```
jarsigner -keystore widgetdev.jks -storepass widgetdev StarBonus.bar
widgetdev
```

Furthermore, the ADB command line tool is used to push the Star Bonus service directly to the memory card without mounting and unmounting it to the development computer in between. With the device connected and Universal Serial Bus (USB) debugging enabled, run the adb command shown below in Listing 5.

Listing 5. Command for pushing Star Bonus service to device.

```
adb push MyWidget.bar /mnt/sdcard/walletdevelopmentwidgets
```

The Mobile Wallet framework monitors the `walletdevelopmentwidgets` folder, and every time something changes in this folder, all widgets in there are reinstalled. Mobile Wallet can be open while pushing new widgets or updating existing ones. When updating a widget, make sure to close the widget in Wallet before pushing the new bar file.

5.6. Star Bonus web server

The Star Bonus web server is implemented for storing transaction data in a persistent manner. The web server is a backend implementation of the Star Bonus service. The implementation is made very simple by using just two files: a PHP Hypertext Preprocessor (PHP) file named start_backend.php and another JSON file named customer_account.json. The web server is hosted on Sasken Finland servers.

The PHP file is called in two cases. The first is when the Star Bonus service is started. In this case, the customer_account.json file content is decoded into JSON object and returned to the Star Bonus service. The returned JSON object has the total accrued bonus points so far and the individual transactions details.

The second case is when the Star Bonus service wants to report the transaction to the web server. At this point, the functionality in PHP file updates the customer_account.json file by adding a new entry with the reported details. At the same time, the total number of bonus points accrued is recalculated.

The JSON file has the total bonus points accrued at the beginning. This number gets updated every time a new transaction is added to JSON file. Under the payment history section, the individual transaction details are stored. Each transaction has the transaction location, time, amount, and the currency. The format of customer_account.json file is shown below in Listing 6.

Listing 6. JSON file content.

```
{
 "currentBonusPoints":23568,
 "paymentHistory":
 [
  {"loc":"StarGas","time":"2016-05-01","amount":15.65,"currency":"e"},
  {"loc":"StarMart","time":"2016-04-15","amount":14.56,"currency":"e"},
  {"loc":"StarMart","time":"2016-04-10","amount":45.00,"currency":"e"},
  {"loc":"StarGas","time":"2016-04-05","amount":26.15,"currency":"e"},
  {"loc":"StarGas","time":"2016-04-01","amount":15.99,"currency":"e"}
  {"loc":"StarGas","time":"2015-05-05","amount":26.15,"currency":"e"},
  {"loc":"StarGas","time":"2015-03-01","amount":15.99,"currency":"e"}
  ]
}
```

The PHP file content is shown in the Listing 7. The PHP file parses the GET parameters. If the transaction details like location, time, and amount are not empty then the JSON file is decoded first. Then the transaction details are added to decoded data and total bonus points are recalculated, and then the JSON content is written back to the file. If the transaction details are not present, then the JSON file content is reported to the caller.

Listing 7. PHP file content.

```
<?php
$file = "customer_account.json";
$backupFile = "customer_account.json.backup";

// Parse GET parameters for new purchase details
if(!empty($_GET))
{
   if($_GET["reset"] == "true")
   {
      file_put_contents($file, file_get_contents($backupFile));
   } else
   {
      $newLocation = $_GET["newLocation"];
      $newTime = $_GET["newTime"];
      $newAmount = floatval($_GET["newAmount"]);
      $newcurrency = $_GET["newcurrency"];
// Add new entry if requested
      if(!empty($newLocation) && !empty($newTime) && !empty($newAmount)
&& !empty($newcurrency))
      {
         // Open local database holding all purchase history
         $json = json_decode(file_get_contents($file), true);

         // Add new entry to json
         $result = array_unshift( $json["paymentHistory"],
array("location" => $newLocation, "time" => $newTime, "paymentAmount" =>
$newAmount, "currency" => $newcurrency) );

         $json["currentBonusPoints"] = $json["currentBonusPoints"] +
floor($newAmount * 10);

         // overwrite local db with new contents
         file_put_contents($file, json_encode($json));
      }
   }
}
```

5.7. Sequence diagram

The sequence diagram shown in Figure 12 explains the sequence of activities involved while starting Star Bonus service and when the user makes the payment. When a payment is made, payment details are added to the Star Bonus service and the bonus points of newer payments are added to existing bonus points.

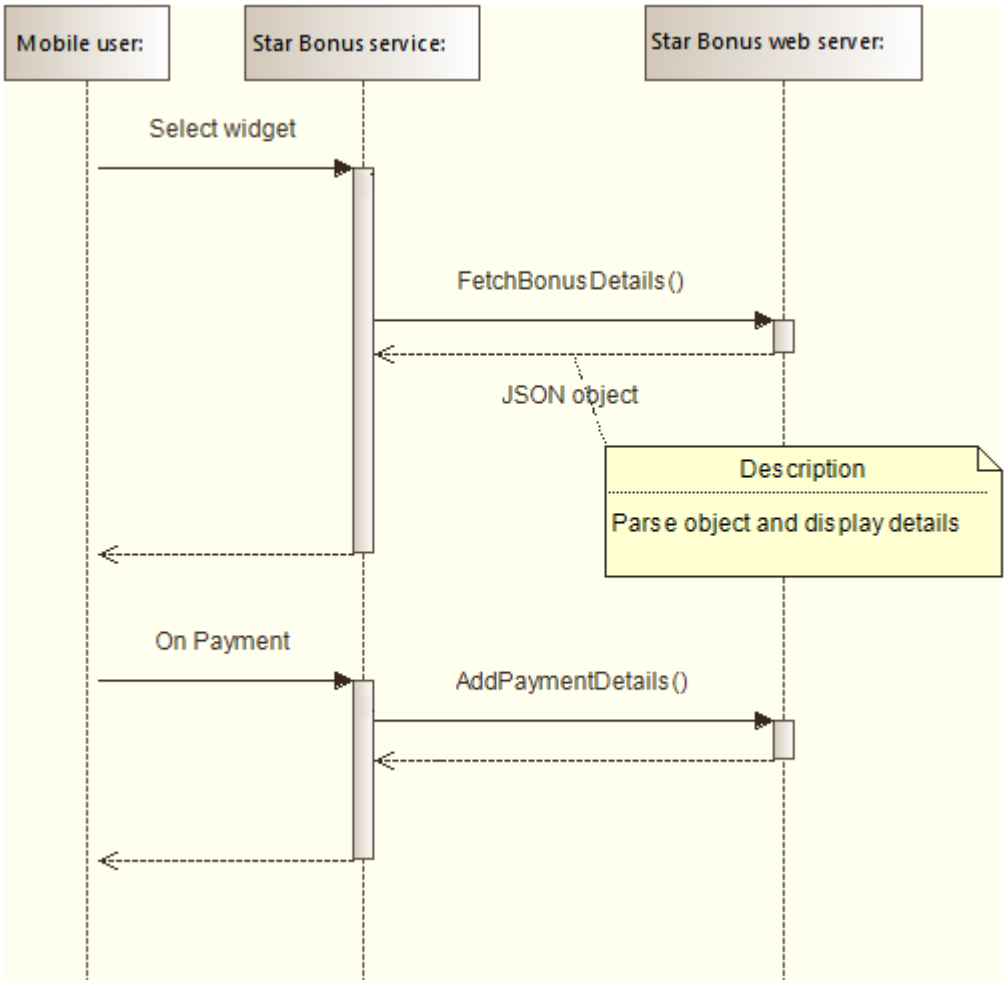

Figure 12. Star Bonus service sequence diagram.

Mobile user is the end user of the Mobile on which Mobile Wallet is running. The **Star Bonus service** is the extension added to the Mobile Wallet application and the client of this extension is running on the Mobile device. Star Bonus service is not a standalone application. It runs inside the Mobile Wallet application. The **Star Bonus web server** is the server side instance of Star Bonus running on the web server.

In the first scenario, the Mobile user opens the Star Bonus service explicitly. This happens if the Mobile user selects and opens the Mobile Wallet first and then selects the Star Bonus service from the list of available extensions. At this point the **FetchBonusDetails()** method of the Star Bonus web server gets called and the details are returned to Star Bonus service using the JSON object.

The JSON object is parsed by the Star Bonus service and the values are shown to the user in a simpler UI with 3 tabs. Details about the UI are discussed in the User Interface Section 5.8. The JSON object returned by the Star Bonus web server has all the transaction details. From these transaction details, Star Bonus service finds out the monthly statistics data.

The second scenario represented in the sequence diagram is when the payment is made by the Mobile user. The payment details are reported to the server using **AddPaymentDetails**() method. The Star Bonus web server updates the transactions database and total bonus points accrued by the user. The updated bonus points are shown to the user the next time they open the Star Bonus service extension of the Mobile Wallet application.

5.8. User Interface

The Star Bonus service has four different views. The UI is very simple to use and intuitive. The views of the Star Bonus service are represented as tabs. The links to the tabs are present towards the right hand side of each page after Star Bonus service is started.

The user has to first select and open the installed Mobile Wallet application. As seen in Figure 13 Star Bonus is one of the available extensions in the Mobile Wallet. This view shows all the available extensions as icons.

By clicking the Star Bonus icon present in Figure 13, the Star Bonus extension service is opened and the screen appears as shown in the second screen capture of Figure 13. This page shows the total available bonus points and the top three purchase locations. StarMart, StarGas and Visa Merchant are the top three purchase locations. This data is fetched from the Star Bonus web server as and when the Star Bonus service is opened. The tabs on the right hand side of this view allow the user to change the pages.

When the page is changed by selecting the tab, the background color behind the active tab becomes lighter compared with other tabs. In Figure 13, the Star Bonus tab has a lighter background compared with Statistics and Transactions tab.

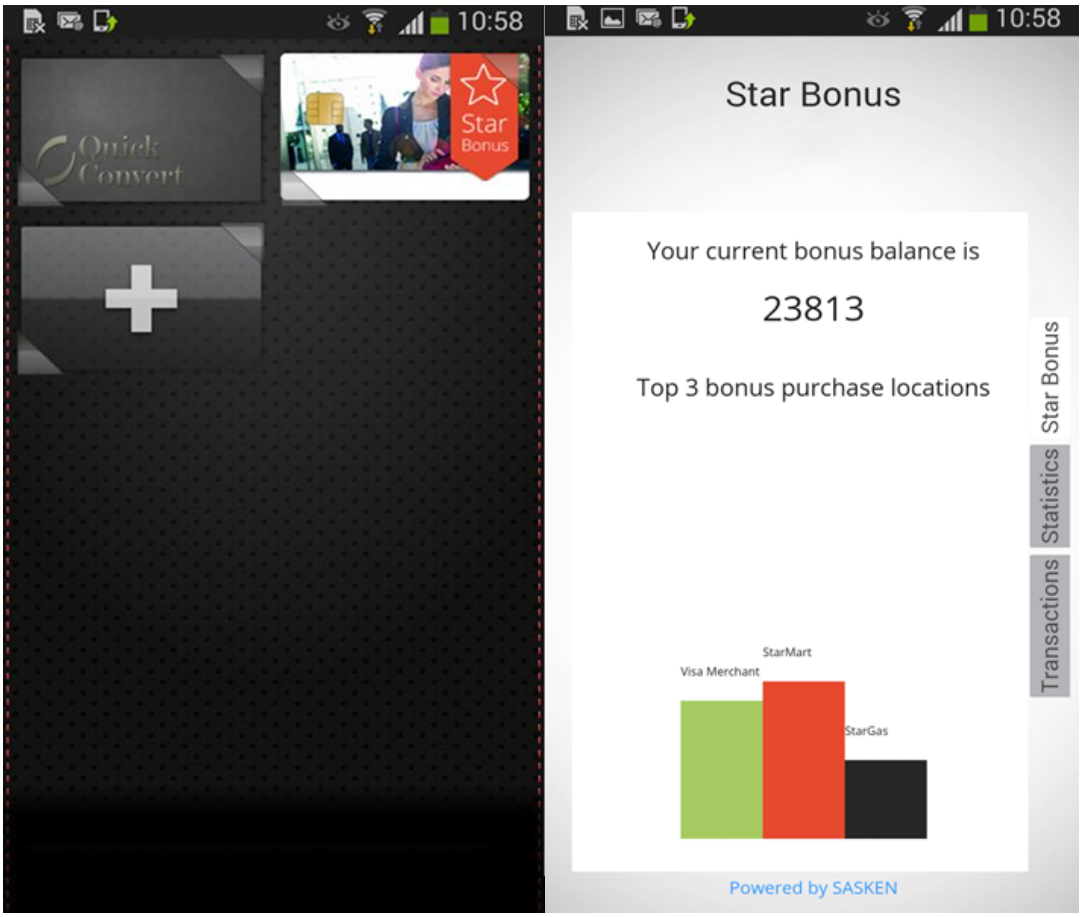

Figure 13. Mobile Wallet initial and summary screen.

By clicking Statistics tab the monthly statistics of the transaction are shown in a page. The page appears as shown in Figure 14. Each row in this view shows details about the month, and the number of bonus points accrued during that month. The size of horizontal bar in green color is relative to the maximum bonus value present under the monthly statistics view.

The final view of the Star Bonus service is the Transaction history page. This page can be opened by selecting the Transactions tab. The Transactions page appears as shown in the second screen capture Figure 14. Each row in this view shows individual transaction details like the data, merchant name, and the purchase value.

When Star Bonus is the active and currently shown UI, then the *back* button on the mobile phone will close the Star Bonus service. Upon closing Star Bonus, the user will see Mobile Wallet application as shown in the first screen capture of Figure 13. The user has to press the *back* key one more time to exit from the Mobile Wallet application.

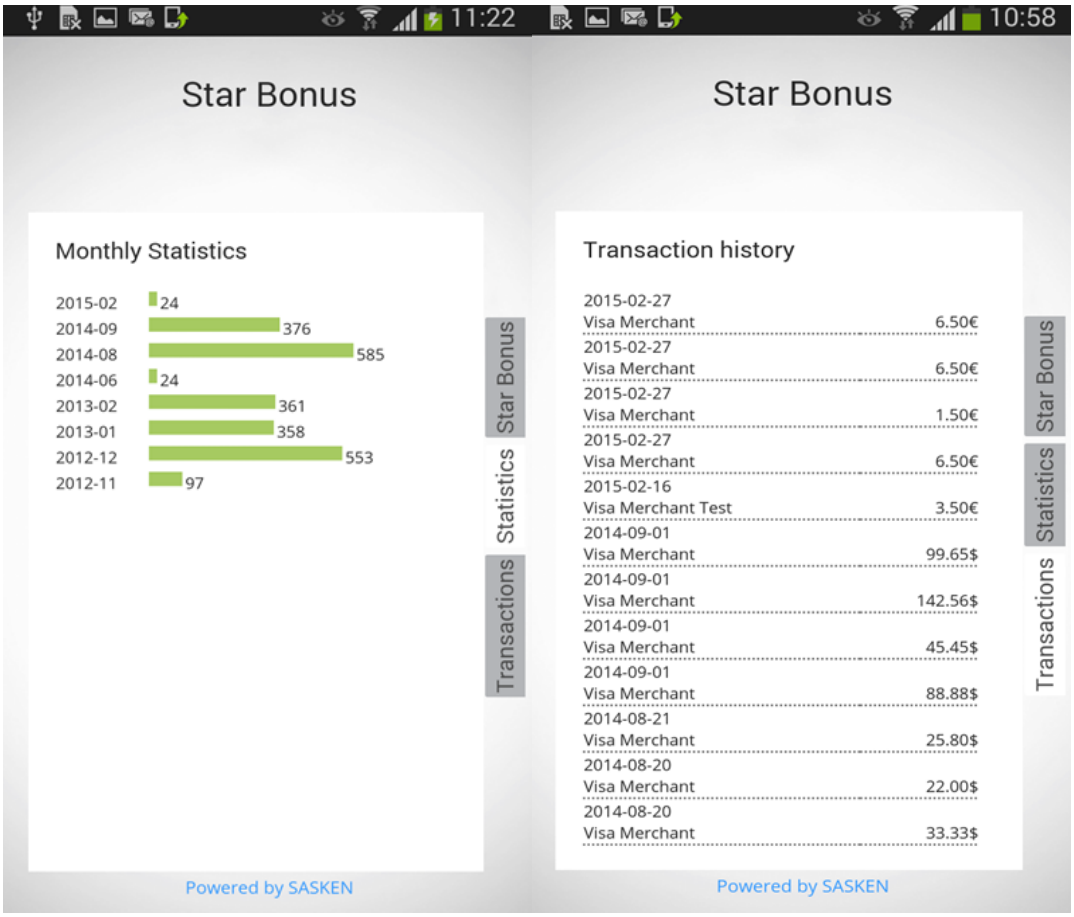

Figure 14. Mobile Wallet statistics and transactions screen.

5.9. Working with different screen sizes

Star Bonus UIs should be fluid enough to support screens of any size or shape. While the range of devices that G&D Mobile Wallet framework officially supports is limited, new devices and platforms are added constantly, and Star Bonus should be responsive enough not to break on new kinds of screens.

Star Bonus should use the existing viewport <meta> tag as defined in the <head> of the widget.html file. This ensures maximum compatibility for different screens and normalizes the CSS pixels between retina/non-retina resolutions. A good rule of thumb for making scalable UIs is to avoid absolute (e.g. pixel based) units and preferring relative units, such as percentages or rem units.

For graphics, SVG is used for scalable UIs, which stay sharp even on large retina screens. Icon fonts are also a great way to make vector graphics that can also be styled with CSS. For testing different screen sizes, the G&D Mobile Wallet emulator provides some common screen sizes for viewing the UI. Sometimes it's hard to avoid absolute units due to device bugs or complex layouts. For these cases, CSS Media Queries provide the means to target certain styles for different screens. Listing 8 shows the example.

In the example shown in Listing 8, we want the .icon dimensions to keep a certain ratio, but still be usable for available screen estate. This would not be possible with relative units, but using Media Queries we can avoid requiring JavaScript to change the dimensions. This way some default dimensions are defined and change the dimensions after certain screen width breakpoints (320px and 480px above).

Listing 8. CSS media queries.

```
.icon {
width: 200px;
height: 100px;
}
@media only screen and (min-width: 320px) {
.icon {
width: 300px;
height: 150px;
}
}
@media only screen and (min-width: 480px) {
.icon {
width: 400px;
height: 200px;
}
}
```

6. Evaluation

In this thesis, the Mobile Wallet concepts and contactless payments using NFC are introduced. Also some of the existing Mobile Wallet solutions like Apple Pay, Google Wallet and Elisa Lompakko are discussed. In addition, Star Bonus service extension is added to the Mobile Wallet. This extension works like a virtual bonus/loyalty card issued to Mobile Wallet user by the retailer.

Developing the entire Mobile Wallet from scratch takes a lot of time. The effort it takes is very high to be able to complete as part of a Master's thesis. Due to this, the existing Mobile Wallet solution is taken and the Star Bonus service extension is added as part of the implementation.

6.1. Benefits

The Star Bonus service extension to the Mobile Wallet provides a value-added service to the user. The bonus points accrued for each purchase are automatically updated and the user can see all their past payment history. Additional services to the Mobile Wallet like the Star Bonus service can be added if the Mobile Wallet architecture allows adding extensions. It is important to consider this while designing the Mobile Wallet architecture.

The Star Bonus service was presented by G&D at MWC-2014 and MWC-2015 as a part of their Mobile Wallet service. The feedback from the MWC events was positive. This case helped G&D to present their Wallet service better to their clients. Having the Star Bonus service as part of their Wallet solution has helped them to present that payment can be combined with loyalty card.

This helped the G&D to showcase to their customers that their Mobile Wallet service is easily adaptable as per the client requirements and the value-added services can be added to their Wallet application. This also raised the interest of retailers towards the G&D Mobile Wallet as the G&D wallet supports integrating loyalty cards into their Mobile Wallet. G&D has continued the development of their Mobile Wallet framework and as per the G&D press release. Their Mobile Wallet framework has been taken into use by Dutch Rabo bank [24].

This also helped Sasken Finland as an organization to pursue further with G&D to provide software services. Having this case helped sales team of Sasken Finland to present the proven capabilities and better engage the G&D customer.

The Star Bonus service decreases the time taken for the payment. The user does not need to take the loyalty card out from the physical wallet during the payment as the Star Bonus service integrates it into the payment process. Overall experience of the user is improved as the user has flexibility to track the bonus points and the history of payments.

6.2. Interviews

Star Bonus service has been developed in close cooperation with the G&D and Sasken Finland Oy sales organization. The developed Star Bonus service was presented at MWC-2014 and MWC-2015 by the G&D team along with their Mobile Wallet service. Here are some comments from the different people involved in the process.

As per Juha Istolahti, Software Sales at Sasken Finland Oy, Giesecke & Devrient (G&D) has been developing comprehensive mobile wallet solution for NFC services which brings all the functions of an electronic wallet onto a common platform. It introduces a framework that allows the deployment of various services such as mobile payments but also ID cards, loyalty cards, public transport tickets, and access keys for buildings and vehicles in the form of an electronic wallet. Customers can use the applications for these services securely and conveniently from their smartphones. Sasken developed a Star Bonus service on top of G&D platform that can be used to demonstrate mobile payments and managing loyalty card credits. This application was introduced in MWC conference in Barcelona 2015. Application received very good feedback at the convention and the Sasken development work was highly appreciated by G&D. Star bonus application is currently used in customer demonstrations.

6.3. Further development ideas

The Star Bonus service developed as part of this thesis demonstrates paying with mobile in a simpler way. This application can be further developed to sort the transaction history as per merchant location and amount. Currently, the transactions are sorted according to date.

The search feature is another further development idea through which user could search the transaction history for a specific merchant. Allowing user to give comments for the transaction is another development idea. The Mobile Wallet application and the Star Bonus service have been tested so far only on Android devices. The development could be extended to Apple and Windows devices as well.

Improvements can be made vis-à-vis data access from the web server. Currently, every time the Star Bonus service is launched, connection is made to the web server and the entire data is fetched. This might not be a problem in the beginning when there is little data to fetch, but as the number of records grow, it’s better to optimize the data

access from the server. It would be also good to consider access to past history even when the internet connection is not available to the mobile.

6.4. Problems faced

The Mobile Wallet industry has gone through quite a few rapid changes from the second half of the year 2014. The Apple has introduced Apple pay and Softcard (formerly Isis Mobile Wallet) is acquired by Google. Google has unveiled an Android Pay during Google I/O 2015. Due to these changes some parts of this document need to be rewritten multiple times. Even now while finalizing the thesis, Google has decided to roll back Google Wallet and move the functionality to the Android Pay application.

As the Mobile Wallet industry is fast changing, most of the references about the topic could be found only from the articles published on the web. There are almost no printed books on the recent developments in the Mobile Wallet industry. Due to this fact, most of the references made in the thesis lead to articles present on the internet.

Developing the Star Bonus service user interface as fluid enough to work for different screen sizes was challenging. By using Scalable Vector Graphics (SVG) instead of Portable Network Graphics (PNG) for all graphics, it was easier to scale the graphics for different screen sizes. Also in the CSS file, use of absolute units such as pixel based measurements are avoided, instead giving preference to relative units such as percentage.

7. Conclusions

This thesis introduces Mobile Wallet that uses NFC technology and presents the Mobile Wallet extension called Star Bonus service. This service demonstrates contactless payment using contactless technology and integrates loyalty cards into the payment. In spite of all the hype about Mobile Wallets, paying with mobile has not yet been widely accepted, primarily due to the complexity of payment ecosystem and failure to bring all involved players to agree on common terms. The second reason is like a chicken and egg problem; consumers do not know about the Mobile Wallet payments because merchants do not offer it, and merchants do not see any demand because consumers do not ask if it is available.

NFC technology has been present for more than ten years, but the Mobile Wallet technology has given a big boost for NFC. NFC payment primarily leads to faster and easier payment at the POS when compared with a traditional way of paying using cash or credit/debit card. NFC-based mobile payments are bringing in a great deal of interest to NFC chip makers, smartphone manufacturers, mobile telecom carriers, payment network processors as well as merchants.

The Mobile Wallet users expect a lot more than just using Mobile Wallet as a credit card. They expect the Mobile Wallet to be a better shopping companion that enables them to store shopping lists, offers, coupons, and product information. However, there is a large disconnect with brands and retailers failing to meet the customer expectation at Mobile Wallet.

Star Bonus service implementation demonstrates that developing an extension to the Mobile Wallet is not complex. It also showed that paying with mobile is very simple, efficient, and the loyalty card can be integrated into the payment. At MWC–2014 and MWC-2015 this application was demonstrated and the feedback was very positive. This thesis was also used as a reference to show the capabilities on the topic both from an individual and an organization point of view.

When it comes to the issue of trust, Mobile Wallets issued by banks have the high trust among Mobile Wallet users. Both banks and credit card networks are traditional financial organizations to which people have entrusted their wealth, so it is natural for consumers to trust them. Because of this factor, the chances of wider acceptance among users are high for the Mobile Wallets issued by banks.

However, it is important to offer flexibility without compromising security, for the user to add the additional services like loyalty cards, and transit cards. This thesis presents future suggestions about the additional value that Mobile Wallet can add apart from the payments. In general, the arrival of Apple Pay and Google Wallet is a big boost for the mobile payments technology.

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