When technological superiority is not enough
The struggle to impose the SIM card as the NFC Secure Element for mobile payment platforms

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Abstract

Mobile network operators have long played an essential role in the Near Field Communication (NFC) mobile payment ecosystem. In most implementations, the SIM card has been the main technical component to secure payments. Currently, mobile payment providers are increasingly planning to place the Secure Element (SE) for authentication in the handset or cloud, rather than on the SIM card. This paper unveils factors that influence stakeholder preferences for the SE location. To structure the analysis, we use a multi-level framework based on concepts borrowed from multi-sided platform theory. Using interviews with stakeholders, we elicit themes and preferences for each level of the framework (provider, technology, and user). Our findings explain why mobile network operators, despite their superior technology, will likely lose the battle for control in the mobile payment ecosystem.

Keywords: mobile payment, ecosystems, multi-sided platforms, secure element

1. Introduction

Due to growing pressures on profit margins, mobile network operators (MNOs) have been looking for opportunities to diversify their traditional “voice and data” business model. The emergence of NFC (Near Field Communication), a short range, high frequency, and low bandwidth wireless communication technology based on RFID (Ok, Coskun, Ozdenizci, & Aydin, 2013), enables the provisioning of new mobile value-added services. Among them, NFC-enabled mobile payments could become a good candidate for diversification. Mobile payments could increase revenues with the collection of transaction fees. Additionally, the service could lead to more stickiness and therefore reduce customer churn (De Reuver, Verschuur, Nikayin, Cerpa, & Bouwman, 2015). Although mobile payments offer promising business perspectives, technical hurdles need to be solved.

In order to secure NFC payment transactions, the so-called secure element (SE) is a crucial component to authenticate users (Reveilhac & Pasquet, 2009). The SIM card is generally considered a secure location for placing the SE (Chen, Mayes, Lien, & Chiu, 2011). A prominent alternative is the embedded SE, which consists of a hardware module soldered onto the mobile handset (Pourghomi, Abi-Char, & Ghinea, 2015; Reveilhac & Pasquet, 2009). The embedded SE architecture was chosen for the first version of Google Wallet in 2011. Another alternative is to emulate a payment card using a software piece. The SE is stored in the cloud rather than on a hardware module (Pannifer, Clark, & Birch, 2014). Recently, hybrid models emerged. For example, Apple Pay uses an architecture in which the SE is present inside the iOS device. The payment credentials are stored in the cloud. A tokenization mechanism is used to secure the transactions.

The alternative SE implementations to the SIM-centric architecture attracted the interest of financial institutions and other payment providers. They have been looking to store the SE on other technologies than the SIM card. Technically-speaking, new mobile payment systems could be launched without the presence and active participation of MNOs. Consequently, the MNO’s clout in the mobile payment ecosystem could be significantly undermined.

The aim of this paper is to unveil factors that influence stakeholder's preference for the SE location. This paper explains why the SIM-centric SE model is losing against the embedded and cloud models. We use multi-sided platform theory as an analytical lens (cf., Hagiu, 2014). The value of an SE architecture depends on its simultaneous acceptance by multiple user groups (i.e., consumers and merchants on one side and payment service providers on the other side). Through qualitative interviews with multiple mobile payment stakeholders, we elicit factors on the level of the providers, the technology and the users.

We focus on NFC-enabled mobile payments that use a mobile device (i.e., contactless cards are beyond the scope of this paper). Although the term "mobile payment" is being used for different types of service scenarios, this paper focuses exclusively on mobile proximity payments using NFC. Mobile proximity payments involve performing authentication and authorization, making a payment, initiating accounting and confirming the completed transaction, through a mobile phone at a physical point of sale (POS) terminal (de Reuver, Verschuur, Nikayin, Cerpa, & Bouwman, 2015). We also focus on post-payments, such as debit/credit cards (i.e., stored value accounts are beyond our scope).

The paper contributes to telecommunication literature on mobile platforms and ecosystems, and specifically the position of MNOs in the mobile payment market. The pivotal and enabling role that MNOs can play in the mobile ecosystem has been a common theme in telecommunications literature, especially in relation to the mobile Internet (Gonçalves & Ballon, 2011; Karippacheril, Nikayin, De Reuver, & Bouwman, 2013; Natsuno, 2003; Peppard & Rylander, 2006; Weber, Haas, & Scuka, 2011; Zhang & Liang, 2011). Yet, there is little research on the reasons why MNOs failed to dominate the mobile payment ecosystem (for more details, refer to the critical review of mobile payment research by Dahlberg, Guo, & Ondrus, 2015). Studying the perspective of payment service providers' complements earlier studies on mobile payment acceptance from the perspective of consumers (e.g., Mallat, 2007) and merchants (e.g., Guo & Bouwman, 2015). Our paper contributes to practice by showing how stakeholders such as financial institutions and other payment service providers make decisions on SE architectures. Such understanding is crucial for informed strategizing by stakeholders. This research is timely, as other type of actors such as Google, Apple and Samsung have entered the mobile payment market.

The paper is structured as follows. We provide an introduction on mobile payment (Section 2). Based on desk research and contemporary examples, we describe the different SE technologies (Section 3) followed by a theoretical background on multi-sided platforms (Section 4). Next, the empirical part of the paper introduces the interview method (Section 5) and results (Section 6). A discussion on how the main findings contribute to literature is provided next (Section 7). The paper concludes with key contributions, limitations and outlook to future research (Section 8).

2. NFC-enabled mobile payment

For many years, MNOs have struggled to design mobile proximity payment solutions. A common standard for communication between mobile phones and merchant terminals was lacking. To solve the issue, MNOs invested into proprietary solutions. Different technologies emerged. Unfortunately, none of them became a dominant standard. In Korea, SK Telecom created their own specification of RFID (Radio-frequency identification) technology, requiring heavy investments in both consumer handsets and merchant payment terminals. Similarly, NTT DoCoMo in Japan rolled out a mobile payment platform using the Sony's FeliCa smartcard standard. One advantage was the existing use of this technology for public transit and other prepaid payment schemes. Merchants already possessed the required equipment to accept mobile payments. NTT DoCoMo only had to distribute compatible mobile handsets to their customers. Despite these limited successes, the high investments in technology required prohibited most MNOs in other countries to replicate these experiences (Ondrus, Gannamaneni, & Lyytinen, 2015).

In 2004, Nokia, Philips, and Sony established the NFC Forum. Then, in 2006, the Nokia 6131 was the first NFC-equipped mobile device. Fortunately, all major handset manufacturers now support NFC. Simultaneously, merchants are increasingly equipped with NFC-ready terminals. Financial institutions are rolling out contactless EMV (Europay, MasterCard and Visa) payment cards, which are compatible with NFC. Thus, more than ever, consumers and merchants have NFC-enabled technology in their hands. The diffusion of NFC handsets and terminals remove the main technological barriers that MNOs faced earlier when rolling out mobile proximity payment systems.

The use of contactless payments is growing but remains marginal compared to other payment methods, at the exception of niche markets such as public transportation. Thanks to a gate infrastructure, transit fare collection can be done with a contactless card or an NFC-enabled smartphone. For this specific application area, viable systems have been launched. For instance, there is Octopus in Hong Kong, T-Money in South Korea, EZ-Link in Singapore, and Oyster in London. Similarly to some of the mentioned countries, in the Netherlands, payment for public transportation is now done via dedicated contactless chip cards. In November 2015, Dutch public transportation providers have started a pilot with emulating the chip card through a mobile application, which currently works only on Android phones. Technically, this solution uses the SIM card for storing the SE, requiring users to replace their SIM card with UICC (Universal Integrated Circuit Card) card, and extends existing mobile wallet applications from two of the three major MNOs Vodafone and KPN. Nevertheless, the development of such solution has been impeded by the SIM-card architecture choice. Consumers must buy a specifically certified smartphone and typically swap their current SIM card. Up to now, the onboarding process and technical requirements were the main barriers for mass adoption of mobile payments in public transit scenarios. Recently, Apple added support for FeliCa Type-F NFC which enables Mobile Suica in Japan[1]. Thanks to an easy registration process without the requirement for additional technology, iPhone 7 users can now use Apple Pay for public transportation.

NFC-enabled mobile payment has received attention in existing literature. March et al. (2010) are among the first to distinguish three options for providing the SE. They explain that these different options affect division of roles related to service provisioning, relation management, and billing and charging. March et al. (2010) also suggest that security and trustworthiness of data and interoperability are key decision criteria for SEs. Ondrus & Pigneur (2009) argue that besides technological issues, organizational and business case factors also play an important role for assessing the viability of NFC-enabled mobile payments. Kazan and Damsgaard (2013) conceptualize NFC-enabled payment as multi-sided platforms, with criteria of network effects, homing costs, switching costs, bundling, envelopment, platform design and technological solutions. Hedman and Henningson (2015) compare different coopetition strategies for realizing mobile payment.

Recent failures to implement NFC-enabled mobile payments led to various studies on hurdles for MNOs. Gannamaneni, Ondrus and Lyytinen (2015) find that lack of collaboration between stakeholders, the absence of technology standards, and low added value for users are main failure factors. Lack of collaboration between stakeholders and difficulties in finding mutually beneficial business models were also main failure factors in other studies (Apanasevic, 2013; de Reuver, Verschuur, Nikayin, Cerpa, & Bouwman, 2015; Ozcan & Santos, 2015). Liu et al. (2015) point to lack of clarity on industry competition and regulatory policies, as well as the need for open communication between stakeholders. Another concern is that low-value payments are generally not profitable and even offered at a loss by banks, which makes it difficult to find a business model. Country-specific institutional and market conditions also play an important role in explaining success or failure of mobile payment initiatives (see e.g., Magnier-Watanabe, 2014; Miao & Jayakar, 2016).

3. SE Architectures

An SE comprises an integrated set of hardware, software, interfaces and protocols for authentication of mobile payment users (Reveilhac & Pasquet, 2009). To do so, the SE provides secure memory, cryptographic functions and a secure environment for execution (Madlmayr et al., 2007). While multiple applications can be stored on the SE, they must be protected from each other and the applications should only be accessible for authorized parties (Madlmayr et al., 2007). In this section,

[1] http://www.apple.com/newsroom/2016/09/apple-pay-coming-to-japan-with-iphone-7.html

we describe the three main technology options for providing an SE: the SIM-centric (3.1), embedded (3.2) and host card emulation - HCE - (3.3) model.

3.1. SIM-centric architecture

A SIM card defines the relationship between the issuer (i.e., MNO) and the consumers. SIM cards are used to identify and authenticate mobile devices to the mobile operator network. Moreover, SIM cards can securely store data and applications. The technology used by SIM cards is comparable to the EMV chip found on payment smartcards. The SIM card is a good candidate for hosting the SE as it includes strong cryptographic calculation power and security (Chen et al., 2011). SIM cards have been designed to be secure and tamper resistant and are guarded by PIN and PUK codes with limited attempts (Abbott & Practical, 2002). The next generation SIM cards (UICC) can store multiple applications from both the operator and third parties. The operating system on UICC cards prevents the applications from accessing or sharing data between them (Alimi & Pasquet, 2009). The UICC can thus be safely used for other applications such as mobile payment, loyalty cards or POS transactions.

The SIM-centric architecture requires MNOs to upgrade the SIM cards in their subscriber base towards the UICC standard. In addition, handsets must be certified since hardware and software implementations of NFC could differ, which generates incompatibility with the payment infrastructure. The need for certification makes MNOs dependent on handset manufacturers for offering NFC compatible devices. Therefore, in order to subscribe to a mobile payment service using the SIM-centric architecture, users need to buy a certified mobile device, obtain a new UICC card, and register their payment card with their MNO and bank.

The SIM-centric architecture has been adopted in several cases. For instance, the Cityzi project in France comprises a consortium of MNOs, financial institutions and other firms (i.e. public transportation, parking, museum, and retailers) to offer NFC services throughout French cities (Andersson, Markendahl & Mattson 2012). A complicating factor is that banks and MNOs are launching their own wallets, for instance Paylib offered by an alliance of the major banks. Although Paylib is currently used for online purchases only, the wallet can be extended to proximity NFC payments (Paylib 2016). French MNO Orange also launched their own wallet called Orange Cash, which relies on a SIM-centric architecture (Orange Cash 2016).

3.2 Embedded SE architecture

The embedded SE is a tamper resistant module that is soldered onto the motherboard of the mobile handset and offers the same level of security as the SIM (Reveilhac & Pasquet, 2009). Similarly to the SIM-centric architecture, the entire application is stored on the hardware element. The implementation of the SE should follow the EMV secure specifications to be accepted by the financial institutions. The chip is embedded within the device during the manufacturing phase and must be personalized after the device is delivered to the user.

One issue with the embedded SE architecture is the limited choice regarding handsets. In practice, only manufacturers with large market shares can equip a sufficient critical mass of handsets with embedded SEs. In addition, consumers cannot put the SE into another handset, implying that each newly purchased handset needs to be personalized.

The embedded SE architecture was implemented in 2011 by Google. The first version of Google Wallet could only work on the Nexus S model with Google’s embedded SE. As sales of the Nexus phone were low, Google Wallet struggled to take off (CNET 2012). The incompatibility of their SE architecture with other Android mobile phones limited further development of Google Wallet. On their side, Apple also implemented an embedded SE into their iPhone 6. However, Apple does not face the same scale challenge as Google due to its dominance in the smartphone market. In addition, as Apple develops both hardware and operating system, there is limited variability between iPhone models. As opposed to Android, Apple’s controlled fragmentation facilitates the diffusion of Apple Pay among all the existing iPhone users.

3.3. Host Card Emulation architecture

HCE refers to the virtualization of the SE into software. In this architecture, the application runs on the operating system of the mobile phone, which is called the "host" (Pannifer et al., 2014). Typically, payment credentials are stored in a cloud-based system. When at a contact point, the handset connects to the cloud upon which it receives a temporary key (i.e., token). To ensure security, keys are often provided in a scarce amount with a limited validity period.

The HCE adoption process for consumers differs from that of the other two options. Consumers install an application and register their payment credentials, without having to visit an MNO or bank local branch.

HCE does not work when the screen or phone is off, as opposed to the SIM and embedded SE architectures (Pannifer et al., 2014). Users also require Internet connectivity for downloading keys. Moreover, consumers need a recent Android mobile device equipped with NFC and the latest version of Android in order to use HCE.

Google adopted the HCE architecture in the version 4.4 of Android. The mobile wallet/application can virtualize and emulate a payment card when using the NFC interface to communicate with contactless payment terminals. Besides payment applications, HCE can emulate any loyalty, transportation, access or identification card (Smart Card Alliance 2014).

4. Theoretical background: Multisided platforms

We conceptualize the SE as the core component of a mobile payment platform. Digital platforms have transformed how digital innovation takes place (Yoo, Boland, Lyytinen, & Majchrzak, 2012). While platforms are often used to refer to an organizing logic of innovation management (Gawer, 2009), we focus here on digital platforms. A platform is defined as a set of stable components that supports variety and evolvability in a system by constraining the linkages among the other components (Tiwana, Konsynski, & Bush, 2010). Typically, platforms are composed of core technological resources that are stable as well as a variable periphery (Baldwin & Woodard, 2008). The stable core of a platform should be that functionality that is highly reusable, generic, stable and certain over time (Tiwana et al., 2010). The periphery of a digital platform comprises additional functionality of modules, which are typically applications that utilize the functionality in the core of the platform (Evans & Schmalensee 2007). In between the core and periphery of the platform, so-called boundary resources mediate between the platform provider and platform users, which are typically software development kits (SDKs) or application programming interfaces (APIs) (Ghazawneh & Henfridsson, 2013). The SE meets the definition of the stable core of a platform as it contains authentication credentials that can be reused in a generic manner for a wide range of current and future payment services, and is likely to remain stable over time.

Multi-sided platforms bring together multiple user groups, whereas the value for one group depends on the size of the other (Hagiu, 2014). The term multi-sided platform is typically used to describe a product, system, service or organization that mediates interaction between two or more groups of agents (Evans et al. 2006; Rochet & Tirole 2003). By mediating interactions between the user groups, platforms create network effects. Network effects arise when the desirability or functionality of a product depends on the number of complementary goods available for it (Katz & Shapiro, 1985). Network externalities imply that a technology's usefulness increases as its installed base of users increases (Katz & Shapiro, 1985). Typically, network externalities are direct if the value of the platform depends on the number of users in the same user group. Indirect network effects (inter-side externalities) occur when the value of a platform for a group of users depends on participation of another group of users (e.g., indirect network effects between users of a game console and game developers) (Evans, 2010; Gawer and Cusumano, 2008; Roson, 2005). Once the adoption of a product or technology has started, these network externalities provide benefits to both new and existing users such as reduced price, lower uncertainty about future versions of platforms and complementary services, communities of users, higher quality products, and new market opportunities. In the case of mobile payment, network effects are mainly indirect and positive, i.e. the more consumers join a platform, the more valuable the platform becomes for merchants, and vice versa. At the launch phase, platform providers may subsidize payment equipment to merchants or offer discounts to the first groups of consumers joining the platform. As such, the anticipated indirect network effects are an important factor to explain preferences for mobile payment platforms. Payment platforms that comprise an SE are typically multi-sided as they are used by consumers and payment providers (Kazan & Damsgaard, 2013; Ondrus & Lyytinen, 2011). The latter group of payment providers are typically banks or payment service providers that utilize the SE for authenticating consumers that make a transaction.

The multi-sided nature of platforms implies that they should be analyzed on different levels. Ondrus et al. (2015) propose three levels of analysis for mobile payment platforms: i) the provider level, ii) the technology level, and iii) the user level. Figure 1 illustrates the different levels for a generic mobile payment ecosystem. The provider level comprises the strategy issues and the roles of platform providers such as MNOs, financial institutions, banks, handset manufacturers. The technology level deals with performance and security traits of the technologies. The user level is mainly concerned with adoption factors for users. As SE architectures concern consumers and payment providers, the only relevant user group to study are consumers. As such, merchants are outside the scope of this paper as they are only involved in other parts of the mobile payment infrastructure such as POS equipment.

<Figure 1 here>

In this paper, we analyze how different SE implementations affect the three levels of analysis in the conceptual model in Figure 1. Using a multi-level framework allows a more holistic understanding as multiple complementary perspectives can be investigated simultaneously.

5. Method

The main goal of the interviews is to elicit which factors influence stakeholder preferences for one of the three options presented in Section 4. Interviewees are all affiliated with one of the stakeholders present in the mobile payment industry (i.e., bank, telecom operator, service provider or consultancy firm), primarily in the Netherlands. Our main interest is in understanding how these stakeholders reason about user level factors, and how that reasoning affects their preferences for one of the three technological options. Therefore, although users are one of the three levels of our theoretical framework, we did not interview consumers or merchants.

Selected interviewees had at least a couple of years of working experience in the industry. We wanted to ensure that they had good insight in the functioning of the industry. In addition, we strived for respondents with technical as well as business expertise. Interviewed candidates were sourced through the personal network of the authors and the client network of a prominent mobile payment security firm. Some interviewees were introduced thanks to a snowballing approach. An overview of interviewees is provided in Table 1.

<Table 1 here>

The interviews were based on a semi-structured approach (Table 2) and lasted between 30 and 60 minutes. We asked open questions on any advantages and disadvantages of the three architectures, loosely based on the three levels of our theoretical framework in Section 3. Respondents received a brief introduction of the study prior to the interview.

<Table 2 here>

Interviews were recorded, transcribed and coded. We analyzed transcripts by first selecting relevant quotations on preferences for one of the three architectures. Analysis was initially done based on open and selective coding (Glaser & Strauss, 2009), making use of clustering techniques (Miles &

Huberman, 1994). Through open coding, we assigned different labels to those quotations. Next, we clustered the codes into the three levels through an inductive approach.

6. Results

Our main concern in this paper is to compare NFC-enabled mobile payment platform solutions provided by MNOs (i.e. SIM-based solutions) with other technological alternatives (i.e. embedded SE and HCE solutions). Therefore, in this section we describe the advantages and disadvantages of the different solutions. Even though comparing embedded SE and HCE to each other is our not our primary aim, we do distinguish the two technologies for reasons of clarity.

6.1 Provider Level

Dependencies of payment providers on the platform provider were a recurrent theme in the interviews. While HCE solutions can be hosted by the service provider or bank in-house, SIM-based solutions imply dependency on MNOs. One of the respondents stressed that "*banks want to stay in control and want limited dependence on other parties, especially if they come from a different sector [like telecommunications]"* [BA2]. Yet, a mobile payment platform can only gain sufficient reach in a given country by simultaneously dealing with multiple MNOs. This dependency creates coordination issues and complexity.

Embedded SE solutions tend to imply dependency on device makers. Interviewees did not agree whether they would prefer to be dependent on operators or on device manufacturers. Interviewees did mention that, for HCE, not having to depend on MNOs or device makers was a clear advantage, although dependencies on operating system vendors still apply.

As previously stated, the SIM-centric architecture is advantageous for MNOs, as they are gatekeepers over what information that is uploaded to the SIM. In order to gain access to the SE, other stakeholders could either partner with MNOs (i.e. jointly develop and offer the platform) or pay a rental fee to the MNOs for securely storing financial credentials and applications on the SIM.

A recurrent theme in the interviews was the lack of trust that payment providers have in MNOs. Several bank interviewees argued they no longer trust MNOs. MNOs were generally referred to as difficult to collaborate with and overly focused on short-term profits [IE2, IE3]. Banks focus more on customer retention, while MNOs are more sales driven organizations. As one bank representative says, "*MNOs have overplayed their hand in the past, as they wanted maximum profit at the expense of the bank's business model"* [BA1]. Since recent collaboration initiatives with telecom operators have largely failed (e.g., the Dutch Travik initiative), banks and other service providers have little confidence in renewed collaboration with operators. One expert [IE6] says, "*there are many examples of failed attempts of MNOs to extend their business. MNOs believe in control to create value and this mind-set is a barrier when entering a new market."*

For embedded SE and HCE solutions, issues of trust, business conditions and past experiences were less relevant. In general, interviewees did point out a lack of experience with (pilot) implementations of the two alternative solutions. As such, embedded SE and HCE solutions appear advantageous as there have not been any disappointing experiences in collaboration yet.

6.2 Technology Level

Regarding the technological performance of the platform itself, interviewees argued that hardware components like the SIM are generally more secure than software solutions like HCE. Hardware is more difficult to alter or to infect with malware [BA2, BA3, IE4]. The process of issuing SIM cards reduces risk of fraud since consumers must identify themselves face-to-face. However, some bank representatives did question whether security is critical, especially for micropayments under ten euros.

Interviewees argued that embedded SE architectures are similarly secure as SIM-centric architectures. Although equally secure, the SIM-centric architecture is still considered superior to embedded solutions as it does not require Internet connectivity or battery. Interviewees also expect HCE to exhibit lower performance since the technology is still less mature than the two competing technologies.

Besides the technological performance of the platform technology, the costs of using the platform were reported to be an important factor, because margins in the payment industry are low [BA1, BA2 BA3, IE3]. Several respondents argued that SIM-centric solutions are too expensive or at least have been overpriced in the past. According to different respondents, MNOs have overestimated the value of the SIM, as they wanted their own mobile wallet and the collection of a fee for each payment transaction processed [BA1, BA3, BA4]. Other interviewees, especially those from telecom operators, argued that their pricing models have been reduced dramatically to remain competitive with alternative solutions. "*We started a new trend as we have lowered the price of the SIM. We don't want that our customers base their decision on costs and therefore we want to offer the SIM for the same price as the costs for a HCE solution. Next, to that banks will be allowed to issue their own mobile wallet. Banks should really look at what they find the best technology and we are confident that the SIM scores well on this"* [MNO1]. Another issue that drives higher costs is the required SIM swap to facilitate authentication services [MNO1, MNO2, IE6]. Most of the SIM cards issued in the past cannot meet the technical characteristics required to facilitate mobile payments. A SIM swap is an extensive and expensive process.

6.3 User Level

An advantage of SIM-based solutions is that they are already present in any handset. Interviewees did point out the difficulty of replacing the SIM with UICC cards. Interviewees explained that hardware is generally more difficult to update than software. Interviewees added that consumer acceptance of SIM-based SE might be higher since consumers will also be able to switch devices and brands without having to change their mobile payment subscription.

Interviewees argued that adoption barriers are lowest with the HCE architecture. They argued consumers can migrate more easily from handset or phone subscription, as they do not need to go through a difficult provisioning process. Therefore, perceived lock-in effects for consumers are lower, and flexibility is higher. HCE solutions can also offer the possibility to use different devices (e.g., tablets, smart watches, smart car) to facilitate a payment [IE2].

Relying on embedded SE implies that only few compatible handsets can be chosen by consumers. Fragmentation of the market due to the variety of handsets is an important factor hindering consumer adoption [MNO1, MNO2, BA2, BA3, IE1, IE4, IE3]. A representative of a bank mentioned that *"the embedded SE differs per supplier and per handset. The embedded SE can even differ per version, for instance not all Samsung Galaxy S6 have similar embedded elements. This means that adjustments to the payment application must be made per device. As the SIM is standardized, we see it as an easier solution for mobile payments"* [BA3].

The uncertainty over which SE architecture will win makes it difficult to estimate potential network effects. This factor hinders consumer adoption for any of the three alternatives. Interviewees observed that stakeholders are experimenting with all three options at the moment. One independent expert commented that there are simply not enough exemplary cases to base a decision upon. Respondents also clearly indicated that they expect new alternatives to emerge and cloud-based solutions to evolve. As such, most interviewees indicated they are not yet willing to make a choice between the technologies. Furthermore, the world of mobile payments is changing rapidly as new technologies are introduced to the market, which means that any implemented solution must be considered as short-term only [BA1, BA3].

6.4 Summary of the findings

Table 3 summarizes findings from the interviews, structured along the three levels of our theoretical framework. Overall, we find that provider level factors mainly relate to dependencies and trust in the platform provider. Technology level factors relate to technological performance as well as costs. User level factors relate to network effects and associated ease of issuing and distributing solutions.

<Table 3 here>

Table 3: Summary table from interviews

	Provider level	Technology level	User level
SIM-centric	- Strong dependencies on MNOs - International MNOs difficult to influence - Complex coordination dealing with multiple MNOs in same country - Lack of trust in MNOs - Past collaboration with MNOs failed - Too diverse business conditions from MNOs	+ Strong cryptography and security + Issuing process is more secure + Does not require battery or Internet connection - Replacing SIM with UICC is costly - SIM-centric solutions are expensive (or have expensive image)	+ SIM is present in any handset - Requires replacing SIM with UICC - Requires certified handset - Several hurdles for consumer adoption - Uncertainties on future technology landscape
Embedded SE	- Moderate dependencies on MNOs - Strong dependencies on handset manufacturers	+ Same level of security as SIM	- Limited choice of compatible handsets - Handset fragmentation - Uncertainties on future technology landscape
Host Card Emulation	+ No dependencies on MNOs - Strong dependencies on operating system vendors	+ Lower security less problematic for micropayments - Less secure than hardware solutions - Requires phone to be on - Requires Internet connection - Less mature technology	+ Low adoption barriers + Offers more flexibility to consumers + Multi-device use cases - Requires newer generation handsets - Uncertainties on future technology landscape

Notes: + Advantage; - Disadvantage

Table 3 shows that all three solutions have advantages and disadvantages, and none of them outperforms the other on all three levels. On the technology level, SIM and embedded SE are preferred over HCE. In terms of technological performance, we find that SIM cards and embedded SE solutions are considered more secure than HCE. Moreover, SIM cards have advantages of not requiring an Internet connection or even battery power. The main downside of the SIM platform is higher costs, although this was debated by several interviewees.

On the provider and user level, we find that HCE is largely preferred over SIM-centric architectures. Banks and payment service providers appear eager to avoid depending on MNOs as they are difficult to collaborate with, and as past experiences harmed trust in MNOs. On a user level, HCE appears to be preferred since the adoption and rollout barriers are lower than for SIM and embedded SE solutions.

7. Discussion

In this section, we analyze the findings from Section 6 on a conceptual level, relating them to concepts of multi-sided platforms.

We confirmed that stakeholders in the mobile payment ecosystem are considering alternative solutions for the SIM-centric architectures, as already predicted by March et al (2010). From the technology level of analysis, we found that SIM-centric architectures still appear to be superior to the embedded SE and HCE models in terms of security as well as performance traits. While our study shows that stakeholders expect HCE architectures to evolve and improve in the future, currently SIM-centric architectures are considered more secure, more reliable and less prone to identity fraud. As a bonus, SIM-centric architectures offer benefits of not requiring Internet connection or even a phone battery. As such, our analysis shows that technological superiority of the platform core technology is an important decision factor for mobile payment platforms. These findings are consistent with technology-oriented literature on NFC-enabled mobile payment platforms (Chen et al., 2011; Reveilhac & Pasquet, 2009).

However, our analysis shows that platform technological superiority is not enough to win the market. Other dimensions such as the dependencies and trust issues in platform providers as well as anticipated network effects among users are also important decision factors. Several interviewees in our study expressed their doubt on what to choose or recommend at this stage of development. These hesitations explain why banks and service providers are currently experimenting with all three technical alternatives.

The interview analysis showed that, on the provider level, avoiding dependencies and mistrust are important factors that explain why payment providers prefer not to work with SIM-centric architectures. HCE allows, in principle, full discretion of the hosting in-house by banks and service providers. They can also outsource hosting of the platform to IT providers that they can monitor directly. As such, the shifting preference towards HCE can be explained from the intention to avoid high multi-homing and switching costs. The desire to reduce dependencies and coordination costs is consistent with platform literature (Tiwana et al 2015). Our findings extend the ideas in mobile payment literature that collaboration problems hinder roll-out (e.g. Gannamaneni et al 2015; Ondrus & Pigneur 2009).

Besides the costs resulting from dependencies, interviewed banks insisted that they feel that operators do not understand their core values (i.e., brand identity) and business logic (i.e., low margins, focused on retaining customers in a defensive fashion). Combined with bad experiences in collaborative platform projects in the past, these observations explain why banks are reluctant to be dependent on MNOs and therefore increasingly opt for embedded SE and HCE solutions. In the case of mobile payment, the shifting preference towards embedded SE and HCE architectures can thus be explained by the lack of trust of banks and payment providers towards MNOs. Our finding is consistent with platform literature which stipulates trust in benevolence of platform providers as an important factor for adoption (Church & Gandal 2004; Gawer & Cusumano 2002). Overall, our results are aligned with past literature on problematic collaboration between banks and MNOs (De Reuver et al 2015; Gaur & Ondrus 2012).

Our interviews revealed that, on the user level of analysis, reaching a maximum number of users is a highly important factor. Interviewees pointed out that minimizing adoption and rollout hurdles while maximizing the handset brands and MNOs that can be reached are important factors for choosing a platform technology. All three solutions are somehow limited in the indirect network effects they can generate. SIM-centric solutions pose restrictions on the handset types that can be targeted, embedded SE solutions are limited to certain handset brands, and HCE solutions are limited to the newer operating systems. Moreover, rapid technology developments in the industry create major uncertainties over which of the three technologies will win. Thus, stakeholders have difficulties to predict the network effects that can be attained in the future. The uncertainty also concerns the choice of platform as there is no clear winning platform. This situation leads stakeholders to shy away from committing to a platform at this stage. Our finding is consistent with platform literature which suggests network externalities are important factors for the value of a platform technology (Katz & Shapiro 1985). In mobile payment literature, network externalities have also been identified as an important factor (Dahlberg et al. 2002; Kazan & Damsgaard 2013). However, the different levels of the technical architecture on which the three competing solutions are found, in combination with uncertainty about future technology developments, make it much more difficult to make trade-offs on expected network externalities.

8. Conclusions

The research objective addressed in this paper is the elicitation of the factors that influence stakeholders' preferences for the SE architecture. We explain why the SIM-centric SE model is losing against the embedded and cloud models. Beyond just being a technical issue, the SE choice can shape the entire mobile payment ecosystem. Based on an architectural choice, some actors could be empowered while others could lose their strategic position in the market. Studying the SE preferences of payment providers allows to better estimate how a mobile payment market could evolve in the future.

This paper also provides an explanation why MNOs are facing difficulty to maintain their position in the mobile payment ecosystem, even though their SIM-centric architectures are technologically superior. While none of the current solutions outperforms the others on all these factors, the SIM-centric architecture is not a clear winner. Our analysis shows that in multi-sided platform markets like mobile payment, besides technological superiority, anticipated network effects, dependencies and trust in platform providers play major roles. As such, our paper contributes to the research stream that applies multi-sided platform concepts in telecommunications literature (Karippacheril et al., 2013).

Despite the identified alignment of our results with prior research, this paper contributes uniquely to literature on mobile payments by empirically showing the factors that influence stakeholder preferences for a specific SE technology. In addition, the paper shows that those factors can be understood by looking at three different levels of analysis: providers, technology, and users. This contribution advances the theoretical understanding about SE choices for mobile payment platforms.

The analysis has practical implications for the strategic focus of MNOs. The story of mobile payment platforms mimics that of the mobile Internet ecosystem (de Reuver, 2011; Weber et al., 2011). Apple and Google already did shake the status quo in the mobile Internet ecosystem by using a different technological approach, and bypassed barriers that were used to defend MNOs' territories. There is a chance that history is about to repeat itself in the mobile payment market. The analysis calls the broader question why MNOs once more missed an opportunity to seize their technological advantage. We argue that the overly focus on control and protecting assets and charging monopolistic prices for using the SIM-centric architecture have been decisive factors. Mobile operators are still stuck in the old thinking of value chains and control rather than enabling an ecosystem of complementary providers to flourish (Peppard & Rylander, 2006).

The relevance of our analysis stretches broader than mobile payments. The SIM-card could become a platform component for new ecosystems, such as in areas of machine-to-machine communication, Internet-of-things (IoT) and connected cars. Unprecedented connectivity will imply high security risks and thus poses a clear need for secure authentication. At the same time, even the SIM-card itself is no longer the exclusive domain of MNOs. For example, Apple is already issuing its own SIM in selected iPads. Another threat is the SIM-less networks that are currently being deployed for IoT by companies such as Sigfox. As such, understanding the decision factors for service providers for adopting the SIM-card as a platform component will become important in novel areas as well.

If MNOs consider lessons from the past, they might be able to reclaim leadership through their SIM cards. Specifically, our findings suggest MNOs should look beyond technological superiority, and address network effects and trust in an early stage. Creating clear and favorable business conditions for every stakeholder in the ecosystem. Avoiding lock-in mechanism could help to foster trust among the different actors. Moreover, promoting the creation of common standards and providing low barriers for adoption helps to foster network effects.

A limitation of the present paper is that our findings are limited to those stakeholders interviewed. Therefore, specific use case scenarios (e.g., public transportation, electronic ID) and their unique implications for the SE were not particularly investigated. In this paper, we attempt to elicit a wide range of factors rather than attempt to generalize commonly shared opinions among stakeholders. Subsequent research may aim at ranking the elicited decision factors to each other. Generalizability of our findings is also constrained as our interviewees are all from the Netherlands, although previous research shows that similar patterns of distrust between banks and telecom operators can be found in other settings.

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