Simless Telecommunication Network: Transitioning from Subscriber Identity Module to Next-Generation Mobile Networks

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ABSTRACT

Technology advancement in the field of Telecoms has led to a rapid digitalization of the mobile ecosystem. Consequently, the mobile eco-structure is moving from a physical SIM to a digital SIM known as the eSIM. While this technical deviation could be the beginning of a new industry, it also poses complex challenges with greater opportunities. This thesis study centers around the goals of discerning the motivations for this technical disruption and the processes and outcomes of transitioning from physical SIM to eSIM. This includes historical review of the SIM cards and its applications in the mobile communication as well as a technical foundation of eSIM and their advantages which include cost effectiveness, flexibility and security. Through survey and statistical analysis, the quantitative data sets are gathered to describe the extent of adoption rates, constrains, trends and end users' preferences of eSIM technology. The qualitative data were gathered through the interview sessions with Telecom providers, a focus group with industry insiders and an ethnographic study of end users to understand how individuals are motivated.

Keywords: eSIM, Telecoms Technology, Mobile Eco-structure, Mobile Communication Technical Foundations, Cost Effectiveness, Statistical Analysis, Qualitative Data.

ÖZ

Telekomünikasyon teknolojisindeki hızlı ilerleme, mobil cihazların ağlara bağlanma biçiminde önemli bir değişime neden oldu. Mobil ekosistem, hem benzersiz zorluklar hem de yeni fırsatlar sunan fiziksel SIM'lerden dijital SIM'lere geçişin bir sonucu olarak gelişiyor. Bu tez, bu teknik değişimin ardındaki motivasyonların yanı sıra fiziksel SIM'den eSIM'e geçişte yer alan süreç ve sonuçlarını da içeriyor. SIM kartların tarihsel bağlamını ve mobil iletişimdeki uygulamalarını incelemek bu çalışmanın temel amacıdır. Ayrıca çalışma, eSIM'lerin teknik temellerini incelemek ve artan maliyet etkinliği, esneklik ve güvenlik gibi avantajlarını açıklamayı amaçlamaktadır. eSIM teknolojisinin benimsenme oranlarını, eğilimlerini ve tercihlerini belirlemek için gereken niceliksel veriler, anketler ve istatistiksel analizler aracılığıyla toplanmıştır. Telekomünikasyon sağlayıcıları, sektördeki kişiler ve son kullanıcılarla yapılan görüşmelerden ve vaka çalışmalarından elde edilen nitel veriler, geçişin ardındaki motivasyonları, kullanılan stratejileri ve sürece dahil olan bireylerin bakış açılarını netleştirmeye yardımcı olmuştur.

Anahtar Kelimeler: eSIM'ler, Telekom Teknolojisi, Mobil Ekosistem, Mobil İletişim Teknik Desteği, Maliyet Etkinliği, İstatistiksel Analiz, Niteliksel Veriler**.**

DEDICATION

"I dedicate this thesis to my father, whose love and encouragement have been my steadfast support system. My tenacity was motivated by his faith in my abilities and his sacrifices. To my mentors and advisors: thank you for shaping my intellectual development and inspiring a lifelong love of learning. My sincere gratitude goes out to my friends for their companionship and for sharing times of both difficulty and success. This work is dedicated to all of the people who have helped me grow both personally and academically. I hope that this thesis will serve as a monument to the inspiration and community that have helped me along this fulfilling path."

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LIST OF ABBREVIATIONS

AES	Advanced Encryption Standard
API	Application Program Interface
ESIM	Embedded Subscriber Identity Modules
GSMA	Global System Mobile Communication Association
IMARC	International Market Analysis Research and Consultants
IOT	Internet of Things
MNO	Mobile Network Operation
OS	Operating System
OTA	Over the Air
UICC	Universal Integrated Circuit Card

Chapter 1

INTRODUCTION

In the sector of telecommunications, there is an indication of rapid change as technology evolve in the industry. Internet Subscriber Identity Module (SIM) cards or Embedded SIMs (eSIM) are changing the telecommunication industry by replacing physical SIM cards to eSIM as our world gets more digitally connected. This change is more extensive and productive to the technology evolution. The objectives of this research introduction are to find out about essential criteria of the shift and provide consequences for the future of networking and the interconnection of our lives.

1.1 Background of the Study

The exchange of physical SIM cards to eSIM in the telecommunications environment is a major influence. Large-scale research on the evolution of technology, client experience, and the development of markets pushed its creation. There is a rapid growing demand for more supply and consumer connectivity alternatives that are clarified. Studies have also shown that eSIM are easier to use than standard SIM cards since they create less waste and need less plastics in the production. Additionally, there has been a test to ensure the reliability and security of this technology, as well as to address data security concerns. Historical studies show and prove the evolution of success, propelling the transformation of eSIM as the future of network communication.

1.2 Terms and the Scope of the Topic

The switch from physical SIM cards to eSIM telecom networks includes certain phases, such as user acceptance, governmental rules and technological advancements. Technically speaking, the scope involves generating and employing compatible hardware as well as positioning the required infrastructure for network provisioning and management. The regulatory features relate to norms that supervise the application of eSIM promises secure compatibility between certain networks and devices. The scope also involves user improvements and education as consumers learn and advance to the features and advantages of eSIM technology. All things considered, as time goes by, eSIM will have a major impact on the telecommunication companies and will proceed to how network connections and the device environment adapt in the future. The terms that we will use are listed below:

1. Physical SIM Card: Standard SIM cards that are put into mobile phones to link them to a mobile network.

2. Embedded SIM: An embedded virtual SIM that replaces physical SIM cards in a device's hardware and allows for remote installation and cellular service activation.

3. Remote Provisioning: Activating and managing cellular services remotely on an eSIM, typically through Over-The-Air (OTA) updates.

4. Network Compatibility: The potential of eSIM technology to establish a smooth connection to a range of global cellular networks, guaranteeing compatibility among diverse providers and geographical areas.

5. Data Protection: Procedures and security measures, like encryption and authentication methods, used to secure user data and privacy when using eSIM technology.

1.3 Outline

The current situation regarding the transition of a physical SIM card to eSIM is a study of a dynamic nature produced by manufacturing partnerships, technological success and legislative reforms. More and more Telecom companies are encouraging eSIM capacity in their manufactures to give consumers more simplicity and freedom. Main corporations in the manufacturing industry are actively promoting the assumption of eSIM, since few global cell manufacturers give eSIM ideas in addition to normal SIM alternatives. Moreover, difficulties such as ensuring that certain devices and networks work together continue to be reliable. Most manufacturers attempt to meet the importance of safety, user protection, and network connectivity by developing standards and regulations to govern eSIM implementation. Despite these challenges, eSIM is gaining acceptance among customers due to its benefits, which include the ability to effortlessly switch carriers, the elimination of physical exchange SIM cards, and reduced natural damage. Stakeholders in the production is coming together with new ideas as the change is moving forward, laying the groundwork for eSIM to take the lead as the standard for mobile connection in the future.

1.4 Importance of the Proposed Research

The main significance of the study that has been implemented on the transition of physical SIM cards to eSIM will have an important effect on how cell phone manufactures develop in the future. The use of eSIM will make a significant change with global implications as technology evolves. It is critical that all manufacturers, including device producers, mobile carriers, customers, and regulatory bodies, collaborate to understand how this change occurs. Manufactures must have a serious consciousness of both user desire and technological specifications in order to combine eSIM capabilities into devices. To properly enable the introduction of eSIM,

manufacturers need to elevate important frameworks and advance network structure in the eSIM nature. Regulatory agencies are important in mounting standards and regulations that promise user protection, portability, and safety. Additionally, for manufacturers to make well-informed choices regarding buying of devices and mobile plans, they must be aware of advantages and impact of eSIM technology. The research gives important information that can improve strategic decision-making, drive innovation, and ultimately influence the future of mobile connections by exploring the challenges of switching to eSIM.

1.5 Research Problems

The switch from a physical SIM card to eSIM elevate a number of research difficulties that need to be inquired into. Guaranteeing smooth capacity across certain devices and network connections is a key research problem. As eSIM assumption elevate, it is vital to address difficulties around device integration and interoperability to ensure a gentle switch for consumers and industry partners. Additionally, there are few concerns regarding the safety of eSIM technology, including problems of authentication protocols, data protection and weakness to online attacks. In order to protect user privacy and data within the eSIM environment, research is important to establish strong encryption standards and security measures. Most challenges also pose a significant problem because different rules govern the implementation of eSIM in different countries. To enable widespread use of eSIM technology, mobile operators, device makers, and regulatory authorities must navigate compliance requirements and understand the regulatory landscape. These research challenges must be addressed in order to remove roadblocks to eSIM advancements and fully realize the potential of this complete technology in the mobile telecoms business.

1.6 Aim of the Research

The main importance of this research is to thoroughly investigate the switch from physical SIM cards to eSIM technology and how it motivates many different sectors of Telecoms including its impact. This research is going to examine challenges associated with the improvement, consumption, and impact of eSIM with best practices and opportunities. This study is particularly undergoing the investigation of consumer and regulatory elements of shifting from physical SIM cards to eSIM, counting network compatibility, device integration, and regulatory frameworks. By overseeing these significant areas, the research shows and provides information into what motivates and hinders the usage of eSIM, as well as reducing problems and increasing benefits. Furthermore, the research aims to add more information by offering helpful consideration and actual data that can lead industry players and the government into good decision making. The objective of this study is to provide information about the successful transformation of SIM card, elevating Telecom networks into robust and more efficient to sustainable future.

1.7 Thesis Organization

There are seven chapters in the thesis. Chapter 1 provides a quick overview of eSIM, terminology, and issue scope, as well as the significance of the research and study aims. Chapter 2 examines the relevant literature that supports this thesis, including the background and development of eSIM, its technological aspects, and its advantages, A comparison between the physical SIM card and hardware integrated eSIM is covered in Chapter 3. The methodology for the thesis and the plan for conducting the survey are covered in Chapter 4. Chapter 5 include a survey conducted by Mobile Live World. Chapter 6 includes a description of the survey poll and its outcomes. Lastly, Chapter 7 presents thesis's discussions and conclusions.

Chapter 2

LITERATURE REVIEW

In this chapter, we will look at the quick progress of SIM cards from mini-SIM to eSIM. eSIM considers the most recent technological advancements while also improving to frequently satisfy the transformation needs of a connected digital world; this change is a watershed moment for the network sector. The purpose of this literature study is to investigate specific aspects of evolution, as well as the benefits, challenges, and future desires related with the transformation.

2.1 History and Evolution of SIM Cards

As its name suggest, a SIM card was used to connect and verify the subscriber. It was established in 1991 from network manufacture by Giesecek and Devrient in Germany using preceding European Telecommunications Standards Institute. Each circuit implanted in a plastic card has a unique number to identify the subscriber and stores user information, including messages. The chip also has access to various tower networks for mobile devices, allowing the user to text, make calls, and browse the internet [1]. Dr. Friedhelm Hillebrand from Germany led a team that built the SIM card, which rapidly spread into an essential part of digital cellular networks. SIM cards were similar to credit cards in shape and were called “full-size” back in the day. On the other hand, SIM cards had to get smaller and more compact along with mobile phones, as shown in Figure 2.1. As a result, SIM cards became smaller, and the mini-SIM, also called the “regular” SIM, was created. It had a size of about 25 mm by 15 mm [1].

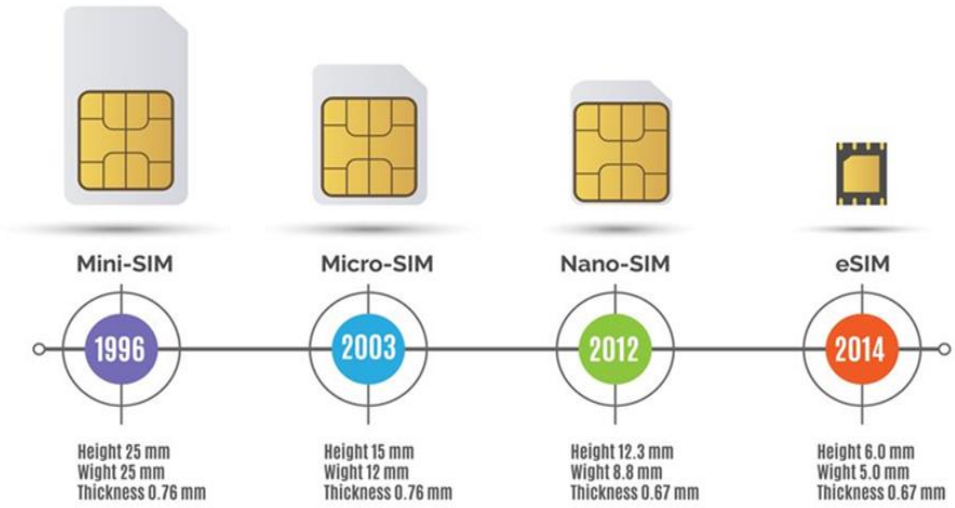

Figure 2.1: Evolution of SIM cards [13].

In 1996, the SIM card had a substantial drop in size. It often fits into a pocket behind the battery in cell phones, around the size of a thumb's upper part. But as technology developed further, the flexibility and user experience of conventional physical SIM cards became less favorable. This gave rise to the examination of solutions, which developed into the creation of this technology. eSIM are major in the new generation of Telecom network communications by giving faster ways to activate mobiles and switch networks. Understanding and gaining information about the history of SIM cards is important to what it means for cellphone communication in the future [2].

2.2 Introduction of eSIM

eSIM was first released in 2014, and it was referred to as a "digital SIM" because it could hold several operator profiles, which are collections of subscriber information and apps that allow for safe mobile network connectivity. It could also be remotely managed in compliance with the Remote SIM Provisioning Specifications of the Global System for Mobile Communications Association (GSMA). The manufacturer has made outstanding investments recently to build the international infrastructure of

eSIM user management platforms. This technology has the ability to connect different manufacturers and easily switch mobile operators without changing SIM cards on their phones.

The GSMA was not certain about the release of eSIM due to security problems. In 2014, approval for eSIM was granted, and a new era in the Telecoms industry was formed [2]. The GSMA is a multinational team that advocates the interests of mobile network services worldwide.

2.3 Technical Aspect of eSIM

The eSIM features include various challenges that are required for its deployment and function. Embedded hardware, which is often included in a device's chipset or a separate chip and used to securely store authentication keys, network configurations, and subscriber data, is a critical component of eSIM. Its feature is remote controllable, which eliminates the requirement for physical input or SIM card replacement by allowing wireless connection and operation of cell phone network profiles.

The eSIM meets all of the specifications defined by manufacturing groups such as the GSMA, ensuring a reliable connection with a variety of mobile network providers and devices. For secure communications, profile management, and remote access, the embedded chip enables device services to have a robust connection.

2.4 Benefits of eSIM

The benefits provided by eSIM are transforming the way subscribers communicate with Telecom networks. The advantages of eSIM are one of unmatched convenience. Subscribers can now save time and effort for SIM card arrangements, which cut of physical connections and permit remote access for mobile phones. The capability of

switching between different mobiles and store more than enough data is what makes it easy and reliable. This adaptability ensures constant connectivity throughout the ecosystem and is applicable to a wide range of devices, including wearables, tablets, smartphones, and Internet of Things (IoT) devices.

Additionally, eSIM providers assist by developing a smooth technology with more firm devices with larger displays or more functions by enabling the insides space. They have strong authentication and encryption features to safeguard user data and guarantee safe communication with mobile networks [3]. Furthermore, eSIM make international connection better by allowing subscribers to change between global and international network profiles. This cut of expensive roaming fees and the problem of having to buy SIM card when you are traveling abroad [4]. eSIM is a priceless piece of equipment for manufacturers because of its capability to support the introduction of 5G network connections.

2.5 Security of eSIM

Imagine that your phone is your house and that the eSIM is a unique lock on the door. Thieves cannot easily remove an eSIM like they can a regular SIM card. The entire phone would need to be taken. Hackers are skilled at fooling the system despite the eSIM being stuck in the phone. They could try to access your phone by acting as you. It would be like someone making a duplicate of your house key without your permission. So, in what way can you assist? The same precautions you take with your house should also be taken with your phone. Make sure you have a solid “alarm system” in place, which may consist of a password or your fingerprint. At this point, you might be asking yourself, “Has anyone ever broken into an eSIM?” It’s not common, but it can happen. Despite its security advantages, eSIM security can be

subverted through various means. Vulnerabilities in the eSIM's software and firmware may be exploited by attackers to gain unauthorized access. Remote attacks, such as man-in-the-middle attacks and OTA exploits, can allow attackers to intercept or manipulate communication between the eSIM and the network; physical attacks (side-channel attacks and tampering) can facilitate extracting the eSIM's sensitive data [17]. Insider attacks as well as contaminated infrastructure during manufacturing can introduce vulnerability with backdoors or malicious modifications. All this can be mitigated through regular updates. Because of this, phone makers are always creating more advanced alarm systems and locks [18].

eSIM security is generally strong and supported by a number of essential components. Encryption technology protects sensitive data, including subscriber identities, during data transmission between devices and networks. In order to prevent unwanted access, authentication procedures are essential and require mutually beneficial verification between the device and the network. One of the main features of eSIM technology is remote supplies, which is protected by strict authentication procedures that confirm the legitimacy of provisioning data and user identity. Secure storage and encryption are two examples of hardware security measures that strengthen against tampering and unwanted access. Accessibility and security are further improved by following to industry standards. Even though security is the top priority in the creation of eSIM technology, monitoring new threats is always important because eSIM stay in place, they are ideal in cases where your phone is stolen. It cannot easily be replaced by theft. It does not, however, imply that your issues have been resolved. Your eSIM contains the coding that stores your digital identity, so if someone figure out how to crack it, they could be able to see everything you are doing online. What is the good news? Even with multiple layers of defense in place, it is a difficult task.

2.6 Security Aspects between eSIM and Physical SIM Card

The security profiles of eSIM and physical SIM cards are remarkably different because of fundamental physical and operational differences. Physical SIM cards are removable, which has consequences in itself. They are easily lost, stolen or swapped, potentially allowing an attacker to take control of the user's mobile network and service. Once a physical SIM card is removed from a device, it can be placed in another in seconds, that SIM has full access to the network that it is registered with [19]. This makes physical SIM cards inherently tamper able and cloneable, it becomes relatively straightforward for an attacker to physically remove the SIM card from a device and extract the data from it before cloning it and injecting it into another device. This physical nature of SIM cards also entails physical measures to prevent tampering, and more importantly security measures when handling such cards, as anyone can extract the card and start probing for data.

On the other hand, eSIM can be locked to a specific device, so if the original device was lost or stolen, eSIM could not be used in any other device. This device-locking capability provides an additional level of security. Remote provisioning enables instant deactivation and reactivation of network profiles, which is handy if the device is stolen or lost; instantaneous response times could prevent any security threat from being leveraged [20]. Thus, the integrated and non-removable nature of eSIM, with enhanced remote management and encryption capabilities, is more secure than a physical SIM card. Figure 2.2 shows security aspect between eSIM and physical SIM [21].

Security Aspect	eSIM	Physical SIM
Physical Security	Embedded in device, cannot be removed	Removable, can be lost or stolen
Risk of Loss/Theft	Low	High
Tampering/Cloning	Harder to tamper or clone due to embedded nature	Easier to tamper or clone
Provisioning	Over-the-air, secured by encryption	Physical handling, risk of human error
Profile Management	Remote, can store multiple profiles securely	Single profile, requires physical change
Access Control	Locked to device, reducing unauthorized use	Can be used in any compatible device
Data Security	Strong encryption and authentication protocols	Vulnerable to physical extraction methods
Risk of Unauthorized Use	Low due to device locking and encryption	High if SIM is removed and used elsewhere

Figure 2.2: Security aspects [21].

2.7 Future Outlooks

As shown in Figure 2.3, in 2021 there were 1.2 billion of eSIM connections in the world, including smartphones, smartwatches, laptops, and tablets, and that 850 million are smartphone connections [25]. In 2025, it is expected to be 3.4 billion, and it is estimated that between 25% (low adoption) to 40% (high adoption) of smartphone connections in the world will be eSIM. In 2030, there is an expectation of 6.7 billion, which will account for 76% of the total number of smartphone connections [26].

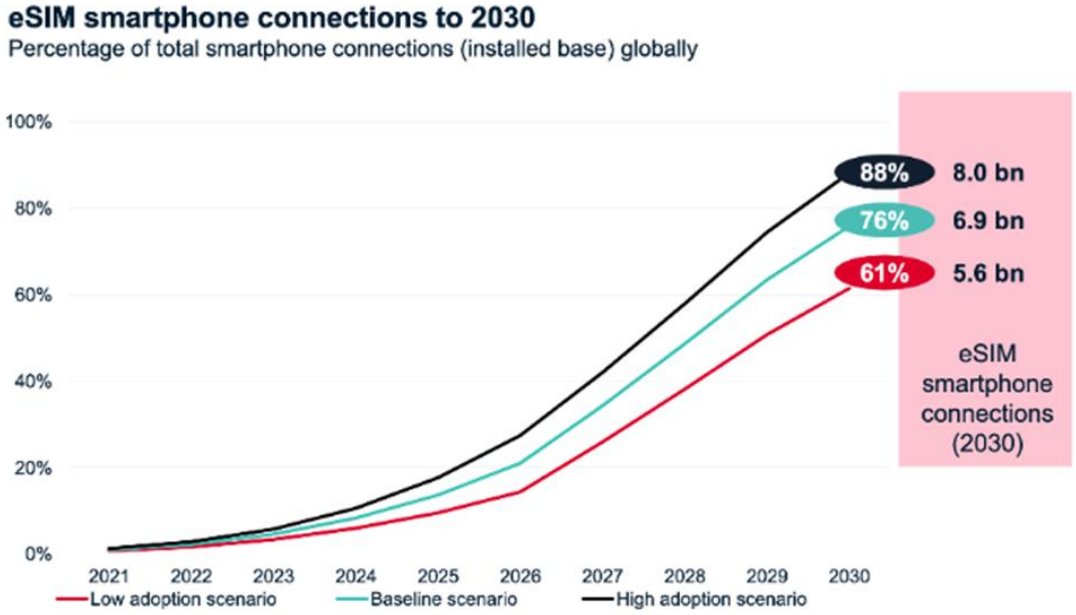

Figure 2.3: eSIM smart phones connections [26].

Another significant component is the travel eSIM market, which is expected to see substantial growth. Total spending in this market is expected to increase from $1.7 billion in 2024 to between $8.7 billion and $10 billion by 2028. This represents a potential growth of up to 410%, with travel eSIMs expected to account for a large share of the overall eSIM market by 2028.

Furthermore, to increase the eSIM subscribers internationally, it would need a collaboration between standard manufacturers and industry participants. The improvements of SIM will be motivated by efforts to modify connectivity and enhance user experience. The future of eSIM is bright as its capable to give robust security and flexibility.

Chapter 3

ESIM DESIGN

In this chapter, we will examine eSIM integrations, which requires sophisticated security measures to protect sensitive data and ensure user privacy. Regulatory compliance and certification processes are vital for meeting industry standards and ensuring interoperability. Furthermore, manufacturing and supply chain issues are crucial in growing eSIM production while ensuring quality and dependability across varied device ecosystems**.**

3.1 Integration of eSIM into Phone Motherboard

The embedded Universal Integrated Circuit Card (eUICC) is the hardware component of a SIM that may be provisioned remotely using the network operator's login credentials. Unlike a regular SIM, an eUICC has a distinct operating system that enables the remote download or maintenance of Mobile Network Operator (MNO) specific credentials, also known as eSIM profiles as shown in Figure 3.1 [6]. It entails numerous steps in the setup process by which an eSIM connects to the wireless network, all of which are necessary to ensure a secure and reliable mobile subscription provisioning procedure. Firstly, the user initiates the activation of an eSIM by asking for an eSIM profile from the MNO. Eventually, the eSIM on the user's smartphone gets activated by the MNO through necessary data provided to the user, such as QR code, activation code, or detailed instructions. Generally, the users can search for cell plans and apply for an eSIM by visiting the MNOs' website or mobile app, however,

they can also visit customer service in a physical store or customer service center to acquire an eSIM profile.

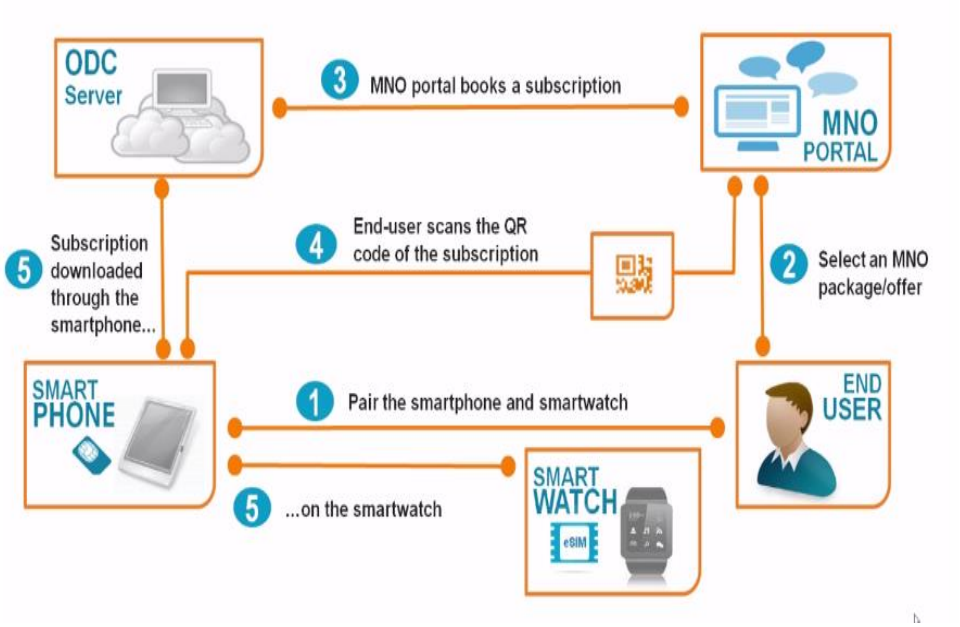

Figure 3.1: eSIM devices subscription activation [6].

Lastly, the device uses the activated eSIM profile to connect to the mobile network. Eliminating the need of having physical SIM cards and enabling handy over-the-air provisioning and maintenance of mobile subscriptions helps to make mobile network connectivity more straightforward. The eSIM module negotiates the terms of access to the cellular network and secures the connection for phone, data and SMS services via communication with neighboring cellular base stations. This new approach (called eUICC for remote SIM provisioning) paves the way for IoT deployments and use cases, connected wearable devices, increases device flexibility and facilitates international roaming.

3.2 Design Optimization for Space and Performance

Aside from understanding the size differences between eSIM and traditional SIM cards, you should be aware that there is no relationship between how fast your mobile

connectivity will be (for example, the rate at which you can download data or connect to the internet given a choice of eSIM or regular SIM), unless, of course, one of the networks that uses eSIM has a faster connection speed. Other factors, including your device's distance from the carrier cell tower, network traffic, network congestion, and others can all have a significant impact on internet speed. One of the primary benefits of eSIM technology is that, once extensively used, it simplifies cellular connectivity provisioning and management, resulting in faster network activation and smoother network switching. To ensure quick chip-to-chip connection setup and subsequent communication, eSIM use extremely efficient protocols and optimized data transfer. Because an eSIM device may switch between available networks and connect to the strongest signal on the fly, without the requirement for the user to swap SIM cards, the dynamic nature of connection improves overall network capability by reducing downtime and improving user experience. Secure communication could be performed faster with potentially better security capabilities embedded into eSIM hardware, allowing for powerful speed. This leads to optimized response times and faster data transfer rates.

Speed is influenced by several elements, the most important of which are the location of cell towers and the configuration of the network. Times may differ greatly between urban and rural areas, depending on the eSIM supplier. In general, cities have quicker speeds than distant places. 4G/LTE speeds are available on compatible networks around the world. Some eSIM packets in some places also support 5G speeds. However, speeds might fluctuate based on a variety of conditions. Older devices may be unable to achieve the maximum eSIM speeds that your devices support.

Extreme weather or snowfall could cause a temporary drop in the speed and strength of the signal [9]. More rapid connectivity, faster data transfer rates and better memory space efficiency offered by eSIM technology contribute to the performance of the network. eSIM share speeds with physical SIM cards. Because eSIM rely on the same mobile networks as physical SIM cards, environmental conditions mostly determine the speed of each technology. In comparable settings, eSIM are not guaranteed to provide faster connectivity speeds than regular SIM cards.

3.3 Integration with Device Ecosystem

eSIM are now widely available for use with tablets, PCs and other mobile devices. With your laptop and a local data plan, you can instantaneously transport to a cafe on the other side of the planet. eSIM integration for smartphones and tablets involves building software Application Programming Interface (API) that enable the device's operating system (such as iOS or Android) to interface with the embedded SIM hardware.

Microsoft's Surface Pro LTE was the first tablet to support eSIM cards [10]. Since the device's 2017 release, other laptop and tablet developers have also included the eSIM to facilitate internet connection. Digital freelancers and people who have to stay linked to their jobs will find this very helpful. In order to facilitate the activation and management of eSIM profiles for a broad variety of smartphone and tablet models, compatibility with common mobile operating system versions is required.

eSIM design, particularly for wearables, entails building firmware that allows for safe and low-power wireless connection with mobile networks. For the wearable use case, eSIM is extremely useful in enabling solo cellular connectivity for devices such as

fitness bands, smart watches, and so on without the requirement for a paired smartphone. In many circumstances, users may be able to manage eSIM profiles directly from their wearable (depending on the wearable operating system platform, such as watch operating system or wear operating system), providing greater portability and user experience.

3.4 Manufacturing and Supply Chain Consideration

The application and penetration of the eSIM are often determined more by considerations relating to manufacturing and the supply chain. In contrast, the commercial roll-out of eSIM technology for different mobile devices is likely to have a significant impact on worldwide business processes in Telecom and MNOs, starting from procurement right through to deployment. Due to the small size and the requirement to integrate the eSIM with devices, some specific processes need to be followed during the manufacturing process.

eSIM technology also makes it possible to simplify the supply chain by freeing up manufacturers to focus entirely on quality of service. For example, eSIM manufacturers must comply with the associated standards to ensure that the card is fit for purpose. These standards apply during card manufacturing and are tested for factors such as robustness against physical influence, resistance to environmental conditions, and they must fulfil development standards of the respective industry. This is a critical aspect in eSIM because faulty workmanship could impact the connection and performance of the device.

Furthermore, the nature of the eSIM supply chain necessitates close collaboration and obtaining materials through foreign suppliers. Nevertheless, Telecom may benefit from

setting a legally binding contract with each of their clients and introducing strict lock-in clauses with a relaxed pricing structure to prevent competition within their territory, as end users could now switch between operators more effortlessly.

Beyond manufacturing and supply chain issues, interoperability and standardization are also key considerations for the large-scale adoption of eSIM technology [10]. Strengthening the resilience of the supply chain can help mitigate the risks associated with disruptions in the supply of such integral components. Manufacturers, mobile operators and regulatory authorities can work together to ensure that the eSIM are compatible with different networks and devices.

As the number of devices currently using eSIM is low compared with traditional phones using SIM cards, manufacturers often form early strategic relationships with suppliers, especially since demand is expected to rise due to the accelerating growth of the IoT and connection-enabled devices. For components, such as semiconductor chips and security element components, on embedded systems to be manufactured and made available on an ongoing basis, they must come from a reliable source.

3.5 User Experience and Interaction with eSIM

Users noted that eSIM provided a better mobile connectivity experience. eSIM holds great promise for transforming the customer engagement process and user experience. Customers see mobile connectivity in a whole new light with eSIM. Everything began to work better. Because of its versatility and use, eSIM technology has had the greatest impact on customer perception and happiness.

Convenience and ease of use are two key advantages of integrated eSIM. When it comes to administering cellular service on devices, the eSIM approach becomes much

more convenient since it shifts to a digital-first strategy whilst eliminating the physical SIM card. For instance, customers no longer need to use physical SIM cards to activate the cellular service, for which they are grateful. Furthermore, it enables users to activate the connectivity on their device quickly and easily by just downloading an eSIM profile or scanning a QR code. As a consequence, the provisioning of services to the devices should be streamlined.

Moreover, user control and convenience are enhanced when network subscriptions and profiles are managed directly from device settings, since users do not have to physically remove and re-insert the SIM card to switch cell plans and providers. This allows maximum flexibility, especially for those hoping to benefit from mobile phone connectivity in response to changing consumer demands (e.g., those travelling between countries). Another is the ease with which eSIM technology can be integrated across a wide range of devices, such as tablets, wearables and other IoT devices. This increases interoperability, helping to create a more interconnected environment with novel use cases that depend on easy data sharing and interconnection enabled by the IoT, such as in automated inventory sharing, asset-tracking and remote monitoring.

As eSIM based devices make users' privacy settings and network connections more visible and easily controlled, they can, over time, build confidence and trust. Decentralized user experience has always been a key element within the eSIM value proposition, and it is easy to see why this is seen as a huge advantage across all sectors as end users expect connectivity to be secure and maintain their privacy. The ease of use, flexibility, security and device agnosticism the technology brings to consumers will, as eSIM developments progress and influence how consumers interact and

control the connectivity on their devices, lead to a more connected and effective transition into a digital future.

Feedback from users has been positive in terms of security (a persistent worry among users), adaptability and ease of use [11]. User experiences are expected to only keep evolving as eSIM usage grows, in conjunction with IoT and Telecom developments that will also spark the next wave of mobile connection and device interoperability design. This development further underscores a larger trend in IoT and Telecoms towards user-centered solutions that are bringing digital connectivity and personalization together.

3.6 Regulatory Compliance and Certification for eSIM

Compliance and certification remain key ecosystem drivers of eSIM implementation and uptake in the Telecom sector. eSIM enabled devices, eUICCs and subscription management servers all belong to the compliance framework that the GSMA had drawn up as a response to a binding requirement – to enable sellers and users to demonstrate the conformance of a product to its requirements in a uniform and easily ascertainable manner. Regulatory compliance ensures consumer compliance and interoperability as this technology is scaled over an increasing range of applications and devices.

Being in line with the requirements set out by the GSMA is another regulatory pathway for integrated eSIM. The standards for compliance and the types of declarations of conformity to be submitted by manufacturers that produce products in accordance with the eSIM specifications (PRD SGP.22 and SGP.21) are defined in the GSMA PRD SGP.24 [15]. As shown in Figure 3.2, the GSMA specifications determine the technical

criteria and rules for eSIM operation, interoperability and security. Once the eSIM device demonstrates the compliance with the technical specifications, a manufacturer is required to complete the declaration of conformity forms developed by the GSMA pursuant to SGP.24.

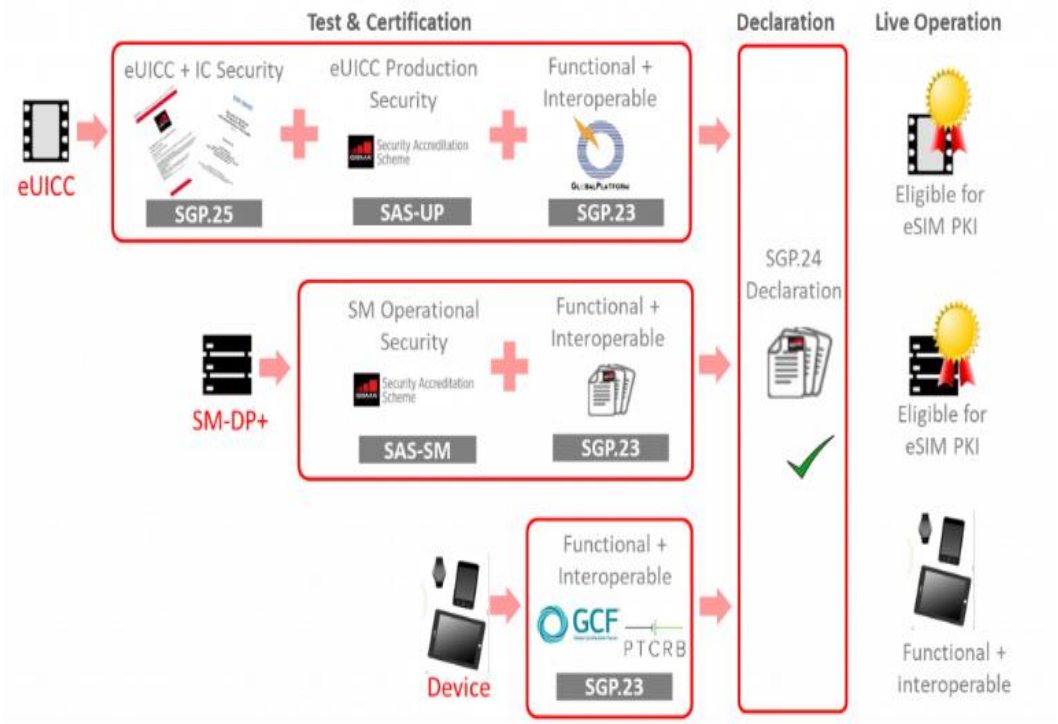

Figure 3.2: Security assurance compliance [12].

As shown in Figure 3.2, testing the remote provisioning and subscription management and security features are often part of the certification process. The compliance criteria objectives are to ensure that the solution is interoperable, functions as designed, and meets the level of the security assurance. The test cases and use have been designed to ensure that an eSIM is suitable for today's mobile network and hardware infrastructure and compliant with the specified quality criteria. A successful declaration of conformity with SGP.24 can be issued, bringing with it entitlement to use of a GSMA eSIM Digital Certificate (PKI) and also recognition of the achievement [12].

Overall, regulatory compliance and certification form an important shared infrastructure for the eSIM ecosystem. It plays a critical role in helping eSIM enabled manufacturers to build consumer trust, increase user security and achieve interoperability. The eSIM's value chains and wider ecosystem leverage the stakeholders' adherence to local laws and industry self-regulation. And as the eSIM grows up and becomes an integral part of the IoT and Telecom application landscape, its continued evolution will depend on ensuring rigorous compliance to support innovation and build trust in a secure, stable user experience.

Chapter 4

METHODOLOGY

In this chapter, we will look at data collection and analysis, as well as research methods and frameworks. The effectiveness and validity of a few components influence the outcome. This chapter's analysis assesses and interprets material presented in the form of statistics or qualitative data. Participants' rights and confidentiality are safeguarded, as is their ethical conduct. The sampling technique outlines how participants are recruited, which improves the research's validity. Research outcomes are influenced by investigations in all disciplines.

4.1 Data Collection Methods

In this research, we collected different data using the questionnaire made for some network services in mobile communication systems. This approach can provide essential information regarding how global giants such as mobile users, mobile manufacturers, and network carriers prefer and use eSIM technology. Some questions include: what are the possible usage cases, such as traveling, cell phone upgrades, or just an IoT device using eSIM? But if there are no eSIM subscriber usage cases, then the mobile service vendor will ask the subscribers to connect to their provided social app or mobile app to communicate with them so that the target consumers can be encouraged. A survey was conducted to provide patterns and trends for understanding the migration of physical SIM cards to eSIM. Once the survey instrument was conducted, a range of quantitative analysis methods were employed to determine the structure and explanation of what proportion and what types of attitudes and behaviors exist regarding the adoption of eSIM by various stakeholders. For example, questions

relating to descriptive statistics such as relative measures (frequency, percentage data, polarity and direction, common denominator, mode), or even regression analysis.

4.2 Sampling Strategy

The process begins by identifying the target social, in most cases, this can be individuals and companies to enforce the involvement of business units in the implementation of the eSIM technology to ensure that all parties are given an equal opportunity to be part of the survey, they'll use sampling to randomly select parties from the population. This can include regulators, Telecom companies, device vendors, mobile subscriber, and industry gurus.

It is mandatory to have a good sample plan, for example, probability sample, so that survey will be more balanced, and the researcher could multiplate the survey results with known confidence level, even if the biased sample population is less, these techniques might give good information from the sample with sufficient varying response from the target audiences. The calculated number of samples serves the primary purpose of being fairly large.

4.3 Data Analysis

Rules and regulations were used to stabilize relationship patterns and aid in the interpretation of the empirical observations; descriptive statistics were used to reduce and identify numerical data; and the researcher summarized the statistics in a dense overview complete with numbers of people interviewed, of hours spent chatting, mean, median, mode and standard deviation.

With respect to the survey responses and data collected from the target audience about eSIM, global market, preferences, trends, as well as scientific publications regarding

these topics in academia, regression modelling, correlation analysis and hypothesis test are applied to quantitatively examine relationships between the variables and test the research hypotheses about eSIM adoption. We present the results in the survey through data visualization methods like graphs and charts to give a clearer picture of the findings, for instance, the charts presented in Chapter 6.

4.4 Ethical Considerations

Firstly, an ethical obligation to ensure informed consent will be enforced in this thesis research on the transition from physical SIM cards to eSIM technology. The purpose, procedures, potential risks, and benefits of the project will be described to participants in a thorough Participant Information Sheet given in Appendix A. All participants will be asked to voluntarily sign a Voluntary Participation Form given in Appendix B indicating awareness and understanding of the study and their voluntary agreement and participation without force. Taking reasonable steps to assure informed consent upholds participants' autonomy by granting them an opportunity to make an informed decision without yielding to force.

Confidentiality and anonymity will be assured. Questionnaires and responses will be stored on cloud-based storage with high access control on the server. Later, all responses will be extracted and stored in a secure database. Identifying information will be deleted to remove identifiable information about individual participants. Researcher will be the only one to have access to the database through a single log-on, ensuring full protection of the participants' personal data. Participants will be informed that their identity and responses will be kept confidential and will not be disclosed to ensure participants' honest responses while also respecting their personal privacy.

Participants will be informed that the research follows the guidelines of the Eastern Mediterranean University Scientific Research and Publication Ethics Board (SRPEB). Ethical approval of SRPEB was obtained before conducting the data collection as shown in Appendix C. Ethical research should be principle-centered, ensuring that no participant is subjected to any physical or psychological discomfort during data collection. Overall, it is important that the researcher respects the rights of the participants and shows respect for their identity.

4.5 Validity and Reliability

In order to ensure the validity of the questionnaire that we used for our survey at Eastern Mediterranean University (EMU), we first compared it with a survey previously conducted by the Mobile World Live – to ensure content validity, the questions of both surveys were reviewed to verify that we covered all major aspects of the subject. We have asked questions related to the familiarity with the eSIMs and their perception of the security level with the transition from physical to eSIMs, their willingness to switch from physical to eSIM and their perception of the learning curve. On the other hand, Mobile World Live asked about the percentage of customer using eSIM and what impact eSIM technology have on customer retention, showing collision to both surveys.

The large overlap between the results of the EMU survey and those of the Mobile World Live survey provided a parameter of high criterion-related validity because it means that both sets of questions addressed the same constructs in a good way. We also found that factor analysis showed the presence of construct validity because questions clustered together to form factors that corresponded to theoretical constructs. Finally, there was test-retest reliability because the same questions were given to

respondents at two different times, and the results converged in a high statistical correlation, suggesting stability over time.

4.6 Rationale for Criteria and Method

The reason to use this questionnaire is that it provides in-depth and structured information about the experiences and perceptions of users when SIM cards are replaced by eSIM. Questionnaires enable to systematically capture data with regards to what are the benefits and perceived security improvements with the new technology and what are the challenges when switching to this new technology. This way, a wide range of experiences, perceptions and opinions is captured, allowing the analysis about how various factors influence adoption of eSIM technology and the satisfaction levels with eSIM usage. By allocating values to the opinions via metrics and asking qualitative questions, this study provides key insights to validate the industry trends, investigate user barriers against this technology and also provide hints for future eSIM improvements.

It is equally critical to establish the criteria for developing questionnaires in order to ensure that the data collected allows the findings to be significant, pertinent and actionable. The random selection of participants involved a simple approach with clear inclusion criteria. Any participant who was a part of the population of EMU and a current user of a mobile phone was eligible to fill out the survey on transitioning from physical SIM to eSIM technology at EMU. The random inclusion of the participants in the survey was ensured by drawing a random sample from the EMU population. It is important to use randomization to ensure that the survey participants are not biased and represent diverse samplings from different parts of the university's population. Therefore, the random selection of participants removed limitations, such as age,

academic discipline, or any other specific group, and allowed for inclusion of a wider sample.

Chapter 5

MOBILE WORLD LIVE SURVEY

In late December 2023, Mobile World Live polled more than 150,000 mobile industry players, mostly C-level executives from operators, device manufacturers, systems integrators and other service providers, to gauge where their industry is headed [28].

5.1 Analyzing the Adoption Rates of eSIM Among Customers

eSIM is a relatively recent telecom invention that is still far from joining the consumer mainstream. One of the poll questions confirms this. It asked respondents what percentage of their customers presently use eSIM. Approximately half of all carriers have an eSIM user base of less than 10% [28].

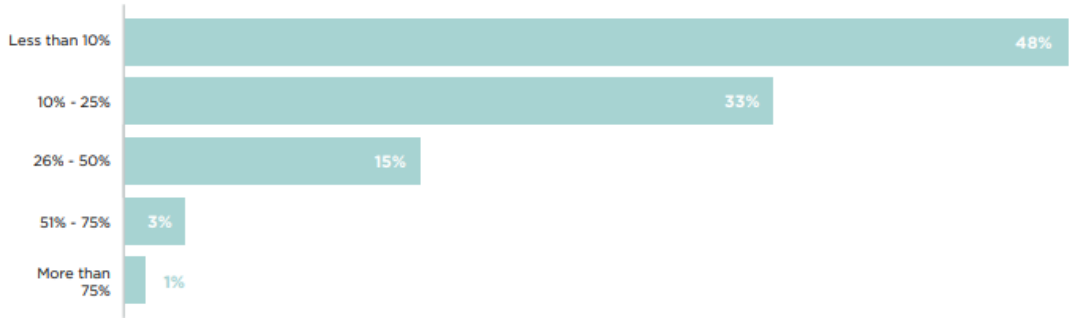

Figure 5.1: What percentage of your customer base is currently using eSIM?

5.2 What Challenge your Organization Faces in Adopting eSIM Technology?

It seems that consumer resistance rather than any technical complexity is the major hurdle to more eSIM uptake. 49% of respondents identified 'lack of consumer awareness or understanding' as 'the greatest barrier to your organization in adopting eSIM technology'. In comparison, just 23% identified integration and 13% regulation [28].

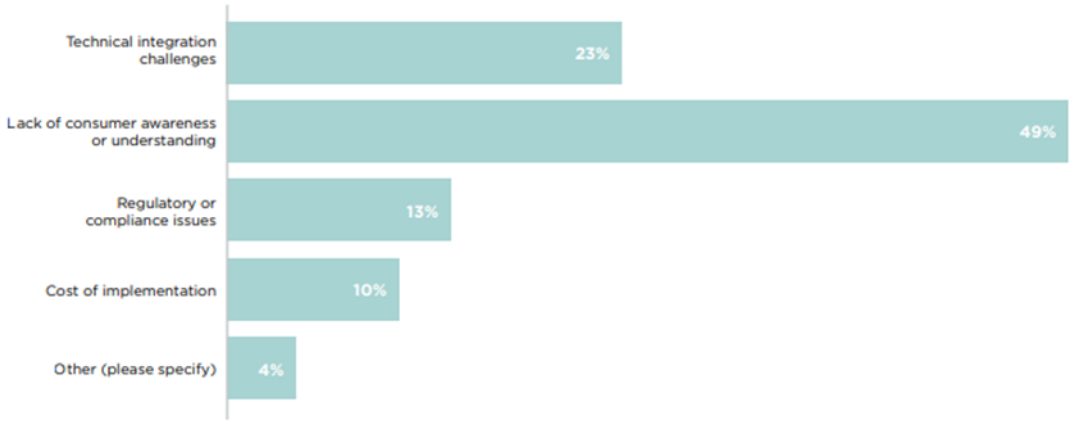

Figure 5.2: What challenge your organization faces in adopting eSIM technology?

5.3 What Impact eSIM will Have on Roaming Revenue?

The respondents were more cautious when it came to roaming. When asked "To what extent do you think that eSIM impact roaming revenues?" 52% answered positively, 28% answered neutral, and 20% answered negatively [28].

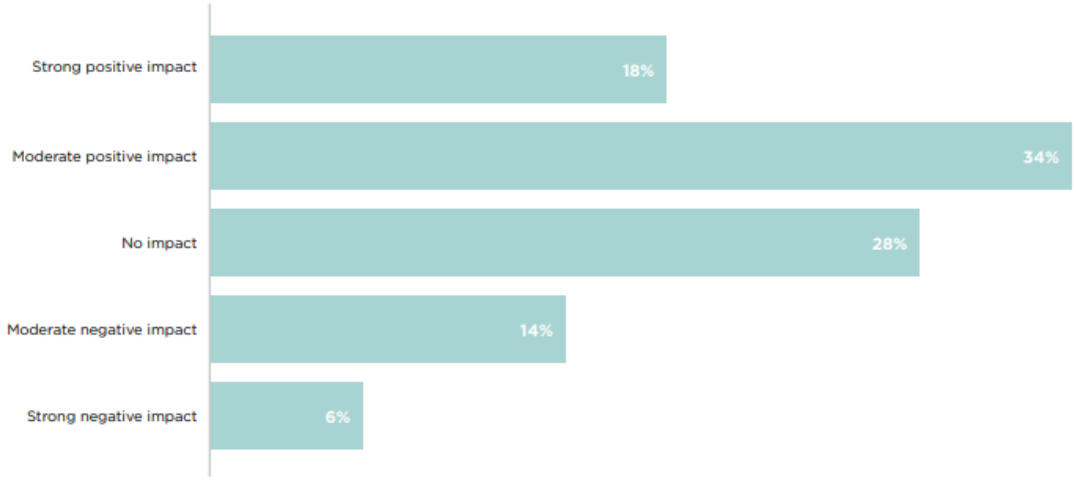

Figure 5.3: What Impact eSIM will Have on Roaming Revenue?

5.4 What Impact eSIM Technology will Have on Customer Retention?

When it was introduced, there was a lot of negative talk about eSIM. It was speculated that eSIM would enable subscribers to switch between carriers more easily – and that power would move from MNOs to device manufacturers. Our survey shows, however, that opinions about eSIM are largely positive. When asked to "what extent does eSIM technology strengthen customer retention", 60% responded that it would be moderate or very strong [28].

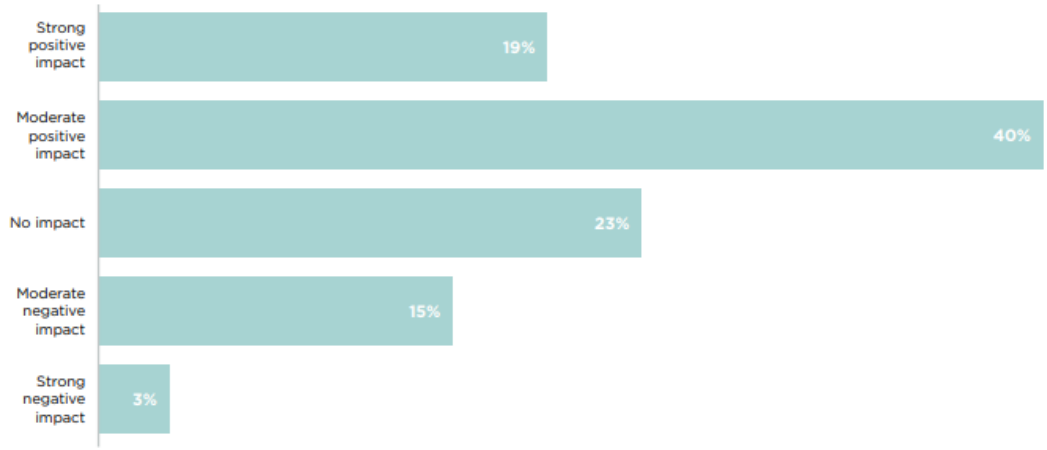

Figure 5.4: What Impact eSIM Technology will Have on Customer Retention?

5.5 When eSIM will Overtake Physical SIM Cards in Mobile Devices?

If we assume that eSIM is indeed the future, then how long these replacement cycles are going to take. Once again, the answers from the survey reflect a cautious viewpoint. When asked "how long it will take eSIM to replace physical SIM cards in mobile phones", 70% said three years and more, and 50% more than five years [28].

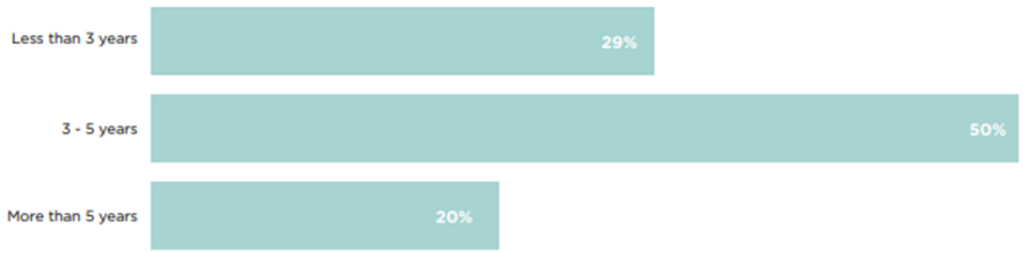

Figure 5.5: When eSIM will Overtake Physical SIM Cards in Mobile Devices?

Chapter 6

RESEARCH SURVEY

An investigation of 136 persons was undertaken to determine their experiences with Internet-based eSIM and mobile services. This study assesses a variety of elements in relation to eSIM. This includes how many people are familiar with the use of eSIM, how secure it is throughout the changeover, and what you think about eSIM, such as their simplicity of use and learning curve. It also contains other variables such as the benefits of eSIM and examples of fraud with prior SIM cards. It outlines some critical difficulties and consumer perspectives on mobile telecommunications, the questionary is included in the Appendix E.

6.1 Familiarity of using eSIM for Mobile Services

Figure 6.1 shows that the data on respondents' acquaintance with eSIM for use in mobile services reveals some fascinating new information regarding their level of understanding. Close to half of the respondents (51.56%) indicated they were extremely familiar with eSIM. This indicates a very large proportion of the sample polled. On the other hand, 14.06% of respondents indicated they were completely unfamiliar with eSIM, and 12.50% had never even heard of them. Anyone who has used an eSIM in their mobile device knows how easy they are to manage and that they offer data at very competitive rates. Therefore, this high rate of awareness is telling us that eSIM have slowly but surely become a very popular choice for mobile customers.

Additionally, the poll reveals that 10.94% of participants just have a passing familiarity with eSIM, while another 10.94% have some familiarity. Although maybe not as much as those who claim to be quite familiar, this combined percentage indicates a wider familiarity with the idea. A more precise assessment of the market's awareness levels would enable targeted marketing to close knowledge gaps and raise awareness of the advantages of eSIM among more people.

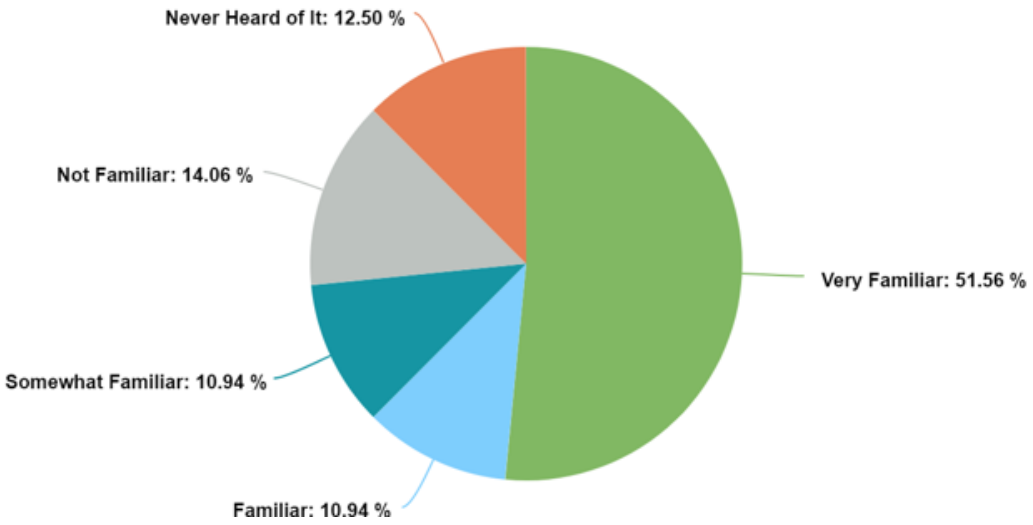

Figure 6.1: Familiarity of using eSIM for Mobile Services.

6.2 Importance of Improved Security when Transitioning to eSIM.

According to the poll results, the majority of respondents believe that switching to an eSIM improves security. Several internet-related security cases, though not all, undoubtedly demonstrate the significance of increased security, even while migrating internet access to SIM cards. Despite the general perception of internet security, just a tiny proportion of individuals asked (7.81%) said they did not believe switching to an eSIM would considerably increase personal security. As previously stated, greater security is of fundamental significance to the majority of respondents (64.06%). The

previous statement illustrates that many people accept the possible risks of using SIM cards for internet access, reinforcing their desire to protect.

Figure 6.2 shows that the second response had the lower scores, with only 28.13% of participants claiming that it is somewhat significant for them, switching to eSIM would increase the security. It is possible to see how many people discussed how significant having strong security measures in the use of an eSIM for people to have more confidence in it. This statement shows that there is a wide awareness about security troubles, being that some participants considered it as less important, and some believe that participants should be confidant about the use of this type of SIM card. In in this way, it seems that while the question of security is not very important to everyone, it shows a great concern when a new technology for mobile devices is applied.

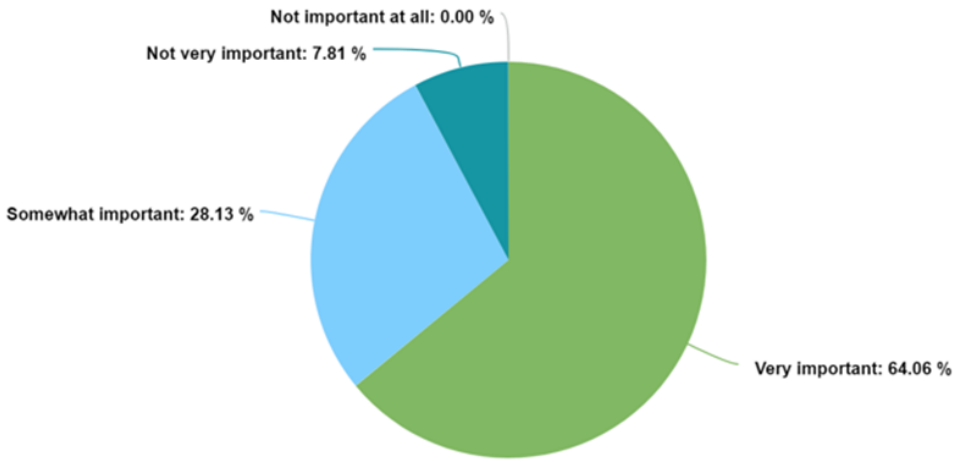

Figure 6.2: Importance of Improved Security when Transitioning to eSIM

6.3 Likelihood of Switching from a Physical SIM Card to an eSIM

Figure 6.3 shows that the findings of the study on whether individuals choose to switch from a physical SIM card to an eSIM indicate that consumers are quite open to switching and combining. 45.31% of respondents have a strong desire to change, whereas 7.81% are unwilling to make a total shift. This clearly indicates that the majority of mobile phone users appear to be more amenable to utilizing eSIM, maybe due to benefits such as convenience, high efficiency, and a low cost of data use.

Furthermore, the data explains the fact that approximately one in every five people (21.88%) is not sure about this switch. Nevertheless, there is a cheerful trend that more people are ready to discern this shift. The group's reluctance may be due to different occasions, such as agreement on services with the current network service, concerns about coverage arrangements, or whether this type of eSIM (similar to an internet device) is appropriate. This minority viewpoint emphasizes the significance of overcoming any adoption barriers, including as perceived danger, a lack of recognized benefits, or a preference for traditional SIM technology. Overcoming this narrow-minded gap will enable mobile service providers to clarify any remaining questions and offer them with the knowledge they need to make informed decisions.

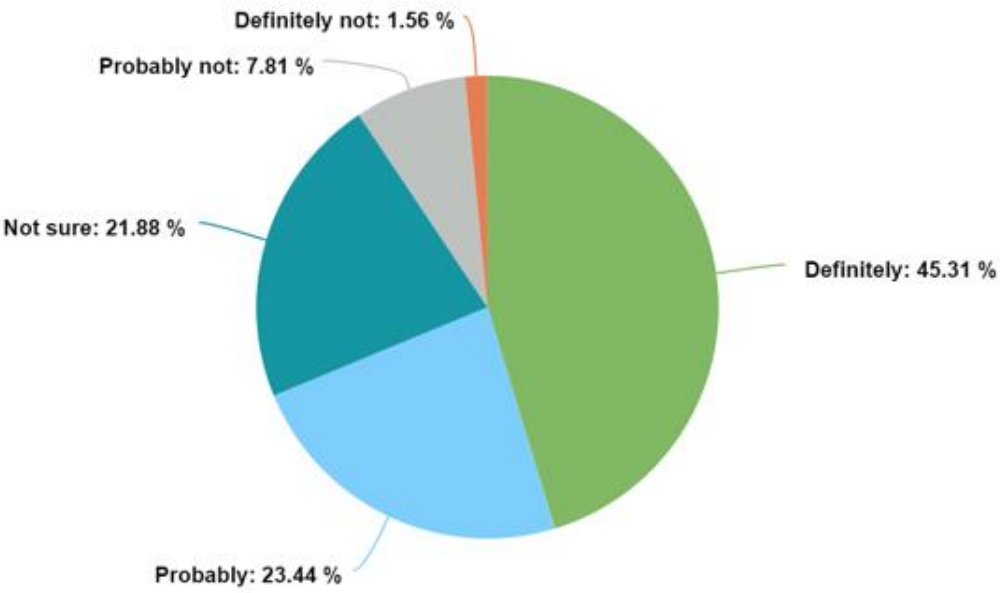

Figure 6.3: Likelihood of Switching from a Physical SIM Card to an eSIM

6.4. Learning Curve and Adjustment Required when using an eSIM

The Figure 6.4 depicts the overall learning curve and level of adjustment required to cope with the new technology linked with the browser service supplied by eSIM. According to the data, the majority (35.94% based on the responses 'Not at all' and 'Slightly') of respondents do not believe that using the service provided by this technology requires significant learning or adjustment. The absence of genuine concerns about complexity or challenge on the part of mobile users suggests that the latter may already become more open to novel solutions that allow for increased versatility or flexibility in performing operations without significantly complicating the level of difficulty in usage or adjustment. According to the findings of this survey, the public perceives eSIM to be universally available and relatively simple to use, without taking a significant amount of effort to understand their workings and then learn how to run them efficiently. We should expect this good perception to increase the acceptance and general use of eSIM as part of conventional mobile services.

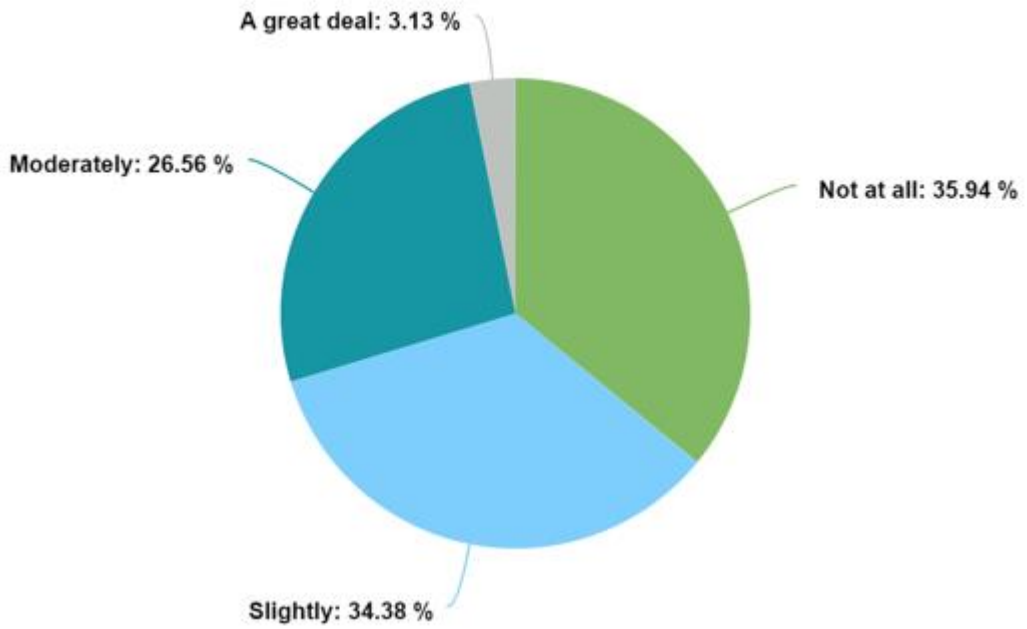

Figure 6.4: Learning Curve and Adjustment Required when using an eSIM

6.5 Advantages Perceived by Respondents when using an eSIM

Figure 6.5 shows that the resulting poll gives us some valuable insights into the many benefits cited by whom-ever used an eSIM. The foremost of the gathered outcomes is that having no need for extra hardware to use an eSIM was among most common benefits named by participants in the poll, scoring 15.64%, as respondents described having eSIM as making it much speedier to get the services up and running (8.38%), while at the same time it helps reduce the waste of physical cards that have no purpose other than being obsolete (19.55%). eSIM are a simpler way of getting mobile services, without having to use additional hardware, thus they are very handy and practical for people who need only simple mobile connection from time to time.

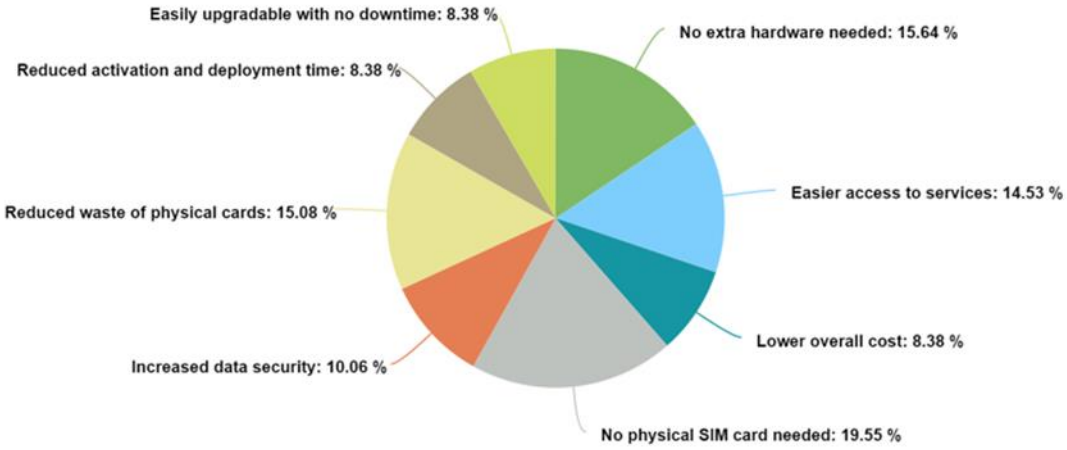

Figure 6.5: Advantages Perceived by Respondents when using an eSIM

6.6 Convenience of using eSIM over Physical SIM Card

Based on the survey results in figure 6.6 it shows that the opinion that eSIM are more convenient to use than physical SIM cards is supported by an overwhelming majority (28.13% of participants who replied ‘Definitely’ and ‘Probably’). At the same time, netizens are skeptical about eSIM as a modern alternative to physical ones, with nearly 12.50%, saying ‘Maybe’ absolutely doubting ‘Are they faster and easier to use?’. The reaction, as evidenced by the survey, is to such a degree that only a tiny proportion of respondents is doubtful about the effectiveness of eSIM in comparison with physical ones, testifying a desire to move towards digital and flexible solutions in the convenience of using mobile communications for modern life that are adjusted to comfort and efficiency while reducing physical handling and being managed through virtual SIM cards.

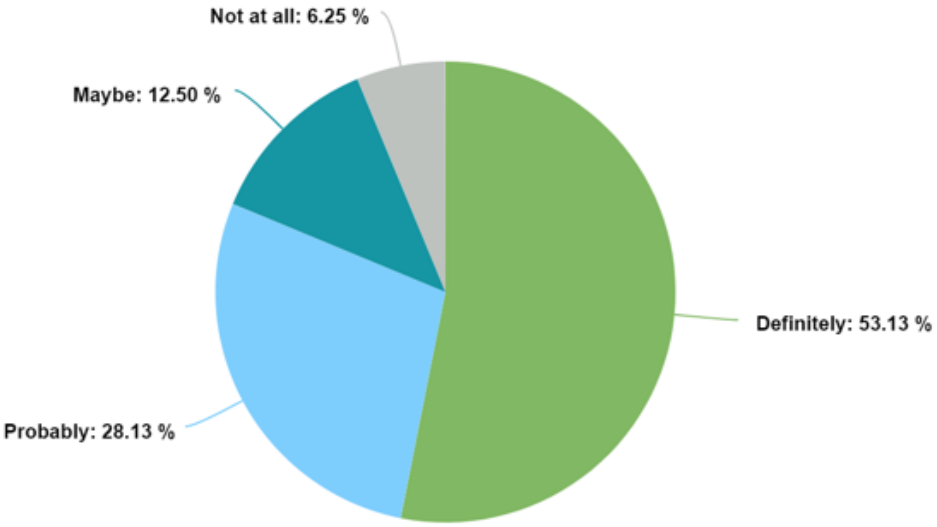

Figure 6.6: Convenience of using eSIM over Physical SIM Card

6.7 SIM Card Fraudulent Effects on Users

From the output, we also see that a considerable number of respondents (42.19%) had ever encountered SIM card fraud. On the other hand, Figure 6.7 shows that there are people who have never had this experience as 57.81%. Although it is a good trend, it also proves that further awareness of cyber security is needed to educate consumers about mobile security and personal data. The SIM card fraud case can take many different forms, such as illegal access to personal information, online shopping money transfer fraud, or identity theft. All these events are undoubtedly very disruptive and bad for a person's daily life. Strong security measures and carefulness are required to confront the crisis as well as understand how to protect the mobile device and personal information from evil or danger on the internet. When the Telecom players can cooperate to take actions to provide a more safe and secure mobile communication service based on a strong security principle equipped with technology solutions, the risks of SIM card fraud can be minimized.

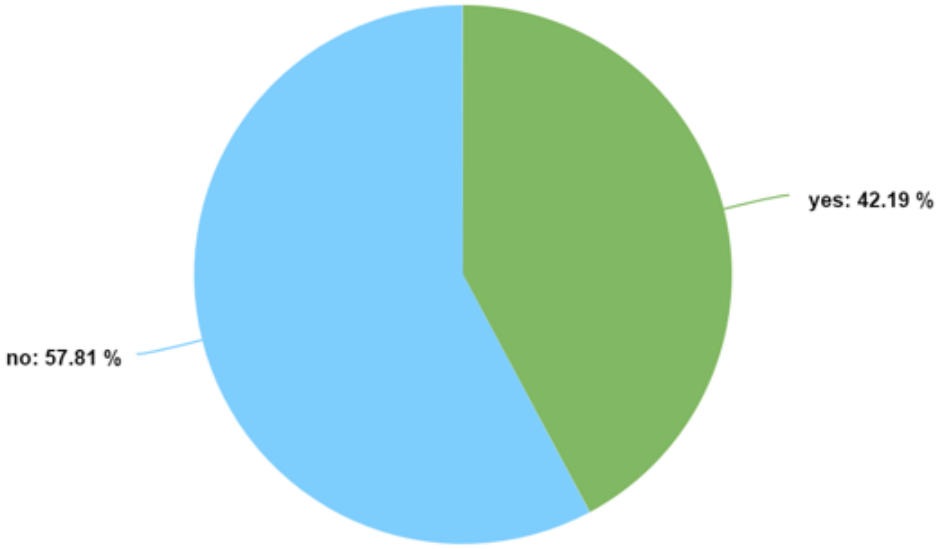

Figure 6.7 SIM Card Fraudulent Effects on Users

6.8 Comparison of Mobile live Survey and EMU Research Survey.

The survey conducted by Mobile Word Live in Chapter 5 and the survey conducted in Chapter 6 shows that eSIM productions is steadily increasing year by year. When it comes to EMU survey, 50% of the responses indicate familiarity with using eSIM technology. Surprisingly, the Mobile Live survey indicates that in less than three years eSIM will surpass physical SIM card use by 29%. One of the most interesting aspects of the Mobile Live survey is that eSIM increases user retention by 19%. On the other hand, the survey conducted in EMU indicates that more than 50% of people who researched eSIM is not ready to switch to it yet.

Both surveys represent two distinct ways of looking at the transition to eSIM technology – one focused on adoption and industry trends, one on users' experience. The survey published by Mobile World Live provides a more macro-level view of the adoption of eSIM technology and associated effects in terms of impacts on customer retention and roaming revenue, along with timing for the replacement of physical SIM

cards with eSIM. For example, it explains that most carriers are still at very low levels of adoption, with many reporting that less than 10 % of their customer base has adopted eSIM and industry views on how eSIM technology might impact customer retention and roaming revenues are described as positive, with a small number of carriers seeing positive effects on retention but many thinking that eSIM will contribute positively to roaming revenue.

On the other hand, the EMU survey delivers micro-level user insights and perceptions about eSIMs with regard to four key topics, including familiarity with eSIM, improvements in security issues, desire to switch from physical to eSIM cards, and perceived learning curve. For instance, the survey reports that improved security is one of the most important reasons respondents would switch from physical to eSIM and many users are already familiar with the new technology. It reports the perceived benefits and SIMs (eg, 'no need for extra hardware' and 'need to learn how to use eSIM'), and it also clarifies the kind of concerns faced by users while switching to eSIM.

The two surveys are related, because they focus on the eSIM transition, but they approach the subject from quite different directions – industry-level trends and impacts, on the one hand, and the individual user experiences and attitudes on the other. In combination, the industry-level data provided in the Mobile World Live survey can complement the user-level insights in the EMU survey, and vice versa, for a more holistic picture of the eSIM transition. The combined data could and should be considered by the mobile industry, governments and consumers, and allow a much fuller picture of the eSIM adoption's impacts – not only its macroeconomic implications but also the micro-level user perceptions associated with the technology.

Chapter 7

DISCUSSION AND CONCLUSION

7.1 Discussion

The transition from a physical SIM card to its digital incarnation via the eSIM technology is a significant change which allows a number of opportunities and introduces certain consequences both for users and service providers. In this study, revolutionary technological change in terms of impact on end users, service companies and regulatory bodies have been discussed. A key benefit from the point of end users is the ease of use and tremendous flexibility. A user is not constrained to a particular Telecom operator or service company. The switch between carriers and manage several profiles without having to change the current SIM card is possible. This feature is particularly valuable to frequent travelers and business customers who need to switch between their personal and professional numbers on a regular basis. It allows them to use the same physical SIM card offered by their primary operator and keep the profile via roaming from their country of origin. Furthermore, eSIM make connecting IoT devices easier as they have limited space for SIM cards. The two advantages mentioned earlier can feed into innovation and the number of use cases for connected devices capable of delivering IoT market growth.

While it comes with a range of benefits, there are also challenges we should consider when it comes to the adoption of eSIM technology. Needless to say, consumers have thousands of devices which are not compatible with eSIM – the older generation must

consume more electricity compared to the new generation. In addition, there is a need to invest in newer devices, which are eSIM-compatible. In other words, the older generation of products may not work properly and can hinder transitioning to eSIM technology, since many users cannot afford to replace all their machines. Since the cost of a new device is not particularly cheap, it can be a serious stumbling block for price-sensitive consumers in various other regions. The use of eSIM technology necessitates compliance with numerous regulatory frameworks, which is rarely emphasized but equally important. Compliance with regional regulatory organizations, particularly those overseeing cybersecurity, is critical, as is respect for various industry standards, which are required to enable the worldwide reach of technology. Mobile connectivity in different regions is regulated by a number of different bodies, some of which have diverging regulations and standards. Compromises have to be made with service providers who must work within these regulatory frameworks and avoid operating outside the law.

7.2 Conclusion

Moving to eSIM technology makes many elements of ownership and use more flexible, beneficial for IoT devices, and user-friendly; yet, this move introduces several problems that must be overcome before the technology becomes generally embraced and usable. First, new devices must be created and acquired as part of the broader move to an environment that supports eSIM. The first hurdle to overcome is compatibility between existing devices and the new technology. Both service providers and manufacturers should encourage each other and their clients to make the transition to eSIM technology as soon as possible. Government regulation and standards need to support this technology implementation and be in place before new devices and compatibility protocols are made and used. This means that industry and government

bodies should work closely together so new regulations and international standards are made then implemented based on unified policies.

Education is the prime step to overcome the barrier of adoption, and the educational resources for users should provide detailed guidance on the fundamentals of eSIM, for instance, how it improves the user experience and its operation. Providers should give users as much information as possible and include resources such as step-by-step guides, tutorials and customer service, to ease the transition process. Considering the challenges, the promises offered by eSIM technology are substantial. It has numerous benefits, including simplifying the mobile connection procedure, increasing user experience, and facilitating the development of the IoT ecosystem. As the technology matures and gets wider adoption, it is likely to be adopted by the majority and replace the physical SIM cards once for all.

Researchers should continue to work towards addressing the testable challenges outlined here, particularly for device compatibility and regulatory compliance, and for educating users about eSIM. By doing that, and overcoming the other foreseeable obstacles that might arise along the way, eSIM technology will finally realize its full potential – and pave the way for a more connected and flexible telecommunications all over the world. Overall, the move to eSIM is a progressive step for the telecommunications industry, and is consistent with the increasing need for flexible, convenient and ubiquitous connectivity in an increasingly online world.

7.3 Future Work

After reviewing the current levels of security, ease of use and information dissemination involved in the shift towards eSIM technology, particularly in relation

to physical SIM cards, there are several paths for future research. One crucial area is an in-depth study on the longer-term security implications. Though initial analysis could identify possible current vulnerabilities and user dilemmas, ongoing research is necessary to understand the evolution of security threats as the maturation of eSIM technology continues. This involves studying the efficacy of current security protocols, how new threat mitigation processes can be developed, and the role of regulations in protecting the user's data. Comparative studies between different regions and service sectors could also determine if and how best practices can be used to increase security or identify gaps that must be addressed.

Another area for future research relates to user experience and information dissemination. A user experience study should improve the eSIM activation and management processes, so that they are more intuitive and easier to use, especially by users with less technical knowledge. This would require interviewing and testing users to find what pain points they have and what they prefer, so that new interfaces and support systems could be developed. Second, to better inform consumers of how to use and get the most out of the eSIM technology, research should test various communication strategies around the world to see how well they educate the public about what an eSIM is and the benefits and functionalities it can offer. This could involve studying the impact of informational campaigns on different audiences, whether they should be involved in partnerships with device manufacturers and service providers, and how platforms could disseminate useful information to diverse user groups.

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APPENDICES

Appendix A: Participant Information Sheet

Title of the Study: Transitioning from Physical SIM to eSIM

Purpose of the Study:

This research aims to identify user experiences and perception while transitioning from physical SIM cards to eSIM technology in modern mobile phones. The questions in this survey will carry insights on pros and cons of using an eSIM and the satisfaction level of users while using the eSIM instead of a physical SIM card. Through this, it will help to improve the eSIM technology and implementation in the future.

Introduction:

You will be provided with an overview of the study and its objectives.

You will be asked to give your informed consent to participate in the survey.

Survey:

Your responses to the survey will revolve around your exposure to both physical SIM cards and eSIM. The questions will pertain to the ease of use, setup process, perceived benefits, challenges, reasons behind purchasing, and overall satisfaction.

Potential Risks:

There is a minimal risk of breach of confidentiality. All data collected will be anonymized and stored securely. Your answers will be used for research purposes.

Voluntary Participation:

Your contribution to this investigation is voluntary, and you are free to terminate your participation at any point during the survey without penalty. If you decide to withdraw,

all of the data that you provided until that point will be deleted, and it will not be included in the study.

Confidentiality:

All information gathered during the study will be treated in the strictest confidence and will be used only for the conduct of this research. Data will be stored in password-protected files and confidentiality will be maintained by the researcher. Your data, when anonymized, would be eligible for publication in peer-reviewed journals or presentation at conferences, but no identifying information would be shared.

Appendix B: Adult Debrief and Voluntary Participation Form

Research Study Title: Transitioning from Physical SIM Cards to eSIM Technology

Principal Investigator: Mello Collins

Contact Information: +90 533 850 72 76

Date:21/05/24

Introduction:

Thank you for participating in our research study about changing from physical SIM cards to eSIM technology. This form helps explain what the study was about, confirms your voluntary participation, and ensures you understand your rights as a participant.

Purpose of the Study:

The study looks at the benefits and challenges of switching from physical SIM cards to eSIM. Your answers will help us learn more about how this change affects mobile phone users.

What You Did in the Study:

You answered some questions in a survey or interview about how you use your SIM card, what you know about eSIM, and what you think about using eSIM instead of physical SIM cards.

Voluntary Participation:

Being part of this study was your choice. You can stop being part of the study at any time, and it’s okay to change your mind. If you decide to stop, it won’t affect you in any way.

Confidentiality:

We will keep everything you told us private. Your name and personal details won’t be shared with anyone, and your answers will be used only for this study.

Risks and Benefits:

There are no risks to you from being in this study. You won't get any direct benefits, but what you shared will help us understand more about using eSIM.

Contact Information:

If you have any questions or worries about the study, you can contact [Mello Collins] at [+90 533 850 7276]. If you have questions about your rights as a participant, you can contact the ethics committee at Eastern Mediterranean University.

Statement of Assent:

By signing below, you agree that you have been told about the study, understand what you were asked to do, and agree to participate.

Participant’s Signature:

_____

Participant’s Name:

_____

Date:

_____

Researcher’s Signature:

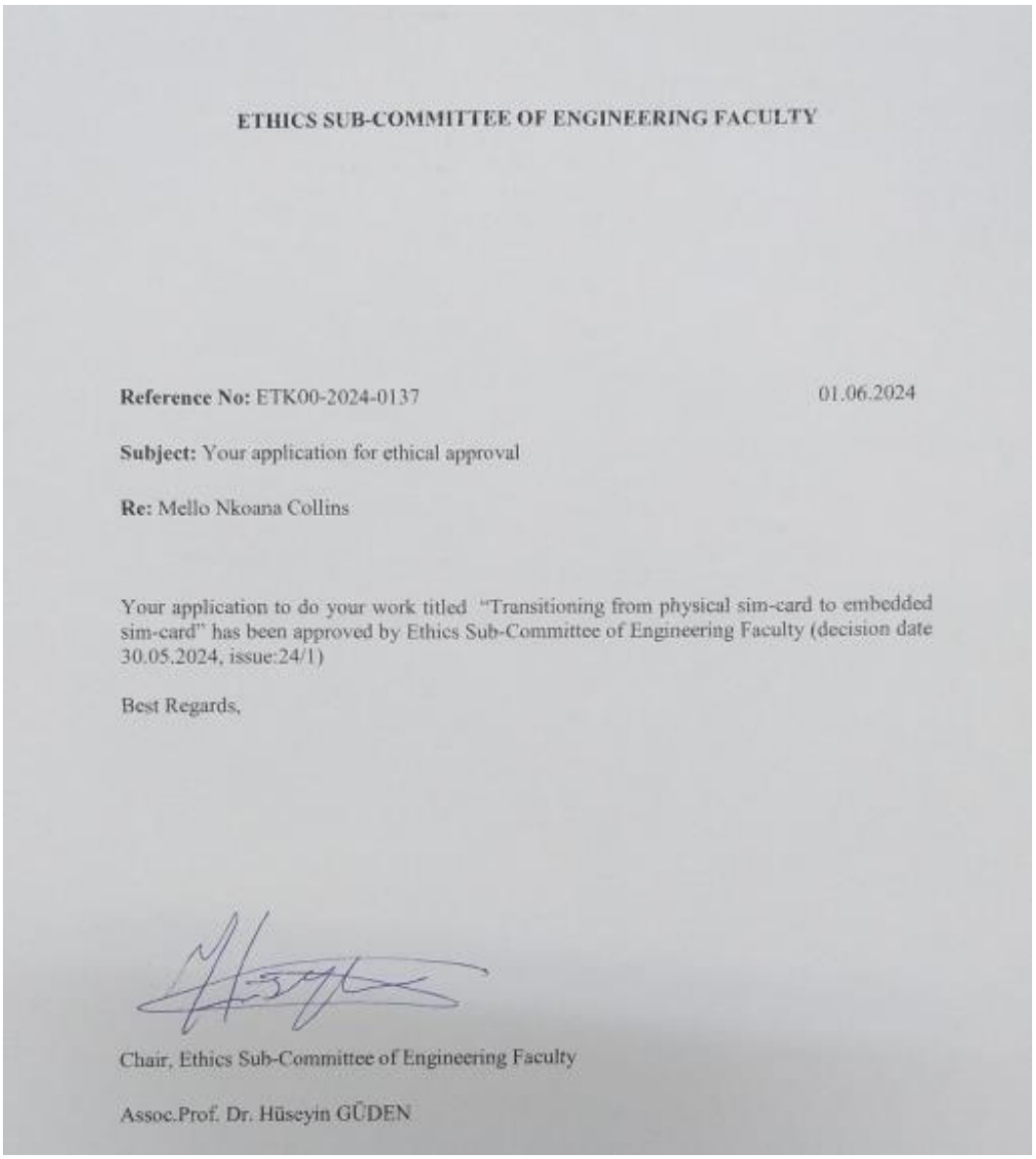
_____

Researcher's Name:

_____Mello Collins_____

Date:

Appendix C: EMU Scientific Research and Publication Ethics Board Approval



ETHICS SUB-COMMITTEE OF ENGINEERING FACULTY

Reference No: ETK00-2024-0137 01.06.2024

Subject: Your application for ethical approval

Re: Mello Nkoana Collins

Your application to do your work titled "Transitioning from physical sim-card to embedded sim-card" has been approved by Ethics Sub-Committee of Engineering Faculty (decision date 30.05.2024, issue:24/1)

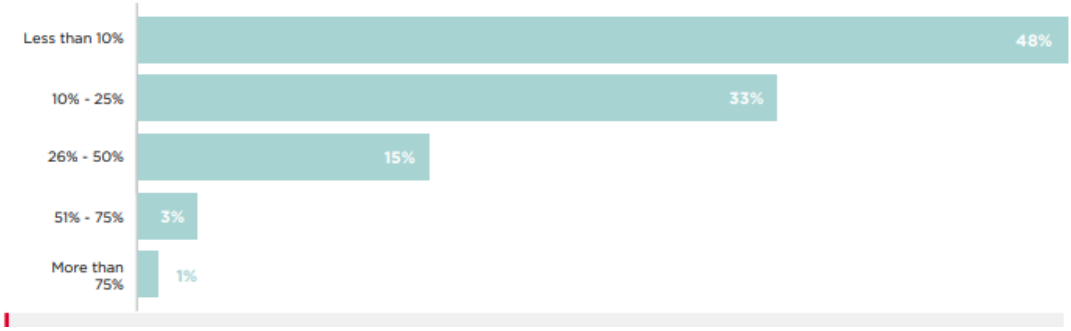
Best Regards,

Chair, Ethics Sub-Committee of Engineering Faculty

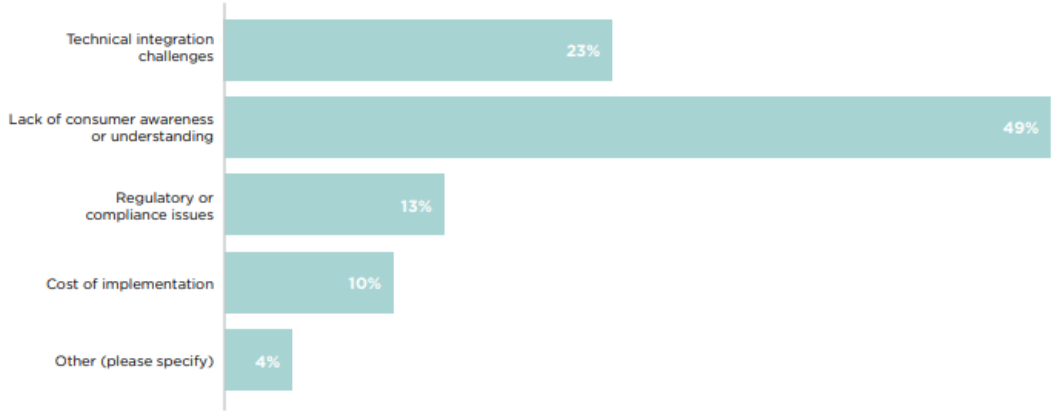
Assoc.Prof. Dr. Hüseyin GÜDEN

Appendix D: Mobile World Live Survey

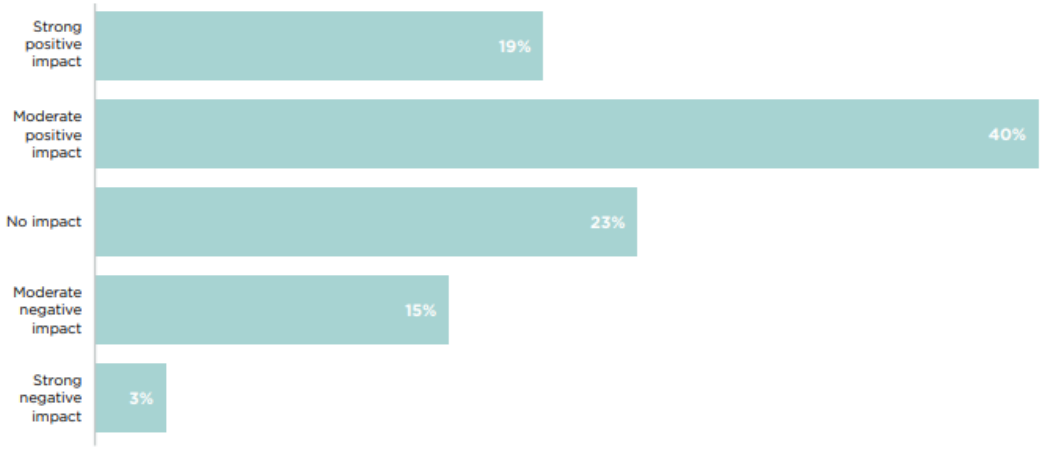
What percentage of your customer base is currently using eSIM?



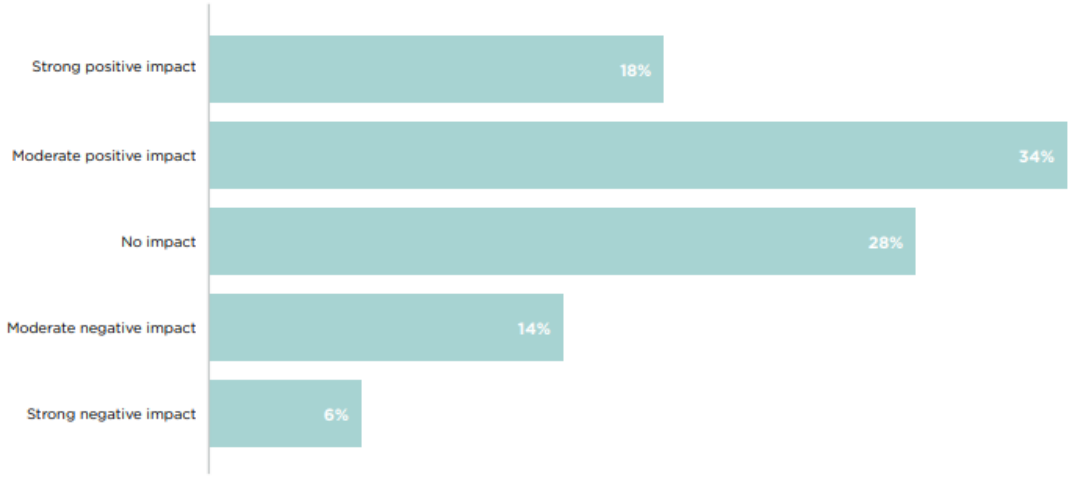
What is the biggest challenge your organisation faces in adopting eSIM technology?



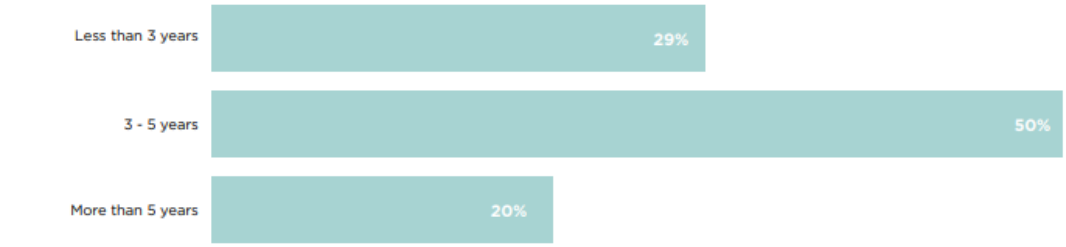
What impact will eSIM technology have on customer retention?



What impact will eSIMs have on roaming revenues?



When will eSIMs overtake physical SIMs in mobile devices?



Appendix E: EMU Survey

SINGLE SELECTION

Q1. How familiar are you with using internet simcards for mobile services?

#	Answers	Answers (%)
A1	Very Familiar	51.56%
A2	Familiar	10.94%
A3	Somewhat Familiar	10.94%
A4	Not Familiar	14.06%
A5	Never Heard of It	12.50%

SINGLE SELECTION

Q2. How important do you think improved security is when transitioning to an internet simcard?

#	Answers	Answers (%)
A1	Very important	64.06%
A2	Somewhat important	28.13%
A3	Not very important	7.81%
A4	Not important at all	0.00%

SINGLE SELECTION

Q3. How likely would you be to switch from a physical Simcard to Internet Simcard?

#	Answers	Answers (%)
A1	Definitely	45.31%
A2	Probably	23.44%
A3	Not sure	21.88%
A4	Probably not	7.81%
A5	Definitely not	1.56%

SINGLE SELECTION

Q4. Does using an Internet Simcard take up too much learning and adjustment?

#	Answers	Answers (%)
A1	Not at all	35.94%
A2	Slightly	34.38%
A3	Moderately	26.56%
A4	A great deal	3.13%

MULTIPLE SELECTION

Q5. What would you say are the main advantages of using an Internet Simcard?

ⓘ *Percent (Respondents) is calculated by dividing each answer count by the total unique respondents.*
Percent (Answers) is calculated by dividing each answer count by the total counts collected.

#	Answers	Respondents (%)	Answers (%)
A1	No extra hardware needed	43.75%	15.64%
A2	Easier access to services	40.63%	14.53%
A3	Lower overall cost	23.44%	8.38%
A4	No physical SIM card needed	54.69%	19.55%
A5	Increased data security	28.13%	10.06%
A6	Reduced waste of physical cards	42.19%	15.08%
A7	Reduced activation and deployment time	23.44%	8.38%
A8	Easily upgradable with no downtime	23.44%	8.38%

SINGLE SELECTION

Q6. Do you feel Internet Simcards are more convenient to use than physical ones?

#	Answers	Answers (%)
A1	Definitely	53.13%
A2	Probably	28.13%
A3	Maybe	12.50%
A4	Not at all	6.25%

SINGLE SELECTION

Q7. have you ever been affected by simcards fraudulent?

#	Answers	Answers (%)
A1	yes	42.19%
A2	no	57.81%