Embedded-SIM (E-SIM) an Overview in Latin America: Implementation, Availability, Advantages and Disadvantages

Hyggor da Silva Medeiros, Leandro de Souza Bezerra, Fernando Trinidad España, Jefferson Tiago Santos de Oliveira

***Abstract* — Search new forms for data management and security is a continuous tendency for mobile operators. Proof of this is the trend of the latest technology related to the Embedded Subscriber Identity Module or Embedded- SIM (E-SIM). Recently there was an increase in the number of devices that offers this technology as security element for the access to the network, however it is clear the lack of consistent information for the implementation of this technology within Latin America. This research presents a current overview about evolution of the embedded subscriber identity module, aiming to present the general characteristics that are part of the network, evaluate the current status of implementation and adoption with Latin America carriers, showing the obstacles in the process of acceptance of new technology by users as well as the advantages, disadvantages of E-SIM in relation to the traditional SIM Card. The investigation was carried out through documentary survey and field research, the data was collected to demonstrate the current perspective of the implementation of E-SIM and adoption by customers and network operators in Latin America. The observed results showed that the adoption of E-SIM in Latin America has been increasing, was observed most of countries have at least one carrier that makes available and offer this service. Regarding the advantages and disadvantages, evidence has been observed place E-SIM like a better technology than SIM Card.**

***Index Terms* — Embedded-SIM, E-SIM, Virtual SIM, SIM Card**

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I. INTRODUCTION

THE constant advancement of mobile technologies lead, to new forms of data management and security every single day by operators. Proof of this is the latest technology related to Embedded subscriber identity module, Embedded-SIM or simply E-SIM. In this investigation, we seek to present E-SIM and its current condition within Latin America presenting its advantages and disadvantages regarding the traditional subscriber identity module (SIM Card) and a prospect of adherence to this new technology.

The SIM (Subscriber Identity Module) Card technology, it summarizes a removable physical card used on mobile phones to store subscriber information, and as security element for mobile networks that is responsible to authenticate the user and connect it to the network, which contains information that identifies the internationally mobile subscriber (IMSI). The traditional SIM it´s a card based on integrated circuits (IC) that store information inside. The SIM Card is widely used worldwide and is a consolidated technology that has been used for over two decades. One of the main advantages of SIM Card is the easy way to substitute for the mobile operators [1].

Embedded-SIM is a newer technology that eliminates the need for a physical SIM Card. E-SIM is incorporated into the mobile device and subscriber information is stored electronically. This technology has gained popularity in recent years, especially in 5G smartphones, smartwatches and other devices connected to the Internet of Things (IoT) [2]. Figure 01 represents the different types of SIM in smartphones.

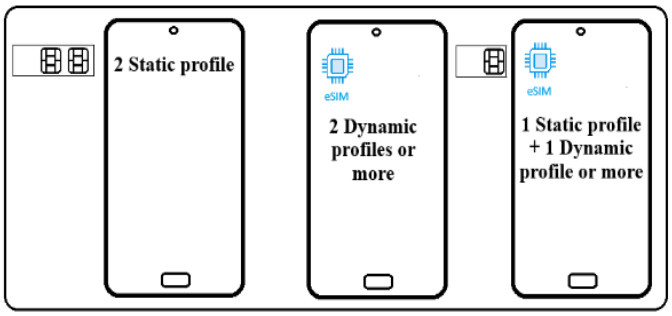

Fig. 1. Types of Subscriber Identity Module (SIM)

E-SIM offers many advantages over the traditional SIM Card. One of the main advantages is convenience. With E-SIM, the user does not need to be concern about changing the physical SIM Card or losing the SIM Card. In addition, E-SIM allows the user to have several profiles in a single device called dynamic profiles, which is especially useful for travelers who need different data plans in different countries. E-SIM has been demonstrated be a more efficient technology than SIM Card, with great potential to meet mobile and IoT market demands [3]. The increase of adoption for E-SIM should grow significantly in the coming years, especially in the health sector, due to its ability to store medical and health information on connected devices [4].

A. Purpose

This research describes the current scenario and evolution of the E-SIM, its objective is to present the general characteristics that integrate the Embedded Subscriber Identity Module the network and to evaluate the current status of implementation and integration with Latin America operators showing the obstacles in the new technology adoption process by customers as well as advantages, disadvantages of E-SIM in relation to the traditional subscriber identity module SIM Card.

Therefore, this research expresses the evolution of the module of E-SIM, as well as the current overview in Latin America, analyzing its advantages and disadvantages in the most current context, observing the prospect of growth of this new technology for coming years.

B. Method

This paper has been created using as a basis a field survey and a documentary analysis regarding embedded-SIM technology, seeking to demonstrate the current perspective of carriers' adoption in Latin America.

The present investigation was directed through the following stages:

• First stage: Research and document analysis through journals that addressed the theme focus of analysis around, Implementation and application of E-SIM in mobile networks.

• Second stage: Field research with historical data survey and interview with operator's technical managers of Latin America, in order to collect the most relevant aspects related to E-SIM technology, its implementation and adoption by users and operators.

• Third Stage: Analyze the advantages and disadvantages between E-SIM and the traditional SIM Card based on literature review.

1) **Application method**

The method was divided into two phases, the first phase documentary research and the second phase historical data survey and interview, both phases aimed to identify and collect data, as well as relevant information to understand the evolution of E-SIM and the current status of accession of this technology in Latin America. The purpose of this approach is to organize the basis of knowledge in common characteristics between E-SIM and SIM Card, considering advantages and disadvantages, allowing an objective analysis in order to generate a broader understanding on this topic.

a) In the first phase. The documentary research corresponds to a bibliographic survey that served as basis for this paper. This bibliographic survey corresponds to the collection of relevant scientific journals related to themes involving SIM Card and Embedded-SIM that have a relationship with topics involving network, mobile devices and new technologies with the purpose of understanding and explaining the studied reality.

   As a source to acquire information and new discoveries the use scientific journals become essential [5], [6]. In this sense were used mainly scientific journals from electronic databases Science Direct; IEEE; Taylor and Francis and Springer.

   The documentary research adopted as a procedure the combination of keywords, (i) SIM Card, (ii) E-SIM, (iii) Embedded-SIM, (iv) Vantage, (v) Advantage, (iv) Network, (vii) Implementation, (viii) Commercializing (iv) Evolution (x) Adoption.

b) In the second phase. The data collect process occurred through the non-probabilistic method for convenience using the historical research of market data provided by the carriers and an interview with the technical managers. The interview occurred through the application of a structured questionnaire with closed and open questions, which was intended to obtain maximum information linked to the object of research.

   The questions applied on the questionnaire were elaborated from topics that guided the main axis of the interviews, such as: which current status of E-SIM in the country, which operators have the E-SIM implemented, which operators are in the implementation process, which adherence of E-SIM technology by carriers, what difficulty in implementing the E-SIM technology and what advantages and disadvantages of the E-SIM system in relation to SIM Card.

II. E-SIM – EMBEDDED SUBSCRIBER IDENTITY MODULE

E-SIM technology has been gaining popularity. This technology allows users to easily change their mobile operators and activate data plans without the need to go to a physical store with physical card (SIM Card) and is therefore a more convenient and flexible solution for Telecommunications operators and end users [7], [8].

E-SIM can be considered an evolution of SIM Card, this new technology is incorporated into devices such as smartphones, tablets and smartwatches and cannot be physically removed, such as traditional SIM Cards.

Telecommunications companies have already started to adopt this technology in their services, seeking to more convenience commercial offers and feasibility to their customers. Today regions such as Europe and Asia have demonstrated a good scenario related to availability of E-SIM. In case of Europe, most relevant carriers offer service to customers in United Kingdom, Germany, Spain, France and Italy. It's in this place where main E-SIM manufacturers are placed as well, which incorporates trust for local operators, since those are well-known companies and their manufacturing follows EU legislation, contributing to local acceptance of this new technology [9]. In Asia the E-SIM scenario is positive, since when the service had its first steps. In 2014 it was constated that Japan had investment in E-SIM since the beginning, providing E-SIM solution-based applications for M2M devices. Besides in Japan, can be cited China, South Korea and India as countries with operators that also provide E-SIM service in Asia [10].

However, the implementation of E-SIM also faces some challenges, such as the lack of standardization in some aspects of technology and the resistance of some operators and customers to adopt it. This is related to the normal live cycle for new technology that require a deployment from the different participants as OEMs, Network operators and retailers involved, additionally need to mention that their adoption can be influenced by consumers resistance to abandon the physical SIM Card, with which they are familiar [11].

Regardless of these challenges, the adoption of E-SIM is expected to grow. The expectation is that by 2025, 30% of smartphones will be equipped with E-SIM technology [10]. In addition, E-SIM also has the potential to be used in other areas, such as IoT devices and connected vehicles [12].

There are some challenges for the adoption of E-SIM, the main limitation being the lack of compatibility of many devices nowadays [1]. In addition, there is resistance from telecommunications operators to adopt E-SIM, as this technology can affect the revenue generated by the sale of physical cards and the massive investment in servers' infrastructure. Therefore, there are several barriers to be transposed until the full implementation of E-SIM technology by all operators in Latin America.

III. OVERVIEW OF THE ELEMENTS REQUIRED TO DEPLOY THE E-SIM TO NETWORK

A. Mobile Network Operator (MNO) and Mobile Virtual Network Operator (MVNO)

Mobile Network Operators (MNOs) are companies that own and operate telecommunications networks, providing mobile communication services directly to end users. They have network infrastructure, frequency spectrum and are responsible for implementing and managing the E-SIM on their devices and networks. MNOs play a central role in implementing new technologies by investing in the infrastructure of their own networks. As for virtual mobile operators (MVNOs), these are companies that also offer mobile communication services, however, they do not have their own network infrastructure. Instead of that, they rent the infrastructure and network capacity from MNOs to provide their customized services and commercial plans to their end users, even though they do not own physical networks, transmission towers or frequency spectrum.

The MNOs have a key role in the deployment and management of E-SIM. They are responsible for deploy this technology into their network's infrastructure, providing subscription profiles to devices, managing customer connectivity, ensuring the security of customer data, and ensuring compliance with local regulations. In case of MVNOs, they can offer connectivity services to their customers by purchasing E-SIM subscription profiles from MNO. The MVNOs benefits from the flexibility of E-SIM as they can serve different markets and segments with customized plans and competitive rates.

E-SIM deployment requires effective collaboration between MNOs and MVNOs. MNOs provide the network infrastructure, capacity and connectivity necessary E-SIM operation, while the MVNOs bring innovation, competition and the ability to offer services variability to customers. However, it's important to consider that not all Latin American countries have a mature MVNO market. Some countries may have regulatory restrictions or market limitations that affects the development of MVNOs. In these cases, E-SIM deployment may be led primarily by MNOs, with less participation from MVNOs.

B. Infrastructure and equipment

The implementation of E-SIM is made using the infrastructure of a telecommunications operator, which requires a qualified operational team and equipment that must be suitable for implementing this new technology, given its complexity. Figure 02 represents general components from an operator's network infrastructure.

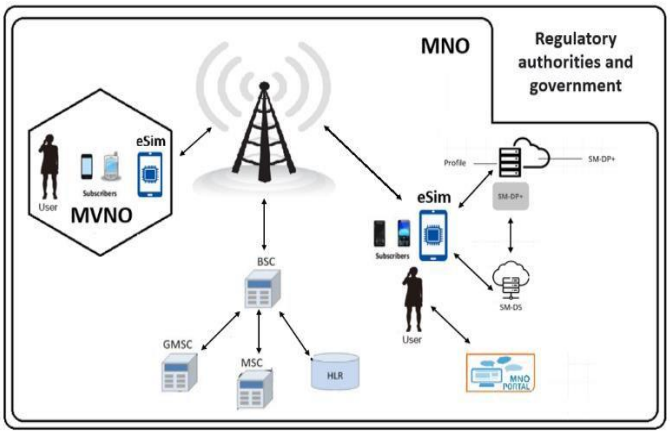

Fig. 2. Network infrastructure elements

Among the common elements that are part of the network infrastructure for the implementation of E-SIM, there are:

- OEM Manufactures: (I) Mobile devices manufacturers are fundamental components for E-SIM implementation no marketing. (II) E-SIM Providers are responsible for providing hardware, profiles and management servers for E-SIM technology.
- E-SIM Profiles: It's necessary to create and manage E-SIM profiles, which contain authentication information, network configuration, and user data. These profiles are loaded into the device's E-SIM, allowing them to connect to operator networks. Operators need provisioning platforms to load E-SIM profiles onto devices to ensure the security and integrity of these profiles during the provisioning process.
- Management Servers: Operators need to implement centralized management servers to provision and manage E-SIM profiles, known as Subscription Management Data Preparation (SM-DP+). These servers are responsible for performing authentication, authorization and provisioning of E-SIM profiles on compatible devices.
- Authentication Systems (Authentication Center - AUC): These are fundamental components for guaranteeing the security of communications. These systems verify the authenticity of devices and E-SIM profiles before allowing access to operator networks, involving the implementation of robust security measures such as two-factor authentication, data encryption and fraud protection.
- Network Infrastructure: The operators need to upgrade their network infrastructure to support E-SIM. This includes the implementation of access networks, such as 4G and 5G networks, and integration with existing subscriber management systems.

C. Regulatory Authorities and Government.

The deployment of E-SIM from operators requires the collaboration and involvement of regulatory authorities, to ensure adequate implementation and compliance with local regulations. The following are the most common regulatory and government authorities that are required for E-SIM deployment in a country. Such as: Ministry of Communications or Telecommunications, Telecommunications Regulatory Agencies, National Telecommunications Commissions, Consumer Protection Agencies.

D. Customers

Customer adherence to the E-SIM is a fundamental aspect for the success of this technology, therefore, to occur it, it's necessary MNOs and MVNOs to encourage customers with intuitive information about it, as a lack of knowledge of this functionality can lead to an initial resistance to its adoption and migration, therefore requiring an effective communication campaign to resolve doubts, promote resources and use of E-SIM.

Another important factor concerns the availability of compatible devices. Customer adoption of the E-SIM also depends on the availability of compatible devices on the market. Operators must work closely with device manufacturers to ensure a wide range of E-SIM compatible smartphones, tablets and wearables are available to consumers. If this offer is not available, customer adoption is impacted, becoming more complex.

Migrate to E-SIM provides benefits to customers, compared to the traditional SIM Card, offering new and advanced features, such as:

- Convenience: E-SIM eliminates the need to change the physical SIM Card, when changing devices (that support this technology) or when traveling abroad, for example. Activation and switching of profiles can be carried out remotely, providing a more fluid and simplified experience.
- Greater Flexibility: With E-SIM, customers can enjoy greater flexibility when choosing between different operators and plans, without having to physically purchase and exchange SIM Cards. They can switch between different operator profiles directly from their device.
- Multiple Device Support: E-SIM allows customers to have multiple devices connected to the same account and phone number. Useful feature for users who have smartphones, tablets and smartwatches, for example, as they can easily share the same data plan across multiple devices.
- Simplified International Roaming: E-SIM offers a simplified international roaming process for

travelers. These customers can easily connect to partner networks in other countries, temporarily activating local operator profiles, without the need to purchase and exchange physical SIM Cards.

- Remote Service and Activation: With E-SIM, customers can avoid frequent visits to operators' physical stores to purchase and activate SIM Cards. This provides greater convenience and reduces dependence on physical points of sale, allowing for a more autonomous and digital experience.
- Environmental Sustainability: E-SIM contributes to environmental sustainability, reducing the waste of physical SIM Cards that can be discarded when changing a device or when purchasing a mobile plan from a new operator. With E-SIM, there is no need to produce, distribute and dispose of physical cards, which reduces the environmental impact.

IV. ADVANTAGES AND DISADVANTAGES OF E-SIM COMPARED TO SIM CARD

The bibliographic survey related to E-SIM presents some advantage and disadvantages of this technology when compared to the traditional SIM Card, however, when analyzed in detail, it is observed that some cases presented are just a new, different way of applying something already implemented in current mobile technology market. In order to clarify this topic, the research made for this article has the purpose to analyze a comparative study between the E-SIM and the traditional SIM Card, presenting their respective advantages and disadvantages within factors considered relevant for MNOs, MVNOs, as well as for customers (end users), these would be: (I) Security; (II) Compatibility; (III) Cost; (IV) Flexibility and (V) Availability.

A. Security

From a security point of view, some researchers disagree in their considerations when it comes to E-SIM. Some authors present the E-SIM as a technology vulnerable to hacking attacks, while others claim that the E-SIM's security is based on encrypted software, offering more protection against cyber-attacks. This security dilemma is mitigated when comparing the E-SIM with the traditional SIM Card, expose the advantage and disadvantage, some of them could be consider as disadvantages of this new technology.

Table I presents the advantages and disadvantages of both technologies from the researchers' point of view regarding security. It is clear that despite the claims of vulnerability of the E-SIM, the traditional SIM Card is also opened/ exposed to failures and security breaches. The most notable difference is the physical accessibility to this hardware component, which can be related to security (in cases of theft, for example), considering that for the E-SIM this component has software and hardware embedded in mobile phone, where its removal is complex and can cause damage to the device, while the traditional SIM Card can be removed in a simplified way.

TABLE I
SECURITY

Advantage
E-SIM
The E-SIM presents encrypted software-based security features, offering protection against cyber-attacks. Security is established by the eUICC (Embedded Universal Integrated Circuit Card) hardware component, which securely enables and manages local profiles and must be certified in conjunction with the GSMA. Furthermore, the SM-DP+, SM-DS and certificate issuer (CI) architecture components perform authentication and security assurance [13], [14].
SIM Card
Traditional SIM Cards used security facilities, including software loading and operator credentials. Therefore, the integrity of SIM Cards was safeguarded. The embedded-SIMs helped in reaching these secure facilities to any location and over the Internet [10].
Disadvantage
E-SIM
The vulnerability of operators' systems and servers to hackers can leave information about user profiles as well as confidential information exposed [15].
SIM Card
From a security perspective, one key distinction between traditional SIM Cards and E-SIMs is that devices with physical SIMs are susceptible to both hardware and software attacks, while devices with E-SIMs are only susceptible to software attacks [16].

B. Compatibility

The E-SIM and the SIM Card have basically the same purposes, however, as it is based on software, the E-SIM offers the user better convenience and versatility due to its idealization and the way in which it is applied, on the other hand the SIM Card stands out over E-SIM in terms of compatibility, as it has a greater number of compatible devices nowadays, being widely supported by mobile phone operators. Table II presents considerations in relation to the advantages and disadvantages between the SIM Card and the E-SIM in relation to compatibility in the view of authors related to this topic.

TABLE II
COMPATIBILITY

Advantage
E-SIM
Wearable devices (e.g., smartwatches) predominate in terms of compatibility with E-SIM, so this type of technology is advantageous for equipment with reduced dimensions. This functionality is also a strong candidate for machine-to-machine (M2M) applications, in terms of compatibility, as it allows these devices to have connectivity included during the manufacturing process and on a large scale, something advantageous for this category of devices. [17], [18].
SIM Card
The traditional SIM Card presents a high compatibility to mobile devices currently on market (smartphones, tablets), allowing them to use important features provided by operators. A SIM Card that supports mobile 4th Generation (LTE), for example, allows devices to support features such as USIM, ISIM (VoLTE), web browsing. Furthermore, those 4G SIM Cards have additional files compared to 2G or 3G with a more secured encryption algorithm, extended data storage and backward compatibility to support 2G and 3G services [1].
Disadvantage
E-SIM
E-SIM compatibility is still expanding, restricted to new releases from the main smartphone companies. Therefore, old models that are still on the market do not support this functionality. Currently in Latin America, high tier smartphones for the most of OEMs brands have E-SIM, while mid and low tier do not support. It is possible to see that other kind of devices, such as tablets, vehicles, computers, drones, among others, do not support E-SIM in most cases [19].
SIM Card
Although the SIM Card is widely compatible with Smartphones, there are categories of devices that cannot use it or that have limitations when applied. In smartwatches, for example, a connection to a mobile network is only possible using E-SIM technology. It is important to highlight that traditional SIM Cards have limited use in Smart Vehicle applications, where the card can suffer damage caused by: exposure to very low or high temperatures, different climatic conditions, corrosion problems, friction and excessive vibrations on highways. low quality, factors that interfere with the use and integrity of the SIM Card. Additionally, there is the fact that SIM Cards are limited to one network at a time, so making an operator's service change in a smart vehicle application can be more complex and time-consuming when compared to the simplicity offered by E-SIM. [20].

C. Cost

A relevant topic to be observed are the costs involved in the adoption and implementation of E-SIM by operators. Since costs affect directly in the adoption process by customers and the price of the service offered, the cost has relevant impact. Table III presents some examples in this regard.

TABLE III
COST

Advantage
E-SIM
Regarding cost, the use of E-SIM can reduce operational costs for mobile service providers, as it is not necessary to produce and distribute physical SIM Cards. Furthermore, users can save money by not having to buy new SIM Cards when switching operators. However, it is important to note that the adoption of E-SIMs can add costs for device manufacturers as the technology is still relatively new. [21].
SIM Card
Economy of scale should be considered; while E-SIM profiles lacks the physical part of traditional SIMs, cost per profile is usually higher than cost per physical SIM; this is because remote SIM provisioning is still a new technology and devices support are still limited compared to physical SIM orders; this might not justify the investment in building local setup and getting it certified. Situation can change in future when it becomes economically efficient for MNOs and MVNOs to invest in building their own local setups [22].
Disadvantage
E-SIM
The implementation of E-SIM requires telecommunications operators to invest in infrastructure and technology, which can result in higher cost for CAPEX and OPEX and prices for the end consumer. The transition to E-SIM may result in additional costs for operators, who may end up passing these costs on to the customer. Furthermore, implementing E-SIM can also be more expensive for mobile device manufacturers, as they have to equip devices with the necessary hardware to support E-SIM [23].
SIM Card
The cost disadvantage of SIM Card can be related to its characteristic of being disposable. From the customer side, when changing to a different operator company, a new SIM Card needs to be purchased. The same scenario occurs during international travels, when a customer needs to buy a local SIM Card to connect with mobile network. Both situations generates additional costs for end users, which is a situation that can be expected or not [23].

Can be observed, researchers suggest that the implementation and maintenance of E-SIM by MNOs can lead to an increase in their operations costs since it is necessary to make investments in infrastructure such as: profile management platforms (SM-DP+), the acquisition of remote management servers (entitlement servers), buildings, among others. These costs generally affect the value of services provided by operators.

The advantages and disadvantages found in each technology, highlighting the influence of costs when adopting the E-SIM or SIM Card. The influence of costs on the implementation of E-SIM is evident in the point of view from certain authors, which in this regard favors the traditional SIM Card, which is already consolidated in operator operations.

D. Flexibility

Flexibility in mobile communication technology is a critical aspect that impacts user convenience and the industry as a whole. The E-SIM stands out for its remarkable flexibility. It empowers users to store multiple operator profiles within a single device, eliminating the need to manually swap physical SIM Cards when changing operators. This feature proves especially advantageous during international travel, where users can activate a profile without acquiring a local SIM Card.

However, it's worth noting that E-SIM compatibility is still limited among devices.

On the other hand, the traditional SIM Card offers a different kind of flexibility – device compatibility. It can be effortlessly used across a wide range of devices, including cell phones, tablets, and laptops. This versatility allows users to change SIM Cards quickly and easily as needed, ensuring that their devices recognize the chip seamlessly. When it comes to user convenience, the E-SIM takes the lead. Its remote programming capabilities enable users to activate and deactivate data plans with ease, adapting to their evolving requirements. In contrast, swapping physical SIM Cards for different operator profiles can be uncomfortable and may involve additional costs.

Despite the advantages of E-SIM technology, its adoption faces challenges. Some users may find the process of transferring mobile number to another device and activating E-SIM profiles complex compared to the simplicity of traditional SIM Card swapping.

Device manufacturers also play a pivotal role; their willingness to implement E-SIM and offer user-friendly interfaces varies, as they are not legally obliged to do so.

In scenarios like massive IoT deployments, where flexibility is essential, the traditional method of swapping SIM Cards becomes problematic and costly. Companies operating in this field often seek to avoid such operations, as they can lead to contractual limitations and synchronization challenges. This underscores the importance of flexibility in mobile communication technology and the ongoing evolution of E-SIM and SIM Card technologies.

Table IV presents some advantages and disadvantages related to the flexibility of E-SIM and SIM Card.

TABLE IV
FLEXIBILITY

Advantage
E-SIM
Regarding user convenience, E-SIM technology can offer significant benefits compared to conventional SIM. E-SIM allows users to easily change network operators without having to change their physical SIM Card. Additionally, the E-SIM can be programmed remotely, allowing users to easily activate and deactivate data plans depending on their needs [24].
SIM Card
The traditional SIM Card offers greater flexibility due to its compatibility feature between devices. The conventional SIM can be used in a wide variety of equipment, including cell phones, tablets and laptops, where in terms of flexibility, it allows the chip to be changed quickly and simply, being quickly recognized by the device that supports it [25].
Disadvantage
E-SIM
The device's mobile data transferring for another device by E-SIM, and its activation as well, can be considered a bit complex for some users when comparing to SIM Card. In addition, device manufacturers may have little incentive to implement E-SIM and provide end users an intuitive way to use it (when available on device), given that they have no legal obligations to comply with it in their products and that operators are suppliers among others rather than customers [9].
SIM Card
The traditional way of changing a mobile operator is by swapping SIM Cards, which becomes problematic and expensive when we consider massive IoT deployments. Every company operating in this field strongly avoids such operations, with the result of being tied to contracts with operators, losing flexibility, and frequently opting for synchronizing changes to product releases, entirely replacing old devices [25].

E. Availability

The last topic of this analysis concerns availability, which is presented in table V. It is possible to identify that the SIM Card is widely more available than the E-SIM, as the SIM Card is a technology that has existed for longer and is used in a variety of mobile devices, including smartphones, tablets and laptops. E-SIM, on the other hand, as it is a recent technology, is not yet available on all mobile devices, but it presents itself as a great option for equipment focused on the internet of things, wearables and other devices due to its way of design, flexibility and security.

TABLE IV
AVAILABILITY

Advantage
E-SIM
E-SIM can be a good option for companies that need to manage large numbers of telephone lines, as it is not necessary to physically purchase and install SIM Cards in each device. Currently in Latin America, the largest telecommunications companies that sell mobile network services provide the E-SIM service, making it an accessible option for users of smartphones and smartwatches that support this type of functionality. In the future, it is expected that with the implementation of the server activation method, it will be possible to increase accessibility to the E-SIM service [26], [27].
SIM Card
The advantage of the SIM Card is its wide availability with most mobile devices and operators. The SIM Card is a well-established technology that has been used in mobile communication for decades. Mobile services are provided by most operators using the traditional SIM Card [24].
Disadvantage
E-SIM
E-SIM technology currently has limited availability on mobile devices. As the technology is emerging, not all mobile devices support this functionality, nor do all operators yet make this option commercially available, which may limit its adoption and use. Furthermore, E-SIM technology is not yet standardized, which can create interoperability problems between different devices and operators, preventing rapid adoption and collaterally impacting its commercial availability by operators [11].
SIM Card
Global roaming can be considered a current challenge for traditional SIM Cards. Global roaming offers based on reprogrammable SIMs have prices close to the upper limit of the market and which tend to be minimized with the adoption of E-SIM. Furthermore, international travelers commonly need to discard their physical cards for a local service option, which is a limiting feature in terms of availability for this option [23].

Some general conclusions can be observed from the documental analysis and statements made by researchers in their articles, where it is possible to conclude, through a comparison between the E-SIM and the traditional SIM Card, the advantages and disadvantages of each technology.

For example, in terms of security there is a greater advantage for the E-SIM in relation to the traditional SIM Card, since the E-SIM has greater security through encryption and the complexity of physically removing this component from a device, when compared to a traditional SIM Card.

Regarding costs, initially the E-SIM becomes more expensive for the operator as it requires an investment in infrastructure for its implementation, unlike the SIM Card which is a consolidated technology for operators. The disadvantage of the SIM Card in relation to the E-SIM in the acquisition cost of purchasing the physical Chip, which does not occur for the E-SIM, as it does not require this item, being an advantage for the end user.

In terms of flexibility, it is clear that both the E-SIM and the SIM Card have advantages to offer, and it is even possible to use them on several devices simultaneously.

In terms of compatibility, a greater advantage of the traditional SIM Card was observed as it is compatible with the majority of existing mobile devices, while the E-SIM's compatibility is limited to the most recent and high-end devices, and there is also greater incompatibility with old equipment. The highlight in this case are the wearables, where the E-SIM predominates in terms of compatibility.

Finally, the analysis of the availability item shows a lower presence of E-SIM in the current market, as it is a new technology that is not yet implemented by all operators in their network infrastructure. The launch of more compatible devices on the market is also considered among the factors that impact E-SIM availability. When compared to the SIM Card, the greater availability of this technology since its inclusion on the market is outstanding.

Therefore, it is clear that both, SIM Card and E-SIM present a variety of advantages and disadvantages, with highlights being one technology or the other, depending on the criteria analyzed. The traditional SIM Card is a more established and widely adopted technology that offers greater compatibility across a wider range of mobile devices. On the other hand, E-SIM is an emerging technology that offers more security, convenience and flexibility in terms of use on different networks. E-SIM still faces challenges in terms of supporting older devices, costs, security and lack of global standardization. The choice between SIM and E-SIM depends on the user's individual needs and preferences and the technical and infrastructure constraints of each market. In general, the E-SIM has more advantages than the SIM Card, but its implementation costs are still considered high and may not justify a massive investment by operators in the short term. However, given the trend of device manufacturers adopting the implementation of this technology in new models, operators can count on a positive long-term return on investment in implementing the E-SIM in their network infrastructure and making this service available commercially.

V. CURRENT OVERVIEW OF E-SIM ADMISSION IN LATIN AMERICA

Latin America is a region of the American continent that has in its formation most countries located in the central and southern part of the continent. The region consists of twenty independent countries, namely: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Ecuador, El Salvador, Guatemala, Haiti,

Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Dominican Republic, Uruguay and Venezuela.

The E-SIM market in Latin America has a significant growth potential, driven by increased insertion of smartphones, wearable and connected devices, as well as the demand for more flexible and convenient services. MNOs and MVNOs are positioned to capitalize on this opportunity and offer innovative solutions to customers.

It has been identified that, in most Latin American countries there are currently at least one operator that provides the availability of E-SIM commercial service to its clients (end users), which indicates a strong adherence of operators to implement and market the service locally. Companies have a remarkable interest in the implementation and sale of this technology, presenting it E-SIM as a trend among future mobile releases of the world's leading manufacturers. In addition, it is common for these companies to highlight to their customers the flexible characteristic of the use of E-SIM, especially for the public composed of international travelers.

Table VI presents a summary of the data collected on the adoption of E-SIM in Latin American countries; Therefore, the commercial availability of E-SIM per country, where telecommunications operators that sell and offer this service in the country, and also the methods of activating the E-SIM profile that are offered to costumers by the operator.

TABLE VI
E-SIM COMMERCIALIZATION IN LATIN AMERICAN

Country	E-SIM Availability	Activation Method	
		QR Code	Remote authorization (by server)
Argentina	Yes	Yes	Yes
Bolivia	Yes	Yes	No
Brazil	Yes	Yes	Yes
Chile	Yes	Yes	No
Colombia	Yes	Yes	Yes
Costa Rica	Yes	Yes	Yes
Cuba	No	No	No
Ecuador	Yes	Yes	No
El Salvador	Yes	Yes	Yes
Guatemala	Yes	Yes	Yes
Haiti	No	No	No
Honduras	Yes	Yes	Yes
Mexico	Yes	Yes	Yes
Nicaragua	Yes	Yes	Yes
Panama	Yes	Yes	No
Paraguay	Yes	Yes	No
Peru	Yes	Yes	No
Dominican Republic	Yes	Yes	Yes
Uruguay	Yes	Yes	No
Venezuela	Yes	Yes	No
Total (%)	90,00 %	90,00%	50,00%

Based on the results, it was found that the adoption of E-SIM in Latin America occurs positively, where 90.00% of the countries that make up this region have at least one operator that makes available and sells this service. This result shows how important the implementation of this type of feature by operator.

The E-SIM profile activation methods surveyed were: QR code qualification and remote qualification (via server). In the first approach, the end user who wants to activate this method needs to move to a physical store of the desired operator and purchase a signature. After this the customer receives a QR code that is associated with your subscription data that is recorded on the equipment as soon as it reads from a mobile device, allowing the E-SIM profile to download.

The second approach presents a similar activation process, but it can be performed without the need to attend a physical store of the operator (remote activation), so the costumer can activate E-SIM from operator web page to realize a contract signature. For all this to work, the operator needs to implement additional components in its network architecture and infrastructure, as well as servers that can allow this kind of approach.

The activation methods adherence can be found in two different situations. First, from the data collected, with QR code activation. This method was found in all countries that have operators that provide E-SIM service. This can be justified by the fact that this was the first activation method that emerged, in addition, it is an approach that requires low cost and simpler to implement compared to activation method by server.

Second, activation by server known as remote authorization, this kind of approach is offered by only 50.00% of operators in Latin American countries, and only a small portion of customers are looking for this type of activation or they find out when going to activate at operator store. It is important to emphasize that even if the operator has an infrastructure necessary to provide this activation method, it is not all mobile devices that can use it, with a distinction of availability between equipment that are from different manufacturers and Operational systems.

It was noted that this approach is made available by operators only for wearable devices of the largest manufacturers, however, the option of activating the E-SIM profile for smartphones remains only by QR code. These factors are justified by the increase in costs that are generated when performing service qualification on different brands and types of devices. For operators, it is more economical to perform the qualification for a group of specific brands or devices. These factors may justify a minor percentage to the remote activation of E-SIM (via server) observed by research.

VI. CONCLUSION

This paper offers a general perspective of the implementation for e-SIM in Latin America, seeking to present the advantages and disadvantages of this technology in relation to the traditional SIM Card as well as the elements that are part of its implementation, thus providing an overview of adoption of this technology by carriers and customers.

The result collected in this research showed the current panorama from E-SIM technology for Latin America as well as the elements that are part of the technology implementation process and its advantages and disadvantages when compared to the traditional SIM Card. As seen in this research the results of the comparison between E-SIM technologies and SIM Card are an important issue, since each one has its own advantages and disadvantages.

The E-SIM is an emerging technology that has recently attracted more attention to popularity in recent years, its advantages include convenience, the ability to have multiple accounts in a single device and the elimination of the need for a physical SIM Card, especially when it comes to application on mobile devices and IoT. In the case of SIM Card has the trust of consumers for offering security and confidence being widely accepted on all commercial mobile devices.

The tendency is for E-SIM to become increasingly popular and adopted in different sectors, especially as mobile technology continues to evolve. Interoperability and standardization are important issues to be addressed, but with the adoption of common standards and appropriate regulations, E-SIM can become a broader and more flexible solution for mobile devices and IoT.

The results obtained from the interview indicated that Latin America operators have seen E-SIM technology as promising. Telecommunications companies show interest in infrastructure investment for this implementation, which is a factor evidenced from the collected results, which demonstrate that 90.00% of Latin American countries have at least one operator that makes available and markets the service of E-SIM. Thus, it is concluded that the advantages presented by this service (highlighting convenience, flexibility and the increase in the amount of profiles), in conjunction with a promising view of this technology that is focused on both the current market and increasing the possibility of opening new businesses, they are decisive factors for operators to make investments in this area.

When comparing E-SIM activation methods, divisor behavior is identified based on the collected results. It was found that all countries have at least one operator that provides activation by QR Code, while almost less than half of countries, about 50.00% of operators offer the service through remote activation (via server) just for smartwatch currently. This feature can be justified in view of the simplicity of the implementation of QR activation technique, and when comparing the costs between the two methods studied, QR activation is an alternative that generates less implementation expenses and maintenance. On the other hand, the data collected also show that there is a trend for the server activation method to be adopted in more regions, taking into account that 50.00% of operators that provide the E-SIM service made investments for this type Method, indicating a trend for the implementation of this activation method to which it will depend on three main factors: the reduction of the infrastructure implementation cost for server activation, the number of devices on the market that support this functionality and the number of customers who adhere to this service.

The investigation also concluded that E-SIM technology has among its main advantages the flexibility in terms of operator`s profile management, convenience for the use and activation of profiles, enables greater simplicity when using mobile network services in foreign countries and allows the use of a high amount of cellular network profiles.

These characteristics are considered attractive to end customers, so it is generally concluded that E-SIM has growth trend in the market, a factor that can be increased, as disadvantages of this service are minimized. For example, in terms of vulnerability and safety, there is a need to apply improvements required to increase the amount of devices and customers that use this service. E-SIM support should also be improved, considered as one of the disadvantages of this functionality, which is not possible to be activated on any device. It is expected that this disadvantage will be minimized according to the main OEMs (original equipment manufacturer). Market makes development and manufacture of new models with E-SIM support, a factor that enables the amount of end customers to use this service, rather increasing the interest that telecommunications companies make investments in E-SIM.

Currently, it is already possible to see a significant presence of the availability and commercialization of the E-SIM service in the main telecommunications operators in most of the Latin America region. This feature has the growth trend as shown in the disadvantages are reduced, allowing the E-SIM service to be more promoted form commercial side, as well as better implemented with more robust activation technologies, for example from server activation, ensuring end users better quality of service linked to greater convenience for contraction, replacement or any other operator profile management action for mobile services.

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