Aalto University
School of Electrical
Engineering

Department of Communications and Networking

Munira Shahnaz

# Value Network Analysis of Embedded Subscriber Identity Module in Machine to Machine Communication

Master's Thesis
Espoo, 3.12.2014

Supervisor: Professor Heikki Hämmäinen, Aalto University, Finland
Instructor : D.Sc. Pertti Ikäläinen, DStill Oy, Finland

ABSTRACT OF MASTER'S THESIS

**Author:** Munira Shahnaz

**Title of Thesis:** Value Network Analysis of Embedded Subscriber Identity Module in Machine to Machine Communication

**Date:** 3.12.2014 **Pages:** 67

**Supervisor:** Professor Heikki Hämmäinen

**Instructor:** D.Sc. Pertti Ikäläinen

SIM card technology has evolved in size and feature over the years. Now machine to machine communication has paved the way of embedded SIM (eSIM) integration into devices. This evolution of eSIM is still a little far off but might become essential sooner rather than later if the traffic, usage and new services of M2M booms. This thesis discusses the possible future scenarios and value networks of eSIM based M2M communication that will shape the ecosystem in the next 10 years time frame.

Necessary background regarding SIM card evolution is discussed before going into the future scenario. The thesis also consists of studies on current cellular network structure, Internet of things and Machine-to-machine communication from various sources to understand both technical and business dynamics of these services. By the virtue of brainstorming sessions and expert interview from industry the basic trends and key uncertainties are refined to use as the basis of scenario planning. Also efforts have been made to identify the business roles and corresponding interested actors to take over these roles through value network configuration method.

Four possible future scenarios are constructed according to Schoemaker's scenario planning method which explore possible changes in the M2M industry due to eSIM. The scenarios reflect the diverse interests of the involved stakeholders and their influence over the market. Value network configurations further investigate the different possible evolution paths to introduce scope for new business models. Analysis and results from this thesis can be a good indicator for future M2M and eSIM ecosystem.

**Keywords:** M2M, eSIM, Scenario Planning, Value Network Configuration

**Language:** English

# Acknowledgements

This master's thesis has been carried out in the Department of Communications and Networking of Aalto University School of Electrical Engineering as a part of the national IoT research program under the DIGILE umbrella.

First of all, I would like to express my sincere gratitude to my supervisor, Professor Heikki Hämmäinen for giving me the opportunity to work under his supervision and guiding me throughout the process.

My heartfelt appreciation goes to my instructor D.Sc. Pertti Ikäläinen for his guidance, encouragements, ideas and advice. I also like to thank Mr. Matti Frisk and Vesa Lehtovirta of Ericsson for their continuous enthusiasm and support throughout the project. I would like to thank the interviewees and participants of brainstorming sessions for their valuable inputs towards the thesis. I would like to thank network business team for their tremendous help on various topics.

Finally, special thanks are due to my family for their continuous support, encouragement and blessing at every step of my life.

Otaniemi, Espoo, 3.12.2014
Munira Shahnaz

# Contents

# List of Tables

# List of Figures

# Abbreviations and Acronyms

**3GPP** 3rd Generation Partnership Project
**eSIM** Embedded SIM
**API** Application Programming Interface
**ARPU** Average Revenue Per User
**B2B** Business to Business
**B2C** Business to Consumer
**CAPEX** Capital Expenditure
**ETSI** European Telecommunications Standards Institute
**eUICC** embedded Universal Integrated Circuit Card
**GSMA** Groupe Speciale Mobile Association
**ITU** International Telecommunication Union
**M2M** Machine to Machine
**MNO** Mobile Network Operator
**MVNO** Mobile Virtual Network Operator
**OPEX** Operational Expenditure
**OTA** Over the Air
**QoS** Quality of Service
**SIM** Subscriber Identity Module
**SLA** Service Level Agreement
**UICC** Universal Integrated Circuit Card
**IERC** IoT European Research Cluster
**IoT** Internet of Things
**LTE** Long Term Evolution
**ICT** Information and Communication Technology
**BSS** Base Station Subsystem
**NSS** Network Switching Subsystem
**OMSS** Operation and Management Subsystems
**BTS** Base Transceiver Station

**BSC** Base Station Controller

**GPRS** General Packet Radio Service

**GGSN** Gateway GPRS Support Node

**SGSN** Serving GPRS Support Node

**MSC** Mobile Switching Center

**MSS** MSC Server

**HLR** Home Location Register

**VLR** Visitor Location Register

**PSTN** Public Switched Telephone Network

**AUC** Authentication Center

**EIR** Equipment Identity Register

**IP** Internet Protocol

**MS** Mobile Station

**LAC** Location Area Code

**PCU** Packet Control Unit

**PLMN** Public Land Mobile Network

**CS** Circuit switched

**PS** Packet Switched

**UMTS** Universal Mobile Telecommunication System

**CDMA** Code Division Multiple Access

**WCDMA** Wide-band Code Division Multiple Access

**UE** User Equipment

**GSM** Global System for Mobile communication

**UTRAN** UMTS Terrestrial Radio Access Network

**EDGE** Enhanced Data rates for GSM Evolution

**GERAN** GSM EDGE Radio Access Network

**DSL** Digital Subscriber Line

**WLAN** Wireless Local Area Network

**CN** Core Network

**RNC** Radio Network Controller

**USIM** Universal Subscriber Identity Module

**SAE** System Architecture Evolution

**EPC** Evolved Packet Core

**HSS** Home Subscriber Service

**MME** Mobile Management Entity

**P-GW** Packet Gateway

**S-GW** Serving Gateway

**RAN** Radio Access Network
**PCRF** Policy and Charging Rules Functions
**FDMA** Frequency Division Multiplexing
**OFDMA** Orthogonal Frequency Division Multiplexing
**HSPA** High Speed Packet Access
**VAS** Value Added Service
**RFID** Radio Frequency Identification
**MTC** Machine Type Communication
**WAN** Wide Area Network
**PAN** Personal Area Network
**LAN** Local Area Network
**PLC** Power Line Communication
**SC** Service Capabilities
**ASP** Application Service Provider
**ECC** Electronic Communications Committee
**CEPT** European Conference of Postal and Telecommunications Administrations
**ICC** Integrated Circuit Card
**ISIM** IP multimedia Subscriber Identity Module
**CSIM** CDMA Subscriber Identity Module
**CPU** Central Processing Unit
**ROM** Read Only Memory
**RAM** Random Access Memory
**EEPROM** Electrically Erasable Programmable Read Only Memory
**MF** Master File
**DF** Directory File
**EF** Elementary File
**ICCID** Integrated Circuit Card Identifier
**IMSI** International Mobile Subscriber Identity
**MSISDN** Mobile Station International Subscriber Directory Number
**PIN** Personal identification Number
**CAT** Card Application Toolkit
**ISDN** Integrated Services Digital Network
**FF** Form Factor
**MFF** M2M Form Factor
**SM** Subscription Manager
**SM-DP** Subscription Manager-Data Preparation
**SM-SR** Subscription Manager-Secure Routing

**OS** Operating System

**ISD** Issuer Security Domain

**ECASD** eSIM Certificate Authority Security Domain

**VNC** Value Network Configuration

**H2H** Human to Human

**ARP** Alternate Roaming Provider

**OECD** Organization for Economic Co-operation and Development

**MVNE** Mobile Virtual Network Enabler

**SP** Service provider

# Chapter 1

# Introduction

Machine to Machine (M2M) communication is coming to the forefront of ICT technology. It is thought of an important component of future ICT infrastructure that is being built up to meet the challenge of 2020 ICT demands. (Affif Osseiran, 2013). Also the network evolution (which is a hybrid of LTE, WiFI and other wireless and wired technology) takes into account that there will be 50 billion devices connected with each other and significant part of it will be M2M devices. This accelerating growth of M2M has paved the way for many research opportunities too. Every aspect of it needs addressing in immediate future. Embedded SIM (eSIM) is one of the key components of this research.

From historical point of view SIM cards had been a key element of cellular network architecture. And by the looks of it this association is set to continue for a foreseeable future due to its involvement in the complex business and technical ecosystem. But with time the SIM card has evolved according to the needs in cellular network architecture. Now it is on its way to evolve as eSIM for utilising it in M2M communication. It can provide the authentication platform of end to end (E2E) connectivity for M2M. Operational efficiency is also a considerable challenge for M2M platform. As the SIM ecosystem is already in practice for many years and some enhancement to it can be considered to be a viable solution to keep the efficiency or to improve it. Cost wise also for operators and platform providers it can be a viable and less complex solution to move forward to connect billions of devices to the cellular ecosystem.

eSIM is yet to penetrate the mainstream market, so it is paramount that this value network analysis will help to get an idea how eSIM can affect the future scenarios of M2M evolution. For M2M communication, global reach and roaming feasibility are big concerns. We will see in coming chapters that eSIM provides remote provisioning to facilitate global roaming and local connectivity, this is seen as a vital point for eSIM usage. As eSIM ecosystem starts to shape up, the new value chain might form for economical reasons. New or adjusted business model will be in place. So, analysis for future scenario is needed for better understanding of future markets. Investing on a new technology is always a risk, in ever changing and fast paced ICT sector nothing is "absolutely about to happen". So when investors and major stakeholders need to risk a lot of money on some solution, they need to analyse all sides of it, sometimes they need to push a solution to reality in order to make the users aware of its merits. All the stakeholders and interested parties need to be very convinced if they are going to put their money into it. A good analytical and systematic approach towards evolution of eSIM can be a good tool for the stakeholders and experts to have an insight to the future. As said before it will not be future prediction but an analysis of different scenarios which is possible to conclude technically and economically.

Scenario planning is a way of analysing future possibilities that are uncertain at this point of time. It will be used as a tool to understand the eSIM evolution to M2M ecosystem. Later, alternate value network configurations of eSIM/M2M are discussed which is essentially a relationship diagram (technical and business) between all the parties (MNO, device vendor, M2M solution owner etc.) involved in eSIM operation. We will discuss this in detail in the course of the thesis. This thesis is part of the national IoT research program under the DIGILE umbrella.

## 1.1 Research Question

Due to a growing market need in M2M communication, discussion has opened for more flexible solutions of authentication. In spite the choice of, e.g., using a wider trusted environment (3GPP, 2010) or founding a new subscription manager role (GSMA, 2011) for remote provisioning, the current trusted relationship for exchanging the SIM credentials will be jeopardised. The new remote provisioning architecture of eSIM offers opportunities to provide services that benefit from security combined with advanced flexibility. Thus the present established market architecture will face the pressure of change as well.

This thesis tries to discuss impact of eSIM in M2M communication. The main research questions are:

1. What are the driving forces (trends and uncertainties) and scenarios that guide the M2M/eSIM evolution?

2. What are the alternative value network configurations for M2M/eSIM deployments?

3. Can eSIM change the industry architecture?

We will try to find the answers of these questions through different methods.

## 1.2 Scope

The scope of this thesis is quite evident from the research questions. We are limiting our focus on the eSIM related scenarios for future M2M ecosystem. So the discussion about eSIM in this thesis naturally limit ourselves to cellular network based M2M communication. We will not consider M2M ecosystem involving wired and wifi technology. Also the scope of this thesis is not to concentrate on the detail of business process or technical understanding of eSIM rather we will emphasise on understanding the eSIM/M2M situation from technology and business point of view.

## 1.3 Methodology

The research methods adopted in this thesis include-

1. Literature survey.
2. Interview with relevant experts and stakeholders.
3. Scenario planning.
4. Value Network Configuration.

Literature review includes ETSI and GSMA specifications, academic journals, white papers, news articles. After gaining sufficient knowledge on the topic and brainstorming session with co workers, interview sessions helped to understand the topic more broadly. Industry experts shared their insight about future industry situation , academicians gave opinions about research perspectives and vice-versa.

These knowledge, obtained from theoretical work and interviews, is used to identify the significant trends/uncertainties for scenario planning method and also used to identify the roles and relationships of different stakeholders to configure value networks.

## 1.4 Organisation of the Thesis

The structure of the thesis is presented in figure 1.1

After introducing the basics of the thesis in the first chapter, the background information

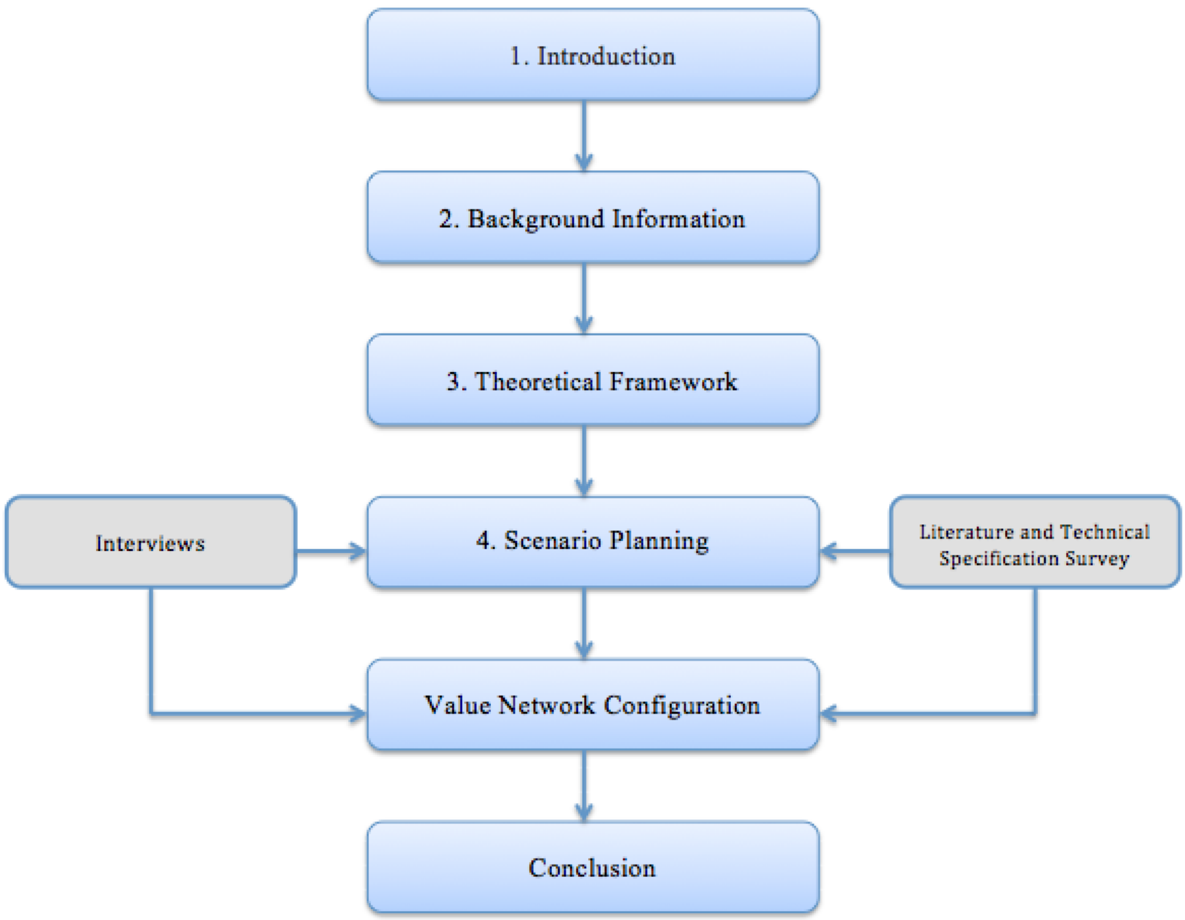


Figure 1.1: Organisation of thesis

chapter discusses the required technologies to understand the functionality of eSIM and eSIM based M2M communication. It describes detail of SIM architecture and its evolution towards eSIM, typical cellular networks where eSIM will be used and M2M ecosystem.

Theoretical framework discusses scenario planning and value network configuration methods which are the basis of value network analysis of eSIM in the thesis.

Chapter 4 deals with the process of constructing scenarios for future eSIM/M2M industry. In this chapter the scenarios are constructed step by step and discussed extensively. Chapter 5 is about constructing value networks based on the identified roles and relationships of the involved actors in M2M ecosystem.

In the concluding chapter the results are discussed and evaluated.

# Chapter 2

# Background Information

This chapter gives overview of the technical aspects that are needed to understand the following chapters. The first section gives brief architecture of current cellular network deployments and technologies; the second section discusses briefly the IoT concept and M2M communication. The third one discusses SIM technology evolution.

## 2.1 Cellular mobile network overview

In this section a brief overview of most widely used cellular network will be presented along with M2M optmization needs for these networks.

### 2.1.1 GSM

The architecture and standards of cellular network evolved immensely since the world's first GSM call on 1st of July in 1987 by then Finnish Prime minister Harri Holkeri by operator Radiolinja. The technological demands of users and the need of modern 'Always on-line' philosophy is the main reason why it has reshaped to current forays into technologies like LTE advanced or small cells. We are also not far behind from 5G either, lots of behind the scenes research activities are ongoing to ensure its arrival.

GSM was first developed in 1980's to accommodate more users in cellular network (Mishra, Ajay R, 2007). It is the most successful offspring of 2nd generation mobile system. It facilitates not only digital voice service for the users but also provides data services. The GSM network architecture is modular, it can be divided into three major subsystems, as can be seen from figure 2.1.

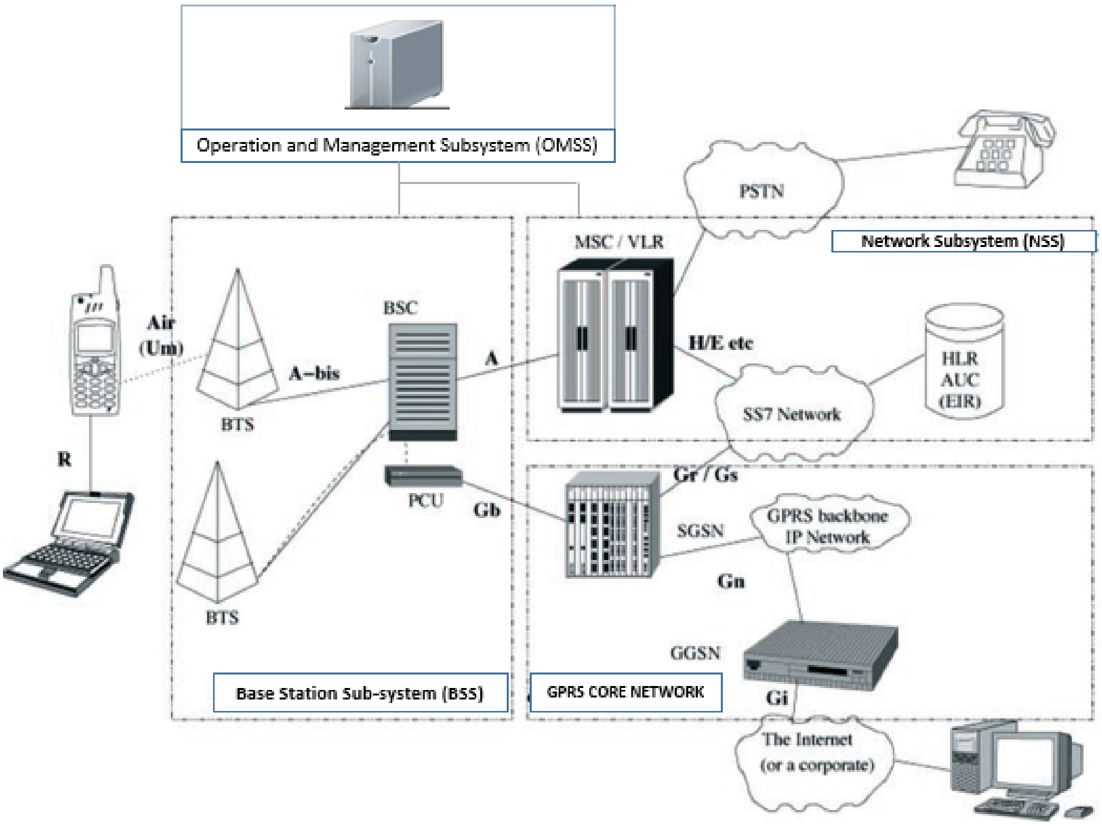


Figure 2.1: GSM network architecture

- Base Station Subsystems (BSS);
- Network switching subsystem (NSS);
- Operation and Management Subsystems (OMSS).

- Base Station subsystem (BSS):

  This subsystem comprises of physical network elements which controls all the radio related functions to communicate with MS (mobile station like Cellphones, laptops with cellular modem etc.)and facilitate the delivery of the GSM service to the end user. Base station controller (BSC), Base Transceiver Station (BTS) is part of BSS. BTS provides radio channels to MS and transmits/receives signals from it. It does signal processing, and necessary conversions of the information it receives from MS to pass it to the larger and more complex BSC. It is connected to BSC by A-bis interface which is closed (same vendor). BSC is responsible for controlling a cluster of BTS of an geographical area (LAC administered), frequency administration and distribution, handover functions and call (data or voice) exchange between multiple nodes. It is connected to MSC via A interface and also rate adaptation and transcoding is done in BSC to map its information to the switching center domain. BSS also comprises PCU which is actually the part of BSC and directs packet data from users via MS and BSC to SGSN(GPRS Support Node), which is part of Core network.

- Network switching subsystem (NSS)

  Network switching subsystem comprises Mobile switching centres and database servers which contains vital information like user information, location information, security information etc. The main switching node is Mobile switching centre (MSC), which performs all the switching functions in circuit and packet domains (CS and PS). This includes routing path identification of calls, signals etc. Each MSC is also designed for a specific geographical area. A variant of MSC is Gateway-MSC, which essentially connects to other public land mobile networks (PLMN) to its home network. Another important part of NSS is Home location register (HLR) and Visitor Location register (VLR), these nodes are essentially database servers which contains all the registration information of users and its locations. Normally there is one HLR per network (PLMN) and one VLR per MSC. Information like IMSI, authentication key, supplementary service data are stored in HLR. It also stores temporary data from SIM cards like current VLR attachment, ciphering parameters etc. VLR mostly stores current data of each MS under its serving MSC. User authentication keys, confidential data is stored and generated in the authentication center (AUC). Equipment and identity register (EIR) stores equipment information. These servers are important component for security and confidentiality purpose.

- Operation and Management Subsystems (OMSS)

  OMSS is basically network operation center from where a cellular network is maintained and operated. In a nutshell OMSS is responsible for administration of network, security implementation, network configuration, performance management, maintenance etc. All the elements of the whole PLMN (BSS; NSS and its components and also transmission network, connectivity solutions) can be accessed via OMSS.

### 2.1.2 UMTS/WCDMA

Universal Mobile telecommunication system (UMTS) is part of the third generation cellular networks (3G). It uses WCDMA technology underneath and its specifications enables it to provide higher coverage and faster data services. The UMTS architecture mainly consists three domains:

User Equipment (UE)

UMTS Terrestrial Radio Access Network (UTRAN)

Core network (CN)

These components are shown in figure 2.2.

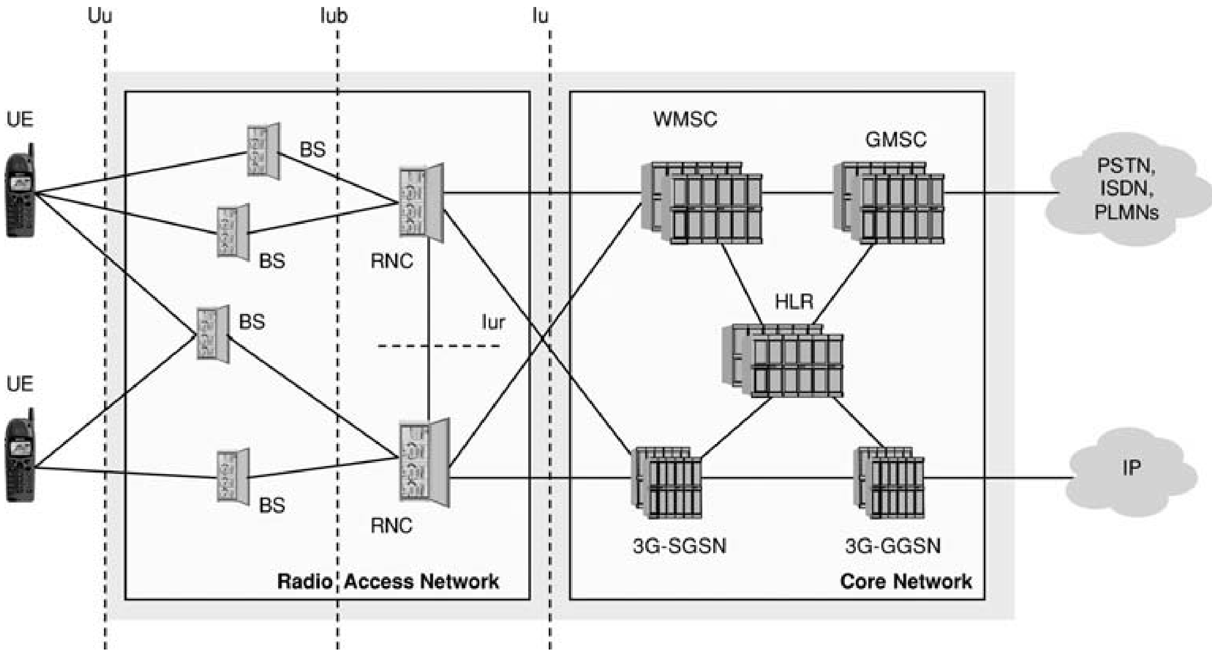


Figure 2.2: UMTS network architecture

The UE mainly consists of mobile equipment. It also includes USIM (Universal SIM) which is necessary to mention here as it is relevant for this thesis work. USIM contains subscription data, identity and authentication information.

The UTRAN part consists base stations (BS or NodeB) and Radio Network Controller (RNC). The NodeB's are like BTS from GSM but differs in some aspects. It provides power control, transmission reception from UE, error correction, etc. RNC is the centre for radio resource management, channel allocation, power control in larger scale, handover control (soft and hard handover), admission control etc. Here each RNC is connected between themselves by lur interface, which was not present in BSC's. The Core network is essentially the same like GSM and mostly based on it. But one key difference is it has to adapted by software to support 3G or UMTS specifications and services.

### 2.1.3 LTE/LTE-A

The need of new and data hungry services has paved to way for the development of 4G/Long term Evolution (LTE). Also improvement in all IP infrastructures enabled low-latency, high-capacity backbone have pushed the cellular technology to adopt new strategy and network architecture. Change in spectrum use policy, emergence of new specifications and scientific breakthrough also played its part to evolve towards LTE.

The architecture of Radio Access network and core network has been completely revisited during the 3gpp standardization of LTE (Dahlman, Erik, Parkvall, and Skold, 2013). This is referred to as system architecture evolution (SAE). In LTE we now see a flat radio architecture (consisting only eNodeB's with gateway) and evolved packet core (EPC). The simplified architecture is shown below in figure 2.3:

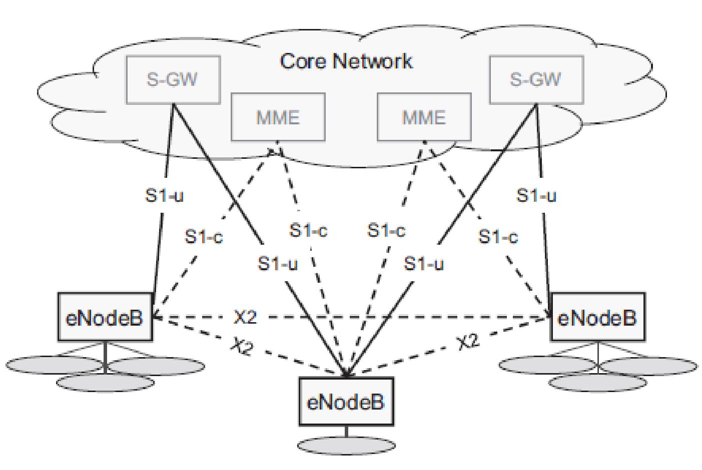


Figure 2.3: LTE network architecture

LTE architecture is simply divided into core and Radio Access part. They are described in brief below:

Core Network:

The EPC is an evolved version of GSM/3G core network with all IP platform, it works only in PS domain. The nodes of EPC can be seen from the figure.

The Mobility management entity (MME) is an intelligent node that performs several core and radio platform of previous networks. Handover functions (bearer control), sleep mode, idle mode to active mode transition handling, security functions are done here. Security key transactions are controlled and supervised in this control plane logical node.

The serving gateway (S-GW) is the first node to direct user plane traffic from eNodeB to the internet via packet data gateway (P-GW). S-GW keeps track of location when users move from eNB to eNB. Charging and statistics information of user data usage is also tracked here. P-GW is the gateway between EPC and internet. QoS maintainance is also directed from here.

Policy and charging rules function (PCRF), Home subscriber Service (HSS) are also part of EPC. HSS is the equivalent of HLR in LTE architecture.

Radio Access network:

eNodeB is the only node that comprises of LTE radio access network which is quite revolutionary compared to GSM and UMTS architecture. All the intelligence of previous BTS/NodeB and some of BSC/RNC level intelligence is crammed into rather small footprint eNodeB. eNodeB is an logical node. eNodeB is connected to EPC by S1 interface. Logically with MME with S1-c and S1-u in user plane to S-GW. eNodeB to eNodeB interface is X2 interface. This interface is important for mobility control and radio resource management functions. ENodeB like its predecessors have cellular architecture and uses normally same frequency bands (900 MHz to 2.5 GHz), but with greater degree of flexibility and robustness (Penttinen Jyrki, 2011). OFDMA and SC-FDMA is the downlink and Uplink modulation scheme from LTE RAN. If we look at these evolution in a diagram, it looks like below figure 2.4, how 3gpp initiatives have shifted technical architecture focus from release to release (Penttinen Jyrki, 2011).

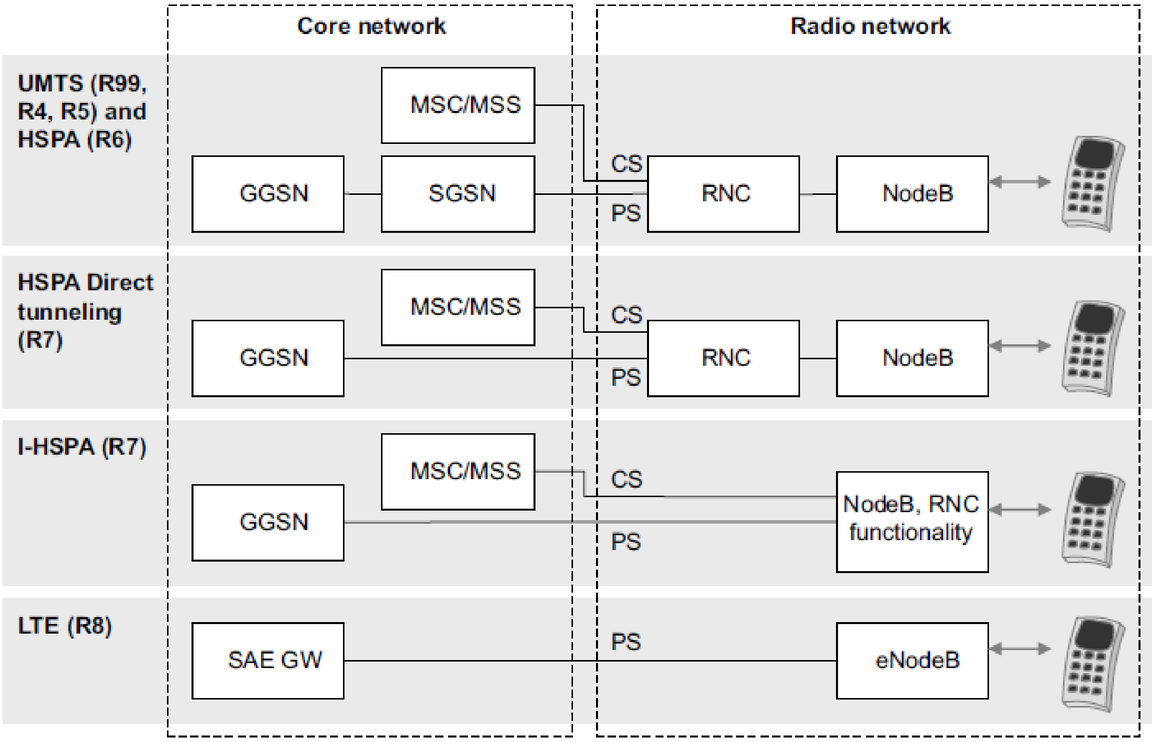


Figure 2.4: Network architecture evolution from UMTS to LTE

### 2.1.4 Cellular network optimization for M2M:

Naturally all cellular network have to adapt for the moderate demand of M2M communication. For M2M application owners cellular network is the most preferred communication medium because it provides possibility for subscription control and E2E visibility of data connectivity, security (Boswarthick, David, Omar and Hersent 2012). Also the coverage of cellular network is huge plus for moving M2M support.

Cellular network needs to be optimized for M2M traffic types. An example of M2M traffic and connectivity requirement is shown in the below figure 2.5:

So the cellular network not only needs to connect the machine to server but also provide D2D connectivity between them. Also operators need to provide M2M service capabilities for its M2M application owners. There are other requirements and scenarios as well. Some are listed below:

- Bulk data communication in case of Device to server case.
- M2M application has to be able to select other M2M peers effectively and easily.
- M2M gateway which aggregates many M2M nodes need to be integrated as well.

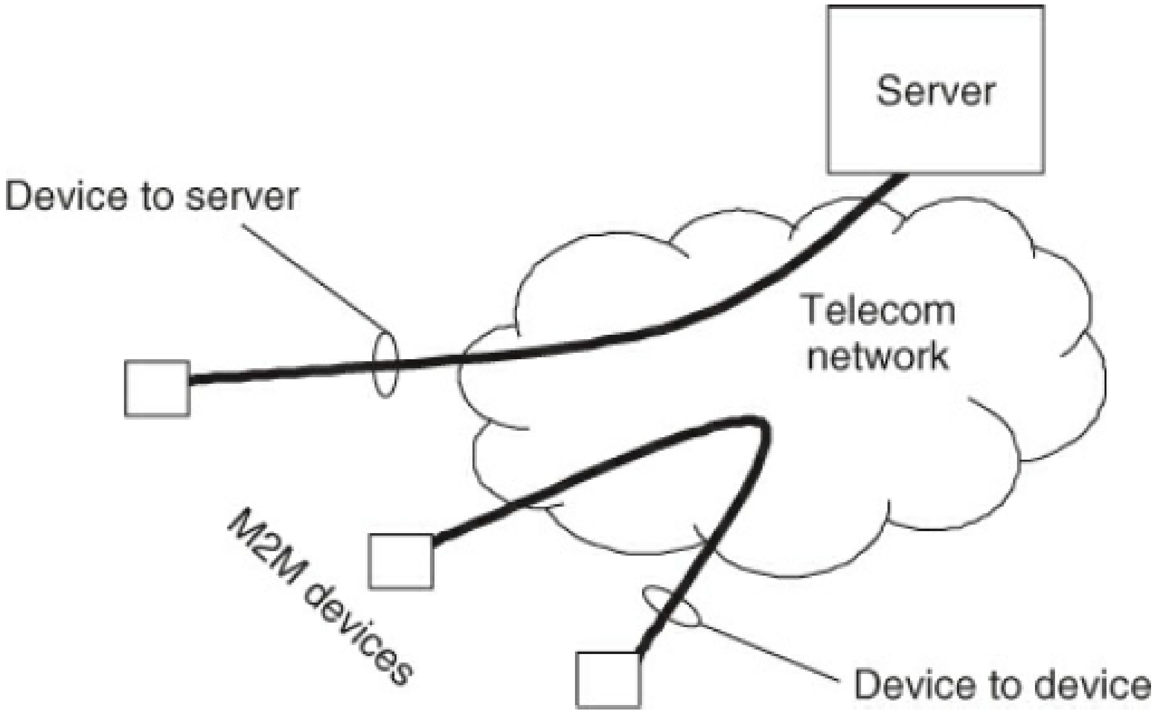

Figure 2.5: Cellular network with M2M communication

- Moving M2M nodes need to be tracked and located efficiently and correctly.
- Connectivity provisioning between fixed networks for domestic M2M applications.
- Provide very secure environment as large number of devices can be under control and can pose potential security threat.
- Free flowing roaming support for cross border M2M services. (such as navigation support).
- Higher data capacity support for real time multimedia based M2M services. (such as video surveillance).

Network optimization for M2M can be divided into 5 different categories (Boswarthick, David, Omar and Hersent 2012):

- M2M data communication is done in a reduced cost to support the finances for large scale device support.
- M2M specific VAS development and maintenance.
- Improved QoS for M2M communication
- Congestion mitigation for mass M2M traffic

- Provide huge capacity for naming, addressing and location services for connected M2M devices.

## 2.2 Introduction to IOT and Machine to Machine communication

Internet of things is addressed as a technological revolution that has the potential to shape the future of communication and the way we live (ITU, 2005). According to ITU-T (2012) definition, IoT is a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual THINGS have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network. It is more like a concept and paradigm that has the objective of enabling 'things' to be connected any time, any place with anything connected in a network (Smith, 2012). However THINGS in the IoT vision may include a wide variety of physical elements like personal objects we carry (e.g. smart phone) or THINGS fitted with tags (e.g. RFID). Such THINGS should have certain characteristics of sensing capabilities, information processing capabilities and communication capabilities.

ITU summarises the key steps for a sensory and intelligent IoT operation. These are (i) item identification (possible through RFID technology), (ii) data collection (by sensor network), (iii) information processing (by embedded intelligence) and (iv) interaction and connection (through miniaturisation and nanotechnology) (ITU 2005). For achieving these functionalities, machine to machine (M2M) communication, wireless sensor network (WSN), radio frequency identification (RFID) and many more technologies are working as enablers (Vermesan et al, 2013). Thus M2M is an integral part of the IoT. The concept of M2M is nothing new rather many niche IoT applications utilize M2M technology for decades. In machine to machine communication a device or a group of devices establishes a bidirectional connection with a business application through communication network for exchanging information. In some cases the group of devices may not directly connected to the application rather connected through a gateway device (Darmois et al, 2012). However the exchange of information should be in an efficient way and may require real time transmission with certain level of latency (Nikaein  Krea, 2011). Alam et al. (2013) addresses M2M as connectivity centric. It focuses on machine type communication (MTC) that involves no human intervention during end-to-end communication of devices.

### 2.2.1 System Architecture of M2M communication

The European Telecommunications Standards Institute (ETSI) proposes a high-level system architecture that provides an end-to-end representation of an M2M system (ETSI, 2013a). In ETSI proposed architecture (shown in figure 2.6) an M2M network has five parts- M2M Device, M2M Gateway, M2M Area network, Communication Network, M2M Applications.

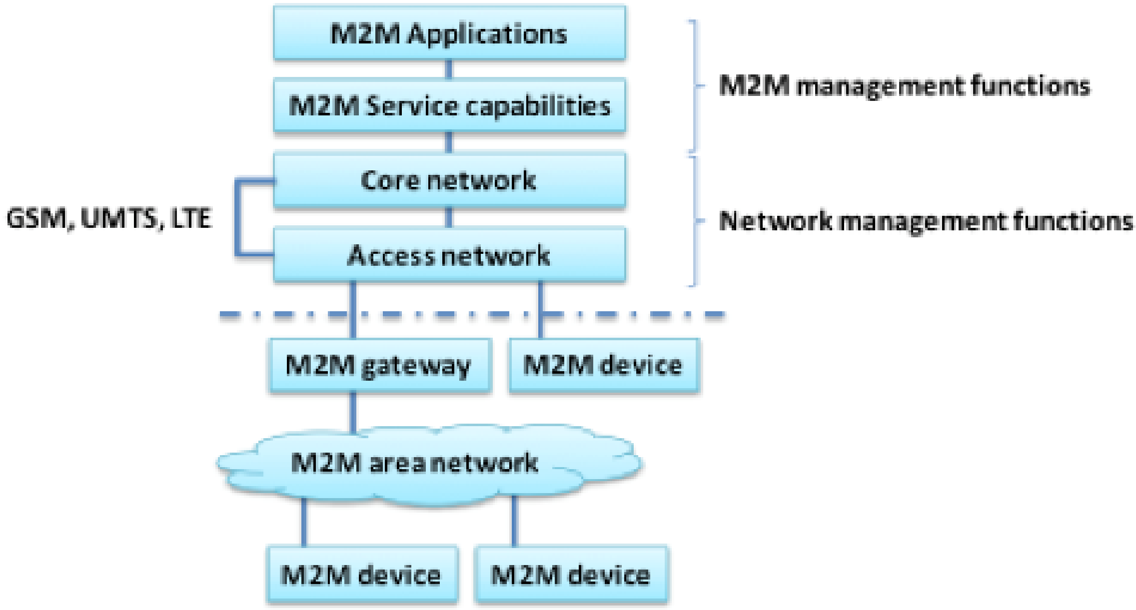


Figure 2.6: Basic M2M functional architecture proposed by ETSI 2013b

M2M device runs one or more M2M device applications using M2M capabilities and network domain functions. Such M2M devices contain M2M communication module for communication part of the M2M device. M2M devices are further embedded in smart devices (e.g. smart meter). Battery powered microcontrollers equipped with computing capability and standard-based communication interfaces (such as WiFi, ZigBee) are used as communication module (Elloumi, 2012). M2M devices can either be directly connected to the M2M core network or a M2M gateway can be used as a network proxy to connect the network devices to network and application domain.

M2M gateway establishes interconnection among the M2M devices by applying M2M service capabilities (ETSI, 2013a). Such a gateway contains WAN communication module and runs M2M application. It may also facilitate some local intelligence to enhance M2M activities.

M2M area network, also known as capillary network is a network of M2M devices and gateways that provides local connectivity between devices and gateways within its coverage using a number of short or wide range communication technologies like Personal Area Network (PAN) or Local Area Network (LAN) technologies in both wireless and wired domain. Examples of PAN technologies include IEEE 802.15.x, Zigbee, Bluetooth. Power Line Communication (PLC) and WiFi are examples of LAN technologies (Elloumi, 2012) .

The communication network can be further divided into three parts- access, transport, core network. xDSL, satellite, GERAN, UTRAN, eUTRAN, WLAN, WiMAX are examples of access network. Core network provides connectivity and network control functions. Moreover M2M service capabilities are exposed through core network. Service capabilities provide functions that are to be shared by different applications, these are software modules that gives specific services as location of a particular device (Elloumi, 2012).

M2M applications is responsible for running the M2M service logic (ETSI, 2013a). An example of M2M application can be utility back-end applications that are used for gathering and processing of smart meter data.

ETSI high level system architecture can also be represented by three domains- Device domain, Network domain and Application domain (figure 2.7).

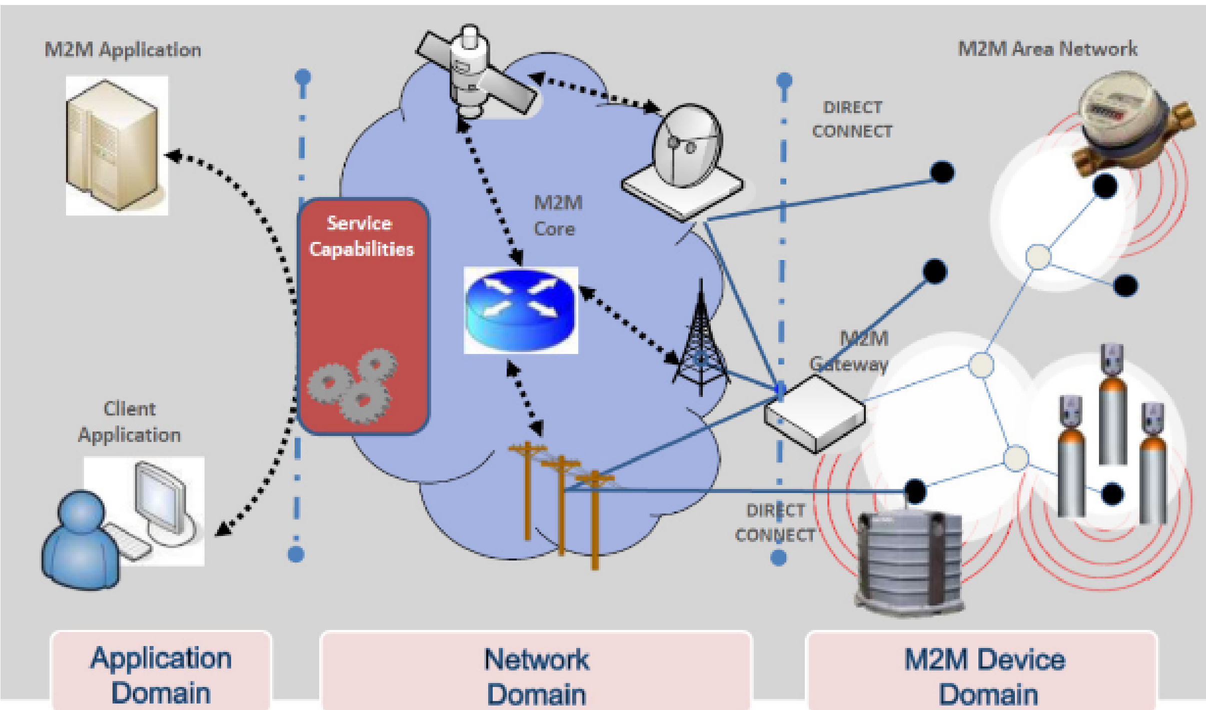


Figure 2.7: Simplified architecture of M2M communication

However ETSI proposed Service Capabilities (SC)s are cornerstone of ETSI M2M work. These capabilities can be exposed to the applications in device domain, network domain or application domain (Elloumi, 2012). ITU-T also proposed such a M2M service layer in their M2M enabled IoT reference model. This layer includes management functions and security functions as well as service and application support functions (ITU-T, 2014).

### 2.2.2 M2M Market

GSMA intelligence (2014) reports about 195 million M2M connections in the year 2013, which shows a 40 percent growth from the year 2010 (Kechiche et al.,2014). This rapid growth in M2M sector is predicted to continue in the future as well. Ericsson (2010) also predicts the number of connected devices will reach 50 billion by 2020. Ubiquitous coverage facility of the wireless communication and decreasing prices of M2M devices along with regulatory requirements fuel the opportunity of mass adoption of M2M across different industries (Viswanathan, 2012).

M2M market is considered as an extension of multiple vertical markets that utilizes M2M technologies. The vertical market segments covered by M2M includes energy, transportation, health care, security and surveillance, public services management (safety and traffic), retail, point of sale, vending, building control / management, industrial automation and control, home automation and control, agriculture and many more (Viswanathan, 2012). However according to GSMA intelligence report (2014) geographic location and regulation have impacts on the adoption rate of M2M services in many industry verticals. Automotive sector is identified as the highest adopted verticals in many regions by many operators while Nordic and southern European market showed much concentration in the energy sector according to this report (Kechiche et al.,2014). Moreover new M2M applications are emerging locally and globally in many new business areas. But this vertically oriented market is fragmented regarding technology, platform, data model and many other things. Interoperability is a big challenge for M2M currently.

Another notable barrier in M2M is the low average revenue per unit (ARPU). ARPU in case of M2M is 10 to 15 times lower than in the case of traditional personal communication (Elloumi, 2012). Because of low ARPU, M2M has a slower growth in the past. But increasingly the revenue generation is shifting from basic connectivity services to more advance value added services (Neeli et. al.). Cross vertical (horizontal) service platforms and enablers are being introduced to reduce cost and bring economy of scale in the M2M market (Kechiche et al.,2014). As the voice revenues reached saturation point, cellular centric M2M draws attention to many players in the industry, specially the mobile network operators. Mobile network operators are trying to improve their position from being bit pipes and bandwidth provider to M2M speciality MVNOs. Gradually mobile network operators are coming forward as M2M service providers by offering new value added services along with connectivity. Many have separate M2M dedicated sales division for corporate customers (Kechiche et al.,2014).

### 2.2.3 M2M ecosystem

A cellular based M2M ecosystem involves many different business entities. All of these entities have different roles in the ecosystem. To understand this ecosystem the relationships among these business entities are needed to be understood.

From manufacturer side the involved entities are SIM vendor, communication module vendor, M2M device vendor. M2M device vendor has business relationship with communication module vendor to facilitate the M2M devices with both short range and wireless communication technologies. In cases where the M2M devices are connected to the network via standalone gateway, vendor or manufacturer of these gateways is also part in the ecosystem. The SIM vendor has direct relationship with the mobile network operator.

In the service provider side of the M2M ecosystem, the players involved can be mobile network operator, mobile virtual network operator, M2M service provider, M2M application service provider, M2M service platform provider. The M2M service provider buys network services from mobile network operator and provide supporting technologies to send the M2M data to M2M application service provider through the network. M2M ASP collects the data and process it. Thus M2M service provider is acting as a bridge between network operator and M2M ASP. M2M service provider has to maintain business relationship with both M2M ASP and MNO. But sometimes the Network operator or some mobile virtual network operator may appear as M2M service provider too. Then the business relationship will be more complex. Moreover the ownership of the M2M device varies in different cases. Thus the M2M ecosystem is not predictable all the time. It may differ from case to case. Different business entities may take multiple roles and a diverse business relationship situation may appear.

As for example, in case of smart metering, the electric utility meters are owned by the utility company and are deployed in the premises of the end users by them. Here utility company is the M2M application service provider or it (the utility company) can deploy some third party company to take that role on behalf of them. This third party may also appear as M2M service provider by ensuring data collection, processing and managing meters through a mobile network, which is owned by a mobile network operator. Thus for bandwidth, M2M service provider needs to have business relationship with a MNO.

The end users here subscribe to the utility service to know their consumption and bill (Boswarthick, 2012).

But unlike the above example, in case of fleet management, the M2M devices are bought, owned and deployed by the end customers. The M2M application service providers are responsible for providing the tracking and scheduling services to the companies, need to track their vehicles. But M2M ASP may not have direct relationship with the companies rather they provide the service through M2M service provider. M2M service provider may be an M2M optimized MNO who uses its own network for data transmission. Zelitron is such a fleet management company which has partnered with Vodafone to offer fleet management services in Greece and Albania. The service platform is developed by Zelitron while Vodafone is responsible for providing the network and data-centre.

Regulators and standardisation bodies are also part of the ecosystem. Regulators enact laws that directly and indirectly influence various technological evolution. A good example is European Union's 20 20 by 2020 regulation (European Commission, 2008) for the EU member states, mandating smart metering for all new home. Such regulation certainly accelerate M2M growth.

Standardization bodies play significant role in the ecosystem by standardizing technologies and allocating resources. Standard solution reduces the chance of market fragmentation and increases the level of interoperability. A market based on good standard ensures balance of power among the entities, which helps the ecosystem to exist. Different standardization bodies work on different aspects of M2M. While 3GPP, 3GPP2 are working on the cellular system and also for service requirements of machine type communication (MTC), ETSI M2M technical committee is working mainly on the M2M service requirements, M2M platform, API. Also standardisation body oneM2M is actively working for standardising a common M2M service layer and its compatible protocols and APIs. They also plan to cover the security and privacy aspect.

### 2.2.4 Barriers in M2M development

M2M development might be hindered by below barriers.

**SIM change and MNO switch**

Some M2M devices require to seal the M2M module and SIM hermetically during the manufacturing process. If the supply chain of such devices are global, then it is not possible to know during the manufacturing time, which country the devices will be exported to or which mobile operator will provide the communication facility. The end customer should have the facility of activating the device anywhere around the globe. And even if the devices are deployed locally or the SIMs are removable, the customers are bound to use one mobile network operator for the end of the device life cycle to avoid cost of removing the SIMs. Sometimes the devices are located in remote and hazardous areas. Thus customers are unable to change the SIM or the mobile network operators in current scenario.

**Delay in standardization**

The M2M solutions present in the market, are mostly proprietary. Lack of interoperability among these proprietary solutions are acting as an impediment for M2M growth. Only standard solutions can stop this fragmentation. Moreover a standard reusable service platform for multiple applications can solve the 'silo' problem in the industry (Elloumi, 2012).

**Security and Privacy Issue**

In many cases, the M2M devices are left unguarded and these can be misused. Such fraudulent case occurs when the SIM is removed from the M2M device and is used in some other smart devices for browsing at a comparatively lower rate offered to that M2M customers by the network provider. This situation can further create unwanted volume of traffic in the network. Presently, the network providers permit any SIM carrying devices to access their network and there is no means to differentiate whether the SIM is used by a smart device or a M2M device. And even if the SIM is guarded and not removed, still passive medium overhearing security issues may happen (Viswanathan, 2012).

Moreover many M2M applications handle confidential user data which require special privacy measurement.

**Numbering and Addressing Issues**

IP addresses (IPv4, IPv6), telephone numbers (E.164), IMSI numbers (E.212) are the three numbers that M2M devices need to work in a mobile network. Based on a research conducted on the member countries of the Electrical Communication Committee (ECC), within the European Conference of Postal and Telecommunication Administration (CEPT), it was revealed that some countries might not be capable of accommodating E.164 numbering requirements for M2M applications in the future. ECC/CEPT also proposed solutions like opening new number range and reorganising the existing numbering plan.

Already Norway has started a completely new number range for M2M application to solve future E.164 number exhaustion problem (ECC, 2010). Usually the public telecommunication providers in a country are assigned with E.212 and E.164 numbers. But different countries have different rules for defining the eligibility of the authorities availing these numbers. As for example in many countries an MVNO is not eligible to have their own E.212 numbers and as a consequence not eligible to make roaming agreements. Assigning these numbers to private organisations may lead to a more dynamic number and increase competition (OECD, 2010).

## 2.3 SIM technology evolution

Among the versatile range of smart card applications, the most widespread and successful smart card application is the use of SIM cards in mobile telephony system. This tamper-resistant microprocessor based smart card is considered as a ubiquitous authentication and security token in every mobile station (MS) of GSM mobile telecommunication system (Richarme, 2008). Also SIM provides portability feature, i. e. it allows the user to remove it from one MS and insert it into another. The term SIM or Subscriber Identity Module generally refers to both the physical card and the software resides on it when it was first designed. It was an integrated circuit card (ICC) which was able to contain only one SIM application. Later 3GPP standards organisation introduced a new SIM application USIM for UMTS. They further named the physical part of the smart card as UICC (Universal Integrated Circuit Card) (Richarme, 2008). A UICC is capable of containing multiple applications of similar kind namely SIM (for 2G), USIM (for UMTS), ISIM, CSIM. UICC is the reliable universal application delivery platform that is capable of working with any 2G, 3G, 4G devices considering that it contains the appropriate SIM application. The evolution is shown in figure 2.8

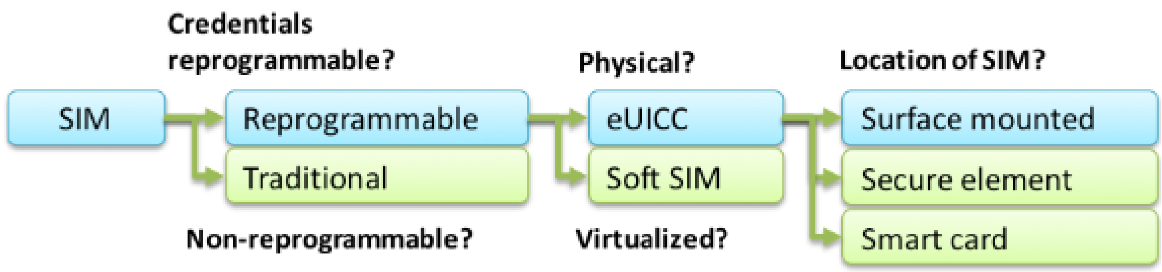


Figure 2.8: SIM card evolution path(CSMG, 2012)

In this thesis paper the term SIM is used to mean UICC and along with its resident application.

### 2.3.1 Architecture and Data

The traditional SIM cards are based on the SIM card technology from the 1990s. The microprocessor in the SIM has no clock or built in power supply. It has a CPU (Central Processing Unit), three types of memory (ROM, RAM, EEPROM) and the interconnecting circuitry (Markantonakis, 2007). The memories have their individual packing density, i.e. no. of bits per silicon area. The Read Only Memory (ROM), sometimes called the chip mask, contains the operating system of the SIM, well tested common functions and constant data. These data can only be written to during the card production time. The Random Access Memory (RAM) is usually used for dynamic storage of program run-time variable. The Electrically Erasable Read Only Memory (EEPROM) can be programmed even after the manufacturing. Thus it is suitable for storing user data, user programs that require modification during operational life of SIM card. In traditional SIM, operator profile information (keys, algorithms etc) and some subscriber data is kept as read-only during manufacture to prevent fraudulent activity. However some data like PLMN list, last dialed numbers are reprogrammable and updatable by user and MNO (Markantonakis, 2007).

In the earlier version of SIM card, the underlying software platform included some basic program routines to manage a controlled communication between the card and the outside world. But with the advancement in smart card processing power, a need for a good smart card operating system, capable of running various application programs, becomes prominent. But as smart card applications were microprocessor specific, portability became a problem (Markantonakis, 2007). However introduction of multi-application smart card platform like Java card, GlobalPlatform solved the portability problem. Such platforms can work with any underlying smart card operating system thus ensure interoperability. The file system in SIM is a hierarchical one, consisting of a root level known as the Master file (MF), directories as Dedicated files (DF) and individual records as Elementary files (EF). Usually the EFs contain general information about the smart card , e.g. the unique Integrated Circuit Card ID (ICCID) (RanklEffing, 2010). The EFs may have transparent, linear fixed or cyclic file structures shown in below table 2.1:

| Transparent | Linear Fixed | Cyclic |
|---|---|---|
| A single block of data | Many records, all are the same length | Many records, all are the same length |
| Used for most files | Used mainly by the Phone-book | Used for Last Number Dialled |

Table 2.1: Linear Fixed or cyclic file structures

Every provisioned SIM contains several required files and those files consequently contains various important data fields. Examples of such data fields that are used for identification are IMSI (International Mobile Subscriber Identity), MSISDN (Mobile Station International ISDN Number) and ICCID (Integrated Circuit Card ID). These files can be accessed through a hierarchy of PIN codes. For particular access, a PIN code must be verified first. If the verification failed, the PIN may become blocked after a certain number of wrong tries. In that case a PIN Unblocking Code (PUK) may be used to remove the block (RanklEffing, 2010). However network operators use Over The Air (OTA) mechanism for remotely accessing the SIM files (Markantonakis, 2007).

### 2.3.2 Function of a SIM

Figure 2.9 shows the basic functions of SIM in GSM system. In addition to provide subscriber identification and authentication of the mobile station to the network, SIM ensure storage of various data like dialling numbers, text messages, personal configuration settings for mobile phone. Also SIM provides various value added services through SIM Toolkit (now called CAT, Card Application Toolkit).

### 2.3.3 Details of Subscriber Identity and Authentication

SIM authentication checks whether certain user is allowed to access the network. The three items that are used in authentication are IMSI, the secret key Ki, the authentication algorithm A3. IMSI is a 64 bit unique identifier in the SIM. The 128 bit secret key Ki is stored in tamper-resistant manner in SIM. The key is generated randomly and individually for each card during the manufacturing process. The algorithm used is not standard rather chosen by the network operators. But the function of the algorithm and the messages required to run the algorithm are standardised (Markantonakis, 2007). When the mobile phone is turned on with a SIM inserted, it attempts to read information from the SIM. The phone is able to read the IMSI if the user does not enable PIN lock. Otherwise the user has to enter his PIN to start up the phone. Basically there is a message exchange between the mobile and the server. Mobile requests for network use by sending the IMSI over a radio signalling channel. Network on the other hand generates a 128 bit random challenge (RAND). With the RAND the network calculates a 32 bit expected response (XRES) using A3 function and also a cipher key (K) using the A8 function. The network

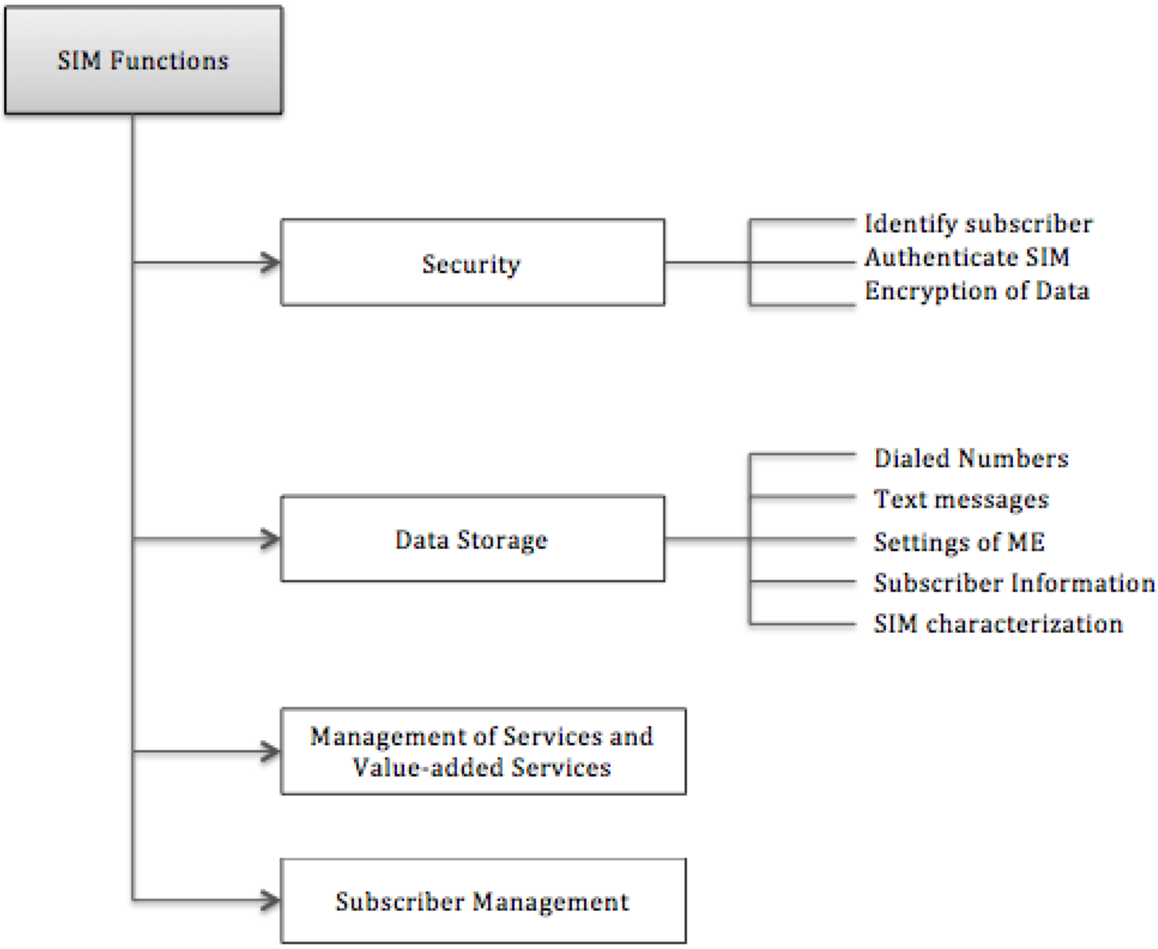


Figure 2.9: Various Functions of SIM card in GSM System (Rankl & Effing, 2010)

sends RAND to the mobile phone that passes it to the SIM card. The SIM card in return prepares a 12 byte of response data containing 4 byte subscriber response (SRES) and 8 byte cipher key (Kc) calculated by the SIM in the same way the network calculated it. The mobile sends the result to the network generated by SIM card. If SRES is matched with XRES, the mobile phone is authenticated and allowed to access the network. One important thing in this authentication mechanism is, that the secret key Ki is never transmitted over the radio channel. Moreover functions A3 and A8 are designed in such a way that it is not possible to determine Ki even if RAND, SRES/XRES and Kc are hacked somehow (Markantonakis, 2007).

### 2.3.4 Traditional SIM Lifecycle

Mobile network operators are the issuers of SIM cards. Though the customers pay for the cards, the cards still belong to the Issuers. Issuers want to retain management rights so that they can control the offering of data and functionality which will ultimately affect their network. The ownership of SIM cards are very crucial for them from both business and security perspective.

Usually an issuer gives required information along with desired electrical, graphical features and agreed profile specification to the SIM card vendor who would then implement the necessary functionalists for producing and delivering the cards. The implementations may be proprietary and it may vary from vendor to vendor. The steps involved in SIM card production include manufacturing of the card body and personalisation of the cards according to operators need. The card body manufacturing includes making the plastic, printing and adding additional elements, followed by embedding the smart card module, testing and initialisation (Markantonakis, 2007). The details of manufacturing are not relevant to this thesis work and will not be discussed in detail.

The personalisation of the cards is done based on the data provided by the issuer and this procedure ultimately produce an individual product for the end customer. The Mobile network operator who is the issuer here, provides required information like ICCID and IMSI to the SIM card vendor. These data usually enters the SIM card via ISDN dial-up data connections or encrypted channels over the Internet (Markantonakis, 2007). Using tapes or other media can also be an option. The data must be encrypted before transmission and decrypted after being transferred to the production network. After decryption validation takes place before generating additional data for the issuer. The additional data include values for keys (e.g. the Ki, OTA keys) and secret PIN and PUK codes. These must be generated with a random generator or are derived by using certain MNO keys and calculation methods. Afterwards issuers are given response files, containing all the generated values. The Issuers or MNO then load the data regarding the card into their system, e.g. HLR/ AuC, OTA servers (Richarme, 2008).

The packaging and distribution of cards are either handled by the SIM card vendor or some other company. SIM cards are then distributed to the retail shops. Post-paid subscriptions are activated and assigned an MSISDN when the subscription is sold where is prepaid subscriptions have pre-assigned MSISDN and are pre-activated (Richarme, 2008). Once the SIMs are in the field, MNOs are able to perform small management operations (like updating the PLMN list or re-branding of the operator name) using the OTA platform. Most SIM card vendors provide OTA platforms to the operators. MNOs also provide various differentiating value added services to the customers using SIM Application Toolkit (Richarme, 2008).

**Form Factor**

The need of saving space on devices has introduced changes in SIM size. The first form factor 1FF or the full size frame has now become obsolete. The second form factor (2FF) has the same thickness as 1FF but the length and width have been reduced. this form factor, also known as Mini SIM is most popular and widely used. Form factor 3FF, known as micro SIM was first used by Apple in their iPhone 4 handset (Rankl  Effing, 2010). The last addition in the form factor is the nano SIM, again introduced by Apple, is 40 percent smaller than the micro-SIM.

Moreover due to widespread development in mobile based M2M communication ETSI standardised SIM solutions specially for M2M devices. The M2M Form Factor 1 (MFF1) uses a socket-able eight pin component, and the M2M Form Factor 2 (MFF2) is a non-removable housing that is soldered on a printed circuit board (ETSI, 2010). The various form factors and their dimensions can be seen from figure 2.10


Figure 2.10: SIM form factor comparison

The traditional SIM has evolved to meet operator and end user needs by ensuring interoperability, secure functionality and flexibility. But technological advancement increases the demand and use scope of SIM technology to a different level. Thus the SIM evolution has become a continuous process.

### 2.3.5 Evolution towards eSIM

The M2M form factors are smaller in size and more durable and tolerant to various operation conditions like temperature, vibration or humidity. But in many cases mobile based M2M communication demands changing the operator without changing the SIM. None of the current SIMs (traditional or M2M) provide this feature. However changing MNO without changing the SIM involves provisioning of MNO credentials remotely over the air. As an option for this the use of virtual SIM has been discussed in the industry. But MNOs addressed such solution as a security threat for their confidential credentials rather they proposed tamper proof hardware based SIM solution. Though the demand for remote provisioning was addressed earlier, but the standardisation work is still going on. The European Telecommunication Standards Institute (ETSI) published their first technical specification with use cases (ETSI, 2013). However Groupe Speciale Mobile Association (GSMA) also published their work on Embedded SIM Task Force Requirements and Use Cases (GSMA, 2011) and Remote Provisioning Architecture (GSMA, 2013). GSMA (2011) proposed the remote provision enabled solution as embedded SIM (eSIM) which they define as a trusted hardware component, may be soldered into mobile device (as per MFF1, MFF2), capable of running network access application (e.g. USIM application) and facilitate secure changing of subscription identity and other subscription data (GSMA, 2011). Thus embedded SIM does not introduce a completely new hardware component. It can be categorised as a reprogrammable, physical and surface mounted element. According to GSMG (2012) report the other suggestions for reprogrammable solutions include virtual SIM, a separate secure element or a reprogrammable smart card solution.

### 2.3.6 Embedded SIM Remote Provision Architecture

GSMA document specifically mentioned that the solutions mentioned are targeted for M2M devices only. Figure 2.11 shows eSIM remote provisioning architecture proposed by GSMA.

GSMA suggests that eSIM will be installed in the M2M device during the manufacturing time of the M2M device. And the eSIM will contain the required credentials of an MNO which will enable the M2M device to connect a network and download the user selected MNO credentials. The eSIM issuer will need to establish a contractual relationship with the MNO providing the initial credentials. However remote access to the eSIM is managed by a Subscription Manager (SM) on behalf of the eSIM issuer and the eSIM

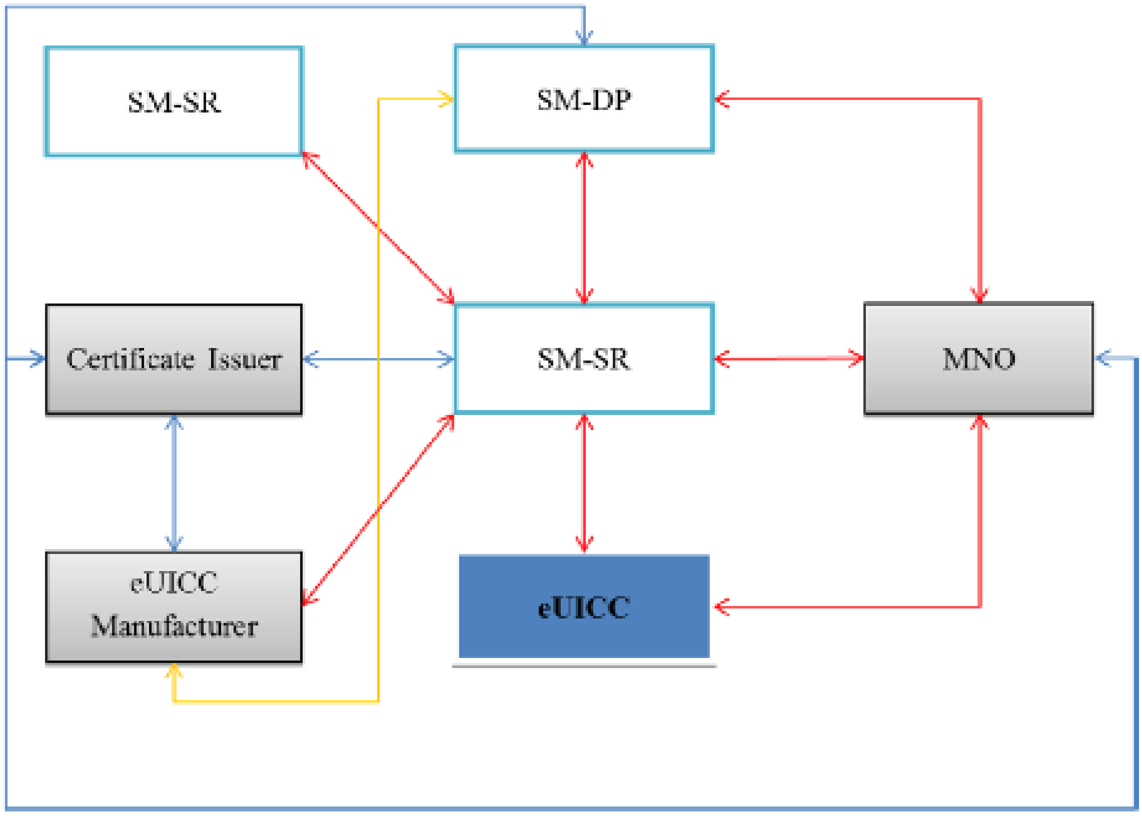


Figure 2.11: eSIM remote provisioning system(GSMA, 2013)

will also contain a Subscription Management client. The SM role can be further splitted, Subscription Manager- Data Preparation (SM-DP) and Subscription Manager- Secure Routing (SM-SR). Once M2M device will be distributed to the customer, customer will make a contractual relationship with his chosen MNO. The chosen MNO will contact with associated Subscription Manager. Subscription Manager will be responsible for preparing and encrypting the appropriate MNO profile, containing the credentials and further will securely delivered to the eSIM. The eSIM SM client will decrypt and load the new MNO profile. Later this MNO profile will be activated and asct as the operational MNO profile (GSMA, 2013a).

### 2.3.7 Embedded SIM Card Architecture

GSMA considers GlobalPlatform specification as a framework for the implementation of eSIM (GSMA, 2013a). As mentioned earlier, GlobalPlatform card specification (GPCS) defines a set of logical components that enhance multi-application smart card interoperability and security. It can work independently on the underlying smart card platform (Markantonakis, 2007). Figure shows a schematic representation of the eSIM according to Global Platform .

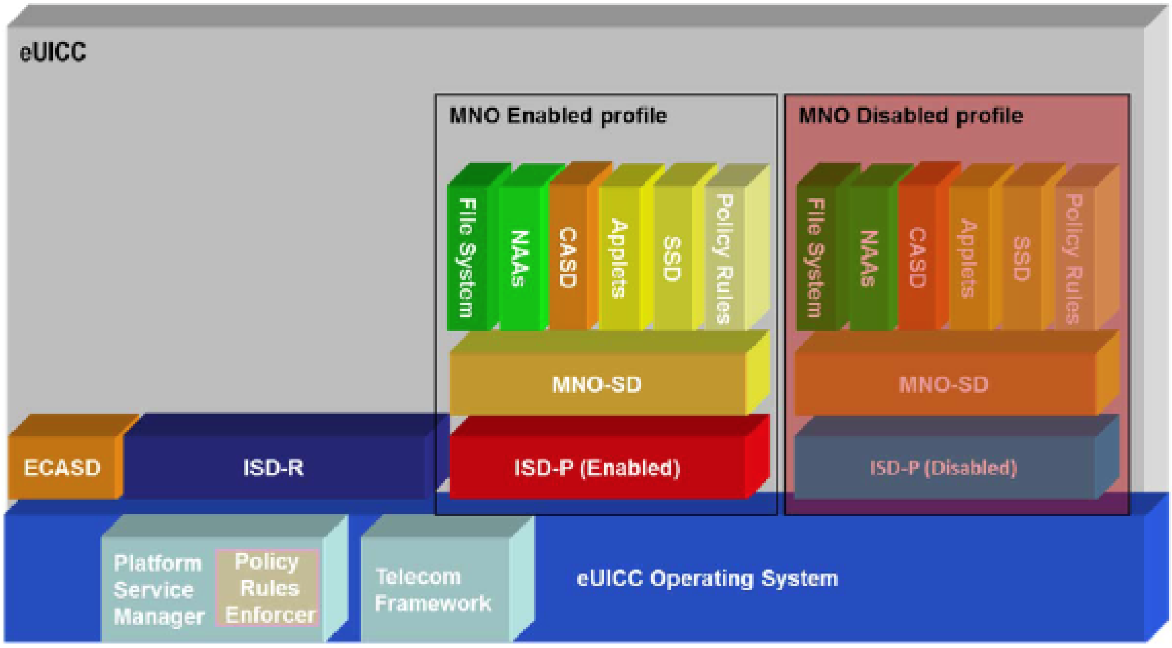


Figure 2.12: Systematic representation of eSIM(GSMA, 2013)

At the bottom is the operating system (OS) that contains the basic platform features. GlobalPlatform also introduces the notion of security domains. Basically these are privileged applications. They are the on-card representative of the off-card entities, capable of initiating secure channels and handling content management functions. Security domains can also receive information from an application. In this eSIM there are three kinds of security domains can be noticed- the issuer security domain (ISD), the MNO security domain (MNO-SD) and eSIM certificate authority security domain (ECASD). Each of these security domain contains confidential data and specific access privilege which ensure the security of the data (GSMA, 2013a). eSIM brings change in the SIM life-cycle

The traditional SIM life-cycle has been discussed elaborately earlier. Fig 2.13 shows a comparison between the traditional SIM life-cycle and eSIM life-cycle. It has been seen from the figure that eSIM personalisation is divided in two phases. After the pre-Issuance part the life-cycle does not follow a linear model rather the eSIM can be provisioned again whenever a new MNO comes into the scene. Thus the re-usability of eSIM makes it very different from a traditional SIM.

Few industry players started to test and demonstrate eSIM concepts. Though the standardisation is not fully standardised, these tested solutions are mostly proprietary. One notable demonstration is done by Telefonica in November 2011. Telefonica managed

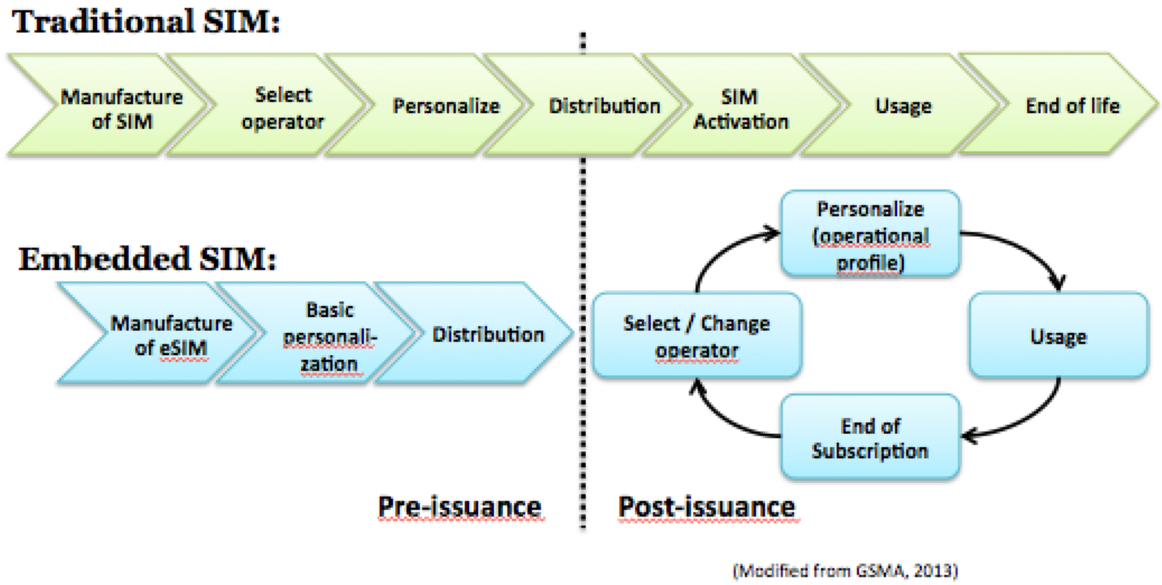


Figure 2.13: Life cycle of traditional SIM and eSIM

secure transfer of an M2M subscription from Telefonica Spain to Telefonica UK, using a pre-standard solution (CSMG, 2012). The solution used subscription management enabled custom SIM card and a subscription management platform developed by Giesecke & Devrient and Telefonica deployed management portal. The test included subscription install, deletion and transfer. Samsung and Telit wireless were also participated as partners. Recently, AT&T has announced a global SIM solution which they claim to meet GSMA specification of eSIM. Global device vendor Apple also recently announced their new Ipad with new Apple SIM. It comes with a new feature of choosing from a pool of MNOs and utilize local tariffs while travelling outside of one's country. Though the technical way outs are not clear at this moment but this feature is one of the important drivers behind the idea of eSIM. All these changes in the industry can be considered as significant steps towards the evolution of eSIM.

# Chapter 3

# Theoretical Framework

This chapter introduces the theoretical framework that are used in the thesis work.

## 3.1 Scenario Planning

Scenario planning is a disciplined method for capturing a range of possibilities for imaginable futures a company may have.

Historically scenario planning has been used in many diverse use cases (Smura et. al 2009). It is used from war game simulations to business strategy making and nevertheless in ICT sector. Scenario planning is a strategy making tool to do long range business planning when there are still considerable uncertainty is present. Recently scenario planning method have gained popularity in fast paced ICT industry to predict the future outcome by calculated construction of several scenarios. These scenarios are not built with pure guess work, it is built up solidly taking into consideration some trends that are almost surely going to happen and some major uncertainties that is going to shape up the different scenarios. Then the resulting different combinations of future trends and uncertainties builds up to the future scenarios.

Scenario planning is originated from war game simulation of Rand Corporation in 1950 (Schoemaker, 1993). Also as indicated before in ICT business it has good amount of involvement, which was started by Karlson et al. (2003), who made assumptions of four scenarios involving the growth of wireless industry from 2003 to 2015. Others also followed the suit to use scenario planning to evaluate the future of many new technologies. As for example Tapio et al.(2009) used scenario analysis to evaluate the future of Internet.

As we pointed out above that scenario construction have two major elements. First one is trends, which are earmarked by industry knowledge base as certain to happen in the future. The other element is called uncertainty, which are important elements that can go one way or another. Uncertainties can not be predicted. They go to different directions in different future scenarios. Or uncertainties are the reason why we see different scenarios form.

Scenario planning can be constructed according to some predetermined rules (Van der Heijden, 1996 ). Firstly, there can be two to four scenario to avoid simplification or complexity. Scenarios must be realistic and consistent with the matter in hand. Scenario must provide new ideas which can be used in the next strategic planning.

Scenario planning is not a future forecast (Schoemaker, 1995) but it acts as a tool which develops understanding about future possible outcomes. Schoemaker described ten steps for scenario planning method. These are :

| | |
|---|---|
| Scope definition | Set time frame and scope of analysis |
| Identify major stakeholders | who is interested? |
| Basic trends identification | what is sure to happen (Political, economical, social and technical) |
| Key uncertainty identification | uncertain events that will shape the future (again political, economical, social and technical) |
| Initial scenario theme construction | put the main uncertainties and trends together |
| Consistency and plausibility check | polishing the initial scenario outcomes |
| Develop learning scenarios | finding most relevant and consistent scenarios |
| Identify research needs | further research on scenarios |
| Develop quantitative methods | analysis of scenarios according to quantitative models |
| Evolve to the final decisive scenarios | Finalising the scenarios |

Table 3.1: Schoemaker's scenario construction method

At the end the constructed scenario can be used by industry experts to have a better understanding for the planning ahead in future.

## 3.2 Value Network Configuration

Value configuration models are used for a better understanding of the firm level value creation logic (Stabell and Fjeldstad, 1998). Stabell and Fjeldstad (1998) introduce three value configuration models, each based on a different value creation logic and a so called primary technology. Among these three models, value network is based on the value creation logic of linking customers to each other, and it is based on the mediating technology (Thompson, 1967). Mediation refers here to network based activities that help in supporting the value creation logic of linking customers to each other (Thompson, 1967).

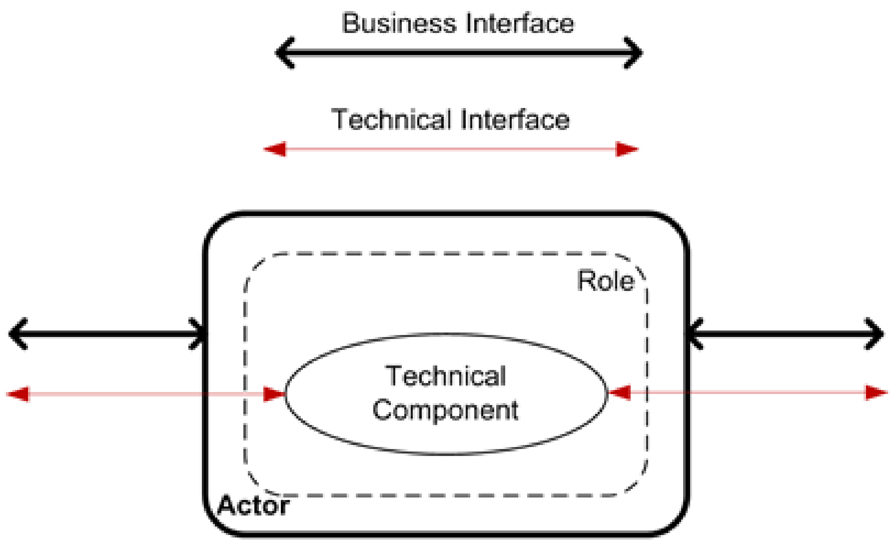


Figure 3.1: The VNC block and its interfaces (Casey et al., 2010)

Along with the de-materialisation of the offered products or services, and the value distribution channel, the value network proves its importance in the analysis of the industries that show strong co-operative behaviour (Peppard and Rylander, 2006). (Peppard, Joe, and Anna Rylander, 2006, p.6). The value network concept focuses on the co-produced value of different economic actors who are interconnected in a network. Stabell and Fjeldstad (1998) mention three primary activities of value network. These are network promotion and contract management, service provisioning and network infrastructure operation. Both internal and external value networks exist. According to Allee (2008), internal value networks describe activity focused sets of relationship between individuals in an organisation. External value networks, on the other hand, describe the relationship between the organisation and its suppliers, investors, business partners and customers (Allee, 2008).

This study adopts the value network configuration (VNC) approach presented by Casey et al. (2010). Casey et al. (2010) describe the VNC as results produced by actors, who perform in their corresponding roles by establishing technical and business interfaces with each other.

# Chapter 4

# Scenario Planning

This chapter discusses the construction of scenario for future eSIM ecosystem. The results obtained are key uncertainties, key trends and first four different scenarios according to the trends and uncertainties.

## 4.1 Scope, Time frame and Major Stakeholders

The scope of the study takes eSIM based M2M services into consideration mainly. For this the potential European M2M market is certainly an ideal place to start. Time frame has been chosen to be 10 years.Though the life cycle of many M2M services can be up to 15 to 20 years or more, technology evolution is way faster. Keeping this in mind, 10 years time frame is selected which is long enough to get an overall view of the emerging technology to be established in the market but reasonable enough to consider possible technology shift to happen.

eSIM based M2M services involve a wide range of stakeholders namely SIM vendor, communication module vendor, device vendor, mobile network provider, system integrator, M2M service provider, application service provider, regulator, legislator.

## 4.2 Key trends

Key trends are identified after analysing the outcome of interviews from industry experts and brainstorming sessions.These trends are almost certain to happen in future and have significant impact on the eSIM and M2M ecosystem. Initially a host of key trends were identified but after careful discussion and analysis the main key trends are selected for the future scenario construction. These trends are discussed in detail below:

**M2M traffic increasing (indoor and outdoor)**

In general cellular M2M devices generate low data volumes. But with the advancement in cellular network communication in the next ten years, IP based LTE will certainly make M2M deployment an easy and affordable option. The fast M2M adoption rate is thus showing clear sign of escalating M2M traffic. In various statistics of expected cellular traffic growth, M2M traffic occupies a significant part. This increase of this traffic is both in indoor (home, office etc.) and in outdoor (roads, park, remote desert etc.).

Moreover the growth in M2M traffic will vary by taking geographical scope into consideration. The international roaming traffic will be small compared to the large national M2M traffic, which is a forecast of industry experts obtained from interview and brainstorming sessions.

**Number of M2M devices increasing**

According to Machina Research, cellular connections will increase to 2.6 billion by 2022 and 22 percent of this will be due to M2M (2012). GSMA also reported 1.4 percent increase in M2M connections from 2010 to 2013. In 2014 the number of M2M connections are forecasted to be 250 million. Moreover increasing percentage of M2M connections in the total cellular connections indicates a progression in the M2M market maturity. Many driving forces are working behind this increase in M2M connections. Wide coverage by advance radio technology, low price of communication module due to continuous development in semiconductor arena are some of the worth mentioned driving forces.

Also regulatory initiatives and government requirements in some region of the world accelerate M2M adoption in the past few years. Two examples can be mentioned regarding this. The first one is European Union issued mandate on smart metering and the second one is eCall project of European commission. Both of these will facilitate massive M2M deployments.

**M2M related big data increasing**

The huge number of connected M2M devices is potential source of 'big data' that can be used to increase both quality of experience and revenue. Application of data analytics can be a useful tool for improving performance in many niche M2M namely smart grids, health-care, automotive and smart homes.

Many software vendors along with leading telecoms vendor like Ericsson, Nokia Solutions and Networks and Huawei are showing interest to offer big data and analytics solutions to enterprises and telecom operators for their M2M solutions. But there are challenges like privacy issues, security and authenticity handling and efficiency problem in this comparatively new sector (Machina, 2013).

**MNO-switchable eSIM for M2M devices (Later in all devices)**

It has been already mentioned that many M2M devices are deployed in systems which are not easily accessible. Changing the SIM for subscription switch or provisioning is not a suitable option. Thus M2M is driving the demand for embedded SIM. Already M2M form factor MFF1 and MFF2 are dedicated for using as embedded SIM (eSIM) in M2M modules. But the adoption of eSIM is likely to start from M2M and gradually it will be used for all other mobile devices.

Apart from the ease of access issue, the main characteristics of eSIM is remote provisioning. And this remote provisioning facilitates the eSIM use for M2M devices. It is not so important for H2H devices to have remote provisioning. This is another indication that eSIM will first come to M2M devices not in consumer mobile devices.

**MNOs forming global M2M alliances**

For offering unified services across multiple geographies, MNOs are motivated to be part of global M2M alliances (GSMA intelligence, 2014). Global M2M Association, M2M World Alliance, Bridge M2M Alliance, Vodafone and its partner markets these are few examples of such operator alliance. Most of these alliances have an offer of 'global SIM' which is commonly usable in the partner MNO's mobile networks. While such alliances are mostly offering global M2M support, some MNOs are maintaining different solutions for their local M2M business.

Moreover these alliances in many cases are forming around a single operating platform from specialized global platform providers like Ericsson and Jasper Wireless. Few large operators join in multiple platforms (Telenor using platforms from both Ericsson and Jasper). MNOs in the alliances are also making partnerships with multiple providers from the value chain to achieve quick capabilities to enter the market.

These alliances may have significant influences in standardising M2M solutions.

**Cloud computing driving centralisation**

For escalating economies of scale in the low-ARPU M2M business, the M2M service providers are being attracted to cloud based platform solutions. Such Internet based architecture both reduces capital expenditures and operating expenses. A significant number of global platform solutions are now cloud based. The device connection platform solutions from Ericsson is a perfect example of cloud based platform solution. Alliances are formed around such cloud based platforms. In other words, these cloud based platforms are appearing as the centre of M2M ecosystem.

**Diversification in offered services**

M2M can be considered as an extension of multiple vertical markets exploiting the benefits of M2M communications. M2M covers a wide range of applications namely health-care, transportation, energy, security and surveillance, public services management, retail, point of sale, vending, building control/ management, industrial automation and control, home automation and control, and agriculture. Even the communication technologies used for these applications can be very diverse. This wide variation in the M2M applications and communication technologies makes interoperability very challenging option and it is hard to generalise M2M.

**Regulator pushing competition for EU mobile roaming**

Though there is no separate M2M roaming regulation but the existing EU roaming regulation keeps pushing competition for the mobile operators. According to EU roaming regulation III, which is affected from July 2014, European customers can buy roaming package from alternate roaming providers (ARP's) regardless of their domestic service provider (DSP). And the customers can use the same SIM and mobile device. This regulation certainly increases the competition for mobile network operators while offering the customers a low roaming price.

Moreover European parliament adopted a package in April 2014, which mentioned about permanent removing of roaming cost in EU zone. But that law will still take some time to get into effect.

## 4.3 Key Uncertainties

The key uncertainties are the issues with an uncertain impact on the emergence of the eSIM in the M2M market. The key uncertainties were formed in similar vein with the basic trends. They are based on the information obtained in the brainstorming session during the interviews and discussion sessions. After collecting ideas for uncertainties, feedback on them was used for selecting the two most important key uncertainties. The choice was validated throughout the interview sessions with interviewees and brainstorming session members.

Here, all the potential uncertainties are discussed. Later on for scenario construction two most important uncertainty is crossed.

**eSIM impact on the level of national MNO-MNO competition: Low vs. High**

Cellular based M2M will presumably have bigger volume in the national level than volume in the international level. This will create competition among the local MNOs. But deploying eSIM may generate variation (Low vs High) in this competition. As for example, regulation can play a very significant role to explicitly control this situation by imposing weak or strong restriction on the remote subscription or operator switching rules. If the remote subscription or operator switching is kept flexible and easy the operators will have to offer better tariff and other facilities than its competitors to retain customers. This will create a highly competitive market for the operators.

**International M2M service provider: MNO family vs. Non-MNO's**

It has been mentioned already that the geographical scope of M2M can both be local and global. Use cases like fleet management generate both local and global traffic. In such cases M2M service provider needs to provide wide coverage both in home and abroad. There may be two solutions to handle such traffic, MNO family or Non MNOs. Usually the local MNOs work with some big global MNOs. As for example Elisa one of the leading MNO in Finland is part of big Vodafone family. Being a part of such MNO family comes with the advantage of offering your customers with wide geographical coverage. Other options can be the non MNO third parties who can ensure global coverage to the customers by providing a common platform for its alliance MNOs. These third parties can be global giants of device (apple) or Internet (google) (OECD M2M report 2012) who can provide M2M service internationally with partnership of MNO's.

**eSIM initial provisioning provider: Non-profit MVNO vs. other MVNOs**

eSIM initial provisioning can be done either by regulatory specified non-profit organisations or by commercial parties. If this is done by non-profit organisation, customers are likely to be benefited with reasonable price for initial provisioning. In case of MVNO provisioning, customers may face high charge. Another usefulness of Non-profit MVNO is they can be closely monitored by regulators, so any chance of mismanagement is unlikely. This uncertainty is dependent upon the regulators measure of control on the eSIM market. There is a high chance that non-profit organisation will provide eSIM initial provisioning if nationwide or continental (EU) regulators have firm grip on eSIM deliverable.

Moreover in international cases, different countries have different regulatory rules which can impede the process of initial provisioning.

**Remote provisioning role for MNO-switching: for profit vs. regulated non-profit**

Like the previous uncertainty this one too is a result of regulators measure of control. Remote provisioning can be done often, so it is an important uncertainty. For profit remote provisioning can increase competition among the stakeholders. On the other hand, non-profit remote provisioning will likely to be controlled by national or international regulators.

**eSIM Platform Solution: Proprietary vs Standard**

Lack of interoperability arises the uncertainty about the future platform solutions of eSIM. If today's proprietary platform solutions keeps continuing in the future that will create fragmentation in the market. Another option can be in 10 to 15 years the solutions will be standardised.

For ensuring long term investment protection, M2M market requires standardisation of related technologies, platforms, data models. However delay in standardisation will affect the whole framework.

**Control of IMSI codes: MNO-controlled vs 3rd party-controlled**

In mobile value chain, the ownership of IMSI or more specifically MNC enables the MNOs to control their business. But M2M value chain is different from mobile value chain and involves many new stakeholders. The possibility of remote provisioning of IMSI in M2M devices with eSIM further triggers the demand for assigning MNC to parties other than MNOs for avoiding operator lock-in (ECC report 212, 2014). Possible third parties can be MVNO, M2M customers (e.g. a utility company). But there are challenges in third party IMSI ownership too. The third parties then have to posses their own authentication/registration platforms. And even if they share it with other MNO or MVNO, there will be security and privacy issues. Recently Holland legalise use of carrier-free SIM card which will certainly bring change in the ownership of IMSI.

In next 10-15 years, the control on IMSI codes is thus uncertain.

**EU regulation of mobile roaming: Generic vs M2M-specific**

According to ERG guideline there is no exemption from roaming regulation for the M2M SIMs. Such M2M SIMs usually follow the same roaming regulation as the other mobile devices follow. But in cases like fleet management the incident of roaming is more frequent and it is an expensive option. In 10-15 years of time period, it is to observe whether the growth of M2M may require to charge the M2M roaming traffic separately or roaming will be neutral to all the traffic regardless of the geography.

## 4.4 Scenario Construction

Two most important uncertainties were crossed to achieve the final scenario matrix. These uncertainties are selected based on interviews and brainstorming session.The first uncertainty is- whether MNO or non-MNO takes the role of M2M service provider. The whole M2M ecosystem will evolve around it. The second most important uncertainty is about the role of initial provisioning provider. The new business role of subscription manager, proposed by GSMA, will have impacts in the process of initial provisioning. At this time it is uncertain that who will pay for the initial provision of the eSIMs. So the chosen two most uncertainties are-

**1. International M2M service provider: MNO family vs. Non-MNOs**

**2. eSIM initial provisioning provider: Regulated Non-profit Organization vs. Commercial for profit entity**

These final scenarios were constructed crossing two key uncertainties. Different combinations of uncertainties create different scenarios with different characteristics and outcome. These scenarios are named in a way so that the idea is highlighted through them. The scenario matrix is presented in below figure with some possible outcomes.

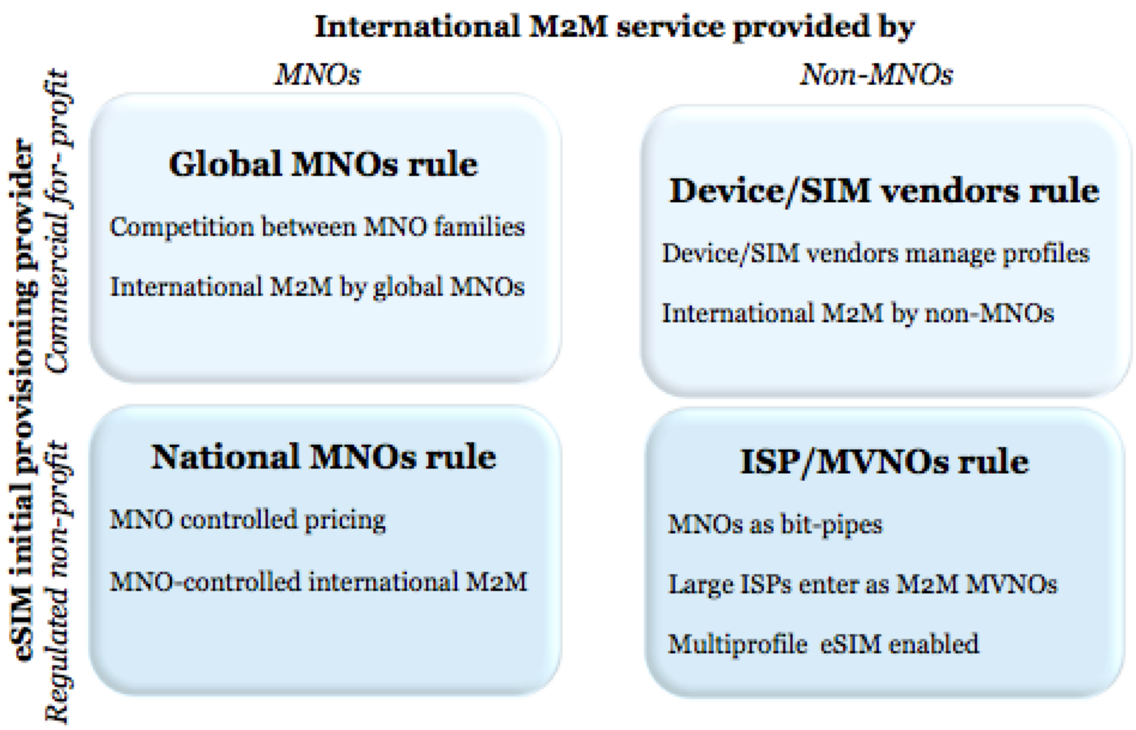


Figure 4.1: Scenario Matrix

These scenarios are described below:

**Global MNOs rule:**

In this scenario, the international M2M service is provided by MNOs under big global MNO family. The initial provisioning is done commercially. MNOs under different MNO family compete with each other not only for providing global coverage but also to meet the local M2M needs. They try to put barriers to refrain the customers to switch to a competing family network. By setting a high switching cost they can retain the customer base. As other barriers they can use proprietary technologies or contracts of long binding period.

MNO can be a candidate for the initial provisioning provider. However as the process of initial provisioning requires only to use that network to provision some other network credentials, the type of provisioning subscription is a temporary short-term contract and it involves little revenue earning. Thus MNOs may not be very interested to become an initial provisioning provider. Rather a special type of MVNO may arise only to facilitate such initial provisioning. The formation and operation of such MVNO is not clear at this moment. In order to facilitate initial provisioning, these MVNOs may have prior business relationship either with SIM vendor or M2M device vendor. Moreover to offer options for a wide number of such short-term subscriptions, they need to make commercial wholesale agreements with many MNOs. Consumer device vendors or SIM vendors who have global footprint may take an interest to form such MVNOs.

However to facilitate customer need of switching operator, the MNOs are bound to give network facilities to remotely provision the new operator's credentials into the eSIM as per the requirements of remote provisioning function. In both initial provisioning and operator switching cases the subscription manager role is very crucial as this role actually performs credentials encrypting and secure routing operation between two MNOs. The MNOs or the SIM/device vendors with global footprint try to keep that role under their control. Customers in this scenario get good tariff offer due to high competition among the MNOs but will face high switching cost for operator switching. Thus there is scope for customer dissatisfaction if the MNOs increase price by taking advantage of this situation. Also device vendor controlled initial provider can introduce attractive offer of device-subscription bundling for the customers.

**Device/SIM vendors rule:**

In this scenario the international M2M service is provided by a non-MNO party. This non-MNO party may be a SIM vendor or device vendor who have large global footprint but they must emerge as specialist M2M MVNOs to offer such service. Local MNOs will compete with such non-MNO party and will try to protect their position as local

M2M service provider instead of being bit pipes. The initial provisioning in this scenario is provided by a commercial or for profit entity that should be as well an actual or virtual network provider. Thus the non-MNO international M2M service provider may also try to grab the initial provisioning, local M2M service provisioning and the subscription management control. They may even involve an MVNE to maintain their regional business. Thus non-MNO party may appear as a big threat for the local MNOs. Emergence of such big non-MNO party as total M2M solution provider creates a monopolistic market. Customers have to pay high price set by the non-MNO parties.

**National MNOs rule:**

International MNO family provides global M2M service in this scenario like the first one. And a non-profit entity will provide initial provisioning facility. Since this is non Profit, it may be a regulator controlled MVNO setup. So MNOs are bound to provide facility to access their network for the initial provisioning. It is more like a political question than a competitive one that which MNO network is used for the initial provisioning. The SIM vendor or the M2M device vendor contact with non-profit initial provisioning provider for necessary actions. As a result MNOs cannot bargain for the wholesale agreement as in the case of commercial initial provisioning. Rather they have to follow the regulated non profit provisioning providers' offer. However this type of regulated non profit setup is likely to work locally. These regulated non-profit MVNOs control local subscription management to provide MNO-change facility for the customers. Initial provisioning will have little impact on the competition in the regular M2M provisioning business. Thus national MNOs seek means to gain profit by controlling pricing.

**ISPs/MVNOs rule:**

In this scenario the local MNOs are in a very critical position. Though only the international M2M service is supposed to be provided by non-MNO party but without proper regulation, the local M2M business may be controlled by such global non-MNO party. Large global ISPs (Internet Service Provider) become M2M specialist MVNO and provide international M2M service. Also such ISPs take an interest to the local M2M business. This will make the national MNO working as bit pipes. Such ISP may offer enabling of multi profiles in eSIM to attract more customers.

Moreover due to non-profit initial provisioning the MNOs are not able to sell wholesale connection for initial provisioning to SIM vendor or device vendor at their preferred price.

One thing should be noted that the business relationship between M2M service provider and initial provisioning provider will depend on the subscription management role. Subscription manager will take the responsibility of securely transferring MNO's credentials to the SIM by using the network provided by the initial provisioning provider. Thus acquiring the subscription management role by M2M service provider or initial provisioning provider will decide the business relationships.

# Chapter 5

# Value Network Configuration

As mentioned earlier, we consider value network configuration approach based on Casey et al. According to this approach the key elements in a VNC are technical component, role, actor, technical and business interface. Each technical component is considered to perform certain technical functionalities. Actors, taking roles are responsible for using the technical component to generate value.

## 5.1 Technical Architecture, Technical components and Roles

For clear understanding the technical architecture (Fig 5.1) has been divided into two parts- one is showing eSIM remote provisioning scenario and another is showing eSIM based M2M service provisioning scenario.

Here for simplification the key important technical components have been considered only. Each oval is presenting a technical component. Also SIM vendor and device vendor are added to the architecture as they have significant role in the M2M value chain. As they are part of production chain and not part of the on-line bit transfer, both of them are represented by rectangular boxes. The red lines between the technical components are showing the technical interface as well as the functional protocols of the technologies used in the technical components.

Supply chain activities among eSIM vendor, device vendor, subscription manager are shown in dotted lines.

Here DEVICE is the machine that is carrying the communication module that is

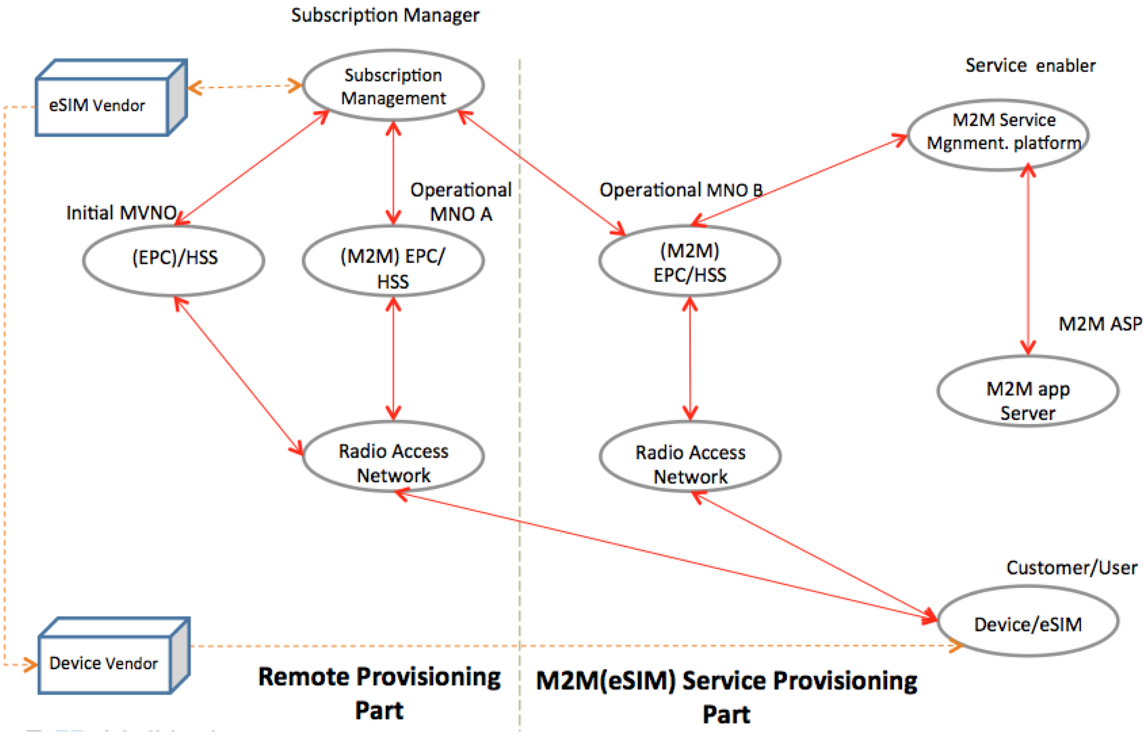


Figure 5.1: Technical architecture used in VNC.

compatible with mobile cellular connectivity. For example electricity meter is a device in smart meter application. eSIM is inserted into the communication module. Cinterion, Sierra wireless, Telit, Qualcomm are few examples of such module manufacturing company.

Remote provisioning of operational profile in eSIM also involves subscription management system. This GSMA-proposed entity has multiple roles like preparing the profile data and also ensuring secure routing for the prepared profiles into the eSIM.

While the radio access network will be shared between the M2M and human-to human traffic, an M2M optimized LTE evolved packet core (EPC) will establish direct communication with subscription management system. Such M2M optimized EPC will consist of HSS dedicated for M2M traffic and also customized gateway node that will serve M2M traffic only.

The central M2M application server in the architecture indicates a device-to-server M2M communication scenario. Between the application server and EPC, valuable M2M service layer will be enabled by M2M service management platform. According to ETSI TC M2M service layer offers a set of service capabilities that are to be shared by different applications and provide specific functions e.g. location of a particular device.

Unlike general mobile communication, more than one mobile network operator may be involved in first time or initial provisioning of eSIM based M2M communication.

Below table 5.1 gives a table which description of the roles involved in the value network configurations.

| | |
|---|---|
| M2M Service Provider (M2M SP) | M2M SP provides the required technologies to deliver data to M2M ASP (see M2M ASP) and (supporting service platform) to the customers. M2M SP may have its own communication network or it buys mobile connectivity from MNO. (e.g. KORE and AERIS) |
| M2M Application Service Provider (M2M ASP) | Entity that provides M2M application functionality and associated services over a network to the end user. ( e.g. ZELITRON SA cooperates with Vodafone (Greece) for provisioning of M2M services and applications, on cars, telemetry, telematics and telecommunications through the GPRS and 3G network to VODAFONE business customers.) * |
| Mobile Network Operator(MNO) | MNO owns its own radio spectrum. It owns both access network, core network. (e.g. Vodafone, Telefonica ) |
| Mobile Virtual Network Operator(MVNO) | MVNO buys radio connectivity from MNO as it is not allowed to have its own radio spectrum. It may own its own HLR. |
| Subscription Manager | Entity responsible for encryption of profile and secure transportation of those encrypted profiles. |
| Mobile Virtual Network Enabler (MVNE, see M2M SP) | MVNE buys (radio connectivity) from MNO and sells (end-to-end connectivity) to MVNO. MVNE typically runs its own mobile core (EPC/HSS, GWs). M2M-optimized MVNE is called M2M Service Provider, see M2M SP. |

Table 5.1: Roles in the VNC

## 5.2 VNCs for initial remote provisioning

The new business role of subscription manager, proposed by GSMA, is the central role in case of initial provisioning of eSIM. Thus the existing actors will involve themselves for getting a hold onto this new role. However the subscription manager role is further divided into Subscription Manager- Data Preparation role and Subscription Manager- Secure Routing role. Each manufactured eSIM must be registered into a database maintained by the entity taking the SM SR role. It is possible to change this registration from one SM SR database to another upon mutual agreement between the involved parties.

**MVNO driven VNC - eSIM provisioning**

Each eSIM in the M2M device will contain an active provisioning profile which will be already enabled or will be enabled later after the purchase of the device. In the first VNC this initial provisioning role along with the subscription manager role are shown to be taken by a specialised Initial MVNO. It will provide the eSIM vendor its own network information as provisioning profile information as well as registration facility with the SMSR. Such MVNO will also have business relationship with the operational MNO, chosen by the customer or end user. Upon request from operational MNO, this initial MVNO will provision the final operational subscription into the eSIM over the air.

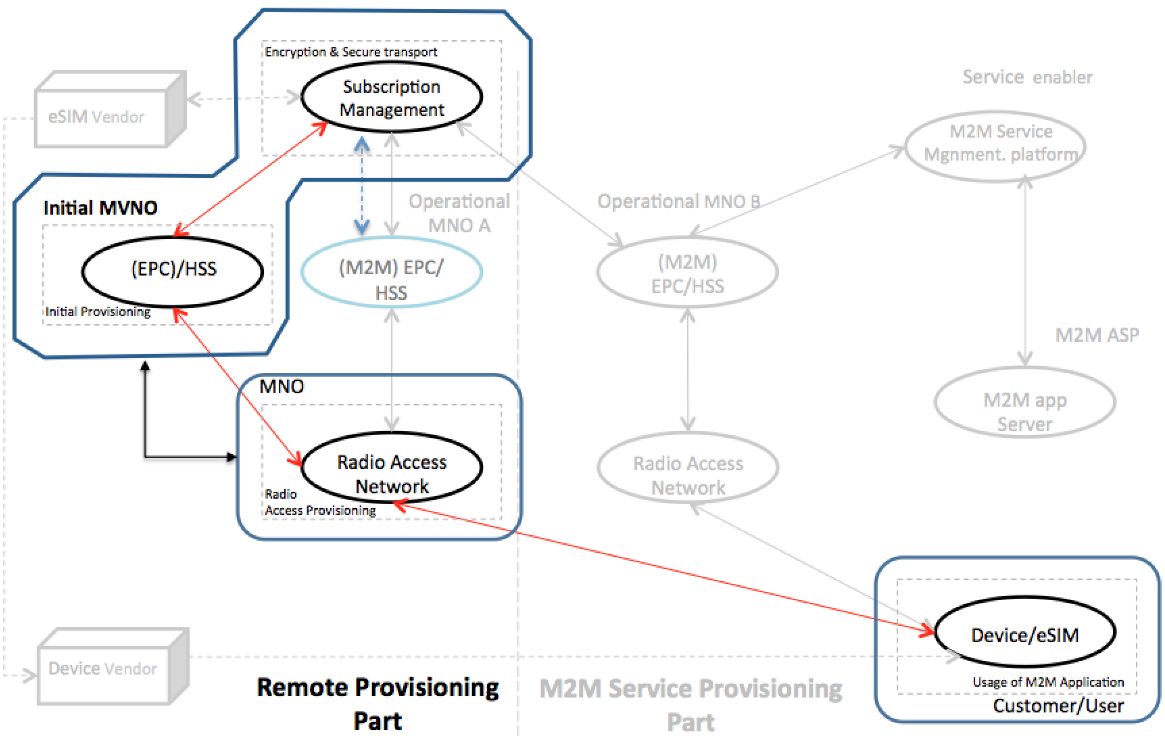

Figure 5.2: MVNO driven VNC - eSIM provisioning

### Vendor driven VNC - eSIM provisioning (a)

In this VNC, eSIM vendor is shown to take the subscription management role along with eSIM production role. In fact SIM vendor is involved in data preparation, i.e. profile encryption anyway, the additional role that will be added in this case is the role of secure routing of the profiles into the eSIM over the air. For accomplishing this, eSIM vendor will agree contracts with MVNO or MNO for providing provisioning network information into the eSIM at the time of manufacturing and further sell those eSIM to the OEM. Moreover operational MNOs will make contracts with the eSIM vendor for provisioning of operational profiles into the eSIMs, registered in the corresponding SM SR under the control of that eSIM vendor. Thus, eSIM vendor taking SM role will establish business relationship with OEM and multiple MNO/MVNO for providing initial provisioning.

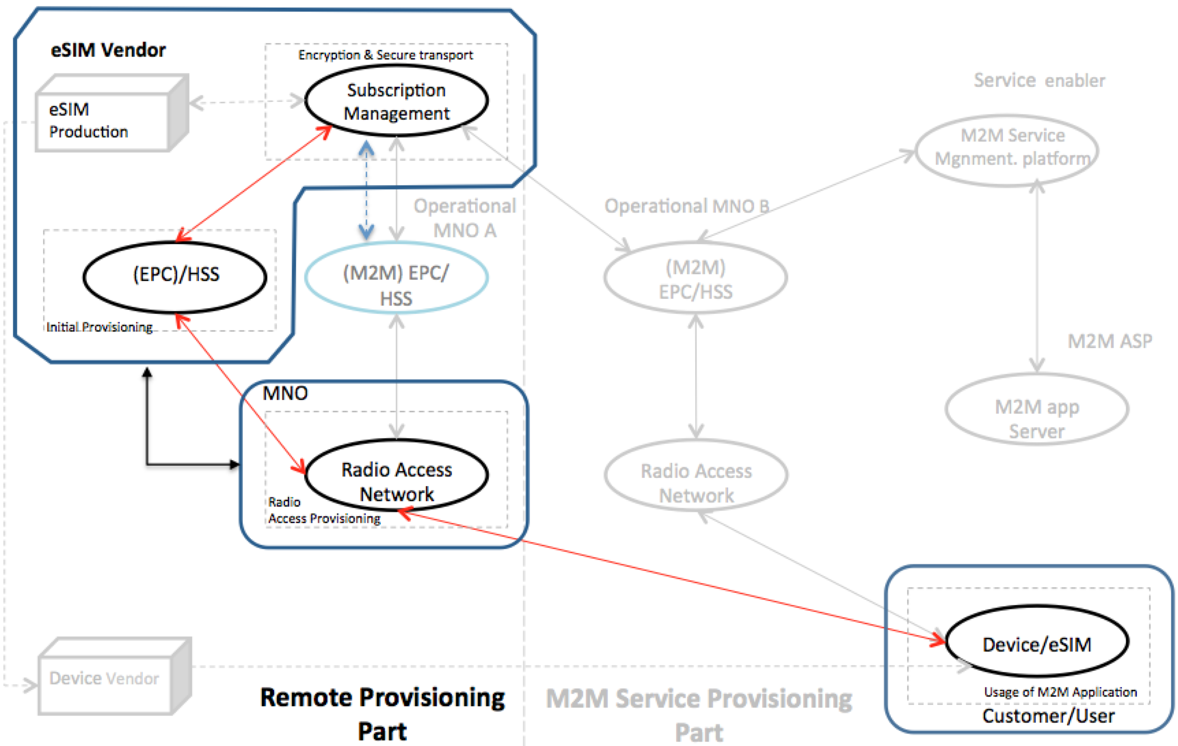


Figure 5.3: Vendor driven VNC - eSIM provisioning(a)

### Vendor driven VNC - eSIM provisioning (b)

In this VNC the eSIM vendors role slightly changes than the previous one. Here the eSIM vendor is not responsible from initial provisioning of operator data into eSIM. They produce and integrate the eSIM and also take care about subscription management. The eSIM vendor maintains a business relation with an MVNO who is responsible for initial provisioning.

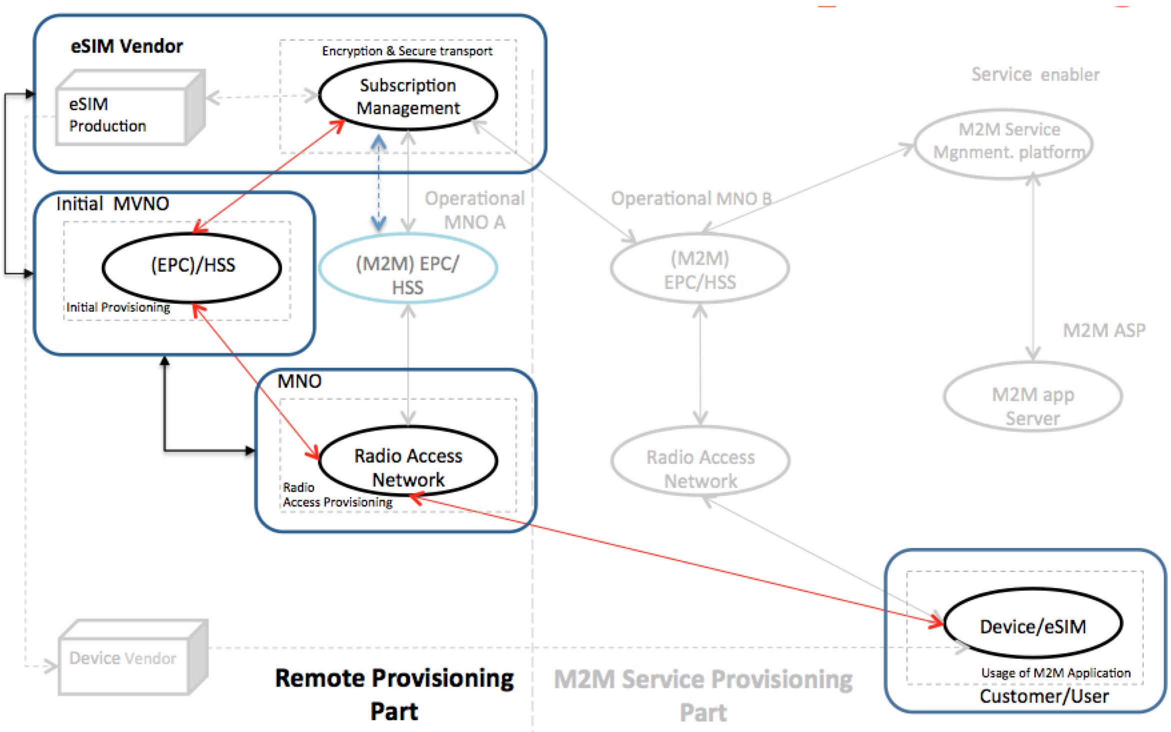


Figure 5.4: Vendor driven VNC - eSIM provisioning(b)

#### Regulator driven VNC - eSIM provisioning

Another option can be a regulated/non-profit organization may appear to take the subscription manager role beside maintaining a central HSS/OTA server to facilitate remote provisioning. Such trusted non-profit set-up can be formed by the government of a country. However for the radio access network, this regulated/non-profit organization will be dependent on the MNO.Such options may run more successfully in the national level.

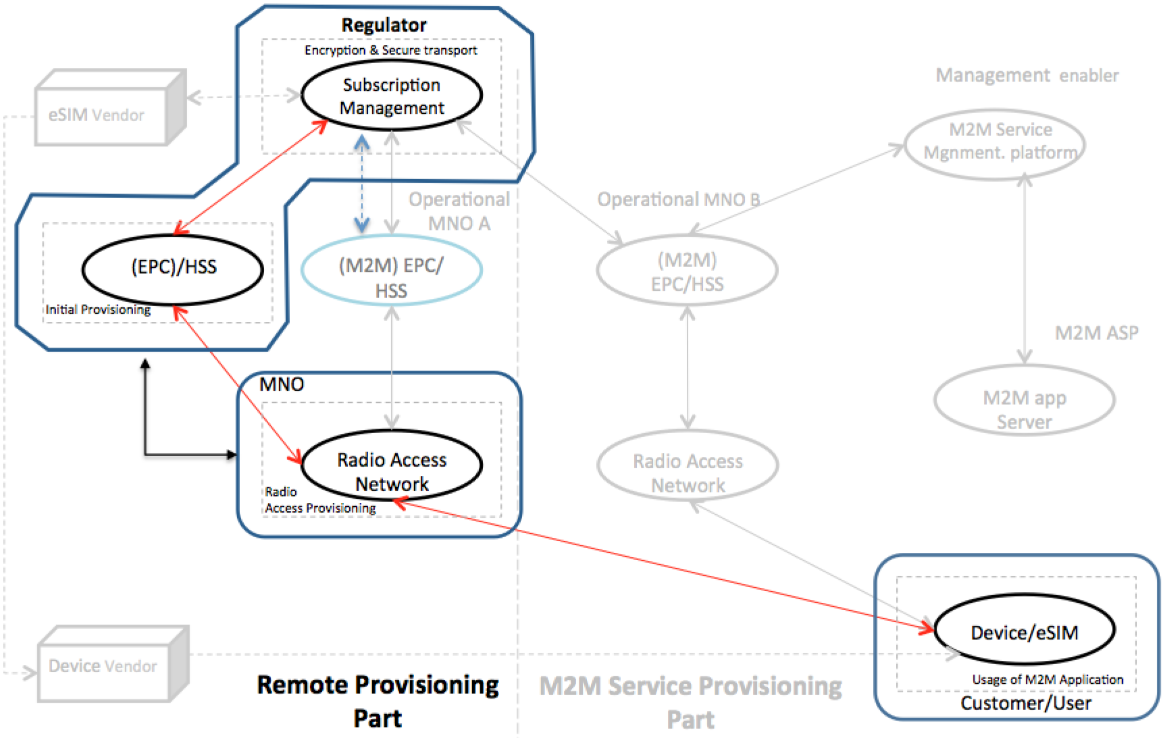


Figure 5.5: Regulator driven VNC - eSIM provisioning

#### MNO driven VNC - eSIM provisioning

In MNO driven remote provisioning VNC, the subscription manager role is taken by MNO. In this case the MNO will try to provide both the provisioning and operational subscriptions to the customers. Also in global situations MNOs in an operator alliance may act as subscription manager for each other. However it is more feasible for the MNO to take the role of SM SR. In case of taking SM role fully, MNO may need to expand its facilities for profile encryption or data preparation as well which would be a completely new business area for MNO.

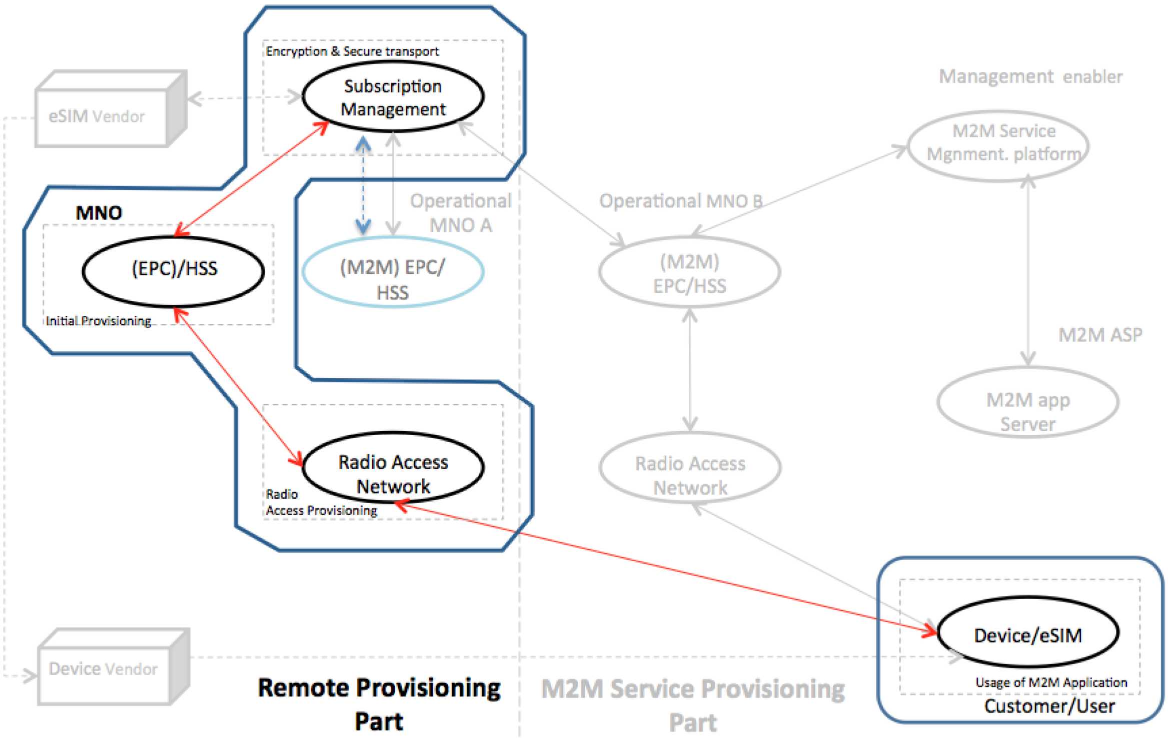


Figure 5.6: MNO driven VNC - eSIM provisioning

## 5.3 VNCs for M2M service provisioning

These VNCs focus on the value networks once eSIM equipped devices are deployed in M2M communication. Thus it can be said that these VNCs are independent of eSIM. These will explore and compare changes between current removable SIM based and future eSIM based M2M industry.

### MNO driven VNC in M2M (a)

In this VNC, MNO plays the role of M2M service provider in the M2M solution. The M2M customer in this VNC will directly approach the MNO for the entire M2M solution. MNO will have its own M2M optimised core and radio access network. The M2M service platform may be either in-house or MNO may partner with a service-based platform provider (e.g Jasper wireless, Ericsson DCP(device connection platform)). MNO will also select the M2M application service provider for the M2M customer.

Thus the corporate customer will establish business relationship with MNO only. Customer will pay the MNO for required initial deployment and also for using its network and service. On the other hand, MNO will share its revenue with M2M ASP and M2M platform provider, if any. Direct relationship with customer will establish MNO in a strong position in the market though it will need to share its revenue with other stakeholders partly. MNO will try to meet the customer demand with its in-house service platform

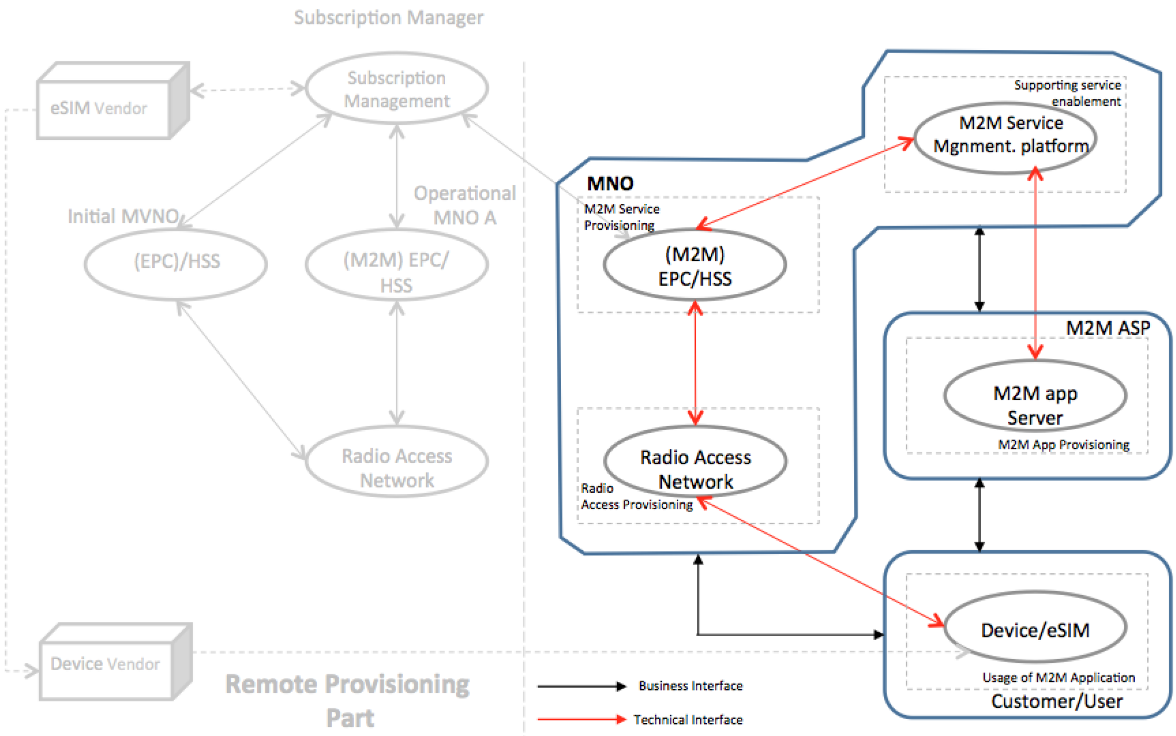

Figure 5.7: MNO driven VNC in M2M (a)

solution and try to minimise its revenue sharing. With such setup, MNO will target to grab the national M2M market. As for example local demand for smart metering can be mitigated with such national MNO driven VNC.

### MNO driven VNC in M2M (b)

In this VNC, customer itself will be the application service provider for its own devices. It will need mobile network to establish communication between the backend application server and eSIM equipped M2M devices. MNO will appear as the M2M service provider for the customer and will provide the necessary connection along with various value added services through its service platform. The service platform can be an in-house production by the MNO or it can be from an external platform provider that serves the MNO as a pay-as-you-go type transactions. In such cases, MNOs will compete each other by offering new value-added-services along with basic connectivity.

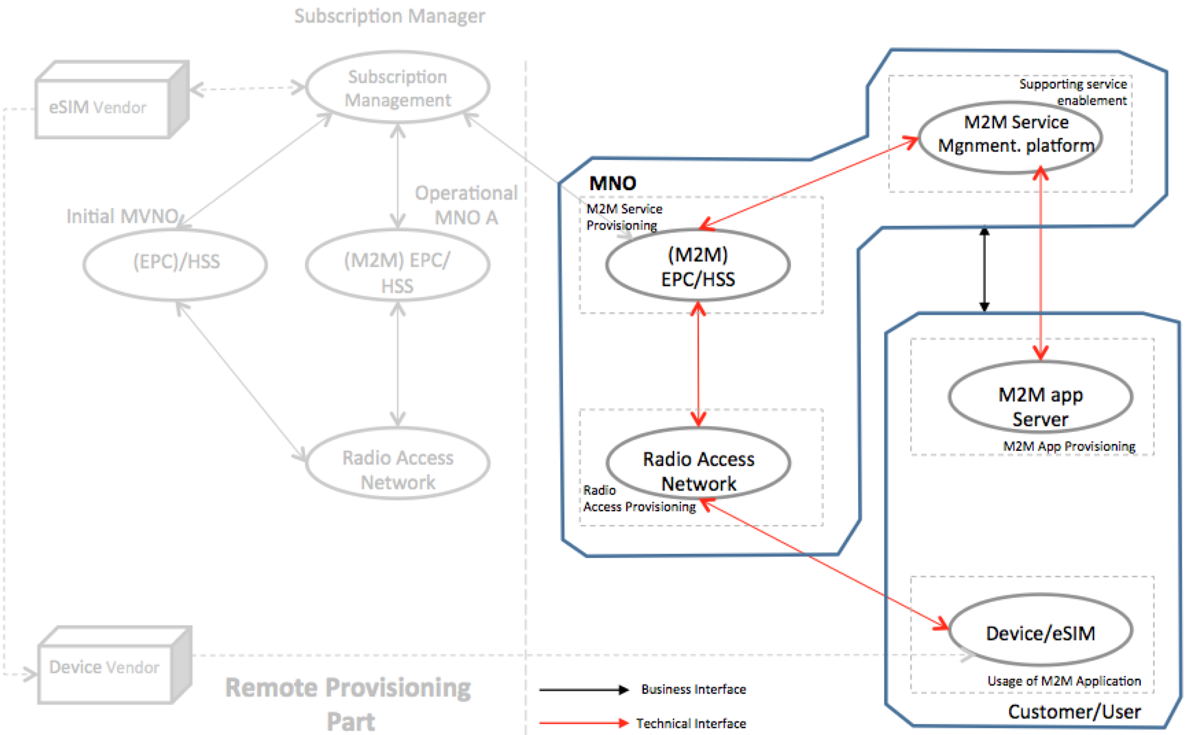

Figure 5.8: MNO driven VNC in M2M (b)

### MNO driven VNC in M2M (c)

The next VNC represents MNO in a higher power position. MNO here is playing the central role in the M2M ecosystem by taking multiple roles such as mobile connection provider, M2M platform provider, M2M application service provider. Global footprint benefits the MNO to expand its M2M business in international level. Deploying its own platform will solve interoperability problems for its customers and bring scalability benefits. Strategic alliances with M2M ASP, in some cases, acquiring them will make MNO self sufficient to provide a complete M2M solution for its customers. M2M customers will be able to grow its business beyond the national territory through services from such global M2M service provider.

The value or money flow in this VNC is from customer to global MNO. Customer will pay the MNO for early or initial deployment and also for ongoing usage of network resources and services. Global telecom giant like Vodafone and AT&T already offer complete M2M solutions to customers. Deploying eSIM will reduce cost and bring more operational flexibility in their business.

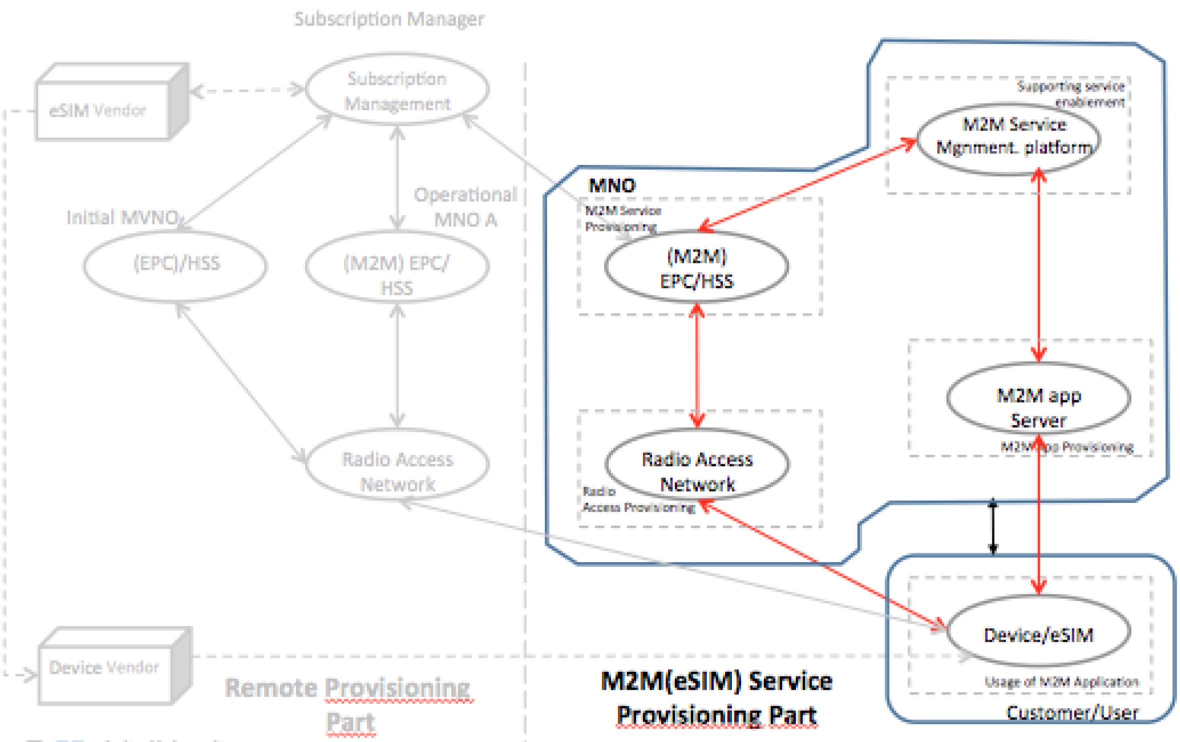

Figure 5.9: MNO driven VNC in M2M (c)

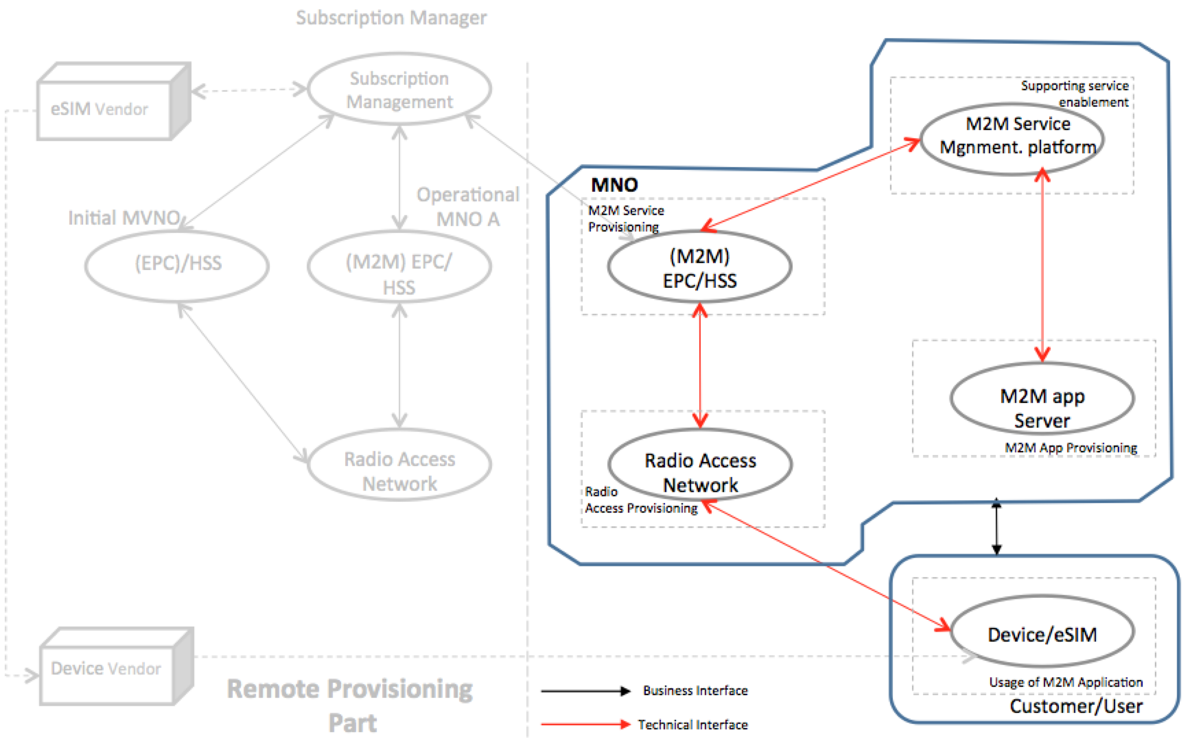


Figure 5.10: MNO driven VNC in M2M(d)

### MNO driven VNC in M2M(d)

In this VNC, MNO offers the M2M device along with subscription. MNO will have its own radio access network and M2M optimised core. It will also deploy its own service platform for adding extra value to its offering. MNO will only depend on M2M ASP for application service and related maintenance.

### MVNO driven VNC in M2M national

This VNC shows M2M specialist MVNO is providing M2M service to the customers. Such MVNO will have its own M2M optimised core and service platform but will have contracts with a MNO for using its bandwidth. Through partnering with a M2M ASP it will also provide the customer M2M application service facility. Thus customer will make business contracts with M2M specialist MVNO only. On the other hand, MVNO will have to share its revenue with MNO and ASP. It is worth noted that MNO in this VNC work as a bit-pipe.

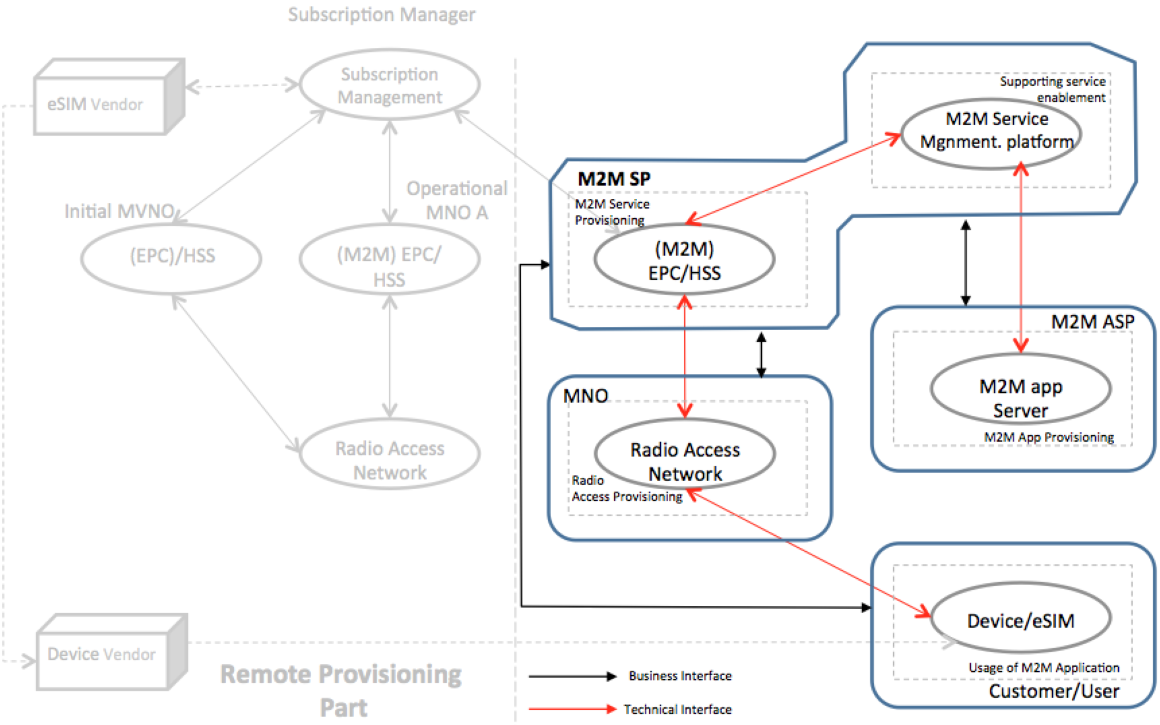


Figure 5.11: MVNO driven VNC in M2M national

### MVNO driven VNC in M2M global

MVNO in this VNC strengthens its position by taking M2M ASP role in addition to own M2M platform and core network. Customer will make contracts with MVNO only for total M2M solution. MVNO on the other hand will share its revenue with MNO for using its radio access network. MNO will only provide the communication service and act more like a bit-pipe.

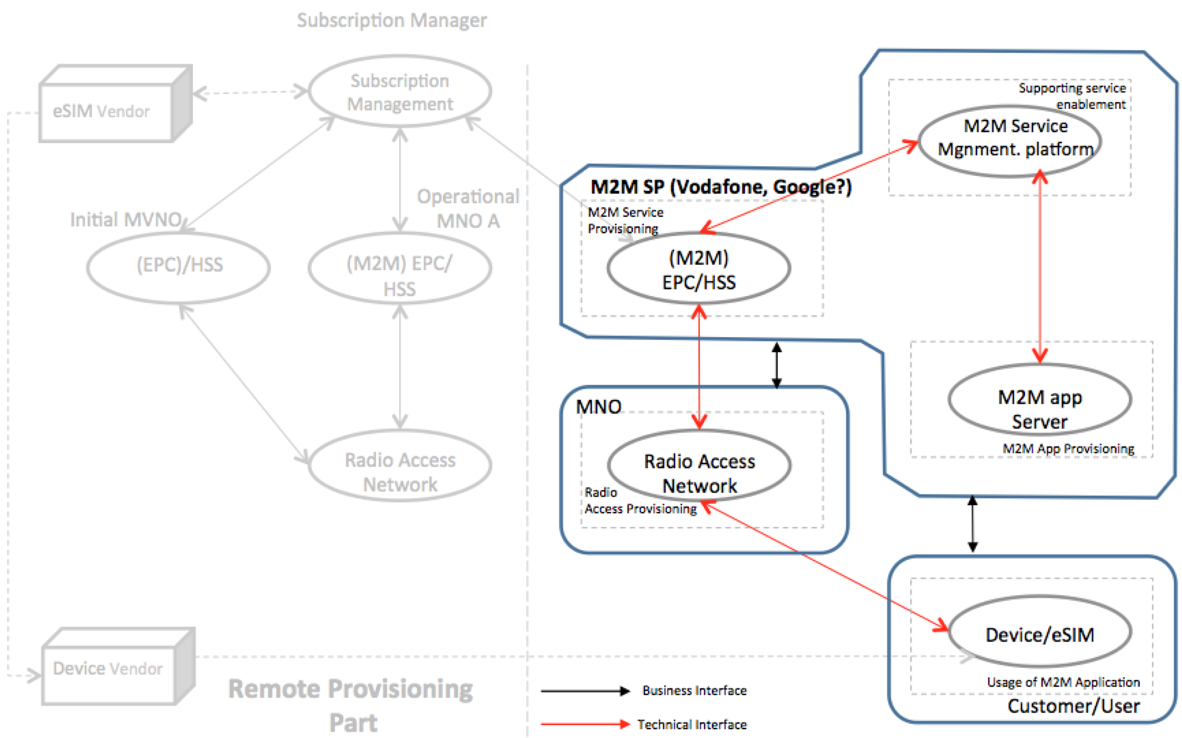


Figure 5.12: MVNO driven VNC in M2M global

### MVNO driven VNC in M2M device vendor

Customer is in the central role of providing M2M service in this VNC. Customer partners with MNO for using its bandwidth and access network. The M2M platform, Application service and M2M optimised core everything else will be deployed by customer itself.

As for example. if a company deploys a large number of M2M devices in the market and it has agreements with a good number of operators all over the world for delivering the M2M service using their wireless networks. The end users do not need to maintain monthly subscriptions for those connections rather they pay the M2M customer for every usage.

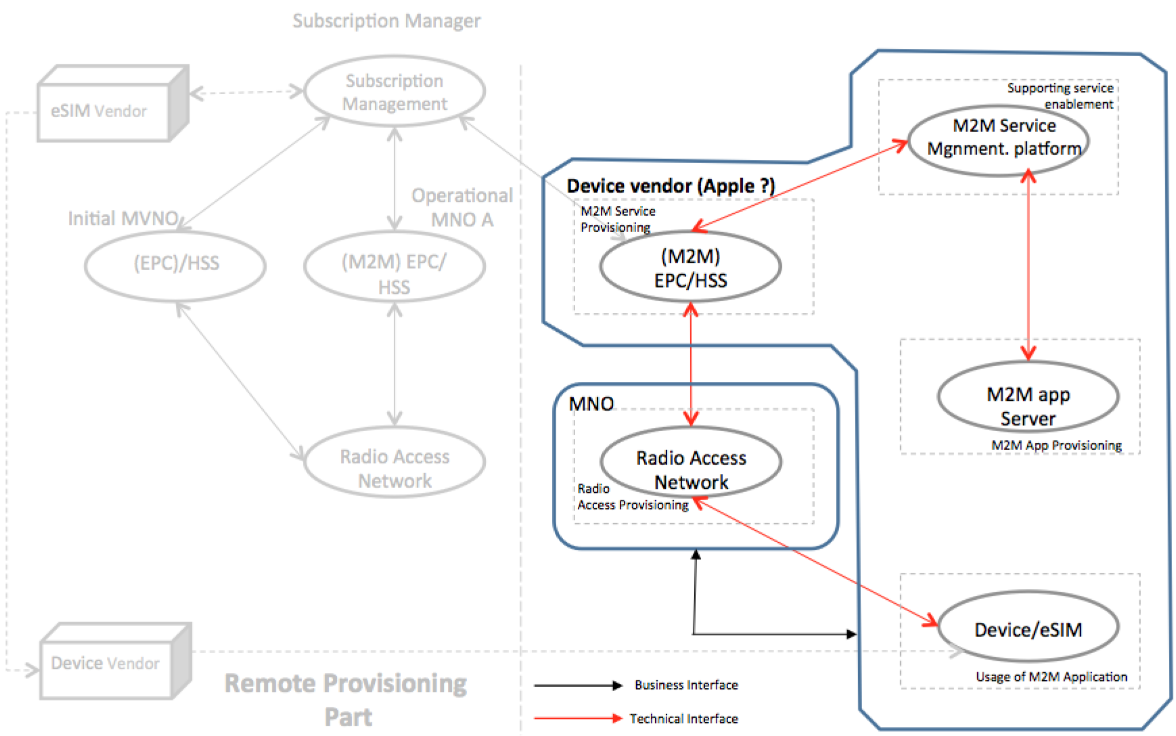


Figure 5.13: MVNO driven VNC in M2M device vendor

# Chapter 6

# Conclusion and results

## 6.1 Results

One of the key findings in this thesis work is that the delay in eSIM implementation is more likely a political problem than a technical problem. Though the standardisation is yet to be completed, but the technology is matured to be used already. The conducted study also finds that eSIM is addressed as a disruption in the current ecosystem by many telecom operators. The mobile network operators are continuously finding new ways to expand their revenue streams by exploiting M2M technology and trying to establish their position in the pivotal role in this sector. In the mean time they want to protect their current position in the telecom ecosystem. One of the basic trends based on experts view is that though eSIM will make its entrance in the M2M niche market, in long term future it will be gradually adopted by the consumer handset market. This will certainly pave the ecosystem in a new way of evolution.

Scenario planning process narrows down two independent uncertainties revolving around the eSIM based M2M communication industry. The first one is the uncertainty about the entity taken the role of M2M service provisioning internationally. And the other uncertainty involves initial provisioning, whether it will be a for-profit or non-profit activity. Combining these two uncertainties generate four alternate future scenarios. The first scenario, Global MNOs rule, presents a scenario where MNOs under different MNO families are in control of the M2M industry by positioning them in the central role of M2M service provisioning and the initial provisioning is a profit based activity. The ISPs rule scenario on the other hand introduces a complete opposite scenario where non-MNO entities appear as M2M service providers and initial provisioning is a regulated non-profit activity. The other two scenarios are variations of these two black and white scenarios. In the SIM/Device Vendors rule scenario, SIM vendors or M2M device vendors are directly involved in M2M service provisioning to the customers and contrary to ISPs rule scenario, initial provisioning is offered by various existing and new entrants in the industry. The National MNOs rule scenario is explained by its name to some extent and other worth mentioning criteria of this scenario is its regulated non-profit activity in the national level.

Value network configuration is used in this thesis to understand the relationship and cooperation among the involved parties in emerging eSIM based M2M communication. The conducted value network configurations focuses on remote provisioning of eSIM and M2M service provisioning using eSIM separately. Remote provisioning VNCs, including both initial provisioning and inter MNO switching of subscriptions, show emergence of new roles like initial provisioning provider and subscription manager. In the M2M service provisioning part the roles involved are already established.The roles taken by different actors in eSIM VNCs will reflect their power position in the industry. The configured value networks explore varying interest of the involved stakeholders and the underlying tension among their power relationships.

## 6.2 Assessment of results

The methods used in this thesis take a top down approach to gain an overview of the whole eSIM based M2M industry. Thus the results achieved from these methods are not precise from technical point of view. The used methods, scenario planning and value network configuration, did not take any particular stakeholder's perspective into account rather tried to examine the results from the perspective of different stakeholders.

The purpose of using scenario analysis as a method is to find the possible future scenarios of M2M industry exploiting eSIM solution. It bounds the uncertainties, presents scenarios that show internal consistency and plausibility. But scenario analysis does not give any future forecasting or probabilities. It is important to be open minded to all future possibilities than to concentrate on any specific scenario. The success of the scenario analysis will be reflected if in the decided time frame, i.e. in 10 years the eSIM based M2M industry can be found in the constructed scenario space, constituting with multiple elements from all of the four scenarios.

The conducted value network configurations help to understand the sources of value in the network based on interdependent relationships. Stakeholders who are able to identify and exploit those sources will be the ultimate winner. Though the concept of eSIM is not entirely new, but its implementation in M2M is still an unexplored area for many. The new feature of eSIM possibly changes the existing ecosystem. Thus new value networks are emerging that may change the power play among the stakeholders and even may promote introducing new entrants in the scene.

## 6.3 Exploitation of results

This thesis focuses on the M2M communication based on eSIM solutions. But experts from the industry anticipated eSIM exploitation in consumer mobile communication as well in the distant future. To their opinion the adoption of eSIM in mobile communication will see a gradual growth and unlikely to happen in this forecasting period of 10 years. Thus, the scope of eSIM is quite immense. The lucrative business opportunities may even inspire new entrants to come forward. Thus the involved stakeholders really need to make cautious moves to fight new and risky challenges.

As mentioned earlier the scenario planning construction does not consider the perspective of any particular stakeholder rather tries to see from perspective that is neutral for all the involved stakeholders. Thus the stakeholders may exploit the result of scenario analysis to plan strategic actions and prepare themselves for the competitive future. Value network configurations on the other hand can be utilised to understand the ecosystem and possible evolution paths of eSIM based M2M communication. It is very crucial to identify and understand the value creating system and make a firm position in the value network. Thus value network configurations can be a method to perceive value dimensions of the involved participants and their influence among each other.

## 6.4 Future research

The current scenarios are based on the assumption that Subscription Manager switches between profiles. However, it will be also relevant to consider that Subscription Manager only activates and deactivates the profiles but does not switch. This means that multiple profiles can also be simultaneously active. This possibility leaves scope for future research related to multi profile enabled eSIMs. This thesis work leads to develop an understanding of the future M2M ecosystem emerged around eSIM through two methods, namely scenario planning and value network configuration. It was mentioned earlier, the quantitative modelling part of the scenario planning process was kept beyond the scope of this thesis. Thus the future research can be extended towards quantifying the scenarios, simulating them and finally evolving toward decision scenarios through iterative process.

Moreover the conducted value network configurations can be a basis for new business model development. The effect of regulators and standardisations bodies in shaping the ecosystem can be further investigated thoroughly.

As mentioned earlier, the delay emergence of eSIM is more like a political issue than a technical one. Though the concept of eSIM is present in the market for quite a while, the potential growth of M2M triggers the necessity to utilise it. The growth of M2M obviously will expand the subscription base of the MNO but eSIM function requirements can reduce MNO's control over the subscription. Moreover by replacing removable SIM, eSIM can become a threat to their regular telecom business. The other stakeholders are also seeking opportunities and examining the situation. In fact eSIM may enable new MVNOs and other new roles like subscription broker and many more for the existing stakeholders and also for the new entrants. It is also evident from the VNCs that eSIM/M2M in national and international level will likely to follow separate evolution paths.

The standardisation bodies are closely attached to the MNOs. Thus MNOs may influence the delay standardisation of eSIM and utilise this delay to prepare themselves to find new ways to sustain their position in the emerging ecosystem. The delay standardisation may lead to a fragmented market. In this era of rapid technological evolution, delay in implementation can replace eSIM with newer innovation and make it obsolete.

# Bibliography

3GPP (2007) 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Study on Facilitating Machine to Machine Communication in 3GPP Systems (Release 8). 3GPP Technical Report 3GPP TR 22.868 V8.0.0 (2007-03).

3GPP (2010) 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Feasibility study on the security aspects of remote provisioning and change of subscription for Machine to Machine (M2M) equipment (Release 9). 3GPP Technical Report 3GPP TR 33.812 V9.2.0 (2010-06).

ALLEE, V. (2008) Value network analysis and value conversion of tangible and intangible assets. Journal of Intellectual Capital, 9, 5-24.

BEALE, MARTIN, and YUICHI MORIOKA "Wireless machine-to-machine communication." Microwave Conference (EuMC), 2011 41st European, 2011.

BOSWARTHICK, DAVID, OMAR ELLOUMI, OLIVIER HERSENT, eds. M2M communications: a systems approach. John Wiley & Sons, 2012.

BENDER, H. & LEHMANN, G. (2012) Evolution of SIM provisioning towards a flexible MCIM provisioning in M2M vertical industries. Intelligence in Next Generation Networks (ICIN), 2012 16th International Conference on.

BOUWMAN, H., VOS, H. D. & HAAKER, T. (2008) Mobile service innovation and business models, Berlin, Springer.

CASEY, T., SMURA, T. & SORRI, A. (2010) Value Network Configurations in wireless local area access. Telecommunications Internet and Media Techno Economics (CTTE), 2010 9th Conference on.

DAHLMAN, ERIK, STEFAN PARKVALL and JOHAN SKOLD. 4G: LTE/LTE-advanced for mobile broadband. Academic Press, 2013.

ETSI (2010) Smart Cards; Machine to Machine UICC; Physical and logical characteristics (Release 9). ETSI Technical specification TS 102 671 V9.0.0 (2010-04).

ETSI (2013a) Machine-to-Machine communications (M2M); Functional architecture. ETSI Technical Specification TS 102 690 V2.1.1 (2013-10).

ETSI (2013b) Machine-to-Machine communications (M2M); M2M service requirements. ETSI Technical specification TS 102 689 V1.2.1 (2013-06).

ETSI (2013c) Smart Cards; Embedded UICC; Requirements Specification; (Release 12). ETSI Technical specification TS 103 383 V12.0.0 (2013-02).

GSMA (2011) Embedded SIM Task Force Requirements and Use Cases, Version 1.0., 21 February 2011. GSM Association. Available online, ftp://ftp.3gpp2.org/TSGS/Working/_2011/2011-0505-TSG-S+TSG-

C_re_eUICC/Embedded%20SIM%20Use%20Cases%20and%20Reqts%20v1%200.pdf. Referred 8th March, 2014.

GSMA (2013a) Embedded SIM Remote Provisioning Architecture, Version 1.1., 17 December 2013. GSM Association Official Document 12FAST.13. Available online, http://www.gsma.com/connectedliving/wp-content/uploads/2014/01/1.-GSMA-Embedded-SIM-Remote-Provisioning-Architecture-Version-1.1.pdf. Referred 9th March, 2014.

GSMA (2013b) GSMA Embedded SIM: Accelerating growth and operational efficiency in the M2M world. GSM Association Reference Messaging Pack, 9th December 2013. Available online, http://www.gsma.com/connectedliving/wp-content/uploads/2012/03/embedded_sim_imv1v091213vFinal.pdf. Referred on 9th March, 2014.

CSMG (2012) Reprogrammable SIMs: Technology, Evolution and Implications. Final paper. 25 September 2012. Available online, http://stakeholders.ofcom.org.uk/binaries/research/telecoms-research/reprogrammable-sims.pdf. Referred on 9th March, 2014.

HATTON, M. "The Global M2M Market in 2013." *Machina research whitepaper*(2013).

KECHICHE, S., GEORGE, D. & JAIN, N. (2014) From concept to delivery: the M2M market today. GSMA Intelligence analysis. February 2014. Available online https://gsmaintelligence.com/files/analysis/?file=140217-m2m.pdf. Referred on 12th May 2014.

MARKANTONAKIS, KONSTANTINOS. Smart cards, tokens, security and applications. Springer, 2007.

MARTSOLA, MIKKO, T. KIRAVUO, AND J. K. O. LINDQVIST. "Machine to machine communication in cellular networks." Mobile Technology, Applications and Systems, 2005 2nd International Conference on. IEEE, 2005.

LEVÄ, TAPIO, HEIKKI HÄMMÄINEN, AND KALEVI KILKKI. "Scenario analysis on future internet." Proceedings of the First International Conference on Evolving Internet (INTERNET 2009). 2009

LIEN, SHAO-YU, KWANG-CHENG CHEN, AND YONGHUA LIn. "Toward ubiquitous massive accesses in 3GPP machine-to-machine communications."Communications Magazine, IEEE 49.4 (2011): 66-74.

MISHRA, AJAY R., ed. Advanced cellular network planning and optimisation: 2G/2.5 G/3G... evolution to 4G. John Wiley & Sons, 2007

OECD (2012) Machine-to-Machine Communications., OECD Publishing. Available online http://www.oecd-ilibrary.org/science-and-technology/machine-to-machine-communications_5k9gsh2gp043-en. Referred on 29th April, 2014.

PENTTINEN, JYRKI TJ, ed. The LTE/SAE Deployment Handbook. John Wiley & Sons, 2011.

PEPPARD, J. & RYLANDER, A. (2006) From Value Chain to Value Network:: Insights for Mobile Operators. European Management Journal, 24, 128-141.

PETSCH, T., et al. "Influence of Future M2M Communication on the LTE system." Wireless and Mobile Networking Conference (WMNC), 2013 6th Joint IFIP. IEEE, 2013.

RANKL, W. & EFFING, W. (2010) Smart card handbook, Chichester, West Sussex, U.K., John Wiley & Sons, Ltd.

SCHOEMAKER, P. J. H. (1995) Scenario Planning: A Tool for Strategic Thinking. Sloan Management Review, 36, 25.

SMURA, TIMO, AND ANTTI SORRI. "Future scenarios for local area access: industry structure and access fragmentation." Mobile Business, 2009. ICMB 2009. Eighth International Conference on. IEEE, 2009.

SINGH, SHUBHRANSHU, AND KUEI-LI HUANG. "A robust M2M gateway for effective integration of capillary and 3GPP networks." Advanced Networks and Telecommunication Systems (ANTS), 2011 IEEE 5th International Conference on. IEEE, 2011.

STABELL, C. B. & FJELDSTAD, Ø. D. (1998) Configuring Value for Competitive Advantage: On Chains, Shops, and Networks. Strategic Management Journal, 19, 413-437.

VAHIDIAN, ELAHEH. "Evolution of the SIM to eSIM." (2013).

OSSEIRAN, A., BOCCARDI, F., BRAUN, V., KUSUME, K., MARSCH, P., MATERNIA, M., ... & FALLGREN, M. (2014). Scenarios for 5G mobile and wireless communications: the vision of the METIS project. *Communications Magazine*, *IEEE*, *52*(5), 26-35.

BARROSO, J. M. D. (2008). 20 20 by 2020: Europe's Climate Change Opportunity.*speech to the European Parliament*, *January*, *23*.

SMITH, I. G. (ED.). (2012). *The Internet of things 2012: New horizons*. CASAGRAS2.

STRATEGY, I. T. U., & UNIT, P. (2005). ITU Internet Reports 2005: The internet of things. *Geneva: International Telecommunication Union (ITU)*.

VERMESAN, O., & FRIESS, P. (EDS.). (2013). *Internet of things: converging technologies for smart environments and integrated ecosystems*. River Publishers.

DARMOIS, E., & ELLOUMI, O. (2012). Introduction to M2M. *M2M communications: a systems approach. John Wiley & Sons*.

NIKAEIN, N., & KREA, S. (2011, APRIL). Latency for real-time machine-to-machine communication in LTE-based system architecture. In *Wireless Conference 2011-Sustainable Wireless Technologies (European Wireless), 11th European*(pp. 1-6). VDE.

ITU-T (2014) M2M service layer: Requirements and architectural framework. ITU-T Focus Group. Version 1.0

ALAM, M., NIELSEN, R. H., & PRASAD, N. R. (2013, JULY). The evolution of M2M into IoT. In *Communications and Networking (BlackSeaCom), 2013 First International Black Sea Conference on* (pp. 112-115). IEEE.

M. ALENDAL, (2010) Operators need an ecosystem tosupport 50 billion connections, Ericsson Business Review, no. 3, p. 42

KECHICHE,,SYLWIA, GEORGE, DAVID, JAIN, NEHA (2014) From Concept to Delivery: The M2M Market Today, GSMA Intelligence.

RICHARME, M. (2008). The virtual {SIM}-a feasibility study.

EU Roaming regulation III, Structural Solutions, High Level Technical specifications v1.0

# Chapter 7

# Appendix A

## 7.1 List Of Interviewees:

Project Manager (M2M), Mobile Operator.

Product Manager (B2B, Mobility Services), Mobile Operator.

Head of Networks, Mobile Operator.

Master Researcher, Equipment and Solution Vendor.

M2M Platform Expert, Equipment and Solution Vendor.

Professor, Dept. Of Communicating and Networking.

Consultant, Technology Consulting Company.