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IMPLEMENTATION OF GSM SERVICES FOR MOBILE VIRTUAL NETWORK OPERATORS

Master`s thesis

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Autorideklaratsioon

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(kuupäev) (allkiri)

Annotatsioon

Lõputöö eesmärgiks on kirjeldada viis GSM teenuse juurutamiseks virtuaalsetele mobiilsidevõrgu operaatoritele ja võimalus kasutada saadud teadmisi reaalses ettevõttes (Top Connect). Uuring näitab kuidas peab olema arhitektuur ehitatud, vastavalt GSM standardidele ja kuidas GSM teenused võivad olla pakutud mobiilsidevõrgu operaatori poolt.

Selle eesmäri saavutamiseks on vaja mõista GSM geograafilise võrgustiku, GSM arhitektuuri ja selle komponente. Lisaks on vaja uurida, milliseid teenuseid saab rakendada, vastavalt GSM standarditele ja mis tüüpi mobiilsidevõrgu operaatorid pakuvad neid. Parim viis neid teenused pakkuda miljonite kasutajate jaoks, on luua Mobile Virtual Network Operator arhitektuur. Paari aasta jooksul MVNO populaarsus on kiiresti kasvanud. Need võivad pakkuda sama GSM teenuseid abonentidele, mis varem ainult klassikalise mobiilsideoperaatorit võiksid. Töös pakkutakse üks võimalik viis, kuidas virtuaalsed mobiilisidevõrgu operaatorid neid teenuseid võivad analüüsida ja realiseerida.

Kokkuvõttes teenused, mis vastavad GSM standardile, olid loodud tegelikus ettevõttes. Probleemide lahenduse analüüs ning arhitektuuri võimalik areng on samuti esitatud. See lahendus on korduvkasutatav ja kasulik erinevatele ettevõtetele, kes otsustasid saada virtuaal mobiilsidevõrgu operaatoriks, seega töö eesmärk on saavutatud.

Käesoleva töö aluseks on autori mitmeaastane töökogemus firmas AS Top Connect tehnik-operaatorina.

Lõputöö on kirjutatud inglise keeles ning sisaldab teksti 69 leheküljel, 3 peatükki, 28 joonist, 5 tabelit.

Abstract

The goal of this thesis is to describe an opportunity of implementation Global System For Mobile Communication services for mobile virtual network operators and an opportunity of using received knowledge in the real company (Top Connect). Research will show how can be mobile network architecture build accordingly to the GSM standard and how GSM services can be provided by mobile virtual network operators.

To reach this goal it is necessary to understand GSM geographical network structure, GSM architecture and its components. Additionally it is needed to investigate what services can be implemented accordingly to the GSM standard and what types of mobile network operators can provide them. The best way to provide these service for millions of users, is to become a MVNO. With few years MVNO popularity has grown rapidly. It has been providing same GSM services to the subscribers as previously only classical Mobile Network Operator did. This thesis uses one possible way of analysis, design and realization of GSM services for the MVNO.

Finally, services for a real company, which meet the requirements of the GSM standard, were created. Analysis of issues and future development is presented as well. This solution is reusable and extendible for different companies, who wish to use that for receiving necessary knowledge. The work completed the necessary goal.

The thesis is in English and contains 69 pages of text, 3 chapters, 28 figures, 5 tables.

Abbreviations

AuC	Authentication Centre
BSC	Base station controller
BSS	Base station subsystem
BTS	Base transceiver station
CAMEL	Customized Applications for Mobile networks Enhanced Logic
CCBS	Completion of Calls to Busy Subscriber
CDR	Call detail record
CEPT	European Conference of Postal and Telecommunications Administrations
CGI	Cell Global Identity
EIR	Equipment identity register
ETSI	European Telecommunications Standards Institute
G-MSC	Gateway mobile switching center
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communication
gsmSCF	GSM Service Control Function
gsmSSF	GSM Service Switching Function
HLR	Home location register
IFW	The Information Framework
IMEI	International Mobile Station Equipment Identity
IMSI	International mobile subscriber identity
ISDN	Integrated Services Digital Network
IWF	Inter-working function
LA	Location Area
LAC	Location area code
LCS	Radio resource location services
ME	Mobile equipment
MMS	Multimedia Messaging Service

MNO	Mobile network operator
MS	Mobile station
MSC	Mobile switching center
MSISDN	Mobile Station International Subscriber Directory Number
MVNE	Mobile virtual network enabler
MVNO	Mobile virtual network operator
PDP	Packet Data Protocol
PLMN	Public land mobile network
PSPDN	Packet Switched Public Data Network
PSTN	Public switched telephone network
RAC	Routing Area Code
RNR	Ring No Reply
SMS	Short Message Service
SMSC	Short message service center
TAP	Transferred Account Procedure
TRAU	Transcoder and Rate Adaptation Unit
USSD	Unstructured Supplementary Service Data
VLR	Visitor Location Register
XML	Extensible Markup Language

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Introduction

The impact of mobile technology on our lives cannot be overemphasized. Mobile telephony is currently considered as a necessity, and mobile technologies are the most popular and fastest growing. Mobile communication systems have evolved in a very short time. Considering the evolution of mobile communication systems, we come to the concept of "generations."

System of the first generation (1G) was analog, implemented on a fairly reliable network, but with limited ability to offer services to subscribers. In addition, they did not allow roaming between networks.

Mobile communication systems of the second generation (2G) are digital. They brought significant benefits in terms of offering customers improved services, increased capacity and quality. The Global System for Mobile Communications refers to the 2G technologies. The increased demand for wireless access to the Internet has led to the further development of 2G. So there is a system called 2.5 G. An example of 2.5G is General Packet Radio Services - a standardized packet data technology that allows to use a mobile communication device to access the Internet.

Further on the base of the 2G was developed the third generation (3G) of mobile telecommunications technology. Example of a 3G mobile cellular system for networks is The Universal Mobile Telecommunications System that based on the GSM standard.

Later 3G was succeeded by the fourth generation (4G) of mobile telecommunications technology. 4G provides mobile ultra-broadband Internet access.

Thus, GSM is the underlying technology on which grew up previous technologies and existing mobile communication systems. GSM probably will be also the underlying technology for the future development in the field of communication. [1]

1. Global System for Mobile Communications

Global System for Mobile Communications is a standard developed by European Telecommunications Standard Institute to describe protocols for digital cellular network.

Firstly acronym GSM was used in 1982 by the European Conference of Postal and Telecommunications Administrations (CEPT). CEPT is a European standardization organization, which is dealing with co-operation on commercial, operational, regulatory and technical standardization issues. The main goal of GSM was to define a new standard for mobile communications in 900 MHz range. Later, CEPT evolved into a new organization named European Telecommunications Standard Institute (ETSI). In 1991, acronym GSM was changed to Global System for Mobile Communications. By 1992, GSM rapidly gained worldwide popularity. By 2014, terrestrial GSM networks cover more than 90% of the world's population and are now used in 219 countries and territories serving more than three billion people and providing travelers with access to mobile services wherever they go [2].

There are 3 phases of GSM standards.

GSM Phase 1

It is the digital standard with data transfer rate up to 9.6 Kbit / s. GSM Phase 1 was completed in 1990.

GSM Phase 2

It is the digital standard with data transfer rate up to 9.6 Kbit / s and includes a range of 1900 MHz. GSM Phase 1 was completed in 1994.

GSM Phase 2+

The main GSM Phase 2+ standards are [3]:

Standard No	Standard Title
3GPPTM TS 45.001	Physical layer on the radio path; General description

3GPPTM TS 45.002	Multiplexing and multiple access on the radio path
3GPPTM TS 45.005	Radio transmission and reception
3GPPTM TS 23.002	Network architecture
3GPPTM TS 41.101	Technical Specifications and Technical Reports for a GERAN-based 3GPPTM system

1.1 GSM Architecture

A GSM network is composed of several functional entities, whose functions and interfaces are specified. Figure 1 shows the layout of a GSM network. The GSM network can be divided into three broad parts. The Mobile Station is carried by the subscriber. The Base Station Subsystem controls the radio link with the Mobile Station. The Network Subsystem, the main part of which is the Mobile services Switching Center (MSC), performs the switching of calls between the mobile users and between mobile and fixed network users. The MSC also handles the mobility management operations. Not shown is the Operations and Maintenance Center, which oversees the proper operation and setup of the network. The Mobile Station and the Base Station Subsystem communicate across the Um interface, also known as the air interface or radio link. The Base Station Subsystem communicates with the Mobile services Switching Center across the A interface [4].

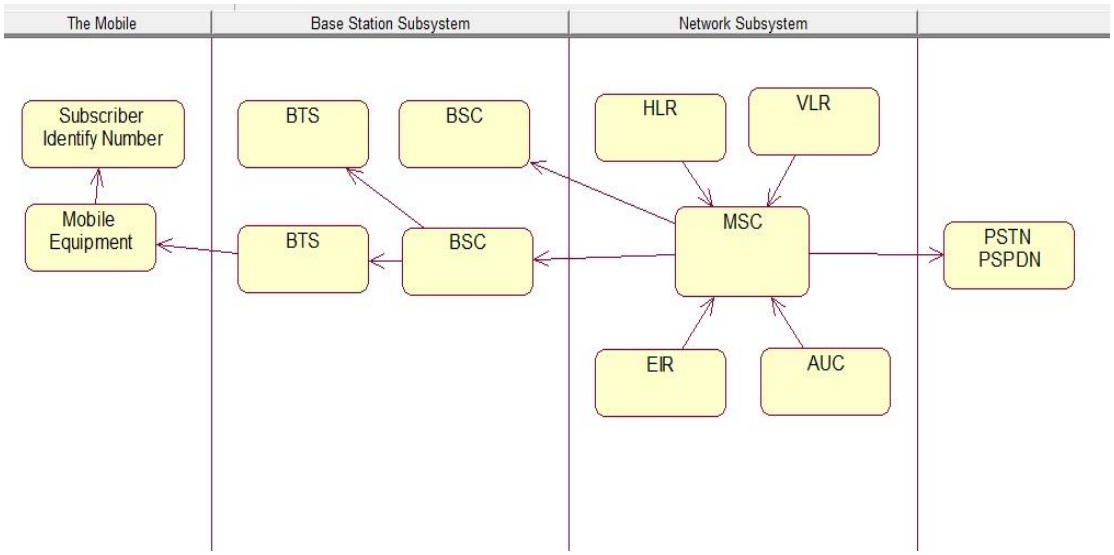

Figure 1. GSM Architecture [4]

1.2 GSM Geographical Network Structure

GSM is a worldwide standard, so due to the mobility of the subscribers, the Geographical Network structure must be subdivided into different elements. The GSM Service Area, PLMN Service Area, MSC Service Area, Location Area and Cell Area are necessary to establish point-to-point connections [5].

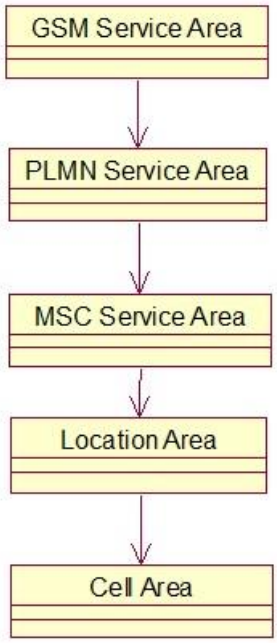

Figure 2. Geographical structures in the GSM [5]

Cell

A cell is the basic unit of a cellular system and is defined as the area of radio coverage given by one BS antenna system. Each cell is assigned a unique number called Cell Global Identity (CGI). [6].

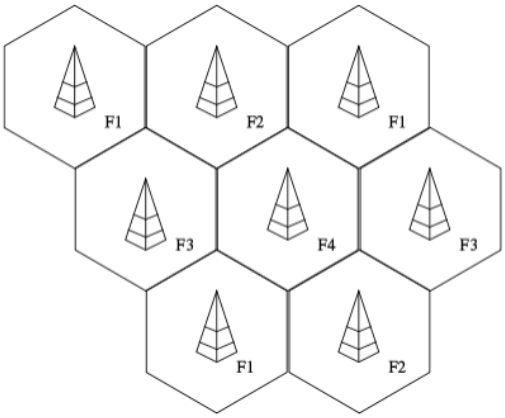

Figure 3. A typical cell distribution. [6]

Location Area

A Location Area is the lowest existing level of the location information of one subscriber and is defined as a group of cells. Within the network, subscribers' location is known by the LA, which they are in. The identity of the LA in which a MS is currently located is stored in the VLR. When a MS crosses the boundary between two cells belonging to different LA's, it must report its new Location Area to the network1. If it crosses a cell boundary within a LA, it does not report its new cell location to the network. When there is a call for a MS, a paging message is broadcast within all the cells belonging to the relevant LA [7].

Mobile Switching Service Area

An MSC service area is made up of a number of LAs and represents the geographical part of the network controlled by one MSC. In order to be able to route a call to a MS, subscriber's MSC service area is also recorded and monitored. The subscriber's MSC service area is stored in the HLR [7].

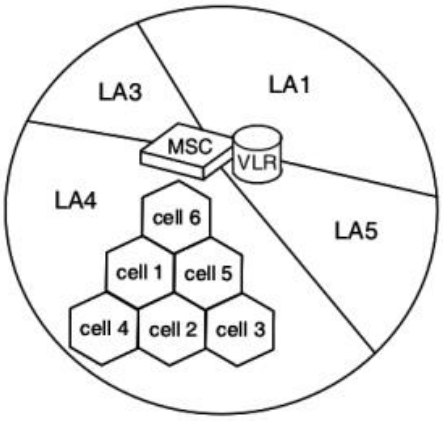

Figure 4. MSC area. [7]

Public Land Mobile Network Service Area

A Public Land Mobile Network (PLMN) service area is the entire set of cells served by one network operator and is defined as the area in which an operator offers radio coverage and access to its network. In any country there may be several PLMN service areas, one for each mobile operator's network.

Global System for Mobile Communications Service Area

The GSM service area is the entire geographical area in which a subscriber can gain access to a GSM network. The GSM service area increases as more operators sign contracts agreeing to work together. Currently, the GSM service area spans dozens of countries across the world from Ireland to Australia and South Africa. International roaming is the term applied when a MS moves from one PLMN to another when abroad [7].

1.3 GSM Components

Accordingly to the 3GPP TS 23.002 standard the GSM network is divided into two main systems: Network Switching System and Base Station System.

1.3.1 Network Switching System

Network Switching System is responsible for carrying out call switching and subscriber-related functions. The main functions of Network switching Subsystem are [8]:

1. Call control. Identifies the subscriber, establishes a call and clears the connection after finishing the conversation.

2. Charging. This gathers up the charging information about the call and transfers it to the billing.

3. Mobility Management. Handles information about subscribers' location.

4. Signaling. Applies to interfaces with the BSS and PSTN.

5. Subscriber data handling. Stores data in the HLR permanently and in the VLR temporarily.

The NSS includes the following functional units: Mobile Services Switching Center (MSC), Home Location Register (HLR), Visitor Location Register (VLR), Equipment Identity Register (EIR), Authentication Center (AUC) and Gateway MSC (G-MSC) [8].

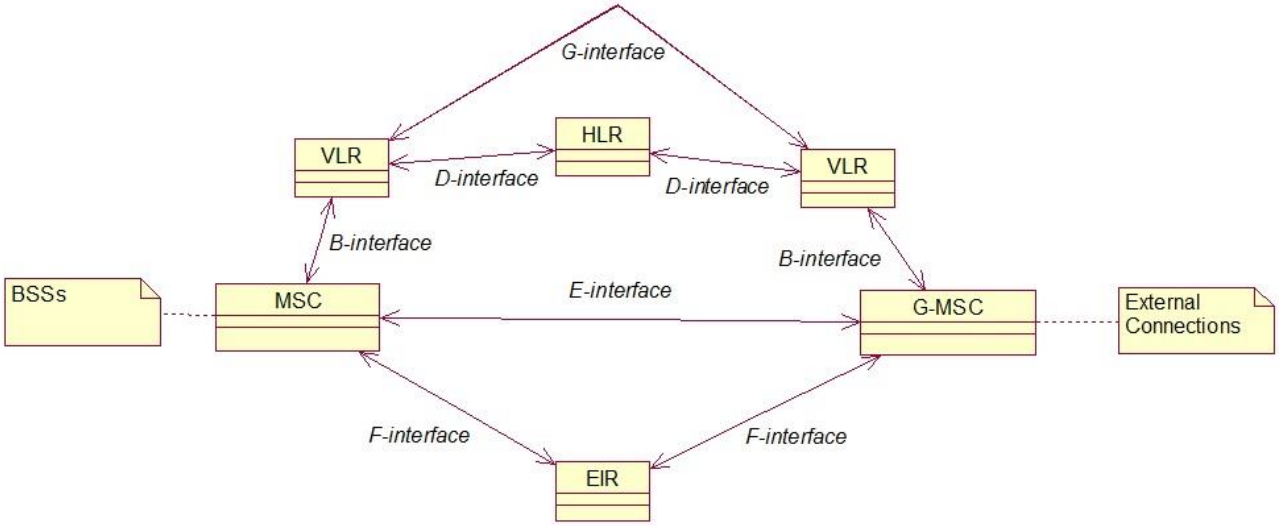

Figure 5. Typical Switching System [8]

Mobile Services Switching Center

The MSC identifies the origin, type and destination of a call. Additionally it offers interfaces into foreign or external networks and connections to other MSC's of the same network. Every MSC is identified by a unique ID.

The MSC is responsible for many important tasks, such as [9]:

- Set up, route and handover calls
- Checking IMEI
- Accounting and charging
- Updating information about subscriber current location in the HLR and VLR

Home Location Register

The HLR is a database used for keeping record of every subscriber, including subscriber's service profile, location information and activity status. The HLR forms the access with subscribers' MSISDN and IMSI number to the relayed information, like

home address or bank account of the person. Additionally the HLR is used as a central register for routing and authentication functionality for every telephone call. The following information can be found inside the HLR: MSISDN, IMSI, restrictions in services (like barring of calls), Supplementary Services, Call deviation, Address of the valid VLR and MSC [9].

Visitor Location Register

The VLR is a database that includes temporary information about subscribers that is needed by the MSC in order to service visiting subscribers. When a mobile station comes to a new MSC area, it must register itself in the VLR. Then VLR will receive data about the mobile station from the HLR or MS. In order to use the services of the network, subscriber must always be registered in the VLR. Later, if the mobile station makes a call, the VLR will already have needed information and there is no need to request data from HLR. The following information can be found inside the VLR: IMSI, MSISD, Authentication data, HLR address [9].

Authentication Center

The AUC provides authentication and encryption parameters of each SIM card that attempts to connect to the GSM core network to verify user's identity. The AUC supports VLR’s work by issuing authentication triplets upon request. Additionally the AUC protects network operators from different types of fraud [10].

Equipment Identity Register

The EIR is a database that has information about the identity of mobile equipment on the network. EIR is responsible for IMEI checking, that prevents calls from stolen, unauthorized or defective mobile stations. The EIR contains three lists [11]:

1. White list. Mobile equipment is allowed to operate in the network.

2. Grey list. Mobile equipment is suspected and needs to be monitored.

3. Black list. Mobile equipment is reported stolen or not allowed to operate in the network.

Gateway Mobile Services Switching Center

G-MSC is the Mobile Service Switching Center with interface to the external networks. Through a G-MSC all mobile to mobile and PSTN to mobile calls are routed. Additional task of G-MSC is to check HLR in order to determinate the MSC, which called MS is currently attached to[8].

1.3.2 Base Station System

The Base Station System is responsible for handling traffic, managing the radio network and arrangement connection between MS and MSC. BSS manages the radio coverage in certain geographical area. One MSC can include several BSS [8].

Additionally, the BSS is responsible for:

1. Radio path control. The BSS takes care of radio channel allocation and quality of the radio connection.
2. Synchronization. Inside the BSS, synchronization is controlled by the BSC. MSC synchronizes the BSC, next the BSC synchronizes the BST.
3. A- Interface and Air signaling. Establishing a point-to-point link between the MS and BSS.
4. Connection between the MS and the NSS.
5. Speech transcoding and Mobility management.

The Base Station System consists of three components:

1. Base Transceiver Station
2. Base Station Controller
3. Transcoding Rate and Adaptation Unit

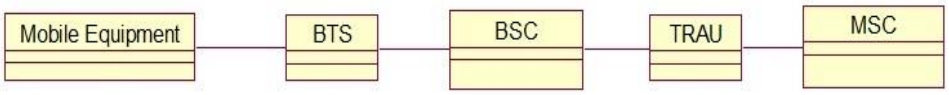

Figure 6. Typical Base Station System. [8]

Base Transceiver Station

Base Transceiver Station is used to facilitate wireless communication between telecoms operator network and subscriber device. This network element is responsible for minimizing the transmission problems and maintaining the air interface. The most important tasks of BTS are:

1. Speech processing.

In order to guarantee connection between MS and BTS without any errors, speech-processing concerns all the functions that BTS performs. The base Transceiver Station can include several Transceivers. Transceivers are responsible for transmission and reception of signals. The BTS has also one or more antennas, which are able to transmit and receive information from and to transceivers. Antennas can be omnidirectional and directional. An omnidirectional antenna radiates or receive equally well in all directions. In a directional antenna radio frequency is focused in one or more directions. For sending and receiving signals from and to antenna duplexer is used. BTS has control functions for Operation and Maintenance, external alarms and synchronization [8].

2. Ciphering.

In order to protect the transmitted speech and data in the air interface, BTS and MS have to cipher and decipher information.

3. Air interface signaling

In order to send and receive information within the network, when the MS was firstly switched on, signaling must be performed. Additionally, it is needed to inform the MS

when the handover is to be performed. Also, to set up mobile originated and mobile terminated call, the signaling is required.

Base Station Controller

Base Station Controller is a central element of Base Station System that controls one or more Base Transceiver Stations. Key Base Station Controller tasks include [8]:

1. Establishment of connection between the Mobile Station and Network Switching Subsystem.

Through the group switch of the Base Station Controller all calls to and from the MS are connected.

2. Collection the statistical data row.

In order to make statistical views, information must be collected from the Base Transceiver Station and Transcoders in the Base Station Controller. Then it must be directed to the Network Management Subsystem.

3. Mobility management.

The BTS is responsible for launching of tremendous number of handovers during a call.

4. Base Transceiver Station and Transcoder control.

The Base Station Controller maintains Transcoders, Base Transceiver Station and collects alarm information.

5. A- Interface and Air signaling support.

The Base Station Controller enables the virtual signaling connection, which is needed between the MSC/VLR and the MS.

Transcoding and Rate Adaptation Unit

Transcoding and Rate Adaptation Unit compresses traffic coming from the mobiles through the base station controllers. In the case of Full Rate it converts between the 64

Kbit/s per channel bit rate at the MSC and the net rate of 13 Kbit/s for the radio interface. This conversion is required between the BSC and MSC. If TRAU is remote from the radio interface, speech or data is transferred between the TRAU and channel codec unit in frames. The length of this frame is fixed - 320 bits (20ms) [12].

2 Global System for Mobile Communications services

GSM is designed to support a lot of different services. They depend on the network, mobile equipment capabilities and client's contract.

In GSM terminology, telecommunication services are divided like Integrated Services Digital Network services into three categories: bearer services or data services, teleservices and supplementary services [8].

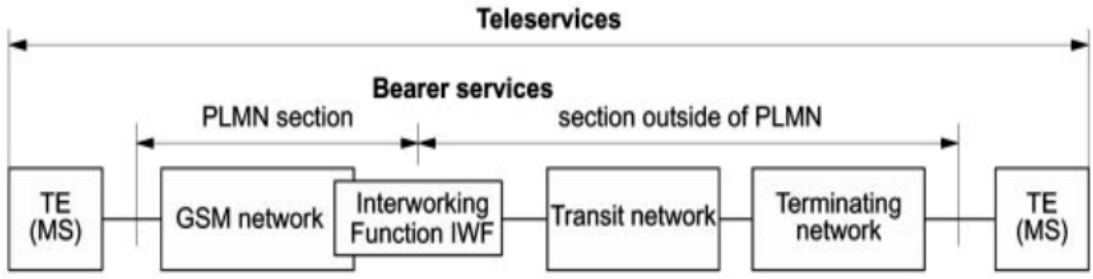

Figure 7. Bearer and Teleservices. [8]

Bearer services are telecommunication services providing the capability of transmission of binary data. It offers data transfer between access points - the user-network interfaces in ISDN. Both bearer and teleservices require special measures inside the PLMN, which must offer special Interworking Functions. The IFW converts the data transmitted over the air interface into a format suitable for the public switched telephone network [13].

Teleservices are telecommunication services providing the complete capability, including terminal equipment functions, for communication between users according to protocols established by agreement between network operators.

In addition to these services, supplementary services are defined that modify or supplement a basic telecommunication service. They supplement the control and modification of extended services. Supplementary services are usable only in connection with telecommunication services [13].

2.1 Bearer services

In the ISDN the basic services are called bearer services –therefore in GSM too. The GSM bearer services propose synchronous and asynchronous data transport capabilities with circuit-switched or packet-switched data rates of 300-900 bit/s and with a 13 Kbit/s bearer service for voice. Bearer Services transport only the coding- and application-independent information between the user-network interfaces. Each bearer service has its own number. For example, BS21 is the bearer service for circuit-switched asynchronous data at 300 bit/s. For GSM data transfer the bearer services are offered in 2 different modes – transparent (T) and nontransparent (NT). In the transparent mode, there is a circuit switched connection between the mobile terminal and the interworking module in the MSC, from where the connection to other network is handled. The most important common characteristics for transparent services are constant bit rate, constant transport delay and residual bit error ratio depended on the current channel conditions. The nontransparent activates a Radio Link Protocol for the additional protection of the data transfer. This protocol terminates in the mobile station and in the MSC. Activation of the nontransparent data service is needed in case of rapidly moving mobile stations or for cases of bad radio conditions. In such situations, the nontransparent mode allows a reliable data transport [14].

Table 1. Bearer Services. [15]

Service	Structure	BS no.	Bit rates (in bit/s)	Mode	Transmission
Data	Asynch	21	300	T or NT	UDI or 3.1 kHz
		22	1200	T or NT	UDI or 3.1 kHz
		23	1200/75	T or NT	UDI or 3.1 kHz
		24	2400	T or NT	UDI or 3.1 kHz
		25	4800	T or NT	UDI or 3.1 kHz
		26	9600	T or NT	UDI or 3.1 kHz
Data	Synch	31	1200	T	UDI or 3.1 kHz
		32	2400	T or NT	UDI or 3.1 kHz
		33	4800	T or NT	UDI or 3.1 kHz
		34	9600	T or NT	UDI or 3.1 kHz
PAD	Asynch	41	300	T or NT	UDI
		42	1200	T or NT	UDI
		43	1200/75	T or NT	UDI
		44	2400	T or NT	UDI
		45	4800	T or NT	UDI
		46	9600	T or NT	UDI
Packet	Synch	51	2400	NT	UDI
		52	4800	NT	UDI
		53	9600	NT	UDI
Altern. speech/data		61	13000 or 9600		
Speech followed by data		81	13000 or 9600		

Accordingly to the EVS- ETS 300 904 standard there are several categories of bearer services [15]:

1. Unrestricted digital information. UDI is designed to offer a peer-to-peer digital link.

2. The 3.1 kHz is external to the PLMN and provides a UDI service on the GSM network. It is used when interconnected with the ISDN or the PSTN service and includes the capability to select a modem at the interworking function.

3. PAD provides an asynchronous connection to a packet assembler/disassembler. This enables the PLMN subscribers to access a packet-switched public data network.

4. Packet enables a synchronous connection to access a PSPDN network and alternate speech and data.

5. Alternate Speech/Data provides the capability to switch between voice and data during a call.

6. Speech followed by Data provides a speech connection first, and then allows to switch during the call for a data connection. The user cannot switch back to speech after the data portion.

2.2 Teleservices

The most important categories of teleservices are speech, SMS, access to Message Handling System, videotext, teletext and facsimile transfer [14].

Table 2. List of Teleservices. [14]

Category	TS no.	Service		Class
Speech	11	Telephone		E1
	12	Emergency call		E1
Fax transmission	61	Speech and fax group 3	T	E2
		alternating	NT	A
	62	Fax group 3 automatic	T	–
			NT	–
Short Message Services (SMS)	21	Short message mobile terminated, point to point		E3
	22	Short message mobile originated, point to point		A
	23	Short message cell broadcast		–
MHS access	31	Access to message handling systems		A
Videotex access	41	Videotex access profile 1		A
	42	Videotex access profile 2		A
	43	Videotex access profile 3		A
Teletext transmission	51	Teletext		A

2.2.1 Voice

Of course, the most basic teleservice supported by GSM is digital voice telephony, based on transmission of the digitally encoded voice over the radio. In the start up phase (E1) each network operator had to implement voice service. There are two teleservices: emergency service (TS12) and regular telephone service (TS11). Both services use full-duplex point-to-point connection. The difference between emergency service and regular telephone service is that TS12 requires an international IWF. For the emergency service the nearest emergency-service provider is notified by dialing three digits [14].

2.2.2 Fax transmission

Implementation of transparent fax service must be planned in the second implementation phase (E2). The fax service uses a transparent bearer service for the transmission of fax data, so it is called transparent. Accordingly to the ITUT-T recommendation T30, the fax protocol is used for coding and transmission of the facsimile data. Additionally, there is another alternative used for voice or for fax – TS61. TS61 is a fax transfer with automatic call acceptance. This service can be used as the interworking solution only for network operator, where multinumbering is used. In case of multinumbering, the subscriber has several MSISDN numbers. Specific teleservices can be associated with each MSISDN number.

2.2.3 Short Message Service

Implementation of Short Message Service must be planned in the third implementation phase (E3). SMS provides the capability to send or receive messages of up to 160 characters at the mobile station if Latin alphabets are used. If non-Latin alphabets like Chinese or Arabic are used, the limit is 70 characters. SMS supports international roaming. This means that you can send short messages to any other GSM mobile user around the world. For SMS, the network operator, has to establish a service center, which accepts short messages from the fixed network and processes them in a store-

and-forward mode. The delivery can be time-shifted and is of course independent of the current location of the mobile station. The transmission of short messages uses a protected, connectionless, packet switching protocol. In case of failure occurs the retransmission of a message [14]. For Mobile Application Part must be realized Mobile Originated SMS transfer and Mobile Terminated SMS transfer.

2.3 Supplementary Services

Supplementary services include several forms of call forward (such as call forwarding when the mobile subscriber is unreachable by the network), caller identification, call waiting, multiparty conversations, charging information, and call barring of outgoing or incoming calls. These call-barring features can be used for example when roaming in another country, if the user wants to limit the communication fees. Supplementary services can be used only on connection with teleservices. Some GSM supplementary services are very similar to those offered in ISDN, but their implementation is often much more complex.

2.3.1 Supplementary Services of Phase 1

For Phase 1, only a small set of supplementary services concern call forwarding. If call forwarding is activated, then calls are not switched through to MS, but they are forwarded to a configurable extension. There are 2 types of the calls forwarding [16]:

1. Conditional – when all calls are rejected

2. Unconditional – when the MS is busy, not reachable, powered off or outside network coverage area.

Additionally, the network operators offer a voice mailbox service. That is function, which allows recording voice massages for later retrieval by the subscriber for incoming calls, if the forwarding feature was activated.

Also, GSM Phase 1 provides supplementary services for barring outgoing or incoming calls. There can be barred outgoing calls, incoming calls, outgoing international calls, and incoming calls when roaming outside.

Table 3. GSM supplementary Services of Phase 1. [16]

Category	Abbreviation	Service	Class
Call offering	CFU	Call forwarding unconditional	E1
	CFB	Call forwarding on mobile subscriber busy	E1
	CFNRy	Call forwarding on no reply	E1
	CFNRc	Call forwarding on mobile subscriber not reachable	E1
Call restriction	BAOC	Barring of all outgoing calls	E1
	BOIC	Barring of outgoing international calls	E1
	BAIC	Barring of all incoming calls	E1
	BOIC-exHC	Barring of outgoing international calls except calls to home PLMN	A
	BIC-roam	Barring of incoming calls when roaming outside the home PLMN	A

2.3.2 Supplementary Services of Phase 2

For Phase 2, there are such supplementary services like Call Waiting (CW) or Hold (HOLD), which enable performing brokerage functions. Also, there are supplementary services like a Conference Call (CONF), which allows the interconnection of several subscribers in one call and Call Transfer. Call Transfer allows a call to be passed to third party.

The Call Line Identification Presentation (CLIP) lets the calling party's MSISDN number appear on the display of the called party. Calling party by activating supplementary service Calling Line Identification Restriction (CLIR) can prevent this.

With the supplementary service Connected Line Identification Presentation (COLP) the caller can request to be shown the reached extensions. By using Connected Line Identification Restriction (COLR) the called party can prevent this announcement.

The Reverse Charging (REVC) allows the called party to assume the charges for the call. These features are responsible for providing calling comfort in GSM network [14].

Table 4. GSM supplementary Services of Phase 2. [14]

Category	Abbreviation	Service	Class
Number identification	CLIP	Calling line identification presentation	A
	CLIR	Calling line identification restriction	A
	COLP	Connected line identification presentation	A
	COLR	Connected line identification restriction	A
	MCI	Malicious call identification	A
Call offering	CT	Call transfer	A
	MAH	Mobile access hunting	A
Community of interest	CUG	Closed user group	A
Charging	AoC	Advice of charge	E2
	FPH	Freephone service	A
	REVC	Reverse charging	A
Additional information transfer	UUS	User-to-user signaling	A
Call completion	CW	Call waiting	E3
	HOLD	Call hold	E2
	CCBS	Completion of call to busy subscriber	A
Multi-party	3PTY	Three-party service	E2
	CONF	Conference calling	E3

2.3.3 Supplementary Services of Phase 2+

Phase 2+ is dealing with many aspects ranging from radio transmission to communication and call processing. The examples of supplementary services on Phase 2+ are mobile access hunting, short message forwarding, Unstructured Supplementary Service Data, multiple subscriber profile, call transfer or Completion of Calls to Busy Subscribers (CCBS). The CCBS realizes when a called subscriber does not immediately accept a call due to an ongoing connection. The calling subscriber can activate the

supplementary service CCBS. CCBS causes the network to notify him at the end of the called subscriber's ongoing call and automatically set up new connection.

Another supplementary service of Phase 2+ is Location Service (LCS). LCS provides the possibility to determinate the exact location of a mobile station down to a few meters. The network already knows the current cell of the user from GSM mobility management cell identifier. But this location accuracy is not sufficient. To provide location service there are two methods to be used: Time of Arrival method (TOA) and Enhanced Observed Time Difference method (E-OTD). Accordingly to the TOA method, the network listens to handover access bursts of the mobile station and is then able to triangulate its position. Accordingly to the E-OTD method, the time difference from different base stations is measured. The accuracy of E-OTD lies between 50 and 125 m. The best way to know the position of a mobile station is to integrate a GPS receiver into each piece of mobile equipment. Then, the mobile station receives current position from GPS satellites [17].

2.4 GSM services providers

2.4.1 Mobile Network Operator

Mobile Network Operator is a telecommunication's service provider of wireless communication services. MNO control all necessary elements to sell and deliver services to the end-users. MNO own the complete telecom infrastructure for hosting and managing mobile communications between the subscribed mobile users with users in the same and external wireless and wired telecom networks.

The main tasks of the Mobile Network Operator are:

- Obtaining the permission to use radio frequencies and services.
- Building the own network.
- Developing the conditions of services.

- Building the billing system.
- Designing a strategic network development plan.
- Technological improvement of infrastructure.

Mobile Network Operators use the full Global System for Mobile Communication.

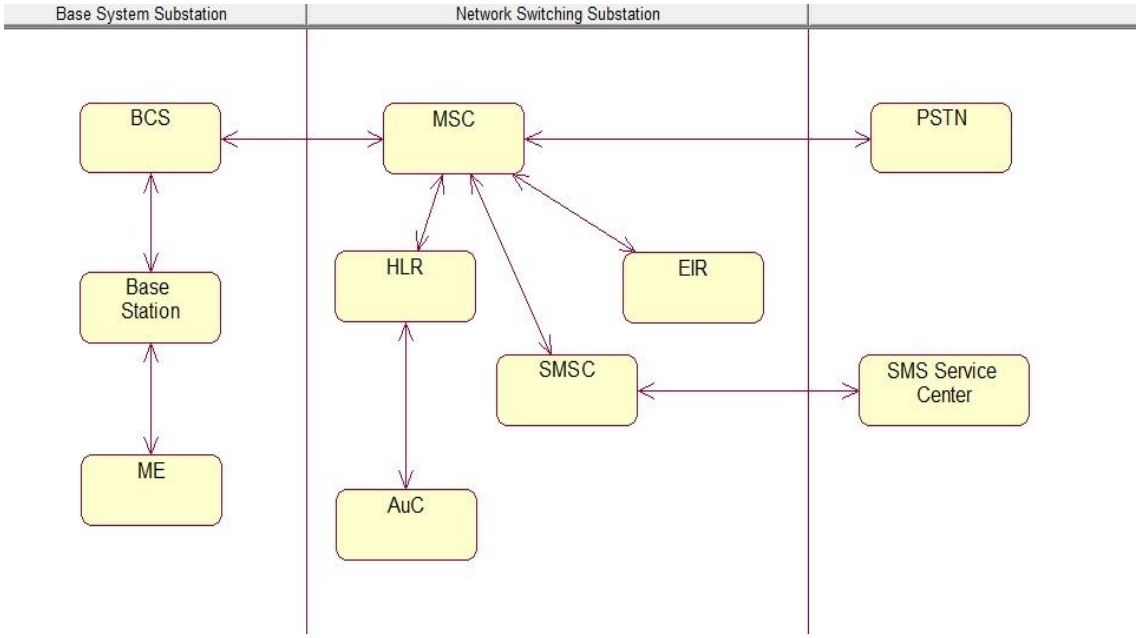

Figure 8. Mobile Network Operator architecture.

Additionally, they have own radio and network access, HLR, MSC, inventory and resource management, and services, billing system and marketing strategies.

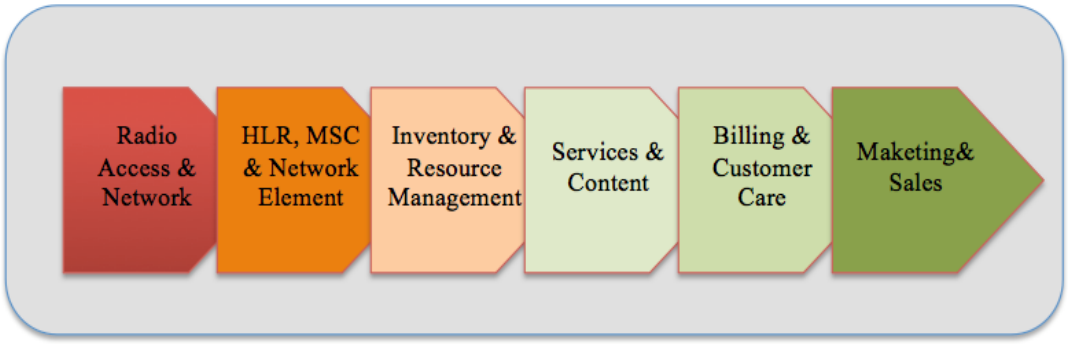

Figure 9. Mobile Network Operator.

2.4.2 Mobile Virtual Network Operator

Mobile Virtual Network Operator is a wireless communications services provider that rent the network of mobile operators to become a fully mobile operator on their own. MVNO does not own licenses for radio frequency spectrum, so it buys this radio frequency spectrum or communication bandwidth from Mobile Network Operator. MVNO usually has its own customer service, billing support systems, marketing and management systems and has full control on resource management, SIM card delivery, marketing and branding systems. Sometimes, MVNO can also implement switching and networking elements in order to have more service fulfillment possibilities. So, it's all gives the possibility to offer the services with the lowest prices to the customers.

There are three types of MVNO [18]:

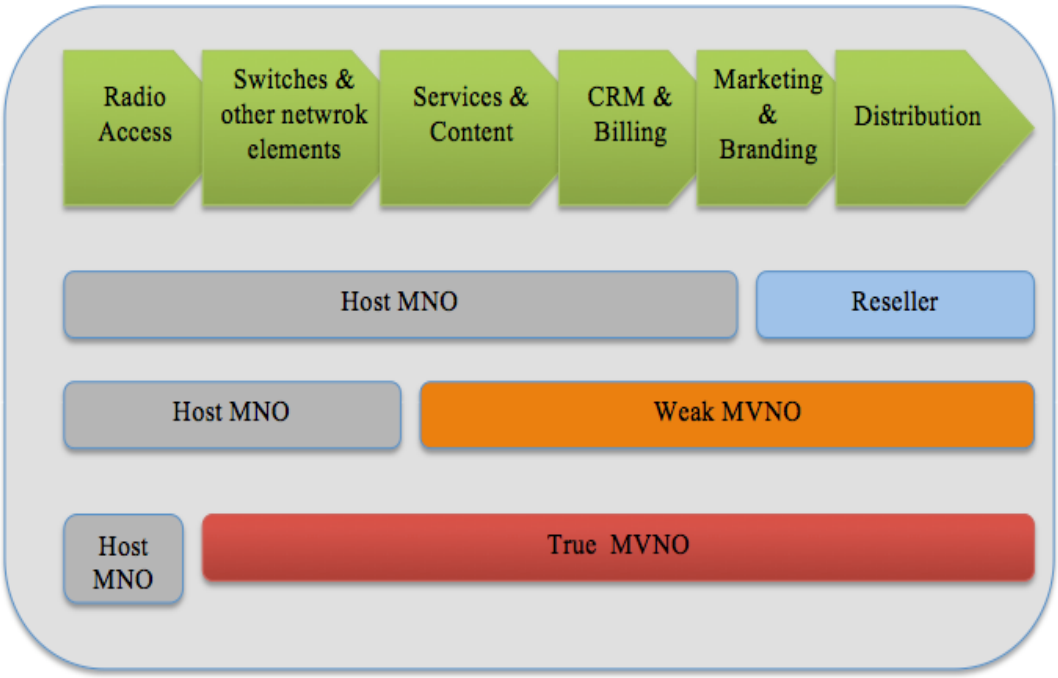

Figure 10. The different types of MVNO. [18]

1. "True MVNO"

That Mobile Virtual Network Operator has own Services, Billing, Marketing, also it implements HLR, Switching and Intelligent Network platform. That gives the possibility to have full flexibility on the tariff design and service design, service implementation, branding, service marketing and they can offer their own SIM card. The main difference between True MVNO and other MVNO types is the possibility to operate independently of the MNOs.

2. "Weak MVNO"

Weak MVNO has also own Services, Billing, Marketing, but it rents HLR, Switching and Services from MNO. In this case, MVNO has control over tariff design, branding and service marketing. That service providers may require NSP individual license if they own or provide bandwidth services, cellular mobile services or mobile application services. Also if they provide public cellular services to end users, ASP license might be needed.

3. “Reseller”

Reseller implements only Marketing and Branding to sell only pre-packaged services, because reseller buys all services from other operators. The key feature that distinguishes resellers is that enhanced resellers do not have their own SIM cards. Additionally, MVNOs that operate as resellers require an ASP license.

Below are provided the differences in the Reseller MVNO and True MVNO architecture.

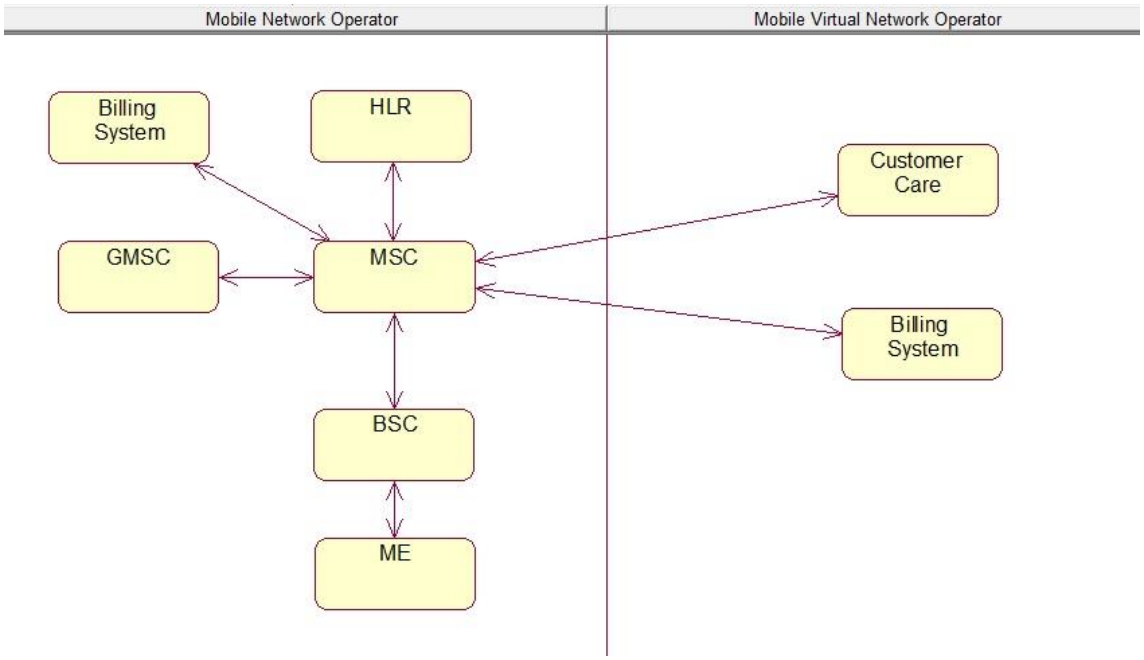

Figure 11. Reseller MVNO. [18]

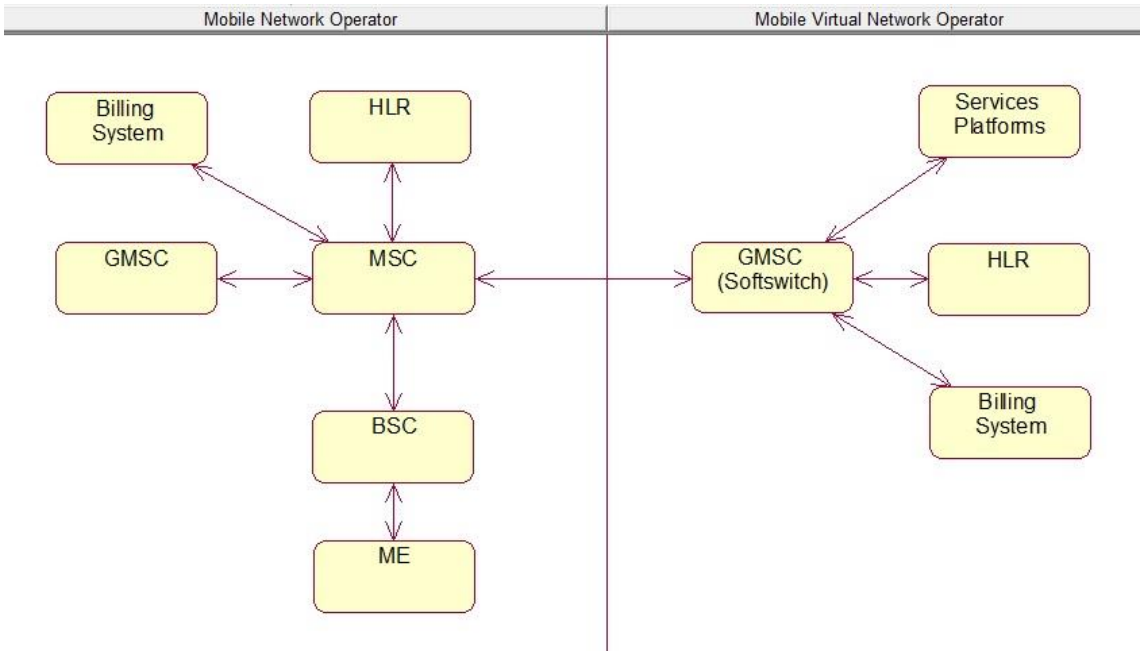

Figure 12. True MVNO. [18]

Advantages of the Mobile Virtual Network Operator [19]:

- Launching MVNO service in the market does not take a lot of time.
- Low total cost of ownership and accelerated return on investment
- Ability to launch fast campaign and promotions.
- Faster time-to-market with new products and services.
- Fast-track integration of additional partners and applications.
- Ability to offer value-added service that is not generally provided by the MNO.
- Possibility of seamless global-roaming.
- Low structure cost.
- Possibility to provide services at extremely discounted rates.

Disadvantages of the Mobile Virtual Network Operator:

- High costs of market entry
- High cost of equipment
- Permitted access to the Host Operators network
- Very complicated billing system between the MVNO itself, the Host Operator and any third-party content provider.

2.4.3 Mobile Virtual Network Enabler

The Mobile Virtual Network Enabler is a special case of the Mobile Virtual Network Operator. MVNE does not directly provide services to the mobile users. It provides the technical architecture and enables mobile services provisioning. MVNE handles set-up, operation and evolution services of the MVNO. For example, a MVNE can provide HLR, SMSC, MMSC, as well as GGSN and BSS.

There are two types of Mobile Virtual Network Enabler [19]:

1. Full MVNE

It operates core network infrastructure, building the capability and capacity to enable wholesale services from Mobile Network Operators. This type of MVNE parallels with "True MVNO" by implementing the same technical architecture. The Full MVNE is the intermediary between the host MNO and a Reseller or Service Operator.

2. Limited MVNE

It operates only elements of the service delivery infrastructure. Additionally, it does not provision the mobile service, limited MVNE leave them to partner companies. In

comparison with Full MVNE, Limited MVNE cannot offer the service innovation. But it also is the intermediary between the host MNO and a Reseller or Service Operator.

3 Realization in the Top Connect

3.1 Company structure

Top Connect is a company that provides a wide range of telecommunications services in the Baltic countries. The main branches are located in Estonia, Latvia and Lithuania. According to the Estonian business magazine "Äripäev", this company is in the list of 20 most successful companies.

The main product of the company is the roaming TravelSim card, which has a high popularity all over the world. Sim card works by using modern USSD CallBack technology. With this SIM card customers can make calls, use GPRS and MMS services at great discount prices. In addition, Top Connect provides a lot of other services: telephony, Internet, the possibility of sending mass SMS messages using a virtual fax.

Top Connect products are not directly distributed by the company. To do this, the company works with a lot of partners, who sell the products under their own brand names. In addition, partners are also performing marketing promotion and primary technical support.

The main divisions of the company Top Connect are following:

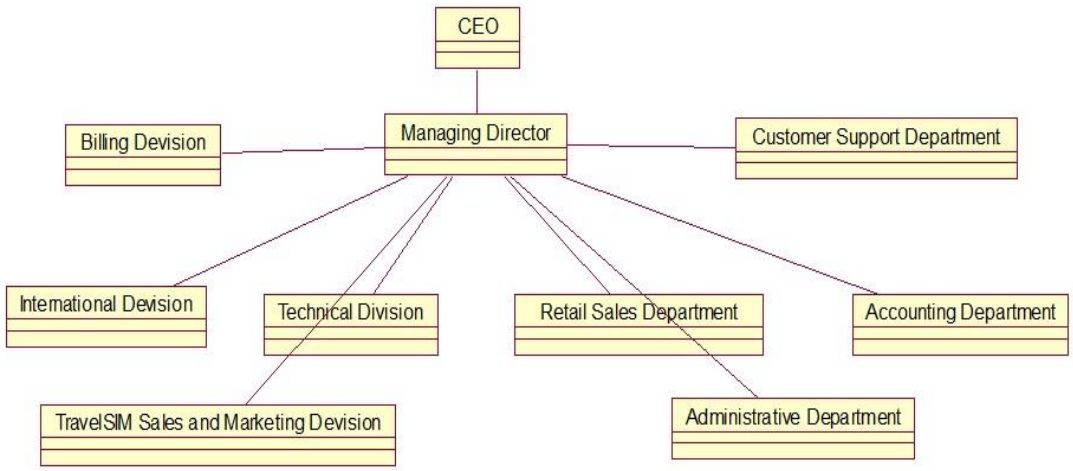

Figure 13. Top Connect Company Structure.

3.2 Analysis

Accordingly to the research made in the second chapter, the different types of mobile operators can provide GSM services. In order to decide what type is better it is suitable to make a value chain analysis. As the MVNE provide services to the MVNO, comparison is done for MNO and MVNE only. Value chain analysis was popularized by Michael Porter and provides the possibility to identify the sources of competitive advantages through analysis of individual activities [20].

Table 5. Value chain analysis of MNO and MVNO

Generic value chain	**MNO**	**MVNO**
Network	Own physical network International roaming	Rented physical network International roaming
Distribution	Shops Online Handset subsidies	No shops Online No handset subsidies
Pricing	High per minute rates Subscription with detailed invoices	Simple and low tariffs, mainly prepaid service
Marketing	Broad product development	Simplistic product development
Customer service	Well trained personal	Mostly automated, online service
Retention program	Advanced loyality schemes Discounts and subsidies	No loyality schemes No subsidies

Accordingly to the listed major advantages and disadvantages we can outline that MVNO in GSM architecture implementation is to be the best practice for the Top Connect.

Additionally, in the second chapter were listed GSM services, which can be provided by the GSM operators. The main list of GSM services, which must be provided to the subscribers all over the world, are following:

- Outbound call
- Inbound call
- GPRS
- SMS

As Top Connect provides these services in the roaming, it has implemented Unstructured Supplementary Service Data. USSD deploys a callback mechanism. Another service that is very popular and can be implemented by using callback mechanism is web callback [21]. Web callback is a service that provides a possibility to make a call from a web site. Scenario of this service implementation is described in the 3.4.5 chapter.

USSD is the main service, which can be provided to the subscriber in the roaming. The main advantages of implementing prepaid roaming with USSD are:

- Simple architecture
- Implementation does not take a lot of time
- Cheap
- Supported by almost all existing networks, thus providing a global footprint.

Roaming is the ability of customers to use their mobile phones or other mobile devices outside the geographical coverage area provided by their normal network operator. When customers travel abroad and use their phones or laptops whilst on a foreign ("visited") network, this is known as international roaming [22].

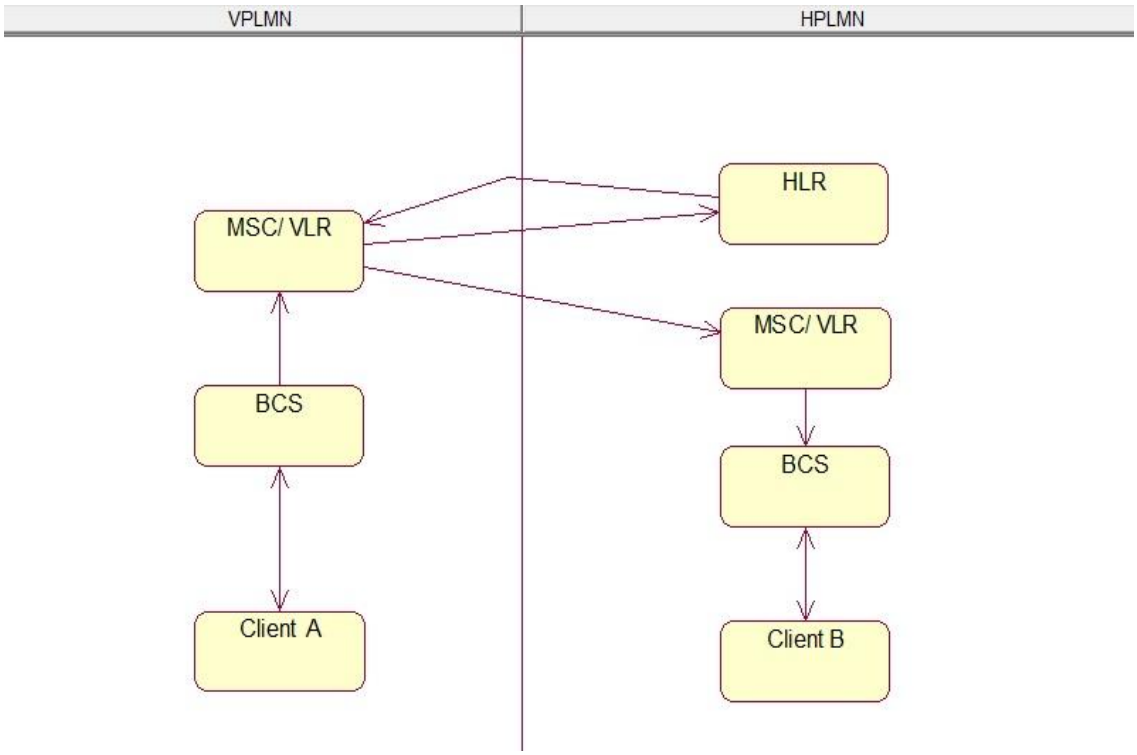

Figure 14. Roaming architecture. [22]

To explain roaming in more detail, Figure 14 shows technical details for international mobile roaming. The mobile user (Mobile User A) is automatically connected to a visited network while roaming and has an international roaming service with their home operator (Home Operator). When he arrives in the visited network, exchange of data between Home Operator and Visited Operator is started, then the subscriber is granted access to Visited Operator's network. Then Mobile User A sends transferred account procedure (TAP) files to a clearinghouse, which forwards them to the Home Operator. TAP files are used for billing of calls while roaming. Home Operator can then pay Visited Operator A the wholesale charges as per call volumes in the TAP file and rates in the wholesale roaming agreement. Visited Operator A pays an International Carrier for carrying the call and handing over the call to Home Operator.

3.3 Architecture design

Top Connect uses EMT and Elion telecommunication companies as its underlying carriers.

Top Connect has four C4 softswitches.

1. Two C4 softswitches in Tallinn

2. C4 softswitch in Vilnius

3. C4 softswitch in Riga

Softswitch is a central device in a telecommunications network that connects telephone calls from one phone line to another. C4 softswitch is used for the routing of large volumes of long distance VoIP calls. It supports up to 12,000,000 Busy Hour Call Attempts (BHCA) and up to 175,000 concurrent calls [23]. There is also C5 Softswitch. C5 softswitch is a telephone switch that is located in the public switched telephone network and directly serves the subscribers.

Additionally, Top Connect uses the PROTEI Intelligent Platform. PROTEI specializes in creating solutions that take full advantage of the most advanced technologies available, designed and developed in-house with strict quality control (ISO 9001:2001 and ISO 14001:2004).

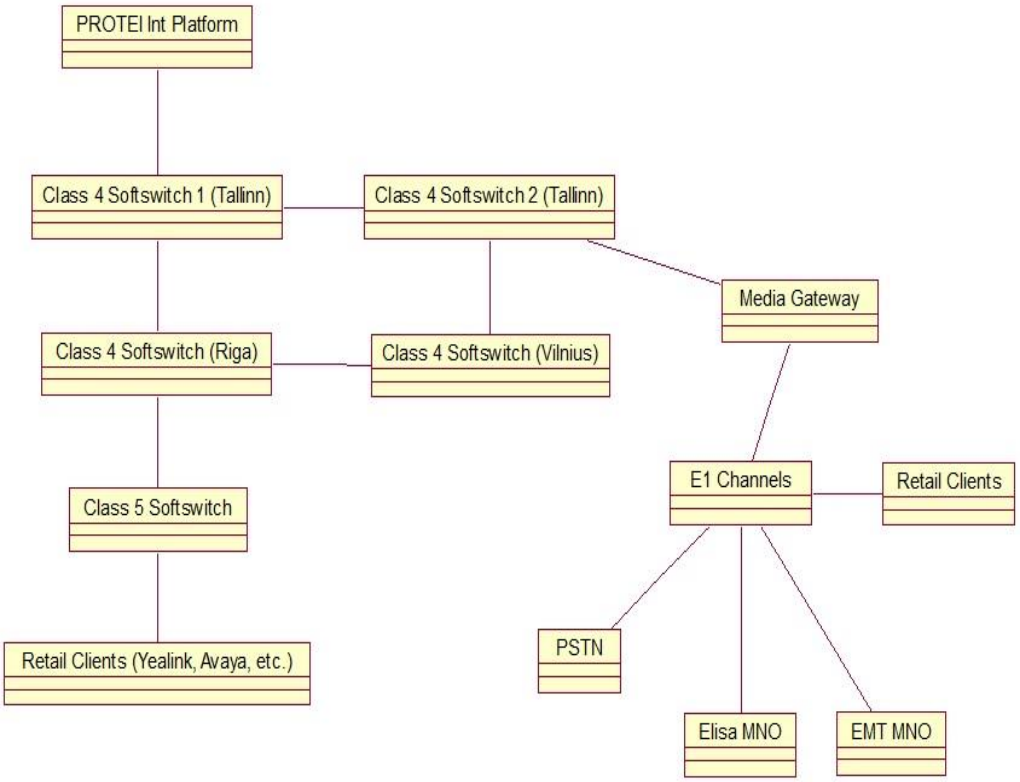

Figure 15. Top Connect full architecture.

Top Connect is a “True MVNO”, so the core structure is very similar to the typical “True MVNO”. The only difference is in the Billing System. Top Connect has 2 Billing Systems, one is for Travel Sim services and it is located in the PROTEI Intelligent Platform and second is for other telecommunication services.

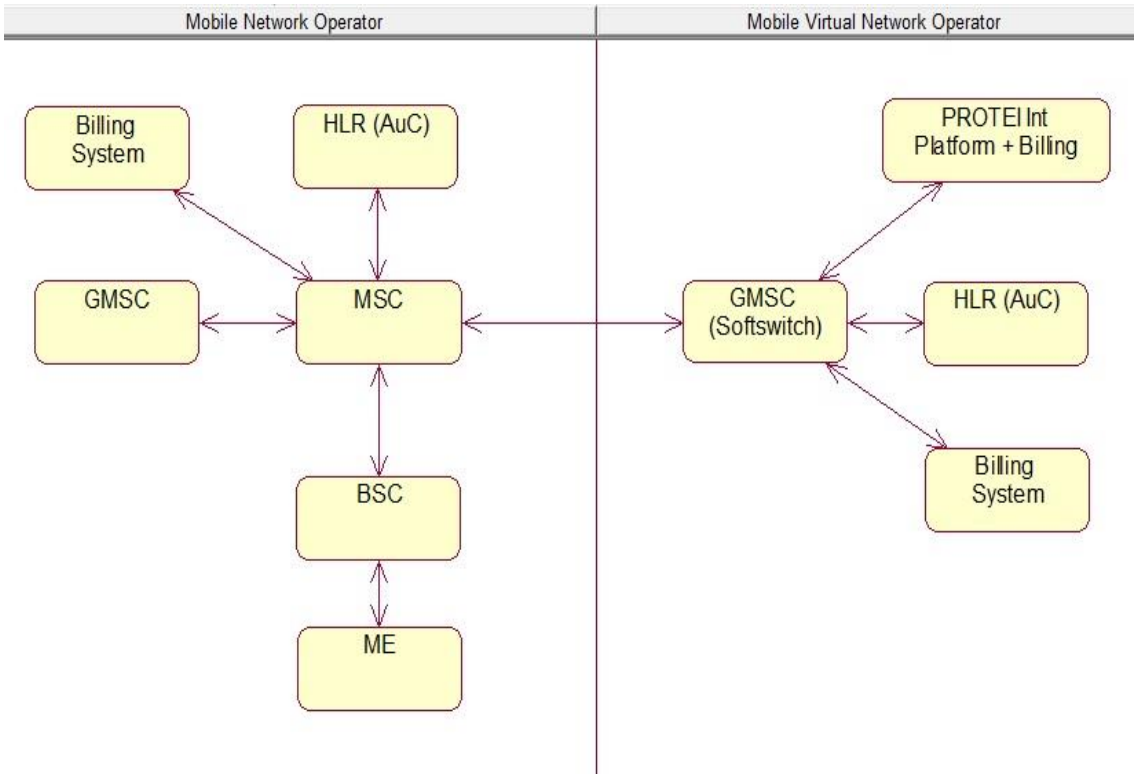

Figure 16. Top Connect MVNO architecture.

On the following scheme is provided an example, how interconnections with the Elion company are made.

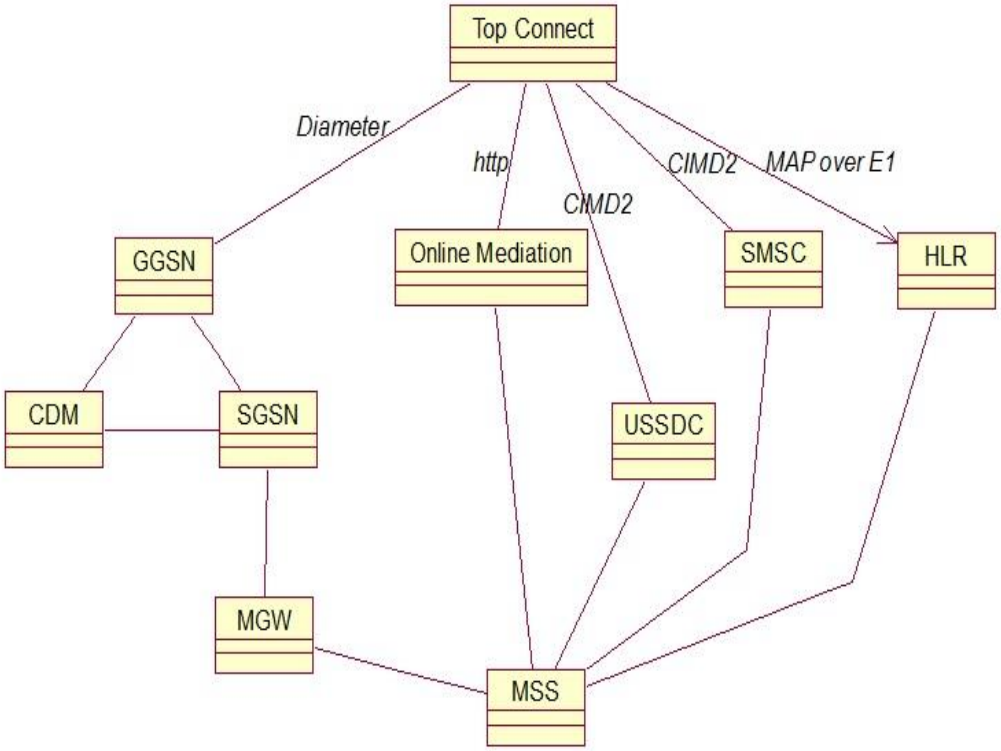

Figure 17. Top Connect interconnection with MNO.

3.4 Services implementation

3.4.1 Outbound calls

All calls in the system are technically incoming calls. Outgoing calls are barred at the sim card with the firmware. Many phones may display messages like "call is denied" or "call barred, call forbidden", while nominally making calls. For the customer it looks very easy. Subscriber simply dials the number and awaits the callback. On receiving this, usually within a few seconds, the customer picks up the phone and connects with the required number. Technically, that call can be described with a complicated scheme.

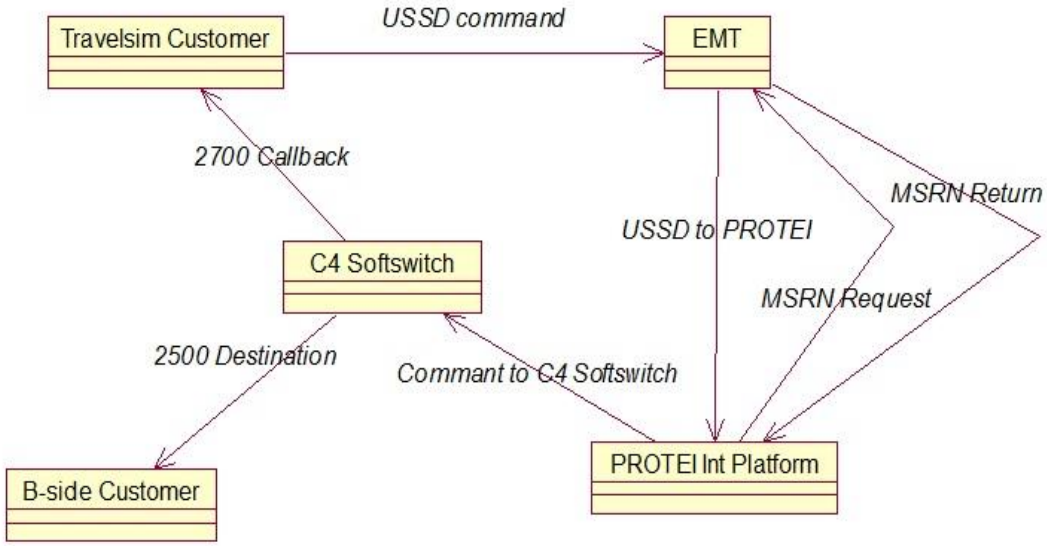

Figure 18. Outbound call.

USSD signaling is the main channel of call transmission between devices and intelligent platform Protei.

All USSD strings contain the prefix * 146 * ... #. EMT partner transfers them to our platform "Protei". Next, the string is processed accordingly to the service logic.

Outgoing call begins with USSD commands sent by the subscriber. All commands of the call has a format * 146 * 00CCNN #, where CC is the country code and NN – destination number.

In most cases, number dialing does not differ from regular dialing. All necessary conversions can be done by software of the sim card. This way of dialing the number is called direct dialing. After receiving the command string from the operator EMT, platform "Protei" retrieves all the information and processes it. In the case of an outgoing call the basic parameters of the card are checked, such as the administrative state (active / blocked), dialed number validity, if there is money on the card to make the call.

Steps of outgoing call committing.

1. A request for a roaming number (MSRN).

MSRN – number that is given from a dynamic pool rooms by the local operator for 1 call. In our case, the roaming number is needed in order to accept a callback. In fact callback is incoming call to a roaming number. In databases records that leg is written in the bin row with the prefix 2800.

2. Getting the roaming number (MSRN).

Roaming number is requested by our system in EMT through the Elion partner channels. In databases records it is written in the bin row with the prefix "E".

3. Callback (Callback).

As mentioned previously obtained roaming number is sent to a callback.

Smart Platform "Protei" cannot make calls. Thus, this command is sent to the station TELES, which in turn makes a call. This leg identified in CDRs by the prefix 2700.

This incoming call should be accepted by the subscriber only if the callback platform adopted "Protei" initiates the fourth arm.

4. Destination number call

The last leg is outgoing call. The station makes a call to the subscriber (B-number). This leg is identified in CDRs by the prefix 2500.

3.4.2 Inbound calls

The schema of incoming calls is very similar to the outgoing, but there are significant differences.

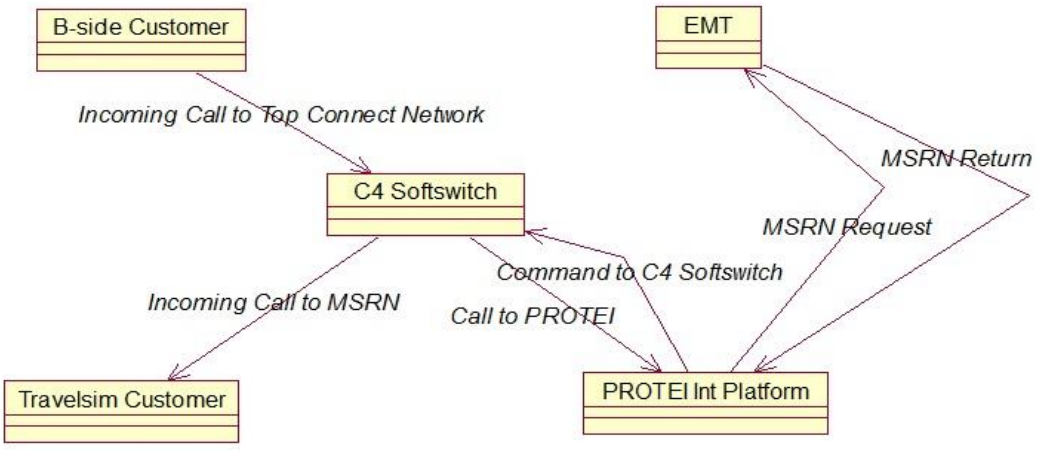

Figure 19. Inbound call.

Steps of incoming call committing.

1. Getting the incoming call by the CSC telecom network from the third operator.

This leg delivers the call to our network from the third operators. In the station records, it will be displayed as the first one. This call can be written with the different prefixes. Prefix depends on the operator that took the call in the network.

2. A request for a roaming number (MSRN).

MSRN – number that is given from a dynamic pool rooms by the local operator for 1 call. In our case, the roaming number is needed in order to accept an incoming call. We need the MSRN number, because the sim card is always working in the roaming mode. In databases records that leg is written in the bin row with the prefix 2800.

3. Getting the roaming number (MSRN).

Roaming number is requested by our system in EMT through the Elion partner channels. In databases records it is written in the bin row with the prefix "E".

4. Incoming call to the roaming number.

Incoming call arrives at the roaming number. For the subscriber this call does not differ from the usual incoming call. This leg is identified in CDRs by the prefix 2600.

3.4.3 General Packet Radio Service

The principle of GPRS can be described as follows:

1. resource provisioning for packet transmission on the base station controller side

2. subscriber authentication procedure (GPRS Attach) and IMEI Check

3. update the location information in the HLR

4. negotiation of stream encryption key

5 . establishing communication between the subscriber terminal and PS Core Network (PDP Context Activation)

6. PDP Context Deactivation

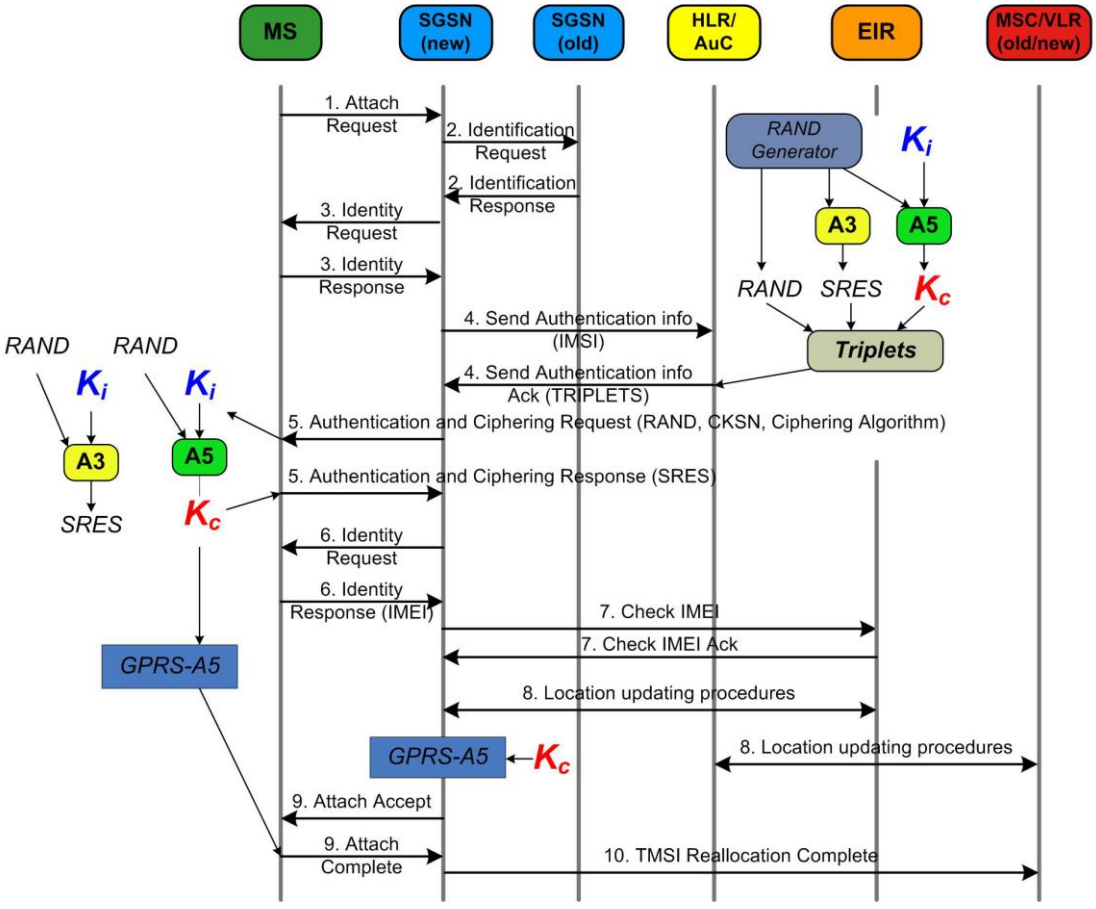

Figure 20. GPRS Attach. [27]

1. Attach Request

GPRS Attach procedure begins with a request from the subscribers' mobile terminal. Subscriber starts using GPRS / EDGE service, for example he is opening browser / checking the mail / trying to send MMS. All these actions initiate Attach Request. If the user wants to connect to the network for the first time, the request will contain the following basic information:

- Attach type: GPRS Attach (only packet data), IMSI attach (only voice services), Combined Attach (combined subscription = voice + data packet)
- P-TMSI (IMSI replacement, if the subscriber is already "known" to SGSN)
- RAI = MCC + MNC + LAC + RAC subscriber location coordinates
- MS network capability
- MS radio access capability

2. Identification Request

If the caller was before in the service area of one SGSN, and then going to another, he needs to re-provide all the information. If the subscriber has been using the services of GPRS / EDGE at the time, the new SGSN will «take» subscriber together with its session, without interruption of service.

3. Identity Request (Req) / Response (Res)

This procedure is carried out only for new subscribers or subscribers for which data were not transmitted (or not transmitted correctly) from the old SGSN. At that time SGSN requests all the data from the user again.

4. Send Authentication Info Req / Res

During this procedure, SGSN on the basis of the IMSI, makes an inquiry to HLR / AuC. HLR is a database of subscribers' network operators. On the side of HLR / AuC, IMSI corresponds to a certain checksum / secret number – Ki. Also on the side of HLR / AuC there is a random generator that generates a random number for our request. Then there is formed, the so-called triplet [TRIPLETS = RAND + SRES (Signed Response) + Kc] data, which consists of:

RAND - random number

SRES – a RAND random number through the A3 algorithm

Kc - a Ki number through the A5 algorithm

Then the triplet is sent to the SGSN.

5. Authentication and Cyphering Req / Res

Values obtained from the HLR / AuC are stored on the SGSN side. To the subscriber mobile station value number RAND is transmitted. On that value are calculated values - SRES and Kc.

6. Identity Check Request (Req) / Response (Res)

This procedure is optional and allows you to check the legality of using the subscriber station in the network operator. If the subscriber is blacklisted, then the service will be blocked.

7. Check IMEI Req / Res

Check IMEI on the EIR. To check legitimacy of the terminal use in the network operator.

8. Location Update Procedures Req / Res

During GPRS Attach procedure the information about the subscriber location is updated. SGSN updates the information in the HLR, and the HLR then updates the data in the MSC / VLR.

9. Attach Accept

After successful completion of all the above operations, SGSN notifies that the GPRS Attach is adopted and the subscriber can make a data connection.

10. TMSI Reallocation Complete

Final stage is to update MSC / VLR about the new TMSI value, which is assigned to the subscriber.

PDP Context Activation

After successful completion of the GPRS Attach procedure, the user can activate PDP Context, which will allow him to use data service.

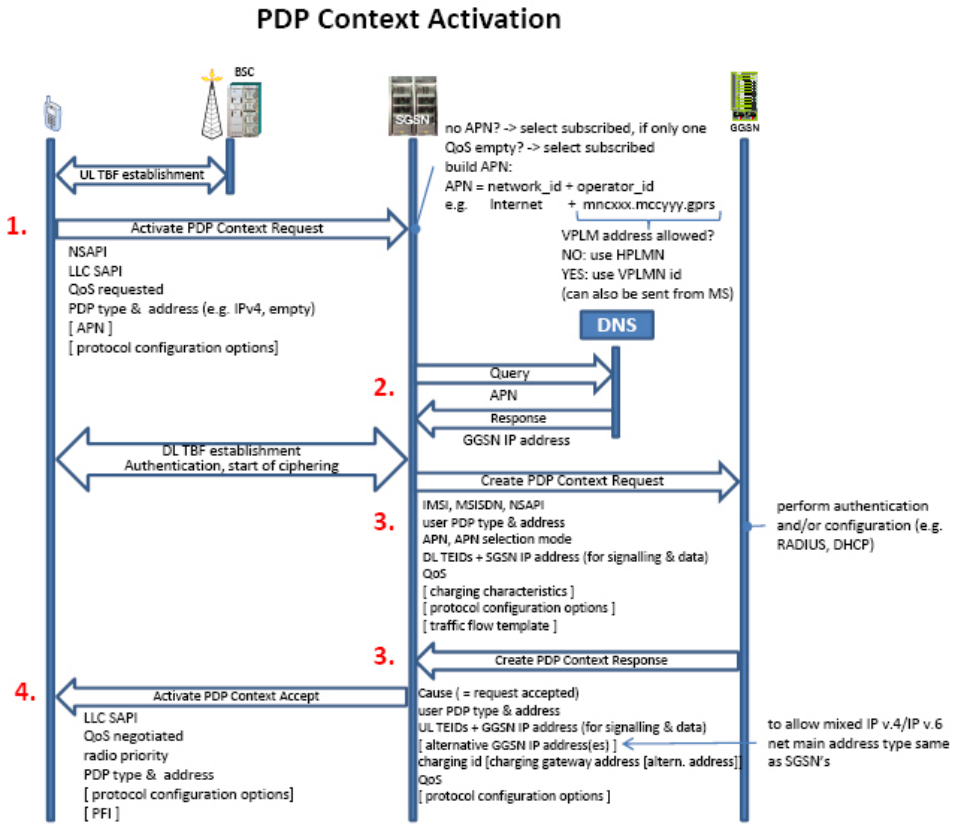

Figure 21. PDP Context Activation. [27]

1. Activate PDP Context Request

This query sends quite a lot of data:

QoS requested - requested subscriber service profile. If this field is empty, the decision to assign profiles will be made by SGSN

PDP type - determines what type of protocol can be used by the terminal for a particular service IP/X.25/etc.

Address - type of address, which is given to the subscriber for communication in the networks [IPv4, IPv6, auto]

APN * [Access Point Name] - The access point name. To determine who will service the user's session.

3.4.4 SMS

The Short Message Service is realized by the use of the Mobile Application Part (MAP). MAP is the SS7 application-layer protocol used to access the HLR, VLR, MSC, EIR, AuC, SGSN [1]. 3GPP TS 23.040 defines the Short Message protocol for the Short Message Service - Point-to-Point (SMS-PP), and 3GPP TS 23.041 for the Cell Broadcast Service (CBS) [2].

Mobile Originated SMS

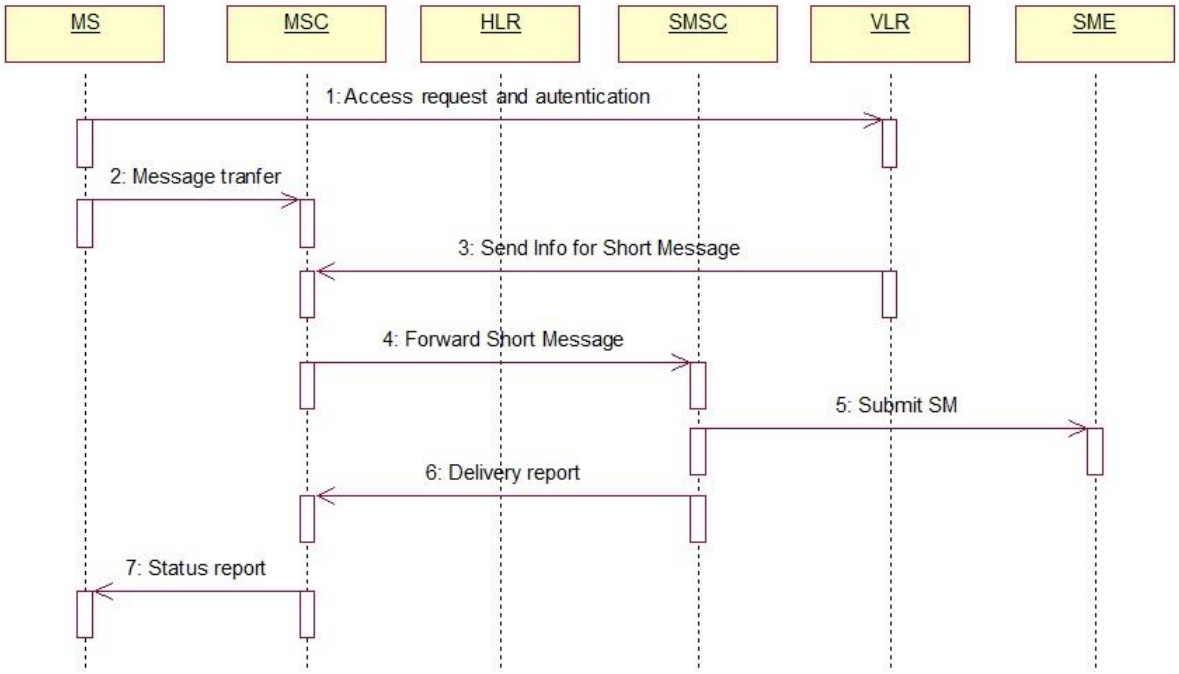

Figure 22. Mobile Originated SMS.

SMS that are sent from a mobile handset are referred to as Mobile Originated SMS. When the subscriber sends a short message, MS is activated and registers to the network, and then the handset sends a text message to the MSC. MSC communicates with the VLR to verify that the message is sent in accordance with the existing supplementary services and MS is not being blocked in the state to send SMS. Then, MSC sends an SMS to the SMSC using Short Message Forward operation. SMSC SMS continues to Short Message Entity. Optionally, the SMSC may also receive an acknowledgment that the SMS was received by SME. The message submission status is then forwarded from the SMSC MSC, to the subscriber's handset.

Mobile Terminated SMS

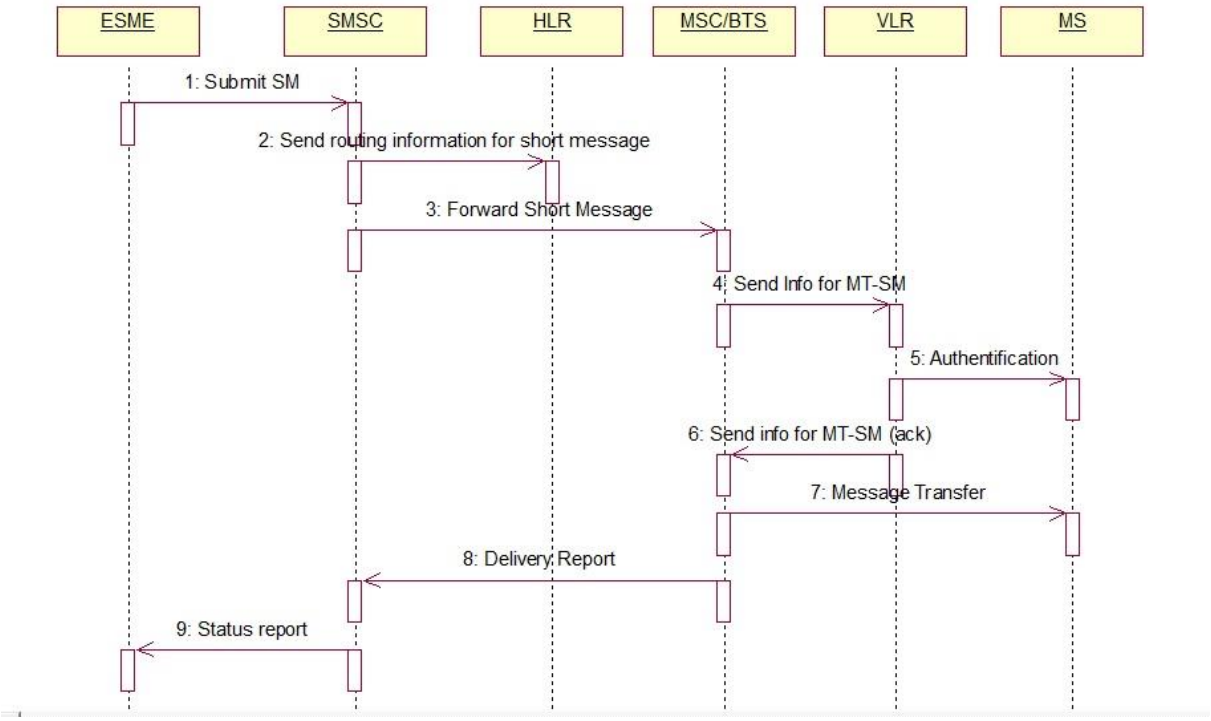

Figure 23. Mobile Terminated SMS.

SMS that are received from a mobile handset are referred to as Mobile Terminated SMS. ESME sends SMS to the SMSC. After receiving the SMS, the SMSC

communicates with the HLR to know the status and location of MS. SMSC continues to the MSC, then it contacts VLR to find out information from MS. MS is included into phase of authentication process. If the MS is active and not blocked, MSC transfers SMS to the MS. The message submission status is then forwarded to the SMSC. In case of SMS delivery failure, the SMSC is also notified so that it can take steps to retry SMS delivery.

3.4.5 Webcall

This service provides a possibility to make calls from web sites to the subscribers.

To make a webcall service following resources are needed:

- Web applet with the implementation of the required functions in the context of this service
- Platform for processing WEB calls. It includes FMS and vendors' specialized applications for the termination of calls via SIP
- TSIM software platform. That platform is needed for possibility of providing services and charging calls.

Access to WebCall server for dealers and partner-id

In order to establish interconnection between WebCall server and different web sites, the service address of Webcall must be specified. To access it from the outside address it must be added to the list on XTM. Partner-id is used to identify the dealer option. By default these setting are saved in index.html file.

Example

```
<input type="hidden" name="x-wp-partner-id"
value="csc_konale_3403456"/>
```

So with every call this unique identifier will be transferred to the CPE. It can be detected in the cdr table. If the partner-id is not detected, the value will be NULL.

Functional requirements for a web applet

Web applet must be available to several dealers at the same time. Additionally it must be possible:

1. To change the language of all text messages and information used in the applet

2. To change the color scheme and font of applet

3. To define dealers' identification information (XML login which is used to interact with XML_Gate).

Main functions of Web applet:

1. Make a call to the subscriber. This function usability is limited by CAPTHCA.

2. Make a call to dealer's technical support. This function usability is limited by CAPTHCA.

Figure 24. Web applet. [23]

Functional requirements for the call from web applet to TSIM number

The web call service is working by the following algorithm:

- If the CAPTHCA code is correctly identified, subscriber initializes function from dealers' web site.
- The applet initializes the XML request (command Web Coverage Service) with dealer's parameters (username / password) at XML_gate.
- Session identifier and TSIM phone number are transmitted in the WCS query parameters
- XML_gate platform checks the dialed TSIM phone number for the appropriate dealer settings. If the call to this number is allowed by dealers' parameters and SIM card, then XML_Gate authorizes the call.

Possible errors

There are 2 kinds of errors that can occur during the calls from Web applet. General errors influence on the global service. That means that WebCall service is not working properly. Additional errors affect only several subscribers and refer to incorrect service usage. Determination of these errors is very helpful in the service troubleshooting. Small quantity of possible general errors demonstrates the high quality of WebCall service implementation.

Statuses of general errors [00XX]:

- 0 Unknown error
- 1 error on voice protocols
- 2 caller hung up the phone
- 3 logic error
- 4 service work is interrupted
- 5 critical logical error
- 6 invalid initialization of service
- 7 service not found

Statuses of additional errors [2EXX]):

- 1 Call Completion by RNR
- 3 Funds reservation error on the map
- 5 Opening card error
- 6 Error of getting the tariff
- 7 Error withdrawals from the card account
- 8 Access denied
- 9 Failed to get MSRN
- 10 Insufficient funds
- 11 Error of getting USER_INFO
- 12 Error 12 before dialing the called party (CallBack)
- 13 Error parsing text USSD request
- 14 Dialed NSN does not fit the mask
- 15 Not enough money when ordering CallBack
- 16 Check User query error
- 17 Call-back is ordered on itself
- 18 Number entering error by using the group extension dialing
- 19 Unable to call by using the group extension dialing
- 20 US_SERVICE blocked
- 21 Roaming is blocked in tariff
- 22 Error in changing US registration status
- 23 Failed to get Euro tariff
- 24 Home Call Back rate is locked
- 25 Query Check Blocked Error

3.5 Future development

Increased competition between mobile operators, as well as reducing average income per user (ARPU), forces operators to find new sources of income. Accordingly to the author's opinion, one of the best ways to optimize Mobile Virtual Network Operator

architecture and provide a full service to prepaid subscribers is to implement CAMEL technology. This optimization will definitely attract new subscribers and will help to hold a strong position on the market. Customized Applications for Mobile Enhanced Logic will provide to the operators ability to offer operator specific services based on IN service logic to GSM subscribers. Especially it is important, when subscriber is in roaming and outside the HPLMN. CAMEL technology is a part of the Virtual Home Environment concept. If the operator uses CAMEL for the services, international standardization or some special interaction between mobile operators are not required. Thus, even the most exclusive and non-standard service, implemented in the home network using CAMEL technology becomes available to all subscribers, no matter where they are [25].

CAMEL is divided into four phases to provide CAMEL functionality as soon as possible. First Phase was standardized in 1997. The standardization of the second phase was finalized in 1998, the third phase in 1999 and the fourth phase in 2002. The CAMEL architecture is based on the Intelligent network (IN) standards, and uses the CAP protocol. CAMEL does not require any additional network equipment modernization (besides the CAMEL protocol support). This makes CAMEL a very effective technology for providing additional services related to intellectual routing of calls and services to roaming subscribers.

To optimize current Top Connect solution, CAMEL First Phase must be implemented firstly.

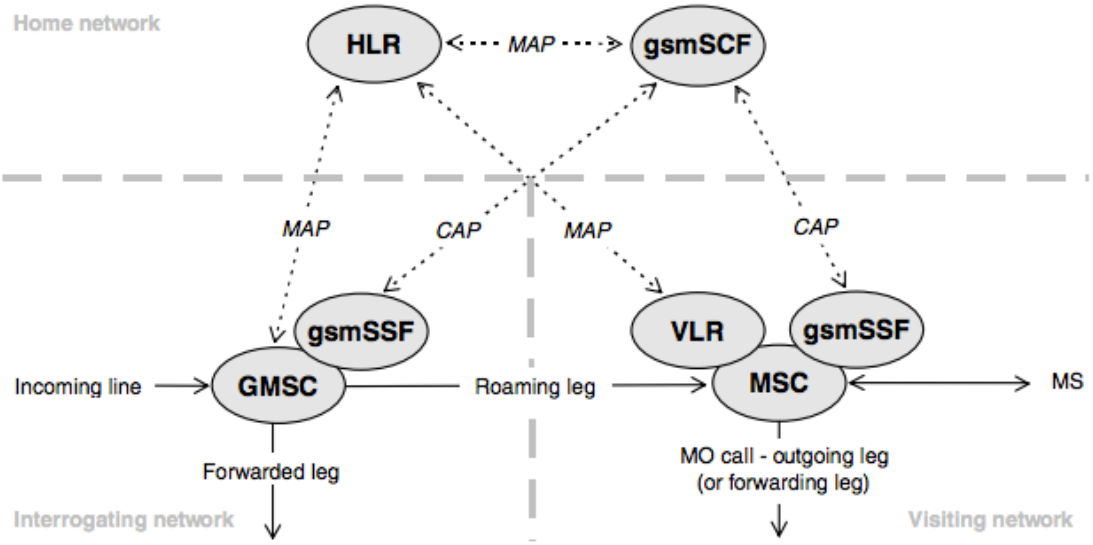

Figure 25. CAMEL Phase 1 Network Architecture[25].

Home network

Home network presents the home PLMN of the CAMEL subscriber. Home Location Register (HLR) stores subscriber related data. It also includes information whether the subscriber has CAMEL service or not. The HLR always resides in the HPLMN of the served CAMEL subscriber. The HLR transfer the CAMEL subscription data to the MSC/VLR and to the GMSC. Additional function of HLR is to apply CAMEL-specific handling for MT calls.

GSM Service Control Function is a service control function, which supports CAP and relevant parts of MAP. The gsmSCF acts as an entity, where the execution of operator specific services takes place. The node in which it resides is called the ‘service control point’.

Visiting Network

Visiting Network is the PLMN where the CAMEL subscriber is roaming. There’re stored location information and the status of the subscriber. Additionally, it is used for handling of originating and forwarded CAMEL calls.

Visitor Location Register (VLR) stores the data about subscribers. That data is received from the HLR of home network. The aim of MSC is to arrange the calls from and to the visiting subscriber. MSC detects if the O-CSI exists for the subscriber, then occurs an initial contact to the gsmSCF. GSM Service Switching Function acts as an interface to the gsmSCF from MSC. The gsmSSF interact with the gsmSCF to get the instructions for CAMEL call handling.

Interrogating network

Interrogating network makes the interrogation of the home network to get the information on the treatment of terminating CAMEL calls. Gateway MSC arranges the terminating calls to the visiting subscriber. GMSC and gsmSSF are the objects, which are related to the handling of terminating CAMEL calls.

As Top Connect uses the USSD control mechanism in the GSM network, CAMEL Phase 2 must be implemented. CAMEL phase 2 gives the possibility for an operator to extend USSD signaling with a USSD interface between HLR and an external application [25].

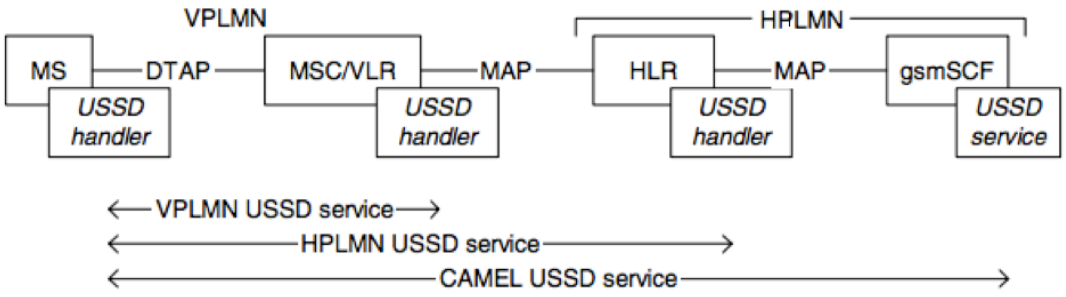

Figure 26. CAMEL interaction with USSD. [25]

An operator may offer a USSD service in the gsmSCF to selected subscribers or to the entire subscriber base. The CAMEL subscription information elements used for this purpose are the U-CSI and the UG-CSI. USSD communication starts from MS to gsmSCF with the MAP message process unstructured SS request. Then it receives the

process unstructured SS ack from the gsmSCF. When it's received, the USSD service is closed.

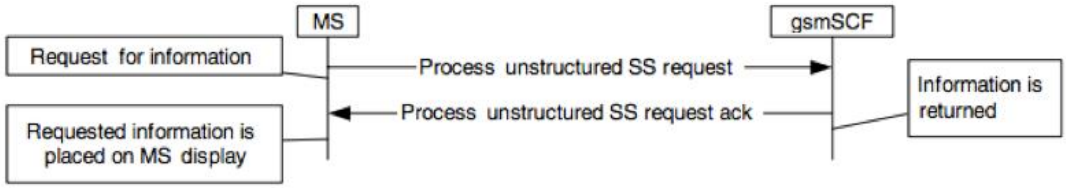

Figure 27. Elementary message sequence for MS-initiated USSD session. [25]

Figure 29. Represents an example of USSD signaling flow between MS and gsmSCF.

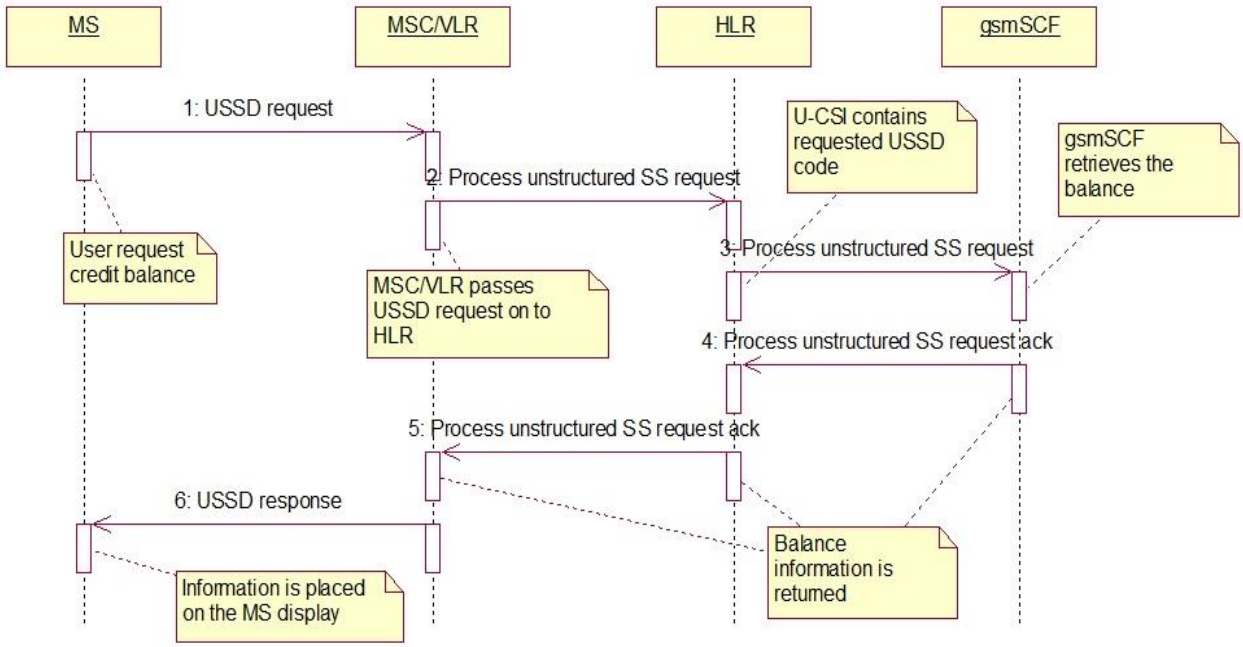

Figure 28. MS-initiated USSD service, single request. [25]

Functionality provided by CAMEL solution

- Ability to control accounting and billing of incoming, outgoing and forwarded calls at home and visited networks in real time;

- Ability to control and account outgoing SMS at home and visited networks in real time;
- Ability to control and charge GPRS sessions by time or used bytes in home and visiting networks in real time;
- Ability to interact with the customer, which is organized on the basis of voice menu (access to information services, activation and deactivation of additional services);
- Opportunity to determine subscriber's current service area and to get information about current status of the subscriber in the network (busy, out of coverage, etc.);
- The possibility of transferring side instructions about call control to the gsmSSF resulting from the application, which are connected via API or external SCP;
- The possibility of the Call Detail Record adapting
- Ability to gather statistics about provided services.

Conclusion

The goal of this thesis was to describe an opportunity of implementation of GSM services for mobile virtual network operators and an opportunity of using received knowledge in the real company (Top Connect). In order to fulfill this aim lots of European Telecommunications Standards Institute and 3rd Generation Partnership Project documents, articles, patents, books were read. As a result, implementation of such GSM services like voice call, data, SMS and web callback for real MVNO Company were described.

Since GSM service is obtainable in more than 200 countries, clients are capable to roam globally without altering their devices or their facility plans. World biggest telecommunication MVNO companies like Republic Wireless, Ting, Page Plus Cellular and Virgin Mobile provide GSM services to the subscribers. MVNO solution will enable operators to offer new services, avoiding high operational expenses and to provide services at extremely discounted rates. These are the major reasons why a lot of new mobile network operators are rapidly moving toward MVNO solutions.

The GSM services deployment by the MVNO is accompanied with great commercial and technical challenges. Mobile Virtual Network Operator does not own the wireless network infrastructure, so it enters into a business agreement with a mobile network operator. In order to avoid network components' interconnection problem with MNO, analysis of GSM architecture, geographical network structure and components should be done.

As MVNO are strengthening their position at the world's leading provider of international pre-paid communications with mobile service, the major impact must be done on managing to keep its calling plans and rates low. One of the best ways to do that is to implement USSD Callback, which can save up to 85% on International Roaming charges.

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