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A case study into Finnish IMS implementation and verification: VoLTE

Metropolia University of Applied Sciences

Bachelor of Engineering

Information Technology

Bachelor’s Thesis

30 November 2018

Metropolia
University of Applied Sciences

Author Title Number of Pages Date	Zherui Hu A case study into Finnish IMS implementation: VoLTE 24 pages + 2 appendices 30 November 2018
Degree	Bachelor of Engineering
Degree Programme	Information Technology
Professional Major	Network Engineering
Instructors	Erik Pätynen, Senior Lecturer

Systematic testing approach to IMS features such as VoLTE, SMS over IP is crucial to ensure reliability, performance and maturity of such features before they are commercially available. This thesis introduces theoretical background of IMS infrastructure, VoLTE component and end to end signaling, and present Telia Finland's IMS requirement as an example of how terminal configuration and testing should be carried out.

The scope of the case study is limited to examples of configuration needed from mobile terminal side to support Telia Finland's IMS network features and focus on the verification steps to ensure both the core functions and supplementary services performance are up to the standard of a commercial launch. Specifically, seven test cases were presented as example on how standard stationary and road testing should be carried out.

As a result of the case study, testing limitations and methodology considerations are offered in thesis conclusion for future implementation of VoLTE features in Finland.

Keywords	IMS, VoLTE, UE

Contents

List of Abbreviations

IMS	IP Multimedia Subsystem
LTE	Long-Term Evolution
VoLTE	Voice over LTE
PSTN	Public Switched Telephone Network
3GPP	Third (3rd) Generation Partnership Project
UE	User Equipment
ISP	Internet Service Provider
CSCF	Call Session Control Function
GW	Gateway
SIP	Session Initiation protocol
SDP	Session Description Protocol
RTP	Real Time Transport Protocol
PIR	Peak Information Rate
CIR	Committed Information Rate
PBS	Peak Burst Size
RAN	Radio-access Network
EPC	Evolved Packet Core
MME	Mobility Management Entity
HSS	Home Subscriber Server
UICC	Universal Integrated Circuit Card
UA	User Agent

PDN	Packet Data Network
DHCP	Dynamic Host Configuration Protocol
PCRF	Policy and Charging Rules Function
SLF	Subscriber Location Function
MGCF	Media Gateway Control Function
CSFB	Circuit Switched Fall Back
UMTS	Universal Mobile Telecommunications System
GSM	Global System for Mobile communications
SRVCC	Single Radio Voice Call Continuity
IMSI	International Mobile Subscriber Identity
APN	Access Point Name
CN	Core Network
RCS	Rich Communication Services
UT	User Interface
XCAP	XML Configuration Access Protocol
MCC/MNC	Mobile Country Codes/ Mobile Network Codes
CW	Call Waiting
DUT	Device Under Testing

MO	Mobile Originating
MT	Mobile Terminating
PS	Packet Switched
CF	Call Forwarding
RAT	Radio Access Technology
GERAN	GSM EDGE Radio Access Network
RSRP	Reference Signals Received Power

1 Introduction

As Long-Term-Evolution (LTE) network deployment quickly finalized in Finland, Finland currently has one of the highest mobile network speeds in the world, with part of the SYV network (stretches from middle-north Finland) reaching CAT.6(300Mbps) speed, and Elisa CAT.16 testing live network deployed in Tampere city center. Non-legacy voice over internet protocol (VOIP) services such as Skype, WeChat video has gained their popularity thanks to the high internet speed as well as Finland's unique unlimited data subscription plans.

However, such ip-based services have failed to provide both emergency call capabilities as well as continued quality of service (QoS), rendering the user experience to below the level of public switched telephone network（PSTN). Consumers are also not able to enjoy legacy ip-based phone calls using their phone numbers due to the need of an external third-party app to establish the ip connectivity.

Hence in Finland, all three of the mobile network operators (DNA, Elisa and Telia) have opted to deploy IMS-based network infrastructure and introduce VoLTE, VoWiFi and SMS over IP to the public. In the case of Telia group in Q3 2017, VoLTE implementation plan has been drawing up and Huawei mobile devices are of great interest to participate in trial period. Naturally, Telia VoLTE project was started in Huawei Finland as part of the strategy to promote technical cooperation with Telia, as well as improving brand awareness. Starting from scratch, soon it became obvious that standard global-applicable configuration file as well as testing cases were not enough for technical acceptance purpose, and individual technical failures were found within the pre-trial period. As a result, improvements on testing process as well as testing scenarios from the Finnish local office were made to address these issues throughout the product testing lifecycle.

The objective of this thesis is to examine the necessary VoLTE configuration from mobile terminal and provide technical verification steps in a systematic way. Testing cases summarized below point out not only fundamental functionality tests on VoLTE service, but also verifies less noticeable aspects such as voice continuity in changing network environment, data-voice compatibility in simultaneous user case, VoLTE compatibility during

conference call mode etc. Experiences gained through two full-cycle product TA period will also be offered at the end of the thesis as reference for service launch preparation.

2 IMS Component and application

This chapter discusses IMS component and application from three aspects: “IMS pre-conditions” introduces most important preconditions needed to implement IMS network. “IMS infrastructure review” looks at overall architecture of IMS and briefly explains the specific function of each component. “IMS core functions” show how different network component interconnect and function.

2.1 IMS preconditions

2.1.1 IP connectivity

IP connectivity is the single most important factor for IMS network implementation. IPV6 protocol is usually utilized to achieve P2P connectivity due to seemingly unlimited IP addresses, and IPV4 protocol is also present in some early IMS deployment (1,2)

IP connectivity from UE (User Equipment) can be obtained either in location where UE is physically registered to ISP network, or in roaming situations where the user connects

to home IMS services via a visiting network that does/does not support IMS services. And theoretically users can still enjoy IMS services from home ISP through IP connectivity facilitated from foreign service providers.

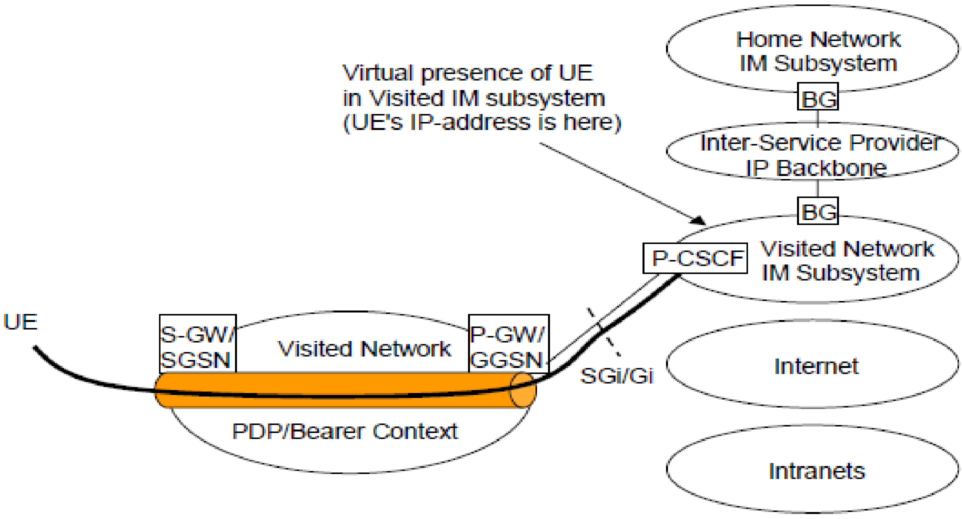

Figure 2-1(13)

Figure 2.1 illustrates the case when UE request IP connectivity from the Visited ISP's network and UE is connected to home IMS through Proxy-Call Session Control Function (P-CSCF) provided by visited ISP via IMS infrastructure (13).

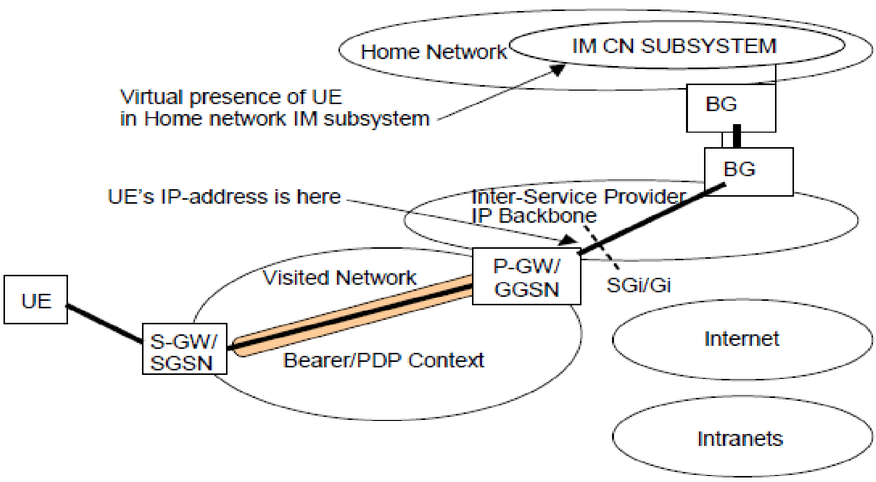

Figure 2-2(13)

Figure 2.2 illustrates when UE obtain IP connectivity from visited ISP's network(P-GW) and obtain IMS applications from home ISP (13).

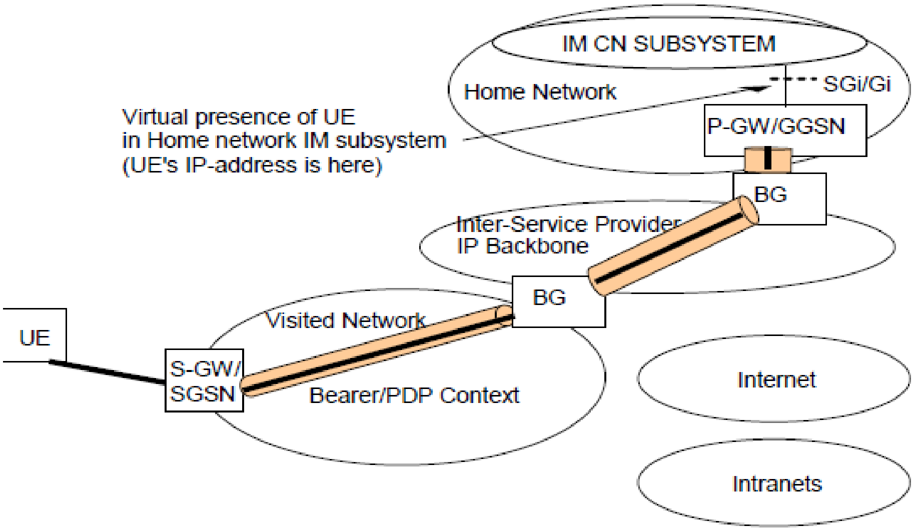

Figure 2.3 (13)

Figure 2.3 illustrates when UE requests IP connectivity from home ISP's network(P-GW) and obtain IMS applications from home ISP (13).

2.1.2 Quality of Service (Qos) for IMS services

IMS services cannot achieve its goal for improved customer experience without continuous quality of service monitoring integrated in the underlying network structure. The UE normally negotiates desired QoS requirement during a Session Initiation protocol (SIP)/Session Description Protocol (SDP) and Real Time Transport Protocol (RTP) to the core network (14). Frequently communicated parameters includes following:

- Traffic type, categorized as video/steaming, voice and text;
- Traffic policy-PIR (peak information rate), CIR (committed information rate), CBS (committed burst size) and PBS (peak burst size)
- Traffic shape, to queue and extract packets for stable rate of transmission.

- Bandwidth allocation

After finishing communication about QoS parameters at application level, UE then reserve desired network resources from mobile access network and start the transmission of packets according to different media type using RTP to the access and transport layer (1,2).

2.1.3 Mobile subscription Charging options

For mobile network operators, charging availability remains one of the most important features that IMS network should be able to offer. For example, a fixed fee of 10 cents/minute can be charged from caller that establishes a VoLTE session, or each time the sender of a text message uses the SMS over IP service.

Charging options can be divided to real-time charging and offline charging. Real time charging means network operators can monitor individual transaction of IMS usage in real time, and for instance charge the caller party 20 cents more immediately after a multimedia file is transmitted during a VoLTE call. Offline charging indicates the traditional mode where a mobile subscriber receives fixed fee invoice each month for the services that was ordered in the subscription contract (1,6).

Fortunately, in Finland none of the operators see IMS service as a potential revenue generation service. Instead, DNA and Elisa have taken the lead to populate VoLTE and SMS over IP as a complimentary service offered to IMS-enabled UEs. The aim is to increase high end device sales and acquire revenue from terminal side.

2.2 IMS architecture review

Referring to figure 2-4, IMS architecture can be divided as the UE, transport and control layer and application/services. UE is the user equipment which supports IMS-based features. Transport layer refers to RAN which is LTE is eNodeB. Control layer is the EPC (Evolved packet core) which contains control elements such as MME and HSS which

also exists in third generation core network. IP services means public internet and IMS network from ISP.

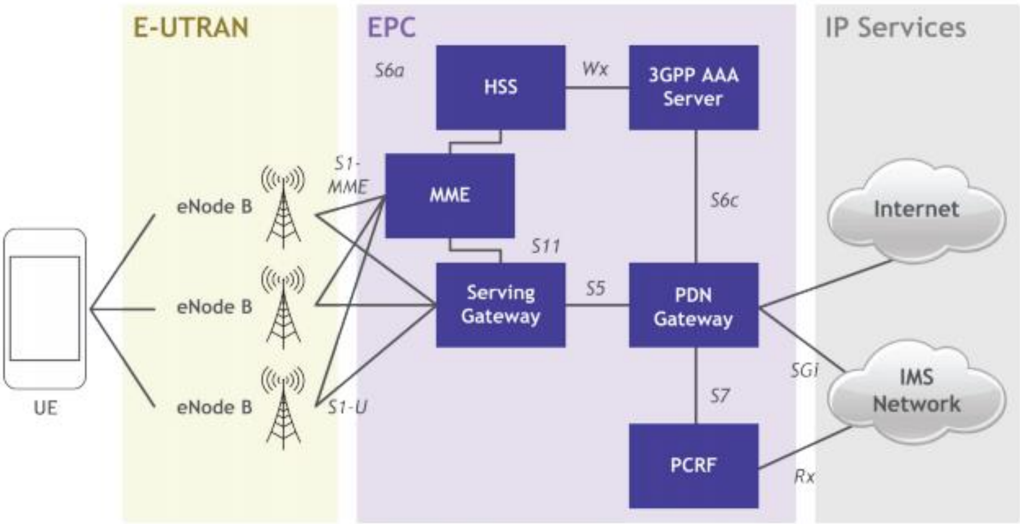

Figure 2-4 (a flat topology where UE, E-UTRAN, EPC and IP services constitute the whole IMS architecture (14).

2.2.1 The UE and its component

The UE means the user equipment in the IMS architecture. According to Sprint white paper (14), Each UE have Universal Integrated Circuit Card (UICC) and a Session Initiation Protocol User Agent (SIP UA).

Universal integrated circuit card is a physical circuit that contains one or multiple applications listed below:

- IMS identity module (ISIM)-provide identity information required by the IMS network
- Subscriber identity module (SIM): provide identity information required by GSM network
- UMTS/CDMA SIM: provide identity information required by UMTS/LTE/CDMA network

The SIP User Agent is the terminal that supervise the SIP session from UE and take responsibility of transmitting-receiving SIP related messages.

In plain words, SIP UA provide fundamental calling functions such as dial, hold, connect and termination.

2.2.2 The evolved packet core (EPC)

The evolved packet core specification comes from 3GPP release 8 back in 2014 for standardized LTE backbone deployment. The purpose is to create a simple network infrastructure that allows separation of control plane and user plane, improving the scalability and performance of the network. As a result, operators can deploy LTE solutions in a cost-effective manner (15).

As shown in figure 2-4, EPC should contain at least four components:

- Serving gateway: The gateway that transport IP traffic from UE to external network. It is the link between E-UTRAN radios and the evolved packet core.

- HSS: Home subscriber server does not change its' functionality between UTMS and LTE network which basics stores home subscriber's information and provide support for situations when subscriber info is needed for authorization, session start/stop etc. (15).

- PDN Gateway: As the name suggests Packet data network gateway connect between LTE EPC to outside IP network. It basically transfers traffic between various PDNs, as well as serve as DHCP server as other policy roles.

- MME: The mobility management entity is the control node that manages the signaling from E-UTRAN. Paging and authentication of the mobile devices is its main responsibility.

Apart from the above mentioned components, Policy and Charging Rules Function (PCRF) is also heavily utilized in EPC for determination of legitimate traffic sessions. For

example, during a VoLTE call session PCRF helps to determine whether the caller is entitled to simultaneous multimedia transfer in real time and create billing data accordingly.

2.3 The IMS Core functions

The IMS core essentially controls session and provide policy on media type control.

The main entities include HSS, CSCF(P/S/I-CSCF), SLF, BGCF and MGCF, which can be seen from the figure below.

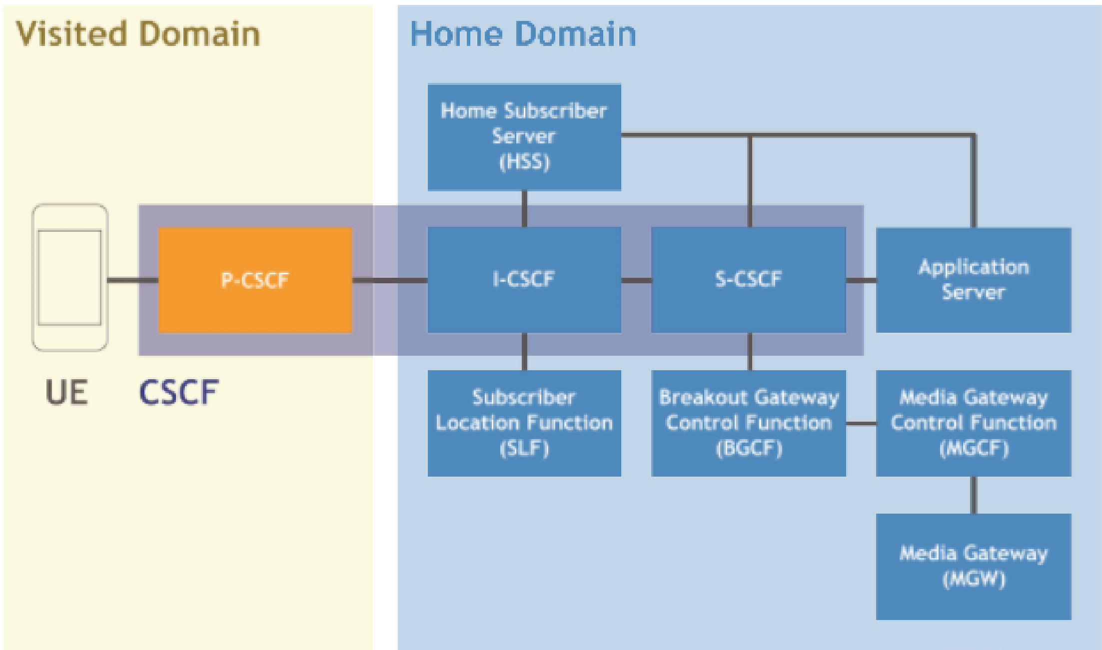

Figure 2-5. Main functionalities of IMS core (13)

Call session control function (CSCF)

The call session control function provides lifecycle management of media sessions, ranging from requesting, establishing, supervising and termination of those sessions. Logically three entities are distinguished within CSCF.

- P-CSCF: The proxy CSCF is the first point that SIP agent from UE will contact and is seen as a “proxy” of UE in other entities point of view. All traffic request is received and transferred from P-CSCF to other CSCF components (13).

- I-CSCF: The interrogating CSCF is the middleman between S-CSCF and P-CSCF, assigning the UE to S-CSCF based on information obtained from HSS.

- S-CSCF: The serving CSCF is a SIP server that handles routing tables, monitors each session status and localizes individual service profiles (1,13).

- SLF: The subscriber location function manages several HSS at a time from the residing network and assign UE request to individual HSS with I-CSCF and S-CSCF.

- MGCF: The media gateway control function is responsible for various tasks relating to codec conversion and media conversion (RTP-PCM).

3 Voice over LTE(VoLTE)

3.1 Introduction to VoLTE

As LTE network itself is a pure IP based packet-switched network (PDN) without a circuit switched domain, it is not possible for UE connected to an LTE network to directly make a call since the callings go from a legacy network (CDN). Considering this difficulty, network operators in Finland have opted for several options, with most popular one being Circuit switched fall back (CSFB). CSFB is an interim solution which means whenever a

UE is establishing or receiving a call, information is sent to LTE network that UE could temporarily fallback to legacy network and make the call from there. When the call is finished, UE can reconnect to the LTE network. (7)

However, as IMS infrastructure supported by Ericsson and Huawei, Telia group has quickly turned its attention to voice over LTE solution which utilizes entities in IMS network and eliminate the need for UE to rely on legacy network. In short, voice over LTE enables voice service to be delivered as data via LTE data bearer, provides more voice capability compare to standard UMTS or GSM network, and ultimately enables a high definition voice call experience for the end customers.

3.2 VoLTE architecture review

The overall VoLTE architecture involves mainly three sections: Access network (LTE), evolved packet core (EPC) and control functions which contain IMS, HSS and PCRF as mentioned before in IMS section above. Figure 3-1 illustrates simplified topology of these three elements.

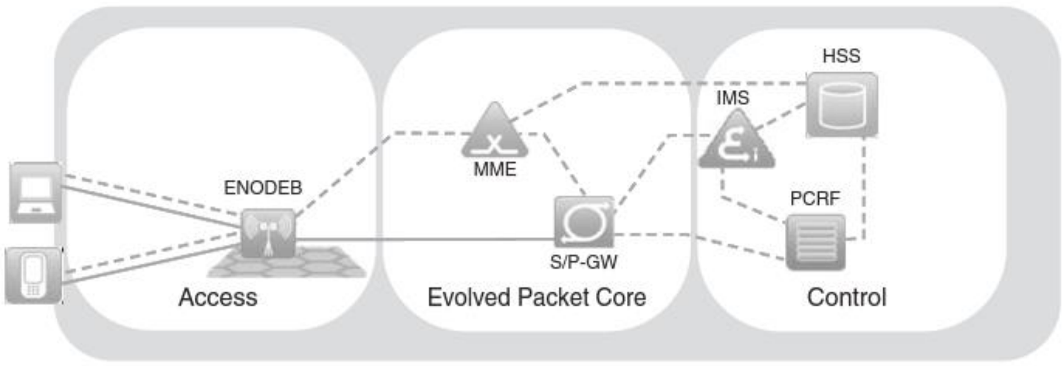

Figure 3-1:Volte system architecture (2)

As can be seen from the topology, UE first connects to the radio access network that essentially only contains evolved NodeB (eNodeB), which is greatly simplified compared to previous UMTS access network. To further explain the mechanism of eNodeB, figure 3-2 illustrate the detailed connecting process from UE to LTE access network.

The two boxes of eNodeB in the topology represent multiple eNodeB on the field (LTE base stations), which handles all the radio level signaling from UE. In case of physical location change or overload of a base station capacity, X2 interface in the topology is responsible for coordinating eNodeB handover. Also, all radio signaling is completed within the access part of the network (2).

The functionality of evolved packet core (EPC) is already explained in chapter 2, and in LTE network EPC infrastructure is flat, containing only MME and S/P-GW. MME is responsible for multiple tasks, the most important being: non-radio signaling; mobility management, handover management; core network signaling between nodes; roaming management; CS fallback from LTE to 3G/GPRS network and SRVCC from LTE to core network as illustrated in the figure below. S/P GW are both user planes responsible for packet routing and switching and roaming identification. The difference between them is the serving GW has the main responsibility of managing inter-eNodeB handover as well as inter-3GPP handover. And P-GW can be seen as DHCP server for UE, with security functionalities (AAA) integrated (2,13).

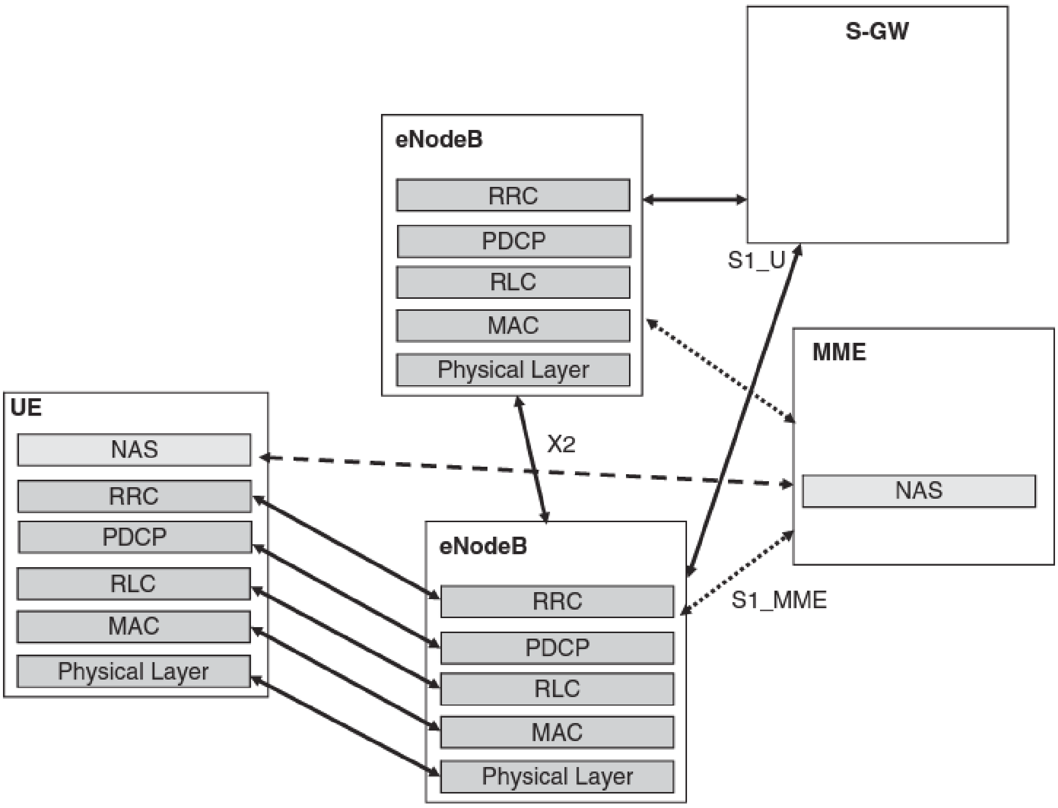

Figure 3-2: LTE radio access infrastructure (2)

The control part of the network is already explained in chapter 2. It can be seen that IMS network offers many services ranging from voice, multimedia and message, with VoLTE only utilizing voice service from IMS infrastructure.

3.3 VoLTE end to end signaling

This section briefly explains the first two phase of VoLTE end to end signaling: VoLTE UE attach and VoLTE UE IMS registration. Detailed process for complete VoLTE end to end signaling can be found in figure 3-3.

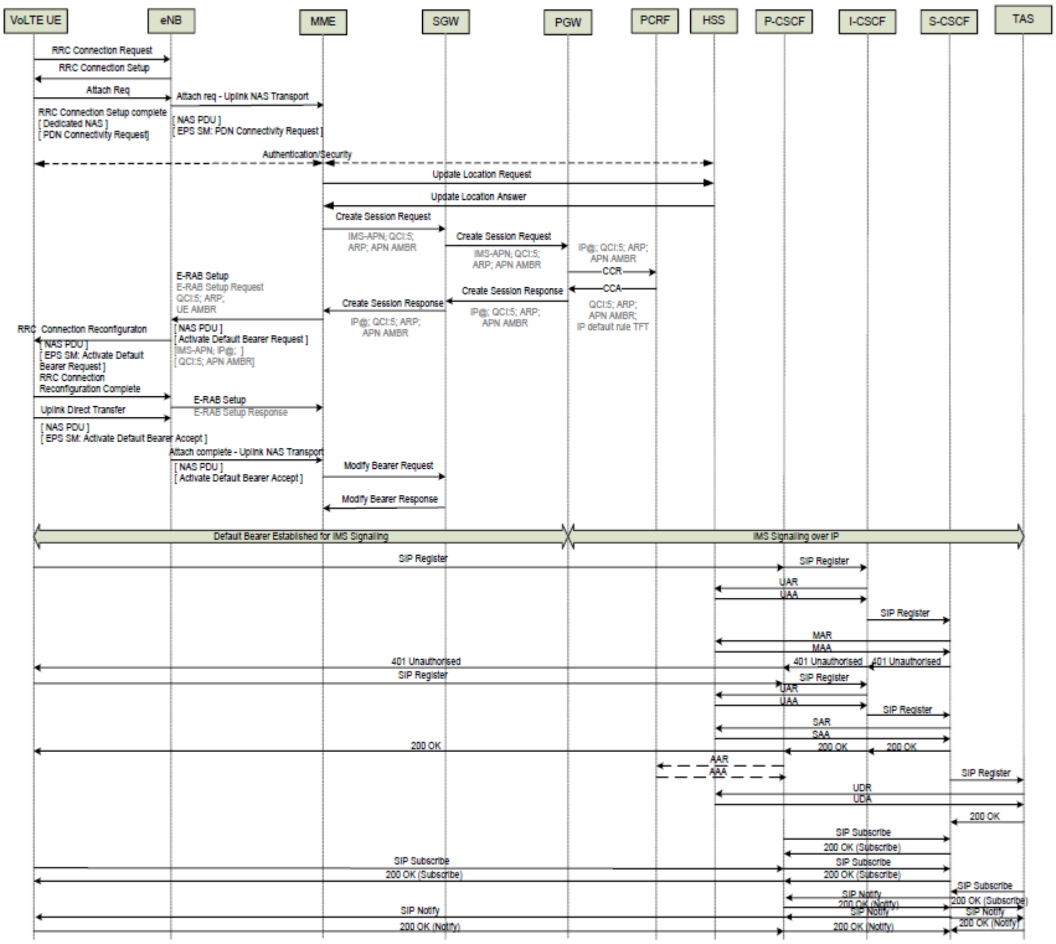

Figure 3-3: VoLTE end to end signaling

The VoLTE capable UE attaches to LTE access network in the same way as 3GPP TS 23.401 defined (4). First, the attach requests are sent from UE to eNodeB with

information containing IMSI, UE DL/UL capability, PDN type, etc. eNodeB then forwards the request to a selected MME based on PRC parameters (2). MME proceeds to communicate security and authentication parameters with UE including NAS-MAC, algorithm detail and ME identity. After finishing the security negotiation, MME then requests location update from HSS for IMSI and subscriber information. HSS replies with confirmed location update with PDN subscription information including profile configuration and APN-AMBR. In the case of Telia Finland, IMS-APN is set according to default APN in the HSS, so there is no need to configure a separate VPN from UE.

After APN negotiation set, MME sends a session creation request to S-GW which contains IMSI, MSISDN, APN-AMBR, location info, etc. to help SGW register the new entry in the EPS Bearer table (4). Serving as a DHCP server, P-GW then allocates ip address for UE and sends a CCR request to PCRF, retrieving PCC policy to be used in IMS signaling process. PCRF in turn applies the policy to the default bearer. Having added the entry in EPS bearer table, P-GW now allocates TEID between control and user plane and starts to route user traffic between IMS network and SGW, with the help of defined policy from PCRF. P-GW then sends session initiation response to SGW, and SGW passes the response to the MME (4).

Receiving UE's IP address, IMS APN, QoS parameters etc. from the SGW, MME send back an attach accept to eNodeB, which cooperate with UE to refresh the RRC configuration parameters, including updated information from the CN. UE then forwards the attached compete message first to eNodeB, then to MME. An uplink connection between UE and the core network is then established. Receiving a modify bearer request from MME, SGW approves the request from MME and completes the downlink connection. UE at this point is attached to the LTE network via the default bearer configured for IMS signaling (4).

The next phase for the UE is IMS registration. The UE first sends a SIP register message to P-CSCF. When P-CSCF receives the request, it adds various headers to the request and forwards it to I-CSCF. I-CSCF then consults with HSS using UE authentication info, and HSS will determine whether both public and private user identity is legitimate. Upon positive decision, P-CSCF forwards the register message to S-CSCF. S-CSCF again sends a multimedia authentication request to HSS and obtains the authentication vectors

for IMS-AKA. S-CSCF then saves the XRES and forms a 401 unauthorized response to P-CSCF. Removing the cipher and integrity key from the 401 response, P-CSCF then combines the keys to the PUI and sends the response to UE (2,4).

UE then sends a new SIP Register request back to P-CSCF, based on a temporary set of IPsec parameters received from the response, and adding an authorization header to the request as well. After receiving the request and confirming the correct IPsec parameter, P-CSCF sends the request to I-CSCF for the second time, this time including the RES parameters. Repeating the previous procedures for checking user authentication message from HSS, I-CSCF forwards the request to S-CSCF. After S-CSCF confirms the RES integrity comparing to the previous XRES extracted from authentication vectors, S-CSCF requests HSS for user profile and completes the UE registration (2,4).

After the UE registration, S-CSCF then provides I-CSCF with an affirmative response which prompts the I-CSCF to generate a permanent security parameter. The parameters are sent downstream to UE again, and UE stores it for future encryption/decryption purposes (2,4). By this state, UE is fully recognizable by IMS network and can utilize VoLTE services.

3.4 VoLTE terminal configuration requirement (Example)

A VoLTE-compatible device needs three separate XML patches to be programmed and installed, namely APNS-CONF, CARRIER-CONFIG and Vendor patch. But before such patches are presented, network operators' VoLTE requirement need to be delivered and supported. An example from Telia group is shown below.

The general requirement as shown in Figure 3-4 as dictated by Telia group, requires UE option to turn on/off VoLTE, set VoLTE instead of CSFB as default calling mode, and use VoLTE calling even when mobile data is disabled.

General	
User editable setting ON/OFF VoLTE	YES
Default setting VoLTE	ON
Registration icon VoLTE	ON
In-call VoLTE icon	YES
In-call HD Voice icon VoLTE	YES
Use VoLTE when mobile data is disabled	YES

Figure 3-4: Telia group IMS requirement-1

Configuration requirement require default APN to be set the same as Telia's internet APN, with APN parameters specified in figure 3-5. Additionally, HOS APN should be used for RCS services such as UT and XCAP.

Configuration	
Default APN for attach	internet
APN name for voice/SMS	ims
APN for Ut/XCAP	hos
P-CSCF doscovery	yes
SIM	No

Figure 3-5: Telia group IMS requirement-2

As shown in figure 3-6, other general requirement includes: emergency call preference is VoLTE-CS-other, location info in both normal and emergency call, volte codec specification, VoLTE as primary option for voice, and IP as primary option for SMS.

Configuration (misc)	
Domain preference emergency calls	Preference order: VoLte, CS, Other NW CS, VoWiFi(normal call, no emergency apn available)
SMS over VoWiFi	YES
Location during normal REGISTER	Yes
Location support in Emergency Calls	Yes
Conference call URI	sip:mmtel@conf-factory.ims.mnc091.mcc244.3gppnetwork.org
Conference call setup	send Refer to users
Conference Call dialog Type	in-dialog
VoLTE codec	nb-amr, wb-amr, evs
Precondition	yes
P-Early-Media	yes
Voice domain preference	Volte
SMS domain preference	ip

Figure 3-6

In figure 3-7, SIP configuration parameters are specified, as well as supplementary service preference like UT and XCAP over VoLTE. Those supplementary services currently are supported by UE, but not from network side.

Configuration SIP	
SIP transport protocols	UDP/TCP
MTU size	1300bytes
SIP timers	T1=2 sec,T2=16 sec, T4=17 sec
Preferred URI type	Both Tel URI/SIP URI supported
SIP session expires method	update
Supplementary Services	
Ut/XCAP over VoLTE	Yes
Ut/XCAP over LTE without IMS registration	Yes
Ut/XCAP over UMTS without IMS registration	Yes
Ut/XCAP over VoLTE when cellular data disabled	Yes
Ut/XCAP when roaming	Yes
USSD domain	CS
Call Waiting	Yes

Figure 3-7

The last part of requirement in figure 3-8 concerns radio features from UE, which specifies VoLTE call handover to 3G/GSM network should be supported via SRVCC (Single Radio Voice call continuity), in-call handover between VoLTE and VoWiFi, and support for TTI bundling, semi-permanent scheduling and robust header compression.

Radio Features	
TTI Bundling	Yes
Semi-Permanent scheduling	Yes
Robust header compression	Yes
SRVCC to 3G	Yes
aSRVCC to 3G	Yes
bSRVCC to 3G	Yes
mid call SRVCC to 3G	Yes
xSRVCC to 2G	Yes
Handover between WiFi and LTE	Yes

Figure 3-8

3.5 VoLTE terminal configuration (Example)

As mentioned before, there are three configuration patches needed for VoLTE-enabled device provided with VoLTE-enabled sim subscription from network operator (9). First one to be configured is carrier-config.xml which is programmed according to VoLTE requirement set in chapter 3.4. All sensitive data and value are substituted by “X”. As can be seen in appendix 1 listing 1:

Row 3-4 specifies the APN and UT reference interface value needed for XCAP supplementary services. Row 5 specifies call waiting mode time in seconds. Row 6-7 set the VoLTE switch to be on by default. And row 8-9 enables UT service even when VoLTE switch is off. Row 10-11 specifies the PLMN list of Telia Finland which covers Telia Suomi and SaunaLahti (discontinued). Row 12-22 dictates authentication method and parameter for VoLTE and VoWiFi call session. IPSec protocol is in use and Ikev1, Ikev2 RCT algorithms, SA lifetime, DPd interval is specified. The remaining part of the configuration belongs to VoWiFi configuration and is not covered in this thesis.

The second configuration file is called “carrier” config and it provides IMS roaming parameters for each European operator which has VoLTE service, so that a user in foreign network still initiate VoLTE phone calls to home network or foreign network users. Listed below in appendix 1 listing 1-a, similar values such as MCCMNC, UT enable, UT NAF/BSF port and UT BSF service address are specified for two network operators.

The third configuration file is APN-config as listed below in appendix 1 listing 1-b. Saunalahti internet/MMS and Telia internet/MMS/HOS is specified. Unless otherwise mentioned, APN profile should contain MCCMNC, APN name, User value, server value, password, mmsproxy, mmscA, APN type and protocol type. The HOS APN is designed for UT/XCAP services.

After completing these three configuration files, UE should be connected to desktop via USB debugging, and once a windows batch file is generated from the configuration XMLs, these configurations can be loaded into the UE, making it test ready.

4 Voice over LTE Verification

After completing configuration file loading, UE is then ready for verification based on priority and nature of the test cases. In general, some 110 test cases should be carried out after each new model UE enters verification stage. In this chapter the most important test case, test procedures and desired testing result is explained to verify a UE’s compatibility with Telia IMS network, and more test cases are attached as appendix 2 at the end of the thesis paper.

From testing equipment point of view, GSMA specification IR.38(8) was always followed which requires at least two UE from Huawei that are configured with IMS-enabled

firmware, and two Telia-provided USIM that access the IMS service in the testing network area. Two USIM that support VoLTE service from Elisa and DNA are also utilized in all test cases.

Moreover, for quality control purposes, test cases listed were performed under three conditions:

- Cross-examination is mandatory for call sessions between Telia-Elisa and Telia-DNA USIM
- For test cases involving voice quality monitoring, five to ten times repetition was required
- For each firmware or IMS network update, verification was performed for priority one test cases

4.1 Priority 1 test cases (Two examples)

Two test cases examples listed below verify the fundamental elements of VoLTE interoperability between UE and network operator. They do not perform any QoS check on each service. A complete test case sequence is attached in Appendix 1 table 1.

1. Configuration in PS domain - Query CW status on UI and Dial Code

   The purpose of this test case is to ensure that UE has registered to Telia IMS network. Except for the “HD voice call” option becoming available in “Call Setting-Sim setting” interface, separate verification is always needed since during the initial configuration patches, UE has enabled the “HD voice call” option even when IMS test network was not available. The test case was conducted according to following sequence:

   1. Ensure the DUT is attached and registered to the Telia IMS service. Initiate a query for Call Waiting status by User Interface. (This step can be completed by click on “call” icon, navigate to “dialer setting” and select “more”)

   2. Initiate another query for Call Waiting on DUT by dial code: *#43#

   Following second step, “call waiting is enabled” message displayed on UE screen, indicating message transmission from Telia IMS network was received on UE, and that UE has registered on the IMS service.

2. PS Voice - SRVCC to UTRAN - voice only

The objective for this case was to verify SRVCC parameters in UE and Telia IMS network was identical, and UE can obtain continued high-quality voice service through the transition from VoLTE call session to UTMS or GSM-based circuit-switched call session. The testing for this purpose was designed to be conducted at two locations:

- Stationary testing was done in Käpyla office building, when VoLTE session was established in good reception location (office area) for five minutes, after verifying good signal strength and voice quality, one UE was then taken to the underground parking area where only 2G signal is present. The voice quality was acceptable throughout the testing length after repetition, and this case was deemed a pass.
- Road testing method was used to determine SRVCC from VoLTE session to UTMS session and VoLTE handover to GSM session. The testing method was created when Telia testing department reported SRVCC failure from VoLTE-GSM session near Itäkeskus area. Eastern Helsinki was then designated driving area and covers 18Km ring road that spans through several area where only UTMS or GSM signal reception was present. During the initial testing voice session was dropped after LTE-3G handover, and testing logs (Huawei proprietary information) were fetched from UE for R&D analysis. Further testing was conducted for this case after R&D provided modified patch files.

4.2 Priority 2 test cases (Three examples)

This segment of test scenarios emphasizes on VoLTE call handover situations as well as domestic roaming cases (Telia-DNA). Call KPI and data performance should also be measured with these test cases. All test cases were performed using two-way verification, that is, the same test case is performed from mobile originating side as well as mobile terminating side. Detailed testing sequence can be found in Appendix 2 table 2

1. PS Voice call establishment setup time and success rate

   This test case was designed to ensure QoS (quality of service) of VoLTE call sessions. Two DUTs was requested VoLTE sessions from each other for one hundred times and each time the session setup time was recorded. The average set up time was then calculated and compared to data available from DNA and Elisa history testing. Connection time below 5 seconds was accepted. Moreover, the success rate of those session request was also monitored, and generally over 93% of success rate was considered a pass. Due to the limitation of comparatively small testing network area, further testing after Telia VoLTE service launching is required.

2. Simultaneous Registration of Wi-Fi-Data and VoLTE

   This test case was designed on the principle of GSMA IR.65(11), to verify whether user can access internet using Wireless connection simultaneously when a VoLTE call session is live. This is important for end user satisfaction since many users in Finland have unlimited data plan, but restricted LTE connection speed such as 50Mbps, and WiFi connection speed in many cases are much faster. The test was done in following order:

   1. Initiate VoLTE call from DUT 1-2, and VoLTE icon is available in both GUI
   2. After enabling Wi-Fi and make successful hotspot registration, yle.fi and MTV website was opened, and video was played for five minutes
   3. A laptop was connected to the same Wi-Fi network that DUT registered, and Wireshark was used to monitor the ip packets transferring to and from DUT. After verifying ip addresses were from wireless network, the test case was considered a pass.

3. Intra-frequency cell reselection, Mobility

   This test case was designed to verify whether DUT reselect cell operated on different frequency which has better signal reception than current registration during a VoLTE call. Failure for UE to do so would result in deteriorating VoLTE call

quality and possible session disconnection. The test was conducted with the help of Telia cell location map. After initiating VoLTE call session at the edge of Käpyla cell No.1 registering to LTE frequency B3, DUT was moved towards cell No.2 operated on LTE band B7. After confirming RSRP of cell No.2 was 2db stronger than cell No.1, DUT was monitored to see if a cell reselection took place. Successful cell reselection was observed, and the case was considered successfully conducted.

4.3 Priority 3 test cases (Two examples)

Test scenarios in this category verifies VoLTE compatibility with other simultaneous services of DUT, to ensure device normal functionality under VoLTE call sessions. The design of such testing cases is often overlooked by terminal manufacturers and regulation parties like GSMA but conducting them in a detailed manner proves to ensure consumer satisfaction is not in any way reduced by VoLTE service, and issues discovered in this phase often help operator in improving VoLTE network as well. Detailed test cases can be found in Appendix 2 table 3.

1. VoLTE call session and FTP Downlink transfer

   This test was created since during the early days of VoLTE deployment by another Finnish operator, large FUT downlink traffic has affected VoLTE call quality, and troubleshooting pointed to bandwidth allocation issues within operator network. During the test, DUT 1-2 VoLTE call session was first established and both UE started streaming YouTube videos in 1080p resolution. Voice call was continued for another thirty minutes while no obvious connection disturbance was noticed. The test case was hence considered a pass after repetition.

2. VoLTE call session in weak signal area(B20)

   This test case was created specifically for Lappeenranta area since many rural area residents reported poor VoLTE connection registering to other Finnish

operators. In this case road test was employed as primary testing method and approximately 12 locations east of Lappeenranta was selected where RSRP< -100dbm. DUT and reference UE was set up according to North/south/west/east direction, where along each direction VoLTE sessions was established five times and voice quality rated. Background statics in certain area was especially poor, and the issue was feedbacked to Telia together with terminal logs.

5 Conclusion

The goal of Huawei VoLTE project is to cooperate with Telia group and commercially launch VoLTE features on several of Huawei's high-end products to promote customer relationship as well as brand awareness.

Through requirement gathering phase, detailed feature requirement was negotiated and decided with Telia and Huawei R&D to produce mutually acceptable technical documentation. Also, during the first product VoLTE testing cycle, three configuration batches along with VoLTE-compatible firmware was delivered and configured in DUTs within the specified schedule.

The second phase of the project involves two rounds of technical acceptance testing conducted from both Telia Finland and Huawei Finland. Several IMS network issues and device VoLTE configuration errors were found in this stage, including SRVCC failure in Helsinki and poor VoLTE service quality in eastern Finland. After correction measures are taken, corresponding testing cases modification were also made to cover such aspects in future testing work. It became obvious that some VoLTE service KPI breaches were not found in both testing phases, and only became noticeable after large-scale trial began. This led to new test cases being developed such as mandatory round trip call session test and SRVCC to GSM handover test in sparsely populated area that uses LTE Band 20. It is also concluded that priority 1 testing should be conducted every time a major network upgrade or firmware update occurred to avoid compatibility issues.

Covering only VoLTE testing within Finnish operators, VoLTE roaming capabilities were not tested between Telia Finland and any of the foreign network operators. It is worth noting that in future testing work, domestic as well as international roaming cases should be facilitated and carried out. Moreover, due to the limitations of Finnish emergency service (112), it is illegal for testing department to repeatedly call emergency number to test VoLTE emergency call features. This poses a risk to ordinary consumers because GSM network in Finland will be phased out in the following years, and if packet switched network cannot connect the user to emergency service due to lack of testing, serious consequences may occur as a result. Additionally, as can be seen from testing cases and the expected results, many of the testing cases rely on subjective experience of the service such as voice quality, background noise and distortions. Hence the testing results are also liable to human errors.

Throughout the TA period for first VoLTE-compatible model X, it became obvious that VoLTE testing approach, like general voice testing, must follow systematic and detailed structure and testing sequence. Hasty conclusion on a testing result always results in performance flaws such as unstable voice session quality, unnoticed voice distortion during handover, etc. For important features such as call waiting, call forwarding, conference call and SRVCC, repetition of at least 10 times is mandatory. Moreover, as new technology VoLTE has shown to have an impact on unexpected domains, such as failure of VoLTE session between two different chipset manufacturers. It is hence important to take all aspects of smartphone functionality into consideration and adapt testing cases to accommodate all user scenarios.

To summarize, VoLTE project with Telia was successful in completing all stages of technical acceptance before VoLTE commercial launch on Huawei devices, and subsequently improved company internal testing guidelines from global standard template to localized testing scheme. New product VoLTE feature launch became much faster as a result of standardized testing procedures and known high risk scenarios. Moreover, as one of the first OEMs who support VoLTE in Finland, Huawei brand awareness was improved especially to tech-savvy consumers who closely follow technology trends, and the additional feature of VoLTE became a revenue-driven point for device sales.

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Appendix 1 Telia Configuration demo: Listing 1a, vendor config example for Telia.

```
    <carrier_config>
        <!-- Volte UI -->
        <int name="utUseApn" value="XX"/>
        <int name="utBsfPort" value="XX"/>
        <int name="callWaitingMode" value="XX"/>
        <boolean name="carrier_default_volte_switch_on_bool"
value="true"/>
        <boolean name="utForbiddenWhenVolteSwitchOff"
value="false" />
        <int name="carrier_default_wfc_ims_mode_int" value="x"
/>
        <string name="vowifiHplmnListItem">24491,
epdg.epc.mnc091.mcc244.pub.3gppnetwork.org</string>
        <string name="Ikev2EncAlg">RCT_ALG_AES128_CBC</string>
        <string name="Ikev2PrfAlg">RCT_ALG_HMAC_SHA1</string>
        <string name="Ikev2HashAlg">RCT_ALG_HMAC_SHA1</string>
        <string name="Ikev2DhGroup">RCT_ALG_MODP2048</string>
        <string name="EspEncAlg">RCT_ALG_AES128_CBC</string>
        <string name="EspAuthAlg">RCT_ALG_HMAC_SHA1</string>
        <int name="Ikev2SaLifeTime" value="xxxxx"/>
        <int name="Ikev2IPsecSaRekeyTimeSec" value="xxxx"/>
        <int name="Ikev2IkeSaRekeyTimerSec" value="xxxx"/>
        <int name="Ikev2DpdInterval" value="xxx" />
        <int name="Ikev2DpdMaxFails" value="x" />
        <int name="vowifiRoamingConfig" value="x"/>
        <boolean name="vowifi_mms_switch" value="true" />
        <boolean name="vowifi_ut_switch" value="true" />
        <boolean name="vowifi_roaming_switch" value="true"/>
        <boolean name="vowifiStaticUnroaming" value="true"/>
        <boolean name="vowifiStaticRoaming" value="true"/>
        <string name="vowifi_UT_APN">hos</string>
        <string name="vowifiRssiThreshold">-xx,-xx,-x,-
x</string>
        <string name="vowifiWifiChip24GConf">-xx,-
xx,x,x</string>
        <string name="vowifiWifiChip5GConf">-xx,-xx,x,x</string>
    </carrier_config>
</carrier_config_list>
```

Listing 1a: Carrier Config example for Telia.

```
    <carrier_config mcc="405" mnc="873">
        <boolean name="carrier_volte_available_bool"
value="true" />
        <boolean name="preferToUseUT" value="true" />
        <boolean name="utForbiddenWhenVolteSwitchOff"
value="false" />
        <int name="utUseApn" value="3" />
        <int name="utNafPort" value="7077" />
        <int name="utBsfPort" value="7080" />
        <string name="utBsfSrvAddr">
bsf.ims.mnc873.mcc405.pub.3gppnetwork.org</string>
    </carrier_config>

    <!-- IN RIL-->
    <carrier_config mcc="405" mnc="874">
        <boolean name="carrier_volte_available_bool"
value="true" />
        <boolean name="preferToUseUT" value="true" />
        <boolean name="utForbiddenWhenVolteSwitchOff"
value="false" />
        <int name="utUseApn" value="3" />
        <int name="utNafPort" value="7077" />
        <int name="utBsfPort" value="7080" />
        <string name="utBsfSrvAddr">
bsf.ims.mnc874.mcc405.pub.3gppnetwork.org</string>
    </carrier_config>
```

Listing 1b: APN config example for Telia.

```
<apn carrier="Saunalahti internet"
    mcc="244"
    mnc="21"
    apn="internet.saunalahti"
    user=""
    server=""
    password=""
    proxy=""
    port=""
    mmsproxy=""
    mmsport=""
    mmsc=""
    type="default,supl"
  />
  <apn carrier="Saunalahti MMS"
    mcc="244"
    mnc="21"
    apn="mms.saunalahti.fi"
    user="xxxxx"
    server=""
    password="xxxxx"
    proxy=""
    port=""
    mmsproxy="62.142.4.197"
    mmsport="8080"
    mmsc="http://mms.saunalahti.fi:8002/"
    type="mms"
  />
  <apn carrier="Telia Internet"
    mcc="244"
    mnc="91"
    apn="internet"
    user=""
    server=""
    password=""
    proxy=""
    port=""
    mmsproxy=""
    mmsport=""
    mmsc=""
    type="default,supl"
  />
  <apn carrier="Telia MMS"
    mcc="244"
    mnc="91"
    apn="mms"
    user=""
    server=""
    password=""
    proxy=""
    port=""
    mmsproxy="195.156.25.33"
    mmsport="8080"
    mmsc="http://mms/"
    type="mms"
  />
  <apn carrier="hos"
    mcc="244"
    mnc="91"
    apn="hos"
    user=""
    server=""
    password=""
    proxy=""
    port=""
    mmsproxy=""
    mmsport=""
    mmsc=""
    type="xcap"
    protocol="IPV4V6"
  />
```

Appendix 2 Detailed Testing scheme for VoLTE table 1. Priority 1 test cases-fundamental feature check.

8040 Configuration in PS domain - Query CW status on UI and Dial Code	1. Ensure the DUT is attached and registered to the IMS service. Initiate a query for Call Waiting status by User Interface. 2. Initiate another query for Call Waiting on DUT by dial code: *#43# ..	1. The DUT is registered in IMS and the status of CW is displayed. 2. The status of CW is displayed on DUT.	Level 1
8110 MO/MT Voice - Communnication HOLD	1. Initiate a PS voice call.from DUT to Client1 2. Set call on hold on DUT. 2. Resume the PS voice call.	1.The voice call is established and both parties can talk to each other. 2. The call is set on hold. 3. The voice call is resumed and both parties can talk to each other.	Level 1
8210 MO Voice - Creating Conference	1.. Initiate a voice call from DUT to Client1. 2. Set call with Client1 on hold and initiate another call to Client2. 3. Setup a Multiparty call from DUT with Client1 and Client2. 4. End call to Client2 but keep call to Client1 ongoing. 5. End call with Client1.	1. The DUT establishes the outgoing voice call to Client1. Both parties can to talk to each other. 2. The DUT sets call to Client1 on hold and establishes the call to Client2. Both parties can talk to each other. 3. The Multiparty call is established between DUT, Client1 and Client2. All parties can talk to each other. 4. Call with Client2 is released. Client1 and DUT participants can still talk to each other. 5. Call with Client1 is released.	Level 1
8310 CW - Activated - Answer Voice Call	1. Activate communication at the DUT. 2. Initiate a voice call from the Client1 to the DUT. 3. Answer call 1 at DUT 4. Initiate a voice call from the Client2 to the DUT. 5. Release call 1 and answer call 2 at DUT 6. Release call 2	1. The DUT is set to "Call Waiting" and gives a notification to the user, that the configuration was successful. 2. Incoming call 1 is indicated at DUT 3.Voice call 1 is established and both parties are able to talk to each other. 4. Incoming call 2 waiting is inticated at DUT. 5. Call 1 is released, call 2 is established and both parties are able to talk to each other. 6. Call 2 is released.	Level 1

Table 1-a. Priority 1 test cases-fundamental feature check.

8320 CW - Activated - Reject Call	1. Activate communication at the DUT. 2. Initiate a voice call from the Client1 to the DUT -> call 1. 3. Answer call 1 at DUT 4. Initiate a voice call from the Client2 to the DUT -> call 2. 5. Reject call 2 at DUT ..	1. The DUT is set to "Call Waiting" and gives a notification to the user, that the configuration was successful. 2. Incoming call 1 is indicated at DUT 3..Voice call 1 is established and both parties are able to talk to each other. 4. Incoming call 2 waiting is inticated at DUT. 5. Call 2 is rejected without any interruption of call 1.
8510 Communication Forwarding - Unconditional/Busy/no reply	1. Configure the DUT with a target number that is used for forwarding all incoming voice calls (unconditional). 2. Initiate a voice call from Client1 to phone number of the DUT. 3. Remove the call forwarding	1. The DUT is set to "Call Forwarding" to the target number and gives a notification to the user, that the configuration was successful. 2. The call form Client1 is forwarded to the target number without any notification at the DUT. 3. The DUT gives a notification to the user, that the configuration was successful.
11040 Supplementary Service - CF - Data-off	1. Configure the DUT with a target number that is used for forwarding all incoming voice calls (unconditional). 2. Initiate a voice call from B-Party to phone number of the DUT. 3. Remove the call forwarding 4. Initiate a voice call from B-Party to phone number of the DUT. ..	1. The DUT is set to "Call Forwarding" to the target number via XCAP and gives a notification to the user, that the configuration was successful. 2. The call form B-Party is forwarded to the target number without any notification at the DUT. 3. The DUT removes "call forwarding" via XCAP and gives a notification to the user that the configuration was successful. 4. The call form B-Party is forwarded to the DUT.
8510 Communication Forwarding - Unconditional- volte swicth on/off	1. Configure the DUT with a target number that is used for forwarding all incoming voice calls (unconditional). 2. Initiate a voice call from Client1 to phone number of the DUT. 3. Remove the call forwarding	1. The DUT is set to .Call Forwarding. to the target number and gives a notification to the user, that the configuration was successful. 2. The call form Client1 is forwarded to the target number without any notification at the DUT. 3. The DUT gives a notification to the user, that the configuration was successful.

Table 1-b: Priority 1 test cases-fundamental feature check

SIM hot swap-VOLTE and non VOLTE SIM	1.Insert VOLTE support sim card in VOLTE area. 2.Make a MO call VERIFY: Check the call should be VOLTE call. 3.Make a MT call VERIFY: Check the call should be VOLTE call. 4.Insert VOLTE not support LTE sim card in VOLTE area. 5.Make a MO call VERIFY: Check the call should be CSFB call. 6.Make a MT call VERIFY: Check the call should be CSFB call. Please repeat step1~6	VOLTE support sim card in VOLTE area, the call should be VOLTE call VOLTE not support LTE sim card in VOLTE area, the call should be CSFB SIM hot swap sim without abnormal behavior	Level 1
8550 Communication Forwarding to VoLTE UE camping on CS	1. Configure the DUT with a target number that is used for forwarding all incoming voice calls (unconditional). 2. Move the DUT to another RAT that the ETUTRAN cell becomes unsuitable. 3. Wait until the DUT is IMS de-registered upon expiry of de-registration timer. 4. Initiate a voice call from Client1 to phone number of the DUT. ..	1. The DUT is set to "Call Forwarding" to the target number and gives a notification to the user, that the configuration was successful. 2. The DUT performs reselection to another RAT and PS voice is disabled. 3.. The DUT is deregistered from IMS. 4. The call form Client1 is forwarded to the target number without any notification at the DUT. ..	Level 1
4010 MO PS Voice - SRVCC to UTRAN - voice only	1. Initiate voice call to/from a phone (PSTN or mobile phone). 2. Move to another RAT that the E-UTRA cell becomes unsuitable.	1. The voice connection in both directions is established and an active voice call indicator is displayed. 2. The UE moves to another RAT cell and continues without interruption of the ongoing voice call.	Level 1
4030 MO PS Voice - SRVCC to GERAN - voice	1. Initiate voice call to/from a phone (PSTN or mobile phone)e. 2. Move to another RAT that the E-UTRA cell becomes unsuitable.	1. The voice connection in both directions is established and an active voice call indicator is displayed. 2. The UE moves to another RAT cell and continues without interruption of the ongoing voice call.	Level 1

Table 2. Priority 2 test cases-Handover and Performance

Test Case Name	Test procedure	Expected results	Priority
9110 MO PS Voice call establishment setup time	1.Initiate voice call from the DUT to a phone (PSTN or mobile phone). 2. Measure the time for call setup from pressing the call button until ringing is indicated at called party. 3. Perform 15 times the steps from 1 to 2 for the DUT ..	1. The voice connection in both directions is established 3. The time for call setup is measured and the average based on 15 repetitions calculated ..	level 2
9120 MO PS Voice call establishment success rate	1. Initiate voice call from the DUT to a phone (PSTN or mobile phone). 2. Note the result whether the call was successful or not. 3. Perform 15 times the steps from 1 to 2 for the DUT ..	1. The voice connection in both directions is established 3. The call successrate shall be calculated based on the results of 15 repetitions. The success rate shall be at least 93%. . ..	level 2
9140 MO PS Voice call long duration - static	1. Initiate voice call from the DUT to a phone (PSTN or mobile phone). 2. Talk between both parties for at least 62 minutes. ..	1. The voice connection in both directions is established 2. Both parties can talk to each other, the call is stable for the entire duration and offers HD voice quality. ..	level 2
9330 MO PS Voice call - Break in/out - 3G	1. Initiate a MO VoLTE call from DUT to Client 1. 2. Answer call on Client 1. 3. At DUT, end voice call to Client 1. 4. Initiate a MO VoLTE call from DUT to Client 1. 5. Answer call on Client 1. 6. At Client 1, end voice call to DUT. ..	1. DUT plays a ring back tone (typical country specific sound pattern indicating that B-Party is ringing). 2. 2-Way (HD) audio connection is established. 3. Voice call is ended between DUT and Client 1. 4. DUT plays a ring back tone (Ctypical country specific sound pattern indicating that B-Party is ringing) 5. 2-Way (HD) audio connection is established. 6.Voice call is ended between DUT and Client 1 . ..	level 2
9350 MO PS Voice call - Break in/out - 2G	1. Initiate a MO VoLTE call from DUT to Client 1. 2. Answer call on Client 1. 3. At DUT, end voice call to Client 1. 4. Initiate a MO VoLTE call from DUT to Client 1. 5. Answer call on Client 1. 6. At Client 1, end voice call to DUT. ..	1. DUT plays a ring back tone (typical country specific sound pattern indicating that B-Party is ringing). 2. 2-Way audio connection is established. 3. Voice call is ended between DUT and Client 1. 4. DUT plays a ring back tone (typical country specific sound pattern indicating that B-Party is ringing) 5. 2-Way audio connection is established. 6.Voice call is ended between DUT and Client 1 . ..	level 2

Table 2-a. Priority 2 test cases-Handover and Performance

9785 Simultaneous Use of WiFi-Data and VoLTE	1. Power on the DUT / Leave flight mode 2. Wait until the devices indicates both LTE and Wi-Fi service 3. Initiate a voice call 4. During the voice call browse the web with the built in web browser 5. End the call 6. Browse to another web page ..	1. The DUT powers up / leaves flight mode correctly. . 2. The device registers to LTE and afterwards performs an VoLTE/IMS registration via the LTE network. The device connects to the Wi-FI network. . 3. Check that VoLTE/IMS over the LTE connection is used to establish the voice call. . 4. Check that the Wi-Fi network is used for browsing the web. This can, for example, be done by using Wireshark in the Wi-Fi network to monitor IP packets to and from the DUT . Note that this check is important and mandatory as from the GUI of the DUT it is not visible if Internet data traffic is handled over the LTE or Wi-Fi interface during the call. 5. The VoLTE call terminates correctly Check that the Wi-Fi network is used for browsing the web. This can, for example, be done by using Wireshark in the Wi-Fi network to monitor IP packets to and from the DUT . Note that this check is important and mandatory as from the GUI of the DUT it is not visible if Internet data traffic is handled over the LTE or Wi-Fi interface during the call.	level 2
11050 SIP Registration - non-VoLTE-Roaming User in visited VoLTE NW	Power on the UE	The DUT does not perform an IMS registration. Instead, it registers for CS services and deactivates its VoLTE functionality. - Verify that the " Protocol Configuration Options " information element in the " PDN connectivity request " message does not contain the request for a P-CSCF IP address. - Verify that the DUT sets the " Voice Domain Preference for EUTRAN " information element to " CS Voice Only ". - Verify that the DUT receives information from the network that VOLTE services are available, i.e. the " Attach Accept " message contains the " eps_network_feature_support " information element in which the " IMS Voice over PS " information element is set to 1.	level 2
11070 CS Voice Calls - non-VoLTE-Roaming User in visited VoLTE NW	1. Power on the DUT 2. Initiate a MO voice call from DUT to B-Party. 3. Initiate a MT voice call from B-Party to DUT. ..	1. The DUT powers up correctly, registers for CS services and deactivates its VoLTE functionality. 2. The DUT requests a CS-Fallback from the network to perform a circuit switched voice call. The voice call is properly established. 3. The DUT receives a paging for an incoming circuit switched call. A CS-Fallback procedure is performed and the call is properly established.	level 2

Table 2-b. Priority 2 test cases-Handover and Performance

12010 SIP Registration - IMS reject - non-VoLTE SIM	Power on the DUT	The DUT registers to the LTE NW. No bearer for the VoLTE APN is established by the network. The DUT may ask to establish a VoLTE default bearer for the VoLTE APN (IMS). This will be rejected by the network (e.g. with reject cause code #27 or #30"). Wait several minutes to ensure that the DUT does not retry to establish the IMS signaling bearer. The test case is failed if a retry is observed. .	level 2
Make a VoLTE call and then turn on/off WIFI hotspot	1.Turn on VoLTE (IMS is registered). 2.Make MO/MT VoLTE call 3.Turn on WIFI hotspot. 4.Use another device/PC to connect WIFI hotspot and surf internet while the DUT is still in the VoLTE call. 5.Turn off WIFI hotspot. 6.Repeat step.1~5 for 10 times.	(1) Other device/PC can surf internet via WIFI hotspot. (2) VoLTE call can be established and worked properly without no sound, drop call... etc. issues. (3) Device is not getting stuck or hang.	Level 2
Turn on/off WIFI hotspot and then send/receive a SMS via IMS	1.Turn on VoLTE (IMS is registered). 2.Turn on WIFI hotspot. 3.Use another device/PC to surf internet. 4.Send a MO SMS from DUT. 5.Receive a MT SMS on DUT. 6.Turn off WIFI hotspot. 7.Send a MO SMS from DUT. 8.Receive a MT SMS on DUT. 9.Repeat step.1~8 for 5 times.	(1) Another device/PC can surf internet via WIFI hotspot. (2) MO SMS can be sent during/after WIFI hotspot. (3) MT SMS can be received during/after WIFI hotspot. (4) Device is not getting stuck or hang.	Level 2
4020 MO PS Voice - SRVCC to UTRAN - voice + data	1. Initiate voice call to/from a phone (PSTN or mobile phone). The voice calls should be performed additionally to FTP data transfer. 2. Move to another RAT that the E-UTRA cell becomes unsuitable.	1. The voice connection in both directions is established, the voice quality is not reduced by FTP transfer and an active voice call indicator is displayed. The FTP data transfer is established and not interrupted or distorted by the call establishment. 2. The UE moves to another RAT cell and continues without interruption of the ongoing voice call and without interruption of the FTP data transfer.	level 2
4040 MO PS Voice - SRVCC to GERAN - voice + data	1. Initiate voice call to/from a phone (PSTN or mobile phone). The voice calls should be performed additionally to FTP data transfer. 2. Move to another RAT that the E-UTRA cell becomes unsuitable.	1. The voice connection in both directions is established, the voice quality is not reduced by FTP transfer and an active voice call indicator is displayed. The FTP data transfer is established and not interrupted or distorted by the call establishment. 2. The UE moves to another RAT cell and continues without interruption of the ongoing voice call. The FTP data transfer is suspended.	level 2
VoLTE compatibility test	1. DUT initate a voice call to B-party whitch is on other chip platforms,e.g. MTK,Qualcomm .Keep the call ongoing 5 minutes. Check if it works well.	1.Voic call works well	level 2
12031 IMS Emergency Call Services	1.DUT is powered up and completes IMS registration with IMS VoPS flag indicating IMS is supported. 2.DUT originates an Emergency Call by dialling eg.112 3.PSAP answers the emergency call 4.Speech in progress between DUT and PSAP 5.Repeat the test for emergency numbers 110 and 911 6.DUT hangs up	2.dialing emergency call successfully	level 2
VoLTE Move out of Coverage, Mobility	1.DUT powered on has performed VoLTE Attach and in Idle 2.DUT has performed an IMS registration 3.Move DUT from VoLTE coverage OOS (Out of Service location) 4.Move DUT back from OOS to VoLTE 5.Once DUT is back in service, initiate MO and MT Call	3.the DUT will end the volte call auto 4.register the volte succfully again;	level 2

Table 3. Priority 3 test cases-interoperability

3020 MO PS Voice + FTP DL - FTP DL setup first	1. Setup FTP data DL transfer with the DUT. 2. Initiate voice call from the DUT to a phone (PSTN or mobile phone). 3. Talk a few minutes	1. The FTP DL transfer is established. 2. The voice call is established between both parties without any interruption of the active FTP transfer. 3. The voice call is stable and offers a good quality without any interruptions.	level 3
3060 MT PS Voice + FTP UL - FTP UL setup first	1.. Setup FTP data UL transfer with the DUT. 2. Initiate voice call to the DUT from a phone (PSTN or mobile phone). 3. Talk a few minutes	1. The FTP UL transfer is established. 2. The voice call is established between both parties without any interruption of the active FTP transfer. 3. The voice call is stable and offers a good quality without any interruptions.	level 3
11010 SIP Registration and Authentication Procedure - Data-off	Power on the UE	Depending on NW configuration the UE performs combined attach procedure, setup of PDN connections to default and IMS APN and registers to IMS . Note: In current DE configuration the UE first attaches to default APN "web.vodafone.de" and then registers to "IMS" APN	level 3
Kpi VoLTE CALL drop count	2.1 ping the website 512KB every 10s VoLTE long call-keep 120min	1、VoLTE CALL success rate>98%; 2、Device should better than Ref ;	level 3
Turn on/off tethering and make a VoLTE call at same time	1.Turn on VoLTE (IMS is registered). 2.Turn on USB tethering and make a MO VoLTE call immedidately,MO VoLTE should be tested during the USB tethering is establishing. 3.Use another device/PC to connect WIFI hotspot and surf internet.ther device/PC should be connected to WiFi hotspot independently, 4.Repeat step.1~3 for 10 times.	(1) DUT can surf internet via USB tethering. (2) VoLTE call can be received and worked properly without no sound, drop call... etc. issues. (3) Device is not getting stuck or hang.	level 3
9210 Active Voice Session - Radio Bearer lost	1. Initiate voice call to/from a phone (PSTN or mobile phone) to the DUT. 2. Place the DUT in a shielded box to simulate loss of radio coverage. 3. Place the DUT back to radio coverage before expiry of the IMS registration 4. Initiate PS voice call from DUT to a Phone (PSTN or mobile phone) ..	1. The voice connection in both directions is established 2. The DUT indicates loss of coverage, the voice call is interrupted 3. The DUT indicates radio coverage and is still registered to IMS 4. The voice connection in both direction is established ..	level 3
MO KPI make a MO VoLTE Call in weak LTE Singal(RSRP< -110dbm)	1、make a MO VoLTE Call in weak LTE Singal(RSRP< -100dbm) 2、Check any abnormal behavior, sound quaity and stability and volte call kpi 3、2 direction compare with iphone or sansumg volte also in weak LTE singal,Repeat for 20 times. Example: To North: Right hand is DUT /LEFT hand is REF->conduct 5 calsl-> To North: Right is REF/LEFT is DUT->conduct 5 calsl-> To South: Right is DUT /LEFT is REF->conduct 5 calsl-> To South: Right is REF/LEFT is DUT->conduct 5 calsl.	1,Volte call Without any abnormal behavior, sound quaity and stability	level 3
Kpi VoLTE CALL success rate (MO call-PSTN)	1.1 VoLTE short call performance test (RSRP<-115dBm 30%，and RSRP>-95dBm 70%) -- call keep more than 30s	1、VoLTE CALL success rate>98%; 2、Device should better than Ref ;	level 3