GTI White Paper

Global TD-LTE Initiative

Global Roaming Tutorial

for LTE only Operators

WHITE PAPER

V1.0

http://lte-tdd.org/

Global Roaming Tutorial

for LTE only Operators

WHITE PAPER

Global TD-LTE Initiative

Version:	1.0
Deliverable Type	□ Procedural Document √ Working Document
Confidential Level	√ Open to GTI Operator Members √ Open to GTI Partners □ Open to Public
Working Group	Business & Services WG
Task Force	Global Roaming Task Force
Contributors	Sprint, YTL, Syniverse, CMCC, CMI, Qualcomm
Editors	Kathleen Leach
Last Edit Date	11-01-2016
Approval Date	02-12-2016

Document History

Date	Meeting #	Version #	Revision Contents
10-10-2015		0.1	First draft version
12-10-2015		0.2	Formatting, editing
02-01-2016		0.3	Add key input for devices
04-01-2016		0.4	Update Introduction, Roaming Basics
06-01-2016		0.5	Editing, terminology
10-30-2016		0.6	Reconcile overlapping contributions
11-15-2016		0.7	Initial Draft for contributor review
12-2-2016	17th GTI WS	1.0	GTI SC Approval

Contents

Executive Summary / Introduction

This white paper provides a business and technical overview of LTE roaming for LTE only Mobile Network Operators (MNO). The information contained is intended to support the GTI operator community as they launch LTE networks and look to expand their reach through roaming relationships or generate revenue by providing roaming capability onto their network.

The white paper will cover key LTE roaming fundamentals and considerations specific for LTE only operators. These operators are frequently new entrants into the Mobile Network Operator (MNO) community and do not operate legacy 3GPP or 3GPP2 networks. The aspects covered are intended to specifically address the needs of these LTE only MNOs as they begin to establish roaming agreements and relationships with other MNOs, both with and without legacy voice and data networks. GSMA standardized requirements and documents are referenced throughout the document.

Terminology

Term	Description
2G	2nd Generation Mobile Network
3G	3rd Generation Mobile Network
4G	4th Generation Mobile Network
5G	5th Generation Mobile Network
APN	Access Point Name
CC	Country Code
CEPT	European Conference of Postal and Telecommunications Administrations
COS	Class of Service
CS	Circuit Switched
CSFB	Circuit switch Fall Back
DCH	Data Clearing House
EPC	Evolved Packet Core
ETSI	European Telecommunications Standards Institute
FCH	Financial Clearing House
FDD	Frequency Division Duplex
FQDN	Fully qualified Domain Name
GPRS	General Packet Radio Service
GSMA	GSM Association
GTI	Global TD-LTE Initiative
HPMN	Home Public Mobile Network
IMEI	International Mobile Station Equipment Identity
IMS	IP Multimedia Subsystem
IMSI	International Mobile Subscriber Identity
IOT	Inter-operator Tariff
IPX	Internet Protocol Packet eXchange

Term	Description
ITU	International Telecommunication Union
KPI	Key Performance Indicator
LBO	Local Break Out
LI	Lawful Intercept
LTE	Long Term Evolution
MCC	Mobile Country Code
MMMB	Multimode Multiband
MNC	Mobile Network Code
MNO	Mobile Network Operator
MVNO	Mobile Virtual Network Operator
OTT	Over-The-Top
PCC	Policy and Charging Control
P-CSCF	Proxy-Call Session Control Function
PCRF	Policy Control Routing Function
P-GW/PDN-GW	Packet Data Network Gateway
PMN	Public Mobile Network
PS	Packet Switched
QCI	QoS Class Identifier
QoS	Quality of Service
RAN	Radio Access Network
RAP	Returned Account Procedure
RAT	Radio Access Technology
RAEX	Roaming Agreement EXchange
RCS	Rich Communications Services
RTDR	Roaming Traffic Data Report
SAE	System Architecture Evolution
SDOs	Standards Developing Organizations

Term	Description
SGSN	Serving General Packet Radio Service Support Node
SGW	Serving Gateway
SIM/USIM	Subscriber Identity Module/Universal SIM
SLA	Service Level Agreement
SMS	Short Message Service
SN	Subscriber Number
SRVCC	Single Radio Voice Call Continuity
SSL	Secure Sockets Layer
SVR	Software Version Number
TAC	Type Allocation Code
TAP	Transfer Account Procedure
TCC	TAP Completion Certificate
TDD	Time Division Duplex
TDD-LTE	Time Division Long Term Evolution
TDM	Time-Division Multiplexing
TLS	Transport Layer Security
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
UNI	User to Network Interface
USSD	Unstructured Supplementary Service Data
VAS	Value Added Service
VoLTE	Voice over Long Term Evolution
ViLTE	Video Over Long Term Evolution
VoWiFi	Voice over Wi-Fi
VPMN	Visited Public Mobile Network
VPN	Virtual Private Network
Wi-Fi	Wireless Fidelity

1. Assumptions and Scope

This white paper provides a business and technical overview of LTE roaming, intended for LTE only Mobile Network Operators (MNO). The information is provided to support the GTI operator community as they launch LTE networks and look to expand their reach through roaming relationships or generate revenue by providing roaming capability onto their network. This paper is intended to be instructional and includes key activities, tasks and considerations an operator should explore prior to launching a roaming agreement and service.

An operator's internal processes prior to establishing a roaming relationship are out of scope for this document, although a checklist with many of these tasks can be found in Appendix A. It is also assumed that the operator will have an established LTE network (RAN and Core/EPC).

2. Industry background

2.1. Standards

In 1991 the first GSM (Global System for Mobile Communications, originally *Groupe Spécial Mobile*) network was launched. Over the course of the previous nine years, the protocols for second-generation (2G) digital cellular networks used by mobile phones were developed. Work originally began in Europe under CEPT (European Conference of Postal and Telecommunications Administrations). The GSM group and the 2G standards were transferred to ETSI (European Telecommunications Standards Institute) in 1989.

The 3rd Generation Partnership Project (3GPP) was formed with the initial scope to develop a globally applicable third-generation (3G) network specification based on the evolution of the GSM specifications. Since that time, the scope of the 3GPP has expanded to include the maintenance of the evolved Global System for Mobile Communications (GSM) specifications and reports as well as the evolution of these radio access technologies. The 3GPP unites global telecommunications standard development organizations (SDOs), known as "Organizational Partners" and provides their members with a stable environment to produce the Reports and Specifications that define 3GPP technologies.

The work within 3GPP covers cellular telecommunications network technologies beyond the radio access technologies. The additional specifications and reports include the core transport network and service capabilities, including work on codecs, security, quality of service, interconnection, roaming and beyond. The combined work then provides complete system specifications. The work of this project also provides specifications for interworking with Wi-Fi networks and for non-radio access to the core network.

The 3GPP regularly contributes to the ITU (International Telecommunication Union), a specialized agency of the United Nations (UN) that is responsible for issues that concern information and communication technologies. Each of the Organizing Partners or SDO's take the 3GPP specifications and transpose them into specific inputs for submission into the appropriate ITU group.

2.2. **GSMA**

The GSMA (Global Suppliers Mobile Association) was formed in 1995 to represent the interests of mobile operators. The GSMA currently unites nearly 800 operators along with another third of that number of companies from the broader mobile ecosystem. These can include handset and device makers, software companies, equipment providers and Internet companies, as well as organisations in adjacent industry sectors that have interest or impacts to the mobile ecosystem. While the GSMA is engaged in a number of activities that support the mobile ecosystem, for the purposes of this paper, only the activities that relate to international roaming, interconnection and interworking are addressed.

Using and referencing the specifications developed by the SDOs (above), the GSMA and its members develop the technical and business requirements and guidelines to enable and support International roaming, interconnection and interworking for mobile networks. These documents are a series of Permanent Reference Documents (PRDs) that are created and maintained by each of the working groups. There are a variety of GSMA working groups, each focused on particular areas to support International roaming, interconnect and interworking. Outlined below are a few key working groups whose documents are referenced for the reader in the remainder of the paper.

- Networks Group (NG) - specifies technical, operational and performance requirements
- Wholesale Agreements and Solutions (WAS) - develops roaming and interconnect agreement templates and wholesale charging principles.
- Interoperability Data specifications and Settlement (IDS) – creates the technical billing and settlement standards and operational processes

- Fraud and Security Group - drives the industry's management of fraud and security matters related to GSM technology, networks and services

The GSMA, given its mission, broad reach and membership, is widely viewed as the supporting and guiding organization to enable International roaming and interworking.

3. LTE Roaming Basics

The diagram (Figure 1) below outlines, at a high level, the key steps for a mobile network operator (MNO) to establish roaming with another MNO. As noted in the scope, the internal processes and organizational structure that an MNO must set up prior to forming roaming relationships are not covered in this paper. Additional information and resources can be found in the Reference and Appendix sections. Another key decision that an MNO must make prior to establishing LTE roaming is whether to establish bi-lateral agreements with individual operators or operator groups versus choosing to use a Roaming Hub approach for reduced complexity and wider initial reach. The advantages and limitations of either decision are beyond the scope of this white paper.

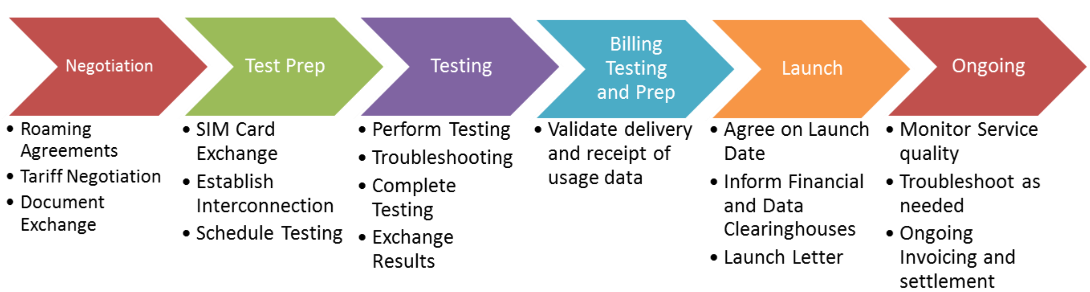


Figure 1-1: High Level Roaming Process

To implement LTE roaming mobile operators must initiate many processes, both internal as well as those to manage their wholesale inter-operator relationships. The remainder of this section highlights some of these processes in greater detail, including reference to the related standardized GSMA documents. These processes generally apply to unilateral, bi-lateral and/or roaming hub approach.

3.1. Negotiation

The negotiation phase to establish a roaming relationship typically starts with internal processes to prioritize the locations as well as the operator group or individual operators where the MNO would like to have roaming capabilities or to support inbound roaming onto their own network. Once the prioritized locations and operators have been determined, including verification of compatible frequencies, instituting agreements between the MNO's is typically the next step.

3.1.1. Roaming Agreements

The GSMA provides roaming agreement templates to help operators establish roaming partnerships. However, operators are free to modify the agreement templates or create their own. Some modifications or deviations specific to the operator(s) are common. The GSMA roaming agreement templates were updated in 2003 to be technology-neutral so they can be used for LTE or other legacy technologies as needed.

The GSMA issued standard roaming agreement templates are separated into two different documents, one covering general terms and conditions and the other with multiple annexes outlining specifics regarding the roaming agreement between partners. Examples of the basic topics that need to be included or addressed between roaming partners are outlined below, including the GSMA reference document.

- GSMA PRD AA.12 - International Roaming Agreement - General terms and conditions
- GSMA PRD AA.13 - International Roaming Agreement – common annexes. Items specific to the roaming agreement between the two roaming partners. Examples of the annexes included are:
  - Agreed settlement procedure (e.g., direct payment, netting)
  - Testing and charging thresholds
  - Security
  - Signalling interconnection and/or IP connectivity
  - Data privacy
  - Fraud prevention procedures
  - Service Level Agreements

3.1.2. Tariff Negotiation

As part of the roaming agreement process, roaming partners must determine and come to agreement on the wholesale charge or tariff for each roaming service that is offered. These are typically referred to as inter-operator tariffs or IOTs. It is advised that MNO's plan sufficient time to complete all of these agreements. While they may be done faster, it is usual for the whole process to take at least 1-3 months to complete.

3.1.3. Document Exchange

Once the roaming agreements have been reached, there is a great deal of basic operational information that needs to be shared and exchanged between roaming partners as they work to establish a roaming relationship. This information ranges from key contacts and services offered to invoicing and billing information. The GSMA utilizes an online database for creating, storing and distributing this MNO specific information, which also stores the standard/default MNO IOT. The database, termed RAEX (Roaming Agreement Exchange), provides a secure, trackable platform to exchange this operational information with roaming partners as well as their agents (E.g. Data Clearing and Financial Clearing houses). Given the inherent sensitivity of a MNO's IOT rates, this information is kept separately from the operational data (termed OpData in the RAEX system) and is distributed separately as well. For historical reference, prior to implementation of RAEX, this operational data was represented in a separate GSMA PRD AA.14. Below is an example of the information that is represented in this agreement.

- RAEX OpData - International Roaming Agreement – individual annexes. Published by an operator to specify operational details that apply to all roaming that takes place in its network.
    - Contacts (including general, financial/invoicing, agents, etc.)
    - Services available by technology (granular)
    - Invoicing information
    - Customer care information
    - Testing, network and SIM/USIM contacts
    - Data privacy
    - Fraud prevention procedures
    - Billing and transfer information
- RAEX IOT
    - Inter-operator tariffs (IOT)

Technical data exchange between the roaming partners is also required during the negotiation phase. In order to prepare for interconnection, interworking and testing, a variety of network specific technical information must be shared between roaming partners as well as with any carriers (IPX Providers and/or Roaming Hubs) used for transport and/or mediation. This data includes but is not limited to overall network identifiers (MCC/MNC, Global Titles, billing codes, etc), network element addressing and routing (FQDN, IP addressing for all IMS/EPC elements, etc), device specific information (IMSI ranges), mechanisms for SMS delivery (i.e., SMS over IP, SMS over SG interface used). In addition, all parameters for supported services, such as voice services (VoLTE, circuit switched voice and circuit switched fallback (CSFB)) are shared as applicable. In the past, operators had shared this information via standardized spreadsheets. Given the detailed information about each specific network, it is advisable to treat this information as confidential.

The GSMA provides a central application to support creation, upload, storage and secure distribution of the technical information. This application uses a separate RAEX database from the operational data and is known by its former document name, RAEX IR.21. There is similar support to document the technical data for roaming hubbing (RAEX IR.85) within the database.

3.2. **Test Prep**

In order to proceed with testing all defined services between roaming partners, a few key steps must be completed. These include:

- Exchange of SIM/USIM cards
- Establish interconnection
- Schedule testing with all involved parties (operator and carrier)

3.2.1. Exchange of SIM/USIM cards

In order to ensure that the end user devices and USIM configuration will operate properly in a roaming scenario, it is necessary for MNO's to send or exchange SIM/USIM cards with their intended roaming partner. The number of requested cards varies by operator, based on their test teams, devices that require support, etc. Typically requests fall within four to ten cards. With LTE and the variety of frequencies, as well as specific operator devices, there are cases where exchange f specific devices has been helpful to advance testing. The parameters for exchange of the SIM/USIM cards, handling of these test cards during the pre-commercial and commercial phases of the roaming relationship are determined and outlined in the International Roaming agreements. As a general rule during the pre-commercial testing phase, MNO's do not send a payable bill/invoice to the home operator (HPMN). Rules and thresholds are established during the negotiation phase for testing using these SIM/USIM are applied during the commercial phase.

It is important that the MNO establish process and procedures for managing the inventory of roaming partner SIM/USIM cards to ensure they are accounted for and used in the appropriate manner. MNO's periodically conduct audits on their testing SIM/USIM cards and their roaming partners should be able to respond to those queries in a timely manner.

3.2.2. Establish Interconnection

This activity is self-explanatory and involves both interconnection to any intermediate carrier or IPX provider along with a full E2E route to the specific roaming partner. This may involve more than the home operator's IPX provider as their route to the end visited network may involve peering with an additional IPX provider directly connected to the visited network. Specific detail on IPX providers, Diameter signalling and overall roaming architecture is provided in later sections of this paper.

3.2.3. Schedule testing

It is important that all parties involved in the testing of a new roaming route or partnership provide sufficient resources to support the testing and typical subsequent troubleshooting to complete the required roaming testing. An MNO who is just beginning LTE roaming can expect testing with a roaming partner to require anywhere from one to six months or longer depending on operator motivation, resources, schedule and services that will be implemented.

3.3. Testing (Network and Device)

Network and Device (SIM/USIM) testing is critical to ensure roamers can use the visited network (VPMN) services or access their network to register and route back to their home network. Each service is tested separately with defined test cases and test scripts. The testing process and test cases used between each operator is bi-laterally agreed, as only a subset of all the available test cases are required, particularly when launching new services. Prior to initiating testing, it is expected that all interfaces and services function properly within each operator's environment. This is necessary to be performed across each type and manufacturer of the involved network entities.

Test procedures and their execution can be done internally or outsourced to a third party. In the case of the HPMN choosing a roaming hub approach, the hub will typically manage all of the network testing.

The GSMA has developed the baseline and specific service testing guidelines and test cases. Collectively these have been referred to as IREG (Interworking, Roaming Expert Group) testing. IREG was the technical working group within the GSMA that defined the test procedures and test process. The group is now known as the Network Group (NG). The primary documentation for testing to support LTE and VoLTE ie the following.

- IR.23 Organisation of GSM International Roaming Tests
    - Defines the methodology for testing, and maintaining in the presence of faults, the inter-Public Mobile Network (PMN) international roaming facility.
- IR.38 - LTE and EPC Roaming Tests
- IR.25 – VoLTE Testing

3.4. Billing Testing and Prep

After baseline and service testing has completed successfully, MNO's proceed with testing their billing systems. Their goal is to determine that their billing system receives the appropriate billing files and verifies that the information received matches the service usage tested.

The GSMA has defined a standard procedure and methodology to exchange billing data and records for roaming call events. The process and file format used is called TAP or Transfer Account Procedure. As similar process and file format has been defined for rejecting and returning invalid call events, the Returned Account Procedure (RAP). To support the testing and verification of TAP and RAP files, the GSMA developed a toolkit for users known as the TAP Testing Toolkit (TTT).

If the MNO employs a data or financial clearing house (DCH, FCH respectfully) to support the data and financial/settlement clearing, as many MNOs do, the clearinghouses must be engaged as part of the process.

Further information on LTE billing and settlement can be found in a later section within this paper.

3.5. Launch

Once all testing and validation of usage data for billing has completed successfully, operators need to agree on a service launch date. This is documented in the form of a launch letter that includes the date of services along with the specific services that will be launched and supported. Prior to launch, roaming partner operators must inform their financial and data clearinghouses (if utilized) of the launch date to ensure they are prepared and ready to support the data clearing and settlement processes as defined. Internally, the HPMN and VPMN need to communicate this new partner launch to the appropriate roaming operations and customer care teams.

3.6. **Ongoing**

The roaming partners and supporting agents work has just begun once commercial roaming has commenced. The HPMN should have a process in place to continually monitor the service quality of the roaming route. During the negotiation phase document exchange, all parties involved should have the appropriate contacts within both the HPMN and VPMN to deal with all aspects of the ongoing support of roaming customers. These include, but are not limited to:

- Roaming manager for general relations
- Roaming operations – for troubleshooting network and customer issues
- Customer care
- Invoicing and billing contacts
- Contacts for all agents in the roaming flow, both network and billing
- Roaming Value Added Services (VAS) (E.g. steering, welcome SMS, Virtual Home Environment, etc.)

4. IPX

Developed by the GSMA to foster open standardized IP connectivity for multiple types of service providers, IP eXchange (IPX) provides for end-to-end Quality of Service (QoS) in support of both roaming and interworking for LTE and IMS. The IPX provides a commercial and technical solution to manage IP traffic. It is an interconnect service that is offered by a variety of providers on a competitive basis but with common agreed technical specifications and using consistent commercial models. The managed network environment is traffic engineered to support specific IP services at specific quality levels. The IPX solution is a premium quality solution that promises errorfree delivery of traffic while offering the flexibility to apply an appropriate level of quality as demanded by each different class of service. IPX offers mobile operators the ability to connect to all of their roaming partners via one (or two for redundancy) connections to the IPX for both LTE and VoLTE roaming and interconnect. IPX offers a managed transport service with:

- Private managed IP backbone based on GSMA IPX Specifications
- MPLS-enabled

- High availability, high bandwidth, multiple PoPs, global
- COS/QoS for multiservice
- SIP proxy
- Network-layer security
- IPv6 support
- Audio/Video transcoding

Some key capabilities of the IPX include:

- Network monitoring
- Troubleshooting
- Interworking of protocols and protocol-variants
- IP version interworking
- Tunnel management
- QoS/QCI (QoS Class Identifier) monitoring and control
- Service or application awareness
- Transaction correlation within and across protocols
- Statistics and reporting

The IPX offers many valuable benefits to mobile operators. It helps operators manage costs by offering a single network that supports many services. The IPX offers differentiated Class of Service (CoS) and end-to-end QoS with Service Level Agreements (SLA). Unlike the internet, the IPX will ensure a level of service and security. It provides support for interworking between IMS and legacy systems facilitating migration to next generation networks. Lastly, IPX offers session-aware interworking for better network control.

The IPX is a private backbone network offering mobile operators with a higher level of security. Commercial agreements give protection to all players as those connected to the IPX agree to sign up to a security code of conduct so a trusted community is created. The IPX is not addressable from the Internet – which makes attacks much more difficult. Individual operator traffic is segregated – thus localizing any security breaches. End user terminals have no visibility of the IPX. They are unable to probe the core networks involved in the management and delivery of the IP services.

The IPX network is much more than just a roaming network. It enables services for transport and interconnect. For instance,

IPX Transport Services:

- Signalling
- CDMA/GPRS/LTE roaming
- WLAN roaming

- Message Interworking (MMS, SMS)

IPX Interconnect Services:

- IP voice telephony (VOIP) interconnect and interworking
- IP video telephony interconnect and interworking
- Push-to-talk over cellular
- Advanced messaging and presence (GSMA RCS)

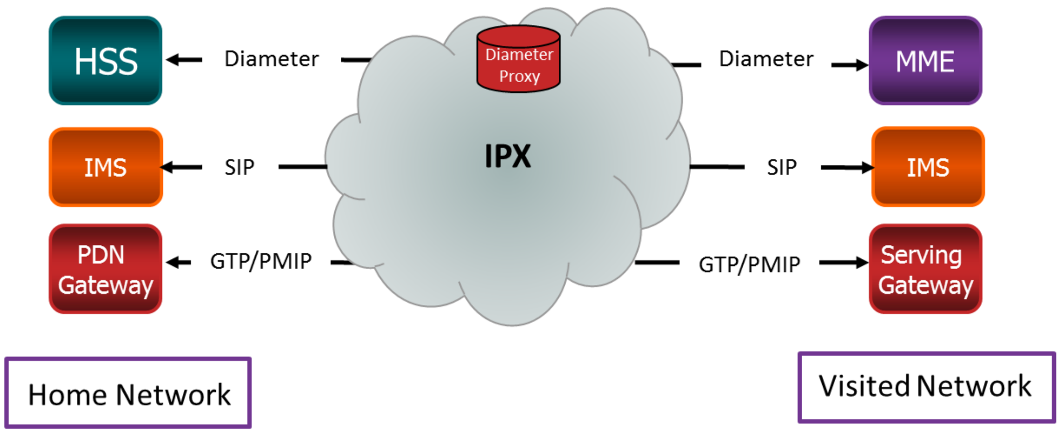


Figure 3-1: IPX Communication Protocols

4.1. Diameter Signalling in LTE Roaming

In LTE/SAE (3GPP Rel. 8), the Diameter protocol has been chosen for many procedures such as location, subscriber, access, handover, authentication, security, identity management and handover services as well as inter-operator signalling network and roaming infrastructure. In an LTE environment, registration messages received would be based on Diameter. Diameter Base Protocol is defined within IETF RFC 3588 (published in September 2003) and 3GPP (like IETF) has also defined some Diameter applications to support more specific requirements in different scenarios.

The Diameter protocol introduces notions of Diameter agents:

- Relay agents: accept requests and route messages to other Diameter nodes based on routing decision performed using list of supported realms, and associated known peers
    - Advertise "Relay Application Identifier" in Capabilities-Exchange-Request (CER)/Capabilities-Exchange-Answer (CEA)
- Proxy agents: relay function and messages modification to implement policy enforcement
    - Advertise supported Diameter applications in CER/CEA

- Redirect agents: return information necessary for Diameter agents to communicate directly with another Diameter node
  - Advertise "Relay Application Identifier" in CER/CEA
- Translation agents: provides translation between two protocols (e.g., RADIUS<->Diameter)
  - Advertise supported Diameter applications in CER/CEA

A Diameter implementation may act as one type of agent for some requests, and as another type of agent for others.

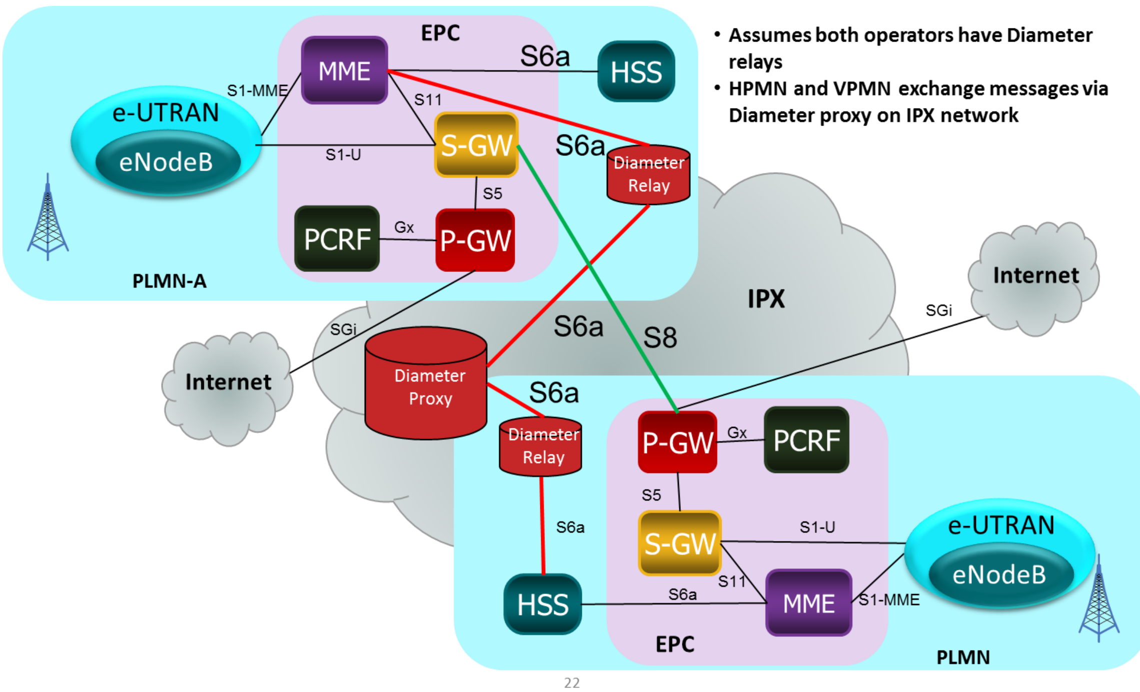


Figure 3-2: Diameter Signalling

The S9 interface based on Diameter is between the hPCRF and vPCRF and is used for Policy Control and Charging (PCC). PCC management occurs at the time of EPS Bearer establishment. In a Home Routing scenario, IPX has visibility into the S8 interface between the S-Gateway and P-Gateway. In Local Breakout (LBO), the IPX does not have visibility into S8 between the S-Gateway and P-Gateway (as P-Gateway is also in the visited network). IPX visibility into the Diameter-based S9 interface is essential to get the "full picture". IPX knows the Policy applied for a LBO session.

Always-on IP connectivity in LTE is enabled by establishing a default EPS bearer during Network Attachment. IMS APN (with QCI=5) used for Default Bearer. Registration message and GTPc message for Default bearer establishment are essentially tied together. IPX visibility into GTPc messages provides a "full picture" including the ability to see what IP addresses were allocated and whether the Default bearer establishment was successful.

4.2. The QoS Paradigm in LTE

Quality of Service (QoS) is the determined throughput, delay, packet error rate, and jitter. Applications, services and users have different traffic patterns and QoS requirements. QoS mechanisms include the control-plane for decision making and the user/data plane for enforcement. In LTE roaming, there are scenarios of home network/visited network mismatch of supported QoS classes. Mobile operators declare their supported QCIs on IR.21. Also, mapping exists between QCI and DiffServ values (DSCP, PHB). Roaming operators must carefully follow PCC architecture guidelines defined in Rel. 8

Extract from 23.401 Annex E Mapping between standardized QCIs and pre-Rel-8 QoS parameter values					Extract from PRD IR.34 Table 6. Traffic classes and their mapping to DSCP values			
QCI	Traffic Class	Traffic Handling Priority	Signaling Indication	Source Statistics Descriptor	Traffic Class	Traffic Handling Priority	Diffserv PHB	DSCP
1	Conversational	N/A	N/A	Speech				
2	Conversational	N/A	N/A	Unknown	Conversational	N/A	EF	101110
3	Conversational	N/A	N/A	Unknown				
4	Streaming	N/A	N/A	Unknown	Streaming	N/A	AF41	100010
5	Interactive	1	Yes	N/A	Interactive	1	AF31	011010
6	Interactive	1	No	N/A				
7	Interactive	2	No	N/A	Interactive	2	AF21	010010
8	Interactive	3	No	N/A	Interactive	3	AF11	001010
9	Background	N/A	N/A	N/A	Background	N/A	BE	000000

Figure 3-3: QoS/QCI mapping to Traffic Class

IMS Signalling is not distinguished today within "Interactive" Traffic Class THP=1 – marked as Diffserve PHB AF31 with DSCP bits 011010. The IPX should continue to use the same Diffserve PHB/DSCP marking for all Interactive Traffic Class with THP=1 (except IMS Signalling) as well as for Pre-Rel.5 SGSNs. So effectively the major changes proposed for IPX are

- Introduction of IMS Signalling in LTE within "Interactive" Traffic Class THP=1 to use Diffserve PHB AF41 and DSCP bits 100010

- Diffserve PHB AF41 and DSCP bits 100010 used today for “Streaming” Traffic Class. It should now be used for “Interactive” Traffic Class for IMS Signalling in LTE
- New Diffserve PHB AF42 and DSCP bits 100100 introduced for “Streaming” Traffic Class

IPX supports QoS in LTE roaming:

- Support for a common Default EPS Bearer using IMS APN with QCI=5
- Support for a common Voice bearer type between Roaming partners – Dedicated EPS bearer with agreed QCI (=1), ARP, MBR, GBR for Voice
- IP Packet marking using Diffserve PHB & DSCP bits in IP CoS field depending on QCI values and Traffic Classes to prioritize traffic
- Mapping between QCI values and 2G/3G QoS information
- IPX could change DSCP bits when exchanging traffic with GRX
- IPX would not alter the DSCP bits in “Transport mode only”
- IPX would provide detailed reports on QCI and QCI mappings performed as KPIs and Performance reports for QCI
- Operators can use these for SLA management

5. LTE Roaming Architecture

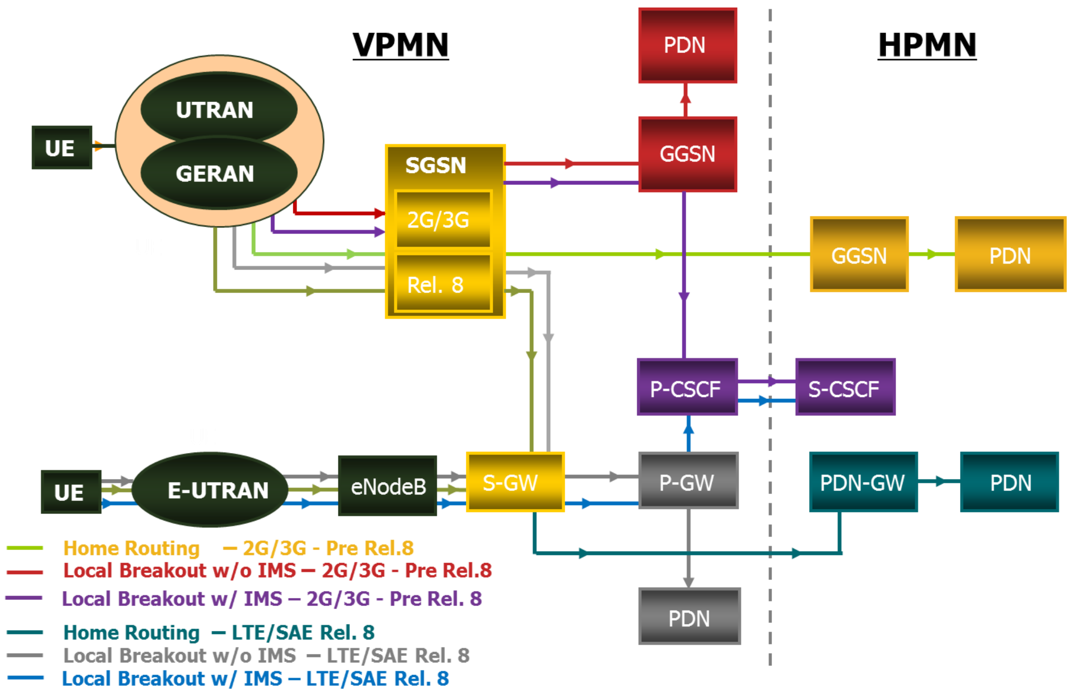
Some primary interfaces used in LTE

Interface	Entities	Protocol
S4	SGSN – SGW	GTP-C/U
S6a	MME – HSS	Diameter
S6b	External AAA function	Diameter
S6c	External AAA function	Diameter
S6d	S4-SGSN – HSS	Diameter
S7	PCRF – P-GW	Diameter
S8	SGW – PGW	GTP-C/U
S9	hPCRF – vPCRF	Diameter
S11	MME – SGW	GTP-C
S13	MME – EIR	Diameter
Gx	PCRF – PCEF	Diameter
Gxc	PCRF – S-GW	Diameter
Gy	PCEF – OCS	Diameter
Mw	P-CSCF – S-CSCF	SIP

Mm	S-CSCF(a) – S-CSCF(b)	SIP
Mb	IMS AGW(a) – IMS AGW(b)	RTCP/RTP
Rx	AF – PCRF	Diameter

5.1. LTE Data Roaming

LTE Data Roaming is primarily based on home routing as shown in the figure below.



5.2. VoLTE Roaming

Initially, there were 4 roaming architectures being discussed in GSMA, namely S8HR (S8 Home-Routed) and three variances with LBO (Local Break Out), i.e. LBO HR (Local Breakout with Home Routed), LBO VR (Local Breakout with Visited Routed), and LBO OMR (Local Breakout with Optimal Media Routing). It was recognized that having multiple options impacts operator's ability to reach global alignment on interconnect and roaming solutions. Therefore, by considering technical realization and relevant business issues, the discussion and comparison is narrowed down to two options, S8HR and LBO VR, which is also known as RAVEL (Roaming Architecture for Voice over IMS with Local breakout). This section will provide high level technical descriptions for the two architectures and to help operators choose their preferred option.

5.2.1. RAVEL/LBO Architecture

In 2011, 3GPP and GSMA performed a thorough study on the specification of VoLTE roaming architecture models based on RAVEL. This model matches the most often used current CS (circuit-switched) business model where the VPMN routes calls and incurs costs for international routing.

In RAVEL, a function called Transit and Roaming Function (TRF) is required to be deployed in VPMN A, such that the call related signalling will be looped back to VPMN A after it has been processed by the HPMN A. VPMN A is then responsible for routing calls directly to HPMN B, as shown in Figure 4-1. Optimal Media Routing (OMR) is used to prevent the user plane from being routed to HPMN A during the call set up signalling. The TRF and OMR together enable the signalling and user plane to be carried on the same path, and thus allowing reuse of the "cascaded billing" model between operators and IPX providers today.

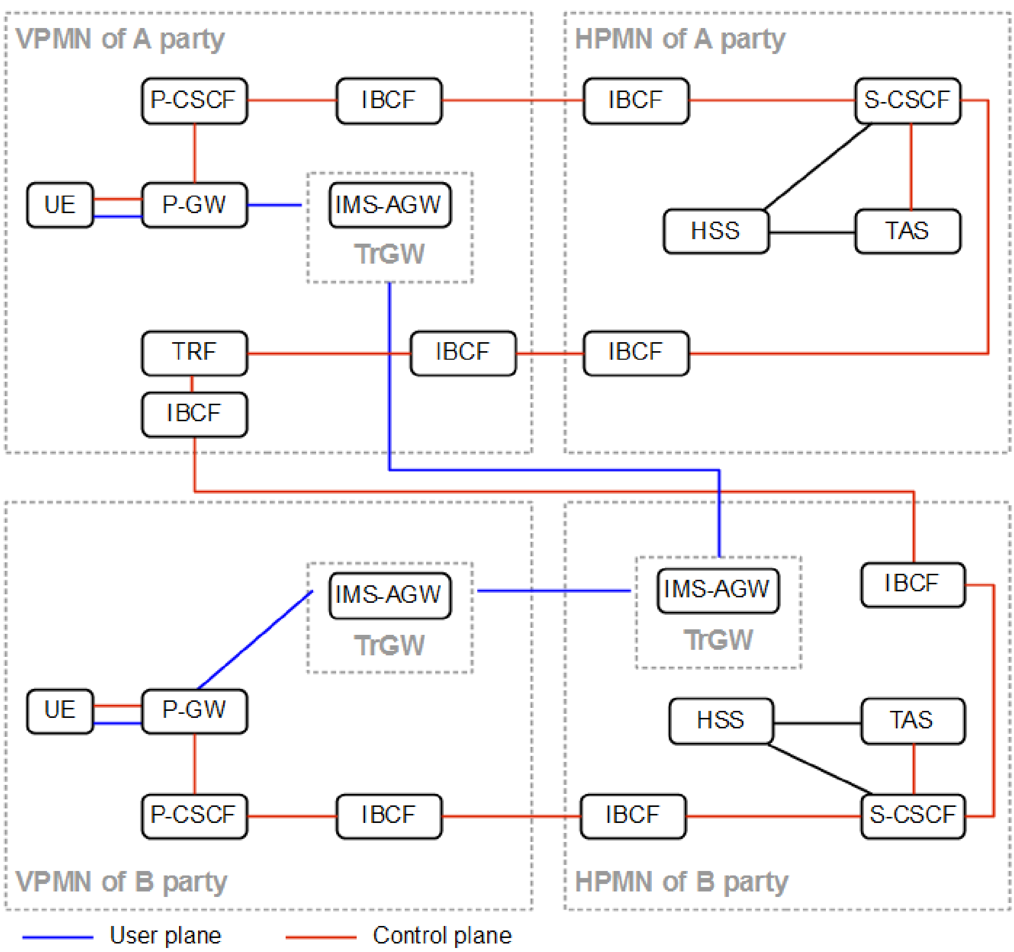


Figure 4-1 Roaming architecture with RAVEL/LBO

The advantages of RAVEL architecture are:

- The charging and service level routing follow the existing 2/3G model which reduces the business negotiation and helps maintain the current situation.

- From a specification perspective, RAVEL is a mature architecture and the whole solution has been well defined by GSMA and 3GPP. However, the vendors' support of TRF and OMR functionalities are based on operators' requirement. It is recommended that operators check with their vendors before selecting this architecture.

- In some particular scenarios, i.e. an inbound roamer calls a VPMN local user or users from the same HPMN roam into the same VPMN, the media path could be shortened by using the OMR function in IBCF, which reduces the transmission delay of media.

The disadvantages of RAVEL architecture are:

- The UNI (User to Network Interface) interoperability issue associated with RAVEL is considered to be the most difficult issue for commercial deployment. Given the flexibility of the SIP protocol and the ease for operators to add customized service features to their subscribers, the VoLTE fragmentation issue between UE (User Equipment) and network has been increasingly recognized in the community. Especially in the roaming scenario, the issue would vary when roaming into different operators. Therefore, comprehensive UNI test according to a unified UNI profile is required for each roaming partner before RAVEL commercial deployment.

- For operators who are planning to adopt RAVEL as their roaming architecture, both visited and home networks are required to deploy an IMS network. In addition, their IPX providers are required to deploy IBCF and OMR functionality, which may cause additional CAPEX. Currently, the speed of IMS deployment worldwide is relatively slow, which directly impacts LBO penetration.

- With RAVEL, since all the EPC entities are in the VPMN, the international interface between PGW in VPMN and OCS in HPMN is missing for online charging.

5.2.2. S8HR Architecture

Different from RAVEL, the architecture of S8HR is most comparable to an LTE data roaming architecture, as shown in Figure 4-2. With S8HR, VoLTE calls are home-routed using IMS APN via the S8 interface with specific QCIs. The advantages of S8HR architecture are clear:

- The IMS UNI with S8HR is provided directly between UE and the HPMN, so there is no UNI issue for the basic voice/video service.

- Since only the EPC is required in the VPMN, operators who have deployed their LTE network are capable of supporting VoLTE roaming services. This has been considered as an opportunity to quickly penetrate VoLTE roaming service.

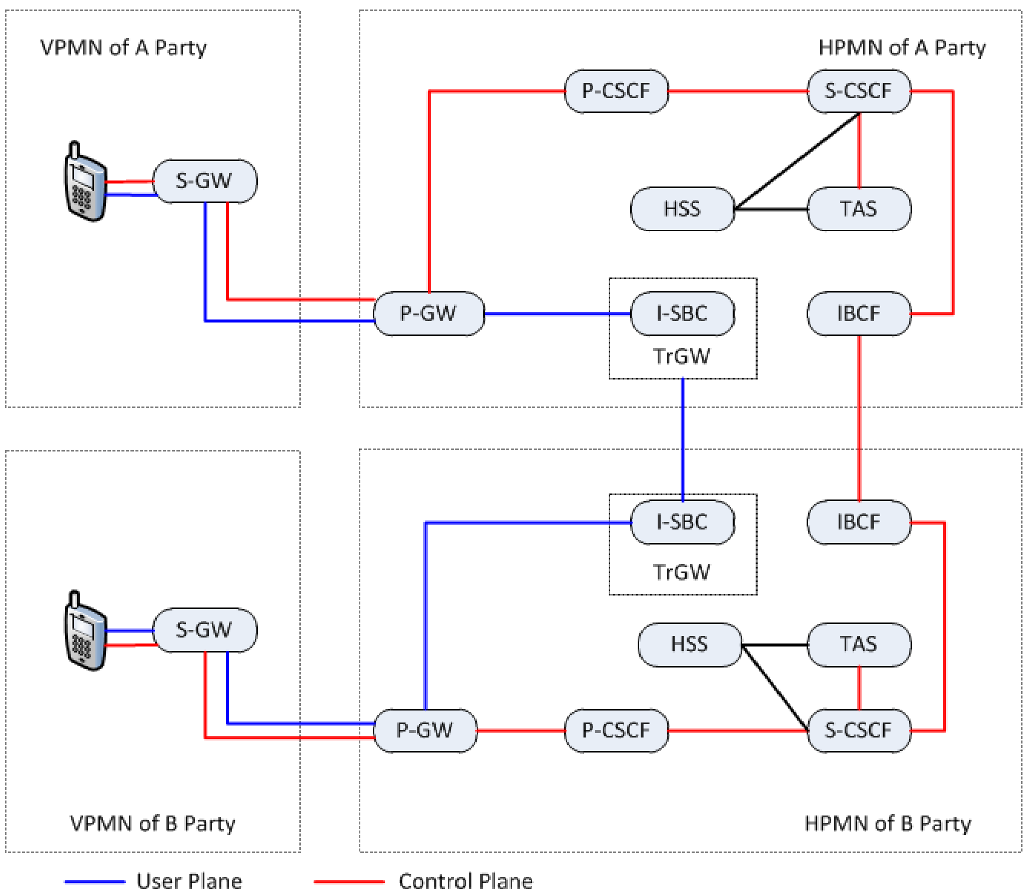


Figure 4-2 Roaming architecture with S8HR

VoLTE roaming via S8HR is quickly gaining momentum. As of late 2016, S8HR was the only architecture used to launch commercial VoLTE roaming. Its popularity is due to many reasons, including:

- As much as 80% of voice calls made during international out-bound roaming are made back to the home country.
- The visited operator charges wholesale tariffs to the home operator for data roaming service only
- The home operator avoids wholesale out-bound roaming charges for VoLTE service
- The home operator avoids wholesale international long distances charges for mobile originated (MO) calls to home country
- With S8HR the remaining 20% of the calls trombone via the home operator
- Higher latency could be detrimental to HD-Voice media quality

However, after a series of technical discussions in GSMA and 3GPP, some outstanding technical issues were identified with S8HR, including UE detectable and UE non-detectable IMS Emergency session handling, Identification of the VPMN ID to the HPMN in a service unaware environment and local number translation and routing. Each of these areas now have solutions identified within 3GPP Standards. The associated technical specifications are due for completion in December 2016 with the specification being introduced into Release 14 by mid-2017. While these issues are being addressed, some considerations for LTE only operators are noted below.

- Since roaming NNI (Network to Network Interface) (from P-CSCF in VPMN to S-CSCF in HPMN) is not available in S8HR, a solution was needed for emergency session handling. In the meantime, operators who have launched VoLTE roaming with S8HR can choose to fall back emergency service to CS. Unfortunately, this is not an option for green field, LTE only operators. Such operators are suggested to support anonymous emergency call, which uses IMEI to authenticate the UE.

- Since S8HR architecture is not service aware at IMS level, the VPMN must support lawful interception on S-GW. VPMN will need a system to turn the intercepted raw IP data into audible voice. The technical solution and specifications to support all aspects of Lawful Intercept (LI) are currently being developed within 3GPP. To allow the VPMN to intercept the message(s) for law enforcement agencies, the HPMN must agree to turn off/disable IPsec confidentiality protection when required by the VPMN. This requirement should be communicated during the negotiation phase and included in the contractual roaming agreements. This provision is already available in the baseline GSMA International Roaming agreements.

- Another issue identified with S8HR is geo-local number translation, as capability available in traditional CS roaming. In order to support an outbound roamer calling a geo-local number when roaming in the VPMN network, the HPMN must be provisioned with all local number mappings from the VPMN(s) by location. The solution defined and being documented in the 3GPP technical specifications is similar to the existing LBO solution, so it should have minimal impact on the HPMN or VPMN to provide the service. As noted above, this should be available in Release 14 in mid-2017.

- S8HR will bring new a QoS based charging model to the existing roaming ecosystem. Roaming partners are required to support APN/QoS/QCI based wholesale charging in their billing system. At the time of release of version 1 of this paper, operators were differentiating their VoLTE service by APN. Use of QoS/QCI in a roaming environment is still being tested and is not yet commercially launched.

5.3. SMS over LTE Roaming and Architecture

There are two primary ways that SMS can be delivered over LTE, SMS over SGs and SMS over IP/IMS (See Figure 4-3). As SMS over SGs is the mechanism to transmit circuit switched SMS over LTE it will not be addressed within this white paper for LTE only operators, but does represent a transition method prior to implementation of SMS over IMS.

In SMS over IP mode, SIP based SMS messages are passed via the IMS. The SMS to be delivered is transmitted in encapsulated SIP messages via an IP Short message gateway (IP-SM-GW entity).

In the IMS network, an IP-Short-Message-Gateway (IP-SM-GW) provides the protocol interworking to submit short messages from the sending UE to the service center (SMS-C), and from the serving center to the receiving UE. It also handles SMS status reports from the serving center to the sender.

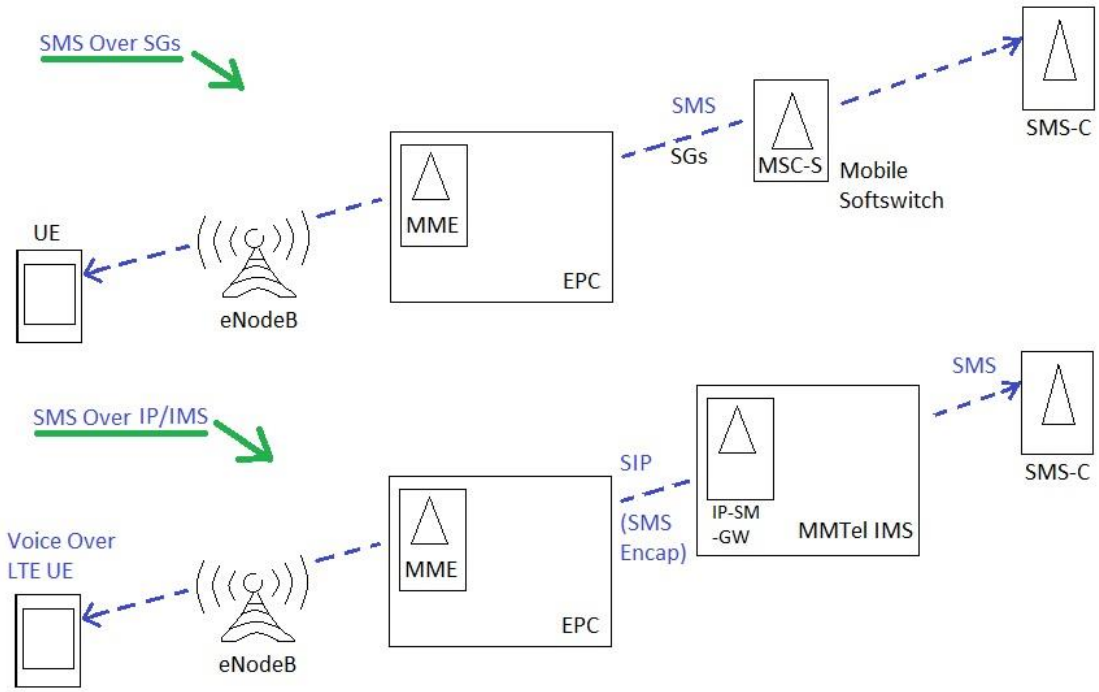


Figure 4-3 SMS over LTE architecture

6. LTE Devices and USIM cards – Roaming Considerations

6.1. One Multimode Multi-band Device to Enable Global Roaming

6.1.1. Multimode Single Device

Multiple mobile networks with mutually incompatible technologies and LTE band fragmentation are the core impediments to broader roaming coverage, limiting end user value. This creates the need for multimode 3G/LTE devices for better voice and mobile broadband roaming coverage, both globally and in some cases locally. The network flexibility of single all-mode mobile devices—supporting all the 2G, 3G and 4G LTE technology modes—is the current key to unlocking the next frontier of smartphone competitive value delivery. As a solution tailored to the current realities of today's technology and consumer marketplaces, all-mode represents the best of multimode LTE across tiers and devices. The advantages of all-mode smartphones are clear and substantial. Back to 2012, GTI published its MMMB device requirements, 5-mode (or say global mode) was recognized as essential for operator's success in 4G era.

Broader roaming is the first and most obvious advantage of multimode 3G/LTE technology for today's LTE smartphones. Without it, the diversity of mobile technologies across major service providers limits coverage and the utility of smartphones for many, if not most, users. The situation in China is a good example, where diversity of modes restricts users from accessing 3G/4G services across different operators using one device.

All-mode smartphones lift this restriction by enabling users to configure a single-SIM device by swapping SIM cards or to use a dual-SIM device to subscribe to multiple operator networks at the same time. All-mode multi-band phones with global support for both LTE-TDD (also known as TD-LTE) and LTE-FDD modes also provide high-end users the flexibility to roam worldwide with the convenience of a single device.

Consequently, all-mode devices give network operators a strong competitive future proofing value proposition to subscribers across all value tiers, enhancing performance now and prolonging the useful life of their smartphones into the future. At the high end, global roaming is made available now. At the low end, the useful life of devices is extended, and the need for second and third devices for greater coverage and access to different operator networks is eliminated. The 3G/4G user experience is improved with better data rates, access to broader services and coverage.

6.1.2. Multiband Consideration

Global spectrum harmonization is always the effort of the telecommunication industry to share the ecosystem and easy-support of global roaming, while due to one reason or the other, LTE is being deployed on difference bands globally, some at 700/800MHz, some at 1800/2100MHz and some at 2300/2600MHz. GTI's multi-mode multi-band device requirements and architectures white paper published in 2012 shown that among GTI operators, 4 TD-LTE bands and 3 FDD bands are highlighted as core bands(as in Table 1) and 4 additional FDD bands are recognized as core roaming bands(Table 2). All those bands are required to be supported by 2012 and also additional 3 FDD bands (Table 3) are required in timeframe of 2014/2015(which means now). Furthermore, GTI also conducted extensive studies on 3.5GHz TD-LTE(B42/43) and some of the region has already allocate and launched TD-LTE service on this band.

Table 1 GTI LTE Core Bands Frequency Definition and Timeframe Requirements

Mode Type	Band No.	Uplink	Downlink	Timeframe
TD-LTE	Band 38	2570-2620MHz	2570-2620MHz	2012

	Band 40	2300-2400MHz	2300-2400MHz	2012
	Band 41	2496-2690MHz	2496-2690MHz	2012
	Band 39	1880-1920MHz	1880-1920MHz	2012
FDD LTE	Band 3	1710-1785MHz	1805-1880MHz	2012
	Band 7	2500-2570MHz	2620-2690MHz	2012
	Band 20	832-862MHz	791-821MHz	2012

Table 2 GTI LTE Core Roaming Bands Required in 2012

Mode Type	Band No.	Uplink	Downlink	Timeframe
FDD LTE	Band 1	1920-1980MHz	2110-2170MHz	2012
FDD LTE	Band 4	1710-1755MHz	2110-2155MHz	2012
FDD LTE	Band 13	777-787MHz	746-756MHz	2012
FDD LTE	Band 17	704-716MHz	734-746MHz	2012

Table 3 LTE bands required for 2014/15 deployments

Mode Type	Band No.	Uplink	Downlink	Timeframe
FDD LTE	Band 2	1850-1910MHz	1930-1990MHz	2014/2015
FDD LTE	Band 5	824-849MHz	869-894MHz	2014/2015
FDD LTE	Band 8	880-915MHz	925-960MHz	2014/2015

To support success of LTE roaming and provide ubiquitous service experience to end users, all those bands to be supported on single-device is necessary. Furthermore, to support true global roaming, support of 2G/3G bands are also required (e.g., GSM Quad-band, B1/2/5/4/8 for WCDMA/HSPA), which would further add the number of the bands that need to be supported for global roaming success. On the other hand, with the LTE evolving globally, most operators have deployed Carrier Aggregation. If need to support CA for roaming, the band combinations are quite a lot.

With the increasing number of bands and their combinations, the RF complexity is growing exponentially. The traditional front-end designs meet challenges since it does not scale to support addition of more bands and their CA combinations, which may result in high cost, increased power and heat, and lower performance due to RF co-existence between different technologies, antenna limitations and wide frequency range. The space is also limited for RF front-end (RFFE) implementation of more bands/combinations. Compact RF design and system level solution shall be considered to address all these challenges and also a joint design of RFFE and modem would benefit the overall performance in terms of power efficiency, signal quality and Tx/Rx performance. Some of the industry players have already made the first step to pack the RFFE components, such as antenna switcher/tuner, PA and enveloper tracker.

6.2. Voice Service in Roaming

6.2.1. One Device, All Voice Solutions

Globally, different operators have different voice solutions, there are mainly 4 approaches:

1. Circuit Switched Fallback (CSFB);
2. Dual-standby or simultaneous Voice-LTE (SGLTE/SVLTE/SRLTE etc.);
3. Dual-SIM;
4. VoLTE/SRVCC.

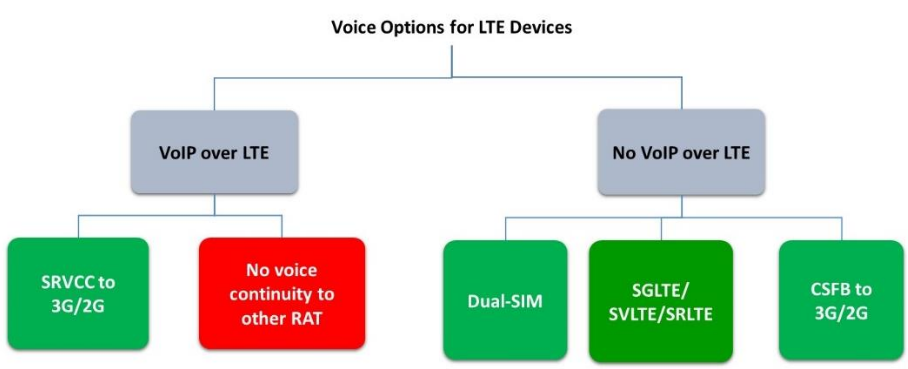


Figure 5-1: Voice Options for LTE Devices

To provide basic roaming services to the users, voice roaming shall be supported by at least smartphones, and to provide true global roaming, all the solutions are necessary to be supported by single device since different regions rely on different solutions. Solution #1-#3 uses 2G/3G CS domain to provide voice service, which is available everywhere due to decades of deployment and operations. VoLTE/SRVCC is yet an emerging technology to rely on PS domain to provide voice service when LTE/VoLTE is available and handover to 2G/3G CS domain for service continuity. Before the VoLTE/SRVCC become fully commercialized globally, 2G/3G CS domain shall still be the choice for voice roaming via solution #1-#3. All the solutions requires the device has to be multimode and multiband capable, aka one device with multimode multiband and all voice solutions.

6.2.2. LTE Dual-SIM – Global and Regional Roaming Enabler

LTE Dual-SIM would be able to provide so called "regional" roaming. One can provide data service with one SIM and use partner's network/SIM to provide voice service, which is extremely suitable for green LTE operators, who did not have or only have limited legacy 2G/3G network coverage. When the VoLTE services are supported by the green LTE operators, it can still rely on partners' 2G/3G network to provide voice service for the region where there is no VoLTE or even no LTE coverage, or say 'roaming' into partners' 2G/3G network. With this, to save CAPEX, the operator can build its LTE coverage by phases, and can also upgrade its LTE network to be VoLTE-capable step by step without impacting users' experience. Below figure highlighted such use cases:

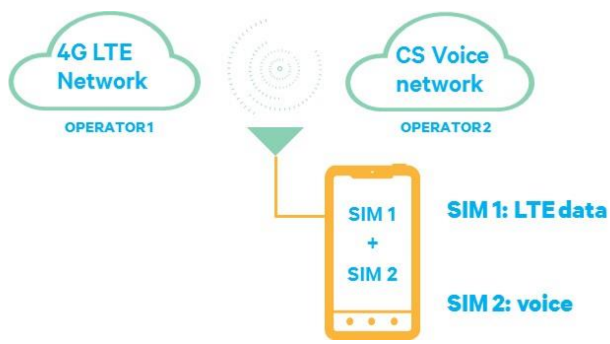


Figure 5-2 w/o VoLTE, Operator 1's LTE data + partners' 3G/2G CS voice

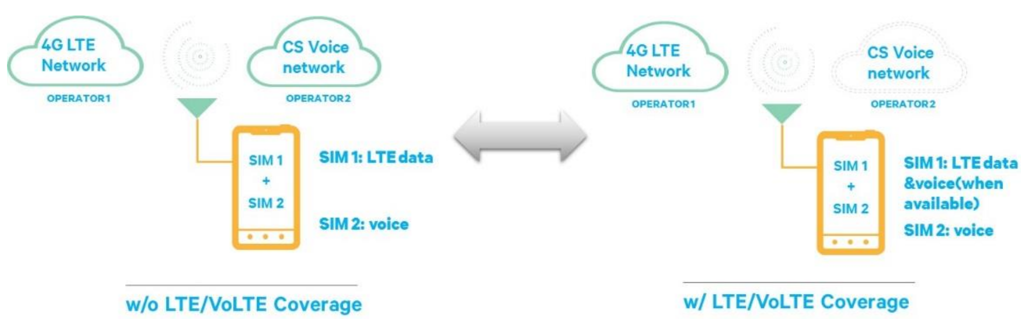


Figure 5-3 Operator 1's LTE data/voice, roaming into partners' 2G/3G network for voice in Non-LTE/VoLTE coverage

Dual-SIM also provide the users' flexibility to be able to keep its home subscription/SIM registered and roamed into another region and at the same time to use another SIM to get full services that provided by local partner operator.

LTE+3G/2G can basically meet the requirement of regional roaming for green LTE operators. To further cover the global roaming requirement, a true global phone is necessary, aka 5/7 mode+3G/2G.

7. LTE Roaming Clearing and Settlement

This section is written from the perspective of impacts and changes to the existing processes, procedures and file formats used with GSM based 2G/3G networks. An LTE-only operator would need to be familiar with all of these processes, files and terminology in order to successfully clear and settle bi-lateral roaming usage. The applicable accounting flows are documented in section 6.3.

Since the TAP record is being used for LTE, there is minimum impact on existing data clearing, invoicing, financial clearing and settlement processes as they have been developed and used within the GSMA. Data Clearing Houses (DCH) will continue to send Roaming Traffic Data Reports (RTDR) to the Financial Clearing House (FCH). FCHs will work exactly as they do today using RTDR as input from the DCHs. Invoices continue to be based on TAP files. Both TAP and RTDR have been updated for LTE. The GSMA updated TAP to support data over LTE in 2010 and for VoLTE in 2012.

7.1. Data Over LTE

For data over LTE roaming, it's possible for the visited operator to use call records from the SGSN and S-GW for home-routed access (like today for GPRS/3GPS) and additionally from the P-GW for local-breakout. New recording entity type codes and types (7:P-GW and 8:S-GW) have been added to the TAP standard to differentiate LTE data from 3G data. In addition, "Cause for termination" values were added to the TAP 3.11 standard. The implementation of data over LTE is a minimal impact on existing operator clearing processes.

7.2. VoLTE and SMSoIP

TAP support for LTE/IMS was implemented in TAP 3.12. The first two IMS services implemented were Voice (VoLTE) and SMSoIP (which is part of the VoLTE standard). Two new TAP records were added specifically for VoLTE:

- Messaging event - SMS-MO and SMS-MT over LTE
- Mobile session - originating and terminating VoLTE

Both records have service parameters to future proof TAP for new messaging and call/session type services that will be implemented on IMS. Future IMS based messaging services will be able to use the same TAP record. MMS and email are generally not IMS based, but likely could be used in the future with Rich Communication Services (RCS).

For VoLTE, new TAP fields in the two new records were added:

- New type of roamer: Public User ID (user@domain)
- New type of destination: Non-charged Public User ID (user@domain)
- New Recording Entity Code/Type: 9:P-CSCF

There are various billing challenges mobile operators will face when implementing VoLTE roaming. For instance there will be no single network element containing all charging elements. There is no direct equivalent in VoLTE for the visited MSC in circuit-switched. Correlation from the data is required from SGSN/S-GW/P-CSCF CDRs via a common Charging ID when dealing with a call that actively hands off from LTE to CS. This is not a standard scenario in 3G, except for the occasional combinations of partial records. The Charging ID is available from the P-CSCF to identify each unique call. It is also available from the S-CSCF in the home network.

Not all of the “usual” TAP information is readily available in the VoLTE roaming scenarios.

Charging for data over LTE is the same as charging for data over 2G/3G, but could potentially be based on QoS or APN. For VoLTE, operators have discussed maintaining the legacy voice roaming retail charging and termination principles, at least initially. This is particularly true for LBO.

7.3. Accounting Flows for Non-IMS (Data over LTE) and IMS (VoLTE and SMSoIP)

7.3.1. Non-IMS Home Routing (Data over LTE)

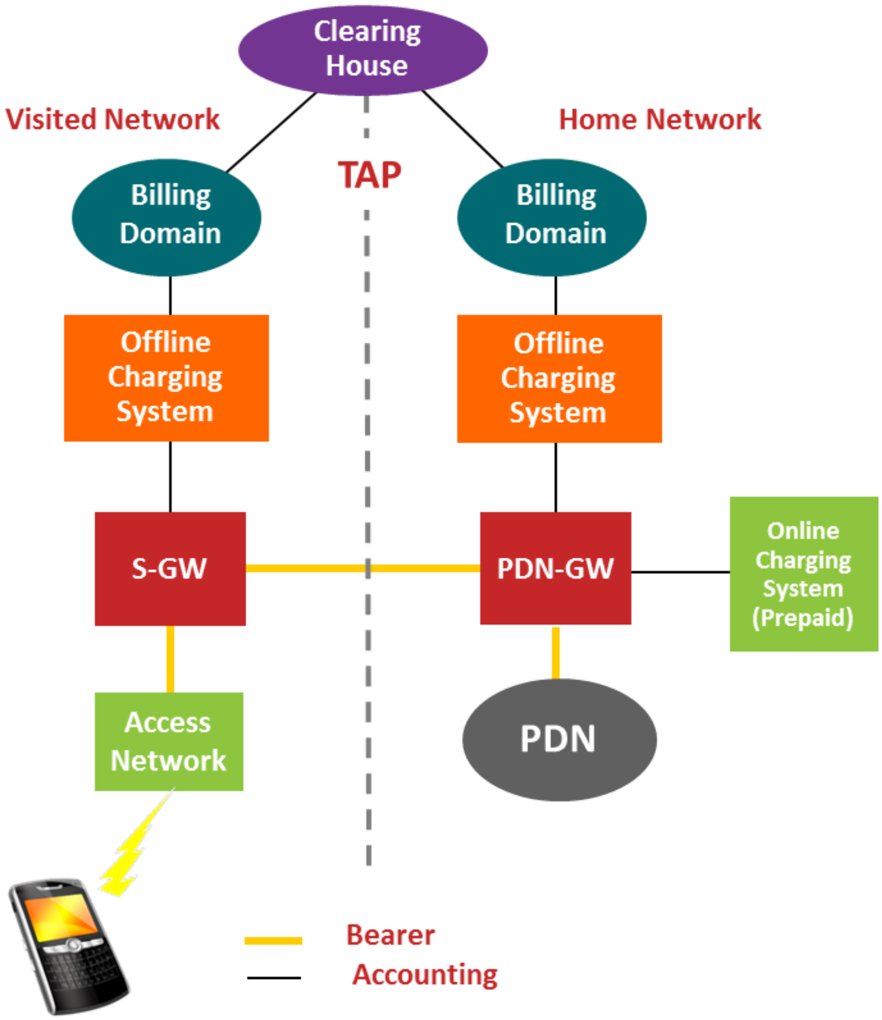


Figure 6-1: Accounting Flows for LTE Data (non-IMS)

No accounting records are sent from the visited to home network. The visited network collects accounting records from the S-Gateway. The home network collects accounting records from the P-Gateway. TAP billing records are sent to the DC. There is no change from the GPRS settlement process. This process is supported by existing GSM billing systems.

7.3.2. IMS Services (S8) Home Routing (VoLTE/SMSoIP)

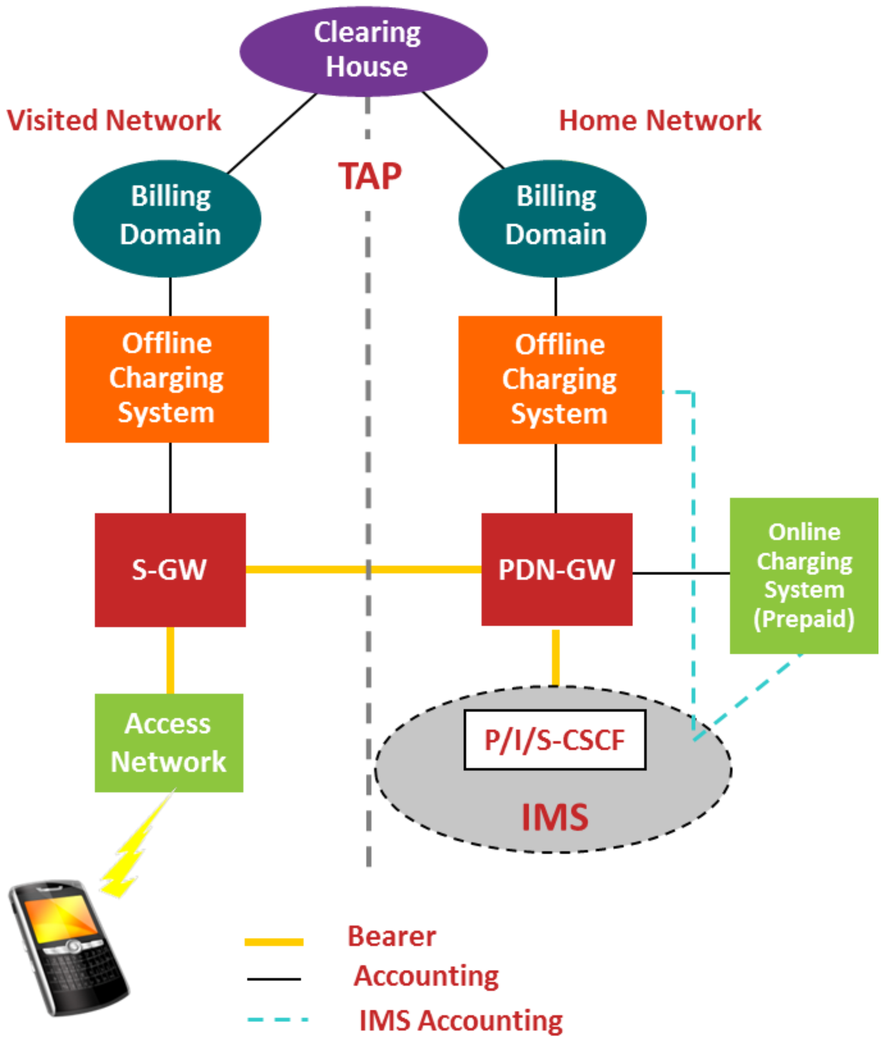


Figure 6-2: Accounting Flows for IMS ((VoLTE and SMSoIP))

Signalling and media is anchored in the home network. No IMS accounting records are available to be sent from the visited network to the home network as no IMS elements are maintained for roaming in the visited network. Records are generated in the home network. The visited network only has visibility into the bearer accounting (i.e., QoS, bearer usage). TAP billing records are sent to the DCH for bearer data usage. There is no change from the GPRS settlement process.

7.3.3. IMS Services Local Breakout (VoLTE/SMSoIP)

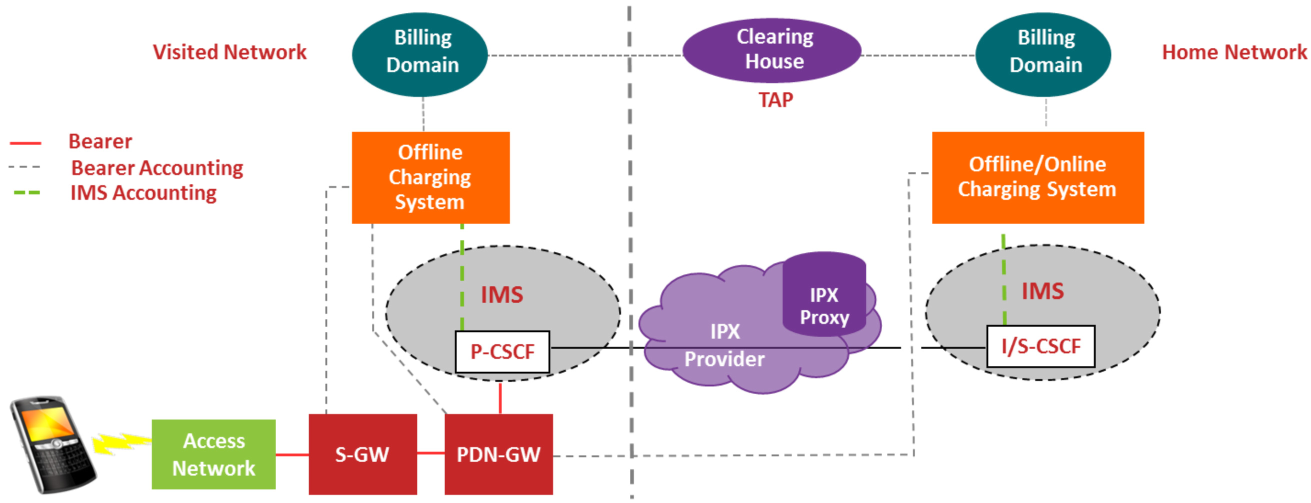


Figure 6-3: Accounting flows for IMS LBO Services (VoLTE/SMSoIP)

Bearer accounting records can optionally be sent from the visited network to the home network. IMS accounting records are generated by the visited P-CSCF and the home S-CSCF. TAP billing records can be sent to the DCH to support legacy settlement and retail billing processes. The IPX provider has access to IMS accounting records

8. LTE Roaming Fraud

GSMA TD.35, the specification for Near Real Time Roaming Data Exchange (NRTRDE) to identify and minimize fraud, was updated to support data over LTE in 2010. Like TAP, only minor, primarily editorial, changes were required to support new network elements (S-GW, P-GW) and new "Cause for termination" values were added. Fraud controls and NRTRDE were defined for CS voice. Although GPRS data exchange is not mandated by the GSMA for NRTRDE, some NRTRDE compliant operators choose to bilaterally agree to include GPRS. These same processes can also be used for data over LTE. The Fraud Forum has chosen not to pursue NRTRDE for VoLTE. The Private User ID is available in the S-CSCF CDRs as well as on the HSS S-CSCF Cx interface. With this information the home operator can determine the IMSI and manage the fraud directly. Additionally, with S8HR VoLTE, the home operator controls the call routing, providing additional controls on fraud.

9. GTI Observations and Conclusions

LTE has become a mature technology that now has a reach extending to 60% of the world's population. Based on an all IP technology, LTE provides a framework for increasing capacity, improving spectrum efficiency, improving cell-edge performance, and reducing latency. All of these advances enable the support of new and advanced services to be delivered.

This white paper provides a business and technical overview of LTE roaming and IMS services for LTE only Mobile Network Operators (MNO). The information contained is intended to support the GTI operator community as they launch LTE networks and advanced services and look to expand their reach through roaming relationships or generate revenue by providing roaming capability onto their network.

Ranging from key LTE roaming fundamentals through architecture, clearing and settlement, this paper outlines many considerations specific for LTE only operators. These operators are frequently new entrants into the Mobile Network Operator (MNO) community and do not operate legacy 3GPP or 3GPP2 networks. The aspects covered are intended to specifically address the needs of these LTE only MNOs as they begin to establish roaming agreements and relationships with other MNOs, both with and without legacy voice and data networks. Given the central role the GSMA has played in International Roaming ecosystem, GSMA standardized requirements and documents were referenced where appropriate for additional guidance to the reader.

APPENDIX A

LTE Roaming Checklist

- ☐ Identify Targeted Roaming Partners
    - o Operators frequently use a standard questionnaire to gather information needed from roaming partner to determine service availability and network compatibility
- ☐ Verify frequency/Device compatibility
- ☐ Prioritize Targeted Roaming Partners
- ☐ Determine method for Interconnection and ensure route
    - o IPX Provider (Need to select and contract)
    - o Direct Interconnection
- ☐ Sign Roaming agreements
- ☐ Negotiate IOT (Typical, but optional)
- ☐ Exchange Operational Data (RAEX OpData)
- ☐ Exchange technical data (RAEX IR.21)
- ☐ Exchange LTE Provisioned USIM cards
- ☐ Exchange LTE devices for testing (To ensure frequency compatibility for CSFB behavior)
- ☐ Complete Datafill as appropriate
- ☐ Open Diameter exchange with your partner
- ☐ Exchange operator specific test scenarios based on services to implement
- ☐ Partner specific Billing system setup
- ☐ Schedule testing
- ☐ Generate TAP files and distribute to partner
- ☐ Verify TAP files against usage recorded
- ☐ Exchange Testing completion letter with partner
- ☐ Sign launch letter and exchange
- ☐ Notify DCH and FCH as appropriate
- ☐ Set up quality monitoring testing
- ☐ Evolve Roaming VAS for LTE support
    - o Steering of Roaming (SoR), Welcome-SMS, VHE, …