Technology Primer on "Understanding the Different Aspects of LTE and Its Impact in Various Areas"

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1. Introduction

Many operators are gearing up to embrace the standardization roadmap defined by 3GPP for the so-called 4G mobile technology to build on the technical foundations of the 3GPP family of cellular systems viz. GSM, GPRS, EDGE, WCDMA and HSPA as well as non-3GPP technologies viz. 1xRTT, EV-DO, 3xRTT. It is imperative that these operators expect the legacy systems, services and applications deployed already to evolve to support the LTE/SAE seamlessly along with the current breed of technologies. Also, as operators start deploying LTE/SAE in a phased manner over several years with different evolution paths, the evolved systems, services and applications will have to also support requirements to facilitate inter-system or intra-system roaming and interworking e.g. GSM->LTE, WCDMA->LTE, EV-DO->LTE, TD-SCDMA->LTE as well as to support the different variants of the technology implementations in the roaming and interworking environment.

The objective of this white-paper is to provide a simplified understanding of the LTE/SAE technology, different architectures, protocols, interfaces involved and to outline the differences from legacy technology environment so as to understand the opportunities and challenges that LTE technology brings to mobile operators and carriers alike.

2. Overview of LTE/SAE

Let us start with an understanding of the basic terminology.

LTE (Long Term Evolution) is the 3GPP quantum leap project to evolve the UMTS technology towards 4G.

SAE (System Architecture Evolution) is the corresponding evolution of the GPRS/3G packet core network evolution.

The key element delivered by LTE/SAE is the EPS (Evolved Packet System) consisting of:

- new air interface E-UTRAN (Evolved UTRAN)
- Evolved Packet Core (EPC) network.

Given that LTE has become the buzzword currently within the mobile industry, it is important to understand what the main drivers behind LTE are:

- Enhanced User Experience
- Simplified Network Architecture (Flat IP-based)
- Efficient Interworking
- Lower Capex and Opex
- High level of Security
- Robust QoS framework
- Common evolution for multiple technologies.

Mobile operators are evolving towards LTE/SAE using different evolution paths:

- 3GPP family: GSM, GPRS, EDGE, WCDMA, HSPA
- Non-3GPP family: 1xRTT, EV-DO, 3xRTT, WLAN, WiMax.

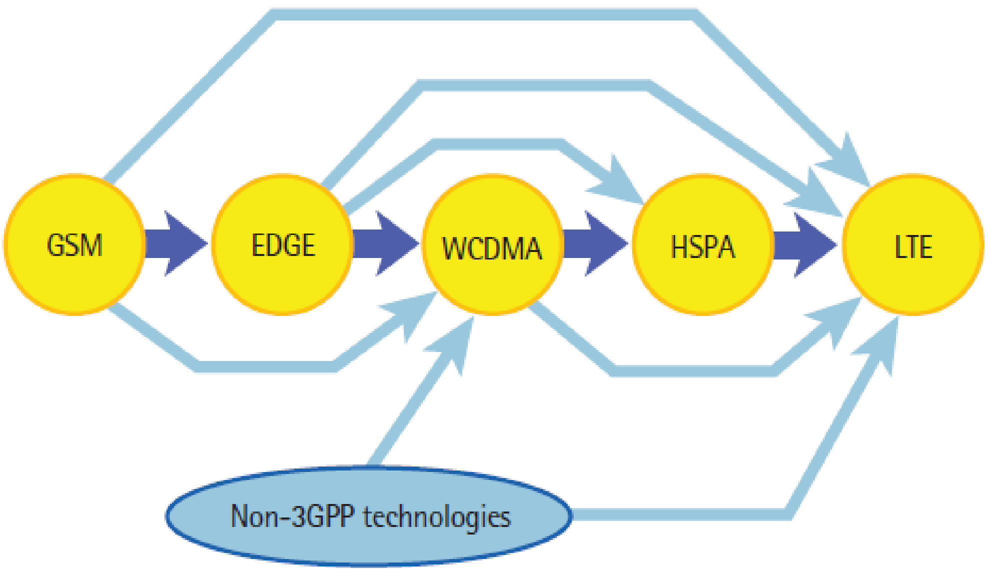


Figure-1: Evolution Paths to LTE/SAE.

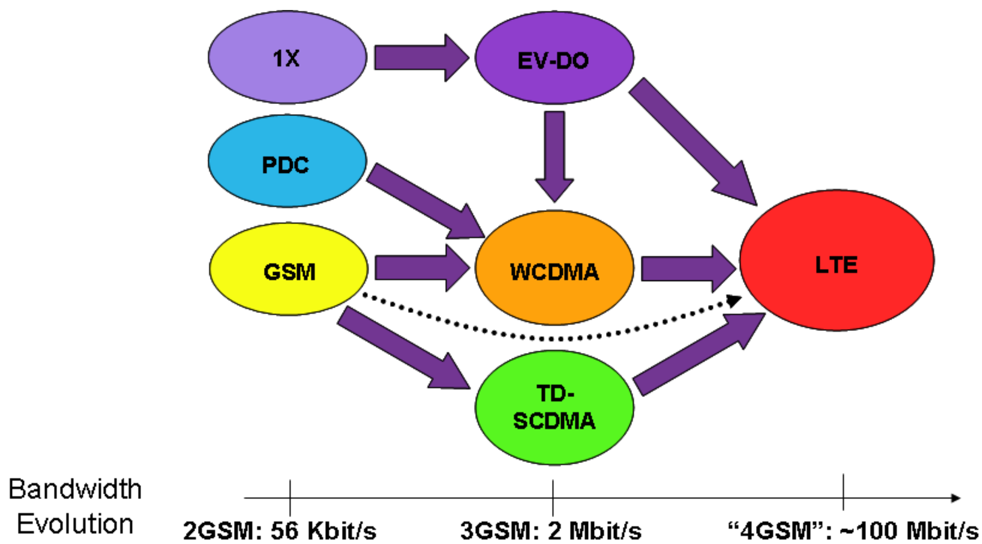


Figure-2: Bandwidth evolution of different generations of technologies.

Underlying characteristics of LTE which would enable the specific needs of the kind of services LTE is expected to bring to the market:

- Real-time, Interactive, Low latency true broadband
- Multi-session Data
- End-to-end QoS/QCI versus only CoS
- Policy control & management

The complexity of LTE can be gauged from the following:

- There are more than 130 3GPP specifications for LTE/SAE
    - 35 specs for Devices, 56 specs for eNodeB, 41 specs for EPC
- LTE/SAE is required to interoperate with 15 different network types
    - 8 Access networks (GSM, EDGE, UMTS, HSPA, HSPA+, CDMA2000, EVDO Rev-A, WiFi)
    - 1 Converged Core network (IMS)
    - 3 CS Core networks (GSM, UMTS, CDMA2000)
    - 3 PS Core networks (UMTS, HSPA+, EVDO Rev-A).

3. LTE Network Architecture

To set the tone for the discussion on LTE network architecture, figure below depicts a comparision between the high-level network architectures for 3G/UMTS and LTE/SAE.

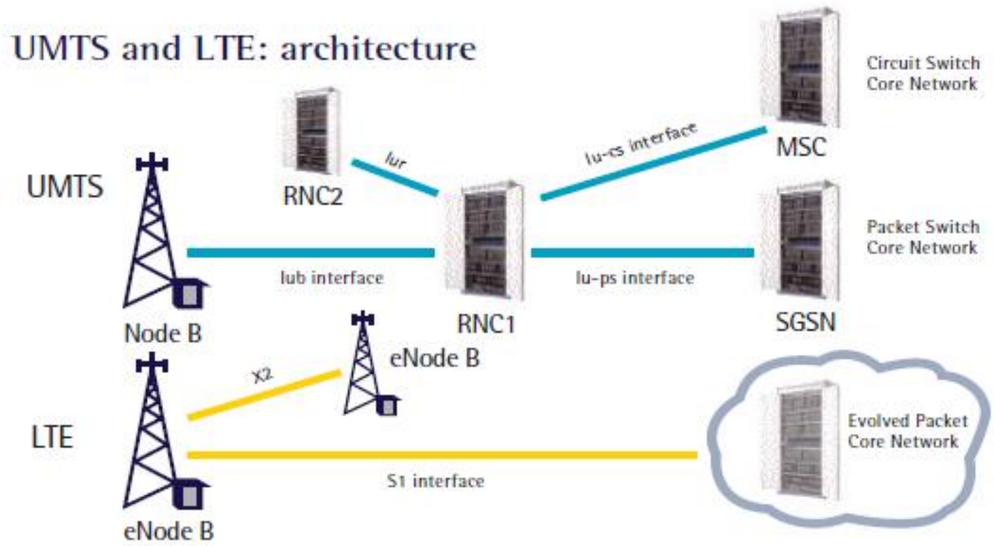


Figure-3: Network Architecture - LTE and UMTS.

It is important to understand first the high-level differences between the legacy 2G/3G Data (Pre-EPS or Pre-3GPP Rel.8) and EPS (3GPP Rel.8) architectures in a very simplified way. Figure-4 below depicts this fundamental difference.

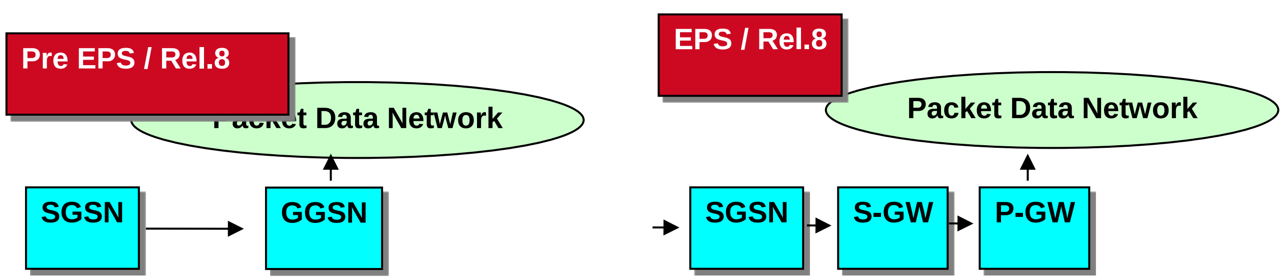


Figure-4: EPS High-level Architecture.

In the EPS 3GPP Rel.8 architecture, the GGSN function is split into 2 separate functions:

- Serving Gateway (S-GW)
- PDN Gateway (P-GW)

The Serving Gateway is a local anchor in the Serving Network (i.e. in the same network as the SGSN).

FBC (Flow Based Charging) functionality is associated with the P-GW.

The PS core network nodes SGSN, S-GW, P-GW generate call records. The S-GW, P-GW call records (for offline charging) closely resemble the GGSN call records.

Figure below depicts the Non-Roaming architecture for LTE for 3GPP accesses.

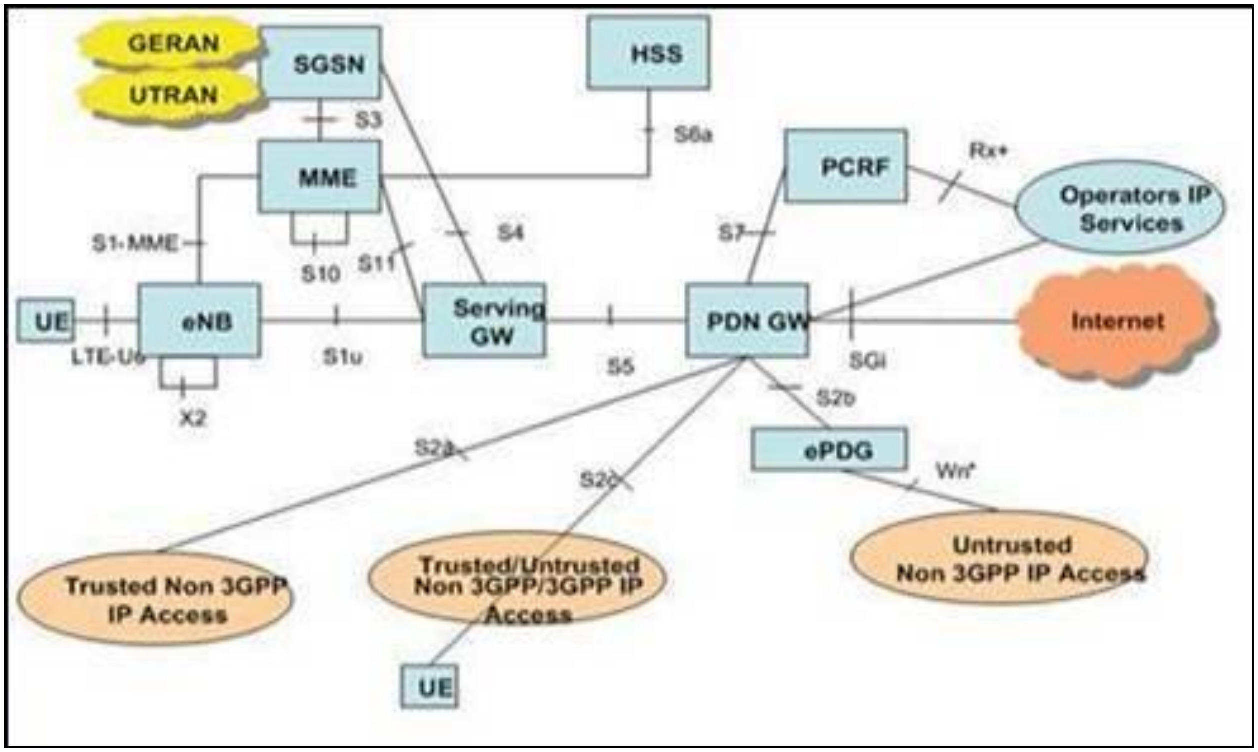


Figure-5: Non-Roaming Network Architecture for LTE for 3GPP accesses.

4. LTE/SAE Network Interfaces

The following is a brief description of the main interfaces or reference points in LTE/SAE architecture:

S1-MME: Reference point for control plane protocol (S1-AP) between E-UTRAN & MME. S1-AP protocol is very similar to RANAP in UTRAN (in fact, it was called E-RANAP earlier).

S1-U: Reference point between E-UTRAN & Serving GW for the per bearer user plane tunnelling and inter-eNodeB path switching during handover. Protocol used is GTP-U.

S3: Reference point between MME and SGSN. It enables user and bearer information exchange for inter 3GPP access network mobility in idle and/or active state. The SGSN might be serving UTRAN, GERAN or both. Protocol used is GTP-C.

S4: It provides related control and mobility support between GPRS Core & 3GPP Anchor function of SGW using GTP-C. In addition, if Direct Tunnel is not established, it provides user plane tunnelling. Also, if a direct S12 tunnel is not established, it also provides user plane tunnelling using GTP-U.

S5: It provides user plane tunneling and tunnel management between SGW & PDN GW. It is used for SGW relocation due to UE mobility and if SGW needs to connect to a non-collocated PDN GW for the required PDN connectivity. Protocol used is both GTP-C and GTP-U.

S6a: It enables transfer of subscription & authentication data for authenticating/authorizing user access to the evolved system between MME & HSS. Protocol used is Diameter (quite different from the tradition Diameter in IETF in the sense that only the protocol header is IP-based whereas the messages and application-layer parameters are 3GPP-specific).

S6b, S6c: It provides external AAA functions for non-3GPP accesses. Protocol used is Diameter.

S6d: It enables transfer of subscription & authentication data for authenticating/authorizing user access to the evolved system between S4-SGSN & HSS. Protocol used is Diameter.

S7: Reference point between PCRF and PDN GW. Protocol used is Diameter.

S8: Inter-PLMN reference point providing user & control plane between SGW in the VPLMN and PDN GW in the HPLMN. S8 is the inter PLMN variant of S5, used for Roaming subscribers only (comparable to the Gp interface in GERAN/GPRS). Protocol used is both GTP-C and GTP-U.

S9: It provides transfer of (QoS) policy and charging control information between the Home PCRF and the Visited PCRF in order to support local breakout function. It is used for Roaming subscribers only. Protocol used is Diameter.

S10: Reference point between MMEs for MME relocation and MME to MME information transfer. It provides mobility functions for Intra-E-UTRAN handover/relocation.

S11: Reference point between MME and SGW. Protocol used is both GTP-C and GTP-U. It should be noted that this interface is optional, since MME and SGW may be combined into one entity.

S12: Reference point between UTRAN/RNC & SGW for user plane tunneling when Direct Tunnel is established; based on the Iu-u/Gn-u reference point using GTP-U protocol as defined between SGSN & UTRAN or respectively between SGSN & GGSN. Usage of S12 is an operator configuration option.

S13: Reference point between MME and EIR. Protocol used is Diameter.

S13': Reference point between SGSN and EIR. Protocol used is Diameter.

Gx: It provides transfer of (QoS) policy and charging rules from PCRF to PCEF in the PDN GW. Protocol used is Diameter.

Gxc: It provides transfer of (QoS) policy and charging rules from PCRF to SGW. Protocol used is Diameter.

Gy: Reference point between PCEF and OCS. Protocol used is Diameter.

Rx: Reference point between AF and PCRF. Protocol used is Diameter.

5. Main Protocols used in LTE/SAE

5.1 Diameter

Today GSM/GPRS/EDGE/UMTS networks use the SS7-MAP (Mobile Application Protocol) protocol for location management, subscriber management, access management, handover services, authentication management, security management, identity management services. However, in LTE/SAE (3GPP Rel. 8), Diameter protocol has been chosen for many of these procedures and is increasingly used for inter-operator signaling network and roaming infrastructure.

The LTE interfaces based on Diameter can be divided into 2 main categories:

- Packet Core related interfaces towards HSS & EIR
  - S6a (MME to HSS) and S6d (SGSN to HSS)
  - S6b, S6c (external AAA functions for non-3GPP accesses)
  - S13 (MME to EIR) and S13' (SGSN to EIR)
- Network signaling for Policy Control & Charging
  - S9 (H-PCRF to V-PCRF)
  - S7 (PCRF to P-GW)
  - Gx (PCRF to PCEF)
  - Gxc (PCRF to S-GW)
  - Rx (AF to PCRF)
  - Gy (PCEF to OCS).

In LTE environment, registration messages received would be based on Diameter (rather than SS7-MAP).

Diameter Base Protocol is defined within IETF RFC 3588 (published in September 2003). Based on Diameter Base Protocol, IETF also defines many Diameter applications to support more specific requirements in different scenarios, e.g. NASREQ, Diameter Credit Control, etc. Diameter has also been used widely in 3GPP systems, e.g. IMS, GBA, Interworking WLAN, Charging systems, PCC, etc. In addition, 3GPP has also defined some specific Diameter applications. The Diameter applications are identified with the application identifier, transferred in Diameter command's header in the Application-ID field. The 3GPP specific application identifiers allocated by IANA are listed in the following table.

Application identifier	Application	3GPP TS
16777216	3GPP Cx/Px	29.228 and 29.229
16777217	3GPP Sh/Ph	29.328 and 29.329
16777218	3GPP Re	32.296
16777219	3GPP Wx	29.234
16777220	3GPP Zn	29.109
16777221	3GPP Zh	29.109
16777222	3GPP Gq	29.209
16777223	3GPP Gmb	29.061
16777224	3GPP Gx	29.210
16777225	3GPP Gx over Gy	29.210
16777226	3GPP MM10	29.140
16777229	3GPP Rx	29.211
16777230	3GPP Pr	29.234
16777236	3GPP Rx	29.214
16777238	3GPP Gx	29.212
16777250	3GPP STa	29.273
16777251	3GPP S6a/S6d	29.272
16777252	3GPP S13/S13’	29.272
16777264	3GPP SWm	29.273
16777265	3GPP SWx	29.273
16777266	3GPP Gxx	29.212
16777267	3GPP S9	29.215
16777268	3GPP Zpn	29.109
16777272	3GPP S6b	29.273

Table: 3GPP specific application identifiers.

The command codes are used for communicating the command associated with the Diameter message. The command code is carried in the Diameter header's Command-Code field. IANA has allocated a standard command code range 300 - 313 for 3GPP. The command codes are presented in the following table.

Command code	Command name	Abbreviation	Specified in 3GPP TS
300	User-Authorization-Request/-Answer	UAR/UAA	29.229
301	Server-Assignment-Request/-Answer	SAR/SAA	
302	Location-Info-Request/-Answer	LIR/LIA	
303	Multimedia-Auth-Request/-Answer	MAR/MAA	
304	Registration-Termination-Request/-Answer	RTR/RTA	
305	Push-Profile-Request/-Answer	PPR/PPA	
306	User-Data-Request/-Answer	UDR/UDA	29.329
307	Profile-Update-Request/-Answer	PUR/PUA	
308	Subscribe-Notifications-Request/-Answer	SNR/SNA	
309	Push-Notification-Request/-Answer	PNR/PNA	
310	Boostrapping-Info-Request/Answer	BIR/BIA	29.109
311	Message-Process-Request/Answer	MPR/MPA	29.140
312	GBAPush-Info-Request/Answer	GPR/GPI	29.109
313			

Table: Command codes allocated for 3GPP.

IANA has allocated the following command code values for the S6a/S6d interface application and S13/S13' interface application.

316	Update-Location-Request/Answer	ULR/ULA	29.272
317	Cancel-Location-Request/Answer	CLR/CLA	
318	Authentication- Information - Request/Answer	AIR/AIA	
319	Insert Subscriber Data-Request/Answer	IDR/IDA	
320	Delete-Subscriber-Data-Request/Answer	DSR/DSA	
321	Purge-UE-Request/Answer	PUR/PUA	
322	Reset-Request/Answer	RSR/RSA	
323	Notify-Request/Answer	NOR/NOA	
324	ME-Identity-Check-Request/Answer	ECR/ECA	

Table: SAE-related Command codes allocated for 3GPP.

The vendor identifier (also known as Enterprise number) indicates the vendor specific attributes, result codes and application identifiers in Diameter commands. The vendor identifier is used in the Vendor-ID field of the AVP header and in the Vendor-Id AVP. The Vendor-Id AVP is used to identify the vendor in the Vendor-Specific-Application-Id. IANA has allocated a vendor identifier value 10415 for 3GPP.

3GPP TS 29.305 defines an Interworking Function to translate between MAP and Diameter (message and parameter mapping).

MAP Message	Diameter Commands
SendAuthenticationInfo	AIR/AIA
UpdateGprsLocation	ULR/ULA
CancelLocation	CLR/CLA
PurgeMS	PUR/PUA
InsertSubscriberData	IDR/IDA
DeleteSubscriberData	DSR/DSA
Reset	RSR/RSA
UpdateGprsLocationInfo	NOR/NOA
ActivateTraceMode	IDR/IDA
DeactivateTraceMode	DSR/DSA

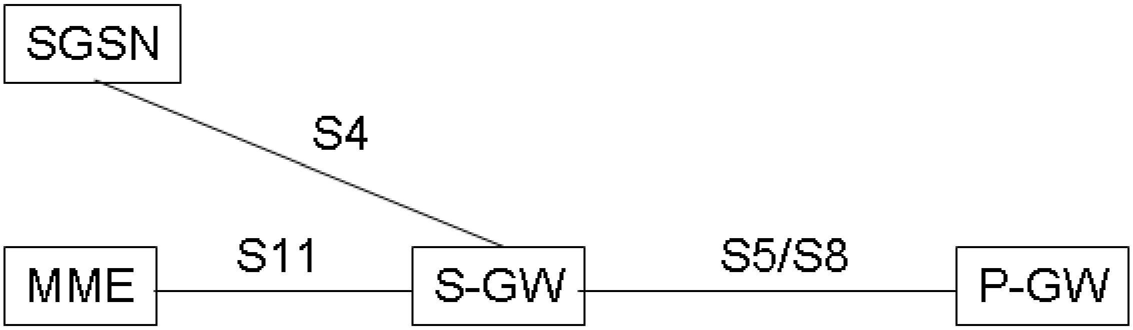
Table: Mapping between GSM-MAP Messages and Diameter Command codes.

5.2 GTP

GTPv0 was defined in 3GPP Rel-97, to provide for GPRS connectivity in 2G systems, but can also be used in 3G systems in the “drop-back” scenario. GTPv1 was defined in 3GPP Rel-99, to provide for PS connectivity in 3G systems, as well as continuing support for 2G systems. GTPv2 has been defined in 3GPP Rel-8, to provide for LTE, which is a PS only access technology. Support for 3G and 2G systems is also provided. Thus, all versions of GTP can provide for 2G and 3G accesses, however, GTPv2 is needed to support LTE.

GTPv2 is used in LTE on the following interfaces for PS roaming:

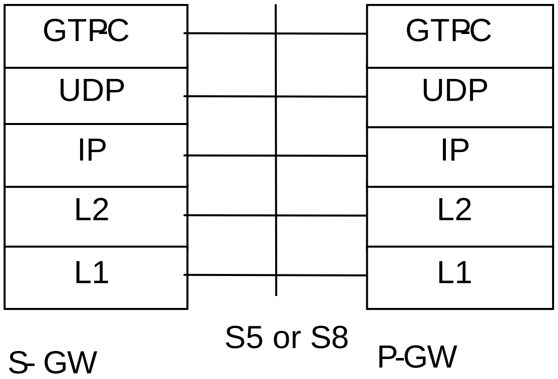
- S4
- S11
- S5/S8 (S5 is intra-operator, S8 is inter-operator, in the same vein as Gn/Gp).



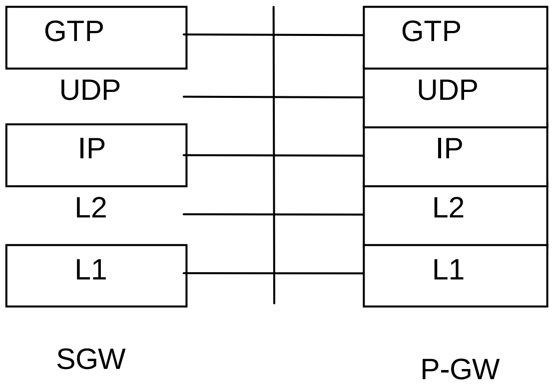
GTPv2 is also used on the S3, S10, S16, Sv and S101 interfaces, however, these are intra-network only and used for services other than roaming.

In establishing a PDP Context in EPS, the mechanism is similar to the procedure in 2G/3G. However, the EPS procedure needs to create and maintain a GTP connection between 3 nodes now (MME, S-GW and P-GW) rather than 2 (SGSN and GGSN).

Both GTP-C and GTP-U are carried over UDP over IP (v4 or v6). GTP-U tunnel is per PDN per QoS per User (i.e. per bearer). Figure below depicts the CP and UP protocol structure for GTP.



GTP Control Plane



GTP User Plane

The GTP tunnel is identified in each node with a TEID, an IP address and a UDP port number. For the control plane, for each end-point of a GTP-C tunnel, The TEID-C shall be unique per PDN-Connection on GTP based S5 and S8 interfaces. The same tunnel shall be shared for the control messages related to all bearers associated to the PDN-Connection. A TEID-C on the S5/S8 interface shall be released after all its associated EPS bearers are deleted.

The following 3GPP specifications are relevant for GTP:

- 3GPP TS 23.401 (stage 2 for GTPv2 as used in LTE)
- 3GPP TS 23.060 (stage 2 for GTPv2 as used in 2G/3G)
- 3GPP TS 29.274 (stage 3 for GTPv2 as used on the CP in LTE)
- 3GPP TS 29.281 (stage 3 for GTPv1 as used on the UP in LTE)

5.2.1 Differences between GTP-v1 and GTP-v2

The following are the main differences between GTP-v1 and GTP-v2:

- GTPv2 enhances the Control Plane only. GTPv1 is still used on the User Plane. GTPv1 has been kept on the UP to avoid impacting RNCs with LTE enhancements, and generally because there was no actual reason to “upgrade” it. Thus, CP header has its version field set to v2, but UP header still has its version field set to v1.

- GTPv2 uses the same transport protocol (UDP) and port numbers (2123 for CP, 2152 for UP) as GTPv1 for both CP and UP.

- GTPv2 reuses the original Control Plane protocol structure of messages and IEs.

- Main design improvement of GTPv2 is that it reduces CP signaling by:

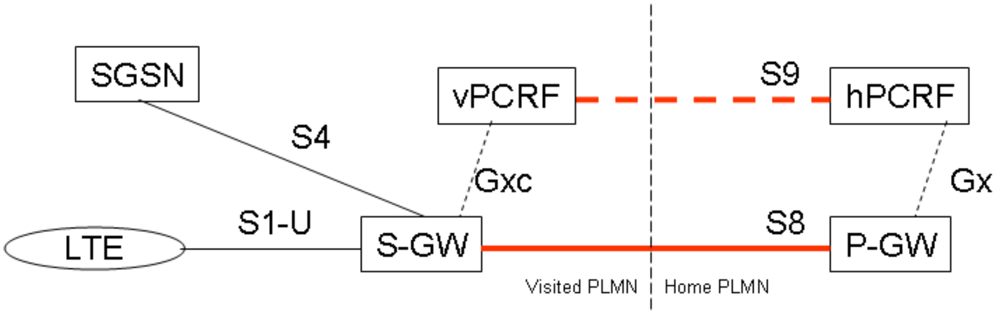
- requiring only one CP association for each PDN connection (so now only one CP association for the primary and any/all secondary PDP Contexts)
- Handovers now require only one message for all PDP Contexts (both Primary and Secondary)
- Multiple CP messages can be “piggy-backed” in the same UDP datagram
- TEID field is now optional in the header (not needed for messages such as GTP Echo Req/Res, and GTP Version Not Supported)

- GTPv2 IEs all use a TLIV encoding. TLIV= Type, Length, Instance, Value
  - Instance is a new concept, that conveys when a particular type is reused (this is similar to defining an ASN.1 type, and then reusing instances of it in one or more messages)
  - Having all IEs containing a length field avoids the issue introduced in late GTPv0 and early GTPv1 when the RAI IE was added
- Support for PPP bearers is removed. Only IPv4, IPv6 and IPv4/IPv6 are supported
- Drop-back to GTPv1 is supported, but drop-back to GTPv0 is not. It should also be noted that in 3GPP Rel.8, GTPv1 is updated also to remove drop back to GTPv0
- QoS is no longer renegotiated in Handovers
  - If current QoS not supported in new MME, the connection is dropped and is rebuilt
  - This means that the QoS IE in MM messages is no longer always available
- GTP’ (charging protocol) is not carried forward into GTPv2. Thus, a GTPv2 CP header does not contain the Protocol Type (PT) bit
- APN FQDN may contain sub-domains in order to discover either an S-GW (at the MME) or P-GW (at the MME or S-GW)
- Load balancing is now aligned with GSMA PRD IR.34, Annex A.1. That is, the node to which a PDP Context establishment was sent to, must respond, and not another node.

5.3 PMIP

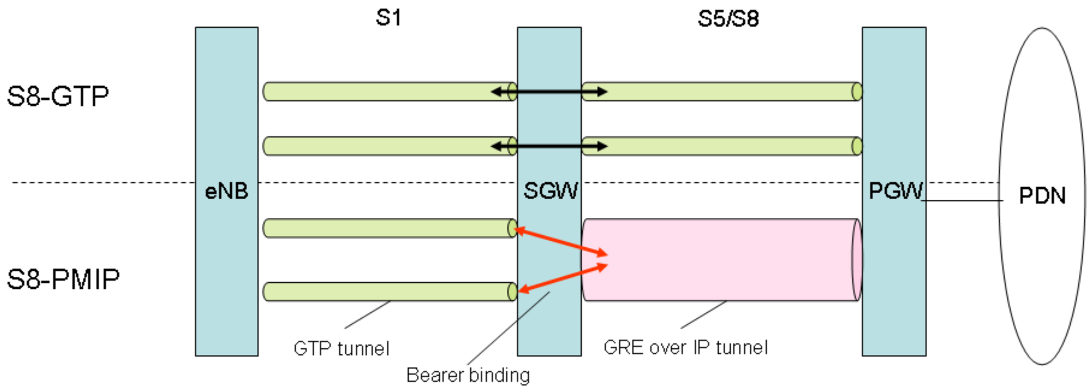
PMIP is an IETF protocol based on IP which provides same capabilities as GTP, but in a different way. PMIP is access technology independent. PMIP provides a single protocol for network-based mobility management to connect any kind of access technology to EPC i.e. 3GPP accesses (e.g. GERAN, UTRAN, E-UTRAN) and Non-3GPP accesses (e.g. 802.11, 802.16, cdma2000). PMIP therefore provides a simpler core for NW-based mobility management and possibly reduced CAPEX/OPEX.

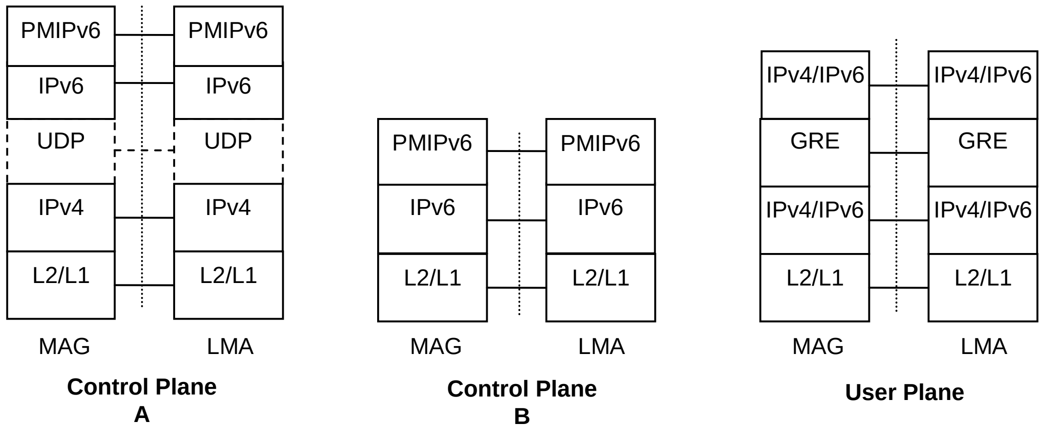
PMIP is a protocol to create connectivity between LMA (Local Mobility Anchor, equivalent to PGW) and MAG (Mobility Access Gateway, equivalent to SGW). PMIP exchanges GRE keys to establish a GRE tunnel. Note that Gxc is used only in case of PMIP-based S5/S8.



When PMIP-based EPC is used, the inter-operator interface will be S8 (PMIP) and S9 (PCC – Diameter). Policy and Charging Control (PCC) can be used if S8-PMIP is used. PCC allows EPC to provide more sophisticated QoS / Charging control. If PCC is not used, then PMIP provides no QoS and no S1 (or S4) bearer binding. Security requirements for PMIP are same as those of GTP.

PMIP has no notion of Bearer (unlike GTP). SGW or PGW determines the path based on the user’s IP address/prefix. SGW aggregates all S1 bearers’ packets into a single PDN connection. SGW performs S1 bearer binding via PCRF signaling. PDN connection data is encapsulated in a GRE over IP tunnel. Bearer QoS is provided via DiffServ marking (requires PCC).





The Control Plane A is for PMIPv6 signals transported over IPv4, and the Control Plane B is for PMIPv6 signals transported over IPv6. When IPv4 transport is used, UDP encapsulation may be used as described in IETF RFC 5844.

The main PMIP messages are:

- Proxy Binding Update (PBU)
- Proxy Binding Acknowledgement (PBA)
- Binding Revocation Indication (BRI)
- Binding Revocation Acknowledgement (BRA)
- Heartbeat Request
- Heartbeat Response.

The following 3GPP/IETF specifications are relevant for PMIP:

- 3GPP TS 23.402 (EPC stage 2)
- 3GPP TS 29.275 (stage 3 for PMIP)
- 3GPP TS 29.215 (stage 3 for PCC)
- IETF RFC 5213 (PMIPv6)
- IETF RFC 2784 (GRE).

6. LTE/SAE Impact in the area of Roaming

Roaming is one domain which is most significantly impacted by the introduction of LTE/SAE. And this impact is in several functional areas and poses various challenges which should be carefully addressed by mobile operators and carriers.

6.1 Home Routing Roaming Scenario

To begin with, it is helpful to understand as to which network elements are located in the Visited network versus Home network in the Home Routing option of roaming. Figure below depicts this, also with an analogy to the legacy 2G/3G Data network.

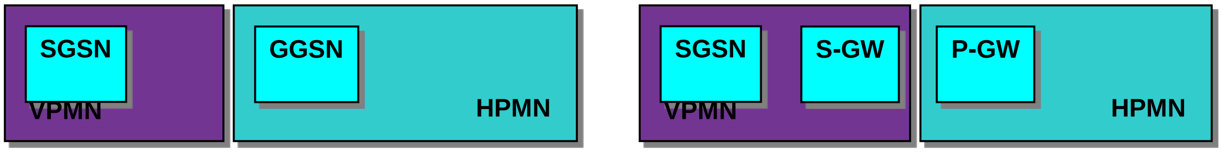


Figure-6: Location of Network Elements in the Home-Routing roaming scenario.

In the case of Home Routing, a P-GW of the Home Network is used (similar to the GGSN in the pre-EPS architecture). As there are 2 network nodes in the VPLMN (SGSN and S-GW) there are 2 possible sources for creation of TAP records in case of Home routing scenario.

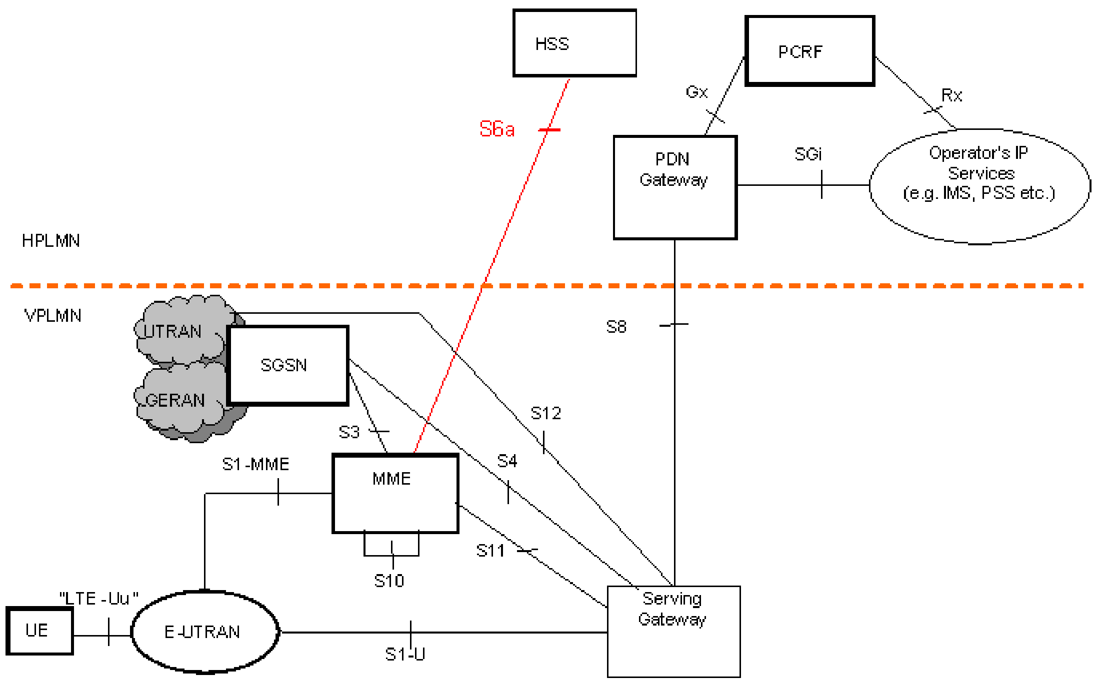


Figure-7: 3GPP LTE Roaming Architecture: Home-routed traffic using GTP based S8.

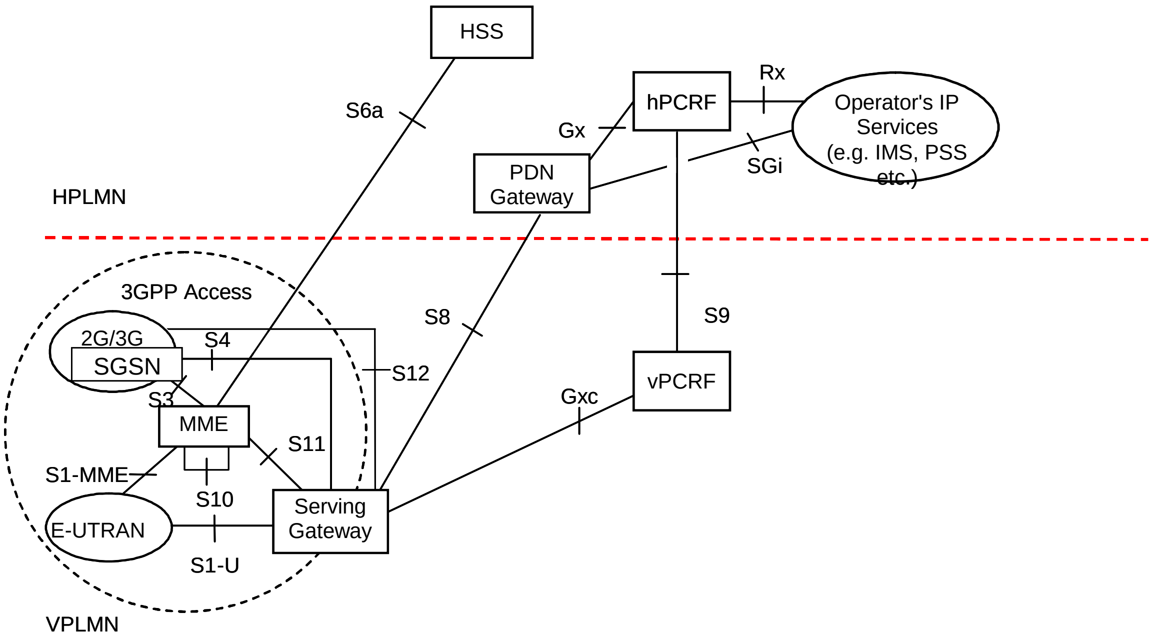


Figure-8: 3GPP LTE Roaming Architecture: Home-routed traffic using PMIP based S8.

6.2 Local Breakout Roaming Scenario

The main drivers behind the Local Breakout option in roaming are:

- Latency reduction for conversational communication within VPLMN country
- Access to local services.

To begin with, it is helpful to understand as to which network elements are located in the Visited network versus Home network in the Local Breakout option of roaming. Figure below depicts this, also with an analogy to the legacy 2G/3G Data network.

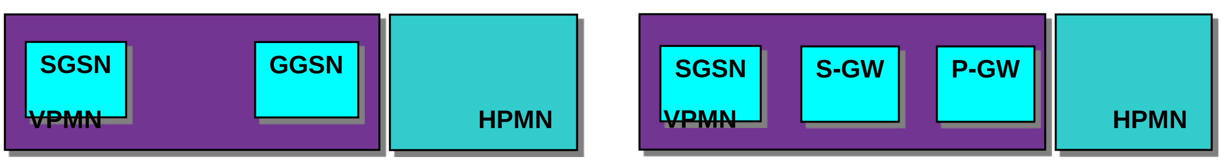


Figure-9: Location of Network Elements in the Local Breakout roaming scenario.

In the case of Local Breakout, a P-GW of the Visited Network is used (similar to the GGSN in the pre-EPS architecture). As there are 3 network nodes in the VPLMN (SGSN, S-GW and P-GW), there are 3 possible sources for creation of TAP records in case of Local Breakout scenario.

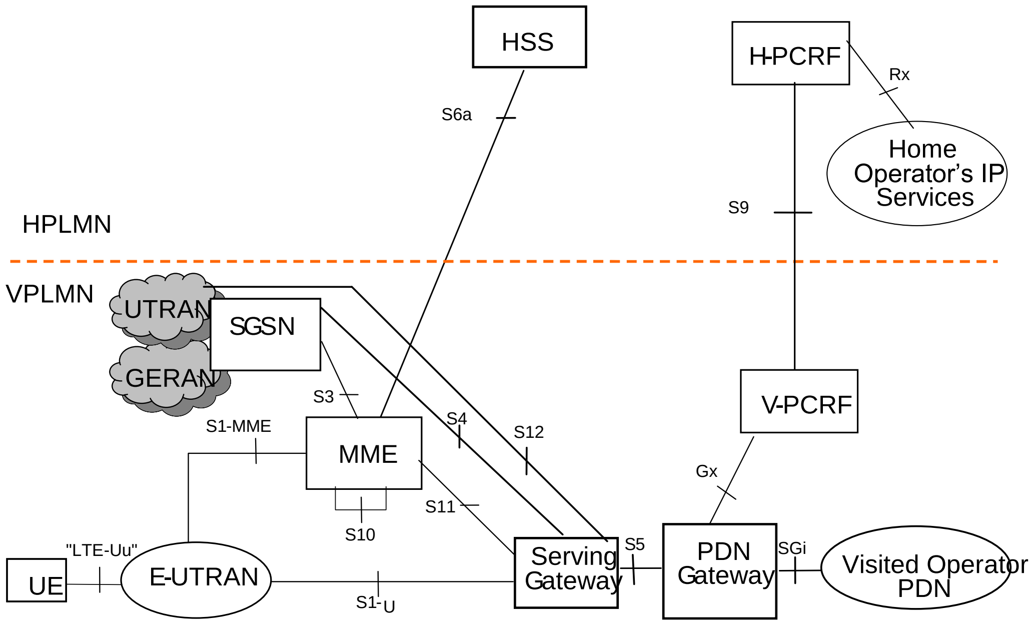


Figure-10: 3GPP LTE Roaming Architecture: Local Breakout using HPMN operator functions.

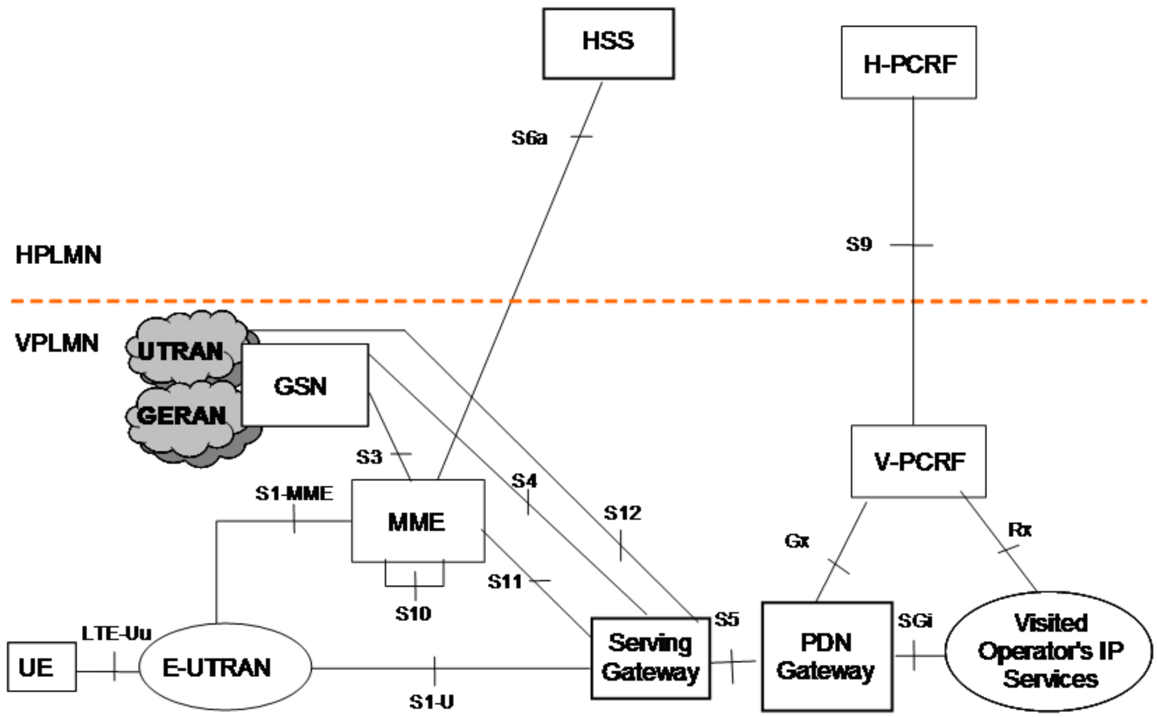


Figure-11: 3GPP LTE Roaming Architecture: Local Breakout using VPMN operator functions.

7. LTE/SAE Impact in the area of Network Interworking

Currently mobile operators use the GRX (GPRS Roaming eXchange) for GPRS, EDGE, 3G, HSPA data roaming and MMS interworking. However, there are several shortcomings or deficiencies in such use of GRX:

- GRX offers no inherent support for LTE or IMS
- GRX is only specified for use by GSM-based mobile network operators whereas LTE will also be embraced by legacy CDMA-based mobile operators
- GRX does not offer required support for a comprehensive QoS framework for LTE.

In order to overcome such limitations, mobile operators can either deploy the appropriate connectivity e.g. private leased lines, which provides the requisite capabilities or use the IPX (IP Packet eXchange) as the inter-operator backbone connectivity. GSMA recommends the use of IPX as the NNI for LTE. IPX is developed by the GSMA to foster open standardized IP connectivity for multiple types of service providers.

- IPX provides for end-to-end QoS in support of both roaming and interworking for LTE and IMS
- IPX is fully backward compatible with legacy GRX networks
- IPX can be used by MNOs, FNOs, ISPs and ASPs.

The IPX supports 3 different types of connectivity options:

- Transport only mode: A bilateral agreement between two Service Providers using the IPX as a transport layer with guaranteed QoS end-to-end. Similar to the GRX without service awareness
- Bilateral Service Transit mode: A bilateral agreement between two Service Providers using the IPX Proxy functions and the IPX transport layer with guaranteed QoS end-to-end. This model provides the opportunity to include service-based interconnect charging in addition to the transport charging of the transport-only model
- Multilateral Service Hubbing mode: A bilateral agreement between two Service Providers using the IPX Proxy functions and the IPX transport layer with guaranteed QoS end-to-end. This model provides the opportunity to include service-based interconnect charging in addition to the transport charging of the transport-only model.

8. LTE/SAE Impact in the area of Wholesale Charging

The GSMA Transferred Account Data Interchange Group (TADIG) has reviewed the impact on wholesale clearing and settlement processes and TAP record specification. Given the possibility to use call records from SGSN & SGW for home-routed access and additionally from PGW for local-breakout, GSMA TADIG is currently planning to add new Recording Entity Type Codes for the SGW and PGW network elements to TAP record specification in May 2010 timeframe (TBC). In addition, the full TAP support for LTE/IMS roaming is currently being evaluated by GSMA working groups.

9. LTE/SAE Impact in the area of Retail Billing processes

Today in the 2G/3G Data roaming environment, mobile operators can choose to use either the TAP records from visited network or the G-CDRs from the home GGSNs to enable retail billing for their subscribers. However, if local breakout option is used in LTE roaming, then CDRs will not be generated by PDN-GWs in the home network which may cause operators to move to retail billing based on visited network TAP records only as the home network does not have any visibility into the local breakout routed traffic. The home network billing systems and associated processes for retail billing may therefore need to be adapted where necessary.

10. LTE/SAE Impact in the area of Messaging

There are differences between how Messaging is handled today in 2G/3G environment and how it will be handled in LTE environment. SMS is fully supported in LTE based on SMS over IP (3GPP Rel.7) using IMS capabilities, basically through the use of IP-SM-GW and ISC, J, Sh interfaces as depicted in figure below.

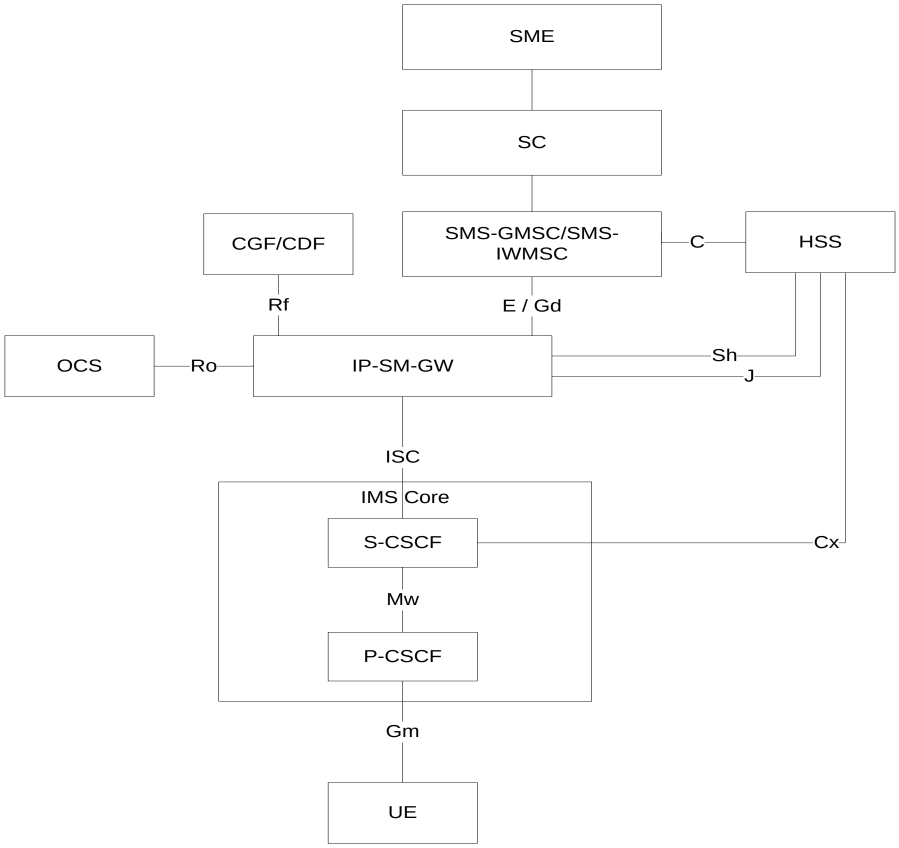


Figure-12: SMS over Generic 3GPP IP access (3GPP TS 23.204).

For Non-IMS environments, 3GPP has defined SMS over SGs (3GPP Rel.8) as the transition solution for support of SMS in LTE, basically using PS capabilities whereby the UE UE remains connected to EPS in LTE and SGs interface between the MSC and MME is used. SGs interface is extension of legacy Gs interface between MSC & SGSN such that MME in LTE environment behaves as SGSN towards external MSC. In case of MT-SMS, SMS is forwarded from SMSC to MSC and then by MSC to MME via SGs interface. The MME then relays the SMS to recipient UE using RRC signaling over LTE radio network. In case of MO-SMS, UE sends the SMS over the LTE radio network using RRC signaling to MME and the MME then relays the SMS to MSC via SGs interface for delivery to SMSC. Alternatively, CS Fallback mode may be used whereby the UE falls back to legacy network i.e. does not remain in LTE.

11. LTE/SAE Impact in the area of Value-Added Services (VAS)

As GSM-based (as well as CDMA-based) technologies have been deployed and matured over decades, mobile operators have developed a comprehensive eco-system of Value-Added Services around the core services of Voice, SMS and Data. Some of these VAS are as follows:

- Steering of Roaming
- Welcome SMS
- VHE (Virtual Home Environment) services

Given that most of these VAS have been designed, developed and deployed based on the SS7 protocols, there is a big paradigm shift with the advent of LTE/SAE which is a fully IP-based environment. Therefore, the introduction of LTE/SAE may have a significant impact in the VAS area.

11.1 Steering of Roaming in LTE

Steering of Roaming is very common today and is widely used by mobile operators. Home operators use SoR to steer their outbound roamers away from specific VPMNs and onto preferred VPMNs for one or more reasons:

- The idea is to reduce roaming costs by achieving higher discounts with preferred networks through the use of traffic thresholds
- Home operators are able to offer special retails tariffs to subscribers for roaming with preferred networks
- Home operators are able to offer better Roaming QoS to subscribers for roaming with preferred networks
- Home operators are able to manage the roaming traffic distribution better
- SoR is also used by Group operators to keep roaming traffic (and revenues) within the Group/Alliance

GSMA has ratified the use of SoR (Binding PRD BA.30 and Non-binding PRD IR.73).

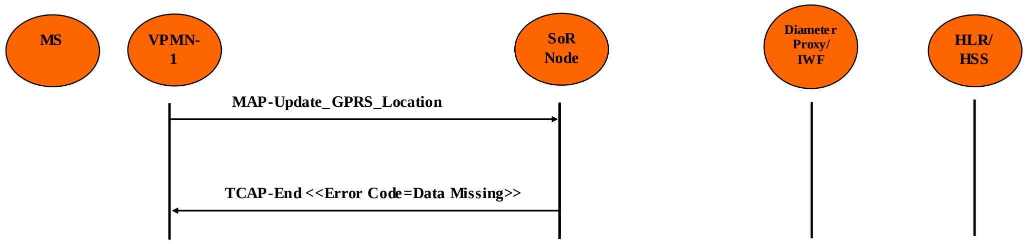
11.1.1 Methods used for Steering of Roaming

There are 2 main categories of methods used for Steering of Roaming:

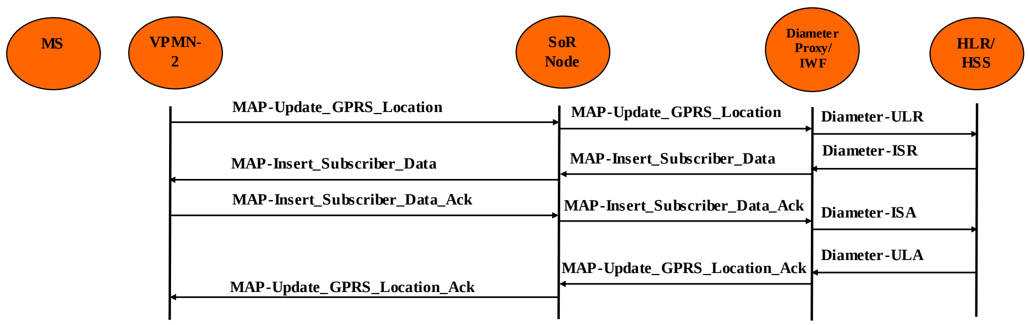
- SS7 based methods: Basically these are Network based mechanisms, whereby the SoR application intercepts the SS7-MAP messages to allow/deny registrations and uses generic MAP error codes for denying LU (only MAP layer is used - SCCP layer is not allowed to be used).

- OTA SIM based methods: Basically these are dynamic PLMN-list based mechanism (i.e. not network based), whereby the SoR application distributes Preferred PLMN list via OTA based on HPMN preferences and the OTA updates trigger Refresh STK.

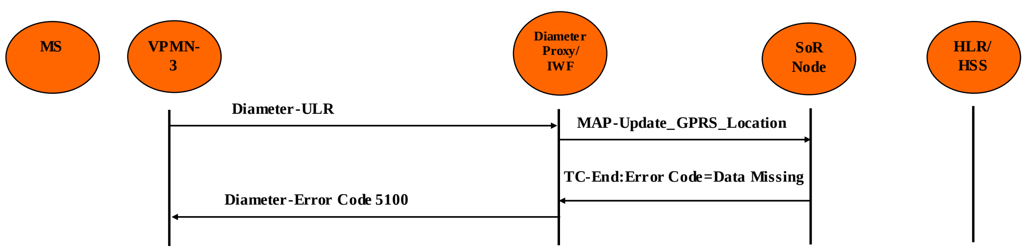
Case-1: VPMN-1 (2G/3G) Not Allowed



Case-2: VPMN-2 (2G/3G) Allowed



Case-3: VPMN-3 (LTE) Not Allowed



Case-4: VPMN-4 (LTE) Allowed

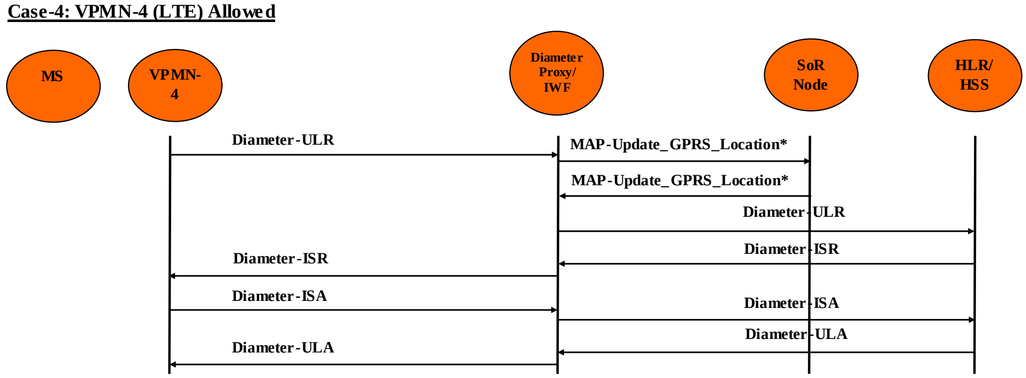


Figure-13: Flow diagrams for Steering of Roaming in LTE/SAE.

12. LTE/SAE Impact in the area of Business Intelligence Services

Most of the Business Intelligence services used in the current mobile environment are designed on the basis of SS7-based signaling paradigm. However, in LTE environment, new protocols are used e.g. Diameter, GTP-C V2 and SIP. This implies that the business intelligence solutions would have to be revisited to support these new protocols and leverage the attributes and functionality available therein.

13. LTE/SAE Impact in the area of Roaming Hub Services

GSMA PRD IR.80 defines the Technical architecture alternatives for the Roaming Hub model, wherein 4 architecture methods are specified for Operator to Roaming Hub connectivity and 2 of these architecture methods are also applicable to the Roaming Hub to Roaming Hub connectivity. However, due to the use of S6a Diameter-based signaling in LTE networks, these existing architecture methods are not able to support LTE in the Roaming Hub model. Therefore, the author has defined a new architecture method called “Diameter Routing” which will be applicable to both inter-Operator and inter-Hub interfaces. Author has presented the proposal to GSMA IREG WG for consideration to revise IR.80 accordingly. This technical architecture method proposed introduces a Diameter based Proxy service, to facilitate mobility management, subscriber profile management and authentication management procedures. This Diameter Proxy support is required for mainly the MME to HSS (S6a) as well as the SGSN to HSS (S6d) interfaces traversing through the Roaming Hub.

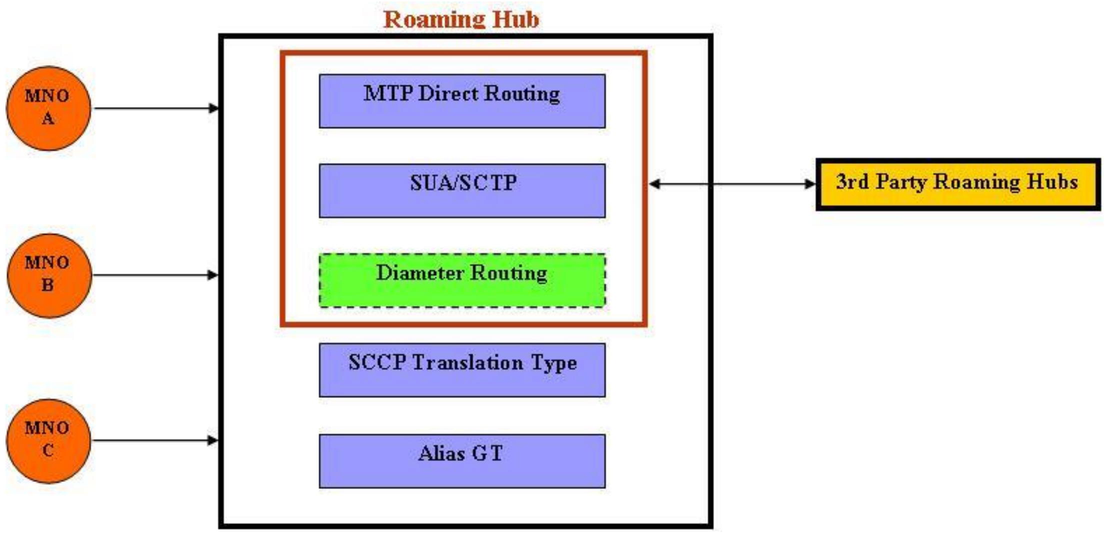


Figure-14: 'Evolved' Roaming Hub Signaling Architecture Overview.

14. Conclusions

With LTE becoming the de-facto standard for evolution of mobile operators from different streams and given the pace of its adoption globally, it becomes quite critical that operators fully understand and evaluate all the aspects of this exciting new technology so as to leverage its potential as well as to mitigate any risks in their evolution strategy and address the impacts in various areas of the ecosystem.

About the Author

Pradeep Bhardwaj is currently Technology Director – R&D at Syniverse Technologies, based in the United Kingdom and is a senior technology advisor providing consulting and direction on the subjects of emerging technologies and trends including all LTE matters within the organization and for its clients. Until recently, he was also the Chairman of the GSMA Hubbing Provider Interworking Group (HPIG) from beginning to end. He is a recognized industry expert with over 20 years of experience with mobile operators and telcos in the areas of 2G/3G, LTE, IMS, International Roaming, Satellite & Data communications. He can be reached at Pradeep.bhardwaj@syniverse.com.