# Voice over IP over LTE (VoLTE)
# Impacts on LTE access

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## 1 Introduction

IMS (IP Multimedia Subsystems) has been around for some time, and many infrastructure vendors have invested heavily in developing IMS capabilities, solutions and products. But market acceptance has been slower than expected. Now, with LTE (Long Term Evolution) taking shape, the IMS platform has been given a new role and a niche that will carry it a considerable distance into the future : VoLTE (Voice over LTE) as specified in Recommendation IR.92 of GSMA. The goal of VoLTE is to emulate the services of the current circuit switched domain called R4, using the IMS architecture. These services include telephony, videotelephony, all the telephony supplementary services, SMS, USSD services and CAMEL services. Another important service is SR-VCC (Single Radio Voice Call continuity) which provides the ability to transition a voice call from the VoIP/IMS packet domain to the legacy circuit switched domain during handover from LTE to 3G/2G. The goal of this tutorial is to present IMS with EPS (Evolved Packet System) as the broadband access network. EPS consists of an IP-based access called LTE (Long Term Evolution of 3G) and a packet core network called ePC (Evolved Packet Core). EPS is a broadband access network connected to the IP world (Internet / Intranet).
This tutorial emphasizes the impacts of IMS over the EPS access network.

## 2 EPS/IMS Architecture

LTE provides IP based access with a very high bitrate. Evolved packet core (EPC) is an all IP core network architecture through which LTE and other 3GPP and non-3GPP access networks connects. EPC also fulfills the requirements for security, QoS, Mobility and connection to IP based services, i.e., IMS.
The term Evolved Packet System (EPS) is also used and just refers to the LTE access network and EPC together.
The LTE consists of eNodeBs which represent high-capacity base stations for LTE radio access technology.
The EPC consists of the following elements :

- The Mobility Management Entity (MME) performs the signaling and control functions to manage the User Equipment (UE) access to network connections, the assignment of network resources, and the management of the mobility states to support tracking, paging, roaming and handovers. MME controls all control plane functions related to subscriber and session management.
- The Serving GW (SGW) is a data plane element whose primary function is to manage user-plane mobility and act as a demarcation point between the RAN and core networks. SGW maintains data paths between eNodeBs and the PDN Gateway (PGW).
- Like the SGW, the Packet Data Network Gateway (PDN GW) is the termination point of the packet data interface towards the Packet Data Network(s) (i.e., IP networks). As an anchor point for sessions towards the external Packet Data Networks, the PDN GW supports Policy and Charging Enforcement Function (PCEF) for the detection of service data flows, policy enforcement (e.g. discarding of packets) and flow-based charging.

Other components of importance for EPC are :

- The Home Subscriber Server (HSS) is the main data storage for all subscriber and service-related data. It hosts 2G/3G, LTE and IMS subscriber data.
- The Equipment Identity Register (EIR) is the database used to check the status of an IMEI (International Mobile Equipment Identity), e.g., if it has been reported stolen.
- Policy and Charging Rules Function (PCRF) is related the gating (blocking/authorizing IP flows) decisions, quality of service policies for the authorized flows as well as on the charging policies applied.
- Subscription Profile Repository is the database which holds the subscriber authorizations for policy and charging control (PCC). These information are used by the PCRF to build PCC rules which are then submitted to the PCEF.
- The Online Charging System (OCS) provides online (or real-time) credit control and quota management for subscriber data sessions.
- The Offline Charging System (OFCS) receives charging data in the form of Charging Data Records (CDRs) and diameter accounting messages from network elements after the subscriber incurs network resource usage.

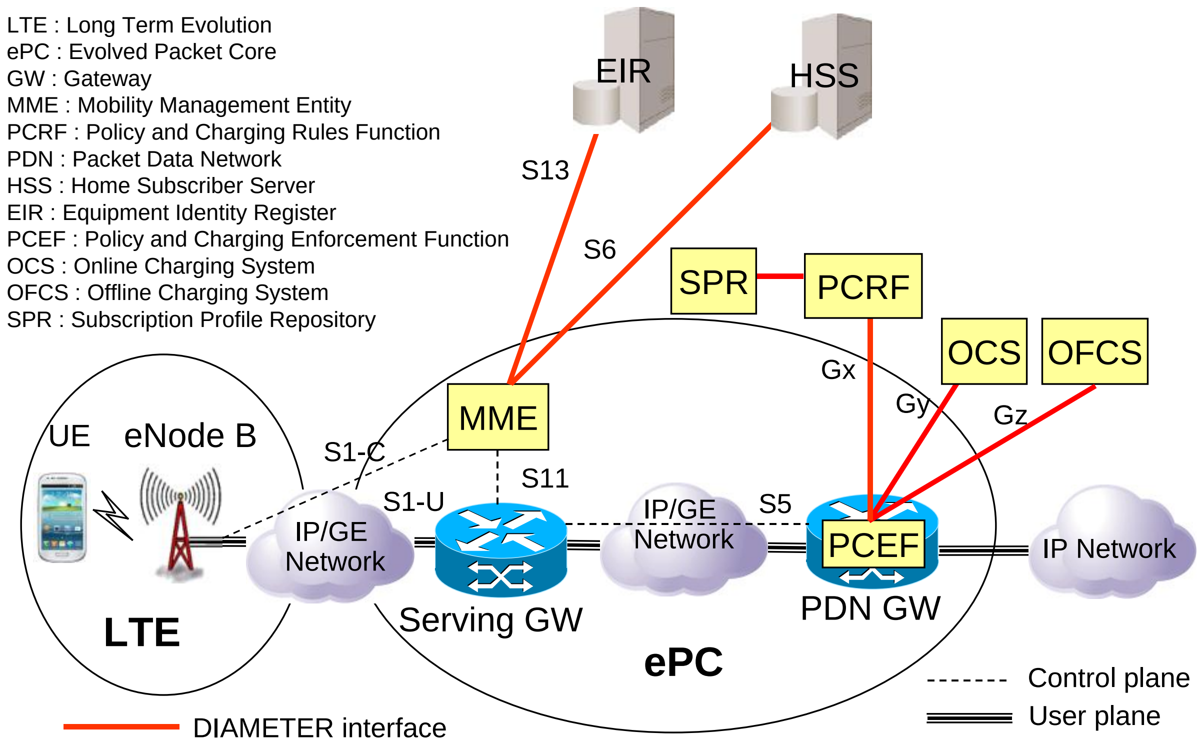


Figure 1 : EPS Architecture

IMS architecture is access independent and can provide IP-based services (e.g., IP telephony) to any broadband user such as EPS user.
IMS shares the Cx interface with the HSS (to obtain authentication vectors and IMS user profile) and Sh interface with the HSS (to obtain service data).
The PCC (Policy and Charging Control) is convergent. It is used by EPS for policy and charging control as well as by IMS for the same purpose.
PCC standard defines two charging interfaces, Gy and Gz, which are used for online and offline charging respectively. The Gy interface connects the PCEF to the Online Charging System (OCS), which is used for flow based charging information transfer and control in an online fashion. The Gz interface is used between the PCEF within the PGW and the Offline Charging System (OFCS), and it is applied when charging records are consolidated in an

offline fashion. The Ro and Rf interfaces are also used for charging in IMS respectively in online and offline fashions.
IMS shares an Rx interface with the PCRF to request allocation of resources in the EPS (e.g., reservation of conversational QoS class for voice or video telephony) to ensure QoS for any IMS multimedia session. Rx commands are generally translated by the PCRF into Gx commands towards the PCEF.

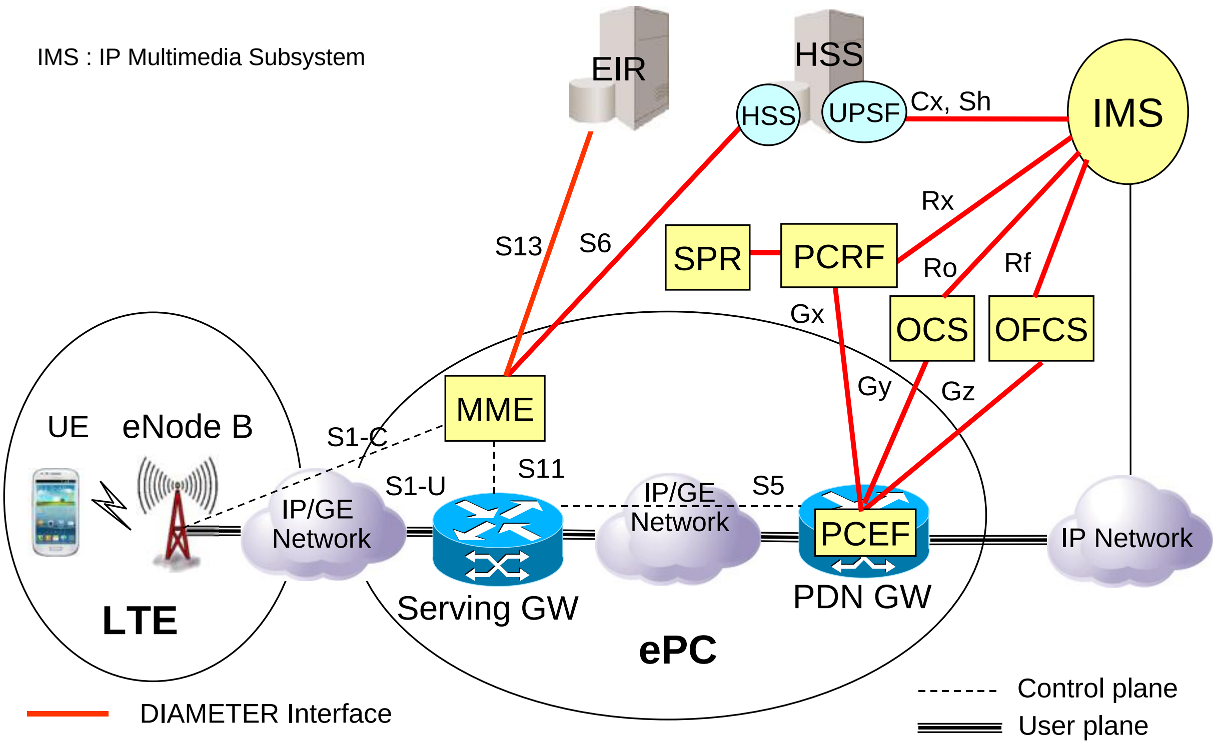


Figure 2 : EPS and IMS

Let’s consider a user who wants to access to Internet services and IMS services. The user will need to establish two default bearers each one with a given APN and QoS. As a result the user will be assigned two IP addresses, one for the Internet activity and one for IMS activity (generally IPv6 address). The two default bearers may have different QoS : for example background QoS for the default bearer related to Internet (QCI = 8 or 9) and Interactive QoS for the default bearer related to IMS (QCI = 5).
This approach allows separating the access to an IP world which supports IMS (Mobile operator’s intranet) from the public Internet network. In this case, access to each of the networks is done through a specific PDN GW, which allows implementing specific policy-enforcement rules or packet filtering algorithms depending on the type of packet network being addressed.
The default bearer for Internet APN will transport all the internet traffic and will decrease the bitrate of these flows when the user will reach his fair use (e.g., 5 Gigabytes) within the billing cycle, while the default bearer for IMS APN will transport SIP signaling only between the UE and the P-CSCF.
The two default bearers are handled by one eNode B, one Serving GW and one or two PDN GWs. Figure 3 shows the two default bearers when the user is in his home network.

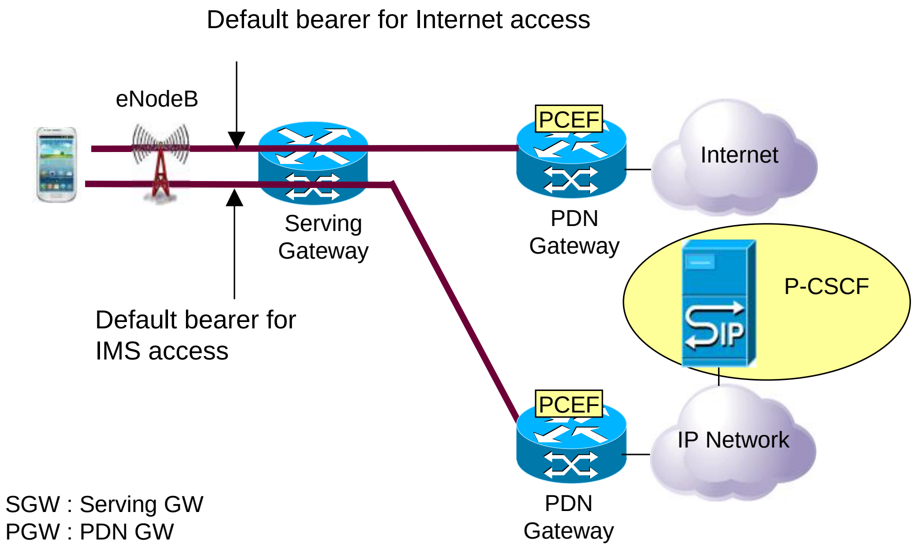


Figure 3 : Connectivity for Internet Access and IMS access when the user is in his home network

# 3 Default and Dedicated bearers

The IMS default bearer just transports the SIP traffic related for example to session establishment/release, USSD service, SMS service, etc.
When the user receives an incoming voice call, a dedicated bearer is established for the transport of real time voice (RTP protocol). This dedicated bearer requires a QoS of conversational class. A dedicated bearer shares the same APN, same IP address than the default bearer it is associated with, but has a different QoS. It is not possible to transport over the same default bearer two IP flows which require different QoS (SIP flow and RTP flow). When an incoming IP packet is received by PDN GW, it knows how to route it over the appropriate bearer thanks to the destination transport address (port number + IP address). The SIP and RTP flows are handled by different processes on the terminal and these processes listen to different port numbers although they share the same IP address.
For a videotelephony call, two media components are generated and encoded differently : voice component and video component. Since these components require different QoS, two dedicated bearers are required, one per component. At the receiving side, the two flows are mixed before being presented.
In the case of a voice call put on hold and another ongoing voice call, only one dedicated bearer is required for the handling of the two voice flows since they share the same QoS.
In IMS, it is also important to handle the XCAP (XML Configuration Access Protocol) traffic. XCAP is a protocol which enables a user configuring his service data (e.g., modifying a call forwarding number, changing his barring services) on the Multimedia Telephony Application Server (MTAS). The XCAP flow is typically carried over the default bearer of the Internet APN.
The concept of dedicated bearer may also apply to the Internet access. Parallel to the default bearer, a dedicated bearer may be established for the transport of the Skype traffic (Conversational QoS) or for the delivery of multimedia networked game commands (Interactive QoS) or for the reception of Video on demand flows (Streaming QoS), if the customer accepts to pay for that QoS and if the service provider proposes such option.

Another important APN is « Emergency ». If the user wants to attach just to establish an emergency call, his UE sends an attach request to the MME with attach type =

« Emergency ». In that case the MME creates a default bearer for Emergency APN and confirms the emergency attachment to the UE. Then, the UE is able to register to IMS and establish the emergency call. A dedicated bearer is opened on Emergency APN to carry the voice traffic.

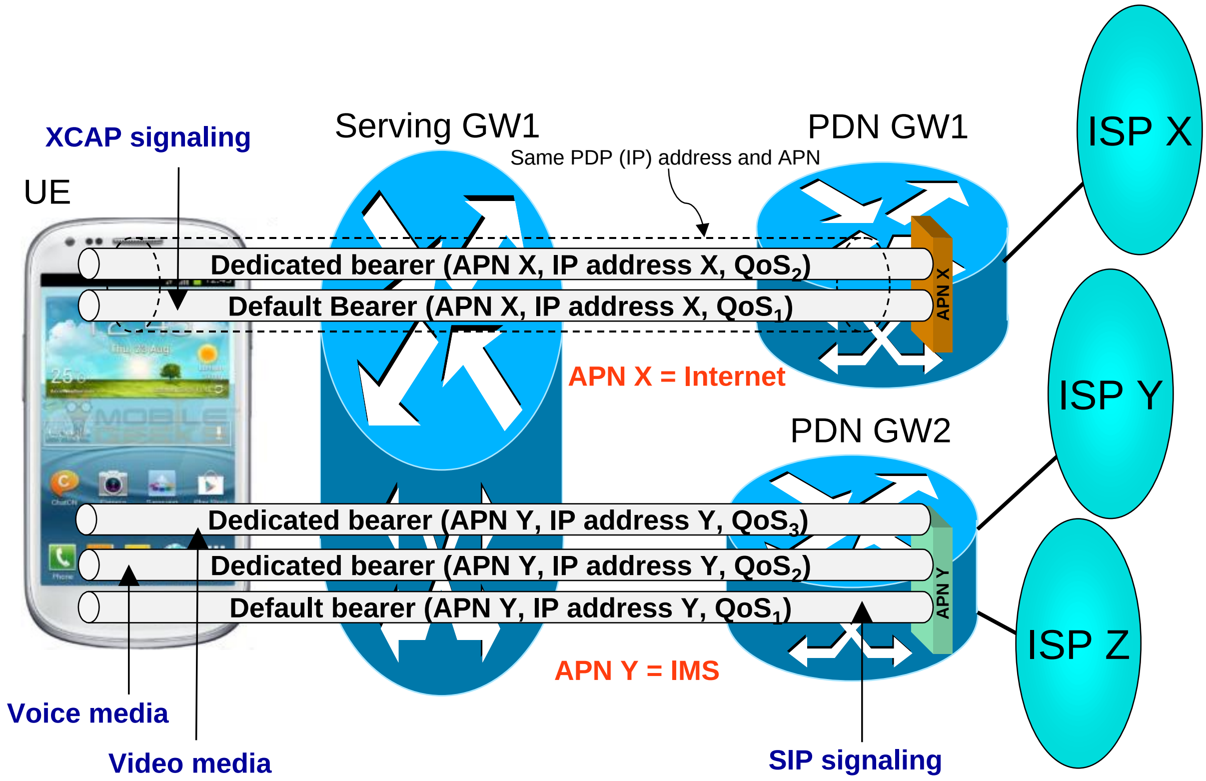


Figure 4 : Default and dedicated bearers

# 4 Establishment of a dedicated bearer for the IMS services

The establishment, modification and release of an IMS session involved exchange of SIP/SDP messages end to end. During this exchange, the UE negotiates a set of media characteristics (e.g., codecs). The P-CSCF, via the DIAMETER-based Rx interfaces it shares with the PCRF, authorizes the IP flows related to the media components selected by the UE, by translating the SDP descriptions into characterization of corresponding IP flows and QoS for these IP flows. Then the PCRF passes these informations to the PCEF/PGW via the DIAMETER-based Gx interface.
When the UE sends a SIP INVITE request to its P-CSCF, this latter originates an Rx AAR command and delivers it to the PCRF. PCRF translates it into a Gx RAR command and routes it to the PCEF/PGW. This request describes the IP flows to be authorized (i.e., RTP/RTCP flows) and the QoS for these flows.

In the case of a VoLTE call, the RTP/RTCP flows are characterized by the following QoS parameters :

- QCI (Quality of Service Class Identifier) set to 1 which corresponds to conversational audio class.
- ARP (Allocation Retention Priority) set to a value comprised between 1 and 15
- Garanteed-bitrate-DL (e.g., 30 kbit/s)
- Garanteed-bitrate-UL (e.g., 30 kbit/s)
- Maximum-bitrate-DL (e.g., 30 kbit/s)

- Maximum-bitrate-UL (e.g., 30 kbit/s)

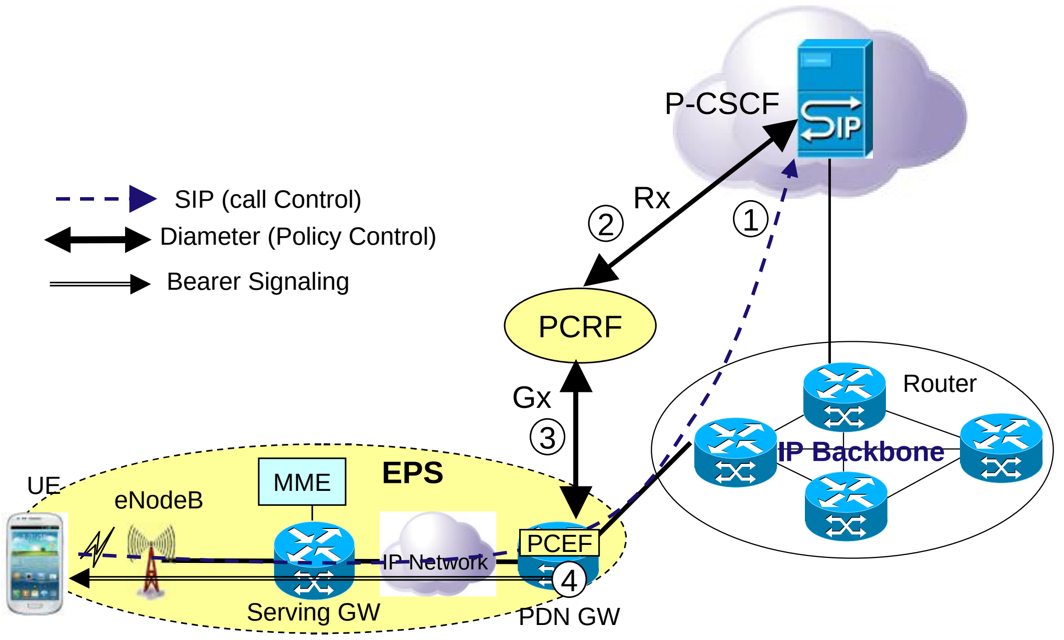


Figure 5 : Policy Control for VoLTE

# 5 UE attachment from a visited EPS network

Let's consider a user who wants to access to Internet services and IMS services from a visited network. The user will need to establish two default bearers each one with a given APN and QoS.

The default bearer for Internet access will apply the "home routed traffic" approach. This means that the PDN GW is located in the home network. This allows the visited network (with its Serving GW) and the home network (with its PDN GW) counting how many bytes the user has sent and received. This is important since charging is always based on volume when the scenario is international roaming. This approach ensures that both operators have all necessary information if charging problems occur. The establishment of the default bearer for Internet access requires IP connectivity between the visited and home networks. This internetwork connectivity is called IPX (IP Exchange Network). IPX may be seen as an evolution of GRX (GPRS Roaming Exchange) with more capabilities to support QoS for the transport of inter-operator IP flows.

The default bearer for IMS access will apply the "local breakout" approach. This means that the Serving GW as well as the PDN GW are located in the visited network. There is no need to bring SIP/IMS signaling from the UE directly to the home network since the first IMS call server (called P-CSCF) who should receive it is in the visited network and since SIP/IMS signaling traffic is not charged to the user.

Applying the home routed traffic model to the IMS APN for VoLTE would be problematic because it would imply that the IMS entry point is also located in the home network.

- The visited network would not anymore be aware of multimedia session (e.g., voice calls) and short messages initiated or terminated by the user, which could lead to smaller roaming revenues for communications service providers.
- Fulfilling regulatory requirements would be challenging or impossible:
    - IMS signaling traffic is expected to be ciphered between the UE and the P-CSCF. This means that the visited network cannot properly perform a lawful interception.
    - IMS emergency session requires the use of the P-CSCF in the visited network.

- In addition, PGW in the home network increases the delay of RTP/UDP/IP packets on the user plane.

This is the reason GSMA in its reference document IR.65 (IMS Roaming & Interworking Guidelines) requires use of PGW and P-CSCF of the visited network for IMS voice and conversational services offered in roaming situations.

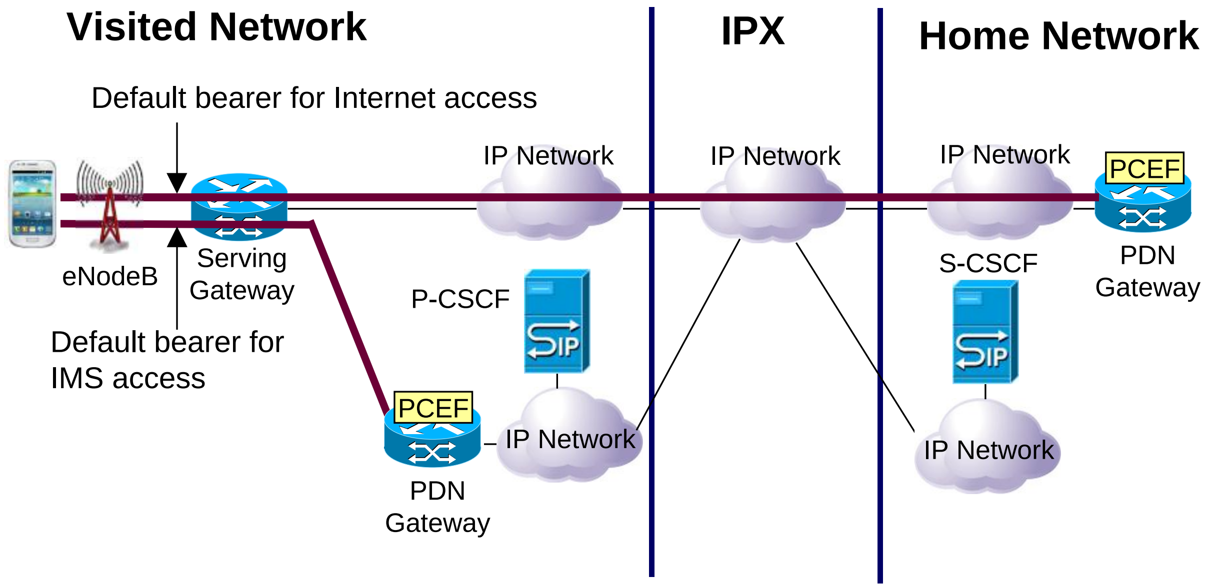


Figure 6 : Connectivity for Internet Access and IMS access when the user is in a roaming situation

# 6 EPS Profile and information related to VoLTE

At first, the communication service provider needs to create a VoLTE subscription for the user. This subscription is permanently stored in the home subscriber server (HSS) and necessary information of it is downloaded to a mobility management entity (MME) when the user performs EPS attach and to a serving call session control function (S-CSCF) when the user performs IMS registration.

Table 1 shows the evolved packet system (EPS) part of the VoLTE subscription data. and gives example value of the parameter for VoLTE usage.

The Subscriber-Status shall indicate if the service is barred or granted. The following values are defined: SERVICE_GRANTED (0), OPERATOR_DETERMINED_BARRING (1).

The MSISDN AVP contains an MSISDN, in international number format.

The Network-Access-Mode indicates if the user may request CS+PS attachment (useful in case of CSFB):or just PS attach : The possible values are PACKET_AND_CIRCUIT (0), Reserved (1), ONLY_PACKET (2).

The Operator-Determined-Barring shall contain a bit mask indicating the services of a subscriber that are barred by the operator.

The AMBR AVP shall include the AMBR associated to the user's subscription (UE-AMBR); Max-Requested-Bandwidth-UL and Max-Requested-Bandwidth-DL shall not both be set to "0".

The STN-SR Identifies the session transfer number for SRVCC; i.e., it provides the tel URI of the SRVCC AS assigned to user.

The APN-Configuration-Profile shall contain the information related to the user's subscribed APN configurations for EPS.

| | |
|---|---|
| IMSI | 208019999999999 |
| APN-Configuration-Profile | See next table for ‘IMS’ APN |
| Subscriber-Status | 0 |
| Network-Access-Mode | 0 |
| MSISDN | +33672999999 |
| STN-SR | +33689999999 |
| AMBR | Max-Requested-Bandwidth-DL=30000000<br>Max-Requested-Bandwidth-UL=15000000 |
| Other EPS data | |

Table 1 : EPS data in the HSS per subscriber

The set of APNs associated with a given user is described by means of APN-Configuration-Profile. APN-Configuration-Profile consists of a set of APN-Configuration. Each APN Configuration which describes a given APN consists of the following information :

- Context Identifier : APN Index. It shall identify that APN configuration, and it shall not have a value of zero. Furthermore, the Context-Identifier in the APN-Configuration shall uniquely identify the EPS APN configuration per subscription.
- Served-Party-IP-Address : A Ipv4 or Ipv6 address may be configured statically during subscription. This field is not filled if dynamic addressing applies.
- PDN Type : Type of IP address to assign to UE if addressing type is dynamic. The address is assigned when this APN is activated.
- Service-Selection : A label according to DNS naming conventions describing the access point to the packet data network, that is APN network identifier.
- EPS-Subscribed-QoS-Profile : The bearer level QoS parameter values for that APN default bearer including QCI (Quality of Service Class Identifier) and ARP (priority and preemption) for the IMS APN, the default bearer should have a QCI equal to ‘5’ and ARP (Allocation Retention Priority) may have its priority equal to a high value, e.g., ‘3, its Preemption-Capability enabled (0) and its Preemption-Vulnerability disabled (1).
- VPLMN Address Allowed : Specifies whether for this APN the UE is allowed to use the PDN GW in the visited operator network. For VoLTE roaming this must be enabled (1) because P-GW is selected always from the visited PLMN (local breakout mode).
- AMBR : It represents the maximum bitrate for the default bearer of this APN, on uplink and downlink. In the case of IMS APN, this bitrate will be used for SIP signaling exchange only. Max-Requested-Bandwidth-DL = 100 000 and Max-Requested-Bandwidth-UL = 100 000 enable assigning a maximum bitrate of 100 kbit/s for SIP signaling transport.

| | |
|---|---|
| Context-Identifier | 1 |
| Served-Party-IP-Address | |
| PDN-Type | IPv4 |
| Service-Selection | Ims.orange.fr |
| EPS-Subscribed-QoS Profile | QCI = 5 ; ARP =1, PC= 0, PV=1 |
| VPLMN-Dynamic-Address-Allowed | 1 |
| AMBR | Max-Requested-Bandwidth-DL = 100 000<br>Max-Requested-Bandwidth-UL = 100 000 |
| Other information for the APN | |

Table 2 : « IMS » APN Configuration

This tutorial has presented the impacts of IMS on EPS :

- Evolution of HLR/HSS to integrate UPSF
- Evolution of PCC to support the new DIAMETER interfaces for IMS, namely Rx (policy control), Ro (Online charging) and Rf (Offline charging).
- Selection of the PCRF which handles the IMS APN of the user using the DIAMETER Agent (DRA).

- Support of the IMS APN and Emergency APN with a default bearer with QCI = 5 and dedicated bearers for voice (QCI = 1) and videotelephony (QCI = 1 for the audio flow and QCI = 2 for video flow).
- Local breakout mode for APN IMS and APN Emergency in VoLTE roaming situation.

The VoLTE seminar proposed by EFORT :

- introduces the IMS requirements that EPS should fulfil
- describes the IMS architecture for EPS access
- presents the IMS protocols (SIP, DIAMETER, H.248, XCAP, RTP/RTCP)
- shows how roaming in IMS applies when an EPS user is in a visited network
- describes how resources are reserved in the EPS access network when an IMS session is established
- illustrates the different IMS procedures considering an EPS user : registration, session establishment/release, MMTel service invocation, SMS delivery, USSD service invocation
- describes how emergency sessions are handled
- describes the MTAS and its telephony services
- presents how  IMS security is handled
- describes the ICS (IMS Centralized Services) architecture
- shows how the voice call continuity is ensured when the user moves from EPS/IMS to 2G/3G R4 and how termination access domain selection occurs for incoming calls..