Mobile Networks Evolution Towards 4G

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Mobile networks of service providers have initially been designed to support voice. With time, Traffic nature has evolved towards more complex data services such as SMS, Internet access or mobile TV. Equipment vendors and mobile service providers have been able to cope with this evolution introducing new modulations, new access technologies and new network technologies.
However, the latest generation of smartphones, particularly the Apple iPhone and Google Android devices, has contributed to exponential growth of data traffic in 3G networks particularly with video streaming services. 4G technology has therefore been anticipated by mobile service providers to better control this evolution in the mobile data usage in an all IP mobile world. The goal of this tutorial is to present the mobile networks evolution towards 4G.

1 Generic Structure of a Mobile Network

A mobile network consists of an access network which implements a radio technology which ensures the user traffic modulation and a core network which ensures terminal mobility (Figure 1). The access network is connected to the core network by a backhauling network. The backhauling network is used to connect the base station controllers to the core network but also the base stations to the base station controller in the access network.
Mobile networks themselves are already well established in very many parts of the world, and mobile networks continue to expand, covering wider and wider areas of the globe. They also develop at a rapid rate and offer more and more services, including many kinds of wideband services, and enable higher and higher bit rates between the terminals and the network. This means that especially the data traffic is growing very fast in many mobile networks. Therefore well-working inter-element connections are necessary for the mobile networks to operate properly, and the role of supporting transport and packet networks is increasing. These transport and packet networks serving mobile networks are called ‘mobile backhaul networks’, or often just backhauling network as they connect a large number of base station sites to a limited number of centralized sites.
The backhauling network is presently experiencing a big change, as the growth of mobile data traffic and development of packet transport technologies and equipment has created a strong push to use packet-based backhauling solutions, both to increase feasible data throughputs and to improve the cost-efficiency of backhauling networks.
Backhauling networks have always been an important part of the overall mobile network business case; connections to the base station sites are important, as their number is very high. These ‘last mile links’ influence significantly the overall network costs. Now when network capacities increase and cell sizes decrease, transport share of the overall network costs tends to increase. Packet-based transport solutions help here, in keeping transport cost increase at a reasonable level. Links of the backhauling network may consist of fiber, copper or microwave. Each of these technologies address a key portion of the backhaul puzzle. Fiber is tipically the right choice for high-capacity routes where logistics are manageable, capacity need is high, and the potential revenue gain offsets the expense. Microwave makes sense for lower capacity long-distance runs where fiber is either logistically or economically infeasible.

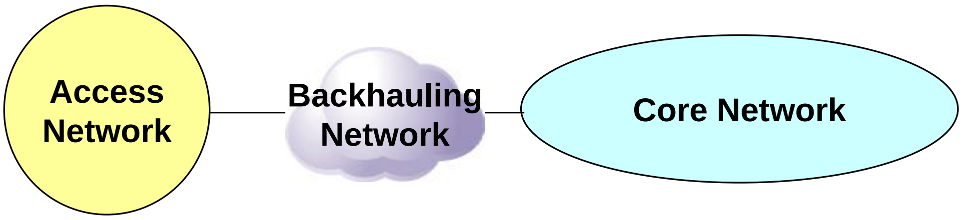

Figure 1 : Generic structure of a mobile network

2 Access Network

The access network ensurse the coverage of given geographical areas called cells. These cells contain the hardware and software required for the communication with the user equipment (UE) (Figure 2).
The 2G access network is called BSS (Base Station Subsystem). It consists of BTSs (Base Transciever Station) and BSCs (Base Station Controller). The BTSs (Base Transceiver Station) are transmitters/receivers with a minimum « intelligence ». The BSC (Base Station Controller) controls a set of BTS. For the user traffic coming from BTSs, the BSC plays the role of a concentrator. For the traffic coming from the core network, the BSC plays the role of a dispatcher, passing the traffic to the appropriate BTS the user is served by.
The 3G access network is called UTRAN (UMTS Terrestrial Radio Access Network). It consists of NodeBs and RNCs (Radio Network Controller). The Node B is equivalent to the BTS of the 2G access network. An RNC is a controller of a set of eNodeBs. It is equivalent to the BTS of the 2G access network.
The 4G access network is called LTE (Long Term Evolution of 3G) or eUTRAN (Evolved UTRAN). It just consists of one type of entity called eNodeB. An eNodeB is functionally equivalent to NodeB and RNC combined together.

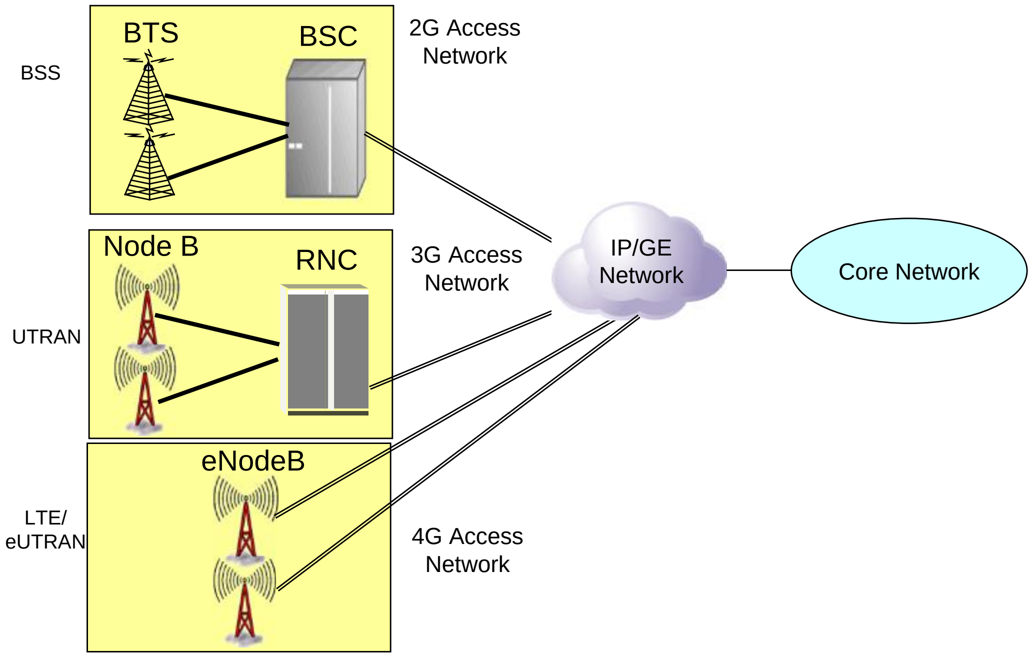

Figure 2 : Access network

3 Core Network

The 2G/3G core network consists of two domains : Circuit switched and packet switched domains.
The circuit switched domain provides telephony services. It initially consisted of voice switched, it has evolved towards an mobile NGN structure called R4. The packet switched domain named GPRS (General Packet Radio Service) provides an access to IP worlds and to their services. The GPRS packet switched network consists of packet switches and is used to transfer IP packets sent from 2G or 3G access networks to Internet or Intranets. Incoming packets from Internet or Intranets are forwarded to the UE with mobility management handling.
With 4G technology, a new core networks is introduced ; it is called ePC (Evolved Packet Core) and is used for conversational services and data services. Conversational services are offered by the IMS (IP Multimedia Subsystem) service platform which is in the IP world, while for 2G/3G accesses, there is a dedicated circuit switched network for telephony services.
LTE + ePC = EPS (Evolved Packet System).
Figure 3 shows the different mobile core networks.

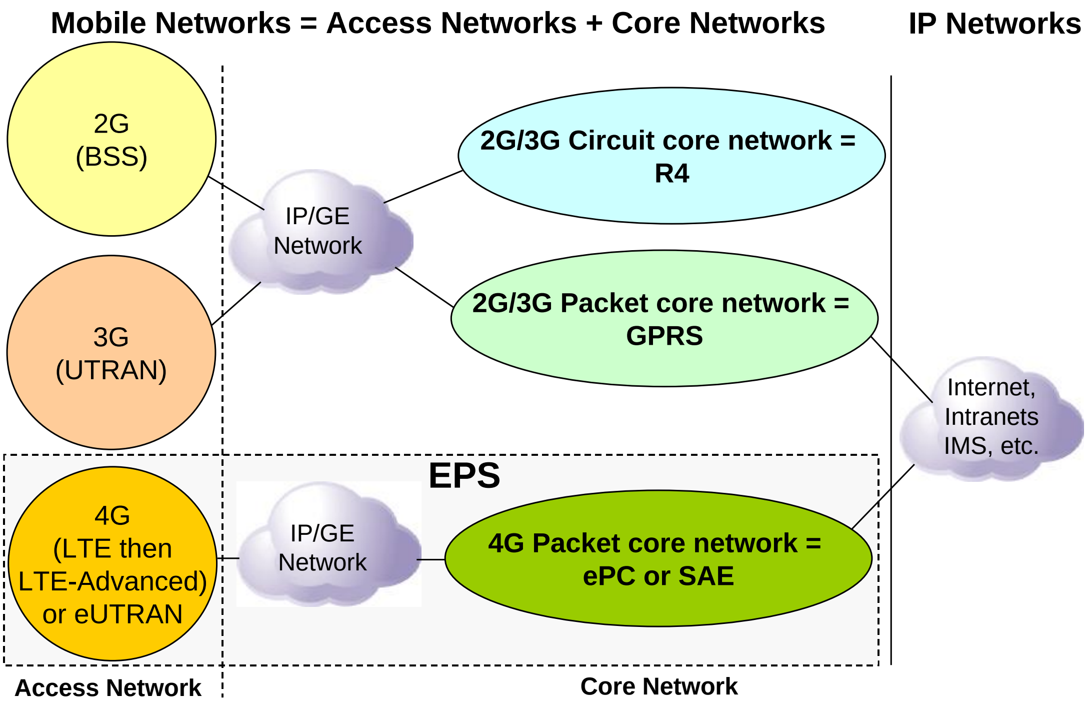

Figure 3 : Core network

The ePC core network is a convergent network enabling mobility of IP packets of the UE, whatever the radio access technology used (GPRS, EDGE, W-CDMA, HSPA, HSPA+, LTE, WiFi) (Figure 4).
It is the same node which is used as the anchor point for the UE bearers, namely the PDN GW. The PDN GW is the node which allocates the IP address to the UE.
Interworking between WiFi (non-3GPP access) and the ePC has been fully specified by 3GPP.
WiFi is optimized for in-building usage and is therefore best suited for a data offloading solution, because according to statistics, we know that about 70% of the mobile data are created indoors.

WiFi networks are consistently high performing owing to their inherent small- cell architecture and their use of widely available unlicensed spectrum.
Thus, adding WiFi to the set of accessible radios can help to optimize user experience.
This solution enables authenticating the WiFi client by the mobile operator; thus this client can access to the mobile services from WiFi access (Mobile TV, MMS, Voice over IP with IMS, RCS, etc.). In addition, mobility management between WiFi and 4G is supported ; this enables a client keeping the same IP address when moving from 4G to WiFi and vice versa, and maintaining his data sessions.

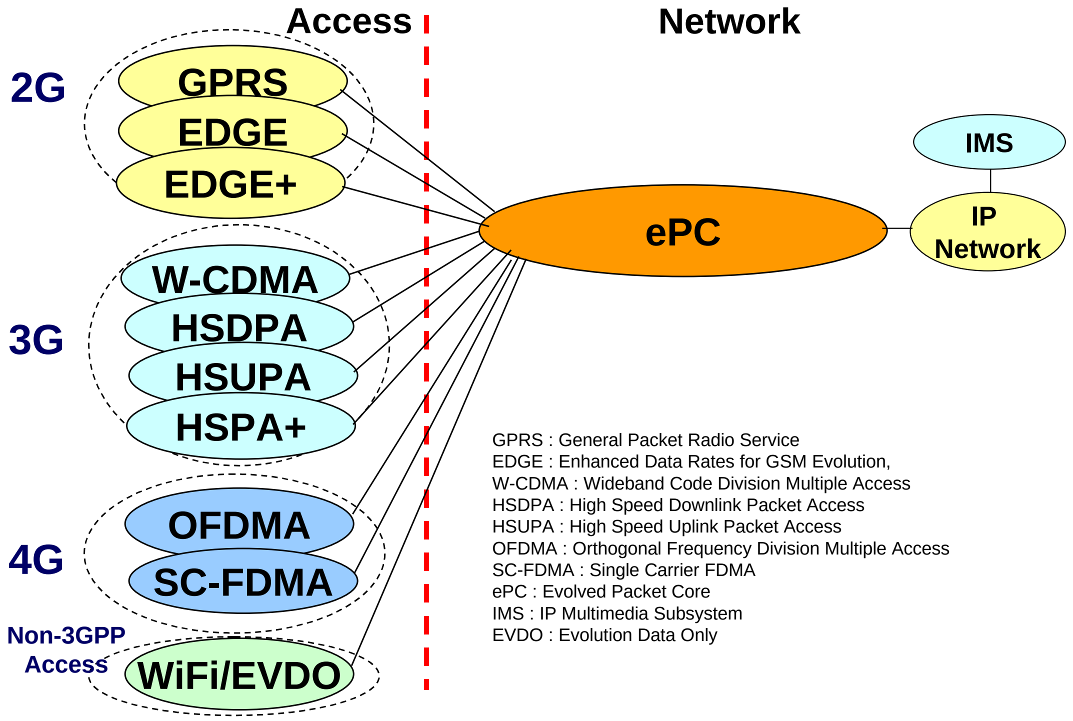

Figure 4 : ePC : Convergent packet core network

4 IP Services

The trend is to propose broadband access to the customer and an associated bundle of broadband services including IP TV (broadcast TV, video on demand) and IP Telephony. This is true for fixed and mobile accesses. Fixed accesses include FTTx, xDSL, cable, WiMAX technologies while mobile accesses include HSDPA/HSUPA, HSPA+, EPS (4G), and EVDO (Evolution Data Only used for supplying high speed data access in CDMA2000-based networks).

The same IP network connects whatever broadband access technology and supports the IP based service architecture. IMS (IP Multimedia Subsystem) s a standardized service architecture for multimedia services such as IP telephony, IP TV, presence, messaging, IP centrex, Conferencing, etc. Apart from the IP services supplied by the service provider, the user may access to any Internet services (Web, mail, file transfer, streaming, Internet telephony, etc.)

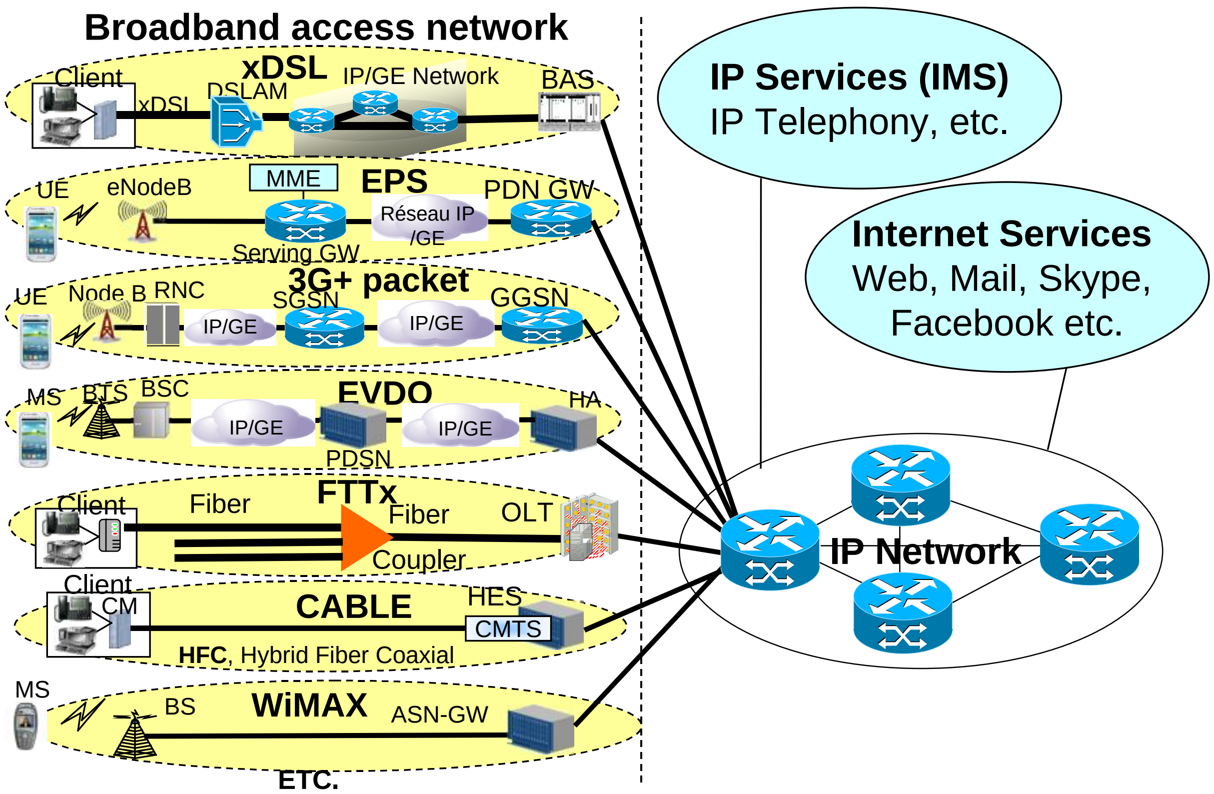

Figure 5 : IP-based Service Architecture and Broadband Access

5 Policy and Charging Control for Mobile Data

To assure fair usage of the EPS network, service providers will need to identify the IP service flows, control these flows (authorize, block, restrict) and charge these flows with two possible charging methods (online and offline charging). For this purpose, a PCC (Policy and Charging Control) architecture has been introduced.

Policy control is related to the function of authorizing/blocking IP flows and providing a given QoS to the authorized IP flows. Charging control is related to the charging of the authorized IP flows.

Mobile data networks operate in a connection oriented mode. The user establishes an end to end connectivity between his UE and the node which terminaux the access (GGSN in 2G/3G and PDN GW in 4G) to send/receive IP packets. This connectivity is called PDP Context (2G/3G) or bearer (4G).

The goal of service providers is to be able on the PDP context/bearer to :

- Identify the IP flows being transported; indeed, each IP flow should be characterized to apply PCC rules on the flow.
- Authorize or block the IP flow (e.g., the freemium service proposed to user without mobile data subscription authorizes them only to send and receive HTTP flow related to Facebook and Twitter. Any other flow is systematically blocked.
- Offer QoS to the authorized flows (e.g., when the fair use is reached, all Internet flows are still accepted but their bitrate is reduced until the next billing cycle unless the user pays additionnal fees with turbo button service to increase the bitrate.
- Charge each IP flow according to different criteria (volume, duration, volume and duration, etc).

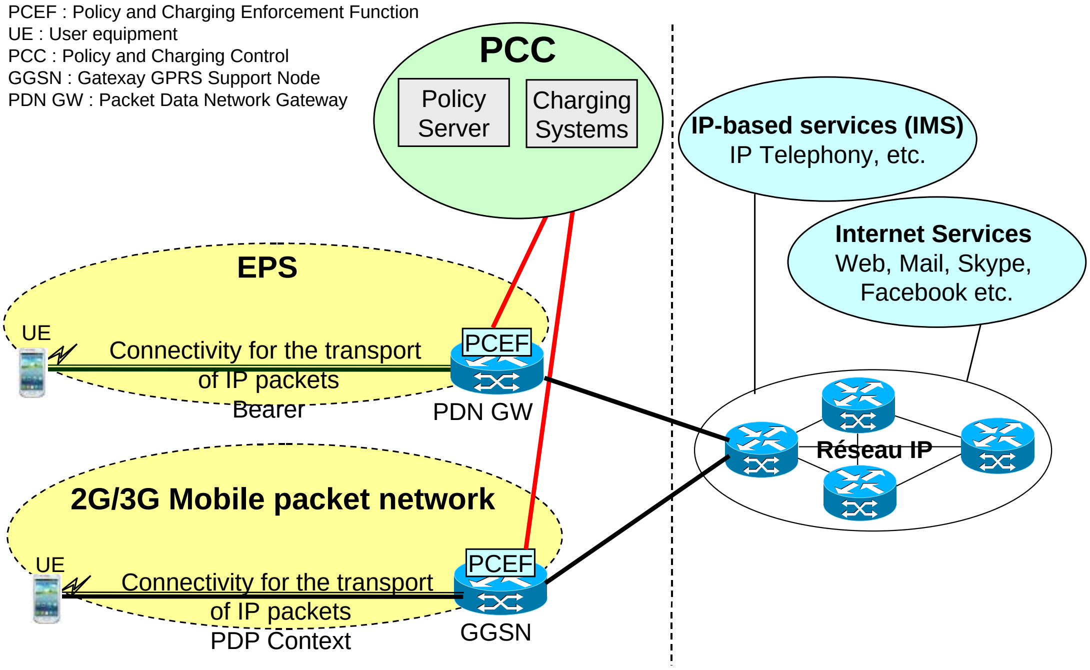

Figure 6 : PCC architecture for mobile data

6 Telephony and 4G : CSFB (Circuit Switched FallBack)

How may telephony be proposed to the 4G customer under 4G coverage ?
As a first step, IMS to provide Voice over IP over LTE will not be put in place due to its complexity and to the fact that it should emulate the whole set of telephony services supplied by the current 2G/3G circuit switched domain.
The short term solution to provide telephony services to 4G clients is CSFB (Circuit Switched FallBack).
When the 4G user is served by a 4G coverage, it attaches to the 4G packet switched domain which only provides access to Internet/Intranets with a very high bit rate. When the user needs to establish a call or receive a call, it is switched from 4G over 2G or 3G assuming that 2G or 3G coverage is available. Only one radio technology can be activated at a time, either 2G, or 3G or 4G. When the user is switched from 4G to 3G, his data sessions are handed over and continue to run with the same IP address and with a lower bit rate, and the voice call may be established, parallel to data sessions. At the end of the call, the terminal switches back to 4G without any data session interruption to get the best possible bit rate. However, when the user is switched from 4G over 2G, his data sessions are suspended and the voice call may be established. At the end of the call, the terminal switched back to 4G and resumes his data sessions.

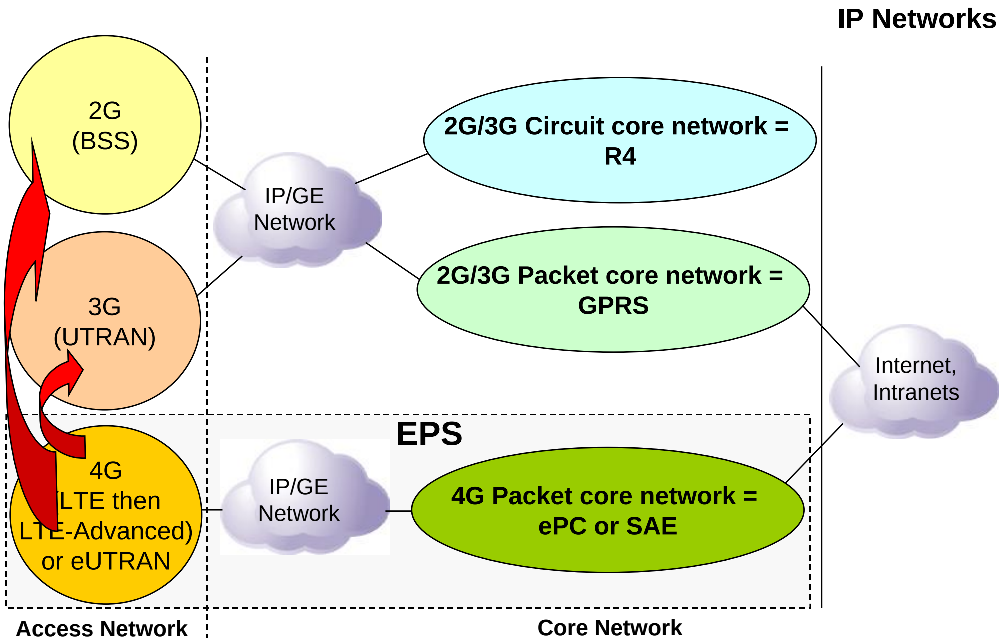

Figure 7 : CSFB solution

7 Telephony and 4G : VoLTE (Voix sur IP sur LTE)

VoLTE or Voice over IP over LTE with IMS must emulate the services supplied by the 2G/3G circuit switched domain and should provide the following services :

- Supplementary services of telephony (call forward, call hold, call completion on busy subscriber, call transfer, call barring, etc.)
- USSD Services

Supplementary services and USSD services are handled by the TAS (Telephony Application Server).

- SMS service : The SMS service is performed via a SIP application server called IP-SM-GW (IP Short Message Gateway). It is a signaling gateway between SIP and MAP and forwards the SMS from IMS to the legacy SMSC, thus reusing the full existing SMS architecture.
- CAMEL services (e.g., Prepaid, VPN, etc.) : The existing CAMEL services are still considered in VoLTE by introducing a SIP application server called IM-SSF (IMS Service Switching Function). It is a signaling gateway between SIP and CAP, forwarding the IMS calls to existing CAMEL service platforms.
- Voice call continuity if the user looses its 4G coverage during the voice communication. Indeed, in 2G and 3G, the voice call is handled by a circuit switched domain and its MSC Servers. A SIP application server named SCC AS (Service Centralization and Continuity) guarantees seamless voice handover from LTE (IMS VoIP) to 2G/3G CS.

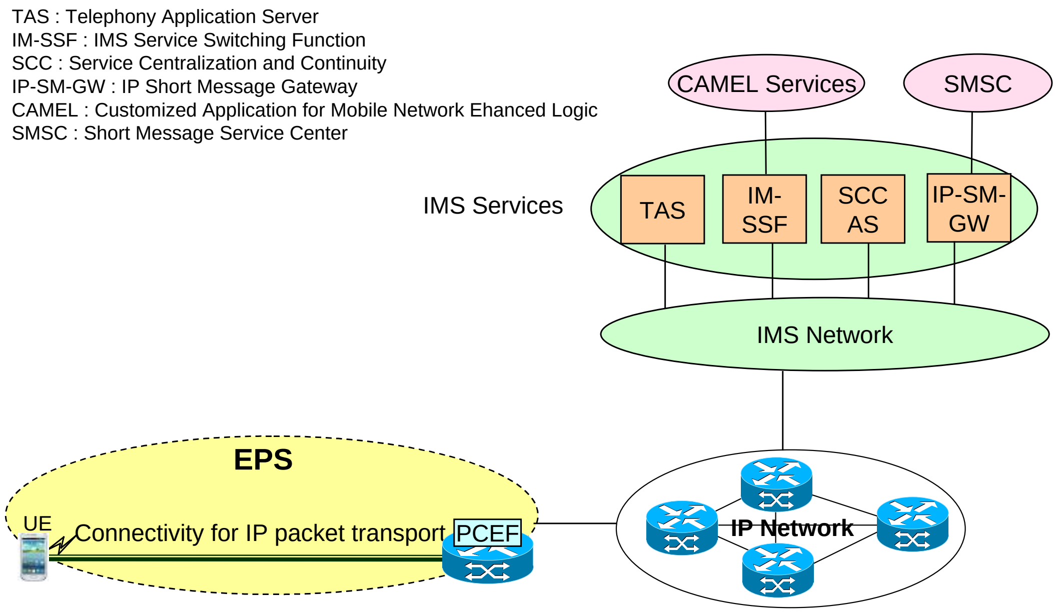

Figure 8 : VoLTE solution with IMS architecture

8 Conclusion

The future 4G Mobile network is called EPS. Its access network is named LTE (3,99G) with its evolution called LTE-Advanced (4G). The keyword eUTRAN is also used. Its core network, ePC is an all-IP network. The overall architecture LTE+ePC is the EPS. It is a broadband access network which provides always-on connectivity to Internet/Intranet, with QoS, mobility, and multicast functionality. To control IP service flows and charge the user for the authorized flows, a PCC architecture is introduced which may be used in 2G, 3G and 4G packet switching. The proposed services to the user are all IP-based services. IMS is the long term architecture to offer multimedia services including voice over IP and SMS (VoLTE). An alternative solution exists to provide the « circuit-switched » services : CSFB.