

Introduction to Evolved Packet Core

This white paper provides a brief introduction to Evolved Packet Core — a new mobile core for LTE. Herein, key concepts and functional elements-EPC gateways (Serving Gateway and Public Data Network Gateway), Mobility Management Entity (MME) and Policy and Charging Rules Function (PCRF)-are outlined, as well as key changes in LTE requirements imposed on the Evolved Packet Core, and the deployment challenges.

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1. Executive summary

EPC is a new, all-IP mobile core network for the LTE — a converged framework for packet-based real-time and non-real-time services. It is specified by 3GPP Release 8 standards (which have been finalized in Q1 2009).

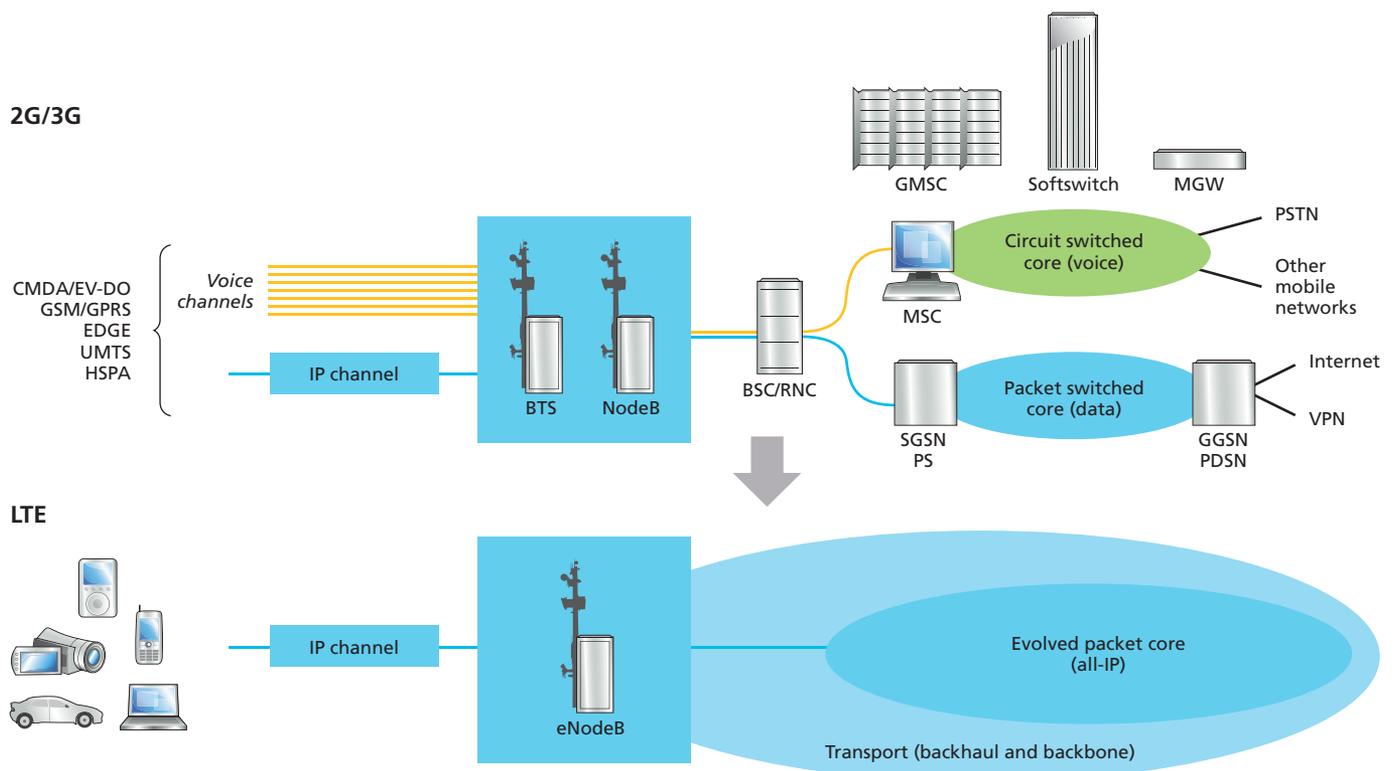
The EPC provides mobile core functionality that, in previous mobile generations (2G, 3G), has been realized through two separate sub-domains: circuit-switched (CS) for voice and packet-switched (PS) for data. As shown in Figure 1, in LTE, these two distinct mobile core sub-domains, used for separate processing and switching of mobile voice and data, are unified as a single IP domain. LTE will be end-to-end all-IP: from mobile handsets and other terminal devices with embedded IP capabilities, over IP-based Evolved NodeBs (LTE base stations), across the EPC and throughout the application domain (IMS and non-IMS).

EPC is essential for end-to-end IP service delivery across LTE. As well, it is instrumental in allowing the introduction of new business models, such as partnering/revenue sharing with third-party content and application providers. EPC promotes the introduction of new innovative services and the enablement of new applications.

EVOLVED PACKET CORE IN BRIEF

- Evolved Packet Core is a new mobile core for LTE
- EPC must address a new set of network requirements to deliver true wireless broadband Quality of Experience (QoE)
- EPC must enable new business models and the rapid introduction of new services

Figure 1. LTE: Evolution from separate CS and PS core sub-domains (3GPP case shown) to one common IP core

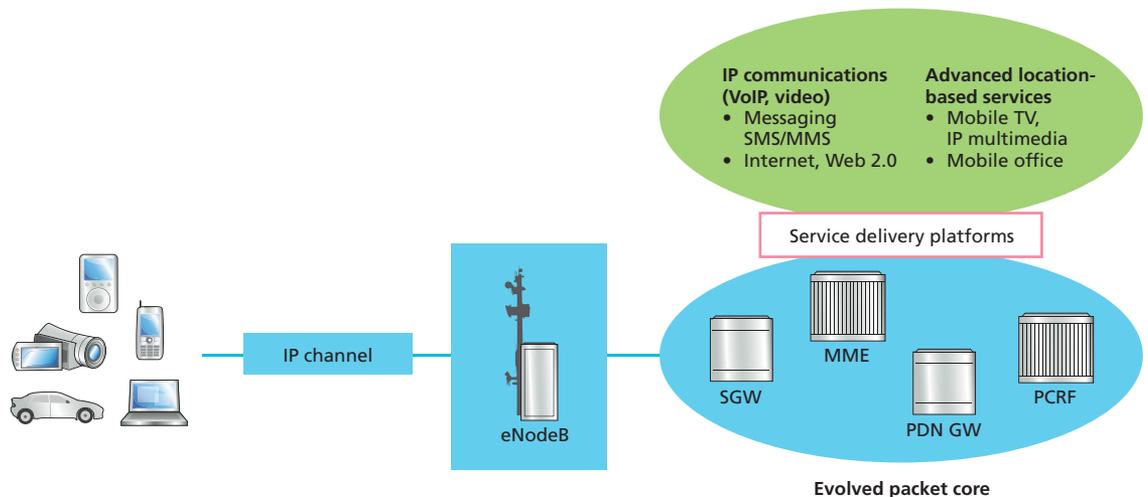


2. Evolved Packet Core overview

2.1 EPC: Radical changes in the network

The EPC is a new, high-performance, high-capacity all-IP core network for LTE. EPC addresses LTE requirements to provide advanced real-time and media-rich services with enhanced Quality of Experience (QoE). EPC improves network performance by the separation of control and data planes and through a flattened IP architecture, which reduces the hierarchy between mobile data elements (for example, data connections from eNodeB only traverse through EPC gateways). Figure 2 shows the EPC as a core part of the all-IP environment of LTE.

Figure 2. Evolved Packet Core – All-IP core for LTE



The introduction of the EPC and all-IP network architecture in the mobile network has profound implications on:

- Mobile services, as all voice, data and video communications are built on the IP protocol
- Interworking of the new mobile architecture with previous mobile generations (2G/3G)
- Scalability required by each of the core elements to address dramatic increases in number of direct connections to user terminals, orders of magnitude of bandwidth increase, and dynamic terminal mobility
- Reliability and availability delivered by each element to ensure service continuity

To address a radically different set of network and service requirements, the EPC must represent a departure from existing mobile networking paradigms.

2.2 EPC: Radical changes in the network

Introduction of EPC with LTE in many ways represents a radical departure from previous mobile paradigms:

- *End of circuit-switched voice*: LTE uses a new paradigm for voice traffic — VoIP. This ends a period of more than 20 years during which one application dictated the whole network architecture. EPC treats voice as it is: just one of many IP-based network applications, albeit an important one that requires superb packet network performance and one that is responsible for significant operator revenues.

- *Evolved wireless broadband*: LTE must match and exceed the QoE of wireline broadband. This is quite different from providing best-effort low-speed web browsing or Short Message Service (SMS) — two data applications for which the existing PS mobile cores were optimized.
- *Mobility as a part of the core network*: In LTE, all mobility management is moved into the mobile core and becomes the responsibility of the MME. This is a consequence of the split of functions previously performed by the RNC and NodeB/BTS. The MME requires a control plane capacity that is an order of magnitude larger than the SGSN or PDSN, and must ensure interworking with 2G/3G legacy mobile systems.
- *End-to-end QoS becomes essential*: LTE must provide superior end-to-end QoS management and enforcement in order to deliver new media-rich, low-latency and real-time services. There is an expected move from four classes of service (CoS) available in 3G to nine QoS profiles with strict performance targets. This must be achieved while ensuring scalability of users, services and data sessions. In addition, although not a part of the 3GPP Release 8 specification set, DPI and other advanced packet processing are required at the beginning.
- *Policy management and enforcement*: In LTE, service control is provided via the Policy and Charging Rules Function (PCRF). This is a big change from previous mobile systems, where service control was realized primarily through UE authentication by the network. PCRF dynamically controls and manages all data sessions and provides appropriate interfaces towards charging and billing systems, as well as enables new business models.

LTE requires significantly more capacity in both the data plane and control plane. The existing 2G/3G mobile core elements cannot fully address LTE requirements without a series of upgrades to the platforms. Most of the existing platforms that are envisaged to evolve to address LTE requirements are ill-suited for high-capacity packet processing. Scaling the packet processing requirements on these platforms results in higher consumption of system capacity, high latency, low performance and dramatic performance/feature tradeoffs. In some cases, performance drops more than 50% or more when features like charging are enabled. Legacy core platforms must dramatically change their product architectures to handle LTE, and even with these architectural changes, they are only a stop-gap solution that may require complex upgrade scenarios to address LTE scalability and performance requirements.

Alcatel-Lucent believes that delivering a new LTE mobile core in the form of newly deployed, purpose-built EPC elements is essential to ensure superior network performance and quality of services and to minimize overall business costs. At the same time, this forward-looking EPC is a cornerstone for further business evolution in mobile networks, allowing the creation of new business models and facilitating rapid deployment of new innovative services.

3. EPC components description

The EPC is realized through four new elements:

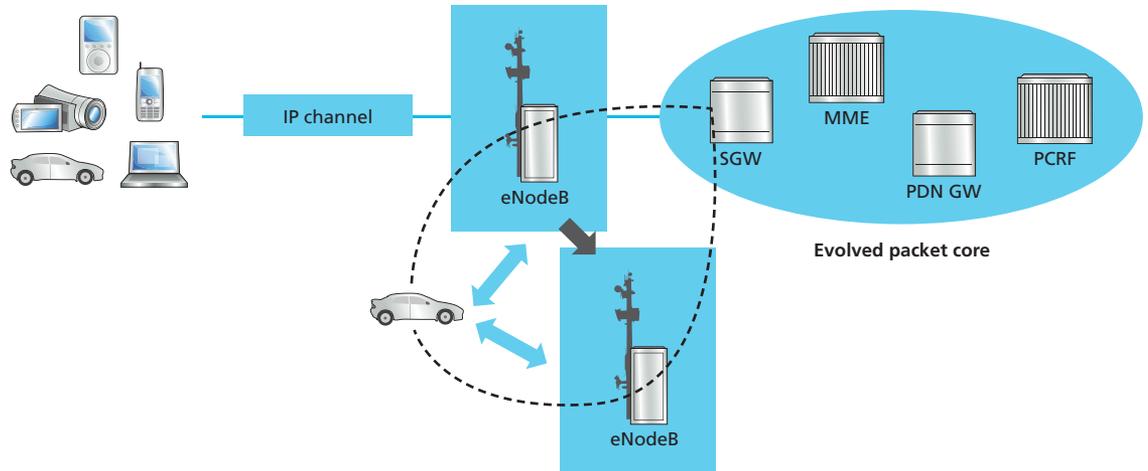
- Serving Gateway (SG-W)
- Packet Data Network (PDN) Gateway (PGW)
- Mobility Management Entity (MME)
- Policy and Charging Rules Function (PCRF)

While SGW, PGW and MME are introduced in 3GPP Release 8, PCRF was introduced in 3GPP Release 7. Until now, the architectures using PCRF have not been widely adopted. The PCRF's interoperation with the EPC gateways and the MME is mandatory in Release 8 and essential for the operation of the LTE.

3.1 Serving Gateway

The 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). From a functional perspective, the SGW is the termination point of the packet data network interface towards E-UTRAN. When terminals move across areas served by eNodeB elements in E-UTRAN, the SGW serves as a local mobility anchor. This means that packets are routed through this point for intra E-UTRAN mobility and mobility with other 3GPP technologies, such as 2G/GSM and 3G/UMTS. Figure 3 shows the Serving Gateway.

Figure 3. Serving Gateway



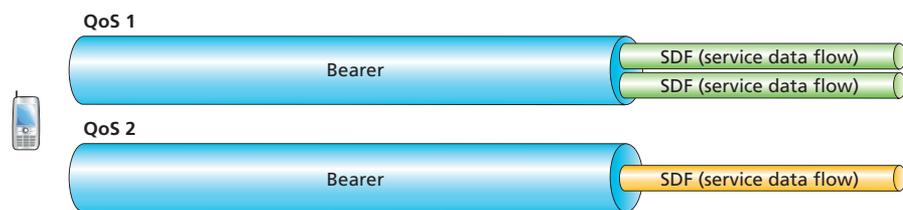
3.2 Packet Data Network Gateway

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). As an anchor point for sessions towards the external Packet Data Networks, the PDN GW supports:

- Policy enforcement features (applies operator-defined rules for resource allocation and usage)
- Packet filtering (for example, deep packet inspection for application type detection)
- Charging support (for example, per-URL charging)

In LTE, data plane traffic is carried over virtual connections called service data flows (SDFs). SDFs, in turn, are carried over bearers — virtual containers with unique QoS characteristics. Figure 4 illustrates the scenario where one or more SDFs are aggregated and carried over one bearer.

Figure 4. Service data flows and bearers

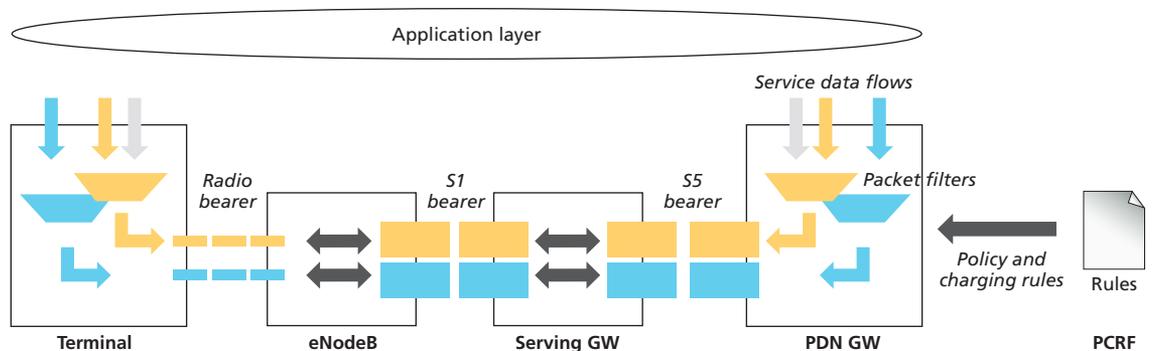


One bearer, a datapath between a UE and a PDN, has three segments:

- Radio bearer between UE and eNodeB
- Data bearer between eNodeB and SGW (S1 bearer)
- Data bearer between SGW and PGW (S5 bearer)

Figure 5 illustrates three segments that constitute an end-to-end bearer. The primary role of a PGW is QoS enforcement for each of these SDFs, while SGW focuses on dynamic management of bearers.

Figure 5. End-to-end data path in LTE



3.3 Mobility Management Entity

The Mobility Management Entity (MME) is a nodal element within the LTE EPC. It 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.

MME manages thousands of eNodeB elements, which is one of the key differences from requirements previously seen in 2G/3G (on RNC/SGSN platforms). The MME is the key element for gateway selection within the EPC (Serving and PDN). It also performs signaling and selection of legacy gateways for handovers for other 2G/3G networks. The MME also performs the bearer management control functions to establish the bearer paths that the UE/ATs use.

The MME supports the following functions:

- *Security procedures*: End-user authentication as well as initiation and negotiation of ciphering and integrity protection algorithms.
- *Terminal-to-network session handling*: All the signaling procedures used to set up packet data context and negotiate associated parameters like QoS.
- *Idle terminal location management*: The tracking area update process used to enable the network to join terminals for incoming sessions.

3.4 Policy and Charging Rules Function

The major improvement provided in Release 7 of 3GPP in terms of policy and charging is the definition of a new converged architecture to allow the optimization of interactions between the Policy and Rules functions. The R7 evolution involves a new network node, Policy and Charging Rules Function (PCRF), which is a concatenation of Policy Decision Function (PDF) and Charging Rules Function (CRF).

Release 8 further enhances PCRF functionality by widening the scope of the Policy and Charging Control (PCC) framework to facilitate non-3GPP access to the network (for example, WiFi or fixed IP broadband access).

In the generic policy and charging control 3GPP model, the Policy and Charging Enforcement Function (PCEF) is the generic name for the functional entity that supports service data flow detection, policy enforcement and flow-based charging. The Application Function (AF) here represents the network element that supports applications that require dynamic policy and/or charging control. In the IMS model, the AF is implemented by the Proxy Call Session Control Function (P-CSCF).

Figure 6. Key PCRF interfaces

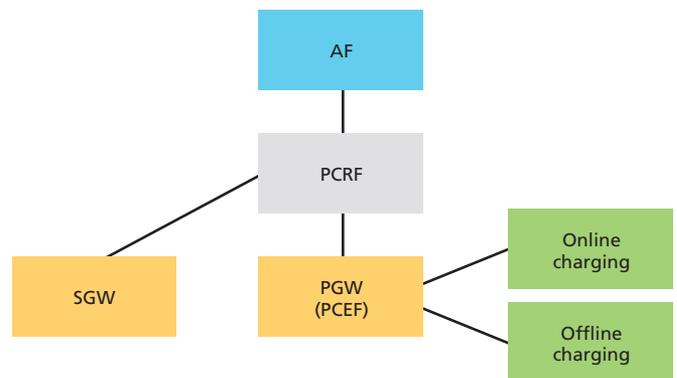


Figure 6 shows how PCRF interfaces with other EPC elements.

4. EPC challenges

As EPC radically changes key networking paradigms for previous generations of mobile core networks, the introduction of Evolved Packet Core must successfully address a number of technological challenges.

In LTE, there are significant technological advances on the radio side (eNodeB). LTE provides more efficient use of the spectrum with wider spectral bands reserved for LTE. This results in greater system capacity and performance. At the same time, the mobile core needs to change to provide higher throughput and low latency; both should come as results of the simplified and improved flat all-IP network architecture.

Delivery of the superior LTE solution and the introduction of new technologies — both on the radio side and in the core — is an important task. The existing (2G/3G) mobile cores, designed and engineered for low-speed, best-effort data, cannot provide the required scalability or ensure high performance.

EPC needs to address a number of key IP aspects for deployment in LTE:

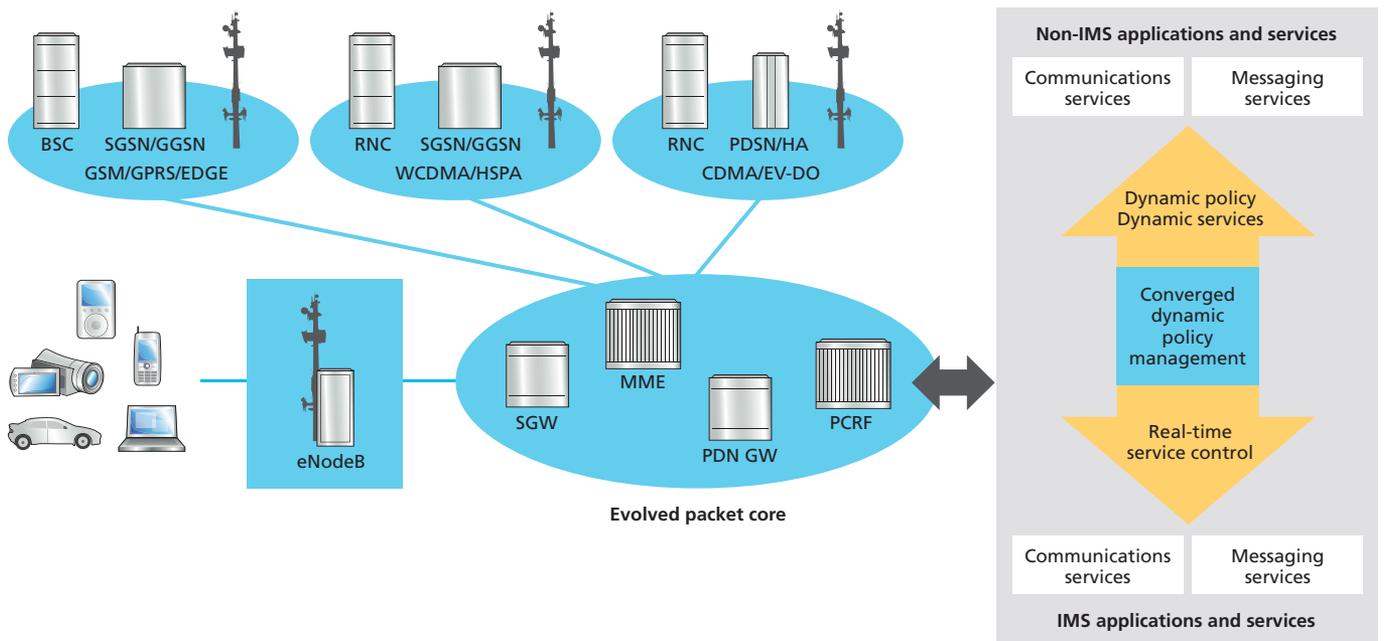
- IP routing and network addressing, and real-time management if IP domains are large
- Centralized vs. distributed network architecture (for MME, SGW and PGW deployment)
- IPv6 (strategy, introduction, coordination with IPv4)

- End-to-end QoS deployment and coordination with underlying transport
- L2 vs. L3 connectivity at the transport layer (eNodeB, SGW, PGW, MME)
- End-to-end security for data and control plane
- Interconnectivity to external networks and VPNs
- Deep Packet Inspection, Lawful Interception

There is a stringent set of requirements for reliable, scalable, high-performance elements due to the dynamic nature of user mobility in LTE, coupled with the short duration of multiple data sessions per UE and large-scale deployment targets. To meet these demands, the EPC elements must be best in class, with superior IP performance. On the product (network element) level, in order to address all these important aspects of EPC's introduction, a new generation of purpose-built, highly scalable mobile core equipment is required, and a strong IP expertise is needed.

Putting all these elements together is as important as delivering all elements with the needed carrier-grade features for LTE. EPC elements must interwork in full harmony as the fairly complex network procedures involve all EPC elements, in both control and user planes. The EPC must address the demanding requirements for multi-dimensional, dynamic management of mobility, policies and data bearers - in an orchestrated manner that enables the highest LTE performance, while ensuring interworking and interoperability with legacy 3G/2G systems. Figure 7 illustrates the dynamic nature of policy and mobility management in LTE.

Figure 7. EPC: Dynamic management of mobility, data sessions and network policies



5. Abbreviations

3GPP	3rd Generation Partnership Project	MNC	Mobile Network Code
3GPP2	3rd Generation Partnership Project 2	MSC	Mobile Switching Center
AF	Application Function	MT	Mobile Terminal
AS	Access Stratum	NAS	Non Access Stratum
CDF	Charging Data Function	NGN	Next Generation Network
CDMA	Code Division Multiple Access	OFDM	Orthogonal Frequency Division Multiplexing
CDR	Charging Data Record	OFDMA	Orthogonal Frequency Division Multiple Access
CGF	Charging Gateway Function	P-GW	PDN Gateway
CRF	Charging Rules Function	PCEF	Policy and Charging Enforcement Function
CS	Circuit Switched	PCRF	Policy and Charging Rules Function
CSCF	Call Session Control Function	PDCP	Packet Data Convergence Protocol
DL	Downlink	PDF	Policy Decision Function
E-UTRAN	Evolved-UTRAN	PDP Context	Packet Data Protocol Context
EDGE	Enhanced Data rates for GSM Evolution	PLMN	Public Land Mobile Network
EMM	EPS Mobility Management	PoC	Push-to-talk over Cellular
eNodeB	evolved NodeB	PS	Packet Switched domain
EPC	Evolved Packet Core	PSTN	Public Switched Telephone Network
EPS	Evolved Packet System	RNC	Radio Network Control
GERAN	GPRS EDGE Radio Access Network	S-GW	Serving Gateway
GGSN	Gateway GPRS Support Node	SAE	System Architecture Evolution
GMSC	Gateway Mobile Switching Center	SDF	Service Data Flow
GPRS	General Packet Radio Service	SGSN	Serving GPRS Support Node
GSM	Global System for Mobile communications	SIM	Subscriber Identity Module
GTP	GPRS Tunnelling Protocol	SIP	Session Initiation Protocol
HLR	Home Location Register	SM	Session Management
HSDPA	High Speed Downlink Packet Access	SMS	Short Message Service
HSPA	High Speed Packet Access	TA	Tracking Area
HSS	Home Subscriber Server	TCP	Transmission Control Protocol
HSUPA	High Speed Uplink Packet Access	TDMA	Time Division Multiple Access
IETF	Internet Engineering Task Force	TDD	Time Division Duplex
IEEE	Institute of Electrical and Electronics Engineers	TE	Terminal Equipment
IMS	IP Multimedia Subsystem	TISPAN	Telecommunication and Internet converged Services and Protocols for Advanced Networking
IMSI	International Mobile Subscriber Identity	UDP	User Datagram Protocol
IMT-2000	International Mobile Telecommunications 2000	UE	User Equipment
ISIM	IMS Subscriber Identity Module	UL	Up-Link
ITU	International Telecommunication Union	UMB	Ultra Mobile Broadband
LTE	Long Term Evolution	UMTS	Universal Mobile Telecommunications System
MBMS	Multimedia Broadcast and Multicast Service	USIM	Universal Subscriber Identity Module
MIMO	Multi Input Multi Output	UTRAN	Universal Terrestrial Radio Access Network
MGCF	Media Gateway Control Function	WCDMA	Wide band Code Division Multiple Access
MGW	Media Gateway	WiMAX	Worldwide Interoperability Microwave Access
MME	Mobility Management Entity		
MMD	MultiMedia Domain		

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