
# The Role of the Diameter Signaling Controller (DSC) in LTE and VoLTE

## A Whitepaper

## May 2012

**Abstract:** The evolution of the 2G/3G to 4G LTE mobile data network focuses on high data-rate, low-latency and packet-optimized architecture integrated with multi radio access technologies. At the heart is the all-IP Evolved Packet Core (EPC) and voice-over-LTE (VoLTE) reuses the IP Multimedia Subsystem (IMS). The control plane of the EPC utilizes Diameter as its base and introduces multiple additional interfaces and reuses the IMS interfaces. The standards bodies have largely ignored the carrier grade aspects of Diameter signaling, e.g., scalability, reliability, redundancy and management. This whitepaper describes the role of the Diameter Signaling Controller (DSC) to address these issues while also serving as a natural host for Diameter-based, value-added applications.

## Introduction

In this whitepaper, the architecture of LTE and VoLTE are presented together with the various Diameter interfaces. The DSC is introduced and the main features are outlined showing how they solve specific problems. Two use cases are included for the DSC in the home LTE network and in the roaming LTE network, together with a third use case where the DSC hosts Diameter-based, value-added applications.

## Diameter Interfaces in LTE and VoLTE

Diameter is used extensively for LTE and VoLTE. Figure 1 gives an overview of the main elements and interfaces that support 4G LTE, VoLTE using IMS and 2G/3G.

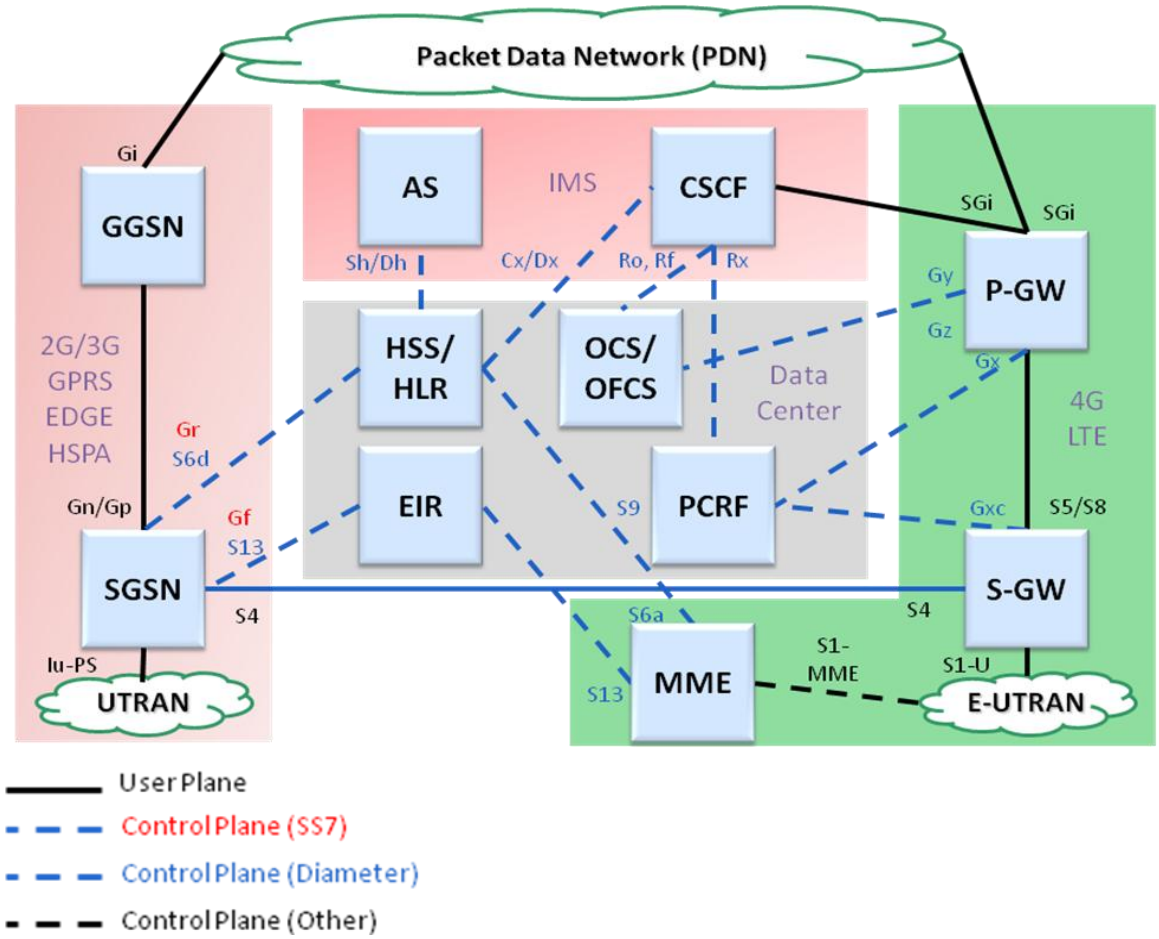


**Figure 1: Diameter Interfaces in LTE and VoLTE**

The evolution of the 2G/3G to 4G LTE mobile data network focuses on high data-rate, low-latency and packet-optimized architecture integrated with multi radio access technologies. At the heart is the all-IP Evolved Packet Core (EPC) featuring the Mobility Management Entity (MME), Serving Gateway (S-GW), PDN Gateway (P-GW) and Policy Charging Rules Function (PCRF). Voice-over-LTE (VoLTE) reuses the IP Multi-media

Subsystem (IMS) that includes the Call Session Control Function (CSCF) and Application Server (AS). The main elements of the 2G/3G network include the Serving GPRS Support Node (SGSN) and the Gateway GPRS Support Node (GGSN). Common to 2G/3G, 4G LTE and IMS are the Home Subscriber Server (HSS) and On-line/Off-line Charging System (OCS/OFCS). The control plane of the EPC utilizes Diameter as its base and introduces multiple additional interfaces, including Gx, Gxc, Gy, Gz, S6a, S6d, S9 and S13 and reuses the IMS interfaces, including Sh/Dh, Cx/Dx, Rx, Ro and Rf. Legacy SS7 interfaces used include Gr and Gf.

A subscriber with a 4G device attaches using the Evolved Universal Terrestrial Radio Access Network (E-UTRAN) and the MME uses the HSS/HLR and EIR to authenticate the subscriber and selects the S-GW and P-GW to give the UE access to the selected PDN. The S-GW and P-GW use the PCRF and OCS to set up the appropriate policy and charging for access to the PDN. A subscriber with a 2G/3G device attaches using the Universal Terrestrial Radio Access Network (UTRAN) and the SGSN and GGSN gives the UE access to the selected PDN. A subscriber with a UE that supports 2G/3G and 4G may roam across networks facilitated by the SGSN to S-GW S4 interface. For voice-over-LTE, the CSCF is involved which uses the HSS, OCS and PCRF to set up a voice call using the user plane thru the S-GW, P-GW to the CSCF using the SGi interface.

Typically, the network is architected with the HSS/HLR, EIR, PCRF and OCS/OFCS located in a central or regional data centers and the SGSN and MME/S-GW distributed across the network for optimal UTRAN/E-UTRAN access, and the GGSN and P-GW positioned for optimal access to the PDN.

Various events in the subscriber device generate Diameter signaling between the various network elements. Such events include attach, detach, tracking area updates that may or may not involve a change in MME/S-GW, policy modifications or charging updates. The distinguishing factor between 2G/3G and 4G is that the number of such events is significantly greater in 4G and they generate an order of magnitude more Diameter signaling than in 2G/3G or IMS.

## The Diameter Signaling Controller (DSC)

The Diameter Signaling Controller (DSC) has evolved from the Diameter relay, proxy and redirect agent defined in the Diameter base by the IETF to meet the needs of the EPC and IMS defined by the 3GPP and GSMA. The Diameter interfaces defined in 3GPP build on the base by adding new commands and AVPs as necessary to support the information flows defined between the elements of the EPC and IMS. The 3GPP also defines a specific use case of the Diameter Routing Agent (DRA) when binding is needed between multiple interfaces to a single instance of the PCRF. The GSMA defines use cases for roaming where a Diameter Edge Agent (DEA) is required to support LTE roaming, and also an Interworking Function (IWF) for LTE roaming into 2G/3G networks or vice versa. For IMS a Subscription Location Function (SLF) allows selection across multiple HSS instances.

However, these are just a few of the use cases that are required and the 3GPP and GSMA standards do not address the requirements of a carrier-grade infrastructure needed to support the Diameter signaling within the EPC and IMS. Figure 2 is a summary of the DSC and the features that need to be supported to make a carrier-grade Diameter infrastructure.

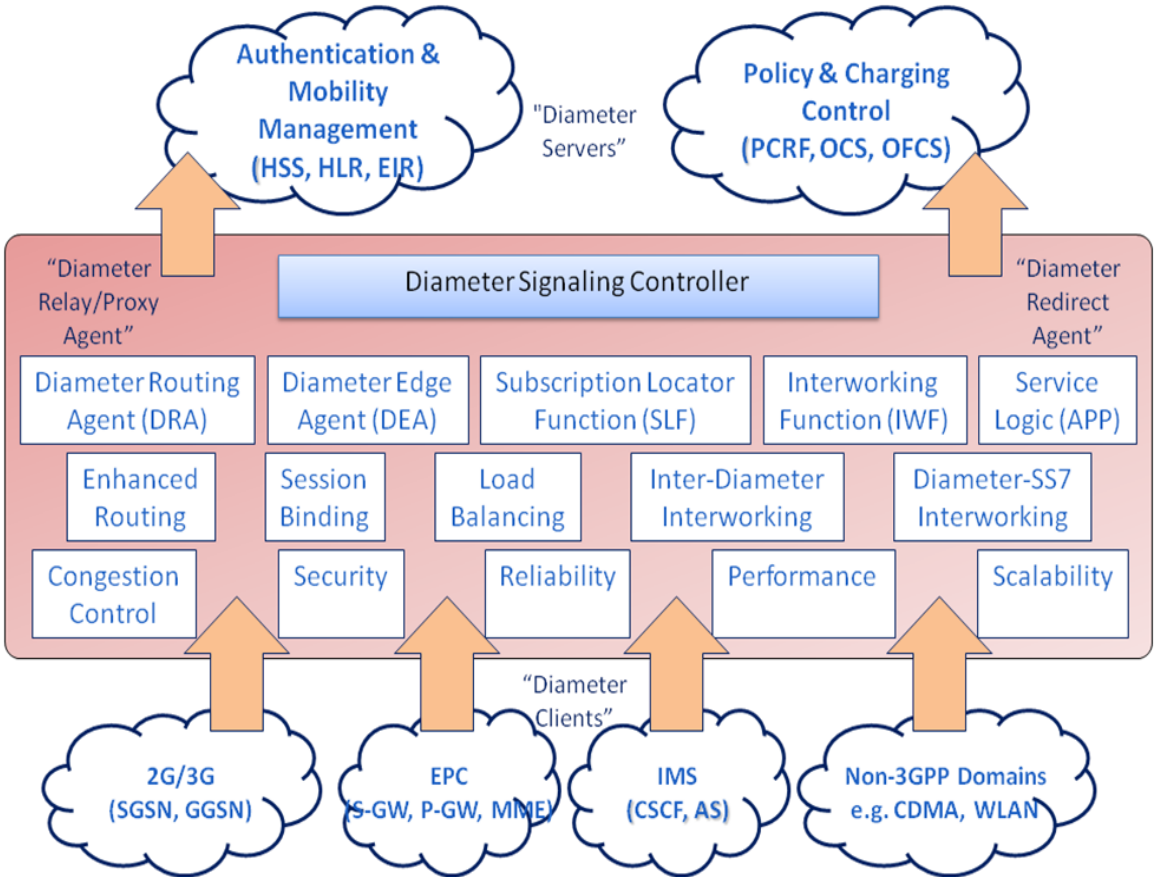


**Figure 2: Features of the Diameter Signaling Controller (DSC)**

The DSC acts as a Diameter Relay, Proxy or Redirect agent for the Diameter clients when accessing the Diameter Servers and provides the following features/benefits:

- **Enhanced Routing**: Rules for routing of Diameter messages may be dynamically configured using any AVP in the Diameter message, giving full flexibility for selecting the server in a distributed network.
- **Load Balancing**: Distribution of messages using multiple AVPs across multiple instances of the same server gives the ability to distribute traffic and facilitates scaling.
- **Session Binding**: Diameter messages are routed to the same instance of a Diameter server across multiple interfaces for the same device or session, which facilitates scaling.

- **Inter-Diameter Interworking**: Clients and servers from different vendors may support different releases or versions of the Diameter interfaces and rules-based interworking is required to allow interoperability. Also there may be differences in Diameter transport including TCP, SCTP, IPv4 and IPv6.
- **Diameter to SS7 Interworking**: Interworking between SS7 MAP/CAP to/from Diameter allows legacy clients to talk to 4G servers and vice-versa.
- **Congestion Control**: Local and peer congestion can be detected and traffic re-routed or rejected to overcome sustained or peak traffic conditions.
- **Security**: Support for TLS and IPsec give the ability to provide secure access for Diameter signaling.
- **Reliability**: Single site 5-nines or more availability and multi-site geographic redundancy in case of site failure gives total reliability of the Diameter signaling.
- **Performance**: Very high performance with low latency.
- **Scalability**: Ability to scale at a single site and distribute across multi-sites allows the network to scale indefinitely.

Finally, since the DSC has valuable information passing through it containing subscriber, policy and charging information which is contained in the different Diameter interfaces, it is a prime location to host value-added services. Hosting applications like roamer steering or real-time analytics has significant operational and CAPEX/OPEX advantages.

## The DSC for the Home LTE Network

The main driver for deploying a DSC in the home network is to facilitate scalability and address vendor interoperability as shown in Figure 3.

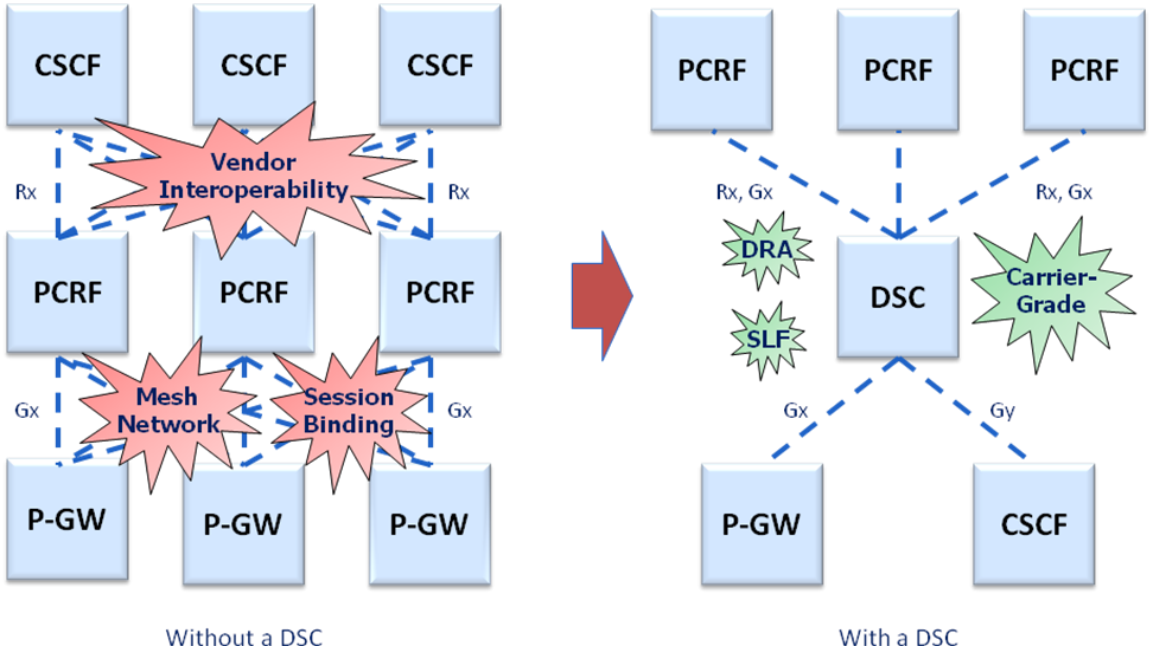


**Figure 3: DSC for the Home LTE Network**

As the network scales and has multiple instances of the same Diameter clients and servers, and as the architecture becomes distributed, the need for a DSC becomes more important. The number of peer to peer connections creates a mesh network that is difficult to manage, and there needs to be a single aggregation point where session binding to a specific server instance can be performed.

When there are multiple vendors for the Diameter clients and servers, and each may support a different 3GPP release of an interface, a different version of the same 3GPP release, a non-conforming version or a version with proprietary AVPs, then a DSC is needed to facilitate interoperability.

The DSC addresses these issues and more to provide a carrier-grade Diameter infrastructure in the Home LTE network that includes, but is not limited to, the 3GPP DRA for session binding the Rx, Gx and Gxc interfaces to a specific PCRF instance and a 3GPP SLF for IMS selection of the HSS.

## The DSC for the Roaming LTE Network

The main drivers for deploying a DSC for roaming across LTE networks is to facilitate security, topology hiding and address 2G/3G to 4G interoperability as shown in Figure 4.

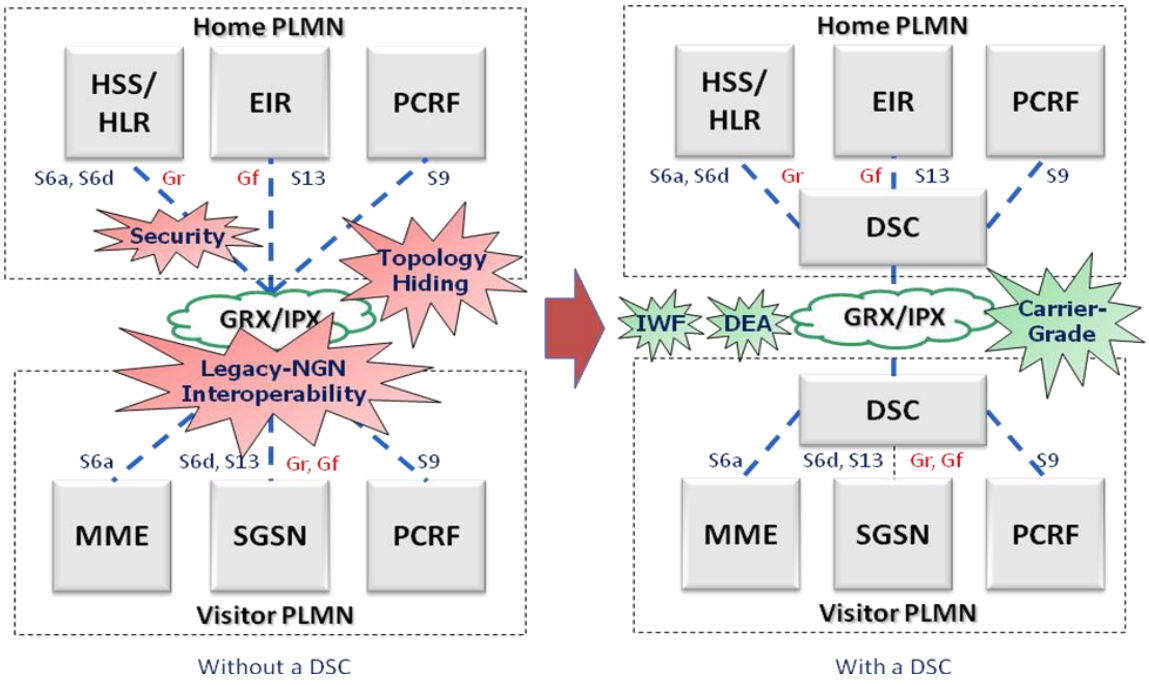


**Figure 4: DSC for the Roaming LTE Network**

When a subscriber roams across LTE networks the visitor PLMN needs to access Diameter servers in the home network to authenticate and control charging and policy. Even when using a GRX or IPX between PLMN's, both MNO's needs to address security

and topology hiding of their PLMN. A DSC can provide these capabilities at the edge of the PLMN.

When roaming from a 4G LTE network to a 2G/3G network, from a 2G/3G network to a 4G network or when there are legacy clients or servers, then a DSC is required to perform interworking of the interfaces from SS7 to Diameter or Diameter to SS7. For example, a MME may need to query using Diameter S6a to an HLR that supports MAP Gr then Diameter to MAP interworking is required, a S-GW may need to query using Diameter Gy to an OCS that supports CAP Ge then Diameter to CAP interworking is required.

The DSC addresses these issues and more to provide a carrier-grade Diameter infrastructure in the home and visitor LTE network that includes, but is not limited to, the GSMA DEA and IWF.

## The DSC for Hosting Diameter Applications

The DSC is located at the core of the Diameter signaling network and in the multitude of Diameter interfaces that pass thru the DSC there is significant information related to the subscriber, policy and charging that makes it an ideal place to locate value-added services as shown in Figure 5.

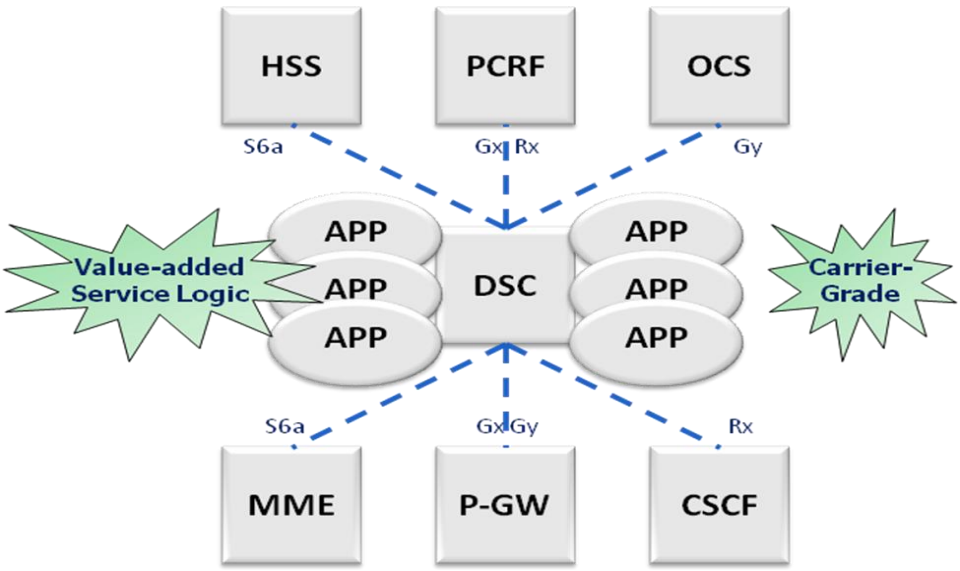


**Figure 5: DSC for Hosting Diameter Applications**

The S6a interface contains information related to the subscriber profile, location and security, the Gx interface contains information on QoS, gating and policy/traffic events, the Rx interface contains information on voice sessions and related events and the Gy/Gz interfaces contains information on charging and related events. Such information

may be utilized to provide value-added service like roamer steering or real-time analytics.

The DSC offers many advantages to host these value-added services. However, the carrier-grade characteristics of the DSC must not be compromised in order to maintain performance, latency and reliability of the Diameter signaling.

## Summary

The control plane of the LTE and IMS networks utilize Diameter in many variants to allow the "clients" in the EPC, IMS, 2G/3G and non-3GPP domains to access the "servers" in the Authentication & Mobility Management and Policy & Charging Control domains. The standards have done a good job in specifying the information flows between these clients and servers, however the carrier-grade infrastructure to support the explosion of Diameter signaling has been omitted. The role of the Diameter Signaling Controller (DSC) is built on the functionality of the DRA, DEA, SLF and IWF and supplements this with the scalability, reliability, redundancy and management capabilities that truly make the Diameter infrastructure carrier-grade. With the richness of the information that flows thru the DSC, this makes it a natural host for value-added applications like roamer steering and real-time analytics.

**About Diametriq:**

Built on the assets of IntelliNet Technologies, a wireless solutions company founded in 1992, Diametriq offers high performance Diameter signaling solutions to meet the needs of LTE wireless operators. The company's standards compliant Diameter Routing Engine™(DRE) includes a Diameter Routing Agent (DRA), Diameter Edge Agent (DEA), a Subscription Locator Function (SLF) and a Diameter Interworking Function (IWF). For more information, visit www.diametriq.com.

## Definitions

| Acronym | Reference | Description |
|---|---|---|
| 3GPP | 3GPP | 3rd Generation Partnership Project. |
| AS | 3GPP | Application Server. An IMS Application Server using SIP. |
| CAMEL | 3GPP | Customized Applications for Mobile network Enhanced Logic |
| CAP | 3GPP | CAMEL Application Part. The TCAP-based SS7 protocol used for IN services. |
| CSCF | 3GPP | Call Session Control Function |
| Cx | 3GPP | The Cx reference point supports information transfer between CSCF and HSS. |
| DEA | GSMA | Diameter Edge Agent. The Diameter proxy agent used in LTE roaming scenarios. |
| Dh | 3GPP | This interface between AS and SLF is used to retrieve the address of the HSS. |
| DRA | 3GPP | Diameter Routing Agent. A DRA ensures that all Diameter sessions for Gx, S9, Gxc and Rx reach the same PCRF when multiple PCRFs are deployed. |
| DRE | Diametriq | Diameter Routing Element. The Diametriq product that implements a DSC. |
| DSC | General | Diameter Signaling Controller. The general term used by the market for a Diameter Agent for all use cases including DRA, DEA, SLF and IWF. |
| Dx | 3GPP | This interface between CSCF and SLF is used to retrieve the address of the HSS. |
| EDGE | 3GPP | Enhanced Data rates for GSM Evolution. The 2.75G data service provided by 3GPP |
| EIR | 3GPP | Equipment Identity Register - The GSM system that stores International Mobile Equipment Identities (IMEI). |
| EPC | 3GPP | Evolved Packet Core. The evolution of the GPRS network to an all IP network consisting of MME, S-GW, P-GW and PCRF. |
| E-UTRAN | 3GPP | Evolved UTRAN. The evolution of the UTRAN to support all-IP LTE. |
| Ge | 3GPP | gprsSSF to gsmSCF. This interface is used by the gsmSCF to control charging for a GPRS session. |
| Gf | 3GPP | This interface is used between SGSN and EIR to verify the status of the IMEI retrieved from the Mobile Station. |
| GGSN | 3GPP | Gateway GPRS Support Node |
| GPRS | 3GPP | General Packet Radio Service. The 2.5G data service provided by 3GPP |
| Gr | 3GPP | SGSN and HLR. This interface is used perform mobility management of the subscriber. |
| GRX | GSMA | GPRS Roaming eXchange. Provides routing and interconnecting for GPRS/UMTS/LTE roaming. |
| GSM | 3GPP | Global System for Mobile. GSM (originally *Groupe Spécial Mobile*), is a standard set developed by the European Telecommunications Standards Institute (ETSI) to describe technologies for second generation (or "2G") digital cellular networks. |
| GSMA | GSMA | GSM Association |
| Gx | 3GPP | PCEF - PCRF/H-PCRF/V-PCRF. This interface provides transfer of policy and charging rules from PCRF. |
| Gxc | 3GPP | S-GW - PCRF/VPCRF. This interface provides transfer of (QoS) policy information from PCRF to the S-GW. |
| Gy | 3GPP | OCS – PCEF. This interface allows for online charging based on the Diameter credit control application. |
| Gz | 3GPP | OFCS – PCEF. This interface allows for the offline charging. |

| Acronym | Reference | Description |
|---|---|---|
| HLR | 3GPP | Home Location Register – the HLR is where subscriber data is stored. |
| H-PCRF | 3GPP | Home PCRF |
| H-PLMN | 3GPP | Home PLMN |
| HSS | 3GPP | Home Subscriber Server - The HSS is the master database for a given user. |
| HSPA | 3GPP | High-Speed Packet Access. The 3G data service provided by 3GPP |
| IMS | 3GPP | IP Multimedia Subsystem - Comprises all CN elements providing multimedia services over the packet domain. |
| IPX | GSMA | IP Packet eXchange. The entity providing the IP connectivity between MNO's. |
| Iu-PS | 3GPP | Interface between the UTRAN and the SGSN. |
| IWF | 3GPP | Interworking Function |
| LTE | 3GPP | Long Term Evolution. |
| MAP | 3GPP | Mobile Application Part. The TCAP-based SS7 protocol used for access to the HLR. |
| MME | 3GPP | Mobile Management Entity - MME is the control plane entity within EPS |
| OCFS | 3GPP | Off-line Charging System. The entity that performs charging in non-real time. |
| OCS | 3GPP | On-line Charging System. The entity that performs real-time credit control. |
| PCRF | 3GPP | Policy and Charging Rules Function - The PCRF acts as a policy decision point for policy and charging control of service data flows and IP bearer resources |
| PDN | 3GPP | Packet Data Network |
| P-GW | 3GPP | PDN Gateway - The P-GW is the gateway which terminates the interface towards PDN. |
| PLMN | 3GPP | Public Land Mobile Network. |
| Ro | 3GPP | Online charging reference point between a 3G network element and the OCS. |
| Rf | 3GPP | Offline charging reference point between a 3G network element and the OFCS |
| Rx | 3GPP | PCRF - Application Function. This interface allows for dynamic QoS and charging-related service information to be exchanged between the Policy and Charging Rules Function (PCRF) and the Application Function (AF). |
| S1 | 3GPP | Interface between E-UTRAN and EPC. S1-MME is control plane to MME and S1-U is user plane to S-GW. |
| S13 | 3GPP | Interface between MME and EIR - This interface is used between MME and EIR to exchange data, in order that the EIR can verify the status of the IMEI retrieved from the Mobile Station. |
| S6a | 3GPP | Interface between MME and HSS - This interface is used to exchange the data related to the location of the mobile station and to the management of the subscriber |
| S6d | 3GPP | Interface between SGSN and HSS - This interface is used to exchange the data related to the location of the mobile station and to the management of the subscriber |
| S9 | 3GPP | HPCRF – VPCRF. This interface provides transfer of policy and charging rules (in case of local breakout of traffic) and/or (QoS) policy information (when Gxx interface applies) between the Home PCRF and the Visited PCRF to support PCC roaming related functions |
| SGSN | 3GPP | Serving GPRS Support Node |
| S-GW | 3GPP | Serving Gateway - The S-GW is the gateway which terminates the interface towards E-UTRAN. |

| Acronym | Reference | Description |
|---|---|---|
| SLF | 3GPP | Subscription Location Function - The SLF selects the HSS containing the required subscriber specific data. |
| Sh | 3GPP | The Application Server (SIP Application Server and/or the OSA Service Capability Server) may communicate to the HSS. The Sh interface is used for this purpose |
| User Plane | 3GPP | The interfaces across the 2G/3G and 4G networks that carry subscriber data sessions including Gn, Gp, Gi, S4, S5, S8 and SGi. |
| UTRAN | 3GPP | Universal Terrestrial Radio Access Network. A collective term for the Node B's and Radio Network Controllers which make up the UMTS radio access network. |
| VoLTE | 3GPP | Voice-over-LTE. The use of IMS to deliver voice services using data sessions over the E-UTRAN. |
| V-PCRF | 3GPP | Visitor PCRF |
| V-PLMN | 3GPP | Visitor PLMN |
| WLAN | 3GPP | Wireless Local Area Network. The non-3GPP access to the EPC. |

## References

| Document | Title |
|---|---|
| 3GPP TS 23.002 | Network Architecture |
| 3GPP TS 23.203 | Policy and Charging Control Architecture |
| 3GPP TS 29.213 | Policy and Charging Control signaling flows and QOS mapping (includes definition of DRA) |
| 3GPP TS 23.401 | GPRS Enhancements for E-UTRAN |
| 3GPP TS 23.402 | Architecture for non-3GPP Access |
| 3GPP TS 29.909 | Diameter-based protocols usage and recommendations in 3GPP |
| 3GPP TS 29.328<br>3GPP TS 29.329 | IMS Sh Interface; Signaling flows and message contents<br>IMS Sh Interface; Protocol details |
| 3GPP TS 29.228<br>3GPP TS 29.229 | IMS Cx and Dx Interface; Signaling flows and message contents<br>IMS Cx and Dx Interface; Protocol details |
| 3GPP TS 29.214 | Policy and Charging Control over Rx |
| 3GPP TS 29.212 | Policy and Charging Control over Gx. (includes definition of Gxc). |
| 3GPP TS 29.215 | Policy and Charging Control over S9. |
| 3GPP TS 29.272 | MME and SGSN related interfaces based on Diameter |
| 3GPP TS 29.002 | Mobile Application Part (MAP) specification (specifies Gr, Gf interfaces) |
| 3GPP TS 29.078 | CAMEL Application Part (CAP) specification (specifies Ge interface) |
| 3GPP TS 32.240 | Charging architecture and principles |
| 3GPP TS 32.299 | Diameter charging applications |
| 3GPP TS 32.251 | Packet Switched (PS) domain charging |
| 3GPP TS 32.295 | Charging Data Record (CDR) Transfer |
| 3GPP TS 32.225 | Charging Data Description for the IMS |
| 3GPP TS 29.305 | 3GPP Interworking Function (IWF) between MAP and Diameter based Interfaces |
| GSMA IR.88 | LTE Roaming Guidelines |
| IETF RFC 3588 | Diameter Base |
| IETF RFC 4006 | Diameter Credit Control Application |
| IETF RFC 4346 | The Transport Layer Security (TLS) Protocol Version 1.1 |
| IETF RFC 5246 | The Transport Layer Security (TLS) Protocol Version 1.2 |
| IETF RFC 3539 | Authentication, Authorization and Accounting (AAA) Transport Profile |