The Evolution of Diameter Signaling

A Whitepaper

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Abstract: The network architecture of the mobile core has evolved to be more complex with many more elements and interfaces added in each release and the signaling has evolved from SS7 to Diameter. This paper analyzes the evolution of the 3GPP mobile core and its interfaces and tracks the evolution of SS7 to Diameter.

Introduction

In this whitepaper, the evolution of the 3GPP architecture from 2G to 4G is presented for the delivery of voice, data and multi-media services. Each successive release of the mobile core architecture is more complex in terms of elements and interfaces and the signaling of the control plan has evolved from SS7 to Diameter.

3GPP Evolution from 2G to 4G

The 3GPP has evolved in releases originally identified by year and then from 2000 by release number as shown in Figure 1 which also identifies the main features introduced in each release and the main elements to support voice, data, multimedia and centralized databases.

Rel-ease	G	Main Features	Voice/Media Elements	Data Elements	Database Elements
96	2	GSM	MSC, GMSC	-	HLR, EIR, SCP
97	2.5	GPRS	"	SGSN, GGSN	"
98	2.75	EDGE	"	"	"
99(3)	3	UMTS	"	"	"
4	3	All IP core	(G)MSC-SVR, CS-MGW	"	"
5	3	IMS	[P|S|I]-CSCF	"	HSS, AS, IM-SSF
6	3.5	HSPA, WLAN	"	PDG, AAA	CRF, PDF
7	3.75	HSPA+	E-CSCF	"	PCRF, O(F)CS
8	3.9	LTE	"	MME, [S|P]-GW ePDG	"
9	3.9	WiMAX	"	"	"
10	4	LTE Advanced	"	"	"

Figure 1: 3GPP Evolution

The elements necessary to support voice and multi-media has evolved from release 96 where an MSC and G-MSC was used to support voice. In release 4 when the all-IP core was introduced a soft-switch approach was taken where the control plane was separated into the MSC Server (MSC-SVR) and the user plane in the Circuit-Switched Media Gateway (CS-MGW). Release 6 introduced the IP multimedia subsystem (IMS) where a SIP-based control plane was introduced with a network of Proxy (P-), Serving (S-) and Interrogating (I-) Call Session Control Function (CSCF) to deliver multi-media services .This was supplemented in release 7 by an Emergency CSCF (E-CSCF) to support emergency calls.

The elements necessary to support data started from release 97 where a SGSN and GGSN were used. In release 6, a PDG was introduced to integrate WLAN access into the mobile core together with an AAA server to support authentication. In release 8 for LTE, the Serving Gateway (S-GW) and the PDN Gateway (P-GW) was introduced. To support the generic non-3GPP, non-trusted access the PDG was extended and enhanced to the ePDG.

For the database elements, the subscriber database started as the HLR, and with the introduction of IMS in release 5 became the HSS. The SCP was used for generic services, but included the prepaid service that evolved into the On-line Charging System (OCS) which was introduced in release 7 together with the Off-line Charging System (OFCS). In release 5, an Application Server (AS) was added to host IMS services with access to legacy SCP using an IM-SSF. In release 6, the Charging Rules Function (CRF) and the Policy Decision Function (PDF) were introduced and combined in release 8 as the Policy and Charging Rules Function (PCRF).

2G Architecture

The architecture of the 2G mobile core for providing voice and data service is shown in Figure 2. It utilizes SS7 control plane signaling to communicate from the voice and data network elements to the centralized databases of the HLR, EIR and SCP.

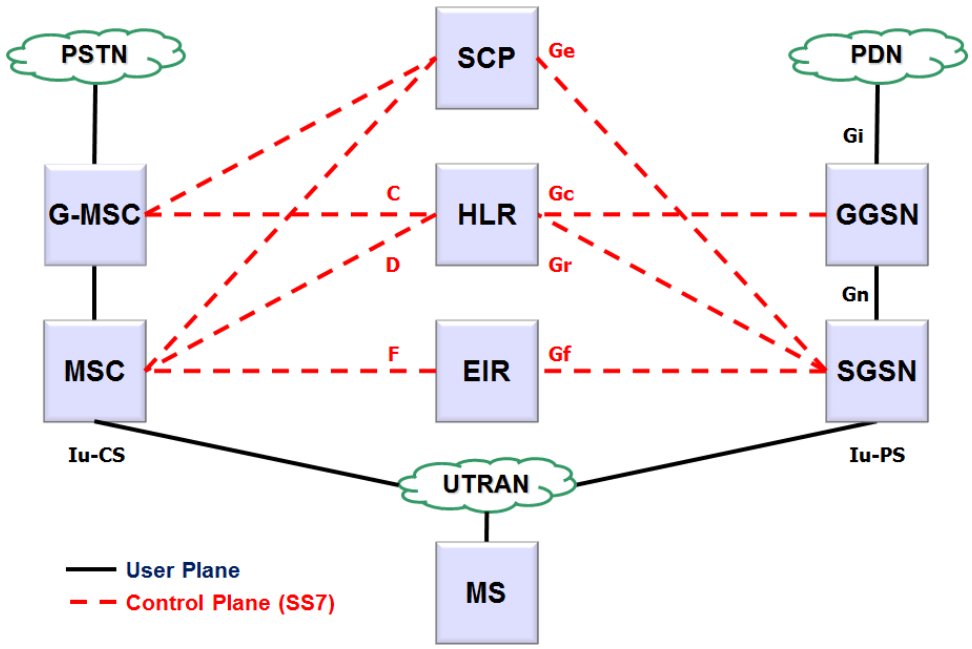

Figure 2: 2G Architecture for Voice & Data

3G Architecture

The architecture of the 3G mobile core for providing voice service is shown in Figure 3. It utilizes SS7 control plane signaling to communicate from the voice network elements to the centralized databases of the HLR/HSS, EIR and SCP.

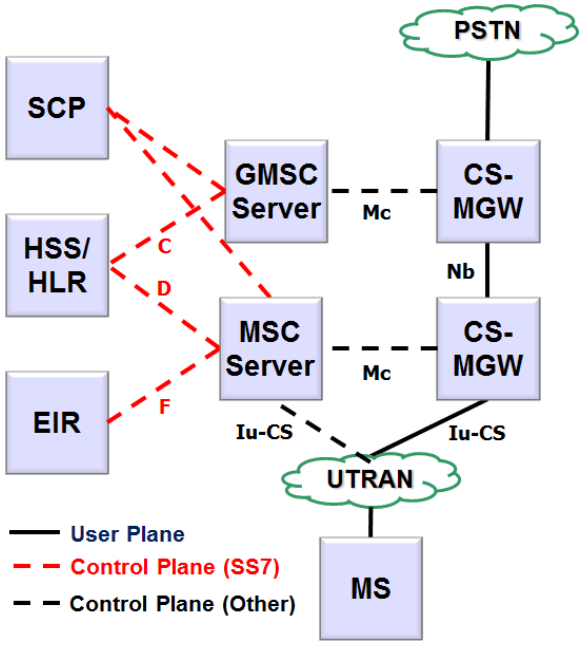

Figure 3: 3G Architecture for Voice

The architecture of the 3G mobile core for providing data service is shown in Figure 4. It utilizes SS7 and Diameter control plane signaling to communicate from the data network elements to the centralized databases of the HLR/HSS, EIR, SCP, OCS and PCRF.

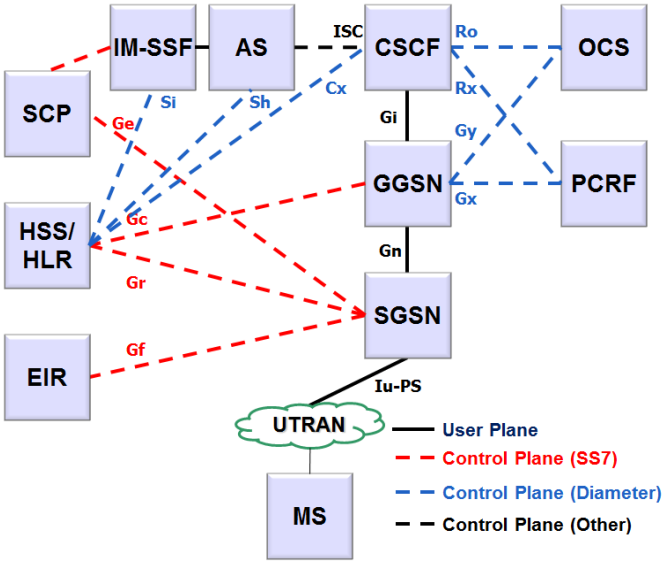

Figure 4: 3G Architecture for Data/Multi-Media

4G Architecture

The architecture of the 2G mobile core for providing data service is shown in Figure 5. It utilizes Diameter control plane signaling to communicate from the data network elements to the centralized databases of the HSS, EIR, OCS and PCRF.

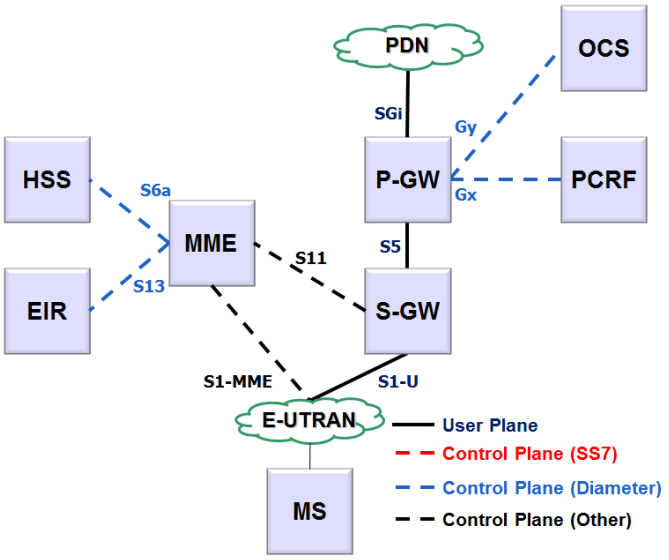

Figure 5: 4G Architecture for Data (LTE)

The architecture of the 4G mobile core for providing voice service is shown in Figure 6. It utilizes Diameter control plane signaling to communicate from the data network elements to the centralized databases of the HSS, EIR, OCS and PCRF.

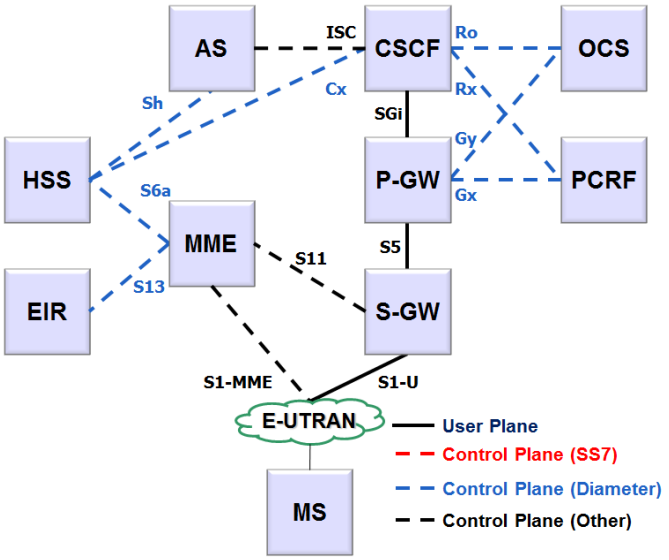

Figure 6: 4G Architecture for Voice/Multi-Media (VoLTE)

Evolution of Interfaces from SS7 to Diameter

We have seen in the evolution from the 2G to 4G architecture that the mobile core has increased in complexity in term of the number of network elements and the interfaces

between them. Also over time, the interfaces have evolved from SS7 to Diameter as shown in Figure 7.

Network Element	2G Voice	2G Data	3G Voice	3G Data	3G MM	4G Data	4G MM
HLR	C, D	Gc, Gr	-	-	-	-	-
EIR	F	G	F	G	-	S13	S13
SCP	CAP	Ge	CAP	Ge	CAP	-	-
HSS	-	-	C, D	Gc, Gr	Gc, Gr Si, Sh, Cx	S6a	S6a, Sh, Cx
PCRF	-	-	-	Gx	Gx, Rx	Gx	Gx, Rx
OCS	-	-	-	Gy	Gy, Ro	Gy	Gy, Ro
OFCS	-	-	-	Gz	Gy, Rf	Gz	Gz, Rf

SS7 Interface → Diameter Interface

Figure 7: Evolution of Interfaces from SS7 to Diameter

Summary

The 3GPP mobile core has evolved over the past 15+ years and has become more complex with many more elements. It has transitioned from a circuit-based core to a packet-based core supporting data-oriented devices rather than voice-centric devices. The signaling interfaces have evolved from SS7 to Diameter and new functions have been introduced like policy. Where will the network go next as we moved ahead to the 5G network!

Definitions

Acronym	Reference	Description
AS/AF	3GPP	Application Server/Function.
CSCF(P-,S-,I-,E-)	3GPP	Call Session Control Function (Proxy, Serving, Interrogating, Emergency)
Cx/Dx	3GPP	Interface between CSCF and HSS/SLF.
DEA	GSMA	Diameter Edge Agent.
DRA	3GPP	Diameter Routing Agent.
DRE	Diametriq	Diameter Routing Element.
DSC	General	Diameter Signaling Controller.
EIR	3GPP	Equipment Identity Register.
EPC	3GPP	Evolved Packet Core.
UTRAN/E-UTRAN	3GPP	Universal Terrestrial Radio Access Network - Evolved UTRAN.
Ge	3GPP	Interface between gprsSSF (SGSN) to gsmSCF (SCP)
Gf/Gr	3GPP	Interface between SGSN and EIR/HLR.
GGSN/SGSN	3GPP	Gateway/Serving GPRS Support Node
GRX	GSMA	GPRS Roaming eXchange.
Gx/Gxc	3GPP	Interface between P-GW/S-GW and PCRF
Gy/Gz	3GPP	Interface between OCS/OFCS and PCEF.
HLR	3GPP	Home Location Register.
H-PCRF/V-PCRF	3GPP	Home/Visitor PCRF
H-PLMN/V-PLMN	3GPP	Home/Visitor Public Land Mobile Network.
HSS	3GPP	Home Subscriber Server
IPX	GSMA	IP Packet eXchange.
Iu-CS/Iu-PS	3GPP	Interface between the UTRAN and the MSC/SGSN.
MAP	3GPP	Mobile Application Part.
MME	3GPP	Mobile Management Entity.
MSC/GMSC	3GPP	Mobile Switching Center or Gateway-MSC
OCS/OCFS	3GPP	On-line/Off-line Charging System.
PCRF	3GPP	Policy and Charging Rules Function.
PDG/ePDG	3GPP	Packet Data Gateway – Evolved PDG
PDN	3GPP	Packet Data Network
P-GW/S-GW	3GPP	PDN/Serving Gateway.
Ro/Rf	3GPP	Interface between the CSCF and OCS/OFCS.
Rx	3GPP	Interface between the CSCF and PCRF.
S13/S13’	3GPP	Interface between MME/SGSN and EIR.
S6a/S6d	3GPP	Interface between MME/SGSN and HSS .
S9	3GPP	Interface between the H-PCRF and V-PCRF.
SLF	3GPP	Subscription Location Function.
Sh/Si/Dh	3GPP	Interface between the AS/IM-SSF and HSS/SLF.
User Plane	3GPP	Carries data across the interfaces Gn, Gp, Gi, S1, S4, S5, S8 and SGi.
VoLTE	3GPP	Voice-over-LTE.

About Diametriq:

Diametriq, offering LTE control signaling solutions to meet the needs of LTE network operators, was built on the assets of IntelliNet Technologies, a wireless solutions company founded in 1992. The company’s services-enabled Diameter Routing Engine™ (DRE) addresses traffic management, interoperability and service migration issues. The 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, visitwww.diametriq.com.