Measuring the Explosion of LTE Signaling Traffic - A Diameter Traffic Model

A Whitepaper

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Abstract: Many of us in the industry have been talking for some time about the "signaling storm" and how Diameter signaling traffic will be clogging the control plane. Has anyone taken the time and effort to study this problem in depth? We at Diametriq have developed a model and did the analysis –*the results may surprise you!* This paper analyzes the combination of the increasing complexity of the mobile core, the explosion of devices, applications and events that require more interaction with the core and presents a model that calculates the amount of signaling traffic a 4G network will be required to handle.

Introduction

In the previous Diametriq whitepaper, we investigated the sources of the explosion of Diameter signaling in 4G LTE and VoLTE networks. In this whitepaper we develop the methodology for a traffic model that captures the key variables that dictate the degree of growth of Diameter traffic. An analysis of the number of devices, the number of events per device, the number of elements and interfaces involved per event shows the explosion in the number of Diameter messages in LTE and VoLTE. A sample traffic model is included here, but there is also a version of the model available on the Diametriq web site at http://www.diametriq.com/lte-signaling-traffic-model/ that allows you to customize the key variables for a personalized traffic model. A more detailed traffic model with more variables and a higher degree of customization may be requested by contacting Diametriq at info@diametriq.com.

The 4G Architecture

The architecture of the 4G mobile core for providing data and voice service is shown in Figure 1. It utilizes Diameter control plane signaling to communicate from the data network elements to the centralized databases of the HSS, EIR, OCS and PCRF.

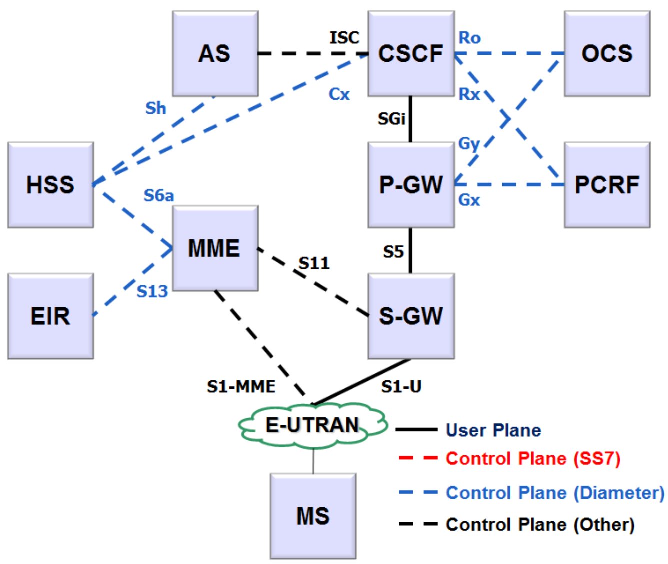

Figure 1: 4G Architecture for Data (LTE) and Voice/Multi-Media (VoLTE)

For this model, the Diameter interfaces to the HSS, EIR, PCRF and OCS are considered. The events that originate from the Mobile Station (MS), e.g., attach, detach, and interact with the Mobile Management Entity (MME), the Serving-Gateway (S-GW) and the PDN Gateway (P-GW) in the EPC core and the Call Session Control Function (CSCF) and Application Server (AS) in the IMS core. The EPC and IMS use the S6a, S13, Sh, Cx interfaces to the HSS/EIR, use Gx/Rx to the PCRF and Gy/Ro to the OCS.

The Diameter Traffic Model

The model is based on events that originate from the mobile station (MS). Each of the events result in actions at the MME, S-GW, P-GW, CSCF and AS that trigger Diameter messages to the HSS/EIR, PCRF and OCS.

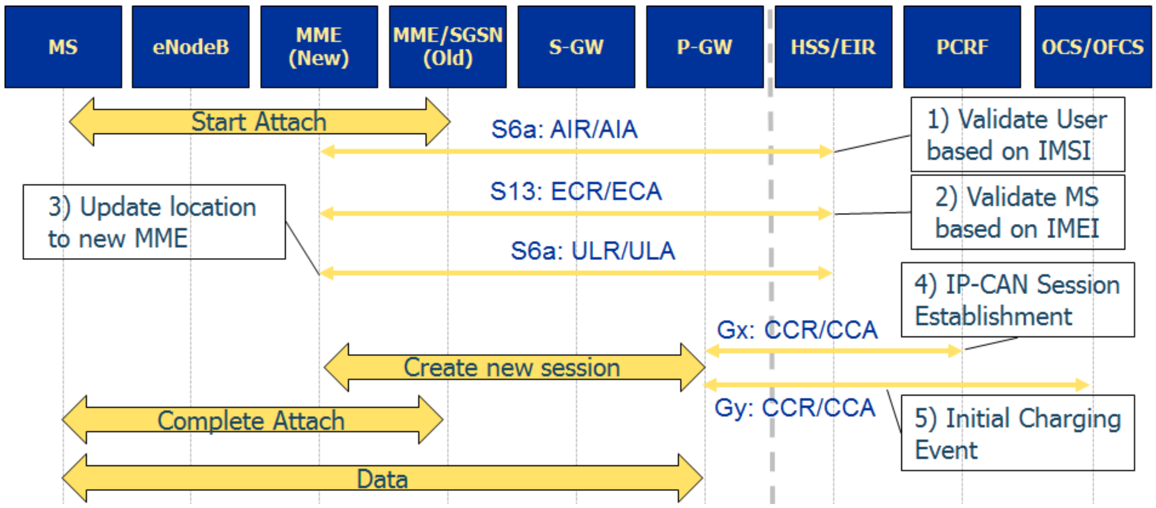

Figure 2: Diameter Messages for Device Attach Procedure

The following are the types of event and the types of Diameter messaging they trigger.

- Attach of the MS to the E-UTRAN: This requires authentication of the MS at the HSS and the EIR using S6a/S13. The HSS updates the MME with the subscriber data, the default data session is created at the S-GW and P-GW requiring policy using Gx from the PCRF and reports the initial charging event using Gy to the OCS. A summary of this procedure is given in Figure 2. There are also variations of this procedure depending on whether the MS is attaching to the same MME as the previous attach (MS in the same tracking area) and whether the default P-GW is being used.
- Tracking Area Update: When the device attaches, it is assigned a list of tracking areas as the registration area. When the MS moves outside the registration area a procedure is required with the MME, S-GW and P-GW to update the location of the MS and possibly change the S-GW and/or MME that involves the use of S6a to the HSS and Gx to the PCRF.
- Service Request: The MS or the network may decide that the data session needs to be modified, e.g. to increase the QoS for a video download or reduce the QoS when the S-GW is overloaded. This requires modification of the data session at the S-GW and P-GW that involves the use of S6a to the HSS and Gx to the PCRF.
- Detach of the MS from the E-UTRAN: When the MS is powered off or the MS has not be used for a prolonged period it detaches from the E-UTRAN requiring the use of the S6a, Gx and Gy.

Additionally, when VoLTE is used, there is a SIP-based client in the MS that uses the data session for the following the types of events and the types of Diameter messaging they trigger.

- SIP Registration: After the MS attaches to the E-UTRAN the SIP client registers with CSCF and uses the Cx interface to the HSS for authentication.
- SIP Re-fresh registration: At regular intervals, the SIP client has to re-register with the CSCF.
- Voice call: When a call is made using the SIP client, the CSCF and AS is involved to deliver the voice/MMS over the data session thru the S-GW and P-GW. The Cx/Sh interface to the HSS is used as well as the Rx interface to the PCRF and the Ro interface to the OCS.
- SIP Deregistration: The SIP client deregisters with the CSCF.

The Diameter Traffic Model uses these scenarios to calculate the number of Diameter messages passing thru the EPC using the following parameters:

- Number of LTE subscribers
- Average number of devices per subscriber
- Number of simultaneous apps per device
- Frequency of attach/detach
- Frequency of tracking area updates
- Percentage of prepaid subscribers
- Percentage of subscribers with policy enabled
- Percentage of subscribers with VoLTE enabled
- Average number of busy hour call attempts per subscriber

The model calculates the total number Diameter messages/second based on the specified parameters and the number of Diameter messages for each of the HSS, PCRF and OCS.

Example Operator Scenario

The Figure 3 shows sample data for the parameters for the model for a 5 year period. These will vary by operator but this data shows how a medium sized operator with realistic growth will experience an explosion of Diameter messages. You can input your own data at the Diametriq web site at http://www.diametriq.com/lte-signaling-traffic-model/ and see how Diameter grows in your network.

Year	2012	2013	2014	2015	2016
Number of LTE subscribers (Millions)	0.5	1	2	5	10
Number of devices per LTE subsriber	1	1.1	1.3	1.5	2
Number of simutaneous apps per device	1	1	1.1	1.3	2
Frequency of device attach/detatch (mins)	30	30	30	30	30
Frequency of tracking area updates (mins)	15	15	15	15	15
Prepaid (%)	80%	80%	80%	80%	80%
Policy enabled (%)	100%	100%	100%	100%	100%
VoLTE enabled (%)	0%	25%	50%	75%	100%
VoLTE BHCA per subscriber	2	2.5	3	3.8	5

Figure 3: Sample Parameters for the Model

It shows LTE subscribe growth from 500K subscribers in 2012 to 10M subscribers in 2016. Initially each subscriber has just one device but this grows until by 2016 each subscriber has two devices. Similarly the number of simultaneous apps grows from1 to 2 over the 5 year period. On average 80% of the subscribers are prepaid and policy is enabled for all subscribers. Initially VoLTE is not enabled, but grows over years until all subscribers have VoLTE by 2016. The average attach/detach frequency is kept constant at 30 minutes and the tracking area updates, a measure of mobility of the subscriber, is an average of 15 minutes. The resulting data from the model is shown in the table in figure 4 below.

Diameter msgs/sec Total	8,667	24,414	74,822	285,250	1,080,000
Diameter msgs/sec per Network					
LTE	8,667	19,067	46,800	145,000	480,000
VoLTE	0	5,347	28,022	140,250	600,000
Diameter msgs/sec per Element					
HSS	5,000	13,903	41,311	150,000	533,333
PCRF	2,778	7,944	25,422	102,917	422,222
OCS	889	2,567	8,089	32,333	124,444

Figure 4: Sample Growth in Diameter traffic

In 2012 there are 8,667 Diameter messages/sec in the EPC, with 5,000 messages/sec going to the HLR/EIR and the next most to the PCRF. This grows to over 1M messages/sec by 2016. This is a 100 times growth in traffic based on realistic growth of LTE subscribers. The charts in Figure 5 show this same data graphically.

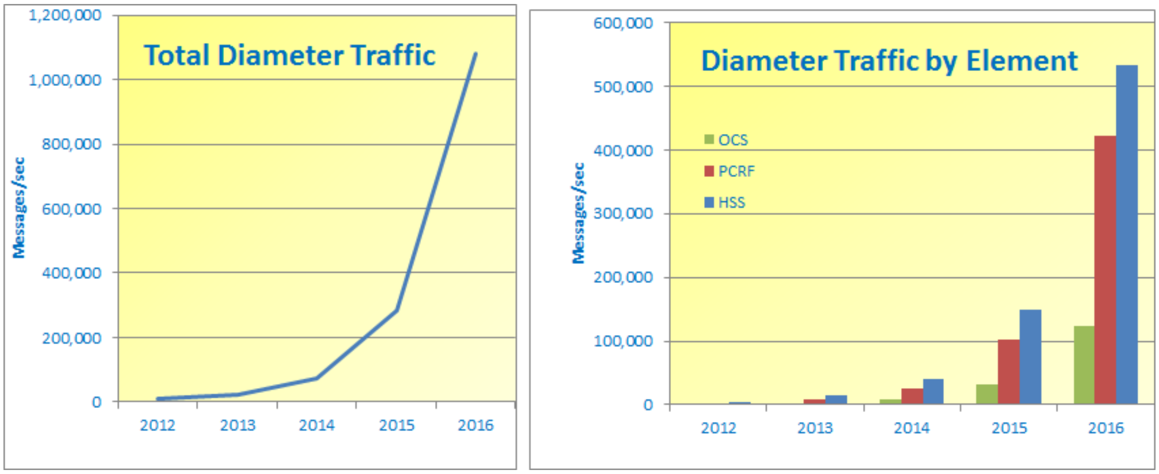

Figure 5: Explosion in Diameter Signaling in 4G

With such an explosion in Diameter signaling this illustrates the need for a carrier-grade infrastructure to support scalability and reliability for Diameter in the EPC. For SS7 the Signaling Transfer Point (STP) was used to facilitate a carrier-grade infrastructure. For Diameter the Diameter Signaling Controller (DSC) is used for providing the same carrier-grade infrastructure in the EPC. As important as the STP was in SS7 networks, the DSC is critical to support this Diameter signaling explosion.

Summary

The SS7 network has a carrier-grade infrastructure including the Signaling Transfer Point (STP) for managing SS7 signaling. The Diameter network includes the use of Relay/Proxy agents and is augmented by the Diameter Routing Agent (DRA) and Diameter Edge Agent (DEA). However, these do not have the same carrier-grade characteristics as the SS7 network, in particular to address the redundancy, scalability and robustness required to handle this explosion of Diameter signaling. This illustrates the critical need for a DSC in the EPC to provide the equivalent carrier-grade characteristics as the STP provides for SS7 networks. For a personalized traffic model please use the Diameter Traffic model™ at http://www.diametriq.com/lte-signaling-traffic-model/. For a more detailed traffic model with more variables and a higher degree of customization, please contact Diametriq at info@diametriq.com.

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 application 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, visit www.diametriq.com.