DIAMETER Signaling Network in EPS : Principles and Architecture

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1 Introduction

2G/3G Mobile Networks consist of a circuit switched core network on one side and a packet switched core network on the other side. The circuit switched domain is called R4 and is made of MSC Servers and MGWs; it provides telephony services including supplementary services, value added telephony services, SMS, USSD-based services, etc.
The packet switched domain is called GPRS and consists of SGSNs and GGSNs and provides access to IP-based networks such as Internet and Intranets.

The signaling protocols used in the circuit switched domain are :

- MAP (Mobile Application Part) for GSM mobility management, SMS transfer, USSD-based services, location-based services, etc.
- INAP (Intelligent Network Application Part) and CAP (CAMEL Application Part) for the invocation of Intelligent Network services such as prepaid, VPN, short number services
- ISUP for the establishment and release of voice calls with external TDM-based networks
- BICC/SIP-I for the establishment and release of calls with other MSC Servers.

The signaling protocols used in the packet switched domain are :

- MAP (Mobile Application Part) for GPRS mobility management and SMS transfer
- GTPv1-C (GPRS Tunnel Protocol - Control Plane) for the establishment and release of bearers (called PDP contexts) used for the transport with mobility of IP packets sent/received by the UE.
- DIAMETER for policy and charging control.

With the evolution of mobile networks towards a 4G network called EPS (Evolved Packet System) which is a all-IP mobile network, signaling protocols should be designed directly over IP. The new core network consists of a packet switched domain named ePC (Evolved Packet Core). The associated signaling protocols are :

- DIAMETER which remains the protocol for policy and charging control
- DIAMETER for EPS mobility management; it replaces MAP used for mobility management in GPRS
- GTPv2-C (GPRS Tunnel Protocol - Control Plane) for the establishment and release of bearers

The new circuit switched domain is IMS (IP Multimedia Subsystem) which signaling protocols are :

- DIAMETER for IMS mobility management (registration, re-registration, de-registration)
- SIP for the establishment/release of multimedia sessions including telephony sessions as well as for SMS delivery
- SIP for the invocation of IMS-based service platforms
- DIAMETER for policy and charging (online and offline) control.

When considering a roaming scenario, the main signaling protocol use between the 2G/3G visited network and the home network is MAP. DIAMETER replaces it for EPS roaming.

This evolution of some SS7 protocols particularly MAP towards DIAMETER requires an associated signaling network. In SS7, the preferred mode of operation is quasi-associated mode with STPs (Signaling Transfer Point) present in the operators networks as well as at the international level. This enables the routing of signaling between operators (especially in case of roaming). DIAMETER requires the same mode of operation with the introduction of DIAMETER agent. The DIAMETER agent is the DIAMETER signaling router.

The goal of this tutorial is to show the usage of DIAMETER in mobile networks. The second section shows the EPS architecture highlighting the importance of DIAMETER for EPS interfaces. The third section presents the role of the Agent and its advantages compared to a DIAMETER signaling network operating in associated mode. The fourth section describes EPS roaming and the need of Agents particularly at the international level.

2 EPS Architecture and DIAMETER presence

The EPS network consists of an access network called LTE (Long Term Evolution) and a new packet switched core network called ePC (Evolved Packet Core). The entities involved in EPS are (Figure 1):

- eNodeB : The eNB is the entity responsible for radio interface transmission and reception. Unlike 2G and 3G network, no radio network controller is present. S1 is the interface between eNodeB and the core network.
- MME (Mobility Management Entity) handles the control plane signaling, and especially for mobility and idle-mode handling.
- The SGW (Serving GW) routes the UE originated IP packets to the PDN GW and transfers the incoming packets to UE via the access network (i.e., eNodeB). It performs lawful interception and charging per user for the inter-operator billing.
- The PGW (Packet Data Network Gateway) is the edge router between the EPS and external packet data networks. It is the highest level mobility anchor in the system, and usually it acts as the IP point of attachment for the UE. It performs flow-based policy and charging.
- The HSS (Home Subscriber Server) is the database handling the subscription data of the EPS user.
- The PCRF (Policy and Charging Rules Function) provides PCC (policy and Charging) rules to the PCEF to enable the PCEF authorizing/blocking/restricting and charging the IP flows originated and received by the UE.
- The PCEF (Policy and Charging Enforcement Function) executes the PCC rules obtained from the PCRF. It applies shallow or deep packet inspection on any IP packet for policy control and invokes the OCS or OFCS for charging.
- The OCS (Online Charging Subsystem) provides online (or real-time) credit control and quota management for subscriber data sessions.
- The OFCS (Offline Charging Subsystem) receives charging data in the form of Charging Data Records (CDRs) and diameter accounting messages from network elements after the subscriber incurs network resource usage.

A large number of EPS interfaces is based on DIAMETER. The following list is not exhaustive :

- S6 (EPS) : S6 interface enables transfer of subscription and authentication data for authenticating/authorizing user access to the EPS. This interface is between MME (Mobility Management Entity) and HSS (Home Subscriber Server).

- S13 (EPS) : S13 interface is used for IMEI check. This interface is between MME and EIR (Equipment Identity Register).
- Gx (EPS) : Gx interface allows the PCEF (i.e., PDN GW) obtaining policy and charging rules from the PCRF. With those rules, PCEF knows how to authorize/block/restrict IP flows and charge those flows.
- Gy (EPS) : Gy is the online charging interface between the PCEF (e.g., PDN GW) and the OCS (Online Charging System)
- Gz (EPS) : Gz is the offline charging interface between the PCEF (e.g., PDN-GW) and the OFCS (Offline Charging System).
- S9 (EPS) : S9 is the interface between the PCRF in a visited network and the PCRF in the home network. This interface is used when the PDN GW who terminates the bearers of the visiting user, belongs to the visited network (not presented on figure 1).
- Rx (EPS) : Rx is the interface enabling IMS to request access network resources (i.e., dedicated bearer) to guarantee the quality of service of the IMS sessions. Rx is between IMS and the PCRF.
- Cx (IMS) : Cx is the interface between the IMS call servers and the IMS database called HSS to authenticate, authorize and locate the user.
- Sh (IMS) : Sh is the interface between IMS Application Servers (ASs) and the HSS to obtain service data required for service execution.
- Rf (IMS) : Rf is the offline charging interface between IMS entities and the OFCS for offline charging of IMS sessions and services.
- Ro (IMS) : Ro is the online charging interface between IMS entities and the Online OCS.

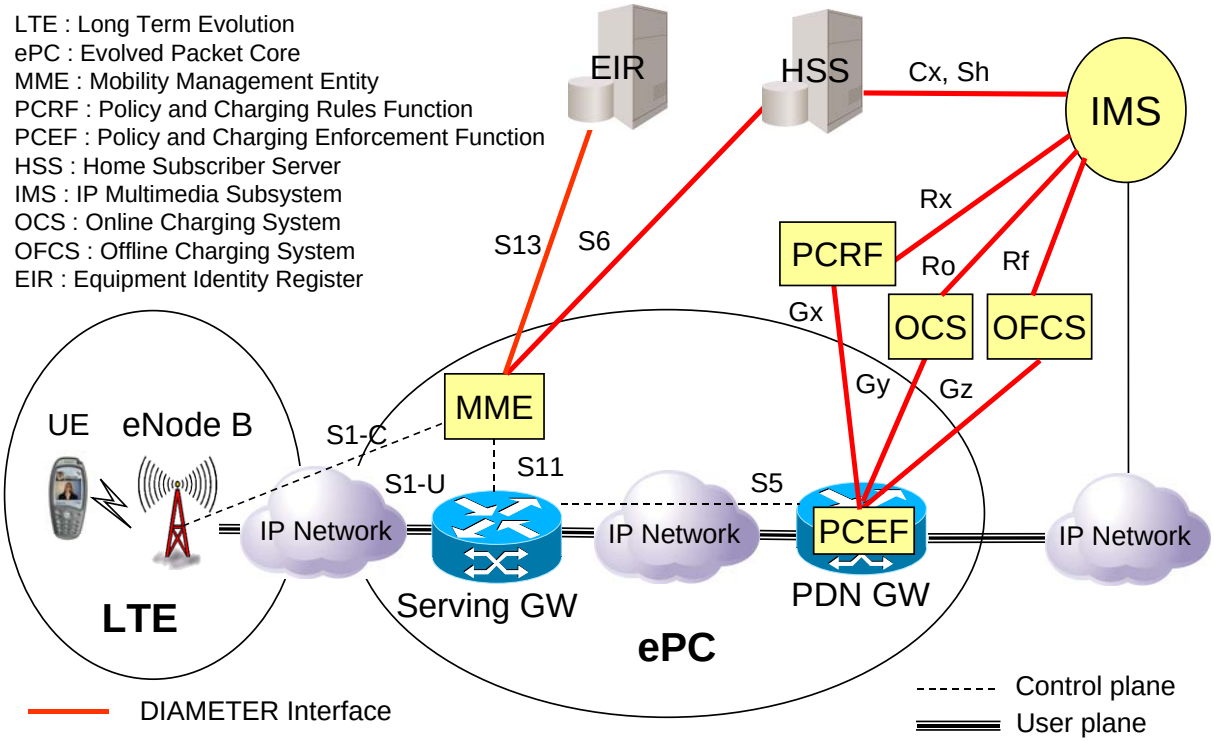

Figure 1: EPS Architecture and DIAMETER Interfaces

3 DIAMETER Agent for EPS

For scalability and configuration simplicity, the quasi-association mode should be chosen by service providers for DIAMETER signaling transport. An agent (similar to STP in SS7/SIGTRAN networks) links all the DIAMETER nodes (MME, HSS, PCEF, PCRF, OCS, OFCS, all IMS entities, etc.) and routes the DIAMETER requests/answers between them. All DIAMETER nodes have one entry in their routing table to deliver any DIAMETER message to the Agent. The DIAMETER agent is able to route between nodes of the same network or between nodes of different networks. To ensure 100% availability, agents are deployed by matted pair. Every DIAMETER client or server is connected to the two Agents of that matted pair.

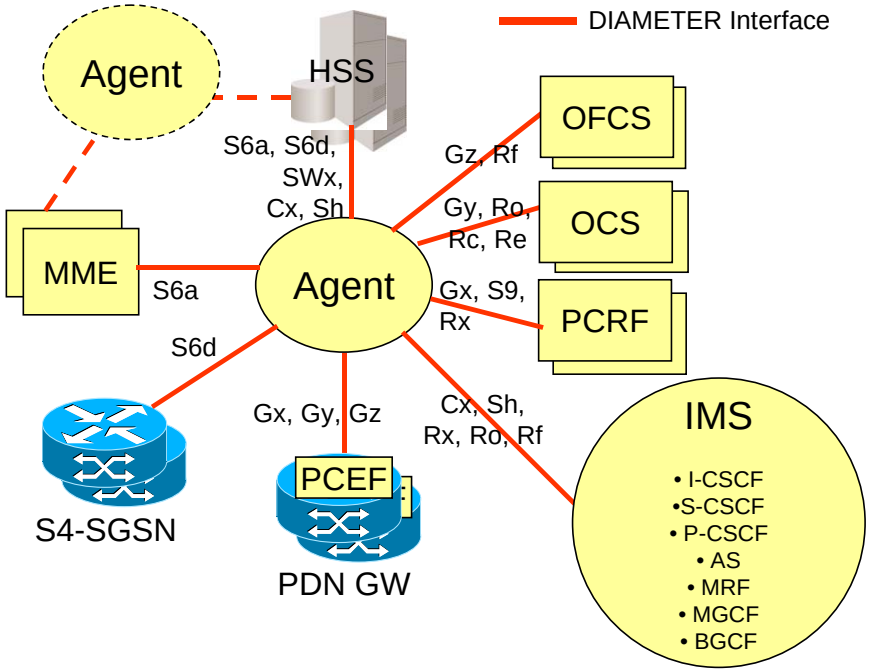

Figure 2 : DIAMETER Agent in EPS

Agents bring a number of advantages to the EPS architecture :

- Scalability : Considering N entities which need to interact with M entities, the number of TCP or SCTP connections between them is NxM if no DIAMETER agent is introduced. The number is N+M if an agent is present. There is a need of quasi-associated mode with agents to guarantee scalability of the DIAMETER signaling architecture.
- Simplification of the network extension : The introduction of a new DIAMETER client or server in the EPS leads to the update of the routing tables of all the entities which need to communicate with the new entity, if no agent is involved. With the presence of an agent, only the routing tables of the agent and the new entity are impacted.
- Network interconnection with topology hiding : The agent enables simplifying the interconnection with other networks for the support of roaming agreements. The agent also hides the topology of the internal network.
- Application layer routing : The agent enables performing application-based routing such as load balancing in the context of PCC (Policy and Charging Control), HSS identification in the case of interaction between MME and HSS, etc.

- AAA protocol conversion : Translation agents are important when migration to DIAMETER occurs. They support interconnection with other domains applying other AAA protocols. As examples the DIAMETER agent may translate MAP into DIAMETER, CAP into DIAMETER, DIAMETER into RADIUS, etc.

4 EPS Roaming and DIAMETER

Assume a roaming scenario where an Orange France user is served by a visited network called Mobistar in Belgium.
The visited MME from Mobistar derives the home domain name of the LTE mobile user with his IMSI. If IMSI is 208019999999999, then home domain name is epc.mnc001.mcc208.3gppnetwork.org (This equals to Orange France)
1. MME looks up its routing table and identifies that for any destination, the next hope is the Mobistar relay agent. An SCTP association exists between the MME and the relay agent. Thus it sends the Diameter S6 Authentication Information Request (AIR) over that SCTP association. The Diameter request provides the following AVPs : Origin host, origin realm, destination realm. There is no destination host because the MME does not know which is the HSS within the home network which hosts the user profile.
2. The Diameter request is received by the relay agent. It analyses the destination realm within the received request and thanks to its routing table, is able to identify the next agent that may handle the request. It forwards the Diameter request to another agent within the home network domain.
3. This proxy agent of Orange France looks up its routing table which tells that for destination realm (epc.mnc001.mcc208.3gppnetwork.org) and S6 application, the destination host is a list including hss1, hss2 and hss3. This proxy agent runs an internal application which input is the IMSI of the user who wants to register as well as the three HSS identities. Since it is a proxy agent, it understands the S6 interface and understands the IMSI AVP. The application returns the HSS identifier the DIAMETER request should be delivered to. The proxy agent adds the destination host AVP to the DIAMETER request and forwards it to the appropriate HSS.
4. 5. 6. The answer returned by the HSS follows the same path as the corresponding request. The answer contains the Origin-Host and Origin-Realm of the HSS.

Destination Realm : epc.mnc001.mcc208.3gppnetwork.org (Orange France)
Origin host : mmec2.mmegi1.mme.epc.mnc010.mcc206.3gppnetwork.org
Origin Realm : epc.mnc010.mcc206.3gppnetwork.org (Mobistar Belgium)
IMSI : 208019999999999

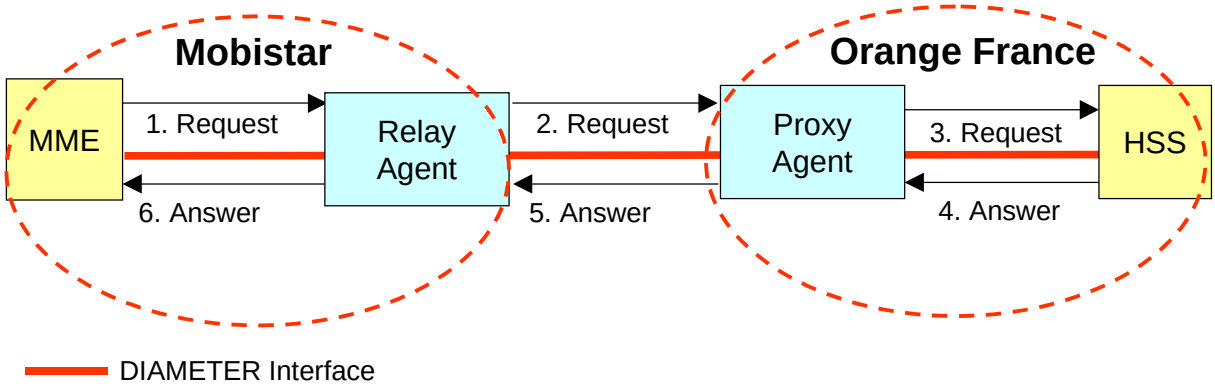

Figure 3 : Possible scenario for MME to HSS interactions in EPS considering a roaming situation

The S6 and S9 interfaces must be handled between domains in roaming situations.

The solution shown in Figure 3 is not totally satisfactory because if Mobistar has negociated 500 roaming agreements, it would need 500 SCTP associations (1 SCTP associated shared with one agent of each roaming partner).
International agents are required to simplify the interconnection between service providers for DIAMETER message routing in roaming situation.
International Brokers such as Syniverse or IBNF will provide international DIAMETER connectivity to service providers. In these conditions, the Mobistar agent only shares one SCTP association with an agent of an international broker instead of 500 SCTP connections (Figure 4).

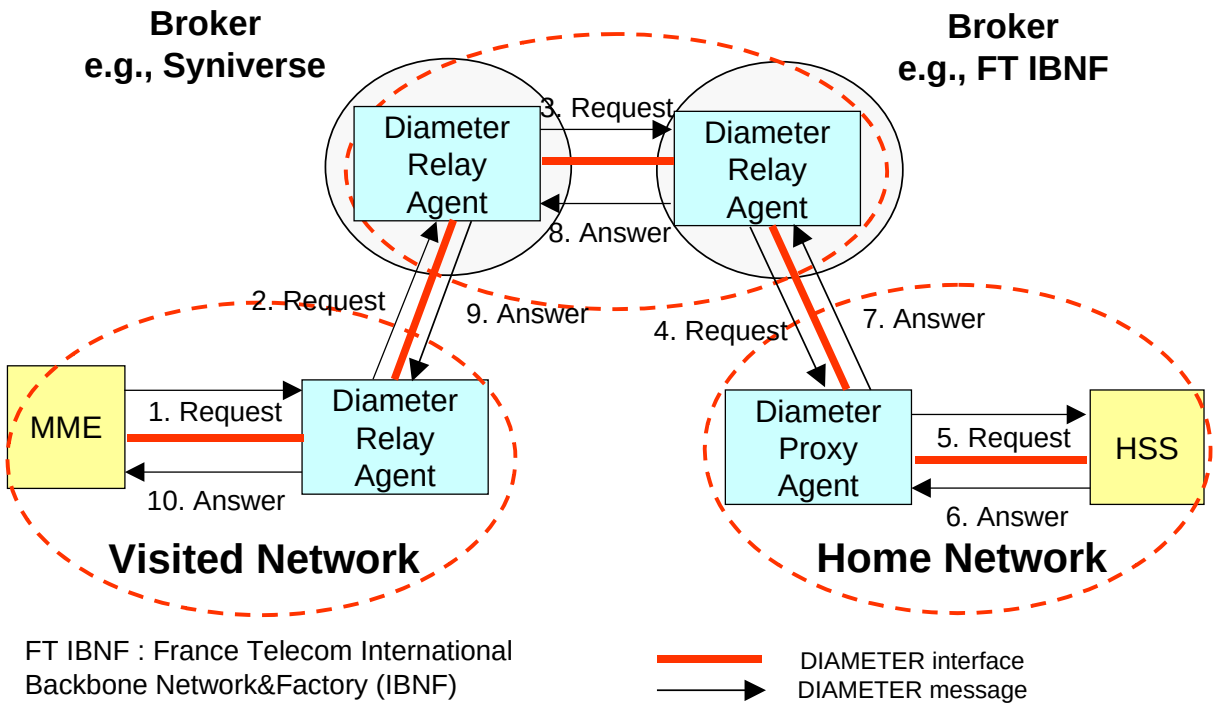

Figure 4 : Roaming and International Agents

5 Conclusion

DIAMETER agents will be important components of the future EPS network as STPs are key entities of the current 2G/3G mobile networks.
DIAMETER agents are mandatory for international roaming in the EPS environment. A hierarchy of agents may exist including intra-operator agents for the routing of DIAMETER signaling related to S6, S9, S13, Gx, Gy, Gz interfaces and inter-operator agents supplied by international brokers for the routing of S6 and S9 interfaces between the visited and home EPS networks.