

## SOLUTIONS FOR ROAMING AND INTEROPERABILITY PROBLEMS BETWEEN LTE AND 2G OR 3G NETWORKS

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**Abstract:** *Roaming is a fundamental requirement of any mobile network, since this is one of the main purposes why communications are “mobile”. Voice, SMS and data have to be available flawlessly to subscribers who are roaming between networks. Having currently evolved from 2G and 3G to LTE, interoperability issues arose. LTE’s modus operandi is fundamentally different (routing is done by Home Routing and Local Breakout, charging processes have differences) so it is not only a problem of linking the core protocols of LTE and 2G or 3G. It would be best to synchronize the two technologies’ principles. This paper seeks to find solutions for interoperability between LTE and legacy 2G or 3G networks.*

**Keywords:** *LTE, 3G, roaming, interoperability, MAP, DIAMETER, policy and charging*

### 1. INTRODUCTION

In the mobile telecommunications world processes such as Mobility, Roaming, Real Time Charging must run flawlessly between different networks [Balan, Sandu, 2010]. Roaming intra-LTE networks has its own structure, but roaming between LTE and 2G or 3G networks and vice-versa encounters incompatibility issues. Since nowadays most of the mobile networks have only just begun to implement LTE, the roaming issue is of actual importance [Kreher, Gaenger, 2010]. This paper aims to find implementable solutions that should facilitate roaming, mobility and interoperability between different networks.

### 2. VIEWS ABOUT ROAMING FROM LTE TO 2G OR 3G

#### 2.1 LTE networks which evolve from 2G or 3G

In this case, the most approachable solution is CS (Circuit Switching) fallback when interworking and roaming functions are required. Another solution is Single Radio Voice Call Continuity (SRVCC) which can bring a voice call from the VoIP/IMS packet domain to the 2G or 3G network circuit domain.

#### 2.2 LTE-only networks with roaming to 2G or 3G

Since LTE has no intrinsic voice support, roaming to 2G or 3G networks is essential. This paper discusses solutions for roaming and interworking.

**2.3 CDMA/TDMA networks which evolve to LTE** - whose interoperability solutions are also approached below

### 3. PROBLEMS IN NOWADAYS’ MOBILITY MANAGEMENT

Regarding mobility and location management and authentication, the Mobile Application Part (MAP) [ETSI] which deals in mobility management messages, is used to communicate between the Home Network and the Visited Network. MAP is based on SS7. On traditional TDM with E1/T1 links, SIGTRAN or SS7 over IP is used.

LTE does not use SS7, but DIAMETER which acts as a replacement for MAP, and supports all its functions [Rumney, 2013].

The architecture for LTE to LTE roaming (red) is shown in Figure 1.

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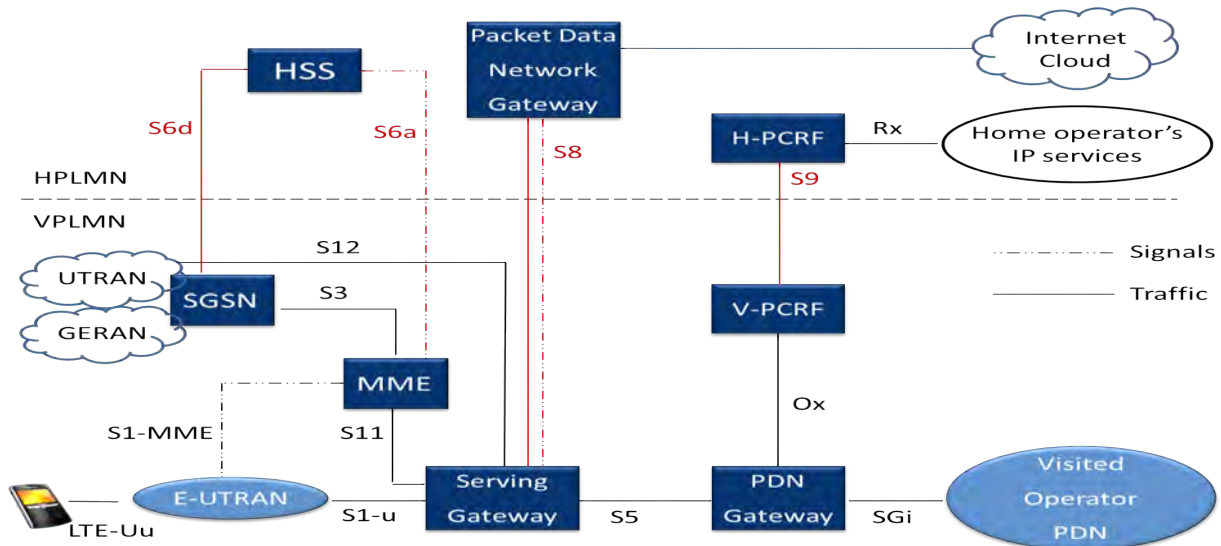


Fig. 1. LTE Architecture. Roaming relevant interfaces are in red

### 3.1 Mobility Management

Interface S6a enables transfer of authenticating and subscription data between MME and HSS (over DIAMETER) for authorizing user access to the LTE network. Generally, the AAA interface is used for authenticating and authorizing. Interface S6d enables AAA related information exchange between SGSN and HSS over DIAMETER protocol.

### 3.2 Policy Control and Charging

Interface S9 transfers QoS policy control and charging information between the Home Policy and Charging Rules Functionality (HPCRF) and Visitor PCRF, based on the DIAMETER protocol. The PCRF is responsible for supporting the detection of service data flow, the charging system based on this data flow and policy enforcement. It is, in short, the policy manager of the LTE technology.

### 3.3 GTP Traffic

Interface S8 carries GTP V2 traffic between the Serving Gateway and the PDN Gateway, which are similar to the SGSN and GGSN, respectively, in the 2G or 3G network.

### 3.4 The DIAMETER protocol

– adapted for LTE [3GPP], supports mobility management for LTE – LTE interworking (DIAMETER-to-DIAMETER) and for LTE – 2G or 3G interworking (DIAMETER to MAP).

DIAMETER uses Attribute Variable Pairs (AVPs) for exchanging data. AVPs encapsulate data depending on the application type. The AVPs are different from vendor to application, and the ones defined in [3GPP] are translated into DIAMETER commands and can be seen in Table 1. For network implementation, mapping DIAMETER to MAP messages, as seen in Table 2 below, is not sufficient. The network processes and parameters have to be synchronized too.

### 3.5 Authentication

There are different types of authentication methods depending on the network. A 2G network uses the Comp 128 algorithm. There are the SRES, RAND and Kc triplets.

Table 1. DIAMETER commands for LTE

AVP Code	Message	Command
316	Update – Location-Request / Answer	ULR / ULA
317	Cancel – Location-Request / Answer	CLR / CLA
318	Authentication – Information-Request / Answer	AIR / AIA
319	Insert Subscriber Data – Request / Answer	IDR / IDA
320	Delete Subscriber Data-Request / Answer	DSR / DSA
321	Purge – UE-Request / Answer	PUR / PUA
322	Reset – Request / Answer	RSR / RSA
323	Notify – Request / Answer	NOR / NOA

Table 2. MAP to DIAMETER mapping

MAP Message	DIAMETER Commands
Send Authentication Info	AIR / AIA
Update GPRS Location	ULR / ULA
Cancel Location	CLR / CLA
Purge MS	PUR / PUA
Insert Subscriber Data	IDR / IDA
Delete Subscriber Data	DSR / DSA
Reset	RSR / RSA
Update GPRS Location Info	NOR / NOA
Activate Trace Mode	IDR / IDA
Deactivate Trace Mode	DSR / DSA

These triplets are computed by the User Terminal or the visited network, encapsulated in the MAP message and sent to the home network.

A 3G network uses the Milenage algorithm. Here are the XRES, RAND, CK, IK, AUTN quintuplets which follow the same path as those from the 2G network.

A 4G network uses the AKA (EPS authentication and key agreement) procedure for authentication. AKA is used to agree on a KASME key. The EPS AKA procedure is always controlled by the network but the UE can refuse the EPS authentication message. First, CK and IK are computed by the Universal Subscriber Identity Module, and then used by the UE in order to compute a new key known as KASME. Afterwards, KASME is saved in the network security module and in the UE memory, while it is attached to the network. The problem resides in the fact that MAP does not support the parameters described previously. Therefore, roaming between a LTE-only network and a 2G or 3G network and vice-versa is not possible because in the first case the 2G or 3G network is not able to supply the 4G authentication parameters, and in the vice-versa case DIAMETER does not support 2G or 3G's authentication parameters.

### 3.6 Location Update

The first message seen in a core network is the Location Update message, regardless of the protocol used, be it MAP or DIAMETER. There are important differences between the 2 networks' location update procedures.

In GSM MAP (see Figure 2), the Insert Subscriber Data message usually transports the full subscriber profile, or, if the subscriber profile does not fit into a single message, the Visitor PLMN requests other ISD messages.

In DIAMETER, the Location Update Answer transports the subscriber profile. The DIAMETER ISD is not used unless the Home PLMN requests a change in the subscriber profile.

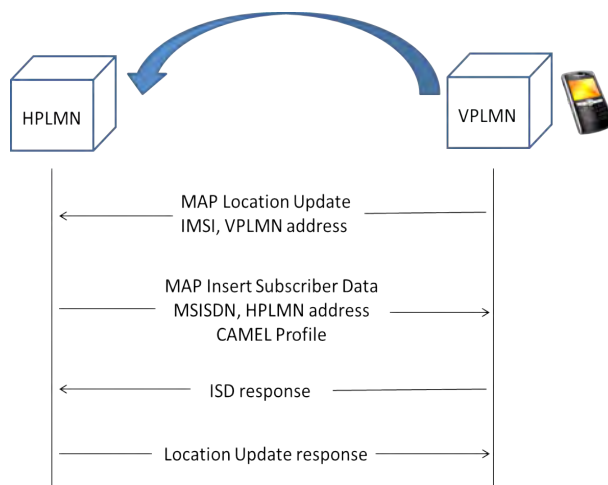


Fig. 2. Location Update procedure for a 2G or 3G network (using SS7 MAP)

In 2G or 3G, INAP-CAMEL is used whenever a subscriber is roaming between networks. LTE does not support CAMEL, so they cannot be mapped with similar DIAMETER parameters – Figure 3.

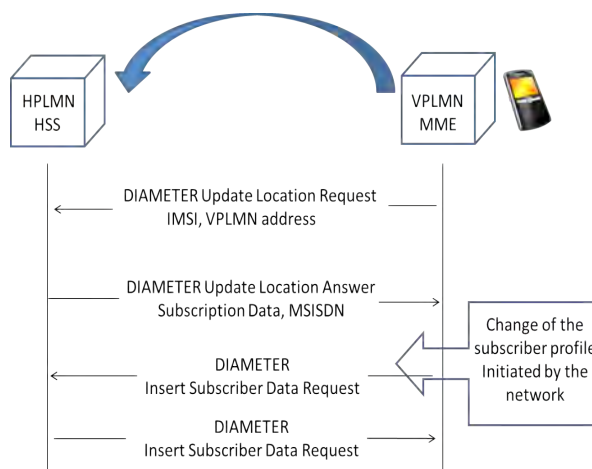


Fig. 3. Location Update procedure for a LTE network

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### 4. MESSAGE ROUTING CHALLENGES

In 2G or 3G networks, which use SS7, the MTP / SCCP layers deal with routing. MTP takes care of point code based routing, and SCCP, which is only a transport protocol, deals with the Global title based routing. DIAMETER is also based on SCTP and does not have an algorithm for message routing and analysis.

It only analyzes parameters which deal in transferring the message to the right destination IP address.

A new element will be defined, “DIAMETER Proxy”, which will enable interoperability, will interpret the routing parameters and will decide on the best way to route towards the destination.

#### 4.1 Local Breakout

The breakout occurs at the Visitor PLMN, so the traffic does not reach anymore the home network.

Hence, there should be an agreement between the home and visited network in order to exchange call control information on the Gy interface. Therefore the PDN at the visited network interact directly with the Charging System at the Home PLMN. As a result of that, Real Time charging is triggered.

### 5. CHALLENGES IN POLICY CONTROL AND REAL TIME CHARGING

GSMA [GSM 09.02] has proposed a model for Online Charging and Policy Control whose issues will be discussed in separate cases depending on the options of LTE to LTE and LTE to 2G or 3G roaming scenarios.

#### 5.1 Home Routing

As seen in Figure 4, the Home Policy and Charging Rules Functionality (H-PCRF) is communicating through interface S9 with the Visited PCRF, but this interface does not carry information regarding data for triggering Real Time Charging. Instead, the Gy interface is doing that, and is also transmitting charging information and call control data which is based on DIAMETER RFC 3588.

There are two problems in roaming from LTE to 2G or 3G networks, regardless of Home Routing or Local Breakout.

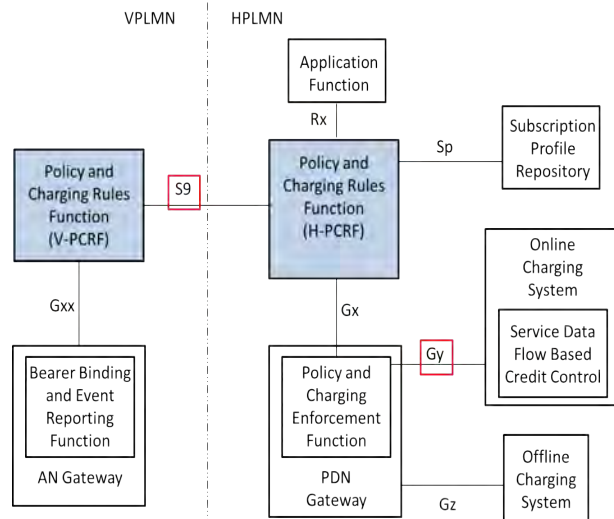


Fig. 4. Home Routing with S9 and Gy Interface outlined

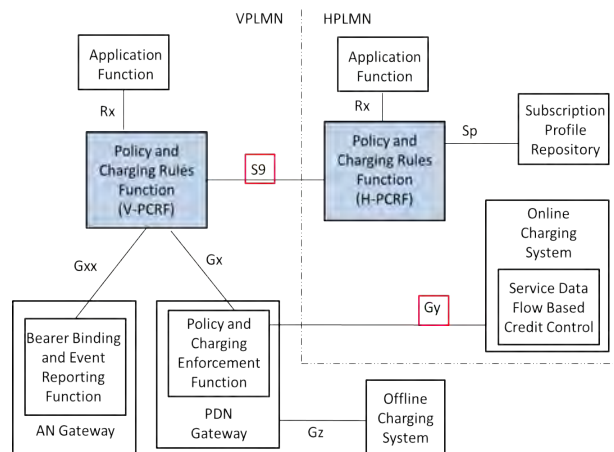


Fig. 5. Local Breakout with S9 and Gy interfaces outlined

2G or 3G networks have no support for policy control functionality, and, therefore, there is no QoS and charging related policy enforcement.

From the charging point of view, the LTE network has its charging (be it voice, data or SMS traffic) handled by the Gy interface (between the PDN Gateway and the Online Charging System), while the 2G or 3G network has different types of charging depending on the type of traffic.

The GGSN (Gateway GPRS Support Node) handles the data charging, the SMSC handles the SMS charging, and the MSCs handle the voice charging, using CAMEL. Hence, the charging differs a lot between the LTE and 2,3G networks.

## 6. PROPOSED SOLUTIONS

### 6.1 Roaming scenario LTE (HPLMN) to 2G or 3G (VPLMN)

In this scenario, the user roams to the 2G or 3G network so the authentication algorithms have to be supported (Comp128 and Milenage). Also, for GPRS, the Gp interface towards the 2G or 3G network has to be implemented in the HPLMN.

A conversion of DIAMETER to MAP is required, and the DIAMETER AIA command must understand the 2G or 3G authentication triplets or quintuplets, respectively. After the successful authentication, location updating follows. We used a new element, DIAMETER to MAP/CAMEL (D2M/C) converter, between the Home and the Visited network (Figure 6).

This D2M/C generates the ISD messages based on the subscription data provided by the 2G or 3G network.

The D2M/C also understands the Real Time charging profile of the subscriber and populates the CAMEL information consequently.

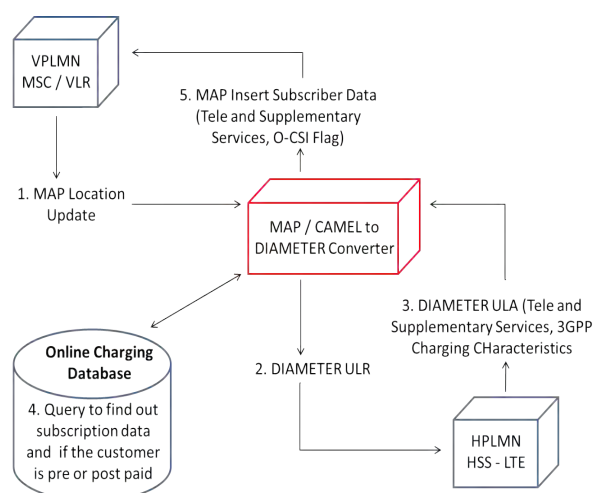


Fig. 6. Proposed solution for Location Update process between LTE and 2G or 3G networks

### 6.2 Roaming scenario 2G or 3G (HPLMN) to LTE (VPLMN)

We suggest Local Breakout as the best solution for this scenario.

In this case, for mobility management, there should be a conversion from S6a to MAP. Also the HLR must support the LTE authentication parameters (KASME).

The MME has to handle the mapping of the of the subscriber data. The VPLMN PDN Gateway has to have a DIAMETER interface towards the Online Charging System at the HPLMN, in order to handle real time charging (see Figure 7).

We considered 2 options when SMS Roaming comes into play. As seen in Figure 8, one is to transfer the SMS by the SG interface between a MSC and a MME.

Another option we suggest is to use a SIP client and send the SMS on it, using a SIP to SS7 converter and forward it to the SMSC, as seen in figure 9.

### 6.3 DIAMETER Proxy

Since DIAMETER does not have the capability for intelligent routing, it will analyze the parameters and the numbering plans which exist in the incoming message from the 2G or 3G network, and it will route the message accordingly. The DIAMETER Proxy proposed in Figure 10 serves for all the routing requirements, be them LTE to LTE or LTE to different networks.

Each Mobile Network Operator (MNO) has to set up S6a/S6d/S9 connectivity for policy control. The DIAMETER Proxy eases up this connectivity because, using it, there is no need for point to point connectivity between the partner networks.

It can act as a roaming hub and only a single one time connection to the roaming hub is required. Hence, the DIAMETER Proxy can be placed between LTE capable networks in order to enable international roaming between all the networks connected to the roaming hub, and between those belonging to another LTE roaming hub.

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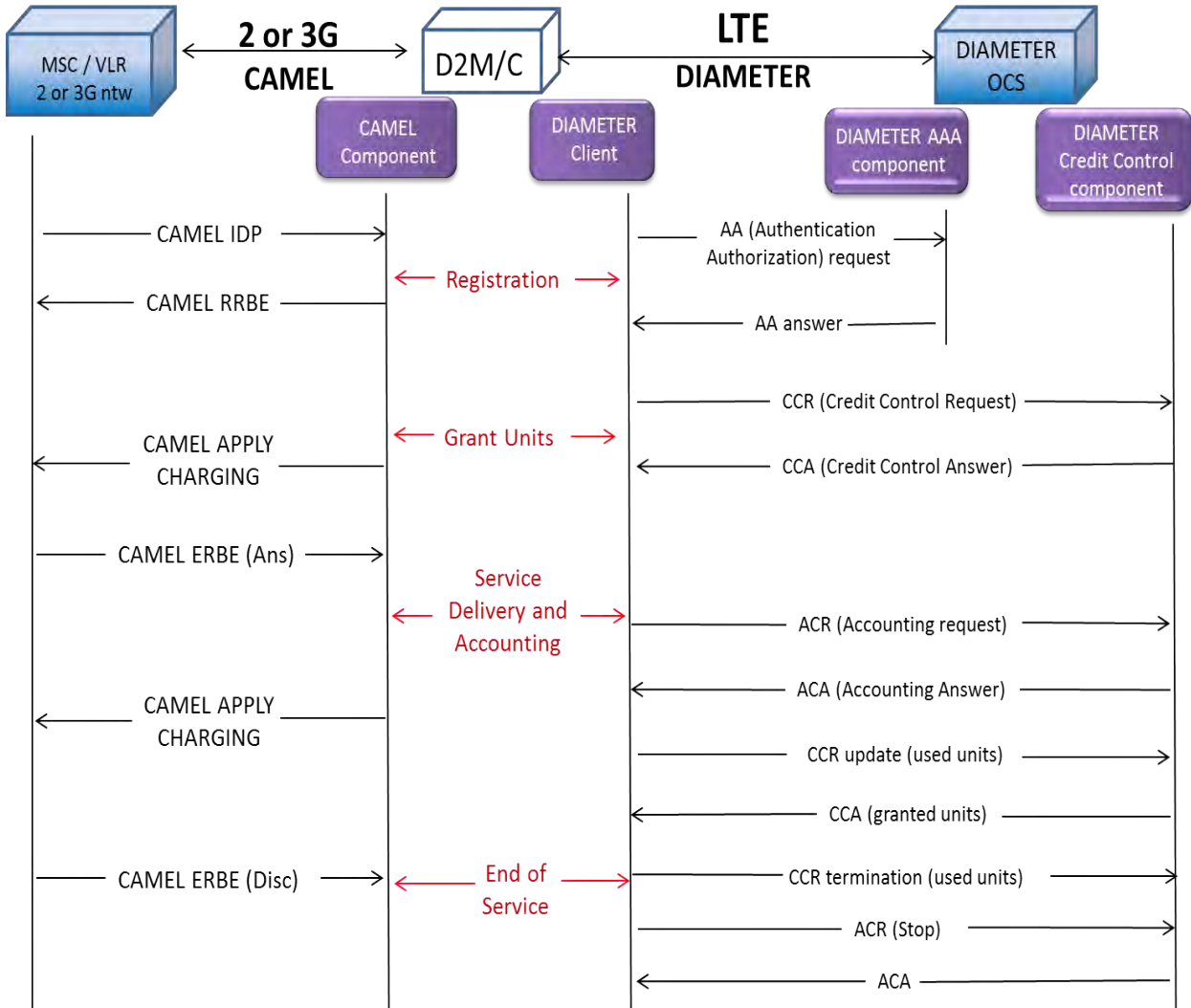


Fig. 7. CAMEL to DIAMETER changeover for Online Charging

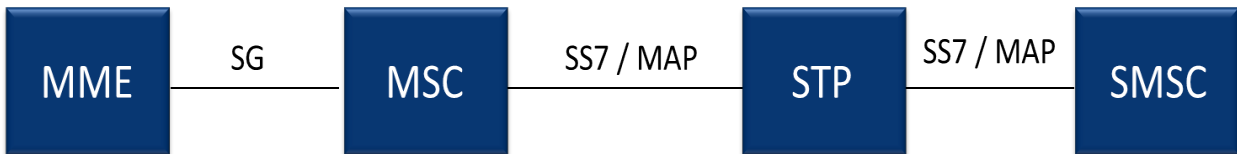


Fig. 8. SMS transfer from LTE to 2G or 3G using the SG interface

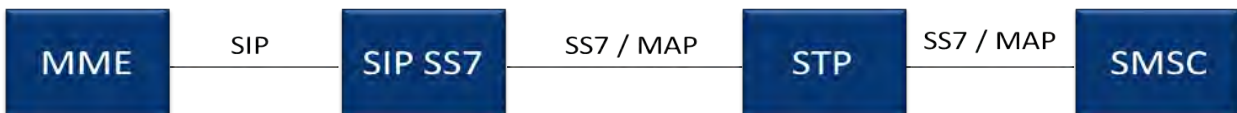


Fig. 9. SMS transfer from LTE to 2G or 3G using IMS client for SMS

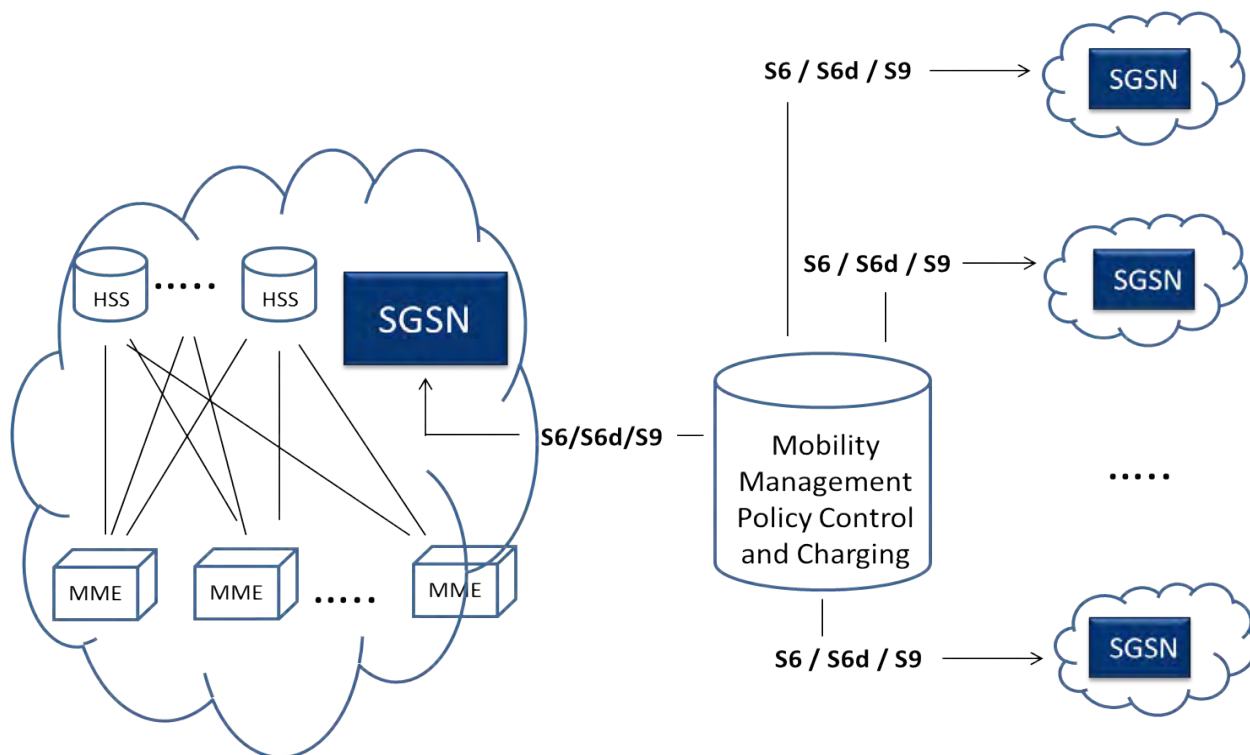


Fig. 10. DIAMETER Routing using DIAMETER Proxy for Roaming and Interworking purposes

### 7. CONCLUSIONS

As with seamless voice over LTE, SRVCC and CS fallback are not the only choices addressing the issues of roaming. Different operators may choose different solutions depending on the profile of their LTE network.

There is still a way to go before implementing a full roaming architecture between all the networks, be them LTE or 2G or 3G.

In this paper, after pinpointing the core problems; the authors suggested specific solutions:

- the use of a DIAMETER to MAP/CAMEL converter,
- the use of the Local Breakout (with dedicated SIP client and a SIP to SS7 converter), the use of a DIAMETER proxy.

Guidelines were given as well, towards implementing these proposed solutions.

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### REFERENCES

1. Balan T. C., Sandu F., Chap. 18 - "*LTE Mobility Solutions at Network Level for Global Convergence*", pp. 405-423, in the Monography "Fourth-Generation Wireless Networks: Applications and Innovations", IGI Global publishers – U.S.A., 2010 – ISBN: 978-1-61520-674-2.
2. ETSI TC-SMG – *Mobile Application Part*, GSM 09.02
3. Kreher R., Gaenger K. – *LTE Signaling: Troubleshooting and Optimization* – 296 pag., John Wiley & Sons inc., 2010 – ISBN: 978-0-470-68900-4
4. Rumney, M. (editor), Agilent Technologies – *LTE and the Evolution to 4G Wireless - Design and Measurement Challenges*, 2nd Edition, 648 pag, John Wiley & Sons inc, 2013 ISBN: 978-1-119-96257-1
5. The GSM Association – "*LTE Roaming Guidelines*" – PRD IR.88, 2009
6. The GSM Association – *Technical Architecture Alternatives for Open Connectivity Roaming Hubbing Model* – CR to PRD IR.80, 2009
7. 3GPP standard 23.216 V 8.6. 2009-12: *Single Radio Voice Call Continuity (SRVCC)* – Release 8
8. 3GPP – *Circuit Switched (CS) fallback in Evolved Packet System (EPS)*; Stage 2 – Technical Standard – TS 23.272
9. 3GPP – *Policy and Charging Control (PCC) over S9 reference point*; Stage 3 – Technical Standard – TS 29.215
10. 3GPP – *Evolved Packet System (EPS); Mobility Management Entity (MME) and Serving GPRS Support Node (SGSN) related interfaces based on DIAMETER protocol* – Technical Standard – TS 29.272