Assembling VoLTE CDRs based on Network Monitoring – Challenges with Fragmented Information

Pál Varga, Dániel Kozma
Dept. of Telecommunications and Media Informatics
Budapest University of Technology and Economics
2 Magyar Tudósok krt., Budapest, Hungary, H-1117
Email: pvarga@tmit.bme.hu, kozma@tmit.bme.hu

Tamás Tóthfalusi
AITIA International Inc.
Telecommunication Division
Budapest, Hungary
Email: tothfalusi@aitia.ai

***Abstract*—Providing proper technical solutions to cover all requirements of the Voice over LTE (VoLTE) service is still a great challenge for operators. Network monitoring is one of the important methods to support service verification, deployment and operations. The VoLTE service utilizes both the LTE Evolved Packet Core (EPC), and the IP Multimedia Subsystem (IMS). These architectures are built on different principles, using protocols with different mindset. Furthermore, they utilize subscriber- and call-related parameters both in redundant and fragmented manners. On one hand, the same data is stored in functional elements of both architectures, which led to partial data redundancy. On the other hand, Call Data Records (CDRs) cannot be assembled by simply capturing signaling on a few given links. Information is fragmented, hence on-the-fly cross-correlation of key parameters is required. To effectively utilize the network and service monitoring system, operators need new methods to correlate the information of various interfaces and protocols. There are many obstacles to overcome here, including information fragmentation in various links, ciphered control messages, and global identifiers hidden by temporary ones.**

I. Introduction

The great increase of mobile data traffic that we experienced lately is expected to keep its exponential growth for the upcoming years. Managing the signaling traffic that controls and supports these data services is a great challenge for the operators. Operations data is large in volume, and complex in nature for the mobile core, especially for the Evolved Packet Core (EPC) of LTE. To provide satisfactory Quality of Service, operators need to have system-wide monitoring in place, which supports them in Fault Management, among others.

For managing voice calls over LTE, signaling messages traverse in many interfaces. Beside using the LTE infrastructure, VoLTE utilizes the IP Multimedia Subsystem (IMS). The IMS is responsible for service control – that includes call control, among others –, and adds another factor to the complexity. IMS has a quite different type of organizational philosophy when compared to those of the mobile cores [1]. Moreover, the VoLTE service has to interact with the 2G and 3G infrastructures, since callers and callees are often attached to those, while simultaneously being attached to 4G. This can further complicate the call tracing.

In order to see a proper big picture with all the details, the control traffic must be captured over various interfaces, and has to be analyzed. Cross-protocol correlation is inevitable: identifiers appearing on one interface help to assemble session data records of an other interface [2]. In relation to VoLTE session- and call establishment, the key information-exchange points are depicted in Figure 1.

The important identifiers of the VoLTE service are stored in various databases and appear in various signaling links. The data presentation have many gaps (making cross-correlation hard), and very often redundant. This paper sets the scene for VoLTE monitoring, shows examples on how scattered the data are, and suggests guidelines on generating Call Data Records from traffic captures, even in complex cases.

II. Technical background

A. LTE architecture

The LTE Evolved Packet Core [3] is a purely packet switched network. The usual telephone service, its related functions, and naturally the data communication services are supported through IP-based packet transfer. The main functional entities of the LTE EPC are briefly the following.

MME (Mobility Management Entity): The MME is mainly responsible for mobility-management.

SGW (Serving Gateway): The SGW is responsible for user traffic stream handling, and controlling the allocation of resource capacities, the changes or deletion of sessions and finishing IP connections.

PGW (Packet Data Network Gateway): PGW can be seen as an edge node of the EPC, since it ensures the connections to external data networks.

HSS (Home Subscriber Server): HSS takes the roles of HLR/AuC (Home Location Register/Authentication Centre) in the LTE network. It can be seen as the data storage that contains the subscribers' service-related data. The HSS stores the subscribers' profile, containing the enabled services and access (e.g. allowed roaming services to external networks).

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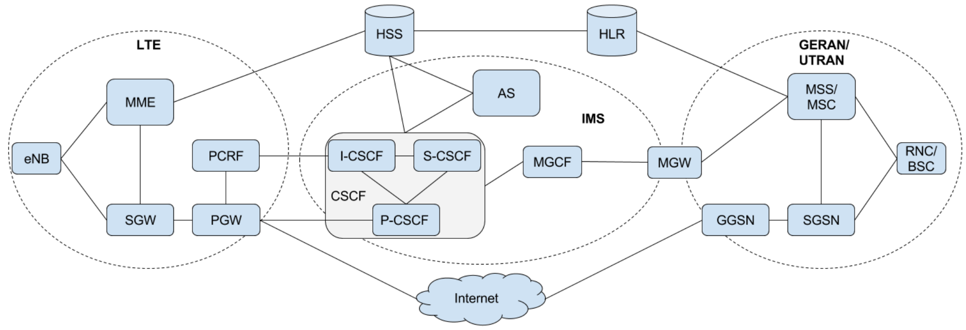

Fig. 1. Core network architecture serving Voice over LTE - including 2G, 3G, 4G and IMS components

PCRF (Policy and Charging Rules Function): Based on its predefined policies and QoS-related rules, the PCRF sends control information to the PGW.

B. IMS architecture

The main idea behind introducing the IMS (IP Multimedia Subsystem) is to create a common, IP-based architecture to grant communication between different telecommunication networking technologies (e.g. 2G, 3G, 4G, fixed phone, Internet). Figure 1 depicts how the IMS fits into the mobile core architectures.

Since these different technologies use various call control protocols in their various interfaces, IMS introduced a homogeneous usage of call control, through SIP (Session Initiation Protocol, [4]).

Figure 1 shows how the differentiated Call Session Control Functions (CSCF) get integrated into the mobile core domains. These submodules serve routing and management tasks, and operate together as the main CSCF network node.

The main signaling protocol of the IMS is SIP (Session Initiation Protocol).

Based on the best practices of protocol technology, we can differentiate two types of messages: request and response. The basic request messages are REGISTER, INVITE, BYE, CANCEL, OPTIONS, ACK, SUBSCRIBE, NOTIFY, MESSAGE and PRACK. Among these, the Invite message marks the start of each call – hence it is very important when generating SIP call records.

The Response messages are also human readable, and have two parts: a (numerical) Status code and a (textual) description (e.g. 200 OK).

The SIP terminology differentiates three types of communication: transaction, dialog and session.

The Invite-dialog sets up a SIP Session, often using an embedded SDP (Session Description Protocol) protocol. The SDP part contains QoS parameters and codec types as control parameter for the multimedia flow.

III. Challenges of Data Fragmentation from the Operator's Perspective

A. Challenges of Subscriber Data Storage and Access

Operators and vendors are facing new challenges with the introduction of VoLTE. The Subscriber Data Management (SDM) is one of the most critical functions in a telecommunication network. The main goal – in case of the convergence of the different networking technologies – is to build a database that can manage subscriber data at scale, with high availability and low latency, and to monetize that data effectively.

Data is floating around everywhere – in applications, in subscribers' billing information, in various networks and in their profiles. The problem is that the data is split across many different databases and is therefore fragmented, duplicated, and difficult to cope with. With centralized data management, data can be easily transposed, transformed and managed by a well-defined system.

A layered approach of this data management is depicted by Figure 2. It is quite visible how the information is fragmented (regarding its storage and access). Until this is not sanitized, data representation will be partially redundant – which can lead to erroneous situations, not to mention the ineffectiveness of this historic partitioning.

The subscriber specific data – that traditionally has been stored in the HSS /HLR/AuC, Application Servers and any other nodes – is going to be stored into one common database [5]. This solution will make it possible for the operators to share and to provision subscriber specific data throughout services of a 3GPP system. In this way, the operator is able to manage the data at the same time with different telecommunication networks and domains, such as 2G/3G/4G/IMS/WiFi.

Such an approach will make network monitoring – and assembling CDRs – easier as well. Until then, we have to collect and assemble the data in a relatively tiresome way, as described in the following chapter.

B. Distributed Monitoring - Fragmented Information

When tracing calls or checking upon CDRs, the two key parameters for the search are the IMSI and the MSISDN (calling/called party number). One of these two parameters – or their temporal counterpart – are always present in any of the signaling links' message sequences that are monitored for CDR creation.

Figure 3 summarizes how these and other important parameters appear in the various links. It also helps getting the point: information on VoLTE calls are fragmented; various parameters appear on various links of the control path. In

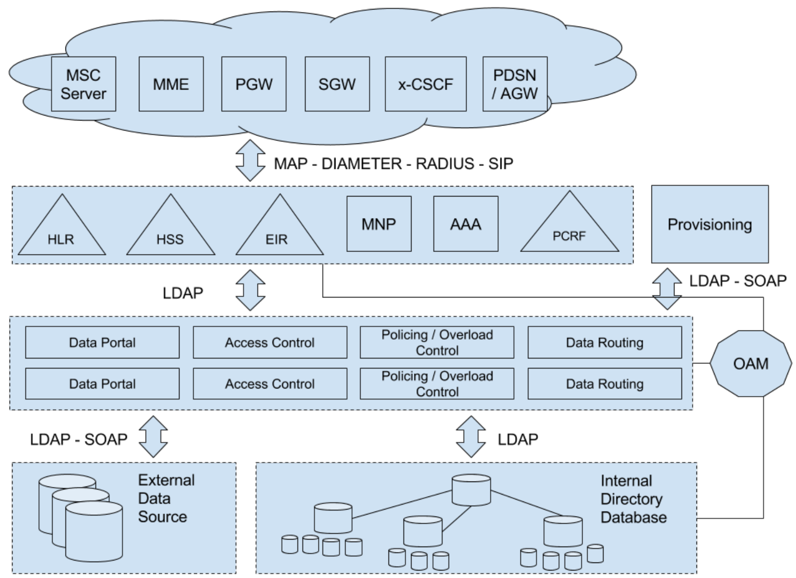

Fig. 2. Data management with fragmented sources and distributed functionalities – in current, converged network cores

order to assemble the VoLTE CDRs, the information appearing in dialogues and messages on different links have to be cross-correlated. To create these cross-correlations, one must understand the interactions among the different protocols in depth. Still, Figure 3 reveals the bonding parameters.

One of the most challenging tasks for the CDR creation is to find a matching IMSI for the S1AP CDRs. S1AP is the application protocol of the S1-MME interface (eNodeB-MME). The challenges here are that (i) S1AP messages usually do not contain the IMSI (except during the first Attach or when the MME does not know the subscriber), and (ii) most of the messages being traversed over S1-MME are encrypted.

Decrypting all S1AP messages are important, since we want to assign IMSI's to these CDRs. In order to do this, the proper encryption keys and corresponding parameters have to be gathered and applied to each encrypted message. These key parameters appear on the S6a (MME – HSS), S10 (inter-MME), and Gr (HLR – SGSN) interfaces. Furthermore, for cases when the user utilizes 2G or 3G technologies beside 4G, keys can appear as well on the Gb (BSC – SGSN), the IuPS (RNC – SGSN), and the S3 (SGSN – MME) interfaces. This makes message decoding, IMSI-associating and CDR generation very complicated, but doable.

IV. Network Monitoring and CDR Assembling

A. *Monitoring Considerations for the IMS domain*

In order to analyze the SIP protocol-content, the transport protocol (e.g. IPv4/IPv6, UDP, TCP, SCTP) encapsulation needs to be handled as well. The SIP content can be broken to pieces as the result of IP fragmentation, or TCP/SCTP segmentation. These needs to be handled in order to obtain the original SIP content in one piece. It is rational to store this purified SIP content as well, to ease the operator's work and further processing tasks.

The final stage of on-the-fly processing is the generation of Call Detail Records. The CDR Assembler takes the SIP messages as input, and uses its internal algorithms (that are going to be detailed in further sections) to generate the CDRs.

B. *Complex SIP call scenarios in IMS*

SIP transactions and dialogs can be differentiated based on their initial request message. Since some of these request types are initiated (and then closed) asynchronously from each other, we should define different record types for each. There can be different call data records built, based on these initial messages: INVITE, REGISTER, SUBSCRIBE, OPTIONS, MESSAGE, and INFO. Figure 4 depicts the CDR types with their basic, CDR-related messages.

Out of these, the INVITE CDR type is the one that contains the actual call detail record, in the classic sense. In other words, an INVITE CDR is a SIP call dialog, which starts from the initial Invite message and finishes at the end of the call (with various ways). Since a call setup procedure contains more transactions, INVITE CDRs include UPDATE, CANCEL and often INFO transactions, as well.

Nevertheless, not all Invite messages mark a freshly starting call. Some of them do actually start the call, while others arrive during the same call, carrying feature modification info.

We differentiate the Invite messages in the call flow based on the value of the To field tag parameter. If the To tag parameter does not exist, we consider it as an initial-Invite Request (starting a call), otherwise it is a Re-Invite (modifying parameters, e.g. QoS settings).

Regarding Invite-dialogs, they start with an initial-Invite request, and finish when one of the following events occurs:

- One of the communication partners sends a Cancel request message, which causes 487-Response message to the Initial-Invite.

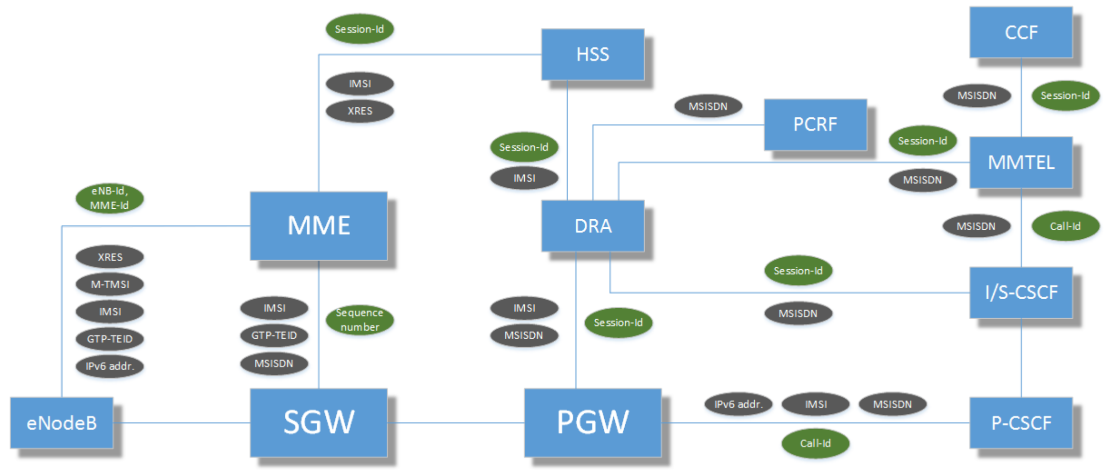

Fig. 3. Parameters appearing in various interfaces of LTE EPC and the IMS

– Bye request and 200 OK Response pair.
– 3XX, 4XX, 5XX or 6XX response to the initial-Invite.

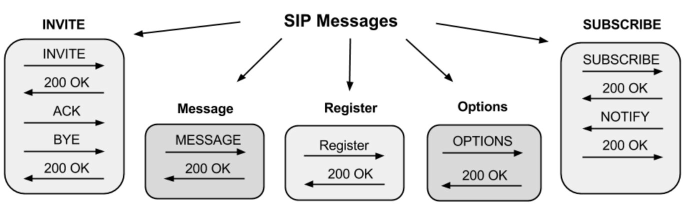

Fig. 4. Different SIP CDR types

V. Collecting user-related identifiers: MSISDN, IMSI, IMPI

There are three important user-related identifiers that support the operator's work during IMS administration tasks. These are

1) MSISDN – in short: the called/calling party number
2) IMSI – the SIM card's identifier, and
3) IMPI – a global, private identifier within IMS – which could also be a concatenation of MSISDN, IMSI, fixed equipment port numbers, and others.

The order of the fields and parameters can be varied within a SIP message. To collect user related information, the CDR-assembling algorithm has to search in many fields and parameters. To recognize the caller, the From field could be the starting point. However, in some cases the From field hides the user, and any user identifiers (such as MSISDN, IMSI or IMPI) can be included in the Contact, P-Asserted-Identity, P-Preferred-Identity or in Remote-Party-ID field, in which the format is also variable.

Recognizing the callee in a SIP dialog could be a more complex task. Although in most cases the called-MSISDN is located in the Request line, To field or in P-Called-Party-ID field, it can appear in an INFO transaction, within the Invite-dialog. Call forwarding is also applicable in IMS, the History-Info field implies this event.

An INVITE message often includes an SDP or XML layer. SDP is for the media session parameters, containing codec related information. The XML part could contain caller and callee MSISDNs (or IMSI or IMPI) and ICID values, as well.

VI. Conclusion

The majority of the LTE operators have not yet launched their Voice over LTE service; the number of global deployments are just around one hundred. One main reason behind this delay is that the infrastructure and the service logic became too complex.

Network and service monitoring is one of the key tools for providing feedback about quality. Regarding calls, monitoring-based CDR assembly is crucial for the operators in order to be able to trace what is working well – and what is not – with the VoLTE service. The current paper presents the challenges of CDR generation, and provides solutions for these challenges – including the messages and parameters to utilize, the interfaces to monitor, the key parameters to use for cross-correlation. In order to deal with such fragmented information, the monitoring system should be equipped with methods of handling and cross-correlating key parameters (IMSI, MSISDN, IMPI, ICID) on-the-fly.

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