LTE SUBSCRIBER SERVICE RESTORATION

METHODS TO MAINTAIN USER SESSIONS IN THE FACE OF MME/SGW NODE EVENTS

APPLICATION NOTE

Alcatel·Lucent

ABSTRACT

As Long Term Evolution (LTE) grows in popularity, more and more subscribers will be added to the network, placing an increasing traffic load on the evolved packet core (EPC). The Mobility Management Entity (MME)/Serving GPRS Support Node (SGSN) and the Serving Gateway (SGW) are the two EPC control and user plane network elements that support subscriber mobility and session management. Prior to 3GPP Release 10.4, when an LTE subscriber was connected to an MME or SGW that failed or restarted, the LTE subscriber session would be dropped — an event which then required the device to reattach to the network. The reattachment of potentially thousands of subscribers could cause a massive spike in network signaling and trigger a signaling storm that may overload the Home Subscriber Server (HSS). Also the LTE mobile users currently in IDLE mode were unreachable until the device initiated a mobility signaling procedure. This could have serious user consequences and lead to customer dissatisfaction.

Alcatel-Lucent recognized the potentially significant impact on the network and subscribers and developed an innovative solution that restores subscriber sessions, even when the MME or SGW they are attached to fails or requires restart. By continuing to deliver user services despite experiencing a significant core network event, the mobile operator maintains a “high-quality, reliable” image with its customers and within the industry.

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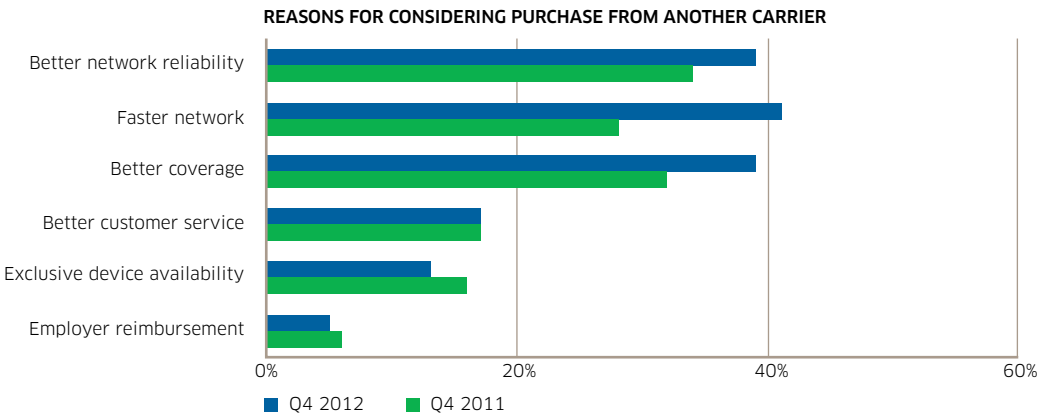
BACKGROUND

The popularity of LTE is growing as mobile subscribers flock in ever greater numbers to smart phones and increase their consumption of mobile broadband. According to a recent Global mobile Suppliers Association (GSA) LTE Subscription report[1], there were more than 200 million LTE subscribers worldwide at the end of 2013, with projections of more than a tenfold increase to 2.5 billion by 2020. Smartphones are the favored mobile device among subscribers today, with over 54 percent of the new devices sold in 2013, and 13 percent of those are LTE (TDD and FDD) devices according to a recent Pyramid Research global smartphone report.[2] This same report forecasts that smartphone sales as a percentage of total mobile device sales will increase to 74 percent with more than 44 percent supporting LTE by 2018. Along with the growth in LTE subscribers is a significant increase in data traffic, as the average LTE user consumes more than twice as much as a 3G user (2.2 times): the average 3G user generates 21 MB of data per day, while its LTE counterpart will consume 45 MB. But more importantly, that gap is increasing every month at a rate of 4 percent, this according to recent Alcatel-Lucent blog (Analytics Beat, Jan 14, 2014)in which 4G/LTE networks data was collected using Wireless Network Guardian networks analytics solution.

As subscribers become more dependent on their smartphones and the speed and performance that LTE provides them, they come to expect that network connectivity and delivery of services will always be provided by their mobile network operator. This is reflected in a Q4-2012 survey by NPD Group[3] of 3500 smartphone buyers in the United States, which identified and compared the top service attributes of US mobile data services. Survey respondents rated service reliability among the top three most important attributes, with speed and coverage being the other two. All three of these attributes rose in importance from a survey conducted a year earlier. Therefore, it is critical for mobile operators to maintain the highest level of service if they are to retain their most profitable subscribers. When network events or failures occur, mobile operators must ensure they don't propagate throughout the network and that the service impact on their subscribers is minimized.

Figure 1. US smartphone users survey results



The NDP Group/Connected Intelligence Carrier Smartphone Report

"CAN YOU HEAR ME NOW?"

Verizon Wireless takes pride in their 4G/LTE network reliability and promotes it as one of their competitive differentiators. In July 2013, when AT&T claimed that it operates America's most reliable 4G/LTE network, Verizon shot back with a full page ad in the Wall Street Journal, citing third-party research from RootMetrics that supports their claim as the most reliable LTE network.

1 Global Mobile Suppliers Association, "LTE Subscription Growth report," March 9, 2014
http://www.gsacom.com/downloads/pdf/Global_LTE_subscriptions_growth_and_regional_shares_to_Q4_2013.php4

3GPP SESSION RESTORATION STANDARDS EVOLUTION

In LTE EPC networks using 3GPP Release 10.4 (June 2011) or earlier, if either the MME, SGW or the link between them fails, even momentarily, the other node of the pair will mass delete all of the user equipment (UE) subscriber context data on those nodes. There are two main consequences to the purging of this subscriber data.

The first consequence is that the subscribers who are connected to this failed MME/SGW node pair will not receive any IP Multimedia Subsystem (IMS) services until the UE initiates another procedure, for example, a tracking area update (TAU) or service request (SR), which first requires a reattachment to the network. This interval between the time when the MME/SGW node fails and the start of another signaling procedure could be up to several hours with the subscriber in IDLE mode and not aware that they are unreachable from the network's view. The lack of timely services delivery has the potential for serious consequences, for example, missed urgent calls or early warning notifications, and, at best, customer dissatisfaction with their mobile service provider's network reliability. This is in contrast to a 2G/3G circuit-switched terminated call that can be immediately delivered to the mobile device even after a mobile switching center (MSC)/visitor location register (VLR) node failure.

The second consequence is a spike in network signaling. With the failed nodes connected to possibly thousands of UEs, the reattach procedure adds extra signaling over the radio network, which could lead to a signaling storm.

Alcatel-Lucent recognized this problem and proposed a feasibility study in 3GPP CT4 group for enhanced EPC restoration procedures in TR 23.857. This study, in which Alcatel-Lucent took a leadership position, was completed and a technical report was issued (3GPP TR 23.857 V1.4.0 (2011-08).

Several change requests (CRs) were specified in 3GPP Technical Specifications in Release 10.5, which enhanced the MME restart and restoration procedure (CR-0156, TS 23.007) and added International Mobile Subscriber Identity (IMSI) to the data downlink notification (DDN) message (CR-0892, TS 29.274).

The enhanced restoration procedures for SGW failure with or without SGW restart consists of MME and Packet Data Network Gateway (PGW) maintaining UE context for a configurable period of time and reconnecting UE to a new SGW or to the old SGW if it has restarted as opposed to the current scheme of detaching a UE upon S11 path failure.

While these CRs address the UE reachability issue with either a MME, SGW node failure or restart, or the S11 path between them fails, it does not prevent the LTE subscriber UE sessions from being dropped nor do they quickly restore sessions once they have been dropped. The Alcatel-Lucent 9471 WMM Session Restoration Server (SRS) aides in this fast restoration problem.

9471 WMM SESSION RESTORATION SERVER

Application features and benefits

Alcatel-Lucent, in working with several large North American LTE mobile service providers (MSPs), addressed this deficiency in LTE/IMS service resiliency by developing an enhanced EPC network solution that maintains UE subscriber sessions when either the MME fails or must restart. The 9471 WMM Session Restoration Server (SRS) is a standalone system used to maintain in real time a backup copy of the UE context data from its client MMEs. If an MME in a pool fails or becomes isolated from the network, the remaining MMEs in the pool can consult the SRS to retrieve the UE context data to complete procedures that were previously managed by the unavailable MME without requiring the UEs to reattach to the network.

The key benefits of the 9471 WMM SRS are:

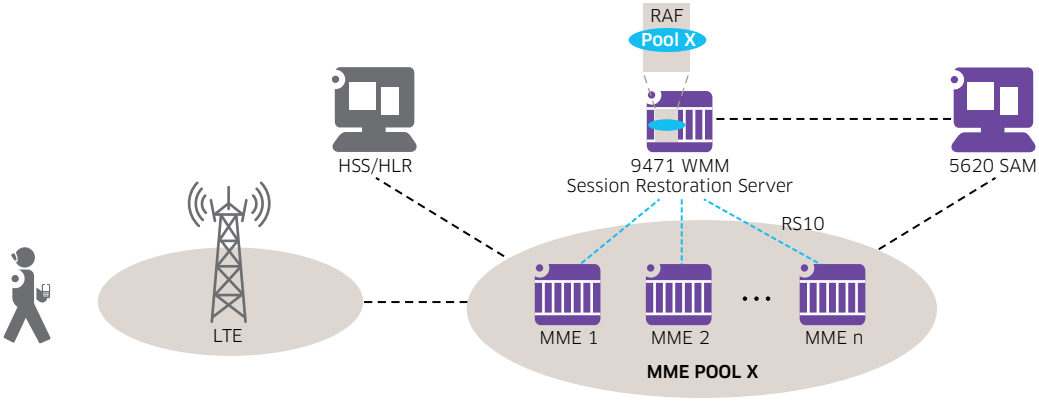
- Subscriber service resiliency is maintained for either an MME or SGW failure with or without restart by providing enhanced restoration procedures to other nodes in the pool.
- The enhanced restoration procedures generate a minimal increase in network signaling.
- The UE does not need to reattach to the network.
- Network-originated IMS services such as voice calls or video services, do not fail because of an MME failure.
- A failed MME does not escalate into a potential Attach signaling storm.

The 9471 WMM SRS maintains UE context restoration data for all the subtending MMEs in its pool. The UE restoration data is a subset of the full UE context data maintained on the MME and consists of security context, bearer context, paging area information and critical subscription data. A restarted MME or a different MME in the SRS's pool can retrieve the data using IMSI or Session Temporary Mobile Subscriber Identity (S-TMSI) as the UE identity to restore UE sessions without reattach. Network events such as Attach, PDN connectivity request, Detach, and TAU (with and without MME or SGW relocation) will trigger each MME in the pool to update their UE restoration data that is sent to the SRS.

9471 WMM SRS product and network architecture

The SRS hardware is no different than that required for the 9471 WMM. It uses the same industry-standard computing platform and high-performance, multi-core processor cards. The SRS software is the same as that of the 9471 WMM with identical release schedules and feature functionality. The key difference between the MME and the SRS is new Restoration Application Function (RAF) software, which manages the UE context restoration data for all the MME clients in a given MME pool. The UE restoration data is maintained on a protected pair of high-capacity processor cards. To provide additional network resiliency, the SRS itself can be deployed in a geo-redundant configuration. Both the 9471 WMM and SRS can fully interoperate with any vendor's radio access network.

Figure 2. 9471 WMM SRS network architecture



The SRS is highly scalable, supporting multiple MMEs per pool and multiple MME pools on a single SRS. Software updates for the SRS follow the same in-service upgrade procedures as the 9471 WMM. The Alcatel-Lucent 5620 Service Aware Manager (SAM) provides the same OA&M functions on the SRS as on the 9471 WMM.

With Network Functions Virtualization (NFV) of the 9471 WMM (vMME), additional configuration options and protection schemes for the SRS are supported. A dedicated virtual machine for the UE context restoration data (vRAF) can be either on the same vMME instance or on a separate, dedicated vSRS instance. The mobile operator has the flexibility to design the SRS network resiliency according to their requirements.

The restoration interface between the SRS and the 9471 WMM (MME) is the “RS10,” a variation of the 3GPP standard S10 (MME) interface. The RS10 protocol specification is based on GPRS Tunneling Protocol (GTP) version 2 and uses Transmission Control Protocol (TCP) instead of User Datagram Protocol (UDP). There are no other 3GPP interface connections required for the SRS to operate in the Evolved Packet System.

SRS enhanced MME session restoration procedures

The SRS is used in conjunction with the enhanced session restoration procedures in both network-originated and mobile-originated scenarios to maintain subscriber connectivity to the network even with an MME failure or restart. The procedures for these two cases are as follows:

1. Network-originated Service Request:
   - ¬ The PGW sends a DDN message to the SGW, which triggers a page request to the MME.
   - ¬ If MME (1) fails (with and without a restart), the SGW-associated MME (1) with UE determines that MME (1) has failed based on one of two conditions: the GTP echo message fails or the MME restart counter is incremented.
   - ¬ With the enhanced restoration procedures in R10.5 and the UE restoration data contained in the SRS, the SGW keeps the bearers for MME(1) for a configurable period and sends the DDN message (with IMSI) to an alternate MME, which then consults with the SRS to retrieve context data for the UE.
   - ¬ The alternate MME then restores the UE sessions on the SGW.
   - ¬ The alternate MME then sends paging messages to the eNodeBs in the paging area received from the SRS and processes the service request.
   - ¬ With UE sessions preserved, all calls go through.

2. Mobile-originated procedure:
   - ¬ With an MME failure (with or without restart), the UE attempts a mobility management (MM) procedure (SR, TAU, etc.).
   - ¬ If MME (1) fails or restarts, the eNodeB that associates MME (1) with the UE determines that the MME (1) failed based on Stream Control Transmission Protocol (SCTP) Heartbeat and redirects traffic to an alternate MME.
   - ¬ If the MME restarts, the eNodeB sends the UEs to the restarted MME if the UEs provide the MME identity (that is, the MME where these UEs were originally registered with when the MME restarted).
   - ¬ The restarted MME will get UE context from the SRS to restore the subscriber (UE) services.
   - ¬ If the MME fails, the alternate MME receives the MM request from the eNodeB for which it has no valid UE context.
   - ¬ The alternate MME then consults the SRS to obtain the UE restoration context data and completes the MM procedure.

Enhanced SGW session restoration procedures

For SGW node failures or restarts, the SRS is not explicitly needed to maintain subscriber sessions. The enhanced restoration procedures for SGW failure with or without SGW restart consists of MME and PGW maintaining UE context for a configurable period of time and reconnecting UE to a new SGW or to the old SGW if it has restarted as opposed to current scheme of detaching a UE upon S11 path failure. The MME can also proactively restore sessions on an alternate SGW by pacing the movement of IDLE users through the initiation of a paging procedure.

In a mobile-originated procedure:

- The UE attempts an MM or SM procedure (SR, TAU, etc.) in the same period in which an SGW fails, restarts, or the S11 path between the MME and SGW is dropped.
- If SGW (1) or S11 path fails, MME (1) that associates SGW (1) with the UE will detect the failure based on the either the restart counter or loss of GTP echo.
- With the enhanced SGW restoration procedures as defined in TS 23.007 R10.5, when MME (1) detects that the SGW (1) or S11 path failed, it maintains UE context data for the UEs associated with SGW (1) and starts the restoration timer. The UE Contexts are retained on the MME for the duration of the timer. Each S11 path has its own timer.
- MME (1) then starts the S1 release of the UEs in connected mode (ECM-connected) and upon S1 release the UE is assigned a new SGW.
- MME (1) releases the S1 of the UEs and relocates them to a new SGW in a prioritized order based upon session type, QCI and state with and without GBR bearers. (Note that UEs in Idle state (ECM-IDLE) that are connected to the failed SGW (1) are prioritized for recovery based on their prioritized APN list).
- As new UE MM requests arrive (SR, TAU, S1 HO, X2 HO), MME (1) then relocates the UE to the new SGW and completes the procedure. (Note that the new SGW selected by the MME may be the original SGW (1) if it as restarted.)
- The PGW maintains the bearer data for the UE for the failed SGW when the link is detected as down or the restart counter is incremented.

SUMMARY

In a competitive LTE market, network reliability is a key attribute that smartphone users consider when selecting a mobile service provider and one that the mobile operators promote and value as a differentiator. LTE service is supposed to provide a better quality of experience, and if it does not meet that expectation then users will question its value and cost. Alcatel-Lucent's knowledge and experience in large-scale LTE network deployments assist mobile operators in designing and building networks with the highest quality of service. This is evident in the identification of areas for network improvement, such as in EPC session restoration procedures where Alcatel-Lucent took a leadership role in getting 3GPP CRs defined and implemented in Release 10.5. The 9471 WMM Session Restoration Server (SRS) takes these enhanced restoration session procedures a step further by providing a simple solution that rapidly restores UE subscriber sessions even when an MME or SGW it is attached to fails or restarts. The SRS, together with these restoration procedure enhancements, ensure timely delivery of user services and prevent network signaling storms due to a flood of subscriber Attach messages.

REFERENCES

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5. Pyramid Research, Global Smartphone Forecast, December 30, 2013
6. NPD Group, Connected Intelligence, "Carrier Smartphone Report," March 2013.

ACRONYMS

2G/3G/4G	second-generation/third generation/fourth generation
3GPP	3rd Generation Partnership Program
APN	Access Point Name
CR	change request
DDN	Data Downlink Notification
eNodeB	evolved Node B
EPC	Evolved Packet Core
FDD	Frequency Division Duplex
GSMA	Global mobile Suppliers Association
GTP	GPRS Tunneling Protocol
GUTI	Globally Unique Temporary ID
HO	Hand over
HSS	Home Subscriber Server
IMS	IP Multimedia Subsystem
IMSI	International Mobile Subscriber Identity
LTE	Long Term Evolution
MM	mobility management
MME	Mobility Management Entity
MSC	mobile switching center
MSP	Mobile service provider
NFV	Network Functions Virtualization
OA&M	Operations, Administration and Maintenance
PGW	Packet Data Network Gateway
RAF	Restoration Application Function
SCTP	Stream Control Transmission Protocol
SGSN	Serving GPRS Support Node
SGW	Serving gateway
SM	session management
SR	Service Request
SRS	Session Restoration Server
S-TMSI	Session Temporary Mobile Subscriber Identity
TAU	Tracking area update
TCP	Transmission Control Protocol
TDD	Time Division Duplex
UDP	User Datagram Protocol
UE	user equipment
VLR	visitor location register

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