Coverage and Quality Radio Analysis for CS Fallback in Long Term Evolution (LTE)

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***Abstract*-This rapid growth of technologies is forcing network operators to upgrade the network to LTE (Long Term Evolution), a 4th generation of mobile network. However, the LTE does not support circuit switch network and only depend on the IP Multimedia Subsystem (IMS) for offering voice and Short Messaging Service (SMS). The CS Fallback in E-Packet System (EPS) allows the provisioning of voice call and other CS domain (E.g. SMS, CS UDI video/USSD/LCS) by reuse of CS domain infrastructure when the UE is served in LTE domain. A CS Fallback allows UE that connect to E-UTRAN will use GERAN/UTRAN to connect to the CS domain. This paper is comparing different technique of handling VoLTE and analyzes one of the approaches (CS Fallback). The performance of the CS Fallback was studied in term of coverage and quality. This experiment demonstrate that in good optimized network, the CS Fallback from LTE to UMTS call setup success rate can be very close to those achieve in the circuit switch systems.**

Index Terms – 3GPP, CSFB, LTE, UMTS, UE, VoLTE, UTRAN, VoLGA, VoIMS, EPS, eNodeB, MME, MSC

I. INTRODUCTION

A majority of mobile operators have decided to install Long Term Evolution (LTE) or 4G as specified by 3rd Generation Partnership Project (3GPP) in Release 8, to support the growth of cellular usage. LTE technology is based on Packet Switching (PS) offered by Internet Protocol (IP) which gives the leverage of flexibility and interoperability for the services [1,2]. LTE has been designed to support only packet-switched services, as in contrast to the previous mobile network, Circuit Switch (CS) model. The wireless communication technology is growing beyond all expectation of telecoms and network equipment vendors. Voice call and SMS become the biggest sources of revenue for mobile operators; however using data service consumes most of the bandwidth.

LTE has been designed to support only packet-switched services, as in contrast to the previous mobile network, Circuit Switch (CS) model. The purposes are to provide Internet Protocol (IP) connectivity between user equipment (UE) and the packet data network (PDN).

There are several techniques to handle voice call and SMS over an LTE network: Circuit Switched Fall-back (CSFB), Voice over LTE via Generic Access (VoLGA) and Voice over IMS (VoIMS). The 3GPP standards body proposed CSFB that when the UE is served by LTE network its enables the provisioning of voice and other CS domain services by reuse of the existing CS infrastructure [3]. Meanwhile VoLGA is proposed by an industry led forum, VoLGA Forum that seeks to enable mobile operators to deliver voice call and SMS over LTE access networks based on the existing 3GPP Generic Access Network (GAN) standard [4]. VoLGA sends traditional voice traffic and signaling through Evolved Packet Switched (EPS) to GSM/UMTS circuit core. VoIMS use the IMS for signaling. IMS support shall be implemented in a flexible manner to allow operators to classified their services and customize them to meet specific user needs [5]. IMS use Session Initiation Protocol (SIP) defined by IETF (Internet Engineering Task Force) for multimedia session control in the internet [6].

II. NETWORK ARCHITECTURE OVERVIEW

There are three (3) main architectures that can provide voice call and SMS services over LTE network; CS Fallback, VoLGA and VoIMS. Each solution presents different technical and operational tradeoff.

A. Circuit Switched Fallback (CSFB)

CSFB is described in 3GPP TS 23.272 [3] and at this time it is arguably the most popular way to supporting voiceover LTE. It's being used by many LTE operators. The mobile network operator's main concern would be the handover of the data connection to UMTS; however, with the wide availability of HSPA+ at the 3G layer, the drop rate may not be significant. Extra signaling and connections are needed between the 3G circuit core and the LTE network. Fig. 1 show the standard architecture interface enables CSFB between these two networks. LTE voice call is provided by CSFB capability without requiring major restructure in the existing mobile CS core domain, for example in charging or routing configurations. The cornerstone of CSFB is the interface between the Evolved Packet Core (EPC) and the CS network which it controls the LTE network connection.

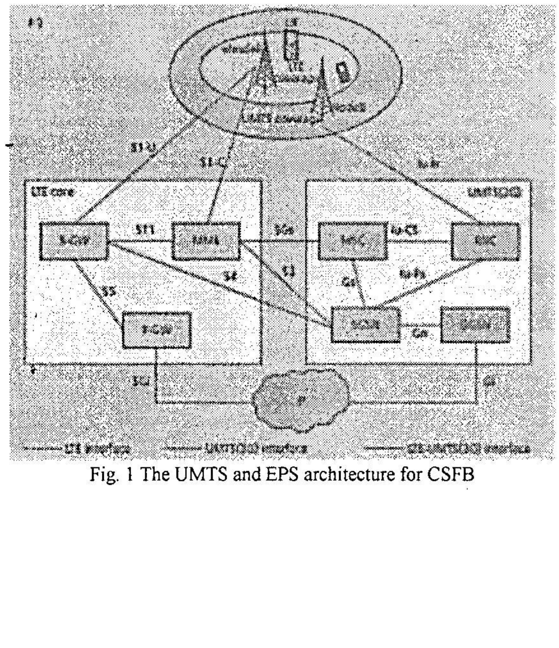


Fig. 1 The UMTS and EPS architecture for CSFB

In Mobile Terminate (MT) condition, a user that camping in LTE is receiving a voice call via paging message, it will route to the Circuit Switch domain. The terminal is informed network is call for voice call and it will change to UMTS domain to continue the voice call service. In case of Mobile Originate (MO) or Mobile Outgoing Call, UE will send a CS Fallback service request to the MME which MME will handle the handover process [7]. After the handover from LTE to 3G network is done the UE continue the conversation of voice call in 3G domain.

B. Voice over Generic Access (VoLGA)

Initially VoLGA was one of the more popular candidates for voice call in LTE, however, recently it seem to have dropped considerably in popularity as its primary forum has not posted news in several years [8]. It is not really a 3GPP standard as such but rather an Application Server (AS), that the LTE network can communicate to. It is defined by the VoLGA Forum and is based on the 3GPP Generic Access Network (GAN) standard which was originally designed to support interworking of voice with Wifi [4]. The following Fig. 2 show the high level VoLGA service presented in requirement paper.

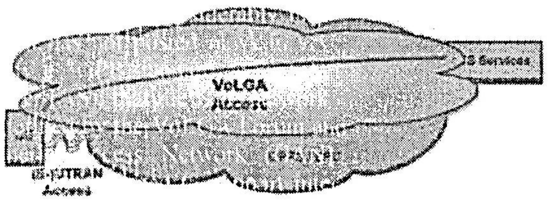


Fig. 2 High-level VoLGA services diagram [4]

VoLGA reuses the principles and goals of GAN. GAN use a controller node, the GAN Controller (GANC), which located between the 3GPP core network and IP access network. The GAN allocate an overlay access between the UE and the CS network without requiring specific improvement or support in the network. This provides a UE with a 'virtual' connection to the CS network. VoLGA services only can be used by the UE when the UE is registered for VoLGA services.

Although VoLGA was a low risk and low cost approach for support mobile operators' main revenue in voice and SMS service, they seem giving up on VoLGA and move forward to invest in the IMS-based solution.

C. Voice over IP Multimedia System (VoIMS)

In the long term, IMS based solutions are the way forward to future as VoIMS profiles; also defined as One Voice by few main operators and equipment vendors. It is not a new standard but rather a simplified Voice over IMS profile selected from IMS option. IMS was introduced by the 3GPP organization to support IP based multimedia service. It was developed in UMTS Release 5 as to introduce service control capabilities into the PS domain. The IMS allows mobile operators handling defined end-user packet switched services. Its design is done in such a way that new services can be efficiently and fast created without interfere the basic UMTS network behavior of SGSN and GGSN [9].

IMS allows interworking with various of existing voice and data network including for mobile phone and fixed line (e.g. PSTN, ISDN, etc). The IMS Core Network shall support the interworking between existing networks. The communication between IMS users and users in CS domain or fixed line domain shall be possible. The users will experience the same services for MO and MT in CS domain voice call. The voice call shall not differ between two systems in term of setup delay and delay in transporting speech between end users.

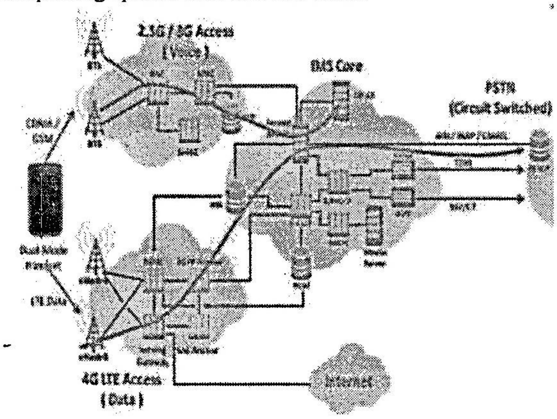


Fig. 3 Voice call and SMS via IMS

The diagram in Fig. 3 shows the voice call flow using IMS. Although of being so complex, IMS offers the best option for long term, efficient support of voice call. It offer a lot of flexibility, however unlike the other two LTE solutions, VoIMS requires UE device support registration, originating, and termination in the form of new voice application which can generate the SIP signaling needed to manage the calls [5]. For a Greenfield operator, IMS is the only voice call solution available short of signing a national agreement with an incumbent voice operator.

III CS FALLBACK PROCEDURES

In this section, the CS Fallback procedure will be describes as define in 3GPP. This includes the procedure for UE attachment, Mobile Originate (MO) call, and Call Release/Reselection. We also report the measured processing times for the procedures collected in live 3G and LTE networks.

In theory, refer table 1 for the MO call setup times. It shows the LTE to 3G CS Fallback by setup method and with comparisons to legacy network.

TABLE 1
MO call setup time [11]

	UMTS					GSM			
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
[illegible]		[illegible]							[illegible]
[illegible]		[illegible]							[illegible]
[illegible]			[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	
[illegible]			[illegible]	[illegible]	[illegible]				
[illegible]				[illegible]	[illegible]			[illegible]	
[illegible]			[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	
[illegible]			[illegible]	[illegible]	[illegible]				
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
[illegible]									
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

In live LTE network, generally the solution installed today is based on Release 8 with Redirection – SIB skipping. In this release, the UE follows 3GPP release 8, but only reads the compulsory SIBs 1, 3, 5 and 7. In this situation, once the UE is in connected mode on the target cell, the SIB11 is delivered to the UE via measurement control messaging. The Release 8 skips SIBs techniques takes about 4.9 seconds to perform CS Fallback. It's slightly longer than call setup in UTMS which 0.9 seconds longer. The reason it takes more time because of it read the compulsory (SIBs 1, 3, 5 and 7) which takes about 0.4 seconds.

A. UE Attachment

In the CS Fallback mechanism, when the UE want to attach to the E-Packet System (EPS), it performs a merged EPS/IMSI attach process. The reason of the combined attach is to register the UE at both the EPS and legacy network [10]. The Fig. 4 shows the sequence diagram of combined EPS/IMSI attachment procedure. Upon registration, the CSFB's supported UE send an attach request to the EPS network. Then EPS should send indication message to the legacy network to notify that the UE is connected to the legacy network as well. MME will send Location Update Request to the Mobile Switching Center (MSC) and Visitor Location Register (VLR) in order to attach the UE to the legacy network.

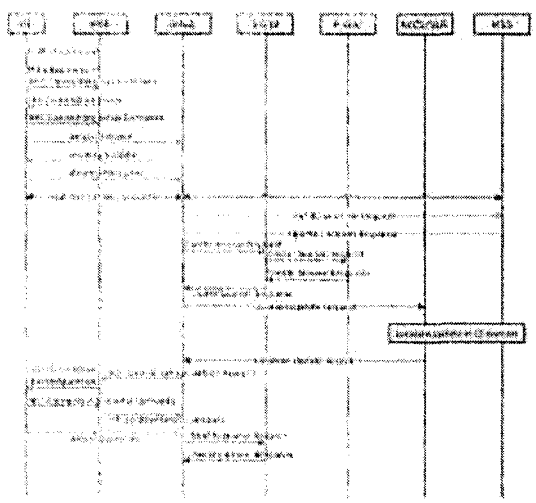


Fig 4 Combined EPS/IMS attach procedure

B. Mobile Originating (MO) call setup

Fig. 5 show the CS Fallback data flow when UE perform a voice call in the LTE network. The following procedures are executed:

Step 1: The *EXTENDED SERVICE REQUEST* message is sent by the UE to the LTE network when UE makes a voice call. It will initiate the CS fallback.

Step 2 and 3: The MME and eNodeB will exchange the pair message of UE *CONTEXT MODIFICATION REQUEST* and *RESPONSE* to show that the UE should fall back to legacy network UTRAN.

Step 4: The message *CONNECTION RELEASE WITH REDIRECTION* to UTRAN will be send by the eNodeB to the UE Radio Resource Control (RRC). This step is to indicate that it will follow the system information and cell identity to attach to the UTRAN cell.

Step 5-9: the eNodeB delivers the UE *CONTEXT RELEASE REQUEST* message to MME to release the bearers between the eNodeB and the SGW. This step takes around 0.2 second [3].

Step 10: After Step 4, the UE will camp on the NodeB as depend on the message of RRC *CONNECTION RELEASE WITH REDIRECTION* to UTRAN in the System Information. Step 10 will takes about 2.3 second for 3GPP Release 8 and 0.3 seconds for 3GPP Release 9 [3].

Step 11-13: The pair message of *RRC CONNECTION REQUEST* and *SETUP* will be exchanges between UE and the NodeB to establish the radio connection. After that, the UE will send the message of *RRC CONNECTION SETUP (CONFIGURATION) COMPLETE* to the NodeB. This step is to acknowledge the establishment of the RRC connection. This step 11-13 takes about 0.3 seconds [3].

Step 14-15: The UE sends the *CALL MANAGEMENT (CM) SERVICE REQUEST* message to begin the CS voice call service establishment procedure. It includes the Circuit-Switched Mobile Originated (CSMO) flag to indicate that it is CS fallback service. The steps 14-15 take about 3.5 seconds [3].

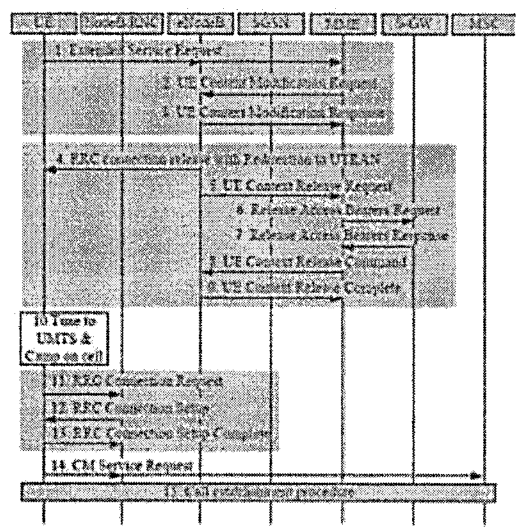


Fig. 5 Mobile Originating Call with CS Fallback

C. Release Call with Immediate-Return

After a voice call is ended, if no UMTS data session in progress, the UE will move from UTRAN to the LTE network immediately. This following Fig. 3 shows the call release with Immediate-Return (IR).

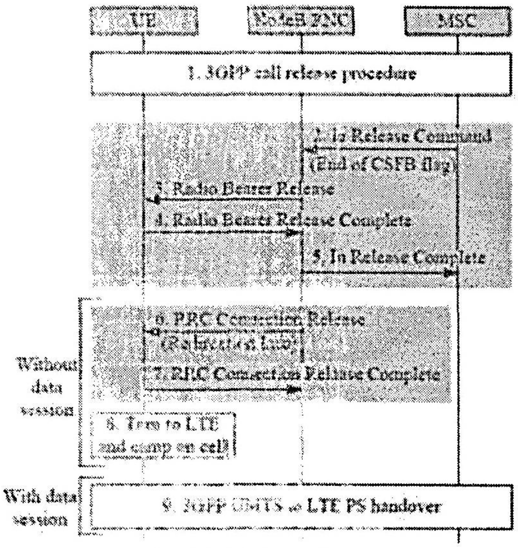


Fig. 6 Call Release with IR

Step 1: The 3GPP call release procedure is performed

Step 2-5: The MSC sends the *IU RELEASE COMMAND MESSAGE* to the UTRAN to release the bearer between the RNC and MSC. This message carries the End of CS Fallback flag to inform that the call which was released is a CS Fallback voice call. The NodeB will release radio bearer with the UE after UE receiving *RADIO BEARER RELEASE* message from NodeB.

Step 6-8: To release the radio bearer, the nodeB sends to the UE the *RRC CONNECTION RELEASE WITH REDIRECTION INFO* message. Then the UE camp to the LTE network.

D. Release Call with Delayed-Return

After the voice call is ended, if the user is engaged in a data session then the UE will camp back to LTE as illustrate in Fig. 6. If there is no data session after the call release, he UE does not need to return to LTE immediately. This procedure is called Call Release with Delayed Returned (DR) as illustrate in Fig. 7.

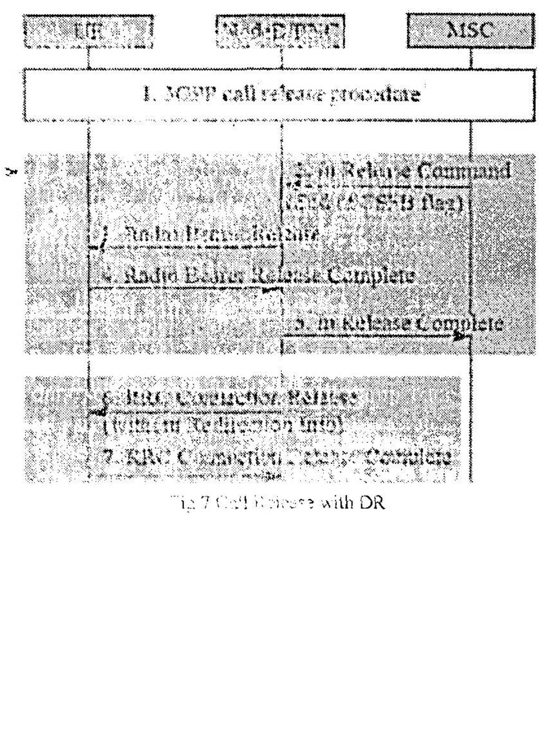


Fig. 7 Call Release with DR

The UE stays in UMTS network with the idle mode after it release the radio connection. In step 1-5 of the release flow is the same as call release with IR. The different is a step 6 which NodeB sends the *RRC CONNECTION RELEASE WITHOUT REDIRECTION INFO* message. The UE then not switch to LTE since this message not contain the Redirection Info and stay on UMTS network in idle mode.

IV METHODS

Nemo Outdoor from Anite PLC is the powerful drive test tool for the wireless network. It is the radio network measurement tools offers a full drive test solution for wireless network testing, mobile network testing, troubleshooting, and optimization. It is used to measure coverage for CS Fallback in LTE network.

A. Drive Test

The drive test is a technique of measuring, calculating and accessing the network coverage, capacity and Quality of Service (QoS) of a mobile radio network. This method include of using a vehicle that have drive test equipment that can record and detect a variety of the parameter of cellular service in a particular geographical area.

In general, the live network had a single 4G frequency and overlapped with multiple 3G frequencies. The 4G networks deployed CS Fallback as defined in 3GPP LTE Release 8. In this study, CS Fallback calls were conducted using commercially LTE capable smart phone. Meanwhile for legacy UMTS calls, the phones were reconfigured to disable LTE.

In this study, the area locations depend on LTE coverage network. This research is only at the areas that have LTE service. The selected area is around UiTM Shah Alam because the area already installed with LTE service since 2013. Due to a lot of traffic and user, major area of UiTM Shah Alam is the selected sites to perform drive test. In the Fig. 8 show the Google Earth software that used to plan the desired drive test route. All the three locations are neighboring to each other's and the three of them record a lot of active users' data than other sites of UiTM campus area.

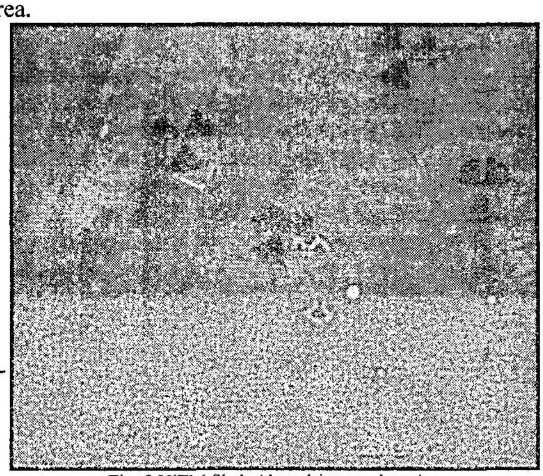


Fig. 8 UiTM Shah Alam drive test location

For the record, LTE already covered all part of UiTM Shah Alam campus as major operators in Malaysia already install NodeB that serving 3G services and E-NodeB for 4G services. For future planning, all operators will expand their 4G service in UiTM Shah Alam campus and the target is before Q3 2015.

As the plan already scheduled, the compulsory tools that need to be ready for drive test which the notebook equipped with:-

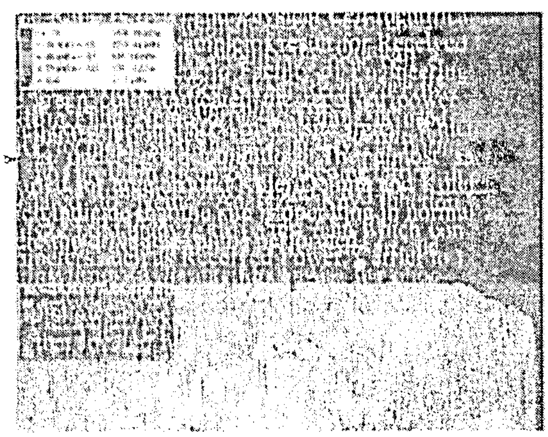
- Nemo Outdoor Software
- Nemo Outdoor Dongle
- LTE test phone with Celcom Simcard
- Global Positioning System (GPS)
- NSN Netact Operating Sub-System (OSS)

B. Data Collection and Analysis

The measurements have been conducted on LTE capable smart phone and Nemo Outdoor software from Anite Ltd. The capability of these tools is they capable to design customized measurement scenarios and its can automatically produce statistical evaluation report.

In CS Fallback voice call, the phone was supported to be in both LTE and UMTS network coverage before CS Fallback voice call was initiated. In majority cases, after CS Fallback released, around 20 seconds waiting time was granted to ensure the phone reselect the LTE network.

The data was collected near cell condition with average LTE Reference Signal Received Power (RSRP) of -75dBm. The Nemo drive test tools is used to scan the RSRP to make sure the site is serve in normal condition and no problem occurred. Outcome from drive test is translated to Nemo Analyze. Key function of Nemo Analyze is to analyze drive test data which contains set of parameters such as Received Power, Carrier to Interference Noise Ratio (CINR) and Physical Cell Identification (PCI). Fig. 9 shows the example of result for Received Power for area that located near to Faculty of Engineering buildings. The green color indicated the received power is -75dBm which cover around 80% of the site signal. Which mean the site is under good condition. The almost same result reported for area around Kolej Delima and Kolej Cempaka which indicate that the site is operating in normal condition where the drive test can be performed.



The test calls have being made at all three sites. In the area of Engineering Complex as the example, the data collected for all 3 sectors where the specific GPS location shown at Fig. 9 and table 2.

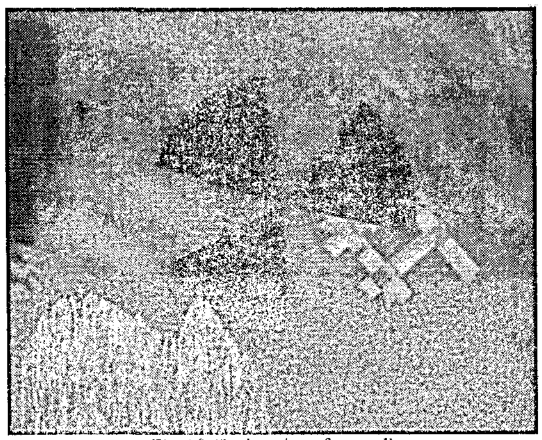


Fig. 10 The location of test call

TABLE 2
Test drive GPS location

Site Name	Cell ID	PCI	LONGITUDE	LATTITUDE
PR UITMKJUTERAN	1	120	101.49931	3.0737729
PR UITMKJUTERAN	2	121	101.49879	3.0732319
PR UITMKJUTERAN	3	122	101.4978	3.074122

Through the tests, mobile log data was saved from phone application and Nemo Outdoor, including LTE protocol and message as well as multiple LTE and UMTS radio access and core network elements. The performance result in term of voice call setup latency and call setup success rate that reflect user experience were gathered from analysis of both UE and radio and core network record.

V. ANALYSIS AND RESULT

In this test, simple mobile originated and terminated voice call service has been analyzed. For each area, there are 3 (three) Physical Cell ID (PCI) which in this study, all 3 sector tested with the test drive tools to measure the CS Fallback.

A. Analysis of CS Fallback usage

The data from OSS is analyzed which the OSS software called NSN Netact. From OSS, the important parameters are extracted which the number of users and percentage of CS Fallback success rate. The recorded time frame is seven (7) days which consist from Saturday to Friday. These data show the users behavior and characteristic in performing CS Fallback voice call. The comparison are made for average CS Fallback calls per day and from the data captured in the busy hour which time at 10:00-12:00 hrs.

The Fig. 10, Fig. 11 and Fig 12 illustrate the result from OSS for site all area which record CS Fallback traffic for a whole week. Generally the data show almost same pattern since all sites under the same area which cover UiTM Shah Alam.

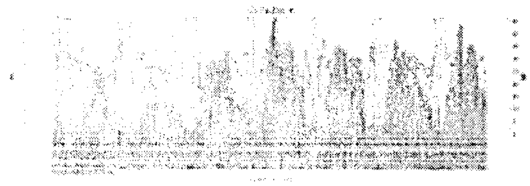


Fig. 10 CS Fallback data at Engineering Complex area

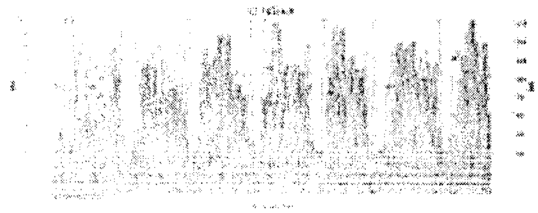


Fig. 11 CS Fallback data at Kolej Delima area

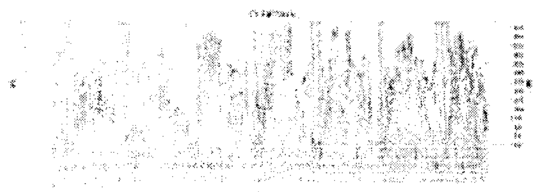


Fig. 12 CS Fallback data at Kolej Cempaka area

Table 3 summarized the CS Fallback average call for the whole week. The number of call per day and call per busy hour at these 3 sites are shown for comparison. Average performance of number of calls in Table 3 are based on data collected from a commercial live LTE network. [illegible] mostly UiTM [illegible] number of calls are less in the weekend than in the working or lecture days. In the busy hours of the weekend, the average call is less than 10 calls in these e-NodeBs. These results show that users aren't likely to perform voice call in the weekend as they want to rest and outing.

TABLE 3
Average CS Fallback call in live network

	ENGINEERING COMPLEX		KOLEJ DELIMA		KOLEJ CEMPAKA	
Day	Busy hour average call	Average call per day	Busy hour average call	Average call per day	Busy hour average call	Average call per day
Saturday	[illegible]	[illegible]	4	[illegible]	14	7
Sunday	10	5	10	5	8	7
Monday	27	14	9	7	24	13
Tueday	[illegible]	[illegible]	11	7	29	14
Wednesday	24	[illegible]	16	7	28	13
Thursday	35	16	10	6	19	12
Friday	30	16	10	7	27	14

Meanwhile in the weekdays, the volumes of users increase drastically. All three sites show the improvement of user's [illegible] that using CS Fallback in the LTE network. For traffic at Engineering Complex, it shows the highest numbers of users because the site serves for Faculty of Engineering (FKE), Faculty of Communication and Media Studies and Baiduri Apartment. At the busy hours, the statistic show the average number of calls is in the range from 27 to 35 calls per busy hour. In a week, the highest average call per day is recorded at Tuesday which 18 call per day.

[illegible] area which covers Kolej Delima and Kolej Teratai, the number of calls is lower than site in Engineering Complex. The average call per day is recorded only 7 calls. For data at busy hour, it recorded only average 7 calls. It's the lowest average call between these 3 sites. Contrary at the area where Kolej Cempaka located which show slightly higher in term of number of calls, its record average 14 calls per day. The serving areas are for Kolej Cempaka, Science Laboratory, and the Center of Islamic Though and Understanding (CITU) which have more LTE users.

B. Analysis of CS Fallback call setup delay

Example for site CSFB test call that perform at the area of Engineering Complex, according to the statistic results, CS fallback setup take about 8 seconds to handover from LTE network to UMTS network. In sector 1, as shown in Fig. 13 and table 4, the UE sent the *EXTENDED SERVICE REQUEST* message to the MME on 13:51:24.252 hours to initiate CS Fallback. The voice call service was established about 8.894 ≈ 8.9 seconds later. Comparing with ideal MO for CSFB Release 8 with redirection – SIB Skipping call setup latency which about 4.9 seconds (Table 1). The different of call setup delay is 4 seconds.

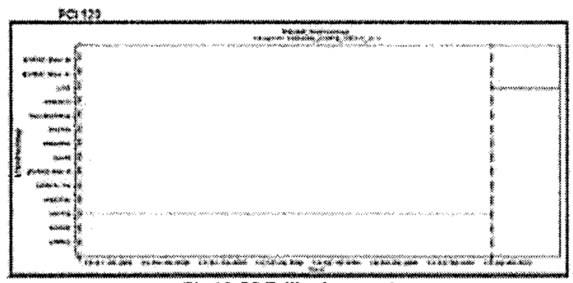


Fig 13 CS Fallback at test 1

TABLE 4
Details of CS Fallback test 1

Event ID	System	Transf. dir.	Time	Message name
L3SM	LTE FDD	Uplink	2014 1 17 13:51:24.252	EXTENDED SERVICE REQUEST
L3SM	UMTS FDD	Downlink	2014 1 17 13:51:33.146	ALERTING
RRCSM	LTE FDD	Downlink	2014 1 17 13:51:55.516	DISCONNECT
RRCSM	LTE FDD	Uplink	2014 1 17 13:51:57.303	RRCConnectionReconfigurationComplete

The *ALERTING* message is forwarded to the UE of the B party. The *ALERTING* message wills initiated the ringing tone on the handset. The voice call ended as the UE send *DISCONNECT* message to the network. This indicates that user finish using the voice call service. After voice call ended, the UE will perform 3G to LTE reselection since there is no UMTS data session performed. The UE will move from UTRAN to LTE network immediately. As shown on Fig. 13 and Table 4, the reselection takes time about 42.2 seconds. The *RRC CONNECTION RECONFIGURATION COMPLETE* message is used to confirm the successful completion of reselection.

As for all data that collected at 3 sites, the call setup delay can vary based on the site deployment. Table 5 illustrates the average call setup delay for all 3 sites. For the comparison, the call setup delay for all sectors is still small and mostly users will not experience the long delay in CS Fallback call. The users will experience the average of 8 to 9 seconds for CS Fallback call setup in the live LTE network.

TABLE 5

Average call setup times

Sector	UiTMKEJURUTERAAN	UiTMDELIMA	UiTMCEMPAKA
1	8.96 s	8.91 s	8.76 s
2	9.53 s	9.34 s	10.24 s
3	8.15 s	8.69 s	8.54 s

C. Comparing CSFB Call to UMTS Call

Generally, based on the result, the CS Fallback call setup delay is around 3 to 4 seconds greater comparing with UMTS call setup. The result reported in this paper represents the average call setup delay in both LTE and UMTS for 5 test calls at all three sites located in UiTM Shah Alam which is among the critical and challenging area for mobile operators. Table 6 summarized the CS Fallback call setup from previous sections. Call setup for legacy UMTS CS call is shown as comparison. Average performances of CS Fallback in Table 6 are based on data collected from live *LTE network* with reasonable RF condition. Higher excess delays could be measured in suboptimal network.

TABLE 6

Summary of call setup time in for UMTS and CSFB call

	UiTMKEJURUTERAAN		UiTMDELIMA		UiTMCEMPAKA	
Sector	UMTS	CSFB	UMTS	CSFB	UMTS	CSFB
1	[illegible].45	8.96 s	6.67	8.91 s	6.50	8.76 s
2	6.28	9.53 s	5.98	9.34 s	6.78	10.24 s
3	6.32	8.15 s	5.83	8.69 s	6.55	8.54 s

VI. CONCLUSION

CS Fallback performance in live LTE networks has been demonstrated in this paper. In the sufficient optimized LTE Release 8 network, the numbers of CS Fallback call is under considerable volume as it shows that most of the users are not upgrade the LTE package. The users that purchase LTE package is not as many of users under 2G/3G package since LTE is a new technology and the users still use the 3G services since it more stable. The other reason is because of the LTE network only covered high density urban area for the time being although mobile operators is continues to invest in the LTE network upgrades and enhancements throughout the Malaysia with Sarawak and Sabah as one of its primary, focusing on rapid LTE network rollout.

As from mobile user point of view, CS Fallback doest cause critical call setup delay. The latency to perform voice call via CS Fallback is still under consideration. The call setup delay only takes around 8 seconds which the difference can be minimized with LTE Release 9 enhancement. The CS Fallback calls involve interaction between LTE and UMTS radio access and core network. The lack of suitable radio planning, interference management and RF optimization of both networks can lead to variety of issue.

There also problem with mobile data drop after CS Fallback but it can be consider non-critical since the automatic reselection occur immediately aner the CS Fallback. The user mostly wouldn't notice that network reselection occurred. However mobile operators should take this as a critical issue to improve the CS Fallback.

CS Fallback technique is still new for major mobile operators at Malaysia. There a lot more to be improved to serve better service to the customers. In general, it has been found that with adequate optimization, CS Fallback performance is good in the LTE network.

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