Performance Evaluation of Handover from UMTS to LTE using Voice Call Continuity

Joyce Namakoye, Rex Van Olst
School of Electrical and Information Engineering
University of the Witwatersrand, Private Bag 3, Johannesburg 2050
Tel: + 27117177232, Fax +27114031929
Email: Joyce.Namakoye@students.wits.ac.za; Rex.VanOlst@wits.ac.za

Abstract - In this paper, we evaluated the performance of voice handover from Universal Mobile Telecommunications System (UMTS) to Long Term Evolution (LTE) using the Voice Call Continuity (VCC) procedure. The VCC handover was modelled on handover signal flows and the analysis was done using mathematical models for each of the partial procedures that made up the total interruption. Mathematical equations were written for the service interruption time within the VCC handover signal flows. The service interruption equation along with its mathematical models was simulated and results were obtained. The results were compared with 3GPP specifications.

Index Terms: VCC, LTE, UMTS, Seamless Mobility

I. INTRODUCTION

In the past three decades, cellular networks have evolved from first generation (1G) analogue networks of the early 1980s to today’s high-speed 3G and 4G networks. As this evolution took place, many industry stakeholders realised that focus should be put on network convergence. In telecommunications, network convergence refers to network architecture designs used to integrate voice and data networks into a single network [1]. The arrival of the Long Term Evolution (LTE) together with the Internet-Protocol Multimedia System (IMS) from the Third Generation Partnership Project (3GPP) brings with it the promise of network convergence and seamless mobility.

LTE comes with a new all-IP packet core known as the Evolved Packet Core (EPC) which has the ability to interconnect all access technologies on a single platform. The IMS on the other hand, defines a highly sophisticated service delivery infrastructure that is independent of the access network, that is to say, a service provider can deliver services to several User Equipment (UE) types which access the network using different access technologies on the same platform [2]. Although the EPC promises high speeds and seamless mobility, LTE faces the problem of backward compatibility with circuit switched (CS) based services such as voice and Short Message Service (SMS). This is because LTE operates entirely within the packet switched domain while earlier cellular networks such as UMTS and Global System for Mobile communications (GSM) provided voice and SMS services in the circuit switched domain. When LTE becomes commercially available, subscribers will expect new exciting services as well as existing services. In addition, network operators will want to leverage their existing UMTS and GSM assets before a complete migration to LTE can be made. It is therefore important to have seamless mobility between LTE and UMTS from the onset of LTE deployment.

Voice Call Continuity (VCC) is one of the schemes that bring the promise of a seamless user experience between LTE and UMTS. 3GPP has standardized VCC in [3]. In this standard, an interworking architecture and methods which allow a User Equipment (UE) to move between IMS and CS domains are defined. For example a UE utilizing CS voice services over UMTS can handover to the packet switched (PS) domain on the LTE network while maintaining a consistent user experience. VCC functionality includes support for automatic network selection by the UE, and how to perform an in-call handover (HO) between access technologies [3].

Seamless mobility across radio technologies is difficult to implement and care must to be taken to ensure that the delay does not distort call quality and that the user is not able to discern network interruption.

In this paper, we examined Voice Call Continuity (VCC) as a solution for seamless mobility between UMTS and LTE. More specifically, we evaluated the performance of voice handover from UMTS to LTE. This paper is organised as follows. Section II gives an overview of VCC and examines its impact and compliance on both the network and the UE. Section III gives the methodology and simulation setup used to perform the evaluation. Section IV presents the results and discusses them. Section V gives conclusions and future work that can be done on the subject.

II. SRVCC OVERVIEW

Voice Call Continuity (VCC) is an application that provides capabilities to transfer voice calls between the CS domain and the IMS network. VCC provides functions for voice call originsations, voice call terminations and for domain transfers between the CS domain and the IMS and vice versa [3]. 3GPP has defined the Voice Call Continuity (VCC) specifications in order to describe how a voice call can be maintained as a mobile phone moves between circuit switched, IMS and packet switched domains [3].
For VCC to be fully operational, enhancements must be made to the UE and to the network. In the case of the UE, the use of multiple access mode devices is mandatory. A multiple access mode device is one that is able to access one or more radio access technologies simultaneously. For example, a VCC capable multi-mode device may have LTE and UMTS modes. This means that the device has the radio and client functionality to access and register on either LTE or UMTS networks. Once registered with one of the networks, the device should be able to support all services supported. The UE must also be enhanced to understand and support the set of modes which network types should be used [3].

Network enhancements must also be made to the core network to enable VCC. Figure 1 shows the VCC reference architecture as defined by 3GPP [3]. The architecture shown is composed of a UMTS core network (shown in blue) and the IMS network (green). Note the inclusion of the VCC application (grey-green stripes) interconnecting with the IMS network and the UMTS networks. The Customized Application for Mobile Enhanced Logic (CAMEL) protocol is used to trigger VCC functionality between the UMTS Mobile Switching Centre and the VCC application [3].

![Figure 1: Voice call continuity architecture](image)

A user terminal with VCC capability will set up a CS voice call in the UMTS network with IMS anchoring as shown in the Figure 2. After setup, the call has a CS bearer from the UE to the MSC. If the terminal is VCC capable, it will transfer this capability to the network at call setup; this triggers the VCC application through communication with the Mobile Switching Centre (MSC) which in addition to setting up the call in the CS domain, communicates with the IMS network to create the IMS call leg [3].

![Figure 2: Circuit Switched call setup with IMS anchoring](image)

If the VCC terminal moves from UMTS to LTE coverage, handover to LTE will occur using the VCC procedure. The existing CS call leg will be released while a new PS call leg is created with the LTE network entities. This is done while maintaining the call in the IMS network and is illustrated in Figure 3 [3].

![Figure 3: UMTS to LTE VCC handover procedure](image)

III. ANALYSIS AND SIMULATION

In order to evaluate the performance of the VCC procedure, the service interruption time of the handover procedure was used. From Figure 3 we extracted the messages for service interruption time which are shown in Figure 4. Service interruption occurs after the Mobility Management Entity (MME) issues the ‘Handover command’ to the UE. From here on until a new PS call leg is created in the LTE network, the call is interrupted.

The expression for service interruption was written based on the mathematical behaviour of the type of the network message. Network messages were split into three parts, radio, network node and remote network messages [4]. The mathematical behaviour on the radio link was defined by the Radio Link Control Protocol model and is given in [5] and [6]. Mathematical behaviour of the network node queuing
was defined by the MM1 queuing model in [7] while queuing at the remote network was given by the MG1 queuing model in [7][8]. From these three models, the service interruption time shown in Figure 4 can be written as in Equation 1.

\[ D_{\text{UTMS} \rightarrow \text{LTE}} = 2D_{\text{Remote}} + 2D_{\text{Internet}} + 2D_{\text{AS}} + 6D_{\text{CSCF}} + D_{\text{UE}} + 3D_{\text{MG}} + 3D_{\text{Radio}} \]

Where, D is the delay resulting from different network elements. Equation 1 along with the mathematical models was modelled using MATLAB. The simulation setup used is shown in Figure 5. The simulation was done under two conditions, that is, static and dynamic conditions. Under static conditions, there was only one UE communicating with the network with preset network conditions. Under dynamic network conditions, the models for radio link behaviour, network node and remote network were modelled in real time.

![Figure 2: UMTS to LTE VCC service interruption time](image)

The parameters that were used for the simulation of the LTE and UMTS networks are shown in Table 1. In queuing theory, λ is the traffic arrival rate while µ is the service rate. \( \rho = \frac{\lambda}{\mu} \) is the measure of demand on a queue.

### Table 1: Simulation Parameters

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![Figure 4: UMTS to LTE interruption time versus BLER](image)

### IV. Results

Figure 6, Figure 7, Figure 8 show the behaviour of the service interruption time for UMTS to LTE VCC handovers under static conditions. The service interruption time was plotted for varying data rates, radio propagation delay and Block Error Rate (BLER) on the radio link. Under static conditions, the service interruption time was found to be much higher (order of 400 and 500ms) than the 3GPP specification of 300ms [9]. The high delay was attributed to the long time taken to set up PDP context in the LTE network as well as the many IMS messages.

It was also observed that for a given BLER, the service interruption time decreased considerably with increased data rate. However, for data rates higher than 1Mbps, there was no significant decrease in the service interruption time. This is due to the constant size of an LTE frame. 1Mbps is sufficient to transmit a control signal in one frame; therefore increase in the data rate does not improve performance.

In Figure 6, it can also be seen that as BLER increased, the service interruption time gradually increased. When BLER was higher than 21%, there was an exponential increase in service interruption time. It’s important to note that for UMTS to LTE handover, a BLER higher than 21% adversely affects service interruption time.
interruption time. For propagation delay of 10-5 or less there was no significant decrease in the service interruption time hence the line plot for 10-5 and 10-6 propagation delay are seen to overlap. However, as the propagation delay increased from 10-3 to 10-2, there was a sharp increase in service interruption time. This behaviour was further illustrated in Figure 8.

The performance for VCC handover from UMTS to LTE was also evaluated under real-time network conditions. Once again the trend in service interruption time versus BLER and propagation delay was found to be similar to static conditions. However, after averaging 500 real-time simulations, it was noticed that the service interruption time was generally less than that under static conditions. Figure 9 shows the interruption time versus the BLER for different orders of propagation delay under real-time conditions. Note that the interruption time is in the order of two hundred milliseconds (200ms) unlike before where it was in the 400ms range. The real time simulation setup therefore yielded much better results than the static conditions.

![Figure 5: Service Interruption time versus BLER](image)

![Figure 6: Service Interruption versus Propagation delay](image)

![Figure 7: Service interruption time under real-time conditions](image)

V. CONCLUSION

In this paper, we evaluated the performance of the VCC procedure for voice handover from UMTS to LTE. Simulation results showed that a UMTS voice call handed over to LTE meets the 3GPP service interruption time requirements of 300ms when simulated under real-time conditions. Results also showed that for a given BLER of less than 21%, the service interruption time was 200ms or less under real-time simulation conditions while it exceeded the 300ms specification under static conditions. In addition, a radio propagation delay of 10-4 or less showed improved performance on the service interruption time in both static and real-time simulations.

Given the above results, an operator wishing to deploy VCC for UMTS and LTE can minimize the service interruption time by reducing errors and propagation delay on the radio link. On the core network, the delay caused by PDP context setup on the LTE network and setup on the IMS network must be minimized. This can be done by improving the queuing performance of the core network nodes.

When hindrances on the radio and core network are properly optimized, it can be said that VCC is a feasible scheme for voice handover from UMTS to LTE.

VI. REFERENCES


Joyce Namakoye received her undergraduate degree in 2006 from Makerere University Kampala Uganda and is presently studying towards her Master of Science degree at the University of the Witwatersrand. Her research interests include Next Generation Networks, Network Convergence, Seamless mobility and LTE.

Rex Van Olst is a Professor at the University of the Witwatersrand and is presently the head of the Center for Telecommunications Access and Services (CeTAS). His research interests include Spectrum management and Network Convergence. He is a fellow of SAIEE and professional member of the Computer Society of South Africa.