SIP-Based Mobility Management for LTE-WiMAX-WLAN Interworking Using IMS Architecture

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Abstract

In this paper, we propose an architecture framework for interworking of Long Term Evolution (LTE), Worldwide Interoperability for Microwave Access (WiMAX) and Wireless Local Area Network (WLAN) technologies. The aim is to offer users of various networks seamless high quality IP-based multimedia services access anywhere at any time. IP Multimedia Subsystem (IMS) is used in the proposed architecture for providing a platform through which telecommunications operators can merge the various networks. A Session Initiation Protocol (SIP) REFER method which provides uninterrupted service continuity is introduced. The proposed LTE-WiMAX and LTE-WLAN tight coupled interworking is compared with the UMTS-WiMAX and UMTS-WLAN tight coupled interworking. The two heterogeneous networks are simulated using OPNET Modeler 17.1. Various metrics are obtained to test the performance of the proposed technique. Results show that successful VoIP session handoffs with acceptable Quality of Services (QoS) levels can be performed. Results also show that the proposed architecture outperforms the pervious architecture.

Keywords: IMS, LTE, WiMAX, WLAN, UMTS, SIP, EAP-AKA, Handoff, Heterogeneous.

1. INTRODUCTION

The evolving demand for mobile Internet and wireless multimedia applications has motivated the evolution of network infrastructure to a new one. The new approach will promise to revolutionize the services offered as peer-to-peer entities, which facilitate sharing. IP Multimedia Subsystem (IMS) represents that new approach. IMS is designed to provide robust multimedia services across roaming boundaries and over diverse access technologies [1]-[4].

The IMS will take communication to the next level by offering enriched communication means, since it is designed to provide robust multimedia services across roaming boundaries and over diverse access technologies. As the IMS networks use the Session Initiation Protocol (SIP) for session establishment, management and transformation, they are able to mix and match a variety of IP-based services in any way they choose during a single communication session and can add or drop services as and when they choose [2]. One of the key challenges in future network management is the guarantee of uninterrupted service continuity over dissimilar networks. To accomplish this continuity demand of mobile users roaming in wireless broadband networks, SIP REFER method is used [5], [6], [7].

In a previous work [8], we proposed a new heterogeneous network architecture that merges Long Term Evolution (LTE), Worldwide Interoperability for Microwave Access (WiMAX) and Wireless Local Area Network (WLAN) in an IMS compatible architecture. The proposed architecture incorporates a LTE core network, a WiMAX network and a WLAN network interconnected with the LTE core through specific functional entities and an IMS in charge of sessions' control. Thus, users can access the LTE Circuit-Switched (CS) based services through the WiMAX and WLAN networks, since they are authenticated in the Authentication, Authorization, and Accounting (AAA) Server and registered in the IMS core. The performance analysis of the proposed architecture was introduced with no mobility consideration.

In this paper, A SIP-based mobility management technique is proposed. When a user roams between different networks, this interworking affects the VoIP sessions and other services access. For uninterrupted service continuity, SIP REFER method is used to process handoff and provide successful mobility management. It follows a make-before-break handoff which prevents the destruction of the initial session if session handoff failed. OPNET modeler 17.1 is used for simulation. The custom task application is used to implement the newly developed SIP model, since OPNET's standard SIP component don't address the specification of the 3GPP's IMS. A custom mobility application is constructed and integrated to OPNET's existing LTE special module. The performance analysis of the proposed integration scheme is compared with IMS-based UMTS-WiMAX and UMTS-WLAN interworking architectures.

The rest of this paper is organized as follows: Section 2 discusses recent work related to IMS networks and the next generation heterogeneous networks. In Section 3, IMS subsystem is discussed in detail. Sections 4 and 5 present the UMTS-WiMAX, UMTS-WLAN and the proposed LTE-WiMAX, LTE-WLAN interworking architectures using IMS, respectively. Section 6 presents network modeling and the performance analysis before we conclude and present our future work in Section 7.

2. BACKGROUND AND RELATED WORK

Since the IMS networks are still in an ongoing activity, the industry and the research community constantly try to face open issues and extend IMS beyond 3G, by proposing interworking architectures that aim on seamless service provisioning. An overview of IMS infrastructure along with its services, applications, and future potential is discussed by Esguevillas et al. in [3]. Munir and Gordon-Ross [4] analyzed in details the SIP-based IMS registration and session setup signaling delay for two novel interworking architectures to integrate WiMAX and third-generation (3G) networks . Munasinghe et al. investigated the behavior and management of a VoIP session for roaming users across network boundaries that incorporates SIP- REFER method in [5]. Angoma et al. proposed in [6] a real environment integrating architecture which guarantees the continuity of service during vertical handover between heterogeneous access networks technologies: WLAN, WiMAX and 3G. Nikolaos et al. [9] presented a complete signaling flow concerning the authorization, registration, session set up and vertical handoff processes, as well as, an analytic model for cost analysis of the proposed architecture. Munasinghe and Jamalipour [10] proposed architecture for interworking heterogeneous all-IP networks with an in-depth analysis of its performance. Vijayalakshmy and Sivaradje [11] presented QoS provisioning interworking model that integrates a WiMAX network, a UMTS network and a WLAN in an IMS compatible architecture and it is compared with WiMAX-UMTS interworking along with IMS. Chowdhury and Gregory [12] provided the results of a performance analysis of two potential 3G/WLAN integration schemes: tight and loose coupling. Mobile IP is used as a mobility management scheme and EAP-AKA for common authentication. Sharma and Leung[13] presented a lightweight, robust, and architecture compatible IMS authentication protocol that implements a one pass IMS procedure by promoting efficient key re-use for a mobile user. They derived an analytical model of the proposed scheme, and conduct numerical analysis that reveal a user authentication delay decrease of more than 50 percent. Then in [14], they presented a lightweight, robust, and architecture-compatible IMS authentication protocol that implements a one-pass IMS procedure by promoting efficient key reuse for a mobile user for LTE-femtocell heterogeneous access networks. Nithyanandan and Parthiban [15] achieved seamless vertical handover in three interworking architectures that merge WLAN and WiMAX networks. El-Mohsen et al. in [16] evaluated VoIP performance parameters of two SIP handoff schemes used as a mobility management protocol between heterogeneous wireless networks. Rizvi et al. in [17] proved that the GGSN-WLAN integration performance is better than the SGSN-WLAN integration for all the applied applications and measurement parameters in UMTS-WLAN interworking architecture. In [18], Q. Duan and E. Lu described a technology to discover and select the network services that guarantee the QoS requirements of different networking applications.

3. THE IP MULTIMEDIA SUBSYSTEM (IMS)

IMS is a global, access-independent and standard-based IP connectivity and service control architecture that enables various types of multimedia services to end-users using common Internet-based protocols. Session Initiation Protocol (SIP) is a rendezvous protocol that is, a signaling protocol designed to establish, manage, and tear down multimedia sessions on the Internet. IMS uses SIP for session establishment, management, and transformation. In addition to the session control protocol there are a number of other protocols that play important roles in the IMS as Diameter, HTTP, etc. [1]-[4], [9], [11].

The IMS is a system architecture designed for supporting multimedia services for transmission over different access technologies. The IMS architecture is a collection of functions linked by standardized interfaces. Some of the IMS SIP entities are responsible for interfacing non-SIP IMS network nodes using different protocols designed for AAA. The IMS is 3-layer architecture. It consists of the Transport Layer, which includes all the entities for the supported access networks; the Control Layer where the core IMS network resides; whereas at the top exists the Service Layer which includes the application servers hosting the IMS services [1], [3], [4], [11].

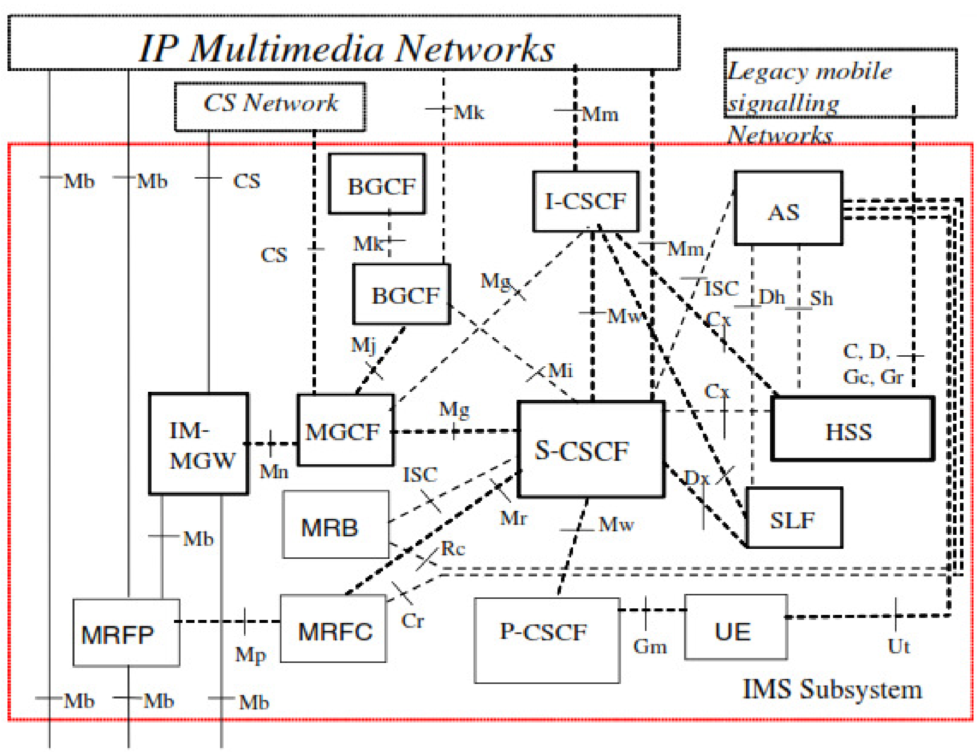


FIGURE 1: The Reference Architecture of the IP Core Network Subsystem.

3.1 IMS Components

The IMS core network, as shown in Figure. 1, predominantly consists of many nodes such as HSS (Home Subscriber Server), SLF (Subscriber Location Function), CSCF (Call/Session Control Function), P-CSCF (Proxy-CSCF), S-CSCF (Serving-CSCF), I-CSCF (Interrogating-CSCF), E-CSCF (Emergency-CSCF), IMS-MG (IMS-Media Gateway), etc. [1] - [4],[9].

3.2 IMS Registration and Session Initiation

IMS-level registration is the procedure which is used to authorize the user to access the IMS network and use the IMS services. It is done after IP connectivity for the signaling that has been gained from the access network and the application level registration can be initiated after the registration to the access is performed. IMS-level registration is accomplished by a SIP REGISTER request and the user is considered to be always roaming [1]-[4], [9], [19].

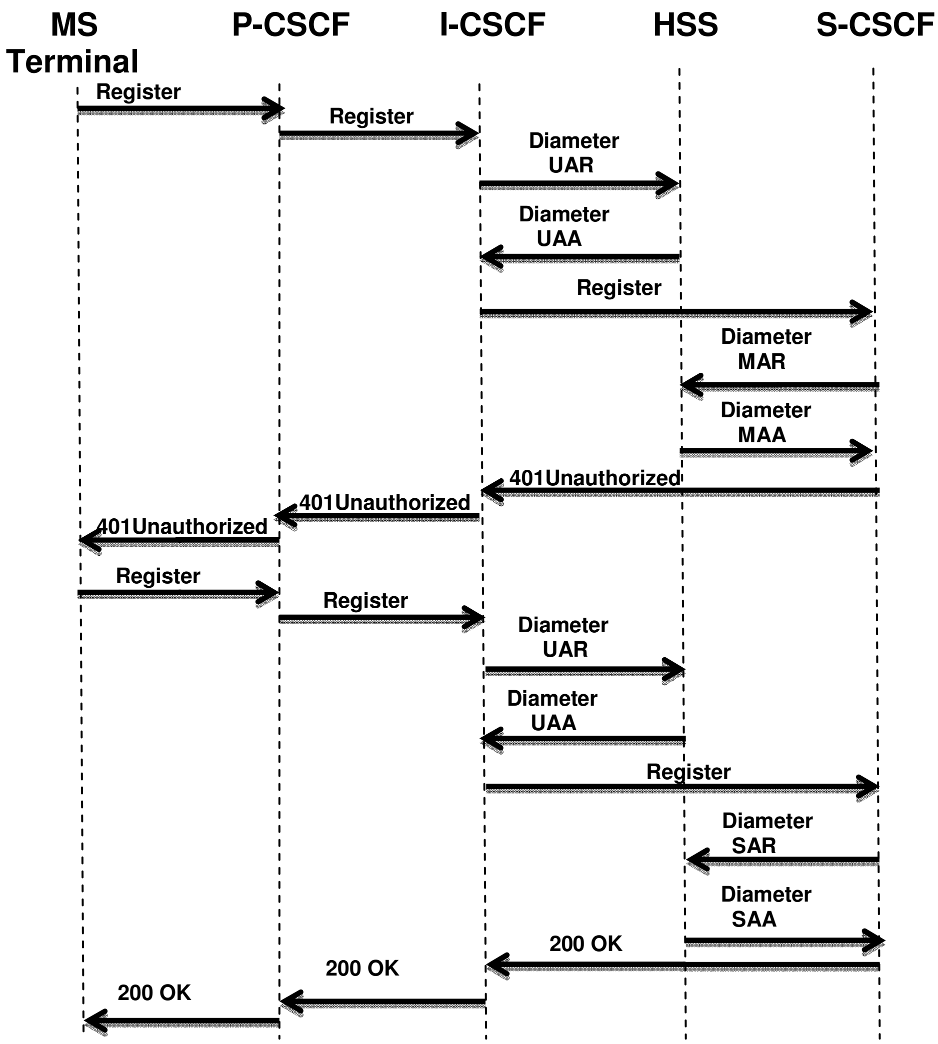


FIGURE 2: Registration at the IMS Level.

As shown in Figure. 2, The Mobile Station (MS) initiates the registration process by sending SIP register information flow to P-CSCF. Upon message reception, the P-CSCF examines the "home domain name" to discover the entry point to the home network as it might not reside to MS' home network. So the SIP "REGISTER" attaches to the information needed and sends the register information flow to the I-CSCF. To indicate whether the user is already registered and allowed, the Cx-Query/Cx-Select-Pull information flow should be sent to the HSS by the I-CSCF. A

Response is sent from the HSS to the I-CSCF and it will contain the S-CSCF name or a list of the qualifications of the available S-CSCFs. Using the name of the most appropriate S-CSCF; I-CSCF sends the register SIP ‘‘REGISTER” to S-CSCF. The S-CSCF contacts HSS to authenticate the MS. The HSS stores the S-CSCF name and the S-CSCF stores the information for the indicated user. A user invitation (‘‘401Unauthorized”) is sent by the I-CSCF to the P-CSCF. The P-CSCF repeats the above presented messages exchange, with exception of the new ‘‘UAA” which this time contains routing information. The S-CSCF returns the 200 OK information flows. The I-CSCF shall release all registration information and The P-CSCF shall store the home network contact information, and shall send information flow to the MS.

When MS wants to have a session with another, it generates a SIP INVITE request and sends it to the P-CSCF which processes the request as in Figure. 3. The S-CSCF plays an important role in service provision as it is always located in the home network and services are always available to the user regardless of whether the user is roaming or not.

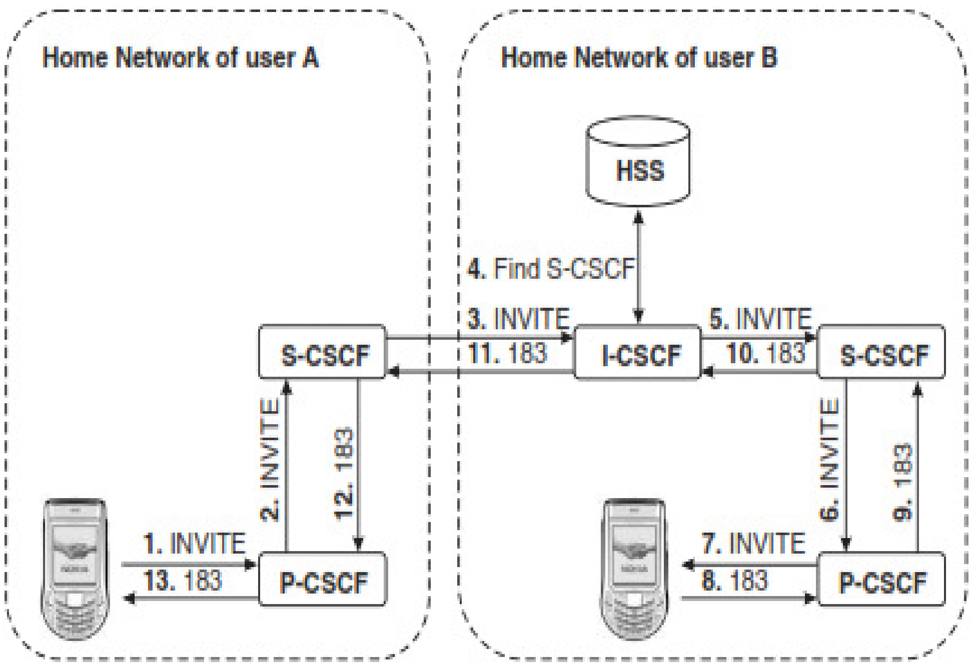


FIGURE 3: IMS Session Establishment Fow.

4. UMTS-WiMAX AND UMTS-WLAN TIGHT COUPLED INTERNETWORKING ARCHITECURES

The previous interworking models integrate UMTS-WiMAX network and UMTS-WLAN network using IMS compatible architecture. They incorporate a UMTS Core Network where the SGSN, the GGSN and the AAA Server reside, a WiMAX and a WLAN network interconnected with the UMTS Core through specific functional entities and an IMS in charge of sessions control.

As shown in Figure. 4, the tight coupling scheme connects WLAN WAG and WiMAX WG with the UMTS core network through Serving GPRS support node (SGSN). The flow of data originates from the WLAN or WiMAX users, goes through the SGSN and the GGSN 3G core network, before reaching the destination network.

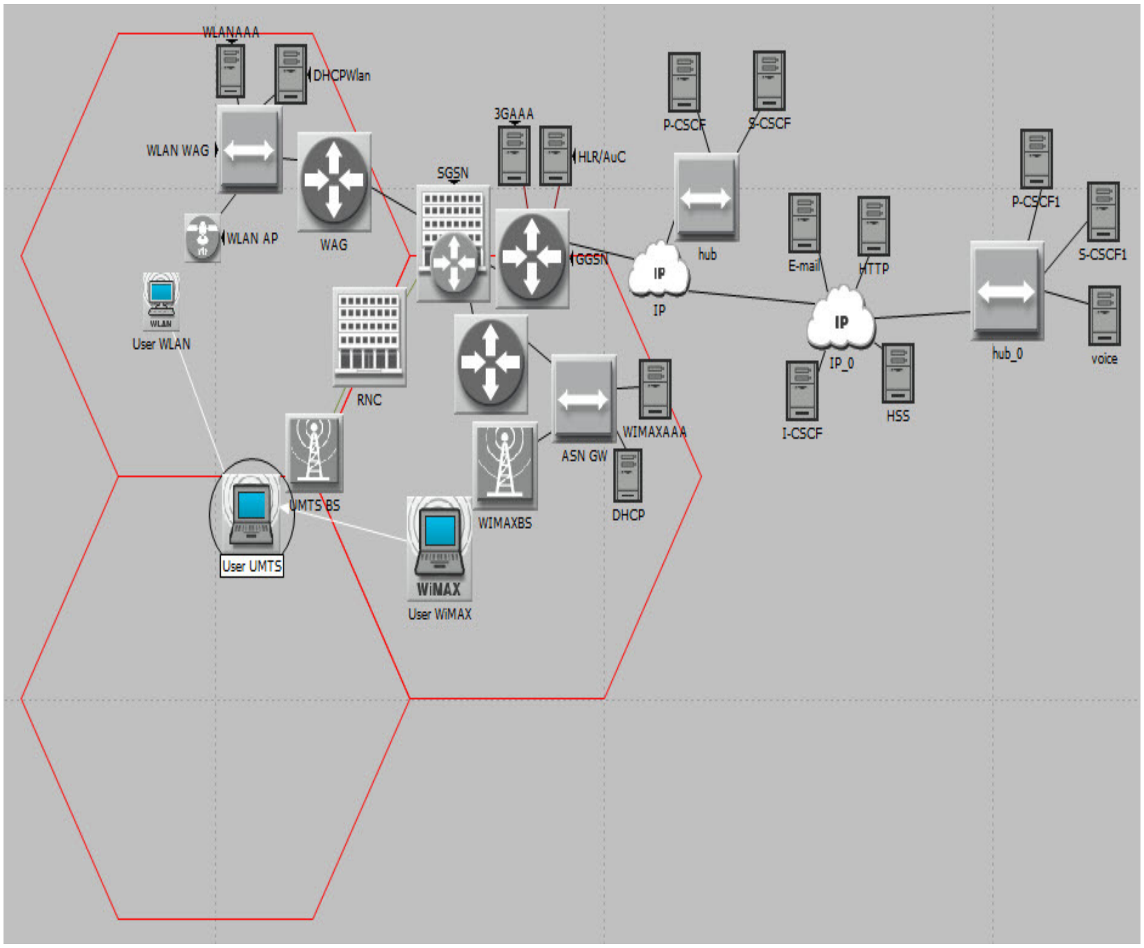


FIGURE 4: UMTS-WiMAX and UMTS-WLAN Interworking Architecture.

5. PROPOSED LTE-WiMAX AND LTE-WLAN TIGHT COUPLED INTERWORKING ARCHITECURE

Our proposed framework architecure, as in Figure. 5, merges LTE-WiMAX network and LTE-WLAN network in an IMS compatible architecture. Our primary focus is to merge WLAN network or WiMAX network with a LTE network and to manage sessions by placing an IMS core on top of technologies. The flow of data originates from the source MS, through the EPC of LTE network, and reaches the destination network. More specifically, EPC of LTE network is directly connected to the WiMAX-GW using 10Gbps_Ethernet duplex link interface, and to WLAN WAG using DS3 interface with point to point for supporting high speed and multimedia traffic. Advanced Ethernet servers are used to implement missing blocks of core network as AAA, DHCP, HLR, CSCF, S-CSCF, P-CSCF and HSS. An IMS core network is connected to the Ethernet hub using 10Gbps_Ethernet duplex interface on top of three technologies. During the exchange of SIP signaling, EPC act as a router by merely forwarding SIP messages.

In the proposed network architecture, each mobile node is equipped with multiple radio interfaces (LTE interface, WLAN interface) in LTE-WLAN network or (LTE interface, WiMAX interface) in LTE-WiMAX network, and a SIP-based handover mechanism is implemented to manage handoff on behalf of the user.

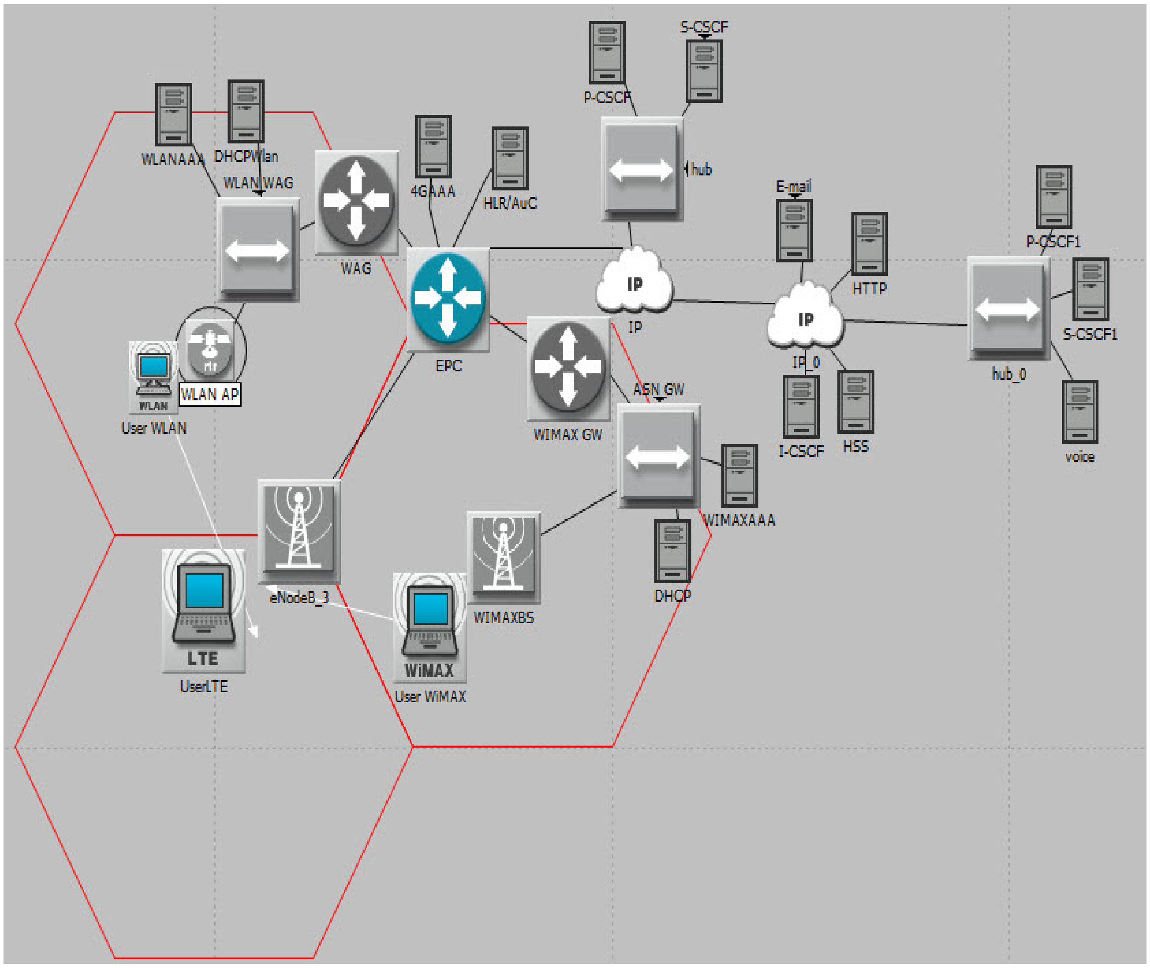


FIGURE 5: LTE-WiMAX and LTE-WLAN Interworking Architecture.

5.1 Core Registration

When MS wants to register to the IMS core through the LTE network, he must first activate a Packet Data Protocol context (PDP). A PDP context is a record that is saved in the EPC, and contains information about the user and about the active session. When the WiMAX or WLAN network is concerned, each user accessing the IMS or data services must be registered in the HLR of the LTE network. As a result, The WLAN and WiMAX users must implement authentication protocols as Extensible Authentication Protocol / Authentication and Key Agreement (EAP-AKA) and The Dynamic Host Configuration Protocol (DHCP) before they can access to the 4G Network.

EAP-AKA is an authentication protocol used by the 4G to provide access security for interworking architecture between WiMAX or WLAN and LTE. It is used to authenticate the user in the Authentication Authorization and Accounting server (4GAAA). EAP-AKA is based on AKA mechanism so the 4G home domain does not delegate responsibility for security and billing authentication to the underlying WLAN/WiMAX network [20], [21]. EAP-AKA procedures as in Figure. 6 use request/response message pair to support mutual authentication and to generate session keys.

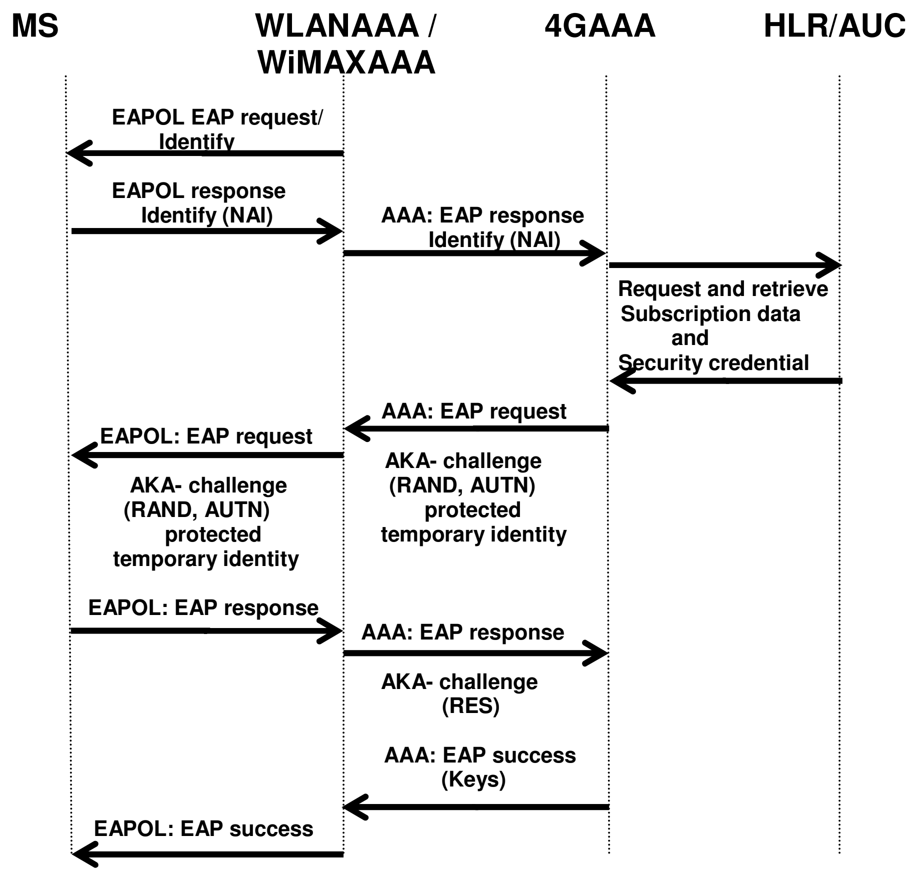


FIGURE 6: Authentication Based on EAP-AKA Scheme.

The Dynamic Host Configuration Protocol (DHCP) [22], as shown in Figure. 7, is a client-server model framework used to allocate network addresses and deliver IP configuration parameters to MS. MS initiates the procedure by sending ‘‘DHCP Discover” message to the DHCP server. The server responds using ‘‘DHCP Offer” message. MS sends back ‘‘DHCP Request” message to request IP configuration parameters. Finally, ‘‘DHCP Response” message is sent back by the server. After obtaining his IP configuration, MS will be able to exchange packets with any other host in the Internet.

Then, all users (LTE/WiMAX/WLAN) can register to the IMS core through the LTE network core using IMS-level registration procedures as mentioned in section 3.

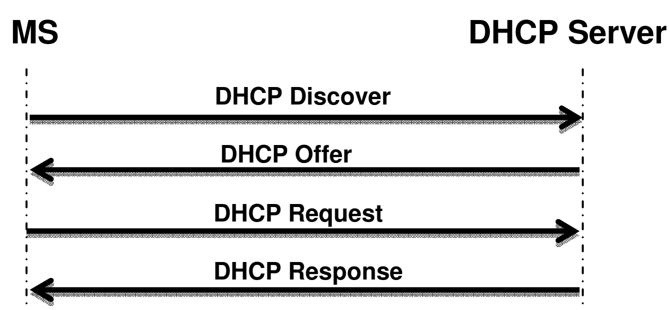


FIGURE 7: DHCP Scheme.

5.2 Proposed SIP REFER Handover Mechanism

When the MS roams to another network, he searches for availability of access networks, decides and starts executing vertical handover. The need for a vertical handoff mechanism arises for handing off an ongoing VoIP session to another network. In order to ensure seamless continuity of services, the SIP REFER method is used to provide both terminal and session mobility. OPNET Modeler 17.1 is used to construct a SIP-IMS network model for validating the interworking of the presented architecture. Since OPNET's standard SIP components do not address the specifications of the 3GPP's IMS, substantial modifications are required. The custom task application is used to implement the newly developed SIP-IMS model and the dual mode mobile node. A custom mobility application which consists of the EAP-AKA authentication, DHCP registration, IMS Registration, session establishment and SIP-based handover messages mechanism is constructed and integrated to OPNET's existing LTE Special Module. The modification and additional nodes required for the proposed architecture are shown in Figure. 5.

Figure. 8 illustrates the SIP REFER protocol applied to perform handover in the proposed architecture. First, the MS interface I performs authentication procedures to access its network. Then, The MS executes the basic session handoff process steps. The new session flow can be initiated after this process is successfully done. It is important to note that until such time, the other interface remains active for the data flow.

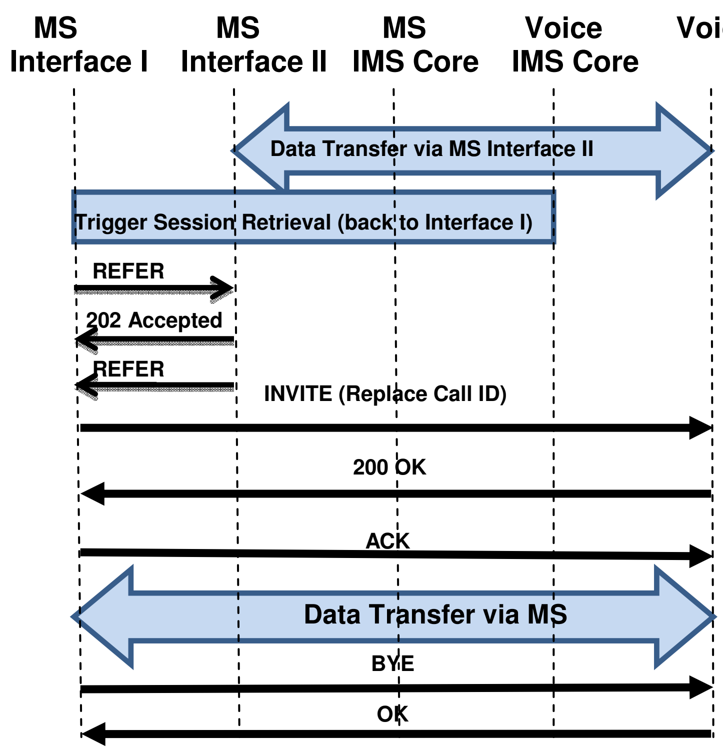


FIGURE 8: SIP REFER Handover Mechanism.

Simulation time is assumed to be 700 seconds for the VoIP application. G.711 VOIP codec with data rate of 64 kb/s is used. Email and WEB browsing activities are implemented as the background traffics. MS switches to a different network each time he performs a handoff. The SIP handoff procedures occur after switching between interfaces of the mobile node using the Routing Information Protocol (RIP). The Transitional Time is considered to be 6 seconds. The Processing Delay and Diameter Delay are considered to be 0.0001 seconds and 0.005 seconds respectively.

6. PERFORMANCE ANALYSIS

To test the performance of the proposed architecture, performance metrics are obtained. These metrics are: task response time, traffic sent and traffic received, jitter, packet end to-end delay. Also, a comparison between the proposed tight coupled architecture and the previous tight coupled networks is presented.

In the following two subsections, the results are estimated in case of a MS handoff between WLAN network and LTE network and between WiMAX network and LTE network, respectively. The results are compared with the previous WLAN-UMTS and WiMAX-UMTS networks.

6.1 LTE-WLAN Internetworking

6.1.1 Task Delay Time

Table 1 records the time taken by each interface to perform the IMS session establishment and SIP Handover tasks in LTE-WLAN and UMTS-WLAN architectures.

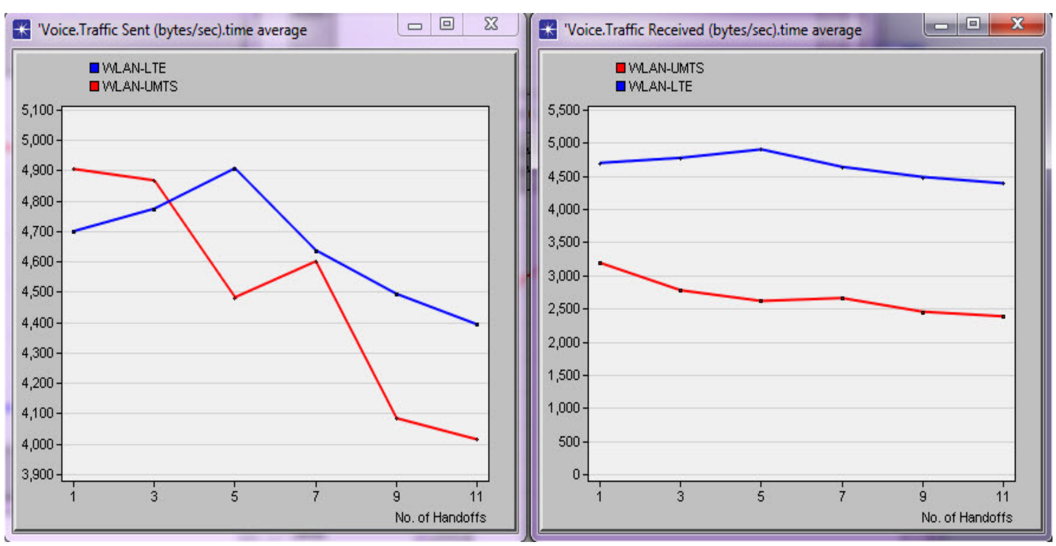
Task \ MS Movement	LTE to WLAN	UMTS to WLAN	WLAN To LTE	WLAN To UMTS
IMS session establishment	0.02944	0.02897	0.142	4.226738
SIP Handover	0.05793	0.05559	0.075	1.110001

TABLE 1: Task Delay Time (seconds).

From table 1, it is noticed that total delay time taken by a user to handoff in LTE-WLAN interworking architecture is lower than total time taken by a user in UMTS-WLAN interworking architecture.. It is apparent that switching to UMTS interface takes higher time than switching to LTE interface.

6.1.2 Voice Traffic

As shown in Figure. 9, it is noted that the voice traffic sent and received decrease as the number of handoffs increases. We also notice that the packet loss in the proposed LTE-WLAN architecture is much lower than the UMTS- WLAN architecture.

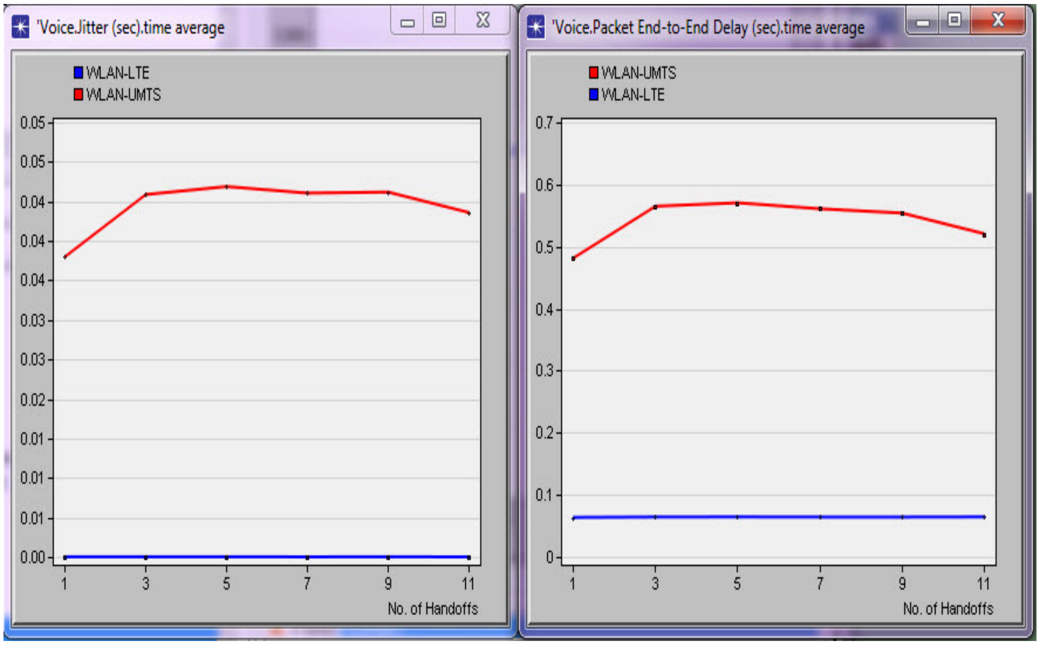


(a) Traffic Sent. (b) Traffic Received.

FIGURE 9: Voice Traffic vs. Number of Handoffs.

6.1.3 Voice Jitter and Voice Packet End to End Delay

Voice Jitter is defined as a variation in the delay of received voice packets. As shown in Figure. 10(a), our proposed coupled architecture has approximately no delay in the received voice packet. Voice end to end delay represents the variation in the end to end delays for voice packets. From Figure. 10(b), the delay variation of the LTE-WLAN coupled architecture is lower than UMTS-WLAN coupled architecture along the simulation time.



(a) Voice Jitter. (b) Voice Packet end to end Delay.

FIGURE 10: Voice jitter and packet end to end delay (sec) during vertical handoff.

6.2 LTE-WiMAX Internetworking

6.2.1 Task Response Time

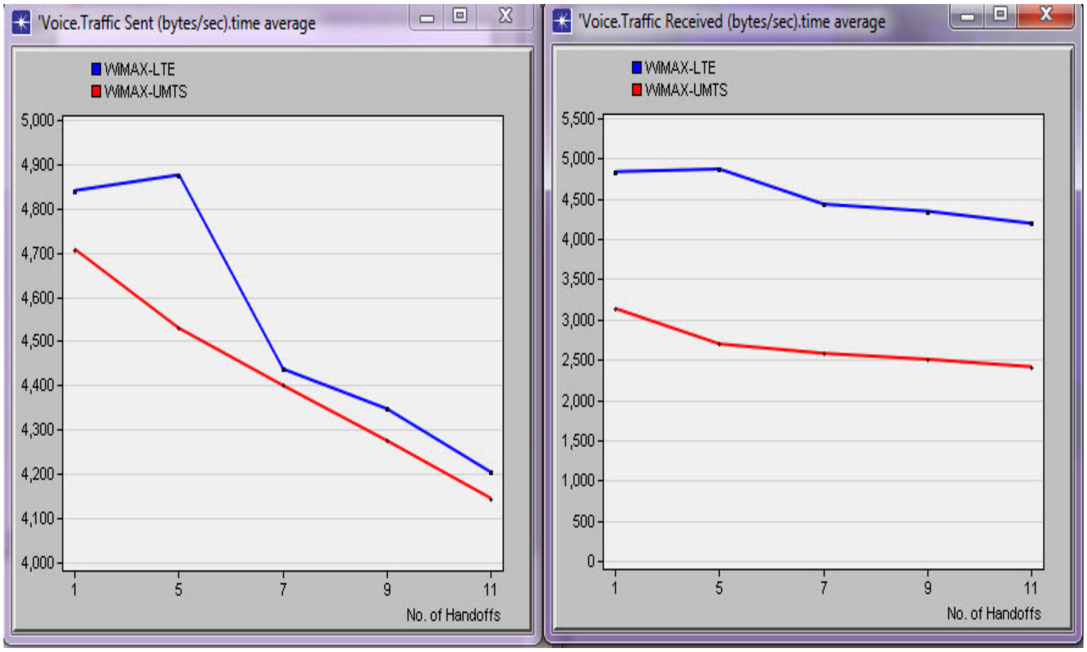
MS Movement / Task	LTE to WiMAX	UMTS to WiMAX	WiMAX To LTE	WiMAX To UMTS
IMS session establishment	0.374395	0.3444	0.142	4.226738
SIP Handover	0.165605	0.1006	0.075	1.110001

TABLE 2: Task Delay Time (seconds).

Table 2 records the task delay times in LTE-WiMAX and UMTS-WiMAX architectures. It is noticed that the time taken by a user to perform SIP-handover in LTE-WiMAX interworking architecture is lower than the total delay taken by a user in UMTS- WiMAX interworking architecture.

6.2.2 Voice Traffic

Comparing Figure. 11(a) and Figure. 11(b) for voice traffic sent and received, it is noted that the packet loss in the proposed LTE- WiMAX architecture is much lower than the UMTS- WiMAX architecture.

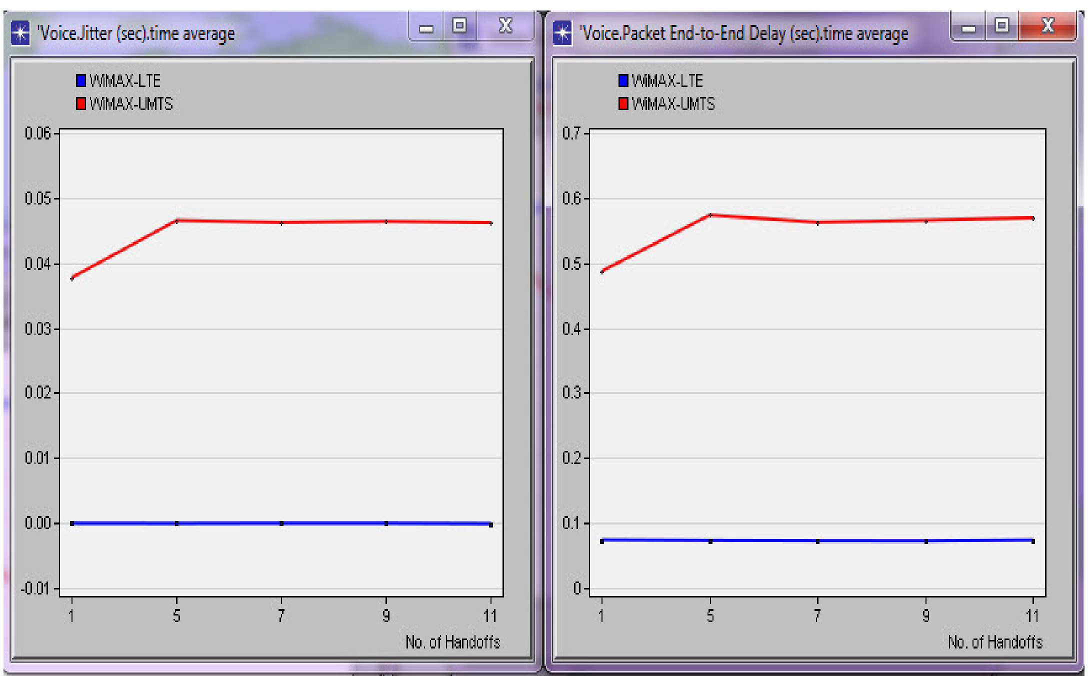


(a) Traffic Sent. (b) Traffic Received.

FIGURE 11: Voice Traffic vs. Number of Handoffs.

6.2.3 Voice Jitter and Voice Packet End to End Delay

As shown in Figure. 12(a), voice jitter in our proposed coupled architecture is approximately zero. From Figure. 12(b), the voice end to end delay of the LTE-WiMAX coupled architecture is lower than UMTS-WiMAX coupled architecture.



(a) Voice Jitter. (b) Voice Packet end to end Delay.

FIGURE 12: Voice jitter and packet end to end delay (sec) during vertical handoff.

Comparing our results with the previous proposed architectures and algorithms in [4], [5], [9]-[12], [15]-[17], the proposed architecture has the advantages of upgrading to the 4G (LTE) which provides higher data rate and less authentication time. Moreover, the proposed architecture uses IMS which is a standardized next generation network that can incorporate a variety of wireless and wire line technological alternatives for users to access the global telecommunication network. Using SIP REFER method in the proposed network provides seamless data services with QoS negotiation for IP multimedia sessions during handoff process to provide successful mobility management. It also prevents the destruction of the initial session if session handoff failed as it follows a make-before-break handoff.

7. CONCLUSIONS AND FUTURE WORK

In this paper, we introduce an architecture framework for integrating LTE, WiMAX and WLAN for seamless service provisioning. We propose a handover procedure which promises uninterrupted service continuity during the switching between different networks. Seamless real-time multimedia services during handoff between two access networks are achieved by SIP REFER method which follows a make-before-break handoff, thus preventing the destruction of the initial session. Using OPNET Modeler 17.1, the results show that the proposed architecture gives high performance for each user during data transfer and shows the capability of performing successful VoIP session handoffs between dissimilar networks whilst maintaining acceptable QoS levels.

Since IMS networks are still in a development stage, we will try in the future to solve open issues concerning session control, authorization, charging, personal mobility, etc. The main motivation for our future work is towards reducing the packet losses during vertical handover between different access networks by applying different mobility management techniques. The aim is to achieve seamless mobility support which is considered one of the most critical research issues to provide uninterrupted wireless services to mobile users in such a heterogeneous network environments.

8. ACKNOWLEDGMENT

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