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Full Length Research Paper

Interworking between WiMAX and UMTS to provide seamless services

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This article represents an interworking architecture between Universal Mobile Telecommunications System (UMTS) and WiMAX where Third Generation Partnership Project (3GPP) IP Multimedia Subsystem (IMS) and Mobile IPv4 are applied together to maintain the continuity of an on-going session and for that to keep the Internet Protocol (IP) address to be static while the consumer having internet and data access is roaming in a heterogeneous networking environment of different Radio Access Technologies. The uniqueness of this architecture is that the user mobile device would have multiple transceivers along with intelligence of making decisions of handover. The proposed device would be capable of monitoring the signal strength and processing the packets received from different networks simultaneously. The article abrogates by narrating the potential advantages of the proposed approach to eliminate the packet loss due to handover.

Key words: IMS, WiMAX, UMTS, intersystem handover, mobile IP, IPv4, SIP, OPNET modeler.

INTRODUCTION

Internet users are expected to have ubiquitous connection in the upcoming Internet Protocol (IP) based on Fourth Generation (4G) networks. The rapid increase in the consumer demand for internet and data access provoked the operators to search for better Radio Access Technologies (RATs) for providing services to the consumers with more efficiently at higher speed. The well established Third Generation (3G) network like Universal Mobile Telecommunications System (UMTS) made it possible to provide high mobility with wide area coverage but can support low to medium data rate which is not sufficient to satisfy data-intensive applications and the service charge is also very high. In addition, UMTS is not suitable for small indoor and densely populated areas. Recently, Worldwide Interoperability for Microwave Access (WiMAX, IEEE 802.16e) was standardized to support mobility to the end user with wider coverage and faster speed. The salient features of the mobile WiMAX (IEEE 802.16e) are high data rates up to 63 Mbps for Down Link (DL) and 28 Mbps for Up Link (UL), Quality of Service (QoS), scalability, security and mobility supporting handover schemes with latencies less than 50 ms (WiMAX Forum™, 2006). Also the deployment cost of the Mobile WiMAX (IEEE 802.16e) is very low. The average 3G spectrum cost per Hz is 1000 times higher than the average WiMAX spectrum cost per Hz in Europe (www.maravedis-bwa.com). However, this convergence of different IP-base networks leads the operators to new challenges in terms of quality and capacity to support QoS with required specifications, even at the cell area running out of bandwidth capacity with so many concurrent users. Henceforth, there should be new opportunities in service handover to other technologies to utilize the spectrum more efficiently.

The idea of intersystem handover between different RATs that differ in terms of spectrums, bandwidths, media access technologies, security mechanisms and so

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Abbreviations: UMTS, Universal mobile telecommunications system; **WiMAX**, worldwide interoperability for microwave access; **3G**, third generation; **QoS**, quality of service; RATs, radio access technologies; **IP**, internet protocol; IMS, **IP** multimedia subsystem; **WLAN**, wireless local area network; **CoA**, care-of-Address; **FA**, foreign agent; **HA**, home agent; **3GPP**, third generation partnership project; **SDP**, session description protocol; **AA**, agent advertisement.

on is being used since the last few years and so many hypotheses of intersystem handover have been proposed between different access technologies. All these proposed hypotheses are based on the existing techniques of intra-system handover. The most common techniques used for intra-system handover are the tight or loose coupling, Third Generation Partnership Project (3GPP), IP Multimedia Subsystem (IMS), Mobile IP (for both IP version 4 (IPv4) and IP version 6 (IPv6)) where each of these techniques deals with a definite layer. However, intersystem handover requires dealing with different layers simultaneously and thus the techniques mentioned above are not competent to provide ubiquitous services for the roaming user through intersystem handover. Henceforth, it was required to mongrelize the available techniques for such handovers which is a key contribution of the research presented in this article.

This article represents an inter-working architecture between two different access technologies capable of maintaining continuity of an on-going session without changing the IP address of the consumer while moving in an area covered by UMTS and WiMAX. The proposed architecture has three main features. Firstly, it uses a mobile device capable of maintaining identical radio links simultaneously with UMTS and WiMAX with two different interfaces for each network. The device is also capable to process, monitor and compare the signals received through different interfaces and making decisions of handover when appropriate. Hence, the handover would be mobile initiated. The idea is that as soon as the user moves into an area having coverage for multiple access technologies, the device will complete the link layer registration with each access technology available there and will start getting services by doing service registration through an appropriate interface according to the priority of selection.

The advantage of this hypothetical mobile device is that it eliminates the latency due to link layer registration after the decision is made to handover in the overlapping area. After the decision of handover the user just needs to make the service registration with the network to get services. In the non-overlapping area, the proposed device would keep transmission going on with the current network while the handover process to the new network would be in progress through the other transceiver. Hence, there would be a moment when the user device would be connected to both networks to provide a make before break type of handover. The second feature of this architecture is that it uses Mobile IPv4 (MIPv4) at the network layer to provide high possible level of mobility between different IP subnets without changing the home IP address that allows maintaining transport and higher-layer connections. MIPv4 permits location independent routing of data in IP based networks where each user is recognized by its home address regardless of its current location. A Care-of-Address (CoA) assigned to the user away from home network by a Foreign Agent (FA) located at the visiting network is to be registered with the home address assigned at Home Agent (HA). The HA receives data from higher-layer and sends it to the appropriate FA which keeps the higher-layer always in dark about the current location of the user. The third feature of this approach is the use of IMS defined by 3GPP capable of supporting any type of access technology (e.g. WiMAX, UMTS, GPRS, Wireless Local Area Network (WLAN) and fixed lines) to support session management and nego-tiation at the application layer. IMS makes it possible to allow a maximum convergence of services by using the same path of signalling for all applications regardless of the access technologies. The base protocol for IMS is the Session Initiation Protocol (SIP) which is capable of supporting all four kinds of mobility defined by Internet Engineering Task Force (IETF).

The proposed method was justified through simulation by OPNET Modeler. Simulation was carried out both for VoIP calls and FTP sessions to test the performance of traffic received by a user during handover between WiMAX and UMTS networks.

The reminder of the article is organised as follows. The next section briefly describes about available different techniques of handover. The third section would present the architecture and working principle of our hypothetical approach of intersystem handover in a few words which is followed by the description of the simulation environment built by OPNET Modeler 14.5 and the results of simulation. Finally we discuss about the results of simulation and abrogate the article with a short concluding remarks and acknowledgement of the research work.

AVAILABLE TECHNIQUES OF HANDOVER

As mentioned previously, the inter-working architectures between different networks proposed until now are based on the available techniques of intra-system handover. This section is pithily introduced with these techniques to explain the motivation of the proposed architecture of this article.

Tight coupling

By definition, tight coupling is a type of coupling that describes a system where all the subsystems are not only linked together, but are also dependant upon each other and they all together share a single workload. It is the main inter-working scheme used until now for handover between WLAN and UMTS. It introduces two more elements Wireless Access Gateway (WAG) and Packet Data Gateway (PDG). The data transfer from WLAN-AP to upper layer servers on internet go through the Core Network (CN) of UMTS. In the tight coupling method used in (Salkintzis et al., 2002), the networks are

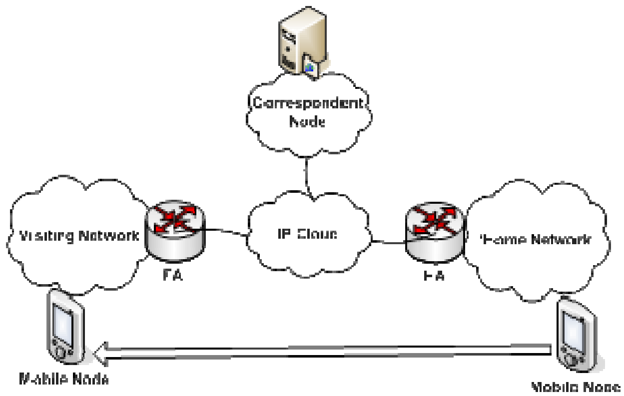

Figure 1. Mobile IP components.

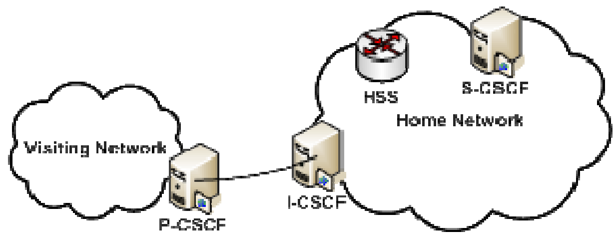

Figure 2. IMS components.

no more independent.

Loose coupling

Loose coupling is a type of coupling where the subsystems can work independently and connects each other through a third medium. It is also being used for handover between WLAN and UMTS. The typical use for loose coupling is when the WLAN is operated by some private operators other than a cellular operator. Hence, the data transmitted through WLAN will not go through a cellular network like UMTS. In loose coupling method used in (Varma et al., 2003), the networks are independent to each other and the data flow directly through the IP network. But in this method the performance of handover is very poor and latency is high.

Mobile IP

As mentioned previously, in Mobile IP each user is assigned a permanent home address and a temporary address, CoA when associated with a visiting network. As shown in Figure 1, Mobile IP introduces two new entities which are HA that stores information about users' permanent home address and FA that stores information about visiting users and also advertises CoA. The permanent home address is used as the destination address for the user trying to communicate with a node and the IP routers forwards all the packets to HA even if the user's current location is away from the home network visiting a different network. The HA redirects the packets towards the FA for the users at the visiting network. The HA gets the CoA from binding table to tunnel the packets appending a new IP header and finally the packets are delivered to the user through the FA by expanding them at the end of the tunnel. Alternatively, on receiving these packets from the user, the FA encapsulates them and tunnels them towards the HA. The HA then expands the packets and sends them to the appropriate destination. This process is known as Triangular Routing that causes some extra delay.

3GPP IMS

IMS was introduced in (3GPP TS 23.228, 2005) to control the IP multimedia services in the application layer. Typical components of IMS are shown in Figure 2. The connection to IMS network can be in various ways using IPv6 (also IPv4 in early IMS) and SIP user agents. The essential parts of IMS are described below:

The Home Subscriber Server (HSS) is the master database to store information about IP Multimedia Public Identity (IMPU), IP Multimedia Private Identity (IMPI), Internet Mobile Subscriber Identity (IMSI), Mobile Subscriber ISDN Number (MSISDN), physical location of the user and performs authentication and authorization for the user.

Proxy Call Session Control Function (P-CSCF) is a SIP proxy that can be considered as the first entrance to the IMS terminal preferably located either in each visited network. Session Border Controller (SBC) is used for this function. The user device discovers its P-CSCF with either Dynamic Host Configuration Protocol (DHCP) or it is assigned in the Packet Data Protocol (PDP) context during registration and it appears on the path of all signalling messages compressing and decompressing to authenticate the user and to establish an IPSec security association when necessary.

A Serving Call Session Control Function (S-CSCF) located at the home network, able to perform session control is the central node of the signalling plane, appears on the path of all signalling messages and is the main entrance to SIP services that uses Diameter Cx and Dx interfaces to get information about user profile from the HSS.

An Interrogating Call Session Control Function (I-CSCF) is another SIP server located at the home network and its IP address is known to the Domain Name System (DNS) of the domain to make it available for remote servers to use it as a forwarding point (e.g. registering) for SIP packets to this domain. It uses the Diameter Cx interface to retrieve the user location and then routes the

SIP request to its assigned S-CSCF. Application servers (AS) located at the home network can be considered as the service provider and it can operate in SIP proxy mode, SIP User Agent (UAS) mode or SIP Back-to-Back User Agent (B2BUA) mode depending on the requested QoS.

A 3GPP IMS based handover was proposed in (Fangmin et al., 2007). But the service continuity was not focused there. In IMS the user sends a “Re-Invite” message to the correspondent node (CN) when the decision of handover is made from one network to another which causes the IP address of the user to be changed and this forces the on-going session to be dropped. In (Munasinghe and Jamalipour, 2007a, b) IMS was used along with Mobile IP to handover between WLAN and UMTS/CDMA2000. However, the mobile device with single interface used was not able to minimize the latency.

Media independent handover (MIH)

Media independent handover (MIH) (IEEE 802.21) standard is defined as manage handover at the physical layer between heterogeneous access networks. MIH provides link layer information to the upper network layers, both internally and externally. Although the standard defines the guidelines to transport the MIH protocol messages to remote entities, namely the need to be reliable and to guarantee security of the messages exchanged, it does not specify a transport mechanism. IEEE 802.21 standard describes a possible design for the MIH transport mechanism; however, it requires a multitude of new protocol elements and is also limited in several technical constraints such as message size and protocol discovery.

PROPOSED METHOD

As mentioned previously, our proposed method applies both Mobile IP and the 3GPP IMS along with a mobile device capable of maintaining simultaneous radio links with different networks and having intelligence of making decision of handover. Architectural issues and the working principle are described below.

Architectural issues

The most important issues of intersystem handover are: session continuity which is of an application layer issue and IP management which is of a network layer issue. So IMS was applied for the application layer and Mobile IP for the network layer. The secondary issues are the latency and the throughput or packet loss. To resolve these issues the preferred type of handover would be of soft handover. However, the mobile device requires having multiple interfaces to communicate with the different networks at the same time as needed for soft handover. Hence, the mobile device used here has two transceivers, one for WiMAX interface and the other for UMTS interface. The mobile device was proposed to have the intelligence of monitoring the signal strength and making decisions of handover.

The next issue was the version of IP to be used. 3GPP IMS was mainly standardised for IPv6 but according to the early releases, IMS is possible to implement using the IPv4 also. The WiMAX can support both IPv4 and IPv6 but the UMTS Serving GPRS Support Node (SGSN) does not support the IPv6. Hence, if IPv6 is used there will be an additional latency regarding to Network Address Translation (NAT) every time signal passing through the SGSN. But if IPv4 is used for IMS, WiMAX and UMTS, it will become a flat platform and the latency related to NAT will be eliminated. So IPv4 is used in our proposed method. The proposed overall network, as shown in Figure 3, comprises of a home network and two visited networks, as the conception of IMS, where UMTS is the home network. Each visited network would have a P-CSCF which is entrance to the IMS. The S-CSCF, I-CSCF, HSS and other IMS components are situated in the home network.

The FA for UMTS networks is the Gateway GPRS Support Node (GGSN) and for WiMAX Network, it is the Access Service Network Gateway (ASN-GW). The HA is situated in the home network. For the session continuity the server should be the same for each QoS. The application server of the IMS is the correspondent node (CN) of mobile IP. The server bandwidth is distributed among the network according to the speed to be supported and server channel frequency is kept less than the channel frequency of the base station so that there remains no in-transit packet in queue during the handover to eliminate the packet loss in the radio path. The base station works as buffer and the length of the buffer depends on the payload of data packets for each of the networks.

Working principle

The block diagram of our proposed handover algorithm is shown in Figure 4; assuming the user is currently connected to UMTS network. WiMAX is the other available networks. The user connection to a network is comprises of link layer registration which is followed by the service registration through IMS. After service registration through IMS the user starts getting services. When the user is connected to one network, the mobile device starts monitoring the signal strength of current network and other existing networks receiving Agent Advertisement (AA) from respective FAs. The mobile device makes the decision of handover at appropriate moment and then the session for handover to target network starts.

Handoff session in the non-overlapping area is illustrated in Figure 5. After the completion of link layer registration and service registration by IMS (step 1 to 3) the user starts getting data through initial network interface. When user moves to the edge of a different network, it gets agent advertisement (step 4) sent with the CoA from the foreign agent of the visiting network and starts monitoring the Received Signal Strength (RSS) and takes the decision of handover when appropriate. After the decision is taken to handover to a targeted network, the mobile device completes the Link Layer Registration (LLR). The (LLR) with WiMAX network comprises of Initial Ranging, SBC Negotiation and Registration. Nevertheless, UMTS link layer registration comprises of RRC connection, GPRS Attach and PDP Activation. At the completion of (LLR), the user registers the CoA to the home agent (step 5 to 6) and thus Mobile IP registration is completed. The next stage is the service handover that initiates the “Re-Invite” message sent from the user to the network with the same user id and session flow information (step 7). When the application server gets this message through the appropriate IMS components, it sends a Session Description Protocol (SDP) message (step 8), “Session Progress”, to the user. Upon receiving the SDP, the user responds by sending an acknowledgement message (step 9), “Ack” to the server. Then the server sends another SDP reply (step 10), “Ok”. Then it is time for the user to update the server with another SDP message, “Update” (step 11). When the server successfully updates the user’s current

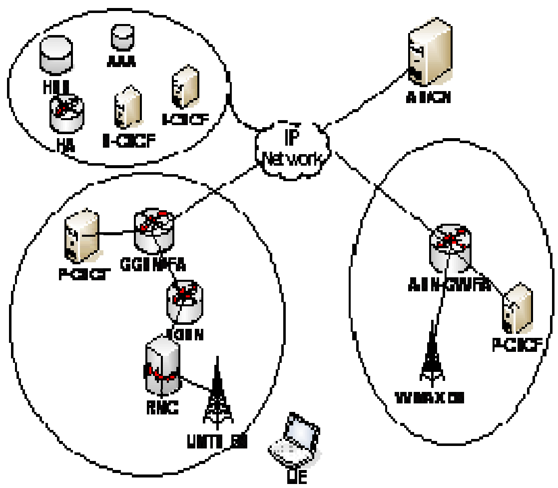

Figure 3. Proposed network diagram.

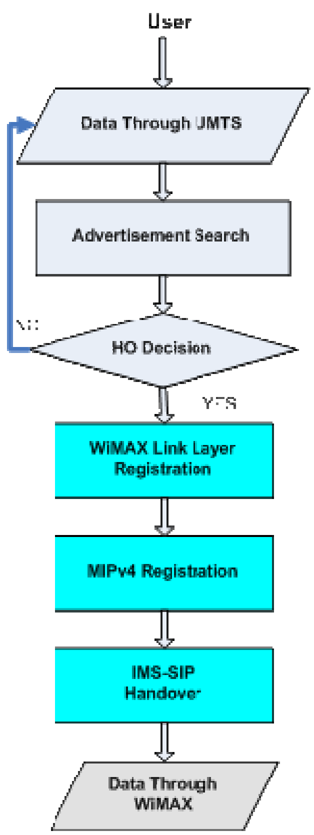

Figure 4. Handover algorithm (UMTS to WiMAX).

information, it generates “Ok” response to the user (step 12). Finally, the user sends a SDP acknowledgement respond, “Ack” to the server (step 13) and the home agent stops sending data towards initial network and starts sending data through the target network. After the first packet is sent to the foreign agent (FA) of target network from the home agent (HA), “Binding Update” is done which prevents the triangular routing of packets between HA, FA and CN (Perkins, 2002).

At this stage, the user mobile device is getting data through the target network interface, whilst the data pipeline is not yet broken with the initial network. Henceforth, the user sends a “Bye” request to the initial network to break the data pipeline (step 14 to15) and thus the handover is completed. Thus the user is always connected to some network during handover which will cause no packet loss for handing over, but the user will experience a change in the service quality when moving from one network access to another. The handoff session in the overlapping area illustrated at Figure 6 is different from that of non-overlapping area. When the user moves to an overlapping area, it completes the link layer registration with both the networks with appropriate interfaces and gets the agent advertisement periodically from both the foreign agents (step 1). The user starts getting data through one of the networks that have the stronger signal strength by completing the service registration (step 2 to 4). The user mobile device is always monitoring the RSSI and takes the decision of handover at an appropriate stage. After that, the mobile device completes the Mobile IP registration (step 5 to 6) which is followed by the service handover (step 7 to 13). At this point, data starts moving through the new network. Next step is the “Binding Update” which is followed by the cancellation of data pipeline with the previous network (step 14 to 15).

To get a seamless handover it is required to have the latency within specifications defined by IEEE and 3GPP and it was an aim of this research to reach the latency within the specification. The latency of the non-overlapping area (the area where the coverage of WiMAX and UMTS network does not overlap each other) consists of the time required for (LLR), Service Handover and Software Processing Delay. However, in the overlapping area (the area where the coverage of WiMAX and UMTS network overlaps each other), Link Layer Registration is done for all available networks together using their respective interfaces as soon as the user moves into the network. Thus in overlapping area the delay for handover consists of only Service Handover and Software Processing Delay. The latency for handover in overlapping area and non-overlapping area can be expressed by the equation (1) and (2) respectively.

$$T_{HO} = T_{LLR} + T_{SH} + T_{SPD} \quad (1)$$

$$T_{HO} = T_{SH} + T_{SPD} \quad (2)$$

Where,
T_{HO} = Total Handover Latency
T_{LLR} = Delay for Link Layer Registration
T_{SH} = Delay for Service Handover
T_{SPD} = Software Processing Delay

Simulation platform

We have implemented our proposed method described in the previous section by the OPNET Modeler 14.5 and carried out the simulations to characterize the performance of the proposed method of vertical handover.

The OPNET Modeler 14.5 provides the WiMAX model group that comprises of a distinct event simulation model and enables the user to assess network performance in Wireless Metropolitan Area Networks (WMAN). It includes the features of the IEEE 802.16e standard. The main Media Access Control (MAC) layer messages are modelled in the model which allows configuring a static burst profile for each link. Five different QoS types naming Unsolicited Grant Service (UGS), Extended-Real-Time Polling Service (ertPS), Real-Time Polling Service (rtPS), Non-Real-Time Polling Service (nrtPS) and Best Effort (BE) are supported. The model includes the support for user mobility, Automatic Repeat reQuest (ARQ),

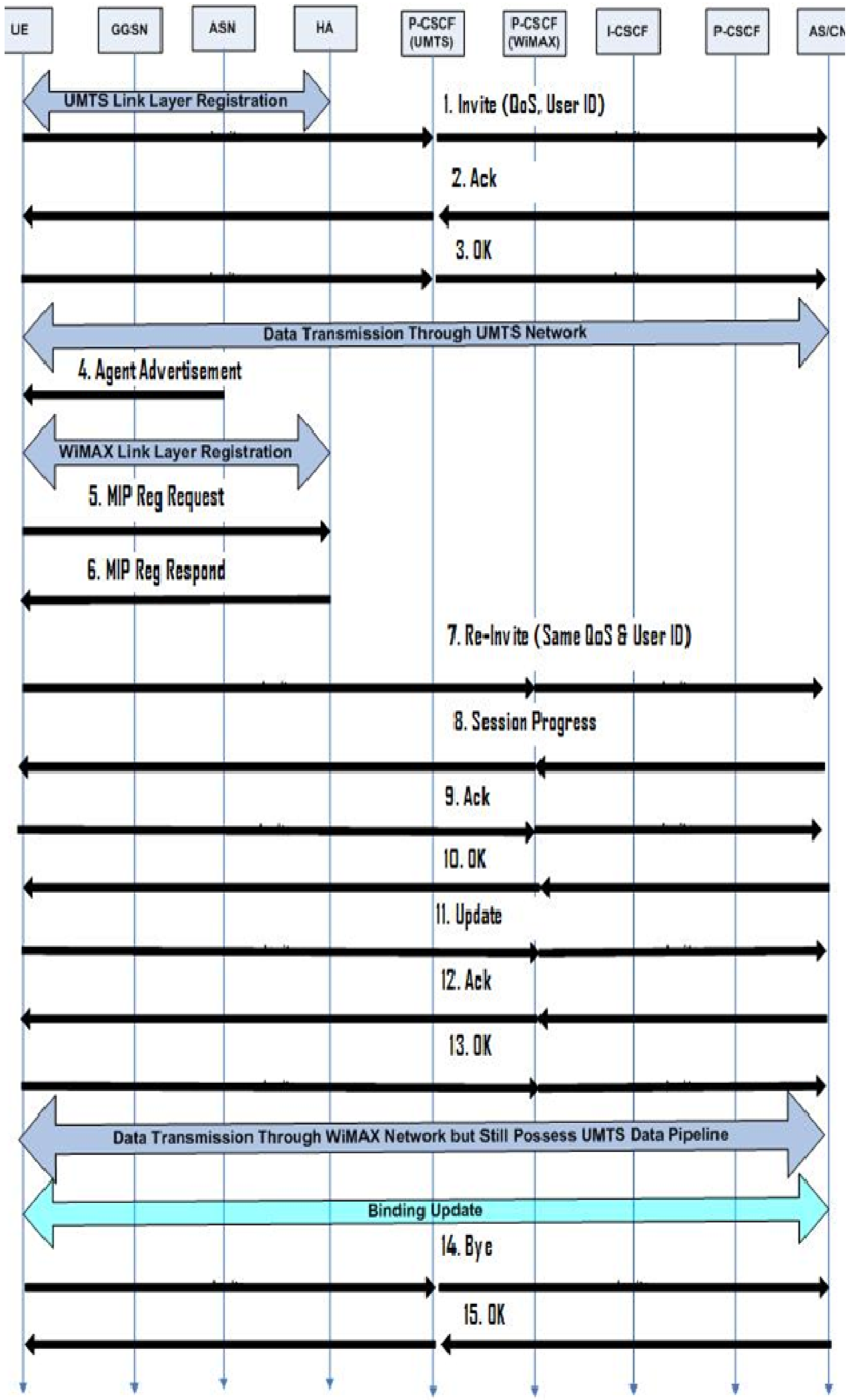

Figure 5. Handoff session in non-overlapping area.

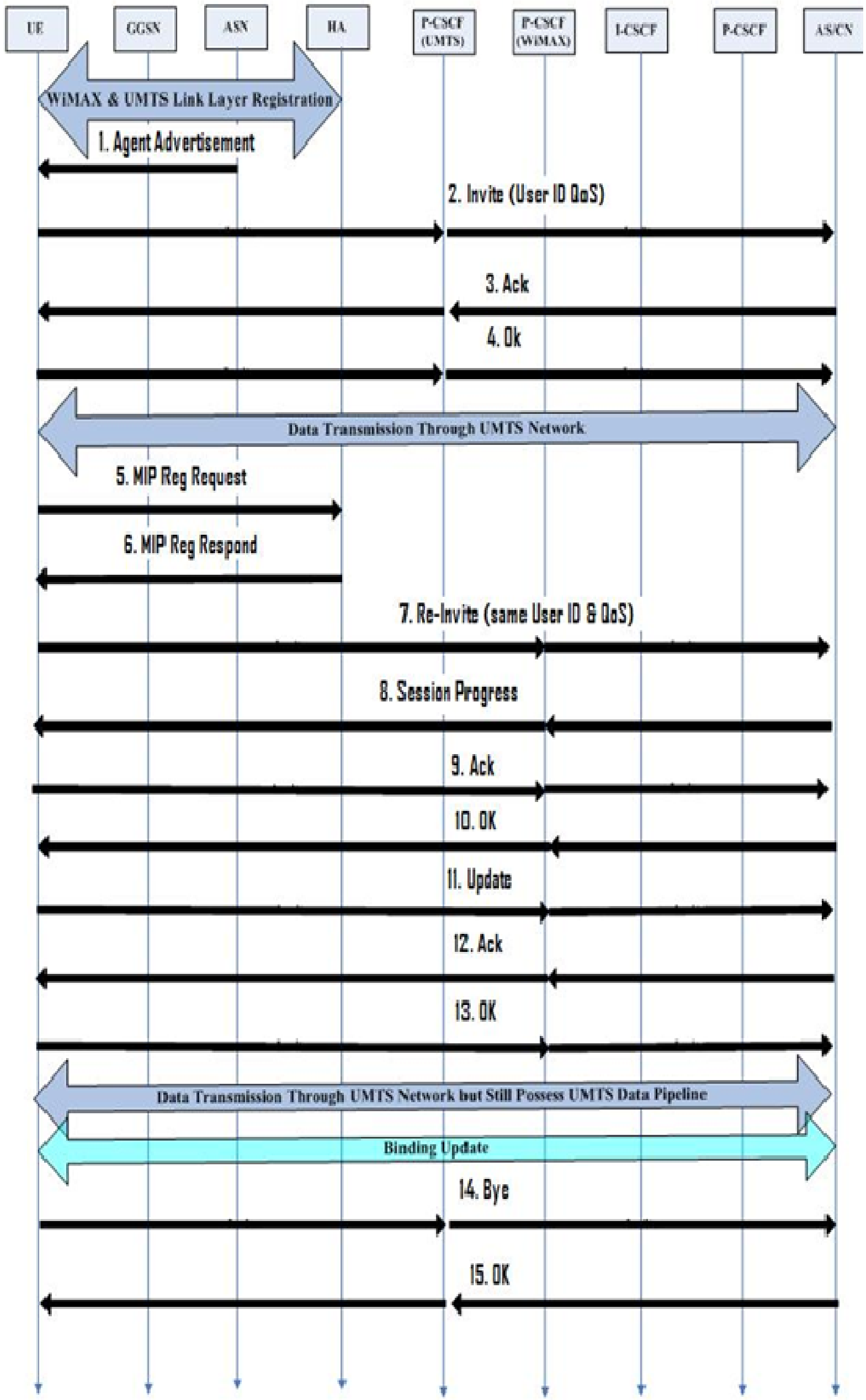

Figure 6. Handoff session in overlapping area.

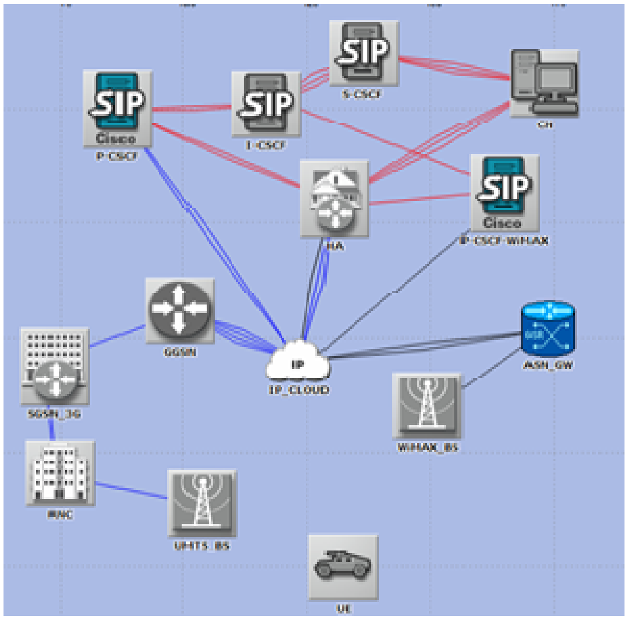

Figure 7. OPNET scenario.

Hybrid ARQ (HARQ) and a retransmission mechanism.

UMTS model offered by the OPNET Modeler 14.5 is based on the 3GPP standard that supports a wide range of features including different traffic classes naming streaming, conversational, interactive and background associated with a QoS profile for each of them that allows to investigate the performance of sensitive traffic in the system. Also the channels like Dedicated Channel (DCH), Downlink Shared Channel (DSCH), Forward Access Channel (FACH) and Random Access Channel (RACH) are supported in the model.

The OPNET Modeler has some limitations and one of the limitations that we faced with the Modeler is that the IMS model is not supported. The SIP-IMS model is available in the contributed models library of the OPNET University Program (Enrique, 2005). We had to make some modification of the available model. Then the WiMAX model was projected to support the IMS. The provided WiMAX model suite supports the Mobile IPv4. But the Mobile IPv4 model suite does not support the binding update which we had to resolve. Next we modified the standard UMTS model also to support IMS and Mobile IP. Finally, we projected a mobile device to support both WiMAX and UMTS interfaces. The scenario developed by OPNET for handover between WiMAX and UMTS is shown in Figure 7.

The UMTS network is connected to the IP-Cloud through the GGSN and the WiMAX network is connected to the IP-Cloud through the ASN-GW. Both WiMAX and UMTS networks have their own P-CSCF to get entrance to IP multimedia services. P-CSCF connects to the I-CSCF where the registration for the IMS is done and S-CSCF selects the server according to the requested QoS by the user. HA is located in the home network and makes the Mobile IP registration for the user moved to a visiting network.

The base stations were set to send the AA at a definite moment when the handover decision was assumed to be taken. However, in reality it is suppose to send AA periodically. This step was taken to reduce the complexity of the simulation. In addition, the decision of handover was out of the scope of this research work, hence we defined the definite moment. The trajectory for the movement of the user defined at the user device. The parameters configured in the OPNET Modeler are summarized in Table 1.

RESULTS AND PERFORMANCE ANALYSIS

The simulation was carried out for FTP session and VoIP call. The average latency for handover from WiMAX to UMTS in overlapping area is 129 ms and in non-overlapping area is 1.826 S. For handover from UMTS to WiMAX, the latency in overlapping area is 117 ms and in non-overlapping area is 1.931 S. The comparison is shown in Figures 8 and 9 respectively.

From Figure 8, it is found that in overlapping area, the handover from WiMAX to UMTS causes higher latency than the handover from UMTS to WiMAX. This is because the service registration in UMTS is higher than the service registration in WiMAX. But according to Figure 9, in non-overlapping area the handover from WiMAX to UMTS causes lower latency than the handover from UMTS to WiMAX. This is because the average delay for GPRS attaches and PDP activation in UMTS is lower than the average delay for initial ranging and WiMAX registration in WiMAX.

When the on-going session is a FTP download, the user experiences an increase in data rate when moving from UMTS network area to WiMAX network area as shown in Figure 10. Conversely, the user experiences a decrease in data rate when moves from WiMAX area to UMTS area as shown in Figure 11.

The novelty of our proposed method is that the user never feels any interruption during handover from one network area to another because of the mobile device with two interfaces; it maintains the dual connection simultaneously with UMTS and WiMAX networks. For the voice call we applied the codec G726 which provide voice at fixed 32 kbps as shown in Figure 12 and the user feels no interruption during the handover.

Finally, we measured the end-to-end (ETE) delay in both the networks for both FTP and VoIP as shown in Figures 13 and 14 respectively. It is the time required for a packet to travel from the host server to the user and it is required to calculate the jitter for handover. For FTP the average delay is higher and it is about 45.7 ms in UMTS and 28.8 ms in WiMAX.

For VoIP the delay is about 31.6 ms in UMTS and 19.8 ms in WiMAX. The ETE delay varies according to the pay load of the traffic. The variation in ETE delay during handover is known as jitter, that is, the time difference for the packets to reach the destination while handed over from WiMAX to UMTS and vice versa. Hence, the jitter for FTP session is about 16.9 and 11.8 ms for VoIP session.

DISCUSSION

This article narrates a mobility-aware architecture for interworking heterogeneous cellular and wireless networks that enables UMTS and WiMAX systems to manage data user mobility under a common platform. Within the centralized common mobility management

Table 1. OPNET configuration parameters.

Parameter	Setting/Description
User movement	UMTS to WiMAX and WiMAX to UMTS
Simulation period	400 simulation S
Agent advertisement	After half way
UMTS data rate	upto 550 kbps
WiMAX data rate	upto 1.6 mbps
Simulation kernel	Kernel type preference
Values per statistics	100
Session starts	After 100 S
Handover starts	After 200 S
QoS type	FTP/VoIP
Service rate	1 per each node
FTP server channel frequency (UMTS)	512.82 Hz
FTP server channel frequency (WiMAX)	1.6 kHz
FTP packet size	1051.5 Byte
Voice server channel frequency	458.72 Hz
voice packet size	72 Byte
Packet generation rate	Constant

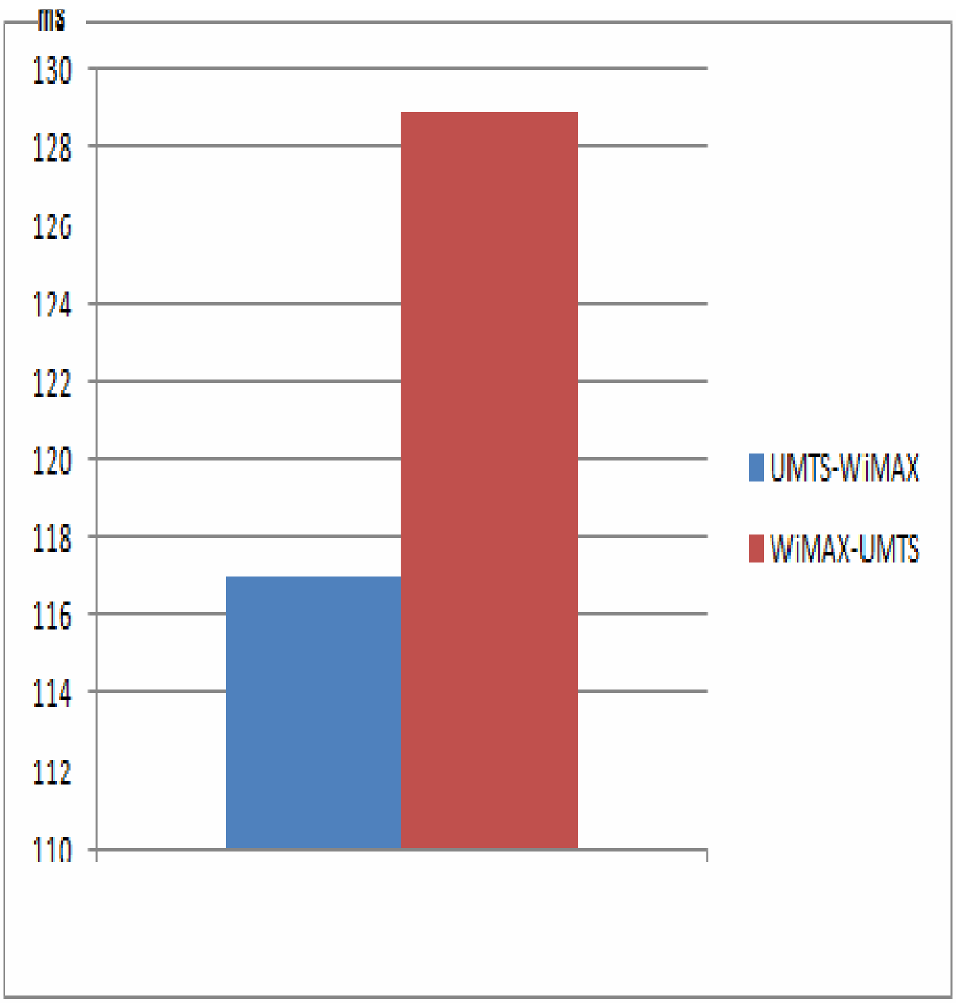

Figure 8. Average latency in overlapping.

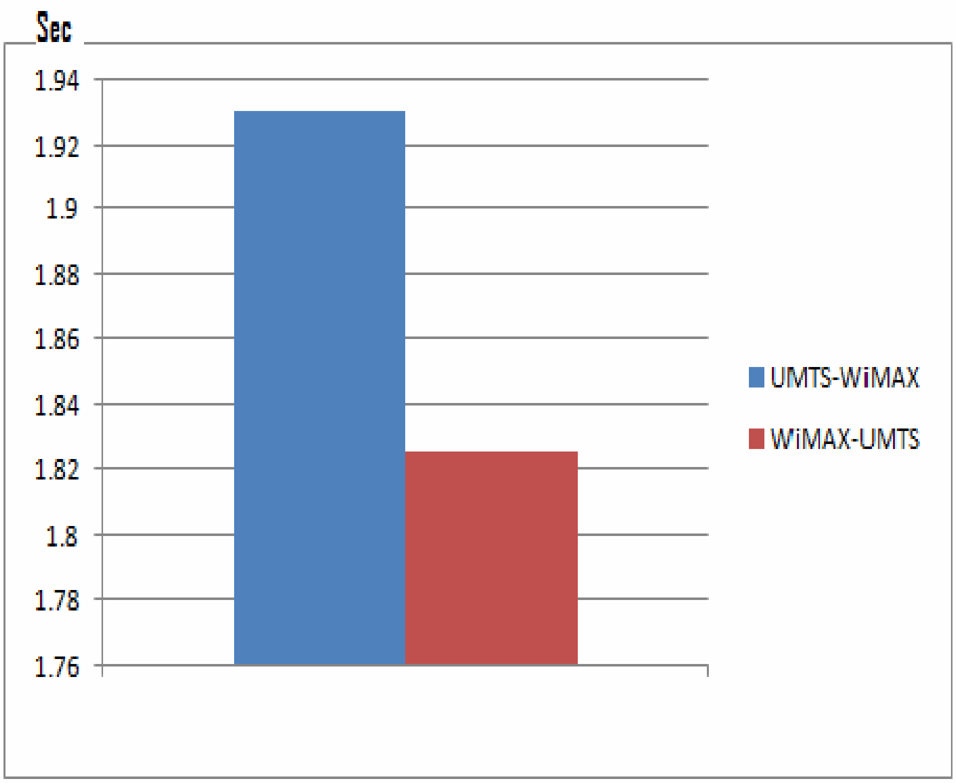

Figure 9. Average latency in non-overlapping area.

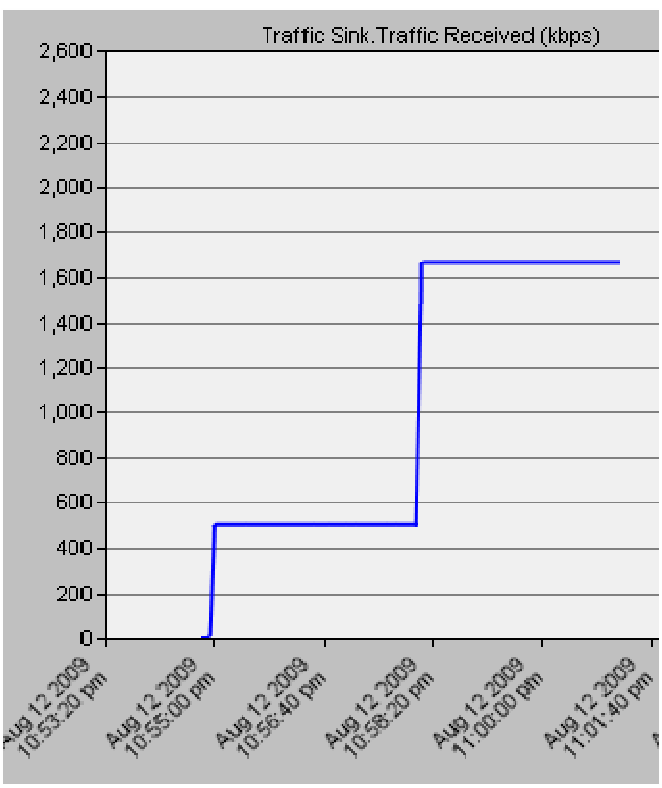

Figure 10. Handover from UMTS to WiMAX (FTP).

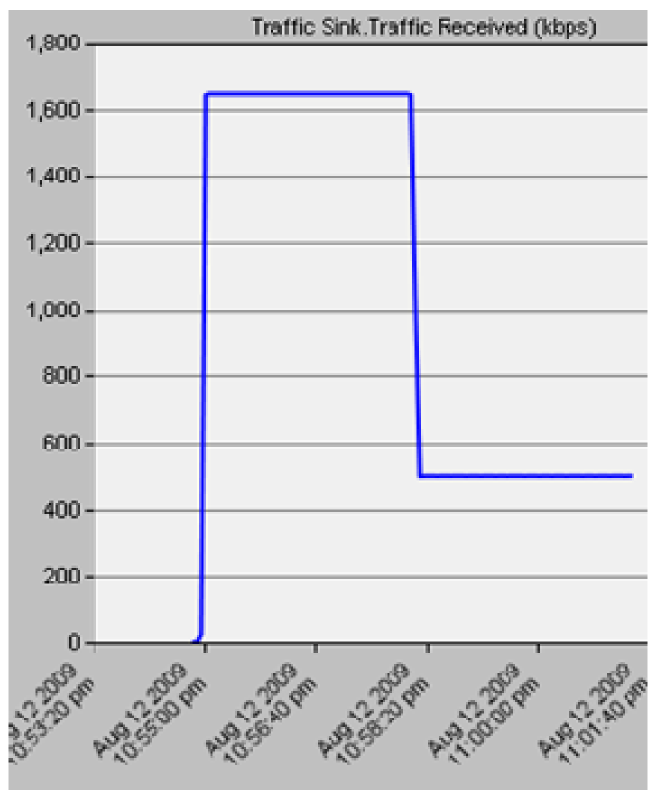

Figure 11. Handover from WiMAX to UMTS (FTP).

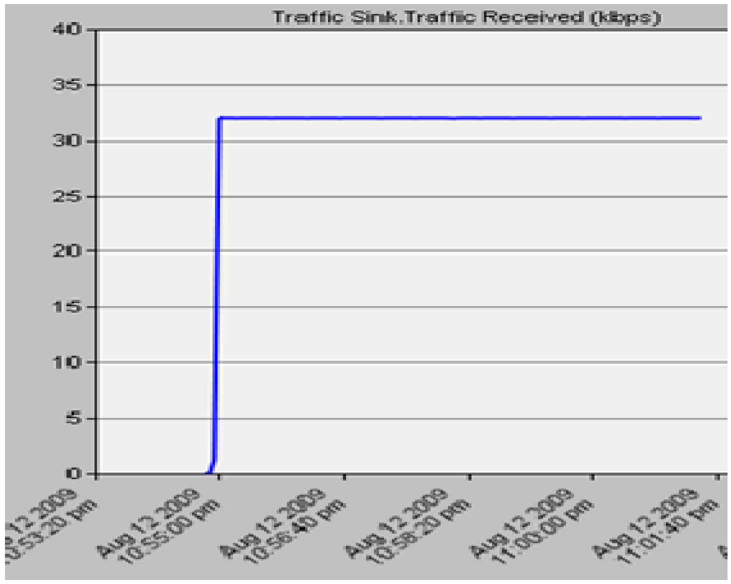

Figure 12. Handover from UMTS to WiMAX (VoIP, G726 at 32kbps).

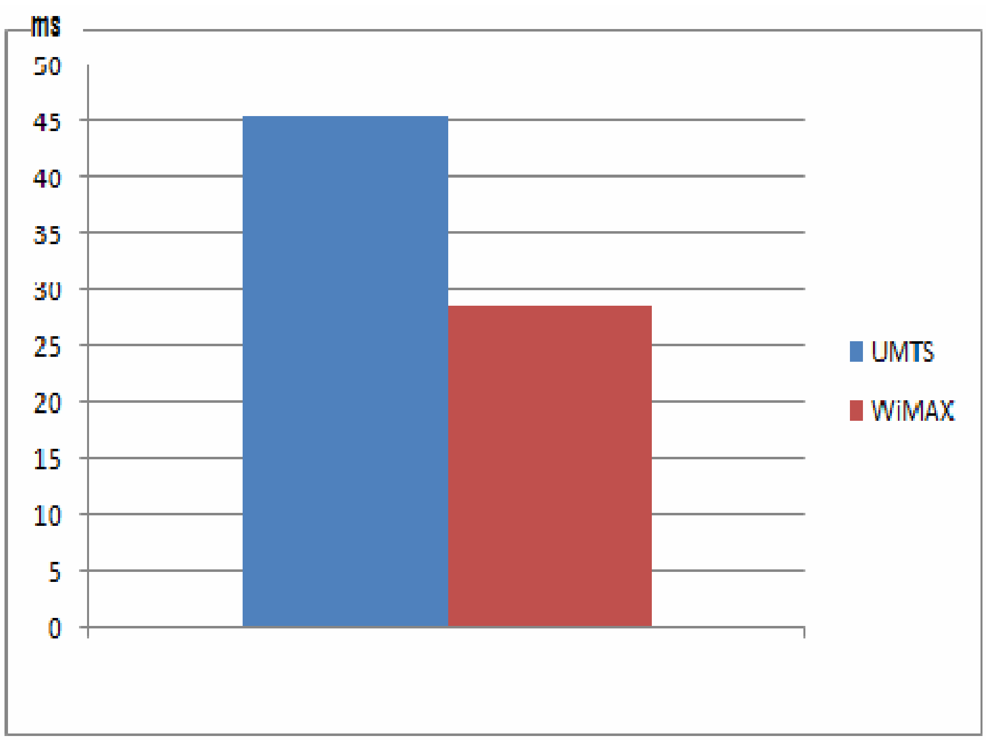

Figure 13. ETE delay (FTP).

platform, both terminal mobility and session mobility was managed in a real-time environment for a roaming data user.

As mentioned above, the aim of this research work was to develop an interworking architecture for provision of seamless service to the user roaming between the coverage areas of WiMAX and UMTS networks, despite the data rate that is to be supported by these two networks. Hence, data rate was set arbitrarily and it was about 1.6 mbps for WiMAX network and 550 kbps for UMTS network. Changing in the data rate would not affect the performance of handover. Figures 10 and 11

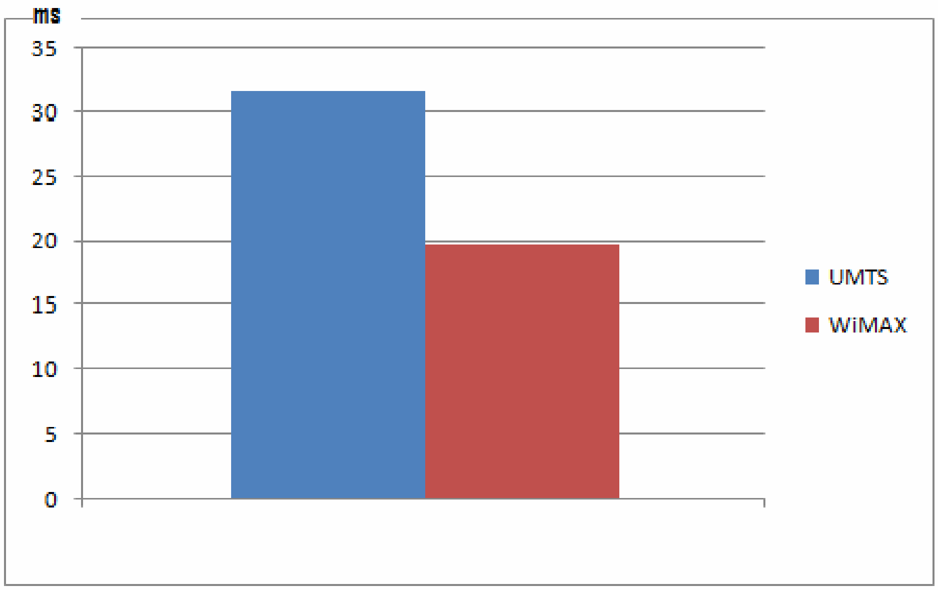

Figure 14. ETE delay (VoIP).

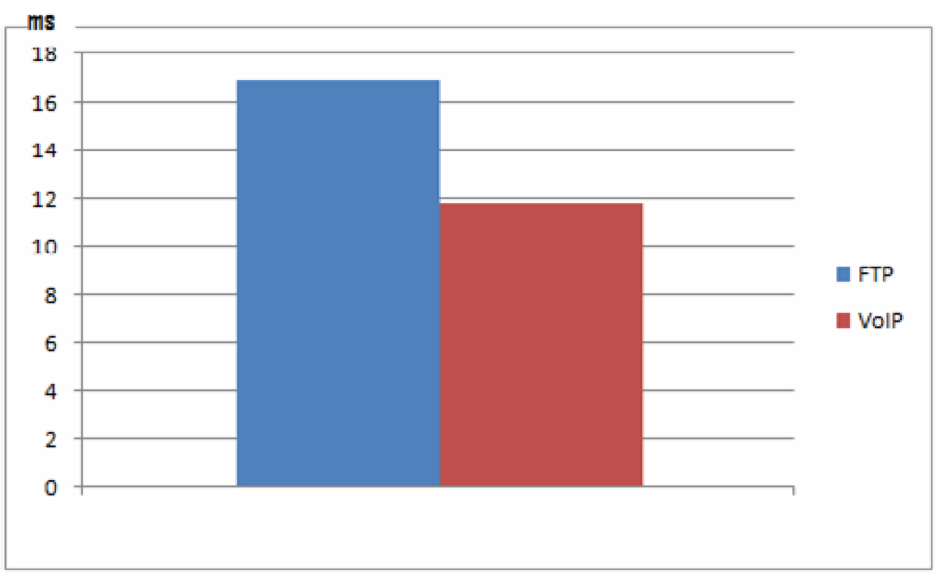

Figure 15. Jitter.

are the proofs for successful handover for FTP sessions. The curves are continuous which represent the provision of handover without any packet loss. The in-transit packets are buffered to the mobile device from UMTS base station while it has already started receiving data from WiMAX network. Additionally, the continuous curve of Figure 12 also proves a successful handover session for VoIP call.

ITU-T G.114 recommends a maximum of a 150 ms one-way latency for VoIP call and a maximum of 50 ms jitter to get a smooth quality of voice. The latency and jitter for FTP session is not as sensitive as it is for VoIP call. Hence, our algorithm and results obtained complies with the ITU-T recommendation for overlapping areas. For non-overlapping area, our mobile device brings the solution to provide seamless services to the end user.

Conclusion

In this article we have introduced our hypothetical idea for intersystem handover that can be applied for both real time and non-real time applications. Granting the high latency for handover in non-overlapping area, our mobile device with multiple transceivers able to maintain radio links between WiMAX and UMTS networks simultaneously results in a make-before-break type of handover. The service can continue through one interface while the other interface is being used for handing over process. Henceforth, there is no packet loss during handover in the radio path and the high latency in non-overlapping area instigates no interrupt on the service to the consumers.

There will be some packet losses due to the flow routing mechanism which do not have anything to do with the handover mechanism and out of the scope of this article.

Last but not the least, the proposed hypothesis that hybridizes 3GPP, IMS and Mobile IPv4 with a mobile device are able to maintain dual connections simultaneously and has the intelligence to take decisions of handover can be an acceptable way out for intersystem handover for the upcoming 4G networks.

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