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An MIH-enhanced fully distributed mobility management (MF-DMM) solution for real and non-real time CVBR traffic classes in mobile internet

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Abstract: The integration of wireless access networks has progressed rapidly in recent years. Within the mobile communication environment, the operator provides multiple interface options for the mobile node (MN) to switch its connection to any access network during mobility to achieve the quality of service (QoS) for various traffic classes. The conventional centralised mobility management (CMM) scheme lacks reliability, dynamic anchoring and a single point of failure. This stimulates the distributed mobility management (DMM) scheme to handle mobility at the access network rather in a centralised manner. Therefore, in this paper, an IEEE 802.21 media independent handover (MIH) enhanced fully DMM (MF-DMM) solution is proposed for real- and non-real-time constant and variable bit rate (CVBR) traffic classes for mobile internetworking applications. The performance factors of handover delay, packet loss rate, throughput and signalling overheads are compared with the existing CMM scheme. The simulation results prove that the presented MF-DMM technique considerably reduces the handover delay while switching to different access technologies and, thus, achieves seamless connection by managing mobile internet protocol (IP) traffic locally.

Key words: Dynamic mobility, handover, mobile internetworking, heterogeneous network, media independent handover, mobility management, constant and variable bit rate

1. Introduction

Internetworking of different wireless technologies such as universal mobile telecommunication system (UMTS), wireless local area network (WLAN), worldwide interoperability for microwave access (WiMAX) and long-term evolution (LTE) provides proficient communication through the backbone internet protocol (IP) core infrastructure. Such internetworking scenarios offer prominent solutions to ubiquitous communication, data rate, bandwidth, cost, signal-to-noise ratio (SNR), security and quality of service (QoS) for different types of traffic classes when compared to traditional wireless networks.The priority of each traffic classes are listed in Table 1. In heterogeneous networks, several integrated issues have to be addressed: QoS mapping, area of coverage, medium access control (MAC) layer integration, handover criteria, etc. Hence, an IEEE 802.21 media independent handover (MIH) provides a framework to integrate the mobile node (MN) into such heterogeneous environment with the help of MIH services (Event service, Command service and Information service). This study utilised MIH services in a common core environment to execute seamless connection during handover

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processes. Nowadays, users wish to access a variety of multimedia applications on their mobile devices with low-cost high-speed connectivity anytime and anywhere, which is one of the essential challenges to be addressed while improving the future generation networks. These multimedia applications require access to a large volume of data via mobile internet. However, the current mobile network architecture is centralised and unable to effectively handle multimedia applications on handheld devices. This motivates distributed mobility management (DMM) to handle MN mobility in a distributed way (i.e. locally at the access network level) without a centralised anchor. The IETF working group has introduced different DMM approaches [1], including fully DMM, partial DMM, SDN-based DMM and routing-based DMM. In this paper, an MIH-enhanced fully DMM (MF-DMM) is proposed in the heterogeneous network to analyse the handover performance of different types of traffic (email, FTP, HTTP, voice, and video). The main focus of this paper are as follows:

- Vertical handover performance: handover delay, overheads, packet loss rate, traffic sent and received.
- Handover decision criteria based on received signal strength (RSS) and resource availability in the candidate network.
- IEEE 802.21 MIH services-based handover procedures.

Table 1. Traffic classes and its priority.

Traffic class (TC) type	**Priority**	**Application**
Conversational - Constant bit rate (CBR) real time traffic	TC1 - High priority	VoIP
Streaming - Variable bit rate (VBR) real time traffic	TC2 - High priority	MPEG
Interactive - Variable bit rate non real time traffic	TC3 - Low priority	FTP
Background - Best effort (BE) traffic	TC4 - Low priority	HTTP

The rest of the work is structured as follows: Section 2 provides the literature survey of existing schemes; Section 3 discusses the proposed MF-DMM approach for efficient handover; Section 4 summarises the results and discussion. finally, Section 5 concludes the scope for future work.

2. Literature survey

The handover operation is a major phase in all heterogeneous architecture to cope effectively with mobile node (MN) mobility management. Hence, an optimised vertical handover (VHO) process is necessary to achieve seamless connection for guaranteed QoS. In this section, the survey of different handover algorithm is addressed, which might be helpful for improving the next-generation networks. The author [2] focused on distributed mobility and authentication mechanism (DMAM) to provide authentication, based on cryptography and hash functions. The neighbour predictive adaptive handoff (NPAH) algorithm is discussed [3] to execute the handoff based on the cost and storage utilisation factor. The integration method [4] based on the extension of MIH for fast proxy mobile IP (FPMIPv6) handover across heterogeneous networks is presented. This approach minimises the occurrence of redundant messages during handover processes through the interaction of FPMIPv6 and MIH services. The DMM of named object information centric network (ICN) based on unique identifiers are explained in [5]. The author evaluated the hard and soft handover with rebinding and multihoming processes to attain the seamless connectivity by ORBIT test beds.

A modified mechanism for partial DMM is clarified in [6], and the results validate how the modified access router (AR) can distribute and manage IP packets during binding update (BU) and binding acknowledgement (BA) processes. The PMIPv6 DMM using IEEE 802.21 MIH services and proactive handover initiate process are also discussed [7] to enhance the handover procedures. This technique decreases the handover delay by 74.61 %. The handover performance of PMIPv6-based DMM was investigated [8] for vehicular velocity in urban atmospheres. Later, an enhanced security authentication for PMIPv6-based partial DMM scheme [9] was introduced. In the traditional PMIPv6, the signalling message between a localised mobility anchor (LMA) and a mobility access gateway (MAG) is protected by the IPsec, but the signalling message between MN and MAG is not protected. The author focused on this issue and provided hash functions to protect the messages between MN and MAG. The authentication cost is quite similar to the traditional PMIPv6 method. The AR and the MAG are rearranged [10, 11], such that a single MAG is responsible for the multiple ARs for reducing the signalling cost during mobility management.

An experimental and analytical method of PMIPv6-based DMM is implemented in a Linux-based environment [12] to validate certain important factors such as cost, data loss and handover latency. Fully distributed PMIPv6 DMM is considered [13] to remove the centralised anchor, layer 2 and 3 signalling between AR and MN, which, in turn, enhances the handover performance. A hybrid centralised DMM architecture [14] is presented to improve the handover performance of high-speed mobile users. Depending on the type of application [15], the mobility requirements are guaranteed by the distributed local mobility anchor without increasing signalling messages.The difficulties and effectiveness of the existing algorithms were analysed. The WLAN (IEEE 802.11b) and WiMAX (IEEE 802.16) networks achieved significant growth and becomes essential wireless access technologies for mobile devices. The integration of these network highly supports multimedia application with high data rate and user mobility in an IP-based infrastructure. This paper, an MF-DMM scheme, was introduced to provide optimised handover procedures across heterogeneous networks for real- and non-real-time applications.

3. An MIH-enhanced Fully DMM (MF-DMM) for real- and non-real-time CVBR traffic

The architecture as shown in Figure 1 consists of WLAN and WiMAX networks. These heterogeneous networks are integrated with an IP backbone to analyse the mobility behaviours of the MN based on MF-DMM scheme. The MNs (Mobile 1_1, Mobile 1_2 and Mobile 1_3) are randomly positioned in the overlapped area of both networks. The Mobile 1_1 and Mobile 1_2 are configured with a random and linear trajectory model. For random mobility model, the prediction of a future state of travel is difficult unlike with a linear mobility of MN. Therefore, the proposed work mainly concentrates on the Mobile 1_1 mobility pattern and analyses the handover performance with different traffic classes. The WLAN access point and WiMAX base stations (BS) are connected to the mobility access router (MAR) MAR1 and MAR2. The MAR1 and MAR2 are responsible for prefix allocation, binding management, and tunnelling for particular networks. Thus, the entire mobility-related issues are handled at the MAR without a centralised anchor. Each MAR maintains a database for every MN (attached to it) and performs handover signalling. The MAR1 and MAR2 are then connected to the IP core network AR1 to access the multimedia services (email, FTP, HTTP, voice and video). The detailed handover process is explained in the following three phases, namely the registration phase, handover to the second WiMAX network, and handover to any other third network.

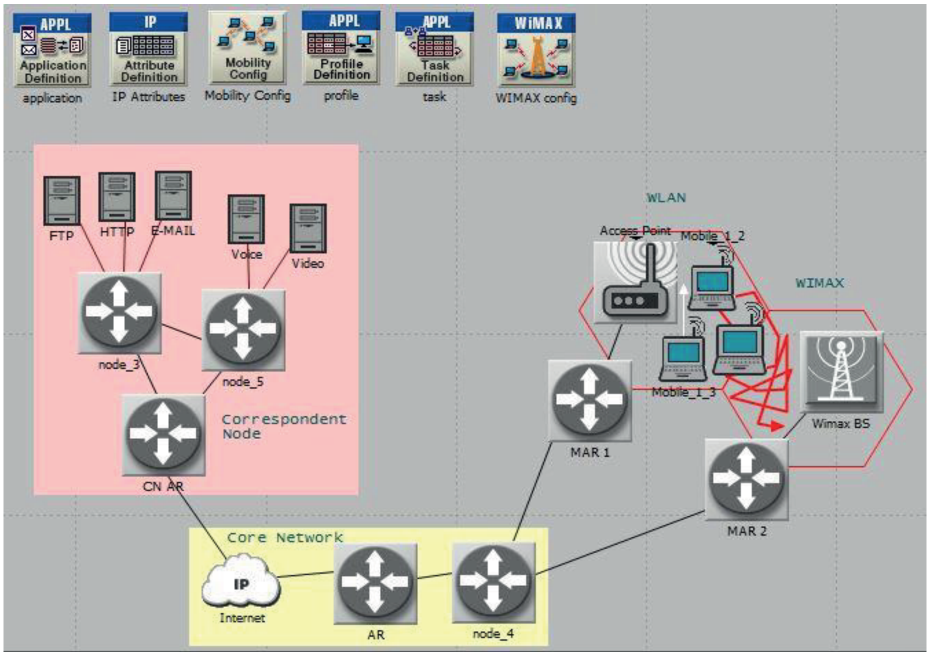


Figure 1. Proposed MIH enhanced fully DMM (MF-DMM) scheme.

3.1. Registration phase (MN initial attachment)

In the initial registration process, it is assumed that the MN (Mobile 1_1) is in home network, say WLAN network.After the authentication process, the MAR1 assigns an IP prefix to the MN by creating a local binding cache entry (BCE). The MN configures its IP1 prefix at the home network and then communicates with the correspondent node (CN). The registration process of MN is clearly depicted in Figure 2. The initial registration delay τ_{reg}^{MN} of the MN at WLAN home network is expressed in (1).

$$\tau_{reg}^{MN} = 2\tau_{AAA}^{WLAN}(req, res) + 2\tau_{MN}^{MAR1}(RS, RA) + \tau_{BCE}^{MAR1}(IP1) + \tau_{Config}^{MN}(IP1) \quad (1)$$

Where, $\tau_{AAA}^{WLAN}(req, res)$ is the authentication request and response delay at AAA server in WLAN network, $\tau_{MN}^{MAR1}(RS, RA)$ is the router solicitation (RS) and router advertisement (RA) delay of the MN at MAR1, $\tau_{BCE}^{MAR1}(IP1)$ is the IP prefix allocation delay of BCE at MAR1 and $\tau_{Config}^{MN}(IP1)$ is the MN IP1 configuration delay.

3.2. Mobility management across WLAN and WiMAX networks

It is assumed that the MN communicates with CN through MAR1 and IP core AR. Later, the MN moves in a random direction towards WiMAX networks and wishes to carry out the previous ongoing session (at WLAN network) to the current network. Therefore, the network initiates the need for handover based on the continuous reception of Link-down triggers and service degradation from the serving WLAN network. The detailed handover procedure is shown in Figure 3.

1. The MN new attachment to the WiMAX network (second network).
2. Registration procedure starts with the authentication process.

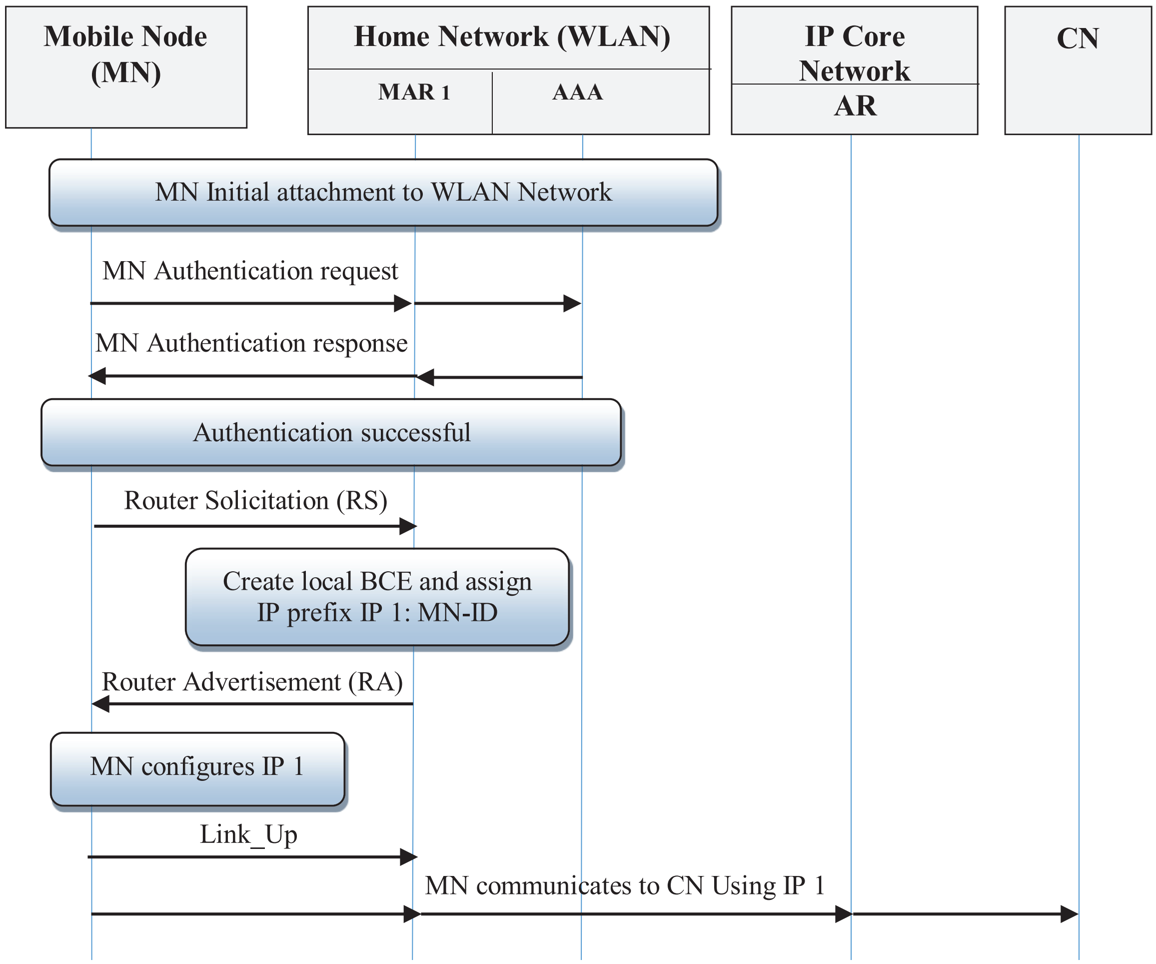


Figure 2. MN Initial registration process.

3. The MAR2 creates local BCE and reserves IP prefix.
4. At the same time, it also enquires about the MN's previous state with the information server (IS).
5. The IS returns with a list of neighbour networks.
6. The MAR2 then identifies the MN's previous state through an exchange of BU and BA messages from one of the MAR in the neighbour network list.
7. The resource availability during the handover process is checked in the target network.
8. Finally, the bidirectional tunnel is established between MAR1 and MAR2. The MN continues its previous session in the new WiMAX network using the old IP1 prefix.

Thus, the vertical handover delay as the MN moves from WLAN to WiMAX network is expressed in the following equations (2)-(4):

$$\tau_{VHO_1} = \tau_{AAA}^{WiMAX}(req,res)+\tau_{MN}^{MAR2}(RS,RA)+\tau_{BM}(MAR1,MAR2)+\tau_{tunnel}(MAR1,MAR2)+\tau_{Config}^{MN}(IP2) \quad (2)$$

The vertical handover delay τ_{VHO_1} is associated with the authentication request and response delay at AAA server in WiMAX network $\tau_{AAA}^{WiMAX}(req,res)$, RS and RA delay of the MN at MAR2 $\tau_{MN}^{MAR2}(RS,RA)$,

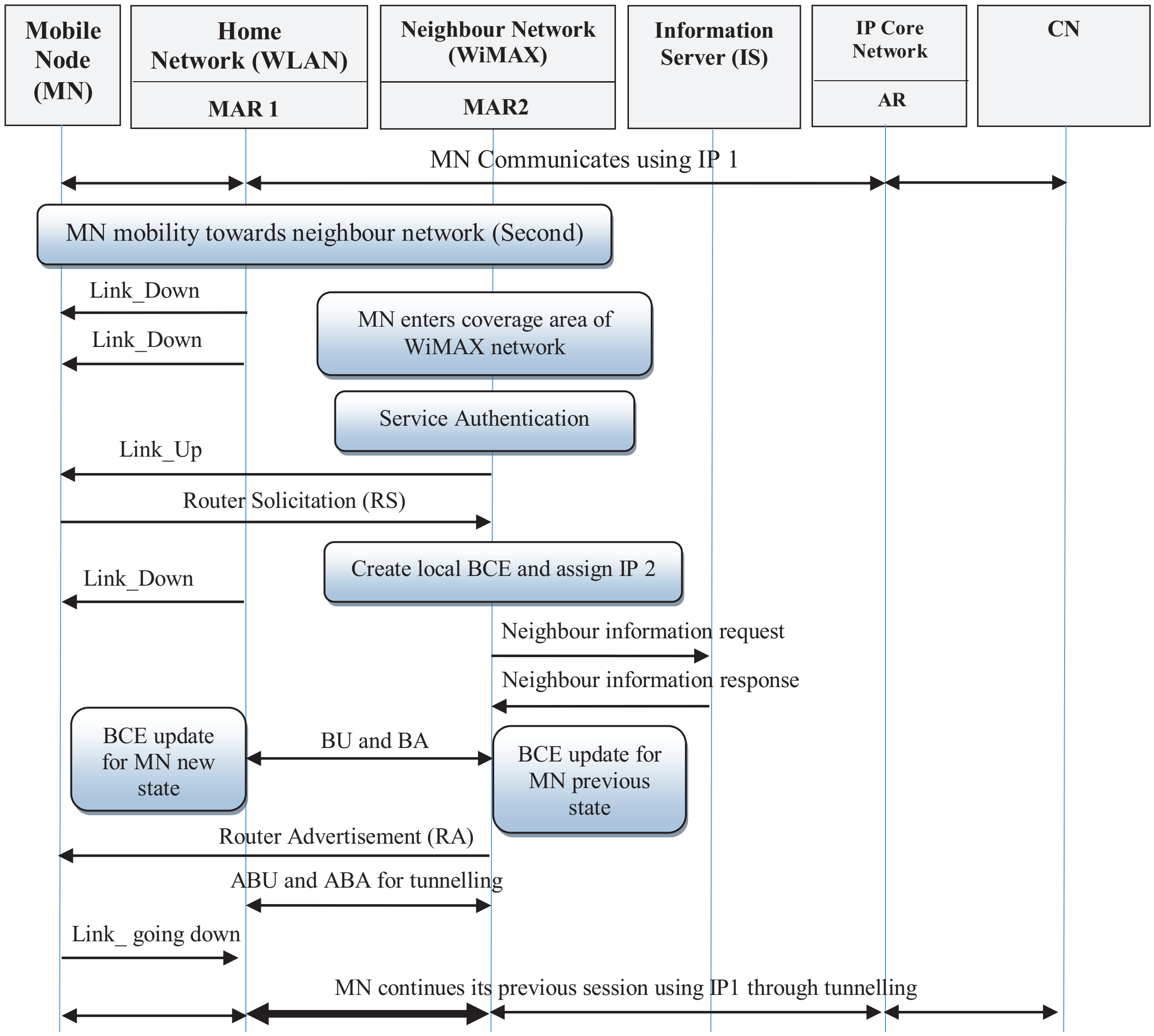


Figure 3. Handover procedure to the WiMAX (second) network.

MN IP2 configuration delay $\tau^{MN}_{Config}(IP2)$, binding management τ_{BM} and tunneling delay τ_{tunnel} between MAR1 and MAR2. The binding management and tunneling delay are expressed by

$$\tau_{BM} = \sum_{i=1}^{n}[\tau^{MARi}_{BU}(req)] + \tau^{MAR1}_{BA}(res) + \sum_{i=1}^{n-1}[\tau^{MARi}_{NBA}(res)] \tag{3}$$

$$\tau_{Tunnel} = \tau^{MAR2-MAR1}_{ABU}(req) + \tau^{MAR1}_{BCE}(update) + \tau^{MAR1-MAR2}_{ABA}(res) + \tau^{MAR2}_{BCE}(update) \tag{4}$$

The τ_{BM} represents the MAR2 sends BU request to all $'n'$ candidate network $\tau^{MAR}_{BU}(req)$, out of which $'n-1'$ network response with negative BA (NBA) $\tau^{MAR}_{NBA}(res)$ to indicate that there is no previous mobility option of the MN at its network. And, MAR1 replies with BA $\tau^{MAR1}_{BA}(res)$ to confirm the MN previous mobility option. Once the MNs previous MAR is known, the next step is to establish the tunnel between MNs current and previous MARs. The τ_{tunnel} depends on the exchange of access binding update (ABU) request $\tau_{ABU}^{MAR2-MAR1}(req)$ and access binding acknowledge (ABA) response $\tau_{ABA}^{MAR1-MAR2}(res)$ between MAR2 and MAR1 with their respective BCE update delay $\tau_{BCE}^{MAR2}(update)$.

3.3. Handover to the third network

Later, the MN again makes a random walk, say towards the third network, and still wants to continue the previous session with the CN. The second handover procedure is clearly depicted in Figure 4.

1. Repeat Step 1 to Step 5 in the previous handover procedures.
2. The MAR2 receives the BU message from the MAR3 and updates its BCE. At the same time, it also informs to the MN home network MAR1 about the MN's new mobility at the MAR3.
3. The MAR1 directly communicates to MAR3 with BA message to indicates the MN home network.
4. Finally, the tunnel is established directly between MAR1 and MAR3 and continues the ongoing session.

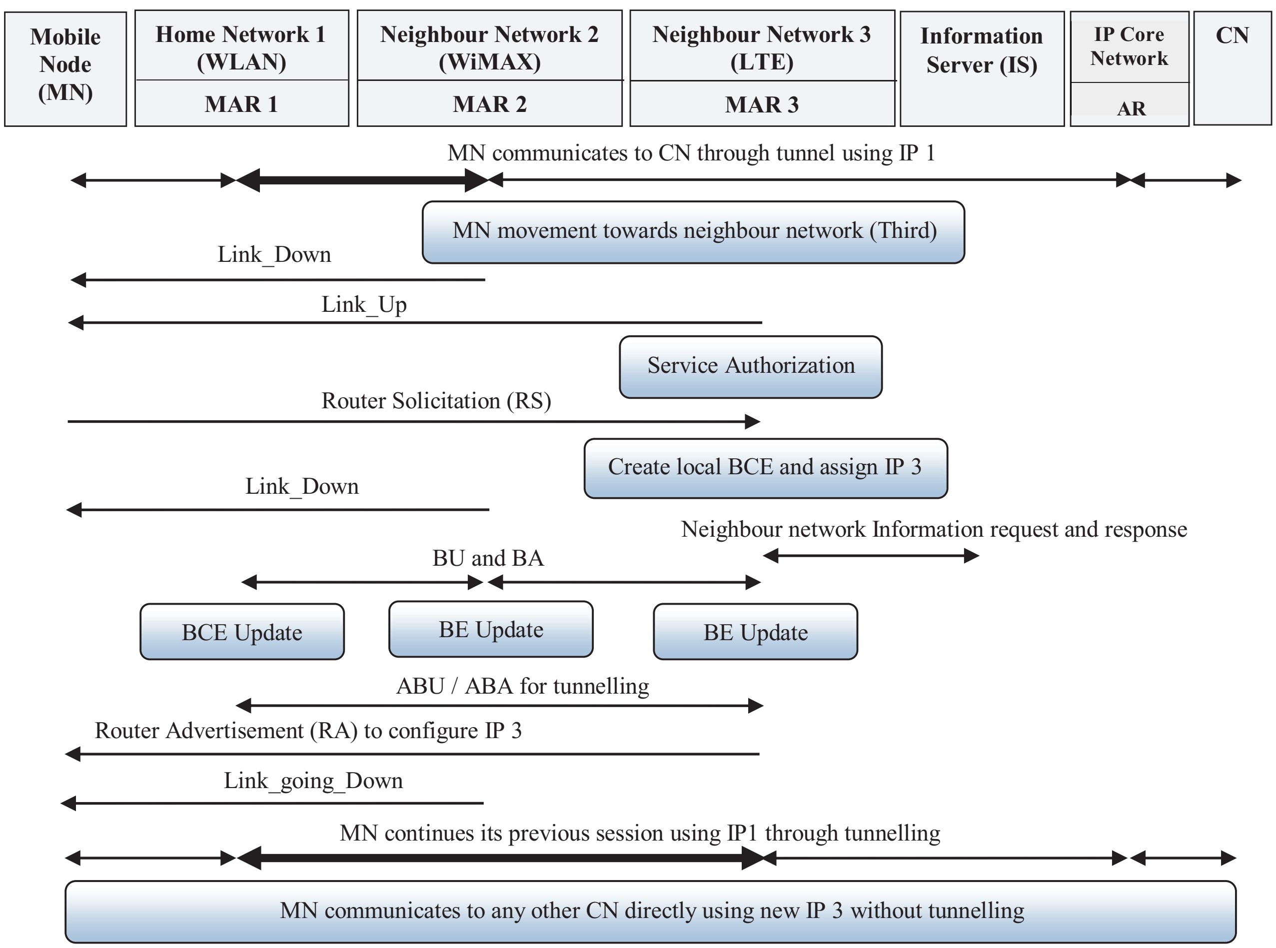


Figure 4. Handover procedure to third network.

The vertical handover delay of the MN moves from WiMAX to any third network is expressed as follows:

$$\tau_{VHO_2} = \tau_{AAA}^{Netw3}(req,res)+\tau_{MN}^{MAR3}(RS,RA)+\tau_{BM}(MAR3,MAR2,MAR1)+\tau_{tunnel}(MAR1,MAR3)+\tau_{Config}^{MN}(IP2) \quad (5)$$

where,

$$\tau_{BM} = \sum_{i=1}^{n}[\tau_{BU}^{MARi}(req)] + \tau_{BA}^{MAR2}(res) + \sum_{i=1}^{n-1}[\tau_{NBA}^{MARi}(res)] + \tau_{BA}^{MAR1}(res) \quad (6)$$

$$\tau_{Tunnel} = \tau_{ABU}^{MAR3-MAR1}(req) + \tau_{BCE}^{MAR1}(update) + \tau_{ABA}^{MAR1-MAR3}(res) + \tau_{BCE}^{MAR3}(update) \quad (7)$$

The vertical handover delay to the third network τ_{VHO_2} is similar to the previous case. The τ_{BM} and τ_{tunnel} depends on the exchange of BU / BA to all $'n'$ candidate network and ABU / ABA between MAR3 and MAR1 with their respective BCE update delay $\tau_{BCE}^{MAR}(update)$.Thus, the MF-DMM completely eliminates the sub-optimal routing paths and minimises the signalling overhead during handover operation. This leads to optimised handover operation across any access technologies and mobility protocols.

4. Simulation results and discussion

This section describes the vertical handover performance across two integrated IEEE 802.16 and IEEE 802.11 networks based on the MF-DMM scheme using OPNET software. The simulation parameters for the configuration of networks (WLAN access point, WiMAX BS) and the MN are listed in Table 2. The MN was initially attached to the WLAN network and later made a random trajectory towards the WiMAX network. The random waypoint mobility configuration was done in the MN. The MN trajectory information like X position, Y position and travel distance in time are listed in Table 3.

Table 2. Simulation parameters.

Parameters 1	**WLAN AP Configuration**	**WiMAX BS Configuration**	**Parameters 2**	**MN Co**
Transmission power	0.005 W	0.5 W	Traffic	Email, FT VoIP, Video
Physical characteristics	Direct sequence	OFDM	Calls	Unlimited
Coverage area	120 m	2 miles	BU max. retry	6
Max. no. of mobile user	100	100	MN speed	10 Km/h
Spectrum efficiency	0.55 bps/Hz	4.8 bps/Hz	BU interval	10
Data rate	11 Mbps	32-134 Mbps	Route optimization	Enabled
Channel bandwidth	20 MHz	20, 25, 28 MHz	Max. handover	6
Frequency band	2.4 GHz	10-66 GHz	MN trajectory	Random

The IEEE 802.16 covers up to 2 miles with the medium mobility support. Log-distance path loss is accounted for mobile propagation in order to make efficient handover decisions. The performance comparison analysis of the presented scheme and the existing centralised approach are described in the following results.

Table 3. MN trajectory path during simulation.

X Pos (m)	Y Pos (m)	Distance (m)	Traverse Time	Ground Speed	Accum Time
8,865.07	4,439.77	n/a	n/a	n/a	00.00s
8,879.53	4,454.23	20.452291	07.36s	6.216097	07.36s
9,053.07	4,685.62	289.235548	1m44.12s	6.213998	1m51.48s
9,139.84	4,714.54	91.464291	32.93s	6.213173	2m24.41s
9,226.61	4,729.00	87.967604	31.67s	6.213386	2m56.08s
9,530.31	4,743.46	304.041395	1m49.45s	6.21399	4m45.53s
9,544.77	4,497.61	246.275155	1m28.66s	6.213646	6m14.19s
9,559.23	4,512.07	20.4518	07.36s	6.215963	6m21.55s
8,951.84	4,772.39	660.82556	3m57.90s	6.213639	10m19.45s
8,937.38	4,801.31	32.337353	11.64s	6.214484	10m31.09s
9,472.46	4,931.47	550.688021	3m18.25s	6.213639	13m49.34s
9,544.77	4,034.84	899.541013	5m23.83s	6.213803	19m13.17s
9,385.69	4,410.84	408.273077	2m26.98s	6.21364	21m40.15s
9,197.69	4,396.38	188.558509	1m07.88s	6.213809	22m48.03s
8,792.76	3,774.52	742.073718	4m27.15s	6.213631	27m15.18s
8,763.84	3,731.14	52.14271	18.77s	6.214167	27m33.95s
8,937.38	3,615.44	208.570687	1m15.09s	6.213335	28m49.04s
9,139.84	3,629.91	202.980636	1m13.07s	6.213969	30m02.11s
9,486.92	4,063.76	555.603278	3m20.02s	6.213624	33m22.13s
9,313.38	5,105.01	1,055.61	6m20.02s	6.213708	39m42.15s
9,472.46	5,076.08	161.687576	58.21s	6.213448	40m40.36s
9,559.23	5,076.08	86.770734	31.24s	6.213208	41m11.60s

4.1. Handover delay and signalling overheads

Handover delay is the process of transferring an ongoing session between different wireless access technologies during MN mobility. Figure 5(a) shows the vertical handover delay between WLAN and WiMAX networks based on the proposed MF-DMM and CMM scheme. The handover occurs at the simulation time interval of 250 s to 1000 s. The peak average value of handover delay during this interval is higher than 50 ms for CMM and lower than 25 ms for MF-DMM technique. The handover delay is 25% lower for the presented scheme. The reason is that, in MF-DMM, the MARs (MAR1, MAR2) are distributed locally (responsible for the prefix allocation, binding update, and tunnelling) and closer to the MN. Thus, the exchange of handover signalling information for binding management BU/BA and tunnelling process ABU/ABA are faster, which, in turn, reduces the handover latency. Also, due to the MIH procedures, the network prepares handovers in advance based on the probability as given in the following equations (8) and (9).

$$Pr(VHO) = PrRSS_t(WLAN/WiMAX) \leq RSS_{thr} \ \ \&\& \ \ RSS_{t+1}(WLAN/WiMAX) \leq RSS_{thr} \tag{8}$$

$$Pr(VHO) = Pr\{MN_t^{WLAN} = link\_going\_down \ \ \&\& \ \ MN_{t+1}^{WLAN} = link\_going\_down\} \tag{9}$$

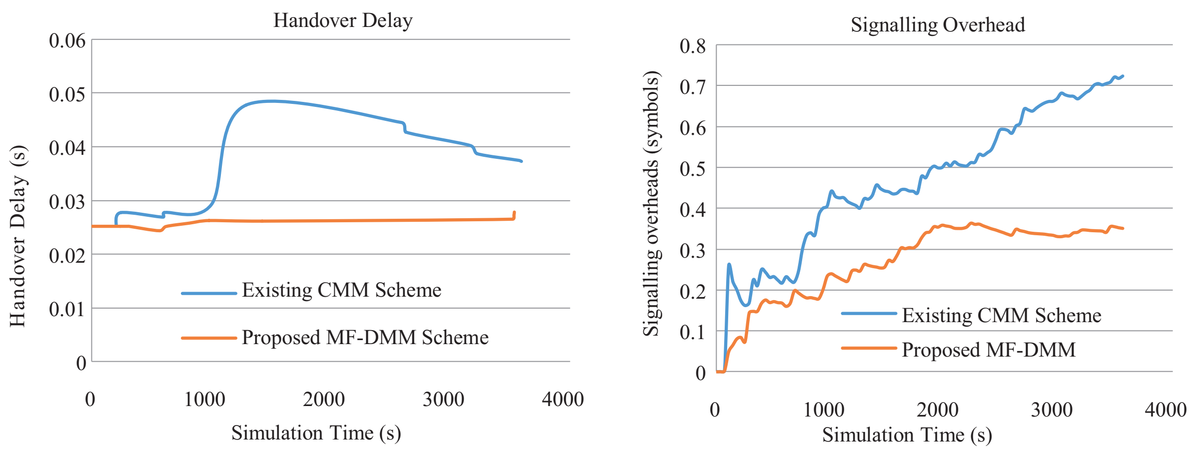


Figure 5. a) Handover delay. b) Signaling overhead.

Equation (8) represents the generalised vertical handover occurrence probability $Pr(VHO)$ of the existing scheme. The handover from WLAN to WiMAX network is executed only if the RSS value of the current network at a time t (RSS_t) and at a time $t+1$ (RSS_{t+1}) is less than the RSS threshold (RSS_{thr}). Similarly, (9) is our proposal, which is based on MIH procedures. The probability of handover occurs if the MN at $WLAN$ network continuously experiences $link\_going\_down$ triggers in the consecutive time samples $'t'$ MN_t^{WLAN} and $'t+1'$ MN_{t+1}^{WLAN}. Therefore, the overall handover delay is minimised for the proposed MF-DMM scheme. Signalling overhead depends on the number of exchanges of signalling information during the handover process. From the Figure 5(b), it was observed that the signalling overhead for the MF-DMM is minimum (0.35 symbols) when compared to the CMM scheme (0.7 symbols). Since the number of route tables addition, entries and the total number of updates at MAR during the handover is less due to the absence of centralised anchor in MF-DMM technique.

4.2. Analysing the QoS of CVBR real and non-real-time traffic classes

The QoS defines the ability of the network to provide guaranteed service in the available bandwidth in terms of delay, throughput, packet loss rate, signal strength, reliability, etc. For different types of traffic classes, priority should be given, and the network has to differentiate the application of the user based on the priority level. The conversational (voice) and streaming (video) classes are highly delay-sensitive and given the highest priority. Whereas the interactive (Email, HTTP) and background (FTP) traffic are delay insensitive and scores lowest priority in the heterogeneous background. The application and profile definition block inserts several predefined applications like email, FTP, HTTP, voice and video into the proposed models to be verified and evaluated. These applications are configured in the presented scenario, and their parameter values are listed in Table 4. Each application has a start time offset (determines when the application starts with relate to the profile start time) and inter-repetition time (gap between the completion of one application and the start of the next series). The traffic sent and received for the mentioned application is captured during the handover process.

Table 4. Application and profile configuration.

Application definitions		**Profile configuration**	
		Start time offset (s)	**Interrepetition time (s)**
Video	Low resolution video	Uniform (5, 10)	Exponential (300)
FTP	High load	Uniform (5, 10)	Constant (100)
Email	High load	Uniform (5, 10)	Constant (300)
Voice	PCM quality speech	Uniform (5, 10)	Exponential (300)
HTTP	Heavy browsing	Uniform (5, 10)	Constant (300)

4.2.1. Conversational and streaming classes

The performance analysis of CBR (voice) and VBR (video) real-time applications are analysed for both the existing CMM and the proposed MF-DMM scheme. Figure 6 represents the voice traffic sent and received by the MN with the corresponding voice server. The voice frame / packet is assigned to 1, with exponentially distributed incoming and outgoing silence length of 0.65 s. It was observed that in both the schemes, the average of 48000 bytes/s (B/s) of voice data is sent, out of which 46500 B/s is received for CMM and 47800 B/s is received for MF-DMM scheme.

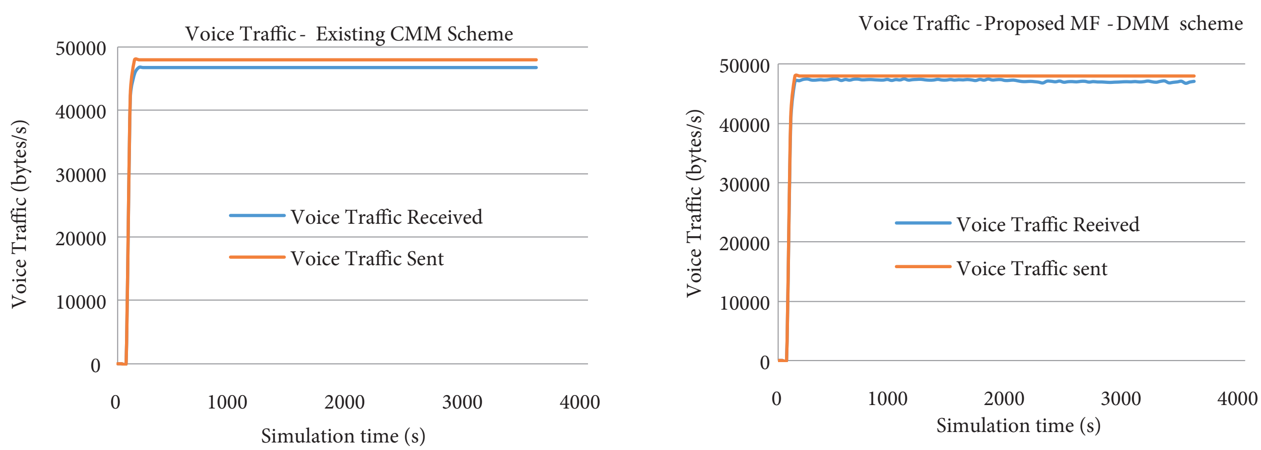


Figure 6. Voice traffic sent and received. a) Existing CMM. b) Proposed MF-DMM.

Both the scheme provides minimum loss of 200 B/s (MF-DMM) and 1500 B/s (CMM), respectively. The conversational (voice) traffic was given the first highest priority in the network as mentioned in Table 1. Similarly, for video traffic, each frame size is 128 × 240 pixels and frame inter-arrival time is 15 frames/s are specified for simulation setup. The average of 920000 B/s is sent for both the schemes as in Figure 7(a) and Figure 7(b). The CMM scheme receives 680000 B/s, whereas the MF-DMM receives 800000 B/s of video streams. The proposed scheme provides lower traffic loss when compared to the CMM scheme. The reason is that, in MF-DMM, the traffic is routed via MAR, which is closer to the MN, while, in CMM, the traffic is routed via centralised anchor and then the AR, which results in increased handover latency. Larger handover delay takes more time to release the traffic from the queue at the AR and tends to traffic loss. The packet delay variation, end-to-end delay is also considered an important factor for traffic loss. This is directly related to the handover latency. Therefore, in the given scenario, handover delay was greatly reduced, thus, minimising traffic loss.

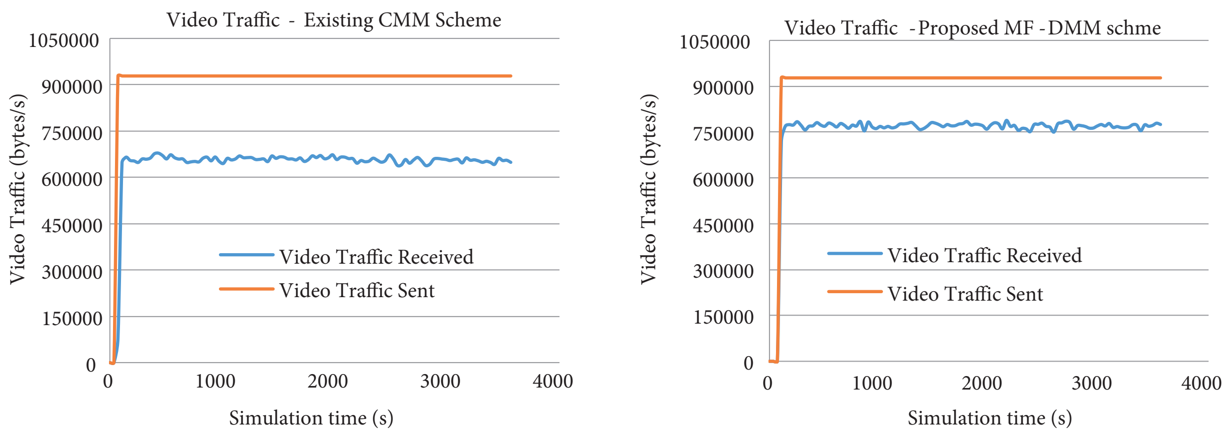
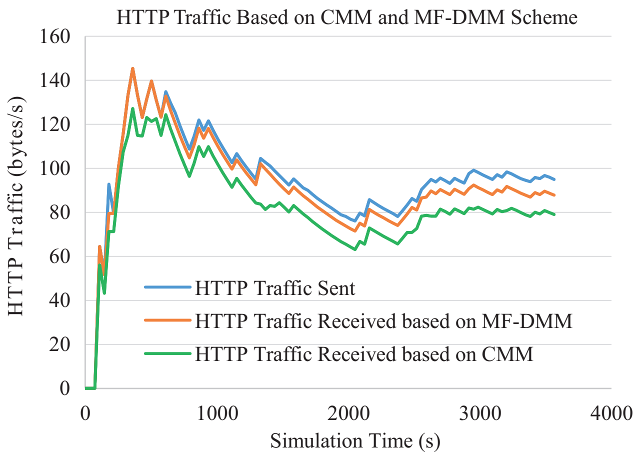


Figure 7. Video traffic sent and received. a) Existing CMM. b) Proposed MF-DMM.

4.2.2. Interactive and background classes

Interactive and background classes comprise email, HTTP and FTP services. For interactive services, the response time depends on the information type, protocols and link quality, whereas the background traffic is delay tolerant and requires an error-free communication. This type of traffic reduces the unnecessary handover and handover failure rate. Figures 8-9 represent the HTTP, email, and FTP traffic sent and received by the MN. The HTTP application represents heavy web browsing. The MN downloads the page from a remote server. From Figure 8(a), it was noted that the peak average value of 148 B/s of HTTP traffic is sent during the simulation time of 250 to 500 s. In this handover time interval, the MN receives or downloads 148 B/s (peak average value) of HTTP streams for MF-DMM and 125 B/s (peak average value) for CMM technique. Due to lower handover delay, the HTTP service offers faster response time and hence, the traffic sent and received are exactly same for MF-DMM when compared to the CMM method.

For email application, high load is considered, and the MN transfers email messages to the mail server. Figure 8(b) indicates that 100 B/s (peak average value) of email traffic is sent during the simulation time of 250 to 500 s. In this interval, no traffic loss occurs, but after that, there is a gradual average loss of 5 B/s (MF-DMM) and 12 B/s (CMM) over the simulation time. In FTP, 50% (Get) of file transfer from server to MN is assumed, and the time between each MNs file transfer request is constantly distributed with a mean outcome of 100 s. The peak average value of 2600 B/s of FTP traffic is sent from the server to MN as shown in Figure 9, out of which 1900 B/s is received for MF-DMM, and 1700 B/s is received for CMM scheme. The email and FTP applications are given lowest priority. Therefore, after completion of the handover, high priority traffic is first released and then the low priority class, which results in gradual traffic loss for both the schemes after handover over the simulation time of 500 to 3600 s. The MF-DMM method outperformed in all the traffic classes with less data loss.



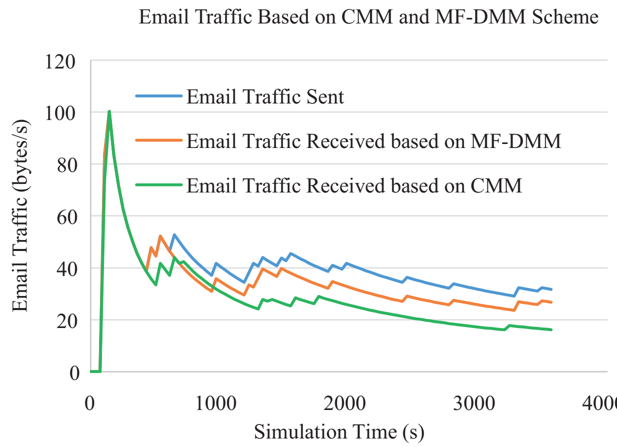


Figure 8. a) HTTP traffic. b) Email traffic.

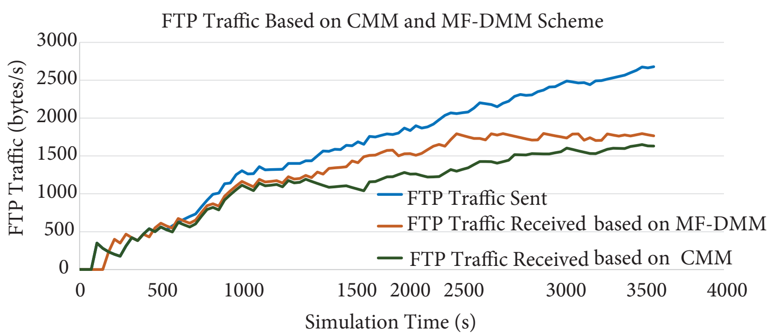


Figure 9. FTP traffic sent and received.

4.3. Uplink and downlink packets dropped

The MN uplink and the downlink packet transmission is suspended during the handover execution phase and resumed after completion of the handover. The handover decision is based on the uplink or downlink channel quality due to user mobility. During this time, the uplink and the downlink packets are queued in the access gateway, and these packets are released from the corresponding AR after completion of the handover.

The presented scheme decreases the uplink (0.2 packets/second(pkts/s)) and downlink (0.6 pkts/s) packet loss ratio by 10% and 30% when compared to the conventional scheme (uplink 0.3 pkts/s and downlink 0.9 pkts/s). Due to minimised handover delay, the MF-DMM technique avoids significant uplink and downlink packets loss as depicted in Figure 10.

4.4. WiMAX delay and traffic performance

The WiMAX delay is associated with the binding management and tunnelling delay during the handover process of the MN. Here, the handover procedure follows MIH standards, and the network prepares the soft handover in advance for the high priority traffic type. This leads to lower binding management and tunnelling delay, which, in turn, minimises the overall WiMAX delay to 0.08 s with respect to CMM scheme of 0.12 s as shown in Figure 11(a). After handover completion, the traffic flows through the WiMAX network with the tunnel between MAR1 and MAR2. Thus, the WiMAX network balances its network load and achieves increased

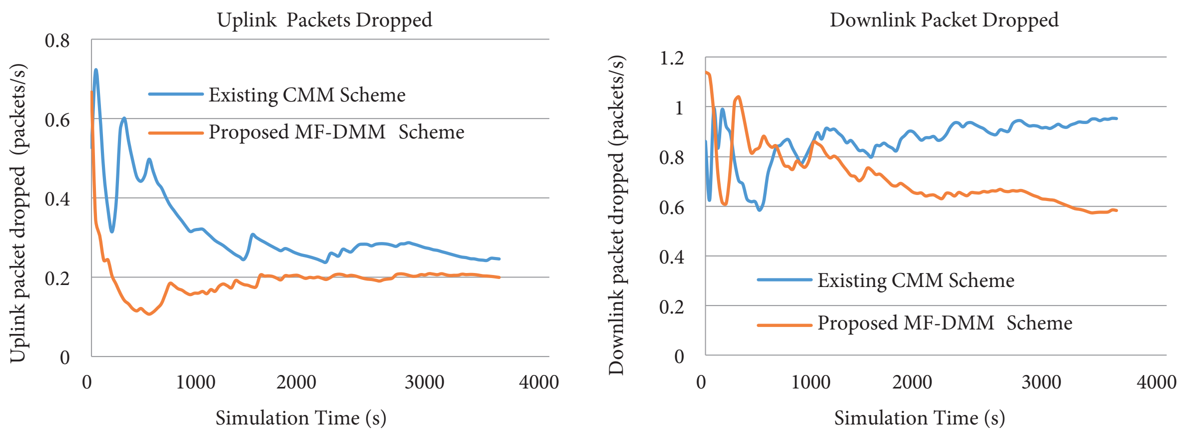


Figure 10. a) Uplink packet dropped. b) Downlink packet dropped.

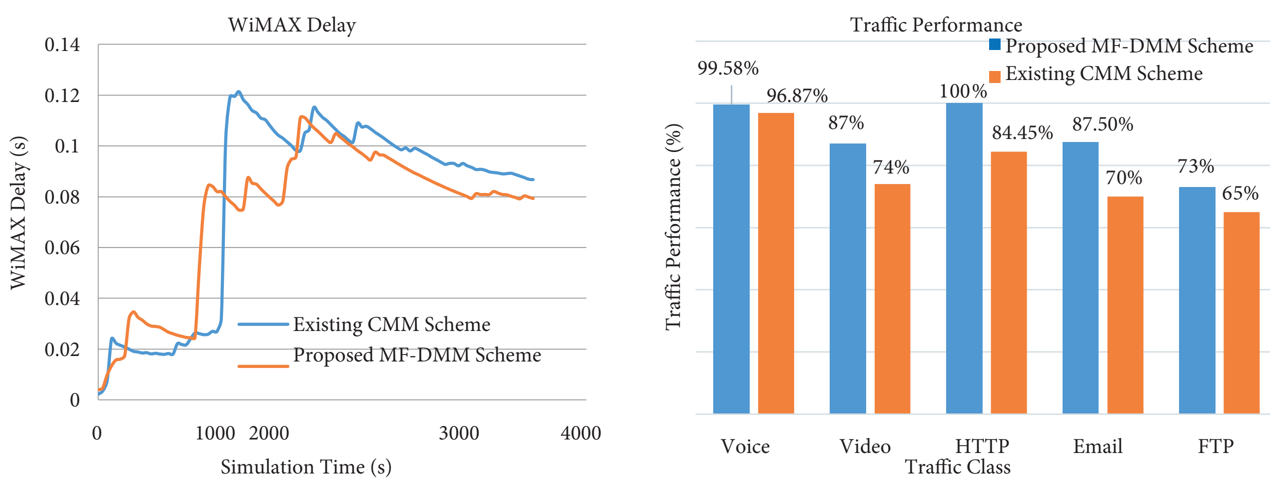


Figure 11. a) WiMAX delay. b) Traffic performance.

system throughput for MN mobility.

Figure 11(b) shows the individual traffic performance of voice, video, HTTP, email and FTP based on the proposed MF-DMM and existing CMM scheme. It was noted that 99.58% of voice traffic is successfully received for MF-DMM and 96.87% for CMM method. Voice traffic must be carefully configured because, resending of voice packets is meaningless and packet loss should not exceed 5% while using G.711 codec. In MF-DMM, the loss rate is below 0.5% when compared to CMM (3%) technique. Video traffic achieves 87% and 74% of success transmission for MF-DMM and CMM scheme. The quality of video cannot be measured rather perceived. Similarly, for HTTP, email and FTP applications, the MF-DMM technique attains 100%, 87% and 73% which is extremely better than the existing CMM method. Table 5 summarises the performance parameters of the integrated WiMAX and WLAN network based on the CMM and MF-DMM schemes. The path loss is measured between the MN and its corresponding BS, and it is 122 dB and 130 dB for the proposed and existing schemes. The total and sub channel transmitting power is adjusted every time during ranging, and it is well maintained for MF-DMM due to lower handover delay and distributed MARs. Similarly, the uplink SNR is measured at the BS for all packets arriving from the particular MN. The presented work achieves better uplink and downlink

SNR due to less path loss when compared to the existing scheme. The simulation results showed that the presented MF-DMM solution greatly supports seamless connectivity, achieves less handover delay, packet drop ratio and increased traffic performance. Hence, the MF-DMM method proved to be more proficient for both delay-sensitive and delay-tolerant applications.

Table 5. Performance analysis of the existing CMM and the proposed MF-DMM scheme.

Parameters	**CMM scheme**	**MF-DMM scheme**
WiMAX delay (s)	0.12	0.08
Uplink packet dropped (pkts/s)	0.3	0.3
Downlink packet dropped (pkts/s)	0.9	0.6
Email traffic (B/s)	Sent [Max, Min]: [100, 40]	
Received: [100, 28]	Sent [Max, Min]: [100, 40]	
Received: [100, 35]		
MAC signaling overheads (symbols)	0.7	0.36
HTTP traffic (B/s)	Sent: 148 (peak value)	
Received:125	Sent: 148 (peak value)	
Received:148		
Uplink SNR (dB)	6	9
Downlink SNR (dB)	-10	15
FTP traffic (B/s)	Sent: 2600 (peak value)	
Received : 1700	Sent: 1500 (peak value)	
Received : 1900		
Pathloss (dB)	130	122
Voice traffic (B/s)	Sent: 48,000	
Received: 46,500	Sent: 48,000	
Received : 47,800		
Video traffic (B/s)	Sent: 920000	
Received: 680,000	Sent: 920000	
Received: 800,000		
Total transmitting power (dBm)	24	26
Subchannel transmitting Power (dBm)	6	7.2

5. Conclusion

The proposed MF-DMM scheme provides an optimised handover operation across heterogeneous networks. The mobile user experiences better QoS for the different types of real and non-real time CVBR (email, FTP, HTTP, VoIP and video) applications with high-speed access to wide coverage. This study found that real-time CVBR scores the highest priority when compared to the lowest priority non-real time traffic. Hence, the voice traffic achieves less than 0.5% of loss for the proposed work. Since it utilises MIH services and DMM for the intelligent handover process. The MARs are distributed and handle the mobility-related signalling locally. The MIH services are helpful for initiating (Link_down, Link_going_down), preparing (handover resource checking) and executing (time to trigger avoids unnecessary and handover failure probability) handovers. The simulation results suggest that the MF-DMM better manages CVBR traffic in terms of the handover delay, traffic sent received and packet loss rate. It is concluded that the MF-DMM approach is the best fit for future network designing. The WiMAX and the recent LTE technologies are much similar to each other with a minor difference. Both the technologies use OFDM and MIMO concept and provide backward compatible with existing GSM and CDMA networks. Therefore, in this paper, we first choose the basic widely used WiMAX network to analyze the handover performance based on the MF-DMM technique for different types of traffic classes. Based on the simulation performance, the advantages and difficulties of the proposed work are examined, which acts as a key to further improve the performance of advanced LTE technologies in the future work. And also, the random mobility behaviour of the multiple MNs will be analysed in future under different integrated scenario based on MF-DMM technique.

References

[1] Shin D, Moses D, Venkatachalam M, Bagchi S. Distributed mobility management for efficient video delivery over all-IP mobile networks: Competing approaches. IEEE Network 2013; 27 (2): 28-33. doi: 10.1109/MNET.2013.6485093

[2] Zubair M, Kong X, Mahfooz S. DMAM: distributed mobility and authentication mechanism in next generation networks. Security and communication networks 2015; 8 (5): 845–863. doi.org/10.1002/sec.1041

[3] AlFarraj O, Tolba A, Alkhalaf S, AlZubi A. Neighbor predictive adaptive handoff algorithm for improving mobility management in VANETs. Computer Networks 2019; 151: 224-231. doi: org/10.1016/j.comnet.2019.01.020

[4] Guan J, Sharma V, You I, Atiquzzaman M, Imran M. Extension of MIH for FPMIPv6 (EMIH-FPMIPv6) to support optimized heterogeneous handover. Future Generation Computer Systems 2019; 97: 775-791. doi: 10.1016/j.future.2019.03.031

[5] Netalkar PP, Maheshwari S, Raychaudhuri D. Evaluation of Network Assisted Handoffs in Heterogeneous Networks. In: IEEE 2020 International Conference on Computer Communications and Networks; Honolulu, HI, USA; 2020. pp. 1-9.

[6] Wang Y. PMIPv6-based partially distributed mobility management modeling and evaluation. In: IEEE 2016 World Automation Congress; Rio Grande, PR, USA; 2016. pp. 1-7.

[7] Balfaqih M, Ismail M, Nordin R, Balfaqih ZA. 802.21-Assisted Distributed Mobility Management Solution in Vehicular Networks. IEEE Access 2017; 5: 9518-9532. doi: 10.1109/ACCESS.2017.2702282

[8] Balfaqih M, Ismail M, Nordin R, Balfaqih Z. Handover Performance Evaluation of Centralized and Distributed Network-Based Mobility Management in Vehicular Urban Environment. In: IEEE 2017 GCC Conference and Exhibition; Manama, Bahrain; 2017. pp. 1-5.

[9] Kim D, Shin Y. An enhanced security authentication mechanism in the environment partially distributed mobility management. In: IEEE 2017 International Conference on Information Networking; Da Nang, Vietnam; 2017. pp. 457-462.

[10] Dutta N, Polkowski Z, Savulescu C, Pathak S. An approach to signaling cost reduction in Proxy MIPv6 for mobility management. In: IEEE 2016 International Conference on Advances in Computing, Communications and Informatics; Jaipur, India; 2016. pp. 1654-1660.

[11] Song B, Shin J, La S, Jeong J. On minimizing signaling costs for PMIPv6-based distributed dynamic mobility management. In: IEEE 2016 Annual Ubiquitous Computing, Electronics & Mobile Communication Conference; New York, USA; 2016. pp. 1-7.

[12] Giust F, Bernardos CJ, Oliva AD. Analytic Evaluation and Experimental Validation of a Network-Based IPv6 Distributed Mobility Management Solution. IEEE Transactions on Mobile Computing 2014; 13 (11): 2484-2497. doi: 10.1109/TMC.2014.2307304

[13] Murtadha MK, Noordin NK, Ali BM, Hashim F. Fully distributed mobility management scheme for future heterogeneous wireless networks. In: IEEE 2015 Malaysia International Conference on Communications; Kuching, Malaysia; 2015. pp. 270-275.

[14] Nguyen T, Bonnet C. A hybrid Centralized-Distributed Mobility Management for supporting highly mobile users. In: IEEE 2015 International Conference on Communications; London, UK; 2015. pp. 3945-3951.

[15] Sun K, Kim Y. PMIP-Based Distributed Session Mobility Management for 5G Mobile Network. In: IEEE 2019 International Conference on Information Networking; Kuala Lumpur, Malaysia; 2019. pp. 453-456.