ISSN 2348-1196 (print)
International Journal of Computer Science and Information Technology Research ISSN 2348-120X (online)
Vol. 2, Issue 3, pp: (304-316), Month: July - September 2014, Available at: www.researchpublish.com

A STUDY OF THE IMPACT OF TRAFFIC TYPE, NODE MOBILITY AND HANDOFF ON THE PERFORMANCE OF MOBILE WIMAX NETWORK

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Abstract: **IEEE 802.16e, Mobile WiMAX is a wireless technology used to provide very high data rate over large areas to larger number of users where broadband is unavailable. It is an attractive solution for providing high-speed internet access in a cost-effective way to people living in both sparsely populated rural areas as well as densely populated urban areas. This popularity is a result of the flexibility, low-cost and user mobility offered by the technology. This paper analyses Mobile WiMAX performance for small, medium and large network scenarios under FTP, HTTP, VoIP and Video conferencing traffic with varied node mobility (0~90km/h) when handoff is enabled or disabled through extensive simulation experiments. In this paper we use OPNET Modeller 15.0 to simulate the performance of WiMAX.**

Keywords: **FTP, HTTP, VoIP, Videoconferencing, node mobility, Jitter, Handoff.**

1. INTRODUCTION

World wide Interoperability for Microwave Access (WiMAX) is an emerging and exciting wireless technology that can support a variety of business and consumer applications, from network backhauling and interconnecting with Wi-Fi and LANs, to voice, audio, data and mobility support[3]. The rapid growth in the area of communication has generated the need of mobility during communication. Mobile WiMAX may change the way people access data, e-mail, audio and video communication services as it provides a faster transmission speed than 3G, broader coverage than Wi-Fi and higher mobility than LAN [3]. Mobile WiMAX can provide services up to a mobile speed of 120km/h at 3.8GHz bandwidth. By adopting a scalable PHY architecture and OFDMA, mobile WiMAX is able to support a wide range of bandwidths (1.25MHz to 20MHz) and coverage (12~15km in LOS) [10].

This thesis investigates how mobile WiMAX performs in various network conditions and how this performance changes due to traffic type node mobility and handoff. To provide realistic results for end users, diverse traffic types (FTP, HTTP, VoIP, and Video conferencing) that are frequently used on wireless networks and diverse node movement speeds(0~90km/h) are also used in the experiments. The impact of the node mobility, traffic type on system performance has been investigated by increasing speed of nodes when handoff is enabled or disabled.

This paper is organized as follow: Section 2 describe the important aspects of Mobile WiMAX, and section 3 describe the research methodology used in this paper. Simulation scenario and results are given in Section 4 and 5, respectively. Finally, Section 6 concludes the paper.

2. IMPORTANT ASPECT OF MOBILE WIMAX

The IEEE Group completed and approved the IEEE 802.16e in December 2005, as an amendment to the IEEE 802.16d standard. IEEE 802.16e is often referred to as "Mobile WiMAX". Mobile WiMAX creates a new market for mobile broadband services [1] . To enable users to move from one cell site area to another the introduction of seamless handoff and a roaming scheme would be needed. Moreover, added 2048 FFT modes facilitate a Scalable OFDMA(S-OFDMA) which can support various FFT sizes to address variable bandwidth from 1.25 to 20MHz. In addition, S-OFDMA optimizes the efficient use of network resources.

The IEEE 802.16e is an interesting technology that delivers carrier classes, high speed and wireless broadband at a much lower cost than cellular and provides much greater coverage than Wi-Fi[14]. Mobile WiMAX does not provide significant improvement in speed, throughput or capacity. However, it provides stable mobile services to portable end user devices, such as laptops and smart phones.

2.1 Features of Mobile Wimax [2]

a) High Data Rates: The inclusion of MIMO antenna techniques along with flexible sub-channelization schemes, advanced coding and modulation all enable the Mobile WiMAX technology to support peak Download data rates up to 63 Mbps per sector and peak Upload data rates up to 38 Mbps per sector in a 10 MHz channel.

b) Quality of Service (QoS): The fundamental premise of IEEE 802.16 MAC architecture is QoS.

c) Scalability: Despite of increasingly globalized economy, spectrum resources for wireless broadband worldwide are still quite disparate in its allocations. Mobile WiMAX technology therefore, is designed to be able to scale to work in different channelizations from 1.25 to 20 MHz to comply with varied worldwide requirements as efforts proceed to achieve spectrum harmonization in the longer term.

d) Security: The features provided for Mobile WiMAX security aspects are best in class with EAP-based authentication, AES-CCM based authenticated encryption, CMAC and HMAC based control message protection schemes. It supports a diverse set of user credentials exists including: SIM/USIM cards, Smart Cards, Digital Certificates, and Username/Password Schemes based on the relevant EAP methods for the credential type.

e) Mobility: Mobile WiMAX supports optimized handover schemes with latencies less than 50 Milliseconds to ensure real-time application such as VoIP perform without service degradation. Flexible key management schemes assure that security is maintained during handover.

2.2 Hand Off

"The handoff is a process during which a mobile station (MS) immigrates from air interfaces for its current Base Station (BS) to air-interfaces of adjacent BS. Handoff is an important process of mobility support in wireless network" [3].
Handoff is unavoidably incurred when a cell is overloaded or a MS moves out of a BS`s signal coverage. Therefore, mobile WiMAX allows both the MS and the network are allowed to do initial handoff like a 3G cell network where the network is always responsible for initiating a handoff[5]. Four typical handoff types are there. They are hard handoff, soft handoff, vertical handoff and horizontal handoff. In this paper Hard Handoff Technique is used to implement the experiment.

3. RESEARCH METHODOLOGY

Computer simulation is widely used as a research methodology for analyzing the performance of wireless network. Computer simulation provides a virtual environment for the design and deployment of components. The OPNET simulator is selected for this experiment. Results were exported from OPNET Modeller to MicroSoft Excel 2000 Sheets and were then used to generate graphics for observation. The usability of OPNET is sufficient to conduct network modeling and performance evaluation.

The advantages of OPNET simulator are

a) Simulate real-life network scenarios by using commercially available network components;

b) Easily resuse and modify network scenarios; c)Cost and Time efficient;

d) Possible to propose network protocol using c language;

e) Possible to insert real-time data from other compatible software.

4. OPNET SIMULATION SCENARIO

In this section we describe simulation scenarios which were used in our analysis. The simulations are performed using the network simulator OPNET

.The performances of this experiments are analyzed by using several parameters such as: Upload Response Time and Download Response Time for FTP, Page/Object Response Time for HTTP, Jitter and Mean Option Score for VoIP, End-to-End delay and Packet Delay Variation for Videoconferencing. Finally Throughput and Packet loss ratio are analyzed.Throughput means average rate of data packets received successfully through network. Download/upload response time is the elapsed time between sending a request and receiving a packet for the application.

Object/Page response time is the time that an http server or system takes to react to a given input. End-to-End delay defines how long it takes for an entire message to arrive at the destination from the time the first bit is sent out from the source. Jitter measures the tendency of packet delay variation two consecutive packets. Mean Opinion Score is a method for expressing real-time video and audio quality. Packet loss ratio is a number of data packet that are lost during transmission. It is measured as the percentage of lost packet from the total number of packet sent.

4.1 Model Description

The experiment is conducted by varying network size, node mobility with/ without handoff. Experiments are performed in a cell size of 2000m X 2000m. Networks sizes of 10, 50, and 100 nodes are used. The random waypoint mobility model is used for trajectory. Traffic loads are classified into three traffic load groups: light, medium and heavy. In addition, network size is also (100 nodes). In FTP, 1000, 5000 and 50000 bytes indicates light, medium and heavy traffic load respectively.classified in to three groups: Small (10nodes), Medium (50nodes) and large.

In HTTP, 500 bytes with 720s page interval time represents light, 1000 bytes with 360s interval time represents medium and 1000 bytes with 60s interval time represents heavy traffic load. In VoIP, G.723 codec (6.3Kbps with silence compression) implies light, G.729.A codec (8Kbps with silence compression) implies medium and G.711 (64Kbps with silence compression) implies heavy traffic load. Lastly, in Video conferencing, 10frames/sec with 128X120 pixels suggests light, 15frames/sec with 128X240 pixels suggests medium and 20frames/sec with 352X240 pixels suggests heavy traffic load.

Finally, all simulations are carried out in blocks of 15minute (900 seconds) simulation time and run at least three times to minimize statistical error. Initially, simulation time was 60mintues; however this caused blue screen error and memory usage problems. Therefore 15minutes of simulation time was considered. All the above parameters are presented in tabular form in following Table 1.

Table 1. Mobile WiMAX Parameters used in the experiments

PARAMETERS	**VALUE**		
OFDM PHY Profiles(Default)	Wireless OFDMA 20 MHz		
Number of Subcarriers	2048		
Frame Duration (milliseconds)	5		
Power(Watts)	0.005		
Bandwidth(MHz)	25		
Area(m)	2000X2000		
Traffic Types	FTP, HTTP, VoIP, Video Conferencing		
Traffic Loads	Light	Medium	Heavy
FTP(bytes)	1,000 bytes	5,000 bytes	50,000 bytes
HTTP(bytes/inter arrival time)	500/ 720 secs	1000/360 secs	1000/60 secs
VoIP(codec)	G.723.15	G.729A	G.711
Video conferencing(bytes)	10f/s_128X1 20	15fs_128X240	20f/s352X240

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Network Sizes(number of nodes)	10,50,100
Mobility (km/h)	0,10,30,50,70,90
Mobility patterns(trajectory)	Random waypoint mobility modeling
Simulation Time	15 minutes(900 seconds)
Hand off	Disabled(scenarios 1-3) Enabled (Scenarios 4-6)

4.2 Application Parameters

The parameters for all four applications used for the experiments are presented in following Tables 2, 3, 4 and 5.

Table 2. FTP Parameter

PARAMETERS	VALUE(LIGHT)	VALUE(HEAVY)
Command Mix(Get/Total)	50%	50%
Inter-Request Time(seconds)	3600	360
File Size(bytes)	1000	50,000
Type of Service	Best Effort	Best Effort
RSVP Parameter	None	None

Table 3 HTTP Parameter

PARAMETERS	VALUE(LIGHT)	VALUE(HEAVY)
HTTP Specification	HTTP 1.1	HTTP 1.1
Page Interval arrival Time(Seconds)	720	60
Object Size(Bytes)	500	1000
Location	HTTP Server	HTTP Server
Type of service	Best Effort	Best Effort

Table 4 VoIP Parameter

Parameters	Light(PCM)	Heavy(GSM)
Encoder Scheme	G.723	G.711
Type of Service	Interactive Voice(6)	Interactive Voice(6)
Compression and Decompression Delay(Seconds)	0.02	0.02
RSVP parameter	None	None

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Table 5 VideoConferencing Parameter

PARAMETERS	VALUE(LIGHT)	VALUE(HEAVY)
Frame Interval arrival Time (frames/seconds)	10	30
Frame Size(bytes)	128X120 pixels	352X240 pixels
Type of Service	Best Effort	Best Effort
RSVP parameter	None	None

Figure 1 illustrates the OPNET simulation environment with a network size of 100 nodes in 10 cells. In the experiments, one cell will contain 10 nodes, 50nodes or 100 nodes only. However, in handover experiments, the node number in one cell will be random.

The objects in the OPNET simulation are a mobile station (or Subscriber station), Base Station, ISP_Backbone, Gateway Routers, PPP_DS3 full duplex cable, WiMAX_config, Profile_config, Application_config, Mobility_config and four application servers. Each Subscriber Station has a unique identification number, auto-assigned IP address or manually configured mobile IP address for handoff, random way point trajectory. Four servers are configured to respond to each of the application`s requests. PPP_DS3 full duplex cable is used between Server and ISP Backbone. A gateway Router is used to provide routing information when handoff occurs. A Base Station is configured to transmit and receive the WiMAX signal as the hub of the local wireless network. It can act as a gateway between a wired network and a wireless network.

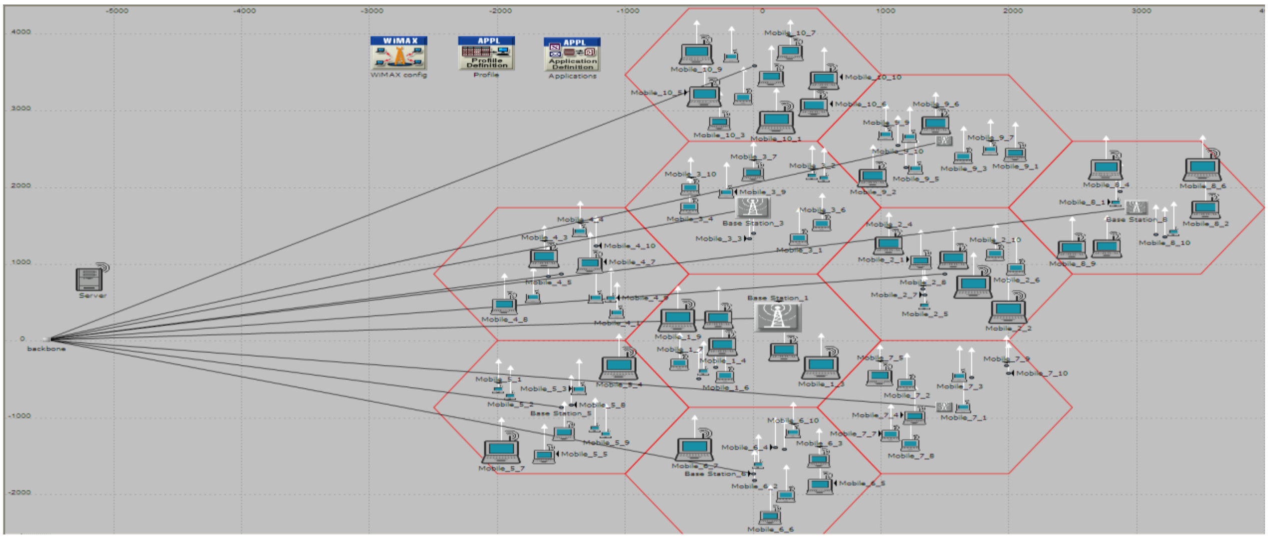

Figure 1 Capture of mobile WiMAX simulation when nodes move randomly within two Access Point`s signal cell

4.3 Simulation Scenario

Six Scenarios are created and experiments for each scenario are conducted multiple times. The aim of the experiments for scenario 1-6 is to see how an increasing speed of nodes and Network Size influence the performance of a WiMAX network when handoff is disabled/enabled. Scenario`s experimental results will summarized throughput and packet loss ratio is shown in the graph. Therefore, the graphs will clearly indicates how system performance has been influenced by increasing speed of node, Network Size when handoff is enabled/disabled.

Nine experiments are done in each scenario. They are throughput, packet loss ratio, end-to-end delay, upload/download response time,Page/object response time , Mean Opinion Score, Packet Delay Variation and Jitter. The Network Environment and Configuration are used in this experiments are illustrated in table 1.

Table 6 shows how the node movement influence the performance of Mobile WiMAX and how performance changes the node speed at the same time when handoff is enabled/disabled.

TABLE 6 Scenario's for Experiment Result (*Node Mobility, Traffic Type and Handoff*)

Scenario	**Handoff Enabled**	**Network size**	**Traffic load**	**Traffic type**	**Node speed**
1	No	Small (10 Nodes)	Light	FTP, HTTP, VOIP, Videocon	0,10,30,50,70 ,90 km/hr
2	No	Medium(50 Nodes)	Medium	FTP, HTTP, VOIP, Videocon	0,10,30,50,70 ,90 km/hr
3	No	Large(10 Nodes)	Heavy	FTP, HTTP, VOIP, Videocon	0,10,30,50,70 ,90 km/hr
4	Yes	Small (10 Nodes)	Light	FTP, HTTP, VOIP, Videocon	0,10,30,50,70 ,90 km/hr
5	Yes	Medium (50 Nodes)	Medium	FTP, HTTP, VOIP, Videocon	0,10,30,50,70 ,90 km/hr
6	Yes	Large(10 Nodes)	Heavy	FTP, HTTP, VOIP, Videocon	0,10,30,50,70 ,90 km/hr

5. RESULT AND ANALYSIS

In the above Section describle four different traffic types (FTP, HTTP, VoIP and Video conferencing) typically used in wireless networks, three different traffic load sizes (light, medium and heavy) and six node speeds (0, 10, 30, 50, 70 and 90km/h) are used in the simulation experiments to examine the impact of traffic type, node mobility and handoff on the performance of mobile WiMAX. This section reports on the combined results from the experiment scenarios 1-3 and 4-6.

5.1 Impact On Node Mobility And Handoff In Ftp

This subsection presents the relevant data (Figures 2 and 3) and discusses changes in FTP download and upload response times when handoff is enabled.

When light FTP traffic is transmitted, there is no significant difference in download/upload times in regards to whether handoff is enabled or disabled. For any node speed, download/upload response times are nearly unchanged. Less than 0.01second time differences are observed.

When medium FTP traffic is transmitted, there are no significant download/upload time differences whether handoff is enabled or disabled up to a 70km/h node speed. For speed above 70km/h, download/upload response times both increase by less than 0.5 seconds.

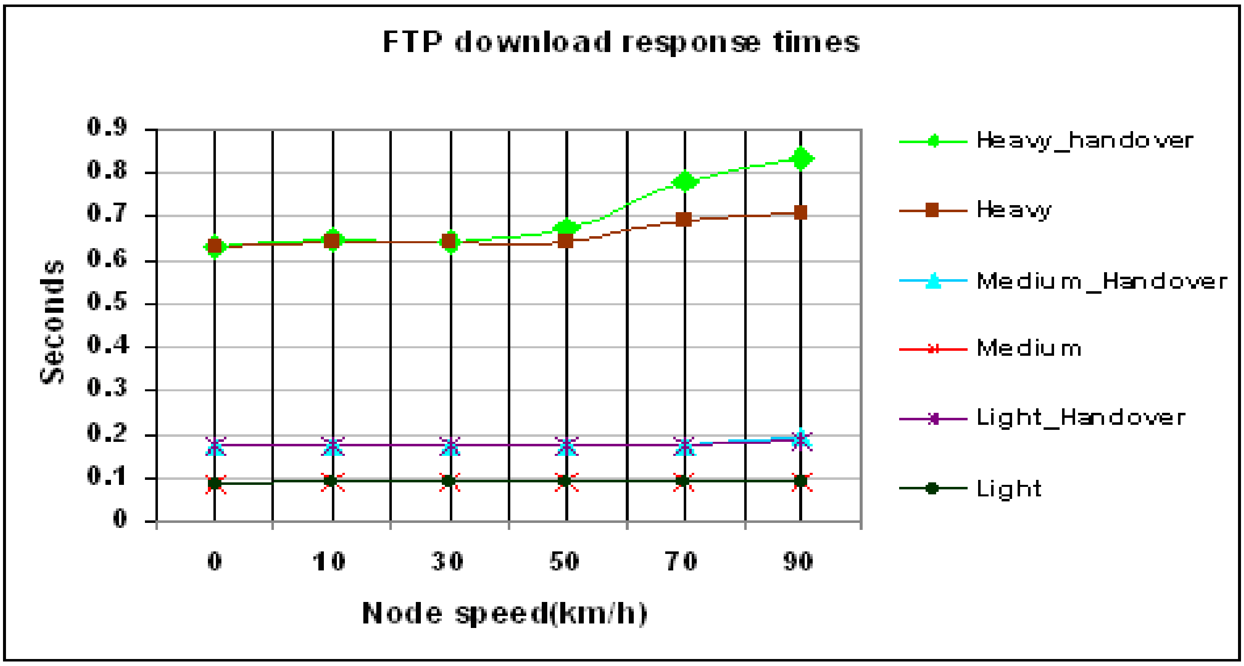

Figure 2 FTP Download response times with and without handoff

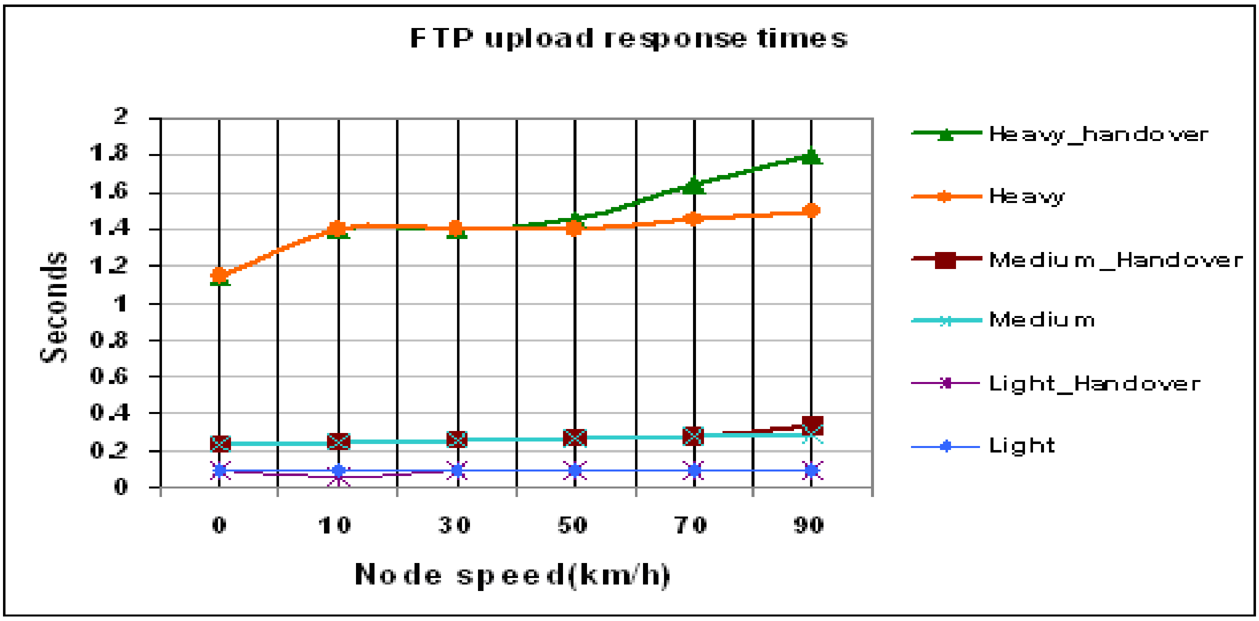

Figure 3 FTP Upload response times with and without handoff

For heavy FTP traffic, there is no significant download/upload time difference between handoff being enabled or disabled, up to a 50km/h node speed. For speeds 50km/h or higher, enabling handoff appears to have an impact on these times. Download and upload response time increase by 0.1 second and 0.3 second respectively when node speed is increased from 50km/h to 90km/h.

5.2 Impact on Node Mobility and Handoff in Http

This section presents and discusses the experimental results for changes in HTTP object and page response times when handoff is enabled. There is no significant object and page response time changes when using handoff for light and medium HTTP traffic transmitted at any node speed. Download and upload response times are nearly unchanged for light HTTP traffic regardless of whether handoff is enabled or disabled. Object and page response times for light and medium HTTP traffic have little increase when handoff is enabled.

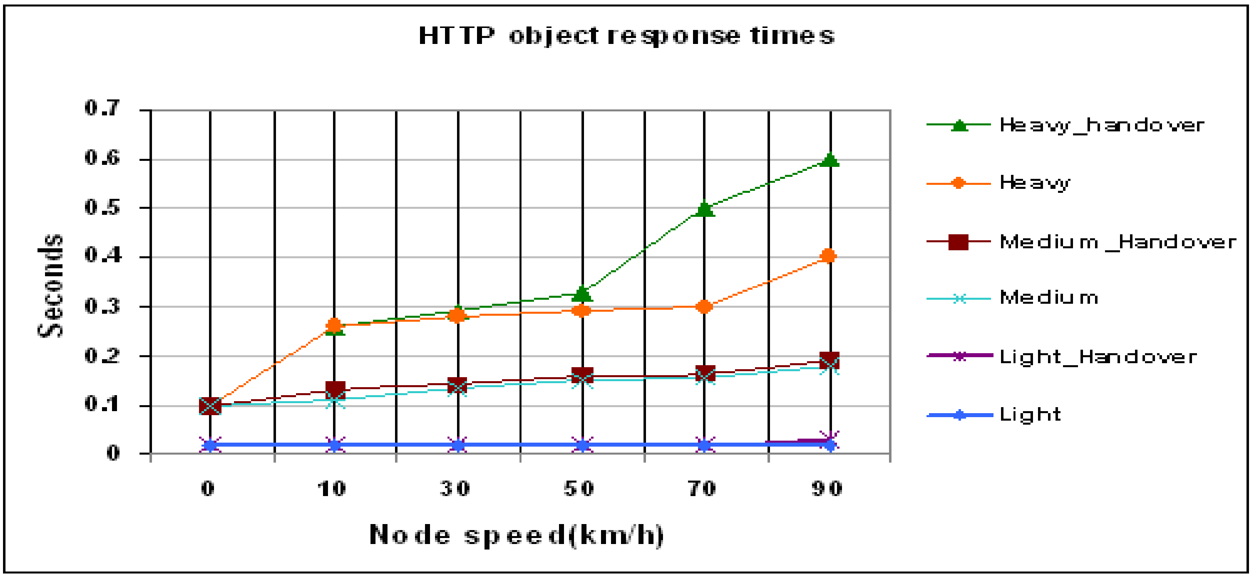

Figure 5 HTTP Object response times with and without handoff

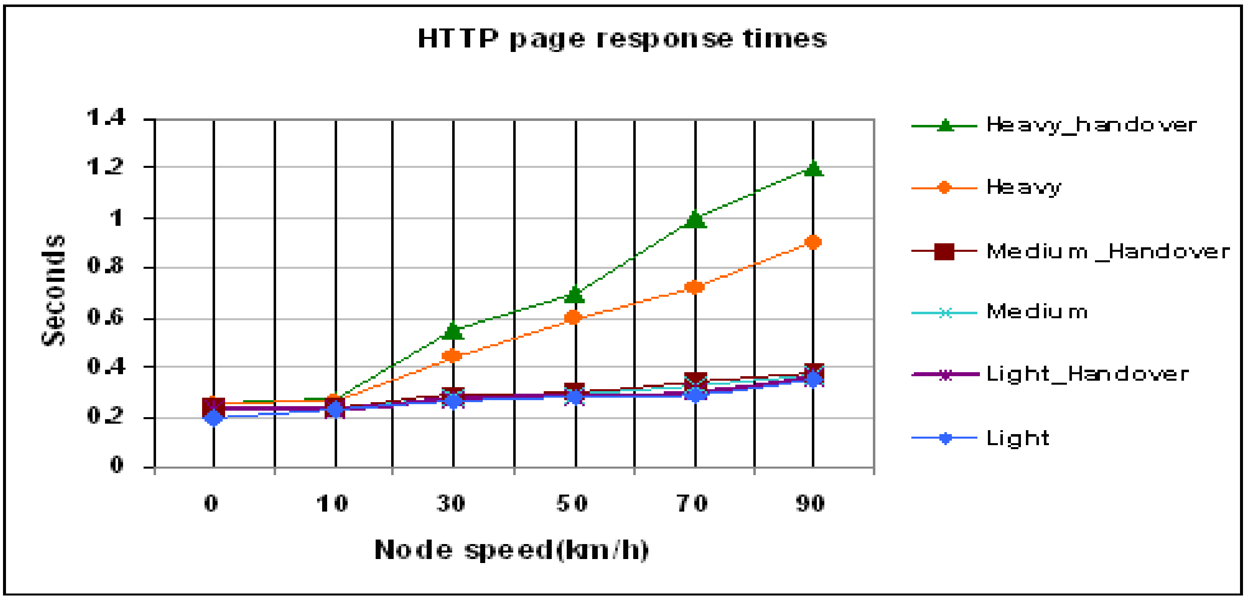

Figure 6 HTTP Page response times with and without handoff

Average object and page response times increase by 0.02seconds and 0.05seconds respectively. There is no clear evidence that handoff has influenced the HTTP page and object response time for light and medium traffic. For heavy HTTP traffic transmitted between a server and moving nodes, enabling handoff causes an increase in response time which is clearly observed for mobile node speeds 30km/h and greater. The impact of handoff becomes stronger has node speed increases. When the speed is 90km/h, page and object response times increase by 0.21seconds and 0.32seconds respectively when compared to those without handoff.

5.3 Impact on Node Mobility and Handoff in Videoconferencing

This section presents and discusses the experimental results of Video conferencing`s PDV and end-to-end delay changes in video conferencing traffic when handoff is enaenabled or disabled. Our interest is to find out how enabling handoff impacts on PDV and end-to-end delay.

As seen in Figures 7 and 8, when a small amount of video conferencing traffic is transmitted between moving nodes, handoff had no significant impact of handoff on WiMAX performance for any node speed. PDV and end-to-end delay increased by 0.001seconds and 0.03seconds respectively when handoff is enabled.

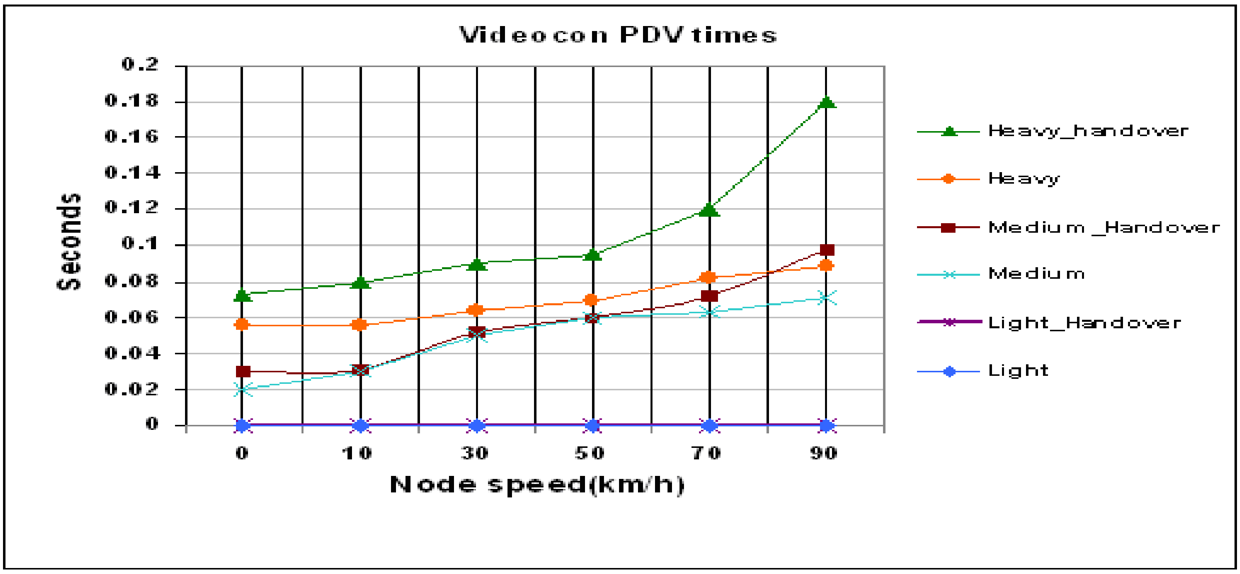

Figure 7 Video conferencing PDV with and without handoff

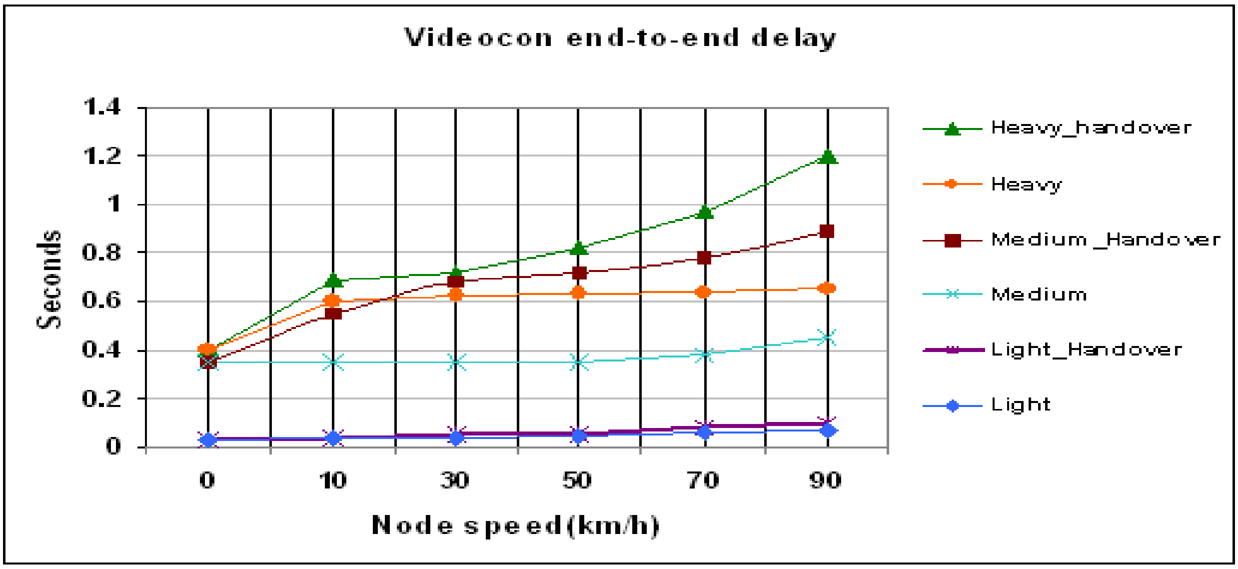

Figure 8 Video conferencing end-to-end delay with and without handoff

Inversely, when medium video conferencing traffic is transmitted between moving nodes, the impact of handoff is clearly observed at any node speed.

When handoff is enabled at a30km/h node speed, PDV only increases by 0.002seconds and end-to-end delay increases by 0.32seconds. However, for a node speed of 90km/h speed of nodes, PDV increases by 0.02seconds and end-to-end delay increases by 0.49seconds.

The impact of handoff for heavy video conferencing traffic is clearly shown in Figures 6.27 and 6.28. When handoff is enabled at a node speed of 30km/h, PDV increases by 0.03seconds and end-to-end delay increases by 0.08seconds while, for a node speed of 90km/h, PDV increases by 0.1seconds and end-to-end delay increases by 0.6seconds.

5.4 Impact on Node Mobility and Handoff In M-Voip

This section reports and discusses the experimental results for m-VoIP jitter and MOS when handoff is enabled. Our interest in this section is to find out the impact of handoff on m-VoIP jitter and MOS. As shown in Figures. 9 and 10, when handoff is enabled, average jitter and MOS are nearly unchanged for light m-VoIP traffic at any node speed. Jitter does not exceed 1ms for any node speed. However, although jitter is maintained at less than 1ms, MOS does not reach a fair level, 4 points at all and is about 2.5 points for any mobile node speed.

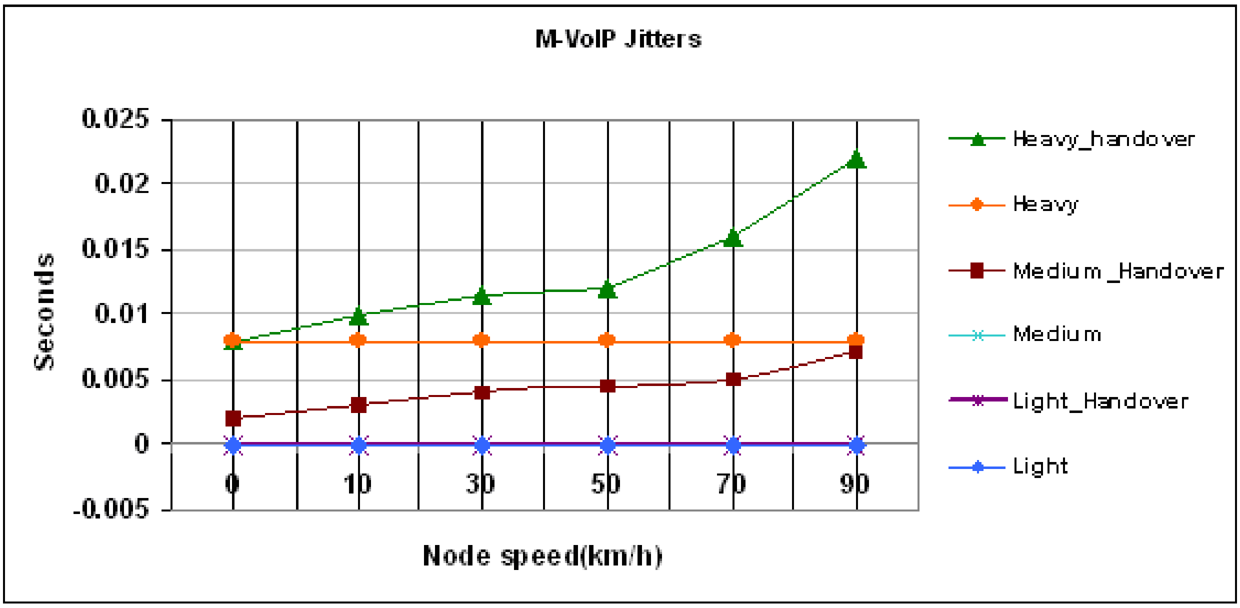

Figure 9 M-VoIP jitter with and without handoff

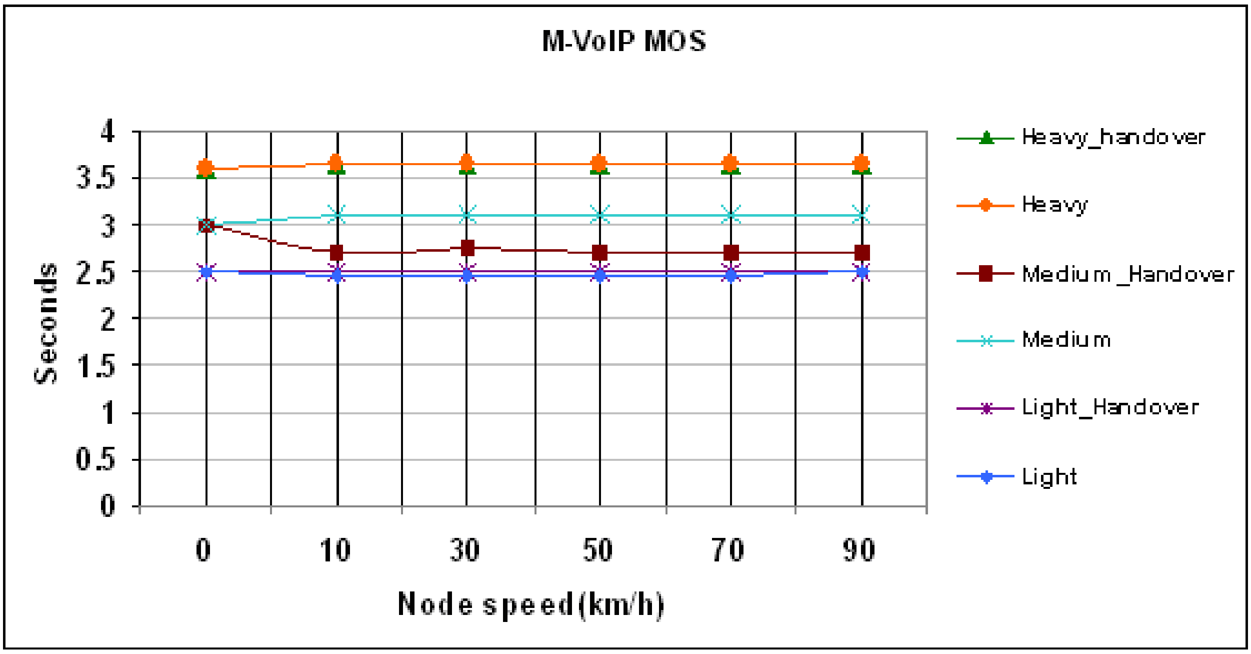

Figure 10 M-VoIP MOS for with and without handoff

On the other hand, when handoff is enabled, average jitter for medium and heavy m-VoIP traffic increases linearly with an increase in node speed. For a 30km/h node speed, jitter increases by 0.002 seconds and 0.003 seconds respectively while for a 90km/h node speed, jitter increases by 0.007seconds and 0.013 seconds respectively.

MOS remains nearly unchanged for all three amount of m-VoIP traffic regardless of the increasing node speed. However, once handoff is enabled, MOS for medium m-VoIP` traffic is about 0.3 points lower and for heavy traffic, MOS is about 0.6 points lower than those before handoff was used. Consequently, even though jitter remains at less than 50ms for any node speed, MOS does not reach a fair level, 4 points, at all.

5.5 Overall Performance Of Mobile Wimax

This section presents and discusses the impact of handoff on the average throughputs and ratios of traffic received/sent (packet loss) for four applications (FTP, HTTP, m-VoIP and Video conferencing) with light, medium and large network size. Our interest in this section is to investigate the impact of handoff on throughput and packet loss.

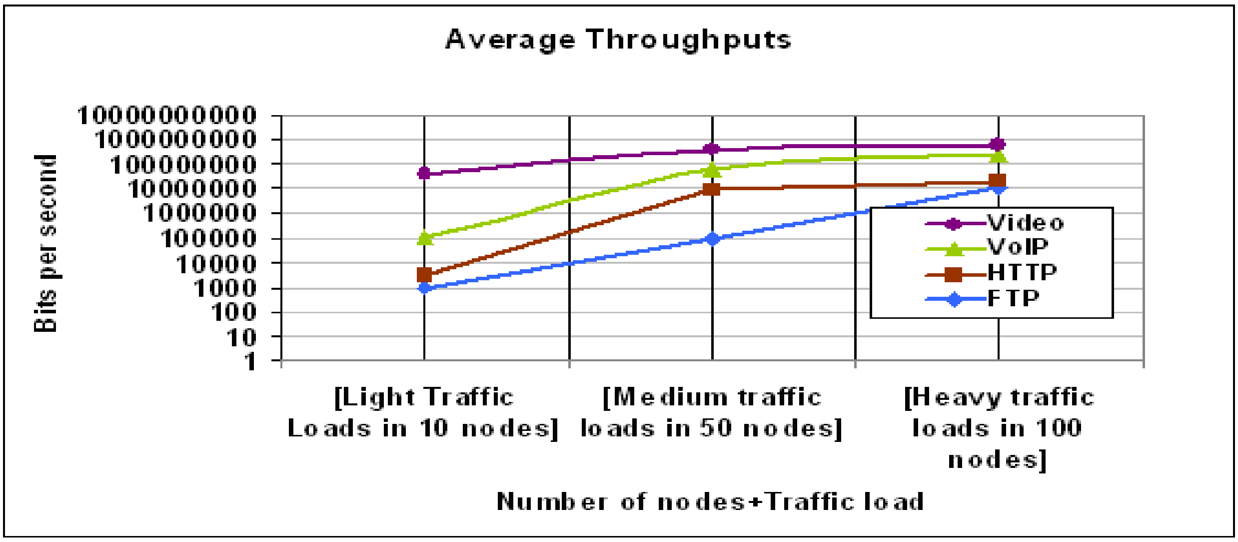

Figure 11 Log scaled average throughputs of four traffic types when handoff is enabled

Figure 11 presents average throughput for four applications when handoff is allowed. Figure 12 and 13 show traffic sent/ received and packet loss ratio. Throughputs for all four traffic types increase exponentially.

As shown in Figure 11, after handoff is enabled FTP average throughput is 37kbps and increases to 2.3Mbps, while HTTP average throughput increases from 38kbps to 3.0Mbps. Video conferencing average throughput increases from 8.5Mbps to 35.2Mbps and m-VoIP average throughput increases from 1.8Mbps to 9.8Mbps.

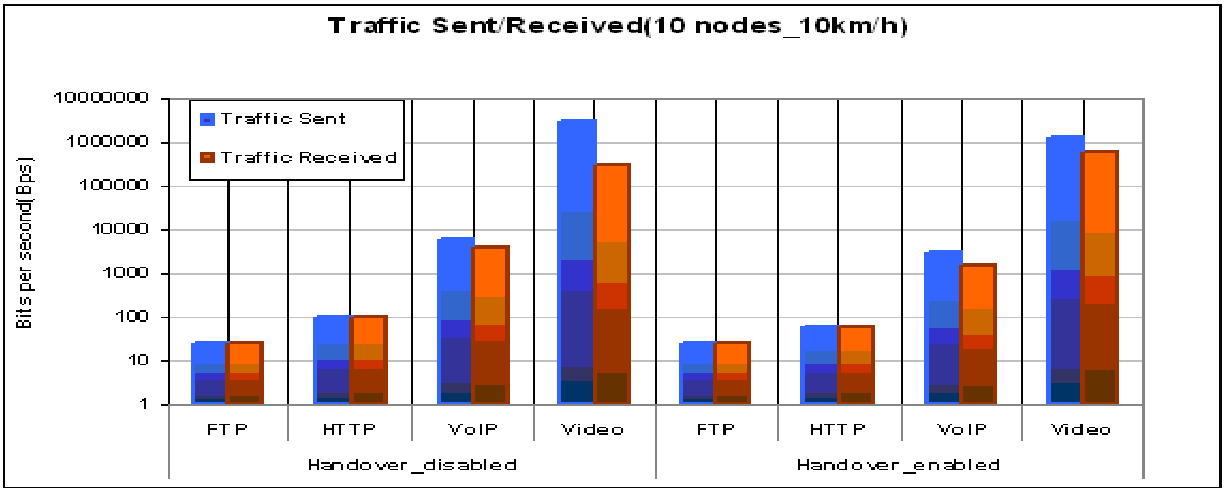

Figure 12 Traffic Sent and Received with and without handoff (10nodes_10km/h)

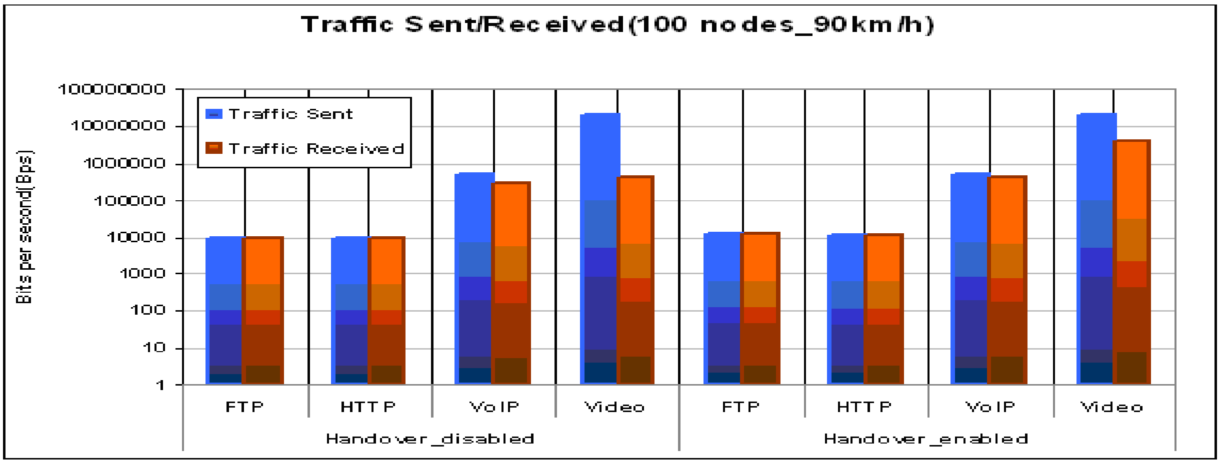

Figure 13 Traffic Sent and Received with and without handoff (100nodes_90km/h)

As shown in Figure 12 and 13, when handoff is enabled average packet loss ratios for all four traffic types decrease slightly. Figure 13 shows that when handoff disabled, packet loss ratio for heavy FTP traffic is 2.17% and when handoff is enabled it decreases to 2.10%. Similarly, the average packet loss ratio for HTTP also slightly decreases from 0.89% to 0.85%. Interestingly, when handoff is enabled, packet loss ratios for both m-VoIP and video conferencing decrease significantly when compared to those in non-handoff situations.

In heavy traffic, Video conferencing packet loss ratio is 97.7% in networks of 100 nodes that move at a speed of 90km/h within the cell. However, after handoff is enabled packet loss ratio decreases to 83.74%. In the same environment, the average packet loss ratio for m-VoIP traffic also decreases moderately from 26.8% to 20.6%.

6. CONCLUSION

This paper analyses WiMAX performance in terms of node mobility, traffic type and Hand off. As a result of this analyses we believe that traffic type may influence the performance of Mobile WiMAX differently. Consequently node mobility does not significantly affects delay-tolerant traffic types (FTP and HTTP) for any node speed. However node mobility significantly affects delay-sensitive traffic types (VoIP and Videoconferencing) .when handoff is disabled, Packet delay is less than one second is maintained regardless of increased node speed. Packet loss ratios for VoIP and Video Conferencing are irregularly high and increase when the traffic volume of the network also increases. Another observation is that average throughput of video-conferencing and VoIP is decreased and packet loss ratio is irregularly increased causing of loss of connection. When hard handoff is allowed, delays in all traffic types are slightly increased, average throughput is fairly increased and packet loss ratio is also fairly decreased. As expected, both FTP and HTTP traffic are transmitted well over WiMAX because they can tolerate a certain amount of delay. However , both VoIP and Video Conferencing packets were not moderately transmitted over the network due to high packet loss. Therefore , the use of soft handoff schemes for reducing the impact of handoff on videoconferencing and m-VoIP is recommended.but soft handoff may impose more constraints on the base station than hard handoff. Therefore, a handoff scheme should be selected on the basis of the available network resources and frequently traffic types or QOS.

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