Performance Analysis of a WiMAX/Wi-Fi System whilst streaming different Video Conference applications with varying network loads

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Abstract - *WiMAX and Wi-Fi are considered as the promising broadband access solutions for wireless MAN's and LANs, respectively. In the recent works WiMAX is considered suitable as a backhaul service to connect multiple dispersed Wi-Fi 'hotspots'. Hence a new integrated WiMAX/Wi-Fi architecture has been proposed in literatures. In this paper the performance of an integrated WiMAX/Wi-Fi network has been investigated by streaming different video conference applications which vary the network load. The difference in performance between the two network connections WiMAX and Wi-Fi is compared with respect to video conferencing. The Heterogeneous network was simulated in the OPNET simulator. Results show that such a heterogeneous network can support a high resolution video conference application and a low resolution video conference application but not a VCR quality video conference application.*

Keywords: Throughput; delay; delay variance; Packet loss; QoS – Quality of Service.

1 Introduction

WiMAX is a popular technology for broadband access in Wireless Metropolitan Area Networks (WMAN) environment. It offers a rich set of features and flexibilities in terms of deployment options and it supports new applications. The physical layer of WiMAX is based on Orthogonal Frequency Division Multiplexing (OFDM), which is widely recognised as the modulation technique for mitigating multipath fading problem associated with broadband wireless system. WiMAX is capable of supporting very high peak data rates. In fact a peak rate of 74Mbps can be achieved when operating with a 20MHz wide spectrum. Under very good signal conditions, even higher peak rates may be achieved by using multiple antennas and spatial multiplexing [1].

One of the potential applications of WiMAX is to provide backbone support for mobile Wi-Fi hotspots. Traditionally wired connections are used as backhaul support for Wi-Fi hotspots. But wired infrastructure is always considered expensive and it should be replaced by wireless backbones. Heterogeneous wireless networks consisting of WiMAX and Wi-Fi have been proposed in the literatures [2], [3]. The architecture of this type of network is shown in Fig. 1.

In this network model a WiMAX base station (BS) serves both WiMAX subscriber and Wi-Fi access points in the coverage area.

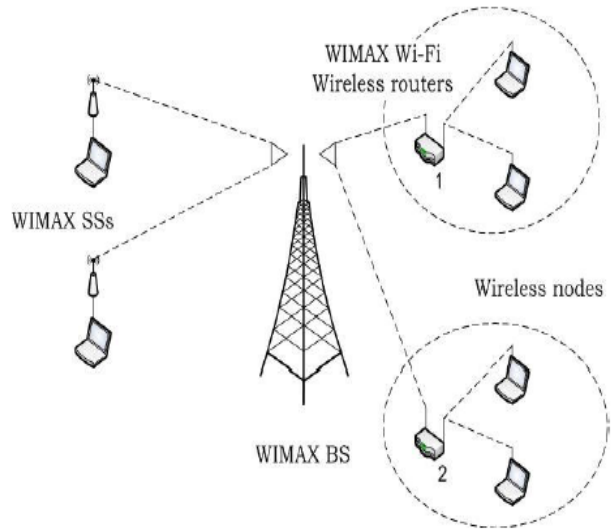

Figure 1 Heterogeneous Network architecture (WiMax/WiFi)

The connection between the WiMAX base station and the WiMAX subscriber station is based on the WiMAX protocol and the connection between the Wireless LAN access points and the Wireless LAN nodes is based on Wi-Fi protocol. Several QoS provisioning mechanisms for integrating WiMAX /Wi-Fi systems have been proposed in literatures [4], [5].

The Quality of Service (QoS) of a Video Conference application is determined by the following parameters; Packet loss: it's a comparative measure of packets received to the total number of packets that were transmitted, Delay: it's a finite amount of time that a packet takes to reach the receiving end point after being transmitted from the sending endpoint, throughput and delay variance (jitter).

In this article we investigated the performance of the WiMAX/Wi-Fi network for different network loads generated by three different Video conference applications.

2 QoS Requirements of a Video Conference Application

QoS parameters for a video conference application are as follows:

Bandwidth and throughput: Bandwidth is the available capacity of connection between two terminals. Throughput slightly differs from bandwidth as it stands for effective bandwidth that is provided by the network.

Delay or latency: It specifies the time it takes for a packet to leave the source and reach the destination.

Jitter (delay variation): Jitter is an interval between subsequent packets. It is caused by network congestion, route alteration etc.

Application	Bandwidth	Sensitivity to:		
		Delay	Jitter	Loss
VOIP	Low	High	High	Med
Video Conferencing	High	High	High	Med
Streaming Video	High	Med	Med	Med
Streaming Audio	Low	Med	Med	Med
Client/Server Transactions	Med	Med	Low	High
Email	Low	Low	Low	High
File Transfer	Med	Low	Low	High

Figure 2 Applications QoS metrics Sensitivity

As can be seen from figure 2 Video Conference applications are highly sensitive to the factors of Delay, Jitter and packet loss. Hence this factors need to be kept at minimum values in order for the QoS to be as high as possible in transmitting or streaming a video application.

For best quality of a picture the above mentioned factors should be kept at the following values [6].

End to end delay should be below 150mS

Jitter should be kept under 30mS.

3. Simulation Methodology

In order to investigate the performance of the integrated WiMAX /Wi-Fi network with respect to a video conference application the OPNET modeller simulation tool was used. The OPNET modeller supports both WiMAX and Wi-Fi technology. Three video conference applications were applied over the network to represent different network loads [6] namely;

- Low resolution video – 45Mbps
- High resolution video – 99Mbps
- VCR quality video – 840Mbps

The network consists of a centrally placed BN_ASN router that has 12 Point-to-point (PPP) links. The router is connected to an application server running the video conference application and 4 logical subnets. Within each logical subnet there is a Base station (BS) based on the WiMAX protocol. Each base station is connected to a WiMAX subscriber Station (SS) which connects to 4 Wireless LAN subscribers such as Laptops etc. The WiMAX subscriber station has two interfaces, the WiMAX interface to communicate with the WiMAX base station and the Wireless LAN interface to communicate with the Wireless LAN based nodes.

The application profile is running in serial mode which means that each application initiates packet generation in a serial manner. The whole process of packet generation lasts till the end of the simulation.

All traffic is discrete. The WiMAX layer was configured with the rtPS (real time polling services) scheduling technique with a maximum sustained traffic rate of 10Mbps and a minimum reserved traffic of 0.5Mbps.

Figure 3 shows the overall network topology.

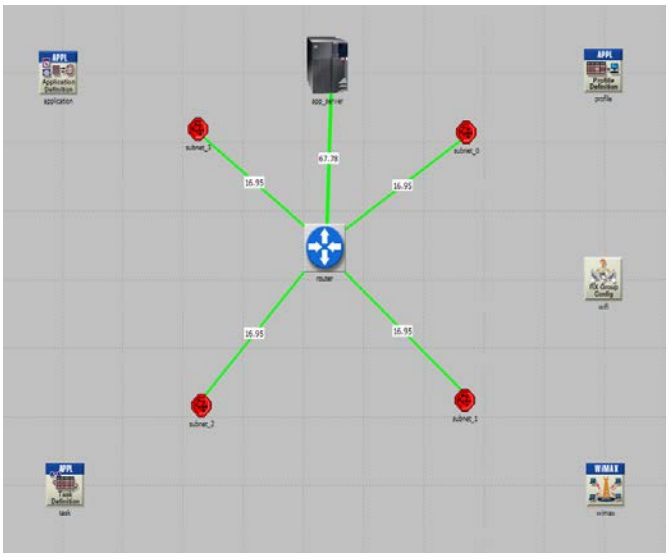

Figure 3 the Network Topology

The topology inside a subnet is shown in detail in figure 4.

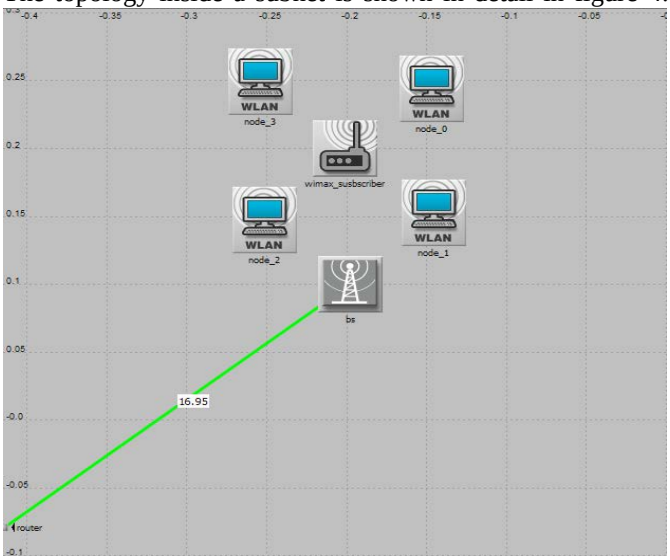

Figure 4 Subnet Topology

The parameters of the WiMAX system are shown in table 1,

Table 1 Parameters of the WiMAX system

Parameters Selected	Values Set
Max No of SS Nodes Supports	100
Transmits Power (W)	0.5
Physical Profile	OFDMA 20MHz
Modulation	Adaptive
Average SDU Size (bytes)	1500
Connection Retries	16
Antenna Gain	15dbi
Service Class Used	Silver
Scheduling type	rtPS

Essentially the parameters set up for the Wi-Fi hotspots are; data rate of between 65Mbps and 600Mbps, physical layer technology of 802.11n 2.4GHz and buffer size of 1,024,000 are all done to enable a video conference application stream over the network without much packet loss and delay, the reason being that the video conference application of high resolution requires high bandwidth of as much as 150Mbps in this case.

The Parameters of the Wi-Fi Hotspots are shown in table 2.
Table 2 Parameters of the Wi-Fi Hotspot

Parameters Selected	Values Set
Physical layer Technology	HT PHY 2.4GHz (802.11n)
Data Rates bits/sec	65Mbps (base)/600 Mbps max
Transmit power	0.005W
Packet received power	-95
Large Packet Processing	Drop
Antenna Gain	14dbi
Access point Functionality	Enabled
Buffer Size	1,024,000
Antenna Gain	14dbi

4. Results

QoS of the Video Conference Application:
As earlier on stipulated the requirements of a video conference application for good picture quality should be as follows [8];
End to end delay should be below 150mS
Jitter should be kept under 30mS.
The performance of the integrated network with respect to the above mentioned factors is as follows;

4.1 Packet end-to-end delay for the whole path WiMAX-Wi-Fi

The packet end-to-end delay for the whole path WiFi-WiMAX is shown in Figure 5 for the different network loads. For the high resolution video conference application the packet delay stabilises on 60mS whilst the low resolution video application stabilises on 45mS. The high resolution video has a higher delay than low resolution because the load of the high resolution video on the network is higher and requires more time to transverse the network.
The VCR quality video application curve does not appear because the load of that application is 840Mbps which leads to a high packet loss on this network. In certain sections of the network the VCR quality video application is not sustained and packet drop is too high, hence it's not possible to get the packet delay for the whole path for this application.

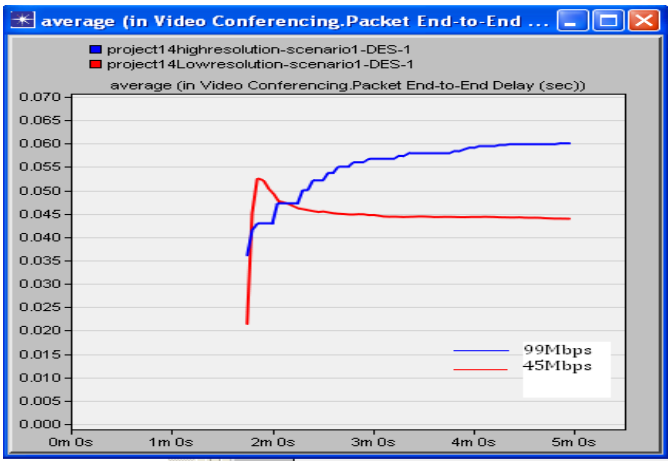

Figure 5 Packet end-to-end delay for the whole path WiMAX-Wi-Fi

4.2 Jitter or Packet Delay Variance for the whole path WiMAX-Wi-Fi

The packet delay variation for the whole path WiFi-WiMAX is shown in figure 6 for the different network loads. For high resolution video the jitter settles on 0.1mS whilst the low resolution video the jitter is about 0.4mS. Generally the high resolution video is a better quality video signal hence producing less jitter or deviation from the signal than the low

resolution video signal. Again VCR quality video does not appear in the graph because of its high network load that leads to high packet drop hence it's impossible to measure the overall network jitter for this application since the application does not complete the path.

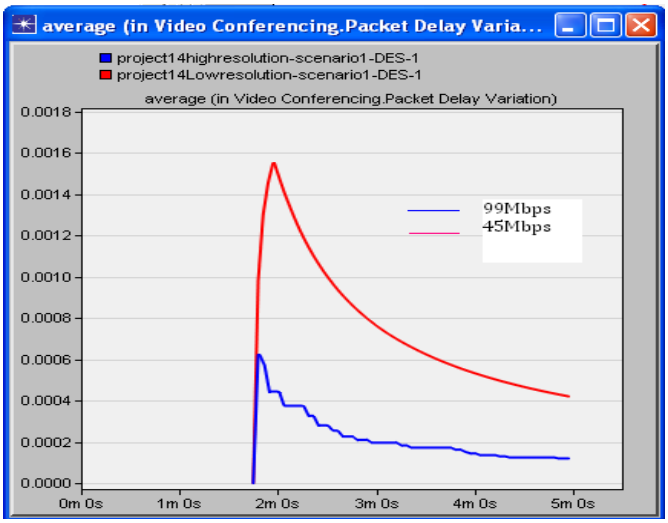

Figure 6 Packet delay variation (jitter) for whole path WiMAX-Wi-Fi

4.3 Throughput of the Wi-Fi connection

The throughput of the Wi-Fi connection is shown in the figure 6 for the different network loads. The throughput for the VCR video quality is higher than for the high resolution video and the low resolution video. However this is because the load on the network from the VCR quality video is highest. The packet dropped for the VCR quality video is also very high.

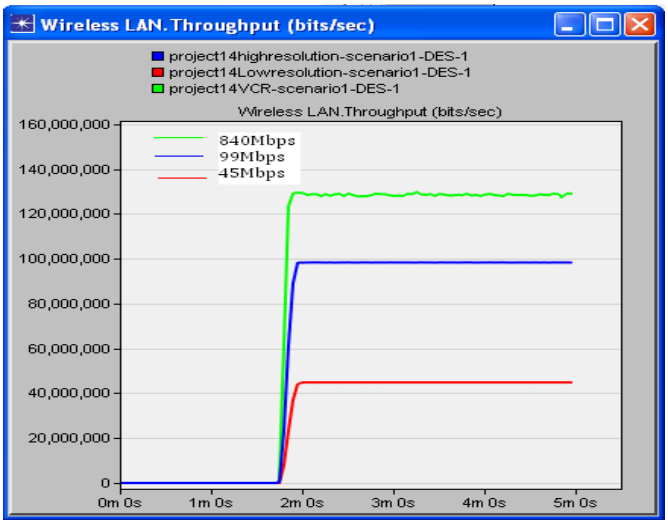

Figure 7 Throughput of the Wi-Fi connection

The curves in figure 7 are total values for the throughput whilst the key chart shows the network loads of those applications.

4.4 Throughput for the WiMAX connection

Essentially the throughput on the WiMAX connection shows a similar pattern to the throughput on the Wi-Fi connection the only difference being that across the WiMAX connection the video conference applications drop more packets hence the throughput on the WiMAX connection for the different video conference applications is less than for Wi-Fi.

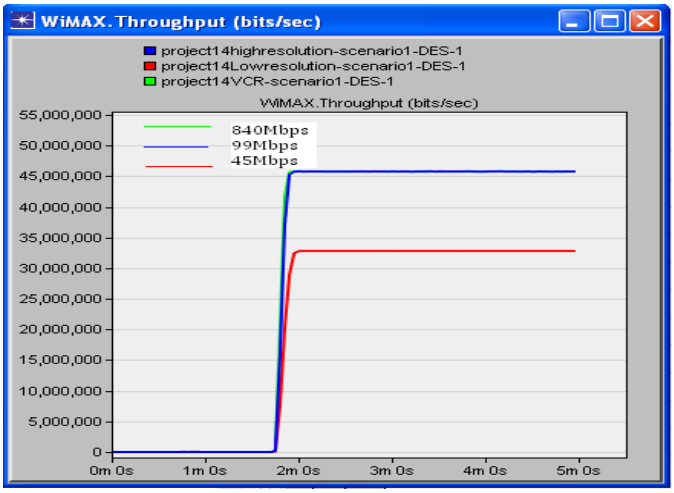

Figure 8 Throughput on the WiMAX connection

4.5 Packet Delay on the Wi-Fi connection

The packet delay on the Wi-Fi connection for the VCR quality video approaches 130mS as can be seen in figure 9 which is relatively high. For the high resolution video it's about 10mS and for the low resolution video it's about 5mS. Again the delay for the VCR quality video is higher than for the other video conference applications due to the fact that the throughput for this application is higher than the other video conference applications.

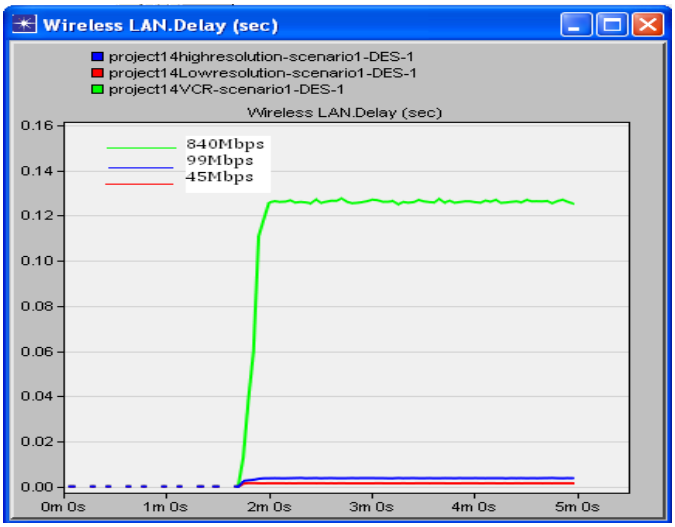

Figure 9 Packet Delay on the Wi-Fi connection

4.6 Packet Delay on the WiMAX connection

The packet delay in the WiMAX connection for the VCR video quality application is about 96mS whilst for high resolution video it's about 94mS and finally for low resolution video its 72mS.

In the WiMAX connection the VCR quality video application has a lower delay as compared to the Wi-Fi connection but relatively high for a throughput of 46Mbps because in this section of the network the VCR quality video drops more packets hence the throughput is lower but the delay is relatively high for such a low throughput because there is congestion in the network. Similarly the delay for the high resolution video and the low resolution video in this WiMAX connection is very high 94mS and 72mS respectively. This are increased values of delay from the values in the Wi-Fi connection due to the fact that there is more packets being dropped in the WiMAX connection due to congestion hence increasing the delay.

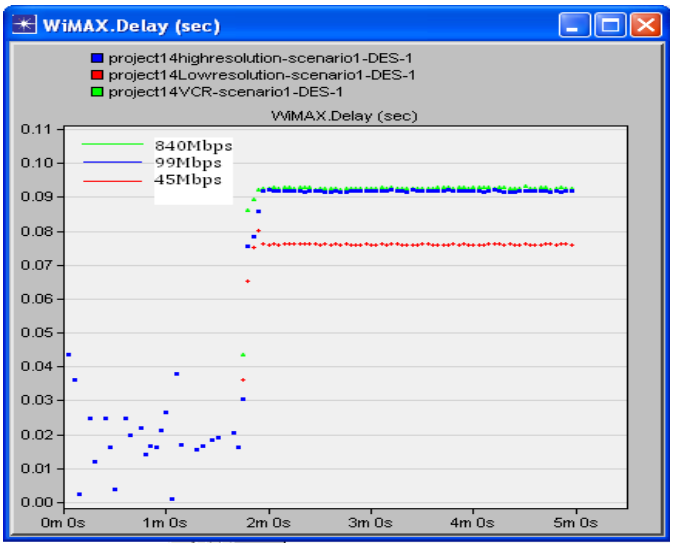

Figure 10 Packet delay on the WiMAX connection

5. Conclusions

In this paper an Integrated WiMAX /Wi-Fi network was modelled whilst streaming video conference applications to determine the performance of the integrated network with respect to the QoS requirements. The network loads were varied by changing the type of video conference application between low resolution video, high resolution video and VCR quality video conference applications. In addition the WiMAX and Wi-Fi connections were compared with respect to throughput and packet delay.

In conclusion a high resolution video application experiences a higher overall network delay as compared to a low resolution video application but has a lower jitter value or packet variance.

Also it was determined that when a network connection experiences congestions and high packet drop rate that network connection would have a higher packet delay than other sections.

Table 3 summarises the results discussed in the conclusion earlier and according to the table the main QoS parameters were satisfied for the high resolution video application and the low resolution video application except for the VCR quality video application which experienced excessive packet drop rate in certain sections of the network exceeding the required QoS parameters necessary for a good video conference transmission.

Table 3 QoS Parameters for Video Conference Application

Parameters	Expected values for a good QoS	High resolution video	Low resolution video
Overall Packet delay	<150mS	<60mS	<45mS
Jitter(Delay Variance)	<30m	0.1mS	0.4mS

6. References

[1] Jeffrey G. Andrews, Ph.D. Arunabha Ghosh, Ph.D "Fundamentals of WiMAX Understanding Broadband Wireless Networking", First Edition, Prentice Hall.

[2] Dave Cavalcanti and Dharma Agrawal, "Issues in Integrating Cellular Networks, WLANS, and MANETs: A futuristic Heterogenous Wireless Networks", IEEE Communication Magazine, June 2005, pp. 30-41.

[3] Dusti Niyato and Ekram Hossain, "Integrating of WiMax and Wi-Fi: Optimal pricing for Bandwidth Sharing" IEEE Communication Magazine, May 2007, pp. 140-146

[4] Kamal Gakhar, Annie Gravey and Alain Leroy, "IROISE: A new QoS Architecture for 802.16 and IEEE 802.11e Internetworking", in the proceedings of IEEE International Conference on Broadband networks", pp. 607-612, October 2005.

[5] Pedro Neves, Susana Sargento Rui and L. Aguiar, "Support of Real-Time Services over integrated 802.16 Metropolitan and Local Area networks", In the proceedings of IEEE ISCC, pp. 15-22, June 2006.

[6] Ahmad Khalifeh, Ashkan Gholamhosseinia, "QOS for Multimedia Applications with emphasis on Video Conferencing", masters project, February 2011, Halmstad University.

[7] Dr. Mayyada Hammoshi, "WiMax Simulation Model to Investigate Performance Factors", Journal of Convergence of Information Technology, January 2011, Volume 6, Number 1.

[8] R.Fantaci, D. Tarchi, "Bridging solutions for a Heterogenous WiMAX-WiFi Scenario, journal of communications and Networks, 2006, 8 pp. 369-377".