Simulation and Performance Evaluation of WiFi and WiMAX using OPNET

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Abstract

Wireless Fidelity (WiFi) network is based on the IEEE 802.11 standard. Worldwide Interoperability for Microwave Access (WiMAX), based on IEEE 802.16, is a standard with similar principles. The main advantage of WiMAX over WiFi is that it covers larger areas and has higher data rates. WiMAX network operators provide WiMAX subscriber units that enable connection to the metropolitan WiMAX network while WiFi units are used for connecting local devices within homes or businesses. In this paper, we use OPNET Modeler to simulate and compare WiFi and WiMAX in a small area network and compare their performance in terms of mobility. Simulation results indicate that WiMAX may carry larger load and has better throughput.

1. Introduction

Wireless Fidelity **(**WiFi) and Worldwide Interoperability for Microwave Access (WiMAX) are Wireless Local Area Network (WLANs) technologies. WiFi is based on the IEEE standard 802.11 while WIMAX operates based on IEEE 802.16. Both standards are designed for the Internet protocol applications. WiFi is optimized for a very high speed WLAN while WiMAX is intended for a high speed Wireless Wide Area Network (WWAN). WiFi has an operating range of a few hundred feet with speeds up to 54 Mbps while WiMAX may operate in the range of up to 40 miles with speeds of 70 Mbps and beyond. WiFi may cover an office or a campus area while WiMAX covers an entire city.

In this paper, we describe a comparative performance analysis of WiFi and WiMAX technologies for a small area network. Two scenarios were designed to carry load and to compare the throughput. In Section 2, WLAN technologies are described. Description of simulated network topologies is given in Section 3. Simulation results are discussed in Section 4. We conclude with Section 5.

2. Wireless Local Area Network Technologies

WLAN technologies have been widely used. They provide free wireless connectivity to the end users, offering an easy and viable access to a network and its services [1]. Wireless technologies, their standards, coverage area range, and service data rate are shown in Figure 1.

WiFi and WiMAX are frequently used for wireless Internet access. WiMAX network operators usually provide a WiMAX subscriber unit that connects the user to the metropolitan WiMAX network and provide WiFi within homes or business for connecting local devices (laptops, WiFi handsets, smartphones).

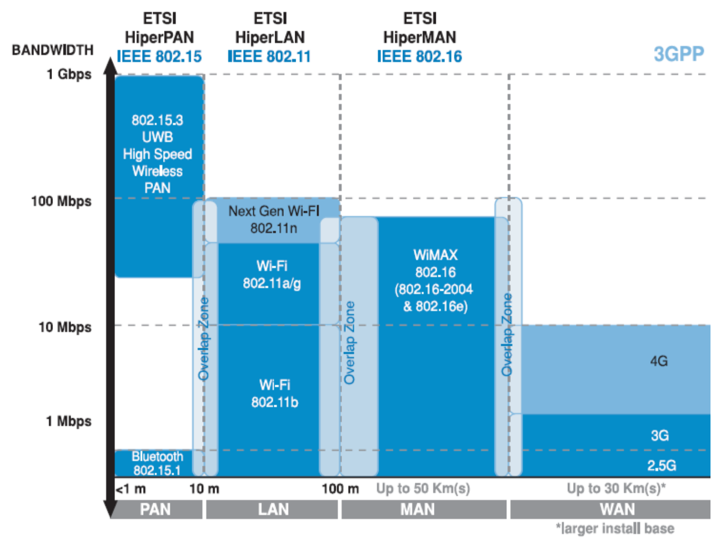
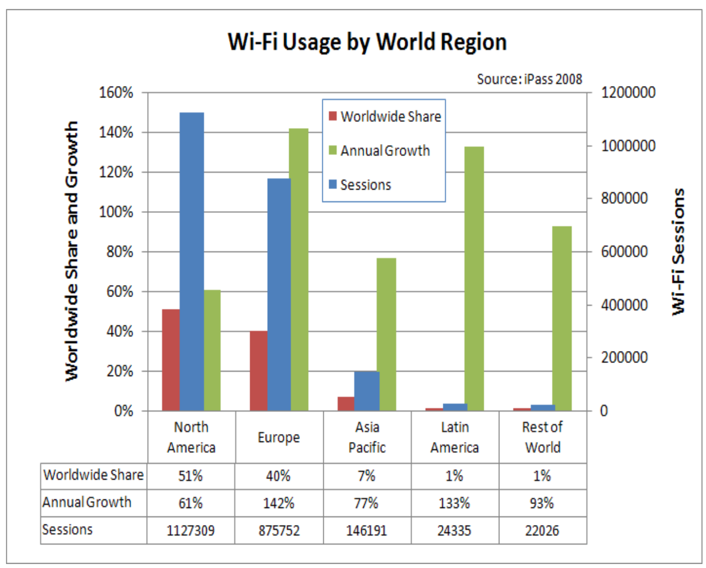


Figure 1: Bandwidth and coverage of wireless technologies [2].

WiFi usage by world region is described in Figure 2. Subscribers in North America and Europe use WiFi more frequently than in other parts of the world having 91% of worldwide WiFi shares. Annual WiFi growth in Europe is much higher than in North America.



	North America	Europe	Asia Pacific	Latin America	Rest of World
Worldwide Share	51%	40%	7%	1%	1%
Annual Growth	61%	142%	77%	133%	93%
Sessions	1127309	875752	146191	24335	22026

Figure 2: WiFi usage by world regions [3].

2.1 WiFi

WiFi is based on IEEE third modulation standard. It operates in 2.4 GHz frequency band and provides data transfer at maximum rate of 54 Mbps. The orthogonal frequency division modulation scheme is used at data rates of 6, 9, 12, 18, 24, 36, 48, and 54 Mbps. It reverts to complementary code keying (CCK) for 5.5 Mbps and 11 Mbps and direct-sequence spread spectrum (DSSS) for 1 Mbps and 2 Mbps [4].

Millions of users rely on WiFi connections for their laptops, mobile phones, play stations, and consumer electronics devices. The access to WiFi is made easy by integration of WiFi into electronic devices. Smartphones and over 97% of laptops are WiFi integrated.

WiFi has two types of components: a wireless client station and an access point (AP), as shown in Figure 3. Wireless client station is any user device such as computer or laptop that has a wireless network card. AP acts as a bridge between fixed and wireless networks. It connects to the cable modem or Digital Subscriber Line (DSL) modem, provides Internet services to wireless and wired Ethernet clients, and organizes and grants access from multiple wireless stations to the fixed network. Users can now connect smartphones to the wireless router for WiFi services to access the Internet over mobile phone [5].

Figure 3: WiFi client/station connection [5].

2.2 WiMAX

WiMAX [6] supports fixed and mobile Internet access. It can be connected with an Internet Protocol (IP) based core network, which is chosen by operators that serve as Internet Service Providers (ISPs). 802.16e uses Scalable Orthogonal Frequency-Division Multiple Access (SOFDMA) rather than Orthogonal Frequency-Division Multiplexing (OFDM). It employs two multiple duplexing schemes: Time Division Duplexing (TDD) and Frequency Division Duplexing (FDD). WiMAX base station uses T1 (1.544 Mbps), which may provide bandwidth to hundreds of Internet subscribers with frequency band frame 10 GHz to 66 GHz [7].

Medium access control (MAC) layer of WiMAX employs a scheduling algorithm for the initial entry of the subscriber station (SS) into the network. The base station (BS) then allocates an access slot to SS and other subscribers may not use the same slot. The scheduling algorithm is used for controlling the bandwidth efficiency and quality of service (QoS) parameters by changing the time slot duration. WiMAX is an all-IP infrastructure that uses the point to multipoint topology to communicate with the subscribers whereas base stations communicate to each other using point-to-point topology. The throughput of the WiMAX lies between the WiFi and 4G mobility. Cell radius of the base stations is 6 miles with service data rate of 40 Mbps. WiMAX can reach more subscribers and can deliver non line of sight services.

WiMAX connections may be fixed or mobile. WiMAX connection set up is shown in the Figure 4. WiMAX provides wide range of applications such as voice over Internet Protocol (VoIP), Internet Protocol Television (IPTV), mobile data TV, mobile emergency response services, and wireless backhaul as substitute for fiber optic cable [8]. The privacy and key management protocol version 2 (PKM v.2) is used in WiMAX for securely transferring keying material between the BS and Mobile Station (MS) [9].

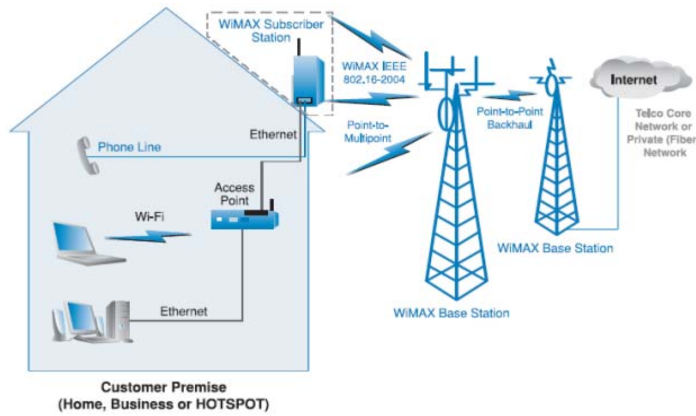


Figure 4: WiFi and WiMAX client/station connections to the Internet [2].

2.3. Comparison between WiFi and WiMAX

WiFi provides an Internet/LAN connection within the range of an AP. WiFi may be used to create a mesh network and provide peer to peer connections between users. To the contrary, WiMAX provides higher bandwidth and larger coverage range to provide high-speed mobile data and telecommunication services such as 4G. WiMAX may be used also to connect WiFi hotspots. MAC layer in WiFi employs contention access if users wish to send data through AP and compete with each other to seek AP's attention. Comparison of WiFi and WiMAX is shown in Table 1 [10].

Table 1: Comparison of WiFi and WiMAX.

Characteristics	WiMAX	WiFi
Half/Full duplex	Full duplex	Half duplex
Application	Broadband wireless access	Wireless LAN
Channel bandwidth	1.25 MHz to 20 MHz	20 MHz
Modulation technique	QPSK, BPSK, 16-QAM, 64-QAM, 256-QAM	QPSK, BPSK, 16-QAM, 64-QAM

Forward error correction	Convolution code Reed-Solomon	Convolution code
Radio technology	OFDM (256-Channels)	OFDM (64-Channels)
Frequency spectrum	Employ 2.3, 2.5 and 3.5 GHz bands	Use 2.4 and 5 GHz bands

3. OPNET Modeler

OPNET [11] is a research oriented network simulation tool. It provides a comprehensive development environment for modeling and simulation of deployed wired and wireless networks. OPNET Modeler enables users to create customized models and to simulate various network scenarios [12]. The wireless module is used to create models for wireless scenarios such as WiFi and WiMAX. The Modeler is object-oriented and employs a hierarchical approach to model communication networks. It provides graphical user interfaces known as editors to capture the specifications of deployed networks, equipment, and protocols. The three main editors are Project, Node, and Process Editors [13].

We used OPNET Modeler 15.0 to simulate WiFi and WiMAX. OPNET provides high-fidelity modeling, simulation, and analysis of wireless networks such as interference, transmitter/receiver characteristics, and full protocol stack, including MAC, routing, higher layer protocols, and applications. It also has the ability to incorporate node mobility and interconnect wire line transport networks [14].

3.1 Model Description

We created three OPNET models for WiFi and WiMAX mobile and fixed local area networks to evaluate their performance.

OPNET models developed for WiFi fixed and mobile stations in a small-scale network of 5 km × 5 km are shown in Figures 5 and 6, respectively. WiMAX mobile stations are shown in Figure 7. The first WiFi scenario consists of eight stationary workstations (node_0 to node_7). In the second scenario, eight WiFi mobile stations are randomly located (mobile_node_0 to mobile_node_7). AP is connected to the switch and to server by a link. Server is configured for four network applications: Hypertext Transfer Protocol (HTTP) heavy, video conferencing, voice, and file transfer heavy. Application definition is set up for the same applications as for the server. In the second scenario, the MS's are randomly moving. WiMAX scenario has one BS and eight MS's that randomly move over defined trajectories that are identical to trajectories in WiFi scenarios.

Video conferencing is an interactive telecommunication technology that allows two or more locations to simultaneously interact via two-way video and audio transmissions. HTTP is the foundation of data communication for the World Wide Web (WWW). The development of HTTP standards has been coordinated by the Internet Engineering Task Force (IETF). File Transfer Protocol (FTP) is designed for transferring files and offers faster overall throughput and better error checking. These applications are selected because they carry most of the load over the Internet.

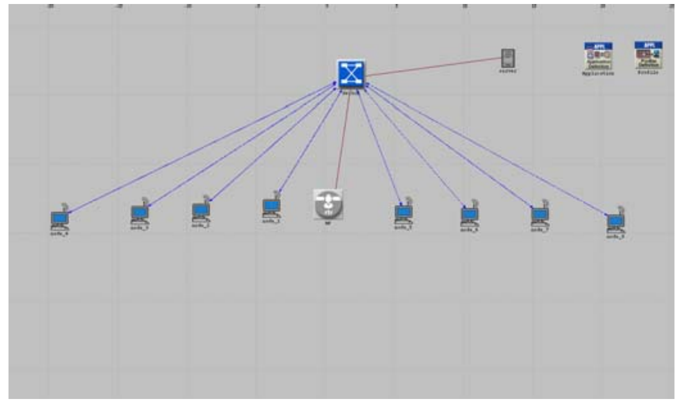


Figure 5: WiFi scenario with stationary workstations.

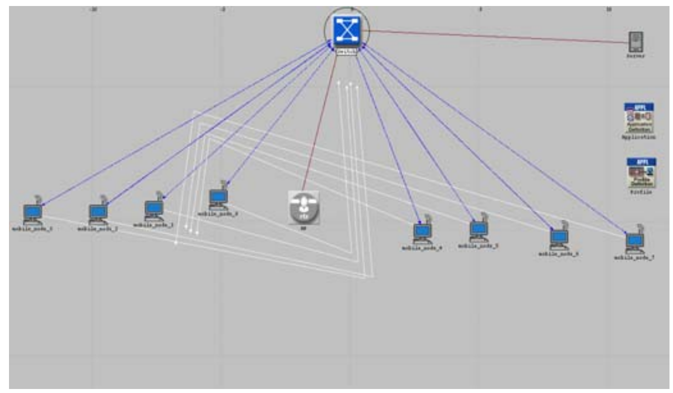


Figure 6: WiFi scenario with randomly located mobile stations.

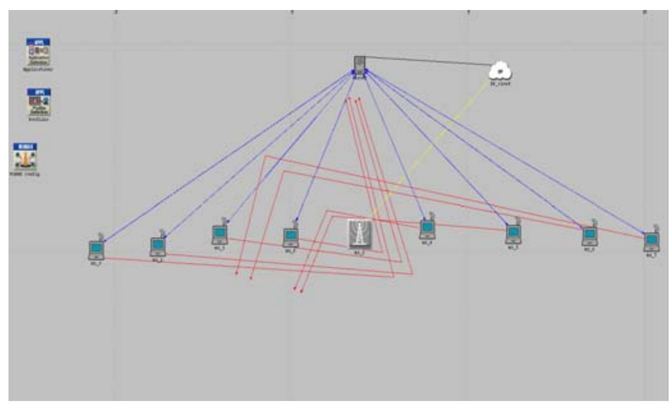


Figure 7: WiMAX scenarios with randomly located mobile stations.

3.2. Parameters Setup

The WLAN parameters used in the model are presented in Tables 2, 3, and 4. Parameters used for mobile and wireless stations are shown in Table 2. We applied the extended rate physical (PHY) layer (802.11g) standard for WiFi scenario with 24 Mbps date rate for both WiFi workstations and the AP. Traffic characteristics are shown in Table 3. The WiMAX parameters are shown in Table 4. Antenna gain of 1 dBi, maximum transmission power of 2W, PHY profile wireless OFDMA with 5MHz, and receiver sensitivity of -200 dBm are used in WiMAX scenarios. The BS parameters for WiMAX scenario are shown in Table 5. Maximum number of SS nodes is

100. Minimum and maximum power densities are -100 dBm and -60 dBm, respectively. We used eight CDMA codes for initial range, handover (HO) range, periodic range, and bandwidth request.

Table 2: Wireless LAN parameters for WiFi scenarios.

BSS identifier	Auto assigned
Access point functionality	Enabled
Physical characteristics	Extended rate PHY (802.11g)
Data rate (bps)	24 Mbps
Transmit power (W)	2.0
Packet reception-power threshold	-95
Short retry limit	7
Long retry limit	4
Buffer size (bits)	256,000

Table 3: Traffic characteristics.

Match property	IP ToS
Match condition	Equals
Match value	Excellent effort

Table 4: Base station WiMAX parameters.

Antenna gain (dBi)	1 dBi
MAC address	1
Maximum transmission power (W)	2.0
PHY profile	Wireless OFDMA 5 MHz
PermBase	1
Receiver sensitivity	-200 dBm

Table 5: Base station parameters.

Maximum number of SS nodes	100
Minimum power density	-100
Maximum power density	-60
Number of initial ranging codes	8
Number of HO ranging codes	8
Number of periodic ranging codes	8
Number of bandwidth request codes	8
Number of transmitters	SISO

4. OPNET Simulation Results

Four applications are used in three scenarios to compare the network load and queuing delay. HTTP traffic sent and received is shown in Figures 8 and 9, respectively. The traffic sent by both mobile and fixed WiFi is identical to the traffic received, which implies no loss. There is also no loss in case of mobile WiMAX traffic sent and received. No loss occurring due to handoff because the WiFi network has only one AP and the WiMAX network has only one BS in each simulation scenario.

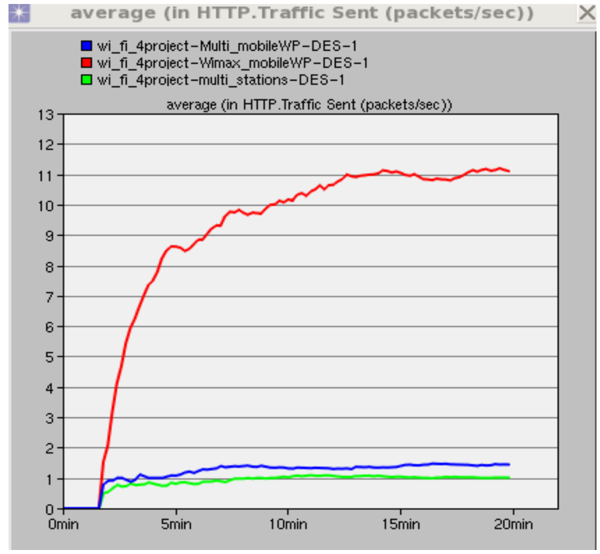


Figure 8: HTTP traffic sent by the server.

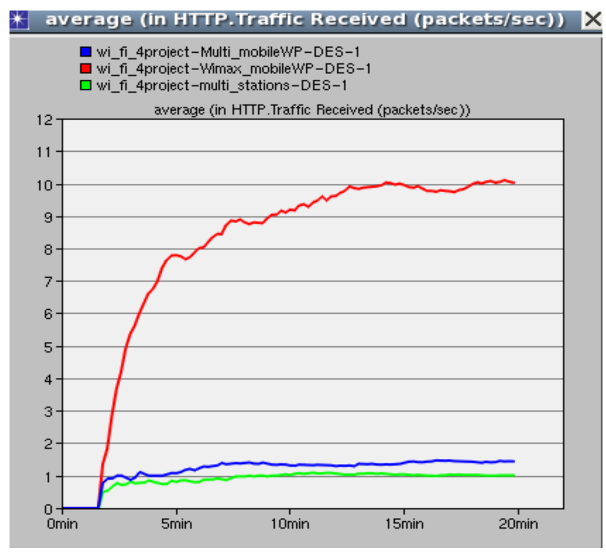


Figure 9: HTTP traffic received by the server.

Average traffic in packets/s sent through the network by the FTP server is shown in Figure 10. FTP traffic received by the server is shown in Figure 11. As expected, fixed WiFi has the least amount of traffic sent compared to mobile WiFi. Mobile WiMAX has the highest average amount of traffic sent, almost seven times the traffic sent over the WiFi network. Since WiFi does not provide the broadband Internet services, WiMAX provides broadband service to carry additional load.

Voice and video applications show similar results. Voice mean opinion score (MOS) is shown in Figure 12. MOS provides a numerical measurement of quality of voice signal transmitted. Mobile WiFi has higher MOS value than mobile WiMAX.

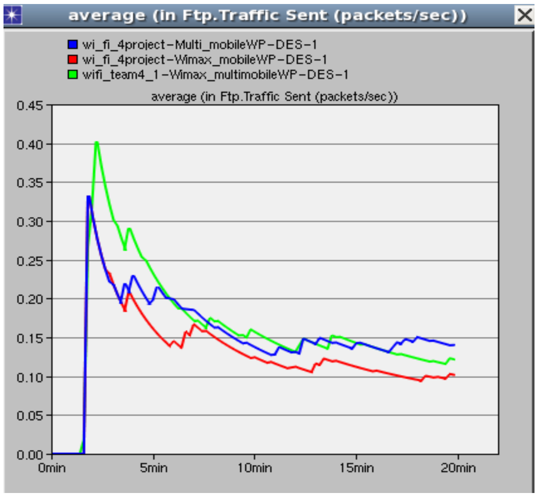


Figure 10: FTP traffic sent by the server.

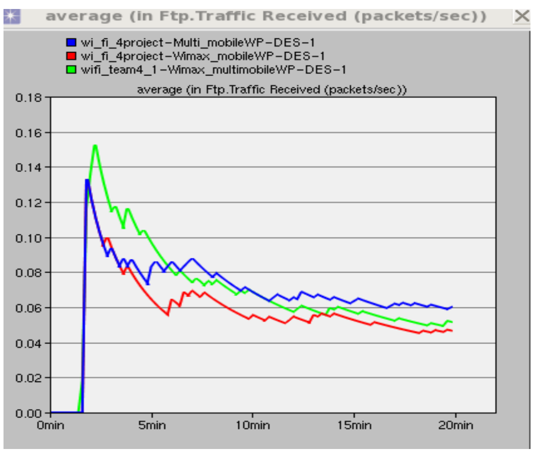


Figure 11: FTP traffic received by the server.

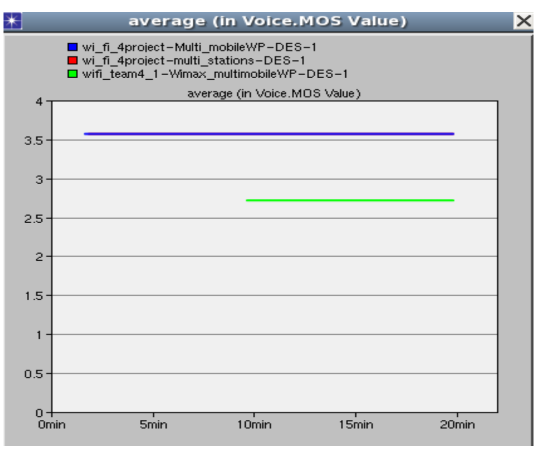


Figure 12: Mean opinion score (MOS) value.

4.1. Simulated Throughput

The average and overlaid point-to-point throughput of the inward link to the server and outward link from the server are shown in Figures 13 and 14, respectively. Point-to-point throughputs for fixed and mobile WiFi are as predicted. WiFi with moving stations has better throughput than fixed WiFi, which is due to the stations moving closer to the AP. WiMAX has higher throughput compared to WiFi scenarios. The throughput of inward link to the server is much smaller compared to the outward link from the server, as seen in Figure 14. In WiFi mobile and WiMAX scenarios, the throughput of the WiMAX network link that carries load from the server has higher point-to-point throughput. WiMAX has better throughput because it is based on a broadband service.

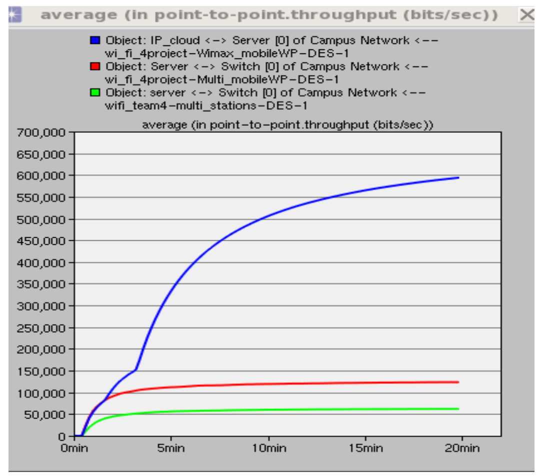


Figure 13: Throughput of the inward link to the server.

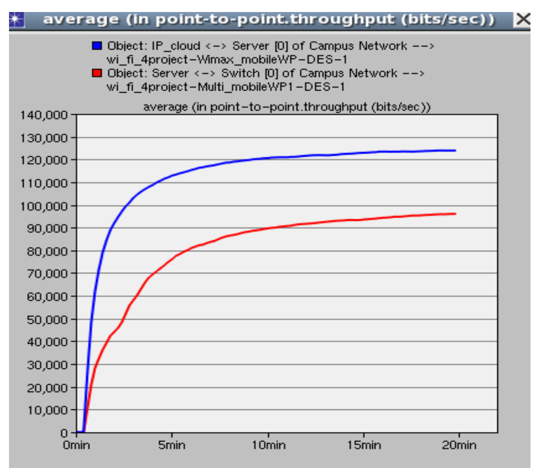


Figure 14: Throughput of the outward link from the server.

The load that AP carries in each network is shown in Figure 15. WiFi carries 25,000 bits over the network while WiMAX can carry 45,000 bits.

The average queuing delay of the server to switch link in WiFi and the IP cloud to server link in WiMAX is shown in Figure 16. It represents the instantaneous measurement of packet waiting times in the queue of the transmitter channel. The measurements of the average queuing delay are taken from the moment when a packet arrives into the queue until the time when the last bit of the packet is transmitted. As expected, this queuing delay for mobile WiMAX in a small area network is smaller compared to fixed and mobile WiFi. The average queuing delay of switch to server link in WiFi and IP cloud to server link in WiMAX is shown in Figure 17. In WiMAX scenario, the queuing delay of this link starts to decrease as the load starts to increase.

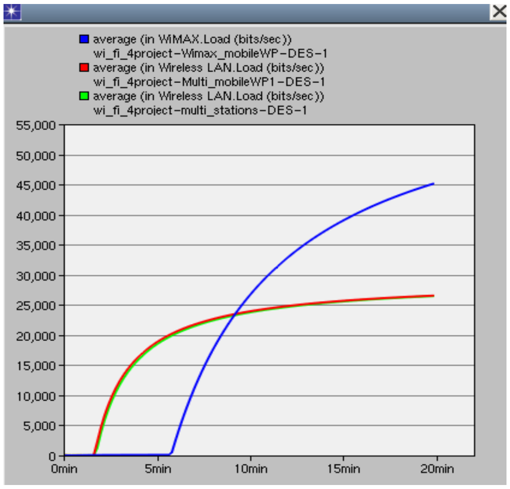


Figure 15: Load of BS and access point.

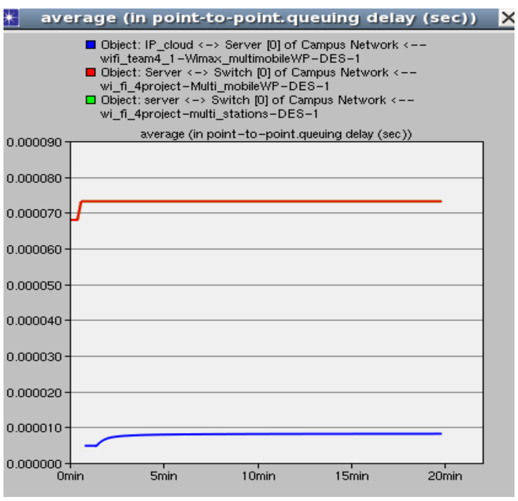


Figure 16: Average queuing delay of the server to switch link in WiFi and the IP cloud to server link in WiMAX.

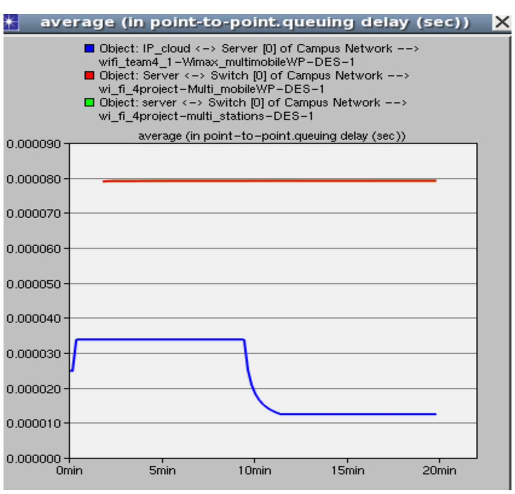


Figure 17: Average queuing delay of the switch to server link in WiFi and the IP cloud to server link in WiMAX.

5. Conclusions

In this paper, we simulated two WiFi and one WiMAX scenarios and compared their throughput and load. WiMAX throughput is higher in case of heavier traffic and wide area range. WiMAX may handle heavier load compared to WiFi. The simulation results show that the WiMAX queuing delay is smaller because WiMAX provides broadband service to carry heavier traffic load over the network. Queuing delays for both WiFi scenarios are identical.

We considered various parameters such as delay, load, and throughput of base station, router, and subscriber station and analyzed their effect on the performance of WiMAX in a local area network. The base station and router delays in WiFi were compared and, as expected, the delay in WiFi router was higher than the delay in the base station. WiMAX is more efficient for delivering more data with less queuing delay when compared to WiFi.

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