Integration of WiFi and WiMAX Services: Bandwidth Optimization and Traffic Combination

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ABSTRACT: *The integration of WiFi and WiMAX will allow seamless connection between users from both systems with a greater capacity, higher bit rates and mobility access. To enable interoperability between WiFi and WiMAX a special gateway is required known as WiFi/WiMAX router. In this paper, we investigate, through the use of OPNET simulation tools, number of WiFi users or hotspots could accommodated by a WiFi/WiMAX router and a WiMAX Base Station. Further, we evaluate the use of suitable applications and network traffic combinations for all WiFi users in order to fully optimize the network within a constrained bandwidth. On top of that, subsequently to investigate more about the hybrid network, the quantity of nodes is supported to 200 users based on the same situation. This type of integration will solves many of the difficulties in last-mile implementations, which also will benefit both users and service providers.*

Keywords: Integration, Optimized, WiFi, WiMAX

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1. Introduction

The integration of WiFi-WiMAX as one of the architecture's aims for the next generation of wireless networks has become increasingly conventional especially in urban areas. The main purpose of such connectivity is to provide users with a variety of applications with higher speed, larger coverage and mobility access. Although several studies have shown the integration of 2.5 and 3G cellular networks combined with WLAN (Wireless Local Area Network), they do not provide Internet connections same as the broadband speeds which is offered by WiMAX (Worldwide Interoperability for Microwave Access)[1]. The arrival of WiMAX technology has met the user's demand for broadband wireless access since its' ability to provide higher speed connection, with a large area coverage alongside with the quality of service assurance [2].

WiFi (wireless fidelity) which also used generally as a synonym for WLAN has a variable data rate depending on the standard, however, mainly the coverage area starts with a minimum of 20 meters up to maximum 100 meters. In order to extend the coverage, the WLANs need to integrate with WMANs technology as the backhaul or a last mile solution[3].The coverage areas of WiMAX cover up to 50km and data rate up to 70 Mbps which is likely suitable apply in a metropolitan area by connecting houses, buildings or cities [4].

The most practical options for internet access in metropolitan networks are WiFi and WiMAX [5]. Currently, there are a number of cities in the world known as "wireless cities" such as Taiwan that could provide the people's to access the wireless internet throughout their entire metropolitan areas [6]. In connection with that, integrating WiFi and WiMAX is the most suitable way to deploy large-scale wireless networks. Besides of the coverage extension, the amount of needed bandwidth is also another issue. The reason is as network applications become greater, bandwidth becomes critical to network efficiency[7]. However, with the WiFi-WiMAX integration, multiple applications can be supported, especially voice and video communications.

To allow the interoperability between WiFi and WiMAX as a hybrid network, a special gateway is needed known as WiFi/ WiMAX gateway [8]. The main use of this gateway is to connect the users of both technologies seamlessly with greater gain access as shown in Figure 1. For this type of combination, the WiFi users connect to the Internet through a WiMAX core network using the WiFi/WiMAX gateway[9]. The WiMAX base station sees the gateway as another WiMAX subscriber station. Since each WiFi/WiMAX gateway can accommodate many WiFi users, the average traffic generated by the gateway is higher compared to WiMAX subscriber stations. As a result, a controlled resource allocation is required between WiFi/ WiMAX gateway and WiMAX base station to optimize the available bandwidth [10].

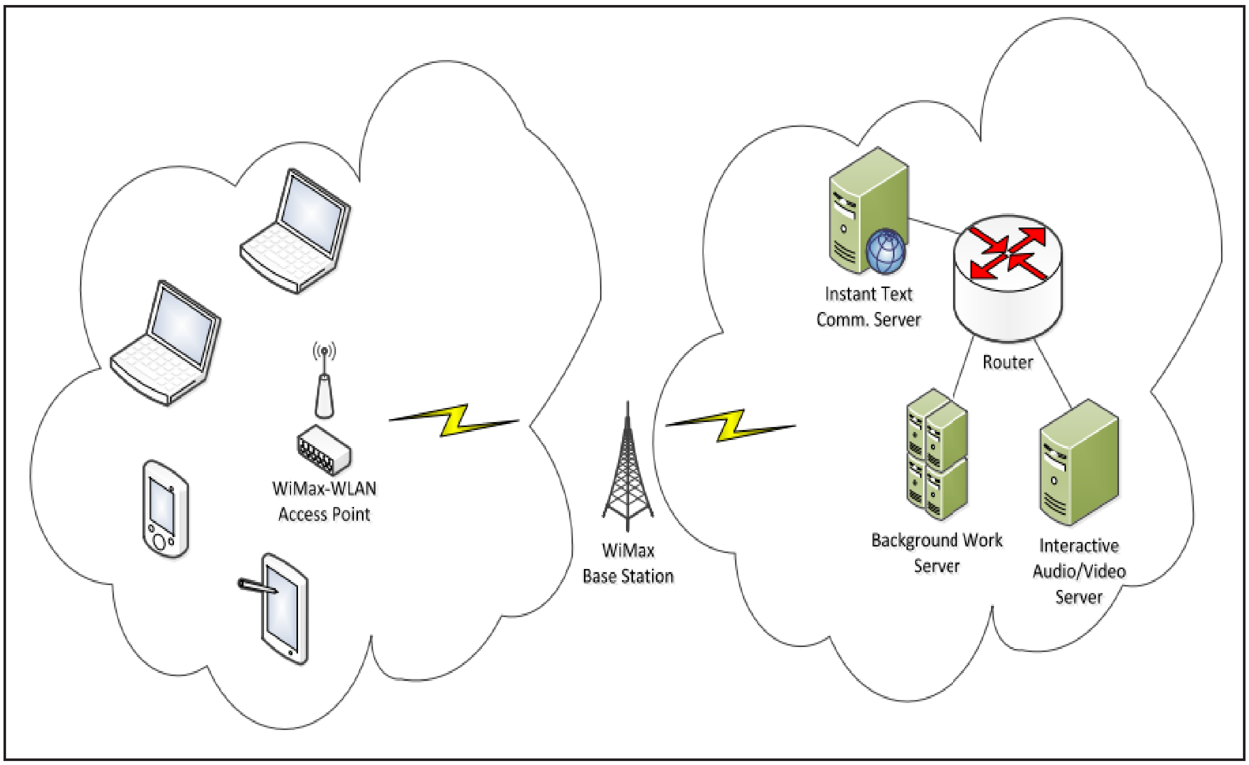

Figure 1. WiFi-WiMAX coexistence topology [6]

1.1 Overview of Paper

The remainder of this paper is structured as follows. In Section 2 an overview about WiFi and WiMAX is explained. In Section 3, we discuss about the interoperability of WiFi and WiMAX based on limitations or shortcomings of the wireless technologies that are used as well as on their benefits to fulfill certain demands. Part 4 includes the simulation parameters and contexts for the scenario. The performance rating of applications allotted for the WiFi users is presented in Section 5. Finally, conclusion appear in Section 6.

2. WiFi and WiMAX

WLAN or also known as 802.11 standards is a technology that allows any electronic device to exchange and transfer data wirelessly in a high speed internet connection within a short range area. The network can support data rates up to 54 Mbps at a range of about 30 to 300 meters [11]. There are five main WLAN specifications: IEEE 802.11a, IEEE 802.11b, IEEE 802.11e, IEEE 802.11g and IEEE 802.11n[12]. Formerly, IEEE802.11a/b/g was utilized widely, however, now the popular usage is for

802.11n standard that operates in the 2.4GHz and 5GHz bands [13]. WiMAX is designed for a long range communication which created by the companies Intel and Alvarion in 2002 and ratified by the IEEE (Institute of Electrical and Electronics Engineers) under the name IEEE-802.16 [14] [15].

3. Integration of WiFi and WiMAX

WiFi is an implementation of wireless local area network within a short range area such as an office, a college or a university campus. WiMAX on the other hand covers a metropolitan area by connecting houses, buildings or cities. WiMAX is different from WiFi in many respects; coverage distances, and data rate[16]. One of the main reasons why WiFi unable to operate at greater distances as WiMAX is that radios operating in the unlicensed frequencies are not allowed to be as powerful as those operated with licenses [17]. Since the power is less, the same effects happen to the distance.

Secondly, the WiFi MAC layer uses contention access, whereas WiMAX uses a scheduling algorithm. Using a contention mode algorithm, users have to compete for data throughput to the access point[18]. In the meantime, by scheduling mode algorithm, it allows the user to only compete once to the access point. As the result, WiMAX outstrip WiFi in terms of throughput, latency, and spectral efficiency [19].

Both WiFi and WiMAX standards are designed for the Internet protocol applications. However, by combining these two technologies, WiMAX can be functioning as a backhaul while WiFi connected directly to the subscriber [20]. The most interesting part is network providers are able to deploy wireless broadband connections to areas not currently served in a short time and cost-effectively since only little or no disruption to existing infrastructures is needed. On top of that by combining WiFi and WiMAX technologies, a more complete suite of broadband services can be offered by service providers. It is because Wi-Fi is known for its high speed connectivity meanwhile high speed and large range connectivity for WiMAX [21].

Although, both the technology the WiMAX and the WiFi provide a wireless connection to last mile problem, their working mechanism is technically different [22]. One of the primary reasons why WiFi unable to work at greater distances as WiMAX is that radios operating in the unlicensed frequencies are not admitted to be equally potent as those operated with licenses [23]. Since the power is less, the same effects happen to the distance. Secondly, the Wi-Fi MAC layer uses contention access, whereas WiMAX uses a scheduling algorithm. Using a contention mode algorithm, users have to compete for data throughput to the access level. In the interim, by scheduling mode algorithm, it lets the user to only compete once to the access level. As the result, WiMAX outstrip WiFi in terms of throughput, latency, and spectral efficiency [24].

4. Simulation Environment

For our system model, we proposed a number of WiFi users that can accommodate a WiMAX base station. On top of that we also proposed the traffic combinations that can fully utilize for the same topology before another base station is needed in the network.

The model consists of 40 WiFi users connected to 1 Base Station through a special access point (AP) namely as WiFi/ WiMAX router. For this type of router, the WiMAX interface is used for communicating with the BS, and WiFi interface for communicating with WLAN stations. This router will convert the WiMAX packets to WiFi packets and route them to the WiFi clients. It also works as WiMAX clients which contain of a number of WiFi nodes. In terms of coverage, since the range of WiFi users is much smaller than WiMAX, this router will act as a link for WiFi users to reach the WiMAX BS. Therefore, in each location the service provider has installed a WiFi/WiMAX router or Customer Premises Equipment (CPE) to establish wireless connectivity from the customer site to the service provider's network.The WiFi clients are placed in circular fashion which surrounds their respective AP or router. The traffic from WiFi/WiMAX router from WiFi hotspots are referred to as WiFi traffic.

We evaluate the idea of planning about the network using a network simulator tool; OPNET Modeler [25] [26]. The OPNET Modeler enables users to create customized models and to simulate various communication networks [27]. It supports friendly graphical user interfaces to capture the specifications of deployed networks, equipment, and protocols. The traffics assign in the network are VoIP (Voice over IP), video conferencing, HTTP browsing and file transfer. The simulation topology is shown in Fig.2 meanwhile the parameters used for WiMAX and WLAN described in Table 1 and Table 2 respectively.

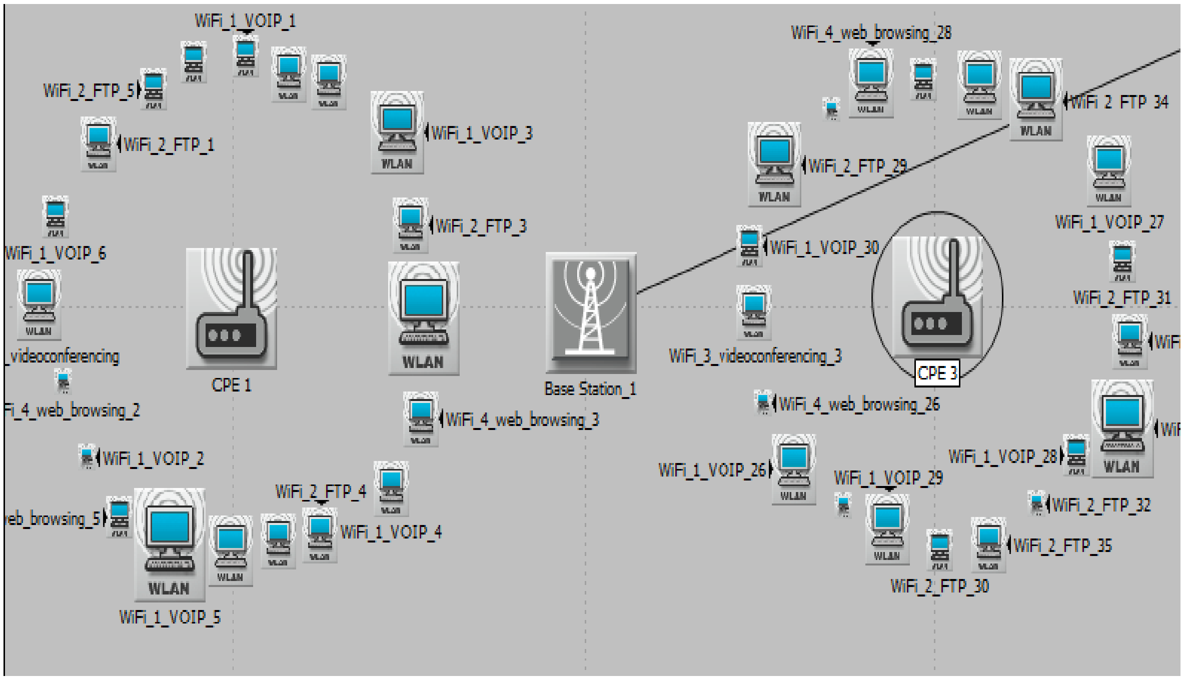

Figure 2. Simulation Topology

Operating Frequency	2.5 GHz
Bandwidth	10 MHz, 1024 (subcarrier)
Maximum Transmission Power	0.5 to 3 W
Antenna Gain	15 to 18 dBi
Receiver Sensitivity	-200 dBm
Min Reserved Traffic Rate (rtPS)	140 kbps
Max Sustained Reserve Traffic Rate (rtPS)	50 Mbps

Table 1. WiMAX Simulation Parameters

Data Rate	54 Mbps
Maximum Transmission Power	0.05 to 0.04 W
Buffer Size (bits)	265 000
Packet Reception Power Threshold	-95 dBm
AP beacon Interval	0.02 sec

Table 2. WiFi Simulation Parameters

5. Results and Discussion

The simulation runs for 10 minutes (600 seconds) and for the purpose of results analysis, a throughput, delay and packet dropped graph will be used. The throughput graph will determine the total data traffic successfully received and forwarded to the higher layer by the WiMAX MAC for WiMAX and WLAN MAC for WLAN connection. On top of that a packet dropped graph for WiMAX is to determine the higher layer data traffic dropped in bits/sec by the WiMAX MAC due to data buffer overflow. Meanwhile packet dropped in WLAN is due to full higher layer data buffer or the size of the higher layer packet, which is greater than the maximum allowed data size defined in the IEEE 802.11 standard.

We conduct several simulation scenarios to evaluate the proposed algorithm. The first scenario evaluates the number ofWiFi users that be accommodated for a single base station. The second scenario evaluates the optimized traffic that be generated based on the same topology[28].The last scenario investigate the network performance when the number of WiFi users increase to 200.

5.1Scenario 1

In this scenario, there are 20 WiFi users on each CPE that connects to a WiMAX Base Station. To optimize the network, we add another CPE that connects to another 20 WiFi users. For this scenario, we investigate the maximum number of WiFi users or hotspots that can accommodate a single WiMAX Base Station. We begin with a minuscule number of users and measure the network operation to recover out the restrictions. Since our primary aim is to make sure that each user will acquire the requested data rate, thus the most important parameter is this scenario is throughput.

Some observations we made are as follows: In Fig. 3 and 4, the throughput of WLAN and WiMAX produced almost the same result measured on either side of WiMAX-WiFi AP.

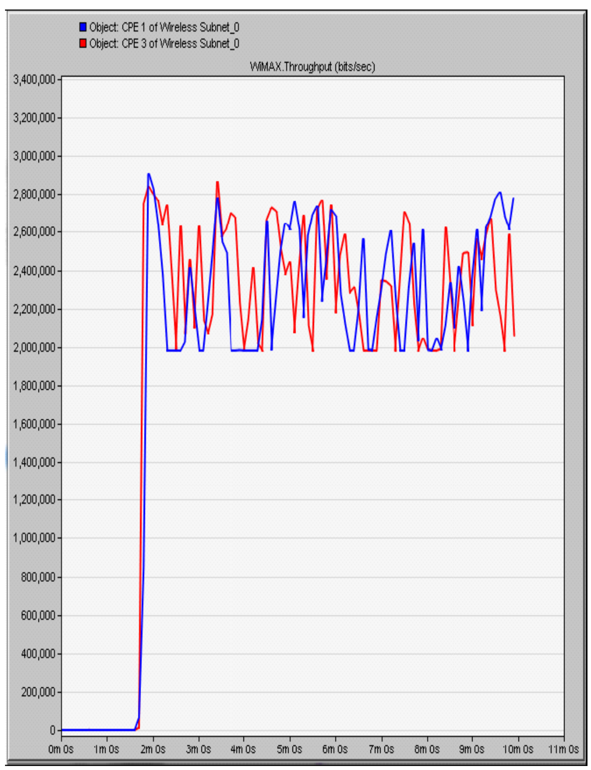

Figure 3. Throughput for WiMAX link(bits/sec)

Based on Figure 3, throughput measured at CPE 1 and CPE 3 for a WiMAX link which is between the CPEs and Base Station is ranged between 2 Mbit/s and 2.8 Mbit/s.

On the other side, throughput measured at CPE 1 and CPE 3 for a WLAN link which is between the CPEs and WiFi users is stabilized at 2 Mbit/s as shown in Figure 4.

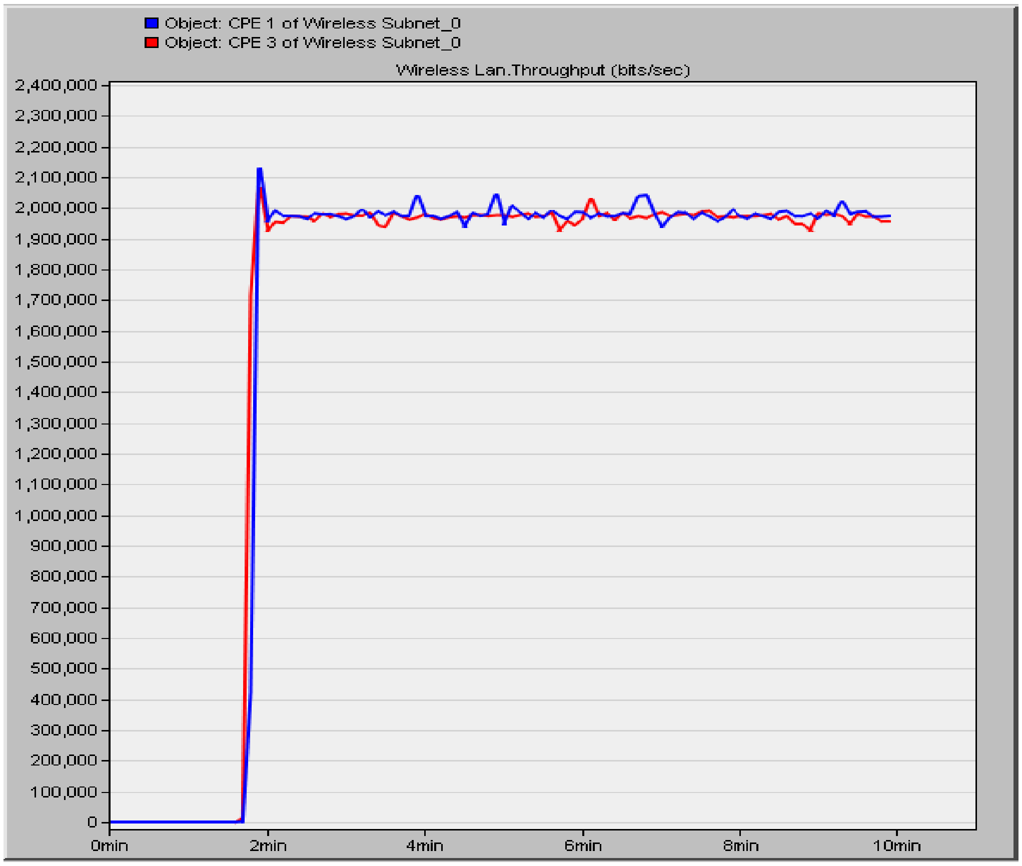

Figure 4. Throughput for WiFi link (bits/sec)

In comparison, that there is not much throughput differentiation for both link which shows that traffic requested by WiFi users are mostly successful received. Next to examine deeply on the differentiation, we measured the packet dropped for both connections.

Further, as depicted in Figure 5, it shows that, there are some packet dropped and lost occurred in WLAN link. However it happened due to data buffer overflow. The buffer acts as a temporary memory to keep data for a while time have several sizes. Nevertheless, to avoid the packet dropped, we tried to increase the buffer size, however it will also increase the delay performance and therefore after a number of experiments, the suitable buffer size is chosen which will optimize the network. Opposite tothat, there is no loss of the WiMAX link as all the data is successfully transmitted and received.

Number of WiFi users	Traffic combinations (application)
6	VoIP
1	Video Conferencing (Skype)
7	File Transfer Protocol
6	Web Browsing

Table 3. Traffic Combination for 20 WiFi Users

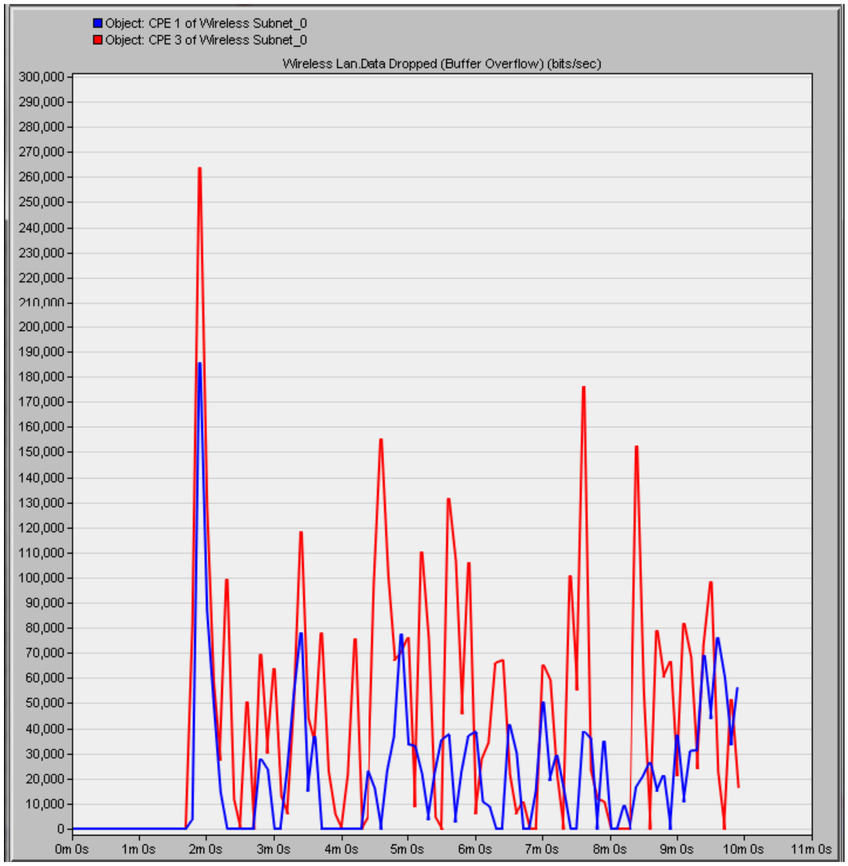

Figure 5. Data dropped (buffer overflow) for WiFi link

5.2 Scenario 2

In the second scenario, the optimized traffic that be generated based on the previous topology is evaluated. Since we have evaluated the optimum WiFi user can accommodate in a single CPE, therefore in this scenario we investigate the effect on the traffic/application assigned to the users. For this purpose, we include the WiFi users with multi-applications starting with the heavy traffics as voice and video communication and also the low bit rate traffics such as file transfer and web browsing. Therefore, in order to fully utilize the network, each WiFi users with their application is guaranteed with minimal or acceptable packet loss. The proposed traffic for 20 WiFi users used in this scenario is described in Table 3.

Since voice is the most highly delay sensitive for real-time applications, the Mean Opinion Score (MOS) value and jitter are investigated in this scenario as illustrated in Fig. 6 and Fig. 7 respectively. MOS is the measurement of the quality of human speech at the end of the destination. Besides dictating the quality in voice and video communication, whether it is a good or bad experience, MOS gives a numerical indication of the perceived quality of the media received after being sent and eventually compressed using codecs. MOS is expressed in one number, from 1 to 5, 1 being the worst and 5 the best. The details of MOS number are as follows: 5-Perfect. Like face-to-face conversation or radio reception, 4-Fair. Imperfections can be perceived, but the sound still clear, 3–Annoying, 2-Very annoying and nearly impossible to communicate, 1- Impossible to communicate.

Figure 6 shows the MOS value for all the WiFi users with a VOIP application which is ranged between 3.85 to 4.05 and based on the MOS table [29], it is defined as good and excellent in quality.

Another important implication of this investigation is the jitter value as described in Fig. 7, which shows zero reading. Jitter is defined as the time difference in packet inter-arrival time to their destination. In VOIP communication, for example, when a frame is sent every 10 ms, some of the packets can immobilize somewhere in between inside the packet network and not arrive at expected regular peace to the destined station. This is because one of the packets encounters some delay on its path and it is received little later than it was seized. The problem encounters to jitter and also mitigate to packet delay. Therefore, for VOIP, it is important the system to experienced zero jitter to have a successful communication network.

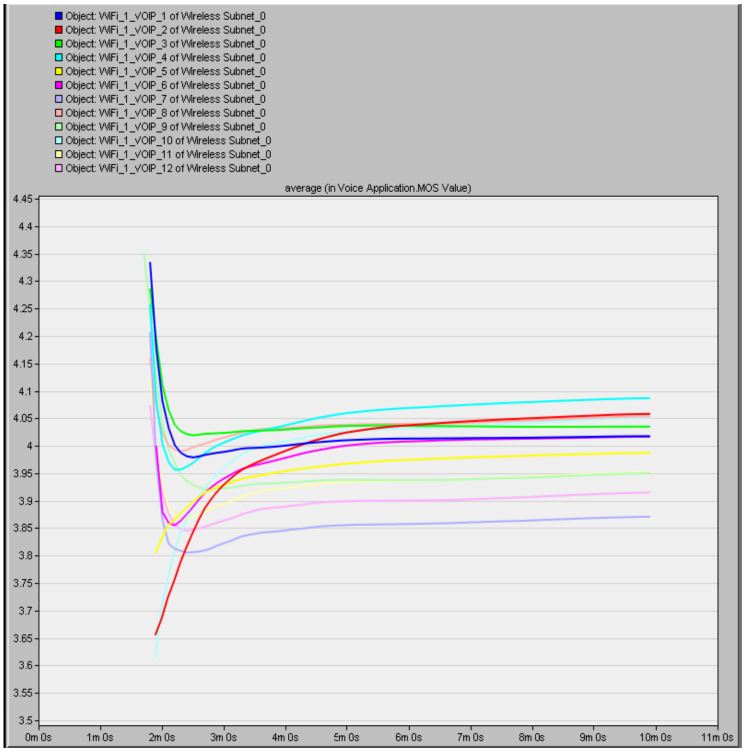

Figure 6. MOS value for WiFi users with VoIP application

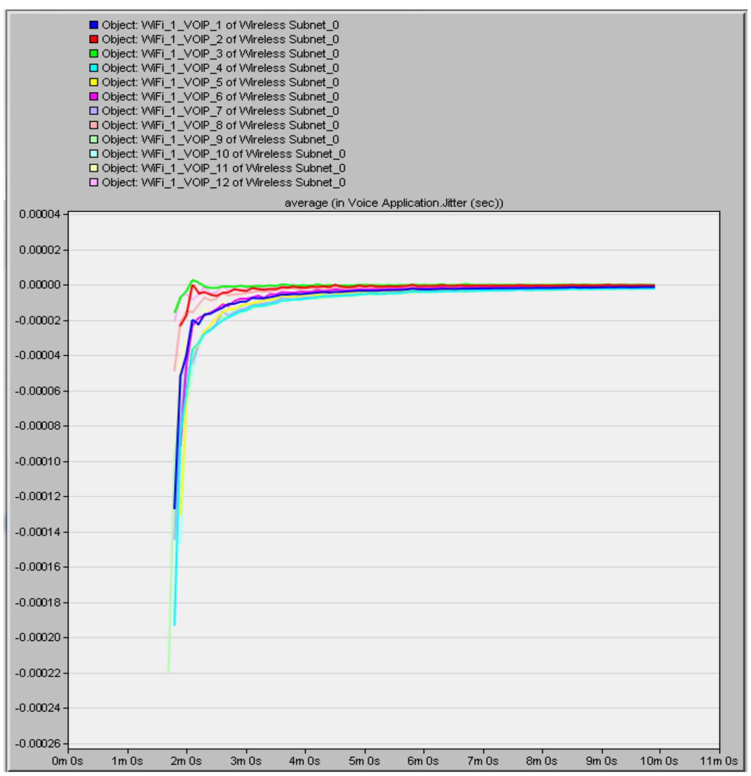

Figure 7. Average jitter for WiFi users with VoIP application

5.3Scenario 3

The third scenario settings is the same as in the previous, however the quantity of users is expanded to 200. In this scenario, there are 5 CPEs which each CPE comprises of 20 WiFi users. The covered area is 500m x 500m allowing for simple placement of the WiMAX CPE and WiFi users and providing minimal drop in data rates or potential interference. The CPE is place a few hundred meters from the base station around the area or central site area. Each device acts as a WiFi AP (Access Point) with a bridged connection to the closest WiMAX base station. The WiFi coverage is aimed at the main area as the effective range is limited to a 2m to 60m radius dependent on obstacles and RF interference from other terminals or devices and wireless equipment. The technical configuration for each WiMAX base station, WiFi/WiMAX router and WiFi user in the simulation is shown in the table IV, V, VI respectively;

Operating Frequency	2.5 GHz
Bandwidth	10 MHz, 1024 (subcarrier)
Transmitter Power	2 W
Antenna Gain	18 dBi

Table 4. WiMAX Base Station

WLAN Standard	HT PHY 5.0GHz (802.11n)
Data rate	6.5Mbps to 60Mbps
Antenna Gain	18 dBi
Modulation	OFDM
Max TX Power	3W

Table 5. WiFi/WiMAX router (CPE)

Standard	
Data rate	6.5Mbps to 60Mbps
Antenna Gain	18 dBi
Modulation	OFDM
Max TX Power	40mW
Buffer size	32 000Bytes

Table 6. WiFi User

Figure 8 indicates throughput of WiMAX links for all 5CPEs declined, which is contrasted as in Figure 3. Previously the throughput for all CPEs are is higher than 2.2 Mbps while now it has dropped to the most minimal of 1.3 Mbps. This is because since more users are sharing the same bandwidth in the same channel. Further on, we explore the throughput for WiFi link as represented in Figure 9.

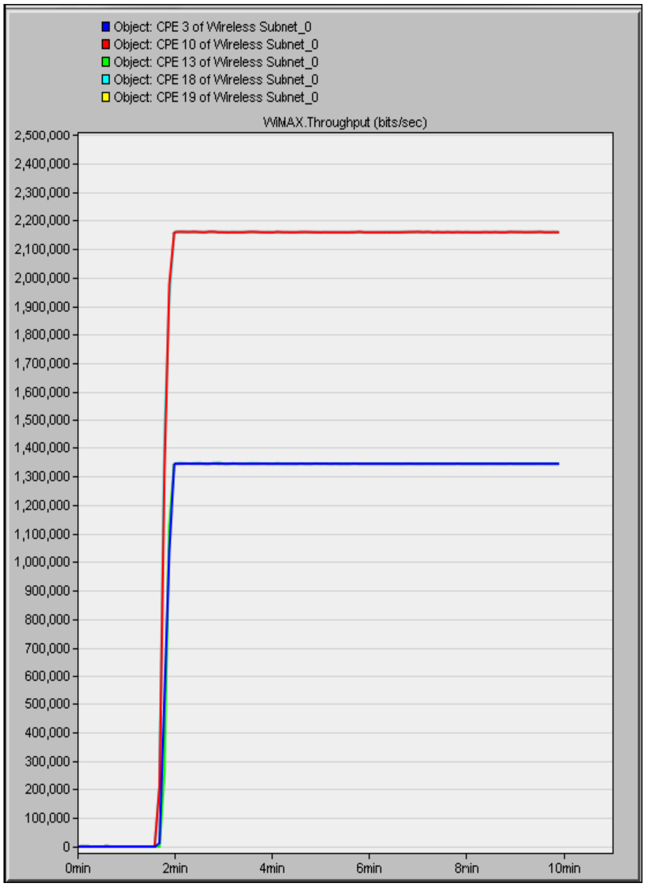

Figure 8. Throughput for WiMAX link(bits/sec)

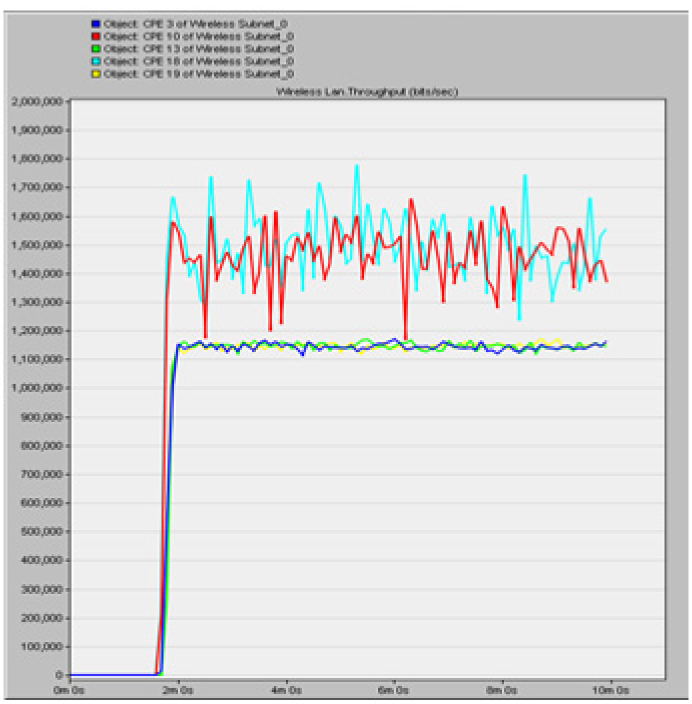

Figure 9. Throughput for WiFi link (bits/sec)

As notice before, since there are 200 users in the current scenario, the throughput for each WiFi user is relied upon to fall which is described in Fig. 9. Throughput of WiFi link at each CPE isbelow2 Mbps and even two's of the CPE are low as 1.2 Mbps. In view of throughput at WiMAX and WiFi link for each CPE at scenario1, the data rate gain for both links are distinctive and it shows that there is packet dropped experienced in the channel. Along these, we examine this behavior by measuring the packet loss as depicted in Figure 10.

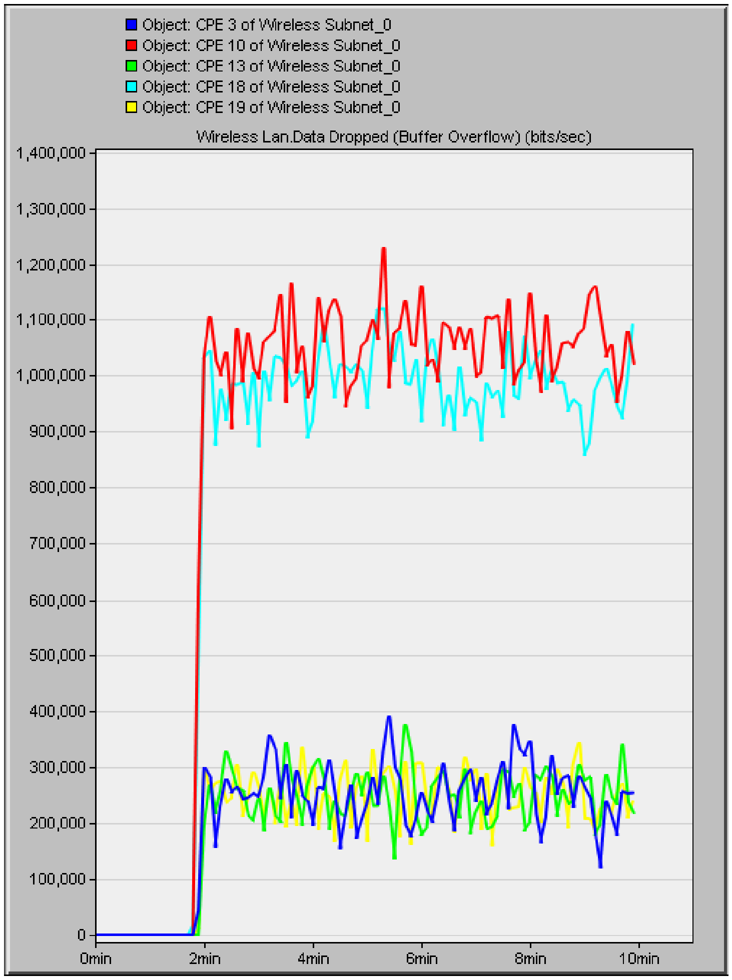

Figure 10. Data dropped (buffer overflow) for WiFi link

As shown in Fig.10, there is a large difference of data dropped for WiFi link compared to the results obtained in Scenario 1. This is due to the increase number of users which some of the WiFi users experienced lower throughput since the network are fully occupied.Another parameter than we quantified in this scenario is jitter. Since in the first scenario we measured jitter for VOIP users, therefore in this scenario, we investigate the same quality of jitter.

Since there are more than 20 users are appointed to VOIP application in this scenario, we only show users with the most astounding average jitter as depicted in Fig.11. Comparing with the previous result, jitter increased from zero to 0.19 seconds. Since more users are added in this scenario, create a higher delay for each user and also increases the latency for both systems.

6. Results and Discussion

In this paper, a research has been explored on the cross system network optimization which involves WiFi and WiMAX particularly in our scenario. The first part of the research covers the number of WiFi hot spots that could accommodate by one WiFi/WiMAX router or also known as CPE. In further, another set of WiFi hotspot and CPE is added to optimized a single

WiMAX base station. The second part proposes the optimized traffic combinations for each WiFi user based on the first scenario. The results are presented in the throughput, delay, packet dropped, MOS and also jitter graphs to evaluate the performance of each scenario. The third part demonstrates the results as the quantity of users in the network is occupied five times more than in the first scenario. Simulation results reveal that the throughput for WiFi users were slightly lower, data dropped was expanded to a certain value which likewise expanded the average jitter in the network.

6.1 Remaining Work

The next stage of this work is the production of an integration of WLAN and LTE (Long Term Evolution) networ

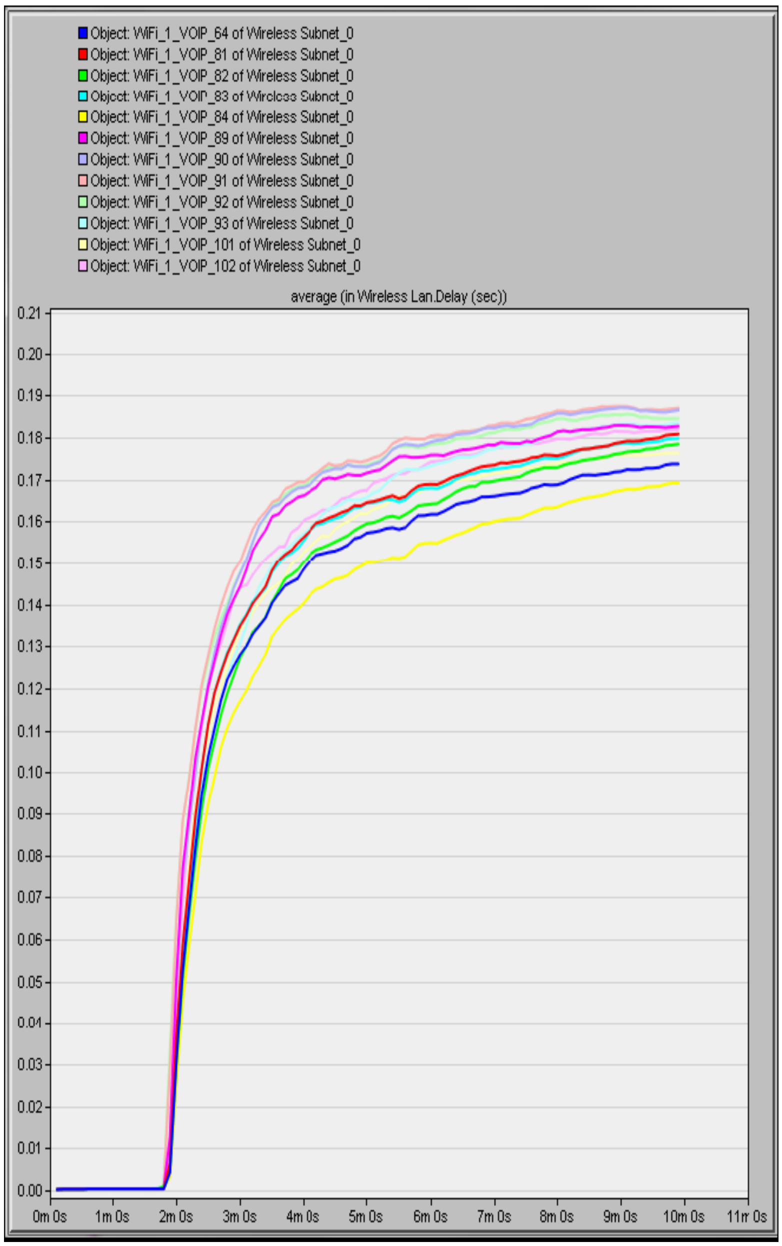

Figure 11. Average jitter for WiFi users with VoIP application

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