

**ENSC 427: COMMUNICATION NETWORKS**  
**Spring 2014**

**Final Project Report**

**Evaluation and Comparison of WiMAX  
(802.16a) and Wi-Fi (802.11a)**

**<http://www.sfu.ca/~tlan/ENSC427Webpage.html>**

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## Abstract

We intend to evaluate and compare performance of WiMAX (802.16a) and Wi-Fi (802.11a) supported by OPNET. We plan to introduce the background information regarding WiMAX and Wi-Fi and use the OPNET 16 to simulate different cases of these two protocols with the expectation to comprehend what leads to their different applications after compare their basic characteristics and behavior under different circumstances.

The rapid increase and widespread of the use of smart phones and many other wireless devices causing the great increase of the demand for the network technologies, and leads to the improvement of such technologies. As one of the most well-known and commonly used protocol, Wi-Fi is used specifically for local network access. In comparison, the WiMAX (Worldwide Interoperability for Microwave Access) is a protocol used for mobile devices to support long-range fast speed information exchange. How their features causing them to have different application draws our interest.

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# 1. Introduction

WiMAX (Worldwide Interoperability for Microwave Access) and Wi-Fi (Wireless Fidelity) are two Wireless Local Area Network (WLANs) technologies that are well known and widely used in normal life. WiMAX and Wi-Fi are frequently used for wireless Internet access. The WiMAX could cover a large area where as Wi-Fi is commonly used for smaller area within homes or business location.

In this paper, we will test and exam the behavior of WiMAX and Wi-Fi in similar environment where some typical scenarios will be set for data gathering. With desire data gathered, we will compare the critical properties of these two technologies such as the throughput and delay, and provide a performance analysis of WiMAX and Wi-Fi communication network. With the analyze of the performance for these two network, we would draw a conclusion for why WiMAX and Wi-Fi are having their unique applications.

## 1.1 WiMAX (802.16a)

The WiMAX (worldwide Interoperability for Microwave Access) is a wireless communication technology which first proposed at 2001 intended to replace Wi-Fi as a wireless transmission method. However the performance of WiMAX is closer to 3.5G (High Speed Downlink Packet Access) which focused on long distance transformation yet having lower transformation speed comparing with Wi-Fi. The original WiMAX version, 902.16a, occupies range of 10 to 66 GHz, and added specifications for 2 to 11 GHz range in 2004 with the updated 802.16-2004 standard. In 2005, WiMAX based on IEEE 802.16e was approved as a new wireless communication standard. It is theoretically capable of providing a maximum speed up to 75 Mbps and can cover a maximum distance of 50 km. As a competitive wireless communication standard, WiMAX is used in 178 countries, with 1.7 million customers in Asia and 1.4 million in the USA and Canada, amongst over 10 million users around the world. As competing advantages, it has more signal coverage, better frequency utilization and bandwidth efficiency, cheaper equipment and lower energy usage than other pre 4G (the fourth generation of mobile phone mobile communication technology standards) standards. The WiMAX does also support mobile product. In fact, the ungraded version of WiMAX, the WiMAX -Advanced, which is based on standard IEEE 802.16m was intended to satisfy the needs for the 4G standard and is now one of the two 4G standards wildly used around the world. In this report, however, we will focus on the behavior of WiMAX based on standard 802.16a. The WiMAX network configuration is shown in Figure.1.

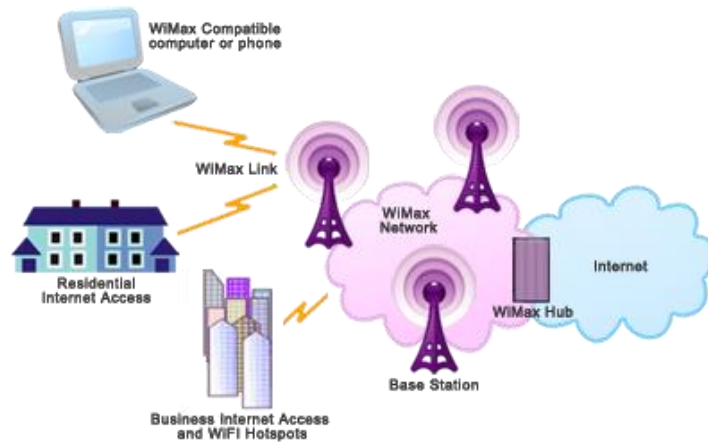


Figure.1 WiMAX network configuration

## 1.2 Wi-Fi (802.11a)

Wireless network is a kind of ability to connected personal computer and handheld devices as terminal wirelessly. Wi-Fi as a trademark of the Wi-Fi alliance is one type of a wireless network communication technology. Wi-Fi as one important part of WLAN is based on the IEEE 802.11 family of standards. There are various types of 802.11 and majority of the wireless router is based on IEEE 802.11a and 802.11g that support a peak physical-layer data rate of 54Mbps and typically provide indoor coverage over a distance of 100 feet [1]. Comparing with the wide coverage of radio waves, the radio coverage based on Bluetooth technology is small that near 30 feet. Therefore, one significant benefit of Wi-Fi over Bluetooth is the wide scope of coverage. Wi-Fi can meet the needs of individual and social information as the transmission speed can deliver 11 mbps.

The IEEE 802.11a was published in 1999. It provides data rates to 54 Mbps in the 5 GHz U-NII bands by using the Orthogonal Frequency Division Multiplexing. Comparing to 802.11 that just three in the 2.4 GHz ISM bands, more spectrums in U-NII bands allows room for 12 non-overlapping channels. In addition, it has development to allow the seamless handoff of communication between the overlapping. The user can use laptop or smartphone to connect to Internet by connecting to wireless router for Wi-Fi services [2].



Figure.2 Wi-Fi Network Configuration

### 1.3 Comparison between WiMAX (802.16a) and Wi-Fi (802.11a)

Since WiMAX and Wi-Fi both are based on IEEE standards, however, Wi-Fi is based on IEEE 802.11 standard and WiMAX is based on IEEE 802.16. For bit rate between Wi-Fi and WiMAX, the range of operating in 20 MHz channel is between 2.7bps/Hz and 54Mbps, nevertheless, the range of WiMAX works between 5bps/Hz and 100Mbps in 20 MHz channel.

Although, WiMAX and Wi-Fi are both belongs to wireless local area network, however, Wi-Fi works faster but in shorter range, mostly used in in-house applications. Whereas, WiMAX operates slower but works over much longer ranges. The speed vs mobility graph is shown in Graph 1.

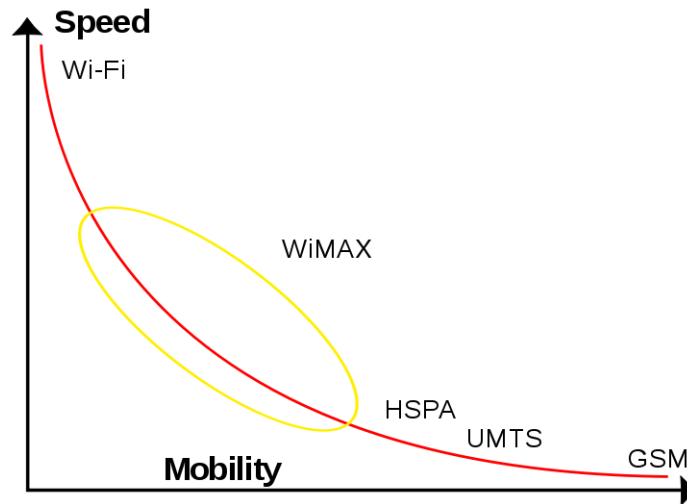


Figure.3 Speed vs Mobility on Wi-Fi and WiMAX

Wi-Fi provides peer-to-peer connections between users and creates a mesh network. To the contrary, WiMAX provides high-speed mobile data and telecommunication services. The characteristics comparison between Wi-Fi and WiMAX are shown in Table 1.

Table.1 Comparison between WiMAX and Wi-Fi

Feature	WiMAX(802.16a)	Wi-Fi(802.11a)
Primary Application	Broadband Wireless Access	Wireless LAN
Frequency Band	Licensed/Unlicensed 2G to 11GHz	5GHz U-NII
Channel Bandwidth	1.25M to 20MHz	20MHz
Half/Full Duplex	Full	Half
Radio Technology	OFDM (256-channels)	OFDM (64-channels)
Bandwidth Efficiency	$\leq 5$ bps/Hz	$\leq 2.7$ bps/Hz
Modulation	BPSK, QPSK, 16-, 64-, 256-QAM	BPSK, QPSK, 16-, 64-QAM
Forward error correction	Convolutional Code Reed-Solomon	Convolutional Code
Encryption	Mandatory-3DES Optional-AES	Optional-RC4 (AES in 802.11i)
Mobility	Mobile WiMAX (802.16e)	In development
Mesh	Yes	Vendor Proprietary
Access Protocol	Request/Grant	CSMA/CA



## 2. OPNET Modeler

OPNET is one tool to simulate the behavior of the oriented network. The simulator makes possible modeling and simulating the wired and wireless network in the comprehensive development environment. It allows users to create customized models and simulate different types of network scenarios. OPNET is used to create models and simulate the wireless scenarios. The Modeler is object-oriented and employs the communication network using the hierarchical method. It allows graphical user to capture the technical data of deployed networks and protocols. The three-tiered OPNET hierarchy consists of three domains including network, node that specifies object in network domain and process that specifies object in node domain. Simulating Wi-Fi and WiMAX by using OPNET Modeler 16.0 provides us high-fidelity modeling, protocol stack such as routing, layer protocols and application, and analysis of deployed network such as throughput, bits received and bits forwarded. It also can show us three kinds of output including vectors, scalars and animations.

We created three OPNET models for Ethernet, Wi-Fi and WiMAX mobile and fixed local area networks to evaluate their performance. The small-scale network 1km \* 1 km is applied by all three OPNET models.

Firstly, Ethernet scenario consists of four stationary workstations (client A to client D), one router and profile definition and application definition. Wi-Fi scenario consists of two stationary workstations, one router and one server and profile definition and application definition. WiMAX scenario consists of one client, one base-station, one server and profile definition and application definition and WiMAX configuration. The router is connected to the switch and to server by a link. Server is configured for four network applications: Hypertext Transfer Protocol (HTTP) medium, Email medium and file transfer heavy. Application definition is set up for the same applications as for the server. Profile definition defines all profiles that can be used within a scenario.

## 3. Simulation Design

### 3.1 Ethernet Scenario

The network topology of the Ethernet scenario is shown below in Figure 4.

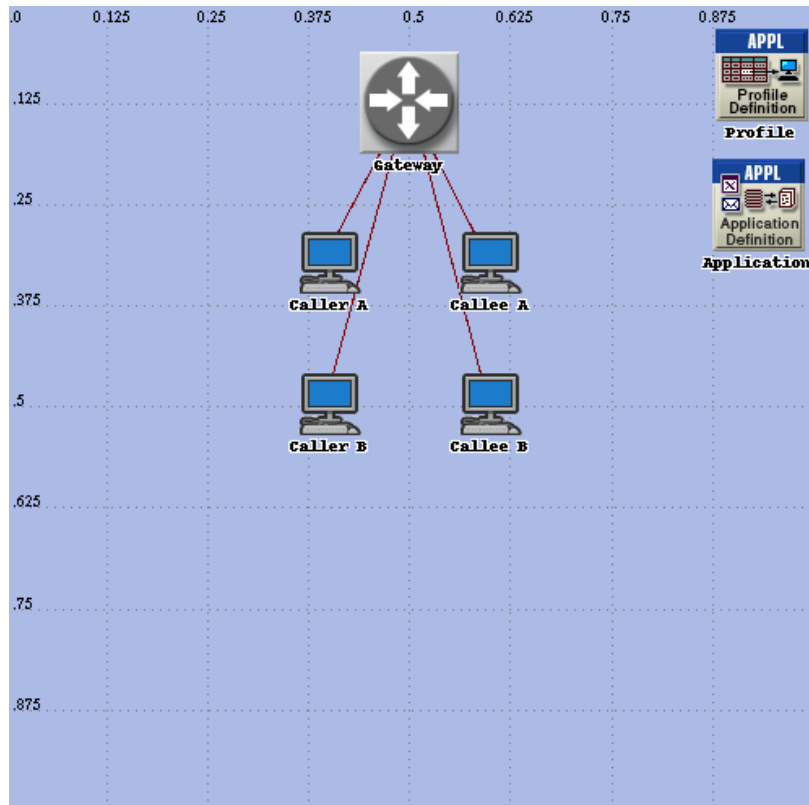


Figure.4 Ethernet Scenario Topology

We created an Ethernet network to collect baseline statistics for comparing Wi-Fi and WiMAX. As Ethernet uses wired connections, but we need wireless connection for Wi-Fi and WiMAX wireless network.

### 3.2 Wi-Fi Scenario

As shown in Figure 5, the topology is put in the office network of 1 km x 1 km, use the Wi-Fi network replaces the Ethernet workstations with Ethernet server station and the gateway with a Wi-Fi router. The access point is specifying as Wi-Fi router. The client\_1 is now 50 m ( $x = -50m, y = 0m$ ) away from the access point and the client\_2 is 100m( $x = -100m, y = 0m$ ) away from the access point. We application definition and profile definition. The parameters for setup are shown in appendix.

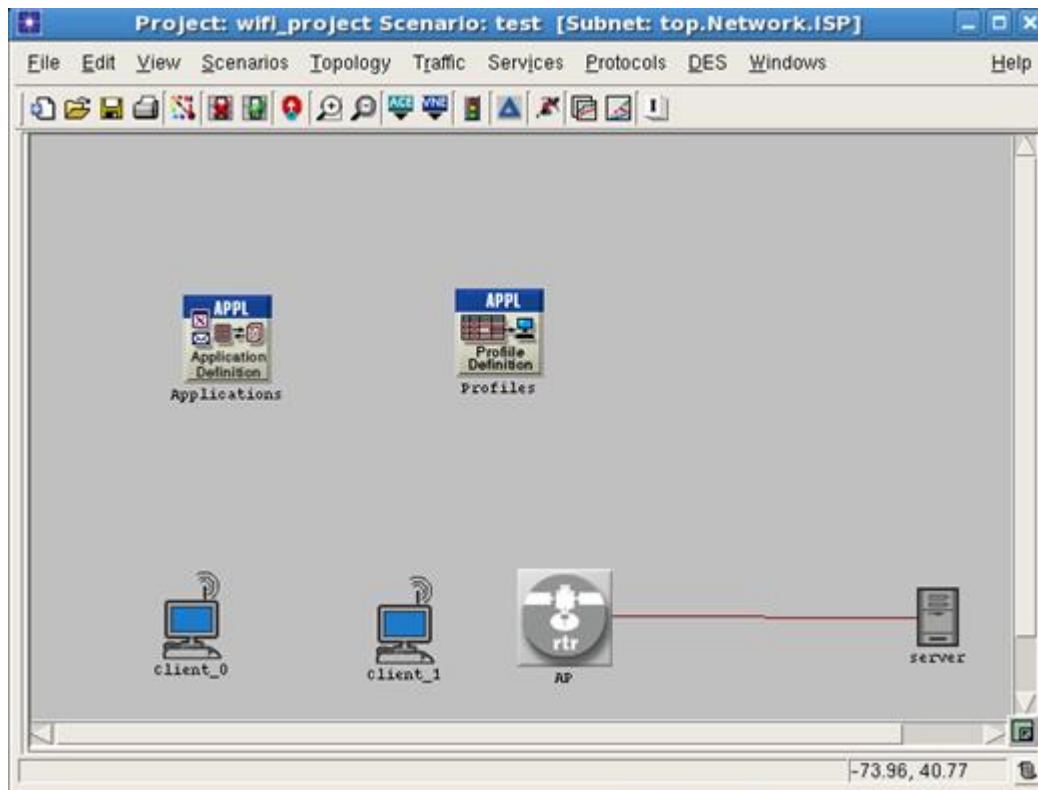


Figure.5 Wi-Fi Scenario Topology

### 3.3 WiMAX Scenario

The WiMAX network is also based off the Ethernet network. As shown in Figure 6, the Ethernet workstations have been replaced with WiMAX workstations and the gateway is now a WiMAX base station router. The client workstation is now 50 m ( $x = -50\text{m}$ ,  $y = 0\text{m}$ ) away from the base station. We need application definition and profile definition WiMAX models in OPNET require an additional configuration node to specify WiMAX parameters. The key parameters are the Efficiency Mode and MAC Service Class Definitions. It is important that the Efficiency Mode is set to Physical Layer Enabled in order to observe any effects of distance. This was a source of confusion during initial simulations as it is set to Efficiency Enabled by default, resulting in zero packet loss. The parameters for setup are shown in appendix.

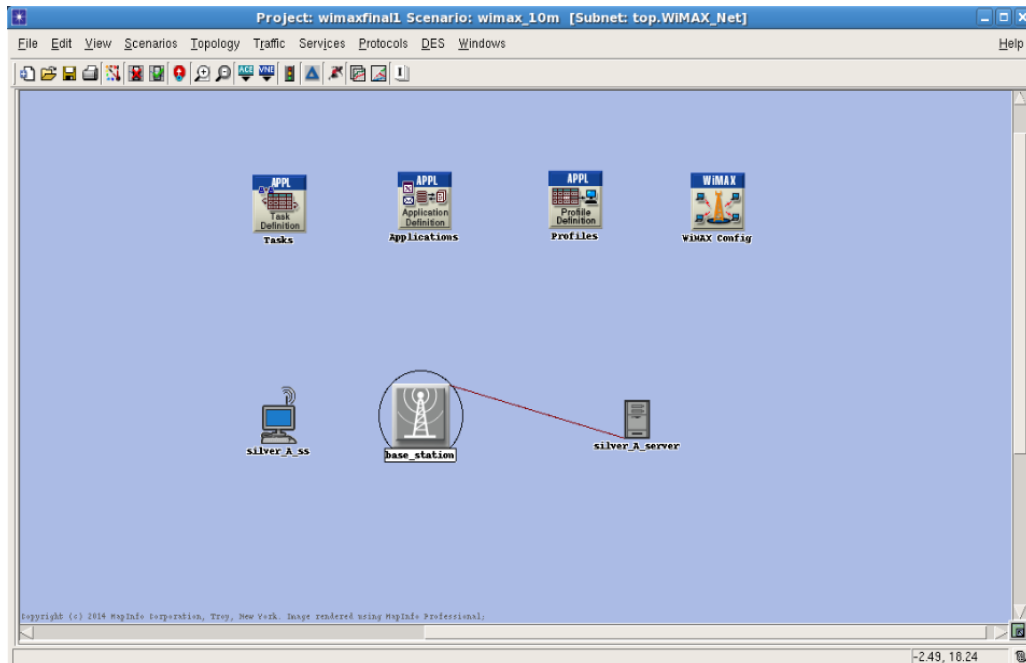


Figure.6: WiMAX Scenario Topology

## 4. Simulation Results

### 4.1 Packets receive/send rate

We have simulated Wi-Fi and WiMAX in three different scenarios where the distance between the client and the access point, or the client and the base station varies with the following values: 10 meter, 200 meter, and 1000 meter. We expect that WiMAX would have a better performance in long distance scenarios and the Wi-Fi would perform better in short range scenarios. This would match the real life applications of WiMAX and Wi-Fi.

The first aspect we compare is the traffic sent and received by the clients. It is critical that the information send is correct and complete. From the difference between the traffic send and received, we can see how well the information was transmitted.

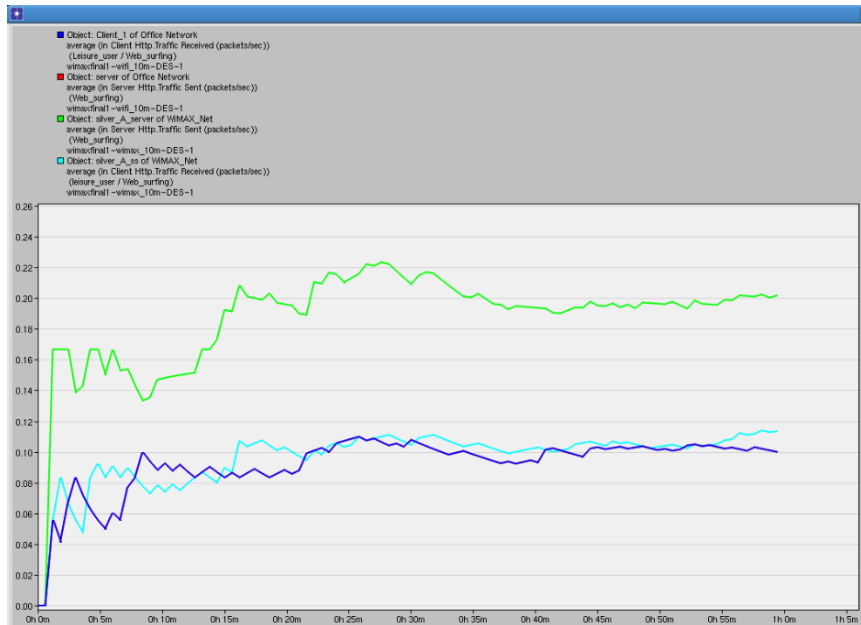


Figure.7 Traffic sent and received by WiMAX and Wi-Fi at 10 meter scenario

Figure.4 shows the performance of both communication networks at 10 meter range. Although 10 meter is not a realistic simulation for WiMAX, we use this extreme scenario to demonstrate the behavior of these two networks in close range environment. In the figure, the green line represents the traffic sent by WiMAX base station, the light blue line represents the traffic received by the WiMAX client, and red line which represents the traffic received by Wi-Fi client is overlapped by the blue line which represents the traffic sent by Wi-Fi access point. As stated earlier, two lines representing Wi-Fi traffic sent and receive overlaps. This means that at 10 meter range, the Wi-Fi transmission is nearly perfect with no packet loss. Whereas the variation between two lines representing the traffic sent and traffic receive for WiMAX meaning that there is some packet loss during the transmission process for WiMAX. This observation suggests that Wi-Fi network is having much better performance at 10 meter scenario.

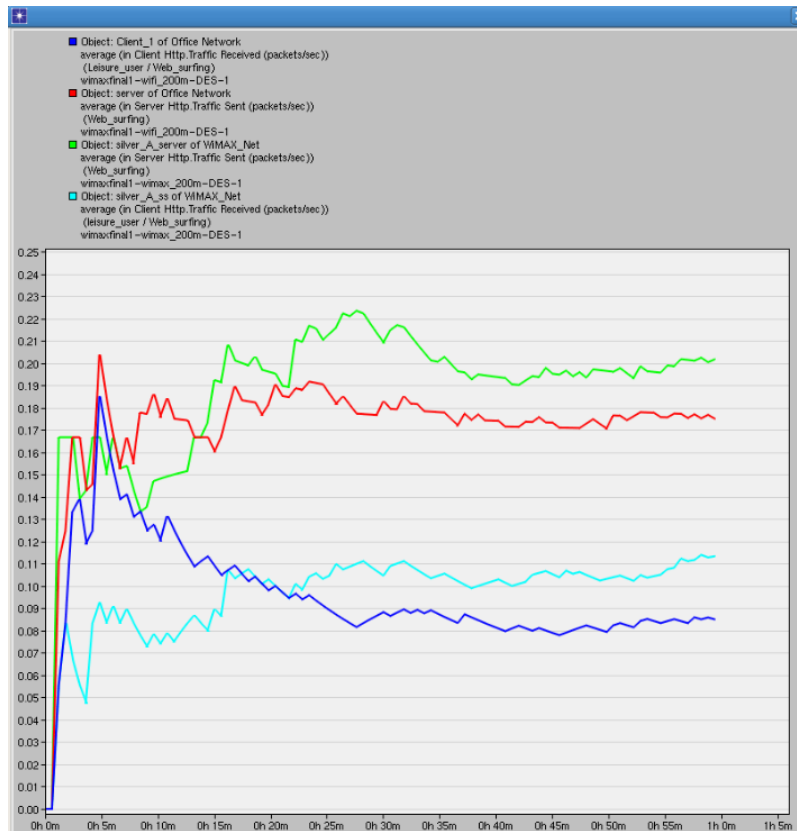


Figure.8 Traffic sent and received by WiMAX and Wi-Fi at 200 meter scenario

Figure.5 demonstrates the performance of the traffic sent and received by the WiMAX network and Wi-Fi network where each line representing same data as 10 meter scenario. This figure shows similar variation between the traffic sent and received for both WiMAX network and Wi-Fi network. However, two lines related to WiMAX network is higher than corresponding lines related to Wi-Fi network. This means that with similar packet loss during the transmission process, the WiMAX have lower overall packet loss rate and is showing a slightly advantage over Wi-Fi.

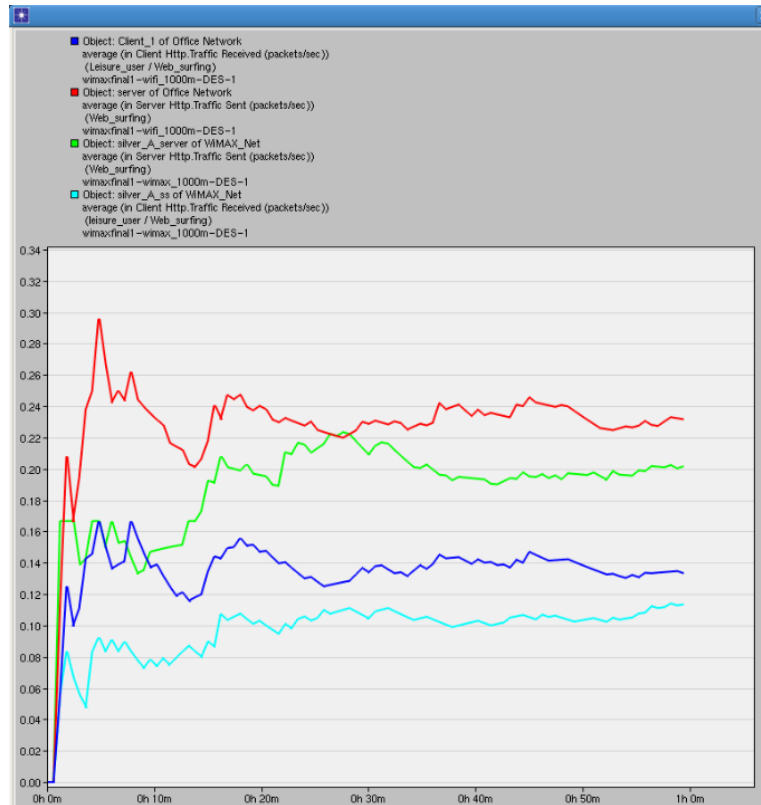


Figure.9 Traffic sent and received by WiMAX and Wi-Fi at 1000 meter scenario

Figure.6 demonstrates the performance of the traffic sent and received by the WiMAX network and Wi-Fi network where each line representing same data as previous two scenarios. In 1000 meters scenario however, the WiMAX start to show advantage over Wi-Fi as it has less packet loss during the transmission process with smaller variation between the traffic sent and received.

## 4.2 Throughput

The average rate of successful packet delivery through the channel is showing visually as the throughput in the following figures. All three figures showing the throughput for WiMAX is higher than Wi-Fi. This suggests that the WiMAX is overall a better communication network by only looking at the aspect of throughput.

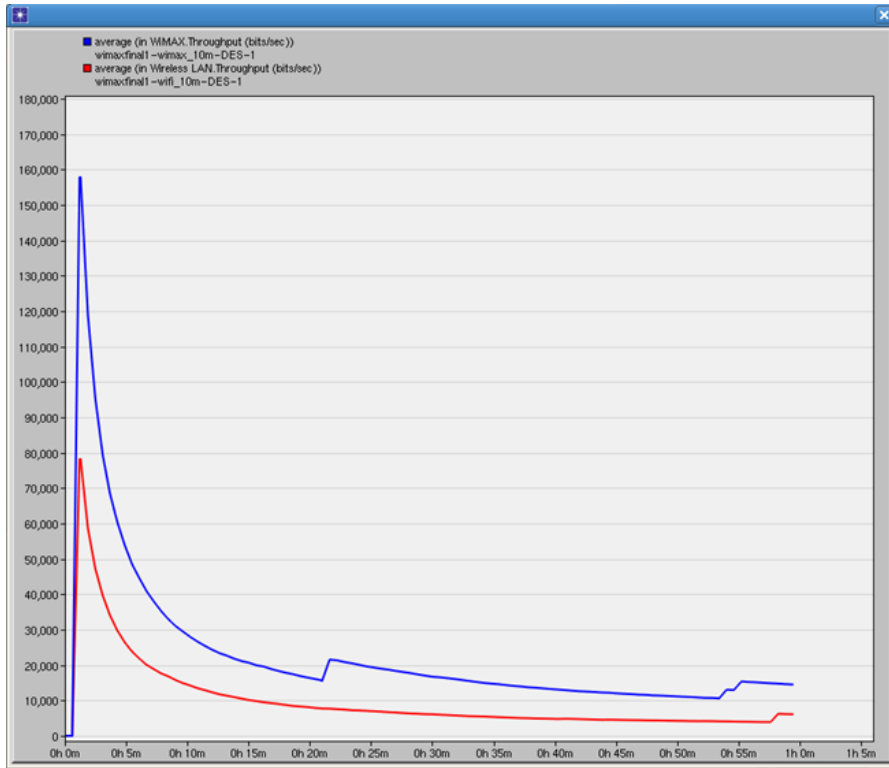


Figure.10 Throughput 10 meter

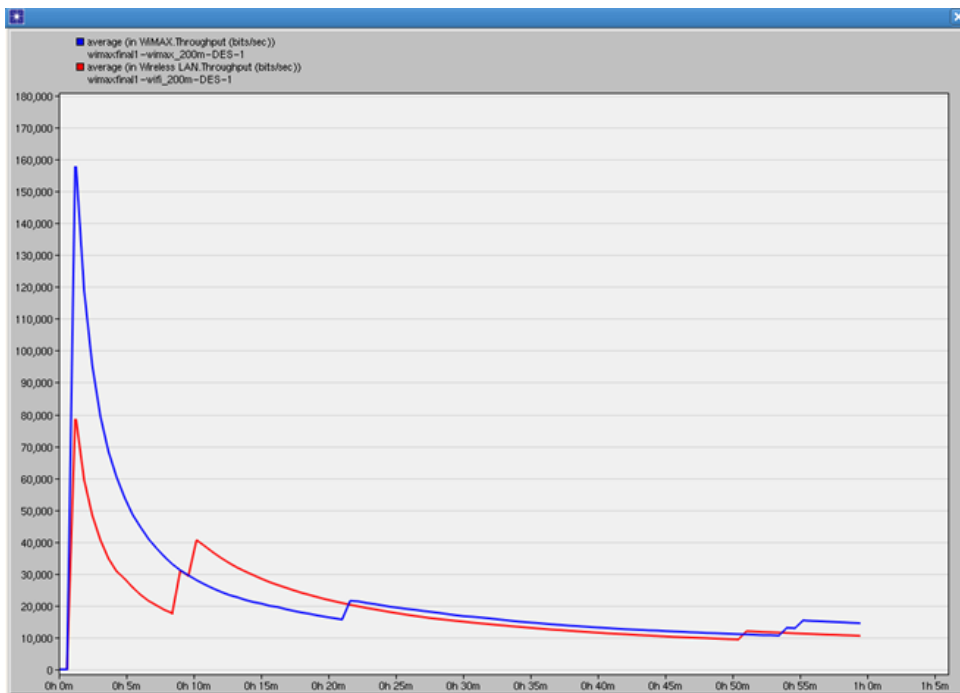


Figure.11 Throughput 200 meter



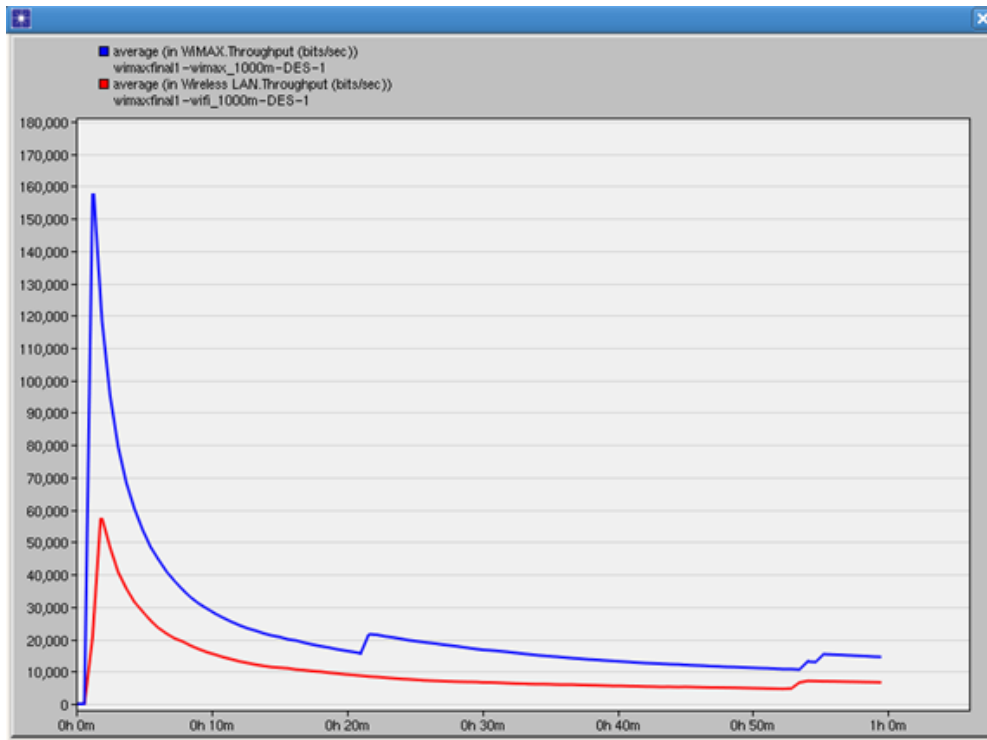


Figure.12 Throughput 1000meter

### 4.3 Delay

Another aspect we compared is the delay. Delay has major impact on people internet accessing experience which is expected to be smooth by any user. The delay provides a more intuitive feel for the performance of the corresponding communication network where a better network would have a lower delay.

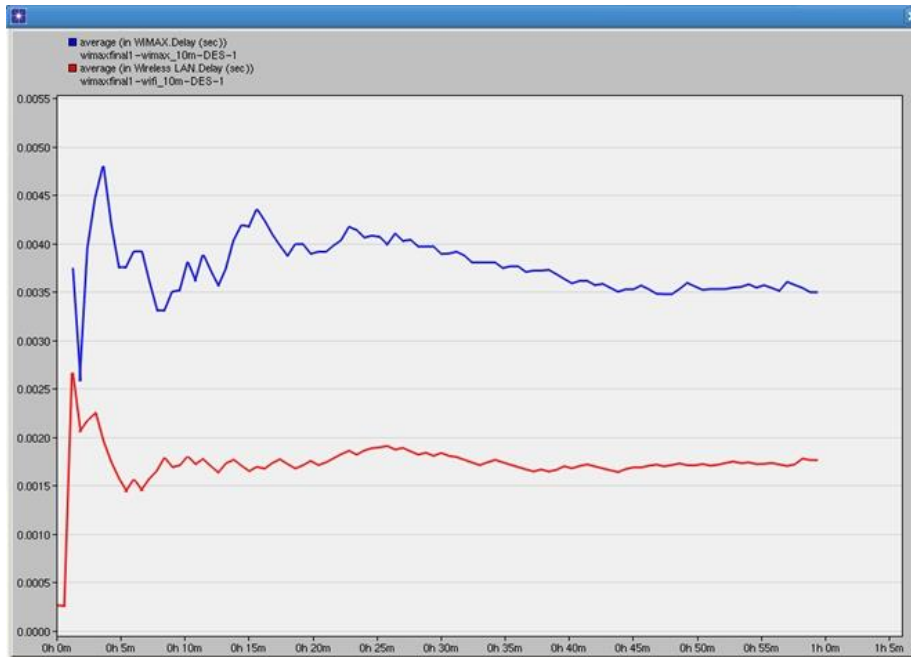


Figure.13 Delay of WiMAX and Wi-Fi at 10 meter scenario

Figure.10 shows the delay of WiMAX and Wi-Fi network at 10 meter scenario where the blue line representing the delay of WiMAX and the red line represent the delay of Wi-Fi. The delay of Wi-Fi is almost halved of the delay of WiMAX. This means the transmission of Wi-Fi is faster and smoother.

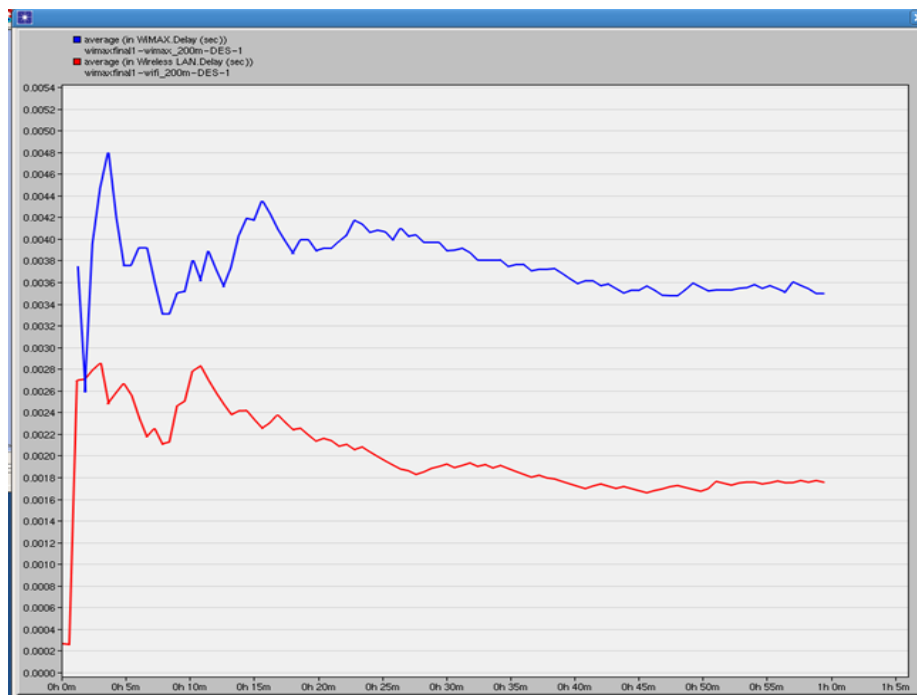


Figure.14 Delay of WiMAX and Wi-Fi at 200 meter scenario

Figure.11 shows the delay of WiMAX and Wi-Fi at 200 meter scenario where each line representing same network as the 10 meter scenario. At 200 meter, Wi-Fi still remains the superiority over WiMAX as its delay still remains lower. This mean the Wi-Fi network is still the faster network within 200 meter range.

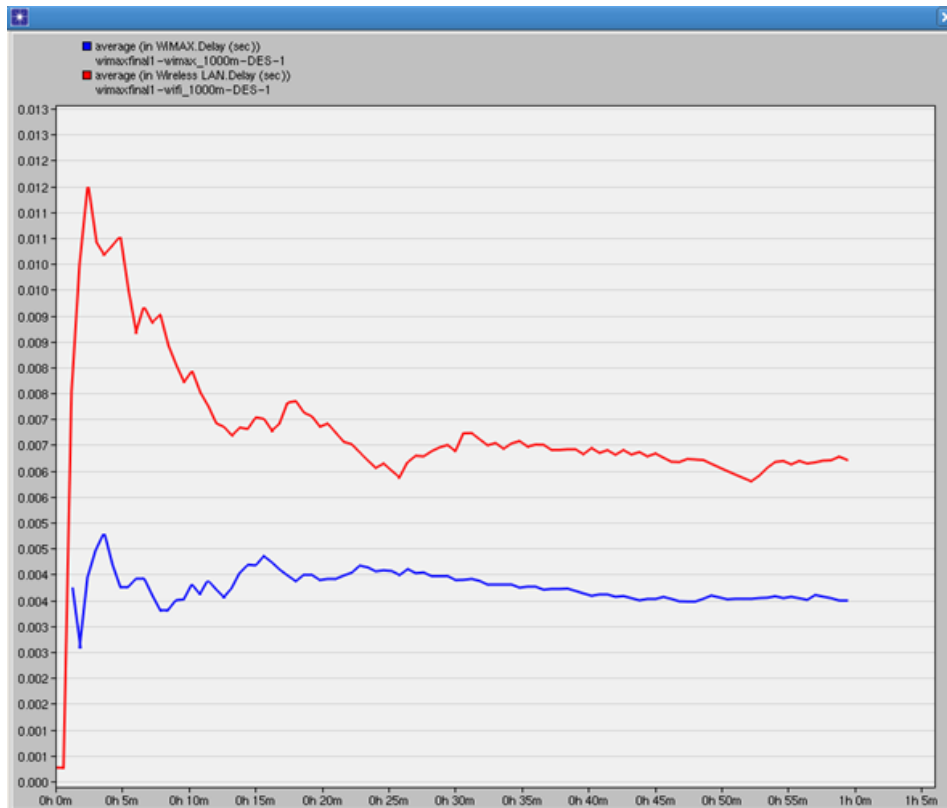


Figure.15 Delay of WiMAX and Wi-Fi at 1000 meter scenario

Figure.11 shows the delay of WiMAX and Wi-Fi at 1000 meter scenario where each line representing same network as pervious two scenarios. In this scenario, the delay of Wi-Fi dramatically increased causing WiMAX became the superior network which has lower delay. This scenario show the sensitivity of Wi-Fi and the stability of WiMAX

By looking at the delay of all three scenarios we notice that while the delay of Wi-Fi network varies with significant differences, the delay of WiMAX network remains stable as the distance between the base station and client increases which stays in the range between 0.0035s to 0.0040s as the distance has increased from 10 meter to 1000 meter. This shows that the WiMAX network is insensitive to distance increase comparing to Wi-Fi.

## 5. Discussions and Conclusions

From the analyses of our data, we can conclude that at 10 meter range scenario, Wi-Fi has better performance with higher band width efficiency and lower delay. However this advantage decays and eventually is exceeded by WiMAX. At 200 meter range both network have similar performance while WiMAX starts to show slightly advantage, and at 1000 meter range WiMAX have better performance and is the better network while have less packet loss rate, higher throughput and lower delay. This result did meet our expectation, and does explain why these two communication networks have their different applications whereas WiMAX is more regional oriented, and Wi-Fi is used for a much smaller area.

The fast transmission speed of Wi-Fi makes it a perfect communication network for close range information transmission. However, it is dramatically affected by the distance between the access point and the client. As a result, Wi-Fi is rarely used for long distance information transmission. Meanwhile, the superiority of WiMAX where it is much less sensitive to distance increases and is capable to remain relatively stable with greatly increased distance makes is a great choice for long distance information transmission.

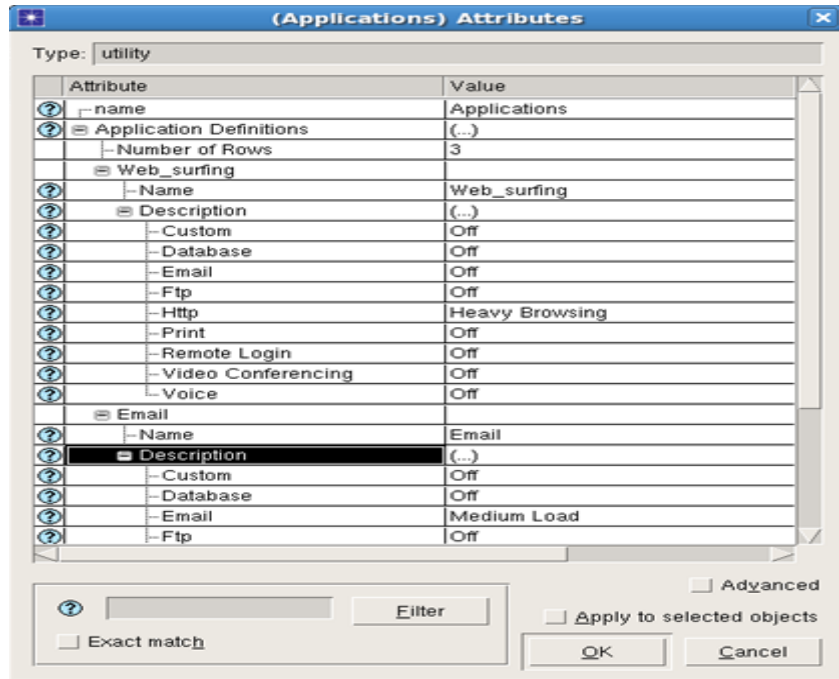
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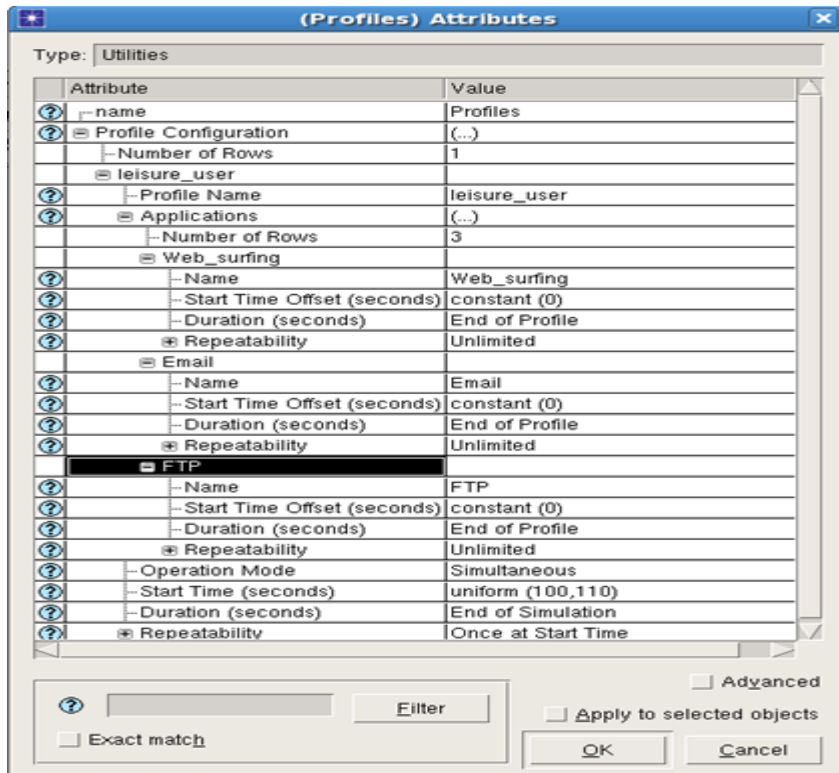
## Appendix:

### Parameters

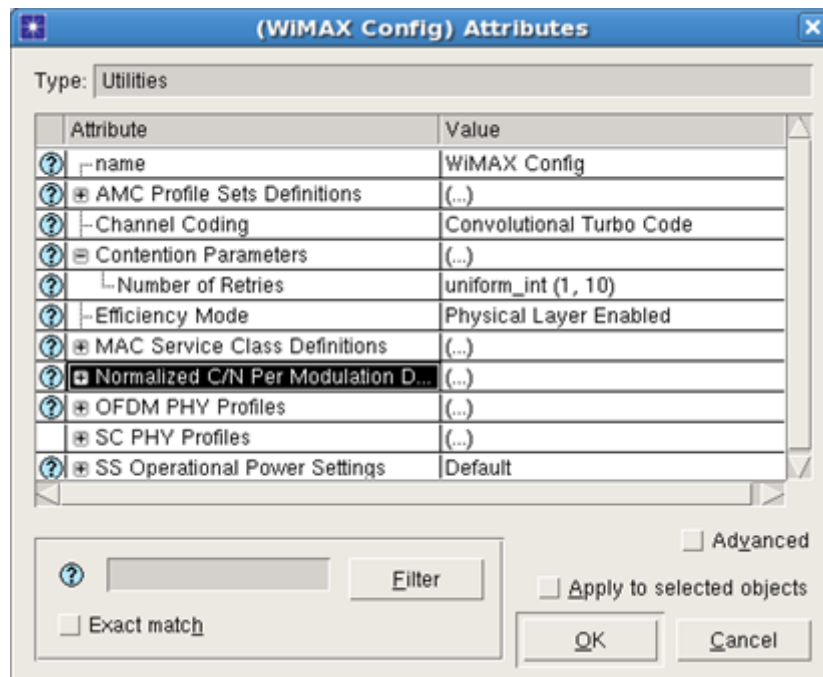
#### Application Definition for WiMAX



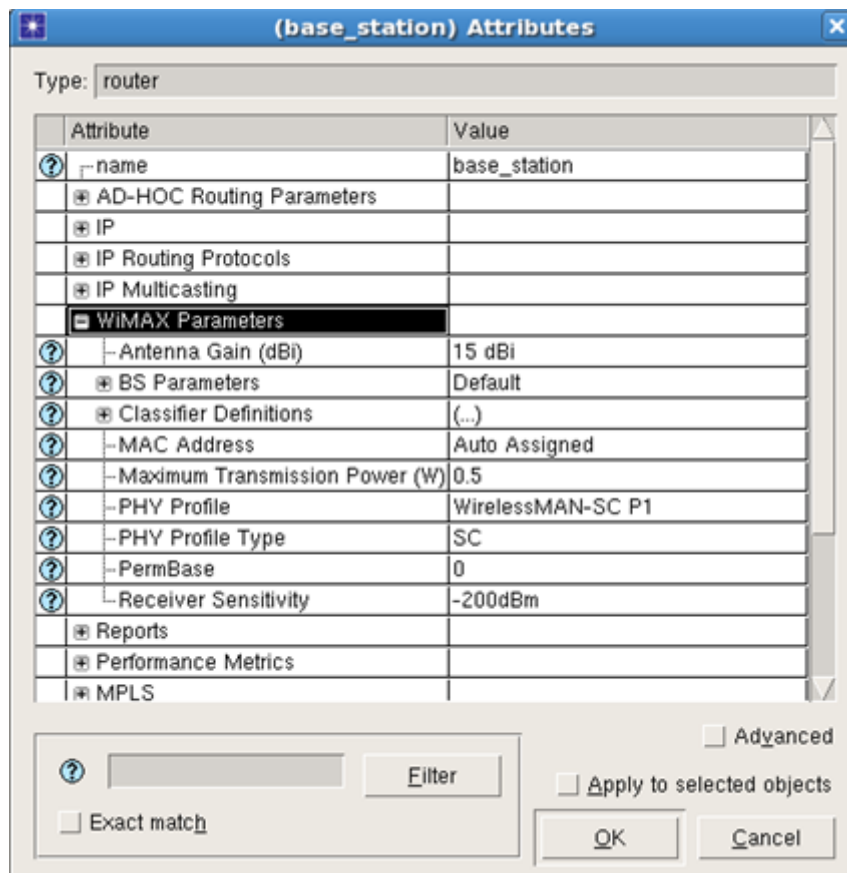
#### Profile Definition for WiMAX



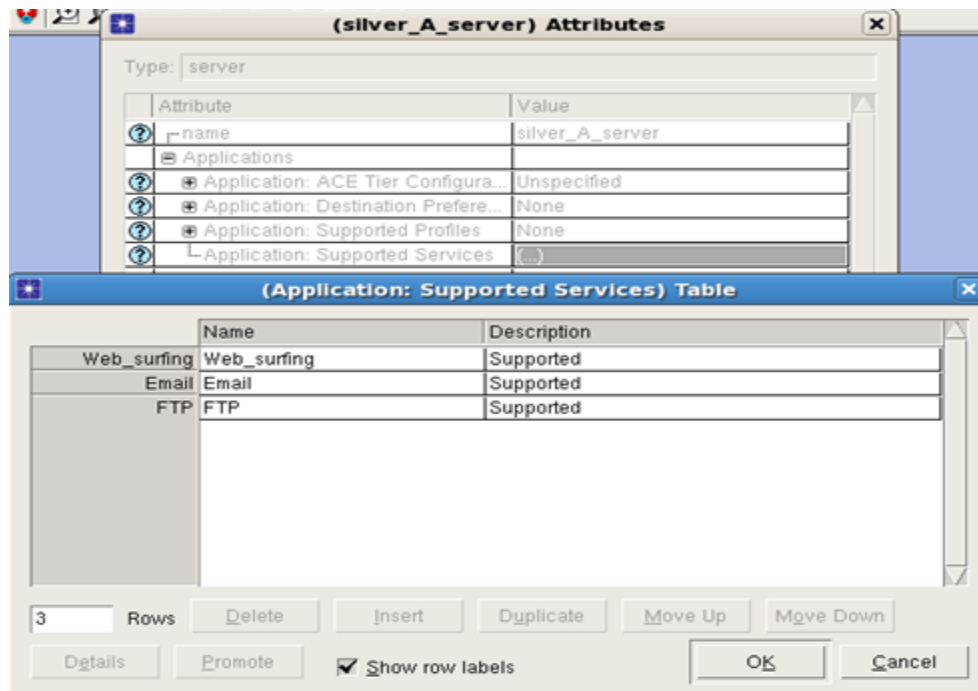
## WiMAX configuration



## WiMAX base station



## WiMAX server



## Profile Definition for Wi-Fi

