Effective Model for Achieving a High Efficiency Level in WiMAX: Karak Case Study

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Summary
Worldwide Interoperability for Microwave Access (WiMAX) is a wireless communication technology that aims to provide wireless data over long distances through various methods as an alternative to cable and digital subscriber line from point-to-point links to full mobile cellular type access. This study is devoted to designing a WiMAX network in Karak City in Jordan, with broadband access insurance for wireless Internet. Moreover, we examined the basic procedures for building a model that simulates a realistic WiMAX network system through four scenarios using the Hypertext Transfer Protocol and Voice over Internet Protocol applications. Finally, the structure and visualization of the basic and additional elements of the WiMAX network are discussed. The additional elements are responsible for the administration, management and maintenance of a network. This study also identifies several approaches to determine the number of base stations required to cover exposed and densely populated areas. Results show that the fourth scenario outweighs the first three scenarios in terms of throughput, transmission delay, and load data. Experiments were conducted using the wireless network simulator OPNET 14.5.

.Key words:
WiMAX, OPNET, throughput, delay, load, HTTP, VoIP.

1. Introduction

The need for data and information with the highest speed and quality is increasing rapidly in all sectors and at all levels of society. Telecommunication networks, particularly the Internet, have become the easiest and fastest means to achieve this objective. Consequently, the demand for advanced communication networks have increased. Thus, high-speed and large-scale services are required in all regions to keep up with the growing demand. Several methods are currently applied to connect to the Internet, access services, and exchange data. In the case of broadband access, service can be obtained by using several methods, such as Wi-Fi and asymmetric digital subscriber line (ADSL) for fixed connections and 4G and 3G for mobile phone connections. Despite the diversity of these technologies, they still suffer from challenges in many aspects, including the need for high speed and to provide services to far areas, such as rural areas and dangerous places. Worldwide Interoperability for Microwave Access (WiMAX) is a broadband wireless communication technology. WiMAX was selected by the WiMAX Forum in 2001 to upgrade the compatibility of the standard and its internal functionality [1]. WiMAX technology is used in many countries worldwide, including Arab countries, such as Jordan, which is the subject of the case study presented in this paper. WiMAX has many applications, such as in banking networks, disaster and public safety, educational networks, rural connections, and medical applications. Despite the advantages and applications of WiMAX technology, it still faces challenges because of several reasons. For example, WiMAX provides satisfactory connection for approximately 70 km [1]. However, researchers are attempting to maintain the quality of service (QoS) provided with the increase in distance. Another challenge faced by WiMAX is communication speed, because when a user moves away from the tower, speed decreases to 14 Mbit/s [3]. Meanwhile, sharing bandwidth among users remains an issue that concerns professionals. Therefore, our study aims to build an effective model in Karak City to control the aforementioned challenges, albeit partially. The remainder of this paper is organized as follows. Section 2 provides a brief description of related works. Section 3 describes the environment of our simulation. Section 4 details the simulation setup and scenario parameters. Section 5 presents the evaluation performance analysis. Section 6 provides the simulation results and analysis. Finally, Section 7 concludes the study.

2. Related Works

The service level received by the user from his/her Internet service provider depends on the parameters of WiMAX. These parameters include delay, load, and throughput. In [4], the OPNET Modeler was used to design a simulator based on the parameters of throughput, average jitter, packet loss, and delay. Then, the standards were analyzed by designing three scenarios using a different number of work stations. In [5], the Voice over Internet Protocol (VoIP) technology was used to analyze three of the most well-known queuing techniques, namely, first in, first out queuing, priority queuing, and weighted fair queuing (WFQ), for WiMAX technology. Experiments were

Manuscript received September 5, 2017
Manuscript revised September 20, 2017

conducted using the OPNET simulator with several criteria, such as packet delay, variation packet, and end-to-end delay. The results showed that the first two types of queuing techniques do not have an effect when the number of workstations is 15. The results also showed that WFQ is preferred over the other methods. In [6], an analytical study of implementing video conferences based on QoS coefficients was conducted. OPNET Modeler 14 was used for the experiments. This previous study aimed to evaluate video conference standards for WiMAX networks by modeling a number of scenarios, such as 64-QAM3/4, QPSK3/4, 16-QAM1/2, 16-QAM3/4, 64-QAM1/2, 64-QAM2/3, and QPSK1/2. A number of QoS parameters were implemented to improve the results. The results showed that the best delay value was 0.02 s when using the 64-QAM3/4-PLE scenario. Meanwhile, the best value for load was 1000–1500 packets/s with the 64-QAM2/AMP scenario and the best throughput value was 9000–10000 packets/s using the 64-QAM3 method/4-FME. In 2017, Kamini et al. [7] simulated and evaluated the WiMAX network performance model based on three different networks, namely, small, medium, and large, with different numbers of subscriber stations (i.e., 15, 25, and 45) used for each network. For the number of base stations, 3, 5, and 8 were used for each network. Three different scenarios were implemented using the simulator. The performance of the system was assessed based on initial ranging activity, delay, and total transmission power. The results proved that the second scenario achieved the highest value in terms of initial ranging activity, whereas the third scenario achieved the lowest value. The third scenario achieved the highest value in terms of delay, whereas the first and second scenarios achieved lower values. The first scenario achieved the highest value in terms of total transmission power, whereas the second scenario achieved the lowest value. As one of the most well-known works on analyzing the performance of the smart grid, Neagu and Hamouda [8] proposed a model for the communications layer based on the WiMAX network. In this model, most known parameters, such as latency, throughput, network capacity, and packet loss, were considered in analyzing the performance of the traffic model resulting from the use of various applications in the Distribution Area Network. Traffic model simulations have been implemented using OPNET based on four common metrics, namely, video surveillance, metering and pricing, voice support for workforce, and electric car. In [10], a survey on various WiMAX QoS parameters that affect the performance of a WiMAX network was conducted in several scenarios. The survey proposed that critical QoS parameters are important in underlining the performance of a WiMAX network. The author investigated various critical QoS parameters, such as throughput, packet loss, average jitter, and average delay for VoIP and video traffic using the ns-2 simulator. The simulation indicated that UGS has the lowest values for these QoS parameters. In [11], the authors conducted a statistical analysis of the QoS parameters of mobile WiMAX. Two important QoS parameters of VoIP service in a mobile WiMAX network were end-to-end delay and jitter. The authors conducted a statistical analysis of these two parameters. Previous works showed that the key parameters that affect the QoS of a network are throughput, delay, jitter (packet delay variance), packet delivery ratio, and packet loss ratio. In [12], a location-based performance scenario and critical QoS parameters, namely, delay and throughput (packets/s), were investigated. The values of the QoS parameters were not optimized because only a small number of nodes were considered. In [13], important QoS parameters in the WiMAX network were investigated. Furthermore, crucial QoS parameters, such as delay, packet dropped ratio, and throughput, were calculated for 3–35 mobile nodes in the WiMAX network. The OPNET module was used to create the WiMAX network architecture, and each QoS parameter was analyzed. The results were helpful in analyzing the QoS parameters of the WiMAX network, and the optimum values of the QoS parameters were obtained with an increase in the number of mobile nodes of the WiMAX network. In [2], the application of a decoration molding technology was described. The application of this technology results in a more desirable design of antennas by adding new values, such as the increased accuracy of dimensions and the capability to design antennas on 3D surfaces.

3. Proposed Model

In this study, a WiMAX network is designed to cover several villages in Karak City. This network must include the basic elements of the general engineering environment of a WiMAX network, such as access service network, backhaul, network operations center, or connectivity service network. Other elements, such as customer service offices, fault management centers, and call centers, are necessary to manage, organize, and facilitate the mechanisms of service recipients with service providers to facilitate access to the service. We used the environment of the OPNET Modeler to build the WiMAX network to implement the simulation model. The number of base stations, subscriber stations, and other parameters should be determined to configure the WiMAX network. Then, the model was simulated and the results were analyzed to determine the feasibility of the implementation of this project in real life. Figure 1 illustrates the main steps for designing our proposed WiMAX network.

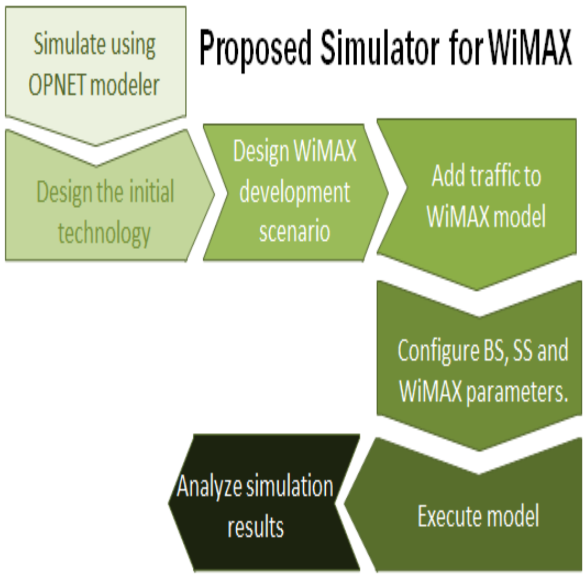

Fig. 1 Steps of the proposed simulation model.

We initially designed and used the WiMAX network using OPNET and configured it to adjust the settings and parameters of this network based on a technical survey conducted in Karak City villages, which considered the geographical terrain, population density, and buildings. From the results of the field survey, the propagation of the transmitter and the covered area were determined. The findings depend on the open areas in the village. Line-of-sight (LOS) propagation was used in open and flat areas, whereas non-LOS (nLOS) propagation was used in high population density areas. Thus, the number of base stations required to cover the villages was determined in terms of area and the required capacity was disregarded. The principles of propagation are described as follows.

1) Open areas (LOS propagation): In these areas, the signal covers approximately 50 km starting from the base station, depending on several factors, such as tower height, transmission power, and environmental obstacles. Thus, the base station covers a circle with a radius of approximately 50 km^2. The area covered by each base station is calculated according to the circle law, as expressed in Equation (1). If we denote the circle area by *A*, then

$$A = \pi r^2, \qquad (1)$$

where r is the radius. Thus, the area of each base station is 3.14 × 502 = 7850 km^2. Hence, according to the area of each village, the number of base stations required to cover the open areas of all the villages can be calculated by finding the dividing product for the open areas of each village at 7850 km^2, as expressed in Equation (2):

$$N = \frac{O}{A}, \ (2)$$

where N is the number of base stations, and *A* = 7850 km^2 is the area of the circle. For example, we assume that the open spaces of the Mutah Region have an area of 47100 km^2; then, according to Equation (2), the number of base stations is 47100/7850 = 6 base stations.

2) High population density areas (nLOS): In this case, the signal reaches a distance of 8 km starting from the base station, which indicates that the signal covers a circle with a radius of 8 km^2. Thus, the area covered by the base station is 3.14 × 82 = 200.96 km^2. Therefore, we assume that the high population density area in Mazar Village is 5500. Then, the number of base stations is 5500/200.96 = 27.368 (28 base stations). Thus, we have calculated the number of base stations required to cover the entire area of Karak for open and densely populated areas.

3) System capacity is the number of subscribers that request the service, where the number of base stations can be increased according to the number of subscribers and the required capacity. This capacity is determined by several factors, including the technical specifications of the base station, the number of sectors, and the broadband channel. In our system, we assume that the number of subscribers that requires this service is half the number of ADSL subscribers with different capacities (i.e., 256 K, 512 K, 1 M, 2 M, 4 M, 8 M, 16 M, and 24 M). The number of subscribers increases as a result of the technological development in the region and the modernity of society. In accordance with the latest version of IEEE 802.16, WiMAX can achieve data transfer rates of up to 100 Mb/s for mobile stations and 1 Gb/s for fixed stations based on the specifications and requirements set by the International Telecommunication Union for International Mobile Telecommunications-Advanced. In this study, the data transfer rate is 75 Mb/s in the 20 Mb/s channel bandwidth, depending on the frequency allowed for the Middle East (i.e., 3.5–5 GHz) [9].

4. Simulation Setup

In this study, we simulated and evaluated a WiMAX network using three common performance measures and QoS. Two scenarios were implemented using Hypertext Transfer Protocol (HTTP) and VoIP applications. The performance of each scenario was assessed based on throughput, load, and delay. The first scenario includes four different sub-scenarios using the HTTP application. Meanwhile, the second scenario has the same scenarios using the VoIP application, with modifications in the number of base stations and subscriber stations in each sub-scenario.

4.1 General description of the scenarios

The simulation model includes two basic scenarios, each of which includes many base stations, with four subscriber stations and a set of links between these stations, as well as a server and the configuration files for the management and organization of the network (i.e., WiMAX configuration, profile definition, and application definition). Figure 2 shows the WiMAX network model.

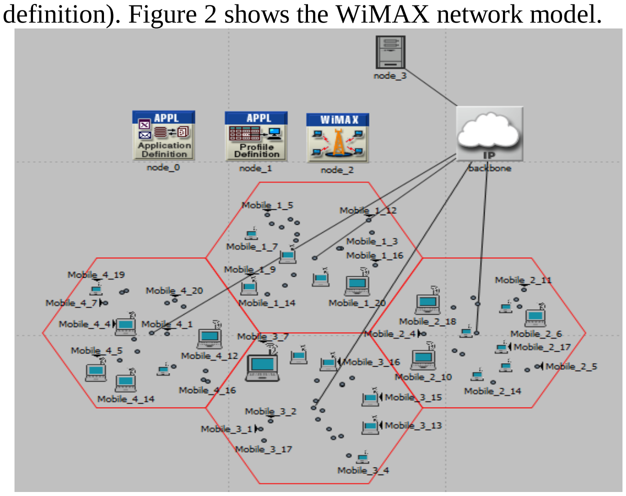

Fig. 2 WiMAX network model

Each scenario includes four sub-scenarios.

4.1.1 First Main Scenario (HTTP application)

The first main scenario is based on the HTTP application with four sub-scenarios. The first sub-scenario consists of 4 base stations with 10 subscriber stations, as shown in Figure 3. In the second sub-scenario, the number of subscriber stations associated with each base station was multiplied by 4 base stations with 20 subscriber stations. In the third sub-scenario, the number of base stations was increased to 8 base stations connected to 10 common stations. Finally, in the fourth sub-scenario, the number of subscriber stations in the third scenario was adjusted to 30 subscriber stations. The following figures illustrate the aforementioned four sub-scenarios. Figure 3 shows the settings adopted for base stations and subscriber stations.

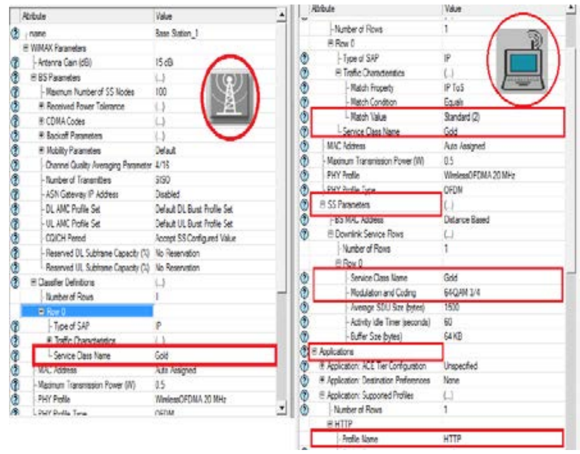

Fig 3. Settings adopted for base stations and subscriber stations

Figure 4 shows the application definition for WiMAX and the WiMAX configuration settings with HTTP application.

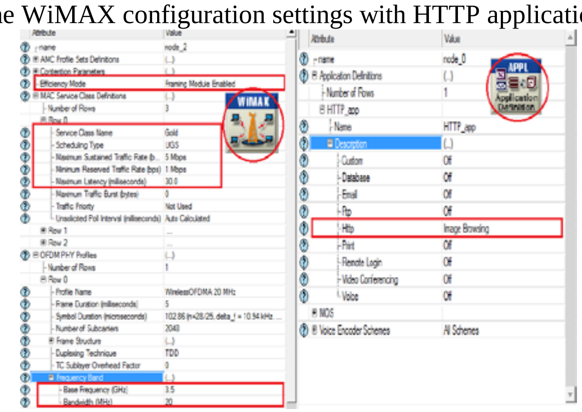

Fig. 4 Application definition for WiMAX and the WiMAX configuration settings with HTTP application

4.1.2 Second Main Scenario (VoIP application)

The second main scenario is based on evaluating the same sub-scenarios used in the first main scenario with the same performance metrics for the second main scenario, but the difference is that VoIP was implemented instead of HTTP, as shown in Figures 5 and 6. Figure 5 shows the settings adopted for base stations and subscriber stations.

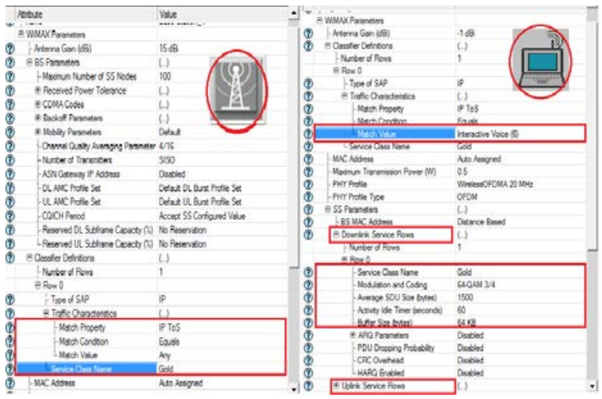

Fig. 5 Settings adopted for base stations and subscriber stations with VoIP application

Figure 6 shows the application definition for WiMAX and the WiMAX configuration file with VoIP application.

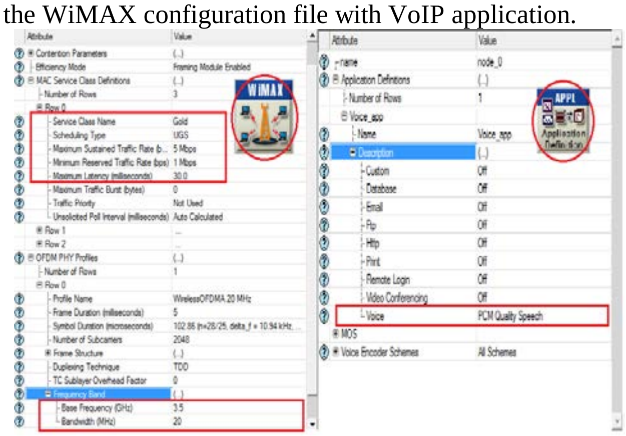

Fig. 6 Application definition for WiMAX and the WiMAX configuration file with VoIP application

5. Performance Analysis and Simulation Results

Our simulation model was evaluated in terms of delay, throughput, and data load.

5.1 Results of the first main scenario

The first sub-scenario in the case of HTTP application achieved a throughput of approximately 5 Mb/s, which doubled in the second sub-scenario as the number of subscriber stations increased to 80 subscribers. Meanwhile, in the third sub-scenario, the number of base stations doubled to 8 stations. However, throughput did not differ significantly from the second sub-scenario. In the fourth sub-scenario, throughput increased significantly, as shown in Figure 7.

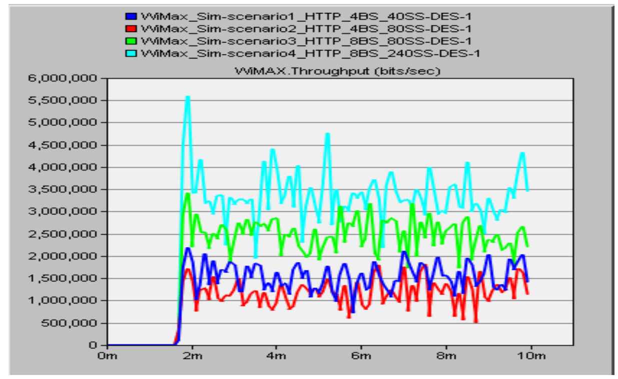

Fig. 7 Throughput of the first main scenario

The delay time achieved in the first sub-scenario was less than that in the second sub-scenario. The lowest delay was achieved in the third sub-scenario and the highest delay was achieved in the fourth sub-scenario because of the number of base and subscriber stations being 8 and 240, respectively, as shown in Figure 8.

Figure 9 shows that the load increased in the second sub-scenario compared with that in the first sub-scenario. Meanwhile, the load did not significantly change in the third sub-scenario compared with that in the second sub-scenario. The load was also significantly changed in the fourth sub-scenario.

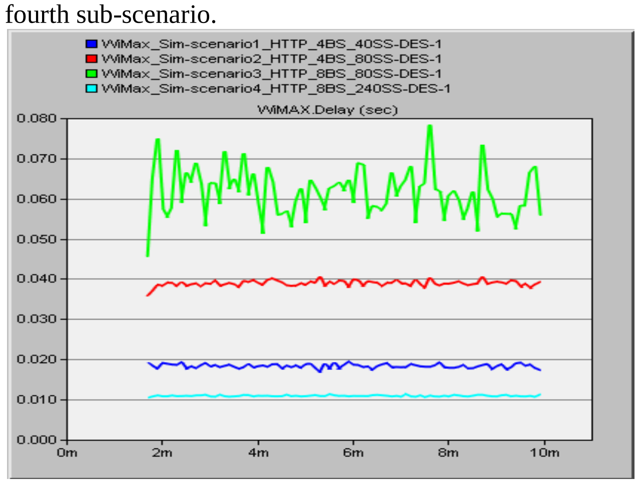

Fig. 8 Delay of the first main scenario

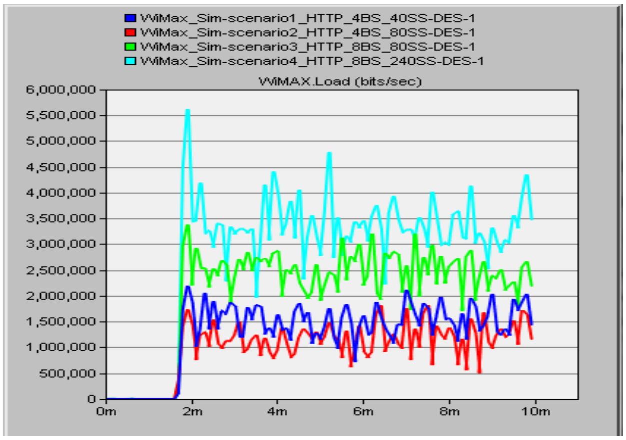

Fig. 9 Load of the first main scenario

5.2 Results of the second main scenario

The first sub-scenario in the case of VoIP application achieved a throughput of approximately 5 Mb/s, which doubled in the second sub-scenario as the number of subscriber stations increased to 80 subscribers. Meanwhile, in the third sub-scenario, throughput did not differ significantly from that in the second scenario as the number of base stations doubled to 8 stations. In the fourth sub-scenario, throughput increased significantly, reaching approximately 90 Mb/s, as shown in Figure 10.
The first sub-scenario achieved less delay than the second sub-scenario. Meanwhile, the highest delay rate was achieved in the third sub-scenario. The fourth sub-scenario also achieved less delay than that in the third sub-scenario, as shown in Figure 11.
Figure 12 shows that the load increased in the second sub-scenario compared with that in the first sub-scenario, but did not significantly change in the third sub-scenario compared with that in the second sub-scenario. Meanwhile, the load significantly changed in the fourth sub-scenario.

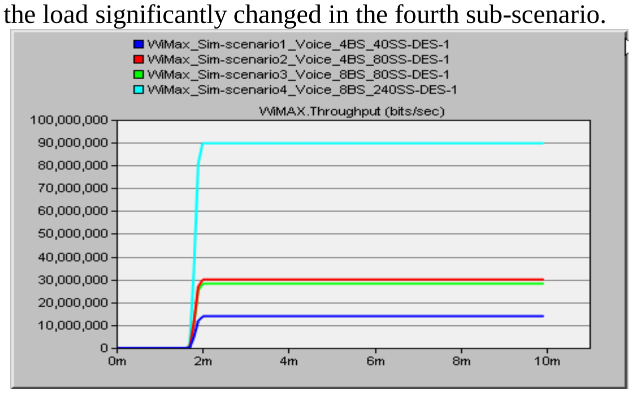

Fig. 10 Throughput of the second main scenario

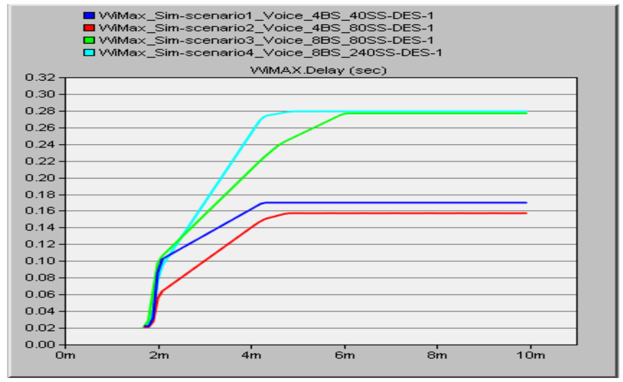

Fig. 11 Delay of the second main scenario

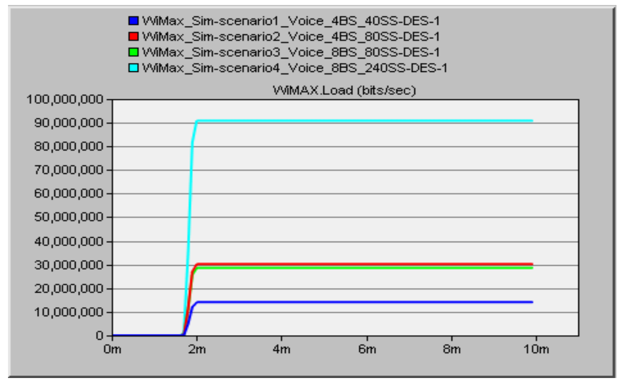

Fig. 12 Load of the second main scenario

5.3 Results of the main scenarios

The results of the two main scenarios are similar. In Figures 13, 14, and 15, the first main scenario achieved a throughput of 25 Mb/s, whereas the second main scenario achieved a throughput of approximately 90 Mb/s. These results were calculated according to the same standards and criteria based on the fourth sub-scenario of the two main scenarios. The first main scenario achieved less delay than the second main scenario. Finally, the load achieved in the first main scenario was less than that achieved in the second main scenario.

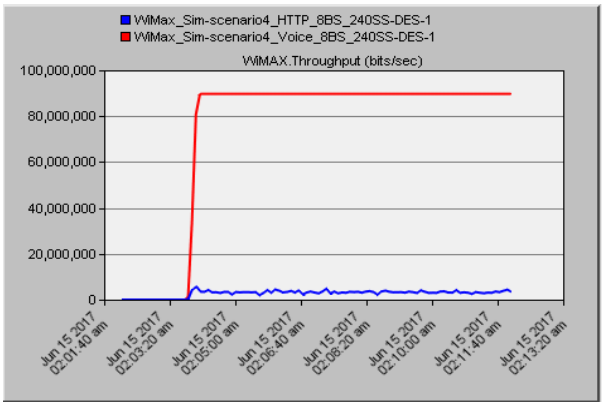

Figure 13 Throughput of the main scenario

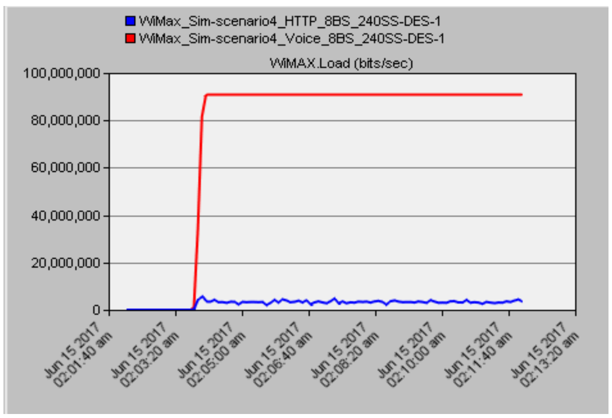

Figure 14: Load of the main scenario

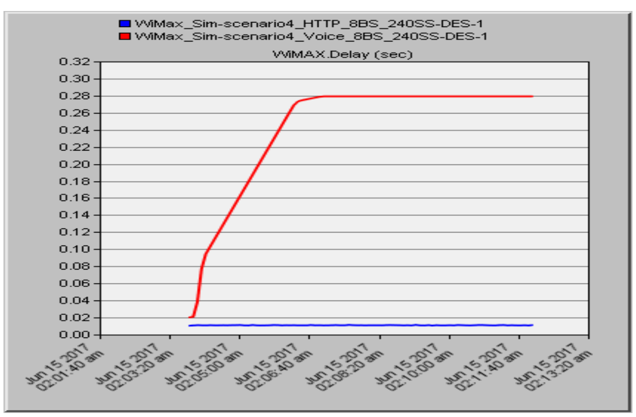

Fig. 15 Delay of the main scenario

6. Conclusions and Future Work

This study proposed a WiMAX technology simulation model, which was created using the OPNET Modeler, for the territory of Karak City. The results proved the effectiveness of the proposed method in Karak City, with the possibility of covering an area of 7850 km^2 with one base station in open areas and one base station for every 200 m^2 in populated areas. Moreover, the results proved that a high transportation rate of up to 100 Mb/s for the trajectory stations can be provided to Karak citizens through the application of a WiMAX network. The transportation rate can be up to 1 Gb/s for static stations. Furthermore, the scenarios that we have redesigned to apply this type of network can be rapidly implemented with low cost because a complex infrastructure is not required. The WiMAX network is flexible; thus, it can be applied to different geographical areas. On the basis of the results obtained in this study, we suggest that the WiMAX network can be implemented in Karak City and the rest of the kingdom cities with several modifications on the parameters to overcome natural obstacles, such as weather and buildings.

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