Improving the Quality of Service of Fixed WiMAX Networks by Decreasing Application Response Time Using a Distributed Model

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Abstract—In the most recent few years, there has been a meteoric rise in the number of different wireless networks, as has the demand for wireless data services and multimedia applications. An improvement in quality of service (QoS) is required in order to meet the ever-increasing demand while also providing a service that is of a higher standard. One of the most cutting-edge technologies, known as World Wide Interoperability for Microwave Access (WIMAX), was developed with the quality of service in mind during its development. Despite utilizing the most recent advancements in technology, the WiMAX network continues to struggle with QoS performance issues. A brand new distributed Client-Server model was designed for the fixed WiMAX Network in order to reduce application response time. This was done in order to improve the quality of service performance. In order to make a comparison with the existing centralized model, the performance of the proposed model was analyzed with OPNET Modeler 16.0. According to the findings, the newly proposed distributed Client-Server system is capable of satisfying the requirements set forth by its users owing to an improvement in QoS performance in terms of application response time when compared to the conventional model. The performance of the network was increased by the deployment of more Base Stations (BSs), Subscriber Stations, and the utilization of client-server Base Stations that were chosen by the Nearest Neighborhood Algorithm that was devised.

Keywords—WiMAX, QoS, application response time, OFDM, FDM base station, subscriber station and OPNET modeler 16.0

1 Introduction

WiMAX has become the clear frontrunner among cutting-edge technologies for establishing high-speed data links over long distances. WiMAX's minimal infrastructure makes it a viable option for resolving issues with last-mile wireless connections caused by things like multipath fading, environmental conditions (such heavy rains), interference, and differing service-level agreements (SLAs). It works particularly well in remote locations where it can be challenging to construct wired infrastructure. One Base Station (BS) and one or more Subscriber Stations (SS) make up the bare bones of a WiMAX network [1]. Downlink (DL) traffic refers to the direction of communication from base station (BS) to serving station (SS), while uplink (UL) traffic refers to the opposite direction of communication (from SS to BS). WiMAX's primary architectures are Point to Multipoint (PMP) and Mesh Architecture. In PMP, a single BS supplies all of the neighboring SSs [2]. While SSs do talk to one another, they often talk to the BS first. Each time the SS makes a connection request, the BS functions as a gateway to the network and is responsible for establishing and managing those connections. However, the mesh architecture is developed when communications between SSs are required. Since connections can be made over multiple hops in a mesh topology, a tree network topology is theoretically possible. The PMP architecture is incompatible with the mesh architecture since it only permits one hop transmission and has less signaling overhead than mesh mode does [3].

Due to the inherent unpredictability and significant variability of wireless infrastructures in comparison to conventional networks [4], the provisioning of QoS in WiMAX networks is done at the Medium Access Control (MAC) layer. WiMAX employs an association-oriented MAC architecture, where all downlink and uplink connections are controlled by the serving Base Station, and each connection is recognized with a connection identifier (CID), for data transmissions within the specific link [5]. The Support for Quality of Service (QoS) is an integral part of this design. For packets with a specific set of QoS parameters, such as traffic priority, maximum sustained traffic rate, maximum burst rate, minimum tolerable rate, scheduling type, ARQ type, the maximum delay, tolerated jitter, service data unit type and size, and bandwidth request mechanism to be used [6], the MAC layer allocates traffic to a service flow identifier (SFID). In recent years, Quality of Service has emerged as a crucial component of data routing in wireless sensor networks (WSNs). When the outcome of recognizing a task depends not only on proper recognizing in the environment but also on timely delivery, QoS necessitates legitimate time data transfer. In order to send voice, images, or data in real time (for example, to notify someone of a time-sensitive, high-priority incident), a specific delay and bandwidth are required [7].

The APM metric known as "Application Response Time" measures how long it takes for an application process to process a user's request for a service. It took into account the user's perspective when measuring. Actually, the user is the most important factor, and there are three main states of performance [8]: satisfaction, tolerance, and frustration. Users frequently engage with the app throughout the day, therefore their overall impression of the app is likely the result of a compilation of many different interactions. Frustration on the network is to be expected if response times are poor, but persistent delays, especially if the user's task is serial in nature, are guaranteed to annoy. For this reason, it is essential that network applications can respond quickly enough to keep up with the new requirements [9].

The proposed new distributed Client-Server model aims to decrease the Application Response Time for the Fixed WiMAX Network, which will improve the QoS performance. In this setup, a Client-Server BSs is chosen to distribute the network using a Nearest Neighborhood Algorithm. OPNET Modeler 16.0 will be used to analyze the results of the comparison between the suggested model and the current Centralized model. While the current centralized approach employs the FDM method of transmission, the proposed Client-Server architecture will use the OFDM method. To find out how much of an upgrade to the network can be expected from using the new distributed Client-Server model, we'll compare its performance to that of the current models. All of the components, including the Base Stations (BSs), the Subscriber Stations (SSs), and the client-server BSs, will combine to establish the quality of service (QoS) levels.

2 Related work

In recent years, both the availability of and demand for wireless data services and multimedia applications have increased dramatically, spurring the development of a plethora of new wireless networks. There has been a lot of study into Quality of Service (QoS) to figure out how to improve service to keep up with rising demand. Many of the articles have dealt with QoS concerns as the IEEE 802.16 standard has been developing and expanding. There is a brief overview of recent research in this area here. Basic mechanisms for achieving QoS in packet networks are reviewed by Guerin and Peris [10]. The mechanisms for providing differentiated services are discussed, as are the control path techniques required to facilitate agreement between users and the network on service definition. The IEEE 802.16 standard's QoS features are based on these ideas.

The integrated QoS Control for IEEE 802.16 is described by Chen et al. [11]. For Point-to-Multi-Point (PMP) mode, a quick signaling system is planned to supply a cross-layer integrated QoS. IEEE 802.16 networks are supported by a cross-layer QoS framework proposed by Mai et al. [12]. This paradigm proposes two novel ways for enhancing performance. Recent developments in network modelling, QoS mapping, and QoS adaptation in terms of delivering end-to-end QoS for video distribution over the wireless internet are described by Zhang et al. [13], who also give a broad framework of a cross-layer network-centric approach. Similarly, Chu et al. [14] propose a same structure for the 802.16 MAC protocol. It consists of a traffic classifier, an upstream scheduler for the SS, and upstream and downstream schedulers for the base station. To provide quality of service for 802.16 networks, a combination of priority scheduling and dynamic bandwidth allocation forms the backbone of the network's architecture. As an added bonus, it suggests productive methods for schedulers to use.

Alavi et al. [15] also offer an open architecture to support QoS mechanisms in IEEE 802.16 standards, which is similar to what is proposed in this study. They argue that the difficulty is in creating an efficient design to achieve the QoS requirements, despite the fact that the IEEE 802.16 standard offers various techniques to do so. That's why it's so hard to guarantee quality of service. They provide a design strategy to implement the suggested architecture for all types of traffic classes as specified by the standard, which would be a significant step toward resolving the problem. Cicconetti et al. [16]

discuss the topic of quality-of-service support in IEEE 802.16 networks. Using a prototype simulation of the IEEE 802.16 protocol, they assess the networks' efficiency.

In [17], Nair et al. detail the media access control techniques deployed in WiMAX networks. Discuss how this MAC protocol’s capability can be used to facilitate WiMAX deployments, including the sorts of provisioning and Quality of Service (QoS) that can be attained. In this article, we discuss the difficulties of implementing the WiMAX MAC to meet quality-of-service requirements. In [18], Sayenko et al. describe a scheduling method for the WiMAX backbone. WiMAX specifications don't specify the scheduling policy, or the algorithm to allocate slots. The door is open for creative enactment. From what they've seen in simulations, it's clear that the suggested scheduling algorithm can meet the needs of all WiMAX service types in terms of quality of service.

3 Research methodology

Simulations were the preferred method utilized for this study's analysis as the key tool employed for the measurement of the response time. The research conceptualized “response time” as the primary unit of measurement. Hence the study's overall goal was to better understand the relationship between the application response time and the application response time model in the context of the network scenario that was used for this study. The context for this research was the network that was utilized for the Fixed WiMAX network. In order to validate the model, the experimental simulations analysis was carried out.

3.1 Conceptual framework

The "Application Response Time" and the "Application Response Time model" in this research established a tradeoff, and the model that was proposed in this study was considered to be more effective as a result of this tradeoff. This is the foundation for the conceptual framework that has been proposed. From the point of view of the user, the Application Response Time (ART) is the most significant quality of service characteristic. It is the period of time that elapses between the sending of a request and the time at which the user is presented with the response to the request. A response time is the amount of time that has passed since an enquiry was made before receiving a response. The formula for calculating the Application Response Time is shown in Equation (1) [7].

$$ART = \frac{n}{r - Tthink} \tag{1}$$

where n is the number of concurrent users r is the number requests per second the server receives $Tthink$ is the average think time (in seconds).

This study proposed to model the application response time because there is a need to improve the situation. In order to do so, we used the average value of the response time that an application uses to respond to a number of requests per second. This value was determined by using the data from the study, and the calculated by Equation (2).

$$ART_{avg} = \frac{\sum_{i=1}^{n}\left(T_{SS_i - App\_server} + T_{\mathrm{Pr}oc}\right)}{r} \tag{2}$$

where
n= number of SS requesting the network information.
$T_{ssi\text{-}App\_server}$ = Time to send a request from SS_i to Application server.
T_{proc} = Time to process a single request from the application server
r = number of requests per second application server is receiving.
Another way to model Application Response Time is to use network response time.

$$ART = NRT + TRT \tag{3}$$

$$NRT = \frac{payload}{bandwith} + \left(APP\,Turns \times RTT\right) \tag{4}$$

where
Network Response Time (NRT) = the time between a user's action and the Network's response to the action.
Transaction Response Time (TRT) = the time taken for the application to complete the transaction.
Payload = the information content in bytes.
Bandwidth = the minimal link speed between client and server.
APP Turns = the number of interactions needed between the client and server to provide a response to the user.
Round Trip response Time (RTT) = the propagation time for data between the client and server.

$$TRT = SRT + CRT \tag{5}$$

where
TRT= Transaction Response Time
STR= Server Response Time
CRT = Client Response Time
where
Server response time (SRT) = the processing time required by the server.
Client response time (CRT) = the processing time required by the client.

The proposed Distributed Client-Server model will be having less application response time as compared to the Centralized Model because; the number of SS requesting from the central server will be less. Thus, the Client-Server BSs selections Algorithm, Client-Server BSs communication Algorithm as well as the Base Station and Subscribers Stations Communications Algorithm are presented. The Nearest Neighborhood Algorithm was used to describe the process of selecting clients and servers, and the flow chart was used to illustrate the process as shown in Figure 1. In this regard, some of the closest BSs will be chosen to serve as Server BSs in order to deliver network information to the closest BSs that do not already have the information.

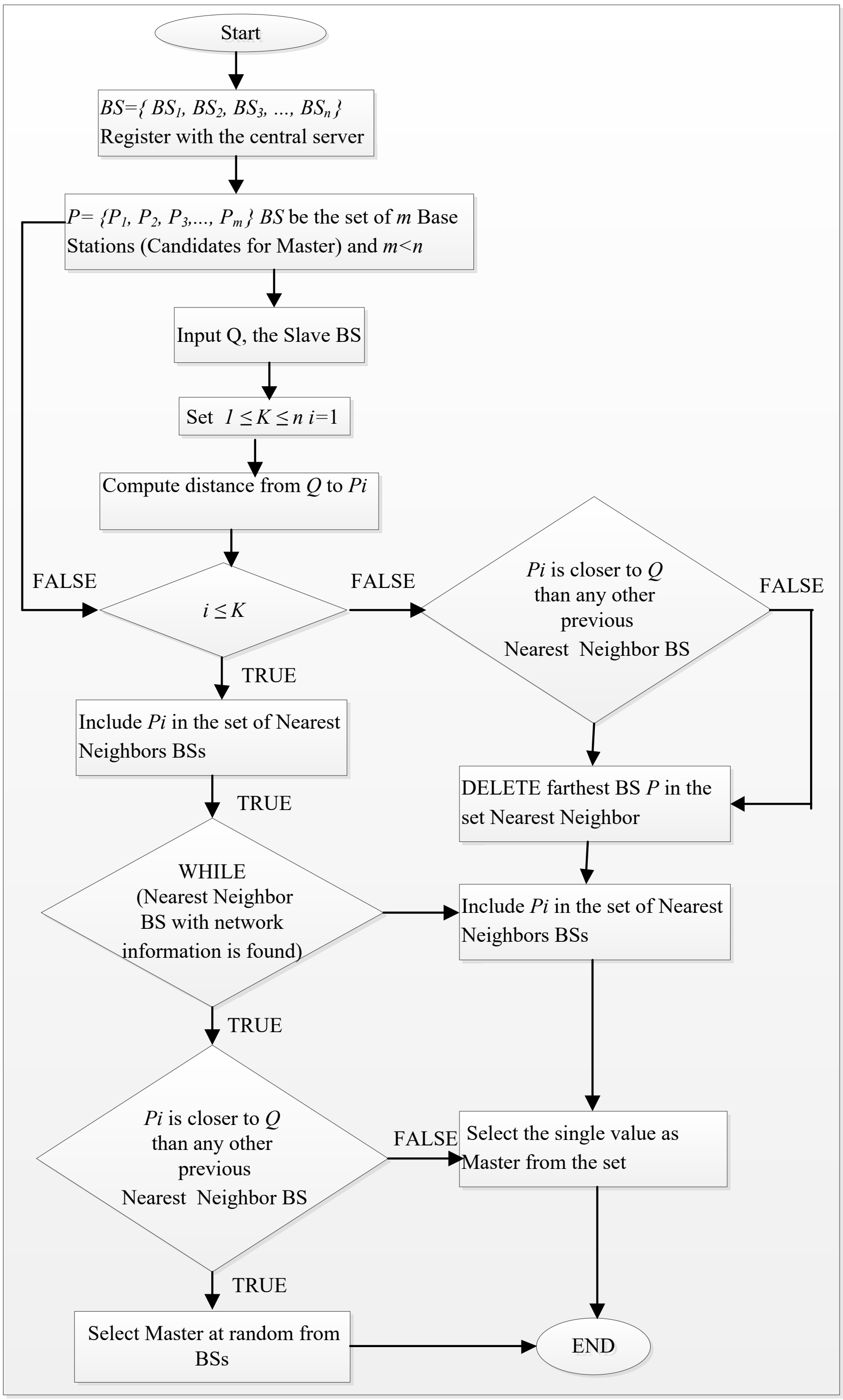

Fig. 1. Client-server BSs selection algorithm

Figure 2 present the algorithm that shows the process of the communication between the central server and a Server BS in order to get network information. At the initial stage of the communication, the selected server BS acts as a client BS. Central server will send an advertised existence message, Server BS also send the existence message, central server send acknowledgement to Server BSs, Server BSs sends network information request. Then the central server sends the authentication request, Server BS send authentication reply containing the authentication information. Finally, the central server process the authentications if the authentication is verified then the central server will sends the network information to the Server BS otherwise the network information be denied as presented in Figure 2.

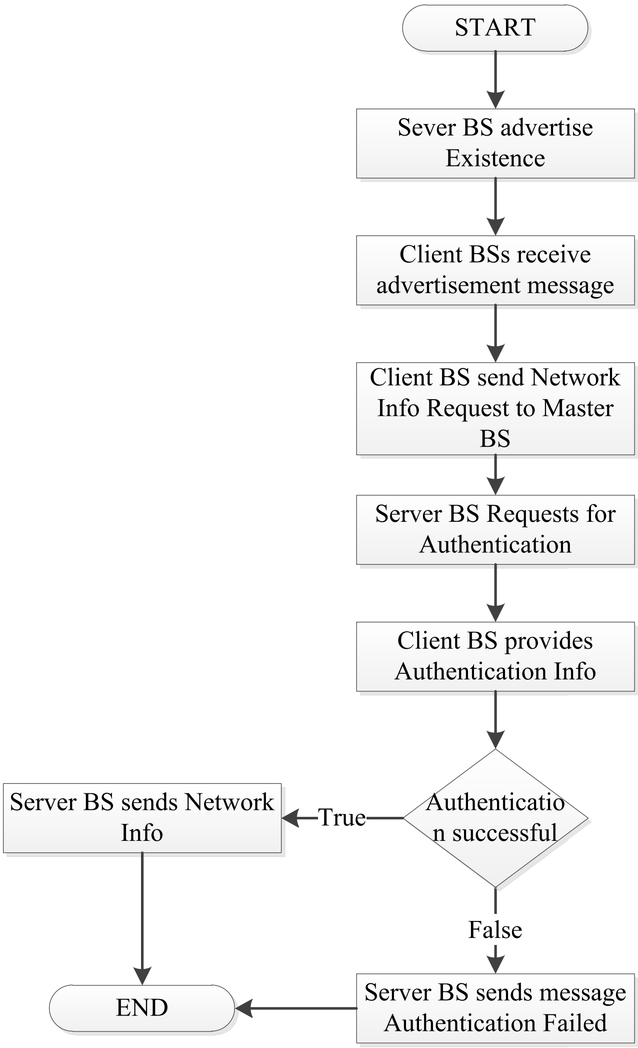

Fig. 2. Client-server BSs communication algorithm

The Base Station and Subscriber Stations communication algorithm described the communication between the BS and SSs for getting network information, where a SS will send network information request to BS, Server BS will send an authentication request to SS for security and others, the SS sends authentication reply to BS, and then the authentication will be processed. If the authentication is verified the network information will be sent to SS as discussed in Figure 3.

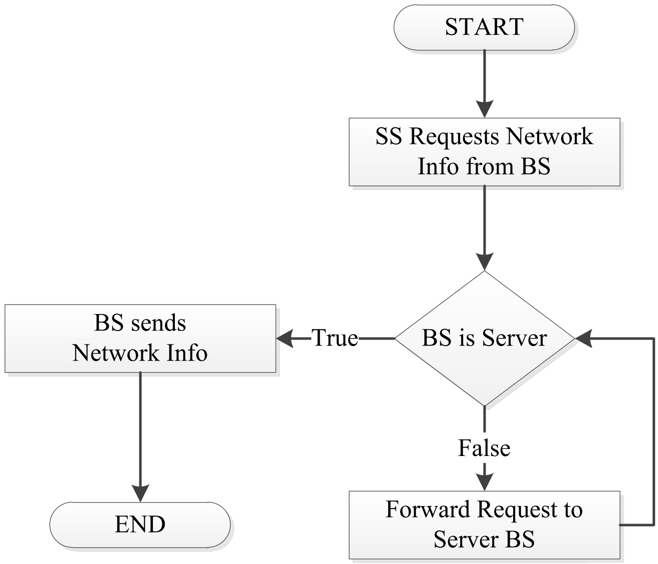

Fig. 3. Base station and subscribers stations communications algorithm

3.2 Experimental simulation setup, configuration and analysis

The scenarios for the current centralized and distributed client-server models are defined in this part, using the same number of base stations and subscriber stations in scenarios 1, 2, 3, and 4. Using the same number of base stations and subscriber's stations, these models are contrasted with one another. Across all four scenario iterations of the proposed Model, there are an increase in the number of selected Server BSs from 1, 2, 3, to 4.

The following network scenarios are deployed with the help of OPNET Modeler 16.0 [19] to evaluate the network throughput, delay and application response time. 4 different simulation scenarios are designed for the Centralized model in the fixed WiMAX network.

Scenarios for the existing Centralized model. The following network scenarios are deployed with the help of OPNET Modeler 16.0 [19] to evaluate the network throughput, delay and application response time. 4 different simulation scenarios are designed for the Centralized model in the fixed WiMAX network.

Scenario 1. In this scenario 1 of the existing Centralized model, 3 WiMAX BSs were simulated with 30 SSs (10 subscriber's stations around each BS). All the BSs are connected to the IP backbone (Internet) using point- to- point protocol (ppp), without any Server BS. Basic parameters associated with WiMAX configuration attributes, application configuration, application profile, task definition, BS configuration and SS for the model are configured as shown in Figure 4.

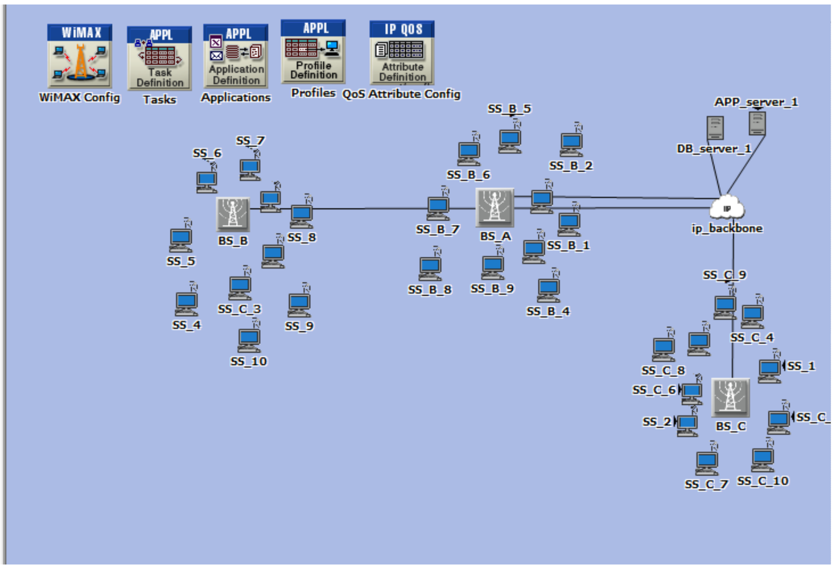

Fig. 4. Scenario 1 for the existing Centralized model

Scenario 2. In scenario 2 of the existing Centralized model, five WiMAX BSs were simulated with 50 SSs, 10 SS around one BS without Server BS. All other parameters are as in scenario_1 of the existing Centralized model.

Scenario 3. In scenario 3 of the Centralized WiMAX, model 8 WiMAX BSs were simulated with 50 SSs, 10 SS around each one BS without any Server BS. All other parameters are as in scenario_1 of the existing Centralized model.

Scenario 4. In scenario 4, 10 WiMAX BSs were simulated with 100 SSs, 10 SSs around each one BS in the subnet without any Server BSs. All other parameters are as in scenario_1 of the existing Centralized model.

Scenarios for the distributed Client-Server model. In this section scenario 1, 2, 3, and 4 of the distributed Client-Server model in the fixed WiMAX network is discussed.

Scenario1. The distributed Client-Server model was presented in Figure 5 in which three (3) WiMAX BSs were simulated, with 10 subscriber stations around each one BS. All the BSs are connected to the IP backbone (Internet) using point- to- point protocol (ppp), with BS A selected as Server a BS by the design Nearest Neighborhood algorithm and the remaining BSs remains Clients as illustrated in scenario 1. Basic parameters associated with WiMAX Configuration attributes, application configuration, application profile, task definition, BS configuration and SS for the model are configured.

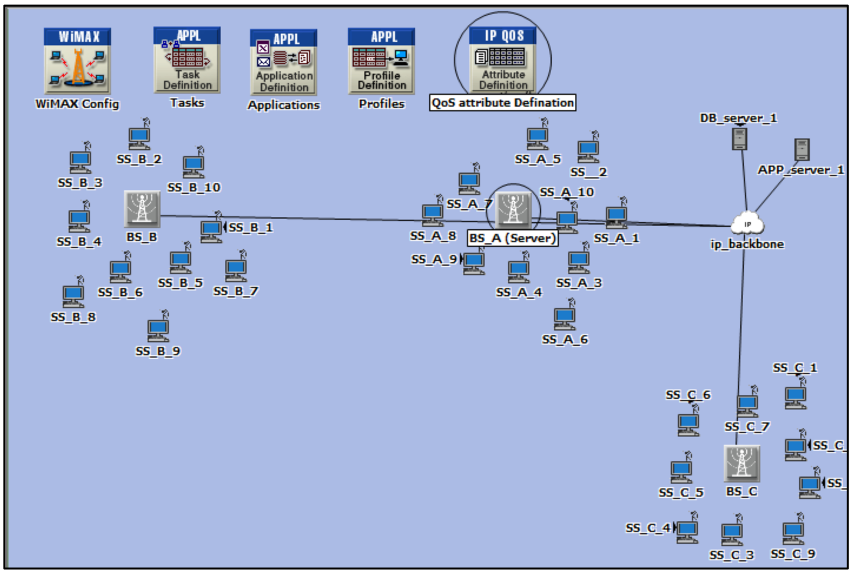

Fig. 5. Scenario 1 for the distributed Client-Server model

Scenario 2. In scenario2 of distributed model, 5 WiMAX BSs were simulated with 50 SSs, 10 SSs around each BS with BS A and D as Servers BSs selected by the design Nearest Neighborhood algorithm and the remaining are Clients. All other parameters are as in scenario_1 of the distributed Client-Server model.

Scenario 3. In scenario 3 of the distributed model 8 WiMAX BSs were simulated, with 10 SSs around each BS. The BS A, B and C as Servers BSs selected by the Nearest Neighborhood Algorithm and the remaining are Clients. All other parameters are as in scenario_1 of the distributed Client-Server model.

Scenario 4. In this scenario 4 of the proposed distributed model, 5 WiMAX BSs were simulated with 100 SSs, 10 subscriber stations around each BS all in the subnets. All the BSs are connected to the IP backbone (Internet) using point- to- point protocol (ppp), with BS in the subnet A, B, C and D as Server BS selected by Nearest Neighborhood Algorithm and the remaining are Clients. Basic parameters associated with WiMAX Configuration attributes, application configuration, application profile, task definition, BS configuration and SS for the model are configured as in scenario_1 of the distributed Client-Server model.

4 Presentation of the results and discussions

Many factors influence response times, and researchers can pick and choose which ones to examine. Typically, this is done in one way to learn more about the relationship between the measured frequency and the window size and round-trip time in a network transmission session [20] or it can be even in an end-to-end fully-informed network with many things that can affect response times [21], for this current study, it dwells on

WiMAX fixed network. However, other approach such as effective usage of unused bandwidth [22], network controller effects on operation [23], network optimization and performance analysis [24], as well as the general concerns and challenges of transmission sessions [25] have been addressed as well.

The application response time simulation results for the centralized and the new propose client-server models. The QoS performance with respect to application response time is affected with the existing centralized solutions in the fixed WiMAX as discussed in the problem statement The Client-Server model was designed to overcome this problem. In this section, the application response time simulation results is classified according to the stated objective. Simulation testing of the application response time for both the Centralized and the new proposed Client-Server models were carried out in the OPNET modeler 16.0 software environments in order to improve the QoS performance. All the simulation runs for 360 minutes.

The scenario 1 simulation results for the Application Response Time is presented in Figure 6. The results obtained from the application response time simulation for the Centralized and the new distributed Client-Server models for the fixed WiMAX network scenario 1.

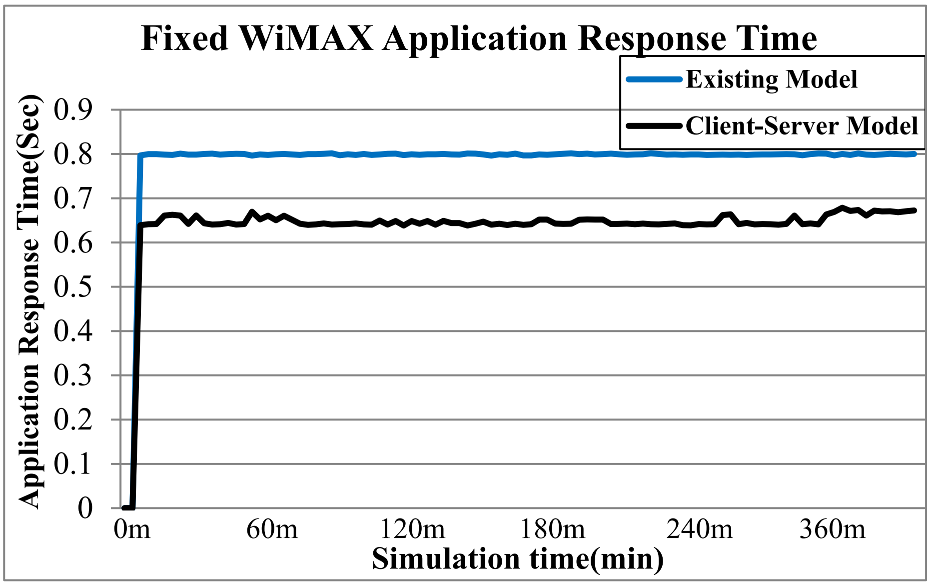

Fig. 6. Scenario 1 simulation results for the application response time comparison

The application response time is represented in sec and time in minutes during the 360 minutes OPNET modeler 16.0 simulations for scenario 1 of the two models. The graph compares the application response time results of the Centralized and proposed new distributed Client-Server models. The X axis represents the simulation time in minutes while the Y axis represents the application response time in sec. The application response time for the new proposed model is represented in black line while the application response time of the Centralized Model is represented in the blue line. The maximum application response time of the Centralized and the new distributed Client-Server models are approximately 0.8185sec and 0.6786 sec, respectively. The proposed model has the maximum value of response time at time t= 310 minutes. The Centralized Model has the maximum response time at time t = 300 minutes. The numbers of requests per second that the server receives in scenario 1 of the two models are the same, but the time it takes to processes in the newly distributed model is less as compared to the Centralized Model, as a result, of client- server architecture.

The scenario 2 simulation results for the application response time, for the centralized and the new distributed client-server models for the fixed WiMAX network present the simulation results obtained for the application response time as described in Figure 7.

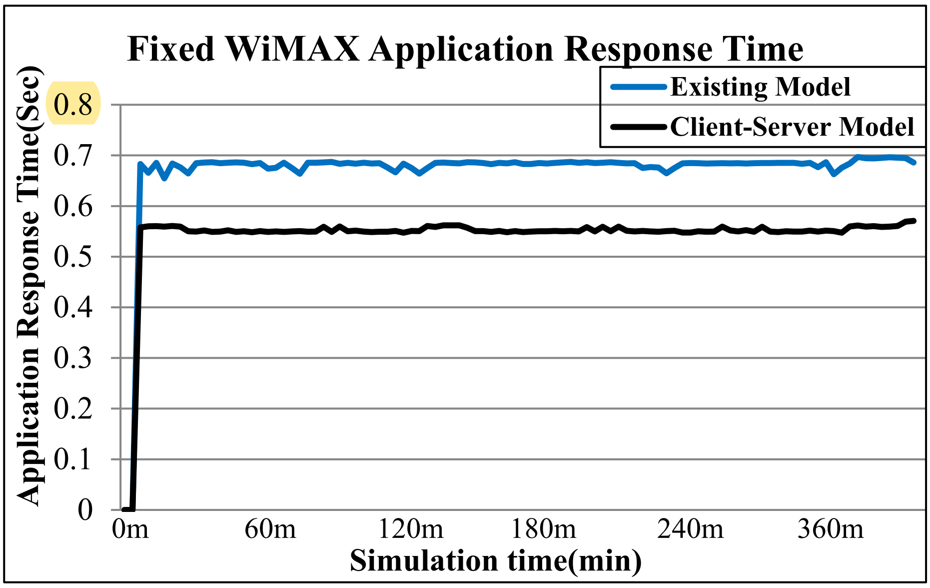

Fig. 7. Scenario 2 simulation results for the application response time comparison

The graph of scenario 2 of the Centralized and the new distributed Client-Server models illustrates the application response time results. The application response time is represented in sec and simulation time in minutes during the OPNET modeler 16.0 simulations for scenario 2 of the two models. The X-axis represents the simulation time in minutes and the models were simulated for 360 minutes. While the Y-axis represents the application response time in sec. The application response time for the new proposed model is represented in black line while the throughput of the Centralized Model is represented with the blue line. The maximum application response time for the Centralized and the new distributed Client-Server models are approximately 0.7000sec and 0.5607sec, respectively. The distributed Client-Server model has the maximum value of response time at time t= 340 minutes. The Centralized Model has the maximum response time at time t = 355 minutes as described in Figure 10. In scenario 2 of both the Centralized and the Client-Server 5 WiMAX BSs and 50 SSs were simulated with one server BS in the proposed model selected by the nearest neighborhood algorithm to distribute the network information to the nearest client BSs.

The scenario 3 simulation results for the application response time is presented in Figure 8 of the scenarios 3 for the Centralized and the new distributed Client-Server models for fixed WiMAX network, the simulation results obtained for the application response time is presented.

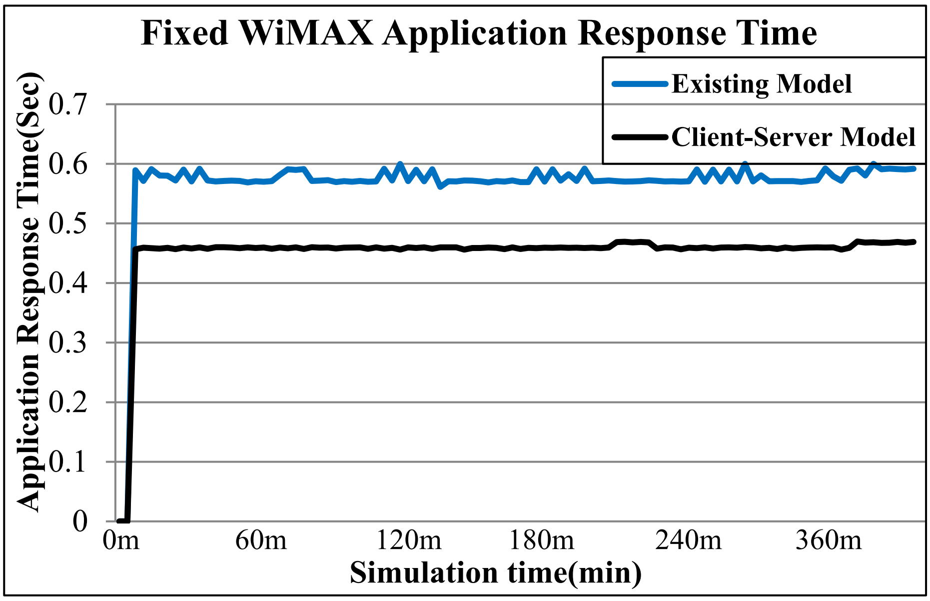

Fig. 8. Scenario 3 simulation results for the application response time comparison

The application response time is represented in sec and the running time for the simulation is represented in minutes during the OPNET modeler 16.0 simulations for the two models. The X-axis represents the simulation time in minutes and the design was simulated for 360 minutes. While the Y-axis represents the application response time in sec. The application response time for the new proposed model is represented in black line while the throughput of the Centralized Model is represented with the blue line. The maximum application response time for the Centralized Model is approximately 0.6000sec at time t= 345 minutes. While that of the new distributed Client-Server model is approximately 0.4591sec at time t= 325minutes. The numbers of requests per second that the server received in scenario 3 of the two models are the same, but the time it takes to processes in the newly distributed model is less as compared to the Centralized Model, as a result, of client- server architecture.

The scenario 4 simulation results for the application response time is presented in Figure 9. The results obtained for the scenarios 4 of the Centralized and the new distributed Client-Server models in fixed WiMAX network for the application response time is described in Figure 9.

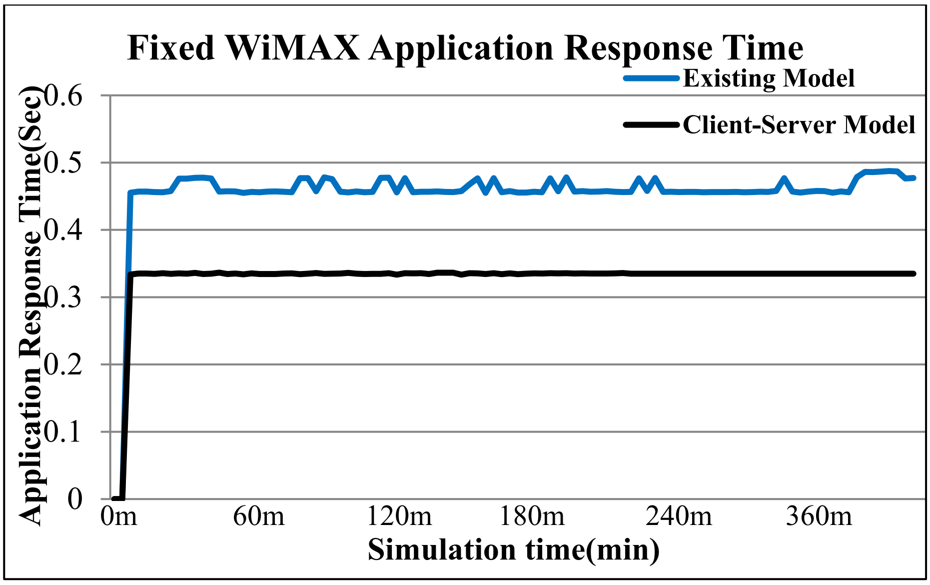

Fig. 9. Scenario 4 simulation results for the application response time comparison

Application response time is represented in sec and the running time for the simulation is represented in minutes during the 360minutes of the OPNET modeler 16.0 simulations for the two models. The X-axis represents the simulation time in minutes and the design was simulated for 360 minutes. While the Y-axis represents the application response time in sec. The application response time for the new proposed model is represented in black line while the application response time of the Centralized Model is represented with the blue line. The maximum application response time for the Centralized Model is approximately 0.4866sec at time t= 355 minutes. While that of the new distributed Client-Server model is approximately 0.3350sec at time t= 125 minutes. The numbers of requests per second that the server receives in scenario 4 of the two models are the same, but the time it takes to processes in the newly distributed model is less as compared with Centralized Model, as a result, of client- server architecture.

The comparison of all Scenario's Average Application Response Time for the Centralized and the New Distributed Client-Server Models is presented in Table 1. The fixed WiMAX average application response time results of the Centralized and new distributed Client-Server models were summarized in the table below.

Table 1. Fixed WiMAX average application response time results

S/N	SCENARIO	CENTRALIZED MODEL (sec)			CLIENT-SERVER MODEL (sec)		
		Minimum	*Maximum*	*Average*	*Minimum*	*Maximum*	*Average*
1.	Scenario_1	0	0.8185	0.4093	0	0.6787	0.3394
2.	Scenario_2	0	0.7000	0.3500	0	0.5607	0.2804
3.	Scenario_3	0	0.6100	0.3050	0	0.4491	0.2246
4.	Scenario_4	0	0.4866	0.2433	0	0.3350	0.1675

From the values obtained in Table 1 indicate that the Centralized Model's average application response time is less as compared to the proposed new distributed Client-Server model. The average application response time results in all the four proposed model's scenarios showed a decreased in application response time as compared to the Centralized Model. Both, the minimum values of the Centralized and the new proposed Client-Server model's application response time start at 0 sec in all scenarios. While the maximum values of the Centralized and the new proposed Client-Server models application response time are from 0.4093sec to 0.2433sec in the Centralized Model from 0.3394sec to 0.1675 sec in the new Client-Server model.

Figure 10 described the average simulation application response time results obtained from the Centralized and the new proposed Client-Server models, scenario 1, 2, 3 and 4.

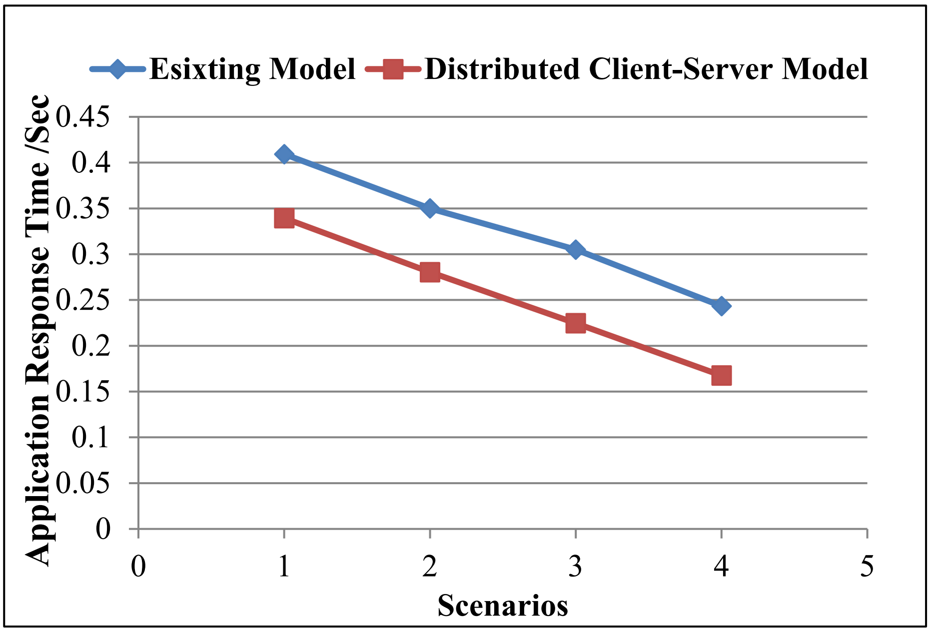

Fig. 10. Fixed WiMAX average application response time for the Centralized and the Client-Server models

The average application response time for the new proposed model is represented by the red line while the application response time of the Centralized Model is represented by a blue line. The results obtained indicate that the proposed Client-Server model has less application response time when compared Centralized Model. The maximum average application response time for the Centralized Model is approximately, 0.4093, 0.3500, 0.3050 and 0.2433sec. While the maximum average application response time for the new distributed Client-Server models are 0.3394, 0.2804, 0.2246 and 0.1675sec respectively. In scenario, 1 the average application response time of the new Client-Server model have maximum value. Also the maximum throughput of the Centralized Model is scenario 1. The summary of the Average Application Response Time Performance is presented in table 2. The percentage of the performance improvement of all Scenarios' average application response time for the existing Centralized and the new distributed Client-Server models are summarized in the Table 2. The performance of the percentage improvements is obtained using the equation (6) below:

$$Percentage\ \ Decrease \ = \frac{original\ value - new\ value}{original\ value} \times 100\% \tag{6}$$

Table 2. Percentage of the performance improvement of all Scenarios' average application response time

SCENARIO	**Average Application Response Time (sec)**		**Percentage Improvement (sec)**
	EXISTING CENTRALIZED MODEL	***CLIENT-SERVER MODEL***	
Scenario_1	0.4093	0.3394	18235322
Scenario_2	0.3500	0.2804	20%
Scenario_3	0.3050	0.2246	26%
Scenario_4	0.2433	0.1675	31%

As illustrated in the Table 2, the percentage of the average application response time simulation results of the two models indicated that the new distributed Client-Server model a has better result as compared them with percentage of the existing Centralized model. The percentage of the average application response time simulation results with the new distributed model improved by 18%, 20%, 26% and 31% in the scenario 1, 2, 3 and 4 of the two models respectively.

5 Conclusion

The WiMAX network technology is one of the most cutting-edge examples of the most recent wireless standard technology designed for metropolitan area networks. In this paper, a distributed Client-Server architecture was designed with the goal of reducing the Application Response Time in the Fixed WiMAX Network. This was done in order to improve the quality of the services that are offered to the end users. The adoption of OFDM method and the addition of Server BSs both contributed to an improvement in the performance of QoS in relation to the application response time parameter. When simulating the designed models, the OPNET modeller 16.0 was the tool of choice. The outcomes of the proposed approach were contrasted with those of the established centralized paradigm. In the Client-Server paradigm, the acquired findings revealed a reduction in the amount of time required for the network application to respond. Additionally, the Internet Service Providers (ISPs) would benefit from this Model in terms of data delivery because it does not operate from a single central server. Additionally, the cost of developing infrastructure will be reduced thanks to this Model. Comparing the percentage of the new distributed Client-Server model's average application response time simulation results with those of the current Centralized model revealed that the new distributed Client-Server model achieved a superior outcome. The new distributed model's simulation results for determining the average application response time have shown an increase of 18%, 20%, 26%, and 31%, respectively, compared to the previous model's results for each of the four possible cases. The model that was proposed will be expanded as part of future work in order to take into account ways to improve the quality of service in terms of delay and throughput, in addition to application response time, which was already taken into account in this study.

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