بسم الله الرحمن الرحيم

Sudan University of Science and Technology

College of Postgraduate Studies

كلية الدراسات العليا

Performance Evaluation of Wimax Quality of Service Scheduling Classes

تقييم جودة الاداء لفئات الجدولة في الواي ماكس

This Thesis is submitted in Partial Fulfillment of the Requirements for Degree of Master in Information Technology

BY:

Eatemad Babiker Abbas El desugi

Supervisor

Dr Niemah Izzeldin Mohamed Osman

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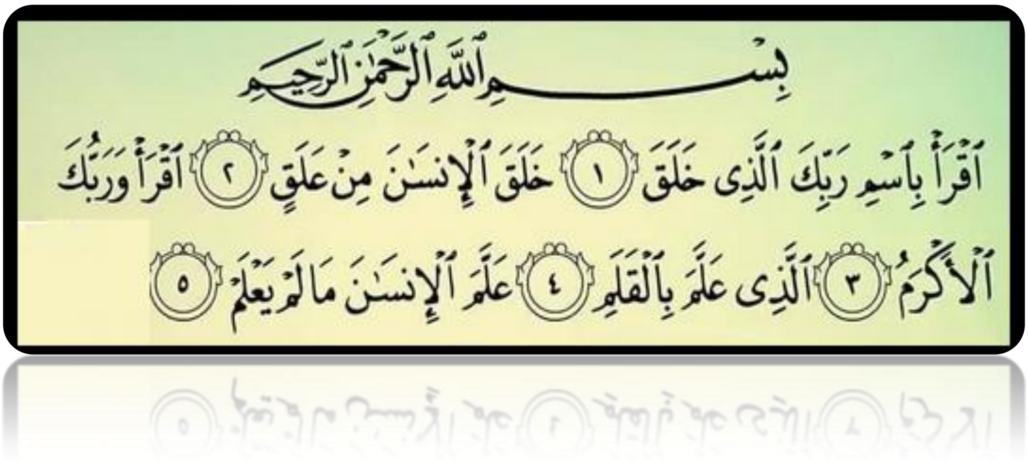

صدق الله العظيم
سورة العلق (1- 5)

Dedication

This study is whole heartedly dedicated to my beloved parents who have been my source of inspiration and gave me strength when I thought of giving up who continually provide their moral, spiritual, emotional, and financial support.

To my husband, brothers, sisters relatives, mentor, friends, and classmates Who shared their words of advice and encouragement to finish this study**.**

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In the Name of Allah, the most merciful, the most compassionate Praise be to Allah, the lord of the worlds; the prayers and peace be upon Mohamed hid servant and messenger.

First, thanks to God who lights our ways and our minds.

The success and final outcome of this search required a lot of guidance and assistance from many people and I am extremely privileged to have got this all along the completion of my research .

All that I have done is only due to such supervision and assistance and I would not forget to thank them.

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I would not forget to thank my friends for their encouragement and more over for their timely support till the completion of my research.

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Abstract

Worldwide Interoperability for Microwave Access (Wimax) is an innovative and cost effective technology that allows fast and easy delivery of broadband wireless access for fixed as well as mobile users. The most famous Wimax quality of service classes are: Unsolicited Grant Services (UGS), Extended Real-Time Polling Services (ERTPS) and Best Effort (BE).This work is comparative study to evaluate these classes in term of packet loss, end to end delay, jitter, throughput and voice traffic sends. The evaluation is carried out using an OPNET simulation. Results show that UGS class out performs ERTPS while the BE class has the least quality compared to other classes.

المستخلص

واي ماكس هي تقنية اتصالات تهدف لتوفير بيانات لاسلكية عبر المسافات الطويلة بعدة طرق من نقطة واحدة لنقاط وصول لهاتف خلوي متنقل . وهي تقنية مبتكرة وفعالة من حيث التكلفة تتيح هذه التقنية التوصيل السريع والسهل لاسلكيا لمستخدمي الهواتف الثابتة والمتنقلة.

أشهر فئات الجودة لخدمة واي ماكس هي : خدمات المنح غير المرغوب فيها (UGS) ، خدمات تمديد الاستقصاء في الوقت الفعلي (ERTPS) وأفضل جهد (BE) .هذه الدراسة عبارة عن مقارنة لتقييم هذه الفئات من حيث عدد الحزم المفقودة ، وتأخير ارسال الحزم ، و معدل الانتاج ، والتشويش ، والإرسال الصوتي . لإجراء التقييم تم استخدام محاكي الشبكات OPNET . أظهرت النتائج أن أداء فئة (UGS) يفوق أداء (ERTPS) ، بينما تعتبر فئة (BE) هي الأقل جودة مقارنة بالفئات الأخرى.

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Chapter One

Introduction

1.1 Overview

Wimax is an innovative and cost effective technology that allows fast and easy delivery of broadband wireless access for fixed as well as mobile users. The name "Wimax" was created by the Wimax Forum, IEEE 802.16. Wimax (Worldwide Interoperability for Microwave Access) is a wireless communications standard designed to provide 30 to 40 megabit-per-second data rates, which was formed in June 2001 to promote conformity and interoperability of the standard. With the 2011 update providing up to 1 Gbit/s for fixed stations. The forum describes Wimax as "a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and Digital Subscriber Line ". [1]

The demand for digital services with high data transfer rates and increasing bandwidth capabilities is rapidly growing. Examples of these services include multimedia services, mobile television, videophone, and video conferences. Thererefore, continuously developing new telecommunications infrastructure that can support these services has become necessary by providing fast Internet access, along with secure and large data transfer rates, and by implementing voice over Internet Protocol (VoIP) and multimedia protocols. VoIP has high bandwidth requirements. Wimax technology, which has high bandwidth and wide transmission range, can be considered suitable for supporting VoIP services for many end users it is a high-capacity wireless transmission technology that is based on IEEE 802.16 standards. The expansion of wireless broadband services to “anytime and anywhere” is the main objective of Wimax [1].

1.2 Problem statement

This research discuses essential QOS scheduling classes in Wimax networks and compares their weak and strong point for each parameters using OPNET Wireless network Simulation.

1.3 Proposed solution:

Develop a simulation for Wimax network for each class to evaluate the performance of each QOS parameter (Wimax load, time average in Wimax, time average in point to point delay , throughput and voice traffic send) then compare between them and analyze results.

1.4 Research objective:

The objective of this research is to rate Wimax classes in terms QOS and to evaluate the performance of each class accordingly

1.5 Methodology:

The evaluation is carried out with a simulation development using OPNET modular three scenarios representing considered QOS classes are simulated. The output is comparison of QOS parameters including : load Point to point delay, throughput and voice traffic.

1.6 Research Scope:

Qos classes for Wimax Netlwork are compared

Real time services

Non real time services.

1.7 Research importance

One of the main characteristics of Wimax is to provide seamless access to voice and multimedia services with strict delay requirements. In this search it is very important to implement an efficient QoS according to the design and optimization principles such as minimizing the number of unnecessary handovers, decreasing delay and increasing system throughput

1.8 Technical benefits

Increasing mobility and flexibility of the workforce, popularity of cloud-based service delivery in organizations, increased sales and improved customer service, enhancing sales meetings with richer media, increasing the productivity of a mobile sales, enhanced mobile functionality in products, and improving quality of service provision through faster access to information or media content.

1.9 Economical benefits

The business environment continues to demand richer communication and collaboration for employees who are increasingly mobile or distributed. Content and services need to be accessible away from the office, and on multiple devices. Businesses are increasingly deploying (or allowing) smart phones and tablets for employee use. Users expect an easy, quick, powerful experience whenever they do anything on these devices and they want the same in their business lives.

1.10 Thesis organization:

This thesis is organized as follows: Chapter 2: This chapter presents an overview of Wimax; the main classes and algorithms are described as well as the architecture. Chapter 3: This chapter discusses previous studies related to research. Chapter 4: This chapter propose the Wimax Quality of Service Classes performance evaluation process Modeling and simulation parameters are explained and simulation using OPNET simulator network. Chapter 5: in finally the quality of services classes performance evaluation is carried out. Chapter 6: This chapter provides a conclusion of the overall study and considerations for future work.

Chapter Two
Literature Review

2.1 ₀ Introduction

With the further development of the communication network, Wimax has major realistic significance and strategic value as a standard facing to “the last kilometer” access, especially when no globally uniform standard is established for broadband wireless access.

There are two main types of such standard: The IEEE 802.16d supporting air interface of fixed broadband wireless access system, and the IEEE 802.16e in the works supporting the air interface of both fixed and mobile broadband wireless access systems.

Wimax is a Broadband Wireless Access Metropolitan Area Network (BWA-MAN) technology based on the IEEE 802.16 standard, which is also called the IEEE Wireless MAN. It is a new air interface standard in connection with the frequency ranges of microwave and millimeter wave.

Its main purpose is to provide a broadband wireless access approach which can be interoperated effectively in the environment of multiple manufacturers with "one-point to multi-point" in the metropolitan area network.

To support different types of data like http, real-time audio and video, VoIP, FTP.

There are various classes in Wimax system: Unsolicited Grant Services (UGS), Real-Time Polling Services (RTPS), non Real-Time Polling Services (NRTPS) and best Effort (BE)[2].

2.2 **Wimax A**rchitecture

Figure (2-1) describes the basic IEEE 802.16 architecture of Wimax which consists of one Base Station (BS) and one (or more) Subscriber Station (SS). Base station acts as a central entity to transfer all the data from subscriber stations in a PMP (Point to multipoint) mode. Transmissions take place through two independent channels: Downlink Channel (from base station to subscriber station) and Uplink Channel (from subscriber station to base station). Uplink Channel is shared between all subscriber stations while Downlink Channel is used only by base station [2].

The standard defines both Time Division Duplexing (TDD) and Frequency Division Duplexing (FDD) for channel allocation.

The IEEE 802.16 is connection oriented. Each packet has to be associated with a connection at MAC level. This provides a way for bandwidth request, association of QOS and other traffic parameters and data transfer related actions. The standard supports four different flow classes for QOS and the MAC supports a request-grant mechanism for data transmission in uplink direction [2].

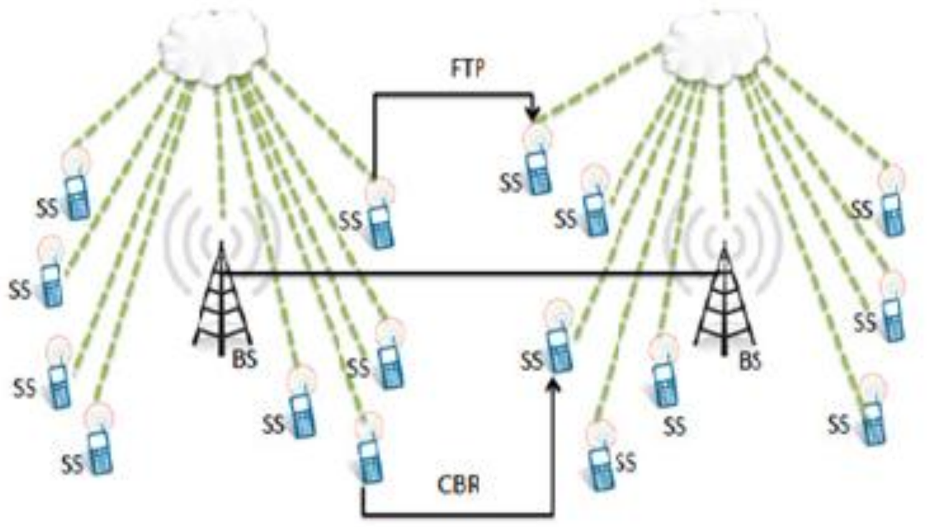


Figure (2-1) Wimax architecture [2]

2.3 Quality of Service (QoS):

The QoS is the ability to manage network's tangible assets to meet the requirements of intangible assets in terms of end-to-end delay, and packets lose .In this section, useful terms and definitions that are related to QoS is presented

2.3.1 Congestion: the lack of bandwidth (BW) will cause congestion. The congestion is happen when there are requirements of BW for the current stream that is greater than the available capacity or impulsive flood in loads or unexpected traffic flowing due to rerouting.

2.3.2 Real Time Application: is defined as the application that needs the data in each packet arrived by a definite time and, if the data has not arrived at that time, it is then really useless. The real-time applications always do not work well across the Internet due to variable queuing delay and congestion losses. Hence, VoIP requires short delay and strict delay variation (jitter) of the packets.

2.3.3 Packet End-To-End Delay: is defined as the difference in the time at which the packet enters the network and the time at which it leaves the network; from synchronized sender to destination; including queuing and intermediate networking devices delay.

2.3.4 Delay Variation (Jitter): is defined as the delay variation between two successive packets belonging to the same traffic stream. The delay jitter is often caused by queuing and rerouting and additional processing delays.

2.3.5 Bandwidth (BW): it is the ability of the network to deliver better service to particular network traffic within IP networks using effective QOS utilization which will result in a maximum use of available bandwidth.

2.3.6 Packet Loss: is defined as the number of packets that are lost during transmission process inside the network within a specified time interval. It is unavoidable under heavy traffic and usage of resources by different applications conditions. Packet loss may be caused by congestion, traffic rate limiting, physical layer errors, and network elements failures.

2.3.7 Throughput: is defined in the network as the total number at which packets are transmitted from source to destination at a defined time period (e.g. packet/seconds)[2].

2.4 Quality of Service Types

The standard does not define a slot allocation criterion or scheduling architecture for any type of service. A scheduling module is necessary to provide QoS for each class. IEEE 802.16 defines the following four types of service flow with distinct QoS requirement:

2.4.1 Unsolicited Grant Services

Constant bandwidth division on the periodic base is provided by this service class. Only one established connectivity is required. The use of UGS aims to develop real-time data streams that contain constant-sized data packets at periodic intervals, such as VoIP without silence suppression. No contention request is made in UGS, and no clear bandwidth request is made by the subscriber station (SS). The base station provides constant-sized access slots at periodic intervals to UGS flows. However, the UGS bandwidth is wasted during inactive voice calls [3] .

2.4.2 Real-Time Polling Services

This service class is used to develop real-time data streams, including variable-sized data packets that run at periodic intervals, such as MPEG videos. The advantage of RTPS is reducing reserved traffic rates. The flows of RTPS are voted by base station (BS) via unicast request voting, which occurs sufficiently frequently to meet the delay requirements of service flows This service requires more request overheads than UGS, but supports variable grant sizes for optimum real-time data transport efficiency[3].

2.4.3 Non-Real-Time Polling Services

This type of service class is used for non-real-time variable bit rate traffic. It supports no delay guarantee, and minimum rate is ensured. This service class develops delay-tolerant real-time data streams for the required variable-sized data packets with minimum bit rate. In addition, NRTPS flows act as RTPS flows and are voted via transmission request voting. Therefore, RTPS flows can also receive a few request voting opportunities during network overcrowding. Furthermore, contention requests are allowed to be used [3].

2.4.4 Extended Real-Time Polling Service

This QoS type supports VoIP along silence suppression. No traffic transmission will occur during the silent period. The QoS parameters are the same as those for the UGS service type. The application of ERTPS . This service class is similar to UGS in that the BS assigns link during active mode and no band width is allocated during the silent period. In this study, the BS needs to poll mobile subscribers to determine whether the silent period has ended [3].

2.4.6 Best Effort

This service class is designed to support data streams that do not require a minimum service level. The flows of best effort (BE) are allowed to use contention request opportunities. The BE service class uses any remaining bandwidth after the required bandwidths of all the other classes have been allocated. This service is used in many applications, such as in emails and the File Transfer Protocol (FTP). These applications do not require strict latency[3].

2.5 Wimax Scheduling Algorithms

Scheduling algorithms are responsible for Distributing resources among all users in the network, and provide them with a higher QoS. Users request different classes of service that may have different requirements (such as bandwidth and delay), so the main goal of any scheduling algorithm is to maximize the network utilization and achieve fairness among all users[2].

2.5.1 Strict Priority

In this algorithm packets are represented by the scheduler depending on the QOS class and then they are assigned into different priority queues, these queues are served according to their priority from the highest to the lowest in which this mechanism may causes some priority QOS classes to be starved [2]. Figure (2-2) describes the strict priority scheduler..

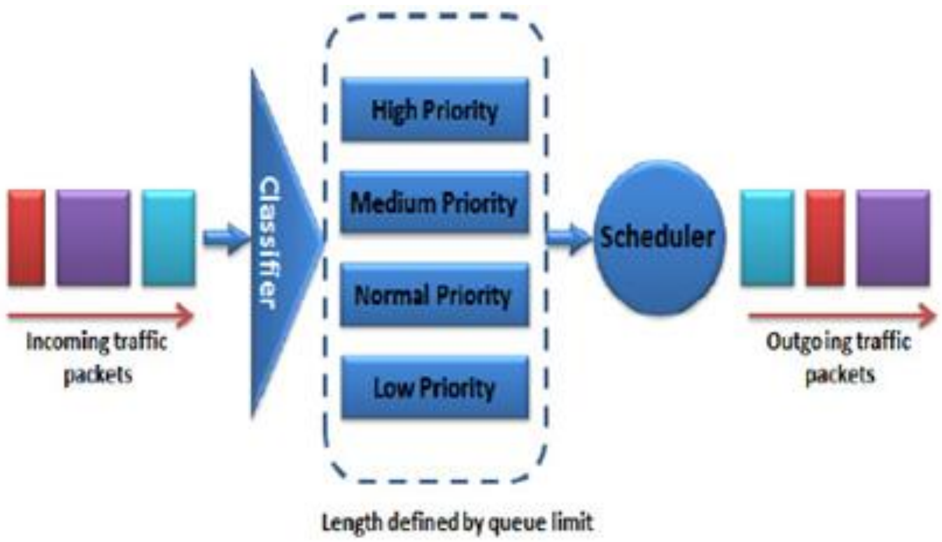


Figure (2-2) Strict Priority scheduler [2]

2.5.2 Round Robin

The procedure of round robin scheduler works in rounds by serving the first packet in each priority queue in sequence according to their precedence till all queues are served and then it restarts over to the second packet in each queue [2]as shown in figure (2-3).

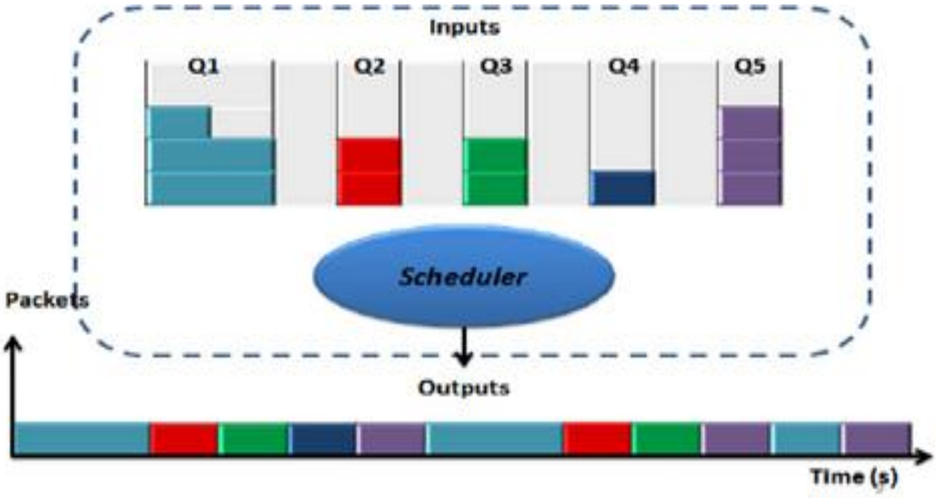


Figure (2-3) Round Robin scheduler [2]

2.5.3 Weighted Round Robin:

In WRR procedure, packets are categorized into different service classes and then assigned to a queue that can be assigned different percentage of bandwidth and served based on Round Robin order as shown in Figure (2-4). This algorithm address the problem of starvation by guarantees that all service classes have the ability to access at least some configured amount of network bandwidth[2]

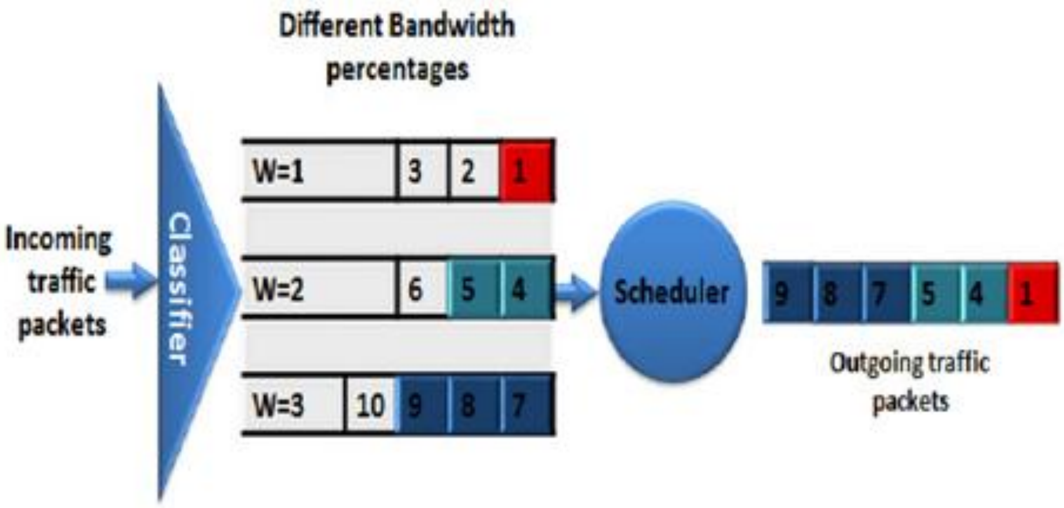


Figure (2-4) Weighted Round Robin scheduler [2]

2.5.4 Weighted Fair Queuing

In this scheduler as describes in Figure (2-5) each flow are assigned different weight to has different bandwidth percentage in a way ensures preventing monopolization of the bandwidth by some flows providing a fair scheduling for different flows supporting variable-length packets by approximating the theoretical approach of the generalized processor sharing (GPS) system that calculates and assigns a finish time to each packet[2].

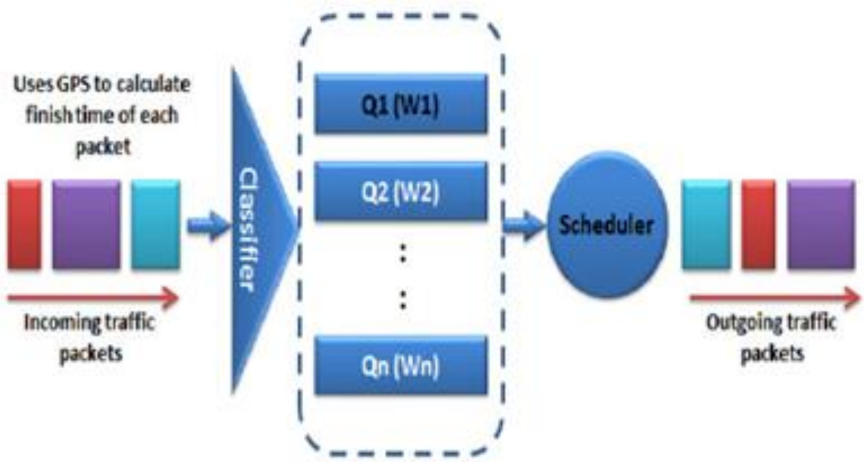


Figure (2-5) Weighted Fair (WFQ) Scheduler [2]

2.5.5 Self-Clocked Fair (SCF) Queuing

SCF Scheduler generates virtual time as an index of the work progress; this time is computed internally as the packet comes to the head of the queue. The virtual time determines the order of which packets should be served next Figure (2-6) illustrates the work progress of SCF scheduler[2]

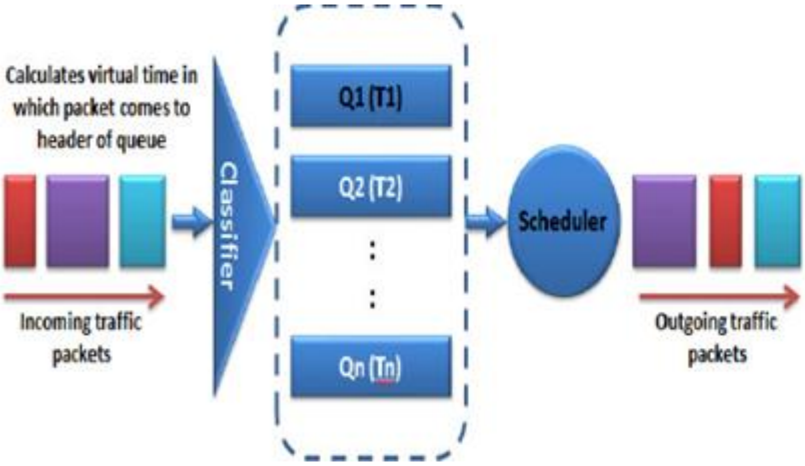


Figure (2-6) Self-Clocked Fair (SCF) scheduler [2]

2.5.6 Diff-Serv Enabled

Diff-Serv uses the 6-bit Differentiated Services Code Point (DSCP) field in the header of IP packets that used to classify packets, by replacing the out dated IP precedence with a 3-bit field in the Type of Service byte of the IP header originally used to classify and prioritize types of traffic [2].

2.6 Summary

This chapter introduces Wimax technology and its architecture and describes quality of service (QoS) classes, parameters and algorithms with figures.

Chapter Three

Related Work

A number of up-to-date related works for the QoS service classes over Wimax networks are described in this section. With the increasing sophistication of technologies in the communications revolution, many approaches have been proposed to improve data transmission through wireless communication.

3.1 Performance Analysis of Wimax (Best Effort and ERTPS) Service Classes for Video Transmission

The study support different types of data like http, real-time audio and video, VoIP, FTP, there are various classes in Wimax system. They try to analyze the performance when multimedia contents are transmitted over Wimax network. Due to stringent delay requirement of real-time multimedia data, a separate class is allocated for it. I.e. RTPS. Thus their objective is to find out that how much they gain advantage by transmitting multimedia over this separate class? This requires a thorough analysis while considering all the scenarios.

Their contribution in this paper is to build an initial framework for answering the above stated questions. The Network Simulator (ns-2) which is a popular tool for the simulation of computer networks has been used to simulate the results. Standard-compliant implementations have been used to authenticate the results [3].

3.2 Priority Control Scheduling for Downlink and Uplink in Wimax Network

In a Wimax schedulers, when scheme needs to be designed for downlink and uplink, the issues of packet delay is paramount. This is even more when considering real time sensitive packets.

In this paper, a priority control scheme (PCS) is proposed to provide better QoS for real time delay sensitive packets in uplink and downlink channel. This is done by classifying the service flow priority of the packets into two types, which are time-delay sensitive and non-time delay sensitive. The performance from the proposed PCS is compared with the Wimax classification service flow priority. The simulation results using OPNET show that the proposed scheme out performs the existing scheme by having less delay[4].

3.3 Performance Analysis of UGS and BE QOS classes in Wimax

This study focuses on analyzing essential QoS parameters for Wimax Network. QoS parameters like packet loss, average throughput, average jitter and average end to end delay are analyzed with CBR traffic and effect of mobility is evaluated using QualNet 6.1 Wireless network Simulator for BE and UGS flows in order to use them in a proper way for real life scenarios[5].

3.4 Performance Evaluation of Different Scheduling Algorithms in Wimax

Scheduling in Wimax became one of the most challenging issues, since it was responsible for distributing available resources of the network among all users; this leaded to the demand of constructing and designing high efficient scheduling algorithms in order to improve the network utilization, to increase the network throughput, and to minimize the end-to-end delay.

In this paper, researcher presented a simulation study to measure the performance of several scheduling algorithms in WIMAX, which were Strict Priority algorithm, Round-Robin (RR), Weighted Round Robin (WRR), Weighted Fair Queuing (WFQ), Self-Clocked Fair (SCF), and Diff-Serv Algorithm[6].

3.5 Two-level Scheduling Algorithm For Different Classes Of Traffic In Wimax Networks

The standard incorporates a QoS architecture that supports both real-time and non-real-time applications. To provide QoS three data schedulers are furnished by the architecture. However, the working of the schedulers is not defined by the standard.

Some researchers have attempted to fill this gap by providing different scheduling schemes. However no scheme has yet been adapted by the standard and the area is still open for new research.

In this article we propose Two-Level Scheduling Algorithm (TLSA) that ensures QOS for all service classes, while avoiding starvation of lower priority classes. Furthermore, it ensures fair resource allocation among flows of the same class. The simulation results show that the algorithm is effective and efficient. [7]

3.6 Classification of The Uplink Scheduling Algorithms In IEEE 802.16

The IEEE 802.16 standard defines the wireless broadband access technology called Wimax, which introduces several interesting advantages including variable and high data rate, last mile wireless access, point to multipoint communication, large frequency range and QOS for various types of applications. However, the actual version of the standard does not define a MAC scheduling architecture in uplink as well as downlink direction.

Efficient scheduling design is left for designers and developers and thus providing QoS for IEEE 802.16 BWA system is a challenge for system developers.

The scheduling architecture must ensure good bandwidth utilization, maintain the fairness between users and respond to the constraints of some applications (i.e. video, voice). In the literature, a good number of articles are available to analyze the performance of the standard; however few studies describing the scheduling algorithm are to be appreciated.

To analyze these studies, a classification based on the scheduling mechanism or method used in the different propositions is presented in this paper.

Some studies are based on traditional algorithms and other studies use new methods and mechanisms that are proposed for the new standard in order to provide QoS.[8]

3.7 Performance Analysis Of Wimax Scheduling Algorithms For QoS Support In PMP Mode

The research get The scheduling algorithm is the crucial point in QoS provisioning over such broadband wireless access (BWA) network. IEEE 802.16 standard supports two different topologies: point to multipoint (PMP) and Mesh.

So a comprehensive performance study of scheduling algorithms in Point to Multipoint mode of Wimax network had been conducted and it also describes Quality of Service over Wimax network.

In the analysis, a Wimax module was developed based on OPNET 14.0 simulator.

Various real life scenarios like data, voice call are setup in the simulation environment. Parameters that indicate quality of service, such as, throughput, average load, average jitter and average delay, are analyzed for different types of service flows as defined in Wimax.

The simulation was carried out for scheduling algorithms such as Priority Queue and MDRR and evaluating the performance of each scheduler to support the different QoS classes.[9]

3.8 Analysis of QoS For Wimax

In last few years there has been significant growth in the area of the wireless communication. The Wireless network is a fast growing area. IEEE 802.16/Wimax is a new network which is designed with quality of service in mind.

The Quality of Service (QoS) has become an important parameter for various types of applications that utilize the network resources. These applications include multimedia services, video streaming, voice over IP, video conferencing etc.

This paper focuses on an analysis of quality of service implemented by the Wimax networks. Wimax is a technology for providing wireless last-mile connectivity. Physical and MAC layer of this technology refers to the IEEE 802.16 e standard that satisfied Quality of Service (QoS) requirements of different applications. Wimax not only defined the features of the cabled access network

3.9 Performance Analysis Of QoS Parameters For Wimax Networks

Quality of Service is an essential parameter to judge performance of any Network. This paper focuses on analyzing essential QoS parameters for Wimax Network.

Essential QoS parameters like delay, Jitter, Packet delivery Ratio (PLR), Packet Loss Ratio (PLR) and throughput have been calculated for 500 mobile nodes in a Wimax network.

Ad Hoc on Demand Distance Vector Routing (AODV) protocol has been chosen as a routing protocol because of its ability to perform well under highly mobile and random conditions.

MATLAB software version R2011 was used for creating Wimax network architecture and Regression analysis is done for each of the QoS parameter.

The results help in critically analyzing QoS parameters for Wimax Network and it has been found that an optimum value of QoS parameters is obtained with increasing number of mobile nodes for Wimax Network

3.10 Summary

This covers somehow related papers and previous researcher works.

Chapter Four

Methodology

4.1 Introduction

As a rapidly growing technology, voice over Internet Protocol (VoIP) enables the transmission of voice data over Internet Protocol (IP)-based networks. VoIP has become an alternative solution for the public switched telephone network given its capability to transmit voice data in the form of digital IP packets over TCP/IP-based Internet, particularly with the significant deployment that occurred in the standard of Worldwide Interoperability for Microwave Access (Wimax, IEEE 802.16) networks.

Simulation is an essential tool for the development and performance evaluation of communication networks. So, we have chosen simulation based methodology for our research. Among the available tools for networks simulation, OPNET Network simulator is used to evaluate the performance of Wimax networks by using various voice codec schemes and by considering several realistic networking scenarios. The Optimized Network Engineering Tool (Opnet modular 14.5) was used to measure and analyze a set of quality of service parameters. Simulations results indicate that the improved selection of voice codecs and statistical distribution significantly affect VoIP performance in Wimax networks. This chapter discuss about OPNET Network simulator and its various tools which use to create network model.

4.2 OPNET Network Simulator

OPNET Network simulator is a tool to simulate the behavior and performance of any type of network. The main difference OPNET Network Simulator comparing to other simulators lies in its power and versatility. IT Guru provides pre-built models of protocols and devices.

It allows to create and simulation different network topologies. The set of protocols/devices is fixed it cannot create new protocols nor modify the behavior of existing ones.

It used to design and study of wired or wireless communication networks, devices, schedulers, protocols and different networks nodes.

It was introduced in 1986 by MIT graduate and OPNET modeled was developed for needs of military. Now it is also used for research work during study period time.

The OPNET environment includes graphical tools for scenarios and models conception, conception, scenarios simulation, data collection and data analysis. OPNET describes the model specification with number of tools; these tools are known as editors.

The editor collect require and handle the modeling information similar to structure of real network systems. This modeling information is organized in the hierarchical manners. Model specifications performed in the Project Editor rely on elements specified in the Node Editor. The rest of the editors are used to define various data models, new links and nodes.

4.2.1 Advantages of OPNET Network Simulator

- OPNET Network Simulator is a open free software.
- Large number of project scenarios that are offered information on OPNET t Network Simulator.
- Can be overlooked using OPNET Network Simulator.

4.2.2 Uses of OPNET Simulator

- Operational validation.
- Application troubleshooting.
- Network planning and design.
- Validating hardware architecture.
- Protocol modeling.
- Traffic modeling of telecommunication networks.
- Evaluating performance aspects of complex software systems.

4.2.3 Discrete event simulation workflow

- Create/import topology/configuration.
- Create traffic.
- Choose statistics.
- Run simulation.
- View results.
- Duplicate or create new scenario.
- Publish results. [10]

4.3 Wimax Scenarios

Wimax scenario is created using nodes and servers s. a network is designed to act as a Base Station (BS) where five data nodes and five voice nodes are assigned to act as a Subscriber Stations (SS) . Wimax scenario is simulated for voice and data application without any mobility model with Wimax best effort scheduling class and the results are noted down. Two networks with the same scenario designed with UGS scheduling class and ERTPS scheduling class and the results are noted down so the result compared

4.4 Simulation Parameters

System parameters like simulation time simulates for 30 minutes of real operation of the network which took around 4.9 minute as simulation time

Table(3-1) : Simulation Parameters

Parameters	**Value**
Simulator	Opnet
Simulation Time	30 min
Antenna Height	5(meter)
No of voice nodes	5 nodes
No of data nodes	5 nodes
Services types (QoS)	BE, ERTPS, UGS

4.5 Summary

This chapter describes the simulation as tool and opnet simulater brifly its advantage ,uses and workflow. Wimax senarios creating by base station serve five data nodes and five voice nodes for 30 miniutes then result was compared with simulation parameters.

Chapter Five

Results and discussion

5.1 Simulation Results

The perceived quality of service can be measured quantitatively in terms of several parameters. In the analysis the throughput, average end to end delay, time average in Wimax data dropped ,Wimax load and voice traffic was considered. The comparative plots of the three class are given in Figure (5-1) to Figure (5-6)

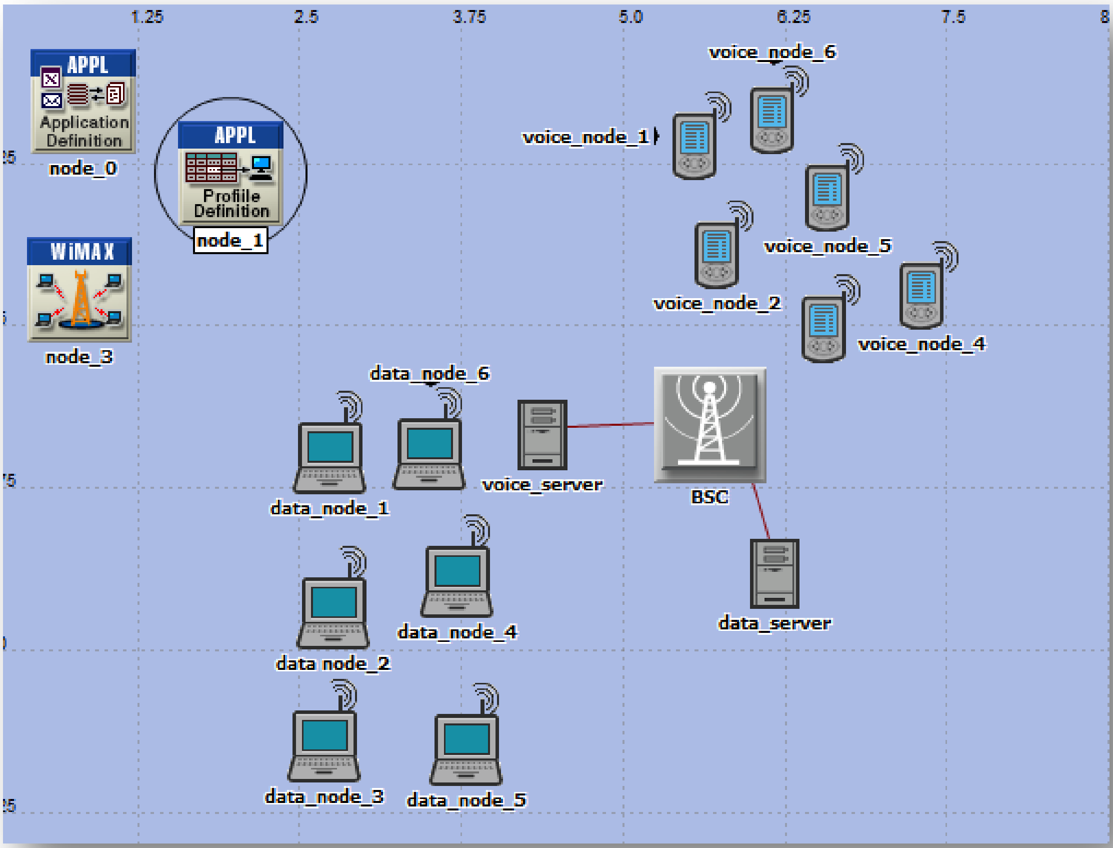


Figure (5-1) opnet Wimax network moduler

5.2 Data Dropped Table (5-1) shows data dropped results for packet by second

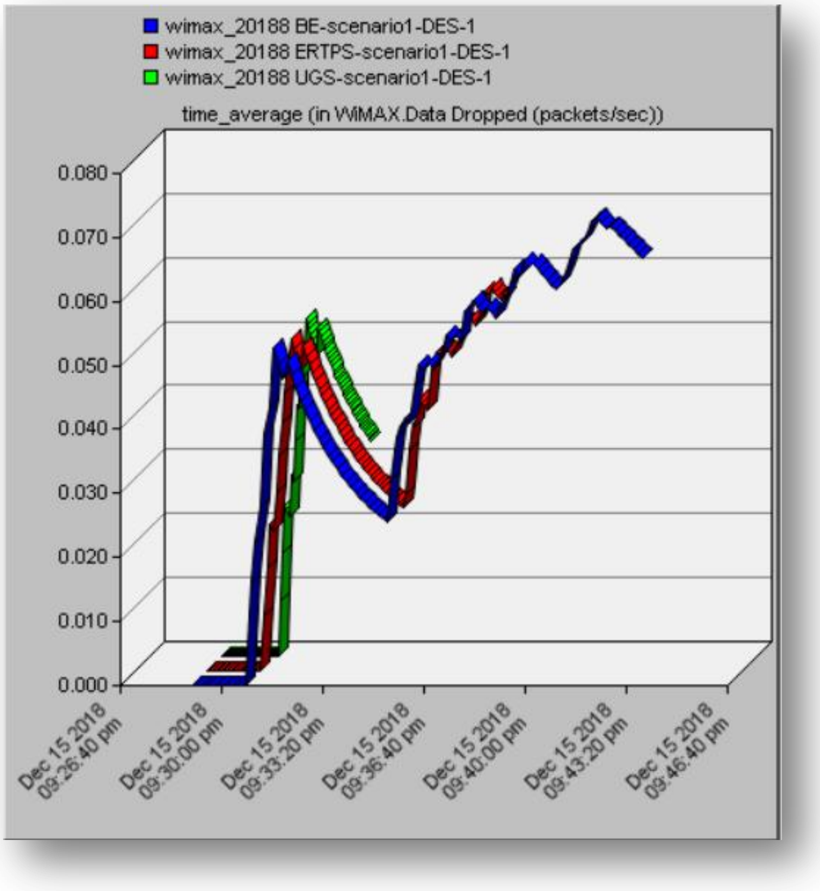


Figure (5-2) time average in Wimax data dropped (packets/sec)

Table (5-1) data dropped results

Class	Data dropped(packets/sec)
UGS	0.051
BE	0.068
ERTPS	0.055

BE class has most data dropped than ERTPS and UGS is best one in data dropped packets

5.3 Point To Point Queuing Delay

BE class clearly has long point to point queuing delay time as it handles applications on best available basis. So, this is the expected result as this service flow is provided with the least precedence and hence it has encountered high delay than ERTPS and UGS is best one in delay time.UGS has the highest value of precedence so as expected it encounters the least delay. Table (5-2) calculates delay results by seconds for each class

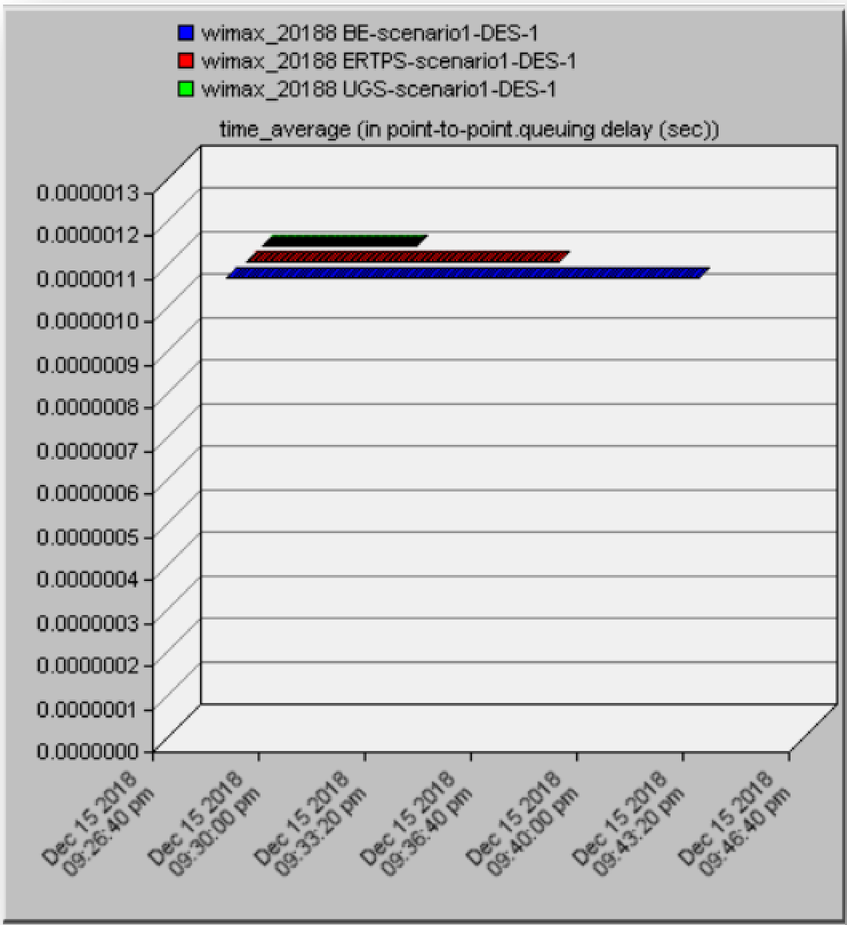


Figure (5-3) time average in point to point queuing delay (sec)

Table (5-2) point to point queuing delay results

Class	**point to point queuing delay**	**Sec**
UGS	0.0000012	6
BE	0.0000011	15
ERTPS	0.0000115	10

5.4 Throughput (packets/sec)

The results show high throughput with UGS service then ERTPS service BE service has low throughput. table (5-3) analyze results in numbers backet/sec

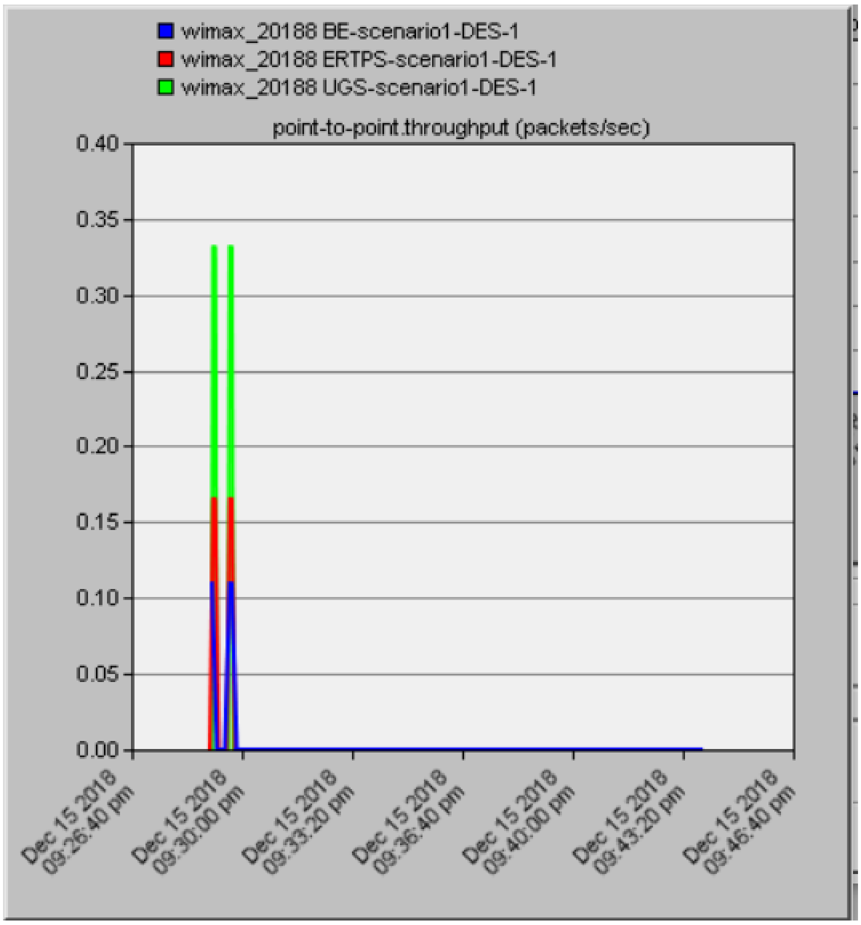
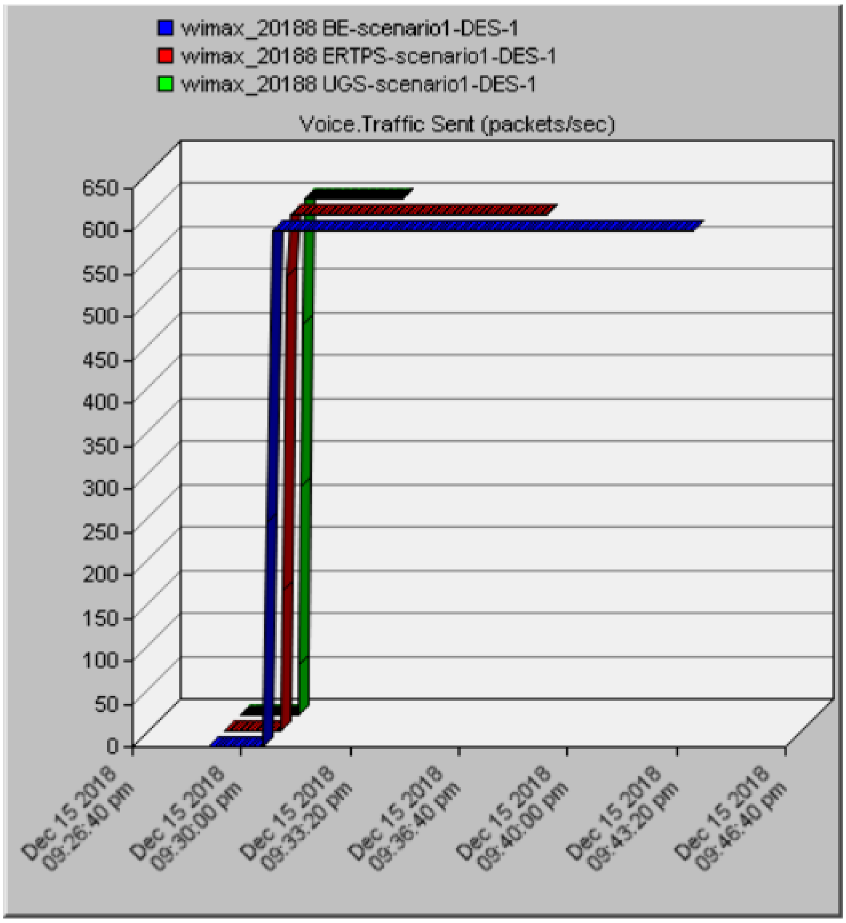


Figure (5-4) time average in point to point throughput (packets/sec) table (5-3) time average in point to point throughput (packets/sec) results

Class	point to point throughput
UGS	0.33
BS	0.12
ERTPS	0.17

5.5 Voice Traffic Results show that UGS class has less voice traffic than ERTPS while BE has long voice traffic time



Figure(5-5) voice traffic sent (packets/sec)

Table (5-4) voice traffic sent (packets/sec)

Class	voice traffic sent	Sec
UGS	640	3
BE	600	10
ERTPS	620	7

5.6 Wimax Load

ERTPS has long load over Wimax network but not for long time while BE has long load time than UGS which get less load less time than the other QOS classes as mentioned in table (5-5)

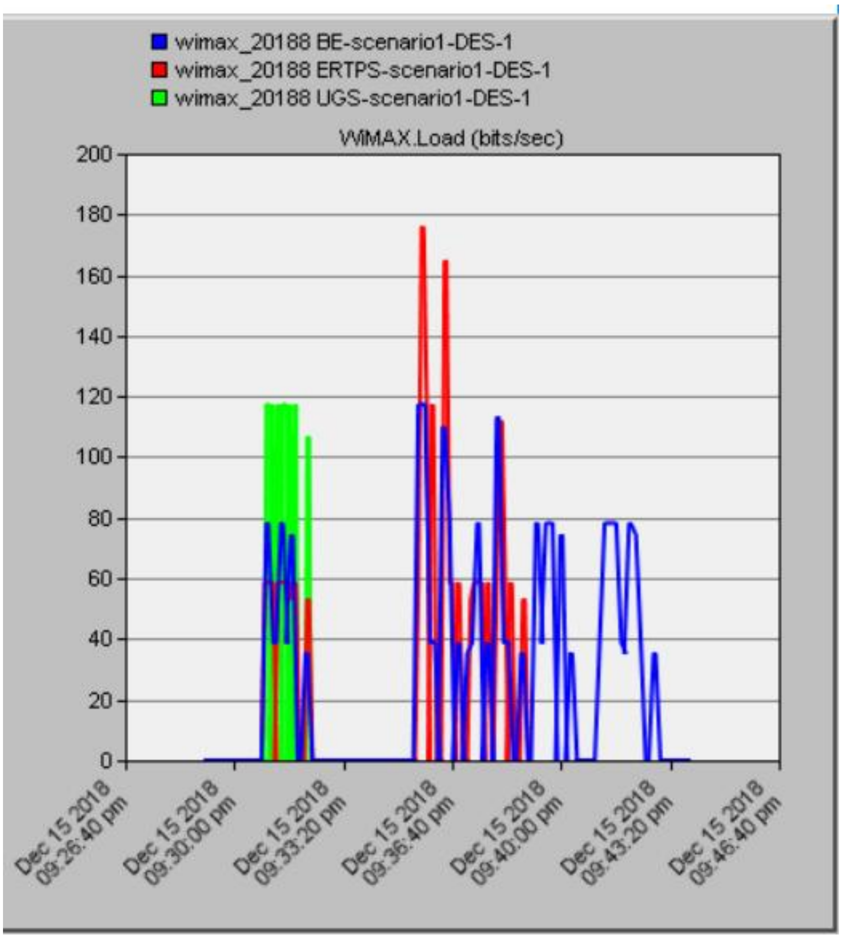


Figure (5-6) Wimax load(bits/sec)

Table (5-5) Wimax load(bits/sec)

Class	Load
UGS	118
BE	118
ERTPS	175

5.7 Summary

This chapter presents the result of simulations scenarios in many parameters (load, throughput, packet data dropped, voice traffic and delay) with tables and figures to each parameters for the three classes

Chapter Six

Conclusion and Recommendations

6.1 Conclusion

This study has compared three Wimax Quality of Service Classes (UGS, ERTPS and BE). A network simulation has been made using OPNET. A number of quality service parameters including packet loss , end to end delay ,throughput and voice traffic send have been evaluated .

The UGS class is the best class in terms of performance followed by ERPTS, while BE class is the least in term of quality.

6.2 Recommendations

To improve this work we recommend evaluating other Wimax Quality of Service classes and include additional parameters to obtain a complete view on Wimax Quality of Services classes' performance.

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