RADIO RESOURC MANAGEMENT IN IEEE 802.16 NETWORKS

Mohamed I. Yousef, Mohamed M. Zahra and Ahmed S. Shalaby

Department of Electrical Engineering, Faculty of Engineering, AL-Azhar University, Cairo, Egypt

ABSTRACT

IEEE 802.16 standard based (WiMAX) is considered one of the important Broadband Wireless Access (BWA) networks based on OFDMA technology. It can be great solution for providing internet access instead of traditional wired broadband networks. This paper presents an algorithm to improve the throughput of downlink as well as to minimize the delay. The approach aims to readjusting the number of OFDMA symbols in TDD mode assigned for downlink by increasing the number of symbols allocated for downlink and reducing the number of symbols allocated for uplink to meet with the QoS requirements. The simulation results carried out via the OPNET modeler prove that the proposed algorithm is capable of improving the throughput and reducing about 80% of system delay for the IEEE 802.16 networks.

Keywords

IEEE 802.16, WiMAX, OFDMA, TDD, QoS.

1. INTRODUCTION

Today, the exploding increase of accessing the Internet has led to the need for the design of new communication networks with higher capacity. For the residential and business customers the need for "last-mile" broadband access is necessary. However, providing "last-mile" broadband access with fiber or coax cable can be very expensive, especially in rural areas and developing countries. A cheaper solution is Broadband Wireless Access (BWA). WiMAX (Worldwide interoperability for Microwave Access) is one of the most emerging technologies for Broadband Wireless Access in metropolitan areas as a viable solution due to its high resource utilization ,easy implementation and low cost. WiMAX networks also provide high data rate applications with a variety of Quality of Service (QoS) demands. Theoretically WiMAX networks which defined by IEEE 802.16 shown in Figure (1) can provide a broadband wireless access up to 50 km for fixed stations and 5-15 km for mobile stations. Initially, the standard was first approved in December 2001; it was using Single Carrier (SC) modulation techniques in the range of 10–66 GHz. As multiplexing scheme, burst Time Division Multiplexing (TDM) was selected which could use both Frequency Division Duplexing (FDD) and Time Division Duplexing (TDD) [1]. Due to higher frequency, Line Of Sight (LOS) propagation is a necessity. In 2003 IEEE 802.16c was updated for lower frequencies in the range of 2–11 GHz to facilities the operation in a Non Line Of Sight (NLOS) modes. This version uses Orthogonal Frequency - Division Multiplexing (OFDM) which was considered the best choice to fight multipath affect for wireless communications. In 2004, the IEEE 802.16d was updated for lower frequencies, so resulting in less attenuation, an enhanced range and better coverage within buildings. Then IEEE 802.16e (the mobile version of the IEEE 802.16-2004 standard) is well implemented with Orthogonal Frequency -Division Multiple Access (OFDMA) as its physical layer scheme [1].

2. IEEE 802.16 ARCHITECTURE

The basic IEEE 802.16 architecture consists of at least one Base Station (BS) and one or more subscriber Stations (SSs) [3]. Figure (2) shows a typical IEEE 802.16 network. IEEE 802.16 specifies the following modes of deployment architectures [4]:

- Point-To-Point (PTP): A connection between one BS and one SS. The PTP mode extends the range over the PMP mode.
- Point-to-Multipoint (PMP): each SS directly communicates with the corresponding BS through wireless links, and the BS is connected to a core network through a wired link.
- Point-To-Consecutive Point (PTCM): It depends on creation of a closed loop through multiple PTP connections.
- Mesh: SSs can communicate with each other directly, extending the coverage of an IEEE 802.16 network.

It must be mention here that PMP mode is more simple and easier to deployment due to its centralized control, and is expected to serve as an important role in the wireless metropolitan area network.

3. MAC LAYER IN IEEE 802.16

The basic distinction of MAC protocol is the duplexing techniques of uplink and downlink. The choice of duplexing techniques may affect PHY parameters as well as impact the features that can be supported. There are two approaches to implement it.

1) Frequency Division Duplex (FDD): In an FDD System, the uplink and downlink Channels use separate subcarriers, which allows the terminals to transmit and receive simultaneously.

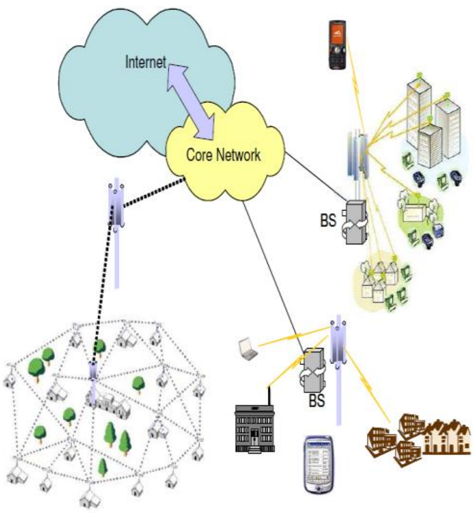

Fig. 1: The Illustration of an IEEE 802.16 Broadband Wireless Metropolitan Area Network [2].

2) Time Division Duplex (TDD): The uplink and downlink transmissions share the same frequency while being allocated in each TDD frame. One TDD frame contains one Downlink and one uplink sub-frame in a TDD frame. This paper will focus on TDD mode.

4. FRAME STRUCTURE

At the MAC layer, the time domain is divided into MAC frames with equal length. Figure (3) describe the Frame structure for IEEE 802.16 network in TDD mode [2]. A MAC frame is consists of a Downlink sub-frame (DL sub-frame) and Uplink sub-frame (UL sub-frame). The DL sub-frame starts with preamble to synchronize SSs with the BS, followed by frame control header (FCH), and followed by several Downlink burst. An UL sub-frame is collected of the contention slot for initial ranging (CSIR), the contention slot for bandwidth request (CSBR) and a number of UL bursts from dissimilar SSs. The first Downlink burst consists of Downlink MAP (DL-MAP), followed by Uplink MAP (UL-MAP) messages, and MAC Packet Data Unit (PDU) which is used to transfer data between MAC layers of BS and SS. The rest of Downlink burst consists of MAC Packet Data Unit (PDU) only. DL-MAP and UL-MAP messages identify the allocation of the transmission bursts along with SSs, counting the related time duration and burst profiles such as the modulation technique and coding rate. CSIR is used for SSs to connect the network. When an SS try to connect the network, it sends initial ranging messages through this slot to obtain the operation parameters, such as transmission power level, frequency. CSBR is deliberate for SSs to send their bandwidth request messages.

5. RELATED WORKS

Many researchers have shown active interest in IEEE 802.16 QoS research. We briefly review some of the existing research, many scheduling algorithms have been proposed. Meng [6] propose a scheduling scheme which aims at extending the Proportional Fairness (PF) to the real time service and provides various QoS requirements.

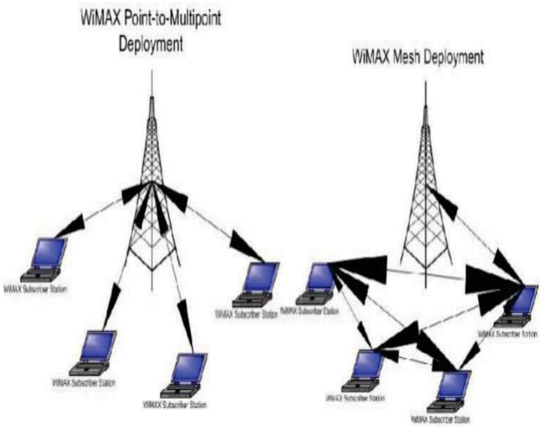

Fig. 2: Mesh and Point-to-Multipoint (PMP) mode [4].

Baban, Shaswar [7] propose scheduling algorithm which can adapt to changes in users' channel conditions. Recently, radio resource management for OFDMA systems has attracted enormous research interests. Ansari, Et al [8] Propose algorithm takes into account the present utilization of downlink and reallocates a certain quantum of free resources to uplink. Polisetty and Thoragu [9] propose a scheme to recycle the unused and free bandwidth without changing the existing bandwidth reservation. Singh and Gupta [10] present a model built with generic MAC PDU which considered useful to analyze the WiMAX system. Alinejad, Et al [11] address the dynamic frame allocation issue in IEEE 802.16j mobile multihop relay (MMR) network for m-health applications.

6. PROBLEM DESCRIPION

As channel bandwidth in wireless network is limited, the effective utilization of scarce resources is important to managers in the telecommunications. Generally QoS means to guarantee a certain level of performance to the data flow which mainly measured in terms of delay, jitter, bandwidth utilization, throughput, and packet loss. In IEEE802.16 (WiMAX) TDD networks which uses a single channel for both downlink and uplink stream the downlink needs may exceed the allocated slots for downlink while the uplink needs may be not exceed 10-40 percent of the allocated slots for uplink. So the unused uplink slots are considered wasted bandwidth. We need to propose a scheme to allow users to utilize the unused bandwidth when it is free.

7. PROPOSED ALGORITHM

The proposed algorithm tries to solve the problem of wasted bandwidth through improves the downlink throughput as well as delay without violating the QoS properties of the uplink traffic.

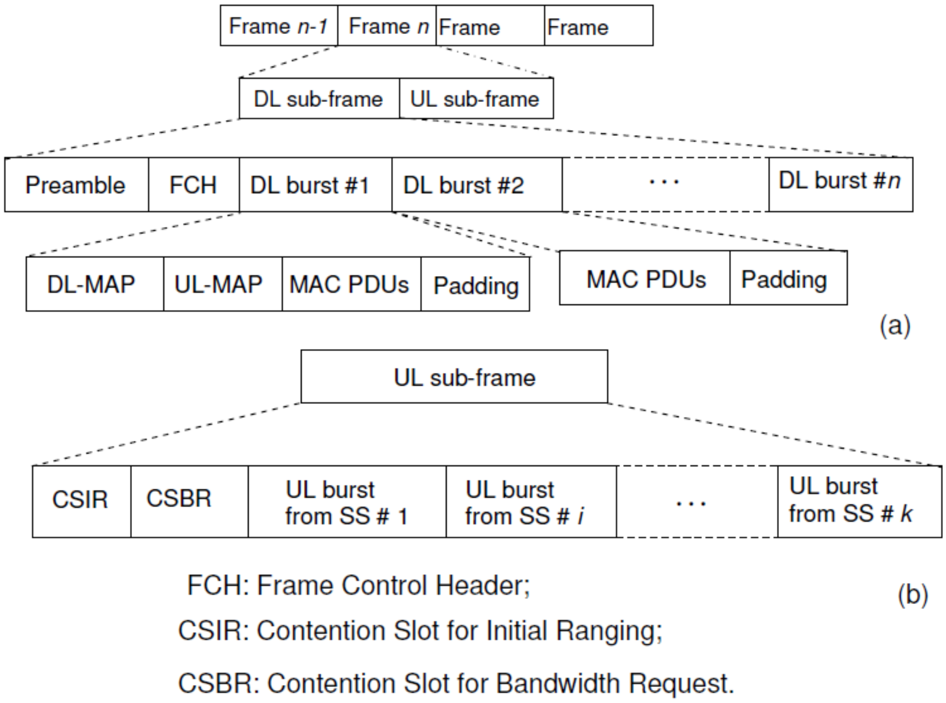

Fig. 3: Frame Structure in IEEE 802.16.

In WiMAX systems TDD is the preferred duplexing mode where transceiver designs for TDD implementations are less complex and therefore less expensive. In this mode the frequency spectrum is divided into multiple subcarriers (grouped into different sub-channels), while TDD requires for each physical WiMAX frame a partitioning in time into a downlink (DL) and an uplink (UL) part which are referred to as the DL sub-frame and the UL sub-frame. The approach aims at readjusting in simple way the numbers of OFDMA symbols dictated for downlink if the QoS properties not provisioned while the uplink throughput equal to load and delay properties are provisioned. The algorithm starts with check the first condition which state if downlink throughput is less than the required load. If this condition is true, the algorithm will check the second condition which state if there is free (unused) OFDMA symbols in the uplink part of the frame. if this condition is true, the algorithm increases the number of OFDMA symbols dictated for downlink step by step by one OFDMA symbol in each step through using the free OFDMA symbols of the uplink then check the first condition until either this condition is false or the there is no free OFDMA symbol.

8. SIMULATION MODEL

The aim of the simulation model is to evaluate the performance of the proposed scheme using the OPNET modeler 14.5 simulator [12] where the IEEE802.16 MAC and PHY levels have been implemented. The implementation of the MAC include the main features of the 802.16 standard, such as frames, packing and fragmentation, bursts, connections, MAC PDUs, the contention periods and ranging. The system parameter used to configure the MAC and PHY layers are summarized in table (1). The simulation assumes error-free channel as it makes it clear to demonstrate guarantee of QoS. The expected effective system capacity downloads /uploads capacity of the model about 8.5 Mbps and about 2.3 Mbps respectively [5]. So to verify the performance of the proposed scheme we chose the download traffic with overhead to go beyond 8.5 Mbps but

TABLE 1. SYSTEM PARAMETERS

parameter	value
Model	PMP
PHY and duplexing mode	OFDMA, TDD
Simulation time	30 min
Frame length and bandwidth	5 ms, 20 MHz
Symbol length	100.8 µs
Delta_f	11.6khz
TTG (Transmit-receive Transition Gap)	100.8 µs
RTG (Receive-transmit Transition Gap)	302.4 µs
FFT size	512
guard period	8/7
Modulation	64QAM
Coding rate	3/4

chose the upload traffic with overhead below 2.3 Mbps. The simulation environment consists of one BS and 6 SSs which are distributed around the BS operating in IEEE 802.16 PMP mode shown in Figure (4). To make the simulation scenario like real scenario the 6 SSs into 4 different categories:-

I. Professional Up/Down user (Prof_U/D_user) 2 users: this kind of user has data to download and need also to upload data. With 0.75 Mbps download traffic and 0.4 Mbps upload traffic for each user.

II. Professional Down user (Prof_D_user) 1 user: this kind of user has numerous data to download merely with download traffic of 4.2 Mbps.
III. High End user (HE_user) 1 user: this kind of user has only data to download with download traffic rate of 2.8 Mbps.
IV. Casual user (C_user) 2 users: this ordinary user type with 0.4 Mbps download traffic rate of each one.

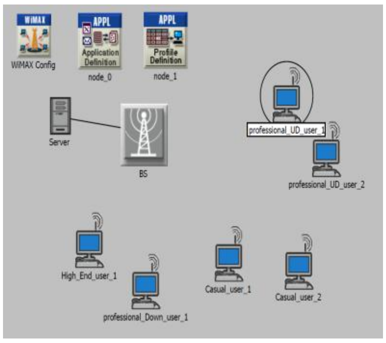

Fig. 4 Simulation scenario

9. RESULTS and DISCUSSION

In this section the output of the simulation is shown and analyzed for two scenarios. The results for first scenario shown in Figures (5 -13) are the consequences of the original IEEE802.16 MAC structure without any modification. Figure (5) represent the total load in comparison with total throughput of the system. As indicated in this representation it can be seen that the maximum load about 11Mpbs which is greater than maximum throughput about 9.3 Mbps. So this scenario suffers from the problem of wasted bandwidth about 1.5Mbps lost data. Figure (6) represent the average delay of the system about 120 ms.

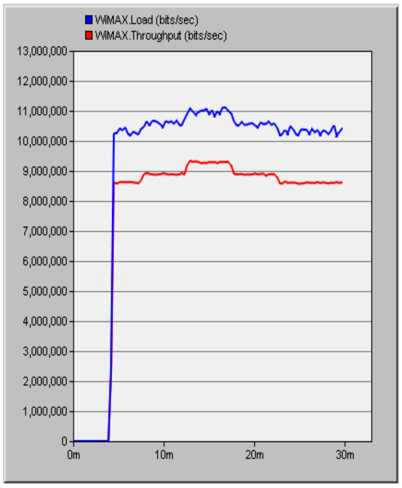

Fig. 5 Total system Load & Throughput

Figure (7) symbolizes the percent of frame utilization for both downlink and uplink sub-frame. It can be stated that downlink utilization is 100 % utilized while uplink about 36% utilized which confirm that the total dropped data are from the downlink data. Figure (8) stands for number of OFDMA symbols for each sub-frame which is almost constant for both uplink and downlink.

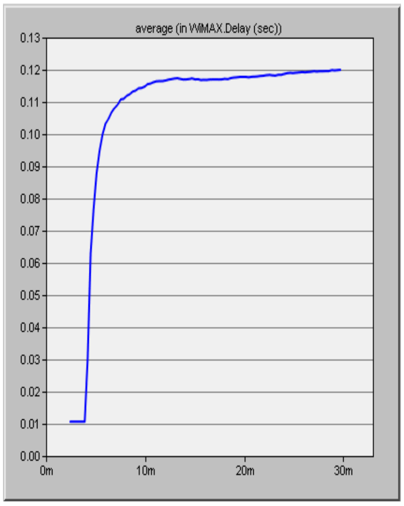

Fig. 6 Average total system Delay

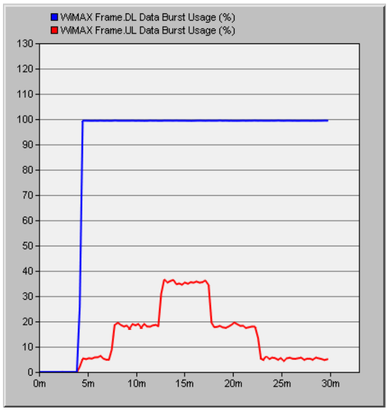

Fig. 7 Frame Utilization

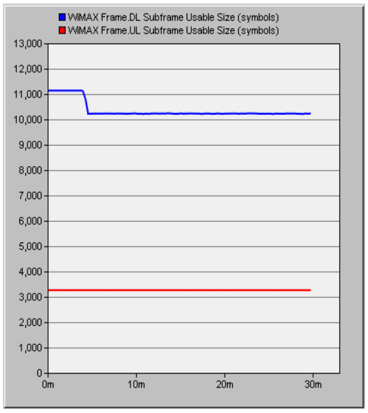

Fig.8 No. of symbol/ Frame

Figures (9-13) represent the average delay for each category user. As indicated in these representations it can be observed that the average delay of 32ms for the upload part of the Professional Up/Down user and 7 ms for the download for the same user. The average delay of 200 ms for the download Professional Down user and about 130 ms for the High End user and between (10-11ms) for the casual users.

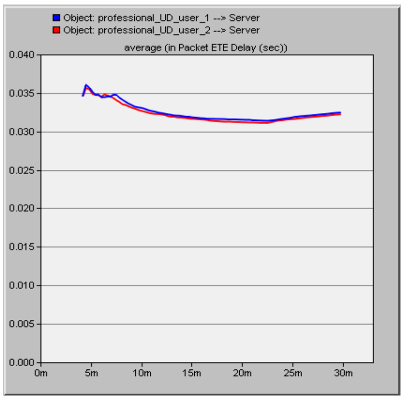

Fig. 9 Average uplink delay Prof_U/D_user

The results for second scenario shown in Figures (14 -22) are the outcome of the modified version of IEEE802.16 MAC structure with the proposed scheme. Figure (14) represents the total load in comparison with total throughput of the system. As shown in this characterization it can be stated that the total system load is identical with total system throughput (~11Mpbs) that mean that there is no dropped data which is confirms the success of the proposed scheme in solving the problem of wasted bandwidth.

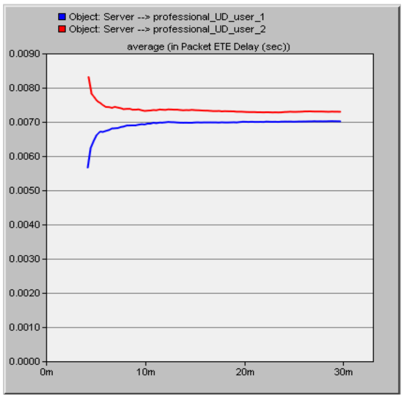

Fig.10 Average downlink delay Prof_U/D_user

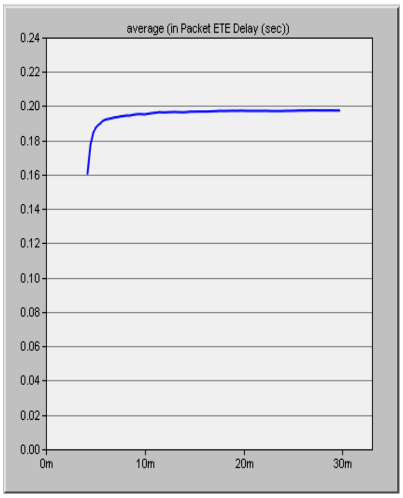

Fig.11 Average downlink delay Prof_D user

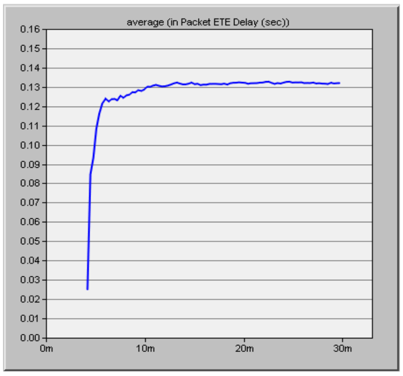

Fig. 12 Average downlink delay HE_user

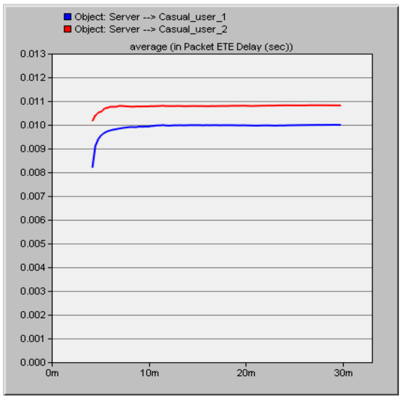

Fig. 13 Average downlink delay C_user

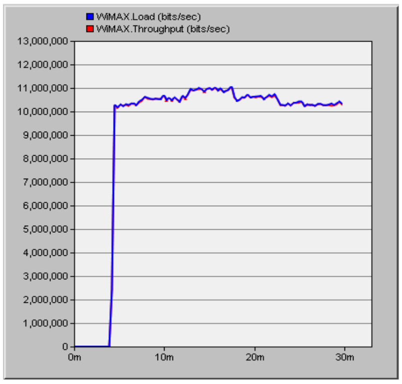

Fig.14 Total system Load & Throughput

Figure (15) represents the total average delay of the system about 23 ms which decreased from 120 ms for the first scenario. This proves that the proposed scheme improves the total system delay with decrease about 80%.

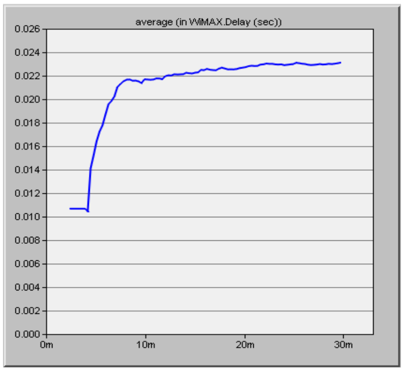

Fig.15 Average total system Delay

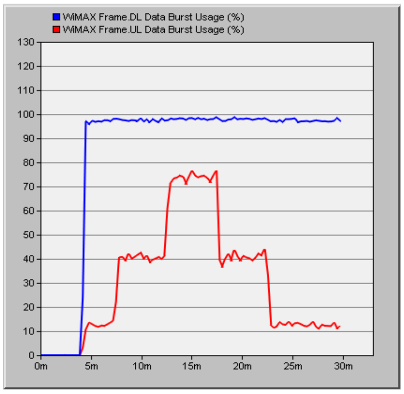

Fig.16 Frame Utilization

Figure (16) indicates the percent of frame utilization for both downlink and uplink sub-frame. It can be stated that downlink utilization is reduced to be 98 % utilized while uplink increased to be about 75% utilized which prove that the free uplink symbols are used to carry download data. Figure (17) stands for number of OFDMA symbols for each sub-frame which show that according to the algorithm the number of OFDMA symbols for downlink is increased and the number of OFDMA symbols for uplink is decreased.

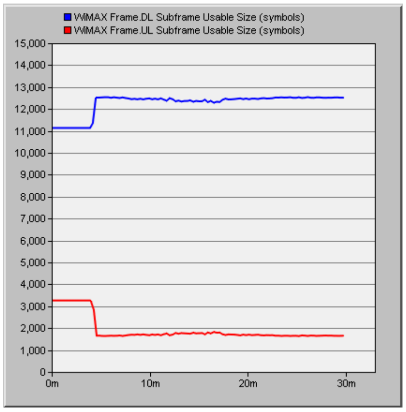

Fig.17 No. of symbol/ Frame

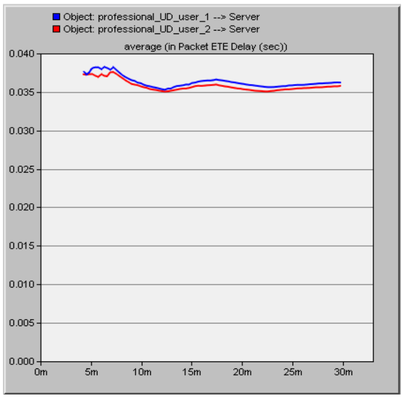

Fig. 18 Average uplink delay Prof_U/D_user

Figures (18-22) characterize the average delay for each category user. It can be stated from these demonstration the average delay a little increased to be 36 ms for the upload part of the Professional Up/Down user and 6.5 ms for the download for the same user. It can be concluded that there is no bad effect on that kind of user.

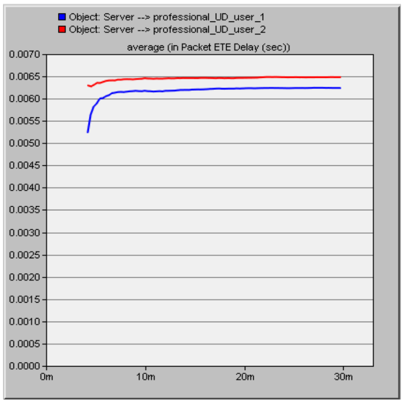

Fig.19 Average downlink delay Prof_U/D_user

Figure (20) represent the average delay of the download Professional Down user. The results in this scenario give decrease to be 37 ms which was 200 ms in the first scenario. This means that the proposed scheme success to decrease about 81% of the average delay for this user.

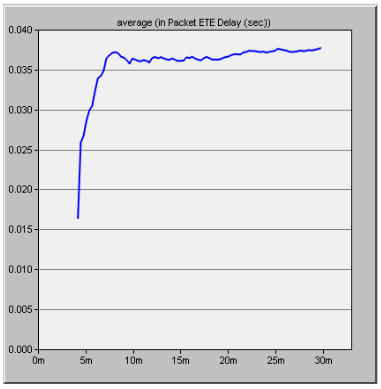

Fig. 20 Average downlink delay Prof_D user

Figure (21) characterizes the average delay of the High End user. This scenario provides decrease to be 13 ms which was 130 ms in the first scenario. This validate that the proposed scheme achieve to decrease about 90% of the average delay for this user. Figure (22) describes the average delay of the casual users. In this scenario offer 10 ms this means that there is no bad effect on that kind of user.

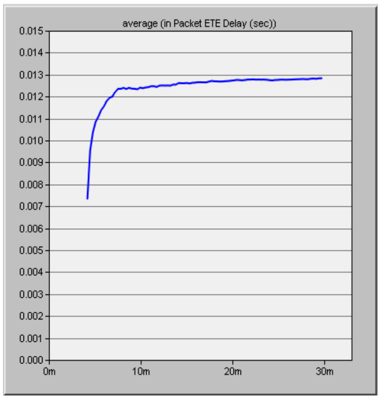

Fig. 21 Average downlink delay HE_user

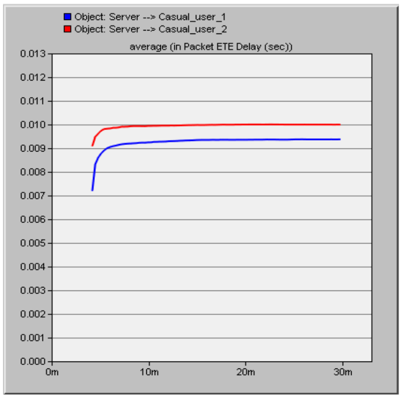

Fig.22 Average downlink delay C_user

10. CONCOLOUTIONS

In this paper, modified version of IEEE 802.16 MAC structure in PMP mode is proposed. The algorithm aims to improve the throughput of downlink as well as to minimize the delay. By increasing the number of OFDMA symbols in TDD mode assigned for downlink and reducing the number of symbols allocated for uplink to meet with the QoS requirements. The simulation results show that the proposed algorithm solves the problem of wasted bandwidth and can decreases the overall average system delay by 80%.

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