https://dx.doi.org/10.22161/ijaers/3.10 *ISSN: 2349-6495(P) | 2456-1908(O)*

Comparative Performance Evaluation of MAC Scheduling Algorithms for QoS Support in P-M-P Wireless Network

Avinash S. Kapse

Research Scholar, Singhania University, Pacheri Bari, Rajsthan, India

Abstract — *The Quality of Service (QoS) provided for different types of multimedia applications such as audio, video, etc. The IEEE 802.16 standard defines different service classes with their associated (QoS) parameters. The MAC scheduling algorithm is the main role performing in QoS provisioning over such broadband wireless access (BWA) network and it is important that the scheduling algorithm have a multi-dimensional objective of satisfying QoS requirements of the users, maximizing system utilization and ensuring fairness among users. In this paper, we present comparative analysis for different types of MAC scheduling algorithms for the uplink (UL) connection. The proposed scheduling algorithms are compared to several other MAC scheduling algorithms for UL traffic under different mixes of traffic and for various characteristics of the IEEE 802.16 MAC layer such as throughput & delay. Simulation results indicate that MAC scheduling algorithms are not suitable for the multi-class traffic in IEEE 802.16 since they do not explicitly incorporate the QoS parameters for the given standard.*
Keywords—IEEE 802.16, MAC, scheduling, QoS, delay.

I. INTRODUCTION

The user interest is increase in wireless broadband internet communications is an effect of both rapid growth and the rising importance of wireless communications and multimedia services to end users. In rural areas, broadband wireless access (BWA) represents an economically practical solution to provide last mile access to the Internet, it is easy to deployment and low cost of its ”light” architecture. Standard activities for BWA are being developed within IEEE project 802, Working Group 16, often referred to as 802.16. The IEEE 802.16 standard is also known in the trade press as Worldwide Interoperability for Microwave Access (WiMAX) [1].

The physical (PHY) layer employs orthogonal frequency division multiplexing access (OFDMA) and supports both fixed and adaptive modulation techniques in the uplink (UL) and in the downlink (DL) directions [2]. Maximum attainable data rates depend upon the modulation schemes used and the condition of the channel. The IEEE 802.16 protocol stack, the (MAC) layer supports two modes: Point-to-Multipoint (PMP) and Mesh (optional). In the PMP mode, the nodes are organized into a cellular-like structure, where the base station (BS) serves a number of subscriber stations (SSs) within the same antenna sector in a broadcast manner, with all the SSs receiving the same transmission from the BS. In the mesh mode, the nodes are organized in an ad-hoc fashion and scheduling is distributed among them.

The IEEE 802.16 is designed to support multimedia service via (QoS) of different service types. Each traffic flow requires different treatment from the network in terms of allocated bandwidth, maximum delay, and jitter and packet loss [3], [4].

Traffic differentiation is thus a crucial feature to provide network-level QoS. The standard leaves QoS support features specified for WiMAX networks (e.g., traffic policing and shaping, connection admission control and packet scheduling) open to vendor algorithm design and implementation. One of the most critical issues is the design of a very efficient scheduling algorithm which coordinates all other QoS-related functional entities. In the DL, the scheduler has complete knowledge of the queue status, and, thus, may use some classical scheduling algorithms, such as

Weighted Round Robin (WRR), Weighted Fair Queuing (WFQ) etc. Priority oriented fairness features are also important in providing differentiated services in IEEE 802.16 networks. Through priority, different traffic flows can be treated almost as isolated while sharing the same radio resource. However, the BS scheduler is non-work conserving, since the output link can be idle even if there are packets waiting in some queues. Indeed, after downlink flows are served in their devoted sub-frame, no additional downlink flows can be served till the end of the subsequent uplink sub-frame. Scheduling uplink flows is more complex since the input queues are located in the SSs and are hence separated from the BS. The UL connections work on a request/grant basis. Using bandwidth requests, the uplink packet scheduling may retrieve the status of the queues and the bandwidth parameters.

II. WIMAX WIMAX & OVERVIEW OF THE IEEE 802.16

The basic IEEE 802.16 architecture is having a one Base Station (BS) and one or more Subscriber Stations (SS). The IEEE 802.16 MAC is a connection oriented mechanism. Both the Base Station & Subscriber Station is immobile, when clients want to connect SS can be mobile station. Base Station (BS) acts as a central entity which transfers all the data from Subscriber Stations in point-to-multipoint architecture. There is one limitation of PMP architecture. Two or more Subscribers Station is not allowed to communicate directly. The BS and SS architectures are connected to each other through wireless links. In the network, each SS creates one or more connections over the data packets which are transmitted to and from the BS. Each connection is having 16-bit connection identifier (CID) in downlink & uplink direction. The MAC management message, which transfers data between SS and BS, manages the information for upcoming frames before actual data transfer. SS downlink channel to get downlink map and uplink map from BS. DL-Map keeps the record regarding downlink sub frames & UL-MAP keeps the information regarding uplink sub frames [5].

To establish a connection, each SS has to perform coverage ranging process and registration process. Coverage ranging process starts by sending ranging request (RANG-REQ) packets to BS in ranging contention slots. SS sends RANG-REQ in each frame till it gets ranging response (RANG-RSP). SS does the capability negotiation.

Registration is also done in request response manner by sending registration request (REG-REQ) packets to BS and then BS send registration packets to SS [6].

Now any SS is ready to setup a connection with BS. Connection is established in the request-response manner [3].There is two broad definitions of quality of services:

User point of view QoS is: The collective effect of service performance which determines the degree of satisfaction of user of the service.

Network point of view QoS is: The architecture that gives the network manager the ability to control the mix of bandwidth, delay, variance in delay and packets loss in the networking order to deliver a network services.(e.g. VoIP, real-time movies)

Usually, second definition is used in wireless communication to use existing resources efficiently by implementing QoS architecture. Network performance characteristics parameter is listed below:

Latency: Transmission delay of packet from source to destination.

Jitter: Variance in transmission delay.

Reliability: The percentage of traffic of packet should be delivered successfully from source to destination.

Data Transmission rate: Amount of data that be carried from source to destination in the allocated period.

The IEEE 802.16-2004 standards support five qualities of services:

UGS (Unsolicited grant service): It uses for the constant bit rate (CBR) services application for real time data stream & fixed size data packets issued at periodic intervals.

rtPS (Real Time Services): It uses for variable bit rate (VBR) services application for real time data streams & variable sized data packets that are issued at periodic intervals. ex. MPEG video.

ertPS (extended real time polling Services): Real time services flows that generate variable sized data packets on a periodic basis. ex. VoIP.

nrtPS (Non-real time polling services): Delay tolerant data streams & variable sized data packets for which a minimum data rate is required ex. FTP with minimum data rate.

BE (best efforts): Data Streams for which no minimum services level is required and therefore may be handle on space available. Ex. HTTP.

III. MAC SCHEDULING ALGORITHMS

The design of the uplink scheduling algorithm for IEEE 802.16 then for the downlink since the UL do not have all information about the SSs such as the queue size. At the BS, the UL scheduling algorithm has to coordinate its decision with all the SSs whereas a DL algorithm is only concerned in communicating the decision locally to the BS. In this section, we will describe the evaluated UL MAC scheduling algorithms considered in this paper. Some of the UL scheduling algorithms is described in more detail whereas for the well-known algorithms such as WRR, EDF and WFQ [6, 7].

Homogeneous scheduling algorithms: These are legacy scheduling algorithms that attempt to address issues such as providing QoS, flow isolation and fairness. The algorithms were originally proposed for wired networks but are used in WiMAX principally to satisfy QoS requirements of the four traffic scheduling services. Algorithms in this category do not address the issue of link channel quality.

Hybrid scheduling algorithms: This category contains algorithms that use a combination of legacy scheduling algorithms in an attempt to satisfy QoS requirements of the four scheduling services. Some of the algorithms in this category also address the issue of variable channel

https://dx.doi.org/10.22161/ijaers/3.10 **ISSN: 2349-6495(P) | 2456-1908(O)**

conditions in WiMAX. An important aspect of algorithms in this category is the overall allocation of bandwidth among the scheduling services. Once bandwidth has been assigned to each class, a legacy algorithm is executed for SSs of the class to determine the bandwidth allocation in that class.

The overall bandwidth distribution is executed at the beginning of every frame while the EDF and WFQ algorithms are executed at the arrival of every packet. The following is the overall bandwidth allocation scheme adopted in our implementation.

$$BW_{ertPS,\,rtPS} = C * \left(\sum_{i \in ertPS,\,rtPS} MRTR_i \right) / \left(\sum_{j=1}^{n} MRTR_j \right)$$

$$BW_{nrtPS,BE} = C * \left(\sum_{i \in nrtPS,BE} MRTR_i \right) / \left(\sum_{j=1}^{n} MRTR_j \right)$$

Opportunistic scheduling algorithms: Scheduling algorithms in this category are primarily focused on exploiting the variability in channel conditions in WiMAX. The algorithms also attempt to satisfy QoS requirements of the four scheduling services and maintain fairness between the SSs.

The proposed resource management model contains a closely coupled scheduling algorithm and a CAC scheme. The focus of our study is to evaluate the performance of the scheduling algorithm only, and therefore the CAC is not implemented. To evaluate this algorithm as it uses queuing theory to satisfy the QoS requirements of the scheduling services. It also uses thresholds to limit the bandwidth allocated to SSs of each class. This is a unique way of limiting bandwidth allocation and ensuring that lower priority SSs do not starve. The algorithm is executed at the Base Station (BS) at the beginning of every frame. The utility of each SS is calculated at the start of a frame and the bandwidth is allocated accordingly. The utility function of a SS is defined as follows,

$$U_{BE}(b_i) = \begin{cases} 1 & \text{if } b_i \geq 0 \\ 0 & \text{Otherwise} \end{cases}$$

Where,

U_{BE} refers to utility for SSs of BE class.

A. Experimental Analysis

The simulation tool chosen for the experiments is based on Network Simulator 2 (NS-2) [4], [6]. Numbers of modifications to the NS-2 extension for WiMAX were made. The detailed description of the changes made to the tool, including the traffic model, transmission modes and choice of MAC layer parameters such as length of uplink preamble and allocation start time. And also discuss the metrics used to evaluate the schemes.

B. Traffic Model

The four different traffic sources are implemented, one for each of the traffic classes. VoIP traffic is modeled for SSs of ertPS class, video streaming for SSs of rtPS class, FTP for SSs of nrtPS class and HTTP for SSs of BE class. The values of all the traffic parameters are based on one connection per SS.

1) VoIP Traffic – ertPS class (Class 2)

An important characteristic of VoIP traffic is the presence of talk spurt and silence spurt. The length of the talk spurt and silence spurt depends on the encoding scheme used. There are numerous encoding schemes such as G.711, G.722, and Adaptive Multi-Rate (AMR) that result in different bandwidth requirements. The model described in [8] that assumes the AMR codec and a packet size of 23 bytes. To suit our simulation needs, modified the model and added some parameters associated with a connection as specified in the IEEE 802.16-2004 standard.

TABLE 3.1: VOIP TRAFFIC PARAMETERS

Parameter	**Value (1 connection per SS)**
Minimum Reserved Traffic Rate (MRTR)	25 Kbps
Average Traffic rate	44 Kbps
Maximum Sustained Traffic Rate (MSTR)	64 Kbps
Maximum Latency	100ms
Tolerated packet loss	10%
Talk spurt length	Exponential random with µ=147ms
Silence length	Exponential random with µ=167ms

2) Video Streaming – rtPS class (Class 3)

The values of a traffic source modeled for video streaming highly depend on the video trace. Based on the discussions in [8] and [9], video streaming has been divided into two broad categories, low quality (64-500Kbps) and high quality (1.5-10Mbps). Implement the low quality video streaming model with packet size uniformly distributed between 150 bytes and 300 bytes.

TABLE 3.2: VIDEO STREAMING PARAMETERS

Parameter	**Value (1 connection per SS)**
Minimum Reserved Traffic Rate (MRTR)	64 Kbps
Average traffic rate	282 Kbps
Maximum Sustained Traffic Rate (MSTR)	500 Kbps
Maximum Latency	150ms
Tolerated packet loss	5%

3) FTP – nrtPS class (Class 4) and HTTP – BE class (Class5)

An FTP traffic generator with a constant packet size of 150 bytes. A value of 45 Kbps for Minimum Reserved Traffic Rate (MRTR) and 500Kbps for Maximum Sustained Traffic Rate is used for each FTP source. An HTTP traffic model is used for the BE class. A value of 64 Kbps for MSTR and a packet size of 100 bytes are adopted in the mode. Although SSs of the BE class do not have MRTR parameter associated with them, since implementation of schemes such as WRR and WFQ require a weight to be assigned to the SSs based on the MRTR, a value of 1 Kbps is used for MRTR.

C. Simulation Parameters

The Table 3.3 lists parameters that are constant throughout the simulation study whereas Table 3.4 lists parameters whose values are varied in the experiments to study the performance of the scheduling algorithms. According to the IEEE 802.16-2004 standard [1], the allocation start time for WirelessMAN-OFDM PHY layer can either be the start of the uplink sub-frame in the current frame or start of the uplink sub-frame in the next frame. The allocation start time is the reference point for the information in the UL-MAP message. In our experiments, the value for allocation start time is set such that all the allocation in the UL-MAP will start in the current frame after the last specified allocation in the DL-MAP. This point in the frame is referred to as Adaptive Time Division Duplexing (ATDD) split. The default values as specified in NS-2 are used for PHY layer parameters such as radio propagation model and antenna type.

1) Working of Scheduling Algorithm

The proposed operational scheduling algorithm is to provide rtPS service flow packets more chance to meet their bandwidth as per requirement and decrease the delay. The figure 4.2 shows apart from checking that the allocated bandwidth is enough for granting a request, the system had to check the QoS polling services, nominal polling jitter and reference time (the time used as a reference to calculate both the generation time and the target of the rtPS data grants) related to the rtPS service flows that are applied. The information gathered from this monitoring is used to approximate the expected delay of each rtPS connection and this scheduling algorithm, is used to calculate the target throughput & delay.

IEEE 802.16 has two modes for allocation bandwidth requested by Subscriber Station:

Grant per Connection (GPC): The bandwidth is allocated as per connection of SS. SS had no scheduler for the packets forwarding to the BS.

Grant per Subscriber Station (GPSS): The bandwidth is allocated to all SS & their connections.

2) System Development Methodology Implementation

This architecture is designed to achieve the following objective:

Packets are scheduled in uplink direction as per their priority, UGS packets having highest priority and after that rtPS and nrtPS packests.

The packets are sent one after another in the downlink direction in SS based on the priority of the packets.

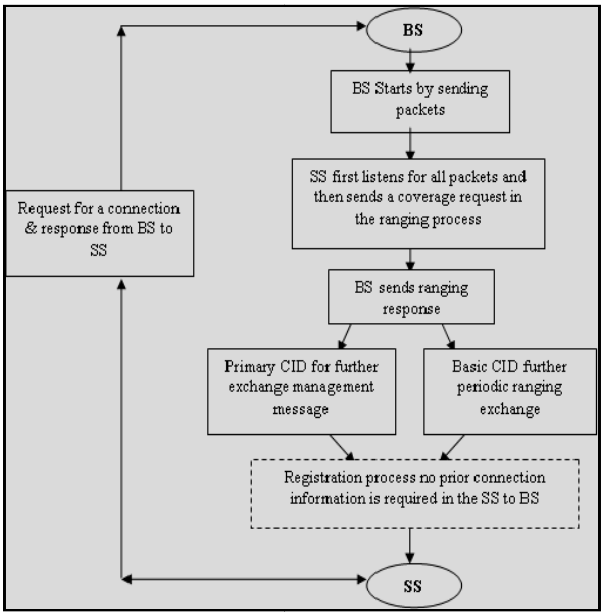

Fig. 1: Flowchart for Network initialization.

The UGS packets are sent first as per FIFO and same type of rtPS and nrtPS packets are sent as per FIFO.

3) Implementation Steps of WiMAX

The drawback of any wireless communication structure is that coverage ranging area data rates are imperfect. To overcome this limitation in WiMAX communication structure the coverage ranging area is increase by changing the bandwidth. The following steps are involved in ns2 for implementing WiMAX point-to-multipoint communication [10, 11].

Step 1: In figure 4.3 we have used the ns-2 version 2.34 for implementing WiMAX point-to-multipoint communication wa1.tcl.

Step 2: The files have been changed are mac-802.16.cc, mac-802_16.h and ll.c, packet.h

Step 3: Add the given parameters in the files mac-802.16.cc, mac-802_16.h

Step 4: For this implementation purpose we have used linux (Fedora 12 version).

https://dx.doi.org/10.22161/ijaers/3.10 ***ISSN: 2349-6495(P) | 2456-1908(O)***

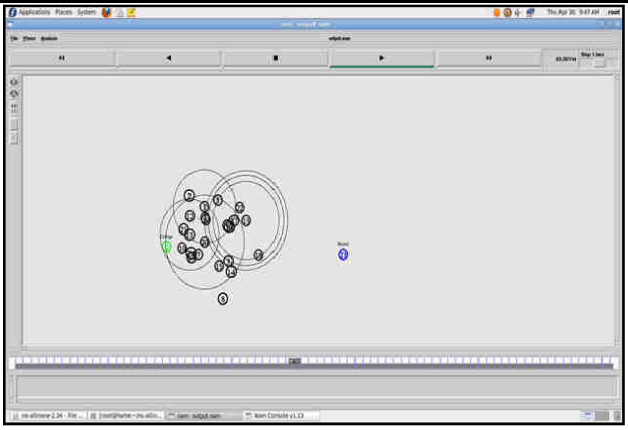

Fig. 2: Figure 4.3: simulation Setup

Step 5: After execution of the wa1.tcl file, the trace file is generated wa1.tr, it includes the information about packets sending & receiving time, packets drop & transfer from BS to SS in figure 4.

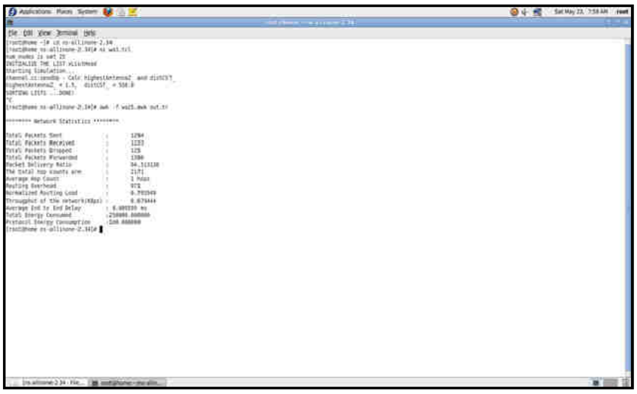

Fig. 3: Trace File

Step 6: For displaying the graph the Microsoft Excel 2007 can be used. Even though we can use the xgraph, gnuplot command in ns-2 & MatLab for graph plotting purpose [12].

TABLE 3.3: FIXED SIMULATION PARAMETERS

Parameter	Value
Physical Layer	WirelessMAN-OFDM
Uplink burst preamble	16 symbols
Allocation Start Time	ATDD split
Frame structure	TDD
Bandwidth	20MHz
DL:UL frame ratio	1:1
OFDM symbol duration	12.5 μs
Node placement	Random
Simulation grid size	1000mx1000m
Simulation time	50 seconds

TABLE 3.4: VARIABLE SIMULATION PARAMETERS

Parameter	Value
Number of SSs	1-9, 1-36, depends on number of SSs selection
Ratio of SS (ertPS:rtPS:nrtPS:BE)	1:1:1:3, 1:1:2:2, 1:1:3:1, 1:2:2:1, 1:3:1:1, 2:2:1:1, 3:1:1:1
Frame Length	2.5ms,4ms,5ms,8ms,10ms,12ms,20ms

IV. ANALYTICAL ANALYSIS

The experiments are executed under different network conditions such as light/heavy load and number of SSs in the network. Except for the bandwidth request as experimental analysis, one slot per SS is reserved for bandwidth request and contention request opportunities. In all the experiments 95% confidence levels are maintained with 5% confidence intervals based on 10 independent runs [13]. WiMAX can provide a sustainable solution for the Indian service providers as some Indian operators having with 3G licenses cannot adequately develop wireless broadband service due to the limited 2X5 MHz bandwidth shortage. Therefore, utilizing 2X20 MHz spectrum in the 2.3 GHz band for the operation of a WiMAX network is a promising candidate solution for realizing next generation all-IP networks [14].

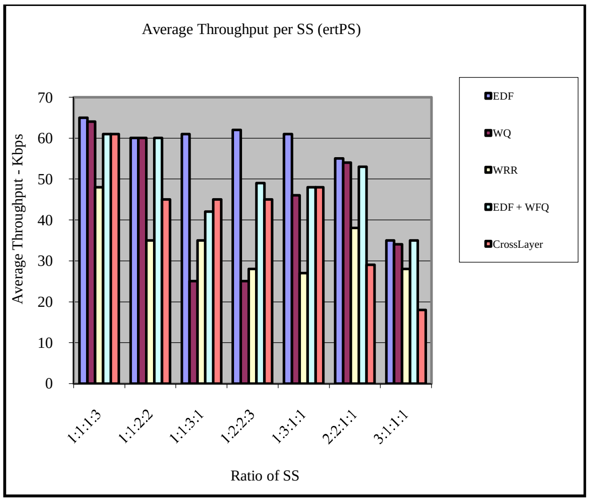

Fig. 4: Graph 4.1: Average Throughput - ertPS

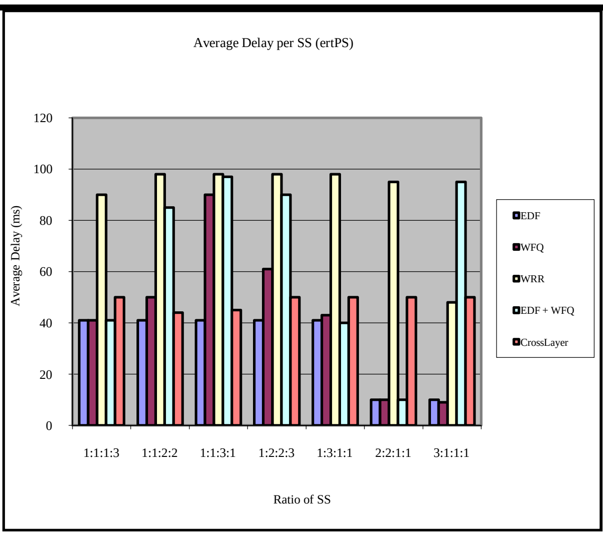

Fig. 5: Graph 4.2: Average Delay per SS – ertPS

Comparison between Experimental Analysis & Analytical Analysis

TABLE 4.1: COMPARISON OF MAC UPLINK SCHEDULING ALGORITHMS IN WIMAX

Algorithms	**Suitable bandwidth request mechanism (Heavy load / light Load)**	**Average Through put (ertPS/rtPS/ nrtPS/ BE)**	**Average Delay/ Packet loss**
EDF	Piggyback / Contention	High/ High/ Low/ Low	Low/ Low
WFQ	Piggyback / Contention	Medium/ High/ High/ Low-Medium	Low/ Low
EDF + WFQ	Piggyback / Contention	High/ Medium-High/ High/ Low-Medium	Medium-High/ Medium-High
Cross layer	Contention / Contention	Low/ Low/ Low/ Low	High/ High

The performance metrics used to evaluate the scheduling algorithms are throughput, delay and packet loss.

TABLE 4.2 COMPARATIVE ANALYSIS FOR SERVICE CLASSES WITH TWO DIFFERENT APPLICATIONS.

Application Type	Parameters	Service Class		
		rtPS	BE	UGS
Video	Throughput	388	435	468
	Delay	0.068	0.052	0.15
	Packet Loss	3.425	9.55	0.353
VoIP	Throughput	279	277	296
	Delay	0.025	0.032	0.013
	Packet Loss	0.0477	0.7229	0.0472

V. CONCLUSION

In this paper we emphasized on a MAC scheduling architecture for IEEE 802.16 standards. The MAC scheduling architecture uses the downlink as well as the uplink scheduling algorithm for improving delay and throughput.

Downlink scheduling is easy because only involved entity is BS and it has all the required information for the same. For uplink scheduling, each SS has to send its queue information to BS. In the operational scheduling algorithm, we have broadcast MAP according to the bandwidth allocation request.

WiMAX P-M-P module was implemented by using ns-2 tool and C++ programming language and flowchart for network initialization is proposed.

It is also observed that BE QoS service class can be used in general condition to get maximum throughput, low latency and low BER. WiMAX may be a viable solution for India as e-services targets to have broadband connection in all secondary schools for ICT purpose.

REFERENCES

[1] Frank Chee-Da Tsai, Jenhui Cheny, Chiang-Wei Chang, Wei-Jen Lien, Chih-Hsin Hung, and Jui-Hsiang Sum, “The Design and Implementation of WiMAX Module for ns-2 Simulator” , Conference on mobile multimedia communication, September 2007, Vol 46, pp 1024-1039.

[2] Borin, J.F. and N.LS.D. Fonseca,”Uplink scheduler and admission control for the IEEE 802.16 standard”. Proceedings of the IEEE Global Telecommunications Conference, Nov. 30-Dec. 2009, IEEE Xplore Press, Globecom, pp: 1-6. DOI: 10.1109/GLOCOM.2009.5425779.

[3] Mardini, W., Y. Khamayseh, M.B. Yasin and G. Obiedat, 2011. “Survey of latest WiMAX technologies and technique”. Int. Rev. Comput. Softw.

[4] A.S.Kaspe” Wimax: A implementation and study its effect for new MAC scheduling algorithm for

improving throughput & delay”, 2011 IEEE International Conference on Computational Intelligence and Computing Research, 978-1-61284-693-4/11/$26.00,pp:135-138.

[5] Chuang, H.S., L.T. Lee and C.F. Wu, 2013.” A cross-layer QoS scheme of non-real-time service in WiMAX”. Int. J. Future Generat. Commun. Network., 6: pp: 87-98.

[6] Hsiao, Y.M., J.F. Lee, J.S. Chena and Y.S. Chu, 2011.” H.264 video transmissions over wireless networks: Challenges and solutions”. Comput. Commun., 34: 1661-1672. DOI: 10.1016/j.comcom.2011.03.016.

[7] Ghazizzadeh, R., P. Fan and Y. Pan, 2009. “A two layer channel aware scheduling algorithm for IEEE 802.16 broadband wireless access systems”. J. Applied Sci., 9: 449-458. DOI: 10.1109/MNET.2009.4305171.

[8] TCS, 2009. “WiMAX base station scheduling algorithms”. Tata Consultancy Services.

[9] M.Vijayalakshmi,Swaroop R.Puranik, et al. " A Cross Layer Scheduling Algorithm in IEEE 802.16e WiMAX Standard to Support RTPS Traffic" CSNT’14 Proceeding of the 2014 Fourth International Conference on Communication Systems and Network Technologies (2014): 347-351.

[10] Angana Chakraborty, Sajal Saha, Indrajit Banerjee and Arnab Gupta “Optimized WiMAX Network Development in India: Specification and Implementation” Springer India 2015 Computational Advancement in Communication Circuits and Systems, Lecture Notes in Electrical Engineering pp: 89-99., DOI 10.1007/978-81-322-2274-3_11.

[11] The ns2 network simulator: available at http://www.isi.edu/nsnam/ns/.ns2.html.

[12] Goyal, P. and A. Sahoo,”A scheduling and call admission control algorithm for WiMax mesh network with strict QoS guarantee”. Proceedings of the 2nd International Conference on Communication Systems and Networks, 2010 Jan. 5-9, IEEE Xplore Press, Bangalore, pp: 1-10. DOI: 10.1109/COMSNETS.2010.5431997.

[13] Yahya Abdullah Yahya Al zahrani “Performance Analysis of the Impact of the Propagation Environments on the WiMAX Service Classes” International Journal of Future Generation Communication and Networking Vol. 8, No. 1 (2015), pp:117-126.

[14] A.Rehan, Mustafa Shakir. "Comparative Analysis of Scheduling Algorithms in IEEE 802.16 WiMAX." Internet, 2014. “International Journal of Computing and Digital Systems”. Scientific Publishing Center, University of Bahrain,pp:: 161-172.