An Adaptive Weight Calculation based Bandwidth Allocation Scheme for IEEE 802.16 Networks

Akash Deep
UIET, Panjab University, Chandigarh, India
akashdeep@pu.ac.in

KS Kahlon
Department of CSE, GNDU Amritsar, India
kskahlon@yahoo.com

Abstract— **WiMAX standard also known as IEEE 802.16 is a wireless MAN standard driven by WiMAX Forum. WiMAX forum defines specification for QoS provisioning for manufacturing of WiMAX equipment by different vendors but the amount of bandwidth allocated to specific service in WIMAX is still an open issue. A number of algorithms have been presented to satisfy the diverse QoS requirements for traffic in WiMAX networks. The focus of all these algorithms is towards real time traffic. Non real time traffic like nrtPS and BE is quite often neglected. This paper is an attempt towards fair allocation of resources to non real time traffic simultaneously taking care of real time traffic also. The approach uses uncertainty principles of fuzzy logic to calculate new weights for different flows and makes allocation based on these new weights. Simulation results show that the proposed scheme was able to meet required performance levels for both kinds of traffic.**

Index Terms—**Scheduling, IEEE 802.16, fuzzy, weight**

I. INTRODUCTION

Ever increasing demand for multimedia application has shifted the focus of wireless fraternity to IEEE 802.16 standard, also known asWiMAX,. It is designed to provide both wired and wireless broadband access in Metropolitan areas [1] [2] guaranteeing minimum quality of service (QoS) for both real and non real types of applications. In order to make resource allocation effective WiMAX support scheduling based channel access in which different resources like time, frequency are allocated in proportion to service priorities calculated on the basis of bandwidth request made by different SS.

Support for varying applications is provided by associating each connection between BS and SS to five different service classes as defined by the standard. UGS

Unsolicited grant service (UGS) applications are fixed size real time applications with streaming on a periodic basis, e.g. VoIP without silence suppression. Real time polling service (rtPS) provides real time applications with variable-size data packets streaming on a periodic basis, e.g. MPEG video. Non-real time polling service (nrtPS)

is for non real time Variable Bit Rate applications that are delay tolerant and require minimum bandwidth guarantee e.g. FTP. Best Effort service(BE) is used for best-effort traffic such as HTTP or www. A new service flow called extended real-time Polling was added in IEEE 802.16e standard to incorporate the advantages of both UGS and rtPS. The signaling mechanism in WiMAX permits SS to predict its bandwidth requirements and request for it from BS and BS makes the allocation on the basis of bandwidth requested and QoS parameters for the connection.

Each frame in WiMAX is divided into two parts : downlink and uplink subframe. Downlink subframe is used by BS to send control and data information to different SS while uplink subframe is utilized by SS for data transmission. Time slots are granted to a connection depending on service flow of connections.IEEE 802.16 standard defines QoS service framework for different services as shown in figure 1. but how much amount is to be allocated for each service has been left as open issue to be explored and implemented by equipment manufacturers. This paper is an attempt in this direction. The proposed scheme uses the dynamism provided by fuzzy logic and can be easily implemented in base stations. This paper is organized as follows. Section-II is devoted to studies available in this direction followed by proposed scheme in the next section. Simulations and results are given in next section and finally conclusion is presented.

II. RELATED WORK

Problem of bandwidth allocation and scheduling of resources together form one of the major challenges in a packet switched network like WiMAX and literature is rich enough with a number of studies in this direction. For the design of new approach authors has studied a number of papers few of these are listed in this sections.

Shreedhar andVarghese[3] presented a changed form of round robin method and named it deficit round

robin(DRR) whch they hope will provide O(1) complexity if specific constraints are met. The scheduler has disadvantage as only one packet can be served from the queue which may lead to real time packet missing their deadlines.

Wongthavarawat et al.[4][5] utilized multiple algorithms for scheduling of different service classes.

After making fixed allocations to UGS, rtPS and nrtPS was scheduled using Earliest Deadline First (EDF) and Weighted Fair Queuing (WFQ) respectively. RR was used for BE traffic. The inter-class scheduling was done using fixed
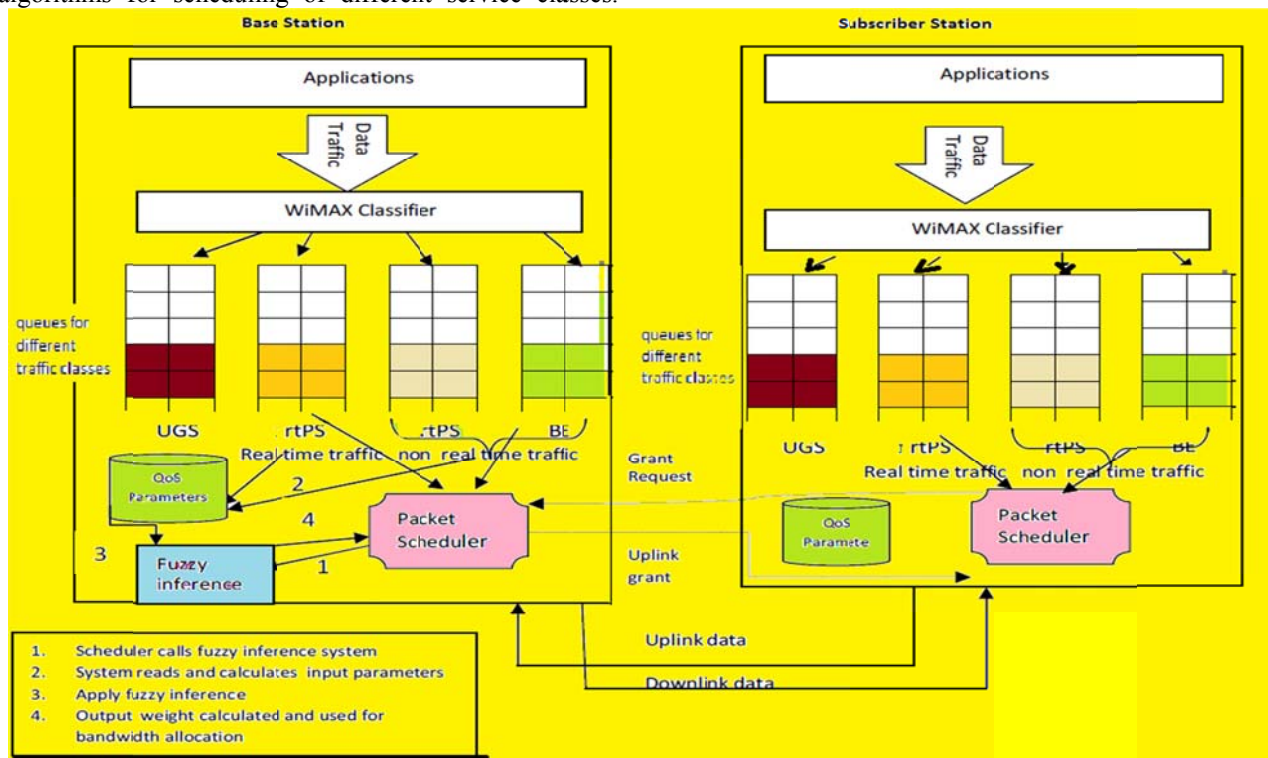

Fig 1 :-QoS in WiMAX

priority in the order of UGS>>rtPS>>nrtPS>>BE. A connection admission mechanism using token bucket has also been proposed.

Ball et al. [6] proposes a RR scheduler instead of assigning priority to real time applications tries to allocate resources to all connection in a round robin fashion. The results indicate that although BE service performs good but performance for real time application is not good enough however algorithm simplifies the complexity as no decision time was required.

Authors of [7] and [8] has proposed weighted round-robin (WRR) and earliest deadline first (EDF) schemes. The transmission in EDF is as per their associated deadlines while WRR provides allocation in round robin manner but different flows or connections are associated weights. Proportional fairness (PF) scheme was implemented by etl al in[9]. Allocation in PF is to the connection with highest priority which may lead to starving of low priority flows. Other schemes like Weighted fair queuing (WFQ) in [10] and modified largest weighted delay first (M-LWDF) in [11] scheme are also available.

J. Sun et al[12] proposed two different schedulers for BS and SS. Priorities to UGS and bandwidth requests opportunities for rtPS and nrtPS connections were assigned at the time of connection setup. Data grants for rtPS, nrtPS classes were scheduled taking into account

bandwidth request information and their minimum requirements. The residual bandwidth was distributed in accordance to pre-assigned weights. Fixed priority scheme was implemented at SS assigning priorities of 1,2,3 and 4 for for BE, nrtPS, rtPS and UGS service classes respectively. UGS is allocated guaranteed bandwidth at the first instant, deadlines for rtPS packets were then calculated based on arrival time and tolerated delay and were scheduled on the basis of approaching deadlines. For nrtPS packets each packet is associated with virtual time that is calculated to guarantee minimum reserved bandwidth and all BE class were scheduled in FIFO manner.

N Liu et al [13] presented another scheme that uses combination of three different schedulers to meet Qos requirements of various classes. Scheduler I serves time sensitive traffic streams like UGS, rtPS and nrtPS and uses EDF algorithm. WFQ was used to schedule minimum bandwidth reserving flows like nrtPS where weights were in proportion to bandwidth requirements while BE also employs WFQ scheduling technique which was implemented by scheduler 3. Weights in scheduler 3 correspond to traffic priorities of each BE connection and these schedulers were served in fixed priority order with scheduler I being assigned highest priority. The proposed scheme used to plan contention and reserved transmission opportunities in accordance to bandwidth availability.

Juliana Freitag *et al*.[14] used the concept of high, intermediate and low priority queues to handle varying types of traffic. High priority queue is used to handle flows that must be scheduled in next frame which includes UGS packets and uni-cast request opportunities for rtPs and nrtPS flows. Intermediate and low priority queues were used to handle rtPS, nrtPS and BE flows respectively. Queues were served using strict priority however starvation was handled as request whose deadline is going to expire is migrated to high priority queue.

One of the most recent work in the field of dynamic scheduling has been done by M. Fathi *et al*[42] where a joint scheduling and CAC method is proposed. WFQ was used initially to assign weights to different classes in accordance to priorities. Bandwidth allocation is done on the basis of packet dropping probability.

The papers discussed in this section indicate that non-real time traffic is always sacrificed to real time traffic which tends to degrade the performance for non-real time applications. In actuality non-real time traffic holds a very large share of traffic on a network. This means that non-real time traffic cannot be neglected and a suitable scheme is necessary for making fair allocations to it.

III. PROPOSED SCHEME

The scheduling problem in WiMAX is quite novel as it has to satisfy a number of applications and these applications tend to have different QoS satisfaction levels. WiMAX has dynamic QoS and SS request resources from BS for transmission on the basis of its incoming traffic. Requirement of incoming traffic can change momentarily in multimedia application and therefore choosing a single and fixed bandwidth allocation mechanism for all sorts of application is not good idea as it may deteriorate QoS levels and real time applications can starve non-real time application like BE and nrtPS. In such situations a bandwidth allocation mechanism that can adapt itself to the changing requirement of QoS will be preferred. Authors in this paper tend to solve scheduling problem in WiMAX using a dynamic approach that is based on the principles of fuzzy logic. The indecisive theories of fuzzy logic are very helpful in providing solution to the problem where designing of exact mathematical models is very difficult. The main aim of the scheduler is to provide fairness in terms of bandwidth allocation to neglected traffic classes of nrtPS and BE.

The traffic in WiMAX consists of combination of real and non-real time applications categorized into 5 different QoS service classes namely Unsolicited Grant Service(UGS), ertPS(extended real time polling service), rtPS (real time polling service), nrtPS(non-real time polling services) and BE(Best Effort). Out of these first three belong to real time traffic class while the last two fall to non real time traffic class. Both these traffic have different QoS parameters ,real time traffic requires a guaranteed delivery of packets within stringent time

constraints while maximum sustainable time requirement of non-real time traffic shall be satisfied by the implemented scheduler. Therefore the designed scheduler shall be able to adhere to these requirements and shall provide a fair share of allocation to both these classes of traffic.

The fuzzy approach proposed in this study takes as input two variables, latency requirements for real time traffic and throughput for non-real time traffic. The output of the fuzzy inference system is weight, whose value will be used to make bandwidth allocations to both these classes. The respective membership functions for all three variables are shown in figures(   ). The fuzzy system is built over five different linguistic variables for all the input and output variables .The membership function are defined as NB(Negative Big), NS(negative small), Z(Zero), PS (Positive small) and PB(positive big). The range of all these variables is from 0 to 1. The rule base consists of 5 x 5=25 rules which is considered to be sufficiently large for two input fuzzy inference system is used for inference database. The rule base has been defined considering the nature and dynamism of input traffic.

The default weight for any flow in WFQ is calculated from the following equation

$$w_i = \frac{R_{min(i)}}{\sum_{i=0}^{n} R_{min(i)}} \qquad (1)$$

Where And $R_{min(i)}$ is the minimum reserved rate for flow(i) and all flows shall satisfy the constraint of equation 2.

$$\sum_{i=0}^{n} w_i = 1 \qquad 0.001 \le w_i \le 1 \qquad (2)$$

The fuzzy system consists of three steps:-fuzzification where the system reads in system input variables ie throughput and latency. Fuzzy reasoning where input state variables read in previous step are manipulated as per the rule base and provides an output value. Last step defuzzification, employs centre of gravity method to calculate a crisp value for our output variable weight. The outputted value is taken as the weight for real time traffic and weight of non-real time traffic is calculated by subtracting from 1 since the total weights for all queues shall satisfy the constraint defined in 2. The bandwidth allocation to different queues is made on the basis of weight assigned to that queue using the bandwidth allocation formula

$$Bandwidth = R_{max} \times \frac{w_i}{\sum_{i=0}^{n} w_i} \qquad (3)$$

IV. RESULTS AND DISCUSSION

In order to implement the concept of adaptive weight calculation for scheduling, a wimax network consisting of one BS and a number of SS was created in a simulator written in C++.The mail aim of the simulation is to check whether the proposed scheduler is successful in providing fairness to nrtPS and BE classes. The performance of these traffic classes is observed with varying number of

real time connections. Performance is studied on the basis of parameters like delay and throughput. Various simulation parameters used are defined in table 1.Simulation is aimed at making sure that the proposed scheme is able to provide a relative good QoS levels or not. This is done by increasing the number of UGS connections in the scenario while keeping number of rtPS and nrtPS fixed. Scenario consists of one BS and 110 SSs. For experimentation 10 ertPS, 10 rtPS connections,

25 nrtPS connections and 25 BE connections were established, and the number of active UGS connections were varied from varies from 10 to 40. The performance is verified by measuring the delay and throughput of real and non real time traffic with an increase in number of UGS connections.
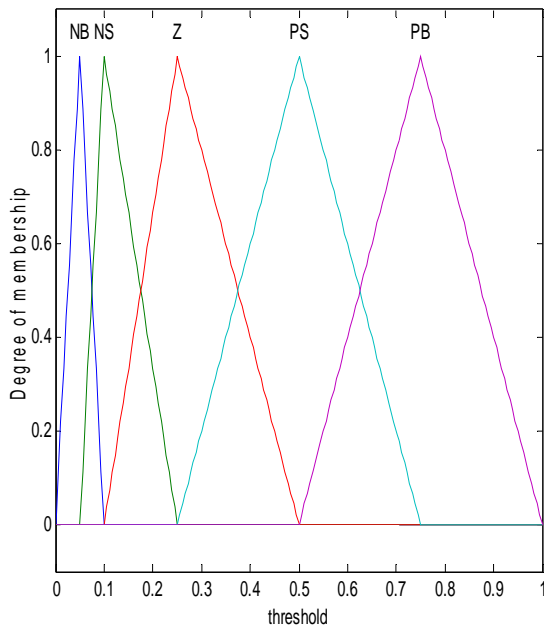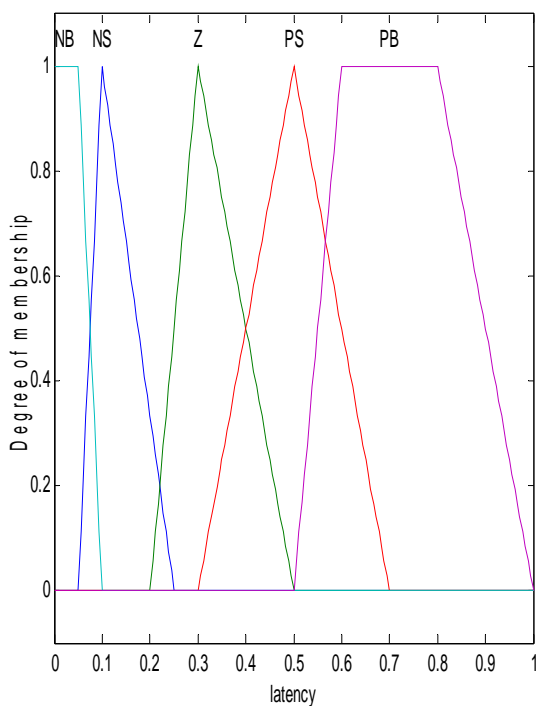

Fig 4 :- Fuzzy membership diagram for output variable weight

Fig 2 :- Fuzzy membership diagram for input variable threshold

Fig 3 :- Fuzzy membership diagram for input variable latency

TABLE 1:
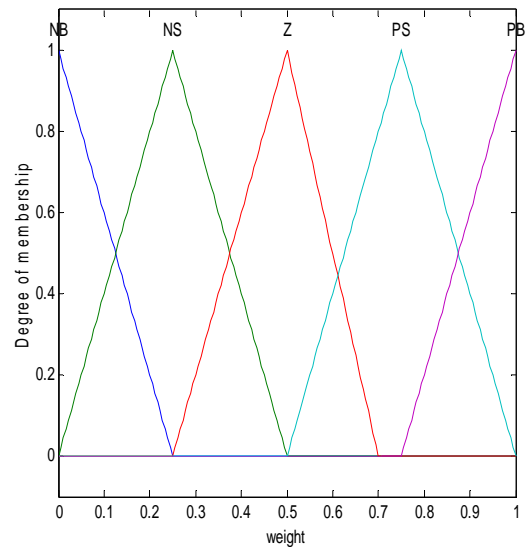SIMULATION PARAMETERS FOR SCENARIO

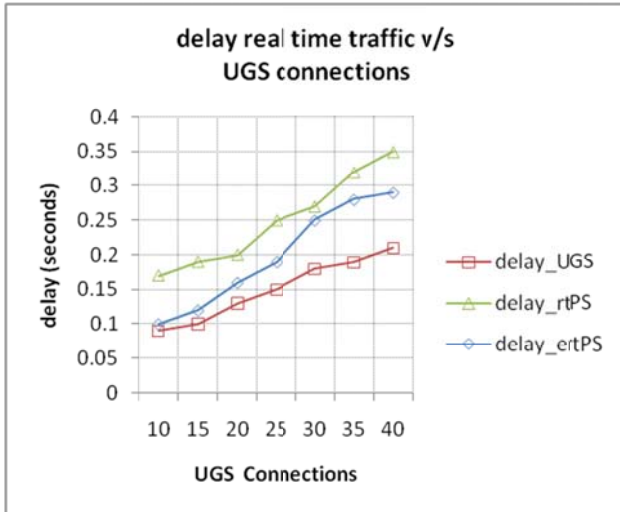| Simulation parameters	
Radio type	802.16 Radio
Operating frequency	2.4GHz
Transmission Power	30(dbm)
Channel Bandwidth	20MHz
FFT Size	2048
Antenna Model	Omni directional
Cell Radius	1500 m
Frame duration	10ms
Number of nodes	110
Base Station	1
Node placement	Unifrom
Mobility Model	Random way point
Pathloss model	Two-ray
Latency for VoIP	<150ms

Fig 5:- Delay of UGS, ertPS and rtPS

Figure 2and 3 shows plot of queuing delay incurred by real time traffic consisting of UGS, ertPS and rtPS traffic classes and non real time classes consisting of nrtPS, BE with an increase in number of UGS connections. The variation in the queuing delay of UGS connections is minimal since they have the highest priority. Delay for ertPS and rtPS classes shows an increase when number of UGS connections approaches above 30 which is understandable as more resources are used to satisfy high priority traffic. The delay for nrtPS and BE traffic classes shows the maximum variations. The delay for both these classes shows steep rise when amount of traffic increased in the network, this was expected since these classes have minimum priority amongst all traffic classes. Inspite of it the delay values are considerably manageable and scheduler was able to provide acceptable levels of delay for all classes.
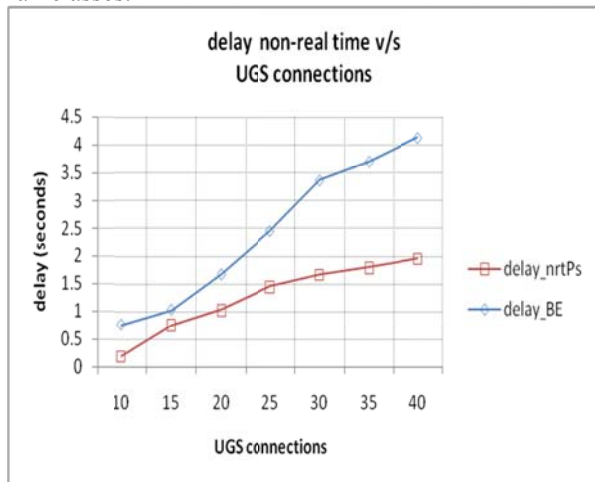

Fig 6:- Delay of nrtPS and BE classes

Figure 7and 8 shows the plot of throughput for real and non real time classes with variations in UGS connections. The graph shows that throughput obtained for UGS is maximum and is almost fixed and does not show any variations as per IEEE 802.16 WiMAX standard. Throughput for ertPS and rtPS was quite good until
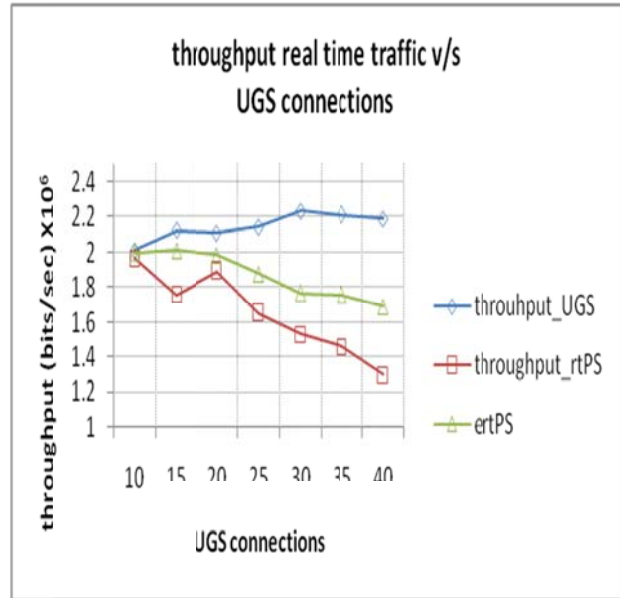

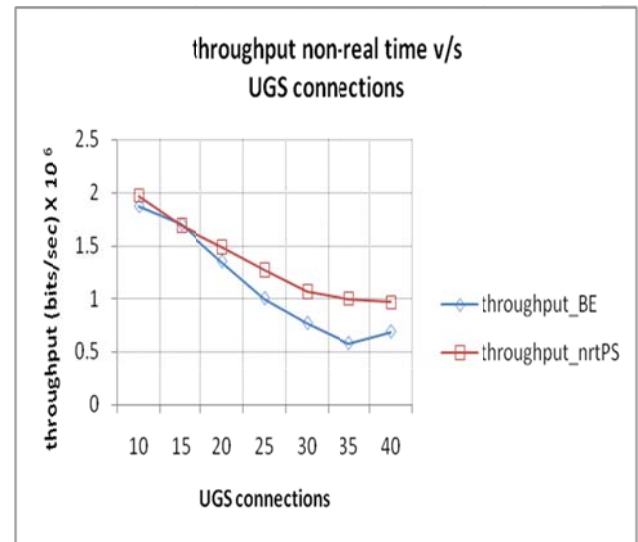Fig 7:- throughput of UGS, ertPS and rtPS

Fig 8:- throughput of nrtPS and BE

number of UGS connection increased beyond a limit after which the throughput for nrtPS started to decrease but the throughput for ertPS is still competitive enough.

Fig. 8 shows the throughput of the nrtPS and of the BE connections. nrtPS throughput shows small oscillations and scheduler provided with minimum bandwidth to achieve minimum threshold levels for nrtPS class. The BE service enjoys the same throughput as enjoyed by nrtPS service for small number of active connections, since the scheduler could have allocated the residual bandwidth to this service. When number of connections is high, the throughput for BE decreases

V.   CONCLUSION

The above study proposed an adaptive scheduler for solving bandwidth allocation problem for WiMAX networks using the concepts of fuzzy logic. The proposed method supported different traffic types as specified by the standard and takes into account the QoS requirements

for making bandwidth allocations. The fuzzy system makes its scheduling decision on the basis of two input variables and gives queue weight as its output. Traffic in WIMAX networks consist of mixture of real and non-real time traffic and simulation shows that proposed scheduler was able to handle both these classes fairly. The scheduler was able to satisfy the latency requirements for real time and minimum throughput requirement for non real time traffic efficiently.

REFERENCES

[1] IEEE, Draft IEEE Standard for Local and metropolitan area networks Corrigendum to IEEE standard for Local and Metropolitan Area Networks—Part 16:Air Interface for Fixed Broadband Wireless Access Systems(Corrigendum to IEEE Std 802.16- 2004). IEEE Std P80216/Cor1/D2. 2005.

[2] IEEE, Draft IEEE Standard for Local and metropolitan area networks Corrigendum to IEEE Standard for Local and Metropolitan Area Networks- Advanced Air Interface. IEEE P80216m/D10, November 2010. 2010: 1-1132.

[3] M. Shreedhar, G. Varghese, "Efficient fair queuing using deficit round-robin" IEEE ACM Transactions on Networking 1996 vol 4, pp 375–85.

[4] K. Wongthavarawat and A. Ganz, "Packet scheduling for QoS support in IEEE 802.16 broadband wireless access systems," *International Journal of Communication System*, vol. 16, issue 1, pp. 81–96, Feb. 2003.

[5] K. Wongthavarawat and A. Ganz, "IEEE 802.16 based last mile broadband wireless military networks with quality of service support," *IEEE Military Communication Conference, 2003. MILCOM 2003*, vol. 2, no. 1, pp. 779–784, Oct. 2003.

[6] C.F. Ball, F. Treml, X. Gaube, and A. Klein, "Performance Analysis of Temporary Removal Scheduling applied to mobile WiMAX Scenarios in Tight Frequency Reuse", *16th Annual IEEE International Symposium on Personal Indoor and Mobile Radio Communications, PIMRC'2005, Berlin*, vol 2,pp 888-894,11 – 14, September 2011.

[7] Cicconetti, C., Erta, A., Lenzini, L., & Mingozzi, E. " Performance evaluation of the IEEE 802.16 MAC for QoS support" *IEEE Transactions on Mobile Computing*, 6(1), 26–38 2007.

[8] V. Sagar, & D Das, "Modified EDF algorithm and WiMAX architecture to ensure end-to-end delay in multihop network" In *IEEE TENCON* 2008

[9] Jalali, A., Padovani, R., & Pankaj, R. "Data throughput of CDMA-HDR a high efficiency high data rate personal communication wireless system", In *IEEE VTC* 2000.

[10] K S Demers and S Shenker, "Analysis and simulation of a fair queuing algorithm", In *SIGCOMM* 1989

[11] M Andrews, Kumaran, K., Ramanan, K., Stolyar, A., & Whiting, P, "Providing quality of service over a shared wireless link" *IEEE Communications Magazine*, 32(9), 150–154.2001.

[12] J. Sun, Y. Yao, and H. Zhu, "Quality of service scheduling for 802.16 broadband wireless access systems," in *IEEE 63rd Vehicular Technology Conference, 2006. VTC 2006-Spring, vol. 3, 7-10, May 2006, pp. 1221–1225.*

[13] N. Liu, X. Li, C. Pei, and B. Yang, "Delay character of a novel architecture for IEEE 802.16 systems," in *Sixth International Conf. Parallel Distributed Comput., Appl. Technol., 2005. PDCAT 2005*, Dec. 2005, pp. 293–296.

[14] Juliana Freitag, Nelson L.S. da Fonseca, "Uplink Scheduling with Quality of Service in IEEE 802.16 Networks" *in IEEE Global Telecommunications Conference, GLOBECOM 2007*, 26-30 Nov 2010, pp 2503 -2508.

[15] Mohammad Fathi , Samaneh Rashidi-Bajgan, Alireza Khalilzadeh , Hassan Taheri, " A dynamic joint scheduling and call admission control scheme for 802.16 networks", *Telecommun Syst (2013) 52:195–202 DOI 10.1007/s11235-011-9555-8 http://www.springerlink.com/ content h81w80515trt0843*