Intelligently Modified WFQ Algorithm for IEEE 802.16 Resource Allocations

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Abstract IEEE 802.16 standard more commonly known as WiMAX is an upcoming standard popularized by WiMAX Forum. Quality of service in WiMAX is provided with help of five scheduling services with different properties. WiMAX standard does not define provisioning for providing bandwidth allocation to different scheduling services. Most algorithms focus on traffic classes having rigid time constraints and classes without real time requirements are neglected This paper proposes modified Weighted Fair Queuing Algorithm using concepts of fuzzy logic for grant of bandwidth to all types of traffic. It enables fair distribution of network resources to low priority traffic classes and helps to improve their performance. Simulations have been done for performance justification and results are encouraging.

Keywords Scheduling · Bandwidth allocation · Simulation · Wimax · IEEE 802.16

1 Introduction to IEEE 802.16 and WiMAX

Growth of rich media applications as a result of mounting popularity of smart phones had awakened wireless community to popularize IEEE 802.16 standard, also known as WiMAX [1, 2]. The inherent architecture of WiMAX is such that it can support real and non real time applications in both wired and wireless scenarios. It must be able to accommodate these application requirements. QoS is IEEE 802.16 is provided with number of mechanisms like Time division duplexing, frequency division duplexing, frame error control, and orthogonal frequency division multiplexing. Each packet in IEEE 802.16 is associated with service flow that

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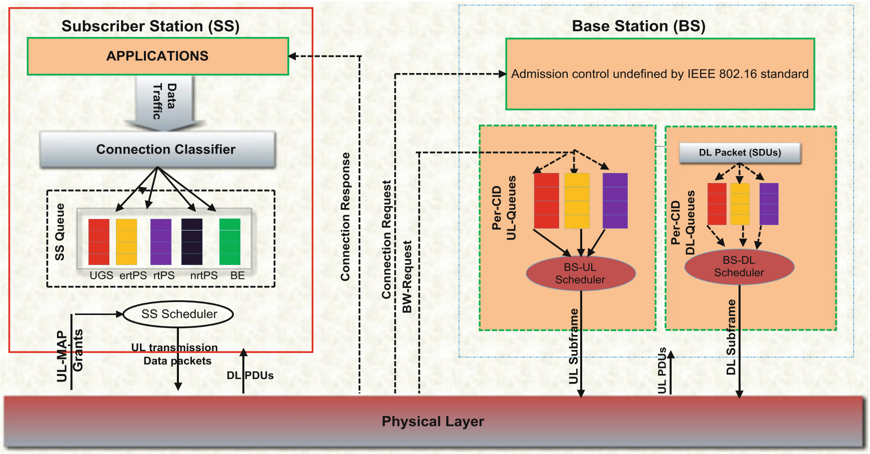


Fig. 1 Scheduling and QoS Framework in IEEE 802.16

helps to implement connection oriented MAC. Base stations and subscribers communicate with help of unidirectional connections. Qualtiy of service framework in WMAx is shown in Fig. 1. Each user application is checked for service to be offered and a specific scheduling service is attributed to handle this flow. The allocation strategy in WiMAX is request grant which is supported with help of five different scheduling service types: unsolicited grant service (UGS), real-time polling service (rtPS), extended real-time polling service (ertPS), non real-time polling service (nrtPS), and best effort (BE). These traffic classes have been designed considering various applications supported by WiMAX and every traffic class has its own priority and quality of service parameters. Priorities for real time scheduling types are more as compared to non real types as specified by standard.

The signaling mechanism in WiMAX allows for implementation of request and grant based algorithm for bandwidth allocation. The subscribers estimated its requirements and communicated it to the base station for required allocations to be made. Base station gathers requirements of all subscribers and keeping in view available bandwidth makes allocations to different subscribers employing a suitable algorithm. Figure 1 defines quality of service framework employed in IEEE 802.16 systems. The standard has only defined framework for quality of service implementation but implementation of specific algorithm has been left to device manufactures. This paper has implemented a scheme to intelligently modify traditional weighted fair queuing algorithm using fuzzy logic for allocating resources to various subscribers in IEEE 802.16 networks. The coming sections explore proposed method.

2 Related Work

This section summarizes some of recent studies for IEEE 802.16 resource allocation problem. The author itself have contributed survey of recent approaches found here [3]. Ball et al. [4] has proposed a round robin variant of scheduler while Jalali et al. [5] has proposed proportional fairness (PF) scheme. Other studies based on fairness allocation of resources have been proposed by Demres [6] and Andrews [7]. Juliana Freitag et al. [8] categorized traffic into three queues according to priority and served these queues using strict priority algorithm. However migration of requests from low level queue to high level queue was allowed for requests with approaching deadlines.

Mukul et al. [9] implemented a dynamic schedulers that used prediction of traffic patterns for rtPS packets. Pheng et al. [10] considered queue length factor and Lagrange's Interpolation function for estimating amount of rtPS packets. Hwang [11] proposed an adaptive allocation strategy based on study of various queue parameters. Fathi et al. [12] proposed another channel aware scheduler in which bandwidth was allocated using law of moving averages. In spite of the availability of large number of algorithms our work is different from previous work as it implements a dynamic system. Fuzzy logic has been exploited to inculcate fairness in bandwidth allocation to all types of traffic classes. Studies discussed in this section indicate that schedulers tend to overlook non-real time traffic resulting in performance dop of non-real time applications and that of overall network degrades significantly. Scheduler shall consider requirements of non real time traffic for decision making. The research presented in this paper addresses the following questions from preceding sections:

- Implementing an allocation scheme taking care of request grant allocation scheme used by WIMAX scheduler
- Modifies WFQ algorithm using uncertainty principles of fuzzy logic
- Improves overall performance of non real time applications

3 Proposed Scheme

Allocation of resources in WiMAX is multifaceted problem as scheduler has the task of catering to requirements of various applications with diverse requirements. WiMAX employs request grant allocation mechanism in a scenario where traits of traffic can suddenly vary in different applications. Traditional WFQ algorithm fails to serve all service classes fairly because real time applications tend to absorb more amounts of resources as their traffic increases. In order to provide fairness to all classes, scheduling strategy shall be able to adapt as there are changes in incoming

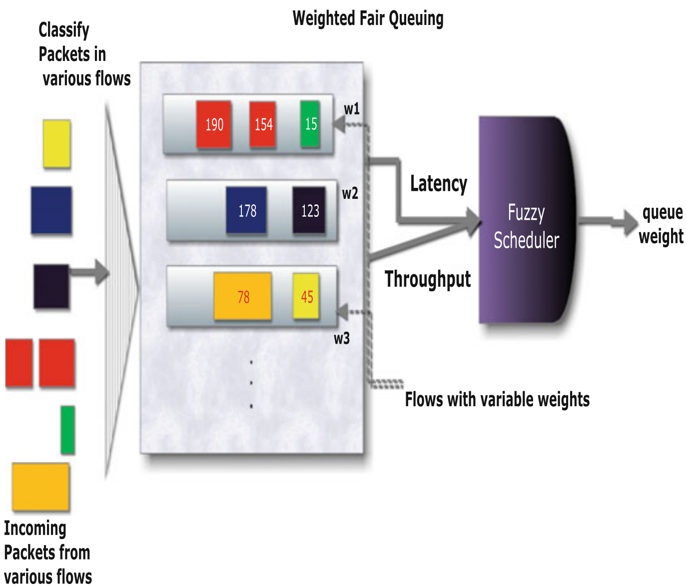


Fig. 2 Proposed Methodology

traffic patterns. Proposed scheme has used vague principles of fuzzy logic to implement a dynamic WFQ algorithm. The algorithm is aimed at providing fairness to all traffic classes in WiMAX. WiMAX scheduling services can be categorized into two major classes: real time having rigid time (latency) requirements like UGS, ertPS, rtPS and non real time class having minimum throughput requirements. Proposed approach extracts information of these two requirements from incoming traffic and modifies weights of queues serving these classes in WFQ algorithm. Both latency and throughput requirements act as input variables of fuzzy based system with weight as output variable. The output value given by fuzzy system is used to alter weight of serving queues in WFQ algorithm. Figure 2 shows the implemented methodology while Figs. 3, 4, 5 defines implemented membership functions used in study. There are total of five linguistic levels used in the study NB, NS, Z, PS, PB. Different variables supports different number of linguistic levels. Table 1 shows the proposed rule base for our fuzzy inference system.

$$\sum_{i=0}^{n} w_i = 1 \quad 0.001 \le w_i \le 1 \tag{1}$$

All flows having weight w_i in a packet switched network shall satisfy constraint of Eq. 1; The constraint makes sure that none of flow is starved and is being offered some minimum portion of bandwidth. The weights in WFQ algorithm remain static and this weight updating process is made dynamic by fuzzy based method. On receiving new bandwidth request, fuzzy inference algorithm is called by base station. The fuzzy system reads values of latency and throughput, fuzzification of

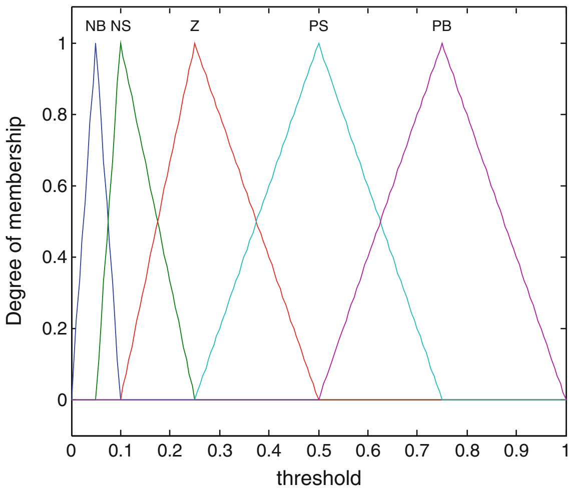


Fig. 3 Membership function for throughput

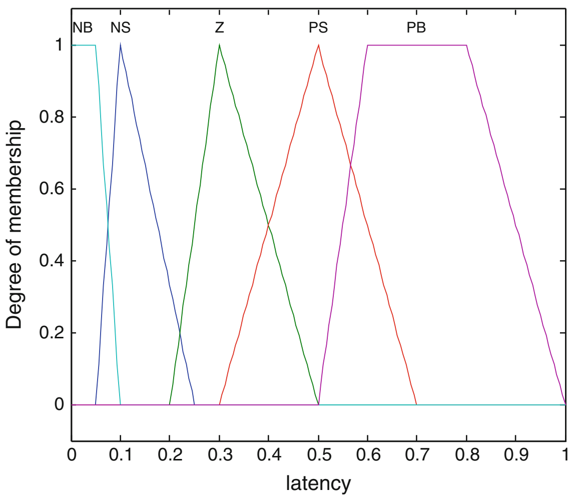


Fig. 4 Membership function for latency

these values is done and fuzzy reasoning is applied to get value of weight in fuzzy form. The said value is defuzzified to get a crisp weight value which is utilized as weights for queues of real time traffic classes. More widely accepted Mamdami's inference has been utilized and center of gravity method is used for de-fuzzification. Allocation of bandwidth to different flows using Eq. 2.

$$\text{Allocated Bandwidth} = R_{max} \times \frac{w_i}{\sum_{i=0}^{n} w_i} \tag{2}$$

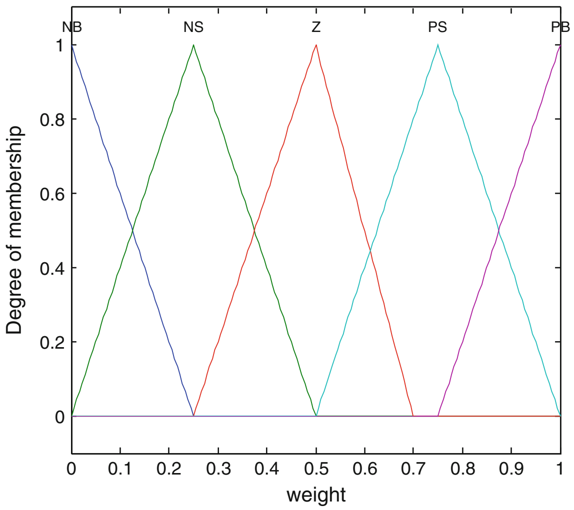


Fig. 5 Membership function for weight

Table 1 Rulebase for fuzzy system

S. no	Latency	Throughput	Weight
1.	PB	NB	NB
2.	PB	NS	NB
3.	PB	Z	NB
4.	PB	PS	NB
5.	PB	PB	NB
6.	PS	NB	NS
7.	PS	NS	NS
8.	PS	Z	NS
9.	PS	PS	NS
10.	PS	PB	NS
11.	NB	Z	PB
12.	NB	PS	PB
13.	NB	PB	PB
14.	NB	NB	PB
15.	NB	NS	PB
16.	Z	NB	Z
17.	Z	NS	Z
18.	Z	Z	Z
19.	Z	PS	Z
20.	Z	PB	Z
21.	NS	NB	PS
22.	NS	NS	PS
23.	NS	Z	PS
24.	NS	PS	PS
25.	NS	PB	PS

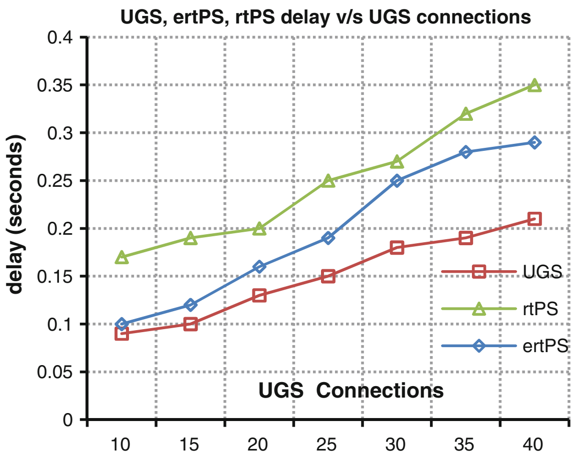
4 Results and Discussion

The proposed scheme is implemented in proprietary simulator written in C ++. Conducted experiments are aimed to evaluate if designed fuzzy inference system can meet quality of service levels of all types of classes in WiMAX. The main aim of scheme is to improve performance offered to various service classes in WiMAX specially non real classes. Evaluation of performance has been done by increasing number of real time connections and measuring delay and throughput parameters. Conducted experiments are discussed below.

Experiment 1 In this experiment number of connections for other real time classes has been kept fixed while UGS connections are increases significantly. Number of rtPS,ertPS and nrtPS connections have been kept as 10,10,25 respectively while UGS connections were varied between 10–40. Figures 6, 7 plots average delay and Figs. 8, 9 plots throughput performance of all classes as amount of UGS traffic is increased. Variations in delay for real time classes are minimum as supported by IEEE 802.16 standard. The delay of non real time classes increases a bit with high number of real time connections but still these values are considerably manageable considering amount of traffic in network. Throughput plots for non real time classes shows small updowns with nrtPS graph having better projections as compared to BE graph because BE does not provide any QOS requirements.

Experiment 2 This experiment studies effects of increase in extent of rtPS service class on other classes. rtPS can severely effect performance of other classes since it is bursty in nature. rtPS connections were taken in range of 5–18 and nrtPS and BE connections were taken as 25 and 40. For performance analysis, comparison delay and throughput has been measured for real and non real time classes respectively. The corresponding plots are presented in Figs. 10, 11. The increase in traffic was able to influence performance of these classes up to only a limited extend.

Fig. 6 UGS, ertPS, rtPS delay versus UGS



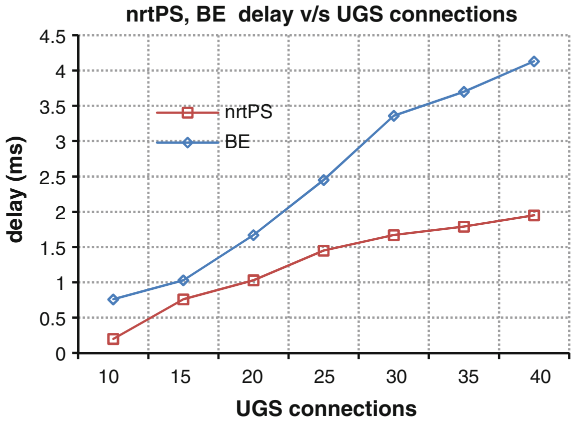


Fig. 7 nrtPS and BE delay versus UGS

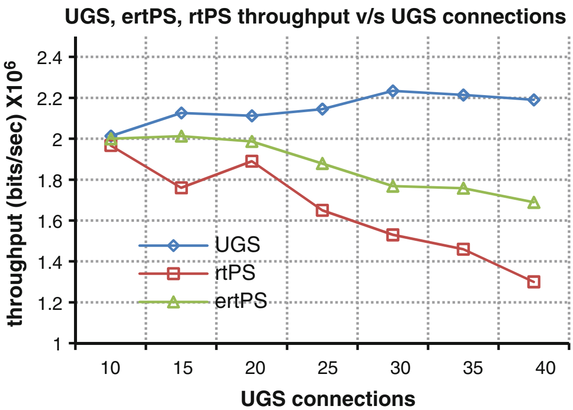


Fig. 8 UGS, ertPS, rtPS throughput versus UGS

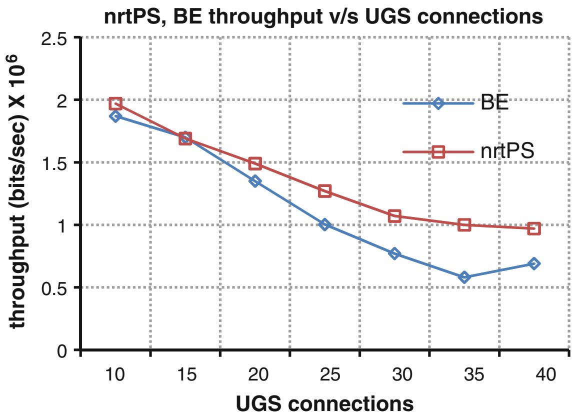


Fig. 9 nrtPS and BE throughput versus UGS

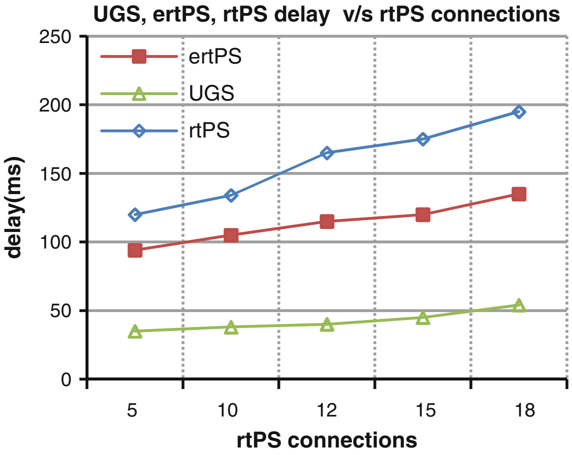


Fig. 10 UGS, ertPS, rtPS delay versus rtPS

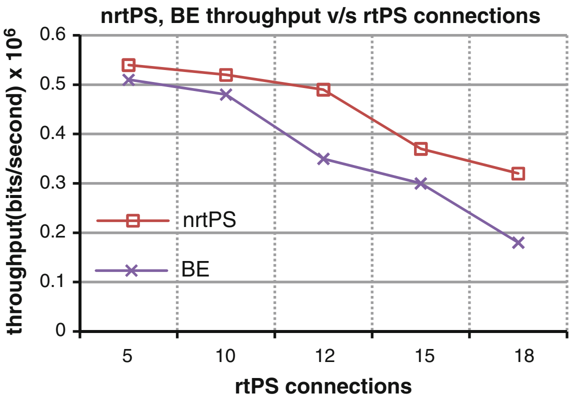


Fig. 11 nrtPS and BE throughput versus rtPS

The performance of BE classes was influenced to greater extent since BE class does not specify any quality of service requirements. Fuzzy inference system shows quick adaptive response towards changes in traffic flow for these classes and offer appropriate slots for transmission.

5 Conclusion

Proposed work in this paper utilizes fuzzy logic techniques to implement an automatic and intelligent version of WFQ algorithm. The dynamism is embedded into system by utilizing values of latency and throughput from incoming traffic to modify weights of queues in WFQ algorithm. The proposed algorithm has been simulated and tested under two different experiments for performance evaluation. The results of method are satisfactory and proposed method was able to provide fair opportunities to both real and non real time traffic flows.

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