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Fuzzy based Priority Scheduler for WiMAX with Improved QoS constraints

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---ABSTRACT---

Wireless Interoperability for Microwave Access (WiMAX) is one of the most familiar broadband wireless access technologies that support multimedia transmission. IEEE802.16 Medium Access Control (MAC) covers a large area for bandwidth allocation and Quality of Service (QoS) mechanisms for various types of applications. Nevertheless, the standard lacks a MAC scheduling algorithm that has a multi-dimensional Technological objective of satisfying QoS requirements of the users, maximizing channel utilization while ensuring fairness among users. So we are proposing a novel Priority based Scheduling Algorithm using Fuzzy logic that addresses these aspects. The initial results show that maximum channel utilization is achieved with a negligible increment in processing time while keeping the priority intact.

Keywords: **WiMAX, Fuzzy, Priority, Scheduling Algorithms**

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1. INTRODUCTION

WiMAX is defined as Worldwide Interoperability for Microwave Access by the WiMAX Forum, formed in June 2001 to promote conformance and interoperability of the IEEE 802.16 standard, officially known as Wireless MAN. The Forum describes WiMAX as “a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL” [1].

1.1 Need for WiMAX: The demand for broadband access everywhere is increasing rapidly as Internet services, enterprise as well as private, are getting more and more reliable, secure and easy to use. It is interesting to note that WiMAX proved its importance during the devastating December 2004 Tsunami in Aceh, Indonesia which completely destroyed the existing infrastructure, and thus crucial communication took place through WiMAX stations deployed rapidly on emergency basis.

1.2 QoS Scheduling: A high level of QoS and scheduling support is one of the interesting features of the WiMAX standard. These service-provider features are especially valuable because of their ability to maximize air-link utilization and system throughput, while ensuring that Service-level agreements (SLAs) are met [2].

The infrastructure to support various classes of services comes from the MAC implementation. QoS is enabled by the bandwidth request and grant mechanism between various subscriber stations and base stations. Primarily there are five buckets for the QoS (UGS, rtPS, ertPS, nrtPS, and BE) to provide the service-class classification for video, audio, and data services. The service scheduler provides scheduling for different classes of services.

2. PROBLEM DESCRIPTION

2.1 Problem Statement: The demand for broadband access everywhere is increasing rapidly as Internet services, enterprise as well as private, are getting more and more reliable, secure and easy to use. Consumers want to access Internet services at an affordable price with an acceptable, relevant performance and speed.

The main objective of this work is to provide an implementation of the IEEE 802.16(e) standard using dynamic fuzzy based priority scheduler.

2.2 Scope: The work proposed focuses on the QoS aspects like delay, throughput and bandwidth utilization. The conventional scheduling algorithms available are not meeting the necessary QoS parameters. To meet these requirements, we propose this novel Fuzzy based Scheduling Algorithm.

3. FUZZY LOGIC

3.1 Introduction to fuzzy logic: Fuzzy logic refers to a logical system that generalizes classical logic for reasoning under uncertainty. In a broad sense, fuzzy logic refers to all of the theories and technologies that employ fuzzy sets, which are classes with unsharp boundaries. Fuzzy logic concept can be used to deal with the imprecise and uncertain information since the network is dynamic in nature.

3.2-The fuzzy scheduler: Basically the fuzzy system consists of four blocks, namely, fuzzifier, defuzzifier, inference engine, and fuzzy knowledge base. The following section explains the working of the general fuzzy system.

3.3-Fuzzification of inputs and outputs: The first step is to take the inputs and determine the degree to which they belong to each of the appropriate fuzzy sets via membership functions. The input is always a crisp numerical value limited to the universe of discourse of the input variable and the output is a fuzzy degree of membership in the qualifying linguistic set (always the interval between 0 and 1). A fuzzy set A in the universe of discourse U is a set of ordered pairs {(x1, μA(x1)), (x2, μA(x2)), . . . , (xn, μA(xn))}, where μA : U → [0, 1] is the membership function of the fuzzy set A and μA(xi) indicates the membership degree of xi in the fuzzy set A.

3.4 Fuzzy inference process: If a fuzzy system has n inputs and a single output, its fuzzy rules Rj can be of the following general format. (Rj) If X1 is A1 j , X2 is A2 j , X3 is A3 j , . . ., and Xm is Amj, then Y is Bj . The variables Xi{i = 1, 2, 3, . . ., n} appearing in the antecedent part of the fuzzy rules Rj are called the input linguistic variables, the variable Y in the consequent part of the fuzzy rules Rj is called the output linguistic variable. The fuzzy sets Ai j are called the input fuzzy sets of the input linguistic variable Xi and the fuzzy sets Bj are called the output fuzzy sets of the output linguistic variable Y of the fuzzy rules Rj .

3.5 Aggregation of all outputs: Since decisions are based on the testing of all of the rules, the rules must be combined in some manner in order to make a decision. Aggregation is the process by which the fuzzy sets that represent the outputs of each rule are combined into a single fuzzy set. Aggregation occurs only once.

3.6 Defuzzification: As much as fuzziness helps the rule evaluation during the intermediate steps, the final desired output for each variable is generally a single number. However, the aggregate of a fuzzy set encompasses a range of output values, and so must be defuzzified in order to resolve a single output value from the set. The most popular defuzzification method is the Centroid calculation, which returns the center of area under the curve. By Centroid method of defuzzification, the crisp output η is calculated using the formula where y is the center point of each of the output

$$\eta = \frac{1}{\Sigma \mu_{x1\cdots xn}^{\text{output}}(y)} \Sigma y \mu_{x1\cdots xn}^{\text{output}}(y) \quad \ldots\ldots\ldots.1$$

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membership function in the output fuzzy set Bj and µoutputx1···xn(y) is the strength of the output membership function .

3.1 The fuzzy scheduler

Fuzzy logic implements human experiences and preferences via membership functions and fuzzy rules. The application of fuzzy logic to problems of traffic control in networks is more attractive. Since it is difficult for a network to acquire complete statistics of the input traffic, it has to make a decision based on incomplete information. Hence the decision process is full of uncertainty. It is advantageous to use the fuzzy logic in the target system because it is flexible and capable of operating with imprecise data. Basically the fuzzy system consists of four blocks, namely, fuzzifier, defuzzifier, inference engine, and fuzzy knowledge base.

The incoming requests in the WiMAX have different variables that play a key role in setting the priority of that particular request. The variables are Expiry Time, Waiting Time, Queue Length, Packet Size and Type of Service. In the proposed fuzzy scheduler we use two different stages namely the Primary Scheduler, FS1 and the Dynamic Scheduler, FS2. This proposed scheduler is named as Dynamic Fuzzy based Priority Scheduler (DFPS). In the proposed Primary Scheduler we used four inputs namely, Expiry time (E), Waiting time (W), Queue length (Q), Packet size (P) and one output, Priority index as shown in Fig.2. Here, the process is considered as multiple input and single output (MISO) system.

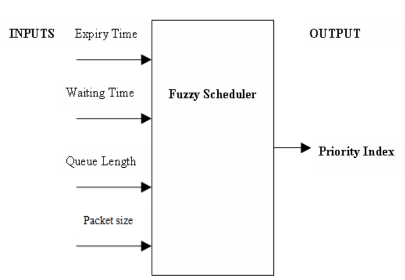

Figure1: Proposed Primary Fuzzy Scheduler

The fuzzy rule table is created based on the membership functions that are carefully designed as explained in table 2. The linguistic terms associated with the input variables are low (L), medium (M) and high (H). Triangular membership functions are used for representing these variables except for the high data rate where a trapezoidal function is used. The bases of functions are chosen so that they result in optimal value of performance measures. For the output variable, priority index, five linguistic variables are used. Only triangular functions are used for the output. This illustration was designed using the fuzzy tool available in the MATLAB.

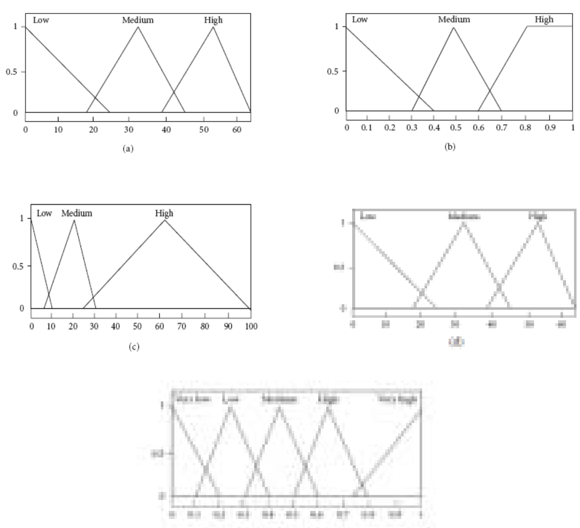

Figure 2: Membership functions (a) Expiry time (in sec) (b) Packet size (in Kbytes) (c) Queue length (in bytes) (d) Waiting time (in sec) and (e) Priority Index

Table 1: *Fuzzy Rule Base*

(a) Expiry Time Vs Waiting Time

Expiry Time	Waiting Time		
	L	**M**	**H**
L	H	L	L
M	M	H	L
H	L	M	H

(b) Packet size Vs Queue length

Packet Size	Queue Length		
	L	**M**	**H**
L	H	M	M
M	L	H	M
H	L	L	H

Priority	UGS	rtPS	ertPS	nrtPS	BE
VL	VH	L	L	VL	VL
L	VH	M	L	L	VL
M	VH	H	M	L	L
H	VH	H	M	M	L
VH	VH	VH	H	M	L

(c) (a) Vs (b)

(a)	**(b)**		
	L	**M**	**H**
L	VL	L	M
M	L	M	H
H	M	H	VH

Table 3: Dynamic Fuzzy Rule Base

The fuzzy rule base for the proposed algorithm is defined with due care and are shown in table 2. For illustration, ‘if packet size is low and queue length is low, then priority index is low’. The ninth rule is interpreted as “If packet size is high and queue length is high, then priority index is very low”. Similarly, the other rules are framed.

The priority index, if high, indicates that the packets are associated with the highest priority and will be scheduled immediately. If the index is low, then packets are with the lowest priority and will be scheduled only after high priority packets are scheduled.

3.2 Dynamic Fuzzy Scheduler:

For a dynamic scheduler, the output of the primary scheduler is given as the input. Apart from this input, the type of service variable is also added as shown in Fig. 5. A membership function and a rule table are created based on the priority index of FS1 and the type of service.

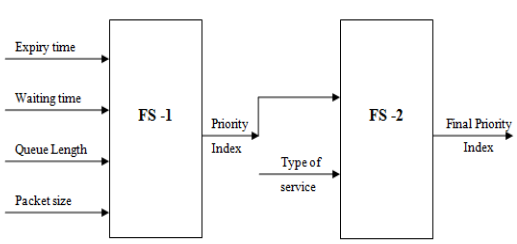

Figure 5: Dynamic Fuzzy scheduler

The Dynamic Fuzzy Rule Base is shown in table 3. This table is carefully designed by taking into consideration of the type of service. As there are five different types of classes the priority levels are set to five different levels starting from Very High (VH), High (H), Medium (M), Low (L) and Very Low (VL).

To illustrate any rule, consider the first column contents. The Priority Index of the Primary Scheduler may be from VH to VL. If the type of service is UGS then that request must be given higher level priority than the other type of services even if the Primary Scheduler FS1 allots them higher priority indices. This rule is used to satisfy the QoS requirements of WiMAX. The final priority index is referred as ή which is the standard notation used in the literature.

Simulation:

4. PERFORMANCE EVALUATION

4.1 Simulation environment: The simulation environment for wireless network systems is MATLAB. First the task of identification of input variables used in the fuzzy logic is performed. Then the calculated priority index is used for scheduling the packet. By this way of scheduling, the service, which are about to expire, or the packets in highly Congested queues are given first priority for sending. As a result of this, the number of packets delivered to the client node and the end-to-end delay of the packet transmission improve. The input expiry time is the variable Time to Live (TTL) set at a default value of 64 seconds. If the packet suffers excessive delays and undergoes multihop, its TTL falls to zero. As a result of this, the packet is dropped. If this variable is used as an input to the scheduler for finding the priority index, a packet with a very low TTL value is given the highest priority.

5. PERFORMANCE METRICS

5.1 Effective channel utilization

The algorithm must utilize the channel efficiently. This implies that the scheduler should not assign a transmission slot to a session with a currently bad link since the transmission will simply be wasted.

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5.2 Fairness

The scheduling algorithm must provide fairness to all the requests with different quality of service classes. The channel starving lower priority BE requests and nrtPS requests must be satisfied too leading to fairness.

5.3 Processing time

The algorithm must be able to provide delay bound guarantees for individual sessions in order to support delay-sensitive applications that largely depend on the processing time.

6. PERFORMANCE COMPARISON

The Performance of the proposed DFPS Algorithm is studied under various metrics. Firstly the Channel utilization aspect is analyzed for proposed DFPS Algorithm versus the conventional scheduling algorithms. Then the percentage of requests granted versus the type of service which reveals the amount of fairness obtained while keeping the priority intact is studied and compared with the conventional scheduling algorithms. Here the study was carried out for different set of requests. Finally the processing time was calculated and compared with the conventional scheduling algorithms.

6.1 Channel Utilization

The channel utilization is calculated. The Figure 6 clearly shows the amount of channel utilized by our proposed DFPS Algorithm. It begins from 10% for 10% of load to almost 85% for full load. So as the number of requests increases the channel utilization also increases. It is inferred that as the requested bandwidth nears the total load, the percentage of channel utilization increases. It is understood from the Figure 6 that the WFQ utilizes as high as 75% OFS utilizes almost 80% for the same set of requests. So the comparisons clearly show that there is under utilization of resources in the existing algorithms. It is also inferred from the graph that at no point the conventional algorithms out performs our proposed DFPS algorithm. Hence it is imperative that maximum channel utilization is achieved in our proposed DFPS algorithm. Generally it lies in the zone of 85% to 90%. So there is no point in pondering of under utilization in our algorithm.

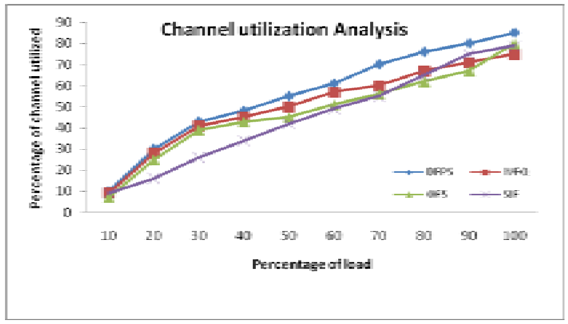

Figure 6: Graph showing the comparison of percentage of Channel utilized using DFPS Algorithm versus conventional Algorithms

6.2 Fairness analysis

In the Figure 7 all the requests of UGS i.e. 100% are granted. 50% of the requests of the rtPS are granted. But in the case of ertPS 30% of the requests are granted. Even though nrtPS and BE have lower priority 50% and 15 % of their requests are granted respectively. It shows that the UGS traffic of WiMAX is handled first and is scheduled without any trouble. This satisfies the basic rule of IEEE 802.16 standard. Then a portion of rtPS and ertPS are also granted depending on the availability and the fuzzy rule base. But the success of our Algorithm is the granting of requests from the lower priority service classes (nrtPS and BE) consistently. Hence here the priority is kept intact while the once channel starving lower priority service classes are been taken care of leading to fairness.

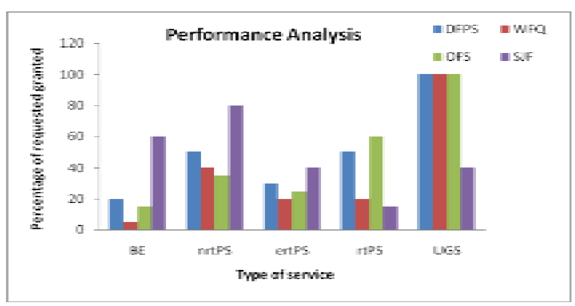

Figure 7: Graph showing the comparison of percentage of request granted for different types of services using DFPS versus conventional Algorithms

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The Figure 7 shows the comparison of the percentage of requests granted for the various types of service classes for different conventional Scheduling Algorithms with the proposed DFPS Algorithm. The graph reveals that the Shortest Job First (SJF) algorithm does not consider priority at all and on sight it violates WiMAX basic rule and also there is no provision for fairness. It is imperative that the First Come First Serve (FCFS) does not care about priority or fairness but it grants the request on first come first serve basis even though it is not shown in the graph. It is inferred from the graph that Weighted Fair Queuing (WFQ), and Opportunistic Fair Scheduling (OFS) [6] - [11] that aims at fairness as indicative of the name grants all the requests of UGS service class. But they grant only 5% and 10% of the least priority one the BE service class respectively where as our proposed Algorithm grants as high as 20% of the requests. Even though there is a little amount of fairness in WFQ and OFS algorithms most of the time the BE service class requests must starve for resources. Hence it is inferred that our DFPS algorithm improves fairness to an extent while keeping the priority intact.

6.3 Processing Time

Eventhough our proposed algorithm is way ahead in fairness, priority and channel utilization, we studied the next aspect the processing time too. Figure 8 shows that the procesing time for our proposed algorithm to grant a full load traffic is 32 milliseconds. Fow lighter loads it was 15 milliseconds. On first sight we may think that it is a bit on the upper side. But for multimedia applications using Internet permits delays upto 400 milliseconds as acceptable one. So as for as quality is concerned we are not on the wrong side but very much on the highly acceptable grounds. Figure 8 visualises the processing time under full load traffic for conventional algorithms. It is seen that WFQ needs 17 milliseconds to grant full load of requests and OFS needs 15 milliseconds and SJF 12 miliseconds. It infers that the conventional algorithms processs the requests much faster than the proposed algorithm. Therefore it is understandable that this novel scheduling algorithm is bit slower than the traditional scheduling algorithms but the fairness and channel utilization it provides overwhelms that setback as this processing time is well within the acceptable standards of streaming of multimedia over the Internet and Wireless Broadband Networks.

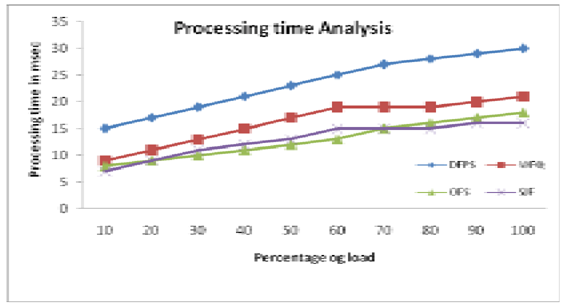

Figure 8: Graph showing the comparison of Processing time using DFPS Algorithm versus the Conventional Algorithms

7. CONCLUSIONS AND FUTURE WORK

A Dynamic fuzzy based QoS Scheduling Algorithm was designed. The DFPS section dealt with the priority setting mechanism under uncertainty conditions by taking into consideration of variables such as expiry time, waiting time, queue length, packet size and the type of service for WiMAX requests. A novelty was introduced here by using a two stage fuzzy system that dynamically sets the priority based n the type of service. Simulation results showed encouraging speeds in computation and better precision in setting the priority. It was noted that the processing time was only 11 milliseconds for setting priority. But the time for scheduling needs additional 21 milliseconds. The results show that a fair amount of fairness is attained while keeping the priority intact. The results also show that maximum channel utilization is achieved with a negligible increment in processing time. Here the dynamic fuzzy based priority scheduler for WiMAX is proposed. Future improvements can be made using Artificial Neural Networks (ANN) for scheduling of QoS with improved channel utilization and fairness simultaneously to further minimize the starvation of the lower priority requests.

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