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A NOVEL QOS SCHEDULING FOR WIRELESS BROADBAND NETWORKS

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Abstract
During the last few years, users all over the world have become more and more familiar to the availability of broadband access. When users want broadband Internet service, they are generally restricted to a DSL (Digital Subscribers Line), or cable-modem-based connection. Proponents are advocating worldwide interoperability for microwave access (WiMAX), a technology based on an evolving standard for point-to multipoint wireless networking. Scheduling algorithms that support Quality of Service (QoS) differentiation and guarantees for wireless data networks are crucial to the deployment of broadband wireless networks. The performance affecting parameters like fairness, bandwidth allocation, throughput, latency are studied and found out that none of the conventional algorithms perform effectively for both fairness and bandwidth allocation simultaneously. Hence it is absolutely essential for an efficient scheduling algorithm with a better trade off for these two parameters. So we are proposing a novel Scheduling Algorithm using Fuzzy logic and Artificial neural networks that addresses these aspects simultaneously. The initial results show that a fair amount of fairness is attained while keeping the priority intact. Results also show that maximum channel utilization is achieved with a negligible increment in processing time.

Keywords:
Fuzzy Logic, Artificial Neural Networks, Priority, Scheduling Algorithms, WiMAX

1. INTRODUCTION

WiMAX is one of the most important broadband wireless technologies and is a viable alternative to traditional wired broadband techniques due to its cost efficiency. It is envisioned that WiMAX will provide the last mile internet access to residential users. This will be particularly useful in regions where wired infrastructure does not exist or cannot be setup, such as rural areas and remote mountainous areas, for instance. 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. For small and medium enterprises, WiMAX will create an economical alternative to expensive leased line solutions. It is necessary to provide guaranteed Quality of Service (QoS) with different characteristics, quite challenging, for Broadband Wireless Access (BWA) networks. 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. A typical WiMAX environment is shown in Fig.1.

1.2 QUALITY OF SERVICES (QOS) AND 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 [1].

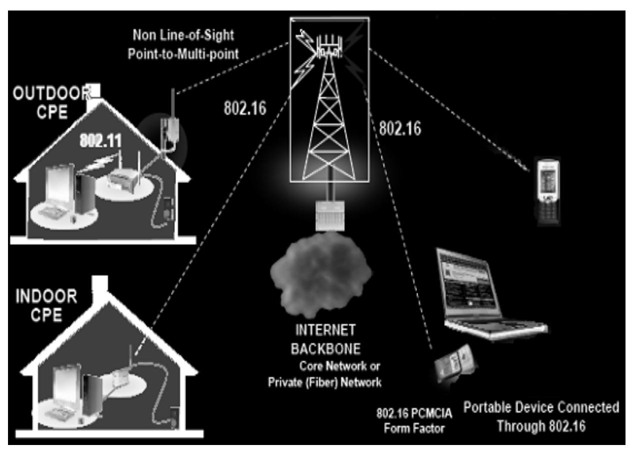

Fig.1. WiMAX environment

The infrastructure to support various classes of services comes from the Media Access Control (MAC) implementation. QoS is enabled by the bandwidth request and grant mechanism between various subscriber stations and base stations. Primarily there are five classes of service for the QoS support namely Unsolicited Grant Service (UGS), Real Time Polling Service (rtPS), Enhanced Real Time Polling Service (ertPS), Non Real Time Polling Service (nrtPS) and Best Effort (BE) to provide the service-class classification for video, audio, and data services. The service scheduler provides scheduling for different classes of services for single user. This would mean meeting SLA requirements at the user level.

1.3 SCHEDULING USING ARTIFICIAL INTELLIGENCE

Even though there are lots of scheduling algorithms, they are not meeting the required QoS. The performance affecting parameters like fairness, bandwidth allocation, throughput, latency are studied and found out that none of the algorithms perform effectively for both fairness and maximum bandwidth utilization simultaneously [2]. So we decided to optimize those two parameters by using an algorithm based on artificial intelligence (AI). Among the three tools of AI the Artificial Neural Network (ANN) has good decision making capability where as its computational time is high. Hence Fuzzy Logic was used for setting priority first and later ANN for scheduling and granting the requests.

1.4 PAPER OUTLINE

This paper is organized as follows: Section 2 describes how the fuzzy logic is used to set priority for the incoming requests of various service classes. The allocation of channel bandwidth with fairness for the various service classes that are allotted different priority levels by the fuzzy systems using the artificial neural networks (ANN) is shown in section 3. In section 4, it is shown that how the performance of WiMAX using the newly proposed Neural network based fuzzy priority scheduling can be studied and the conclusions in section 5.

2. SETTING OF PRIORITY USING FUZZY LOGIC

The IEEE 802.16 standard divides all services into five different classes [3] namely Unsolicited grant service (UGS), Real-time polling service(rtPS), Enhanced Real-time polling service (ertPS), Non real-time polling service (nrtPS) and Best effort (BE).The requests come from any of those five services. These requests 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.

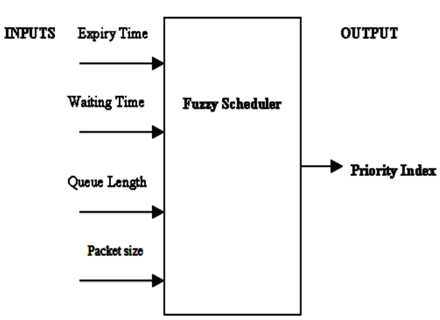

Fig.2. Proposed Primary Fuzzy Scheduler

The fuzzy rule table is created based on the membership functions that are carefully designed as explained in table.1. 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. These illustrations were designed using the fuzzy tool available in the MATLAB.

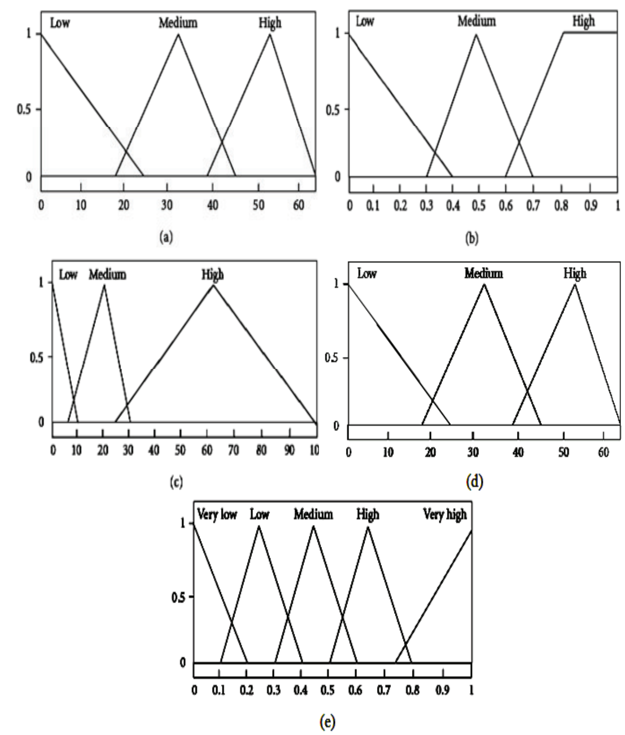

Fig.3. Membership functions (a) Expiry time (in sec) (b) Packet size (in Kilobytes) (c) Queue length (in bytes) (d) Waiting time (in sec) (e) Priority Index

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	L	M	H
M	L	H	M
H	H	M	L

(c) (a) Vs. (b)

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

The fuzzy rule base for the proposed algorithm is defined with due care and are shown in table.1. 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. 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. 4. A membership function and a rule table are created based on the priority index of FS1 and the type of service.

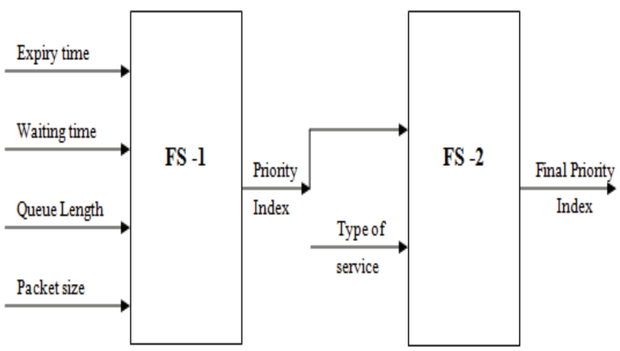

Fig.4. Dynamic Fuzzy Scheduler

2.1 DYNAMIC FUZZY SCHEDULER

The Dynamic Fuzzy Rule Base is shown in Table. 2. 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).

Table.2 Dynamic Fuzzy Rule Base

Priority	UGS	rtPS	nrtPS	BE
VL	VH	L	L	VL
L	VH	M	L	VL
M	VH	H	L	VL
H	VH	H	M	VL
VH	VH	H	M	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 iş referred as ή which is the standard notation used in the literature.

3. SCHEDULING USING ANN

The next step is scheduling of the prioritized input received from the DPFS. Since neural networks have high computational speeds we decided to use ANN. A neural network is a massively parallel-distributed processor that has a natural propensity for storing experiential knowledge and making it available for use. Artificial neural network is a nonlinear signal-processing device, which is built from interconnected elementary processing devices called neurons. Either humans or other computer techniques can use neural networks, with their remarkable ability to derive meaning from complicated or imprecise data, to extract patterns and detect trends that are too complex to be noticed. A trained neural network can be thought of as an "expert" in the category of information it has been given to analyze. This expert can then be used to provide projections given new situations of interest and answer "what if" questions.

An ANN can have the following features:

- Adaptive learning
- Self-Organization
- Real Time Operation

In artificial neuron as shown in Fig.5 each input is multiplied by a corresponding weight and all of the weighed inputs are then summed to determine the activation level of the neuron. In spite of diversity of network paradigms, almost all are based upon this configuration. A set of inputs labeled $x_{1,}\ x_{2\ldots\ldots}\ x_n$ is applied to the artificial neuron. These inputs collectively referred to as the vector X that imitates to the signals into the synapses of a biological neuron. Each signal is multiplied by an associated weight $w_{1,}\ w_{2,}\ \ldots, w_n$ before it is applied to the summation block, labeled Σ. Each weight corresponds to the "strength" of a single biological synaptic connection. The set of weights is referred to collectively as the vector W. The summation block, adds all of the weighed inputs algebraically, producing an output called NET. This may be stated in vector notation as follows:

NET = XW

$NET = x_1 * w_i + x_2 * w_2 + x_3 * w_3 + \ldots + x_n * w_n$

Fig.5 shows an Artificial Neuron model in vector form.

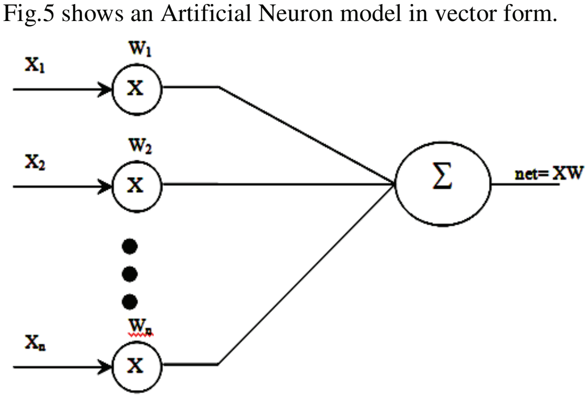

Fig. 5 Artificial Neuron

3.1 PROPOSED ANN

The proposed ANN is shown in Fig.6. It consists of three layers. The first layer is the input layer and the second layer is the modified form of Kohonen layer. The final layer is the modified form of Grossberg layer. The proposed ANN deals with the efficient allocation of the available bandwidth based on the Priority Index set by the DFPS with a measure of Fairness to all the service classes. The input layer receives the prioritized outputs from the DFPS. These inputs are organized in the order of their priority. Now the output of this layer is given as the input to the modified Kohonen Layer. The modified Kohonen layer is used to predict whether the given input is within the threshold value. Depending on the availability of the channel bandwidth the threshold value is set. If the incoming request is below the threshold value then that request is forwarded to the next layer, the Grossberg layer. If not, that request is rejected. But it happens on extreme circumstances. In the Grossberg layer, the inputs are summed up and it calculates how many requests can be granted within the threshold.

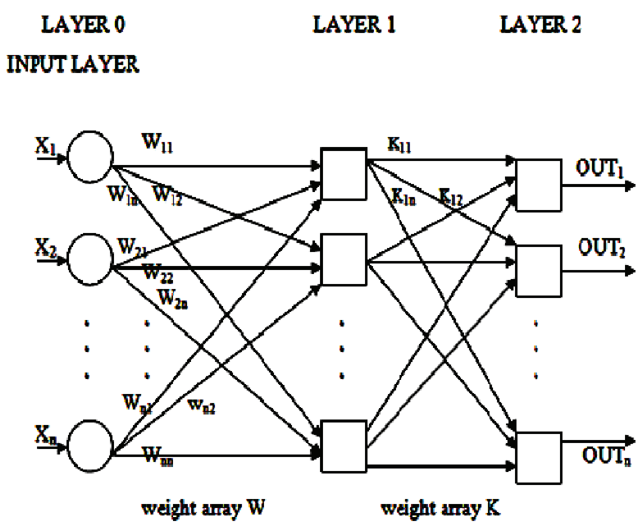

Fig.6. Proposed ANN

Each neuron in the Grossberg layer outputs the value of the weight that connects it to the single nonzero Kohonen neuron.

3.2 SIMULATIONS AND RESULTS

The proposed Neural Network based Fuzzy Priority Scheduling Algorithm (NFPS) was tested in the C++ and the MATLAB simulation environments.

Let us consider 20 requests that require different bandwidths. These requests are first organized based on their priority levels by the DFPS based on the fuzzy rule base. Once the priority levels are set the requests are given to the proposed ANN Network. We begin the work here by setting the threshold value. It is selected in such a way that almost all the resources are utilized. Here it is set as 10000. The first request value is compared with the threshold value at the modified Kohonen Layer and since it is less than the threshold value the request is permitted and forwarded to the modified Gross berg Layer. Similarly all the 20 requests are compared with the threshold value and if the request value is less than the predefined threshold value then it is forwarded to the next layer. The fourth request is rejected as its value is higher than the threshold value. Out of the available 20 requests all the 19 requests barring request 4 are forwarded to the modified Gross berg layer. Now all these Kohonen Neurons that reach the modified Gross berg layer are summed up and the sum must be within threshold value. As the summation begins the proposed algorithm at the modified Gross berg layer, sums up requests 1, 2, 3, 5, 6, 7 and 8 and as it lies within the threshold value i.e. 8000 are scheduled. If the request 9 is also added then it adds up to 13000 that cannot be accommodated. So the request 9 is rejected at this stage. The algorithm now stops scheduling here. This stage concludes the scheduling of requests without fairness. Here only the higher priority ones are scheduled and the requests with lower priorities are not considered for scheduling and a portion of channel remains unutilized. To avoid under utilization [4] and to use this unused resource by the requests with lower priority the algorithm makes a novel change here. Here the algorithm goes for the next requests which have lower priorities. The request 10 cannot be scheduled as it is greater than the available bandwidth value. Now requests 11, 12, 13,14,16,18 and 20 are granted from the lower priority ones making sure that the unutilized channel is also utilized assuring maximum channel utilization. Moreover the once channel starving lower priority ones are also taken care-off leading to fairness.

4. PERFORMANCE EVALUATION AND COMPARISON

The Performance of the proposed NFPS Algorithm is studied under various metrics. Firstly 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. Then the Channel utilization aspect is analyzed for proposed NFPS Algorithm versus 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 algorithms.

4.1 FAIRNESS ANALYSIS

In the following Fig.7 all the requests of UGS (5) i.e. 100% are granted. 60% of the requests of the rtPS (4) are granted. But in the case of ertPS (3) 40% of the requests are granted. Even though nrtPS (2) and BE (1) have lower priority 60% and 40 % 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.

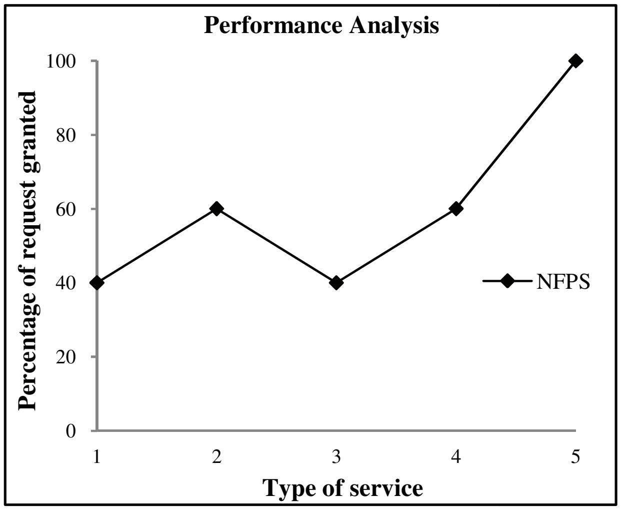

Fig.7. Graph showing percentage of request granted for different types of services using NFPS Algorithm

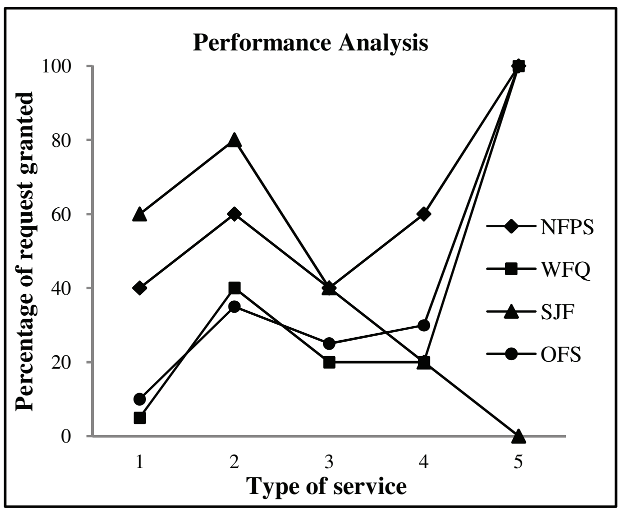

Fig.8. Graph showing the comparison of percentage of request granted for different types of services using NFPS Algorithms Vs. conventional Algorithms

The Fig.8 shows the comparison of the percentage of requests granted for the various types of service classes for different conventional Scheduling Algorithms with the proposed NFPS 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) [5], [8] and Opportunistic Fair Scheduling (OSF) [6] , [7] 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 40% 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 NFPS algorithm improves fairness dramatically while keeping the priority intact.

4.2 CHANNEL UTILIZATION

Similarly the channel utilization (Fig.9) is also calculated and the following figure shows that for a given set of requests, the channel utilization is absolutely 100%. The Fig.10 clearly shows the amount of channel utilized by our proposed NFPS Algorithm. It begins from 5% for one request to almost 90% for 20 requests. 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 Fig.11 that the WFQ utilizes as high as 75% and 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 NFPS algorithm. Hence it is imperative that maximum channel utilization achieved in our proposed NFPS algorithm. Generally it lies in the zone of 90% to 100%. So there is no point in pondering of under utilization in our algorithm.

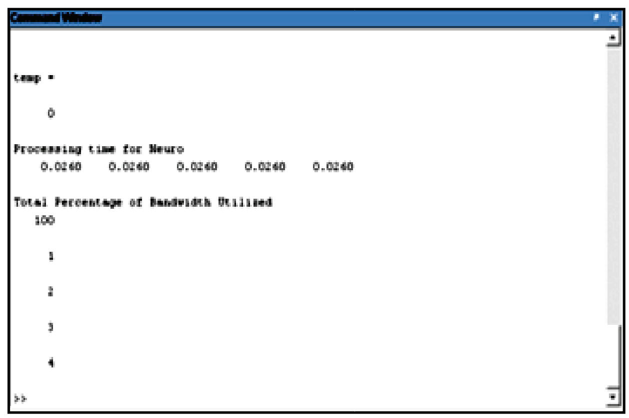

Fig.9. Simulated Window Showing Percentage of Channel Utilized Using NFPS Algorithm

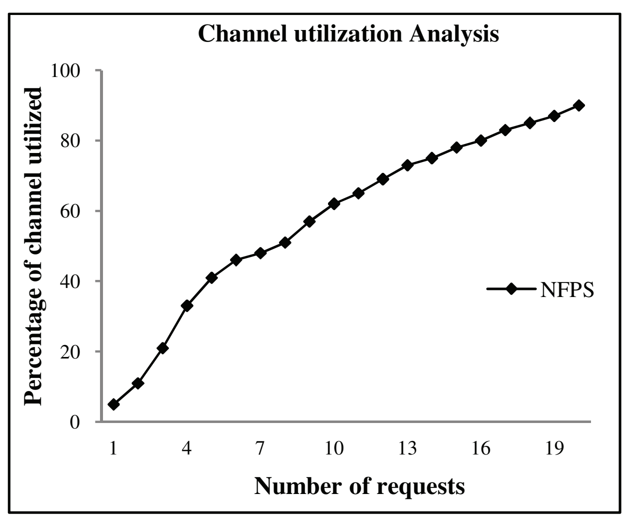

Fig.10. Graph showing percentage of channel utilized using NFPS Algorithm

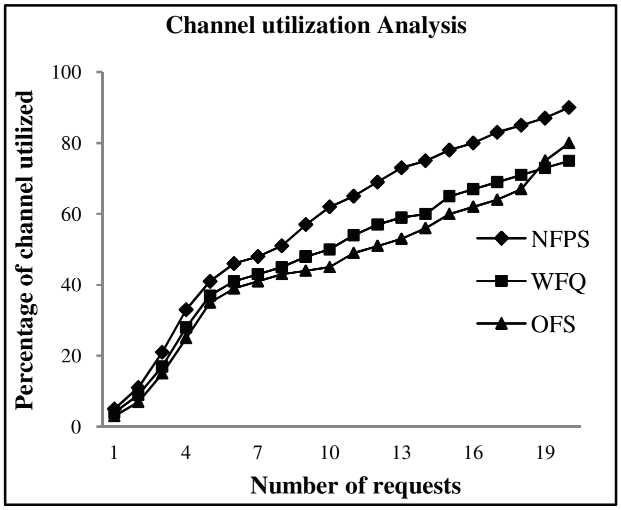

Fig.11. Graph showing the comparison of percentage of Channel utilized using NFPS Algorithms versus the conventional Algorithms

4.3 PROCESSING TIME

Eventhough our proposed algorithm is way ahead in fairness, priority and channel utilization, we studied the next aspect the processing time too. Fig.11 shows that the procesing time for our proposed algorithm to grant 20 requests is 42 milli seconds. 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.

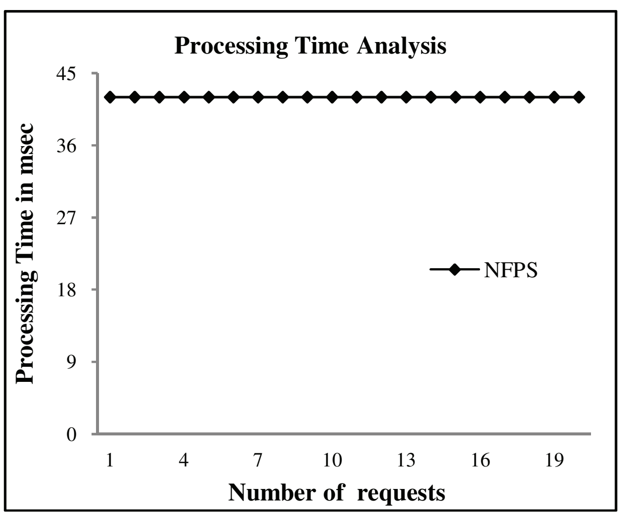

Fig.12. Graph showing processing time using NFPS Algorithm

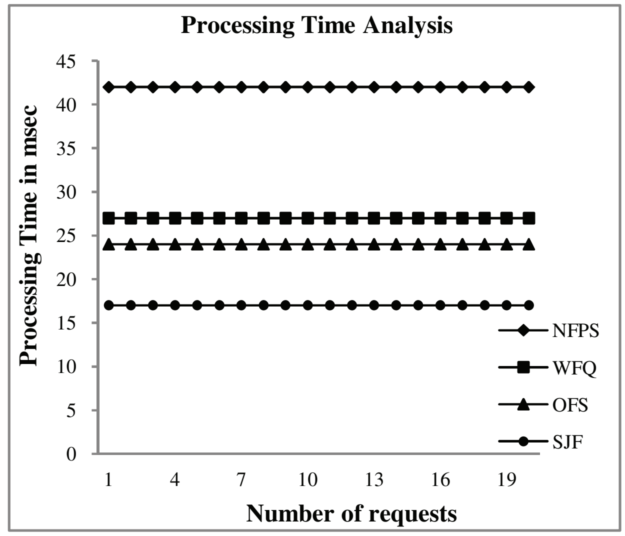

Fig.13. Graph showing the comparison of Processing time using NFPS Algorithms versus the conventional Algorithms

Fig. 13 visualises the processing time for 20 requests for different conventional algorithms. It is stated that WFQ needs 27 milliseconds to grant 20 requests and OFS needs 24 milliseconds and SJF 17 miliseconds. It infers that the conventional algorithms process the requests 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.

5. CONCLUSIONS AND FUTURE WORK

A novel Neural Network based Fuzzy Priority Scheduling Algorithm was designed. The fuzzy 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. Simulation results showed encouraging speeds in computation and better precision in setting the priority. The neural section took care of the bandwidth allocation mechanism by considering the fuzzy prioritized outputs as its input. 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. It is proposed to study the performance of our proposed algorithm under bursty traffic conditions and with fully loaded network conditions on near future.

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