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PERFORMANCE ANALYSIS OF AI BASED QOS SCHEDULER FOR MOBILE WIMAX

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Abstract
Interest in broadband wireless access (BWA) has been growing due to increased user mobility and the need for data access at all times. IEEE 802.16e based WiMAX networks promise the best available quality of experience for mobile data service users. WiMAX networks incorporate several Quality of Service (QoS) mechanisms at the Media Access Control (MAC) level for guaranteed services for multimedia viz. data, voice and video. The problem of assuring QoS is how to allocate available resources among users to meet the QoS criteria such as delay, delay jitter, fairness and throughput requirements. IEEE standard does not include a standard scheduling mechanism and leaves it for various implementer differentiations. Although a lot of the real-time and non real-time packet scheduling schemes has been proposed, it needs to be modified to apply to Mobile WiMAX system that supports five kinds of service classes. In this paper, we propose a novel Priority based Scheduling scheme that uses Artificial Intelligence to support various services by considering the QoS constraints of each class. The simulation results show that slow mobility does not affect the performances and faster mobility and the increment in users beyond a particular load have their say in defining average throughput, average per user throughput, fairness index, average end to end delay and average delay jitter. Nevertheless the results are encouraging that the proposed scheme provides QoS support for each class efficiently.

Keywords:
WiMAX, QoS, Fuzzy Neural Networks Based Scheduling Algorithm, Multimedia Transmissions, Media Access Control and Mobility

1. INTRODUCTION

Mobile WiMAX (Worldwide Interoperability for Microwave Access), based on IEEE 802.16, is providing broadband wireless access with high speed, large coverage and a variety of services. A WiMAX base station can provide broadband wireless access in range up to 30 miles (50 km) for fixed stations and 3 to 10 miles (5 to 15 km) for mobile stations with a maximum data rate of up to 70 Mbps [1]-[4] compared to 802.11a with 54 Mbps up to several hundred meters, or CDMA 2000 (Code-Division Multiple Access 2000) with 2 Mbps for a few kilometers. In addition to providing high data rate services over large distances in open rural areas, the provisions for QoS and the associated scheduling algorithm designs are a key issue in Mobile WiMAX. Moreover, the 802.16e standard enhancement was designed to support mobile communication at vehicular speeds. Since Mobile WiMAX system provides various real-time and non-real-time services, appropriate resource allocation schemes are required to support QoS (Quality of Service) of each service efficiently. A key feature of the WiMAX technology is that it is a connection oriented technology, which provides a strong support for QoS management. This fact introduces many new problems into the already difficult realm of the network simulation, as both the wireless media and QoS specific aspects need to be considered during the model design. Several theoretical studies have been reported in literature to evaluate the Mobile WiMAX system level performance and the effectiveness of radio resource management. On the other hand, several simulation models have been proposed in this community to support Mobile WiMAX simulation such as QualNet [5], Opnet [6], and NS-2 [7] and while these simulation models provide generally good support for most basic protocol features, the implementation and performance evaluation of versatile QoS scheduling has not been discussed extensively in publications. Moreover there are several researches for packet scheduling algorithms to support various services in OFDMA system. Authors in [8] and [9] proposed efficient packet scheduling schemes to assign resources for real-time and non-real-time packets together in OFDMA system, these schemes are needed to be modified to apply Mobile WiMAX system which provides multiple service classes. In [10] authors proposed a multiclass scheduler structure in OFDMA system. This scheduler has separated class buffer which prioritized with urgency of each classes and as long as the higher class buffer has packets, the lower class will never be serviced. It also suggest the joint algorithm to solve the problem, this algorithm does not consider QoS characteristics of each class. The research in [11] performed a survey of the WiMAX scheduling algorithms and discussed the key issues and design factors in QoS scheduling. The advantages and drawbacks of major scheduling algorithms such as Round Robin, Weighted Fair Queuing and Early Deadline First algorithms were summarized and compared. The research in [12] compared the random access scheme with the Round Robin based polling service in Mobile WiMAX for bandwidth scheduling. The performance evaluation showed the advantages of Round Robin polling in high traffic scenarios. The research in [13] proposed a systematic framework of Mobile WiMAX QoS scheduling based on OFDMA radio resource management. The study showed the correct selection of scheduling algorithm is critical to support combinations of real-time and non-real-time traffic flows. Similar research studies regarding WiMAX QoS scheduling can be found in [14]-[15]. The authors in [16] presented the implementation methodology of an ns-2 based WiMAX simulation model in which the QoS scheduling was achieved by traffic class prioritization implementation. Other similar research studies regarding IEEE 802.16d based WiMAX QoS simulation models can be found in [17]-18]. In [19] authors propose a packet scheduling scheme to support multiple services efficiently with considering the QoS characteristics of each class by selecting a service class first after considering characteristics of each class and then choosing an appropriate user in selected class. Recent researches concentrate on providing a better trade-off between fairness and throughput while keeping the priority requirements intact. Since mobility an uncertainty component plays a vital role in Mobile WiMAX we are proposing a Fuzzy based priority Scheduler. The rest of this paper is as follows, section 2 introduces the Fuzzy Scheduler for Mobile WiMAX system, section 3 proposes the Neuro Fuzzy based Priority scheduling scheme. Modeling, Results and Performance Evaluation are carried out in section 5. Finally section 6 gives a conclusion.

2. QOS SCHEDULING ALGORITHM

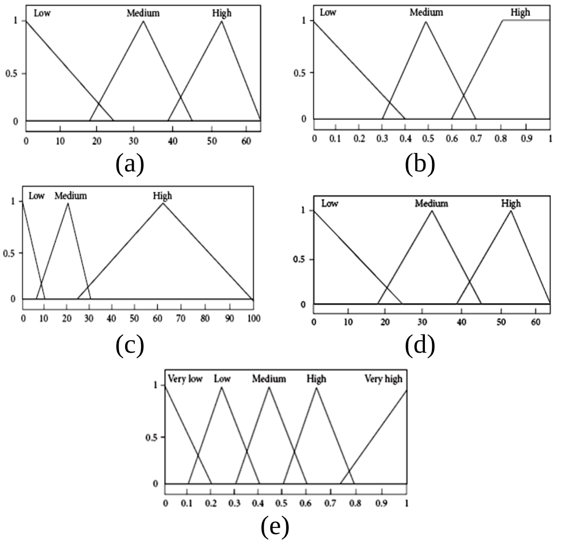
Fuzzy logic implements human experiences and preferences via membership functions and fuzzy rules. The application of fuzzy logic to problems of traffic control in networks is more attractive. Since it is difficult for a network to acquire complete statistics of the input traffic, it has to make a decision 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 and uncertain information since the network is dynamic in nature. Basically the fuzzy system consists of four blocks, namely, fuzzifier, defuzzifier, inference engine, and fuzzy knowledge base.

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 $\{(x1, \mu A(x1)), (x2, \mu A(x2)). . . (xn, \mu A(xn))\}$, where $\mu A : U \rightarrow [0, 1]$ is the membership function of the fuzzy set A and $\mu A(xi)$ indicates the membership degree of xi in the fuzzy set A. 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 A1j, $X2$ is A2j, $X3$ is A3j . . . 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 Aij 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 .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. 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,

$$\eta = \frac{1}{\sum \mu_{x1.....xn}^{\text{output}}(y)} \sum y \mu_{x1.....xn}^{\text{output}}(y) \qquad (1)$$

where, y is the centre point of each of the output membership function in the output fuzzy set B_j and $\mu_{x1.....xn}^{\text{output}}(y)$ is the strength of the output membership function.

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, Mobility 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.



(a) (b)

(c) (d)

(e)

Fig.1. 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

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. This illustration was designed using the fuzzy tool available in the MATLAB.

Table.1. Fuzzy Rule Base (a) Expiry Time Vs Waiting Time (b) Packet Size Vs Queue Length (c) (a) Vs (b)

(a). Expiry Time vs. Waiting Time

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

(b). Packet Size vs. Queue Length

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

(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” (20). 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 and Mobility parameter are also added as shown in Fig.2. A membership function and a Dynamic Fuzzy Rule Base table are created based on the priority index of FS1 and the type of service first and then with the different aspects of mobility factor as shown in Table.2.

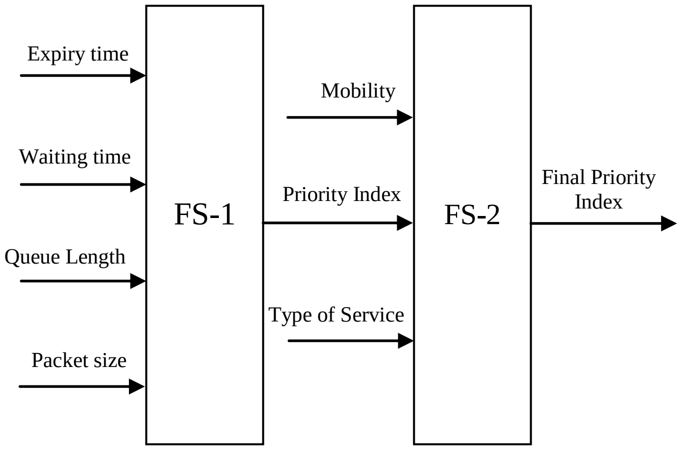


Fig.2. Dynamic Fuzzy scheduler

Table.2. Dynamic Fuzzy Rule Base

(a). Guaranteed Services for Different Priority Levels

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

(b). Final Priority Index at various traffic conditions with mobility

Priority	**Moving towards slowly**	**Moving away slowly**	**Moving towards fastly**	**Moving away fastly**	**Moving in circular fashion**	**Moving in random fashion**
VL	L	L	VL	VL	VL	VL
L	M	M	L	VL	L	VL
M	M	M	M	L	M	L
H	H	H	H	M	H	M
VH	VH	VH	VH	H	VH	H

In this Table.2, rule base and index 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. Finally the various aspects of mobility of the device are carefully monitored. The priority levels vary for different aspects such as the devices moving slowly towards the base station and away from the base stations. Similarly the priority levels changes for moving towards base stations fastly and moving away fastly. Apart from this the priority levels are defined for different motions of devices viz. in a circular fashion or in a random manner. The final priority index is referred as ή which is the standard notation used in the literature.

3. SCHEDULING OF REQUESTS USING ANN

The next step is the scheduling of the prioritized input received from the DFPS. The proposed Neural Networks based scheduler is shown in Fig.3. It consists of three layers [21]. 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 defined by the layer. 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, which happens only on extreme circumstances. In the Grossberg layer, the inputs are summed up and it calculates how many requests can be granted within the threshold value. The remaining requests are discarded. The equations and the algorithms governing the Kohonen and Grossberg layers are stated below.

Kohonen layer:

$$Y(i) = \sum_{n=1}^{N} X(n) * W(n) \tag{2}$$

where,

Y is the output

X is the bandwidth of each request

N is the total number of requests

$W(n)$ is the weight for each request

$$W(n) = \begin{cases} 1 & \text{if } (n = i) \\ 0 & \text{if } (n \neq i) \end{cases}$$

Modified Grossberg layer:

$$Z(i) = \sum_{n=1}^{N} Y(n) * W(n) \tag{3}$$

where,

Z is the output of modified Grossberg layer

$W(n)$ is the weight for each request

$$W(n) = \begin{cases} 1 & \text{if } (n <= i) \\ 0 & \text{if } (n > i) \end{cases}$$

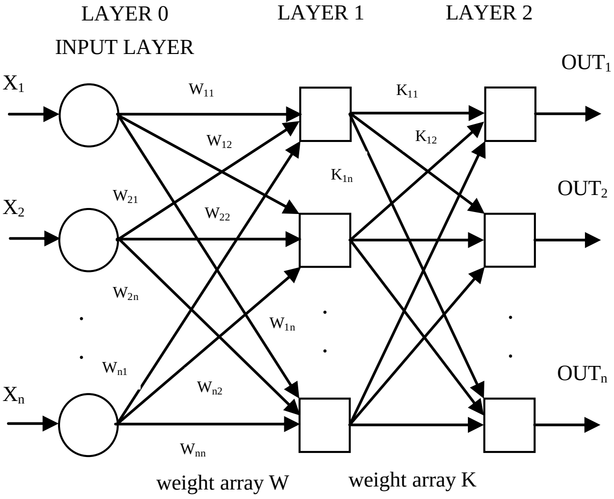


Fig.3. Proposed ANN

Algorithm: Scheduling using ANN

Input: Prioritized Request, Threshold Value

Output: Scheduling the request

```
For i=1 to n do
In Kohonen layer
    a. If input < threshold, send to Grossberg layer else the request is rejected.
In Grossberg layer
    b. Compare Sum of bandwidth of requests with threshold
       If possible, set Sum as bandwidth of the request
       Else go for the next request.
    c. Sum = Sum + Bandwidth
    d. If threshold > Sum, Set the tag of request to not possible and store the request number as limit
       Else select low priority request starting from bottom
    e. Repeat steps b and c
    f. If threshold > Sum, tag the lower priority request as possible and select the next low priority request
       Else Tag the low priority request as not possible and select the next low priority request. Then, go to step g.
    g. If Low priority request number = Limit, stop
       Else go to step e.
```

4. MODELING AND SIMULATIONS

In this section we perform our simulation study to evaluate the throughput and fairness performance of the already implemented Round Robin (RR), Max CINR (MC), Fair Throughput (FT), Proportional Fair (PF) [22] and proposed NFPS scheduling algorithms. AMC mode is enabled throughout the simulation for automatically adjusting the modulation and coding scheme based on the link quality. The simulation scenario is illustrated in Fig.4, where a variable number of subscriber stations are within the coverage area of a single BS. The nearest distance from SS to BS is 1m and the farthest distance is 7000m. Other stations are distributed evenly in the remaining space, providing equal inter-station distances. Here the traffic used is Constant Bit Rate (CBR) and the traffic rate is scenario dependent.

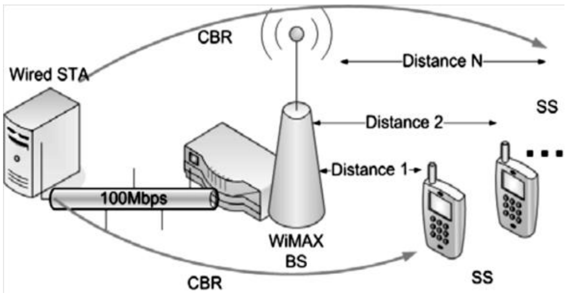


Fig.4. WiMAX Environment

5. PERFORMANCE EVALUATION

Following Fig.5 and Fig.6 shows the throughput and fairness performance tradeoff using these five scheduling algorithms for both the large distance and short distance scenarios. It is clear from these figures that throughput efficiency and fairness are the tradeoff for QoS scheduling: an algorithm can achieve better throughput only at the expense of reduced fairness, and vice versa. Through these simulation results we can see that the MC scheduling algorithm achieves better throughput in large distance scenarios with diverse channel conditions for different users.

The fairness performance of MC is the worst among these five algorithms. This is because MC favors users with high signal quality and better communication channels while users with bad communication link may be deprived of any bandwidth resource allocation. On the other hand, the FT algorithm achieves the best fairness among these five algorithms, but the throughput performance is the lowest, especially in the large-distance scenario with diverse user channel conditions. For the proposed NFPS algorithm achieves better throughput at short distances and a performance that matches the average for longer distances. Fairness of proposed NFPS is at its best for shorter distances and a close second to FT for longer distances. The PF and RR algorithms tune the throughput-fairness tradeoff and achieve better balances. The proposed NFPS matches PF and RR in balancing the trade off among throughput and fairness at various distances.

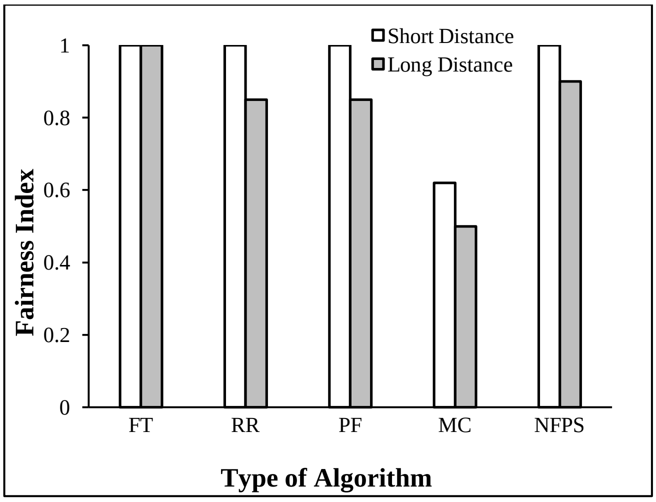


Fig.5. Index of Fairness vs Algorithms

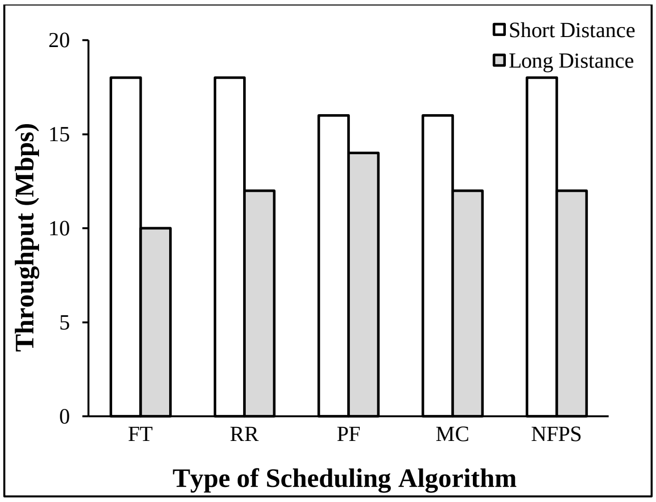


Fig.6. Throughput for different Scheduling Algorithms

In order to evaluate these five scheduling algorithms under more realistic conditions we run a simulation scenario with multiple users and various communication distances as illustrated in the scenario below[23]. In this scenario, each user has a CBR data flow of 1Mbps. Fig.6 illustrates the total throughput with various numbers of active users served by a BS using different scheduling algorithms. It is clear that the total throughput increases with more users and more traffic required to be transmitted over the Mobile WiMAX network. Fig.7 shows the average per-user throughput for these five scheduling algorithms. With the increased number of users the average throughput for each user is reduced. The MC scheduling algorithm achieves the best throughput efficiency performance among these five scheduling algorithms. This is because the MC algorithm explores the differences of communication channels among those users and allocates more communication resource to those users with better channel conditions. The FT scheduling algorithm achieves the lowest total throughput among all five scheduling algorithms. This is because fairness has a higher service priority than throughput efficiency in FT scheduling and the total throughput efficiency of FT scheduling is negatively affected because of the high priority of fairness in its scheduling. The RR scheduling algorithm which allocates bandwidth resources based on equal service opportunity achieves higher throughput than FT but lower throughput than MC. The PF scheduling algorithm achieves the highest throughput at longer distances and a close second for shorter distances among these five scheduling algorithms. The proposed NFPS Scheduling algorithm proves to be a better option for shorter distances and a close second for longer distances as well. In this paper the scheduling fairness is quantitatively evaluated by the metric of “fairness index” as described in [24]. The fairness index is defined as a value between 1 and 0, the higher the index, the better the fairness performance. According to the results in this Table.3 we can see that the fairness performance of the FT algorithm is the best among these five scheduling algorithms. The MC scheduling algorithm achieves the worst fairness performance but its throughput performance is the highest among these five algorithms. The RR and PF algorithms achieve better tradeoff between throughput and fairness. Comparing Fig.6 to Fig.8 we can see that the throughput, efficiency and fairness are the two major components forming a tradeoff relationship for the QoS scheduling algorithms in Mobile WiMAX. MC scheduling achieves the best throughput performance among these five scheduling algorithms, but the fairness performance is the worst. FT scheduling algorithm, on the other hand, achieves the highest fairness index but the lowest total throughput. RR achieves better throughput performance than FT but lower than the others and the fairness performance of RR is better than the others except that of FT. PF scheduling can flexibly tune the tradeoff off throughput and fairness. The proposed NFPS achieves better fairness and throughput at shorter distances and a close second in fairness and throughput at longer distances. So the proposed NFPS proves to be a better option in providing tradeoff between throughput and fairness in mobile WiMAX.

Table.3. Fairness Index

	4 nodes	**8 nodes**	**16 nodes**	**32 nodes**
FT	1	1	0.9	0.9
RR	0.9	0.8	0.7	0.65
PF	0.9	0.8	0.6	0.55
MC	0.75	0.75	0.6	0.5
FPS	1	1	0.9	0.85

Similarly the performances of the five scheduling algorithms are studied in Fig.7 at various loads say 4 nodes, 8 nodes, 16 nodes and 32 nodes. Fairness index of FT scheduling algorithm is the best among algorithms under view. The fairness index of RR, PF and MC reduces drastically with load. But the proposed NFPS algorithm proves a rank above the remaining algorithms and again comes a close second at higher loads and stands tall with FT till 16 nodes. As far as throughput performance at various loads is concerned FT performance is very poor and RR is slightly better. But the performance of PF and MC increases with load and the proposed NFPS has similar performance till 16 nodes and for 32 nodes it falls a bit. While comparing per user performance the FT and RR fairs poor and MC has the best throughput. PF and NFPS have similar performance till 16 nodes and NFPS falls a bit for 32 nodes. To look at the effect of mobility while having a number of SSs within the same cell, we created a scenario where the number of mobile SSs was varied from 4 to 32 as 4, 8, 16 and 32. These stations were placed within the single WiMAX cell in a circular orientation around the BS with equal distances of 50 meters away [25]. A single 550 meter radius WiMAX cell was used with a single base station connected via a 100 Mbps Fast Ethernet link to a traffic generator. First a single stationary subscriber station (SS) was placed within the cell at varying distances with an increment of 50 meters. Once the SS is 500 meter away, the increment in distance was reduced to 10 meter only to look at the performance at a more granular level when approaching the edge of the cell. The traffic generated to the SS was a constant bit rate (CBR) traffic with packet size of 1024 bytes and an inter packet departure interval of 16ms, i.e. the bit rate was 512Kbps. The buffer at the base station was chosen as 50KB buffer. The throughput, packet delay and delay jitter [26] results for this experiment showed no significant difference when varying the distance except when reaching the edge of the cell where a sharp drop in throughput coupled with a sharp increase in jitter was noticed. Now the number of SS is increased in the order of 4, 8, 16 and 32 and traffic was generated from the CBR traffic generator to all SSs through the BS. The average end to end delay was measured as the number of SSs was increased adding to the load exerted on the BS. As expected, and as shown in table, the greater the load represented in the number of SSs connected to the BS the greater the end-to-end delay and jitter experienced. Later mobility was added to the SSs. The placed SSs were programmed to move all inward or outward within the cell with respect to the BS at different specified speeds. The simulation was done for two Scheduling algorithms namely the Conventional Scheduling algorithm and the proposed NFPS Scheduling algorithm.

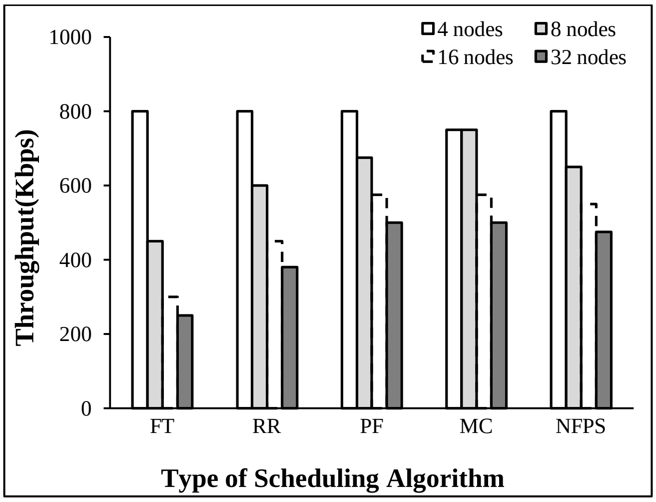


Fig.7. Throughput in Kbps for different Scheduling Algorithms in various Loads

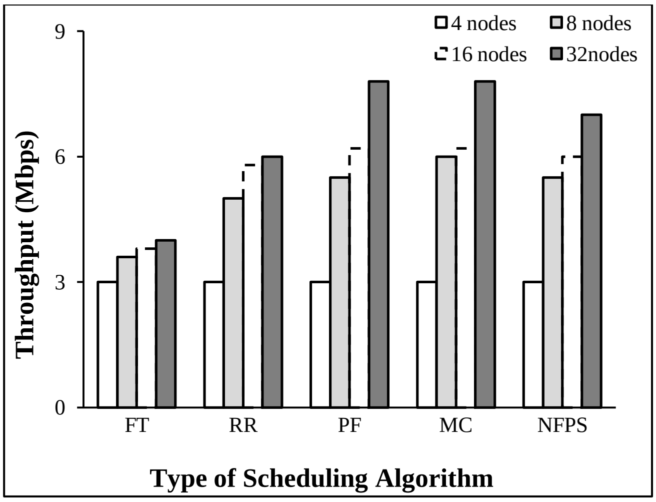


Fig.8. Throughput in Mbps for different Scheduling Algorithms in various Loads

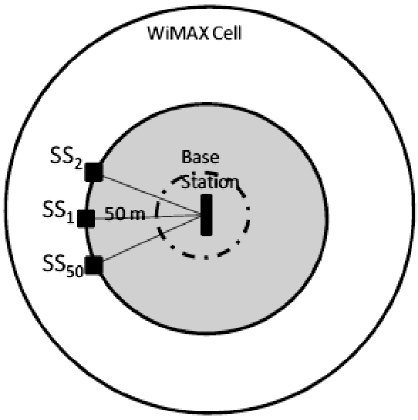


Fig.9. WiMAX Cell between Subscriber and Base Station

Table.4. Average Throughput

Description	4 nodes		8 nodes		16 nodes		32 nodes	
	Conv. (KB)	NFPS (KB)	Conv. (KB)	Conv. (KB)	Conv. (KB)	Conv. (KB)	Conv. (KB)	NFPS (KB)
Moving Inwards 50km/hr	520	520	520	520	520	520	520	520
Moving Outwards 50km/hr	520	520	520	480	480	480	480	520
Moving Inwards 5km/hr	520	520	520	500	500	500	500	520
Moving Outwards 5km/hr	520	520	520	490	490	490	490	520

Table.5. Average End to End Delay

Description	**4 nodes**		**8 nodes**		**16 nodes**		**32 nodes**	
	Conv. (ms)	**NFPS (ms)**	**Conv. (ms)**	**NFPS (ms)**	**Conv. (ms)**	**NFPS (ms)**	**Conv. (ms)**	**NFPS (ms)**
Moving Inwards 50km/hr	23	25	23	25	23	25	20	22
Moving Outwards 50km/hr	22	23	22	23	22	23	110	115
Moving Inwards 5km/hr	21	23	21	23	21	23	50	55
Moving Outwards 5km/hr	20	22	20	22	20	22	90	95

Results for the average end to end delay, delay jitter and throughput at a chosen SS are shown in Table.4 to Table.6. The number of SSs was limited to 32 since more data loss was noticed when the number exceeded that. As seen from table the throughput started to drop once the number of SSs approached 20 with about 8% for the case of a SS station moving outward at the speed of 50 Kh-1. However, no throughput degradation was noticed in the case where the SS was moving inward at the same speed of 50 Kh-1. While, the end to end delay results showed a consistent behavior at the same speed with increasing number of SSs, varying the speed and direction showed inconsistency as the number of SSs increased. This inconsistency was also noticed when looking at the delay jitter results when the load reaches 32 nodes. Average end to end delay performance is better for the conventional algorithm at higher loads whereas the NFPS fares better for delay jitter performance even at higher loads.

Table.6. Average Delay Jitter

Description	**4 nodes**		**8 nodes**		**16 nodes**		**32 nodes**	
	Conv. (ms)	**NFPS (ms)**	**Conv. (ms)**	**NFPS (ms)**	**Conv. (ms)**	**NFPS (ms)**	**Conv. (ms)**	**NFPS (ms)**
Moving Inwards 50km/hr	8	7.5	8	7.5	8	7.5	7.2	7.1
Moving Outwards 50km/hr	8	7.5	8	7.5	8	7.5	8.2	7.6
Moving Inwards 5km/hr	8	7.5	8	7.5	8	7.5	7.1	7.1
Moving Outwards 5km/hr	8	7.5	8	7.5	8	7.5	7.5	7.3

6. CONCLUSION

In this paper a Neural Network based QoS Scheduling Algorithm for mobile WiMAX 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, Type of service for WiMAX requests and mobility of the nodes. Simulation results showed better precision in setting the priority. The NFPS section took care of the bandwidth allocation mechanism by considering the fuzzy prioritized outputs as its input. Here we have presented an in-depth performance study of four major scheduling algorithms: RR, MC, FT and PF for Mobile WiMAX and compared them with the performance of the proposed NFPS Scheduling algorithm. RR achieves better throughput performance than FT but lower than the others and the fairness performance of RR is better than the others except that of FT. The proposed NFPS achieves better fairness and throughput at shorter distances and a close second in fairness and throughput at longer distances. So the proposed NFPS proves to be a better option in providing tradeoff between throughput and fairness in mobile WiMAX. Similarly the performances of the five scheduling algorithms are studied at various loads viz. 4 nodes, 8 nodes, 16 nodes and 32 nodes. Fairness index of FT scheduling algorithm is the best among algorithms under view. The fairness index of RR, PF and MC reduces drastically with load. The proposed NFPS algorithm proves a rank above the remaining algorithms and comes a close second at higher loads and stands tall with FT till 16 nodes. Results for the average end to end delay, delay jitter and throughput were measured for NFPS algorithm and compared with the conventional algorithm. The number of SSs was limited to 32 since more data loss was noticed when the number exceeded that. The throughput started to drop once the number of SSs crossed 16 with about 8% for the case of a SS station moving outward at the speed of 50 Kh-1. However, no throughput degradation was noticed where the SS was moving inward at the same speed of 50 Kh-1. While, the end to end delay results showed a consistent behavior at the same speed with increasing number of SSs, varying the speed and direction showed inconsistency as the number of SSs increased. This inconsistency was also noticed when looking at the delay jitter results when the load reaches 32 nodes. Average end to end delay performance is better for the conventional algorithm at higher loads whereas the NFPS fares better for delay jitter performance even at higher loads. NFPS has degradation in performance for the end to end delay at higher loads but an improvement in performance is show cased in delay jitter performance even at higher loads. Researches may be concentrated to improve efficiency at greater speeds and longer distances for a heavier traffic with mobility of SS in a random fashion.

REFERENCES

[1] IEEE 802.16j-2009, Part 16: IEEE Standard for Local and Metropolitan Area Networks: Air Interface for Fixed Broadband Wireless Access Systems, 2009.

[2] IEEE P802.16Rev2/D2, Part 16: DRAFT Standard for Local and metropolitan area networks: Air Interface for Broadband Wireless Access Systems, 2007.

[3] IEEE 802.16-2004, Part 16: IEEE Standard for Local and Metropolitan Area Networks: Air Interface for Fixed Broadband Wireless Access Systems, 2004.

[4] IEEE Std. 802.16e-2005, IEEE Standard for Local and metropolitan area networks, Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems, 2005.

[5] http://www.scalable-networks.com.

[6] http://www.opnet.com.

[7] W Wang, H Sharif, M Hempel, T Zhou, P Mahasukhon and T Ma, "Implementation and performance evaluation of a complete, accurate, versatile and realistic simulation model for mobile WiMAX in NS-2", *IEEE International Conference on Communications*, pp. 1-5, 2010.

[8] http://info.iet.unipi.it/~cng/ns2mesh80216/.

[9] http://w3.ant.nist.gov/seamlessandsecure/doc.html.

[10] S Ryu, B Ryu, H Seo and M Shi, "Urgency and efficiency based wireless downlink packet scheduling algorithm in OFDMA system", *IEEE 61st Vehicular Technology Conference*, Vol. 3, pp. 1456-1462, 2005.

[11] J Shen, N Yi, A Liu and H Xiang, "Opportunistic Scheduling for Heterogeneous Services in Downlink OFDMA System", *International Conference on Communications and Mobile Computing*, Vol. 1, pp. 260-264, 2009.

[12] W Park, S Cho and S Bahk, "Scheduler Design for Multiple traffic Classes in OFDMA Networks", *IEEE International Conference on Communications*, Vol. 2, pp. 790-795, 2006.

[13] S I Chakchai, R Jain and A K Tamimi, "Scheduling in IEEE 802.16e mobile WiMAX networks: key issues and a survey", *IEEE Journal on Selected Areas in Communications*, Vol. 27, No. 2, pp. 156-171, 2009.

[14] C Huang, H Juan, M Lin and C Chang, "Radio resource management of heterogeneous services in mobile WiMAX systems", *IEEE Wireless Communications*, Vol. 14, No. 1, pp. 20-26, 2007.

[15] Q Ni, A Vinel, Y Xiao, A Turlikov and T Jiang, "Investigation of bandwidth request mechanisms under point-to-multipoint mode of WiMAX networks", *IEEE Communications Magazine*, Vol. 45, No. 5, pp. 132-138, 2007.

[16] C Cicconetti, I Akyildiz and L Lenzini, "FEBA: A bandwidth allocation algorithm for service differentiation in IEEE 802.16 mesh networks", *IEEE/ACM Transactions on Networking*, Vol. 17, No. 3, pp. 884-897, 2009.

[17] J Huang, V Subramanian, R Agrawal and R Berry, "Joint scheduling and resource allocation in uplink OFDM systems for broadband wireless access networks", *IEEE Journal on Selected Areas in Communications – Special issue on broadband access networks: Architectures and protocols*, Vol. 27, No. 2, pp. 226-234, 2009.

[18] Y Gao, X Zhang, D Yang and Y Jiang, "Unified simulation evaluation for mobile broadband technologies", *IEEE Communications Magazine*, Vol. 47, No. 3, pp. 142-149, 2009.

[19] E Lee and H K Park, "Packet Scheduling Scheme for Multiple Services in Mobile WiMAX System", *Second International Conference on Computer and Network Technology*, pp. 60-63, 2010.

[20] D David Neels Pon Kumar, K Murugesan and S Raghavan, "A Novel QoS Scheduling For Wireless Broadband Networks", *ICTACT Journal on Communication Technology*, Vol. 1, No. 3, pp 143-148, 2010.

[21] D David Neels Pon Kumar, K Murugesan, S Raghavan and M Suganthi "Neural Network based Scheduling Algorithm for WiMAX with Improved QoS Constraints", *International Conference on Emerging Trends in Electrical and Computer Technology*, pp. 1076-1081, 2011.

[22] D David Neels Pon Kumar and K Murugesan, "Performance Analysis of Neural Networks Based Priority Scheduler for WiMAX under Bursty Traffic Conditions", *European Journal of Scientific Research*, Vol. 76, No. 3, pp. 351-365, 2012.

[23] W Wang, H Sharif, M Hempel, T Zhou, B Wysocki and T Wysocki, "Implementation and Performance Evaluation of QoS Scheduling Algorithms in Mobile WiMAX in NS-2 Simulator", *International Conference on Signal Processing and Communication Systems*, pp. 1-6, 2010.

[24] R Jain, D Chiu and W Hawe, "A quantitative measure of fairness and discrimination for resource allocation in shared computer systems", *Computing Research Repository*, 1998.

[25] K Kalyanam and P Indumathi, "A Simple QoS Scheduler for Mobile WiMAX", *World Academy of Science, Engineering and Technology*, Vol. 70, pp. 896-899, 2010.

[26] D M Ali and K Dimyati, "Performance Analysis of Delay Jitter in Mobile WiMAX Systems", *International Conference on Information and Electronics Engineering*, Vol. 6, 2011.