An Enhanced Scheduling Scheme for QoS in Mobile WiMAX Networks
D. David Neels Pon Kumar, Jithin Raj, K. Arun Kumar, K. Murugesan

Abstract-The Worldwide Interoperability for Microwave Access (WiMAX) standard, that is, the IEEE 802.16e standard supports point-to-multipoint (PMP). Scheduling in WiMAX become one of the most challenging issues, since it is responsible for distributing available resources among users to meet the QoS criteria such as delay, delay jitter, fairness and throughput requirements. However, no specific scheduling mechanism has been defined to provide QoS through five kinds of service class differentiation. In this paper we propose a novel Priority based Scheduling scheme to support various services by considering the QoS constraints of each class. The simulation results show the average throughput, average per user throughput, fairness index, average end to end delay and average delay jitter with different loads and different speeds. From these results it is concluded that the proposed scheme provides QoS support for each class efficiently for Mobile WiMAX.

Index Terms - Delay Jitter, Fairness Index, Qos, PMP, Mobile WiMAX

I. INTRODUCTION

WiMAX is an emerging broadband wireless last mile technology to provide higher speeds of up to 70 Mbps for longer distances say 30 miles of radius for distributing broadband wireless data over wide geographic areas. WiMAX is used due to extend broadband capabilities, supporting very high bandwidth, providing wide area coverage. WiMAX offers a rich set of features with a great deal of flexibility in terms of deployment options and potential service offerings. It can provide two forms of wireless service such as Line-of-Sight (LoS) service and Non-Line-of-Sight (NLoS) service. A WiMAX system consists of two parts a WiMAX Base Station (BS) and a WiMAX receiver.

Fig 1: Operational Principles of WiMAX Technology

Fig 1 explains the basic diagram of WiMAX technology. The IEEE 802.16e standard divides all services into five different classes 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 application of these service classes are shown in the Table 1. Since Mobile WiMAX system provides various real-time and non-real-time services as mentioned above, appropriate resource allocation schemes are required to support QoS (Quality of Service) of each service. A key feature of the WiMAX technology is that it is a connection oriented technology, which provides a strong support for QoS management

Table 1 Application, Band Width, Latency and Jitter of Each Service Classes

<table>
<thead>
<tr>
<th>Class</th>
<th>Application</th>
<th>Bandwidth</th>
<th>Latency</th>
<th>Jitter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Interactive Gaming</td>
<td>50 kbps</td>
<td>&lt; 25 msec</td>
<td>N/A</td>
</tr>
<tr>
<td>2</td>
<td>Voice Telephone(VoIP) Video conference</td>
<td>32064 kbps</td>
<td>160 msec</td>
<td>&lt; 50 msec</td>
</tr>
<tr>
<td>3</td>
<td>Streaming Media</td>
<td>5 kbps – 2 Mbps</td>
<td>N/A</td>
<td>&lt; 100 msec</td>
</tr>
<tr>
<td>4</td>
<td>Instant Messaging Web Browsing</td>
<td>10 Kbps – 2 Mbps</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>5</td>
<td>Media Content Download</td>
<td>&gt;2 Mbps</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

II. LITERATURE SURVEY

In [1] the author proposed Modified Priority Algorithm to improve the throughputs and fairness of the BE. The other service classes are not mentioned in this paper. In [2] various scheduling algorithms for the various traffics in mobile WiMAX is discussed. These Scheduling algorithms do not clearly consider all the required QoS parameters. In [3] surveys of the WiMAX scheduling algorithms are done and discussed the key issues and design factors in QoS scheduling. The authors of [4] give an idea about Exponential Rule Based algorithms. The advantages and drawbacks of major scheduling algorithms such as Round Robin, Weighted Round Robin(WRR), Deficit Round Robin (DRR) and Modified Deficit Round-Robin (MDRR) algorithms are summarized and compared in [5]. The advantages of Round Robin polling in high traffic scenarios are explained in [6]. In [7] authors 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. The authors in [8] presented the implementation methodology of an ns-2 based WiMAX simulation model in which the QoS scheduling is achieved by traffic class prioritization implementation. The simulation results in [9] show that properly chosen scheduling algorithm can provide high service standards to support the QoS required for different type of traffics and users. In [10] authors propose a packet scheduling scheme to support multiple services efficiently by considering the QoS characteristics of each class by selecting a service class first after considering characteristics of each class. Several simulation models have been proposed to support Mobile WiMAX simulation, such as QualNet [11], Opnet [12], and NS-2 [13]. The research in [14] 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 [15]-[16]. On the other hand, only a few simulation studies have been published or reported in literature, largely ignoring the implementation and evaluation of various scheduling algorithms to support versatile Mobile WiMAX QoS simulations.

III. PROPOSED SCHEDULING ALGORITHM

The main objective of this work is to provide an implementation of the IEEE 802.16(e) standard using dynamic fuzzy based priority scheduler. Here scheduling is done in two stages. The requests are classified in terms of priority using fuzzy logic and the requests are scheduled using Neural Networks.

A. Classification Of Priority Using Fuzzy Logic

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. A fuzzy set A in the universe of discourse U is a set of ordered pairs \{(xi, μA(xi)), (x2, μA(x2)), . . . , (xn, μA(xn))\}, where μA : U \rightarrow [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. 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 Xn is Anj, then Y is Bj. The variables X(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 A1j 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. The final desired output for each variable is generally a single number. By Centroid method of defuzzification, the output η is calculated using the formula

\[ η = \frac{1}{\sum_{i=1}^{n} y_i \mu_{output}(\eta_i)} \sum_{i=1}^{n} y_i \mu_{output}(\eta_i) \]  

Where y is the centre point of each of the output membership function in the output fuzzy set Bj and \( \mu_{output}(\eta_i) \) is the strength of the output membership function. 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 four inputs namely, Expiry time (E), Waiting time (W), Queue length (Q), Packet size (P) and one output, Priority index are used as shown in Fig 2. According to fuzzy rule ‘if packet size is low and queue length is low, then priority index is low’. Similarly “If packet size is high and queue length is high, then priority index is high”. 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. This is illustrated in Table 2.

![Fig 2: Dynamic Fuzzy Scheduler](image)

<table>
<thead>
<tr>
<th>Expiry Time</th>
<th>Waiting Time</th>
<th>Queue Length</th>
<th>Packet Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>M</td>
<td>L</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
<td>M</td>
<td>H</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Expiry Time</th>
<th>Waiting Time</th>
<th>Queue Length</th>
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<tr>
<td>L</td>
<td>L</td>
<td>M</td>
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<td>M</td>
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<td>M</td>
</tr>
<tr>
<td>H</td>
<td>M</td>
<td>M</td>
</tr>
</tbody>
</table>

![Table 2 Fuzzy Rule Base](image)
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). This rule is used to satisfy the QoS requirements of WiMAX.

Algorithm 1: Setting up the priority

**Input:** Expiry Time, Waiting Time, Packet Size, Queue Length, Type of Service, Mobility

**Assumptions:** The above said first four inputs are in 3 scales (H, M and L) and last input is in 5 scales (VH, H, M, L and VL).

**Output:** Highest Priority Request

For i=1 to n do
   a. Compare Expiry Time and Waiting Time which arrives at Priority index 'a'.
   b. Compare Packet Size and Queue Length which arrives at priority index 'b'.
   c. Compare 'a' and 'b' (3 scale output) which arrives at Intermediate Priority1 (5 scale output).
   d. Compare Intermediate Priority with Type of Service that arrives at Intermediate priority2
   e. Compare Intermediate Priority2 with mobility factor which arrives at Final Priority Index.
   f. Arrange the requests in descending order.

B. Scheduling of Requests Using Artificial Neural Network (ANN)

After classification the requests are scheduled. Here scheduling is done using artificial Neural Network. The proposed Neural Networks based scheduler consists of three layers as shown in Figure 3. 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 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. If the incoming request is below the threshold value then that request is forwarded to the next layer, the Grossberg layer. If the incoming request is above the threshold value then that request is rejected. The output equation of Kohonen layer is given by
\[ Y(i) = \sum_{n=1}^{N} Y(n) \times W(n) \]  \hspace{1cm} (2)

Where Y is the output
X is the bandwidth of each request
N is the total number of requests

The output equation of Grossberg layer is given by
\[ Z(i) = \sum_{n=1}^{N} \beta(n) \times W(n) \]  \hspace{1cm} (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 \neq i \end{cases}

Algorithm: Scheduling using ANN

**Input:** Prioritized Request, Threshold Value

**Output:** Scheduling the request

For i=1 to n do
   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.

IV. SIMULATION AND PERFORMANCE EVALUATION

In this WiMAX environments is created and then apply the proposed NFPS at different scenarios. Then compare performance evaluation of various algorithms such as Round Robin (RR), Max CINR (MC), Fair Throughput (FT), Proportional Fair (PF) and proposed NFPS scheduling algorithms [17],[18]. Fig 4 shows the comparison of throughputs for different scheduling algorithms. Through these simulation results it is clear that the PF scheduling algorithm achieves better performance.
throughput in long distance scenarios and FT, RR and NFPS achieve excellent throughputs at shorter distances. Throughput of NFPS is similar to RR and MC algorithms and a close second to PF algorithm at longer distances. Fairness Index of various Algorithms at long distance (7km) and short distance (1m) is shown in Fig 5. As the fairness performance of various algorithms is based on fairness index.

Fig 4: Throughput for Different Scheduling Algorithms

Fig 5: Fairness Index of Various Algorithms

The value of fairness index lying between 0 and 1. For high fairness index, fairness performance is high. From graph it is clear that FT algorithm is the best among these five scheduling algorithms. The MC scheduling algorithm achieves the worst fairness performance. From the above two comparisons it is summarized that FT scheduling algorithm 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 algorithm achieves better throughput in long distance scenarios and the fairness is also better. MC scheduling achieves the best throughput performance among these five scheduling algorithms, but the fairness performance is the worst. 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 provide a tradeoff between fairness and throughput. Fig 6 and Fig 7 shows Throughput for different Scheduling Algorithms at various Loads. From these it is seen that the proposed NFPS algorithm. The throughput performance of FT 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. Fairness index for different Scheduling Algorithms at various Loads is shown in Fig 9. 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.

Fig 6: Per User Throughput in Kbps for Different Scheduling Algorithms at Various Loads

Fig 7: Throughput in Mbps for Different Scheduling Algorithms at Various Loads

Fig 8: Fairness Index for Different Scheduling Algorithms at Various Loads

Then simulations are done under different mobility. Two cases are considered SS moving inwards BS and moving outwards BS. The simulation was done for two Scheduling algorithms namely the Conventional Scheduling algorithm and the proposed NFPS Scheduling algorithm. These results are shown in Table.3, Table.4 and Table.5. From these we can see that the average throughput, average end to end delay, average delay jitter
is comparably better than Conventional scheduling algorithms.

Table 3: Average Throughput

<table>
<thead>
<tr>
<th>Description</th>
<th>4 nodes</th>
<th>8 nodes</th>
<th>16 nodes</th>
<th>32 nodes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Conv. (KB)</td>
<td>NFPS (KB)</td>
<td>Conv. (KB)</td>
<td>NFPS (KB)</td>
</tr>
<tr>
<td>Moving Inwards 50km/hr</td>
<td>520</td>
<td>520</td>
<td>520</td>
<td>520</td>
</tr>
<tr>
<td>Moving Outwards 50km/hr</td>
<td>520</td>
<td>519</td>
<td>520</td>
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</tr>
<tr>
<td>Moving Inwards 5km/hr</td>
<td>520</td>
<td>520</td>
<td>520</td>
<td>520</td>
</tr>
<tr>
<td>Moving Outwards 5km/hr</td>
<td>520</td>
<td>519</td>
<td>520</td>
<td>518</td>
</tr>
</tbody>
</table>

Table 4: Average End to End Delay

<table>
<thead>
<tr>
<th>Description</th>
<th>4 nodes</th>
<th>8 nodes</th>
<th>16 nodes</th>
<th>32 nodes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Conv. (ms)</td>
<td>NFPS (ms)</td>
<td>Conv. (ms)</td>
<td>NFPS (ms)</td>
</tr>
<tr>
<td>Moving Inwards 50km/hr</td>
<td>23</td>
<td>25</td>
<td>23</td>
<td>25</td>
</tr>
<tr>
<td>Moving Outwards 50km/hr</td>
<td>22</td>
<td>23</td>
<td>22</td>
<td>23</td>
</tr>
<tr>
<td>Moving Inwards 5km/hr</td>
<td>21</td>
<td>23</td>
<td>21</td>
<td>23</td>
</tr>
<tr>
<td>Moving Outwards 5km/hr</td>
<td>20</td>
<td>22</td>
<td>20</td>
<td>22</td>
</tr>
</tbody>
</table>

Table 5: Average Delay Jitter

<table>
<thead>
<tr>
<th>Description</th>
<th>4 nodes</th>
<th>8 nodes</th>
<th>16 nodes</th>
<th>32 nodes</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Conv. (ms)</td>
<td>NFPS (ms)</td>
<td>Conv. (ms)</td>
<td>NFPS (ms)</td>
</tr>
<tr>
<td>Moving Inwards 50km/hr</td>
<td>8</td>
<td>7.5</td>
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<td>7.5</td>
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<td>Moving Outwards 50km/hr</td>
<td>8</td>
<td>7.5</td>
<td>8</td>
<td>7.5</td>
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<tr>
<td>Moving Inwards 5km/hr</td>
<td>8</td>
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<tr>
<td>Moving Outwards 5km/hr</td>
<td>8</td>
<td>7.5</td>
<td>8</td>
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</table>
V. CONCLUSION

In this paper study of performance comparison of different scheduling algorithms such as RR, MC, FT and PF with proposed NFPS algorithm is done. These comparisons are based on throughput, fairness, delay jitter and end to end delay. The results show the proposed NFPS is better option in providing tradeoff between throughput and fairness in mobile WiMAX. Also average end to end delay performance is better for the conventional algorithm at higher loads whereas the delay jitter performance of NFPS is better even at higher loads. Therefore, the proposed NFPS scheduling can provide tradeoff between throughput, jitter and end to end delay.

REFERENCES


AUTHOR’S PROFILE

D. David Neels Pon Kumar was born in India, in 1971. He completed his B.E degree in ECE in 1992 and M.E. degree in Digital Communication and Networking through Anna University Chennai in 2004. He is pursuing PhD in Wireless Networks through Anna University Chennai since 2007.He has 10 years of industrial experience in India and has 8 publications in International journals and presented 10 papers in International and National conferences. He is a member of ISTE, IEEE and IAENG. He is a reviewer in IET Networks.

K. Murugesan was born in India, in 1969. He obtained his BE degree in ECE and ME Degree in Microwave and Optical Engg. From Madurai Kamaraj University in 1990 and 1995 respectively. He earned his PhD Degree in the Faculty of Information and Communication Engg. From Anna University Chennai in 2001. His area of interest is Optical and Wireless communication. He has 25 publications at International and National journals. He has presented 25 papers at International and National conferences. He has authored 7 books. Dr. Murugesan is guiding 11 PhD candidates and 2 have completed PhD under his guidance. He is an active member of ISTE student chapter and has won the Best Chapter Secretary award during 2006-2007 in Tamil Nadu and Pondicherry Section. He is a Fellow of IE (I) and IETE. He is also an
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