# A Survey Of Various Schedulers Used For Fair Bandwidth Allocation In Wimax: Ieee 802.16

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**Abstract**: Wireless Interoperability for Multiple Access (WiMAX) is one of the emerging fields in High Speed Wireless Communication which has enormous capabilities because of the area it covers and the connection speed it provides. A new standard for WiMAX known as Mobile WiMAX 802.16e was introduced in 2005. This included all mandatory features of 802.16-2005 with some additional features such as OFDMA, downlink and uplink MIMO and Beamforming Features (BF). It can be termed as a futuristic technology because it is capable to provide simultaneous support for web, voice, video and multimedia traffic. For the effective handling of these different types of traffic several traffic classes are used. For QoS support in WiMAX, the traffic is classified into these classes and scheduling algorithms are used for optimized flow of data. This paper classifies and discusses various types of schedulers available for scheduling of data BS

**Index Terms**: WiMAX, IEEE 802.16, Scheduling, Bandwidth Allocation, Fuzzy, TOPSIS, AHP

## 1. INTRODUCTION

Wireless broadband is an emerging technology which offers data transfers at high speed which can be up to many gigabits per second between devices which can be classified either as stationary or on the move [1]. The main advantages of WiMAX system are that it offers high throughput, good QoS, supports high coverage and security. WiMAX is certified by WiMAX forum [2] based upon IEEE 802.16 standard. Two standards which constitute WiMAX are Fixed WiMAX (802.16d) and Mobile WiMAX (802.16e) [5].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". With this much development in this field, still a considerable amount of research needs to be done to maximize the output of WiMAX in terms of improving signal strength, Quality of Service (QoS) and Quality of Experience (QoE)..

## 2. PROBLEMS WITH WIMAX

### A. Increasing SNR value as we move away from the host

As the distance from the host increases, the SNR (Signal to Noise ratio) value also increases which results in packet collisions and hence lower speeds. This problem can be tackled easily if we could develop some efficient algorithms which lower packet collision even when we have high SNR value. It has been proved that reducing the power of WiMAX signal reduces the SNR value but it is also directly proportional to the area covered i.e. the less the wattage of WiMAX, the less the SNR value and the less will be the distance covered by it. And if the wattage is increased, the coverage will increase and the SNR value will also increase significantly [6]. From here we can deduce that the decreasing the signal power cannot be a permanent solution. Instead some changes are needed to be done on the algorithm level for getting more positive results. The WiMAX forum was bestowed with the responsibility to make sure that the compatibility and interoperability of WiMAX devices does not have any issues. For this the forum gives the credential of "WiMAX Forum Certified" to the compatible devices of IEEE 802.16 standard and ETSI HiperMAN Standard [7]. WiMAX equipment is fully compatible with 802.16 standard and will be declared as "WiMAX Forum Certified" but on the other hand all equipment which are purely dependent upon this standard were not awarded the credential as the ultimate goal of WiMAX forum is interoperability between HiperMAN and IEEE 802.16 standard. [8]

### B. Influence of terrain on signal

WiMAX signals are highly affected by the terrain through which they propogate. Although the effect of terrain has been reduced to an extent by using OFDMA and more efficient antennas but it still remains a field in which a lot needs to be explored yet.

### C. Effect of NLOS (Non Line of Sight) on signal

NLOS has a very big effect on WiMAX signals and the penetration power of signal is not so that that it could cross any obstacle in its path without getting disrupted. This may be an another field of research with enormous possibilities. Advanced antenna technologies have improved the penetration power of WiMAX signals but not to the extent that the full potential of WiMAX could be explored.

D. Guarantee of fairness to subscribers running various applications. However it might be difficult for scheduler to judiciously provide prompt service to every request made as priority would be given to applications needing real time data.
E. Optimized Utilization of Channel: The Channel must be optimized to serve various requests simultaneously and throughput should be on the higher end.
F. Assured QoS delivery: Scheduler should be able to guarantee QoS requirements that were agreed upon during the time of establishment of connection.
G. Complexity Criteria for Scheduler: The complexity during the implementation of scheduler algorithm should be trivial especially for Real-Time applications as they have their own strict time requirements.
H. Efficiency: The scheduler should be efficient on parameters

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such as throughput, delay, scalability and robustness.
I. Graceful degradation of scheduler performance under heavy network loads [9].

## 3. LITERATURE REVIEW

WiMAX has been recently labeled as one of the few contending technologies for next generation of wireless networks. Among the other features of this technology, QoS and Radio Resource Management are the topics on which maximum research is being done. Many research groups have proposed schemes for physical slot, call admission and control, and bandwidth allocation strategies. Scheduling is the heart of QoS for WiMAX networks. The throughput of uplink or downlink is proportional to the number of subcarriers allocated to the corresponding SS and the achievable rate of each subcarrier [10]. WiMAX standard IEEE 802.16e supports five service classes namely, UGS, ertPS, rtPS, nrtPS and BE. All of these classes have different QoS requirements. Considering the QoS requirements and the mobility of users in the coverage area with variable channel status, allocation of resources in fair manner and efficiently is a complex issue [11, 12]. The objective of WiMAX scheduling is to ensure that the QoS requirements for all the five classes are met efficiently. In order to make sure that this requirement of different service classes is met, several researchers have came up with different algorithms. [14] Apart from the commonly used techniques in WiMAX, mobile WiMAX IEEE 802.16e used some special techniques which are dependent upon quality of signal. The parameters used here are temporal fairness and throughput fairness. [15] The QoS in WiMAX is dependent upon better and optimized scheduling algorithms, the modulation scheme used needs to be selected along with the code rate [16]. Since the discovery of wireless networks, scheduling for resource allocation has always been a major point of research [17]. The main task of the scheduler is to maintain desired levels of QoS, fairness and throughput of the network. To achieve QoS and fairness, researchers have constantly worked upon several scheduling algorithms from different computing backgrounds and studied their implementation and effect on network performance [18]. For the sake of better understanding of the problem and analyzing various theories available, the types of schedulers can be classified into four different categories which are as follows:

- Traditional Schedulers
- Hybrid Schedulers
- Dynamic Schedulers
- Soft computing based schedulers

A classification was done by Akashdeep [9] also in his thesis work but the author found out that the additional category of cross-layer schedulers could be accumulated into hybrid schedulers only. With the inception of first WiMAX standard in 2001: Christian Hoymann [20] and K. Wongthavarawat et al. [21] proposed a scheduling framework for WiMAX networks. Authors of [20] made a MATLAB model for the same whereas [21] proposed a hierarchical structure for scheduling.

### 3.1 Traditional Schedulers

Traditional schedulers came into being when WiMAX was in its initial phase. These schedulers are based upon the studies of breakdown of queues of various queuing theory principles such as Round Robin (RR), Weighted Round Robin (WRR) and Weighted Fair Queuing (WFQ). Ball et al. [19] used Round robin scheduler to overcome starvation of non- real time classes, which works on principle of allocation of equal responses to all traffic classes in Round Robin fashion. Sayenko et al. [22] presented scheduling solution based conceptually on Round Robin scheduling and found that WRR (Weighted Round Robin Scheduling) which behaves in conservative manner by skipping empty queues and starting to serve next queue when all packets from the current one are sent and thus assign weight based on priority is unfit for IEEE802.16 networks. In Round Robin Scheduling major flaw is unfairness generated due to different packet sizes used by different flows. This was overcome by a modified Round Robin Scheduler termed as Deficit Round Robin Scheduler (DRR) which is implemented by M. Shreedher et al. [14] to achieve nearly perfect fairness in terms of throughput and the complexity was O(1). Cicconetti & his coworkers [23] also worked for QoS maintenance in IEEE 802.16 standard. They illustrated several metrics on which its performance depends such as offered load partitioning i.e. distribution pattern of traffic among SSs, connections within each SSs and traffic sources within each connections, fame duration mechanisms for requesting UL( uplink) bandwidth. They took reserved traffic rate as basic QoS parameter of a flow and based on it proposed that for implementation of schedulers in 802.16 MAC classes of Latency Rate (LR) scheduling algorithm may not be well suited.

### 3.2 Hybrid Schedulers

Hybrid scheduler as the name suggests are those special type of schedulers which combine of several scheduling techniques to accumulate various service types. They have an advantage over the traditional schedulers that a scheduler that different scheduler combinations can be used to serve specific application type. In addition to this the unused bandwidth may be more effectively utilized. In this type of schedulers, resources are distributed on first hierarchical level and scheduling techniques are applied afterwards. Wongthavarawat et al. [24] [25] first introduced the concept of using hierarchy in schedulers for scheduling issues in WiMAX. Different algorithms were used by them for scheduling of different service classes. A scheduling algorithm was proposed by Chen et al. [26] which used TDD mode which took care of both uplink and downlink allocation of data. The scheduling was divided into two layers of hierarchy. Deficit fair priority scheduling (DFPQ) will be used at first level which further we implemented using two techniques: Policy based upon transmission where downlink was given more priority. The preference for assignment of priorities is as follows

- RTPS
- NRTPS
- BE

At the second level different algorithms were used for scheduling which is as follows

- EDF for RTPS
- RR for BE
- WFQ for NRTPS

Maode Ma et al. [27] suggested a tier scheduling framework which supported load balancing between uplink and downlink. The three tier scheduling was divided as follows:

| Tier | Source | Work |
|---|---|---|
| Tier 1 | BS | Bandwidth allocation across service class |
| Tier 2 | SS | Determine number of slots granted by BS & SS |
| Tier 3 | SS | Determination of transmission priority of data packets at SS |

***Table 3.1:*** *Scheduling strategy by [27]*

Juliana Freitag et al. [28] worked on a different strategy than others to handle varying types of traffic. The concept of high, intermediate and low priority scheduling was used. High priority is used to serve that flow that includes UGS packets and unicast requests for rtPS and nrtPS flows whereas intermediary and low priority queues were used to handle rtPS, nrtPS and BE flows. Mohammad Masri et al. [29] further extended the work of Juliana Freitag et al. [28] and incorporated the problem of scalability and GPSS (Grants per subscriber station) mode for datagrant instead of GPC (Grants per connection) which was believed to be a bottleneck with scalability.

### 3.3 Dynamic Schedulers

The study done by Mukul et al. [30] states that an adaptive approach is followed during the process of bandwidth scheduling. A stochastic adaptive scheduler was proposed by him for rtPS traffic which will work after receiving a bandwidth request. An effort was done by the authors using staircase function and network calculus to reduce the delay and length of queue. But in simulations the data flow was assumed to be generic and no statistical function on data entry was applied. Z. Peng et al. [31] tried to improve the proposed work by Mukul et al. [30] by applying some tools and on data entry and Langrange's Interpolation function to get an estimate of data arrival rate. Jin-Yup Hwang et al. [32] proposed to divide traffic models into two types viz. NRTV for real time and FTP for non-real time traffic. The proposed adaptive traffic allocation scheduling method provided priority to traffic class group as well as to the SS pertaining to that class group. Real time traffic was scheduled using Round Robin and non-real time traffic used proportional fair algorithms.

### 3.4 Soft Computing based Schedulers

In light of the recent advancements in the field of soft computing, this area has a lot of potential in optimization of scheduling algorithms. The various soft computing techniques which have proved very successful over are period of time are game theory, neural networks, fuzzy logic, generic algorithm etc. These techniques have been applied in WiMAX scheduling over a period of time in the area of resource allocation. Here we will discuss the work done by various researchers in the area of WiMAX scheduling using soft computing. A generic algorithm based approach was used by R. Gunasekaran et al. [33] in which he represented a computer network as graph with nodes signifying stations and edges as connections. Based upon this, the made a M*N matrix where M represented number of time slots in a frame and N denotes the number of nodes. Some nodes were identified after that which could transmit and receive simultaneously without any conflict. This enhanced the performance of the network. C. Huanga et al. [34] simulated the scenario of WiMAX scheduling using autonomic system. He used this scenario specifically for forced transmission of multimedia handoffs and for the optimization of bandwidth while using it in heterogeneous system. A fitness function was made which caters to the need of bandwidth requirement of a newly admitted connection. A particle swarm optimization algorithm was used by N. Sharma et al. [35] which customized to maximize the capacity of OFDMA by adaptively assigning sub-channels to the users. This customized algorithm worked on discrete particle positions which is very much different from the classical particle swarm optimization algorithm which only holds good for the continuous particle positions. Authors have also provided with the fact that this particular algorithm could work very efficiently in systems such as WiMAX where wireless channel changes rapidly. Raliean et al. [36] used artificial neural networks for prediction of traffic characteristics in WiMAX. The work was focused to test the various configurations of artificial neural network and compare the quality of forecasting on real time data on the WiMAX network developed by Alcatel. This is one of the rarest works done in this field which involved taking samples from real time dataset. Kahlon et al. [37] proposed a fuzzy logic based intelligent system which is based upon weights of queues which keeps changing according to need, serving real time and non-real time traffic dynamically and hence simplifying fair resource allocation problem. Author proposed that weights to be calculated on three parameters which are:

- Amount of real time and non-real time data.
- Alteration in throughput requirements.
- Latency requirement of real time input data

Akashdeep [9] in his thesis work proposed a fuzzy system which gave an edge over old algorithms used, by using Fuzzy Logic principles for serving various queues and implementing scheduling decisions. The fuzzy acted as an extension to WFQ scheduler where weights are being calculated based upon an existing rule base published in [37]. The results were taken in MATLAB using the rule base and were then applied in simulations to a model made using QUALNET 5.2 simulator and the results were an improvement over the pre-existing system. The intelligence of the system proposed enabled WiMAX to handle applications with high traffic load very easily which in turn could have choked a normal network.

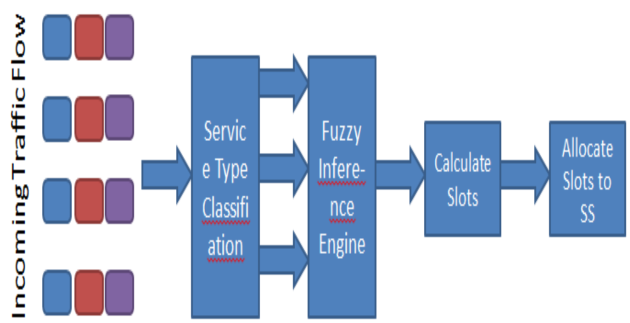


***Fig. 1: Fuzzy Inference System Model***

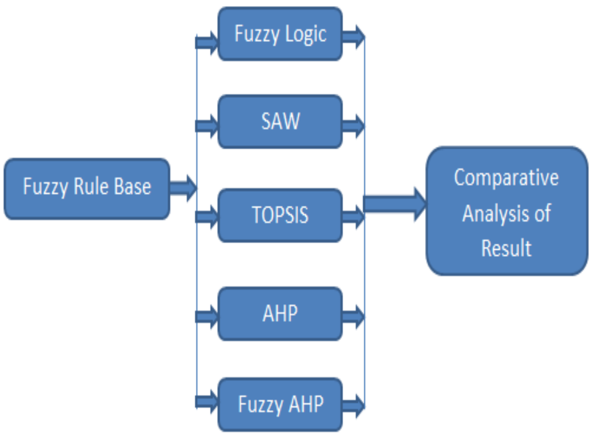


***Fig. 2: Fuzzy Inference Engine***

### 3.4.1 Simple Additive Weighting (SAW)
SAW is the most simple and most widely used MADM method for decision making. The equation for calculation of scores is:

$$P_i = \sum_{j=1}^{m} w_j * ( m_{ij} )$$

Raman et al. [38] extensively used Simple Additive Weighting (SAW) and TOPSIS in his work to optimize decision making to represent the elements in the comparison matrices for voice, video and best effort applications. Rao [39] has presented various MADM methods. Among these, most popular methods are SAW, MEW, TOPSIS, PROMETHEE and ELECTRE. AHP method is widely used for providing weights to these MADM methods.

### 3.4.2 Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)
TOPSIS was developed by Hwang et al. [40]. First weights are obtained by AHP and after that decision matrix is normalized. After that the weights of the normalized matrix are obtained, the ideal best and worst solutions are obtained. Using Euclidian distance, the separation of best and worst solutions are calculated from ideal solution. The most relatively close solution is considered as the final solution.

### 3.4.3 Analytical Hierarchy Process (AHP)
AHP was first implemented by Saaty [41] in 1980. AHP is one of the most commonly used MADM approach and has a wide usage among various fields where decision making is required. AHP is very frequently used to provide selection indices for different alternatives considered. AHP was used for selection of milling machine in Paramasivam et al. [42] and authors of [43] also used it in optimizing supply chain management. The advantages of using AHP are [38]:
(1) It can grip quantitative as well as qualitative data.
(2) It helps the decision maker to organize the critical aspects of a problem in a hierarchical structure.
(3) Decision makers can derive criteria weights and substitute scores from pairwise comparison matrices of AHP.
(4) The reliability of the pairwise comparison matrix can be restrained.
(5) Very compound problems can be solved by coalescing AHP with various operation research methods.

The main steps of AHP include the following [44]:
- Hierarchical organization of the problem
- Pairwise construction of matrices for comparison
- Calculation of weights from judgment matrices
- Ranking of substitutes

### 3.4.4 Fuzzy AHP
In Fuzzy AHP, judgments in the comparison matrices are represented as fuzzy sets. Linguistic terms such as important, less important, more important may be used for the sake of conversion to numerical values as done in their work by Cabrerizio et al. [45].

## 4. CONCLUSION
The classification of various types of schedulers was done in the paper and the major work done in the past by many eminent researchers was discussed. Scheduling in WiMAX IEEE 802.16 using soft computing techniques is a very popular area of research and with the advancements in soft computing over past years new horizons have opened up for research. It has been found that the schedulers using soft computing have more optimized results as compared to other techniques discussed.

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