International Journal of Advance Engineering and Research Development (IJAERD)
Volume 1,Issue 7,July 2014, e-ISSN: 2348 - 4470 , print-ISSN:2348-6406

Performance of Different Scheduling Algorithms in WiMAX

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Abstract: Worldwide Interoperability for Microwave Access (WiMAX) networks were expected to be the main Broadband Wireless Access (BWA) technology that provided several services such as data, voice, and video services including different classes of Quality of Services (QoS), which in turn were defined by IEEE 802.16 standard. The main objective of the broadband wireless technologies is to ensure the end to end Quality of Service (QoS) for service classes. Wimax is a revolution in wireless networks which could support real time multimedia services. In order to provide QoS support and efficient usage of system resources an intelligent scheduling algorithm is needed. The design of detailed scheduling algorithm is a major focus for researchers and service providers. In this paper, we presented a review study to measure the performance of several scheduling algorithms and proposed scheduling algorithms in Wimax.

Keywords: WiMAX, IEEE 802.16, Quality of Services (QoS), Scheduling, First Come First Serve (FCFS), Shortest Job First (SJF), Strict Priority (SP), Round Robin (RR), Weighted Round Robin (WRR), Weighted Fair Queuing (WFQ), Self Clocked Fair (SCF) Queuing, Diff-Serv (DS).

I. INTRODUCTION

Worldwide Interoperability for Microwave Access (WiMAX) or IEEE 802.16d/e is typically considered as the most reliable wireless access technology. Getting High bit rate and reaching large area in a single base station is possible in this technology. So the subscriber station can extend up to 30 miles. Hence connectivity to end users becomes cost-effective. Installation of wired infrastructure can become cost-effective or technically achievable when the qualities like low cost, high speed, rapid and easy deployment in Wireless Metropolitan Area Network (WMAN) is combined with the last-mile access. WiMAX technology based on the IEEE 802.16 standard has a very rich set of features. Indeed, it is a very promising Broadband Wireless Access (BWA) technology. The main objective is to have a highly efficient use of radio resources while transmitting different types of services. These services can have different constraints such as the traffic rate, maximum latency, and tolerated jitter. IEEE 802.16 power control and other capacity estimations were studied in. IEEE 802.16 defines the layer 1 (Physical (PHY)) and layer 2 (Data link or Media Access Control (MAC)) of the Open System Interconnection (OSI) seven layer network model. The different types of standards for PHY supports are Single Carrier (SC), Single Carrier Access (SCA), Orthogonal Frequency Division Multiplexing (OFDM) and Orthogonal Frequency Division Multiple Access (OFDMA). Recent researches focus mainly on the OFDM and OFDMA PHY supports. These standards define two operational modes for communication namely: mesh mode and point-to-multipoint mode. In mesh mode, the SSs can communicate with each other and also with the BS. In point-to-multipoint mode, SSs are supposed to communicate only through BS. BS has dedicated buffers and slots for downlink connection. During uplink, slots are allotted per SS and not per connection. Uplink channel is shared by all SSs, whereas downlink channel is used only by BS. The MAC layer functions of IEEE 802.16e are described in Fig. 1. Internet Protocol (IP), Ethernet and Asynchronous Transfer Mode (ATM) traffic are supported by convergence sub-layer. This layer converts the traffic into MAC data units. Wimax network provides broadband access for services having different QoS requirements and different traffic priorities. It is the responsibility of the MAC layer to schedule the traffic flows and to allocate the bandwidth such that QoS requirements of each flow are satisfied. IEEE 802.16e is expected to provide QoS for fixed and mobile users. QoS depends upon a number of implementation details like scheduling, buffer management and traffic shaping. The responsibility of scheduling and BW management is to allocate the resources efficiently based on the QoS requirement of the services.

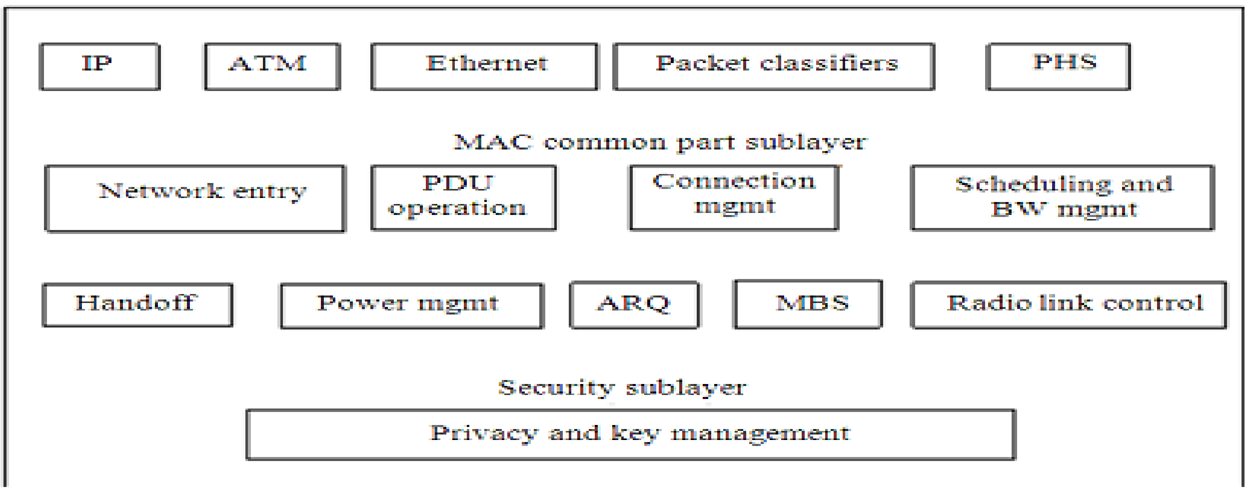

Fig. (a) MAC Layer

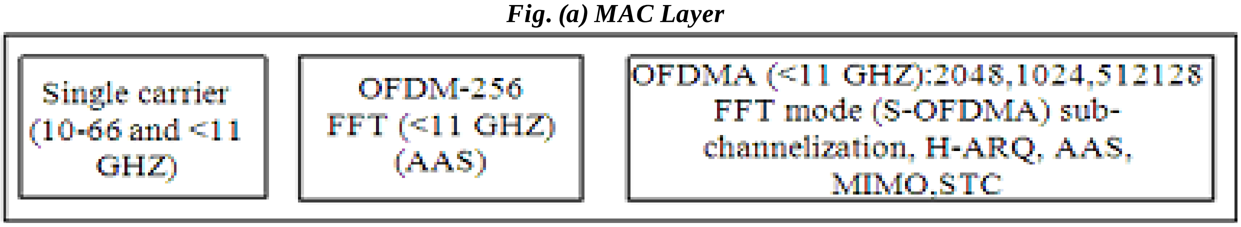

Fig. (b) PHY Layer
Fig. 1 IEEE 802.16e-2005 protocol stack (a) MAC Layer and (b) PHY Layer

II. ARCHITECTURE OF WIMAX

WiMAX based on the standard IEEE 802.16, which consist of one Base Station (BS) and one or more Subscriber Stations (SSs), as shown in Fig. 1, the BS is responsible for data transmission from SSs through two operational modes: Mesh and Point-to-multipoint (PMP), this transmission can be done through two independent channels: the Downlink Channel (from BS to SS) which is used only by the BS, and the Uplink Channel (from SS to BS) which is shared between all SSs, in Mesh mode, SS can communicate by either the BS or other SSs, in this mechanism the traffic can be routed not only by the BS but also by other SSs in the network, this means that the uplink and downlink channels are defined as traffic in both directions; to and from the BS. In the PMP mode, SSs can only communicate through the BS, which makes the provider capable of monitor the network environment to guarantee the Quality of Service QoS to the customers.

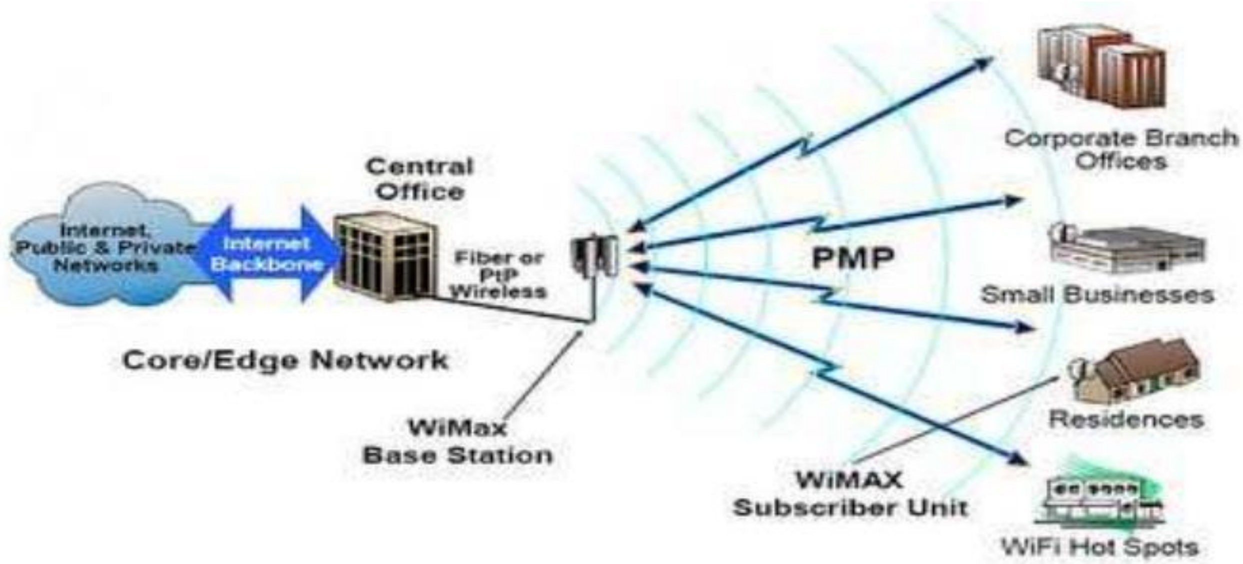

Fig. (a) Point-to-Multipoint (PMP) WiMAX Network

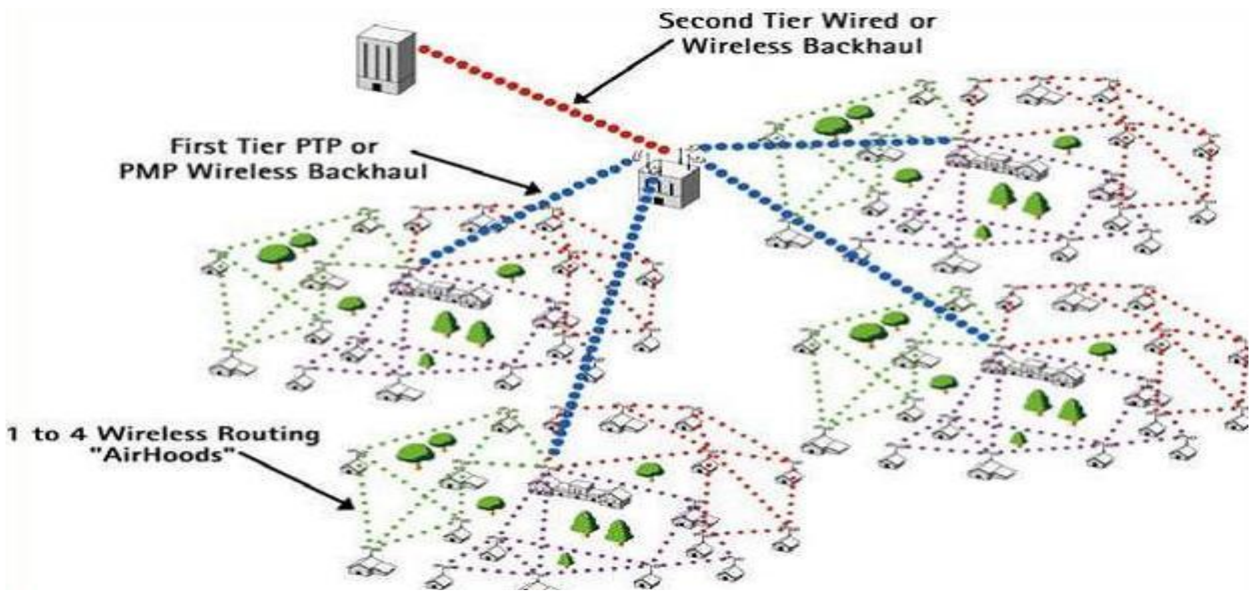

Fig. (b) Mesh WiMAX Network.

Fig.2 WiMAX Architecture (a) Point-to-Multipoint and (b) Mesh WiMAX Networks.

III. SCHEDULING

IEEE 802.16 MAC layer adopts a connection oriented architecture in which a connection must be established before data communications. Each connection is assigned a unique identifier (connection IDI) and it is associated with a service flow which defines the desired QoS level of the connection. In a standard scheduling framework, data packets arriving at the BS are classified into connections which are then classified into service flows. Packets of same service flow are placed in a queue and then further classified based on their service priorities of the connection. For packets in multiple queues with different service requirements, a packet scheduler is employed to decide the service order of the packets from the queues. If properly designed a scheduling algorithm may provide the desired service guarantees. The scheduler should consider the following important parameters:

- The traffic service type.

- The set of QoS requirements of the connections.
- The capacity of bandwidth for data transmission.
- The bandwidth requirements from the connections.
- Waiting time of bandwidth request in the system.

The main focus of the scheduling is to provide best possible end-to-end performance for the applications. The objective is to maximize the total throughput, reduce the packet loss rate, delay and power consumption and to improve the efficiency when satisfying the QoS requirements of different service classes. The SS with highest priority is selected to transmit in the frame. The priority of the SS is calculated based on the traffic class it belongs to.

IV. SERVICES AND CLASSES IN WIMAX

4.1. Services

- **UGS (Unsolicited Grant Service):** This service support real time packets with fixed size. In this service, the BS periodically allocates a fixed amount of bandwidth resources to the subscriber station and the SS does not need to send bandwidth request.
- **rtPS (Real Time Polling Service):** This service support real time packets with variable size. In this service, the BS periodically polls the SS about its uplink bandwidth request and allocates bandwidth to it in the next uplink sub-frame.
- **ertPS (Extended Real Time Polling Service):** It basically works similarly to UGS but the SS has the opportunity to request the BS to allocate different amount of bandwidth whenever the SS needs to change the transmission rate.
- **nrtPS (Non-Real Time Polling Service):** This service is designed to support non real time and delay tolerant services that require variable size data grant burst types on a regular basis such as File Transfer Protocol (FTP).
- **BE (Best Effort):** This service is designed to support data streams that do not require any guarantee in QoS such as Hyper Text Transfer Protocol (HTTP).

4.2. Classes

- **Class 1** (UGS, rtPS, ertPS).
- **Class 2** (nrtPS).
- **Class 3** (BE).

V. WIMAX SCHEDULING ALGORITHMS

Scheduling algorithms are responsible for Distributing resources among all users in the network, and provide them with a higher QoS. Users request different classes of service that may have different requirements such as bandwidth and delay, so the main goal of any scheduling algorithm is to maximize the network utilization and achieve fairness among all users.

5.1. First Come First Served (FCFS)

The simplest scheduling algorithm is the First Come First Served (FCFS) scheduling algorithm. With this algorithm, processes are assigned to the main unit in the order they request it. The implementation of the FCFS algorithm is easily managed with a FIFO queue. There is a single queue of ready processes and new processes or requests are added to the tail of the ready queue. This algorithm executes the processes from the ready queue one by one. FCFS algorithm is shown in the Fig. 3.

Fig. 3 FCFS Scheduling Algorithm

5.2. Shortest Job First (SJF)

A different approach to scheduling is the Shortest Job First (SJF) scheduling algorithm. This algorithm associates with burst time of each process. This algorithm makes the queue of the incoming processes according to their burst time (i.e. from lower to higher) and executes them one by one. So the process having lowest burst time executes first. If the next burst time of two processes are the same, FCFS scheduling is used. SJF algorithm is shown in the Fig. 4.

Process	Arrival Time	Execute Time	Service Time
P0	0	5	0
P1	1	3	3
P2	2	8	8
P3	3	6	16

Fig. 4 SJF Scheduling Algorithm

5.3. Strict Priority (SP)

The SJF algorithm is a special case of the general priority scheduling algorithm In SP algorithm packets are represented by the scheduler depending on the QoS class and then they are assigned into different priority queues, these queues are served or executed according to their priority from the highest to the lowest as shown in Fig. 5.

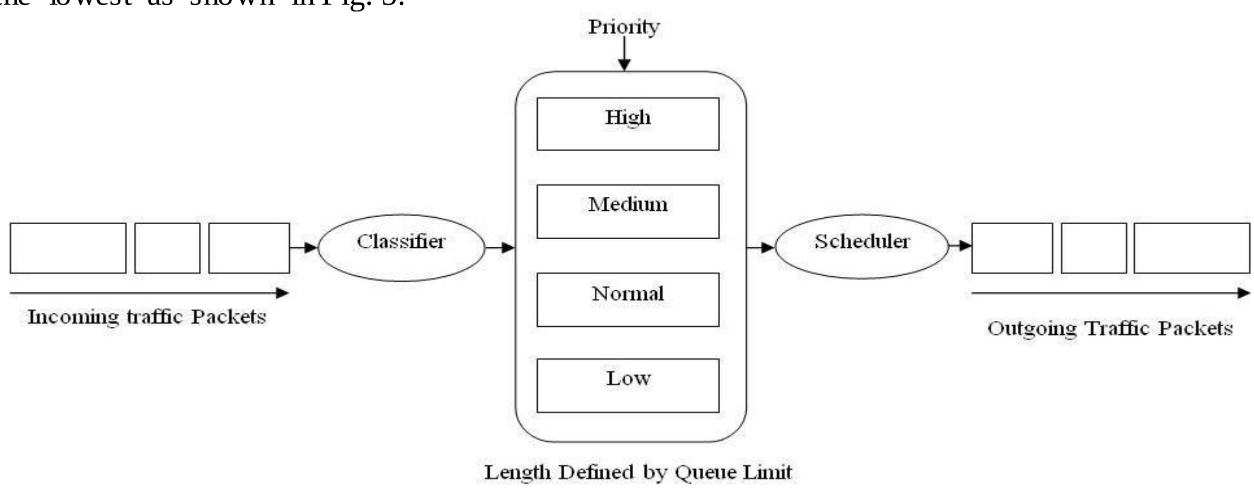

Fig. 5 SP Scheduling Algorithm

5.4. Round Robin (RR)

The Round-Robin (RR) Scheduling Algorithm is designed especially for time-sharing systems. It is similar to FCFS scheduling, but pre-emption is added to switch between processes. A small unit of time, called a time quantum or time slice, is defined. A time quantum is generally from 10 to 100 milliseconds. The ready queue is treated as a circular queue. To implement RR scheduling, we keep the ready queue as a FIFO queue of processes. New processes are added to the tail of the ready queue. The RR scheduler picks the first process from the ready queue, sets a timer to interrupt after 1 time quantum, and dispatches the process. The process may have a burst of less than 1 time quantum. In this case, the process itself will release voluntarily. The scheduler will then proceed to the next process in the ready queue. Otherwise, if the burst of the currently running process is longer than 1 time quantum, the timer will go off and will cause an interrupt to the operating system. A context switch will be executed, and the process will be put at the tail of the ready queue. The RR scheduler will then select the next process in the ready queue. RR scheduling shown in Fig. 6.

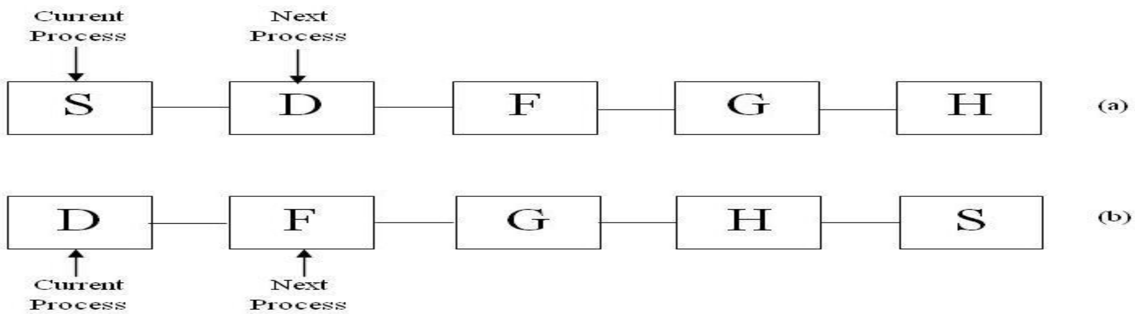

Fig. 6 RR Scheduling Algorithm

5.5. Weighted Round Robin (WRR)

In WRR scheduling algorithm, packets are categorized into different service classes and then assigned to a queue that can be assigned different percentage of bandwidth and served based on Round Robin order as shown in Fig. 7. This algorithm address the problem of starvation by guarantees that all service classes have the ability to access at least some configured amount of network bandwidth.

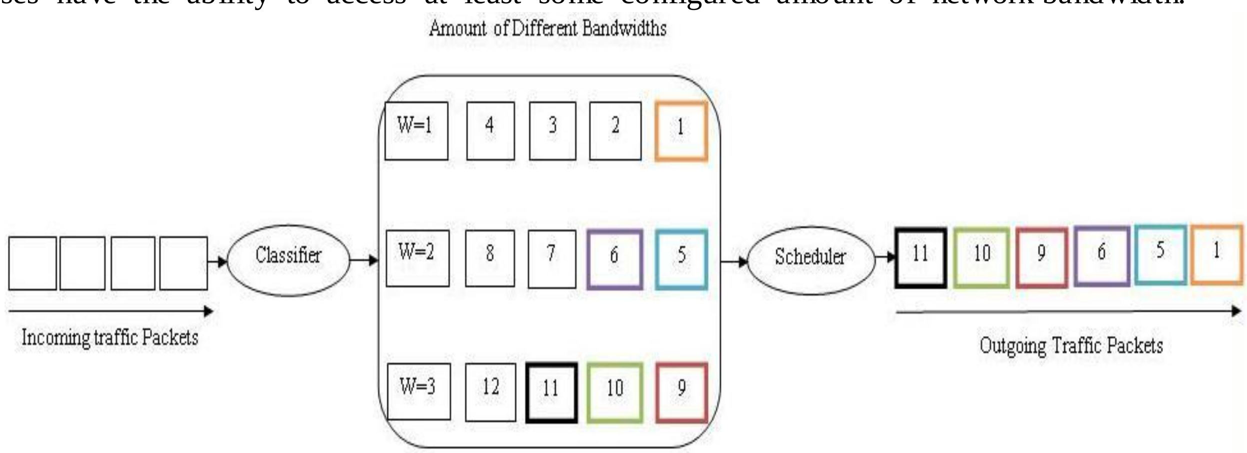

Fig. 7 WRR Scheduling Algorithm

5.6. Weighted Fair Queuing (WFQ)

In Weighted Fair Queuing (WFQ) scheduling algorithm, each flow of packets is assigned different weight to has different bandwidth percentage in a way ensures preventing monopolization of the bandwidth by some flows providing a fair scheduling for different flows supporting variablelength packets by approximating the theoretical approach of the generalized processor sharing (GPS) system that calculates and assigns a finish time to each packet as shown in Fig. 8.

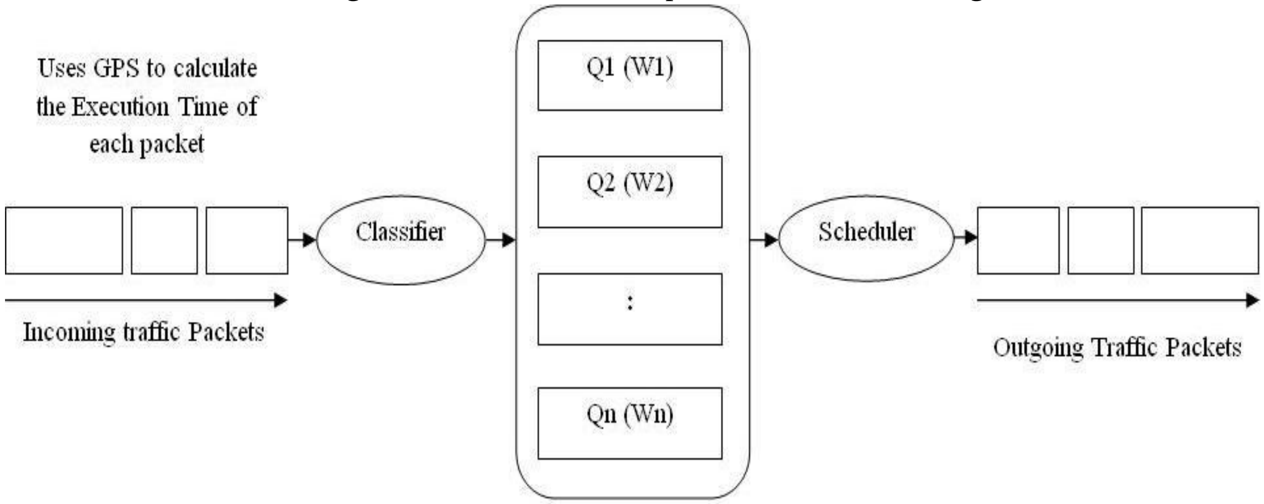

Fig. 8 WFQ Scheduling Algorithm

5.7. Self Clocked Fair (SCF) Queuing

Self Clocked Fair Scheduler generates virtual time as an index of the work progress; this time is computed internally as the packet comes to the head of the queue. The virtual time determines the order of which packets should be served next. Fig. 9 illustrates the work progress of SCF scheduler.

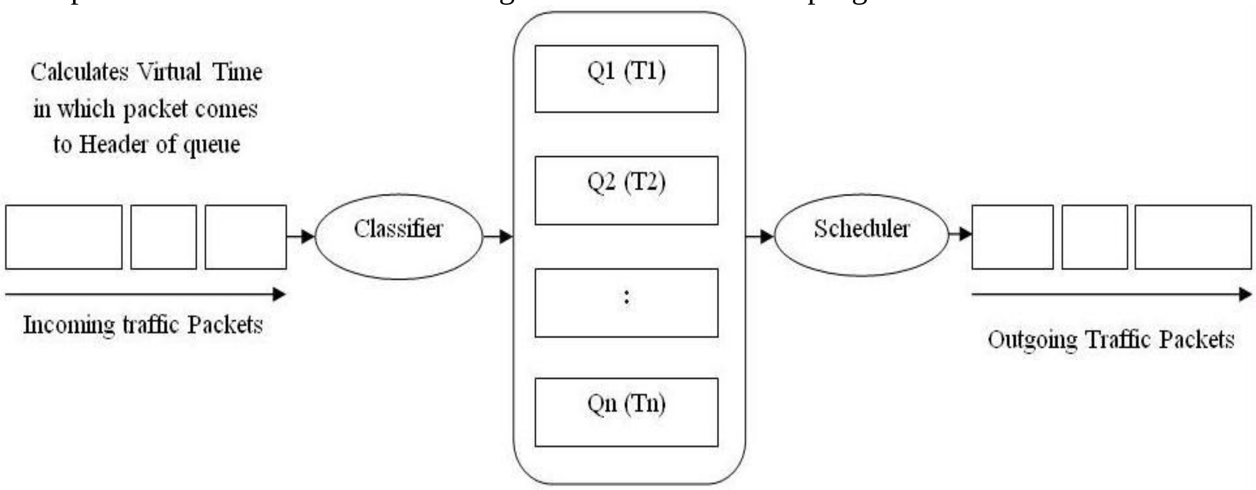

Fig. 9 SCF Scheduling Algorithm

5.8. Multilevel Queue Scheduling

Another class of scheduling algorithms has been created for situations in which processes are easily classified into different groups. A common division is made between Foreground (Interactive) processes and Background (Batch) processes. These two types of processes have different response-time requirements and so may have different scheduling needs. In addition, foreground processes may have priority (externally defined) over background processes. A multilevel queue scheduling algorithm partitions the ready queue into several separate queues shown in Fig.10. Processes are permanently assigned to one queue, generally based on some property of the process, such as memory size, process priority, or process type. Each queue has absolute priority over lower-priority queues and also each queue has its own scheduling algorithm. The foreground queue might be scheduled by an RR algorithm, while the background queue is scheduled by an FCFS algorithm.

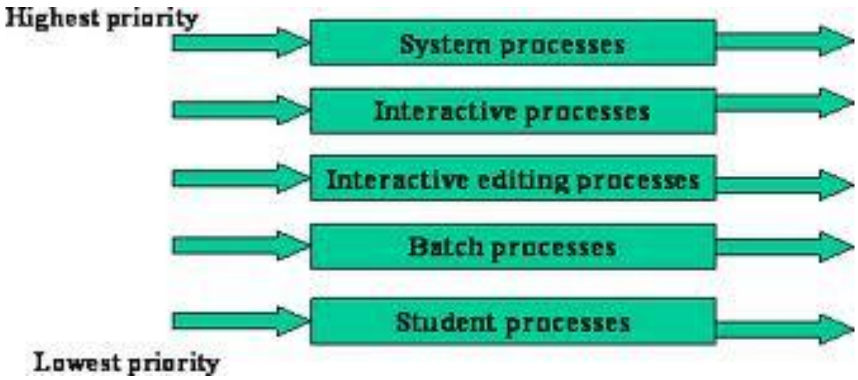

Fig. 10 Multilevel Queue Scheduling Algorithm

5.9. Multilevel Feedback Queue Scheduling

Normally, when the multilevel queue scheduling algorithm is used, processes are permanently assigned to a queue when they enter the system. If there are separate queues for foreground and background processes, processes do not move from one queue to the other, since processes do not change their foreground or background nature. This setup has the advantage of low scheduling overhead, but it is inflexible. The multilevel feedback-queue scheduling algorithm, in contrast, allows a process to move between queues. The idea is to separate processes according to the characteristics of their CPU bursts. If a process uses too much CPU time, it will be moved to a lower-priority queue. This scheme leaves I/O-bound and interactive processes in the higher-priority queues. In addition, a process that waits too long in a lower-priority queue may be moved to a higher-priority queue shown in Fig.11.

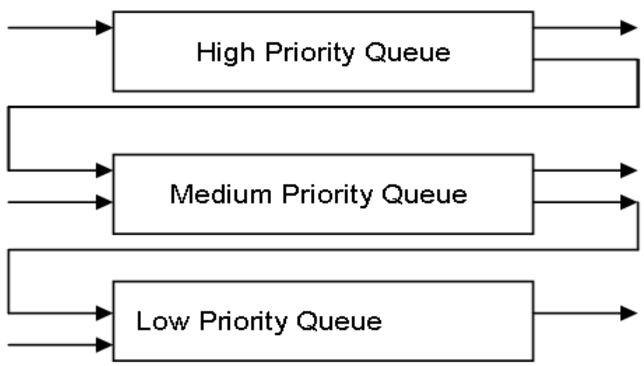

Fig. 11 Multilevel Feedback Queue Scheduling

5.10. Diff-Serv (DS) Enabled:

Diff-Serv Uses the 6-bit Differentiated Services Code Point (DSCP) field in the header of IP packets that used to classify packets, by replacing the out dated IP precedence with a 3-bit field in the Type of Service byte of the IP header originally used to classify and prioritize types of traffic.

VI. LITERATURE REVIEW

[1] In this study, a channel aware cross-layer scheduling algorithm for Wimax networks has been proposed. This scheme employs Signal to Noise Ratio (SNR) value which allocates bandwidth based on the information about the quality of the channel and service requirements of each connection. The proposed algorithm is described in detail and evaluated through series of simulation. The simulation results prove that the proposed algorithm reduces the packet loss rate and delay and thus improves throughput by 12.8%. [2] In this paper, we design a joint routing, scheduling and admission control protocol for WiMax networks. In the adaptive scheduling, packets are transmitted as per allotted slots from different priority of traffic classes adaptively, depending on the channel condition. A bandwidth estimation technique is combined with route discovery and route setup in order to find a best route. The admission control technique is based on the estimation of bandwidth utilization of each traffic class, with the constraint that the delay requirement of real-time flows should be satisfied. The current available bandwidth is estimated for all the nodes and for the new incoming flows, it estimates the requested bandwidth and decides to admit this new flow or not. By simulation results, we show that our proposed protocol achieves better throughput and channel utilization while reducing the blocking probability and delay. [3] The goal of this paper is to survey the core issues in the design of schedulers for IEEE 802.16 networks and study the various techniques available in literature. Neural Networks have been utilized by researchers over the years to solve a large set of optimization problems in the field of active queue management techniques and network communication. This paper proposes a back propagation neural based approach for scheduling of IEEE 802.16 networks. The proposed technique is novel and has sound theoretical and practical base available in other fields of communication. [4] This paper aims at proposing requirements for a common WiMAX Evaluation Suite. The authors depict the limitations of the mentioned TCP benchmark and suggest the basic WiMAX topology as well as the scenarios and the output parameters that allow comparing: TCP protocols, scheduling algorithms and QoS requirements fulfillment in a simulator. Moreover we point out the comparison criteria for particular aspects of WiMAX technologies. [5] In this paper, we propose a traffic aware scheduling algorithm for VoIP applications in WiMAX networks. We study the performance of our proposed method and compare it with that of some conventional methods. The tradeoff between delay and bandwidth efficiency is discussed, and it is shown that using our scheduling method enhances the efficiency of VoIP over WiMAX. [6] In this paper, focusing on the point-to-multipoint mode, we propose a priority-based fair scheduling algorithm for subscriber stations to serve a mixture of uplink traffic from different scheduling services and provide an analytical model for evaluating user-perceived delay performance under this scheduling scheme. The model is supported and validated by a simulation study. We present numerical results to illustrate the effect of traffic load and other design parameters on WiMAX message delay.

VII. PERFORMANCE EVALUATION (SIMULATION)

The scheduler was implemented in the IEEE 802.16 module in Network Simulator (NS-2) simulator. The NS-2 is a widely used tool for the simulation of packet switched networks. It gives huge support for simulation of TCP routing and Mac protocols over wired and wireless networks. Network elements in NS-2 simulator are developed as classes in object oriented manner. It has Object Tool Command Language (OTCL) interpreter for easy user interface, has input models which is written in Tool Command Language (TCL) scripts. A base station and a subscriber station can be set up as a node in NS-2. When the number of nodes increases the amount of packets received and sent increases. For a single node configuration the simulation would run fairly. But as the number nodes increases the packet traffic will arise. The simulated network uses a Point to Multipoint topology (PMP) with a centralized Base Station (BS) and the Subscriber Station (SS). The distance between MSS and BS ranges from 1600 to 1800 meters. In our simulation, for sending the bandwidth request from all SSs, uni-cast polling is used. Here, the Grant per Subscriber Station (GPSS) bandwidth allocation scheme is used. In the simulation, number of calls generated by SSs is varied and is randomly generated.

VIII. CONCLUSION AND FUTURE SCOPE

We have provided an extensive survey of recent WiMAX scheduling algorithms and proposals that provide and enhance QoS. All the relevant QoS functionalities are discussed in this paper. Call Admission Control (CAC) is an important QoS component in WiMAX networks as it has a strong relationship with QoS parameters such as delay, dropping probabilities, jitter and scalability. Therefore, we present a classification and a description of CAC algorithms proposed in the literature for PMP mode. We describe CAC proposals for PMP mode. The QoS platform designers need to be familiar with WiMAX characteristics. So in this paper, we have present cross-layer designs of WiMAX/802.16 networks. A number of physical and access layer parameters are jointly controlled in synergy with application layer to provide QoS requirements. Most important QoS key concepts are identified. Relations and interactions between QoS functional elements are discussed and analyzed with cross layer approach consideration. The performance of Strict Priority, Round Robin, Weighted Round Robin, Weighted Fair Queuing, Self-Clocked Fair Queuing, and Diff-Serv scheduling algorithms is measured mainly in terms of size and number of BS output queues within WiMAX network. The five QoS classes are included in the simulation. The results showed that the output queue size and number do not affect the server throughput and end-to-end delay for a specific scheduling algorithm. In addition, the best scheduling algorithms with queue management and resource utilization are RR, WRR, SCF, WFQ, and DS in order. Best results are obtained from the proposals given by the authors i.e. maximize the total throughput, reduce the packet loss rate, delay and power consumption and to improve the efficiency when satisfying the QoS requirements of different service classes.

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