Design of Scheduling Algorithm based on Earliest Departure Time for QoS Requirements in WiMAX Networks

Dr.D.Saraswady*,S.FouziyaSulthana,Dr.V.Saminathan***
*(Department of ECE, Pondicherry Engineering College, Puducherry)
**(Department of ECE, Karpaga Vinayaga College of Engineering and technology, Maduranthagam)

ABSTRACT

The IEEE 802.16 is a standard for broadband wireless technologies which provides guaranteed quality of service (QoS) with different characteristics. This standard provides four different scheduling services: Unsolicited Grant Service (UGS), real-time Polling Service (rtPS), non-real-time Polling Service (nrtPS), and Best Effort (BE). To get a guaranteed QoS, an effective scheduling algorithm should be designed. This paper presents the design of a scheduling technique based on the earliest departure time (EDT) of the packets which enters to the base station. This algorithm is analyzed in two different ways. First, it aims to provide differentiated service according to the QoS requirements. Second it is designed to provide service differentiation in downlink traffic delivery even in non ideal channel conditions. The simulation results show that the proposed algorithm provides service differentiation, increased throughput and allocates bandwidth with lesser delay for real time services.

Keywords- EDT based QoS aware algorithm, EDT based channel aware algorithm, QoS, service classes.

1. INTRODUCTION

Wireless interoperability for microwave access (WiMAX) is one of the most popular broadband wireless access technologies today, which aims to provide high speed broadband wireless access for wireless metropolitan area networks (WMANs). Compared to the complicated wired network, a WiMAX system only consists of two parts: the WiMAX base station (BS) and WiMAX subscriber station (SS). Therefore, it can be built quickly at a low cost. WiMAX fits between wireless local area networks and wireless wide area networks. This standard introduces several interesting advantages including variable and high data rate (upto 75 Mbps), last mile wireless access (upto 50 km), and point to multipoint communication, large frequency range, and QoS for various types of applications. However, the actual version of the standard does not define a MAC scheduling architecture in uplink as well as downlink direction. Efficient scheduling design is left for designers and developers and thus providing QoS for IEEE 802.16 BWA system is a challenge for developers [1].

In [2], the paper addresses a channel-aware scheduling algorithm conceived for point-to- multi point WiMAX architecture. It aims at enabling downlink traffic delivery with differentiated service treatment, even in nonideal channel conditions. A study of IEEE 802.16 MAC protocol operated with the WMAN-OFDM air interface and with full duplex stations has been simulated in [3]. To provide excellent QoS, schedulers are considered as the main part of the technology. Several scheduling algorithms have been proposed for TDMA, CDMA and multihop packet networks [4]. Scheduling algorithms are important components in the provision of guaranteed quality of service parameters such as delay, delay jitter, packet loss rate, or throughput. The design of scheduling algorithms for mobile communication networks is especially challenging, given the highly variable link error rates and capacities, and the changing mobile station connectivity typically encountered in such networks.

The challenge for BWA networks is in providing QoS simultaneously to services with very different characteristics. It has been evaluated [5] that QoS support in wireless networks is a much more difficult task than in wired networks. The mechanisms for supporting QoS at the IEEE 802.16 medium access control (MAC) layer have been analyzed in many papers. During the last few years, users all over the world have become more and more accustomed to the availability of broadband access. This has boosted the use of a wide variety both of established and recent multimedia applications [6]. However, there are cases where it is too expensive for network providers to serve a community of users. This is typically the case in rural and suburban areas, where there is slow deployment of traditional wired technologies for broadband access.

One of the features of the MAC layer of 802.16 is that it is designed to differentiate service among traffic categories with different multimedia requirements [7]. IEEE 802.16e is known as mobile WiMAX, has gained much attention recently for its capability to support high transmission rates in the cellular environments and QoS for different applications [8]. In order to effectively support video streaming, voice over internet protocol (VoIP) and data services radio resource management including multiple connection assignment, scheduling controls are essential.

The scheduling architectures for WiMAX networks can be classified in two categories: traditional methods and new methods. Traditional methods follow algorithms and methods used in other types of networks. New methods are based on the development of new techniques for the scheduling which are designed particularly for this standard. This paper concentrates on designing a scheduling algorithm for downlink (DL) to effectively support real time applications in WiMAX networks.

2. WiMAX MAC LAYER SERVICES

The IEEE 802.16 standard supports two network architectures namely point to multipoint (PMP) mode and mesh mode. The mesh mode is an optional architecture. The network architecture of PMP mode is illustrated in Fig.1.

PMP network has one base station (BS) and multiple subscriber stations (SSs). The BS is the central control point and regulates all the traffic on the network. IEEE 802.16 is a connection oriented service with which each SS needs to establish a service connection to the BS. An SS first sends a message to the BS for requesting services on the network. The connection between the BS and an SS could be either DL (from BS to SS) or uplink (from SS to BS). The multiple access schemes in WiMAX include both frequency division duplexing (FDD) and time division duplexing (TDD).

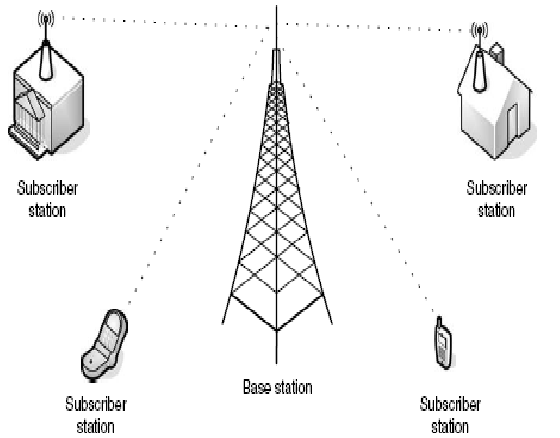

Fig.1 PMP NetworkAarchitecture

The 802.16 MAC provides QoS differentiation for different types of applications that might operate over 802.16 networks. Four QoS classes are provided by the MAC in the IEEE 802.16 standard.

1. Unsolicited grant service (UGS) is designed to support real time service flows that generate fixed size data packets on a periodic basis. The service offers fixed-size grants on a real time periodic basis, which eliminate the overhead and latency of SS requests and assure that grants are available to meet the flow's real-time needs.
2. Real-Time Polling Services (rtPS) is designed to support real-time service flows that generate variable size data packets on a periodic basis, such as MPEG video. The service offers real-time, periodic, unicast request opportunities, which meet the flow's real time needs and allow the SS to specify the size of the desired grant. This service requires more request overhead than UGS, but supports variable grant sizes for optimum data transport efficiency.
3. Non-Real-Time Polling Services (nrtPS) is designed to support non-real-time services that require variable size data grant burst types on a regular basis. For this service to work correctly, the request/transmission policy setting shall be set such that the SS is allowed to use contention request opportunities. This results in the SS using contention request opportunities as well as unicast request opportunities and unsolicited data grant burst types.
4. Best Effort (BE) services are typically provided by the Internet today for web surfing.

The following is the set of QoS parameters to support above service classes.

1. Maximum sustained rate (MSR): The peak data rate (in bps) of a service flow. This service rate shall be policed for the wireless link to assure its conformance as measured in average over time
2. Minimum reserved rate (MRR): The minimum reserved data rate (in bps) for a service flow. This rate is guaranteed for the service.
3. Maximum traffic burst: The maximum burst size (in bytes) for a service flow.
4. *Maximum latency:* The maximum latency (in milliseconds) between the reception of a packet by BS/SS and the transmission of the packet by SS/BS.
5. Tolerated jitter***:*** The maximum delay variation (in milliseconds) of a service flow.

From the above set of QoS parameters we consider only MSR and MRR for our simulation work.

3. DESIGN OF SCHEDULER

There are many number of packet scheduling algorithms have been proposed for WiMAX network. The design of those algorithms is

challenged by supporting different levels of services, fairness and implementation complexity and so on. Schedulers operate across different sessions (connections or flows) in order to ensure that reserved throughputs and bounds on delays are met. The function of a scheduling algorithm is to select the session whose head-of-line (HOL) packet is to be transmitted next. This selection process is based on the QoS requirements of each session.
The proposed algorithm is named as earliest departure time (EDT) based QoS aware algorithm. In proposed algorithm packets are scheduled based on the priority of the user service class. Our algorithm gives first priority to UGS service, because it is a real time service with constant bit rate traffic. By giving high priority to this service our algorithm ensures the required data rate with minimum delay without dropping/losing too many packets. Since rtPS is a real time service with variable bit rate traffic, the next priority is given to this service with minimum delay. Even dropping of few packets in rtPS service does not affect the reception quality. The nrtPS service class gets the third priority, because it is a non-real time service. For this service also the proposed algorithm provides almost the required data rate as requested by the users, but without delay consideration. The last priority will be given to BE service, because it is provided by the internet today for web surfing.

In this algorithm, each packet of the connections get the opportunity to schedule by the scheduler, based on priority of the service class and based on the QoS parameters accepted during the connection establishment. In our algorithm MRR is considered for UGS service to ensure the requested data rate. For BE service MSR is considered because it is not necessary to serve the requested data rate by the scheduler .Since it is a non real time service and delay is tolerable in this service, scheduler allocates the data rate based on the resource availability at that instant. In rtPS and nrtPS services both MSR and MRR parameters are considered, because these services support variable bit rate traffic.

3.1 Calculation of tag value

The scheduling architecture for the proposed algorithm can be realized as in Fig. 2.

When the packet enters to the base station it is classified based on the type of service and they are put in their appropriate queue. The EDT based QoS aware algorithm schedules each and every packet, based on the QoS parameter accepted during the connection establishment. Based on the QoS parameter of the each user, departure time is calculated for each packet of the connection. Here departure time is the time taken by the packet to move from the queue to the frame.

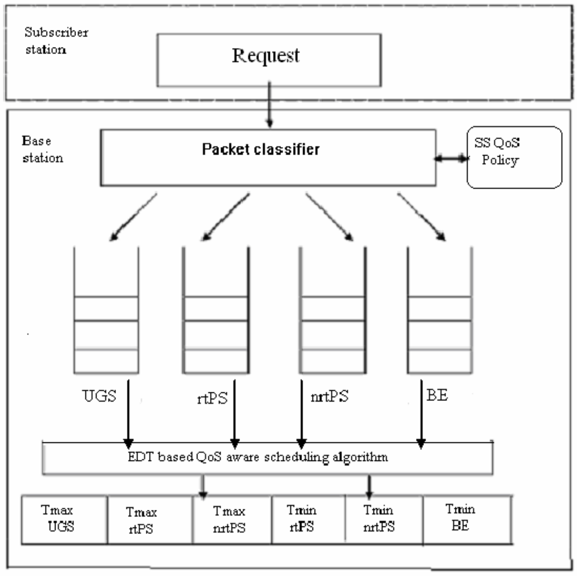

Fig. 2 Scheduling Architecture for EDT based Algorithm

Decision to schedule the packet is made based on the following equation.

Departure time $_{min}$ (T_{min}) = fn (Departure time$_{last,}$ MSR, Packet size)

Departure time$_{max}$ (T_{max})= fn (Departure time$_{last,}$ MRR, Packet size)

Where T_{min} and T_{max} are the tag values calculated based on the QoS parameters and Departure time$_{last}$ is the last packet transmitted time. The packets which have higher values of T_{max} are mapped first and then the packets with T_{min} values are mapped inside the frame. The calculation of T_{min} and T_{max} for each packet inour algorithm will give the desired QoS for the users. Scheduling of packets based on EDT based algorithm for N^{th} frame is shown in Fig. 3.

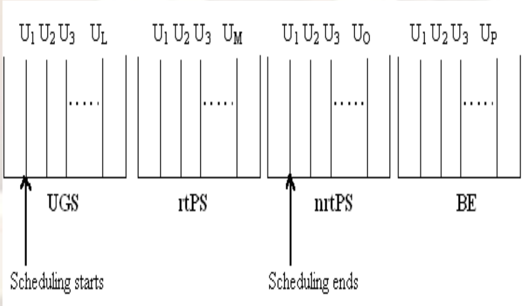

Fig.3 Scheduling of Packets using EDT based Algorithm for N^{th} frame

Scheduling of packets based on EDT based algorithm for $N+1^{th}$ frame is shown in Fig.4.

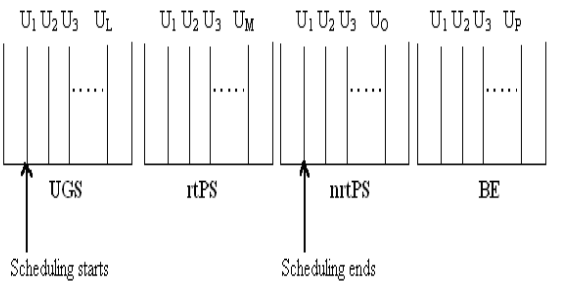

Fig. 4 Scheduling of Packets using EDT based Algorithm for N+1th frame

It is observed that in both the frames scheduling of packets starts from UGS type service. It shows that the proposed algorithm gives service priority based on the QoS parameters accepted during the connection establishment. When we incorporate channel conditions in this algorithm, the packets are scheduled based on the tag values and channel conditions. The steps followed in EDT based channel aware algorithm is as follows,

1. Classify the user based on the service class type.
2. Calculate the tag (when to transmit) based on the QoS parameter of the user.
3. From the tag value prepare T_{min} list based on the channel conditions of the user.
4. In each frame select the service class based on the priority (starting from UGS...) for scheduling of T_{max} packets.
5. Then schedule the T_{min} packets based on the channel conditions.
6. This scheduling will continue till all the users are scheduled or no more space to schedule the data in the current frame.

4. SIMULATION SCENARIO

The performance of the proposed algorithm is analysed using the metrics throughput and delay. This metrics are analysed for two conditions. One is for ideal channel condition and another is for channel aware condition. Throughput of scheduler is defined as the maximum bandwidth allocated by the scheduler with respect to the requested data rare by the subscriber stations and the delay is defined as the time taken by the scheduler to allocate bandwidth for the packet in queue. The simulation parameters used in this work is shown in the Table 1.

Table 1. Simulation Parameters

S.No	**Simulation Parameters**	**Description**
1	MAC Layer	802.16
2	System Bandwidth	10MHz
3	Input Rate	20KBps
4	Packet Size	200 Bytes
5	Interarrival Time	20ms
6	Frame Duration	5ms
7	Subcarrier Allocation	PUSC
8	FFT Size	1024
9	Modulation Scheme	QPSK (6 bytes per slot), QAM 16 (12 bytes per slot), QAM 64 (18 bytes per slot)
10	Total No. of slots in DL	450 (30,15)
11	Link Bandwidth	Min 540 KBPS
12	Channel Model	Erceg channel model
PHY Layer is considered		

The simulation results obtained for EDT based algorithm with and without channel aware condition is discussed as follows.

4.1 Throughput Analysis

[1] The simulated throughput of EDT based algorithm for ideal channel condition is shown in Fig. 5.

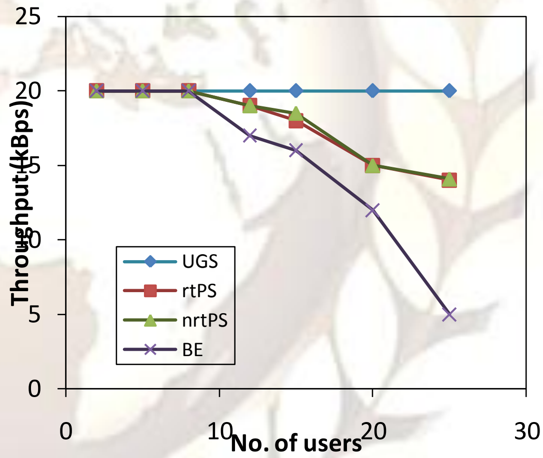

Fig.5 Throughput of EDT based algorithm with ideal channel condition

From the result it is observed that the throughput for UGS type service is high and constant irrespective of the number of users. For rtPS service our proposed algorithm provides almost equal and constant throughput as the number of users increases. Hence the EDT based algorithm gives better throughput for real time services when compared with the other existing algorithm. For non real time services such as nrtPS and BE, the throughput get decreased as the number of users increases. This is because, priority is given for real time services when compared with non real time services. It is observed from the simulation result that even though the system is overloaded our proposed algorithm gives desired QoS for real time services. The throughput of EDT based algorithm with channel condition is shown in Fig. 6. Since the allocation of users is based on tag value and channel conditions the throughput is slightly increased when compared with ideal channel conditions.

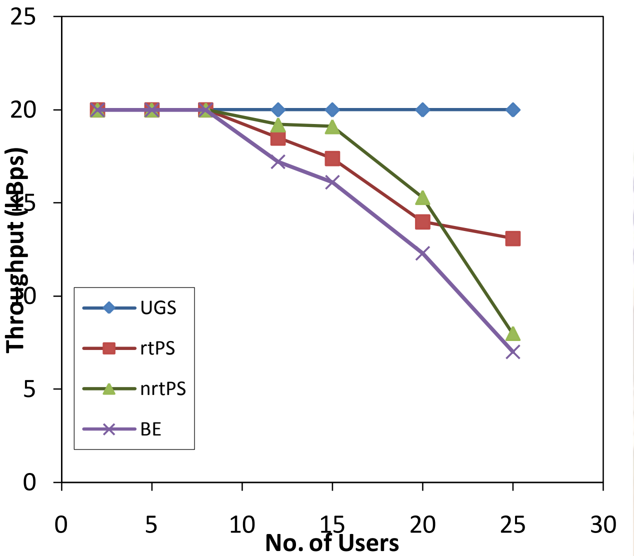

Fig. 6 Throughput of EDT based channel aware algorithm

The overall throughput obtained with the random number of users with and without channel aware condition is shown in Fig. 7.

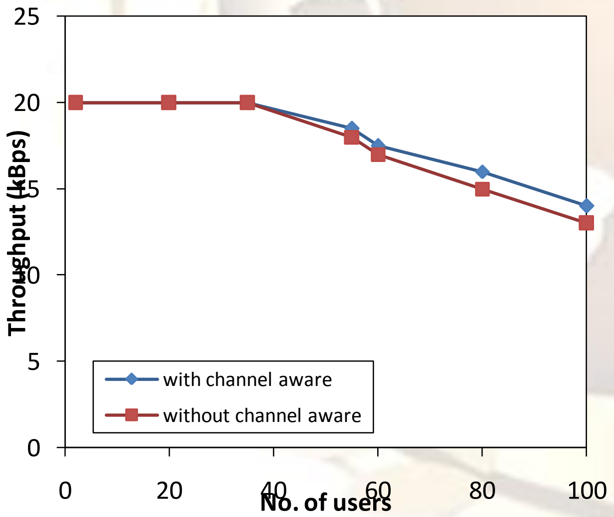

Fig. 7 Overall throughput analysis

It is observed that the throughput get decreases as the number of users increases. This is because of the non availability of resources when the system gets overloaded. But the throughput is high for channel aware condition when compared with, without channel aware condition.

4.2 Delay Analysis

The simulated delay of EDT based algorithm for ideal channel condition is shown in Fig. 8.

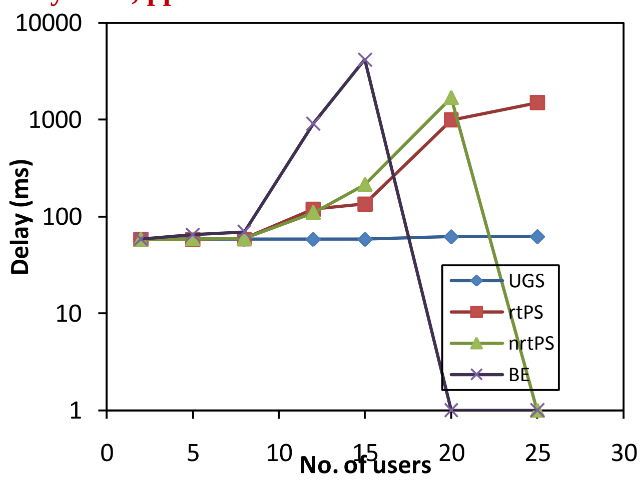

Fig. 8 Delay of EDT based algorithm with ideal channel conditions

From the simulation result it is observed that the EDT based algorithm takes lesser time to allocate resources for UGS service when compared with other types of services. From the graph it is observed that the delay obtained for UGS service increases slightly as the number of users increases. For rtPS service also the EDT based QoS aware algorithm provides almost lesser delay as the number of users increases. Thus the simulation result shows that even for overloaded system our proposed algorithm provides lesser delay for real time services. For non real time services such as nrtPS and BE, the time taken by the EDT based algorithm is higher. From the graph it is clear that the delay of nrtPS and BE services increases as the number of users increases. This is because priority is given for real time services when compared with non real time services.

The delay of EDT based algorithm with channel condition is shown in Fig. 9. Since the allocation of users is based on tag value and channel conditions the delay is decreased when compared with ideal channel conditions.

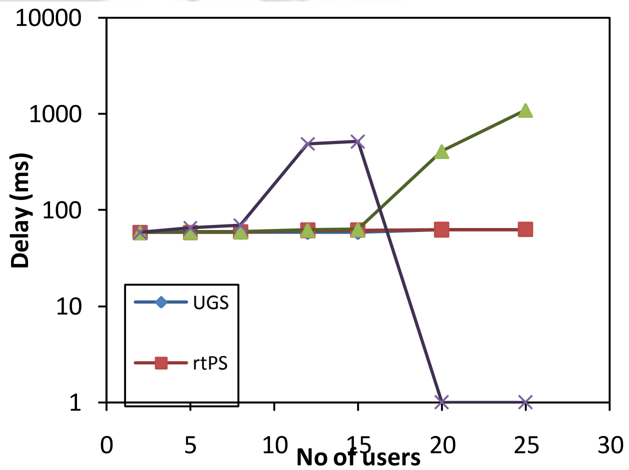

Fig.9 Delay of EDT based channel aware algorithm

The overall delay obtained with random number of users with and without channel aware condition is shown in Fig. 10. It is observed that the delay gets increased as the number of users increases. This is because of the non availability of resources when the system gets overloaded. But the delay is less for channel aware condition when compared with, without channel aware condition.

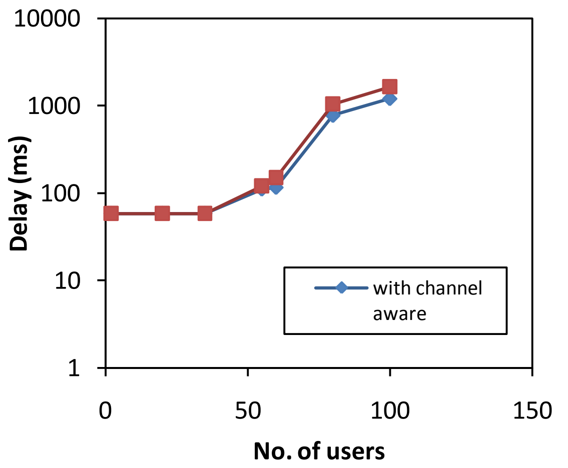

Fig. 10. Overall delay analysis

5. CONCLUSION

The WiMAX operating environment, with its variability in both time and space, raises additional challenges in the design of effective schedulers. The schedulers should be able to provide hard QoS guarantees and fair resource allocation .In this paper, the performance results of EDT based scheduling algorithm is presented with ideal and channel aware condition. From the simulation results it is concluded that EDT based algorithm, provides service differentiation and it schedules the packet based on the QoS requirement of the user. So the unfairness among the users is overcome and also the proposed algorithm offers the higher throughput to real time services with lesser delay.

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