Multimedia Supported Uplink Scheduling for IEEE 802.16d OFDMA Network

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***Abstract*-- In this paper we have proposed a multimedia supported uplink scheduler for IEEE 802.16d OFDMA network, which includes a proportional fair (PF) scheduler in base station (BS) and earliest due date scheduler (EDD) in subscriber station (SS). The PF scheduler in the BS allocates the OFDMA resources to each SS according to their bandwidth request. The EDD scheduler in the SS utilizes the allocated resources according to the packet deadline thus provides QoS guarantee. The proposed system is simulated using C programs and extensive simulation results were presented. The simulation is carried out with varying OFDMA frame size (5msec, 10msec) and coding rates (16QAM CTC 1/2, 16QAM CTC 2/3) and the throughput and delay performance is compared. Our results indicate that the proposed scheduler performs well for VBR applications with excellent delay guarantees and improved throughput.**

I. INTRODUCTION

THE IEEE 802.16 is an emerging standard for broadband wireless access (BWA) to provide higher data rates with less complexities and to overcome the limitations of a broadband wired network. The IEEE 802.16 standard specifies the physical (PHY) and medium access control (MAC) layer which supports both asynchronous transfer mode (ATM) and internet protocol (IP) higher layers. It is structured to support multiple PHY specification such as wireless MAN single carrier (SC) modulation scheme for fixed line of sight (LOS) operation and orthogonal frequency division multiplexing (OFDM), orthogonal frequency division multiple access (OFDMA) and SCa schemes for mobile non line of sight operations (NLOS). Worldwide interoperability for microwave access (WiMAX) system, sponsored by an industry consortium called the WiMAX forum is based on technologies of this family.

The MAC layer of the IEEE 802.16 has three sublayers. Service specific convergence sublayer (SSCS) is the first sub layer that provides mapping of various types of higher layer flows. MAC common part sublayer (MAC CPS) is the second sub layer that provides the MAC core functionality such as bandwidth allocation and scheduling, connection establishment and maintenance, MAC framing and headers. The third sub layer is security sublayer (SS) which defines mechanisms for secured access.

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Lot of works is being carried out in designing a proper scheduling algorithm for the emerging IEEE 802.16 networks. The algorithms so far proposed have lot of shortcomings in terms of limited service classes consideration and performance enhancement. There are few scheduling algorithms have been proposed for variable bit rate (VBR) based applications so far. In [1] an uplink scheduling mechanism for VBR voice application was proposed by considering exponential ON and OFF time. The work is done only for voice application. Various scheduling mechanism for single carrier IEEE 802.16d system is discussed in [2]. In [3] the MAC performance is analyzed for various frame size. In [4] the cross layer issues and burst profile performance is discussed. In this paper a proportional fair scheduler in the BS and an EDD scheduler in the SS is proposed and the performance is analyzed with two different coding rates and frame sizes.

The rest of the paper is organized as follows; Section II provides an overview of the QoS related features of the IEEE 802.16 standard. The proportional fair scheduler for VBR based multimedia application is discussed in Section III. The EDD scheduler is discussed in section IV. Section V deals with simulation model and VI analysis the results for the given model. Finally the paper concludes with the scope for future work is given in section VII.

II. ARCHITECTURE AND QOS FEATURES OF IEEE 802.16

The architecture of the network has the centralized BS and multiple SS to support point to multipoint with the optimal mesh topology. BS of the network controls and manages the entire system and SS acts as an interface between end users and the BS. IEEE802.16 defines a connection-oriented MAC protocol that supports multiple physical layer specifications.

Each service flow is identified by a unique service flow identifier (SFID). SFID is a 32-bit quantity that uniquely identifies a service flow to both the subscriber station and base station. Whenever a service flows is activated, a unique 16 bit connection identifier (CID) will be also assigned. When new call arrives in the SS, the required bandwidth is requested by the SS. The BS is capable of allocating bandwidth in the following two modes viz., grant per connection (GPC), in which bandwidth is assigned to each connection individually in the SS, and grant per subscriber station (GPSS), in which BS allocates resources to SS for all the connection established in the SS, thus SS re-distributes the OFDMA resources allotted by BS to its connections. The latter is more efficient, when there are many connections are active per terminal.

IEEE802.16 standard provides a mechanism to support QoS for both uplink and downlink traffic through SS and BS. The principal mechanism for providing QoS is to associate packets traversing the MAC interface with a service flow. A set of QoS parameters such as average delay, minimum reserved bandwidth, traffic priority along with the direction are associated with each service flow. The IEEE 802.16 standard defines four types of service flows, each with different QoS requirements as given below.

A Unsolicited Grant Service (UGS):

The UGS is designed to support real-time service flows that generate fixed size data packets on a periodic basis, such as T1, E1 and Voice over IP without silence suppression. This service receives fixed size unsolicited data grants (transmission opportunities) on a periodic basis. Therefore, it eliminates the overhead and latency of requiring the SS to send requests for data grant.

B Real Time Polling Service (rtPS):

The rtPS is designed to support real-time service flows that generate variable size data packets on a periodic basis, such as MPEG video. This service offers periodic unicast request opportunities, which meet the flows real-time needs.

C Non-Real Time Polling Service (nrtPS):

This service is introduced for non-real-time flows which require variable size data grants on a regular basis, such as high bandwidth FTP. This service offers unicast polls on a periodic basis, but using more spaced intervals than rtPS.

D Best Effort Service (BES):

This service is designed to support best effort traffic and offers no guarantee. SS is allowed to use both contention and unicast request slots.

III. BS PROPORTIONAL FAIR SCHEDULER

The general system model containing both proportional fair scheduler and EDD scheduler is depicted in Fig. 1.The scheduler in the BS allocates OFDMA resources to each SS proportionally based on the received bandwidth request.

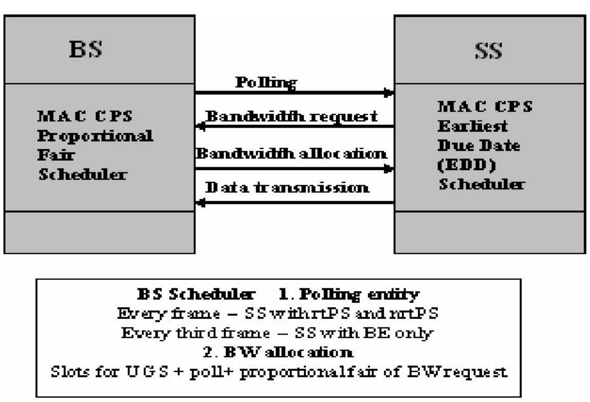

Fig. 1. General system model containing both Proportional fair scheduler and EDD scheduler.

The minimum resource required for data and MAC management message for uplink is one slot, which contains three OFDM symbols in time domain and one sub channel in frequency domain where as one sub channel contains 16 data sub carriers.

The BS scheduler allocates the unicast bandwidth request slot in each frame for the SS either with the rtPS or nrtPS service active. The SS which contains only BE service get the opportunity to send the bandwidth request in every third frame. The BS scheduler allocates resource in the following hierarchical manner. First for the UGS service and then for polling the SS's to send band width request as per the services active in that SS and finally the remaining OFDMA resources are allocated for sending the buffered data in the SS for which the bandwidth request is received.

Consider the number of SS in a network is n, and then resource allocated to each SS is given by (1),

$$BA_i = \frac{(BR_i/bps)*(TR-(\sum_{i=1}^{n} P_i + UGS_i))}{(\sum_{i=1}^{n} BR_i/bps)} \qquad (1)$$

$$NS_i = BA_i + p_i + UGS_i \qquad (2)$$

Where,

NS_i = number of slots allocated to i^{th} SS

BA_i = number of slots allocated for requested bandwidth

UGS_i = slots need to allocate for UGS application

BR_i = received bandwidth request from the i^{th} SS in bytes

bps = bytes per slot (12 for 16QAM CTC 1/2 and 18 for 16QAM CTC 2/3)

TR = total OFDMA resource in slots

P_i = slot needed for polling the SS. This is one slot for each frame if station has rtPS or nrtPS service and one slot for every three frame if station has only BE service class only.

IV. SS EDD SCHEDULER

The EDD scheduler is shown in Fig. 2.The scheduler to be designed has to meet QoS requirements such as throughput, latency, delay-jitter, packet loss ratio of each service, efficient utilization of BW and

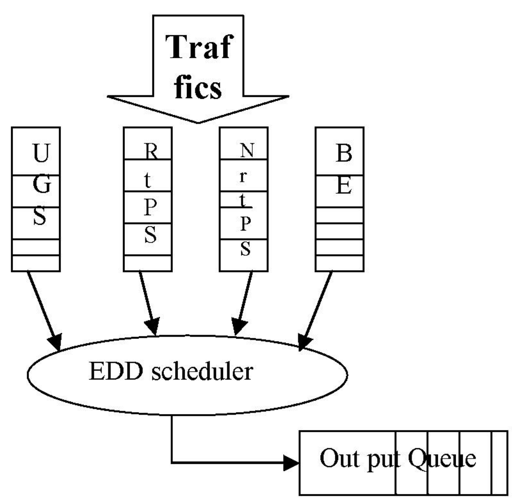

Fig. 2. Queuing model in each SS and Scheduler.

avoid starvation of low priority service. Proper design of scheduler is necessary to maintain the QoS requirements of the service.

The multimedia supported EDD scheduler resides in SS and serves the packets in the order of the deadline assigned to each packet. All the applications generated in SS are classified in to any one of four traffic classes such as UGS, rtPS, nrtPS and BE. EDD scheduler in SS takes the earliest due packet from the four traffic queues and put in to output queue. Always the packet which has the earliest deadline will be served first.

V. SIMULATION MODEL

The simulation is carried out with the following system parameters.

An IEEE 802.16d OFDMA system with one BS and five SS is considered. The OFDMA system is designed with 10MHz channel bandwidth with 2048 FFT sub carriers. Different multimedia applications such as voice, video and data are generated randomly in each SS and are mapped in to various WiMAX service classes. The packet inter arrival time of each application is exponentially distributed. The simulation is performed with two different frame sizes and two different coding rates. The other simulation parameters are shown in Table I as discussed in [12].

TABLE I
SIMULATION PARAMETERS

Parameter	5ms OFDMA frame	10ms OFDMA frame
No of Subchannel	70	70
No of data sub carrier	16	16
Selected no of OFDM symbols for UL and DL	(26 (DL), 21(UL))	(49 (DL), 45(UL))
Symbol/slot	3	3
Total slots for UL frame	1470 OFDM symbols, 490 slots	3150 OFDM symbols 1050 slots

The downlink frame contains only DLMAP and ULMAP fields and there will not be a DL bursts field as DL traffic is not considered for simulation purpose. The traffic models used for simulation are shown in table II.

TABLE II
TRAFFIC MODELS USED FOR SIMULATION

Application type	Delay latency (msec)	Data rate (kbps)	Packet Inter arrival time (msec)	Slots needed for 16QAM ½	Slots needed for 16QAM 2/3
UGS	20	64	20	14	10
rtPS	40	640	4	27	18
nrtPS	50	420	4	18	12
BE	200	210	8	18	12

Several assumptions have been made to reduce the complexity of the simulation model:

- The effects of propagation delay are neglected.
- The channel is error – free that means that each transmitted packet was successfully and correctly received at its destination.

VI RESULTS AND ANALYSIS.

In this section the normalized throughput and delay performance of the proposed scheduler is presented. We have assumed that any packet which crosses the delay latency will be dropped. Normalized throughput is given as

$$\text{Normalized Throughput} = \frac{\text{Total no of packets Transmitted}}{\text{Total no of packets Transmitted} + \text{Total no of packets dropped}} \quad (3)$$

A. Normalized Throughput Performance

Figs. 3, 4, 5 and 6 shows the throughput performance of the proposed BS proportional fair – SS EDD scheduler for various service classes.

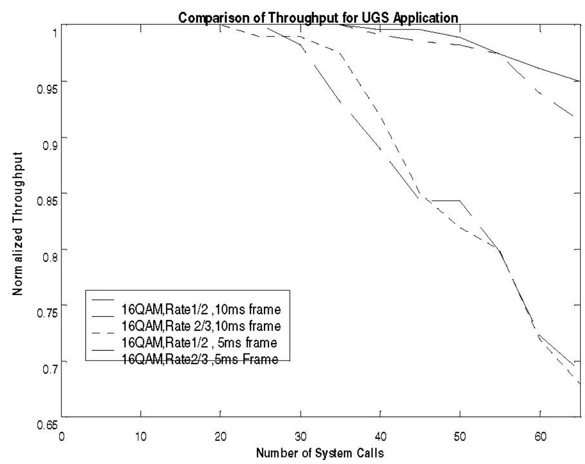

Fig. 3. Throughput Performance of UGS Application for 10ms and 5ms frame.

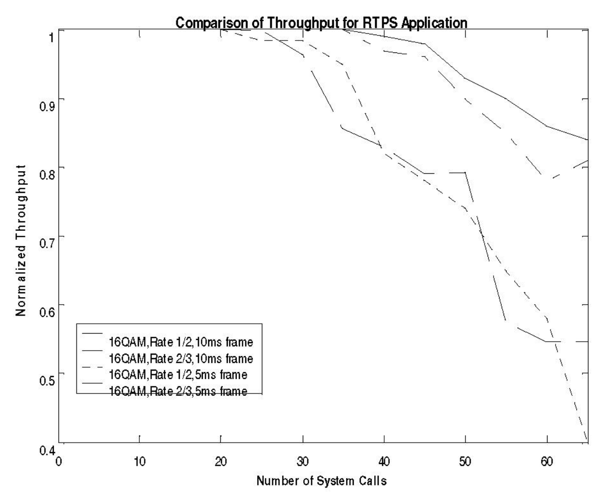

Fig. 4. Throughput Performance of rtPS Application for 10ms and 5ms frame.

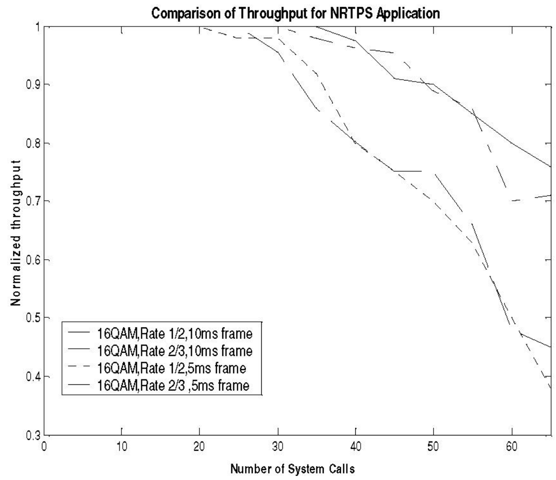

Fig.5. Throughput Performance of nrtPS Application for 10ms and 5ms frame.

The normalized throughput of each application is calculated for different coding rates and OFDMA frame size.

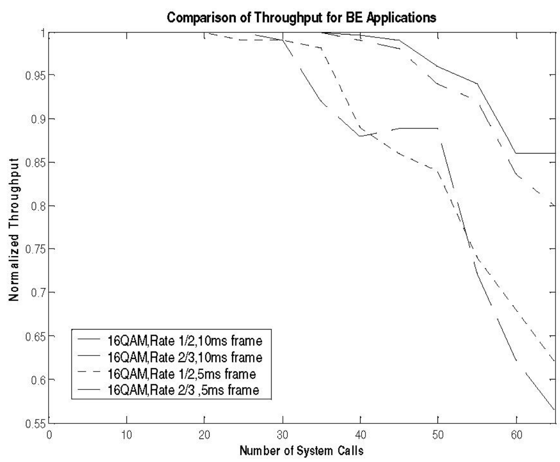

Fig. 6. Throughput Performance of BE Application for 10ms and 5ms frame.

The normalized throughput of each application is calculated for different coding rates and OFDMA frame size as given in (3),

Fig.3 shows the normalized throughput for UGS application. Even though BS scheduler allocates the resources unsolicited for UGS, these resources are stolen by other service class packets due to their earliest dead line parameter.

Fig. 4 shows the normalized throughput for rtPS application and Fig.5 shows throughput performance of nrtPS application. BE services are not much affected even during less over load condition due to EDD scheduler in the SS which is shown in Fig.6.

From the simulation results it is observed that under low load condition the throughput performance is similar for all PHY parameters (coding rate and frame size). When the number of calls increases, the normalized throughput is reduced as the number of lost packets increasing. The normalized throughput performance is enhanced as the frame size (10msec frame) is increased because of the reduced overhead. But when the system uses higher coding rate (16QAM CTC 2/3) the throughput performance is increased drastically and the packet loss is reduced heavily.

B Delay Performance

Figs. 7, 8, 9 and 10 show the delay performance of the proposed BS proportional fair – SS EDD scheduler. EDD scheduler which resides in the SS provides the delay guarantee for all kind of applications. Fig.8 shows the delay performance of UGS application for different PHY parameters. During heavy load condition also, EDD scheduler provides the delay guarantee. It is observed from the simulation results that the delay is little bit reduced if the system uses higher coding rate. Also it is observed that for higher frame sizes, the delay occurs more. So 5msec frame is more suitable for UGS application. The delay performance of the rtPS, nrtPS and BE are shown in Figs 9, 10 and 11. The PHY impact is similar to that of UGS application.

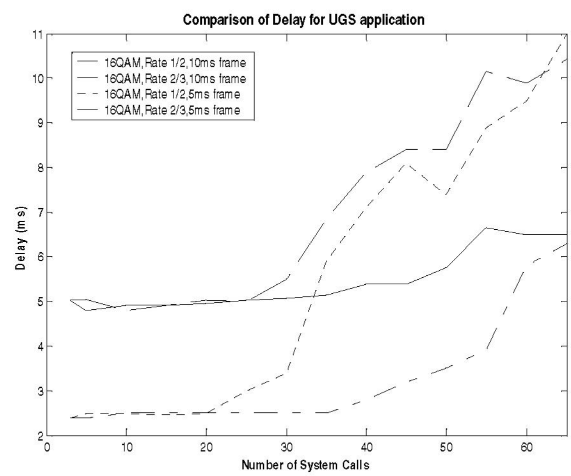

Fig. 7. Delay Performance of UGS Application for 10ms and 5ms frame.

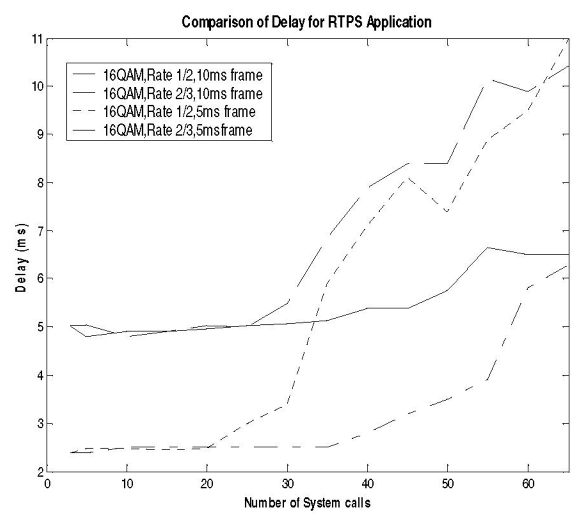

Fig. 8. Delay Performance of rtPS Application for 10ms and 5ms frame.

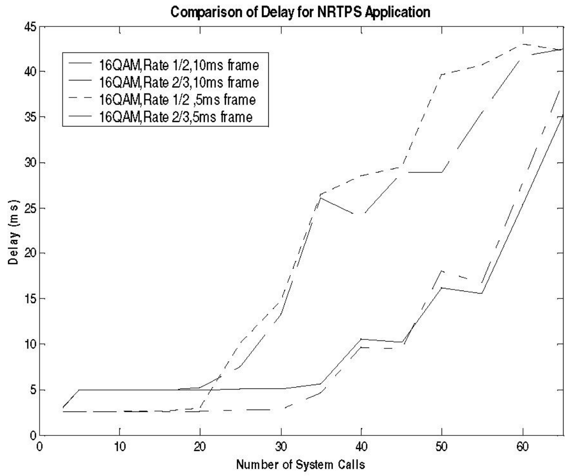

Fig. 9. Delay Performance of nrtPS Application for 10ms and 5ms frame.

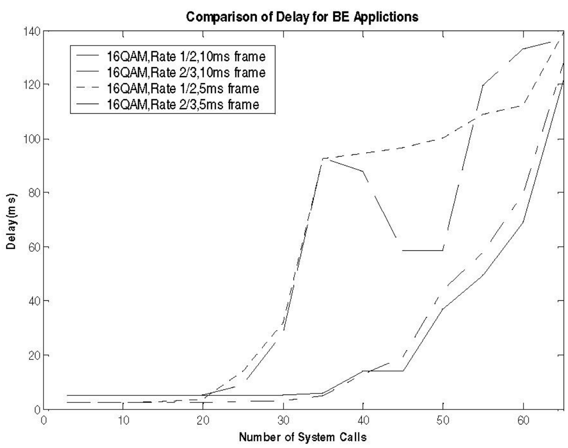

Fig. 10. Delay Performance of BE Application for 10ms and 5ms frame.

VII. CONCLUSION AND FUTURE WORK

In this paper, multimedia supported SS EDD scheduler and BS proportional fair scheduler has been proposed. From the simulation results it is observed that for higher code rates (2/3), both the delay and throughput performance was improved when compared with lower coding rates (1/2).Also it can be observed that for higher frame sizes, throughput performance was improved slightly, whereas the delay performance was degraded when compared with smaller frame sizes. Finally, the simulation results show that the combination of both schedulers provides delay guarantees and improved throughput for multimedia applications. In this work, only uplink scheduling is considered, which can be extended for downlink scheduling and also contention based CDMA bandwidth request can be included.

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IX. BIOGRAPHIES

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