A Novel Parameterized QoS based Uplink and Downlink Scheduler for Bandwidth/Data Management over IEEE 802.16d Network

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Abstract: Recent developments in Broadband Wireless Access (BWA), caused users to use multimedia, real–time and high bandwidth intensive applications that lead to a new era of research and development in wireless networks. IEEE 802.16 standard has come forward as BWA solution to fulfill the requirements of users. Even though IEEE 802.16 standard defines scheduling service flows and quality of service parameters, but scheduling of these flows to maintain QoS and fairness among flows is left open for researchers. In this paper we developed a scheduling architecture for IEEE 802.16 in both uplink and downlink directions. Our scheduling architecture includes QoS parameters like maximum sustained rate, maximum latency, tolerated jitter, minimum reserved bandwidth, request transmission policy, traffic priority, burst size, SDU size and queue information for various scheduling service flows. We use First in First out (FIFO), Earliest Deadline First (EDF) and Self Clocked Fair Queuing (SCFQ) to schedule different flows to achieve QoS and efficient bandwidth utilization.

Index Terms: IEEE 802.16, Quality of Service, Broadband Wireless Access, Medium Access Control, Self Clocked Fair Queuing

I. INTRODUCTION

Broadband wireless access (BWA) has turned out to be the best most efficient way to handle business and home demand for fast internet access, voice/video services, integrated data, resource sharing and utilization, mass data transfer and multimedia applications. It has advantages over its wired competitors, such as fast deployment, ease of implementation, lower maintenance cost, lower upgrade cost, high data rate and high scalability.

In this paper we develop an efficient scheduling architecture that incorporates mandatory Quality of Service (QoS) parameters. We have also evaluated the behavior of fragmentation under this scheduling architecture. The rest of this paper is organized as follows. In the next section, we provide an overview of IEEE 802.16 standard (more specifically MAC layer) and describe some of their QoS related features. In Section II we discussed related work. We then propose our scheduling architecture in Section IV. In section V we discuss results. Finally, we conclude with a summary in Section VI.

II. BACKGROUND

IEEE 802.16d [11] standard defines an air interface for fixed point to multipoint BWA that is competent of providing various services. The architecture mainly consists of two components, a Base Station (BS) and a number of Subscriber Stations (SS). Figure 1 depicts the BWA system architecture. Both BS and SS are fixed, whereas users inside a building may be fixed or mobile. Communication takes place from the BS to the SSs (Downlink (DL)) and from SS to BS (Uplink (UL)). DL transmission is carried through Point to Multipoint access method, and UL is conducted by Time Division Duplexing (TDD) on demand basis. IEEE 802.16d specifies physical layer that operates on 2-11 GHz and 10-66 GHz frequency bands. The data rate supported by these two frequency bands is dependent upon the channel bandwidth and modulation technique.

Orthogonal Frequency Division Multiple Access (OFDMA) is a potential multiple access scheme that can very efficiently cope with these impairments. It considerably reduces frequency fading and inter-symbol interference [7]. The MAC layer of IEEE 802.16 is divided into three parts: Privacy sublayer, MAC common part sublayer and convergence sublayer. Each packet has to be linked with a unique connection in the MAC layer. SSs use bandwidth request mechanism to specify UL bandwidth requirements to the BS. BS
polls SS by allocating bandwidth to them for the purpose of making bandwidth requests. Bandwidth can be requested by sending a bandwidth request packet or by piggybacking it with a data packet. Requests can be aggregated or incremental. The IEEE 802.16 standard defines the following two ways for allocation of bandwidth grants: Grant per Connection (GPC) and Grant per Subscriber Station (GPSS).

The standard defines four types of scheduling services, each one with distinct QoS requirements. Each connection is linked with a single scheduling service and each scheduling service is linked with a set of QoS parameters that measure its behavior. The following four scheduling services are supported by IEEE 802.16. Unsolicited Grant Service (UGS), Real-Time Polling Service (rtPS), Non Real-Time Polling Service (nrtPS) and Best Effort Service (BE) flows. The key service information elements (IEs) for the above mentioned scheduling services the Maximum Sustained Traffic, Minimum Reserved Traffic Rate, Maximum Latency, Tolerated Jitter, Traffic Priority and Request/Transmission Policy. The scheduler is in charge of controlling the common UL bandwidth as well as distributing resources to flows to maintain quality. Fragmentation, Piggybacking, Concatenation, and Contention processes are used to maintain QoS, resource utilization and bandwidth guarantee.

III. PREVIOUS WORK

M. Hawa and D. W. Petr in 2002 suggested an uplink scheduling architecture for IEEE 802.16 and DOCSIS (standard for delivering broadband services over Hybrid Fiber Coax) with GPC grant mode. They are more focused on DOCSIS rather than IEEE 802.16 [1]. Guosang Chu et. al. in July 2002, suggested Weighted Round Robin (WRR) as uplink scheduling algorithm with GPSS (Grant per Subscriber Station) grant mode [3]. They chose five priority queues with dynamic priority competitive ratio parameter assignment. Aura Ganz and Kitti Wongthavarawat in 2003, suggested uplink bandwidth allocation algorithms based on flow type and strict priority from highest to lowest - UGS, rtPS, nrtPS and BE [5]. Victor Rangel et. al. in 2004, suggested a scheduling algorithm named EBSA that combines Early Deadline First and Prioritization, Round Robin and Weighted Fair Queuing to match CBR and VBR traffic over the IEEE 802.16 air interface [8]. Jianfeng Chen et. al. in 2005, suggested Quality of Service (QoS) enhancement of IEEE 802.16 standard, based on cross layer optimizations in PMP mode [4]. Supriya Maheshwari in 2005 has described a scheduling architecture based on GPSS grant mode with WFQ for downlink scheduling and min-max fair allocation for uplink scheduling [2]. Vandana Singh et. al. in 2006, developed new scheduling algorithms for the IEEE 802.16d OFDMA/TDD based broadband wireless access system, in which radio resources of both time and frequency slots are dynamically shared by all users [12]. Claudio Cicconetti et. al. in 2006, assessed the performance of IEEE 802.16 in two of the most promising scenarios(residential and small and medium-sized enterprise (SME)) envisaged by the Wimax forum [7] and they also evaluated the effectiveness of rtPS, nrtPS, and BE through simulation in [10]. Abhishek Maheshwari in 2006, proposed Weighted Fair Queue (WFQ) based MAC scheduling architecture for IEEE 802.16 WirelessMANs in both uplink and downlink directions [6]. Xiaojing Meng in 2007 proposed a scheduling algorithm for OFDM/TDMA based on WiMAX network to extend proportional fairness scheme to multiple service types with diverse Quality of Service requirements [9].

In previous work, number of authors proposed scheduling architecture for IEEE 802.16 and most of them concentrated on Uplink Scheduling. Some of them also proposed downlink scheduling, but all these scheduling architectures and mechanisms ignored the QoS parameters defined by IEEE 802.16 to achieve stringent quality of service. All authors used static weights for different scheduling algorithms, while the dynamic calculation of weights was ignored. At present there is a need for scheduling architecture, which will use all mandatory parameters defined by the IEEE 802.16 to schedule packets, and to achieve the QoS requirements of different applications.

IV. SCHEDULING ARCHITECTURE

We proposed a scheduling architecture as shown in Figure 2 for the IEEE 802.16d in the mac layer that incorporates the QoS parameter. Our proposed QoS scheduling architecture is composed of a BS Uplink Bandwidth Management Module, BS Downlink Bandwidth Management Module, SS Uplink Scheduler, BS Downlink Scheduler, Packet Ordering Module and Fragmentation Module. We designed this scheduling architecture to meet the QoS of each flow, and still achieve high system bandwidth utilization under GPSS (Grant per subscriber station).

BS Uplink Bandwidth Management Module

This module, as shown in figure 3, has the responsibility for allocating bandwidth to each SS flow for UL transmission. Its main function is to produce a UL map for all SS according to their bandwidth requirements, to achieve excellent QoS for each flow under the limited information of each queue. It also keeps fairness among different flows and Subscriber Stations under overloaded conditions. It assures the delay guarantee to UGS and rtPS flows. Bandwidth is allocated to each SS in the following way:
- Amount of bandwidth allocated to each SS in regular intervals by the QoS parameters of connection associated with each connection.
- Amount of bandwidth requested by each SS for UL transmission.
- Amount of bandwidth required periodically by SS's UGS flow.

BS distributed UL bandwidth among various SSs in the following way. 

**Bandwidth Allocation to UGS:** BS allocates bandwidth to each UGS UL flow according to QoS parameters negotiated during connection setup. These parameters include Maximum Sustained Rate and SDU size to define the interval for allocating bandwidth. If the number of UGS flow increases then Tolerated Jitter is used as an ordering parameter. If two flows are equal in Tolerated Jitter, then Maximum Latency is used to break a tie.

**Bandwidth Allocation to rtPS:** BS fulfills the requirements of rtPS flow whenever there is an entry in its queue. So BS provides unicast polling request to each rtPS flow to meet the QoS. BS fulfills the BW request of rtPS flows for different SSs. Maximum Latency is used as an ordering parameter. If two flows are equal in Maximum Latency then priority will be given to that flow which has lower Maximum Sustained Rate and Minimum Reserved Traffic Rate.

**Bandwidth Allocation to nrtPS:** BS provides unicast request opportunities to each nrtPS flow to meet the QoS. After fulfilling the requirements of all UGS and rtPS flows, BS provides the requested bandwidth to different SS for nrtPS flow and Traffic Priority parameter used as an ordering parameter. If two flows are equal in Traffic priority then priority will be given to that flow which has less bandwidth as compared to the other, and that is calculated from Maximum Sustained Rate.

**Bandwidth Allocation to BE:** After fulfilling the requirements of all UGS, rtPS, and nrtPS flows, BS fulfills the requirements of all BE flows by allocating bandwidth according to Maximum Sustained Rate and Last Polling Time. The parameter Traffic Priority is used as an ordering parameter. If two flows are equal in Traffic priority, then priority will be given to that flow which has less bandwidth as compared to the other, and that is calculated from Maximum Sustained Rate.

**SS Uplink Scheduler**

After allocation of bandwidth from UL Bandwidth Management module, SS uplink scheduler as shown in figure 4, responsibility is to schedule packets from the respective queues of UGS, rtPS, nrtPS and BE. First we schedule UGS packets, because there is fixed bandwidth allocation from BS side. UGS packets are queued by FIFO mechanism. rtPS Packets are serviced by Earlier Deadline First mechanism, and ordering parameter is Maximum Latency. nrtPS Packets are

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Figure 2. Scheduling Architecture for IEEE 802.16

Figure 3. Uplink Bandwidth Scheduling

Figure 4. SS Uplink Scheduler
queued by Earlier Deadline First mechanism and ordering parameter is Maximum Latency and Traffic Priority. BE Packets are queued by First Come First Serve mechanism. We use a variant of WFQ scheduling algorithm that is Self Clocked Fair Queuing (SCFQ), to schedule rtPS, nrtPS and BE packets that avoid to costly computation of round number in WFQ. A weight is calculated dynamically for each class of scheduling services by the size of the queue and a constant (weight) priority connections with each flow and bandwidth distributed among flows by calculated weight.

**BS Downlink Bandwidth Management Module**

This module, as shown in figure 5, has responsibility for allocating bandwidth to each SS for DL transmission. Its main responsibility is to produce a DL map for all SSs according to their bandwidth requirements. To allocate DL bandwidth among different SSs is easier than UL bandwidth allocation, because BS has all information for each scheduled service flow. It is also the responsibility of this module to keep fairness among different flows and SS under overloaded conditions. The module assures the delay guarantee to UGS and rtPS flows as we increase the number of flows. BS distributes UL bandwidth among various SSs by the following strategies. Bandwidth Allocation to UGS: BS fulfills the requirements of UGS flow whenever a UGS packet is queued in its queue. BS allocates bandwidth to flow according to packet size. If the number of UGS flow increases then Tolerated Jitter is used as an ordering parameter. If two flows are equal in Tolerated Jitter, then Maximum Latency is used to break a tie. Bandwidth Allocation to rtPS: BS satisfies the requirements of rtPS flow whenever number of rtPS-packets is in its queue. The parameter Maximum Latency is used as an ordering parameter. If two flows are equal in Maximum Latency, then that flow has the priority, which has less allocated bandwidth, and it calculated from Maximum Sustained Rate and Minimum Reserved Traffic Rate. While ordering flows, there is one important aspect where a flow, which is much closer to maximum latency, is crossing a deadline. Here it is better to drop the packets instead of allocating very costly bandwidth. Bandwidth Allocation to nrtPS: BS fulfills the requirements of all nrtPS flows according to size of packets that are queued in its queue. The parameter Traffic Priority is used as an ordering parameter. If two flows are equal in Traffic priority, then that flow has the priority, which has, less allocated bandwidth as compared to the other, and that is calculated from Maximum Sustained Rate and Minimum Reserved Traffic Rate. Bandwidth Allocation to BE: At last it fulfills the requirements of all BE flows. Traffic Priority is used as an ordering parameter to allocate bandwidth among BE service flows. In the second stage, BS allocates DL bandwidth to all SSs. Service flows that have not gotten bandwidth in the current frame will get it in the next.

**BS Downlink Scheduler**

After bandwidth allocation from downlink bandwidth management module, BS Downlink Scheduler’s as shown in figure 6, responsibility is to schedule packets from the respective queues of UGS, rtPS, nrtPS and BE according to allocated bandwidth. First we schedule UGS packets, because there is fixed bandwidth allocation, so that it can meet QoS efficiently. After scheduling UGS packets, the remaining bandwidth is allocated among rtPS, nrtPS and BE flows. These packets are scheduled by SCFQ scheduling algorithm, which finds the finish number of each packet before its introduction into the respective queue, and this algorithm also updates the round number after each arrival and departure of packets. Weight is calculated by the mechanism described in SS Uplink Scheduler.

**Fragmentation Module**

This module is mainly responsible for allowing efficient use of granted bandwidth relative to the QoS requirements of a connection. We do not fragment the UGS connection, because there is fixed allocation of bandwidth. This process is performed before BS scheduler and SS scheduler schedule the packets. Its main task is to fragmenting the packets whose size is greater than that allocated for a packet. In these cases header overhead increases, but this can be compensated.
for through efficient utilization of bandwidth allocated to each SS.

V. RESULT

We performed a number of simulation tests in Network Simulator 2 (NS-2) to show the effectiveness and performance of our proposed scheme. Figures 7 and 8 show the Mean Mac delay of scheduling service flows to SS (UL and DL) when the number of SSs increases from 2 to 24. It is found that mean delay of all scheduling flows in UL direction increases gradually after overloaded condition, except for UGS. With UGS flows, BS provides a unicast request opportunity to all rtPS connections at a predefined time.

Mean delay of each type of traffic in DL direction remains constant because queues are empty. When the system is overloaded, the average delay of BE and nrtPS flows increases more sharply than UGS and rtPS flows. Flow Priority and delay tolerant traffic are the main parameters for providing bandwidth for UGS and rtPS flows. Scheduling algorithm tries to maintain the reserved rate allocated to UGS and rtPS connections as the number of subscriber stations increases, and it also tries to shape the rate of quarantine to other flows.

![Figure 7. Mean Mac delay of Scheduling Services (UL)](image1)

![Figure 8. Mean Mac Delay of Scheduling Services (DL)](image2)

VI. CONCLUSION

In this paper we proposed a scheduling architecture, IEEE 802.16 standard, for UL and DL direction that incorporates QoS parameters associated with each scheduling service. Packets are scheduled according to these QoS parameters. We concluded that DL scheduling is easy to arrange, because BS has all the information about flows and updated queue, so we can easily schedule packets. We concluded that to achieve quality of service, efficient utilization of bandwidth and fairness, the best method is to design such an architecture that incorporates all QoS parameters, so a flow can meet its delay and bandwidth guarantee. This approach can save a BS from excessive computation and databases management overhead for each flow. Finally, we concluded that such architecture is best for the varied quality of service requirements of different flows in UL and DL directions.

REFERENCES


