Uplink Scheduling Algorithms in IEEE 802.16Broadband Wireless Access Systems: A Survey

Shahid Md. Asif Iqbal
Mohammad Iftekhar Monir
Taufique Sayeed

Abstract :
WiMAX is one of the most important broadband wireless technologies and is anticipated to be a viable alternative to traditional wired broadband techniques due to its cost efficiency. WiMAX supports multimedia applications such as voice over IP (VoIP), voice conference and online gaming. It is necessary to provide Quality of Service (QoS) guaranteed with different characteristics for Broadband Wireless Access (BWA) networks. However, the actual version of the standard does not define a Media Access Control (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 system developers. The scheduling architecture must ensure good bandwidth utilization, maintain the fairness between users and respond to the constraints of some applications (i.e. video, voice). A good number of articles are available to analyze the performance of the standard. To analyze these studies, a survey based on the scheduling mechanism or method used in the different propositions is presented in this paper. Some studies are based on traditional algorithms and other studies use new methods and mechanisms that are proposed for the new standard in order to provide QoS.

Keywords:- *BWA, IEEE 802.16, QoS, Scheduling, WiMAX,*

I. INTRODUCTION

WiMAX (Worldwide interoperability for Microwave Access) is one of the most emerging technologies for Broadband Wireless Access (BWA) in metropolitan areas by providing an exciting addition to the current broadband techniques for the last-mile access. It is demonstrated that WiMAX is a viable alternative to the cable modem and Digital Subscriber Line (DSL) technologies due to its high resource utilization, easy implementation and low cost. Furthermore, WiMAX not only enhances the existing features of the competitive cabled access networks, but provides high data rate applications with a variety of Quality of Service (QoS) requirements.

The basic IEEE 802.16 architecture consists of one Base Station (BS) and one (or more) Subscriber Station (SS). BS acts as a central entity to transfer all the data from SSs in a PMP

(Pont to multipoint) mode. Transmissions take place through two independent channels: Down-link Channel (from BS to SS) and Uplink Channel (from SS to BS). Uplink Channel is shared between all SSs while Downlink Channel is used only by BS. The standard defines both Time Division Duplexing (TDD) and Frequency Division Duplexing (FDD) for channel allocation. The IEEE 802.16 is connection oriented. Each packet has to be associated with a connection at MAC level. This provides a way for bandwidth request, association of QoS and other traffic parameters and data transfer related actions.

The standard supports four different flow classes for QoS and the MAC supports a request-grant mechanism for data transmission in uplink direction. The standard does not define a slot allocation criterion or scheduling architecture for any type of service. A scheduling module is necessary to provide QoS for each class. IEEE 802.16 defines the following four types of service flow with distinct QoS requirement:

Unsolicited Grant Services (UGS): designed to support real-time data streams consisting of fixed-size data packets issued at periodic intervals. Unsolicited grants allow SSs to transmit their Protocol Data Units (PDUs) without requesting bandwidth for each frame such as T1/E1 and Voice over IP without silence suppression.

Real-Time Polling Services (rtPS): designed to support real-time data streams consisting of variable-sized data packets on a periodic basic, such as moving pictures experts group (MPEG) video.

Non-Real-Time Polling Services (nrtPS): designed to support delay-tolerant data streams consisting of variable sized data packets for which a minimum data rate is required such as FTP.

Best Effort (BE) Services (Default): designed to support no periodic unicast requests are scheduled by the BS. The BE class has been introduced to provide an efficient resource utilization for low-priority elastic traffic, such as telnet or HTTP.

Actually, the standard provides specification for these different services, but does not specify any scheduling architecture. Few scheduling algorithms have been proposed to solve the problem. This paper is a survey to compare these architectures based on the mechanism or method used in these different propositions.

The remainder of this paper is organized as follows: Section II presents our classification of the uplink scheduling algorithm in IEEE 802.16. Section III shows a comparison between these algorithms, in term of advantages and disadvantages. Finally, Section IV concludes this paper and presents the future works.

II. CLASSIFICATION OF SCHEDULING ALGORITHMS

The scheduling architecture can be classified into two categories: classical methods, based on traditional scheduling algorithms like First in First out (FIFO), Round Robin, etc. and new methods that are developed for the new standard based on new techniques for the scheduling. This classification is illustrated in Figure 1.

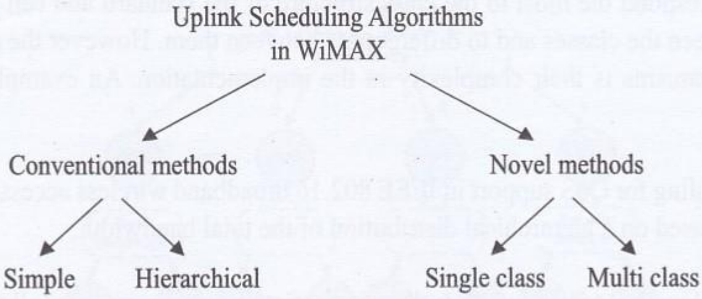

Figure 1. Classification of Scheduling Algorithms

A. Conventional methods

Most of the mechanisms proposed for the scheduling in IEEE 802.16 are based on algorithms and methods used in other type of networks (i.e. wired network). There are mechanisms that use these algorithms with a simple way and other mechanisms that modify the structure of these algorithms in order to have a more complex architecture that can respond to the standard needs in term of QoS.

1) Simple mechanisms:

Usually, the traditional methods are not very proposed in its simple scheme without modification of the principal architecture. Examples of such methods: FIFO, Fair Queuing, Round Robin. In Figure 2 we illustrate a scheduling architecture based on a simple mechanism.

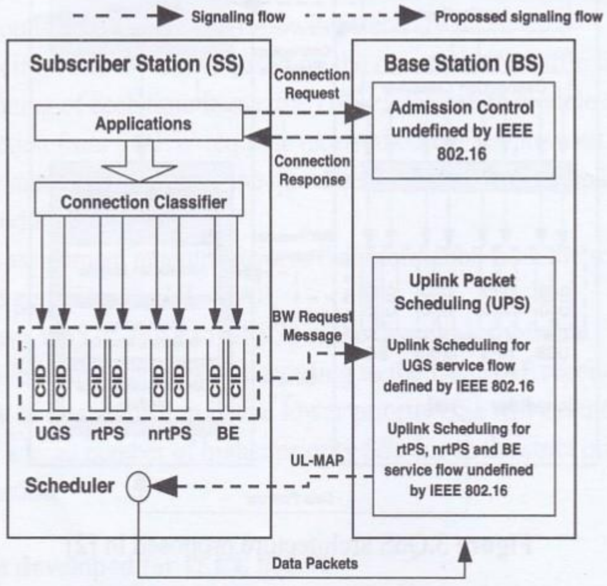

Figure 2. IEEE 802.16 QoS architecture

2) Hierarchical mechanisms:

This type of mechanisms is the most proposed for the IEEE 802.16 scheduling. In fact, these mechanisms respond the most to the class structure of the standard and can serve to maintain fairness between the classes and to differentiate between them. However the problem with this kind of mechanisms is their complexity in the implementation. An example is presented as follows.

Packet scheduling for QoS support in IEEE 802.16 broadband wireless access systems [2]: This is a method based on a hierarchical distribution of the total bandwidth.

The overall allocation of bandwidth is done in a strict priority manner i.e. all the higher priority SSs are allocated bandwidth until they do not have any packets to send. The Earliest Deadline First (EDF) scheduling algorithm is used for SSs of the rtPS class, Weighted Fair Queue (WFQ) is used for SSs of the nrtPS class and FIFO for SSs of the BE class. Besides the scheduling algorithm, an admission control procedure and a traffic policing mechanism are also proposed. All these components together constitute the proposed QoS architecture.

With this new structure, a modification of the QoS architecture in the IEEE 802.16 standard takes place. This modification is illustrated in Figure 3.

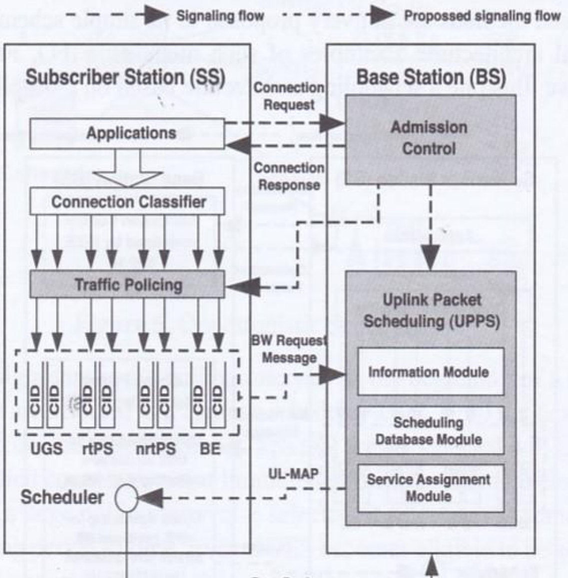

Figure 3. QoS architecture proposed in [2]

The hierarchical structure of the bandwidth allocation in the UPS is shown in Figure 4.

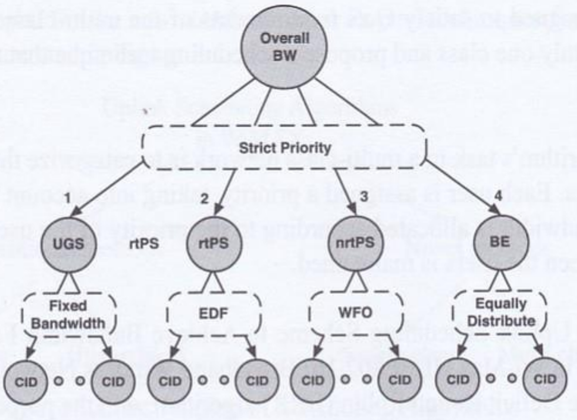

Figure 4. Hierarchical structure of bandwidth allocation

The proposed UPS consists of three modules: information module, scheduling database module and service assignment module. Here is a brief description of the connection establishment using the QoS architecture Figure 3:

- An application that originates at an SS establishes the connection with BS using connec tion signaling. The application includes in the connection request the traffic contract (bandwidth and delay requirement).
- The admission control module at the BS accepts or rejects the new connection.
- If the admission control module accepts the new connection, it will notify the UPS module at the BS and provide the token bucket parameters to the traffic policing module at the SS.

After the connection is established, the following steps are taken:

- Traffic policing enforces traffic based on the connection's traffic contract,
- At the beginning of each time frame, the UPSs information module collects the queue size information from the BW-requests received during the previous time frame. The information module will process the queue size information and update the scheduling database module
- The service assignment module retrieves the information from the scheduling database module and generates the UL-MAP.
- BS broadcasts the UL-MAP to all SSs in the downlink subframe.
- SS's scheduler transmits packets according to the UL-MAP received from the BS.
  A drawback of this algorithm is that lower priority SSs will essentially starve in the presence of a large number of higher priority SSs due to the strict priority overall band width allocation

B. Novel methods developed for IEEE 802.16

A good number of new scheduling algorithms have been proposed recently. Some of these techniques are designed to satisfy QoS requirements of the multi-class traffic in one scheme while other treat only one class and propose a scheduling technique that fits its characteristics.

1) Multi class:

A scheduling algorithm's task in a multi-class network is to categorize the users into one of the pre-defined classes. Each user is assigned a priority, taking into account its QoS requirements. Subsequently, bandwidth is allocated according to the priority of the users as well as ensuring that fairness between the users is maintained.

An Opportunistic Uplink Scheduling Scheme to Achieve Bandwidth Fairness and Delay for Multiclass Traffic in Wi-Max (IEEE802.16) Broadband Wireless Network [3]: The proposal is an extension of the Deficit Round Robin (DRR) algorithm with the purpose of satisfying delay requirements of multi-class traffic in WiMAX. The proposed algorithm uses a deficit counter and a quantum size just like the DRR algorithm. Here the BS takes into account the following three parameters at scheduling instant

- Channel characteristics [SINR1, SINR2, L SINRk]
- Queue lengths [q1 (t), q2 (t), L qk (t)]
- Delay counters [d1 (t), d2 (t), L dk (t)]

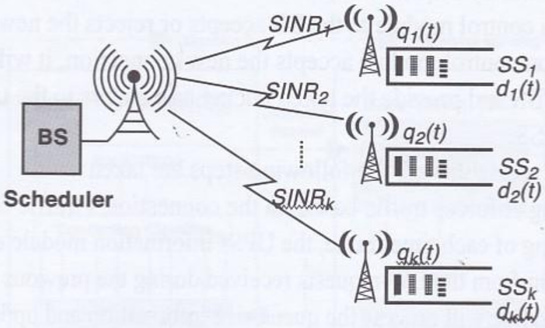

Figure 5. Opportunistic Scheduling

A critical part of the algorithm is the polling interval. At the beginning of a polling interval, a set of schedulable SSs are selected that forms a schedulable set. Until the next polling interval, SSs are selected only from the schedulable set. SSs that are not selected will have their quantum accumulated in the deficit counter. A major limitation of this algorithm is selecting an appropriate polling interval. If a large polling interval is selected, it will result in some of the SSs being denied service for a long period of time. Even if a SS becomes eligible to be added to the schedulable set, it will not be considered until the next polling interval.

2) Single class:

Scheduling algorithms may consider the sending rate of Transmission Control Protocol (TCP) flow. TCP-aware Uplink Scheduling for IEEE 802.16 [4]: The proposed algorithm does not require explicit bandwidth request from a SS. It estimates the amount of bandwidth required by the SS based on the current sending rate of the connection at the SS. The purpose of the algorithm is to provide reasonable fairness among the SSs based on the max-min fairness criteria while providing high frame utilization. To provide fairness, the algorithm requires knowing the demand of each SS. The demand is defined as the amount of bandwidth requested for achieving the maximum throughput so as not to be limited by the channel bandwidth. The algorithm provides reasonable fairness among SSs of the BE class.

This scheduling algorithm treats the BE traffic because it is difficult to estimate the amount of required bandwidth due to dynamic changes of the sending rate of this traffic. The sending rate of a Transmission Control Protocol (TCP) flow is changed over time due to the AIMD (Additive Increase Multiplicative Decrease) feature in a short-term period and also to changes of the available bandwidth in a long-term period.

III. COMPARISON BETWEEN THE STUDIED ALGORITHMS

In this chapter performance of the scheduling algorithms discussed in Chapter II are studied under different conditions.

The opportunistic scheduling algorithm primarily focuses on exploiting the variability in channel conditions in WiMAX.

The hierarchical algorithm studied here is a hybrid scheduling algorithm that combines EDF, WFQ and FIFO scheduling algorithms.

The multi-class technique uses Opportunistic Deficit Round Robin (O-DRR).

In order to illustrate the main difference between the studied algorithms, Table 1 is drawn that shows the advantages and disadvantages of these algorithms.

Table 1: Comparison of studied algorithms

Scheduling Technique	Algorithm	Advantages	Disadvantages
Simple	FIFO	Simple QoS	No QoS guarantee
Hierarchical	EDF + WFQ + FIFO	support in terms of bandwidth and delay	Strict priority may cause starvation of low priority SS
Multi-class	O-DRR	- Low complexity - ensures delay requirements of users	SSs may starve for service
Single-class	TCP-Aware	- no need for request -QoS guarantee	- Used for one class - Bottleneck

IV.CONCLUSION AND FUTURE WORK

In this paper, a survey of the uplink scheduler in IEEE 802.16 networks is performed. The classification is based on the method and mechanism used in the scheduling algorithms.. Future work involves implementation of a packet scheduling algorithm and study its performance in term of delays, throughput and packet loss.

REFERENCES

[1] IEEE 802.16-2004, "IEEE Standard for Local and Metropolitan Area Networks – Part 16: Air Interface for Fixed Broadband Wireless Access Systems", October 2004.

[2] K. Wongthavarawat, and A. Ganz, "Packet scheduling for QoS support in IEEE 802.16 broadband wireless access systems", *International Journal of Communication Systems*, vol. 16, issue 1, pp. 81-96, February 2003.

[3] H.Rath, A.Bhorkar and V.Sharma, "An Opportunistic Uplink Scheduling Scheme to Achieve Bandwidth Fairness and Delay for Multiclass Traffic in Wi-Max (IEEE 802.16) Broadband Wireless Networks", *Proceedings of IEEE Global Telecommunications Conference*, pp.1-5, November 2006.

[4] S.Kim and I.Yeom, "TCP-aware Uplink Scheduling for IEEE 802.16", IEEE *Communications Letters*, pp.146-148, February 2007.EEE, 1982, pp. 175-181.