Overview of a MAC Scheduling Algorithm for IEEE 802.16 Wireless Networks

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ABSTRACT

In this paper we have presented the literature survey of proposed MAC based quality of service (QoS) architecture for Wi-MAX Point-to-Multipoint networks scheduling algorithm.

The Wi-MAX is IEEE 802.16 Wireless network standard which recently for Broadband Wireless communication. The IEEE 802.16 advantages includes variable bit rate and high data rate, last mile wireless access, point to multipoint communication, large frequency range and QoS for various types of applications.

With respect of the above advantages of IEEE 802.16 Wireless network is drawback in MAC scheduling architecture in uplink as well as downlink direction. In this paper we propose MAC scheduling architecture for IEEE 802.16 Wireless networks in both uplink and downlink direction to broadcast the frame.

Keywords

MAC, QoS class scheduling, IEEE 802.16, BWC, NBWC.

1. Introduction

The IEEE 802.16 standards provide wireless broadband internet for the “first-mile to Last-mile” or “First point to last point” connection. They are also known as Wi-MAX standards. Wi-MAX is based on wireless metropolitan area networking. It provides very high data throughput over long distance in a point to multipoint. Wi-MAX can provide wireless services up to 20 or 40 miles away from the base station. This technology aims to provide broadband wireless access to residential and small business applications, as well as to enable internet access in countries without any wired infrastructure [5].

The above mentioned advantages of IEEE 802.16 Wireless network prepare a platform for this standard to full fill with the other wireless communication technologies like Wi-Fi. The requirement from IEEE 802.16 is to provide QoS for all possible applications in both (uplink and downlink) directions. The IEEE 802.16 is likely to emerge as a recent technology for cost effective for every where broadband wireless access, supporting fixed, roaming, portable and fully mobile operations offering integrated voice, video and animation data services. The point-to-multipoint (PMP) architecture of IEEE 802.16 can be installing in easy and cost effective manner in large geographical areas and rural areas where no wired infrastructure is available.

The data transfer between the uplink (SS-BS) and downlink (BS-SS) directions with the help of Time Division Multiple Access (TDMA) in MAC protocol. The time is divided in to frames separated by time intervals. Each frame is divided between uplinks sub frame and downlink sub frame.

The downlink sub frame contains two fields for managing allocation of wireless communication.

1. DL-MAP: downlink bandwidth allocation map to tell the SS of the timetable and physical layer transmission packets bursts.
2. UL-MAP: uplink bandwidth allocation map. It controls the amount of time each SS is given access to the channel in the next uplink sub frames [3].

In the above mentioned architecture, there is a requirement to allocate slots to each SS to full fill each client’s requirements. In order to better support QoS requirement of clients, the standards defines key parameters like minimum delay & high throughput, but when & where to use there parameters to get maximum QoS performance parameter s are listed below.

Delay: We can measure delay by calculating difference between sending bytes and received bytes.

Throughput: We can find out the throughput by calculating number of bytes received per simulation time.

2. Wimax & Overview of the IEEE 802.16

The basic IEEE 802.16 architecture is having a one Base Station (BS) and one or more Subscriber Stations (SS). The IEEE 802.16 MAC is a connection oriented mechanism. Both the Base Station & Subscriber Station are immobile, when clients want to connect SS can be mobile station. Base Station (BS) acts as a central entity which transfers all the data from Subscriber Stations in point-to-multipoint architecture. There is one limitation of PMP architecture. Two or more Subscribers Station is not allowed to communicate directly. The BS and SS architectures are connected to each other through wireless links. In the network, each SS creates one or more connections over the data packets which are transmitted to and form the BS. Each connection is having 16-bit connection identifier (CID) in downlink & uplink direction. The MAC management message, which transfers data between SS and BS, manages the information for upcoming frames before actual data transfer. SS downlink channel to get downlink map and uplink map from BS. DL-Map keeps the record regarding downlink sub frames & UL-MAP keeps the information regarding uplink sub frames [8].

To establish a connection, each SS has to perform coverage ranging process and registration process. Coverage ranging process starts by sending ranging request (RANG-REQ) packets to BS in ranging contention slots. SS sends RANG-REQ in each frame till it gets ranging response (RANG-RSP). SS does the capability negotiation, authentication in sequence after successful RANG-RSP. Registration is also done in request response manner by sending registration request (REG-REQ) packets to BS and then BS send registration packets to SS [6].

Now any SS is ready to setup a connection with BS. Connection is established in the request-response manner [3].

There are two broad definitions of quality of services:

1. *User point of view QoS is:* The collective effect of service performance which determines the degree of satisfaction of user of the service.
2. *Network point of view QoS is:* The architecture that gives the network manager the ability to control the mix of bandwidth, delay, variance in delay and packets loss in the networking order to deliver a network services.(e.g. VoIP, real-time movies)

Usually, second definition is used in wireless communication to use existing resources efficiently by implementing QoS architecture.

Network performance characteristics parameters are listed below:

Latency: Transmission delay of packet from source to destination.

Jitter: Variance in transmission delay.

Reliability: The percentage of traffic of packet should be delivered successfully from source to destination.

Data Transmission rate: Amount of data that be carried from source to destination in the allocated period.

The IEEE 802.16-2004 standards support five qualities of services:

1. *UGS (Unsolicited grant service):* It uses for the constant bit rate (CBR) services application for real time data stream & fixed size data packets issued at periodic intervals.

2. *rtPS (Real Time Polling Services):* It uses for variable bit rate (VBR) services application for real time data streams &variable sized data packets that are issued at periodic intervals. ex. MPEG video.

3. *ertPS (extended real time polling Services):* Real time service flows that generate variable sized data packets on a periodic basis .ex. VoIP.

4. *nrtPS (Non-real time polling services):* Delay tolerant data streams & variable sized data packets for which a minimum data rate is required ex. FTP with minimum data rate.

5. *BE (best efforts):* Data Streams for which no minimum services level is required and therefore may be handle on space available. Ex. HTTP.

3. Literature Survey

3.1 Design of QoS or Scheduling Architecture

In [8], the authors have described their scheduling architecture through ns2 [2] simulations. This scheduling architecture is based on GPSS grant mode with min-max fair allocation for uplink scheduling and WFQ for downlink scheduling. The uplink scheduling is not exactly GPSS mode scheduling because in first stage slots are circulated into four uplink flows (on max-min fair basis) then each flow bandwidth is circulated into SSs. Moreover constant weights are used for UGS (weigth 4), rtPS (weigth 3), nrtPS (weigth 2) and BE(weigth 1) flows. The choices of these (constant) weights do not have any underlying justification. In SS uplink scheduler of their architecture, SSs send bandwidth request packets (just after finish sending UGS packets) to BS in unicast uplink slots selected to this SS. In simulation analysis of this study, the authors are more determined on number of SSs rather than the number of flows.

In [9], the suggested uplink scheduling algorithm is Weighted Round Robin (WRR) [10] with GPSS grant mode. The duration of contention slots and uplink data slots are dynamically circulated according to bandwidth requirements. The authors chose five priority queues with dynamic priority ready for action ratio parameter assignment. In the ratio assignment has no justification. The authors has use some traffic policing and traffic shaping methods to stop SSs using more than allocated bandwidth. In this paper no simulation or analysis results are given.

In [11] the authors suggest QoS enhancement of IEEE 802.16 standard based on cross layer optimizations. These optimizations include traffic classifications and packet mapping strategies of Different services. The authors also design some admission control mechanism at BS. A hierarchical (two-layer) scheduling algorithm is deployed at BS. Six queues are defined according to their direction (uplink and downlink) and service classes (rtPS, nrtPS and BE). Fixed bandwidth allocated to UGS flows (and deducted the same from total available bandwidth before two-layer scheduling). Deficit Fair Priority Queue (DFPQ) [14] is used as first layer scheduling algorithm. In the context of scheduling algorithms for different flows (except UGS), Early Deadline First (EDF) used rtPS, WFQ for nrtPS and Round Robin (RR) for BE flows. This work is more towards cross layer QoS optimization rather than QoS scheduling algorithm for IEEE 802.16 architecture. The author presents simulation results to show the effectiveness of their cross layer QoS architecture without mentioning their simulation platform.

In [12], the authors have designed an analytical model of MAC protocol for BWA systems with a traffic scheduling mechanism based message and SSs priorities.

In [13], the authors suggest uplink bandwidth allocation algorithms based on flow type and strict priority from highest to lowest - UGS, rtPS, nrtPS and BE. The authors use simulation model developed in C++ to show the effectiveness of their algorithm.

4. Proposed Scheduling Algorithm

A single hop (node) Wi-MAX provides high flexibility to attain quality of service in terms of data throughput, achieving the same in multi hop Wi-MAX is challenging.

One of the major problem is dealing with the ability of IEEE 802.16 MAC to manage traffic generated (scheduling) by multimedia application or multimedia streaming from transmission of the neighboring Wi-MAX node.(i.e. rural environments).

4.1 Proposed MAC Scheduling Architecture

The IEEE 802.16 standard categorizes the uplink sub-frame into three parts namely coverage ranging period, bandwidth contention period and data uplink. We can say that BandWidth Contention (BWC) mode [1, 2]. We can also say that there are two situations:

1. *BWC (Bandwidth Contention):* Bandwidth contention is available.

2. *NBWC (No Bandwidth Contention):* In this mode no bandwidth contention is available & the uplink sub frame is divided in to two parts coverage ranging period & data uplink period.

As mentioned in [3] that flow isolation is also necessary at the router (BS is a router also) in the case of unresponsive flows. Our proposed scheduling architecture broadly contains five parts− WFQ unit, BS allocation unit, SS uplink unit, BS downlink unit, and Classifier unit. WFQ unit has been used two times in our architecture. One copy of WFQ unit is insides the BS allocation unit and the other outside copy used for downlink scheduling.

4.1.1 WFQ unit

This unit is solely responsible for allocating the available bandwidth to different flows in ratio of their assigned weights. In the WFQ scheduling algorithm [12] is an approximation of Generalized Processor Scheduling and requires

1. Weights assigned to each flow and queue length for each flow. WFQ algorithm calculates the stop time of every arriving packet and adds this packet in Generalized Processor Sharing (GPS) queue. The stop time of every packet is function of its size, weight assigned to its flow.
2. The stop time of the last packet in its queue Packets are dequed from GPS queue in stop time order.

For WFQ scheduling procedure using the uplink direction, each SS has to communicate two effects

1. The number of packets waiting on its number of connection(s) and the sizes of the waiting packets. For UGS, nrtPS and BE flows, the SS has to send the total number of waiting packets
2. For rtPS flows SS has to add sizes of different packets. We can say that complete information as queue information which has to be sent to BS. WFQ scheduling algorithm in downlink direction is directly forward as the BS has all queues information and assigned weights to respective application [12].

4.1.2 SS Uplink Unit

This unit is responsible for allocating data uplink slots for connections. These slots are used by an SS to send data in the uplink direction. BS wants to know the queue information (number of coming up packets and size of each packet) of connections at each SS for WFQ scheduling. This WFQ for uplink direction is completed virtually at the BS, in fact the BS knows queue information of connections from previous frame status and it can almost simulate GPS listing and enlisting purpose. For each enlisting call, BS allocate slots to the corresponding CID (CID with which this packet is connected by Classifier module) and it is related to the enough number of slots left in uplink sub-frame [7].

In ranging process, each SS chooses its connection window, waits for that many slots then sends Ranging Request (RANG-REQ) packets to BS. Any SS will keep doing the same in each frame till it gets Ranging Response (RANG-RSP) from BS. Once any SS got RANG-RSP from BS, it sends Registration Request (REG-REQ) to BS and waits for the Registration Response (REG-RSP). Once any SS gets REG-RSP from BS, it is now ready to send connection request with specified flow type to BS [4].

In NBWC mode, these architecture does not have any bandwidth contention period, so any SS sends the request packets (ranging, registration and connection) in ranging period only, while in BWC mode the request packets (registration and connection) are sent in bandwidth contention period[3].

4.1.3 BS downlink Unit

This unit is accountable for whole downlink scheduling of packets from BS to SSs. BS uses WFQ unit for downlink scheduling of packets. When the uplink sub-frame packets ends, BS first broadcast DL-MAP and UL-MAP, then RANG-RSP packets, then REG-REP packets, then CONN-RSP packets then starts sending downlink data packets to SSs. The downlink channel is always broadcast channel. The weights for different flows in downlink direction are same as in uplink direction. The WFQ scheduling is not virtual here (as in the case of BS allocation module) because BS already has the entire waiting lengths and size of each downlink packet.

4.1.4 Classifier Unit

This unit is responsible for the association of incoming IP packets with connections. We are doing this association based on the flow-id of incoming IP address packets. Therefore each SS maintains many MAC level FIFO queues. The number of MAC level queue is same as the connections formed between this SS and BS. Equivalently each connection has its own MAC level queue maintained at SS side. Incoming packets are queued in respective MAC level queue after classification.

4.2 Working of Scheduling Algorithm

The operational scheduling algorithm is to provide rtPS service flow packets with more chance to meet their bandwidth as per requirement and decrease the delay. In fig.4.2 shows Apart from checking if the allocated bandwidth is enough for granting a request, the system has to check the QoS polling services, nominal polling jitter and reference time (the time used as a reference to calculate both the generation time and the target of the rtPS data grants) related to the rtPS service flows that are apply.

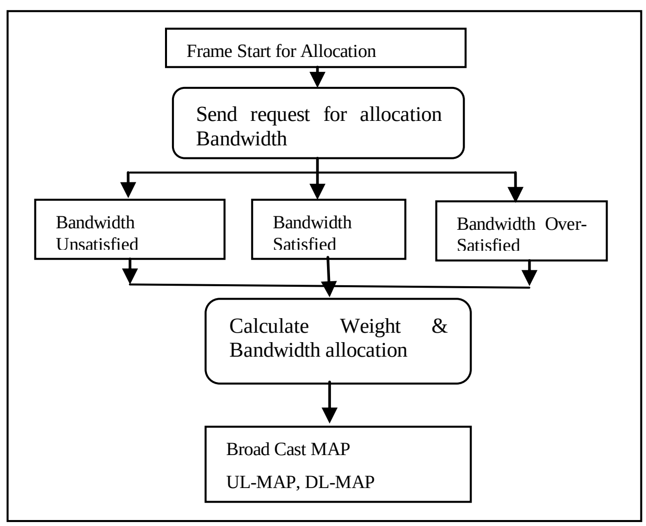

Fig. 4.2 Operational Flowchart of Scheduling Algorithm

The information gathered from this monitoring is used to approximate the expected delay of each rtPS connection and the proposed scheduling algorithm, is used to calculate the target throughput & delay.

5. Conclusion

In this paper we emphasis on a MAC scheduling architecture for IEEE 802.16 standards. The MAC scheduling architecture uses WFQ as the downlink as well as the uplink scheduling algorithm for improving delay and throughput.

Downlink scheduling is easy because only involved entity is BS and it has all the required information for the same. For uplink scheduling, each SS has to send its queue information to BS. As clear in the standard, SSs can send their bandwidth request to BS either in bandwidth argument period or in unicast a slot which is allocated to SSs in each frame or through return the connections demands with data packets.

In the operational scheduling algorithm, we have broadcast MAP according to the bandwidth allocation request.

6. References

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