# QoS Provisioning Through Bandwidth Granting Scheme for Wireless Networks

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*Abstract*— **Quality of Service (QoS) is an essential element in modern wireless networks such as WiFi, Long Term Evolution (LTE) and Worldwide Interoperability for Microwave Access (WiMAX). The QoS provisioning of a wireless network can be secured in the scheduling, admission control, bandwidth granting and queuing components that reside at the MAC layer. This paper focuses on the bandwidth granting mechanism for uplink traffic transmission. Until now, not much study has been done by researchers on improvements of this particular mechanism although it is an important component in QoS framework. Through our experiments, it is discovered that the network performance could be further improved by introducing custom-designed mechanisms in the bandwidth granting process. Another thing to note is that not all the common scheduling algorithms are appropriate to be implemented since the information on the bandwidth granting process is very limited. Furthermore, the design of bandwidth granting mechanism must be simple and fast. Thus, by taking into account these limitations and concerns, two mechanisms have been proposed and evaluated in this study. The traditional and typical approach used in bandwidth granting scheme is bench-marked and compared with our proposed mechanisms. The simulation results show that our proposed mechanisms outperform the conventional approach.**

***Keywords- scheduling;bandwidth granting;quality of service; 4G; wireless network***

## I. INTRODUCTION

Worldwide Interoperability for Microwave Access (WiMAX) is an example of broadband wireless access (BWA) and defined by IEEE in its IEEE 802.16 standards [1][2]. The IEEE 802.16 standard is further divided into two categories which are the IEEE 802.16d (fixed WiMAX) and the IEEE 802.16e (mobile WiMAX) [2]. The recent development in the WiMAX standard has allowed many service providers to adapt this technology as the alternate solution for last-mile delivery.

Theoretically, broadband access to an area blanketed by a radius of 31 miles can be covered using the WiMAX technology [1], [2]. This distance is achieved when using WiMAX for line-of-sight (LOS) backhaul service. However, for a deployment in the urban environment, it is difficult to achieve LOS between the receiver and the BS. In NLOS WiMAX, the signals arriving may come from reflected paths, scattered energy and some diffracted propagation paths. Hence, the area size is significantly lesser with only a radius of 3 to 5 miles covered.

Its higher bandwidth and large area coverage compared to other BWAs makes WiMAX a suitable solution for many applications. Some examples of these applications include high quality Voice over Internet Protocol (VOIP), Video on Demand (VoD) and Internet Protocol Television (IPTV) services.

The ability to be able to support multimedia applications such as IPTV and VoD is a challenging task faced by Internet Service Providers (ISP) worldwide. The Quality of Service (QoS) assurance for these multimedia applications is usually implemented from the application layer to the physical layer. Unlike other layers, the layer 2 (or the MAC layer) is varied from one technology to another. It is highly dependent on the medium access technology, especially when using wireless as the medium of access.

As one of the prominent 4G technologies, WiMAX is designed to support all kind of services with QoS assurance. In general, the MAC layer is responsible to assure the quality of packet delivery. There are many components in the MAC layer that assist in QoS provisioning. Some examples include the Call Admission Control (CAC), uplink/downlink schedulers, ranging, fragmentation and defragmentation, classifier and MAC management entity. The entire MAC architecture for subscriber station (SS) and base station (BS) is shown in Fig. 1.

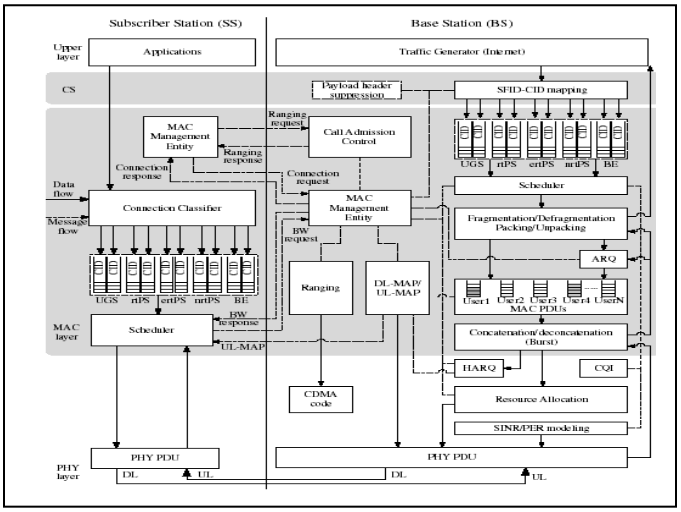

Fig. 1. MAC architecture for IEEE 802.16

Incoming traffic is categorized into five service classes in IEEE 802.16 [1], [2]. The five service classes are the Unsolicited Grant Service (UGS), Extended Real-time Polling Service (ertPS), Real-Time Polling Service (rtPS), Non-Real Time Polling Service (nrtPS), and Best Effort (BE). UGS traffic is aimed for VOIP service without silence suppression while ertPS service is for VOIP with silence suppression. Meanwhile, rtPS is designed for real-time Internet application such as VoD and online gaming. Both nrtPS and BE are targeted on non-real time services. Specifically, nrtPS is focused on the non-real time services that require bandwidth in variable sizes.

The main contribution of this study is addressing the issues in bandwidth granting scheme at base station in WiMAX network, which has been overlooked by many researchers. Unlike uplink scheduler or downlink scheduler, information is very limited during bandwidth granting scheme. BS is unlikely to know the queue status, incoming packet rate or packet delay from the bandwidth requested message obtained from SS. Thus, most of the recent scheduling techniques are unable to work in bandwidth granting protocol. Proportional bandwidth granting schemes have been proposed and investigated in this study.

This paper is organized as follows. Section II presents the bandwidth request/granting process of the IEEE 802.16e and Section III describes the proposed bandwidth granting mechanisms. Section IV depicts the simulation experiment environments and discusses the simulation results. Lastly, conclusions and future plans are presented in Section V.

## II. BANDWIDTH REQUEST/GRANTING PROCESS

Despite there being several QoS components in the MAC layer, our research is only focused towards the bandwidth granting mechanism for uplink transmission. The bandwidth granting process happens only at the BS when a SS is requesting bandwidth for its uplink transmission, whereby uplink transmission is defined as the transfer of packet from a SS to the BS. The uplink transmission is much more complicated than the downlink transmission because the information required by the uplink transmission is very limited compared to the downlink transmission. Local information such as the queue size is always available in the downlink transmission [3] but not for the uplink.

Before an uplink transmission can commence, a SS is required to send a bandwidth request message to the BS. The bandwidth request message can be sent either explicitly or implicitly. In the explicit approach, the bandwidth request is attached and embedded in the data message while in the implicit approach, the bandwidth request is the only message sent to the BS. Another common bandwidth request approach is the contention based [4] approach. Contention based approach in the IEEE 802.16 is identical to the contention approach used in the IEEE 802.11. See TABLE I for the eligibility of bandwidth request for different service classes. The IEEE 802.16 standard allows the bandwidth request to be done on per connection basis or per station basis. The bandwidth request per station is claimed to be more efficient due to the low management message usage [5].

TABLE I UPLINK REQUEST RULES

| UL request/grant | UGS | rtPS | nrtPS | BE |
|---|---|---|---|---|
| Implicit | | √ | √ | √ |
| Explicit | | √ | √ | √ |
| Contention based | | | √ | √ |

Upon receiving a bandwidth request message, the BS stores the message in a queue based on its arrival time. The bandwidth request messages are processed by the bandwidth granting module before a new frame starts. This bandwidth granting process is very challenging since the information available is limited [6], [7]. From the bandwidth request messages received, the BS only have the information on the amount of bandwidth needed by the SS and the service class requirements. The situation becomes worse when the requests are from homogeneous application or the requesters are having similar QoS requirements. In this context, the BS can only depend on the amount of bandwidth needed during the bandwidth granting process. Due to the above concerns, many scheduling algorithms commonly used in uplink/downlink scheduler are not suitable in the bandwidth request module. For instance, strict priority policy used in downlink scheduler [7], [8] is meaningless when the requests are from homogeneous applications. Weighted round robin [10], deficit round robin [11], weighted deficit round robin [12], worst-case fair weighted fair queuing [13], earliest deadline first [14] and other packet information based scheduling approaches from [15], [16] and [17] are not able to be implemented in bandwidth granting module because of the unavailability of packet and queue information from the SS. Moreover, the bandwidth granting scheme is always neglected by many researchers and the most typical algorithm used in the bandwidth granting scheme is first-come-first-serve basis [9], [18]**.** Hence, a custom-designed mechanism for the uplink bandwidth granting is needed and essential. We observed that the bandwidth granting mechanism which is not getting adequate attention of researchers has an important role in QoS provisioning of an IEEE 802.16e network. Experiment results have proven that the network performance (throughput and jitter) can be improved by introducing custom-designed bandwidth granting mechanism.

## III. PROPORTIONAL BANDWIDTH GRANTING SCHEMES

The proposed bandwidth granting schemes consist of i) proportional byte based (PBB) and ii) proportional physical slot based (PPSB). In general, the amount of granted bandwidth of a SS depends on the following:

- Total amount of bandwidth request
- Individual amount of bandwidth request
- Total amount of available bandwidth

Total amount of bandwidth request is the summation of all individual bandwidth requests from each SS at the current cycle. Meanwhile, individual amount of bandwidth request is referring to the bandwidth request received by BS for each SS. Last but not least, total amount of available bandwidth is given by the vacancy slots, which are ready for transmission in the next cycle.

The proportional byte based approach in bandwidth granting mechanism, PBB, is first presented in this research. The PBB mechanism keeps the individual bandwidth request in the byte format, which is its original value extracted from the bandwidth request message. The amount of granted bandwidth is calculated according to the percentage of occupancy by an individual bandwidth request. More bandwidth is given to those requesters who have higher bandwidth demands without consider any channel condition or modulation scheme. Unlike the approach used by [9] and [18], all requesters will be given some amount of the available bandwidth in PBB. At least some portions of the bandwidth will be granted to every SS and hence, starvation of SS can be avoided. This approach intended is to give fairness to all of the requested too. The formula for PBB in bandwidth granting is as in (1).

$$BW_i = \left\lfloor \frac{BR_i}{\sum BR} BW \right\rfloor \tag{1}$$

where $BW_i$ is the amount of granted bandwidth and $BR_i$ is the amount of individual bandwidth request for the *i*th request respectively. $\sum BR$ represents the total amount of the bandwidth requests while for the *BW,* this is the total available bandwidth.

The second mechanism, PPSB is similar to PBB but it also takes into account the concern in [19], whereby the conversion from bandwidth request in byte to physical slot causes extra unused bandwidth to be allocated. In order to overcome this issue, PPSB converts the amount of bandwidth request, the total amount of bandwidth and the available bandwidth from byte to physical slot before any bandwidth allocation calculation. The conversion of byte to physical slot requires the Channel Quality Indicator (CQI) data for each SS. Overall, a better CQI is able to carry more data as compared to a lower CQI. PPSB mechanism also provides a more accurate allocation when there are different wireless network conditions in a scenario. As known, poor CQI requires more physical slots to send the same amount of data compared to those SSs in a better CQI network. The byte to physical slot conversion is based on (2).

$$\mathrm{BRPhySlot} = \frac{\mathrm{BRbyte}}{\mathrm{bytePS}} \tag{2}$$

where *BRPhySlot* is the bandwidth request in physical slot unit, *BRbyte* is the bandwidth request in byte unit and the *bytePS* reflects the amount of data in bytes that can be carried by a physical slot, which depends on Uplink Interval Usage Code (UIUC) as in TABLE II. In general, a higher UIUC index will result more bytes per slot. Maximum 27 bytes per physical slot is defined in [3].

TABLE II UIUC INDEX AND BYTE PER PHYSICAL SLOT

| UIUC Index | Number of Byte per Slot |
|---|---|
| 1 | 6 |
| 2 | 9 |
| 3 | 12 |
| 4 | 15 |
| 5 | 18 |
| 6 | 24 |
| 7 | 27 |

Upon the conversion, the amount of granted bandwidth is then calculated by using (3). Through this approach, the loss during the conversion may be identified. PPSB is also designed for network scenario whereby more than one wireless conditions or modulation and coding schemes are found in a WiMAX network.

$$\mathrm{BWPS_i} = \left\lfloor \frac{\mathrm{BRPhySlot}_i}{\sum \mathrm{BRPhySlot}} \mathrm{BWPhySlot} \right\rfloor \tag{3}$$

where $BWPS_i$ is the amount of granted bandwidth in physical slot unit and $BRPhySlot_i$ is the amount of individual bandwidth request in physical slot for the *i*th request respectively. $\sum$*BRPhySlot* represents the total amount of the bandwidth requests whereas the *BWPhySlot* is the total available bandwidth in physical slot.

## IV. SIMULATION EXPERIMENTS

### A. Simulation Model and Environment

The simulation experiments were conducted using Qualnet network simulator version 5.0. The network scenario is a single cell with a BS and 10 SSs as in Fig. 2. All the SSs are located 150 meter away from the BS. The network simulation parameters for our experiment are as presented in TABLE III.

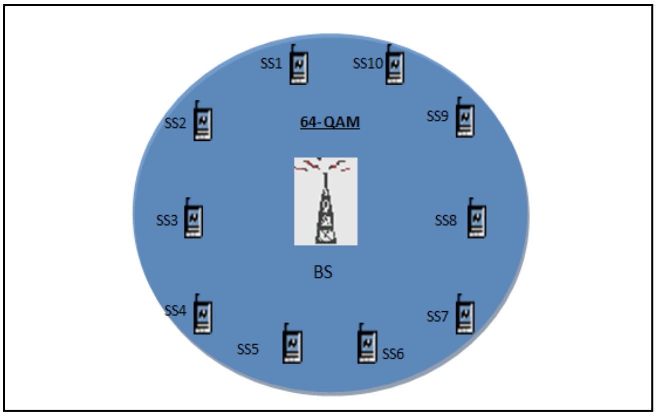

Fig. 2. Simulation scenario

TABLE III SIMULATION PARAMETERS

| Simulation Parameters | |
|---|---|
| PHY | OFDMA |
| Bandwidth | 20MHz |
| Cyclic Prefix, FFT Length | 1/8, 2048 |
| UL/DL Frame Length | 10ms |
| Modulation | 16,64-QAM |
| Antenna Type | Omni-directional |
| Simulation Duration | 0 - 90s |
| Wait UCD/DCD timeout interval | 25s |
| UCD/DCD | 5s |

In order to validate the performance of the proposed bandwidth granting mechanisms in a homogenous environment, some slight modifications on the incoming traffic which base on [18] is used. Only rtPS traffic is selected and it is examined in our experiments. The performance of the proposed granting mechanisms in handling the traffic from the same service class is to be observed in our study. Furthermore, rtPS is designed for video and multimedia transmission, whereby both are more challenging and demanding. All the SSs were equipped with 2 uplink traffic with a 0.8 Mbps and a 1.2 Mbps traffic load respectively. Both implicit and explicit mechanisms were allowed in the bandwidth request mechanism.

The experiments were simulated in a network scenario, whereby no different modulation scheme and coding or no different wireless network condition were created. A network scenario with only one type of wireless network condition, the 64 QAM was simulated. Our intention in this context was to test the efficiency of the proposed bandwidth granting mechanisms in the IEEE 802.16e network.

Our proposed bandwidth granting mechanisms is benchmarked against the common bandwidth granting mechanism (CBGM) approach used by [9], [18] and the statistical approach (SA) from [20]. The network performance metrics; throughput, delay, and jitter, are makred as the major assessment elements in this study. We also assumed that there will be no new incoming traffic during the simulation.

### B. *Simulation Results and Discussions*

Fig. 3 shows the total average end-to-end throughput for CBGM, PPSB, PBB and SA over the simulation time. The SA produces the highest throughput for the first 20 seconds of the simulation time. During the first 20 seconds, bandwidth requests for all SSs are at a moderate level, the reserved bandwidth is significant to be distributed fairly by using SA approach [20]. However, the performance of SA is overtaken by PPSB and PBB after the 30 seconds mark. The proposed PPSB and PBB always perform better than CBGM in this study. PBB mechanism achieves 1.29% higher total throughput in average as compared to CBGM. The gap of difference between the PBB and CBGM becomes smaller along the simulation time. Also, it is observed that there is no significant difference between the PPSB and PBB in terms of throughput. These results indicate that byte to physical slot conversion issue is negligible in proportional approach when all the SSs are within the same modulation scheme and coding.

The total average end-to-end delay is presented in Fig. 4. CBGM has the best performance for the first 30 seconds. For 40 seconds and onwards, SA has the lowest latency. There is a very significant different between CBGM and other approaches at the 10 seconds mark. The difference between PBB/PPSB and CBGM gets lesser as the simulation time passes. It averages about 12% higher delay between PBB/PPSB and CBGM at the 90 seconds mark. Similar to the findings of the above, both PPSB and PBB do not have significant difference in the delay performance. For instance, PBB is only 0.5% better than PPSB at the 90 seconds mark. Also, SA is the best performance for this category except during the first 30 seconds.

From Fig. 5, for the total average end-to-end jitter, it is observed that both the PBB and PPSB mechanisms have improved the jitter performance of IEEE 802.16e networks, regardless of the simulation time. It is also observed that the SA has the worst results in this context. The jitter is improved from the range of 4.6% (at 10 seconds) to 2.1% (at 90 seconds) when comparing the PPSB with CBGM. This phenomenon reflects that the PPSB and PBB mechanism spare some bandwidth to every SS instead of one or two greedy SS. Greedy SS requests and consumes a majority of the available bandwidth than others. The network becomes less healthy when the number of greedy SS increases. It is observed that the PPSB and PBB have an impact in controlling the greedy SS but it is not significant enough.

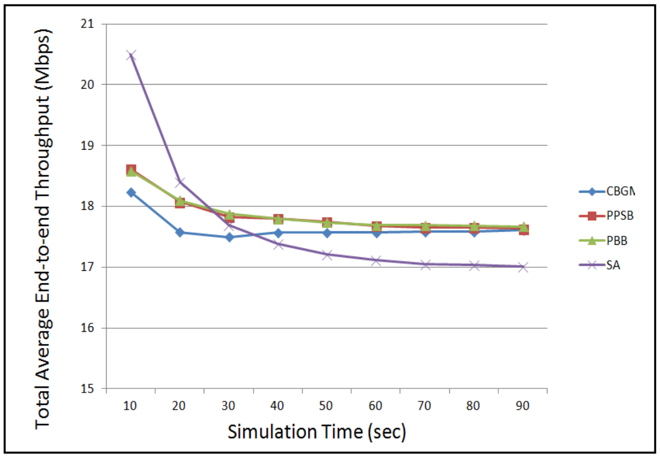

Fig. 3. Total average end-to-end throughput

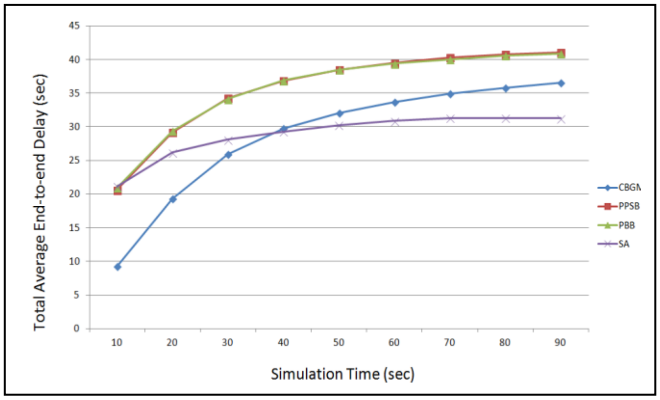

Fig. 4. Total average end-to-end delay

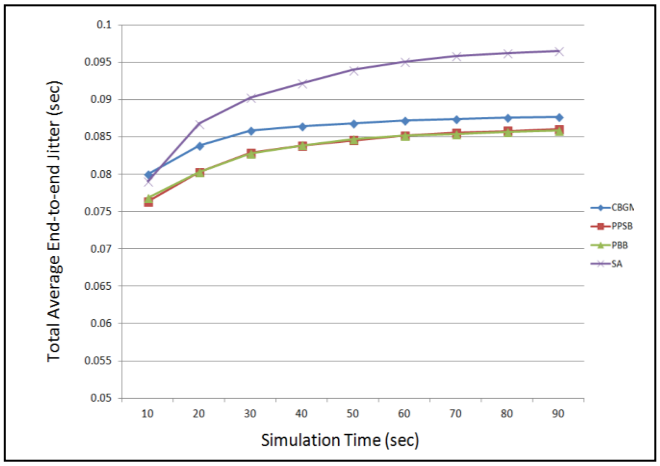

Fig. 5. Total average end-to-end jitter

## V. CONCLUSION AND FUTURE DIRECTION

PPSB and PBB have the better average throughput and jitter, as observed from the simulation results. However, both PPSB and PBB failed to improve the delay, which is one of the crucial performance metrics for rtPS traffic. The poor delay result cannot be compromised for real-time application although a better result in throughput and jitter could be achieved. In conclusion, the PPSB and PBB are not suitable for real-time traffic. PPSB and PBB are for non-real-time applications (nrtPS traffic) that do not have delay stringency and only target on the throughput. We also observed that some mechanisms to regulate the greedy bandwidth requesters and custom-designed bandwidth granting scheme is urgently needed, especially for homogenous application.

From the results obtained, the proposed PBB and PPSB will be tested again by using nrtPS traffic, which does not have delay requirement. The modulation scheme and coding is another important consideration in carrying out a research in wireless networks. Hence, more network scenarios in different modulation schemes and codings will be created for a more extensive testing in the future.

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