Intensive Bandwidth Request and Handling Design in PMP

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Abstract
This paper carried out a study on the uplink bandwidth request and handling for different service classes in WiMAX. Real time Polling Service (rtPS) acquires uplink bandwidth through contention based and polling mechanism. Each of the rtPS service is polled by base station (BS) on a periodic basis. Long waiting in polling mechanism may delays packets transmission. In this paper, we observed that polling mechanism used by rtPS could be further improved. On top of that, bandwidth wastage is observed when a BS is allocating bandwidth in uplink transmission. Conversion from bandwidth request in byte to physical slot (PS) causes extra unused bandwidth been allocated. A more precise conversion from byte to PS could ease this problem. Thereby, this paper proposed a scheme to overcome these two problems. Two sub modules of the proposed scheme were introduced at BS and customer premise equipment (CPE) respectively. Through extensive simulations, results show that the proposed scheme improves the performance for both real time and non real time polling services.

Key words:
Quality of service, bandwidth request, IEEE 802.16, WiMAX.

1. Introduction

In modern data communication, network accesses are moving toward wireless technologies, such as 3.75G, 4G, wireless Asynchronous Transfer Mode (ATM) and Long Term Evolution (LTE). Worldwide Interoperability for Microwave Access (WiMAX) or IEEE 802.16 is one of the 4G broadband wireless accesses (BWA) that delivers high-speed Internet services in several large geographical areas. WiMAX is also considered as a wireless version of the Ethernet which able to provide broadband access to a large number of clients with some salient features, for example quality of service (QoS) and security.

The design of WiMAX is typically consists of two major components which are WiMAX Base Station (BS) and its receiver (WiMAX CPE). As defined in IEEE 802.16 standard [1-3], there are two types of network architecture in WiMAX: point to point and point-to-multipoint (PMP). The point to point or known as backhaul is used when there are two or more BS points are interconnected to exchange data. In contrast, BS acts as central point to all the customer premise equipments (CPEs) and serves as a hub and gateway between wired and wireless network in point-to-multipoint. Thus, the BS is able to serve hundreds of different CPEs in its network with different requirements.

Triple-play service is a challenging commitment to today's broadband technologies. Users tend to have voice service, online video and Internet surfing simultaneously. Therefore, broadband access technologies must capable to categorize the user's traffics into different classes and serve the traffic according to the QoS needs. In WiMAX, incoming traffics are classified into 5 different QoS classes which are: 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). Among these, UGS is targeted on voice application with constant bit rate and ertPS is proposed for voice over IP (VOIP) without silence suppression that has variable rate and delay requirements. Meanwhile, rtPS is associated with real-time video application such as Moving Pictures Experts Group (MPEG). Delay insensitive applications, like File Transfer Protocol (FTP) and web browsing are grouped under nrtPS and BE service classes respectively.

UGS has the highest priority in IEEE 802.16 with several mandatory QoS parameters such as minimum reserved traffic rate, maximum sustained traffic rate, maximum latency and tolerated jitter. ertPS is the second highest in QoS ranking, followed by rtPS. Both service classes are stringent in delay and therefore minimum reserved traffic rate, maximum sustained traffic rate and maximum latency are defined as their QoS parameters. On the other hand, non real time service classes (nrtPS and BE) are bounded by maximum sustained traffic rate. However, nrtPS service class needs to maintain a minimum reserved traffic rate since a minimum data rate is required by file transfer applications.

In order to support the five different service classes in WiMAX, media access control (MAC) layer has been designed and enhanced [1-3]. The specific tasks are distributed on all the sub modules in MAC layer. Scheduler, one of the sub modules in MAC layer, has its role in bandwidth distribution and allocation. However, scheduling algorithms are proprietary implementation

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according to [1]. Therefore, we address the issues in bandwidth request mechanism at CPE as well as the bandwidth request handling technique at BS. In general, the contributions of this study are:
1. Investigate the bandwidth request processes at CPE and mitigate those factors that caused deterioration in network performance.
2. Proposed bandwidth request handling technique at BS that correlates to bandwidth request mechanism at CPE.

This paper is organized as follows; Section 2 presents related research backgrounds and the motivations of our work. Section 3 covers our proposed scheme with detail explanation. Simulation parameters and traffic models are discussed in Section 4. Section 5 discusses simulation results and Section 6 concludes this study.

2. Motivation and Related Work

PMP broadband communication is the focus in this paper because the authors are investigating the bandwidth request and the centralized bandwidth allocation. In PMP mode, each CPE does not communicate directly to other CPE but BS. BS decides the downlink (DL) and uplink (UL) transmission in the network. DL is the transmission direction from BS to CPE while UL means transmission from CPE to BS. In DL transmission, all CPEs are in listening state when BS is sending out the user and management data. DL transmission is highly depending on its DL scheduler. Among the research studies on DL scheduler, round robin (RR), weighted round robin (WRR), deficit round robin (DFF), weighted fair queue (WFQ), earliest deadline first (EDF), proportional fairness (PF) and static priority (SP) had been proposed and evaluated in [4 -6]. On top of that, combinations of several common schedulers were also proposed. In [7], evaluation of SP+WFQ and EDF+WFQ+FIFO had been carried out. A DL bandwidth scheduling scheme to allocate downlink bursts in a heuristic way was proposed in [8].

Process of UL transmission in UL is more sophisticated than DL. In UL, both BS and CPE have their own independent procedures to allocate and acquire bandwidth. In CPE, a routine to check the current queue size for each service flow will be called before a bandwidth request message been constructed. In general, the information on queue size is used as the amount to request bandwidth in next cycle. Besides, a predictive approach in bandwidth request based on the queue size and the rate mismatch between packet arrival and service rate was proposed in [9]. Bandwidth request messages built from all service flow are then inserted onto queues according to their service classes. Subsequently, bandwidth request messages are sent to BS in an opportunistic or polling basis. However, bandwidth request is not applicable to UGS service class. UGS bandwidth is directly granted by BS without any bandwidth request required. For rtPS and nrtPS, periodic polls and contention based bandwidth request are applied. BS fixed a periodic interval to poll all its rtPS and nrtPS service flows. This mechanism is very effective in order to maintain the QoS structure in WiMAX. For BE, the least service class in IEEE 802.16, has only the contention based access to handle its bandwidth request.

On the other hand, once BS received bandwidth requests from service flows, the requests will be stored in a queue. Right before the next cycle starts, BS will assign the available bandwidth on per CPE basis according to the QoS priority and request amount. Bandwidth amount is converted to physical slot (PS) and inserted into uplink map (UL MAP) message to inform the details of the uplink allocation to the CPE through broadcast. This process in called bandwidth request handling in WiMAX.

With the uplink allocation message in UL MAP received, the CPE will revoke its UL scheduler to perform data transmission. Similar to the scheduling approaches proposed in DL at BS, RR, WRR, DFF, WFQ, EDF, PF, SP and priority based in [10] schedulers are been implemented as UL scheduler. In addition, [11] proposed two layers scheduling architecture with Deficit Fair Priority Queue (DFPQ) which inherit Deficit Weighted Round Robin (DWRR) proposed by [12] at first layer. In second layer, it associate rtPS connections with EDF, nrtPS connections with WFQ and BE connections with RR respectively.

Other than the scheduling focus in MAC layer only, several studies on cross layer design for MAC and physical (PHY) layer condition of WiMAX are analyzed. The authors in [13] proposed using priority based scheduling algorithm at MAC layer for a several connection offers prescribed delay, rate guarantee, flexibility and scalability with minimal implementation complexity. At PHY layer, each connection uses the adaptive modulation and coding (AMC) scheme so that the connection is updated dynamically. In [14] the author proposed two tier priority scheduler and bucket based burst allocator. The framework considers network throughput, long term fairness, real time traffic, sub frame utilization and also burst allocation complexity. In [15], a cross layer design framework of video multicasting for robust IPTV services over IEEE 802.16 networks was introduced, where a joint design of source and channel coding techniques in last hop wireless channel was investigated. The proposed framework was characterized by a suite of manipulative mechanisms of interplay between novel modified Multiple Description Coding (MDC) techniques on scalable video.

From the related works above, we observed that the processes on building bandwidth request message at CPE and bandwidth request message handling at BS have crucial roles in UL resource management. With good design of bandwidth request constructer and bandwidth request message handler, performance of a PMP network could be maximized.

Polling and contention based bandwidth request are the methodologies to acquire UL bandwidth from BS. Contention based scheme is relied on the backoff algorithm to compete the opportunity in sending the bandwidth request message. Hence, this strategy is not efficient for rtPS and nrtPS, which have variable rate and large amount of data. Therefore, polling mechanism is proposed in [1-3] to cater the QoS requirements of these two service classes. rtPS and nrtPS service flows will be polled by BS based on periodic interval time. Thus, improper timer configuration on the polling interval time will result degradation of network performance.

Second, bandwidth request is on connection basis and the bandwidth allocation is on per CPE basis in WiMAX. BS accumulates all the allocated bandwidth of a CPE and informs the CPE regarding its UL slot through UL MAP. Scheduler which handle the bandwidth request message at BS must capable to distribute the resources fairly among the CPE or service flows by considering other factors besides the QoS service classes concerns.

3. Proposed Scheme

In this study, we only consider the UL transmission where there are involvement of bandwidth request message constructor and bandwidth request handler. The objectives of our research are twofold: 1) Improve the performance of real time service flow by enhancing the bandwidth request processes and 2) the bandwidth utilization is improved by removing extra allocated bandwidth. To achieve the objectives, intensive bandwidth request and handling (IBRH) scheme from us is proposed. The main goal of our scheme is to utilize the bandwidth request opportunity of nrtPS by rtPS traffics and minimize the bandwidth wastage.

IBRH scheme consists of a sub module called rtPS Rapid Request (rRR) in the bandwidth request module of CPE and a rtPS Redundant Detection and Normalized (rRDN) sub module in the bandwidth request handling module at BS. rRR sub module takes the advantage on nrtPS polling method by putting in the rtPS bandwidth request together with nrtPS. Compared to technique in [16, 17] where the polling method is isolated between rtPS and nrtPS, rRR approach incorporated some of the bandwidth request of rtPS with nrtPS. Through this, bandwidth request from rtPS can be updated regularly and precisely. Meanwhile, no changes for the bandwidth request on other service classes. By this approach, the interval gap for rtPS polling could be smaller down and its QoS performance improved. The algorithm of rRR is depicted in Algorithm 1 below.

Algorithm 1: rRR sub module
```
For i to n service flow do
 calculate its current queue size
 If flow's service class == nrtPS
    check the status of rtPS polling
    If  status of rtPS polling == pending
       calculate the bandwidth request of rtPS service flow
       // total up rtPS request and own bandwidth request
       bandwidth request = rtPS request + queue size
   else
    bandwidth request  =  nrtPS request
 else
   bandwidth request = queue size

End For
```

rRDN sub module is resided in the bandwidth allocation module of BS. The rRDN is designed for two goals, which are to detect and remove nrtPS bandwidth request redundancy and to allocate not more than requested bandwidth. The full algorithm for rRDN is discussed in Algorithm 2 below. As the counter part of rRR which allows rtPS bandwidth request to consolidate with nrtPS service, rRDN is formed to ensure that is no redundant bandwidth occurs. Redundant bandwidth occurrence is where rtPS is received as well as the consolidated bandwidth request for both rtPS and nrtPS. In this incident, rRDN will has to remove the extra request from the nrtPS bandwidth request (rtPS bandwidth request is consolidated with nrtPS request). In addition, rRDN implements the removal engine in byte to PS conversion. In the [16, 17], the conversion from byte to PS is done by rounding up the amount PS to the largest integer as described in (1).

$$BR\ in\ PS = \left\lceil \frac{BR\ in\ byte}{byte\ per\ PS} \right\rceil \qquad (1)$$

where *BR in PS* is bandwidth request of a service flow in PS unit and *BR in byte* is the amount of bandwidth request queued in BS. The byte per PS is determined by the UIUC index of an uplink flow as in Table 1. UIUC index is proposed in [1] to identify the network condition. Our rRDN sub module adopted the wireless network condition as one of the factor to remove extra allocated bandwidth. In contrast, the conversion from byte to PS in rRDN is done by rounding up the amount PS to the smallest integer as described in (2). The advantage of our conversion is it will never assign more bandwidth than requested. Although the amount of PS the rRDN could save may not be a lot in a cycle but it is significant when number of bandwidth request and CPE increased. Through this approach, our approach will able to minimize the probability of unused bandwidth wastage. Simulation results obtained illustrated rRDN sub module allocates bandwidth more fairly and improvement in network performance achieved.

$$BR\ in\ PS = \left\lfloor \frac{BR\ in\ byte}{byte\ per\ PS} \right\rfloor \quad (2)$$

Table 1: UIUC value and its bytes per PS

UIUC index	Byte per PS
0	6
1	9
2	12
3	15
4	18
5	21
6	24
7	27

Algorithm 2: rRDN sub module
Sort according to QoS service classes
For i **to** n bandwidth request message **do**
//to ensure not more than requested bandwidth assigned
BR in PS = floor(bandwidth request / UIUC byte per PS)
//special case where bandwidth request is less than 1 PS
If BR in PS ==0 **&&** bandwidth request not 0
BR in PS = 1

If available PS > 0 **&&** BR in PS > 0

If BR in PS < available PS
allocated PS = allocated PS + BR in PS
available PS = available PS – BR in PS
else
allocated PS = allocated PS + available PS
available PS = 0
else
continue
End For

4. Simulation Parameters and Traffic Models

4.1 Simulation parameters

The traffic models and simulations parameters have been selected according to the guidelines provided in [16] and [18]. All scenarios are in a single cell with a BS covering a distance of 100m in a circular mode. The number of CPE is 50 and traffic configurations are also based on [18]. Table 2 depicts the network simulation parameters of the experiments.

4.2 Traffic models

rtPS, nrtPS and BE are the traffic models we considered in this study. UGS traffic is not included because of its granted bandwidth scheme after admission. We simulate rtPS connections by referring to H.264 and MPEG 4-encoded videos. For nrtPS, it is a FTP application and BE is for normal web browsing. The characteristics of traffic types are summarized in Table 3.

Table 2: Network Simulation Parameters

Simulation Parameters	
PHY Mode	OFDMA
Carrier Frequency, Bandwidth	2.4 GHz , 20MHz
Subcarrier Permutation Band	AMC
Cyclic Prefix (CP)	1/8
FFT Length	2048
Frame Length	20ms
Ratio of DL to UL	1:1
Path Loss Model	Two Ray
BS Transmit Power	20dBm
BS, SS Antenna Height	30m,1.5m
Modulation	16,64-QAM
Antenna Type	Omni-directional
Simulation Duration	0 - 90s
Wait UCD/DCD timeout interval	25s
UCD/DCD	5s
TTG/ RTG	10 US
SSTG	4US
Bandwidth request minimal backoff value	2
Bandwidth request maximum backoff value	15

Table 3: Traffic Parameters

Application	Real time Video	FTP	HTTP
Traffic Type	VBR	VBR	VBR
Scheduling class	rtPS	nrtPS	BE
Start time	15s	15s	15s
End time	75s	75s	75s
Mean bit rate	2Mbps	51Mpbs	2kbps

4.3 Uplink Request Manager (URM)

In order to distinguish the advantages of our design, we simulated another bandwidth request mechanism that we refer to as Uplink Request Manager (URM). This URM scheme merely implements the standard specifications and as in [16, 18]. The key properties of this URM include the following:

1. Bandwidth Requests for each service class are independent and not consolidate.
2. Allocated bandwidth in PS is converted from number of byte of bandwidth request and its decimal value after conversion is always round up to the nearest integral value.

5. Simulation Results

The simulations scenarios are designed to illustrate the performance of IBRH and how it is compared to URM. All simulations are run at least 10 times and results are averaged and presented.

Average end to end delay is an importance performance metric for real time traffic. The high latency causes poor data delivery in real time applications. Thus, a comparison between URM and IBRH on average end to end delay is presented in Fig. 1. As shown in Fig. 1, IBRH scheme always achieve lower average end to end delay as compared to URM. It is about 4% to 5% lower with IBRH throughout the simulation time except for 40, 50 and 60 seconds. The difference between URM and IBRH is smaller at simulation time of 40, 50 and 60. This result is correlated with the average end to end throughput achieved by URM in rtPS traffic. From 40 to 60 seconds, URM has higher throughput than IBRH for rtPS traffic and this led the difference in latency become small.

Fig. 2 is the average end to end throughput for rtPS. The Fig. 2 depicted not much different between two schemes especially when the simulation time is longer. IBRH is outperformed than URM for the first 30 seconds but URM shows higher throughput after 30 seconds. However, the variance becomes less significance from 70 seconds onwards. On average, there is only 0.39% of difference between URM and IBRH for rtPS traffic.

For nrtPS service flow, IBRH always has higher average end to end throughput than URM as described in Fig. 3. IBRH recorded between 118Kbps to 424Kbps higher throughput compared to URM. In other degree, it is 1.41% to 5.28% higher. The higher achievement of IBRH indicates the rRDN sub module successfully remove extra bandwidth request from being allocated to service flows. nrtPS service flow is for non real time applications and it could tolerate with latency or delay. Therefore, no comparison on delay is provided for nrtPS.

The aggregate throughput is illustrated in Fig. 4. IBRH gives high aggregate throughput than URM. The improvements are only less than 2% when the simulation time is less than 40 seconds. This is because the input traffics are yet loaded fully. From 50th simulation time and onwards, the increment of aggregate throughput by IBRH has reached 3% to 5%. Thus, we speculate the aggregate throughput will improve by 2% to 5% regardless the simulation time.

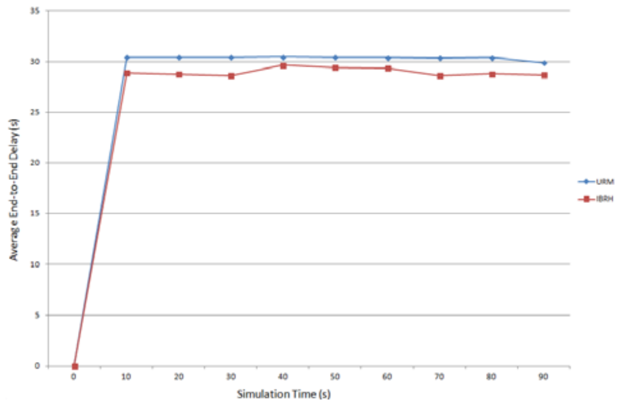

Fig. 1 Average end to end delay

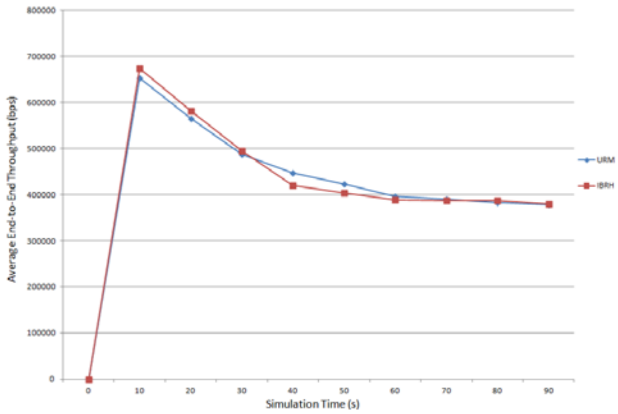

Fig. 2 Average end-to-end throughput for rtPS

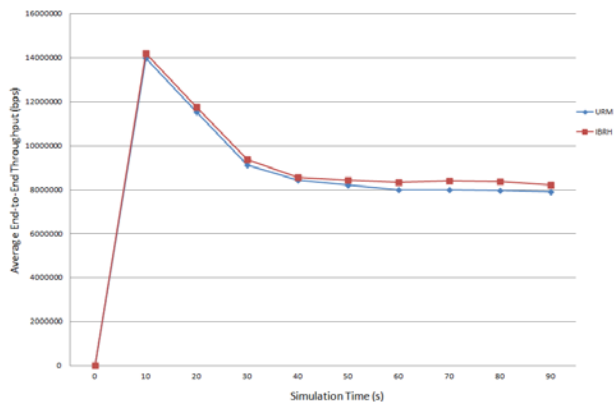

Fig. 3 Average end-to-end throughput for nrtPS

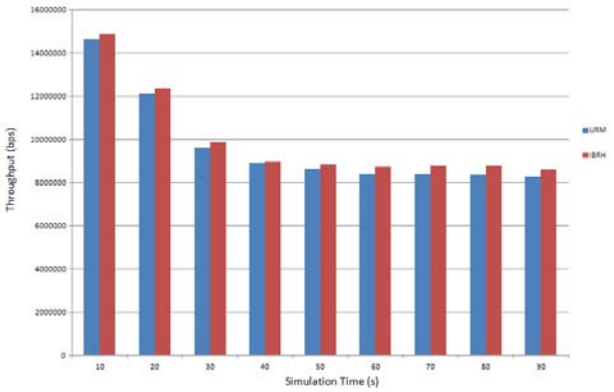

Fig. 4 Aggregate throughput

7. CONCLUSION

In conclusion, the proposed scheme improved the performance of rtPS and nrtPS as expected. Although the throughput for rtPS does not improved always in IBRH scheme, the scheme did reduce the latency of rtPS significantly. Moreover, IBRH increases the network throughput for nrtPS and the aggregate throughput of the network. Our simulation results confirm that IBRH scheme not only improve the throughput, but also reduce the delay of real time service class. But, there may still be bandwidth wastage in the redundant bandwidth caused by the amount of redundant bandwidth may not necessary be used by all the current packets. A future investigation may be needed to overcome this issue.

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