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Performance Evaluation of IEEE 802.16 Grids using scheduling Algorithms

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Abstract

IEEE 802.16 standard was designed to support the bandwidth demanding applications with quality of service .Bandwidth is reserved for each application to ensure the QoS. For variable bit rate applications, however, it is difficult forth subscriber station (SS) to predict the amount of incoming data. The key concern on the bandwidth allocation and scheduling for non real time traffic are the fulfillment of its minimum throughput requirement and improvement of bandwidth utilization with acceptable delay. This paper proposes a simple and efficient scheduling framework for allocating bandwidth to non real time Polling Service (nrtPS) users in IEEE 802.16 grid. In this framework, jointly selective repeat ARQ at the MAC layer and adaptive modulation and coding techniques at the physical are considered. Numerical simulations demonstrate that the proposed scheduling approach provides a graceful compromise between bandwidth utilization and packet delivery delay while maintaining the minimum throughput requirements of nrtPS applications. Thus proves the efficiency of the proposed framework. The simulation is done for unicast scenario.

***Keywords*— WiMAX, IEEE 802.16, Bandwidth Recycling, scheduling algorithm.**

1 INTRODUCTION

The Worldwide Interoperability for Microwave Access (WiMAX), based on IEEE 802.16 standard standards is designed to facilitate services with high transmission rates for data and multimedia applications in metropolitan areas. The physical (PHY) and medium access control (MAC) layers of WiMAX have been specified in the IEEE 802.16 standard. Many advanced communication technologies such as Orthogonal Frequency-Division Multiple Access (OFDMA) and multiple-input and multiple-output (MIMO) are embraced in the standards.Supported by these modern technologies, WiMAX is able to provide large service coverage, high data rates and QoS guaranteed services. Because of these features, WiMAX is considered as a promising

Bandwidth from the base station (BS) before any data transmissions. In order to serve variable bit rate (VBR) applications, the SS tends to keep the reserved bandwidth to maintain the QoS guaranteed services. Thus, the amount of reserved bandwidth transmitted data may be more than the amount of transmitted data and may not be fully utilized all the time. Although the amount of reserved bandwidth is adjustable via making bandwidth requests (BRs), the adjusted bandwidth is applied as early as to the next coming frame. The unused bandwidth in the current frame has no chance to be utilized. Moreover, it is very challenging to adjust the amount of reserved bandwidth precisely. The general concept behind our scheme is to allow other

SSs to utilize the unused bandwidth left by the current transmitting SS. Since the unused bandwidth is not supposed to occur regularly, our scheme allows SSs with non-real time applications, which have more flexibility of delay requirements, to recycle the unused bandwidth. Consequently, the unused Bandwidth in the *current* frame can be utilized. It is different from the bandwidth adjustment in which the adjusted bandwidth is enforced as early as in the next coming frame. The rest of this paper is organized as follows. In Section 2, we provide the background information of IEEE 802.16. Motivation and related works are presented in Section 3. The proposed scheme is presented in Section4. The analysis of the proposed scheme and simulation results are placed in Section 5 and Section 6. In Section7, three additional scheduling algorithms are proposed to enhance the performance of the proposed scheme. At the end, the conclusion is given in Section 8.

2 BACKGROUND INFORMATION

The IEEE 802.16 standard specifies three types of transmission mediums supported as the physical layer (PHY): single channel (SC), orthogonal frequency-division multiplexing (OFDM) and Orthogonal Frequency-Division Multiple Access (OFDMA). We assume as the in our analytical model since it is employed to support mobility in IEEE 802.16e standard and the scheme working in OFDMA should also work in others. There are four types of modulations supported point-to-multipoint (PMP) mode in which the SS is not allowed to communicate with any other SSs but the BS directly. Based on the transmission direction, the transmissions between BS and SS's are classified into downlink (DL) and uplink (UL) transmissions. Time Division Duplex (TDD) and Frequency Division Duplex (FDD) supported in IEEE 802.16. Both UL and DL transmission scan not be operated simultaneously in TDD mode but in FDD mode. In this paper, our scheme is focused on the TDD mode. In WiMAX, the BS is responsible for scheduling both UL and DL transmissions. All scheduling behavior is expressed in a MAC frame. All coordinating information including burst profiles and offsets is in the DL and UL maps, which are broadcasted at the beginning of a MAC frame. There are two types of BRs defined in the IEEE 802.16standard: incremental and aggregate BRs. The BS resets its perception of that service's needs upon receiving the request. Consequently, the reserved bandwidth maybe decreased.

3 MOTIVATIONS AND RELATED WORK

Bandwidth reservation allows IEEE 802.16 grid to provide QoS guaranteed services. The SS reserves the required bandwidth before any data transmissions. Due to the nature of VBR applications, it is very difficult for the SS to make the optimal bandwidth reservation. It is possible that the amount of reserved bandwidth is more than the demand. Therefore, the reserved bandwidth cannot be fully utilized. Although the reserved bandwidth can be adjusted via BRs, however, the updated reserved bandwidth is applied as early as to the next coming frame and there is no way to utilize the unused bandwidth in the current frame. In our scheme, the SS releases its unused bandwidth in the current frame and another SS pre-assigned by the BS has opportunities to utilize this unused bandwidth. Utilization improvements have been proposed in the literature. In a dynamic resource reservation mechanism is proposed. It can dynamically change the amount of reserved resource depending on the actual number of active connections.. It can improve the utilization of bandwidth while keeping the same QoS guaranteed services and introducing no extra delay.

4 PROPOSED SCHEME

The objectives of our research are twofold: 1) The same QoS guaranteed services are provided by maintaining the existing bandwidth reservation. 2) The bandwidth utilization is improved by recycling the unused bandwidth. To achieve these objectives, our scheme named *Bandwidth Recycling* is proposed. The main idea of the proposed scheme is to allow the BS to pre-assign a CS for each TS at the beginning of a frame .The CL is broadcasted followed by the UL map. To reach the backward compatibility, a broadcast CID (B-CID) is attached in front of the CL. More over, a stuff byte value (SBV) is transmitted followed by the B-CID to distinguish the CL from other broadcast DL transmission intervals. The UL map including burst profiles and offsets of each TS is received by all SSs within

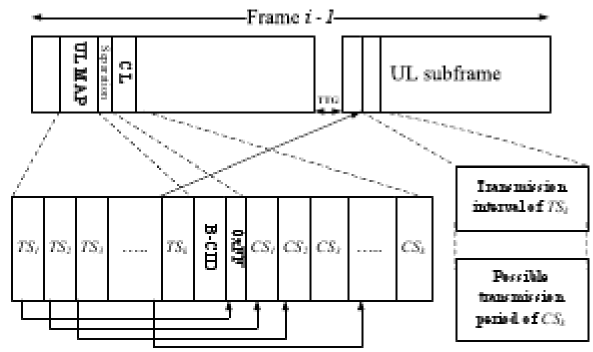

Fig.1. The mapping relation between CSs and TSs in aMAC frame information.

Residing in the CL maybe reduced to the mapping information between the CS and its corresponding TS. The BS only specifies the burst profiles for the SSs which are only scheduled on the CL. *CSj* is scheduled as the corresponding CS of *TSj* , where $1 \leq j \leq$ k. When *TSj* has unused bandwidth, it performs our protocol introduced in Section 4.1. If *CSj* receives the message sent from *TSj*, Our proposed scheme is presented into two parts: the protocol and the scheduling algorithm. The protocol describes how the TS identify the unused bandwidth and informs recycling opportunities to its corresponding CS.

4.1 Protocol

According to the IEEE 802.16 standard, the allocated space within a data burst that is unused should be initialized to a known state. Each unused byte should be set as a padding value (i.e., 0xFF), called stuffed byte value (SBV). If the size of the unused region is at least the size of a MAC header, the entire unused region is initialized as a MAC PDU. The padding CID is used in the CID field of the MAC PDU header. In this research, a TS with unused bandwidth transmits only a SBV and a RM shown in Fig. 2. The SBV is used to inform the BS that no more data are coming from the TS. On the other hand, the RM comprises a generic MAC PDU with no payload shown in Fig. 3.The mapping information between CL and UL map is based on the basic CID of each SS. Messages to release the unused bandwidth within a UL transmission interval.via this agreed modulation. However, there are no agreed modulations between TS and CS. For example, Fig. 4 illustrates the physical location of the BS, TS and CS, respectively. The radius of the dished circle is *KL*, where *L* is the distance between TS and BS and *K* is the ratio of transmission range of BPSK to the transmission range of QPSK depending on the transmission power. Since both UL map and CL can be received by the CS,the CS knows the UL transmission period of its corresponding TS. This period is called the UL transmission interval. The CS monitors this interval to see is received from its corresponding TS. Once received, the CS starts to recycle the unused bandwidth by using the burst profile residing in either UL map or CL until using up the rest of the TS's transmission interval. If the CS does not have any data to transmit, it simply pads the rest of the transmission interval.

4.2 Scheduling Algorithm

Assume *Q* represents the set of SSs serving non-real time connections (i.e., nrtPS or BE connections) and *T* is the set of TSs. Due to the feature of TDD that the UL and DL operations cannot be performed simultaneously, we cannot schedule the SS which UL transmission interval is overlapped with the target TS. For any TS, *St*, let *Ot* be the set of SSs which UL transmission interval overlaps with that of *St* in *Q*. Thus, the possible corresponding CS of *St* must be in $Q-Ot$. All SSs in $Q-Ot$ are considered as candidates of the CS for *St*. A scheduling algorithm, called *Priority-based Scheduling Algorithm* (PSA), shown in Algorithm 1 is used to schedule a SS with the highest priority as the CS. The SS with higher SF has more demand on the bandwidth. Thus, we give the higher priority to those SSs. The highest priority is given to the SSs with zero CG. Non-real time connections include nrtPS and BE connections. We select one with the largest CR as the CS in order to decrease the probability of overflow.

5 SIMULATION RESULTS

Our simulation is conducted by using Qualnet; we provide the validation of theoretical analysis and simulation results.

5.1 Simulation Model

Our simulation model comprises one BS residing at the center of geographical area and 50 SSs uniformly distributed in the service coverage of BS. The parameters of PHY and MAC layers used in the simulation are summarized in Table 1. PMP mode is employed in our model. Since our proposed scheme is used to recycle the unused bandwidth in UL sub frame, the simulation only focuses on the performance of UL transmissions.

Parameters	Value
Node number	51 (including BS)
Frame duration	20MS
UL/DL subframe duration	10MS
Modulation scheme	BPSK, QPSK, 16QAM, 64QAM
DCD/UCD broadcast interval	5S
TTG/RTG	10US
SS transition gap (SSTG)	4US

TABLE 1
The system parameters used in our simulation

Parameters Value Node number 51 (including BS)Frame duration 20MSUL/DL sub frame duration 10MSModulation scheme broadcast interval transition gap (SSTG) 4USTABLE 1The system parameters used in our simulation CBR is a typical traffic type used to measure the performance of grid in WiMAX research. As mentioned earlier, the size of each packet is modeled as Poisson distribution and the packet arrival rate is modeled as exponential distribution the real time connection stops to generate datafrom 75th to 100th second. It is for investigating the performance of our scheme when the large amount of unused bandwidth is available. Therefore, the number of active connections may be different during the simulation Application.

5.2 The Performance Metrics

The simulation for evaluating the performance of the proposed scheme is based on the three metrics:

1) *Throughput gain (TG):* It represents the percentage of throughput which is improved by implementing our scheme. The formal definition can be expressed as:

$$TG = (Trecycle - Tno\_ recycle) /(Tno\ recycle)$$

Where *Trecycle* and *Tno recycle* represent the throughput with and without implementing our scheme, respectively. The higher *TG* achieved shows the higher performance that our scheme can make

2) *Unused bandwidth rate (UBR):* It is defined as the percentage of the unused bandwidth occupied in the total granted bandwidth in the system without using bandwidth recycling. It can be defined formally as:

$$UBR = (Bunused\_bw)/(Btotal\ bw)$$

Where, *Bunused_bw* and *Btotal bw* are the unused bandwidth and total allocated bandwidth, respectively. The *UBR* shows the room which an be improved by our scheme. The higher *UBR* means the more recycling opportunities.

3) *Bandwidth recycling rate (BRR):* It illustrates the percentage of bandwidth which is recycled from the unused bandwidth. The percentage can be demonstrated formally as:

$$BRR = BrecycledBunused\ bw$$

5.3 Simulation Results

This presents the percentage of the unused bandwidth in our simulation traffic model . It shows the room of improvement by implementing our scheme. From the simulation results, we conclude that the average *UBR* is around 38%. In the beginning, the *UBR*

goes down. The purpose to have in active real time connections is to simulate a network with large amount of unused bandwidth and evaluate the improvement of the proposed scheme in such network status. The evaluation is presented in the later of this section. The simulation results of recycling rate are presented in Fig. 9. From the figure, we observe that the recycling rate is very close to zero at the beginning of the simulation. It is because that only a few connections transmit data during that time and the network has a light load.

Fig. 10 shows the total bandwidth demand requested by SSs during the simulation. In the figure, the dashed line indicates the system bandwidth capacity. During the simulation, the BS always allocates the bandwidth to satisfy the demand of real time connections due to the QoS requirement.

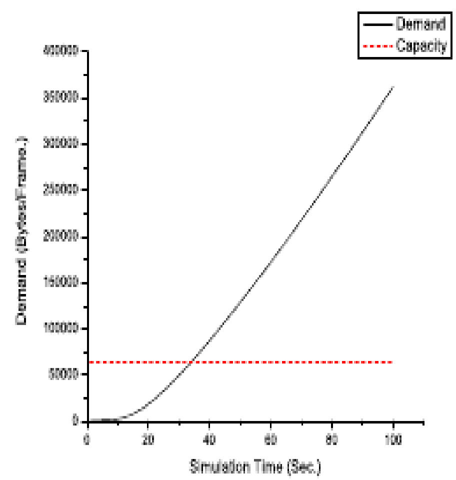

Fig. 10. Total Bandwidth Demand

Therefore, the amount of bandwidth allocated to non-real time connections may be shrunk. At the same time, the new non-real time data are generated. Therefore, the non-real time data are accumulated in the queue. It is the reason that the demand of bandwidth keeps increasing. It shows that our scheme can have significant improvement on *TG* when the large amount of unused bandwidth is available.

7 FURTHER ENHANCEMENTS

As our investigation, one of the factors causing recycling failures is that the CS does not have data to transmit while receiving a RM. To alleviate this factor, we propose to schedule SSs which have rejected BRs in the last frame because it can ensure that the SS scheduled as CS has data to recycle the unused bandwidth. This scheduling algorithm is called *Rejected Bandwidth Requests First Algorithm* (RBRFA). It is worth to notice that the RBRFA is only suitable to heavily loaded grid with rejected BRs sent from non-real time connections (i.e., nrtPS or BE). Notice that only rejected BRs sent in the last frames are considered in the RBRFA for scheduling the current frame. The RBRFA is summarized in Algorithm 2.The BS grants or rejects BRs based on its available resource and scheduling policy. In RBRFA, if the BS grants partially amount of bandwidth requested by a BR, then this BR is also considered as a rejected BR.

8 CONCLUSIONS

Variable bit rate applications generate data in variant rates. It is very challenging for SSs to predict the amount of arriving data precisely. Although the existing method allows the adjust the Delay Improvement (%) Scheduling, Simulation results of delay improvement bandwidth requests in each frame, it cannot avoid the risk of failing to satisfy the QoS requirements. The basic goal is to minimize the amount of bandwidth being actually provisioned for committed bandwidth traffic while keeping the cost of MAC signaling to a minimum. The proposed mechanism dynamically changes the amount of reserved resources between a small number of values (two in the base model) depending on the actual number of active connections while limiting the number of transitions by imposing a hysteresis behavior. In particular, it is not necessary to update the resource reservation whenever a traffic flow is activated or terminated. A Markov chain model yields two performance parameters: the reserved bandwidth and the transition rate. A new parameter, noted thetas, has been introduced in addition to the performance parameters discussed to minimize the global cost of the system.

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