Quality of Service Scheduling Based on GPSS in IEEE 802.16 WiMax Networks

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***Abstract*—IEEE 802.16 standard is proposed for providing high data rate and middle-range access to Internet through wireless access channel. The increasing of data rate, access range, and total number of wireless nodes makes the wireless media access control more difficult and critical. Our objective is to provide a fair and efficient allocation to all the users to satisfy their quality of service. In this paper we introduce a new scheduling architecture and algorithm based on GPSS mode for IEEE 802. 16 broadband wireless access standard. The proposed solution which is practical and compatible to the IEEE 802.16 standard, provides QoS support for different traffic classes. OPNET simulation studies show that the proposed solution provides real-time services and high bandwidth required services with low delays. This study will help network architects to decide the system parameters as well as the kind of traffic characteristics for which the network can provide QoS support.**

***Keywords*—QoS, GPSS, IEEE 802.16, WiMax, Sceduling**

I. Introduction

IEEE 802.16 utilizes contention and piggybacking to send requests to the BS for transmission opportunities on the upstream channel. The base station (BS) is the one responsible for assigning such transmission opportunities to different subscriber stations (SSs) and also for assigning a certain contention interval where such reservations can be made. For providing different types of network traffic, such as Voice, Video, FTP and HTTP, IEEE 802.16 [1] defines four types: Unsolicited Grant Services (UGS), Real-Time Polling Services (rtPS), Non-Real-Time Polling Services (nrtPS), and Best Effort (BE) services. Then, various service classes provide diverse applications with different QoS requirements in WiMax.

An extra feature in IEEE 802.16 is that a SS is allowed to request transmission opportunities either as Grants per Connection (GPC), or as Grants per Subscriber Station (GPSS), in which a SS requests transmission opportunity as a bundle for all the service flows it is maintaining. The SS then holds the responsibility for reassigning the received transmission opportunities between the different service flows. This allows hierarchical and distributed scheduling to be used. The advantage of GPSS is that bandwidth in SS side could be flexibly allocated among traffic streams according to which has been already allocated, and it also supports real-time traffic better particularly when rigid delay-sensitive link urgently requests for more bandwidth. While bandwidth should not be gained by responding to links, SS will still allocate resources to them and this technique is called bandwidth stealing. The bandwidth reallocation in SS required more complicated schedule algorithm thus raising the complexity of SS. What's more, for trying to satisfy the demand of real-time traffic, the traffic bandwidth with low priority may be preempted due to the bandwidth reallocation.

IEEE 802.16 defines a structure of QoS. For supporting all kinds of multimedia services which have different requirements for QoS, IEEE 802.16 indicates that it should add module of access control. This module is used to control number of connections that asks to get in the system, and schedule module for upload bandwidth, which is used to control bandwidth assigning of centralized-control system to base-station node. But the standard doesn't descript exact definition. IEEE 802.16 is a connection oriented protocol and either data packet or control packet is based on connection, so it defines functions of building connection and sorting connections in structure of user station node. There is also a module of scheduler for upload bandwidth in user station node, which is used for assigning local bandwidth. But the module has only one kind of implement called UGS-periodic fixed bandwidth allocation. There isn't definition for other schedule. Although IEEE 802.16 defines mechanisms of upload schedule for UGS, the standard doesn't descript other way of schedule just like rtPS, nrtPS, BE service flow. Furthermore, it doesn't define access control too. But all of these are important and indispensable to QoS implementation. So the studying and implementation of schedule method is the important part just like rtPS, nrtPS, BE service flow in expending the structure of 802.16 QoS and the part that 802.16 should include for QoS implementation.

Max-Min fair schedule strategy is brought forward for guarantee fairness between flows in cable network. Fairness is an important estimate index for the schedule which is used in the best-effort schedule strategy but not important to the method that guarantee connection by payment for the service based-on the percent of resource using. We always have to allocate exiguity resource in a group of users. All of the users have the same authorization for asking for these resources. Some users may require less resource than others. How to solve this problem? It should use the wide-used strategy: Max-Min fair schedule strategy. Intuitionally, fairness allocation means allocating the least of all requirements to the users. The remainder is allocated to the users who require more. We define Max-Min fair schedule strategy as follow: allocate by the order that requirement for resources increases. There isn't requirement source which is allocated more resources than it needs. The requirement source which doesn't get enough resources will get average allocation.

This paper is organized as follows. Part II introduces some related work in this area. Part III describes the proposed architecture and the scheduling algorithm in detail. Simulation results of the proposed algorithm are provided in Section Ⅳ. We

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conclude the paper and point out some future research directions in section V.

II. RELATED WORK

A new QoS architecture is proposed in [1]. In this architecture, the detail description and access control of upstream bandwidth allocation schedule are attached to BS. However, that paper didn't give specific framework implementation and detailed design idea, so the correctness of result can not be proved. Another schedule algorithm is proposed in [2] in which different schedule algorithms are used according to SS, BS and different service types. The problem is that the algorithm just simply introduced schedule algorithms in wired network and neither simulation nor theoretical analysis was given in that paper. In paper [3], although it gave detailed description to the schedule framework mentioned in paper and proved the validity of that framework by utilizing simulation tool QualNet, distinction between these request data packets and those data packets which are sent during bandwidth competition process was not mentioned. Compare with the stream's impact, author pay more emphasis on how the number of SS gave impact on system in the process of simulation experiment. In paper [4], authors gave an uplink schedule architecture which is in GPC authorized pattern and supports both IEEE 802.16 and DOCSIS. In paper [5], it improved the schedule architecture which already existed in system 802.16 and adopting different packet schedule algorithms including correspondent access control for different traffics based on improved schedule architecture.

For achieving quality of service (QoS) with high data rate, [6-8] mentioned that IEEE 802.16 defines different service flow types to support different priorities for bandwidth allocation, but IEEE 802.16 did not define and detail the scheduling mechanism of transmission. Therefore, [6-8] proposed detail scheduling mechanisms for WiMax. These approaches waste bandwidth when both the BS and SS are silent of using UGS service. The other problem while applying EDF is that packet deadline is difficult to expect in the rtPS services. Moreover, a large number of resources are required to monitor network state and maintain scheduling database. Therefore, for overcoming the above-mentioned problems, we propose an efficient approach with an efficient scheduling architecture to increase the network bandwidth and real-time services. The proposed approach guarantees the fairness between SSs, and obtains shorter delay and more bandwidth allocation.

III. QOS ARCHITECTURE AND SCHEDULING ALGORITHM

A. *QoS Architecture*

We propose an improved QoS model based on the original QoS framework. It has to send an access request to BS before SS establishes a connection. BS's access module decides whether the request is confirmed or not depending on the system bandwidth and the request of QoS requirements of the new link. As the request is satisfied, it will be confirmed. If the request is permitted, BS will submit the details of the QoS to the SS. So we can classify the packets into one of the four services by the QoS details of connections and allocate different connection IDs(CIDs) to them in application layer. As shown in Fig.1.

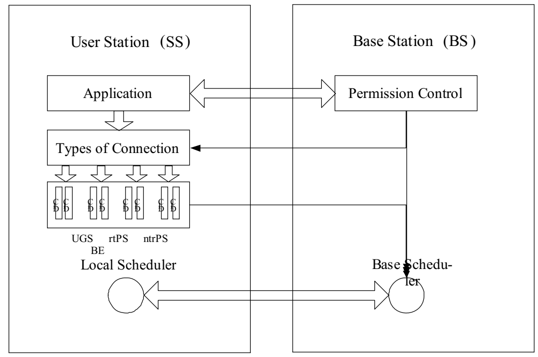

Figure 1. Our QoS Architecture

B. *Scheduling Algrithm of BS and SS*

In our scheduling algorithm, BS adopts the simple Max-Min fair scheduling method. This method guarantees fairness between the SSs and simplifies the scheduling module on BS. It also transferred the part of the scheduling functions to SSs and processed in SSs. The implementation with Max-Min scheduling algorithm had proposed by some authors, but they didn't convert the allocated bandwidth into specific time slot number. So, their methods can't satisfy the request of the time slot allocation in IEEE 802.16 standard. However, we converted the allocated bandwidth into the specific time slot number in our scheduling algorithm.

The architecture of SS upstream scheduler is shown in Fig.2. It adopts priority scheduling structure to satisfy the QoS requests of the traffics with high priority. On the other hand, through admission control mechanism control the data rate with the highest priority traffics, it also ensures the traffics with low priority to obtain certain bandwidth so that they won't be starved. The scheduling methods within the traffics are different as same as their characteristics. Such as rtPS traffic is more sensitive to the delay, so it adopts EDF scheduling algorithm to allocate the bandwidth between rtPS traffics.

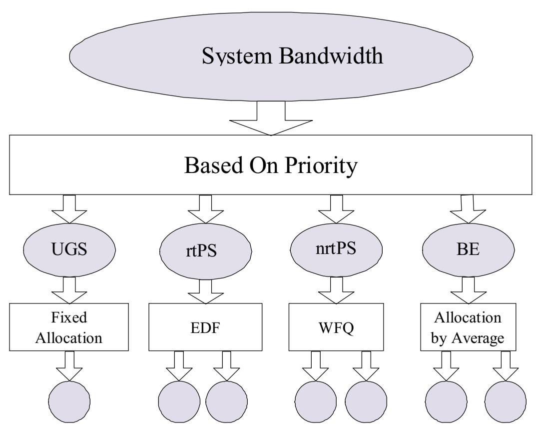

Figure 2. SS Scheduling Architecture

We propose a complete QoS framework in this paper, in which we implement the local scheduling module on SSs and the base station scheduling module on BS, which connection classification and access control will be implemented in the future work. We assume the new access request is permitted, and it is classified into one of the UGS, rtPS, or BE nrtPS traffics by access classification module and approved by BS.

IV. PERFORMANCE EVALUATION

A. OPNET Simulation Environment and Configures

OPNET 10.0 is a design platform based on object-oriented, which uses object-oriented modeling. Each kind of nodes uses the same modeling. Different kinds of nodes are set different parameters. This makes setting of network topology structure and parameters easy. We get kinds of parameters in the network by simulation statistics (frame length, simulation time, System bandwidth, slot and so on). We take the parameters as showed in Table I.

TABLE I. SYSTEM PARAMETERS TABLE

Frame length (ms)	Bandwidth (Mbps)	slot	BS	Simulation time
1	40	5000	1	15

Our simulation traffic includes UGS, rtPS and BE traffics. NrtPS traffic has been ignored because we can convert it to rtPS or BE under some condition. There are two simulations. 1) We take fixed number of SSs and the connections of SS. Compare throughput and delay of different traffic in GPSS and GPC by change the rate of packet send to increase system load. 2) We change the number of SSs to change system load to get throughput, delay and loss rate of different traffic.

The number of SS is 10, every SS has 2 rtPS traffics, 1 UGS traffic, 1 BE traffic. Table II, III shows traffic parameters in detail. When system load ratio is 90%, the competitive slot of BE should be changed by the number of SSs as showed in Table IV.

TABLE II. TRAFFIC PARAMETERS

Traffic	Packet length（bit）	Delay demand（S）
Best Effort(DATA)	1024	
Rtps_1(MPEG4)	1024	0.003/0.01
Rtps_2(MPEG4)	1024	0.003/0.01
UGS(CBR)	1280	0.02

TABLE III. TRAFFIC LOAD

BE(Mbps)	UGS(Mbps)	rtPS1(Mbps)	rtPS2(Mbps)	System load (%)
1.024	0.64	1.024	1.024	10
2.048	0.64	2.048	2.048	20
2.048	0.64	5.12	5.12	30
5.12	0.64	5.12	5.12	40
10.24	0.64	5.12	5.12	50
2.048	0.64	10.24	10.24	60
6.84	0.64	10.24	10.24	70
10.24	0.64	10.24	10.24	80
10.24	0.64	12.80	12.80	90

TABLE IV. COMPETITIVE SLOT OF BE

Number of SS	2	4	6	8	10
Time slot	4	6	6	10	10

B. Analysis of Throughput and Delay

In the scene which has fixed nodes number we compare the throughput of three traffics and also the system. At last we compare the throughputs of the SSs with different system loads. The rtPS delay demand of GPC mode is 0.01s, and the rtPS delay demand of GPSS is 0.03s. We see that rtPS delay and delay jitter could be smaller, and the QoS demand of rtPS acquires better guarantee while the system throughput is maintained. It proves what the fore part of the paper says that SSs can handle the conditions of rtPS connections better and can control the rtPS delay and bandwidth allocation stricter. This meets the QoS demand of rtPS connections better.

The compare of throughput and delay is shown in the Fig.3, Fig.4, Fig.5 and Fig.6. They tell the traffics with high priority are fully satisfied in bandwidth allocation. The rtPS throughput will decrease as the system load is overloading (traffic load = 0.7) (Fig.3). First, the ratio of rtPS traffic to BE traffic is 3:1 in the Max-Min scheduling on BS, therefore the throughput of rtPS should be set an upper limit. Second, the scheduling method on SSs controls the sending rate of the rtPS and the relevant loss strategy to prevent the traffics with low priority (BE) from starving.

From Fig.4, we see the system fulfills the delay requirement of UGS and rtPS all the time, and it keeps the delay value of UGS traffics relatively stable.

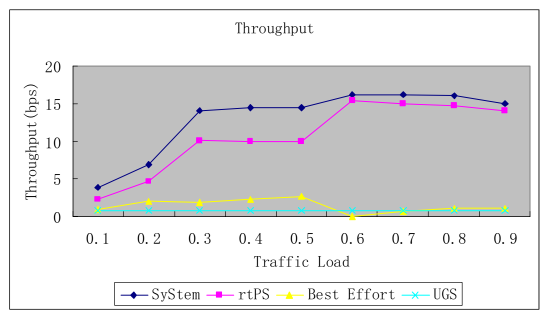

Figure 3. System Throughput

We compare throuhout ratio and delay of UGS and rtPS, and packet loss rate of the rtPS between schedule structure in this paper and the standard FCFS (Fig.5).The comparison results indicate that the fixed bandwidth allocation of this paper can satisfy the need of standard in UGS. That is to allocate fixed bandwidth with speed cycle of packet arrival. Delay of UGS increases linearly with the node increment. The reason is with nodes doubling, so the periodic time between asks doubles accordingly.

When the load of system decreases, just like the number of nodes is 2 or 4, results are same between the scheduler algorithm in this paper and in the standard; But when the load increases (number of nodes is more than 6), throughout ratio of rtPS in the schedular algorithm in this paper is higher than that in the standard obviously (Fig.6). The reason is that in FCFS, it enhances the priority of node which has the number less than others and the priority of BE. That causes bandwidth and throughout ratio of rtPS decreases.This is also the reason of high packet-loss ratio in FCFS.

According to the rtPS packet loss rate in figure 6, it can be shown that on the one hand, the schedule framework in this paper can guarantee lower packet loss rate of rtPS traffic since we have set higher priority to rtPS traffic; on the other hand, packets are lost when the nodes are 6, and at that time traffic load = 0.54. Although system load is only 1/2, TDD channel multiplexing is adopted here. Therefore the data traffic can be transmitted only on upstream link, i.e. the available bandwidth is only half the actual bandwidth. When system overloaded(number of nodes are 8, 10), the packet loss rate of rtPS traffic increased rapidly, this is because on the side of BS Max-Min schedule algorithm has been adopted and weight ratio between rtPS and BE is 3:1 which restricted bandwidth of rtPS traffic. That in turn increased the packet loss rate of rtPS when system overloaded; finally, the overall packet loss rate of rtPS is quite high, which is related to SS's sending request for bandwidth. Because the rtPS bandwidth request has always been sent in just one frame before deadline, therefore once the system is overloaded and other frames can not meet its need there's no choice but discarding packets which leads to the high packet loss rate of rtPS traffic.

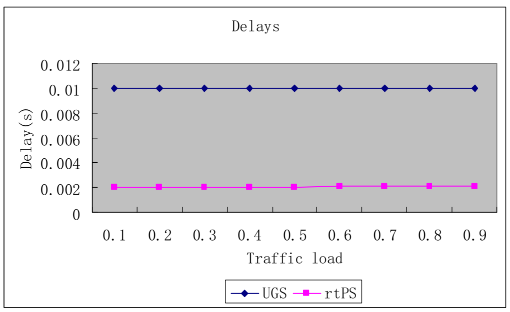

Figure 4. Delay of Different Classes

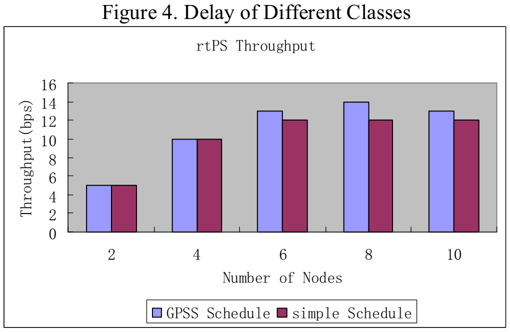

Figure 5. rtPS Throughput

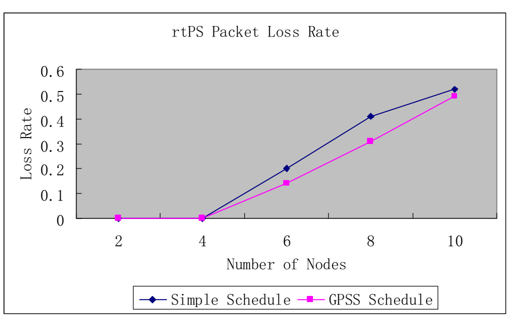

Figure 6. rtPs Packet Loss Rate

C. Discuss

OPNET simulation experiments show that our proposed scheduling method satisfies the delay requirements of real time traffics when the system throughput unchanged. At the meantime, as the base station adopts the Max-Min fair scheduling method so SSs are equal to each other. Our simulation results prove the advantages of our scheduling method by comparing the data of two methods. Then we proved our method fulfills the UGS scheduling strategy which is defined in standard by comparing our scheduling method and standard scheduling methods. It also satisfies QoS requirements of real time traffics well.

V. Conclusions

For increasing efficient of using limited wireless resources in WiMax, we propose an efficient scheduling architecture and algorithm with the high bandwidth and the low delay. Under the GPSS mode, SS can acquire rtPS queue information more accurately and therefore posses a better control on rtPS delays; under the precondition of assurance for rtPS link delay, it can work well without wasting too much bandwidth. The throughput and delay of UGS could meet the requirements of real-time traffic. The throughput of rtPS is obviously superior to the other algorithms, but delay goes up with the increase of nodes that is because rtPS packet loss rate is lower than normal algorithm and fortunately it can be controlled in the required range. On the other hand, rtPS packet loss rate is obviously superior to normal schedule. The throughput and delay of BE algorithms is obviously lower than those of normal schedule algorithms since system first meet the demand of high priority services. This algorithm can fully guarantee the fairness between SS. Finally, OPNET simulation results demonstrate that the proposed approach improves the throughput and delay of UGS, rtPS and BE obviously.

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