Achieving QoS for IEEE 802.16 in Mesh Mode

Fuqiang LIU[1] Zhihui ZENG[1] Jian TAO[1] Qing LI[1] Zhangxi LIN[2]

[1]School of Electronics and Information Engineering, Tongji University, 200092, Shanghai, P. R. China

[2]Department of ISQS, Texas Tech University, Lubbock, TX 79409-2101, USA

Abstract

The MAC protocol of IEEE 802.16 standard specifies scheduling mechanisms about mesh mode in detail, while its channel resource allocation and reservation management protocols are open for further standardization. This paper proposes a slot allocation algorithm based on priority, which is to achieve QoS on MAC layer. We conducted a simulation to study packet delay, delay distribution, and throughput based on proposed algorithm. The simulation results show that our algorithm achieves QoS with low delay and low packet drop rate of high priority.

Keywords: IEEE 802.16; QoS; Mesh; MAC

1. Introduction

In past few years, IEEE 802.11 Standard has been widely adopted in SOHO, offices, cafés and airports. However, this standard has been handicapped in transmission distance, bandwidth, Quality of Service (QoS), and transmission security. The advent of IEEE 802.16 [1] standard is emerging as a promising broadband wireless technology to finally resolve the "last mile" problem of Internet access in conjunction with IEEE 802.11. IEEE 802.16 is to provide high-speed broadband up to 75 Mbps with the coverage of metropolitan area with Medium Access Control (MAC) layer QoS supporting, and will be widely deployed in the upcoming years.

IEEE 802.16 MAC protocol is mainly designed for point-to-multipoint (PMP) access in wireless broadband application. To accommodate the more demanding physical environment and different service requirements of the frequencies between 2 and 11 GHz, the 802.16a project enhanced the function on MAC to provide automatic repeat request (ARQ) and support for mesh [2]. The Mesh mode is the extension to the PMP mode, with the advantage of less coverage path loss, coverage and robustness improved exponentially as subscribers are added, the larger user throughput over multiple-hop paths than PMP's [3][4]. In application, it specially meets the needs of outdoor military training, wireless MAN in oil fields, middle or small corporations, and so on.

The PMP mode of 802.16 MAC protocol is connection-oriented. It provides different levels of QoS to meet all kinds of transmission services, including data, video and voice over IP (VoIP). The protocol indicates that QoS can be achieved with the connection identifier (CID). However, the method for the QoS problem remains an open issue for further exploration. Chu et al. [5] proposed the QoS architecture for the 802.16 PMP mode, but none describes any algorithm for achieving QoS for 802.16 Mesh network as of now. This paper is to report our recent study in the implementation of QoS for IEEE 802.16 in the Mesh mode. We first introduce scheduling mechanisms in Mesh mode. And then we propose a slot allocation algorithm based on priority to provide some QoS guarantee, and analyze the performance of the algorithm by simulation results.

2. Scheduling Mechanisms in the Mesh Mode

There are two frame scheduling methods in Mesh mode: centralized scheduling and distributed scheduling. Distributed scheduling can be divided into coordinated distributed scheduling and uncoordinated distributed scheduling. The difference of them is whether scheduling messages with collision. In this paper, we mainly address the coordinated distributed scheduling.

A MAC frame structure in Mesh mode is described in Fig. 1:

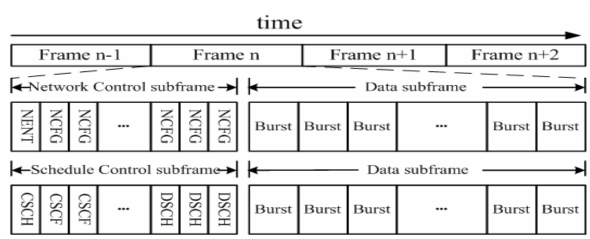

Fig. 1: Frame structure in Mesh mode

MAC frame comprises control subframe (consisting of several slots) and data subframe (divided into 256 minislots). Control subframe is divided into network control subframe and schedule control subframe. The detail of control messages can be found in paper [1]. In coordinated distributed scheduling, MSH-DSCH message is the key component in the whole scheduling process.

During distributed scheduling, request and grant of channel resource are delivered by MSH-DSCH message among nodes, while every node sends its available channel resource table to neighbor nodes with Mesh Distributed Schedule (MSH-DSCH) messages. A MSH-DSCH message shall include the following fields:

1) **Scheduling IE**: includes the next MSH-DSCH transmission time and Holdoff Exponent of the node and its neighbor nodes.
2) **Request IE**: conveys the resource request of the node.
3) **Availability IE**: implies the available channel resource of the node.
4) **Grants IE**: conveys grant or confirm information of channel resource.

Before transmitting MSH-DSCH message, a node determines the next MSH-DSCH transmission time by MeshElection() algorithm given in the protocol [1].

The Three-way Handshake process shown in Fig. 2 is an important process for the requester to initiate a frame transmission:

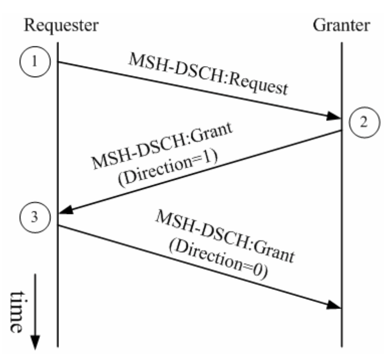

Fig. 2: Three-way handshake process

After a requester has sent the request information, the granter deals with the request through a given slot allocation algorithm during the MSH-DSCH transmission time. If the algorithm returns success, the granter transmits the grant information to the requester. Then the requester copies the grant information and sends it back to the granter as the acknowledgement.

In 802.16 MAC protocol, slot allocation algorithm is not specified but is open for further definition. This provides the flexibility for implementing agents to specify in accordance with different needs. In the following, we will discuss a slot allocation algorithm in detail, and investigate the QoS in MAC layer.

3. Achieving QoS in MAC Layer

IEEE 802.16 has defined four classes of services in the PMP mode: Unsolicited Grant Service, Real-time Polling Service, Non-real-time Polling Service, and Best Effort. However, these classes of services are not configurable in the Mesh mode. According to the protocol, the 16-bit CID in the genetic MAC header can be used to distinguish between unicast and broadcast frames, define service parameters, and identify link IDs. The CID of a unicast packet contains three definable fields: Reliability, Priority/Class, and Drop Precedence (Fig. 3).

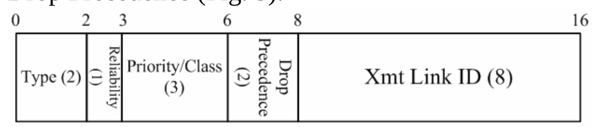

Fig 3: CID of a unicast packet

Reliability refers to retransmit or not (0 indicates no retransmit while 1 indicates retransmit more than 4 times). Priority/Class refers to the priority of the packet. Drop Precedence refers to the probability of the packet when congestion occurs. The three QoS parameters are defined in the protocol, while the slot allocation algorithm using the three parameters is not available.

To achieve QoS features in the Mesh mode, we design a simple slot allocation algorithm for determining a reasonable transmission time by looking up the channel resource table after receiving a request and returning the detail of slot occupation information. The algorithm performs the following steps:

1) Compute the number of minislots (R) requested for transmitting within a frame, according to its Demand Level and Demand Persistence;
2) Get the next MSH-DSCH transmission time (T) from the neighbor table which is stored locally;
3) Look up R continuous available minislots at the same position of the continuous frames (the number is Demand Persistence) starting from time T.
4) If step 3 is successful, return Grant to the requester.
5) If step 3 fails, return failure information.

This simple algorithm is not sufficient to assure QoS and needs further improvement. In the improved algorithm, we set a check point along the first available time slots and a threshold in the channel resource table. The number of allocated minislots represents the utilization of the data subframe in a certain degree. The threshold is set a value between 0 and 256. When the utilization level of the data subframe at check point is lower than the threshold, the network is considered under good condition and will treat transmission requests with the same priority. When the utilization level is higher than the threshold, indicating the network is in congestion, the algorithm returns failure information when low priority request comes.

We call the improved algorithm A1. The drawback of A1 is that one check point is not enough and may cause mistakes under some circumstances. The more comprehensive method is to add in check point 2. This upgraded algorithm is named A2. When the utilization level at check point 1 is lower than the threshold, the algorithm turns to check the utilization level at check point 2. If exceed, search a frame from check point 2 whose utilization level is below the threshold and allocate minislots for the frame.

4. Simulation Results and Analysis

We select Network Simulator V.2 [6], a popular network simulation package, for the simulation. In the simulation, all nodes are in one-hop neighborhood to avoid hidden-terminal problem. We do not consider mobility and channel issues in our simulation.

Three types of traffics are used here: elastic data flow, real-time CBR flow, and real-time VBR flow. *Data nodes*, the nodes generating the elastic data flow, generate Poisson packet streams with rate λ, each with a fixed size of 825 bytes. The number of data nodes is set to 15. The length of a CBR packet is 240 bytes generated at regular intervals of 30ms, which gives a data flow rate of 64Kbps, corresponding to some constant bit rate encoding scheme for the audio file. The VBR flow is simulated by using an exponential ON/OFF model, characterized by 4 parameters: average burst (ON) period, average silence (OFF) period, fixed source rate during burst period (same as that of CBR), and fixed packet length during burst period (same as that of CBR). Mean burst time is set to 1s and mean silence time to 1s. Node pairs communicate each other by transmitting packets continuously. Source nodes generate 10 flows of data or CBR or VBR to other nodes. In the simulation, the packets of elastic data flow have a lower priority than CBR and VBR packets. The parameters in the simulation network are described in Table 1.

In Fig. 4(a), CP indicates check point, and TH indicates threshold. As we can see, when we keep the number of data nodes as 15 and increase the number of CBR nodes, the average delay of CBR packets has an increasing trend. However, the average delay differs when using different algorithms and parameters. It is obvious that when the check position and the threshold are the same, A2 is better than A1.

Table 1. Parameter settings in the simulation network

Parameter	**Value**
Channel Rate	50 Mbps
Frame time	1 ms
Holdoff Exp	0
Slot time	6.25 μs
Minislot time	3.516 μs
Simulation time	10 s

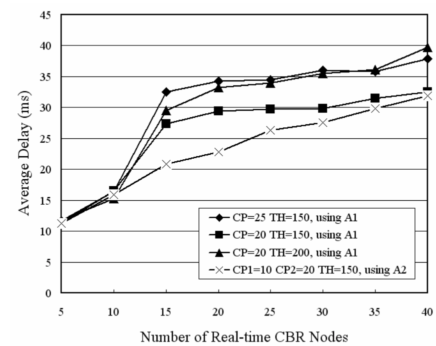

Fig. 4(a): Average delay vs. number of real-time CBR nodes

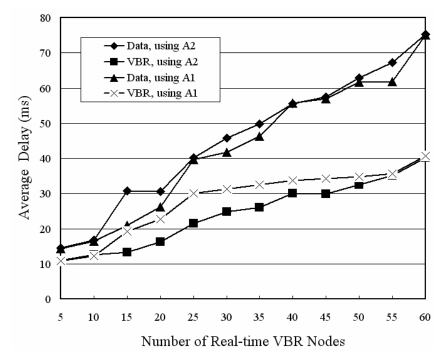

Fig. 4(b): Average delay vs. number of real-time VBR nodes

In Fig. 4(b), CP=25, TH=150 to A1 and CP1=10, CP2=25, TH=150 to A2 respectively. Whichever algorithms above we use, the disparity between the average delay of data packets and VBR packets is increasing, when the number of VBR nodes is added. And the average delay of VBR packets never exceeds 40 ms during the experiment. At the same time, the delay curve of the simulation using A2 is always below the one using A1, from which we can conclude that the performance of A2 is better than that of A1.

From Fig. 5, we can see that because of the high priority of the Real-time CBR packets, its delay curve is on the left of that of the date packets. That means the higher the priority is, the less the delay is. We can also see that when we use A2, the delay curve of the

CBR packet is on the left of that of A1. However, the data packets delay curve does not have any significant difference. It also implies algorithm A2 is better than A1.

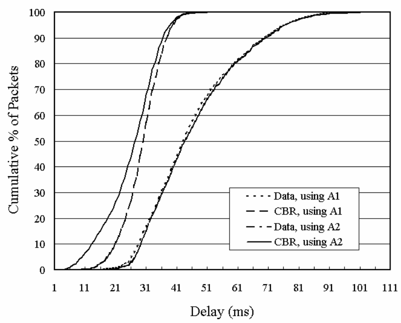

Fig. 5: Delay distribution of the elastic data flow and CBR when using different algorithms

In the form of histogram, Fig. 6 shows that, given 15 data nodes with a constant data flow, when the number of VBR nodes increases, the overall throughput of VBR nodes increases proportionally while that of data nodes decreases. When the number of VBR nodes is more than 25, the overall network throughput will be the highest and its change will not be obvious.

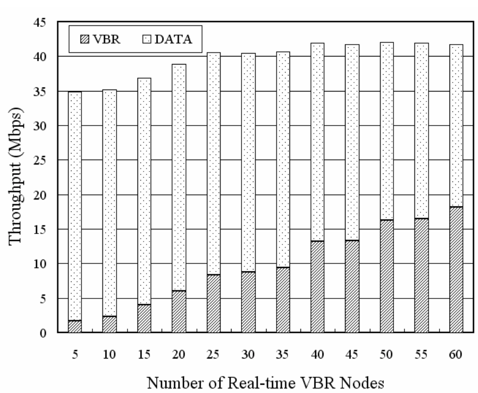

Fig. 6: Throughput vs. number of real-time VBR nodes

Fig. 7 shows the change of delay and drop rate with regard to the location of check point for the data nodes and real-time VBR nodes respectively. The simulation was configured with 15 nodes and 35 real-time VBR nodes, using algorithm A1 and the threshold 150. When the value of the check point is 16, the average delay of data nodes and real-time VBR nodes reaches the least. It means that there must be a relationship between the position of check point and the performance of the algorithm. In addition, the setting of the check point has a significant influence on the packet drop rate of lower prioritized packets; and when the value of the check position increases, the packet drop rate of lower prioritized packets decreases; meanwhile, the packet delay of the higher prioritized packets increases. So far how to set the position of the check point remains untouched because it is beyond the scope of this research phase.

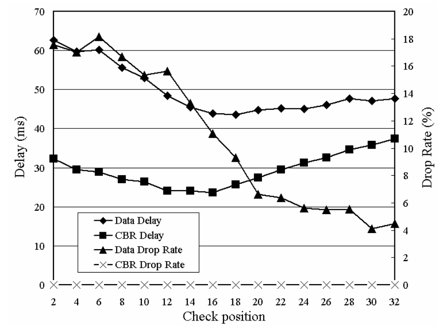

Fig. 7: Delay and drop rate with regard to the position of check point

5. Conclusion

This paper proposes a slot allocation algorithm based on prioritization for IEEE 802.16 in the Mesh mode to achieve QoS with a low delay and low packet drop rate for high prioritized data flows. It is important to further consider multi-hop networks with mobile nodes in the future and generalize this research outcome according to the IEEE 802.16e standard.

*Supported by National 973 Program (No.2004CB719802) and NSF of Shanghai (NO.024119026)

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