Channel Access Delay Analysis of IEEE 802-16 Best Effort Services

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Abstract— One of the basic QoS service classes in IEEE 802.16 network is Best Effort (BE). This service class supports services that don't need any QoS requirements like minimum bandwidth. However many of existing demands like web browsing and FTP involve in this class. Channel access mechanism in BE is based on stand-alone bandwidth requests in bandwidth request contention periods. In this paper we investigate channel access saturation delay of IEEE 802.16 Best Effort services via analytical modeling. Simulation results validate our model.

Keywords-component IEEE 802.16 Standard, Best Effort services, Bandwidth request, analytical modeling.

I. INTRODUCTION

The IEEE 802.16 standard (WiMAX) has been introduced in 2001[1]. In 2004, IEEE organization modified it into IEEE 802.16-2004 with respects to quality of service aspects and after that introduced IEEE 802.16e with respects to mobility aspects [2]. This standard supports two modes: PMP (Point to Multipoint) and mesh. In PMP, as the basic mode of standard, subscriber stations (SS's) are in the Line of Sight (LOS) of base station (BS). In mesh mode, SS's can communicate with BS through other SS's. IEEE 802.16 supports four types of services:

- Unsolicited Grant Service (UGS): is designed to support real-time data streams consisting of fixed-size data packets issued at periodic intervals, such as T1/E1 and VoIP without silence suppression. It offers fixed-size grants on a real-time periodic basis, which eliminates the overhead and latency of SS requests and assures that grants are available to meet the flow's real-time needs.
- Real-time Polling Service (rtPS): is designed to support real-time data streams consisting of variable-sized data packets that are issued at periodic intervals, such as MPEG videos. It offers real-time, periodic, unicast request opportunities, which meet the flow's real-time needs and allow the SS to specify the size of the desired grants.

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- Non-real-time Polling Service (nrtPS): is designed to support delay-tolerant data streams consisting of variable-sized data packets for which a minimum data rate is required, such as FTP. The nrtPS offers unicast polls on a regular basis, which assures that the service flow receives request opportunities even during network congestion.
- Best Effort service (BE): is designed to support data streams for which no minimum service level is required and therefore may be handled on a space-available basis. SS is allowed to use contention request opportunities.

But many of today's networks including internet do not support any quality of service (QoS) level and only supports Best Efforts services. In new networks, we see a tendency to implementation of QoS level supports in today networks. But this is very costly and therefore these QoS levels implementations are very slowly. For example, Korean IEEE 802.16e implementation, named WiBro [3], as the first traditional implementation of WiMAX, only supports Best Efforts services.

Today, because of lower costs, performance analysis of networks is performed by many researchers and is an interesting study. References [4-6] give performance analysis of WiMAX via simulations results. References [7-10] proposed analytical works for performance and delay models for IEEE 802.11 network. But, IEEE 802.16 has different mechanism in bandwidth allocation. In opposition to the contention nature of WiFi for channel access, channel access in WiMAX is according granted accesses and therefore there is not any collision in transmission data periods. References [11] and [12] give analytical models for delay and performance in mesh mode of WiMAX, but in PMP mode, based on our knowledge, there is a gap on analytical models of performance and delay.

This paper organized as follows; Section II defines the IEEE 802.16 Best Effort service mechanism. Section III consists of our analytical model for delay in Best Effort service in WiMAX. We conduct model validation via simulations in section IV and conclude the paper in section V.

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II. IEEE 802.16 Best Effort Service Mechanism

IEEE 802.16 standard supports two mechanisms that SS's use them to indicate to the BS that they need uplink bandwidth allocation: stand alone bandwidth request and piggybacking. Stand alone bandwidth requests are incremental requests (increment current perception of the bandwidth) or aggregate requests (replace current perception of the bandwidth). The Best Effort services use this type of bandwidth request, only in bandwidth contention period. Figure 1 shows bandwidth request contention period position in the uplink subframe structure. Piggyback bandwidth request is an optional choice and always be incremental request [2].

In Best Effort services, contention period and collisions on it, affects on the network throughput and performance. The BS controls assignments on the uplink channel through the uplink access definition (UL-MAP) messages and determines which minislots are subject to collisions. Collisions may occur during request intervals.

The WiMAX contention resolution supported method defined in standard is based on a truncated binary exponential Backoff, with the initial Backoff window (BW_{min}) and the maximum backoff window (BW_{max}) controlled by the BS. The values are specified as part of the uplink channel descriptor (UCD) message and represent a power-of-two value.

When an SS has information to send and wants to enter the contention resolution process, it sets its internal Backoff window equal to the Request Backoff Start defined in the UCD message referenced by the UCD Count in the UL-MAP message currently in effect. The SS shall randomly select a number within its Backoff window. This random value indicates the number of contention transmission opportunities that the SS shall defer before an eligible transmission that defined by request information elements (IEs) in the UL-MAP messages. Each IE may consist of multiple contention transmission opportunities.



Figure 1. WiMAX uplink subframe structure

After a contention transmission, the SS waits for a data grant burst type IE in a subsequent map. Once received, the contention resolution is complete. Otherwise the SS shall consider the contention transmission lost and now increase its Backoff window by a factor of two, as long as it is less than the maximum Backoff window. The SS shall randomly select a number within its new Backoff window and repeat the deferring process described above. This retry process continues until the maximum number Request Retries for bandwidth requests of retries has been reached. At this time, for bandwidth requests, the PDU shall be discarded. The maximum number of retries is independent of the initial and maximum Backoff windows that are defined by the BS.

III. ANALYTICAL MODEL OF BEST EFFORT SERVICE

In this section we proposed an analytical model for Best Effort services in WiMAX. If SS has many requests, it tries to send requests for its connections sequentially. We first introduce some basic notation and measurements and then proposed analytical model with related equations for bandwidth requests delay.

A. Basic Measurements:

Let $BW_{max,i}$ is the maximum Backoff window of node *i*. Current value of Backoff window of node *i* gives as follow:

$$BW_{current,i} = \delta^{j} BW_{\min,i} \quad 0 \le j \le L_{retry}$$
(1)

Where $\delta=2$ and $BW_{min,i}$ is the minimum value of Backoff window of node *i*, *j* is the Backoff stage and L_{retry} is the retry limit. Each SS may have one or many connection in a same time, therefore C_i denotes the number of connections in node *i*. Let $P_{c,i}$ be the probability of a lost or collide request and $P_{s,i}$ is the probability of a successful request for node *i* during a generic slot time. We have

$$p_{s,i=}\left(\frac{ContentionDuration-1}{ContentionDuration}\right)^{\sum_{j=1,j\neq i}C_j}$$
(2)

$$p_{c,i} = 1 - p_{s,i} = 1 - \left(\frac{ContentionDuration - 1}{ContentionDuration}\right)^{\sum_{j=1,j\neq i} C_{j}} (3)$$

After each successful request, number of nodes in bandwidth request contention decreases by factor P_s where P_s is probability of successful request transmission which is equal for all nodes at the same time.

B. Transmission Saturation Delay:

To calculate delay parameter in network we proposed a transmission Markov model shown in figure 2 that models transmission status of one node.



Figure 2. WiMAX Best Effort transmission Markov model

Where $P_{c,i,j}$ is the probability that node *i* request collide or lost in Backoff stage *j*, P_{drop} is the probability that SS couldn't transmit its request after L_{retry} and therefore drops the packet and $P_{s,i,j}$ is the probability that SS *i* transmits its request successfully in Backoff stage *j*. parameters $P_{c,i,j}$, P_{drop} and $P_{s,i,j}$

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are easily calculated from formula (2) and (3). Proposed Markov model stages probability are:

$$p_{j} = p_{0} \prod_{k=0}^{j-1} P_{c,i,k} \qquad 1 \le j \le L_{retry}$$
(4)

$$p_{Transfer} = \sum_{k=0}^{L_{retry}} P_{s,i,k} p_k = \sum_{k=0}^{L_{retry}} P_{s,i,k} \left(p_0 \prod_{j=0}^{k-1} P_{c,i,j} \right)$$
(5)

$$p_{Transfer} + \sum_{i=0}^{L_{reny}} p_i = 1$$

$$\Rightarrow p_0 = \frac{1}{1 + \sum_{k=1}^{L_{reny}} \prod_{m=0}^{k-1} P_{c,i,m} + \sum_{k=0}^{L_{reny}} P_{s,i,k} \prod_{m=0}^{k-1} P_{c,i,m}}$$
(6)

Let S_i be the reminder of time which SS needs to send a successful request in stage *i*. Saturation delay until successful transmission, denoted with E[S], is estimation of the sum of all $\overline{S_i}$ like follow:

$$\overline{S}_{0} = p_{0} \times \left[\frac{BW_{\min}}{FrameOpp} \right] + P_{c,i,0} \times \overline{S}_{1}$$

$$\overline{S}_{1} = p_{1} \times \left[\frac{\delta \times BW_{\min}}{FrameOpp} \right] + P_{c,i,1} \times \overline{S}_{2}$$

$$\vdots$$

$$\overline{S}_{retry-1} = p_{retry-1} \times \left[\frac{\delta^{retry-1} \times BW_{\min}}{FrameOpp} \right] + P_{c,i,retry-1} \times \overline{S}_{retry}$$

$$\overline{S}_{retry} = p_{retry} \times \left[\frac{\delta^{retry} \times BW_{\min}}{FrameOpp} \right]$$
(7)

$$E[S] = \sum_{k=0}^{L_{recy}} \overline{S}_{k}$$

$$\Rightarrow E[S] = \left[\sum_{k=0}^{L_{recy}} \left[p_{k} \times \left[\frac{\delta^{k} \times BW_{\min}}{FrameOpp} \right] \times \prod_{j=0}^{k-1} P_{c,i,j} \right] \right]$$
(8)

Where $BW_{min} \leq \delta^{x*} BW_{min} \leq BW_{max}$ and *FrameOpp* is the number of bandwidth request transmission opportunities in one frame. To calculate throughput of the Best Effort services in node or network, this time should be add to the transmission time of data. Therefore with increases in *E[S]*, throughput will be decreased.

IV. SIMULATION RESULTS

In this section we compare analytical findings with simulation results. We develop a C++ code to simulate delay conditions. BW_{max} is considered to be 1024 and L_{retry} equals to

10. For simplicity we suppose that each node has only one connection. Simulation results presented in figures 3 tol1 are average values for different SS's in simulation. Results show that our model is coincidence with the simulation results.



Figure 3. Number of frames spent with BWmin=10 and FrameOpp=10



Figure 4. Number of frames spent with BWmin=10 and FrameOpp=15



Figure 5. Number of frames spent with BWmin=10 and FrameOpp=20

As shown in figures 3, 4 and 5, if we increase *FrameOpp* in each frame, the transmission saturation delay will be decreased; but we should attend that this situation decreases useful uplink time slots for uplink data transmission in a frame.

As shown in figures 6, 7 and 8, if we increase BW_{min} when *FrameOpp* grows, we can get better delay conditions. For example, comparing results of figure 6 (BW_{min} =15, *FrameOpp*=15) with results of figure 4 (BW_{min} =10, *FrameOpp*=15) it can be seen that maximum delay decreases

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from 4 frame to 3. Comparing results from figures 5, 7 and 8 also acknowledge this.



Figure 6. Number of frames spent with BW_{min} =15 and FrameOpp=15



Figure 7. Number of frames spent with $BW_{min}=15$ and FrameOpp=20



Figure 8. Number of frames spent with $BW_{min}=20$ and FrameOpp=20

Figures 9, 10 and 11 show that if BW_{min} be greater than *FrameOpp*, the delay will be increased. For example, comparing results of figure 3 (BW_{min} =10, *FrameOpp*=10) with results of figure 9 (BW_{min} =15, *FrameOpp*=10) and results of figure 10 (BW_{min} =20, *FrameOpp*=10) show that delay is decreased. Comparing results of figures 4, 6 and 11 also acknowledge this.



Figure 9. Number of frames spent with BWmin=15 and FrameOpp=10



Figure 10. Number of frames spent with BW_{min}=20 and FrameOpp=10



Figure 11. Number of frames spent with BWmin=20 and FrameOpp=15

V. CONCLUSION

IEEE 802.16 standard supports four types of services to ensure QoS requirements for different classes of services. In these types, Best Effort class is a well known class that many of today's traffics involve in this class. This class does not support any bandwidth requirements and use stand alone bandwidth requests in bandwidth contention periods. Because of contention nature of these requests, some of the requests have been collided and therefore network throughput will be decreased. In this paper we proposed an analytical model to calculate saturation delay in bandwidth request. Our model shows that with a bigger contention period in each slot, safe bandwidth request transmission probability will be increases. Also with a BW_{min} value near the *FrameOpp* value, the Best results can be achieved. For future work, we decide to extend and complete our model with respect to grant types supported by WiMAX.

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