An Adaptive Bandwidth Reservation Method for IEEE 802.16 BWA System: Using Data Mining Techniques

Mona Mojdeh, Hamed S. Alavi, Nasser Yazdani, and Caro Lucas

Abstract—**The need for broadband wireless access systems in residential and small-to-medium sized business environments is increasing due to their requirement for higher bandwidth network access. IEEE 802.16 Air interface standard is truly a state-of-art specification for fixed broadband wireless access systems employing a point-to-multipoint (PMP) architecture. Providing quality of service for different types of services, defined in this standard, has become a challenging problem for BWA designers. This paper presents an adaptive bandwidth reservation method based on data mining techniques focusing on dynamic parameters of service classes. Simulation results show that our method improves quality of real-time services in terms of delay and jitter significantly.**

***Index Terms*—Broadband Wireless Access System, Data Mining, IEEE 802.16 standard, Quality of Service**

I. Introduction

TODAY'S customers require service providers to offer high-speed "always on" Internet services. Broadband Wireless Access is a clear choice for carriers planning to deliver voice and broadband data services to residential and business customers with the advantages of rapid deployment, high scalability, low maintenance and upgrade costs and finally, granular investment to match market growth [3]. The IEEE Computer Society and Microwave Theory and Techniques Society have developed fixed BWA standards within their 802.16 working group. The scope includes PMP systems operating in the frequency range 10-66GHz containing both the Physical and MAC layers. This is now a published IEEE Standard for metropolitan area networks [1].

These standards utilize different mechanisms to provide Quality of Service requirements. While the mechanisms have been mentioned in standards, the details of the designs have been directly left to developers. To answer QoS needs in these systems, previous work have addressed issues such as scheduling, admission control, and traffic shaping in different ways. The solution proposed in [3] includes an upstream scheduler and a traffic shaper module to provide QoS for MAC protocol of IEEE 802.16 BWA systems. [4] Suggests an scheduling architecture and the way it deals with each type of service flow. [6] provides an architecture in which downstream generation is described based on an scheduling algorithm. Another architecture defined by [2] proposes a design that considers admission control, schedulers and traffic policers with focus on the uplink packet scheduler.

While resource reservation as a challenging issue plays an important role to provide quality of service in BWA systems, it has remained an unanswered concern. To reserve bandwidth particularly for real-time services, utilizing some kind of traffic prediction seems to be beneficial. Comparable works in this area includes [9], which proposes a new algorithm based on data mining that can do association rule mining and association analysis for predicting traffic network flow. A model for bursty traffics was explored by [10]. It utilizes this model to define association rules in order to predict such traffics.

In this paper, we introduce a novel resource reservation mechanism for IEEE 802.16 based on traffic prediction using data mining methods, which improves delay and jitter, particularly critical for real-time services.

The rest of this paper is organized as follows. Section II provides an overview of IEEE 802.16 standards. We then describe the bandwidth reservation problem in details in section III. We explain our adaptive model for traffic prediction based on data mining technique in section IV. Section V gives the performance evaluation of the proposed method through experiments. Finally we conclude in section VI.

II. IEEE 802.16 Broadband Wireless Access

The IEEE 802.16 standards for fixed BWA systems support metropolitan area network architecture. It assumes a point-to multipoint topology with a Base and several Subscriber Stations. Base Station controls and manages the entire system and Subscribers perform as interface between end users and the Base Station (Figure 1).

The downlink channel on which data flow is directed from BS to SSs uses TDM scheme and the uplink channel in opposite direction applies TDMA scheme [7, 8]. The IEEE 802.16 standards define a connection-oriented MAC protocol that supports multiple physical layer specifications. The physical layer air interface is optimized for bands from 10 to 66 GHz.

IEEE 802.16s define four types of service flows, each with different QoS requirement [1]:

<u>Unsolicited Grant Service (UGS):</u> UGS is designed to support real-time service flows that generate fixed size data packets on a periodic basis such as T1,E1 and Voice over IP without silence suppression. The service offers fixed size

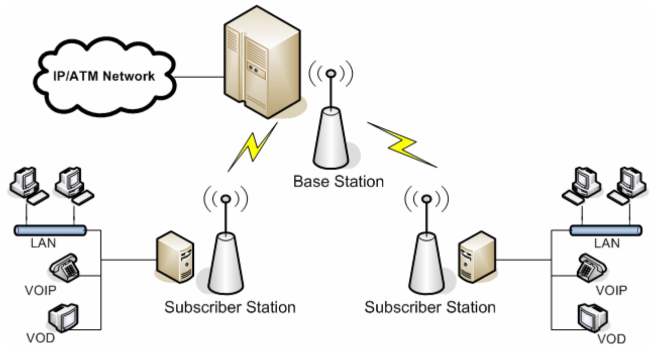

Fig. 1. Broadband Wireless Access.

grants on a real-time periodic basis, which assure that grants are available to meet the flow's real-time needs.

Real Time Polling Service (rtPS): rtPS is designed to support real-time service flows that generate variable size data packets on a periodic basis, such as moving pictures experts group (MPEG) video.

Non-Real Time Polling Service (nrtPS):This service is for non-real-time flows which require better than best effort service, e.g. bandwidth intensive file transfer like FTP applications.

Best Effort Service (BE): This service is for best effort traffic such as HTTP. There is no QoS guarantee.

IEEE 802.16 standards use specific request and grant mechanism in which each SS indicates the amount of uplink bandwidth it needs to the BS. The BS is allowed to allocate bandwidth in two modes; Grant Per Connection (GPC), in which bandwidth is assigned to each connection, and Grant Per Subscriber Station (GPSS), in which an SS requests for transmission opportunities for all of its connections and is allowed to re-distribute the bandwidth among them. The latter is more suitable when there exists many connections per terminal and it is mandatory for systems using the 10–66 GHz PHY specification [1].

III. Bandwidth Reservation

IEEE 802.16 standards define a particular request and grant mechanism that calls for a practical appropriate design. An efficient technique is proposed in this section to provide the mechanism. According to this mechanism, BS polls each SS in specific intervals. This can be done by the use of allocating extra bandwidth or sending a Polling message. On the other hand, each SS is responsible for generating and sending bandwidth requests in appropriate situations [1].

The general method for this mechanism is to generate requests after data arrived in SSs input queues [2]. While this is suitable for non real-time services it makes unacceptable delay for real-time services. IEEE 802.16 time line shown in 2 demonstrates how this method increases delay for real-time services. Data received by SS at Ts is too late to be processed for generating associated request during current frame and the procedure is deferred to E1. Generated request arrives at BS sometime between F2 and F3. It takes BS several frames to evaluate and grant the request (F3 to Fn+3 as depicted in 2). The grant is then sent at Fn+3 by BS and processed at En+3 by SS. Thus, now the data can be sent and would be received by BS sometime between Fn+4 and Fn+5. As can be seen, this method causes arriving data to be delayed at least for 6 frames, which can be intolerable for real-time traffics, especially when evaluating the request in BS takes more than several frames (n increases). To solve this problem, a method that predicts coming traffic and generates requests before the real data arrives seems to be essential.

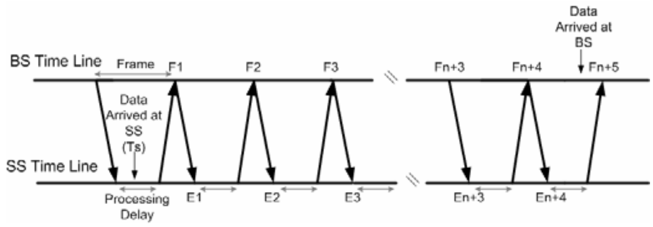

Fig. 2. 802.16 Time Line

IV. Traffic Prediction: Using Data Mining Techniques

To be able to predict the traffic, we have used decision tree classifiers, as a widely used data mining technique [11]. The goal is to purify data items at each level of decision tree, through splitting them based on appropriate common attributes. It is desirable to have leaves with maximum possible members and also maximum possible purity. In our model, each leaf at the bottom of the tree denotes a range predicted for next packet size.

To construct the decision tree appropriate attributes and conditions are required for each level. Partitioning attributes in the proposed model is based on the history of the traffic. The main idea is that new coming packet size depends on volume of data received earlier. Partitioning conditions at each level are chosen in a way that they result in the maximum possible purity at their children [11]. Figure 3 shows an instance of constructed tree with "Average Packet Size in 80ms" as first level attribute that stands for average size of packets arrived during last 80ms. It is partitioned into three splits providing the best purity at the next level of tree. This procedure is repeated for each level with reduced durations of traffic history, coming to "Current Packet Size" as the last

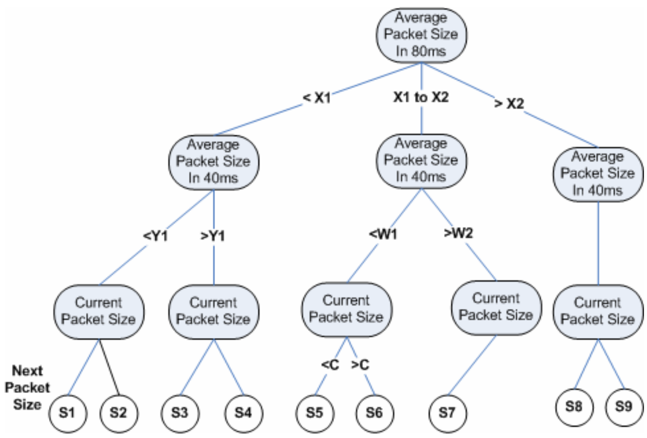

Fig. 3. Decision Tree Classifier.

level's partitioning attribute.

Thus, for each coming packet, next packet size is estimated by traversing the tree, using traffic history properties, and locating the appropriate leaf. For example, average packet size in 80ms between X1 and X2, average packet size in 40ms less than W1, and current packet size greater than C leads to prediction of S6 as next packet size.

V. Simulation Results

In order to analyze the proposed model, we applied data items of about 10,000 packets from a real-time MPEG traffic to train our classifier decision tree. Data set is grouped into 28 classes, each covering a range of 500 bits for next packet size, starting from 0 reaching 14000 bits. Purity in each split is computed as follows:

$$Gini(S) = 1 - \sum_{i=1}^{k} P_i^2$$

In which P_i is the fraction of instances in split S that are in class i. At each level split S is partitioned into splits $S_1,...,S_r$ to achieve maximum information_gain_ratio according to following formulas [11].

$$Purity(S_1,...,S_r) = \sum_{i=1}^{r} \frac{|S_i|}{|S|} Gini(S_i)$$

$$Information\_gain(S,\{S_1,...,S_r\}) = Gini(S) - Purity(S_1,...,S_r)$$

$$Information\_content(S,\{S_1,...,S_r\}) = -\sum_{i=1}^{r} \frac{|S_i|}{|S|} \log_2 \frac{|S_i|}{|S|}$$

$$Information\_gain\_ratio = \frac{(Information\_gain(S,\{S_1,...,S_r\}))^{1.2}}{Information\_content(S,\{S_1,...,S_r\})}$$

To evaluate our model, two sets of packets, each containing 150 packets, were applied to the decision tree. The results of our prediction together with the real traffic are illustrated in 4 and 5 for the two data sets. The graphs show that the predicted traffic curve adapts and follows the real traffic curve.

In order to prove the performance of our method we have developed a simulation tool in a java based environment. The goal of the experiment was to show how the proposed method for traffic prediction improves QoS parameters.

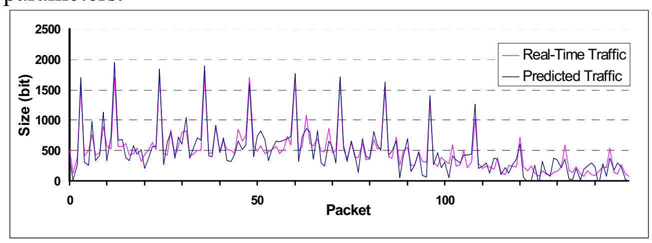

Fig. 4. Predicted and Real Traffic for the First Data Set

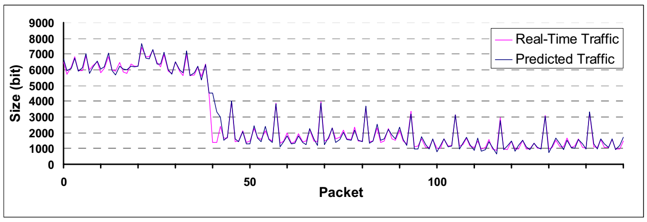

Fig. 5. Predicted and Real Traffic for the Second Data Set

As depicted in figure 6, the model consists of a Base and four Subscriber Stations with max uplink and downlink capacity of 80Mbps. Each SS has four service flows with mentioned average loads.

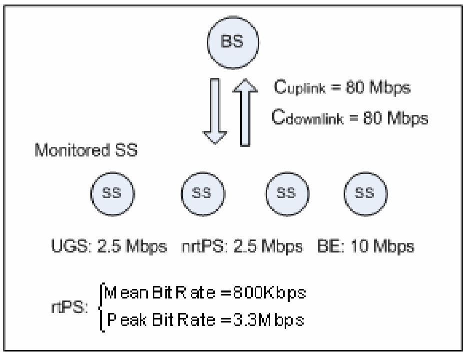

Fig. 6. Simulated Model

Figure 7 demonstrates packets' delay in two experiments applying two methods for bandwidth reservation with and without traffic prediction. As can be seen, utilizing prediction method not only lessens delay, but also decreases jitter parameter. The achieved results are due to the fact that the discussed method decreases maximum delay of 6+n frames to 3, as the time line in figure 2 shows. For instance, a packet arriving at SS at Ts, has already reserved enough bandwidth by prediction method, and would be received by BS some time between F2 and F3. Furthermore, the elimination of parameter n results in a great reduction in jitter.

It is worth noting that the forecasting method might cause less bandwidth utilization which is defined as the proportion of the total bandwidth granted to each SS utilized for data and message transmission. The fact is due to requests predicted more than actual SS's needs. Figure 8 illustrates that while the previous method utilizes bandwidth completely; overestimate prediction causes less bandwidth utilization at some points.

VI. Conclusion

We propose an adaptive bandwidth reservation method based on data mining techniques for IEEE 802.16 Air interface standard. To the best of our knowledge, there has been no similar work previously. Our simulation results illustrate high performance of our technique. The proposed method improves delay and jitter metrics which are key quality of service parameters in real-time services.

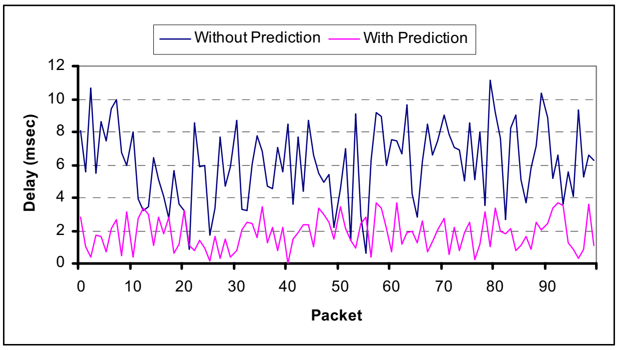

Fig. 7. Delay

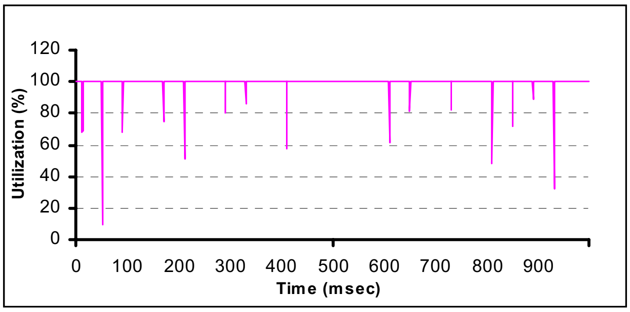

Fig. 8. Bandwidth Utilization

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