Dynamic Call Admission Control for Enhanced GoS of UGS Connections during "Busy Hour" in WiMAX

Angelos Antonopoulos and Christos Verikoukis

Telecommunications Technological Centre of Catalonia
Parc Mediterrani de la Tecnologia (PMT) - Building B4
Av. Carl Friedrich Gauss 7, 08860
Castelldefels (Barcelona), Spain
{aantonopoulos,cveri}@cttc.es

Abstract. In this paper we introduce a dynamic connection admission control (CAC) mechanism for IEEE 802.16 broadband wireless access Standard. Our algorithm has been developed considering the problem of "busy hour" in communications traffic variation during a typical day. The proposed solution, which is compatible to the IEEE 802.16 Standard, provides higher priority to VoIP calls compared to other types of traffic in the network. The performance of the proposed algorithm is evaluated by means of computer simulations and compared to simple traditional admission control schemes.

Keywords: Admission Control, Busy Hour, WiMAX, IEEE 802.16, Medium Access Control (MAC).

1 Introduction

IEEE 802.16 Standard [1] was introduced in order to provide a Broadband Wireless Access (BWA), thus making it an attractive alternative solution to well-known wired technologies like xDSL and cable modem access. In the IEEE 802.16 architecture there are two types of stations: base station (BS) and subscriber station (SS). Each SS can serve a number of users who have access to the network. Both BS and SS are fixed, but inside the SS, users can be either static or mobile. Communication can take place in two different modes: Point-to-Multipoint (PMP) mode and Mesh mode. In PMP mode, the BS is the central entity that decides the transmission and reception schedules of the SSs, while in Mesh mode traffic can be routed directly between SSs without the need of BS. Our study is based on PMP architecture, where the communication path between BS and SS has two directions: uplink (from SS to BS) and downlink (from BS to SS), multiplexed either in time or frequency domain (TDD and FDD respectively).

Admission control is the mechanism that decides whether one new connection should be accepted or rejected, depending on network available resources. More

P. Chatzimisios et al. (Eds.): MobiLight 2010, LNICST 45, pp. 346–355, 2010.

sophisticated admission control algorithms respect the QoS requirements of the connections in terms of delay, jitter and other network characteristics in order to provide a more reliable service to the end users [4],[5],[6].

In this paper, we propose a new connection admission control algorithm that gives priority to VoIP calls, especially during the "busy hour", when the arrival rate of the connections is the highest rate observed during the day. IEEE defines the "busy hour" as "the uninterrupted period of 60 minutes during the day when the traffic offered is the maximum" [11]. To the best of our knowledge, there is no proposed solution that tries to face the phenomenon of "busy hour", while the most of the work gives priority to real time services since they have been admitted by the system.

The rest of this paper is organized as follows. Section 2 provides an overview of IEEE 802.16 Medium Access Control (MAC) layer. Section 3 outlines the related work on admission control schemes for WiMAX networks in the literature. In Section 4 we introduce our proposed connection admission control method. The numerical results are provided in Section 5 and we conclude in Section 6 .

2 Overview of IEEE 802.16 Broadband Wireless Access (WiMAX) MAC Layer

2.1 Introduction

In this section we briefly review the mechanisms that IEEE 802.16 uses in order to provide the end user with quality of service.

Even though the physical layer specifications and the signaling mechanism for information exchange between BS and SS are well defined in the standard, the admission control and the resource allocation strategies have been left undefined, as it is shown in Figure 1.

2.2 Medium Access Control (MAC) Layer

IEEE 802.16 Medium Access Control layer, defined as connection-oriented, is designed to support different QoS requirements for different services. Based on that, the standard describes the following four types of services:

- Unsolicited Grant Service (UGS) is designed to support real-time service flows that generate fixed-size data packets (CBR traffic) on a periodic basis, such Voice over IP.
- Real-Time Polling Service (rtPS) is designed to support real-time service flows that generate variable sized data packets (VBR traffic) on a periodic basis, such as Moving Pictures Expert Group (MPEG) video.
- Non-Real-Time Polling Service (nrtPS) is designed to support non-real-time service flows that require variable size data grants, like File Transfer Protocol (FTP).
- Best Effort service (BE) is designed to provide efficient service for best effort traffic like Hyper-Text Transfer Protocol (HTTP)

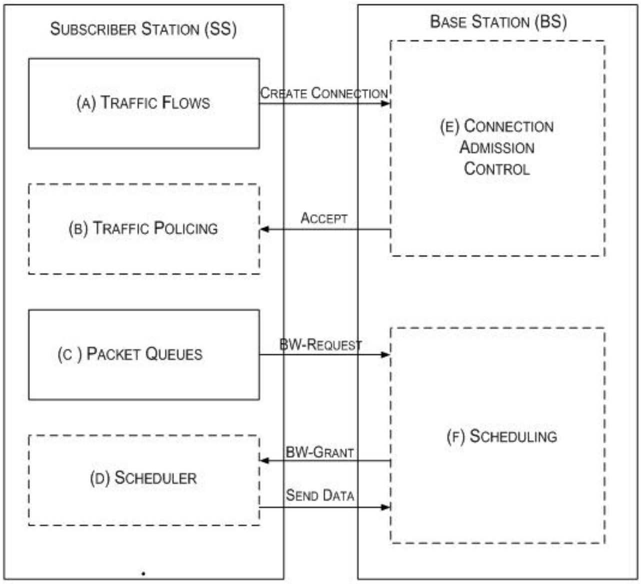

Fig. 1. IEEE 802.16 QoS Architecture

The traffic scheduler located at the BS decides on the allocation of physical slots in each time frame by considering the following parameters for each of the active connections:

- the scheduling service type that the connection belongs to;
- the QoS parameter values of the connection;
- the queue size of the data for transmission;
- the capacity of the available bandwidth.

2.3 Bandwidth Allocation and Request Mechanisms

Requests refer to the mechanisms that SSs use in order to notify the BS that they need bandwidth allocation for their upstream transmissions. There are two methods for transmitting bandwidth requests to the BS:

- Grant per Connection (GPC): Bandwidth is granted explicitly to each connection.
- Grant per Subscriber Station (GPSS): All connections from the same SS are treated as a single unit and bandwidth is allocated accordingly by the BS.

The latter case (GPSS) allows SS to distribute bandwidth among its connections, considering their QoS agreements, thus making it suitable for many connections per terminal, while the former case (GPC) is mostly appropriate for few users per SS.

3 Related Work

There have been some proposals presented in the literature to support QoS in IEEE 802.16 networks. Most of them focus on scheduling algorithms while only few face the connection admission control problem.

Wang et al. [2], proposed a dynamic admission control, using a degradation model as the number of connections increases. In [3], the authors suggest a hierarchical structure for bandwidth allocation, but they use a simple admission control that does not provide any guarantees in terms of delay and jitter.

To overcome this problem, the authors in [4] have proposed an admission control that uses priority queues, serving the UGS connections at first and providing delay and bandwidth guarantees to all the connections that have been admitted as well.

A predictive admission control algorithm is proposed by Castrucci et al. in [5]. The analysis that the algorithm performs anytime a new flow arrives, consists in (i) prediction of the network delay, (ii) comparison of the predicted delay with the delay threshold of the new flow and (iii) comparison with the delay threshold of the already accepted flows.

In [6], a new connection is admitted if there is enough bandwidth to accommodate it and the QoS of existing connections is maintained. The new connection receives QoS guarantees in terms of both bandwidth and delay.

An innovative work is presented in [7], concerning speech quality aware admission control. The proposed CAC, based on E-Model, has been designed considering the objective mouth-to-ear transmission quality.

In [8], the authors introduce an admission control and bandwidth allocation algorithm, based on game theory, considering Nash equilibrium for two players: BS and the new connection.

Finally, there have been some works in literature that try to evaluate the performance of admission control models in WiMAX networks [9], [10].

4 Dynamic Admission Control

As it derives from IEEE 802.16 service types, UGS flows are the most common way for daily communication, while the non-UGS flows are used to support web applications. Furthermore, recent studies have shown that the proportion of VoIP users will continue to grow from 28% of users in 2008 (up from 20% of users in 2007) to more than 50% in 2010 [13]. Due to that fact, our proposed CAC focuses in UGS flows, giving them higher priority comparing to the other three types of flows of the standard.

The problem becomes more intense if we take under consideration the variation of daily traffic volume, where there is a peak during the "busy hour" [11]. In Figure 2 the mean number of calls per minute to a switching centre taken as an average for periods of 15 minutes during 10 working days (Monday - Friday) is depicted. At the time of the measurements there were no reduced rates outside working hours [12].

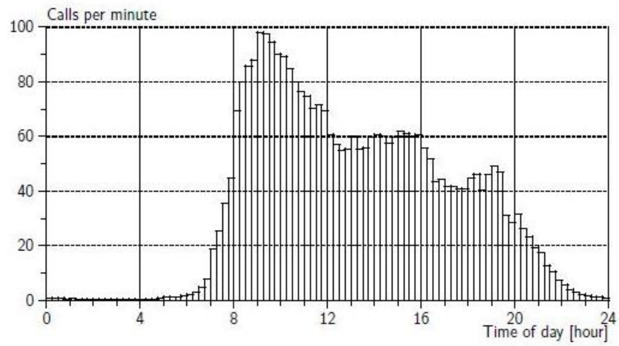

Fig. 2. Typical 24-hour traffic variation

It makes sense that we should give higher priority to VoIP calls during these hours, even if we have to reject some requests from the rest flows, under certain conditions.

The target of the proposed connection admission control algorithm is to provide enhanced Grade of Service (GoS) to VoIP calls, by improving the acceptance rate of the UGS flows. Grade of Service is defined as the probability of a call being blocked or delayed more than a specified interval. From a practical aspect it could also be defined as the probability of a user receiving a network busy signal in a telephone service and can be measured using the following equation:

$$GoS = \frac{Number\_of\_lost\_calls}{Number\_of\_offered\_calls} \tag{1}$$

Using our CAC, the BS accepts all the UGS flows if the available bandwidth suffices, in order for the flows to be served. In case of rtPS and nrtPS flows there is a blocking probability that depends both on the arrival rate of UGS requests and on the available bandwidth as well. In order to deal with BE connections, the requests are always admitted. However, no bandwidth allocation is considered, since BE flows do not need any QoS guarantees.

It is clear that during the "busy hour" the arrival rate of UGS flows is the highest rate observed during the day, thus we may have to reject some requests coming from the other service types, although there is enough bandwidth for them to be served. Moreover, it is common that the daily traffic variation establishes our ability to predict an increase in VoIP calls. Still, taking into consideration the above, we are obliged to reserve the system resources.

The proposed connection admission control algorithm has two parameters: the arrival rate of UGS requests and the available bandwidth of the system. The blocking probability for the other connections increases either when the arrival rate of the VoIP requests increases or when the available bandwidth decreases. We approximately estimate the capacity we need in order to serve all the upstream connections using the following type:

$$C_{need} = \sum_{i=UGS,rtPS,nrtPS} \rho_i \times B_i \tag{2}$$

In the above expression, ρ_i, defined as traffic intensity, is a measure of the average occupancy of the base station during a specified period of time. It is denoted as $\rho_i=\lambda_i/\mu_i$, where λ_i is the arrival rate for each flow and μ_i represents the mean service rate, while B_i is the bandwidth needed for each type of connection. The index i corresponds to different service types and can take values {UGS, rtPS, nrtPS}.

In case that the system bandwidth suffices to serve the flows of all service types, the blocking probability equals zero. Due to this fact, the proposed admission control has the same output with classic admission control schemes under conditions of light traffic in the network. On the contrary, in overloaded environments where the bandwidth is not sufficient for all the connections, we should use an admission control algorithm in order to give different levels of priority to the various connections.

The arrival rate of the UGS requests can be defined as λ_{UGS}. If this rate is higher than one specific threshold there will be a blocking probability for the requests of the other service types. This threshold is defined by the administrator / operator of the network, by considering the network parameters, as the arrival rate of VoIP calls during "busy hour". The values' range of this probability fluctuates between $Pblock_{min}$ and $Pblock_{max}$, depending on the available bandwidth of the system. In the extreme case when we have no available bandwidth the overall blocking probability becomes $Pblock_{max}$. To the contrary, when the total bandwidth of the system is available and no connections are being served, i.e. $BW_{available}/BW_{total} = 1$, the blocking probability becomes $Pblock_{min}$, as there is enough bandwidth in order for the connections of all types to be served. These borderline values are selected by the system's operator according to each traffic class' desired level of priority. On the other hand, whenever the arrival rate of UGS connections is smaller than this arrival rate threshold, we assume that we are off "busy hour" and, therefore, the blocking probability equals zero. The pseudo-code of the proposed Call Admission Control algorithm is presented in TABLE 1.

5 Performance Results

In order to evaluate the performance of our CAC algorithm we have developed an event driven C++ simulator. Simulations have been carried out, assuming a WiMAX - OFDMA physical interface between BS and SSs, using the TDD duplexing technique, a channel bandwidth of 10MHz and 1024 subcarriers. The frame duration is 5 msec and the OFDMA symbol duration of 102.86 μsec. The modulation scheme chosen for downlink and uplink direction is 16-QAM with code rate 3/4. In this section we present the simulation set up and results of our experiments.

Table 1. Dynamic Admission Control Algorithm

Algorithm. Dynamic Admission Control
$C_{need} = \rho_{UGS} \times B_{UGS} + \rho_{rtPS} \times B_{rtPS} + \rho_{nrtPS} \times B_{nrtPS}$
if (arrival_rate $\geq$ threshold) **then** {
if(total_BW $\geq C_{need}$)
$P_{blocking} = 0$
else if (total_BW $< C_{need}$){
Rate_of_available_BW = available_BW / total_BW
Fixed_rate = Rate_of_available_BW/4 %% normalize the value between 0-0.25 %%
Dependence = 0.25 - Fixed_rate
$P_{blocking} = Pblock_{min}$ + Dependence }}
else if(arrival_rate < threshold) %% when we are off "busy hour",$P_{blocking}$ becomes zero %%
$P_{blocking} = 0$

5.1 Simulation Scenario

We assume that the arrival rate of requests for new connections follows a Poisson distribution with mean value 1 connection/sec (because of the traffic intensity), while the service time is exponentially distributed with mean time 60 and 50 seconds for the UGS and the rest flows respectively. For simplicity, but without the loss of generality, we treat the two flows (rtPS, nrtPS) as one with the same characteristics (i.e. arrival rate, bandwidth demand). In this point we must clarify that this simplification concerns only the admission control process since, after being accepted, the two classes are treated according to their different priorities. Furthermore, as we have already mentioned, BE connections are always admitted in the system, without any QoS guarantees.

Using the physical layer that was described above, we derive an overall bandwidth of 4 Mb/s for the uplink traffic, while the bandwidth that each rtPS / nrtPS connection uses is 128 kb/s. The codec chosen to generate VoIP traffic is the G.711, resulting to a constant bit rate of 64 kb/s. The system parameters are presented in Table 2.

Under these assumptions, the system can serve about 98% of the UGS calls, if all the requests of the other classes are rejected, which means that we have an over-loaded simulation environment. In the specific case where all the requests

Table 2. System Parameters

Bandwidth	4Mb/s
$\boldsymbol{\lambda_{UGS}}$	Poisson(1 connection/sec)
$\boldsymbol{\lambda_{rtPS,nrtPS}}$	Poisson(1 connection/sec)
$1/\boldsymbol{\mu_{UGS}}$	Exponential (60 sec)
$1/\boldsymbol{\mu_{rtPS,nrtPS}}$	Exponential (50 sec)
$\boldsymbol{B_{UGS}}$	64kb/s (G.711)
$\boldsymbol{B_{rtPS,nrtPS}}$	128kb/s
Threshold	0.2 calls/sec
Pblockmin	0.6
Pblockmax	0.85

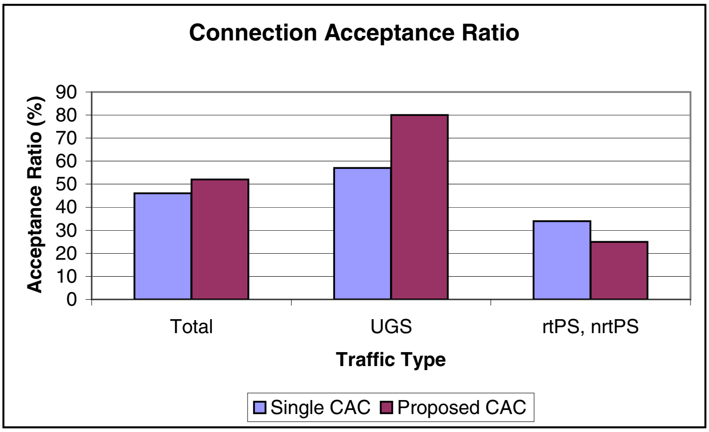

Fig. 3. Flow Acceptance Ratio for all classes of traffic

are being accepted if there is enough bandwidth, no matter the class that they belong to, the system serves about 57% of the UGS flows and 34% of the other flows.

Our aim is to serve more VoIP calls by reducing the Grade of Service of the UGS connections. Simulation results showed that, using our CAC, we can increase the served VoIP calls up to 80% which is a significant enhancement comparing to 57% we have without using this algorithm. At the same time, the ratio of the accepted connections of the rest two classes decreases to 25%, but this makes sense as our aim is to give priority to UGS flows (Figure 3).

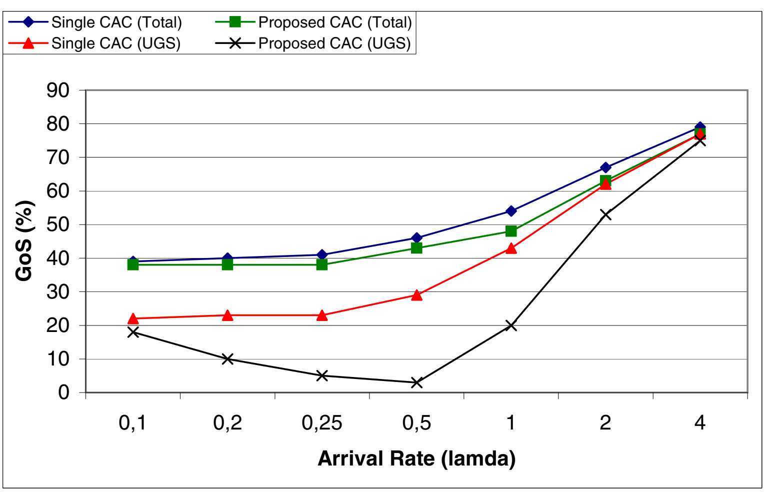

Fig. 4. Grade of Service vs. UGS Connections Arrival Rate

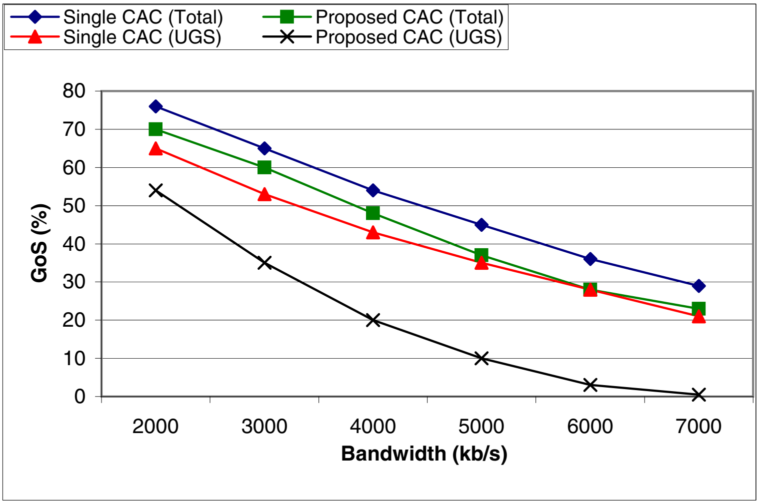

Fig. 5. Grade of Service vs. Total Bandwidth

Comparing our proposed dynamic admission control to traditional schemes for different values of arrival rates for the UGS connections, we observe that our CAC outperforms single admission control methods, without any deterioration in the overall system performance. Figure 4 depicts the Grade of Service among various arrival rates of UGS connections. It is observed that, using our proposed CAC, a better system performance in terms of VoIP communication is achieved, as there is a significant enhancement in GoS (2-26%) of UGS connections. Furthermore, the overall system performance is improved as the acceptance ratio of the total number of connections is increased. As far as networks with restricted bandwidth capabilities are concerned, we observe that the proposed dynamic admission control is superior to single methods for different values of system bandwidth. In Figure 5 the GoS for various values of system bandwidth is presented. In all cases the proposed CAC outperforms single admission control schemes, as it improves the GoS both for UGS connections (11-23%) and for the total number of connections (6-8%) as well.

6 Conclusion

In this paper, a new connection admission control algorithm for IEEE 802.16 architecture is presented. Compared to simple admission control methods, the proposed solution improves the Grade of Service of UGS connections, as the Base Station serves more VoIP calls by considering the "busy hour" phenomenon. In order to achieve better results in terms of QoS requirements, CAC should be accompanied by an optimum transmission scheduling. In our future work we shall focus our research on such issues.

References

1. IEEE Standard, IEEE Standard for Local and metropolitan area networks, Part 16: Air Interface for Fixed Broadband Wireless Access System, IEEE Std 802.16-2004 (June 2004)
2. Wang, H., Li, W., Agrawal, D.P.: Dynamic Admission Control and QoS for 802.16 Wireless MAN. In: IEEE Wireless Telecommunications Symposium, pp. 60-66 (April 2005)
3. Chen, J., Jiao, W., Wang, H.: A Service Flow Management Strategy for IEEE 802.16 Broadband Wireless Access Systems in TDD Mode. In: IEEE International Conference on Communication, ICC 2005 (2005)
4. Chandra, S., Sahoo, A.: An efficient call admission control for IEEE 802.16 networks. In: Proc. IEEE Workshop on Local and Metropolitan Area Networks (LANMAN), New Jersey, USA, pp. 188–193 (June 2007)
5. Castrucci, M., Delli Priscoli, F., Buccella, C., Puccio, V., Marchetti, I.: Connection Admission Control in WiMAX networks, White Paper
6. Wongthavarawat, K., Ganz, A.: Packet Scheduling for QoS Support in IEEE 802.16 Broadband Wireless Access Systems. International Journal of Communication Systems 16, 81–96 (2003)
7. Bohnert, T.M., Staehle, D., Kuo, G.-S., Koucheryavy, Y., Monteiro, E.: Speech Quality Aware Admission Control for Fixed IEEE 802.16 Wireless MAN. In: ICC 2008, IEEE International Conference on Communications, May 19-23, pp. 2690–2695 (2008)
8. Niyato, D., Hossain, E.: A game-theoretic approach to bandwidth allocation and admission control for polling services in IEEE 802.16 broadband wireless networks. In: Proceedings of the 3rd international conference on Quality of service in heterogeneous wired/wireless networks, Waterloo, Ontario, Canada, August 07-09 (2006)
9. Kwon, E., Lee, J., Jung, K., Ryu, S.: A Performance Model for Admission Control in IEEE 802.16. In: Braun, T., Carle, G., Koucheryavy, Y., Tsaoussidis, V. (eds.) WWIC 2005. LNCS, vol. 3510, pp. 159–168. Springer, Heidelberg (2005)
10. Ghazal, S., Mokdad, L., Ben-Othman, J.: Performance Analysis of UGS, rtPS, nrtPS Admission Control in WiMAX Networks. In: ICC 2008, IEEE International Conference on Communications, May 19-23, pp. 2696–2701 (2008)
11. Weber, J.: Dictionary of English Language Traffic Terms. IEEE Transactions on Communication Technology 16(3), 365–369 (1968)
12. Iversen, V.B.: Analysis of real teletraffic processes based on computerized measurements. Ericsson Technics (1), 1–64 (1973); Holbk measurements
13. Report Study, Enterprise VoIP Market Trends 2009-2012. Osterman Research Inc. (February 2009)