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An Improved Call Admission Control (CAC) Scheme in IEEE 802.16e Networks

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ABSTRACT
In this paper, an enhanced CAC scheme is proposed to overcome the problem of resource wastage in 802.16e networks. It introduces an adaptive threshold that dynamically adjusts the quantity of reserved bandwidth for handoff-connections based on the traffic intensity of a handoff requests. An extensive simulation experiments have been conducted to evaluate the performance of the proposed scheme. The simulation results illustrate that the proposed scheme significantly improves the network efficiency as compared to the other scheme in terms of reducing the new connection blocking probability and handoff connection dropping probability.

KEYWORDS
Handoff connection dropping probability — New connection blocking probability — Mobile WiMAX.

1. Introduction

The IEEE 802.16e standard [1] is one of the wireless technologies that provides ubiquitous wireless access at high bandwidth, wide coverage and low cost of deployment to residential users and small businesses [2]. The standard sets out two specifications, the physical (PHY) and media access control (MAC) layers. It has several advantages, including ease and cost of deployment, first-mile/last-mile access, and QoS support for multimedia applications at the MAC layer [3, 4, 5]. Because multimedia applications must support different types of traffic simultaneously, each of which has different quality of service (QoS) requirements from the network, such as bandwidth, delay, jitter, and packet loss, providing QoS to these traffic classes represents a challenge. Therefore, CAC schemes are essential to providing the required level of network QoS [6, 7].

CAC scheme is a process in which a new or a handoff connection is accepted into the network only if its QoS can be satisfied while ensuring the QoS of the existing connections is not degraded [8] according to availability of network resources. Handoff is the process of transferring mobile station (MS) connection from its connected BS that suffers worse signal quality to a neighboring BS with the best quality signal. The scheme prioritize a handoff user to a new network user in order to provide better user-perceived satisfactions. The design of a CAC mechanism must consider the need for available bandwidth to achieve the QoS requirements for the handoff connections. Therefore, the BS should reserve a certain quantity of bandwidth for upcoming handoff connections only and allot the remaining for new connections. The CAC scheme is considered effective if its able to simultaneously provide the QoS to the admitted connections and efficiently utilize the network resources. Since 802.16e is an extension to the original standard 802.16, the earlier CAC schemes are proposed in 802.16 [9, 10, 11, 12] that support only new connections in order to improve the bandwidth utilization as well as QoS of various service classes. Nonetheless, the schemes ignore to consider handoff connections because the fixed standard do not support mobility. Because mobile standard supports mobility, the later schemes are also proposed in [13, 14, 15, 16] with consideration to both new and handoff connections. Among these, dynamic CAC and bandwidth reservation (BR) scheme in [16] is one of the recently used scheme that adaptively defines the admission criteria based on the traffic loads and adopts an adaptive QoS technique. The technique efficiently utilized network resources and assured QoS for admitted new connections and handoff connections. However, its adjusted the amount of reserved bandwidth for handoffs connections based on the arrival of handoff and new connections by considering a fixed maximum reserved bandwidth threshold for handoff connections that may lead to a waste of resources during frequent arrival of new and handoff connections.

In this paper, we propose *an improved CAC scheme* for 802.16e networks to improve upon the efficiency of dynamic CAC and BR [16]. It introduces an adaptive threshold that adaptively reserved the quantity of bandwidth for handoffs connections based on a traffic intensity of the handoff connections. The proposed scheme is evaluated through extensive simulations conducted by discrete event simulation. The performance of the proposed algorithm is compared and evaluated by means of simulation results with dynamic CAC and BR [16]. The results show that the proposed scheme has significantly improves the network resource utilization as compared to dynamic CAC and BR scheme in terms of reducing the new connection blocking probability and handoff connection dropping probability.

This paper is organized as follows: Section 2 briefly reviews the IEEE 802.16e standard, and Section 3 addresses related work on CAC schemes. In Section 4, describe the proposed scheme. Section 5 presents the performance evaluations, and conclusion in Section 6.

2. Overview of IEEE 802.16e standard

The standard [1] defines two layers to support both fixed and mobile wireless metropolitan area networks (WMANs). The MAC layer sits atop the PHY layer and mediates between it and the layers above. The protocol that operates the MAC layer performs the main tasks of the standard, such as QoS provisioning, (CAC), bandwidth allocation, and scheduling. It supports two modes of operation: point-to-multipoint (PMP) and mesh. The former is a cellular-like structure that supports communication between a base station (BS) and a set of subscriber stations (MSs) in broadcast fashion. The BS is the central controller, regulating all communications between itself and a set of MSs. Each MS can represent a single or multiple users. The two paths of communication between the BS and the MSs are the uplink (UP; from MS to BS) and downlink (DL; from BS to MS) directions. In contrast, mesh mode supports multihop communication between MSs. In this paper, PMP is considered as the main operational mode.

The PHY layer is responsible for transmitting bits over the wireless channel by means of the adaptive modulation and coding (AMC) technique. AMC supports two transmission modes, frequency-division duplexing (FDD) and time-division duplexing (TDD). In FDD mode, uplink and downlink data are sent on different frequencies. In contrast, in TDD mode both UP and DL data are sent using the same frequency but in different time slices. Both duplexing modes operate in a frame format. Each frame is partitioned into DL and UP subframes. The DL subframe is used by the BS to transmit data and manage messages to an MS, while the UP subframe is used by all MSs to transmit data. it's uses an Orthogonal Frequency Multiple Access (OFDMA) slot as its smallest unit of resource.

The MAC layer is a connection-oriented protocol that has the advantage of controlling network resource sharing among individual connections. The protocol maps both connected and connectionless traffic to a unique connection identifier (CID). If traffic coming from an upper layer arrives at the MAC layer, the MS attempts to establish a connection with the BS. The BS employs a CAC scheme that checks whether the resources available can ensure the QoS of the new connection while maintaining the QoS guarantees for the existing users. With the acceptance of a new connection, the BS responds to the MS with a CID to use for the UP and DL directions. Once a connection is set, the MS can request bandwidth from the BS. The BS grants bandwidth using the grant per subscriber station (GPSS) approach. Once the MS receives its bandwidth from the BS, its packet scheduler distributes the bandwidth among its own active connections. The CAC and request grant bandwidth allocation components of the BS provide support to different applications with various QoS requirements. The 802.16 standard partitions applications into service classes as follows

The *unsolicited grant service* (UGS) periodically generates constant-size data packets for real-time traffic such as VoIP without silence suppression. UGS is sensitive to transmission delays, and the BS allocates grants to the MS in an unsolicited fashion using the maximum sustained traffic rate (MSTR), traffic priority, and maximum latency tolerance as its QoS requirements.

The *real-time polling service* (rtPS) generates variable-size data packets for real-time traffic such as MPEG video. It has less stringent delay requirements and is periodically polled by the BS for each MS to individually determine its bandwidth requirement. Its mandatory QoS specifications are the minimum reserved traffic rate (MRTR), MSTR, traffic priority, and maximum latency tolerance.

The *extended real-time polling service* (ertPS) generates variable-size data packets for real-time traffic such as VoIP with silence suppression. It combines features of both UGS and rtPS and has strict, guaranteed delay requirements and provides unicast grants in an unsolicited manner by the BS, as with UGS. Because UGS grants are of constant size whereas ertPS grants vary in size, an MS can request a change of its bandwidth grant to suit its requirements. The ertPS QoS requirements are MRTR, MSTR, traffic priority, maximum latency tolerance, and delay jitter tolerance.

The *non–real-time polling service* (nrtPS) generates variable-size data packets for non–real-time traffic such as FTP. It has minimum bandwidth requirements that are delay tolerant. It is polled by the BS in order for each MS to state its desired bandwidth. The QoS requirements are MRTR, MSTR, and traffic priority.

The *best-effort service* (BE) is designed to support traffic for which delay and throughput are not guaranteed, such as HTTP. It requests bandwidth through contention request opportunities and unicast request opportunities.

3. Related Work

Several CAC schemes have been proposed to address the problems that affect service class applications in IEEE 802.16e. This section provides an overview of some major CAC schemes that have been applied in 802.16 and 802.16e networks.

In [9], a dynamic admission control scheme is proposed according to the scheduling services defined in a fixed standard. It uses bandwidth reservation and degradation in order to provide QoS to the service classes. The bandwidth reservation is used to give higher priority to the UGS service class because it is widely used by people for their daily communication. The degradation is supported by rtPS and nrtPS service because of the variable generation of packets. The two-service classes have varying bandwidth requirements between the MSTR and MRTR. In this approach, only the nrtPS class is degraded. The paper illustrates that the scheme provides maximum priority to the UGS service class and maximum bandwidth utilization by bandwidth degradation as well as minimization of the blocking probabilities of the service classes. However, handover to mobile users is ignored because the standard does not support mobility. A similar approach has also been proposed in [10], with the only difference being the giving of a reservation to the rtPS service class.

In [14], a CAC scheme is proposed for the non-provisioned service flow in mobile WiMAX, which supports new arrival and handoff connections. The scheme used guard channel and proportional bandwidth-borrowing policy in order to assign high priority to handoff connections than new originating connections. The two policies used provide a reasonable priority order to a new and handoff connections to various service classes. The proposed scheme maximized the bandwidth utilization and reduced the connection-blocking probability as well as the connection-dropping probability of the two connections. However, if handoff connections do not consume the entire reserved resources, a certain portion may be wasted because it can never be used to admit a new connections.

In [15], a CAC scheme is proposed in order to assure QoS to different scheduling service classes in mobile WiMAX. The scheme groups the scheduling service classes into real time and non-real time service classes. The scheme uses a dynamic guard channel that is dynamically changed between a minimum bandwidth reserved threshold and a maximum bandwidth reserved threshold, based on the arrival and departure of handoff connections. This dynamic adjustment gives handoff connections the opportunity to use the maximum reserved bandwidth when the handoff requests arrive heavily. The scheme reduces handoff dropping and new call blocking probabilities. However, when the level of handoff requests is low, the amount of reserved bandwidth will be almost fixed. As a result, the scheme behaves like the fixed guard channel policy, which may also lead to a waste of network resources.

In [16], dynamic CAC and BR schemes are proposed for mobile WiMAX that both improve the efficient utilization of network resources and assure the QoS for admitted new and handoff connections. The scheme dynamically adjusts the admission criteria based on the network loads and an adaptive QoS approach. Linear adaptation is used to regulate the admitted connections when there is no available available. If the new and handoff connections are admitted into the network based on this criterion, then the bandwidth reservation scheme is dynamically adjusted to the quantity of the reserved bandwidth for handoffs based on the arrival of new and handoff connections. The authors showed that the schemes enhance the efficiency of the resource utilization as well as assuring QoS for new and handoff connections. However, it uses a fixed maximum reserved bandwidth threshold based on a new and handoff arrival connection to adjust its adaptive threshold, and this may lead waste of network resources under frequent arrival of the new and handoff connections.

In order to address the aforementioned problem, an improved CAC scheme is proposed to enhance the efficient utilization of resources

4. Proposed scheme

In this section, an improved CAC scheme that enhances the joint CAC and BR scheme in [16] is described. First, however, the shortcomings of the joint CAC and BR scheme are presented. The scheme used an adaptive threshold that is dynamically changed based on the arrival of handoffs and new connections by employing a fixed maximum bandwidth reservation for handoffs. Since the adaptive threshold is updated based on the minimum and maximum reserved bandwidth thresholds, and when both the new and handoff connection arrival rate occurs frequently , then some resources may be left unused and hence lead to an inefficient utilization of network resources. For example, Let assume the total bandwidth (B) in the network be 100 units and the network is empty in the beginning. Suppose that 80 new connections, and 10 handoff connections arrived sequentially in the network. Each of the connection arrived is assumed to request a unit of bandwidth. The scheme also assumed the minimum and maximum reserved threshold for bandwidth to be 0 and 90, respectively. The initial adaptive threshold is computed to be 45 units. From Figure 1, it shows the first 90 connections (80 new and 10 handoff) are accepted into the network. However, the last 10 new connections are rejected because the dynamic adjustments of the adaptive threshold uses the arrival of both new and handoff connections. It also shows that 20 units of bandwidth are left unused and can never be used to admit a new connections. Therefore, the bandwidth resource is inefficiently utilized.

To address the shortcoming of the CAC and BR described above, firstly, an admission criterion is derived below:

The admission criteria are designed according to the network load (nl). The b_i criteria is derived based on three cases as

Case 1:

When $nl < nl_{th}^{0}$

$$b_i = b_i^{max} \tag{1}$$

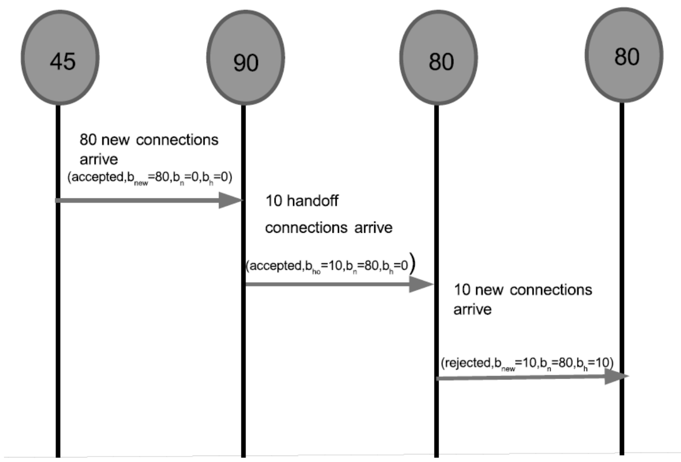

Figure 1. *The process of connection admissions with the dynamic CAC and BR scheme*

where nl_{th}^{0} is the minimum threshold of network loads and b_i^{max} is the maximum bandwidth requirements corresponding to the highest QoS for connection i.

Case 2:

When $nl < nl_{th}^{n}$, $nl < n \leq N-1$

$$b_i = \alpha b_i^{max} + (1-\alpha) b_i^{min} \tag{2}$$

where b_i^{min} is the minimum bandwidth requirements corresponding to the lowest QoS for connection i.

Case 3:

When $nl < nl_{th}^{N-1}$, $nl < n \leq N-1$

$$b_i = b_i^{min} \tag{3}$$

where nl_{th}^{N-1} is the maximum threshold of network loads

Then to accept a handoff or a new connection based on the admission criterion above, the bandwidth allocated to an admitted handoff and new connection is denoted as $b_j^{h}(t)$ and $b_j^{nw}(t)$, respectively, over time.

A handoff connection $h_{con-accepted}(t)$ is accepted into the network when

$$h_{con-accepted}(t) = (b_i^{hof} + \sum_{t=0}^{n} (b_i^{h}(t) + b_i^{nw}(t)) \leq B) \tag{4}$$

where b_i^{hof} is the handoff admission criterion of the handoff connection shown in the admission criteria defined above and B is the total bandwidth. The term in the RHS ensures the maximum bandwidth is not exceeded.

The system capacity B may vary over time because the mobile standard supports multiple transmission rates. The transmission data rate with a given MCS can be evaluated as

$$R_{MCS_i} = (N_{Data\_SC}/T_S) * B_{MCS_i} \tag{5}$$

where N_{Data_SC} is the number of data sub-carriers, T_S is the symbol period, and B_{MCS_i} is the amount of information in bits/symbol with respect to the i_{th} MCS.

Then, introduced an adaptive threshold, adopted from [19], to dynamically change the bandwidth reservation threshold for handoff connections based on the traffic intensity of the handoff connections.

$$th_{adap} = \lfloor \rho_{hof} \times \beta \rfloor \times b_i^{hof} \tag{6}$$

where $\rho_{hof} = \frac{\lambda_{hof}}{\mu_{hof}}$ denotes the traffic intensity, λ_{hof} is the arrival rate for handoff connections, and μ_{hof} is the mean service rate. In addition, b_i^{hof} is the bandwidth required for each handoff connection, while $\beta \in [0,1]$ represents the bandwidth reservation factor.

A new connection is accepted $n_{con-accepted}(t)$ based on the admission criterion defined earlier, when the condition below holds:

$$n_{con-accepted}(t) = [(b_i^{new} + \sum_{t=0}^{n} (b_i^{h}(t) + b_i^{nw}(t)) \leq B - th_{adap})] \tag{7}$$

where b_i^{new} is the new bandwidth admission criterion. The first term in the RHS ensures that new and existing connections do not exceed the adaptive threshold.

The pseudocode for the proposed scheme is in algorithm 1.

Algorithm 1: A proposed scheme.

```
th_adap ← ⌊ρ_hof × β⌋ × b_i^hof
At time epoch t
for (all pending connection c and service class i in c ) do
    if (BS has more BW) then
        b_i ← b_i^max
    else if (BS has ordinary BW) then
        b_i ← α b_i^max + (1 − α) b_i^min
    else
        b_i ← b_i^min
    if (type is handoff and service class i) then
        if (b_i^hof + Σ_{t=0}^n (b_i^h(t) + b_i^nw(t)) ≤ B then
            accept handoff
            th_adap ← ⌊ρ_hof × β⌋ × b_i^hof
        else
            reject handoff
    else
        if (b_i^new + Σ_{t=0}^n (b_i^h(t) + b_i^nw(t)) ≤ B − th_adap
        then
            accept new connection
        else
            reject new
end
```

5. Performance Evaluation

This section evaluates the performance of dynamic CAC and BR [16], and the proposed scheme. The schemes are evaluated in terms of new connection blocking rate and the handoff connection dropping rate, by means of simulations. The discrete event simulation developed in [17] for WiMAX networks is used. In the experiments, the arrival rates of new connections and the handoff connections is assume to be Poisson arrivals: the mean departure rate has also been assumed to be $\frac{1}{10th}$ of the arrival rate. In addition, BS is assumed to know the bandwidth requirements of each connection with respect to its current MCS. The MCS parameters are shown in Table 1 and, the simulation used a 2x2 MIMO mechanism. The simulation parameters are presented in Tables 2.

Table 1. Modulation and coding parameters for 10 MHz Channel [18].

Modulation	Coding rate	Downlink	Uplink
QPSK	$\frac{1}{2}CTC, 6\times$	1.06	0.78
	$\frac{1}{2}CCT, 4\times$	1.58	1.18
	$\frac{1}{2}CTC, 2\times$	3.17	2.35
	$\frac{1}{2}CTC, 1\times$	6.34	4.70
	$\frac{3}{4}CTC$	9.50	7.06
16 QAM	$\frac{1}{2}CTC$	12.67	9.41
	$\frac{3}{4}CTC$	19.01	14.11
64 QAM	$\frac{1}{2}CTC$	19.01	14.11
	$\frac{2}{3}CCT$	25.34	18.82
	$\frac{3}{4}CTC$	28.51	21.17
	$\frac{5}{6}CTC$	31.68	23.52

Table 2. *Parameters for IEEE 802.16e PHY data rates [18].*

Parameter	Downlink	Uplink
System bandwidth	10 MHz	
FFT size	1024	
Null Subcarriers	184	
Pilot Subcarriers	120	280
Data Subcarriers	720	560
Symbol period	102.9 μs	
Frame duration	5 ms	
OFDM symbols/frame	48	
Data OFDM symbols	44	

The simulation setup in this scenario considers all the scheduling service classes in Mobile WiMAX networks, each service class is associated with the QoS requirements shown in Table 3. The scheduling services are assumed to have uniform probabilities of occurrence, with which the arrival rates of new connections and handoff connections are λ_n and λ_h, respectively. The ratio of handoff arrival to new connection arrival rates is considered to be 1:1.

Table 3. *Parameters for IEEE 802.16e PHY data rates.*

class	Maximum rate (kbps)	Minimum rate (kbps)
UGS	100	100
rtPS	100	25
ertPS	75	25
nrtPS	60	20
BE	20	0

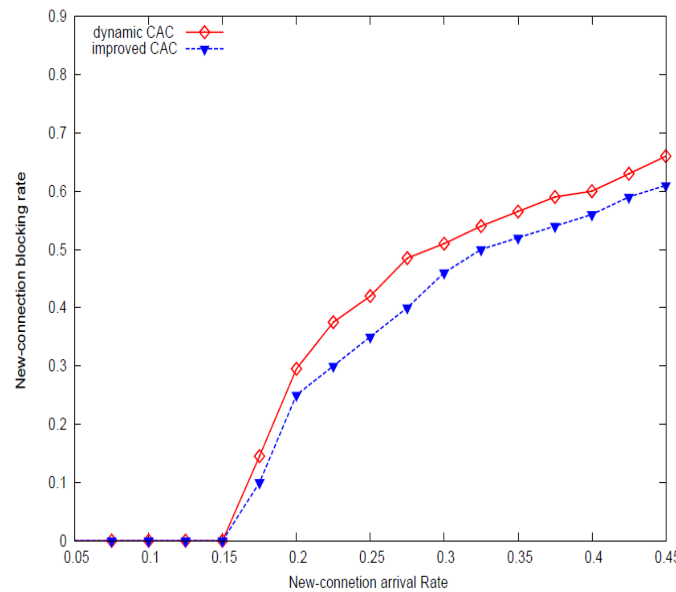

Figure 2. *Blocking rates of new connections with the traffic rates of 1:1.*

In the experiment, the impact of an equal traffic ratio between new and handoff connections is evaluated.

Fig. 2 shows the blocking rates of new connections with the traffic rates of 1:1 for dynamic CAC and BR, and the proposed scheme. It shows that from 0.05–0.15 traffic arrival parameter, the schemes have similar performance because of the low traffic load, but as the intensity of the traffic increases, the proposed scheme performs better than the other scheme. The increase in network efficiency is attributed to the adaptive threshold introduced, that prevent reserving too much resources for handoff connections that remain unused as a result of the fixed maximum bandwidth threshold, but are now used to admit more new connections because of the appropriate computation of an adaptive threshold according to the traffic intensity.

Fig. 3 shows the dropping rates of handoff connections with the traffic rates of 1:1 for dynamic CAC and BR, and the proposed scheme. The figure shows that the proposed scheme has a similar performance with the dynamic CAC and BR when the arrival rate is within the range 0–0.1. But it shows that within the range 0.1–0.45, the proposed scheme has superior performance

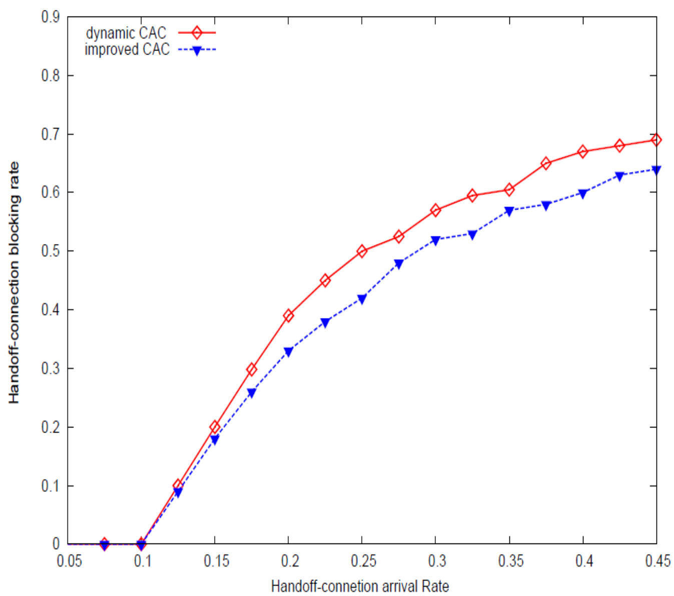

Figure 3. *Dropping rates of handoff connections with the traffic rates of 1:1.*

than the other scheme. The reason for this is that during the frequent arrival of handoff connections the proposed scheme appropriately adjust an adaptive reserved bandwidth threshold for handoffs according to the traffic intensity of the handoff connections.

6. Conclusion

In this paper, an improved CAC scheme is proposed that efficiently utilizes the network resources in IEEE 802.16e networks. The adaptive threshold has been introduced to adjusts the reserved bandwidth for handoff connections using the handoff traffic intensity to improve the efficient utilization of network resources. A number of simulation experiments were conducted to evaluate its performance. The simulation results have demonstrated that the proposed scheme significantly outperforms the other scheme in terms of reducing the new connection blocking probability and handoff dropping probability .

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