Improved CAC Scheme for WiMAX with Adaptive Bandwidth Reservation and Degradation Policy

Zuber Patel and Upena Dalal

***Abstract*—**In wireless networks, packet scheduling and Call Admission Control (CAC) play vital to ensure quality of service (QoS) provided to users. A single scheduling algorithm cannot guarantee all the QoS without the support of a suitable CAC and vice versa. In this paper, CAC mechanism is investigated in detail in context of IEEE 802.16 networks. The paper proposes a CAC algorithm that reserves bandwidth for both handoff and new calls. This avoids excessive blocking and starvation of new calls in the network. It also introduces QoS degradation strategy to increase number of admitted calls. Simulation results shows improvement of proposed scheme over new call bounding and fractional guard channel schemes in terms of number of admitted calls and new call blocking rate.

***Keywords*—**Bandwidth Reservation, Blocking rate, Call Admission Control (CAC), New Call Bounding (NCB).

I. Introduction

WITH ever increasing number of wireless users, it is becoming increasingly difficult to serve users' (or subscribers) requirement of voice calls, video conference calls and data transfer due to scarce spectrum resource allocated to wireless systems across the globe. Efficient mechanisms are needed to control radio resources which can satisfy needs of users and maximize the overall system capacity at the same time. IEEE 802.16 [1] based networks support such mechanisms in terms of scheduling and call admission control. Both call admission control (CAC) and scheduling algorithm play a key role to guarantee quality of service (QoS) demands of WiMAX subscribers. In this paper we focus on CAC mechanism where admission control mechanism is employed in the central stations of IEEE 802.16 networks.

CAC based schemes are classified as centralized, distributed or collaborative [2] depending on concentration of operation. Centralized scheme implements CAC at central Switching Centre (SC) to handle services supported by the communication network. The information from central node such as Base Station (BS) of cell is aggregated at SC where admission decision is taken; then, the BS is instructed to execute decision. This type of centralized CAC scheme has high efficiency but excessive control data exchange and complexity make them impractical. In distributed approach, decision making part of CAC is installed at BS of each cell and each BS executes CAC process interdependently of others. Hence, these schemes are more reliable and less complex. But due to lack of global information of network parameters, they are less efficient. Collaborative approach combines advantages of both centralized and distributed CAC where information regarding resource allocation and admission control is exchange between neighboring cells, though decision is taken by BS of each cell. Collaborative CAC offers increased reliability but it has disadvantage of high overhead.

The CAC algorithm proposed in this paper is based on reserving bandwidth exclusively for new calls as well as handoff calls. It also incorporates novel degradation strategy applied to different service classes of WiMAX connections to increase admitted calls in network. The reservation threshold of new call is made adaptive with change in relative traffic intensity of handoff and new calls. This results in a balanced performance in terms of new call blocking and handoff dropping rate. Degradation strategy [3] lowers QoS criteria of connections gradually when network load increases above certain threshold. Connections belong to UGS, rtPS and nrtPS classes are considered for degradation. The extent of degradation is limited to maintain acceptable quality of connections.

The remainder of this article is organized as follow. In Section 2, we briefly discuss related work done in the literature. Basic operating principle of CAC and few popular schemes are discussed in Section 3. Section 4 describes and analyses the proposed CAC algorithm. In Section 5, we construct simulation scenarios and discuss results. Section 6 draws our conclusions.

II. Related Work

Admission Control algorithms use different criteria for accepting or rejecting a connection emerging from network. Many algorithms [4] [5] are based on estimation of network delay by predicting queue size in subscriber stations (SSs). A connection is accepted if estimated delay is less than or equal to threshold value, otherwise rejected. The work in [6] uses

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both bandwidth and delay control as admission criteria in decision making part of CAC. CAC scheme that estimates the usable link capacity of WiMAX network at vehicular speed and uses this information in making a CAC decision is proposed in [7]. In next-generation wireless networks, call admissions should be designed so that it can be performed across many cells of network. Keeping this in mind, [8] has proposed Gateway Relocation Admission Control (GRAC) which considers admission control and Access Service Network Gateway (ASN GW) relocation jointly to improve the performance of networks.

It is widely accepted that users are more annoyed by call dropping than by call blocking. Therefore, it is generally more important to keep ongoing connection unbroken than admitting new ones. Therefore, a handoff call is given higher priority to access the network resources. Various CAC schemes based on handoff priority have been proposed in the literature. One of these schemes depends on reserving a portion of link capacity for handoff calls. This scheme is called the *cutoff priority scheme* [9]. On the other hand, the *fractional guard channels schemes* depend on admitting a new call with certain probability. This scheme is more general than cutoff priority scheme and it was first proposed by [10] and used extensively thereafter. A CAC scheme named *New Call Bounding scheme* [11] limits number of new calls to be admitted into network and handoff call is rejected only when all channels in the cell are used up. Improved versions of new call bounding scheme are presented in [12] [13] that smoothly throttles the admission rates of calls according to their priorities as well as it aims to provide multiple prioritized traffic with a desired QoS.

III. CAC FOR MOBILE AND WIRELESS NETWORKS

A. CAC – Operating Principle

CAC is a radio resource management mechanism vital to enhance capacity and satisfy QoS needs in wireless networks. The basic idea of CAC is restrict number of connection requests to ensure the QoS of individual connections. An efficient CAC policy should provide following features: (1) Efficient priority assigning mechanism for handoff calls and calls of different service classes (2)Exhibit low call blocking probability (CBP) and low call dropping probability (CDP) (3)Allocate resources fairly (4)Achieve a high network throughput and (5)Avoid congestion. The admittance of a new call, according the CAC scheme employed, should not violate QoS requirement of ongoing calls. Admission criteria are based on not only the available network resources but also the QoS needs of the requesting and admitted calls. Hence, the decision should be taken considering many parameters. It is also desirable to maximize the utility [14], efficiency and revenue of the network while at the same time fulfilling with the QoS demands of users. The admission criteria in the decision making part of CAC scheme should also consider heterogeneous network environment [15] [16] having different class of traffic.

Implementing CAC scheme is quite a challenge because traffic in wireless data network is inherently chaotic and bursty and traffic burst are extremely difficult to be predicted. Variable link quality and mobility of users make CAC even more complicated. In particular, a call admitted in certain cell may have to be handed off to a neighboring cell due to mobility of users. The handoff is big concern here because it is necessary to preserve continuity of the call while at the same time offering at least minimum acceptable QoS. In handoff process, the new cell may not have any available resource to serve handoff call, resulting in handoff failure commonly known as call dropping. The probability that an ongoing call is terminated is called call dropping probability (CDP). Since users are more annoyed by call dropping than by call blocking, the CAC algorithm should keep CDP as low as possible by assigning higher priorities to handoff call compared to new calls. When different types of traffic exist in network, VoIP calls may be given higher priority [17] than other type of traffic.

B. Popular CAC Schemes

In this section, we highlight existing admission control algorithms which are popular and inspired our approach. First, handoff priory-based schemes are discussed. Fig.1a and b illustrate the resource allocation in the cutoff priority algorithm and new call bounding (NCB) algorithm respectively. In the cutoff priority algorithm, both handoff calls and new calls can be admitted if the total number of new calls and handoff calls in the network is equal to or less than a predefined threshold, T_{cp}, less than the total capacity C. When

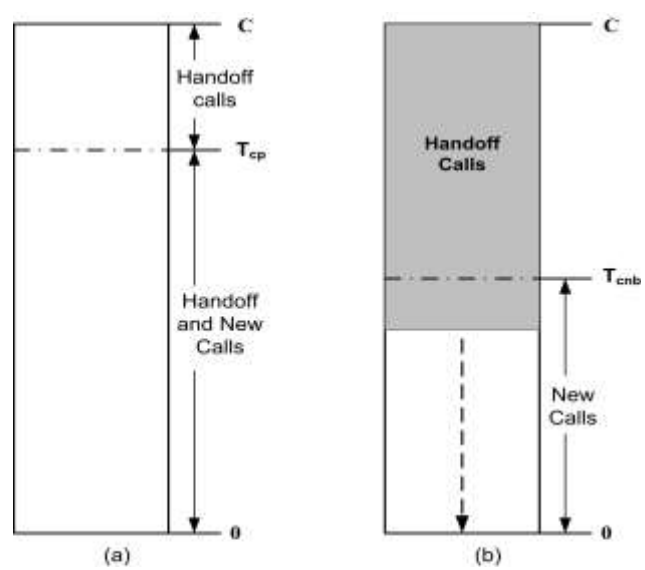

Fig. 1: Resource allocation in (a) Cutoff priority algorithm (b) New call bounding algorithm

sum of new calls and handoff calls in the network exceeds T_{cp}, new calls are blocked, only handover calls are admitted. Once the total number of calls exceeds link capacity C, handover calls are dropped. The NCB algorithm limits the number of new calls up to threshold T_{ncb}, which is also less than the total capacity C. As shown in Fig. 1b, handoff calls utilize the resources in $C - T_{ncb}$ first. If the number of new calls is less than T_{ncb}, handoff calls can use more resources than $C - T_{ncb}$. However, the number of new calls is always less than T_{ncb}. If we denote N as number of accepted new calls and M as number of accepted handoff calls, then relation $N < min(T_{ncb}, C - M)$ holds.

The other popular CAC algorithm is based on Fractional Guard Channel (FGC) policy [10] that effectively reserves a non-integral number of guard channels for handoff calls by rejecting new calls with some probability that depends on the current channel occupancy. In general, in FGC policy, a new arriving call will be admitted with probability β_i when number of occupied channels is i (i=0,1, . . . , N-1). Handoff call will always be admitted unless there are no free channels available. Particular cases of FGC are *Limited FGC* (LFGC) and *Uniform FGC* (UFGC) policies. LFGC finely controls communication service quality by effectively varying the average number of reserved channels by a fraction of one whereas UFGC accepts new calls with an admission probability independent of channel occupancy. In the work of [18], recursive formulas are derived for new call blocking and handoff failure probabilities for various FGC schemes. The effect of mobility on the maximum system capacity achieved by different FGC policies was also evaluated in [18]. Comparison between LFGC and UFGC based on revenue and hard constraint on blocking and dropping probabilities has been discussed in [19].

IV. Proposed CAC Algorithm

Our method is motivated by issues of *blocking probabilities* and number of *admitted connections*. Both parameters are adversely affected by scarce wireless bandwidth resource. So we need to come up with a solution that can handle both. Practically, we want that blocking probability should not be excessively high and admitted connections should increase.

A. Bandwidth Allocation Policy

The common criteria to evaluate the performance of all CAC schemes proposed are CDP and CBP. CDP and CBP [2] can be measured by determining calls dropped and blocked respectively during specified time window. Both CDP and CBP are mainly dependent on traffic load, the number of ongoing calls, bandwidth requirement of each call and policy applied for handoff calls. As we discussed in Sec. 3.2, most CAC schemes reserve bandwidth dedicatedly for handoff connections. Handoff calls also shares remaining link capacity with new calls. This may reduce CDP of handoff calls but at the expense of increasing CBP of new calls. The excessive CBP signifies inefficient CAC design which needs to be addressed. In order to achieve balanced performance, we propose that a small fraction of link bandwidth should be reserved exclusively for new (local) calls as well. The objective of our idea is to simultaneously reduce CDP for handoff calls and CBP for new calls. The situation is depicted in Fig. 2 where there are two dedicated reservations, BR_{ho} for handoff calls and BR_n for new calls. The rest of link capacity is shared by both handoff and new calls. Once the utilization of shared portion is exhausted, both types of calls may start utilizing their reserved portions.

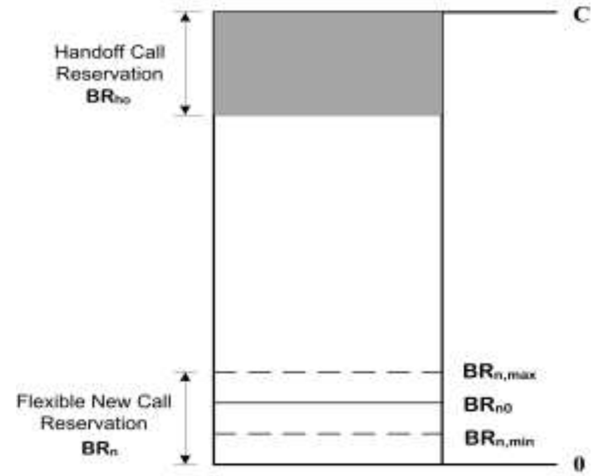

Fig. 2: Resource reservation in proposed CAC scheme

In our proposal, we use fixed handoff reservation in order to achieve deterministic CDP performance but make reserved portion for new call adjustable depending on relative traffic intensity of handoff and new calls. If traffic intensity of handoff calls is higher than new calls, the shared bandwidth portion can be extended by lowering reservation BR_n. Similarly, if traffic intensity of handoff calls is lower than new calls, the reserved portion of new calls is augmented by increasing BR_n. Initially, reservation of new calls is first set to nominal value BR_{n0} and then can be decreased gradually up to $BR_{n,min}$ and increased gradually up to $BR_{n,max}$. Thus, by sensing relative traffic intensity in both type of calls and dynamically adjusting threshold better performance in CDP as well as CBP can be achieved.

B. Degradation Policy

In order to improve bandwidth utilization efficiency and hence to increase number of admitted connections, we employ degradation mechanism. The basic idea of this scheme is to adopt lower QoS criteria of connections under heavy load of network traffic. Under low to medium traffic conditions, higher QoS criteria of connections are used. As network load increases above certain threshold, QoS criteria is gradually degraded (relaxed) but up to certain extent. For different service classes, we adopt different approaches for degradation. We consider three QoS classes [20] UGS for VoIP calls, rtPS for video streaming and nrtPS for non real time data. Since BE class doesn't have QoS provision, connections of BE are always accepted.

In order to adaptively change QoS criteria with network load, we use non-linear approach for all service classes. In this approach, QoS criteria of a service classes begin to degrade when network load cross minimum threshold ρ_{min}. The degradation stops when network load reaches to ρ_{max} as shown in Fig. 3 The non linear approach ensures that the degradation is very gradual initially (when load exceeds ρ_{min})

and aggressive as network approaches ρ_{max}. Thus, bandwidth allocation is degraded as

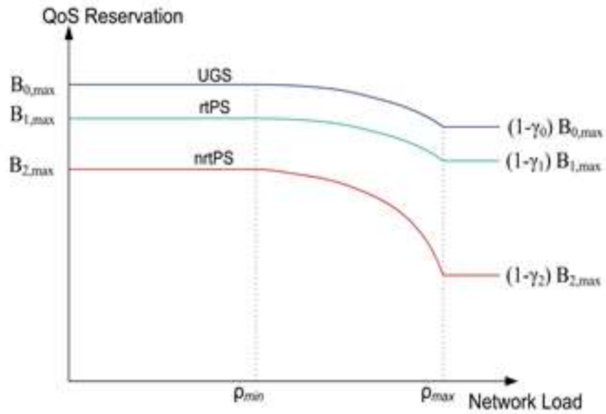

Fig. 3: Nonlinear degradation of three service classes

$$B_i = (1-\gamma_i)B_{i,max} + \gamma_i B_{i,max}\sqrt{1-\sigma^2} \quad (1)$$

$$\text{where, } \sigma = \begin{cases} 0, & \rho < \rho_{min} \\ \dfrac{\rho-\rho_{min}}{\rho_{max}-\rho_{min}}, & \rho_{min} \le \rho \le \rho_{max} \\ 1, & \rho > \rho_{max} \end{cases} \quad (2)$$

where $B_{i,max}$ is the maximum bandwidth requirement corresponds to highest QoS and γ_i (<1) is degradation factor of i^{th} class of connection. It is to be noted that higher the γ_i more aggressive the degradation is. Since UGS and rtPS are used for real-time VoIP calls and video streaming, degradation in these classes is kept much lighter than nrtPS class to maintain acceptable quality. Hence, as shown in Fig. 3, degradation of UGS and rtPS is much lighter than nrtPS class. Additional bandwidth obtained with degradation increases admitted connections in the network. The condition for accepting or rejecting call can now be established by computing bandwidth allocated to existing new calls and handoff calls and bandwidth requirements of calls to be admitted. Denoting B_{en} and B_{eh} as bandwidth allocated to *existing* handoff and new calls respectively, new handoff call is admitted if following condition is satisfied.

$$Handoff\_accept = (B_{eh} + B_{en} + B_{ih}) \le C - BR_n \quad (3)$$

where B_{ih} is bandwidth criterion for a handoff call to be admitted as per (1). Similarly, a new call is accepted if

$$Newcall\_accept = (B_{eh} + B_{en} + B_{in}) \le C - BR_{ho} \quad (4)$$

where B_{in} is bandwidth criterion for new connection (to be admitted) given by (1). It is to be noted that the total capacity of link C also varies as PHY layer of IEEE 802.16 support different rates with adaptive modulation and coding schemes (MCS). Based on MCS and the number of supported users, our CAC scheme can estimate the current system capacity and network load and update the information periodically every frame period.

V. Simulation Results and Discussions

The performance of proposed scheme is evaluated in the environment of IEEE 802.16 networks with central BS and multiple mobile stations (MSs). Proposed CAC scheme is developed and configured in NS-2 [21] using WiMAX module from NIST. Simulations are carried out by varying new call and handoff call arrival rates. Simulation setup assumes wireless network with single WiMAX BS and multiple MSs where MSs are mobile nodes with average mobility of 5 m/s. The simulation environment uses 1024-point FFT, Two Ray Ground wireless channel model and Poisson's traffic arrival. The objective of simulations is to evaluate the performance of NCB, LFGC and proposed CAC scheme in terms of new call blocking rate, handoff call dropping rate and admitted calls. Results are obtained considering UGS, rtPS and nrtPS class of traffic in wireless network.

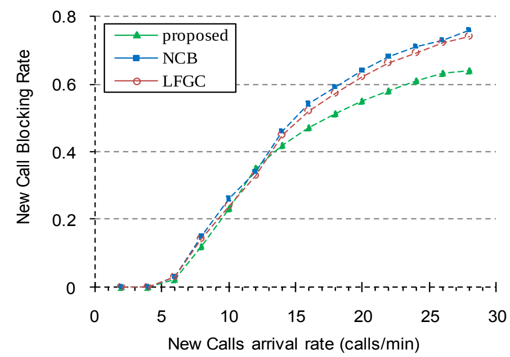

Fig. 4: Blocking rates of new connections when λ_h:λ_n is 1:1

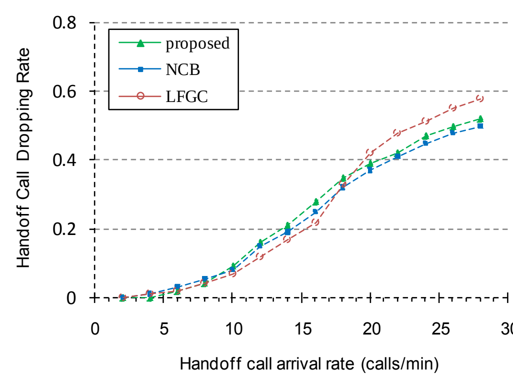

Fig. 5: Handoff dropping rates when λ_h:λ_n is 1:1

Performance CAC algorithms in terms of new connection blocking rate and handoff call dropping rate is shown in Fig. 4 and 5 respectively with ratio of handoff arrival rate λ_h to new connection arrival rate λ_n is 1:1. It is shown that proposed CAC scheme has lowest new connection blocking rate whereas NCB scheme has highest blocking rate. This exhibits the ability of proposed scheme in reducing blocking rate through exclusive allocation of bandwidth to new calls. The blocking rate performance of LFGC scheme is almost identical to NCB. The handoff dropping rate of NCB algorithm is found to be lowest under moderate to high network load whereas LFGC offers highest handoff dropping rate under high traffic. Our scheme closely follows NCB as shown in Fig. 5.

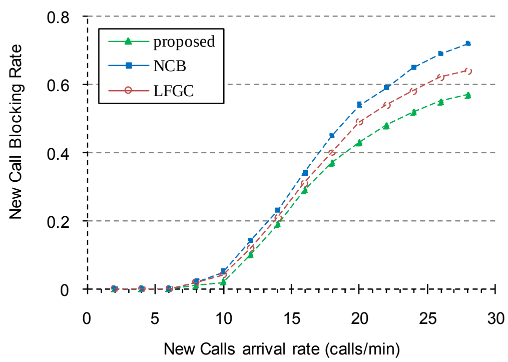

Fig. 6: Blocking rate of new connections when λ_h:λ_n is 1:10

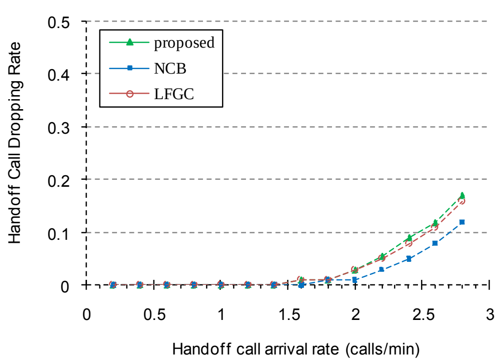

Fig. 7: Handoff dropping rates when λ_h:λ_n is 1:10

Fig. 6 and 7 represent the new call blocking rate and handoff dropping rate respectively when ratio of handoff arrival rate λ_h to new call arrival rate λ_n is 1:10. In this scenario, we observed that the new call blocking rate of proposed scheme is again lowest. Since NCB scheme limits number of new calls in the network, blocking rate of new calls using NCB is higher than LFGC schemes. Handoff call dropping rate of LFGC and proposed scheme is identical but slightly higher than NCB scheme as shown in Fig. 7.

Next we compare these three schemes on the metric called *acceptance ratio*, defined as the ratio of number of requests admitted by the CAC to total number of requests. Fig. 8 and 9 show plots of acceptance ratio (expressed in percentage) versus new call arrival rate and versus handoff arrival rate for three different schemes. For both new calls and handoff calls, proposed scheme performs best. This is because of QoS degradation strategy adopted by our scheme creates additional bandwidth for calls and increases number of admitted connections. It is also seen that LFGC performs better than NCB for new calls whereas NCB performs better than LFGC for handoff calls**.**

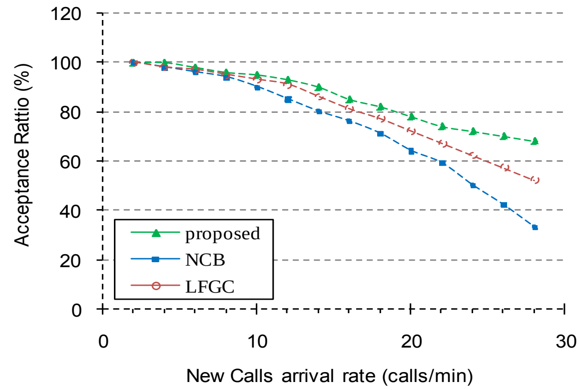

Fig. 8: Call Acceptance ratio when λ_h:λ_n is 1:1

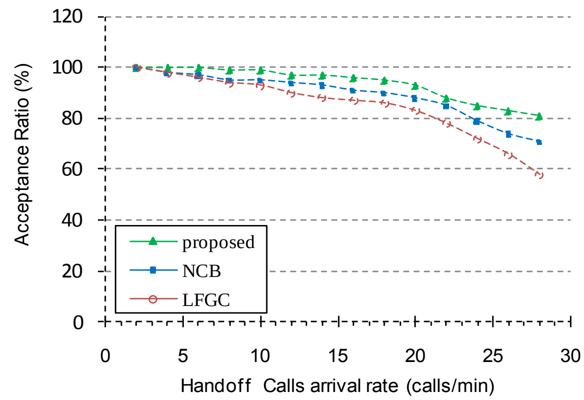

Fig. 9: Call Acceptance ratio when λ_h:λ_n is 1:10

VI. Conclusion

The CAC scheme proposed in this paper incorporates bandwidth reservation for new calls and degradation policy in order to improve blocking rate performance and to increase admitted connections. The degradation mechanism slightly increases complexity of proposed scheme but overall impact is very small. Simulation results show that our scheme outperforms NCB and LFGC schemes in terms of blocking rate and admitted connections. NCB offers lowest handoff dropping rate but exhibits high call blocking rate. It is also seen that LFGC has higher acceptance ratio than NCB for new calls but for handoff calls NCB performs better than LFGC.

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