A Dynamic QoS-Aware Call Admission Control Algorithm for Mobile Broadband Networks

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Abstract— Call admission control (CAC) is one of the vital components in the management of the scarce wireless network resources in mobile broadband networks. Recently, a QoS-aware CAC algorithm with Bandwidth Reservation (BR) and Bandwidth Degradation (BD) (QACAC-BR-BD) was proposed to improve resource utilization and ensure QoS for all classes. However, the algorithm wastes network resources due to a static bandwidth degradation mechanism used to degrade existing connections without recourse to the amount of resources needed in the presence of inadequate resources. A dynamic QoS-Aware CAC (DQACAC) scheme is proposed to improve resource utilization. The DQACAC employs a pre- bandwidth degradation technique to determine whether the amount of resources obtained from the degradation will be sufficient or otherwise for the requesting connection. The algorithm also employs a dynamic BD mechanism to degrade different amount of resources from existing connections when resources are insufficient. We conducted extensive simulation experiments to assess the efficiency of the proposed algorithm. The simulation results indicate that the proposed scheme outperforms the benchmark scheme in terms of reducing the New Connections Blocking Probability (NCBP); thus, resulting to an efficient resource utilization.

Keywords—handoff connection; adaptive bandwidth degradation; bandwidth reservation; mobile broadband networks; call admission control

I. INTRODUCTION

The desire for high speed Internet necessitated the evolution from the first generation (1G) to the fourth generation (4G) of mobile broadband technologies namely: Long Term Evolution Networks (LTE) and Worldwide Interoperability for Microwave Access (WiMAX) [1]. As compared to other 4G networks, WiMAX has gained great attention especially in developing countries due to its low cost of deployment [2]. The technology supports diverse traffics demands such as high bandwidth and Quality of Service (QoS) guarantee features like delay, jitter, and packet loss. These traffics can be grouped into five service classes namely; unsolicited grant service (UGS), extended real-time Polling Service (ertPS), real-time Polling Service (rtPS), non–real-time Polling Service (nrtPS) and best-effort service (BE) [3]. However, meeting the QoS demands for these classes become a herculean task due to scarce wireless network resources such as bandwidth. Therefore, radio resource management (RRM) algorithms such as Call Admission Control (CAC) are required to efficiently manage the resources.

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The CAC is a technique deployed in determining the admissibility or otherwise of a connection request, depending on whether the required QoS of both the requesting and ongoing connections will be met [3]. A variety of CAC algorithm solutions have been proffered to improve resource utilization and ensure QoS [3, 4, 5]. The schemes proposed in [4, 5] efficiently utilize resources but the admission criteria deployed starve the high and low priority connections under moderate or heavy traffic load. The schemes also waste resources when the handoff connection (HC) traffic is below the anticipated level due to a fixed reservation technique used. While the scheme in [3] is a variant of [5] that further enhances resource utilization and guarantees QoS for all classes. However, it may waste wireless resources as it deploys a static degradation mechanism that degrades the same amount of resources from all degradable classes without recourse to whether or not the degraded resources can accommodate the bandwidth demands of the requesting connections.

In this paper, a dynamic QoS-Aware CAC algorithm is proposed to mitigate waste of resources. The algorithm introduces a dynamic bandwidth degradation mechanism to degrade variable amount of resources from existing connections. It also deploys a pre-degradation check mechanism to determine the sufficiency or otherwise of the resources to be obtained from degrading existing calls. We assess the performance of the proposed algorithm against the performance of the QACAC-BR-BD algorithm in [3] using a discrete event simulator. The simulation results indicate that the proposed DQACAC surpasses the compared scheme with regards to reducing the NCBP.

The rest of the paper is organized as follows. Related call admission control algorithms are reviewed in Section II. The basic idea of Dynamic QoS-Aware CAC algorithm is presented in Section III. The performance comparison is discussed in Section IV. Finally, Section V concludes the paper.

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II. Related Works

This section presents a review on several CAC schemes that have been proposed to ensure efficient management of wireless network resources as well as QoS as follows:

In [6], a CAC scheme for non-pre-provisioned service flow is proposed to ensure QoS and improve resource utilization. The scheme uses a guard channel to reserve a fixed or dynamic amount of bandwidth for handoff users in order to prioritize handoff connection over a new connection. It also employs a bandwidth borrowing policy to borrow bandwidth from existing connections with lower priority; thus, increasing the number of admitted connections into the network. The scheme achieves high bandwidth utilization as well as reduces the Call Blocking Probability (CBP) and Handoff Call Dropping Probability (HCDP). However, a fraction of network resources may be wasted if all the resources reserved for handoff connections are not used because they cannot be utilized in accepting other connections. In addition, the scheme is unfair to nrtPS and BE service classes because of its borrowing policy.

To ensure fairness for non-UGS services during busy hour, [7] proposed an enhanced call admission control scheme. The scheme dynamically reserves bandwidth for UGS calls based on the traffic intensity when it increases beyond a set limit. It also admits a UGS call if available resources are enough to serve it under intense network traffic. In addition, it also checks if the CBP of connections other than the UGS exceeds a certain threshold, following which reservation for UGS calls is terminated so as to admit other service classes into the network. The scheme improves the fairness for non-UGS calls when arrival rates is low but increases CBP due to the high blocking probability threshold set for non-UGS calls and the reservation policy used.

In [8], a call admission control scheme with dual partition (DP-CAC) is proposed to improve utilization of resources. The DP-CAC uses two partitions derived from the total link bandwidth. One partition (P_v) is dedicated for traffics with variable bit rate (VBR) and the other partition (P_c) is dedicated to traffics with constant bit rate (CBR). The scheme utilizes maximum traffic rate for the admission of traffics that support CBR if the total bandwidth of admitted connections is less than the bandwidth of $P_{c.}$ A traffic that can thrive with VBR is admitted based on its sustainable rate requirements and it is assigned to P_v if the available bandwidth is less than the bandwidth of P_v. The scheme lowers CDP and hence increases service flow (SF) acceptance under high influx of traffic. However, the dual partitioning mechanism used may eventually waste resources since the resources for a particular partition might be over provisioned.

Reference [9] proposed a traffic-aware CAC (TACAC) to ensure efficient utilization of network resources. The TACAC prioritizes VoIP calls over other service classes during 'busy hour'. It also uses a dynamic bandwidth reservation mechanism based on the intensity of VoIP connections to reserve bandwidth for UGS connections while it shares the remaining resources to other service classes. The scheme improves network utilization but increases the CBP of non-UGS connections when arrival rates increase beyond the anticipated level.

In order to improve the throughput of all service classes, an Efficient Connection Admission Control (ECAC) scheme is proposed in [10]. The ECAC scheme admits new service flows if the bandwidth needed is less than the available bandwidth and sets a fixed threshold for all the classes in order to prevent some calls from being starved. The scheme also degrades the bandwidth of BE services in order to admit a real-time flow when available resources are insufficient. It reduces the CBP and thus increases the throughput of all service classes. However, the threshold set for all calls may amount to resource wastage if the traffic of a particular service class is below the anticipated level.

Reference [11] proposed a fuzzy logic partition-based CAC (FZ-CAC) algorithm to reduce CDP and increase the admission rate of HCs. The FZ-CAC scheme divides the system bandwidth into three: CBR, VBR and handover (HO) partitions. It admits CBR, VBR and HO traffics based on bandwidth available in their respective partitions. It also adjusts the bandwidth of HO when there is a call drop by borrowing from either CBR or VBR partition so that more HO traffics can be admitted into the network. The scheme reduces CDP of HO connections but may lead to increase in CBP of CBR and VBR traffics due to the borrowing policy used.

Reference [12] proposed a utility-based admission control to effectively improve user satisfaction and maximize the resource utilization. The scheme reserves resources for anticipated handoff connections. It admits a new connection request with the highest marginal utility function. Marginal utility function is the degree of users' satisfaction, which is calculated based on bandwidth demand and corresponding utility of each connection. The scheme improves resource utilization and also lowers HCDP. However, it increases the NCBP due to the fixed reservation policy used.

In [4], a revamped CAC Scheme with adaptive BR and BD was proposed to prevent unnecessary call blocking and starvation of new admitted connections into the network. The CAC scheme reserves a fixed amount of resources for handover connections (HC) and an adjustable amount for new connections (NC) based on arrival rate of the traffics. The remaining resources are shared by both handoff and new calls when their reserved resources are exhausted. It employs a bandwidth degradation mechanism based on a non-linear technique to degrade the bandwidth of the admitted service classes according to traffic load under insufficient resources. The scheme improves resource utilization and increases the number of admitted calls in the network. However, the scheme uses fixed reservation technique for HCs, which may waste resources when the HC traffic is below the anticipated level.

Reference [5] proposed a dynamic CAC and BR scheme to improve resource utilization and ensure QoS of the admitted calls. The scheme uses the current network load to dynamically regulate the criteria for admission such that connections are given maximum required data rates when resources are sufficient and given minimum when resources are insufficient. It also dynamically reserves resources for HCs subject to the influx of requests. It improves resource utilization by accepting more connections and provides adaptive QoS to admitted connections. However, the mode in which the algorithm admits can starve the low priority calls when the traffic load is moderate or heavy; thus, increasing the dropping rate.

A QoS-Aware CAC with BR and BD scheme was proposed in [3] to avoid starvation and improve resource utilization. The scheme introduces a new admission criterion according to service classes in order to increase the acceptance rate of connections into the system. The criteria also employ a BD policy to admit more users in the presence of inadequate resources. It also utilizes a dynamic threshold to tune the quantity of bandwidth reserved for HCs subject to the system load. The scheme accommodates more users as well as guarantees QoS to the different connection classes. However, it wastes resources due to fixed BD policy used.

To fix the shortcoming highlighted above, we propose a Dynamic QoS-Aware CAC algorithm for Mobile Broadband Systems to prevent resource wastage thereby efficiently utilizing network resources.

III. Dynamic QoS-Aware CAC Algorithm

This section presents the Dynamic QoS-Aware CAC algorithm, a variant of the QACAC-BR-BD algorithm presented in [3]. However, the drawback of the QACAC-BR-BD algorithm is highlighted. The algorithm admits UGS, rtPS, or ertPS connections based on their maximum sustainable traffic rate (MSTR) and admits nrtPS or BE connections based on the minimum required traffic rate (MRTR). However, when the system lacks sufficient resources to accept a NC request, the scheme deploys a fixed bandwidth degradation mechanism to degrade rtPS and ertPS calls so as to admit more connections into the network. The degradation is carried out on these calls because of their varying QoS requirements from maximum rate to minimum rate. The degradation mode employed can result to wastage of network bandwidth because resources are degraded without recourse to the amount needed. Thus, prompting a call to be dropped when the degraded resources cannot be enough to admit the requesting call.

To address the problem highlighted above, a Dynamic QoS-Aware Call Admission Control Algorithm is proposed. First, the scheme adopts an adaptive bandwidth reservation threshold in [3] to reserve resources for handoff calls.

Then, a pre-bandwidth degradation technique is proposed to determine the amount of resources required as well as whether or not the degraded resources can meet the requested bandwidth. The technique is derived as follows:

Firstly, the amount of bandwidth assigned to any connection $i \in \{1, 2, 3, \ldots n\}$ where i is a connection belonging to class j for $j \in \{\text{ertPS, rtPS}\}$ to meet its MSTR and MRTR is presented as

$B_{j,i}^{MSTR}$ and $B_{j,i}^{MRTR}$, respectively.

Secondly, the amount of degradable bandwidth for each connection in class j is derived as:

$$X_{j,i} = \left\{ f(t) \left(B_{j,i}^{MSTR} - B_{j,i}^{MRTR} \right) \right\} \tag{1}$$

where, t indicates the call type which can either be HC or NC and f(t) given as:

$$f() = \begin{cases} 0, & handoff \\ 1, & new \end{cases} \tag{2}$$

Equation (2) is a function that determines a connection type (i.e. whether it is a HC or a NC) and returns 0 if the call is a HC otherwise it returns 1.

The total degradable bandwidth for class j is given as:

$$B_j^d = \sum_{i=1}^{n} X_{j,i} \tag{3}$$

Finally, Equation (4) presents the pre-bandwidth degradation mechanism:

$$B_r = \begin{cases} B_{UGS}^{MSTR}, & B_U - B_j^d + B_{UGS}^{MSTR} \leq B_t \\ B_{non-UGS}^{MRTR}, & B_U - B_j^d + B_k^{MRTR} \leq B_t \\ 0, & otherwise \end{cases} \tag{4}$$

where B_r is the requested bandwidth, B_t is the total bandwidth of the system, B_{UGS}^{MSTR} is the bandwidth request for UGS connections since they only support MSTR, $B_{non-UGS}^{MRTR}$ is the MRTR requirement for non-UGS connections, and B_U is the total bandwidth utilization of the system.
B_U is derived as:

$$B_U = \sum_{i=1}^{n} (B_{UGS,i} + B_{rtPS,i} + B_{ertPS,i} + B_{nrtPS,i} + B_{BE,i}) \tag{5}$$

Next, the scheme introduces a dynamic degradation procedure based on a bandwidth intelligent function derived as follows:

First, the current bandwidth utilization after degradation before assignment is given as

$$B_u^d = B_u - B_n^d \tag{6}$$

where B_n^d is the amount of bandwidth needed from the degradation procedure which is derived as,

$$B_n^d = B_r - B_a \tag{7}$$

where B_a is the bandwidth available in the system.

Then, the bandwidth intelligent function (I(B)) is given as:

$$\text{I(B)} = 1 - \frac{B_t - B_u}{B_t - B_n^d} \tag{8}$$

Finally, the variable step size is calculated as follows:

$$\text{l} = \text{I(B)} * (B_{d(k,j)})^{\alpha} \tag{9}$$

where $B_{d(k,j)}$ is the degradable bandwidth from a call having priority k (i.e. k =1, 2, 3, 4, 5) and belonging to the class j with degradation factor α = (2,3) corresponding to the priorities of ertPS and rtPS to ensure that varying amount of resources are degraded. That is, the lower the priority of a call, the higher the amount of resources to be degraded from it.

IV. PERFORMANCE EVALUATION

The performance evaluation of the proposed CAC scheme against the QACAC-BR-BD in [3] is implemented on a discrete event simulator developed using C++ programming language. The evaluation is based on the NC blocking rate and the HC dropping rates. The simulation captures the new connection and handoff connection scenarios. The topology of the network is as shown in Figure 1 with an assumed Poisson arrival of the connection requests. The average number of connections leaving the system is assumed to be 1/10th of the number entering, with the base station knowing the bandwidth requirements of each connection with respect to its current modulation and coding scheme. Also, other simulation parameters are: 10 MHz bandwidth, 1024 FFT size, with 184, 120 and 720 null, pilot and Data subcarriers respectively. Furthermore, a symbol period of 102.9 µs, 5ms frame duration, 48 OFDM and 44 Data OFDM symbols are used.

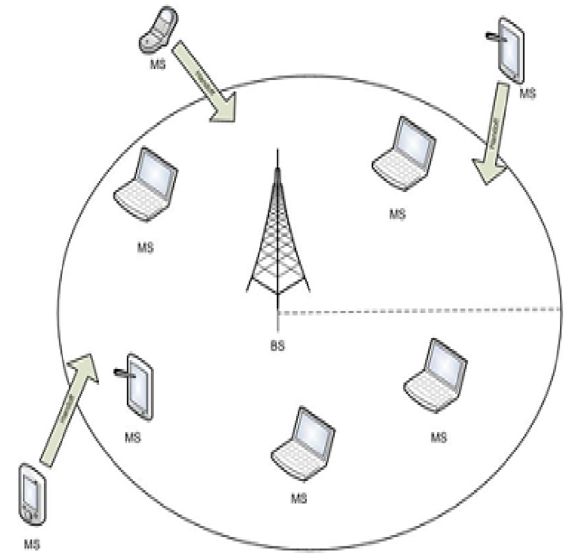

Fig. 1. Topology of the simulation enviroment [3].

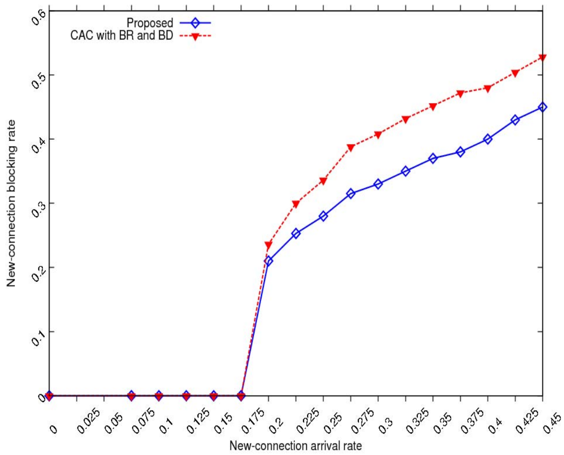

Fig. 2 Blocking rates of NCs

Figure 2 shows the blocking rates of NCs for QACAC-BR-BD and the proposed scheme. The figure demonstrates that under low traffic intensity, both schemes tend to have identical results, but as the traffic intensity increases, the proposed algorithm outperforms the compared scheme. The proposed algorithm achieves better performance because of the pre-bandwidth degradation mechanism that checks the appropriate amount of resources to be degraded and the dynamic degradation mechanism that prevents unnecessary degradation of the existing connections.

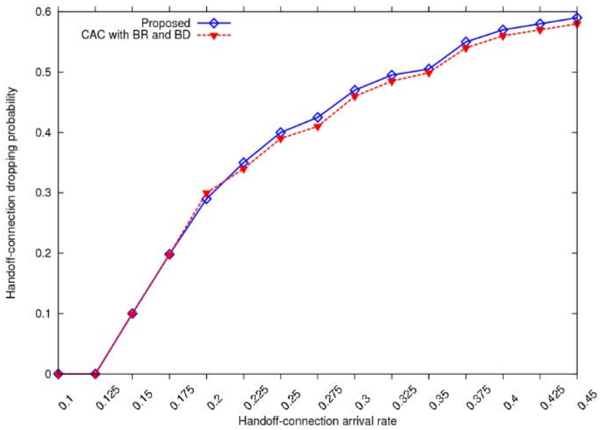

Fig. 3 Dropping rates of HCs

Figure 3 shows the dropping rates of HCs for QACAC-BR-BD scheme and the proposed algorithm. It indicates that the proposed algorithm has similar performance as compared to the QACAC-BR-BD in terms of the HCDP. This is largely due to the bandwidth reservation threshold that is used to adaptively reserve resources for HCs depending on the traffic intensity of the HCs for both schemes.

V. CONCLUSION

The paper proposes the Dynamic QoS-Aware CAC (DQACAC) scheme to improve resource utilization. The scheme introduces a bandwidth pre-check mechanism to ensure that degraded resources are sufficient to carter for the bandwidth needs of requesting connections before the degradation is performed. It also deploys a dynamic bandwidth degradation mechanism to degrade varying amount of resources from ertPS and rtPS connections. Simulation experiments were conducted to evaluate the performance of the DQACAC scheme against the QACAC-BR-BD algorithm. Simulation results show that the DQACAC scheme performs better as regards to reducing new connection blocking rates under increased traffic rate when compared to the benchmark algorithm. In future works, we hope to incorporate a delay precheck mechanism to ensure that the delay requirements of existing and requesting delay sensitive conditions is ascertained before admission of requesting connections.

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