An Improved Call Admission Control Mechanism with Prioritized Handoff Queuing Scheme for BWA Networks

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Abstract. Nowadays, due to increased demand for using the Broadband Wireless Access (BWA) networks in a satisfactory manner a promised Quality of Service (QoS) is required to manage the seamless transmission of the heterogeneous handoff calls. To this end, this paper proposes an improved Call Admission Control (CAC) mechanism with prioritized handoff queuing scheme that aims to reduce dropping probability of handoff calls. Handoff calls are queued when no bandwidth is available even after the allowable bandwidth degradation of the ongoing calls and get admitted into the network when an ongoing call is terminated with a higher priority than the newly originated call. An analytical Markov model for the proposed CAC mechanism is developed to analyze various performance parameters. Analytical results show that our proposed CAC with handoff queuing scheme prioritizes the handoff calls effectively and reduces dropping probability of the system by 78.57% for real-time traffic without degrading the number of failed new call attempts. This results in the increased bandwidth utilization of the network.

1. Introduction

In recent years, various BWA networks such as the Worldwide Interoperability for Microwave Access (WiMAX) [1] or the Long Term Evolution (LTE) [2] are being developed rapidly to support heterogeneous applications such as real-time video, voice over IP (VoIP) and web browsing. To manage the heterogeneous incoming calls that have stringent QoS requirements more sophisticated CAC mechanism are to be developed [3]. Moreover, to control handoff dropping probability certain measures have to be employed to prioritize handoff calls over new calls since it is commonly accepted that dropping an ongoing handoff call is more annoying than dropping a new incoming call [4]. Several reservation and non reservation based policy with bandwidth degradation CAC mechanism [5-7] have been proposed in the literature to mitigate the problem related to the handoff calls. However, the concept of queuing to hold handoff request when bandwidth is unavailable even after the bandwidth degradation of admitted calls has not been included in the more efficient non reservation based CAC mechanism [7]. That is why in this paper, we have proposed an improved CAC mechanism that allow queuing of handoff call attempts if necessary to reduce dropping probability to a further extent and thereby increasing the user satisfaction in terms of seamless communication. An analytical model based on Continuous Time Markov Chain (CTMC) [8] is developed for the more realistic analysis of the proposed CAC mechanism. BWA services are categorized into Class-1, Class-2 and Class-3 traffic depending upon their QoS requirements and tasks to perform. The services which come under the Class-1 and Class-2 traffic are real-time (RT) VoIP and Video respectively while Class-3 traffic performs tasks related to non real-time (NRT) FTP, e-mail and web browsing.
2. Description of the proposed CAC mechanism
A BWA system with homogenous cells is considered along with a single Base Station (BS) under a reference cell. The proposed CAC mechanism is shown in figure 1. Both newly originated and handoff calls are admitted in the network if bandwidth is available. But if bandwidth is not available, the new call is admitted by allowable bandwidth degradation of the ongoing Class-3 calls and the handoff calls are queued and get admitted when an ongoing call is terminated with a higher priority than the new call. Allowable bandwidth degradation of both Class-2 and Class-3 ongoing calls in the target cell is executed to admit the handoff calls. Three separate queues with queue size $QL_1$, $QL_2$ and $QL_3$ are used to hold the handoff request of three different traffic classes respectively. Priority (Class-1>Class-2>Class-3) is maintained while admitting the handoff calls. The arrival process of the Class-1, Class-2 and Class-3 new calls is Poisson with average rates of $\lambda_1$, $\lambda_2$ and $\lambda_3$ respectively and that of for handoff calls $\lambda_{h1}$, $\lambda_{h2}$ and $\lambda_{h3}$ respectively.

![Figure 1. Proposed CAC mechanism](image)

3. Analytical model for proposed CAC mechanism
It is assumed that BS changes state from one to another upon the admission or rejection or queuing of a traffic call. Further, the BS either admits or rejects or queued up only one traffic call at a particular instant of time.

![Figure 2. CTMC Model for the proposed CAC mechanism](image)
So, the next state of the BS depends only on the present state of the BS but does not depend on the previous states of the BS. Therefore, the states of the BS form a Markov Chain. In this scenario, the BS can uniquely be represented in the form of a six dimensional Markov Chain based on the number of admitted connections \((n_1, n_2, n_3)\) in the network as well as number of handoff connections \((h_1, h_2, h_3)\) waiting in the queue of each traffic type. The state space \(n_1, n_2, n_3, h_1, h_2, h_3\) for our proposed CAC scheme is obtained based on the Markov chain in figure 2.

4. Results and Discussions

The values of the system parameters have been set as shown in table 1 for the performance evaluation. From the CTMC model steady state probabilities of each state of the BS have been evaluated and are used to derive several QoS performance parameters such as bandwidth utilization (BU), handoff queuing latency, new connection blocking probability (NCBP) and handoff connection dropping probability (HCDP).

| Parameters                        | Values                        |
|-----------------------------------|-------------------------------|
| Arrival rate ratio of Class-1, 2, 3 traffic both for \((\lambda_1 : \lambda_2 : \lambda_3)\) 3:2:1 and \((\lambda_{a1} : \lambda_{a2} : \lambda_{a3})\) |                               |
| Mean service time                 | \(1/\mu_1 = 1/\mu_2 = 1/\mu_3\) |
| Specified Handoff latency (SHL)   | < 50 ms                       |
| Total BW in kbps                  | 15360 kbps                    |
| Queue Length (QL_i)               | Infinite                      |
| BW for Class-1(B_1) in kbps       | 256                           |
| BW for Class-2(B_2) in kbps       | 1024 (max), 512 (min)         |
| BW for Class-3(B_3) in kbps       | 1024 (max), 256 (min)         |

Figure 3a shows the handoff queuing latency against handoff call arrival rate \(\lambda_h\) for all traffic classes. With increase in \(\lambda_h\), mean number of handoff calls waiting in the queue increase due to unavailability of bandwidth in the network and thereby increasing mean queuing latency of each traffic class. Observations reveal that handoff queuing latency violates specified handoff latency (<50ms) whenever \(\lambda_h\) exceeds 8.5 and 3.5 respectively for Class-2 and Class-3 traffic. For highest priority delay sensitive Class-1 traffic, handoff queuing delay is observed to be negligible. Figure 3b,c,d show the handoff call dropping probability against \(\lambda_h\) of Class-1, Class-2 and Class-3 traffic respectively with handoff queuing scheme and without handoff queuing scheme. A significant improvement in the dropping probability of Class-1 RT traffic is observed when the CAC mechanism is incorporated with the handoff queuing scheme. The reduction in the dropping probability of Class-1 traffic is observed to be 78.57% at arrival rate =10. Dropping probability is also observed to be reduced for Class-2 RT traffic (figure 3c) with the introduction of the queuing scheme in the CAC mechanism. But close observation reveals that the dropping probability of Class-2 traffic does not improve rather remains same whenever its call arrival rate crosses 8.5. This is because of the violation of specified handoff latency above this arrival rate. On the other hand, from figure 3d it has been observed that dropping probability of Class-3 traffic is not quiet impressive. Improvement in the performance occurs only up to the arrival rate = 3.5 and beyond this the performance is observed to be diminished. This happens because of the two main reasons, Firstly, the violation of the specified handoff latency and secondly, assignment of the lowest priority among all other services. However, Class-3 traffic being NRT traffic its speculative performance does not hamper the overall performance of the proposed CAC mechanism in the network. The proposed CAC mechanism with handoff queuing scheme enhances the BU of the
network by 5% as observed from figure 3e. Moreover, the NCBP for Class-1, Class-2 and Class-3 traffic both for ‘with queuing scheme (+Q)’ and ‘without queuing scheme’ as observed in figure 3f are more or less same. We have only found up to 3% deviation in the curve by introducing the handoff queuing scheme. It reveals that introduction of the handoff queuing scheme does not increase the NCBP of the system. Hence, in other words it can be said that QoS of the BWA network is improved in terms of HCDP and BU without degrading NCBP by our proposed CAC mechanism.

5. Conclusion
In this paper, we propose an improved CAC mechanism with prioritized handoff queuing scheme that handles the handoff calls whenever no bandwidth is available even after the bandwidth degradation of the admitted calls. Handoff calls, if any waiting in the queue get admitted when an ongoing call is terminated with a higher priority than a newly incoming call. An analytical model using CTMC is developed and evaluated for the proposed scheme to estimate the system performance. It is seen that our proposed scheme can achieve the dropping probability for the different traffic classes at a desired level without much degrading the blocking probability and increase the user satisfaction in terms of seamless communication while at the same time enhances resource utilization.

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