Performance Evaluation of a Call Admission Control Protocol for Cellular networks

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Abstract

Call admission protocols play a central role in determining both the performance of any network, and the revenue of the network. The call admission protocol must decide either to accept the call or reject it, Thus having an impact on both the quality of calls and the network revenues. The call admission protocol must deal with multiple classes of calls having different requirements, requesting different quality of service and with different priorities. In this paper, we propose a protocol for call admission control in cellular networks. Our protocol can effectively deal with multiple traffic classes each with different bandwidth requirements and different priorities. We also present simulation results for our protocol and compare it with existing protocols. Simulation results show that our protocol can give preferential treatment for high priority traffic without affecting the network utilization.

Key words: call admission protocols, bandwidth allocation, fairness, cellular networks

1. Introduction

When a call requests admission in a specific cells, the call admission control protocol must decide either to accept or reject this call. In making he decision to accept or reject the call many factors must be taken into consideration, such as the requesting call bandwidth, the current network load, the call priority, and of course the effect of the decision on the network revenue. A good Call Admission Control (CAC) protocol will try to be fair, fast, reduces customer inconvenience, and produces a good bandwidth utilization leading to increasing revenue for the carrier.

Call admission is not a problem that is unique to wireless networks. This problem is applicable to almost every type of networks. However, in cellular wireless networks there is an added complication. While in wire-line networks the resources are reserved for the call at set-up time and need not change after that, in cellular wireless networks when the mobile node moves from a cell to another cell, bandwidth must be requested in the new cell. Since the path of the node is knot known before hand, that add more complexity to the call admission protocol.

Another issue we have to deal with in cellular wireless networks is the call drop probability vs. call rejection probability. Requests for the bandwidth could be made by a new call, or a handoff request from a call in a neighboring cell. From the customer point of view, rejecting a new call is better than dropping a call because of a handoff. This must taken into consideration by the admission protocol.

One point we want to stress here is the *fairness* of the protocol. The absolute fairness as introduced in [11] may not be the best policy for fairness. The optimal solution under this policy is when all requests has the same rejection ratio. However, in today's networks, where customers may pay different fees for accessing the networks, and where the protocol has to deal with newly generated calls, and handoff calls from nearby cells, one must not be absolutely fair in call acceptance or rejection. Customers who pay more should get a preferential treatment when it comes to accepting or rejecting their request. Also, it is generally accepted [5] that it is less convenient to the customers to be denied access to the network that dropping their call when moving from cell to another cell (handoff should be completely transparent to the customers), which means that the call dropping probability (due to handoff) must be much less than call rejection probability for new calls.

Today's networks to some extent, and definitely's future networks support different types of traffic (data transfer, audio, and video are common in today's networks). Each has its own bandwidth requirements, and its own QoS requirements. Even customers in the same categories, may require different bandwidth and/or different QoS if they are willing to pay more. A good CAC protocol should take these factors into consideration when deciding to admit a call.

In this paper we present a new CAC protocol for wireless cellular networks. Our protocol takes into consideration the required bandwidth of the call, the available bandwidth in he cell, and the priority level of the requesting customer in deciding whether to admit the call or not. We present simulation results to show the performance of our protocol.

The organization of this paper is as follows. In section 2 we present a brief review for previous work in CAC protocols. Section 3 presents our proposed precool and Section 4 presents the simulation setup and results. We end our paper with a conclusion and future work

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2. Previous Work

The easiest and most simple admission control is FCFS. In FCFS if a request arrives and there is enough bandwidth to accommodate it, the call is admitted, otherwise it is rejected. FCFS produces a good utilization of the medium, however it has been shown to be biased against calls that require high bandwidth. besides, it does not support priority.

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In [14], the authors proposed to divide the bandwidth into segments, and the call requests grouped into different categories, such that a call request in group *i* can only be accepted if there is enough bandwidth in segment *i*. The main problem with this technique is the waste of the bandwidth since we could have unused bandwidth in one segment, and call requests in other segments being turned down.

The authors in [8] studied the performance of some widely known call admission control protocols under more general (more accurate) assumptions and provided good approximations for the network performance. In [2], the authors proposed a model for heterogeneous multi-class environment that permits call transition between different classes. They also show that under some assumptions, the optimal policy has the shape of *Multi-Priority Threshold Policy*.

In the cutoff priority scheme [15], [12], a portion of the bandwidth is reserved and could be used only for handoff calls. In [16], new calls are admitted with a certain probability that depends on the number of busy channels. The main idea here is to give a priority for handoff calls over new calls.

In another scheme, handoff and new calls are accepted as long as there is enough bandwidth. If there is not enough bandwidth, then either handoff calls are blocked and new calls are pout in a queue [9], or vice versa. Call admission in a *Low Earth Orbit* (LEO) is investigated in [6].

The effect of waiting time in the queue on the new and handoff calls is investigated in [4], they also investigated the effect of the buffer size and the number of guard channels on the system performance for both microcells and macrocells. They proved that good provisioning of the buffering scheme and the number of guard channels can greatly affect the dropoff probability.

The authors in [7] proposed 2 call admission protocols. The first, Independent Multiclass One-Step Prediction Complete Sharing (IMOSP-CS), where the bandwidth is shared between all handoff calls. The second Algorithm is Independent Multiclass One-Step Prediction Reservation (IMOSP-RES), where Portions of the bandwidth is reserved for diffferent classes of handoff calls. However, the algorithm did not guarantee high resource utilization.

In [10], the authors proposed a distributed algorithm for call admission in which information about the neighboring cells are taken into consideration in admitting any new call. They succeeded in guarantying an upper bound on the call dropping probability and in the same time allowing a high resource utilization.

A simple but rather efficient algorithm for call admission is presented in [13], where the authors proposed the use of a single buffer to hold the call request if there is not enough bandwidth. The call is held in the buffer until there is enough bandwidth and then admitted, or held in the buffer up to a maximum waiting time then dropped. Their protocol works fine and produces good results if there is not a huge disparity between the requested bandwidths.

In [18] the authors investigated and compared the performance of six different call admission control protocols. However all the six protocols were for a single type of traffic and single QoS requirements.

3. Our Protocol

We assume a cellular system in which the coverage area is divided into cells. There is some overlap between the cells that helps in a smooth handoff. New calls are admitted to each cell when user try to connect and request a specific bandwidth that depends on the application. We assume that the users ask for a specific bandwidth that can not be negotiated. From the user point of view, the call is either admitted, or rejected (busy network). From the network point of view, the user either admitted, rejected, or queued waiting for another user releasing some bandwidth. The queueing period should be small enough such that the user will not notice it.

In a differentiated service model (DiffServ) [3], different users can require different QoS and pay accordingly. Since in this paper we are considering a call admission protocol, we will consider only the quality of service concerned with call admission (call rejection ratio), or call migration (handoff drop ratio).

We assume *N* different classes of customers, each with a different arrival rate, service time, and bandwidth requirements. We also assume that is the arrival rate for a customer in class *i* is Poisson with rate of λ_i customers per second, the service rate of each customer is $1/\mu_i$ seconds, and require a bandwidth B_i. If a call request from class *i* arrives at the base station, if there is enough bandwidth for it and the remaining bandwidth in the cell is more than or equal T_i(a threshold for accepting class i calls), the call, is accepted. Else, if there is not enough bandwidth to accommodate this call, and there are no waiting calls in the buffer, and the remaining bandwidth > T_i, the call is put in the waiting buffer until there is enough bandwidth to be accepted. Else, if there is another call in the buffer, or if the buffer is empty but the remaining bandwidth < T_i, the call is rejected. Thus T_i acts as a parameter to set the priority of class i, the higher the threshold, the less the priority of that class. The priority could be set according to any criterion. It could be set high for customers who are willing to pay more, or could be set high to handoff calls.

3.1 Protocol description

This protocol is simple and can be described in an algorithmic form as follows:

Assume the capacity of the channel is *C*, class *j* requires a bandwidth of b_j per call, and its threshold is T_j

```
//remaining is the remaining bandwidth capacity
//in the cell
// A request from class j arrives
if ( (remaining >= $b_j$ ) && (remaining >= $T_j$))
   accept the call
else if (remaining < $b_j$) && (remaining >=$T_j$) &&
buffer=empty
   accept the call and store it in a buffer
   else if (remaining < $T_j$)
   reject
```

3.2 Markov Chain Representation

A system using the above mentioned protocol, and assuming a Poisson arrival and exponential call time, can be described by a multidimensional Markov chain, *(k+1)* dimensional chain, where *n* is the number of user classes as follows:

The state space consists of (*k+1*)-tuple $(n_1, n_2, \ldots, n_k, n_{k+1})$, such that $\sum_{i=1}^{k} n_i b_i \le C$ where $n_i, 1 \le i \le k$ are the number of calls in class *i* admitted in the system, while n_{k+1} is the class of the call waiting in the buffer, if zero, that means the buffer is empty (no calls are waiting). Two constraints on the space state of the markov chain

$$\sum_{i=1}^{k} b_i n_i \le C, \textit{ and } \text{if } n_{k+1} > 0 \Rightarrow b_{n_{k+1}} > C - \sum_{i=1}^{k} b_i n_i > T_{n_{k+1}} \quad (1)$$

The constraint simply states that the bandwidth of the total admitted calls can not be more than the channel bandwidth, and if there is a waiting call, then the remaining bandwidth is greater than or equal to the threshold for the call waiting class (otherwise, it shouldn't have been admitted to the buffer). For a complete mathematical analysis of the Markov Chain, the reader is refereed to [1].

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4. Simulation Setup

We consider a cellular system where the traffic arrival pattern for class *i* calls is Poisson with parameter λ_i. The call duration for class *i* calls is exponential with average time of $1/\mu_i$. The arrival rate for handoff calls is considered to be of a different class.

4.1 Simulation Results

We have simulated the above protocol using CSIM [17], we also simulated the protocol in [13] in order to compare our protocol with.

In our simulation, we considered a system with total bandwidth of *C=100* units of bandwidth, different types of customers can arrive, each has its own arrival rate, service time, and bandwidth requirements.

Figure 1. shows the rejection ratio vs. network utilization for three classes of traffic (CL1, CL2, CL3). The Figure also shows the performance of the protocol prosed in [13]. We assumed that all classes have the same arrival rate, the same service rate, and the same bandwidth requirements. CL1 is the highest priority traffic with threshold set to 0, followed by CL2 with threshold of 4, finally CL3 with threshold of 6. The graph shows the rejection ratio vs. the network utilization. The graph shows that the rejection ratio for CL1 is kept below 2% even for high network utilization, while the rejection ratio for low priority traffic increases with increasing the network utilization.

In Figure 2. we assumed three types of traffic class 1 and 2 require 4 ubits of B.W. Class 3 requires 20 units of B.W. The service time for the 3 classes are set to 2, the interarrival time for classes 1 and 2 are set to 0.8, with class 3 traffic used to control the network utilization.

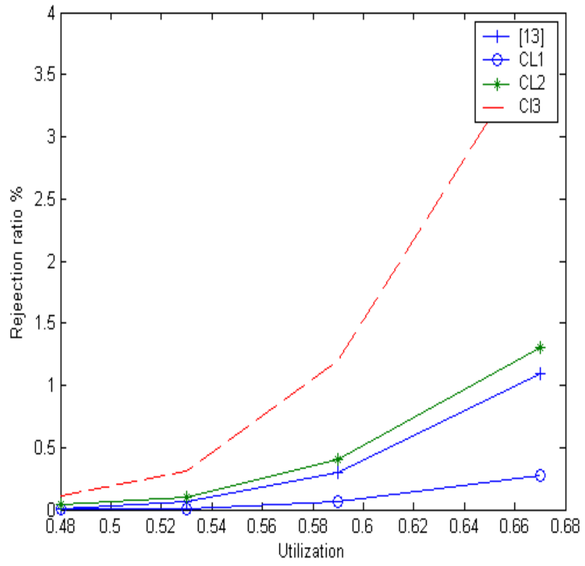

Figure 1. rejection ratio vs. arrival rate

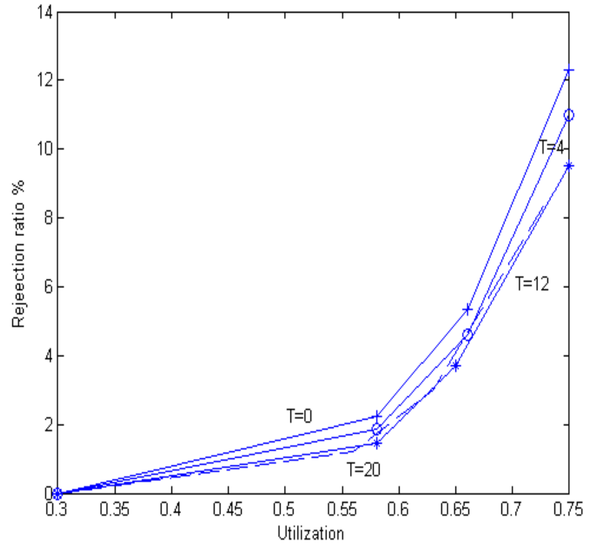

Figure 2. arrival rate vs. utilization for class 2 calls

The graph shows the rejection ratio for class 1 vs. utilization for different values of threshold for classes 2 and 3 (threshold for class 1 is set to 0). Note that by increasing the threshold for classes 2 and 3, the rejection ratio for class 1 drops. In essence we are protocting class 1 traffic from the effect of increasing a high bandwidth traffic (class 3) by adjusting the threshold appropriately.

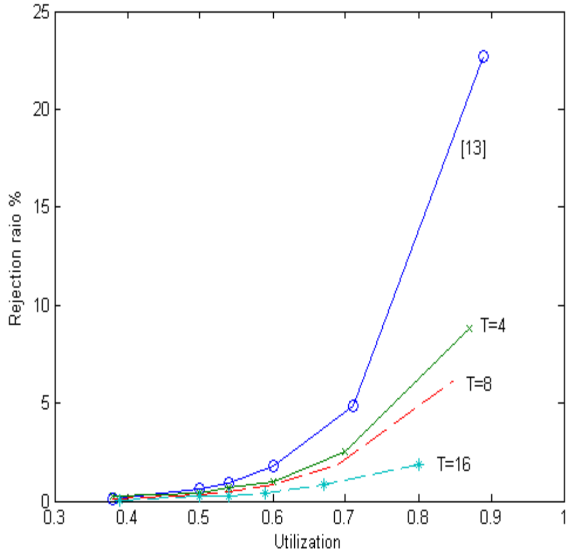

Figure 3. Rejection ratio vs. threshold for class 2

Figure 3.shows the same scenario as Figure 2, but in this case, class 1 is the high baqndwidth traffic (10), while bandwidth for classes 2 and 3 are set to 4. The network utilization is increased by increasing class 1 traffic. usually a high bandwidth traffic will suffer the most under traditional call admission control. However, as the Figure shows, the rejection ratio for class 1 traffic is kept below 2% by increasing the trheshold for the other 2 trafic types.

These three experiemtns shows that we can control the priority of any traffic type in a network by controlling the threshold. In this paper we consider that the threshold is set apriori and is determined by the traffic type, it remais to be seen what will be the effect of dynamically changing the treshold and its effect on the network stability.

5. Conclusions

In this paper, we presented a new call admission protocol for cellular networks. Our protocol provides a differentiated fairness without sacrificing the channel utilization, our results show that by controlling the threshold for the differnet traffic types, we can control the acceptance ratio for any traffic.

In this work, we assumed the bandwidth for a class is constant during the life time of the call and is determined during the admission procedure. For future work we plan to study the effect of decreasing the bandwidth allocated to the call without terminating it (bandwidth borrowing). Also we would like to investigate how to dynamically adjust the threshold and its effect on the network stability.

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