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Integration of Pricing with Call Admission Control

Mehrdad Manaffar and Hamidreza Bakhshi
Faculty of Engineering, University of Shahed, Tehran, Iran

Abstract: Due to the importance of congestion in networks, we look for a method that can reduce the network congestion. In recent years considerable efforts have focus on the call admission control that provide the desired QoS but cannot reduce the network congestion, so in this study we introduce a new scheme that add an additional dimension (dynamic pricing) to CAC in order to reduce congestion. Dynamic pricing encourages users to use resources efficiency. In this scheme price depends on the network load so it can reduce congestion. We compare the performance of our scheme in term of congestion prevention with conventional systems where no pricing block is implemented. These results show improvement that can be achieved by the integration of pricing in the call admission control process in networks.

Key words: Call admission control, dynamic pricing

INTRODUCTION

The rising demand for mobile communication services is increasing the importance of efficient use of the limited bandwidth and frequency spectrum. In recent years, considerable efforts have focused on the Channel Allocation and Call Admission Control (CAC). Call Admission Control is a provisioning strategy used to limit the number of call connections into the networks in order to reduce the network congestion and provide the desired Quality of Service (QoS) to users in service (Fang and Zang, 2002; Chang *et al*., 1994; Hong and Rappaport, 1986; Lin *et al*., 1994; Ramjee *et al*., 1997; Hou *et al*., 2002). Due to the user's mobility and variable link quality, the CAC becomes more complicated in wireless networks. An accepted call which has not completed its service in the current cell may have to be handed off to another cell. During this process, the call may not be able to obtain a channel in the new cell to continue its service due to the limited available resources in wireless networks, which will lead to call Dropping. Because users are more sensitive to call dropping than new call blocking, handoff calls are normally assigned higher priority over new calls.

Thus, the new calls and handoff calls are usually treated differently in terms of resource allocation. New call blocking probability and handoff call blocking probability are two important connection level QoS parameters. In addition to an Increase in the number of users, ever more demanding applications will appear, resulting in ever greater resource requirements. The limited radio frequency spectrum available can no longer support this increasing demand. An alternative solution is to keep the current network capacity and to make the users' demand fit this limited capacity. This is the basic principle which leads to dynamic pricing.

The price of making a call depends on the network load, it can be very high when congestion occurs or very Low to encourage users to make calls during off-peak periods. In this study we describe this topic by more details.

CALL ADMISSION CONTROL

Various CAC schemes have been proposed (Fang and Zhang, 2002). It can be classified into 3 categories:

Guard Channel (GC) schemes: Some channels are reserved for handoff calls. The cutoff priority scheme: Is to reserve a portion of channel for handoff calls; whenever a channel is released, it is returned to the common poll of channels (Chang *et al*., 1994).

Queuing Priority (QP) schemes: In this scheme, calls are accepted whenever there are free channels. When all channels are busy, new calls are queued while handoff calls are blocked, new calls are blocked while handoff calls are queued or all arriving calls are queued with certain rearrangements in the queue.

Channel borrowing schemes: When all the channels in a cell are occupied, the cell borrows channels from other cells to accommodate the incoming handoff calls.

Corresponding Author: Mehrdad Manaffar, Faculty of Engineering, University of Shahed, Tehran, Iran

The current CAC schemes cannot avoid congestion because they do not provide incentives for users to use the channel resources effectively. So we add an additional dimension to call admission control to solve this problem.

INTEGRATING PRICING AND CALL ADMISSION CONTROL

Network users act independently and sometimes "selfishly" without considering the current network traffic conditions. Hence, system overload situations are unavoidable. If each user requests the resources that maximize his/her individual level of satisfaction, the total utility of the community will decrease so that there must be some mechanism to provide incentives for users to behave in ways that improve overall utilization and performance. This can be achieved through pricing.

Current wireless networks use flat pricing schemes: users are charged with by a rate or based on the time of the day. However, the price is independent of the current state of the network. Hence, such systems cannot provide enough incentives for users to avoid congestion; in this paper we describe a new scheme which integrates pricing with call admission control (Fig. 1).

The system is contains of 2 blocks: pricing block and call admission block (We use guard channel scheme at the CAC block (Chang *et al.*, 1994)). One of our purposes is to maximize total user utility, it can be shown that there exist new call arrival rate where the total user utility is maximized and therefore, the network resources are optimally utilized which is named optimal call arrival rate λ^* (Hou *et al.*, 2002).

It should be noted here that maximum total user utility also means that channel resources are most efficiently utilized. When arrival rate becomes less than the optimal value, users can get better quality than their QoS requirements, but some channel resources are wasted and from the perspective of the service provider, this means less revenue. On the other hand, when arrival rate becomes greater than the optimal value a large number of users are blocked when trying to initiate their calls or when trying to hand off to another cell in the middle of a call, which means that the QoS degrades and may become unacceptable.

The pricing block works as follows: when the traffic load is less than the optimal value, a normal price is charged to each user, the normal price is the price that is acceptable to every user. When the traffic load increases beyond the optimal value, dynamic peak hour price will be

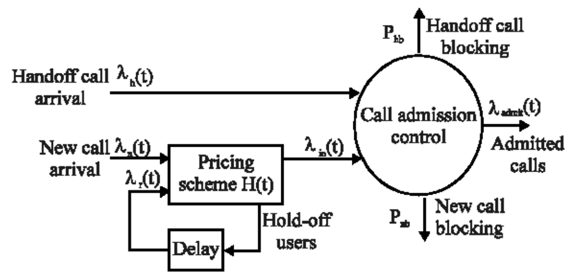


Fig. 1: Integration of pricing schene with call admission control

charged to users who want to place their calls at this time. The decision about the peak hour fee is based on the actual network conditions and not only on the time of the day. The following points should be noted in the Fig. 1.

The handoff call arrival rate λ_h is determined by the new call arrival rate λ_n and other system parameters. The handoff calls do not go through the pricing block because they are a continuation of previously admitted calls and their operation is governed by the price agreed upon at the time of the call acceptance.

During the period in which the dynamic peak hour price is charged to users, if some users are not willing to accept the extra charge, they will choose not to place their calls at this time. These users can make their calls later when the network conditions change and the price decreases; arrival rate is denoted by λ_r.

We define the system function of pricing block H(t) as the percentage of the incoming users that will accept the price at time t.

$$\{\lambda_n(t) + \lambda_r(t)\} H(t) = \lambda_{in}(t) \tag{1}$$

The congestion pricing block should be designed in such a way that, by adjusting H(t) according to current traffic condition, λ_{in} always meets the following requirement:

$$\lambda_{in}(t) \le \lambda^* \tag{2}$$

This requirement guarantees that the cell will not be congested and, therefore, the quality of service of the callers in service can be guaranteed.

PRICING CALCULATIONS

Monetary incentive can influence the way that users use resources and is usually characterized by demand functions. Demand function describes the reaction of users to the change of price (Hou *et al*., 2002). We use the demand function as:

$$D[(p(t)] = Exp(-(p(t)/p_o - 1)^2) \quad (3)$$

Where, ρ_o is the normal price, p(t) is the price charged to users at time t, which is the sum of normal price and extra peak hour price. D(p(t)) denotes the percentage of users that will accept this price. According to definition of H(t) and D(p(t)) we can find out that: H(t) = D[p(t)] so we have:

$$H(t) = \frac{\lambda_{in(t)}}{\lambda_{n(t)} + \lambda_r(t)} \le \frac{\lambda^*}{\lambda_{in(t)} + \lambda_r(t)} \quad (4)$$

$$p(t) = D^{-1}(\min(\frac{\lambda^*}{\lambda_n(t) + \lambda_r(t)}, 1)) \quad (5)$$

SYSTEM MODEL IN CAC

The assumptions involved in this model are stated as:

- The system has inputs of new and handoff calls generated according to a Poisson distribution with mean rates of λ-n and λ-h.
- The service time, denoted by T-m is assumed to be exponentially distributed with mean 1/u-m.
- There is C channels available in the system. And two of them are used as guard channels.
- The system provides a finite queue with capacity N_n, for new calls and finite queue with capacity N_h for handoff calls in the handoff area.

We define (n_1, n_2) as the system state, where n_1 is the sum of the number of occupied channels and the number of hand off calls waiting in the queue, n_2 is the number of new calls waiting in the queue, obviously $0<n_1<c+N_n$ and $a<n_2<N_h$. The state transition diagram of such system is shown in Fig. 2 (Chang, 1994). From this diagram we can obtain the state probability and calculate the performance parameters (such as the average blocking probabilities, the average waiting time….). Blocking of a new call may occur for 2 reasons. One is that as a new call originates, the number of available idle channels is less than or equal to c-h and there are no free buffers left in the waiting queue. The other is that although a new call has been accepted and is waiting in the queue, it fails to

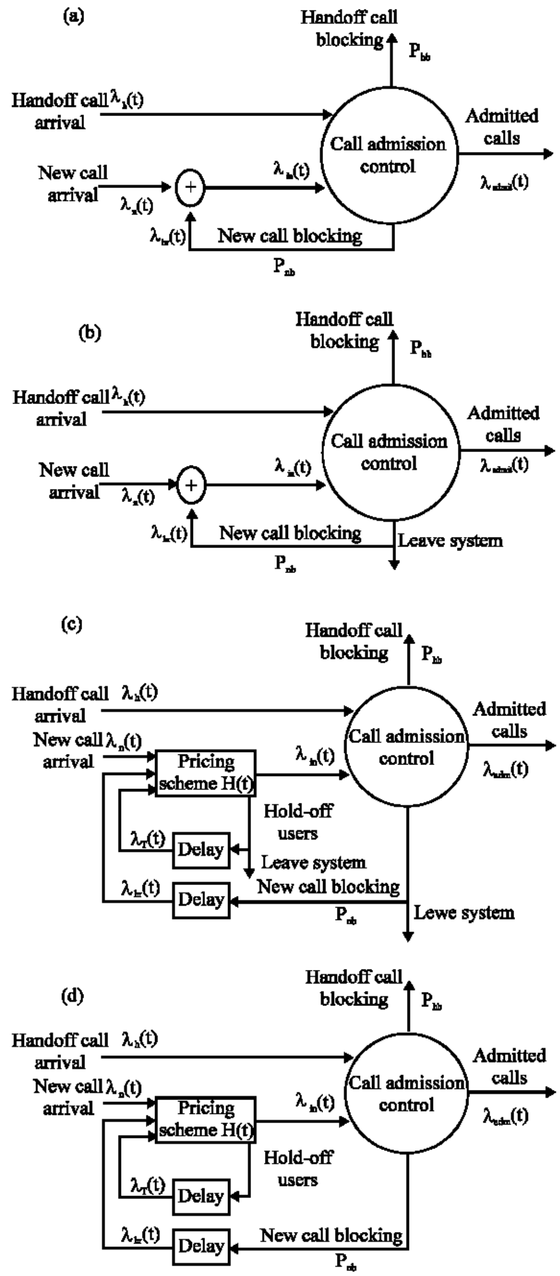


Fig. 2: The diagrams of experiments 1, 2, 4 and 5, (a) Experiment 1 CSwR. (b) Experiment 2 CSwRL.(c) Experiment 4 PSwR. (d) Experiment 5 PswRL

access a free channel within its patience time and so reneges from the system. The blocking probability of an arbitrarily selected new call can be obtained by:

$$p_B^N = \sum_{n1=c-ch}^{c+Nh} p_{n1,Nn} + \sum_{n1=c-ch}^{c+Nh} \sum_{n2=0}^{Nn} p_{n1.n2} R_n(n_1.n_2) \quad (6)$$

Where $R(n_1, n_2)$ is the reneging probability of an arbitrarily selected new call given that the system state is (n_1, n_2) just at the instant when the call is accepted and put in the waiting queue (Chang *et al*., 1994). Blocking of an arbitrarily selected handoff call occurs in 2 situations. The first is that there are no free channels and no free buffers available as the call moves into a handoff area.

The second is that, although the handoff call has been accepted by the system and is waiting in the queue, the call cannot access a free channel within its dwell time in the handoff area and so is dropped from the queue by the system. The blocking probability of the arbitrarily selected handoff call, can be similarly obtained by:

$$p_B^H = \sum_{n2=0}^{Nn} p_{c+Nh,n2} + \sum_{n1=c}^{c+Nh-1} \sum_{n2=0}^{Nh} p_{n1,n2} R_h(n_1, n_2) \qquad (7)$$

Where $R(n_1, n_2)$ is the dropping probability of the arbitrarily selected handoff call given that the system state is (n_1, n_2) just at the instant when the call is accepted by the system and waits in the queue (Chang *et al*., 1994).

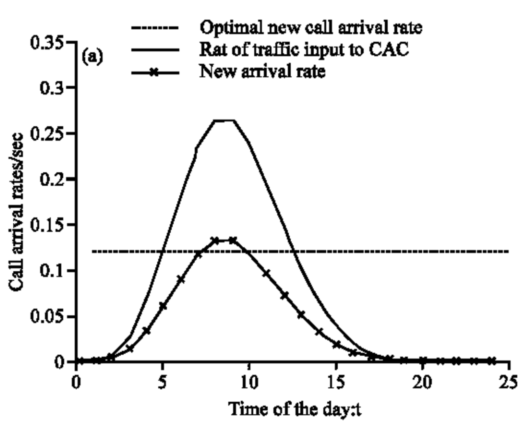
MODELS

In order to study and observe how our schemes can solve the problem of congestion in wireless networks, we perform 5 experiments (Fig. 2). The specific setting for each experiment is as follows:

- No pricing block is implemented. Users blocked by CAC (blocked users) retry after waiting some time. We refer to this as Conventional System with Retry (CSwR).
- No pricing block is implemented. One third of the blocked users leave the system and the rest wait And retry. We refer to this as Conventional System with Retry and Loss (CSwRL).
- A user that does not accept the current price (hold off users) waits for some time and retries, while blocked users do not retry and they are cleared from the system. This is the scenario implied by Fig. 1. We refer to this as Pricing System with Hold off Retry (PSwHR).
- Both hold-off users and blocked users retry after waiting some time. We refer to this as Pricing System with Retry (PSwR).
- One third of the hold off users and one third of blocked users leave the system and the rest of the hold-off and blocked users will wait some time and retry. We refer to this as Pricing System with Retry and Loss (PSwRL).

RESULTS

The results of conventional system (CSWR and CSWRL) that do not use pricing in the call admission control process to control the traffic are presented in Fig. 3. We can see that such systems are congested because in some period the rate of traffic input to CAC block is greater than the optimal new call arrival rate. Figure 4 shows that when we use pricing the rate of traffic input to CAC block is always less than the optimal new call arrival rate, so it reduce the network congestion. We also observe that the rate of traffic input to CAC block for PSwHR, PSwR and PSwL are different. PSwR has the longest "flat" period, PSwHR has a slightly shorter one and PSwRL's "flat" period is much shorter than the previous models. This difference is due to Different user behavior modes in these 3 experiments.



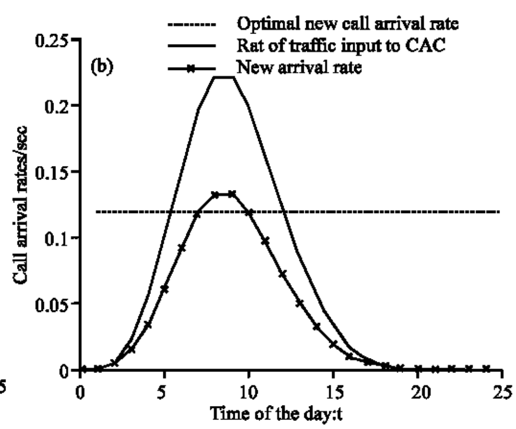


Fig. 3: Experiments CSWR (a) and CSWRL (b)

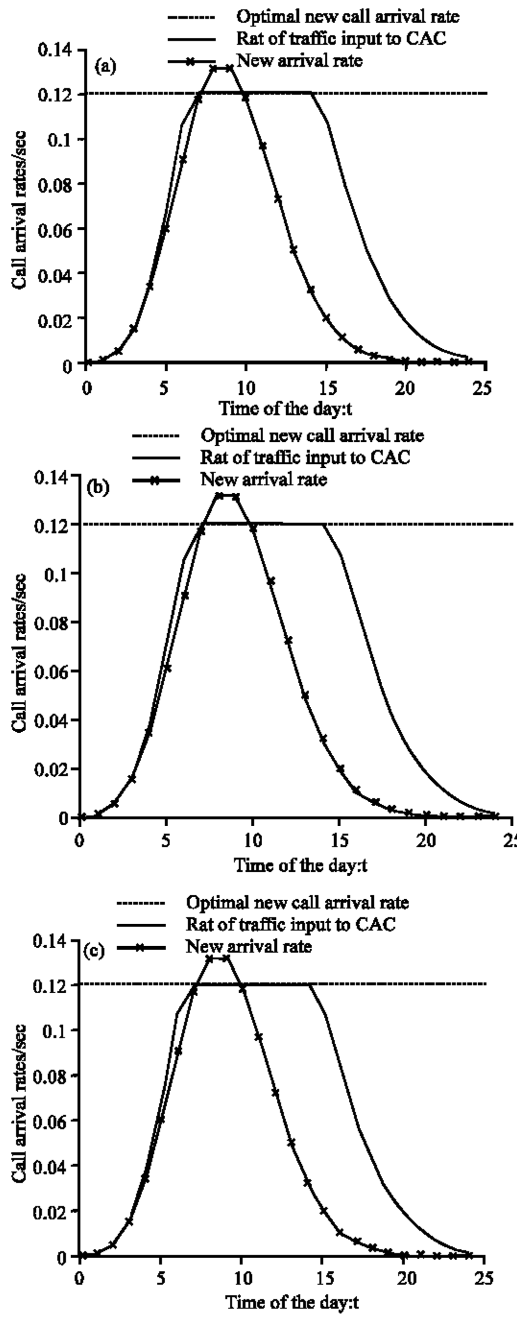


Fig. 4: Experiments PSWHR (a), PSWR (b) and PSWRL(C)

CONCLUSION

Congestion is one of the most intense problems: In the current wireless networks. With the emerging next generation wireless services, conditions will become even worse since users are allowed to use more bandwidth and transmit a large volume of data or even real-time video. Traditional CAC schemes focus only on the desired Qos but they cannot reduce the network congestion. In this study, we investigate the role of network pricing, Not only as a means of generating income for the service/network provider, but also as an additional element to control the efficient use of available Resources in networks. Therefore, we propose the integration of call admission control with a dynamic congestion pricing scheme that provides incentives to users to use the wireless resources efficiently. The problem of network congestion has been extensively studied via simulation. Our current and future research in this area mainly concentrates on extending this approach and studying the improvements and benefits that can be achieved by our proposed integration when we take into account the existence of multiple services with different QoS requirements that are available in wireless systems and may impact the network operation.

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