THE IMPACT OF PREDICTION ON THE PERFORMANCE OF A DISTRIBUTED CALL ADMISSION CONTROL FOR MULTIMEDIA MOBILE NETWORKS

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Abstract

In this paper, we investigate the impact of prediction on the performance of our distributed call admission control scheme developed for cellular mobile multimedia networks [8]. In this scheme, each cell involved in the call admission process should decide whether it will be able to support a particular user in the future. However, since the decisions for future users are taken according to local information about the future, they are assigned different confidence degrees. The associated confidence degrees depend of many parameters. It is clear that the time in the future for which the decision are taken has great impact on the confidence of that decision. The available bandwidth when taking the decision also affects the confidence. In fact to give a complete picture the confidence degrees also depend on the efficiency of the call admission routine. In this paper, simulations are presented with an analysis of the impact of the confidence degree on the performance of the distributed call admission control scheme.

Introduction

Cellular mobile networks have to continue supporting their mobile users after they leave their original cells. This rises a new challenge to Call Admission Control (CAC) algorithms. A call admission process should not only take into consideration the available resources in the original cell but also in neighboring cells as well.

Mobile users are in a growing demand for multimedia applications, and the next generation wireless networks are designed to support such bandwidth greedy applications. The (wireless) bandwidth allocated to a user will not be fixed for the lifetime of the connection as in traditional cellular networks, rather the base station will allocate bandwidth dynamically to users. Many evolving standards for Wireless Broadband Systems, UMTS and IMT2000 have proposed solutions to support such capability [1] [2] [3].

Several call admission algorithms have been proposed for wireless networks to support multimedia users with dynamic bandwidth requirements (e.g. [4]). These algorithms take only local information in the admission decision process, which result in a high call dropping probability. Call Dropping Probability (CDP) is an important connection level QoS parameter in wireless mobile networks. To reduce the call dropping probability, few other CAC algorithms which take into consideration information from neighboring cells have been proposed [5][6][7]. However, those algorithms only support users with fixed bandwidth requirements.

In [8] we have proposed a Distributed Call Admission Control scheme designed for wireless mobile multimedia networks with dynamic bandwidth allocation. The call admission process involves the cell that receives the call admission request and a cluster of neighboring cells so the user will not be dropped due to handoffs. Consequently, the network will provide a low call dropping probability while maintaining a high resource utilization.

In this scheme, each cell involved in the call admission process gives a response of whether it will be able to support a user in the future. However, since the responses for future users are computed according to local information about the future, they should not be assigned the same confidence degree. Indeed, responses corresponding to the near future are more likely to be more accurate than those of the far future. The associated confidence degrees depend of many parameters. It is clear that the time in the future for which the response is computed has great impact on the confidence of that response. The available bandwidth when computing the response also affects the confidence. In fact to give a complete picture the confidence degree also depends on the efficiency of the call admission routine. However, this later is difficult to determine.

In this paper, we investigate the impact of the confidence degree on the achieved performance of the CAC scheme, in terms of average bandwidth utilization and call dropping probability. Results show that a good choice of how to compute these confidence degrees is crucial for the distributed CAC scheme to give the best performance.

The paper is organized as follows. In section 2, we describe the model of the system considered in this paper and define the dynamic mobile probabilities used by our distributed call admission control algorithm. In section 3 we present the call admission process involving a cluster of neighboring cells. In section 4 we investigate the impact of the confidence degree on the performance of the call admission process. Finally, section 5 concludes the paper.

System model

We consider a wireless/mobile network with a cellular infrastructure that can support mobile terminals running applications which demand a wide range of resources. Users can freely roam the network and experience a large number of handoffs during a typical connection. We assume that users have a dynamic bandwidth requirement. The wireless network must provide the requested level of service even if the user moves to an adjacent cell. A handoff could fail due to insufficient bandwidth in the new cell, and in such case, the connection is dropped.

To reduce the call dropping probability, we have proposed in [8] to make neighboring cells participate in the admission decision of a new user. Each involved cell will give its local decision and then the cell where the request was issued will finally decide if the new request is accepted or not. By doing so, the new admitted connection will have more chances to survive after experiencing handoffs.

We use the notion of a cluster similar to the shadow cluster concept [9]. The idea is that every connection exerts an influence upon neighboring base stations. As the mobile terminal travels to other cells, the region of influence also moves. The cells influenced by a connection are said to constitute a cluster. Each user in the network, with an active connection has a cluster associated to it. The cells in the cluster are chosen by the cell where the user resides. The shape and the number of cells of a user's cluster depend on factors such as user's current call holding time, user's QoS, terminal trajectory and velocity.

We consider a wireless network where the time is divided in equal intervals at $t = t_0, t_1, ..., t_m$. Let j denote a base station in the network, and x a mobile terminal with an active wireless connection. Let $K(x)$ denote the set of cells that form the cluster for the active mobile terminal x. We write $P_{x,j,k}(t) = [P_{x,j,k}(t_0), P_{x,j,k}(t_1), ..., P_{x,j,k}(t_{m_x})]$ the probability that mobile terminal x, currently in cell j, to be active in cell k, and therefore under the control of base station k, at times t_0, t_1, t_2, ..., t_{m_x}. $P_{x,j,k}(t)$ represents the projected probabilities that mobile terminal x will remain active in the future and at a particular location. It is referred to as the Dynamic Mobile Probability (DMP) in the following. The parameter m_x represents how far in the future the predicted probabilities are computed. It is not fixed for all users and can depend of the user QoS or the actual connection elapsed time.

Those probabilities may be function of several parameters such as: handoff probability, the distribution of call length for a mobile terminal x, cell size, user mobility profile, etc. Of course, the more information we have, the more accurate are the probabilities, however the more complex is their computation.

For each user x in the network, the cell responsible for this user decides the size of the cluster $K(x)$. The cells in $K(x)$ are those involved in the CAC process. The cell responsible for user x sends the DMPs to all members in $K(x)$ specifying whether the user is a new one (in which case the cell is waiting for responses from the members of $K(x)$) or not.

DMPs could range from simple probabilities to complex ones. Simple probabilities can be obtained by assuming, for example, that call length is exponentially distributed, call arrival process follows a Poisson distribution, handoff probabilities are equal in any direction and so on.

DMPs can also be complex, for example by including information about user mobility profiles. A method for computing dynamic mobile probabilities taking into consideration mobile terminal direction, velocity and statistical mobility data, is presented in [5]. Other schemes to compute these probabilities are presented in [6] [7]. To compute these probabilities, one can also use mobiles' path/direction information readily available from certain applications, such as the route guidance system of the Intelligent Transportation Systems with the Global Positioning System (GPS).

The call admission control process

Local call admission control

At each time t_0 each cell, in a cluster $K(x)$ involved in our CAC process for user x, makes a local CAC decision for different times in the future $(t_0, t_1, ..., t_{m_x})$. Based on these CAC decisions, we call Elementary Responses, the cell makes a final decision which represents its local response to the admission of user x in the network. Elementary responses are time dependent. The computation of these responses is different depending on the user location and type. The user can be either a local new user or a new user that has a non null probability to be in this cell in the near future.

The network tries first to continue supporting old users and uses the DMPs to check if a cell can accommodate a new user who will possibly come to the cell in the future. The cell can apply any local call admission algorithm to compute the elementary responses. We write $r_k(x,t)$ the elementary response of cell k for user x for time t. We assume that $r_k(x,t)$ can take one of two values: -1 meaning that cell k can not accommodate user x at time t; and 1 otherwise. A detail description of how to compute the elementary responses is presented in [8].

Since the elementary responses for future foreign users are computed according to local information about the future, they should not be assigned the same confidence degree. Indeed, responses corresponding to the near future are more likely to be more accurate than those of the far future.

We write $C_k(x,t)$ the confidence of cell k in its elementary response $r_k(x,t)$. Cell k has to compute (or simply choose) the confidence degree $C_k(x,t)$, typically between 0% and 100%. The confidence degrees depend of many parameters. It is clear that the time in the future for which the response is computed has great impact on the confidence of that response. The available bandwidth when computing the elementary response also affects the confidence. In fact to give a complete picture the confidence degree also depends on the efficiency of the call admission routine. However, this later is difficult to determine.

If for user x, cell k has an elementary response $r_k(x,t)$ for each t from t_0 to t_{m_x}, those elementary responses are weighted with the corresponding DMPs $P_{x,j,k}(t_0)$ to $P_{x,j,k}(t_{m_x})$, to compute the final response. The final response from cell k to cell j concerning user x is then:

$$R_k(x) = \frac{\sum_{t=t_0}^{t=t_{m_x}} r_k(x,t) \times P_{x,j,k}(t) \times C_k(x,t)}{\sum_{t=t_0}^{t=t_{m_x}} P_{x,j,k}(t)} \quad (1)$$

where $C_k(x,t)$ is the confidence of cell k in the elementary response $r_k(x,t)$. To normalize the final response, each elementary response is also divided by the sum over time t of the DMPs in cell k. Of course, the sum $\sum_{t=t_0}^{t=t_{m_x}} P_{x,j,k}(t)$ should not be null, which otherwise means that all the DMPs for cell k are null. Finally, cell k sends the response $R_k(x)$ to the corresponding cell j.

Distributed call admission control

Here the decision takes into consideration the responses from all the cells in the user's cluster. The admission process concerns only new users seeking admission to the network, not already accepted ones. We assume that cell j has already decided the cluster $K(x)$ and that cell j has already assigned to each cell k in the cluster $K(x)$ a weight $W_k(x)$. Each weight represents the importance of the contribution of the associated cell to the global decision process. Usually, the more a cell is involved in supporting the user, the higher is its weight value. Weights $W_k(x)$ depend on the DMPs. We use the following formula to compute the weights $W_k(x)$:

$$W_k(x) = \frac{\sum_{t=t_0}^{t=t_{m_x}} P_{x,j,k}(t)}{\sum_{k' \in K(x)} \sum_{t=t_0}^{t=t_{m_x}} P_{x,j,k'}(t)} \quad (2)$$

The final decision of the call admission process for user x is based on:

$$D(x) = \sum_{k \in K(x)} R_k(x) \times W_k(x) \quad (3)$$

If $D(x)$ is higher than a certain threshold, we call acceptance threshold, the user x is accepted; the user is rejected otherwise. The more higher is $D(x)$ the more likely the user connection will survive in the event of a handoff.

The impact of the confidence degree

In this section we investigate the impact of the confidence degree on the performance of the CAC scheme. We evaluate the performance of the distributed CAC scheme when using different confidence degree formulas.

To compute the confidence degrees we first use a formula that uses the percentage of available bandwidth when computing the elementary response as an indication of the confidence the cell may have in this elementary response. The confidence degrees are computed using eq. 4:

$$C_k(x,t) = e^{(p-1)} * p^n \tag{4}$$

where p is a real number between 0 and 1 representing the percentage of available bandwidth at the time of computing the elementary response. And $n \geq 1$ is a parameter that is chosen experimentally to obtain the best efficiency of the call admission routine.

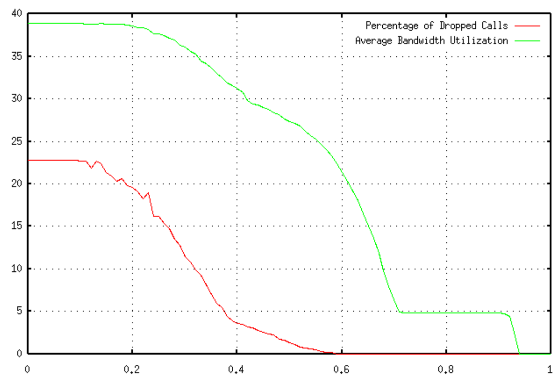

Figure 1: The average bandwidth utilization and the percentage of dropped calls when $n = 3$

Figure 1, shows the CAC scheme performance when $n = 3$. The higher curve depicts the average bandwidth utilization according to the acceptance threshold, while the lower curve shows the percentage of dropped calls according to the acceptance threshold. Figure 2 shows the CAC scheme performance when $n = 4$.

Figure 3 depicts the average bandwidth utilization according to the percentage of dropped calls achieved when $n = 1$, $n = 2$, $n = 3$ and $n = 4$. According to this figure, the four schemes achieve comparable performance. For the same call dropping percentage the four schemes achieve the same resource utilization.

Another important parameter that affects the confidence degrees is time. To take time into consideration, the confidence degrees are computed using eq. 5:

$$C_k(x,t) = e^{-\frac{(t-t_0)}{t_{max}}} * (1 - \frac{t-t_0}{t_{max}})^m \tag{5}$$

where t is the time for which the elementary response is computed and t_0 is the time at which the admission request is processed. And $m \geq 1$ is a parameter that is chosen experimentally to obtain the best efficiency of the call admission routine.

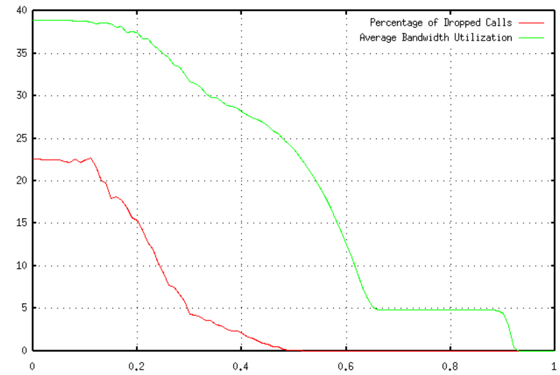

Figure 2: The average bandwidth utilization and the percentage of dropped calls when $n = 4$

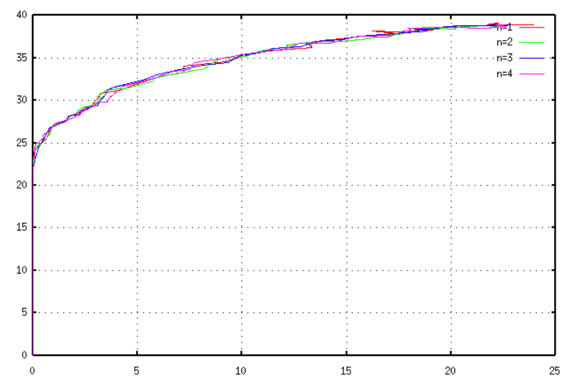

Figure 3: The average bandwidth utilization according to the percentage of dropped calls for $n = 1, 2, 3, 4$

Figure 4, shows the CAC scheme performance when the confidence degrees are computed using eq. 5 and $m = 3$. The higher curve depicts the average bandwidth utilization according to the acceptance threshold, while the lower curve shows the percentage of dropped calls according to the acceptance threshold.

Figure 5 shows the CAC scheme performance when $m = 4$.

Figure 6 depicts the average bandwidth utilization according to the percentage of dropped calls achieved when $m = 2$, $m = 3$, $m = 4$ and $m = 5$. According to this figure, the four schemes achieve comparable performance. For the same call dropping percentage the

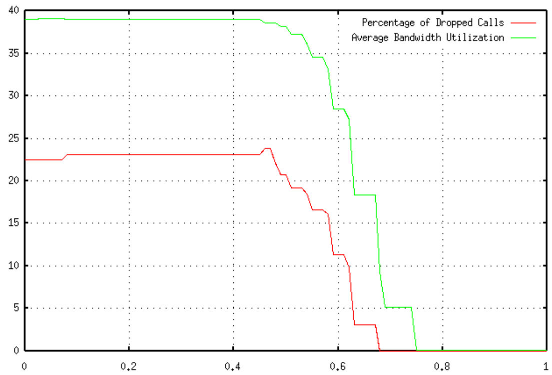

Figure 4: The average bandwidth utilization and the percentage of dropped calls when $m = 3$

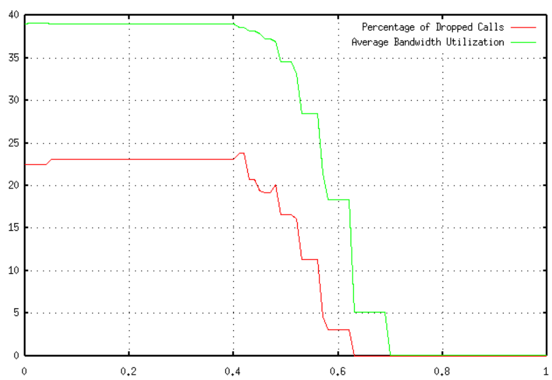

Figure 5: The average bandwidth utilization and the percentage of dropped calls when $m = 4$

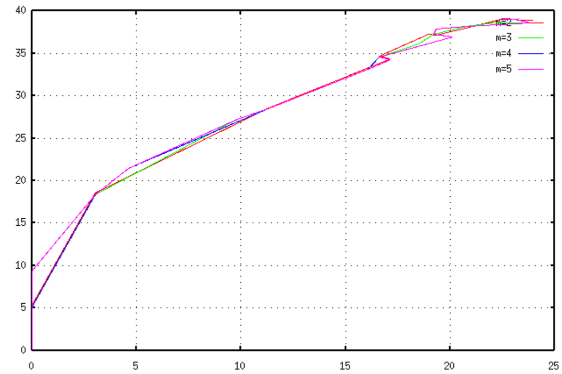

Figure 6: The average bandwidth utilization according to the percentage of dropped calls for $m = 2, 3, 4, 5$

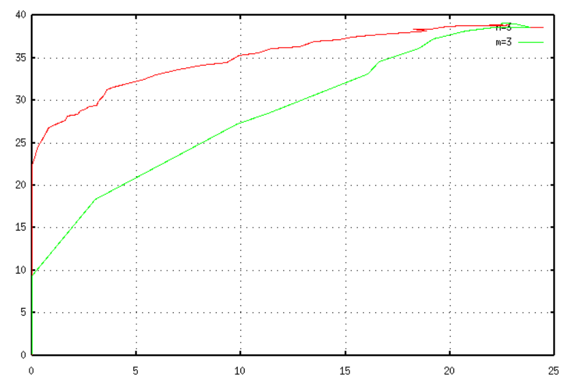

Figure 7: The average bandwidth utilization according to the percentage of dropped calls for $n = 3$ and $m = 3$

four schemes achieve the same resource utilization.

Now, let us compare the performance of the call admission control scheme when using eq. 4 and eq. 5. Figure 7 depicts the performance of the CAC scheme when the confidence degrees are computed using eq. 4 and $n = 3$ (higher curve), and when the confidence degrees are computed using eq. 5 and $m = 3$ (lower curve).

According to this figure, the scheme using eq. 4 with $n = 3$ outperforms the scheme using eq. 5 with $m = 3$.

In fact, according to fig. 3 and fig. 6, the scheme using eq. 4 with $n \in \{1, 2, 3, 4\}$ outperforms the scheme using eq. 5 with $m \in \{2, 3, 4, 5\}$.

This result can be explained by the fact that eq. 4 affects the elementary response for the users at each time step differently according to the available bandwidth. This allows the scheme to differentiate between users with high precision and thus refuse those users who will most likely be dropped before finishing their calls.

However, the confidence degree computed using eq. 5 affects all users at a particular time step in the same way. This is because the confidence degree in this case does not depend on the user. Indeed, according to eq. 5, the confidence degree depends only on the time parameter. This does not allow the scheme to differentiate between users in a precise fashion which explains the bad performance of this scheme in comparison to the scheme using eq. 4.

A combination of eq. 4 and eq. 5 was also considered. The obtained results are similar to those using eq. 4.

Other formulas were simulated as well, but not presented here for lack of space. The main result is that a good choice of how to compute the confidence degrees is crucial for the distributed CAC scheme to give the best performance. The confidence degrees that take into consideration user's information will allow the scheme to differentiate between users and will generally lead to better performance.

Conclusion

We have described a call admission control scheme suitable for wireless multimedia networks. The proposed scheme operates in a distributed fashion by involving, in a call admission decision, not only the cell where the call originated, but also a determined number of neighboring cells. Each cell involved in the CAC process associate a confidence degree to its response reflecting the confidence it has in this response. In this paper, we have compared the performance of our distributed call admission control scheme when using different formulas for computing the confidence degrees. Results show that a good choice of how to compute these confidence degrees is crucial for the distributed CAC scheme to give the best performance.

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