Cell Based QoS Provisioning Scheme for Indoor Wireless Network

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Abstract

In recent years, the rapid growth of the demand for wireless multimedia services makes the provision of quality of service (QoS) as an important issue. It is more important in an indoor environment. One of the key requirements of QoS is to reduce the dropping probability of handoff calls. It can be reduced by a proper call admission control (CAC) algorithm.

In this paper, we propose a call admission control scheme that is adequate to an indoor environment to resolve requirement of the dropping probability. Simulation experiments are used to evaluate the performance of the proposed scheme.

1. Introduction

In recent years, the rapid growth of the demand for wireless multimedia services makes the provision of quality of service (QoS) as an important issue. These multimedia applications require larger bandwidth than voice traffic. Also, the required bandwidths among applications are different. This difference is clear in the indoor environment. For example, IMT-2000 system is designed to support up to 2Mbps of data rate for an in-building environment compared to 384Kbps for pedestrians.

One of the key requirements of QoS is to reduce the dropping probability of handoff calls. It is generally considered that the dropping of a handoff call is less desirable than the blocking of a new call [1]. In this paper, we propose a call admission scheme that is adequate to an indoor environment to resolve requirement of the dropping probability.

Dropping probability can be reduced by proper call admission control (CAC) algorithm. Call admission control rejects a new call when it compromises the QoS of ongoing calls, even if there is enough bandwidth to admit a new call.

Accurate information on bandwidth availability is required for call admission control. There have been two approaches to obtain necessary information for the call admission control. The first approach is to predict the path of a mobile with the assumption that the direction and the velocity of the mobile are known [2], [3]. Its drawback is to require mobile's complete mobility information. The second is to use adjacent cells' information [4], [5]. This is inherently based on limited information of the system. Drawbacks of both approaches come from the scalability problem. In other words, these schemes were built in a distributed manner in a system with a large numbers of cells. In an indoor environment, however, the number of cells is limited. Thus, a centralized call admission control algorithm can be adopted that can fully utilize the information of the indoor environment.

Implementation of the call admission control operation is largely divided into two categories. The first category is the explicit reservation of unused bandwidth for adjacent cells [4]. This method may cause waste of the bandwidth.

The second is based on prediction of future bandwidth utilization [2]. If it is anticipated that a new call will degrade the QoS of current calls, it does not have admission to the system. The proposed scheme falls into the latter method.

In this paper, we focus on the traffic characteristics of indoor cells instead of individual mobile. We build a matrix of handoff probability between cells in a building using the characteristics of each cell. Based on the matrix, the amount of future bandwidth utilization of each cell is predicted with a normal probability distribution. A new call is denied entry to the system if its bandwidth requirement exceeds future bandwidth availability.

2. Call admission control scheme

2.1 Characteristics of handoff traffic in an indoor environment

The traffic in an indoor environment has different characteristics from the outdoor situation. Users in the indoor environment will require much more bandwidth than that of the outdoor environment, and the coverage of a cell is smaller than the coverage of outdoor cells. Thus, an accurate call admission control operation is required in an in-building situation. In an indoor environment, on the other hand, the centralized call admission control algorithm can be adopted, as the number of cells is limited.

In an indoor environment, traffic characteristic of a cell varies largely with spatial (office, cafeteria) and temporal (office hour, lunch time) aspects of the cell. Moreover, the aspect of the variation appears differently for each building. Accordingly, obtaining general traffic model is a difficult task. However, proper traffic modeling is required in order to develop a call admission control algorithm. Spatial features of a cell can be traced with computational intelligence proposed in [6], or with the cell profile proposed in [7]. For a special purpose building, such as multiplex cinema or subway station, a fairly accurate cell profile may be obtained. We can use computational intelligence such as hidden markov chain in general cases. To chase temporal changes, we additionally suggest the use of scenario profiles of time zones similar to the spatial profile.

We suppose that we can build a handoff probability matrix between cells in an entire building with these methods. In the proposed call admission control scheme, additional traffic parameters are not needed; that is, we do not need to know call inter-arrival time and service duration time.

2.2 Probability distribution of handoff traffic

We assume that real time traffic has preemptive priority over non-real time traffic. Therefore delay is not taken into account in this paper. We consider a key QoS metric to be the dropping probability (P_{drop}) and the blocking probability (P_{block}) of calls.

When a new call arrives, it has three parameters, 1) desired bandwidth (BD), 2) minimum required bandwidth (BM), and 3) maximum allowed dropping probability (P_{QoS}). We consider that the bandwidth is multiple of the unit bandwidth, bu , and time of the system is divided in equal intervals, Δt . Δt is a time interval that the probability of handoff more than once within Δt is negligible, e.g. $\Delta t = 10$ secconds .

Let us define some necessary notations. We denote N as the number of cells, $m_{ij}(t)$ as a probability that a user in cell i will make a handoff to cell j during $[t, t+1)$, $x_i(t)$ as total amount of traffic load in cell i at time t, $c_i(t)$ as bandwidth capacity of cell i at time t, $B_{ij}(t)$ as bandwidth of user j in cell i at time t, $BM_{ij}(t)$ as minimum required bandwidth of user j in cell i at time t,

$T_{ij}(t)$ as total amount of handoff traffic from cell i to cell j during $[t, t+1)$, $A_i(t)$ as amount of newly generated traffic in cell i during $[t, t+1)$, and $D_i(t)$ as amount of ended traffic in cell i during $[t, t+1)$. $x_i(t)$ can be easily measured, and $m_{ij}(t)$ is determined by methods discussed in the previous section.

The expected value of the traffic load in next time interval is expressed as

$$E[x_i(t+1)] = \sum_{j=1}^{N} x_j(t) m_{ji}(t) + E[A_i(t) - D_i(t)]. \quad (1)$$

We currently neglect the effect of $E[A_i(t) - D_i(t)]$. It will be considered later. Then equation (1) becomes

$$E[x_i(t+1)] = \sum_{j=1}^{N} x_j(t) m_{ji}(t) = \sum_{j=1}^{N} E[T_{ji}(t)]. \quad (2)$$

$T_{ji}(t)$ follows binomial distribution. That is,

$$P[T_{ji}(t) = n] = \binom{x_i(t)}{n} m_{ji}(t)^n \left(1 - m_{ji}(t)\right)^{x_i(t) - n}. \quad (3)$$

Binomial distribution is approximated by a normal distribution. Thus equation (3) is approximated as

$$T_{ji}(t) \sim N(x_j(t) m_{ji}(t),\ x_j(t) m_{ji}(t)(1 - m_{ji}(t))). \quad (4)$$

As $T_{ji}(t)$ and $T_{ki}(t)$ ($j \neq k$) are independent of each other, $x_i(t+1)$ is also approximated by normal distribution,

$$x_i(t+1) = \sum_{j=1}^{N} T_{ji}(t)$$

$$\sim N\left(\sum_{j=1}^{N} x_j(t) m_{ji}(t),\ \sum_{j=1}^{N} x_j(t) m_{ji}(t)(1 - m_{ji}(t)) \right) \quad (5)$$

The effect of call arrival and departure is ignored in equation (5). We introduce a margin α_i to take the effect into consideration. α_i is a design parameter. Thus we finally get the probability distribution of $x_i(t+1)$ as

$$x_i(t+1) \sim N\left(\sum_{j=1}^{N} x_j(t) m_{ji}(t)(1+\alpha_i),\ \sum_{j=1}^{N} x_j(t) m_{ji}(t)(1 - m_{ji}(t)) \right). \quad (6)$$

2.3 Call Admission Control Scheme

When a call arrives in cell i, two following conditions are checked.

<Condition 1>

$$x_i(t) + BM \leq c_i(t)$$

<Condition 2>

$$P[x_i(t+1) + BM > c_i(t+1)] \leq P_{QoS}$$

Condition 1 is for current bandwidth availability, and condition 2 is for anticipation of future bandwidth availability. According to the results of this checking procedure, call admission decision is made. Table 1 illustrates call admission decisions.

Condition 1	Condition 2	Decision
Yes	Yes	Admit new call immediately
No	Yes	Admit at the beginning of $t+1$
Yes	No	Reject new call
No	No	Reject new call

Table 1. Call admission decisions

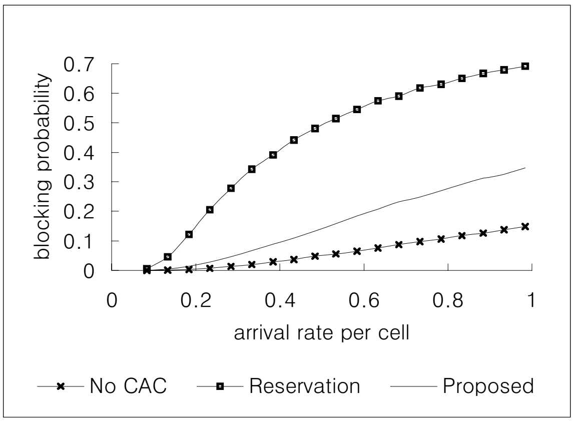

Figure 1. P_{block} of CAC schemes

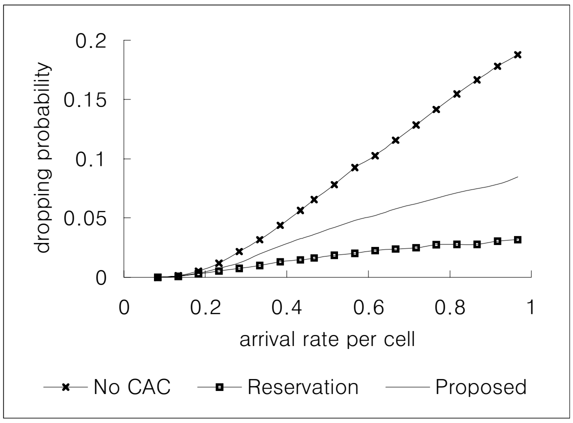

Figure 2. P_{drop} of CAC schemes call admission

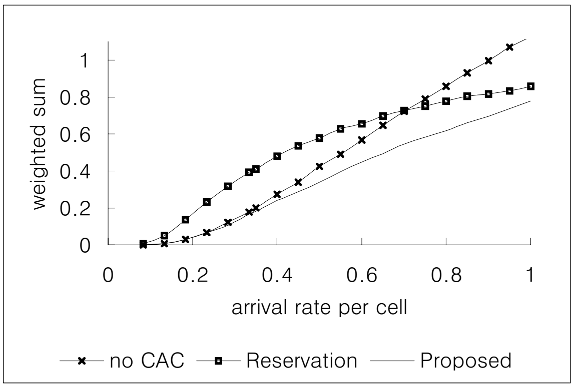

Figure 3. $5 \times P_{drop} + P_{block}$ of CAC schemes

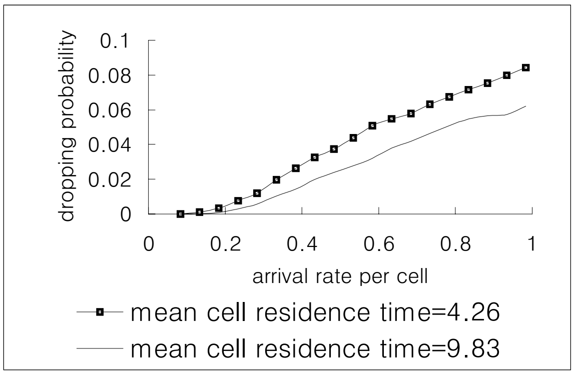

Figure 4. Effect of mobility with the proposed scheme

3. Simulation results

In this section, the performance of the proposed scheme is verified. To simplify the simulation environment, soft handoff and soft capacity are not considered. We consider a two-story building which has twelve cells. Call arrival follows Poisson process. The arrival rate varies with experiments. Call duration time is exponentially distributed with mean of 10 minutes. Cell residence time is also exponentially distributed with mean $1/(1-m_{ii})$ for cell *i*. Overall mean cell residence time is 4.26 minutes. We suppose there are two types of customers. For customer I, (BD , BM , P_{QoS})=(4, 2, 0.05), and for customer II, these values are (8, 4, 0.05). Capacity of a cell is 50. We fixed the design parameter α_i as 0.1 throughout the experiments.

We compared three call admission control schemes. First is 'no' call admission control scheme (if the available bandwidth is larger than minimum required bandwidth, admit new call), second is bandwidth reservation, (reserve minimum required bandwidth in all adjacent cells), and the last is the proposed scheme.

The blocking probabilities and the dropping probabilities of three schemes are depicted in Figure 1 and Figure 2 respectively. As for the blocking probability, no control scheme shows best performance. This is because ‘no’ call admission control scheme does not allow a priority for existing calls. The reservation scheme gives poor performance. It means that the reservation scheme does not make efficient use of the bandwidth resource. However this scheme shows good performance for the dropping probability. The proposed scheme maintains relatively low dropping probability and moderate blocking probability. When we give weights to the dropping probability with five times of the blocking probability, the proposed scheme indicates minimum values for the weighted sum. It is depicted in Figure 3.

In Figure 4, we examined the effect of the mobility with the proposed scheme. As mean cell residence time increases, the dropping probability increases. When cell residence time approaches call duration, actual dropping probability remains constant near the desired P_{QoS}. Figure 4 suggests that a further investigation of the proposed scheme is required to guarantee QoS in a large mobility condition.

4. Conclusion

The provision of QoS is an important issue for recent wireless networks, and dropping probability of a call is one of the key QoS requirements. In an indoor environment the characteristics of traffic is different from an outdoor situation. Therefore new call admission scheme is required. In this paper, we propose a call admission control scheme that is adequate for an indoor environment.

We build a handoff probability matrix that contains spatial and temporal aspects of a building using cell profile and computational intelligence. Based on the handoff probability, we predicted the amount of future bandwidth utilization. If a new call requires bandwidth which exceeds future bandwidth availability, the call is denied.

The proposed scheme was compared with other schemes by means of simulation experiments. The proposed scheme maintains relatively low dropping probability along with moderate blocking probability. When we give weights to the dropping probability with five times of the blocking probability, the proposed scheme indicates the best performance. However, further revision is required to guarantee QoS in a large mobility situation.

References

[1] I. Katzela and M. Naghshineh, "Channel Assignment Schemes for Cellualr Mobile Telecommunication Systems: A Comprehensive Survey", IEEE Personal Communications, June 1996.

[2] D. A. Levine, I. F. Akyidiz, and M. Naghshineh, "A Resource Estimation and Call Admission Algorithm for Wireless Multimedia Networks Using the Shadow Cluster Concept", IEEE Transaction on Networking, Vol. 5, No. 1, Feb 1997.

[3] S. K. Das, R. Jayaram, N. K. Kakani, and S. K. Sen, "A Call Admission and Control Scheme for Quality of Service (QoS) Provisioning in Next Generation Wireless Networks", Wireless Networks, Vol. 6, 2000.

[4] C. Olivera, J. B. Kim, and T. Suda, "An Adaptive Bandwidth Reservation Scheme for High-Speed Multimedia Wireless Networks", IEEE Journal on Selected Areas in Communications, Vol. 16, No. 6, May 1998.

[5] S. Choi and K. G. Shin, "Predictive and Adaptive Bandwidth Reservation for Hand-Offs in QoS-Sensitive Cellular Networks", ACM SIGCOMM 1998.

[6] V. K. Bharadwaj and A. Karandikar, "Hidden Markov Model based Resource Estimation and Call Admissions in Mobile Cellular networks", IEEE ICPWC 1999.

[7] S. Lu, R. Srikant, and V. Bharghavan, "Adative Resource Reservation for Indoor Wireless LANs", IEEE GlOBECOM 1996.