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이동통신시스템의 효율향상을 위한 통합채널운용체계*

장 근 녕**

Integrated Channel Management Schemes in Cellular Mobile Systems*

Kun-Nyeong Chang**

■ Abstract ■

Channel management is critical in designing a cellular mobile system that offers high capacity and high quality. In this paper, an integrated channel management scheme is proposed, which consists of a dynamic channel allocation scheme and an admission control scheme. The dynamic channel allocation scheme allocates a call request the channel which minimizes the impact on its interfering cell, and consists of two types of channel allocation strategies: nominal channel allocation strategy and non-nominal channel allocation strategy. The admission control scheme named the variable cutoff priority scheme reserves some frequency channels for handoff calls in each cell the number of which varies according to the blocking probability of handoff calls in that cell. Computational tests are performed to evaluate the performance of the proposed scheme in terms of overall blocking probability, defined by the weighted value of the blocking probabilities of new calls and handoff calls. The results show that the proposed scheme yields better performance than other compared schemes.

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** 신라대학교 경영학부

1. Introduction

The tremendous growth of mobile user population requires efficient use of the limited frequency spectrum allocated to mobile communications. An efficient method to increase frequency spectrum utilization in a mobile communication system is the cellular structure approach which divides spatially geographical region into a number of cells. A base station is established in each cell, and every mobile station in the cell communicates through the base station via a channel, where channel is denoted by a frequency band (FDMA), a time-slot within a frame (TDMA), or a particular code (CDMA), depending on the multiple access technique used [3, 13]. Then, channel management is critical in designing a cellular mobile system that offers high capacity and high quality, which consists of several resource allocation tasks such as channel allocation, admission control, channel base station assignment, and channel power control, *etc* [1, 13, 14, 17].

Several channel allocation schemes have been suggested in the literature [2-4, 8-10, 16, 20, 21]. The fixed channel allocation (FCA) is one of the most common schemes adopted in many cellular systems. In FCA, a set of nominal channels is permanently assigned to each cell according to the estimated traffic intensity. When a call arrives in a cell, one of nominal channels assigned to that cell is allocated to that call. In the dynamic channel allocation (DCA), all channels are placed in a pool and assigned dynamically over the cells in a service area to meet traffic requirements. DCA has long been pursued as the answer for coping with time and spatial variations of traffic demand in mobile communication networks. In addition, DCA has a particularly prominent role in future microcellular networks as a means to relieve the need for frequency planning.

An admission control policy is important to prevent the system from becoming overloaded and to ensure sufficient channels for handoff requests. In many practical situations, the blocking of a handoff call is critical since it will result in a disconnection of the call in the middle of conversation. Therefore, several priority schemes to reduce the chances of unsuccessful handoffs have been suggested [5-7, 11, 12, 15, 18, 19].

The simplest way of giving priority to handoff calls is to reserve some frequency channels for calls being handed off into the cell, known as the cutoff priority scheme (CPS) [7, 12]. Under CPS, priority is given to handoff calls by exclusively assigning them a certain number of channels called guard channels. The remaining channels called ordinary channels are shared by both calls. A new call is blocked if the number of free channels is less than or equal to the number of guard channels. However, a handoff call is blocked only when all the channels are busy in the cell. Another policy which gives priority to handoff calls is the threshold priority scheme (TPS) [5]. Under TPS, a handoff call is accepted as long as channel is free. However, a new call is accepted only if the number of new calls in progress is below a threshold value and a free channel is available.

In this paper, an integrated channel management scheme is proposed, which consists of a dynamic channel allocation scheme and an admission control scheme. The dynamic channel allocation scheme consists of two types of channel allocation strategies: nominal channel allocation strategy and non-nominal channel allocation strategy. The admission control scheme named the variable cutoff priority scheme (VCPS) reserves some frequency channels for handoff calls in each cell the number of which varies according to the blocking probability of handoff calls in that cell. Computational tests are performed to evaluate the performance of the proposed scheme in terms of overall blocking probability, defined by the weighted value of the blocking probabilities of new calls and handoff calls.

The remainder of the paper is organized as follows. In section 2, an integrated channel management scheme is proposed. The system model is described in section 3, and computational experiments are performed in section 4. Finally, section 5 summarizes the results.

2. Integrated Channel Management Scheme

In this section, an integrated channel management scheme is proposed, which consists of a dynamic channel allocation scheme and an admission control scheme.

2.1 Dynamic Channel Allocation Scheme

A cellular mobile system consisting of N cells and M channels is considered. Assume that channels are represented by the positive integers $1, 2, \cdots, M$. A set of nominal channels which is designed through some FCA scheme [9, 10, 21] is assigned to each cell.

In this subsection, a dynamic channel allocation scheme named the impact-based dynamic channel allocation scheme is proposed, which consists of two types of channel allocation strategies: nominal channel allocation strategy and non-nominal channel allocation strategy. First, the nominal channel allocation strategy is applied when a call request arrives. Next, the non-nominal channel allocation strategy is applied if a channel can't be allocated to that call request by the nominal channel allocation strategy.

2.1.1 Nominal Channel Allocation

If there are free nominal channels when a call arrives in a cell, a free non-nominal channel is allocated to the call request. If more than one nominal channel is free, then the free nominal channel which minimizes the impact on its interfering cells is allocated.

The impact, which results from the allocation of a free nominal channel j to a call in cell i in question, is defined by

$$C_i(j) = \sum_{\forall k \in I_i} \frac{1 - CA_k}{1 + L_{kj}}.$$

This value represents the sum of bad effects on interfering cells of cell i due to the use of nominal channel j by cell i. Here the set I_i denotes the set of interfering cells of cell i. The parameter L_{kj} represents the number of cells which prevent cell k from using channel j because of the co-channel interference. Finally, CA_k represents the channel availability rate of cell k. One simple way of defining the channel availability rate of cell k is CN_k/N_k, where N_k is the number of nominal channels assigned to cell k and CN_k is the current number of free nominal channels of cell k.

The scheme selects the free channel that yields the lowest impact value $C_i(j)$. If there is more than one free channel with the same lowest impact value $C_i(j)$, the lowest numbered channel among them is selected.

2.1.2. Non-nominal Channel Allocation

If there is no nominal channel, then a free non-nominal channel is allocated to the call request if possible. If more than one non-nominal channel is free, then the free non-nominal channel which minimizes the impact on its interfering cells is allocated.

The impact, which results from the allocation of a free non-nominal channel j to a call in cell i in question, is defined by

$$C_i(j) = w \sum_{\forall k \in I_i \cap S(j)} \frac{1 - CA_k}{1 + L_{kj}} + (1 - w) \sum_{\forall k \in I_i - S(j)} \frac{1 - CA_k}{1 + L_{kj}}$$

This value represents the sum of bad effects on interfering cells of cell i due to the use of non-nominal channel j by cell i. The first value and the second value represent the sum of bad effects on nominal cells and non-nominal cells of channel j respectively. Nominal cells of channel j mean cells to which the same channel j is allocated as a nominal channel, and non-nominal cells of channel j mean all the other cells except nominal cells of channel j. Here the set $S(j)$ denotes the set of nominal cells of channel j, and the parameter w is a weighting factor $(0 \le w \le 1)$.

The scheme selects the free non-nominal channel that yields the lowest impact value $C_i(j)$. If there is more than one free channel with the same lowest impact value $C_i(j)$, the lowest numbered channel among them is selected.

2.2 Admission Control Scheme

In this subsection, an admission control scheme named the variable cutoff priority scheme (VCPS) is proposed. Under CPS, priority is given to handoff calls by exclusively assigning them a certain number of channels called guard channels. Under VCPS, the number of guard channels, NG_i, of cell i varies according to the blocking probability of handoff calls in that cell by the following rules:

Rule 1: Increase NG_i by 1 if the condition $B_i^h > UB_i^h$ is satisfied for s minutes and NG_i is less than $NG_{\max}$.

Rule 2: Decrease NG_i by 1 if the condition $B_i^h < LB_i^h$ is satisfied for s minutes and NG_i is greater than 0,

Here, B_i^h denotes the blocking probability of handoff calls in cell i, which is computed as the ratio of the total number of handoff calls blocked to the total number of handoff call arrivals. The bound parameters UB_i^h and LB_i^h denote the upper bound and the lower bound of the blocking probability of handoff calls in cell i respectively, and $NG_{\max}$ denotes the maximum number of guard channels whose value is determined by the following procedure:

Step 1. Initialize the parameters $NG_{\max}$, $\overline{NG}_{\max}$, LB^n, UB^n, LB^h, and UB^h.

Step 2. Perform the following steps 2.1 and 2.2 at intervals of t minute.

Step 2.1 If $B^n > UB^n$ or $B^h < LB^h$, then

$NG_{\max} = \max\{0, NG_{\max} - 1\}$ and

$NG_i = \min\{NG_i, NG_{\max}\}$ for all i.

Step 2.2 If $B^n < LB^n$ or $B^h > UB^h$, then

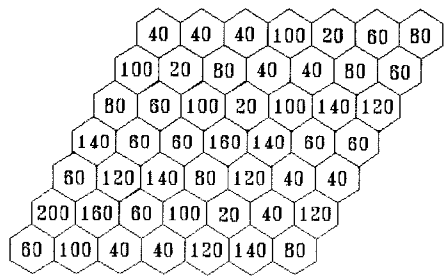
$NG_{\max} = \max\{\overline{NG}_{\max}, NG_{\max} + 1\}$.

Here, $\overline{NG}_{\max}$ denotes the upper bound of the maximum number of guard channels, and B^n and B^h denote the blocking probabilities of new calls and handoff calls for the whole system respectively. The bound parameters $LB^n(LB^h)$ and $UB^n(UB^h)$ denote the lower bound and the upper bound of the blocking probability of new calls (handoff calls) for the whole system respectively. Step 2.1 decreases $NG_{\max}$ by 1 if possible when $B^n > UB^n$ or $B^h < LB^h$, and Step 2.2 increases $NG_{\max}$ by 1 if possible when $B^n < LB^n$ or $B^h > UB^h$.

3. System Model

In this section, the simulation scenario, the assumptions made and the performance measures are described. For a test example, a regular cellular mobile system with nonuniform traffic distribution is considered, which is found in [21] as shown in [Figure 1]. The numbers represent the new call arrival rates in the respective cells. The mean call holding times of new calls and handoff calls are assumed to be 3 minutes. The number of available channels is 70, and the minimum cochannel reuse distance is $\sqrt{21}r$, where r is the cell radius.

The performance of the system is evaluated in terms of the weighted blocking probability B^w. This probability is estimated as follows: where



[Figure 1] Cellular mobile system with nonuniform traffic distribution

$$B^w = \alpha B^n + (1-\alpha)B^h,$$

α is a weighting factor. Since the blocking probability of handoff calls is considered to be more important than that of new calls, in general, $\alpha < 0.5$.

4. Computational Experiments

Computational experiments have been performed for the proposed scheme and other existing schemes. Tests are made for different traffic conditions depending on the call origination rate and the handoff probability. For the origination rate, 75%, 80%, 100% and 105% of the values in [Figure 1] are used, and the handoff probability of a call is taken to either 40% or 60%.

In [Figure 2] - [Figure 5], the test results are summarized. In the figures, TDCA, IDCA and ICM represent the timid dynamic channel allocation scheme, the proposed impact-based dynamic channel allocation scheme, and the proposed integrated channel management scheme respectively. In TDCA, all channels are placed in a pool, and the lowest numbered one among available channels is assigned when a call arrives in a cell. In TDCA and IDCA, the complete sharing policy is used to control the admission of new and handoff calls, where no distinction is made between two types of calls. In IDCA and ICM, the uniform allocation scheme is used to design a set of nominal channels for each cell, and the weighting factor w is set to 0.5.

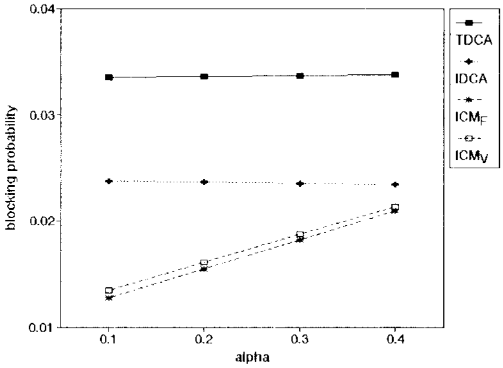
In the tests, two types of ICM, ICM_F and ICM_V, in which the values of parameters are not like each other, are considered. In ICM_F, the upper bound of NG_{max}, $\overline{NG}_{max}$, and the initial value of NG_{max} are set to 10, and the bound parameters UB_i^h, LB_i^h, LB^n, UB^n, LB^h, and UB^h are set to 0.02, 0.015, 1.0, 0.0, 1.0, and 0.0 respectively, and the time parameters s and t are set to 3 minutes. Note that, in ICM_F, the maximum number of guard channels is fixed to 10. In ICM_V, $\overline{NG}_{max}$ and the initial value of NG_{max} are set to 10 and 5 respectively, and the bound parameters LB^n, UB^n, LB^h, and UB^h are set to 0.05, 0.02, 0.02, and 0.01 respectively, and the values of other parameters are equal to those of ICM_F. Note that, in ICM_V, the maximum number of guard channels $\overline{NG}_{max}$ varies between 0 and 10 according to the bound parameters LB^n, UB^n, LB^h, and UB^h.

[Figure 2] and [Figure 3] show the overall performance for high handoff probability (60%). For the whole range of weighting factor α, ICM_F shows better performance than other schemes. [Figure 4] and [Figure 5] show the overall performance for low handoff probability (40%). For $\alpha \leq 0.2$, ICM_F shows better performance than other schemes. However, for $\alpha = 0.4$, ICM_V shows better performance than other schemes. For $\alpha = 0.3$, the performance of ICM_F and ICM_V is indistinguishable. [Figure 2] - [Figure 5] show that the performance of ICM, especially ICM_F, is better as the weighting factor α is smaller.

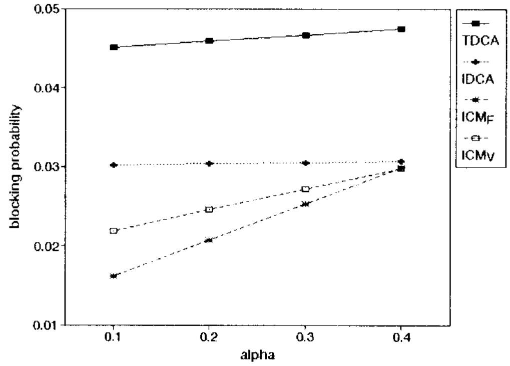
The test results indicate that ICM_F shows better performance than ICM_V in a system with high handoff call rate. However, in a system with low handoff call rate, ICM_F shows better performance than ICM_V for low weighting factor α and vice versa for high weighting factor α. In conclusion, the results also indicate that IDCA and ICM are efficient channel management schemes, especially when reducing handoff failure is a more important design issue, regardless of a little additional burden.

5. Conclusions

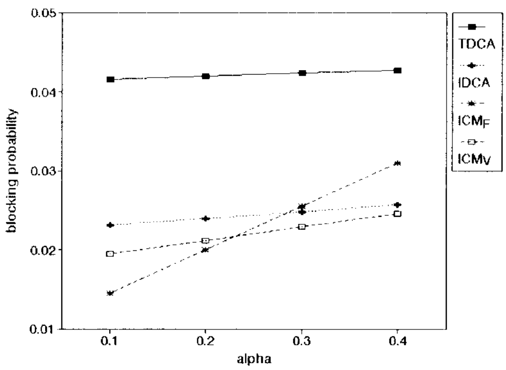
In this paper, an integrated channel management scheme is proposed, which consists of the impact-based dynamic channel allocation (IDCA) scheme and the variable cutoff priority scheme (VCPS). The IDCA scheme consists of two types of channel allocation strategies: nominal channel allocation strategy and non-nominal channel allocation strategy. Under VCPS, the number of guard channels for each cell is different, and varies according to the blocking probability of handoff calls in that cell. Computational tests are performed to evaluate the performance of the proposed scheme in terms of overall blocking probability. The results show that the proposed scheme yields better performance than other compared schemes.



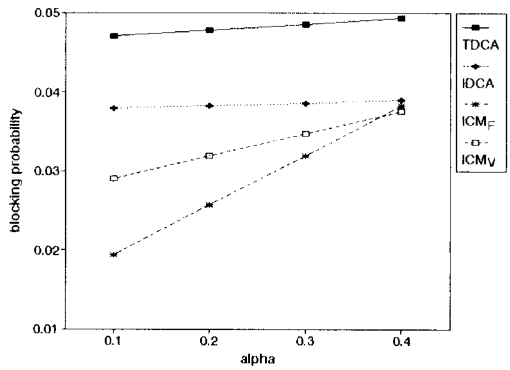
[Figure 2] Overall blocking probability for origination rate of 75% and handoff probability of 60%



[Figure 3] Overall blocking probability for origination rate of 80% and handoff probability of 60%



[Figure 4] Overall blocking probability for origination rate of 100% and handoff probability of 40%



[Figure 5] Overall blocking probability for origination rate of 105% and handoff probability of 40%

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