A Traffic Dispersion Strategy in Fiber-Optic Multitier Cellular System

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Abstract

Using frequency borrowing, we propose a channel allocation scheme in hierarchical cell structure. The proposed scheme is suitable for downtown environment in which bulky hot spot cells occur periodically at specific times. Performance is evaluated in view of blocking, handoff dropping probability and FA efficiency.

1 Introduction

Channel allocation strategy has a great effect on the performance of cellular system. Because, it gives additional resource to system if it works well. Typically, it can be classified into Fixed Channel Allocation(FCA) and Dynamic Channel Allocation(DCA). FCA allocates fixed numbers of channel to a cell. In DCA, a cell can use any channel that does not interfere with the channels used by its neighbor cells. In hierarchical cellular system, there are two trends of channel allocation strategy. One disperses traffic based on velocity threshold for cell selection. The other uses handoff call allocation[1]. These schemes can be used in case that hot spot occurs sparsely. However, in case that hot spot occurs in several adjacent cells simultaneously, these schemes can not work well.

This case appears in downtown environment. In this environment, there is severe traffic congestion at specific time period such as office-going hour and closing hour. It occurs periodically and we define this condition as 'Rush-hour' in this paper. During rush-hour, mobiles move very slowly, new call attempts are largely increased and handoff attempts rarely happen. So, there occur many consecutive hot shot cells.

These conventional schemes use macrocell resources to solve hot spot problem. But, compared with capacity requested in rush-hour case, the capacity of macrocell is negligible. So, new strategy to get more resources is needed.

This paper is organized as follows. In Section II, we proposed a new traffic dispersion strategy in Fiber-optic multitier cellular system. In Section III, we describe the system model and analyze the system performance. Also, we perform numerical analysis and discuss the results. Finally, we summarize our results and conclude this paper.

2 Proposed Scheme

In this paper, we consider CDMA based hierarchical cell structured system using bunch concept[2],[3]. From bunch concept, all FAs and CEs of system are located in CS(Central Station). We assume that this system is located in downtown region. We also assume that macrocell and

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its embedded microcells have at least two FAs, respectively. Each macrocell and microcell have different FAs. In this system, macro/microcell selection is determined by speed of mobile.

In normal case, many mobiles are serviced in macrocell because traffic is not heavy and there are many fast mobiles. But during rush-hour, almost all mobiles are supported in microcell because traffic is heavy and the speed of mobile is very slow. And almost all microcell become hot spot cell. Frequency Borrowing Channel Allocation(FBCA) scheme which we propose in this paper can prevent this hot spot problem.

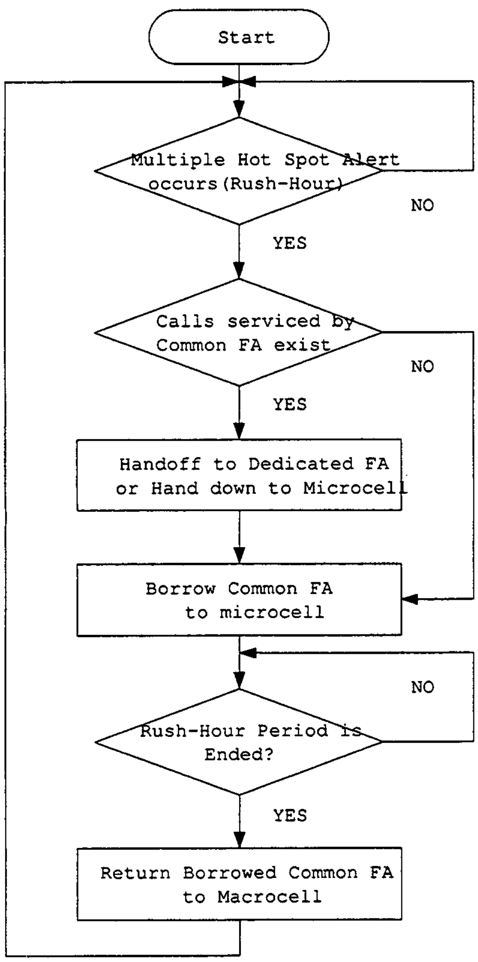


Figure 1. Flow Chart of FBCA Scheme

If the same numbers of FA are provided to each macrocell and its embedded microcells, respectively, microcells can support much more users than macrocell because there are many microcells in the area of one macrocell. From this point, we propose FBCA scheme that FA of macrocell is borrowed to microcells. The algorithm is shown in Fig. 1.

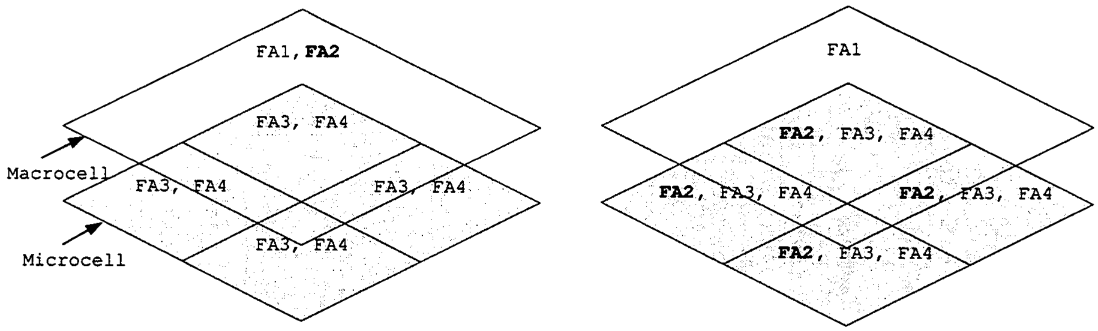
FAs of macrocell is divided into dedicated FA and common FA. Dedicated FA is used only in macrocell and common FA can be borrowed to microcell. When a call is originated, a channel of dedicated FAs is assigned. After all channel of dedicated FAs are used, channels of common FAs are assigned. When rush-hour traffic condition occurs, common FAs are borrowed to microcells according to traffic load as shown in Fig. 2. If there are mobiles serviced by the FA which is to be borrowed to microcell, the mobiles are handoffed to other FA or handdowned to microcells. In most rush-hour cases, all common FAs have no mobile to service. Because there are a few mobiles to be serviced in macrocell during rush-hour period.

This borrowing can be easily implemented using centralized resource property of bunch system. There is no additional interference in this system, because a region covered by a FA of macrocell is the same after the FA is borrowed to microcells. By using this technique, the capacity of each microcell increases greatly and the hot-spot problem can be solved. If rush-hour period ends, the borrowed FA is returned back to macrocell. Mobiles serviced by the FA are handoffed to other FA of the microcell.

To use this scheme, each microcell must have additional Channel Elements(CE) corresponding to common FA of macrocell. Even though this scheme needs additional CEs, this scheme can use FA more efficiently. Because FA is limited resource and CE is relatively unlimited resource, FBCA scheme has enough merit.

3 Modeling & Analysis

To perform analysis, we assume that the system is hierarchical cell structure which has one macrocell and 10 microcells. Assume that each macrocell and microcell have N different FAs. Let each FA



(a) Normal Case (b) Rush-hour Case

Figure 2. FA Allocation in Each Cases

serve C CEs. We use the manhattan cell model as shown in Fig. 3. We assume that there is no queue and no reservation channel for handoff call. Let new call arrival rate be λ_n and side length of a microcell be R. We also assume that mobile is uniformly distributed on the street with constant speed, V.

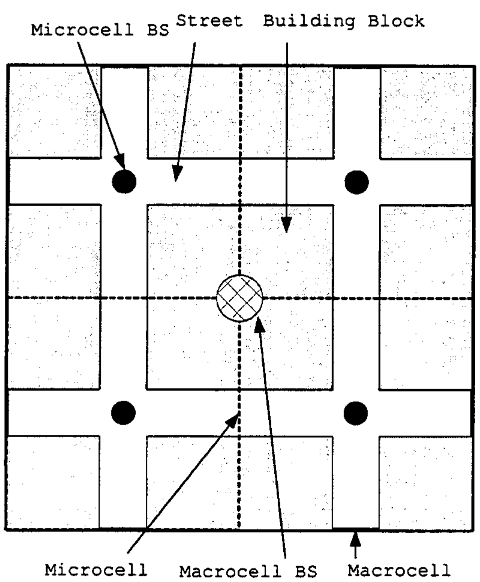


Figure 3. Hierarchical Cell Structure composed of one macrocell and four microcells

Let call duration time be T_c. We assume that T_c is exponentially distributed with mean μ_c^{-1}. Then pdf and cdf of T_c is shown as

$$\begin{aligned} f_{T_c}(t) &= \mu_c e^{-\mu_c t} \quad , \text{for } t \geq 0 \\ F_{T_c}(t) &= 1 - e^{-\mu_c t} \quad , \text{for } t \geq 0. \end{aligned} \tag{1}$$

Let sojourn time of new call be T_n. And, pdf and cdf of T_n is given by

$$\begin{aligned} f_{T_n}(t) &= \frac{V}{R} \\ F_{T_n}(t) &= \frac{V}{R}t. \end{aligned} \tag{2}$$

Moreover, the handoff probability of new call, P_N is calculated as

$$\begin{aligned} P_N &= P(T_c > T_n) \\ &= \int_0^\infty (1 - F_{T_c}(t)) f_{T_n}(t) dt \\ &= \frac{V}{R \cdot \mu_c}. \end{aligned} \tag{3}$$

Let sojourn time of handoff call be T_h. Because, T_h has constant value R/V, the handoff probability of handoff call, P_H is found to be

$$\begin{aligned} P_H &= P(T_c > T_h) \\ &= \int_0^\infty (1 - F_{T_c}(t)) f_{T_h}(t) dt \\ &= e^{-\mu_c \frac{R}{V}} . \end{aligned} \tag{4}$$

From (3) and (4), handoff call arrival rate, λ_h is given by

$$\lambda_h = \frac{\lambda_n(1-P_B)P_N}{1-(1-P_{HD})P_H} \quad (5)$$

where P_B is new call blocking probability and P_{HD} is handoff call dropping probability.

As we assume that there is no queue and no reservation channel, P_B and P_{HD} have the same value and are calculated from Erlang-B formula as

$$P_B = P_{HD} = \frac{(\frac{\lambda_n+\lambda_h}{\mu_c})^{C_h}/C_h!}{\sum_{x=0}^{C_h}(\frac{\lambda_n+\lambda_h}{\mu_c})^x/x!} \quad (6)$$

where C_h is the number of total channel.

4 Numerical Results

We investigate numerical examples in case that $\mu_c = 0.01$, $N = 2$, $C = 20$ and $R = 550m$. We only consider rush-hour case because performances in normal case are the same whether FBCA scheme is used or not. We assume the speed of mobile, V is $1m/s$ in rush-hour case.

Numerical results are shown in Fig. 4. We compare FBCA scheme with conventional schemes. It can be seen that blocking probability and dropping probability of FBCA scheme is much lower. Because we assume that there are no queue and reservation channel for handoff call, blocking probability is the same as dropping probability. From these results, we can see that extra resources is generated by FBCA scheme.

We also calculate numerical examples in case that number of common FA is changed. If common FA of macrocell is increased, macrocell can borrow FAs to microcell more and more. Fig. 5 shows that as more FAs are borrowed to microcell, we can get more extra resources.

To evaluate FA efficiency of FBCA scheme, we calculate the number of FA needed to guarantee 2% blocking probability. To guarantee QoS, a system requires some amount of CE. We assume the interference limitation of CE per a FA, C is 20. For example, if the number of needed CE is 22,

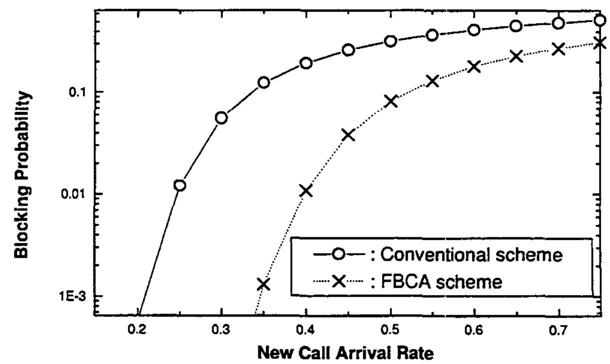


Figure 4. New Call Blocking and Handoff Call Dropping Probability vs. New Call Arrival Rate

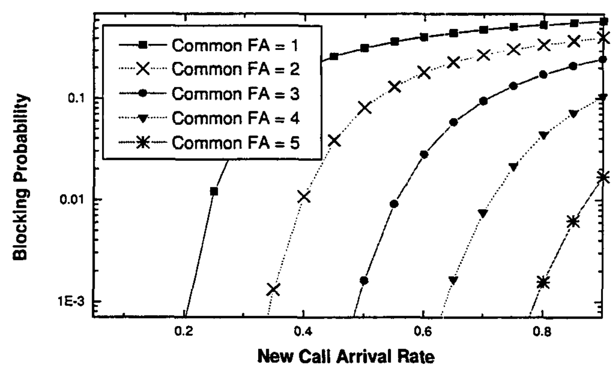


Figure 5. Blocking and Handoff Dropping Probability with changing the number of common FA

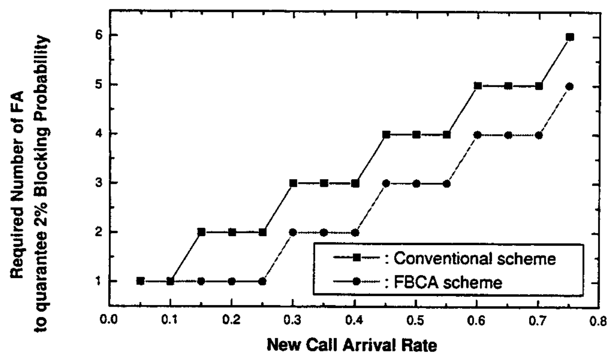


Figure 6. Required Number of FA to Guarantee 2% Blocking Probability vs. New Call Arrival Rate

this system requires 2 FAs. From Fig. 6, we can see that FBCA scheme requires less number of FA to guarantee the same QoS. That is FBCA scheme uses FA more efficiently.

5 Conclusions

In this paper, we proposed FBCA scheme in hierarchical cell structure. In this scheme, FA of macrocell is borrowed to microcell. By borrowing FA, proposed scheme can solve successive hot-spot problem in rush-hour case. From numerical analysis, we can see that proposed scheme can increase capacity and reduce number of FA needed to guarantee QoS.

References

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