AN EXCLUSIVE INTERGROUP HANDOFF ALGORITHM IN FIBER-OPTIC MICROCELL/PICOCELL RADIO SYSTEM

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Abstract – To solve the cost problem of micro/picocell system, the fiber-optic cellular system was proposed. In this system, all channel elements are managed in Central Station, not in each base station. In this paper, we propose and analyze a new intergroup handoff in the fiber-optic cellular system. The proposed scheme supports handoff with keeping current channel. Performance is evaluated in view of blocking and handoff refused probability. The numerical results show that the proposed scheme provides better performance than conventional soft handoff scheme.

I. INTRODUCTION

IMT-2000 system would reduce cell size based on microcell or picocell to provide multimedia services and support increasing users. By reducing cell size, we can increase the system capacity. The smaller cell size provides the smaller coverage area per base station and the physical network needs a large number of base station as well as a large infrastructure interconnecting the base stations. But the building of base station needs very high-cost. In view of communication services, cost must be kept low in order to acquire the mass consumer market.

To solve the cost problem of micro/picocell system, the fiber-optic cellular system was proposed[1]-[3]. The fiber-optic radio system is also called HFR(Hybrid Fiber Radio) system or optical-feeder system or bunch system. This system is composed of Base Station(BS) and Central Station(CS). The BS of this system is just a radio port such as a cheap

dummy antenna. A BS is connected to CS using optical fiber network. To save cost, the existing optical network such as CATV network can be used as the interconnection network between radio port and CS. It makes us install this system easily with very low-cost.

In this fiber-optic cellular system, all Channel Elements(CE) and call processing hardwares are located in the CS. The CEs can be allocated to calls, which are originated in the coverage area of a CS, dynamically using Spectrum Delivery Switch(SDS) [2]. The radio port(base station) just broadcasts and receives the radio signals. Then, the received signals are carried to a CS. In the CS, call processing hardware is shared among multiple radio ports and this can improve a trunking efficiency.

The use of microcell/picocell gives more capacity, but this makes the increase of handoff in the system. Also there are many hot-spot cells because the traffic distribution is nonuniform. To solve these problems, the group simulcast technique was suggested [3]. By adjusting the simulcast group dynamically, the system can reduce handoff rates and protect the outbreak of hot-spot cell. Because all radio ports within a group broadcast and receive signals as if they are in the same cells.

There are four types of handoff in the fiber-optic system using group simulcast technique. The simple explanations of each type are as follows:

1. *Intercell Handoff:* The Intercell handoff occurs when a call is moved between microcell/picocells which are within a same simulcast group. The softer handoff scheme is usually used as the Intercell handoff procedure in the CDMA based

system..

2. *Intergroup Handoff:* The Intergroup handoff appears when a call is moved from one simulcast group to the other simulcast group. In the CDMA based fiber-optic microcell/picocell cellular system, IS-95 soft handoff scheme is usually used.

3. *InterCS Handoff:* The InterCS handoff happens when a call is moved from cells(or groups) which are covered by a CS to cells/groups which are covered by the other CS.

4. *Group Handoff:* When groups are reorganized by dynamic group simulcasting, a cell which is located in a group can be transferred to the other group. In this case, all calls in that cell must be handoffed simultaneously to the target group. This type of handoff is named 'Group Handoff'.

This fiber-optic cellular system can be built based on both CDMA and TDMA methodology. Here, we consider a CDMA based system. In the CDMA based fiber-optic microcell/picocell cellular system, IS-95 soft handoff scheme is usually used in intergroup Handoff. But the use of soft handoff scheme wastes so many CEs and induces heavy signal traffic for handoff. So, the modified handoff scheme suitable to the fiber-optic cellular system is needed.

This paper is organized as follows. In Section II, we proposed a new intergroup handoff scheme exclusive to the fiber-optic cellular system. In Section III, we describe the system model and analyze the system performance in view of blocking probability and handoff refused probability. Also, we perform numerical analysis and discuss the results. Finally, we summarize our results and make conclusions.

II. PROPOSED SCHEME

In this section, we propose a new intergroup handoff scheme in the CDMA based fiber-optic microcell/picocell system. In the proposed scheme, a user continues to use his current channel even if a handoff occurs. This scheme uses the unique property of the fiber-optic cellular system such as central control of CE in the CS. In this system, a CS manages all channels of cells which are controlled by the CS. If a call occurs in a group, the CS allocates CE to the call. When the call is to be handoffed, the call sends a handoff request signal to the CS. When the CS receives the handoff request signal, it switches the occupied CE of the call from current group to target group. There is no difficulty to implement this switching behavior from the practical point of view. That is, the call is handoffed to target group with

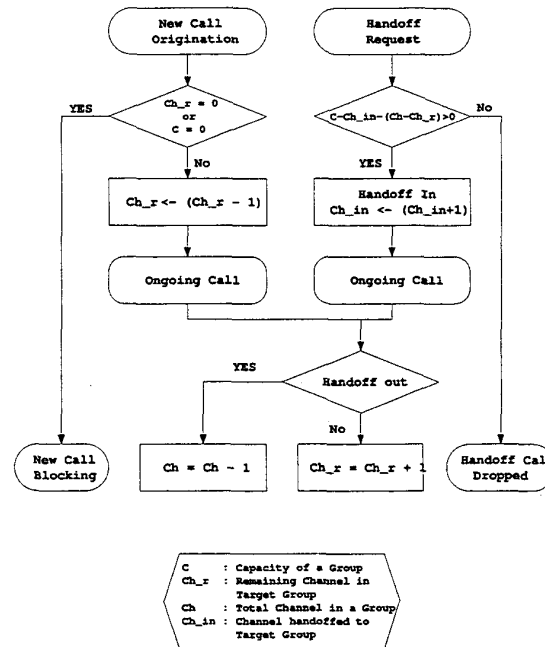keeping its occupied CE. This algorithm is shown in Fig. 1.

Figure 1: Proposed Handoff Algorithm

The proposed scheme has many advantages. First, this scheme makes the system serve more users using the same CE. Because there is no soft handoff, this scheme can save CE with providing QoS level similar to soft handoff scheme. This scheme also provides lower handoff refused probability than soft handoff scheme. In conventional soft handoff scheme, a handoff call is blocked in case that there is no CE in the target cell or group. But, in the proposed scheme, a call is handoffed to the target group with keeping its CE. So, there is no handoff call blocking if there is no interference limitation of capacity. Besides, the signal traffic for supporting handoff between radio port and CS can be diminished. The only signal traffic for supporting handoff is the handoff request signal from mobile to CS.

III. MODELING & ANALYSIS

We analyze the proposed scheme for two systems. One is the system with SDS and the other is the system without SDS. To perform numerical analysis, we define that the system consists of simulcast groups which are controlled by a CS. It is shown in Fig. 2. We consider that there are no queues and no reserved channel for handoff calls.
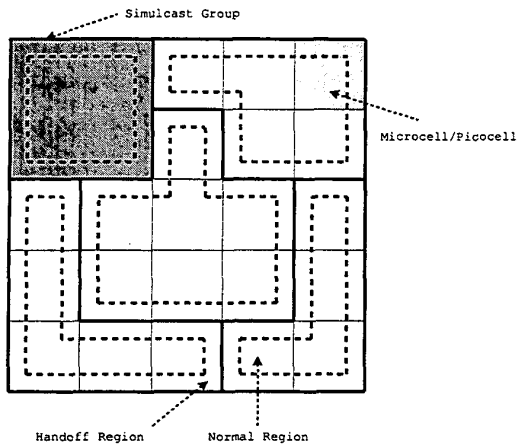
Figure 2: Description of system composed of 25 cells and 5 groups

The System with SDS

In this system, we assume that there is no interference limitation. The total allowable channel of the system is assumed to be C. The new call arrival rate in a group is assumed to be Poisson distribution with rates λ_n. Let the call duration time be T_c. We assume that T_c is exponentially distributed with mean μ_c^{-1}.

Using the birth-death process, we can derive the state transition diagram in view of total system which is shown in Fig. 3. The state of this process is defined as $S(i)$ and i means the number of calls in a system which is controlled by a CS. Let $P(i)$ be the steady-state probability. We define that total new call arrival rate in the system, λ_{tn} is $N \cdot \lambda_n$, where N is the number of group in the system.
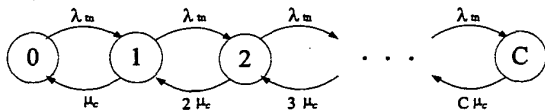

Figure 3: State-Transition Diagram of the SDS System

We evaluate the performance of proposed scheme in view of blocking probability and handoff refused probability. A new call is blocked when $i = C$, and the blocking probability in view of the total system is calculated from Erlang-B formula as

$$P_B = P(C) = \frac{(\frac{\lambda_{tn}}{\mu_c})^C / C!}{\sum_{x=0}^{C} (\frac{\lambda_{tn}}{\mu_c})^x / x!} . \qquad (1)$$

There is no handoff refused probability because we assume that there is no interference limitation in this system.

The System without SDS

In this system, we assume that there are C_h channels initially assigned to each group. Also, we assume that there is interference limited capacity, C in each group. The new call arrival rate in a group is assumed to be Poisson distribution with rates λ_n. Also, let the handoff call arrival rate from neighbor groups be λ_h. Let the call duration time be T_c. We assume that T_c is exponentially distributed with mean μ_c^{-1}. Let the cell dwell time be T_d which is exponentially distributed with mean μ_d^{-1}.

We can derive the state transition diagram in view of total system[4]. It is shown in Fig. 4. The state of this process is defined as $S(i, j, k)$,where i is the number of calls handoffed from neighbor cells, j is the number of calls originated in current cell, and k is the number of calls handoffed to neighbor cells.

There are eight sets of state-transition rate. Each of those is symbolized by character from A to H. These sets are shown in Fig. 4. We define the transition to right direction be X1 and the transition to left direction be X2 if the set of transition is X. Then, each state-transition rate sets are defined as follows:

- A1 : a new call is originated in current group

- A2 : a call in current group is ended

- B1 : a call in current group is ended

- B2 : a new call is originated in current group

- C1 : a handoffed call from neighboring group is coming

- C2 : a handoffed call from neighboring group is ended or handoffed to other group

- D1 : a handoffed call from neighboring group is ended or handoffed to other group

- D2 : a handoffed call from neighboring group is coming

- E1 : a handoffed call from current group is ended

- F2 : a handoffed call from current group is ended

- G1 : a call is handoffed to neighboring group

- G2 : a handoffed call from current group is moving back to current group

- H1 : a handoffed call from current group is moving back to current group

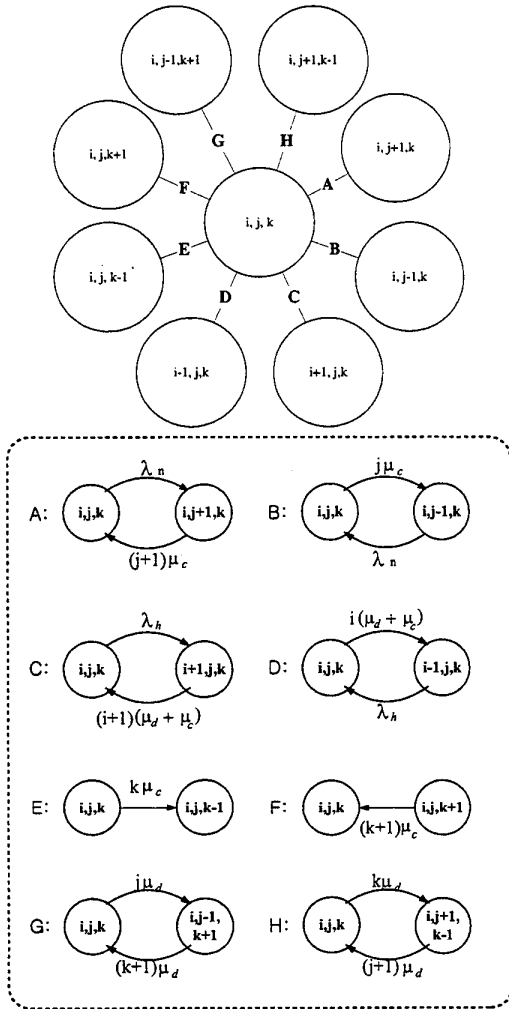Figure 4: State-Transition Diagram of the non-SDS System

- H2 : a call is handoffed to neighboring group

Let $P(i,j,k)$ be the steady-state probability of $S(i,j,k)$. In this model, we assume that if a handoff call is expired, the channel is returned to its original group. Then, we can calculate the handoff call from neighbor groups arrival rate, λ_h as

$$\lambda_h = \sum_{i=0}^{C-C_h}\sum_{j=0}^{C_h}\sum_{k=0}^{C_h-j} (i+j)\cdot\mu_d\cdot P(i,j,k)$$
$$+ \sum_{i=C-C_h+1}^{C}\sum_{j=0}^{C-i}\sum_{k=0}^{C_h-j} (i+j)\cdot\mu_d\cdot P(i,j,k) \quad (2)$$

We evaluate the performance of proposed scheme in view of blocking and handoff refused probability. A new call is blocked when all channels in the group are occupied or the interference limited capacity in the group is filled. This case occurs when $i+j = C$ or $j+k = C_h$. And the blocking probability is given by

$$P_B = \sum_{j=0}^{C_h}\sum_{k=0}^{C_h-j-1} p(i,j,k)|_{i=C-j}$$
$$+ \sum_{j=0}^{C_h}\sum_{i=0}^{C-j-1} p(i,j,k)|_{k=C_h-j} \quad . \quad (3)$$

A handoff call is dropped only when the interference limited capacity in the group becomes full, namely $i+j = C$. And the handoff refused probability is given by

$$P_{hr} = \sum_{j=0}^{C_h}\sum_{k=0}^{C_h-j} p(i,j,k)|_{i=C-j} \quad . \quad (4)$$

IV. NUMERICAL RESULTS

Based on analysis results, we can calculate the numerical examples for two systems such as the system with SDS and the system without SDS. In each system, we calculate the numerical results of the proposed channel keeping handoff scheme and the soft handoff scheme. We use computer programmed iterative approach described in [5] to obtain numerical results.

System with SDS

We investigate several numerical examples in case that $\mu_c = 0.01$ and $\mu_{dg} = 0.03$. We calculate the numerical result of soft handoff scheme based on the state transition diagram of [6]. In the soft handoff scheme, we assume that handoff region dwell time is exponentially distributed with mean of 10 sec and the ratio of handoff region in the system is 0.3.

We perform the comparison of soft handoff scheme and proposed channel keeping handoff scheme. In this comparison, we assume that the system consists of five groups. Each group has 20 CEs. So, the CS has 100 CEs in the fiber-optic radio system. Also, in the soft handoff scheme, we assume that $a = 0.3$ and Q has the value of 0 and 10. These results are shown in Fig. 5 and Fig. 6. From numerical results, we can see that the blocking and handoff refused probability of proposed scheme are lower than those of soft handoff scheme. A handoff call of the proposed scheme occupies only one channel even though that of soft handoff scheme occupies two channels. That's the

reason that the proposed scheme has good performance with respect to not only handoff refused probability but also blocking probability. In this system, the handoff refused probability of proposed scheme is shown to be zero because of the assumption that the system has no interference limitation.
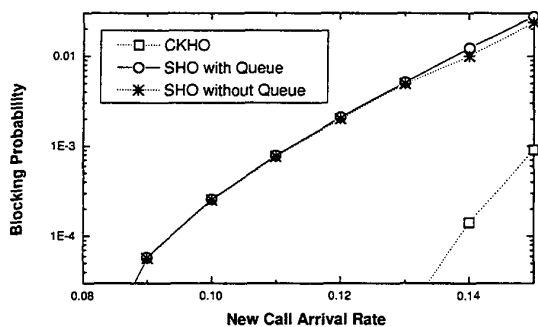

Figure 5: Comparison of Soft Handoff Scheme and Proposed Scheme in the SDS System: Blocking Probability vs. New Call Arrival Rate
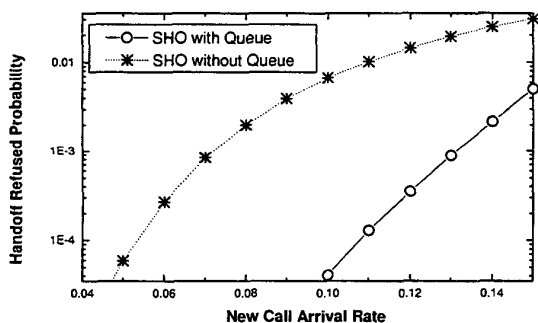

Figure 6: Comparison of Soft Handoff Scheme and Proposed Scheme in the SDS System: Handoff Refused Probability vs. New Call Arrival Rate

System without SDS

In this system, the analysis model of soft handoff is the same as ordinary cellular system. So, we calculate the numerical result based on the state transition diagram of [4].

We evaluate the performance of the proposed channel keeping handoff scheme in this system. We consider two conditions. First condition is that the total number of initially assigned channel, C_h is changed

when the interference limited capacity, C is fixed. In the second condition, we investigate numerical results with fixing the total number of initially assigned channel, C_h and varying the interference limited capacity, C. The results are shown in Fig. 7 through Fig. 10.

In the first condition, we analyze the blocking probability and handoff refused probability when $C = 30$. From Fig. 7, we can see that the bigger the value of C_h, the lower the blocking probability. On the other side, as C_h is bigger, the handoff refused probability become higher as shown in Fig. 8. This phenomenon occurs because the bigger C_h makes the more capacity for new call and this induces the smaller capacity for handoff call in the interference limited condition.
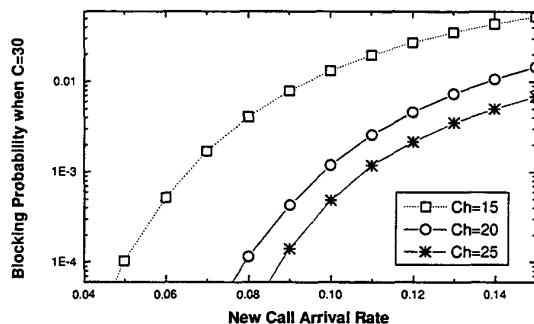

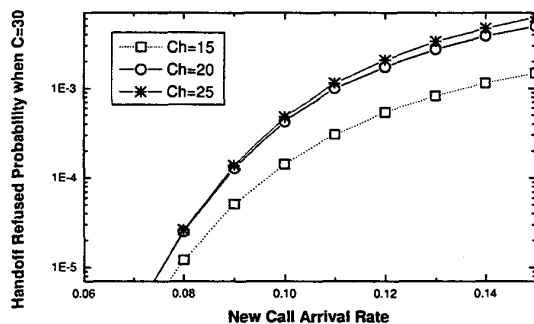Figure 7: Proposed Scheme in the non-SDS System: Blocking Probability vs. New Call Arrival Rate with varing Ch

Figure 8: Proposed Scheme in the non-SDS System: Handoff Refused Probability vs. New Call Arrival Rate with varing Ch

In these results, the handoff refused probabilities when C_h is 20 and 25 have little difference. But in the case of blocking probability, the difference is relatively great. This means that the smaller the gap between C_h and C, the more the performance improvements under the situation of fixed C.

To investigate the performance in the case that C is changed, we assume the condition that $C_h = 20$. In Fig. 9 and Fig. 10, we can see that the higher the value of C, the lower the blocking probability and the handoff refused probability. As the interference limited capacity is increased, the more handoff call from other cell can be serviced in this cell without disturbing new call arrival. So, both the blocking probability and the handoff refused probability have lower value.
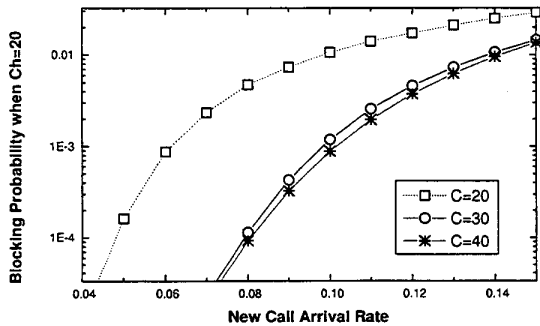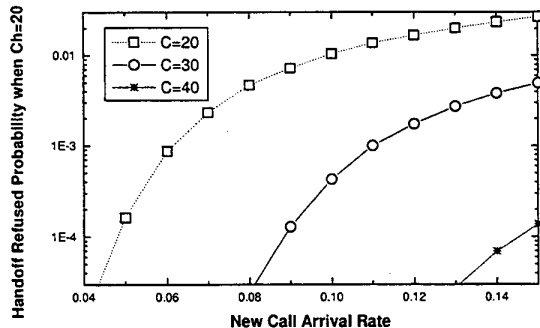
From these results, we can see that the blocking probability when $C = 30$ and $C = 40$ are alike, while the handoff refused probabilities of them have big difference. That's because C_h is fixed, and the total available offered load in this cell is limited.

We compare the numerical result of proposed scheme with that of soft handoff scheme. We investigate numerical example in the case of $\mu_c = 0.01$, $\mu_d = 0.03$, $C_h = 20$, and $C = 30$. The analysis condition of soft handoff scheme is the same as that of the system with SDS. The numerical results are shown in Fig. 11 and Fig. 12. In these figures, CKHO and SHO means the proposed channel keeping handoff scheme and soft handoff scheme, respectively. Numerical results show that the blocking and handoff refused probability of proposed scheme are lower than those of soft handoff scheme.
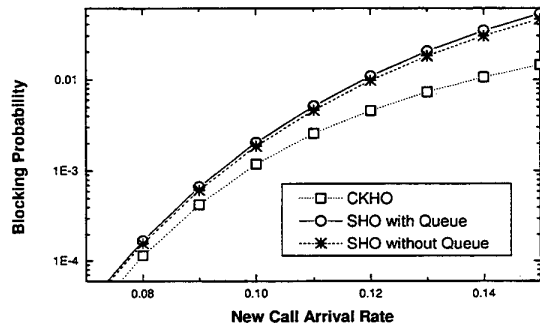

Figure 9: Proposed Scheme in the non-SDS System: Blocking Probability vs. New Call Arrival Rate with varing C

Figure 11: Comparison of Soft Handoff Scheme and Proposed Scheme in the non-SDS System: Blocking Probability vs. New Call Arrival Rate

Figure 10: Proposed Scheme in the non-SDS System: Handoff Refused Probability vs. New Call Arrival Rate with varing C
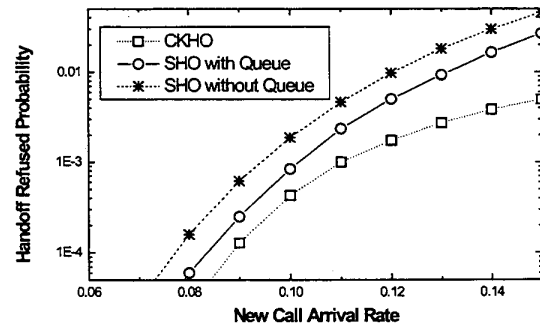

Figure 12: Comparison of Soft Handoff Scheme and Proposed Scheme in the non-SDS System: Handoff Refused Probability vs. New Call Arrival Rate

V. CONCLUSIONS

This paper proposed a new intergroup handoff scheme which is exclusive in fiber-optic cellular system. The proposed scheme has many advantages such as the increase of channel efficiency, the reduction of handoff refused probability, and the decrease of signal traffic for handoff. We analyzed the proposed scheme for two systems which are using SDS or not. Using the Markov chain, we performed system analysis in view of blocking probability and handoff refused probability. From numerical results, we can see that the proposed approach has better performance than conventional soft handoff scheme.

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