PERFORMANCE ANALYSIS OF HANDOFF ALGORITHM IN FIBER-OPTIC MICROCELL/PICOCELL RADIO SYSTEM

Young-uk Chung and Dong-Ho Cho

Communication and Information Systems Lab.
Department of Electrical Engineering
Korea Advanced Institute of Science and Technology (KAIST)
373-1 Kusong-Dong Yusong-Gu Taejon, Korea
TEL: +82-42-869-3467, FAX: +82-42-867-0550
e-mail: thatfox@comis.kaist.ac.kr, dhcho@ee.kaist.ac.kr

Abstract - The fiber-optic radio system was proposed to solve the cost problem of micro/picocell system. In this system, all channel elements in a system can be dynamically assigned when the SDS is used. In this paper, we analyzed the performance of soft handoff used as intergroup handoff in the CDMA based fiber-optic cellular system with SDS. Performance is evaluated in view of blocking and handoff refused probability. The numerical results show that the smaller the handoff region or the more the channel, the larger the system capacity. We can also see that the larger queue makes the handoff refused probability lower.

I. INTRODUCTION

IMT-2000 system would reduce cell size using a 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 stations and 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. 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 radio system, all Channel Elements (CE) and call processing hardwares are located in the CS. The CEs are allocated to calls dynamically using Spectrum Delivery Switch (SDS)[2]. The radio port (base station) just broadcasts and receives the radio signals and 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 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 algorithm 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 is covered by one CS to cells/groups which is 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 system can be built based on both CDMA and TDMA methodology. Here, we consider CDMA based system. In this paper, we analyze the performance of softhandoff algorithm which is used as the intergroup handoff in the CDMA based fiber-optic microcell/picocell radio system.

This paper is organized as follows. In Section II, we describe the system model with Intergroup softhandoff algorithm. In Section III, we analyze the system performance in view of blocking probability and handoff refused probability. In Section IV, we perform numerical analysis and discuss the results. Finally, we summarize our results and make conclusions.

## II. SYSTEM MODELING

The system environments considered in this paper is the fiber-optic microcell/picocell radio system. In this system, a CS manages all Channels of cells which is controlled by the CS. To perform numerical analysis, we make several definitions and assumptions.

First, we define that the system consists of simulcast groups which are controlled by a CS. In this paper, we use the soft handoff algorithm defined in IS-95 standard. We consider that there are queues for handoff calls and the maximum length of queue is assumed to be Q. And, we assume that there is no handoff arrival from the neighboring system. The total allowable channel of the system is assumed to be C. We also assume that there is no interference limitation in this system. We divide a group into two regions such as normal and handoff region as shown in Fig. 1. The normal region is surrounded by the handoff region.

Let the rate of the handoff region in a group be \( a \). Then, \( a \) is given by

\[
\frac{\text{area of handoff region}}{\text{area of a group}} = a
\]

Figure 1: Description of system composed of 25 cells and 5 groups

Any cell shape can be adopted in this analysis. But the rate of the handoff region and the normal region is dependent on cell shape.

The total new call arrival rate is assumed to be Poisson distribution with rates \( \lambda_n \). Let the new call arrival rates in normal region and handoff region of the total system be \( \lambda_{nn} \) and \( \lambda_{nh} \), respectively. Under the assumption that new call arrivals are uniformly distributed all over the system, \( \lambda_{nn} \) and \( \lambda_{nh} \) are found to be

\[
\lambda_{nn} = (1 - a) \cdot \lambda_n \tag{2}
\]

\[
\lambda_{nh} = a \cdot \lambda_n \tag{3}
\]

Let the call duration time be \( T_C \). We assume that \( T_C \) is exponentially distributed with mean \( \mu_C^{-1} \). Let the mean dwell time in the whole group, the mean normal region dwell time and the mean handoff region dwell time be \( T_{dg}, T_{dn}, \) and \( T_{dh} \) respectively. \( T_{dg}, T_{dn}, \) and \( T_{dh} \) are also assumed to be exponentially distributed with mean \( \mu_{dg}^{-1}, \mu_{dn}^{-1}, \) and \( \mu_{dh}^{-1} \), respectively. There are relations between the mean dwell time in the whole group and the mean dwell time in each region. And the related functions are described as follows[4].

\[
T_{dn} = 2^{\log_{10}(1-a)} \cdot T_{dg} \tag{4}
\]

\[
T_{dh} = 16^{\log_{10} a} \cdot T_{dg} \tag{5}
\]

## III. SYSTEM ANALYSIS

Using the birth-death process, we can derive the state transition diagram in view of total system[4]. The state of this process is defined as

\[
s = (i, j, k) \quad i, j, k \geq 0 \tag{6}
\]

where \( i \) is the number of calls in the handoff region of the total system, \( j \) is the number of calls in the normal
region of the total system, and \( k \) is the number of calls in the queue of the total system. Let the total number of occupied channels in state \( s \) be \( N(s) \). Because the call in the handoff region needs two channels from the total system's point of view, \( N(s) \) is given by \( N(s) = 2i + j + k \) and \( N(s) \leq C \).

We summarize state-transition rates as follows:

- \( \lambda_{mn} = (1-a) \cdot \lambda_n \): total new call arrival rate in the normal region
- \( \lambda_{mh} = a \cdot \lambda_n \): total new call arrival rate in the handoff region
- \( \mu_C \): total call completion rate
- \( \mu_{th} = \mu_{dn} \): region transition rate from normal region to handoff region
- \( \mu_{tn} = \mu_{dh} \): region transition rate from handoff region to normal region

One call in queue means that one channel is insufficient. The incoming event into queue happens when a call in normal region is handoffed but there is no remaining channel or when a new call is originated in handoff region but there remains only one channel. Because we assume that there is no handoff arrival from the neighboring system, a handoff does not occur if there is no call in normal region of system. And, the outgoing from queue occurs when a call in system or in queue is ended. When a call is moved from handoff region to normal region, it happens, too. It also occurs when a call in queue is out from handoff region and is dropped or when a call in queue returns to the normal region of its source group.

Figure 2: An Example of State-Transition Diagram when \( C=6 \)

Figure 3: Sets of State-Transition Rate

An example of state-transition diagram when \( C = 6 \) and \( Q = 6 \) is shown in Fig. 2. There are seven sets of state-transition rate. Each of those is symbolized by character from A to G. These sets are shown in Fig. 3. We define the transition to right direction be \( X_1 \) and the transition to left direction be \( X_2 \) if the set of transition is \( X \). Then, each state-transition rate sets are defined as follows:

- \( A1 \): a new call is originated in normal region
- \( A2 \): a call in normal region is ended
- \( B1 \): a new call is originated in handoff region
- \( B2 \): a call in handoff region is ended
- \( C1 \): a call in normal region is handoffed
- \( C2 \): a handoff call is entered in normal region
- \( D1 \): a call in normal region is ended
- \( E1 \): a new call is originated in handoff region
- \( E2 \): a call in queue is ended or dropped, or a call in handoff region is ended
- \( F1 \): a call in queue is ended or dropped, or a call in handoff region is ended
- \( G1 \): a call in normal region is handoffed
- \( G2 \): a handoff call is entered in normal region, or a handoff call in queue is returned to normal region of it's source group
Let the steady-state probability of the state \( s(i, j, k) \) be \( p(i, j, k) \). The total incoming rate of a state is equal to the total outgoing rate from the state and there is a flow equilibrium equation for each state. The sum of the steady-state probability is equal to 1. Using this condition, we can solve flow equilibrium equations and get steady-state probabilities. We use computer programmed iterative approach described in [5] to obtain the stationary state probabilities.

We evaluate the performance of soft handoff algorithm in fiber-optic cellular system in view of blocking probability and handoff refused probability. A new call is blocked when the total number of occupied channel is equal to \( C \), and the blocking probability in view of the total system is given by

\[
P_{Bn} = \sum_{B_n} p(i, j, k) \tag{7}
\]

where \( B_n = \{(i, j, k)|C = (2i + j + k)\} \)

We define that the handoff refused probability is the handoff call dropping probability. That means the condition when the queue is all occupied and a handoff request is refused forever. We do not include the condition that all channels are occupied when a call is handoffed. So, the handoff refused probability, \( P_{hr} \) is given by

\[
P_{hr} = \sum_{B_h} p(i, j, k) \tag{8}
\]

where \( B_h = \{(i, j, k)|C = (2i + j + k), k = Q, j > 0\} \)

IV. NUMERICAL RESULTS

We investigate several numerical examples in the case of \( \mu_c = 0.01 \), and \( \mu_{dg} = 0.03 \). To evaluate the performance of soft handoff in this system, we investigate numerical results with changing the channel capacity, \( C \), the fraction of handoff region in a group, \( a \), and the length of queue, \( Q \). The results are shown in Fig. 4 through Fig. 9.

We analyze the performance when \( C = 100 \) and \( Q = 10 \). From the results, we can see that the higher the value of \( a \), the higher the blocking probability and the handoff refused probability. Calls in the handoff region occupy two channels. So, the larger the handoff region, the more the number of calls which use two channels. This generates the effect diminishing available channels in the total system's point of view.

To detect the performance in the case that \( C \) is changed, we analyze in the condition of \( a = 0.3 \) and \( Q = 10 \). We could see that the higher the value of \( C \), the lower the blocking probability and the handoff refused probability. Because we assume that there is no interference limitation, a system can serve more users if there are more available channels.

The use of queue gives priority to handoff calls. If there is no remaining channel, new calls are blocked. But handoff calls are not dropped but are queued until there happens remaining channel. And, the more the number of handoff call in queue, the smaller the number of channel which can be allocated to new call. So, the longer the length of queue, the lower the handoff refused probability and the higher the blocking probability. To obtain results, We analyze the performance when \( C = 100 \) and \( a = 0.3 \). And we can confirm the thought from the results.

V. CONCLUSIONS

In this paper, we analyzed the performance of soft handoff algorithm in fiber-optic cellular system by...
using the Markov chain. We performed system analysis in view of blocking probability and handoff refused probability. We investigated numerical examples with changing the value of channel capacity, $C$, the fraction of handoff region in a group, $a$, and the maximum length of queue, $Q$.

From numerical results, we found that the higher the value of $a$, the higher the blocking probability and the handoff refused probability. And, we could see that the higher the value of $C$, the lower the blocking probability and the handoff refused probability. Also, the longer the queue length, $Q$, the the lower the handoff refused probability.

REFERENCES


