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무선 이동통신의 핸드오프에 대한 성능분석

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Performance Analysis of Handoff in Mobile Cellular Networks

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요 약

이 논문에서는 한 셀 안에 고정된 수의 채널을 핸드오프에 할당하고 처리되지 못한 핸드오프 통화를 큐에 대기시키는 방법을 고려하였다. 기존의 연구가 핸드오프의 입력프로세스를 프아송 프로세스로 하여 분석한 것에 비해 본 논문은 입력 프로세스를 MMPP로 가정하여 분석하였다. 수치해법을 이용해 전이행렬의 극한분포를 구했으며 성능분석의 척도로 new call blocking probability와 forced termination probability를 사용하여 핸드오프 입력프로세스를 프아송 프로세스로 한 모델과 비 교 분석하였다.

ABSTRACT

A traffic model and analysis for cellular mobile radio telephone system with handoff are described. We consider fixed channel assignment. Our channel assignment scheme also employs the queueing of handoff attempt. In this paper, we assume the handoff call attempt to be a two-state MMPP to consider the arrival of handoff call varing according to the change of environment of neighboring cell. In a simulation study, we obtain the steady-state probability and performance measures such as the new call blocking probability and the forced termination probability. These performance measures of the MMPP handoff call attempts are compared with those of the Poisson handoff call attempts.

I. Introduction

Future wireless network will provide communication services to a large number of mobile users everywhere. The cellular architecture consists of fixed base stations interconnected through a fixed network(usually wired), and of mobile units that communicate with base station via wireless links. The mobile unit communicate with each other, as well as with other networks, through the base station and network. A set of channels is allocated to each base station. Many dynamic channel allocation schemes have been proposed. These schemes may improve the performance of the cellular networks. However, for practical reasons, the channel allocation is usually done in a static way. In this work, we will consider only fixed(static) channel assignment.

When a mobile user wants to communicate with another user or base station, it must first obtain a channel from one of the base station that hears it. If a channel is available, it is assigned to the user. In the case all the channels are busy, the new call is blocked. This kind of blocking is called new call blocking. The user releases the channel under either of the following scenarios: 1)the user completes the call, 2)the user moves to another cell before call is completed. The procedure of moving from one cell to another, while a call is in progress, is called handoff. While

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performing handoff, the mobile unit requires that the base station in the cell, that it moves into will allocate it a channel. If no channel is available in the new cell, the handoff call is blocked. This kind of blocking is called handoff call blocking due to the mobility of the users. For convenience in subsequent discussion, we define the cell into which the mobile is moving and desires a handoff as the *target* cell for the handoff. Furthermore, we call the cell which the mobile is leaving, the *source* cell of the handoff at- tempt.

In section 2, we will introduce the analytic models in Hong and Rappaport(1986) to investigate effects of unsuccessful handoff attempt and forced termination of call attempt and to examine the relationships between performance characteristics and system parameters. This model and performance measures are now used in dynamic channel allocation technique as well as in that of fixed channel allocation. In section 3, we assume the handoff call attempt to be a MMPP. The MMPP assumption of handoff call attempt make the transition diagram complicated compared with Poisson assumption. Heffes and Lucantoni(1986) and Meier-Hellstern(1987) suggest the methods for the approximation of arrival processes to the two-state MMPP. In this section, we get the generator of our model. In section 4, we have a numerical study of the proposed handoff procedure. The blocking probability P_B of new call attempts as well as the probability of forced termination P_F of nonblocked calls are considered as functions of the number of handoff channels. And the performance measure of the MMPP handoff call attempt is compared with the model that simplifies the handoff call attempt as Poisson distribution.

II. Channel Assignment Scheme of Hong and Rappaport

2.1 Traffic Model

We denote the average number of new call originations per second per unit area as λ_a. Then

$$\lambda_R = \frac{3\sqrt{3}}{2} R^2 \lambda_a . \quad (1)$$

Where, R is the cell radius for a hexagonal cell is defined as the maximum distance from the center of a cell to the cell boundary and λ_R is the average new call origination rate per cell. Additionally, handoff attempt are made with an average handoff attempt rate per cell denoted λ_{Rh}.

The channel holding time T_H in a cell is defined as the time duration between the instant that the channel is occupied by a call and the instant it is released by either completion of the call or cell boundary crossing by the mobile. We let the random variables T_M denote the unecumbered message duration, that is, the time an assigned channel would be held if no handoff is required. And we define the random variables T_n as the time for which a mobile resides in the cell from which the call is originated. The distribution of T_n is affected by the maximum speed of a mobile $V_{\max}$. Random variable T_M and T_n are used for the calculation of P_N in the section 2.2. In the paper of Hong and Rappaport[2], T_H and T_N are assumed to be exponentially distributed with means $1/\mu_H$ and $1/\mu_M$ respectively.

The probability that a new call does not enter service because of unavailability of channels is called the blocking probability P_B. We denote the probability that a new call which is not blocked is ultimately forced into termination by P_F. To calculate P_F, it is convenient to define another probability P_{fh}. This denotes the probability that the given handoff attempt fails. It represents the average fraction of handoff attempts which are unsuccessful.

2.2 Channel Assignment Schemes

Priority is given to handoff attempts by assigning C_h channels for handoff calls among the C channels in a cell. The remaining $C-C_h$ channels are shared both new calls and handoff calls. And queueing of handoff attempt is allowed. But no queueing of new call attempt is allowed.

If the received power level from the base station of the source cell falls below the receiver threshold level before the mobile being assigned a channel in the target cell, the call is forced into termination. When a channel is released in the cell, it is assigned to the next handoff call attempt waiting in the queue (if any). If more than one handoff call attempt is in the queue, the first-come-first-served queueing discipline is used. Let T_Q be the time for which a mobile is in the handoff area. For simplicity of analysis, we assume that T_Q is exponentially distributed with mean $1/\mu_Q$.

We define the random variable X as the elapsed time from the instant that a handoff attempt joins the queue to the first instant that a channel is released in the fully occupied target cell. For the state number less than C, X is equal to zero. Succinctly, X is the minimum remaining holding time of those calls in progress in the fully occupied target cell. So, X is exponentially distributed with mean $1/\mu_H$.

We define the random variable T_i, to be the remaining dwell time of the attempt which is in the i^{th} queue position when another handoff attempt joins the queue. Under the memoryless property, distributions of all T_i and T_Q are identical.

Let P_j be the steady-state probability that the system number is j. Then the probability of blocking P_B is as follows.

$$P_B = \sum_{j=C-C_h}^{\infty} P_j \tag{2}$$

And the probability of a handoff attempt failure P_{fh} is as follows.

$$P_{fh} = \sum_{k=0}^{\infty} P_{C+k} P_r \text{ \{Handoff attempt fails given it enters the queue in position } k+1\} \tag{3}$$

If we define $P_{fh|k}$ as the rightmost term in this equation, then the following equation holds.

$$(1 - P_{fh|k}) = [\ \textstyle\prod_{i=1}^{k} P(i|i+1)] \cdot \Pr \text{ \{get channel in first position\}} \tag{4}$$

in which $P(i\,|\,i+1)$ represents the probability that the attempt in position $i+1$ moves to position i before its mobile leaves the handoff area. Then the following holds.

$$1 - P(i|i+1) = \Pr(T_{i+1} \le X,\ T_{i+1} \le T_1, \cdots, T_{i+1} \le T_i) = \frac{\mu_Q}{C_{\mu H} + (i+1)\mu_Q}, \quad \text{for } i = 1, 2, \cdots. \tag{5}$$

And,

Pr {get channel in the first position}

$$= \Pr\{T_1 > X\} = \frac{C_{\mu H}}{C_{\mu H} + \mu_Q} \tag{6}$$

And the probability P_F that a call which is not blocked is eventually forced into termination is as follows.

$$P_F = \sum_{l=1}^{\infty} P_{fh}(P_{N(1-P_{fh})})^{l-1} P_H{}^{l-1}) = \frac{P_{fh} P_N}{1 - P_H(1 - P_{fh})} \tag{7}$$

where, P_N is the probability that a new call which is not blocked will require at least one handoff before termination and P_H is the probability that a call which has already been handed off successfully will require another handoff before completion. For details, see the papers of Hong and Rappaport[2].

III. MMPP Handoff Call Attempt

In the paper of Hong and Rappaport[2], the handoff attempt is assumed to be a Poisson process. But this kind of assumption is not suitable for the situation that the arrival of handoff call varies according to the change of environment of neighboring cells. So we assume the arrival process of handoff call to be a two-state MMPP which is a doubly stochastic process.

3.1 Two State MMPP

In this subsection, we introduce a Markov Modulated Poisson Process(MMPP). Markov Modulated Pro-

Fig. 1 Two-state MMPP

cess, also called doubly stochastic process, uses an auxiliary Markov process in which the current state of Markov process controls(modulates) the probability distribution of the traffic. MMPP is suitable for the situations where the call attempts have burstness and correlation.

For a given state space $S=\{s_1, s_2, \cdots, s_M\}$, MMPP uses Poisson process as the modulated mechanism. In this model, while in state s_i, the arrivals occur according to a Poisson process with rate λ_i. In many cases, two-state MMPP is assumed for the simplicity.

We have a two-state continuous-time Markov chain where the mean duration times of the states 1 and 2 are $1/r_1$ and $1/r_2$, respectively. When the chain is in state $j(j=1,2)$, the arrival process is a Poisson process with rate λ_j. Then the row vector of equilibrium probabilities for the state of the MMPP is

$$\pi=[\pi_1, \pi_2]=\frac{1}{r_1+r_2}[r_2, r_1],$$

and the mean arrival rate λ_{Rh} is as follows.

$$\lambda_{Rh}=\lambda_1\pi_1+\lambda_2\pi_2=\frac{\lambda_1 r_2+\lambda_2 r_1}{r_1+r_2} \quad (8)$$

3.2 Generator of MMPP Handoff Call Attempt

In this work, two states of MMPP are defined as loose state and dense state according to the quantity of users in neighboring cells. So we have a two-state continuous time Markov chain where the rates of loose state and dense state are r_1 and r_2, respectively. The arrival process is a Poisson process with rate λ_{h1}, when the chain is in loose state and with rate λ_{h2} when the chain is in dense state. And new call attempts are assumed to be generated according to a Poisson process with rate λ_R.

Let $N(t)$ be the sum of the number of channels being used in the cell and the number of handoff attempts in the queue at time t. Then the generator G of $N(t)$ is as follows.

$$G=\begin{bmatrix} A_0 & U_0 & 0 & 0 & 0 & 0 & \cdot & \cdots \\ D_1 & A_1 & U_1 & 0 & 0 & 0 & \cdot & \cdots \\ 0 & D_2 & A_2 & U_2 & 0 & 0 & \cdot & \cdots \\ 0 & 0 & D_3 & A_3 & U_3 & 0 & \cdot & \cdots \\ 0 & 0 & 0 & D_4 & A_4 & U_4 & \cdot & \cdots \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdots \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdots \end{bmatrix} \quad (9)$$

where,

$$A_0=A-\Lambda_1$$

$$A_i=\begin{cases} A-\Lambda_1-iM_1, & \text{where } 1\le i=C-C_h-1 \\ A-\Lambda_2-iM_1, & \text{where } C-C_h\le i\le C \\ A-\Lambda_2-iM_2, & \text{where } i\ge C+1 \end{cases}$$

$$U_i=\begin{cases} \Lambda_1, & \text{where } 1\le i=C-C_h-1 \\ \Lambda_2, & \text{where } C-C_h\le i\le C \end{cases}$$

$$D_i=\begin{cases} iM_1, & \text{where } 1\le i=C \\ iM_2, & \text{where } i\ge C+1 \end{cases}$$

and

$$A=\begin{bmatrix} -r_1 & r_1 \\ r_2 & -r_2 \end{bmatrix},$$

$$\Lambda_1=\begin{bmatrix} \lambda_{h1}+\lambda_R & 0 \\ 0 & \lambda_{h2}+\lambda_R \end{bmatrix},$$

$$\Lambda_2=\begin{bmatrix} \lambda_{h1} & 0 \\ 0 & \lambda_{h2} \end{bmatrix},$$

$$iM_1=\begin{bmatrix} i\mu_H & 0 \\ 0 & i\mu_H \end{bmatrix},$$

$$iM_2=\begin{bmatrix} C_{\mu H}+(i-C)\mu_Q & 0 \\ 0 & C_{\mu H}+(i-C)\mu_Q \end{bmatrix}$$

We should compute the steady state probability $P = (P_0, P_1, \cdots, P_C, P_{C+1}, \cdots)$ of G, which satisfies $PG = 0$ and $Pe = 1$ to calculate many performance characteristics such as the probability of forced termination and handoff blocking probability by the steady state probability.

There are several computational methods for steady-state analysis. For an infinite quasi-birth-death(QBD) process without level-dependent transition, the steady state solution is of the so-called matrix geometric form. And for an finite level dependent transition QBD process, the folding algorithm can be used. The generator G in (9), however, has infinite level-dependent transition. So there are no direct way to get the steady-state probability P. In the next section, we will get the steady-state probability P and performance characteristics through simulation.

IV. Numerical Study

In this section, we get the steady-state probability P of G with numerical method and we get the values of performance measures of the models with Poisson handoff call attempts and MMPP respectively by simulation. The numerical results obtained for our model are discussed here. The average of an uncumbered message duration $1/\mu_M = 120s$ and the maximum speed of a mobile $V_{max} = 60mi/h$ are used for the calculation. A call origination rate per unit area, λ_a, is 0.01 *call/sec/mi*^{2}. A total of 20 channels per cell $(C = 20)$ with two handoff channels per cell $(C_h = 2)$ with cell radius $R = 2mi$ is assumed. And the mean dwell time for a handoff attempt $1/\mu_Q$ is assumed to be $1/10\mu_H$. We let the ratio of $\lambda_{h1} : \lambda_{h2}$ to be $1:2$. We simulate for two cases, in the first case we let $(\gamma_1, \gamma_2) =$ (0.01, 0.02) and in the second one $(\gamma_1, \gamma_2) =$ (0.01,0.03). In the second case, The dwell time of dense state is longer than that of the first.

We compute the values of the newcall blocking probability and the forced termination probability with varing ratios $\gamma_0 = \lambda_{Rh}/\lambda_R$. In the model with Poisson handoff call attempts, the mean arrival rate of the MMPP is used for the rate of the handoff call attempts.

As shown in Figure 2, 3, 4, 5, when the γ_0 is small, the newcall blocking probability and forced termination probability of the model with MMPP handoff call attempts are larger than those of the model with Poisson handoff call attempts with rate λ_{Rh}. This is due to the fact that we let the rate of the Poisson handoff call attempts to be the mean arrival rate of the MMPP. The model in which the handoff call attempts is assumed to be the Poisson process cannot consider the effect of the dense state of MMPP. When γ_0 is small, i.e. the average rate of loose state and dense state is small, the blocking of calls always ari-

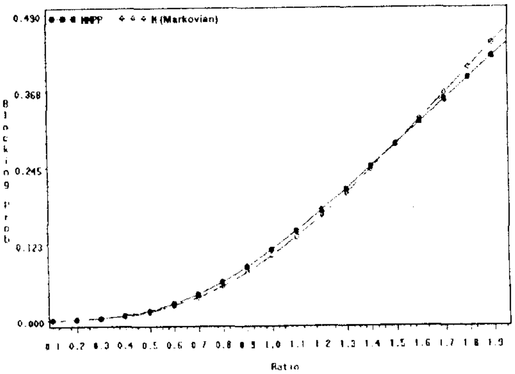

Fig. 2 P_B, $(\gamma_1, \gamma_2) = (0.01, 0.02)$ and $\lambda_{h1} : \lambda_{h2} = 1:2$

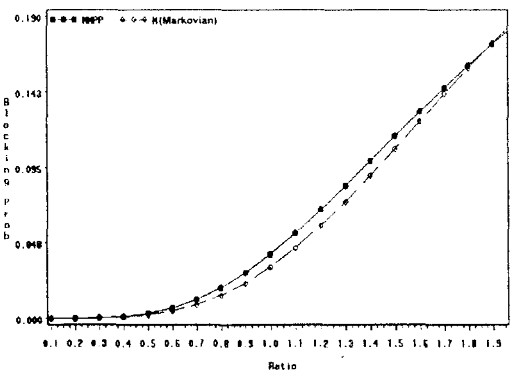

Fig. 3 P_F, $(\gamma_1, \gamma_2) = (0.01, 0.02)$ and $\lambda_{h1} : \lambda_{h2} = 1:2$

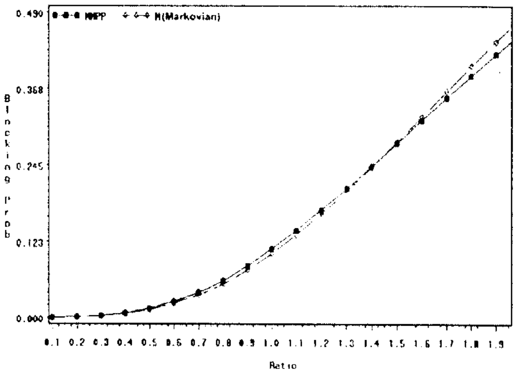

Fig. 4 P_B, $(\gamma_1, \gamma_2) = (0.01, 0.03)$ and $\lambda_{h1} : \lambda_{h2} = 1:2$

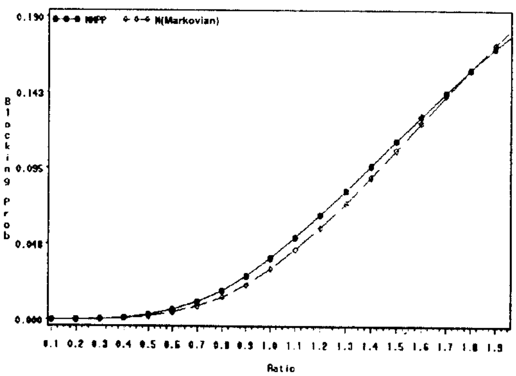

Fig. 5 P_F, $(\gamma_1, \gamma_2) = (0.01, 0.03)$ and $\lambda_{h1} : \lambda_{h2} = 1:2$

ses with low probability in the model with Poisson handoff call attempts. However, in the model with MMPP handoff call attempts, the blocking of calls arises with high probability while the state of handoff call attempts is in the dense state. As the ratio increases, performance measures of the model with Poisson handoff call attempts are larger than those of the model with MMPP. We can explain this fact with the loose state in the similar way.

In real situations, handoff call attempts have rates varying over time and have burstness and correlations. So MMPP is more suitable for a real process. In conclusion, analyzing the cell in which the mean rate of handoff call attempts is smaller than that of new call attempts, with the model with Poisson handoff call attempts tends to underestimate the performance measures in these simulations. The ratio at which the blocking probabilities of the model with Poisson handoff call attempts become greater than those of the Model with MMPP, decreases as the ratio of the mean duration time in the dense state to that in the loose state increases for fixed rate of λ_{h1} and λ_{h2}.

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