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ANALYTIC MODELING FOR SOFT HANDOFF IN CDMA BASED WIRELESS CELLULAR NETWORK USING GUARD CHANNEL ASSIGNMENT SCHEME

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Abstract

In Cellular networks, blocking occurs when a base station has no free channel to allocate to a mobile user. Handoff is the process of changing the channel associated with the current mobile user while a call is in progress. If free channel not available in moving cell, then progressive call is blocked. To reduce handoff blocking probability handoff prioritization Scheme using guard channels has been applied in CDMA network. The main goal of this research paper is to investigate the handover research issues and developing schemes which can handle handovers traffic in order to support on-going calls when mobile users are switching between base stations. Finite buffering queueing model has been developed with Poisson arrival process to analyze the soft handoff problem in CDMA system. Here the reneging behavior of queued handoff calls is also considered and different performance measures have been developed.

Keywords:

CDMA;
Soft Handoff;
Base station;
Overlap region;
Guard Channel.

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1 Introduction

Mobility in cellular network is the most important feature. Continuous service can be achieved by using handoff (or handover) procedure from one cell to another. Handoff is the process of changing the channel (time slot, frequency, spreading code, or combination of them) associated with the current mobile user while a call is in progress. It is frequently initiated either by crossing a cell boundary or by deterioration in quality of the signal in the present channel. Handoff is divided into two categories: hard handoff and soft handoff. They are also characterized by "break before make" and "make before break." In hard handoffs, current resources are released before new resources are used but in soft handoffs, both existing and new resources are used during the handoff process. Poorly designed handoff schemes tend to generate very heavy signaling traffic and, thereby, a dramatic decrease in quality of service. Handoff occurs when a call has to be handed off from one cell to another as the mobile user moves between cells. In a traditional "hard" handoff, the connection to the current cell is broken, and then the connection to the new cell is made. This is known as a “break-before make" handoff. Since all cells in CDMA use the same frequency, it is possible to make the connection to the new cell before leaving the current cell. This is known as a "make-before-break" or "soft" handoff. Soft handoff requires less power, which reduces interference and increases capacity. The implementation of handoff is different between the narrow band and the CDMA standards. This is an effort to analyze a soft handoff strategy, taking into consideration the trade-offs between selecting system parameters and the performance benefits. We consider a scenario involving two base stations and a single mobile, where the changes in the pilot signal strength are tracked and a conditional decision is made allowing communication with only one base station. This results as an outcome of simple measurements, which determine the strongest signal and results in handover to the corresponding base station. In a CDMA system the same frequency band is shared between all the cells. Thus there is well defined efficient bandwidth utilization. Though there is frequency reuse the orthogonal nature of the waveforms serves to distinguish between the signals that occupy the same frequency band. A typical handoff scenario is taken into account wherein the need for a mobile to alter its frequency or rather to switch its carrier frequency is negated. The main idea of a soft handoff scheme is to ensure that there is connectivity with the old base station while the new base station has been assigned to take control over the communication link. This way at a given instant of time the mobile maintaining a constant communication link with at least one base station simultaneously ensuring a non disrupted call activity.

Cellular communication system requires handoff to provide seamless service for mobile users, moving from one cell to other cell in mobile network. Code division multiple access has received a great deal of attention as a multiple access method for future mobile networks. Its main advantages are higher radios capacity and the capability of flexible data transmission. Lee [1]-[2] presented his overview on mobile communication system and explained different term and future related to mobile communication system and also provided general description of code division multiple access (CDMA) system. Gilhousen et al. [3] discussed on code division techniques for multiple access and developed personal handy phone system. Jabbari et. al.[4] proposed a system for personal mobile communication using hard handoff. Khan et al. [5] discussed linear and exponential back off techniques for the uplink common channel packet transmission in wide band CDMA for Poisson arrival process. Greenberg et al. [6] proposed a scheme how to assign distinct number of code channels to each traffic class. Kim and Sung [7] gave different analytical schemes for handoff analysis based on hard handoff in mobile communication system. They also developed an analytical model for soft handoff in CDMA systems by introducing the concept of an overlapping region between adjacent cells and the handoff call attempt rate and the channel holding times are derived. Applying these results to a non-prioritized CDMA system, the effects of soft handoff and the mean cell residual time are also investigated. Lee et al. [8]-[9] analyzed performance of channel borrowing handoff scheme based on user mobility in CDMA cellular system and also studied the soft-handoff mechanism and compares its performance with the hard handoff.

Trivedi et al. [11] have presented the CTMC, MRM and SRN models for performability study of a variety of wireless systems. They also calculated and analyzed different call blocking probability for wireless systems and wireless cellular systems. Xiaomin et al.[12] investigated a new soft handoff scheme for CDMA cellular systems. They proposed a scheme which frequently measures and estimates the relative mobility of new handoff calls. When all channels in a cell are occupied, the non controlling channel of a handoff call in CCS is converted to a new real handoff call. This scheme does not increase interference to other users and does not degrade the quality of the soft handoff process. Xiaomin et al. [13] investigated the features of a cellular geometry in code-division multiple-access (CDMA) systems with soft handoff and distinguishes controlling area of a cell from coverage area of a cell. Some important characteristics of the cellular configuration in soft handoff systems are used to propose a new design of efficient call admission control (CAC) in CDMA systems. Ali and Pierre [14] presented a novel analytical model in order to evaluate the new call blocking probability and the call dropping probability of the optimal voice admission control algorithm redefined in loosely coupled 3G/WLAN networks.

Awasthi [15] developed directed retry scheme for cellular radio system having both type of traffic voice and data. He found that the directed retry scheme play an important role to reduce blocking probability of handoff calls. Nisha et al. [16] studied the efficient channel allocation and handoff strategies to guarantee continuous service with good Qos (Quality of service) to mobile multimedia users. They also discussed on handoff protocols, handoff management issues and handoff decisions. Awasthi [17] analyzed hand-off performance in personal communication system using splitted rating channel technique. He observed that from the simulation results that the blocking probabilities of handoff calls can be reduced by using splitted rating channel and directed retry schemes.

Elmadina et al. [18] proposed an optimal algorithm for automatic controlling and adapting Global System for Mobile Communication (GSM) power system for handoff. They found that the use of this technique reduce the handoff blocking probability. Kesavan and Palani [19] presented a semi analytical model to study the performance degradation of soft and hard handoff schemes in a downlink CDMA system due to delay in the completion of handoff decisions. A simulation comparison of the handover traffic channel assignment schemes was done by Adewale et al. [20]. Gohil et al. [21] analyzed the performance of handoff algorithm that use a fixed value of RSS threshold of initiates the handoff process. The concept of overlap region between adjacent cells and develop an analytical model for hard handoff in CDMA system introduced by Awasthi [22]. He also discussed the balking and reneging behaviors of calls and found that the blocking probabilities are decreased as number of channels in a cell or service rate increases.

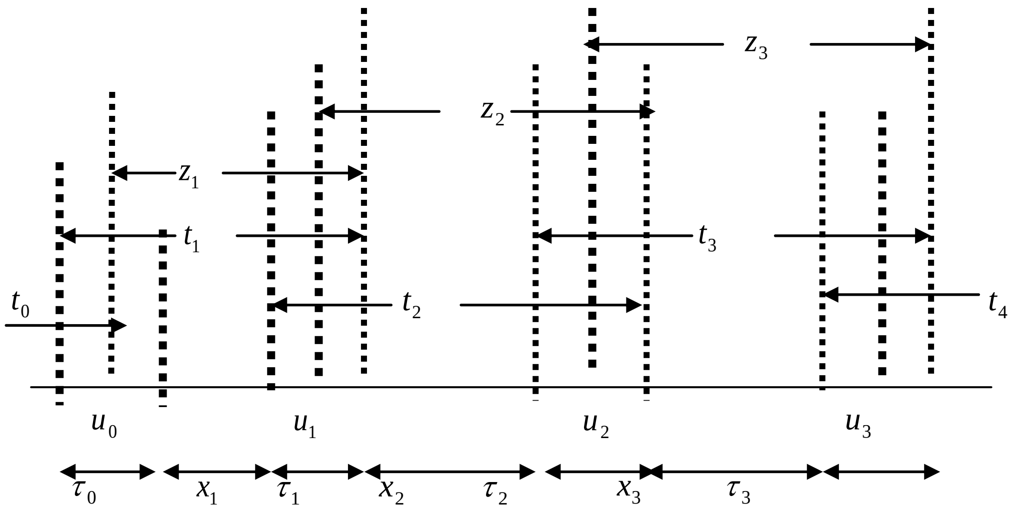
In this paper, we have developed the mathematical model for soft handoffs in CDMA system to analyze the problem of handoff in cellular radio system. In this model, the reneging behavior of queued handoff calls in finite buffering is also considered. Different performance measures like blocking probability of new calls, call incompletion probability, blocking probability of handoff calls etc. have been developed.

2 The Soft Handoff Model

The following assumptions are used in this model:

- The call arrival to/from a handset is following a Poisson process. The new call arrival rate to a cell is λ_n and the handoff call arrival rate is λ_h.
- The mobile residence time z_i in a cell i has an exponential distribution with the density function given by $f_m(z_i) = \theta e^{-\theta z_i}$ (1)
- p_n = New call blocking probability
- p_h = Probability that a handoff call is blocked because no free channel in the is available probability
- t_{nrt} = be the network response time and is exponentially distributed with mean β_1
- The reneging of calls according to exponential distribution with parameter ν.
- The call holding time tc is exponentially distributed with the mean $1/\mu$
- C= No of channels allocated to each cell
- C_h = Number of guard channels reserved for handoff calls in each cell

- p_f = forced termination probability or the probability that a handoff call is blocked because no channel is available
- p_{nc} = call in compilation probability
- α_s = The probability that a soft handoff call is blocked because the network response time is too long.
- π_i = the steady state probability that there is i customer in the system at any arbitrary point of time.



(Figure 1: The time division diagram for Soft handoff model)

For the demonstration purpose, we assume that a mobile handset can connect up to two radio links in a CDMA system. Figure 1 illustrates the timing diagram for the soft handoff model. The notations t_i, τ_i and x_i represent the time that a handset can receive the signal from cell i, time that the handset stay in the overlapping area (or overlay time) and the time that the handset stays in the non overlapping area of cell i respectively. Let z_i be the residence time of the handset at cell. In soft handoff, a communicating handset at cell i utilize one channel during the non-overlapping period x_i and is looking for a second radio link is found at time u_i, then the channel occupancy time of the handset at cell i+1 is the minimum of z_{i+1} and the remaining call holding time. Assume that t_i is exponentially distributed, then by the memory less property, z_i has also the same distribution as t_i i.e. it exponentially distributed with mean

$$\frac{1}{u} = \frac{1}{\eta} + \frac{1}{\gamma} + \frac{1}{\gamma} = \frac{(\gamma + 2\eta)}{\gamma\eta} \tag{2}$$

For fixed period of time, the number of calls visited by a mobile user is independent of the handoff schemes and the moving rate of a mobile user in soft handoff is θ.

$$\frac{1}{\theta} = \frac{1}{\eta} + \frac{1}{\gamma} = \frac{(\eta + \gamma)}{\eta\gamma} \tag{3}$$

Let α_s be the probability that a soft handoff call is blocked because the network response time is too long. In soft handoff scheme, probability of blocking a handoff call due to no radio channel is

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available is less than the blocking probability of new call. In soft handoff blocking probability of handoff calls due to no radio channel is available is less than new call blocking probability i.e. $p_h \prec p_n$.

The probability that a handoff call is blocked because no radio channel is available or due to the network response time is too long is given by

$$p_f = 1-(1-\alpha_s)(1-p_h) \tag{4}$$

The handoff calls arrival rate in a cell is given by

$$\lambda_h = \frac{\theta(1-p_n)\lambda_n}{\mu+\theta[1-(1-\alpha_s)(1-p_h)]} \tag{5}$$

The call incompletion probability is derived as

$$p_{nc} = p_n + \frac{\theta(1-p_n)[1-(1-\alpha_s)(1-p_h)]}{\mu+\theta[1-(1-\alpha_s)(1-p_h)]} \tag{6}$$

3 Mathematical Analysis

The queueing model dealing with soft handoff scheme for a cellular radio system with finite buffering of handoff calls has been developed. There is C channels available in each cell of the cellular radio system of which C_h are assigned to handle handoff calls in each cell. The handoff scheme has been modeled using M/M/C/K finite buffering model. The channel time of a call in a cell is the minimum of the remaining call holding time and the remaining cell residence time. The channel occupancy time is exponentially distributed with rate $(\mu+\theta)$. The net traffic to the system is $(\lambda_n+\lambda_h)$. In this system two types of calls are arrive 1) new calls and 2) handoff calls. The balking behaviors of calls are also considered. We assume that a handset can connect up to two radio links in a CDMA system.

To compute p_n and p_h, the soft handoff scheme has been modeled using Markov process with state S(n), where n$\geq$0 represents the number of busy channels in queueing system. Transition rate diagram of Markov Process has been given in figure 2. When the process is in state S(n) for 0$\leq$n$\prec$C, n channels are busy. The effective call traffic to a cell at the state S(n) is $(\lambda_n+\lambda_h)$ and the process moves from states S(n) to S(n+1) with this rate. Since a busy channel is released with the rate($\mu+w$) and the process moves from state S(n) to S(n-1) for 0$\prec$n$\leq$C with the rate n($\mu+w$). When the process is in state S(C+j) where j $\geq$0, all the channels are busy and j handoff calls are looking for the second links. When a call arrives at state S(C+j), then call is dropped if it is a new call. On the other hand, if the call is a handoff call, then it is trying to connect to the second link before it leaves the overlay area during this a call may be walk from the system. Thus the process moves from state S(C+j) to state S(C+j+1) with rate λ_h for j$\geq$0. Since all channels are busy, the first completion among the C connected calls releases its channel with rate γ . For those j handoff calls that look for the second links, before the second links are available, the calls may leave the system in three cases:

(1) The handset leaves the overlapping area with rate γ and is forced terminated.

(2) The call is completed with rate μ .

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(3) The call may be reneged with rate ν .

Thus the first such call leaves the system with the rate $j(\mu+\gamma+\nu)$ and the process moves from the state S(C+j) to state S(C+j+1) with rate $\left[C(\mu+w)+j(\mu+\gamma+\nu)\right]$ for j $\succ$ 0.

Let π_i be the steady state probability for S(i). Then

$$\pi_i = \begin{cases} \dfrac{(\lambda_n+\lambda_h)^i}{!i(\mu+\omega)^i}\pi_0, \quad 0 \le i \le C-C_h \\ \dfrac{(\lambda_n+\lambda_h)^{C-C_h}(\lambda_h)^{i-(C-C_h)}}{!i(\mu+\omega)^i}\pi_0, \quad C-C_h+1 \le i \le C \\ \dfrac{(\lambda_n+\lambda_h)^{C-C_h}(\lambda_h)^{C_h}(\lambda_h)^i}{!C(\mu+\omega)^C \prod_{j=1}^{K-C}\left[C(\mu+\omega)+j(\mu+\gamma+\nu)\right]}\pi_0, \quad C+1 \le i \le K \end{cases} \tag{7}$$

Where P_0 can be obtained by using normalization condition

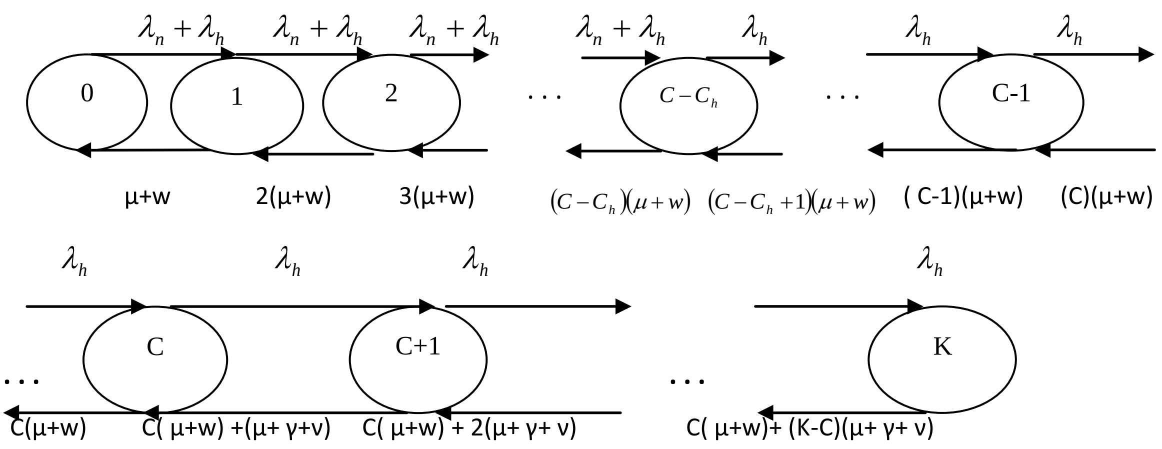
$$\sum_{i=0}^{K}\pi_i = 1 \tag{8}$$

and

$$\pi_0 = \left\{ \sum_{i=C+1}^{K} \frac{(\lambda_n+\lambda_h)^C((1-\beta)\lambda_h)^{i-C}}{C!(\mu+\omega)^C \prod_{j=1}^{K-C}\left[C(\mu+\omega)+j(\mu+\gamma+\nu)\right]} + \sum_{i=0}^{C-C_{hh}} \frac{(\lambda_n+\lambda_h)^i}{i!(\mu+w)^i} + \sum_{i=C-C_h+1}^{C} \frac{(\lambda_n+\lambda_h)^{C-C_h}(\lambda_h)^{i-(C-C_h)}}{!i(\mu+\omega)^i} \right\}^{-1} \tag{9}$$

By using steady state probability given in (4), we calculate various blocking probabilities as blocking probability for new call is given by

$$p_n = \sum_{i=C+1}^{K}\pi_i \tag{10}$$



(Fig. 2: Transition rate diagram for M\M\C\K System)

Suppose that a handoff call C_t arrives at time t when the cell is in state S(i) (i=C+j) and the call leaves the overlapping area at time t+ τ. Let τ_c be the remaining call holding time of C_t at t i. e. the call will be completed at time t+ τ_c . Consider c+j outstanding calls that arrive at the cell earlier than

C_t. Let among these C+j calls, the first call leaves the system (either completes, expires or leaves the cell) at time t+t_j.

Then the density function for t_j is

$$f_j(t_j) = [C(\mu + w) + j(\mu + \gamma + \nu)]e^{-[C(\mu+w)+j(\mu+\gamma+\nu)]t_j} \quad (11)$$

If $t_j \prec \tau$, then at time t+t_j; C_t sees C handsets in conversations and j-1 handoff calls looking for the second links. Now consider the first call that leaves the system among these C+j-1 calls (excluding C_t). Let the call leaves the system at time t+$t_j + t_{j-1}$.

Let $T_j = t_0 + t_1 + t_2 + \ldots t_j$

For a call C_t arriving at state S(i) (i=C+j, j≥ 0), the probability that C_t is blocked is

$$P_r\left[\tau \prec T_j \; and \, \tau \succ \tau_c / S(C+j)\right]$$

$$= \int_{t_j=0}^{\infty} --- \int_{t_0=0}^{\infty} \int_{\tau=0}^{T_j} \int_{\tau_c=0}^{\tau} \gamma e^{-\lambda\tau} \mu e^{-\mu\tau_c} \left[\prod_{k=0}^{j} f_k(t_k)\right] d\tau_c d\tau \; dt_1 ... dt_j$$

$$= \frac{(j+1)\gamma}{C(\mu+\omega) + (j+1)(\mu+\gamma+\nu)} \quad (12)$$

The probability that no radio resource is available for a handoff call is

$$p_h = \sum_{j=0}^{K-C} P\left[\tau < T_j \; and \; \tau > \tau_c / S(C+j)\right]\pi_{C+j}$$

$$= \sum_{j=0}^{K-C} \frac{(j+1)\gamma \; \pi_{C+j}}{C(\mu+\omega) + (j+1)(\mu+\gamma+\nu)} \quad (13)$$

The probability that a soft handoff call is blocked due to the network response time is too long is given by

$$\alpha_s = P_r\left[t_{nrt} > \tau_i^*\right]$$

$$= \frac{\gamma}{\gamma + \beta_1} \quad (14)$$

4 Further work

The guard channel prioritization schemes are established only when the number of free channels is less or equal to predefined threshold. The value of threshold directly affects the probability of the call blocking. Several other schemes to allocate channel for the handover request in the queue discipline have been proposed .For example queuing of new call arrivals is possible and is less sensitive regarding the queuing time than the case of handover. In this scheme new call will be accepted if the number of free channels apart of those reserved for handover is enough for the new request otherwise the call will be placed in the queue. As soon as the channel is released by the completing a call or outgoing of the handover request as the new call is served immediately from the FIFO queue. Queuing of the new calls involves the concept of the guard channel and queuing schemes. The performance analysis of queuing new call provide that the blocking of the handover calls decreases with the queuing probability of the new calls and increased in the total carried traffic because new calls will be ultimately served. The handover prioritized schemes also achieves less force termination probability compared to other schemes. Thus it is obvious from the above concept that the future scope of the handoff prioritization schemes is more than the other schemes.

5 Discussions

We derived mathematical model to analyze the problem of handoffs in CDMA (Code Division Multiple Access) network. Reneging behaviors of queued handoff calls with only voice traffic of new and handoff calls have been considered. Formulae for different type blocking probabilities have been developed and effect of reneging behaviors of calls on performance indices is summarized. The guard channel prioritization schemes are established only when the number of free channels is less or equal to predefined threshold. The value of the threshold directly affects the probability of the call blocking. resources must be available to support the mobile user else the user will suffer a forced termination of his call in progress. Therefore careful resource allocation along with call admission control is required to mitigate the chances of forced chances or blocking probability of a call.

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