Journal of Computer and Mathematical Sciences, *Vol.8(12), 739-749 December 2017* *ISSN 0976-5727 (Print)*
(An International Research Journal), *www.compmath-journal.org* *ISSN 2319-8133 (Online)*

Handoff Analysis in CDMA Based Wireless Cellular Network using Hard Handoff Model

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(Received on: November 26, 2017)

ABSTRACT

In Code division Multiple Access (CDMA) based cellular network, all cells share the same frequency bands and user can transmit simultaneously. In hard handoff, the old radio link is established and a handset always communicates with on base station (BS) at any given time. In the handoff procedure, the network needs to set up the new voice path for the handoff call. This setup time is referred as the network response time. If the old radio link is disconnected before the network completes the setup, the call is forcedly terminated. In this paper we introduce the concept of overlap region between adjacent cells and develop an analytical model for hard handoff in CDMA system. Balking and reneging behaviors of calls have also considered in this model. Different performance measures using variation in different parameters are calculated and results have been analyzed graphs.

Keywords: CDMA, Handoff, Base station, overlap region.

1. INTRODUCTION

With the rapid demand of wireless communication services, mobiles users are expecting the same level of availability and performance from wireless communication systems as traditional wireline networks. In general, wireless systems are characterized by their scarce radio resources which limit not only the service offering but also the quality of service (QoS). Mobility causes dynamic variations in link quality and interference levels in cellular systems, sometimes a particular user change its serving base station because of his/her mobility. This change is known as a handoff. In hard handoff, the old radio link is broken before the new radio link is established, and a handset always communicates with one BS at any given time. In the handoff procedure, the network needs to set up the new voice path for the handoff call. This setup time is referred to as the network response time if the old radio link is disconnected before the network completes the setup, the call is forced terminated.

Thus, even if idle channels are available in the new cell, a handoff call may fail if the network response time for link transfer is too long. A handoff failure may not necessarily cause a call drop. It is normally some time-out mechanism for the voice or signaling path which leads to a dropped call. Cellular communication system requires handoff to provide seamless service for users, moving across cells. Code division multiple access has received a great deal of attention as a multiple access method for future mobile networks. It main advantages are higher radios capacity and the capability of flexible data transmission.

Lee[1,2] gave his overview on the system and explains different term and future of the mobile communication system and general description of code division multiple access (CDMA) system. They also analyzed power control scheme in (CDMA) system. Gilhousen *et al*.[3,4] proposed spread spectrum or code division techniques for multiple access and developed personal handy phone system. Jabbari *et al*.[5] developed a system for personal mobile communication system using hard handoff. Yeung and Nanda[6] proposed a scheme for channel management in microcell/macrocell cellular radio systems. Sandouk *et al*.[7] analyzed performance of CDMA voice signals. Ramakrishna and Holtzman[8] discussed a scheme for throughput maximization in a dual-class CDMA system. Khan et. al.[9] investigated linear and exponential back off techniques for the uplink common channel packet transmission in wide band CDMA for Poisson arrival process. Greenberg *et al*.[10] described how to assign distinct number of code channels to each traffic class. Kim and Sung[11] proposed many analytical schemes for handoff analysis based on hard handoff in mobile communication system. They developed an analytical model for soft handoff in CDMA systems by introducing 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 investigated. Lee *et al*.[12,13] analyzed performance of channel borrowing handoff schema based on user mobility in CDMA cellular system and also studied the soft-handoff mechanism and compares its performance with the hard handoff. A mathematical structure for the handoff problem had developed by Rajat P. and Venugopal V. V.[15]. They also presented an easily implementable hysteresis threshold approximation and shown that it retains the adaptive nature of the LO algorithm. Kishor S. Trivedi *et al*.[16] have presented our research work on handoff performance in wireless cellular radio system. They developed tractable analytic models for the wireless system with hard handoff, and hard handoff including channel failures. They also obtained closed form solutions to new call blocking probabilities and handoff call dropping probabilities. Kishor S. Trivedi *et al*.[17] have presented the CTMC, MRM and SRN models for performability studyof a variety of wireless systems. By solving the two-level models, we can compute performability measures, such as call blocking probability and handoff call dropping probability, for wireless systems and wireless cellular systems with handoff, base repeaters, and control channels. Hamdaoui & Ramanathan[18] implemented a soft handoff scheme called soft handoff. Through analytic and simulation studies, they showed show that SHIP achieves significant performance improvements. Bhuvaneswari and George[19] provided an overview of handoff types, performance metrics, handoff schemes and handoff algorithms has been provided. This survey gives an idea to us about the existing schemes and algorithms to handle handoffs. Nisha & Sunil[20] summarized different handover schemes like soft handover, hard handover, vertical handover and horizontal handover. Liton (2013) presented an overview about the issues related to handoff initiation and decision and discuss about different types of handoff techniques in wireless communication. Imeh *et al*. (2014) have analyzed the performance of soft handoff in a realistic cellular network and revealed the problems associated with soft handoffs in telecommunication systems. They have also proposed a SH model, implementing same using realistic data for the purpose of improving the performance of the system, taking into consideration different coverage areas and diverse propagation exponents.

In this chapter, we have developed the mathematical model for hard handoffs in CDMA system to analyze the problem of handoff in cellular radio system. In this model, the balking and reneging behaviors of queued handoff calls also considered. The system capacity is to be considered finite. We have calculated different performance measures like blocking probability of new calls; call incompletion probability, blocking probability of handoff calls etc.

2. THE TRAFFIC MODEL

The queueing model dealing with soft handoff scheme for a cellular radio system with finite capacity is developed. There is C channels available in each cell of the system. In this system two types of calls are arrive 1) new calls and 2) handoff calls. The balking and reneging behaviors of calls are also considered. We assume that a handset can connect up to two radio links in a CDMA system.

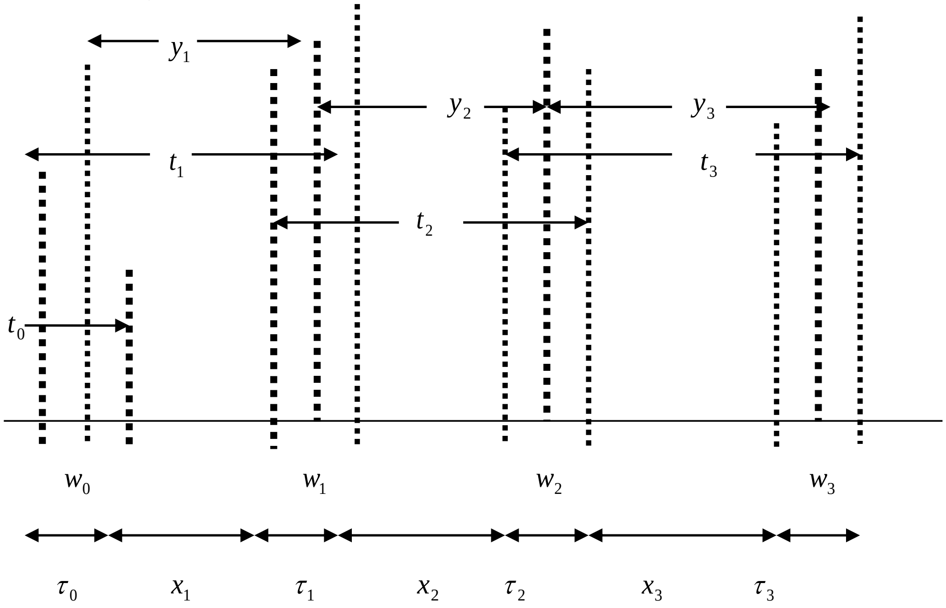

Figure 1: The timing diagram for the Hard handoff model

In the figure (1),

t_i = time that a handset can receive the signal from cell i i. e. the time that the handset resides in cell i

τ_i = the overlapping time i. e. the time that the handset resides in the overlapping area of the cell i

y_i = the time that the handset stays in the non-overlapping area of cell i

In Hard handoff, a communication mobile unit is switched from cell i to cell (i+1) at some point within τ_i . The handoff occur at time z_i , i=0, 1, 2, . . .

According to hard handoff scheme, the residence time of the handset at cell i is

$$y_i = w_i - w_{i-1} \tag{1}$$

Let x_i be the nonoverlay period. If E[x_i] = $\frac{1}{\eta}$ and E[τ_i] = $\frac{1}{\gamma}$, then E[y_i]=E[x_i]+E[τ_i]=$\frac{1}{\theta}$

Or $\frac{1}{\theta} = \frac{1}{\eta} + \frac{1}{\gamma}$

Or $$\frac{1}{\theta} = \frac{\gamma+\eta}{\eta\gamma} \tag{2}$$

Since the radio link between the base station and the mobile unit is broken before it is connected in hard handoff, the link transfer may fail due to long response time even if radio channels are available in the new base station.

The following assumptions are considered 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 q_i in a cell i has an exponential distribution with the density function given by
  $$f_m(q_i) = \theta e^{-\theta q_i} \tag{3}$$
- p_n =New call blocking probability
- p_r =Probability that a handoff call is blocked because no free channel in the is available probability
- The balking of calls according to exponential distribution with balking probability β
- The reneging of calls according to exponential distribution with parameter υ.
- The call holding time tc is exponentially distributed with the mean $1/\mu$
- p_f = forced termination probability or the probability that a handoff call is blocked because no channel is available

- p_{nc} = call incompletion probability
- α_h = The probability that a hard handoff call is blocked because the network response time is too long.
- P_i = the steady state probability that there is i customer in the system at any arbitrary point of time.
- $1/\eta$ =Mean time that the handset stays in non-overlay area.
- $1/\gamma$ =Mean time that the handset stays in overlay area.
- $1/\theta$ =Mean residence time of the handset at cell.
- $1/\beta_1$ =Mean network response time.

3. MATHEMATICAL ANALYSES

We are considering only one case to model soft handoff CDMA system. The steady state probabilities for this case are obtained as follows.

3.1 M\M\C\K Model

Using birth-death process as shown in the figure (2), the steady state probabilities for this model are given by

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

$$P_i = \begin{cases} \dfrac{(\lambda_n + \lambda_h)^i}{i!\left(\mu + \omega\right)^i}\pi_0\,, \quad 0 <= i <= C \\[2ex] \dfrac{(\lambda_n + \lambda_h)^C \left\{(1-\beta)\lambda_h\right\}^{i-C}}{C!(\mu+\omega)^C \prod_{j=1}^{K-C}\left[C(\mu+\omega) + j(\mu+\gamma+\nu)\right]}\pi_0\,, \quad C+1 <= i <= K \end{cases} \tag{4}$$

Since, we know that

$$\sum_{i=1}^{n} P_n = 1 \tag{5}$$

Hence

$$P_0 = \left\{ \sum_{i \succ C+1}^{K} \frac{(\lambda_n + \lambda_h)^C \left((1-\beta)\lambda_h\right)^{i-C}}{C!(\mu+\omega)^C \prod_{j=1}^{K-C}\left[C(\mu+\omega) + j(\mu+\gamma+\nu)\right]} + \sum_{i=1}^{C} \frac{(\lambda_n + \lambda_h)^i}{i!(\mu+w)^i} + 1 \right\}^{-1} \tag{6}$$

By using steady state probability given in (4), we calculate various blocking probabilities as

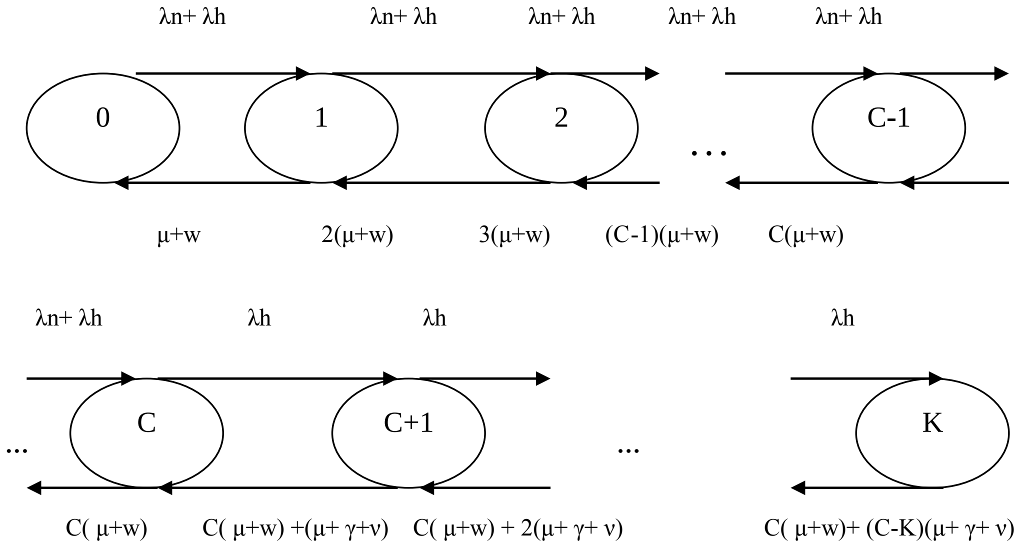

Fig. 2: Transition rate diagram for M\M\C\K System

A handoff call is forced terminated if the network response time is to long with probability α_h or no channel is available with probability p_r.

Since a non-prioritized scheme is considered, so $p_r = p_n$

And

$$p_f = 1-(1-\alpha_h)(1-p_n) = 1-(1-\alpha_h)(1-p_r) \tag{7}$$

From Lin[14], we have

$$\lambda_h = \frac{\theta(1-p_n)\lambda_n}{\mu+\theta[1-(1-\alpha_h)(1-p_n)]} \tag{8}$$

The channel occupied time of a call in a cell is the minimum of the remaining call holding time (The call holding time for a handoff call has the same distribution as a new call because of the memory less property of the exponential distribution) and the remaining cell residence time. So, the channel occupancy time is also exponentially distributed with rate ($\mu+\theta$). The net traffic to the system is ($\lambda_n+\lambda_h$).

Let C be the number of channels in a cell. The Hard handoff can be modeled by an M/M/C/K system and from the Erlang-B formula

$$p_r = p_n = \left[\frac{(\lambda_n+\lambda_h)^C}{(\mu+\theta)^C C!}\right]\left[\sum \frac{(\lambda_n+\lambda_h)^i}{(\mu+\theta)^i\, i!}\right]^{-1} \tag{9}$$

The incompletion probability Lin[14] is derived as

$$p_{nc} = p_n + \frac{\theta(1-p_n)\left[1-(1-\alpha)(1-p_n)\right]}{\mu+\theta\left[1-(1-\alpha)(1-p_n)\right]} \tag{10}$$

To compute p_n and p_r, the hard handoff scheme can be modeled by a Markov process with ststes S(n), where $n \geq 0$ represents the number of busy channels. 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 (μ +w) and the process moves from state S(n) to S(n-1) for $0 \prec n \leq C$ with the rate n(μ +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. 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 C(μ +w). For those j handoff calls who look for the second links, before the second links are available, the calls may leave the system in two cases:

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

(2) The call is completed with rate μ.

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

Since a new call is blocked when the system is in state S(n) where $n \geq C$ at its arrival, the originating call blocking probability is

$$p_n = \sum_{n=C+1}^{K} P_n \tag{11}$$

Suppose that a handoff call C_t arrives at time t when the cell is in state S(n) where n=C+j and the call leaves the overlay area at time t+τ_i. Let τ_C be the remaining call holding time of handoff call at time t i.e. the call will be completed at time t+τ_C. By the memory less property, τ_C has the same exponential distribution as t_C.

Suppose 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

$$f_j(t_j) = [C(\mu + w) + j(\mu + \gamma + \nu)]e^{-[C(\mu+w)+j(\mu+\gamma+\nu)]t_j} \tag{12}$$

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 $T_j = t_0 + t_1 + t_2 + ...t_j$

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

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

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

$$= \frac{\left(j + 1\right)\gamma}{C\left(\mu + \omega\right) + \left(j \ \ + 1\right)\left(\mu + \gamma + \nu\right)} \tag{13}$$

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

$$p_r = \sum_{j=0}^{K-C} P_r\left[\tau < T_j \ \ and \ \ \tau > \tau_c / S\left(C + j\right)\right] P_{C+j}$$

$$= \sum_{j=0}^{K-C} \frac{\left(j + 1\right)\gamma \ P_{C+j}}{C\left(\mu + \omega\right) + \left(j + 1\right)\left(\mu + \gamma + \nu\right)} \tag{14}$$

3.2 Derivation of α_h

Let τ_i (the time that the handset stay in overlapping area) and t_{nrt} (the network response time) are exponentially distributed with rates γ and β_1 respectively. In soft handoff, let τ_i^* be the period between the handset connects to the cell and when the handset leaves the overlapping area. For hard handoff, the handoff procedure is initiated when the signal of the new link is better than the old link. Thus we can assume that E$\left\lfloor \tau_i^* \right\rfloor = 0.5E\left\lfloor \tau_i \ \right\rfloor$ and then the probability that a hard handoff call is blocked due to the network response time is too long is given by

$$\alpha_h = P_r\left\lfloor t_{nrt} \succ \tau_i^* \right\rfloor$$

$$= \int_{\tau_i^*=0}^{\infty} \int_{t_{nrt}=\tau_i^*}^{\infty} \beta_1 \, e^{-\beta_1 t_{nrt}} \gamma e^{-\gamma \tau_i^*} dt_{nrt} d\tau_i^* = \frac{\gamma}{\left(\gamma + \beta_1/2\right)} = \frac{2\gamma}{2\gamma + \beta_1} \qquad (15)$$

4. RESULT AND DISCUSSION

In this section, we have calculated the numerical results and draw graphs to show the effect of different parameters on the blocking probabilities. Simulation technique has been applied to analyze the numerical results. Some graphs have been presented here to show the effect of different parameters on different blocking probabilities.

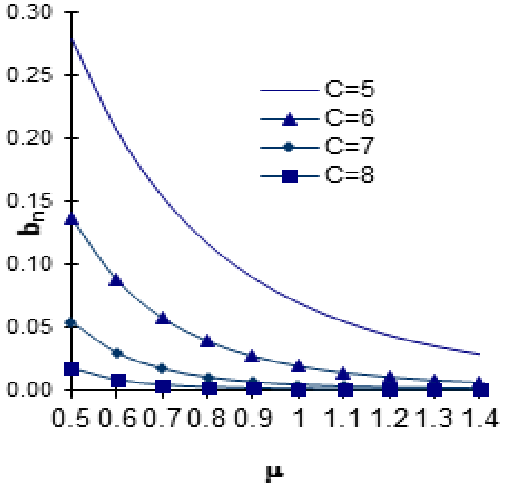

Fig 1 : Blocking Probability of New calls vs. service rate

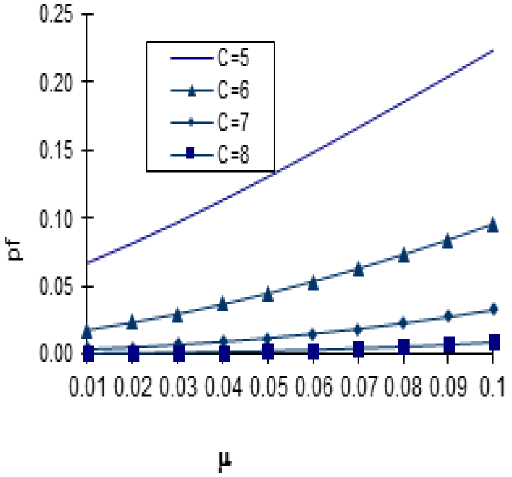

Fig. 2 : Blocking Probability of handoff calls vs. service rate

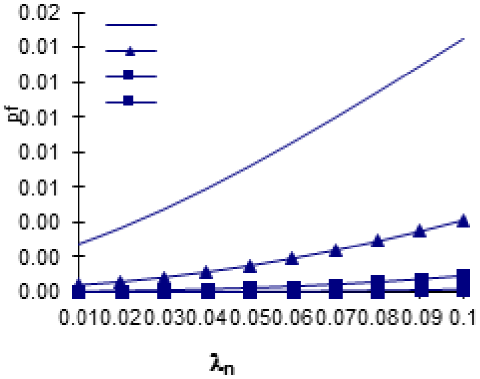

Fig. 3 : Blocking Probability of Handoff calls vs. arrival rate of new calls

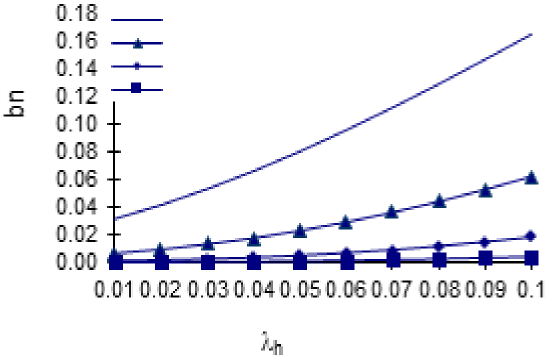

Fig. 4: Blocking Probability of New calls vs. arrival rate of handoff calls

5. DISCUSSIONS

We derived mathematical model with simulation to analyze the problem of handoffs in CDMA (Code Division Multiple Access) network. Balking and reneging behaviors of queued handoff calls are considered in this chapter. We have considered only voice traffic of new and handoff calls. Different types of blocking probabilities have been derived. Simulation results are calculated to show the effect of different parameters on blocking probabilities. In this chapter effect of Balking and reneging behaviors of calls on performance indices are summarized. From results it is conclude that:

1. As number of channels in a cell or service rate increase, then the corresponding blocking probabilities decrease.
2. The blocking probabilities decrease with increase in arrival rate of both type of calls (New and Handoff).

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