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Performance Evaluation of Cellular Radio System with Directed Retry

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Abstract: *In this paper the arrival of calls (new and handoff) in personal communications services (PCS) network are modeled according a Markov Arrival Process (MAP). The purpose of our study is to improve the performance of the cellular mobile system by using directed retry scheme. The cut of priority scheme have also been applied to provide priority to handoff calls. Here we construct tractable model using fixed channel assignment scheme with priority to handoff voice calls. The proposed directed retry scheme with finite buffering for handoff voice calls is useful for improving the handoff blocking probability of handoff voice calls. The integrated traffic model has been constructed for finite population. FIFO fashion has been taken for arrival calls. The balking behavior of the calls has also been taken into consideration. The expressions for various performance indices viz. blocking probabilities for different traffic, overall blocking probability, offered carried load etc. are determined for above model. It is clear from the analytical results that by increasing overlapping area and retrying in overlapping area, a substantial improvement can be achieved.*
Keywords: Markov Arrival Process, fixed channel assignment scheme, directed retry scheme, balking, FIFO, Handoff.

I. Introduction

The important feature associated with mobile communication system is that it provides services to the user at any time and everywhere. Communication Technology plays a great role in business, information media, science & technology and educational development. The potentiality of the future cellular market is incredibly large because more than half of the world's population lives away from a cellular phone.

When a new call is originated in the cellular network and attempted in a cell, one of the channels assigned to the base station of the cell is used for communication between the mobile user and the base station (if any channel is available for the call). If the channels assigned to the base station are in use, the call attempt is assumed to blocked and cleared from the system. When a new call gets a channel, it keeps the channel until the call is completed in the cell or the mobile moves out of the cell. When the call is completed in the cell, the channel is released and becomes available to serve another call. When the mobile user crosses a cell boundary and enter into an adjacent cell while the call is in progress, the call requires channel frequency in a new base station for continue the call. If no channel is available in the new cell into which the mobile user moves, the handoff call is terminated.

With the increasing demands for the wireless system has been designed with micro-cellular architectures in order to provide a high capacity services. However, the reduced coverage area of a cell has led to the undesirable consequence of an increase in the number of handoffs. As the handoff rate increases, bandwidth management and traffic control strategy become more challenging problems in wireless networks.

Handoff is an action of switching a call in progress in order to maintain continuity and the required quality of service (QoS) of the call when a mobile user moves from one cell coverage to cell coverage. Due to users' mobility, the media access control protocol becomes much more complicated in the current cell may have to be handed off to another cell. During the process, the call may not be able to get a channel in the new cell to continue its service due to the limited resource in the wireless networks, which will lead to the call dropping. Since the users tend to be much more sensitive to a call dropping then to a call blocking, so the new calls and the handoff calls can be treated differently in terms of the resource allocation. Handoff calls are normally assigned a higher priority over the new calls.

The queuing models and performance measures of mobile network have attracted several researchers working in the area of communication technology.

Hong and Rappaport [1986] gave traffic model and performance analysis for cellular mobile telephone systems with prioritized and non-prioritized. Zhang and Yum [1989] proposed a comprised study of channel assignment strategies in cellular mobile telephone systems. Srivastava and Rappaport [1991] provided analytical models for overlapping coverage area in cellular and micro-cellular communication systems. Yum and Yeung [1995] gave a new analytical model for finding the call blocking probability of a cellular mobile system with directed retry. They also provided a second analytical model for obtaining the probability of additional handoff.

Chu and Rappaport [1997] proposed a model with overlapping coverage and channel assignment in micro-cellular communication systems. Jain [1999] proposed an analytical model to predict the performance of cellular communication non-homogeneous traffic originated from finite population in cellular radio system. She also studied the directed retry assignment scheme, which allows call to access the neighboring base station in case it cannot be served by the base station in which it is located.

In this paper, we have developed an analytical model to study the call blocking probability of system using with directed retry scheme. In this scheme a caller tries to access the neighboring base station in case it cannot be served by the base station in which it is located. The directed retry scheme is applicable only in the overlapping area, which is developed by neighboring cells. Here handoff calls given more priority over data packet calls.

II. Traffic Model:

The queuing model dealing with cutoff priority scheme for a cellular system with mixed traffic (voice & data calls) originated from finite population using directed retry scheme is developed. We have also considered the balking behaviors of queued handoff voice calls.

The assumptions and notations involved in this model are as follows:

Two types of traffic voice and data calls originated from finite population of size M are served in First in first out (FIFO) order based on cut-off priority rule. In each cell of the network four types of calls (i) new voice (ii) new data (iii) handoff voice (iv) handoff data arrive in Poisson fashion with mean rates λ_{nv}, $\lambda_{np,}$ $\lambda_{vh,}$ and λ_{ph} respectively. There are C channels associated with each cell of the system. In order to protect handoff calls, we assume that the handoff calls have priority over the new calls. For this purpose C_h channels among C are reserved for handoff calls. When a new call is arrived, it can be served successfully if the number of ideal channels is greater than C_h. A single call/data packet may be occupying only one channel. The call holding time (patience or dwell time) i.e. the time for which mobile user remains in the handoff area is denoted by μ_d and assumed to be exponentially distributed with mean 1/ μ_d. The service rate for voice (data packet) calls is denoted by $\mu_{v\,(}\mu_{p)}$ respectively.

The balking of custers according to exponential distribution with balking probability β. In each cell, voice calls also arrive from its neighbouring cells due to directed retry with rate σ_{nv} and σ_{vh} for new voice calls and for voice handoff callls respectively. It is assumed that random subscriber has a constant probability of hearing one extra transmitter. This probability is influenced by percentage of overlapped area in a cell.

Coinsider the cellular structure of seven cells with a fraction (f_i) of overlapping area for a cell i and the set of neighbouring cells S_i.

Denote

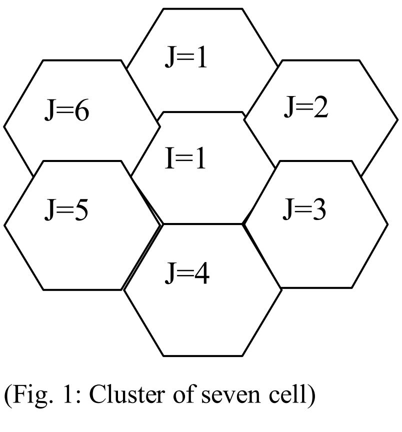
$|S_i|$ = The number of neighbouring cells of a cell i

$$\frac{1}{\mu} = \frac{1}{\mu_p} + \frac{1}{\mu_d}$$

$$\lambda = \lambda_n + \lambda_h$$

Where $\lambda_n = \lambda_{np} + \lambda_{nv} + \sigma_{nv}$

And $\lambda_h = \lambda_{ph} + \lambda_{nh} + \sigma_{vh}$



(Fig. 1: Cluster of seven cell)

Let P_k be the steady state probability that there are k attempts in the system.
We define the following blocking probabilities:
b_{nvi} = Probability that a new voice call is blocked in cell i
b_{np} = Probability that a new packet attempt is blocked
b_{ph} = Probability that a packet handoff is blocked
b_{vhi} = Probability that a voice handoff call is blocked in cell i
σ_{nvi}= Traffic due to directed retry of new voice calls in cell i
σ_{vhi}= Traffic due to directed retry of voice handoff calls in cell i
f_i =Overlapping area of cell i which is obtained by overlapping with nearly cells
B= Over all blocking probability that any type of call is blocked
CL = Offered carried load

III. The Mathematical Analysis

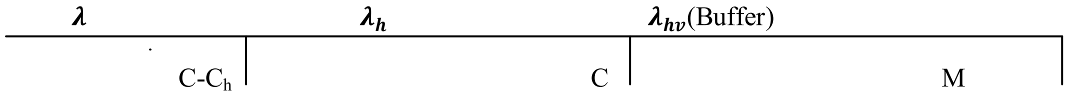
Here we are considering only one case to model cellular radio system. The steady state probability for this case is obtained as follows:

M\M\C\K\M Finite Population Model:

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

$$P_k = \begin{cases} \left(\dfrac{!M}{!k!M-k}\right)\left(\dfrac{\lambda}{\mu}\right)^k P_0, \quad 0 <= k <= C - C_h \\ \left(\dfrac{!M}{!\,k!\,M-k}\right)\dfrac{(\lambda)^{C-C_h}(\lambda_h)^{k-(C-C_h)}}{(\mu)^k} P_0, \quad C - C_h < k <= C \\ \dfrac{!M}{!M-k!C\,(\mu)^c} \dfrac{(\lambda)^{C-C_h}(\lambda_h)^{C_h}\left[(1-\beta)\ \lambda_{hv}\right]^{k-C}}{\prod_{j=1}^{k-C}\left[C\mu + j*\mu_d\right]} P_0, \quad C+1 \le k \ge M \end{cases}$$

…(4.1)



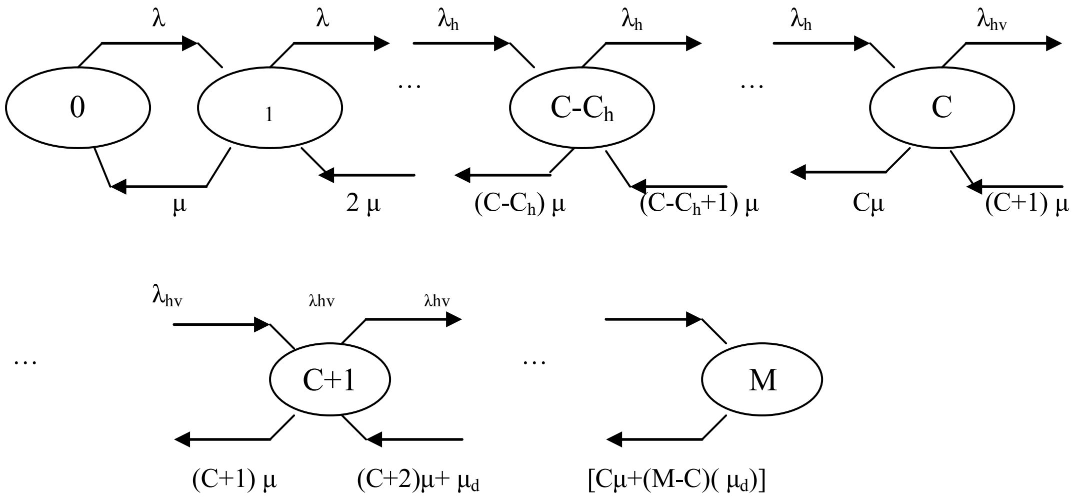
Where P_0 can be obtained by using normalization condition

$$\sum_{k=0}^{M} P_k = 1 \qquad \textbf{… (4.2)}$$

$$b_{np} = b_{nvi} = \sum_{k=C-C_h}^{M} P_k \qquad ...(4.3)$$

$$b_{vhi} = P_M \qquad ...(4.4)$$

$$b_{ph} = k = \sum_{k=C+1}^{M} P_k \qquad ...(4.5)$$



(Figure 2: Transition rate diagram for finite population model)

IV. Overall blocking probability and carried load

The overall blocking probability in a cell can be obtained by taking into consideration the cell where the call is originated. We consider the cluster of seven hexagonally shaped cells to compute the overlap covering area of the central cell i with the adjacent j (j=1, 2, 3, 4, 5, 6) cells. The analysis is done for individual cell i where in calls are assumed to arrive from finite population of size M.
.
The overall blocking probability for voice handoff calls is

$$B_{vh} = (1 - f_i) b_{vhi} + f_i\, b_{vhi} \sum_j b_{vhj} \qquad \dots (4.6)$$

The overall blocking probability for new voice calls is

$$B_{nv} = (1 - f_i) b_{nvi} + f_i\, b_{nvi} \sum_j b_{nvj} \qquad \dots (4.7)$$

The overall blocking probability that all types of calls are blocked is given by

$$B = \frac{\lambda_{nv} B_{\mathbf{n}v} + \lambda_{np} b_{\mathbf{n}p} + \lambda_{vh} B_{vh} + (1-\beta)\lambda_{ph} b_{ph}}{\lambda} \qquad \dots (4.8)$$

The carried load is given by

$$CL = \frac{\lambda_{nv}(1-B_{\mathbf{n}v}) + \lambda_{np}(1-b_{\mathbf{n}p}) + \lambda_{vh}(1-B_{vh}) + (1-\beta)\lambda_{ph}(1-b_{ph})}{\lambda} \qquad \dots (4.9)$$

V. Calculation of directed retry traffic

Here we provide a technique to compute arrival rates due to directed retry. The retry is allowed only for handoff voice calls in the case when these cannot get a free channel in the cell to which it is moving. Since overlapping area f_i is not too large so that there are little retry.

For convenience, we can assume that blocking probabilities in cell i and j are independent to each other.

The traffic due to directed retry is as follows:

$$\sigma_{nvi} = \sum_j \lambda_{nvj} prob.(cell\ j\ is\ blocked\ and\ cell\ i\ is\ not\ blocked\ for\ new\ voice\ traffic).prob.(a$$

$$new\ voice\ call\ is\ directed\ to\ cell\ i / cell\ j\ is\ blocked\ and\ cell\ i\ is\ not\ blocked\ for\ new\ voice\ calls)$$

$$= \sum_j \lambda_{nvj}.b_{nvj}(1 - b_{nvi})\frac{f_i}{|S_j|}, j \in S_j \qquad ...(4.10)$$

similarly

$$\sigma_{vhi} = \sum_j \lambda_{vhj} prob.(cell\ j\ is\ blocked\ and\ cell\ i\ is\ not\ blocked\ for\ voice handoff\ traffic).prob.(a$$

$$handoff\ voice\ call\ is\ directed\ to\ cell\ i / cell\ j\ is\ blocked\ and\ cell\ i\ is\ not\ blocked\ for\ handof\ voice\ calls)$$

$$= \sum_j \lambda_{vhj}.b_{vhj}(1 - b_{vhi})\frac{f_i}{|S_j|}, j \in S_j \qquad ...(4.11)$$

Using above results, we compute blocking probabilities including arrival rates due to directed retry. We provide an iterative procedure to compute performance characteristics as follows:
Step 1: $\sigma_{nvi} \leftarrow 0$, $\sigma_{vhi} \leftarrow 0$, $\delta \leftarrow 1$
Step 2: If | δ|< ϵ (say .00001), go to step 5, otherwise go to step 3.
Step 3: Compute B_{nv} and B_{vh}.
Step 4: Compute new σ_{nvi} and σ_{vhi}. Calculate $_{\delta}$, which is the difference between the old σ_{vhi} and the new σ_{vhi}. Go to step 2.
Step 5: Compute b_{np}, b_{ph}. Also compute B_{vh}, B_{nv}, B and CL.

VI. Numerical Results

In this section, we have calculated the numerical results and draw graphs to show the effect of different parameters on the blocking probabilities.

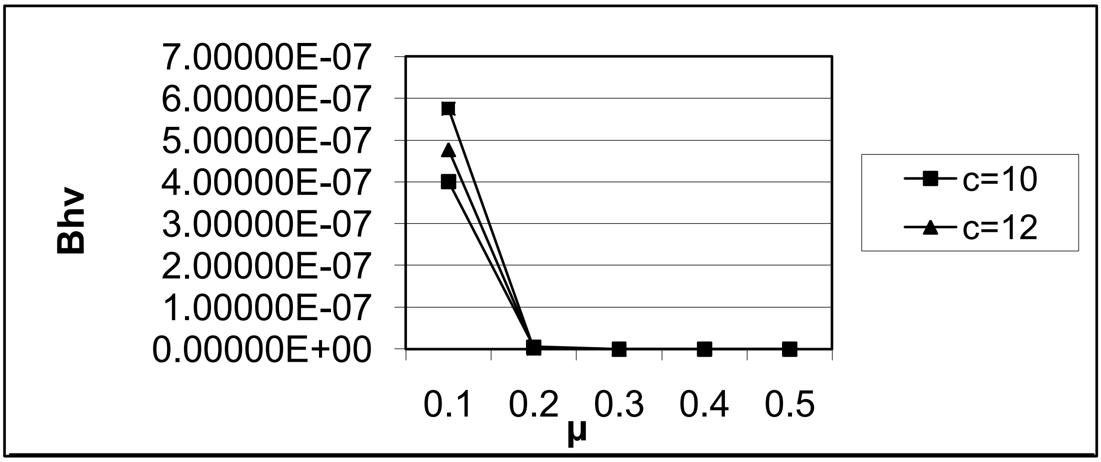


Fig. 1: Blocking probability of handoff voice calls vs. mean service rate

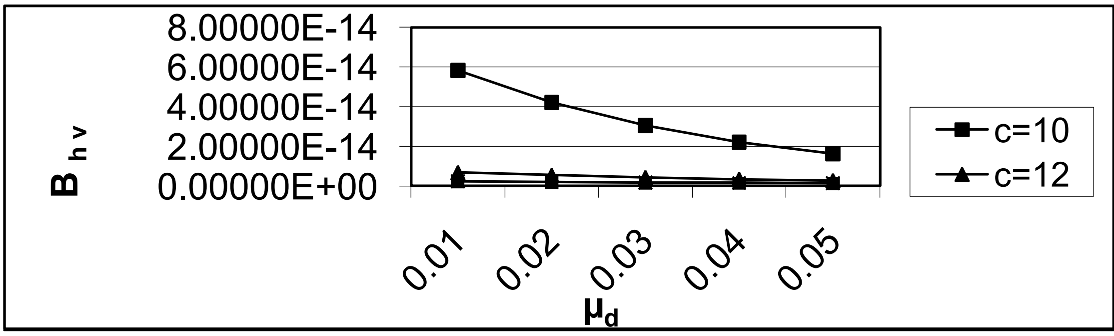


Fig. 2: Blocking probability of handoff voice calls vs. mean dwell time

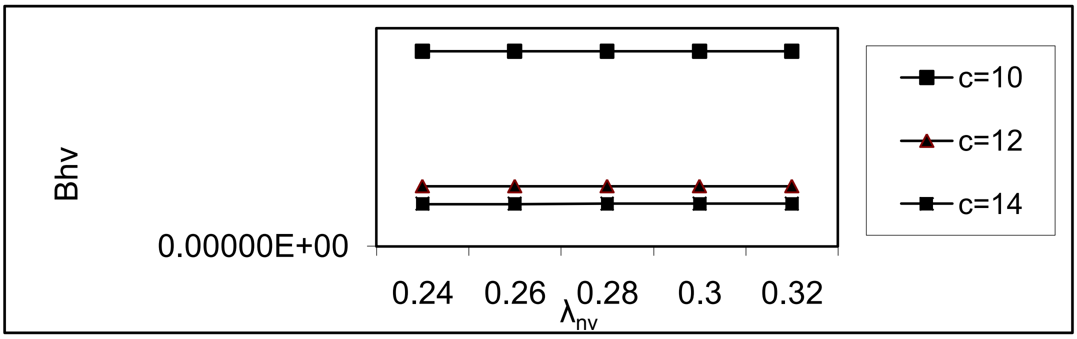


Fig. 3: Blocking probability of handoff voice calls vs. mean arrival rate of new voice calls

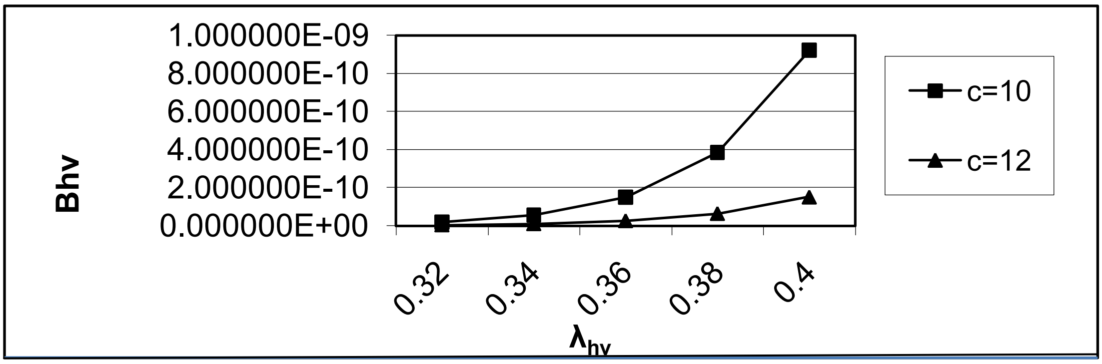


Fig. 4: Blocking probability of handoff voice calls vs. mean arrival rate of handoff voice call

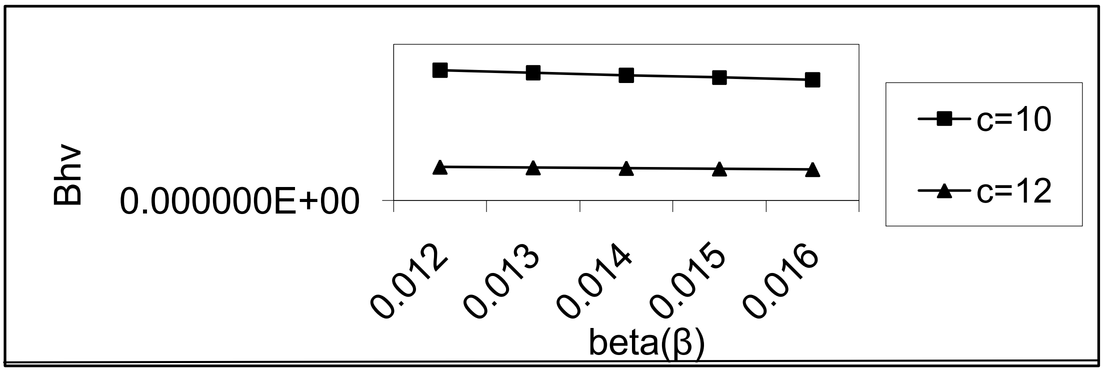


Fig. 5: Blocking Probability of handoff voice calls vs. balking parameter

VII. Conclusion:

The analytical method described is used to compute performance of various measures. The programming of the simulation has been done in C language. We have developed directed retry scheme for cellular radio system having both type of traffic voice and data. Various performance measures have been computed by using iterative algorithm. We have given more priority to voice handoff calls in comparison to data packets calls. It is clear from analytical result that the directed retry scheme play an important role to reduce blocking probability of handoff voice calls. It should be noted that only mobile users in the overlap area can take advantage of the directed retry scheme.

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