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Analysis of Wireless Microcellular Network for High Speed User with Prioritize Handoff Procedure

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Abstract

For a user in wireless mobile radio telephone system forced termination of an ongoing call due to lack of free channel is clearly less desirable than blocking of a new call attempt. In this paper vehicular speed user is considered, priority is assigned to handover call over new call attempts and blocked handover calls are placed in a finite storage queues. Therefore some channel assignment strategies with handover prioritization, guard channel concept have been proposed in order to decrease the probability of forced termination of handover calls. Total new call blocking probability and handover forced termination probability is evaluated and a suitable function for the mean service time at each position in the queue is theoretically estimated. Quality of Service (QoS) is obtained by introducing a threshold in the maximum waiting time of a handover call in the queue. If the mean service time at queue of a handover call is found to be greater than this threshold, this call will be blocked. Simulation result shows that this scheme provides satisfactory performance for both new and handover call.

Keywords: Forced termination, handover, blocking probability, queuing of calls, mean queue waiting time, Quality of Service (QoS).

Introduction

The performance of cellular mobile radio telephone systems in which cell size is relatively small and handoff procedure for high speed user has an important effect is investigated in this paper. Spectrally efficient mobile radio service for a large number of customers can be provided by cellular systems [6, 7]. The service area is divided into cells. Users communicate via radio links to base stations in the cell. Channel frequencies are reused in cells that are sufficiently separated in distance so that mutual interference keeps within tolerable levels. In case of microcellular networks handover management has been one of the most important and challenging issues. It will become more challenging in near future when more user should be accommodate that will cause more frequent handover within limited resources and to support not only voice traffic but also multimedia traffic such as video. As the user moves with vehicular speed frequent handover will occur. This may reduce the Quality of Service (QoS) below an acceptable level. Also the chances of dropping a call due to factors such as the availability of free channels decrease with the number of handover attempts increases. All these issues place additional challenges on the design and dimensioning of microcellular wireless networks. Increasing the handoff rate, the probability of an ongoing call to be dropped due to a lack of free channel is high. This probability is also described as the probability of forced termination of handover calls (*PF)* and it is a major criterion in performance evaluation of microcellular systems. In ideal case, we would like to avoid handover drops so that ongoing connections may be preserved as in a QoS-guaranteed in wired network. However, this is impossible in practice due to unpredictable fluctuations in handover traffic load.

Each cell can, instead, reserve fractional bandwidths of its capacity, and this reserved bandwidth can be used solely for handovers, not for new connection requests. It is assumed those handover connection request arrival rates are at poisson process [9]. Therefore, some channel assignment strategies with handover prioritization, guard channels [1], have been proposed in order to decrease the probability of forced termination. Hong and Rappaport [1] first proposed and analyzed a priority queuing model, according to which handover calls can be queued if all channels in the target cell are busy. If any channel is released while the mobile is in the handoff area, the first call in the queue occupies this channel. Infinite queue size is here considered. Chang et al. [3] later on proposed a two dimensional Markov chain queuing model for both types of calls, and in their model they also proved that it is not necessary to provide a very large queue size, thus a finite queuing is more suitable and realistic. Guerin [2] made also use of handover guard channels and new call queuing by proposing a two-dimensional Markov chain model. In his model, Guerin managed to find a closed-form solution for the state probabilities.

The Prioritized Handover Procedure: In order to study the handover queuing and present the impact of a queue on the system performance, it is necessary to analyze the prioritized handover procedure. The main aspects that have to be considered are (1) The mean channel holding time; (2) The cell radius; (3) The user mobility; (4) The mean call duration; (5) The guard channel reservation for handover calls.

The channel holding time T_H in a cell is defined as the time duration between the instant that a channel is occupied by a call and the instant it is released by either completion of the call or a cell boundary crossing by a portable, whichever is less. This time is a function of the cell radius R and of the maximum mobile velocity $V_{\max}$. We assume that the mean call duration T_M is the time an assigned channel would be held if no handoff is required and has an exponential distribution with mean value T_M ($\equiv 1/\mu_M$). The speed of a mobile in a cell is assumed to have a uniform distribution on the interval [0, *V*max]. The time for which a mobile resides in a cell to which the call is originated (is handed off) is denoted T_n (T_h). The probability density functions of these holding times are [1]:

$$fT_n = \frac{2V_{\max}}{\pi R^2}\sqrt{R^2 - \left(\frac{V_{\max}t}{2}\right)^2}, \qquad 0 \le T \le \frac{2R}{V_{\max}}, \tag{1}$$

$$fT_h = \frac{V_{\max}}{\pi\sqrt{R^2 - \left(\frac{V_{\max}t}{2}\right)^2}}, \qquad 0 \le T \le \frac{2R}{V_{\max}} \tag{2}$$

The channel holding times of a new and handover call are given by:

$$T_{Hn} = \min\left(T_M, T_n\right)$$
$$T_{Hh} = \min\left(T_M, T_h\right)$$

Finally, it is proved [1] that the pdf of T_H is a function of the equations above and can be approximated to a negative exponential distribution with mean $T_H = 1/\mu_H$. The value of μ_H can then be calculated using the following equation:

$$\int_0^\infty \left(F_{TH}{}^C(t) - e^{-\mu_H t}\right)dt = o \tag{3}$$

Where $F^C{}_{TH}$ is the complementary distribution function of the channel holding time.!

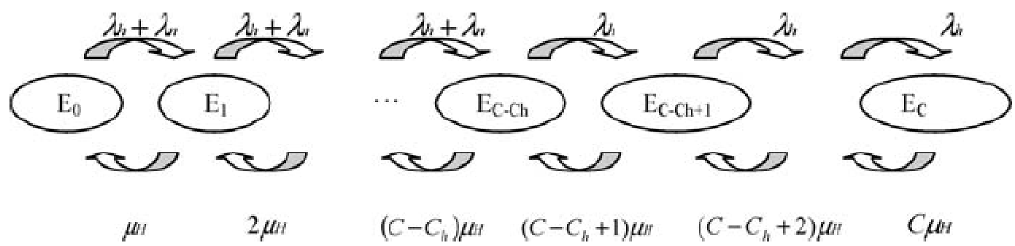

Figure 1: State-transition diagram for the prioritized handover procedure.

Priority can be given to handoff attempts by assigning C_h channels exclusively for handoff calls among the C channels in a cell. Both the new and the handoff calls can share the remaining $C - C_h$ channels .We define the state E_j of a cell such that there are j calls in progress and let P_j represent the steady-state probability to find this cell in state E_j. The probabilities can be determined by using a Markovian birth-death process in Figure 1.

Let λ_n and λ_h be the new calls and the handoff calls arrival rate, respectively. Denoting

$\lambda = \lambda_n + \lambda_h$ as the total call arrival rate, then we can set

$$\lambda_h = a\lambda \tag{4}$$

The offered load *L in* a communication system is defined as

$$L = \frac{(\lambda_h + \lambda_n)}{\mu_H} \tag{5}$$

Using the steady-state equations from Figure 1, we conclude:

$$P_j = \begin{cases} \dfrac{(\lambda_n + \lambda_h)^j}{j!\,\mu_H{}^j} P_0, & 0 \le j \le C - C_h \\ \dfrac{(\lambda_n + \lambda_h)^{C-C_h}\,\lambda_h{}^{j-(C-C_h)}}{j!\,\mu_H{}^j} P_0, & C - C_h \le j \le C \end{cases} \tag{6}$$

Where P_0 denotes the probability of having 0 channels in use (calls in progress) and is derived by the total probability $\sum_{j=0}^{C} P_j = 1$

$$P_0 = \left[\sum_{j=0}^{C-C_h} \frac{(\lambda_n + \lambda_h)}{j!\,\mu_H{}^j} + \sum_{j=C-C_h+1}^{C} \frac{(\lambda_n + \lambda_h)^{C-C_h} (\lambda_h)^{j-(C-C_h)}}{j!\,\mu_H{}^j} \right]^{-1} \tag{7}$$

The probability of blocking for a new call is the sum of the probabilities that the state number of the base station is larger than or equal to C - C_h. Hence

$$P_B = \sum_{j=C-C_h}^{C} P_j \tag{8}$$

The probability of handoff attempt failure $P_{f\,h}$ is the probability that the state number of the base station is equal to C. Thus

$$P_{fh} = P_C \tag{9}$$

Mathematical Analysis of the Proposed Handover Procedure: In this section we study a handover-prioritized procedure, according to which a handoff attempt may be queued if the state number in the cell is equal to *C* (All channels in the cell are busy).. Queuing of handoff calls can increase total carried traffic as well as minimize blocking probabilities. Therefore, as an alternative to the systems proposed in [1,2,8]. T_Q is the time that this attempt remains queued at a position *q* depends normally on whether or not a channel becomes available as long as the mobile is still in the handoff area. In this area, the average received power level by a mobile is between the handoff threshold level initiation of the handover procedure and the receiver threshold level [1]. A handoff attempt that joins the queue will be successful, if both of the following events occur before the mobile moves out of the handoff area:

1. All of the attempts which joined the queue earlier than the given attempt have been disposed
2. A channel becomes available when the given attempt is at the first position in the queue.

On the basis of our consideration, T_Q should have an upper bound. In order to have an effective system, a call must not be allowed to remain at a buffer position more than a maximum time threshold. Moreover, the queue size has to be limited because it is more realistic and practical than the infinite buffering. For this reason queue size is considered finite. The maximum value of the mean service time $T_Q = 1/\mu_Q$ is here obtained by the mean waiting time W_h in the queue.

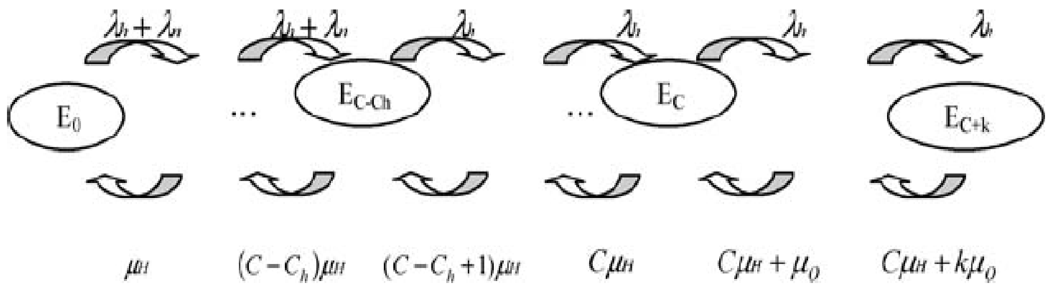

Figure 2: State transition diagram of the queuing traffic model.

The same analysis as in Section 2 is used here and a similar Markovian birth-death process with k positions in the queue calculates the system steady-state probabilities in Figure 2.

Using the steady-state equations from Figure 2, we conclude:

$$P_j=\begin{cases}\dfrac{(\lambda_n+\lambda_h)^j}{j!\,{\mu_H}^j}P_0, & 0\le j\le C-C_h\\[2ex] \dfrac{(\lambda_n+\lambda_h)^{(C-C_h)}(\lambda_h)^{j-(C-C_h)}}{j!\,{\mu_H}^j}P_0, & C-C_h+1\le j\le C\\[2ex] \dfrac{(\lambda_n+\lambda_h)^{(C-C_h)}(\lambda_h)^{j-(C-C_h)}}{C!\,{\mu_H}^C\prod\limits_{i=1}^{j-C}(C\mu_H+i\mu_Q)}P_0, & C+1\le j\le C+k\end{cases}\tag{10}$$

In the same way as in Section 1, we can obtain the probability

$$P_0 \quad P_0 = \left[\sum_{j=0}^{C-C_h} \frac{(\lambda_n + \lambda_h)^j}{j!\,\mu_H{}^j} + \sum_{j=C-C_h+1}^{C} \frac{(\lambda_n + \lambda_h)^{C-C_h}\,\lambda_h{}^{j-(C-C_h)}}{j!\,\mu_H{}^j} + \sum_{j=C+1}^{C+k} \frac{(\lambda_n + \lambda_h)^{C-C_h}\,\lambda_h{}^{j-(C-C_h)}}{C!\,\mu_H{}^C \prod_{i=1}^{j-C}(C\mu_H + i\mu_Q)} \right]^{-1} \tag{11}$$

Now, we define the waiting time of a queued handoff call as the time of an arbitrarily selected handoff call between the moments it is accepted and begin waiting in the queue to the moment it successfully accesses a free channel. Given that the state of the system is when the call arrives and waits in the queue, we denote the waiting time by $W_h(j)$. Clearly, $0 \le q \le k-1$ and $W_h(j)$ can be obtained by the following formula [1]:

$$W_h(j) = -\frac{1}{\mu_Q}\ \ln(1 - R_h(j)) \tag{12}$$

Where "ln" is the natural logarithmic function and $R_h(j)$ is the dropping probability of an arbitrary selected handoff call, given that the system state is $j = C + q$ just at the instant the call is accepted by the system and waits in the queue. This probability is derived later on in this section. Consequently, the average waiting time of a handoff call, denoted by $\overline{W_h}$ can be obtained by:

$$\overline{W_h} = \frac{\sum_{j=C+1}^{C+k} P_j W_h(j)}{\sum_{j=C+1}^{C+k} P_j} \tag{13}$$

As we can easily conclude, W_h is a function of the mean queue service time $T_Q = 1/\mu_Q$. Thus, setting an upper bound $(W_h)_{\mathrm{MAX}}$ for the waiting time in the queue, we can solve for T_Q and find the corresponding maximum allowable mean service time at every position. Of course, this solution of T_Q should be inside the interval $[0, +\infty)$. From Equation (13), it is obtained that:

$$(\overline{W_h})_{MAX} = f(\overline{T_Q})_{MAX} \Rightarrow (\overline{T_Q})_{MAX} = f^{-1}((\overline{W_h})_{MAX}) \tag{14}$$

The blocking probability of the new calls is the sum of the probabilities that the state number of the cell is larger than or equal to $C - C_h$. Hence:

$$P_B = \sum_{j=C-C_h}^{C+k} P_j \tag{15}$$

As we already mentioned, the blocked handover calls join a queue. A handover attempt that enters the queue at the position $q(0 \le q \le k - 1)$ will be successful, if it manages to reach the first position of the queue and get a channel before its mean service time becomes greater than the calculated from Equation (14) value. Thus, the handoff blocking probability can be expressed mathematically as

$$P_{fh} = \left[\sum_{q=0}^{k-1} P_{C+Q} \times \Pr(attempt\_fails\_given\_it\_enters\_the\_queue\_in\_position\_(q+1)) \right]$$

$$+ P_{C+k}$$

or

$$P_{fh} = \sum_{q=0}^{k-1} P_{C+Q} R_h (C+q) + P_{C+k} \tag{16}$$

In order to derive the probability of a handoff failure in the queue $R_h(C + q)$, we assume that:

$$1 - R_h(C+q) = \left[\prod_{i=0}^{q} P(i/i+1) \right] \times \Pr(call\_remains\_in\_queue) \tag{17}$$

The probability of transition from position i +1 to i is denoted by $P(i/i +1)$ in Equation (17) and is contributed by two probabilities [3]:

i. The remaining channel holding time of any of the C calls in progress is smaller than each of the following:
   - The remaining channel holding time of any of the other ($C - 1$) calls in progress.
   - The service time of any of the i waiting handoff calls.
   - The service time of the waiting handoff call of interest.

ii. The remaining service time of any of the i handoff calls waiting in the queue is smaller than each of the following:
   - The channel holding time of any of the C calls in progress.
   - The service time of any of the other ($i - 1$) waiting handoff calls.
   - The service time of the waiting handoff call of interest.

Thus, the transition probability can be obtained by:

$$P(i/i+1) = \frac{C\mu_H + i\mu_Q}{C\mu_H + (i+1)\mu_Q} \tag{18}$$

The second term in Equation (17) is a logical condition that can have only two values. If the mean service time at this position is smaller than or equal to the maximum mean service time threshold (derived by Equation (14)), this term is set to “1”. Otherwise, it is set to “0”. Thus:

$$\Pr\text{ (Call\_remains\_in\_queue)} = \begin{cases} 1 \; \overline{T_Q} \leq \left(\overline{T_Q}\right)_{MAX} \\ 0 \; otherwise \end{cases} \tag{19}$$

Finally, by substituting (17), (18), (19) into (16), we have:

$$P_{fh} = \begin{cases} \sum_{q=0}^{k-1} P_{C+Q}\left[1 - \prod_{i=0}^{q} \frac{C\mu_H + i\mu_Q}{C\mu_H + (i+1)\mu_Q}\right] + P_{C+k}, \overline{T_Q} \leq \left(\overline{T_Q}\right)_{MAX} \\ \sum P_{C+q} \;\; otherwise \end{cases} \tag{20}$$

At this point, it is important to introduce a new probability, which is more important than P_{fh}. When the cell radius is small, the probability that a mobile crosses a cell boundary during call duration is higher. Thus, from the user's point of view, the probability P_F that a call, which is not blocked, is eventually forced into termination is a very significant parameter in mobile systems. This will occur if the call succeeds in each of the first $(k - 1)$ handoff attempts that it requires, but fails on the k th attempt. Therefore:

$$P_F = \frac{P_{fh} + P_N}{1 - P_H\left(1 - P_{fh}\right)} \tag{21}$$

Probabilities P_N and P_H in (21) denote the handoff demand of new and handoff calls, respectively and can be obtained by [1]:

$$P_N = \Pr\left(T_M > T_n\right) = \int_0^{\infty} e^{-\mu M t} f\, T_n(t) dt \tag{22}$$

$$P_H = \Pr\left(T_M > T_h\right) = \int_0^{\infty} e^{-\mu_M t} f T_h(t) dt \tag{23}$$

Simulation results and comparison: In this section we present the results of our model and some comparisons are made with other known schemes. Generally, our proposed prioritized handover and finite queuing procedure leads to a significant optimization on the handover forced termination probability.

The following assumptions have been made during simulation:

- Connection request are generated according Poisson process
- The mean call duration, T_M *is* 120 seconds.
- The maximum speed of a mobile is 60 miles/hour or 96 kms/hour.
- The total number of available channels in each cell is $C = 20$.
- $C_h = 2$ channels of each cell are reserved only for handover calls.

- The cell radius is 1 km.
- The handover call to total call is $\lambda_h \cong \frac{\lambda}{3}$. this value is based on statistical measurements in real cellular systems.
- The queue length is set to $k = 3, 5$.

In order to calculate the other values that are involved in the simulation, we have used the appropriate equation presented in this paper. For example, to calculate the mean channel holding time (T_H), we substitute the values in Equations (1–3) and find out that $\mu_H \approx 1/85$ sec−1. The probability of handoff demand of new calls (P_N) and handoff (P_H) calls are calculated by using equation (22) and (23) respectively.

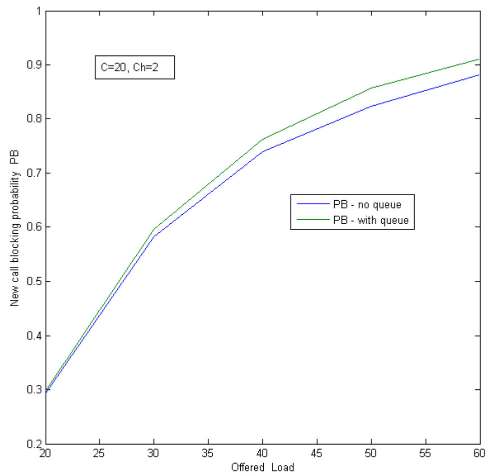

Figure 3: New call blocking probability versus offered load for queue and Non-queue strategy (C =20, C_h =2)

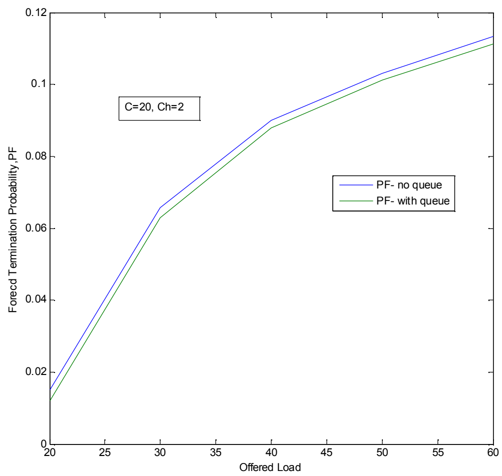

Figure 4: Handover forced termination probability, P_F versus offered load for queue and non-queue strategy. (C=20, C_h=2).

Figure 3 and figure 4 shows probability of new call blocking (P_B) and probability of handover forced termination (P_F) as a function of offered load for priority handover scheme and for our proposed handover queuing priority and finite storage scheme. It is observed from figure 3 that new call blocking probability for queue strategy is higher than non-queue strategy over a few ranges of parameter. This is due to the fact that in queue strategy blocked handover calls can be queued for a short duration of time while the mobile resides in handover area between the cells.

Figure 4 shows the comparison between the forced termination probabilities for queue and non-queue strategy. It is observed from figure 4 that forced termination probability of handover calls for queue strategy is smaller than non-queue strategy. We get this superiority of forced termination probability of handover call for queue strategy (priority scheme II) by queuing the delayed handoff attempts for the service time (The time for which a mobile resides in the handoff area) of the mobile in the handoff area. Service time depends on system parameters such as the speed and direction of the mobile travel and the cell size of the mobile in the handoff area.

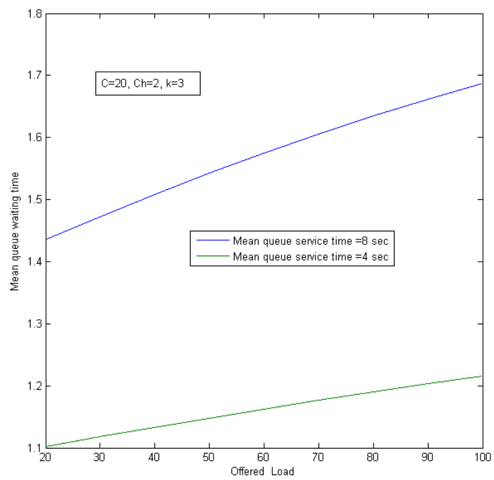

Figure 5: Mean queue waiting time versus offered load for different mean queue service times queue length k =3 (C=20, C_h=2, k=3, T_Q=4, 8 seconds)

It is observed from figure 5 that mean queue waiting time increases with increasing mean queue service time for a fixed queue length k=3.

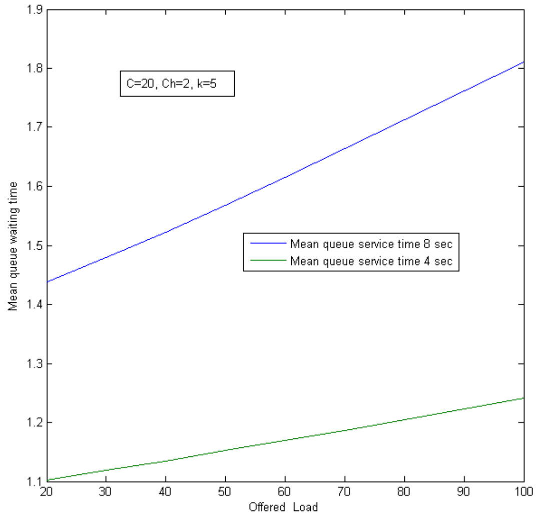

Figure 6: Mean queue waiting time versus Offered load for different mean queue service times queue length k=5 (C=20, C_h=2, k=5, T_Q=4, 8 seconds)

It is observed from figure 6 that for larger queue size mean queue waiting time initially almost same but it increases gradually with the increasing offered load.

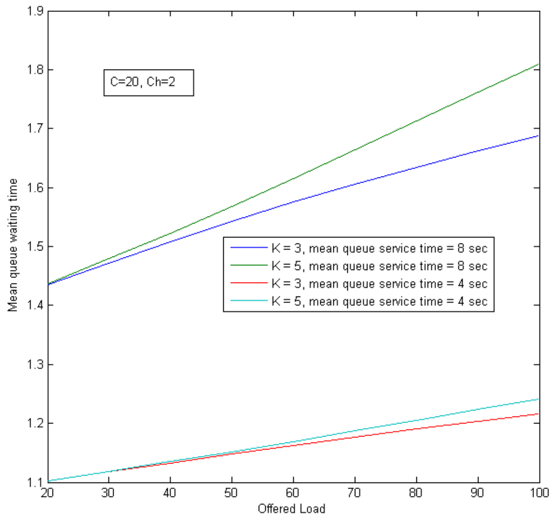

Figure 7: Comparison of Mean queue waiting time versus offered load for different queue size and mean queue service times (C=20, C_h=2, T_Q = 4, 8 seconds, K=3, 5)

Figure 7 shows the comparison between the result of figure 5 and 6. It is observed that mean queue waiting time increases with increasing offered load. For various values of the mean queue service time and for different queue sizes, one can noticed from figure 7 that as the offered load increases, the increment in $\overline{W_h}$ is more significant for a queue length of $k = 3$ than for a queue length of $k = 5$. This is due to the fact that in larger queue more handoff calls can wait, so the average waiting time is larger. It is also found that for the same service time with different queue sizes difference between mean queue waiting times as a function of offered load is smaller. But for different service time with different queue sizes difference between mean queue waiting times as a function of offered load is higher.

Conclusion

In this paper we have dealt a complex telecommunication traffic model based on prioritized handover procedure and finite storage queuing. The prioritized handover is achieved by reserving a small number of channels of each cell exclusively for the handover calls and only blocked handover calls are allowed to enter a finite storage queue. As a result high speed user can continue their call more easily. Here high speed user with multimedia call is also considered for this reason bandwidth management is also a important factor. Simulated result shows that new call blocking probability (P_B) is slightly larger for our proposed (queue strategy) scheme than non-queue scheme over a few ranges of parameters while forced termination probability (P_F) is lower for our proposed scheme than non-queue scheme which is desired. It is also found that mean queue waiting time is larger for larger queue size and different for different service times. The basic idea of our approach is that any blocked handover call should not wait in the queue for a very long time, either if this call is still in the handover area. Finding the suitable function for the mean waiting time in the queue, we have calculated an upper bound for the mean service time at each queue position.

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