International Journal of Electronics Communication and Computer Engineering
Volume 4, Issue 1, ISSN (Online): 2249–071X, ISSN (Print): 2278–4209

Performance Analysis of Prioritized Call Admission Control Schemes for Integrated Traffic in Wireless Network

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***Abstract* - Wireless/mobile communication systems are becoming increasingly popular in recent years. As the wireless resources are scarce, it is important to allocate resources efficiently and carefully, in order to achieve maximum output. The call admission control schemes play a significant role in providing the desired quality of service (QoS) by judiciously assigning the radio channels that are available in a micro cell. In this paper, we present two call admission control (CAC) schemes for wireless mobile network, (i) Prioritized call admission control (PCAC) scheme (S1) and (ii) Prioritized call admission control scheme with releasing function (S2). Both schemes support integrated traffic i.e. data and voice for both new and handoff attempts. Guard channel concept is used to give the priority to the handoff attempts. To admit more handoff attempts in the cellular system, buffering process is used for the handoff attempts. The concept of balking and reneging is also incorporated for both the schemes. The calls arrive in poisson fashion whereas channel holding time and cell residence times are exponentially distributed. The arrival rate of handoff attempts is computed by using iterative algorithm. Various performance metrics such as blocking probability of new call, blocking probability of handoff data/voice attempts, time out probability of handoff data/voice attempts, force termination probability of handoff data/voice attempts, waiting time of handoff data/voice attempts, carried load, etc. are determined. The sensitivity analysis has also been carried out to facilitate the insights of controllable parameters for real time systems.**

***Keyword* – Wireless mobile network, Call admission control, Handoff attempts, Priority, Balking, Reneging, Guard-channels, Releasing function, Blocking.**

I. INTRODUCTION

In wireless cellular network the service region is divided into cells, each of which is equipped with base station having a number of channels. Two different types of calls are shared by these channels i.e. the new calls and the handoff calls. The new calls are those, which are initiated by the mobile user in the current active cell whereas the handoff calls are those, which are initiated in other cells and handed over to the current active cell due to mobility of the user or otherwise. When a new call arrives to the cell, where all the channels are busy, it may be queued/blocked depending upon the call admission control scheme used. Two key goals of call admission control in the wireless/mobile networks are the efficient system resource utilization and improvement in the quality of service.

During the past decade, intensive research has been done and various handoff priority-based call admission control schemes have been investigated. A multi class calls admission control mechanism based on a dynamical reservation pool for handoff requests has been proposed by Hu and Sharma [5]. A dynamically adaptive channel reservation scheme has been developed by Salamah and Lababidi [15]. In this scheme handoff reserved channels have been assigned to new calls depending upon the locality principle, in which the base station with the help of location estimation algorithms in the mobile location centre predicts the position of mobile terminal. Islam and Murhed [7] have investigated an advance resource reservation and call admission control scheme for cellular networks to achieve efficient results in case of network congestion. For real time and non-real time traffic in cellular network, a channel allocation scheme with efficient bandwidth reservation was proposed by Krishna *et al.* [10]. In this scheme, initially some channels are reserved for handoff calls and later the channels are reserved dynamically, based on the user mobility. Goswami and Sawin [4] derived a finite population limited fractional guard channel (FPLFGC) policy for cellular network which allows the reservation of a real number of channels rather than an integer number of channels. For next generation wireless networks a call admission control scheme with two parameters, delay and signal to interference ratio was considered by Walingo and Takawira [16].

Today’s wireless communication networks are designed to provide the integrated services to the user, with predefined QoS space requirements. Zhang and Rappaport [19] have proposed a call admission control algorithm for guaranteed QoS in asymmetric integrated multimedia traffic in mobile network. A channel allocation scheme for voice and data traffic in wireless PCS network has been explored by Jain [8]. Islam *et al.* [6] proposed a model for three dimensional mixed traffic in cellular network for both limited and unlimited users. Yilmaz and Chen [18] derived the constraint for optimal pricing for multiple service classes in wireless cellular networks. An end-point admission control algorithm was proposed Moghim *et al.* [12] to manage the network traffic more efficiently. To evaluate the call blocking/dropping probability in a heterogeneous wireless network, Falowo [3] developed an analytical model using terminal-modality-based joint call admission control algorithm (TJCAC).

With the increasing use of mobile units for various applications, the issue of bandwidth allocation has become even more challenging problem to overcome in recent wireless communication systems. To resolve this problem various call admission control algorithms are developed for efficient allocation of available bandwidth, which also guarantee the QoS requirements. Pati *et al.* [13] described techniques for bandwidth reservation and call admission control for wireless mobile networks. An adaptive call admission scheme to control the bandwidth operation of an on going connection when the communication system was over loaded was developed by Prihandoko [14]. In this scheme multimedia traffic is classified in two forms i.e. real time and non real time traffic. Meybodi and Beigy [11] provided an adaptive and autonomous call admission algorithms for cellular mobile network in which a learning automation algorithm was used to minimize the blocking probability of new calls subject to the constraint on the dropping probability of the handoff calls. A framework called conservative and adaptive quality of service (CAQoS) to perform the quality of service for both real time and non real time traffic in wireless network was presented by Yee *et al.* [17]. The need for frequent bandwidth reallocation and to achieve lower call blocking and handoff dropping rates was explored. AlQahtani and Mahmoud [1] discussed a general framework for wide range of call admission control algorithms. They studied the performance analysis of call admission control schemes in multi-traffic mobile wireless networks and developed a simulation tool to test and verify their results. A call admission control scheme based on supervised learning technique for QoS optimization in heterogeneous network was proposed by Bashar *et al.* [2]. Kokila *et al.* [9] analysed the performance of 3G network through the throughput (TP) and dynamic partitioning (DP) CAC schemes.

In the present paper, we present two call admission control schemes (i) prioritized call admission control scheme without releasing function and (ii) prioritized call admission control scheme with releasing function. The guard channels are used to give the preference to handoff attempts so as to achieve the objective to reduce the blocking of handoff attempts. Further more, the handoff data and handoff voice attempts are queued up separately. While waiting in the queue, the handoff data and handoff voice attempts may balk or renege from the system. The rest of the paper is structured as follows. The traffic model description by stating the requisite assumptions and notations being used in the formulation of the mathematical model is presented in section 2. The call admission control schemes without and with releasing function are discussed along with the governing equations and related performance measures in section 3. The algorithm to compute handoff traffic is outlined in section 4. The sensitivity analysis has been performed to examine the effect of various parameters on the system performance in section 5. Finally, conclusions are drawn in section 6.

II. MODEL DESCRIPTION

We develop a traffic model for a cellular system, where all cells are statistically identical and each cell is served by a unique base station and the number of channels allocated to individual cell. There are two different arrival streams i.e. new arrival and handoff arrival, at each base station. Each stream is further divided into two classes, class 1 for voice attempts and class 2 for data attempts. Therefore, total four different types of input traffic i.e. new voice attempts, new data attempts, handoff voice attempts and handoff data attempts are served by the channels; the arrival rate of all types of calls follow the Poisson distribution. The service time i.e. call holding time and call residence time of mobile users in a micro cell for both data and voice attempts are assumed to have an exponential distribution with mean $1/\mu$ and $1/\eta$, respectively.

For modeling purpose, the following notations are used:

L (K)	Buffer size for handoff data (voice) attempts.
C	Total number of channels in a micro cell of the cellular system.
r	Number of reserve channels for handoff attempts in a micro cell.
λ_{nd} (λ_{nv})	Arrival rate of new data (voice) attempts.
λ_{hd} (λ_{hv})	Arrival rate of handoff data (voice) attempts.
λ_n (λ_h)	Integrated arrival rate of handoff data (voice) attempts; $\lambda_n = \lambda_{nd} + \lambda_{nv}$, $\lambda_h = \lambda_{hd} + \lambda_{hv}$.
Λ	Integrated arrival rate of attempts i.e. $\Lambda = \lambda_{nd} + \lambda_{nv} + \lambda_{hd} + \lambda_{hv}$
σ	Integrated service rate, i.e. $\sigma = \mu+\eta$.
B_{nd} (B_{nd})	Blocking probability of new data (voice) attempts.
B_{hv} (B_{hd})	Blocking probability of handoff voice (data) attempts.
B_o	Overall blocking probability.
Q_{hd} (Q_{hv})	Average queue length of handoff data (voice) attempts.
B_{fhd} (B_{fhv})	Force termination probability of handoff data (voice) attempts.
B_{thd} (B_{thv})	Time out probability of handoff data (voice) attempts.
W_{hd} (W_{hv})	Average waiting time of handoff data (voice) attempts.
CL	Carried load of the system.
P_n	The probability that there are 'n' voice/data attempts in the system.
$P_{i,j}$	The probability that there are $(C\text{-}r + i + j)$ attempts in the system, where i and j denote the handoff voice attempts and handoff data attempts, respectively.

III. CALL ADMISSION CONTROL SCHEMES

This section is devoted to present call admission control policies by giving priority to handoff attempts. In subsection 3.1, we discuss a call admission control scheme without releasing function whereas in subsection 3.2 call admission control scheme with releasing function is described.

3.1 Prioritized call admission control scheme without releasing function (S1)

In this policy, some channels (i.e. guard channels) out of total channels are reserved for handoff attempts to give them priority over the new attempts. Initially all types of attempts are allowed to occupy the channels; after a threshold level i.e. *C-r* calls, only handoff attempts are accepted. In the case of heavy handoff traffic, when all available channels are busy, the handoff attempts are queued in a finite buffer. Handoff voice and handoff data attempts are separately queued in their own queues of finite capacity. Balking and reneging concepts are also incorporated in this scheme i.e. the calls/packets may balk or renege from the system if channels are occupied. Whenever all channels are occupied, the handoff data packets and handoff voice calls may renege exponentially from the system with parameters α_d and α_v, while they join the queue with probability β_d and β_v, respectively. The reneging parameters are also considered as time out parameters i.e. when attempts are waiting in the queue and if the waiting time reaches to a certain limit, then the attempts will not get the service and force to leave the system. When both handoff data and handoff voice attempts are buffered in the queue, then priority is given to the handoff voice calls over the handoff data packets i.e. handoff voice call gets the service whereas handoff data packet leaves the system as its waiting service time is over. The state transition diagram showing the traffic flow is depicted in fig. 1.

We construct the system of equations governing the traffic model for scheme S1 as follows:

$$\sigma P_1 - \Lambda P_0 = 0 \qquad (1)$$

$$(n+1)\sigma P_{n+1} - (\Lambda + n\sigma)P_n + \Lambda P_{n-1} = 0\,; \qquad 0 < n < C\text{-}r \qquad (2)$$

$$\begin{aligned}&(C-r+1)\sigma\{P_{0,1}+P_{1,0}\}-(\lambda_{hv}+\lambda_{hd}\\&\qquad +(C-r)\sigma)P_{C-r}+\Lambda P_{C-r-1}=0\end{aligned} \qquad (3)$$

$$\begin{aligned}&(C-r+2)\sigma\{P_{1,1}+P_{2,0}\}-\{\lambda_{hv}+\lambda_{hd}\\&\qquad +(C-r+1)\sigma\}P_{1,0}+\lambda_{hv}P_{C-r}=0\end{aligned} \qquad (4)$$

$$\begin{aligned}&(C-r+2)\sigma\{P_{0,2}+P_{1,1}\}-\{\lambda_{hv}+\lambda_{hd}\\&\qquad +(C-r+1)\sigma\}P_{0,1}+\lambda_{hd}P_{C-r}=0\end{aligned} \qquad (5)$$

$$\begin{aligned}&\{C-r+(i+1)\}\sigma\{P_{i,1}+P_{i+1,0}\}-\\&\{\lambda_{hv}+\lambda_{hd}+(C-r+i)\sigma\}P_{i,0}+\lambda_{hv}P_{i-1,0}=0\,;\\&\qquad 2\le i\ \le r\text{-}1\end{aligned} \qquad (6)$$

$$\begin{aligned}&\{C-r+(j+1)\}\sigma\{P_{0,j+1}+P_{1,j}\}-\{\lambda_{hv}+\lambda_{hd}\\&+(C-r+j)\sigma\}P_{0,j}+\lambda_{hv}P_{0,j-1}=0\,;\\&\qquad 2\le j\ \le r\text{-}1\end{aligned} \qquad (7)$$

$$\begin{aligned}&\alpha_d P_{r,1}+(C\sigma+\alpha_v)P_{r+1,0}-(\beta_v\lambda_{hv}\\&\qquad +\beta_d\lambda_{hd}+C\sigma)P_{r,0}+\lambda_{hv}P_{r-1,0}=0\end{aligned} \qquad (8)$$

$$\begin{aligned}&(C\sigma+\alpha_d)P_{0,r+1}+(C\sigma+\alpha_v)P_{1,r}-(\beta_v\lambda_{hv}\\&\qquad +\beta_d\lambda_{hd}+C\sigma)P_{0,r}+\lambda_{hd}P_{0,r-1}=0\end{aligned} \qquad (9)$$

$$\begin{aligned}&\alpha_d P_{i,1}+[C\sigma+\{(i+1)-r)\}\alpha_v]P_{i+1,0}-[\beta_v\lambda_{hv}+\\&\beta_d\lambda_{hd}+\{C\sigma+(i-r)\alpha_v\}]P_{i,0}+\beta_v\lambda_{hv}P_{i-1,0}=0;\\&\mathrm{r}+1\le i\le r+K-1\end{aligned} \qquad (10)$$

$$\begin{aligned}&[C\sigma+\{(j+1)-r)\}\alpha_d]P_{0,j+1}+\{C\sigma+\alpha_v\}P_{1,j}\\&-[\beta_v\lambda_{hv}+\beta_d\lambda_{hd}+\{C\sigma+(j-r)\alpha_d\}]P_{0,j}\\&+\beta_d\lambda_{hd}P_{0,j-1}=0;\ \ \mathrm{r}+1\le j\le r+L-1\end{aligned} \qquad (11)$$

$$\beta_v\lambda_{hv}P_{r+K-1,0}-(C\sigma+K\alpha_v)P_{r+K,0}=0 \qquad (12)$$

$$\beta_d\lambda_{hd}P_{0,r+L-1}-(C\sigma+L\alpha_d)P_{0,r+L}=0 \qquad (13)$$

$$\begin{aligned}&\{C-r+j+(i+1)\}P_{i+1,j}+\{C-r+i+(j+1)\}P_{i,j+1}\\&-\{2(C-r+i+j)+\lambda_{hd}+\lambda_{hv}\}P_{i,j}+\lambda_{hv}P_{i-1,j}\\&+\lambda_{hd}P_{i,j-1}=0;1\le i\le r-1,1\le j\le r-1,2\le i+j\le r-1\end{aligned} \qquad (14)$$

$$\begin{aligned}&(C\sigma+\alpha_v)P_{i+1,j}+\alpha_d P_{i,j+1}-\{\beta_d\lambda_{hd}+\beta_v\lambda_{hv}\\&\qquad +2(C\sigma)\}P_{i,j}+\lambda_{hv}P_{i-1,j}+\lambda_{hd}P_{i,j-1}=0\,;\\&\qquad \mathrm{i}\ne 0,\ \mathrm{j}\ne 0,\ \mathrm{i}+\mathrm{j}=\mathrm{r}\end{aligned} \qquad (15)$$

$$\begin{aligned}&P_{i,j+1}\{(j+1)\alpha_d\}+P_{i+1,j}[C\sigma+\{(i+1)+j-r\}\alpha_v]\\&+P_{i,j-1}\beta_d\lambda_{hd}+P_{i-1,j}\beta_v\lambda_{hv}-[\beta_v\lambda_{hv}+\beta_d\lambda_{hd}\\&+\{C\sigma+(i+j-r)\alpha_v\}+j\alpha_d]P_{i,j}=0;\\&r\le i\le r+K\text{-}2,\ 1\le j\le r,\ r+1\le i+j\le r+K\text{-}1\end{aligned} \qquad (16)$$

$$\begin{aligned}&\{C\sigma+(i+1)\alpha_v\}P_{i+1,j}+[\{i+(j+1)\}-r]\alpha_d P_{i,j+1}\\&+\beta_v\lambda_{hv}P_{i-1,j}+\beta_d\lambda_{hd}P_{i,j-1}-\{\beta_v\lambda_{hv}+\beta_d\lambda_{hd}\\&+(C\sigma+i\alpha_v)+(i+j-r)\alpha_d\}P_{i,j}=0;\\&1\le i\le r,\ r\le j\le K+L\text{-}5,\ r+1\le i+j\le K+L\text{-}4\end{aligned} \qquad (17)$$

$$\begin{aligned}&[C\sigma+\{(i+1)+j-r\}\alpha_v]P_{i+1,j}+[\{i+(j+1)\}-r]\\&\alpha_d P_{i,j+1}+\beta_v\lambda_{hv}P_{i-1,j}+\beta_d\lambda_{hd}P_{i,j-1}-\{\beta_v\lambda_{hv}+\beta_d\lambda_{hd}\\&+\{C\sigma+(i+j-r)\alpha_v\}+(i+j-r)\alpha_d\}P_{i,j}=0;\\&2\le i\le r\text{-}1,\ 2\le j\le r\text{-}1,\ r+1\le i+j\le 2r\text{-}2\end{aligned} \qquad (18)$$

$$\begin{aligned}&\{C\sigma+(i+1)\alpha_v\}P_{i+1,j}+[\{i+(j+1)\}-r]\\&\alpha_d P_{i,j+1}+\beta_v\lambda_{hv}P_{i-1,j}+\beta_d\lambda_{hd}P_{i,j-1}-\{\beta_v\lambda_{hv}\\&+\beta_d\lambda_{hd}+(C\sigma+i\alpha_v)+(i+j-r)\alpha_d\}P_{i,j}=0;\\&\qquad 1\le i\le r,\ r+1\le j\le r+L\text{-}2,\\&\qquad K+L\text{-}3\le i+j\le K+L-2\end{aligned} \qquad (19)$$

$$\{C\sigma+(i+1)\alpha_v\}P_{i+1,j}+(j+1)\alpha_d P_{i,j+1}$$
$$+\beta_v\lambda_{hv}P_{i-1,j}+\beta_d\lambda_{hd}P_{i,j-1}-\{\beta_v\lambda_{hv}$$
$$+\beta_d\lambda_{hd}+(C\sigma+i\alpha_v)+j\alpha_d\}P_{i,j}=0;$$
$$r+1\le i\le K-1,\ r+1\le j\le L-1,$$
$$K+r-1\le i+j\le K+r+1 \tag{20}$$

$$\beta_v\lambda_{hv}P_{K-1,L}+\beta_d\lambda_{hd}P_{K,L-1}-\{(C\sigma+K\alpha_v)+L\alpha_d\}P_{K,L}=0 \tag{21}$$

$$\{C\sigma+(i+1)\alpha_v\}P_{i+1,L}-\{\beta_v\lambda_{hv}+(C\sigma+i\alpha_v)$$
$$+L\alpha_d\}P_{i,j}+\beta_v\lambda_{hv}P_{i-1,L}+\beta_d\lambda_{hd}P_{i,L-1}=0;$$
$$r\le i\le K-1,\ r+L\le i+j\le K+L-1 \tag{22}$$

$$\beta_v\lambda_{hv}P_{i-1,j}+\beta_d\lambda_{hd}P_{i,j-1}-\{(C\sigma+i\alpha_v)$$
$$+L\alpha_d\}P_{i,j}=0;$$
$$1\le i<r-1,L+1\le j\le r+L-1,\ i+j=r+L \tag{23}$$

$$\beta_v\lambda_{hv}P_{i-1,j}+\beta_d\lambda_{hd}P_{i,j-1}-\{(C\sigma+K\alpha_v)$$
$$+j\alpha_d\}P_{i,j}=0;$$
$$K+1\le i\le r+K-1,\ 1\le j\le r-1,\ i+j=r+K \tag{24}$$

$$(j+1)\alpha_d P_{i,j+1}-\{\beta_d\lambda_{hd}+(C\sigma+i\alpha_v)$$
$$+j\alpha_d\}P_{i,j}+\beta_v\lambda_{hv}P_{i-1,j}+\beta_d\lambda_{hd}P_{i,j-1}=0;$$
$$i=K,\ r\le j<L-1,\ K+r\le i+j\le K+L-1 \tag{25}$$

The analytical solution of the above set of differential equations is tedious, so we approach to use the well established successive over relaxation (SOR) method. It is an iterative numerical technique by which we can obtain the approximate solution for the steady state probabilities.

Performance Indices

The above set of (1)-(25) is solved by using SOR method for finding the steady state probabilities. Now we establish the explicit formulae for some performance measures in terms of steady state probabilities as follows:

- The blocking probability of new data packets (B_{nd}), new voice calls (B_{nv}) and new attempts (B_n) are given by

$$B_{nd}=B_{nv}=B_n=1-\sum_{i=0}^{C-r-1}P_i \tag{26}$$

- The blocking probability of handoff data packets is obtained as

$$B_{hd}=P_{0,r+L}+\sum_{i=r}^{K}P_{i,L}+\sum_{\substack{i=1\\ \text{with}}}^{r-1}\sum_{\substack{j=L+1\\ i+j=r+L}}^{r+L-1}P_{i,j}+\sum_{\substack{i=K+1\\ \text{with}}}^{r+K-1}\sum_{\substack{j=1\\ i+j=r+K}}^{r-1}P_{i,j} \tag{27}$$

- The blocking probability of handoff voice calls is computed using

$$B_{hv}=P_{r+K,0}+\sum_{j=r}^{L}P_{K,j}+\sum_{\substack{i=K+1\\ \text{with}}}^{r+K-1}\sum_{\substack{j=1\\ i+j=r+K}}^{r-1}P_{i,j}+\sum_{\substack{i=1\\ \text{with}}}^{r-1}\sum_{\substack{j=L+1\\ i+j=r+L}}^{r+L-1}P_{i,j} \tag{28}$$

- The overall blocking probability is given by

$$B=\frac{\lambda_n B_n+\lambda_{hd}B_{hd}+\lambda_{hv}B_{hv}}{\Lambda} \tag{29}$$

- The average queue length of handoff data packets is determined by using

$$L_{hd}=\sum_{i=0}^{r}\sum_{j=(r+1)-i}^{(r+L)-i}(i+j-r)P_{i,j}+\sum_{i=r+1}^{K}\sum_{j=1}^{L}jP_{i,j}+\sum_{i=K+1}^{r+K-1}\sum_{j=1}^{(r+K)-i}jP_{i,j} \tag{30}$$

- The average queue length of handoff voice calls is given by

$$L_{hv}=\sum_{j=0}^{r}\sum_{i=(r+1)-j}^{(r+K)-j}(i+j-r)P_{i,j}+\sum_{j=r+1}^{L}\sum_{j=1}^{K}iP_{i,j}+\sum_{j=L+1}^{r+L-1}\sum_{i=1}^{(r+L)-i}iP_{i,j} \tag{31}$$

- The average number of handoff voice calls is equal to $(1-B_{hd})\lambda_{hd}$ whereas the mean dropped packets in the unit time is given by $\alpha_d L_{hd}$. Therefore, the time out probability for handoff data packets is given by

$$TOP_{hd}=\alpha_d L_{hd}[(1-B_{hd})\lambda_{hd}]^{-1} \tag{32}$$

- The time out probability for handoff voice calls is

$$TOP_{hv}=\alpha_v L_{hv}[(1-B_{hv})\lambda_{hv}]^{-1} \tag{33}$$

- The force termination probability of handoff data packets is the sum of blocking probability of handoff data packets and the time out of handoff data packets and is obtained as

$$FTP_{hd}=B_{hd}+(1-B_{hd})TOP_{hd} \tag{34}$$

- The force termination probability of handoff voice calls is computed as

$$FTP_{hv}=B_{hv}+(1-B_{hv})TOP_{hv} \tag{35}$$

- By using Little's formula the average waiting time of handoff data packets is given by

$$W_{hd}=L_{hd}[(1-B_{hd})\lambda_{hd}]^{-1} \tag{36}$$

- The waiting time of handoff voice calls is

$$W_{hv}=L_{hv}[(1-B_{hv})\lambda_{hv}]^{-1} \tag{37}$$

- The carried load of the system is calculated by using

$$CL=\frac{(1-\lambda_n)B_n+(1-\lambda_{hd})B_{hd}+(1-\lambda_{hv})B_{hv}}{\Lambda} \tag{38}$$

3.2 Prioritized call admission control scheme with releasing function (S2)

In this scheme, all the assumptions and notations are same as mentioned in the previous scheme S1, but here we incorporate an additional feature of releasing function for new attempts. The transition flow diagram for this scheme is given in fig. 2. In heavy traffic condition in the network, it becomes difficult to deal with the overflowing traffic. In this case it is necessary to serve the new attempts in a different manner. This can be achieved by using modified scheme where the new attempts can also occupy the reserved channels, in case of light traffic of handover attempts provided these channels are available. Following reserve channel-releasing function is used for this purpose:

$$f(i+j)=\frac{1}{\sqrt{i+j+1}},\ where\ C-r\le i+j\le C \tag{39}$$

It is a decreasing function of the chance of occupying reserved channels by new attempts.

For this scheme, (4)-(9) and (14)-(15) of the previous case are replaced by following (40)-(47), respectively and the remaining equations are same as mentioned for previous scheme.

$$(C-r+1)\sigma(P_{0,1}+P_{1,0})-P_{C-r}[\lambda_{hd}+\{(\lambda_{nv}f(0)) \\ +\lambda_{hv}\}+C-r\sigma]+\Lambda P_{C-r-1}=0 \tag{40}$$

$$(C-r+2)\sigma(P_{1,1}+P_{2,0})-P_{1,0}[\lambda_{hd}+\{(\lambda_{nv}f(1)) \\ +\lambda_{hv}\}+(C-r+1)\sigma]+\{(\lambda_{nv}f(0))+\lambda_{hv}\}P_{C-r}=0 \tag{41}$$

$$(C-r+2)\sigma(P_{0,2}+P_{1,1})-P_{0,1}[\lambda_{hd}+\{(\lambda_{nv}f(1)) \\ +\lambda_{hv}\}+(C-r+1)\sigma]+\lambda_{hd}P_{C-r}=0 \tag{42}$$

$$(C-r+i+1)\sigma(P_{i,1}+P_{i+1,0})-P_{i,0}[\lambda_{hd}+\{(\lambda_{nv}f(i)) \\ +\lambda_{hv}\}+(C-r+i)\sigma]+\{(\lambda_{nv}f(i-1))+\lambda_{hv}\}P_{i-1,0}=0; \\ 2\le i\le r-1 \tag{43}$$

$$(C-r+j+1)\sigma(P_{0,j+1}+P_{1,j})-P_{0,j}[\lambda_{hd}+ \\ \{(\lambda_{nv}f(j))+\lambda_{hv}\}+(C-r+j)\sigma]+\lambda_{hd}P_{0,j-1}=0; \\ 2\le j\le r-1 \tag{44}$$

$$(C\sigma+\alpha_v)P_{r+1,0}+j\alpha_d P_{r,1}-(\beta_v\lambda_{hv}+\beta_d\lambda_{hd} \\ +C\sigma)P_{r,0}+[\{\lambda_{nv}f(r-1)\}+\lambda_{hv}]\lambda_{hv}P_{r-1,0}=0 \tag{45}$$

$$\{C-r+j+(i+1)\}P_{i+1,j}+\{C-r+i+(j+1)\}P_{i,j+1} \\ -[2(C-r+i+j)+\lambda_{hd}+\{(\lambda_{nv}f(i+j))+\lambda_{hv}\}]P_{i,j} \\ +[\{\lambda_{nv}f(i+j-1)\}+\lambda_{hv}]P_{i-1,j}+\lambda_{hd}P_{i,j-1}=0; \\ 1\le i<r-1,\ 1\le j<r-1,\ 2\le i+j\le r-1 \tag{46}$$

$$(C\sigma+\alpha_v)P_{i+1,j}+\alpha_d P_{i,j+1}-\{\beta_d\lambda_{hd}+\beta_v\lambda_{hv}+ \\ 2(C\sigma)\}P_{i,j}+[\{\lambda_{nv}f(r-1)\}+\lambda_{hv}]P_{i-1,j}+\lambda_{hd}P_{i-1,j}=0; \\ i\ne 0,\ j\ne 0,\ i+j=r \tag{47}$$

Performance Indices

Now, we provide some measures of performance to describe the system performability and efficiency corresponding to the scheme S2 as follows:

Blocking probability of new attempts is

- $$B_n=1-\left(\begin{array}{l}\sum_{n=0}^{C-r}P_n+\sum_{\substack{i=1\\ with\ j=0}}^{r-1}P_{i,j}\\ +\sum_{\substack{j=0\\ with\ i=0}}^{r-1}P_{i,j}+\sum_{i=1}^{r-2}\sum_{\substack{j=1\\ with\ 2\le i+j\le r-1}}^{r-1}P_{i,j}\end{array}\right) \tag{48}$$

Other performance measures are obtained by the same formulae as given by (27)-(38) for scheme S1 without releasing function.

IV. COMPUTATION OF HANDOFF TRAFFIC

We use the following iterative algorithm to compute the arrival rates of handoff voice/data attempts. The blocking probabilities and arrival rates of new attempts and the handoff arrival rates are interdependent and given by the following relation:

$$\lambda_{hd}=\frac{\eta(1-B_n)}{\mu+\eta B_{hd}}\lambda_{nd}\ \ and\ \ \lambda_{hv}=\frac{\eta(1-B_n)}{\mu+\eta B_{hv}}\lambda_{nv} \tag{49}$$

Handoff Algorithm

```
set $\lambda_{hd}=0$ and $\lambda_{hv}=0$
while $|\delta|<\varepsilon\ (say\ \varepsilon=.00001)$ do
set $B_n$, $B_{hd}$ and $B_{hv}$
set $\lambda_{hd}=\frac{\eta(1-B_n)}{\mu+\eta B_{hd}}\lambda_{nd}$
and $\lambda_{hv}=\frac{\eta(1-B_n)}{\mu+\eta B_{hv}}\lambda_{nv}$
set $\lambda_h=\lambda_{hd}+\lambda_{hv}$
set $\delta=\left|\frac{old(\lambda_h)-new(\lambda_h)}{new(\lambda_h)}\right|$
end while
return ($B_n$, $B_{hv}$, $B_{hd}$, $B$, $CL$,
        $L_{hv}$, $L_{hd}$, $TOP_{hv}$ $TOP_{hd}$,
        $FTP_{hv}$, $FTP_{hd}$, $W_{hv}$, $W_{hv}$)
end Algorithm
```

V. SENSITIVITY ANALYSIS

In this section, the sensitivity analysis is carried out to examine the analytical results. The coding for the computer program is done in software MATLAB. We choose the system parameters as: C=10, r=3, L=6, K=4, μ = 1.5, η= 0.65, α_d = 0.4 and α_v = 0.2. The arrival rates of new data packets and new voice calls are taken as λ_{nd}=2.4 and λ_{nv}= 2.2. Various performance indices for the proposed schemes are summarized in tables 1-2 and figs 3-4. We present a comparison between two suggested schemes through figs 3-4. The smooth (dotted) lines show the results corresponding to S1 (S2).

Table 1 (2) display the effect of β_v on the time out probability of handoff data packets (TOP_{hd}), time out probability of handoff voice calls (TOP_{hv}), forced termination probability of handoff data packets (FTP_{hd}), forced termination probability of handoff voice calls (FTP_{hv}), waiting time of handoff data packets (W_{hd}) and waiting time of handoff voice calls (W_{hv}) and carried load (CL) for different values of λ_{nd} and λ_{nv} for S1 (S2), respectively. In all the cases, it is clear that all the indices except carried load give the increasing trend on increasing β_v with the increase in arrival rate of new attempts. Carried load of the system decreases on increasing the arrival rate of new attempts as well as the joining probability of handoff voice calls.

Figs 3(a-c) show the effect of arrival rates of data attempts (λ_{nd}) on the blocking probability of new attempts (B_n), blocking probability of handoff data attempts (B_{hd}) and blocking probability of handoff voice attempts (B_{hv}) respectively, for different values of joining probability of handoff voice attempts (β_v). Fig. 3(a) shows that B_n increases slightly on increasing λ_{nd}. Here, we notice that B_n reveals the decreasing trend for S2 in comparison to S1. Figs 3(b-c) exhibit that B_{hd} and B_{hv} increase slowly with the increase in λ_{nd}. However, B_{hd} and B_{hv} give the more prominent decreasing pattern for S1 in comparison to S2. In figs 4(a-c), we show the effect of λ_{nd} on overall blocking probability of attempts (B_o), average queue length of handoff data packets (L_{hd}) and average queue length of handoff voice calls (L_{hv}) respectively, for different values of β_v. From fig. 4(a) we observe the increasing trend in B_o by varying λ_{nd}. It is clear that B_o decreases for S1 in comparison to S2, which is as per our expectation. Figs 4(b-c) show that L_{hd} and L_{hv} slightly increases by increasing λ_{nd}. In both the figs, we notice the increasing pattern for L_{hd} and L_{hv} for S1 in comparison to S2.

Overall, we conclude that the blocking probabilities increase on increasing the arrival rate of new attempts as well as the joining probability of handoff voice calls. It is noticed that by using S2, we can reduce the blocking probability of new attempts and overall blocking probability of both new and handoff attempts to some extent.

VI. CONCLUSION

To satisfy increasing diverse access requirements, the call admission control scheme must be carefully designed to provide the guaranteed QoS to the mobile users. In this paper, we have developed the integrated traffic model for call admission control in wireless network. Two different call admission control schemes without and with releasing function are proposed. As the arrival rate of handoff attempts depend upon the arrival rate of new attempts, we have suggested an iterative algorithm to compute the arrival rate of handoff attempts. The incorporation of balking and reneging parameters makes our model more closer to real life situations. The computational tractability of SOR method is validated by taking numerical illustration. It is hoped that the developed schemes may be helpful to the system designers and engineers to reduce the blocking probability of handoff calls to a desirable extent. Thus it may reduce the congestion in case of heavy traffic conditions in wireless communication networks so that the desired grade of service can be achieved. Our work can be further modified by applying the subrating scheme for the handoff attempts.

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Table 3: Effect of β_v on performance indices for different values of λ_{nd} and λ_{nv} for first scheme (S1)

λ_{nd}	λ_{nv}	β_v	TOP_{hd}	TOP_{hv}	FTP_{hd}	FTP_{hv}	W_{hd}	W_{hv}	CL
2.4	2.2	0.3	2.6E-07	1.1E-07	2.6E-07	1.1E-07	6.6E-07	5.7E-07	0.981821
2.4	2.2	0.6	3.2E-07	1.5E-07	3.2E-07	1.5E-07	8.2E-07	7.7E-07	0.981819
2.4	2.2	0.9	3.9E-07	1.9E-07	3.9E-07	1.4E-07	9.7E-07	9.8E-07	0.981818
2.5	2.2	0.3	3.0E-07	1.3E-07	3.0E-07	1.3E-07	7.5E-07	6.5E-07	0.980736
2.5	2.2	0.6	3.6E-07	1.7E-07	3.6E-07	1.7E-07	9.1E-07	8.7E-07	0.980734
2.5	2.2	0.9	4.3E-07	2.2E-07	4.3E-07	2.2E-07	1.0E-06	1.1E-06	0.980733
2.6	2.0	0.3	2.6E-07	1.2E-07	2.6E-07	1.2E-07	6.7E-07	6.1E-07	0.981820
2.6	2.0	0.6	3.2E-07	1.6E-07	3.2E-07	1.6E-07	8.0E-07	8.1E-07	0.981819
2.6	2.0	0.9	3.8E-07	2.0E-07	3.8E-07	2.0E-07	9.5E-07	1.0E-06	0.981817
2.6	2.1	0.3	3.0E-07	1.3E-07	3.0E-07	1.3E-07	7.5E-07	6.7E-07	0.980735
2.6	2.1	0.6	3.6E-07	1.8E-07	3.6E-07	1.8E-07	9.1E-07	9.0E-07	0.980734
2.6	2.1	0.9	4.3E-07	2.2E-07	4.3E-07	2.2E-07	1.0E-06	1.1E-06	0.980733

Table 4: Effect of β_v on performance indices for different values of λ_{nd} and λ_{nv} for second scheme (S2)

λ_{nd}	λ_{nv}	β_v	$T0P_{hd}$	$T0P_{hv}$	FTP_{hd}	FTP_{hv}	W_{hd}	W_{hv}	CL
2.4	2.2	0.3	1.8E-06	1.1E-06	1.8E-06	1.1E-06	4.7E-06	5.7E-06	0.998535
2.4	2.2	0.6	2.1E-06	1.4E-06	2.1E-06	1.4E-06	5.4E-06	7.3E-06	0.998534
2.4	2.2	0.9	2.4E-06	1.7E-06	2.4E-06	1.8E-06	6.1E-06	8.9E-06	0.998533
2.5	2.2	0.3	2.0E-06	1.2E-06	2.0E-06	1.2E-06	5.1E-06	6.3E-06	0.998434
2.5	2.2	0.6	2.3E-06	1.6E-06	2.3E-06	1.6E-06	5.8E-06	8.0E-06	0.998433
2.5	2.2	0.9	2.6E-06	1.9E-06	2.6E-06	1.9E-06	6.6E-06	9.9E-06	0.998432

2.6	2.0	0.3	1.5E-06	1.0E-06	1.5E-06	1.0E-06	3.9E-06	5.3E-06	0.998625
2.6	2.0	0.6	1.8E-06	1.3E-06	1.8E-06	1.3E-06	4.5E-06	6.7E-06	0.998625
2.6	2.0	0.9	2.0E-06	1.6E-06	2.0E-06	1.6E-06	5.1E-06	8.1E-06	0.998624
2.6	2.1	0.3	1.8E-06	1.2E-06	1.8E-06	1.2E-06	4.7E-06	6.1E-06	0.998482
2.6	2.1	0.6	2.1E-06	1.5E-06	2.1E-06	1.5E-06	5.3E-06	7.7E-06	0.998481
2.6	2.1	0.9	2.4E-06	1.8E-06	2.4E-06	1.8E-06	6.0E-06	9.4E-06	0.998480

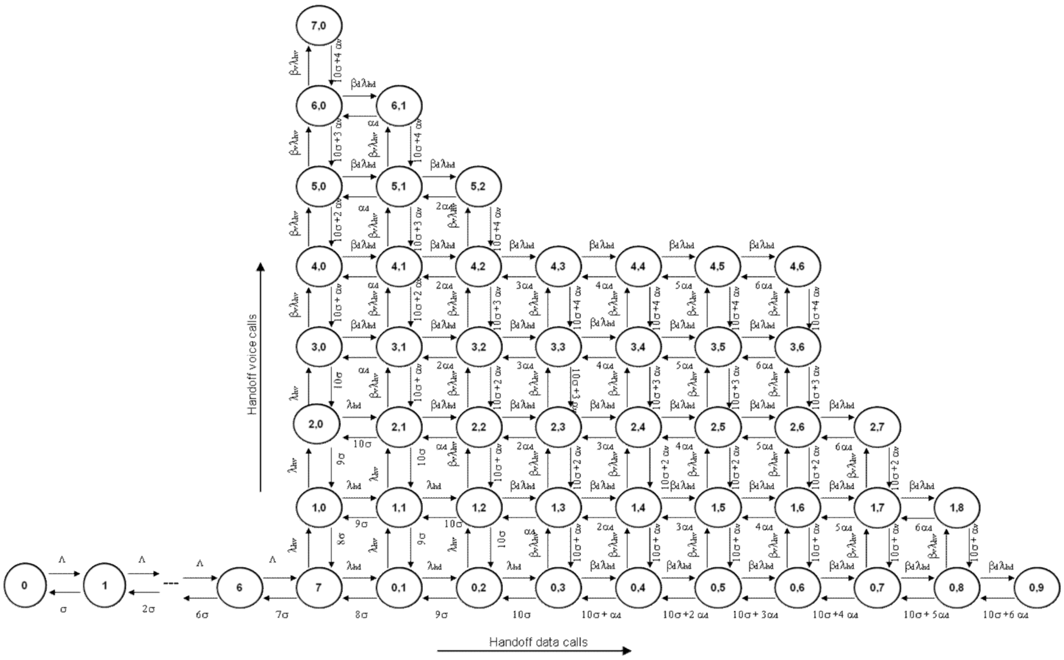


Fig.1. State transition diagram for call admission control scheme without releasing function (S1) for C = 10, r = 3, L = 6 and K = 4.

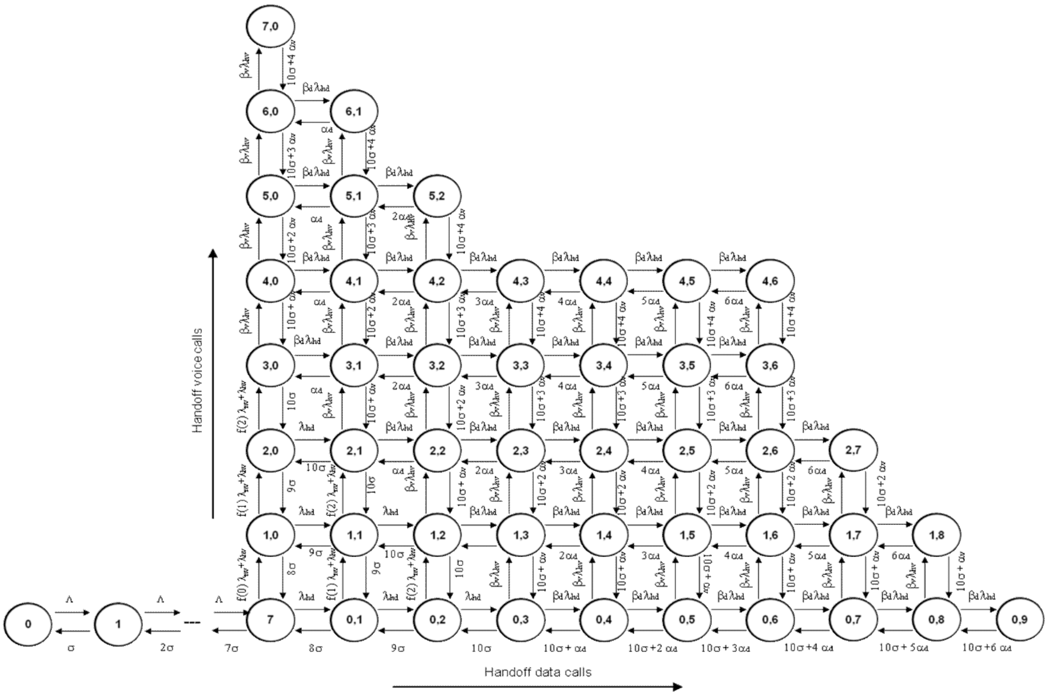
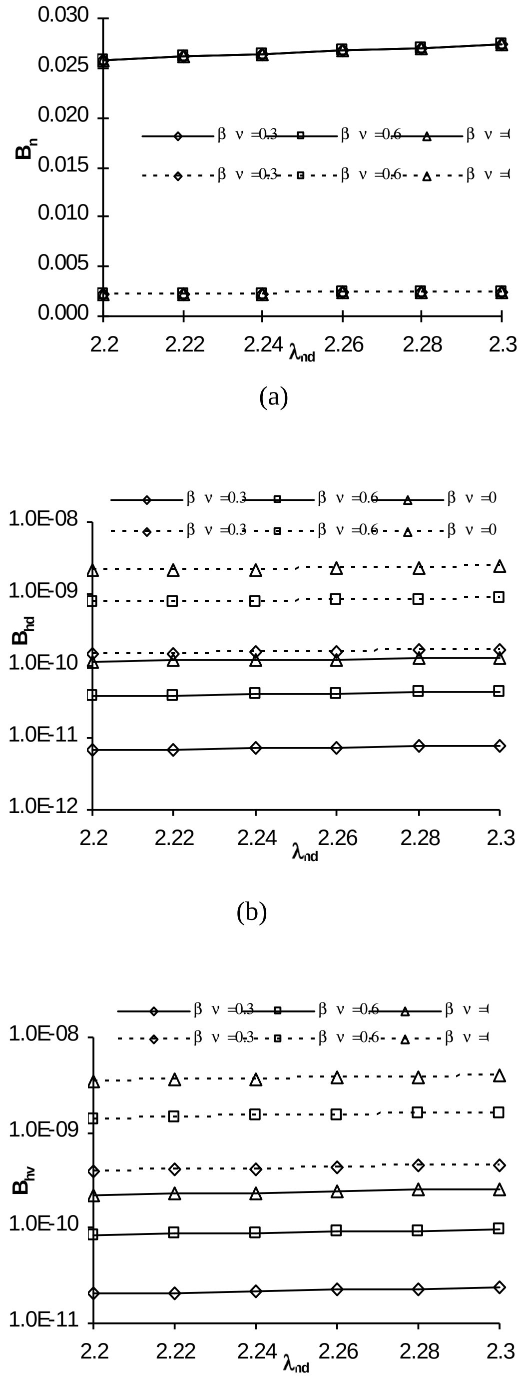


Fig.2. State transition diagram for call admission control scheme with releasing function (S2) for C = 10, r = 3, L = 6 and K = 4.

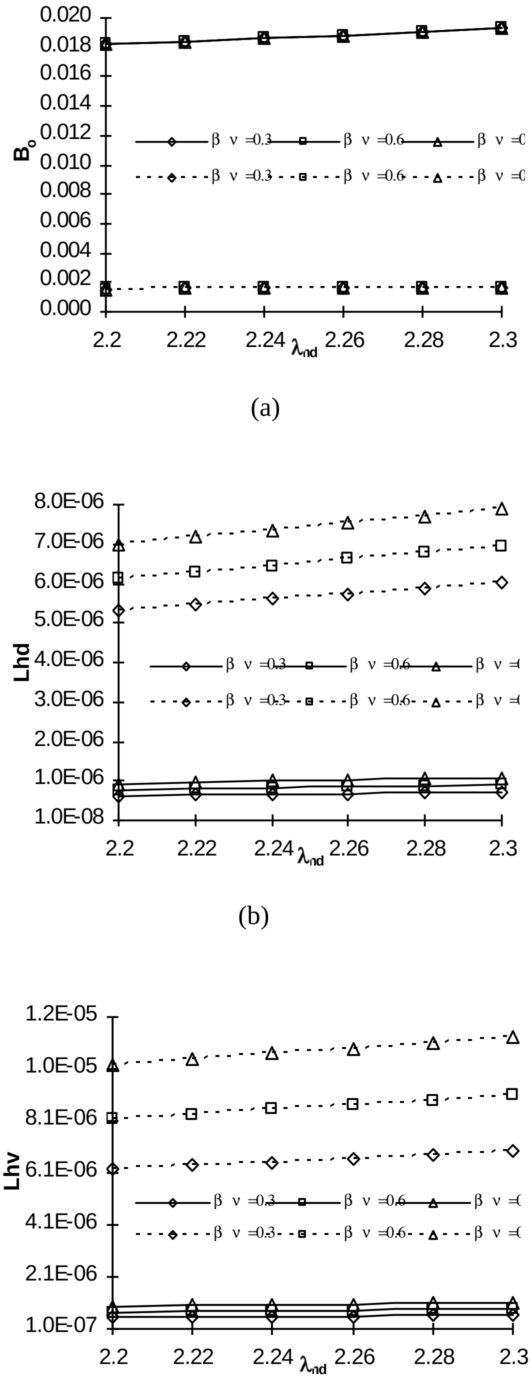


(a)

(b)

(c)

Fig.3. Effect of λ_{nd} on (a) B_n (b) B_{hd} (c) B_{hv} for different values of β_v.



(a)

(b)

(c)

Fig.4. Effect of λ_{nd} on (a) B_o (b) L_{hd} (c) L_{hv} for different values of β_v.