African Journal of Mathematics and Computer Science Research Vol. 2(8), pp. 167-178, September, 2009
Available online at http://www.academicjournals.org/ajmcsr

Full Length Research Paper

Adaptation of the preemptive handoff scheme in an integrated mobile communication environment

Chiranjeev Kumar[1*] and Rajeev Tripathi[2]

[1]Department of Computer Science and Engineering, ISM University, Dhanbad – 826 004, Jharkhand (India) or #New D/17, Teacher's Colony, ISMU Campus, Dhanbad.
[2]Department of Electronics and Comm. Engineering, MNNIT, Allahabad – 211 004, UP (India).

Accepted 10 August, 2009

A new preemptive handoff scheme in integrated mobile communication environment is presented in this paper. The preemptive handoff schemes have worked in such a way that data types of lesser priority have been preemptive in an ad-hoc fashion. In the proposed scheme, the cell is divided into two regions, the usable area and the handoff region. The right of preemption has been given to incoming handoff real-time (voice) calls. The incoming handoff calls can only preempt ongoing calls present in the handoff region. Calls present in the usable area are not touched. Thus, a degree of protection is offered to the ongoing calls in the handoff region, whatever type of calls they may be.

Key words: Preemptive handoff, non-preemptive handoff, real-time traffic, non-real time traffic, blocking probability.

INTRODUCTION

The main concern that has plagued the world of mobile communications is the optimum trade-off required between various parameters that determine the Quality of Service (QoS) for the mobile system (Wen and Wanijun, 2008; Brzezinski et al., 2008; Lin Yang and Alouini 2007). The most important parameter concerning mobile communications is the call dropping probability due to an incoming handoff call. Many handoff schemes have been proposed in the past and their performances have been analyzed and simulated using different techniques.

The handoff schemes, without and with preemptive priority procedures, for integrated wireless mobile networks are proposed and analyzed in Qing-An and Dharma (2002), Li et al. (1998). The service calls are categorized into four different categories:

i. Originating Voice Calls.
ii. Originating Data Calls.
iii. Voice Handoff Request Calls.
iv. Data Handoff Request Calls.

We assume two separate queues for two handoff services. A number of channels in each cell are reserved exclusively for handoff request calls. Out of these channels, few are reserved exclusively for voice handoff request calls. The remaining channels are shared by both originating and handoff request calls. In preemptive priority scheme, higher priority is given to voice handoff request calls over data handoff request calls and can preempt data service to the queue if, upon arrival, a voice handoff request finds no free channels (Weiyao et al., 2008).

An analytical model for integrated real-time and non-real-time service in a wireless mobile network with priority reservation and preemptive priority handoff schemes is proposed in Jingao et al. (2003), Haung et al. (2000), Nidal and Hossam (2004). The service calls are categorized into four different types: Real Time and Non-real Time Service Originating Calls, and Real Time and Non-real Time Handoff Service Request Calls.

Accordingly, the channels in each cell are divided into three parts: one is for Real Time Service Calls only, the second is for Non-real Time Service Calls only and the last one is for Overflow of handoff requests that cannot be served in the first two parts. In the third group, several channels are reserved exclusively for real time service handoffs so that higher priority can be given to them. in addition, a real time

*Corresponding author. E-mail: k_chiranjeev@yahoo.co.uk. Tel: +91-9431125793 (M), +91-326-2235489 (O), +91-326-2235589 (R). Fax: +91-326-2210028.

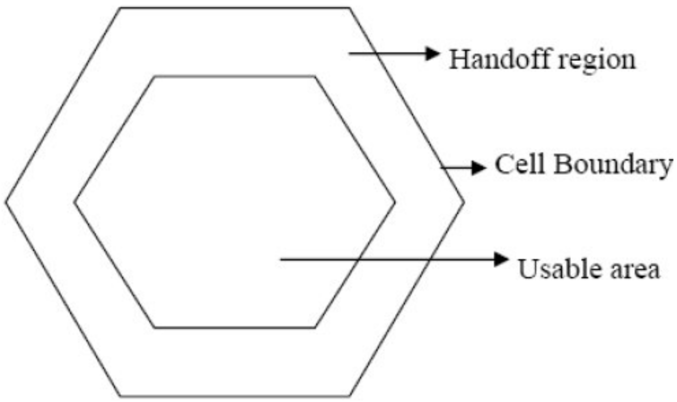

Figure 1. Cell site showing usable area and handoff region

service handoff request has the right to preempt non-real time service in the preemptive priority handoff scheme if no free channels are available, while the interrupted non-real time service call returns to its handoff request queue.

In Wei et al. (2005), Nidal and Hossam (2004), two different handoff schemes in integrated wireless mobile networks are proposed and analyzed. The channels in each cell are divided into two parts and are pre-allocated for real-time and non-real time services. To increase channel utilization, one type of service is allowed to borrow channels from the other under certain constraints. Depending on whether or not non-real time service calls can be interrupted, two channel borrowing schemes: Non-preemptive and Preemptive are obtained.

In Shensheng and Wei (2004), the total number of channels allocated to a cell is dynamically assigned in three parts: channels for Voice Traffic exclusively, channels for Data Traffic exclusively and channels shared for both Handoff Voice and Handoff Data. With the afore-mentioned scheme, performance measures such as new voice/data blocking probability, handoff voice/data dropping probability, channel utilization and busy time period in the cell are analyzed.

There are two handoff schemes that have been proposed in Mehmet and Urbashi (2001). They are Non-preemptive Handoff Scheme and Preemptive Handoff Scheme. The total numbers of channels in a reference cell 'N' have been divided into two groups: Real-time Service Channels (RC) group and Non Real-time Service Channels (NC) group. In the non preemptive borrowing scheme, real-time handoff requests are allowed to borrow channels from NC only if there are idle channels in NC (Nidal and Hossam, 2004). Other types of service calls do not borrow channels in any cases. The second type called preemptive borrowing scheme is a two-way borrowing scheme in which a real-time service handoff request is allowed to borrow a channel from NC, and a non real-time service call is allowed to borrow an idle channel from RC. The former is preemptive while the latter is non preemptive (Skalli et al., 2007; Haitao et al., 2006)

The system model is discussed in section 2. The proposed handoff scheme in a purely voice environment is presented in section 3. Section 4 presents the details of handoff scheme in an integrated environment. Finally, our conclusion is presented in section 5.

SYSTEM MODEL

On the basis of the power transmitted by the BTS (Base Transceiver Station), the cell is divided into two regions/parts, namely the usable area and the handoff region as shown in Figure 1.

The power received by the mobile user present at any point in the usable area is well above the threshold power level required for the generation of a handoff request. The handoff region, that is, the outer part of the cell that touches the cells adjacent to the cell under consideration is the region where handoff requests are generated. In this region, the power received by the user is below the threshold power required for the generation of a handoff request. The moment the user crosses the power threshold required for the generation of a handoff request, the user generates a handoff request.

To analyze the above division, done on the basis of the power transmitted by the BTS, a parameter '*p*' is defined which gives the probability of a user being present in the usable area. Conversely, the term *(1-p)* gives the probability of the user being present in the handoff region. The term '*p*' also gives the size of the usable area of the cell. It can be said that the larger the value of '*p*', the greater the size of the usable are of the cell and thus, more the number of users in the usable area. Conversely, if the value of '*p*' is small, then the usable area would be smaller. Hence, the handoff region would be larger. Thus, smaller the value of *p;* the more the number of users in the handoff region.

Purely voice environment

Assumptions: It is assumed that the users are homogeneously distributed throughout the cell under consideration, unlike in a real life like scenario where they may be distributed in a heterogeneous fashion; densely populated regions of the cell and sparsely populated regions of the cell under consideration do not arise in these assumptions. The users are distributed all over the cell evenly.

The above assumption also gives rise to the fact that if the total number of users in a cell are given by a number, say '*N'* then the total number of users present in the usable area of the cell is given by the number *pN*, and the number of users in the handoff region is given by the number *(1-p)N.*

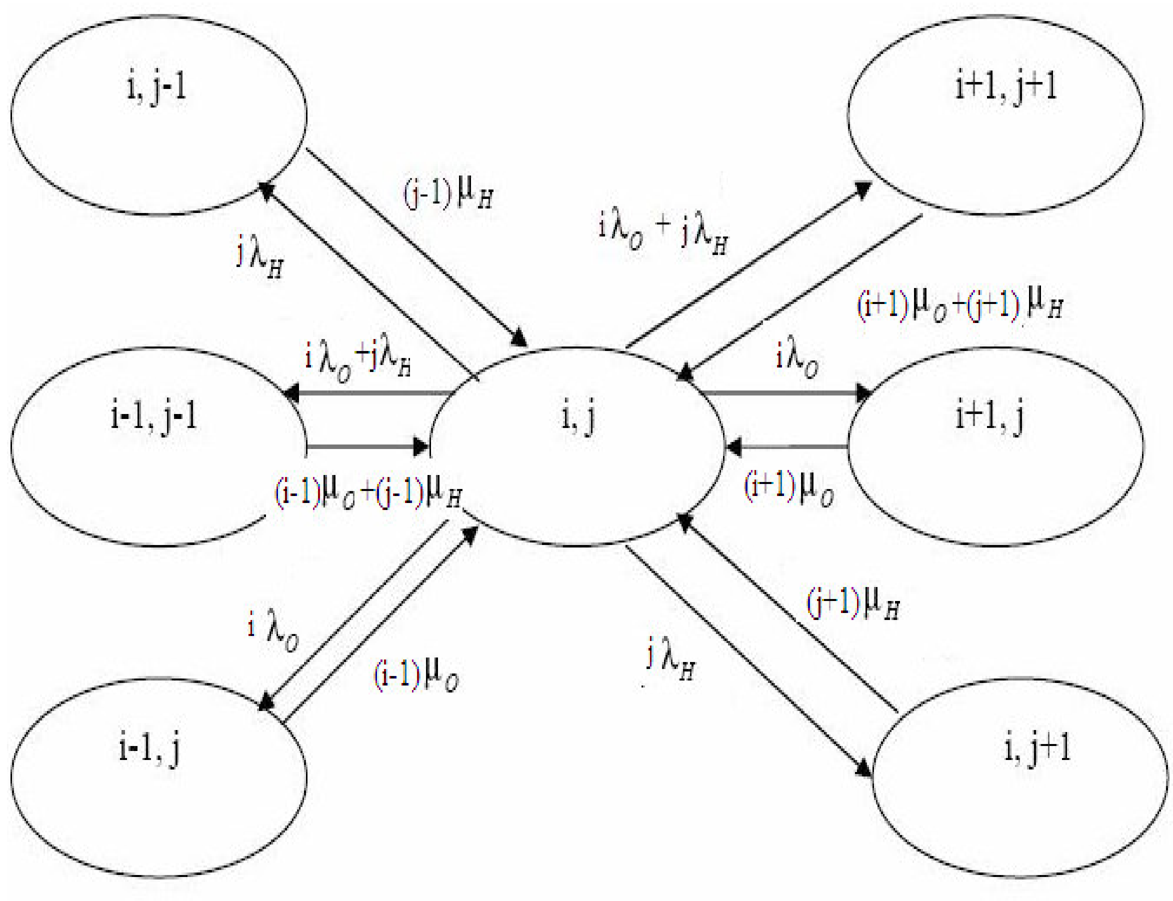

Figure 2. Steady state diagram for Originating Voice Calls.

Working of the model

Since the mobile environment under consideration here is totally a voice environment, the concept of non-real time traffic (data traffic) does not arise here. There is only one type of traffic present, that is, real-time traffic (voice traffic). However, there are two types of calls present, namely, Originating voice calls and Handoff voice calls.

Originating voice calls are those calls that are generated by the mobile users from within the cell. Handoff voice calls are those calls that arrive from the cells adjacent to the cell under consideration after having generated handoff requests in the cells in which they were previously present.

Due to the division of the cell into two parts, the originating voice calls and the handoff voice calls do not overlap with each other. In other words, the right of preemption is given to handoff voice calls and they can preempt only those calls present in the handoff region. They cannot preempt an ongoing voice call present in the usable area of the cell. The Originating voice calls are not given any preemptive priorities at all, that is, they cannot preempt any ongoing voice call present in the usable area or the handoff region of the cell.

Performance analysis

The total number of channels found in the usable area are *pN* and the total number of channels found in the handoff region are *(1-p)N*.

Let i (channels holding calls in the usable area) and j (channels holding calls in the handoff region) be variable parameters.

Thus,

$0 \leq i \leq pN$ or $i \in [0, pN]$

and

$0 \leq j \leq (1-p)N$ or $j \in [0, (1-p)N]$

Let *P(i, j)* be the steady-state probability of state *(i, j)*, λ_O be arrival rate of originating voice calls, λ_H be arrival rate of handoff voice calls, μ_O be channel holding time before a handoff request is generated, and μ_H be dwell time in handoff region. The steady state diagram for originating voice calls is shown in Figure 2.

The complete transition balance equation for the above steady-state diagram is:

$$(4i\lambda_0 + 4j\lambda_H)P(i,k) = ((i+1)\mu_0 + (j+1)\mu_H)P(i+1,j+1) + (i+1)\mu_0 P(i+1,j) + (j+1)\mu_H P(i,j+1) + (i-1)\mu_0 P(i-1,j) + ((i-1)\mu_0 + (j-1)\mu_H)P(i-1,j-1) + (j-1)\mu_H P(i,j-1) \quad (1)$$

The originating voice calls blocking probability is:

$$B_{OR} = \sum_{j=0}^{(1-p)N} P(pN,j) \quad (2)$$

Thus, we have the blocking probabilities of the handoff calls:

$$B_H = \sum_{i=0}^{pN} \sum_{j=0}^{(1-p)N} P(i,(1 \quad p)N \quad j) \quad (3)$$

Using a queue

Once the user passes through the handoff region of the cell under consideration, the call is dropped by the system as it isn't allowed to preempt. Due to this issue, the blocking probability of handoff voice calls is not optimized.

To improve this scenario, a simple queue is introduced. The handoff voice calls that haven't been allotted any channel and are about to be dropped can be placed in a simple queue, albeit for a very short period of time.

Mathematically, the blocking probability of incoming handoff voice calls when using a queue can be represented by:

$$B_{HQ} = \sum_{i=0}^{pN} \sum_{j=0}^{(1-p)N} P(i,(1-p)N-j,M) \quad (4)$$

Where M is the length of the queue.

Numerical result

Let:
$N = 10$
λ_O = Varies from 1 to 10 erlangs
$\lambda_H = 0.3\,\lambda_O$
μ = Channel dwell time
μ_O = Dwell time in the usable area: $p\mu$
μ_H = Dwell time in handoff region: $(1-p)\mu$
M = Length of Queue: 5
λ_Q = Arrival rate of calls into the Queue: 2 Erlangs
μ_Q = Maximum amount of time spent in Queue: 1

The simulation was carried out on an NS-2 Simulator. For a voice environment, the graphical results expected from the simulations are exactly as expected from the theoretical and logical analysis of the systems performance.

For originating voice calls, it is seen from Figure 3 that as the size of the usable area decreases, the probability of blocking of the calls increases and vice versa.

For handoff voice calls, it is seen (Figures 4 and 5) that as the size of the usable area decreases, that is, the size of the handoff region increases, the probability of blocking of the calls decreases and vice versa.

Integrated environment

Description of traffic

In an integrated environment, there are both voice calls (real-time traffic) and data calls (non real-time traffic). Based on their nature, the two types of mobile traffic can be further divided into the following:

i. Originating Voice Calls.
ii. Handoff Voice Calls.
iii. Originating Data Calls.
iv. Handoff Data Calls.

The priority is given to voice calls. An ongoing data call being dropped or blocked can be tolerated. But a mobile user cannot accept an ongoing voice call being dropped or being blocked. Thus, the incoming handoff voice calls are given the right to preempt ongoing calls. Whereas, all other types of calls, the originating voice calls, the originating data calls and the handoff data calls are not allowed to preempt, that is, the priority of preemption is not given to them.

The proposed scheme however provides some amount of protection to the data calls that are present in the usable area of the cell. The incoming handoff voice calls preempt only those ongoing calls that are present in the handoff region. But they do not preempt only ongoing data calls. The incoming handoff calls first check if there are any ongoing data calls present in the handoff region. If ongoing data calls are present, then they are preempted. If no ongoing data calls are present, then the incoming handoff voice calls preempt the ongoing voice calls which has the weakest signal strength that is, which are more close to the boundary, such calls will be transferred.

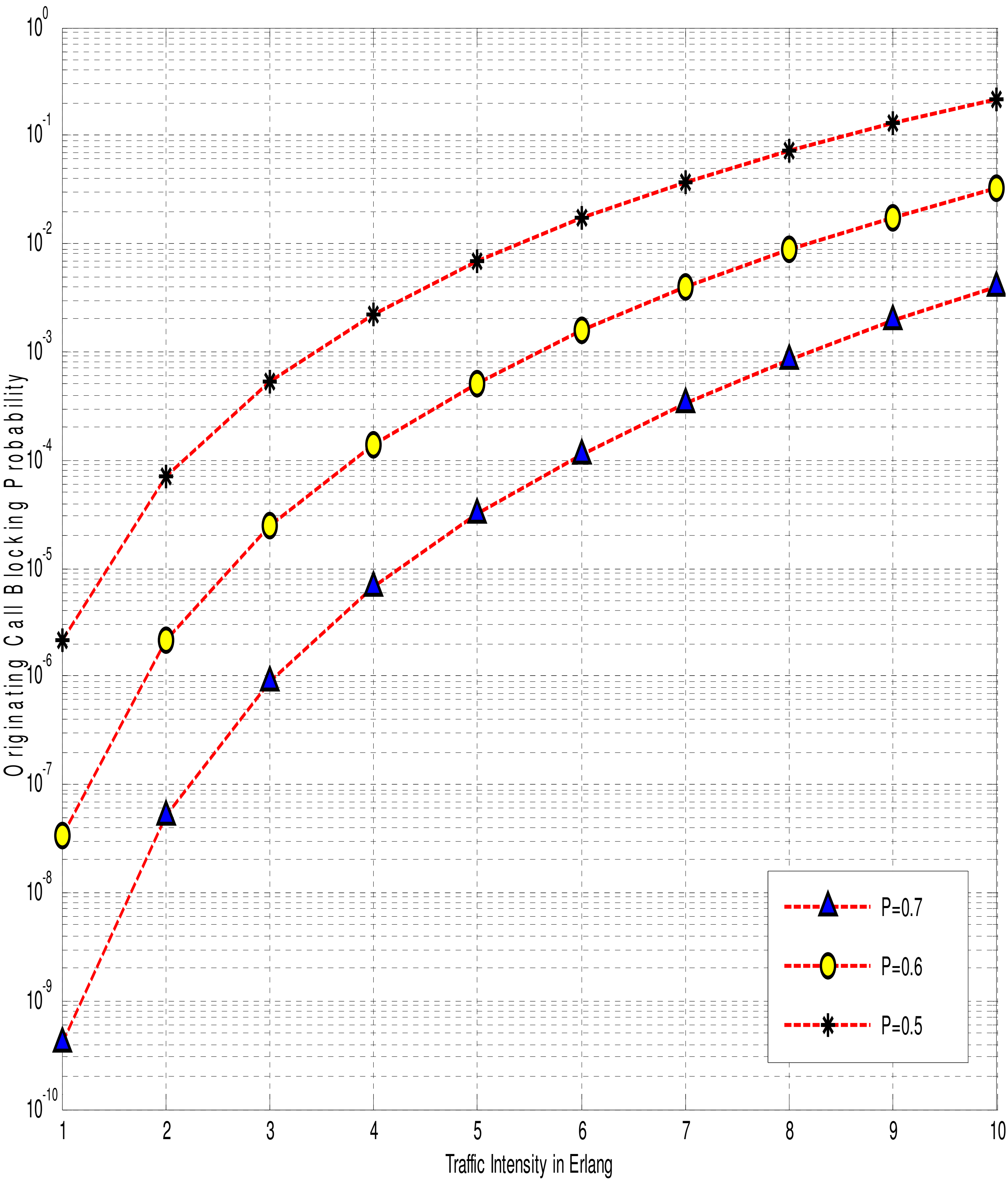

Figure 3. Originating Voice Calls blocking probabilities.

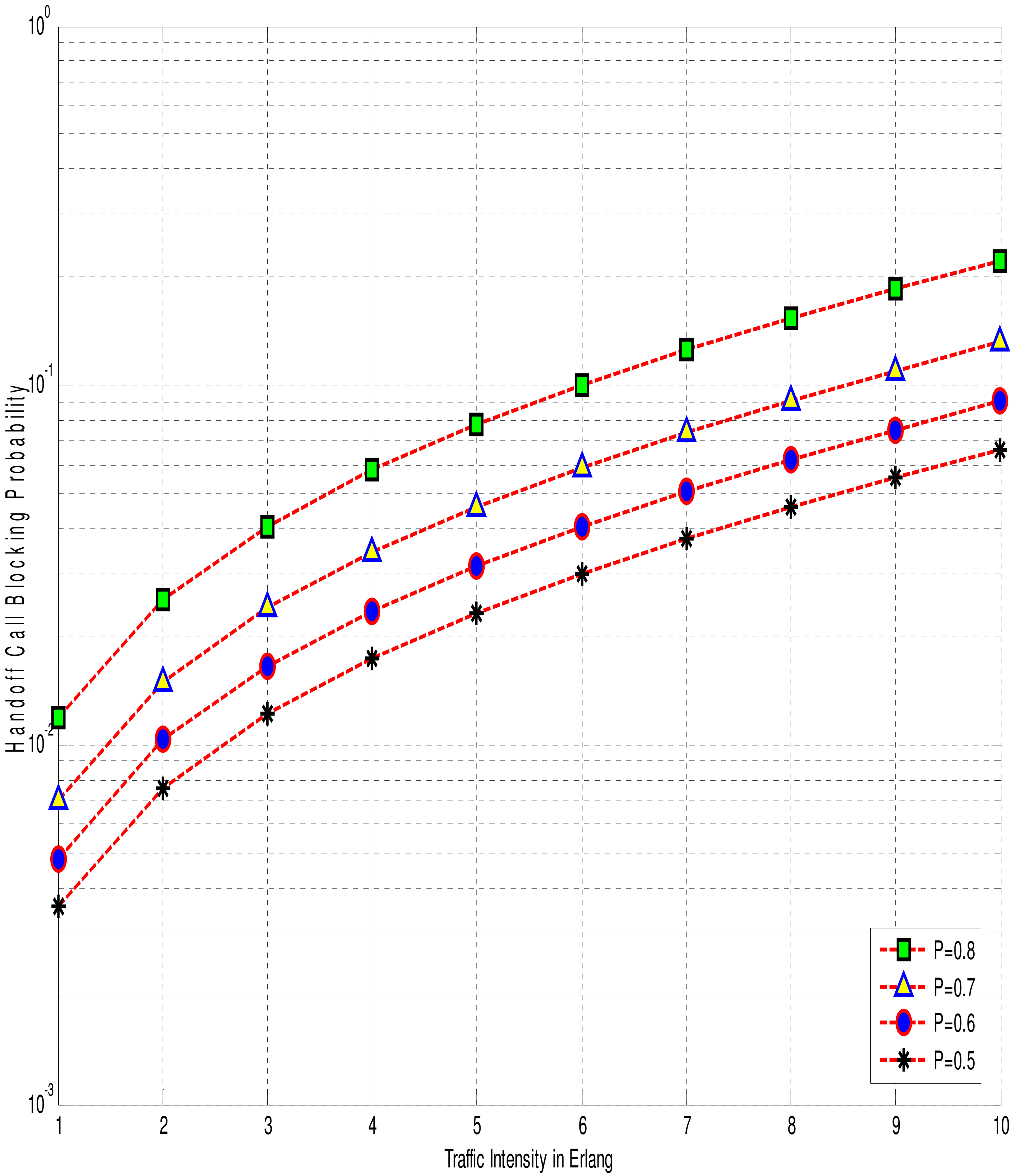

Figure 4. Handoff Voice Calls blocking probabilities.

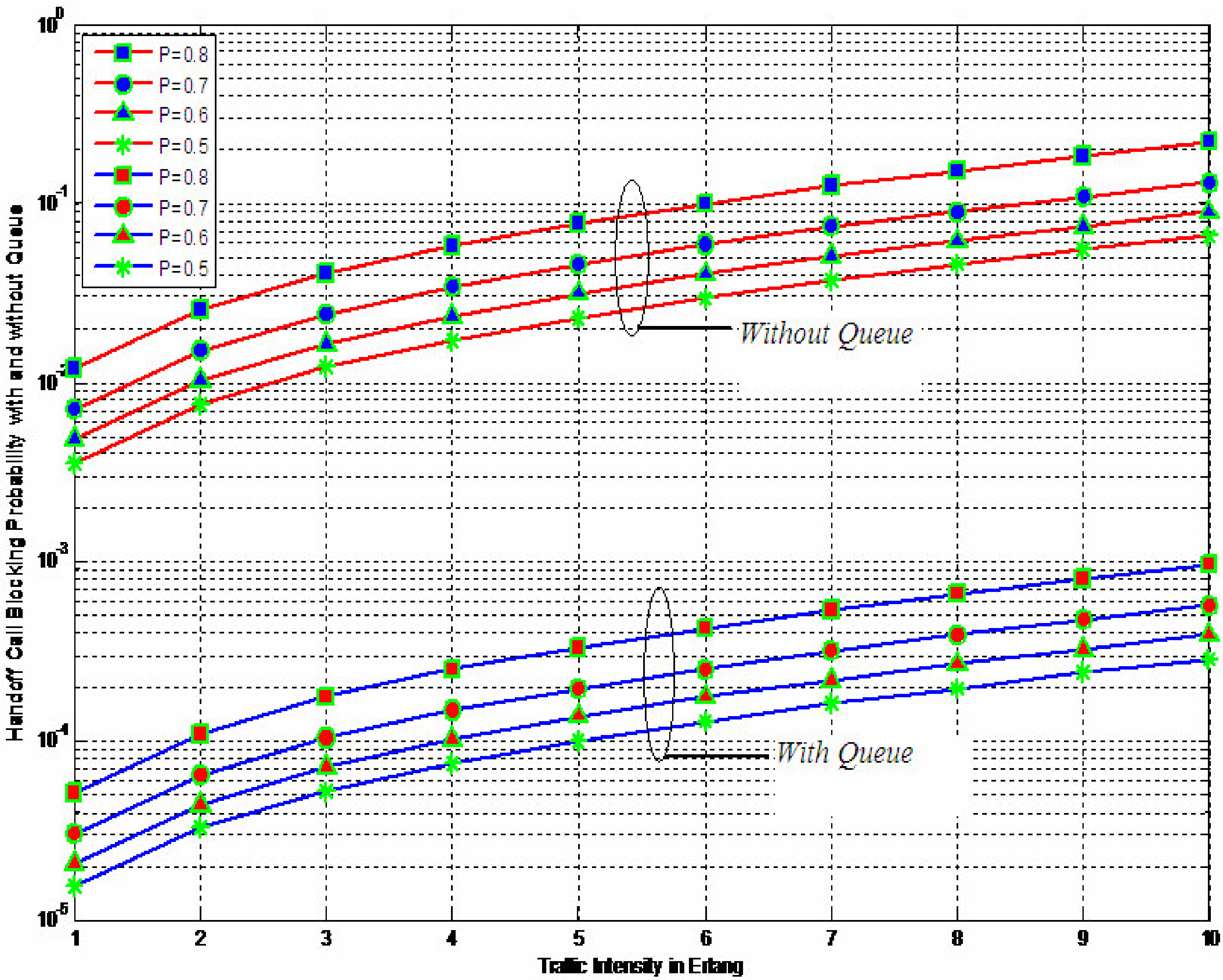

Figure 5. Handoff Voice Calls blocking probability with and without queue.

Performance analysis

There are a total number of *'N'* channels allocated to a cell. They are divided into *'Nr'* (real-time call holding channels) and *'Nd'* (non real-time call holding channels).

Let i = channels holding voice calls (real-time calls) in usable area, j = channels holding voice calls (real-time calls) in the handoff region, k = channels holding data calls (non real-time calls) in usable area, and l = channels holding data calls (non real-time calls) in the handoff region.

The total number of channels holding voice calls in the usable area is *pNr.*

The total number of channels holding voice calls in the handoff region is *(1- p)Nr.*

The total number of channels holding data calls in the usable area is *pNd.*

The total number of channels holding data calls in the handoff region is *(1-p)Nd.*

Therefore,

$0 \le i \le pNr$ or $i \in [0, pNr]$

$0 \le j \le (1-p)Nr$ or $j \in [0, (1-p)Nr]$

$0 \le k \le pNd$ or $k \in [0, pNd]$

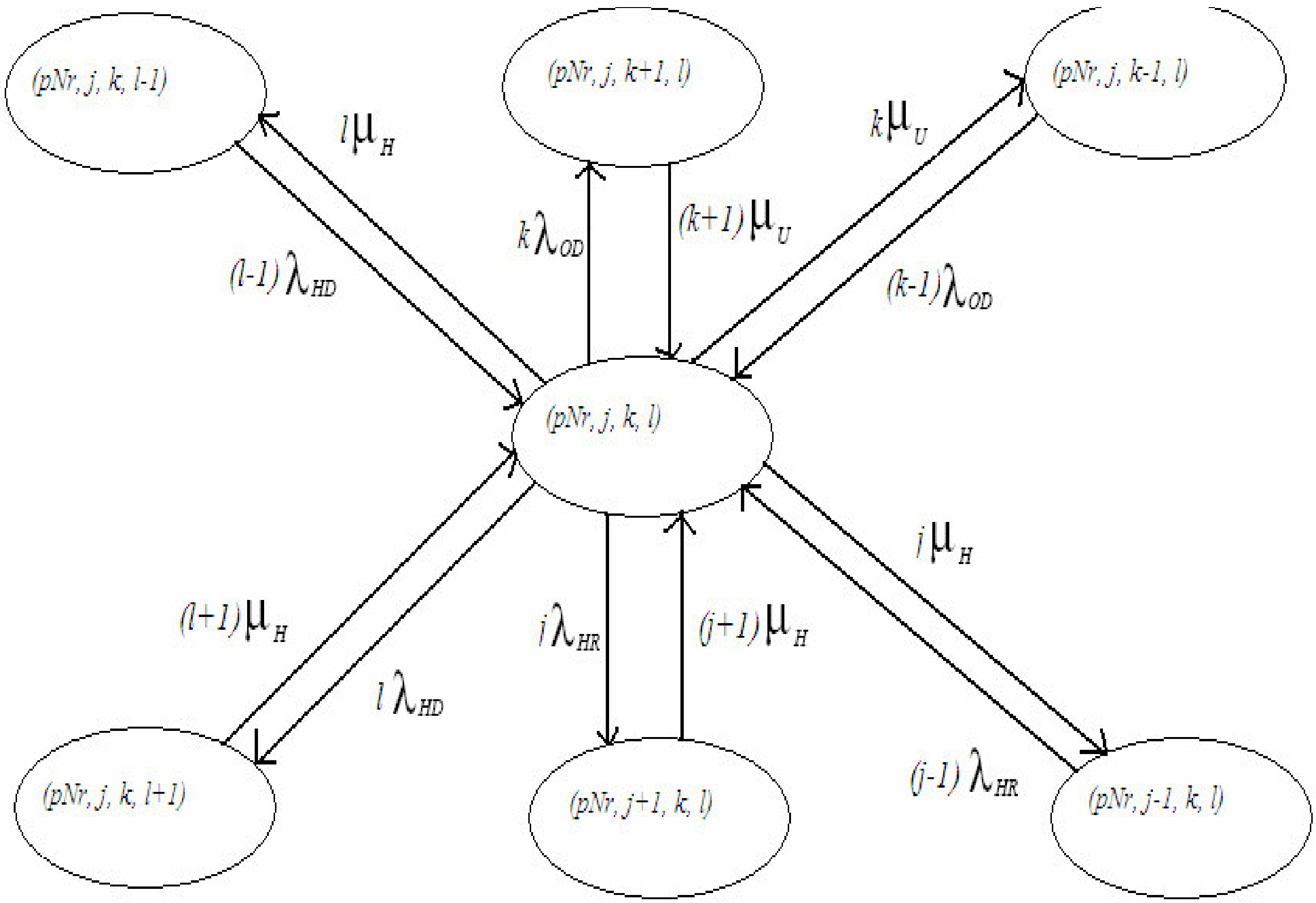

Figure 6. Steady state diagram for Originating Voice Calls.

$0 \le l \le (1-p)Nd$ or $l \in [0, (1-p)Nd]$

A parameter β is defined which gives the probability of a data call being present in the handoff region. Thus, ($1-\beta$) is the probability that all the calls present are real-time calls in the handoff region.

The parameter β is mathematically calculated as:

$$\beta = (1-p)\,\lambda_D$$

The steady-state transition diagram for originating voice calls is shown in Figure 6:

The complete transition balance equation for the above steady-state diagram is:

$$\{j(\lambda_{HR}+\mu_H)+k(\lambda_{OR}+\mu_U)+l(\lambda_{HD}+\mu_H)\}P(pNr,j,k,l) = (j+1)\mu_H P(pNr,j+1,k,l) + (j-1)\lambda_{HR}P(pNr,j-1,k,l) + (k-1)\lambda_{OR}P(pNr,j,k-1,l) + (k+1)\mu_U P(pNr,j,k+1,l) + (l-1)\lambda_{HD}P(pNr,j,k,l-1) + (l+1)\mu_H P(pNr,j,k,l+1) \quad (5)$$

The blocking probability of originating voice calls is:

$$B_{OR} = \sum_{j=0}^{(1-p)Nr} \sum_{k=0}^{pNd} \sum_{l=0}^{(1-p)Nd} P(pNr,j,k,l) \quad (6)$$

A handoff call will preempt data calls and voice calls present only in the handoff region. It will first search for a data call to preempt. If no data calls are present, then it will preempt a voice call (real-time call).

The blocking probability of an incoming handoff voice call is:

$$B_{HR} = \beta * \sum_{i=0}^{pNr} \sum_{j=0}^{(1-p)Nr} \sum_{k=0}^{pNd} \sum_{l=0}^{(1-p)Nd} P(i,j,k,[(1-p)Nd-l]) + (1-\beta) * \sum_{i=0}^{pNr} \sum_{j=0}^{(1-p)Nr} \sum_{k=0}^{pNd} P(i,[(1-p)Nr-j],k,0) \quad (7)$$

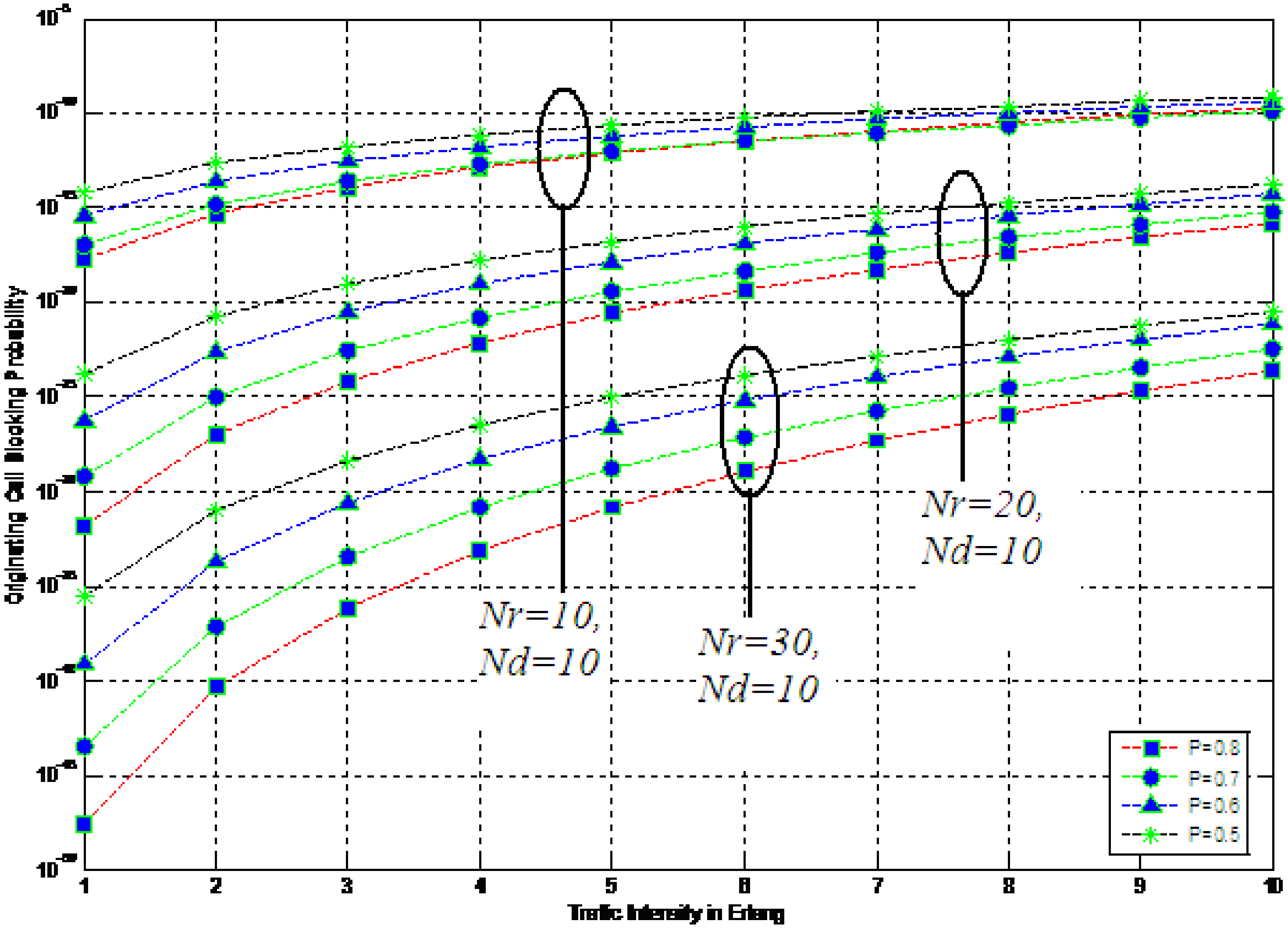

Figure 7. Blocking probability of Originating Voice Calls.

$$B_{PD} = \sum_{i=0}^{pNr} \sum_{j=0}^{(1-p)Nr} \sum_{l=0}^{(1-p)Nd} P(i, j, pNd, l) \qquad (8)$$

Numerical result

Let:
N = 30
Nr = 20
Nd = 10
λ_{OR} = 10 Erlangs
λ_{HR} = 0.3 λ_{OR}
μ = Channel dwell time

μ_U = Dwell time in usable area: ($p\mu$)

μ_H = Dwell time in handoff area: ($1-p$)μ

λ_{OD} = Originating data calls (2 Erlangs)

λ_{HD} = Handoff data calls (0.3 λ_{OD})

It is observed that for originating voice calls (Figure 7), as the usable area decreases, the probability of blocking increases and vice versa. For handoff voice calls (Figure 8), as the handoff region increases, the blocking probability decreases and vice versa. One thing that needs to be mentioned here is that as the ratio of *Nr* to *Nd* increases, the system approaches optimization.

For originating data calls (Figure 9), again as the usable area increases, the blocking probability decreases

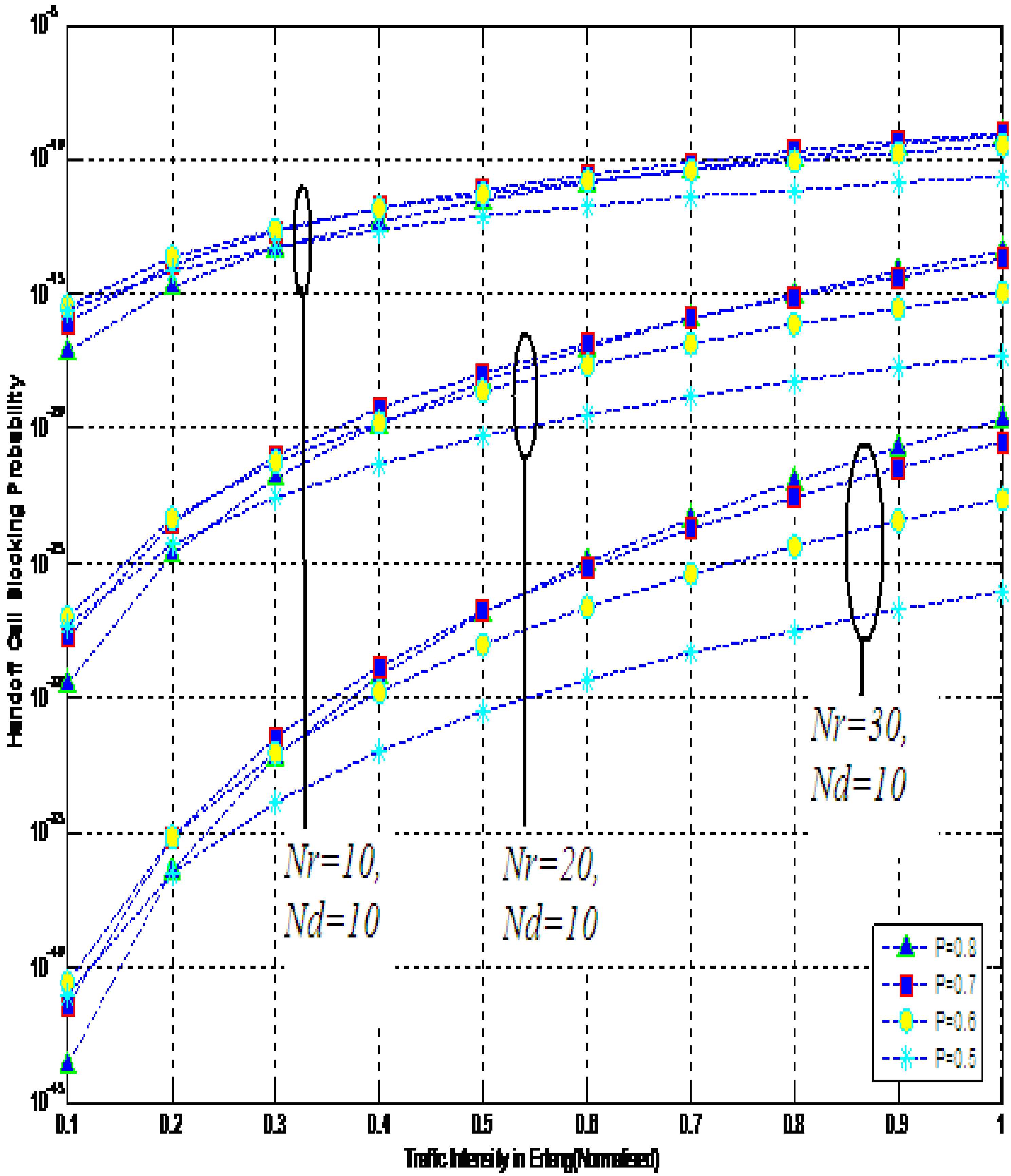

Figure 8. Blocking probability of Handoff Voice Calls.

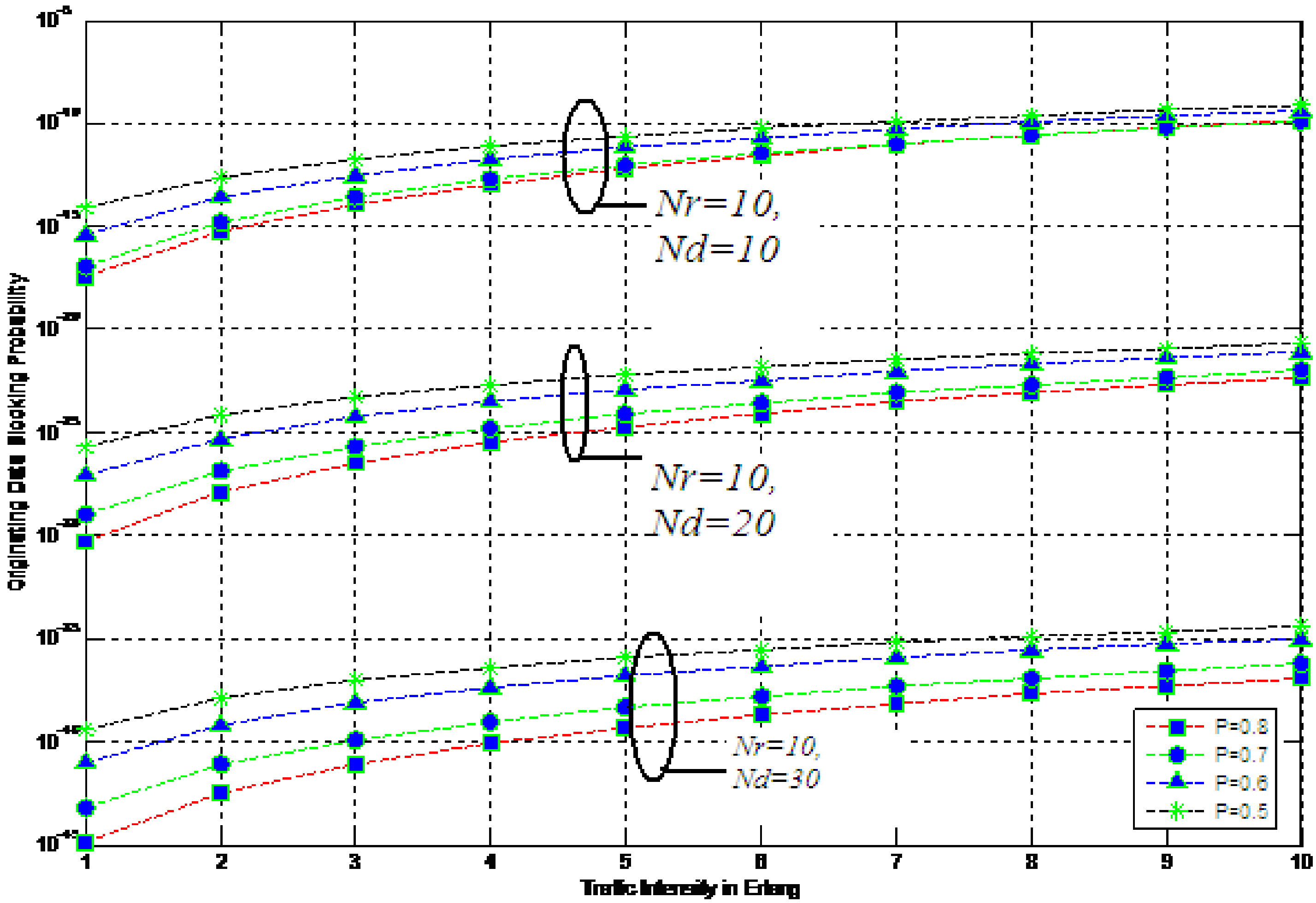

Figure 9. Blocking probability of Originating Data Calls.

and vice versa. For data calls, as the ratio of *Nd* to *Nr* increases, the system approaches optimization

Conclusion

It is seen that the proposed system offers a degree of protection to data calls from preemption unlike previous preemptive schemes. However, the need of the time is to find a proper trade off between the ratios of *Nr* to *Nd* and *Nd* to *Nr* for optimum system performance. Also, the analysis of the proposed system is based on data that is assumed for simplicity and not on real life statistical data. Work can also be done keeping the proposed preemptive scheme in mind but with statistical data in hand.

REFERENCES

Brzezinski A, Zussman G, Modiano E (2008). "Distributed Throughput Maximization in Wireless Mesh Networks via Pre-Partitioning", IEEE/ACM Transactions on Networking. 16 (6): 1406–1419.

Haitao W, Fan Y, Tan K, Jie C, Qian Z, Zhensheng Z (2006). "Distributed Channel Assignment and Routing in Multiradio Multichannel Multihop Wireless Networks", IEEE Journal on Selected Areas in Communications. 24(11): 1972-1983.

Haung YR, Lin YB, Ho JM (2000). "Performance analysis for voice/data integration on a finite mobile systems," IEEE Trans. Veh. Technol. 49(2): 367–378.

Jingao W, Qing-An Z and Dharma PA (2003). "Performance Analysis of

Li B, Zeng QA, Mukumoto K, Fukuda A (1998). " A preemptive priority handoff scheme in integrated voice and data cellular mobile systems," in Proc. Int. Conf. Comm. Technol., vol. 1.

Lin Y, Alouini MS (2007)."A Fault-Tolerant Channel-Allocation Algorithm for Cellular Networks With Mobile Base Stations", IEEE Transactions on Vehicular Technology. 56(1):349-361.

Mehmet A, Urbashi M (2001). "Variations on Optimal and Suboptimal Handoff Control for Wireless Communication Systems," IEEE J. Sel. Areas Commun.19 (6).

Nidal N, Hossam H (2004). "Bandwidth Reservation Policy for Multimedia Wireless Cellular Networks and its Analysis", Proceedings of the IEEE International Conference on Communications, pp. 3030-3034.

Nidal N, Hossam H (2004). "Prioritized Multi-class Adaptive Framework for Multimedia Wireless Networks," Proceedings of the IEEE International Conference on Communications, pp. 4295-4300.

Preemptive and Priority Reservation Handoff Scheme for Integrated Service-Based Wireless Mobile Networks," IEEE Transactions on Mobile Computing. 2(1): 65-75.

Qing-An Z, Dharma PA (2002). "Modeling and Efficient Handling of handoffs in Integrated Wireless Mobile Networks," IEEE Trans. Vehicular Technol. 51(6):1469-1478.

Shensheng T, Wei L (2004). "A Channel Allocation Model with Preemptive Priority for Integrated Voice/Data Mobile Networks," Proceedings of the First International Conference on Quality of Service in Heterogeneous Wired/Wireless Networks, pp. 181-188.

Skalli H, Ghosh S, Das SK, Lenzini L (2007). Conti, M., "Channel Assignment Strategies for Multiradio Wireless Mesh Networks: Issues and Solutions", IEEE Comm. Mag. (45) 11: 86-95.

Wei Li, Hang C, Dharma PA (2005). "Performance Analysis of Handoff Schemes with Preemptive and Non preemptive Channel Borrowing in Integrated Wireless Cellular Networks," IEEE Trans. Wireless Comm. 4(3):1222-1233.

Weiyao H, Jie C, Shaoqian L (2008). "A Channel Allocation Algorithm for Minimizing Handoff Rate in Cognitive Radio Networks", 4th International Conference on Wireless Communications, Networking and Mobile Computing (WiCOM '08), pp 1-4.

Wen-Hsing K, Wanjiun L (2008). "Utility-based radio resource allocation for QoS traffic in wireless networks", IEEE Trans. Wireless Comm. 7(7): 2714–2722.