# Hybrid Queuing Strategy to Reduce Call Blocking in Multimedia Wireless Networks

Dong Chun Lee[1], Il-Sun Hwang[2], and Robert Young Chul Kim[3]

[1] Dept. of Computer Science Howon Univ., Korea
ldch@sunny.howon.ac.kr
[2] R&D Network Manag. Supercom. Center KISTI, Korea
[3] Dept. of CIC Hoogik Univ., Korea

**Abstract.** In this paper, we propose a hybrid queuing strategy to reduce the blocking rate of channel allocation for multiple priority calls in Multimedia Wireless Networks (MWN). The proposed scheme is provided with an analytic model, wherein a Two- Dimension Markov Process. In numerical results, our method show correct analytic model and has better performance result than previous work in MWN.

## 1 Introduction

For delivering the desired levels of Quality of Service (QoS) in Wireless Networks (WN) to multiple types of mobile users, an improved channel allocation mechanism is required. It is to obtain a high-admitted traffic and to reduce blocking rate while guaranteeing the protection of calls in restricted channels [2], [8]. More recently, to reduce the blocking rate of channel allocation in WN, previous work has been proposed the schemes that make use of queuing method [5]. The schemes are classified calls in WN as voice call and data call. Intuitively, when channels are busy, waiting only the hand-off data call in a queue can reduce the blocking rate of the hand-off data call. The blocking rate of voice call can be also reduced by giving priority to voice call in a queue environment [8], [9]. However, the previous works consider only two types of traffic and have limitations for reducing the high blocking rate of multiple priority calls by allocating channels efficiently in WN. An efficient queuing scheme for multi-class calls in MWN can reduce the blocking rate of calls in restricted channels in a cell. So we have been introduced two queuing schemes that reduced the blocking rate of multiple priority calls in channel allocation in MWN [6],[7].

In order to obtain the better QoS for channel allocation, we propose an improved queuing scheme for multiple calls, which is investigated the hybrid queuing strategy in MWN.

## 2 Related Work

The previous scheme has been considered two types of traffic (voice calls and data packets), which is supported by a set of C channels plus a buffer of size K-C

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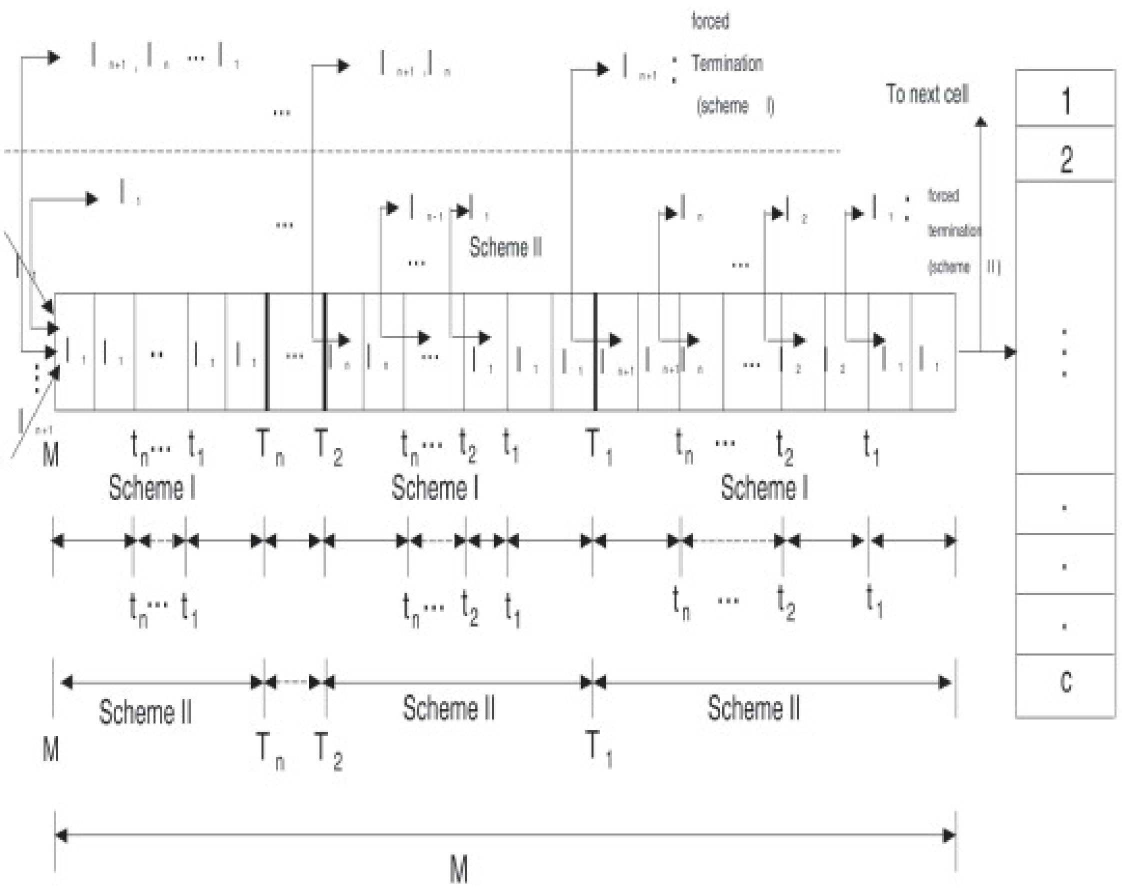
[9]. Any type of arrival has access to any facility but voice call can preempt the service of data packet which return to the queue next to the last voice call arrival. Thus this scheme has a system with preemptive priority in the C channels and Head-of-the-Line (HOL) priority in the queue, where voice has a priority over data packet. A call in such a system is blocked only if there are already K calls in the system while a data packet is blocked if the system is full. Moreover, any type of traffic must leave the queue after a finite time because the vehicle has to leave the cell. This scheme is depicted in [9] and the state diagrams are given in two dimensional case. In schemes, the blocking probabilities and the mean waiting times with two types of traffic calls are given in [9].
We have been proposed two queuing schemes with n priority calls which are based on priority control methods [6],[7]. First scheme shows the queuing model to be proposed in our work using Head of Line priority control [1].
The queue is logically divided by threshold values $T_i$. When multiples calls arrive in a queue, each call waits in intervals of each threshold value, which high priority call prior to low priority call waits in the queue. When each call arrives in a queue of which state is over its threshold values, it is terminated by force and blocked. These calls cannot allocate channels or the portable must makes out of the coverage area. If the highest priority call $\lambda_1$ arrives in the queue which state is over the first threshold value $T_1$, it is terminated by force and allocated channels in a cell. If the queue size M is full, all of n+1 class calls are terminated by force irrespective of their priorities.
The second scheme also shows the basic queuing model to be proposed in our work using Partial Buffer Sharing(PBS) priority control. When multiple calls arrive in the queue, each call waits in the queue which is divided by threshold values and shares the queue partially irrespective of priority. But when each call arrives in the queue which state is over its threshold values $T_i$, it is terminated by force. If the lowest priority call $\lambda_{n+1}$ arrives in the queue which state is over the first threshold value, it is terminated by force and blocked. The channel cannot be allocated for this call because it shares the queue by the first threshold value $T_1$. If multiple calls arrive in the queue which state is over the second threshold value $T_2$, the lowest priority call $\lambda_{n+1}$ and the second lower priority call $\lambda_n$ are also terminated by force. The channels cannot be allocated for those calls because they only share the queue by the first threshold value and the second threshold value. If queue size M is full, all of n+1 class calls are terminated by force irrespective of their priorities. In two schemes, analytic model are also given in [6],[7].

## 3 Hybrid Queuing Strategy

Fig. 1 shows a hybrid queuing model that integrate two previous methods with multiple priority calls.

In this queuing scheme, when multiple calls $\lambda_i$, 1≤i≤n+1 arrive in a queue,each call shares the queue partially without regard to priority, and waits




Sub-threshold value of scheme I : $t_i$, 1 ≤ i ≤ $n$
Threshold value of scheme II:$T_I$,1≤i≤n
Threshold value of hybrid scheme:$T_i \leq t_i \leq t_2 \cdots \leq t_n \leq T_{i+1}, 1 \leq i \leq n-1$

**Fig. 1.** The hybrid queuing model with (n+1) priority calls in a cell.

in the queue as intervals of each threshold value $T_i$ of scheme II. And also multiple calls in threshold value $T_i$ wait in the queue according to sub-threshold value $t_i$ of scheme I depending on priority i. When each call arrives in the queue of which state is over its threshold value $T_i$ and sub-threshold value $t_i$ of scheme I, it is terminated by force and blocked. These calls cannot allocate channels or the terminal must leave to next cell. If the second lowest priority call $\lambda_n$ is over its threshold value $T_n$ of scheme II, and If multiple calls are over its sub-threshold value tn of scheme I while the call waits in threshold value $T_i$ of scheme II, they are terminated by force and blocked. The calls must also leave the cell because the channels cannot be allocated for them.
To analyze the proposed queuing model, we assume the followings: (a) Arrival calls are modeled as Poisson process with arrival rates $\lambda_i$ of i class traffic. (b) The waiting time and the channel holding time of multiples calls have the exponential distributions with service rate $\mu_q$ and service rate $\mu$, respectively. (c) Queue size M is finite (K-C) and FIFO discipline is served in each threshold area. (d) A cell is equipped with C permanently assigned channels. (e) The model for multiple calls is M/M/C/M/K.

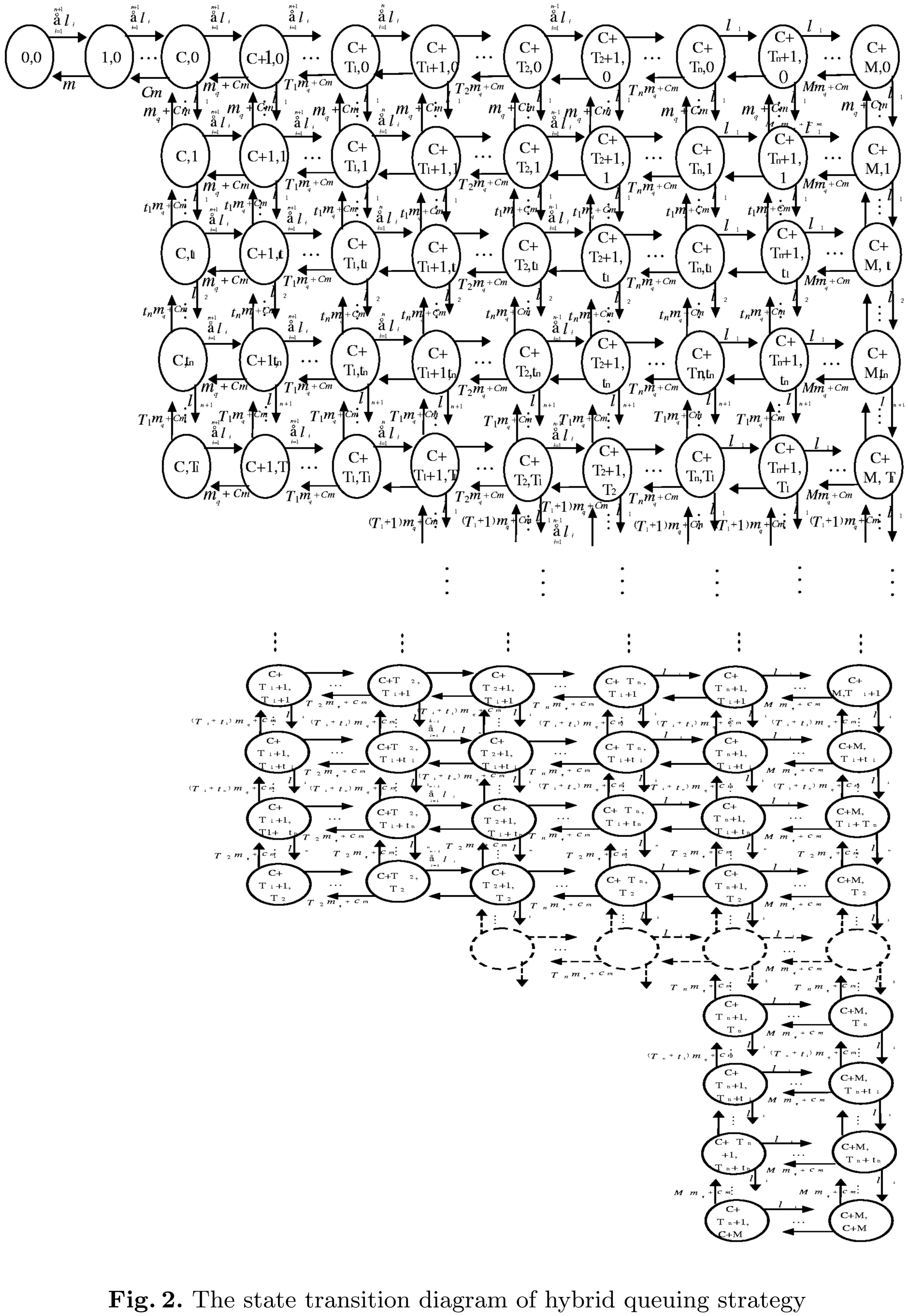



**Fig. 2.** The state transition diagram of hybrid queuing strategy

An analytic model is carried out by resolving a two- dimensional Markov Chain, where each state (i, j) represents the number i of multiple calls in any threshold values $T_i$ of scheme II and the number j of multiples calls in any sub-threshold value $t_i$ of scheme I within any threshold value $T_i$ of scheme II. Let $P_{ij}$ (t) = Pr [I (t) = i,J(t) = j] denotes the probability that the process is in state (i, j) at time t and let $P_{ij} =$ $_{ij}$ (t) denote the steady state probability that the process is in state (i, j). From the state transition diagram of Fig. 5, let us classify the state diagram into (n+1) parts as follows:

(part 1) $0 < i < C, \quad j = 0$
(part 2) $C < i \le C + T_1, \quad j = 0, 1, \cdots, t_1, t_1 + 1, t_n, \cdots, T_1,$

$\vdots$

(part n+1)
$C + T_n < i \le C + M, \quad j = 0, 1, \cdots, t_1, t_1 + 1, t_n, \cdots, T_1, T_1 + 1, \cdots, T_1 + t_1, \cdots, T_{n-1}, \cdots, T_n \cdots M, t_n < j \le T_1$

It can be observed that the state space can be partitioned into (n+1) parts of state to obtain the steady state probability P(i,j).

part 1 0<i<C, j=0

$$p(i,j) = \frac{(\sum_{i=1}^{n+1} \lambda_i)^i}{i!\mu^i} P(0,0) \tag{1}$$

part 2 C≤ i≤ C+$T_1$,

$$\mathbf{p(i,j)} = \left[\begin{array}{l}
\frac{(\sum_{i=1}^{n+1} \lambda_i)^c}{C!\mu^c} \frac{1}{\prod_{k=1}^{i}(K\mu_q + C\mu)} (\sum_{i=1}^{n+1} \lambda_i)^{i-C} \frac{1}{\prod_{m=1}^{j}(m\mu_q + C\mu)} (\lambda_1)^j p(0,0) \\
\qquad ,0 \le j \le t_1 \\
\frac{(\sum_{i=1}^{n+1} \lambda_i)^c}{C!\mu^c} \frac{1}{\prod_{k=1}^{i}(k\mu_q + C\mu)} (\sum_{i=1}^{n+1} \lambda_i)^{i-c} \frac{1}{\prod_{m=1}^{t_1}(m\mu_q + C\mu)} (\lambda_1)^{t_1} \\
\{\frac{1}{\prod_{m=t_1+1}^{j}(m\mu_q + C\mu)} (\lambda_2)^{j-t_1}\} p(0,0) \quad ,t_1 \le j \le t_2 \\
\vdots \qquad \vdots \\
\frac{(\sum_{i=1}^{n+1} \lambda_i)^c}{C!\mu^c} \frac{1}{\prod_{k=1}^{i}(K\mu_q + C\mu)} (\sum_{i=1}^{n+1} \lambda_i)^{i-c} \frac{1}{\prod_{m=1}^{t} n(m\mu_q + C\mu)} (\lambda_1)^{t_1} \\
\{\frac{1}{\prod_{m=t_n+1}^{j}(m\mu_q + C\mu)} (\lambda_2)^{j-t_{n-1}}\} \\
\times\{\prod_{k=2}^{n}(\lambda_k)^{t_k - t_{k-1}}\} p(0,0) \quad ,t_{n-1} < j \le t_n \\
\frac{(\sum_{i=1}^{n+1} \lambda_i)^c}{C!\mu^c} \frac{1}{\prod_{k=1}^{i}(K\mu_q + C\mu)} (\sum_{m=1}^{n+1} \lambda_i)^{i-c} \frac{1}{\prod_{m=1}^{t_{n-1}}(m\mu_q + C\mu)} (\lambda_1)^{t_1} \\
\{\frac{1}{\prod_{m=t_{n-1}+1}^{j}(m\mu_q + C\mu)} (\lambda_n)^{j-t_{n-1}}\} \{\prod_{k=2}^{n-1}(\lambda_k)^{t_k - t_{k-1}}\} p(0,0) \\
t_n < j \le T_1
\end{array}\right. \tag{2}$$

$\vdots$

Part n+1 $C + T_n < i \le C + M$

$$\mathbf{p(i,j)} = \left[\begin{array}{c} \frac{(\sum^{n+1}\lambda_i)^c}{C!\mu^c}\frac{1}{\prod_{k=1}^{T_n}(K\mu_q+C_\mu)}(\sum_{i=1}^{n+1}\lambda_i)^{T_1-C}(\sum_{i=1}^{n}\lambda_i)^{T_2-T_1} \\ \cdots(\lambda_2+\lambda_1)^{T_n-T_{n-1}} \\ \times\{\frac{1}{\prod_{k=T_{n+1}}^{i}(m\mu_q+C\mu)}\times(\lambda_1)^{i-T_n}\}\times(\lambda_2)^{T_n-(T_{n-1}+t_n)} \\ (\lambda_3)^{T_{n-1}-(T_{n-2}+t_n)}\cdots(\lambda_n)^{T_2-(T_1+t_n)}(\lambda_{n+1})^{T_1-t_n} \\ \times\{\frac{1}{\prod_{m=1}^{T_n}(m\mu_q+C\mu)}(\lambda_1)^{t_1+t_2\cdots+t_{n-1}+t_n}\}\times\{\frac{1}{\prod_{m=T_n+1}^{j}(m\mu_q+C\mu)}(\lambda_1)^{j-T_n}\} \\ \times\{\prod_{k=2}^{n}(\lambda_k)^{t_k-t_{k-1}}\} \\ \times\{\prod_{k=2}^{n-1}(\lambda_k)^{t_{k+1}-t_k}\}\cdots\times\{\prod_{k=2}^{3}(\lambda_k)^{t_{k+n-3}-t_{k+n-4}}\} \\ \{\prod_{k=2}^{2}(\lambda_k)^{t_{k+n-2}-t_{k+n-3}}\}P(0,0), \quad T_n<j\le M \end{array}\right. \quad (3)$$

Here, initial probability P (0, 0) is obtained from equations (1) using the normalization condition.

$$\sum_{i=o}^{M}\sum_{j=0}^{M}P(i,j)=1 \quad (4)$$

From equations (1) - (4), we can obtain blocking probability ($P_b^{(i)}, 1\le i\le n+1$) depending on priority i can be obtained by

$$P_b^{(1)} = \left(\sum_{j=0}^{t_1}P(M,j)+\sum_{j=T_1+1}^{T_1+T_2}P(M,j)\cdots+\sum_{j=T_n+1}^{M}P(M,j)\right),$$

$$P_b^{(2)} = \sum_{i=T_n+1}^{M}\left(\sum_{j=t_2+1}^{T_1}P(i,j)+\sum_{j=T_1+t_3+1}^{T_2}P(i,j)\cdots+\sum_{j=T_{n-2}+t_{n-1}+1}^{T_{n-1}}P(i,j)\right)$$

$$\vdots \qquad\qquad \vdots$$

$$P_b^{(n+1)} = \sum_{i=T_1+1}^{M}\left(\sum_{j=T_1+1}^{M}P(i,j)\right), \quad (5)$$

where $P_b^{(1)}$ is the blocking probability with which the highest priority call$\lambda_1$ occurs when it arrives in the queue whichever state is over the first sub-threshold value $t_1$ within each threshold value $T_1$ and over the queue size M, and $P_b^{(n+1)}$ is the blocking probability with which the lowest priority call $\lambda_{n+1}$ occurs when it arrives in the queue whichever state is full from $n^{th}$ threshold value $t_n$ within each threshold value $T_i$ and over the first threshold value $T_1$.
From equations (2)–(3), the mean waiting time $W_q^{(i)}$ depending on priority i can be obtained using Little's Rule [4].

$$W_q^{(1)} = \frac{1}{\sum_{i=1}^{n+1}\lambda_i}\left[\sum_{i=0}^{M}i\left(\sum_{j=0}^{t_1}P(i,j)+\sum_{j=T_1+1}^{T_1+t_2}P(i,j)\cdots+\sum_{j=T_n+1}^{M}P(i,j)\right)\right],$$

$$W_q^{(2)} = \frac{1}{\sum_{i=1}^{n} \lambda_i} \left[ \sum_{i=T_1+1}^{M} i \left( \sum_{j=T_1+1}^{t_1} P(i,j) + \sum_{j=T_1+t_2+1}^{T_1+t_3} P(i,j) \cdots + \sum_{j=T_{n-1}+t_n+1}^{T_n} P(i,j) \right) \right],$$

$$\vdots \qquad \vdots$$

$$W_q^{(n+1)} = \frac{1}{(\lambda_1)} \left[ \sum_{i=0}^{T_1} i \left( \sum_{j=t_n+1}^{T_1} P(i,j) \right) \right], \tag{6}$$

where $W_q^{(1)}$ is the mean waiting time that the highest priority call $\lambda_1$ waits in the queue until the first sub-threshold value $t_1$ within each threshold value $T_i$, and $W_q^{n+1}$ is the mean waiting time that the lowest priority call $\lambda_{n+1}$ waits in the queue until $n^{th}$ sub-threshold value $t_n$ within each threshold value $T_i$.

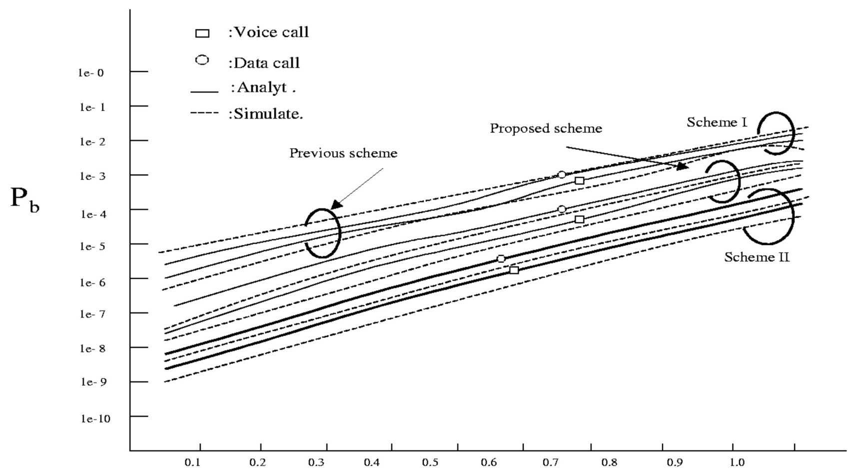



**Fig. 3.** Blocking probability vs. traffic intensity p.

## 4 Numerical Results

For the performance of the proposed hybrid queuing scheme, we verify the proposed scheme using the computer simulation and simulation model can be characterized as follows: (a) Simulation is performed by SIMSCRIPT II.5 Package using discrete time event scheduling. (b) The calls are arrived $10^7 \sim 10^8$ times in a cell. (c) Modules of simulation have PREAMBLE,MAIN, INITIAL, ARRIVAL, DEPARTURE, and STOP.SIM.

In Fig. 3, the proposed method is compared to the previous schemes with two types of traffic (voice call and data call) in aspect of the blocking probability. In numerical results, we are given for the following parameters: high priority call$\lambda_1$ is voice call, low priority call$\lambda_1$ is data call, queue size M is 40, threshold value T is 20, first sub- threshold value $t_1$ is 10, and number of channel per-cell C is 40.

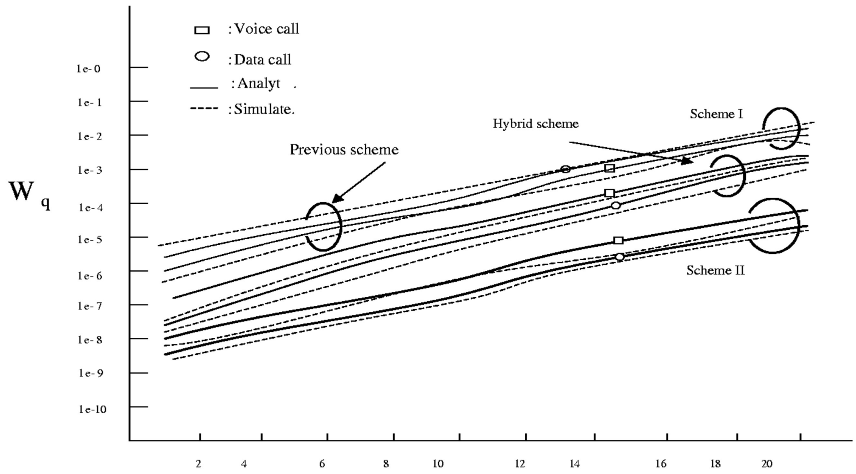



**Fig. 4.** Mean waiting time vs. arrival rate $\lambda$

Compared to the previous scheme, the proposed method shows the better performance result than previous scheme or our previous scheme I in terms of the blocking probability with two types of traffic because the method is based on hybrid priority control.
For the mean waiting time in Fig.4, our previous scheme I also shows the same performance result compared to previous scheme because our previous scheme I is based on HOL control traffic. However, the proposed hybrid strategy shows better performance result than the previous scheme because the scheme is based on hybrid priority control with two types of traffic.

## 5 Conclusions

We proposed on hybrid queuing strategy with traffic control to reduce the high blocking rate of multiple priority calls for channel allocation in MWN. In numerical results, the proposed method is better performance than our previous scheme I in terms of the blocking probability, and than our previous scheme II with respect to the mean waiting time under same priority. Proposed method must be getting better analytic model than previous schemes.

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