INSTITUTE OF POLICY AND PLANNING SCIENCES

Discussion Paper Series

No. 975

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by

Yosuke Horibe and Yongbing Zhang

February 2002

UNIVERSITY OF TSUKUBA
Tsukuba, Ibaraki 305-8573
JAPAN

# A Mobility Based Resource Predictive Scheme with QoS Guarantees in Multimedia Wireless Networks

Yosuke Horibe† and Yongbing Zhang‡

†Undergraduate Program in Policy and Planning Sciences,
University of Tsukuba, Tsukuba, Ibaraki 305–8573 Japan
‡Institute of Policy and Planning Sciences, University of Tsukuba,
Tsukuba, Ibaraki 305–8573 Japan

**Abstract**

In the next generation wireless networks, multimedia data such as videos and data in addition to voice may play key role in most applications. It is therefore important to provide quality-of-service (QoS) guarantees for these multimedia applications. This paper proposes an adaptive bandwidth (communication channel) reservation scheme to provide QoS guarantees for multimedia traffic carried in high-speed wireless cellular networks. The proposed scheme utilizes the user mobility information, such as the position wherein a user is located and the power level that the user receives from the base stations (BSs), to reserve the channels in order to support the seamless data communication. Using this scheme, not only the connection dropping probability but also the connection blocking probability can be reduced significantly compared with the other existing algorithms.

**Keywords:** Adaptive channel reservation, quality-of-service guarantee, reservation probability, and multimedia wireless networks.

## 1 Introduction

Next generation wireless networks are expected to support multimedia applications, i.e., video, voice, and data [1, 2, 3, 4, 5, 6, 7]. It is therefore important that these networks provide quality-of-service (QoS) guarantees. QoS provisioning for multimedia traffic has been extensively studied for wireline networks. However, provision of QoS in wireless networks becomes complex due to user or mobile host (MH) mobility. If an MH hands off, it releases the current serving channel at the current cell and reserves a new channel at its forward neighboring cells. The problem becomes even more challenging as recent wireless networks have been implemented based on small-size cells to allow high transmission capacity, and thus to achieve better performance. Small-size cells increase the handoff rate, and result in rapid changes in the network traffic conditions, making QoS guarantees difficult. In multimedia wireless communication networks, connection dropping due to the failure of handoffs is more severe, comparing with new connection blocking, .

In this paper, we propose a new channel reservation scheme that provides high degrees of QoS guarantees but reduces the waste of unnecessary channel reservation for multimedia traffic carried in cellular mobile networks. The proposed scheme utilizes the user mobility information, such as the position of a user in a cell and the power level of the user received from the surrounding base stations (BSs), so that the channel reservation can be determined more accurately than the previous algorithms [8, 9]. MHs monitor the power levels received from the BSs and make the reservation autonomously to the BSs. The BSs, on the other hand, receive the reservation requests from the MHs and process them according to a priority queue discipline.

# 2 Related Work

In order to guarantee QoS for multimedia applications, an MH attempts to reserve channels at its neighboring cells so that successive handoffs to these cells can be guaranteed. Many papers have studied the resource bandwidth reservation algorithms [8, 10, 9, 2]. In [8], the reservation algorithm, called FR in this paper, provides QoS guarantee for each connection request by reserving a full channel at each neighboring cell simultaneously. This algorithm is apparently too conservative and wastes a large amount of system resources, resulting in low channel utilization (CU) and high connection blocking probability (CBP). As can be seen in the results of this paper, this algorithm also leads to a higher dropping probability than other algorithms. On the other hand, a probabilistic reservation algorithm, called static reservation (SR) algorithm in this paper, was proposed in [9]. This algorithm utilizes the statistical mobility information of users at each cell and reserves channels at the neighboring cells with some probability determined based on the statistical information. In this way, unnecessary channel reservation can be reduced, resulting in low connection dropping probability.

# 3 Channel Reservation Algorithm

In this paper, we propose an adaptive probabilistic channel reservation algorithm that reserves free channels for MHs at their neighboring cells with some probabilities so that handoffs to these cells can be guaranteed. The channel reservation is implemented on a client/server basis, where an MH works as a client while a BS acts as a server. It is assumed that BSs process handoff calls with high priority in the sense that if they have free channels they will satisfy the handoff requests first. It is also assumed that an MH moves around autonomously and monitors continuously the power levels of the BSs that he/she can sense.

The proposed algorithm reserves channels for a user at its neighboring cells based on where it is located and how strong it senses the power levels of its neighboring BSs. If it is at or near to the center of a cell, is has apparently no or little need to reserve a channel at its neighboring cells. On the other hand, if it is located near to the boundary with other neighbors, it needs to reserve a free channel at its neighbors with a higher probability.

In order to describe the proposed algorithm, the following notation is used.

$p_i$ power level received from the current serving BS

$p_j$ power level received from the BS of neighbor $j$

$p_{th}$ threshold used for handoff and $p_{th} \le p_i$; i.e., if the power level of the current serving BS is lower than $p_{th}$, the user attempts to perform a handoff.

$r^x_{ij}$ probability of channel reservation by MH $x$ at cell $i$ to cell $j$; i.e., $0 < r^x_{ij} \le 1$.

# Reservation algorithm

The reservation algorithm contains two components: a *client component* used for making channel reservation requests for MHs and a *server component* used for receiving the requests and for processing the requests based on a priority queue discipline. The requests from the MHs are put into a priority queue wherein the request with the highest reservation probability is allocated at the head of the queue.

## Client component

An MH activates the client component to make a channel reservation request to the BSs of its neighboring cells. How much it should reserve at a neighboring cell depends on the power level it receives from the current serving BS and from the neighboring BS. For a user located in cell $i$, the client component is implemented by the following three steps.

**Step 1.** Measure the power level of each BS it can sense. The BSs include its current serving BS and neighboring BSs. If the power level just measured is largely different from that of last measurement, i.e., if the difference of the power level between two measurements is greater than a predefined threshold, then go to step 2. Otherwise, continue to measure the power level of the BSs.

**Step 2.** Determine the probability of channel reservation at neighboring cell $j$ based on the following relation.

$$r^x_{ij} = \frac{p_i}{p_i + p_j - p_{th}}. \tag{1}$$

**Step 3.** Send the reservation request to neighboring cell $j$.

## Server component

A BS contains two processing queues: one for possible handoff calls from the neighboring cells and another for new connection requests originated at its serving cell. The queue for handoff calls follows a priority queue discipline while the queue for new connection requests is based on an first-in-first-out discipline. A BS may receive three kinds of requests: a channel reservation request from an MH located at a neighboring cell, a handoff request from an MH moving from a neighboring cell to its service area, and a new connection request originated at its service area. A handoff request is processed with a higher priority than a new connection request. Furthermore, the handoff request with the highest probability is put at the head of the reservation queue.

A BS does not fully reserve a channel for each request but adds the request probabilities together to form an *accumulated channel request*. Free channels are assigned to the accumulated channel request as shown in Figure 1. Note that an MH may request more than one channel simultaneously as shown in Figure 1. For a channel reservation request, the server component of cell $j$ is implemented by the following 4 steps.

**Step 1.** Receive a channel reservation request from an MH $x$ located at neighboring cell $i$.

**Step 2.** Put the request at the right position in the priority queue according to its request probability $r_{ij}^{x}$.

**Step 3.** Reserve free channels for the accumulated channel request. If there is no free channel, record this request and go to the next step.

**Step 4.** Reserve free channels if the accumulated channel request is not satisfied whenever a free channel is available.

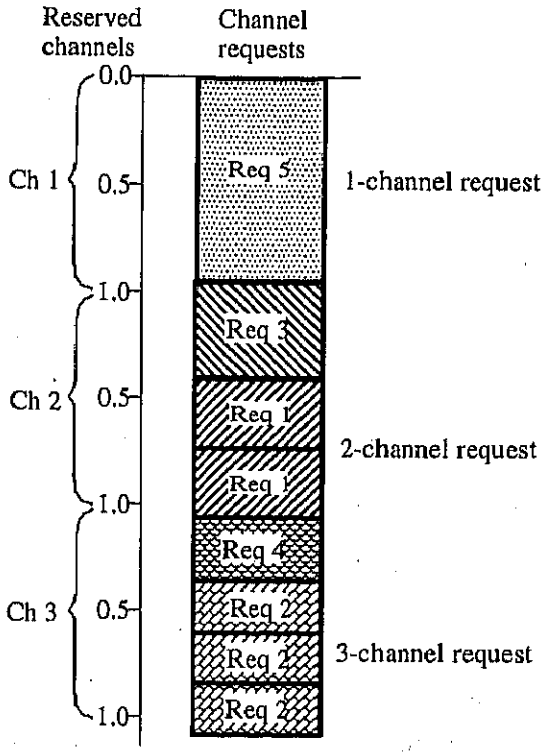


Figure 1: Probabilistic channel reservation.

For a handoff request, the server component executes the following two steps.

**Step 1.** Assign a reserved channel to the handoff request. If there is no reserved channel, record this request and go to the next step.

**Step 2.** If the handoff call is still active and any reserved channel is available, go to Step 1. Otherwise, delete the handoff request if the handoff request is dropped; i.e., the connection is forced to termination.

For a new connection request, the server component performs a channel assignment as follows.

- Assign a free channel to the new request if there is any free channel. Otherwise, block the request.

## 4 Numerical Results

Simulation experiments are used to evaluate the proposed algorithm, denoted by adaptive reservation (AR) algorithm in the figures, and compare it with the Full Reservation (FR) algorithm [8] and the Static Reservation (SR) algorithm which uses the statistical information of user mobility for probabilistic reservation [9]. An extreme algorithm, denoted by NR in the figures, that used no channel reservation is also implemented for comparison. The performance measures used for comparison are the connection dropping probability (CDP), connection blocking probability (CBP), and channel utilization (CU). The performance measures are defined as follows.

$$CDP = \frac{\text{Number of dropping flows}}{\text{Number of total handoff flows}}, \tag{2}$$

$$CBP = \frac{\text{Number of blocking flows}}{\text{Number of total flows}}, \tag{3}$$

$$CU = \frac{\text{Mean communication time} \times \text{Number of succeeded requests}}{\text{Total number of channels} \times \text{Simulation time}}. \tag{4}$$

The simulated system contains $10 \times 10$ cells and each cell is modeled by a square region as shown in Figure 2. Each cell has 8 neighboring cells and contains $6 \times 6$ mesh areas as shown in Figure 2. MHs are randomly allocated in each mesh area at the beginning and each MH moves to its neighboring areas or stays at the same area with equal probability. The power level received at a mesh area of cell $i$ from BS $j$ is indicated by $pw_j, j = 0, 1, ..., 8$ where BS 0 denotes the current serving BS. The power level, $pw_j$, received from a BS at a mesh area is set from 0 to 10 by considering the power attenuation as shown in Figure 2.

It is assumed that the connection duration time is exponentially distributed with a mean $\mu$ of 1 hour. The request arrivals follow the Poisson process with a mean $\lambda$ of 0.5 times/hour. The number of channels at each cell is 20. The traffic load is indicated by Erlang on a channel and is changed from 0.1 to 1.0. In the simulation, it is assumed that each connection request requires

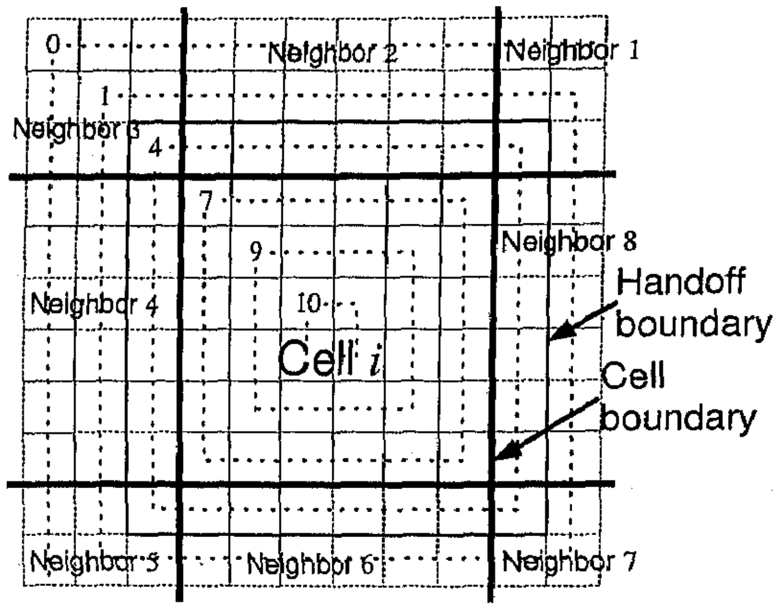


Figure 2: Cell model.

only one channel at once. The results shown in the figures were obtained with 95% confidence interval and within 5% of the sample mean.

## 4.1 Performance Evaluation

Figure 3 shows the connection dropping probabilities of the algorithms under consideration for various traffic load. It can be seen from this figure that FR degrades rapidly when the traffic load increases, because it reserves one full channel at every neighboring cell for each MH. The AR algorithm proposed in this paper, on the other hand, performs much better than the other algorithms and its CDP is very low even when the traffic load is high, e.g., its CDP is less than 1% at load of 1.0, which is two times smaller than that of SR. This is because that AR utilizes more accurate MH location information in channel reservation decisions and therefore reduces the waste of system resources, especially at high traffic load.

Figure 4 shows the channel utilization of the algorithms. From this figure, it can be observed how effective each channel is used. It can be observed that AR provides better channel utiliza-

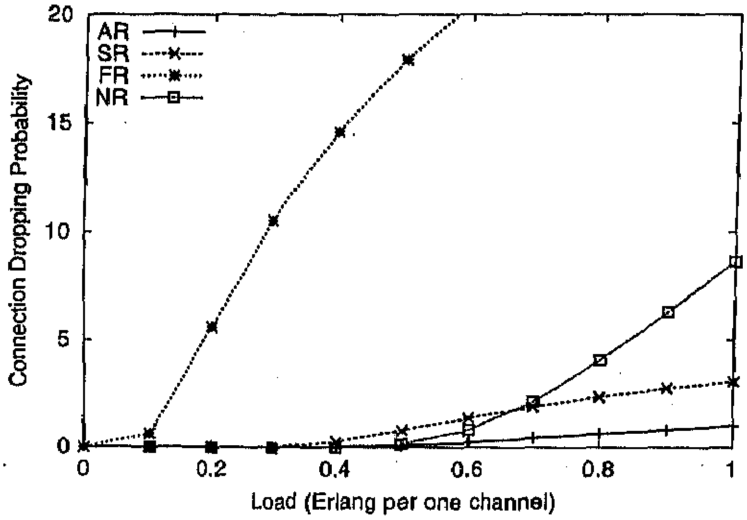


Figure 3: Connection dropping probability vs. traffic load.

tion than other reservation algorithms. The NR algorithm shows the highest channel utilization, because it does not consider QoS guarantees and does not reserve any channels for handoff calls. Another reason for this result comes from the system model used in simulation. For simplicity, we use the square cell model as shown in Figure ??. In a more realistic model like the hexagonal cell model, each cell has less neighboring cells and therefore much less channel reservation can be realized. Therefore, we consider a worse case in this paper.

Figure 5 shows the connection blocking probabilities of various algorithms. It is observed that CBP increases sharply after some traffic load point, since the reservation algorithms need to reserve free channels for the active connections. When the load increases, more channels need to be reserved and the system becomes saturated rapidly. From this figure, it can be observed that AR provides much lower CBP than other algorithms. This means using AR more MHs can be accepted by the system. The reason for that NR shows the lowest CBP is similar to that described before.

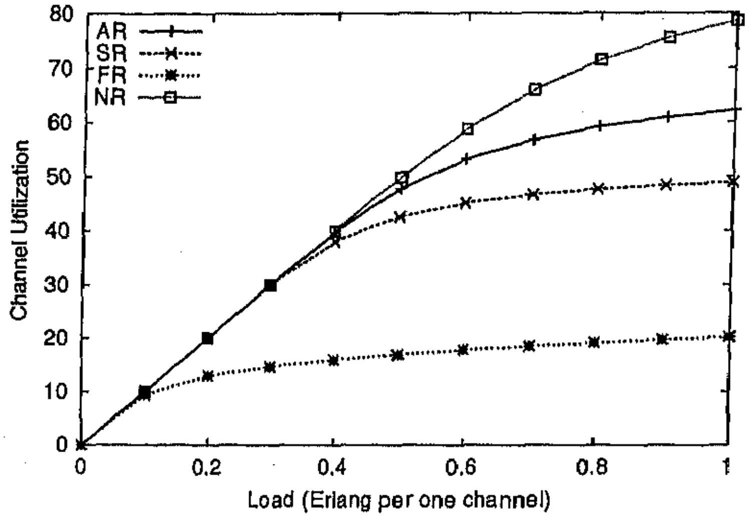


Figure 4: Channel utilization vs. traffic load.

## 4.2 Parameter Tuning

The performance of a QoS-guaranteed algorithm depends heavily on how to reserve free channels for possible handoff requests. In this paper, we propose two parameter tuning schemes that control the amount of the reserved channels. The first one is a *scaling factor* denoted by $a, 0 < a \leq 1$ used for tuning the accumulated reservation channel. That is, only the $a$ percent of the accumulated channel request is reserved. The second one is a *threshold factor* denoted by $t, 0 \leq t < 1$ used for excluding the requests with too small reservation probabilities. That, the requests with a probability less than $t$ is not taken into account.

Figures 6–8 show the performance of AR using the tuning parameters. It can be seen from these figures that tuning the scaling or threshold factor can improve CU and CBP but inevitably worsen CDP. However, since CDP is not sensitive to the tuning factors while CU and CBP do, choosing an appropriate tuning parameter can suppress big degradation of CDP while improve CU and CBP largely.

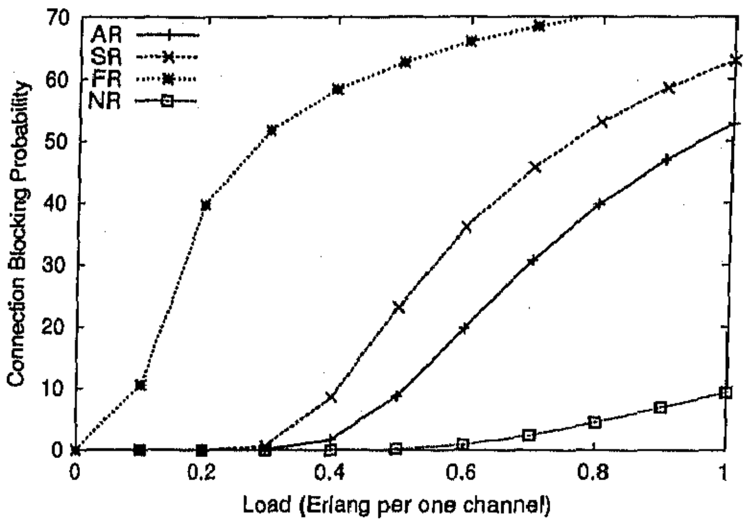


Figure 5: Connection blocking probability vs. traffic load.

# 5 Conclusions

In this paper, we proposed an adaptive probabilistic channel reservation algorithm for QoS-guaranteed multimedia applications in wireless networks. It is shown that the proposed algorithm improves the performance (connection dropping probability, channel utilization, and connection blocking probability) significantly over the previous algorithms. In the next generation wireless networks, e.g., CDMA-based systems, each BS broadcasts continuously synchronous signals for each MH to control its signal power. The proposed algorithm is expected to combine this functionality at MH in order to implement a power monitoring machanism from the BSs.

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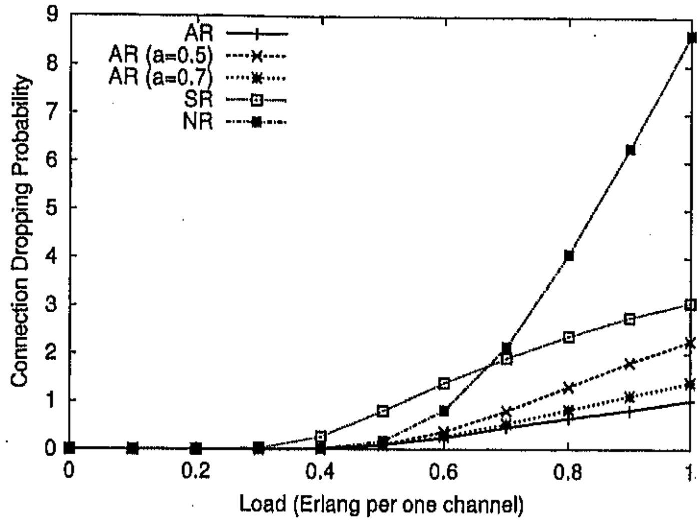
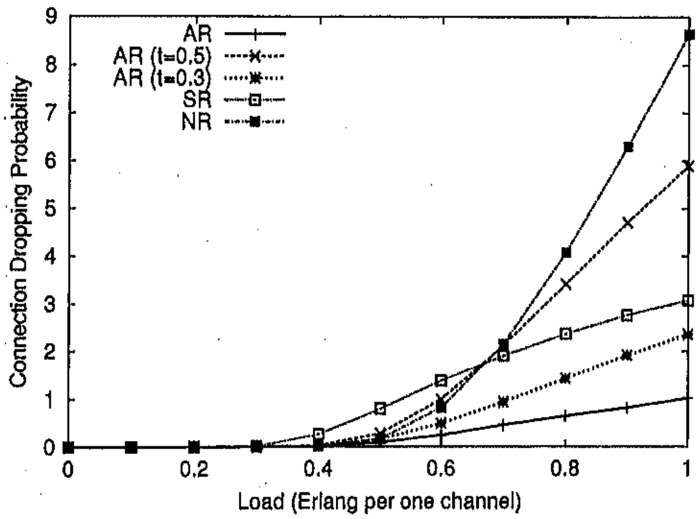
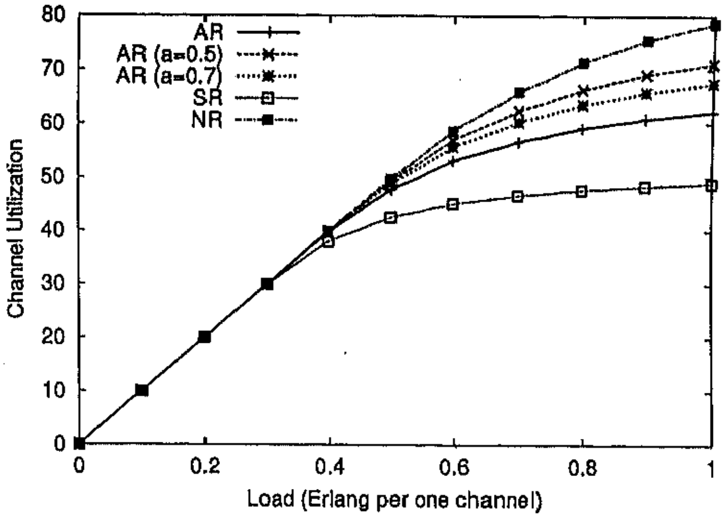


(a) Scaling factor $a$.

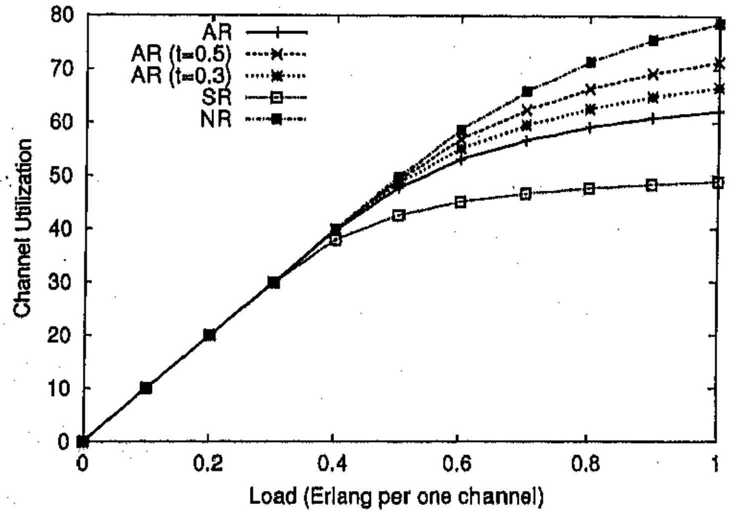


(b) Threshold factor $t$.

Figure 6: Connection dropping probability with parameter tuning.

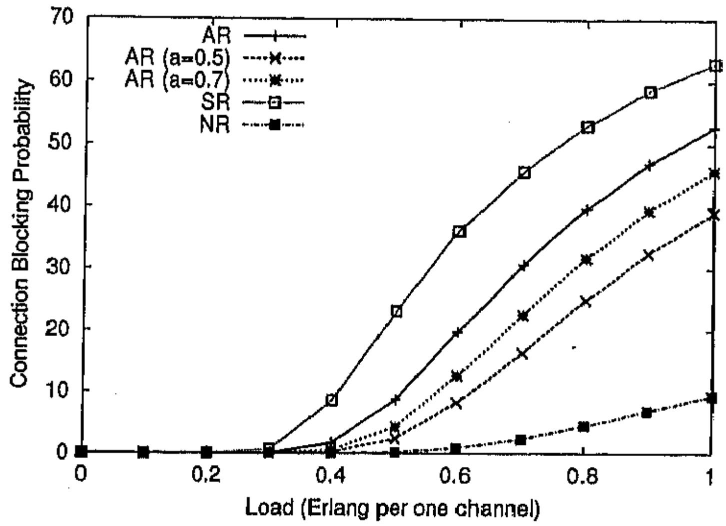



(a) Scaling factor $a$.

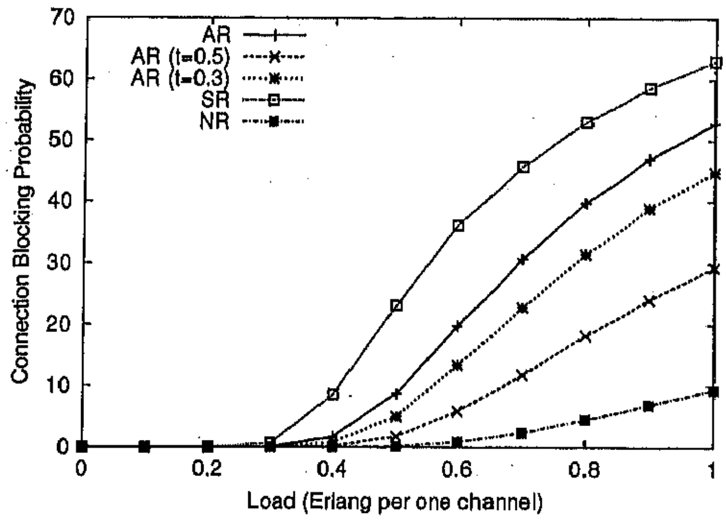



(b) Threshold factor $t$.

Figure 7: Channel utilization with parameter tuning.




(a) Scaling factor $a$.




(b) Threshold factor $t$.

Figure 8: Connection blocking probability with parameter tuning.