A NEW PRIORITY POLICY FOR CHANNEL ASSIGNMENT IN PCS NETWORKS

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ABSTRACT

This paper presents a new policy called the threshold priority policy (TPP) for channel assignment in personal communication service (PCS) networks. The performance of this policy is compared with the performance of the well-known cutoff priority policy (CPP). The major performance measures used include blocking probability of new calls, forced termination probability, overall blocking probability and call non-completion probability. Several simulation experiments are done to study the sensitivity of the different policies to parameters such as offered load and portable mobility. These results are used to validate the analytical results obtained in an earlier study.

INTRODUCTION

The advent of personal communication service (PCS) networks [5] has greatly facilitated mobile communications over the past few years. The service area of a PCS network consists of sub-areas called cells. This paper assumes a fixed channel assignment where a group of frequency channels are assigned to each cell. These channels must serve new calls (i.e., calls which originate within the cell) and handoff calls (i.e., ongoing calls transferred from one cell to another due to the mobility of the portables).

Since the forced termination of a handoff call can be more disruptive to a user than a busy signal, several policies with priority to handoff calls have been proposed [4]. One of the policies which has been studied in detail is the cutoff priority policy (CPP) [7, 6]. Priority is ensured by dedicating a subset of channels, called *guard channels*, to handoff calls. A new call is accepted only if the *total* number of calls in progress, regardless of their type, is below a cutoff value and a free channel is available. This paper presents a new priority policy called the threshold priority policy (TPP) [2]. Under TPP, a new call is accepted only if the number of *new* calls in progress is below a threshold value and a free channel is available.

This paper compares TPP with CPP using major performance measures including new call blocking probability (p_N), forced termination probability (p_F), overall blocking probability (B) and the call non-completion probability (p_{NC}) [3]. The use of TPP for channel assignment was first proposed in an earlier study [2]. Analytical models were used to compare the performance of TPP and CPP for various values of offered load and portable mobility. In this paper, simulation is used to compare the performance of TPP and CPP and these results are used to validate the analytical results obtained earlier.

ANALYTICAL MODEL

The PCS network is assumed to be homogeneous and in statistical equilibrium. Each cell is assigned N channels. Since a single cell is representative of the behavior of other cells in the service area, the focus of this study is restricted to the flow of calls to and from a single cell [3, 8]. The major assumptions used in this study are similar to those used in earlier models [1, 5, 6]: (i) New call attempts and handoff call attempts follow a Poisson process with mean rates λ_N and λ_H respectively, (ii) portable residence time, call duration and channel holding time are exponentially distributed with means $1/\eta$, $1/\mu$, and $1/\mu_{ch}$ respectively, and (iii) portable mobility pattern is arbitrary.

Let $\theta = \mu/\eta$. Let y denote the control parameter. For CPP, y denotes the number of guard channels. For TPP, if x denotes the maximum number of new calls that can be accepted, then $y = N - x$. For CPP (TPP), given a cutoff (threshold) parameter x, the values of p_N and p_H can be easily determined [2]. Given p_N and p_H, the expressions for p_F, p_{NC} and λ_H are given by

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[3, 2]: $p_F = p_H/(p_H + \theta)$, $p_{NC} = p_N + p_F(1 - p_N)$, and $\lambda_H = \lambda_N[1 - p_N]/(p_H + \theta)$.

For the numerical experiments, the number of channels was set to 10, and the mean call duration was set to 3 minutes. The offered load was varied from 3 Erlangs to 5 Erlangs, in increments of 0.5 Erlangs. For a given call duration, the experiments were repeated for different values of mobility (i.e., $\theta = 2.0, 1.0$ and 0.5). For each experiment, y was varied from 1 to N. λ_H was initially set to $0.1\lambda_N$. An iterative procedure (as in [5]) involving p_N, p_H and λ_H was used. The iterations were stopped when there was no change in the λ_H values within four significant figures or if the number of iterations exceeded 20000.

SIMULATION

A simulation model was developed for TPP and CPP and the results were compared with those of the analytical model. The simulation model was written in ARENA [9] and run on an IBM-compatible PC (Pentium 200 processor). ARENA is a general purpose simulation language, and with the graphics interface and built-in modules for queueing analyis (for example, blocking and balking), it is easy to model TPP and CPP.

The input parameters were assigned values similar to those used in the analytical model. The value of λ_H was initially set to λ_N/θ. Similar to the analytical model, an iterative procedure involving λ_H was used. Every 2,000 minutes, a new λ_H was calculated using the equation given in the previous section. If the change in the λ_H values was more than four significant figures, then the λ_H value was updated.

Each experiment was run 10 replications each of which simulated performance over 10,000 minutes. Observations from the first 10,000 minutes were discarded to eliminate the initial transient period, and the averages of 10 replications (i.e., a total of 100,000 minutes) were used to plot the graphs shown in Figures 1 to 8.

The new calls were generated from exponential random variates with a mean of $1/\lambda_N$. The handoff calls were also generated from the exponential random variates with a mean of $1/\lambda_H$. The values of p_N and p_H were estimated at the end of the simulation run. These values were then used to determine p_F and p_{NC}, as outlined in the previous section.

COMPUTATIONAL RESULTS

Figures 1 to 8 show the results of the computational experiments for specific values of input parameters. In these figures, the simulation results are denoted by solid lines (and also by superscript s) and the analytical results are denoted by dotted lines (and also by superscript a). The following terminology is used for the study of performance: low load (i.e., offered load of 3 Erlang), high load (i.e., offered load of 5 Erlang), low mobility (i.e., $\theta = 2$), and high mobility (i.e., $\theta = 0.5$).

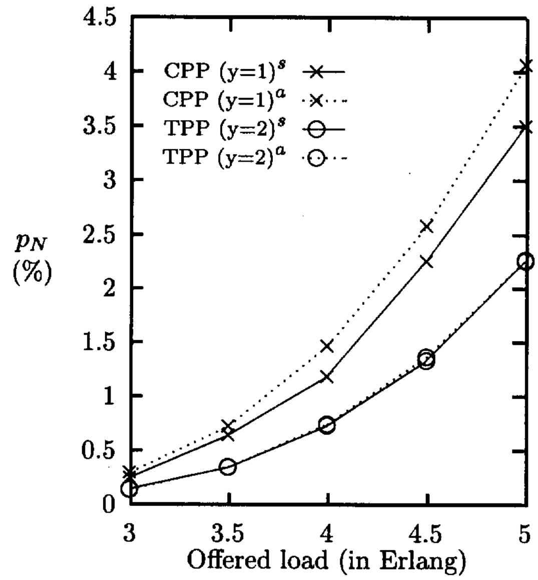

Figure 1: Impact of offered load on new call blocking probability

Figure 1 shows the impact of offered load on the blocking probability of new calls (p_N) at low mobility. Figure 2 shows the impact of offered load on forced termination probability (p_F) at low mobility. It can be seen that the results of the simulation and the analytical model are quite close. It can also be seen that while TPP tends to dominate CPP in terms of minimizing p_N, CPP tends to dominate TPP in terms of minimizing p_F. A similar behavior is exhibited by both CPP and TPP at high mobility (not shown in figure).

Figures 1 and 2 indicate that there is a tradeoff between p_N and p_F i.e., a low value of p_N results in a high value of p_F and vice versa. To capture this tradeoff between p_N and p_F, the overall blocking probability can be considered as a unified measure of performance [1, 3]. This is defined as $B = \alpha \cdot p_N + (1 - \alpha) \cdot p_F$, where $0 \leq \alpha \leq 1$. Since p_F is considered to be more important than p_N [3], $\alpha < 0.5$.

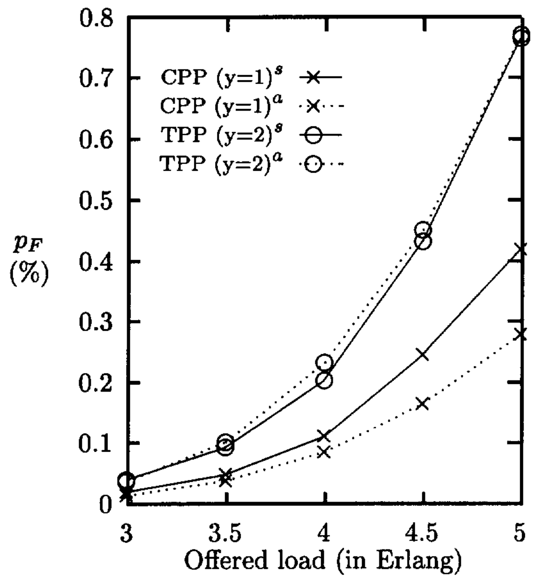

Figure 2: Impact of offered load on forced termination probability

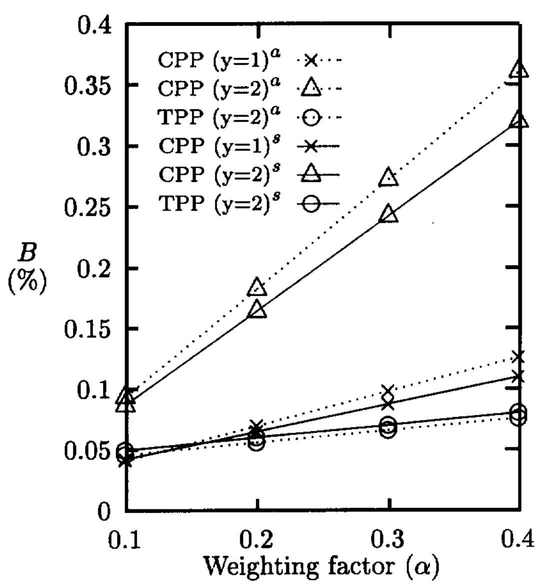

Figure 3: Impact of weighting factor on overall blocking probability (Low load, low mobility)

Figures 3 and 4 show the impact of weighting factor (α) on B at low load. It can be seen that at low mobility, CPP tends to dominate TPP in terms of minimizing B only when α is less than about 10%. This behavior is valid even at higher mobility except that the range of α for which CPP dominates TPP is increased to approximately 20%. Figures 5 and 6 show the impact of α on B at high load. The results are similar to those at low load except that the range of α for which CPP dominates TPP are higher (i.e, approximately upto 20% at

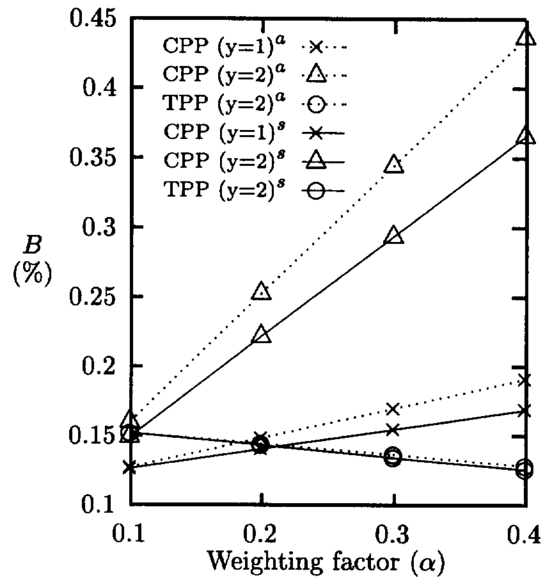

Figure 4: Impact of weighting factor on overall blocking probability (Low load, high mobility)

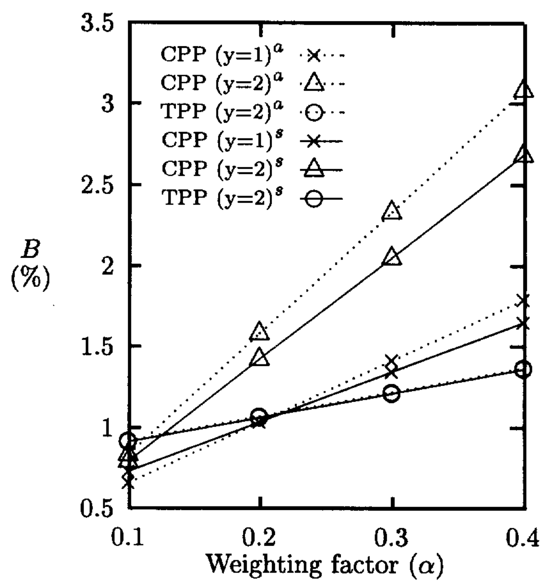

Figure 5: Impact of weighting factor on overall blocking probability (High load, low mobility)

low mobility and upto 30% at high mobility).

It can be seen that the simulation results closely follow those obtained from the analytical model. In addition, as in the analytical results, the simulation results show that at high load and high mobility, $p_N(CPP)$ exceeds the common grade of service requirement (i.e., 2 percent) for cellular systems, while $p_N(TPP)$ does not for the given values of control parameter.

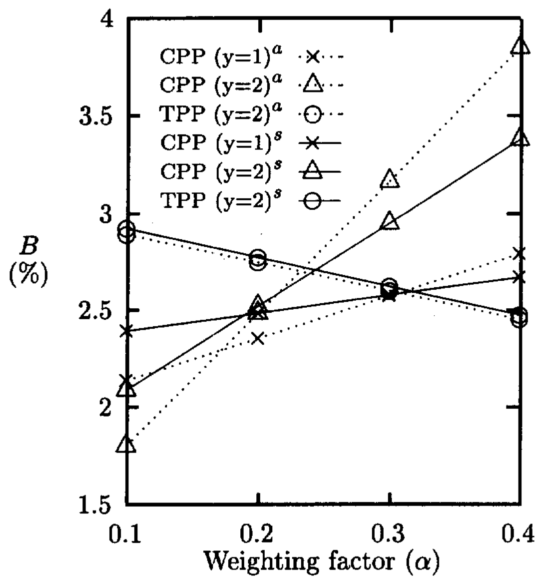

Figure 6: Impact of weighting factor on overall blocking probability (High load, high mobility)

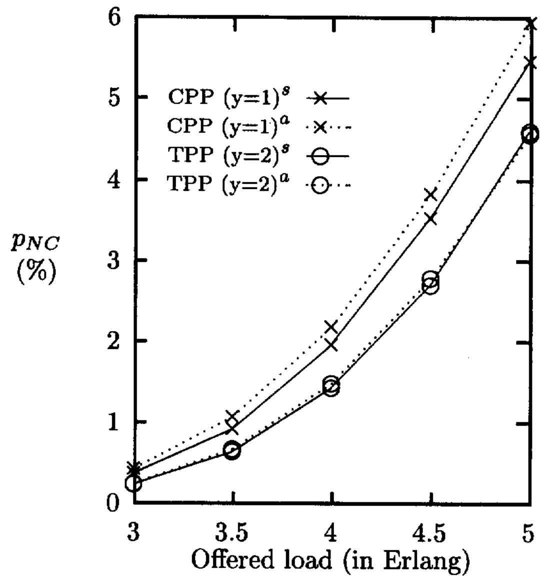

Figure 8: Impact of offered load on non-completion probability (High mobility)

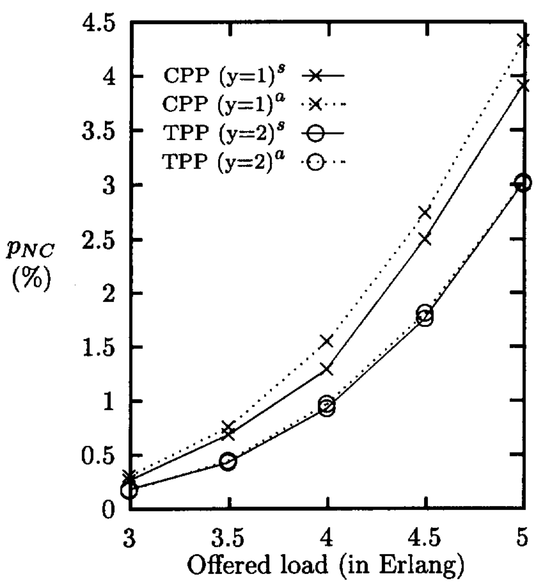

Figure 7: Impact of offered load on non-completion probability (Low mobility)

Another performance metric which is used to capture the tradeoff between p_N and p_F is the call non-completion probability (p_{NC}) [3, 5]. Figures 7 and 8 show that TPP tends to dominate CPP in terms of minimizing p_{NC} at low and at high mobility, respectively. Analytical results as well as simulation results show that for both TPP and CPP, p_{NC} increases with an increase in offered load and increase in mobility.

It can be seen from the above figures that the simulation results clearly support the validity of the analytical approach in determining the major performance measures discussed in this paper.

CONCLUSION

This paper presents a new policy called the threshold priority policy (TPP) for channel assignment in personal communication service (PCS) networks. The performance of this policy is compared with the performance of the well-known cutoff priority policy (CPP). The major performance measures used in this study include the following: blocking probability of new calls, forced termination probability, overall blocking probability and call non-completion probability.

The use of TPP for channel assignment was first proposed in an earlier study [2]. Analytical models were used to compare the performance of TPP and CPP for various values of offered load and portable mobility. In this paper, simulation is used to compare the performance of TPP and CPP and these results are used to validate the analytical results obtained earlier. The results from the analytical model and from simulation experiments show that for overall blocking probability, CPP is more attractive than TPP only if the relative importance of p_F to p_N is very high. In terms of the non-completion probability, TPP tends to dominate CPP at low as well as high mobility.

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