Priority Policies for Channel Allocation in Cellular Radio Networks

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Abstract

In cellular radio networks, the service area is divided into a certain number of cells. Each cell is assigned a set of frequency channels and must deal with two types of calls - new calls and handoff calls. In many practical situations, the blocking of a handoff call is critical since it will result in a disconnection of the call in the middle of conversation. Therefore, several priority schemes to reduce the chances of unsuccessful handoffs have been suggested.

The simplest way of giving priority to handoff calls is to reserve some frequency channels for calls being handed off into the cell, known as cutoff priority policy (CPP). Under CPP, priority is given to handoff calls by exclusively assigning them a certain number of channels called *guard channels*. The remaining channels called *ordinary channels* are shared by both calls. When a new call is generated, it is blocked if the number of free channels is less than or equal to the number of guard channels. However, a handoff call is blocked only when all the channels are busy in the cell.

Another policy which gives priority to handoff calls is the threshold priority policy (TPP). Under TPP, a handoff call is accepted as long as channel is free. However, 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. The concept of TPP was used earlier for congestion control in store-and-forward networks.

Under CPP and TPP, the optimal channel allocation problems are mathematically formulated as follows. Let λ_i^n and λ_i^h be the traffic demands in erlangs of new calls and handoff calls in cell i, respectively, and let m_i be the number of available channels in cell i. Then, for CPP, the blocking probabilities of new calls and handoff calls in cell i are, respectively, given by

$$BN_i(m_i, x_i) = \frac{\dfrac{\lambda_i^{x_i}}{x_i!} + \lambda_i^{x_i} \sum_{j=1}^{m_i - x_i} \dfrac{(\lambda_i^h)^j}{(x_i + j)!}}{\sum_{j=0}^{x_i} \dfrac{\lambda_i^j}{j!} + \lambda_i^{x_i} \sum_{j=1}^{m_i - x_i} \dfrac{(\lambda_i^h)^j}{(x_i + j)!}} \quad \text{and} \quad BH_i(m_i, x_i) = \frac{\dfrac{\lambda_i^{x_i} (\lambda_i^h)^j}{m_i!}}{\sum_{j=0}^{x_i} \dfrac{\lambda_i^j}{j!} + \lambda_i^{x_i} \sum_{j=1}^{m_i - x_i} \dfrac{(\lambda_i^h)^j}{(x_i + j)!}},$$

where $\lambda_i = \lambda_i^n + \lambda_i^h$ and x_i is the cutoff parameter (i.e.., $m_i - x_i$ is the number of guard channels) in cell i. And, for TPP, the blocking probabilities of new calls and handoff calls in cell i are, respectively, given by

$$BN_i(m_i, x_i) = \frac{\sum_{j=0}^{x_i} \frac{(\lambda_i^n)^j (\lambda_i^h)^{m_i-j}}{j!(m_i-j)!} + \sum_{k=0}^{m_i-x_i-1} \frac{(\lambda_i^n)^{x_i} (\lambda_i^h)^k}{x_i! k!}}{\sum_{j=0}^{x_i} \sum_{k=0}^{m_i-j} \frac{(\lambda_i^n)^j (\lambda_i^h)^k}{j! k!}} \quad \text{and}$$

$$BH_i(m_i, x_i) = \frac{\sum_{j=0}^{x_i} \frac{(\lambda_i^n)^j (\lambda_i^h)^{m_i-j}}{j!(m_i-j)!}}{\sum_{j=0}^{x_i} \sum_{k=0}^{m_i-j} \frac{(\lambda_i^n)^j (\lambda_i^h)^k}{j! k!}},$$

where x_i is the threshold parameter in cell i.

Then, the prioritized channel allocation problem which minimizes the overall blocking probability, defined by the weighted value of the average blocking probabilities of new calls and handoff calls, while ensuring the co-channel interference constraints is as follows:

$$\begin{aligned}
\min\ & \alpha \sum_{i=1}^{N} w_i^n BN_i(m_i, x_i) + (1-\alpha) \sum_{i=1}^{N} w_i^h BH_i(m_i, x_i) \\
s.t.\ & m_i = \sum_{j=1}^{M} f_{ij}, \quad \text{for } i = 1, \ldots, N, \\
& x_i \le m_i, \quad \text{for } i = 1, \ldots, N, \\
& f_{sj} + f_{tj} \le 1, \quad \text{for } j = 1, \ldots, M, \text{ and all interfering cell pairs } (s, t), \\
& m_i, x_i : \text{nonnegative integer}, \quad \text{for } i = 1, \ldots, N, \\
& f_{ij} = 0 \text{ or } 1, \quad \text{for } i = 1, \ldots, N,\ j = 1, \ldots, M,
\end{aligned}$$

where α is a weighting factor, and $w_i^n = \lambda_i^n / \sum_{i=1}^{N} \lambda_i^n$ and $w_i^h = \lambda_i^h / \sum_{i=1}^{N} \lambda_i^h$. Since the blocking probability of handoff calls is considered to be more important than the blocking probability of new calls, in general $\alpha \le 0.5$. The decision variable f_{ij} is a binary integer variable indicating channel allocation where $f_{ij} = 1$ represents that channel j is allocated to cell i and $f_{ij} = 0$ otherwise.

This is a nonlinear integer programming problem, which is NP-hard because it can be easily reduced to the independent set problem known to be NP-complete. To deal with the problem more conveniently, the concept of pattern is used. This concept helps to avoid obtaining many equal symmetric solutions which may occur by permuting channels with unaltered value on the objective function. A pattern is a set of cells to which a channel can be allocated without causing co-channel interference. The prioritized channel allocation problem is converted into a simpler form through the concept of pattern. Then a quite satisfactory approach called simulated annealing is applied to the simplified problem.

Numerical tests have been performed for a cellular radio network with nonuniform traffic distribution. The test results show that CPP_S and TPP_S provide high-quality solutions compared with other channel allocation methods, and TPP_S provides better solutions than CPP_S for only the network with lower traffic load and lower mobility.