A NEW DYNAMIC CHANNEL MANAGEMENT SCHEME

TO INCREASE THE PERFORMANCE INDEX OF FOR CELLULAR NETWORKS

Konstantinos Ioannou¹, Stavros Kotsopoulos¹ and Stavros Koubias²

¹ Wireless Telecommunications Laboratory, Dept. of Electrical and Computer Engineering, University of Patras
² Applied Electronics Laboratory, Dept. of Electrical and Computer Engineering, University of Patras

Corresponding author’s name: Konstantinos Ioannou

Address: Wireless Telecommunication Laboratory, Dept. of Electrical and Computer Engineering, University of Patras, Rio, Patras, 26500, Greece.

Phone: +302610997301, +306937030405

Fax: +302610997302

E-mail: ioannou@ee.upatras.gr

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Konstantinos Ioannou¹, Stavros Koubias² and Stavros Kotsopoulos¹

Abstract: This letter presents a Dynamic Channel Management Scheme (DCMS), using both an One-Layer Cellular Architecture (OLCA) and a Two-Layer Cellular Architecture (TLCA), for use in areas with random offered traffic load. The philosophy of DCMS is that it is based either on OLCA or TLCA proposed to the optimization of the handoff blocking probability performance of High-Speed Moving Terminals (HSMT) and the call blocking probability of the rest calls in a congested urban area, with random offered traffic load. Also the number of channels assigned to microcells and umbrella cell, is regulated dynamically in order to have the above results.

INTRODUCTION: The rapid increase in demand for mobile communications has led the industries into research and development efforts towards a new generation of wireless cellular systems. One of the major challenges in such networks is the utilization of limited resources, effectively, in order to provide high availability of service. The performance index used for measuring the efficiency of a channel assignment scheme is the call blocking probability and especially the handoff blocking probability. A great effort has been spent in order to study the channel assignment and the handoff process and to minimize the involved handoff blocking probability [1],[2],[3]. The handoff blocking probability is considered to be more important than the blocking probability of new calls, because the calls are already in active mode and the corresponding QoS is more sensitive for the handoff calls. An examined model adopts a traffic analysis for cellular mobile networks with prioritized handoff procedure, where all calls are serviced by the microcells (Typical Cellular System - One Layer Cellular Architecture– OLCA)[1],[2]. Also, is shown a model where handoff calls of HSMT are serviced by the umbrella layer and both the new calls of HSMT and Low Speed Moving Terminals (LSMT) and the handoff calls of LSMT by the microcellular layer. The number of channels that assigned to microcells and umbrella cell is fixed for long time periods and is selected in order to contribute to the decrement of the mean call blocking probability, during this long period. [3]. The following assumptions, without affecting the results, are considered: a) the terminals are characterized as LSMT or HSMT according to the speed they move. b) Random offered traffic load in every microcell and c) same mean channel holding time $T_h$ and $\mu_h$ ($\mu_h = 1/T_h$) are considered for HSMT and LSMT both in microcells and umbrella cell.

New and handoff calls of LSMT are generated in the area of microcell $(i)$ according to a Poisson point process, with mean
rates of $\Lambda^i_R(\ell)$, $\Lambda^i_{Rh}(\ell)$ respectively, while new calls and handoff calls of HSMT are generated with mean rates of $\Lambda^H_R(\ell)$, $\Lambda^H_{Rh}(\ell)$ per cell. The relative mobilities for microcell i are defined as:

$$a_L(\ell) = \Lambda^L_R(\ell)/\left(\Lambda^L_{Rh}(\ell) + \Lambda^L_R(\ell)\right)$$  for LSMT (1),

$$a_H(\ell) = \Lambda^H_R(\ell)/\left(\Lambda^H_{Rh}(\ell) + \Lambda^H_R(\ell)\right)$$  for HSMT (2).

The total relative mobility for both HSMT and LSMT, for microcell (i), is given by:

$$a_{T}(\ell) = \left(\Lambda^L_{Rh}(\ell) + \Lambda^L_R(\ell)\right)/\left(\Lambda^H_{Rh}(\ell) + \Lambda^H_R(\ell) + \Lambda^L_{Rh}(\ell) + \Lambda^L_R(\ell)\right)$$  (3).

The offered load for microcell i is:

$$\text{Toff}(\ell) = \left(\Lambda^L_{Rh}(\ell) + \Lambda^L_R(\ell) + \Lambda^H_{Rh}(\ell) + \Lambda^H_R(\ell)\right)/\mu_H$$  (4).

---

**THE PROPOSED DYNAMIC CHANNEL MANAGEMENT SCHEME BASED BOTH ON A ONE-LAYER CELLULAR ARCHITECTURE AND ON A TWO-LAYER CELLULAR ARCHITECTURE:** The DCMS is based both on a One-Layer Cellular Architecture as described in [1],[2] and on a Two-Layer Architecture, as TLCA described in [3]. The number of layers (one or two) that is used depends on which architecture gives better optimization to the cellular system proposed to the offered traffic load. Let n be the number of microcells that consist the microcellular layer. The total offered load in the system is:

$$\text{tot}_{\text{off}} = \sum_{i=1}^{n} \text{Toff}(\ell)$$  (5). Let $C_S$ is the total number of channels in the system. In the microcellular layer, priority is given to handoff attempts by assigning guard channels $C_H(i)$ exclusively for handoff calls of LSMT among the $C(i)$ channels in microcell i. The remaining ($C(i)-C_H(i)$) channels are shared by both new calls of HSMT and LSMT and handoff calls of LSMT [3]. Let $C_u$ be the channels assigned to umbrella cell to serve only handoff calls of HSMT. Hence: $C_S = \sum_{i=1}^{n} C(i)+C_u$  (6). The mean rate of generation of handoff calls of HSMT is $\Lambda^H_{Rh}(\ell)$ for cell i, so the mean rate generated in the umbrella is $\sum_{i=1}^{n} \Lambda^H_{Rh}(\ell)$.

The proposed scheme investigates both the handoff and new call blocking probability in microcells and in the umbrella cell. It is applicable in areas with random offered traffic load. The number of the allocated channels to every microcell and umbrella cell is regulated by a micro-controller located in the Master Switching Center (MSC). The regulation is based upon the level of the occurred call blocking probability (handoff and new call) and tends to reduce it. More specifically, channels from cells with low call blocking probabilities are removed and assigned to cells with higher call blocking probability. A reduction to a high call blocking probability is of major importance than an increase to a low call blocking probability. Also, in the proposed scheme, the optimal number of channels is assigned to umbrella cell and microcellular layer, in order to improve the performance of handover calls of HSMT, as in TLCA scheme. In very low offered traffic load the application of OLCA presents better performance compared to the TLCA Consequently, in the DCMS – TLCA, the ratios $C(i)/C_S$ for $i=1:n$ and $C_u/C_S$ are regulated.
dynamically in the time period, with the criterion of decreasing the blocking probabilities in microcells and umbrella cell, contributing to the improvement of performance blocking probability of moving terminals. In very low offered traffic load the architecture of the cellular system is based on a One-Layer Cellular Architecture.

The steady state probabilities that \( j \) channels are busy in microcell (i) can be derived from figure 1a [1],[2],[3]:

\[
P^m_j(i) = \begin{cases} 
\frac{\left(\Lambda_R^H(i) + \Lambda_R^L(i) + \Lambda_{R0}^L(i)\right)^j}{j! \mu_H^j} P_0^m & \text{for } j = 1,2,\ldots,C(i) - C_d(i) \\
\frac{\left(\Lambda_R^H(i) + \Lambda_R^L(i) + \Lambda_{R0}^L(i)\right)^{C(i)-C_d(i)} \left(\Lambda_{R0}^L(i)\right)^j \left(\Lambda_{C(i)}^L(i)\right)^{1-(C(i)-C_d(i))}}{j! \mu_H^j} P_0^m & \text{for } j = C(i) - C_d(i) + 1,\ldots,C(i) 
\end{cases} \quad (7)
\]

where \( P_0^m(i) = \sum_{k=0}^{C(i)-C_d(i)} \sum_{k=C(i)-C_d(i)+1}^{C(i)} \frac{\left(\Lambda_R^H(i) + \Lambda_R^L(i) + \Lambda_{R0}^L(i)\right)^k \left(\Lambda_{R0}^L(i)\right)^{C(i)-k-C_d(i)} \left(\Lambda_{C(i)}^L(i)\right)^{k-(C(i)-C_d(i))}}{k! \mu_H^k} \quad (8)\]

The blocking probability for a new call (either for HSMT or LSMT) in microcell (i) is the sum of probabilities that the state number of the microcell is \( \geq C(i) - C_d(i) \). Hence:

\[
P^m_n(i) = \sum_{j=C(i)-C_d(i)}^{C(i)} P^m_j(i) \quad (9).
\]

The probability of handoff attempt failure \( P_{fh}^m(i) \) is the probability that the state number of the microcell is equal to \( C(i) \). Thus:

\[
P_{fh}^m(i) = P^m_C(i) \quad (10).
\]

For the umbrella cell, the steady state probabilities that \( j \) channels are busy can be derived from figure 1b [1],[2],[3]:

\[
P^u_j = \frac{\left(\sum_{i=1}^{n} \Lambda_R^H(i)\right)^j}{j! \mu_H^j} P_0^u \quad \text{for } j = 1,2,\ldots,C_u \quad (11)\]

where \( P_0^u = \left[ \sum_{i=1}^{n} \left(\Lambda_R^H(i)\right)^k \right]^{-1} \quad (12)\]

The probability that a handoff call will be blocked in the umbrella cell is \( P^u_{fh} \) and is the probability that state number of the cell is equal to \( C_u \). Thus:

\[
P^u_{fh} = P^u_C \quad (13).
\]

The mean call blocking probability (\( P^m_{nl} \)) for the microcellular layer (n microcells), considering new calls of LSMT and HSMT and handoff calls of LSMT is defined as:

\[
P^m_{nl} = \frac{\sum_{i=1}^{n} \left(\Lambda_R^H(i) + \Lambda_R^L(i)\right) P^m_n(i) + \Lambda_{R0}^L(i) \cdot P_{fh}^m(i) \right]}{\sum_{i=1}^{n} \left(\Lambda_R^H(i) + \Lambda_{R0}^L(i) + \Lambda_R^L(i)\right) \right]} \quad (14)
\]

RESULTS: Figure 2 shows the handoff blocking probability of HSMT against \( T_{off}^T \). Figure 3 shows the mean call blocking probability of the microcellular layer \( P_{nl} \) as a function of \( T_{off}^T \). In both figures is represented the performance of a One-Layer Cellular Architecture (OLCA) [1]. Also is shown the performance of a Two-Layer Cellular Architecture (TLCA) [2]. Lastly, is
represented the performance of the DCMS–TLCA. In the performed simulation, the number of microcells is considered to be n=3, C_s=180 without affecting the generality of the model. The following parameters are also considered: C_s(i)=0.1C(i) for i=1:n, T_H=80s. Table 1 represents the relative mobilities and the ratio of the offered traffic load in microcells to the total offered traffic load in system.

Curves of figures 2 and 3 show that the DCMS–TLCA has the same results with TLCA, concerning the handoff call blocking probability of HSMT, but improves the mean call blocking probability of the microcellular layer and has better performance comparing with TCS. Applying the DCMS–TLCA to a cellular network we manage to decrease the P_nl comparing to TLCA. Comparing the DCMS – TCLA with the TCA there is a decrease in P_nl for traffic load over 30 erl. For offered traffic load less than 30 erl the umbrella layer is removed and the channels that were assigned to that layer are assigned to the microcells.

CONCLUSION: A new Dynamic Channel Management Scheme Based both on One-Layer Architecture Layer and on A Two-Layer Cellular Architecture, applicable in areas with random offered traffic load, has been proposed to achieve low handoff call blocking probability and mean call blocking probability of microcellular layer. The goal of this scheme is that assigns dynamically channels to microcells and to umbrella cell in proportion to call blocking probabilities. Moreover, according to the obtained results, the handoff call blocking probability of the HSMT and the mean call blocking probability has been optimized in low and high offered traffic load.

REFERENCES


Authors’ affiliations:
Konstantinos Ioannou1 and Stavros Kotsopoulos1 (Wireless Telecommunication Laboratory, Dept. of Electrical and Computer Engineering, University of Patras, Rio, Patras, 26500, Greece, phone: +302610997301; fax: +302610997302; e-mail: Ioannou@ee.upatras.gr.)

Stavros Koubias2 (Laboratory of Applied Electronics, Dept. of Electrical and Computer Engineering, University of Patras, Rio, Patras)
Figure Captions

Fig. 1: State Transition diagram for: (a) microcell (i) and (b) umbrella cell of DCMS-TLCA

Fig. 2: Handoff blocking probability of HSMT against total offered traffic load in the system.

Fig. 3: Mean call blocking probability of the microcellular layer \( P_{n0} \), against total offered traffic load in the system

Fig. 4: Relative mobilities and Offered traffic load in microcells
Fig. 1

\[
\left(\lambda_R^i(i) + \lambda_R^H(i) + \lambda_R^{\mu H}(i)\right) \left(\lambda_R^L(i) + \lambda_R^H(i) + \lambda_R^{\mu H}(i)\right) \left(\lambda_R^L(i) + \lambda_R^H(i) + \lambda_R^{\mu H}(i)\right) \Lambda_R^L(i) \Lambda_R^L(i) \Lambda_R^L(i)
\]

(a) \hspace{2cm} (b)

\[
\sum_{i} \lambda_R^H(i) \sum_{i} \lambda_R^{\mu H}(i) \sum_{i} \lambda_R^{\mu H}(i) \sum_{i} \lambda_R^{\mu H}(i) \sum_{i} \lambda_R^{\mu H}(i) \sum_{i} \lambda_R^{\mu H}(i)
\]
Figure 2

Blocking Probability of handover calls

- OLCA
- TLCA
- DCMS
Figure 3

Total Mean Call Blocking Probability (Pnl)

Total Mean Call Blocking Probability

Total offered load in system (Erlangs)

- DLCA
- TLCA
- DCMS
Table 1

<table>
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<th>1st microcell</th>
<th>2nd microcell</th>
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