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Performance of a Dynamic Channel Assignment Technique in Hierarchical Structure for Mobile Communications Networks

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Abstract: **-** This paper presents a dynamic channel assignment technique in hierarchical structure for Mobile Communications Networks. This technique optimizes the handover call blocking probability performance of High-Speed Moving Terminals (HSMT). Traffic of Low-Speed Moving Terminals (LSMT) is absorbed by a micro cellular architecture solution and traffic of new calls of HSMT is abrorbed by a higher layer architecture, based on a macro cell umbrella solution. The results show, that assigning dynamically in the time period the optimum number of channels in each microcell and in each layer, the handover call blocking probability of HSMT is optimized without affecting the mean call blocking probability of microcellular layer.

Key-Words: - Wireless Communications, Dynamic Channel Management Scheme, Hierarchical Architecture

1. Introduction

One of the major design objectives of wireless cellular communication systems is high network capacity and flexibility, while taking into account time varying traffic loads and radio link quality. The limited radio frequency spectrum requires cellular systems to use efficient methods to handle the increasing service demands.

Nowadays, mobile communications systems are experiencing a rapid increase in the number of subscribers, which places extra demands on the capacity of cellular systems [1]. This is especially true for GSM systems, which have been experiencing a tremendous growth rate in recent years and have become the leading cellular standard. It is expected that the wireless communications will be the dominant mode of data access technology in the next century [2]. The large growth in the use of personal communications is increasing the demands to realize reliable and efficient links. In terms of mobile communications, this growth leads to a network architecture in which the cells must be made increasingly smaller. The most serious problem that arises in such systems is the handoff (handover), which occurs when a mobile user moves from one micro cell served by one wireless gateway (BTS) to a neighboring micro cell served by another [3]. The majority of existing terrestrial wireless communication systems are based on the cellular concept [4,5]. The underlying network structure is composed of a fixed network with wireless last hops between *Base Stations* (BSs) and *Mobile Terminals* (MTs). The fixed communication network connects the base stations to controllers, a.k.a. *Mobile Switching Centers* (MSCs), that manage the calls and track all mobile terminal activities in a cell [6,7]. In some systems, multiple base stations are used to serve the same area. Hence, a *multi-layer cellular network* is formed [8,9].The handoff problem becomes more serious, as the speed of terminals increases. When the handoff rate increases, the probability that an ongoing call will be dropped due to the lack of a free channel is high.

2. Proposed channel assignment technique based on a multi-layer cellular architecture

A multi layer structure in the Network is introduced in order to dedicate different layers to different types of subscribers according to their speed and the type of their call (new or handover call) in the same geographical area. The practical implementation of the different layers doesn’t require any special hardware setting but the behavior of the Network and the mobiles can be driven by mean of the software parameters according to the philosophy chosen for the multi layer Network [10].

The philosophy here presented, which has been recommended for GSM Networks by Nokia manufacturer, introduces a two layer architecture of structuring the network in a way that it can handle the microcellular layer by the use of one more above it, the “Umbrella layer” which is implemented by means of an “Umbrella cell” [10], [11], [12]. Figure 1 shows the hierarchical cellular system, containing a geographical region tessellated by an umbrella cell, which overlays several micro cells.

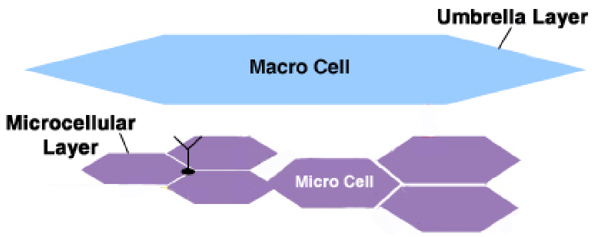

Figure 1: Hierarchical Cellular System

A new dynamic channel assignment technique is proposed for optimizing the handoff blocking probability.

The goal of this technique is to determine the number of channels that should be assigned both to each microcell and to the umbrella cell, under the condition that the total number of channels is fixed, so as to reduce the blocking probability, especially for HSMT. The number of channels that assigned to each microcell could be different in microcells and depend on the call blocking probability of each one. In microcells with the greater call blocking probability the channels that assigned are more than a microcell with smaller call blocking probability. Figure 2 presents the algorithm used in the proposed dynamic channel assignment technique.

The terminals are characterized as low speed moving terminals (LSMT) or high speed moving terminals (HSMT) ones, if they move slow or fast, respectively. The following are assumed: a) new coming and handoff calls of LSMT as well as new calls of HSMT are serviced by the microcellular layer, b) the Umbrella layer, services only handoff calls of HSMT, c) the microcellular layer is considered as an entity.

Let C_S be the channels that are available 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 cell i. A new call is blocked if the number of available channels in the cell is less than or equal to $C_h(i)$ when the call is originated. The remaining C(i)- $C_h(i)$ channels are shared by both new calls of HSMT and LSMT and handoff calls of LSMT ones. Moreover, let C_u be the channels assigned to umbrella cell to serve only handoff calls of HSMT. Hence, the total number of channels in the system, considering 3 cells in the microcellular layer, is:

$$C_S = \sum_{i=1}^{3} C(i) + C_u \quad (1)$$

New and handoff calls of LSMT are generated in the area of micro cell i according to a Poisson point process, with mean rates of $\Lambda_R^L(i)$, $\Lambda_{Rh}^L(i)$ respectively, while new calls of HSMT are generated with mean rate of $\Lambda_R^H(i)$ in micro cell i. Handoff calls of HSMT are generated with mean rate $\Lambda_R^H(i)$ per cell i, so the mean rate that is generated to the umbrella cell is $\Lambda_R^H = \sum_{i=1}^{3} \Lambda_R^H(i)$ (2).

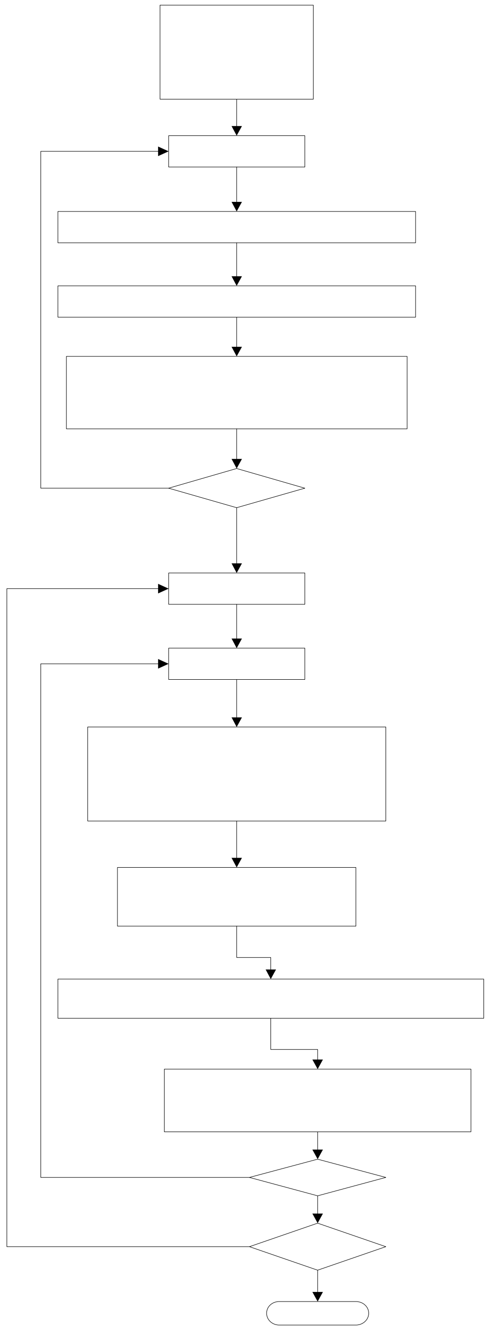

Figure 2: Algorithm used in the proposed dynamic channel assignment technique

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The relative mobilities for every microcell i are defined as:

- $a_L(i) = \dfrac{\Lambda^L_{Rh}(i)}{\Lambda^L_{Rh}(i) + \Lambda^L_R(i)}$ (3) for LSMT
- $a_H(i) = \dfrac{\Lambda^H_{Rh}(i)}{\Lambda^H_{Rh}(i) + \Lambda^H_R(i)}$ (4)f or HSMT

$$a_{HL}(i) = \frac{\Lambda^H_{Rh}(i) + \Lambda^H_R(i)}{\Lambda^H_{Rh}(i) + \Lambda^H_R(i) + \Lambda^L_{Rh}(i) + \Lambda^L_R(i)} \quad (5)$$

for LSMT and HSMT.

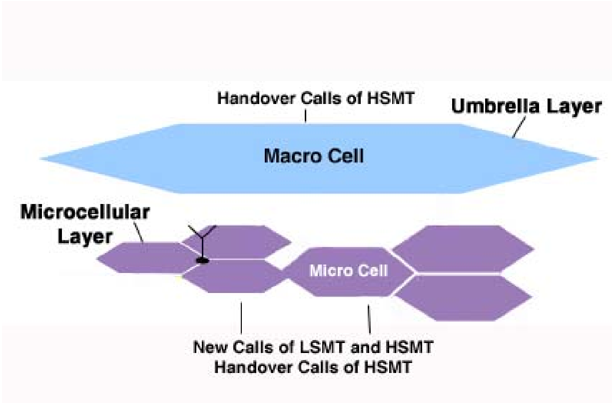

Figure 3: Proposed multi layer architecture

We also define for every microcell i the ratio l(i) that denotes the ratio of offered load in cell i toward to total offered load in system:

$$l(i) = \frac{\Lambda^H_{Rh}(i) + \Lambda^H_R(i)}{\sum_{n=1}^{3}\left(\Lambda^H_{Rh}(i) + \Lambda^H_R(i) + \Lambda^L_{Rh}(i) + \Lambda^L_R(i)\right)} \quad (6)$$

Using the architecture based on multi-layer architecture and adjusting the ratio C_u/C_S, according both to the total traffic load offered in the system and to $\alpha_L(i)$, $\alpha_H(i)$ and $\alpha_{HL}(i)$, we choose both the appropriate ratio of C_u/C_S and the number of channels that assigned to every microcell, that optimize handover call blocking probability of HSMT with the smallest effect in the call blocking probability in the rest calls.

For every micro cell, the steady state probabilities that j channels are busy can be easily be derived from the state transition diagram shown in Figure 4 [4], [13] [14]

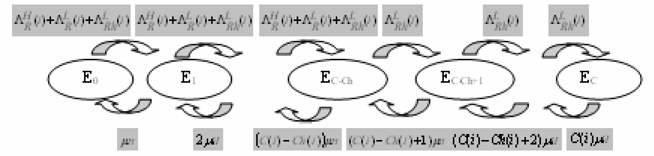

Figure 4: State Transition diagram for each microcell

and then:

$$P^m_j(i) = \begin{cases} \dfrac{\left(\Lambda^H_R(i) + \Lambda^L_R(i) + \Lambda^L_{Rh}(i)\right)^j}{j!\,\mu_H{}^j} P^m_0(i) & j = 1,2,\ldots,C(i) - C_h(i) \\ \dfrac{\left(\Lambda^H_R(i) + \Lambda^L_R(i) + \Lambda^L_{Rh}(i)\right)^{C(i)-Ch(i)} \Lambda^L_{Rh}{}^{j-(C(i)-Ch(i))}(i)}{j!\,\mu_H{}^j} P^m_0(i) & j = C(i) - C_h(i) + 1,\ldots,C(i) \end{cases} \quad (7)$$

where

$$P^m_0(i) = \left[\sum_{k=0}^{C(i)-C_h(i)} \frac{\left(\Lambda^H_R(i) + \Lambda^L_R(i) + \Lambda^L_{Rh}(i)\right)^k}{k!\,\mu_H{}^k} + \sum_{k=C(i)-C_h(i)+1}^{C(i)} \frac{\left(\Lambda^H_R(i) + \Lambda^L_R(i) + \Lambda^L_{Rh}(i)\right)^{C(i)-C_h(i)} \Lambda^L_{Rh}{}^{k-(C(i)-C_h(i))}(i)}{k!\,\mu_H{}^k}\right]^{-1} \quad (8)$$

where $\mu_H = 1/T_H$ and T_H is the channel holding time.

The blocking probability for a new call (either for HSMT or LSMT) per micro cell is the sum of probabilities that the state number of the base station is larger than or equal to $C\text{-}C_h$. Hence:

$$P^m_B(i) = \sum_{j=C(i)-Ch(i)}^{C(i)} P^m_j(i) \quad (9)$$

The probability of handoff attempt failure $P^m_{fh}(i)$ in microcell i is the probability that state number of the base station is equal to C(i). Thus:

$$P^m_{fh}(i) = P^m_C(i) \quad (10)$$

For the umbrella cell, the steady state probabilities that j channels are busy can be derived from the state transition diagram shown in Figure 5 [4], [13], [14]

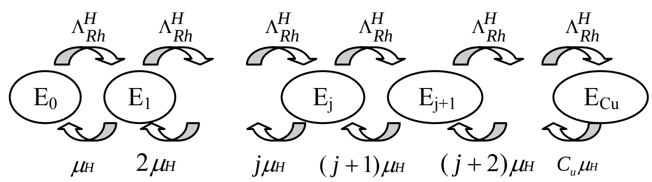

Figure 5: State Transition diagram for umbrella cell

and then:

$$P^u_j = \frac{\left(\Lambda^H_{Rh}\right)^j}{j!\,\mu_H{}^j} P^u_0 \quad \text{for } j = 1,2,\ldots,C_u \quad (11)$$

where:

$$P^u_0 = \left[\sum_{k=0}^{Cu} \frac{\left(\Lambda^H_{Rh}\right)^k}{k!\,\mu_H{}^k}\right]^{-1} \quad (12)$$

The probability that a call will be blocked in the umbrella cell is P_{fh}^{u} and is the probability that state number of the base station is equal to C_u. Thus:

$$P_{fh}^{u} = P_{Cu} \quad (13)$$

The mean call blocking probability for the microcellular layer (P_{nl}), considering new calls of LSMT and HSMT and handoff calls of LSMT is defined as:

$$P_{nl} = \frac{\sum_{i=1}^{n}\left(\left(\Lambda_R^H(i)+\Lambda_R^L(i)\right)*P_B^m(i)+\Lambda_{Rh}^L(i)*P_{fh}^m(i)\right)}{\sum_{i=1}^{n}\left(\Lambda_R^H(i)+\Lambda_{Rh}^L(i)+\Lambda_R^L(i)\right)} \quad (14)$$

where: n is the number of cells the microcellular layer consists.

Therefore, the quality of service for handoff calls especially for HSMT must be guaranteed while allowing high utilization of wireless channels. Recently, intensive research on channel allocation schemes has been in progress to reduce the handoff blocking probability. The objective of our architecture is to guarantee the required handoff blocking probability for HSMT.

3. Results

Figure 6 shows the mean call blocking probability of the microcellular layer against total offered traffic load in the system. Figure 7 shows the handoff blocking probability of HSMT, respectively as a function of the total offered traffic load in the system [10].

Curve (i) represents the performance of a typical GSM system, with no umbrella layer and all calls are served by micro cells. Curve (ii) represents the performance of a cellular system with umbrella layer [10] where handover calls of HSMT are served by the umbrella layer and new calls of HSMT and LSMT and handoff calls of LSMT by the microcellular layer. In Curve (iii) is shown the performance of a cellular system where handover calls of HSMT are served by the umbrella layer and new calls of HSMT and LSMT and handoff calls of LSMT by the microcellular layer. Besides, channels are assigned dynamically according to the offered traffic load in every microcell and in the umbrella cell.

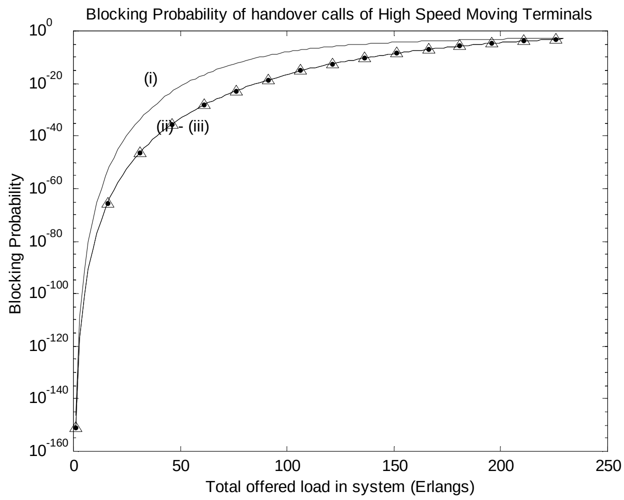

Figure 6: Handoff blocking probability of HSMT against total offered traffic load in the system Cs=240.

Captions

(i) Architecture with no Umbrella Layer

(ii) Architecture with Umbrella Layer and C_u=72

(iii) Dynamic Channel Assignment Technique based on Architecture with Umbrella Layer and C_u=72

For our simulation we assumed 3 microcells under an umbrella cell, with the following parameters: C_S=240, C_u=72, C_h(i)=0.1C(i), call duration T_H=80s. For microcell 1: $a_L(1)$=0.4, $a_H(1)$=0.45 $a_{HL}(1)$=0.43, l(1)=0.5, for microcell 2: $a_L(2)$=0.37, $a_H(2)$=0.40 $a_{HL}(2)$=0.38 l(2)=0.3 and for microcell 3: $a_L(3)$=0.45, $a_H(1)$=0.47 $a_{HL}(1)$=0.46 l(3)=0.2.

Curves show that using both the multi-layer architecture and the dynamic channel assignment technique based on multi-layer architecture, the handover call blocking probability of high speed moving terminals improves toward to architecture without umbrella layer. Besides there is a small increase in the mean call blocking probability of microcellular layer using the multilayer architecture. Adopting the dynamic channel assignment technique based on this architecture this increase is smaller for total offered traffic load between 0 and 50 erlangs. For load greater than 50 erlangs the there is a decrease in mean call blocking probability. Thisas a result of adopting the dynamic channel assignment based on the two-layer architecture, as well as adjusting both the ratio C_u/C_S and the number of channels that assigned to every microcell according to the total traffic load, $\alpha_L(i)$, $\alpha_H(i)$ and $\alpha_{HL}(i)$.

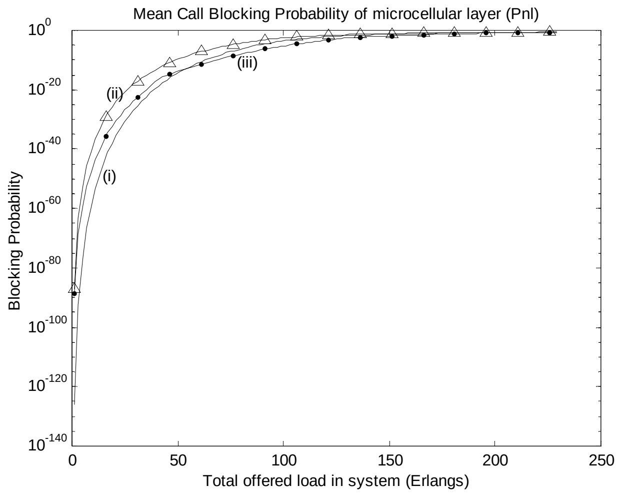

Figure 7: Total Mean call blocking probability of the microcellular layer (P_{nl}), against total offered traffic load.

Captions

(i) Architecture with no Umbrella Layer

(ii) Architecture with Umbrella Layer and C_u=72, C_S=240

(iii) Dynamic Channel Assignment Technique based on Architecture with Umbrella Layer and C_u=72, C_S=240

4. Conclusions

A new dynamic channel assignment technique in hierarchical structure for Mobile Communications Networks which optimizes the handover blocking probability of high speed moving terminals is proposed. This technique gives satisfactory results in terms of the handover blocking probability of high speed moving terminals, and, moreover there are fewer effects on the mean call blocking probability of the rest calls, compared to the architecture with no the umbrella layer.

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