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Adaptive Shared Channel Assignment Scheme for Cellular Network to Improve the Quality of the Handoff Calls

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Abstract: *In this paper, an adaptive channel assignment scheme is proposed to ensure the quality of services for the wireless networks. The proposed scheme divides the channels into two categories, the guard channels and the shared channels. The number of guard channels is estimated by the Markovian model in order to keep the handoff calls higher priority. The remaining channels, called shared channels, can be used by both new calls and handoff calls. The proposed scheme based on incoming rates of handoff and new calls allocates channels for guard and shared channels. In addition, this approach is able to provide quality of service guarantee in terms of handoff dropping rate. From the simulation, the proposed scheme significantly improves the dropping rate and the blocking rate in comparison with the existing methods.*
Keywords: *Channel assignment; Wireless network; Guard channels*

I. Introduction

The main resource constraint in the wireless network is the channel available for transmission, with the increased demand of bandwidth capacity due to scarceness of the inherent bandwidth. The traffic loads in wireless network changes drastically with time and the number of user and these the demand of channels is dependent of time and number of users and positions of cells. Therefore, it is important to develop an effective method for efficiently aligning the channel to cells.

There are 2 major methods for improving the performance of cellular network. The first method is to limit the service range of every cell, to get more cell and to employ the method of cell reuse. By this method, the service quality can refined, channels can be reused and realigned to different cells. In this way, each cell has to pass through more cells and the number of hand off operations will then be increased. The other method is to design an effective assignment scheme of channels. Basically there are 3 kinds of assignment methods.

- Resource Reuse [TDMA and FDMA]
- Fixed Channel Assignment [FCA]
- Dynamic Channel Assignment [DCA]
- Hybrid Channel Assignment [HCA]

In resource reuse method two channel can reuse the same set of channel provided that, they are at a suitable distance called reuse distance. The FCA method assigned a group of channel to each cell where different group of channels are assigned to different cells. It is convenient and well functioned when the demand is fixed. But this method has lack of flexibility to satisfy the requirement if the demand is dynamic. On the other hand the DCA method provides high flexibility where no channels are preassigned to each cell. When a cell made, the Base State[BS] of the cell issue a request for a channel to MSC[Mobile Switching Centre] that manage all channels. The HCA method combines aspects of both FCA and DCA methods, i.e it assigns some fixed channels to every BS as FCA and the remaining channels are assigned to the BS when they are overloaded.

The blocking rate and dropping rate are the two main parameters used to evaluate the quality of service in wireless network. Blocking rate denotes the rejection of new calls while the dropping rate denotes the cancellation rate of hand off calls. The new call is the newly initiated call and the handoff call is the existing call and the ongoing call is that which is going to transfer from one cell to other cell.

II. Previous works

In this section, some methods for improving the performance of wireless networks are introduced. The first part is the channel assignment methods in cellular base stations. The second one is the Guard Channel methods.

1.1. Channel assignment methods

There are three basic channel assignment methods in cellular wireless networks. The first one is the fixed channel assignment method (FCA). This method assigns a fixed number of channels to each cell. Different channels are assigned to different cells. Each cell only can use its channels. When a call arrives at one cell with no free channels, the call will be blocked or dropped. This method is convenient and well functioned when the demand is fixed. However, in the real world the traffic is non-uniform and changes drastically with time. This method is lack of flexibility to satisfy the dynamic requirement of channels.

On the other hand, the dynamic channel assignment method does not assign any channel to each cell. The mobile switching center manages all channels in an area of several cells. When a call arrives at these cells, the base station of the cell will issue a request for a channel to mobile switching center. If the center owns free channels, it will accept this call. Otherwise, this call will be blocked. This method provides high flexibility, because different cells can obtain different channels according to their requirements. But all channels are allocated by the center, the center therefore easily become the bottleneck due to the high traffic load.

The hybrid channel assignment method combines both of features of FCA and DCA methods. It assigns some fixed channels to every base station as FCA, and the remaining channels are handled by mobile switching center. When a call arrives at a cell with no channel available, the base station will issue a request for a channel to the mobile switching center. This method gives fewer loads to center than DCA and provides more flexibility than FCA.

1.2. Guard channel method

The channel assignment algorithms employ a threshold to define the current traffic status. If the occupancy of the channels is less than the threshold, the traffic is light; otherwise, the traffic is heavy. In this way, the channels used in a base station can be divided into two parts: the shared channels and the guard channels, as shown in Fig. 1. Moreover, the arriving calls can be classified into two classes, the new call and the handoff call, according to whether the call is a new call or not. The shared channels can be used by both the new calls and the handoff calls, while the guard channels are dedicated to the handoff calls. In this way, the handoff call is given higher priority than the new call. If the traffic is light, the base station can accommodate both kinds of calls. On the other hand, if the traffic is heavy, only the handoff call can be accepted. Once the channels are exhausted, all arriving calls will be rejected. It is worth to notice that to drop the handoff call is more destructive than to block the new call, because the handoff call is an existing and working call. To drop a handoff call means to disconnect a communicating call. However, there is not a concrete method to evaluate the threshold value.

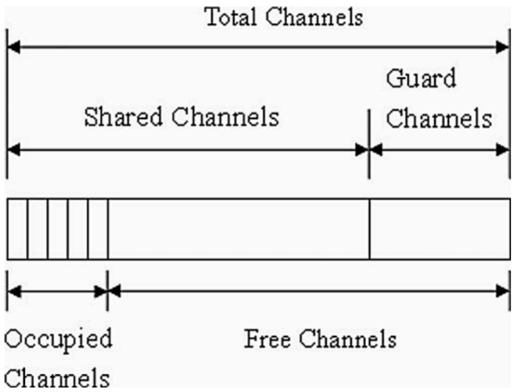

Fig. 1. Guard channel (GC) method.

III. Dynamic channel assignment scheme

In this section, the proposed method is introduced. The Markovian model is presented to estimate the number of guard channel. Next, an adaptive assignment method for new calls is developed to allocate the guard channel more precise.

3.1 Markovian model

In this subsection, the Markovian model, as shown in Fig. 2, is developed to illustrate the system behavior of wireless network, by which the quality of services can be easily investigated. Let p_i be the probability of i active mobile stations, where $i = 0, \ldots, C_t$, C_t denotes the number of total channels, and TH denotes the threshold. Basically, the channels can be assigned to new calls or handoff calls when the number of occupied channels is less than TH. Otherwise, the channels only can be assigned to handoff calls.

Thus if the arrival rate of handoff calls (λ_h), the arrival rate of new calls (λ_n), the service rate (μ), and the number of available channels (C_t) are applied to Eq. (4), the dropping rate can be derived. The service rate is defined as

$$\mu = \frac{\lambda_n + \lambda_h}{\lambda_h} \, . \, \mu_h + \frac{\lambda_n + \lambda_h}{\lambda_h} \, . \, \mu_n \tag{1}$$

Where μ_n and μ_h denote the service rates of new calls and handoff calls, respectively

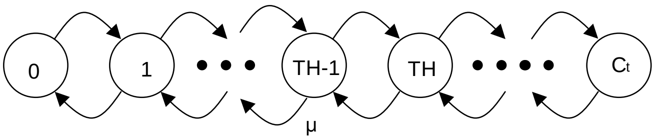

Fig. 2. Markovian model.

Assume that the system is in the steady state. p_i can be obtained as

$$p_i = \begin{cases} i!\left(\frac{\mu}{\lambda_n+\lambda_h}\right). p_0 & 0 < i \le TH \\ i!\left(\frac{\mu}{\lambda_n+\lambda_h}\right)^{TH}\left(\frac{\mu}{\lambda_h}\right)^{i-TH} p_{0,} & TH < i \le C_t \end{cases} \tag{2}$$

For normalization, first let

$$\sum_{i=0}^{TH} i!\left(\frac{\mu}{\lambda_n+\lambda_h}\right)^{i} p_0 + \sum_{i=TH+1}^{C_t} i!\left(\frac{\mu}{\lambda_n+\lambda_h}\right)^{TH}\left(\frac{\mu}{\lambda_h}\right)^{i-TH} p_0 = 1 \tag{3}$$

Then

$$p_0 = \left(\sum_{i=0}^{TH} i!\left(\frac{\mu}{\lambda_n+\lambda_h}\right)^{i} + \sum_{i=TH+1}^{C_t} i!\left(\frac{\mu}{\lambda_n+\lambda_h}\right)^{TH}\left(\frac{\mu}{\lambda_h}\right)^{i-TH}\right)^{-1} \tag{4}$$

In this way, the dropping rate of handoff calls (p_d) will be

$$p_d = c_t!\left(\frac{\mu}{\lambda_n+\lambda_h}\right)^{TH}\left(\frac{\mu}{\lambda_h}\right)^{C_t-TH} . \left(\sum_{i=0}^{TH} i!\left(\frac{\mu}{\lambda_n+\lambda_h}\right)^{i} + \sum_{i=TH+1}^{C_t} i!\left(\frac{\mu}{\lambda_n+\lambda_h}\right)^{TH}\left(\frac{\mu}{\lambda_h}\right)^{i-TH}\right)^{-1} \tag{5}$$

And the blocking rate of new calls will be

$$p_b = \sum_{i=TH}^{m} \frac{1}{i!}\left(\frac{\mu}{\lambda_n+\lambda_h}\right)^{TH}\left(\frac{\mu}{\lambda_h}\right)^{i-TH} . \left(\sum_{i=0}^{TH} i!\left(\frac{\mu}{\lambda_n+\lambda_h}\right)^{i} + \sum_{i=TH+1}^{C_t} i!\left(\frac{\mu}{\lambda_n+\lambda_h}\right)^{TH}\left(\frac{\mu}{\lambda_h}\right)^{i-TH}\right)^{-1} \tag{6}$$

If the tolerable dropping rate is p_{td}, the number of channels TH can be determined to satisfy the condition that p_d has to be less than or equal to p_{td}, as shown in eq. (7).

$$p_d = c_t!\left(\frac{\mu}{\lambda_n+\lambda_h}\right)^{TH}\left(\frac{\mu}{\lambda_h}\right)^{C_t-TH} . p_0 \le p_{td} \tag{7}$$

3.2 Assignment method of new calls

Although the dropping rate of handoff calls can be guaranteed by reserving proper number of guard channels, the new calls can be rejected due to the channel utilization greater than the threshold. The guard channels are dedicated to the handoff calls and cannot be used by the new calls in the previous research. In this subsection, a new assignment method is developed to allocate the guard channels more efficiently.

The process of assignment method has two steps. This first step is to obtain the probability of channel assignment. Based on the threshold (TH), the cells can be classified into two classes, the hot cell and the cold cell, which present the heavy loaded cell and the light loaded cell respectively. A cell is a hot cell, if the number of occupied cells is greater than the threshold, $C_u > TH$. Otherwise, the cell is a cold cell. In addition to accept the handoff call, the cold cell can accept the new call. On the other hand, the hot cell accepts the handoff calls, but accepts the new call only with the probability of channel assignment according to the Eq. (8). The probability of channel assignment for new calls, denoted as $PCA(C_u)$, is defined according to current traffic loads.

$$PCA\,(C_u) = \begin{cases} \sin\left(\left(\frac{C_u - TH}{C_t - TH}\right).\frac{\pi}{2} + \pi\right) + 1, & \text{if } TH \le C_u \le C_t \\ 1, & \text{if } C_u < TH \end{cases} \tag{8}$$

Given the number of occupied channel C_u, the probability value PCA can be obtained by the Eq. (8). The value of PCA is equal to 1 when the value of C_u is less than or equal to TH, which also demonstrates that the larger the C_u, the lower the $PCA(C_u)$. The $PCA(C_u)$ value is located between 0 and 1. The detailed pseudo code of the adaptive channel allocation is shown in the following.

channel_allocation( )
{
λ_h= the current arrival rate of handoff call;
λ_n= the current arrival rate of new call;
y = the tolerable dropping rate;
C_t = the number of total channels;
C_u = the number of occupied channels;
TH = the value of threshold such that

$$p_d = c_t!\left(\frac{\mu}{\lambda_n+\lambda_h}\right)^{TH}\left(\frac{\mu}{\lambda_h}\right)^{C_t-TH} . p_0 \leq p_{td};$$

If (the arriving call is a handoff call)
If (C_t -C_u > 0)
Accept this call;
Else
Drop the handoff call;
Else /* new call */
If (C_u < TH)
Accept this call;
Else

$$F = \sin\left(\left(\frac{C_u-TH}{C_t-TH}\right).\frac{\pi}{2}+\pi\right)+1;$$

if (r < F)
Accept this new call;
else
Block the new call;
}

IV. Simulation result

The wireless network with 25 cells is studied to investigate the performance, as shown in Fig. 3. Each base station is assumed to own thirty channels. The arrival rates of new calls (λ_n) are assumed to be 1/6 (call/s). The arrival rates of handoff calls (λ_h) are in the range of 0.08–0.25 (call/s). The service rates of new calls (μ_n) and handoff calls (μ_h) are 1/60 (call/s) and 1/60 (call/s). That means serve time of a call is 60 seconds. It is assumed that the tolerable dropping rate (p_{td}) is 10^{-3}.

The proposed scheme is compared with the guard channel method. Six kinds of fixed guard channel methods are investigated, including GC_0, GC_1, GC_3, GC_5, GC_10, and GC_15, in which the numbers of reserved channel for guard channels are 0, 1, 3, 5, 10, and 15, respectively. Fig. 4 show the dropping rates for different arrival rates of handoff calls when the arrival rate of new call is 1/6. Evidently, the proposed scheme, GC_10, and GC_15 is capable of controlling the dropping rate under the tolerable dropping rate, 10^3, while GC_0, GC_1, GC_3, and GC_5 cannot satisfy the requirement of the tolerable dropping rate when the arrival rates of handoff calls become larger. This is due to the fact that the more channels reserved for the guard channel will result in the lower dropping rate.

Fig. 5 presents the blocking rate versus the arrival rate of handoff calls. The blocking rate increases with the arrival rate of handoff calls. This is due to that most bandwidth will be occupied by the handoff calls when the arrival rate of handoff calls. As a result, new calls cannot acquire the required channels. Although the dropping rates of GC_10 and GC_15 are also meet the requirement of the tolerable dropping rate (10^3), the blocking rates of these two methods are worse than the proposed scheme. This is because GC_10 and GC_15 allocate too many channels for handoff calls, and therefore few channels can be allocated to new calls. Even though the guard channels are idle, they cannot be allocated to new calls. On the other hand, the proposed scheme adaptively allocates the guard channels. When most guard channels are idle, they are allocated to new calls with high probability. When most guard channels are busy, they are allocated to new calls with low probability.

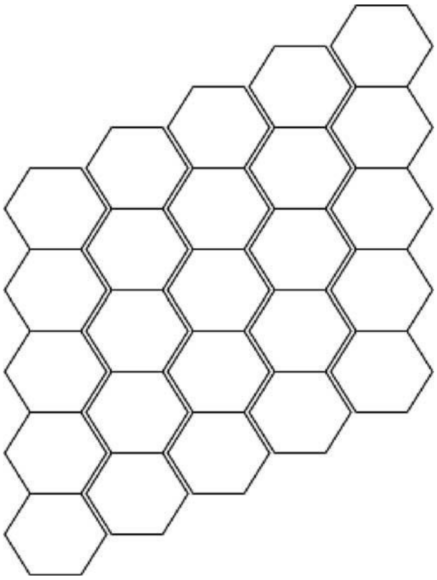

Fig. 3. The simulated wireless network with 25 cells.

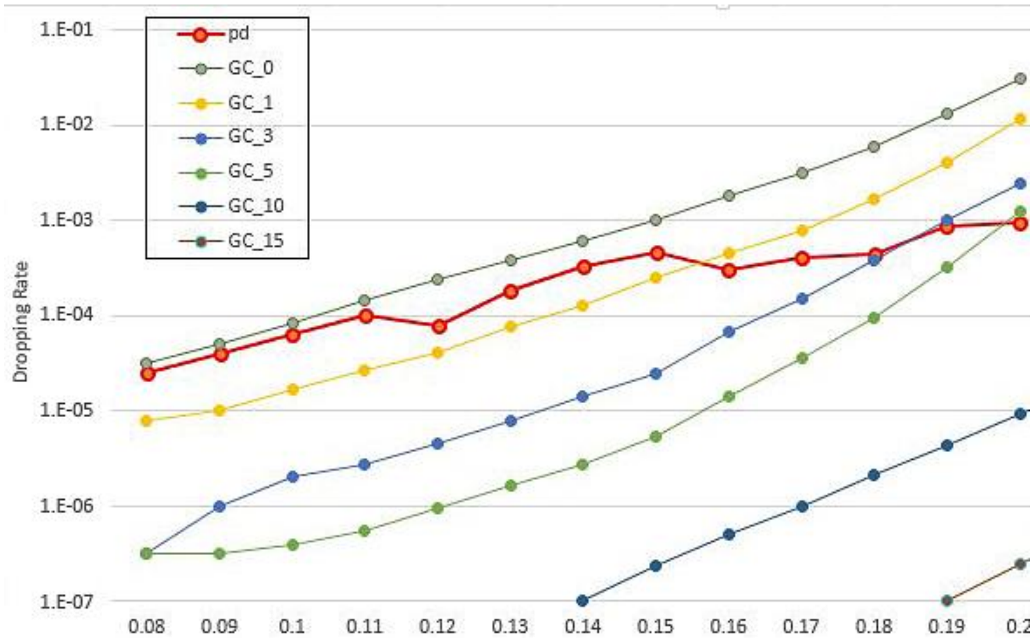

Fig. 4. The dropping rate with different arrival rate of handoff call (λ_n= 1/6).

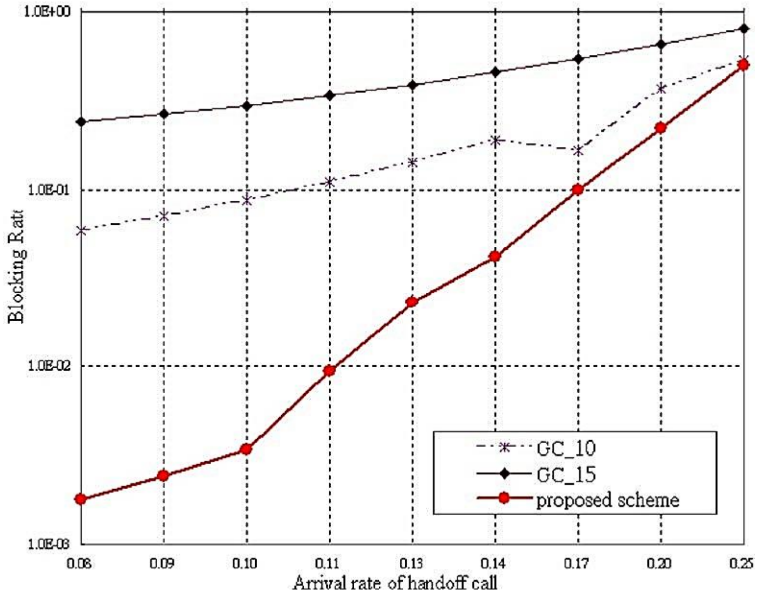

Fig. 5. Blocking rate versus arrival rate of handoff call (λ_n= 1/6).

Fig. 6 presents the throughput versus inter-arrival time of handoff calls for GC_10, GC_15, and proposed schemes. The throughput decrease with the inter-arrival time of handoff calls. This is

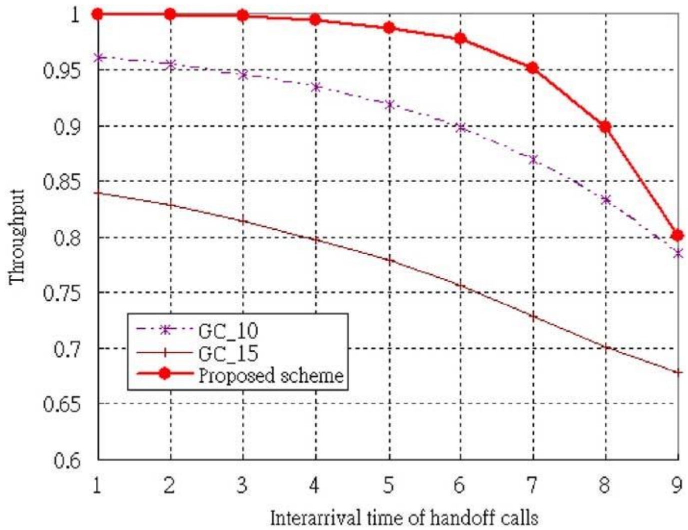

Fig. 6. Throughput versus arrival rate of handoff call.

because the higher inter-arrival time indicates the less arriving handoff calls. Obviously, the proposed scheme is able to adaptively allocate proper number of guard channels from time to time. When the load is light, the proposed scheme will allocate few guard channels. When the load is heavy, it will conversely allocate more guard channels. The proposed scheme may effectively allocate most channels for both new calls and handoff calls, and may reduce the idle channels while there are channel requirements from new calls. However, GC_10 and GC_15 allocate a large number of channels for handoff calls. When a large amount of arriving handoff calls lead to the exhaustion on common channels, no channels are available for new calls and a lot of new arriving calls will blocked. In the mean time, even though there still have a lot guard channels available, they cannot be allocated to new calls in GC_10 and GC_15. Consequently, the throughput of proposed scheme is evidently superior to that of GC_10 and GC_15, as shown in Fig. 6.

V. Conclusions

In this paper, the proposed adaptive channel assignment algorithm is able to dynamically control the quality of service, and improve performance in wireless network. The proposed scheme consists of two parts. First, it employs the Markovian model to effectively estimate the threshold, which indicates the number of channels required by handoff calls. Based on the threshold, the cells can be classified into two classes. when the channel occupancy of a cell is less than threshold, this is a cold cell. Otherwise, it is a hot cell. Next, if a cell is in cold state, it can accept both kinds calls, the new call and the handoff call. If it is in hot state, the handoff call can be accepted with no condition, but the new call only can be allocated a channel with a probability. In addition, the proposed scheme provides QoS guarantee by keeping the handoff dropping rate below a desired level. The simulation results show that the proposed scheme can effectively overcome the problems that the traffic load changes very fast and is distributed non-uniform in the wireless network.

Moreover, the proposed scheme is capable of confining the dropping rate below the pre-defined limitation, and enhancing the blocking rate significantly in comparison with other schemes.

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