PAPER Special Section of Papers Selected from JTC-CSCC '94

A Flexible Hybrid Channel Assignment Strategy Using an Artificial Neural Network in a Cellular Mobile Communication System

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SUMMARY A novel algorithm, as *an advanced Hybrid Channel Assignment strategy*, for channel assignment problem in a cellular system is proposed. A difference from the conventional Hybrid Channel Assignment method is that flexible fixed channel allocations which are variable through the channel assignment can be performed in order to cope with varying traffic. This strategy utilizes the Channel Rearrangement technique using the artificial neural network algorithm in order to enhance channel occupancy on the fixed channels. The strategy is applied to two simulation models which are the spatial homogeneous and inhomogeneous systems in traffic. The simulation results show that the strategy can effectively improve blocking probability in comparison with pure dynamic channel assignment strategy only with the Channel Rearrangement.
key words: *hybrid channel assignment, cellular system, channel rearrangement, artificial neural network, dynamic channel assignment*

1. Introduction

The cellular concept is the key of achieving high spectral efficiency. On Channel Assignment problem in a cellular radio system, the efficiency of channel usage is a very important issue. And there are typical three methods which are well-known Fixed Channel Assignment (FCA), Dynamic Channel Assignment (DCA) [1]-[3] and Hybrid Channel Assignment (HCA) [4], [5] methods. In general, the efficiency depends on the channel assignment algorithm. Many DCA methods have been studied to overcome the disadvantage of FCA method which is the lack of adaptation to traffic bursts and is to be overly sensitive to time and spacial changes in traffic. HCA method which takes a combination of FCA and DCA methods is more effective artifice to improve the efficiency. However, in the conventional HCA method, it has been found that the ratio of the fixed channels to the dynamic channels affects blocking probability in the system and the optimum ratio depends on the offered traffic intensities [5]. This means that the performance of HCA method depends mainly on the performance of FCA method employed in the system because the relation between offered traffic and the number of the setting fixed channels affects the efficiency of channel usage on these channels and the inadequate fixed channel allocations result in decreasing the efficiency.

On the other hand, in the situation that a smaller cells structure is explored for a future system, with shrinking cell sizes, the radio network planning process (i.e., involving to allocate efficiently channels to apply FCA method to base stations) becomes more complicated as the structures of each cell are usually different, resulting in the complicated interference conditions owing to the radio frequency propagation from topography, and additional base stations must be also anticipated [3]. And then, it is also considered that the information about traffic distributions in time and space can not be rightly obtained. Subsequently, in the conventional HCA method, it is expected that the adaptive fixed channel allocations would not be performed for the uncertainty, which involves that the good performance of FCA method can be expected no longer.

In this paper, Flexible Hybrid Channel Assignment (FHCA) algorithm, as an advanced HCA strategy which is able to cope with the variations of the traffic distributions, is proposed, in which the strategy to allocate variably the fixed channels to cells is presented while retaining the fine concept of the conventional HCA method. The variable fixed channel allocations are decided through DCA employed in this strategy and so the fixed channels are able to be allocated provisionally to cells with flexibility to meet the traffic distributions. DCA method employed in this strategy significantly utilizes Channel Rearrangement technique using *the artificial neural network algorithm* previously proposed by authors [6], in order to achieve high channel occupancy on the fixed channels. Therefore, in this FHCA strategy, the efficient fixed channel allocations can be performed. For the problem on the different structures of each small cell, the channel assignment rule based on *the interference network model* as detailed in Ref. [6] is used, in order to execute DCA in the complicated interference conditions. The channel assignment problem by this model is formulated by graph theoretic method, in which the

Manuscript received October 31, 1994.
Manuscript revised January 17, 1995.
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model describes the cochannel interference constraint which is defined by the cochannel interference level for any pair of cells and is evaluated previously at the radio network planning process. Simulation studies of this strategy are presented for two cases of the homogeneous and inhomogeneous distributions in offered traffic. Section 2 describes the proposed algorithm. In Sect. 3, the simulation results are shown and discussed. Finally Section 4 concludes.

2. FHCA Algorithm

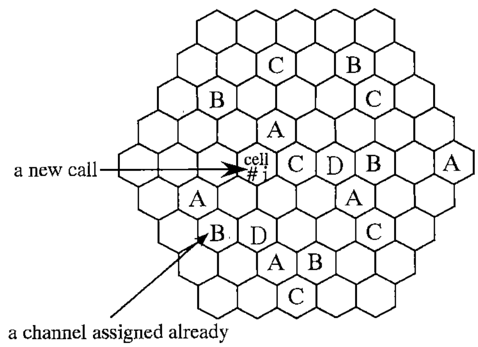
The concept of FHCA strategy is that more channels should be used as the fixed channels to apply FCA method in the cells to which they are allocated if the spacial channel occupancy η_s on each of them is higher in the system and if the time channel occupancy η_t on them is high enough in the respective cells resulting from allocating with the adaptability to the traffic distribution, where η_s implies the number of the cells to which a channel can be allocated (or assigned) simultaneously and η_t implies the *time-like* rate of using a fixed channel for the calls in a cell to which the channel is allocated and is defined by:

$$\eta_t = \frac{\text{[total time of assigning the fixed channels allocated to the cell to the calls]}}{\text{[total time of allocating the fixed channels to the cell]}}.$$

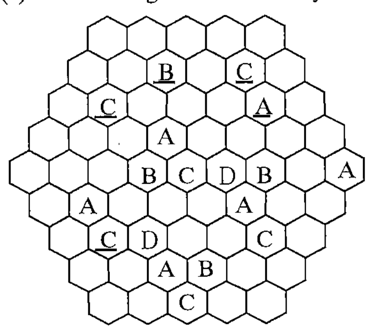
This idea is based on the conventional HCA method. But the significant difference from the conventional one is that the fixed channel allocations are variable and flexible in order to cope with varying traffic. It is performed by deciding the fixed channels and the allocations of them through DCA employed in FHCA strategy, in which the channels with higher η_s are allocated provisionally as the fixed channels to the respective cells according to each condition of the channel assignments obtained by the DCA method (as described below). That is, this FHCA algorithm is an alternative approach for the problem which is subject to the channel assignment that (i) some channels with higher η_s according to the traffic distribution are provisionally allocated as the fixed channels to their respective cells and (ii) some fixed channels are released from the fixed channels group to the dynamic channels group if η_t on them becomes lower in some cells, to which they are allocated, resulting from the inadequate fixed channel allocations. It is expected that such a Channel Assignment strategy implementing flexible fixed channel allocations will be able to be effective method and overcome the disadvantage of FCA method in the conventional HCA method which is the lack of adaptation to the changes in traffic. Also, in this FHCA strategy, it is not necessary to implement the intractable planning process (i.e., previously allocating fixed channels to the base stations) which is required in the conventional method, because the fixed channel allocations can be decided through DCA method. In the following, the flowchart of FHCA algorithm is presented after describing about the role of Channel Rearrangement utilized significantly in FHCA algorithm in order to achieve the flexible fixed channel allocations.

2. 1 Role of Channel Rearrangement

In DCA systems, Channel Rearrangement technique by which a channel can be assigned to a new call (origination) by weeding the internal congestion (call conges-

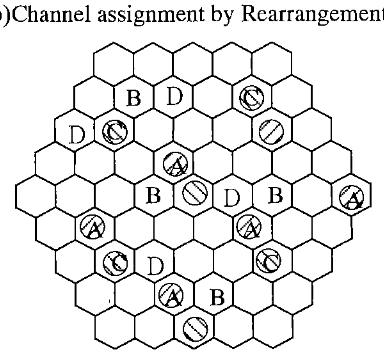


(a) internal congestion in DCA system.



A: denote the rearranged channels.

(b)Channel assignment by Rearrangement.



⊘: denote the cells to which are allocated channel A.

⃠ : denote the cells to which are allocated channel C.

(c) a condition of the Channel assignment after deciding the fixed channels by the successful Rearrangement.

Fig. 1 An example of Channel Rearrangement on the conventional channel assignment rule (the 2-belt buffering system) and an example for the decision of fixed channels.

tion) resulting from implementing a simple DCA method such as the first available method [1] is an effective method to improve the efficiency of channel usage [2], [6]. In the system employing Rearrangement technique, a new call is blocked only when the Channel Rearrangement is not successful. And also, a channel assignment by the successful Rearrangement results in the improvement of η_s on some channels and the reduction of η_s on fewer channels. By way of example, it is shown in Fig. 1 (a) as a representation of a internal congestion and Fig. 1 (b) in which a channel B is assigned to a new call in a cell # i by Channel Rearrangement. For simplicity, it is assumed here that the conventional DCA rule (; the 2-belt buffering system [2]) is applied to this system, in which the interference cells for the cell # i are comprised of 19 cells (i.e., 18 cells surrounding it and including itself) and the rule implies that a channel assigned to cell # i can not simultaneously reuse in the interference cells. As the result of the successful Rearrangement, it is seen that η_s (; the number of the cells to which a channel can be assigned simultaneously) on the channels A and C can be enhanced and η_s on B is reduced. The successful Rearrangement results in the improvement of η_s on some channels according to the distribution of calls in the system, and also the dynamic channel assignments using the minority (i.e., channel B) will become easier for calls originating afterwards because they are more sparsely used in the system.

In FHCA algorithm, only when a successful Rearrangement is carried out, both of the decision how to allocate the channels as the fixed channels to the cells and the decision of the release from the fixed channels group to the dynamic channels group over the fixed channels which have decided already are implemented. We then use the mean value of η_s on the whole system channels (N_c) for the criterion of these decisions. The criterion is given by $d_{th}=r/N_c$, where r is the number of simultaneous calls in the system at the time. That is, after the successful Rearrangement, the dynamic channels is going to be allocated provisionally as the fixed channels (to apply FCA method) to the respective cells to which the channels are assigned at the time if η_s on these channels exceed d_{th}, and also some fixed channels which has been already decided will be used as the dynamic channels afterwards if η_s on the channels do not exceeds d_{th}. For example, the value of d_{th}, as the mean value of η_s on four channels, is 4.5 in Fig. 1 (b), and channels A and C can be then added to the fixed channels group and are allocated to the respective cells to which each of two channels is assigned at the time because η_s on each of them exceeds $d_{th}=4.5$. And, for the condition in Fig. 1 (c) in which the next internal congestion occurs through the channel assignments and the successful Rearrangement is then carried out, the fixed channel C that the η_s is lower than $d_{th}=4.25$ at the time is released to the dynamic channels group.

For the condition (ii) for the channel assignment problem as described above, we then consider the method that the decision indicating whether the η_t on each fixed channel is higher or not is done by observing η_s on the fixed channels. This implies that η_t on some fixed channels may become lower in some cells to which they are allocated when these allocated provisionally produce more excessive allocations on the number in these cells for the inadequate fixed channel allocations and it may result in reducing η_s on them more frequently. So, we consider the procedure that η_s on each of the fixed channels is observed whenever Rearrangement is required for the internal congestion.

This criterion d_{th} on the decisions of the fixed channels provides the system employing this strategy with flexibility to varying the simultaneous calls and requires that η_s on each of the fixed channels is always higher.

Furthermore, for the purpose of moreover improving η_s on some of the fixed channels from the effect of Rearrangement, we scheme to apply the Rearrangement for only fixed channels group, in which assigning a fixed channel to a new call is tried. As soon as a internal congestion occurs, this procedure of Channel Rearrangement in the allocations of the fixed channels is carried out, in which this Rearrangement problem belongs to the conventional dynamic channel assignment problem as considered in Refs. [2], [6] and is subject to a Channel Assignment that a fixed channel is assigned to the new call by Channel Rearrangement using only fixed channels while retaining the number of the fixed channels which have been allocated to the respective cells. When it is successful, only the allocations of the fixed channels can be changed while allocating a fixed channel to the cell in which the new call originates, and fewer fixed channels with lower η_s may be then released to the dynamic channels group based on d_{th}. When it is not successful because a solution to this Rearrangement problem is not able to be found, the Rearrangement for only dynamic channels group is then applied, in which assigning a dynamic channel to a new call without changing the fixed channel allocations at the time is tried. These successful Rearrangements results in the improvement of η_s on some channels according to the traffic distribution in the system.

Consequently, the role of Channel Rearrangement in FHCA algorithm is to improve the efficiency of channel usage on both of the fixed and the dynamic channels, and then, this FHCA strategy implementing the flexible fixed channel allocations may perform to satisfy those conditions (i) and (ii) about the subject to the channel assignment described in the opening in this section.

2.2 FHCA Algorithm

The flowchart of FHCA algorithm is given in Fig. 2. In this algorithm, one flag "*flag* (x)" which represents whether the channel x is a fixed channel or not, one array "*fix* (i, x)" which represents whether the fixed channel x is allocated to a cell # i or not, and two counters "*fcr* (x)" and "*dcr* (y)" which represents the number of the cells assigned the fixed channel x and the dynamic channel y, respectively, are prepared as shown in the flowchart. Whenever the call originates, the HCA method employing both FCA method and the simple DCA strategy (without Rearrangement), in which the DCA strategy applies the channel assignment rule based on *the interference network model* as presented in Ref. [6], is executed according to "*fix* (i, x)" and "*flag* (x)" as same as the conventional HCA method. This HCA method is applied, with the proviso that only the DCA strategy will be executed until the Rearrangement using *the artificial neural network algorithm*, which is also based on *the interfer-*

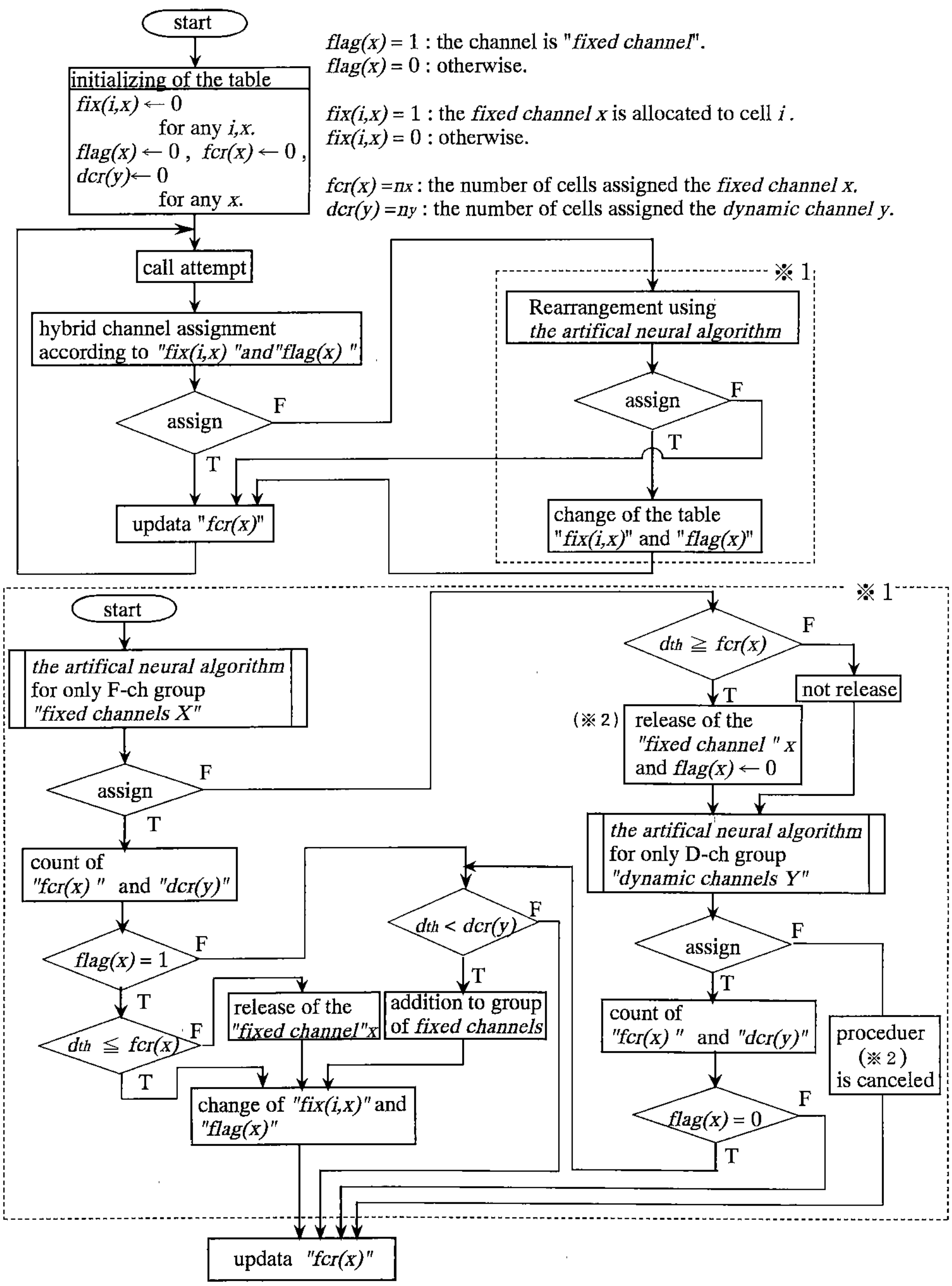


Fig. 2 Flowchart of FHCA algorithm.
※ 1 Flowchart of the algorithm for the decision of fixed channels.

ence network model, proposed by Ref. [6] is successful and the fixed channels are then decided. By deciding the fixed channels group, we can implement the HCA method as same as the conventional one, in which the Channel Reassignment procedure [4], [5] is installed also.

When a new call meets with the internal congestion for the first time, the Rearrangement for the whole system channels is executed because all channels then belong to the dynamic channels group. When the next Rearrangement is required after the fixed channels group are given to the system by the first successful Rearrangement, *the artificial neural algorithm* is applied for the fixed channels group as described above in order to accept a new call. The "*artificial neural algorithm* for only the fixed channels group" can be executed by forbidding the Rearrangement for the dynamic channels (in *the artificial neural algorithm* [6]: it means that only the output $V_{i,x}$ of the neuron for any fixed channel x are active, i.e., variable, and $V_{i,y}$ for any dynamic channel y are inactive, i.e., invariable). If a solution that a fixed channel can assigned to the new call is not found by *the artificial neural algorithm*, the procedure of the release of some fixed channels is then implemented based on d_{th} and next the "*artificial neural algorithm* for only the dynamic channels group" (in *the artificial neural algorithm* [6]: it means that only the output $V_{i,y}$ of the neuron for any dynamic channel y are active) is executed in order to assign a dynamic channel to the new call. If a solution as a Channel Assignment that is to assign a channel to the new call can not be obtained by these "*artificial neural algorithm*," the decisions on the release and the addition of the fixed channels are not done and also the procedure of the release implemented after the "*artificial neural algorithm* for only the fixed channels group" is canceled.

3. Simulation Results

3.1 System Parameters

For simulation studies, we consider two cases which are the models of homogeneous and inhomogeneous traffic distributions in space. The homogeneous case implies that the traffic distribution is uniform over all cells. In the inhomogeneous case, the model as described in Ref. [7] is applied, in which the traffic distribution function in a large city is approximately expressed by:

$$p(R)=(1/2\pi)\{(\text{In } 10)/k\}^2 10^{(-R/k)},$$

where R [Km] is the distance from the center in the city area and $k=20$. The relative traffic intensity for a cell is represented in Fig. 3.

Simulations are performed based on the following assumptions:

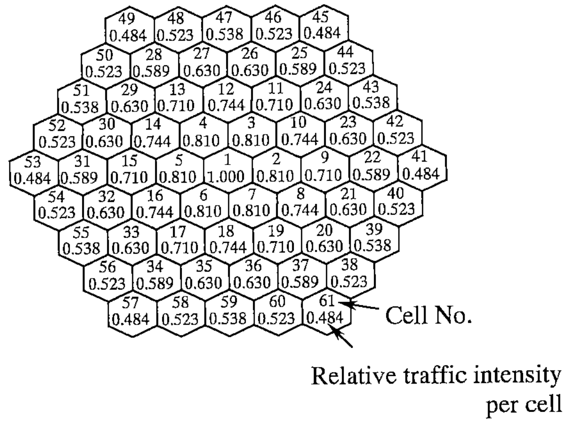


Fig. 3 Inhomogeneous traffic distribution in the simulation model.

- A service area is comprised of 61 cells as shown in Fig. 3. The radius of a cell is 1 km. The system channels is 49 channels ($N_c=49$). In this system using the channel assignment rule based on *the interference network model*, it is assumed that the propagation pass loss is 40 [dB/dec] (i.e., the received carrier or interference level is inversely proportional to d^4, where d is the distance from the transmitter to the receiver) in this system and the CIR requirement is 14.5 dB (as well as in Ref. [6]), in which this CIR value corresponds to the 2-belt buffering system in the conventional DCA rule as shown in Fig. 1.
- The arrival of request for service forms a Poisson process and the mean value of the holding time is 1.5 minutes.

To evaluate the performance of this FHCA strategy, the following conventional strategies are compared.

FA strategy: First-Available method [2].
RNN strategy: the DCA strategy with the Rearrangement technique using "*the artificial neural network algorithm*," as presented in Ref. [6].
FHCA strategy: the proposed FHCA algorithm.

RNN strategy is a pure DCA strategy and is different from **FHCA** strategy in the point whether the fixed channels exist in the system employing the strategy or not. Only **FA** strategy uses the conventional channel assignment rule based on the 2-belt buffering system and is especially simulated for reference data.

3.2 Evaluation of Performance and Discussions

The characteristics of blocking probability (: B_p) versus traffic intensity offered to each cell (: a) for the homogeneous system are shown in Fig. 4, in which the statistics are taken from the central 7 cells (from the cell No. 1 to No. 7 in Fig. 3). For the inhomogeneous system, the characteristics are shown in Fig. 5, in which the statistics are taken from the whole 61 cell and the offered traffic intensity (: a_m) is represented on the

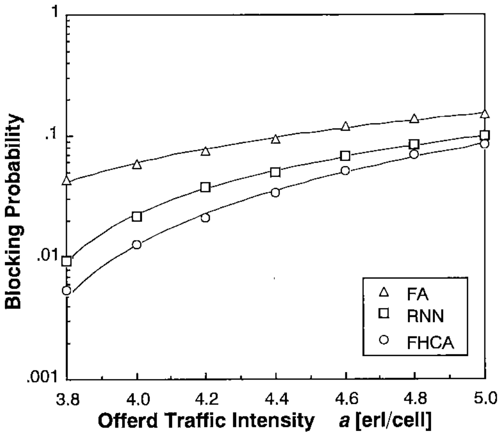


Fig. 4 Characteristics of blocking probability versus offered traffic intensity for the homogeneous system.

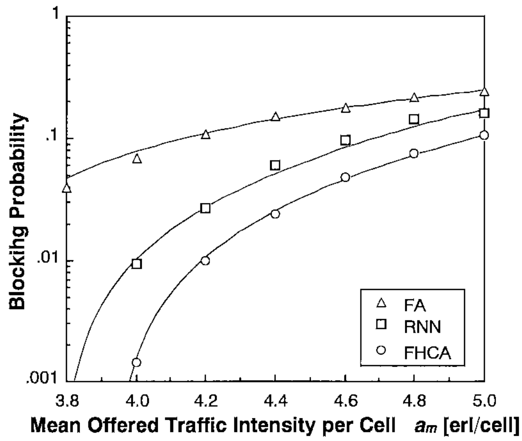


Fig. 5 Characteristics of blocking probability versus offered traffic intensity for the inhomogeneous system.

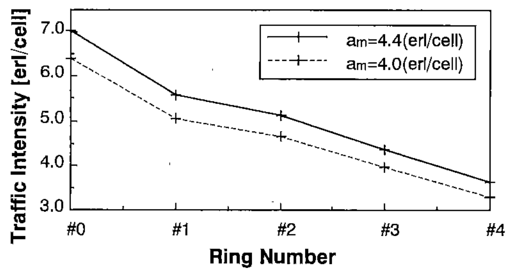
mean value of offered traffic intensity per cell. In the both cases, it is seen that **FHCA** strategy outperforms **RNN** strategy, in which the blocking probabilities by **FHCA** strategy are always lower than by **RNN** strategy. Also the results indicate that the efficiency of channel usage is improved by **FHCA** strategy. Table 1 summarizes the data on the mean value of the number of simultaneous calls per channel on both the fixed and dynamic channels, obtaining by the observations throughout these simulations, in which the data on the number of fixed and dynamic channels on the average include. For each case, the mean value of the number of simultaneous calls per fixed channel by **FHCA** strategy is about 1.2 times as large as one per dynamic channel by **RNN** strategy. It is shown that **FHCA** strategy can substantially enhance η_s on the fixed channels.

In particular, in order to evaluate the relationship between the inhomogeneous offered traffic intensity and the blocking probability for each cell, the statistics are also taken from each cells ring, i.e., a center cell

Table 1 The mean value of the number of simultaneous calls per fixed channel (F-ch) and per dynamic channel (D-ch).

(erl/cell) \ strategy		FHCA < F-ch group >	FHCA < D-ch group >	RNN < D-ch >
homogeneous system	a=4.8	6.90 (28.7) ※1	4.25 (20.3) ※2	5.71
	4.4	6.78 (27.2)	3.89 (21.8)	5.42
	4.0	6.22 (25.4)	3.66 (23.6)	4.94
inhomogeneous system	a_m=4.8	6.54 (30.2)	4.01 (18.8)	5.50
	4.4	6.44 (27.2)	3.93 (21.8)	5.21
	4.0	6.03 (27.5)	3.48 (21.5)	4.84

※1: the mean value of the munber of fixed channel
※2: the mean value of the munber of dynamic channel



(Representation of traffic intensity offerd for a cell in each ring on the average)

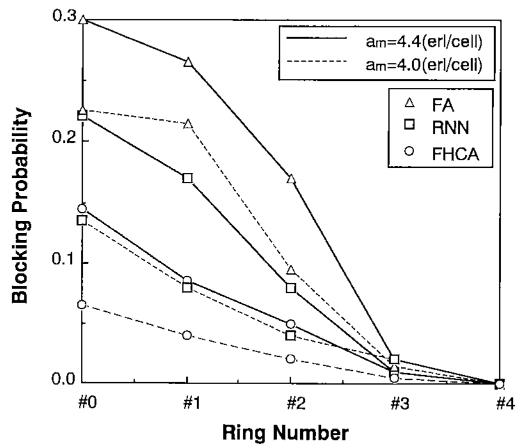


Fig. 6 Characteristics on blocking probability for each of rings.

(: #0-ring), 6 cells (: #1-ring from cell No. 2 to No. 7), 12 cells (: "# 2-ring from cell No. 8 to No. 19), 18 cells (: # 3-ring from cell No. 20 to No. 37), and 24 cells (# 4-ring from cell No. 38 to No. 61), respectively. And the data from the simulations at a_m=4.4 and 4.0 [erl/cell], which show B_p for each of these five rings, are plotted in Fig. 6, where the illustration of the traffic intensity offered to a cell in each of these rings on the average is included. At a_m=4.4, **FHCA** strategy has about 14% blocking in the center cell (# 0-ring) while

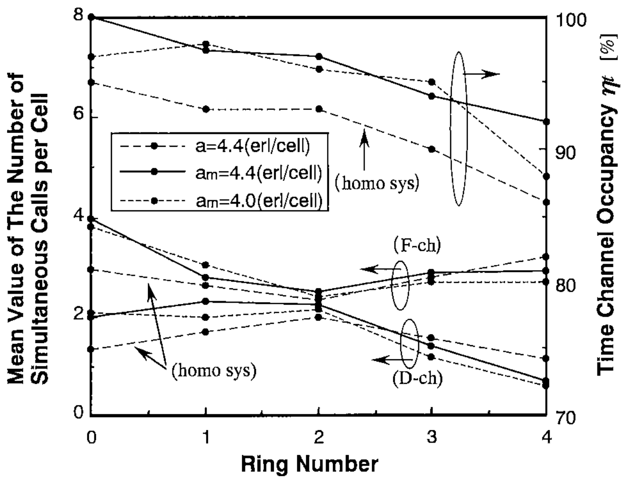


Fig. 7 The mean value of the number of simultaneous calls per cell for each of rings on the fixed channels and the dynamic channels and time channel occupancy on fixed channel: η_t in inhomogeneous system.

the blocking by **RNN** strategy is well over 20%. By **FHCA** strategy, the tolerable blocking in all rings can be achieved at $a_m=4.0$. However, by **RNN** strategy, the property of the blocking at $a_m=4.0$ is similar to one by **FHCA** strategy at $a_m=4.4$. This better performance of **FHCA** strategy can be demonstrated in Fig. 7, The mean value of the number of simultaneous calls for a cell in each of these rings on both the fixed and the dynamic channels, which indicates how many fixed and dynamic channels are always used in the respective cells, are plotted in Fig. 7. And also, on the fixed channels, the time channel occupancy for a cell in the respective rings; η_t, are plotted in Fig. 7. The data at $a=4.4$ for the homogeneous system are also included as reference data. It is seen that more fixed channels with the higher time occupancy over 90% ($90\% < \eta_t$) are used in # 0- and # 1-rings, to which higher traffic intensity is offered, and more dynamic channels are also assigned to these rings. Consequently, it is to be verified that **FHCA** strategy is able to perform to satisfy those conditions (i) and (ii) about the subject to the Channel Assignment as described in Sect. 2 and also that the high performance results from accommodating Channel Assignment to the traffic distribution with the good combination of the fixed channels and dynamic channels. Additionally, it is considered that the property in which especially on the fixed channels the simultaneous calls in a cell in # 3- and # 4-rings is comparatively high stems from well-known edge effect that the cells around the edges in this service area do not have enough neighboring cells to cause calls to be blocked.

4. Conclusion

Flexible Hybrid Channel Assignment strategy as an advanced HCA method is proposed in order to cope with varying traffic distributions in cellular mobile communication systems. In this strategy, the variable fixed channel allocations can be implemented by utilizing the Channel Rearrangement technique using *the artificial neural network algorithm*. It is shown that this strategy can improves blocking probability by performing the higher efficiency of channel usage as compared with the pure DCA strategy only with the Channel Rearrangement technique. This strategy is able to cope with both of the variations of the offered traffic in practical systems by the good combination of the flexibility in the fixed channel allocation and adaptability in the dynamic channel assignment and the complicated interference conditions in a future smaller cells system by using the channel assignment rule based on *the interference network model*. It is expected that this is a quite valuable alternative approach for the channel assignment problem when the artificial neural network architecture with effective run time will be realized.

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