Capacity Improvement with Dynamic Channel Assignment and Reuse Partitioning in Cellular Systems

Steven Li Chen and Peter Han Joo Chong

Abstract: **In cellular mobile communications, how to achieve optimum system capacity with limited frequency spectrum is one of the main research issues. Many dynamic channel assignment (DCA) schemes have been proposed and studied to allocate the channels more efficiently, thus, the capacity of cellular systems is improved. Reuse partitioning (RP) is another technique to achieve higher capacity by reducing the overall reuse distance. In this paper, we present a network-based DCA scheme with the implementation of RP technique, namely dynamic reuse partitioning with inteference information (DRP-WI). The scheme aims to minimize the effect of assigned channels on the availability of channels for use in the intefering cells and to reduce their overall reuse distances. The performance of DRP-WI is measured in terms of blocking probability and system capacity. Simulation results have confirmed the effectiveness of DRP-WI scheme. Under both uniform and non-uniform traffic distributions, DRP-WI exhibits outstanding performance in improving the system capacity. It can provide about 100% capacity improvement as compared to conventional fixed channel assignment scheme with 70 system channels.**

Index Terms: **Cellular mobile communications, channel rearrangement, dynamic channel assignment, reuse partitioning.**

I. INTRODUCTION

In cellular mobile communications, since the given frequency spectrum is limited, how to effectively make use of the spectrum to achieve optimum system capacity at some minimum quality of service, is of paramount importance. The conventional way of allocating channels is called fixed channel assignment (FCA) [1]. In FCA, a set of nominal channels is assigned to each cell on a semi-permanent basis. FCA is a very simple radio resource management strategy, however, it is not able to adapt to the uneven and time-varying traffic nature. Dynamic channel assignment (DCA) is a good approach to overcome such disadvantage. In DCA, all channels are potentially available in all cells, i.e., any channel can be used by any cell as long as the co-channel interference remains acceptable [2]. Clique packing [3] is considered as a model of an idealized DCA method that can provide the lower bound of blocking probability for any practical DCA.

Distributed DCA (DDCA) has been paid much attention due to much simpler resource management compared to centralized DCA. In DDCA, the channel assignment decision is made by each base station (BS) and/or mobile station (MS), and the information of the whole service area is not required. In cellular communication systems, DDCA schemes are normally classified into two categories—network-based and measurement-based schemes [4]. In network-based schemes [5]–[8], each BS relies on the information of channels in its vicinity to make a channel assignment. These schemes are applicable in high-mobility systems and macrocellular systems in which shadow fading changes rapidly. These schemes are appropriate for TDMA cellular systems, including IS-136 and GSM. Measurement-based schemes [9], [10], are based on real-time signal strength measurements. They may be used in low-mobility systems, fixed wireless access systems, packet-switched systems, and microcellular systems.

A network-based DDCA scheme, namely dynamic channel assignment with interference information (DCA-WI), was introduced in [5] to increase the capacities of TDMA cellular systems. In DCA-WI, the channel assignment is based on minimizing the impact of every assignment on channel availability in all the interfering cells. The objective of DCA-WI is similar to [6]. In [11], the graph theory was used for computation in order to obtain the optimum channel. Thus, as the number of cells increases, large computation efforts are required as mentioned in [11]. DCA-WI provides a systematic approach to the channel selection by the use of the ordered channels and the interference information tables (IITs). Every channel is ordered and an IIT is used in each BS. The IIT contains necessary and sufficient local information for each BS to make a channel assignment decision. In addition, DCA-WI uses techniques of single channel reassignment for new calls and channel rearrangement for completed calls in order to enhance the performance. It has been shown that DCA-WI outperforms other existing schemes [6]–[8] in both uniform and nonuniform traffic distributions. However, these DDCA schemes [5]–[8] have not achieved the optimum performance because the assignment policies of these DDCA schemes rely on mobiles on the edge of the cell, i.e., worse-case assumptions; thus, a single cluster size is assumed and it has limited the efficiency of spectrum utilization. In fact, for mobiles close to the BS, they are able to tolerate higher interference and thus can be assigned channels with smaller cluster size to improve system capacity.

Reuse partitioning (RP) [12] is a very useful technique to achieve high spectrum efficiency in cellular systems by using different cluster sizes. In RP, a cell is divided into several concentric regions and each region has a different cluster size. A mobile close to its BS is assigned a channel with a smaller reuse distance, whereas a mobile far from its BS with low signal quality is assigned a channel with larger reuse distance. In this way, overall reuse distance is decreased and channels could be used more frequently to provide larger system capacity. The performance analysis of RP with FCA system (FRP) has been studied

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The authors are with the Network Technology Research Centre, the School of Electrical and Electronics Engineering, Nanyang Technological University, Nanyang Avenue, Singapore 639798, email: {p144102719, ehjchong}@ntu.edu.sg.

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in [13]–[15]. In [14], it shows that with total system channels of 140, a 2-region RP with FCA system can improve the system capacity by about 25% compared to conventional FCA. More importantly, many cellular companies have already deployed RP since mid-1990s [16].

In this paper, a channel assignment scheme called dynamic reuse partitioning with interference information (DRP-WI), which integrates DCA-WI with two-region RP, is presented. DCA-WI has demonstrated its strong optimizing ability in [5]. In this paper, its performance will be further illustrated to be close to the idealized DCA model by the comparison to clique packing. Moreover, RP is applied with the result of lowering overall channel reuse distance in the system. With the combined effect of the two, a much larger system capacity is expected. The capacity can be further increased by allowing calls in the inner region to use, i.e., 'overflow into,' channels allocated to the outer region. Some network-based DDCA schemes with RP were proposed and studied [17], [18]. In [17], the scheme can improve the system capacity by about 60% over conventional FCA scheme with 140 system channels. However, in this paper, simulation results show that DRP-WI can provide about 70% capacity improvement over conventional FCA scheme with 140 system channels, and nearly 100% improvement with 70 system channels. More importantly, the implementation of RP does not much complicate the original DCA-WI algorithm.

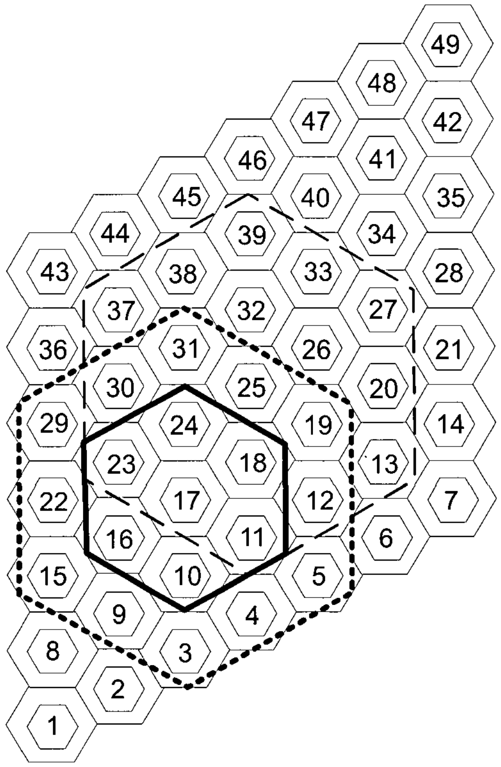


Fig. 1. A 49-cell system layout with 2-region reuse partitioning.

II. DRP-WI SCHEME

A. Network Scenario

A service area of 49 regular hexagonal cells is considered, as shown in Fig. 1. Each cell is divided into inner and outer concentric regions, which are associated with cluster sizes of 3 and 7, respectively. When a channel is used in an inner-cell (refer to inner region of a cell), which has a cluster size of 3, the same channel cannot be reused in the first tier neighboring (whole) cells due to co-channel interference constraint. For the same reason, a channel used in an outer-cell (refer to outer region of a cell), which has a cluster size of 7, cannot be reused in the first two tiers neighboring (whole) cells. This concept is illustrated in Fig. 1. The small hexagonal region in solid line describes the interference range for the inner cell 17, and the two bigger hexagonal areas which are drawn in dotted line and dash line refer to outer-cell 17's and 25's interference range, respectively. From [14], the radii for inner, r_i, and outer, r_o, regions are given by

$$\frac{N_i}{r_i^2} = \frac{N_o}{r_o^2} \tag{1}$$

where N_i and N_o are the cluster sizes for inner and outer region, respectively.

B. Interference Information Table (IIT)

The IIT is used to record the channel status in each cell. When RP is implemented, each cell is divided into inner and outer regions, and the system channels are partitioned into two subsets accordingly. For example, if total number of channels, M, available in the system is 70, total number, C_i, of 17 channels (hereafter referred to as inner channels) are dedicated to inner region and total number, C_o, of 53 channels (hereafter referred to as outer channels) are dedicated to outer region. Since inner channels and outer channels operate independently and have different cluster size, each cell will contain two different IITs for inner region and outer region. Tables 1 and 2 show the IITs of cell 17 for inner and outer region, respectively. The channels are numbered from 1 to 17 in Table 1 and from 18 to 70 in Table 2. It is noted the 17 channels (inner channels) allocated to the inner region can be used only by inner region calls (calls originated from inner region), while the 53 channels (outer channels) assigned to outer region, are used by outer region calls (calls originated from outer region). If *overflow* (described in Section III) is allowed, inner region calls could use the outer channels.

B.1 Legend Explanation

The legends used in the IITs are described as follows. In any IIT of cell i, the first column first lists the cell number of cell i (hereafter referred to as *OWN CELL*) and then followed by cell i's interfering cells (hereafter referred to as *IF CELLs*). Since the cluster sizes for inner-cell and outer-cell are 3 and 7, respectively, inner-cell has 6 interfering cells, whereas outer-cell has 18 interfering cells. All other columns contain the information of channels allocated to the inner/outer region in the system. Thus, each row indicates the channel status for a particular cell.

A letter **U** or **U'** in the box indicates a channel is occupied in the *OWN CELL* or one of the *IF CELLs*. **U'** is only used for an outer channel which is used by an *overflow* call from inner region. Therefore, **U'** only appears in IITs of outer-cells. For example, in Table 1, channels 1, 6, and 16 are used in cell 17

Table 1. IIT of inner-cell 17.

Cell	Inner region channel number								
no.	1	2	3	4	5	6	...	16	17
17	**U**					**U**		**U**	
10			**L**	**U**					
11			**L**		**L**				
16			**L**				...		**U**
18				**L**	**L**				
23				**L**					
24			**U**	2**L**					

Table 2. IIT of outer-cell 17.

Cell	Outer region channel number								
no.	18	19	20	21	22	23	...	69	70
17		**U'**			**U**				
:									
:									
22	**U**		**L**	**U**		**L**	...	2**L**	
:									
30				**L**		**U'**			**L**
31	**L**		**L**	**L**					**L**

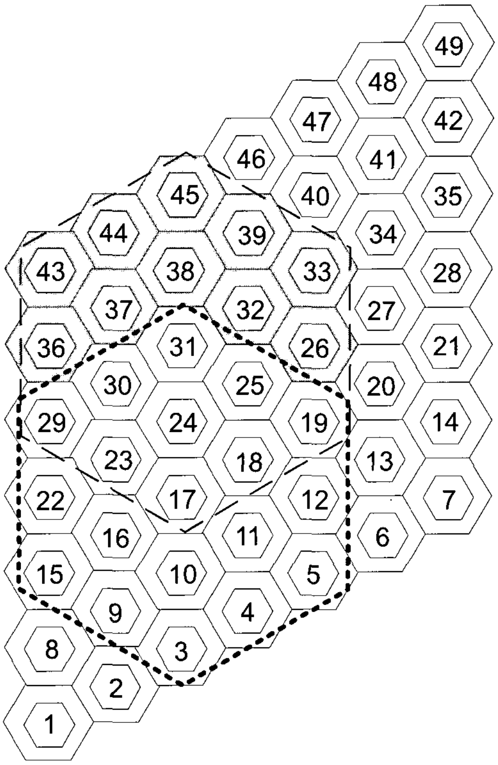
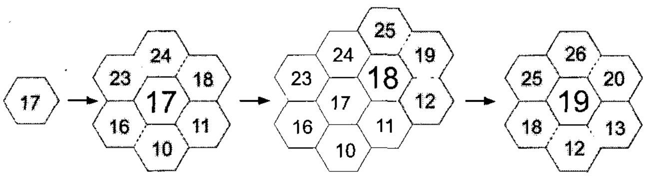


Fig. 2. An example of channel 20 locked in cell 31 in IIT of outer-cell 17.



(1) (2) (3) (4)

Fig. 3. The updating process for an inner channel to be assigned in cell 17.

and channel 17 is used in cell 16. In Table 2, channel 19 is used by an overflow call (inner region call) in cell 17 and channel 18 is used by an outer region call in cell 22. A letter **L** means the channel, say channel k, is locked in an *IF CELL* because one of *IF CELL*'s interfering cells, which is not an interfering cell of the *OWN CELL*, uses channel k. Thus, that *IF CELL* is not allowed to use channel k. In *OWN CELL*'s point of view, an **L** in *IF CELL* is only because a channel is used in a cell outside *OWN CELL*'s interference range. Therefore, an **L** for a channel in an *IF CELL* will not prohibit *OWN CELL* from using that channel. For instance, in Table 2, channel 20 is locked in cell 31. This is because one interfering cell of cell 31, say outer-cell 44 as shown in Fig. 2, which does not belong to any *IF CELL* in IIT of outer-cell 17, has used channel 20. Thus, from Table 2, we know that cell 31 cannot use channel 20. However, such locking information will not affect the availability of channel 20 for *OWN CELL* 17 to use. A symbol of 2**L** means that two such interfering cells of *IF CELL* use that corresponding channel. However, a letter **U** or **U'** in the channel column will prohibit *OWN CELL* from using that channel due to co-channel interference constraints. For example, channel 3 in Table 1, and Channels 18 and 23 in Table 2 cannot be used in cell 17.

B.2 Table Updating

Any channel assignment and channel release will initiate an updating procedure. When an *OWN CELL* decides to assign a channel j to a new call, (1) it first updates its IIT by inserting a letter **U** in the [*OWN CELL*, channel j] box, (2) and then it informs its *IF CELLs* by inserting a letter **U** in the [*OWN CELL*, channel j] boxes in their IITs. As mentioned, **U'** instead of **U** is used if it is an overflow call. (3) After that, each *IF CELL* informs its interfering cells, (hereafter referred to as other *IF CELLs*), which are not fell within the *OWN CELL*'s interference range, that the particular channel j is locked, i.e., a letter **L** is inserted in [*IF CELL*, channel j] boxes in other *IF CELLs*' IITs. (Note that **L** is additive.) (4) Finally, other IF CELLs with **L** inserted inform all their interfering cells its latest number of locked cells (the cells with **L**) on that particular channel. The updating for channel release follows the same procedure, except that "removing **U**/**U'**" is operated instead of "inserting **U**/**U'**" and an **L** is subtracted rather than added.

An example of a typical updating process for an inner channel 2 to be assigned in cell 17 with reuse factor of 3 is shown in Fig. 3. (1) **U** is updated in IIT of inner-cell 17: A letter **U** is inserted in [cell 17, channel 2] box of cell 17's IIT. (2) **U** is updated in IITs of *IF CELLs* of inner-cell 17: A letter **U** is inserted in [cell 17, channel 2] box of cells 10, 11, 16, 18, 23, and 24's IIT. (3) **L** is updated in IITs of other *IF CELLs* (Fig. 3 shows the other *IF CELLs* of *IF CELL* 18): A letter **L** is inserted in [cell 18, channel 2] box of cells 12, 19, and 25's IIT. (4) Other *IF CELLs* inform their interfering cells about the number of locked cells. (Fig. 3 shows that the locked information for the inner channel has changed in cell 19 and thus, cell 19 will keep its interfering cells informed.)

III. CHANNEL ASSIGNMENT STRATEGY

In DRP-WI scheme, there are two co-channel interference constraints, which are associated with cluster sizes of 3 and 7 for the inner and outer region, respectively. Therefore, the cluster size of an inner region channel is 3 and it will affect its neighboring cells in the first tier. Similarly, the cluster size of an outer region channel is 7 and it will affect its neighboring cells in the first two tiers.

A. DRP-WI without and with Overflow

In this paper, both DRP-WI without and with overflow schemes will be studied. Without overflow, when a new call arrives in the inner region, that inner region call will be assigned a channel from a pool of inner channels as shown in Table 1. If no inner channel could be used, that inner region call will be blocked. Similarly, when a new call arrives in the outer region, that outer region call will be assigned a channel from a pool of outer channels as shown in Table 2. If no outer channel could be used, that outer region call will be blocked. With *overflow*, if an inner region call cannot find a suitable inner channel for use, then that inner region call is allowed to find a channel from a pool of outer channels for use. If no outer channel could be used, that inner region call is blocked. However, the reverse is not allowed. It means that outer region call cannot use a channel from the pool of inner channels due to co-channel interference constraints. If an inner region call uses an outer channel, the cluster size for this outer channel is still 7.

The channel assignment considers using any free channel or channel required a single channel reassignment based on cost functions as shown in (2) and (3). A free channel means that there is no **U** or **U'** in a column. For instance, in Table 1, channels 2 and 5 are free channels. Single channel reassignment is considered when there is only one **U** or **U'** in a column except in the first row. For example, channels 3, 4, and 17 in Table 1 and channels 18, 21, and 23 in Table 2 are suitable for single channel reassignment.

B. Cost Function

This channel assignment scheme attempts to minimize the effect of the assignment on channel availability in all *IF CELLs* of any *OWN CELL*. In other words, for every channel assignment, DRP-WI tries to minimize the number of newly affected adjacent cells, in which the channel cannot be used due to the assignment. The "newly affected cells" exclude the cells which already cannot use the channel before the channel assignment. Such technique of impact evaluation on a free channel assignment has been proposed in [9]. In [9], for any assignment of a free channel, the DCA scheme tries to minimize the increase of forbidden zone for a new call. The idea of DRP-WI is based on this technique and applies to 2-region cells in order to use 2 cluster sizes instead of a single cluster size in [9]. It can be expressed as (2). The impact of any assignment is evaluated by a cost function, $C(x)$, and an assignment with less cost is favorable. When single channel reassignment is considered in DRP-WI, the cost function is realized in (3). In DRP-WI, these two cost functions $C(x)$ described below can be applied for both inner and outer region channel assignment with different reuse distances. The cost for assigning a free channel j in an *OWN CELL* i is expressed as

$$C(j) = I(i) - L(i,j) \tag{2}$$

where $I(i)$ is the total number of interfering cells of *OWN CELL* i and $L(i,j)$ refers to the number of *IF CELLs* of *OWN CELL* i, which are locked for channel j. From (2), it is clear that cost decreases as the number, $L(i,j)$, of locked cells increases since remains constant. In other words, an assignment affects the availability of channel j on the *IF CELLs* unless if $L(i,j)$ is larger. For example, as mentioned, channel 5 is a free channel in Table 1. Currently, two *IF CELLs* (i.e., cells 11 and 18) of cell 17 are locked for channel 5, so they are not allowed to use this channel. However, the rest of four *IF CELLs* (i.e., cells 10, 16, 23, and 24) can use channel 5. If free channel 5 is considered for channel assignment in cell 17, this channel will not be allowed to use in the four *IF CELLs* anymore due to co-channel interference. In other words, we make channel 5 unavailable to additional four *IF CELLs* for such assignment, and the cost of this assignment is $C(5) = I(17) - L(17,5) = 6 - 2 = 4$. On the other hand, if free channel 2 is considered for channel assignment in cell 17, the cost will be 6 since all 6 *IF CELLs* are affected. Therefore, channel 5 is more preferable than channel 2 for a channel assignment with lower cost.

As the traffic load in the system increases, less free channels are available as expected. To reuse the channels more frequently and effectively, single channel reassignment is considered in DRP-WI scheme. With the introduction of single channel reassignment, the blocking probability can be further reduced due to a better packing of the channels because it increases the chance for a new call to get a channel. Although multi-channel reassignment could be a further option under the same idea, it will also increase the complexity of the algorithm. Therefore, only single channel rearrangement is considered in DRP-WI.

In the case of single channel reassignment, if channel j is used by an *IF CELL* n, and *OWN CELL* i wants to use channel j, then *IF CELL* n might switch the on-going call (currently using channel j) from channel j to a free channel k depending on the cost function defined as

$$C(j) = [I(i) - L(i,j)] + [L(n,j) - L(n,k)] \tag{3}$$

where $L(n,j)$ refers to the number of *IF CELL* n's interfering cells which are locked for channel j and $L(n,k)$ refers to the number of *IF CELL* n's interfering cells which are locked for channel k. It is shown that the first part of the cost function is just a free channel assignment as in (2), because it is indeed a free channel assignment after channel j is switched in *OWN CELL* i. The second part of the cost function is used to calculate the cost of channel switching from channel j to k in *IF CELL* n. For instance, if the number of locked cells increases after the call is switched from channel j to channel k, i.e., $L(n,j) < L(n,k)$, it will introduce negative cost to the function. That means less interfering cells' availability is affected by this channel switching. The sum of these two parts calculates the overall impact of newly affected cells by assigning channel j in *OWN CELL* i.

When there is more than one suitable channel for assignment, the channel with least cost is selected. If there is more than one channel with least cost, the higher order channel is selected. The ordering of the channels is described as follows.

- A channel with larger number of locked cells has a higher order. For example, in Table 2, the order of channel 21 is higher than that of channel 18.
- If a channel order cannot be decided by the previous comparison, the order of a free channel is higher than that of single reassignment channel. For example, in Table 2, the order of channel 69 is higher than that of channels 18 and 23.
- If there is more than one free channel with equal number of locked cells, a lower-numbered channel has higher order. For instance, in Table 2, the order of channel 20 is higher than that of channel 70.
- If there is more than one single reassignment channel with equal number of locked cells, a lower-numbered channel has higher order. For example, in Table 1, the order of channel 3 is higher than that of channel 4. The order of channel 18 is higher than that of channel 23 in Table 2.

C. Channel Rearrangement

Channel rearrangements for completed calls are also considered. Two types of rearrangements, intra-region and inter-region rearrangements, are suggested to further improve the performance of DRP-WI scheme. Intra-region rearrangement means that an on-going call is switched between channels belonged to either inner or outer region. Inter-region rearrangement can be interpreted as an on-going overflow (or inner region call) call is switched from an outer channel to an inner channel. Thus, inter-region rearrangement is performed only if overflow is allowed in the system.

When an inner channel is released, an inter-region rearrangement will be first performed if overflow is allowed. If there is any inner region call using outer channel, that overflow call is switched to the just freed inner channel. If this process is successful, an intra-region rearrangement for outer region calls is followed. If no overflow calls are found, an intra-region rearrangement for inner region calls is performed. The purpose of inter-region rearrangement is to free an outer channel in order to support any call originated in either inner or outer regions. If overflow is not allowed in the system, an intra-region rearrangement for inner region calls is simply performed. When an outer channel is released, only intra-region rearrangement for outer region calls is conducted.

In an inter-region rearrangement process, if there is more than one overflow calls, the channel used by an overflow call with least locked cells is switched. If more than one such channel with the same least locked cells is available, larger-numbered channel is preferred. In an intra-region rearrangement process, a channel with least locked cells is switched to the released channel provided that the number of locked cells of that channel is less than that of the released channel. If there is more than one such channel, the highest-numbered channel is selected. If the number of locked cells is equal, the channel is still switched provided that the number of this channel is higher than that of the released channel. If more than one such channel is available, larger-numbered channel is preferred.

IV. SIMULATION RESULTS

In this section, the average call blocking probability, P_b, and capacity of DRP-WI are evaluated. The cellular system being simulated consists of 49 hexagonal cells and each with 2 regions as shown in Fig. 1. In this network-based scheme, an MS will be served by a BS as long as the MS is within the cell coverage of the BS. It is assumed that the BS is located at the center of the cell. In the simulation, low-mobility MS is assumed, i.e., the MS will remain in the same region of a cell during the course of a call. According to (1), the ratio between the radii of inner region and outer region can be calculated as $r_i/r_o = \sqrt{N_i/N_o} = \sqrt{3/7}$. Thus, the inner radius is simply equal to $r_i = \sqrt{3/7}r_o$. The arrival of new calls is assumed to be a Poisson process, and the call duration is exponentially distributed with a mean of 180 seconds. Three cases, where total number M of 70, 140, and 210 channels available in the system are simulated. The simulation results are presented for DRP-WI with both uniform and nonuniform traffic distributions and compared to available results for the FCA, FRP, local packing (LP) [6], EBCA [8], DCA-WI, and clique packing schemes.

In order to avoid the boundary effect when uniform traffic distribution is evaluated, wrap-around of the 49-cell plane in both dimensions is used in the simulation. In other words, the left-most and the right-most columns in the 49-cell plane as shown in Fig. 1 are connected with each other, and so are the top and the bottom rows. Since $P_b = 1\%$ is considered as a reasonable design target, the results of system capacity (or supported traffic load) used in this paper are referred to $P_b = 1\%$. For the simulation shown in this paper, the 95% confidence intervals are within $\pm 5\%$ of the average values shown.

A. Uniform Traffic Distribution

A simpler alternative implementation for DRP-WI is to eliminate the capability of overflow. Fig. 4 presents the average call blocking probability for DRP-WI with no overflow with $M = 70$, where overflow from inner region to outer region is not allowed, in a uniform traffic distribution. Different channel combinations, $C(Ci, Co)$, for DRP-WI have been simulated and three of them are shown in the figure. Among all the combinations, C(21,49) yields the lowest P_b. The P_b for FCA is obtained using the Erlang B formula, and the P_b for 2-region FRP is obtained from [14]. The capacity value of FCA at $P_b = 1\%$ is 4.46 Erlangs. The traffic loads that can be supported by LP, DCA-WI, FRP, DRP-WI with C(19,51), C(21,49), and C(23,47) are 6.79, 7.32, 5.31, 7.88, 8.24, and 8.1 Erlangs, respectively. These values correspond to the increase of 52%, 63%, 19%, 77%, 85%, and 82%, respectively compared to the FCA scheme.

Fig. 5 shows the comparison of clique packing and DRP-WI with C(21,49) for inner and outer regions without the consideration of overflow. The performance of clique packing is evaluated by 21 channels with 1-belt buffering in the inner region and 49 channels with 2-belt buffering in the outer region, respectively. The clique packing in this case provide the lower bound

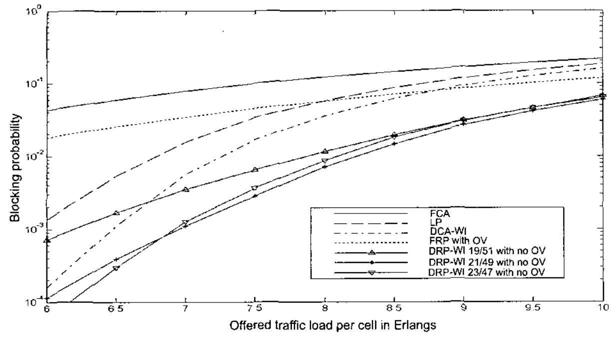


Fig. 4. P_b of DRP-WI without overflow for uniform traffic distribution with $M = 70$.

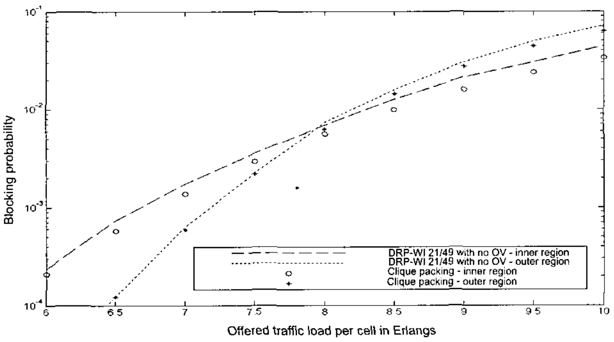


Fig. 5. Comparison of DRP-WI without overflow and clique packing for uniform traffic distribution with $M = 70$.

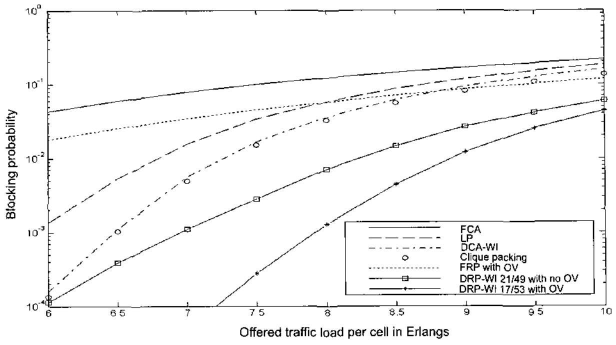


Fig. 6. P_b of DRP-WI for uniform traffic distribution with $M = 70$.

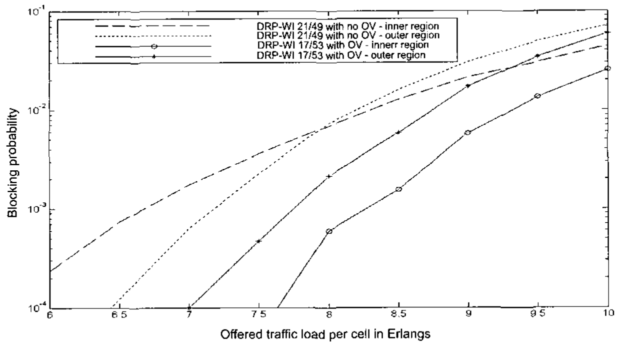


Fig. 7. P_b of different regions in DRP-WI without overflow and with overflow for uniform traffic distribution with $M = 70$.

that DRP-WI with C(21,49) can reach. It is seen that the outer region of C(21,49) performs almost as good as the clique packing, whereas, the performance of the inner region of C(21,49) is slightly worse than that of clique packing. The reason is that, as it is introduced in Section III, DCA-WI algorithm much relies on the information of interfering cells. When this algorithm is applied to regions with small reuse distances, the cost functions will be presented with relatively greater discrepancies since the number of interfering cells is small. For example, for cluster size of 3, the number of locked cells in a particular channel only varies from 0 to 6, whereas, for cluster size of 7, the variation is from 0 to 18. Therefore, when cluster size is larger, the results from cost function can reflect the impact of the channel assignments more accurately.

If overflow is allowed, the channel combination of C(17,53) performs the best. This combination is obtained from the ratio of area of the inner region to the outer region in a cluster of its own. Fig. 6 illustrates the performance of DRP-WI with overflow for C(17,53). The performance of clique packing with 70 channels in 2-belt buffering system is also shown. It can be seen that DRP-WI with overflow performs better than that without overflow. The capacity value at $P_b = 1\%$ is about 8.91 Erlangs, which is about 10% more over DRP-WI without overflow and nearly 100% capacity improvement over FCA scheme.

Fig. 7 presents the inner and outer region blocking probabilities of DRP-WI C(21,49) without overflow and DRP-WI C(17,53) with overflow. It is shown that C(17,53) with overflow has a much lower blocking probability in inner or outer region compared to C(21,49) without overflow. The overflow capability allows C(17,53) to have much more ability for inner region calls to access channels than those in C(21,49) without overflow. Also, the larger number of outer region channels, $C_o = 53$, provides more channels for outer region calls. Although overflow does introduce the unfairness of accessibility for different regions, DRP-WI with overflow can perform much better than that without overflow in both regions.

Fig. 8 shows the simulation results for $M = 210$. Without overflow, DRP-WI with C(63,147) outperforms other combinations. DRP-WI with C(51,159), which is also obtained from the ratio of area of the inner region to the outer region in a cluster of its own, can achieve the optimum system capacity when overflow is permitted. The traffic loads that can be supported at $P_b = 1\%$ by FCA is 20.3 Erlangs. The result of clique packing with 210 channels in 2-belt buffering system is also presented. The corresponding capacity values for LP, DCA-WI, and DRP-WI without overflow for C(63,147) and DRP-WI with overflow for C(51,159) are 25.13, 25.65, 30.83, and 32 Erlangs, respectively. Compared to FCA scheme, the improvements are 24%, 26%, 52%, and 58%, respectively. This improvement over FCA is lower than that in the case for $M = 70$. This is because the trunking efficiency is higher for FCA when M is larger. This observation agrees with [2]. However, the capacity of FRP is 25.85 Erlangs, which is equivalent to 27% improvement over FCA, while for $M = 70$ only 19% improvement is achieved. The reason behind is the trunking efficiency of FRP is also increased with larger M. Thus, FRP can provide more improvement over FCA when the number of system channels is larger.

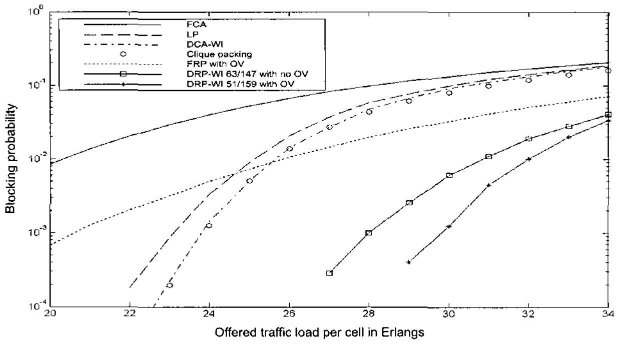


Fig. 8. P_b of DRP-WI for uniform traffic distribution with $M = 210$.

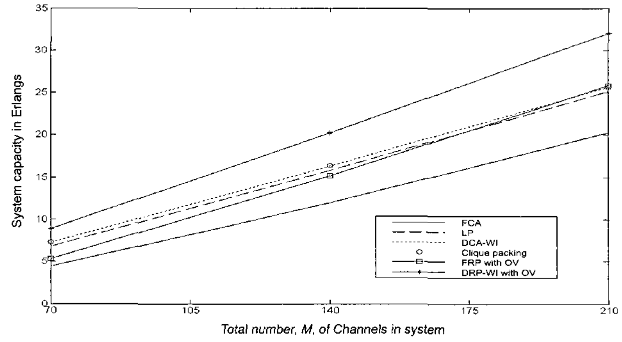


Fig. 9. System capacity of different schemes at $P_b = 1\%$ for uniform traffic distribution with M from 70 to 210.

The traffic loads that can be supported at $P_b = 1\%$ for various schemes with different values of M in uniform traffic distribution are shown in Fig. 9. When M is increased from 70 to 210, DCA-WI is able to closely match the performance of clique packing, which is considered as an idealized DCA. This can also be seen in Figs. 6 and 8 as well. It is seen that, compared to FCA, LP, DCA-WI, and clique packing, the capacity of FRP increases in greater gradient as M increases. More interestingly, when the number of system channels is 210, FRP even outperforms other DCA schemes due to its much better trunking efficiency. When RP is implemented in DCA-WI, i.e., DRP-WI, it provides a huge capacity gain. When M is increased from 70 to 140 and further to 210, DRP-WI can improve the capacity by nearly 100%, 70%, and 58%, respectively over conventional FCA.

B. Nonuniform Traffic Distribution

Comparison of results for nonuniform traffic distributions for $M = 70$ and 210 channels are performed using distributions of Fig. 2 in [8] ("distribution A") and Fig. 6 in [7] ("distribution B"), respectively. With nonuniform traffic distributions, wraparound is not used. In distribution A, the call arrival rates for each cell range from 20 to 200 calls/hour according to Poisson distribution and the average offered load per cell averaged over the 49 cells is 4.59 Erlangs. Distribution B shows higher nominal call arrival rates and a corresponding larger number of channels available, $M = 210$ is used. For distribution B, the offered load per cell averaged over the 49 cells is 21.9 Erlangs.

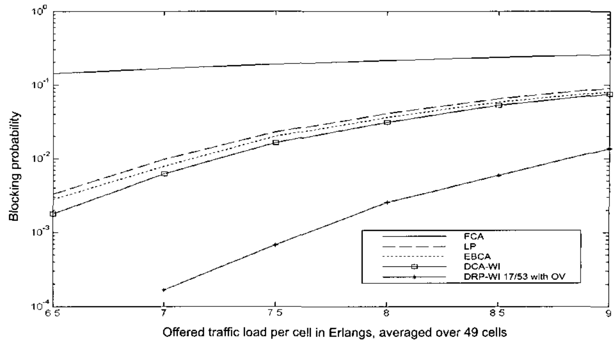


Fig. 10. P_b of DRP-WI for nonuniform traffic distribution A with $M = 70$.

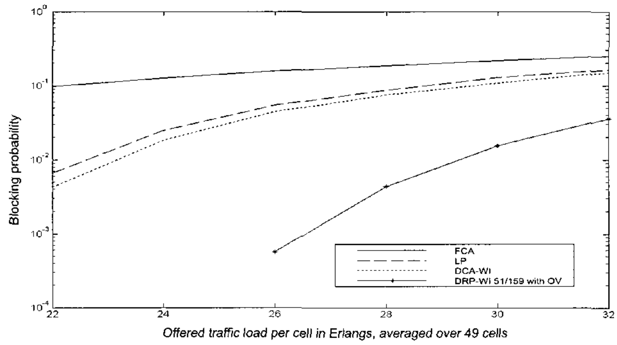


Fig. 11. P_b of DRP-WI for nonuniform traffic distribution B with $M = 210$.

It has been found that the channel combinations, $C(17, 53)$ for $M = 70$ and $C(51, 159)$ for $M = 210$, used in uniform traffic distribution can also achieve optimum performance under nonuniform traffic distributions.

Fig. 10 shows the P_b over 49 cells for FCA, LP, EBCA, DCA-WI, and DRP-WI with overflow schemes. It can be seen that the P_b for DCA-WI is slightly lower than that of LP and EBCA. However, DRP-WI provides much lower blocking probability than others. The capacity for FCA, DCA-WI, and DRP-WI are 3.0, 7.3, and 8.8 Erlangs. The capacity improvements for DCA-WI and for DRP-WI over FCA are 143% and 193%, respectively. The performance of DRP-WI under nonuniform traffic distribution B is shown in Fig. 11. The capacity supported by FCA is 14 Erlangs. The values for LP, DCA-WI, and DRP-WI are 22.6, 23.2, and 29.3 Erlangs, which are equivalent to 61%, 66%, and 109% improvement over FCA. It proves that DRP-WI also performs well in nonuniform traffic cases.

V. CONCLUSION

This paper presents a new channel assignment scheme, dynamic reuse partitioning with interference information, (DRP-WI), which integrates dynamic channel assignment with interference information (DCA-WI) and reuse partitioning (RP). DCA-WI is an effective network-based distributed assignment scheme. It outperforms other existing schemes and can provide about 63% improvement over FCA for 70 system channels. RP is also a very useful technique to improve spectrum efficiency.

With the combination of DCA-WI and RP, DRP-WI improves the system capacity tremendously over FCA, LP, DCA-WI, clique packing, and FRP. Under uniform traffic distribution, DRP-WI can provide nearly 100% improvement over FCA for 70 system channels. This is a substantial capacity improvement for cellular systems. Under nonuniform traffic distributions, DRP-WI is able to show its efficiency on spectrum utilization and it can provide a great capacity gain compared to FCA and other DCA schemes. Furthermore, the optimum combination of channel allocation can be obtained from the ratio of area of the inner region to the outer region in a cluster of its own for both uniform and nonuniform traffic distributions. In conclusion, DRP-WI performs well in both uniform and nonuniform traffic distributions to provide higher capacity for cellular systems.

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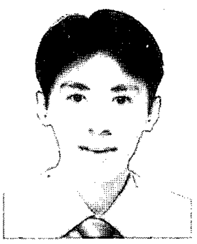
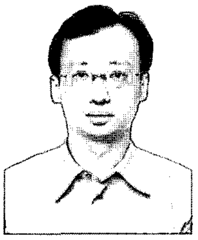


Steven L. Chen was born in Guangdong, China, on December 3, 1979. He received the B.Eng. (1st Class Honors) and M.Eng degrees in electrical & electronic engineering from Nanyang Technological University, Singapore, in 2002 and 2004, respectively. His research interests are wireless communication systems and radio resource allocation and optimization for the systems.



Peter H. J. Chong was born in Hong Kong, China, on June 4, 1970. He received the B.Eng. (with distinction) in electrical engineering from the Technical University of Nova Scotia (currently Dalhousie University), Halifax, NS, Canada, in 1993, and the M.A.Sc. and Ph.D. degrees in electrical engineering from the University of British Columbia, Vancouver, BC, Canada, in 1996 and 2000, respectively. Between July 2000 and January 2001, he worked with Advanced Networks Division at Agilent Technologies Canada Inc., Vancouver, BC, Canada. Between Feburary 2001 and May 2002, he was a Research Engineer in the Radio Communications Laboratory at Nokia Research Center, Helsinki, Finland, and was involved in research on WCDMA and standardization. Since May 2002, he has been with the School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore, as an assistant professor. He was a Technical Program Committee Chair for IEE 2nd Mobility Conferecne 2005. His research interests are in the areas of wireless and mobile communications systems including channel assignment schemes, radio resource management, multiple access, and mobile ad hoc networks.