Distributed Dynamic Channel Borrowing With Call-On-Stay Scheme for Cellular Mobile Networks

A.K.Sachan[1] Dr.R.C.Jain[2] Dr.R.L.Rana[3]

ABSTRACT : In this paper, a new distributed dynamic channel-borrowing with call on stay scheme based on compact pattern is presented. If a new or handoff call is put on hold for a short while in a cell, in the absence of an available channel, it is highly likely that the local base station will soon find a channel for the call. This scheme does not require system wide information about the local cell and its interfering cells. In the proposed, *DDCA* algorithm is said to have failed to assign a channel to a call only if a waiting call is delayed for longer than a threshold period called maximum delay. The impact of small values of maximum delay on the average delay suffered by all calls in the network is negligible, but the reduction in failure rate is significant.

KEYWORDS : cellular networks, dynamic channel assignment, channel borrowing scheme, performance, and simulation.

1. INTRODUCTION

The demand for mobile cellular communication services is increasing rapidly. A major limitation is to support a large number of users in the limited availability of radio frequency spectrum. The capacity of cellular communication becomes one of the main issues. One method is to increase the capacity of cellular systems to reduce the cell size. However, the drawback of this solution is an increase in the number of Base-Stations (*BS*) and hence cost.

Another approach is to use more efficient channel assignment schemes. There are two basic methods for assigning channels to cells. One is the fixed channel assignment [1], where the allocated cellular spectrum is divided into *N* channels sets and *M* neighboring cells, grouped into a cluster. Each cell in a cluster is then permanently assigned one of the *N* channel sets as its nominal channel *(NC)* set and the same channel set is reused in the corresponding cell in every cluster. The second method is dynamic channel assignment *(DCA)* [2], [3] in which all channels are potentially available to all cells, thus providing the facility to cope with variations in traffic.Channel assignment schemes can be implemented in several ways. Firstly, a channel can be chosen by a mobile terminal, based on its local carrier-to-interference ratio (*CIR*) measurement. Secondly, the channel can be assigned by a central controller. Thirdly, a channel can be chosen by a local *BS* based on its knowledge of the available channels in its vicinity. A *BS* can gather channel status in its vicinity in two ways:

1) Measure the *CIR* parameters for each channel and

2) Exchange information with the other *BS* within a minimum reuse distance of a channel.

One major advantage of channel borrowing allocation (*CBA*) with call-on-stay scheme over *CBA* scheme is the improvement of their blocking performance [7].

In this paper, a channel borrowing *DCA* scheme with call-on-stay is proposed. A *CBA, BS* of a cell *A* chooses a channel *j*, which is locked in the largest number of

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interfering cells of cell *A*. We say that a channel *j* is locked in cell *k* if channel *j* cannot be used in cell *k* because it is being used in some interfering cells of cell *k*. We also refer to cell *k* as a locked cell for channel *j*, channel assignment is based on the minimum effect on all interfering cells. The Interference Information Table contains the information of local cells and interfering cells. The *CBA* is distributed *DCA* scheme in which the channel use in each cell is selected by its local base station from the information provided by its Interference Information Table. Simulation results show that this proposed *CBA* with call-on-stay yields a lower blocking probability than previous *CBA* schemes [7].

2. Interference Information Table and Channel Updating

The Interference Information Table [7] is an extension of the augmented channel occupancy table [8], each cell has knowledge of the channel used in the local cell and the interfering cells. In addition, the interference information table includes channel interference information from which each cell knows if the channels in the interfering cells are locked. Channel Borrowing With Call-On-Stay Scheme makes use of this information to reduce the blocking probabilities.

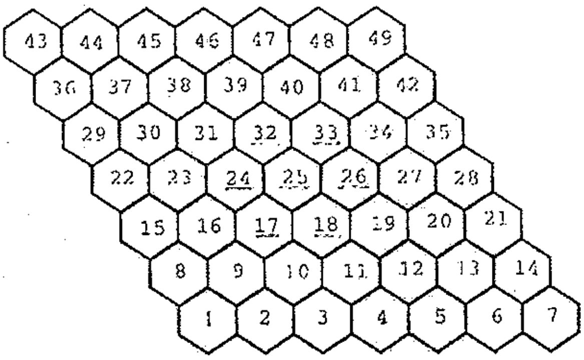

Fig.1. A cellular system with 49 cells for *N*=7

Table1. Interference Information Table of cell 25.

Cell No.	Channel No.									
	1	*2*	*3*	*4*		...	*67*	*68*	*69*	*70*
25		*U*		*U*						
32			*L*	*L*		...	*L*	*L*	*L*	*U*
:	*:*	*:*	*:*	*:*			*:*	*:*	*:*	*:*
17			*U*	*2L*			*L*	*U*		*U*
:	*:*	*:*	*:*	*:*	*:*		*:*	*:*	*:*	*:*
33				*L*						
List of Interfering cells: 11,12,13,17,18,19,20,23,24,26,27,30,31,32,33,37,38,39										
Channel Order List: 21,22,...,30,20,19,18,...,2,1,70,69,...,32,31										

In its Interference Information Table, each cell lists all the interfering cells. For the cluster size, *N*, of 7, the same channel can not be reused in the cells located in the first and second tiers. In Fig. 1, there are 18 interfering cells for cell 25. Thus, if channel *i* is used in cell 25, then channel *i* can't be used in any one of the 18 interfering cells of cell 25 due to co-channel interference constraints. The Interference Information Table for cell 25 is shown in Table 1. The first column indicates the local cell number, 25 and its interfering cells. The first row lists all available channels in the system shown in the table 1.

Table 2. Interference Information Table of cell 17.

Cell No.	Channel No.									
	1	*2*	*3*	*4*	*5*	...	*67*	*68*	*69*	*70*
17			*U*					*U*		*U*
22				*U*		...				
:	*:*	*:*	*:*	*:*			*:*	*:*	*:*	*:*
3				*U*						
:	*:*	*:*	*:*	*:*	*:*		*:*	*:*	*:*	*:*
25		*U*		*U*						
List of Interfering cells: 3,4,5,9,10,11,12,15,16,18,19,22,23,24,25,29,30,31										
Channel Order List: 41,42,...,49,50,40,39,38,...,2,1,70,69,...,52,51										

Letter *U* in the cell's row indicates that the corresponding channel is used in that cell. The letter *L* in an interfering cell's rows indicates that the corresponding channel is a locked channel in the interfering cells. For example, in Table 1, channels 4 is a locked channel in cell 17 with a label of *2L* because two interfering cells of cell 17, namely cells 3 and 22 which are not interfering cells of cell 25, uses channel 4 as seen in Table 2.

The channel update (channel assignment, channel release or channel reassignment) is simple and involves three steps. After the *BS* of cell *k* decides to assign channel *j* to a call, (1) it inserts a label *U* in the first row and channel *j's* column of its Interference Information Table, (2) it informs all its interfering cells that channel *j* is used in cell *k*; this means that a *U* is put in cell *k's* row and channel *j's* column in each interfering cell's Interference Information Table, and (3) each interfering cell of cell *k*, say cell 1, will inform its interfering cells which are not interfering cells of cell *k* that channel *j* is locked in cell 1.

Channel release is done following a similar three-step procedure. When cell *k* decides to release channel *j*, (1) cell *k* will inform its local cell that channel *j* is released, and (2) inform all its interfering cells that the channel *j* is released in cell *k*, then (3) each interfering cells which are not the same interfering cells of cell *k* that channel *j* is no longer locked in cell 1. Channel reassignment involves channel release and channel assignment.

3. Channel Borrowing Allocation Scheme

When a new call requests a channel in cell *k*, its *BS* will make an available channel list (ACL) based on the channel information from cell *k's* Interference Information Table. A channel is selected from the ACL. If the ACL is empty, the new call is blocked. The channel assignment may involve an inter-cell single channel reassignment. When a call in cell *k* using channel *j* is completed, intra-cell channel reassignment is performed in order to reduce call blocking probability.

3.1 Available Channel List (ACL)

The ACL in cell *k* contains all its free channels and all its locked channels with only one locking cell (i.e., channels with an empty box in the first row and exactly one box labeled *U* in the channel column) in which there is atleast one free channel for inter-cell single channel reassignment. The channels in the list are ordered as follow: (1) a channel with a large number of locked cells has a higher order; for example, in Table 1, the order of channel 67 is higher than that of channel 69, (2) a free channel has higher order than a locked channel; for example, in Table 1, the order of channel 69 is higher than that of channel 68, and (3) the order follows the Channel Order List (COL)are ordered as follows: The *M* total available channels are numbered from 1 to *M* and divided into *N* channel sets, $G_1, G_2, \ldots, G_N$, where *N* is the cluster size. The COL in a cell with cluster size i, $i=1, 2, \ldots, N$, is as follows: $G_i, G_{i-1}, \ldots, G_1, G_N, G_{N-1}, \ldots, G_{i+1}$ where the channels in G_i are ordered from low number to high number and the channels in other channel sets are ordered from high number to low number as shown in Table 1. The first channel in COL has the highest order.

3.2 Channel Assignment Strategy

In channel borrowing allocation scheme, a channel is selected, which has the smallest value of the cost function *E*. First, cell *k* uses the highest ordered free channel *f* in its ACL to calculate $E(f)$ which is given by:

$$E(f) = I(k) - D(k, f) \ldots (1)$$

Where $D(k, f)$ is the number of locked cells of channel *f* in cell *k's* Interference Information Table and $I(k)$ is the total number of interfering cells of cell *k*. Then cell *k* calculates $E(j)$ for all the locked channels in its ACL. If a locked channel j has a locking cell l and the call using channel j in cell l is switched to channel i which has the highest number of locked cells, then $E(j)$ is given by

$$E(j) = [I(k) - D(k, j) - 1] + [D(l, j) - D(l, i)] \ldots (2)$$

In this scheme, the inter-cell single channel reassignment using $E(j)$ is based on the minimum effect on the interfering cells in both borrower and the locking cells. If more than one channel has the smallest value of E, the one which has the highest order in the ACL is selected.

Inter-cell double channel reassignment was also simulated. If no free channel or locked channel with one locking cell is available in the ACL, then find a locked channel j with two locking cells in which each locking cell must have atleast one free channel for channel reassignment. For simplicity, the call using channel j in each locking cell is switched to the free channel with the largest number of locked cells.

3.3 Intra-Cell Channel Reassignment

Various intra-cell channel reassignment schemes which switch an on-going call to a released channel have been studied [9], [10]. They use the concept of channel ordering to minimize the traffic carried on the borrowed channels. In channel borrowing assignment scheme, the channel reassignment is based on the interference information. If channel j is released in cell k, a call in cell k using channel i which has the least number of locked cells is switched to channel j provided that the number of locked cells of channel i is smaller than that of j. If there is more than one such channel, the channel with the lower order in the COL is switched. If the number of locked cells of channel i is equal to that of channel j, the call is switched to channel j provided that the order of channel i is lower than that of channel j in COL. If there is more than one such channel, the channel with the lower order in the COL is switched.

4. Improving the Performance of Channel Borrowing Allocation Scheme

We hypothesized that if channel assigned is delayed for a short while, it is highly likely that a call which would otherwise be blocked or dropped. Based on this hypothesis, we proposed novel way to boost the performance of channel borrowing allocation scheme is given in this paper [7]. According to this scheme, all arriving calls in the cell (newly generated in the cell or moving in neighboring cells) are put on hold queue. The call at the head of the queue is considered for channel assignment. If the call has already spent more time than a predetermined maximum delay (MD), then the call is said to be blocked or dropped depending on whether it is a new call or a call arriving from another cell, respectively.

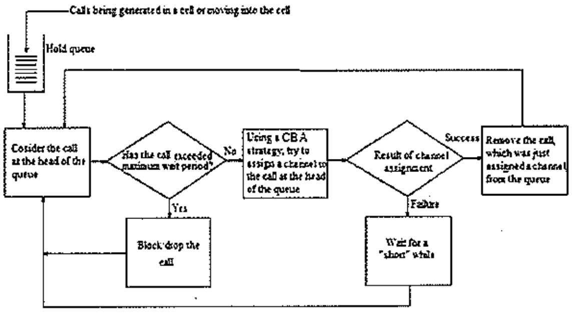

Fig.2. Delayed channel assignment

If the call has not been held up from more than the specified maximum delay, we try to assign a channel to the call using CBA scheme. If the channel assignment succeeds, the call is removed from the queue. In case the channel assignment fails, we revisit the queue after a short while and try to assign a channel to the call at the head of the queue.

5. Simulation Results

As a novel approach to mobility modeling and against the traditional hexagonal cellular geometry formulation [4], orthogonal coordinate system has been used in this research for positioning users throughout service area.

The traffic distribution throughout the service area is assumed to be non-uniform and to reflect the PCS environment, the total number of channels has been chosen to be 70. Finally, the call duration pdf used in the simulation is truncated Gaussian with a mode of 90 seconds. Call holding maximum delay *MD* is variable, such as 5, 10, 15, 20, 25 and 50 seconds. Minimum call duration is 30 seconds and maximum call duration of 600 seconds.

In deriving results compare to the *CBA* scheme with call-on-stay method to *CBA* scheme. For assessing the performance of the proposed scheme in a highly mobile environment, three other teletraffic performance indexes have been evaluated in addition to the blocking probability. These three metrics are hand-off failure probability, probability of forced termination (the probability that a call that was originally accepted by the system is interrupted during its process due to handoff failure) and call not completed probability (which is defined as the probability that a call is terminated incompletely by either blocking or forced termination) [5]. The average blocking probability is less as compared to the *CBA* scheme as shown in Fig. 3 to Fig .7 . respectively show the average blocking probability, handoff failure probability, probability of forced termination and call not completed probability of our proposed scheme in comparison to *CBA* scheme. The capability of the proposed scheme for performing in a highly mobile environment is evident from these results.

Further investigations based on reported results [4], [6] indicate that the proposed scheme can effectively and impressively compete with well known existing schemes such as *BDCL* and *CPMCB*, both which utilize more complicated decision making processes for their *CA* operations (specially *BDCL*) and therefore inflict additional network management complexity upon the system.

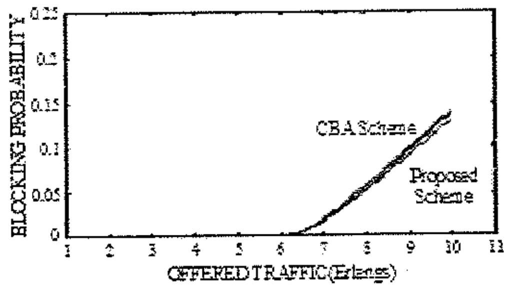

Fig. 3: Average blocking probabilities of the proposed *CBA* with call-on-stay scheme and *CBA* scheme versus offered traffic (Erlangs).

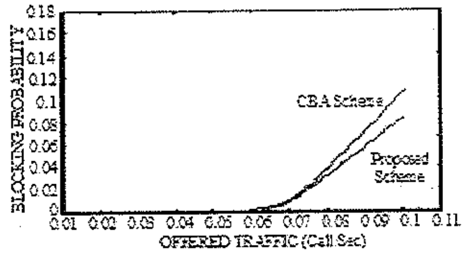

Fig. 4: Average blocking probabilities of the proposed *CBA* scheme with call-on-stay and *CBA* scheme versus offered traffic (Call/Sec).

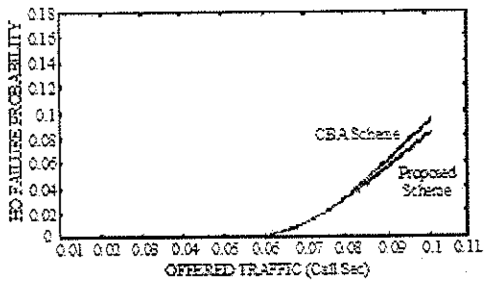

Fig. 5: Average HO failure probabilities of the proposed *CBA* with call-on-stay scheme and *CBA* scheme versus offered traffic (Call/Sec).

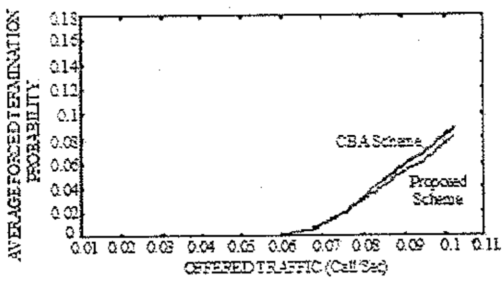

Fig. 6: Average forced termination probabilities of the proposed *CBA* with call-on-stay scheme and *CBA* scheme versus offered traffic (Call/Sec).

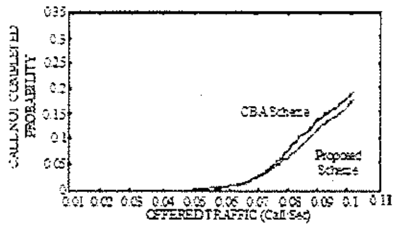

Fig. 7: Average call not completed probabilities of the proposed *CBA* with call-on-stay scheme and *CBA* scheme versus offered traffic (Call/Sec).

Further investigations based on reported results [5] indicate that the proposed scheme can effectively and impressively compete with well known existing schemes such as *BDCL* and *CPMCB*, both which utilize more complicated decision making processes for their *CA* operations (specially *BDCL*) and therefore inflict additional network management complexity upon the system.

6. Conclusion

A *CBA* with call-on-stay scheme has been proposed and its performance has been extensively evaluated by means of an initiative cellular network simulator that has been developed aiming to simulate a mobile communication environment as realistically as possible. The results denote its capability fitness for being used in high capacity cellular systems and utilizing the spectrum efficiently. The proposed scheme, which is applicable to 3G cellular systems with minimum modifications, exploits *CP* concept and efficient release and reallocation techniques.

7. Acknowledgement

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8. References

[1] Lee, W.C.Y. *"Mobile Cellular Communication Systems"*, 2nd Ed. New York: McGraw- Hill, 1995.

[2] Cox, D., Reudink, D., "*A comparison of some channel assignment strategies in large-scale mobile communication systems,*" *IEEE Trans. Com.*, Vol. COM-20(Apr. 1972), pp. 190-195.

[3] Nanda, S., Goodman, D., "*Dynamic resource acquisition: Distributed carrier allocation for TDMA cellular systems,*" *IEEE GLOBECOM '91(1991),* pp. 883-889.

[4] J.D.Parsons, "*The Mobile Radio Propagation Channel*", West Sussex: John Wiley & Sons, 2nd Ed., 2001.

[5] L.Ortigoza-Guerrero & A.H.Aghvami, "*A prioritized handoff dynamic channel allocation strategy for PCS*", IEEE Trans. Veh. Technol., Vol. 48, No. 4(1999), pp. 1203-1215.

[6] Vahid Tabataba Vakili & Arash Aziminejad , "*A new channel borrowing assignment scheme with enhanced teletraffic performance suitable for high capacity mobile cellular systems*", MA, Artech House, 2003.

[7] Peter H.J.Chong, Cyril Leung, "*A new channel borrowing scheme with interference information for cellular systems*", IEEE Trans. Veh. Technol., Vol. 48, No. 4, (1999), pp. 20-24.

[8] I.C.Chao, P., "*Local packing- Distributed dynamic channel allocation at cellular based station*", IEEE Globecom'93(1993), pp.293-301.

[9] Zhang, M., Yum, T., "*Comparisons of channel assignment strategies in cellular mobile telephone systems*", IEEE Trans. Veh. Technol., Vol. 38, No.4(Nov.1989), pp. 211-215.

[10] Chang, K., Kim, J., Yim, C., Kim, S., "*An efficient borrowing channel assignment scheme for cellular mobile systems*", IEEE Trans. Veh. Technol., Vol. 57, No.2,(May.1998) pp.602-608.

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