Estimation on efficient of distribute channel allocation schemes for cellular network

Do Huu Tri[1,*], Vu Duy Loi[2], Bui Thien Minh[3]

[1]*Ministry of Information and Communication (MIC), 18 Nguyen Du Street, Ha Noi*

[2]*Center of Information Technology Office of Central Commitee of Communist Party of Vietnam, 1 Hung Vuong Street, Ha Noi*

[3]*Viet Nam Post and Telecommunication Group (VNPT), 1 Dao Duy Anh, Dong Da Street, Ha Noi*

Abstract. The efficient management and sharing of the spectrum among the users is an important issue, frequency channels have to be reused as much as possible in order to support the many thousands of simultaneous call in any typical of mobile system. In cellular architecture, cell is serviced by a base station located at its center. A number of cells are linked to a mobile switching center which also acts as a gateway of the cellular network to the existing wired networks liked PSTN, ISDN or LAN-WAN based networks. A base station communicates with the mobile station through wireless links, and with the MSC's through wire-line links. This paper deals with some estimations on efficient of distribute channel allocation scheme for cellular networks and then LBSB scheme is selected to improve it's efficient, that is, the first, channel borrowing is not only neighbours but in compact pattern and the second, when a cell become hot, it repeat to borrow channel until reaching average degree of coldness of networks, that mean $X = C.(d_c^{avr} - d_c)$.

1. Introduction

Efficient of distribute channel allocation scheme is estimated by: new call blocking probability, drop call, number of hand off, delay of channel assignment and traffic. In selecting a channel assignment method, the objective is to gain a high degree of spectrum utilisation for a given a quality of service with the least possible number of database lookups and simplest possible algorithms at the base station or MSC. In this paper, we present distribute channel allocation schemes in way systematic, estimation advantage and weak point of them.

2. Channel borrowing and locking schemes (FCA)

The cellular networks were implemented using static frequency channel assignment: after careful frequency planning, channels are assigned to cell sites and these sets aren't changed except for a new long-term reconfiguration, this is fixed channel assignment, FCA.

---

* Corresponding author. Tel.: (84) 0912285227
  E-mail: dhtri@mic.gov.vn

The first proposed scheme was Simple Borrowing (SB) scheme [1] In this scheme, when an incomming call request arrives in the cell and there are no more available nominal channels, the base station can borrow a channel from a neighbouring cell to serve the call request, provided this frequency does not interfere with the existing calls. MSC supervises the borrowing procedure following an algorithm that favours channels off cells with less traffic demand. The cells (within a distance of one or two cell units away from the borrower cell) that have a nominal channel of the same frequency as a borrowed channel will not be able to use it because of the co-channel interference. Therefore, the MSC "locks" the frequency channel in those cells. The MSC keeps a record of free, serving, borrowed and locked channels. The SB scheme gets a lower call blocking probability than FCA under light and moderate traffic conditions of the expense of additional storage requirement at the MSC and the need for database lookups. In heavy traffic conditions, the channel utilisation efficiency in SB is very much degraded because the locked channels reduce the available capacity.

2.1. Hybrid Channel Borrowing Schemes

The main problem with the SB scheme is the absence of control in the number of channels that can be lent by a cell. In the Simple Hybrid Channel Borrowing scheme (SHCB) [2], the set of channels assigned to a cell is divided into two groups, A and B. Group A channels are local channels that can only be used to sever call requests inside the cell. Neighbouring cells can borrow channels of group B which are "borrowable" channels. The ratio A:B is determined a priority, the optimum ratio depends on the percentage increase in the traffic density.

The Borrowing with Channel Odering (BCO) scheme (BCO) [3] also divides the nominals channels into two groups, but the local to borrowable ratio varies dynamically according to the current traffic conditions. The channels of the cell are ordred such that the first channel has the highest priority to be assigned to the next local call, and the last channel is given highest priority to be borrowed by neighbouring cells. If the base station performs this functionality, then the MSC needs to be informed about the resulting assignment. The MSC uses an adaptive algorithm to calculate and update each channel probability of being borrowed, base on traffic conditions. If the channel frequency is free in the three nearest co-channel cells, only then the channel is suitable for borrowing.

Borrowing with Direction Channel Locking (DBCL) [4] is similar to BCO with channel reassignment. However, DBCL uses an efficient way to lock channels. When a channel is locked, it is locked only in the directions that would cause co-channel interference. Cells located toward the free directions can borrow or lock the channel.

SHCB scheme performs better than FCA with light and moderate traffic. Under heavy traffic load, the point where SHBC outperforms FCA will be dependent on the A:B ratio. BCO and DBCL schemes outperformed FCA in all kind of traffic conditions. DBCL outperforms BCO and also a dynamic channel allocation scheme called Locally Optimised Dynamic Assignment Strategy (LODA).

2.2. Distributed Channel Borrowing Schemes

These schemes are Distributed Load Balancing with Selective Borrowing D-LBSB [5]. BCO and DBCL use centralised control inside the MSC. The MSC has to keep a record of free, serving, borrowed and locked channels and to label them with updated priority. The need for a continuous up-to-date global knowledge of the entire mobile network can lead to a slow response and a heavy signalling load. To alleviate this problem, several authors have proposed modifications to make the schemes more distributed.

The D-LBSB scheme migrates channels from a cell with available channels (called "cold cell") to an overload cells (called "hot cell"). Together with the borrowing channel algorithm a channel assignment strategy is used.

Initially, **C** channels are allocated to each cell in the network. The classification of a cell as hot or cold depends on its degree of coldness d_c. If $d_c \leq h$ (a determined threshold), then the cell is hot, otherwise it is cold. The determination of **h** depends on the average call arrival and termination rates of the entire cellular network, **C** and also the probability of channel borrowing rates from the other cells. Typical values of h are 0,2 or 0,25. The mobile user is clasified as new, departing or others according to the rules in figure 1.

The base station periodically monitors the quality of the received signal strength (RSS) from each user through special control channels. If RSS of the user is less than a certain threshold, the user is within one of the shaded peripheral regions in the boundary of a cell.

A cold cell cannot borrow channels and a hot cell canot lend channels. Three parameters determine the suitablility of a cell to be a lender, **L**: degree of coldness dc_L, nearness D_{BL} and hot cell blockabde H_{BL}. Nearness is the cell distance between the borrower cell **B** and the lender cell **L**. The hot cell blockade is the number of hot co-channel cells of the lender that are not co-channel cells of the borrower.

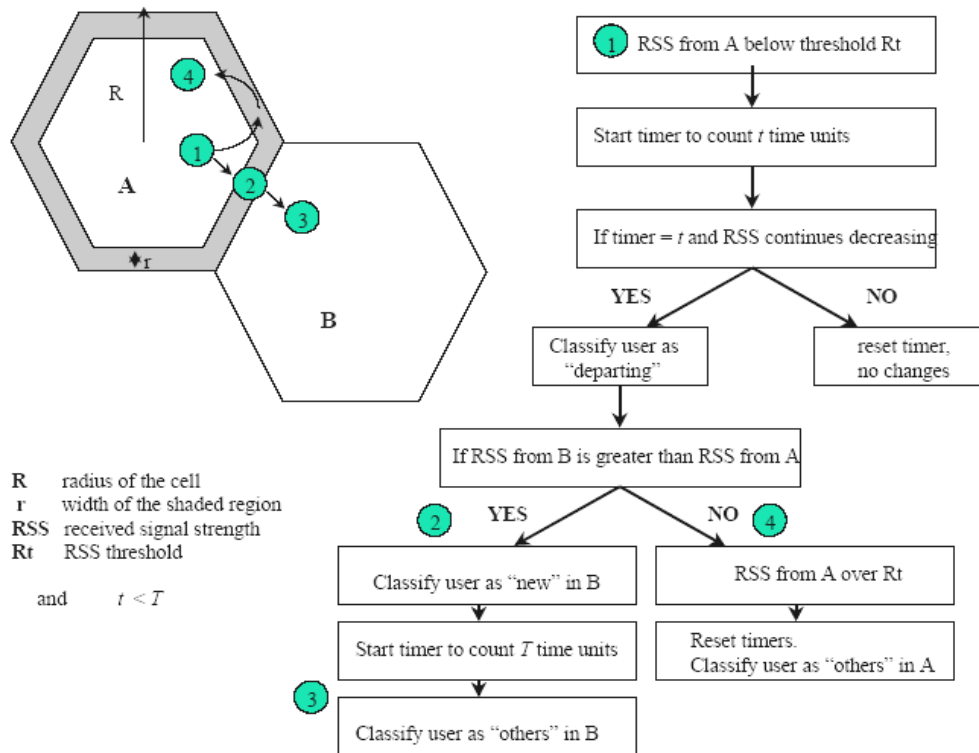|	
R	radius of the cell
r	width of the shaded region
RSS	received signal strength
Rt	RSS threshold

and $t < T$

Fig 1. Classification of Mobile users.

The best lender is the cold cell in the compact pattern that maximise the value of this function:

$$F_{BL} = \frac{dc_L}{\dfrac{D_{BL}}{R_{cp}} \cdot \dfrac{1 + H_{BL}}{7}} \tag{1}$$

R_{cp} is the radius of the compact pattern in term of cell distance, $1 \leq D_{BL} \leq R_{cp}$, $0 \leq H_{BL} \leq 6$ for hexagonal cellular geometry. R_{cp} and 7 are used for normalisation. The value of the function is proportional to the degree of coldness of the cell and inversely proportional to D_{BL} and H_{BL}. Another criterion is the lender **L** should not be hot after lending a channel.

The base station stores the number of departing users heading toward the i_{th} cell in the i_{th} element of array **NumDepart**. The objective of this information is to possibly borrow a channel from the neighbouring cell i and assign it to departing user heading towards that cell.

A hot cell needs to borrow channels until it reach the average degree of coldness dc_{avr}. When a cell becomes hot, the number of available channels is h x C, the number of channels to be borrowed (**X**) to reach dc_{avr} can be canculated by solving the equation:

$$dc_{avr} = \frac{h.C + X}{C} \tag{2}$$

As seen in figure 1, it can be assumed $r \ll R$ and the shaded portion of the cell has an area approximately given by the product of the perimeter (**p**) of the cell times **r**. Supposing **K** is the average density of mobile users making calls in a cell, it easy to derive that the number of departing users is K x p x r. If the user of borrowed channel is confined to departing users only, then K x p x $r \geq$ **X** and **r** is given by:

$$r \geq \frac{C(dc_{vr} - h)}{Kxp} \tag{3}$$

Each cell keeps as local parameters its **NCC** (Set of non-co-channel cells, considering its compact pattern), **CC** (set of co-channel cells), **dc**, H_{NCC} (set of hot non-co-channel cells), H_{CC} (set of hot co-channel cells).

Algorithm:

1. **B** sends messages to the cold neighbouring cells **L** for which **NumDepart[L]** is greater than 0. The message contains **NCC**, H_{NCC}, $D_{BL}=1$ and requests the cell to computes F_{BL}. Each **L** cell computes H_{BL}, F_{BL} and send back to **B**.

2. **B** order the **L** cells by decreasing values of F_{BL} and selects the cell with highest F_{BL}. The selected lender computes the set of its co-channels, which are non-co-channel with **B** by comparing **NCC** with its own **CC**.

3. Channels start to be borrowed from the lender cell until the number of borrowed channels is equal to **NumDepart[L]** or the basic criteria is violated, the lender become nearly hot, after lending the channel, the lender cell instructs its co-channel cells which are non-co-channel cells of **B**, to lock that frequency channel. The same procedure is excuted for the other cells in the listed order until the number **X** of borrowed channels is reached and the algorithm is terminated, or list of cells is exhausted, whereupon it gives step 4.

4. **B** sends messages requesting F_{BL} to the **L'** cells. The cold **L'** cells will answer.

5. **B** selects **L'** with highest F_{BL}. **L'** computes the set of its co-channels which are non-co-channel with **B**. Step 4, 5 are repeated until **X** reached.

Channel reassignment strategy:

The set of available channels can be divided into local and borrowed channels. Hot cells have both, cold cells only local channels. The channel demand is classified into four classes:

Class 1 requests have highest priority to receive a channel, these are handoff requests. It tries to minimise the probability of disrupting ongoing calls.

Class 2 requests are the channel requests by originating calls.

Class 3 requests are requests for channel re-assignments, they are requested by a cell site function that monitors state of the channels. The re-assignments are divided in two types: The reassignments of type 1 are for reassigning a departing user using a local channel to borrowed channel, if the borrowed channel is not used to satify class 1 and 2 demands. Requests of class 3 are for reassignment of type 1.

Class 4 request are re-assignments requests of type 2.

Although the authors of the D-LBSB scheme claim the channel assignment strategy prioritises handoff requests are classified differently, the execution of the channel assignment algorithm does not prioritise handoff requests. Each request is treated independently and discarded if blocked. Therefore handoff requests and incoming call requests have same priority, because they are treated equally inside the algorithm

In D-LBSB, the borrowing algorithm is not executed every time a call or handoff request is made and there are not more available channels to accommodate the request as is done in BCO and DBCL schemes. It is trigerred before the nominal channels are all used, once **h** is reached. Moreover, it does not get only one channel, but a certain number of channel **X**, the actual number depending on the average traffic load of the whole network. D-LBSB does not perform as well as BCO and DBCL, but it is less complex and it proves to be much faster as the load of traffic increases compared with its centralised version.

Simulation results:

Communication network commercial simulator (OPNET) is used. The results show in the figures were obtained with 90% confidence interval and within 5% of the sample mean. The simulated cellular system contains N=100 cells, C=40 channels per compact. Two interger values x and y ($1 \leq x, y \leq 10$) are used to describe the location of the cells. The shift parameter s_i, s_j were set to be 3 and 2, respectively, call arrival at each cell was assumed λ. The hold time of a call was assumed to be distributed based on an exponential distribution with a mean $1/\mu$ of 500s, h=0,25. In order to determine the position of user in a cell, a cell is modeled as a circle with a grid of size 100x360. A user location is determined by using a radial method, a pair of (γ, θ) to indicate position of a user, where γ denotes the distance of the use from the center of the cell and θ denotes the angle from a common reference line. It is assumed that a user can moves to a position over 100 from the center, a handoff occurs. The allocation of the new user is given at random.
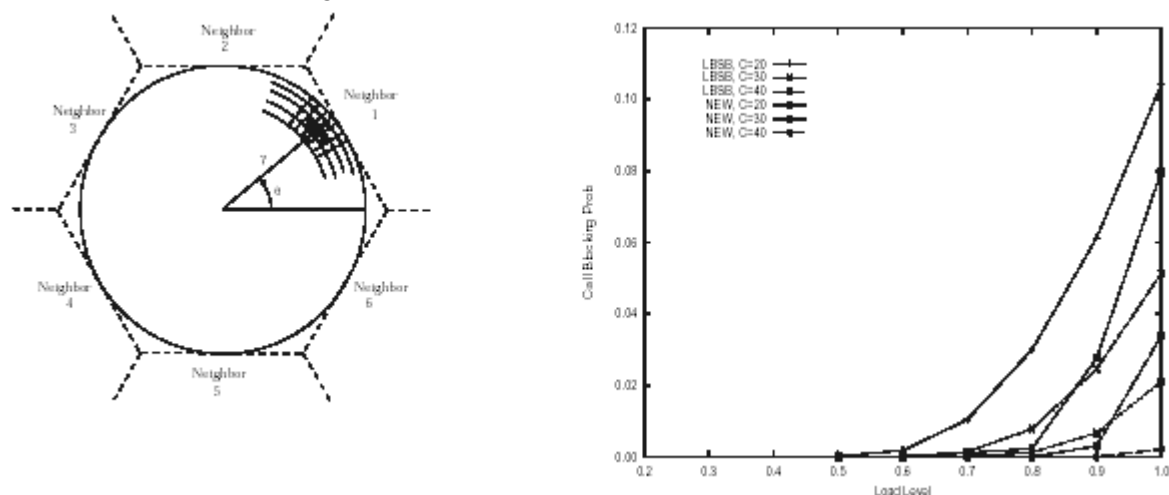

Fig 2. Simulation result.

The cell model used in this paper is expected to be more efficient than the other one in the literature since when a handoff occurs the new possition in the new cell is clearly determined. The time period, α, used for determining a departing user was set to 10 times units. If a user keeps departing for at least 5 times in shadow region for the last period α, it is classified as a departing user. Otherwise, it is a local user.

Figure 2 show the call blocking probablity of the D-LBSB algorithm for various values of C, the number of channels initially allocated to each cell under the fixed assignment schemes. The load level used here denotes the ratio of the call arrival rate at one channel in a cell to the call service rate a channel. It was assumed that an arriving call in a cell is served immediately if there are any channels available for use in a cell. From figure 2 show that the value C has strong effects on the call blocking probablity.

3. DCA schemes

Dynamic channel assignment scheme (DCA) is to assign a channel to a call request with minimum cost, but respecting the signal interference constraints. The cost is evaluated by a cost function. The cost function can be formulated taking into account the future blocking probability in the vicinity of the cell, the usage frequency of the candidate channel, the reuse distance, channel occupancy distribution under current traffic conditions, radio channel measurements of individual mobile users, average blocking probability of the system. The differentiation factor in DCA schemes is formulation of the cost function.

3.1. Centralised DCA schemes

Locally optimised dynamic assignment scheme (LODA) [4] is a DCA scheme whose cost function is based on the future blocking probability in the vicinity of the cell. Simulation results comparing LODA with DBCL show that DBCL has better performance.

Several DCA schemes formulate a cost function that maximises the channel efficiency   by optimising the reuse channel distance packing. These schemes perform well in light and moderate traffic conditions but they are not able to maximise the channel reuse in heavy traffic load because the best candidates most probably are already serving call requests.

3.2. Distributed DCA schemes

The distributed DCA schemes are normally cell-based schemes or signal strength measurement based schemes. In cell based schemes, the channel assignment is performed by the base station. The base station (not the MSC as in centralised schemes) is responsible for keeping information about current available channel in the vicinity. The local packing dynamic distributed channel assignment scheme (LP-DDCA) [6] uses an augmented channel occupancy (ACO) matrix for channel assignment. The ACO matrix contains all the local and vicinity information needed for the selection of a channel. The base station keeps the ACO matrix updated. The LP-DDCA with adjacent channel interference constraint takes into account this kind of channel interference when selecting a channel from ACO matrix. Both schemes provide near optimum channel assignment, but cause excessive exchange of status information between cells.

Another signal strength measuarement based scheme is the Channel Segregation scheme (CS) [7]. This scheme is a self-organised DCA. Each base station scans channels when selecting an

available channel with acceptable signal interference. Each base station will attribute to each channel a probability of channel selection P(i). The channel "selectability" order is performed independently by each base station and is reviewed through learning methods. For each call request, base station selects channel with highest P(i). Then base station need to checks if the use of that channel is possible by measuring its power level. If the power level is good enough then this channel is considered idle, allocated to serve the call request and its "selectability" increased. If not the channel is busy and P(i) is decreased. If all channels are busy the call is blocked. The CS scheme is autonomous and adaptive to change in traffic load. Simulation results show that blocking probability is greatly reduced compared to FCA and DCA schemses and quickly reach a sub-optimum channel allocation. CS uses the channels efficiently and reduces the need for channel reallocation due to interference. CS is a good solution for TDMA/FDMA.

4. Flexible channel assignment schemes FlCA

The cell sites have a sufficient number of pre-assigned nominal channel to accommodate light traffic. The remaining channels are kept in a central pool and assigned to cell sites in need. The dynamic assignment can have a scheduled or predictive approach. In the scheduled approach, the assignment of channels is made at determined peaks of traffic. In the predictive approach, the traffic intensity is measured constantly at all cells and the MSC can reallocate the channel at any time. Ratio of fixed and dynamic channels is a significant parameter that defines the performance of the system. For heavy traffic loads FCA gives better blocking probability than FlCA, FCA will make better use of the minimum reuse distance than FlCA.

5. Conclusion

FCA is too limiting for mobile networks and several strategies have been proposed to maximise frequency channel allocation and minimise call blocking probability. DCA schemes perform better under low traffic intensity. Modified FCA schemes have superior performance in high traffic loads. DCA schemes use channels more efficiently and for the same blocking rate have a lower forced call termination than FCA schemes. In DCA, there is not pre-assignment of frequency channels to the cells of the cellular network. All frequency channels are kept in a central pool. When there is a channel request in one base station, the MSC chooses the appropriate frequency channel that gives maximum channel efficiency taking into account all the signal interference constraints. The chanels are assigned for the duration of a call, after the call has finished, the channel is returned to the central pool or reallocated to a mobile user inside the same cell site that was controlling the channel before.

However, the near optimum channel allocation is the at the expense of high overheads through its use of centralised allocation schemes. This overhead mean that such schemes aren't practicable for large networks. DCA schemes with limited inter-cell communication suffer less overhead, but need to sub-optimum allocations. Such schemes are being proposed for microcellular systems as this cell structure allows inter-cell information sharing by interference measurement and passive non-intrusive monitoring at each base station. For macrocellular systems, FCA with channel borrowing offers good results and less computational complexity than DCA. However, FCA variant schemes with best result use centralised control inside MSC, although they are less complex than DCA there is still a need to maintain up-to-dated global knowledge of entire mobile network, leading to a slow response and a heavy signalling load.

Next section, we propose method to determine number of channels need to borrow when a cell become hot in D-LBSB scheme and the channel priority borrowing. In D-LBSB scheme, the channel is borrowed from neigbough cells only, but for us, when uses move to any direction, it may not stop in a neigbough cells, it stop in any cell in compact pattern. So, when a cell become hot, algorithm is propose that allow hot cells borrow frequecy channel in any cell in compact pattern. In this method, number of channel need to borrow is $X=C.(d_c^{avr}-h)$, in fact, when a cell become hot, it should be to borrow channel until it reach average degree of coldness of networks, $X=C.(d_c^{avr}-d_c)$. In next paper, we are going to present our algorithm and result of simulation.

References

[1] I. Katzela, M. Naghshineh, Channel Asignment Schemes for Cellular Mobile Telecommunication Systems: A Comprehensive Survey, *IEEE Personal Communications Magazine* Vol 3, No 2 (1996) 10.

[2] T.J. Kahwa, N.D. Georganas, A Hybrid Channel Assigment Scheme in Large-Scale, Cellular-Structure Mobile Communication Systems. *IEEE Trans on Communications* Vol. 26, No 4 (1978) 432.

[3] Said M. Elnoubi, Rajendra Singh and Someshwar C. Gupta, A new frequency channel assignment algorithm in high capacity mobile communication systems. *IEEE Trans on Vehicular Technology* Vol. VT-31, No 3 (1982) 125.

[4] Ming Zhang, Tak-Shing P. Yum. Comparisions of Channel Assignment Strategies in Cellular Mobile Telephone Systems. *IEEE Trans on Vehicular Technology* Vol. 38, No 2 (1991) 387.

[5] Sajal K.Das, Sanjoy K.Sen, Rajeev Jayaram and Prathima Agrawal. A Distributed Load Balancing Algorithm for the Hot Cell Problem in Cellular Mobile Networks. Proceedings of the 1997 6th *IEEE International Symposium on High Performance Distributed Computing* (1997) 254.

[6] I. Chih-Lin, Pi-Hui Chao, Local Packing – Distributed Dynamic Channel Allocation at Cellular Base Station. Proceedings of *IEEE Global Telecommunications Conference (GLOBECOM'93), part 1,* Vol. 1, New York, NY, USA (1993) 293.

[7] Y. Furuya, Y. Akaiwa, Channel Segregation: a Distributed Channel Allocation Scheme for Mobile Communication Systems, *IEICE Trans* Vol 74 (1991) 949.