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An Effectual Algorithm on Hybrid Channel Allocation in Cellular Mobile Network

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ABSTRACT: *In this paper, we have introduced a hybrid channel allocation (HCA) mechanism which is a combination of fixed channel allocation (FCA) and dynamic channel allocation (DCA). The algorithm of this mechanism minimizes the probability of call blocking and call dropping by considering hybrid channel borrowing technique in FCA and cell-based channel distribution in DCA. To reduce the communication overhead due to information gathering about base stations (BSs), we use a coupon based mechanism. We have given more importance to handoff calls. The simulation result shows the reduction in the dropping rate of handoff calls and blocking rate of fresh calls by implementing disaster channel management.*

Keywords: Cellular Topology, Channel Pool, Disaster Channel, Handoff Call & Fresh Call.

1. INTRODUCTION

Channel allocation is a process of assigning channels to cells in a cellular mobile network. The channels in a cell are assigned to the users for communication. This assignment of channels first to cells and then to calls is made according to a predetermined channel allocation algorithm.

Whatever may be the channel allocation method, the users do not like at all to hear the very common voice message *"all channels are busy, please try after sometime".*

There are three main classification of channel allocation mechanism. They are *fixed channel allocation* (FCA), *dynamic channel allocation* (DCA) and *hybrid channel allocation (*HCA). In FCA, required number of channels is assigned to all the cells after complete analysis of traffic. It is static and cannot be changed. But channel borrowing techniques can be used. In DCA, the channel assignment is not static. All the channels are kept in a *channel pool*. Whenever a user in a particular cell dials a number, the channel is assigned to that cell and call, from the *channel pool*. The channel will be returned to the pool after the termination of the call. The salient features of FCA and DCA are combined to maximize the channel utilization in HCA.

Some simple and common principles are followed by each and every channel allocation scheme. But a channel allocation method always considers some important parameters. The parameters are *frequency reusability, minimum frequency reuse constraints* and *changing traffic*. So an efficient channel allocation scheme must reuse mostly the available frequency by considering the minimum frequency reuse constraints. The FCA scheme considers both of the first two parameters in an optimum manner but fails to manage the third one. But DCA scheme meets all of the above requirements.

When a user moves from one cell to another, such call is known as *handoff call*. A call in a cell without user mobility to other cell is called as *fresh call*. We may prefer to block a *fresh call* than to drop a *handoff call*.

2. CHANNEL ASSIGNMENT SCHEMES

The three main different types of schemes for channel allocation in mobile network are fixed channel allocation (FCA), dynamitic channel allocation (DCA) and hybrid channel allocation (HCA).

2.1 Fixed Channel Allocation

In fixed channel allocation (FCA) strategy, a fixed number of channels are assigned to each and every cell permanently. The cells use their respective channels for communication and control. The cells may use the same set of frequencies or channels in accordance with the co-channel reuse constraint (Leonard Schiff, 1970, pp. 12-21). In case the traffic is uniform, the same number of channels is assigned to each and every cell. But in case of non-uniform traffic, different number of channels is assigned to different cells. How many channels are to be assigned to a particular cell are decided by considering the traffic situation properly. The result of simulation of non uniform compact channel allocation algorithm provides better call blockage probability in the system (Zhang and Yum, 1991, pp. 387-391).

In FCA, high traffic cells borrow channels from low traffic cells. This technique is known as *channel borrowing technique*. The different methods of channel borrowing are summarized in (Katzela and Naghshineh, 1996, pp. 10-31). The methods of borrowing may be simple or hybrid. If all the channels are available for borrowing, then it is known as *simple borrowing*. If the available channels are partitioned into borrowable and non-borrowable channels, then the scheme is known as *hybrid borrowing*. If the traffic is not heavy then *simple borrowing* scheme is found to be more efficient. A comparison of all of these techniques is provided in (Kuek and Wong, 1992, pp. 271-276).

2.2 Dynamic Channel Allocation

In dynamic channel allocation, all channels are kept in a central *channel pool*. Whenever a new call requires a channel, it will be assigned from this *channel pool*. After the conversation completes, the same channel will be returned back to this pool (Kazunori Okada and Fumito Kubota, 1991, pp.938-941), (Katzela and Naghshinesh, 1993).

There are two types of DCA scheme: *Centralized DCA* and *Distributed DCA*. In *centralized DCA*, there will a main server that maintains the central *channel pool*. This server takes care of all channel allocation procedure. This strategy provides optimal or near optimal channel allocation. However, they require a lot of computational signaling effort because the centralized location has to be aware of available channels and the necessary parameters required making an optimum decision on allocating channel to an incoming call. These parameters could be how channels are allocated in co-channel cells, what are the signal strength values for the channel under consideration, what is the expected traffic load in and around the region, and so on. Also, because decision mechanism is centralized, it is not robust and a failure here could lead to an entire system wide shutdown.

Distributed DCA is further divided into two classes: *cell based DCA* and *measurement based DCA*. In *cell based DCA*, the base station of a particular cell maintains a table of information about the channels in its vicinity cells. The base station assigns channels to its users based on this table. It allocates channels optimally because BSs can communicate with each other to obtain knowledge of the entire system. All the BSs communicate with one another to update this table. It increases the traffic due to frequent communication which is the main disadvantage of this scheme.

To overcome the disadvantage of the above scheme, signal-strength or measurement-based techniques are used. In this technique, the base station assigns the channels by considering the received signal strength of the mobiles in its vicinity. Here there is no need to communicate with other BSs. This channel assignment scheme is fast, effective and simple. But it is affected by additional co-channel interference. This problem creates network insecurity and channel disturbance (C.L I and P.H.Chao, 1993), (Okada and Kubota, 1991), (Ravi, Niranjan and Mukesh, 1995, pp. 47-56). This strategy does not provide optimal allocation of channels. Such scheme does, however, provide some capacity increases and are implemented in digital cordless systems like *digital enhanced cordless telephone*.

2.3 Hybrid Channel Allocation (HCA)

The hybrid channel allocation is a mixture of FCA and DCA. In this type of channel allocation, all the available channels are partitioned into two sets of channel: static set and dynamic set. The static set of channels is assigned to all the cells that are fixed at all the time just like as the case in FCA. The dynamic set of channels is shared by all the cells just like DCA to maximize the flexibility and performance. The channels are allocated from static or dynamic set depending on the situation.

An evolutionary strategy (ES) in hybrid channel assignment is investigated in (Geetali, Alioune and Ivan, 2005) which optimize the channel performance by minimizing the call blocking and call dropping probabilities.

3. PROBLEM ANALYSIS & REVIEW OF ARTICLES

The capacity of a cellular network can be enhanced by considering many factors. An efficient channel allocation mechanism is one of those factors. The main problem here is that how to assign channels to cells and calls so that the probability of call blocking and dropping will be minimized. When a call is initiated in a particular cell, a free channel has to be assigned to that call. The problem arises when there is no free channel to attend this call. So we need to borrow channels from neighbour cells. What if there is no free channel to borrow? In case borrowable channels are there, we cannot borrow channels just like that because it may create channel interference problem. In the same time, it is not at all good for a cell to lend a channel to another cell by dropping or blocking a call in its own area. The channel assignment algorithm is efficient and effective if it works successfully in any type of traffic situation. When the traffic is uniform, the problem of channel assignment is simple. But when it is non-uniform, the problem is complex or complicated. In FCA scheme, it is important to plan that how many channels are borrowable and how many channels are non borrowable. If the scheme is DCA, then which type of DCA to be followed: centralized or distributed? Whether to adopt FCA or DCA or HCA? These are some of the problem areas to analyze.

Whenever there is no possibility to assign a channel to a *fresh call*, then the call will be blocked. It is tolerable. But at any cost, a continued call should not be dropped or terminated. We need to take care to continue *handoff calls*. So what should be the mechanism to do so? We need to analyze all of the problems properly so that we can reach at an efficient channel allocation algorithm.

We reviewed fixed channel allocation schemes (Susil Kumar Sahoo, 2012, pp. 44-47) as well as dynamic & hybrid channel allocation schemes (Susil Kumar Sahoo and Prafulla Kumar Behera, 2012). We also made a comparative analysis on various channel allocation schemes towards an efficient assignment strategy in cellular mobile network (Susil Kumar Sahoo and Prafulla Kumar Behara, 2012, pp. 47-51). In this comparison, it is found that DCA techniques perform 30 to 40% better than FCA. DCA schemes are also more preferable for maximizing power control and handoff strategies. But in the same time, FCA strategy is better under heavy traffic load. It has maximum possible of reusability of channels. So it is very difficult to say which scheme is actually more efficient. That is why we propose a hybrid channel allocation (HCA) algorithm that can take selective advantages of both FCA and DCA to minimize the probability of call blocking and call dropping. We have also taken special care for handoff calls in this algorithm.

4. METHODOLOGY OF PROPOSED HCA DESIGN

The methodology that we introduce in our proposed HCA design is explained below. It includes Traffic Analysis & Cellular Network Plan, Mobile Communication System, Proposed Channel Allocation Plan, Procedure Flow Diagram & Algorithmic Design for HCA and Procedure Flow Diagram & Algorithmic Design for Handoff Call.

4.1 Traffic Analysis & Cellular Network Plan

A comprehensive traffic analysis for the total network area is done first. The total number of people living in the area is roughly calculated. The total number of expected mobile users is estimated. The traffic can be of three classifications: Heavy traffic in case of cities, average traffic in small towns and low traffic in rural areas. We have to also analyze the user mobility. We need to gather all valuable information from different people of that locality regarding the way they are interested in mobile communication. We will adopt different information gathering tools for the same. We can understand the minds of the people regarding different requirements of using the mobile phones. This traffic analysis is highly desirable because we can plan the strategy of channel allocation after understanding the traffic conditions of the total network area.

The *cellular topology* is a special case of an infrastructure multi base station network configuration that exploits the frequency reuse concept. Radio spectrum is one of the scarcest resources available, and every effort has to be made to find ways of utilizing the spectrum efficiently and to employ architecture that can support as many users as possible with the available spectrum. In this fashion, the available capacity is multiplied each time a new base station is set up because the same spectrum is being reused several times in a given area.

The fundamental principle we need to implement here is that of dividing the coverage area into a number of contiguous smaller areas called as *cells* which are each served by its own radio base station. The main advantages of cellular systems with small cells are: *higher* *capacity, less transmission power, only local interference* and *robustness*. We need to group the cells into *clusters*. Each cluster utilizes the entire available radio spectrum. We fix the cluster size by analyzing the traffic.

We can plan the cellular network by relating the bandwidth, number of cells, frequency reuse factor and capacity of the network. If W is the total available spectrum, B is the bandwidth needed per user, N is the frequency reuse factor and m is the number of cells required to cover the total area, then the number of simultaneous users n is calculated by the following equation (1):

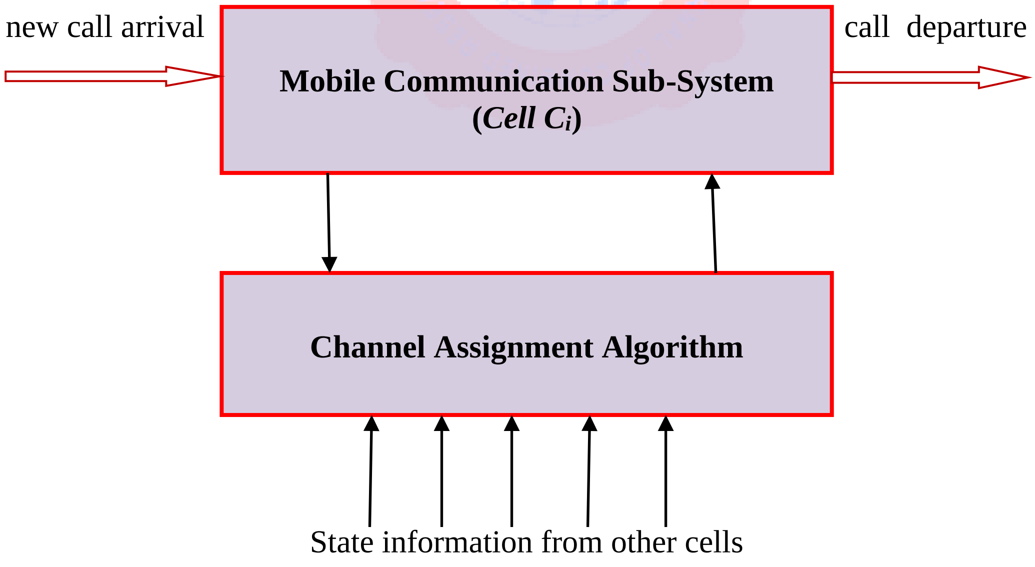
$$n = m\,(W / N) / B \qquad (1)$$

In particular, we observe in equation (1) that the capacity of our network can be increased by increasing m and by decreasing N.

4.2 Mobile Communication System

Let us consider a cellular mobile communication system. The system can be considered as a discrete-time event system.
The total network area is divided into so many *cells*. Each *cell* c_i, can be considered as a mobile communication sub system as shown in figure 1. Two major events which are modeled as stochastic variables with appropriate probability distributions may occur in each cell. The events are *call arrivals* and *call departures*.

Figure 1: Mobile Communication System



In particular, new call arrivals in *cell i* are independent of all other arrivals and obey a Poisson distribution with a mean arrival rate λ, as shown by equation (2)

$P_n(t)$ = prob {n arrivals occur in (0,t)}

$$= \frac{(\lambda t)^n}{n!} e^{-\lambda t} \quad (2)$$

The interarrival time $T_{arrival}$ has an exponential density, defined by

$$f(T_{arrival}) = \lambda e^{-\lambda Tarrival} \quad (3)$$

Call holding time $T_{holding}$ is assumed to be exponentially distributed with mean call duration $1/\mu$. The density function is given by

$$f(T_{holding}) = \lambda e^{-\mu Tholding} \quad (4)$$

For accurate path loss prediction, field measurement must be performed (Susil Kumar Sahoo and Prafulla Kumar Behara, 2011, pp. 34-36). The free space path loss (FSPL) actually encapsulates two effects. Firstly, the spreading out of electromagnetic energy in free space is determined by the inverse square law, i.e

$$S = P_t (1 / 4\pi d^2) \quad (5)$$

In equation (5), S is the power per unit area or power spatial density (in watts per metre-squared) at distance d, P_t is the total power transmitted (in watts).

We should note here that this is not a frequency-dependent effect. The second effect is that of the receiving antenna's aperture, which describes how well an antenna can pick up power from an incoming electromagnetic wave. For an isotropic antenna, this is given by

$$P_r = S (\lambda^2 / 4\pi) \quad (6)$$

In equation (6), P_r is the received power. We should note that P_r is entirely dependent on wavelength and hence on frequency.The total loss is given by the ratio P_t / P_r .

4.3 The Proposed Channel Allocation Plan

Under low to moderate traffic loads, dynamic channel allocation (DCA) strategies perform far better than fixed channel allocation (FCA) techniques. Because DCA is based on random arrivals of mobiles and random allocation of channels to them, unless maximizing the "packing" of channels is an optimization criterion, it is likely that distances larger than what is required may separate co-channels. This will prevent channels from being reused as often as possible, resulting in less capacity in larger loads. But FCA is simple and maximizes channel utilization under heavy traffic load. DCA however, reduces the fluctuations in the call blocking probabilities, as well as forced call termination. FCA strategies require a lot of "offline" effort in frequency planning. DCA strategies need plenty of effort in real time for channel allocation.

Indeed, hybrid channel allocation strategies have also been investigated. The total number of channels is portioned into fixed and dynamic sets. The ratio of fixed to dynamic channels becomes important in the performance of the system. HCA schemes have been shown to perform better than FCA schemes for load increases up to 50%.

After completing a comparative analysis on various channel allocation schemes, we propose a HCA algorithm that can perform better in all traffic conditions. Our scheme is a mixture of FCA and cell-based distributed DCA. We have also reserved a portion of channels for disaster management in handoff calls. Our channel allocation scheme works as follows:

Different number of channels is assigned to all the cells by fully considering the traffic parameters. It is completely a non uniform channel allocation mechanism. The fraction between the number of fixed channels and dynamic channels for a particular cell is completely based on traffic analysis. On an average in a moderate traffic area, in each and every cell, 50% of total assigned channels are fixed for FCA, 50% for cell-based DCA. The hybrid channel borrowing technique is used in FCA in which 60% of total available channels of a cell are non borrowable, and 30% of channels are borrowable by other cells and remaining 10% of channels kept as *disaster channels* to handle handoff calls or emergency fresh calls. Here priority is knowingly given to handoff calls than *fresh calls*. We have taken care to minimize call dropping probability of *handoff calls* because it is always preferable to block a *fresh call* than dropping a *handoff call*. If there is no arrival of *handoff calls*, then these *disaster channels* may be intelligently assigned to *fresh calls* for maximum utilization. Otherwise it will be very wrong in reserving the *disaster channels* when there are no handoff calls. So these channels can be assigned to fresh calls whose request probability is a function of the mobility of the users. If there is arrival of *handoff call*, then request probability is equal to zero. At this situation the *disaster channels* will be assigned to *handoff calls*. But when there is no arrival of *handoff call* (request probability is equal to one), these channels can be assigned to *fresh calls.*

After knowing the disadvantages of measurement-based DCA, we propose to go with cell-based DCA. The communication among the BSs is established by using a *coupon based mechanism* to get knowledge of entire system. This mechanism is introduced to minimize the communication overhead which generally occurs in cell-based DCA. According to this, many patterns are made by grouping so many shared cells. Each pattern will have a coupon. This coupon will circulate among the cells to gather information about the channels currently assigned to each cell. The cell that holds the coupon will update the resources. This process of communication will not disturb the network operation and it will minimize the overhead of data communication.

4.4 Algorithmic Design & Procedure Flow Diagram for HCA

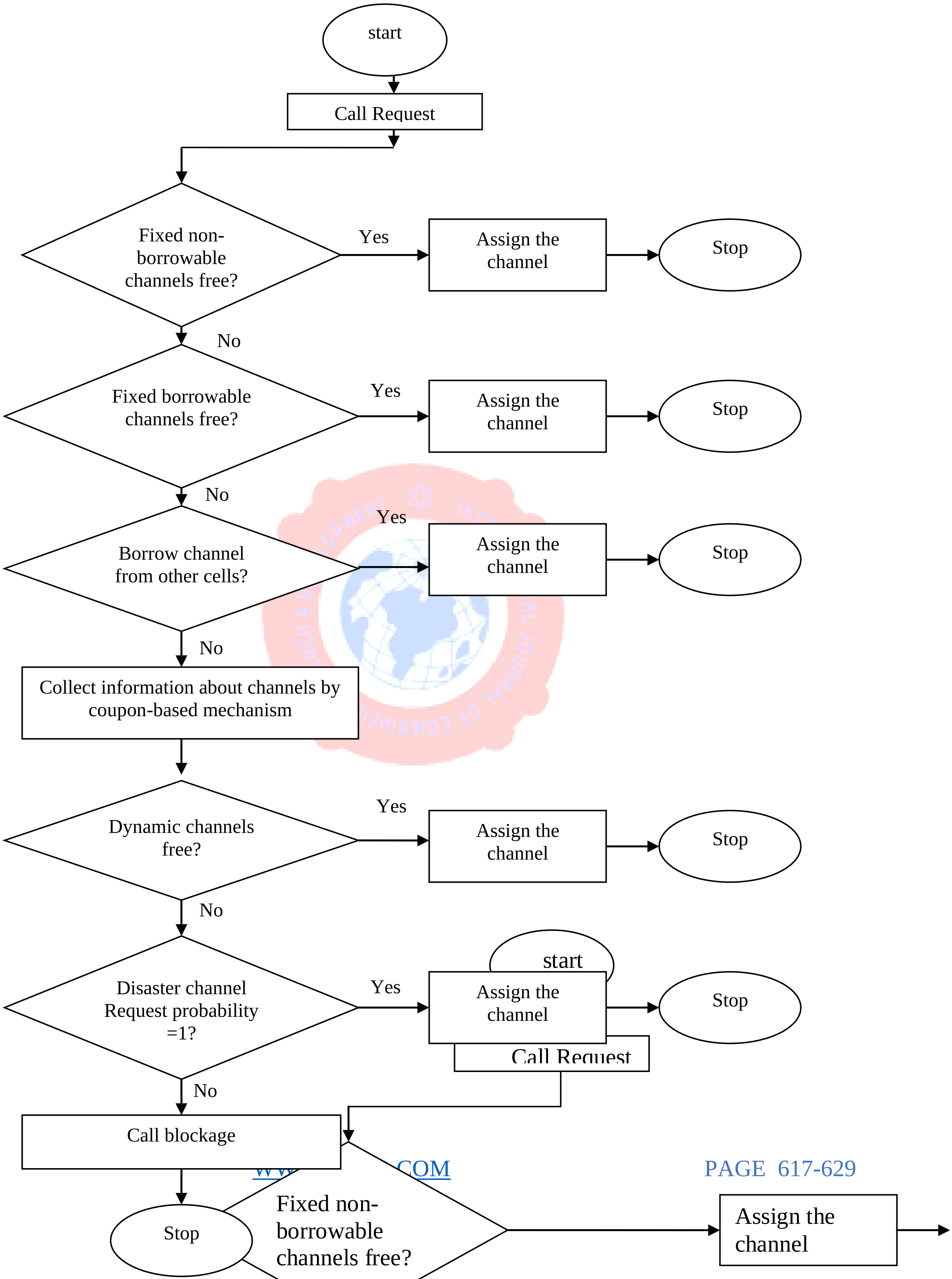
The procedure flow diagram for HCA is given in figure 2 and the proposed algorithm for HCA is given below:

1. The user in a particular cell dials a telephone number
2. If a non- borrowable fixed channel is free in that cell
   then assign that channel to the call.

   else if borrowable fixed channel is free in that cell
   then assign that channel to the call. else go to step 3.
3. If channel can be borrowed from neighboring cells by considering all types of constraints in channel interference
   then assign that channel to the call else go to step 4.

4. Collect information about channels that are currently allocated for each cell by coupon-based mechanism.
5. If a cell-based dynamic channel is available
   then assign that channel to the call else go to step 6.
6. If (request probability = = 1) which means if there is no arrival of handoff call.
   then assign a disaster channel to the call else the call is blocked.

Figure 2: Procedure Flow Diagram for HCA



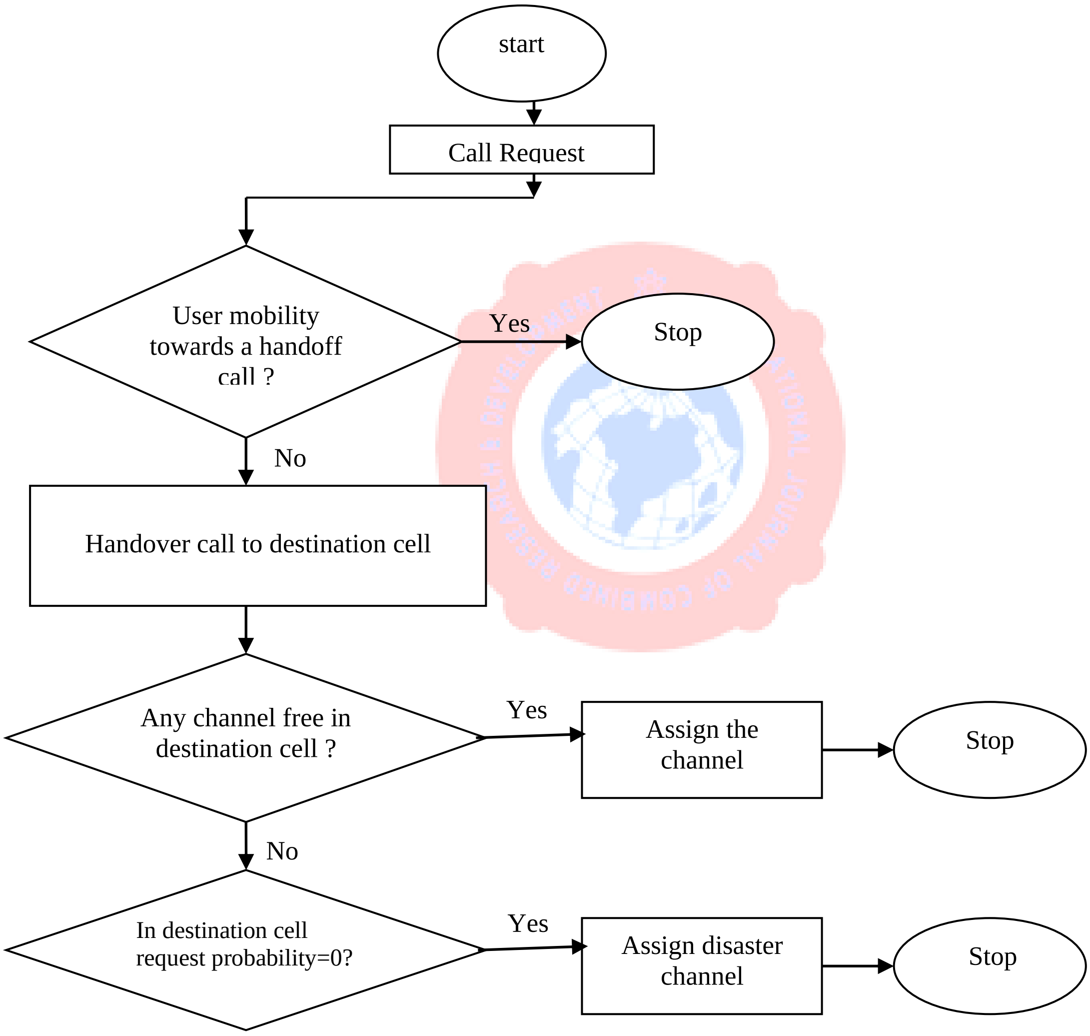
When a call is initiated in a cell, if a fixed non- borrowable channel is free then it will be assigned to the call. If it is not available, then it will be searched from borrowable channels. If any borrowable channel is free, then it will be assigned. If both of the above cases are failed, a channel will be borrowed from neighboring cells by considering all types of constraints in channel interference. If it is not possible to borrow, then channel assignment will be made from cell-based DCA. This will be done by collecting information about channels that are currently allocated for each cell by *coupon-based mechanism*.

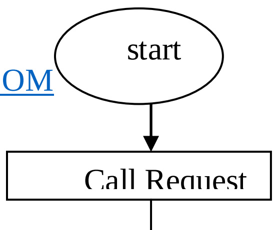
If there is no channel in DCA quota, then *disaster channel assignment* may be done. But it is allowed if request probability is equal to one which means it is allowed if there is no arrival of *handoff call*. When all the above possibilities fail, then the call will be blocked.

4.5 & Algorithmic Design & Procedure Flow Diagram for Handoff Call

The procedure flow diagram for handoff call is given in figure 3. Care should be taken when a user with conversation moves from one cell to another cell. This type of call is called as *handoff call*. This call should not be dropped or terminated at any cost. Our algorithm for handling handoff calls works as follows:

Figure 3: Procedure Flow Diagram for Handoff Call





First, it will be tried to handover the call to the destination cell. If any channel in destination cell is free, it will be assigned to continue the call. Otherwise the destination cell will assign the *disaster channel* of its own which is mainly reserved for handoff calls to attend that call.

The proposed algorithm for handoff call is given below:

1. When the user moves from a cell to another cell with continuing the conversation at that time the source cell hands over the call to destination cell.
2. If any channel in destination is free
   then assign that channel to the call

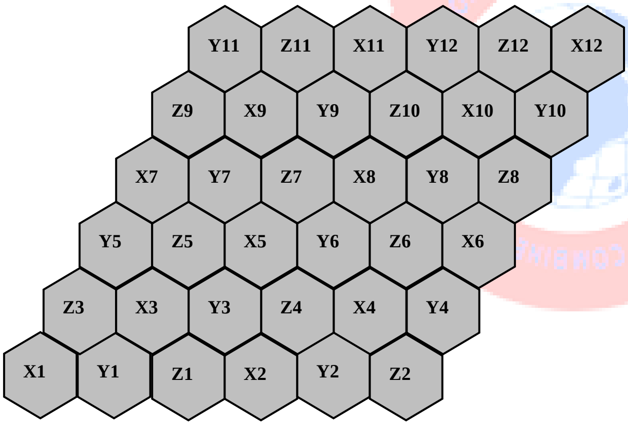
   else
   assign the disaster channel of destination cell to the call which is mainly reserved for handoff calls.

5. SIMULATION

5.1 Simulation Model

The performance of the proposed HCA algorithm was evaluated by simulating a mobile communication system consisting of 36 hexagonal cells divided into three disjoint subsets (i.e X, Y, Z) as shown in figure 4. Each cell has six neighbors.

Figure 4: 6*6 Cellular System Model



5.2 Assumption & Parameters

The assumptions and parameters used in simulation include:

- The average one way communication delay between two cells is 4 millisecond that covers both the transmission delay and propagation delay.
- The mean call arrival rate in a cell (λ) and mean service time is 3 minute.
- The call holding time obeys an exponential distribution with a mean call duration $1/\mu$. Throughout this report, $1/\mu = 180$ second was used for all calls.
- The offered traffic ρ_i in cell i is given by: $\rho_i = \lambda / \mu$
- In total, there are 396 channels available. Each cell has 132 primary channels, although the number of channels may vary.

5.3 Simulation Procedure

To simulate the mobile communication system as a discrete-event dynamic system, a simulation clock is maintained. It gives the current value of simulated time of the whole system. The simulation clock is advanced according to the time of occurrence of the most imminent future event, which can be a call arrival or a call departure. To this end it is necessaryto maintain dynamically a list of future events. If the event occurring is a call arrival, a set of steps is performed, resulting in either the call being blocked or served by a channel. On the otherhand, if the event is a call departure, the occupied channel is released. After the event is processed accordingly, the channel usage information in each cell is updated and the time clock is advanced. To calculate the system performance, the number of new call arrivals and number of blocked and dropped calls are recorded.

5.4 Performance Evaluation

The performance of a channel assignment algorithm at a particular traffic loading is assessed by measuring the new call-blocking probability P_n, given by

P_n = (number of blocked calls in a cell) / (number of new call arrivals at the cell)

The handoff call-dropping probability P_m, is given by

P_m = (number of dropped calls in a cell) / (number of handoff calls)

5.5 Simulation Result

The simulation is carried out under uniform traffic for simplicity. But the same can be also done in inhomogeneous traffic distributions, time varying traffic patterns, and channel failures. Figure 5 shows that message complexity or communication overhead to get knowledge of entire system is significantly reduced due to implementation of coupon based mechanism. Our HCA algorithm also reduces the overall blocking rate of fresh calls and dropping rate of hand off calls due to the introduction of disaster channel management which is shown in figure 6.

Figure 5: Communication Overhead vs Call Arrival

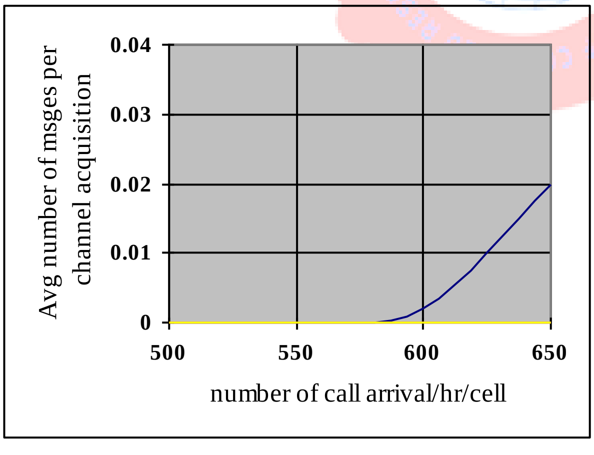
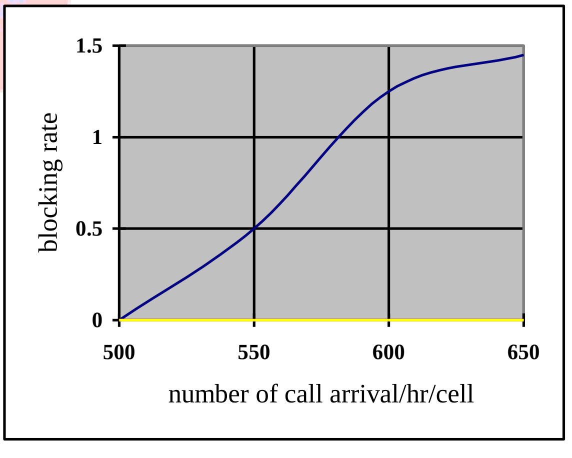


Figure 6: Blocking Rate vs Call Arrival



6. CONCLUSION

The proposed HCA algorithm makes efficient use of channels using *hybrid channel borrowing technique* and *cell-based distributed dynamic channel* assignment. To minimize communication overhead for getting knowledge of the entire system, a *coupon based mechanism* is introduced. Most importantly, the reserved *disaster channels* not only reduce the call dropping probability of *hand off calls* but also minimize the call blocking probability of *fresh calls*. The performance of our algorithm is satisfactory compard to past HCA algorithms. Our algorithm suits for any type of traffic condition just by adjusting the fraction of number of fixed and dynamic channels.

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