

REDUCING CALL BLOCKS IN CELLULAR NETWORK WITH NON-UNIFORM TRAFFIC CONDITIONS

Abhijit SHARMA¹, Pratik SHARMA², Rituparna CHAKI³, Uma BHATTACHARYA⁴

Abstract. In cellular networks, while the motivation behind all basic channel assignment strategies is the better utilization of the available frequency spectrum with the consequent reduction of the call blocking probability in each cell, very few of them deal with the problem of non-uniform traffic demand in different cells which may lead to a gross imbalance in the system performance. Mobile users in hot cells (the cells with heavy traffic loads) may suffer from low throughput due to the load imbalance problem. In this paper, we propose a cost effective and simple load balancing scheme that can effectively reduce the overall call blocking. A common set of channels are determined dynamically which can be used simultaneously in all the cells. Cell tiers with different radii are used to cope with the interference introduced by using same set of channels simultaneously in all cells. The performance of the proposed scheme is presented in terms of call blocking probability and channel utilization. Simulation results show that the proposed scheme can reduce the call blocking significantly in highly congested cell.

Keywords: Cellular Network, Load Balancing, Call Carrying Capacity, Hot Cell, Frequency reuse partitioning, Cell Tiers, Channel Allocation.

1. Introduction

In view of the remarkable growth of the mobile communication markets and the still very limited frequency spectrum allocated to this service, the efficient management and sharing of the spectrum among numerous users become important issues. This limitation means that the frequency channels have to be reused as much as possible in order to support the many

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thousands of simultaneous calls that may arise in any typical mobile communication environment. The concept of cellular architecture thus evolved which is conceived as a collection of geometric areas called cells (typically hexagonal-shaped), each serviced by a base station (BS) as shown in Figure 1. A number of BS's are again linked to a mobile switching centre (MSC) which also acts as a gateway of the cellular network to the existing wire-line networks like PSTN, ISDN or any LAN-WAN based networks. A base station communicates with the mobile stations (or users) through wireless links, and with the MSC's through wired links.

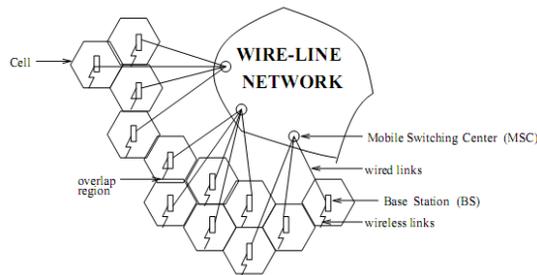


Figure 1. Cellular Network

Radio network operators are always pursuing network planning scheme that is both performance and revenue-assuring. Time-varying geographical traffic distributions bring problem to that goal as many cells may become densely-populated with users in the case of events or emergencies. Also, few cells may experience temporary congestion during peak hours. For enhancing capacity and coverage quality to meet the growing traffic demand, a network operator usually seeks to employ several approaches such as cell splitting and cell sectoring[1]. Cell splitting is the most effective solution in presence of large number of hot cells in a cellular network. However, cell splitting is very expensive when few numbers of hot cells exists in the cellular network, as it requires additional equipment such as power plant, radio transceiver, antennas etc. Also, the cell sectoring is economically not desirable since new equipment is needed to upgrade Omni cell system to sectorized cell system.

Proper channel assignment schemes are required for using limited radio channels efficiently and thereby increasing the traffic capacity. The original cellular channel allocation strategy is FCA (Fixed Channel Allocation) where the channels are strictly distributed among cells and the utilization of spectrum is inefficient[2]. Capacity can be increased by adding complexity and relaxing channel allocation rules, so two channel allocation schemes, DCA (Dynamic Channel Allocation) and HCA (Hybrid Channel Allocation) were brought forward, which can dynamically reserve all of or part of channels for all the users in a service area[2]. Although DCA or HCA scheme can deal with non-uniform traffic and improve system capacity, they add complexity to communication system.

In Channel Borrowing schemes, if a cell needs a channel in excess of the channels previously assigned to it, that cell may borrow a channel from one of its neighboring cells. The major problem with channel borrowing is that when a cell borrows a channel from a neighbor cell, other nearby cells are prohibited from using the borrowed channel because of co-channel interference. This can lead to increased call blocking over time.

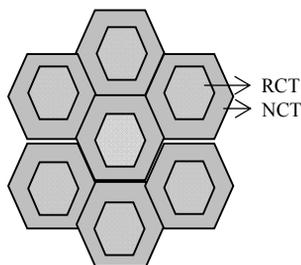


Figure 2. A two tier seven cell cellular System

Reuse partitioning is the technique of using multiple reuse factors in the same cellular system[3]. The main objective of reuse partitioning is to provide an increase in system capacity over that which can be achieved with a single factor, without relaxing SIR (Signal to Interference Ratio) performance requirements. In two-zone reuse partitioning, each cell is divided into two concentric sub cells, tiers or zones, the inner zone and outer zone, each corresponding to a different reuse factor[4-6]. The idea behind reuse partitioning is that because the inner zone is closer to the base station, the power level required for a desired Carrier to Interference Ratio (CIR) in the inner zone is much lower than the outer zone. As a result, the channel reuse factor of inner zones can be smaller than that of outer zones, which results in higher spectrum efficiency compared to the system without reuse partitioning. In comparison with cell splitting, the advantage of reuse partitioning is that the RF capacity can be increased without the deployment of more base stations[5].

In spite of the existing schemes, however, the more spectral efficient frequency reuse partitioning scheme still deserve to be studied, to improve the system performance further more. Also, based on our review work in Section 2 it has been observed that none of the earlier papers on reuse partitioning have addressed the problem of congestion due to time-varying geographical traffic distributions, which led to the motivation of our work in this area. In this paper, we propose to use this reuse partitioning scheme to cope with the problem of traffic overloads and thereby congestion in the cellular network during peak hours. Cell tiering is achieved by splitting cells into two tiers: Reduced Coverage Tier (RCT) and Normal Coverage Tier (NCT), as shown in Figure 2. The power that is transmitted by the mobile stations and the base station in the RCT is less than that in the NCT. A mobile station is allocated a RCT or a NCT channel depending on its location in a cell. A channel already allocated in the RCT of a cell can be allocated to the RCT of other neighboring cells simultaneously without degrading QoS of the system.

The remainder of this paper is organized as follows. Review work is discussed in Section 2, in Section 3 we introduced our system model and provided the description of our proposed scheme, in Section 4 the process of channel allocation is elaborated, in Section 5 simulation environment is presented, in Section 6 we have shown the results and analyzed the performance of the proposed method and finally in Section 7 we draw our conclusions.

2. Review Work

Earlier work on load balancing mostly assumed a centralized controller that governs the base stations and the mobile stations with access to all the necessary information[7-9]. However, centralized approaches, for load balancing, may require excessive computational complexity and message overhead, which increase exponentially in the size of the network. Distributed cell load balancing is also being considered as a basic requirement in upcoming standards. For example, IEEE 802.16m WiMAX2 recently included parameters such as cell load and cell type in the system information broadcast[10, 11]. For load balancing, a cell breathing technique was investigated in[7]and[12]. It contracts (or expands) the coverage of congested (or under-loaded) cells by reducing (or rising) the power level, and therefore the load becomes more balanced. A framework for user association problem in wireless networks is proposed in[13]which is specifically focused on distributed load balancing under spatially inhomogeneous traffic distributions and showed the optimality condition of cell coverage areas that minimizes generalized system performance function. A hybrid channel allocation algorithm [1]sends a multi-level hot-spot notification based on the current hot-spot level of the cell, which, request more than one channel for assignment to the requesting cell. Also, this scheme can reduce control message overhead needed to acquire each channel individually. A hybrid dynamic load balancing algorithm in heterogeneous wireless networks for packet services [14]adopts the combination of TRU (two-dimensional resource unit) borrowing scheme and load transfer scheme among overlapping heterogeneous cells. The hot-spot cell can not only borrow TRUs from neighbor homogeneous light-loaded cell, but also can transfer loads into overlapping heterogeneous cell with light load. An on-line algorithm which dynamically controls the associations of relay stations with base stations and associations of mobile units with relay stations and base stations is proposed in [15]where relay stations (RS) are used to transfer over-loaded traffic from hot cells to neighboring cooler cells.

For higher spectral efficiency and simpler spectrum planning, an aggressive frequency reuse is desired. Unfortunately, a smaller reuse factor reduces the carrier-to-interference (C/I) margin since neighboring cells or sectors may transmit data simultaneously. To balance inter-cell interference mitigation and spectral efficiency, a few schemes have been proposed[16-19]. The reuse partitioning scheme was proposed to focus on spectral efficiency more than inter-cell interference mitigation compared to predefined reuse scheme (PRS) [16, 17]. The soft frequency reuse partitioning scheme (SFRPS) was proposed to increase spectral efficiency compared to reuse partitioning scheme (RPS) [18, 19].

In[20], the author proposed an analytical model to evaluate the performance of Frequency Reuse Partitioning (FRP) based cellular systems. The authors introduced a simple channel assignment procedure that selects a channel randomly from unassigned channels. The service area of a cellular system is divided into hexagonal cells of equal size, with the base stations at the center of each cell. Also, each cell is divided into two zones; inner zone using total system channel ($F = \{F_0, F_1, F_2\}; c$), and outer zone using one third of the total system channel ($F_i, i=1,2,3; c_o$, inner channel; $c_i = c - c_o$). When a call arrives, a MS requests a channel. If it is a MS in the inner zone (inner MS), one of the unassigned channels from among set F is randomly chosen and is assigned to the MS. Otherwise, if it is a MS in the outer zone (outer MS), one of the unassigned channels from among its outer

channels (F_0, F_1, F_2) is assigned to the MS. In either case, if there is no channel available, the call is blocked and is cleared. After the call is admitted, the assigned channel is released and becomes available to other calls upon the completion of the call.

In [21], a load balancing scheme is proposed where a borrowed channel is used in borrower as well as in lender cell simultaneously. To cope with the interference introduced by simultaneous use of borrowed channel, cell tiers with different radii are used. Simulation results shows that the scheme can effectively balance the load among cells of a cellular cluster.

A hybrid channel allocation algorithm is proposed in [22] where the available channels are divided into two disjoint sets: one set of channels is assigned to each cell on FCA basis (fixed set), while the others are kept in a central pool for dynamic assignment (dynamic set). The algorithm sends a multi-level hot-spot notification to the central pool on each channel request that cannot be satisfied locally at the base station. This notification will request more than one channel be assigned to the requesting cell, proportional to the current hot-spot level of the cell. This also reduce control message overhead needed to acquire each channel individually.

3. System Model & Proposed Scheme

Non-uniform traffic demand is considered in the given cellular network. The cellular system consists of 19 hexagonal cells. The results from the center hexagonal cell and its six surrounding cells are used to avoid the boundary effect. Radius of each cell is R . The total available channels are allocated according to fixed channel assignment scheme, forming a cluster of N cells. Let us consider, the number of pre-allocated channels to a particular cell in the cluster is Ch .

The central cell of the cluster is considered to be the most congested cell. The coverage area of each cell in the cluster is divided into two tiers: Reduced Coverage Tier (RCT) and Normal Coverage Tier (NCT). The radii of the RCT and NCT are considered as R' and R respectively where $R' = R/\sqrt{N}$, as explained in Section 3.2. Where N is the cluster size. The selected value of R' ensures that a channel allocated at RCT of any cell in the cluster can be reused simultaneously at RCTs of all other cells in the cellular system without interference, as explained in Section 3.2.

Both the tiers (RCT and NCT) in a cell share a base station (or cell site). A channel allocated to a particular cell can be used in all of its tiers but not simultaneously. The steps of channel allocation are given in Section 4. The mobile terminals in the RCT and NCT are at different distances from the cell site. Thus, with power control these mobile terminals can use the channels. All the two tiers (RCT and NCT) uses two different transmitted power levels based on the radii of the respective tiers. RCT uses low transmitted power level than NCT.

The arrival rate and leaving rate of calls are equal among all NCTs and also equal among all RCTs of the cells. But the arrival rate of hot cells is considered to be higher than cold cells. All arrival processes are assumed to follow Poisson distribution, and channel holding time is exponentially distributed.

All the cells under consideration are connected to a MSC (Mobile Switching Center) through wired connection. MSC keeps information about all the allocated and unused

channels in each individual cell in the given cellular system. MSC also maintain a global pool of channels. The channels available in global pool can be allocated only to the call requests originated at RCT. A cell can request a channel from this global pool, if required, to serve the call requests from its RCT. A particular channel from the global pool can be used simultaneously in the RCT of all the cells. During congestion the proposed algorithm attempts not to allocate any of its pre-allocated channel to a call requests from RCT.

The MSC processes four different types of messages sent by the cells on various situations during channel allocation. The details of the different messages along with the steps taken by MSC is described in Section3.1. Figure 3 presents a flow chart of this message processing by MSC.

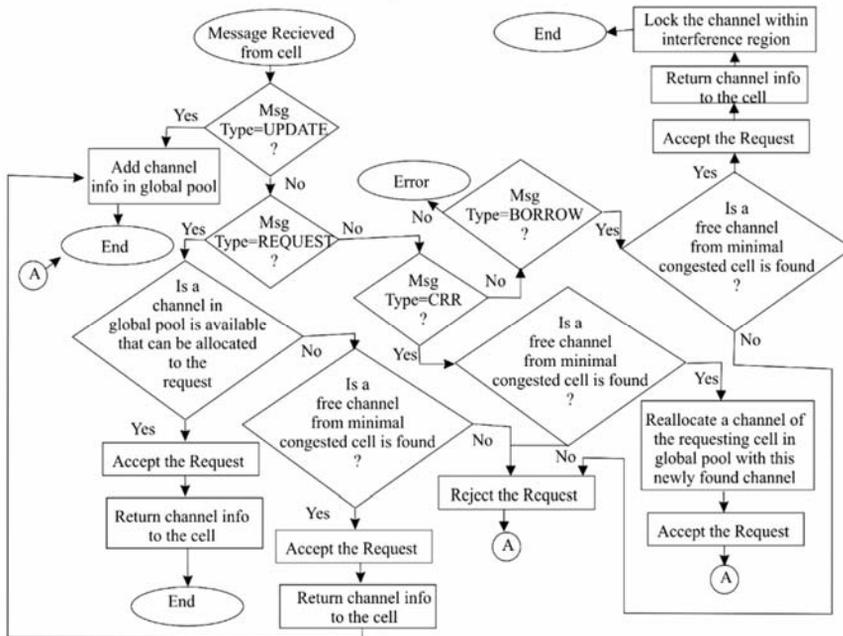


Figure 3. Flow Chart to show processing of different messages at MSC

3.1. Message Processing by MSC

Depending on the situation during channel allocation, a cell can send four different types of messages to MSC. On response to that MSC takes certain steps, the details of which are given below. A flowchart given in Figure 3 illustrates the processing of different messages at MSC.

i) UPDATE MESSAGE

When a call request arrives in the RCT of a particular cell, say Cell_m, the Cell_m can allocate an unused channel to the call request from its pre-allocated channels. MSC adds this channel in the global pool so that the other cells can

also use this channel in their RCT. For this, Cell_m sends an UPDATE message to MSC containing information about this allocated channel. Once the channel is added into global pool, the channel information is removed from the list of pre-allocated channels of Cell_m. However, the Cell_m can get back this channel from global pool if required by sending a Channel Return Request (CRR) message to MSC.

ii) REQUEST MESSAGE

A cell sends a REQUEST message to MSC when it needs a channel from global pool to serve a call request in its RCT. On receiving this message, the MSC allocates (if possible) an unused channel from global pool to the cell which had sent the REQUEST message. If no such unused channel is available in the global pool, the MSC can try to find a free channel from neighbor cells (preferably from least loaded cell) and if channel is found it will be added in to the global pool. Now this newly added channel will be allocated to the cell which had sent the REQUEST message.

iii) CHANNEL RETURN REQUEST (CRR) MESSAGE

During congestion, a cell sends a Channel Return Request (CRR) message to MSC if it wants to take back one of its pre-allocated channel from the global pool. After receiving a CRR message from Cell_m, MSC will perform the following tasks:

- a) One of the channels, Channel_{mi}, belonging to Cell_m in global pool will be marked for return.
- b) MSC will then try to find a free channel from neighbor cells (preferably from least loaded cell). If such channel is found MSC will accept the CRR of Cell_m and the found channel, Channel_x, will be added in to the global pool. If no such channel is found, the CRR of Cell_m will be rejected.
- c) If CRR is accepted, MSC will initiate a handoff from Channel_{mi} to Channel_x for all the cells which are already using the Channel_{mi}.
- d) Channel_{mi} will be removed from the global pool and returned to Cell_m.

iv) CHANNEL BORROWING REQUEST (CBR) MESSAGE

In response to Channel Borrowing Request (CBR) message from a cell, MSC selects an unused channel from the neighboring cells. The request is rejected if no such channel can be selected. The selected channel is then allocated to the requesting cell. The requesting cell is called as the borrower cell and the cell to which the borrowed channel originally belongs is called the lender cell. While the borrower cell is using the channel no cell within the reuse distance from the borrower cell can use the borrowed channel simultaneously. On completion of the call the borrowed channel is returned to the lender cell.

3.2. Radius Computation for Reduced Coverage Tier (RCT)

The key characteristic of a cellular network is the ability to re-use frequencies for increasing both coverage and capacity. Adjacent cells must use different frequencies, however there is no problem with two cells sufficiently far apart operating on the same frequency. The elements that determine frequency reuse are the reuse distance and the reuse factor.

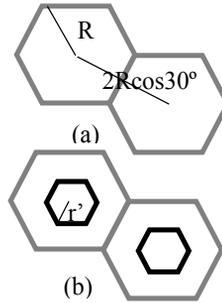


Figure 4. Adjacent hexagonal cells

The reuse distance, D is calculated as

$$D = R\sqrt{3N} \quad (1)$$

Where R is the cell radius and N is the number of cells per cluster [23].

From equation (1), we get

$$Q = \frac{D}{R} = \sqrt{3N} \quad (2)$$

Where, Q is called the co-channel reuse ratio. A small value of Q provides large capacity whereas a large value of Q improves the transmission quality because of smaller level of co-channel interference.

In Figure 4(a) two adjacent hexagonal cells are shown which uses two different sets of frequencies (channels). The actual center-to-center distance between these two adjacent hexagonal cells is $2R\cos30^\circ$ or $\sqrt{3}R$. Maintaining the co-channel reuse ratio, we can create two virtual cells at the centers of the adjacent large hexagonal cells as shown in Figure 4(b). Same set of frequencies can be allocated to these virtual cells if minimum co-channel distance, which equals $\sqrt{3}R$, is maintained between them.

Let r' is the cell radius and d' is the reuse distance for these virtual cells.

Then,

$$Q = \frac{D}{R} = \frac{d'}{r'}$$

or,

$$r' = \frac{Rd'}{D}$$

$$r' = \frac{\sqrt{3}R^2}{R\sqrt{3N}}$$

$$r' = \frac{R}{\sqrt{N}} \quad (3)$$

3.3. Mobile Proximity and Tier Selection

The channels are allocated depending on the user’s location (Cell Tier) in the cell from which a channel is requested. Location of a user can be tracked by a base station. A base station is a sensor that keeps discovering and serving mobile terminals within its radio range. To determine the appropriate cell tier for channel allocation, predetermined Mobile Proximity Threshold (MPT) is used. The threshold value MPT is decided on the basis of the size of RCT. The base station allocates channels based on the received signal strength indication (RSSI) from mobile terminals. The RSSI of a mobile terminal is compared with the predetermined Mobile Proximity Threshold and then a tier is determined for channel allocation to the mobile terminal, as given below:

IF RSSI < MPT
 a channel is allocated to the mobile terminal in RCT.
 ELSE
 a channel in NCT is allocated.

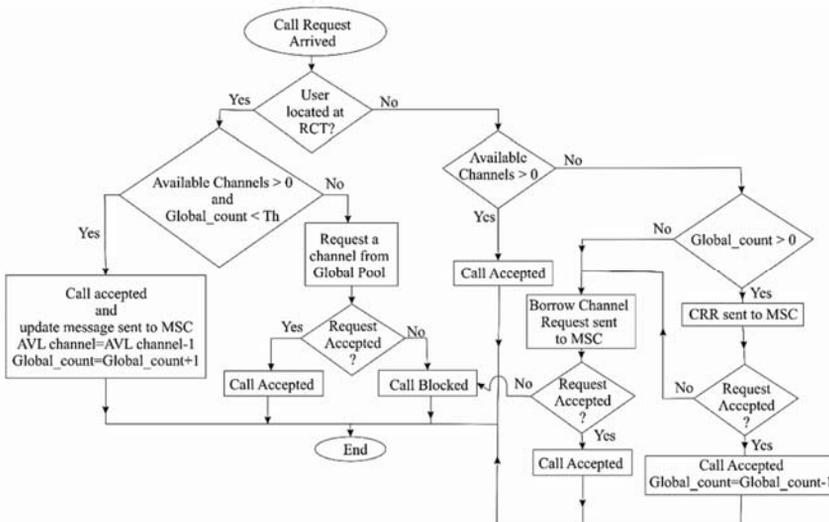


Figure 5. Flow Chart to show process of channel allocation

4. Steps of Channel Allocation

This section discusses the process of channel allocation in the proposed scheme. A flow chart of the process of channel allocation is given in Figure 5. Table 1 contains the description of the variables used in Figure 5.

4.1. Steps of Channel Allocation in Reduced Coverage Tier (RCT)

This section will describe the process of channel allocation when a mobile station, located within RCT of a cell $Cell_m$, requests a channel for a new call. To serve this call request, an unused channel can be allocated either from pre-allocated channels of $Cell_m$ or from global pool of channels. Whenever a pre-allocated channel is used to serve a call request from RCT, that channel is also added into the global pool. To decide whether a channel from pre-allocated channels of $Cell_m$ or from global pool of channels will be allocated, a predetermined threshold 'th' is used. The threshold 'th' is important because it affects the number of messages sent to MSC from a cell and delay in channel allocation. A large value of 'th' decreases the number of 'request' messages sent to MSC from a cell. Consequently, a large value of 'th' also decreases the delay in channel allocation to a call requests as there exists some delay in sending a 'request' message to MSC and getting a channel from global pool. Similarly, a small value of 'th' decreases the number of 'CRR' messages sent to MSC from a cell. Since, small value of 'th' is used less number of pre-allocated channels are allocated in RCT of the cell. CRR message may require a handoff which further increases the delay in channel allocation. Thus, less number of CRR message reduces the overall delay in channel allocation. Also, a large value of 'th' increases the number of 'update' messages sent to MSC as more number of pre-allocated channels are allocated in RCT. Hence, a trade-off must be needed for the value of 'th'.

Table 1. Description of the Variables Used In Flow Chart

| Notation | Description |
|--------------|--|
| Th | A predefined threshold |
| Global_count | Number of channels of the cell already added into global pool. |
| AVL Channel | Number of channels available in the cell |
| RCT | Reduced Coverage Tier of the cell |

The authors in [24] classified a cell as hot depending on a threshold h typically whose values are 0.2, 0.25 etc., and determined by the average call arrival and termination rates, and also by channel borrowing rates from other cells[24]. The values of h such as 0.2 or 0.25 indicates that when only 20% or 25% of pre-allocated channels respectively are available in a cell, the cell is considered as hot cell. Considering this in the proposed work the 'th' is considered as $1/4^{\text{th}}$ of the number of pre-allocated channels for the simulation purpose. Thus, whenever 25% of pre-allocated channels are allocated to serve call requests in RCT the remaining unused channels are set aside to serve call requests in NCT.

There exists following two situations for allocating channel to a call request from a mobile station located within RCT of a cell $Cell_m$.

If the total number of channels from Cell_m added into the global pool is less than 'th', an unused pre-allocated channel, Channel_x, from Cell_m is allocated to the call request. And then an 'update' message is sent to MSC so that the Channel_x can be added into the global pool. Once the channel is added into global pool, the channel information is removed from the list of pre-allocated channels of Cell_m. However, the Cell_m can get back this channel from global pool if required by sending a Channel Return Request (CRR) message to MSC. As already mentioned, a channel from global pool can be used simultaneously by all the cells of the cluster only in their RCTs and MSC keeps track of the utilization of channels by all cells in a cluster.

Otherwise, if the total number of channels from Cell_m added into the global pool is not less than 'th', a 'request' message is sent to MSC for requesting a channel from the global pool. In response to this message the MSC can allocate a channel, which is not currently being used by Cell_m, from global pool (if possible) to the call request.

In either case, if no channel could be allocated to the call requests, then the call request is blocked.

4.2. Steps of Channel Allocation in Normal Coverage Tier (NCT)

This section will describe the process of channel allocation when a mobile station, located within NCT of a cell, Cell_m, requests a channel for a new call.

If a pre-allocated channel of Cell_m is available, then that unused channel is allocated to the call request.

If no such unused pre-allocated channel is available in Cell_m, then, it is checked that whether any pre-allocated channel of the Cell_m is currently added in global pool. If any such pre-allocated channels of Cell_m exists in global pool, a CRR (Channel Return Request) message is sent to MSC from Cell_m. Section 3.1 describes the processing of CRR message by MSC. If CRR is accepted, then MSC will return one of the pre-allocated channel of Cell_m and that returned channel will be used to serve the call request. MSC ensures that the returned channel is not currently being used in the neighboring cells of Cell_m in the Cluster.

If no channel could be allocated by following the above two steps, the Cell_m sends a channel borrowing request to MSC. If MSC accepts the channel borrowing request then the Cell_m will get a borrowed channel that can be allocated to the call request. On completion of the call borrowed channel will be returned to the lender cell.

Still, if no channel could be allocated to the call requests, the call request is blocked.

5. Experimental Results and Performance Comparisons

To assess the performance of the proposed scheme, simulation is performed using MATLAB. We model a multi-cell mobile cellular network with a wrap-around cell layout, which ensures that all cells experience the same interference characteristics. The cellular system being simulated consists of 19 two-tier (RCT and NCT) hexagonal cells. The radii of the RCT and NCT are considered as R' and R respectively where $R' = R/\sqrt{N}$, where N is the cluster size (number of cells in a cluster). In Scenario-I cluster of N = 3 cells while in Scenario-II cluster of N = 7 cells are considered. Number of full duplex voice channels

allocated in each cell (RCT and NCT) is 36. Thus, the total number of channels for the considered system in Scenario-I is $N*36$ i.e., $3*36 = 108$ channels while in Scenario-II, the total number of channels for the considered system is $N*36$ i.e., $7*36 = 252$ channels. The distribution of user (mobile station) in the system is random in nature. The user can be at any position in any cell. Equal number of users is assumed in RCT and NCT. A centralized MSC maintain a global pool of channels. The channels available in global pool can be allocated only to the call requests originated at RCT of any cell. MSC keeps information about all the allocated and unused channels (pre-allocated channels as well as channels from global pool) in each individual cell in the given cellular system. New call arrivals are assumed to follow a Poisson distribution with mean rate λ and the call holding time is assumed to follow an exponential distribution with mean $1/\mu$. The central cell is considered as the hot cell while all other cells are considered as cold cells. The traffic load of all cold cells are kept constant throughout the simulation while the traffic load of the central hot cell is varied from two times to seven times than the traffic load of any other cold cells in the system. The algorithm considers the path loss exponent $\alpha = 3.5$ and standard deviation of shadowing $\sigma = 8$ dB to obtain the results. To allocate channels the algorithm considers the carrier-to-interference ratio (CIR) in each co-channel stays above the required value $CIR_{min} = 10$ dB. Here the carrier C represents the received signal power in a channel, and the interference (I) represents the sum of received signal powers of all co-channels. Blocking probability and channel utilization are the two important parameters that have been considered for evaluation of the proposed scheme. Blocking probability is calculated as $\text{Blocking Probability} = (\text{number of calls blocked}/\text{number of incoming calls})$, whereas, channel utilization is the ratio of the channel utilized (Number of active calls) to the total channels of the system. In the presented graphs system load indicates total number of calls requested during simulation.

In order to evaluate the proposed scheme, it is compared with other existing schemes in two different scenarios on the basis of cluster size.

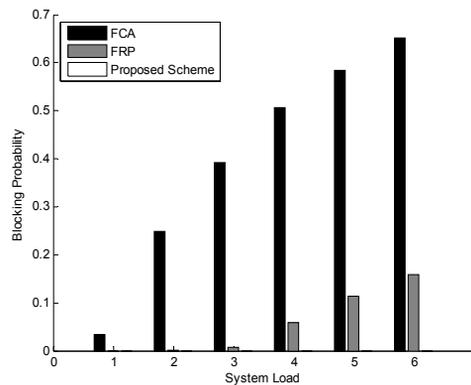


Figure 6. Comparison of call blocks for central hot cell in Scenario-I

5.1. Scenario-I

In Scenario-I, the available channels are allocated according to fixed channel assignment scheme, forming a cluster of $N = 3$ cells. The proposed scheme is compared with a simple fixed channel allocation strategy (FCA) [25] and a Frequency Reuse Partitioning (FRP) based [20] cellular systems. Figure 6 show the variations of the call blocking probabilities for the central hot cell with the increasing offered load. Initially the blocking is low as the traffic load is low. As traffic load increases blocking also increases. From the figure it is observed that the simple FCA results highest call blocks among the three schemes as it does not includes any load balancing strategy. The FRP scheme show better results than the simple FCA scheme. This is due to the fact that the FRP scheme reuses channels in the inner tier of all the cells. As a result it utilizes channels effectively to decrease the call blocks in inner tier. The proposed scheme also reuses channels in the inner tier (RCT) of all the cells. During congestion, the proposed scheme serves the call requests originating in RCT of the hot cell by allocating channels belonging to neighbor cells. Thus, the unused pre-allocated channels of the hot cell are allocated to serve the call requests originated in NCT. Further, the unused channels of the least congested neighbor cells are also utilized to serve the call requests originated in NCT of the hot cell, if needed. As a result, the proposed scheme is effective in decreasing the call blocks of both RCT and NCT. Hence, it is justified that the number of blocked calls is zero in all cases in the proposed scheme when compared with simple FCA and FRP schemes.

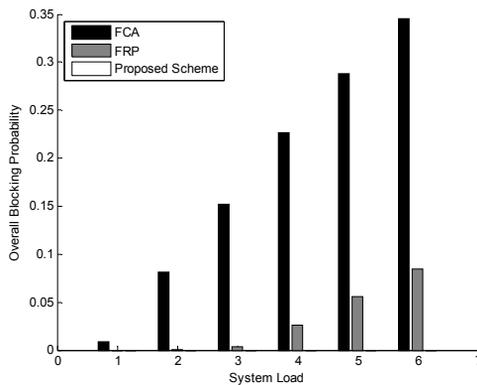
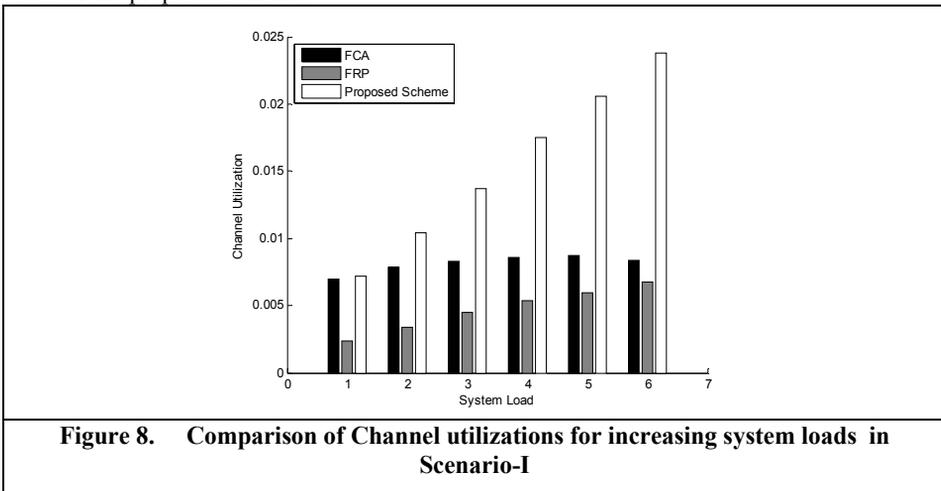


Figure 7. Comparison of overall call blocks for seven central cells in Scenario-I

Similarly, Figure 7 illustrates the variations of the overall call blocking probabilities of the central hot cell along with the surrounding six neighbor cells with the increasing offered load. During low congestion the overall call blocks of the proposed scheme is minimum among all the other schemes. But the overall call blocks in the proposed scheme is more than the FRP scheme during high traffic loads. In proposed scheme during congestion channels are borrowed from neighbor cells to serve the call requests from NCT. This decreases the system capacity of the lender cells. Also, as this channel cannot be allocated in any other neighbor cells simultaneously, it causes to increase the call blocks of call requests from RCT. If the borrowed channel could have been allocated to RCT instead of NCT, a single such channel could have served multiple call requests from RCT of

several cells. Thus, in case of FRP scheme we observe a lesser overall call blocks as this scheme does not allow any such borrowing for NCT users.

Figure 8 depicts that the channel utilization of the proposed scheme is much higher than the other two schemes. In the proposed scheme a single channels that is allocated in RCT can be used to serve call requests from RCT of other cells. Hence, it can serve more call requests than the total number of available channels. At the same time, during congestion most of the unused channels from neighbor cells are also utilized in serving the call requests from NCT of the hot cell. Due to this, we observe more channel utilization in case of the proposed scheme.



5.2. Scenario-II

In Scenario-II, the available channels are allocated according to fixed channel assignment scheme, forming a cluster of $N = 7$ cells. The result of the proposed scheme is compared with an existing scheme (HCA)[22] which is a hybrid channel allocation (HCA) algorithm and with another existing load balancing scheme (LBS)[21] which also follows tiering concept.

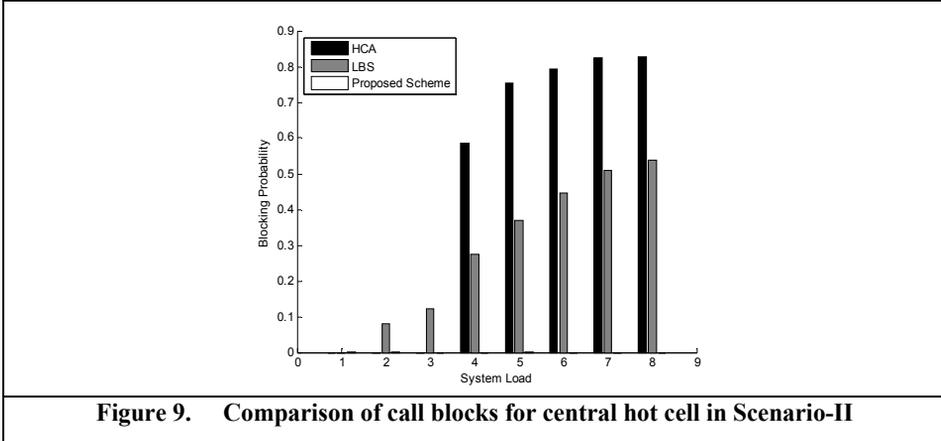


Figure 9. Comparison of call blocks for central hot cell in Scenario-II

Figure 9 show the variations of the call blocking probabilities for the central hot cell with the increasing offered load. From Figure9 it is clearly evident that thenumber of blocked calls is zero in all cases in the proposed scheme when compared with other schemes. In low congestion situations the HCA scheme performs well in reducing the call blocking but as the congestion increases the performance degrades significantly (as depicted in Figure9). During less congestion in HCA scheme the call blocks are zero, since, the call requests are also served by allocating channels from the central pool. But, as the congestion increases the central pool becomes empty and sudden rise in call block are observed. During high congestion call blocks in LBS are less compared to HCA. This is due to the fact that the LBS utilizes channels more efficiently than HCA (Figure 10) asbecause a borrowed channel is used in borrower as well as in lender cell simultaneously. In case of HCA, channel utilization decreases during high congestion, because, the hot cells reserves multiple channels from the central pool (depending on their congestion level) and most of these channels remains unutilized.

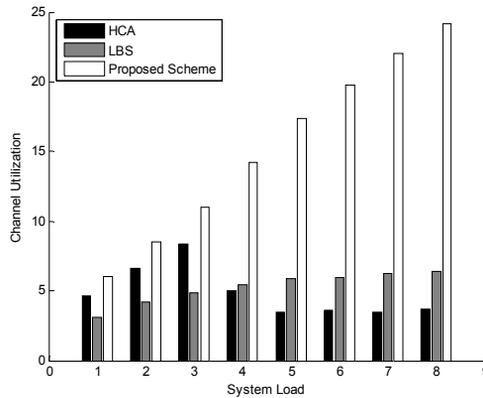


Figure 10. Comparison of Channel utilizations for increasing system loads in Scenario-II

6. Conclusions

A simple and cost effective load balancing scheme is proposed in this paper to solve hot cell problem. The proposed scheme uses tiering concept such that a channel can be utilized simultaneously in multiple cells. Thus the proposed scheme will enhance the channel reuse in the given cluster and hence is effective in reducing the overall call blocks in the given cellular system. Result analysis shows that under various traffic loads, the proposed scheme significantly reduces the blocking of calls from the given cellular network. The proposed scheme can also decrease the congestions efficiently from multiple hot cells. Since, the radii of the reduced coverage layer of the cells are reduced; the system can experience a slight increase in total number of handoff call requests.

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