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A Hybrid Resource Allocation Strategy with Queuing in Wireless Mobile Communication Networks

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Abstract

The main objective of third and future wireless mobile communication networks is to provide services efficiently to the mobile users in all environments. In wireless mobile Communication the channel allocation and quality of service are the major factors and important issues to decide the system performance. Here in our work a Hybrid Channel Allocation(HCA)strategy for channel allocation and queuing technique applied to Hybrid Channel Allocation strategy for Quality of Service(QoS) provisioning are implemented. The proposed HCA strategy considers new calls in Fixed Channel Allocation (FCA) method and handoff calls in Dynamic Channel Allocation (DCA) method to reduce the call blocking and call dropping probabilities. The application of queuing technique applied to HCA strategy increases the efficiency of the cellular system performance especially in micro and pico cellular environments and effectively utilize the available allocated radio spectrum. The performance shows the decrease in call blocking and dropping and an increased number of users in the available channels.

Keywords: Fixed Channel Allocation (FCA), Dynamic Channel Allocation (DCA), Hybrid Channel Allocation (HCA), Quality of Service (QoS), Call Dropping Probability (CDP), Call Blocking Probability (CBP)

1. Introduction

The radio spectrum allocated to wireless cellular mobile communication system is fixed one. Efficient use of available spectrum will produce an increased number of users. The fundamental operational principle of wireless cellular mobile communication system (WCMCS) is the reuse of frequencies at different places within the areas of service. Reusing the same frequency will not interfere, as it will be attenuated enough. In doing this, the carrier to interference ratio (CIR) and the radio spectrum reuse efficiency are improved. The channel allocation strategy is the technique used to make the most efficient and intelligent way of utilizing the available radio spectrum by the way in which channels are allocated to mobile multimedia calls.

The third and future generation wireless communication networks will support heterogeneous traffic, consisting of voice, video (JPEG & MPEG) and data as multimedia. The Quality of service (QoS) is the major issue for these applications in any kind of communication networking environment. The wireless QoS is the complex problem due to the time varying characteristics of the channel and user mobility. In this work, an efficient channel allocation strategy with QoS provisioning framework is applied to third and future generation wireless networks. Here a Hybrid Channel Allocation (HCA) strategy [HCA is the combination of Fixed Channel Allocation (FCA) and Dynamic Channel Allocation (DCA) strategies] for multimedia mobile calls and queuing technique are considered. Because queuing technique is the effective and efficient way to reduce the new call blocking and handoff call dropping probabilities. Hence the implementation of HCA with queuing will effectively increases the channel utilization and thus providing QoS.

2. Overview on channel allocation strategies

The bandwidth or channel allocation strategies are developed to utilize the available radio spectrum effectively and efficiently. This will impact the performance of the system particularly as to how calls are managed when a mobile user making a new call or the user handoff from one cell to another cell.

2.1 Fixed Channel Allocation (FCA) strategy

In this method, each cell is allocated to predetermined set of channels, if all the channels in the cell are occupied, then the call is blocked, and the mobile subscriber does not receive the service. The frequency reuse distance (D) and the co-channel interference (Q) are the factors to be considered for allocating set of channels to the particular cell. This is a very simple method for allocating channels. Here there is no delay time for getting the channel or service, if the channels are free but at the same time once all channels are occupied, no one get the service from the network until any one of the user will disconnect their call.

Channel borrowing approach: In FCA, the channel borrowing approach is also used. In this the cell is allowed to borrow the channels from a neighboring cell, if all of its own channels are already occupied. The Mobile Switching Centre (MSC) supervises the borrowing procedure and ensures that, the borrowing of the channels does not disrupt or interfere with any of the call in progress in the donor cell.

2.2 Dynamic Channel Allocation (DCA) strategy

In this method, the channels are not allocated to different cells permanently. Instead, each time, a call request is made, the serving Base Transceiver Station (BTS) request a channel from the Mobile Switching Center (MSC), if centralized control is used or otherwise, sometimes for the decentralized control, the BTS request a channel from the Base Station Controller (BSC) itself. The switch then allocate a channel to the requested cell following an algorithm that takes into account, the likelihood of future blocking within the cells, the frequency of use of the candidate channel, the reuse distance of the channel, any other cost functions. Accordingly the MSC or BSC only allocates a given frequency or channel, if that frequency or channel is not presently in use in the cell or any other cell, which falls within the minimum restricted distance. The minimum restricted distance is given by $D = \sqrt{3K}\,R$ and $D/R = Q = \sqrt{3K}$ is the co-channel interference reduction factor. Where R is the radius of the cell coverage and K is the frequency reuse pattern i.e. cluster size. Dynamic channel allocation strategies will reduce the likelihood of blocking, which increases the trunking capacity of the system, since all the available channels in the system are accessible to all of the cells. DCA strategies require the MSC or BSC to collect the real-time data or information on channel occupancy, traffic distribution, and radio signal strength indicators (RSSI) of all channels on a continuous basis. This will increases the storage and computational load on the system, and increases the delay time for allocating channel to a particular mobile user but at the same time, it gives the advantage of increased channel utilization and decreased probability of blocked calls. Normally in MSC decentralized control method is used instead of centralized controller since decentralized control has

Less delay for allocating channels compare to centralized control method

Less computations load on the MSC which interns requires the less storage (Memory space) as compare to centralized control method.

Because of decentralized control, the fault identification and trouble shooting are easy.

2.3 Hybrid Channel Allocation (HCA) strategy

In HCA strategy, the total set of channels is divided into two subsets. The first subset of channels is assigned to the cells of the system according to the FCA strategy. The second set is kept in a central pool and assigned dynamically to the cells on demand to increase the flexibility. Therefore, there are two types of channel allocation strategy at the same time i.e., the combination of FCA and DCA strategy. Here for allocating channels, the fixed to dynamic ratio is very important one. This fixed to dynamic ratio depends upon the statistical nature of the cell i.e., depends on number of new calls and hand off calls initiated in peak hours and also in normal hours.

3. Steady state performance of cellular wireless networks

It is essential to know the steady state performance of the cellular wireless networks to evaluate the performance of our proposed HCA strategy with queuing. In the cellular wireless networks geographic region is divided into hexagonal cells with six neighbors each. It is the commonly used network model. A user enters the network in any cell, provided there is enough bandwidth available, otherwise the call is blocked. The users keep on moving from one cell to another i.e., neighboring cell provided the Mobile Unit (MU) finds the required bandwidth in the next cell. If it is not, then the call is dropped. The Steady State Utilization (SSU) is a parameter that gives an insight into the load, a system can support without loss. Take a fully loaded system i.e., maximum number of users in each cell and the users are move in and around the system frequently. Assume users are permanent and they do not leave unless they get dropped. The utilization at this condition is the steady state utilization of the system. The Steady State Arrival Rate (SSAR) is the arrival rate that will keep the system functioning at its steady state utilization. For a system with finite call durations, there is a corresponding arrival rate to keep the system functioning at the steady state utilization. The arrival rate at this condition is the steady state arrival rate and it is given by

$$SSAR = \left(\frac{Util_{ssu} \text{ x Max. users}}{T} \right) \quad (1)$$

Where

$Util_{ssu}$ is steady state utilization and 'T' is the average call duration time

3.1 SSAR analysis of cellular wireless networks

Consider a fully loaded system i.e. maximum number of users in each cell. Assume that the call duration of a user on average is 'T' and the arrival rate is 'λ'. The number of users that arrived in the system during the time interval 'T' is given by

$$N_{arrivals} = \lambda T \qquad (2)$$

Some of the users that arrive are lost due to blocks and drops. Now the number of users that exist in the system is expressed as

$$N_{users} = (1 - loss)\,\lambda T \qquad (3)$$

By dividing both side of the above equation by maximum number of users, then it becomes

$$\frac{N_{users}}{Max.users} = (1 - loss)\frac{\lambda T}{Max.users} \qquad (4)$$

The left side of the above equation gives system utilization. Therefore

$$Util = (1 - loss)\frac{\lambda T}{Max.users} \qquad (5)$$

From this

$$\lambda = \frac{Util}{(1 - loss)}\frac{Max.users}{T} \qquad (6)$$

The above expression relates the arrival rate with utilization. The simulation for different call arrival rate with 10% loss is shown in figure 1. By rearranging the above expression we will get

$$T = \frac{Util}{(1 - loss)}\frac{Max.Users}{\lambda} \qquad (7)$$

This expression relates the average time duration of the call (T) with utilization. The simulation for different call duration time with 10% loss is shown in figure 2. If the system with loss is equal to zero and utilization is equal to steady state utilization, then the arrival rate at this point the steady state arrival rate.

4. Related work

Variety of work has been done in the area of channel allocation strategies considering new calls and handoff calls. Minimizing the handoff occurrence is one possible solution. Virtual tree connection method (A.S. Acampora, & M. Naghshineh, 1994) is the example solution. The model in (C. Oliverira, J.B. Kim, & T. Suda, 1998) allocate bandwidth to a call in the cell where the call request originates and at the same time reserves the same amount of bandwidth in all neighboring cells for the call. A hierarchical cell model is proposed in (L.O.Guerrero , & A.H.Aghvami, 1998) in which macro cells and micro cells are taken, and it allocates the bandwidth to appropriate cell according to the velocity of the mobile unit (MU). The scheme in (S.Bajaj, L.Breslau, D. Estrin, K.Fall, & S.kumar, 1999) compares the model by assuming utilization and loss separately. Here the solution is to avoid the bandwidth shortage of the cell by reserving the resource, in which direction the mobile user moves. The model in (P. Ramanathan, K.M. Sivalingam, P. Agrawal, & S. Kishore, 1999) considers the acceptance of new call is, according to an approximately calculated probability of a mobile unit induces handoff. By reserving some amount of bandwidth for new calls and handoff calls in advance, so that, the blocking and dropping probabilities can be reduced (Tao Zhang, & Prathima Agarwal, 2001).Here the resource reservation is considered for reducing the dropping probability. To utilize the available spectrum effectively the 'Spectrum holes' i.e., prediction of resource availability in advance is discussed in (V.Syrotuik et..al., 2004).Resource prediction is also a method to reduce handoff call droppings.

In order to meet "anywhere and anytime" concept, the future wireless network is converge into heterogeneous cellular network to support multimedia calls. For this, the good and bad threshold state method is examined in (L.Xu.X.shen & J.W.Mark, 2005) to reduce the dropping probabilities. But for real time traffic (example voice or video) with delay constraint, if a mobile station is in bad channel state for relatively long period, the multimedia call quality will be very much decreased and probably the call will be disconnected from the network. Since it only considers the threshold condition of a multimedia call. An analytical model of cellular mobile communication networks with instantaneous movement is investigated in (Wei Li, & Xiuli Chao, 2004). This is very much useful to cost analysis for updating location and paging in wireless cellular mobile networks. In the bandwidth allocation, various requests of an MU for communication quality should be satisfied. Our work presents a new class of channel allocation method that overcomes some of the critical limitations of existing methods by considering hybrid channel allocation with queuing. The proposed method is simple and especially suitable for micro and pico cellular multimedia wireless networks.

5. Objective and organization of the work

The main objective of our work is to present an efficient channel allocation strategy for multimedia calls used in future wireless cellular mobile communication networks formed by micro and Pico cellular structures.

Section 2 deals with introduction about different channel allocation strategies and section 3 discusses the steady state performance of the wireless cellular system with different call arrival rate and different call duration timings. Section 4 expresses the related work in this area in a short manner. Section 6 presents the proposed hybrid channel allocation (HCA) strategy with queuing technique applied to the same. Section 7 briefs the performance results with conclusion.

6. Proposed Hybrid Channel Allocation strategy

Hybrid Channel Allocation (HCA) is the combination of Fixed Channel Allocation (FCA) and Dynamic Channel Allocation (DCA). Here a portion of total frequency channels will use FCA and the rest will use the DCA. In HCA the channel allocation is done as follows, when a new or handoff call arrives at the cell BTS, the first attempt to serve, it is by a nominal or fixed channel, if there is no fixed free channel, then a channel from a dynamic set is assigned to the calls. If this also fails, then the call is blocked. The ratio of fixed to dynamic channel, is a significant parameter that determines and defines the performance of the system in much, the same manner that the ratio of nominal to borrowable channels defines the performance of a strategy with channel borrowing. In general, the fixed to dynamic ratio of the channel is a function of the traffic load and would vary over time according to the offered load distribution estimations. In HCA strategy, different methods are followed for channel allocation to multimedia mobile calls.

The normal method is, when a new call or a handoff call arrives to the Base Transceiver Station, the channels are allocated first in FCA strategy, if there is no free channels available in FCA, then channels are taken from DCA pool and allocated in DCA strategy, The second is, our proposed strategy, in which whenever a new call arrival to the BTS, the channels are allocated in FCA, and for the handoff call arrivals the channels are allocated in DCA strategy. The simplified model of our proposed HCA strategy is shown in figure 3. The first subset of channels are assigned to a cell, in FCA strategy for new calls, and the second subset of channels are assigned to the calls as DCA strategy for handoff calls. Here we consider FCA strategy for new calls because as far as new calls are considered delaying the call to provide the service or connection is better than blocking the call. But at the same time, for handoff calls, providing continuous connection with minimum acceptable call quality is better than dropping a call in the middle of the service during handoff. Hence DCA strategy is proposed for handoff calls.

6.1 Proposed HCA strategy with queuing technique

The proposed hybrid channel allocation with queuing technique is shown in figure 4. The flow chart is self explanatory one. Whenever a new call arrives to BTS, the channels are allocated in fixed manner i.e. FCA method and for handoff call arrival the channels are allocated dynamically i.e. DCA method. Here the fixed to dynamic ratio is the important factor and it varies according to the traffic conditions and cell site nature. All the new and handoff calls are queued before channel allocation and then they are added. It gives the present traffic condition of a particular cell. Before allocating the calls of new or handoff type to particular channel allocation strategy i.e., DCA or FCA, queuing the calls are effective way to reduce the blocking and dropping probabilities, if the calls are arrived in bundles. But for sequential arrival of calls, queuing is not effective. Generally, in practical situation the calls are arrived in bundles during the busy or peak hours. Hence queuing is needed one at all times. If the prediction method is implemented in BSC for distributed control or MSC in centralized control then which predicts the future bandwidth requirement by using present traffic condition. This prediction will also considerably reduces the new call blocking and handoff call dropping probabilities.

6.2 Call admission procedure in our proposed HCA strategy

In our proposed HCA strategy, the call admission procedure is shown in figure 5. In this for new calls, if the system having capacity to accommodate the call, then the call is admitted otherwise the call is blocked. For handoff calls, the capacity is estimated and then according to the constraints in DCA, the call is admitted.

6.3 Channel allocation for new calls and handoff calls in HCA strategy

The FCA method for new calls and DCA method for hand off calls in HCA strategy are shown in figure 6 & 7 respectively. In the fixed channel allocation for new calls, if the base station in the cell having capacity, then the call is accepted otherwise the call is blocked. In the dynamic channel allocation for handoff calls, the frequency reuse distance (D) and co-channel interference reduction factor (Q) are considered and then the channel is allocated to a call. In this both handoff reservation and handoff release calls are considered. In case, the above constrains are not satisfied, then the call is dropped. If the call is handoff release then the channel is released and kept in MSC or BSC pool for allocating channels to other handoff reservation request.

6.4 Queuing technique applied to our proposed HCA strategy

In order to improve the performance and efficiency of our system, first we consider HCA strategy for channel allocation. Secondly to avoid the call blocking of new calls and dropping of handoff calls, queuing technique is applied to HCA strategy for still better performance of the cellular wireless networks. In this, the MSC will queue the new call requests and handoff call requests before allocating the channel instead of rejecting them, if the cell site is busy. The queuing technique is effective only when the new call requests and handoff call requests are arrived at the MSC in batches or bundles. If the call requests are arriving uniformly, then queuing technique is not needed. In practical situations, calls are arrived to MSC or BSC in bundles during the busy hours. Hence queuing is the essential process to avoid call blocking and dropping in the cellular wireless networks.

Consider λ_1 and λ_2 are the arrival rate of new calls and handoff calls per second respectively. Take M_1 and M_2 are the queue size of new calls in FCA and handoff calls in DCA respectively of the HCA strategy. Assume the cell is having totally 'N' number of channels. Queuing analysis for new calls and handoff calls are shown below.

6.4.1 Queuing of calls not applied to new calls and handoff calls

In this case, the blocking probability (p_b) of the handoff call and new call is given by

$$p_b = \frac{a^N}{N!} P(0) \tag{8}$$

Where

$$P(0) = \left(\sum_{n=0}^{N} \frac{a^N}{n!} \right)^{-1} \tag{9}$$

This is nothing but an erlang 'B' formula to calculate the blocking and dropping probability of new and handoff calls.

6.4.2 Queuing of calls applied only to new calls and not on handoff calls

In this case, the blocking probability of the new call (p_{nq}) with queue is given by

$$p_{nq} = \left(\frac{b_1}{N} \right)^{M_1} Pq(0) \tag{10}$$

Where

$$Pq(0) = \frac{1}{N! \sum_{n=0}^{N-1} \frac{a^{n-N}}{n!} + \frac{1 - \left(\frac{b_1}{N} \right)^{M_1+1}}{\left(1 - \frac{b_1}{N} \right)}} \tag{11}$$

Now the call dropping probability (p_{nd}) of the handoff call is given by

$$p_{nd} = \frac{1 - \left(\frac{b_1}{N} \right)^{M_1+1}}{1 - \left(\frac{b_1}{N} \right)} \text{ x } \frac{1}{N! \sum_{n=0}^{N-1} \frac{a^{n-N}}{n!} + \frac{1 - \left(\frac{b_1}{N} \right)^{M_1+1}}{1 - \left(\frac{b_1}{N} \right)}} \tag{12}$$

6.4.3 Queuing of calls applied only to handoff calls, and not on the new calls

Here the call dropping probability (p_{hd}) of the handoff call is given by

$$p_{hd} = \left(\frac{b_2}{N} \right)^{M_2} x \frac{1}{N! \sum_{n=0}^{N-1} \frac{a^{n-N}}{n!} + \frac{1 - \left(\frac{b_1}{N} \right)^{M_1+1}}{1 - \left(\frac{b_1}{N} \right)}} \tag{13}$$

and the call blocking probability (p_{hb}) of the new call is given by

$$p_{hb} = \frac{1-\left(\frac{b_2}{N}\right)^{M_2+1}}{1-\left(\frac{b_2}{N}\right)} \times \frac{1}{N!\sum_{n=0}^{N-1}\frac{a^{n-N}}{n!} + \frac{1-\left(\frac{b_1}{N}\right)^{M_1+1}}{1-\left(\frac{b_1}{N}\right)}} \qquad (14)$$

Where $b_1 = \frac{\lambda_1}{\mu}$, $b_2 = \frac{\lambda_2}{\mu}$ and $a = \left(\frac{\lambda_1 + \lambda_2}{\mu}\right)$

$1/\mu$ is the average calling time in seconds, including new calls and handoff calls in each cell.

7. Performance evaluation and Conclusion

The performance analysis of our proposed hybrid channel allocation with queuing of new calls and handoff calls are given in section 6. For simulation purpose, each cell having 78 channels (N) and the call holding time of 101 seconds = 0.028 hours are taken. From the total available channels N, in our proposed HCA strategy the fixed to dynamic ratio of the channels are taken as 7: 3 for new and handoff calls. The arrival rate of new calls (λ_1) is taken as 2270 and handoff calls attempted (λ_2), per hour is taken as 80. From the analysis of queuing and simulation results in HCA strategy, it is seen that, with queuing of new calls in HCA, the probability of blocking (p_b) is reduced compare to without queuing in FCA method. The response result is shown in figure 8. But at the same time, queuing of new calls only resulting an increased call dropping probability (p_d) on the handoff calls shown in figure 9. This situation should be avoided. However, at the same time, queuing of handoff calls only, shown in figure 10 will give, reduced call dropping probability (p_d) of the handoff calls with single space queue. Hence it is very worthwhile to implement a simple single space queue for handoff calls to reduce call dropping probability. Since in a single space queue method of adding queues in the handoff calls does not affect the call blocking probability (p_b) of the new calls. From the analysis of with queuing and without queuing, as shown in figure 11 for a HCA and DCA strategy respectively, for handoff calls it is seen that by applying a single space queue to the handoff calls will reduce the call dropping probability in a considerable amount, as compared with without queuing method. In wireless environment resource allocation for a call is very complex and complicated process. This will directly affect the overall system performance and the mobile users. Here our proposed HCA strategy with queuing shows that, as compared with normal FCA and DCA strategies, the new call blocking and handoff call dropping probabilities are very much reduced in a reasonable amount and thus this will increase the micro and pico cellular wireless system performance. It also satisfies the mobile user's requirements during busy peak hours and in normal environments. The simulation of HCA strategy with queuing shows that, it should always be aware that, the queuing of the handoff calls are more important than the queuing of new calls. Because the call drops during the handoff will disturbs the mobile users more than getting a new call connection with delay.

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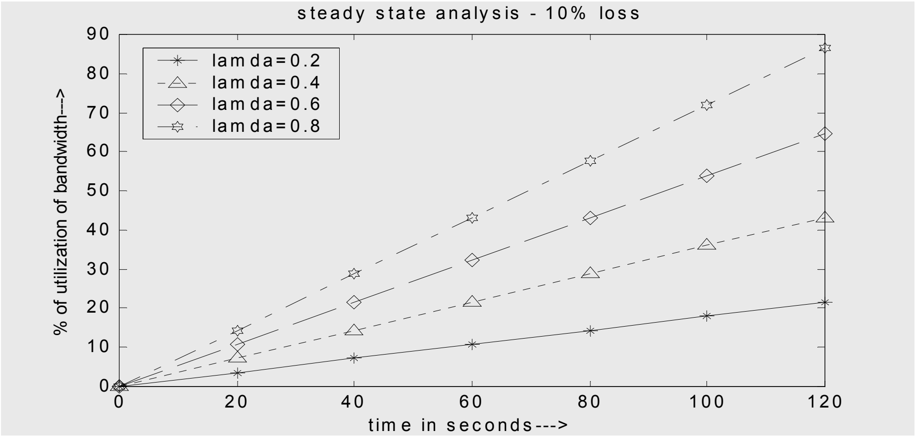

Figure 1. Steady state response with 10% loss for different call arrival rates

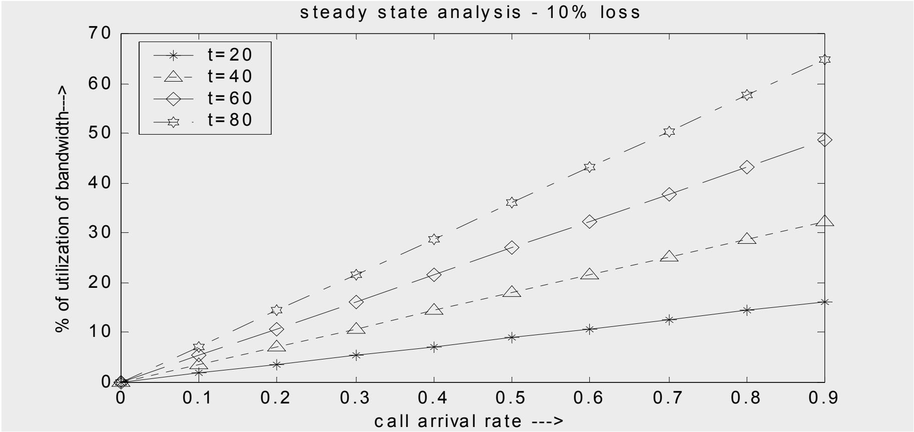

Figure 2. Steady state responses with 10% loss for different average call duration time

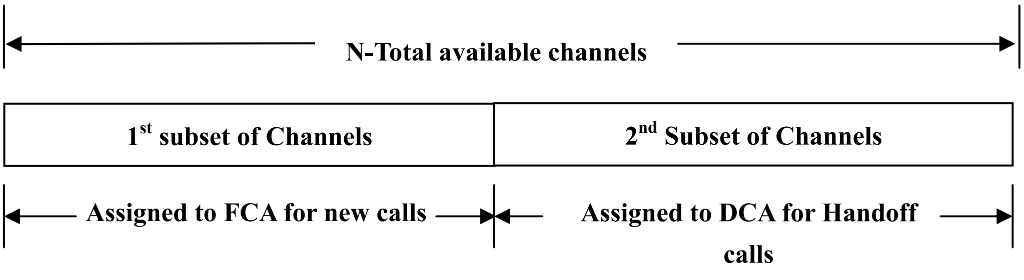

Figure 3. Channel Allocation in HCA Strategy

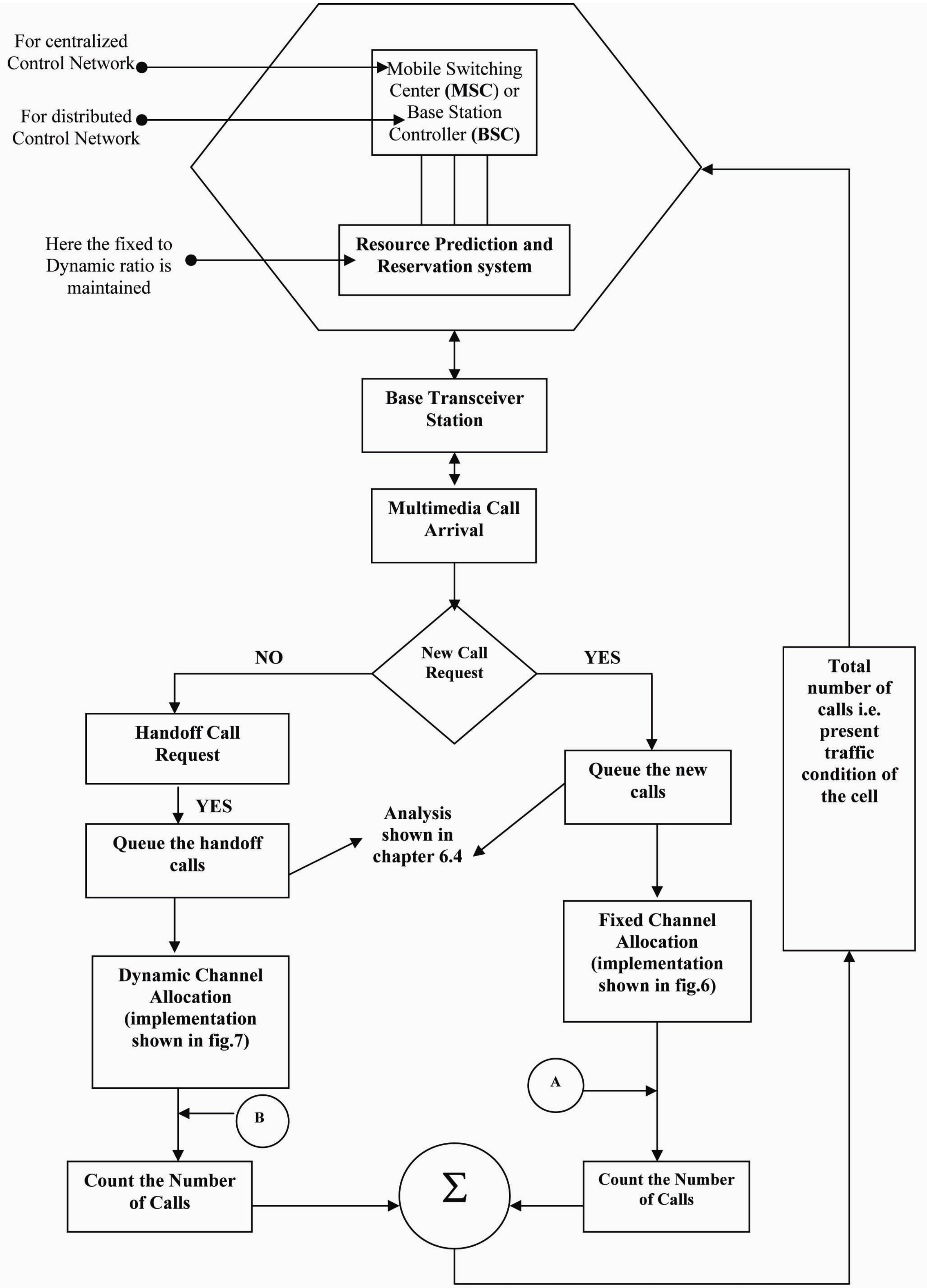

Figure 4. Proposed Hybrid Channel Allocation Strategy with Queuing Technique

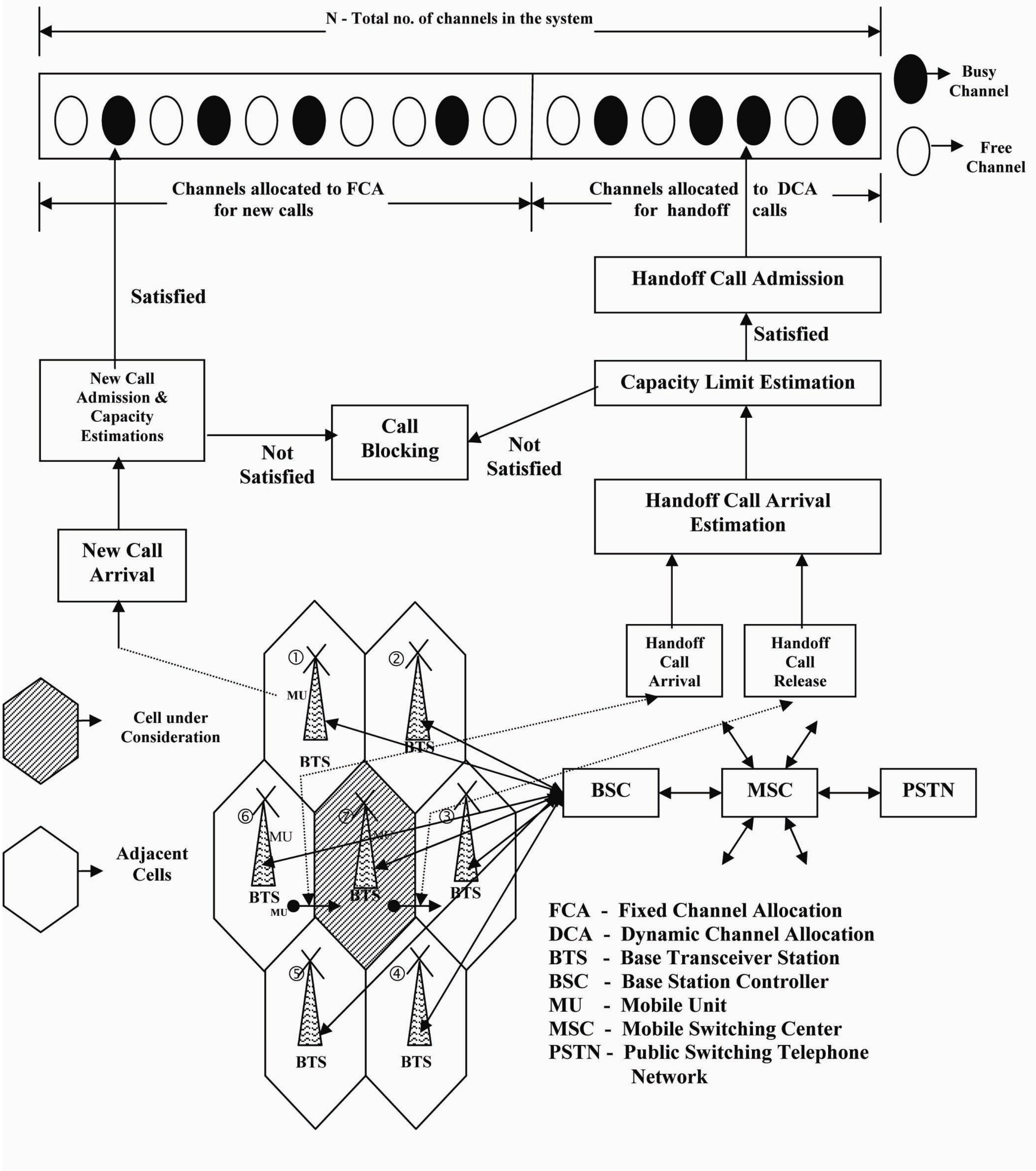

Figure 5. Call Admission Procedure in our Proposed HCA Strategy

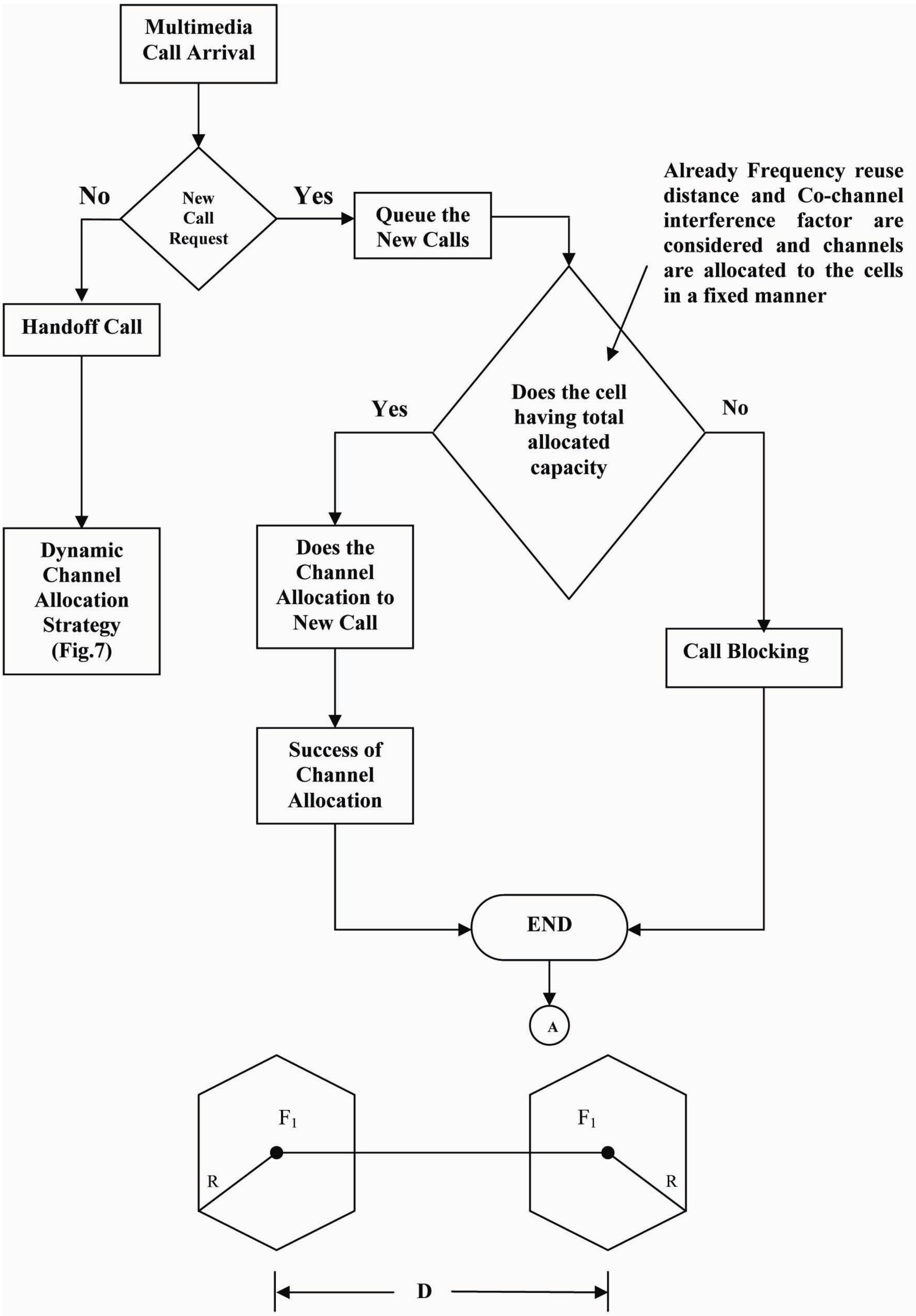

Figure 6. Fixed Channel Allocation for New Calls in HCA Strategy

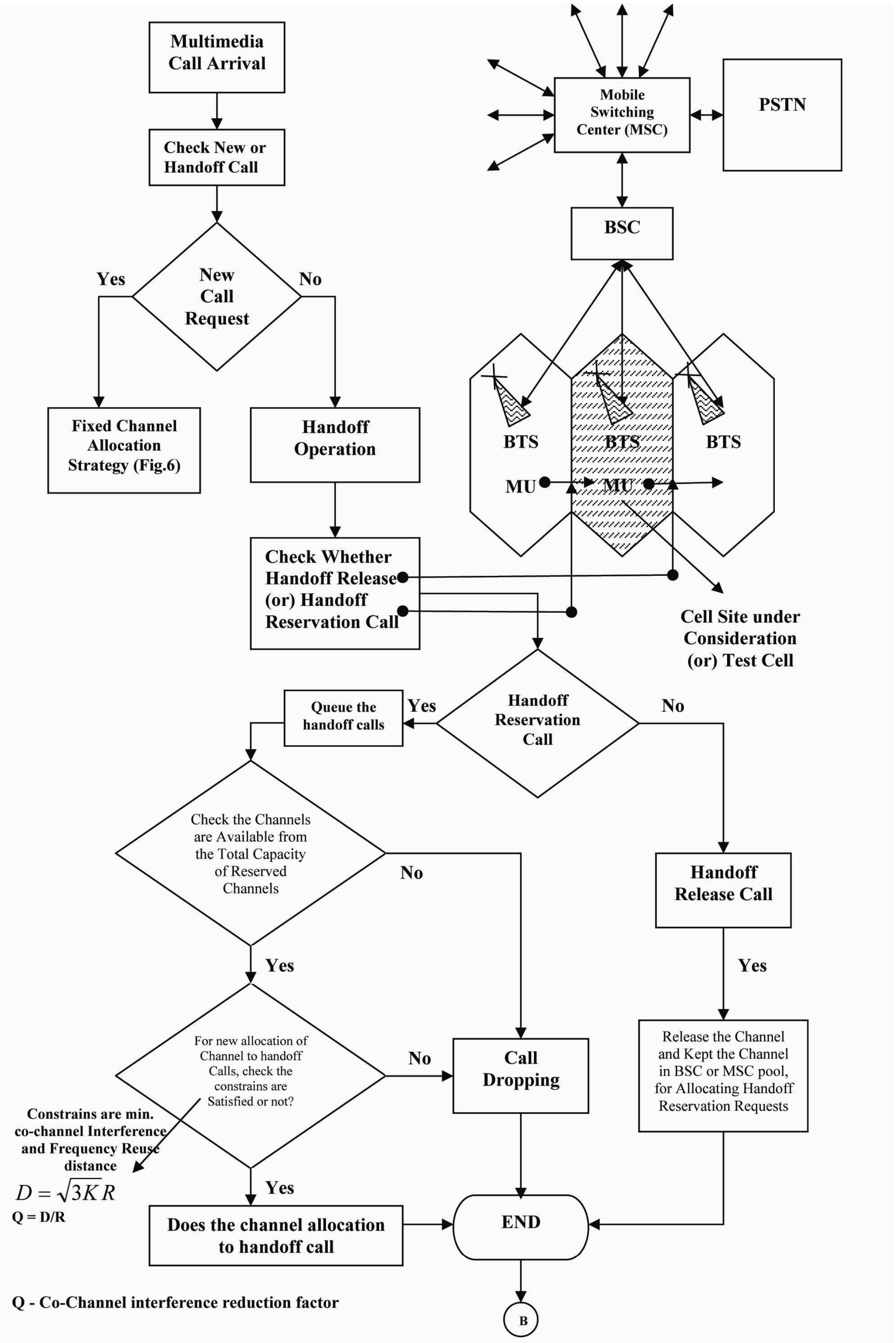

Figure 7. Dynamic Channel Allocation for Handoff Calls in HCA Strategy

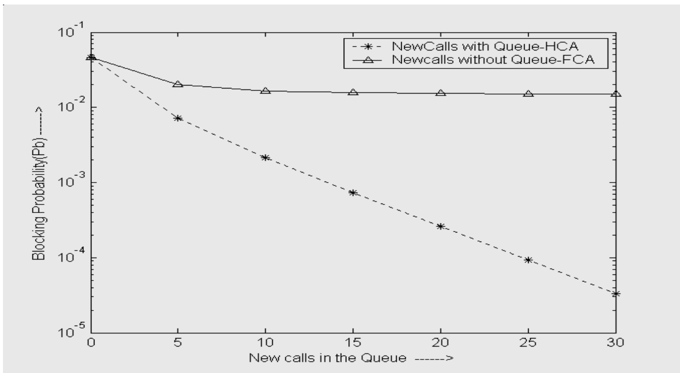

Figure 8. New call blocking probability (Pb) comparison between FCA and HCA strategies

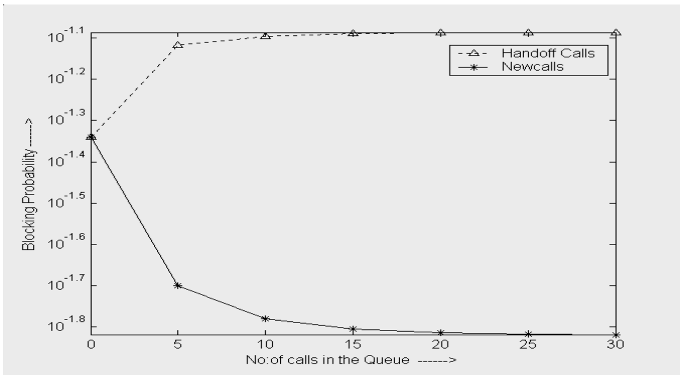

Figure 9. Call blocking probability comparison between new calls and handoff calls with new calls queued

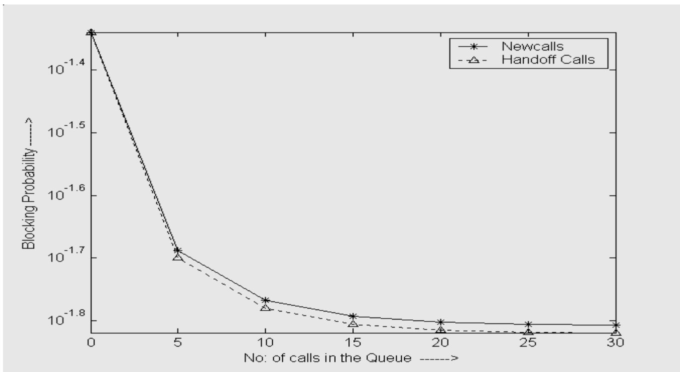

Figure 10. Call blocking probability comparison between new calls and handoff calls with handoff calls queued

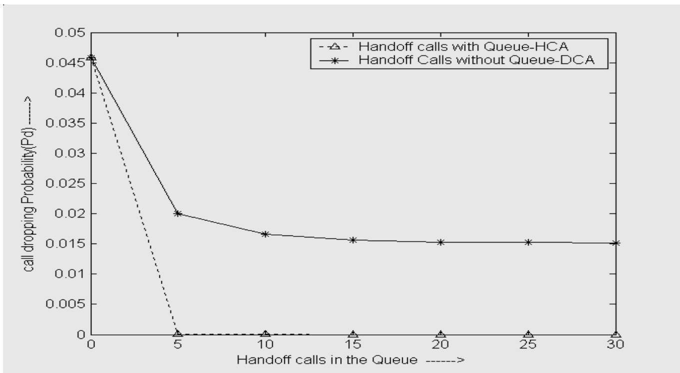

Figure 11. Handoff call dropping probability (Pd) Comparison between DCA and HCA strategies