

A Channel Allocation Algorithm for Efficient QoS Provisioning in Wireless Networks

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Abstract

Next generation high-speed cellular networks are expected to support multimedia applications, which require QoS provisions. Since radio spectrum is the most expensive resource in wireless networks, it is challenge to support QoS using limited radio spectrum. However, efficient use of such limited spectrum becomes more important when there is a heavy traffic in the network. The use of available channels has been shown to improve the system capacity. The role of channel assignment scheme is to allocate channels to cells in such way as to minimize call-blocking probability or call dropping probability and also maximize the throughput. This paper presents a new hybrid channel allocation (HCA) which is the combination of fixed channel allocation (FCA) and dynamic channel allocation (DCA). A network becomes heavy when the bandwidth available in the cells is not enough to sustain the users demand and call will be blocked or dropped. The result shows that HCA algorithm significantly reduces the call-blocking probability in heavy traffic load and can improve the bandwidth utilization while providing QoS guarantees. Furthermore, all channels will be placed in a central pool and on demand will be assigned to the base station. When a call using such a borrowed channel terminates, the cell may retain the channel depending upon its current condition therefore HCA has comparatively much smaller number of reallocations than other schemes. It also shows that it behaves similar to the FCA at high traffic and to the DCA at low traffic loads as it is designed to meet the advantages of both.

Keywords

Cellular Network, Quality of Service, Channel Allocation Schemes, Radio Spectrum

I. Introduction

Next generation high-speed cellular networks are expected to support multimedia applications (video, voice and data). As such, it is important that these networks provide quality of service (QoS) guarantees. The growth of mobile telephone traffic in wireless cellular networks, along with the limited number of radio channels available in the network, requires the need of efficient reuse of channels. An efficient channel allocation strategy is needed should exploit the principle of frequency reuse to increase the availability of channels to support the maximum possible number of calls at any given time. A given frequency channel cannot be used at the same time by two cells in the system if they are within a distance called minimum channel reuse distance, because it will cause radio interference (also known as co-channel interference). However, if this channel allocation strategy is not carefully designed, some channels may be wasted. Since the radio spectrum is the most expensive resource in wireless networks, and it is a challenge to support QoS using limited spectrum.

The rest of the paper is organized as follows: section 2 describes the channel allocation algorithms for wireless communication. In section 3 system architecture is described. Section 4 presents

the performance evaluation such as call-blocking probability. In section 5, we conclude the paper.

II. Channel Allocation Algorithms

Many channel allocation algorithms have been proposed [1-4, 6, 8, 10] in the literature, and can be divided into three major categories: Fixed Channel Allocation (FCA), Dynamic Channel Allocation (DCA), and Hybrid Channel Allocation (HCA). In FCA schemes, a fixed number of channels are assigned to each cell according to predetermined traffic demand and co-channel interference constraints. FCA schemes are very simple; however, they are inflexible, as they do not adapt to changing traffic conditions and user distribution. In order to overcome these deficiencies of FCA schemes, DCA schemes have been introduced. In DCA schemes, channels are placed in a pool (usually centralized at Mobile Switching Center (MSC) or distributed among various base stations) and are assigned to new calls as needed. Any cell can use a channel as long as the interference constraints are satisfied. After the call is over, the channel is returned back to the central pool. At the cost of higher complexity and control message overhead, DCA provides flexibility and traffic adaptability. However, DCA schemes are less efficient than FCA under high load conditions [2], mainly due to high overhead involved in exchanging control messages. To improve the performance, some DCA schemes use channel reassignment, where on-going calls may be switched, when possible, to reduce the distance between co-channel cells [1,2]. Another type of DCA strategy involves channel borrowing mechanism from neighboring cells. In such a scheme, channels are assigned to each cell, as is normally done in the case of FCA. However, when a call request finds all such channel busy, a channel may be borrowed from a neighboring cell if such cell borrowing will not violate the co-channel interference constraints [1-5].

It is observed that with low traffic intensity DCA uses channels more efficiently than FCA because of flexible channel assignment and shows good performance. But with high traffic intensity, DCA does not show better performance than FCA.

The disadvantages of DCA are as follows[5]

- DCA has higher blocking rate than FCA at high traffic intensity.
- DCA requires more radio equipment as each base station.
- DCA requires elaborate control for channel assignment.

HCA techniques are designed by combining FCA and DCA schemes in an effort to take advantages of both schemes. In HCA, 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 fixed set contains a number of channels that are assigned to cells as in the FCA schemes and such channels are preferred for use in their respective cells. When a mobile host needs a channel for its call, and all the channels in its fixed set are busy, only then a request from the dynamic set is made. The ratio of the number of fixed and dynamic channels plays an important role. It has

been found that if the ratio is 50% or more, FCA performs better than HCA.

In general, a channel allocation algorithm consists of two parts: a channel acquisition algorithm and a channel selection algorithm. The channel acquisition algorithm is responsible for collecting information from other cells and making sure that cells will not use channels that can cause interference. The channel selection algorithm is used to choose a channel from a large number of available channels in order to achieve better channel reuse.

The channel allocation problem becomes even more challenging when there is a heavy traffic in the network for some duration of time. A cell becomes heavy when traffic generated in that cell exceeds far beyond its normal traffic load for that particular hour.

This paper presents a new HCA scheme that takes into account the level of traffic intensity in a cell in terms of a heavy traffic in the network. The proposed scheme is simple to implement and offers low-overhead in terms of the number of control messages exchanged between the base station and MSC on channel acquisition and release phases.

III. System Architecture

A. System Model

The geographic area of wireless cellular network is divided into several hexagonal-shaped cells. Each cell is served by a base station, usually present at the center of the cell. The base stations are connected with one another through a fixed wired (or wireless) network, in general. A mobile host can communicate only with the base station in its cell directly. When a mobile host wants to set up a call, it sends a request to its base station in its cell by the control channel. The call can be set up only if a channel is assigned to support the communication between the mobile host and the base station. No two cells in the system can use the same channel at the same time if they are within minimum channel reuse distance; otherwise, channel interference will occur.

The count of number of calls originated either successful or unsuccessful is kept by the base stations over a given period of time. This count will help the base station to determine its current level of traffic intensity and send proper notification to its Mobile Switching Center (MSC).

As system uses a hybrid channel allocation algorithm, the total number of channels (C) is divided into two distinct sets: the first set (A) contains channels for fixed assignment while the second set (B) contains the channel for dynamic assignment i.e. $C=A \cup B$. The base station maintains temporary pool (called T) to retain a channel that was originally transferred from dynamic pool at MSC.

The system uses a frequency reuse factor N. The fixed channels are assigned to a cell statically as in FCA; while dynamic channels are kept in a centralized pool at MSC.

Let r be the ratio of the number of dynamic channels to the total number of channels available in the system, i.e.,

$$r = B / C$$

The ratio r will remain fixed in the system (i.e., it will not change dynamically over the period of time). The value of r is a design parameter, and it depends on the designer's view about the heterogeneity (or difference) in traffic volumes in different cells in the network. For example, if most of the cells in the network having the heavy traffic, then it's better to keep the ratio $r > 0.5$.

The notation of heavy traffic in a cell is an integer-valued number

L , such that

$$L \in \{0, 1, 2, \dots, M\}$$

where M represents a pre-defined maximum level supported by the system. The value for L represents the fact that up to L borrowed channels can be retained by the base station after a call on the borrowed channel from that cell terminates. The hybrid channel allocation algorithm will use the appropriate value of L in several of its steps.

B. Hybrid Channel Allocation Algorithm

The proposed hybrid channel allocation algorithm is described in two phases: channel acquisition phase and channel release phase. The steps taken by mobile host, base station and MSC are outlined below.

Set L to 0 at the beginning to indicate that, at the present time, the channel request can be accommodated from the fixed (static) list assigned to the cell.

1. Channel Acquisition Phase

The following Steps are taken from Mobile Host/ Base Station sides during a channel acquisition phase:

- When a mobile host wants to initiate a call, it sends the channel request on the control channel to its related base station.
- If the base station has an available channel from its current fixed channel list (i.e., set F), it will assign the channel to the mobile host, and channel acquisition phase terminates.
- If no channel from the fixed list for the cell is available, then the base station updates the value of L as follows:

$$L = L + 1;$$

$$L = \max(L, M);$$
- The base station then sends a request to borrow a channel from the central pool located at MSC. It also includes the current value of L in the channel request; and the maximum value of L is a pre-defined number M .
- When the base station successfully acquires a channel from the dynamic pool at MSC, it also adds the channel to its temporary pool (T).

The following steps are taken from MSC Side during a channel acquisition phase:

- The MSC, on receiving a channel request from the base station assigns up to L channels, if available, from the pool allocated for dynamic assignment to the requesting base station (even the call generated by the mobile host needed only one channel) and the channel acquisition phase terminates. The main reason of assigning up to L channels (instead of only one) is a proactive measure, as the "borrowing" event indicates that the probability of the cell covered by the requesting base station becoming heavy might be on the rise, and an assignment of several channels with one request will definitely involve less overhead (in terms of control messages exchanged) as compared to several single channel requests.
- If the MSC cannot assign even one channel, then the call will be blocked and the channel acquisition phase terminates.

2. Channel Release Phase

The following Steps are taken from Mobile Host, Base Station, and MSC sides during a channel release phase:

- When a call terminates on a channel c_i , at a mobile host, the base station needs to find out which type of channel the call belonged to. If the channel belonged to is from the fixed (static) pool maintained at the base station, the channel is returned to the pool and channel release phase terminates.

- However, if the channel c_i , being returned belonged to the dynamic pool at MSC, the base station estimates the current level of heavy traffic, h , in the cell.
- If h is less than or equal to the old value of level L , meaning that the congestion in the cell is the same or easing, the base station checks its temporary pool (T) and retains only up to h channels in a random order, and all the remaining channels (if any) in T are returned back to the pool at MSC.

If h is greater than the old value of level L (i.e., $h > L$), meaning that the congestion in the cell is getting worse, the channel c_i is retained in the cell and is returned to the base station's temporary pool (T); the channel c_i is not returned back to MSC at this time.

IV. Performance Evaluation

Several QoS metrics can be used to evaluate and compare the performance of the proposed algorithm with the existing ones. In this paper, we considered the followings metrics: Call blocking probability, the average number of control messages sent from the base station to MSC in order to acquire one channel from the pool holding dynamic channels, and the average number of control messages sent from the base station to MSC in order to release one channel to the centralized pool.

The call blocking probability is defined as the ratio of the number of new calls initiated by a mobile host which cannot be supported by existing channel arrangement to the total number of new calls initiated; i.e., the probability that a call arriving to a cell finds both fixed and dynamic channels busy. It is defined as

$pb = \text{number of calls lost by the system} / \text{the total number of new calls initiated}$

In the classical hybrid channel allocation algorithms reported in the literature, one control message is exchanged between the base station and the MSC in order to acquire exactly one channel from the dynamic pool resident at MSC, and the similar comments are true for channel release phase. However, the proposed algorithm makes "bulk" acquisition of the channels per request, and "bulk" release of channels per request depending upon the traffic intensity. That means that the number of control messages needed in the proposed algorithm is expected to be low as compared to the classical hybrid allocation algorithms.

A. Simulation Parameters

The simulated cellular network consists of a 2D structure of 7×7 hexagonal cells, with each cell having six neighbors. As frequency reuse factor of 7 is assumed (i.e. $N=7$).

If arrivals of calls occur according to Poisson process and that the call duration is exponentially distributed with a mean of 3 minutes. The traffic in a cell can be in of the two states at any time: normal and heavy. The mean call arrival rate in a cell of normal traffic is λ calls per minute. When a cell in a heavy traffic state, the call arrival rate in the cell is assumed to be 3λ calls per minute. The mean rate of changing from normal to heavy state is $1/30$, while the mean rate from heavy state to normal state is $1/3$. The ratio r is also changed from 0.1 to 0.8. The system load intensity is defined with respect to arrival rates and call service in a cell that can switch back and forth from normal to heavy state. The value of M is also varied from 4 to 8.

B. Simulation Results

The proposed algorithm was simulated using discrete- event simulation model in C++, and the call blocking probability and the number of control messages exchanged were studied under various system parameters.

Fig. 1 shows the results of blocking probabilities for the proposed algorithm for various values of r for $M=4$, while Figure 2 shows the results for various values of r for $M=8$. The results are also compared with the static Fixed Channel Assignment (FCA) algorithm. Figure 3 shows the average number of control messages sent per dynamic channel acquired from the pool at MSC, while Figure 4 shows the average number of control messages sent for each dynamic channel returned to the centralized pool at MSC.

C. Comparisons and Observations

The main advantage of the proposed protocol is that it can adapt to dynamic strategy at low traffic load to static strategy (FCA) at higher traffic load. This fact is verified by simulation, as shown in fig. 1 and 2.

When $M=4$ (as shown in fig. 1), the proposed strategy is better than FCA at system loads less than about 0.8, and higher value of r gives better results in this region. At higher system loads, the performance of the proposed algorithm approaches to FCA, and the lower values of r give better performance (closer to FCA) in this region. If we increase the value of maximum heavy traffic level (M), the system performance, in general improves, in both regions of low and high system loads. Such reason of improvement in result is due to the fact that at higher traffic load, the more channels are available and Figures 3 and 4 shows the average number of control message exchanged on each dynamic channel acquired (or returned) from the central pool at MSC. It should be noted that in all classical HCA (or DCA) algorithms, we need to send one control message on the event of channel acquisition or release for every channel request from the base station. The proposed algorithm offer a very low overhead in terms of control message exchanges, as the "bulk" channel acquisitions or releases are done through a single control message. Higher values of the ratio " r " offer even low over head, especially at higher traffic intensities. This is due to the fact that most of the channels are available in the central pool at MSC for dynamic channel assignments, and the channel requests are likely to be fully fulfilled at higher traffic intensities.

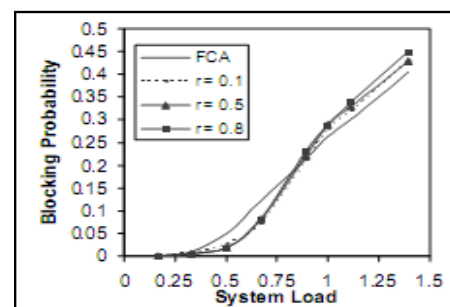


Fig 1: Simulation Result of Proposed Algorithm for Various Values of r for $M=4$

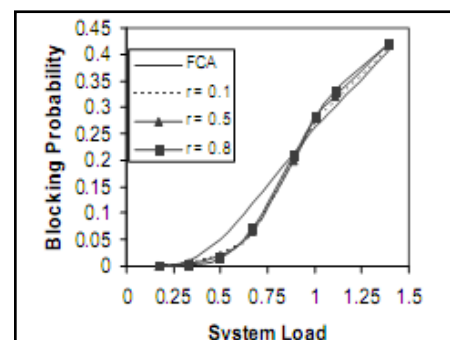


Fig. 2: Simulation Results of Proposed Algorithms for Various Values of N for $M=8$

V. Conclusion

A HCA method uses co-channel as criterion, and tries to reduce call blocking probability by assigning co-channels to cells those placed in central pool. Like other hybrid channel allocation methods, this method divided into two groups: group (A) and group (B). The first group (A) of the method is fixed channel allocation and second group (B) of method is dynamic channel allocation. The main advantage of this algorithm is that it can adapt to dynamic strategy at low traffic load and to fixed strategy at higher traffic intensity. If we increase the value of heavy traffic (L), the system performance in both regions of the low and high traffic intensity. This paper presents a new hybrid channel allocation algorithm that sends a multi-level "heavy traffic" 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 heavy traffic level of the cell. This also reduce control message overhead needed to acquire each channel individually. The simulation study of the protocol indicates that the protocol has low overhead, and it behaves similar to the FCA at high traffic and to the DCA at low traffic loads.

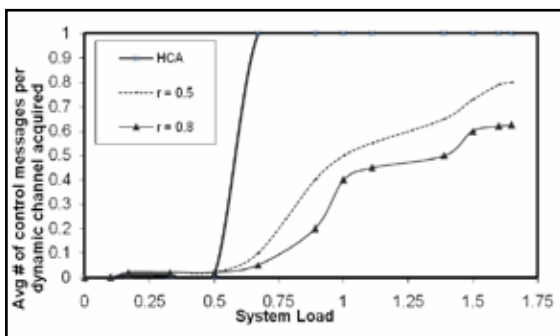


Fig. 3 (a): Average Number of Control Messages per Dynamic Channel Acquired from $M=4$

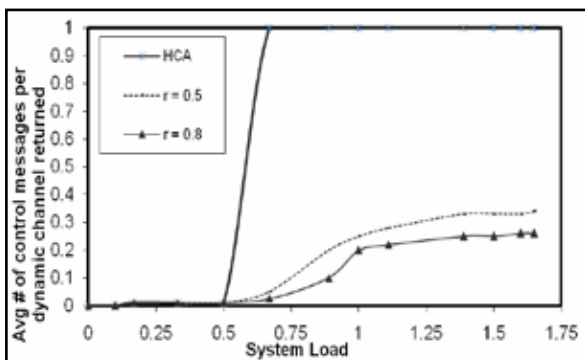


Fig. 3 (b): Average Number of Control Messages per Dynamic Channel Returned for $M=8$

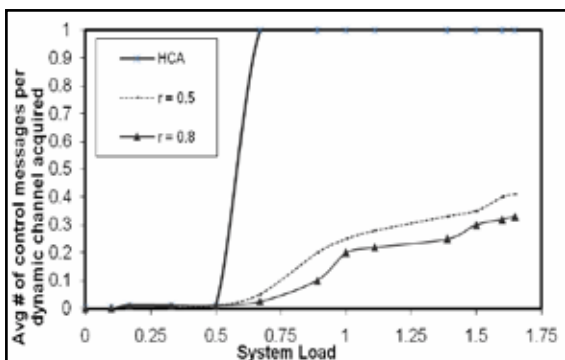


Fig. 4: Average Number of Control Messages per Dynamic Channel Returned for $M=8$

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