

# TRAFFIC LOAD ADAPTIVE HYBRID CHANNEL ALLOCATION IN WIRELESS COMMUNICATION NETWORK

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## Abstract

The mobility of the cellular users indicates non-uniform load (traffic) in different regions of the wireless network. This calls for a channel allocation technique which is able to adapt with the changing load pattern in different regions. The paper addresses the issue of efficient time bound channel allocation in cellular network with non-uniform traffic load distribution. The proposed technique identifies “heavy load” cells and partitions the cells of the network into groups where the “heavy load” cells will act as a group head. The number of such groups is not known *a priori*. A pure dynamic channel allocation technique, whether central or distributed, may require more computation and allocation time. A hybrid channel allocation technique being a combination of fixed and dynamic allocation can prove to be better time efficient channel allocation technique for real-time wireless communication networks. In this paper, we propose a hybrid traffic aware channel allocation technique which adapts itself on the basis of altering load patterns for every region. The technique is based on backpropagation algorithm for identifying the traffic trends of different regions or cells and utilizes the information for clustering cells and spectrum allocation in an intra-cluster manner.

## Key Words

Fuzzy clustering, traffic prediction, message complexity, channel acquisition delay, call blocking rate

## 1. Introduction

With the growing demand in the use of wireless-based communication systems, the design of frequency allocation effectively and efficiently at real time is extremely crucial. The wireless communication can cause significant interference for users in close proximity. The remarkable increase in the number of cellular users with limited available spectrum made the time bound effective management

of the spectrum absolutely essential. To support multiple calls in any typical wireless environment, it is necessary to optimally reuse the available frequency. In a wireless communication network, the available spectrum is divided into disjoint channels where each channel is divided into sub-channels (using orthogonal frequency-division multiple access (OFDMA)) and then time division duplexing (TDD) is deployed to divide each sub-channel into slots. The cellular system was designed to include the concept of different cells using the same channel given that the cells are separated by a minimum reuse distance [1]. The channel allocation strategy considers three different types of constraints – co-channel interference, adjacent channel interference and co-site interference; as any significant interference can deter any communication session. In co-channel interference, a frequency slot assigned to one cell cannot be reused by any cell within its co-channel interference range. The effect of co-channel interference can be reduced by ensuring that two different cells are simultaneously allotted the same sub-carrier slot when the said cells are separated by a minimum reuse distance [1]. The reuse distance is defined as the distance between the centres of the cells that can use the same channel. The adjacent channel interference is caused by adjacent cells using adjacent frequency. To minimize the effect of adjacent channel interference a minimum separation of certain number of channels must be maintained between adjacent cells. The channels assigned to the same cell must as well maintain a minimum separation of certain number of channels to avoid any co-site interference. A channel allocation strategy should always adhere to the frequency reuse theory for better and effective communication.

Over the years, different approaches have been proposed to resolve the problem of channel allocation. The channel assignment strategy is categorized as either fixed [2] or dynamic [3]–[9]. The concept of fixed and dynamic channel allocation has been combined to develop hybrid channel allocation [10]–[13]. A comprehensive comparison of some of these techniques has been presented in [14], [15]. In case of fixed channel assignment (FCA) schemes, a set of non-interfering channels are permanently allocated to each cell irrespective of the amount of traffic. The same set of channels may be allotted to two different cells which

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are separated by the minimum reuse distance. The fixed allocation scheme has less overhead and simple to cater, but fails when the traffic generated exceeds the number of channels available with the cell. In case the traffic is more than the available spectrum can support, the surplus call requests are blocked/dropped. In centralized dynamic channel assignment (DCA) schemes, there is a central hub of channels from where channels are directly allocated on the basis of request(s) raised. A hybrid channel assignment (HCA) schemes uses both fixed and DCA strategies, whereby a portion of the spectrum is assigned fixed set to each cell, and channels can be acquired from a global pool in case the user need exceeds the available fixed spectrum.

The non-uniform pattern of the user requirement in the wireless network can cause failure in fixed channel allocation scheme when there is rise in demand as compared to the number of channels available. The dynamic channel allocation improves the performance of network for non-uniform traffic but increases the channel allocation time. In case of central distributed allocation, all available channels are maintained centrally and allocated to respective cells on request. But a failure in the central system will have a huge impact on the entire system. Our paper presents an HCA scheme with fixed and distributed dynamic channel allocation technique [16].

Many algorithms have been proposed for dynamic as well as hybrid channel allocations which handle the non-uniform traffic issues in different ways, some of which are relevant to this study.

Reference [10] presents a hybrid channel allocation scheme which is based on some hot-spot concept. The base station sends a multi-level hot-spot notification to the Mobile Switching Station along with call request that cannot be allotted locally at the base station. The channel acquiring time is increased when channels are not available with the base station. The mode of dynamic channel allocation is centralized, which makes the system vulnerable as any flaw in the central pool will propagate to the entire system. The study [11] presents an algorithm using a hybrid channel allocation technique where each cell is the owner of a group of fixed set of channels and shares a central hub of dynamic channel with a traffic prediction module. The traffic prediction estimates the possible number of fixed channels a cell will require in the future, based on the recent traffic history. The algorithm uses centralized dynamic allocation which can be unreliable if there is a problem in the global pool of channels. Reference [3] delivers two guiding principles: the concept of best suitability and the interference property with distributed acquisition algorithm for designing channel selection algorithms. It further ensures that the borrowed channels are retained, using the concept of temporal locality while adapting to the network load. The concept of negotiation of multi-agent system proposed in [4] which address the resource allocation problem with the concept of negotiation among multiple agents. But the work does not consider users mobility and their precedence. The authors [8] present a genetic algorithm-based cellular radio channel allocation and fuzzy-based call dropping algorithm. Though the combined algorithm achieves

significant enhancement in quality of service and provides a better signal-interference ratio as compared to other dynamic channel allocation schemes but has a higher channel allocation delay. Reference [17] distributes disjoint set of channels to mobile service stations which ensures that large number of channels will be allotted to high traffic cell and lesser number of channels to be loaded in sparse traffic cells. The algorithm does not induce any intra-cell handoffs. The scheme has a low overhead but has higher channel acquisition delay and lower reliability as the cell requests are processed by the mobile service station (MSS).

The work [18] used a fuzzy clustering technique for distributed dynamic channel allocation where cluster heads were randomly selected, without taking any account the concept of non-uniform traffic. The criteria of selecting the cluster head(s) was to randomly select a cell as cluster head. Once a cluster head is selected, the procedure recursively selects other cells (as cluster heads) which are at distance of 3 cell radii unit from the centre of said cell. This method continues for all the cells in the network. The other cells were then clustered according to different cluster heads. The main objective of this technique was to reduce the message complexity in distributed dynamic channel allocation technique. The performance in terms of channel acquisition delay degrades for real-time non-uniform traffic.

All the channel allocation techniques referred above have considerably high message complexity resulting in higher resource cost for channel allocation and sometimes even fail to adapt to the changing traffic load. On the contrary the proposed technique caters to the moving traffic need and minimizes the overall channel acquisition delay.

In this paper, we propose a simple load sentient fuzzy cluster-based hybrid channel allocation technique, where the upcoming traffic of each cell is predicted based on certain pre-defined factors using backpropagation technique. The cells with heavy traffic are selected as heads and other cells are clustered with respect to the heads into different clusters using mutual distance as a membership function. Each cluster has a distinct cluster head. The dynamic channels are assigned to the cluster heads for distributing channels to the member cells of the cluster. It is proved through simulation that the proposed algorithm is able to efficiently find an optimal solution for the channel assignment problem.

The paper is organized as follows. The preliminaries are discussed in Section 2. Section 3 presents the problem formulation. An overview of the performance of the proposed technique is presented in Section 4. Section 5 concludes the paper.

## 2. Preliminaries

### 2.1 Backpropagation Technique

The backpropagation technique [19] is a modified feed forward method of training a neural net in which the initial system output is compared to the desired output, and the

system is adjusted until the difference between the two is minimized. The error in each iteration is calculated as:

$$\epsilon = f(\text{actual output} - \text{desired output})$$

where  $\epsilon$  is the error and  $f$  can be a linear or non-linear function depending on the activation function used by the neuron(s) in the network.

In this algorithm once the network is trained, the network will categorize the incoming traffic data of each cell as high, medium and low.

## 2.2 Fuzzy Clustering

The technique ‘‘clustering’’ is used in many classification algorithms. Cluster analysis categorizes data into groups referred to as ‘‘clusters’’ where similar data elements fit into the same cluster and dissimilar objects are placed into different clusters. The ensuing data partition improves data interpretation and reveals information about its internal constitution. The crisp clustering algorithms divide a data set into groups, where data objects with ‘‘similar features’’ are grouped under the same cluster whereas dissimilar data objects should be placed into different clusters. Each data can be a member of only one cluster.

In real applications the cluster members might not be exclusive, so fuzzy clustering technique [20] is often more appropriate for the data set. Membership function is used to assign each data to cluster(s) instead of crisp assignments of the data to any cluster. Each object can be a part of more than one cluster simultaneously depending on its membership value (which ranges from zero to one) with respect to the clusters.

$$\mu_{ij} \in [0, 1], 1 \leq i \leq x\text{-dimension}, 1 \leq j \leq y\text{-dimension}$$

In the proposed technique, when the value of membership function  $\mu$  is 0 it indicates that a particular cell is not a part of a cluster and the value ranges from greater than 0 to less than 1 in other cases.

## 3. Problem Formulation

In this section, we formally describe in detail the system model and the formulation of the channel allocation problem.

### 3.1 System Model

Given a set of frequency spectrum specified for wireless communication and a sample cellular architecture (collection of geographical regions marked as cells), an optimum channel assignment strategy for non-uniform traffic has to be developed so that the channel acquisition delay is minimum with negligible or no interference involved.

A hybrid channel allocation algorithm is presented that adapts to various traffic patterns in different geographical regions. In this paper, we assume that the given cellular model has  $9 \times 9$  cells (9 rows and 9 columns), where each cell has 6 adjacent cells (cells with common boundary) as shown in Fig. 1.

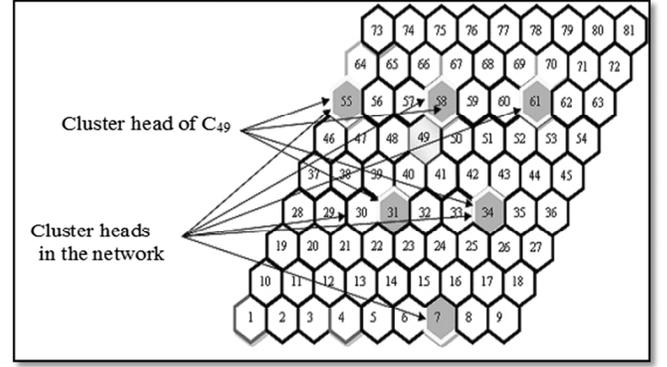


Figure 1. System model with  $9 \times 9$  cellular system showing the overall cluster heads in the network and the cluster head of a cell  $C_{49}$ .

#### 3.1.1 Interference Model

A circular model of interference has been used. If the radius of transmission of a cell  $C$  (base station in  $C$ ) is denoted as  $R$ ; it indicates that there is no interference from the signal transmitted by node  $N$  outside the circle (with radius  $R$ ) of transmission.

It is further assumed that the value of the minimum reuse distance  $D_{\min} = 3$  cell radii unit (where cell radii is in meter), *i.e.*, two cells  $C_1$  and  $C_2$  can use the same channel if the distance between their centres is at least 3 to avoid any co-channel interference. If two nodes from  $C_1$  and  $C_2$  respectively (assuming distance  $(C_1, C_2) > 3$ ) are involved in a call using sub-channel  $p$ . To facilitate this call successfully the following criteria need to be satisfied.

1. Cells  $C_1$  and  $C_2$  must not be involved in any other call transmission/reception in sub-channel  $p$  to ensure that a sub-channel  $p$  does not serve two transmissions in the same channel slot.
2. Interfering neighbours  $INC_1$  of  $C_1$  must not use (transmission/reception) sub-channel  $p$  simultaneously. Otherwise the transmission will suffer interference.
3. Interfering neighbours  $INC_2$  of  $C_2$  (transmission/reception) must not use sub-channel  $p$  simultaneously. Otherwise the transmission will suffer interference.
4. A frequency gap of  $n$  bands must be maintained between two successive sub-channels to minimize adjacent channel interference.

There are 100 sub-channels. The number of slots per sub-channel is 128. The sub-channels are modelled according to Rayleigh fading.

#### 3.1.2 Traffic Model and Prediction

We have assumed that the rate of call arrival follows Poisson distribution and any call lasts for approximately 180 s.  $\lambda$  denotes the rate of arrival of the new calls/requests. The value of  $\lambda$  for highly loaded cell is selected to be thrice than the low traffic cell. The source and destination nodes move at a speed of 5 m/s.

The proposed method initially numbers the cells randomly and calculates the current load and the projected load (referred as load index) of each cell using

Table 1  
Data Structure Used for Algorithm

Symbol	Description
$C_i$	Refers a cell where $i$ is the cell number $1 \leq i \leq 81$
$\text{centre}_{x,y}$	Centre coordinates of a cell
$\text{Clh}_i$	List of cluster heads
$M_i$	List of member cells under each cluster head
$\text{ML}_i$	List of interfering neighbours for each cell in $M_i$
$\text{FCh}_i$	Sub-carriers for fixed allocation
$\text{DCh}_i$	Sub-carriers for dynamic allocation
$\text{Ch}_i$	List of frequency sub-channels available
$\text{Chu}_i$	list of used frequency currently used by $C_i$
$\text{MemC}_{ij}$	Membership value of cell $i$ with respect to cluster head $j$ where $C_j \in \text{Clh}_i$
$\text{MClh}_{ij}$	List of cluster heads of cell $C_i$
$\text{LC}_i$	Current load of a cell
$\text{PLC}_i$	Projected load of a cell
$\text{LIndxC}_i$	Load index of a cell

backpropagation algorithm. The input data includes current load in the cell (LC), past traffic pattern ( $T_p$ ), average handoff ( $N_h$ ). Projected load is calculated based on current load, average traffic pattern (average of last 30 days) and average handoff based on recent history (last 30 days). The network is trained for classifying the input data as high, medium and low. The algorithm is intermittently executed to track changing pattern of the traffic load. The cells with high loads (current + projected) are selected as cluster heads. If two cluster heads are mutually interfering (*i.e.*, physically located within minimum reuse distance), then the contending cell with highest load is selected as cluster head. Now, the given cellular model is partitioned into a number of clusters (w.r.t. each cluster head) and assigns each cell into one or more clusters depending on their respective membership value. The membership value of each cell is calculated as the distance between the centre of the cell and the centre of the cluster heads. The available spectrum is divided into two disjoint groups fixed and dynamic. The fixed channel slots are distributed among all cells based upon their respective load index. The dynamic frequency spectrum set is allotted to the cluster heads. On arrival of a new/handoff call the cells send a request to their respective cluster head(s) whenever there is no unused fixed channel slot available for any new request. The cluster head(s) search for a free subcarrier and notify the other cluster heads of the cell, to check for any probable interference. Then finally a sub-channel, if available, is allocated to the requesting cell. For identifying the channels which can cause interference in a cell, each cluster head maintains a list of its member cells and

their respective interfering neighbours along with their current channel usage information. The cell releases the sub-channel as soon as the call is over. Intermittently the projected load of cells are recalculated and if there is an appreciable rise as compared to the usual load index a cell might retain the acquired sub-channels adapting to the changing traffic trends.

Now we propose an algorithm for load adaptive sub-channel allocation. Table 1 illustrates the set of variables and information structure concept is used for the algorithm.

### 3.2 The Algorithm

Input: Cellular model and call requests.

Output: Load adaptive cellular model.

The initialization phase of the algorithm identifies the traffic load of each cell and forms the clusters with cluster head.

#### 3.2.1 Initialization

##### Procedure Initialization

1.  $C_i \leftarrow$  The cells are numbered from 1 to 81  
 $C_i.\text{centre}_x, C_i.\text{centre}_y \leftarrow$  initialized with row and column number
2. for  $i = 1:81$  do  
 $C_i.\text{FCh} \leftarrow$  Fixed\_Sub\_Channels  
// Step 3 to Step 11 is for Traffic load computation and cluster head selection
3.  $C_i.\text{LC} \leftarrow$  Alive calls in progress + New call requests + New Handoff requests
4.  $C_i.\text{PLC} \leftarrow$  call proc backprop( $C_i.\text{LC}, T_p, N_h$ )  
Calculate avg\_traffic.
5. If  $C_i.\text{PLC} / C_i.\text{LC} \gg \text{avg\_traffic}$  handled by each cell then  
value  $\leftarrow$  very high  
else if  $C_i.\text{PLC} / C_i.\text{LC} > \text{avg\_traffic}$  handled by each cell then  
value  $\leftarrow$  high  
else if  $C_i.\text{PLC} / C_i.\text{LC} \approx \text{avg\_traffic}$  handled by each cell then  
value  $\leftarrow$  medium  
else if  $C_i.\text{PLC} / C_i.\text{LC} < \text{avg\_traffic}$  handled by each cell then  
value  $\leftarrow$  low  
else if  $C_i.\text{PLC} / C_i.\text{LC} \ll \text{avg\_traffic}$  handled by each cell then  
value  $\leftarrow$  very low  
end  
 $C_i.\text{LIndxC} \leftarrow$  value
6. Sort  $C_i.\text{LIndxC}$   
Select  $\text{Clh}_i$  where  $i \in 1: 81$
7.  $M_m.\text{MemC}_{ij} \leftarrow f\{\text{distance}(C_i.C, \text{Clh}.C_j)\}$  where  
 $1 \leq m \leq 81$   $m \neq j$  and  $j \in$  Cell number of cluster heads  
and  $0 \leq f\{\text{distance}(C_i.C, \text{Clh}.C_j)\} < 1$   
Let distance ( $C_i.C, \text{Clh}.C_j$ ) is denoted by ED

where  $\text{distance}(C_1, C_2) = \text{Euclidean distance between centers of cell } C_1 \text{ and } C_2 \text{ respectively.}$

Therefore,

$f\{ED\} \leftarrow 0 \text{ for } ED \geq D_{\min}$

$f\{ED\} \leftarrow |ED - D_{\min}| / D_{\min} \text{ for } ED < D_{\min}$

// The membership value for each cell other than cluster heads is calculated w.r.t cluster heads.

8. The cells are assigned to cluster(s) based on their membership value. The list of member cells for each cluster is calculated.
  9. for  $j \in \text{Cell number of cluster heads}$   
 $\text{Clh}_j.\text{ML}_i \leftarrow \{ C_i : \text{distance}(C_i, C_j) < D_{\min} \ \& \ i \neq j \}$  ;  
 $D_{\min} = 3 \text{ where } 1 \leq i \leq 81$   
// The list of interfering neighbors for each member cell is identified and recorded by the respective cluster heads. If there exists a cell  $C_i$  such that  $\text{distance}(C_i, C_j) > D_{\min} \ \& \ i \neq j$  for all  $C_j$  then  
 $\text{Clh}_j.\text{ML}_i \leftarrow \{ C_i | \text{distance}(C_i, \text{Clh}_j) = \min(\text{distance}(C_i, C_j) \text{ for all } C_j) \}$
  10. // The list of channel used by any member cell is procured  
 $\text{Clh}_j.\text{Chu} \leftarrow \text{List\_used\_sub\_channel}$
  11.  $\text{Clh}_j.\text{DCh} \leftarrow \text{Dynamic\_Sub\_Channels}$
- End Initialization

**Lemma 1.** *A cell which is not a cluster head can be a member of at most 4 clusters.*

**Proof:** Let the centre of a cluster head  $\text{Clh}_{ij}$  be  $i, j$ . The other possible cluster heads (depending on load) will have centres as  $\{i + m, j\}; \{i, j + m\}; \{i - m, j\}; \{i, j - m\}; \{i - m, j + m\}; \{i + m, j - m\}; \{i - m, j - m\}; \{i + m, j + m\}$  where  $m \geq 3$  (since  $D_{\min} = 3$ )

Now let a cell  $C$  with centre  $i + a, j + b$  be the member of the cluster with cluster head  $\text{CH}_{ij}$  where  $|a| \leq 2$  and  $|b| \leq 2$  (since  $D_{\min} = 3$ ).

Now  $\text{Mem}_{C_{i+a, j+b}} = \text{EuclideanDistance}(C, \text{Cluster-Heads}) / D_{\min}$  such that  $0 \leq \text{Mem}_{C_{i+a, j+b}} \leq 1$

Let  $m = 3, a = \pm 1$  and  $b = \pm 1$

**Case 1:  $m = 3, a = 1$  and  $b = 1$**

The only cluster heads which are at a distance  $< D_{\min}$ , from cell  $C$  are with centres  $\{i, j\}; \{i + m, j\}; \{i, j + m\}; \{i + m, j + m\}$ .

**Case 2:  $m = 3, a = 1$  and  $b = -1$**

The only cluster heads which are at a distance  $< D_{\min}$ , from cell  $C$  are with centres  $\{i, j\}; \{i + m, j\}; \{i, j - m\}; \{i + m, j - m\}$ .

**Case 3:  $m = 3, a = -1$  and  $b = 1$**

The only cluster heads which are at a distance  $< D_{\min}$ , from cell  $C$  are with centres  $\{i, j\}; \{i - m, j\}; \{i, j + m\}; \{i - m, j + m\}$ .

**Case 4:  $m = 3, a = -1$  and  $b = -1$**

The only cluster heads which are at a distance  $< D_{\min}$ , from cell  $C$  are with centres  $\{i, j\}; \{i - m, j\}; \{i, j - m\}; \{i - m, j - m\}$ .

By induction it can be said that is true for all values of  $a, b$  when  $m = 3$ . Therefore, it can be concluded that a cell which is not a cluster head can be a member of at most four clusters.

The next part of the algorithm is for searching and acquiring channel in a non-interfering manner.

### 3.2.2 Call Request – Searching and Acquiring a Channel

#### Procedure Call\_Request

1. A cell  $(M_k, C_i)$  sends call requests (for new and handoff calls) to its respective cluster head(s) if it does not have any free fixed carrier, where  $k \in \text{Cell number from 1:81-Cell number for cluster heads}$
2. Call Procedure Search\_Channel( $\text{Clh}_j.\text{DCh}$ )
  1. If Search\_Channel( $\text{Clh}_j.\text{DCh}$ )  $\neq$  null  
 $\text{Clh}_j.\text{Chu} \leftarrow \text{Clh}_j.\text{Chu} \cup \text{channel}_p$  where  $\text{channel}_p \in \text{Clh}_j.\text{DCh}$   
Broadcast\_all\_clusterheads( $\text{channel}_p$ )
  2. If Search\_Channel( $\text{Clh}_j.\text{DCh}$ ) = null  
Call Procedure Reject\_Call

/\*On receiving rejection of request from any cluster head, another search for available sub-carrier slots is initiated. If no free carrier is available with any cluster heads, the call is rejected.\*/

End Call\_Request

#### Procedure Search\_Channel( $\text{Clh}_j.\text{DCh}$ )

Begin

If Selected  $\text{Clh}_j.\text{DCh} \cap \text{Clh}_j.\text{Chu} \leftarrow \emptyset$

return selected  $\text{channel}_p$  //  $\text{channel}_p \in \text{Clh}_j.\text{DCh}$

else return null

End Search\_Channel

#### Procedure Reject\_Call

Drop/Block Call

End Reject\_Call

**Lemma 2.** *Let any cell (which is not a cluster head) be a member of maximum  $n$  number of clusters, then the average message complexity of the technique  $6n^2$ .*

**Proof:** Let any cell (which is not a cluster head) be a member of maximum  $n$  number of clusters. Now each cluster has a cluster head; so  $n$  numbers of cluster heads are there.

In the first step of the proposed technique the mobile host (at the arrival of a call request) requests for a channel from the Base station. If a fixed sub-channel is available no further messages are exchanged (message complexity in this case is 0).

If no free fixed sub-channel is available then the base station communicates to all  $n$  cluster heads (message complexity for to and fro communication is  $2 \times n$ ).

Each cluster head searches for a free non-interfering sub-channel and once it is obtained communicates with rest  $(n - 1)$  cluster heads for approval (for first attempt the message complexity for this search and approval procedure is  $n \times (n - 1)$ ).

Therefore, the average message complexity for any requesting cell other than cluster heads is calculated as:

$$\text{Avg\_message\_complexity} = \sum_i (2 \times n) + n \times (n - 1) \times i$$

where  $i$  is the number of unsuccessful attempts (including searching for fixed sub-channels)

If  $i = 3$  (for 3 unsuccessful attempts)

$$\begin{aligned} \text{Avg\_message\_complexity} &= (0 + (2 \times n + n \times (n - 1)) \\ &+ (2 \times n + n \times (n - 1) \times 2) \\ &+ (2 \times n + n \times (n - 1) \times 3)) / 4 \\ &= 6n^2 \end{aligned}$$

In the call terminating phase the cell will release the dynamic channel (if acquired, in case of non-availability of free fixed sub-channel) and remove the same from the list of used channel. Only in case the projected load of the cell appreciates to a greater extent, the cell will be able to retain the channel for use.

### 3.2.3 Terminating a Call – Releasing a Sub-Channel

#### Procedure Call\_Termination

If  $\text{PLC}_i > \text{Threshold}$

Retain channel<sub>p</sub>

else

$\text{Clh}_j.\text{Chu} \leftarrow \text{Clh}_j.\text{Chu} - \text{channel}_p$

Release channel<sub>p</sub>

End Call\_Termination

/\*A cell releases a dynamic sub-channel as soon as the call terminates. If there is an appreciable rise in load index a sub-channel might be retained with permission from concerned cluster head.\*/

For evaluating the changing traffic load of each cell a traffic load computation is executed intermittently (Step 3 to Step 11). This processing is separate from the channel acquiring procedure and the modification of cluster and cluster head(s) (if needed) is uploaded dynamically.

To project the future traffic pattern of a cell and estimating the threshold (avg\_traffic) of the system, the traffic prediction module is used.

### 3.2.4 Traffic Prediction through Backpropagation Algorithm for Determining Threshold

Procedure backprop (long int C\_load, long int traffic, long int handoff) /\*backpropagation procedure with 3 layers, 3 nodes in the input layer, 2 nodes in the hidden layer and 1 node in the output layer\*/

begin

1. Calculate the inputs
2. Calculate the output
3. Calculate the error with known target
4. Modify weights.
5. Repeat Step 1 to Step 5 till error < 0.002

## 4. Simulation and Performance Analysis

In Section 3, we described the system model and subsequently presented a load aware distributed channel allocation algorithm for the system. We have used network simulator NS-2 (**Version 2.35**), for the simulation. It is a discrete event driven network simulation tool for implementing and analysing different parameters of communication networks. The wireless model consists of the “MobileNode” with additional supporting features that allow simulations of wireless cellular network. The mobility features including node movement are already provided. Result of the simulation is provided within a trace file that contains all occurred events. Table 2 refers to the parameters used for simulation scenario.

Table 2  
Simulation Parameters with their Corresponding Values

Parameters	Values
Area of simulation	450 m × 450 m
Grid size	50 m <sup>2</sup>
Mobile nodes number	100–160
Antenna model	Omni-directional
Propagation delay of the wireless link	1 ms
Propagation delay of the wired link	10 ms

The proposed algorithm adapts itself to the changing traffic load in any cell. The message complexity of the algorithm is low, and hence it is energy efficient. In any channel allocation technique the other two essential factors contributing to the performance are the delay between requests generated and actual allocation and the number of call blocks and call drops. The proposed channel allocation scheme is analysed with some existing techniques in terms of four different performance criteria.

- i. Message complexity
- ii. Channel acquisition delay
- iii. Call block rate
- iv. Channel utilization ratio

Message complexity refers to the number of messages exchanged at the time of acquiring a channel [1]. The channel acquisition delay is defined as the time difference between the call request initiation by a cell and the actual channel allocation (if possible) to the requesting cell. The call blocking probability refers to the number of call requests granted to the actual number of requests generated [1]. Channel utilization ratio gives an estimate of the overheads involved during transmission.

For evaluating the four factors, the simulation scenario (Table 2) is used with each cell having 6 adjacent cells with common boundaries as shown in Fig. 1. It has been assumed there are 10 channels in the system where the ratio of dynamic to fixed channel is 4:1. The minimum reuse distance  $D_{\min}$  is considered as 3 cell radii unit  $\approx 22$  meter. Hence, the number of interfering neighbours is 18. The

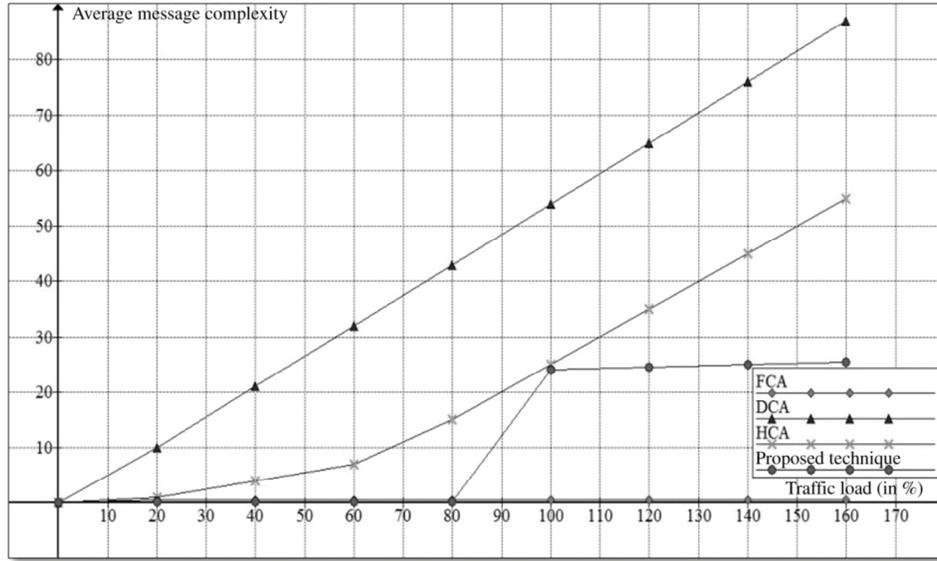


Figure 2. Performance analysis of the proposed algorithm showing message complexity for non-uniform traffic.

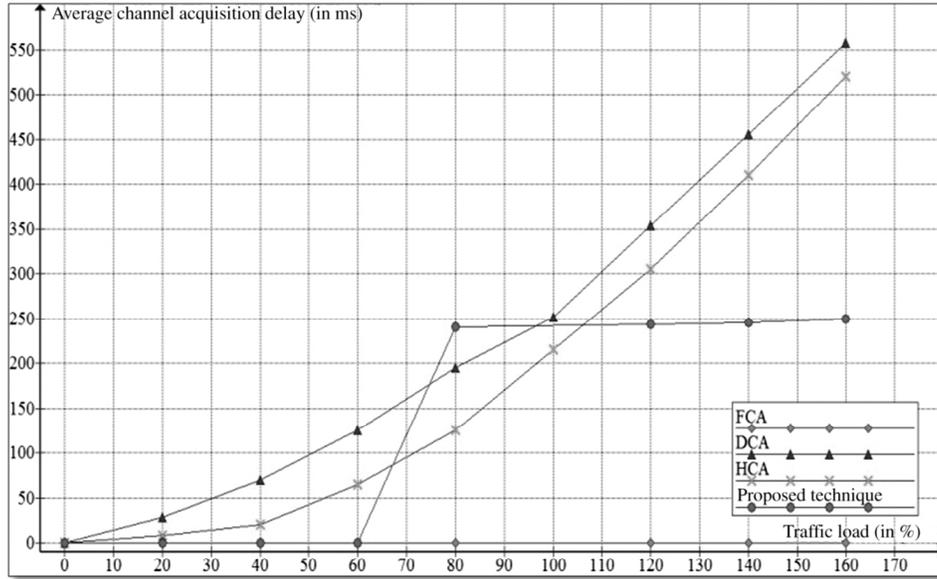


Figure 3. Performance analysis of the proposed algorithm showing channel acquisition delay for non-uniform traffic.

performance of the proposed algorithm is depicted using NS-2 with xgraph utility. The factors – message complexity, channel acquisition delay, call block rate and channel utilization ratio – are considered as follows:

- i. *Message complexity*: The message complexity in this case is determined by the number of message exchange between the cell base station and the cluster head(s). The average message complexity for any call in a cell other than cluster heads is  $(0 + (2 \times n + n \times (n - 1)) + (2 \times n + n \times (n - 1) \times 2) + (2 \times n + n \times (n - 1) \times 3)) / 4 = 6n^2$  (for three unsuccessful attempts including searching for fixed channels) where  $n$  is the number of cluster heads for a cell. In maximum possible case  $n = 4$ , *i.e.*, average message complexity is 96. The message complexity of simple, DCA [21], FCA [22] and HCA

[10] is compared with the proposed technique (shown in Fig. 2). The performance of our algorithm is better than DCA and HCA, but due to fixed allotment of channels the FCA have least message complexity.

- ii. *Channel acquisition delay*: Considering non-uniform load distribution throughout the network, the average channel acquisition delay can be calculated as  $6 \times n^2 \times T$  (less than DCA [21], HCA [10] but more than FCA [22]) shown in Fig. 3. The latency involved was mainly due to the message transmission between base station of requesting cell and its cluster head(s). Considering local channel searching time to be insignificant and  $T =$  message transmission delay between two cells (with the assumption that the fourth search will be successful).

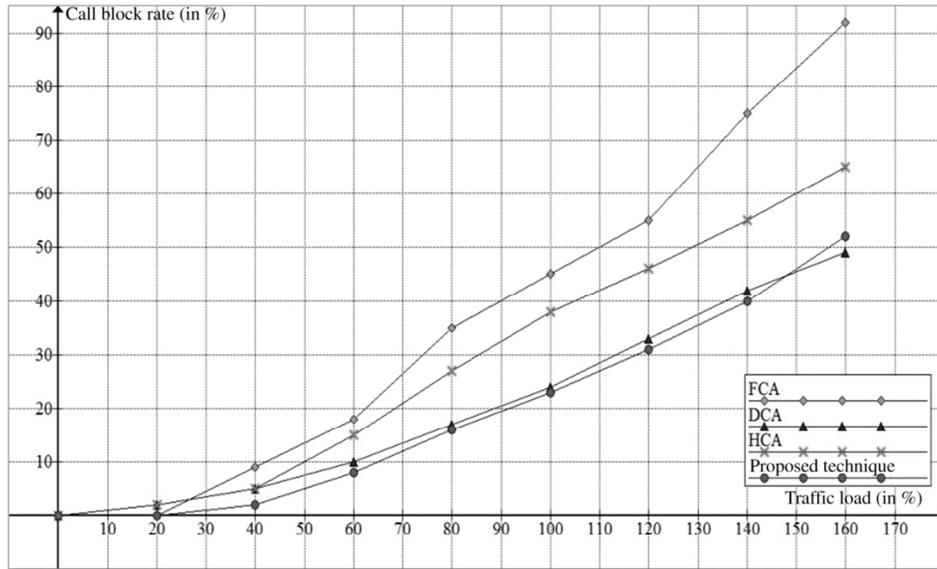


Figure 4. Performance analysis of the proposed algorithm showing call blocking rate for non-uniform traffic.

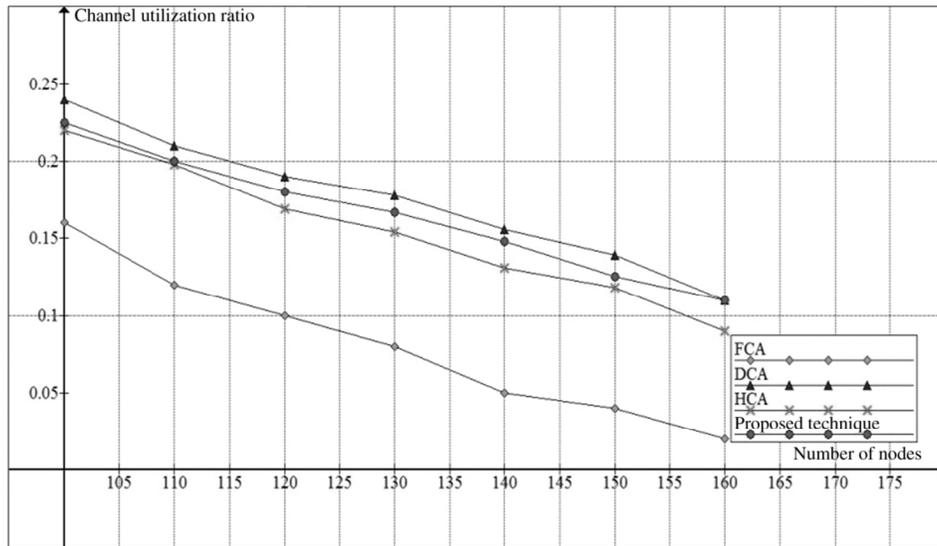


Figure 5. Performance analysis of the proposed algorithm showing channel utilization ratio for non-uniform traffic.

iii. *Call block rate*: Assuming non-uniform distribution of traffic the blocking rate is insignificant till 40 calls (assuming if average load distribution is only within the same cluster and reusability of channels with  $D_{\min} = 3$ ). The blocking rate appreciates as the number of calls shoot over 50.

The call blocking rate when compared with DCA [21], HCA [10] was as good as our algorithm (shown in Fig. 4) with rise in % of traffic load. The call blocking rate of the FCA [22] rises sharply as the traffic load increases.

iv. *Channel utilization ratio*: The channel utilization ratio considers the data bits transmitted and also includes the overhead incurred for the transmission. It is defined as the ratio of the information actually

transmitted and the channel bandwidth utilized. The channel utilization is very poor in FCA scheme and is improved in dynamic and hybrid channel assignment schemes (Fig. 5).

## 5. Conclusion

The paper proposes a load adaptive hybrid channel allocation technique for solving the problem of spectrum management in wireless communication network. The simulation results show that the message complexity and channel acquisition delay is negligibly affected by the rise in the number of calls. Further the values of the aforesaid parameters are lower as compared to simple DCA, HCA [10]. The overall performance of the proposed technique is

better than the three techniques discussed in the previous section, as the FCA is practically not feasible for non-uniform traffic. With non-uniform traffic, it is important that the heavily loaded cells (cluster heads in this technique) have higher preference over sparsely loaded cells. The “fuzzy clustering” technique based on traffic load ensures that the cluster heads have highest priority and hence have decision-making capability. The technique adapts to the changing traffic load, making it efficient for any geographical region with a combination of high and sparse traffic. The number of messages exchanged is greatly reduced as the cluster head(s) do not need to exchange messages for their own call requests (which are large in number and dominates the total number of calls in the network). Hence this factor greatly reduces the overall channel acquisition delay. The use of the concept of hybrid channel allocation (with the principle of OFDMA) further improves the overall spectrum utilization.

## Acknowledgement

This work is an expansion of the authors’ earlier published work, cited as [18], which offers a distributed dynamic channel allocation technique for uniform traffic using fuzzy clustering. The work proposed in this paper extends the concept of fuzzy clustering of cells for real-world scenario with non-uniform traffic and presents a load aware hybrid channel allocation technique.

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