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# Performance Analysis of OBDLB Channel Allocation Algorithm

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## ABSTRACT

Mobile computing has found increased applications and gained importance in the last decade. In modern cellular radio systems, the number of subscribers is likely to grow rapidly. Increasing the capacity of these systems, i.e., the number of users per unit area that can be managed at some predefined level of service quality is of vital importance. This paper proposes an Optimized blocking dropping load balancing (OBDLB) channel allocation scheme. Vertical layered agent architecture (INTERRAP) has been chosen to make the dynamic decisions and do the computation in the remote destination in order to reduce the network traffic and efficiency of resource allocation. Simulation results have shown that the call dropping rate of the proposed scheme is only 0.1% for a small sized network under light load and 37% for large sized network under heavy load when channel holding time is 100 seconds.

## General Terms

Agent & Multi-agent, Channel Allocation.

## Keywords

Hybrid Channel Allocation, Dynamic Channel Allocation.

## 1. INTRODUCTION

The past five decades have seen surprising progress in computing and communication technologies that were stimulated by the presence of cheaper, faster, more reliable electronic components in the market. The design of smaller and more powerful devices enabled their mobility, which is quickly changing the way we compute and communicate. Wireless and mobile networks are emerging as networks of choice, due to the flexibility and freedom they offer. The use of satellite, cellular, radio, sensor, and ad hoc wireless networks, wireless local area networks (LAN), small portable computers, and personal communication systems (PCS) is increasing. These networks and devices support on the move computing trend, known as mobile computing, nomadic computing, or computing anywhere anytime. The applications of mobile computing and wireless networks include e-commerce, personal communications, telecommunications, monitoring remote or dangerous environments, national defense (monitoring troop movements), emergency and disaster operations, remote operations of appliances, and wireless Internet access.

Explosive growth has been witnessed during the last few years in the demand for mobile communication services, particularly in cities [8]. From available studies, it is clear that this rate of increase in mobile communication services will continue for quite some time [1]. In order to make an arrangement for this projected increase and solving the present crisis of channel scarcity for mobile radio use, some improvements to mobile wireless systems have been recommended.

One of the favored and most frequently used techniques for increasing the capacity or efficiency of frequency spectrum utilization is the implementation of a cellular architecture in mobile communication. In the cellular architecture approach, the entire geographical area is divided into cells or zones and each cell is serviced by a mobile service station (MSS), which is located at the center of each cell. In the cellular systems, instead of using one powerful transmitter, many low power transmitters are deployed throughout the coverage area. Each transmitter talks to many mobiles at once, using one channel per mobile. Channels use pair of frequencies for communication, one frequency for transmitting the call and another frequency for receiving the call. When a mobile device, also called a mobile host (MH), wants to start a communication session with another MH, it sends a connection request to the nearest MSS through a control channel. After receiving the request, the MSS searches for a free radio channel which must not be in use in that cell or in neighboring cells, otherwise interference of signals would occur. If such a free radio channel is found, the MSS will inform the MH to use it. Then, the MH starts sending and receiving data packets through the selected free channel, and the MSS will forward those packets to and from other parts of the wired network.

The remaining paper is structured as follows. In Section 2 channel allocation problem is discussed. In Section 3 we present proposed OBDLB algorithm for frequency channel allocation. We investigate the performance of the proposed algorithm in Section 4. Finally, the paper is concluded in Section 5 by discussion of options for improvement.

## 2. THE CHANNEL ALLOCATION PROBLEM

The Channel Allocation Problem has two aspects [5]:

i. Frequencies are allocated to a pair of wireless communication connections in such a way that data transfer between every connection is possible. The frequencies must be selected from a pre-specified set and different frequencies should be allocated to each connection. For bidirectional traffic, two frequencies should be selected one for each direction.
ii. The frequencies allocated to different connections may interfere with each other resulting in a loss of signal quality. The following two conditions must be satisfied for interference to take place:
    a) The frequencies must either be close on the electromagnetic band or harmonics of one another. However, latter effect is very limited.

b) The two interfering connections must be very close to each other. The interfering signals must have similar energy levels at the positions where they may disturb each other.

The radio frequency band $[f_{min}, f_{max}]$ provided to service provider is generally partitioned in a set of channels, and all the channels are having same bandwidth $\delta$ of frequencies. The channels are generally numbered from *1* to *N*, where $N = (f_{max} - f_{min})/ \delta$ and the existing channels are denoted by the domain $D = \{1, . . . , N\}$. It may happen that not all the channels from a domain D are available for a particular connection. The channels available for a particular connection *v* form a subset $D_v \in D$ and information can be transmitted from transmitter to receiver on each available channel. Two channels are required for bidirectional communication, one for each direction. The second channel is always ignored n the models considered in the literature. Instead of using one band $[f_{min}, f_{max}]$, most of the applications use two bands $[f^1_{min}, f^1_{max}]$ and $[f^2_{min}, f^2_{max}]$ of N channels: one with the channels $\{1, . . . , N\}$, and another with the channels $\{s + 1 , . . . , s + N\}$, where $s >> N$. Therefore, the backward connection uses a channel which is shifted s channels up in the frequency domain. The *s* should be chosen in such way that backward channels do not interfere with the forward channels. As a result, every allocation for the forward channels can directly be transformed to an allocation for the backward channels with comparable performance.

The two-way traffic creates several problems, as interference may not be symmetric: if a transceiver pair $(t_1, t_2)$ transmitting on frequencies $f$ and $(f + s)$ from $t_1$ to $t_2$, and another transceiver pair $(s_1, s_2)$ transmitting on frequencies $g$ and $(g + s)$ where $f$ and $g$ interfere, $(f + s)$ and $(g + s)$ interfere, the amount of interference at $t_1$ and $t_2$ may be different because these transceivers may possibly be having different distances from $s_1$ and $s_2$. This aspect is also overlooked by most researchers.

Based on the application, one or multiple connections may be set between the same end points. Therefore, this is modeled by assuming that $(c_z \in Z^+)$ frequencies are allocated to connection *v*. Therefore, with the introduction of an extra value for certain combination of frequencies $(f,g \in D)$, the interference between frequencies allocated to the same connection can only be avoided. In practical conditions and based on the demand for connections, the value $c_z$ may vary with time. Through this property, the methods suggested to deal with the channel allocation problem can be divided into three categories: Fixed Channel Allocation (FCA), Dynamic Channel Allocation (DCA), and Hybrid Channel Allocation (HCA).

In FCA, radio channels are allocated to each connection in advance and allocation is based on the forecasted demand. Therefore, in order to satisfy the demand for connections the radio channel allocation is not allowed to change on-line. Whereas, in DCA schemes frequencies are allocated on-line to the wireless connections in such a way that the actual demand is met and the interference is minimized. Finally, HCA scheme is a combination of FCA and DCA and is implemented to get an enhanced overall performance of the network. In HCA schemes some of the frequencies are allocated to every connection beforehand, whereas rest of the frequencies can be used for on-line allocation upon request.

# 3. INTERRAP: VERTICAL LAYERED ARCHITECTURE

INTERRAP is a technique to model resource-bounded interacting agents by associating reactivity with deliberation and cooperation capabilities [7]. INTERRAP is based on a BDI architecture, i.e., the informational, motivational, and deliberative state of an agent [2], which is explained through beliefs, goals, a rather generalized version of plans, and intentions. Agent input (perception) is connected to agent output (action) through a set of operations that describe the inter-relationship between different mental categories of an agent. However, as compared to BDI architectures like [3], [4], the mental categories and the operational relationships between them are derived into three hierarchical layers and link them through a hierarchical control mechanism. The implementation of above mentioned design decisions resulted in an INTERRAP agent architecture, shown in Fig. 1.

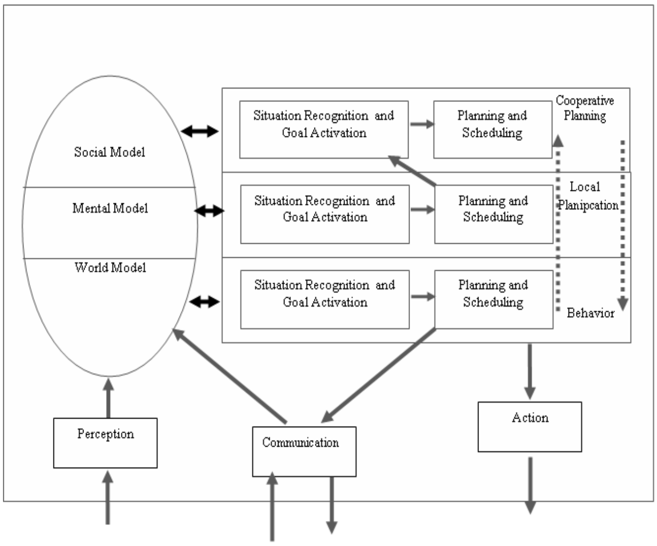

**Fig. 1: INTERRAP Agent Architecture**

## 3.1 The Control Unit

The control unit of INTERRAP agent architecture has three layers, i.e., behavior-based layer, local planning layer, and cooperative planning layer, which are explained as:

### *3.1.1.1 Behavior–Based or Reactive Layer*

The job of a reactive layer is to allocate channels to the new as well as to the handoff calls. The basic channel allocation algorithm used in this layer for allocating channels is explained as follows:

### *3.1.1.1 Proposed Algorithm : Optimized Blocking Dropping Load Balancing (OBDLB) Algorithm*

To achieve the objectives of research work, a hybrid channel allocation algorithm Optimized Blocking Dropping Load Balancing (OBDLB) is proposed.Various steps that are involved in allocating channels to the calls are shown below:

***Step 1****. Call is received*

***Step 2****. System first checks whether it is a new call or a handoff call*

***Step 3**. If it is a handoff call*

- *a. System first identifies the cell-Id or a sector-Id of the cell or the sector where the call is coming from*
- *b. After identifying the cell or sector Id, the system then moves on allocating the free channel to the call*
- *c. The search for the free channels begins with the nominal channels first that are allocated to the cell and it then moves to step 1*
- *d. If free nominal channel is not found then search process shifts to the dynamic channels present in the cell and it then moves to step 1*
- *e. If all the dynamic channels are also busy then the free channel is searched from a pool and then it moves to step 2.*

***Step 4**. If received call is a new call*

- *a. After identifying the cell or sector Id, the system then moves on allocating the free channel to the call*
- *b. The search for the free channels begins with the dynamic channels that are allocated to the cell and it then moves to step 1*
- *c. If free nominal channel is not found then search process shifts to the dynamic channels present in the cell and then it moves to step X*
- *d. If all the dynamic channels are also busy then the free channel is searched from a pool and it moves to step Y.*

***Step X:***

1. *Select a first frequency channel from a cell*
2. *Find a free time slot in the selected frequency*
3. *If a free time slot is found then allocate it to the call*
4. *If free time slot is not found in the selected frequency then move to next frequency*
5. *Search all the frequencies to find a free time slot*

***Step Y:***

1. *Select one frequency channel from the poll*
2. *Before allocating a frequency channel to the call, compare if number of channels present in the cell ≥ threshold level of 25% (a cell cannot hold more than 25% of the total channels allocated to the network)*
3. *If number of channels present in the cell is more than the threshold value then no more channel would be allocated to the call and the call would either be blocked or dropped*
4. *If number of channels present in the cell is less than the threshold value then channel is selected from a poll for allocation to the cell*
5. *Channel is allocated to the cell if it satisfies the cost function. The cost is based on the interference constraints, current degree of coldness*

   *If no channel is found from the pool that satisfy the cost function then call would be dropped or blocked*

## 3.2 Local Planning Layer

Local Planning performs channel reassignment based on signal-to-noise ratio calculations. When a departing user releases the channel, the reactive layer performs the following re-assignment decisions:

- If it is a dynamic channel, it will either be allocated to a new call or given back to the pool, depending upon the traffic load in that particular cell
- If it is a nominal channel, it will be re-assigned to a new user or non-departing user.

## 3.3 Co-operative Planning Layer

The Co-operative planning layer performs the load balancing of the entire network in order to keep the low rates of call blocking and droppings by moving the calls from heavily loaded cells, also called hot cells to less loaded cells or regions. This process is called deliberate traffic handoff.

# 4. PERFORMANCE MEASUREMENTS

A simulation program is written in Java to evaluate the performance of proposed algorithm. Proposed algorithm is examined through a simulated network consisting of network arranged in a n * n grid.

The key network performance measures used for the comparisons are:

1. Call dropping rate:
   total number of handoffs rejected / total number of handoffs requested.

2. Call blocking rate:
   total number of new calls rejected / total number of new calls requested.

## 4.1 Scenario 1-Network Size:49 Cells, Radio Channels:45

Scenario 1 consists a cellular network with 49 cells arranged in 7 * 7 grid. Total of 45 frequencies are allocated to the entire network. All the clusters are assigned with 7 nominal channels and rest of the channels is kept in a central pool. The channel reuse distance is assumed to be three cell units. In each cell, calls originate at random location and each mobile station uses the nearest base station. The call arrival process follows a poisson process and the average call duration of 25 secs, 70 secs and 100 secs is chosen for comparisons. It is also assumed that mobiles could function on any channel as dictated by the base stations and the base stations could transmit on any frequency assigned to them by the agent.

**No. of Calls = 5000 (approx.) in 900 seconds**

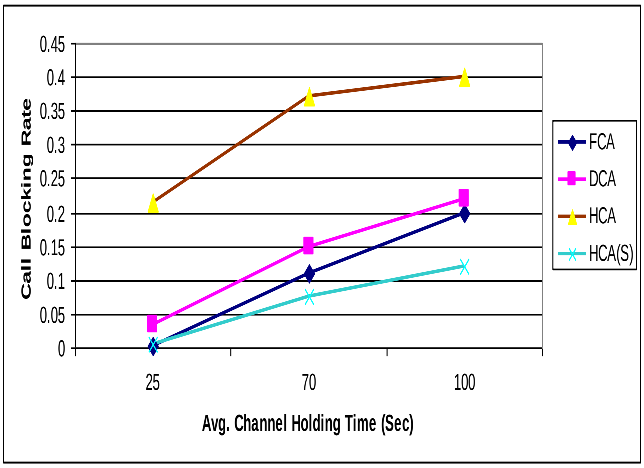

**Fig. 3: Call Blocking Rate under Light Load for Scenario 1 (Network Size: 49 Cells, Radio Channels: 45)**

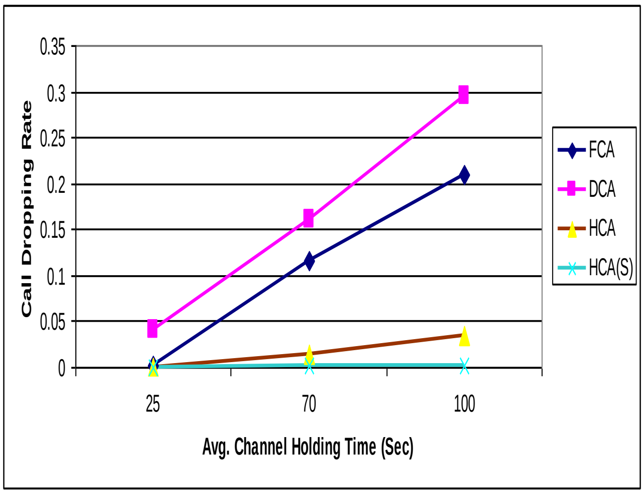

**Fig. 4: Call Dropping Rate under Light Load for Scenario 1 (Network Size: 49 Cells, Radio Channels: 45)**

The Fig. 3 shows the traffic blocking rate for a cellular network using FCA, DCA, HCA and HCA(S). The Y-axis represents the call blocking rate in the entire network and is computed by finding the ratio of blocked calls to offered calls in a given time period. The time period chosen in this case is 900 secs. The X-axis represents the average channel holding time of each call. The results in the graph (Fig. 3 & 4) show that HCA in this case slightly underperforms than the FCA and DCA. This is expected because when one cell reaches the threshold of channel availability all the other cells are also reaching the same threshold. But HCA(S) gives the lowest call blocking rate for increase in the avg. channel holding time from 25 secs to 100 secs. Fig. 4 shows the avg. call dropping rate with the traffic load of 5000 calls in 900 secs. HCA(S) gives the lowest call dropping rate followed by HCA. It is also interesting to note that under light load both FCA and DCA do not perform better than HCA and HCA(S). This was expected because HCA improved the handoff rejection rate as few calls are dropped as compared to FCA and DCA. This is due to the heuristic proposed inside the agent joint plan and it proves that the load balancing feature of the agent negotiation is behaving exactly as expected.

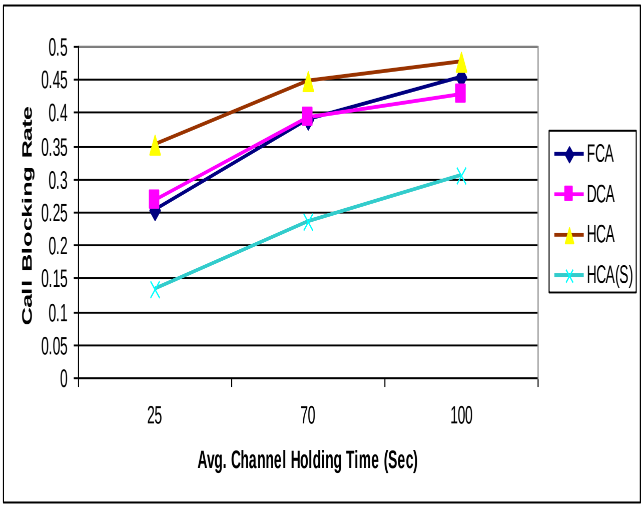

**Fig. 5: Call Blocking Rate under Heavy Load for Scenario1 (Network Size: 49 Cells, Radio Channels: 45)**

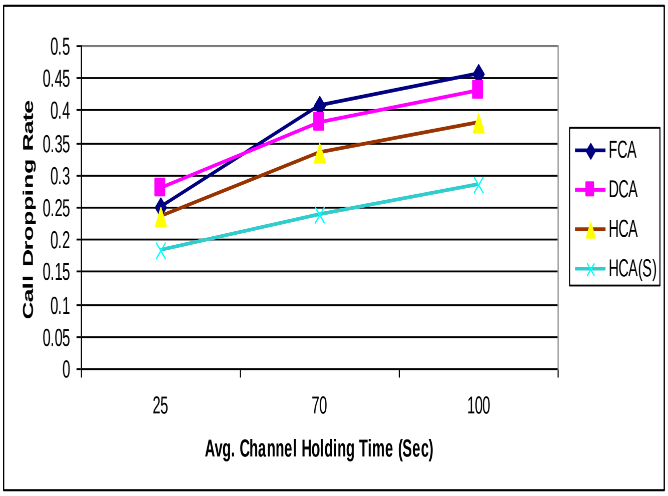

**Fig. 6: Call Dropping Rate under Heavy Load for Scenario1 (Network Size: 49 Cells, Radio Channels: 45)**

As expected the overall average call dropping rate of HCA(S) and HCA is lower than given by FCA and DCA under heavy load with different channel holding times. The call blocking rate of HCA(S) is lowest which is followed by FCA, DCA and HCA. This is due to the balancing feature of the agent negotiation and is behaving exactly as expected.

## 4.2 Scenario 2-Network Size:100 Cells, Radio Channels:45

It is now known that handoff blocking rate of both HCA and HCA(S) is much below the FCA and DCA but only HCA(S) gives lowest call blocking rates. In this scenario both call blocking rate and call dropping rate are computed on a different network size. Simulation scenario 2 has the same input parameters as scenario 1 and only the total network size has been increased from 49 cells to 100 cells of 10 * 10 grid.

**No. of Calls = 10,000 (approx.) in 900 seconds**

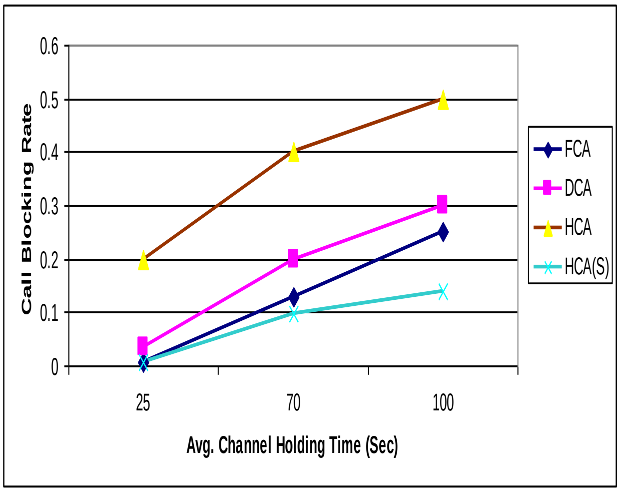

**Fig. 7: Call Blocking Rate under Light Load for Scenario 2**
**(Network Size: 100 Cells, Radio Channels: 45)**

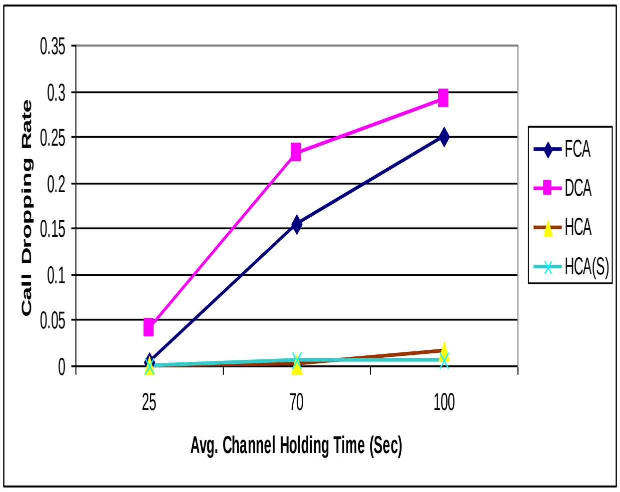

**Fig. 8: Call Dropping Rate under Light Load for Scenario 2**
**(Network Size: 100 Cells, Radio Channels: 45)**

The Fig. 7 shows the call blocking rate under different channel holding times. Only HCA(S) is capable of showing less call blocking rates than FCA and DCA but HCA gives higher rates. So therefore, only HCA(S) is capable of coping with the volume of the traffic by giving lower blocking rates.The Fig. 8 shows the effect of channel holding time on various channel allocation schemes. For FCA and DCA increasing the channel holding time from 25 seconds to 100 seconds has an adverse effect on the call dropping rate which is much higher than the HCA and HCA(S), which shows that the load balancing feature has been working well.

**No. of Calls = 18,000 (approx.) in 900 seconds**

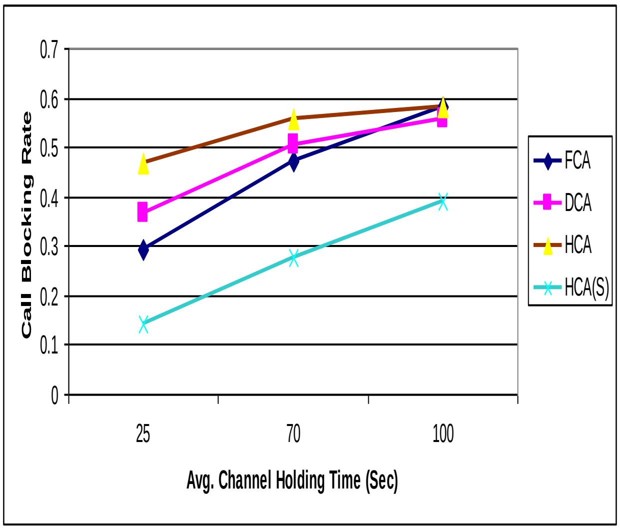

**Fig. 9: Call Blocking Rate under Heavy Load for Scenario 2**
**(Network Size: 100 Cells, Radio Channels: 45)**

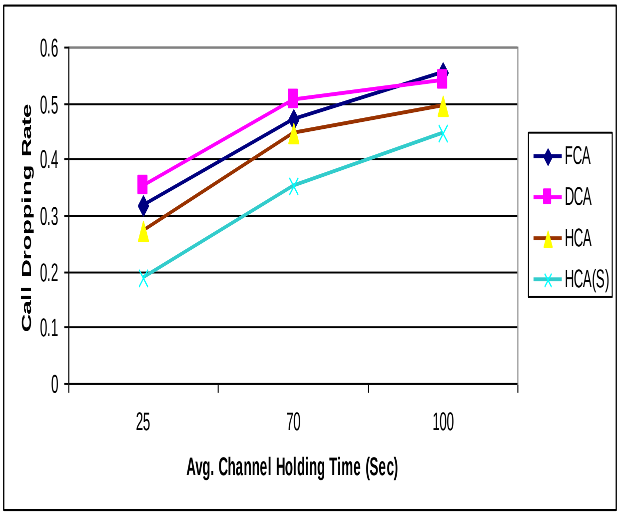

**Fig. 10: Call Dropping Rate under Heavy Load for Scenario 2**
**(Network Size: 100 Cells, Radio Channels: 45)**

From Fig. 9 and Fig. 10 we notice that the HCA(S) shows lowest call blocking rates. When the channel holding time is low all the schemes show different call blocking rates but when it is increased to 100 seconds all the schemes except HCA(S) show nearly same call blocking rates and the curve for the HCA has shown some decline. Whereas, both HCA and HCA(S) has performed better under heavy load by showing the low handoff dropping rates than the other schemes.

## 5. CONCLUSION

Hybrid channel allocation algorithm has been proposed for improving the capacity, which uses co-channel reuse distance as a criterion, and tries to achieve high efficiency of channel use by assigning co-channels to cells that are close to each other by co-channel reuse distance. In the simulations, the performance of OBDLB algorithm is compared with the conventional cellular channel allocation algorithms using

FCA and DCA which are based on channel borrowing and channel locking. Call blocking rate and call dropping rate have been taken as two key network performance measures for comparisons. Both HCA and HCA(S) perform exceptionally well in the case of handoff call droppings because handoff call rejections in HCA and HCA(S) are very less. This has happened due to the involvement of multiple agents in the joint plan that are present in the neighborhood of hot cells and, therefore, load balancing feature of the agent negotiation is behaving exactly as expected.

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