Genetic Algorithm Based Call Drop Reduction Model During Handoff in Mobile Communication

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Abstract

This paper highlights the potential of using genetic algorithms to solve cellular resource allocation problems. Generally, cellular resource allocation deals with how and when to allocate radio frequency channels to mobile hosts. The algorithm exploits the potential of genetic algorithm to design a fault-tolerant cellular resource allocation model. In some cases the load over a single cell is increased, so it needs more channels than it actually has to minimize the traffic problem and the number of the blocked hosts. On the other hand it is possible that the load on a cell is less than its channel capacity, so there is wastage of channels. We solved this problem by taking the extra channels from the cells that have a less load and allocate it to the cells that have an over load, temporarily. The algorithm is also solved the problem of handover using reserved channel technique, so we implement the dynamic channel allocation using genetic algorithm to minimize the number of blocked hosts and the handoff failures (as a part of the blocked hosts) in the mobile computing network system.

Keywords

Cell, Channel Allocation, Mobile Computing, Handoff, Genetic algorithm

I. Introduction

An important problem in the operation of a cellular telephone system is how to efficiently use the available bandwidth to provide good service to as many customers as possible. This problem is becoming critical with the rapid growth in the number of cellular telephones. Mobile telephone systems take advantage of the fact that many callers can use a communication channel i.e. a band of frequencies can be used simultaneously if these callers are spaced physically far apart such that their calls do not interfere with each other. The minimum distance at which there is no interference is called the channel reuse constraint [2].

In a cellular system, the service area is divided into a number of regions called cells. In each cell there is a base station that handles all the calls made within the cell. The total available bandwidth is divided permanently into a number of channels. Channels must then be allocated to cells and to calls made within cells without violating the channel reuse constraint. There are many ways to do this, some of which are better than others in terms of how reliably they make channels available to new calls. If no channel is available for a new the call is lost, or blocked, which is unacceptable [1-2].

The Genetic Algorithm (GA), useful for optimization problems, is based on the Darwin's theory of "survival of the fittest." Individuals, from the population of potential solutions, reproduce and solutions are refined successively over the number of generations. In the recent past, the application of GA has attracted the attention of researchers of numerous disciplines (e.g., operation research, economics, social sciences, life sciences, etc.) for problem solving [4, 13]. Researchers of mobile computing have used GA for the channel allocation problem. Zomaya and Wright used it for channel allocation and compared it to a greedy borrowing heuristic [1]. Kassotakis et al. proposed Hybrid GA for reusing isochronous channels in multiple access telecommunication networks [2]. An evolutionary genetic DCA for resource management is proposed by Asvial et al. that aims to provide optimum channel allocation for specified interference constraints using minimum cost as a metric [3].

The work described here exploits GA for the effective management of radio resources in dynamic channel allocation with channel borrowing. The next section discusses the channel allocation problem with a few important issues in mobile computing. A few related models are also given. In Section III, a short discussion over the Genetic Algorithm is made, followed by some GA-based channel allocation models. In Section IV, the proposed Improved GA (IGA) for channel allocation is described. Section V, lists the experiments conducted for the channel allocation

II. Channel Allocation in Mobile Computing

Wireless networking greatly enhances the utility of portable computing devices. The technical challenges that mobile computing must surmount to achieve this potential are hardly trivial. The main issues stem from three essential properties of mobile computing, i.e., communication, mobility, and portability. Wireless networks communicate by modulating radio waves or pulsing infrared light. Wireless networks are linked to the wired network infrastructure by stationary transceivers. The area covered by an individual transceiver's signal is known as cell. Cell radii vary from tens of meters in buildings to hundreds of meters in cities or tens of kilometers in the countryside. Cellular systems use small cells due to frequency reuse, less transmission power, and thin interference [6].

The ability to change locations yet connected to the network increases the possibility of the volatility of some information. Certain data considered static for stationary computing becomes dynamic for mobile computing. Moving mobile hosts will use different network access point or "addresses" [10] and, so, needs more location sensitive information than stationary devices. The handover is a common problem that arises due to mobility [9].

Over the years, not only have the number of mobile devices increased, but the applications running on the mobile devices are also getting more data driven. Due to increasing load, the number of mobile hosts that could not connect to the destination is increased. There are two ways to solve this problem. One is to increase the number of channels (radio frequency) with the corresponding increase in cost. The other is to utilize the current infrastructure efficiently so that the best performance is achievable. Obviously, the second option is better and preferable. In a mobile network, the number of wireless channels is usually limited and is reused. Channel reuse is defined as: If one channel is outside the interference range of other, it can reuse the same frequency and, thus, utilize the scarce resource. The efficient reusability of the channels improves the performance of the network. In Fixed Channel Allocation (FCA), the assignment of frequencies to a cell is fixed. This is inefficient if the traffic load on a channel varies from time to time and, thus, Dynamic Channel Allocation (DCA) is often used instead. A better method, in case of heavy load in one cell and light load in neighboring cell, is to borrow frequencies from neighbor cells. Cells with more traffic are dynamically allotted more frequencies. This scheme is known as Borrowing Channel Allocation (BCA) and is used in GSM systems; however, it requires careful traffic analysis. Other methods to deal with excess load in mobile networks in addition to channel borrowing are channel sharing and cell splitting [7]. Particularly, cell splitting is very common in many real cellular networks [8]. The channel allocation problem involves how to allocate borrow able channels in such a way that it maximizes the long term and/or short-term performance of he network [6]. The performance metric in the present work, to evaluate the proposed IGA for channel allocation, is the number of blocked hosts. A host is blocked if it enters into a cell but cannot get a channel. It is obvious that more blocked hosts result in performance degradation of the network. Thus, reduction in blocked hosts is sought in the present work. The number of borrowings should also be as few as possible because more borrowings incur more network traffic. The other metric that can be used to evaluate the performance is the number of "hot cells," a cell without any free channel [1]. A cell is considered "hot" when all the channels in a cell are allocated to hosts. Hot cells are undesirable because mobile hosts will be denied a service upon entering the cell.

Some relevant channel allocation models that use techniques other than channel borrowing are described below.

A. Cell Splitting

Cell splitting, used in many real cellular networks [8], works by breaking down cells into smaller cells. This is accomplished by having several different levels of cell coverage. These different levels are called macro and micro cells. A macro cell is essentially an umbrella over a set of micro cells. There are obvious drawbacks to this scheme as it prevents being implemented throughout the network because of cost involved. A secondary concern is the extra traffic introduced by the additional cells [1].

B. Least Interference

In the least interference method, the Access Point (cell) scans all available channels and selects the channel with the lowest interference power. If more than one channel shares the same lowest interference power, the channel used previously will be selected and, if none were used previously, the channel with the lowest number is selected [11].

C. Channel Segregation

In the channel segregation method, an ordered list is given to each Access Point (AP) and this list is updated according to interference conditions. The AP will scan the interference power for the highest priority channel in the ordered list. If the scanned interference power is below a threshold, this channel will be selected and the scanning process ends. The priority of each channel in the list is updated by a given function. The initial priority list can be arbitrary and is set to follow the channel number [11].

A Genetic Algorithm (GA) is a search algorithm based on the principles of evolution and natural genetics. GAs combines the exploitation of past results with the exploration of new areas of the search space. By using survival of the fittest techniques combined with a structured yet randomized information exchange, a GA can mimic some of the innovative flair of human search. A generation is a collection of artificial creatures (strings). In every new generation, a set of strings is created using information from the previous ones. Occasionally, a new part is tried for good measure. GAs is randomized, but they are not simple random walks. They efficiently exploit historical information to speculate on new search points with expected improvement. The majority of optimization methods move from a single point in the decision space to the next using some transition rule to determine the next point [11]. This point-to-point method is dangerous as it can locate false peaks in multimodal (many-peaked) search space. By contrast, GA works from a database of points simultaneously (a population of strings)

The mechanics of a simple GA are simple, involving nothing more complex than copying strings and swapping partial strings [6]. Simplicity of operation and power of effect are two main attractions of the GA approach. The effectiveness of the GA depends upon an appropriate mix of exploration and exploitation. Three operators to achieve this are: selection, crossover, and mutation. Selection according to fitness is the source of exploitation. The mutation and crossover operators are the sources of exploration. In order to explore, they must disrupt some of the strings on which they operate. The trade-off of exploration and exploitation is clearest with mutation. As the mutation rate is increased, mutation becomes more disruptive until the exploitative effects of selection are completely overwhelmed [2].

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One of the most important aspects that control a GA's performance is the encoding method chosen. The encoding refers to the method by which the problem parameters are mapped into a chromosome [2].

III. Related GA-Based Channel Allocation Models

Wong and Wassell proposed a dynamic channel allocation model using GA for a broadband fixed wireless access network. In the proposed model, the aim is to allocate the channel so as to reduce the Signal to Noise Ratio (SNR) and, at the same time, meet the traffic demands. They compared their model with Least Interference and Channel Segregation models of channel allocation and are able to show that their GA-based model achieves an SNR gain as compared with the other two methods [11]. A hybrid genetic (HGA) approach for channel reuse in multiple access telecommunication networks is proposed by Kassotakis et al. [2]. They combined GA with a local search algorithm to ensure the reliability property of GA with the accuracy of the hill-climbing method. The performance of the proposed HGA is compared, via simulation, to that of the graph coloring algorithm (GCA) of [12] and it is concluded that GCA's performance is comparable to that of HGA at light/medium load, while HGA solutions massively outperform GCA once at heavy network load. The evolutionary genetic DCA for resource management in mobile systems is proposed by Asvial et al. The proposed chromosome structure is the combination of traffic load and interference limited DCS. The constraints in interference used in the algorithm include the co-site interference, the co-spot beam interference, and the adjacent co-spot beam interference. Total interference is proposed to be minimized in the model [3].

Zomaya and Wright proposed a GA-based DCA model in which they modified the mutation genetic operator of GA for channel allocation problem. The fitness function used considers the hotcells, current borrowings, and present and future blocking. They compared their model with FCA and greedy borrowing heuristics for the average number of blocked channel metric and are able to show that the model works better than FCA and has a slight edge from the heuristic model [1].

4. Proposed Model

A. Channel Allocation Models

Channel allocation algorithms are usually studied under the following two models [2]:

1. Resource Planning Model

The set of all cells is partitioned into k disjointed subsets, So,S1,……..Sk-1, in such a way that the geographical distance between any two cells in the same subset is at least Dmin. If the distance between any two cells in the same subset is exactly Dmin ,then the partition is called an optimal partition. The set of all channel available in the system is divided into k disjointed subsets correspondingly : PC0,PC1…….PCk-1. Channels in PCi are pre allocated to cells in Si and are called primary channels of cells in Si, and secondry channels of cells in Sj ($j \neq i$) [1-2].

When assigning a channel to support a call, a cell , Ci always selects a primary channel first if this possible. A secondary channel is selected by Ci, only when no primary channels is available for Ci. If ci selects a primary channel it can use this channel without consulting with any neighbor. Otherwise Ci selects a primary channel, it can use this channel without consulting with any neighbor. Otherwise, Ci needs to consult with the neighbors to which the selected secondary channel has been pre allocated (i.e., the selected secondary channel is a primary channel of these neighbors). After a call using a secondary channel terminates, the secondary channel must be returned to the cell to which the selected secondary channel has been pre allocated [1-2] .

2. Non-Resource Planning Model

In this model all the channels are kept in a set which is known to each cell. Channels are not pre allocated to any cell.Whenever a cell needs a channel to support a call it first checks whether there is any channel which is allocated to it and is not being used. It picks one if such a channel exists. Otherwise it sends a request message to each of its neighbors to ask for their channel usage information . Based on the information it receives from its neighbors, it begins to compute the set of channels that it can borrow. If the set is not empty ,it selects a channel from this set and consults with its neighbors on whether it can borrow this channel to use . After a call using a borrowed channel terminates, the borrowed channel is not return [6-7].

B. Fault-Tolerance

In general fault tolerance is the ability of a system to respond gracefully to an unexpected hardware or software failure. For our model of channel allocation in mobile computing the fault-tolerance is the ability of a cell to continue communication for its mobile hosts even if there are in sufficient channel available.

We proposed a GA based fault tolerant algorithm to optimize the channel allocation in a mobile computing system. So this algorithm is an efficient approach to maintain the network connections of wireless mobile host s without being affected by the failure [1].

C. System Model

The proposed model has the following assumptions:

1. Cells are assumed to be hexagonal
2. Allocation under the resource planning model[2], i.e:
   - Primary channels are initially pre allocated to each cell.
   - The secondary (borrowed) channels must be returned to the cell from which it has been borrowed as soon as the call over.
3. Number of channels per cell is distributed according to the initial demand in each cell (based on the past experience and statistics of the usage of channels in cells).
4. Mobile hosts are distributed randomly among cells in proportion to the number of channel per cell.
5. A cell can lend the same channel to any of its neighbors, for using it concurrently ,provided the borrowing cells Ci and Cj satisfy:
   - $Ci - Cj \neq 1$,
   - $Ci - Cj \neq$ number of neighbor cells in a row
   - $Ci - Cj \neq$ number of neighbor cells in cell pattern

   it is assumed that cells have been numbered in increasing order of enumeration in fig.
6. Each cell has a set of reserved channels (in proportion to primary channels) which will immediately be given to a crossover mobile host (to handle handovers). But at the same time the cell will search for a new channel. As soon as I gets the new channel, it will be allocated to that mobile host, so that the reserved pool is maintained.
7. Since the probability of applying mutation is often very small, it is assumed to be zero.
8. The performance of algorithm is evaluated by measuring the average number of blocked hosts and Handoff failures in each generation.

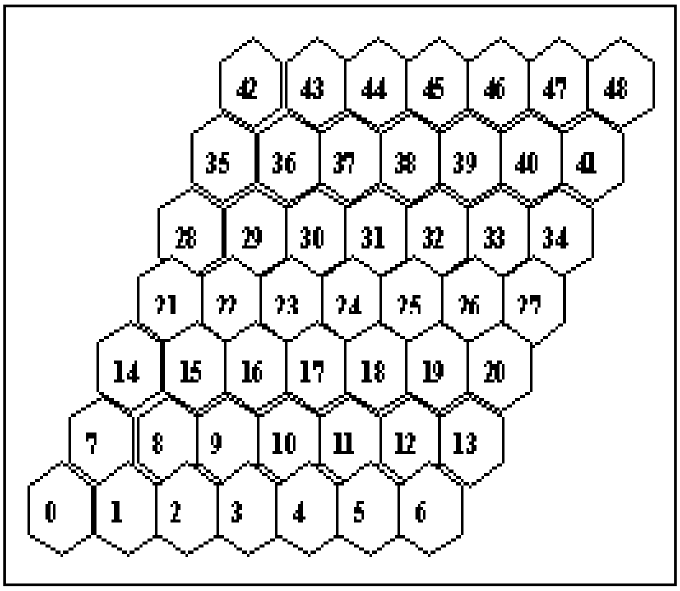


Fig. 1: Grid Celluler Network

D. Aim of the Algorithm

The algorithm exploits the potential of genetic algorithm to design a fault-tolerant cellular resource allocation model.

In some cases the load over a single cell is increased, so it needs more channels than it actually has to minimize the traffic problem and the number of the blocked hosts. On the other hand it is possible that the load on a cell is less than its channel capacity, so there is wastage of channels. We solved this problem by taking the extra channels from the cells that have a less load and allocate it to the cells that have an over load, temporarily.

The algorithm is also solved the problem of handover using reserved channel technique, so we implement the dynamic channel allocation using genetic algorithm to minimize the number of blocked hosts and the handoff failures (as a part of the blocked hosts) in the mobile computing network system.

E. The Encoding used

- Each cell is represented by a gene .
- A gene is an array of length 14
- The first location of the gene array is for keeping the number of blocked hosts.
- The second location of the gene array is for keeping the number of free channels.
- The next 6 location contain information about channels lending to 6 neighbors
- The last 6 location contain information about channels borrowing from 6 neighbors
- Genes are combined into a supergene and the supergenes together give the information of the whole network
- The gene of a cell and the genes of its 6 neighboring cells from a matrix of 7*14.
- All the GA operations are performed on the supergene.

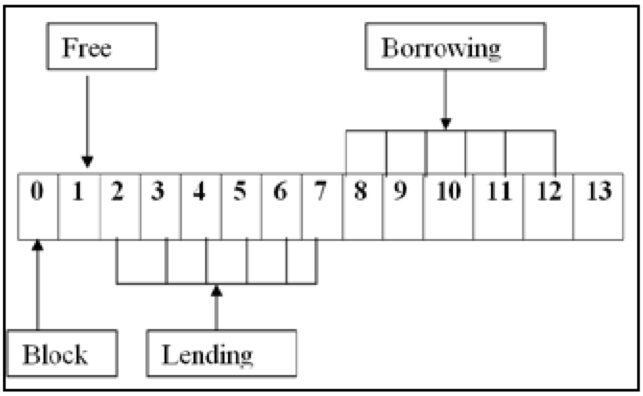


Fig. 2: Gene Structure

F. An Explanation of Main Function in the Algorithm

1. Lend_Borrow

- This function perform the following tasks:
- It permits a cell to lend the same channel to any of its neighbors. For using it concurrently, provided the two borrowing cells Ci and Cj satisfy:
  Ci-Cj $\neq$ 1
  Ci-Cj $\neq$ number of cells in a row
  Ci-Cj $\neq$ number of neighbor cells in a cell pattern .
- Handle the handover problem using the reserved channels
- Search for a new channel for the cross over mobile hosts

2. Crossover

The crossover operation occurs between two supergenes (two matrices) and generates two offspring from them i.e. two new matrices [1]. After this operation we get two different generations.

from each matrix in this process we take two rows one each from the two matrices. In the process we take a cut point, which is point between 1 and the highest column number. Then we divide each row (on which we are applying the crossover into two parts. The first part is the elements before the cut point, the second part is the elements in the rows after the cut point.

For the elements before the cut point we swap them with each other.

For the elements after the cut point first we search after the cut point for the first parental row, which elements are common with the element after the cut point of the second row. Then we look in which order the common element occur in the second row. Then we repositioned the common elements according to the order as they are in the second row. For the elements after cut point in the first row , which are not common with the second row, we keep them in the same position as they are in the fist parental row before the crossover. So now the entire row of the first offspring is formed in the same way we generate the elements of the second offspring from the elements after cut point of second parental row and the elements after the cut point of the first parental row [1].

3. Update

This function is used to recalculate the cell information after using the crossover operation.

If number of hosts greater than the available free channel then:

- Free channel number is updated to zero.
- Lending part of the gene is updated to zero
- The borrowing part of the related neighbors is updated to zero.

If number of hosts less than the available free channels then:

- Blocked hosts number is updated to zero.
- Borrowing part of the gene is updated to zero.
- The lending part of related neighbors is updated .

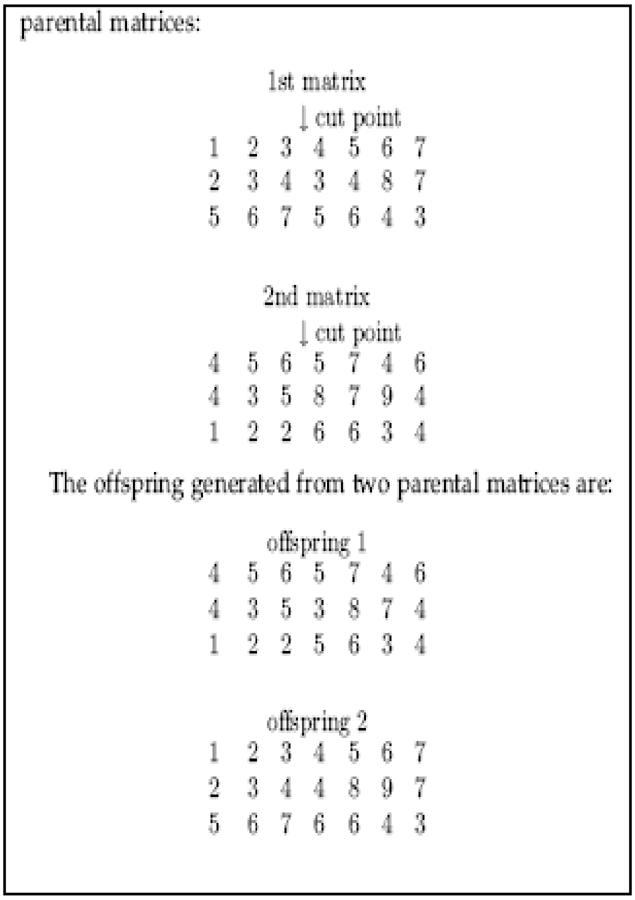
4. Fitness

This function is used to measure the fitness value of each gene; the fittest gene with the best fitness value will be selected for the objective to minimize the number of blocked hosts and handoff failures.

Our fitness function is :

Fitness=Handoff Failure – Handoff Failure after Iteration

The fittest gene here is the gene with the lowest fitness value.


parental matrices:

1st matrix
↓ cut point
1 2 3 4 5 6 7
2 3 4 3 4 8 7
5 6 7 5 6 4 3

2nd matrix
↓ cut point
4 5 6 5 7 4 6
4 3 5 8 7 9 4
1 2 2 6 6 3 4

The offspring generated from two parental matrices are:

offspring 1
4 5 6 5 7 4 6
4 3 5 3 8 7 4
1 2 2 5 6 3 4

offspring 2
1 2 3 4 5 6 7
2 3 4 4 8 9 7
5 6 7 6 6 4 3

Fig. 3: Crossover Operation

G. The Algorithm

1. Input the total number of channels and mobile hosts .
2. Assign channels to each cell based on the initial demand.
3. Input generation_no..
4. Initialize generation_index=0.
5. Initialize total_blocked_hosts=0.
6. Distribute the host among the cell in proportion to each cell capacity
7. Create initial population.
8. Calculate number of free_channels and blocked_hosts of each cell.
9. Repeat steps 10 to 18 until generation_index=generation_no.
10. Performed Lend_Borrow( ).
11. Perform Crossover( ).
12. Perform Update( ).
13. Calculate Fitness( ).
14. Select the best gene as the current gene.
15. Calculate again the free_channes and handoff_failure of each cell.
16. Output the number of handoff failures resulted in the current generation.
17. Increment generation_index
18. Average_Handoff_Failure= total_Handoff_Failure/genr_no.
19. Output average handoff failures.

V. Experiments and Conclusion

A. Simulation Parameters

- The simulation study carried out by writing program in C++.
- The simulated cellular network consisted of 20 cells.
- The crossover probability is 1.
- Various values for the total number of channels and hosts in the network tested.
- The performance of the proposed model is evaluated by measuring the average number of blocked host in network.
- The results are represented in performance graphs.
- In the performance graph the X-axis is always number of generations. The Y-axis are Handoff Failure.

Experiment 1:
Number of Host=200
Number of Channel=100
Number of generation=30

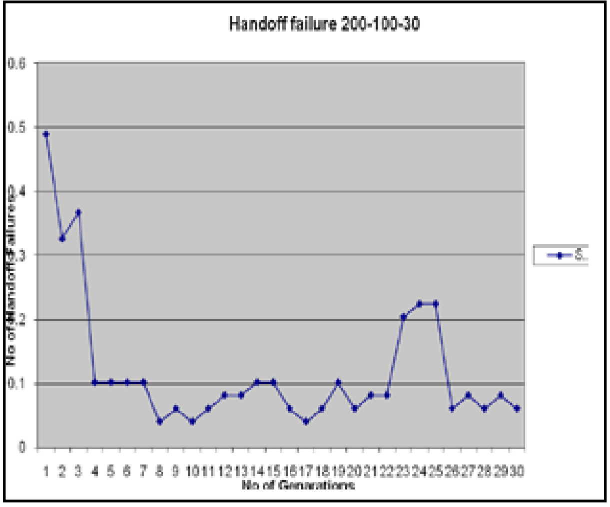


Fig. 4:

Experiment 2:
Number of Host=200
Number of Channel=100
Number of generation=40

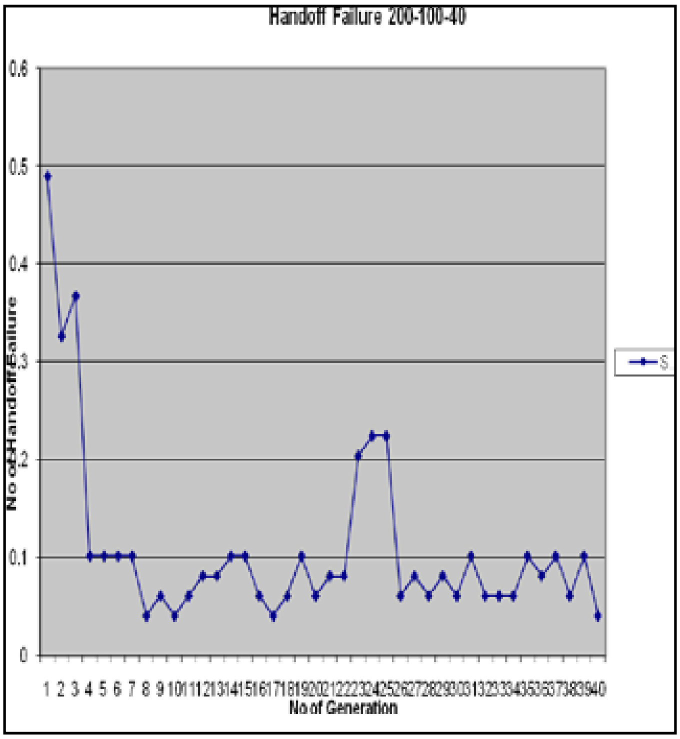


Fig. 5:

Experiment 3:
Number of Host=200
Number of Channel=50
Number of generation=20

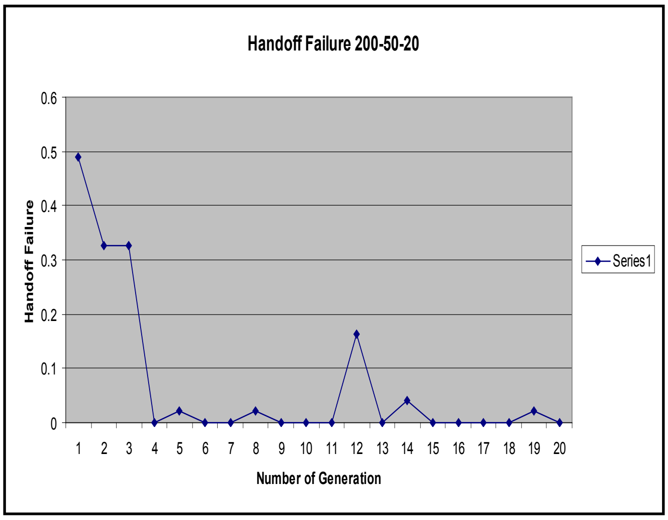


Fig. 6:

Experiment 4:
Number of generation=20
Number of Host=250
Number of Channel=50

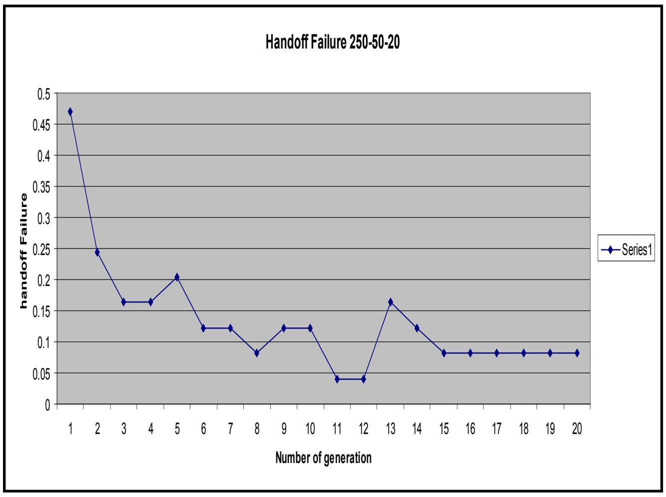


Fig. 7:

VI. Conclusion

We proposed a GA based fault tolerant channel algorithm to optimize the channel allocation in a mobile computing network system under resource planning model Our algorithm is an efficient approach to maintain the network connections of wireless mobile hosts without being affected by the failures. We have observed that the initial distribution of channels per cell according to the initial demand of each cell based on the past experience and statistics, greatly reduces the number of blocked hosts. We found that the well and efficient usage of the reserve channel to handle the crossover mobile host, minimize the number of handoff failure. The reused channel technique which allows a cell to lend the same channel to many of its neighbors, to use it concurrently without any interference improved the utilization of the available channels and therefore the network.

The performance of our proposed model is evaluated by simulating experiments to carryout the number of handoff failures. We found that by increasing the number of generations, the handoff failures decrease.

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