GA BASED FAULT-TOLERANT CHANNEL ALLOCATION MODEL IN MOBILE COMPUTING

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BY

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CERTIFICATE

This is to certify that the dissertation entitled "**GA based Fault-Tolerant Channel Allocation Model in Mobile Computing**" which is being submitted by **Lutfi Mohammed Omer Khanbary** to the School of Computer and Systems Sciences, Jawaharlal Nehru University, New Delhi, in partial fulfillment of the requirements for the award of the degree of **Master of Technology** in Computer Science is a bona fide work carried out by him under the guidance and supervision of **Dr. D.P. Vidyarthi**.

The matter embodied in the dissertation has not been submitted for the award of any other degree or diploma.

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Dedicated to

My dear parents…

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ABSTRACT

An efficient allocation of communication channels is critical for the performance of mobile cellular network as the bandwidth allotted for cellular communication is limited. The limited frequency spectrum is divided into a finite number of wireless channels. The objective of channel allocation is to assign a required number of channels to each cell such that both efficient frequency spectrum utilization is provided and interference effects are minimized. Channel assignment is therefore an important operation of resource management and its efficient implementation increases the capacity and quality of service of the cellular systems. The choice of the channels allocation scheme should cope with the time and spatial variations of the traffic demands in the cellular networks to avoid too many call blockings and to efficiently use the network resources. Therefore the major goals in design and implementation of cellular networks are to provide high throughput as well as reliable and high quality wireless communications among mobile users.

In this dissertation we exploit the potential of Genetic Algorithm, a useful tool for optimization problems, to design a fault-tolerant cellular resource allocation model. The model tries to optimize allocation of a prime cellular resource (i.e. channels) that are usually smaller in numbers.

Some times the load over a single cell is increased so it needs more channels than it actually has, to minimize the traffic congestion 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, resulting in wastage of channels. We solve this problem by taking the extra channels from the cells that have a less load and allocate it to the cells that are overloaded, temporarily.

Some essential concepts in cellular network are discussed in chapter one. Also different channel allocation strategies are explained in this chapter.

We discussed the importance of channel allocation with respect to mobile computing. Different methods for enhancing the capacity of the mobile network are mentioned in chapter two. As the handover is one of the main issues in mobile computing, a section is provided to explain different methods for handling the handover process.

Since we have used the Genetic Algorithm in our work, a brief description about the Genetic Algorithm and the main GA operations is deliberated in chapter three. Few related Genetic Algorithm based channel allocation models are also discussed in this dissertation in chapter three.

In chapter four, the proposed model with all the assumptions and the complete algorithm for channel allocation are explained. An efficient reuse technique for managing the available channels is introduced in our work. The proposed model also solves the problem of handover using reserved channels technique.

Finally the dissertation, with the help of graphs, provides simulation results to demonstrate the performance of the model, and a comparison of the model with a previous work in chapter five. Some remarkable conclusion has been made for the whole work in concluding section.

So this work accomplishes the dynamic channel allocation, using Genetic Algorithm, for minimizing the average number of blocked hosts and handover failures in the mobile computing network system.

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Chapter 1

Introduction

1.1 Channel Allocation in Mobile Computing

1.1.1 The Cellular Concept

The cellular concept is a novel way to ensure efficient utilization of the available radio spectrum. The area to be covered by a cellular network is divided into smaller regions called *cells*, which are usually considered to be *hexagonal*. This is because of the shapes which can completely cover a two-dimensional region without overlaps (fig.1.1).

An idealized model of the cellular radio system consists of an array of hexagonal cells with a base station (BS) located at the center of each cell [13], (fig. 1.2).

a. Ideal cell b. Actual cell c. Different cell models

Figure 1.1: Shapes of cell coverage area

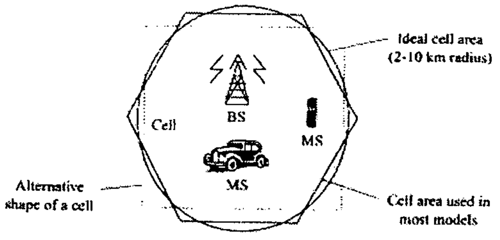


Figure 1.2: Cell with BS and MSs

The available spectrum in a cell is used for *uplink* channels for mobile terminals (MTs),called also mobile stations (MSs), to communicate with the BS, and for *downlink* channels, for the BS to communicate with MTs(fig.1.3).All users in the cell are served by the BS [13],[14]. Under ideal radio environments, the shape of the cell can be circular around the microwave transmitting tower. The radius of the circle is equal to the reachable range of the transmitted signal.

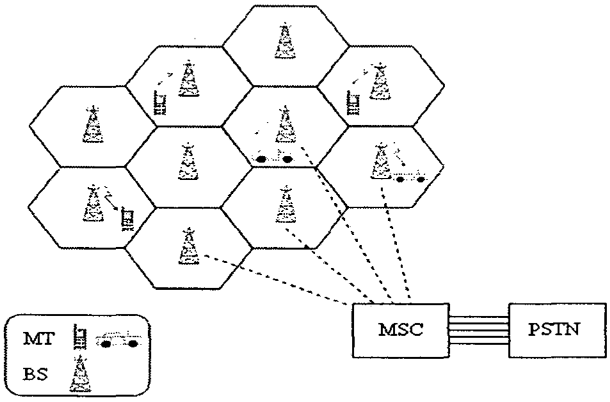


Figure 1.3: Cellular system

1.1.2 Cellular reuse of channels

The fundamental and elegant concept of cells relies on *frequency reuse*, that is, the usage of the same frequency by different users separated by a distance, without interfering with each other, this interference is called *cochannel interference*. Frequency reuse depends on the fact that the signal strength of an electromagnetic wave gets attenuated with distance. A *cluster* is a group of cells which uses the entire radio spectrum. The cluster size N is the number of cells in each cluster (fig.1.4). No two cells within a cluster use channels of the same frequency [3]. Clustering ensures that cells which use the same frequency are separated by a minimum distance D, called the *reuse distance* (fig. 1.5).

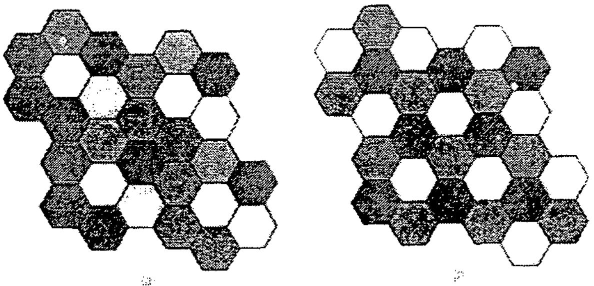


Figure 1.4: Examples of reuse patterns: (a) N=7 and (b) N=3

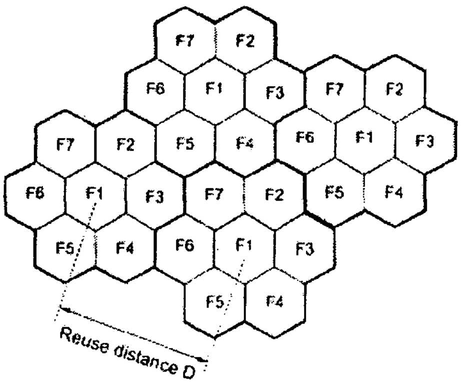


Figure 1.5: Frequency reuse

1.1.3 Handoffs

An important concept that essential for the cellular networks is handoff (also called handover). When a user moves from the coverage area of one BS to the adjacent one while still involved in a communication to continue the call, we say handoff occurs. A handover is defined, as a change of radio channel used by a mobile terminal. The new channel may be within the same cell (intracell handoff) or in a different cell (intercell handoff). They are an important issues in microcellular Systems where the cell radius is small [3],[13].

1.2 Channel Allocation Strategies (CASs)

1.2.1 What is Channel Allocation Strategies

The name channel allocation strategy (CAS) is given to the technique used to make the most efficient and equitable use of the available radio spectrum, in which channels are allocated to cells on a fixed or dynamic basis. The quality of the received signal that can be achieved in each channel and the cochannel interference achieved by frequency reuse are the most important factors in determining the number of channels with a certain quality that can be used for a given wireless spectrum. The performance of a CAS should also result in an increase in the spectrum efficiency. In addition, a CAS must be flexible enough to handle dynamic system reconfiguration and non-uniform traffic.

1.2.2 Types of CASs and their Classification

There are many features that can be used to classify CAS techniques. Each has its particular features and applications.

The most common basis is to compare the CASs in terms of the manner in which cochannels cells are separated. In this classification, CASs are divided into *FCA*, *DCA* and combining the first two, *HCA* strategies.

A second important classification of CASs is based on the way they are implemented. They can either be *centralized* or *distributed* [3].

- **Centralized approach**

In this approach a request for channel allocation is sent to and processed by a central controller, called the *Mobile Switching Center (MSC).* MSC is the only one that has access to system-wide channel usage information. It is responsible for allocating channels to cells in such a way that no cochannel interference arises and channels are used in an efficient manner. Since it is a centralized approach, it suffers from the single-point failure problem. The functioning of the whole system depends solely on the MSC. In addition, this approach is not scalable because the MSC can become a bottleneck when the traffic load of the system is very heavy [2], [15], [16].

- **Distributed approach**

In this approach there is no central controller such as MSC. Instead, a BS exists in each cell. BSs share the responsibility to allocate channels. Each BS makes this decision independently, based on its local information. BSs exchange information when necessary. The BS in the cell that wants to borrow a channel and the BS in the cell that grants the channel work together to ensure that no cochannel interference arises. Distributed CASs require much less signaling because each BS in each cell keeps information about the status of current available channels in its neighborhood and every change is communicated only between the BSs involved [17], [18].

1.2.2.1 Fixed Channel Allocation (FCA)

In the FCA strategy, the area of the service is partitioned into a number of cells and the same number of channels is permanently assigned to each cell (called nominal channels) according to a reuse pattern. FCA strategy is very simple and easy to implement. The uniform distribution of channels performs very well under uniform traffic loads (where the same traffic load is offered to every cell in the system). In FCA, a new call can only be served by the nominally assigned channels. If all the channels are busy, then the call is blocked from the system. One of the main drawbacks of FCA, when it has to face non-uniform traffic distributions [3].

1.2.2.1.1 Channel Borrowing Schemes

Another way to overcome the effects of nonuniform loading is to borrow free channels from neighboring cells. When a channel is borrowed several other cells are prohibited from using it. This is called *channel locking*. The number of cells in which the borrowed channel has to be locked depends on the reuse pattern N being used, the type of cell layout, and the type of initial allocation of channels to cells.

For example, considering Figure 1.6, if a reuse pattern of 7 is used and a channel borrowing has occurred (cell *P* has borrowed a channel from cell A_3), then the channel has to be locked in the first and second tiers of cells surrounding the cell that borrowed the channel (cell *P*)-this includes cochannel cells A_2 and A_4 [3].

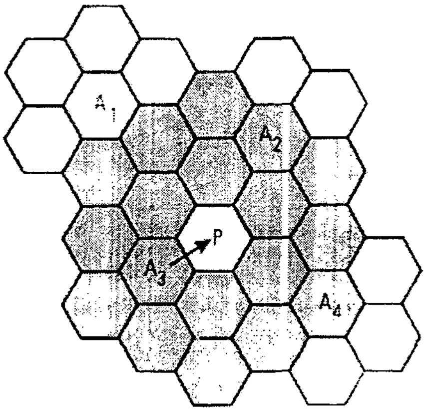


Figure 1.6: Channel borrowing and directional locking

Channel borrowings are temporary and last only for the duration of a call. Once calls are completed, the borrowed channels are returned to their original cells and locked channels are released.

Channel borrowing strategies only need local and neighboring cell information. Several channel borrowing strategies have been proposed. They can be classified into *simple* and *hybrid (complex)* [3].

- **Simple Borrowing Schemes**

A simple borrowing scheme implies that if all channels allocated to a cell are being used, then additional channels can be borrowed from any cell that has some free unused channels. Such a cell is called a donor cell. An obvious choice is to select a donor from among adjacent cells that has the largest number of free channels. This is known as borrowing from the richest. A further consequence is to return the borrowed channel to the donor if a channel becomes available in the cell that initially borrowed a channel. Such an algorithm is denned as basic algorithm with reassignment. Another alternative is to select the first free channel found for borrowing when the search follows a predefined sequence; this is known as the borrow first available scheme.

- **Complex Borrowing Schemes**

The basic strategy for complex schemes is to divide the channels into two groups, one group assigned to each cell permanently and the second group kept reserved as donors to be borrowed by neighboring cells. The ratio between the two groups of channels is determined a priori and can be based on estimated traffic in the system. An alternative, known as borrowing with channel ordering, is to assign priorities to all channels of each cell, with highest-priority channels being used in sequential order for local calls in the cell while channel borrowing is done starting from lowest-priority channels.

Channel borrowing schemes perform better than FCA under low and moderate traffic loads, but fail to perform better than FCA under heavy loads, because when traffic is low, the number of borrowed channels is small and they cope with the fluctuations of the offered traffic, but when the offered load is high, the number of borrowings may proliferate to such an extent that the channel utilization drops drastically. This is caused by channel locking. It may happen, nevertheless, that the set of neighboring cells from which a channel can be borrowed contain several channels available to lend. In such a case, an algorithm is used to select one of the candidate channels for borrowing. This algorithm is called the *cost function* [3].

1.2.2.2 Dynamic Channel Allocation (DCA)

In contrast to FCA, in DCA strategies there is no relationship between the channels and the cells and every channel can be used in any cell as long as the cochannel reuse distance and the interference constraints are fulfilled. The channels are used in the cells only for the duration of the call. DCA algorithms do not require channel planning and have shown a better performance than FCA strategies under low and moderate traffic load conditions. However, when heavy traffic load conditions are present in the system, DCA strategies do not outperform FCA strategies, especially when the traffic is nonuniform.

Perhaps the major disadvantage that DCA strategies have in comparison with FCA strategies is the fact that not only the transceivers for the nominal channels must be available at every BS but, in some cases, the transceivers of all of the channels. The number required depends on the DCA strategy itself. The most important classification of DCA strategies is that which distinguishes them as *centralized* and *distributed* [3].

- **Centralized DCA Schemes**

In centralized DCA strategies channels are assigned to incoming calls by a central controller from a central pool. These strategies differ from each other in the type of cost function used to select the candidate channel to attend incoming calls. The use of a central controller implies a huge amount of signaling load produced by communication between each BS and the central controller. That is why this type of DCA strategy is applied primarily to macrocellular environments, where a large geographical area is served by cells of large radii. The availability of channel status information makes the efficiency of centralized DCA strategies far better than distributed DCA strategies because the knowledge of the channels status in every single cell facilitates making a better decision on which channel to use. Several simulation and analysis results have shown that centralized DCA schemes can produce near-optimum channel allocation at the expense of a high centralization overhead.

There are several examples of centralized strategies proposed in the literature, such as:

- First available (FA).
- Locally optimized dynamic assignment (LODA).
- Selection with maximum usage on the reuse ring (RING).

The simplest of them is the FA strategy. In FA, the first available channel within the reuse distance encountered during a channel search is assigned to the call. Since no cost function is evaluated to select the optimum channel, the FA minimizes the system computational time. In the LODA strategy, the selected cost is based on the future blocking probability in the vicinity of the cell in which a call is initiated. In the RING strategy, a candidate-channel is selected that is in use in the most cells in the cochannel set. If more than one channel has this maximum usage, an arbitrary selection among such channels is made to serve the call. If none is available, the selection is made based on the FA scheme.

• Distributed DCA Schemes

Distributed schemes are more attractive for implementation in microcellular systems due to the simplicity of the assignment algorithm in each BS.

Distributed DCA strategies are less stable than centralized schemes because the former are affected by local changes (e.g., traffic variations) that could spread through the whole system, hence affecting its performance. Centralized systems, on the other hand, may detect local variations and cope with them quickly, avoiding abrupt fluctuations in the blocking probability in areas with traffic problems.

Distributed DCA strategies can be classified into those that rely on information about the channel status in neighboring cells (cell based) and those that relay on signal strength measurements. In the cell-based strategies, the BSs assign channels to incoming calls based on information about the current status of channels in their vicinity. This information is updated continuously. The performance of cell-based DCA strategies is not as optimum as that shown by centralized DCAs, and signaling load between BSs increases as the offered load increases.

In DCA strategies that assign channels relying purely on local signal strength measurements there is no need for a BS to communicate with any other BS in the network. Thus, the system is self-organizing and cellular planning is totally avoided. The delay in

the channel assignment process is practically nil. These types of strategies allow maximum packing only at the expense of increasing cochannel interference in ongoing calls in adjacent cells. This may produce forced termination and deadlocks.

1.2.2.3 Hybrid Channel Allocation (HCA)

In HCA strategies the total set of channels is divided into two subsets. The first subset of channels is assigned to the cells of the system according to the FCA strategy. The second subset is kept in a central pool and assigned dynamically to the cells on demand to increase flexibility. Therefore, there are basically two types of CAS at the same time, FCA and DCA.

When a new call arrives at a cell, the first attempt to serve it is by a nominal or fixed channel. If there is no free nominal channel, a channel from the dynamic set is assigned to the call. If this fails, then the call is blocked.. The ratio of fixed-to-dynamic channels is a significant parameter that defines the performance of the system in much the same manner that the ratio of nominal-to-borrowable channels defines the performance of a strategy with channel borrowing. In general, the ratio of fixed-to-dynamic channels is a function of the traffic load and would vary over time according to offered load distribution estimation [3].

Chapter 2

Channel Allocation Problem

With the significant increase of the mobile users, the numbers of mobile devices have increased. So due to the increasing load, the number of mobile hosts that could not connect to the destination is also 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. The efficient reusability of the channel improves the performance of the network. The Fixed Channel Allocation (FCA), in which assignment of frequencies to cell is fixed, does not allow channel reuse. This is inefficient if the traffic load on channel varies from time to time and Dynamic Channel Allocation (DCA) is used in place. 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 of Borrowing Channel Allocation (BCA) is used in GSM systems. However, it requires careful traffic analysis. There are many other ways to deal with excess load in mobile networks in addition to channel borrowing, such as cell sectoring and cell splitting [10].

2.1 Capacity Enhancement

Methods have been devised to enhance the capacity of cellular networks. It has been observed that the main reason for reduction of cellular network capacity are off-center placement of antennas in the cell, limited frequency reuse imposed by a strict clustering scheme, and inhomogeneous propagation conditions. The nearest BS is not always the best for a mobile station, due to shadowing, reflections, and other propagation-based features [13]. A few methods to improve the capacity are as follows.

2.1.1 Cell-Splitting

Non-uniform traffic demand patterns create *hotspot* regions in cellular networks, which are small pockets with very high demand for channel access. The blocking probability in a hotspot region must not be allowed to shoot up. This gave rise to the cell-splitting concept. A different layer of cells which are smaller in size, and support users with lower mobility rates, is overlaid on the existing (macro-cells) cellular network. These are called micro-cells. While macro-cells typically span across tens of kilometers, micro-cells, are usually less than 1 Km in radius [13]. Very small cells called Pico-cells, of a few meters' radius, are also in use to cover indoor areas (fig. 2.1).

If a highly mobile user is handled by the micro-cellular layer, there is overhead of too many handoffs. In fact, the handoffs may not be fast enough to let the call continue uninterrupted.

As the coverage area of new split cells is smaller, the transmitting power levels are lower, and this helps in reducing cochannel interference.

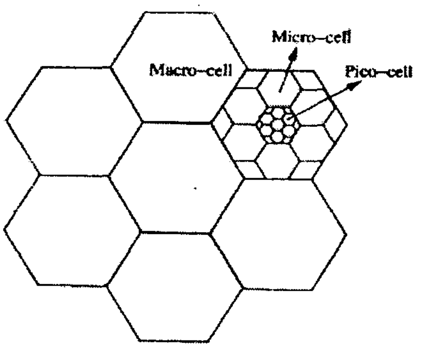
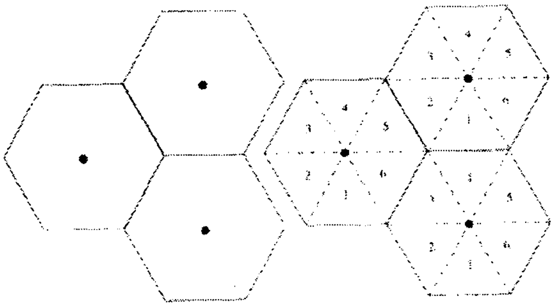


Figure 2.1: Cell-splitting

2.1.2 Cell-Sectoring

This concept uses space division multiple access (SDMA) to let more channels to be reused within a shorter distance. Antennas are modified from omnidirectional to sectorized, so that their signals are beamed only in a particular sector, instead of being transmitted symmetrically all around. This greatly reduces the downlink interference. A cell is normally portioned into three 120-degree sectors or six 60-degree sectors (fig.2.2). When sectoring is used, the channels of the cell must be subdivided and allocated to the different sectors. The number of handoffs is also increased due to inter-sector handoffs being introduced [13].



(a) Omnidirectional (b) Sectorized

Figure 2.2: Cell sectoring

2.1.3 Power control

Cellular networks face the "*near-far*" problem. An MT which is very close to the BS receives very strong signals from the BS, and its signals are also extremely strong at the BS. This can possibly drown out a weak signal of some far-away MT which is on an adjacent frequency. To avoid this problem, the BS must issue power control orders to the MTs to receive a fairy constant, equal power from all MTs, irrespective of their distance from the BS. MTs which are farther away from the BS transmit at higher power than nearby MTs, so that the received power at the BS is equal. This saves power for the MTs near the BS, and avoids excessive interference. Reduction the interference increases the capacity of the cellular network [13].

In cellular system for mobile communication each transmitter covers a certain area. The cell radii vary from tens of meters in buildings to hundreds of meters in cities or tens of kilometers in the countryside. Some cellular systems use a number of small cells due to the following advantages:

- **Frequency Reuse:** If one transmitter is outside the interference range of other it can reuse the same frequency and thus using efficiently the most scarce resource frequency. As most mobile phone systems assign frequencies to certain users, this frequency is blocked for other users. But frequencies are scare resource and, thus, the number of concurrent users per cell is very limited. Huge cells do not allow more users. On the contrary, they are limited to less users per square km. This is also the reason for using very small cells in the cities – where many more people use mobile phones.
- **Less Transmission Power:** Small cell solves the problem where a receiver far away from the base station lacks signal power. Because the power aspect is a problem for mobile stations, a receiver far away from the base station will need much more transmission power than the current few watts. But energy is a serious problem for mobile handled devices.
- **Less Interference**: As the distance between sender and receiver is less, there is less chance of interference. Long distance between sender and receiver results in more interference. With small cells, mobile station and base station only have to deal with local interference.
- **Robustness**: Cellular systems are decentralized and, thus, more robust against failure of single components. If one antenna fails, this defect only influences within a small area.

But the small cells also have some disadvantages:

- **Infrastructure:** Cellular system needs a complex infrastructure to connect all base stations. This infrastructure include many antennas, switches for call forwarding, location registers to find a mobile station etc. This makes the whole system expensive.
- **Handover needed:** The mobile system has to perform a handover when changing from one cell to another. Depending on the cell size and speed of movement, the handover can happen quite often.

- **Frequency Planning:** To avoid interference between transmitters using same frequencies, frequencies have to be distributed carefully. On one hand the interference should be avoided, on the other hand only a limited number of frequencies are available.

The channel allocation problem involves how to allocate borrowable channels in such a way that maximizes the long term and/or short-term performance of the network [19]. A host is blocked if it enters into a cell but cannot get a channel. Obviously, the more blocked hosts the worse will be the performance of the network. Number of borrowings should also be minimized, because more borrowings incur more network traffic.

Situations can occur when the load may increase beyond the system's capability. Specifically, when all the channels of a cell are allocated then the cell is called "Hot Cell". Hot cell must be avoided because a mobile host will be denied a service upon entering the hot cell. There are several schemes to handle situations like this [18] ,[27].

Channel borrowing uses cochannel locking to eliminate cochannel interference that occurs when a neighboring cell borrows a channel [5]. A neighbor cell can borrow a channel if it is free i.e. not already allocated to a local host. There are number of decisions to be made at the time of channel borrowing, including where to borrow and when to borrow.

2.2 Handover Handling

Methods for decreasing the probability of forced termination by prioritizing handovers at the expense of a tolerable increase in call blocking probability have been devised in order to increase the quality of cellular service [3]. These methods are the NPS [21], the RCS [21], the first in first out (FIFO) priority scheme [25], the measured based priority scheme [25], and the subrating scheme (SRS). They are classified into three categories: basic, queuing [24], and subrating [22].

There are no restrictions on combining any of these channel allocation strategies for handover with any of the FCA, DCA, or HCA strategies, described previously, in order to tackle both the blocking of new users and the blocking of handover calls.

We discussed few interesting handover methods as follows.

2.2.1 No priority Scheme (NPS)

In the NPS, BSs handle the handovers in exactly the same manner as new call arrivals; therefore, the blocking of handover calls is the same as the blocking of new calls.

2.2.2 Prioritized Scheme

The simplest way to give priority to handover calls is by specially reserving channels for them in every cell. The guard concept was introduced in [21]. In this scheme the available channels in a cell are divided into two sets. *A* ; a set of channels that attend nominal new calls (calls attended by nominal channels are nominal calls) as well as handover calls and *B* ; a set of channels that attend handover calls only. This scheme provides improved performance at the expense of a reduction in the total admitted traffic and an increase in the blocking of new calls. Another shortcoming of the employment of guard channels, especially with fixed channel assignment strategies, is the risk of inefficient spectrum utilization. Allowing the queuing of new calls may ameliorate this disadvantage.

The queuing of handover requests is another generic prioritization scheme offering reduced probability of forced termination [23], [24]. Queuing handover techniques can be used in conjunction with guard channels. In this strategy there is again a trade-off with the increase in total carried load [20]. The scheme is described as follows. When the power level received by the BS in the current cell falls to a certain threshold, namely the handover threshold, the call is queued for service from a neighboring cell. The call remains queued until either an available channel in the new cell is found or the power by the BS in the current cell drops below a second threshold called the receiver threshold. If the call reaches the receiver threshold and a new channel has not been found, then the call is terminated [19].

Queuing handover requests is made possible by the existence of the time interval that the MS spends between these two thresholds. This interval defines the maximum allowable waiting time in the queue. Based on the traffic pattern and the expected number of requests, the maximum size of the handover queue can be determined [19].

A handover may still be dropped because the handover request has no choice but to wait until the receiver threshold is reached. So when there is a high demand for handovers, they will be denied queuing due to the limited size of the handover queue. The basic queuing discipline in a queuing handover request is FIFO [20].

2.2.3 Subrating Scheme (SRS)

In the SRS [22], if a BS does not have a free channel to attend a handover call, a new channel is created to attend it by subrating an existing call. Subrating means an occupied full rate channel is temporally divided into two channels at half the original rate: one serves the original call and the other serves the handover request [22], [26]. The blocking probabilities (combined forced termination of-existing calls and blocking of new call attempts) of this new scheme compare favorably with the standard scheme (non-prioritizing) and the schemes proposed previously.

However, this scheme presents an additional complexity of implementing on-the-fly subrating and the impact of continuing the conversation on a lower rate channel (which may lower speech quality or increase battery drain) [22].

Chapter 3

Genetic Algorithm and GA based Channel Allocation

Genetic Algorithms have been extensively used in various optimization problems. Channel allocation, being an optimization problem, has found an appropriate use of GA. In this chapter GA and related GA based models have been discussed in brief.

3.1 Genetic Algorithm (GA)

Genetic Algorithms (GAs) were invented by John Holland in the 1960s and were developed by Holland and his students and colleagues at the University of Michigan in the 1960s and the 1970s [4].

A genetic algorithm is a search procedure based on the principle of evolution and natural genetics (see table 3.1). GA combines the exploitation of past results with the exploration of the search space. By using *survival of the fittest* technique combined with a structured yet randomized information exchange, a GA can mimic some of the innovative flair of human search.

Natural	Genetic Algorithm
chromosome	string
gene	feature or character
allele	feature value
locus	String position
Genotype	structure
phenotype	Parameter set, a decoded structure

Table 3.1

Comparison of Natural and GA Terminology

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 applications of GA have attracted the attention of researchers of numerous disciplines (e.g. operation research, economics, social sciences, life sciences etc.).

A GA is a collection of artificial creatures (strings).In every new generation, a new set of strings is created using information from the previous ones. Occasionally, a new part is tried from good measure. GAs are randomized, but they are not simple random walks. They efficiently exploit historic information to speculate on new search points with expected improvement [5],[8],[9].

The majority of optimization methods move from a single point in the decision space to the next point using some transaction rule. This method may be harmful as it can locate a false peak in multimodal (many-peaked) search spaces. By contrast GA works from a database of points simultaneously, a population of strings, climbing many peaks in parallel [4].

In GA we start with an initial population and then we use some genetic operators on it for appropriate mixing of exploitation and exploration. GAs are different from most normal optimization and search procedures in four ways:

1. GAs work with a coding of the parameter set, not the parameters themselves.
2. GAs search from a population of points, not a single point.
3. GAs use payoff (objective function) information, not the derivatives or other auxiliary knowledge.
4. GAs use probabilistic rules (operators), not deterministic rules.

3.1.1 Simple Genetic Algorithm (SGA)

A simple genetic algorithm consists of an initial population followed by selection, crossover and mutation [4], (fig. 3.1).

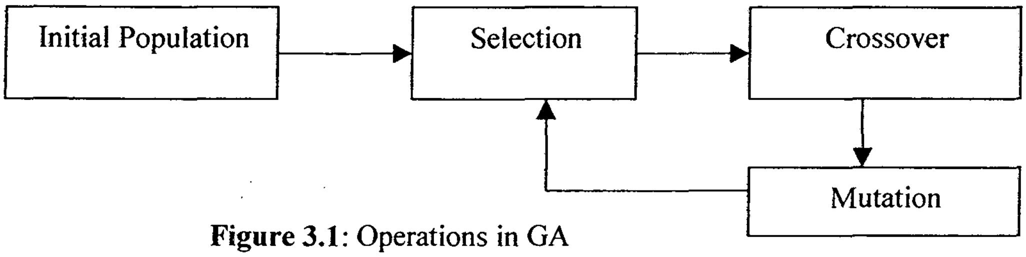


Figure 3.1: Operations in GA

- **Selection**

Selection operator selects best results among the chromosomes through some objective function (*fitness function*) which is used to rank the quality of a chromosome. A fitness value is assigned to the chromosome by a fitness function and the chromosome is evaluated with this value for survival. So the fitness of the chromosome depends on how well that chromosome solves the problem at hand (strings with a higher value have a higher probability of contributing one or more offspring in the next generation). This operator is an artificial version of natural selection, a Darwinian "survival of the fittest" among string creatures. In natural populations fitness is determined by the creature's ability to survive predators, pestilence, and the other obstacles to adulthood and subsequent reproduction, the objective function is the final arbiter of the string-creature's life or death.

- **Crossover**

The idea of the crossover is to swap some information between a pair of chromosomes to obtain the new chromosome (fig.3.2). Simple crossover may proceed in two steps. *First*, members of the newly reproduced strings in the mating pool are mated at random. *Second*, each pair of strings undergoes crossing over as follows: an integer position k along the string is selected uniformly at random between 1 and the string length less one $[1, l-1]$. Two new strings are created by swapping all characters between positions $k + 1$ and l inclusively.

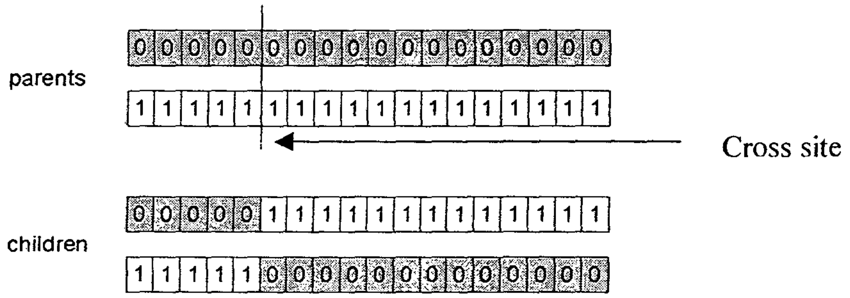


Figure 3.2: A simple crossover operation in GA

- **Mutation**

In mutation a chromosome is altered a little bit randomly to get a new chromosome.

The mutation operator is used to introduce new genetic material (e.g. 0 or 1). As a result of its generality, it is an insurance policy against premature loss of important notions. It has several weaknesses. The main weakness is taking-borrowing decisions ahead of time that may result in non-optimality because of two reasons. First, their effectiveness is not measured in the fitness function and second these decisions degrade the future quality of service [5]. The probability of applying mutation operation is often very small. Mutation rates are similarly small in natural populations.

3.1.2 The Encoding Scheme

The encoding refers to the method by which the problem parameters are mapped into a chromosome. There are many ways to encode the chromosome. Most GA applications use fixed-length, fixed-order bit strings to encode candidate solutions. Though *Binary* encodings (bit strings) are the most common encodings; there are also *Many-Character* and *Real-Valued* encodings [4].

Two basic principles for choosing a GA coding

1. ***The principle of meaningful building blocks :***
   The user should select a coding so that short, low-order schema are relevant to the underlying problem and relatively unrelated to schemata over other fixed positions.
2. ***The principle of minimal alphabet :***
   The user should select the smallest alphabet that permits a natural expression of the problem.

3.2 Related GA based Models

GA has been used in quite a few models of channel allocation. A dynamic channel allocation model using GA for a broadband fixed wireless access network is proposed by Wong and Wassell. In this 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. Their GA based model is compared with Least Interference and Channel Segregation models and are able to show that the GA based method achieves a SNR gain as compared with the other two methods [11].

A hybrid genetic algorithm (HGA) for channel reuse in multiple access telecommunication networks is proposed by Kassotakis et. al [6]. They combined GA with a local search algorithm to ensure 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) proposed in [12] and it is concluded that GCA performance is comparable to that of HGA at light/medium load, while HGA solutions massively outperform the GCA at heavy network load.

An Evolutionary genetic DCA for resource management in mobile systems is proposed by Asvial et. al. The chromosome structure proposed by them 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-spotbeam interference and the adjacent co-spotbeam interference. Total interference is proposed to be minimized [7].

Zomaya and Wright have proposed a GA based DCA model in which they have modified one genetic operator mutation. They have compared their model with the FCA and greedy borrowing heuristics for average number of blocked channels metric and are able to show that the model works better than FCA and slightly has an edge from heuristic model [5].

A fault-Tolerant Distributed Channel Allocation Scheme is proposed by J.Yang et. al. In this scheme, they assumed a 3-cell cluster model which belongs to the non-resource planning model, where a cell may borrow a channel even based on some partial channel usage information it receives from some of its neighbors. A cell can lend a channel to multiple borrowers (at most three) as long as any two of them are not neighbors [2]. They proved that their scheme outperforms than Prakash et. al. algorithm [17].

An Improved GA (IGA) model is proposed by S.S.Maha et. al. In the proposed work, GA is applied for channel allocation in DCA with channel borrowings. A new genetic operator called 'Pluck' is introduced for improving the simple GA and the proposed method is referred as Improved Genetic Algorithm (IGA).The idea behind the pluck operation is to add some knowledge by selecting some chromosomes that may not be giving good result right now but may lead the system to a stabilized state for a better result in future [1]. They compared their work with the model proposed by Zomaya and have shown that the IGA performs better for improving the channel utilization.

Chapter 4

The Proposed Model

In this chapter a fault tolerant channel allocation (FTCA) model is proposed that uses Genetic Algorithm for minimizing the blocked hosts and reducing the handover failure.

4.1 Channel allocation models

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

- ***Resource planning model***

The set of all cells is partitioned into *k* disjointed subsets, $S_0, S_1, \ldots, S_{k-1}$, in such a way that the geographical distance between any two cells in the same subset is at least D_{min}. If the distance between any two cells in the same subset is exactly D_{min}, then the partition is called an *optimal partition.* The set of all channels available in the system is divided into *k* disjointed subsets correspondingly: $PC_0, PC_1, \ldots, PC_{k-1}$. Channels in *PCi* are preallocated to cells in *Si* and are called *primary channels* of cells in *Si*, and *secondary channels* of cells in S_j, $(j \neq i)$.

When assigning a channel to support a call, a cell, *Ci,* always selects a primary channel first if this is possible. *A* secondary channel is selected by *Ci*, only when no primary channel is available for *Ci.* If *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 preallocated (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 it has been preallocated.

- *Non-resource planning model*

Under non-resource planning, all the channels are kept in a set which is known to each cell. Channels are not preallocated 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.

In the proposed model, if a host cannot find a channel either to make a new call or to continue a handoff call then this host is said to be a *blocked host.*

4.2 Handover

When a mobile host moves from one cell to any of the neighboring cells then the new cell which it is moving into is responsible for allocating a new channel from its reserved pool to support the handoff call, if this new channel can be allocated then we say the handoff call is successful otherwise the call is dropped and a handoff failure occurs.
We assumed in the proposed model that 40 percent of the hosts are moving randomly to the neighboring cells in the network.

4.3 Fault-Tolerance

In general fault-tolerance is the ability of a system to respond gracefully to an unexpected hardware or software failure. In our model of channel allocation the fault-tolerance is the ability of a cell to continue communication for its mobile hosts even if there are insufficient channels available. The proposed algorithm is an efficient approach to maintain the network connections of wireless mobile hosts without being affected by the failures.

The proposed model is a fault-tolerance model since we maximize the reuse of the same channel concurrently between the neighboring cells without any interference. Also we keep a reserved channels to handle the handoff calls for the crossover mobile hosts.

4.4 System Model

The proposed FTCA model has the following important points:

- Cells are assumed to be hexagonal (fig. 4.1)
- Allocation is under the *resource planning* model [2], i.e. :
    - ❖ *Primary* channels are initially preallocated to each cell.
    - ❖ The *secondary* (borrowed) channels must be returned to the cell from which it has been borrowed as soon as the call is over.
- 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).
- For the experiment, mobile hosts are distributed randomly among cells in proportion to the number of channels per cell.
- A cell can lend the same channel to any of its neighbors, for using it concurrently, provided the two borrowing cells C_i and C_j satisfy:
    - ❖ $C_i - C_j \neq 1$.
    - ❖ $C_i - C_j \neq$ number of cells in a row.
    - ❖ $C_i - C_j \neq$ number of neighbor cells in cell pattern.

  It is assumed that cells have been numbered in increasing order of enumeration (fig. 4.1). This step will insure that same channel is not being used by two neighbors and no interference will occur.
- Each cell has a set of reserved channels (in proportion to primary channels) which will immediately be given to a cross over mobile host (to handle handover). But at the same time the cell will search for a new channel. As soon as it gets the new

channel, it will be allocated to that mobile host, so that the reserved pool is maintained.

- Due to the weaknesses of mutation mentioned in chapter 3 (sec. 3.1.1), the probability of applying mutation in the proposed model is assumed to be zero.
- The performance of the algorithm is evaluated by measuring the average number of *blocked hosts* and *Handoff failures* in each generation.

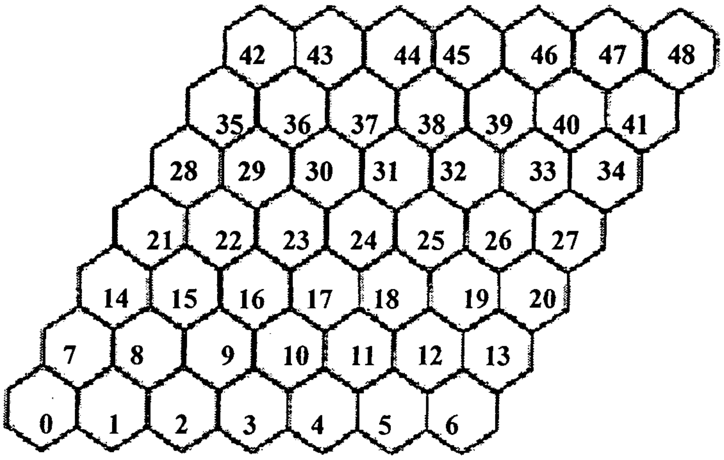


Figure 4.1: grid cellular network

4.5 Aim of the algorithm

This 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 are overloaded, temporarily.

The algorithm also solves 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.

4.6 The Encoding used

- Each cell is represented by a gene.
- A gene is an array of length 14 (fig.4.2).
- 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 locations contain information about channels lending to 6 neighbors.
- The last 6 locations contain information about channels borrowing from 6 neighbors.
- Genes are combined into a supergene, and all the supergenes together give the information of the whole network.
- The gene of a cell and the genes of its 6 neighboring cells form a matrix of 7 * 14.
- All the GA operations are performed on the supergene.

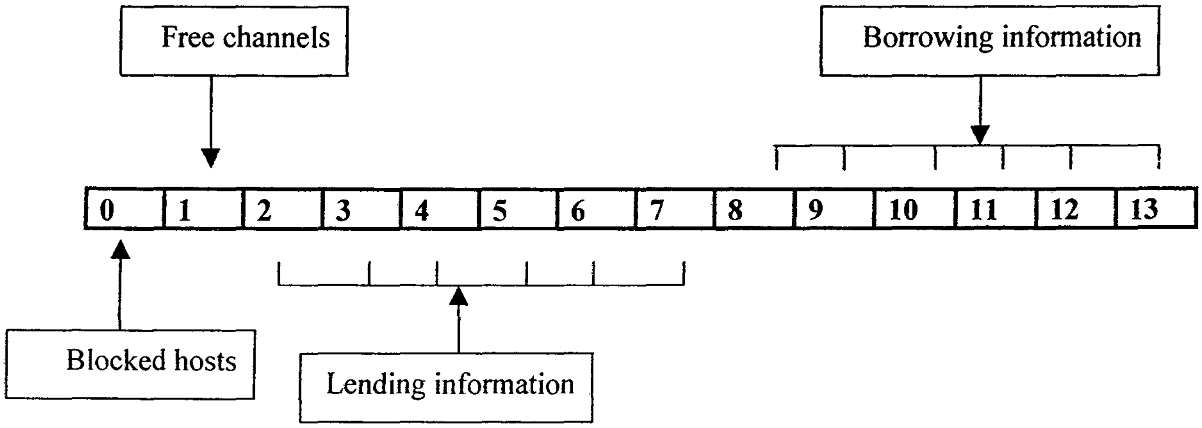


Figure 4.2 : Gene structure

4.7 An explanation of main functions in the algorithm

Lend_Borrow

This function performs 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 C_i and C_j satisfy:
    - $C_i - C_j \neq 1$.
    - $C_i - C_j \neq$ number of cells in a row.
    - $C_i - C_j \neq$ number of neighbor cells in cell pattern.

- Handle the handover problem using the reserved channels
- Search for a new channel for the cross over mobile host.

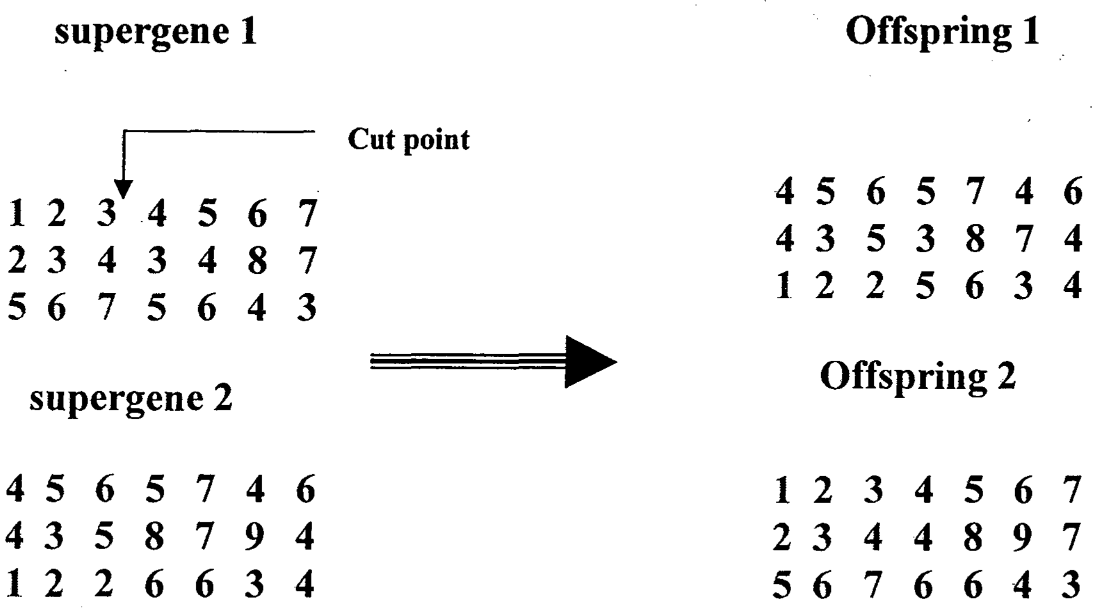
Crossover

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 genes.

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) in to 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 (fig.4.3).

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 elements after the cut point of the second row. Then we look in which order the common elements 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 first 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].



supergene 1

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

supergene 2

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

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

Figure 4.3: Crossover operation

Update

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

If the number of hosts greater than the available free channels 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.

If the 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 the related neighbors is updated.

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 = blocked_hosts – reserved_channels – prime_channels.

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

4.8 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 hosts among the cells 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. Perform 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_channels and blocked_hosts of each cell.
16. Output the number of blocked_hosts resulted in the current generation.
17. Increment generation_index.
18. total_blocked_hosts = total_blocked_hosts + blocked_hosts.
19. Average_blocked_hosts = total_blocked_hosts / generation_no.
20. Output average_blocked_hosts.

Similarly at step 16 and 20 the handoff failure will be observed.

Chapter 5

Experiments and Conclusion

In this chapter, we evaluated the performance of our proposed algorithm and compared it with the algorithm proposed in [1].

5.1 Simulation parameters

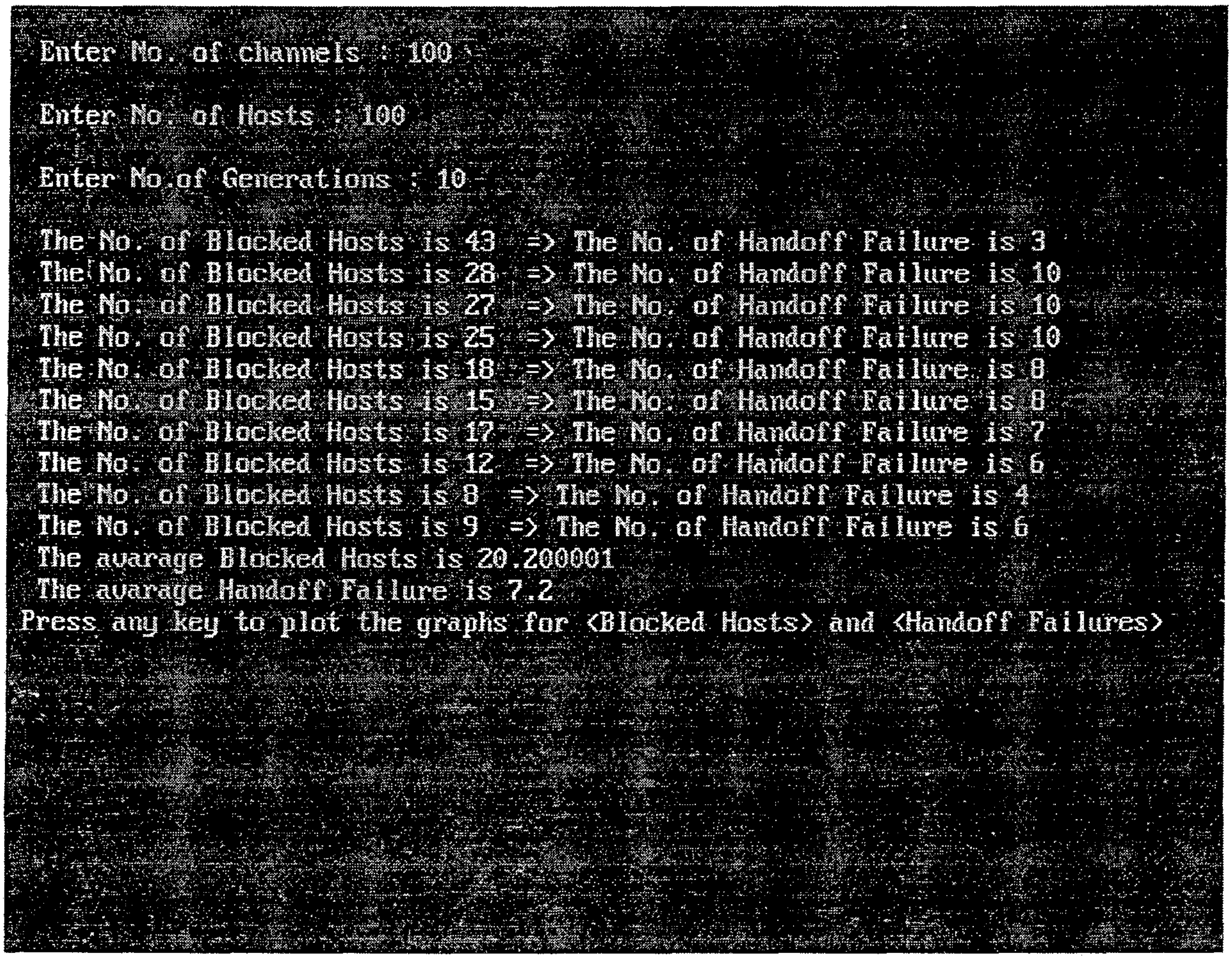
- The simulation study carried out by writing program in C++.
- The simulated cellular network consisted of 20 cells.
- The crossover probability is 1.
- Various values for the total number of channels and hosts in the network tested.
- The performance of the proposed model is evaluated by measuring :
  - The average number of *blocked hosts* in the network.
  - The average number of *handoff failures* in the network.
- The results are represented in performance graphs.

In the performance graph, the X- axis is always the number of generations. The Y-axes are blocked hosts and handoff failures for two experiments.

5.2 Sample Run of the Program

A sample runs of the program, in figures 5.1,2 and 3, are showing the results and the corresponding graphs with the following inputs:

- Number of channels is 100.
- Number of Hosts is 100.
- Number of generations is 10.



```
Enter No. of channels : 100

Enter No. of Hosts : 100

Enter No.of Generations : 10

The No. of Blocked Hosts is 43  => The No. of Handoff Failure is 3
The No. of Blocked Hosts is 28  => The No. of Handoff Failure is 10
The No. of Blocked Hosts is 27  => The No. of Handoff Failure is 10
The No. of Blocked Hosts is 25  => The No. of Handoff Failure is 10
The No. of Blocked Hosts is 18  => The No. of Handoff Failure is 8
The No. of Blocked Hosts is 15  => The No. of Handoff Failure is 8
The No. of Blocked Hosts is 17  => The No. of Handoff Failure is 7
The No. of Blocked Hosts is 12  => The No. of Handoff Failure is 6
The No. of Blocked Hosts is 8  => The No. of Handoff Failure is 4
The No. of Blocked Hosts is 9  => The No. of Handoff Failure is 6
The avarage Blocked Hosts is 20.200001
The avarage Handoff Failure is 7.2
Press any key to plot the graphs for <Blocked Hosts> and <Handoff Failures>
```

Figure 5.1: sample run of the program

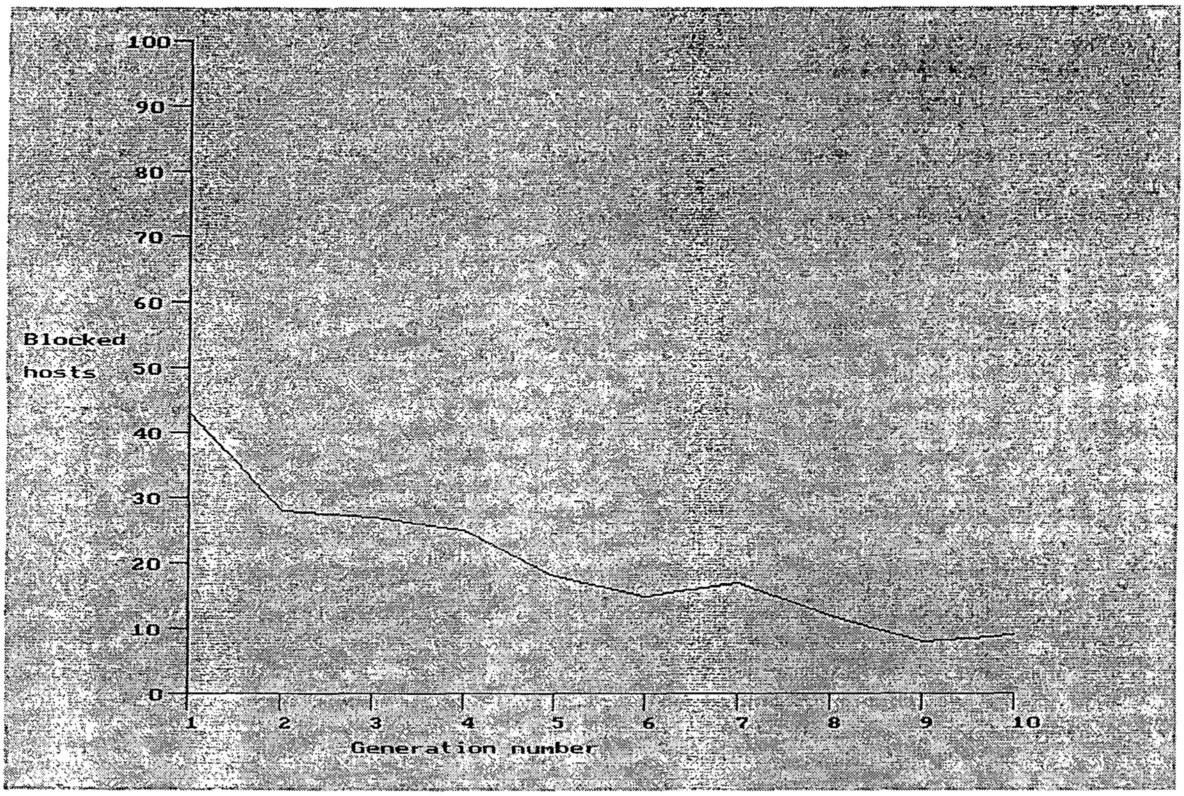


Figure 5.2: sample graph for Blocked hosts

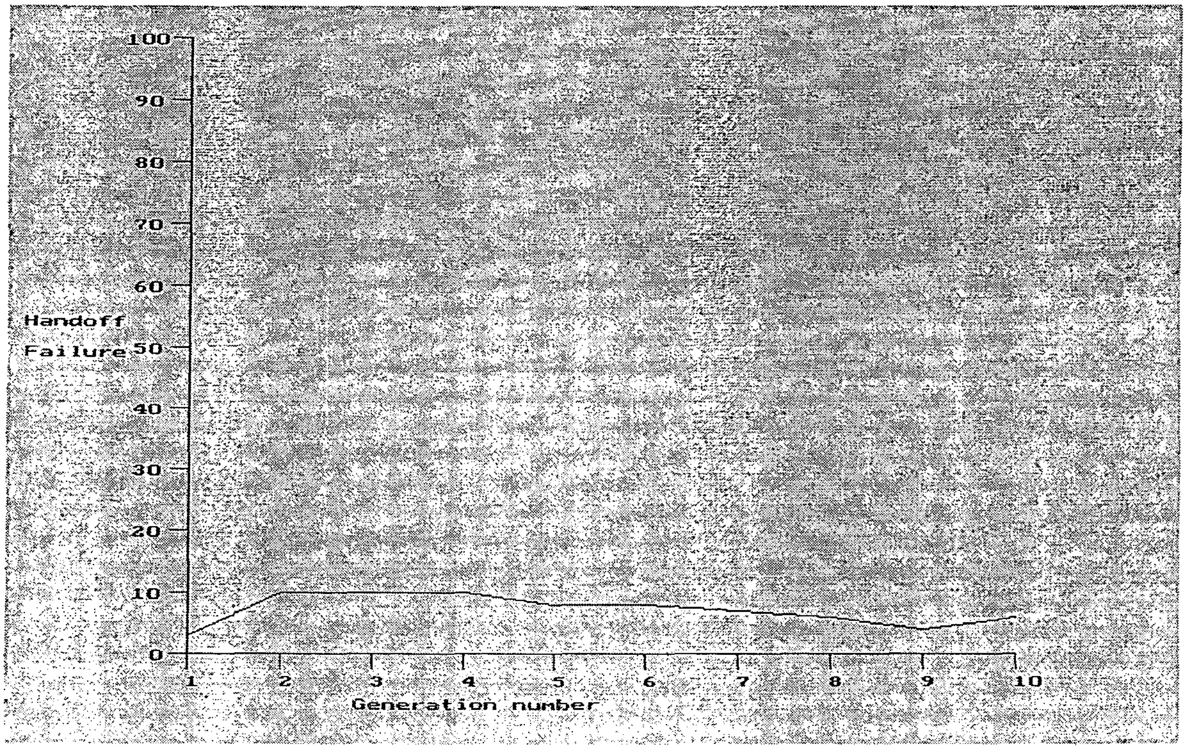


Figure 5.3: sample graph for Handoff failures

5.3 Blocked Hosts Experiment

In this section, we performed experiment to calculate the average number of blocked hosts with generation number 10 and 20.
The input values are as the following:

- Number of Channels: 50, 100, 150, 200.
- Number of Hosts: 50, 100, 150, 200.

5.3.1 Simulation Results for 10 generations

The following graphs show the performance for 10 generations:

50 Channels

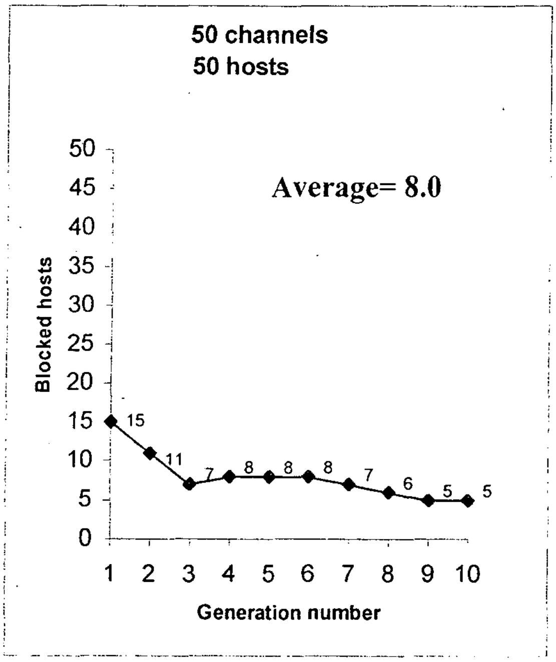


Fig.5.4. 50 channels, 50 hosts

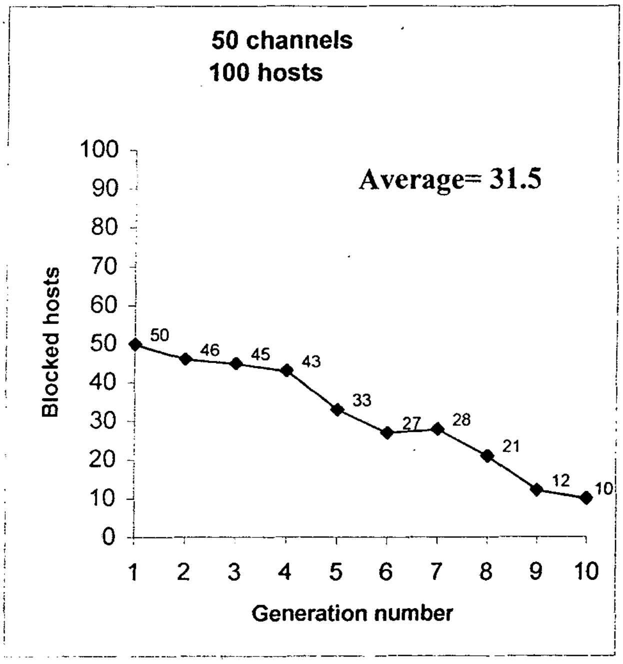


Fig.5.5. 50 channels, 100 hosts

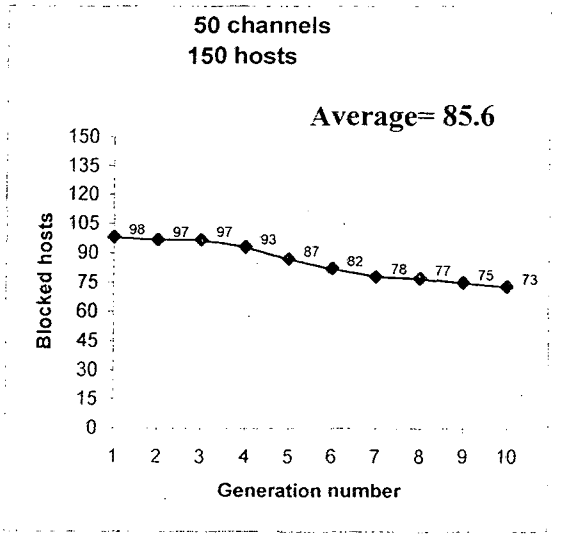


Fig.5.6. 50 channels, 150 hosts

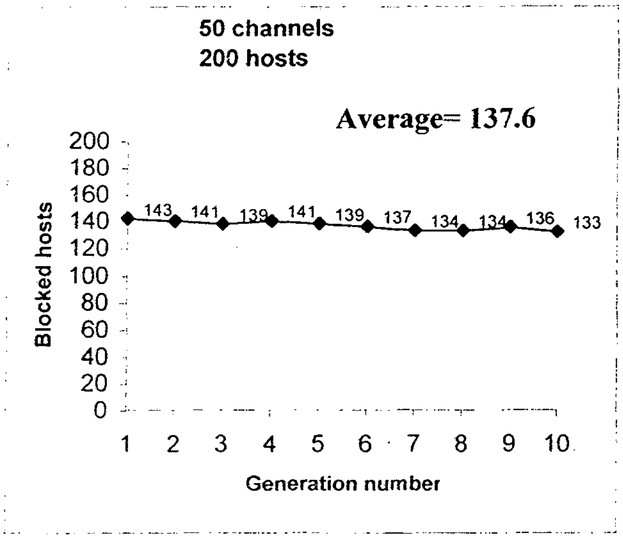


Fig.5.7. 50 channels, 200 hosts

100 Channels

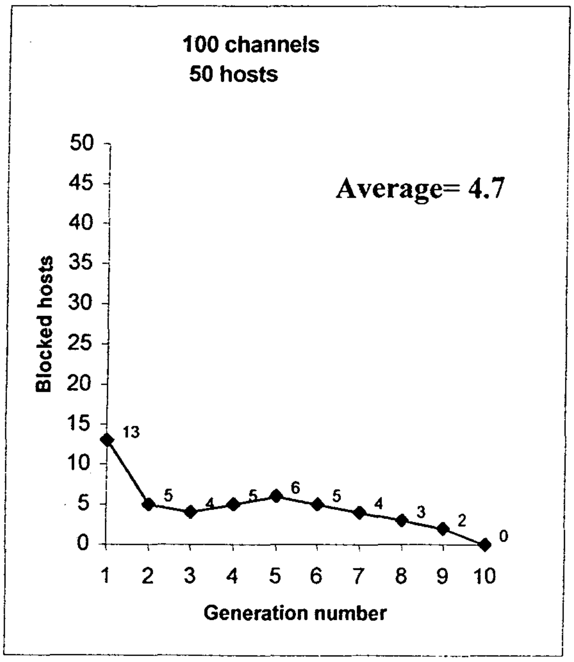


Fig.5.8. 100 channels, 50 hosts

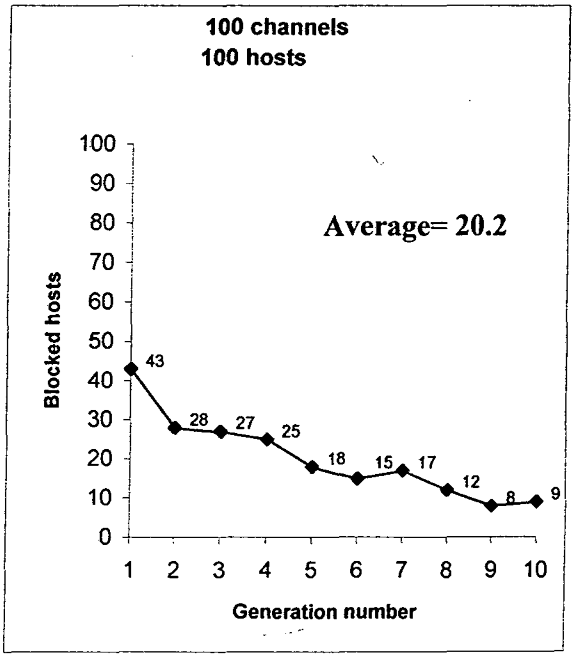


Fig.5.9. 100 channels, 100 hosts

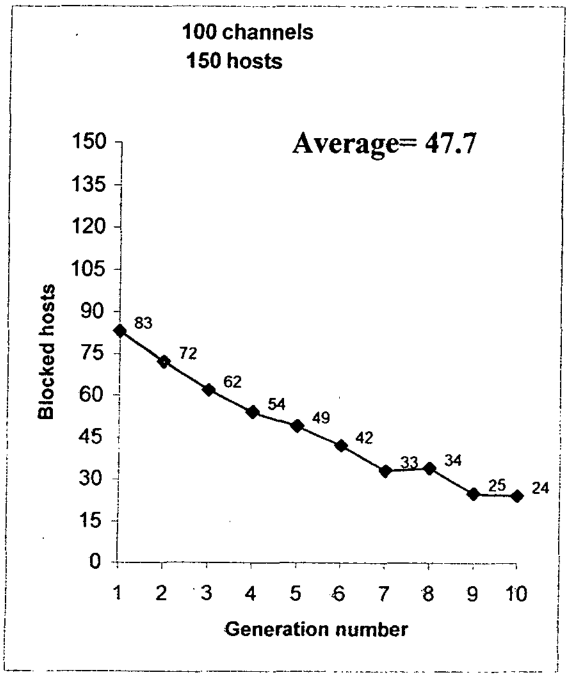


Fig.5.10. 100 channels, 150 hosts

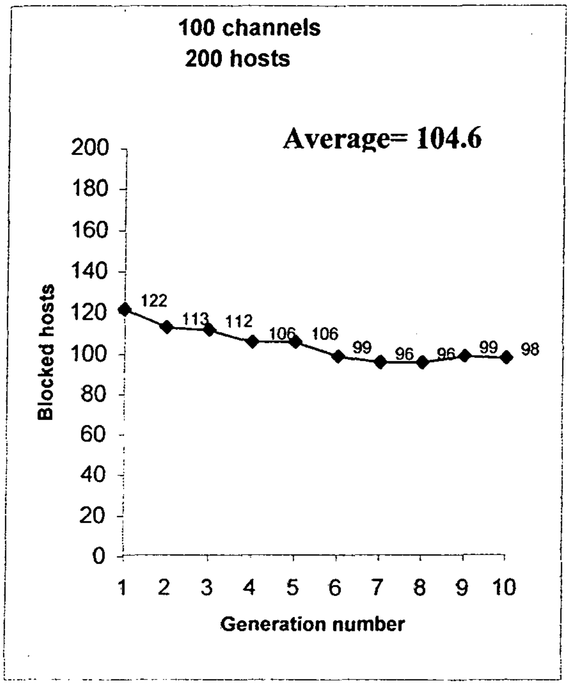


Fig.5.11. 100 channels, 200 hosts

150 Channels

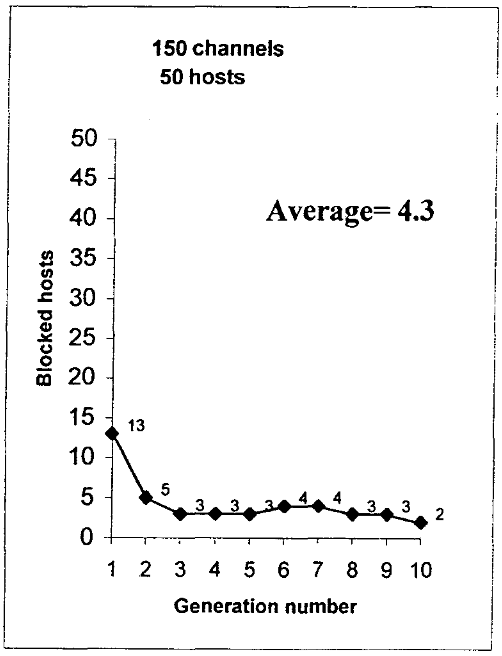


Fig.5.12. 150 channels, 50 hosts

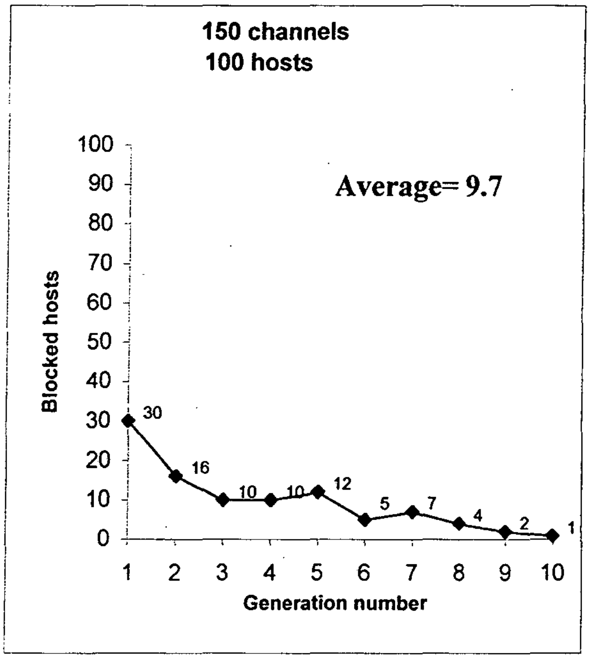


Fig.5.13. 150 channels, 100 hosts

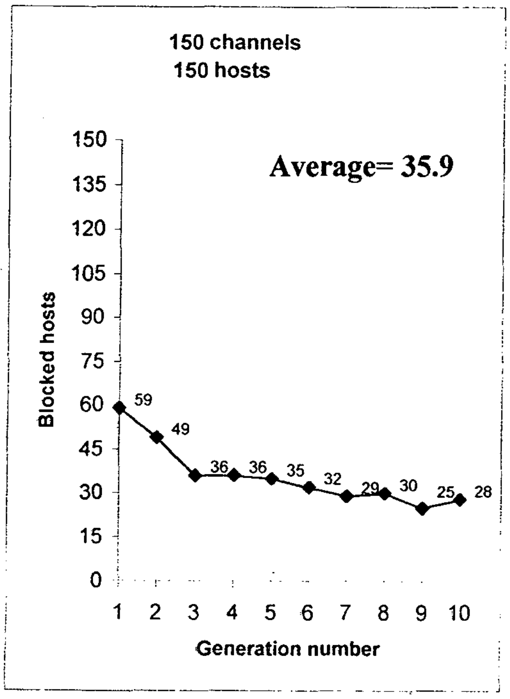


Fig.5.14. 150 channels, 150 hosts

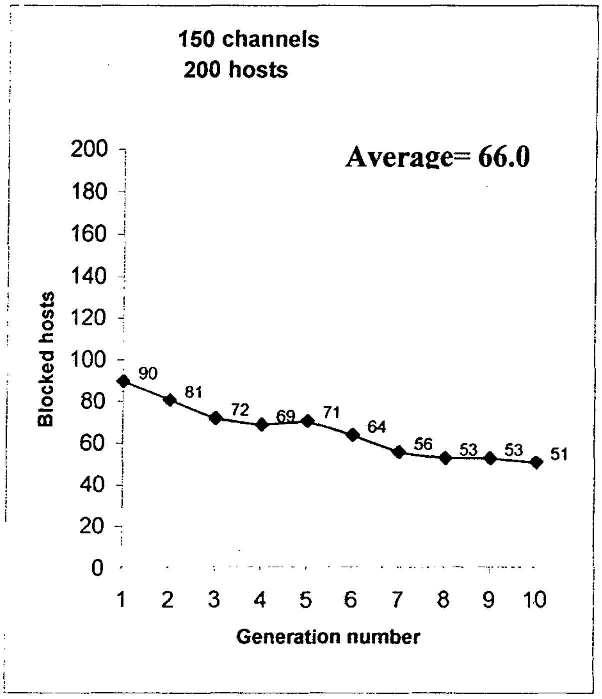


Fig.5.15. 150 channels, 200 hosts

200 Channels

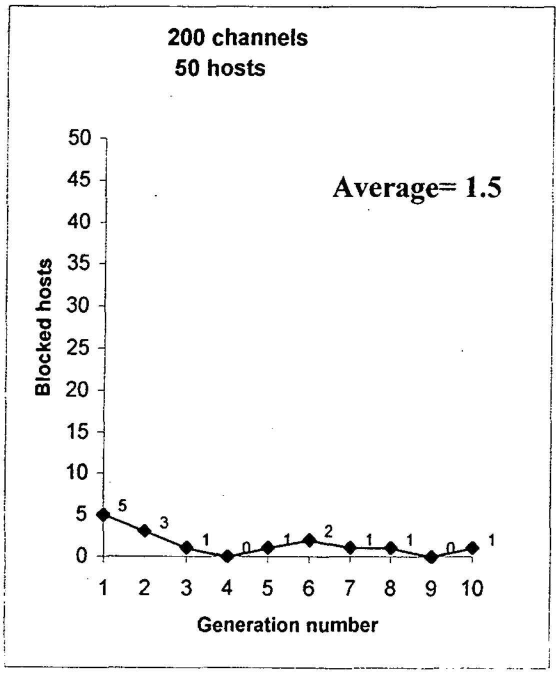


Fig.5.16. 200 channels, 50 hosts

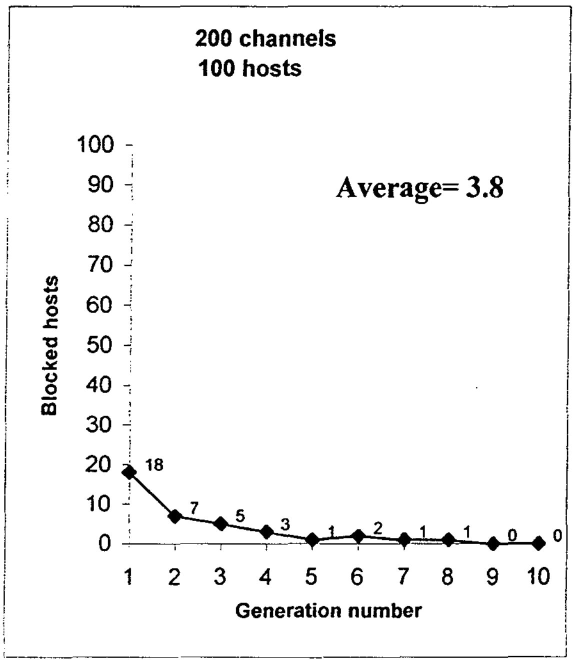


Fig.5.17. 200 channels, 100 hosts

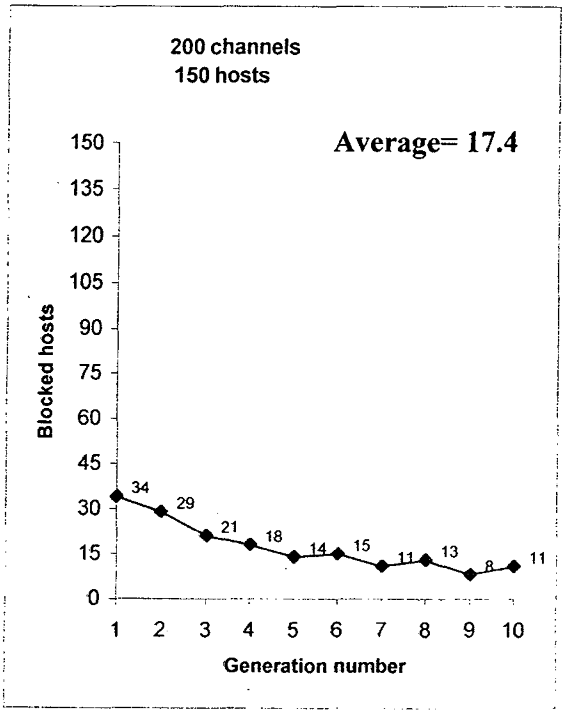


Fig.5.18. 200 channels, 150 hosts

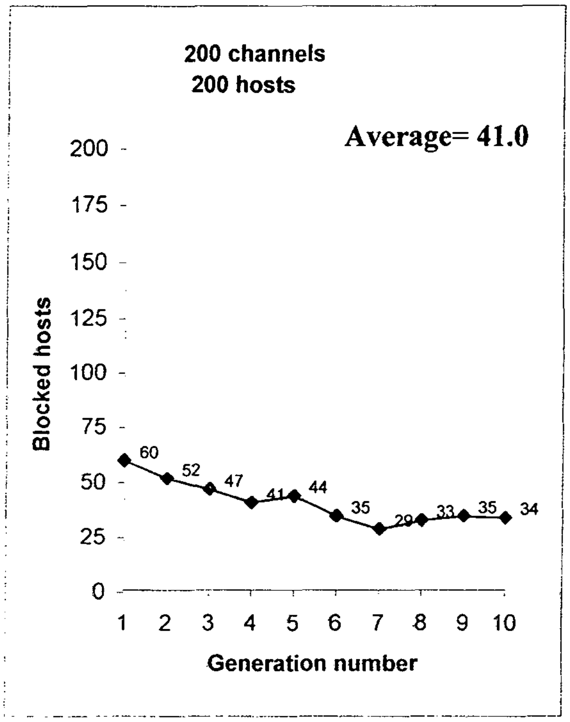


Fig.5.19. 200 channels, 200 hosts

5.3.2 Simulation Results for 20 generations

Here the experiment is conducted with the same set of data. Only the number of generations is increased from 10 to 20. The following graphs show the performance for 20 generations:

50 Channels

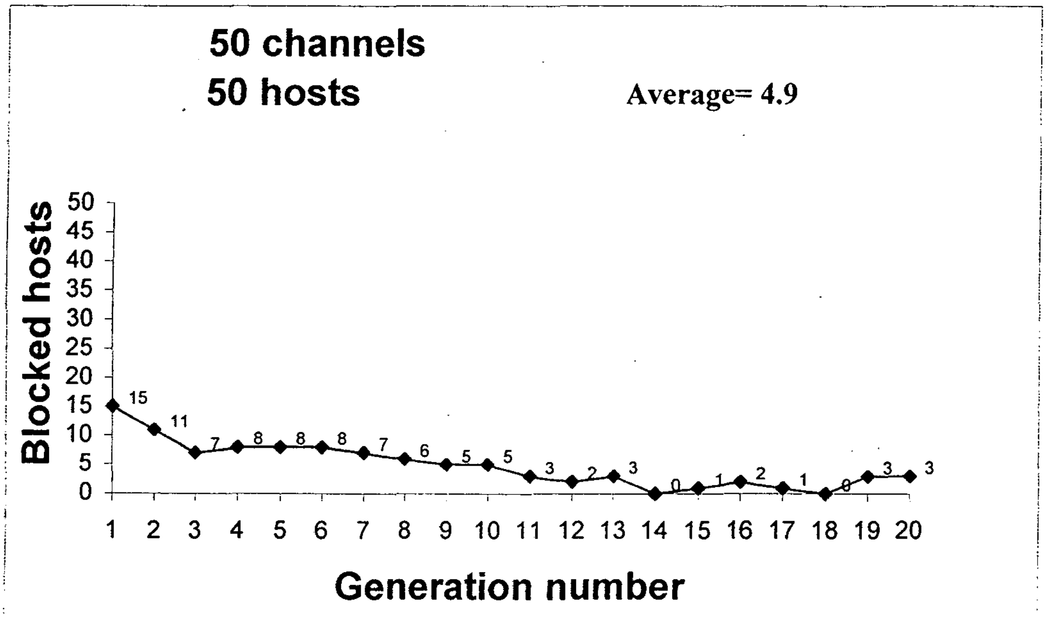


Fig.5.20. 50 channels, 50 hosts

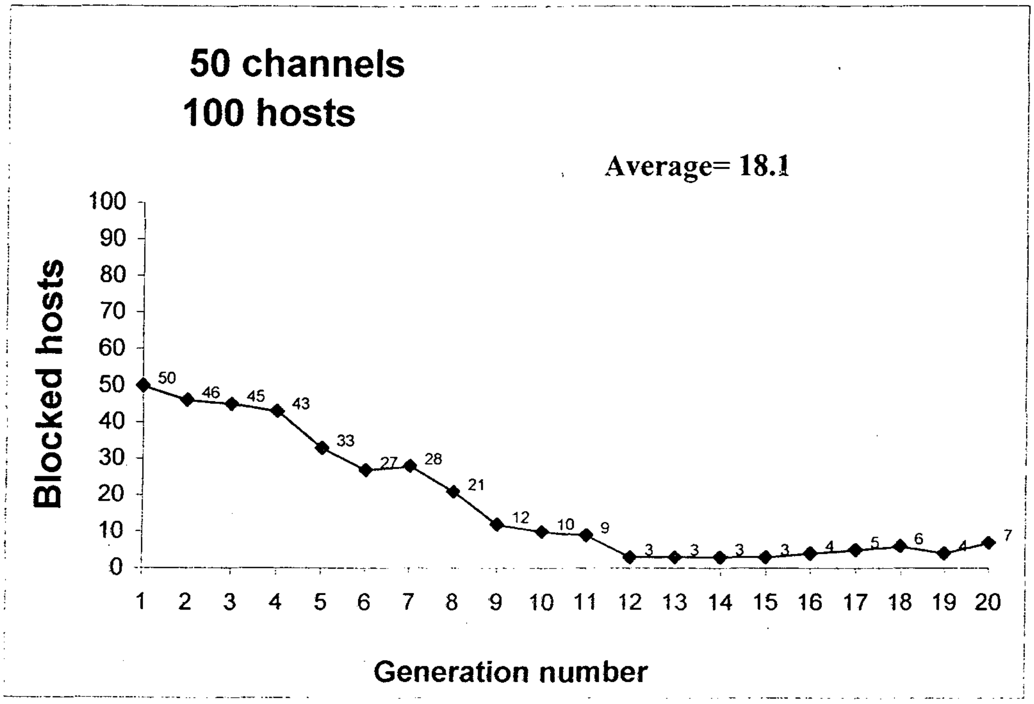


Fig.5.21. 50 channels, 100 hosts

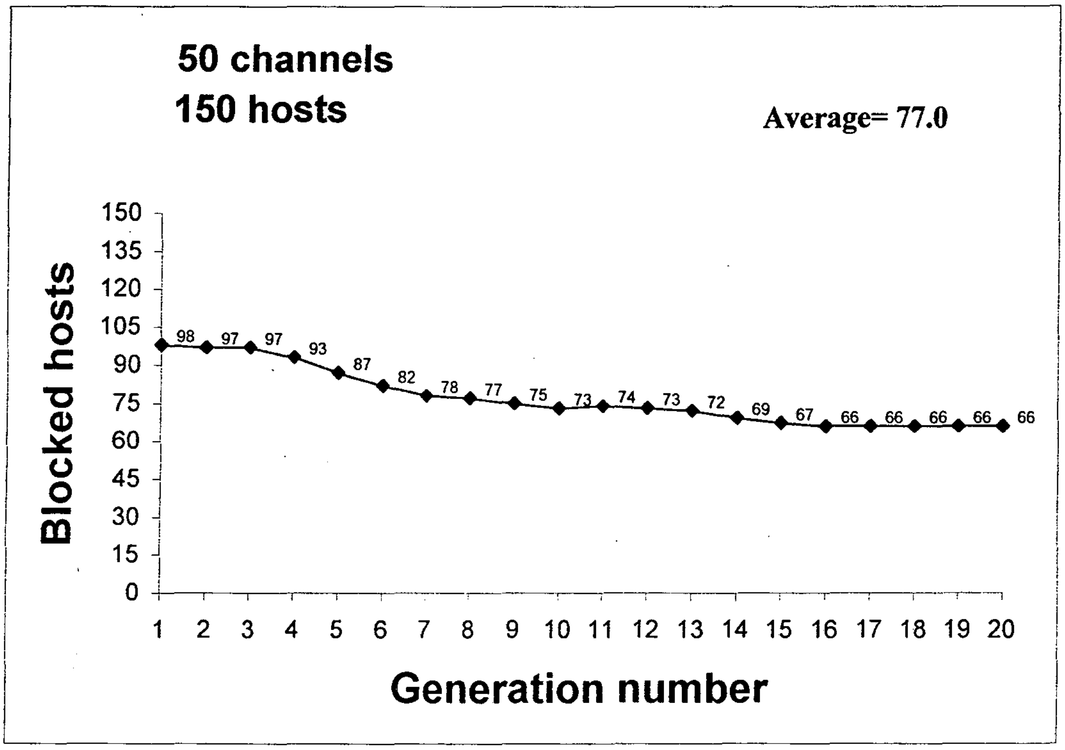


Fig.5.22. 50 channels, 150 hosts

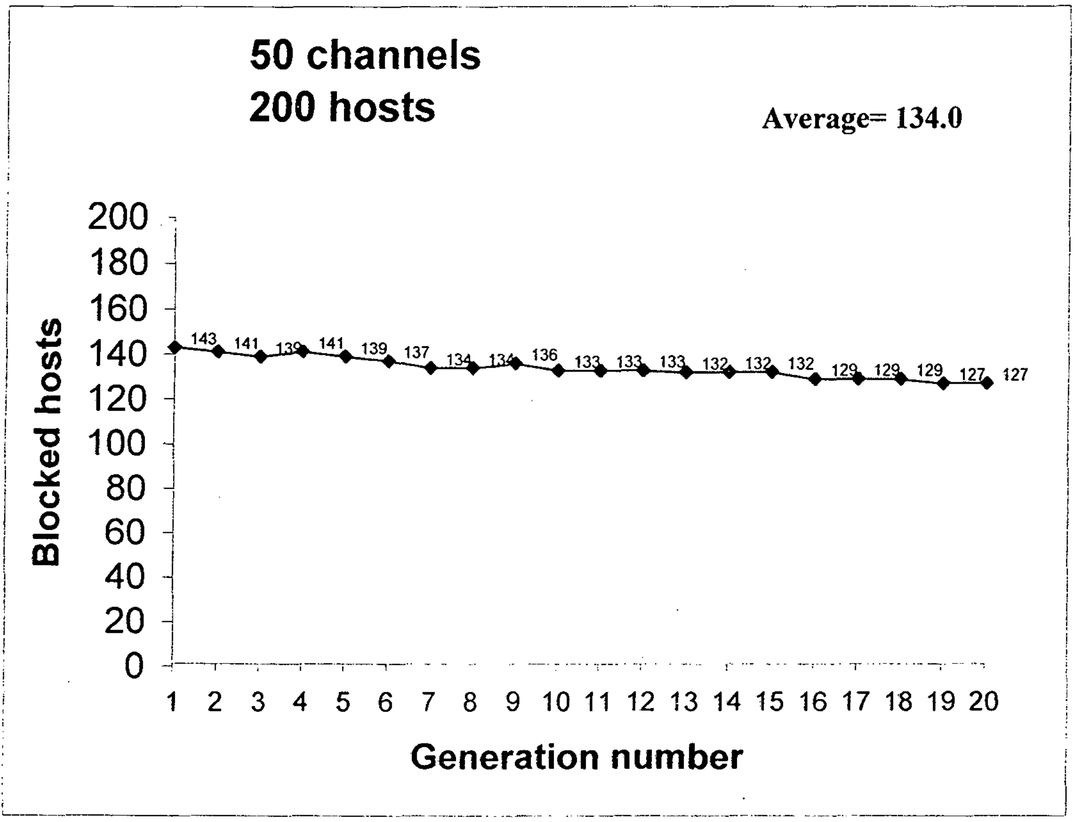


Fig.5.23. 50 channels, 200 hosts

100 Channels

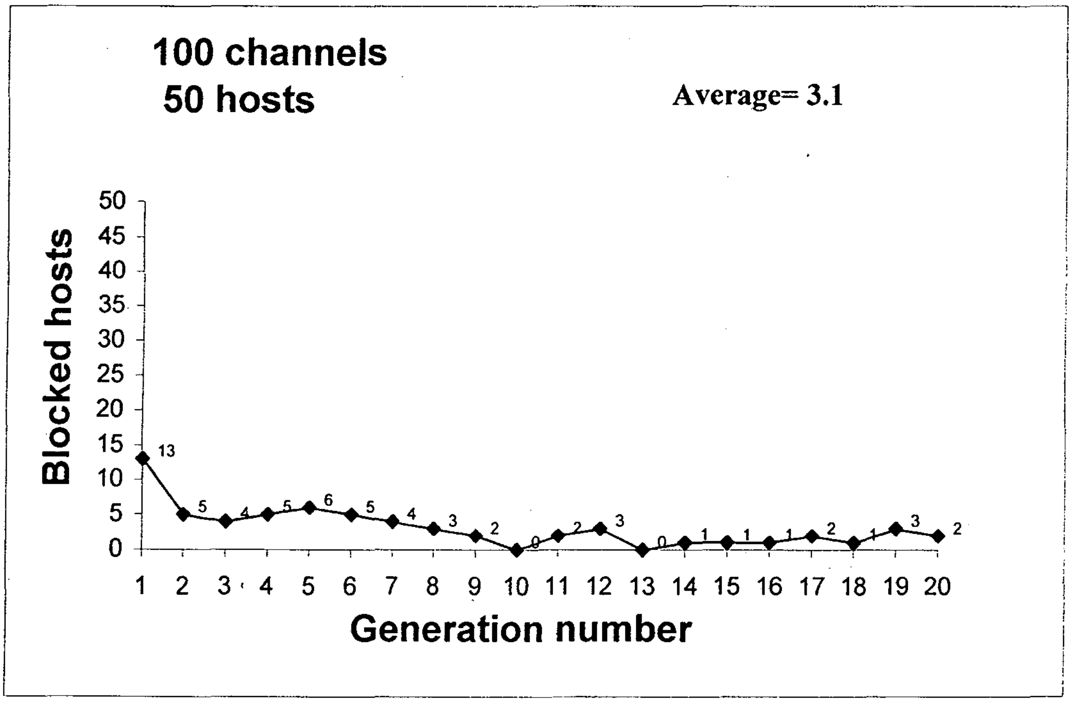


Fig.5.24. 100 channels, 50 hosts

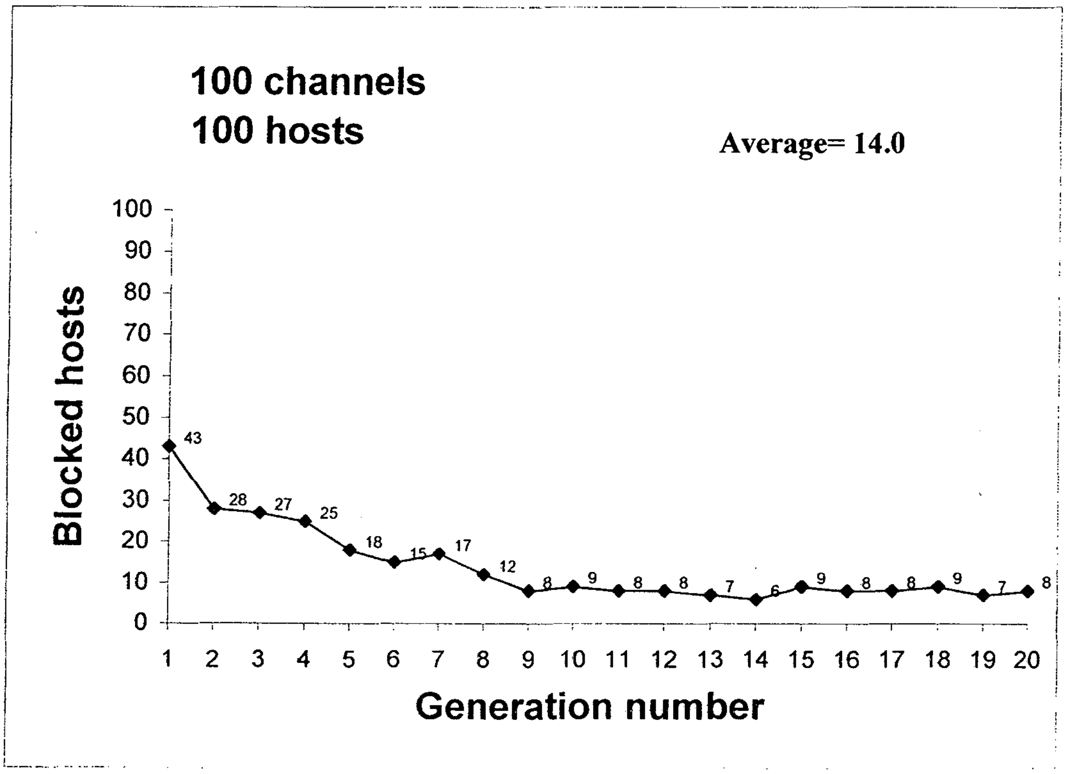


Fig.5.25. 100 channels. 100 hosts

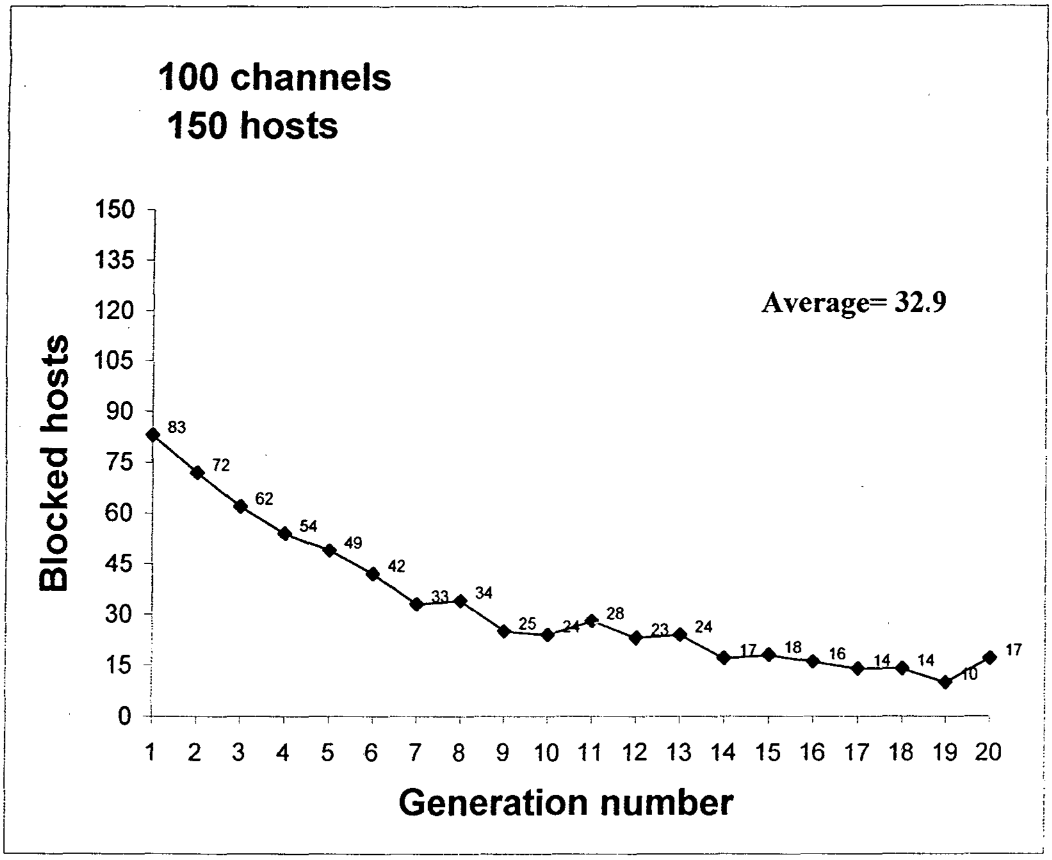


Fig.5.26. 100 channels, 150 hosts

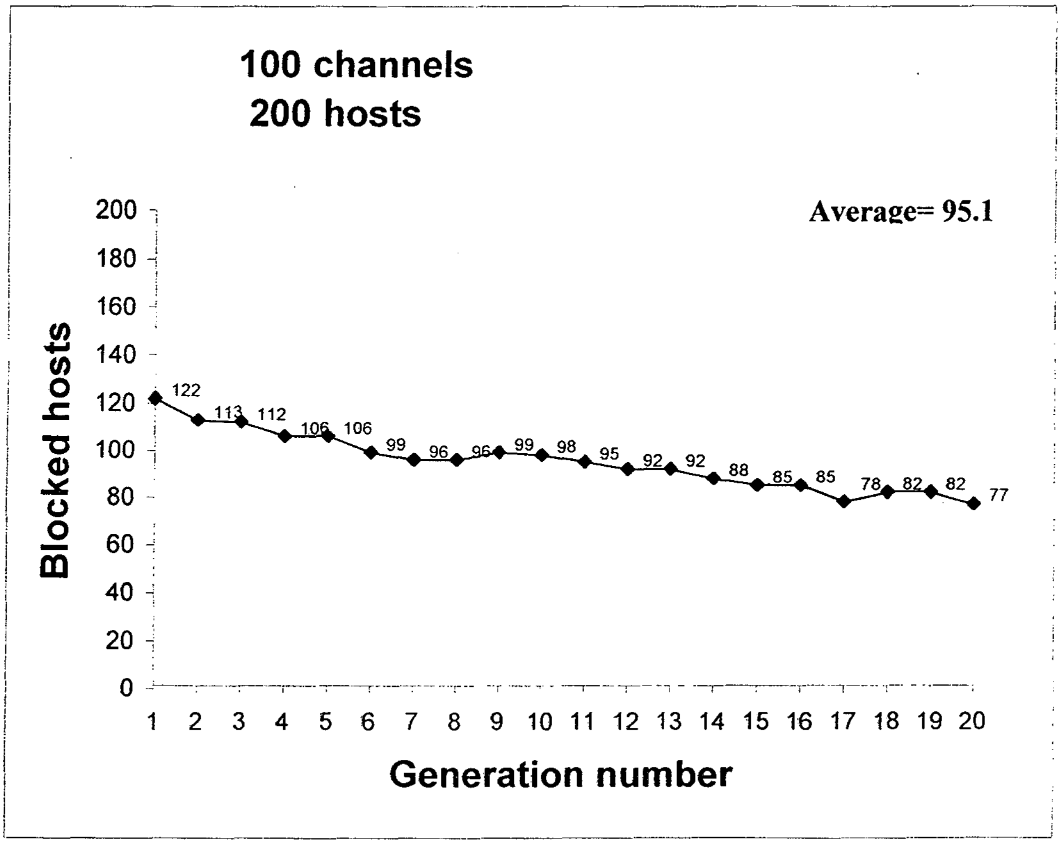


Fig.5.27. 100 channels, 200 hosts

150 Channels

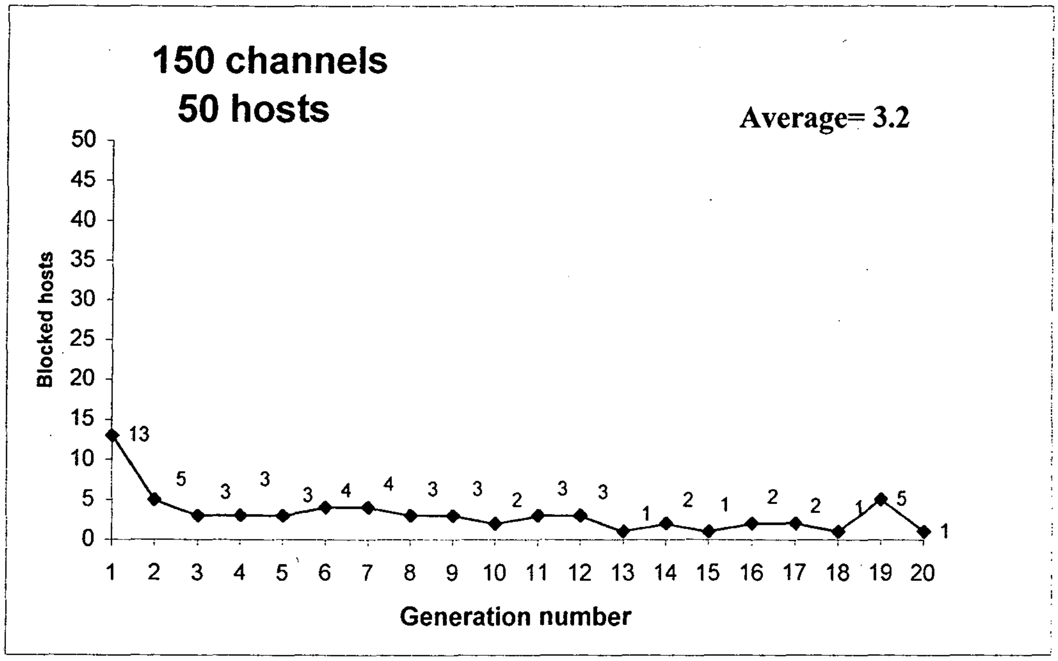


Fig.5.28. 150 channels, 50 hosts

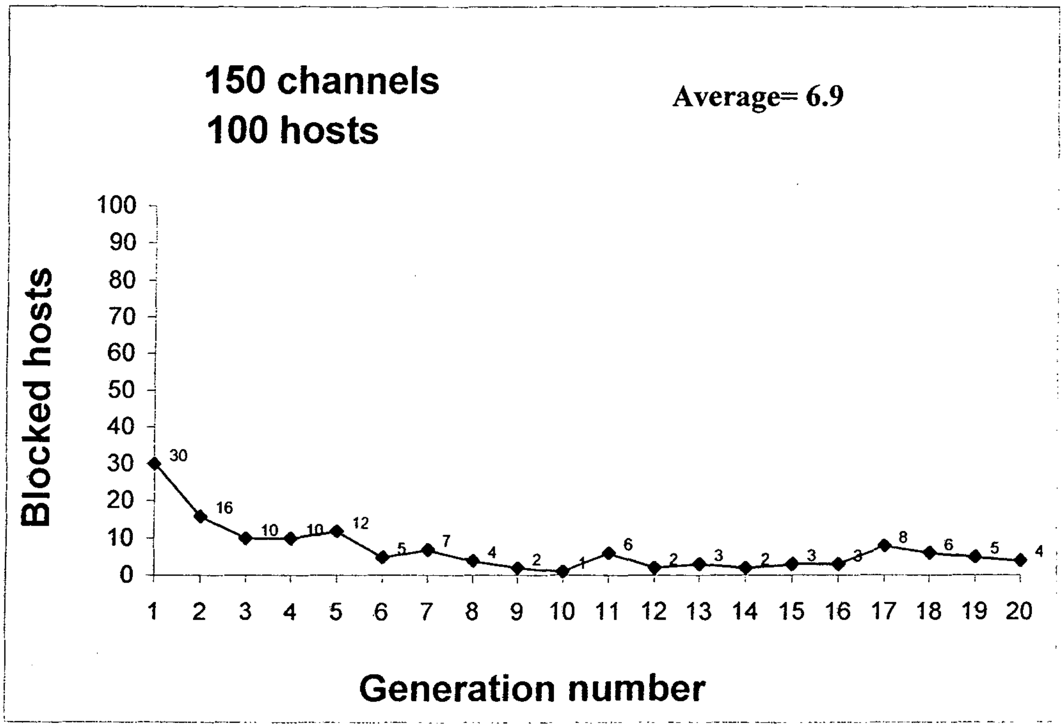


Fig.5.29. 150 channels, 100 hosts

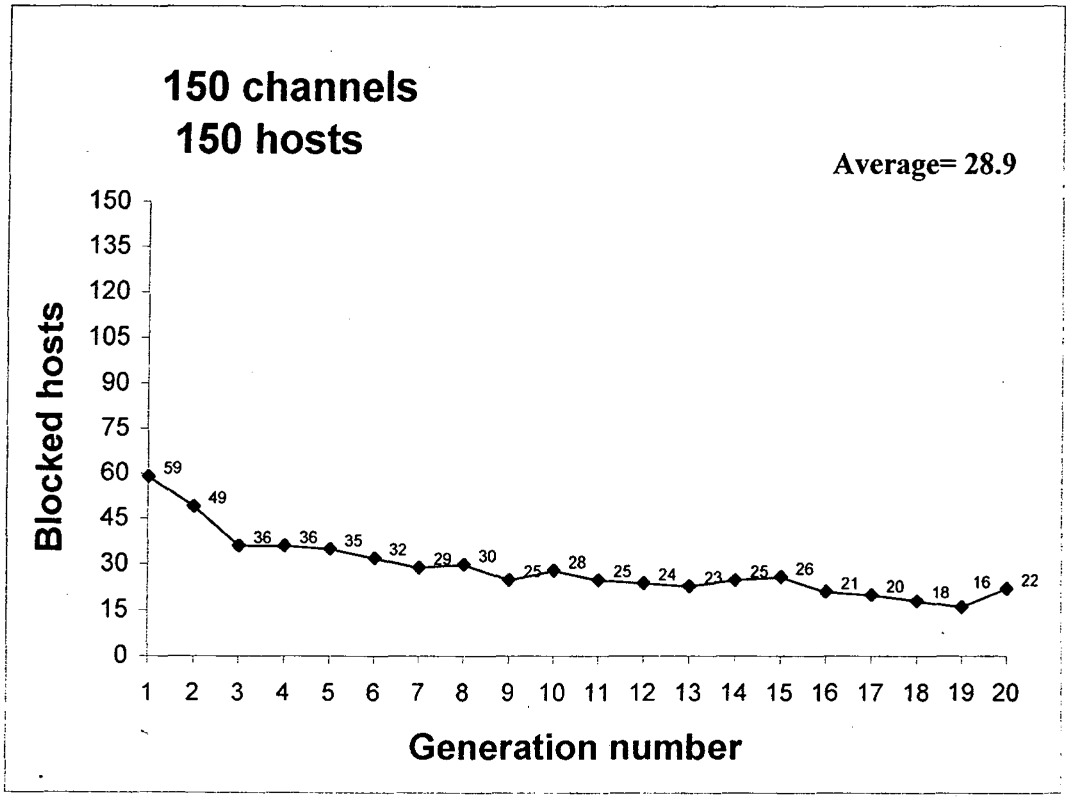


Fig.5.30. 150 channels, 150 hosts

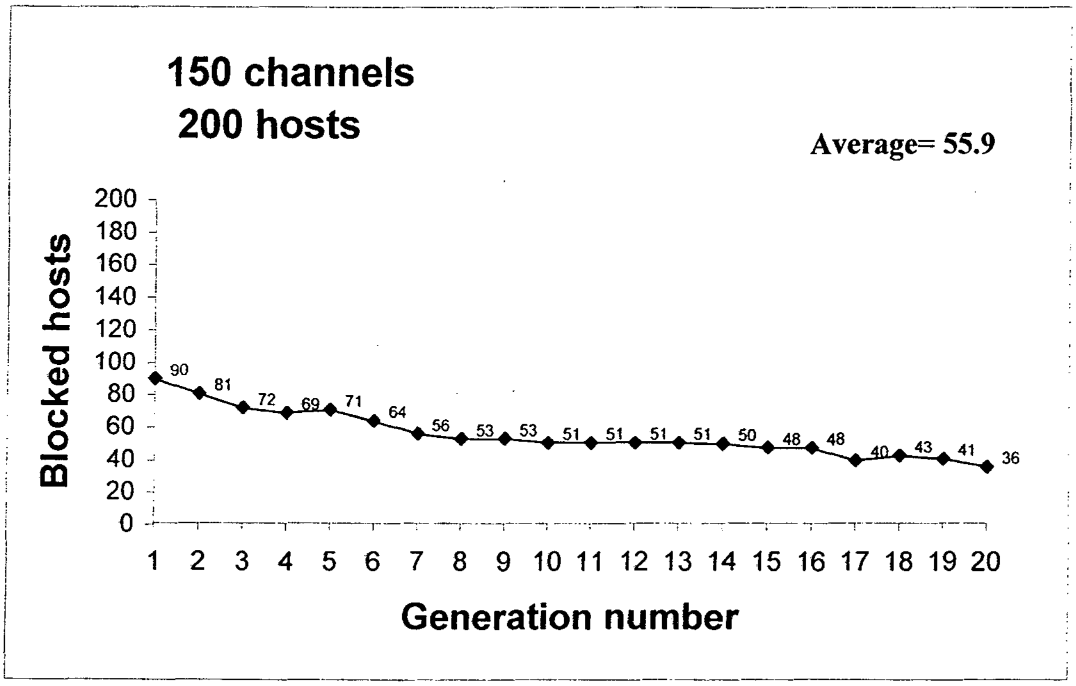


Fig.5.31. 150 channels, 200 hosts

200 Channels

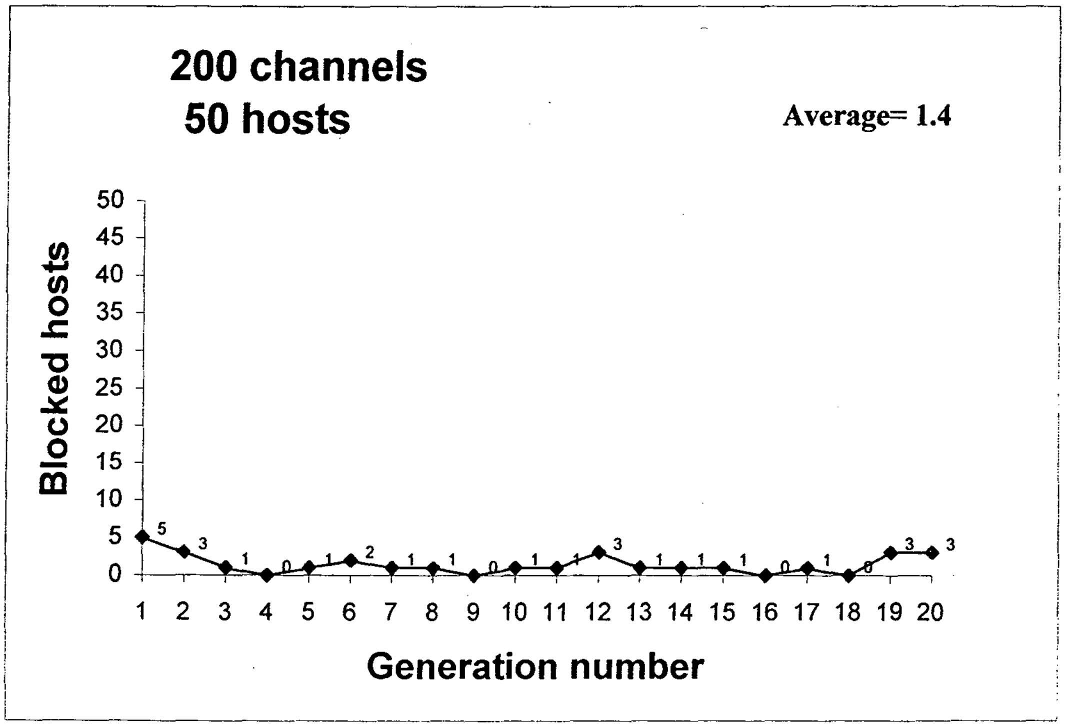


Fig.5.32. 200 channels, 50 hosts

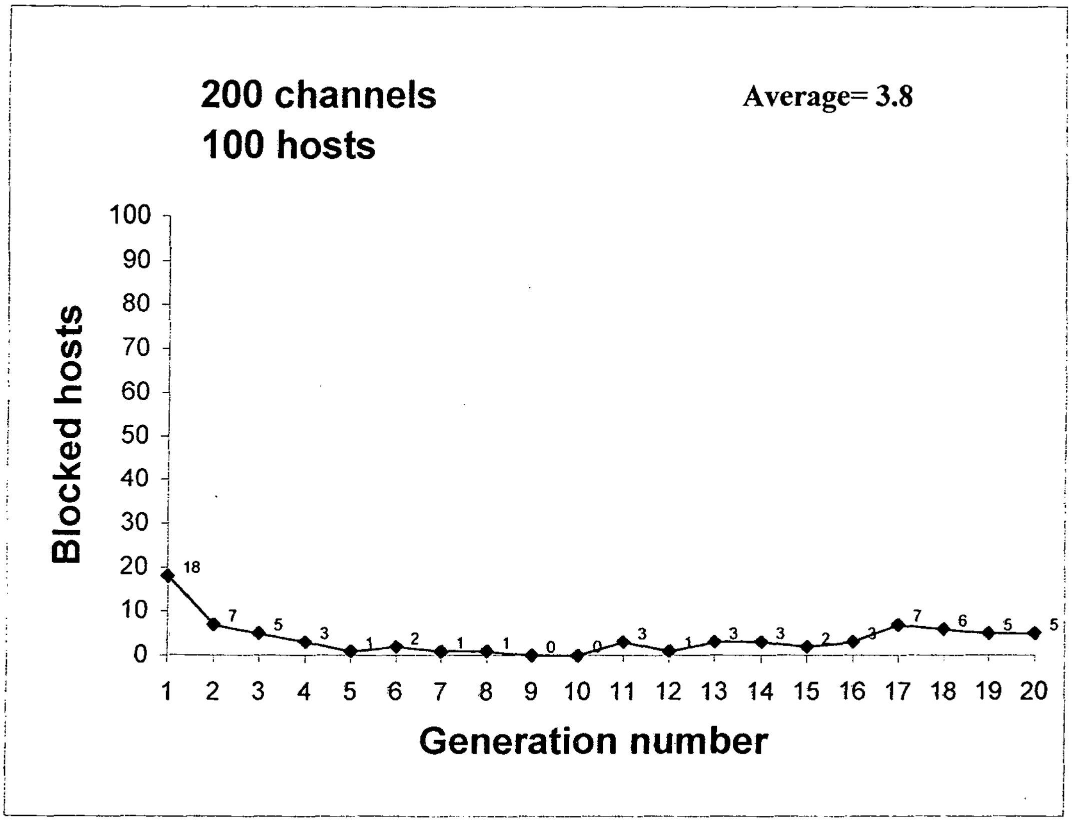


Fig.5.33. 200 channels, 100 hosts

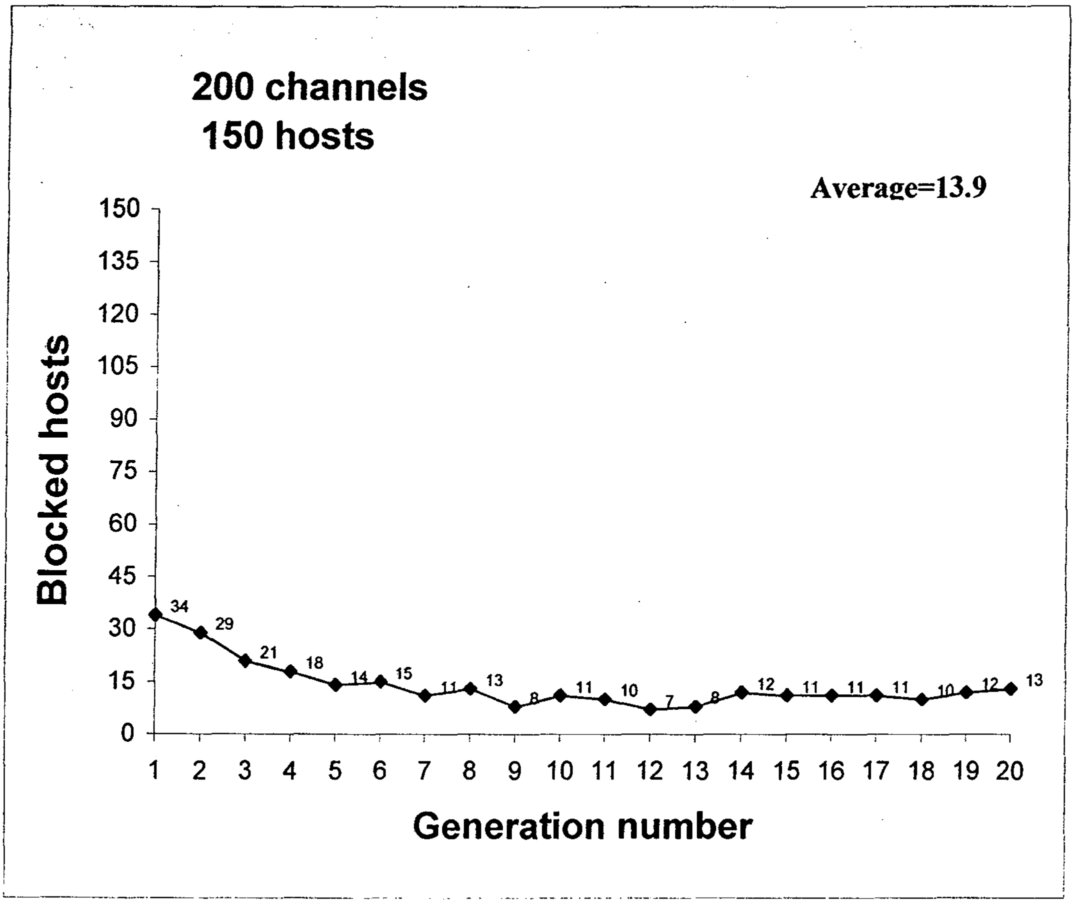


Fig.5.34. 200 channels, 150 hosts

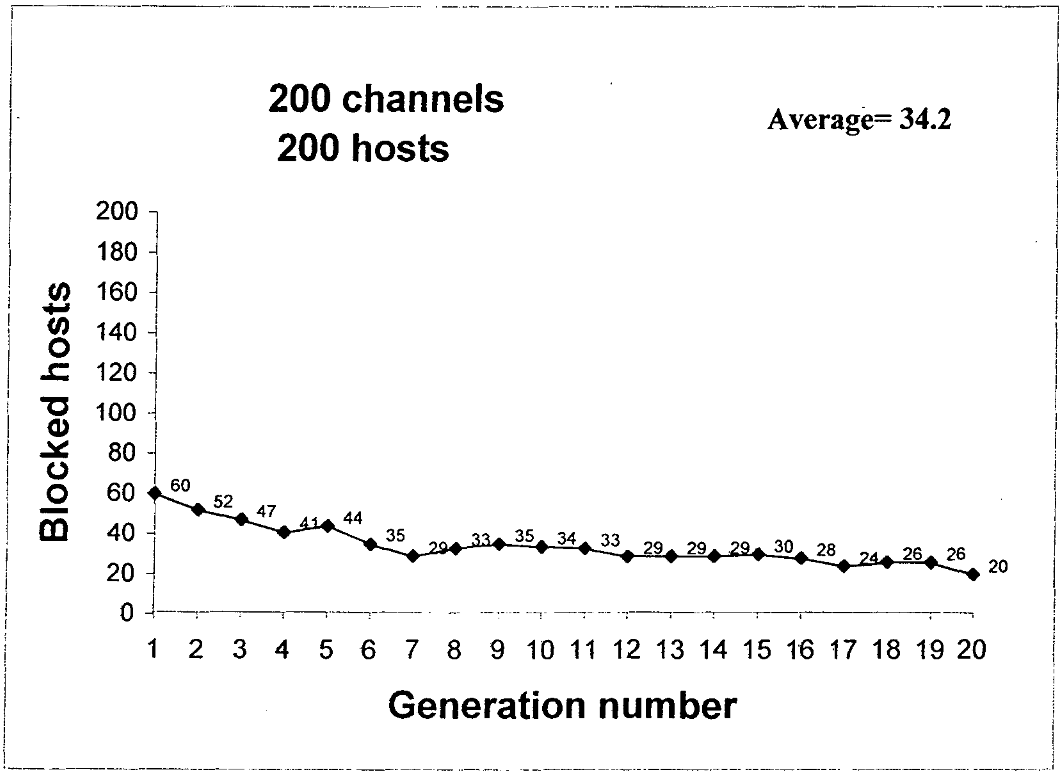


Fig.5.35. 200 channels, 200 hosts

Results, of experiment for 10 generations, are summarized in a table (Table 5.1) as below:

Table 5.1 Average Blocked Hosts in 10 Generations

		Channels			
		50	**100**	**150**	**200**
Hosts	**50**	8.0	4.7	4.3	1.5
	100	31.5	20.2	9.7	3.8
	150	85.6	47.7	35.9	17.4
	200	137.6	104.6	66.0	41.0

Same table is converted into graph :

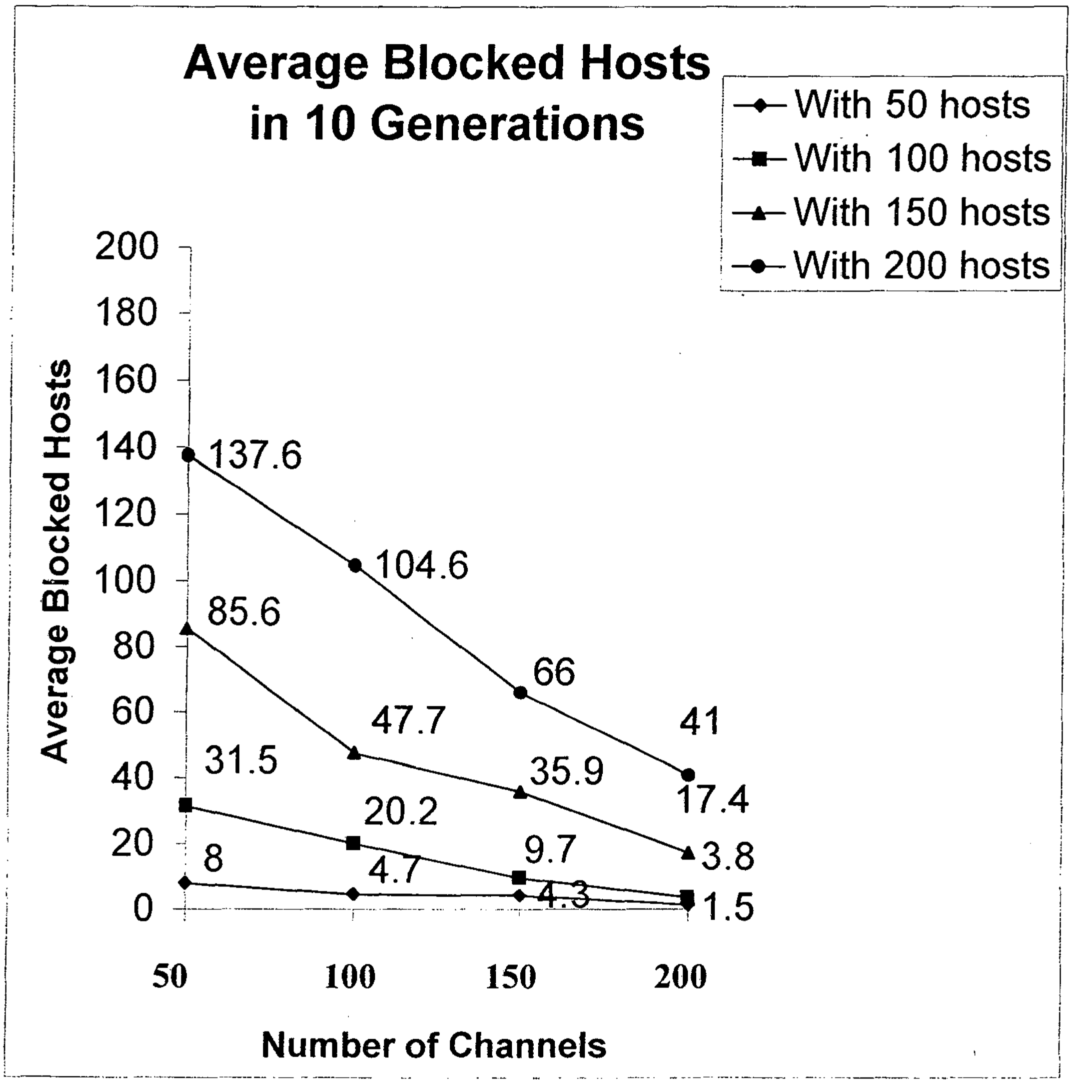


Fig.5.36. Results for 10 generations

Similarly, results for 20 generations are represented in a table (Table 5.2) as below:

Table 5.2 Average Blocked Hosts in 20 Generations

		Channels			
		50	**100**	**150**	**200**
Hosts	**50**	4.9	3.1	3.2	1.4
	100	18.1	14	6.9	3.8
	150	77	32.9	28.9	13.9
	200	134	95.1	55.9	34.2

Same table is converted into graph :

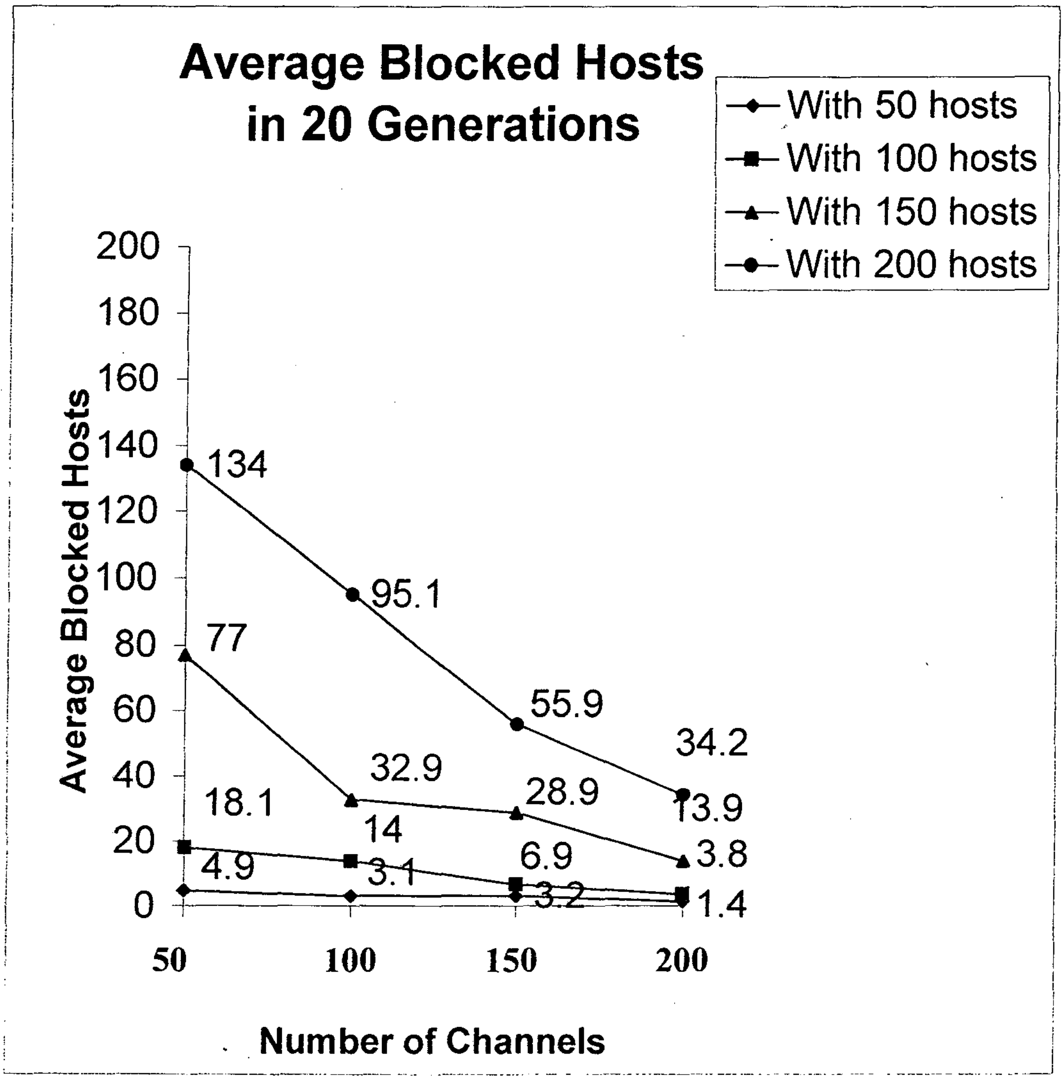


Fig.5.37. Results for 20 generations

5.4 Handoff Failures Experiment

In this section, we performed experiment to calculate the average number of handoff failures with generation number 10 and 20.

The input values are as the following:

- Number of Channels: 50, 100, 150, 200.
- Number of Hosts: 50, 100, 150, 200.

5.4.1 Simulation Results for 10 generations

The following graphs show the performance for 10 generations:

50 Channels

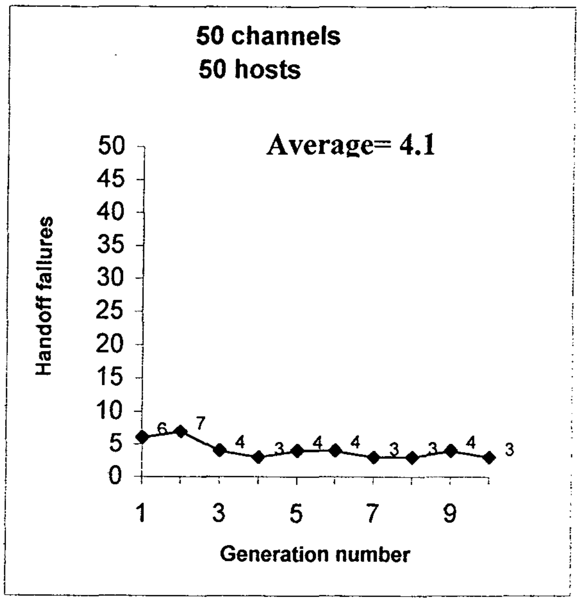


Fig.5.38. 50 channels, 50 hosts

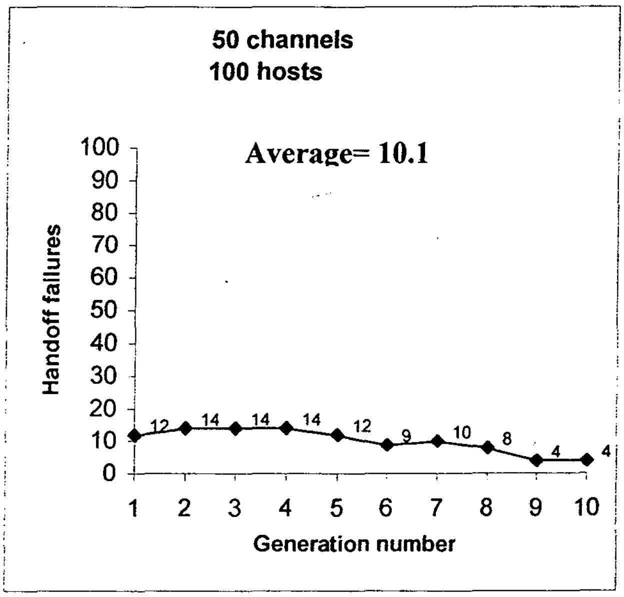


Fig.5.39. 50 channels, 100 hosts

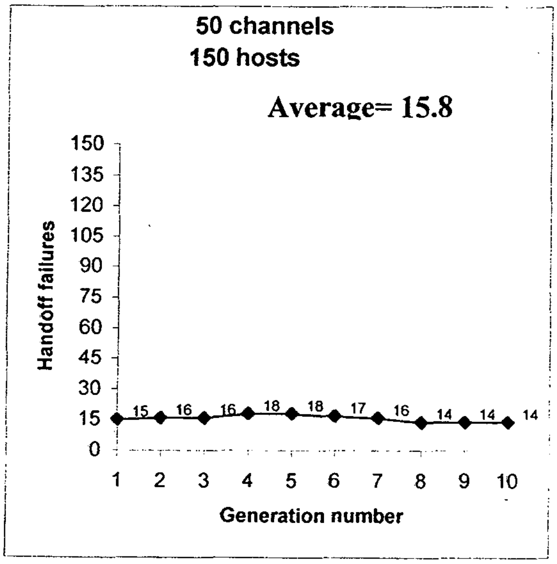


Fig.5.40. 50 channels, 150 hosts

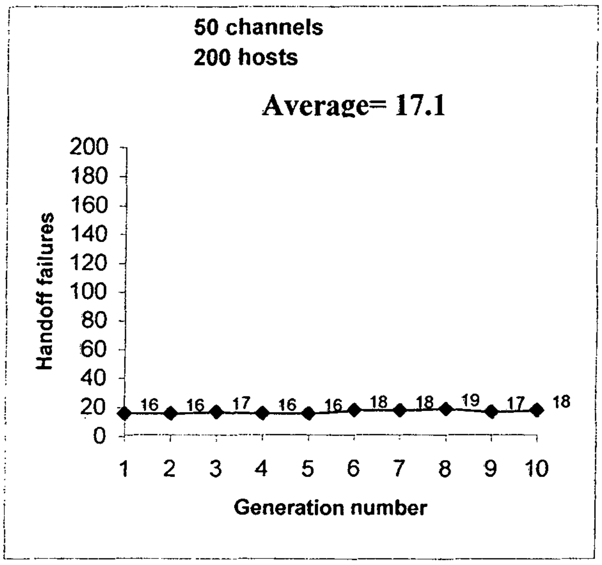


Fig.5.41. 50 channels, 200 hosts

100 Channels

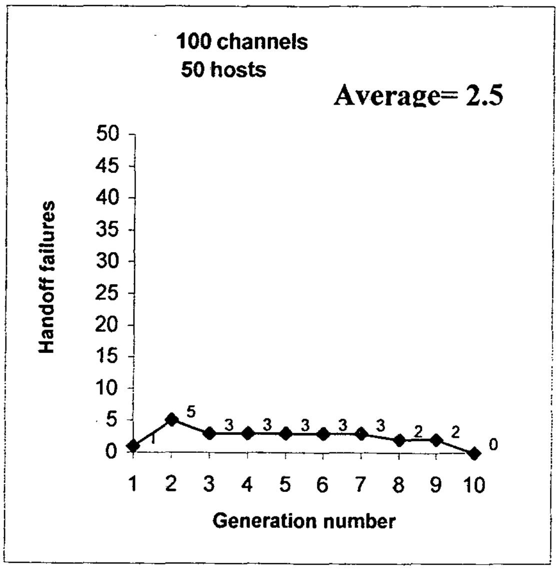


Fig.5.42. 100 channels, 50 hosts

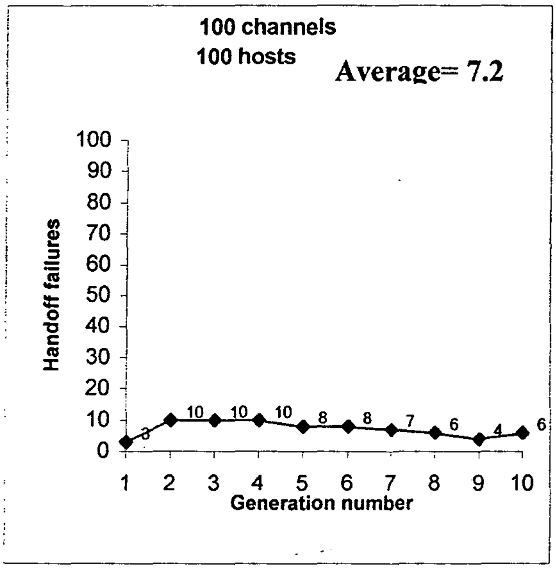


Fig.5.43. 100 channels, 100 hosts

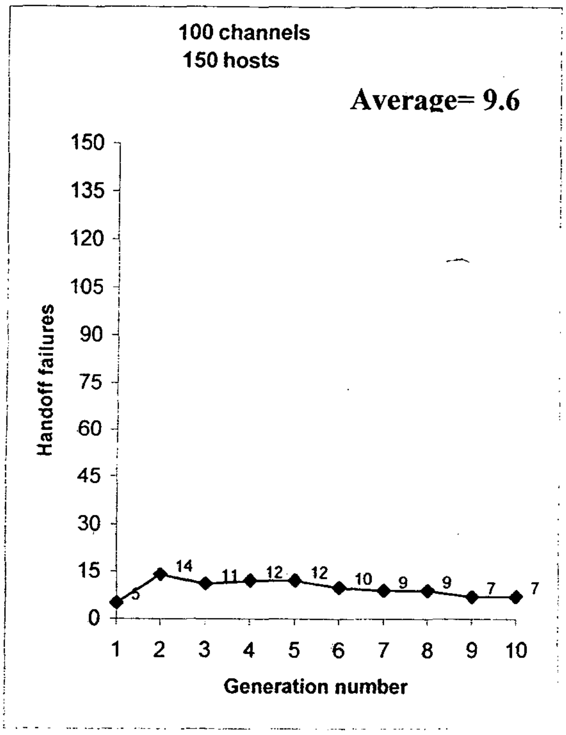


Fig.5.44. 100 channels, 150 hosts

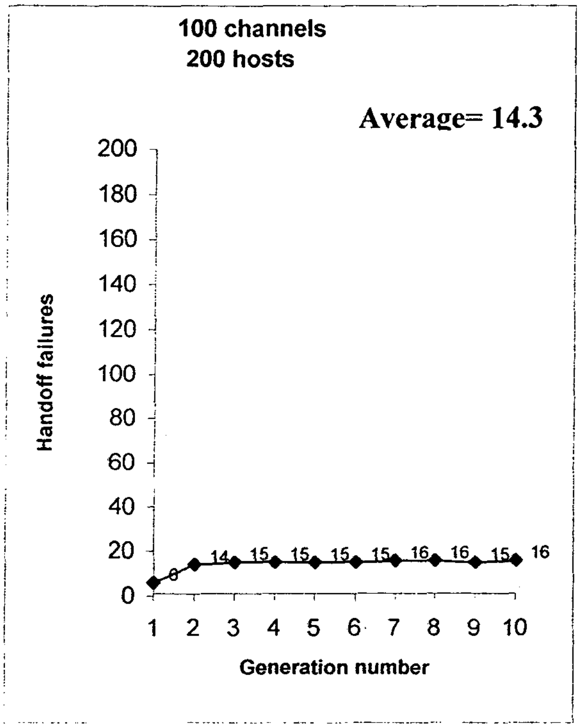


Fig.5.45. 100 channels, 200 hosts

150 Channels

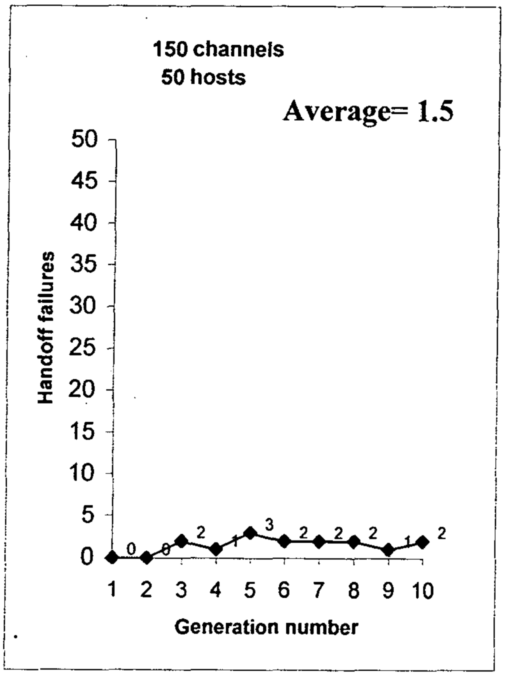


Fig.5.46. 150 channels, 50 hosts

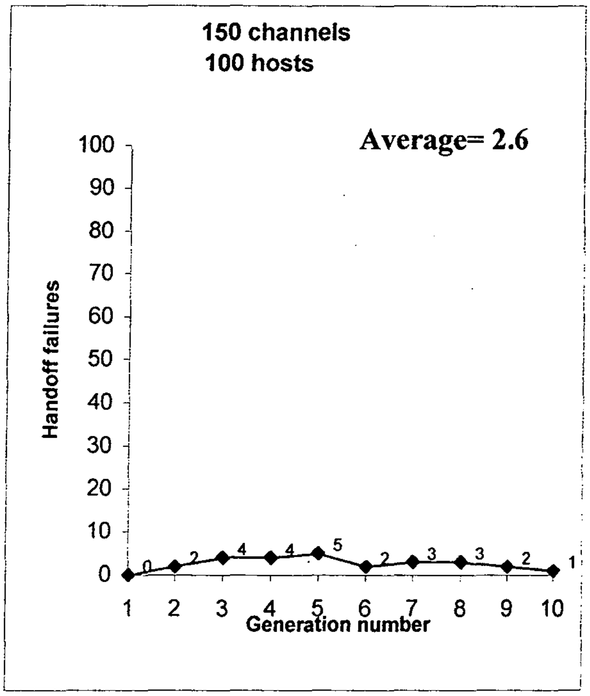


Fig.5.47. 150 channels, 100 hosts

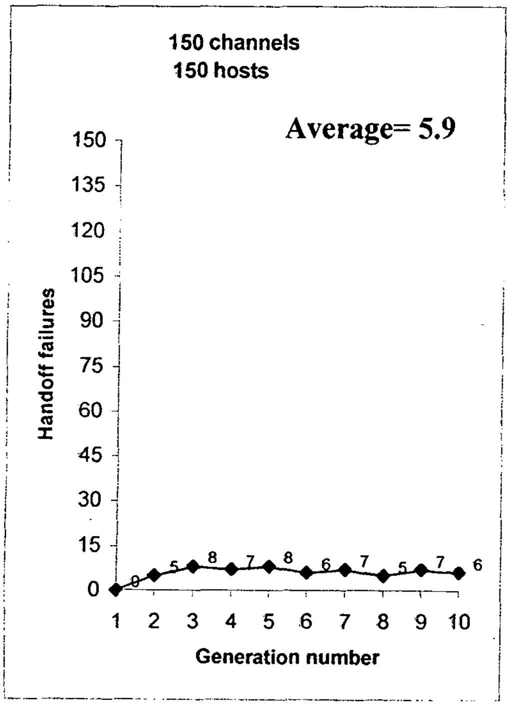


Fig.5.48. 150 channels, 150 hosts

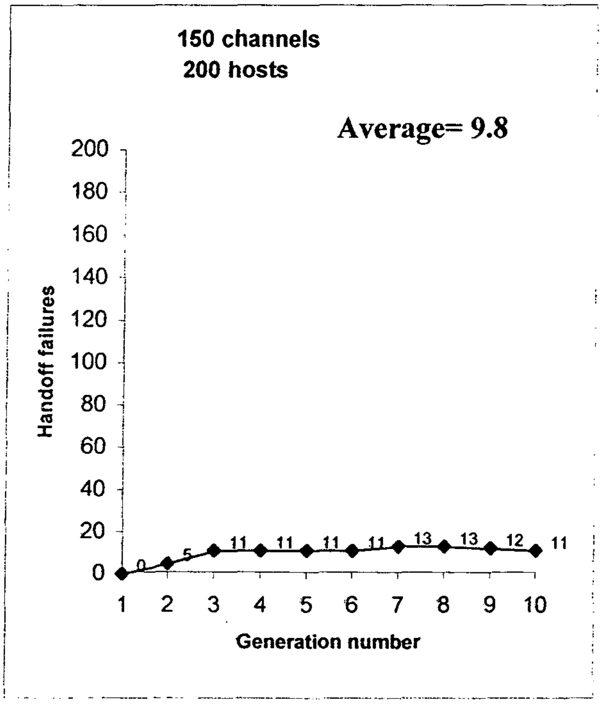


Fig.5.49. 150 channels, 200 hosts

200 Channels

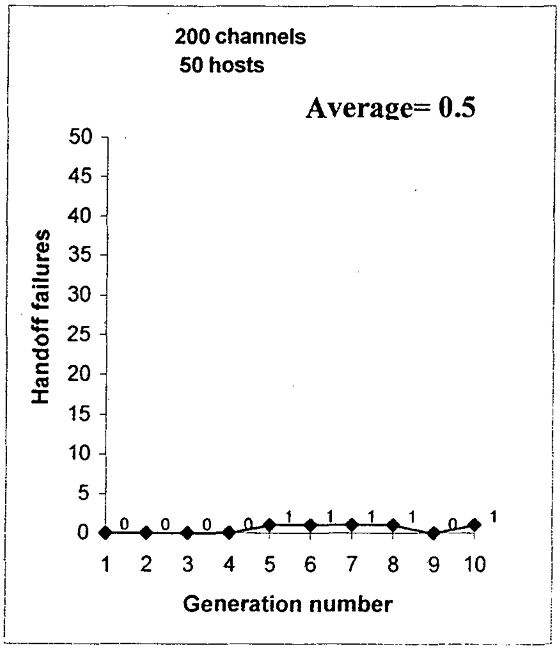


Fig.5.50. 200 channels, 50 hosts

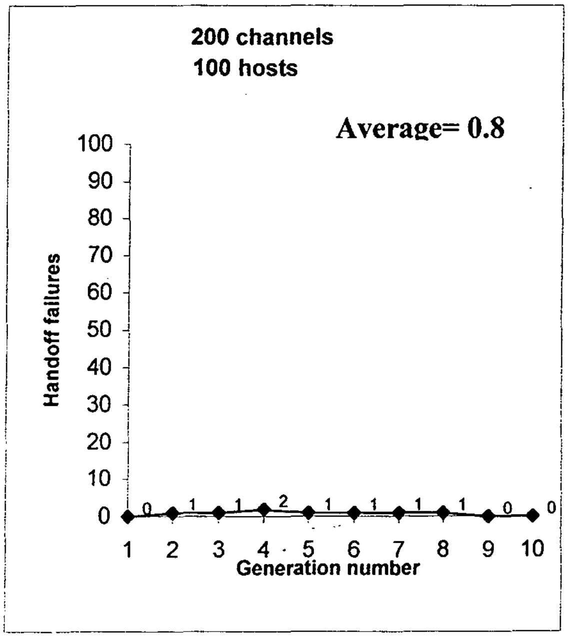


Fig.5.51. 200 channels, 100 hosts

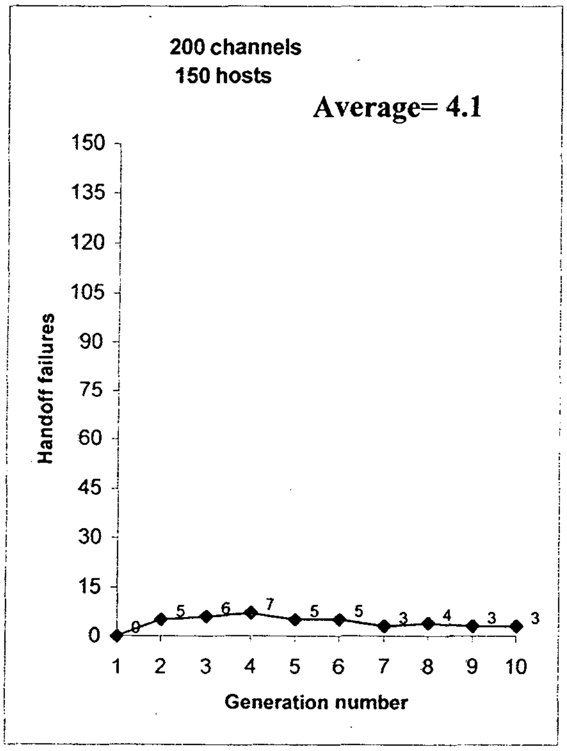


Fig.5.52. 200 channels, 150 hosts

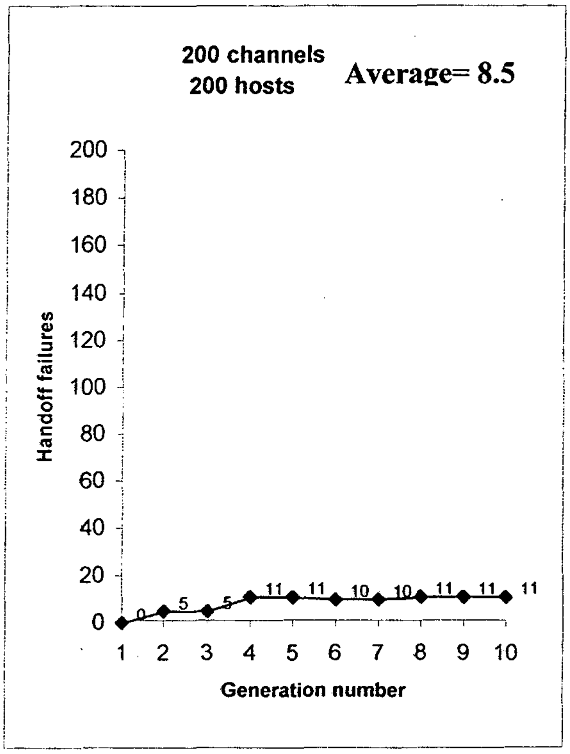


Fig.5.53. 200 channels, 200 hosts

5.4.2 Simulation Results for 20 generations

The following graphs show the performance for 20 generations:

50 Channels

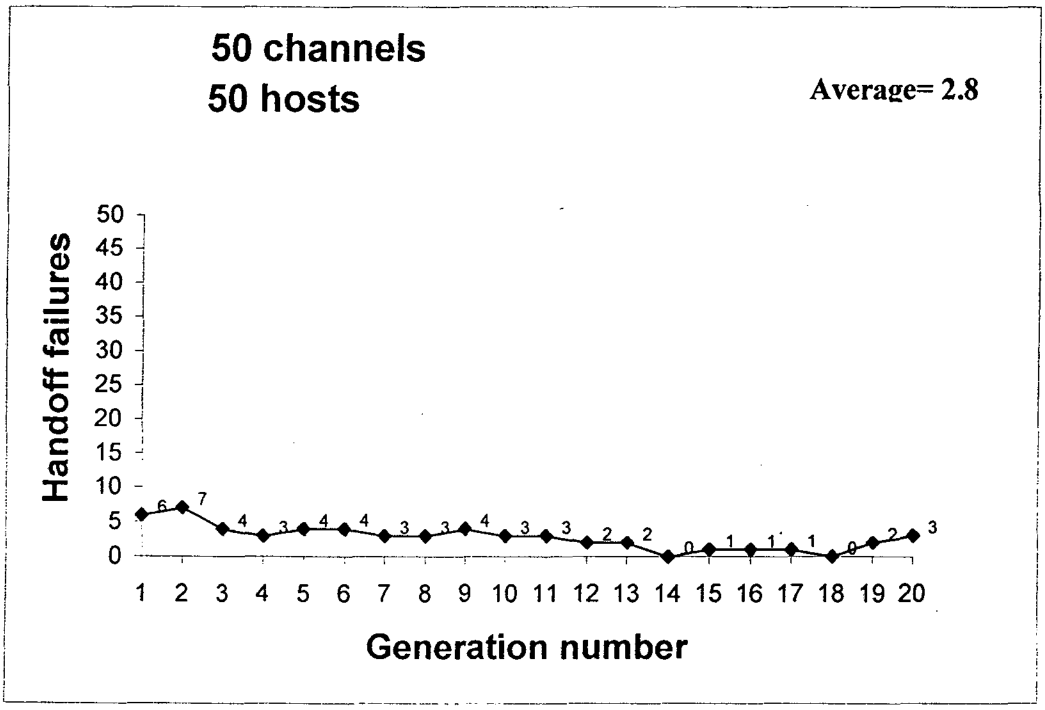


Fig.5.54. 50 channels, 50 hosts

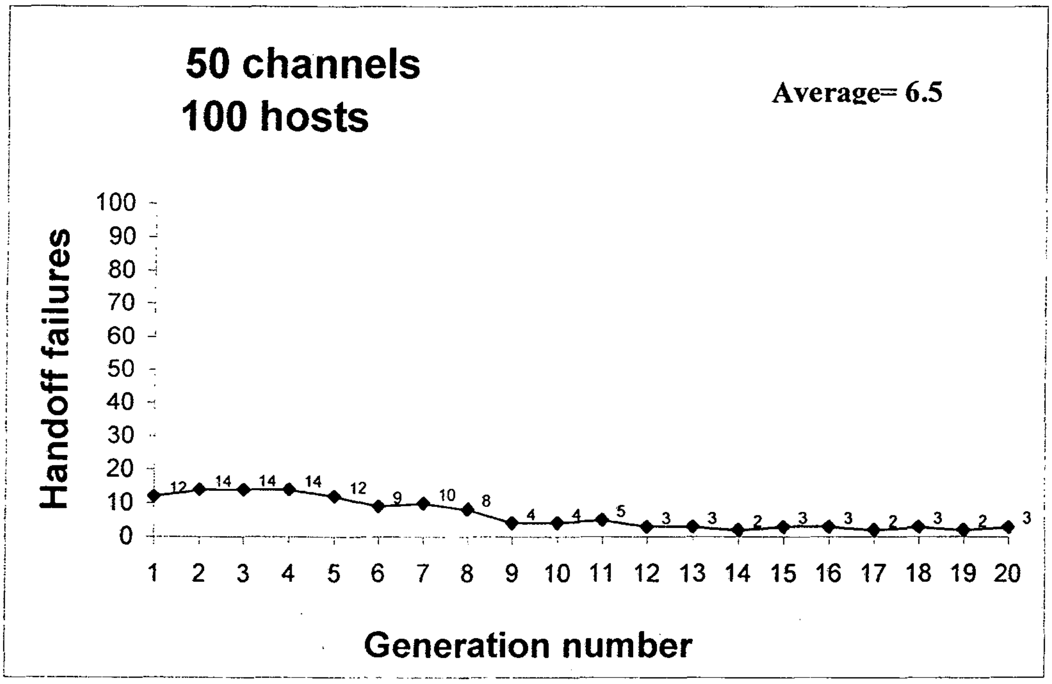


Fig.5.55. 50 channels, 100 hosts

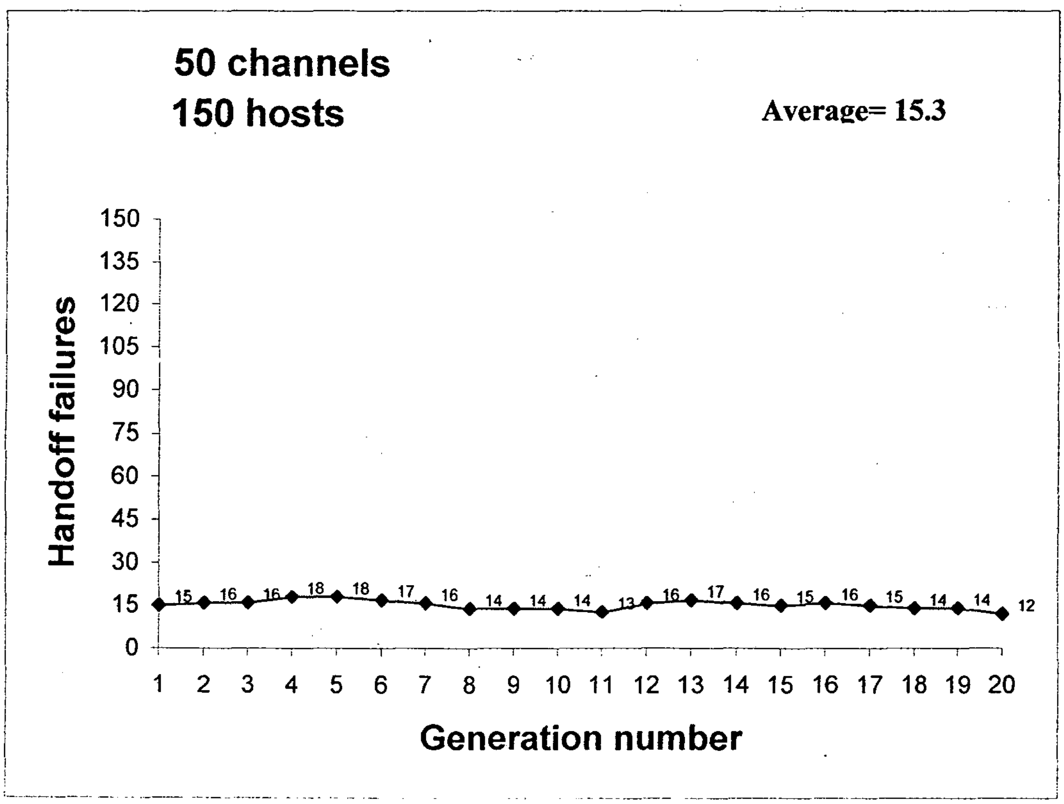


Fig.5.56. 50 channels, 150 hosts

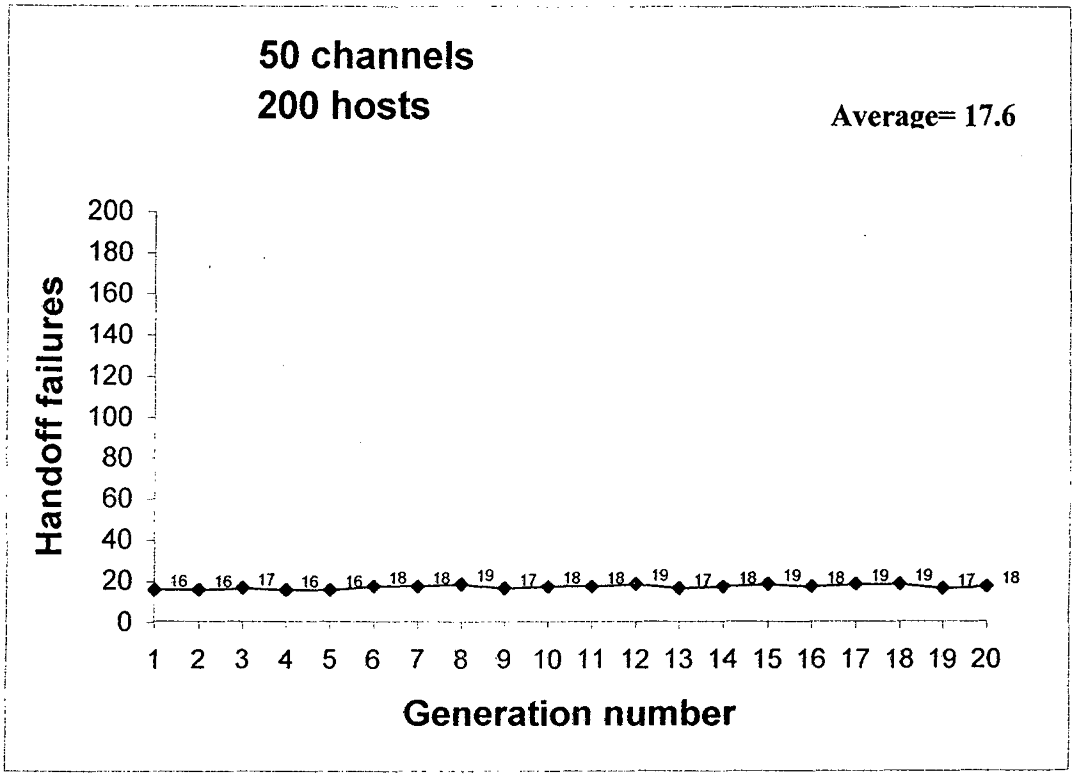


Fig.5.57. 50 channels, 200 hosts

100 Channels

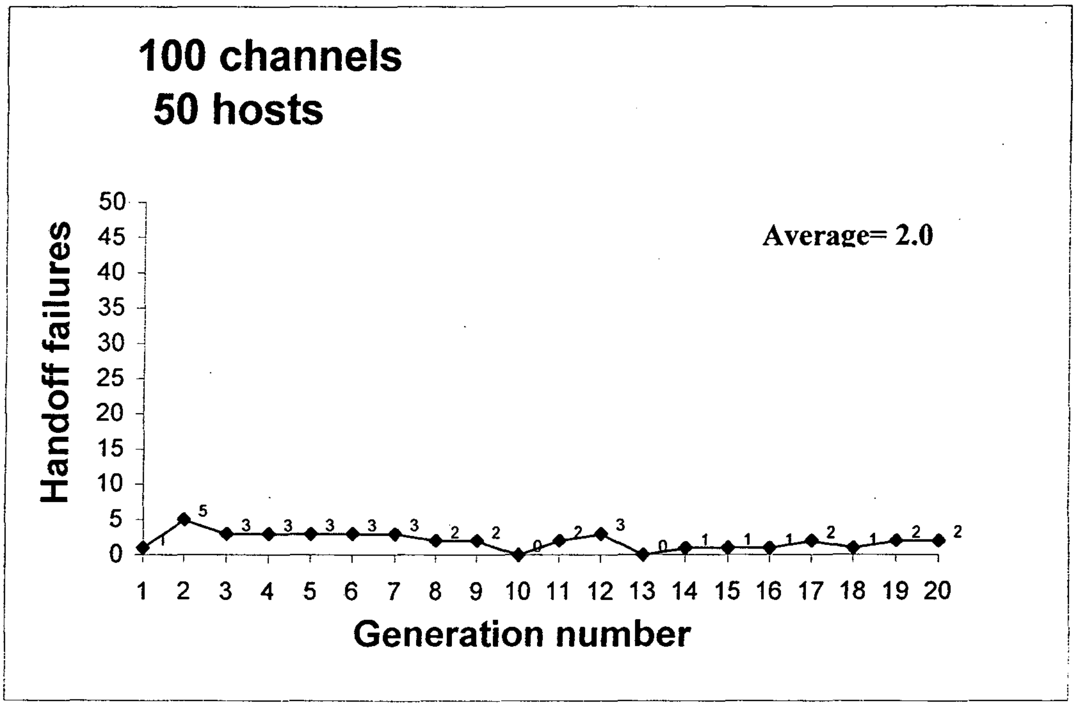


Fig.5.58. 100 channels, 50 hosts

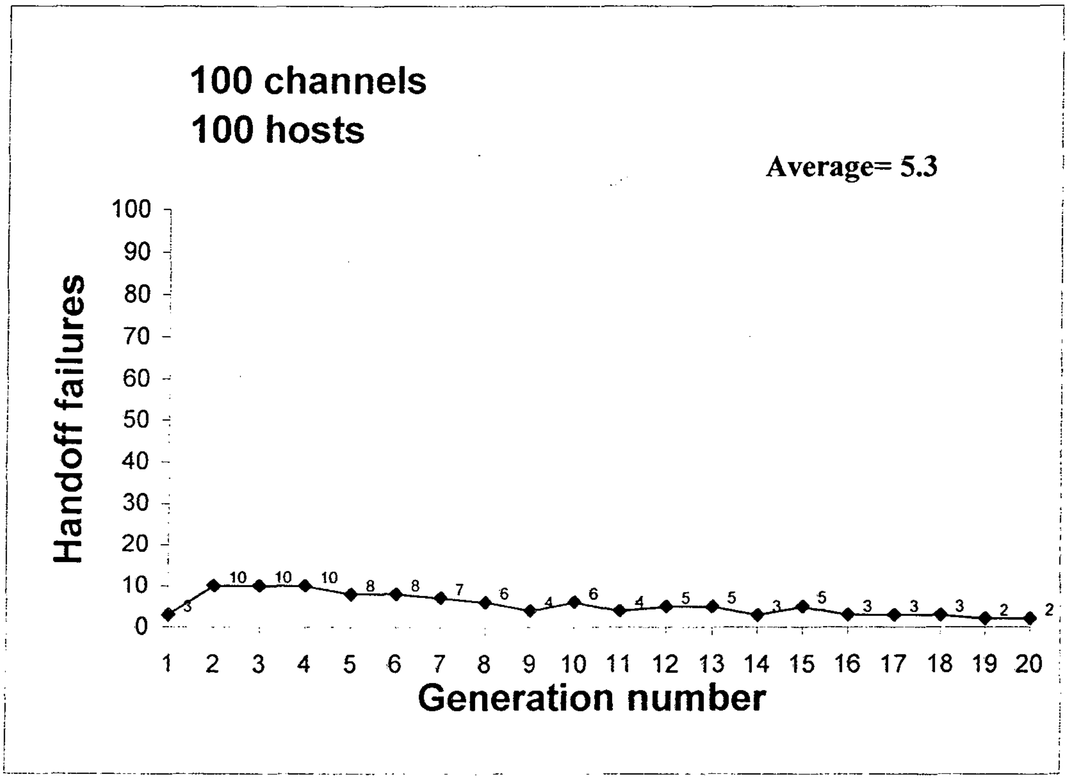


Fig.5.59. 100 channels, 100 hosts

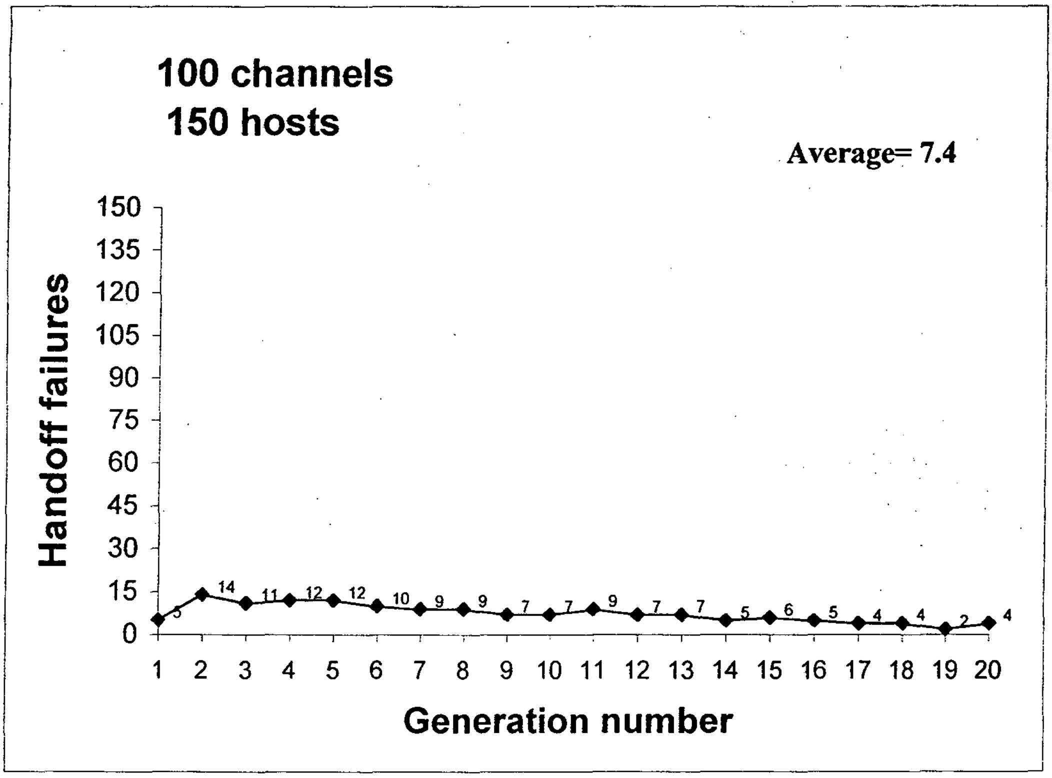


Fig.5.60. 100 channels, 150 hosts

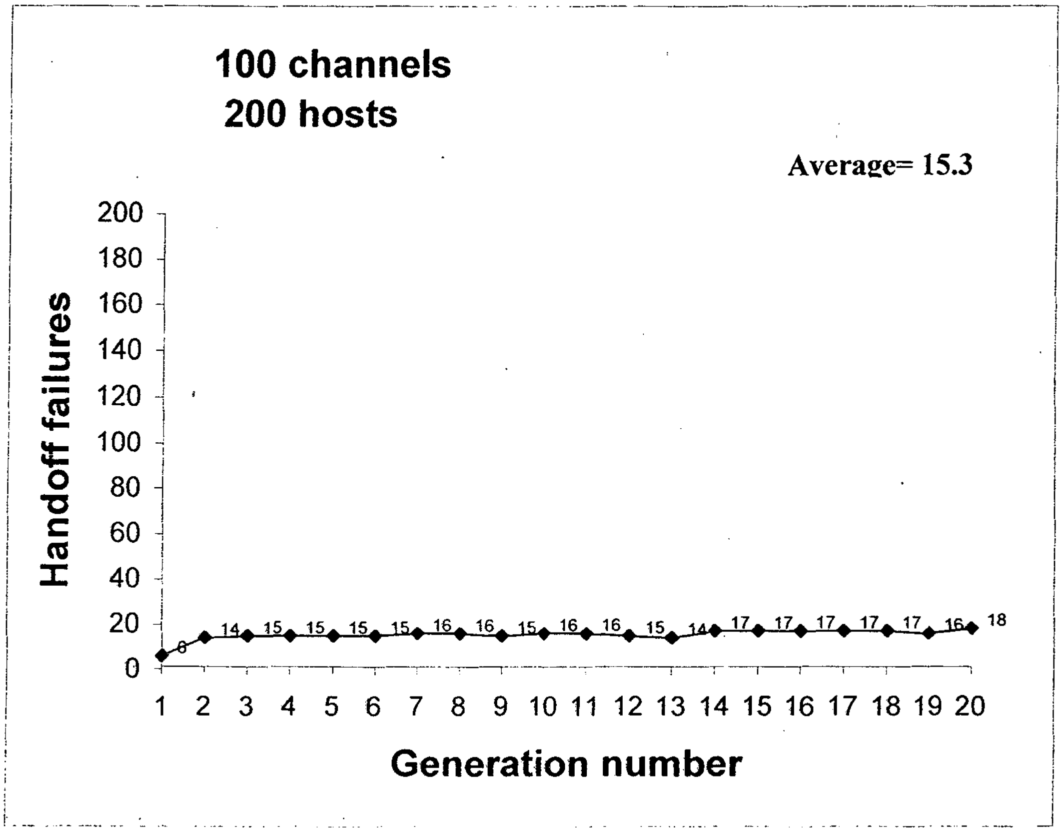


Fig.5.61. 100 channels, 200 hosts

150 Channels

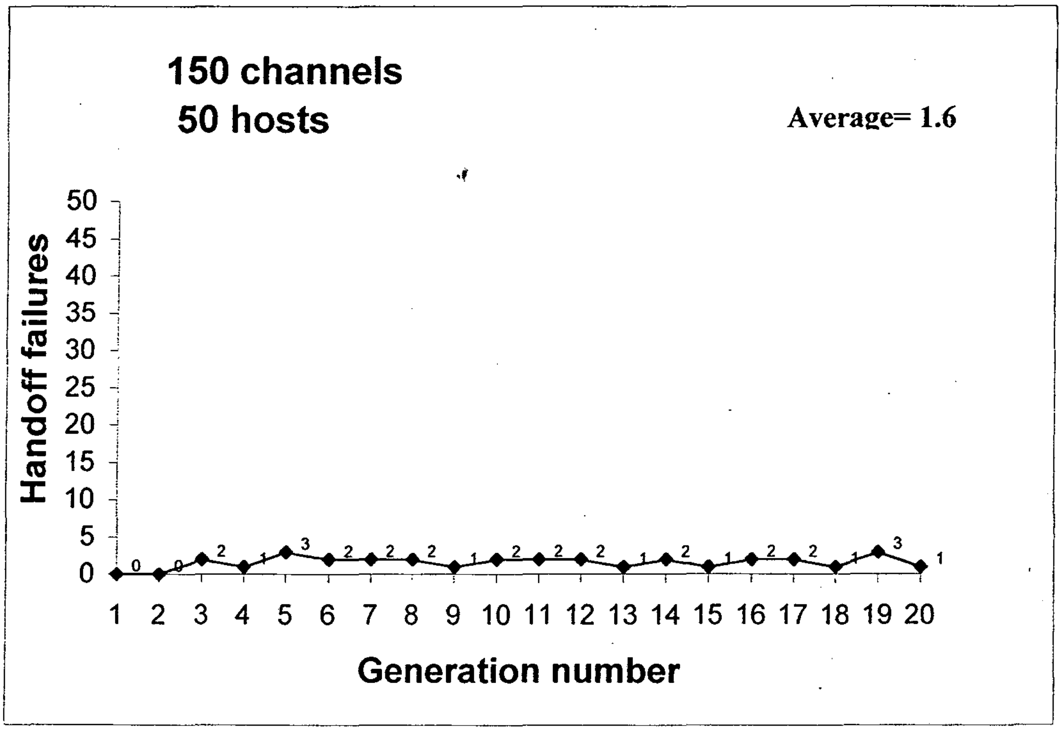


Fig.5.62. 150 channels, 50 hosts

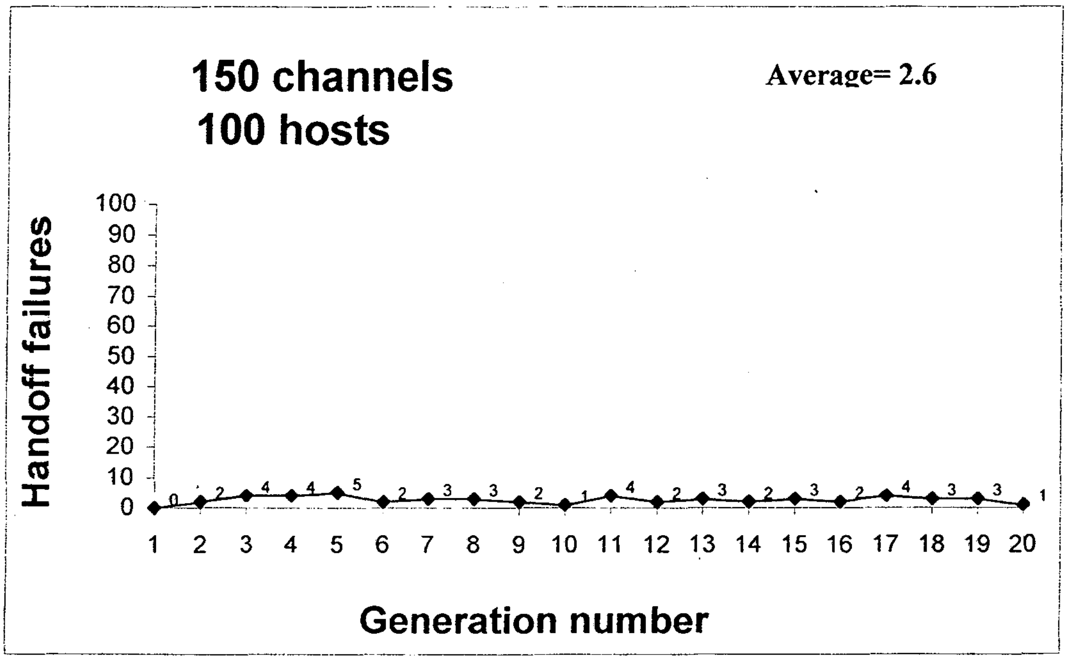


Fig.5.63. 150 channels, 100 hosts

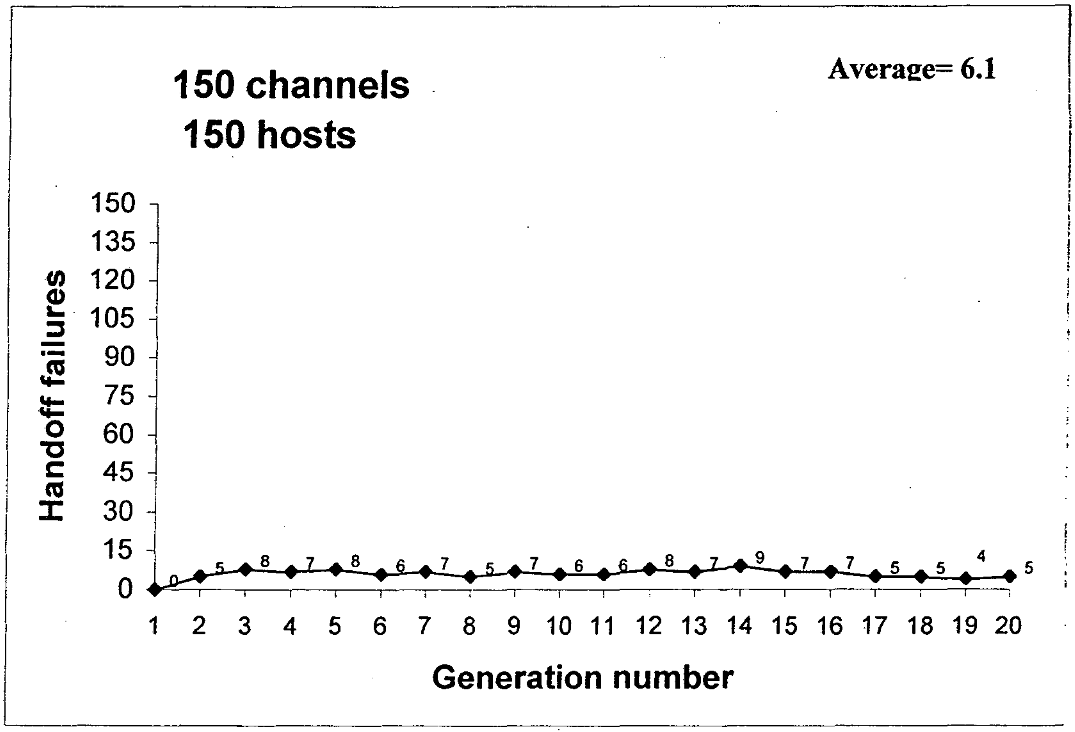


Fig.5.64. 150 channels, 150 hosts

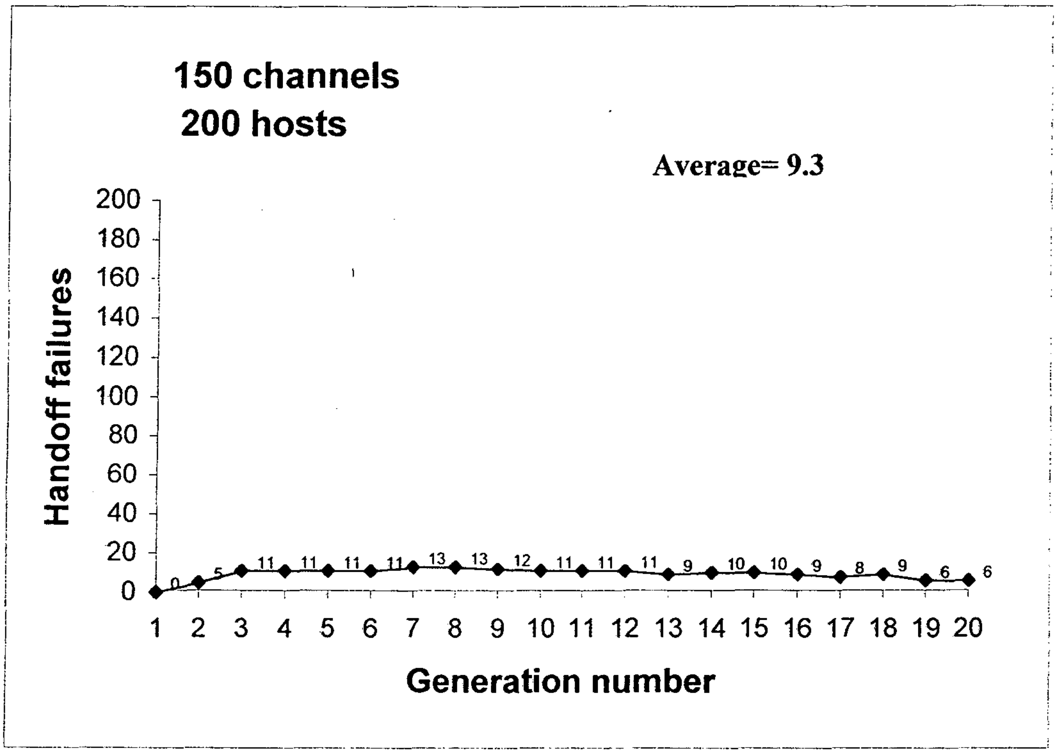


Fig.5.65. 150 channels, 200 hosts

200 Channels

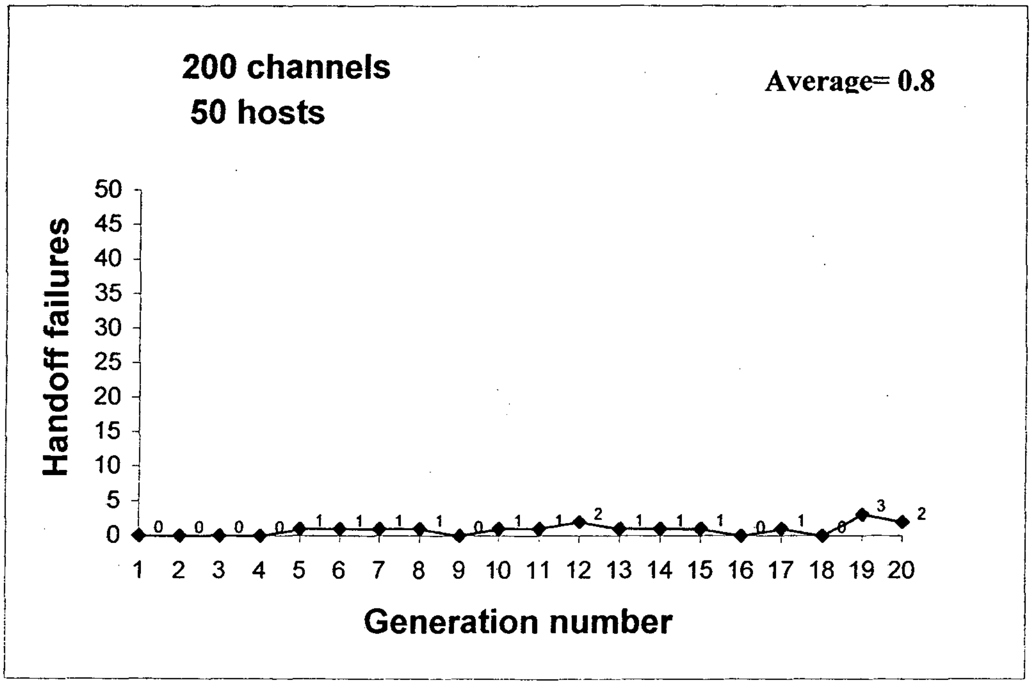


Fig.5.66. 200 channels, 50 hosts

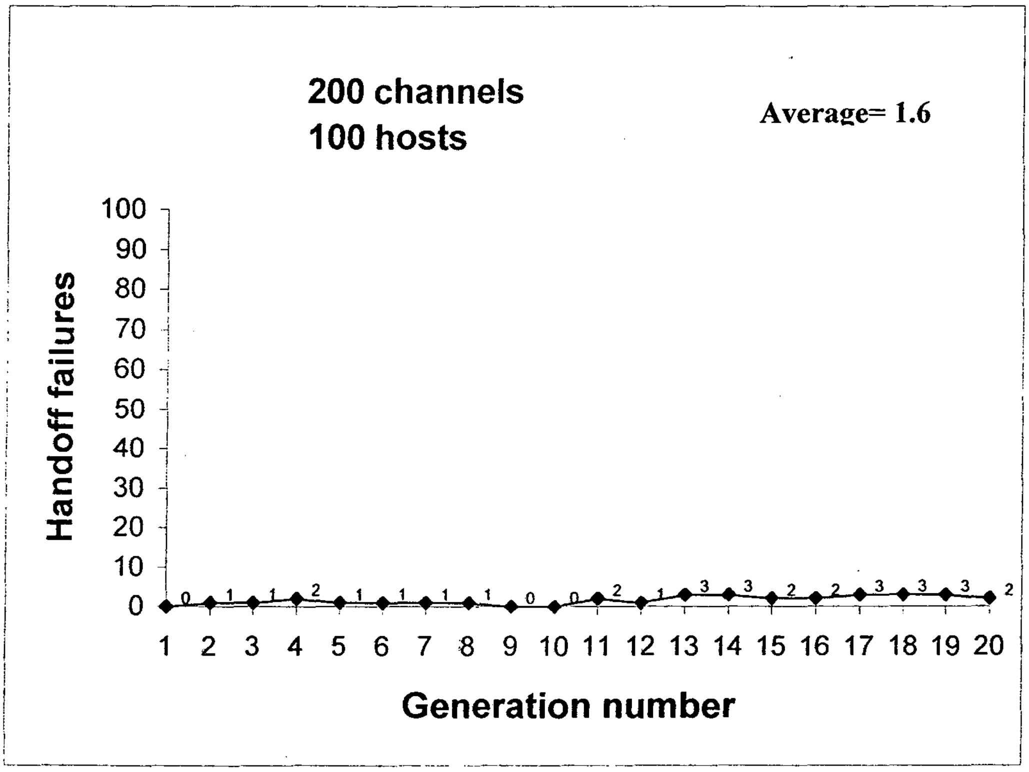


Fig.5.67. 200 channels, 100 hosts

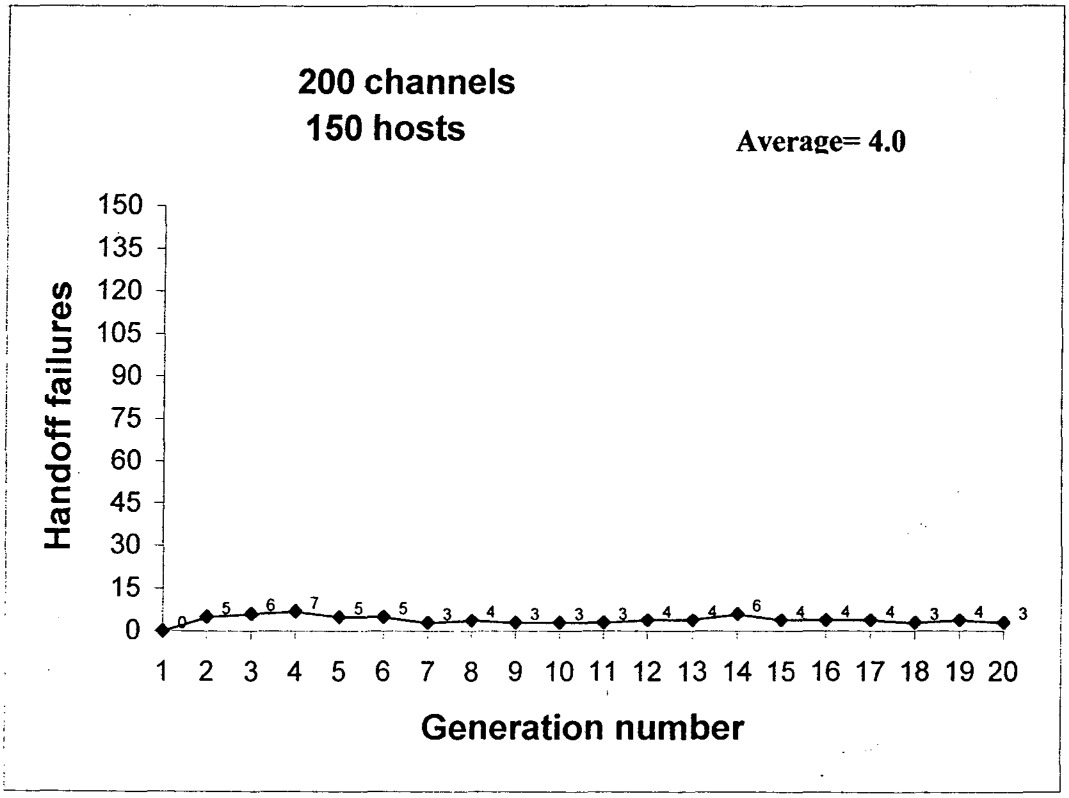


Fig.5.68. 200 channels, 150 hosts

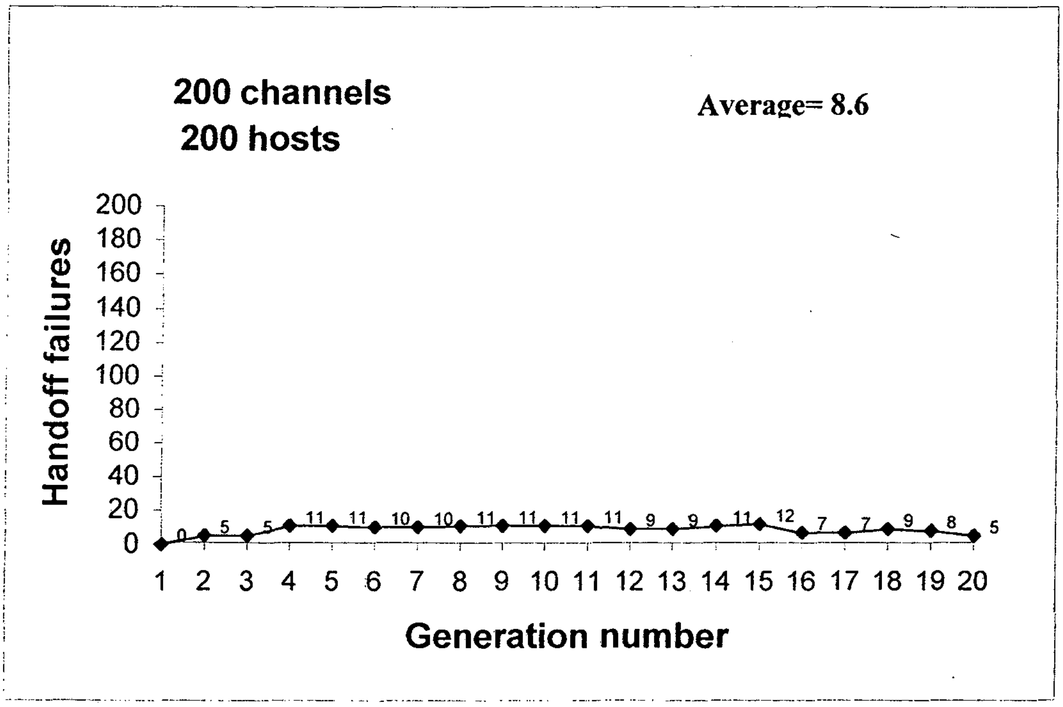


Fig.5.69. 200 channels, 200 hosts

Results are again summurized in tables 5.3 and 5.4 for 10 and 20 generations respectively.

Also the graphs are plotted for both.

Table 5.3 Average Handoff Failures in 10 Generations

		Channels			
		50	**100**	**150**	**200**
Hosts	**50**	4.1	2.5	1.5	0.5
	100	10.1	7.2	2.6	0.8
	150	15.8	9.6	5.9	4.1
	200	17.1	14.3	9.8	8.5

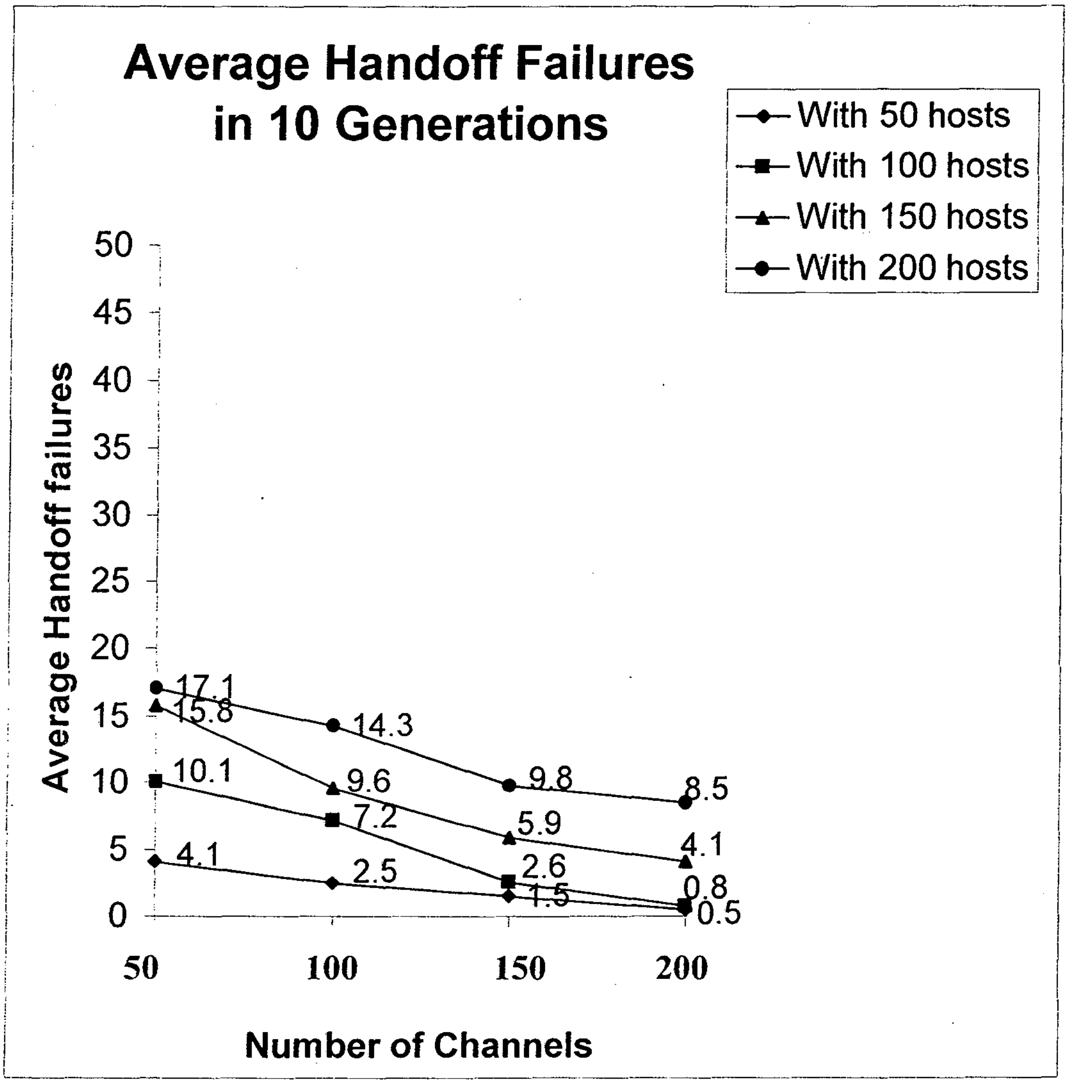


Fig.5.70. Results for 10 generations

Table 5.4 Average Handoff Failures in 20 Generations

		Channels			
		50	**100**	**150**	**200**
Hosts	**50**	2.8	2.0	1.6	0.8
	100	6.5	5.3	2.6	1.6
	150	15.3	7.4	6.1	4.0
	200	17.6	15.3	9.3	8.6

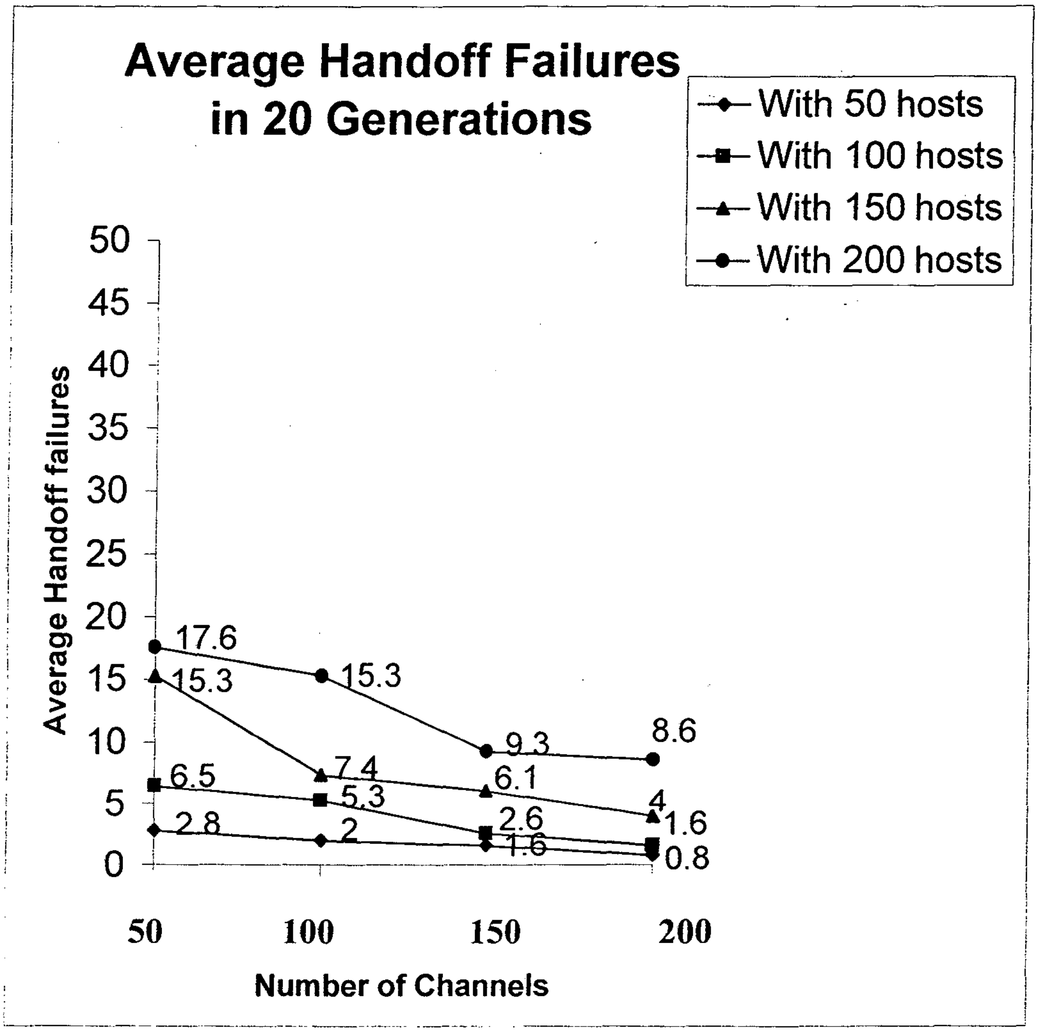


Fig.5.71. Results for 20 generations

5.5 Observations

From the performance graphs of blocked hosts and handoff failures, we observed the following points:

- The average number of blocked hosts and handoff failures is low in comparison with the input values of hosts and channels.
- There is an obvious minimization in the number of hosts and handoff failures during the successive generations, i.e. there is improvement in the efficiency of the algorithm and therefore the channels utilization. For example in 10 generations and 100 channels, if the hosts are 100, 150 and 200, then the average blocked hosts are 20.2, 47.7 and 104.6 respectively, while in 20 generations the corresponding results are 14.0 ,32 and 95.1 respectively.
- Similarly, in 10 generations and 100 channels, if the hosts are 50,100 and 150, then the average handoff failures are 2.5, 7.2 and 9.6 respectively, while in 20 generations the corresponding results are 2.0, 5.3 and 7.4 respectively. Further, we observed that the solution converges by 20 generations.
- In the handoff failures graphs we can see the use of the reserved channels to provide free channels to the cross over mobile hosts keeps the initial values of the handoff failures very low and in many cases minimized it to zero.
- The efficient use of our search function for free channels to maintain the reserved pool unaffected, led to prevent the increment of the handoff failures beyond a very low maximum value.
- Although in some cases the number of channels is small compared to the number of hosts, but the efficient reuse of the available channels still carried out a good results.
- We can see the convergence in the values of the blocked hosts and handoff failures only when the number of the mobile hosts is very high compared to the number of the available channels.

5.6 Comparative study

In this section, we compared our FTCA algorithm with the results of the blocked hosts obtained by IGA algorithm in [1], where the genetic algorithm is improved by introducing a pluck operation to reduce the number of blocked hosts.

Since the total number of channels in algorithm [1] is 190 channels, so we used the same number of channels for the comparison. The number of hosts is 50 and 100 through 10 and 20 generations.

Performance comparison graphs are shown below:

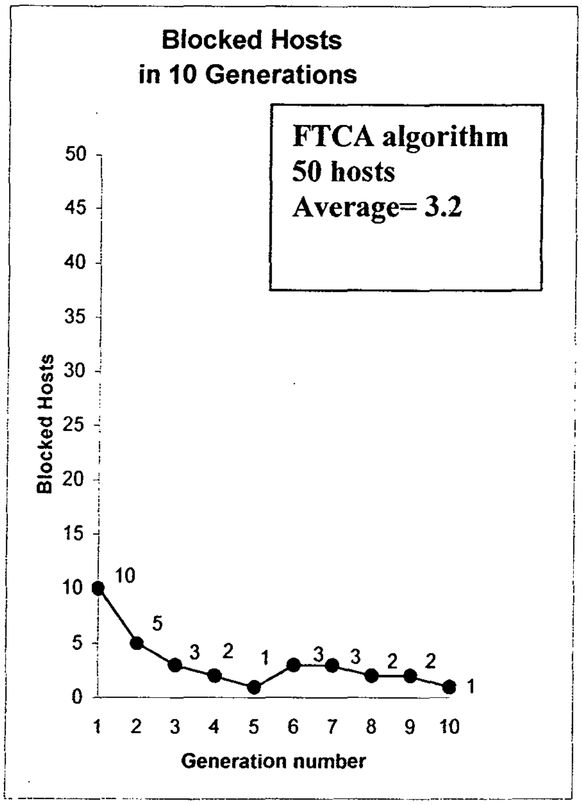


Fig.5.72. **FTCA** with 50 hosts in 10 generations

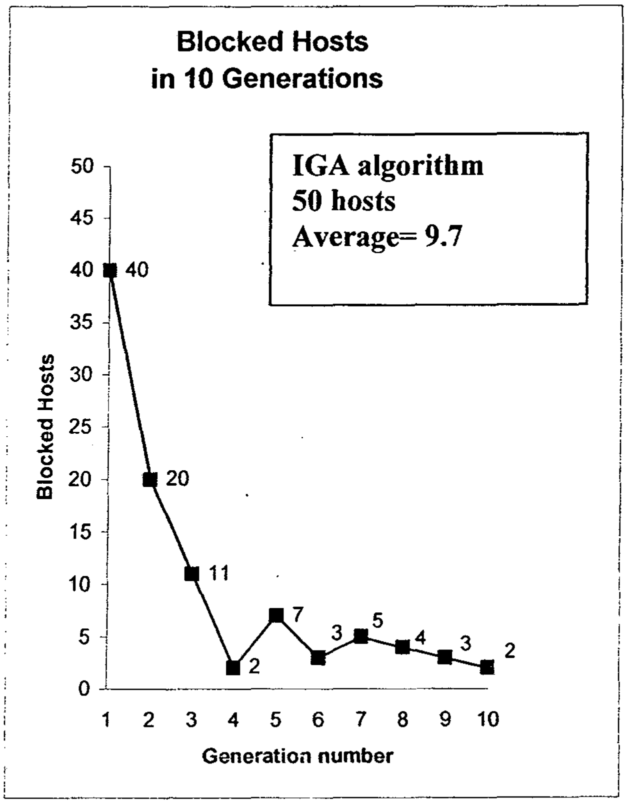


Fig.5.73. **IGA** with 50 hosts in 10 generations

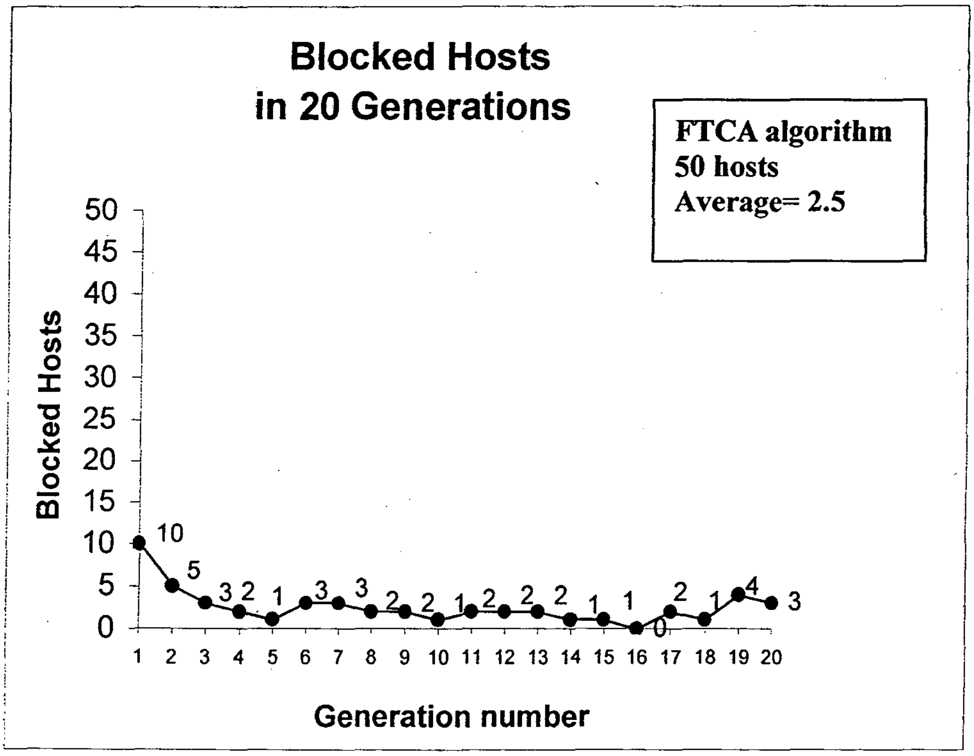


Fig.5.74. **FTCA** with 50 hosts in 20 generations

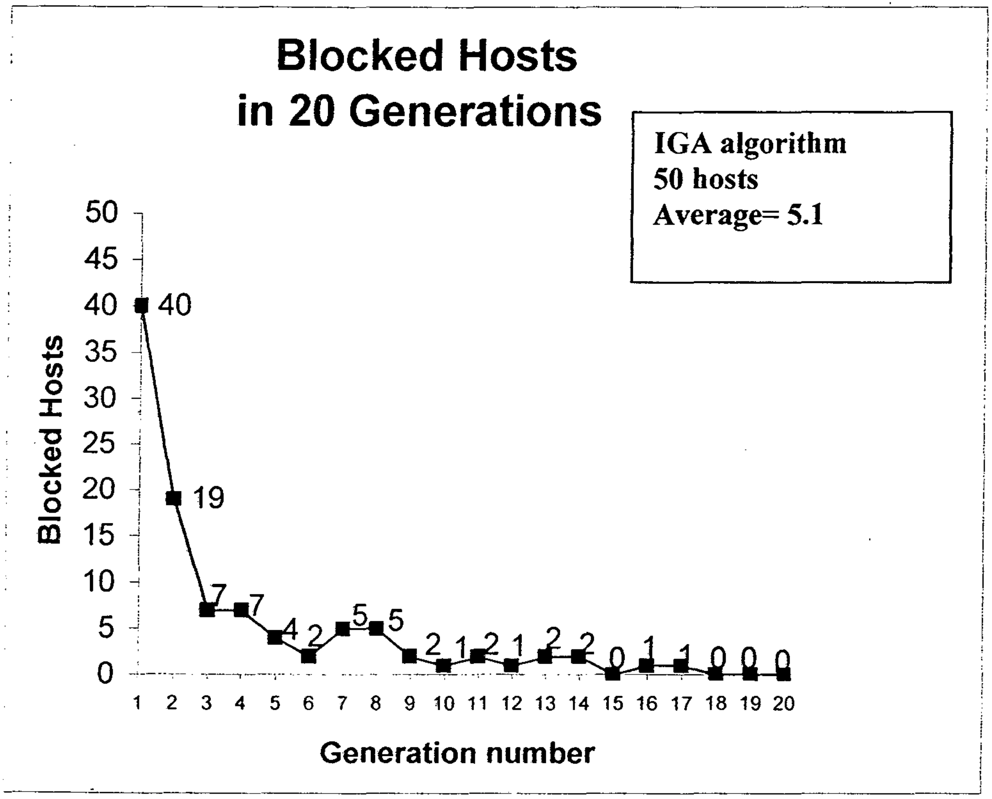


Fig.5.75. **IGA** with 50 hosts in 20 generations

Same experiment is conducted for 100 hosts and 190 channels. The results are as follows:

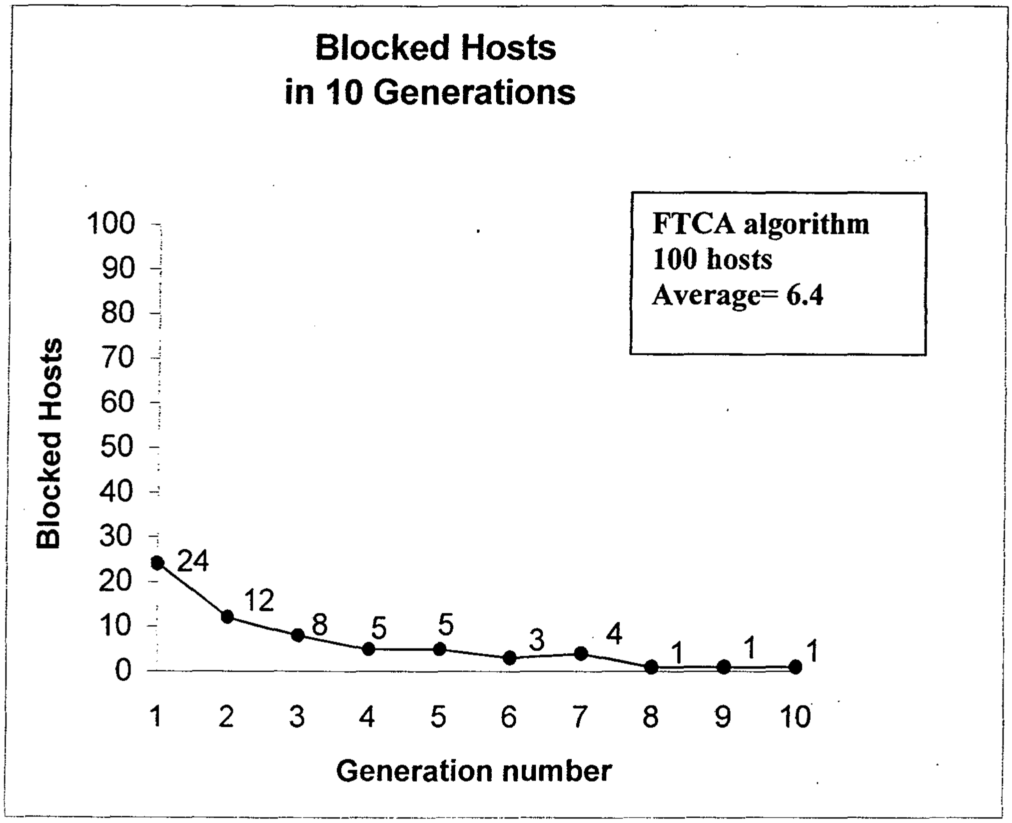


Fig.5.76. FTCA with 100 hosts in 10 generations

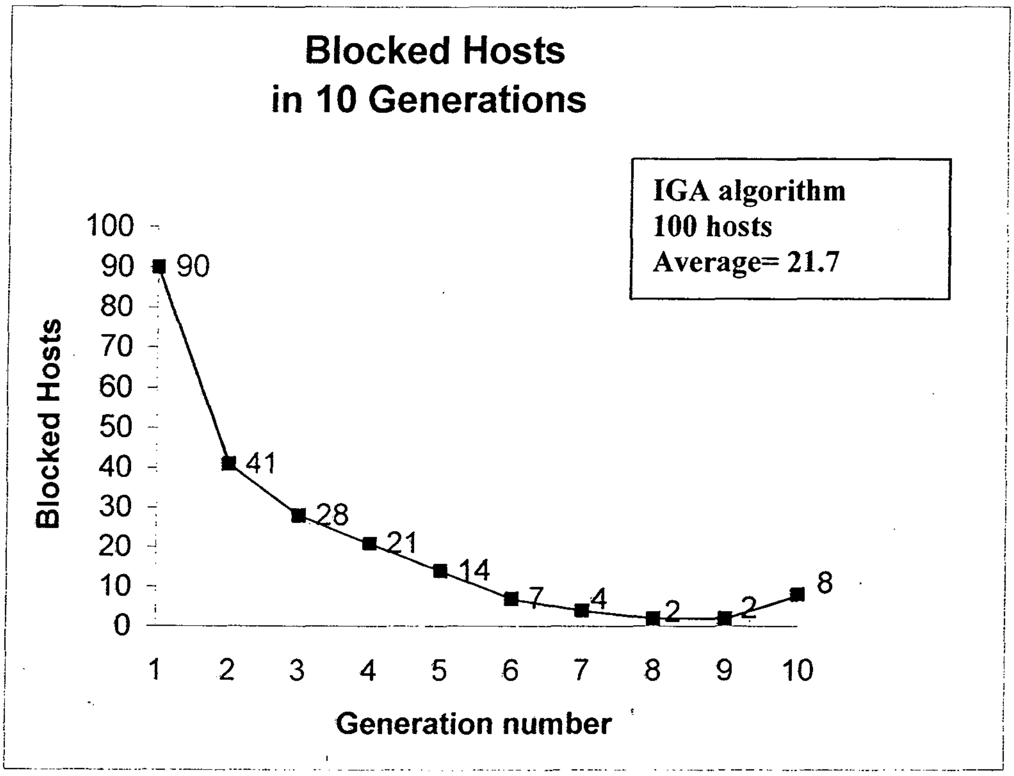


Fig.5.77. IGA with 100 hosts in 10 generations

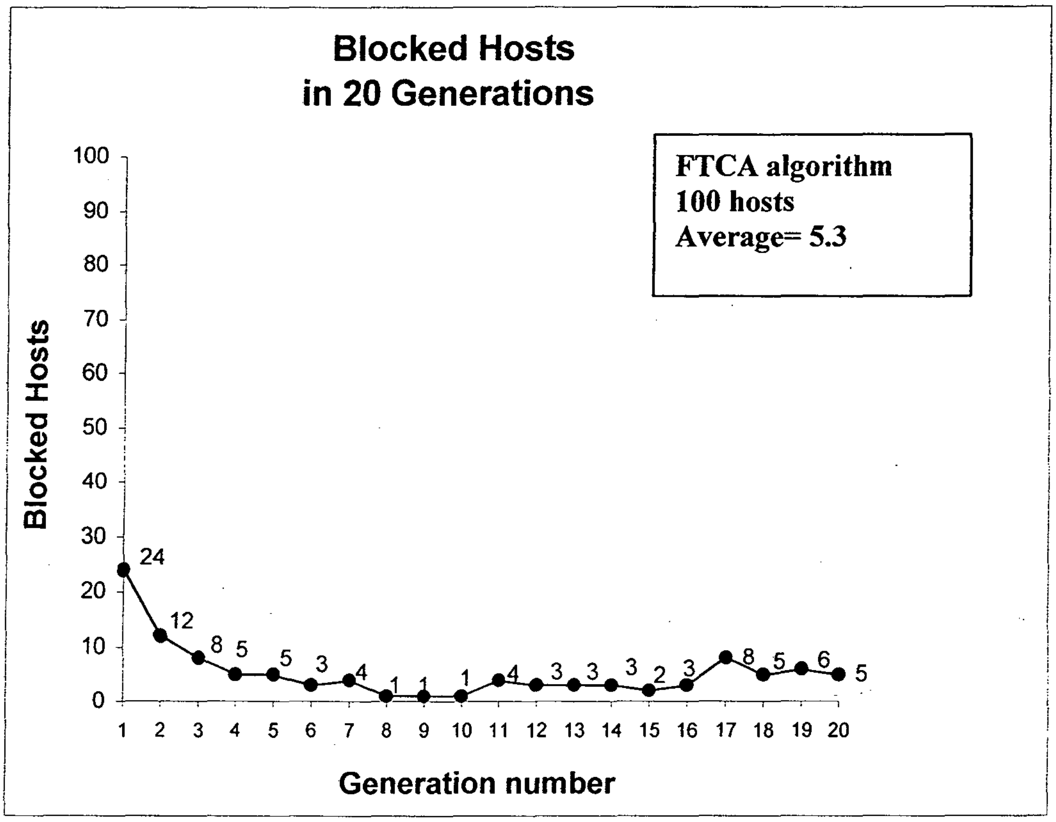


Fig.5.78. **FTCA** with 100 hosts in 20 generations

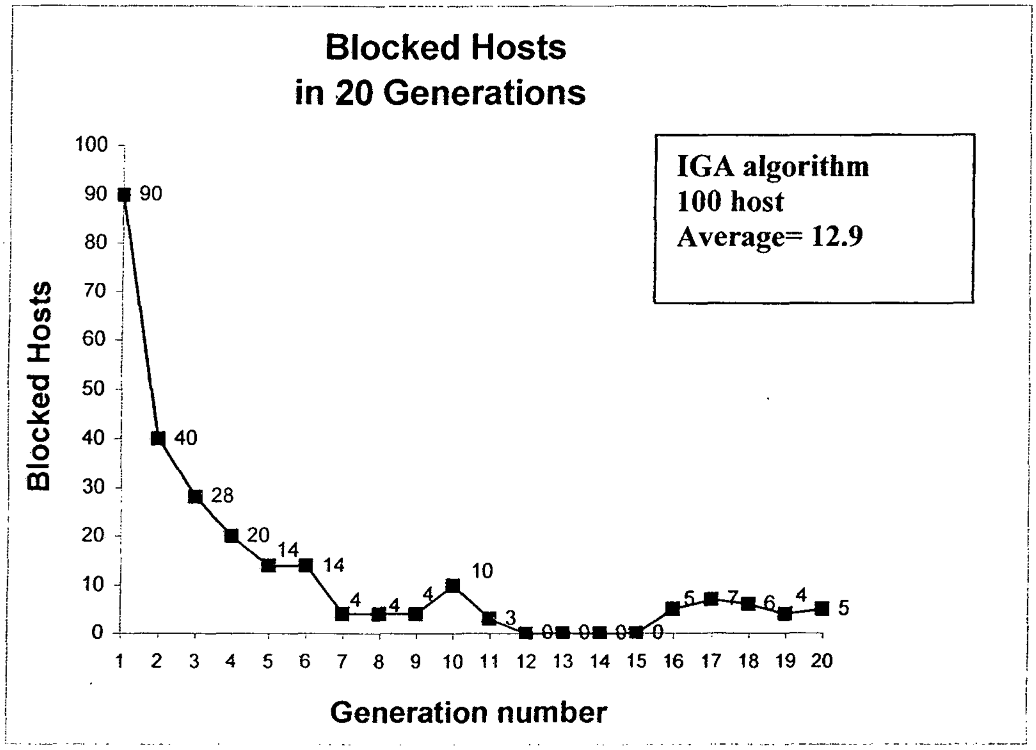


Fig.5.79. **IGA** with 100 hosts in 20 generations

5.6.1 Comparison of Results

For cumulative comparison, an experiment is carried out for 50,100 hosts over 10 and 20 generations, the results were as follows:

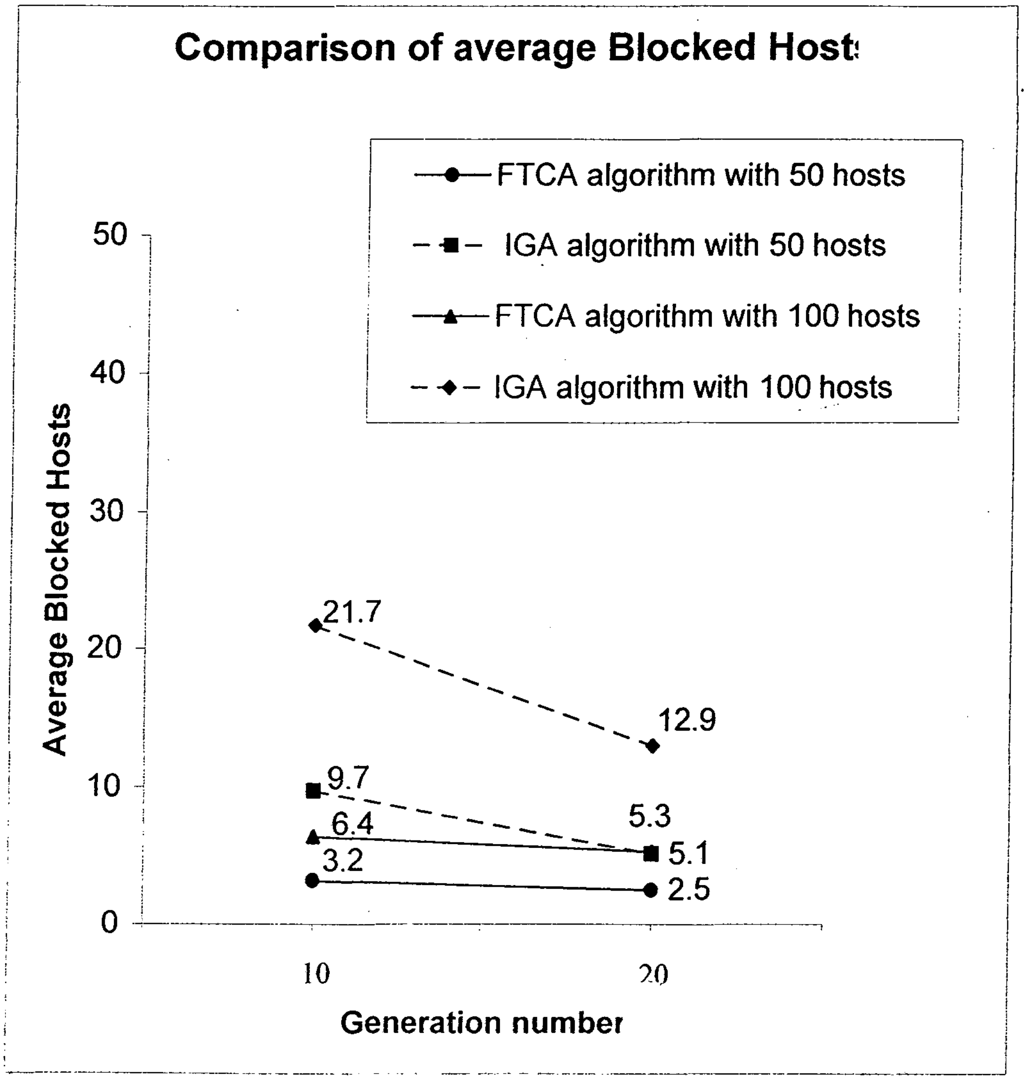


Fig.5.80. **IGA** versus **FTCA** for varying hosts and generations

5.6.2 Observations

- From the above graphs it is obvious that our FTCA algorithm outperforms the IGA algorithm in [1].
- The average number of blocked hosts in FTCA model is less than that of [1] in both 10 and 20 generations. For example it can be seen that the average number of blocked hosts for 50 hosts in 10 and 20 generations in case of FTCA algorithm is 3.2 and 2.5 respectively, while in the other algorithm it is 9.7 and 5.05 respectively. Also in case of 100 hosts, our algorithm results are 6.4 and 5.3 respectively, while the IGA algorithm gives 21.7 and 12.9 respectively.
- In our FTCA model, by using the technique of distributing the channels according to the initial demand of each cell, the initial values of the blocked hosts are significantly minimized compared to that of the other algorithm, which reduced the overall number of blocked hosts.

5.7 Conclusion and Future Work

- 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 FTCA 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 reserved channels, to handle the crossover mobile hosts, minimizes the number of handoff failures.

- 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, improves the utilization of the available channels and therefore the network.

- The performance of our proposed FTCA model is evaluated by simulating experiments to carryout the number of blocked hosts and handoff failures.

- We conducted the experiment separately for handoff failure to observe the handling of handoff.

- It is found that, by increasing the number of generations, both the average number of blocked hosts and handoff failures decrease.

- Simulation runs and result comparison, proves that our FTCA algorithm outperforms the algorithm in [1].

- The technique used in the crossover operation introduced by [1], improves the performance of our FTCA algorithm and therefore enhanced the overall system performance.

- The proposed FTCA algorithm takes care of the crossover mobile hosts by handling the handoffs using reserved channels.

- We intend to simulate the performance of the proposed FTCA algorithm for larger geographical areas, greater number of cells, and a larger number of hosts.

- It is also intended to improve the performance of GA for channel allocation by introducing better operator or incorporating problem specific knowledge.

- Further, we propose to provide more channel allocation models using better heuristics.

List of Acronyms

BCA	Borrowing Channel Allocation
BS	Base Station
CAS	Channel Allocation Strategy
GA	Genetic Algorithm
DCA	Dynamic Channel Allocation
FA	First Available
FCA	Fixed Channel Allocation
FIFO	First In First Out
FTCA	Fault-Tolerant Channel Allocation
GA	Genetic Algorithm
GCA	Graph Coloring Algorithm
GSM	Global System for Mobility
HCA	Hybrid Channel Allocation
HGA	Hybrid Genetic Algorithm
IGA	Improved Genetic Algorithm
LODA	Locally Optimized Dynamic Assignment
MS	Mobile Station
MSC	Mobile Switching Center
MT	Mobile Terminal
NPS	No Priority Scheme
RCS	Reserved Channel Scheme
RING	Selection with maximum usage on the reuse ring
SDMA	Space Division Multiple Access
SGA	Simple Genetic Algorithm
SNR	Signal to Noise Ratio
SRS	Subrating Scheme

Publications

[1] Lutfi Mohammed Omer Khanbary, D.P.Vidyarthi, "*GA Based Fault-Tolerant Channel Allocation in Mobile Computing*". Communicated to IEEE Transactions on Mobile Computing.

Bibliography

[1] S.S.Maha Patra, K.Roy, S.Banerjee and D.P.Vidyarthi, "*Improved Genetic Algorithm for Channel Allocation with Channel Borrowing in Mobile Computing*", Scheduled in IEEE Transactions on Mobile Computing, vol. 5, no 7, July 2006.

[2] J.Yang, Q. Jiang, D. Manivannan, and M. Singhal, "*A fault-Tolerant Distributed Channel Allocation Scheme for Cellular Networks* ", IEEE Transactions on Computers, vol. 54, no. 5, May 2005.

[3] Lauro Ortigoza-Guerrero, A. Hamid Aghvami, "*Resource Allocation in Hierarchical Cellular Systems* ", Artech House, 2000.

[4] David E. Goldberg. "*Genetic Algorithms in Search, Optimization, and Machine Learning*", Pearson, 2005.

[5] Albert Y. Zomaya, Michael Wright, "*Observation on Using Genetic Algorithms for Channel Allocation in Mobile Computing*", IEEE Transaction on Parallel and Distributed Systems, vol. 13, no. 9, pp. 948-962, Sep. 2002.

[6] Ioannis E. Kassotakis, Maria E. Markaki, Athanasios V. Vasilakos. "*A Hybrid Genetic Approach for Channel Reuse in Multiple Access Telecommunication Networks*", IEEE Journal on Selected Areas in Communication, vol. 18, no. 2, pp. 234-243, Feb. 2000.

[7] M. Asvial, B.G.Evans, R. Tafazolli, "*Evolutionary Genetic DCA for Resourse Management in Mobile Satellite Systems*", IEE Electronics Letters, vol. 38, no. 20, pp. 1213-1214, Sep. 26, 2002.

[8] Melanie Mitchell. "*An Introduction to Genetic Algorithms*", MIT Press, London 1999.

[9] A.K.Tripathi, D.P.Vidyarthi and A.N. Mantri, "*A Genetic Task Allocation Algorithm for Distributed Computing System Incorporating Problem Specific Knowledge*", International Journal of High Speed Computing, vol. 8, no. 4, pp. 363-370, 1996.

[10] K.Y. Lim, M. Kumar, S.K. Das. *"Message Ring-Based Channel Reallocation Scheme for Cellular Networks*",Proceedings of International Symposium on Parallel Architectures, Algorithms, and Networks, pp,426-431,1999.

[11] Shin Horng Wong, Ian Wassell. *"Dynamic Channel Allocation Using a Genetic Algorithm for a TDD Broadband Fixed Wireless Access Network",* Laboratory for Communications Engineering, University of Cambridge, Cambridge CB2 1PZ, UK.

[12] N. F. Huang, H. I. Liu, "*A Study of Isochronous Channel Reuse in DQDB Metropolitan Area Networks*", IEEE/ACM Transactions Networking, vol. 6, no. 4, pp. 475-484, 1998.

[13] C. Siva Ram Murthy and B.S. Manoj, *"Ad Hoc Wireless Networks Architectures and Protocols ",* Pearson, 2004.

[14] Agrawal, Zeng, "I*ntroduction to Wireless and Mobile Systems"*, Thomson, 2003.

[15] J.C.-I. Chuang, "*Performance Issues and Algorithms for Dynamic Channel Assignment"*, IEEE J. Selected Areas Comm. vol. 11, no. 6, pp.955-963, Aug. 1993.

[16] R. Mathar and J. Mattfeldt "*Channel Assignment in Cellular Radio Networks*", IEEE Trans. Vehicular Technology, vol. 42, no. 4, pp. 647-656, Nov.1993.

[17] R. Prakash, N.G. Shivaratri, and M. Singhal, "*Distributed Dynamic Fault-Tolerant Channel Allocation for Cellular Networks*", IEEE Trans. Vehicular Technology, vol. 48, no. 6, pp. 1874-1888, Nov.1999.

[18] G. Cao and M. singhal, "*Distributed Fault-Tolerant Channel Allocation for Cellular Networks*", IEEE J. Selected Areas Comm. vol. 18, no. 7, pp.1326-1337, July 2000.

[19] Katzela, I., and M. Naghshineh, "*Channel Assignment Schemes for Cellular Mobile Telecommunication Systems: A Comprehensive Survey* ", IEEE Personal Comm. Mag., vol. 3, no. 3, pp.10-31, June 1996.

[20] Tekina, S., and B. Jabbari, "*Handover and Channel Assignment in Mobile Cellular Networks* ", IEEE Comm. Mag., vol. 29, no. 11, pp.42-46, Nov. 1991.

[21] Hong, D., and S. S. Rappaport, "*Traffic Model and Performance Analysis for Cellular Mobile Radio Telephone Systems with Prioritized and Nonprioritized Handoff Procedures*", IEEE Trans. Vehicular Technology, vol. 35, no. 3, pp. 77-92, Aug..1986.

[22] Lin, Yi-Bing, Anthony R. Neorpel, and Daniel J. Harasty, "*The Sub-Rating Channel Assignment strategy for PCS Hand-offs* ", IEEE Trans. Vehicular Technology, vol. 45, no. 1, pp. 122-129, Feb.1996.

[23] Neorpel, Anthony and Yi-Bing Lin, "*Handover Management for PCS Network* ", IEEE Personal Comm. Mag., vol. 4, no. 6, pp.18-24, Dec. 1997.

[24] Bing Lin, Yi, et al., "*Queuing Priority Channel Assignment strategies for PCS Hand-off and Initial Access* ", IEEE Trans. Vehicular Technology, vol. 43, no. 3, pp. 704-712, Aug.1994.

[25] Tekinay, Sirin, and Bijan Jabbari, "*A Measurement-Based Prioritization Scheme for Handovers in Mobile Cellular Networks* ", IEEE Trans. Vehicular Technology, vol. 10, no. 8, pp. 1343-1350, Oct.1992.

[26] Lin, Yi-Bing, et al., "*PCS Priority Channel Assignment strategies for Hand-off and Initial Access* ", IEEE Personal comm., vol. 1, no. 3, pp. 47-56, Third Quarter 1994.

[27] D. Dimitrijevic, J. Vucetic, " *Design and Performance Analysis of the Algorithms forChannel Allocation in Cellular Networks* ", IEEE Trans. Vehicular Technology, vol. 42, no. 4, Nov.1993.