

Service-Oriented Channel Allocation For Maximum Reliability

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ABSTRACT —Mobile computing involves bulk data transmission over the transmission media. To achieve highly reliable data transmission, wireless mobile networks require efficient reliable link connectivity, regardless of terminal mobility and, thus, a reliable traffic performance. Mobile networks consist of mobile hosts, base stations, links, etc. that are often vulnerable to failure. It is desirable to design a reliable network, in terms of services of both the base stations and the communication channels of the network, for the reliable transmission of the data. The objective of this study is to design an appropriate reliability-based model for channel allocation that retains the overall system reliability with acceptable system performance. The system may achieve acceptable performance not only during normal operations but also under various component failures. A genetic algorithm, which is a search procedure based on evolutionary computation, is suited to solve a class of complex optimization problems. The potential of the genetic algorithm is used, in this paper, to improve the reliability of the mobile communication system. The proposed model designs a reliable mobile communication system, irrespective of the mobile hosts that change their position due to mobility. A simulation experiment to evaluate the performance of the proposed algorithm is conducted, and results reveal the effectiveness of this model.

Index Terms: Byzantine failure, channel allocation, channel reuse, failure, genetic algorithm (GA), handoff, reliability.

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I. INTRODUCTION

A CELLULAR system divides a geographical communication area into smaller regions called cells, which are usually hexagonal for analytical and experimental purposes. A typical mobile network environment consists of cells, each of which is serviced by a base station (BS) located at the center of the cell. The BS provides a connection end point for the roaming mobile hosts (MHs). The BS is interconnected by wired or wireless media. The channel-allocation problem deals with the allocation of frequency channels of the given network to the MHs. Two important concepts in channel allocation are cellular reuse of channels and handoff. The fundamental and elegant concept of cells relies on the channel or frequency reuse, i.e., the usage of the same channel by different MHs separated by a minimum distance, without interfering with each other (cochannel interference). Handoff occurs when a user moves from the coverage area of one BS to the adjacent one while it is still involved in communication. A new channel will be assigned to the MHs to continue the ongoing communication. The new channel may be within the same cell (intracell handoff) or in a different cell

(intercell handoff). These issues are important in microcellular systems where the cell radius is small.

A channel-allocation algorithm consists of two phases: 1) channel acquisition and 2) channel selection. The task of the channel acquisition phase is to collect the information of

free available channels from the interference cells and ensure that the two cells within the minimum reuse distance do not share the same channel. The channel-selection phase deals with the selection of a channel from the available free channels to get better channel utilization in terms of channel reuse.

The growing importance of mobile networks has stimulated active research into how data can reliably be transmitted over the mobile communication network. This approach suggests allocating channels to the MHs in the presence of various failures in the form of uncertainties. The failure includes signal fading, channel interference, weak transmission power, path loss, etc. This paper suggests a novel idea of channel allocation based on the reliability aspect of the system.

Reliability is the ability of a system to successfully perform its functions in routine and in hostile or unexpected circumstances.

Reliability is the probability that the network, with various components, performs its intended function for a given time period when operated under normal (or stated) environmental conditions. The unreliability of a connection is the probability that the experienced outage probability for the connection is larger than a predefined maximum tolerable value. The connection reliability is related to the traffic parameters.

The MH changes its access point time to time. This instance poses several challenges in terms of ensuring system

reliability. The increasing reliance on wireless networks for information exchange makes it critical to maintain reliable communications. Even a short downtime may cause substantial data loss; thus, these networks require high level of reliability. Reliability is a crucial parameter, because any failure will not only has direct cost on maintenance but may also result in dropped calls and terminated connection. This condition may be more catastrophic in mobile computing, because it may result in Byzantine failure. Failures that inhibit communications or result in the loss of critical data are of immense importance.

The reliability-based channel-allocation model rarely figures in the literature; however, some of the models that address the other reliability issues in cellular networks have been mentioned in brief here. An optimal forward-link power allocation model for data transmission was proposed .A soft handoff/power distribution scheme had been proposed for cellular CDMA downlinks, and its effect on connection reliability had been studied by Zhao et al.. A neural network-based multicast routing algorithm was proposed by Vijay et al. to construct a reliable multicast tree that connects the participants of a multicast group. A protocol called the reliable mobile multicast protocol was proposed in to provide reliable multicast services for mobile IP networks. The mobility agent in the mobile IP was extended to assist reliable multicasting for mobile devices.

In recent years, the applications of a genetic algorithm (GA), which is a useful search procedure for optimization problems, have attracted the attention of researchers of various disciplines as a problem-solving tool. The GA is a search procedure based on the natural evolution. The GA has successfully been applied for various optimization problems for which no straightforward solution exists. Researchers of mobile computing have used the GA for channel-allocation problems. The GA has also been extensively applied for the task-scheduling problem in distributed computing systems.

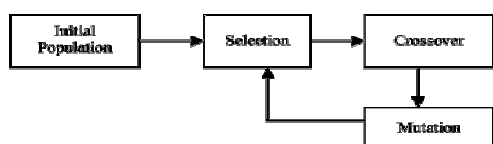


Fig. 1. Operations in the GA

II. GENETIC ALGORITHMS

The GA is a search procedure based on the principle of evolution and natural genetics. The GA combines the

exploitation of past results with the exploration of the new areas of the search space by using the “survival-of-the-fittest” technique combined with a structured yet randomized information exchange. In each new generation, a set of strings is created by using information from the previous ones. Occasionally, a new part is tried from the good measure. The GA is randomized, but it is not a simple random walk. In GAs, we start with an initial population, which is derived from the solution space. Genetic operators are then applied on the population for the appropriate mixing of exploitation and exploration. A selection strategy is used to carry forward the better population for reproduction. A simple GA consists of an initial population followed by selection, crossover, and mutation operations as shown in Fig. 1.

- 1) **Initial Population:** Initial population is the set of potential solutions to the problem. To start with, the number of solutions is generated by using any method (e.g., greedy). Borrowing the terminology from genetic engineering, the population is also called a chromosome or a string. On the initial population, various genetic operators are applied in GA.
- 2) **Selection:** The selection operation selects good results among the chromosomes by using some objective function (fitness function). The fitness function is used to rank the quality of the chromosomes. A fitness value is assigned to the chromosome, and the chromosome is evaluated with this value for its survival. The fitness of the chromosome depends on how well that chromosome solves the problem at hand. A chromosome (string) with a higher value has a higher probability of contributing to one or more offspring in the next generation.
- 3) **Crossover:** The idea of crossover is to swap part of the information between a pair of chromosomes to obtain the new chromosome. 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 uniformly selected at random between 1 and the string length less than one $[1, l - 1]$. Two new strings are created by inclusively swapping all characters between positions $k + 1$ and l [3] .
- 4) **Mutation:** In mutation, a chromosome is slightly randomly altered to get a new chromosome. The mutation operator is used to introduce a new

genetic material (e.g., 0 or 1). As a result of its generality, it is an insurance policy against the premature loss of important notions. The probability of applying mutation is often very low. Mutation rates are normally small in natural populations.

A. GA-Based FTCA Model

The FTCA algorithm is designed under the resource planning model, i.e., primary channels are initially preallocated to each cell. Furthermore, the secondary (borrowed) channels must be returned to the cell from which it has been borrowed as soon as the communication is over.

Each cell has a set of reserved channels (in proportion to primary channels), which will immediately be given to a crossing over MH (to handle handoff). However, at the same time, the cell searches for a new channel. As soon as it gets the new channel, it is allocated to the crossed over MH so that there served channel pool is intact.

For experimental purposes, the MHs are randomly distributed among the cells in proportion to the number of channels per cell. It is assumed that the MH movement across the cells is stochastic.

- 1) **Encoding Used:** Each cell is represented by a chromosome. A chromosome is an array of length 14. The first location of the chromosome array represents the number of blocked hosts. The second location of the chromosome array is for the number of free channels. The next six locations contain the information about the channel lending to six neighbor cells. The last six locations contain the information about the channel borrowing from six neighbor cells. The chromosome of a cell and the chromosomes of its six neighboring cells form a matrix of 7 * 14, which is called a super chromosome. Chromosomes are combined into a super chromosome, and all the super chromosomes together give the information of the whole network. All GA operations are performed on the super chromosome.

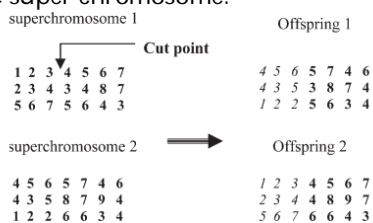


Fig 2 Crossover operation

- 2) **Crossover:** The crossover operation occurs between two superchromosomes (two matrices) to generate two offspring from them i.e., two new matrices. After this step, we get two new different chromosomes. In Fig. 2, two example superchromosomes are taken, and the crossover operation is illustrated. Crossover site is the cut point in the figure..

III. PROPOSED MODEL

In the mobile network, the system is potentially confronted with a wide range of path characteristics to each receiver e.g., different delays, link failure rates, packet losses, and competing congestion on the paths to the different receivers. Different users perceive different channel quality based on their location. The concern here with the link failure rate is in terms of the failure of the BS and channel assigned to the MH for communication.

The work proposed here considers the channel allocation based on the failure rate of the BS and the channel. With the failure of the BS, we mean the total interference level of signals received from the terminal equipment at the BS, the strength of the transmission power, the signal-to-noise ratio between the terminal equipment and the BS, etc.

Certain assumptions have been laid down in the model. As with most of the channel-allocation models, cells are assumed to be hexagonal for simplification and analytical reasons. Each cell has one BS that is responsible for allocating the channels for the hosts inside the cell and the crossing-over hosts to this cell. For experimental purposes, MHs are randomly distributed among the cells, depending on the capacity of the cell. It is assumed that the MHs' movement across the cells is stochastic. The channels are assigned to the cells according to the initial requirement of the network traffic. The probability of applying mutation is often very low. The main weakness of mutation in the channel-allocation problem is the taking-borrowing decisions ahead of time that may result in nonoptimality for two reasons: 1) Their effectiveness is not measured in the fitness function,

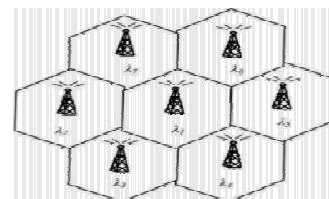


Fig 3: Bss with different failure rates

and 2) these decisions degrade the future quality of service [3], Each cell has a set of reserved channels that will immediately be given to a crossing-over MH .The performance of the algorithm is evaluated by measuring the maximum reliability value of the simulated model for the allocation.

The proposed algorithm exploits the potential of the GA to improve the reliability of the communication network system by assigning the channels to the MHs based on the reliability computation. The computation of the reliability parameter depends on two factors: 1) the reliability of the BS and 2) the reliability of the channels. The assignment of the channels to the MHs based on the reliability parameter enhances the overall reliability of the mobile network system.

A. Explanation of the Model: The reliability of the communication session depends on the services of the BSs and the links (channels) over a time T, in which the communication is made between the MHs and the corresponding node. The availability of these services depends on the failure rates of the devices (BS) and the links (channels). As previously mentioned, the failure of the BS is determined by various factors such as the total interference level of signals received from the terminal equipment at the BS, the strength of the transmission power, and the signal-to-noise ratio between the terminal equipment and the BS. The failure of the channel is determined by the traversal time of a physical path, which is its MMRT. We, in this model, have chosen the reliability parameter to be represented by exponential distribution.

The reliability of the BS over time t is $e^{-\lambda t}$, where λ is the failure rate of the BS, and t is the time of a session i.e., in which the BS is involved in communication between the terminal devices.

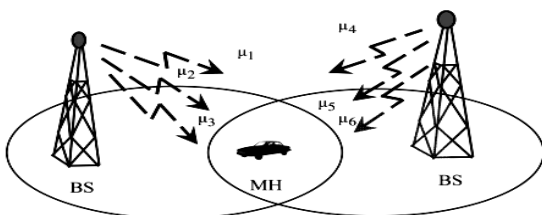


Fig.4. Network- assigning channels with different failure rates

If the number of BSs used in the network system for one whole session is m, then the reliability of all the BSs R_B in the network for the session is

$$R_B = EXP \left[- \sum_{k=1}^m \lambda_k t_k \right]. \quad (1)$$

This equation is due to the fact that the different BS with different failure rates (λ) are involved over the different time period in one session.

Similarly, if the number of total channels used in one session is n, then the reliability R_C of all these channels for that session is

$$R_C = EXP \left[- \sum_{i=1}^n \mu_i t_i \right] \quad (2)$$

where μ is the failure rate of the channel (see Fig. 4).Note that the total time taken in a session is T and is evaluated as

$$T = \sum_{i=1}^n t_i + \sum_{k=1}^m t_k. \quad (3)$$

The GA is used as a tool for optimizing (maximizing) the reliability, for both the BSs and the channels, in the proposed model. The population with better reliability value, in each generation, will participate for reproduction in one or more of the next generations. To observe the effect of communication time on the reliability of the designed network system, an experiment has been conducted for different sessions over the different time periods. An experiment is conducted for the new initiated calls and for the handoff calls.

B. Fitness Function: Based on (1) and (2), the total reliability R_T of the network system for a communication session is given by

$$R_T = R_B \times R_C. \quad (4)$$

To obtain the best reliability for the designed network system, the reliability R_T in (4) will be maximized. This function gives the total reliability of a communication session at any time T.

C. Algorithm

This section proposes a channel-allocation algorithm to optimize the reliability of the network system using the

GA. The algorithm uses a channel-allocation strategy similar to the one with reliability optimization. The algorithm is given as follows.

1. Input the total number of channels and the MHs.
2. Assign channels to each cell based on the initial demand.
3. Input generation_no. // for how many generations to carry on the experiment.
4. Initialize generation_index =0. // used as the index.
5. Initialize Max_system_reliability =0.
6. Create the initial population.
7. Allocate channels to hosts based on the strategy.
8. Repeat Steps 9–14 until generation_index= generation_number.
9. Perform the genetic operations as in Section II.
10. Score the population based on the reliability fitness function. Select the best superchromosome as the current superchromosome.
11. Output current_ system_reliabilty resulted in the current generation.
12. Increment generation_index.
13. 14.If(current_system_reliability>Max_system_r
eliability)Max_system_reliability=current_ system_reliability.
14. Output Max_system_reliability.

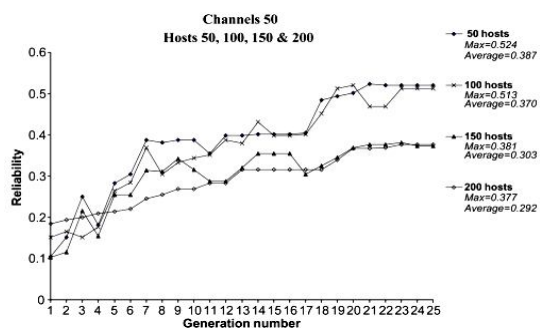


Fig.5 Fifty channels with varying numbers of hosts

IV. EXPERIMENTAL EVALUATION

In this section, the performance of the proposed algorithm is evaluated. The experiment is conducted up to 25 generations. It has been observed that the solution converges by 25 generations. The experiments have been designed by writing programs in C++.

- 1) Simulation Parameters: The simulation parameters used in the experiment are listed as follows.
 - The simulated cellular network consists of 20 cells.
 - The total number of channels and hosts in the network are varying.
 - The reserved channels, for all the experiments, are 30% of the total number of channels and are distributed among the cells in proportion to the distribution of the MHs. For example, in the experiments with 50, 100, 150, and 200 channels, the reserved channels are 15, 30, 45, and 60, respectively
 - The handoff probability is considered to be 30%, which is in conformity with that of the reserved channels. The results are represented in the performance graphs, where the x-axis represents the generations, and the y-axis denotes the reliability value.
- The experiment is conducted for random values (ranges) of BS failures λ and channel failures μ . The maximum value obtained over the generations is taken as the solution. The input values are as follows.
- $\lambda = 0.1 - 0.3$, and $\mu = 0.4 - 0.8$;
 - Number of channels: 50, 100, 150, and 200;
 - Number of hosts: 50, 100, 150, and 200.

Furthermore, we conducted the experiment by varying the values of λ and μ . First, it is conducted when $\lambda = 0.1 - 0.3$ and $\mu = 0.5 - 0.9$. Simulation has been carried out again for the four sessions, and the average value is shown in the graph in Fig. 10

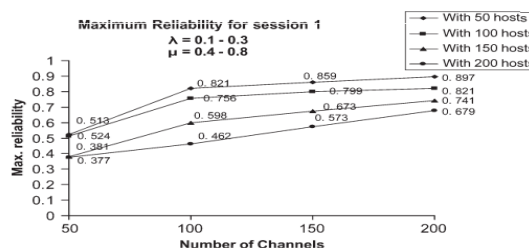


Fig6:Result of session1

V. OBSERVATIONS

Before making our concluding remarks, the following observations have been derived from the results obtained in Section IV.

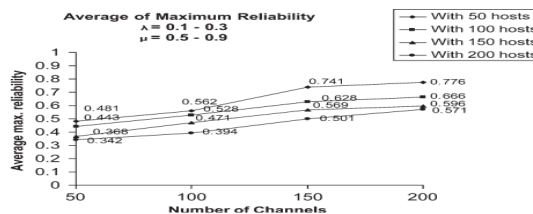


Fig7: Average results of sessions

- Both the maximum reliability value and the average reliability value increases over the generations, as shown in Figs. 7.

VI. CONCLUSION

In this paper, a reliability-based model that uses the GA to optimize the reliability in mobile computing network has been proposed. The proposed model is an effective approach to make the network connections more reliable. It has been observed that the well-managed and efficient usage of the better channels (with lower failure rates) and delivering them to the MHs greatly increases network reliability. The performance of the proposed model has been evaluated by conducting the simulation experiment. It is found that, over the generations, both maximum reliability and average reliability increase, and the result converges after certain generations. The model cannot be compared with any other method, because no other work conducts the channel allocation based on reliability values. The proposed model can be incorporated with other similar models to increase their reliability and effectiveness. In the future, we intend to observe the effect of increasing the reliability on the other quality-of-service parameters of the network system.

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