

Genetic Algorithm for Optimizing Connectivity in Disaster Scenario

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Abstract: *This article presents evolutionary computation approach for increasing connectivity in disaster scenario. An effective disaster management requires rapid coordination of existing resources. At time of disaster, it becomes difficult to maintain Connectivity. Connectivity is considered to be of critical importance in disaster scenarios due to constrained and mobile conditions. In this paper we propose Genetic Algorithm for maintaining connectivity even in disaster conditions. Due to the complexity of the problem and the number of parameters to be considered, a genetic algorithm combined with the network simulator NS-2 is proposed. Specifically, NS-2 is used to model the communication layers and provide the fitness function guiding the genetic search.*

Keywords: Genetic Algorithm, MANET, Connectivity, NS-2, and Disaster scenario

1. Introduction

Natural disasters usually occur suddenly and unexpectedly, resulting in loss of life as well as severe damage to property and the surrounding environment. Therefore, it is important to perform effective contingency plans to tackle natural disasters. A natural disaster scenario is highly complicated and dynamic. Communications systems in disaster scenarios are most likely to be destroyed or non-functioning. In disaster response scenarios, rescue team should take action quickly in order to reduce further risk and fatalities.

MANET is group of mobile nodes that form network without need of underlying infrastructure. These nodes have power constraints, limited coverage area, and each node can act as a router in the network. In disaster scenario connectivity as quality of service should be guaranteed in order to achieve required level of management. In this article we propose evolutionary based approach called Genetic Algorithm to solve connectivity issue in disaster scenario. Each node has different feature in terms of mobility. On the other hand, the power transmission is a design factor; it depends on the technology used. The transmission power is normally fixed and only varies due to environmental conditions. Communications in disaster scenarios are carried out during very short periods of time and normally such communications are broadcasting packets shared by nodes in order to inform and alert other nodes about the situation. These messages are normally forwarded from a source node to a destination node. Routing protocols for ad hoc networks define the rules followed by the nodes in order to seek and find reliable communication path among nodes. These algorithms should deal with mobile and variant conditions. The routing protocols for ad hoc networks are normally categorized as reactive and proactive routing protocols. The reactive protocols are more suitable for mobility conditions and consequently, more suitable for disaster scenarios. Although many reactive routing protocols have been proposed for ad hoc communications, there is still a lack of specific reactive routing protocols for disaster scenarios. In general, reactive routing protocols use flooding as the broadcasting technique to discover communication routes.

This technique can be also used to disseminate broadcasting information. The reachability of nodes depends on the efficiency of the flooding technique. Collisions and congestion are the classical problems, which deteriorate the performance of the flooding technique.

Connectivity issue in disaster conditions can also be observed as topology problem. In Topology problems objective is to find optimal topology to optimize several parameters. The use of NS-2 to evaluate the fitness function is very interesting since it allows the designer to model the communication layers and the signal propagation models. Xu et al. [6] included a GA in NS-2 for analyzing topology control in ad hoc wireless networks. The implemented topology control was able to calculate the suitable node's coverage area to minimize the energy consumption. To summarize, this article deals with increasing connectivity guarantees in disaster scenarios. The main objective is to demonstrate whether evolutionary computation techniques can be applied to disaster management in order to improve the reachability of ad hoc networks in such constrained conditions. The network simulator NS-2 [1] is useful to model the communication layers of ad hoc networks whereas the motion generator Bonn Motion [1] creates the movements of nodes in a disaster scenario. The connectivity issue in disaster scenarios is stated in Section 2, while Section 3 contains the proposed approach to solve the connectivity problem, and Section 4 describes the implementation of the genetic algorithm. Sections. Finally, the conclusions are presented in Section 5.

2. Network Design Challenges

In disaster management connectivity is important issue. When disaster occurs, fast responses and coordination is expected. Disaster affects failure of few nodes resulting in loss of connectivity. A high connectivity among nodes is desired in disaster. However features such as mobility of nodes, noisy and damaged environment and limited power transmission makes scenario unfeasible to maintain connectivity among nodes in disaster. Furthermore connectivity among nodes in different areas is even more

critical. Factors which degrade performance of network in disasters are

A. Frequent Topology Change

In disaster conditions network topology changes frequently due to node failure, damage, addition, energy depletion, or channel fading. This increases complexity of design.

B. Severe Energy, Computation, and Storage Constraints

Sensor nodes are highly limited in energy, computation, and storage capacities. Percentage of average energy consumed by network in disaster should be minimum since energy is limited resource.

C. Many - to - One Traffic Pattern

In disaster management, the data sensed by sensor nodes flow from multiple source nodes to a particular sink, exhibiting a many - to - one traffic pattern.

D. Dynamic and Unreliable Environment

Disasters results in a dynamic unreliable environment. On one hand, the topology of a sensor network may change frequently due to node failures, damages, additions, or energy depletion.

E. Noise

Nodes are linked by a wireless medium, which become noisy, error prone, and time varying in disaster. Probability of noise in disaster is very critical issue since intensity of noise is more in disaster.

F. Channel Fading

The connectivity of the network may be frequently disrupted because of channel fading or signal attenuation.

G. Normalized Routing Load

This efficiency of routing protocol in disaster is lowered. Thus with normalized routing load, efficiency of routing can be increased.

H. Adaptability

Network must be designed in such a way that it should be able to adapt itself even in disaster. While designing such network above mentioned challenges should also be considered. Hence adaptability is important design issue.

I. Node Failure

Disaster causes failure of nodes in network. In order to maintain connectivity nodes which got destroyed due to disaster should be detected. Thus disaster scenario has diverse complexities. With rapid growth of complexity and scale of problem domain, creating efficient simulation for disaster management has become key requirement for research industry and management.

3. Proposed Approach

Due to the complexity of the problem and the number of parameters to be considered, a genetic algorithm combined with the network simulator NS-2 is proposed for disaster management. Genetic algorithms are set evolutionary algorithm. They use techniques, which inspired from evolutionary biology such as inheritance, selection,

crossover and mutation. NS-2 is object oriented simulator. It is widely used by research and academics in order to simulate both wired and wireless networks. NS-2 is used to evaluate fitness function. TCL is programming used. Bonnmotion is freely available mobility generator. It creates and analyzes mobility of nodes in network. Results can be verified with help of c program to check weather desired optimal outcome has been achieved or not. If desired optimal outcome is not achieved then new generation are again created with help of genetic operations such as crossover and mutation as shown in fig1.

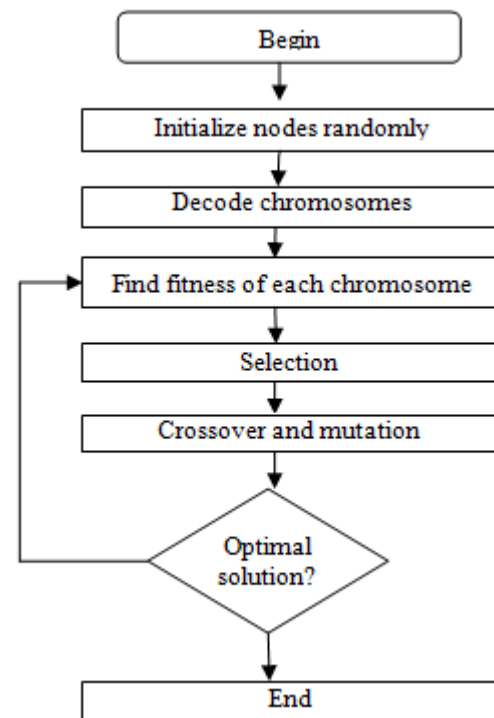


Figure 1: Flow chart of GA

4. Genetic Algorithm Implementation

Genetic algorithms are computational model which are inspired from evolution. These algorithms encode potential to provide solution to specific problem. The mechanism is based on the selection scheme from $(\mu+\lambda)$ evolution strategy. The algorithm maintains a population of N_t chromosomes. The fitness function evaluates the goodness of each chromosome. The μ best chromosomes are included directly in the next generation. The algorithm starts using an initial population P_i that is composed of N_t chromosomes. Goldberg studied the optimum number of chromosomes for a population according to the chromosome's length. Goldberg's main conclusion was that the optimum population size value gets higher as the chromosome's length increases. The initial population is generated randomly in order to preserve the diversity in the population. The GA is based on two operations, crossover and mutation. These operations are responsible for generating λ chromosomes of a new population. The crossover consists of using two members of a population P_j to generate two new members of the next population P_{j+1} by crossing their genetic information. The new chromosomes contain genetic information from the predecessors. The purpose of mutation is to change the genetic information of a chromosome

included in P_j to generate a new chromosome of P_{j+1} . Fig. 1 illustrates proposed genetic algorithm.

A. Chromosomes Encoding

A chromosome C_i is a set of positions of the sink nodes. The nodes are deployed forming a collaborative network working along with the mobile nodes. We denote $K (P_1, P_2, P_3 \dots P_n)$ as the set of parameters coded to form the chromosome, where n is the total number of parameters. Each parameter is coded using a number of bits B_l (from $l = 0$ to $l = n$). The chromosome's length is defined as follows

$$L = \sum_{l=0}^n B_l \quad (1)$$

B. Evaluation Function

In genetic algorithm fitness function is evaluated. Fitness function is evaluated with help of simulation in NS-2. Fitness function determines goodness of chromosomes. The fitness function interprets the chromosome in terms of physical representation and evaluates its fitness based on traits of being desired in the solution. But Fitness function must accurately measure quality of chromosomes.

Therefore, the fitness function that involves computational efficiency and accuracy of parameters is defined as follows

$$f_i = \frac{1}{\sum_{j=1}^{l_i-1} C_{g_{i(j)}, g_{i(j+1)}}} \quad (2)$$

Where f_i represents the fitness value of the chromosome, l_i is the length of the chromosome, $g_{i(j)}$ represents the gene (node) of the locus in the j chromosome, C and is the link cost between nodes. The fitness function of GAs is generally the objective function that requires to be optimized. In a sense, the fitness function can be thought of as fully reflecting the objective function. The fitness function has a higher value when the fitness characteristic of the chromosome is better than others. In addition, the fitness function introduces a criterion for Selection of chromosomes.

C. Selection

The selection process is used in order to improve quality of population. Through this process, selection chances of high quality chromosomes in next generation are increased. The selection thereby focuses the exploration on promising regions in the solution space. Selection pressure characterizes the selection schemes. It is defined as the ratio of the probability of selection of the best chromosome in the population to that of an average chromosome. Hence, a high selection pressure results in the population's reaching equilibrium very quickly, but it inevitably sacrifices genetic diversity (i.e., convergence to a suboptimal solution). There are two basic types of selection scheme used commonly in current practice: (1) proportionate and (2) ordinal-based selection Both selection schemes suffer when the selection pressure is inadequate (i.e., low or high). Proportionate selection picks out chromosomes based on their fitness values relative to the fitness of the other chromosomes in the population. It is generally more sensitive to selection pressure. Hence, a scaling function is employed for redistributing the fitness range of the population in order to adapt to the selection pressure. Examples of such a selection type include roulette wheel selection, stochastic remainder selection, and stochastic universal selection. Ordinal-based

selection schemes select chromosomes based not upon their fitness, but upon their rank within the population. The chromosomes are ranked according to their fitness values. It is noted that the selection pressure (intensity) is independent of the fitness distribution of the population, and is based solely on the relative ranking of the population. Since the selection pressure is the degree to which the better chromosomes are favored, it drives the GAs toward improved population fitness over succeeding generations.

D. Transition procedure

The procedure used to generate a new population P_{j+1} from the previous population P_j is as follows:

- 1) The best 20% chromosomes are copied from P_j to P_{j+1} . This ensures that the best individuals of each population will be included in the next generation. Thus, the likelihood of using a good chromosome for reproduction operations becomes higher.
- 2) The new 80% of the chromosomes are generated by using crossover and mutation operations. This aims to favour the diversity of the chromosomes. P_c denotes the probability of a chromosome i to take part in a crossover operation. Similarly, P_m is the probability of a chromosome i to take part in a mutation operation.

E. Crossover

The new 80% of the next population is obtained using crossover operation.

The probability P_c of a C_i is calculated as follows

$$P_{C_i} = \frac{f_f(C_i)}{\sum_{i=0}^n f_f(C_i)} \quad (3)$$

The term $f_f(C_i)$ stands for the evaluation of the fitness function for the chromosome C_i . In this way, the best chromosomes are most likely to be selected. Note that the genetic algorithm is an Elitist algorithm where the best individuals always pass to the next generation. The crossover operation is illustrated in Fig. 5. A two-point crossover operation has been implemented. The two points of cross are denoted by P_{K_1} and P_{K_2} , where $0 \leq K \leq l$ and l is the size of the chromosome. The value of K_1 and K_2 are randomly chosen for each crossover operation and always $K_1 < K_2$. These points divide each chromosome into three parts namely RG_j , MG_j and LG_j . The two new chromosomes are then obtained swapping $LG_{j,1}$ by $LG_{j,2}$, and $RG_{j,1}$ by $RG_{j,2}$.

F. Mutation

The new population is obtained by mutation operation. Mutation operation is to make small changes in chromosomes. These changes consist of modifying one chromosome's bit. The position of the mutated bit is denoted by P_m , where $0 \leq m \leq l$. The value of P_m is randomly chosen for each mutation operation

G. Stopping Criteria

We consider $P_{av,j}$ as the population's average fitness function, then stopping criterion can be formulated as

$$S_c \rightarrow P_{av,j+1} \leq P_{av,j} \quad (4)$$

The population's average fitness function has been chosen as the stop criterion of the genetic algorithm.

5. Conclusions

In this article we have presented an overview of genetic algorithm for optimizing connectivity in disaster scenario. We have outlined design challenges first followed by Genetic algorithm as proposed approach for disaster Management.

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