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# A Genetic Algorithm for Dynamic Routing and Its Performance Evaluation

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Recently, traffic control (routing) has become an important issue, because of the enlargement of the computer network scale and the increase of traffic information. For efficient communication, it is necessary to avoid the congested traffic route and to select a route which has a shorter delay time in order to disperse the load of communication circuits. The route is not fixed beforehand, but is decided according to the change of the network environment. In this paper, a new dynamic routing method using the genetic algorithm is proposed. The network is modeled by a tree, and the individual genes express the connected nodes from the root to the leaf. As a result, genetic operations become easy and an efficient routing can be achieved. The simulation results show that the proposed method can find faster the communication route compared with methods proposed so far.

# 遺伝的アルゴリズムを用いた動的ルーティングとその性能評価

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近年のコンピュータネットワークの急速な規模拡大やトラフィックの増加に伴い、通信経路の制御 (ルーティング) は重要性を増している。効率の良い通信を行うためには、輻輳状態にある経路を回避し、より通信遅延時間の少ない経路を選択することによって、通信回線に関する負荷を分散する必要がある。そのためには、あらかじめ通信経路を固定化するのではなく、常に変化しているネットワーク環境に応じて動的に通信経路を決定していかなければならない。本論文では、遺伝的アルゴリズムを用いた動的ルーティング手法を提案する。本手法では、遺伝的操作が複雑であるという従来の手法の問題点を解決するために、ネットワークを Tree で表現し、通信経路の遺伝子を Tree の分岐点で表す。本手法の性能を評価するために、シミュレーション実験を行った。その結果、遺伝的操作が簡単になり、従来の手法より効率的なルーティングを行うことが示された。

## 1 Introduction

In the recent years, routing has become an important issue, because of the enlargement of the computer network scale and the increase of traffic information. For efficient communication, it is necessary to avoid the congested traffic route and to select a route which has a shorter delay time in order to disperse the load of communication circuits. The route is not fixed beforehand, but is decided according to the change of the network environment.

So far, some routing methods such as Shortest Path First (SPF) and Route Information Protocol (RIP) have been proposed. The drawback of these methods is that when the network scale become large, the volume of communication becomes large, so the network performance decreases very much. To cope with this problem, the intelligent routing algorithms can prove to be very efficient [1].

Genetic Algorithm (GA) is a good approach for dynamic routing. GA is based on the interaction between individuals and the natural environment [2]. GA generates a sequence of populations by using genetic operations – crossover and mutation – among individuals. As a result, only individuals that fit the natural environment can survive and leave offsprings. The routes in a network can be expressed by individuals. Based on the repeating of genetic operations, it is possible to find the best route which fits the network environment, so an efficient communication can be achieved.

Two source routing methods which use GA have been proposed [1],[3]. In [1], the adaptive routing mechanism has a load balancing system among alternative paths. This routing mechanism is called Load Balancing Routing (LBR). In [3], the effectiveness of adaptive source routing method using GA is shown. In these methods, GA individual genes are used to express the connected nodes which through communication routes. However, the problem of these methods is that the genetic operations are very complicated.

In order to solve the problems of the above-mentioned methods, we propose a new routing method which is called GADR (Genetic Algorithm for Dynamic Routing). In the GADR method, first the network is modeled by a tree. Then the individual genes express the connected nodes from the root to the leaf. The simulations are carried out for two network types. The network model 1 has 8 nodes and the network model 2 has 20 nodes.

The organization of this paper is as follows. The network models will be introduced in Section 2. In Section 3, the routing algorithm will be presented. Simulation results are discussed in Section 4. The conclusions are given in Section 5.

## 2 Network Model

When GAs are used for dynamic routing, the routes of the network are expressed by individuals. But this results in poor efficiency of the genetic operation. In order to improve genetic operations, in the GADR method, the network is transformed into a tree model.

The network model 1 is shown in Fig.1. The node A is the source node and the node H is the

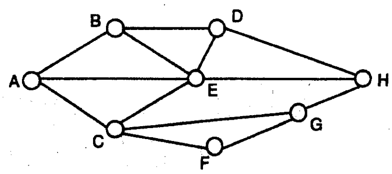


Figure 1: Network model 1.

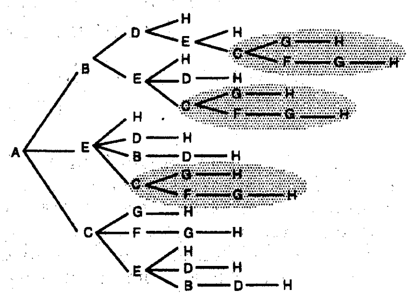

Figure 2: Tree model 1 of network model 1.

destination node. All communication routes are expressed by the tree model shown in Fig.2. In the shaded areas is shown the same communication part from node C to H. To decrease the number of genes in a chromosome, the tree model of Fig.2 is changed as shown in Fig.3. By using the tree model 2, each tree junction is considered as a gene and the communication route is a chain of the genes which is called chromosome.

The network model 2 with 20 nodes is shown in Fig.4. By using the same method as in the case of the network model 1, the tree model 2 of the network model 2 is constructed as shown in Fig.5.

By using the tree model, only one communication route can be built by each chromosome. Therefore, it is easy to apply crossover and mutation operations.

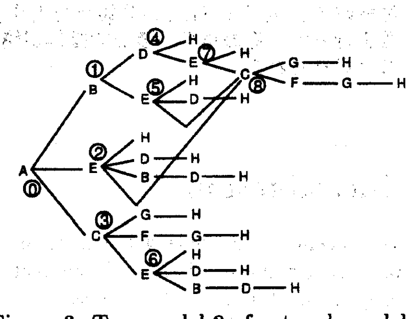

Figure 3: Tree model 2 of network model 1.

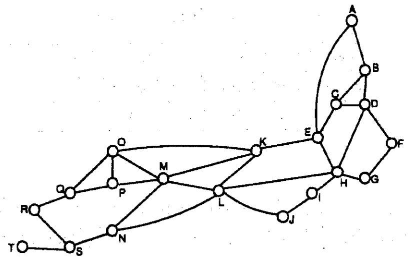


Figure 4: Network model 2.

# 3 Routing Algorithm

In this section, the GADR algorithm is explained. It includes source routing, gene coding and genetic operations.

## 3.1 Source Routing

The GADR method is based on the source routing mechanism. In the source routing mechanism, a complete route from the source node to destination node is decided from the source node. A transmitting node knows the communication routes. Therefore, if the data is large in quantity, it is possible to divide the flow data by using different paths. Furthermore, it is also possible to select a route efficiently because the source node knows the complete information about the network. However, if the network scale is very large, the number of routes arriving in a moment of time can become large. Therefore, is very difficult for the network to handle this large amount of data information.

## 3.2 Gene Coding

Gene coding is very important to achieve efficient genetic operations. Genes decide the characteristics of chromosomes. Chromosomes together construct an individual, whose characteristics depend on the chromosomes. The pattern of gene combinations is called the "genotype". Furthermore, the individual formed by the interaction of genotypes is called "phenotype". In the methods proposed up to now, the genotype and phenotype were the same. Genes are put in chromosomes in the same order the nodes form the communication route. In this case, if genetic operations are chosen randomly, the new offsprings of a population may be unsuitable individual populations. As a result, a communication route between two adjacent nodes does not exist and complicated genetic

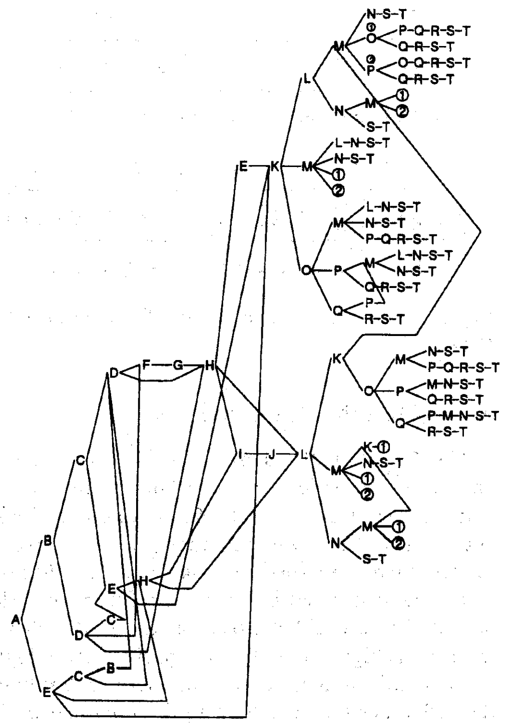

Figure 5: Tree model 2 of network model 2.

operations should be carried out in order to find a new communication route. Also, the individuals of a population have different sizes, therefore the crossover operation is very difficult.

In this paper, in order to simplify the genetic operations the network is expressed by a tree network. The genes are expressed by the nodes of a communication route. A phenotype pattern is expressed uniquely by a genotype. Each gene includes information of the adjacent nodes. The genotype gives information about a communication route. The length of the chromosome is constant. Therefore, the crossover operation becomes very easy. In previous methods, the interaction between the adjacent genes in a chromosome was necessary. On the other hand, in the GADR method this interaction is not necessary. So, the mutation operation becomes easy. The GADR method gives various individuals. Therefore, the GADR evolution becomes faster.

In Fig.6 there are shown two chromosome examples for the route "A-B-D-E-C-F-G-H": (a) shows the chromosome model of the LBR method and (b) shows the chromosome model of the GADR method.

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| A | B | D | E | C | F | G | H |

(a) Chromosome model of the LBR method.

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| BEC | DE | HD BC | GFE | HE | HDC | HDB | HC | GF |

(b) Chromosome model of the GADR method.

Figure 6: Chromosome examples for the route "A-B-D-E-C-F-G-H".

### 3.3 Genetic Operations

The GADR method uses the following genetic operations: selection, crossover and mutation.

In the selection method, the ranking model and elitist model are used together. In the ranking model, each individual is ranked by their fitness. The rank is decided based on the fitness and the probability is decided based on the rank. When the rank is high, the individual probability is high. Because fitness is used as a measure for ranking, the difference between high rank individual probabilities and low rank individual probabilities is bigger. Therefore, the individuals in the ranking model are evolved faster than other models. The ranking model is used when the individual selection probability is decided. In the elitist model, the individual which has the highest fitness value in a population is left intact in the next generation. Therefore, the best value is always kept and the routing algorithm can converge very fast to the desired delay time. The elitist model is used after the mutation.

In the crossover method single point crossover is used. The crossover point is selected in the same locus of two selected individuals. The mutation is carried out only in the genes which have nodes in the communication route (see loci 0,1,4,7,8 in Fig.6(b)).

The individual fitness is based on the communication route delay time. If the delay time is lower, the individual fitness is higher.

## 4 Simulation

### 4.1 Simulation Method

For the simulation, two types of networks with 8 nodes shown in Fig.1 and 20 nodes shown in Fig.4 are used. Two assumptions have been considered. The delay time is set at each link and a sudden congestion situation is assumed in the route which is currently used. Then, the GADR algorithm searches for a new communication route in order to avoid the congested link. The genetic operations are repeated until the best route is found or the initialized generation size is achieved. Then, the delay time versus simulation step for LBR and GADR methods are depicted. To compare both methods, the first population is selected the same. The parameters used in the simulations are shown in Table 1.

Table 1: Simulation parameters.

| | |
|---|---|
| population size | 5, 10, 20, 30 |
| crossover rate(%) | 70, 80, 90, 100 |
| mutation rate(%) | 1, 5, 10, 20 |

### 4.2 Simulation Results

**Network model 1**

Network model 1 is shown Fig.1. The GADR and LBR methods are compared for different population sizes as shown in Table 2 and for different crossover rates as shown in Table 3.

If the algorithm has to search all network routes to find the best route, the rate of searching time for each individual is 100% (i.e. each alternative route is investigated). In Table 2 and Table 3, the rate A(%) shows the case when both methods find the best route. Otherwise, the rate B(%) shows the case when the initialized generation size is achieved, but the algorithms don't find the best route. From the results of Table 2 and Table 3, we conclude that the GADR method can find the best route faster than the LBR method. As population size increases, the rates A and B decrease. The smaller the rate value, the better the algorithm performance is.

Fig.7 shows the characteristics of delay time ver-

Table 2: Different population size performance.

| population size | rate A(%) | | rate B(%) | |
|---|---|---|---|---|
| | GADR | LBR | GADR | LBR |
| 5 | 10.0 | 11.7 | 4 | 14 |
| 7 | 5.3 | 6.1 | 0 | 4 |
| 10 | 2.9 | 3.4 | 0 | 0 |

Table 3: Different crossover rate performance.

| crossover rate | rate A(%) | | rate B(%) | |
|---|---|---|---|---|
| | GADR | LBR | GADR | LBR |
| 60% | 2.9 | 3.4 | 0 | 0 |
| 70% | 3.1 | 3.9 | 0 | 0 |
| 80% | 3.1 | 4.0 | 0 | 2 |
| 90% | 3.4 | 3.9 | 0 | 2 |

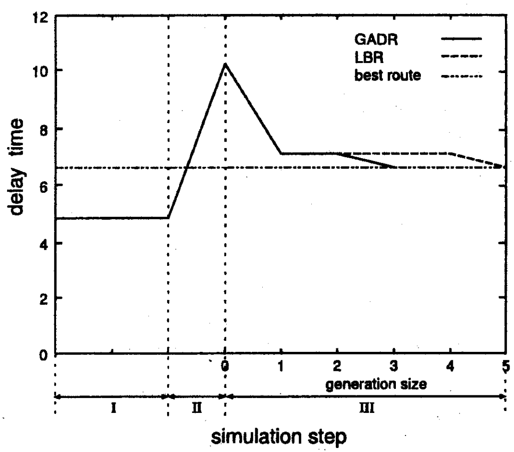


Figure 7: Comparison of the GADR and LBR method.

sus the simulation step for the GADR and LBR methods. The simulation step consists of three parts: step I is the communication state, step II is the congestion state and step III is the algorithm operation state. Step III (generation size) shows how many genetic operations are needed in order to find the best route.

The GADR method can find the best route faster than the LBR method. This means, the GADR method performance is better than the LBR method.

**Network model 2**

Network model 2 is shown Fig.4. The GADR and LBR methods are compared for different population sizes, crossover rates and mutation rates as shown in Table 4. The population size is 10 and 20. The mutation rate changes from 1% to 20% and the crossover rate changes from 70% to 100%. The values inside the table show the rate when both methods find the best route. The GADR method can find the best route faster than the LBR method.

Fig.8 shows the characteristics of delay time versus simulation step for the GADR and LBR meth-

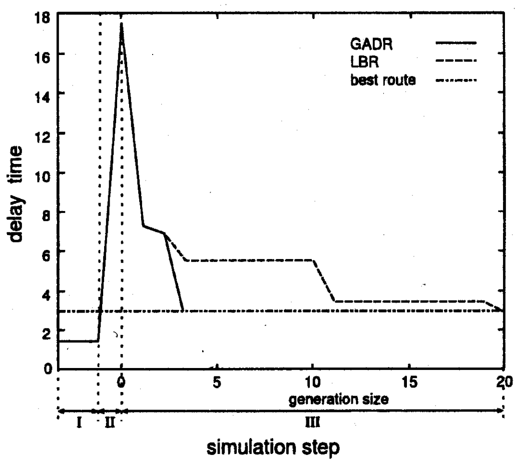


Figure 8: The comparison by the number of simulation step.

ods. The GADR method performance is better than the LBR method.

When the population size is 5 the rate A increases. This means, the number of genetic operations to find the best route increases. When the population size is 10 the result is improved, and when the population size is 20 the result improves much more. However, when the population size is 30, the time to do a genetic operation increases very much, so both methods can not do an efficient search. We conclude that, the best population size is 20. The change of crossover rate doesn't have much affect on the results of algorithms. If the mutation rate is small, the created population types are limited. Otherwise, if the mutation rate is big, the delay time doesn't decrease. Therefore, the methods need time to find the best route. We conclude that 10% to 20% is the best mutation rate.

## 4.3 Performance of Algorithms and Complexity of Genetic Operations

From Table 2, 3 and 4, we can see that the performance of the GADR method is better than the LBR method. In the case of network model 1 with 8 nodes, the difference in the rates between the two methods is small, but in the case of network model 2 with 20 nodes, the difference in the rates is bigger. As the size of the network gets larger, the difference in the rates becomes bigger,

Table 4: Rate A(%) of the GADR and LBR methods.

| population size 10 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| mutation rate | crossover rate 70% | | crossover rate 80% | | crossover rate 90% | | crossover rate 100% | |
| | GADR | LBR | GADR | LBR | GADR | LBR | GADR | LBR |
| 1% | 49.5 | 52.0 | 46.2 | 54.2 | 49.5 | 56.4 | 44.6 | 47.6 |
| 5% | 36.3 | 44.0 | 40.9 | 43.6 | 40.8 | 46.6 | 39.3 | 41.1 |
| 10% | 27.7 | 37.1 | 31.7 | 41.1 | 30.9 | 33.9 | 31.5 | 39.1 |
| 20% | 30.5 | 35.9 | 27.3 | 33.9 | 19.9 | 32.9 | 20.4 | 28.1 |

| population size 20 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| mutation rate | crossover rate 70% | | crossover rate 80% | | crossover rate 90% | | crossover rate 100% | |
| | GADR | LBR | GADR | LBR | GADR | LBR | GADR | LBR |
| 1% | 17.4 | 21.1 | 14.9 | 21.3 | 18.6 | 21.3 | 17.4 | 20.9 |
| 5% | 13.2 | 16.8 | 16.6 | 23.7 | 14.7 | 18.7 | 17.8 | 18.4 |
| 10% | 16.9 | 18.7 | 16.1 | 20.9 | 17.9 | 26.7 | 15.6 | 25.7 |
| 20% | 12.9 | 15.9 | 13.4 | 21.2 | 12.6 | 22.3 | 15.9 | 26.7 |

so the GADR method performance becomes much better than the LBR method. This means, the GADR method avoids the congested link faster than the LBR method, because the search number for finding the best route is smaller compared with the LBR method. Therefore, the GADR method can adapt to the network changing environment rapidly.

The LBR genetic operations are more complex than the GADR genetic operations. The time for generating a new population with the GADR method is about 6 times faster than with the LBR method. The LBR method complexity of genetic operations is because new individuals populations (routes) may not exist.

The individuals of the LBR method are created partially, so always the individuals will be generated in the same part of the network. On the other hand, the GADR method can create various individuals (routes), so the GADR method can get the best route faster than the LBR method.

# 5 Conclusion

In this paper, we proposed a new method for dynamic routing based on genetic algorithm, which is called the GADR method. In the GADR method, the network is expressed by tree models so genetic operations become simple. The performance of the GADR method was investigated by simulations. From the simulation results, we conclude:

- The GADR method has an efficient search, therefore the time to find the best route is shorter compared with the LBR method.
- As population size increases, the rates A and B decrease. The smaller the rate value, the better the algorithm performance is.
- As the size of the network increases, the GADR method performance becomes much better than the LBR method.
- The LBR genetic operations are more complex than the GADR genetic operations.

In the future, we would like to extend the study when the network has more than one congestion state.

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