TELKOMNIKA, Vol.11, No.3, September 2013, pp. 603~610
ISSN: 1693-6930, accredited A by DIKTI, Decree No: 58/DIKTI/Kep/2013
DOI: 10.12928/TELKOMNIKA.v11i3.985

Computer Network Reliability Optimization Calculation Based on Genetic Algorithm

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Abstrak

Cara efektif untuk mengurangi biaya jaringan komunikasi dengan meningkatkan kehandalan sistem transmisi jaringan komputer adalah salah satu target penting dari perhitungan optimasi kehandalan jaringan komputer. Oleh karena itu, dalam perhitungan optimasi kehandalan jaringan komputer, perlu untuk mengintegrasikan biaya komunikasi jaringan media, menghitung kehandalan dengan optimasi model matematika dan faktor lainnya. Makalah ini menjelaskan algoritma genetika dan proses implementasinya, serta penerapan algoritma genetika untuk mengetahui biaya link jaringan dan perhitungan optimasi kehandalan jaringan tersebut. Selain itu, hal ini ditunjukkan dari hasil simulasi yang dilakukan bhwa algoritma genetika secara efektif dapat memecahkan masalah perhitungan optimasi reliabilitas yang sulit untuk diselesaikan dengan algoritma tradisional jaringan lainnya, sehingga dapat mempercepat kecepatan perhitungan jaringan komputer dan mengoptimalkan hasil perhitungan jaringan.

Kata kunci: *algoritma genetika, kehandalan, jaringan komputer, optimasi*

Abstract

How to effectively reduce the network node link cost by improving the reliability of computer network transmission system is one of the important targets of computer network reliability optimization calculation. Therefore, in the computer network reliability optimization calculation, it is necessary to integrate the computer network link medium cost, network reliability optimization mathematical model and other factors. This paper describes genetic algorithm and its implementation process, as well as the application of genetic algorithm to the network link cost and network reliability optimization calculation. In addition, it is indicated from the simulation results that genetic algorithm can effectively solve the reliability optimization calculation problem which is difficult to solve by the traditional algorithm of network, so as to speed up the calculation speed of computer network and optimize the network calculation result.

Keywords*: genetic algorithm, reliability, computer network, optimization*

1. Introduction

With the development of computer communication technology, the requirement for the reliability of network information transmission is increasingly higher. What's more, the dependence of various industries on the computer network data is stronger, such as banking, medical industry and network marketing industry, etc. Corresponding security requirement is also increasingly stricter. Computer network usability refers to that the computer network ensures mutual connection capability among all users of computer network in a way of a spanning tree. Its main parameter measures include: network connectivity, survivability and effectiveness of damage resistance network components, etc. How to effectively ensure the reliability of computer network data transmission is one of the concerns of people. There are a lot of defects in using traditional solution to solve this complicated NP problem. It is not a good way to solve this problem. Based on this study phenomenon, the paper proposes conducting optimization calculation of the computer network reliability by using genetic algorithm, so as to realize implementation process of the algorithm based on some examples.

2. Explanation of Concepts Related to the Study

2.1. Computer Network Reliability Optimization

The computer can be connected to the network, maintain the network communication capability and complete corresponding data transmission in a specific time under a certain

Received February 18, 2013; Revised June 29, 2013; Accepted July 16, 2013

operation, load and command control. This is called the computer network reliability. It requires a relatively complete scientific system. It is characterized by system engineering science. Computer network reliability can be divided into the following types:

1) α Terminal Reliability: Make the information communication between the meeting point s and original point t, there is at least one normal link to ensure the data transmission, i.e. α terminal reliability;
2) γ Terminal Reliability: In the communication system, there is a probability of normal link in a set composed of designatedγnodes, in, so as to ensure the reliability of data transmission. This is called γ terminal reliability;
3) All Terminal Reliability: There may be coverage of normal data link between any two nodes. This is called all terminal reliability.

2.2. Genetic Algorithm

Genetic algorithm is used to simulate the process of data transmission by using biological natural selection and genetic mechanism. Establish the optimized information search function suitable for the whole network through population search and information exchange between individuals. It requires easy operation, comprehensive functions and outstanding advantage, which is suitable for the whole network, so as to solve the problem of data transmission. When using genetic algorithm to conduct optimization calculation of the network reliability, firstly, it is required to establish genetic algorithm solution, take sequence as the chromosome of coding, and elements composed of the coding as the gene of genetic algorithm, so as to form the initial population of a set of chromosomes. Finally, produce optimized individuals which meet the stop standard through fitness operation, selection operation, crossover operation, mutation operation and other operations, so as to be suitable for the backbone network data transmission design with the highest comprehensive degree.

3. Description of Problems

3.1. Problem Assumptions

(1) Assume that there are many transmission paths between two nodes of the computer transmission medium used, and there is only one straight line link transmission, then the network transmission of data can be described by mathematical model G = (N, L). (2) The network transmission stability is good, so the network node itself won't have any fault. (3) There is no direct relationship between the length of network link medium and reliability of computer network. (4) There is no direct relationship between the network equipment problems and network data transmission, i.e. there are only two statuses of network and network link: normal operation and fault.

3.2. Mathematical Model for Problem Calculation

(1) Network link medium cost matrix is shown in the following formula (1):

$$C_0 = \begin{bmatrix} c_{11} & c_{12} & \cdots & c_{1n} \\ c_{21} & c_{22} & \cdots & c_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ c_{m1} & c_{m2} & \cdots & c_{mn} \end{bmatrix} \quad (1)$$

In the formula: C0 refers to the medium cost matrix, C_{ij} refers to the link medium cost between i, j（$1 \le i \le m, 1 \le j \le n$）.

(2) Mathematical computation formula of network link medium is shown in the following (2), (3):

$$MinC = \sum_{i=1}^{N} \sum_{j=1}^{i} c_{ij} g_{ij} \quad (2)$$

$$D_i a_{ij} \le \alpha(i, j = 1, \cdots, N)$$
$$\sum_{j=1, j \ne i} g_{ij} \ge \beta(i = 1, \cdots, N) \quad (3)$$

In the formula: C refers to the cost of information in the network, N refers to the number of nodes transmitted by the computer network, $D_i a_{ij}$ refers to the number of medias of the most logical link between i and j (including direct link), while α and β refers to the constraint constant of reliability of computer network nodes. When the value of g_{ij} is 1, there is a direct link between node i and j, when the value of g_{ij} is 0, there is no direct link between node i and j.

(3)Calculation Method of Link Medium Reliability. According to the above calculation method, detailed calculation formula of link medium calculation is shown in (4):

$$R_0 = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_n \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} \quad (4)$$

In the formula, R_0 refers to the reliability matrix of computer network, r_{ij} refers to link medium reliability between computer network nodes. Among them, $1 \le i \le m, 1 \le j \le n$.

When the whole network is available, computers in the network can be connected to each other. Each node in the normal condition can form a spanning tree of figure G, so as to ensure the normal work of the network. At any time of the normal operation of the network, perhaps only $L' \subseteq L$ succeeds, network line is in the normal state of information transmission. At this time, the reliability of the network when all the network nodes are in a normal working state can be calculated by the formula (5):

$$\prod_i^N P(n_i) \quad (5)$$

In the formula, $P(n_i)$ refers to the reliability of i links medium in the computer network, n_i refers to the i node in the network, while N refers to the number of nodes in the computer network.

(4) Computer network reliability modeling formula. When the network is in a good working condition, the maximum of data transmission in the network is R. At the same time, C≤C0, thus enabling the whole computer network to be in a normal working condition. Detailed calculation formula is shown in the following (6):

$$R = \left| \sum_{\Omega} \left| \prod_{i \in L} P(l_i) \right| \bullet \left| \prod_{i \in (L/L')'} (1 - P(l_i)) \right| \right| \bullet \prod_{i=1}^{n} P(n_i) \quad (6)$$

Ω refers to all sets under normal working condition of the computer network, among which, l_i refers to the i line medium in the computer network.

4. Analysis of the Application of Genetic Algorithm in the Optimization Process of Computer Network Reliability

4.1. Mathematical Modeling Analysis of Optimization Process

In order to provide data to transfer in the computer and simplify the computer network nodes storage and communication NP problems, in the process of modeling, principle and method based on the service order is adopted to process and analyze the queuing model of the data. Ignore the time delay of link processing and node in the calculation. The following formula (7) can be used to describe the calculating route selection and capacity distribution time:

$$Z_P = \min(\sum_{i \in L} \left\{ \frac{D \sum_{m \in M} \lambda_m X_{im}}{\sum_{i \in K} C_k \gamma_{ik} - \sum_{m \in M} \lambda_m X_{im}} + \sum_{k \in K} f_k \gamma_{ik} + \sum_{k \in K} \upsilon_k \gamma_{ik} (1/\mu) \sum_{m \in M} \lambda_m X_{im} \right\}) \quad (7)$$

In the formula (7), there are constraint conditions shown as below, so as to ensure the successful network reliability optimization process:

$$(1/\mu) \sum_{m \in M} \lambda_m X_{im} < \sum_{k \in K} \upsilon_k \gamma_{ik} \quad i \in L$$

$$\sum_{k \in K} \gamma_{ik} = 1 \quad i \in L$$

In the formula (7), λm refers to the message delivery rate of node m in the network, the average length of message is 1 / μ, K refers to the number of optional capacity types, C refers to the network information link capacity set, fk refers to the information flow when choosing K type of capacity, Vk refers to the changeable information flow, D refers to the delay of unit information transfer, Xim refers to 1 and 0. According to the definition mentioned above, when the node is passing the link, the value is 1, while it is 0 when the node is not passing the link. The value of Yik is 1, 0, the network distribution capacity value is 1 when it is directly passing the link, while it is 0 when it is not directly passing the link.

Through the formula (7) calculation, a complicated nonlinear equation including selection route and distribution capacity can be got. It is an optimized mathematical modeling model with constraint conditions, which can be solved through genetic algorithm.

4.2. Optimization Design of Genetic Algorithm

As genetic algorithm can effectively make an optimization design of the reliability of computer network, and it can meet the demand of network optimization, thus using this method can obviously improve the efficiency of the network data transmission. In the detailed design, firstly, it is required to input relevant data and control parameters of genetic algorithm, confirm the scope of initial population and adaptive value function according to the parameters, use ergodic matching method for competitive selection, and then conduct hybrid processing operation and global optimizing processing operation, until getting the global approximate optimal solution which meets the convergence conditions.

4.3. Solving Process of Genetic Algorithm

Genetic algorithm adopts the idea of biological natural selection and genetic mechanism, while the designed random search algorithm searches the optimal point in the network through the population search and exchange of individual information, so as to realize the optimization of the algorithm design. Its algorithm process is as follows:

```
Begin
  i←0
  Initialize p(i)
  Calculate p(i)
While the result is not desired, end the condition do
  begin
  Reconstruct p(i), we can get c(i);
  Calculate c(i);
  Select p(i+1) from p(i) and c(i);
   i←i+1
  end
  end
```

4.4. Design Optimization of the Detailed Genetic Algorithm

(1) Gene Expression. In the actual computer network design, one-dimensional binary code is adopted in this paper, so as to confirm N nodes network gene in the computer network. Detailed design is shown in the following Table 1:

Table 1 Computer Network Gene Node

N1	N2	…
G11	g21	…
…	…	…
G1n	g21	…

If there are four nodes in the network, its network gene node becomes a gene expression, which is shown in the following Table 2, while the network structure formed is shown in the following Figure 1.

Table 2 Four-node Computer Network Gene Node

N1	N2	N3	N4
0101	1010	0101	1010

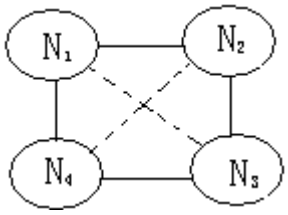

Figure 1. Four-node Gene Node Network

(2) Selection of Fitted-value Function. In order to ensure the safety of the network data transmission and effectively prevent the data diddling in the genetic algorithm, make a descending sort of the cost value of initial population data, set the coding of data with minimize cost value as 1 and the coding of data with maximum cost value as PoP_size, then the corresponding fitted-value function is: $f(x)=(x-1)/(PoP\_size-1)$.

In the formula, x refers to the sort position of individual data in the network cost, PoP_size refers to the scale of the population, with the corresponding constraint conditions: $1 \le x \le PoP\_size$.

(3) Evolution Calculation. According to the above fitted-value calculation method confirmed above, evolution calculation uses rounding selection. It is assumed in the selection, selection probability of each gene is proportional to its fitted-value, for any genes whose fitted-value is f_k, relationship among the selection probability P_k, the fitted-value f_k and sort range of population coding PoP_size is as the follows:

$$P_k = f_k / \sum_{j=1}^{PoP\_size} f_i$$

(4) Genetic Calculation. There are two modes of genetic calculation in the computer network optimization calculation, including crossover mode and mutation mode.

1) Crossover Mode. Crossover mode is a method that take random cross within the effective range ([1,N]) of the computer network node, and produce random numbers to determine the genetic cross position, so as to realize completing the operation with a node. In this way, it can ensure the connectivity of computer network data. However, sometimes the

possible data does not represent the connectivity of network data, showing network error, this requires algorithm adjustment. 2) Mutation Mode. The first step is to determine the detailed range of mutation gene and the detailed number of mutation genes. And then replace old gene with the selected gene fragment, corresponding operation is as follows:

□Assume that the mutated gene is x, then $x = [x_1\ x_2\ \cdots\ x_k]$

□According to the number of genes, randomly select integers, $k \in [1, n]$, $\mu \in [1, n]$

□According to the genetic mutation and the produced generation x', then $x' = [x_1\ x_2\ \cdots\ x'_k\ \cdots\ x_k]$, among which, x'_k is $[x_k^1\ x_k^\mu]$.

□If step □ cannot be realized, then turn to step□.

(5) Adjustment of the Algorithm. Adjust corresponding algorithm according to the result of optimization algorithm. Make a judgment of the network connectivity structure for each gene expression in the algorithm.

□If g_{ij} = 1, then execute the original crossover and make gene data mutation operation, so as to complete data operation.

□If g_{ij} = 0, according to the requirements of the genetic algorithm, make g_{ij} = 1;

□If g_{ij} = 1, according to the requirements of the genetic mutation, make g_{ij} = 0;

□If the step □ cannot be realized, then judge and test the network connectivity.

5. Example of Simulation

According to the above analysis of genetic algorithm, a computer network communication system is developed based on the assumption in the first part of the paper. It is assumed that there are six nodes in the computer network system, so the developed detailed mathematical model is described above through the computer network reliability optimization experiment and multiple times of calculation for the experiment. The application of genetic algorithm to the experiment of reliability optimization of computer network can improve the reliability of the network. Relevant data of network link medium cost tested by the experiment, plus the calculation of cost matrix C0 data matrix, the corresponding results are shown in the following matrix:

$$C_0 = \begin{bmatrix} 0 & 5 & 6 & 14 & 16 & 6 \\ 5 & 0 & 8 & 2 & 5 & 10 \\ 6 & 8 & 0 & 3 & 6 & 11 \\ 14 & 2 & 4 & 0 & 2 & 6 \\ 16 & 6 & 11 & 1 & 0 & 4 \\ 6 & 10 & 9 & 6 & 5 & 0 \end{bmatrix}$$

Through relevant data of reliability tested by experiment and the calculation of reliability matrix C0, corresponding results are shown in the following matrix:

$$R_0 = \begin{bmatrix} 0 & 0.980 & 0.953 & 0.992 & 0.990 & 0.960 \\ 0.980 & 0 & 0.972 & 0.988 & 0.996 & 0.990 \\ 0.950 & 0.970 & 0 & 0.960 & 0.950 & 0.998 \\ 0.991 & 0.998 & 0.964 & 0 & 0.930 & 0.920 \\ 0.998 & 0.995 & 0.958 & 0.930 & 0 & 0.970 \\ 0.961 & 0.993 & 0.998 & 0.920 & 0.970 & 0 \end{bmatrix}$$

According to the above assumption, the number of computer network nodes is N=6, the constraint constant for computer network node reliability optimization isα=2,β=2 respectively. After completing the whole operation calculation and 100 times of iteration of genetic operation, the value of total cost of network link medium is 46 and the maximum value of computer network reliability is 0.885 through simulation solution. Therefore, we can find that the integrity and security of the system is reliable and the optimization of network reliability based on genetic algorithm is reasonable, thus meeting the requirements of computer network reliability optimization. The detailed simulation curve of computer network reliability based on genetic algorithm is shown in the following Figure 2.

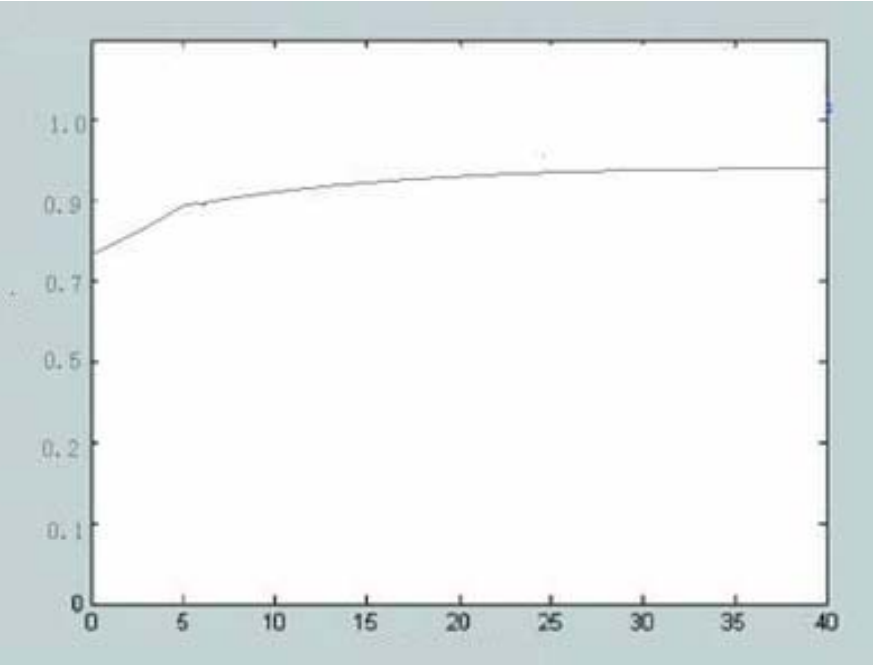

Figure 2. Curve of Simulation

6. Conclusion

Through the above calculation analysis and simulation test, the algorithm structure of genetic algorithm is simple, so it is easy to operate in the computer network application. It is characterized by high efficiency of search, quick solving speed and strong practicability. The optimal solution approximation can be gained in global calculation of network, so as to improve the transmission efficiency of network. Compared with the traditional calculation algorithm of network transmission, genetic algorithm has obvious advantages in the calculation of computer network reliability optimization, which shortens the network calculation time and improves the calculation speed of computer network. Therefore, the calculation results can be effectively optimized, the way of network transmission can be improved and the performance of operation can also be improved greatly. In addition, the use of genetic algorithm can effectively realize the objective of reduction of network cost and reduce network losses, and the reliability of network can be further improved based on the original reliability, also, the performance of network can be optimized.

Meanwhile, the problems of link medium cost, matrix reliability optimization and mathematical model solution are also considered. In this paper, genetic algorithm is applied to the computer network reliability optimization calculation, so as to effectively solve the problem of network algorithm optimization, thus achieving the purposes of reducing the network link medium cost, improving the network reliability and optimizing the network calculation. The algorithm is simple, which is easy to be realized by programming with a good readability. Finally,

the practical application of genetic algorithm is proved through simulation example, which is very helpful for solving the above problems.

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