Research Article

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Topology optimization of computer communication network based on improved genetic algorithm

https://doi.org/10.1515/jisys-2022-0050
received October 28, 2021; accepted February 26, 2022

Abstract: The topology optimization of computer communication network is studied based on improved genetic algorithm (GA), a network optimization design model based on the establishment of network reliability maximization under given cost constraints, and the corresponding improved GA is proposed. In this method, the corresponding computer communication network cost model and computer communication network reliability model are established through a specific project, and the genetic intelligence algorithm is used to solve the cost model and computer communication network reliability model, respectively. It has been proved that GA can solve the complex problems of computer working environment better, which is 80% higher than the general algorithm, and can select the optimal scheme pertinently.

Keywords: genetic algorithm, computer communication network, to optimize

1 Introduction

With the further strengthening of social informatization, people will rely more and more on all kinds of networks, requiring the network to provide convenient, rapid, accurate, safe, and high-quality services. At the same time, the scale of the network continues to expand, the connection area and the length of the network are also rapidly expanding. Up to now, human beings have developed many new large-scale complex equipment and systems, such as computer communication network system, communication system, automated production line system, banking service system, nuclear power plant, large passenger aircraft, and military system [1]. The common characteristics of these systems are complex structure and powerful function. The system needs the support of complex hardware and software to complete the scheduled function, and sometimes also needs the participation of people. Once the system breaks down, it will cause losses of different degrees to society, economy, and environment. Therefore, system reliability, one of the most important indicators of system efficiency, has become a research direction attracting much attention [2]. Therefore, the study of computer communication network reliability has very important theoretical significance and practical value. To ensure that the system can work safely and reliably, theoretical research needs to mainly focus on the optimization design of network reliability, and other indicators of the optimization system, such as link cost, maintenance cost, delay, blocking rate, response time, etc., should be taken into account on the basis of improving network reliability [3].

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In practical engineering applications, designers mainly consider two aspects when constructing network systems: network performance and investment cost. Because of the high cost of network system, cost is often a very important constraint factor in network topology design. For most networks today, a small improvement in their topology design can save a certain amount of money. Through re-optimization, considerable cost savings can be achieved by applying new ideas and technologies without reducing system performance [4].

2 Literature review

Studies have shown that Liu and Wang, taking computer communication network as an example, conducted a detailed study and discussion on the problem of topology optimization design of large-scale network based on full terminal reliability [5]. Sengottuvelan and Prasath conducted exploratory research on the reliability optimization problem of all-terminal network, and applied heuristic methods and GAs to solve this kind of optimization problem for the first time, achieving more effective and satisfactory results than traditional methods [6]. Miao et al. verified that calculating 2-terminal reliability, K-terminal reliability, and all-terminal reliability is NP-hard problem. In general, foreign research works in this field have been carried out in depth, and many valuable research results have emerged [7]. Chang and Yang studied the Si1000-based wireless M-Bus communication system design, as shown in Figure 1 [8]. Abdessamad et al. believed that the optimization design model of route selection and link capacity distribution in computer communication network is a complex nonlinear 0–1 planning if solved by traditional mathematical method, cannot quickly and effectively sum engineering satisfactory solution, based on the basic idea of transmission algorithm, and designed an optimization algorithm which is completely different from the traditional method [9]. Afsharinejad et al. studied its value through the application of contingency algorithms in computers [10]. Osamy et al. proposed a QoS routing algorithm based on improved casting based on delay bandwidth constraints. In this algorithm, a combination of weighted depth priority search and roulette is used to ensure the diversity of the initial population, while improving the basic variation process and proposing methods to guide the variation [11]. Xu et al. have proposed a location information hiding method based on effectively protecting user privacy with improved GAs [12]. Liu et al. extracted the features of location information together with the association rules: the vector quantitative fusion method is used for the data hiding design after information coding [13]. Aizaz and Sinha performed the encryption key construction of location information based on improved GAs, encrypted and quantified location information, and realized the flow chart of location information hiding optimization as shown in Figure 2 [14].

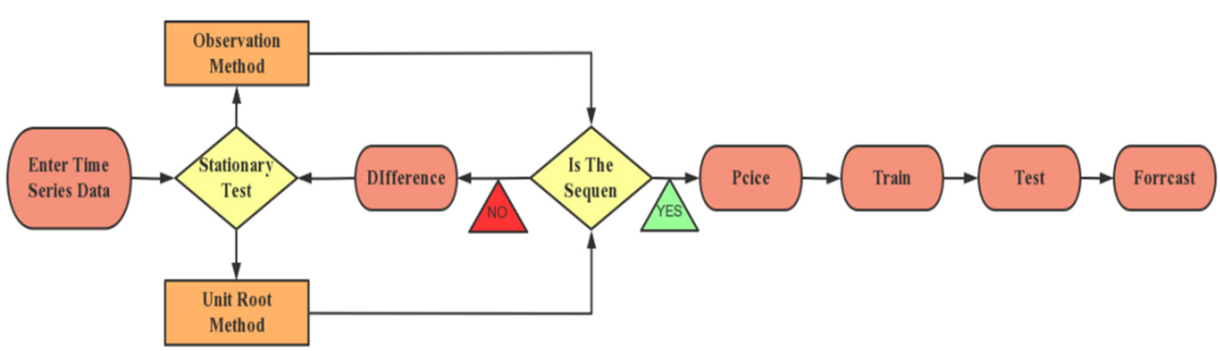

Figure 1: Design of a wireless M-bus communication system based on Si1000.

Based on the synthesis of the existing research, this article proposes the reliability analysis and optimization research based on improved GA, aiming to discuss the process of reliability model

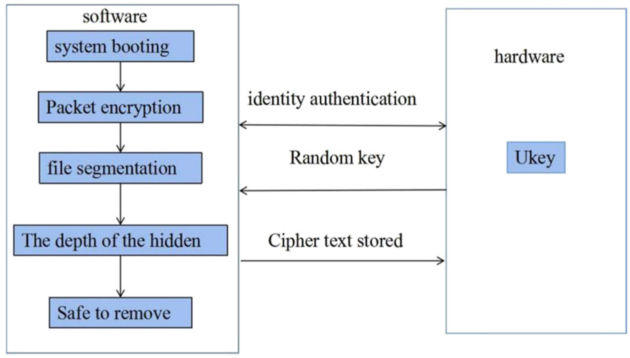

Figure 2: System overall framework diagram.

establishment and reliability analysis, to provide necessary security service strategy for engineering application, and study the multi-objective optimization of network reliability, so as to establish a construction method based on reliability purpose, and give a specific implementation case through intelligent optimization algorithm.

3 Case analysis

This section gives two examples of topology optimization design of computer communication networks. Example 1 maximizes the reliability of a given ARPA network with 5 nodes and 7 links, constrained by given cost. The mathematical description is as follows:

Let $X = (x_1, x_2, \ldots x_7)$ make maximize.

$$\sum_{i=1}^{7} x_i(y_{il}, y_{i2} \cdots y_{im}) = 11 \cdots 1, \tag{1}$$

$$\text{together} \quad \text{with } \delta\ (x) \geq 3, \tag{2}$$

$$\sum_{i=1}^{7} c_i x_i \leq 17.0. \tag{3}$$

The computer network diagram of 4 nodes and their gene expressions are shown in Table 1.

Table 1: Gene expression table of computer network nodes

N_1	0101
N_2	1010
N_3	0101
N_4	1010

Choice of fitness function: Effectively prevent the occurrence of deception in the GA, the cost values of individuals in the population are arranged according to their numerical size. The ordering code of the individuals with the smallest cost value is set as 1, and the ordering code of the individuals with the largest cost value is set as pop-size, so the fitness function is designed as follows:

$$f(x) = (x - 1)/(\text{Pop})\_\text{Size} - 1. \tag{4}$$

According to the algorithm flow of GA and the adjustment algorithm flow of GA, the simulation solution is carried out step by step. When the number of genetic operation iterations is 100, the simulation process terminates. The simulation results show that the minimum cost of computer network link is 45, and the maximum reliability of computer network is 0.875. The simulation curves of computer network link cost and computer network reliability are shown in Figure 3, respectively.

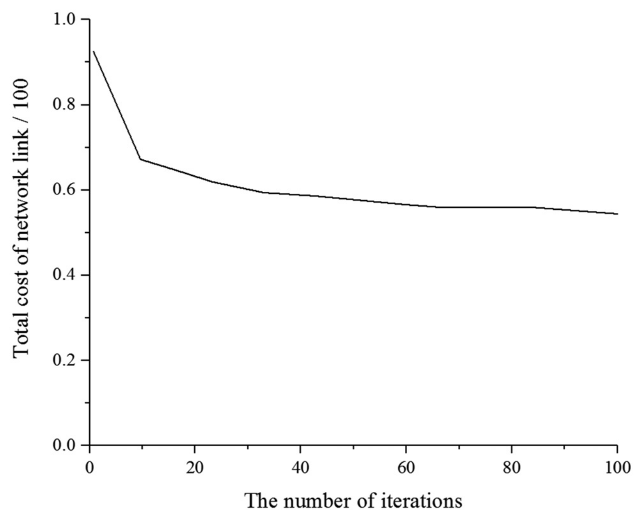

Figure 3: Computer network link cost simulation curve.

The reliability of nodes is considered. The reliability of service centers is 0.95, that of workstations is 0.9, that of links between service centers is 0.9, that of links between service centers and workstations is 0.85, and RMIN = 0.9. The GA proposed in this article is run in the Matlab environment, the GA parameters are: population size POPXZE = 100, maximum iteration times MAXGEN = 500, crossover rate P_c = 0.3, mutation rate P_m = 0.7, the number of iterations of the program is 32, each run randomly generates different populations. And then the best results of those 32 times are taken and compared. Its topological structure is shown in Figure 4. In the figure, the thick line represents the link of the backbone network, and the thin line represents the link between the center and the client, as follows.

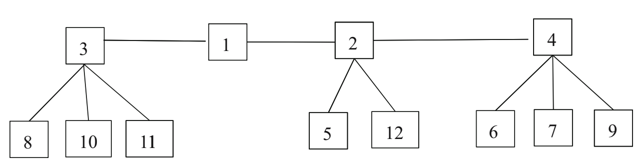

Figure 4: Network structure in $W_e = W_r = W_d = 1/3$ mode.

Many experiments show that under the same condition (there is no expected optimal solution in the initial population), the optimal solution appears in about 50 generations by using the traditional GA, and the algebras are relatively scattered. However, using the GA presented, the optimal solution appears in about 15 generations, and occurs most frequently in less than 50 generations. Moreover, the general algorithm is targeted and the proposed algorithm is universal.

4 Discussion

4.1 Basic principles of GA

The basic principle is that GA is a group iterative process. That is to say, the application of GA is randomly selected in the initial population, in accordance with the laws of the natural selection of the fittest, through generations of change and continuous competition, line selection, breeding, hybridization, and mutation, thus constantly getting better next generation group, and so the cycle of evolution finally get a good group most suited to the current environment. In using GA to obtain the optimal solution, not only the basic structure is relatively simple, but also does not have any restrictions and requirements on the nature of the objective function. In the search, genetic characteristics will be used to constantly find the search direction of the optimal solution, and the optimal solution can be obtained quickly and accurately from the whole function value [15,16].

(1) Component of GA: GA includes five parts: Gene expression, initial population determination, gene fitness calculation, genetic operation (crossover and variation), and evolutionary operation (selection).
(2) GA process: GA provides a general framework for solving complex system optimization problems, which does not depend on the domain and type of the problem. For a practical application problem requiring optimization calculation, the following steps can be generally used to construct a GA to solve the problem.
    (a) Determine the decision variables and various constraints, that is, determine the individual phenotype X and the solution space of the problem;
    (b) Establish an optimization model, that is, to determine the type of objective function (whether to seek the maximum value of the objective function or the minimum value of the objective function) and its mathematical description or quantitative method;
    (c) Determine the chromosome coding method representing the feasible solution, that is, determine the individual genotype X and the search space of GA;
    (d) Determine the decoding method, and determine the corresponding relationship or conversion method from individual genotype X to individual phenotype x;
    (e) Determine the quantitative evaluation method of individual fitness, that is, determine the target function value $f(x)$ to individual fitness $F(X)$.
    (f) Design genetic operators, that is, determine the specific operation methods of selection operation, crossover operation, mutation operation, and other genetic operators;
    (g) Determine the relevant operating parameters of GA, that is, determine the initial population popsize and evolution of GA.

The coding method of feasible solution and the design of genetic operator are two main problems which need to be considered in the construction of GA, and also two key steps in the design of specific GA. Different optimization problems need to use different coding methods and different genetic operators, which are closely related to the specific problem to be solved, so the understanding of the problem to be solved is the key to the success of GA application.

4.1.1 Coding

Topology design of computer communication network is concerned with the representation of the connection between two nodes, so this kind of problem and the encoding and decoding between chromosomes is very convenient that is to use the binary strategy. The specific approach is: first, each link to be selected is naturally sorted according to the node numbers of its two ends, and then each link to be selected is regarded as a gene in the chromosome in this order. When the gene value is 1, the corresponding link is selected to join the network. Otherwise, vice versa. Therefore, the length of chromosomes should be equal to the number of links to be selected, and each chromosome represents a topological design scheme.

4.1.2 Chromosomes meet the connectivity process

The primary condition for topological design of computer communication network is connectivity, so when we construct chromosomes, we carry out connectivity check for each chromosome obtained in the process of GA, and the process is as follows:

Return true if the obtained chromosome satisfies $\sum_{i=1}^{n} x_1(y_1, y_2, \cdots y_n) = 11 \cdots 1,\quad \delta(x) \geq m - 1$, otherwise return false.

4.1.3 Fitness function

The fitness function should reflect optimization objectives and constraints. Therefore, the fitness function is defined as:

$$F(X) = f(x) + \lambda\left(c_1 - \sum_{i=1}^{n} c_i x_i\right), \tag{5}$$

where λ is the penalty factor.

4.1.4 Select operation

The crossover operation of GA requires two individuals to be selected for combined operation. Individuals are selected according to the following probabilities:

$$p_i = F_i \bigg/ \left(\sum_{j=1}^{M} F_J\right) > 0. \tag{6}$$

4.1.5 Adaptive adjustment of control parameters

To prevent the premature convergence of GA and to speed up the search speed, the strategy of M. Strinvas was adopted, that is to dynamically adjust the crossover probability P according to the evolution of population and the probability of variation P_m. The specific determination process is as follows: $F_{\max}$ is set as the fitness value of the best individual in a generation population, F_w is the average fitness value of this generation population, denoted by $\delta = F_{\max} - F_{\text{avg}}$, so it can be believed that the smaller δ is, the smaller the difference between individuals in this generation population is, and the population tends to converge. The larger δ is, the greater the difference between individuals in this generation is, and the degree of convergence is small [7–17]. Therefore, in order to prevent premature population convergence, when δ is small, P_c and P_m should be increased. When δ is large, P_c and P_m should be reduced. It can be expressed as follows:

$$P_c = k_1/(F_{\max} - F_{\text{avg}}),\quad p = k_2/(F_{\max} - F_{\text{avg}}). \tag{7}$$

The above formula shows that in the process of evolution, P_c and P_m can be adjusted at any time according to the actual situation to make the GA have stronger search ability. However, the above equation also leads to a high probability of destruction of the optimal individual when evolution has converged to the global optimum. To overcome this phenomenon, it is necessary not only to prevent premature convergence but also to protect the superior individuals. Therefore, P_c and P_m are correspondingly different for different individuals in the same generation. Individuals with high fitness should be protected to reduce P_c and P_m. For individuals with low fitness, P_c and P_m were increased accordingly. The above two formulae can be modified as follows:

$$P_c = k_1/(F_{\max} - F_{\text{avg}}), \quad p = k_2/(F_{\max} - F_{\text{avg}})F_c \geq F_{\text{avg}}, \tag{8}$$

$$P_c = k_3 F_c < F_{\text{avg}}, \tag{9}$$

$$P_c = k_2/(F_{\max} - F_{\text{avg}})/(F_{\max} - F_{\text{avg}})F_m \geq F_{\text{avg}}, \tag{10}$$

$$P_c = k_4 F_m < F_{\text{avg}}, \tag{11}$$

where F_c is the maximum fitness of the two crossover individuals, F_m is the fitness of the mutant individuals, and k_1, k_2, k_3, and k_4 are constants.

4.2 Requirements for optimal design of computer communication network

(1) Reliability: Computer network in the specified conditions (operation mode, maintenance mode, load conditions, temperature, humidity, radiation, etc.) under the specified time (1,000 h, a quarter, etc.) to maintain connectivity and meet the communication requirements of the ability is called computer network reliability. The reliability of computer network is the probability that the network will complete the specified function within the specified time (1,000 h, a quarter, etc.) under the specified conditions (operation mode, maintenance mode, load condition, temperature, humidity, radiation, etc.). Computer network reliability has three types: (1) 2-terminal reliability, that is, in the probability graph, the probability that there is at least one normal link between the specified source point S and the terminal point T. (2) γ terminal reliability, that is, in the probability graph, the probability that there is a link in normal operation between any two pairs of nodes in the set composed of γ nodes is specified. (3) Full terminal reliability, that is, in the probability graph, the probability that there is a link in normal operation between any two nodes is specified [18,19].

4.3 Computer communication network optimization design based on GA

The main steps of computer communication network optimization design using GA are as follows:

(1) Establish a coding scheme: The encoded sequence becomes a chromosome, and the coding element called Gene randomly generates a group of initial chromosomes, which become the initial population;
(2) Fitness operation: Each chromosome in the population is decoded into a set of solutions, through which the fitness of each chromosome can be calculated;
(3) Selection operation: Determine the probability of inheritance of each chromosome to the next generation population based on the size of fitness, and randomly generate the next generation of chromosomes [9,20];
(4) Crossover operation: After pairing chromosomes in the population, part of the chromosomes is exchanged according to crossover probability;
(5) Mutation operation: Change the gene value of its chromosome at the mutation point according to the mutation probability. Steps (2)–(10) are repeated until a good individual meets the stop rule is produced [11,21]. After the combination of satisfaction optimization and GA, in the process of optimization with GA, the value of comprehensive satisfaction function is taken as the adaptive value, and the design of backbone network with the highest comprehensive satisfaction is the optimization result.

4.4 Analysis of optimization results

The proposed GA runs in the MATLAB environment, and the parameters of the GA are: population size Popxze = 100, MAXGEN = 500, crossover rate $p_c = 0.3$, mutation rate $p_m = 0.7$, the program has 32 iterations, each run randomly generates small identical populations, and then compares the best results obtained from these 32 times. If network cost, average delay, and reliability are equally important during optimization, the weights of the three performance indicators are $W_e = W_r = W_d = 1/3$, respectively, in the calculation of integrated media satisfaction, and the optimization results are shown in Table 2. In the process of initialization and variation, the solutions that meet the reliability constraints are removed, so the reliability can be considered little [22,23]. Then, the network cost and average delay are equally important, so the weights of the three performance indicators are respectively $W_c = W_d = 0.5$ and $W_r = 0$ when calculating the comprehensive satisfaction. The optimization results are shown in Table 2. It can be seen that better satisfaction can be obtained under the reliability conditions of these small equal weights. It can be said that after adopting GA, satisfactory solution can be found in the shortest time, and the NP-hard problem with high reliability and low cost can be successfully solved, and the topology optimization problem of computer communication network can be realized and solved quickly [24–26].

Table 2: Performance indexes and GA optimization results under different weights

A weight	Network fee	Reliability	Cost satisfaction	Reliability satisfaction	Overall satisfaction
$W_e = W_r = W_d = 1/3$	601	1	0.895	1	0.985
$W_c = W_d = 0.5$ $W_r = 0$	609	0.9353	0.975	0.963	0.956

5 Conclusion

The general mathematical model of topology optimization design of computer communication network is established first, and then the GA and corresponding strategy are designed to solve this kind of problem. Example results show that the algorithm presented can effectively solve such problems, and can be used to solve general 0–1 programming problems, so it has a strong promotion value.

Acknowledgment: Science and technology research and Development Plan of Langfang in 2021, Research on collaborative innovation development path of Beijing-Tianjin-Hebei Artificial intelligence industry. Project No.: 2021029060.

Conflict of interest: The authors declare that they have no competing interests.

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