# Multi-objective Optimal Method for Computer Communication Network Based on Reliability Theory Combined with Genetic Algorithm

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***ABSTRACT:*** *Optimization of computer communication network based on reliability theory is problem with multiple constrained conditions. Based on the analysis of reliability theory of computer communication theory, this research discussed the multi-objective optimal model in computer communication network combining with principle of multi-objective optimal design and completed a set of analysis on network communication system at the request of the given reliability goal of optimal design. Finally, it is found that, algorithm of computer communication network optimal design based on reliability theory is effective.*

**Keywords:** Reliability, computer communication network, multi-objective optimization

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## 1. Introduction

As computer communication technology rapidly develops, researches on system reliability draws more and more attention. System reliability optimization is also called network comprehensive analysis. Traditional research method includes dynamic programming, Lagrange multiplier method, gradient method, heuristic method, geometric programming, integer programming, etc.. Recently, researches on network comprehensive analysis has obtained significant development with the development of neural network and evolutionary computation technology. Optimal design of communication network mainly concerns factors such as network cost, average time delay and reliability; reliability and network cost are the main factors in such a age that communication network develops rapidly. Core of network optimal design is how to make network reliability as high as possible with network cost as low as possible; however, it is a NP-hard problem [1,2].

To date, multi-objective network optimization based on reliability restraint is seldom studied at home, and generally network minimum cost is taken as constraint condition for network topological structure design. Domestic scholars further studied network design. Liu Xiaoe et al. studied network topological structure design based on network reliability and gave out mathematical model [3]. Some others studied solving network topological structure design by genetic algorithm based on multi-objective decision. Based on the analysis of computer network reliability theory, this paper proposed to carry out multi-objective optimal design of computer network reliability using genetic algorithm, in order to provide some technical support and theoretical guidance for relevant research through analysis of theory and specific example.

## 2. Computer Communication Network Reliability Theory

Relevant concepts of computer network reliability as a system engineering science has developed into a complete system over more than half a century. Scholars at home and abroad classify measure of computer network reliability into four kinds, i.e., connectivity pf computer network, survivability of computer network, damage resistance of computer network and effectiveness of computer network component under multi-mode [3]. If computer network is normal, then basic node and component from network must provide reliable link for every user terminal. Therefore, connectivity of computer network, the most common in reliability studies in related fields, is generally measured by reliability of computer network.

(1) Reliability of computer network. The ability of computer network keeping connectivity and meeting communication capacity under specified conditions such as operation mode, maintenance mode, loading condition, temperature, humidity and radiation and specified time such as 1,000 h and one quarter is called computer network reliability. It reflects the support of computer network topological structure to normal operation of computer network, thus is one of the important parameters of programming, design and operation of computer network.

(2) Computer network reliability degree. The probability that computer network fulfilling specified functions under specified conditions such as operation mode, maintenance mode, loading condition, temperature, humidity and radiation and specified time such as 1,000 h and one quarter is called computer network reliability degree recording as R(t) ($R(t)= P\{T>t\}$). Computer network degree can be divided into three types:

1) 2 terminal reliability degree, i.e., probability of having at least one normally operated link between source point s and meeting point t, recording as Rel2(G).

2) $\lambda$ terminal reliability degree, i.e., probability of having normally operated link between any two pairs nodes within set composed of $\lambda$ nodes in probability graph, recording as Rel $\lambda$ (G).

3) All terminal reliability degree, i.e., probability of having normally operated link between any two nodes in probability graph, recording as RelA(G).

It can be known from the above definition that, when $\lambda = 2$ or $\lambda = n$, then the terminal reliability degree is 2 terminal reliability degree or all terminal reliability. Therefore, 2 terminal reliability degree and all terminal reliability degree can be considered as the special case of $\lambda$ terminal reliability degree. Generally, Rel (G) is used to express the generic terms of three kinds of computer network reliability degree.

## 3. Multi-Objective Theory

Multi-objective optimization problems, also called multi-objective optimization problems or vector optimization problems, refers to minimize or maximize multiple different objective function under a set of constraint conditions. The significance of multi-objective optimization is to find one or multiple solutions of a problem, thus to make the designer accept all target value [3,4]. Therefore, single objective optimization problems is considered as one special case in multi-objective optimization problem. The problems encountered by the departments such as engineering technology, production management and national defense construction are all multi-objective problems. For instance, while designing backbone network of computer network communication network, how to make the cost and time delay as small as possible and reliability and survivability as large as possible is generally considered. We can say, multi-objective problem widely exists in practical life and even can be seen everywhere.

General mathematical form of multi-objective problem is [4]:

$$\begin{cases} V-\min\{F(x)\} = \min\{f_1(x),\ f_1(x),\cdots,\ f_m(x)\}^T \\ s.t. \begin{matrix} g_i(x) \le 0(i=0,1,2,\cdots,m) \\ h_i(x) \ge R(i=0,1,2,\cdots,m) \end{matrix} \end{cases} \tag{1}$$

Where V-min {F(x)} is the abbreviation of multi-objective maximum (vector form) model.

F(x)= min {f1(x), f1(1), ... fm(x)}, m>1 is the vector target function of the problem. gi(x) and hi (x) stand for the constraint condition of the problem.

Compared to single objective optimization problem, multi-objective optimization problem is featured by: (1) multiple objects should be as good as possible under given conditions; (2) the objectives all exist independently, with coupling or conflict between each other; improvement of some objectives often induces deterioration of other criterion. Therefore, the conflict between the optimal solutions of all objectives is hard to be concerned at the same time and also can not be the best at the same time;(3) all objectives generally have no common measuring standard, thus hard to be compared or fuzziness exists between target function and constraint condition.

As multi-objective optimization problem exists the above characteristics, the solution that meets the requirements of designers should have certain satisfaction in a sense. Solution for traditional multi-objective optimization problem is based on the optimization of single objective problem, and most solutions are always stick to search for the optimal solution of problem. It is contradictory with the characteristics of multi-objective optimization problem essentially. Besides, optimal solution with such significance is hard to be found or even does not exist. Therefore, people propose concept of efficient solution and weak efficient solution and meanwhile propose to solve multi-objective optimization problem by evaluating function. Its basic idea is, to construct evaluation function by evaluating multiple-objective of problem according to some optimization strategy or decision making intention, thus to transform the solution of multi-objective optimization problem into the solution of single objective optimization problem and take the obtained solution that meets the condition of efficient solution or weak efficient solution as the solution of multi-objective optimization. In such sense, the solution can considered as the satisfaction of multi-objective optimization problem.

To date, many scholars have studied a wealth of solutions for multi-objective optimization. These solutions can be divided into two kinds [5]. One kind is method transforming more to less. It is a multi-objective solution based on single objective; the other is parallel solution for multiple objectives, which is mainly based on computer intelligence currently.

## 4. Multi-Objective Optimization Algorithm of Computer Communications Network Based on Genetic Alogorithm

Genetic algorithm, a novel optimization method proposed recently, is an adaptive and global optimizing probability search method formed by simulating inheritance and evolution of creature in natural environment; it is featured by good global property, easy operation, parallel search and group optimization orientation [5]. Genetic algorithm is mainly applied in NP-hard problems in reliability design, since it is able to deal with complex problems that traditional optimization method can not solve though carrying out parallel global and adaptive automatic search by objective function under the guidance of probability criteria, without restrained by property of optimization problem, form of optimization criterion, form of model structure, amount of parameters to be optimized and constraint condition.

Main procedures of genetic algorithm is as follows:

1) confirm a kind of coding scheme; sequence after coding becomes chromosome; elements that make up coding is called gene; a group of initial chromosome randomly generated becomes initial population;

2) Fitness operation: decode all chromosomes in the population, and the results obtained are considered as a group of solution; then figure out the fitness of all chromosomes by operation;

3) Select operation: probability of every chromosome entailing to the next generation of population is confirmed by fitness; and chromosomes of the next generation is randomly generated;

4) Crossover operation: pair the chromosomes in the population and then exchange some chromosomes according to crossover probability;

5) Mutation operation: change the genic value of the chromosome at change point according to mutation probability.

Procedures from 2) to 5) should be repeated until excellent individual meeting stopping rule is obtained. After combining satisfactory optimization and genetic algorithm, the backbone network with the highest comprehensive satisfaction that meets the requirements of user is the optimization result when comprehensive satisfaction functional value is taken as the adaptive value during the process of optimization of genetic algorithm [6,8].

**5. Analysis of Optimization Results**

The example proposed is the communication network of four service centers (n=4) and eight work stations (m=8). Every center connects three stations at most (gi=3). It can be known from the practical network, cost of link between service center i and j is the highest, therefore, $w_{1ij}$ is randomly generated in [100, 300]; the cost of link between service center i and work station j is relatively low, therefore, $w_{2ij}$ is generated in [1, 100] . Total communication flow of service center i (ci) is 50. Value of $w_{1ij}$ and $w_{2ij}$ is as follows:

$$w_i = \begin{bmatrix} 0 & 250 & 240 & 120 \\ 250 & 0 & 245 & 258 \\ 240 & 245 & 0 & 118 \\ 120 & 258 & 118 & 0 \end{bmatrix}$$

$$w_2 = \begin{bmatrix} 38 & 8 & 42 & 92 & 15 & 71 & 91 & 66 \\ 68 & 75 & 12 & 96 & 15 & 43 & 13 & 1 \\ 45 & 11 & 10 & 8 & 59 & 8 & 13 & 56 \\ 64 & 24 & 39 & 16 & 45 & 76 & 13 & 39 \end{bmatrix}$$

Reliability of node is concerned in this study. Reliability of service center is 0.95, work station 0.9, link between service center 0.9, link between service center and work station 0.85 (RMIN=0.9).

Genetic algorithm proposed is operated under matlab environment. Parameter of generic algorithm is: size of population POPXZE=100, maximum iterative time MAXGEN=500, crossover rate pc=0.3 and mutation rate pm=0.7, program iteration times is 32. Different populations are generated randomly in every operation. Then the best result obtained from the 32 times of iteration.

Parameters set by generic algorithm in literature [4] is used to obtain the value of cost, average time delay and reliability, in order to design the parameter of satisfaction unction of all performances. While calculating satisfaction of network cost, $a_1$ takes 700, $a_2$ takes 900 and $a_3$ takes 1200. While calculating satisfaction of average time delay, $b_1$ takes 0.5, $b_2$ takes 0.9 and $b_3$ takes 1.5. While calculating satisfaction of reliability, $c_1$ takes RMIN, $c_2$ takes 0.946, $c_3$ takes 1; moreover, a=0.7, b=0.8 and c=0.7.

During optimization, network cost Wc , average time delay Wd and reliability Wr are attached the same importance, values of the three performance indexes are Wc=Wr=Wd =1/3 during calculation of comprehensive satisfaction. Optimization results is shown in table 1.

| **Weight** | **Network cost** | **Reliability** | **Satisfaction for cost** | **Satisfaction for reliability** | **Comprehensive reliability** |
|---|---|---|---|---|---|
| Wc=Wr=Wd =1/3 | 601 | 1 | 0.995 | 1 | 0.984 |
| Wc=Wd= 0.5, Wr=0 | 609 | 0.9354 | 0.974 | 0.962 | 0.995 |
| Wc=0.8 Wd=0.2 Wr=0 | 541 | 0.9137 | 1 | 0.935 | 0.996 |

Table 1. Optimization Result of Performance Indexes and Generic Algorithm under Different Weight

The results shows that center node is 1 and 2. There are three lines while transforming into tree structure, i.e., (3,1), (1,2) and (2,4). Work station is 2,4,4,3,4,3,3,2. Topological structure is shown in figure 1. The thick line in the figure stands for the link of backbone network while the thin line stands for the link between center and client; it is the same in figure 2.

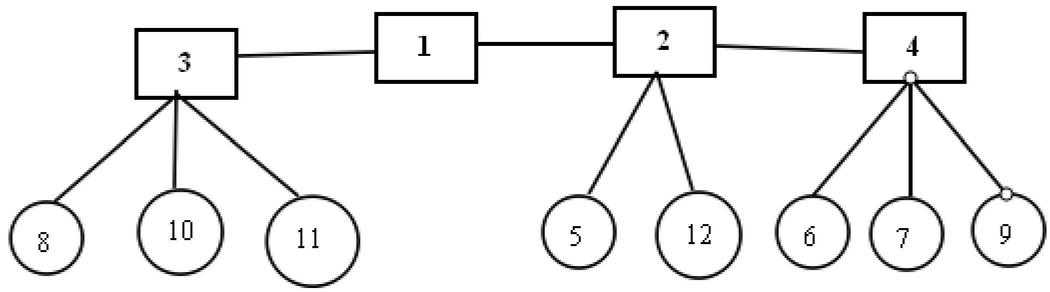


Figure 1. Network structure when $W_c=W_r=W_d=1/3$

In the process of initialization and mutation, reliability can be ignored and solution that does not meet the constraint of reliability is removed. Then network cost and average time delay are attached the same importance. While calculating comprehensive satisfaction, weights of three performance indexes are Wc=Wd=0.5 and Wr=0. The optimization result is shown in table 1. The result shows that, center node is 1 and 2. There are three lines while transforming to tree structure, i.e., (3,1), (1,2), (2,4). Work station is 3,1,3,3,4,4,4,2. Topological structure is shown in figure 2.

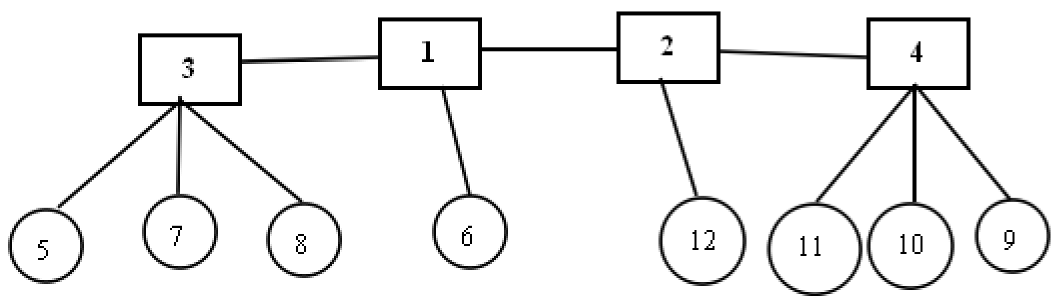


Figure 2. Network structure when $W_c=W_d=0.5$ and $W_r=0$

If network cost is slightly important than average time delay, then Wc=0.8 ,Wd=0.2, Wr=0. Optimization result is shown in table 1. The results show that center node is 1 and 2. There are three lines while transforming to tree structure, i.e,. (3,1), (1,2) and (2,4). Work station is 3,1,3,3,1,2,2,2,2. Network structure is shown in figure 3.

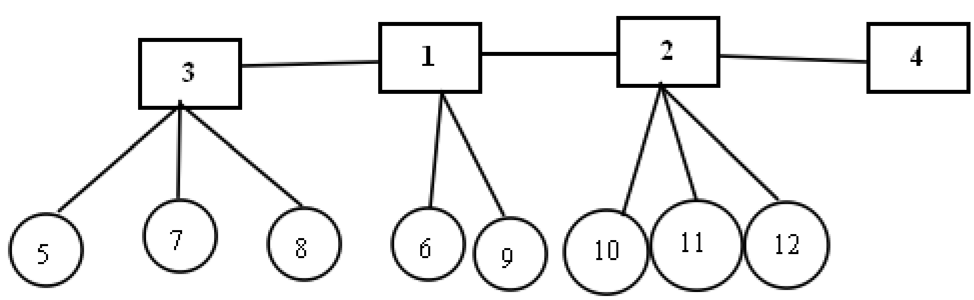


Figure 3. Network structure when $W_c=0.8$ ,$W_d=0.2$, $W_r=0$

It can be known from the analysis process above that, under the condition of reliability degree with different weight, relatively good satisfaction can be acquired. We can say, multi-objective optimization combined with genetic algorithm can figure out satisfactory solution within the shortest time, successfully solve NP-hard problems with high reliability and low cost, and rapidly realize and solve the topological optimization problem of computer communication network.

## 6. Conclusion

1) This study discusses and analyzes the theory of computer communication network reliability. Reliability reflecting the support of computer network topological structure giving to the normal operation of computer network is a important parameter for programming, design and operation of computer network.

2) This study also analyzes the principle and method of multi-objective optimization design and the detailed implementation process of generic algorithm and comprehensively proposes the function expression of satisfaction for cost and reliability of multi-objective optimization.

3) Multi-objective optimization combined with generic algorithm can figure out the satisfactory solution with the shortest time, thus successfully solve NP-hard problem with high reliability and low cost. Therefore, satisfaction optimization can effectively solve network topological optimization. Satisfaction function of performance index can be adjusted according to different application situation and design intention, with a great flexibility.

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