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Computer simulation-based network topology genetic algorithm reliability study

Xunzhong Quan[1,2] and Huafeng Li[1]

[1]State Key Laboratory of Mechanics and Control of Mechanical Structures, Nanjing University of Aeronautics and Astronautics, Nanjing, Jiangsu, China
[2]Huainan Normal University, Huainan, Anhui, China

ABSTRACT

With social development, people rely on computer network more and more, and also have higher requirements on network communication reliability, and computer network communication reliability optimization is a topological structure optimization process, it involves network expenses, average delay and reliability, is a multi-objective optimization process. The paper analyzes computer network communication reliability multi-objective optimization model, proposes algorithm of applying genetic algorithm to do objective optimization solution ,adopts binary system one-dimensional codes, linear queuing obtained fitness function and genetic operation method to design genetic algorithm solution process, finally uses two examples simulation results to verify algorithm reliability and effectiveness.

Key words: Topological structure, network communication; multi-objective optimization, genetic algorithm, reliability

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INTRODUCTION

Wei Shuang-Jing(2014) pointed out that by far studies on computer communication network reliability was main studying contents of modern information technology, and to implement computer communication network reliability, it should carry on optimization design on it [1]. And computer communication network reliability optimization objectives are more, therefore the optimization process is a kind of multi-objective optimization process, and solution path of a multi-objective optimization is converting multi-objective optimization into single objective problem, Wang Ya-Li(2014)pointed out that adopted genetic algorithm to make solution on converting multi-objective optimization into single objective by weighted coefficient method could get relative satisfied optimization result in shorter time [2]. Tian Yin and others (2014) utilized a kind of genetic algorithm and Floyd algorithm-based mixed solution process to solve train communication network comprehensive programming model , and got satisfied result [3-5].

However, computer network communication reliability optimization object is a topological structure, therefore, the paper based on previous research, proposes algorithm of applying genetic algorithm to solve topological multi-objective optimization model, in the hope of providing theoretical references for computer network communication reliability promotion.

COMPUTER COMMUNICATION NETWORK RELIABILITY

Liu Xiao-E(2002)pointed out that computer network reliability relative concept as a system engineering science, through above half a century development, it has formed relative complete and sound system, domestic and foreign relative scholars has summarized computer network reliability into four main types [4],respectively as following :

1) Computer network connectivity.

2) Computer network survivability.
3) Computer network damage resistance.
4) Computer network components working effectiveness under multi-mode.

Jin Qin-Feng and others (2009)pointed out that if computer network operated normally, basic nodes and components in network should provide reliable links for each user terminal, therefore computer network connectivity is most widely in reliability correlation fields researching, calculate computer network connectivity generally uses computer network reliability to measure [5-10].

So-called computer reliability refers to computer network can ensure to always remain normal operation stats in regulated time, keep network communication connectivity and fulfill basic network communication demand on certain operation required conditions, temperature and humidity conditions, maintenance manner conditions , radiation conditions as well as loading conditions.

In computer network programming designing and operating designing, its reliability is key judgment parameter to reflect computer network topological structure is good or not , which has important significances in ensuring computer network normal steady running .Just because the importance of the parameter, it needs a measurement way, the paper thinks that computer network reliability degree is probability of reliability fulfillment.

$$R(t) = P\{T > t\} \tag{1}$$

In formula(1) $R(t)$ represents computer network reliability degree, in addition, computer network reliability degree has following three types :

1) Two terminals reliability degrees:It refers to that in probability graph; assigned source point s and meeting point t have one normal running link probability at least that is recorded as $\mathrm{Re}\,l_2(G)$[5].
2) λ Terminal reliability degree: it refers to in probability graph, assigned λ pieces of nodes constructed set's any two pairs of nodes have normal running links' probability that is recorded as $\mathrm{Re}\,l_\lambda(G)$[5].
3) Entire terminal reliability degree:It refers to in probability graph, between assigned any two nodes, both have normal running links probability at least that is recorded as $\mathrm{Re}\,l_A(G)$[5].
4) By above computer network reliability degree three types definitions, it is clear when $\lambda = 2$ or $\lambda = n$,λ terminal reliability degree is two terminals reliability degree or entire terminal reliability degree, so two terminals reliability degree and entire terminal reliability degree can be regarded as λ terminal reliability degree particular case, in general, use $\mathrm{Re}\,l(G)$ to express above three kinds of computer network reliability degree generic terms [5].

Liu Qiang and others(2001)pointed out with communication network technology rapidly development, system reliability researches attracted more and more people attentions, communication network reliability two most core problems, one was how to calculate probability of network keeping connectivity that was reliability calculation problem, the second one was system reliability optimization problem, network programming problem contained network topological structure designing, broadband configuration and so on, and restricted by actual factors, so it could be summarized as optimization problem, with communication technological development, large capacity optical fiber transmission system and intelligentized high-speed digital switching technology had been widely used, let more and more operation to be concentrated on fewer nodes and circuits, equipment disabled case in high-speed network would cause network interruption or handling capacity declining, even data lost, therefore network reliability optimization designing was particularly important [6].

THEORETICAL BASIS

Multi-objective optimization theoretical basis

Multi-objective optimization problem's mathematical model generally is as formula (2) shows.

$$\begin{cases} \mathrm{V-min} \quad f(x) = [f_1(x), f_1(x), \vdots, f_1(x)] \\ s.t \qquad x \in X \\ \qquad\quad X \in R^m \end{cases} \tag{2}$$

In formula(2), $\mathrm{V-min}$ represents vector minimization, Chen Ting (1997)pointed out that multi-objective optimization problem optimal solution and single objective optimized optimal solution had essentially differences, so to correctly solve multi-objective optimization problem, it should define its optimal solution concept [7].

Definition: If $x' \in X$ and it doesn't have another feasible point $x \in X$ that lets $f_i(x) \geq f_i(x'); i = 1,2,\cdots,p$ to be true, and from which one serious inequation is true at least, then call x' to be multi-objective optimized one Pareto optimal solution.

As definition shows , all Pareto optimal solutions composed set is called Pareto optimal solution set, multi-objective problem solution's primary link is looking for a Pareto optimal solution set in decision space, in the solution set, to every Pareto optimal solution, a objective-oriented improvement is at the cost of reducing another objective functions, so let multiple objectives to simultaneously arrive at optimal value is impossible, and it can only make coordination and tradeoff among them, let each objective function to try to arrive at approximately optimal as much as possible. Hu Yu-Da (1990)pointed out except for some special multi-objective programming , most of multi-objective scale cannot be solved directly, generally adopted method is converting multi-objective optimization problem into single objective optimization problem that its optimization methods are relative mature, from which more used methods are weighted method and constraint method, there are lots of methods can be uses in the aspect, such as voting analytic hierarchy process 、average weighting method、ideal point method、virtual target method and other mathematical programming methods [8].

Multi-objective optimization is a kind of optimization problem, it has widely practical application, due to each object is generally mutual competitive that cannot let every objective simultaneous to arrive at optimal, multi-objective optimization solution by far is still a difficulty, especially for large scale problem, generally it cannot solve optimal solution, and only can solve Pareto optimal solution, however solving Pareto optimal solution generally is not an easy task.

Mathematical programming method handling with multi-objective problems guiding thought , firstly is providing respective objective weight, importance degree or objective expectation information and other preference information in problems according to decision-maker understanding on problems, making table quantitative handling with multi-objective, and then apply mathematical programming method to make single objective optimization on it ,obtain unique Pareto optimal solution, analyst system altering prior value, solve a series of single objective optimization problems, and compose approximate Pareto optimal solution set. Jia Xiao-Ping (2003) pointed out above thoughts shortcomings in three aspects[9],as following:

1) Due to set preference information value in advance, reduce searching space, it cannot avoid missing better Pareto optimal solution [9].
2) With objective function increasing , prior value is difficult to distribute , running times will also rapid increase[9].
3) Systematic change prior value cannot ensure Pareto optimal solution balanced distribution in the leading edge [9].

Multi-objective optimization model genetic algorithm solution theoretical basis

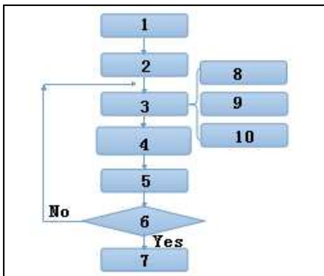
Sui Xun-Xue(2006)pointed out multi-objective problem essence lied in that in most cases, each sub objective was mutual conflicting that simultaneous let objective to arrive at optimal was impossible, so solved multi-objective problem final way was making coordination and tradeoff as well as compromise among each sub objective [10].And weighting coefficient method is just the reflection of the thought, the method compromises objectives according to relative importance degree, and adopts linear combinative forms to convert multi-objective optimization problem into single objective problem, as formula (3)shows:

$$\min f(x)=\sum_{k=1}^{n}\omega_k f_k(x) \tag{3}$$

In formula(3) $f_k(x)$ represents each sub objective function, before weighting, it needs to make regularization processing ,the purpose is to eliminate each objective function differences in unit and order of magnitudes. ω_k represents importance weighting coefficient, generally take $\sum \omega_k = 1$,and $\omega_k > 0$. n represents sub objective functions amount.

San Bing-Bing and others(2008)pointed out they discover in practice that irrational regularization method would unintentionally add or weaken some objectives, cause importance weighting coefficient could not correctly reflect objective importance degree, optimization objective would deflect from expectation, better regularization was utilizing formula to convert each sub objective function into dimensionless quantity in the range of 0~1 [11].

Genetic algorithm is a kind of new type optimization method that proposed in years, is a kind of adaptive global optimization probability searching algorithm formed through simulating biology genetic and evolve process in natural environment, has good overall importance, easily operating, parallel searching and group optimizing features. Due to genetic algorithm is not limited by optimization problem own attributes, optimization criterion forms, model structural forms, optimized parameters amount and with or without constraint conditions so on , it only adopts objective function to make parallel global adaptive automatic searching under probability criterion guiding then can handle with complex problems that traditional methods are hard to solve, has very high robust attributes and widely applicability, therefore genetic algorithm is mainly applied to some NP-hard problems such as reliability designing aspects. Genetic algorithm process is as Figure 1 shows.



Start optimizing
Initial population
Evaluate individual
Genetic operation(selection、crossover、mutation)
Produce offspring
Meet ending conditions
Output optimal solution
Get objective function
Regularize objective function
Weighting method calculates fitness

Figure 1: Genetic algorithm flow chart

GENETIC ALGORITHM-BASED MULTI-OBJECTIVE OPTIMIZATION MODEL ESTABLISHMENT AND ALGORITHM DESIGNING

Genetic –algorithm-based multi-objective optimization model establishment

Firstly it needs to make three hypothesis as following:

1) Computer communication network nodes are absolute reliable.
2) Computer communication network can be described as an undirected graph G in mathematical significance.

In undirected graph G, there is no self-loop link, and any two points only have a direct route at most.
As formula(4)shows a typical reliability network optimization problem.

$$\begin{cases} \min C_z = \sum_{i=1}^{N}\sum_{j=1}^{i} s_{ij}c_{ij} & s_{ij}=0,1 \\ dia_{ij} \le \alpha & i,j=1,\cdots,N \\ \sum_{\substack{j=1 \\ j\ne i}}^{N} s_{ij} \ge \beta & \end{cases} \tag{4}$$

In formula(4) C_z represents computer network construction total cost, N represents network total nodes number, s_{ij} represents 0-1 variables, when $s_{ij}=1$,it represents there are direct routes in node i and node j , c_{ij} represent circuit s_{ij} cost, dia_{ij} represents the minimum hop count(hop) that node i to node j should go through , α represents corresponding constraint constant, β represents reliability constraint constant. The paper applies genetic algorithm to make multi-objective optimization solution on typical reliability network. Among them, genetic algorithm included elements are codes, initial population set, fitness function designing, control parameter setting, genetic operation designing, these elements constitute genetic algorithm core contents.

1) Coding purpose: convert optimization problem solution space into genetic algorithm easier operating coding space, general coding way simulates biological chromosome structure to make serial coding.
2) Fitness function: is a kind of evaluation function, used to evaluate individual survivability in the whole group.
3) Initial population: the population generation generally is at random, but to let genetic algorithm searching to be more effective, it can also select initial population according to experiences.

Genetic operation: Generally designed genetic operation has selection, crossover, and mutation and so on, in order to let genetic algorithm to be more effective, it should do parameter selection carefully, reference should be defined including population scale, genetic algebra, crossover probability, mutation probability and so on.

Standard genetic algorithm steps are as following:

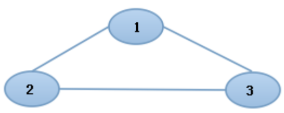
STEP1. Let evolution algebra $g=0$, and provide initial population $P(g)$.
STEP2. Estimate value on $P(g)$ every individual.
STEP3. Select two individuals from $P(g)$, and fulfill crossover and mutation operating on two individuals , and get net generation population $P(g+1)$,let $g=g+1$.
STEP4. If meet ending condition, then algorithm is over, otherwise transfer to STEP2.

Genetic algorithm designing

The paper adopts binary one-dimensional coding way, network coding on N code is as following:

$N1$	$N2$	$N3$	$\cdots$	Nn
$S_{1,1}\cdots S_{1,n}$	$S_{2,1}\cdots S_{2,n}$	$S_{3,1}\cdots S_{3,n}$	$\cdots$	$S_{n,1}\cdots S_{n,n}$

Among them, $S_{i,j}=1$ represents node i and node j have direct route, $S_{i,j}=0$ represents node i and node j don't have direct route, as Figure 2 shows 3 nodes network chart and corresponding codes.



N1	N2	N3
011	101	110

Figure 2: Three nodes network chart and corresponding codes

Adopt linear queuing method that is to calculate population's every individual expense function value, and rank according order from big to small, largest expense individual position code is 1,smallest expense individual position code is k ,then fitness function expression is as formula (5) shows:

$$f(r)=\frac{r-1}{k-1} \tag{5}$$

In formula(3) r represents individual position in expense sequence, k represents population size, When population size is fixed , k is constant, and meets $1\le r\le k$, $f(r)$ represents individual X fitness, its value is between 0and1 , smallest expense individual's fitness function value is 1, largest expense individual's fitness function value is 0.

If set population size to be k , from which individual X fitness value is $f(r)$, then selected probability p_{Xr} is as formula(6)shows:

$$p_{Xr} = \frac{f(r)}{\sum_{r=1}^{k} f(r)} \qquad (6)$$

Random node crossover method refers to generate random number between [1,N] ,formulate chromosomal chiasma position, crossovers just one node position per one time, such method advantage is it can let parent excellent gene segment to be reserved and entail to next generation, remain original connectivity to maximum level.

Mutation operator is making variation on chromosome some position gene values, to binary-based codes, mutation operation is taking negation of these positions gene values, its basic steps are as following:

STEP1. Randomly define gene position in the range of chromosome coding range.

STEP2. Use set mutation probability P_m in advance to make mutation on these gene positions' gene values, according to experiences, P_m generally takes value between 0.001and0.01.

Due to chromosome pair's crossover and variation, it may generate chromosome that cannot correctly express network connection structure, so it needs to make adjustment, algorithm process description is as following:

```
for   chromosome nodes coding after its individual crossover, variation ;
   for j=1,N
      if position Si,j=1   then
   else
      if Si,j=1   then Si,j=0
   end for
end for
```

By above adjusting operators, it can provide guarantee for network structural coding accuracy. Yan Ping-Fan(2000) pointed out in lots of application, if it finds population individual has already tended to steady state, then ends algorithm, by several times iteration, algorithm always restrains in certain times, can approximately think it arrives at minimum value that means finding out optimal solution or satisfied solution [12]. Miller G, Todd P.(1998)pointed out due to algorithm adopted 0-1coding way, so it was very convenient for constraint conditions checking, adopted adjacent matrix step method to judge chromosome coding met constraint conditions or not, to constraint conditions, only needed to check node coding included number of "1" [13].

SIMULATION ANALYSIS

The paper researched first simulation calculation example's network topological structure is as Figure 3 shows.

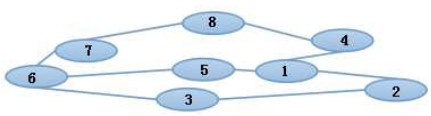


Figure 3: Communication network topological structure schematic diagram

In Figure, nodes number is 8, minimum hop constraint constant $\alpha = 3$, and single connectivity constraint constant $\beta = 2$, applied genetic operating iteration times are 300times,each route cost is as Table 1 shows.

Table 1: Each route cost table

Node	Node1	Node2	Node3	Node4	Node5	Node6	Node7	Node8
Node1	0							
Node2	26	0						
Node3	45	42	0					
Node4	34	51	60	0				
Node5	27	36	32	38	0			
Node6	36	48	40	35	22	0		
Node7	43	55	43	39	28	16	0	
Node8	51	68	73	27	50	41	43	0

Apply Table 1 each route cost status, carry on genetic algorithm-based computer network communication reliability optimization result, get project minimum cost is 277,iteration times-cost-based simulation curve is as Figure 4 shows.

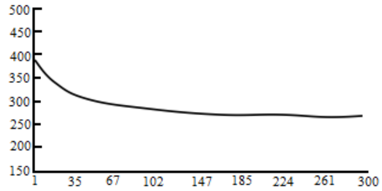


Figure 4: Iteration times-cost –based simulation curve

The second simulation algorithm example is a communication network that includes four service centers and eight work stations, from which every service center connects to three work stations at most, according to practical network expense status, the paper set service center route expense $w_{1ij} \in [100,300]$, set service center and work station route cost $w_{2ij} \in [1,100]$,service center i total communication flows $c_i = 50$, w_1 value status and w_2 value status are as Table 2 shows.

Table 2: Among service centers as well as service center and work station route expense table

No.	Among service centers				No.	Service center and work station							
	1	2	3	4		1	2	3	4	5	6	7	8
1	0				1	38	8	42	92	15	71	91	66
2	250	0			2	68	75	12	96	15	43	13	1
3	140	145	0		3	45	11	10	8	59	8	13	56
4	120	258	118	0	4	64	24	39	16	45	76	13	39

Service center reliability is 0.95, work station reliability is 0.9, reliability of routes among service centers is 0.9, reliability of routes between service center and work station is 0.85, minimum reliable rate is 0.9,run genetic algorithm parameters under Matlab environment, take population size as 100, minimum iteration times are 500times, crossover rate is 0.3, mutation probability is 0.7, program iteration times are 32times, when calculate network expense satisfaction, take a1=700,a2=900,a3=1200, when calculate average delay satisfaction, take b1=0.5,b2=0.9,b3=1.5, when calculate reliability satisfaction, take c1=0.9,c2=0.946,c3=1, in addition take a=0.7,b=0.8,c=0.7. If set network expense to be Wc, average delay to be Wr, reliability to be Wd, then optimization result is as Table 3 shows, in the table ,it takes Wc=Wr=Wd=1/3;Wc=Wr=0.5,Wd=0;Respectively carry on network expense, reliability, expense satisfaction, reliability satisfaction and comprehensive satisfaction on above three kinds of values.

Table 3: Each function indicator and genetic algorithm optimization result under different weights

Weight	Network expense	Reliability	Expense satisfaction	Reliability satisfaction	Comprehensive satisfaction	Tree structure
Wc=0.5 Wr=0.5 Wd=0	609	0.9354	0.974	0.962	0.995	1,2 (3,1),(1,2),(2,4) 3,1,3,3,4,4,4,2
Wc=0.8 Wr=0.2 Wd=0	541	0.9137	1	0.935	0.993	1.2 (3,1),(1,2,),(2,4) 3,1,3,3,1,2,2,2,2
Wc=1/3 Wr=1/3 Wd=1/3	601	1	0.995	1	0.984	1,2 (3,1),(1,2,),(2,4) 2,4,4,3,4,3,3,2

CONCLUSION

On the basis of summarizing computer network reliability theory , the paper knows that its reliability measurement way is probability value and computer network reliability fulfilled probability, and network reliability degree optimization process is optimization designing of its topological structure, the paper provides multi-objective optimization-based network communication reliability degree model, and designs genetic algorithm-based multi-objective optimization problem solution algorithm. Apply simulation examples to verify algorithm reliability and convenience, it gets conclusions as following:

Genetic algorithm can get satisfied multi-objective optimization result in shortest time. Genetic algorithm can successfully solve NP-hard problems of high reliability and low cost, rapidly implement and solve computer communication network topological optimization problem. By simulation result satisfaction degree, it verifies the paper's genetic algorithm designing effectiveness.

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