An Anycast Routing Algorithm Based on Genetic Algorithm

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Abstract: - Anycast refers to the transmission of data from a source node to (any) one member in the group of designed recipients in a network, which has been defined a standard communication model of IP version 6. In order to implement multi-destination and multi-path anycast routing on the heavy load network, this paper proposes a new anycast routing algorithm based on genetic algorithm and presents a heuristic genetic algorithmic to solve shortest path routing optimization problem. The network simulation experimental results show that this algorithm can capable of finding optimization anycast routing path and getting more resolution at less time and more balanced network load, enhancing the search ratio.

Key-Words: - Anycast Routing; Anycast Routing Algorithm; Genetic Algorithm; Service Model

1 Introduction

Anycast is a network addressing and routing scheme whereby data is routed to the "nearest" or "best" destination as viewed by the routing topology. The term is intended to echo the terms unicast, broadcast and multicast.

In unicast, there is a one-to-one association between network address and network endpoint: each destination address uniquely identifies a single receiver endpoint.

In broadcast and multicast, there is a one-to-many association between network addresses and network endpoints: each destination address identifies a set of receiver endpoints, to which all information is replicated.

In anycast, there is also a one-to-many association between network addresses and network endpoints: each destination address identifies a set of receiver endpoints, but only one of them is chosen at any given time to receive information from any given sender.

Anycast is used in IPv6 as a method of updating routing tables. One host initiates an update of a router table for a group of hosts, sending the data to the nearest host. IPv6 can determine which gateway host is closest and sends the packets to that host as though it were a unicast communication. That host then sends the message on to its nearest router until all the routing tables in that group are updated.

Anycast routing has been defined a standard communication model of IP version6，and anycast illustration is as follows (Fig.1).

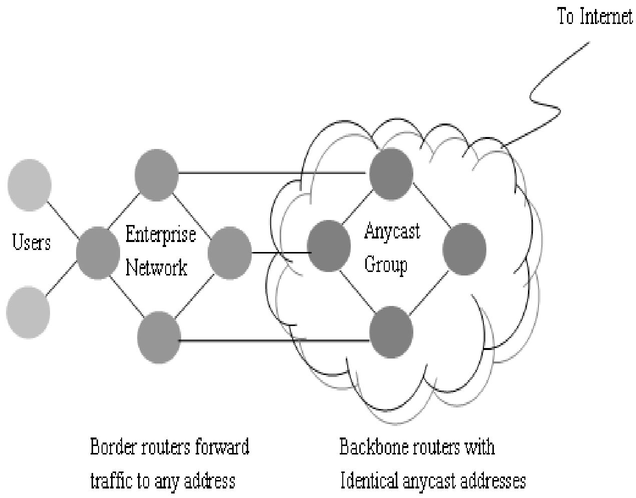

Fig.1 Anycast Illustration

Various methods have been proposed for any-casting communication. These techniques can be classified mainly into two groups: anycasting in the application-layer and anycasting in the network-layer. Application-layer anycasting include research on the model of anycast communications and selection strategy of the target site. Network-layer anycasting is mainly composed of the routing table and routing algorithm in communication.

To enable efficient job delivery in optical grids, several routing algorithms are proposed in the world [1]:

- SAMCRA*, an update of the samcra algorithm;
- Maximum flow pseudo-optimal bound;
- Best Server and Best Delay heuristics.

In order to implement multi-destination and multi-path anycast routing on the heavy load network, this paper proposes a new anycast routing algorithm based on genetic algorithm and presents a heuristic genetic algorithmic to solve shortest path routing optimization problem.

2 introduction of the GA

The genetic algorithm (GA) searches the solution space of a function through the use of simulated evolution, i.e., the survival of the fittest strategy.

In general, the fittest individuals of any population tend to reproduce and survive to the next generation, thus improving successive generations.

However, inferior individual can, by chance, survive and also reproduce. The GA has been shown to solve linear and nonlinear problems by exploring all regions of the state space and exponentially exploiting promising areas through mutation, crossover, and selection operations applied to individuals in the population [2].

2.1 Characteristics of the GA

The GA is a search technique, based on the principles of natural evolution, which is usually applied to optimize controlled parameters and constrained functions.

The important terms and principles as follow:

(1) Codes on solution have evolution.

The codes of optimal problem solution are called chromosomes. Since the solution is coded, the research on optimization of function is based on codes. The one important topic of a GA is encoding and decoding.

The codes of optimal problem solution are called chromosomes. Since the solution is coded, the research on optimization of function is based on codes. The one important topic of a GA is encoding and decoding.

(2)Law of natural selection decides which chromosomes have more offspring than others.

In the GA, fitness function is created by objective function, which will be optimized. The fitness functions ensure that the more chromosomes are fitting, the more offspring is generated.

(3)New chromosomes retain characteristics of parent chromosomes.

Crossover takes two chromosomes and produces two new chromosomes. The two new chromosomes retain characteristics of parent chromosomes from parent chromosomes gene.

(4)New chromosomes is different from parent chromosomes

Randomly mutant made the difference.

Genetic algorithm is a stochastic algorithm simulating the process of natural evolution, which is usually applied to optimize controlled parameters and constrained functions.

The GA work as follow (Fig.2).

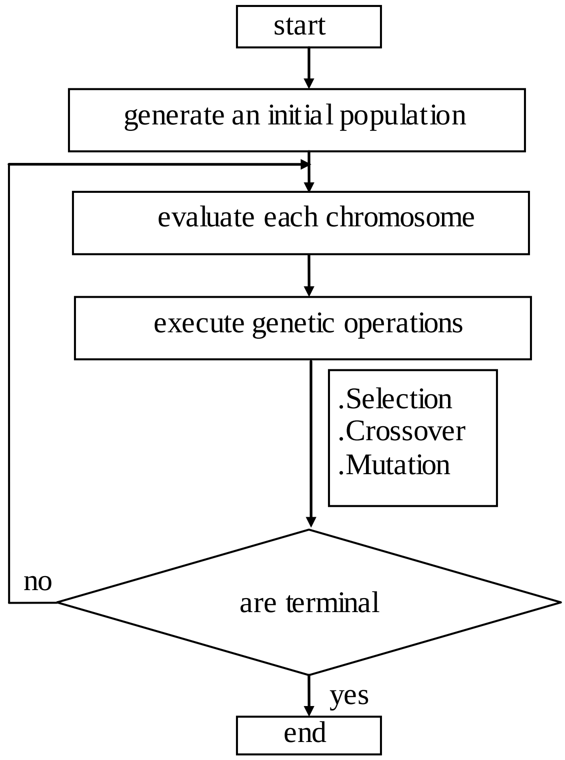

Fig.2 Genetic algorithm flowchart

2.2 A Common Algorithm

A GA is summarized as follow, and each of the major components is discussed in detail below[3].

Step1:

Supply an initial population Pop(1) of N individuals and respective codes of function solutions, t: =1;

Step2:

Calculate each of chromosomes Pop_i (t), which is in population Pop (t), fitness function

$$f_i = fitness\left(Pop_i\left(t\right)\right) \tag{1}$$

Step3:

Calculate each of chromosomes selection probability

$$p_i = \frac{f_i}{\sum_{j=1}^{N} f_j}, i = 1, 2, \cdots, M, \tag{2}$$

By P_i, a new population is generated from Pop (t)

newPop(t+1)={ Pop_j(t) | j=1,2,⋯, N};

Remark: A chromosome in population Pop(t) may be repeatedly selected.

Step4:

Generate a population crossPop(t+1) by crossing consecutive pairs chromosomes from newPop (t+1). Crossing probability is Pc.

Step5:

Mutate a gene of a chromosome by small probability p. Generate a population mutPop (t+1), t: =t+1, a new population Pop (t) = mutPop (t)

Step6:

Repeat step (3) until termination

Step7:

Print out best solution found

2.3 Fundamental Issues

The use of a genetic algorithm requires the determination of six fundamental issues: the creation of the initial population, chromosomes representation, the selection method of the new pop population, the genetic operators making up the crossover function, the mutant method, and termination criteria. The rest of this section describes each of these issues.

Issue1. Initial population.

The GA must be provided an initial population as indicated in step (1). The most common method is to randomly generate solutions for the initial population. However, since GAs can iteratively improve existing solutions (i.e., solutions from other heuristics and/or current practices), the beginning population can be seeded with potentially good solutions, with the remainder of the population being randomly generated solutions.

Issue2. Chromosomes representation

For any GA, a chromosome representation is needed to describe each individual in the population of interest. The representation scheme determines how the problem is structured in the GA and also determines the genetic operators that are used. Each individual or chromosome is made up of a sequence of genes from a certain alphabet. An alphabet could consist of binary digits (0and1), floating point numbers, integers, symbols (i.e., A, B, C, D), matrices, etc. One useful representation of an individual or chromosome for function optimization involves genes or variables from an alphabet of floating point numbers with values within the variables upper and lower bounds.

Issue3. The selection method of the newpop population

A common selection approach assigns a probability of selection, Pi, to each individual, i based on its fitness value as indicated in step (2) (3). The chromosome, which has larger fitness function value, has more chance to be selected in new population. This selection method is call roulette wheel selection.

Issue4. The genetic operators making up the crossover function

Crossover (or mating) is the way in which "genetic" information from two parent chromosomes is combined to generate "offspring". In step (4), the parent chromosomes and crossing size are randomization.

Issue5. The mutant method

While the crossover operation leads to a mixing of genetic material in the offspring, no new genetic material is introduced, which can lead to lack of population diversity and eventually "stagnation"-- where the population converges on the same, nonoptimal solution. The GA mutation operator helps to increase population diversity by introducing new genetic material. The common method is select one genetic to mutate by minimal probability.

Issue6. Termination criteria

The GA moves from generation to generation selecting and reproducing parents until a termination criterion is met. The most frequently used stopping criterion is a specified maximum number of generations. Another termination strategy involves population convergence criteria. In general, GAs will force much of the entire population to converge to a single solution. When the sum of the deviations among individuals becomes smaller than some specified threshold, the algorithm can be terminated.

3 Anycast service model

Anycast is communication between a single sender and several receivers topologically nearest in a group. All the destination hosts have the same addresses, those constitute a group.

As originally defined [3], Anycast refers to the transmission of data from a source node to (any) one member in the group of designed recipients in a network. Anycasting provides a stateless best effort delivery of an anycast datagram to at least one host, and preferably only one host, which serves the anycast address.

Anycast is communication between a single sender and several receivers topologically nearest in a group. The term exists in contradistinction to multicast, communication between a single sender and a group of selected receivers, and unicast, communication between one sender and one receiver in a network. The Anycast's network topology is as follows (Fig.3).

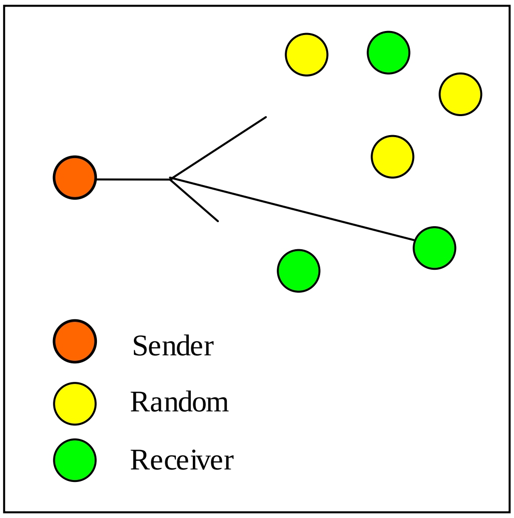

Fig.3 Anycast network topology

In this definition, an IP anycast address is used to define a group of servers that provide the same service. A sender desiring to communicate with only one of the servers sends datagrams with the IP anycast address in the destination address field. The datagram is then routed using anycast-aware routers to at least one of the servers identified by the anycast address [4].

The basic model of anycast describes as follows:

$$G = (V.\ E) \tag{3}$$

Where $V = (v_1, v_2, \cdots, v_n)$ is a collection of computer network nodes, $E = (e_1, e_2, \cdots, e_{nw})$ is the sets of the network links. Each link e_i has a link bandwidth B_i.

An anycast requests can be stated as follows:

$$\begin{cases} R = (S, D, B, N) \\ G(D) = \{D_1, D_2, \cdots D_m\} \\ \qquad (D_1, D_2, \cdots D_m \in V) \\ G(S) = \{S_1, S_2, \cdots S_n\} \\ \qquad (S_1, S_2, \cdots S_n \in V \cap S_1, S_2, \cdots S_n \notin G(D)) \end{cases} \tag{4}$$

Where R is an anycast request;

D is a group of destination nodes, which provide the same service to the source node; G (D) is a group of destination hosts;

S is a group of source nodes, which request services to the destination nodes;

B is the transmission bandwidth;

N is transmission delay, and N transmission path can also be expressed as the maximum allowable links, assuming that all links have the same transmission delay and the transmission delay of the path is equivalent to the accumulation of all link's transmission delay.

Anycast routing problems can be described as follows:

To establish a network G = (V, E) and an anycast QoS request R = (G (S), G (D), B, N), for the G (S) in every source to find a node S. From the source to the node G (D) in any one node of a transmission path P, enables network on each link [k, 1] are not less than the bandwidth B, but also on the path P. Link Not more than a few and require the path to achieve the minimum of delay, in order to achieve a balanced network load.

If the path p_{ij} is a viable path for the link $(S \to G(D))$, we can defined the path parameters p_{ij} for $link[i, j]$.

$$p_{ij} = \begin{cases} 1, (i, j) & \in path \\ 0, (i, j) & \notin path \end{cases} \tag{5}$$

Then $Delay(Path)$ and $Cost(Path)$ of the path can be defined:

$$\begin{cases} \text{delay(path)} = \sum_{i=1}^{n} i \sum d_{ij} p_{ij} & i, j = 1, 2, \cdots, n \\ \text{cost(path)} = \sum_{i=1}^{n} i \sum c_{ij} p_{ij} & i, j = 1, 2, \cdots, n \end{cases} \tag{6}$$

Mathematical descriptions of the problem are as follows [5]:

for a path P_i for each $S_i \in G(S)$, subject to

for all dege$[k, l] \in E$

$$\min \left\{ \sum_{t=1[k,l].in.P_i}^{n} \sum delay([k, l]) \right\}$$

$$\sum_{t=1.and[k,l].in.P_i}^{n} B_i < B_{k.l}$$

Where $Delay(i, j)$ is the network delay of every $Link(k, l)$ in path P_i.

B_i is the flow of the path P_i which associated with service requests.

P_i is satisfying condition: $Delay(i, j)$ of every $Link(k, l)$ in path P_i is less than N_i.

Each $Link(k, l)$ in path P_i, the sum of the requested flow $\sum_{t=1.and[k,l].in.P_i}^{n} B_i$ is less than the bandwidth of the link $B_{k.l}$.

4 Anycast Routing Algorithm Based on Genetic Algorithm

4.1 Data structure of Anycast routing algorithm

The network simulation topology can be expressed as link matrix $R_{rout} = [r_{i,j}]$. Because the network simulation topology is undirected graph, link matrix R_{rout} is a symmetric matrix, that is

$$R_{rout}[i][j] = R_{rout}[j][i] \qquad (i, j) \in V \qquad (7)$$

If there are not the link which is directly connected between the node i and j, $R_{rout}[r_{i,j}] = 0$; if there are the link which is directly connected between the node i and j, $R_{rout}[r_{i,j}] = i \times j$.

List DL is established for a group of destination nodes, and list SL is established for a group of source nodes. Matrix R_{eq} stores the demand of source nodes send to destination nodes.

To each source node S, if the group of the destination nodes is $G_s[D] = \{d_1, d_2, \cdots, d_k\}$, then Matrix R_{eq} can be expressed as follows according to a row of elements in the source node:

$$\mathrm{R}_{eq}[i][D_1] = \mathrm{R}_{eq}[i][D_2] = \cdots = \mathrm{R}_{eq}[i][D_m] \qquad (8)$$

List matrix R_{rout} is established for the candidates obtained. A row of the matrix stores all the candidates of a source nodes S, and the candidate path is gradually generated with the extension of chromosomes in the course of evolution.

4.2 Design Element of Algorithm

The key of the Algorithm is how to apply the genetic algorithm in the anycast communication model and how to solve the encoding mode, population selection, fitness function, crossover strategy, genetic mutation, legality of the path and other issues in algorithm.

We encode a path by listing up node IDs from its source node to its destination node based on a topological database of a network.

For example, a path from node 2 to node 9 is encoded into a list of nodes along the path: [2 4 8 3 10 9].

Actually, our anycast routing algorithm is a genetic algorithm, which utilizes the results of Jaffe's algorithm in creation of initial population and path mutation operator. The basic components and general flow of GA are described in Fig. 1.

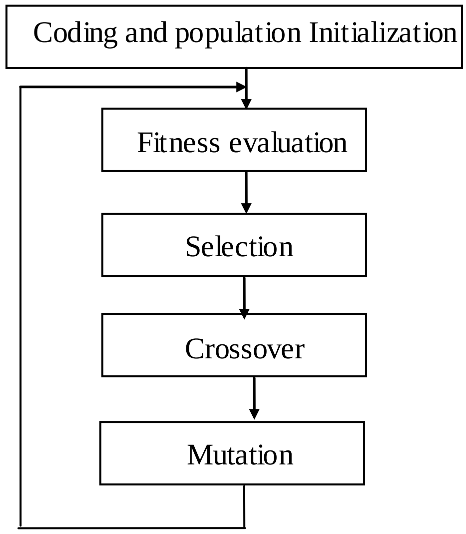

Fig.4 The general flow of GA

4.2.1 Creation and encoding of initial population

Coding application of chromosome is the key issue of the genetic algorithm. An effective way is that as the solution of chromosome Coding, through genetic algorithms to calculate the evolution of direct access to the optimal solution.

On the other hand, coding of the chromosome should facilitate the genetic operation. This select set of chromosomes coding is long, that is all gene blocks of chromosome is the same number. As anycast routing of the candidates is indefinite long sequence of nodes.

Indefinite long nodes have been adopted for the coding of chromosome in this paper. A chromosome is a viable path from the source node to node of anycast communication. Because the coding of the chromosome is uncertain long, the paper identified by genetic manipulation has a corresponding improvement.

A node n is selected randomly from all nodes in the topological data base of a network; the n Dijkstra algorithm is adopted to calculate the shortest path from source node s to n, and n to the destination node t, respectively. Then we connect the two paths as a single one, and the juncture is the node n. If between the two paths there is a not her same node before node n, take it as the juncture point.

In the above Dijkstra algorithm, single link metric is adopted, which is defined as the function of multiple constraints.

4.2.2 Fitness function

The design of fitness function should reflect the objective of the problem, and it is the basis of the selection operation, the each individual's fitness can be calculated by the fitness function.

According to the characteristics of anycast routing algorithm, the fitness function is defined as follows [7]:

$$\begin{cases} fitness(path(s,t)) = \dfrac{\lambda \cdot f_d}{Cost(path(s,t))} \\ f_d = \begin{cases} 1, & Delay(path(s,t)) \le Limit \\ \eta, & Delay(path(s,t)) > Limit, (0 < \eta < 1) \end{cases} \end{cases} \quad (9)$$

Where path(s, t) denotes a path between the source node s and the destination node t; λ is a positive real coefficient; f_d is penalty function of delay.

4.2.3 Selection method

The algorithm adopts the method to preserve the best individual and fitness proportional method, that is, at first select the best individual directly to a copy of the next generation before the crossover and mutant of the population; the rest of the individual to choose from the most basic ratio choice of law, that is, the probability of each individual selected is actually in proportion to the fitness.

In our algorithm, elitist model is adopted as the selection operator, which means at first the selection operation is executed according to the Monte Carlo method, and then the chromosome with highest fitness is copied to the next generation directly. This GA could finally converge to the global optimal solution.

4.2.4 Path crossover

On the basis of the character of the problem, the algorithm defines the crossover operation according to the local cross. As a result of coding of the method is indefinite length, so the single-point cross operating of the method is different from the classic genetic algorithm, in the cross-operation is not directed against the location of the gene for gene, but the value of the gene (that is, the node).

Path crossover is conducted in the following steps (see Fig. 4):

(1)Two nodes p1 and p2 is randomly selected from the population, then we identify all the nodes in the two individual in addition to the source nodes and destination nodes, at last set up a set of the public nodes S, that is listed up as potential crossing nodes.

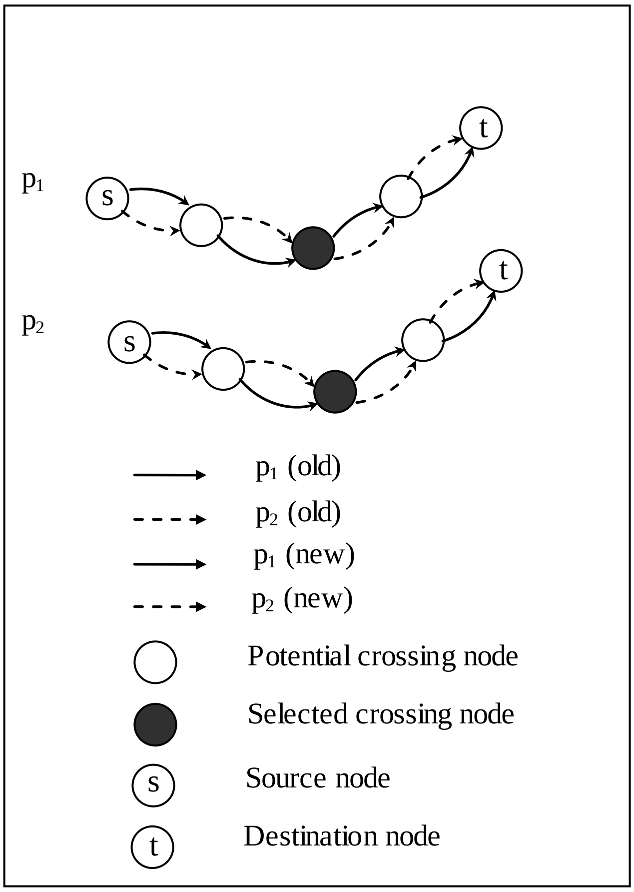

Fig.4 path crossover

(2)If the set S=ϕ， then p1 and p2 don's need to crossover.

(3)A node d is selected randomly from the potential crossing nodes and taken as the crossing node.

When no common node exists among the pair of paths, we do not perform this crossover. The pair of paths, which has no similarities, is not worth crossing over because forcing crossover of such a pair may cause random regeneration of path.

The new entity can ensure that the link connectivity by cross-operation.

4.2.5 Path mutation

Mutation operation is aimed at maintaining the diversity of groups and avoiding the process of solving a local optimum. According to this method of coding rules, we have adopted a variation of double-operation, that is, with a new link that is randomly generated substitute for the path of the chromosome mutation.

Path mutation is conducted in the following steps (see Fig.5):

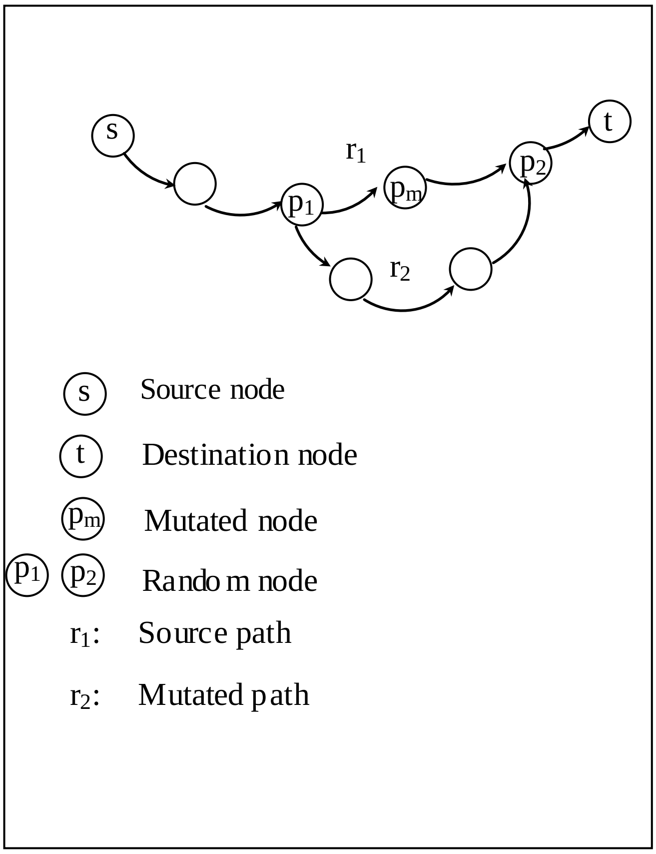

Fig.5 path mutation

(1)At first a node p_m is selected randomly from the source path excluding the source node and destination node, then it taken as the mutation node.

(2)Two gene's nodes p_1 and node p_2 is randomly selected from the source path according to the mutation node p_m (the node p_1's location is behind the node p_2's location);

(3)Generate the shortest path r_2 between the predecessor p_1 and successor p_2 of the mutation node p_m.

(4) r_2 replaces r_1, and the obtained path replace the old path.

4.3 Anycast Routing Algorithm Based on Genetic Algorithm

Algorithm design idea is: first initial routing table structures, and in accordance with the routing tables initial population structure, and then routing calculation and genetic evolution at the same time, the current node in the evolution, the routing table pass the next node , the next node for routing table updates, for the corresponding extension of chromosomes, and then continue to evolve until the purpose of nodes, thus obtained source node to node purpose of sowing the most optimized routing.

The algorithm's flowchart is as follows (see Fig.6):

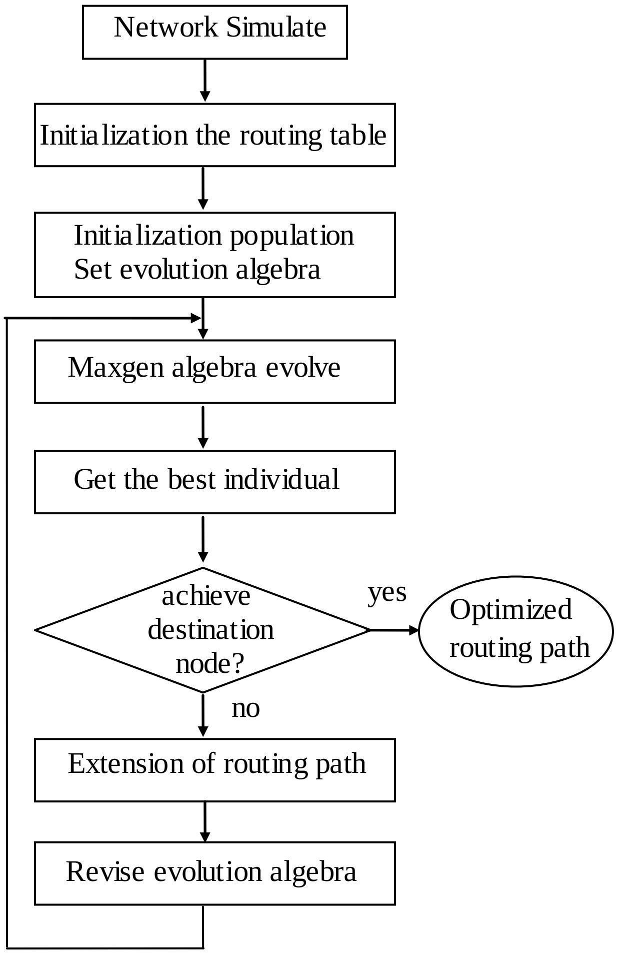

Fig.6 Algorithm of flowchart

Below are the specific algorithm described:

Algorithm: Anycast-Routing
Input: Network topology Rout [ ] [ ];
Source nodes list SL;
Destination nodes list DL;
Output:
Optimization of anycast-routing path P;
Begin
Step1
Construction initial routing table;
Select the source node;
The initial node of path P is node S;
Serial of the nodes m=0;
for each node s in SL;
{
for i =0 to N (total number of network nodes)
do
{
if Rout[s, i] is existent
then

```
        {
         Node i added into the path P;
         Validity verification of the path P;
          if the path is legal
           then
        {
          if (i in DL)
           then
           {
            Path P added into matrix Rout[m] [k++];
            }
          else
           {
          path P added into the queue CQ;
            }
          }
        }
      }
    }
while queue CQ≠ ϕ do
  {
    The first path P dequeues in queue CQ;
    The end node of path P = s;
    for j=0 to N ( the total number of nodes)
    do
     {
      if Rout[s, j] is existent then
       {
        Node j added into the end of path P;
        Validity verification of the path P;
         if the path is legal
           then
          {
           if (i in DL)
             then
             {
              Path P added into matrix Rout[m]
              [k++];
             }
             Else
             {
              Path P added into the queue CQ;
             }
           }
         }
       }
     }
 K[m] =k;
 Candidate path collection of the node;
 m++;
 Go to next source node;
Step2
Set up evolution algebra: maxgen;
Initial population according to the routing tables
(that is Rout [ ] [ ]);
Calculation of individual fitness;
Find the best individual as the source
chromosomal;
for i =0 to maxgen do
{
 if the change of the best individual fitness is
    satisfy condition
   then
    {
     Get optimal solution of the anycast routing;
     Loop termination;
     }
  else
    {
    Progeny Chromosomes obtained from making
    crossover, mutation and replication operation
    on the parent chromosome;
    Calculation of progeny individual fitness;
    Find the best progeny individual as the new
    source chromosomal;
    }
 }
    The parent individual population change
    according to the new routing table
    Modify evolution algebra
}
Show the optimal path P
End
```

As the algorithm is a dynamic optimal routing algorithm, that is the routing algorithm is side, the updated routing table, while genetic evolution. So do not get too many node status information to a network routing, this greatly reduced the burden on the network and improve anycast routing speed. At the same time it has reduced storage costs.

4.4 Network simulation Experiment

The generation of Simulation networks using the methods proposed by Waxman [8], it can be randomly generated the network's topology that has actual characteristics. This method has been used by many researchers.

The method proposed by waxman is summarized as follow: N network nodes are generated randomly in a certain region, the distance between network nodes is indicated by Euler distance, any two nodes between i and j connect according to a certain probability, and the probability has a direct bearing on the distance between of the nodes. So that the connection between of the nodes is associated with the distance between the nodes, and the side have a probability of a decision by the following formula:

$$p_e(i,j) = \beta \exp \frac{-Dis(i,j)}{\alpha * L_{\max}} \quad (10)$$

The network topology used in our simulations shown in Fig.7, which has 30 network nodes. Before simulation, some parameters should be given: Link delay random generate in the [l-10], the network bandwidth random generate in [0-15], the cost of the network random generate in the [1-30].

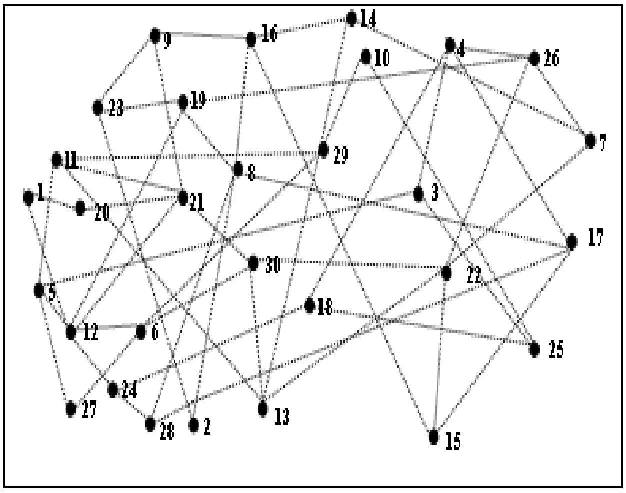

Fig.7 Topology of the random network

4.4.1 Analysis of Algorithm's astringency

Figure 8 and 9 were given those demonstrating the changes of the path delay and path cost of each source node according to the evolution of algebra in Gs (A). The algorithm convergence is quick and the cost of the path is minimized in the chart.

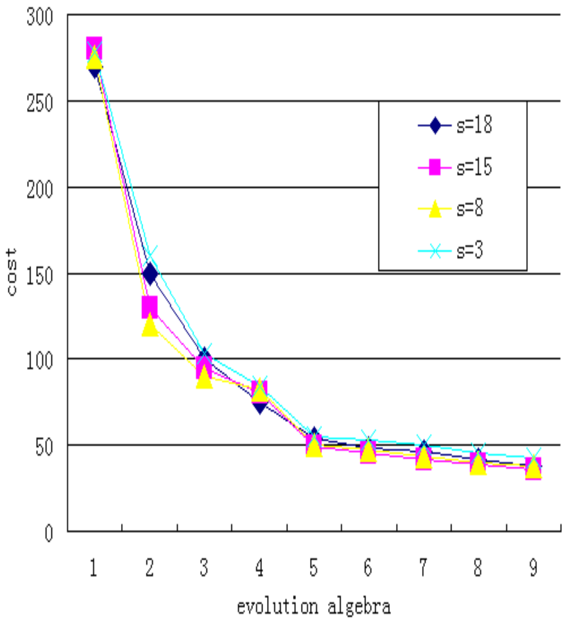

Fig.8 The path delay of different source nodes

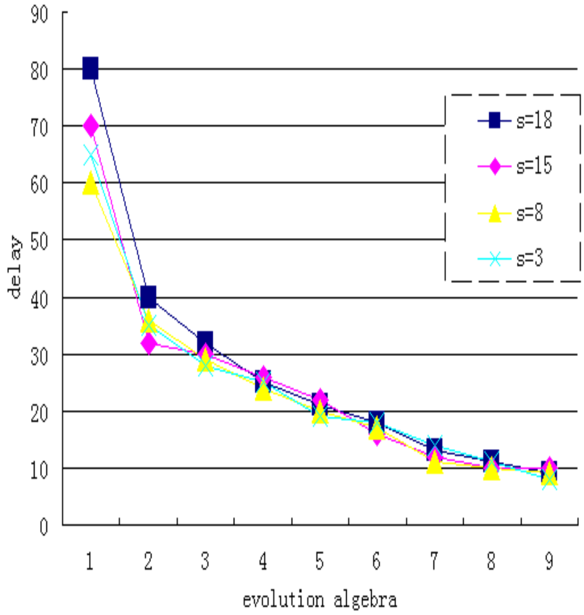

Fig.9 The cost of different source nodes

4.4.2 Analysis of Algorithm's validity

Before simulation, some parameters should be given: population size Popsize=10; randomly selected probability Select = 0.55; delay constraint Dc=0.55; crossover probability Pc = 0.7 and the mutation probability Pm = 0.05.

There are an Anycast routing request R = (S, D, A), G (A) = (1, 11, 14, 29), Gs (A) = (3, 8, 15, 18), S $\in$ Gs. By simulation from S to G(A) like all the members of the optimal path as shown in table 1, in which bold path simulation is the optimal solution.

The experimental data shows that are Algorithm to choose an optimal performance of the elected members of the group broadcast to users.

5 conclusions

A new anycast routing algorithm based on genetic algorithm is proposed to solve the key problem to implement multi-destination and multi-path anycast routing on the heavy load network in this paper. The main conclusions are summarized as follows. The proposed algorithm perturbs the existing multicast tree as little as possible when group membership changes and it has also very good cost performance because the source node may not be involved in the route computation nor needs only small computation.

The individual is encoded by listing up node IDs from its source node to its destination node based on a topological database of a network. Each individual is a viable path in the network topology and is optimized directly by the crossover and mutant. The network simulation experimental results show that

Table 1 simulation results

R_1=（3，40，A）					
	S	Path(S→G(A))	Delay	Cost	fitness
1	3	4→26→7	25	55	2.0654
2	**3**	**5→11**	**8**	**24**	**3.8654**
3	3	4→26→7→10→14	31	86	0.3125
4	3	5→11→29	26	34	1.2563
R_1=（8，40，A）					
	S	Path(S→G(A))	Delay	Cost	fitness
1	8	17→4→18→7	21	64	0.7528
2	8	19→12→5→21→11	32	96	0.3215
3	**8**	**29→14**	**9**	**23**	**3.5464**
4	8	19→12→6→29	28	55	0.9654
R_1=（15，40，A）					
	S	Path(S→G(A))	Delay	Cost	fitness
1	**15**	**22→7**	**10**	**23**	**3.5654**
2	15	22→30→21→11	26	46	1.2562
3	15	22→30→13→14	34	66	0.5463
4	15	22→30→13→29	21	35	0.9864
R_1=（18，40，A）					
	S	Path(S→G(A))	Delay	Cost	fitness
1	18	4→26→7	18	24	1.7634
2	18	24→12→5→11	35	52	0.6749
3	18	4→26→7→10→14	36	54	0.5217
4	**18**	**25→10→29**	**15**	**20**	**2.0143**

our algorithm was capable of finding optimization anycast routing path and has good convergence property, and the algorithm of iteration number is reduced obviously.

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