Research on Anycast Routing Algorithm Based on Genetic Algorithm

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Abstract: - Anycast is a new network service, 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 experimental simulation results show that this algorithm can get more resolution at less time and more balanced network load, enhance search ratio and the availability of network resource and improve the quality of service.

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

1 Introduction
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.

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 has been defined a standard communication model of IP version 6.

Various methods have been proposed for anycasting communication. These techniques can be classified into two group: application-layer anycasting and network-layer anycasting. 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 anycasting communication.

To enable efficient job delivery in optical grids, several routing algorithms are proposed [1]:
- SAMCRA*, an update of the SAMCRA algorithm;
- Maximum flow pseudo-optimal bound;
- Best Server and Best Delay heuristics.

This paper presents a new anycast routing algorithm, the idea is the use of genetic algorithms on the network anycast request routing, the shorter the delay to local optimum, the search algorithm to increase efficiency, thereby enhancing network Utilization and quality of service.

2 Introduction of the GA
The 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. 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.

(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 gene.

(4) New chromosomes is different from parent chromosomes

Randomly mutant made the difference.

2.2 A Common Algorithm

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

Step1: Supply an initial population pop (1) of N individuals and respective codes of function solutions, t = 1;

Step2: Calculate each of chromosomes popi(t), which is in population pop(t), fitness function fi = fitness(popi(t));

Step3: Calculate each of chromosomes selection probability

\[ p_i = \frac{f_i}{\sum_{j=1}^{M} f_j}, i = 1, 2, \cdots, M \]  

By (1), a new population is generated from pop(t)

newpop(t+1) = \{ popj(t) | j = 1, 2, ..., N \};

Remark1: A chromosome in population pop (t) may be repeatedly selected [3].

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

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.

3 Anycast service model

The basic model of anycast is as follows:

\[ G = (V, E) \]  

Where \( V = (v_1, v_2, \cdots, v_n) \) is a collection of computer network nodes, \( E = (e_1, e_2, \cdots, e_n) \) is the network link collection. Each link \( e_i \) have the link bandwidth \( B_i \). An anycast requests may be expressed as [4]:

\[ R = (S, D, B, N) \]

\[ G(D) = \{D_1, D_2, \cdots, D_m\} \quad D_1, D_2, \cdots, D_m \in V \]  

\[ G(S) = \{S_1, S_2, \cdots, S_n\} \quad S_1, S_2, \cdots, S_n \in V \]

Where R is an anycast request, Anycast address D is a group of destination nodes, which provide the same service to the source node. G (D) said that a group of destination hosts. S is a group of source nodes. B for the transmission bandwidth. N demand for transmission latency, such as the need to simplify the delay, N transmission path can be expressed as the maximum allowable number of links (assuming that all links have the same transmission path of delay and delay equivalent to all the transmission path chains delay the accumulation).

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 \( [k, l] \) 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 \( \text{path} \) is a viable path for the link from S to G (D), we can defined the path parameters \( P_{ij} \) for link(i,j).

\[ P_{ij} = \begin{cases} 1, (i, j) \in \text{path} \\ 0, (i, j) \notin \text{path} \end{cases} \]

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

\[ \text{delay(path)} = \sum_{i=1}^{n} \sum_{j=1}^{n} d_{ij} \cdot P_{ij}, \quad i, j = 1, 2, \cdots, n \]

\[ \text{cost(path)} = \sum_{i=1}^{n} \sum_{j=1}^{n} e_{ij} \cdot P_{ij}, \quad i, j = 1, 2, \cdots, n \]  

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 degree \( [k,l] \in E \)

\[ \min \left\{ \sum_{t=1}^{n} \sum_{[k,l]\in E} \text{delay}([k,l]) \right\} \]

\[ \sum_{t=1}^{n} \sum_{[k,l]\in E} B_{k,l} < B_{k,l} \]
Where, \( \text{Delay} \ [i,j] \) is the 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. The path of the \( P_i \) request to meet the conditions are: the delay of every link \([k,l]\) in path \( P_i \) is less than \( N_i \). Each link \([k,l]\) in the network, \[
\sum_{t=1}^{t=1} \text{and}[k,j] \in P_t \] 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

Network simulation topology can be expressed by link matrix \( R_e = [r_{ij}] \), the network topology \( R_e \) is undirected graph, so link matrix is a symmetric matrix, that is \[
R_e[i][j] = R_e[j][i] \quad (i, j) \in V \quad (6)
\]

If the node \( i \) and \( j \) are not directly connected to the link, \( R_e[i,j] = 0 \); if so directly connected to the link, \( R_e[i,j] = ij \). List \( dA \) storage system for the purpose of generating group nodes, in the remaining sites in the choice of a service request the source site group, with \( sA \) chain store. Matrix \( Req \) stores the sent demand of source nodes to destination nodes, for any source node \( S \), if the destination nodes is the group \( G_s \) \( (D) = \{d1, d2, \ldots, dk\} \), that is \[
R_{eq}[i][D_j] = R_{eq}[i][D_2] = \cdots = R_{eq}[i][D_m] \quad (7)
\]

List matrix \( Rout \) for storage of the candidates obtained path, and any line of the matrix stores all the candidates path of one source nodes \( S \), but 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, cross-strategy, genetic variation, and the path of legality and other issues in algorithm.

4.2.1 Formation and coding 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.

4.2.2 Fitness function

Fitness function is the basis for the choice operation, used to calculate the each individual's fitness, then choose individual. According to the objective of anycast routing algorithm, we design the fitness function for \([7]\):

\[
\text{fitness}(path) = \frac{\lambda \cdot f_d}{\text{Cost}(path)}
\]

\[
f_d = \begin{cases} 
1, & \text{Delay}(path) \leq \text{Limit} \\
\eta, & \text{Delay}(path) > \text{Limit}, (0 < \eta < 1)
\end{cases}
\]

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.

Below are the specific method described:

Algorithm: Anycast-Routing
Input: Network topology \( R_e \), source node chain \( sA \), destination nodes \( List \ dA \)
Output: Optimization of the anycast path \( P \)
Begin
Step 1
//Construction initial routing table
Select the source node
The initial node of path \( P \) is node \( S \)
For \( i = 0 \) to \( N \) (the total number of network nodes) do
{}
If matrix\( [s, i] \) is existent then
{...}
Node i added to the path P
Path P Added to the matrix Rout[m][k++]
}
}
Step2    // According to the routing tables
constructed initial population
Set Evolution algebra
While (the path P of optimal individual
characterization did not reach the objective of group
nodes) do
{
  For each path P in Rout [ ] [ ] do
  {
    S is the last node of path P
    for i=0 to N ( the total number of network nodes )
    do
      If matrix[s, i] is existent then
      {
        Node i added to the path P
        Path P legality of testing
        If Path is legitimate then
          If (i in dA) then
            Path P Added to the matrix Rout[m] [k++];
      }
    }
  }
}
Under the new routing table, the father of individual
population also extended accordingly
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 with the actual characteristics of
the network's plans, has been used by many
researchers. As shown on Fig.1.

Set parameters: Link delay random generate in
the [1-10], the network bandwidth random generate in
[0-15], the cost of the network random generate in the
[1-30].

4.4.1 Analysis of Algorithm’s astringency
Figure2 and 3 were given the changes of the path
delay and path cost of each source node with the
evolution of algebra in Gs (A). As can be seen from
the chart convergence quickly; but also to ensure
delay at the same time constraints. Algorithm so that
the path to minimize the cost of overhead.
4.4.2 Analysis of Algorithm's validity
Set the parameters of the GA Popsize=10. Randomly selected probability Select = 0.55. Cross-rate Pc = 0.7. Mutation rate = 0.05. There are Anycast routing request R=(S,D,A), G(A) = (1, 11, 14, 29), Gs(A) = (3, 8, 15, 18), S ∈ 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
This paper presents a new Anycast routing algorithm, the idea is the use of genetic algorithms on the network anycast request routing. The network experimental simulation results show that this algorithm can get more resolution at less time and more balanced network load, enhance search ratio and the availability of network resource and improve the quality of service.

Table 1 the simulation results

<table>
<thead>
<tr>
<th>R1=(3,40,A)</th>
<th>S</th>
<th>Path(s→G(A))</th>
<th>Delay</th>
<th>Cost</th>
<th>fitness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>4→26→7</td>
<td>25</td>
<td>55</td>
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</tr>
<tr>
<td>2</td>
<td>3</td>
<td>5→11</td>
<td>8</td>
<td>24</td>
<td>3.8654</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>4→26→7→10→14</td>
<td>31</td>
<td>86</td>
<td>0.3125</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>5→11→29</td>
<td>26</td>
<td>34</td>
<td>1.2563</td>
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<table>
<thead>
<tr>
<th>R1=(8,40,A)</th>
<th>S</th>
<th>Path(s→G(A))</th>
<th>Delay</th>
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<tbody>
<tr>
<td>1</td>
<td>8</td>
<td>17→4→18→7</td>
<td>21</td>
<td>64</td>
<td>0.7528</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>19→12→5→21→11</td>
<td>32</td>
<td>96</td>
<td>0.3215</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>29→14</td>
<td>9</td>
<td>23</td>
<td>3.5464</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>19→12→6→29</td>
<td>28</td>
<td>55</td>
<td>0.9654</td>
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<table>
<thead>
<tr>
<th>R1=(15,40,A)</th>
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<th>Path(s→G(A))</th>
<th>Delay</th>
<th>Cost</th>
<th>fitness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15</td>
<td>22→7</td>
<td>10</td>
<td>23</td>
<td>3.5654</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>22→30→21→11</td>
<td>26</td>
<td>46</td>
<td>1.2562</td>
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<tr>
<td>3</td>
<td>15</td>
<td>22→30→13→14</td>
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</tr>
<tr>
<td>4</td>
<td>15</td>
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References: