A Multiple QoS Anycast Routing Algorithm based Adaptive Genetic Algorithm

LI Taoshen, GE Zhihui
School of Computer, Electronics and Information
Guangxi University
Nanning, China
{tshli@gxu.edu.cn, Gezhihui@gxu.edu.cn}

Abstract—**The anycast is a new network addressing and routing scheme, and has been defined as a standard communication model in IPv6. By analyzing the characters of anycast service, an anycast routing model with multiple QoS constraints and a felicitous estimate function of the optimal route path are presented in this paper, and a multiple QoS anycast routing algorithm based adaptive genetic algorithm is proposed. This algorithm uses adaptive probabilities of crossover and mutation to solve the problem of computing probabilities of crossover and mutation over and over again in simple genetic algorithm. Using fitness scaling can guarantee the diversity of populations in process of running, and is beneficial to global optimal solution. The results of network experiment show that this algorithm is effective and available. It can satisfy the constrained condition of multiple QoS, balance network load fairly, and improve the quality of network service.**

Keywords- anycast; Quality of Service(QoS); routing algorithm; adaptive genetic algorithm; load balance

I. INTRODUCTION

With the rapid development of Internet and the increasing connections between network hosts, the demands for network service have exceeded its capacity, which has brought great impacts on the application of Quality of Service (QoS) service such as Video on Demand (VOD) and IP telephone etc. Anycast is a new network addressing and routing scheme, and has been defined as a standard communication model in IPv6[1]. It is designed to support server replication by allowing applications to select and communicate with the "best" server, according to some performance or policy criteria, among the replicated servers[2]. Anycast service is an important research topic of network and communication technology, and has broad application proppects and research value in a wide range of new multimedia application and integrated services network. The design for effective secure anycast routing protocol and algorithm is a hot spot in anycasting research.

The anycast routing problem (ARP) of finding a optimum path from a source node to any member of destination group, with multiple QoS requirements, is a nonlinear combination optimization problem, which is proved to be a NP complete problem[3][4]. Thus, meta-heuristics method is likely to be the only viable approach to the problem [5][6].

The genetic algorithm (GA) is an adaptive heuristic search method based on population genetic[6]. Some researchers have used GA to solve ARP problem. In [7], the authors propose a genetic algorithms applied in anycast routing. The works of [8] is to develop some anycast routing algorithms with multiple QoS constraints. These anycast routing algorithms based GA can satisfy the constrained condition of multiple QoS requirements, balance network load fairly in varying degree. However, these algorithms have used the fixed probabilities of crossover and mutation, and may generate bad genetic factor while perform crossing and mutation operating so that form a link to not exist or limitless circulation.

The adaptive genetic algorithm(AGA) is an efficient approach for multimodal function optimization using genetic algorithm(GA)[10]. It uses adaptive probabilities of crossover and mutation to realize the twin goals of maintaining diversity in the population and sustaining the convergence capacity of the GA. Based on AGA, this paper researches QoS anycast routing model and QoS anycast routing algorithm with multiple QoS constraints.

The remainder of this paper is as follows. Section 2 discusses related works in anycast routing. Section 3 gives the network model and problem formulation of the anycast routing with multiple QoS requirements. Section 4 describes an anycast routing algorithm based on AGA. Simulation experiments and results are presented in Section 5 and some concluding remarks are given in Section 6.

II. ANYCAST ROUTING PROBLEM FORMULATION

Generally a communication network is defined as a directed graph $G=(V,E)$ with node set V and edges set E, and $|V|=n$, $|E|=m$, Edge $(i,j)\in E$ has four, namely bandwidth capacity $b_{i,j}$, delay $d_{i,j}$, the packet loss rate $pl_{i,j}$ and cost $c_{i,j}$. For each edge (i,j), $b_{i,j}$ is known as the bandwidth capacity of the link from node i to node j, $d_{i,j}$ is the required delay and $pl_{i,j}$ is the required packet loss rate when data pocket pass through the link, and cost $c_{i,j}$ is the used cost of the link.

Given an anycast packet with anycast (destination) address

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A, let $G(A)= \{d_1,d_2,\ldots, d_q\}$ ($q<n$) denote the group of designated recipients, $S= \{s_1,s_2,\ldots, s_k\}$ ($k<n$)denote the group of source hosts that may send packets with anycast address A. Each source node has a bandwidth requirement of B units, delay requirement of D units, package loss rate of PL units on each edge that it uses to send data to destination. The ARP problem is that of finding a set of paths $\{p_1,p_2,\ldots, p_k\}$ ($k<n$) from each member of S to any member of $G(A)$. Each path p_i(i=1,2,…,k) represents the path from the node s_i □S to one of the member node of $G(A)$.

In QoS metric parameters, bandwidth is protuberance metric parameter, delay and cost are addable metric parameters, but package loss rate is multiple metric parameters. The functions of bandwidth,delay, package loss rate and cost of a feasible path p can be formulated as followings:

$$Bandwidth\,(p) = \min b_{i,j} \quad i, j = 1,2,\cdots,n \tag{1}$$

$$Delay\,(p) = \sum_{i=1}^{n}\sum_{j=1}^{n} d_{ij} \quad i, j = 1,2,\cdots,n \tag{2}$$

$$Ploss(p) = \sum_{i=1}^{n}\sum_{j=1}^{n} pl_{ij} \quad i, j = 1,2,\cdots,n \tag{3}$$

$$Cost\,(p) = \sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij} \quad i, j = 1,2,\cdots,n \tag{4}$$

The objective of anycast routing algorithm with QoS requirements is that choose a feasible path which can meet the condition of bandwidth, delay and package loss rate constraints and its cost is minimum in all paths from S to $G(A)$. That is, the path selected by anycast routing algorithm with QoS requirements must simultaneous satisfy following conditions:

$$Bandwidth\,(p_i) \geq B \quad i = 1,2,\cdots,k \tag{5}$$

$$Delay(p_i) \leq D \quad i = 1,2,\cdots,k \tag{6}$$

$$Ploss(p_i) \leq PL \quad i = 1,2,\cdots,k \tag{7}$$

$$\min \sum_{i=1}^{k} Cost\,(p_i) \quad i = 1,2,\cdots,k \tag{8}$$

III. OUR ALGORITHM

A. Algorithm's description

Based on adaptive genetic algorithm, we propose a multiple QoS anycast routing algorithm based adaptive genetic algorithm(AGA-AR). The idea of algorithm is as follows：

(1) Accoding to $|G(A)|=k$, determines k paths from each member of S to any member of $G(A)$ by using the depth-first search algorithm, which k paths use to construct initial populations.

(2) Calculates selection probability of each destination node by using bandwidth, delay, network load parameters of there nodes. This probability will determine routing selection.

(3) A scale factor of fitness value is used to extend or reduce individual fitness value. It may overcome premature phenomenon existed in the Standard GA (SGA).

(4) When algorithm runs, the probabilities of crossover and mutation, P_c and P_m can be adjusted depending on the fitness values of the-solutions. By using adaptively adjusting P_c and P_m, we can maintain the diversity of populations and provide a solution to the problem of deciding the optimal values of P_c and P_m, i.e., P_c and P_m need not be specified at all.

The AGA-AR algorithm is described as follows:

Input : network $G=(V,E)$, $G(A)$, S,
Anycast QoS request $R=(S,G(A), B,D,PL)$.
P_c, P_{c1}, P_{c2}, P_m, P_{m1},P_{m2}, *Select*, ε, r_d , r_{pl}
Population size: *Popsize,*
The maximum number of iteration: *Maxgen*,

Output:, an optimal routing path that satisfied with the QoS request R.

```
{
  gen=0;
  Find_population(); //Accoding to |G(T)|=k, determines k
                        sub-population;
  Init_population();  // Initialize population
  Evaluate(); //calculate fitness value for each path, and
                 select optimal individuality as chromosome;
  While(not satisfy stop condition or gen <maxgen)  {
     gen++;
     Select();  // select Popsize individualities from
                    Population to construct new populations
     Crossover(); // perform crossing operation to Pc*Popsize
                     chromosomes in new populations
     Mutate();    // perform mutation operation to Pm*Popsize
                     chromosomes in new populations
     Repair_chrom(); // perform reparation operation to repair
                         loop caused by above operation
     Evaluate();    // calculate fitness value for each
                       chromosome in the population,
     According variance in fitness for chromosomes, increase or
  decrease fitness value of each chromosome, and adjust the
  values of Pc and Pm .
     According fitness value of each chromosome, retain optimal
  individualities in the population
    } //end_while
     Output the optimal solution of each sub-population.
     Finally, find out a optimal routing path p.
}
```

B. Fitness function

According to optimizing objective requirement of anycast QoS routing with QoS requirements, fitness function of the algorithm can be defined as follows：

$$f_i'(T) = \frac{f_{avg}}{f_{avg}-f_{\min}} \times f_c \times (A \times f_d + B \times f_{pl}) + \frac{-f_{\min} \times f_{avg}}{f_{avg}-f_{\min}} \tag{9}$$

where, f_{avg} is average fitness value in population, f_{max} is a new maximum fitness value in population, f_{min} is a new minimum fitness value in population.

f_c= ε / *Cost*(*path*)

$$f_d = \begin{cases} 1 \;, & Delay\;(path\;) \leq D \\ r_d \;, & Delay\;(path\;) > D \end{cases}$$

$$f_{pl} = \begin{cases} 1 & Pack\_Loss(path) \leq PL \\ r_{pl} & Pqck\_Loss(path) > PL \end{cases}$$

Where， ε is positive real coefficient; *A and B* are positive weight coefficient of f_d and f_{pl} respectively, which represent the proportion of delay and package loss rate in the fitness function separately, and their value are set by system according to actual application. f_d is a penalty function of delay measurement. If routing path satisfy restraint condition, f_d=1; otherwise, $f_d = r_d$ $(0 < r_d < 1)$. f_{pl} is a penalty function of package loss measurement. If routing path satisfy package loss restraint condition, f_{pl}=1; otherwise, $f_{pl} = r_{pl}$ $(0 < r_{pl} < 1)$. Obviously, the value of r_d and r_{pl} determine the punitive degree.

C. Crossing operator

Because the selection of crossing probability P_c directly influence algorithm's convergence, the determination the value of P_c is very important and inconvenient. In our algorithm, we adopt a method that P_c changes with the fitness value automatically. Supposed P_{c1} is maximum crossing probability of the individuality which fitness value is largest in populations, P_{c2} is minimum crossing probability of the individuality which fitness value is smallest in populations, the value of P_c is calculated by the following formula:

$$P_c = \begin{cases} P_{c1} - \dfrac{(P_{c1} - P_{c2})(f' - f_{avg})}{f_{\max} - f_{avg}} & f' \geq f_{avg} \\ P_{c1}\ , \quad f' < f_{avg} \end{cases} \tag{10}$$

D. Mutation operator

The purpose of mutation operation is to keep up population diversity and prevent solution process from falling into local optimum. The determining the value of mutation probability P_m is also inconvenient. In AGA-AR, we also use fitness value to change P_m. Supposed P_{m1} is maximum mutation probability of the individuality which fitness value is largest in populations, P_{m2} is minimum mutation probability of the individuality which fitness value is smallest in populations. The formula to calculate P_m is as follow:

$$P_m = \begin{cases} P_{m1} - \dfrac{(P_{m1} - P_{m2})(f_{\max} - f')}{f_{\max} - f_{avg}} & f' \geq f_{avg} \\ P_{m1}\ , \quad f' < f_{avg} \end{cases} \tag{11}$$

IV. ALGORITHM'S ANALYSIS AND EXPERIMENT

A. Complexity analysis

Supposed *maxgen* is maximum iteration number, *pop_size* is scale of population, *n* is total number of network. The complexity of our algorithm mainly depends on the depth-first search algorithm to generate primary population, crossing operation and mutation operation. The complexity of the depth-first search algorithm in graph is $O(n^2)$, the complexity of crossing and mutation operation is $O(maxgen \cdot pop\_size \cdot n^2)$. So complexity of our algorithm is $O(maxgen \cdot pop\_size \cdot n^2)$.

Obviously, complexity of our algorithm is close correlated to node number (n) of network.

B. Convergence analysis

We evaluated AGA-AR algorithm in Network Simulator (NS2). NS2 is a kind of very popular network simulator software on the network research and design[16]. But it lacks the ability to simulate anycast routing protocol. In experiment, we have extended the routing modules of NS2 using C++ and Otcl language, and added some modules to support anycast QoS routing.

Figure 1 shows the topology of the network. The node of network represents router or switching machine in actual network, and the random connection represents link in actual network. Link bandwidth capacity takes a random value in [40～80] , the each link delay is a value in [3~15] , each package loss rate is a value in [2~8], and , each cost is a value in [5～10].

Supposed *Pop_size*=20, *maxgen*=90, *Select*=0.55 (path selection factor), P_c=0.45, P_{c1}=0.9, P_{c2}=0.6, P_m=0.1, P_{m1}=0.1, P_{m2}=0.001, ε=0.1, $r_d = r_{pl}$=0.001. *S*={1, 2,3,10}, *G*(*A*)={6,16,27, 29}

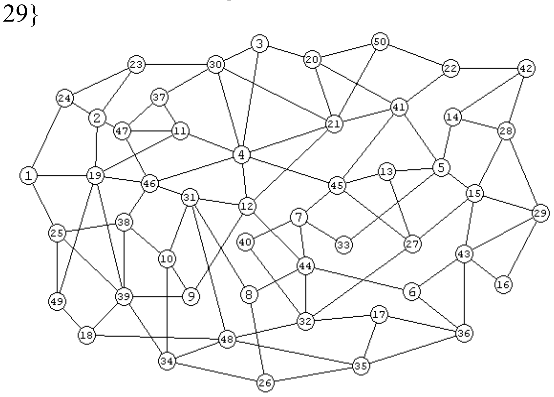

Fig 1. A network topology

Fig. 2 shows change situations in the path delay of different source node with the change of evolution number. Fig. 3 shows the path cost of different source node vs. evolution number. As seen at Fig. 2 and Fig. 3, the algorithm's convergence is very good, and the path cost reaches minimum value while guarantee delay constraint.

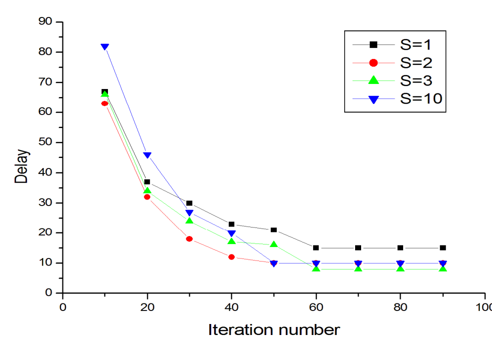

Figure 2. the path delay of different source node vs. iteration number

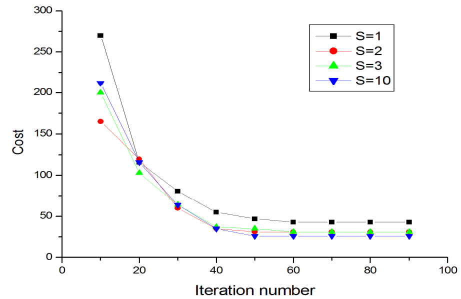

Figure 3. the path cost of different source node vs. iteration number

V. CONCLUSIONS

By analyzing the characters of anycast service, this paper presents an anycast routing model with multiple QoS constraints and a felicitous estimate function of the optimal route path. Based on this model, an anycast routing algorithm based adaptive genetic algorithm with QoS constraints is proposed. We analyze the complexity and performance of the AGA-AR by experiments. Under the conditions of larger scale of network, the AGA-AR converges to the global optimum in fewer generations and gets stuck at a local optimum fewer times. The results of experiment demonstrate that the AGA-AR is effective and available.

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