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Research of a Genetic Algorithm to Improve Performance for Multicast Routing

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***Abstract*—As for the performance, the problem of multicast routing question with multiple QoS restraint is a keynote. This paper provides and describes a network model and refined function, and it is fit for the research of real-time QoS under multi-cast routing. A QoS multicast trees algorithm, which is based on the improved Genetic Algorithm, will be discussed. This improved algorithm refines the multiple QoS parameter. The simulation result proved by this algorithm is with the ability of convergence, credibility. It can also fit for the real-time requirement of the multimedia network. Experiment result show the validation of this algorithm and it will improve the practical routing effect.**

Keywords—QoS; multicast routing; genetic algorithm; multimedia network

I. INTRODUCTION

IP multicast is information from the source node and is sent to a network of a plurality of destination nodes in the form of communication, which is a large number of business network in existence of point to multipoint communication needs of the inevitable result. Now many emerging multimedia services, such as video on demand, video conferencing, distributed database and so on, is not only related to multiple users, and for delay sensitive. In order to support the existence of a large number of such applications, delay constrained multicast routing algorithm becomes more and more important. This algorithm is to find a connection to the source node to the destination node of a minimum cost multicast tree, from a source node to a destination node delay does not exceed the given time limit. Routing has the advantages of information transmission along the tree, only in the tree branch office copy, in the path of the joint part can be shared bandwidth, thereby saving cyber source. Delay constrained multicast routing problem can be formulated as a constrained Steiner tree problem, this is a NP-Complete problem.

Kompella[2] provides a satisfying end-to-end delay constraint multicast routing heuristic algorithm. Its approach is, first of all ask any two nodes meet delay constrained minimum cost path, and then to the heuristic algorithm based on minimum spanning tree to generate routing tree. Since then, and many researchers put forward related heuristic algorithm. Including the Mehrdad Parsa[3] proposed BSMA algorithm, the idea is the first Dijkstra shortest path algorithm derived from the source node to the destination node delay the most short-circuit constitute a multicast tree, in does not violate the delay constraints, by replacing the high cost of the tree in which charge is reduced ceaselessly in the alternate side, use the K shortest path algorithm.

This algorithm to the multicast tree cost, average performance is only optimal solution is 7%, but the time complexity of the algorithm is very high, not used to solve large networks[4].CRA[5] algorithm similar to the Dijkstra shortest path algorithm, each selected by computing node to the source node with minimum cost and satisfies the delay constrained nodes connected to the tree. The algorithm complexity is low $O(n^2)$. But the resulting tree may not cover all of the destination node, the source node to the destination node even if the timing constraints path[5].

II. CONSTRAINED MULTICAST ROUTING

The genetic algorithm is put forward in recent years is a new optimization algorithm, it has a parallel search, finding excellent advantages of groups. It is widely used to solve the NP problem. For a multicast problems also exist, a solving method based on genetic algorithm.

Turner[5] proposed a general genetic algorithm, this algorithm uses the N x N one-dimensional binary encoding mechanism (where N is the number of network nodes), this encoding method is the algorithm code, the decoding process is complex, and the algorithm of the search space with the network scale increases dramatically increases, the efficiency of the algorithm is low.

Raymond[6] also put forward a kind of multicast genetic algorithm, but the algorithm is easy to fall into the premature convergence, the accuracy of the algorithm is not good. In this paper the characteristics of multicast routing problem, put forward a kind of genetic algorithm, algorithm using tree encoding mechanism, designed for solving the problems of crossover and mutation operation. All of these algorithms are all centralized algorithm, namely node must be stored the entire network topology, in order to determine the multicast routing.

Network with undirected simple graph representation $G = (V, E)$, where V represents a communication node, E represents the link, and in each link $(u, v) \in E$, we defines two parameters:

The link cost $c(u, v)$ and link delay $d(u, v)$.

$c(u, v)$ can be a link using a price or link some cyber source using state measure. $d(u, v)$ represents the time delay experienced by a packet over a link, Given a source node s and destination node set $D = \{d_1, d_2, \dots, d_k\}$.

Delay protocol for all destination nodes as Δ. Node s and a destination node set, as well as all destination nodes D delay delay constrained multicast routing algorithm agreed, to construct a tree root as the source node s, containing the destination node set D minimum cost ulticast tree T(T tree is a tree here cost of each edge of the whole cost requirements) leaf nodes of the tree for the purpose of node in the tree, and each destination node delay to satisfy the delay constraint Δ.

The destination node delay is defined along the multicast tree from the source node to the destination node in the path (denoted as P （s, d_i）) on each side of the total delay.

III. IMPROVED GENETIC ALGORITHM

A. Generation of Initial Population

In this algorithm, each individual (chromosome) is covered by the source node and the destination node set a sub-tree, namely individual using tree structure, genetic operation is a direct role in such individuals.

The utility model has the advantages of tree encoding makes genetic operation significance of intuitive, and without coding space and space conversion. Saving algorithm time. The individual is generated using random depth-first search algorithm, the basic approach is: starting from the source node, randomly select an associated with the nodes will be connected, two; and then choose from the node to randomly select associated with a node, in connection to determine if there is a loop, such as loop start node selection, doing so until the search to all destination nodes.

B. Fitness Function

The fitness function genetic algorithm is used to determine the individual quality standard, the algorithm of the individual is a covering of the source node and the destination node of the subtree, its cost is small, the better the performance of that tree.

Therefore its fitness should be higher, at the same time that the delay of the fitness values must be high. Therefore, the algorithm of setting the individual T fitness function:

$$\mathrm{f}(T) = \frac{1}{\sum_{e \in T} c(e) \times \delta} \tag{1}$$

$c(e)$ is the cost of edge e. For $\delta = \max_{i \in D} |\Delta - act_i|$, it is a destination node, Δ is the delay constraint value, act_i stands for located along the tree from the source node to the destination node d_i of the actual value of time delay. From the fitness function, tree cost less, fitness value will be larger, at the same time, when the individual goal node delay is small, fitness will be greater.

C. Selection Operator

Genetic algorithm based primarily on Darwin's natural selection process, therefore the selection intensity size plays a key role in. The steps of selection and the three factors, which is the sample space, sample selection mechanism and probability.

Sample space by a factor of two Description: size and element (parents or children) pop_size is the group size, and off_size stands for each generation of resulting offspring size. In the rule of the sample space, its size and equal to pop_size, contains the offspring individuals and a part of parent individuals. In increasing the sample space, its size is equal to $pop\_size + off\_size$, contain progeny and parent of all individuals. This paper uses the rule of the sample space.

From the choice of individual in the sample space, the algorithm utilizes roulette wheel selection method. Roulette wheel method is the most basic genetic algorithm selection method. In this method, each individual selection probability and its fitness value proportional to. Namely, f_i is the fitness for the individual i , its choice probability is P_i as:

$$P_i = f_i \Big/ \sum_{j=1}^{pop\_size} f_j \tag{2}$$

Probability p_i reflects the fitness of individuals i in the whole group of individual fitness sum in proportion, the expectations for the individual i is

$$e_i = pop\_size \times p_i \tag{3}$$

In addition algorithm also adopts the best individual preservation strategy, the basic idea is to group the highest individual fitness value does not cross directly copied to the next generation. The advantages of this method are, evolutionary process of a generation of optimal solution cannot be damaged by crossover and mutation operation.

D. Crossover Operation

The crossover operation refers to the two father individual portions of the structure to replace the reorganization and the generation of new individual operation. Through the cross, search ability of genetic algorithms to improvement.

Algorithm through the roulette random select crossover of two parent individuals T_m and T_f, with probability 1 cross after new individual T_0.

According to the characteristics, definition is fit for the problem of crossover operation, which adopts a local optimization idea. First of all, two parent generation of common boundary quilt generation inheritance. This is done by taking into account the parent shared edges should be on the optimal solution of larger contribution, this generation shall inherit. In the offspring inherit these edges, formed may be a disconnected graph. How to make the graph connectivity, generates a better performance of the individual, we draw lessons from the thought of literature6, the use of local optimization technique, the cross of the individual is contained to the and nodes of all possible subtrees in a performance the best subtree. Cross the approach is: first to be formed in the subgraph are classified. For convenient description.

Subgraph can be divided into 3 types:

- First type subgraph including the source node, recorded as G_s,
- Second types of sub graph including a destination node, if there are ksubgraph, they are recorded as $f_1, f_2 \cdots f_k$,
- Third type is that does not contain any destination nodes of the sub-graphs.

The subgraph is connected, the third types of deleted, because it does not contain the destination node. In order to carry out the subgraph is connected, on second types of sub graph to find its" leader" node, given below in" leader" node definition.

E. Leader Node

Assume f as mentioned in the second types of sub graph. For each node x in the definition of f , we define Leader node as:

$$delayslack(x) = \min_{y \in D}\{\Delta - D_f(x, y)\} \tag{4}$$

D is a destination node set, $D_f(x, y)$ stand for located along a subgraph of the path from node x to node y delay.

$delayslack(\ )$ is defined for each node the value, because if the subgraph f connected by the same subgraph G_s through node x , then the source node to the node of the maximum allowable delay $delayslack(x)$.

Call a node l for a subgraph f of the" leader" node, recorded as $l = leader(f)$.

If it satisfies:

$$delayslack(l) \leq delayslack(x), \forall x \in f \tag{5}$$

General note.

$$delayslack(f) = delayslack(leader(f))$$

For each subgraph$f_1, f_2, \cdots, f_k$ identified, $delayslack(f_i)$.

To calculate each subgraph f_i from a source node s to a node $leader(f_i)$ satisfies the time delay for the cost $delayslack(f_i)$, which is the shortest circuit with low cost, subgraph f_i is connected to G_s by the road $CR(s, leader(f_i), delayslack(f_i))$.

Seeking the source node $leader(f_i)$ to the node satisfies the time delay of the cost $delayslack(f_i)$, which is the shortest circuit is a delay constrained unicast problem.

Using DCUR algorithm[5] is solved. After this intersection operation after the new individual to ensure its cost is low, and as far as possible to meet the delay constraint. Here are the crossover operation process and DCUR algorithm simple description.

F. Crossover Process

Following is ready to calculate $delayslack(f_i)$ for each subgraph$f_1, f_2, \cdots, f_k$ $\ i = 1,2, \cdots, k$. If there exists a subgraph f_i , whose $delayslack(f_i)$ is less than 0, then the shortest path subgraph G_s and through time delay.

The remaining m subgraph, according to their values are arranged from small to large as $f_1, f_2, \cdots, f_m$ arranged by $delayslack(f_i)$, each subgraph operation repeat. Subgraph f_i identified routing $P = CR(s, leader(f_i), delayslack(f_i))$, determine the road and intersection w of P and G_s, subgraph f_i and G_s connected.

The starting point w for the road P and the subgraph f_i, connection, there are two cases:

Situation1: 1 road P and subgraph f_i connected, without any other subgraph intersect, then the subgraph f_i and G_s directly connected, form new G_s, as shown in figure 1;

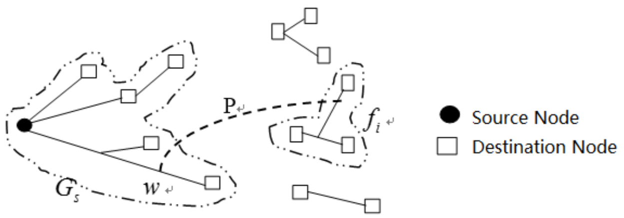

FIGURE I. USE CASE FOR CROSSOVER OPERATION SITUATION 1

Situation2: Road P and subgraph f_i connected, if the P first and another subgraph $f_l (i \neq l)$ intersect, then through the first subgraph is connected. The P and subgraph f_l form new G_s, and then with the other subgraph.

As shown in figure 2. By definition $delayslack(f_i)$, and connected subgraphs f_l and G_s, each node in f_l delay timing constraints. The DCUR algorithm is used to seek from the source node s to the specified node d satisfies the time delay Δ of the cost of the most short-circuit, the procedure is as follows: If DCUR algorithm begins, from the source node s to d delay the shortest path (LD) of the total delay Δ is less than one, indicating the existence of a certain delay path.

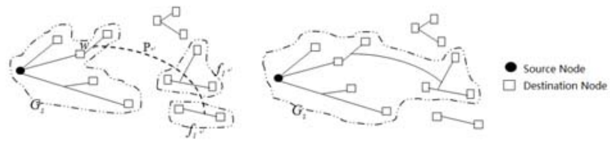

FIGURE II. USE CASE FOR CROSSOVER OPERATION SITUATION2

When the algorithm to the node v, DCUR computing path has been established on the value of time delay $delay(s, v)$. And records from the v to d cost shortest path (LC) on the next node v_LC_next.

Then calculated from v_LC_next to d from the LD delay value $LD(v\_LC\_next, d)$, judgement.

$$delay(s, v) + delay(v, v\_LC\_next) + LD(v\_LC\_next, d) \leq \Delta \tag{6}$$

If the inequality holds, then the node is added v_LC_next to the already established part way.

If inequality does not hold, then the selected nodes v_LD_next, this process has been advanced to the node d.

The complexity of algorithm (for the number of network nodes) is $O(n^2)$.

G. Mutation Operation

The mutation operation to keep the diversity of the population, to avoid falling into local optimal solution. Mutation mode is as follows: first randomly choose the variability of the individual, random deletion of the tree and find some boundary.

No connected graph of each sub graph, then randomly selected in other side will form the connected graph to a tree.

IV. Algorithm analysis

A. Convergence Analysis

The proposed algorithm can converge to the global optimal solution. Because of this genetic algorithm adopted the following strategies:

1) With probability 1 for crossover operation mutation probability;

2) Mutation probability $P_m \in (0,1)$;

3) According to the proportion of choice and in the choice of preserved before the best individual.

Samline3 proposed that satisfy the theorem 2.7 three a condition of genetic algorithm can converge to the optimal solution.

But in the actual solution, and the global optimal solution of the time complexity of this algorithm. By limiting the total number of iterations, find out a better feasible solution.

B. Complexity Analysis

From the description of the algorithm, the complexity of the algorithm is composed of several main operation decision. They are named as: the initial individual tree depth-first search algorithm, crossover operation and correction process.

Map the depth-first search algorithm complexity $O(n^2)$, it is only in the initial population. Cross coupled to DCUR algorithm, its complexity is $O(n^2)$.

Therefore the complexity of the algorithm $O(gen * pop\_size * n^2)$, gen is the total number of iterations, pop_size as the population size; n as the number of network nodes.

C. Generation of Initial Population

Simulation of networks generated by the method proposed by Waxman4, it can generate random practical characteristics of network chart, it has been used by many researchers.

The method is as follows: a network node N within a certain area of randomly generated, network node distance using Euler distance between any two nodes. And edges between nodes i and j, according to the distance between the according to a certain probability of generating.

Edge probability is generated by the following formula:

$$P(\{i,j\}) = \beta exp\frac{-d(i,j)}{\alpha L} \tag{7}$$

$d(i,j)$ is determined and the distance between i and j.

L is the maximum distance between points, α and β is the values of parameters (0,1].

When β increasing, network edge density increases. When α the reduction, network distance small side relative to the distance from the edge of the density increases. Network side price equal to the distance between the network nodes. Edges of the delay is equal to the distance between nodes 0 and 1 multiplied by a random number between.

This delay and the cost is positive, to guarantee that the generated network connect. By adjusting the parameters for α and β the distance, small edges being greater than the probability of the long side of the probability of the existence of. And the average degree of the nodes of the graph is 2 to 4, because these two features are the actual network should have.

Through the simulation of the main two aspects on algorithm performance analysis:

The convergence of the algorithm is analyzed;

Algorithm to obtain the multicast tree cost performance analysis.

Our genetic algorithm simulation, using KMB algorithm as a basis for comparison. Genetic algorithm and KMB algorithm in different delay conditions were compared.

The KMB algorithm is to solve the unconstrained Steiner tree problem is a famous algorithm. Its average performance compared to other similar algorithms is better, for the optimal solution of the 105% .

Because KMB algorithm does not consider the delay constraint, we get the multicast tree cost less than genetic algorithm to get the multicast tree. But the average performance of KMB algorithm, this algorithm and compare. A parameter r_A used in simulation, as

$$r_A = \frac{1}{M}\sum_{i=1}^{M}\frac{c(T_{GA})}{c(T_{KMB})} \tag{8}$$

$c(T_{GA})$ expresses the use of genetic algorithms to obtain the multicast tree cost, M as the number of experiments.

V. System Simulation

A. Convergence Analysis

Figure 3, 4, 5 and 6 gives the algorithm in reference [7] presents examples of experimental results. In the number of nodes is 18 network (Figure 7), figure 7 block is representative of the source node.

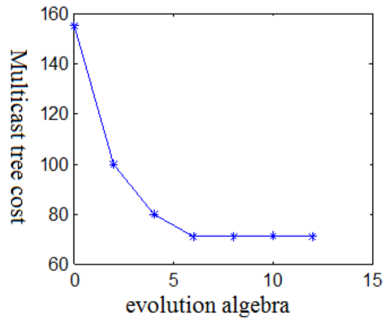

FIGURE III. CONVERGENCE OF COST VARIATION WITH EVOLUTION ALGEBRA FOR Δ=25

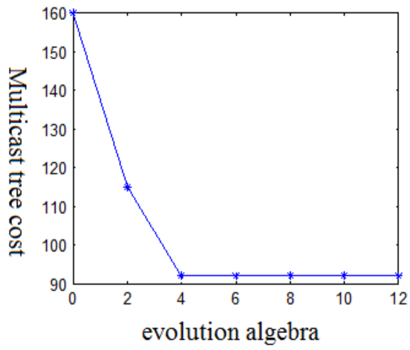

FIGURE IV. CHANGES IN COST WITH EVOLUTION ALGEBRA FOR Δ=9

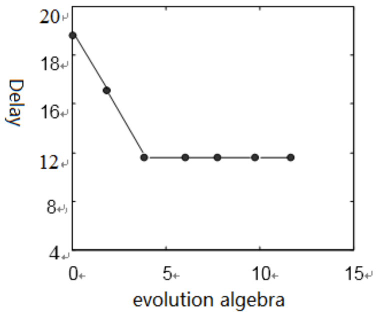

FIGURE V. THE CHANGE OF TIME DELAY WITH EVOLUTION ALGEBRA FOR Δ=25

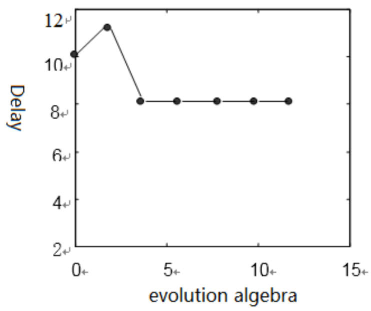

FIGURE VI. THE CHANGE OF TIME DELAY WITH EVOLUTION ALGEBRA FOR Δ=9

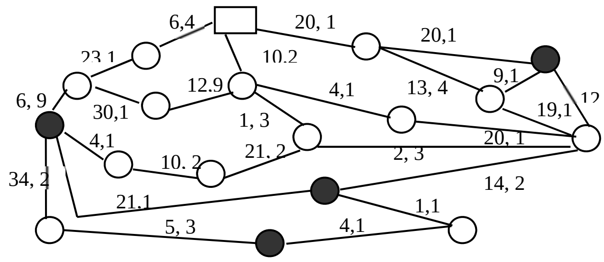

FIGURE VII. GRAPH FOR 18 NODES

The black box represents the destination node, on the edge of the values for the edge cost and time delay. For different delay constrained convergence condition, can see, the genetic algorithm converges very fast. In this simulation, the initial population size pop_size is set to 10, the mutation probability is 0.01, number of generation is 30.

B. Cost and Performance

In the following experiments, we will genetic algorithm with KMB algorithm in different delay time constraints are compared. The delay constraint is from the source node to the destination node of the shortest path in the maximum delay, the genetic algorithm and KMB algorithm compared with the proportional coefficient using r_{GA-0};

Secondly, the delay constraint check for the KMB algorithm to obtain the multicast tree all destination nodes to delay the maximum, while the two algorithm corresponds to the proportion coefficient of third kinds of representation r_{GA-1};

Delay constraint is set in front of two kinds of delay constrained average value, in this case, the proportion coefficient is$r_{GA-1/2}$.

In the experiment, the genetic algorithm parameter settings: initial population size pop_size of 80, mutation probability is 0.01, number of generation is 200. M As of 200.

Figure 8 algorithm in networks with different scales and KMB algorithm is compared with the results of the simulation, in order to discuss the algorithm by network size influence n.

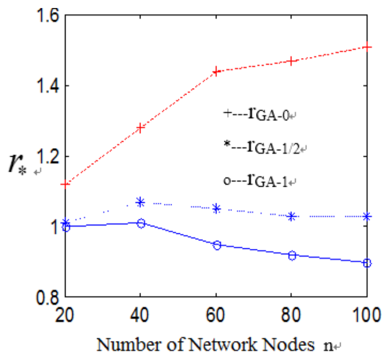

FIGURE VIII. GENETIC ALGORITHM PERFORMANCE EFFECT ON N NETWORK NODES

At the destination node number m is the number of network nodes 15%, figure 9 presents the algorithm in the destination node number changes, with the KMB algorithm comparison results. In this experiment, network size remained unchanged, set of 80.

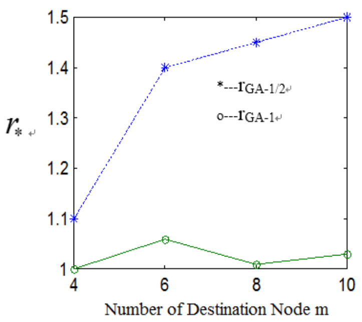

FIGURE IX. GENETIC ALGORITHM PERFORMANCE EFFECT ON M DESTIONATION NODES

The experimental results show that the genetic algorithm in network scale, change and the destination node number changes, genetic algorithm and KMB algorithm ratio remained at less than 1.6, which indicates that the genetic algorithm the average performance is good.

Especially in the delay constraint set up for the KMB algorithm to get the multicast tree all destination nodes delay maximum, from Figure 8 and figure 9 can be seen in the genetic algorithm and KMB algorithm to get the similar cost multicast tree.

Because the KMB algorithm performance is no constraint multicast routing algorithm with good performance is a, therefore results may indicate genetic algorithm to seek the good performance of the multicast tree, and the algorithm is very stable, the average performance.

VI. Conclusions

Based on the delay constrained multicast routing problem undertook study, put forward a kind of high performance multicast routing algorithm, using the genetic algorithm to solve the problem. Algorithm for individual use tree coding, each individual directly corresponding to figure in a sub-tree, crossover and mutation operators directly on such subtrees are optimized. In order to get better performance individual, crossover design incorporating local optimization idea, and combined with heuristic algorithm. Experimental results show that the genetic algorithm has good performance, and stable.

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