Routing method of quantum genetic algorithm

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Abstract

Quantum genetic algorithm was applied in the work to solve multiple-QoS routing problems of bandwidth-delay constraint, thus meeting current requirements for multimedia messaging. Mathematical model and constraint condition of QoS routing were established, analysing algorithms principles and steps that how quantum genetic algorithm optimized QoS routing. By comparing average fitness and maximum polymerization fitness under different running times, quantum genetic algorithm can effectively find optimal solutions to multiple-QoS routing problem.

Keywords: genetic algorithm, quantum genetic algorithm, mathematical model, route choice, fitness

1 Introduction

Quantum genetic algorithm is a probability evolutionary algorithm with combination of quantum computing and genetic algorithm. State vector expression of quantum was introduced to genetic code, using quantum logic gates for chromosomal evolution, achieving better results than genetic algorithm. Therefore, there are important theoretical and practical values in solving practical problems with quantum genetic algorithm. QoS routing involves multi-objective optimization problems, thus the selection of appropriate algorithm has critical influence on the control of network bandwidth, delay and cost [1-3].

2 Quantum genetic algorithm

2.1 QUANTUM BIT ENCODING

A two-state quantum system, acted as an information storage unit in quantum computer, was called quantum bit. Quantum bit or qubit is the smallest information unit in quantum computing. A quantum bit has three states, namely $|0>$ state, $|1>$ state, and superposition state between $|0>$ and $|1>$. Therefore, the state of any quantum bits can be described as [4]:

$$|\varphi>=\alpha|0>\beta|1>,$$

where α, β are called probability amplitude of corresponding state of quantum bits, satisfying the normalization condition:

$$|\alpha|^2+|\beta|^2=1.$$

2.2 QUANTUM GATE RENEWAL

As the executing agency of evolution operations, quantum gates are selected according to specific issues. Quantum Rotating Gate was chosen in the work, with the following adjusted operation:

$$U(\theta_i)=\begin{bmatrix}\cos(\theta_i) & -\sin(\theta_i)\\ \sin(\theta_i) & \cos(\theta_i)\end{bmatrix}. \quad (1)$$

Renewal process is as follows:

$$\begin{bmatrix}\alpha_i^{'}\\ \beta_i^{'}\end{bmatrix}=U(\theta_i)\begin{bmatrix}\alpha_i\\ \beta_i\end{bmatrix}=\begin{bmatrix}\cos(\theta_i) & -\sin(\theta_i)\\ \sin(\theta_i) & \cos(\theta_i)\end{bmatrix}\begin{bmatrix}\alpha_i\\ \beta_i\end{bmatrix}. \quad (2)$$

From Equation (2) we can obtain:

$$\begin{cases}\alpha_i^{'}=\alpha_i\cos(\theta_i)-\beta_i\sin(\theta_i)\\ \beta_i^{'}=\alpha_i\sin(\theta_i)+\beta_i\cos(\theta_i)\end{cases}. \quad (3)$$

Therefore,

$$|\alpha_i^{'}|^2+|\beta_i^{'}|^2=[\alpha_i\cos(\theta_i)-\beta_i\sin(\theta_i)]^2+ \\ [\alpha_i\sin(\theta_i)+\beta_i\cos(\theta_i)]^2=|\alpha_i|^2+|\beta_i|^2=1. \quad (4)$$

Then it can be transformed as:

$$|\alpha_i^{'}|^2+|\beta_i^{'}|^2=1. \quad (5)$$

3 Qos routing problem

Currently, Internet network mostly adopts *best – effort* routing protocol with the shortest-path routing strategy, thus the requirements cannot be satisfied for receiving and transmitting multimedia information. From network users' perspective, QoS (Quality of Service) routing algorithm should firstly meet users' QoS request, namely finding a

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transmission path corresponding to various conditions from source node to destination node. From facilitators' perspective, the use of network resources can be optimized through QoS routing algorithm [5, 6].

Users' Qos is decided by various parameters of network. QoS defined by RFC2216 refers to packet transmission characteristics described through parameters of bandwidth, delay, delay jitter and packet loss rate. Only by meeting users' requirements of QoS parameters can network reach the required services quality of network.

Typically, the topology and link state information of network can be abstracted as a weighted graph $G(V,E)$ in Figure 1 [7]:

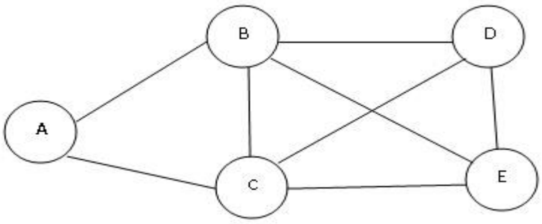


FIGURE 1 Network topology diagram of QoS routing

Vertices in Figure 1 represented network nodes; edges referred to network links; $V=(V_1,V_2,...,V_n)$ was the set of all switching nodes of router; $E=(E_1,E_2,...,E_n)$ indicated the link set connecting routers. QoS routing selection was to find the route satisfying requirements of network QoS from Figure 1.

4 QoS routing based on quantum genetic algorithm

4.1 MATHEMATICAL MODEL OF QOS ROUTING

A mathematical model of QoS routing should be established for better analysis and solutions of problems. A,B,C,D,E in Figure 1 represented the routes, while ligatures between two routes were pathways of routes. Each link was expressed with cost, width and delay, respectively.

Based on above analysis, issues of cost, bandwidth and delay are key factors affecting QoS routing. Not all factors should be considered in design of specific routing algorithm, because too complex algorithm will affect actual application of algorithm. Therefore, appropriate algorithms should be designed for different practical needs, dealing with different constraints [8-10].

For any links, (a,b) and $D(a,b)$ expressed the delay of link generation; $B(a,b)$ represented available bandwidth of the link; $C(a,b)$ was the cost of communication process.

Assuming the delay of path between u,v is:

$$delay(u,v)=\sum_{(a,b)\in P(a,b)} D(a,b)\,. \tag{6}$$

Available bandwidth of $P(u,v)$ is:

$$width(u,v)=\min_{(a,b)\in P(u,v)} B(a,b)\,. \tag{7}$$

The cost of $P(u,v)$ in communication process is:

$$\cos t(u,v)=\sum_{(a,b)\in P(a,b)} C(a,b)\,. \tag{8}$$

The mathematical model of QoS routing can be implied from Equations (6), (7) and (8), as well as constraint condition of QoS routing. The mathematical model is as follows:

Objective function:

$$\cos t(T)=\min(\sum_{(a,b)\in Er} C(a,b))\,. \tag{9}$$

Constraint condition:

$$\begin{aligned}&\forall v\in M,\ \sum_{(a,b)\in P_T(u,v)} D(a,b)\le D_{\max}\\&\forall v\in M, Width(P_T(s,v))\ge W_{\min}\end{aligned}\,. \tag{10}$$

4.2 ALGORITHM FLOW OF QOS ROUTING BASED ON QUANTUM GENETIC ALGORITHM

Based on principles of quantum genetic algorithm and the mathematical model of QoS routing, algorithm flow of the work is as follows:

1) Initialize population $Q(t_0)$, and randomly generate n chromosomes encoded with quantum bits;

2) Measure each individual of the initial population $Q(t_0)$ to obtain corresponding definite solutions;

3) Evaluate the fitness of each definite solution;

Fitness function:

$$\cos t(T)=\min(\sum_{(a,b)\in Er} C(a,b))\,. \tag{11}$$

In the Equation, $C(a,b)$ represented the required cost of passing links in communication process. The smaller of fitness function value, the lower of communication cost.

4) Record optimal individual and corresponding fitness;

x_i was the i-th place of current chromosome; $best_i$ the i-th place of optimal chromosome; $f(x)$ fitness function; $s(\alpha_i,\beta_i)$ rotation angle direction; $\Delta\theta_i$ rotation angle size.

The calculated fitness $f(x)$ was compared with $f(best_i)$ - the fitness of current optimal individual in its population $f(best_i)$. If $f(x)>f(best_i)$, then the corresponding quantum bits should be adjusted, making probability amplitude (α_i,β_i) evolve toward the direction conductive to emergence of x_i. If $f(x)>f(best_i)$, then probability amplitude (α_i, β_i) should evolve toward the direction conductive to emergence of $f(best_i)$.

5) Determine whether the calculation process can be completed: exit if the end conditions were met, or continue calculation;

6) Measure each individual of population $Q(t)$, and obtain corresponding definite solutions;

7) Evaluate the fitness of each definite solution;

8) Adjust individuals with quantum revolving gat $U(t)$, and obtain new population $Q(t+1)$;

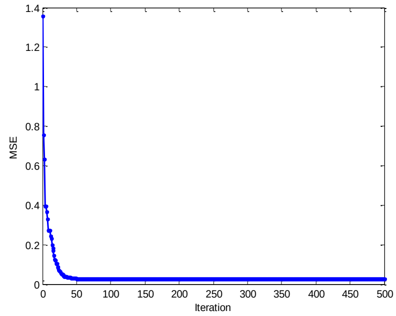
9) Record optimal individual and corresponding fitness;

10) Return to Step 5) with iterations $t = t+1$.

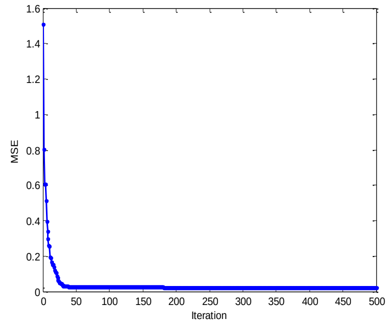
5 Simulation analysis

In order to verify the validity and effectiveness of the algorithm, corresponding parameters should be set as follows. Maximum genetic algebra: 500; population size: 40; maximum delay constraints: $D_m = 10$; minimum bandwidth constraints: $W_m = 100$; crossover probability: $p_c = 0.3$; mutation probability $p_m = 0.15$; passed path: $num\,\mathrm{var} = 8$.

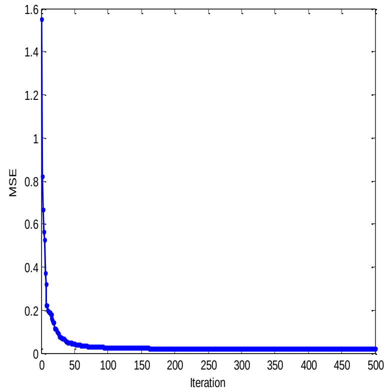
Convergent graph of different running times was shown in Figure 2:



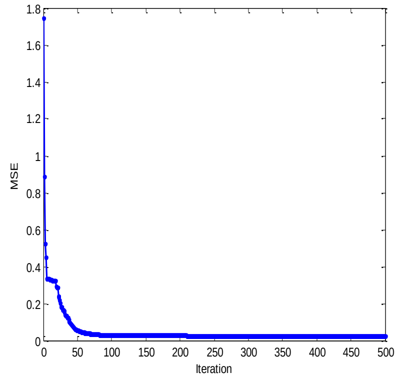
a) 1 running time



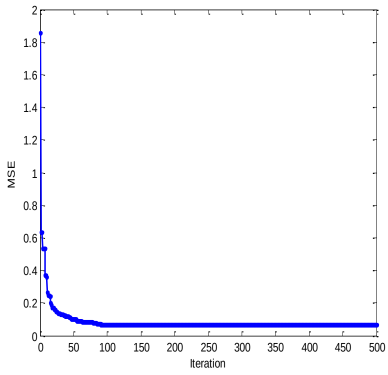
b) 5 running times



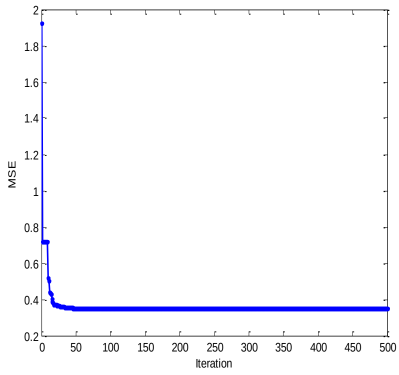
a) 10 running times



b) 20 running times



a) 25 running times



b) 50 running times

FIGURE 2 Convergent graph of different running time

Simulation results were shown in Table 1:

TABLE 1 Optimization results of fitness function

Running times	Average fitness	Maximum polymerization fitness
1	11.2616	0.1848
5	10.7399	0.1872
10	10.5234	0.1895
20	10.1735	0.1935
25	9.6875	0.1957
50	9.3012	0.1984

Table 1 showed that average fitness value presented a decreasing trend with increase of running times. The required cost of individuals continued decreasing, while maximum polymerization fitness value showed an increasing trend with increase of running times. This indicated that individuals' fitness more and more adapted to required conditions of specific issues. Meanwhile, better results could be obtained through running times of quantum genetic algorithm.

6 Conclusions

In the work, quantum genetic algorithm—integrating principles of quantum computing with genetic algorithm—was applied to QoS routing. Objective function and constraint condition were determined by constructing a mathematical model of QoS routing. Then, simulation solving was conducted in accordance with the principles and steps of the algorithm in the work. Simulation results showed that individual required cost presented a decline trend with increase of running times; individual fitness showed a rising trend with the increased of running times. Therefore, better results can be obtained with multiple running times of quantum genetic algorithm.

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