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Quality of Service Multicast Routing in Ad-Hoc Networks Based on Genetic Particle Swarm Optimization Algorithm

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Abstract. *With a large number of emerging multimedia in high-speed networks, multicast has become one of the key technologies for the Ad Hoc network to support multimedia services. Aiming to overcome the drawback of slow convergence and premature to solve Quality of Service multicast routing problems in the existing genetic algorithms (GA), and on the basis of the core ideas of particle swarm optimization algorithm (PSO) and GA, this paper combines the two algorithms and proposes a genetic particle swarm optimization algorithm(GPSO) basing on the improved particle swarm optimization algorithm as the mainline, and the mutation idea of GA to avoid the algorithm from falling into local optimality. In the establishing and maintaining of ad-hoc network multicast process, the proposed algorithm is implemented to accelerates the convergence speed of the GA and enhancing the ability to avoid premature maturity. Finally, simulation experiments prove that the GPSO algorithm can accelerates the convergence speed significantly and enhances the ability to avoid premature maturity in solving the QoS multicast routing problem of Ad Hoc networks.*

Keywords: *Ad-Hoc Network; Quality of Service; Multicast Routing; Genetic Algorithm; Particle Swarm Optimization Algorithm.*

1. INTRODUCTION

Ad Hoc is a multi-hop system consisting of a mobile routing and forwarding system with a collection of mobile nodes. The network nodes movement makes the network topology constantly change, the bandwidth and energy of the nodes are limited. Therefore, The quality of service multi-cast routing protocol for wired network design is no longer applicable. How to design a multicast routing protocol that satisfies multiple quality of service constraints has become one of the keys and difficult points in the research of Ad Hoc networks [1].

Due to the dynamic change of the Ad Hoc network topology, finding a path that meets the QoS requirements becomes a multi-constrained NP problem. Nowadays, particle swarm algorithm is commonly used to solve this multi-constrained NP problem [2]. Compared with genetic algorithm and ant colony algorithm, The idea of particle swarm algorithm is simple, with few parameters, easier to improve, and can better meet actual needs.

Genetic algorithms have been widely used in recent years, but most of them use standard genetic algorithms, and seldom used hybrid genetic algorithm in solving QoS multicast routing problem. The algorithm proposed in literature [3] is easy to "premature", and no measures are given to suppress the phenomenon of "premature". The initial population in literature [4] and [5] adopts randomized, in this way, the fitness value produced is not very ideal, and the close relative combination between the better evolutionary chromosomes loses the sign of group diversity.

In recent years, many researches have merged GA and PSO to form a hybrid algorithm. There are three hybrid forms. First, maintain the independence of PSO and GA, divide the sample set into multiple subgroups, and perform genetic algorithm and particle swarm respectively. The algorithm compares the optimal fitness value to obtain the global optimal fitness value and samples; second, the genetic operator will be introduced into the fourth of the particle swarm algorithm, using cross search and adjusting the inertia weight, after the evolution to a certain degree, the partial the particles undergo mutation processing to solve the non-linear and multi-extreme problem in engineering problems; third, after all individuals in the population undergo PSO smaller algebraic evolution, select the best particles for genetic replacement, The initial population of GA is generated by the optimal individual in PSO. After genetic manipulation, the speed and position of the individual are updated by PSO to achieve two information exchanges [6–8].

With the increasing application of mobile ad-hoc networks, the distribution in addition to the multicast capability of the network, the real-time application also requires service quality assurance, such as ensuring a certain bandwidth requirement, meeting end-to-end delay, and minimizing communication costs, and other optimal routing schemes under different quality of service constraints [9]. This puts forward new requirements for the application of mobile Ad Hoc networks, that is, to have multiple quality of service constraints.

Literature [10] proves that quality of service multicast routing problems based on multiple irrelevant addable metrics are NP-complete problems. Generally speaking, The solution to this problem uses heuristic algorithms, but due to the large computational cost of the algorithm, it cannot be applied to large-scale networks. Researchers have explored the introduction of intelligent algorithms into the solution of the quality of service multicast routing problem in wireless networks. Literatures [11,12] respectively proposed the quality of service multi-cast routing problem of wireless network basing on GA and ant colony algorithm, and achieved good convergence, but due to the low initial pheromone of ant colony algorithm and the premature phenomenon of GA, Which affects the selection of the optimal path for the convergence speed of the routing algorithm. Literature [13] proposes A hybrid ant-colony algorithm to solve the wireless network multi-cast routing problem. The algorithm combines the ant-colony algorithm with the GA, uses the GA for generating the pheromone distribution, and then uses the ant-colony algorithm for finding the global optimal solution, which can effectively improve the search and the speed of the shortest route. Literature [14] combined chaos and GA to optimize the wired network multicast routing, which effectively overcomes the premature problem. literature [15] proposing a quality of service routing algorithm basing on a GA. Literature [16] uses different coding methods and proposes a particle swarm-based quality of service routing algorithm. However, various algorithms themselves have certain Advantages and disadvantages, for example, the PSO has the advantages of few setting parameters, fast speed calculation, simple and easy implementation, but it is easy to be *trapped* into local optimal solution in the later stage of evolution, and the GA has the characteristics of large search range and parallelism. The algorithm is relatively complex and the search speed is slow [17]. Therefore, many researchers have begun to combine different intelligent algorithms and achieved good results. This paper proposes a kind of ad-hoc network quality of service multi-cast routing algorithm by combining the characteristics of PSO and GA and proposes a fusion based on PSO and GA, the algorithm makes full use of the rapidity and global convergence of PSO to accelerate the GA in route discovery and maintenance. The mixed algorithm has the following characteristics: 1)While improving the genetic operator, the PSO idea is applied to the mutation operation; 2)In the mixing process, the information is transmitted, and the speed and location of the individuals who are not selected for mutation are updated again to further the individuals, the perfection and maturity.

2. QUALITY OF SERVICE MULTI-CAST ROUTING PROBLEM MATHEMATICAL MODEL

The quality of service multi-cast routing problem is usually described as a directed graph G (V, E) where V represents set of network nodes, while E represents set of two-way link, and s ∈ V is the multi-cast source point. , M ⊆ {V. {s}} is the set of multicast endpoints, R represents positive real numbers. For every link e ∈ E, define three metrics which are: delay(e): E >R, cost (e): E >R and bandwidth(e): E > R. For any network node n ∈ V, two metrics were defined, namely delay (n): V >R and packet_loss(n) :V >R. Then for a given source point s ∈ V, the multi-castTree T(s, M) consists of the destination set M, s, and M has below relationship [18]:

1) $delay(pT(s,t)) = \sum_{e \in PT(s,t)} delay(e) + \sum_{e \in PT(s,t)} delay(n)$ *(1)*

2) $cost(T(s,M)) = \sum_{e \in T(s,M)} cost(e)$ *(2)*

3) $bandwidth(pT(s,t)) = \min(bandwidth(e), e \in pT(s,t))$ *(3)*

4) $packet\_loss(pT(s,t)) = 1 - \prod_{n \in PT(s,t)} (1 - packet\ loss(n))$ *(4)*

In which, pT (s,t) is the routing path from source point s to destination point t on the multi-castTree T(s, M).

The consequence for Quality of Service multi-cast routing is to found a T(s, M) that satisfy:

1) Delay constraints: delay (pT (s,t)) ≤ D
2) Bandwidth constraints : bandwidth (pT (s,t)) ≥ B
3) Packet loss constraints : packet_loss (pT (s,t)) ≤ PL
4) In all multicast trees that satisfy the conditions (1 to 4), cost T(s, M) is the smallest.

Where, B represents bandwidth constraint, D, PL is the bundles of the multicast endpoint delay and packet loss rate respectively. In this paper, it is assumed that all the multicast endpoint constraints are the same.

3. GENETIC PARTICLE SWARM OPTIMIZATION ALGORITHM DESCRIPTION

Particle Swarm Optimization (PSO) is a new evolutionary algorithm proposed by Kennedy and Eherhaet in 1995. The algorithm is based on the concept of population and fitness. Each particle represents a candidate solution in the solution space and has a position and a velocity. The algorithm starts with a group of randomly initialized particles. Through the selection of generations, the position and speed are constantly updated for optimization.

The performance evaluation of each particle is based on the fitness function. Each particle has a memory, which can retain the current individual best position (pbest) of the particle and the current best position (gbest) of the group. After finding these two optimal solutions, the speed and position of the particles will be updated according to equations (5) and (6) [19]:

$$vc_{i+1} = w * vc_i + Le1 * rand1 * (pbest)-p_i) + Le2 * rand2 * (gbest-p_i) \quad (5)$$

$$p_{i+1} = p_i + vc_{i+1} \quad (6)$$

Where vc_{i+1} represent the velocity of the current particle, vc_i represent the velocity of the previous generation particle, p_{i+1} is the position of the current particle, p_i is the position of the previous generation particle, and w is the inertial weighting coefficient for balancing the capabilities of local and global search of the algorithm. rand1and rand2 are random numbers between (0,1). Le1 and Le2 are learning factors, usually Le1 = Le2 = 2. On the other hand, the (GA) adopts the evolutionary principle based on the survival of the fittest. The algorithm randomly generates an initial population, and each individual in the population is termed as a chromosome. The algorithm repeatedly uses basic GA operations such as selection, duplication, crossover, and mutation for the chromosomes that contain possible solutions. The fitness function is used to evaluate and select each individual, and then the method of crossover and mutation is used to continuously generate a new generation of individuals so that the individuals continue to evolve toward the objective function (fitness function), and so on until the convergence condition or the number of iterations is met. Mutation operation is a remarkable feature of a GA, which can expand the algorithm search space and avoid falling in the local optimal solution. According to the respective characteristics of the algorithm, the advantages of particle swarm optimization algorithm and GA are combined to form a hybrid algorithm. This paper draws on the mutation idea of a GA and introduces adaptive mutation operators in PSO algorithm to generate new individuals. Effectively avoid the algorithm from falling into the local optimal solution too early.

4. *GPSO ALGORITHM IMPLEMENTATION PROCESS*

4.1. PARTICLE CODING

Adopt the way of path sequence number coding, First, number the nodes in the network, where Node = [1,2,...,n], in which, n represents the number of network nodes. The individual particles in the group represent the slave source node. A route to the destination node is represented by d. Second, the initial path is generated by the depth-first search algorithm. For example, p = [3,5,4,6,8] represents a path from node 3 to node 8, and passes through node 5,4,6.

4.2. PARTICLE MOTION

The quality of service *path optimization problem is a typical discrete problem, and the typical PSO evolution equation is suitable for continuous functions, so it cannot be used directly. This algorithm uses particle crossover to replace equations (5), (6). The specific implementation method is that the individual particle updates the particle by learning the particle's individual extreme value and the partial fragment of the extreme value of the particle group by First, randomly select two positions in the individual extreme value or the group extreme value (start node and the destination node are not including the path). Second,* *combine the path segment between these two positions with the current particle. The specific operation method is to find the first and last nodes of the optimized path segment by:*

(1) *If the first and last nodes exist in the current particle at the same time, directly replace it with the optimized segment (The fragment in the particle).*

(2) *If the start node of the optimized path fragment is in the current particle, insert the optimized fragment into the current particle, and then search for a path from the optimized fragment end node to the destination node.*

(3) *If the optimized path segment is in the current particle, insert the optimized segment into the current particle, and then search for the path from the start node of the optimized segment to the source node.*

(4) *If the left and right nodes of the segment are not in the current particle, give up learning and wait for the next step.*

4.3. MUTATION OPERATION

To avoid particle swarm optimization algorithm from falling into the local optimum, the mutation operation can be introduced by referring to the idea of a GA. The mutation method can expand the search range of particles. In this paper, the adaptive mutation is used and the mutation probability pm is given by:

$$Pm = 1 - \frac{1}{1+e^{-k\Delta}} \qquad (7)$$

Where, $k > 0$, $\Delta = f_{max} - f_{avg}$, *and* f_{max} *represents the fitness value of the global optimal particle for this round of selection.* f_{avg} *is the average value of those points in the particle where the fitness value is better than the average value. The specific method of performing mutation operation on particles is to randomly select two positions of the particles (excluding the source node and destination node).*

4.4. GENETIC PARTICLE SWARM OPTIMIZATION ALGORITHM FLOWCHART

Figure (1) shows the overall framework flowchart of the GPSO algorithm.

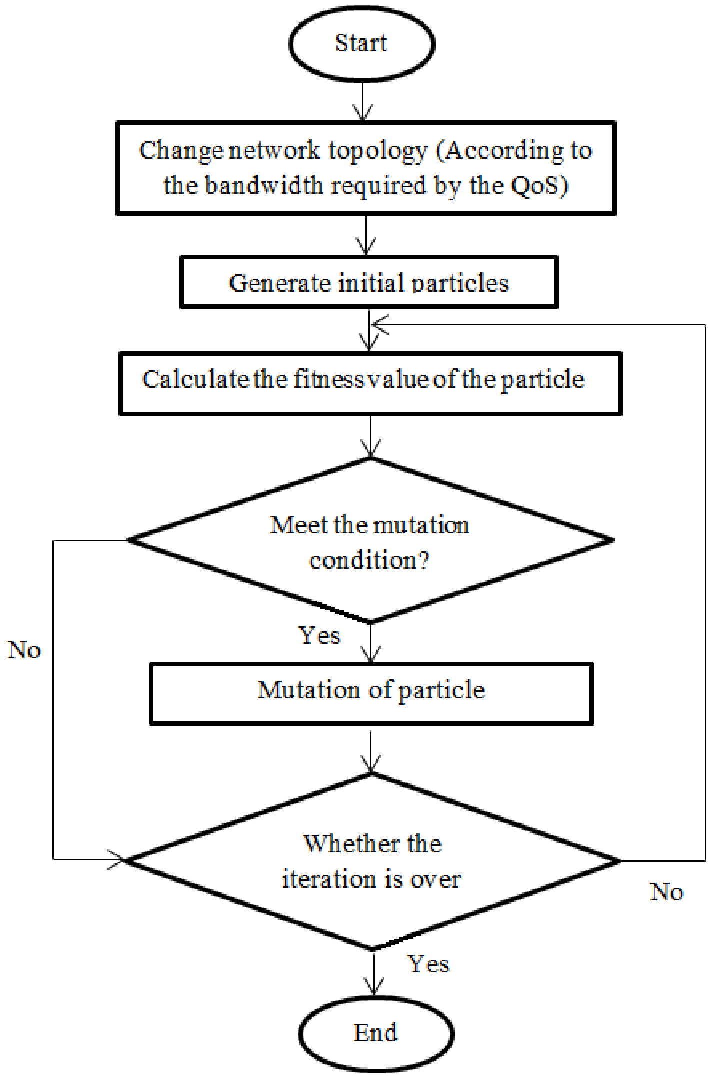

Fig. 1. Flowchart of GPSO algorithm

4.5. ALGORITHM STEPS

1) *Read the network parameters to form an adjacency matrix G.*
2) *According to the bandwidth required by QoS, delete links that do not meet the bandwidth requirements to form a simplified adjacency matrix G.*
3) *Randomly use a depth-first search algorithm Generate several paths as initial particles.*
4) *Calculate the fitness value of the particles to find the individual optimal and group optimal particles.*
5) *Update the particles according to the method described in section 4.2.*
6) *If the variation is satisfied and conditions are met, the particle will be mutated once.*
7) *Return to step 4 to continue updating until reaching the convergence accuracy or reach the maximum number of iterations*

8) *Return to the optimal path found by the algorithm. Figure 1 shows the overall framework flow chart of the algorithm.*

5. *SIMULATION RESULT AND ANALYSIS*

To study the multicast routing performance of GPSO algorithm in mobile Ad Hoc networks, a Matlab programming platform is used for verification. A network simulation diagram is randomly generated: a network of 15 nodes can select the source node and the destination node, randomly change the delay constraint D of the destination node, bandwidth constraint B, and packet loss rate PL. Assuming the existing routing request (5,13); 5 is the source node, 13 is the destination node, the constraints are D = 16, B = 50, PL = 0.001 and D = 26 , B = 45, PL = 0.001 (for simplicity, the constraints of all multicast endpoints in the experiment are the same). The number of selected particles is 10, and the number of generations is 20. The path calculated by the algorithm in this paper is p = [5,7,2,9,13], while the traditional method based on the shortest path selects the route is [5,7,1,13]. Since the bandwidth between nodes [7,1] is only 45, the shortest path method will completely saturate this link. Figure (2) shows the network topology used in the simulation, shortest path using PSO and GPSO algorithms respectively, while the relationship between the evolutionary algebra and the fitness function is shown in Figure (3). It can be seen that the particle swarm optimization algorithm is initially accepted. The speed is faster, but the convergence accuracy is poor. This is because the particle swarm optimization algorithm only uses the optimal solution information in the initial population, and cannot perform a comprehensive search on the solution space, which can easily fall into the local optimal. The GA adopts crossover and mutation operation lacks clear guidance, so the search ability to find the optimal solution is weak, and the initial speed rate convergence is slow. while the speed of the GPSO algorithm faster and the accuracy is better.

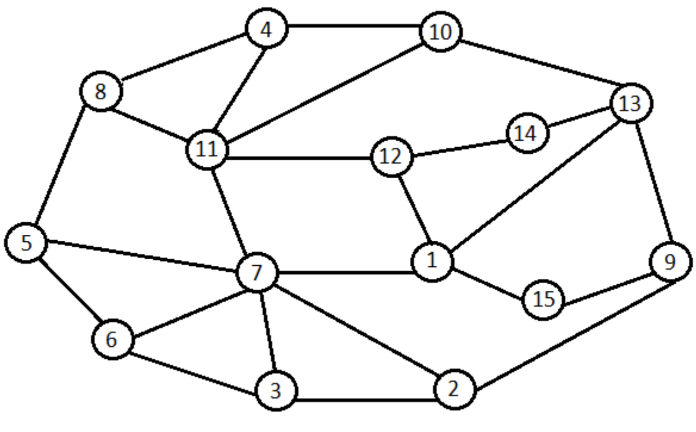

Fig. 2. Network topology

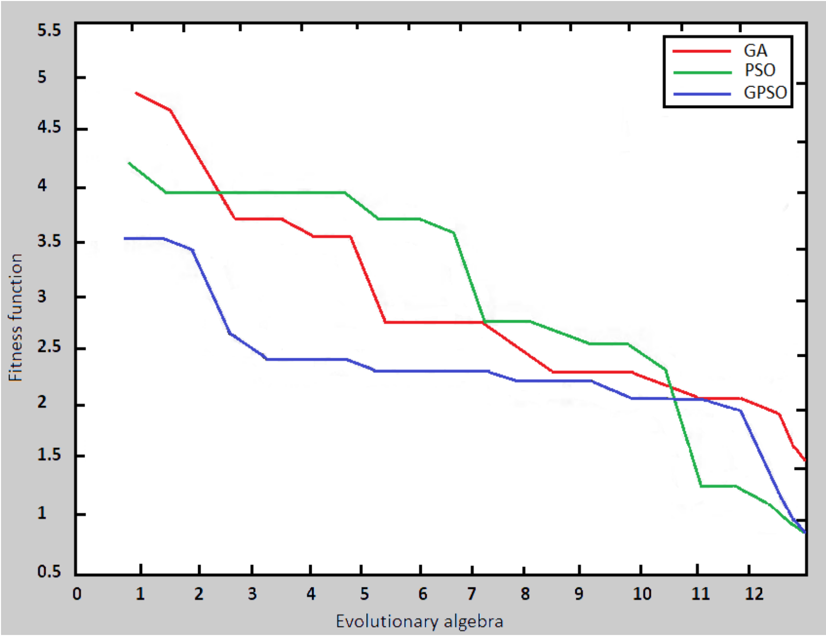

Fig. 3. Comparison of GA, PSO algorithm, and GPSO algorithm

6. *CONCLUSIONS*

This paper combines the advantages of GA and PSO algorithms, the proposed GPSO algorithm applied to solve the multi-cast routing optimization problem in Ad-Hoc network with multiple quality of service constraints, By improving the mutation operator among genetic operators and introducing the idea of particle swarms to improve the running speed of the algorithm, the optimal solution is better obtained. Compared with GA and PSO algorithms, the optimization performance of GPSO is more prominent. The excellent performance of the algorithm is verified through simulation experiments, where the network load evenly distributed, has better convergence speed and accuracy than pure GA or PSO algorithm in the selection of optimized path in Ad Hoc networks.

REFERENCES

[1] Kuppusamy SP, Ramasamy S, Thangamuthu GS. A survey on end-to-end performance metrics of QoS-aware multicast routing protocols for mobile ad hoc networks. Int. J. Netw. Virtual Organ., **16**, 283–97 (2016).

[2] Guo K, Lv Y. Optimizing Routing Path Selection Method Particle Swarm Optimization. Int. J. Pattern Recognit. Artif. Intell., (2020).

[3] Krishna S, Raj A, Gayathri IK. Delay optimization in manets using Knapsack and genetic algorithm, 2018.

[4] Zhang G, Wu M, Duan W, Huang X. Genetic Algorithm Based QoS Perception Routing Protocol for VANETs. (2018).

[5] Khelifa S, Maaza ZM. Enhancing energy efficiency in mobile ad hoc networks using genetic algorithms. Comput. y Sist., **24**, 1107–19 (2020).

[6] Dixit S, Singhai R. A PSO-Based Approach for Improvement in AODV Routing for Ad Hoc

Networks, Advances in Intelligent Systems and Computing, 2020, Springer, pp.379–89.

[7] Anand V, Pandey S. New approach of GA–PSO-based clustering and routing in wireless sensor networks. Int. J. Commun. Syst., **33**, e4571 (2020).

[8] Anand V, Pandey S. New approach of GA–PSO-based clustering and routing in wireless sensor networks, 2020.

[9] Chander D, Kumar R. QoS Enabled Cross-Layer Multicast Routing over Mobile Ad Hoc Networks, Procedia Computer Science, 1 January, 2018, Elsevier B.V., pp.215–27.

[10] Zhang X, Zhang X, Gu C. A micro-artificial bee colony based multicast routing in vehicular ad hoc networks. Ad Hoc Networks, **58**, 213–21 (2017).

[11] Zaheeruddin, Lobiyal DK, Prasad S. An elitist nondominated sorting genetic algorithm for QoS multicast routing in wireless networks. Swarm Evol. Comput., **33**, 85–92 (2017).

[12] Wang R, He G, Wu X, Wang F, Hu Y. Multicast optimization and node fast location search method for wireless sensor networks based on ant colony algorithm. J. Digit. Inf. Manag., **15**, 303–11 (2017).

[13] Zhang X, Shen X, Yu Z. A novel hybrid ant colony optimization for a multicast routing problem. Algorithms, **12**, (2019).

[14] Mahseur M, Boukra A. Quality of service (QoS) optimization in a multicast routing: A hybrid solution. Int. J. Appl. Metaheuristic Comput., **10**, 27–54 (2019).

[15] Singh S, Koslia M, Poonia RC. A GA-QMR: Genetic Algorithm Oriented MANET QoS Multicast Routing. Recent Patents Comput. Sci., **11**, 268–75 (2018).

[16] Murugeswari R, Devaraj D. Multiconstrained QoS multicast routing for wireless mesh network using discrete particle swarm optimization. Adv. Intell. Syst. Comput., **517**, 847–59 (2017).

[17] Yousif ST. Congestion Management in MPLS Network Based on Hybrid Particle Swarm Algorithm. **13**, 109–15 (2021).

[18] Saber N, Mestari M. Multicast Routing Problem in Communication Networks: State of the Art, 2019.

[19] El-Mihoub T, Tholen C, Nolle L. Towards reducing the impact of localisation errors on the behaviour of a swarm of autonomous underwater vehicles. Mendel, **26**, 1–8 (2020).