Multi-constrained QoS Multicast Routing based on the Genetic Algorithm for MANETs

[1]G. Santhi and [2]Alamelu Nachiappan

[1]Assistant Professor, Dept. of Information Technology,
Pondicherry Engineering College, India.
shanthikarthikeyan@pec.edu ([1]corresponding author)
[2]Professor, Dept. of EEE,
Pondicherry Engineering College, India.

Abstract: A wireless MANET is a collection of wireless mobile hosts that dynamically create a temporary network without a fixed infrastructure. The topology of the network may change unpredictably and frequently. Therefore, multicast routing in ad hoc networks is a very challenging problem. This paper proposes a multi-constrained QoS multicast routing method using the genetic algorithm. In this work, Genetic Algorithm is used to determine the optimal multicast routing satisfying the quality of service requirements such as total delay, total delay jitter, packet loss and total bandwidth. By selecting the appropriate values for parameters such as crossover, mutation, and population size, the genetic algorithm improves and tries to optimize the routes. Simulation results indicate its better performances compared to other methods.

Keywords: Multicasting, MANETs, genetic algorithm, mobile nodes, Quality of service

1. Introduction

A MANET is a multi-hop wireless network composed of mobile hosts communicating with each other without the support of a fixed network infrastructure. Wireless links are formed or destroyed whenever one mobile host moves in or out of transmission ranges of other mobile hosts. Intermediate mobile hosts between two communication nodes act as routers [1, 2]. Thus, the mobile hosts operate both as hosts and routers in MANET. When the hosts are mobile, they are free to move randomly and organize themselves arbitrarily. The creation of routing paths is affected by the addition and deletion of mobile hosts. Thus, the topology of the wireless network changes unpredictably and frequently. As a result, unicast or multicast routing in ad hoc networks becomes a challenge due to this dynamic nature.

The basic function of Quality-of-Service (QoS) routing is to find a better path based on QoS metrics, such as end-to end delay, jitter (also called delay variation), bandwidth guarantee, and packet loss probability. QoS routing is much more complicated than regular routing because of routing under multiple constraints. In addition, most QoS routing algorithms consider the optimization of resource utilization. The problem of QoS routing is difficult because multiple constraints often make the routing problem intractable, and the dynamic of network state makes it difficult to gather up-to-date information in a large network. Wang and Crowcroft have shown that the problem of finding a path subject to constraints in QoS routing are NP-complete [3]. Genetic Algorithm was introduced by John Holland in 1960. It is a meta-heuristic adaptive search algorithm based on natural biological evolution theory. It can be applied to a wide range of engineering problems to obtain faster results [4-6].

2. Multi-constrained QoS Aware Multicast Routing Model

Assume that a network is represented as a weighted graph G = (V, E), where V denotes the set of vertices as nodes and E denotes the set of edges as communication links connecting the nodes. |V| and |E| denote the number of nodes and links in the MANET, respectively. Without loss of generality, only digraphs are considered in which there exists at most one link between a pair of ordered nodes. In G (V, E), considering a QoS constrained multicast routing problem from a sender to multi-receiver hosts. The multi-constrained spanning tree is defined to be a multicast tree $T = (V_T, E_T)$ rooted at s, where $V_T \subseteq V$, $E_T \subseteq E$, $s \in V_T$. Let 's' be the source node of a multicast tree T. A multicast delivery tree is a tree rooted at a source node 's' and spans M, where $M = M^* \cup \{s\}$, $M^* = \{t_1, t_2, \ldots t_m\}$ is the set of receiver hosts and 'm' is the number of receiver hosts in multicast delivery tree T . In a delivery tree T ($T \in G$) rooted at source 's' and spanning all of the receivers M, a path from the source 's' to the receiver 't' is denoted by p(s, t).

Let R be the set of positive weights and R^+ be the set of non-negative weights. For a multicast delivery tree $T = (V_T, E_T)$, for any link $e \in E_T$, the following QoS metrics can be defined.

delay function: Delay (e): E R
bandwidth function : Bandwidth (e): E R
cost function: Cost(e): E R
jitter function: Jitter (e): E R^+
packet loss function: Packet loss (e): E R^+

Each routing path p(s, t) from a source 's' to a destination node 't' in a multicast tree T has a measured value of $delay_{max}$, $jitter_{max}$, $bandwidth_{min}$, and packet $loss_{max}$ that should be limited by the QoS constraints. In this, the delay and jitter are additive metrics, the bandwidth is a concave metric and packet loss rate is a multiplicative metric. For a path p(s, t), the following QoS parameters are defined.

$$delay_{max}(p(s,t)) = \sum_{e \in p(s,t)} delay(e) + \sum_{n \in p(s,t)} delay(n) \quad (1)$$

$$jitter_{max}(p(s,t)) = \sum_{e \in p(s,t)} jitter(e) + \sum_{n \in p(s,t)} jitter(n) \quad (2)$$

$$bandwidth_{min}(p(s,t)) = \min\{bandwidth(e), e \in p(s,t)\} \quad (3)$$

$$packetloss_{max}(p(s,t)) = 1 - \prod_{e \in p(s,t)} (1 - (packetloss(e)) \quad (4)$$

The proposed QoS routing algorithm should satisfy some constraints to support real-time multimedia communication. In this work, four QoS constraints are defined: D_T, J_T, B_T and L_T. D_T is the maximum end-to-end delay constraints, J_T is the maximum jitter (delay variation) constraint, B_T is the minimum available bandwidth constraint, and L_T is the maximum packet loss rate constraint of a routing path. The QoS-based multicast routing problem is to find the T(s, M) which satisfies the following QoS constraints.

$$delay_{max}(p(s, t)) \leq D_T \quad (5)$$

$$jitter_{max}(p(s, t)) \leq J_T \quad (6)$$

$$bandwidth_{min}(p(s, t)) \geq B_T \quad (7)$$

$$packet\ loss_{max}(p(s, t)) \leq L_T \quad (8)$$

where, the $delay_{max}$(p(s, t)), $jitter_{max}$ (p(s, t)) and packet $loss_{max}$ (p(s, t)) are the maximum values of end to end delay, jitter and packet loss rate from the source 's' to the destination 't' in the multicast tree T should be inferior or equal to the delay threshold D_T, J_T, and L_T. Also $bandwidth_{min}$(p(s, t)) is the minimum bandwidth in every link in the whole multicast tree which must be greater or equal to the minimum bandwidth B_T.

Here, the QoS multicast routing problem with constraints represents a minimization problem, where their fitness function is to find a multicast tree 'T' which minimizes the weighted combination of cost, delay, jitter, bandwidth and packet loss after satisfying the QoS constraints. Thus, the problem can be formulated as follows.

$$\textbf{Minimize } f(T(s, M)) = w_1 f_c + w_2 f_d + w_3 f_j + w_4/f_b + w_5 f_{plr} \quad (9)$$

where

$$f_c = cost(T(s, M)) \quad (10)$$

$$f_d = \max\{\textstyle\sum_{t \in T} delay(p(s,t))\} \leq D_T \quad (11)$$

$$f_j = \max\{\textstyle\sum_{t \in T} jitter(p(s,t))\} \leq J_T \quad (12)$$

$$f_b = \min_{t \in T}\{bandwidth(p(s,t))\} \geq B_T \quad (13)$$

$$f_{plr} = max\ \{\sum_{t \in T} packet\ loss(p(s,t))\} \leq L_T \quad (14)$$

Here, f_c is the cost of the multicast tree, f_b is the minimum available bandwidth on each edge of the multicast tree which must be greater or equal to the minimum bandwidth B_T. f_d, f_j and f_{plr} are the maximal delay, jitter and packet loss rate from the source 's' to the more delayed destination in the multicast tree T should be inferior or equal to the threshold values D_T, J_T and L_T. And w_1, w_2, w_3, w_4 and w_5 are the objective weighting coefficients used to evaluate the problem relating to the importance of these QoS routing objectives. *Cost(T(s,M))* represents the cost of the multicast tree. For optimal performance of a network, cost, delay, jitter and packet loss rate must be minimized and bandwidth must be increased. Hence the fitness function f*(T(s,M))* is a minimization function.

3. Genetic Algorithm

Genetic algorithm is also a searching algorithm that employs the ideas of natural selection and the genetic operators of crossover and mutation [8-10]. In each generation, a new population of solutions is created by exchanging and combining the information obtained from the solutions of the previous generation. In genetic algorithm, the variables of the problem are like the genes in a chromosome. A context in each bit of string is called chromosome. One gene of a chromosome represents one possible solution. A flowchart of a typical genetic algorithm is shown in Figure 1.

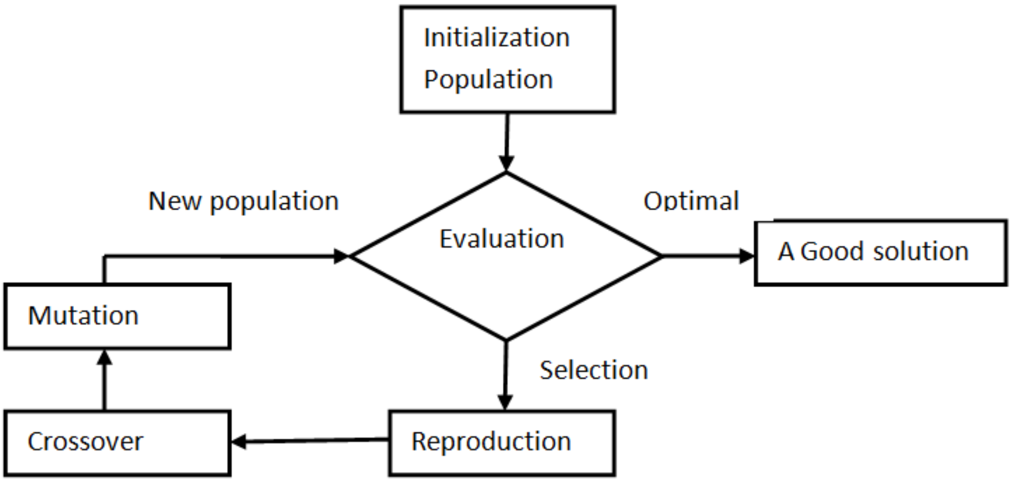

Figure 1. The flowchart of a simple genetic algorithm

The different phases of GA for natural evolution through encoding, selection, crossover and mutation operations are discussed as below.

Encoding

The chromosomes of the multicast tree are represented by tree structure encoding to save the time of conversion between encoding space and solution space. Different possible trees are recorded as the solution set. The different parameters such as delay, delay jitter, packet loss, bandwidth and cost are calculated for each of the tree in the solution set.

The Genetic Operators

- ***Selection***: It is a process of selecting some of the strings from the search space. Using Stochastic Uniform Selection, twenty random strings are selected from the string set.
- ***Crossover***: It is a process of mixing and matching two strings to evolve with a better one. Standard uniform crossover technique is used for the crossover of two parents selected randomly from the matting pool. In this problem, the crossover probability is kept as 0.8.
- ***Mutation***: It is a process of changing a small part of the string synonymous to genetic mutation in biological theory. The probability of mutation is kept as 0.4. Mutation enables the search to be extensive rather than getting constrained within local optima.

Fitness Test

The fitness function affects directly the convergent speed of genetic algorithm and whether the global optimum is found. The fitness value of a chromosome is the value of the fitness function for the solution (e.g., a multicast tree) represented by the chromosome. The fitness value uses the following form.

$$f(T(s, M)) = w_1 f_c + w_2 f_d + w_3 f_j + w_4/f_b + w_5 f_{plr} \quad (15)$$

Besides satisfying the conditions in Equations (6.8) – (6.11), the route selection is based on fitness value. The fitness function *f(T(s, M))* is to select the best route. By maximizing the fitness value i.e *fit = 1/(1+f)*, the multicast tree minimize the delay, jitter, packet loss and cost values and maximize the bandwidth value. This means that a packet from source to receivers is transmitted with least cost and a long lifetime.

4. Simulation Results

The GA parameter values considered for the simulation are (i) number of generations - 100, (ii) mutation - 0.4, (iii) crossover – 0.8. The weights for QoS parameters are assigned randomly. The Figure 2 shows the change of average objective function value with the change of number of generations. This algorithm can quickly generate the optimal solution. It takes 12 generations to find the feasible path and hence it proves its low time complexity.

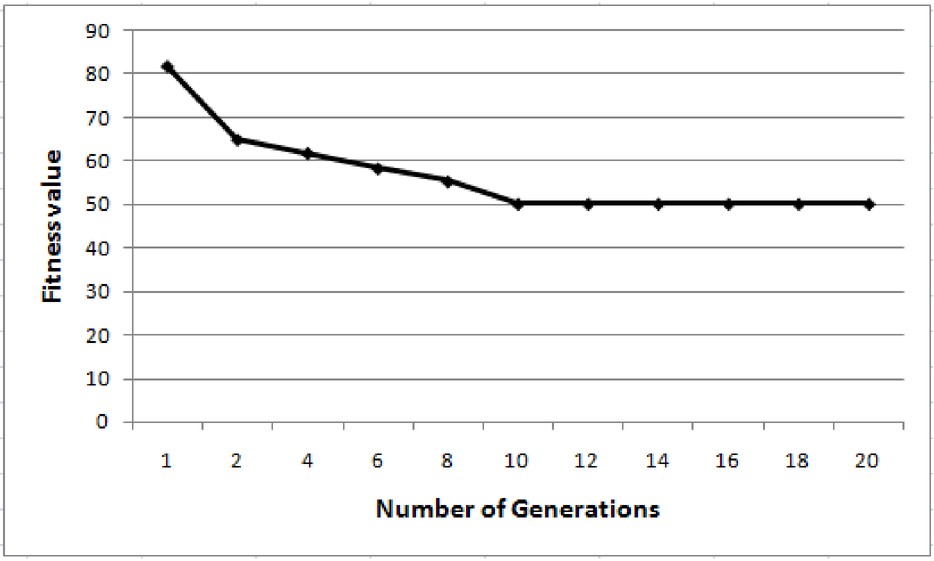

Figure 2. The Fitness value in various Generations

5. CONCLUSION

In this work, an attempt is made to choose the optimal multicast route satisfying the quality of service requirements such as bandwidth, end-to-end delay, delay jitter and packet loss rate. The simulation results depicting the best fitness value with respect to generations. By selecting the appropriate values for parameters such as crossover, mutation, and population size, the genetic algorithm can be used to select the optimal multicast route from a list of routes satisfying the quality of service constraints much faster.

REFERENCES

[1] Aaron Striegel and Manimaran, G. “A Survey of QoS Multicasting Issues”, IEEE Communications Magazine, Vol.40, No.6, pp.82-87, 2002.

[2] Wang, Z. and Crowcroft, J. “Quality of Service Routing for Supporting Multimedia Applications”, IEEE Journal on Selected Areas in Communication, Vol.14, No.7, pp.1228–1234, 1996.

[3] Wang, Z., Liang, Y. and Wang, L. "Multicast in Mobile Ad Hoc Networks", in Proc. IFIP International Federation for Information Processing, Vol.258, pp.151-164, 2008.

[4] G. M. B. Oliveira and P. T. Araujo, “Determining Multicast Routes with QoS and Traffic Engineering Requirements Based on Genetic Algorithm,” *Proceeding of IEEE Conference on Cybernetics and Intelligent Systems*, Singapore, 1-3 December 2004, pp. 666-670.

[5] S. C. Rai, B. B. Mishra, A. K. Nayak, R. Mall and S. K. Pradhan, “A Multi-Objective Pareto Optimal Genetic Algorithm for QoS Multicasting,” *Proceeding of IEEE International Advance Computing Conference*, Patiala, 2009, pp. 1303-1307.

[6] A. Roy and S. K. Das, “Optimizing QoS-Based Multicast Routing in Wireless Networks: A Mullti-objective Genetic Algorithmic Approach,” *Proceedings of the* 2nd *In-ternational IFIP-TC*6 *Networking Conference on Net-working Technologies, Services, and Protocols, Lecture Notes in Computer Science*, Berlin Heidelberg, Vol. 2345, Springer-Verlag, 2002, pp. 28-48.

[7] A. Roy, N. Banerjee and S. K. Das, “An Efficient Multi- Objective QoS-Routing Algorithm for Wireless Multicasting,” *Proceeding of IEEE Vehicular Technology Conference*, San Diego, Vol. 3, 2002, pp. 1160-1164.

[8] D. Pinto and B. Baran, “Solving Multi-Objective Multicast Routing Problem with a New Ant Colony Optimization Approach,” *Proceeding of* 3rd *International IFIP/ACM Latin American Conference on Networking*, New York, 2005, pp. 11-19.

[9] J. Crichigno and B. Baran, “Multi-Objective Multicast Routing Algorithm for Traffic Engineering,” *Proceeding of* 13*th IEEE Inernational Conference on Computer Communications and Networks* (*ICCCN*), Chicago, 2004, pp. 301-306.

[10] S. Marwaha, D. Srinivasan, C. K. Tham and A. Vasilakos, “Evolutionary Fuzzy Multi-Objective Routing for Wireless Mobile Ad Hoc Networks,” *Proceeding of Evolutionary Computation* (*CEC*’04), San Diego, Vol. 2, 2004, pp. 1964-1971.