Journal of Statistics Applications & Probability
An International Journal

http://dx.doi.org/10.18576/jsap/100308

Multi-Objective Multicast Routing based on Ant Colony Optimization in Mobile Ad-Hoc Networks.

*Mahmoud A. Mofaddel**, *A. Younes and Hamdy H. El-Sayed*

Faculty of Computers and Information, Sohag University, Sohag, Egypt

Received: 26 May 2020, Revised: 20 Jun. 2020, Accepted: 26 Jun. 2020.
Published online: 1 Nov. 2021

Abstract: The current paper presents a new algorithm based on Anti Colony Optimization (ACO), which finds optimum path and multicast tree optimizes total weight (cost, delay and hop) of the multicast tree. Experimental results prove that the proposed algorithm outperforms a recently published Multi-Objective Multicast Algorithm specially, designed for solving the multicast routing problem.

Keywords: Ad-hoc networks, AODV, ACO, Delay, Hop count, Cost.

1 Introduction

Wireless Ad-hoc network has extended more and more because of its applications and services. Ad hoc network is a type of wireless network and does not include any infrastructure. In this network, each node acts as a host and router. Suggests that each node while moving in its environment, sends and receives its data packet and relays data packets of other nodes to reach their destinations. The topology of these networks always dynamic. Also their nodes move freely is no control center to support network topology, configuration or reconfiguration it [1].

The main challenges of Ad-hoc networks is routing. Best routing algorithm plays a significant role in performance improvement. Problems, such as limited bandwidth, limited power and end to end delay, are the main reasons for the need of an ideal and quick routing algorithm. Many routing algorithms have been presented for these networks, and each of them has self-special benefits. The routing algorithms are classified to main classes, proactive and reactive [2]. One of the famous routing algorithms is AODV [3], which is one of the useful and effective reactive algorithms.

Graphs can model numerous things, such as transforming networks, traffic control networks, neural networks, communication networks and,... Routing problem can be also modeled to graph too, each host can be a vertex and each link between two hosts can be an edge. Therefore, routing problem can be considered the shortest path problem (SPP) in a graph. In AODV algorithm a path with minimum hop count is selected as optimum path [1].

ACO was proposed by [4] and is a population stochastic optimization technique. It is inspired by the foraging behavior of ants, where the population of ants works collectively to generate the shortest path from the source to the destination. The solution is built step by step and depends on (i) long term joint population memory (pheromone) and (ii) some additional information about the problem (heuristic information). After the solution is constructed by the ants, some pheromone is deposited onto the edges of the path which leads to better solution i.e. more pheromone is deposited onto the edges of good solutions. Gradually, the concentration of pheromone on the edges corresponding to good solutions builds up evolving a global optimum solution.

In Single Objective Problem (SOP), there is just one objective [5]. AODV algorithm is an example of these problems.

*Corresponding author e-mail: mmofaddel@gmail.com

Single objective methods are inappropriate for problems. Finding best solution in this kind of problems depends to multi objectives. thus, a new kind of problem called Multi Objective Problem emerged in. it, multi objective play role [6]. In shortest path problem [7], we can consider multi objectives on each edge, such as cost, time, distance as well as and solve this problem based on multi objectives or selected paths can satisfy multi objectives. Hence Multi Objective Shortest Path Problem (MOSPP) can find optimum path based on multi objectives.

Multicast is a form of group communication in which data is forwarded concurrently to a set of target destinations. The grows development in multimedia applications, like video/audio conferencing, distance education and online gaming, etc [8], are examples. Multi Objective Multicast Paths Problem (MOMPP) requires multicast communication with strict quality-of-service guarantee for different parameters such as bounded cost, time, distance and hop count. The underlying model of multicast routing is Spanning tree.

Mobile network feature broadens the horizon for intruders to penetrate the network and causes performance degradation. This differs from classical MANET protocols where major efforts have been made on single network parameter based routing decision.

This article present a new algorithm based on Anti Colony Optimization (ACO) which finds optimum path and multicast tree that minimizes the total cost, delay and hop count based on multi objectives. Evaluation of the new method shows that considering multi objectives influences routing metrics improves the performance, and give better results for the parameters that has been used. Also the algorithm can find optimal solution quickly and has a good scalability.

The rest of the paper is organized as follows: Section 2 presents the problem description and formulation. Sections 3 describes Ant Behavior. Proposed algorithm is presented in Section 4. Section 5 shows experimental results. Finally, Section 6 is dedicated to conclusion.

2 Problem Descriptions and Formulation

A wireless mobile ad hoc network is usually represented as a graph G=(N,E), where N denotes the set of nodes and E denotes the set of communication links connecting the nodes. |N| and |E| denote the number of nodes and links in the network respectively. We consider the multicast routing problem with bandwidth and delay constraints from one source node to multi-destination nodes. Let $X = \{n_0, u_1, u_2, \ldots\ldots u_m\} \in N$ be a set from source to destination nodes of the multicast tree, where n0 is source node, and U= {u1 , u2 … um } denotes a set of destination nodes. Multicast tree T= (NT , ET), where NT $\subseteq$N, ET $\subseteq$E, there exists the path PT (n0 , d) from source node n0 to each destination node d $\in$ U in T. e(i,j) is a link from node i$\in$N to node j$\in$N. Three non-negative real value functions are associated with each link e(e$\in$E): cost C(e), delay D(e), and available bandwidth B(e). The link cost function, C(e), may be either monetary cost or any measure of the resource utilization, which must be optimized. The link delay, D(e), is considered to be the sum of switching, queuing, transmission, and propagation delays. The link bandwidth, B(e), is the residual bandwidth of the physical or logical link. The link delay and bandwidth functions, D(e) and B(e), define the criteria that must be constrained[9].
The cost of the path PT is defined as the sum of the cost of all links in that path and can be given by

$$C(P_T) = \sum_{e \in P_T} C(e) \tag{1}$$

The total cost of the tree *T* is defined as the sum of the cost of all links in that tree and can be given by:

$$C(T) = \sum_{e \in E_T} C(e) \tag{2}$$

The total delay of the path $P_T(n_0,d)$ is simply the sum of the delay of all links along $P_T(n_0,d)$:

$$D(P_T) = \sum_{e \in P_r(r_0,d)} D(e), \qquad d \in U \tag{3}$$

The delay of multicast tree *T* is the maximum value of delay in the path from source node n_0 *to* each destination node $d \in U$.

$$D(P_T) = \max(\sum_{e \in P_r(r_0,d)} D(P_T), \qquad d \in U \tag{4}$$

The hop of the path PT is defined as the sum of the hop of all links in that path and can be given by:

$$H(P_r) = \sum_{e \in P_T} H(e) \tag{5}$$

The hop of multicast tree is defined as the sum of the hop of all links in that tree and can be given by:

$$H(T) = \sum_{e \in T_T} H(e) \tag{6}$$

The vector $SW(P_T)$ of the path P_T consists of the vector sum of the vectors corresponding to arcs.

$$SW(P_r) = C(P_T) + D(P_T) + H(P_T) \tag{7}$$

Where $SW(P_T)$ is the weight of the shortest path tree (P_T).

The objective of presented problem is to find a multicast routing tree (T) such that minimizes the cost $C(T)$, the delay $D(T)$, and the hop $H(T)$. The problem can be formulated as follows:

$$\text{Minimize}\, W(T) = \sum_{e \in E_T} (C(T) + D(T) + H(T)) \tag{8}$$

Where $W(T)$ is the weight of a multicast routing tree (T). The cost $C(T)$, the delay $D(T)$, and the hop $H(T)$ are defined as follows:

$$C(T) = \sum_{e \in E_T} C(e) \tag{9}$$

$$D(T) = \max\left(\sum_{e \in P_T)} D(P_T)\right) \tag{10}$$

$$H(T_r) = \sum_{e \in T} H(e) \tag{11}$$

3 Ant Behaviors

Ant colony is one of machine learning models [11-15]. Along the path on which the ant moves, it lets out a special material called pheromone. This material can be sensed and detected by ants to be used as a guide to move and to find food. Ant colony behavior may be changed based on the exchanged information to find the optimal path between the nest and the food location.

An ant will move from node i to node j with probability:

$$P_{i,j} = \frac{(\tau_{i,j}^{\alpha})(\eta_{i,j}^{\beta})}{\sum (\tau_{i,j}^{\alpha})(\eta_{i,j}^{\beta})} \tag{12}$$

Where:
$\tau_{i,j}$ is the amount of pheromone on edge i; j,
α is a parameter to control the influence of $\tau_{i,j}$
β is a parameter to control the influence of $\tau_{i,j}$
$\eta_{i,j}$ is the desirability of edge i; j (typically $1/d_{i,j}$)
α, β are user defined parameters ($0 \le \alpha, \beta \le 1$):

Amount of pheromone is updated according to the equation

$$\tau_{i,j} = (1-\rho)\tau_{i,j} + \Delta\tau_{i,j}^{total} \quad (13)$$

Where:

$\tau_{i,j}$ is the amount of pheromone on a given edge i; j

ρ is the rate of pheromone evaporation and $\rho \in (0, 1)$

$\Delta\tau_{i,j}$ is the amount of pheromone deposited, typically given by

$$\Delta\tau_{i,j} = \begin{cases} \frac{1}{L_k} & if\ ant\ k\ travels\ on\ edge\ i;\ j \\ 0 & othjerwise \end{cases} \quad (14)$$

Where L_k is the cost of the k^{th} ant's tour (typically length).

4 The Proposed Ant Algorithm

Assuming n_0 is a source node, and $U = \{u_1, u_2 \ldots u_m\}$ denotes a set of destination nodes, the proposed algorithm generates n paths from n_0 to each $u_i \in U$. To solve the multi-objective multicast routing problems, an ant moves through a path using the corresponding probabilities function and update Pheromone on that path after finishing each iteration. The following steps describe the proposed algorithm:

Ant algorithm for solving the multicast routing problem

1. Define the node numbers of a network (say |N| nodes).
2. Generate the network of |N| nodes.
3. Check the connection of the proposed network.
4. If the proposed network is not connection, then repeat from step 2.
5. Define n_0 (source node) and U (a set of destination nodes) as shown in section 2.
6. Set $\mathcal{P}$ (The number of candidate trees).
7. Set $n_r = 1$ (Candidate tree number).
8. Set $g = 0$ (g is a loop counter.), and put m (m is the number of ants) ants into S.
9. For each destination node $u_i \in U$, generate P_i, the set of paths for each destination node u_i.
10. Assign an initial value $\tau_k = 0$; to the pheromone intensity of every path P_k, k=1,2,…n,
11. Begin the first tour;
12. Let m ants move from S to u_i on P_i equally (the ants number in each path pk is equal).
13. Compute the pheromone amount left by x ants at p_k ($\Delta\tau_k$)using Eq. (14).
14. Update the local pheromone τ_k using Eq. (10).
15. Begin a new tour
16. Set $g = g + 1$;
17. Compute the corresponding probabilities function $P_{i,j}$ using Eq. (12).
18. Compute $\Delta\tau_k$ using Eq. (14)
19. Update the global pheromone τ_k using Eq. (13)
20. Repeat from step 9 until g_{max}
21. Compare τ_k values to get the best path for the destination u_i.
22. End For
23. Collect the all best path ($P_{i,j}$) to get the multicast tree.
24. Set $n_r = n_r + 1$.
25. Store the tree information.
26. If $n_r < \mathcal{P}$ goto step 8 to generate new candidate tree.
27. Printout the best tree.
28. End

5 Experimental Results

In this paper an optimistic vision was made to ensure MANET with Omni-direction antenna reliable while giving the specific focus to augment QoS delivery and the nodes have the same energy and transmission range. Observing major existing works, it can be found that most of the at hand protocols focus on network performance enhancement, which achieves a cumulative optimal solution [10].

In this section, we show the efficiency of the proposed MACO algorithm and the MAODV algorithm by applying it on mobile ad hoc networks with Omni-directional antenna with n (number of nodes) =10 and compare the results obtained by our ant algorithm with the results obtained by a classical MAODV protocol. The delay, hop count and cost are used as a parameters of comparisons to test the performance.

The parameters setting in the proposed algorithm are, as follows: number of nodes=10, source node is the node no. 1, destination nodes are 7, 8, 9, and 10, and radius of transmission range =6. The results obtained by MACO and MAODV are shown in Table 1.

Analysis performance of these protocols has been performed in reference to the proactive routing protocol MAODV in terms of path cost distance, hop count and delay. A comparison results of MAODV and MACO and their inferences as presented in Table 1 and the following figures. Figure 1. depicts the comparison between MAODV and MACO protocols on the mobile ad hoc network graph that has been used. The figure shows that the total cost of routes in MACO is better than that in MAODV. It gives us the same route with minimum cost.

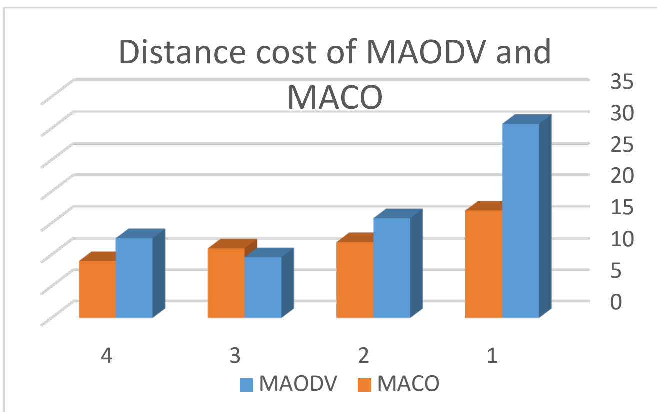

Fig. 1: shows the distance cost comparison of MAODV and MACO.

Table 1: The candidate route set from source node 1 to each destination node delay, hop count and distance cost for MAODV and MACO.

	MAODV				**MACO**			
Destination node	**The paths route**	**Delay**	**Hop**	**Des. Cost**	**The paths route**	**Delay**	**Hop**	**Des. Cost**
7	1 4 9 10 8 3 5 7	10.65	7	30.6978	1 4 5 3 7	5	4	17

8	1 4 9 10 8	7.6	4	15.7678	1 3 5 10 8	10	4	12
9	1 4 9	3.6	2	9.6056	1 4 5 9	3	3	11
10	1 4 9 10	5.6	3	12.6056	1 3 5 10	8	3	9

Figure (2): shows that this approach enables our proposed Multi-Objective MACO routing protocol to exhibit more reliable data transmission than the native MAODV routing protocol as observed the hop count of MACO is less than MAODV. This efficacy evaluation could be observed from the results obtained (Figure 1, Figure 2 and Figure 3).

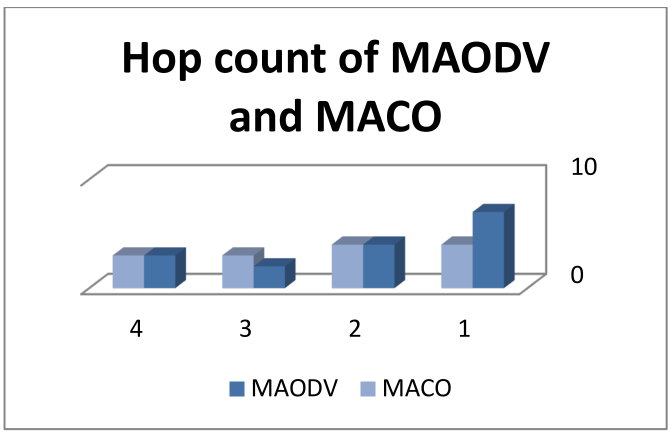

Fig. 2: depicts the hop count comparison of MAODV and MACO.

Figure 3 presents delay performance by the proposed MACO routing protocol, where it can be found that it outperforms classical MAODV because of minimum cost, hop count and delay as shown in figures. In other words, MACO assures reliable transmission and efficient performance other than MAODV. In addition, it avoids iterative network discovery during any link.

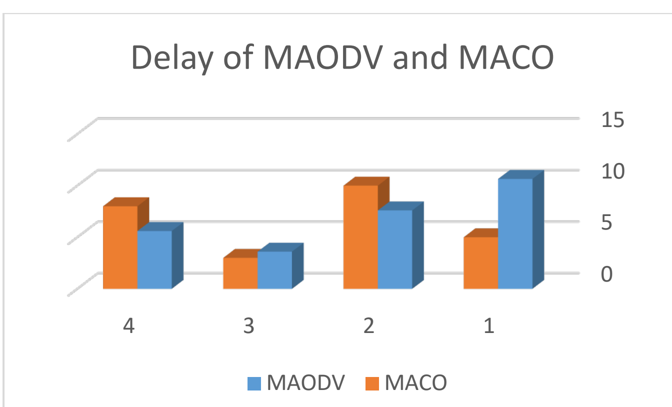

Fig. 3: shows the delay comparison between MAODV and MACO.

Table 2: Statistics of MAODV and MACO for distance cost.

	N	Mean	Std. Deviation	Std. Error Mean
MAODV	4	17.1692	9.36343	4.68171
MACO	4	12.2500	3.40343	1.70171

Table 3: Statistics of MAODV and MACO for Hop count.

	N	Mean	Std. Deviation	Std. Error Mean
MAODV	4	4.0000	2.16025	1.08012
MACO	4	3.5000	.57735	.28868

Statistical analysis has been made for the proposed routing protocol and the standard MAODV protocol. It shows that the Mean, Std. Deviation and Std. Error Mean of MACO is less than MAODV in all comparisons except in delay the Std. Deviation and Std. Error Mean of MACO is less in very little other than MAODV as shown in Tables (2, 3 and 4).

Table 4: Statistics of MAODV and MACO for Delay**.**

	N	Mean	Std. Deviation	Std. Error Mean
MAODV	4	6.8625	3.00704	1.50352
MACO	4	6.5000	3.10913	1.55456

Finally, Summary of the overall analysis of the performance of the protocols is summarized in Table 5. It indicates that there is greater improvement in the above mentioned parameters with MACO over MAODV. Here, the MACO routing protocol exhibits that Delay improved 1.45%, which is higher than the native MAODV protocol. Similarly, hop count performance of our proposed MACO routing protocol over classical MAODV routing approach improved 2%. Finally, the cost performance of our MACO protocols improved 17.7% other than classical MAODV. Accordingly, the proposed MACO routing protocol exhibits better even with increase in nodes or network density.

Table 5: Comparative analysis.

parameters	MAODV	MACO	Percentage of Improvement
Delay	27.45	26	1.45
Hop count	16	14	2
Cost	68.6768	49	17.7

6 Conclusion

In this paper, the cost, delay and hop are addressed as multi-objective multicast routing problem. Ant colony algorithm is one of the heuristic algorithms that can solve this problem, so it has been used to tackle the presented problem. This paper solved the multicast routing problem subject to the total of cost, delay, and hop count. The experimental results illustrated that the results of MACO are better than those of MAODV. Also experimental results illustrated that the proposed algorithm can enable better performance in terms of delay, hop count and cost exhaustion that affirms its suitability for real-time communication. The algorithm can guarantee the requirement of multimedia group communication for quality of service.

Conflicts of Interest:

The authors declare that there is no conflict of interest regarding the publication of this article.

References

[1] Hamideh Babaei and Morteza Romoozi: "Multi Objective AODV Based On a Realistic Mobility Model", IJCSI International Journal of Computer Science Issues., **7(3)**, (2010).

[2] Elizabeth M. Royer and Chai-Keong Toh: "A Review of Current Routing Protocols for Ad Hoc Mobile Wireless Networks, IEEE Personal Communications., **6(2)**, 46-55(1999).

[3] C. E. Perkins and E. M. Royer: "Ad Hoc on demand distance vector (AODV) routing", IET Internet Draft, draft-ietf-manet-aodv-l4.txt, Jul, 2003.

[4] M. Dorigo, G. Caro and L. Gamberdella: "Ant Algorithms for Discrete Optimization"., **5(2)**, 137-192(1999).

[5] P. L. Yu and M. Zeleny: "The techniques of linear multiobjective programming", RAIRO., 351-71(1974).

[6] M. Zeleny: "Linear multi-objective programming", Berlin: Springer., 1974.

[7] A. Warburton: "Approximation of Pareto Optima in Multiple-Objective ,Shortest-Path Problems" perations Research., **35(1)**, 70-79(1987).

[8] Sunita Prasad, Zaheeruddin and D. K. Lobiyal: "Multiobjective Multicast Routing in Wireless Ad Hoc Networks – An Ant Colony Approach", 978-1-4673-4529-3/12/$31.00 c, 2012 IEEE.

[9] A. Younes: "A Genetic Algorithm for Finding the K Shortest Paths in a Network", Egyptian Informatics Journal., **10(2)**,(2010).

[10] Shashi Raj K and Siddesh G K: "MULTI OBJECTIVE OPTIMIZATION ASSISTED NETWORK CONDITION AWARE QOS ROUTING PROTOCOL FOR MANETS:MNCQM", international Journal of Computer Networks & Communications (IJCNC)., **11(4)**, (2019).

[11] An autonomous competitive learning algorithm using quantum hamming neural networks M Zidan, A Sagheer, N Metwally 2015 International Joint Conference on Neural Networks (IJCNN)., 1-7(2015).

[12] A novel autonomous perceptron model for pattern classification applications A Sagheer, M Zidan, MM Abdelsamea Entropy ., **21(8)**, 763(2019)

[13] Low-cost autonomous perceptron neural network inspired by quantum computation M Zidan, AH Abdel-Aty, A El-Sadek, EA Zanaty, M Abdel-Aty AIP Conference Proceedings., **1905 (1)**, 020005(2017)

[14] A quantum classification algorithm for classification incomplete patterns based on entanglement measure AH Abdel-Aty, H Kadry, M Zidan, Y Al-Sbou, EA Zanaty, M Abdel-Aty Journal of Intelligent & Fuzzy Systems., **38 (3)**, 2809-2816(2019)

[15] Quantum classification algorithm based on competitive learning neural network and entanglement measure M Zidan, AH Abdel-Aty, M El-shafei, M Feraig, Y Al-Sbou, H Eleuch, ... Applied Sciences., **9 (7)**, 1277(2019).