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Research Article

Multiobjective Multicast DSR Algorithm for Routing in Mobile Networks with Cost, Delay, and Hop Count

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Tremendous evaluation of wireless mobile communication needs more efficient algorithms for communication systems. The use of conventional single-objective optimization algorithms may be unsuitable for real applications, because they act to the detriment of the rest of the performance parameters like lifetime network, delay, cost, and hop count; for this reason, multiobjective is needed. This paper presents performance evaluation and compares between the Multicast MDSR and MAODV with MACO. The proposed MDSR is concerned with change of the route discovery phase, where the route selection is based on the shortest path of route reply packets on the route with calculating the number of hop counts. Also, this article compares our MDSR modification with the evaluation algorithm based on Ant Colony Optimization (ACO), which finds the best path and multicast tree optimizes total weight (cost, delay, and hop count) of the multicast tree using multiobjective. Experimental results proved that the proposed MDSR algorithm is more efficient than MAODV and MACO in the total weight (cost, delay, and hop count), respectively. Moreover, the MACO outperforms MAODV for multicast routing problem.

1. Introduction

Mobile Ad hoc Network (MANET) structure is different from the wire networks and wireless networks. Because there is no centralized management, the nodes can move freely at any time and any way. Therefore, the function of routing protocols of MANET is that the nodes should act as a host and router. Furthermore, routing protocols must be suitable for the dynamic topology of MANET [1, 2]. MANET routing protocols are classified into proactive protocols such as DSDV and WRP [3] and reactive protocols such as DSR [4] and AODV [5]. For proactive protocols, each node always keeps the recent paths to each node in the network and has data to send sometimes. On the other hand, reactive protocols create the route on demand. Several studies demonstrated that the reactive routing protocols are better than proactive routing protocols due to packet delivery ratio, less consumed bandwidth and power consumption, and less routing overhead. DSR protocol is a famous reactive protocol. The present paper addresses performance analysis and compares the modified version of MDSR protocol and two protocols (MAODV and MACO). Like all reactive routing protocols, DSR protocol includes two main phases: route discovery phase and route maintenance phase. For route discovery stage, route is determined between any two nodes based on the shortest path metric with minimum hop count also. The shortest path between any two communicating nodes satisfies the minimum end-to-end delay [6–9].

A route established with high reliability between the links must have high quality. The link quality changes normally with time, where it depends on the atmospheric phenomena, nodes mobility, fading, path loss factor, and so on.

Using graphs can simulate and model numerous things which include transformation, traffic control, neural networks, and communication. Also, the routing problem could be solved and modeled with a graph by determining that each host could be a node and each distance between two hosts could be link edge. The routing problem could be classified as a shortest path problem (SPP) in a graph. In the AODV algorithm, a path with a minimum hop count is selected as the optimum path [10].

Multicast consists of multicommunication where data are sent to a set of target destinations. Multiobjective Multicast Paths Problem (MOMPP) needs multicast communication with rigorous quality of service to different parameters such as cost, time, distance, and hop count.

This article improves the DSR algorithm, which finds the best path and multicast destinations that minimize the total cost, delay, and hop count-based ending on multiobjectives. The evaluation of the algorithm based on multiobjectives improves the performance and presents better results for the parameters that have been used. The algorithm can find an optimal solution quickly and has good scalability compared to other protocols.

The paper is organized as follows: Section 2 presents related work. Section 3 introduces the problem description and formulation. Sections 4 presents the MACO algorithm. Section 5 presents the MDSR protocol. Section 6 addresses experimental results. Finally, Section 7 is devoted to conclusion.

2. Related Work

ACO, which has been presented in [11], is a probabilistic technique that solves the computational problems which can be reduced to find good paths for graphs. Ants are stranded for multiagent methods inspired by the behavior of real ants. The pheromone-based communication of biological ants is the most used model. After the solution is established by the ants, some pheromone is success to establish the route which leads to the best solution. Usually, the concentration of pheromone on the route links is corresponding to a good solution optimum path.

For Single-Objective Problem (SOP), there exists only one objective [12]. AODV algorithm is an example of these problems. These methods are uncomfortable for this type of problem. The best solution for this problem depends on multiobjectives. Thus, a good type of this problem named Multiobjective Problem appeared in [13, 14]. Hence, Multiobjective Shortest Path Problem (MOSPP) could find the optimum path based on multiobjectives.

Paper [15] developed an effective new multiobjective approach to MANET proactive protocol where objectives reduce the average end-to-end delay, maximize network lifetime, and maximize package delivery. They developed Dijkstra's algorithm expansion algorithm to deal with multiple objective guidance problems using the compound utility approach. They developed multiobjective routing mechanism of OLSR called OLSR_MO.

Paper [16] introduced a multiobjective algorithm based on ant colonies to build a multicast tree for data transmission in a computer network. The proposed algorithm simultaneously improves the total weight (cost, delay, and hop) of the multicast transmission tree. Experimental results demonstrate that the proposed algorithm trumps a recently deployed multiobjective multicast algorithm specifically designed to solve the multicast routing problem. Also, it can find a better solution with rapid convergence speed and high reliability.

Paper [17] presented a new algorithm depending on Ant Colony Optimization (ACO) that can find the best path and multicast tree to improve total weight (cost, delay, and hop) of the multicast tree. Experimental results proved that the proposed algorithm performs well for the recently published multiobjective multicast algorithm specially designed for solving the multicast routing problem.

The combination use of single-objective optimization algorithms may be inappropriate for fact applications because they work at the expense of the other performance parameters. For example, the goal of maximizing coverage in WSN requires a scattered mode of contract, which increases the cost of energy to connect. Thus, maximizing network lifetime is important. Similarly, the scattered deployment of sensor nodes aggravates communication. Moreover, to save energy, it is better to transfer sensor data at a reduced distance in each hop. However, this increases the cumulative time to transfer data from the source to the final destination. Hence, the reduction of the energy cost of communications in WSN contrasts the goal of reducing the end-to-end access time. For this reason, the set of constraints in order to enhance the performance of WSNs is a critical challenge [18, 19].

3. Problem Description and Formulation

MANET could be represented as a graph $G = (N, E)$, where N is the number of nodes and E is the number of edges. The multicast problem for routing with delay and bandwidth is calculated from the source node to multidestination nodes. $X = \{n_0, u_1, u_2, \ldots, u_m\} \in N$ represents the multicast tree from the source to destination, where n_0 is the source node and $u = \{u_1, u_2 \ \ldots \ u_m \}$ is a group of destination nodes. Multicast tree $T = (N_T, E_T)$, where $N_T \subseteq N$ and $E_T \subseteq E$, and there exists the path PT (n0, d) from source node n0 to each destination node d∈U in T. e (i, j) is the edge from node i∈N to node j∈N. The functions are calculated for each link e (e∈E), cost C (e), delay D (e), hop H (e), and bandwidth B (e). The parameters must define the criteria that must be constrained [20].

The cost of the path P_T could be calculated by

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

The total costs of the tree T could be given by

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

The total delay of the path P_T (n0, d) could be calculated by

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

The delay of multicast tree T could be calculated by

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

The hop count summation of all links could be given by

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

Hops of multicast tree 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 is

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

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 are defined as follows:

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

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

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

4. The Multicast Ant Algorithm

(1) Assuming that 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 multiobjective multicast routing problems, an ant moves through a path using the corresponding probabilities function and updates pheromone on that path after the end of each iteration. The following steps describe the problem solved with the ant algorithm:

(2) The multicast routing problem is solved by ant algorithm.

(3) Set the node numbers ($|\mathrm{N}|$ nodes).

(4) Create the network of $|\mathrm{N}|$ nodes.

(5) Test the network connection.

(6) If there is no connection, then repeat step 2.

(7) Define n_0 (source node) and U (a set of destination nodes).

(8) Set $\mathscr{P}$.

(9) Set $n_r = 1$.

(10) Set $g = 0$ (g is a loop counter), and put ants into S.

(11) For each destination node $u_i \in U$, generate Pi and the group paths for each destination node u_i.

(12) Initial value $\tau_k = 0$; to the pheromone intensity of every path Pk, $k = 1, 2, \ldots, n$.

(13) Begin the first tour.

(14) Let m ants transfer from S to u_i on P_i equally (the ant number in each path p_k is equal).

(15) We could calculate the pheromone amount left by x ants at p_k ($\Delta\tau_k$) using $\Delta\tau_{i,j}$ which is given by

$$\Delta\tau_{i,j} = \begin{cases} \dfrac{1}{L_k} & \text{if ant } k \text{ travels on edge } i;\ j, \\ 0 & \text{otherwise,} \end{cases} \tag{12}$$

where L_k is the cost of the kth ant's tour (typically length).

(16) Update the local pheromone τ_k using equation (10).

(17) Make a new cycle.

(18) Set $g = g + 1$.

(19) An ant will move from node i to node j

$$P_{i,j} = \frac{\left(\tau_{i,j}^{\alpha}\right)\left(\eta_{i,j}^{\beta}\right)}{\sum\left(\tau_{i,j}^{\alpha}\right)\left(\eta_{i,j}^{\beta}\right)}, \tag{13}$$

where $\tau_{i,j}$ is the pheromone quantity on edge i, j, α is a control of the influence parameter of $\tau_{i,j}$, β is a control of the influence parameter of $\tau_{i,j}$, $\eta_{i,j}$ is the approbation of edge i, j (typically$1/d_{i,j}$), and α, β are user defined parameters ($0 \le \alpha, \beta \le 1$).

(20) Compute $\Delta\tau_k$ using equation (14).

(21) Update the global pheromone τ_k using the amount of pheromone according to the equation

$$\tau_{i,j} = (1 - \rho)\tau_{i,j} + \Delta\tau_{i,j}^{\text{total}}. \tag{14}$$

(22) Repeat from step 8 until g_{max}.

(23) Compare τ_k the values to obtain a better path for the destination u_i.

(24) End.

(25) Collect all short paths ($P_{i,j}$) to get the multicast tree.

(26) Set $n_r = n_r + 1$.

(27) Store information of tree.

(28) If $n_r < \mathscr{P}$ go to step 8 to generate new candidate tree.

(29) Output the optimum tree.

(30) End.

5. The Proposed Algorithm

The path is established when the source node initiates a route request or it broadcasts the RREQ message. After that route reply is initiated by the destinations nodes, and its route reply is sent by RREP messages.

5.1. Start MDSR Algorithm

5.1.1. RREQ Discovery

(1) Forward route requests RREQ messages to search for destination nodes

(2) RREQ propagate forms the source node to the destinations.

5.1.2. RERP Initiation. Multicast RERPs traverse through these paths back to inform multicast paths of the destinations at the source and intermediate nodes.

5.1.3. Data Transfer. Transfer all the data over the best baths.

5.1.4. RERR Initiation

(1) RERR is created when a node fails

(2) The node which sends data will have time-out

(3) RERR packet will be sent to the sender of the data packet

5.1.5. RERR Processing. RERR processing will be done by intermediate nodes which receives the RERR packet. Upon receiving the RERR packet, the following steps take place:

(1) From the routing table of the nodes, remove all those entries where the entry of the next node in the routing table is equal to the successor of the current nodes in the path field of the RERR packet.

(2) Add the entries in the routing table for all nodes that are successor of the current node in the path field of the RERR packet.

(3) If current nodes are unequal to destination nodes,

Then prepend the nodes' address and send the packet towards the multicast destination

Else

Do not forward RERR.

And

Go to step 2 of RREQ discovery

End of algorithm.

Algorithm flowchart is shown in Figure 1.

6. Experimental Results

In this paper, we supposed the network with omnidirectional antenna is reliable while giving the specific focus to augment QoS delivery and the nodes have the same energy and transmission range. Most protocols focus on network performance enhancement, which achieves a cumulative optimal solution, and performance is must [21].

Parameters used for modified MDSR 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. All the results obtained by comparing protocols are shown in Table 1.

Classification of these protocols is referenced to proactive routing protocols in terms of path cost distance, hop count, and delay. Comparison results of MDSR, MAODV, and MACO are obtained and their inferences are presented in Table 1 and the following figures. Figures 2–8 depict the comparison between MDSR, MAODV, and MACO protocols on the mobile network graph that has been used. The figures show that the best path routes in MDSR and MACO are better than MAODV which is shown in Table 1.

Figure 6 shows that this approach enables the proposed Multiobjective MACO routing protocol in paper [17] to exhibit more reliable data transmission than the native MAODV routing protocol as it is observed that the hop count of MACO is less than that of MAODV, and the modified MDSR is less than the others, respectively. This efficacy evaluation could be observed from the results obtained (Figures 6–8). MDSR shows better performance.

Figure 7 shows that the modified MDSR has better performance than Multiobjective MACO routing protocol in paper [17] to exhibit more reliable data transmission than the native MAODV routing protocol. As observed, the delay of MDSR is less than that of MACO and MAODV, respectively. This efficacy evaluation could be observed from the results obtained (Figures 6–8). The MACO is better than MAODV and the MDSR is better than MACO.

The cost performance by the MACO routing protocol modified MDSR 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, MDSR assures reliable transmission and efficient performance other than MACO and MAODV. In addition, it avoids iterative network discovery during any link.

Statistical analysis has been made for the modified MDSR and the MACO protocol that has been proposed in paper [17] with the standard MAODV protocol. Table 2 shows statistical analysis comparisons of cost between protocols. The mean of MACO is less than that of others but the std. deviation and std. error mean of MDSR are less than those of MAODV and MACO, as shown in Table 2.

Table 3 shows the statistical analysis of hop count comparisons between protocols. The mean of MDSR is less than that of other protocols but std. deviation and std. error mean of MACO are better than those of MDSR and MAODV.

Table 4 shows the statistical analysis of delay comparisons between protocols. The means, std. deviation, and std. error mean of MDSR are less than those of other protocols. The MDSR performs best.

A summary of the overall analysis of the performance of the protocols is presented in Tables 5, 6, and 7. It indicates that there is greater improvement in the abovementioned parameters with MDSR over MACO and MAODV. Here, the MACO routing protocol exhibits that the delay improved 1.45% which is higher than the native MAODV protocol and the improvement of MDSR is 11.45% other than MADOV. The improvement of MDSR compared to MACO in delay is 10%, suggesting that the MDSR is the best.

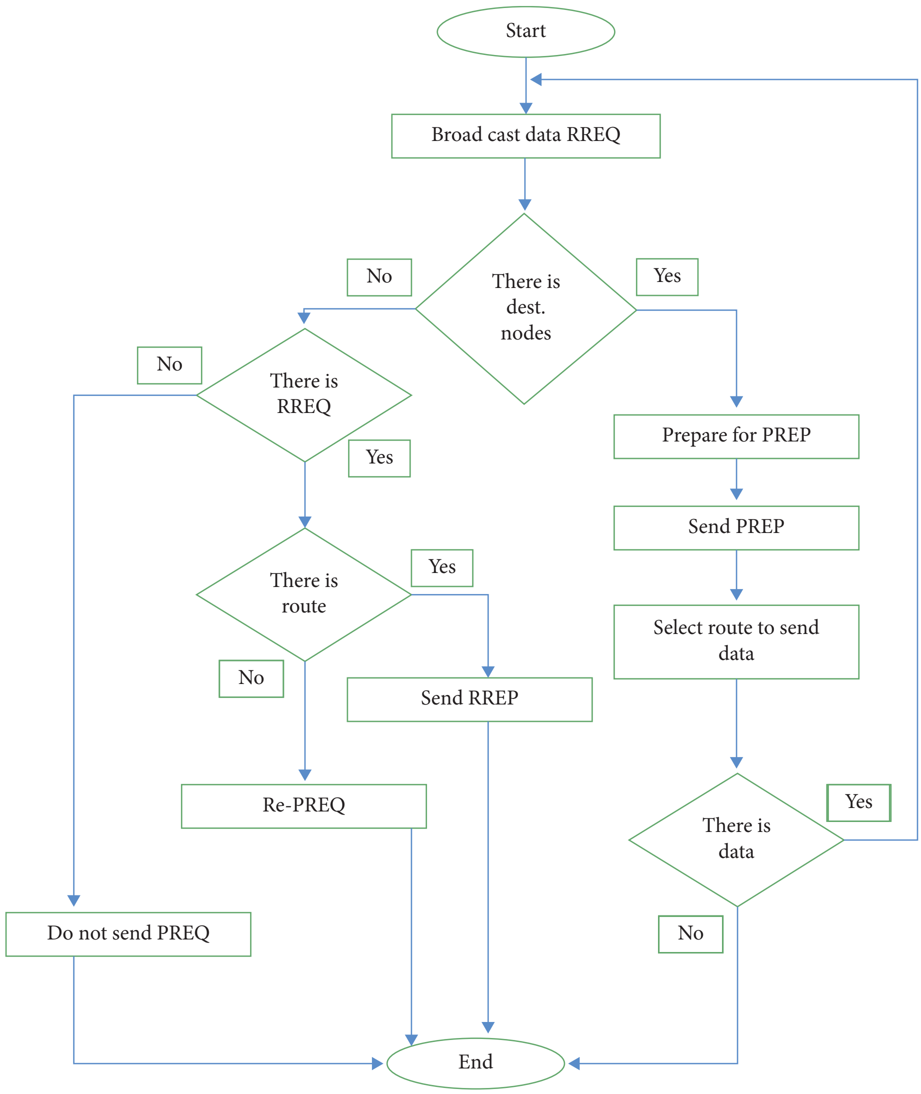

Figure 1: : Flowchart for MDSR routing protocol.

Table 1: Route from source node 1 to selected destination nodes, delay, hop count, and distance cost, for MAODV, MACO, and MDSR.

Des. node	MAODV			MACO			MDSR		
	Delay	Hop	Des. cost	Delay	Hop	Des. cost	Delay	Hop	Des. cost
7	10.65	7	30.6978	5	4	17	4	3	13.2111
8	7.6	4	15.7678	10	4	12	5	4	15.7678
9	3.6	2	9.6056	3	3	11	3	2	9.6056
10	5.6	3	12.6056	8	3	9	4	3	12.6056

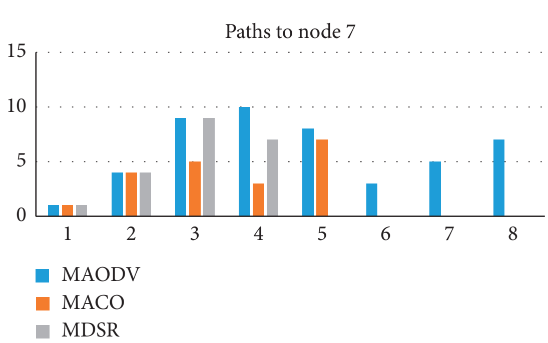

Figure 2: The path distance to node 7.

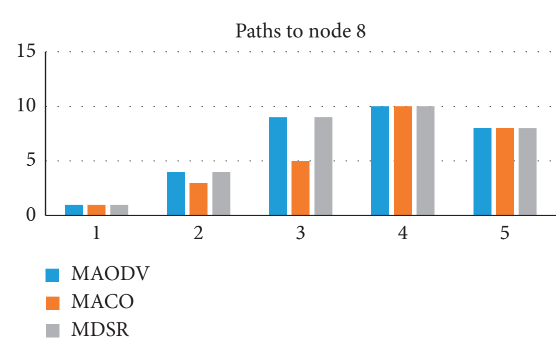

Figure 3: Comparison of the paths' distance to node 8.

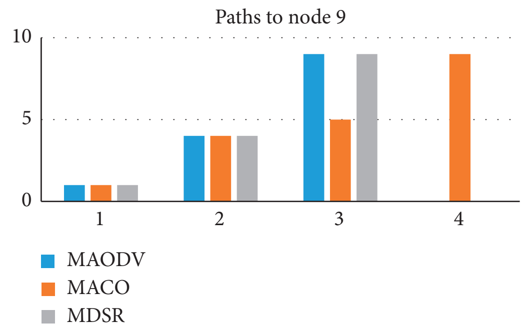

Figure 4: The path distance to node 9.

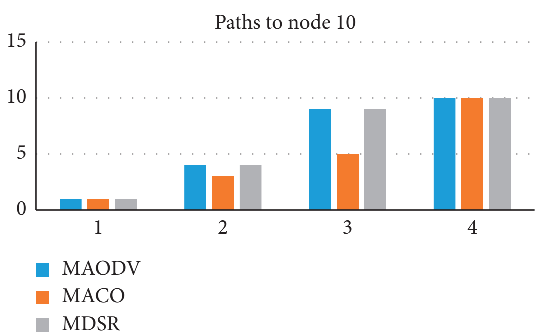

Figure 5: The path distance to node 10.

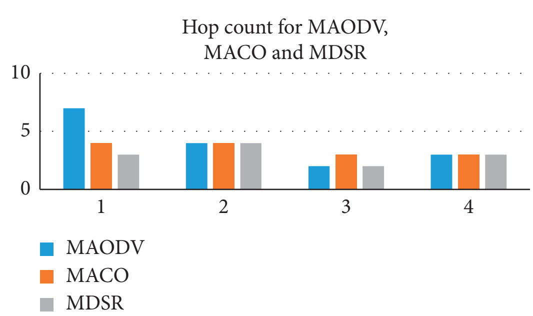

Figure 6: The hop count comparison of MAODV, MACO, and MDSR.

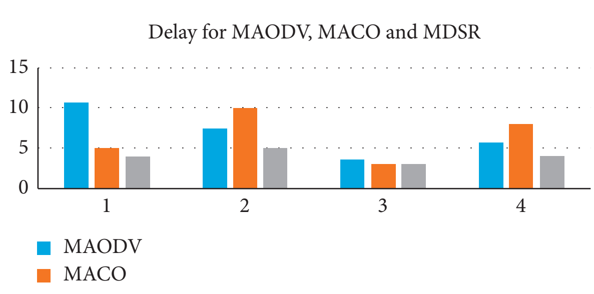

Figure 7: The delay comparison between MAODV, MACO, and MDSR.

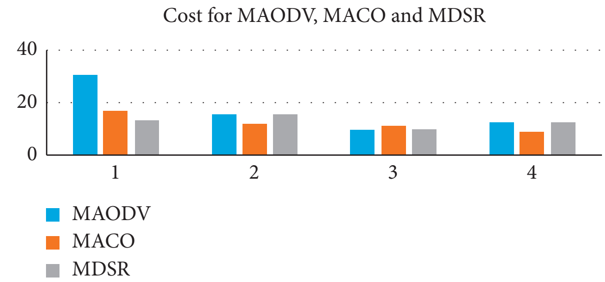

Figure 8: The distance cost comparison of MAODV and MACO.

Table 2: Statistics of MAODV, MACO, and MDSR for cost.

Protocols	N	Mean	Std. deviation	Std. error mean
MAODV	4	17.1692	9.36343	4.68171
MACO	4	12.2500	3.40343	1.70171
MDSR	4	12.7975	2.53106	1.26553

Table 3: Statistics for MAODV, MACO, and MDSR for hop count.

Protocols	N	Mean	Std. deviation	Std. error mean
MAODV	4	4.0000	2.16025	1.08012
MACO	4	3.5000	.57735	0.28868
MDSR	4	3.0000	.81650	0.40825

Table 4: Statistics of MAODV, MACO, and MDSR for delay.

Protocols	N	Mean	Std. deviation	Std. error mean
MAODV	4	6.8625	3.00704	1.50352
ACO	4	6.5000	3.10913	1.55456
MDSR	4	4.0000	.81650	0.40825

Table 5: Comparative analysis between MAODV and MACO.

Parameters	MAODV	MACO	Percentage improvement
Delay	27.45	26	1.45
Hop count	16	14	2
Cost	68.6768	49	17.7

Table 6: Comparative analysis between MACO and MDSR.

Parameters	MACO	MDSR	Percentage improvement
Delay	26	16	10
Hop count	14	12	2
Cost	49	51.1901	2.1901

Table 7: Comparative analysis between MAODV and MDSR.

Parameters	MAODV	MDSR	Percentage improvement
Delay	27.45	16	11.45
Hop count	16	12	4
Cost	68.6768	51.1901	17.4867

Similarly, the hop count performance of the MACO routing protocol over the classical MAODV routing approach improved 2%. However, the improvement of MDSR other than MAODV is 4% and 2% from MACO. Finally, the cost performance of modified MDSR and MACO protocols improved 2.1901% and with the classical MAODV improved 17.4867%. The results show that the modified MDSR routing protocol exhibits better even with an increase in nodes or network density.

7. Conclusion

Our experimental results discussed the efficiency of the modified MDSR protocol other than MACO and MAODV algorithms which are presented in [17]. The results that are obtained from the modified DSR are compared to the results that are obtained from MACO algorithm and results obtained from the classic MAODV protocol.

The cost, delay, and hop are considered multiobjective routing problems. ACO algorithm is one of the multiobjective algorithms that can solve this problem; so, it has been used to solve the presented problem with the MDSR and MAODV. This paper solved the problem of multicast routing using the total cost, delay, and hop count. The results and comparisons depicted that the results of MDSR are better than MACO and MAODV. Also, experimental results illustrated that the modified MDSR algorithm shows better performance in terms of delay, hop count, and cost and the MACO is also better than MAODV exhaustion that affirms its suitability with real-time communication and has better performance of cost, hop count, and stable in delay. The algorithm achieves the requirement quality of service of communication.

Data Availability

All data generated or analysed during this study are included in this published article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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