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Swarm Based Hybrid ACO-PSO Meta-Heuristic (HAPM) for QoS Multicast Routing Optimization in MANETs

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Abstract
For large and dynamic networks, traditional MANETs multicast routing protocols are not appropriate for searching the optimal paths considering QoS constraints as the problem leads to NP-complete in nature. Biologically inspired algorithms like Ant colony optimization (ACO), Particle swarm optimization (PSO) and Artificial Bee Colony have attracted great attention from researchers to solve the combinatorial problem. ACO and PSO provide more reliable routes as compared to traditional methods. In this paper, we have proposed 'Hybrid ACO-PSO Meta-Heuristic (HAPM)', a combination of ACO, PSO, and a dynamic queue mechanism to improve QoS constraints and minimize QoS the data dropping. Simulation is performed in NS2 and the results revealed that the presented HAPM algorithm provides better efficiency in terms of Packet Delivery Ratio (PDR), Ent-to-End Delay, Hop Count (H_c), Routing Overhead) and Throughput as compared to ACO, PSO, hybrid ACO-PSO, Enhanced-Ant-AODV and Cuckoo Search Optimization AODV (CSO-AODV). The PDR in HAPM is improved by 20%, 11%, 8%, 2% and 0.6%; delay of HAPM is reduced by 54%, 47%, 40%, 49%, and 30%; routing overhead of HAPM is reduced by 49%, 41%, 23%, 10% and 17%; throughput of HAPM is improved by 40%, 28%, 11%, 8% and 36% as compared to ACO, PSO, hybrid ACO-PSO, Enhanced-Ant-AODV and Cuckoo Search Optimization AODV (CSO-AODV) respectively. The Hop count of HAPM has also been reduced by 90%, 87%, and 83% compared to ACO, PSO, and Enhanced-Ant-AODV respectively. The proposed HAPM does not overburden the time complexity in our implementation.

Keywords Ant colony optimization · Particle swarm optimization · Mobile ad-hoc network · Route optimization · Dynamic queue · Quality of service (QoS)

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1 Introduction

There are primarily two types of wireless network models- one with fixed infrastructure and another without any infrastructure. In a fixed infrastructure network, there is a central coordinator called Access Point (AP) through which communication between nodes is performed. The disadvantage of this type of model is the large overhead of keeping the routing tables. In the network having no infrastructure, there is no central coordinator for communication between the nodes and is called Mobile Ad Hoc Networks (MANETs). Thus, MANET is defined as a network that is a group of mobile nodes and operates without a central coordinator. There are no specific topology and nodes can enter and quit the network and transfer the messages at any time. MANETs have remarkable features such as—multi-hop routing, self-creation, self-organization, self-administration, self-directed terminal and dynamic network topology. Because of these exclusive features, MANETs are used for military operations, recuse operations, business works, classrooms and conferences. However, due to limited resource availability, lack of authorization facilities, self-configuring, self-healing and the dynamic nature of network topology, MANETs have some specific issues like routing, multicasting, improving Quality of Service (QoS) constraints and security, which have made it very popular in the research area.

Multicasting is the network's capability of group communication. Copies of a single message from the source node/nodes are forwarded to a set of destinations specified by a single address [1]. In multicasting, there is a group of nodes interested in sharing a particular data. Any node can join or leave the group at any time and a node may be a member of more than one group. i.e. the membership of the group is dynamic. There is no restriction on the location and number of nodes in a group. Multicast Routing (MR) saves bandwidth by avoiding re-transmission of data and reducing RO. Searching the optimal path between a source node and a group of destinations and provisioning QoS constraints like maximum PDR, minimum E2ED and minimum RO has become necessary to support real-time-based applications such as video conferencing and audio conferencing and webcasting. However, due to MANET's large size and dynamic nature, the MR problem is a challenging issue for communication networks and contributes to NP-complete in nature. Routing algorithms are classified into three classes:—reactive, proactive and hybrid routing algorithm. The traditional routing protocols Ad Hoc On-Demand Distance Vector (AODV) [2], Destination-Sequenced Distance-Vector Routing (DSDV) [3], Dynamic Source Routing (DSR) [4], Optimized Link State Routing Protocol (OLSR) [5] and ZRP [6] are not suitable for large and dynamic networks due to increasing the computational complexity [7–10].

Due to increasing the number of terminals in the network day by day, the communication process has become complex. In this scenario, the complexity in multicast routing is also rises and becomes a prime concern to the research community. The researchers have developed several techniques; out of them, Swarm-based multicast routing protocols received more attention to find the optimal routes in large and complex networks [11, 12]. Therefore, a novel attempt can be made by developing swarm-based multicast routing or hybridized swarm-based multicast routing. Hybrid ACO-PSO Meta-Heuristic (HAPM) along with dynamic queue to improve the QoS algorithm have been proposed to solve the multicast routing problem. The paper is systematized as follows: Sect. 2 briefly introduces AODV, ACO, and PSO methods. Section 3 discusses various related routing protocols that are currently in use. The proposed work's design process is described in Sect. 4. The simulation tool's basis and performance indicators are described in Sect. 5.

2 Background

2.1 AODV

Ad hoc On-Demand Distance Vector Routing (AODV) [2] is a routing protocol used by mobile nodes in the ad hoc network having the following features:-

1. It adopts the flooding mechanism of DSR [4] for route finding and route repair by using Route Request packets (RREQ), Route Reply Packets (RREPs) and Route Errors (RERRs).
2. It adopts the sequence number (Seq_N) procedure of DSDV [3] to avoid old/broken loops.

When the route is requested in the network, the source node relays the RREQ to all its neighbors to find the destination node. The destination node sends the RREP to the source node after receiving RREQ. The source node then begins forwarding the data through the chosen route to the destination node. Each node contains a routing table for storing data about routes. The following entries are there in the routing table:-

1. Destination ID to identify the destination node.
2. Destination Seq_N to avoiding routing loops.
3. Hop Count (H_c) to reach the destination.
4. Lifetime to detect link failure by using Route Error (RERR) packets.

AODV [13] offers quick adaptation to highly dynamic topologies to give better performance than other traditional routing protocols. However, the performance degrades as the network size increases and thus inappropriate for large size networks.

2.2 ACO

Ant colony optimization (ACO) [14] is a famous swarm intelligence approach based on the food-seeking behavior of ants. Ants deposit a particular quantity of a chemical substance (named as pheromone) which serves as a route marker for the successor ants. Initially, ants select a random path between nest and food. They can discharge a variable amount of pheromone trails on their ways. On the premise of deposited secretion quantity, the newer ant selects the optimal path having higher secretion concentration that is the shortest path among all remaining alternative paths. The concentrations of the pheromone of the shortest path are more than that of all other remaining paths.

2.3 PSO

Particle swarm optimization (PSO) is a computational method based on swarm intelligence algorithm. It was suggested by Kennedy and Eberhart in [15], arising from two different concepts: the idea of swarm intelligence centered on the observation of swarming activities by certain types of animals (such as birds and fish) and the field of evolutionary computation. PSO has been applied to several real-life problems due to its unique

searching mechanism and easy implementation. PSO uses agents called particles, which form a swarm flying in search space looking for the best solution. A brief overview of the preceding works considering one or two QoS constraints for searching the optimal route in MANET is presented in next section. We present an overview of existing conventional ACO and PSO-based routing methods.

3 Related Works

Perkins and Bhagwat [3] proposed DSDV routing protocol that provides the shortest path. However, it consumes a large amount of bandwidth and extra routing overhead. Johnson and Maltz [4] proposed DSR routing protocol that is not suitable for large and dynamic networks due to high overhead. Perkins and Royer [2] suggested AODV, suitable for the dynamic network but consumed more bandwidth. Hass and Pearlman [6] proposed ZRP, which reduces the routing overhead. Jacquet et al. [5] proposed OLSR, which also reduces routing overhead. However, all these traditional routing algorithms are not suitable for large and dynamic networks due to computational complexity. Recently, researchers show their interest in using swarm intelligence (SI) for routing in MANET. Ant colony optimization (ACO) [14], particle swarm optimization (PSO) [15], bacterial foraging optimization and artificial bee colony (ABC) are examples of swarm intelligence.

Di Caro and Dorigo [16] proposed AntNet, which takes more time to propagate routing information. Gunes et al. [17] proposed ARA routing algorithm that reduces routing overhead only in low mobility. Hussein and Saadawi [18] presented ARAMA routing algorithm, which considers only delay and hop counts as QoS constraints. Di Caro et al. [19] proposed AntHocNet routing algorithm, which generates high overhead. Asokan et al. [20] proposed ADSR routing algorithm, which generates more routing overhead than DSR. Osagie et al. [21] presented PACONET routing algorithm where PDR is the same as compared to AODV. Wang et al. [22] proposed HOPNET routing algorithm, which produces less routing overhead. Deepalakshmi and Radhakrishnan [23] presented AMQR routing algorithm, which considers PDR, E2ED, RO as QoS constraints. Venkata et al. [24] proposed QAMR routing overhead, which generates more RO than AODV. Al-Ani and Seitz [25] proposed QoRA routing protocol, which consumes more bandwidth and energy. Ziqiang et al. [26] presented PSO based multicast routing algorithm, which produces a multicast tree having minimum cost. Manoj et al. [27] proposed HACOPSO hybrid routing protocol, which produces a multicast tree having the minimum cost and satisfies QoS constraints. Girgis et al. [28] designed a tree-growth based ACO (TGACO) algorithm, which includes delay and jitter as cost function for the multicast tree. Nassir and Abdelghani [29] designed bio-inspired OLSR routing protocols based on GA. It improves the protocol performances in terms of PLR, NRL and E2ED. CSO-AODV [30] routing protocol based on enhancing the Cuckoo Search (CS) technique gives better result in terms of PDR, packet drops, and overhead. Enhanced-Ant-AODV [31] uses combining AODV and ACO ideas to improve QoS constraints and provide better results than AODV, DSR, and Enhanced- DSR in terms of PDR, throughput, and delay.

In the multicast routing, finding the optimal path between source node to destination nodes also needs to meet the QoS constraints like maximum PDR, minimum E2ED, minimum $H_{c,}$ minimum routing overhead, and maximum throughput. However, large and dynamic network and a combination of two or more QoS constraints, multicast routing

problem has become NP-hard problem. Various routing protocols have been developed, but they are not suitable for such this type of network.

Table 1 presents the chronological summary of references used in the literature review.

4 Design Methodology

ACO and PSO are two of the most successful swarm intelligence approaches. Because of their self-organizing behavior, optimal path discovery, multipath support and topological change adaptability. ACO and PSO-based multicast routing protocols are appropriate and flexible. The ACO method is more resilient, but the PSO algorithm is a global minimization approach that produces faster results and needs fewer algorithm parameters. That's why, in order to address the multicast routing problem, we are combining ACO and PSO.

The proposed hybrid ACO-PSO Meta-Heuristics (HAPM) is the output of the fruitful hybridization of the two most popular swarm-based algorithms ACO and PSO in combination with AODV for multicast routing problem. The proposed HAPM routing algorithm improves the quality of service (QoS) of the MANET.

4.1 Pseudo-Code for Searching Fresh Route

The flowchart of the proposed HAPM routing method for searching the fresh route is shown in Fig. 1. In pseudo-code 1, input Z_n mobile nodes, S_i and r_i is the source node and destination node respectively. Apply AODV algorithm initially searches the fresh routes by sending Route Request packets (RREQ) to their adjacent nodes. After getting routes, ACO calculates the probability of each link to select the link having a higher probability than all other connected links to the same node. ACO is the pheromone-based communication where ants deposit pheromone along their routes. This pheromone value is calculated in every intermediate node based on the number of receiving ant packets by neighbour nodes and finally select the path based on higher pheromone value. ACO uses the following Eq. (1) to calculate the probability of the edge to move. After selecting the path having higher probability, ACO uses trust-based path selection based on threshold packet delivery to avoid the collision and congestion problem in the network. When the data delivery by a node is higher than 70% it means that the node is trusted and there is less chance of collision and congestion. But, on the other hand, if the data delivery by a node is less than the threshold then discards that path.

$$p_{si}^{k} = \frac{\text{no of ant } e_{si}}{\text{total ants}} \tag{1}$$

where P^{k}_{si} probability where ant k select edge si, e_{si} link between sth node to ith node.

4.2 Pseudo-Code for Route Break

The flowchart of the proposed HAPM routing method for searching the routes when there is a link break as shown in Fig. 2. In pseudo code 2, after selecting the route, PSO is applied to enhance the network's reliability. When the links break during the data communication, PSO searches the new routes for route re-establishment. When the selected paths break, PSO uses a local search method based on minimum delay (E2ED) and minimum

Table 1 Chronological summary of references used in the literature review

SL. No	Existing schemes	Author	Routing approach	Compare with	No. of nodes	Remarks
1	DSDV	Perkins and Bhagwat [3]	Proactive	–	–	Single Shortest Path High overhead Consume more bandwidth
2	AntNet	Di Caro and Dorigo [16]	Reactive	OSPF, SPF, BF, Q-R, PQ-R, Daeman	8, 14, 57	Improve delay and PDR
3	DSR	Johnson and Maltz [4]	Reactive	–	–	Save bandwidth Large delays Scalability problems
4	ZRP	Hass and Pearlman [6]	Hybrid	–	–	Reduce overhead Less delay
5	OLSR	Jacquet et al. [5]	Proactive	–	–	Reduce the control overhead
6	ARA	Gunes et al. [17]	Reactive	AODV, DSR, DSDV	50	Not support high mobility
7	AODV	Perkins and Royer [2]	Reactive	DSR	–	Less overhead than DSR Large delays Consume more bandwidth
8	ARAMA	Hussein and Saadawi [18]	Reactive	–	30	Reduce route discovery Reduce route maintenance
9	AntHocNet	Di Caro et al. [19]	Hybrid	AODV	50	Improve PDR, E2ED, Jitter High overhead
10	PSO	Ziqiang et al. [26]	Reactive	ACO, GA, IA	20–200	Minimum cost of the multicast tree Execution time is less
11	ADSR	Ashokan et al. [20]	Reactive	AODV	100	Improve PDR, delay High overhead
12	PACONET	Osagie et al. [21]	Reactive	AODV	50	Improve delay High overhead
13	HOPNET	Wang et al. [22]	Hybrid	AODV, ZRP, AntHocNet	50	High overhead Not suitable for the large network

Table 1 (continued)

SL. No	Existing schemes	Author	Routing approach	Compare with	No. of nodes	Remarks
14	AMQR	Deepalakshmi and Radhakrishnan [23]	Reactive	AODV, AntHocNet	20, 40, 60, 80, 100	Improve PDR, E2ED, Jitter High overhead Congestion problem
15	QAMR	Venkata et al. [24]	Reactive	AODV, OLSR, AntHocNet	50	Improve PDR, delays High overhead
16	HACOPSO	Manoj et al. [27]	Reactive	PSOTREE, TGBACA	100	Improve E2ED, Jitter
17	QoRA	Al-Ani and Seitz [25]	Reactive	AODV, CLWPR	100	Consumes more bandwidth and energy
18	TGACO	Girgis et al. [28]	Reactive	TGBACA	25	Low cost to generate the multicast tree Less execution time
19	CSO-AODV	Mandhare et al. [30]	Reactive	AODV, ACO, PSO	10–100	Not mentioned about the delay
20	GA-OLSR	Nassir and Abdelghani [29]	Hybrid	OLSR	10, 20	Improve PLR, NRL and E2ED Suitable for a small network
21	Enhanced-Ant-AODV	Sarkar et al. [31]	Reactive	AODV, DSR, Enhanced- Ant-DSR	10–100	Not mentioned about packet loss ratio and jitter

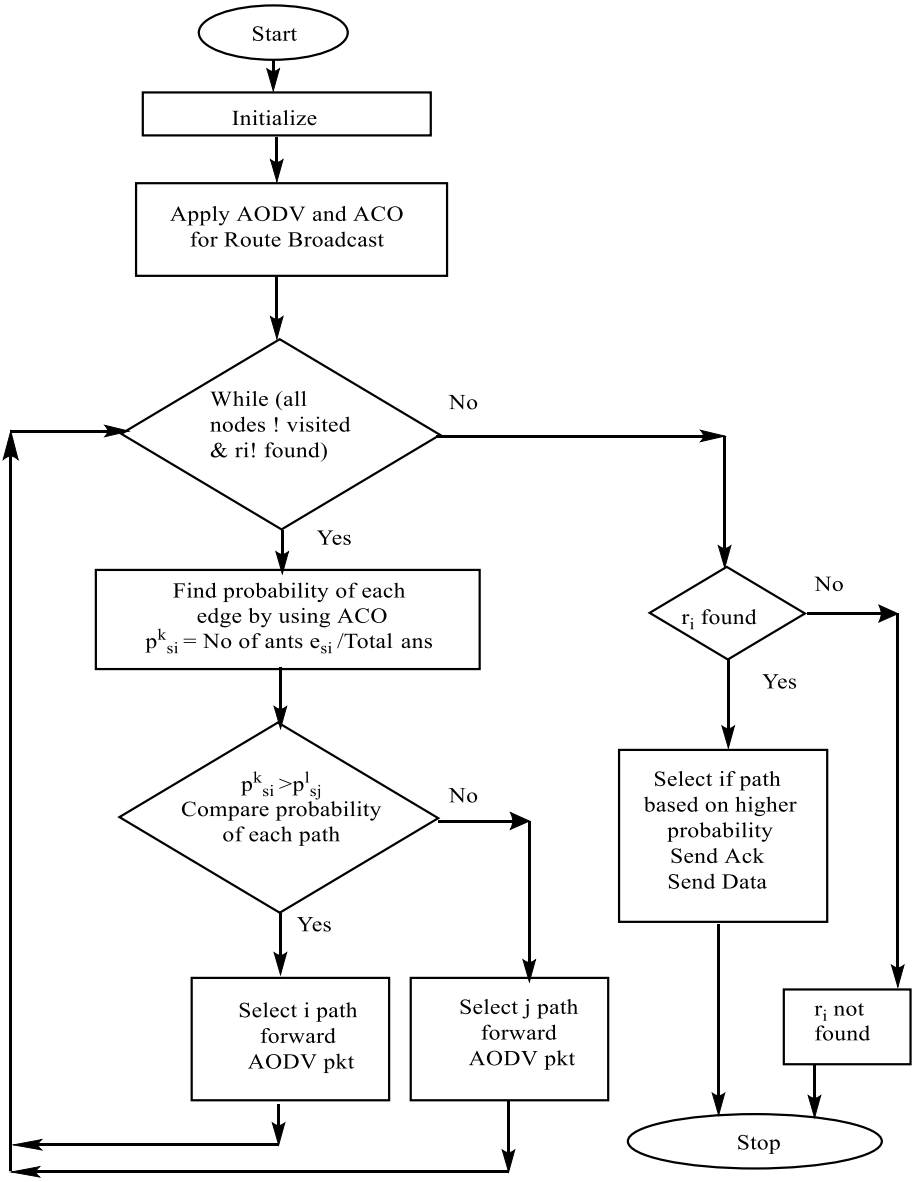

Fig. 1 Schematic diagram of the proposed HAPM approach for route search

hop count (H_c). Due to less dropping of packets during the re-establishment of routes, the execution time of the proposed HAPM does not overburden even the use of hybridization. PSO uses the following Eq. (2) to calculate g_{best}.

$$g_{best} = min\left(\left(e_{si}\right) \,\&\, min\left(\mathrm{H_c}\left(e_{si}\right)\right)\right) \tag{2}$$

where e_{si} Link between sth node to ith node, g_{best}: Global best position among all particles, *E2ED*: End-to-End Delay, $H_{c:}$ Hop Count.

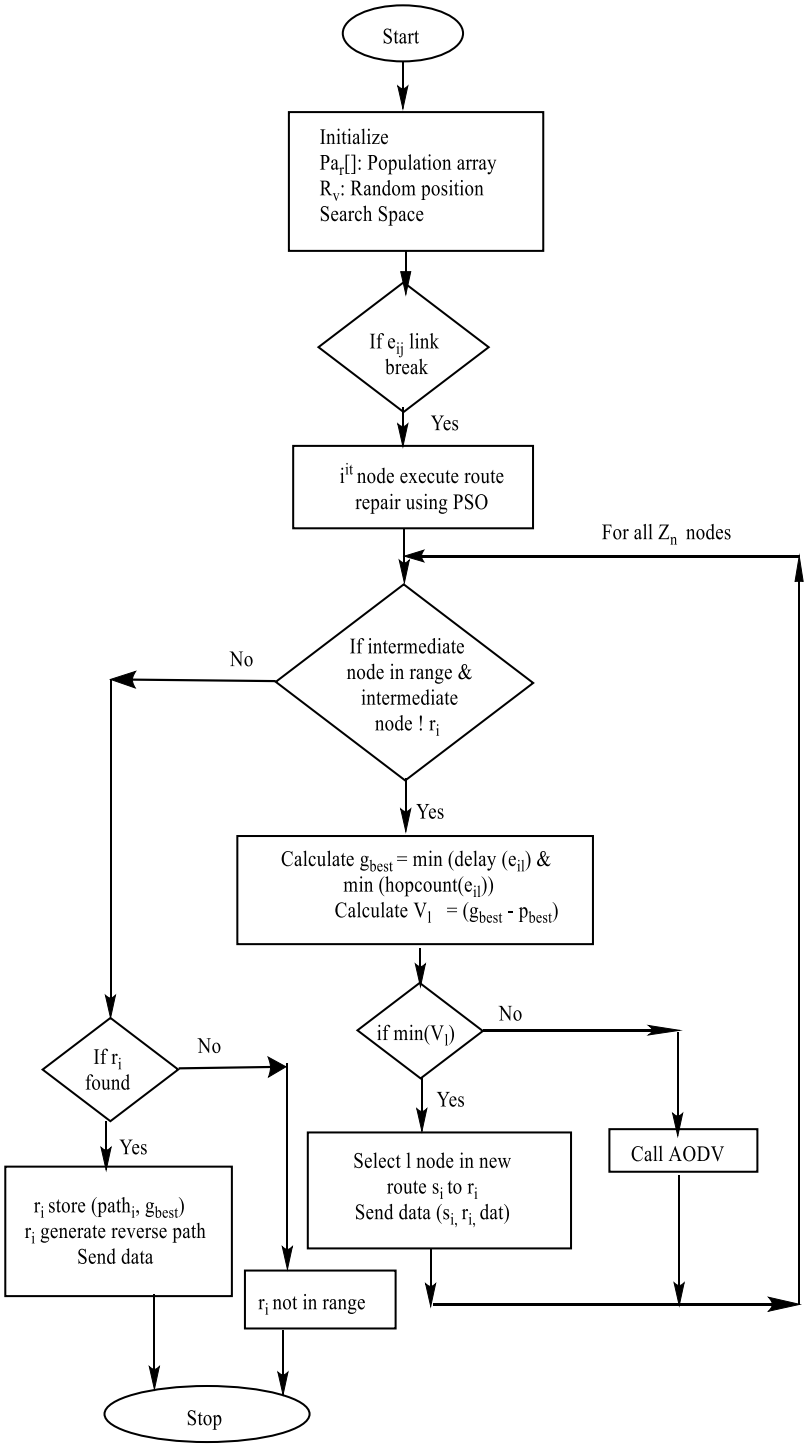

Fig. 2 Schematic diagram of the proposed HAPM approach for route break

In this proposed method, Queuing mechanism and acknowledgment-based data rate changing are also used after a little bit of modification. The queue method sets the queue size dynamically based on data arrival in the concerned node. Another technique is acknowledgment-based data delivery to control the flow while the data-sending rate is higher and data drop in between routes. When the source node does not get any acknowledgment from the destination nodes, the source node starts to search the new routes after waiting three times of Round Trip Time (RTT). In the other case, when the source node gets dynamic time acknowledgment from the destination nodes, the source node computes the acknowledgment delay difference and sets the new data rate. The new data rate is inversely proportional to the delay, and thus the proposed work improves the network quality of service (QoS) in MANETs.

The fitness function of HAPM routing method is evaluated by a function that includes PDR, E2ED, and hop count QoS constraints. Fitness function is formulated as:

$$f_e = \frac{1}{PDR > 70\%} + \mathrm{E2ED}_{min} + \mathrm{Hc}_{min} \tag{3}$$

where f_e Fitness function, *PDR* Packet Delivery Ratio, *E2ED* End-to-End Delay, H_c Hop Count.

It is needed to minimize the objective function f_e, to improve the QoS by maintaining high PDR, low delay and low hop count.

Pseudo-code 1: HAPM algorithm for route search

Input:
Z_n: *n number of mobile nodes*
s_i: *source node* $\in Z_n$
r_i: *destination node* $\in Z_n$
i_k: k^{th} *intermediate node* $\in Z_n$
d_n: *queue* $\forall Z_n$ *(initial 50)*
ψ: *Radio Range 550m*^{2} $\forall Z_{k=1}^{n} = Z_{k-1}$
AODV: ad hoc routing
ACO: Ant optimization (optimization during initial search)
PSO: Particle swarm (optimization during route repair)
ack_n: n^{th} *acknowledge in* s_i
a_d: $(ack_n - ack_{n-1})$ *acknowledge delay difference*
S^p: *set path based on probability (initial empty)*
e_{si}: *link* s^{th} *to* i^{th} *node*
P^k_{ij}: *probability where ant k select edge* e_{ij}
p_{best}: *best position*
g_{best}: *best particle*
$Pa_r[]$: *population array*
R_v: *random position*
Φ: *search space 550m*^{2}
V_l: *velocity of* l^{th} *node*
$path_i$: *path between* s_i *to* r_i
Output: *Data Send, Data Receives, overhead, delay, packet delivery ratio, throughput.*
Procedure:
Step1: Z_n *use ACO* (s^p)
s_i *call (AODV,* s_i, r_i*)*
Broadcast (AODV, s_i, r_i*)*
Step2: While $\forall Z_n$*! visited ||* r_i*! found* ***Do***
$p^k_{si} = \frac{no\ of\ ant\ e_{si}}{total\ ant}$
If $p^k_{si} > p^l_{sj}$ ***then***
Select i node
Forward (AODV, s_i, r_i*) next hop*
Else
Select j node
Forward (AODV, s_i, r_i*) next hop*
End if
End do
Step3: If r_i *found* ***then***
Select p^k_{sr} *where probability higher*
Send ack r_i *to* s_i
Send_data(s_i, r_i, *data)*
Else
r_i *not found or out of range*
End if

Pseudo-code 2: HAPM algorithm for route break

```
Step 1: Z_n initialize Pa_r [], R_v under φ
        If e_ij link break then
          i^th node execute route_repair(i^th, r_i, PSO)
Step 2: for i= 1 to n
        If l_k in ψ && l_k != r_i then
                Calculate g_best = min (delay (e_il) &
                                   min (hopcount(e_il))
                Calculate V_i= (g_best - p_best)
         If min (V_i) then
                Select l node in new route s_i to r_i
                Send_data (s_i,r_i, data)
        Else
                Call (AODV, s_i, r_i)
         End if
        Else if i_k in ψ && i_k == r_i then
                 r_i store(path_i, g_best, l_i∈ path_i)
                  r_i generate reverse path to s_i
                  s_i receives ack from r_i
                Send-data (s_i, r_i, path_i)
                Else
                r_i not reachable or not in range
         End if
        End for
        End If
Step 3:  send-data (s_i, r_i, data)
Step 4: s_i check d_{j=1}^{n} those nodes in path_i
Step 5: for j 1 to n
      If data receives at i^th node && i_j != r_i then
          d_j ← d_j+ 1
           i_j check route table to send next-successor
          Calculate delay
         Else if data forward from i^th node&& i_j != r_i     then
          d_j ← d_j- 1
         i_j forward (s_i, r_i, data) to next-successor
         Else if data receives at i^th node&& i_j == r_i then
         d_i ← d_i+ 1
         Retrieve data from d
         Send ack to s_i from reverse path_i
         Else
          r_i not in ψ or path_i break
         Connection terminate
         End if
         End for
Step 6: acknowledgement delay calculate for rate change
         If a_d > a_d-1 then
         s_i minimize data rate
         Else
                 Data rate not change
                 Send-data (s_i, r_i, data)
         End if
```

5 Performance Evaluation

5.1 Simulation Background

Numerous simulation tools are available to implement Manet's environment, such as OPNET, NS-2, OPNET++, GloMoSini, NETSIM and QualNet. The simulator selector depends on the type of networks and protocols supported by that particular simulator. Here, the NS-2 simulator is used to compare the efficiency of MANET routing protocols, which is an open-source simulator developed in C^{++} and OTCL languages.

Six different network topologies having 50, 60, 70, 80, 90 and 100 nodes are considered for simulation. The available literature also considered the same range of nodes as shown in Table 1. Initially, nodes are randomly placed within the square simulation area of size 1000*1000 sq. m. Nodes move randomly in the simulation area. The total simulation time considered is 480 s. The network pause time is set from 0 to 10 s. Other simulation parameters are shown in Table 2.

5.2 Performance Measuring Parameters

In this paper, QoS parameters and time complexity are considered to analyze the efficiency of the proposed HAPM multicast routing technique. Considered QoS constraints PDR, E2ED, H_c, RO and TP are discussed in Sects. 5.2.1–5.2.5 respectively and time complexity is discussed in Sect. 5.2.6.

5.2.1 Packet Delivery Ratio (PDR) (%)

PDR depends on how many packets are sent (S_p) and how many packets are received (R_p). S_p depends on two factors: data rate and path availability. S_p can be used to calculate the

Table 2 Simulation parameters

Parameters	Used in simulation
Platform	Ubuntu 18.04
Network type	MANET
Simulator	NS-2.35
MAC type	IEEE 802.11b
Area	1000*1000 sq. m
No. of nodes	50, 60, 70, 80, 90, 100
Transport layer	TCP, UDP
Traffic type	FTP, CBR
Packet size	512 Bytes
No. of connection	15–20
Antenna model	OmniAntenne
Propagation model	TwoRayGround
Queue mechanism	Droptail/PriQueue
Mobility model	Random waypoint
Simulation time	480 s
Pause time	0–10 s

efficiency of the routing protocols. The source nodes send more packets in the network when the data rate of the link is high and more paths are available between source nodes and destination nodes. R_p depends on three factors- path availability, queue utilization and bandwidth. The destination nodes get more packets as there are more routes between the source node and destination nodes, proper utilization of buffer queue occurs at intermediary nodes and endpoint nodes, and choose the paths having maximum bandwidth than other paths. PDR is measured as the ratio of entire packets received (R_p) by the receiver to the total packets sent (S_p) by the sender node. PDR is used to calculate the efficiency of the routing protocols. For an efficient routing protocol, PDR should be maximum.

$$PDR = \frac{\sum Rp}{\sum Sp} * 100 \tag{4}$$

5.2.2 End-to-End Delay (E2ED) (ms)

E2ED is the cumulative estimated time to transmit data to the destination nodes successfully. It depends on four factors- communication link, the queuing process of data, channel availability, re-transmission of data packets and link break. E2ED is used to calculate the efficiency of the routing protocols. For an efficient routing protocol, E2ED should be minimum.

$$\text{i.e.} \quad E2ED = TD + Prop_D + PD + QD \tag{5}$$

where *TD* Transmission Delay, *Prop_D* Propagation Delay, *PD* Processing Delay, *QD* Queuing Delay.

5.2.3 Hop Count (H_c)

H_c is the basic measurement of the distance in the network. It is the cumulative number of intermediate nodes through which the data has to travel to the destination node. H_c is used to calculate the efficiency of the routing protocols. For an efficient routing protocol, H_c should be minimum.

$$H_c = \frac{THc}{Rpackets} \tag{6}$$

where TH_c Total Hop counts, $R_{packets}$ Total successfully received packets by the receiver.

5.2.4 Routing Overhead (RO)

RO is the ratio of total packets sent (S_p) to the total control packets sent (C_p). It depends on four factors- Delay, frequent node motion, network congestion and link breakage. RO is used to calculate the efficiency of the routing protocols. For an efficient routing protocol, RO should be minimum.

$$RO = \frac{Sp}{Cp} \tag{7}$$

5.2.5 Throughput (TP) (Mbps)

TP is the rate at which data reaches the destination nodes from the sender nodes. It depends on some factors like- Change in topology, network congestion, delay, packet loss. TP is used to calculate the efficiency of the routing protocols. For an efficient routing protocol, TP should be maximum. Mathematically TP can be represented as-

$$TP = \frac{Total\ data\ received}{Transmission\ time} \tag{8}$$

5.2.6 Time Complexity

We have extracted the simulation time for analysis of the time complexity. As the algorithm used is randomized, the exact time complexity is hard to achieve.

6 Result and Discussion

6.1 PDR Analysis

Table 3 and Fig. 3 represent the results of PDR for ACO, PSO, Hybrid ACO-PSO, Enhanced-Ant-AODV, CSO-AODV and proposed HAPM routing models with six networks topologies 50, 60, 70, 80, 90 and 100 nodes. From Fig. 3, we observe that PDR increases with the network size for all the methods and the PDR of HAPM are much superior as related to other considered methods The PDR in HAPM is improved by 20, 11, 8, 2 and 0.6% from ACO, PSO, hybrid ACO-PSO, Enhanced-Ant-AODV and CSO-AODV respectively.

6.2 E2ED Analysis

Table 4 and Fig. 4 show the results of E2ED for ACO, PSO, Hybrid ACO-PSO, Enhanced-Ant-AODV, CSO-AODV and proposed HAPM routing models with six networks topologies 50, 60, 70, 80, 90 and 100 nodes. From Fig. 4, we observe that E2ED decreases as the network size increases for all the cases. The performance of the proposed HAPM is better as compared to others for E2ED analysis. Delay is also reduced by 54, 47, 40, 49, and 30% from ACO, PSO, hybrid ACO-PSO, Enhanced-Ant-AODV and Cuckoo Search CSO-AODV respectively.

Table 3 PDR (%) values of considered algorithms

No, of nodes	ACO	PSO	Hybrid ACO-PSO	Enhanced-Ant-AODV	CSO-AODV	Proposed-HAPM
50	83.33	86.75	87.98	90.12	91.11	91.65
60	76.95	83.94	85.31	90.17	91.07	91.15
70	70.62	83.22	87.75	92.43	93.21	93.37
80	81.83	84.5	89.04	94.67	94.89	96.93
90	80.3	85.88	88.81	94.23	94.78	95.13
100	77.52	83.74	88.32	93.10	97.89	98.17

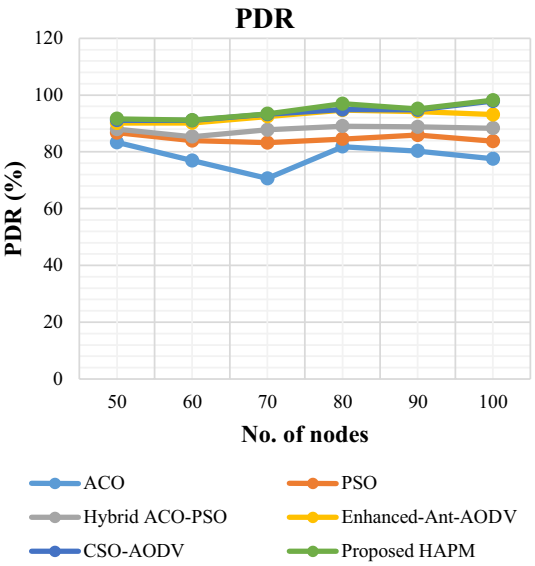

Fig. 3 PDR of considered algorithms with varying node

Table 4 E2ED (ms) values of considered algorithms

No. of nodes	ACO	PSO	Hybrid-ACO-PSO	Enhanced-Ant-AODV	CSO-AODV	Proposed-HAPM
50	0.32	0.25	0.22	0.16	0.2	0.18
60	0.32	0.28	0.25	0.22	0.23	0.18
70	0.35	0.3	0.28	0.32	0.19	0.15
80	0.31	0.28	0.26	0.34	0.17	0.12
90	0.28	0.26	0.25	0.28	0.21	0.1
100	0.25	0.21	0.13	0.32	0.19	0.1

6.3 H_c Analysis

Table 5 and Fig. 5 show the results of H_c for ACO, PSO, Hybrid ACO-PSO, Enhanced-Ant-AODV, CSO-AODV and proposed HAPM routing models with six networks topologies 50, 60, 70, 80, 90 and 100 nodes. From Fig. 5, we observe that H_c decreases as the network size increases The H_c of proposed HAPM and Hybrid ACO-PSO are almost the same. Hop Count has also been reduced by 90, 87 and 83% from ACO, PSO and Enhanced-Ant-AODV and CSO-AODV respectively.

6.4 RO Analysis

Table 6 and Fig. 6 show the results of RO for ACO, PSO, Hybrid ACO-PSO, Enhanced-Ant-AODV, CSO-AODV and proposed HAPM routing models with six network topologies 50, 60, 70, 80, 90 and100 nodes. From Fig. 6, we observe that RO of ACO, PSO, Hybrid ACO-PSO, and HAPM increases as just the number of nodes tends

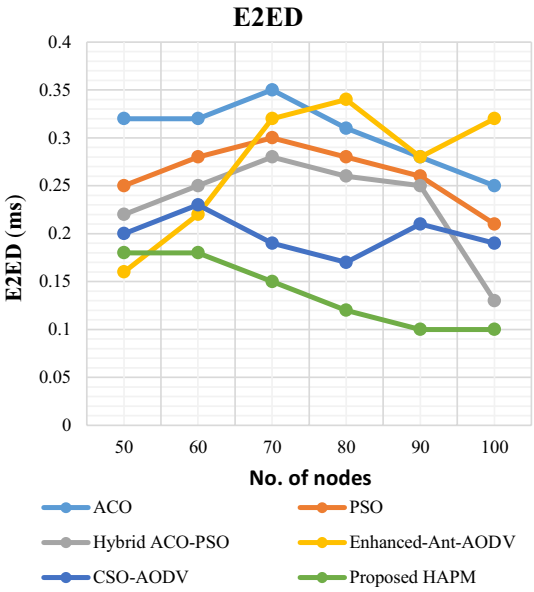

Fig. 4 E2ED of considered algorithms with varying nodes

Table 5 Average hop count values of considered algorithms

No of Nodes	ACO	PSO	Hybrid-ACO-PSO	Enhanced-Ant-AODV	CSO-AODV	Proposed-HAPM
50	5.6	4.09	1.94	2.4	2.9	1.25
60	3.86	3	0.05	1.9	1.8	0.14
70	2.89	2.47	0.05	1.5	1.5	0.08
80	2.42	1.92	0.08	1.6	1.7	0.18
90	2	1.41	0.06	1.2	1.1	0.06
100	1.45	0.73	0.03	1.1	0.9	0.01

to rise. The routing overhead of the proposed HAPM is minimum among all the others. Routing overhead is reduced by 49, 41, 23, 10 and 17% from ACO, PSO, hybrid ACO-PSO, Enhanced-Ant-AODV and CSO-AODV respectively.

6.5 Throughput Analysis

Table 7 and Fig. 7 show the results of throughput for ACO, PSO, Hybrid ACO-PSO, Enhanced-Ant-AODV, CSO-AODV and proposed HAPM routing models with six networks topologies 50, 60, 70, 80, 90 and 100 nodes. From Fig. 7, we observe that throughput of ACO, PSO, Hybrid ACO-PSO and HAPM increases as the number of nodes increases. The proposed HAPM presents better performance than ACO and PSO methods in terms of throughput. Throughput of HAPM is 40, 28, 11, 8 and 36 more than ACO, PSO, hybrid ACO-PSO, Enhanced-Ant-AODV and CSO-AODV respectively.

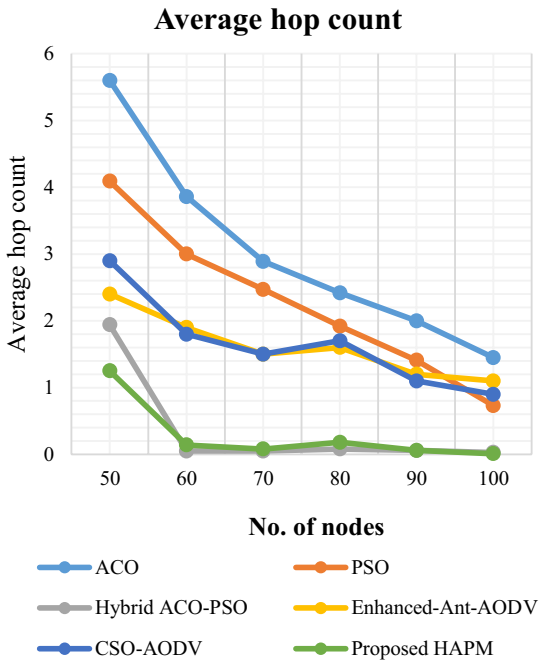

Fig. 5 Hop count of considered algorithms with varying nodes

Table 6 Routing overhead values of considered algorithms

No. of nodes	ACO	PSO	Hybrid-ACO-PSO	Enhanced-Ant-AODV	CSO-AODV	Proposed-HAPM
50	8.17	6.09	4.77	4.5	3.5	3.44
60	9.99	8.97	5.66	5.32	5.1	4.61
70	11.98	10.98	7.35	6.21	7.21	5.99
80	17.98	14.94	9.71	8.91	8.28	7.71
90	19.91	15.97	14.38	10.11	11.12	9.65
100	23.21	21.52	18.62	17.16	19.45	15.19

6.6 Time Complexity

Table 8 and Fig. 8 show the execution time for ACO, PSO, Hybrid ACO-PSO, Enhanced-Ant-AODV, CSO-AODV and proposed HAPM routing models with six network topologies 50, 60, 70, 80, 90 and 100 nodes. From Fig. 8, we observe that the execution time of Hybrid HAPM is more than ACO and PSO but less than Hybrid ACO-PSO. The time complexity is comparable to other considered algorithms. The hybridization does not overburden the time complexity in our implementation.

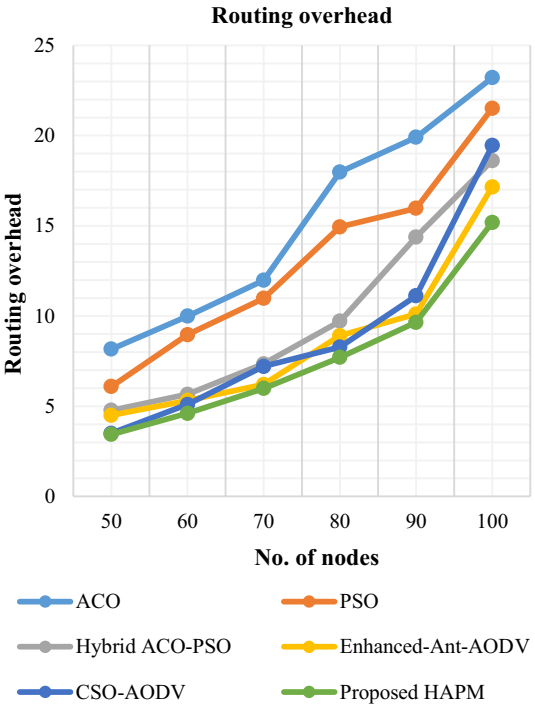

Fig. 6 Routing overhead of considered algorithms with varying nodes

Table 7 Throughput (Mbps) values of considered algorithms

No. of nodes	ACO	PSO	Hybrid ACO-PSO	Enhanced-Ant-AODV	CSO-AODV	Proposed-hybrid
50	6.97	7.61	8.82	9.3	6.95	10.35
60	6.88	8.65	10.1	10.05	7.89	11.03
70	6.63	8.06	10.39	11.10	9.10	11.58
80	6.93	9.18	11.04	11.15	8.34	12.1
90	7.87	8.92	10.69	11.32	9.12	12.41
100	7.52	8.5	11.2	12.19	10.32	13.01

7 Conclusion

The novelty of this work is the efficient hybridization of the two most popular swarm-based algorithms ACO and PSO in combination with AODV for solving the multicast routing problem without increasing the complexity. The main contribution of this work is-

1. Appropriate use of conventional routing technique AODV that can perform very well for the static network, for broadcast in the initial phase.
2. The use of great optimizer ACO that explores better paths in less time, to choose the optimal route with the trust-based path feature as presented in Sect. 4.

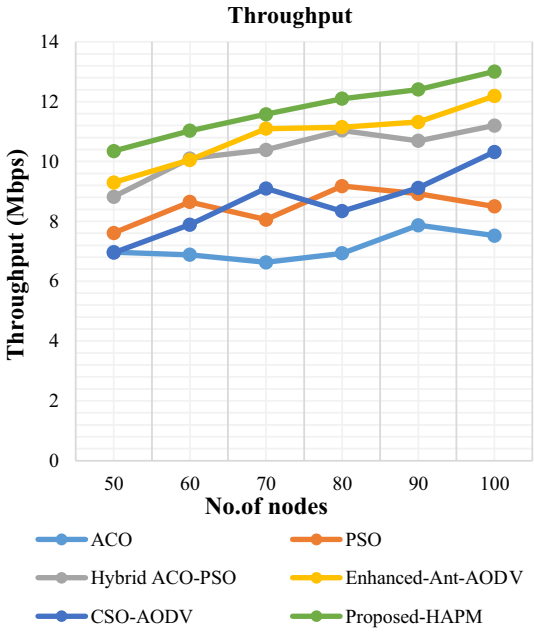

Fig. 7 Throughput of considered algorithms with varying nodes

Table 8 Execution time (ms) of considered algorithms

No. of nodes	ACO	PSO	Hybrid-ACO-PSO	Enhanced-Ant-AODV	CSO-AODV	Proposed- HAPM
50	200,400	127,800	241,200	230,000	220,000	21,000
60	210,000	180,600	270,000	250,000	262,000	242,400
70	270,600	210,000	308,400	261,200	272,000	282,000
80	301,800	244,200	361,200	3,478,000	368,000	342,000
90	330,000	304,800	372,000	350,600	389,000	360,000
100	362,400	330,000	438,000	400,000	420,000	402,000

3. The use of PSO for selecting alternative paths is based on the minimum delay and minimum hop count to provide remedies in case of a link break.

The number of ants decides the probability of selecting the paths in ACO. When the link breaks, PSO uses minimum delay and minimum hop count to calculate g_{best} and select the efficient node with low velocity to provide new routes. The efficiency of the proposed HAPM multicast routing is calculated by five QoS constraints namely PDR, E2ED, H_c, routing overhead and throughput and compared to ACO, PSO and Hybrid ACO-PSO, Enhanced-Ant-AODV and CSO-AODV. From the result and discussion section, we can conclude that out of the considered algorithms, the proposed HAPM routing algorithm gives better performance. The results confirm that the PDR and throughput of the proposed algorithm is increased by 20% and 8% respectively than Enhanced-Ant-AODV, which ranks better than other considered techniques. The delay, routing overhead and hop count of the proposed HAPM is reduced by 49%, 10%, and 83% respectively than

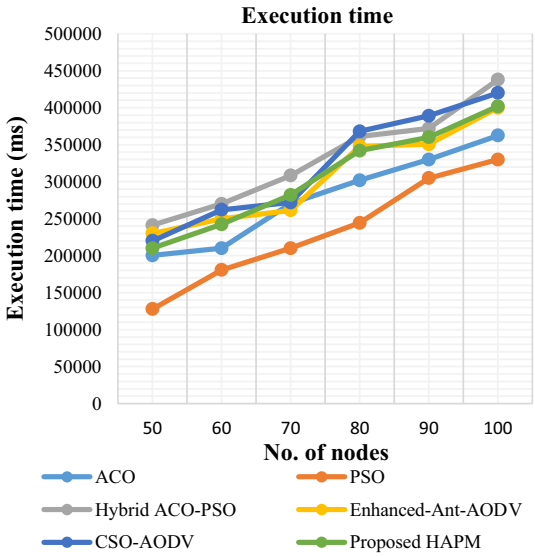

Fig. 8 Execution time of considered algorithms with varying nodes

Enhanced-Ant-AODV. This work can be extended in the future to support some other QoS constraints like privacy and security.

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