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An Enhanced ACO Routing Protocol for Flying Ad Hoc Network

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Abstract: In the modern world, technology is essential to human survival. The rapid growth in the number of UAVs in recent decades, as well as their discovery through enormous prospective, has altered and shift the usage of re-searchers and users. UAVs can be utilized to effectively accomplish complicated jobs when arranged as an ad hoc network, leading to the well-known flying ad hoc networks (FANETs). FANET is a communication technology that enables communication between flying nodes that are in motion in the sky. The dynamic characteristics of FANETs, such as high node mobility, bandwidth limitations, frequent route failure, and dynamic topology, as well as disconnections and high overhead that lower protocol performance, diminish routing efficiency. This study proposes the Hybrid Ant Colony Optimization Routing Protocol (HACORP) to improve the shortest path routing procedure's execution. The shortest path of the proposed protocol has the lowest communication costs and the fewest hops between the starting and ending flying nodes. There are two parts to HACORP. The HACORP uses a distance computation tool to calculate the distance between flying nodes in step I. Step II instructs the ants to create a shorter data transmission line with the fewest number of hops by using origination-based ant colony optimization. In every aspect, the shortest approach improves protocol performance.

Keywords: FANETs, HACO, Distance calculation method, Ant colony optimization.

I. INTRODUCTION

Unmanned aerial vehicles (UAVs), also called as RPAs (remotely piloted aircraft) or drones, are pilotless aerial vehicles that can be controlled remotely by a ground pilot or autonomously by an onboard computer. UAVs have been used by the military for over 25 years. Currently, the UAVs will be used in an urgency to assist medical personnel and the general public during the COVID-19 pandemic. They are categorized by altitude, strength, and weight and can be used for a variety of purposes, including commercial and military ones. Land control stations accompany the smaller group of UAVs, consists moving components (like mobile, laptop etc.) Drones for various applications have improved in recent years as a result of increased research and development. The UAV is still having a scope of experiment. FANETs are now a reality as a result of significant progress and advancement in the area of wireless communication technologies. FANET is a network of UAVs (unmanned aerial vehicles) and ground-based stations (GBSs) that communicate with one another without requiring any prior communication configuration. That is, communication between these entities should be done on the fly, with both unmanned aerial vehicles and GBSs involved in data transmission. This framework, in general, selects individual UAVs with additional capabilities to act as gate ways between GBSs and other UAVs, greatly extending the network's reach. (Mahmud & Cho, 2019) . This section is broken down in to 3 sub-sections to achieve this aim. The first is dedicated to the most widely used FANET organizations. The second section describes the various FANET communications. Finally, the distinct traits and characteristics of FANETs are discussed. Throughout the following subsections, we will always refer to Figure 2. FANET (flying ad hoc network) is a form of networking that allows unmanned aerial nodes (UAVs) to communicate with base stations (Sahingoz, 2014) Flying UAVs are self-contained nodes capable of making distributed decisions in the air (e.g., adjusting speed and direction) rather than receiving centralized decisions from the ground. When compared to existing ad-hoc networks like MANETs and VANETs, FANET has unique characteristics. The following factors make flying nodes vulnerable to frequent link dis- connections and network distribution: In 3-dimensional space, there’s a lot of moving about flying speeds range from 40 to 450 kilometers per hour compared to 10 to 120 kilometers per hour Node density is low. Furthermore, the movable flying nodes that are usually fitted through limited-energy batteries source have high energy consumption. This means that increasing transmitting power to provide long-range contact in FANETs would not solve the problem of frequent disconnections. As a result, creating long lasting term, dependable, and robust links and path is critical for increasing route life-time and improving service quality (QoS) this means that increasing transmitting power to provide long-range contact in FANETs would not solve the problem of frequent disconnections. Multiple UAVs work together to form an ad hoc n/w in multi-UAV scenario. The multi-UAV scenario has 3

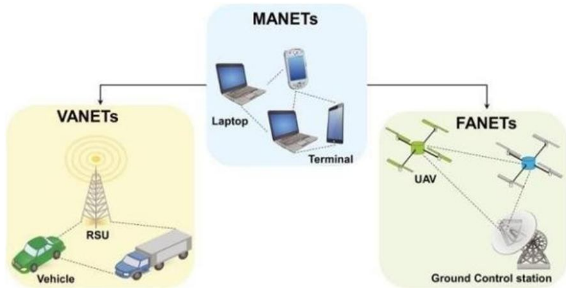

Figure. 1. Broad classification of MANET

major advantages over the single- UAV scenario. For starters, FANETs improve network scalability by allowing multiple UAVs to expand coverage. Second Because many UAVs can structure an ad hoc network or tie directly to radio-access communications. FANETs improve n/w robustness and dependability in a challenging working atmosphere (for example. due to bad weather). A large swarm of UAVs (or multi-UAV swarm) can mitigate the breakdown of a single UAV during process. Finally, FANETs can disperse load across unmanned aerial vehicle, reducing each UAV's weight and, as a result, the amount of energy required to reachand maintain a given altitude, resulting in a longer route life-time.

The BS then evaluates the data and generates messages, such as warning messages in the event of an influence on human life and activities. (Bekmezci et al., 2013).

II. ROUTING IN FANET

Following are the requirements of routing in FANETs:

1) Since unmanned aerial vehicles (UAVs) must adjust to an extremely dynamic network topology with less node density, as well as link disconnection and network partitions, they must have high adaptability. Path discovery (i.e., constructing routes for data dissemination) and maintenance (i.e., reestablishing routes) in FANETs must be sufficiently adaptive to increase route reliability (or robustness). (Tareque et al., 2015)
2) This necessitates the ongoing updating of the routing table, which keeps track of routes and their costs, as well as the identification of trustworthy routes.
3) High scalability, because UAVs are required to handle large-scale application that necessitate many unmanned aerial vehicles with varying node densities.
4) As Un-manned aerial vehicles are battery powered, they must design path with enough residual energy to avoid link dis-connections and n/w partitions caused by node failures [83], thus extending path life-time.
5) Low latency, as unmanned aerial vehicle must cater to real time applications like multi-UAV swarm collision prevention and disaster relief and rescue operations. As a result, route exploration and maintenance must reduce latency.
6) Unmanned aerial vehicles must collect facts or sense findings as of an only or numerous sites & communicate them to radio-access communications for dealing out and supervisory. As a result, path research and maintenance should produce high-bandwidth paths.

III. THE PROPOSED HACORP

After cal. distances, the rou-ting table of each node is up-dated with compute distances. The proposed HACORP was designed to find the shortest route b/w the source and the destination with min.cost and fewest hops. The distance measurement method (DCM) is used in step.1. For find the space b/w two moving nodes by distance formula. Nodes will be operated in promiscuous mode until one hop neighbors have been together, at which point the flying nodes route tables will modified with a list of one hop neighbors. Each node's routing table contains a list of its neighbour after it exits promiscuous mode. The node then uses the distance formula to calculate distance b/w itself and its neighbors using the neigh-bour list as a guide. After the distances calculated, each node's routing table is modified with computed distances. (Ramamoorthy &Thangavelu, 2021a) The SBACO algorithm was use in phase 2 to search the optimized route from source to destination point with fewest no. of hops. The SBACO refers to a node's routing table, which is used to determine its neighbours and their distance from it. The SBACO employs its mechanisms to find and preserve the optimized route based on defined neighbors with distances.(Ramamurthy & Thangavelu, 2021b) SBACO includes the route-discovery, route-reply, data-transfer, and route-maintenance processes.

In order to search the destination, the source agent ant produces forward ants depending on the source neighbor list. In the route discovery process, forward ants deposit pheromones based on distance and previous pheromone value in intermediate nodes based on neighbor's lists before they reach their destination. Back- ward ants change the pheromones value upon the route; depend on evaporation charge, previous pheromones, & space to preserve path stability in the route-reply process. Following is the mechanism for response, The route selection protocol at the source analyses path cache information after reply process to search the shortest route. The shortest route is one having, fewest hops and the shortest distance. Data transfer can only be started after the data transfer-ant has found shortest route in Data transfer process. The route maintenance ants in the route maintenance process are in charge of the broken path. We propose the HACORP forflying ad hoc networks in this context. Architecture of proposed protocol is shown in Figure 2. As per Fig.2 In phase1. Proposed protocol uses the DCM towards determines the space b/w nodes. To find various paths in

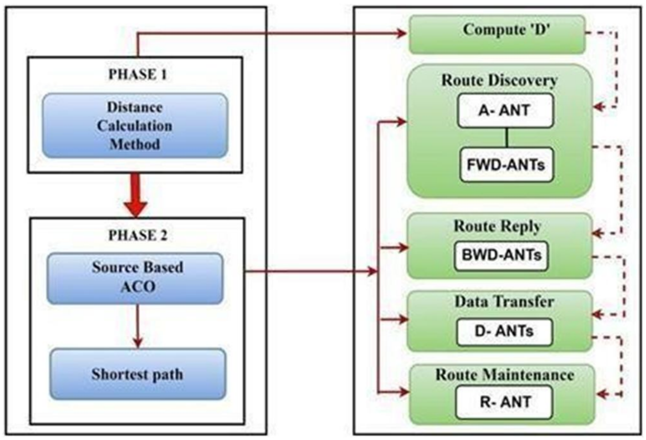

Figure. 2. Architecture of HACO: Hybrid Ant Colony Optimization

phase.2. SBACO uses their processes like route finding & respond. Following that, throughout the data transfer process, SBACO uses a route selection algorithm to determine the shortest path with the fewest hops. SBACO uses its route- maintenance strategy to deal with link failures. The n/w is referred to as a weighted graph in the proposed -scheme (G). Nodes and edges between nodes are included in

G. The letter G is represented by

$$G = (N, r) \qquad 1$$

Where = {1......................... } represents collection of nodes in G & r represent a group of edges called route b/w nodes. Eq. 2 shows the route formation as.

$$= \{(i, j): i, j\epsilon\ \} \qquad 2$$

In Equation.2, i, j represents the edge b/w nodes. Where N is nodes.

1) Step-1: Calculation Of Distance: Distance Calculation Method (DCM)

In step 1, the DCM (distance cal. method) uses the distance formula to calculate distance b/w two nodes. The DCM assumes every node in the n/w having the Global position system (GPS) facility. The distance formula as in Eq. 3 is used to cal. the distance b/w two nodes as shown in Fig. 2. Let us assume A-B as 2 forward moving nodes and the distance Db/w A-B is cal. By using formula.

$$Dij = \sqrt{((X2 - X1)^2 - (Y2 - Y1)^2)} \qquad 3$$

In Eq.3 (X2−X1) is the horizontal and (Y2−Y1) represents the vertical distances b/w nodes A and B. The 'Dij' represent the distance b/w two nodes. Eq. 4 shows the structure of 'Dij'.

$$Dij = D(i, j), edge(i, j)\epsilon\ r \qquad 4$$

And 'Dij' symbolize distance b/w nodes, r symbolizes route b/w nodes. The 'i' & 'j' represent edges in route r. arrangement of edges is known a path. Every time nodes B receive BM (beacon message) from nodes A, nodes B compute the accurate distance b/w two nodes by Equation. 3. Fig.3 computes the Distance cal. method used to cal. the distance b/w nodes A-B. To cal. the distance b/w two nodes, we suppose A represents the sender pt. nodes & B represents the receiver pt. nodes. together two nodes operated in promiscuous mode to receive the (BM) beacon message. In one-hop mode, promiscuous nodes can listen or transmit beacons. The beacon is created and broadcast by First A.

All one-hop nodes of A receive the emitted beacon (As represent in Fig.3, nodes B is the one-hop nodes of A). After receiving a signal, each node updates its routing tables. Each node routing database iz restructured with a list of neigh. (NL) nodes once beacons are exchanged. When computing the distance, the sender nodes use their routing table's NL to locate their neighbors. The Ds are determined using Eq.3 depending on the NL between a sender and its neighbors. The computed Ds are saved in the routing tables of the receiving nodes. In Table 1beacon message is represented. The sequence no. (S num) in the BM (beacon message) is use to reject replica msg. Hop Count is initiated to zero; this initialization limits broad-casting of beacon to the only one-hop neigh. Table.2. represents the routing table of each node. Every node maintains distances for all its direct one hop nodes.

2) Step 2: On the Basis of Source: Source-Based ACO (SBACO)

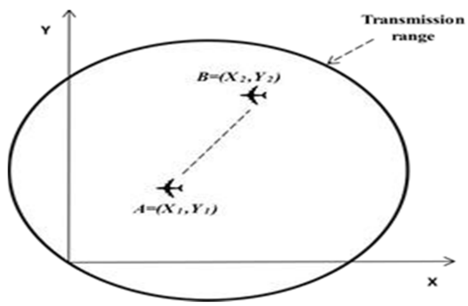

Figure. 3. Distance calculation between two nodes.

The ACO uses the SBR (source-based routing) principle to direct data packets between source and destination. A sender of a packet may use the SBR to determine the direction that the packet must take. The source node in SBR contains all the regarding information needed for the route the packet. To get to its actual destination, the packet follows its header. The central concept of SBR is the collection of path data. The ACO's key analogy is that each and every ant colony having a proper nest, which contains thousand-millions of ants. The colony's ants start their journey from their nest to search food source pt. Ants in nest take various route to get around, and as soon as they do, they leave a special chemical hormone called pheromone on the route they take. The chemical material pheromone attracts insects, and by depositing their pheromone, more ants will migrate in the same direction. If the ants search the source of food, they come back to their home (nest) at regular intervals with an enough amount of the food. The min. time interval holds the shortest path of all time intervals. The remaining ants are led down a road that will lead them to their destination with less time of interval. The deposited pheromone will starts to degrade (evaporate) over time, and path intensity suffers as a result. With chemical substance pheromone deposit and update models, the ACO algorithm are used to strengthen the route with continuous pheromone depositing based on the evaporation rate. ACO is used in new proposed model to find out the optimize (shortest) path b/w source pt. and destination pt. depend on dist. and pheromone chemical deposit concentration, and source-based routing is used to direct & assist the ACO ants in transferring data packets in the shortest direction. Agent Ant (AANT), Forward moving-Ants (FWD-ANTs), Backward moving-Ants (BWD- ANTs), Data Transfer Ants (DANTs), and Acknowledgment ants (ACKANTs) route maintenance ant (RANT). AANT and FWDANTs are used in the path discovery process. the BWDANTs are used in route reply process. This data transfer system employs DANTs and ACKANTs. In the maintenance process, the RANT is used. The proposed protocol's algorithm is shown in Table 3. The promiscuous mode is represented in Table by steps 1 through 3. The random deployment of nodes is the first step in promiscuous mode, and then nodes run in promiscuous mode to create their one hop neighbors list (Neighbor List) (step 2 and step 3). Step 1 of proposed work is concerned with DCM. DCM is represented by steps 4 and 5. In DCM, nodes use their NL to measure the distance between themselves and their neigh (step 4). The nodes then save the estimated Ds in their routing tables (step 5).In step 2, the SBACO is depicted. The route reply will be allowed if FWD Ants follow the Neighbor List of the source to begin the journey and then follow the destination point. Otherwise, based on its Neighbor list, it will forward FWD-ANTs. Forward ants (FWD-ANTs) maintain the route cache and collect the chemical pheromones in their direction using the pheromone put model when moving. The path response is indicated in step 7. This method uses destination to send BWDANTs with route information to the source point. The BWDANTs update the chemical pheromone on route depends on the pheromone update model and consolidates pheromone depends on the pheromone summative model as they move towards the source. The data transfer mechanism is defined in Step 9. It uses the PSSV algorithm to cal. the shortest route based on BWDANTs data. During this method, DANTs and ACKANTs are generated to transmit and acknowledge the data using the shortest route possible.

The route maintenance process is described by Step 9. The source assumes the route is broken down if no ACKs are received. The nodes closest to the linkage breakdown generate R- ANT to report a link split the source pt. The source for RANT uses PSSV to cal. a route or promiscuous -mode, step 1 and step 2 to search a latest route.

IV. EXPERIMENTAL RESULTS

The performance parameters of the HACO are evaluating using MATLAB R2019a on the windows10 platform. The value of simulation parameters is scheduled in table. In simulations, the no. of nodes is set to 30,40,50,100, and150. Omnidirectional antennas are installed on each UAV. The packet size is 1 MB, with the Base station as the destination point. Every node is aware of the destination's position.

TABLE 1.
SIMULATION PARAMETERS

Parameter	Consideration rate of parameter
Platform for simulation	MATLAB R2019a
Simulation time	180 second
Topology area	1000*1000*1000
Model of mobility	Random -way -point (RWP)
Speed of movement	10m/s
Traffic –type	Constant –bit-rate (CBR)
Size of packet	512 bytes
No. of nodes	40(ex. base station)
Initial energy of nodes	100 joules
Evaporation rate	ρ=0.2,0.3,0.5,0.6

A. *Parameters*

To calculate the performance of HACORP against FANT, ARA, AODV, and Ant-Net, following performance characteristic parameters are as following-

1) *Packet Delivery Rate (PDR)*

It can be defined as the ratio of the total no. of packets successfully delivered to the destination to the total no. of packets sent from the source node. The PDR is determined as follows:

$$D = \frac{\sum_{=1} akt D}{\sum_{=} pkt\,sent} \qquad 5$$

PDR is determined utilizing parameters like packets transmitted from the source pt. and packets delivered to the destination pt. in all scenarios. Mathematically,

PDR= algebraic sum of packets received at destination) + (algebraic sum of packets transmitted from source pt.)

2) *Packet Loss Rate (PLR)*

It refers to the total no. of packets sent from a source pt. that were not received at their intended destination pt. The PLR is calculated using the following formula:

$$\text{PLR} = \left(\sum_{i=1}^{n} No.of\ packet\ sent - \sum_{i=1}^{n} No.of\ packets\ received\right)*100 \qquad 6$$

PLR can be calculated using characteristics like packets transmitted from the source and packets received at the destination for all circumstances. The packet loss ratio (PLR) is the percentage of packets that do not reach their intended destination.

3) Throughput (T)

It is the ratio of total data bits reached to the final destination point for the total simulation time (t). The Through-put is cal. as

$$= \left(\frac{\sum akt}{t} \right) \qquad 7$$

In all the cases, the through-put is calculated by the use of parameters like packets reached at final dest. Pt. and simulation time (t). Mathematically terms used in through-put calculation are the algebraic sum of the received packets and time unit (t).

4) Average End-To-End Delay (EED)

The avg time taken for a data packet to arrive at its dest. Is called EED. The unit of EED is mill-seconds. The EED is cal. using Eq. 8. EED is calculated utilizing parameters such as packet arrival and start times in all circumstances. The statistical parameters for assessing EED are the arrival time of packets at the destination point and the start time of packets from the source point.

$$\text{EED} = \Sigma \text{ (arrival time of packet-start time of packet)} \qquad 8$$

B. Simulation Results

In the simulation result, the performance characteristics of HACO routing protocol is compared against AODV (fatemidikhl and Rafsanjani 2018). the MATLAB simulation tool is used to simulate the proposed and existing protocols. The biological algorithm is used in proposed protocol. The improved ACO is used in proposed HACO routing protocol to search the optimized (shortest) route using the source-based routing principle and dist. cal. tool. The AODV protocol is a on demand-oriented routing protocol. To direct packets, the proposed protocol employs source-based routing principle. Source- based routing is a concept of on-demand routing.

C. Why HACO Instead of Existing Protocols?

The newly proposed protocol HACO is designed, search for optimal (shortest) route for packet routing with the fewest number of hops. In comparison to the traditional protocols (AODV) the HACO routing protocol minimizes ant searching time and increase the converging velocity, avoid blind packet broadcasting, provides fast packet processing, and avoids stagnation issues. The local optima problem is avoided by HACO routing protocol improved ACO. In order to handle route failures more efficiently than current protocols, HACO routing protocol has implemented a new route management mechanism. For data transmission, HACO routing protocol uses a non-congested optimized path having min. no. of hops count that increases their overall efficiency.

TABLE II.
EXPERIMENTAL RESULTS

Parameters	Protocols	
	HACO	*AODV*
Average PDR	98.80%	97.20%
Average PLR	0.01%	0.03%
Through put	509.7kbps	474.8kbps
End-to-End delay	0.29 sec	0.58 sec

1) Packet- Delivery -Rate (PDR)

The new proposed HACO routing protocol outperforms AODV routing protocol, in terms of packet delivery. This is accomplished by using HACO routing protocol to search the shortest path with min. cost and the fewest hops. In proposed HACO, the DCM aids in selection of the min. cost route, while the source-based enhanced ACO directs packets to the defined shortest paths with the fewest hops. The HACO routing protocol uses DCM to maintain a secure high quality optimal (shortest) path at min. cost for bigger node density and high packet distribution. The processing requirements for AODVare very high. The source in HACO knows how to get to the destination. Since the source is aware of the route, it can process the packet header in less time. The faster packet processing delivers more packets than the current protocol. The use of the same route for an extended period of time would result in heavy traffic and conges-tion on the route. The packet distribution proportion is reduced when the route is congested. The stagnation problem is solved in HACO using an updated pheromone revise model based on the distance node parameter.

The problem of stagnation is solved in the chemical substance pheromone update model by selecting the direction depends on pheromone attraction. The path's pheromone attraction changes over time, depending on the eva-poration rate, old pheromone meaning, and dist. In case the present connection fails, HACO will find a new route without having to restart the discovery process. Route failure in HACO does not result in creation of a new path. It notifies the source of connection failure and then after uses, route selection process for find the next most secure and shortest path for data transfer.

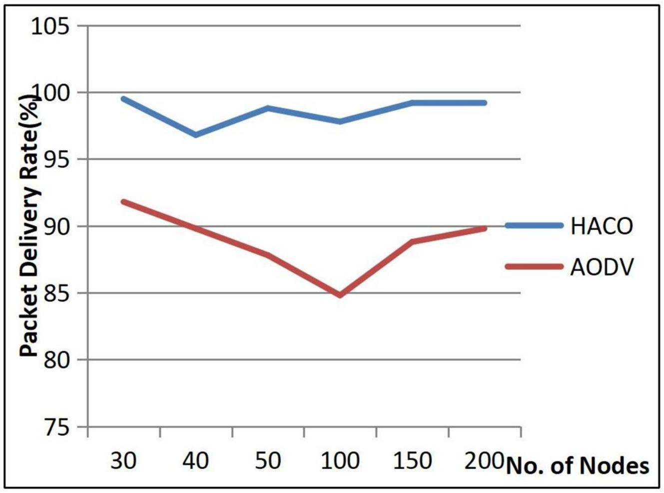

Figure. 4. comparison of packet delivery rate for traditional AODV and proposed HACO Protocol

2) Packet Loss Rate (PLR)

Connection congestion, erratic transmission rates, long contact distances, and packet collision all contributed to packet loss. Connection congestion is avoided in HACO by maintaining a constant transmission rate. For data transmission, the HACO uses the shortest route with the lowest cost and the fewest hops. The proposed protocol's course has a short contact gap. Source-based routing is used in the proposed protocol to prevent packet collisions. Packet loss is caused by inconsistent routes and AODV's longer delay. Ant-Net's ACO has poor connection stability in Ant colony optimization routing algorithm, when nodes density is too high, loss of packet occurs. The new proposed protocol establishes a clear path b/w source pt. and destination pt. with a min. hop-count. Packets are not delayed by using a path with a short contact gap. In HACO, the use of DCM to choose short distance edges enhance stability of connection. In the proposed protocol, variation in node density has no effect on the shortest route. In all three situations, the HACO always builds the non- congested shortest path using short distance edges and min. hops.

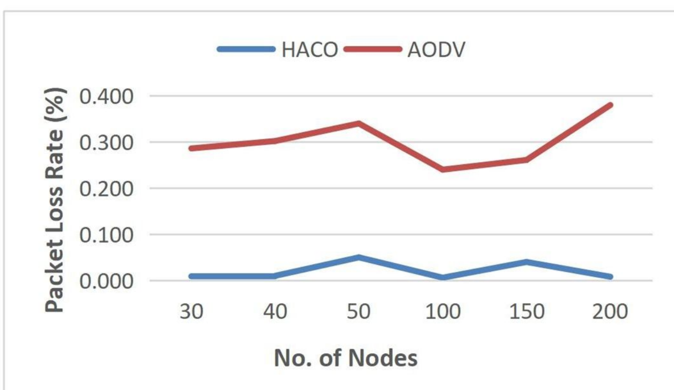

Figure. 5. comparison of packet loss rate for traditional AODV and proposed HACO Protocol

3) Throughput (T)

HAC O performs better with respect to the traditional routing in terms of throughput. DCM has been implemented in HACO to speed up convergence and reduce ant search time. DCM prevents ants from wandering aimlessly and assists nodes in choosing the next node based on the shortest path. The Ant Net searching method has a time-consuming search, which lowers through-put. The use of DCM in HACO helps to minimize search time.

To prevent stagnation, HACO employs an updated pheromone update model. It solves the problem of stagnation by selecting a path on the basis of node parameter called distance. The use of the shortest route with-out the problem of stagnation improves throughput in HACO due to quick convergence, low ant search time, and making use of shortest path without having the problem of stagnation.

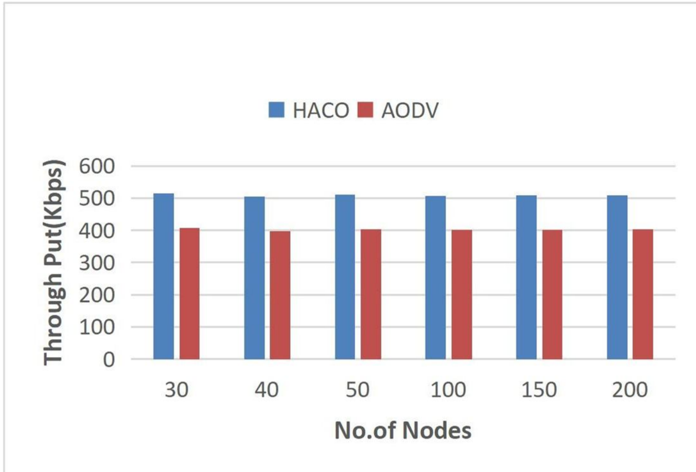

Figure. 6. comparison of throughput for traditional AODV and proposed HACO Protocol

4) Average END-TO-END Delay (EED)

It raises as the no. of nodes rises. Packet latency is reduced in HACO by taking the quickest route with the fewest hops and minimal congestion. In HACO, the source based ACO and DCM steer packets to the optimal (shortest) path having the fewest hops. Congestion is minimized by maintaining a steady transmission rate. When the DCM and source- based ACO are applied to HACO; the shortest route is identified in a fraction of time. We use source-based ACO in the proposed protocol to avoid this delay. When node density is high, AODV's route discovery takes a long time, resulting in a long end-to-end t.The reason for this is that in high-density nodes, AODV has a harder time selecting a high-throughput route. HACO finds high-throughput routes to r regardless of the no. of nodes. In this proposed model, the route maintenance ant allows the source to call the route selection process instead of the path searching process in the event of a missing ACK. Without using a route searching process, the route selection procedure searches the next shortest path. Because of this advantage, HACORP is able to outperform traditional routing protocol.

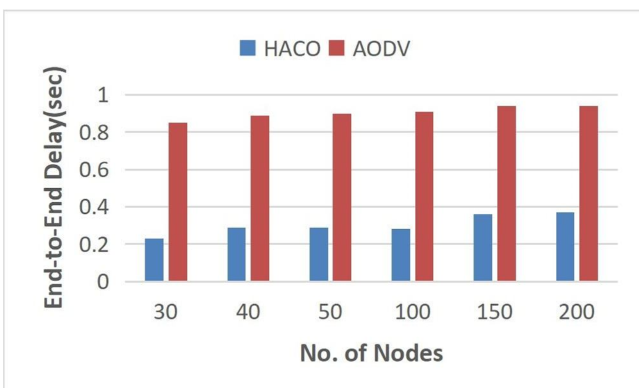

Figure. 7. comparison of End-to-end delay for traditional AODV and proposed HACO Protocol

V. CONCLUSION

To increases the performance efficiency of the routing process in FANETs, a completely new proposed routing protocol named HACO is proposed in this paper. The DCM and SBACO combination at HACO minimize ant explore time, increases convergence speed, avoids packet blind broad- casting, provide quicker packet processing, and avoids stagnation issues. PDR and Throughput in HACO are improved by using optimized route without stagnation easy packet processing, and fast convergence speed. PLR is reduced by taking the shortest, non-congested path. Overhead is reduced by avoiding acts like blind packet broadcasting and multiple responses to a single packet.

EED is reduced by quickly selecting the least-hope, on-congested shortest route. With respect to PDR, throughput, EED, and PLR, simulation results reveal that HACO performs better than traditional AODV protocol. In the future, we plan to expand HACO with already existing the FANET system to high-traffic scenarios with flying nodes to compute performance measures such as through-put, packet- loss -rate, avg end-to- end delay, and packet-delivery- ratio.

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