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Comprehensive Comparison and Analysis of Nature Inspired ACO based Routing Algorithms in Ad Hoc Networks

Deepika Dhawan[1] and Rajeshwar Singh[2]
[1]Ph.D. Research Scholar, Department of Electronics and Communication Engineering, IKG Punjab Technical University, Jalandhar (Punjab), India.
[2]Department of Electronics and Communication Engineering, Doaba Khalsa Trust Group of Institutions, SBS Nagar (Punjab), India.

(Corresponding author: Deepika Dhawan)
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ABSTRACT: Nature inspired Ant Colony Optimization (ACO) is one of many optimization methods used for optimization in Ad-Hoc Network. It is inspired by the behavior of ants from real life, as ants navigate in the real world to find food or for any other purposes. In Mobile Ad Hoc Networks (MANETs) the most daunting part is to find the location of the nodes to which the information is destined to reach. This is because of the mobility of the nodes in MANETs. The nodes in MANETs are mobile i.e. all the nodes in the network are constantly moving in space. Using ACO, we are able to find the optimal path to the destination node from the source node. Nature inspired ACOs have formulated many optimization algorithms which have found real promising results for the optimization problem in MANETs. In previous research paper, we have proposed few algorithms and simulated it, we have also compared the Quality of Service (QoS) results as to find out how our algorithms perform in comparison with others published algorithms, but the limitation is that we could not have done a comprehensive comparison and analysis of our proposed algorithm with different variety of the algorithms. So, in this paper, we dive deep into the comprehensive analysis of many other published and implemented algorithms and compare them at an exhaustive level with our own proposed algorithm.

Keywords: ACO, ADSR, AODV, AD-ZRP, ADSR, Ad Hoc Networks, QoS

I. INTRODUCTION

MANETs are a unique type of network in which the node of the network is mobile. Due to the mobility of the nodes in the network there are many problems that arise while finding a solution for the optimization problem. The nodes in the network can also get disconnected from the network because of their mobility. The mobility of the nodes in this type of network makes finding an optimal solution (route selection) for MANETs daunting task. Nodes in the network can join or leave the network because of their mobility which is the consequence of having an infrastructure-less network which is also not centralized. In MANETs, all the node are able to act as a router which enables them to maintain and discover the routes through which they can propagate the information to their destination nodes. Route maintenance is quite a difficult task in MANETs because of the dynamicity the network possesses. Routing is an important part of the network communication because of the factors like congestion, reliability, and throughput depends upon the routing information. Routing is simply a term for choosing the path from the source to the destination to send over any information within the network. The ideal case is when an algorithm can deliver packets with a minimum amount of delay and overhead.

Ant Colony Optimization (ACO) [1] is a subset of Swarm Intelligence. The algorithm is adopted from the behavior of the ants in real life for the search of food. Ants deposit pheromone while walking anywhere. When the ants search for food and encounter an intersection, they have to decide which path to follow next, so due to the pheromone laid by the other ants on any other path, the ant is more likely to choose the path with the high pheromone level. The high pheromone deposit on a path is an indication that it is very high usage, but also the pheromone level decreases over time due to the diffusion effect.

In the rest of the paper, section II briefly summarises the related work. In section III we describe in detail about our previous proposed algorithms and other well-performing algorithms. In section IV we present simulation and experimental results and discuss the outcomes over major factor affecting any protocol. Finally, in section V we discuss the results, and in section 6 conclusions and future scope are presented.

II. RELATED WORK

MANETs has seen a lot of development is the last few years as researchers are very much intrigued by the subject, so many routing protocols have been proposed in the past few years [2]. However, all of the protocols are categorized usually categorized among proactive, reactive, and hybrid protocols. As in proactive protocols, every node beforehand has established a path to every other node in the network. These types of protocol help improve the end to end delay and lower it which make the algorithm efficient. However, the maintenance of these type of protocol is too high as the unused path also occupies an important part of the available bandwidth.

In Reactive Routing (DSR [3], AODV [4], TORA [5]) unlike the proactive, the routes are established on – demand, i.e. when a node wants to send a packet it has to first find a route to the destination then carry on with

sending the packet. Which leads to the decrease in the routing overhead. And maybe in some cases the end-to-end delay increases.
Some Hybrid protocols such as ZRP [6] which combines the feature of both the proactive and the reactive protocols and benefit from both of their advantages. The network in this protocol is divided into two regions/zones, where intra zones are proactive and inter-zones are reactive. Energy consumption tends to be higher in this type of protocols.
In ANT-AODV [7], [8] ACO is repeatedly used to continuously make routes between nodes proactively and AODV is used to finding routes reactively i.e. on-demand. The proactive routing decreases the end-to-end delay for data delivery to the destination. However, as other proactive approaches, Ant/AODV also as a consequence gets an increase in high routing overhead which initiates congestion.
Ant-DSR [9] uses three types of ants, hello ants, unicast ants, broadcast ants, the hello ants are used when it is about to start to detect the neighbors, the unicast ants discover the routes proactively and stores the route in the cache. The broadcast ants detect the neighbors.
For fast data transferring scenario HOP NET [10], ADZRP [11] are approached. In ADZRP ACO inspired Zone based hybrid routing protocols are proposed. These are very much similar to ZRP. They maintain the intra-zone routing table proactively and apply ACO for Inter-zone reactive routing i.e. reactively.
Many algorithms which consider link reliability the main factor other than any other factor are also proposed in the past few years. Like in [12] an enhanced multi-path dynamic source routing algorithm is proposed (EMP-DSR). Many energy-aware routing protocols are also proposed in the past few years, like in [13], [14], energy-aware ARAMA protocol and an energy-aware ZRP protocol are proposed respectively.

III. DETAILED DESCRIPTION OF VARIOUS ALGORITHMS

In this section, we are going to understand all the aspects and factor that many progressive and most used optimization algorithms implement. In this section we are going to discuss on the following algorithms in detail:

A. ACO-EE Routing Algorithm (Our proposed algorithm).
B. Dynamic Source Routing (DSR)
C. E-Ant-DSR
D. Ant-Dynamic Source Routing (ADSR)
E. Ad-Hoc on-Demand Distance Vector (AODV)
F. AD-Zone Routing Protocol

A. ACO-EE Routing Algorithm (ACO-EERA)

ACO-EERA or ACO-EE Routing algorithm is an abbreviation of Ant Colony Optimization based Energy Efficient Routing Algorithm. This algorithm is proposed by us in an attempt to reduce energy consumption in network operation. Energy consumption in any network can be a major challenge to tackle, it is also a major factor in any network as we can afford the high energy consumption in any network because it might collapse the network or a specific node due to exhaustion of energy might get dead. So energy consumption of a node is a crucial factor in our algorithm.
This algorithm is based upon the Ant Colony Optimization using Ad-Hoc On-Demand Distance Vector. Like in general ACO algorithms implements 3 main functions: ConstructAntSolutions, UpdatePheromones, and DaemonActions, the algorithm ACO-EE routing Algorithm also implements above stated 3 functions. These 3 functions perform as following for the ACO-EE Routing Algorithm. The ConstructAntSolutions is a function/procedure in which the ants find a solution to the constructed graph. InUpdatePheromones the algorithm updates the pheromone level in the graph and paths. And in the DaemonActions function, the algorithm performs the centralized action required to find a solution.
In ACO-EE Routing Algorithm the pheromone tables are stored in each ant's memory. This pheromone table is like a matrix, where the neighboring nodes are defined as rows and columns are the corresponding destinations.
ACO-EE Routing Algorithm implements a different strategy for sending the data packets and the ants. The next hop for an ultimate destination d, when it has multiple hops, the selection of the next hop is decided randomly with the Eq. 1.

$$\frac{({\tau^k}_{id})^{\alpha}(E_i\overline{{FTE_\iota}^k})^{\beta}}{\sum_{j\in N_i}({\tau^k}_{jd})^{\alpha}(E_i\overline{{FTE_\iota}^k})^{\beta}} \qquad (1)$$

Where E_i denotes the energy level of the next hop node i, and $\overline{{FTE_\iota}^k}$ is the link quality and the congestion factor between node k (the current position of the node) and it's neighbor i (the node it is considering to hop), it is also known as frame transmission efficiency. E_i is computed as shown in Eq. 2

$$E_i = E_i^{remaining} / E_i^{initial} \qquad (2)$$

Where $E_i^{remaining}$ is the energy remaining in the next possible hop node and $E_i^{initial}$ is the energy of the next possible hop node's initial energy.
The neighboring nodes which have less remaining energy or have bad links in the network are selected less due to the probabilistic data which will also distribute the traffic in according to the probabilities for each neighbor in the routing table.

B. Dynamic Source Routing (DSR)

DSR [3] is an algorithm specifically designed for the use of multihop wireless ad hoc networks of mobile nodes. The DSR protocol consists of two main mechanisms which allow to maintain and discover routes in MANETs. The two main mechanisms are:
(i). Route Discovery: Route discovery is a mechanism by which a source node which wants to send data to destination node obtains a route from the source to destination. This process is only executed when the source node wants to send data to the destination node but does not already know the route.
ii). Route Maintenance: Route maintenance is the process in which the source node is able to detect using the route to the destination that if the topology of the network has changed in such a way that it can no longer use the route to its destination because a link to the node does not work any longer. When the routing mechanism detects that a link or path is broken the source can use any other nodes it happens to know to the destination. It can also call for the process to find a new path to the destination for subsequent packets. This mechanism can only be used when the packets are in the process of sending.

DSR implements a reactive approach which floods the network with table update messages which are required in this type of approach the intermediate nodes also reduces the control overhead by using the route cache information efficiently [16].
However one of the disadvantages of the DSR can be that the Route maintenance mechanism cannot repair a broken link locally the connection setup delay is higher in these types of table-driven approaches. The protocol performs well in static and low mobility environment, but the performance of the protocol degrades when the mobility of the nodes increases.

C. E-Ant-DSR

The E-Ant-DSR [15] incorporates ACO and DSR to maintain and discover the best routes among the nodes. Even though in E-Ant-DSR the ACO needs limited computation and power from the individual nodes, it still provides with the effective routing. Due to the artificial ant's adapting capability, ACO can keep the routing tables efficiently updated.
(i). Route Discovery: When a packet needs to be sent, it first checks for existing routes in the cache. When there is no route then the route discovery mechanism is initiated. The process of the route discovery is as follows. The source sends Req. ants packets through all the reliable links. If the intermediate nodes of the network happen to know a path to the desired destination already, then there is no need to repeat the whole process and find the path again, this way it can save time. And if it doesn't know the path to the destination then in a sparse network like all the blind flooding technique used by many algorithms, it also does the same except for a small change i.e. the Request Ant packet is forwarded to all the nodes other than to the node it has received the request from.
(ii). Route Maintenance: This is a crucial part in MANETs, as we know in MANETs the dynamic of the network changes and route which were found at one point of time may not remain as good as the time when they were found. The network topology is infrastructure-less, so the mobility of the nodes will them the nodes to be in a different position in space than they were before, and so the routes which are now less used due to any such reason, the pheromone deposited on the route will eventually evaporate slowly. The pheromone decay technique used for each route in the E-Ant-DSR algorithm is shown in Eq. 3

$$\varphi = \varphi \times e^{\frac{t \times v_{avg}}{k_{ACK}}} \qquad (3)$$

Where t is a time in seconds, k_{ACK} is the number of acknowledgment messages. And V_{avg} average of the maximum speed limit of the nodes.
For higher node speed evaporation of pheromone occurs faster. In a case where the mobility is high, the route will not exist for a long time. Now the data delivery will fail if any packet is sent through any broken route, and as a consequence, the routing overhead will also increase. So for the sake of efficiency here the pheromone level is set on the basis of the node mobility.
(iii). Energy consumption in E-Ant-DSR is defined as the sum of the energy consumed during the data transmission (E_{DATA}), consumption of energy during discovery of route (E_{RD}), and the echo message (E_{ECHO}) that are broadcasted. So that equation will form as shown in Eq. 4

$$E_{TOTAL} = E_{ECHO} + E_{RD} + E_{DATA} \qquad (4)$$

D. Ant-Dynamic Source Routing (ADSR)

ADSR [9] or Ant Dynamic Source Routing is a type of reactive/on-demand protocol. ADSR mainly focuses on three main parameters, which are jitter, energy, and delay. The nodes in the MANETs are required to maintain the cache of the route. In this route cache, all the source routes are stored and the route cache is regularly updated as new routes are found in the network. This optimization protocol majorly consists of two main operations as similar to other protocols namely Route discovery mechanism and Route maintenance mechanism.
(i). Route Discovery: In Route discovery, this protocol at first looks for an existing path in the route cache for the destination. If the route is not present then it initiates a route discovery process for the destination by sending a route Req packet. Now a route reply is generated and sent back from the destination if the request packet has reached the destination or the request packet has reached at a node which promises the path to the destination node, in which case the node that promises to have the path to the destination sends back a route reply (taking into consideration that the route available from the intermediary node has not expired as can still successfully send over the data). It also contains the information where if the packet reaches the destination or the intermediate node, it stores the information about the hops taken, in the exact sequence the hops were taken. Is the destination is sending the route reply then the record of the route (route record in which the sequence of the hops are stored) is sent along with the route reply? However, if the node is not the destination node and it is the intermediate node which has the route cached to itself, then upon the request for the route reaching to the intermediary node then, the cached route will be appended in the route record and generate route reply.
Also in the route discovery process of the DSR, forward ants and backward ants are used.
(ii). Route maintenance: Route maintenance is done by the use of the acknowledgments and the route error packets. The acknowledgments verify whether the operations were correctly performed on the route links or not. In ADSR FANT (Forward Ant) and BANT (Backward Ant) are added and sent along with the route request and route reply process respectively.

E. Ad Hoc On-Demand Distance Vector (AODV)

AODV [4] is a distance vector protocol which is on-demand or reactive in nature. This means that the AODV chooses its path depending upon the number of hops it will have to take in order to reach the destination. This particular network protocol supports unicast and multicast routing. This algorithm is inspired by the Bellman-Ford algorithm except this algorithm is on demand.
(i). Route Discovery: The working of the algorithm is very simple and basic. If a node wants to send a packet to any destination node d, then the source node will send a ROUTE REQUEST to all its neighboring nodes for the path to the destination node d. If any of the neighboring nodes happen to know the path to the destination then a ROUTE REPLY will be returned to the source.
In any other case if the neighbor node does not know the path, then each neighbour will forward the packet with their neighbours except to the source where the

request was received from, and it will increment in the number of hops taken to reach the destination, so that the protocol can evaluate at the end which path to choose.
The same type of packet is used for a reverse route to the source and the process is repeated until a route has been found.
(ii). Route maintenance: In this part, if the neighboring node is no more available and the ROUTE REQUEST was sent to a neighboring node, then the path is no longer available as well. To keep track of the neighbors of any node the AODV protocol uses a HELLO packet on a regular interval to check and keep track of active neighbors. The active neighboring nodes can be described as the neighboring nodes which were used in a previous session of packet delivering. If there is no response from any of the neighboring node then the source/originator node (node which initiated the HELLO packet for its neighbor) deletes all the routes associated with that node of which it kept track of in its route cache. This method is an actually good part of the route maintenance as there is no need of keeping information about the nodes which are no longer available to use for any operation in the network. These HELLO packets can be interpreted as the ping requests, like in ping request we ping any specific network element and wait for a reply, any type reply will only be received if the network element is still healthily functioning. The same is the case with the HELLO packets, if the nodes are active and are in a state to forward a packet and function properly then it must reply to the originator of the HELLO packet as to let it know that it is working and can perform any operation needed by the network.
Another case in route maintenance can be that if the route or link is broken while transmitting any packet or data a ROUTE ERROR packet will be dispatched to let know all the previous nodes who forwarded the packet for transmitting to the destination that there is an error and the link to the destination is broken [17]. This is done by unicast to the previous senders of the packet and the original sender of the packet.
The advantage of implementing the AODV protocol can be that the delay for the connection setup is lower as compared to other basic protocols. Also, it only establishes routes on demand and to find the latest route of the destination sequence number are used which tells the nodes as to which path it should follow to reach the destination as per the latest route found. However the intermediate node can sometimes lead to routes which are not consistent as and if the sequence number of the source is old and the intermediate node possesses a higher sequence number to the destination, it is not definite that the intermediate node possesses the latest sequence number which will as a consequence lead to having stale entries in the network. And the multiple ROUTE REPLY packet sometimes leads to heavy overhead control.

F. AD-Zone Routing Protocol (ADZRP)

AD-ZRP or Ant-based Zone Routing Protocol [11] is a reactive protocol which is based on Zone Routing protocol and HOPNET which is a hybrid protocol based on Ant Colony Optimization. AD-ZRP takes several restrictions into account such as processing power, bandwidth, energy consumption, etc. AD-ZRP is based on ZRP which along with ACO helps to make the route maintenance and route discovery a much more efficient task using the pheromones used in ACO.

The Zone Routing Protocol [6] itself is a hybrid routing protocol i.e. it is proactive and reactive. It takes advantage of both types of the routing protocol. It enables pro-active discovery which let's discover local nodes in the neighborhood of the source or the originator. It also enables reactive which enables it to communicate to the local neighboring node found. The Route request is forwarded by the Broadcast Resolution Protocol (BRP). Its BRP's responsibility to forward the requests. The ZRP divides its network into different zones. However, each node may fall into the multiple overlapping regions in a network and all of the regions or zones can vary in size.
The zone's size is determined by the radius of the length instead of any geographical measurement. The radius of the length determines the zone where the number of hops is called the perimeter of the zone. The AD-ZRP similarly to the ZRP is very beneficial and efficient for large networks. It consists of many components which put together can give the full routing benefit to the protocol. As AD-ZRP is a reactive protocol and even while the ZRP is a hybrid protocol it indicates to the fact that this protocol is a hierarchical protocol, but it is important to notice that the protocol is a flat protocol. One of many inherited benefits of the AD-ZRP protocol from the ZRP is that it gives less control overhead as compared to other reactive protocols.

IV. SIMULATION AND EXPERIMENTAL RESULTS

This section comprises of the system environment that the protocols are run upon and the results yielded by the protocol. In this section, all of the protocols are rigorously tested and the results are presented. The graphical representation of the results of the protocol is generated in MATLAB.

A. System environment

All of the Protocols namely ACO-EERA, DSR, ADSR, E-AntDSR, AODV, AD-ZRP are tested for the analysis of factors such as Energy consumption, Packet Delivery Ratio, End to End delay. Also, the protocols are simulated in Network Simulator 2.35, with the following system configuration:

- Processor: Intel i3 processor
- Ram: 6 GB
- Operating system: Fedora 23

B. Parameters

The parameters provided for the testing of the protocols are as mentioned below in table 1.

Table 1: Simulation Parameters.

Parameters	Value
Number of Nodes	20
Antenna Type	Omni Antenna
Simulation Time	20 Sec
Initial energy	100 KJ
Area	1000 * 1000
Mac Type	Mac/802.11
Rx Power	0.3
Tx power	0.6
Protocols	ACO-EERA,ADSR,DSR,E-AntDSR,AODV, AD-ZRP

C. Executions and Results

The protocols are tested for the major and challenging factors we find for a protocol to possess.

The metrics chosen for the testing are:

End to End Delay: End to end delay is the time taken for a data packet to reach the destination from its origination, the source. Mathematically, End to end delay is defined as Eq. 5.

$$\text{End-to-End delay} = \frac{\sum e}{P} \quad (5)$$

Where. e is $Td - Ts$

Table 2: End to End Delay of various protocols.

Name of the Protocol	End to End Delay (ms)
ACO-EERA	41
AODV	67
E-AntDSR	160
DSR	440
ADSR	390
AD-ZRP	325

After finding the protocols' results the graphical representation for the end-to-end delay for all the protocols aregiven below in Fig. 1. From figure 1 we can infer that the End to End delay time for the ACO-EERA is the least which mean that it takes the least time in comparison with other algorithms for a data packet to reach the destination node from the source node.

The time (ms) consumed by ACO-EERA is 41ms. After ACO-EERA the next protocol to have the least delay of all protocols is AODV, which has consumed 67ms. The protocol which has 3rd least delay is E-AntDSR which has a delay of 160ms. Other protocols such as DSR has 440ms of delay, ADSR has a delay of 390ms and AD-ZRP has a delay of 325ms.

-Energy consumption: Energy consumption in a network is defined as the total consumption of energy after completing the carious operation needed in order to achieve the success of sending the packet to its destination from the source. This includes discovering the path, sending data, and the broadcasting of messages in some protocols.

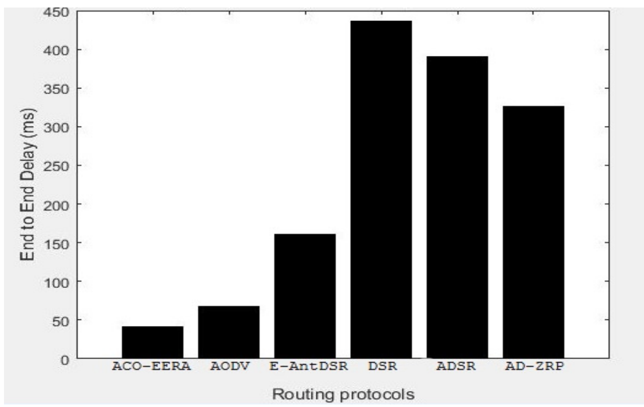

Fig. 1. Graphical Representation of End-to-End Delay.

This factor can be expressed in mathematical form as already shown in Eq. 4

$$E_{TOTAL} = E_{ECHO} + E_{RD} + E_{DATA}$$

After execution the following results are achieved. From Fig. 2 we can infer that the protocol ACO-EERA consume the least energy as compared to all the other protocols. Energy Consumed by ACO-EERA is 1.2KJ.

Table 3: Energy Consumption of various protocols.

Name of the Protocol	Energy Consumption (KJ)
ACO-EERA	1.2
AODV	2.6
E-AntDSR	1.5
DSR	4.8
ADSR	2.9
AD-ZRP	3.0

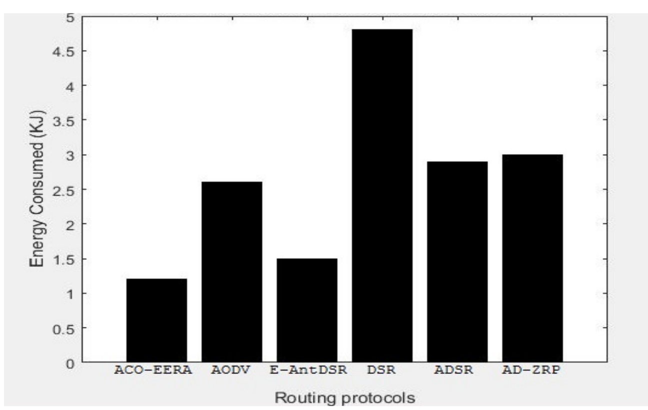

Fig. 2. Graphical Representation of Energy Consumption.

It is least of all the protocols and the next protocol which consumed the least energy after ACO-EERA is E-AntDSR which has consumed 1.5KJ of energy during the whole network operation. However, the highest energy consumption is done by DSR, a whopping 4.8KJ. Other protocols are in the mid-range like AODV has consumed 2.6KJ of energy, ADSR has consumed 2.9KJ and AD-ZRP has consumed 3KJ of energy.

-Packet delivery Ratio: Packet delivery ratio in MANETs is defined as the total number of packets received over the number of packets originally sent. The mathematical equation for the metric can be written as shown in Eq. 6

$$PDR = \frac{\sum_i No.\ Ofreceivedpacket}{\sum_i No.ofpacketsendbysource} * 100 \quad (6)$$

Upon calculating the packet delivery ratio, we get the following result:

Table 4: Packet Delivery Ratio of various protocols.

Name of the Protocol	Packet Delivery Ratio (%)
ACO-EERA	91.58
AODV	81.65
E-AntDSR	89.13
DSR	38.07
ADSR	56.11
AD-ZRP	66.25

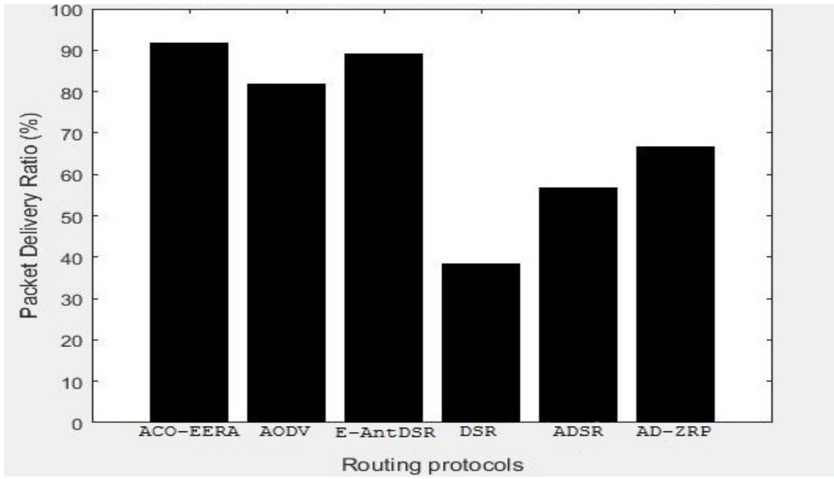

Fig. 3. Graphical Representation of Packet Delivery Ratio.

From figure 3 we can infer that according to the simulation yielded graphical representation the performance of the ACO-EERA proves to be at a higher rate than other protocols, which means that our proposed protocol performs better in comparison with other widely used and different types of protocols. Our protocol yields a packet delivery ratio of 91.58%, whereas the next highest protocol i.e. E-AntDSR yields a result of 89.13%. Other protocols are very distant but after E-AntDSR next best output is by AODV which yields a result of 81.65%. The packet delivery ratio of DSR, ADSR, and AD-ZRP are 38.07, 56.11 and 66.25 percent respectively.

V. RESULTS AND DISCUSSION

The simulation was carried out on Network Simulator using the parameters mentioned in table.1. The results obtained for three major metrics i.e. End-to-End Delay, Energy consumptions and packet delivery ratio are presented in the Table 2, 3, and 4 respectively.

The End to End delay time for the ACO-EERA is the least which mean that it takes the least time to deliver packets in comparison with other algorithms for a data packet to reach the destination node from the source node. The time (ms) consumed by ACO-EERA is 41ms. After ACO-EERA the next protocol to have the least delay of all protocols is AODV, which has consumed 67ms. The protocol which has 3rd least delay is E-AntDSR which has a delay of 160ms. Another protocol such as DSR has 440ms of delay, ADSR has a delay of 390ms and AD-ZRP has an End to End delay of 325ms.

The simulations also give results for energy consumption on simulation parameters mentioned in Table 1. ACO-EERA consumes the least energy as compared to all the other protocols. Energy Consumed by ACO-EERA is 1.2KJ which is least of all the protocols and the next protocol which consumed the least energy after ACO-EERA is E-AntDSR which has consumed 1.5KJ of energy during the whole network operation. However, the highest energy consumption is done by DSR, a whopping 4.8KJ. Other protocols are in the mid-range like AODV has consumed 2.6KJ of energy, ADSR has consumed 2.9KJ and AD-ZRP has consumed 3KJ of energy.

The result obtained for Packet Delivery Ration also shows that the performance of the ACO-EERA proves to be at a higher rate than other protocols, which means that our proposed protocol performs better in comparison with other widely used and different types of protocols. Our protocol yields a packet delivery ratio of 91.58%, whereas the next highest protocol i.e. E-AntDSR yields a result of 89.13%. Other protocols are very distant but after E-AntDSR next best output is by AODV which yields a result of 81.65%. The packet delivery ratio of DSR, ADSR, and AD-ZRP are 38.07, 56.11 and 66.25 percent respectively.

VI. CONCLUSION AND FUTURE SCOPE

In this paper, we have compared and analyzed six major algorithms to its depth from which one of the algorithms is proposed in our previous work i.e. Ant Colony Optimization Based Energy Efficient Routing Algorithm (ACO-EERA) which is based on the behavior of ants from the real world. Our proposed algorithm is a nature-inspired optimization technique which optimizes certain factor for energy efficient routing in Ad Hoc Networks which are very much important for the network operation. Also, we have simulated proposed algorithm along with five other well-known and widely used protocols which are of various types i.e. reactive, proactive and hybrid. We have found the results of our proposed protocol to be much promising and efficient. The ACO-EERA has successfully tackled the issues we have addressed in the paper i.e. the QoS is maintained or rather improved. The ACO-EERA has successfully yielded better results than compared to AODV, E-AntDSR, DSR, ADSR, AD-ZRP algorithms on metrics like packet delivery ratio, end to end delay and energy consumption. This protocol was rigorously analyzed, simulated and compared; and has yielded better results than other compared protocols, which is ideal to implement for real-world problems.

The proposed protocol ACO-EERA is simulated on Network Simulator and we need to verify for real-time scenario implementation in our future research work. Also, the performance of the proposed algorithms is verified only on three metrics i.e. End-to-End Delay, Energy Consumption and Packet Delivery Ratio for a fixed number of nodes and fixed initial energy. Also, ACO-EERA needs to be verified for a varying number of nodes, varying deployment area and the varying speed of nodes for different initial energy in our future research work.

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