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Enhanced-Ant-AODV for Optimal Route Selection in Mobile Ad-Hoc Network

Dipika Sarkar*, **Swagata Choudhury**, **Abhishek Majumder**
Department of Computer Science & Engg, Tripura University (A Central University), Agartala - 799022, India
* Corresponding author.
E-mail addresses: sarkardipikacse@gmail.com, choudhuryswagata15@gmail.com, abhi2012@gmail.com

Biographical notes: Dipika Sarkar has obtained her B.Tech degree (Computer Science and Engineering) from West Bengal University of Technology in 2014 and M.Tech (Computer Science and Engineering) from Tripura University (A Central University) in 2016. Her areas of interest and research include mobile ad-hoc network, wireless sensor network, network security and cryptography etc.

Swagata Chowdhury has obtained her B.Tech degree (Computer Science and Engineering) from Tripura Institute of Technology in 2014 and M.Tech (Computer Science and Engineering) from Tripura University (A Central University) in 2016. Her areas of interest and research include image processing, mobile ad-hoc network, wireless sensor network, network security and cryptography etc.

Abhishek Majumder received his B.E. degree in Computer Science & Engineering from National Institute of Technology, Agartala and M.Tech. degree in Information Technology from Tezpur University, Assam in 2006 and 2008, respectively. He is currently working as an Assistant Professor in the Department of Computer Science & Engineering, Tripura University (A Central University), Suryamaninagar, India. He is a member of IEEE and Institution of Engineers (India). His areas of interest are Wireless Network and Cloud Computing.

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Abstract—Selection of an optimal path is a challenging issue in Mobile Ad-hoc network (MANET). This paper proposes a new mechanism for route selection combining Ad-hoc On-Demand Distance Vector (AODV) protocol with Ant Colony Optimization (ACO) to improve Quality of Service (QoS) in MANET. Based on the mechanism of ant colony with AODV, the finest route for data delivery is selected using pheromone value of the path. In the proposed work, pheromone value of a route is calculated based on end to end reliability of the path, congestion, number of hops and residual energy of the nodes along the path. The path which has highest pheromone value will be selected for transmission of the data packet. The simulation result shows that the proposed scheme outperforms AODV, Dynamic Source Routing (DSR) and Enhanced-Ant-DSR routing algorithms.

Keywords— Mobile Ad-hoc Networks, Dynamic Source Routing, Ad-hoc On-Demand Distance Vector Routing, Ant Colony Optimization, Quality of Service, Route Selection .

I. INTRODUCTION

Ad-hoc networks are collection of mobile nodes communicating with each other using wireless media without any fixed infrastructure. Mobile ad-hoc network (MANET) (Pahlavan and Krishnamurthy, 2011; Giordano, 2002; Yadav and Rishiwal, 2011) dynamically forms a network without any support of central management. Because of this dynamic nature, routing in MANET is difficult when some QoS requirements need to be satisfied. There are many routing protocols that can fulfill various QoS requirements but none of those protocols supports those requirements altogether. In this paper, an enhanced technique combining Ad-hoc On Demand Distance Vector (AODV) with Ant Colony Optimization (ACO) (Dorigo and Stu1etzle, 2004) mechanism is developed. In proposed technique, before a node sends a data packet to another node, like AODV, it finds out the route to the destination. For finding the route, the sender node broadcasts Route Request packets (named as ReqAnt packets) in the network. This is same as biological ants which first spread out in many directions for searching food. After finding the food source, they deposit pheromone on their way back to the home, so that other ants can get knowledge about the path. Similarly, in the proposed technique the ReqAnt packets are broadcasted in the network. They collect information about the path namely: end to end reliability of the route, congestion along the route, residual energy of the node along the route and length of the route. After receiving the ReqAnt packet, the destination calculates pheromone count of a route considering the path information stored in ReqAnt and sends back the RepAnt (Route Reply packet). The route of highest pheromone count is considered for routing data packets. The ACO based Enhanced AODV outperforms AODV and other ACO routing schemes in various scenarios.

Organization of the paper is as follows. Section 2 presents the problem statement of the research work. Section 3 discusses some of the existing schemes. The proposed enhanced ANT AODV scheme is presented in section 4. In section 5 the simulation results of the proposed scheme is compared with AODV, DSR and enhanced ANT DSR. Finally, in section 6 conclusion and future work has been presented.

II. RELATED WORK

A brief overview of the previous works done on the route optimization techniques based on swarm intelligence in MANET is presented in this section.

Hang Zhang et.al (2017) and Peng Zhou (2013) discussed various aspects of ant colony routing (ACR) protocols in which selection of next hop is based on the pheromone and heuristic information of the network. Each node maintains a pheromone table and heuristic information table. In pheromone table, the table entry indicates the expectation of selecting a node as next hop towards destination. In heuristic information table, the table entry indicates the heuristic criteria such as position, energy, number of hops, latency etc. Probability is used to select a next hop. The node having maximum probability among its adjacent nodes is selected as the next hop. The pheromone deposition process enhances pheromone i.e. chance of selecting a particular route to attract traffic for better routing. The pheromone evaporation process reduces pheromone or chance of selecting a particular route to avoid the link of poor quality.

Mano Yadav et.al (2011) proposed an improved routing algorithm based on the ant colony optimization (ACO) technique. The improved ACO (I-ACO) performs routing with updated pheromone information by using two models namely, transition probability model and directional probability model. Transition probability helps in finding location of the next node in the movement of ants. The directional probability helps in finding next node towards the direction of destination. This technique reduces the end to end delay of packet and provides high data packet delivery ratio. But this technique results in high control overhead and high energy consumption due to the lack of energy management.

Ahmed M. Abdel-Moniem et.al (2010) proposed Multi-Route AODV Ant routing algorithm (MRAA). In this technique, AODV discovers routes reactively i.e. on demand and ACO creates routes between nodes irrespective of the demand i.e. proactively. The technique reduces the end-to-end delay during data packet delivery. Packets are delivered to the destination in lesser time with lower overhead because the technique uses alternate paths for data delivery. But storing and maintaining backup routes is an overhead.

Imane M.A. Fahrnv et.al (2012) and Z. Albayrak (2014) proposed Predictive Energy Efficient Bee Routing algorithm (PEEBR) which predicts the amount of energy that will be consumed by all the nodes along the paths. The technique uses bee Colony Optimization which uses two types of bee agent named as the scouts and the foragers. This routing technique focuses on determining optimal path for routing based on its goodness ratio. The technique is inspired from the bee's food search process based on two important parameters namely: the amount of energy consumed by each node along a single path and the end-to-end delay. These parameters together represent the path goodness. The technique consumes least battery power for route discovery, evaluation and selection and reduces the end to end delay. However, the technique cannot give good results in case of frequent topological changes.

Kiran Manjappa et.al (2013) proposed a routing scheme for MANET based on termite's hill building mechanism. It is named as Mobility Aware termite (MA-termite). The technique uses the coordination adapted by the termites in hill building process for sending the packet to the destination. Mobile node is represented as a termite hill. It stores the pheromones towards the destinations in the pheromone table. The node having highest destination pheromone count is considered as the next node. The pheromone update and decay on a link is proportional to the distance between the nodes of that link. Highly mobile neighbors cause high decay of pheromone. On the other hand, for the low mobility neighbors pheromone decay will be low. This technique has less route breakups and produces less overhead. Since the cross layer concept is included here, it is little bit complex in operation compared to others.

T Srinivasan et.al (2006) proposed a bird flocking behavior routing (BFBR) protocol for highly mobile ad-hoc Networks. The protocol has two parts: one is encounter search which is used for route discovery and the other is direction forward routing which is used for route maintenance. Unlike conventional broadcast mechanisms, the protocol saves bandwidth by avoiding unnecessary link traversals. Encounter search mechanism minimizes link traversals during route discovery. The Direction forward routing helps in maintaining local surroundings of each node to ensure connectivity of route. Thus it reduces the routing overhead. However, the mechanism is quite complex for maintaining the route.

Sanjay K. Dhurandher et.al (2011) proposed Peer to Peer Bee Algorithm (P2PBA) that is designed with an aim towards providing an efficient peer-to-peer (P2P) file search in MANETs. This scheme uses swarm-based intelligence, which is based on the foraging behavior of honey bees. In this scheme a file is broken down into packets. These packets are then distributed over a selective bunch of sites. However, parameters such as energy saving, security concerns and heterogeneity of node have not been taken into consideration.

Rao et.al (2014) has proposed AODV routing protocol with nth back up route (AODV nth BR). The protocol provides source node with more than one back up routes in case of a link failure in the network. It is a modified form of the existing AODV routing protocol in such a way that for packet delivery from source to destination more than one route is available. The selection of nodes for routing is done efficiently on the basis of distance and energy available with the nodes. In this scheme, every node is checked for its transmission energy and with the help of distance vector the next nearest node is found out. The nearest node is again checked if it has enough energy for transmission. This process continues until a suitable node is found for transmission.

Sudip Misra et.al (2011) proposed Bird Flight-Inspired Routing Protocol (BFIRP) based on energy and position. In this technique, the data packets are forwarded to the destination considering the energy of the node and the distance of the node from the destination. The protocol also considers the degree of closeness of the node to the great circle path which connects the intermediate and the destination nodes. The protocol lacks the bandwidth consumption issues.

Harmanjot Singh et.al (2017) proposed AODV-Reliability (AODV-R), a clustering Ant Colony Optimization based routing protocol for finding shortest path by removing the congestion. AODV-R uses ACO algorithm to improve the selection of shortest path algorithm. AODV-R selects the most reliable path which reduces the possibility of link breakages in changing network topology. However, the technique doesn't fulfil the requirement of QoS routing.

Aymen Al-Ani et.al (2015) proposed QoS-aware Routing based on Ant Colony Optimization (QoRA). QoRA calculates QoS parameter locally and avoids congestion during data transmission with the help of two architectural components. The first element is the QoRA entity which runs on each node to identify suitable paths according to the specified QoS requirements. The second component is the SNMP entity consisting of the Simple Network Management Protocol (SNMP) agent and the Management Information Base (MIB). SNMP locally obtains the relevant information for the node. Based on these information or values, the QoS parameters will be calculated and congestion is avoided during data packet forwarding. But the technique poses with high end to end delay.

Shubhajeet Chatterjee et. al (2015) proposed a reactive routing protocol combining ACO with Dynamic Source routing (DSR) named Enhanced Ant DSR. The technique uses ACO to select the optimal path. The pheromone count (probability for selecting a path) of a route is calculated considering Link Metric (LM), Congestion Metric (CM) and hop count. On forwarding the route request at every intermediate node LM, CM and hop count is updated. The sender node gets the information (length, congestion level and connectivity level) about a route from the route reply packet. It calculates the pheromone value of the routes and selects the route having highest pheromone value for data transmission. This technique can fulfill most of the basic QoS requirements. But since DSR is used, the header size of the packets increases with increase in path length. This causes routing overhead in the network.

Table 1 shows a comparison of the proposed scheme with the other existing schemes in terms of route selection parameters.

Table1: Comparison table

Existing Schemes/Protocols	Route Selection Parameters. Distance	Connectivity level	Energy	Congestion	Node's position information needed	Designed for
AODV	√	×	×	×	×	MANET
DSR	√	×	×	×	×	MANET
AODV-R	√	×	×	×	×	VANET
QoAR	√	√	×	√	×	VANET
BFIRP	√	×	√	×	√	MANET
AODV nth BR	√	×	√	×	×	MANET
P2PBA	√	×	×	×	×	MANET
BFBR	√	×	×	×	√	Highly MANET
MA-termite	√	√	×	×	×	MANET
PEEBR	√	×	√	×	×	MANET
MRAA	√	√	×	×	×	MANET
I-ACO	√	√	×	√	×	MANET
Enhanced Ant DSR	√	√	×	√	×	MANET
Proposed Enhanced Ant AODV	√	√	√	√	×	MANET

III. PROBLEM DEFINITION

Because of its dynamic nature, routing in MANET is difficult. Node failures and link breakages in the network may cause loss of the network resources. A fundamental issue arising in MANETs is the selection of the optimal path between any two nodes. For routing of data packets in ad-hoc network many schemes have been proposed such as Ad-hoc On-demand Distance Vector (AODV) (Perkins et al., 2003; Perkins and Royer, 1999) routing and Dynamic Source Routing (DSR) (Johnson and Maltz, 1996). But these conventional routing protocols use minimum hop count or shortest path as the main metric for path selection.

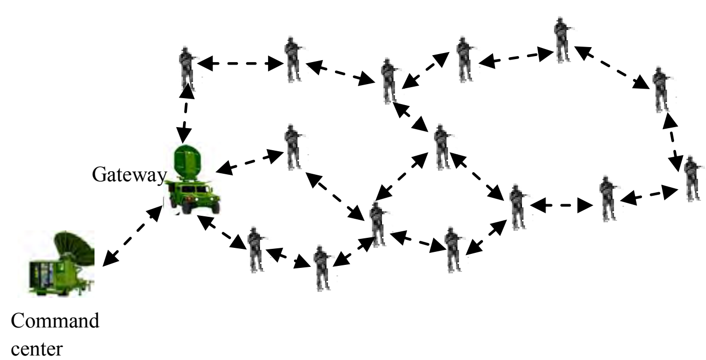


Figure 1: Scenario of ad-hoc network in battle field.

The routing becomes more challenging in tactical ad-hoc network used in battle field. In tactical ad-hoc network multimedia data needs to be transmitted. Therefore, it requires to support Quality of Service (QoS) (Kang et al., 2011). Figure 1 shows a scenario where video and audio data will be transmitted by the soldier to the command center as well among themselves. For ensuring QoS several factors need to be considered that could affect the quality of the chosen path. Some factors which are important for selecting an optimal path from source to destination in the abovementioned scenario are: received signal strength of the nodes, congestion, number of hops in the path and residual energy of the nodes. Received signal strength needs to be considered to select a path which has higher reliability. Network topology changes very quickly in tactical ad-hoc network. If a path is selected having intermediate nodes with less received signal strength among themselves, due to small movement also the link will be broken. In the abovementioned scenario all the nodes except the gateway and the command center are run by battery. Therefore, energy is a critical issue (Sandeep et al., 2015) for survival of the network. If the path contains nodes having less residual energy, the battery of those nodes will be exhausted and the route will be broken. So, residual energy of intermediate nodes is also an important factor for selecting a path from source to destination. Since the soldiers in the abovementioned scenario will be transmitting video and audio data also, the selected path needs to have less congestion. If the path contains congested links, the end-to-end delay will increase which is not good for real time video and audio transmission. Therefore, congestion of the links in the path from source to destination is a critical factor for path selection. In the abovementioned scenario the communication from source to destination is multi-hop. If the path contains large number of hops, the performance of the path will deteriorate (Son et al., 2012). Therefore, hop count of the path from the source to destination is an important factor for selecting a path. Many routing (Ahmad et al., 2016) protocols have been designed to fulfill various QoS requirements. Some of the route optimization schemes for ad-hoc networks are: ant colony routing (ACR) (Zhou, 2013), improved ant colony optimization (I-ACO) based routing (Yadav et al., 2011), multi-route routing algorithm based on AODV and Ant Colony Optimization (ACO) (Abdel-Moniem et al., 2010), bee colony optimization based routing (Fahmy et al., 2012), termite's hill building mechanism routing (Manjappa et al., 2013), bird flocking behavior routing (BFBR) (Srinivasan, et al., 2006), Peer to Peer Bee Algorithm (P2PBA) (Dhurandher et al., 2011), AODV nthBR (Rao and Singh, 2014), Bird Flight-Inspired Routing Protocol (BFIRP) (Misra and Rajesh, 2011), AODV-R (Harmanjot Singh, et al., 2017), QoS-aware Routing (QoRA) (Aymen Al-Ani et al., 2015) and enhanced ANT DSR routing (Chatterjee and Das, 2015). But none of these protocols consider all these four factors together while selecting the path from source to destination. Therefore, an optimal route selection technique needs to be developed which considers received signal strength or reliability, congestion, residual energy and route length for selecting a path from source to destination in tactical ad-hoc network.

In figure 2 let source node 1 wants to send data to the destination node 5. If route is not available at node 1, it will initiate the route discovery process. Route discovery process of different schemes follows different flooding mechanism based on the parameters they use for route selection. During route discovery process, the existing schemes use the corresponding parameters given in table 1 for selecting the path from source to destination. After path selection, data packets are sent from 1 to 5 through the selected path. The common problem with all the existing techniques is that none of them has considered all the four important factors together such as, distance, connectivity level, energy and congestion for optimal path selection to make more robust and efficient routing.

For example, the route discovery process of enhanced ANT DSR (Chatterjee and Das, 2015) as shown in figure 2 starts with sending Req.Ant packets through all available links stored in Received Signal Strength Metric (RSSM) cache of the sender node. The intermediate node checks its route cache. If it finds more than one paths, the path having the highest pheromone count is selected. This path is added at the Intermediate Node Address (INA) stack of the Req.Ant and the fields hop count, CM and LM are also updated by the path information. The intermediate node than sends Rep.Ant to the source on behalf of the destination. If it cannot find any path, it checks the INA field of the Req.Ant. If its address is not found in INA, it first stores the copy of the packet in its cache. Then it sets a timer for the life time of this duplicate packet and updates the Hop Count, CM and LM fields of the packet. After that it adds its own address in the INA field of Req.Ant. Now for sparse mode, the node will forward the packet to all available links except the link it has come through (quite similar to DSR route discovery). In dense mode network, the node will select the link which has the highest ratio of $\frac{\text{RSSM(Received Signal Strength Metric)}}{\text{NNCM(Non Linear Node Congestion Metric)}}$ and forward the Req.Ant packet through that link only. In figure 2 let the technique works in sparse mode. Let node 1 wants to send packet to node 5. Node 1 does not have a route to node 5 in its route cache. So, it broadcasts Req.Ant through the links $1\rightarrow2$ and $1\rightarrow6$. Both nodes 2 and 6 search their route cache for a route to the destination. Let, node 2 and 6 do not have a route to the destination in their route cache. Therefore, the hop count, CM and LM fields of Req.Ant will be updated. The nodes again rebroadcast Req.Ant through all the links stored in RSSM cache. This process continues till the Req.Ant reaches the destination. On receiving the Req.Ant the destination node 5 updates its route cache and sends back Rep.Ant through the routes $5\rightarrow4\rightarrow3\rightarrow2\rightarrow1$ and $5\rightarrow8\rightarrow7\rightarrow6\rightarrow1$. On receiving the Req.Ant node 1 selects the path having highest pheromone count. Let, the route $1\rightarrow2\rightarrow3\rightarrow4\rightarrow5$ has the highest pheromone count. Therefore, data packets from node 1 to node 5 are sent through the route $1\rightarrow2\rightarrow3\rightarrow4\rightarrow5$.

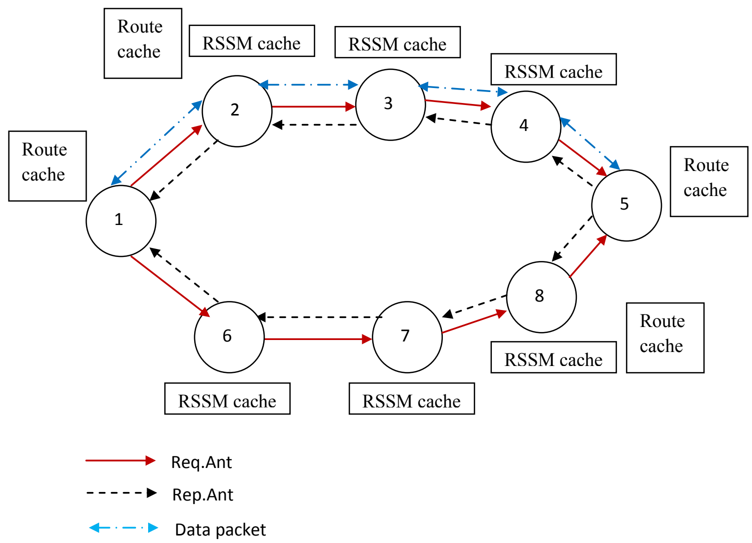


Figure 2: Example scenario of a route selection process.

The problem with this technique is, it does not give emphasize on energy conservation issue. The important QoS parameter 'energy' is not involved in route selection mechanism. Moreover, the entire path is appended with each packet header, so packet size is more. Using AODV protocol instead of DSR, reduces the size of packets (header) as the route information is stored in the routing table of each node. Therefore, data packets do not have to contain entire route. Path looping problem is encountered in case of DSR and to overcome the looping scenario additional mechanism has been developed in this scheme. This is an overhead. AODV is loop free due to destination sequence number associated with routes. So, no extra method has to be applied or developed to overcome looping scenario. Destination sequence numbers are used to find the latest route to destination. Due to this the connection setup delay will be less.

IV. PROPOSED SCHEME

In this section, the proposed Enhanced_ANT_AODV scheme has been presented. Unlike the existing metrics the proposed scheme considers more number of critical factors for optimal route selection. Enhanced-Ant-AODV constructs an optimal route from source to destination by considering the link quality, congestion, residual energy and number of hops along the path. Each node keeps some information in its routing table. A minimum level of residual energy should be available in a node for considering it as an intermediary node. When the residual energy of any node becomes less than or equal to the threshold energy, it will not be considered as an intermediary node. Similarly there is a threshold for received signal strength to consider some node as next hop. Therefore, two thresholds are used in this scheme,

- SIGNAL_THR: A threshold value, below which received signal strength will not be accepted.
- RE_THR: A threshold value, below which residual energy of a node will not be accepted.

Every node calculates its pheromone count value with Received Signal Strength Metric (RSSM), Congestion Metric (CM), Residual Energy Metric (REM) and Hop-count Metric (HCM) as defined in equation (1) and stores the value in its routing table.

When a node wants to send data packets to the destination it first checks whether it has a route to the destination. If a route is present data packets are sent through the route. If no route is present, it executes the algorithm for route request sending process shown in figure 7. The source node broadcasts Route Request packet (REQ-ANT). On receiving REQ_ANT the neighbor nodes execute the algorithm for route request forwarding process shown in figure 8. They create a reverse link to the originator of REQ_ANT. Then they calculate the pheromone count and update the routing table. If the residual energy of the nodes is more than threshold, they rebroadcast REQ_ANT. This process is followed by all the intermediate nodes till the REQ_ANT reaches the destination. When the destination node receives REQ_ANT it executes the algorithm for receiving route request shown in figure 9. It updates its routing table with the entry of source node. Then it executes the algorithm for Route Reply (REP_ANT) sending process shown in figure 10. After waiting for certain time period for receiving REQ_ANT through all the paths, it selects the path having highest pheromone count. It sends Route Reply packet (REP_ANT) to the next hop to reach the originator of the REQ_ANT. On receiving the REP_ANT the intermediate node executes the algorithm for route reply forwarding process shown in figure 11. It updates its routing table with the entry of REP_ANT's originator. Then it forwards the REP_ANT to the next hop to reach the originator of REQ_ANT. This process continues till REP_ANT reaches the destination. When REP_ANT reaches the originator of REQ_ANT it executes the algorithm for route reply receiving process shown in figure 12. It updates the routing table and thus a path will be created from source to the destination. The source then sends data packet through the established path.

4.1. Calculation of pheromone count

During selection of next hop for forwarding the route request to the destination, the nearest node is not always preferable. This may be because of congestion and lack of energy in that node. Therefore, the scheme considers pheromone value for selecting next hop. Let, there exists a link from node i to node j. The pheromone value of the link PC_{ij} can be calculated as,

$$PC_{ij} = \frac{Rn_{ij} \times En_j}{Cn_j \times Hn_{ij}} \quad (1)$$

Where, Rn_{ij} is the received signal strength at node j from node i, En_j is the residual energy of the node j, Cn_j is the congestion in node j, Hn_{ij} is the number of hops that the route request has traversed from the originator to node j via node i.

4.1.1. Received Signal Strength Metric (RSSM)

Received signal strength of each link determines the reliability of the link which can predict link breakage during data transmission. Received signal strength (RSS_{ix}) from neighbour node i at a distance x can be expressed as (Chatterjee and Das 2015),

$$RSS_{ix} = \frac{G_e \times G_t \times S_t}{\left(4\pi \times \frac{x}{\lambda}\right)^2} \quad (2)$$

Where, G_t is transmitting antenna gain, S_t is utmost transmission power of transmitting antenna, λ is the wavelength used in MANET.

From received signal strength a threshold (T_j) is calculated in neighbor node j as given in (Chatterjee and Das 2015),

$$T_j = \frac{G_r \times G_t \times S_t}{\left(4 \times \pi \frac{0.9054R}{\lambda}\right)^2} \quad (3)$$

Where, G_r is receiving antenna gain, R be the range of antenna. Depending on the threshold value (T_j), RSSM of the link (i,j) is calculated. The value of Received Signal Strength Metric (RSSM) at node j for the link (i,j) is 0 if RSS_{ix} is less than T_j or is equal to $\left(1 - \frac{T_j}{RSS_{ix}}\right)$ if RSS_{ix} is greater than or equal to T_i.

4.1.2. Congestion Metric (CM)

Congestion among the nodes can be determined by the buffer occupancy (Kang et al., 2005; Patel et al., 2010). The Queue Length is the number of packets present in the buffer of each node. As the number of packets enters or leaves the network, the length of queue keeps on changing. The Queue Length helps to detect whether a node in the network is congested or not. In Enhanced-Ant-AODV drop tail (Patel et al., 2010) queue is used for getting the queue length which determines the congestion in a node. In Drop Tail, when the queue buffer is filled up to maximum capacity, the next incoming packets will be dropped till the queue is full.

Total number of packets arriving at the node at a rate of λ during time interval t is calculated as,

$$N = \lambda t \quad (4)$$

4.1.3. Residual Energy Metric (REM) calculation

The energy level of nodes in the network is represented by the energy model. A node has an initial energy at the beginning. The node loses a particular amount of energy for every packet transmitted and every packet received. As a result initial energy of a node gets decreased at any specified time. The remaining energy in a node after receiving or transmitting packets at any specified time is the residual energy.If the residual energy of a node is too low to transmit the data towards destination, data transmission will be obstructed. The formula for calculating residual energy is mathematically expressed as (Sarkar and Datta, 2012),

$$E_i^{res}(t)=E_i^0 - C_t \quad (5)$$

Where, $E_i^{res}(t)$ is residual energy at time t, E_i^0 represents the energy initially present at node i, C_t is the energy consumption of node i until time t. Let p, p' and p'' be the number of packets transmitted, received and overheard respectively. $E_{tx}(p,i)$ is the energy required for transmission of p number of packets from node i. $E_{rx}(p',i)$ is the energy required for reception of p' number of packets by node i. $E_o(p'',i)$ is the energy required for overhearing of p'' number of packets by node i. Therefore, C_t can be calculated as (Fotino et al., 2007),

$$C_t = E_{tx}(p,i) + E_{rx}(p',i) + E_o(p'',j) \quad (6)$$

Where, E_{tx} and E_{rx} denote the amount of energy consumed by node i for transmitting a packet to node j and for receiving a packet from node j respectively.

$$E_{tx}(p,i)= I*v*t_b \quad (7)$$

Where, I represents the current measured in ampere, v represents the voltage measured in volt, and t_b is the time taken in seconds to transmit the packet p.

4.1.4. Hop-count Metric (HCM)

Hop-count metric at every intermediate node calculates number of hops a packet has come through along its way from the original source of the route request. It is incremented by 1 when proceed to next hop.

4.2. Frame Format

The proposed scheme uses modified forms of route request (RREQ), route reply (RREP) and routing table. The modified route request, route reply and routing table are named as route _request, route_ reply and routing _ table respectively.

4.2.1. REQ_ANT

In the proposed scheme, RREQ of AODV is modified by appending an extra field called pheromone_count. The rest of the fields are same as RREQ packet of AODV. The frame format of REQ_ANT is shown in figure 3.

Src_address (32 bit)	Src_sequenceno (32 bit)	Request_id (32 bit)	Dest_address (32 bit)	Dest_sequenceno (32 bit)	Hop_Count (8 bit)	Pheromone _count (20 bit)

Figure 3: Enhanced-Ant-AODV REQ_ANT frame format

The source node sends the REQ_ANT by setting the value of pheromone count as 0. During the propagation of REQ_ANT over the network, every intermediate node adds its pheromone count with the Pheromone _count value of the REQ_ANT. Upon reaching the destination node the packet's Pheromone_count field determines the level of connectivity of that route.

4.2.2. REP_ANT

RREP of AODV protocol is modified by appending an extra field named Pheromone_count. All the other fields are same as AODV RREP packet. The frame format of REP_ANT is shown in figure 4.

Source_address (32 bit)	Destination_address (32 bit)	Destination_sequenceno (32 bit)	Lifetime (32 bit)	HopCount (8 bit)	Pheromone_count (20 bit)

Figure 4: Enhanced-Ant-AODV REP_ANT frame format

The destination node updates the Pheromone_count of REP_ANT with the highest pheromone count value among multiple REQ_ANTs it received. Then it sends back REP_ANT through the path having highest Pheromone_count.

4.2.3. Routing table

In the proposed scheme four new fields have been added namely RSSM, CM, REM and Pheromone_count. Figure 5 shows the fields of routing table.

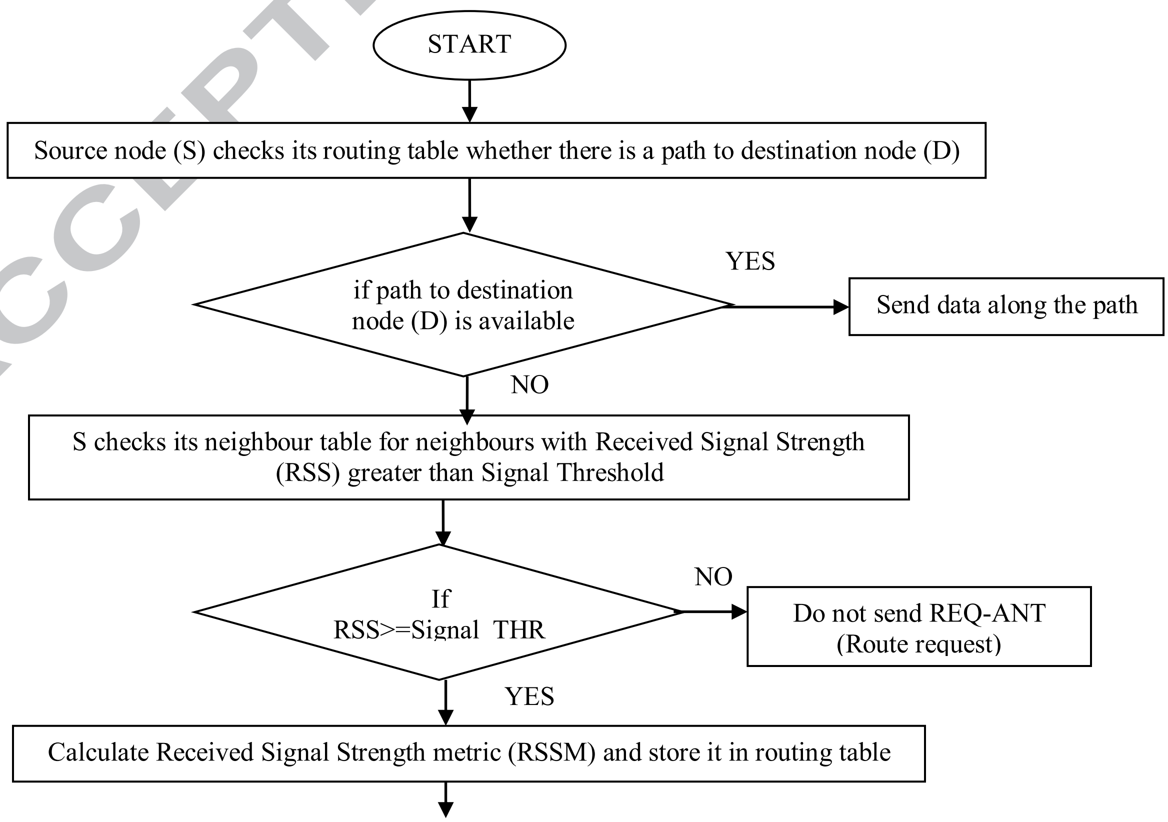
Destination_address (32 bit)	Sequence_No (32 bit)	HopCount (16 bit)	Next_Hop (32 bit)	RSSM (20 bit)	CM (20 bit)	REM (20 bit)	Pheromone_count (20 bit)

Figure 5: Enhanced-Ant-AODV routing table structure

RSSM stores the Received Signal Strength from the corresponding next hop node. CM field stores the Congestion Metric value of the node. REM stores the Residual Energy Metric value of a node. The Pheromone_count field stores the value of pheromone count of the path from source to the current node. Rest of the fields are same as AODV.

4.3. Work Flow Design

The flow chart of the proposed technique is shown in Figure 6.



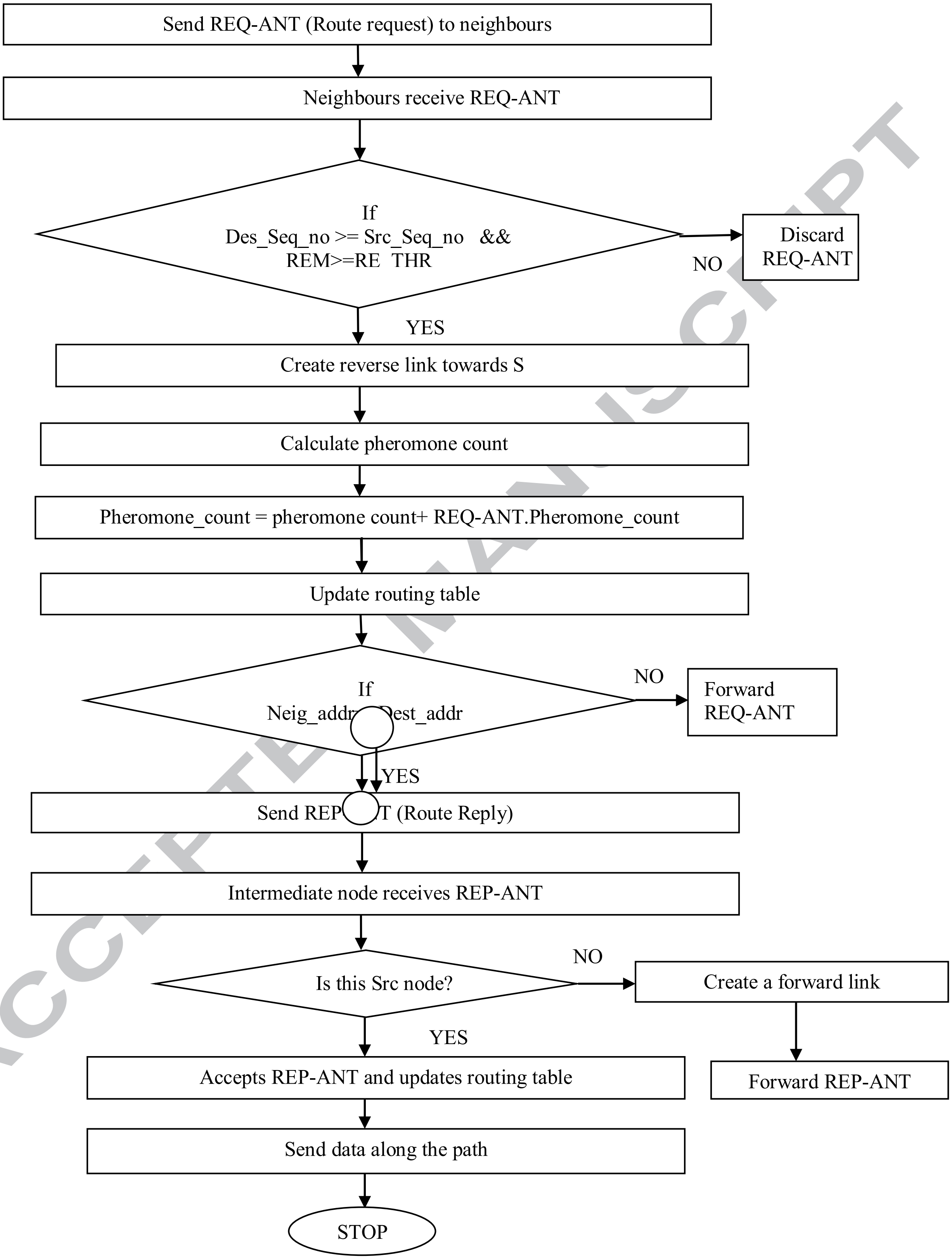


Figure 12: Flow chart of Enhanced-Ant-AODV.

4.4. Routing process

The algorithm has six parts namely: route request initialization process, route request forwarding process, route request receive process, route reply sending process, route reply forwarding process and route reply receiving process.

When the source node wants to send data to the destination, it checks whether there is a path from source to destination. If there is a path, data is sent through the path. Otherwise, route discovery process will be initialized. In this process, the source node checks whether its neighbor nodes are having received signal strength greater than or equal to SIGNAL_THR. If yes, neighbor nodes' RSSM value will be calculated. Routing table entry of the neighbors will be created. Calculated RSSM value is stored in the RSSM field corresponding to the entries of neighbor nodes. The Pheromone_count field corresponding to those entries is set to 0. The REQ_ANT message will be sent to the neighboring nodes setting Pheromone_count to 0. The algorithm for route request initialization process is shown in figure 7.

```
At source node :
    data_send (s,d)                    //  s is the source node ,  d is the destination node
    {                                  // 'rt' is an entry in routing table for destination node d.
    if (rt != 0)                       //  rt = 0 indicates no entry for destination d in  routing table.
     send data to d ;
    else
    send_REQ_ANT (d) ;
     }
/* source sends REQ_ANT */
  send_REQ_ANT (d)
        {
            if (nb_RSSix>= SIGNAL_THR)        //nb_RSSix : Received Signal strength from neighbor node
                                                stored in every nodes neighbor table.
                {
                  calculate RSSMi ;
                  updater_table ;              //  'r_table' is the routing table.
                  broadcast (p) ;              //s broadcasts REQ_ANT packet 'p' to find route to d.
                }
        }
```

Figure 7: Route request initialization process.

When the neighbor node receives REQ_ANT, it checks whether it is the destination node. If it is not the destination, it checks whether its residual energy is less than RE_THR. If yes, REQ_ANT will be discarded. Else, an entry of REQ_ANT's originator node will be created in the routing table. The content of Hop_Count field carried by the REQ_ANT will be incremented by 1. It is stored in hop count field corresponding to that routing table entry. Then it calculates the pheromone count value using the values of received signal strength, congestion metric, residual energy metric and hop count. The calculated pheromone count is added with the value carried by the Pheromone _count (rq_phcount) field of REQ_ANT. The result is the stored in Pheromone_count (rt_phcount) field corresponding to the entry of originator node in the routing table. The result is also stored in Pheromone _count field of REQ_ANT. Then the node rebroadcasts REQ_ANT. The algorithm for route request forwarding process is shown in figure 8.

```
At intermediate node :                  /* intermediate node receives REQ_ANT */
receive_REQ_ANT (packet p)
{
        if (p.rq_dst != this_address)     // check whether the node is the destination (p.rq_dst) node or not.
        {                                 // 'this_address' is the address of the current node.
                if (REM <= RE_THR)
                        discard REQ_ANT;
                else
                {
                        receive REQ_ANT;
                        create a reverse link to the source of REQ_ANT;
                        hopcount = p.hopcount +1;
                        calculate pheromone_count;
                        update pheromone_count;        //  rt_phcount= rq_phcount + pheromone_count
                        update r_table;
                        send_REQ_ANT (d);
                }
        }
}
```

Figure 8: Algorithm for route request forwarding process.

If receiver node of REQ_ANT is the destination, it creates an entry of REQ_ANT's originator in the routing table. It calculates the pheromone count and adds it with the content of Pheromone_count field of received REQ_ANT. Then it stores the result in Pheromone_count field corresponding to that routing table entry. The algorithm for receiving route request process is shown in 9.

```
At destination node :                   /* destination node receives REQ_ANT */
dest_receive_REQ_ANT (packet p)
        {
        if (p.rq_dst = = this_address)
                {
                update pheromone_count;        //  rt_phcount= rq_phcount + pheromone_count
                update r_table;
                }
        }
```

Figure 9: Algorithm for route request receive process.

After waiting for a certain time period, the destination node may receive multiple REQ_ANTs. It updates the pheromone_count field corresponding to the entry of source node in the routing table with the highest pheromone count value among multiple REQ_ANTs. Then it unicasts REP_ANT with Pheromone_count (rp_phcount) equal to highest pheromone count towards the source of REQ_ANT through the route which has highest pheromone count. The algorithm for route reply sending process is shown in 10.

```
At destination node :                   /* destination node sends REP_ANT */
    send_ REP_ANT (S)
    {
        if (p.rq_dst = = this_address)
        {
                rp_phcount = max(rq_phcount);          //  rp_phcount = max(rt_phcount)
                Send REP_ANT to the source node;
        }
    }
```

Figure 10: Algorithm for route reply sending process.

When REP_ANT is received by some node, it checks whether it is the destination. It not, it creates a routing table entry of REP_ANT's originator. It calculates the pheromone count and adds the calculated pheromone count with the content of Pheromone_count field of the REP_ANT. Then it stores the result in the Pheromone_count field corresponding to that routing table entry. It also stores the result in Pheromone_count field of REP_ANT. It forwards the REP_ANT to the next hop to reach the destination. The algorithm for route reply forwarding process is shown in figure 11.

```
At intermediate node :                    /* intermediate node sends REP_ANT */
 receive_REP_ANT (packet p)
 {
        if (this_address != p.rp_dest)     // checking whether receiving node is the destination of REP_ANT.
        {
                 create a forward link towards the destination node d by updating routing table;
                  p.hopcount = p.hopcount +1;
                  forward REP_ANT packet p;
          }
   }
```

Figure 11: Algorithm for route reply forwarding process.

When REP_ANT is received and it is the destination, it creates a routing table entry of the REP_ANT's originator. It updates the Pharomone_count field of that routing table entry. Then, the source can send the packet to the destination. The algorithm for route reply receiving process is shown in figure 12.

```
At source node :                          /* source receives REP_ANT */
 src_receive_REP_ANT (packet p)
             {
                if (this_address = = p.rp_dest)
                   {
                   receive REP_ANT packet p;
                   Send_data (s,d); //  send data along the path through which REP_ANT arrived.
                   }
             }
```

Figure 12: Algorithm for route reply receiving process.

An example scenario for routing and data transfer is shown in figure 13.

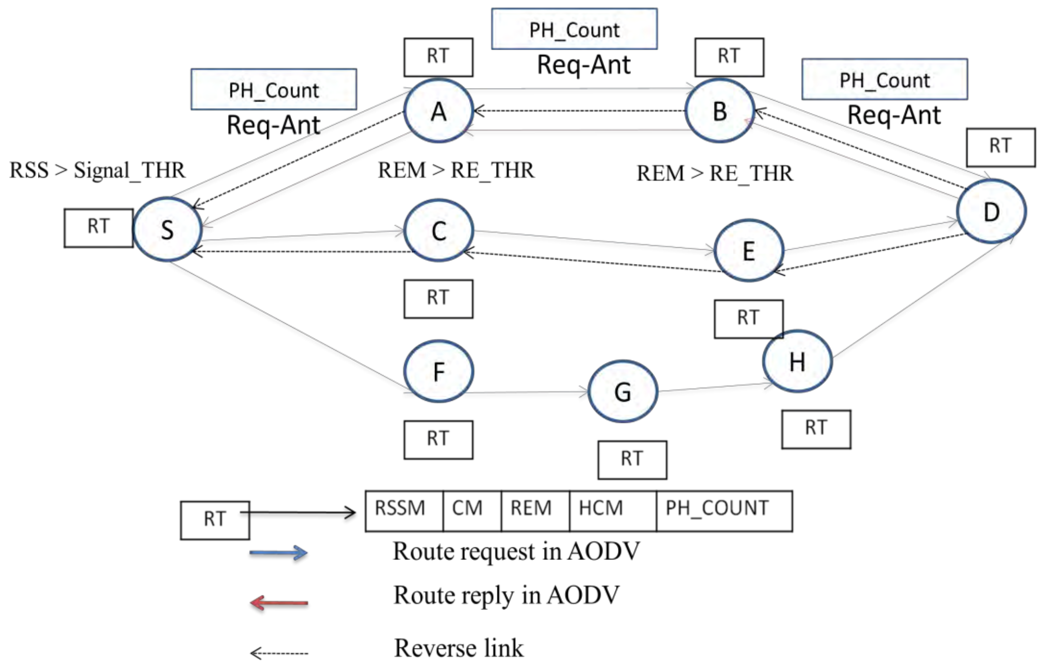


Figure13: Example scenario of route selection process of Enhanced-Ant-AODV.

Suppose, node S is the source and node D is the destination. Let node S wants to send data to destination D. Node S checks whether there is a path to the destination. Let there is no path to destination D. A, C, F are neighbours of S. Node S checks its neighbour table for the entries of node A, C and F and get their received signal strength (RSS_{ix}) values. It also gets their corresponding threshold values (Chatterjee and Das, 2015). Let, RSS of node A is 112dbM and its Signal_THR is 62. RSS of node C is 88dbM and its Signal_THR is 54. RSS of node F is 94dbM and its Signal_THR is 72. All these three neighbours satisfy the signal threshold value. Then S calculates corresponding RSSM and stores it in the routing table (RT). Pheromone count value (PH_COUNT) corresponding to the entries of node A, C and F in routing table of node S is initialized to 0. Node S now sends REQ-ANT packet to A, C, F. Node A, C, F after receiving REQ-ANT packet checks whether their residual energy is below a certain threshold. Let, residual energy of node F falls below threshold, so it will not further process the REQ-ANT. Node A and C satisfies the threshold and thus creates a reverse link towards S in its routing table. Node A will now calculate pheromone count value considering RSSM, CM, REM and HCM values corresponding to node S. Node C also does the same thing. Then they update the PH_COUNT corresponding to the entry of S by adding the calculated pheromone count with the content of Pheromone_count (PH_Count) field of REQ-ANT frame. Both node A and C rebroadcasts REQ-ANT after putting updated pheromone count in Pheromone_count field. Let, node B and E satisfy the threshold for residual energy. On receiving the REQ-ANT, node B and E create reverse link to nodes A and C respectively and update corresponding pheromone count. After updating the Pheromone_count field REQ-ANT will be rebroadcasted by B and E. On receiving the REQ-ANT destination D updates the pheromone count. Now there are two paths found (S-A-B-D) and (S-C-E-D) from source S to destination D. Let the path (S-A-B-D) is having the highest pheromone count among the two paths. Therefore, D sends back REP-ANT to node S through the path (D-B-A-S). A path is established between the source S and destination. Now S can use the path (S-A-B-D) to send data to D. Thus, the proposed scheme considers received signal strength, hop count, residual energy and congestion for selecting an optimal route from source to destination.

V. SIMULATION AND PERFORMANCE EVALUATION

5.1. Simulation Environment

In this section, performance evaluation of the proposed scheme in various simulation scenarios is portrayed. Simulations were performed in NS2.35, which provides support for a number of routing protocols for wireless networks. Network Simulator (NS) (Fall and Varadhan, 1999) is an object oriented simulator which consists of two languages, OTcl interpreter as frontend and C++ as backend. Comparison of the performance of the proposed protocol with well known protocols AODV, DSR and E-DSR (Chatterjee and Das, 2015) has been done. Simulation parameters are presented in Table 2. Throughput, packet delivery ratio, end to end delay and percentage of node survived are the metrics used to measure the performance of the protocols. Performance of the protocols has been evaluated by varying the parameters in namely, number of nodes, node speed and data rates in the network. Out of these three simulation parameters, any one is varied while keeping specifications of other parameters constant.

In the simulation, 100 nodes move around in a rectangular area according to random waypoint (RWP) mobility model (Navidi and Camp, 2004; Bettstetter et al., 2004). Initially, nodes are distributed randomly in the simulation area. Each node uses omnidirectional antenna having radio range of 250m. The nodes move at maximum speed of 10m/sec. The traffic sources start at random times from the beginning of the simulation and stay active throughout. The source generates CBR (constant bit rate) traffic. It generates UDP packets at the rate of 4 packets/sec. Each packet is of 512 bytes. In simulation, the pause time has set to zero in order to test the dynamic nature of the proposed protocol. Energy consumption is set to 1.6 W while transmitting (txPower), 1.2 W while receiving (rxPower) and 1.15 W when in idle state (Gupta and Das, 2002; Zheng et al., 2017). According to RWP model, to generate random motion movement, a tool called setdest has been used and another tool called cbrgen is used to generate a random data communication scene. RWP is implemented in the simulation tools NS2 (Issariyakul and Hossain, 2012) and GloMoSim (Kathirvel, 2011) and used in many evaluations of network algorithms and protocols. Performance analysis in the presence of mobility is of major importance in the design of computer networks and wireless communications. Since real movement patterns are difficult to obtain, that is why synthetic mobility models are used which resemble the behavior of real mobile entities to some extent. Based on such models, basic conclusions with respect to critical network parameters can be provided. Spatial distribution of network nodes moving according to RWP model is non uniform in general. In this stochastic model, each node of the network randomly selects a destination point and moves towards it in a rectangular deployment region. The speed with which each node moves towards the destination point is uniformly distributed between 0 m/s and the maximum speed limit. After the node arrives at the destination point, it remains stationary for the specified time period and reiterates the described procedure. RWP mobility model is used in this simulation because this model resembles with the movement pattern of the users moving with mobile phone which are forming the MANET (Pramanik et al., 2015; Rojas et al., 2005; 2005).

Table 2
Parameters used in simulation

Simulation parameter	Values /Type
Channel type	Channel/Wireless channel
Simulation area	1800m X 840m
Simulation time	200s (Zheng et al., 2017; Ghayvat et al., 2016; Xing et al., 2008; Nayak et al., 2012)
Mobility model	Random Waypoint
Propagation model	Propagation/Free Space
Agent type	UDP
Application type	CBR
MAC protocol	IEEE 802.11(IEEE Computer Society LAN MAN Standards Committee, 1997)
Initial energy	100J (Chatterjee and Das, 2015; Nayak et al., 2012; Uddin et al., 2017; Zhou et al., 2016)

5.2. Performance Metrics

While analyzing the protocols, four performance metrics have been considered:

i. Throughput: Throughput means the average amount of data (bits) received by the destination nodes per unit time within the network. In this paper, it has been expressed in kilobits per second (Kbps) (Uddin et al., 2017). Mathematically, it can be defined as,

$$\text{Throughput} = \frac{\text{No. of bytes received} * 8}{\text{Simulation time} \times 1024}\ \text{Kbps} \tag{8}$$

ii. Packet Delivery Ratio: Packet delivery ratio is the ratio of the total number of data packets received by destination nodes to the total number of data packets generated or sent by source nodes in the network (Uddin et al., 2017). Mathematically, it can be defined as,

$$Packet\ Delivery\ Ratio = \frac{\text{No.of received packets}}{\text{No.of sent packets}} \quad (9)$$

iii. Average end to end delay: Average end to end delay defines the average time (in milliseconds) that is required to travel from source nodes to destination nodes by all the data packets in the network (Uddin et al., 2017).

$$Average\ End\ to\ End\ delay = \frac{1}{N}\sum_{n=1}^{N}(R_n - S_n) \quad (10)$$

Where, S_n= Time at which n^{th} data packet is sent

R_n= Time at which n^{th} data packet is received

N = Number of data packets

iv. Percentage of node survived: Percentage of node survived is measured as the percentage of nodes that have survived out of total number of nodes when the simulation ends.

$$Percentage\ of\ node\ survived = \frac{\text{No.of nodes survived}}{\text{Total no.of nodes}} * 100 \quad (11)$$

5.3. Results and Discussion

In this section a comparative performance analysis is carried out among the proposed Enhanced-Ant-AODV, Enhanced-Ant-DSR, AODV and DSR. The performance is compared in terms of throughput, data packet delivery ratio, end to end delay and percentage of node survived for varying number of nodes, node speeds and data rates.

5.3.1. Effect of node number

Figure 14, 15, 16 and 17 show the effect of varying node number on throughput, packet delivery ratio, average end to end delay and percentage of node survived respectively. In all these cases, node number is varied from 10 to 100 such as 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100. Node speed is taken as 10 m/s and data rate is taken as 16 kbps. Maximum number of CBR traffic connection is taken as 10.

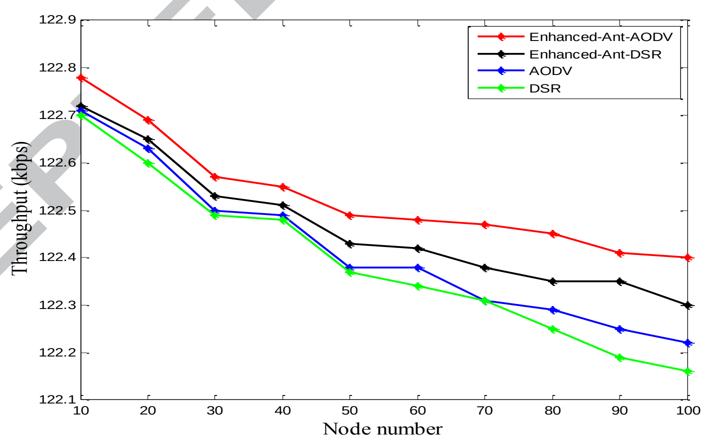


Figure 14: Effect of Node number on Throughput.

Figure 14 shows higher throughput of Enhanced-Ant-AODV compared to Enhanced-Ant-DSR, AODV and DSR for varying number of nodes. The reason behind this is, in Enhanced-Ant-AODV stable paths are selected considering nodes having less congestion, higher residual energy, higher received signal strength from the next hop. Therefore, there will be less number of path breakages and more packets will be delivered per second. As the number of nodes increases more route management packets will be transmitted causing more congestion in the network. So, throughput of all the schemes decreases with increase in number of nodes. But, the throughput of Enhanced-Ant-AODV remains higher because of optimal path selection.

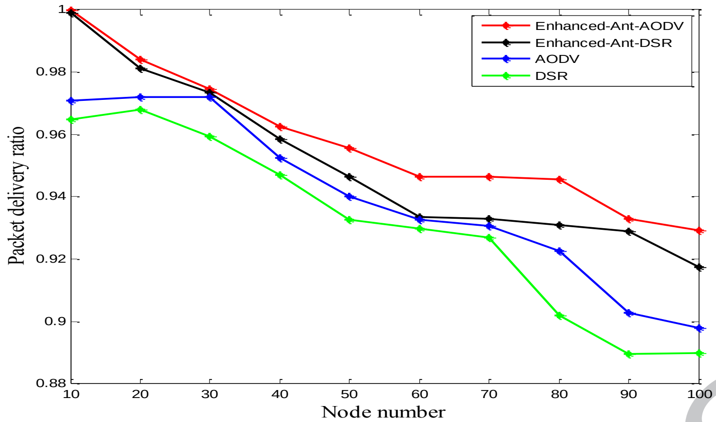


Figure 15: Effect of Node number on Packet Delivery Ratio.

Figure 15 shows better packet delivery ratio of Enhanced-Ant-AODV when compared with Enhanced-ant-DSR, AODV and DSR. For packet delivery ratio to be high it is necessary that packet drops during transmission is less. When path breaks in the middle of the transmission, packets are buffered in the queues of the nodes for a long time. The queues become full and packets are dropped. This leads to lower the performance of the protocol. In Enhanced-Ant-AODV the link breakage is less and hence the packet drop is less.

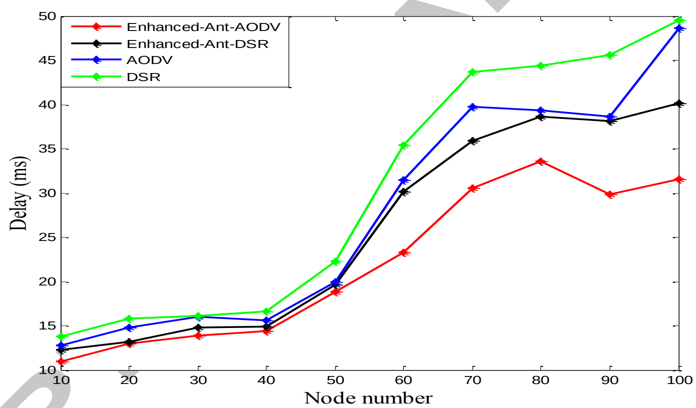


Figure 16: Effect of Node number on Average end to end delay.

Figure 16 shows that the end to end delay of Enhanced-Ant-AODV is less as compared to other protocols. As the number of nodes increases end to end delay increases in case of all the protocols. But delay in Enhanced-Ant-AODV reduces after a certain point and thus outperforms Enhanced-Ant-DSR, AODV and DSR. As in Enhanced-Ant-AODV congestion, residual energy, received signal strength and hop count is considered while selecting a path from source to destination, path breakage in large network is less. When there is less route breakage, data need not to be queued in the buffer for long intervals. This decreases the queuing delay and hence finally decreases the average end to end delay.

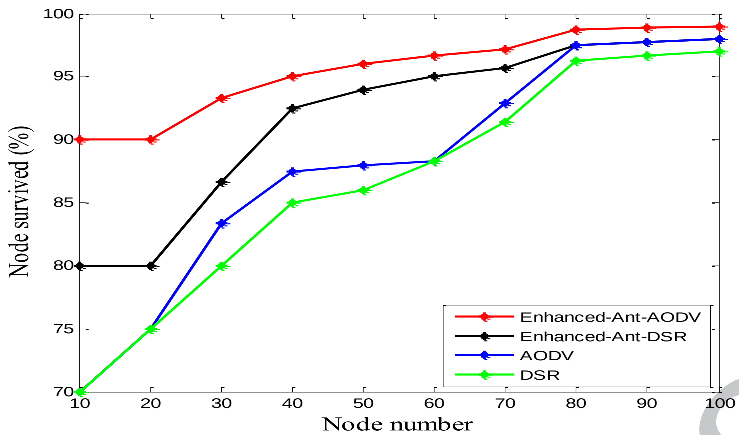


Figure 17: Effect of Node number on Percentage of node survived.

Figure 17 shows that in case of all the protocols, percentage of node survived at the end of simulation increases as number of node increases. Even if node number increases only selected nodes are taking part in communication as there are maximum 10 connections between source and destination. Thus, most of nodes are alive in case of large network. Among all, Enhanced-Ant-AODV shows better performance compared to other protocols because residual energy of the nodes is considered while selecting the path from source to destination. Very few percentages of nodes have died at the end of simulation in case of Enhanced-Ant-AODV.

5.3.2. Effect of node speed

Figure 18, 19, 20 and 21 show the effect of varying node speed on throughput, packet delivery ratio, average end to end delay and percentage of node survived respectively. In these cases node speed is varied from 5 m/s to 50 m/s such as 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50. Node number is taken as 20 and data rate is taken as 16 kbps. Maximum number of CBR traffic connection is taken as 10.

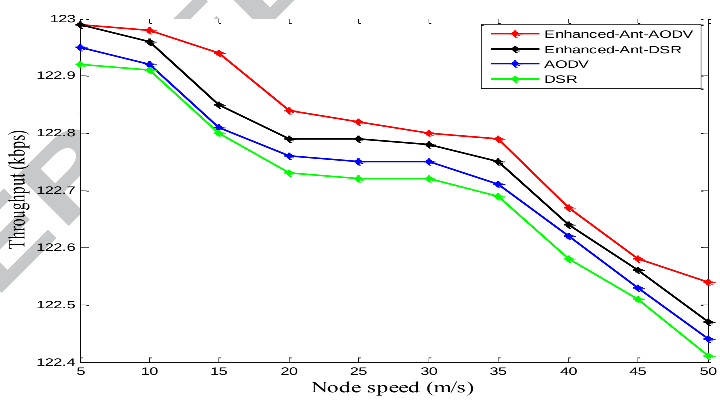


Figure 18: Effect of Node speed on Throughput.

Figure 18 shows that with the increase in node speed the throughput of all the schemes decreases but the proposed scheme performs better than others. Due to increase in node speed, node movement becomes faster that results in loss of connectivity and degradation in the throughput. As Enhanced-Ant-AODV selects stable paths by considering residual energy, received signal strength and congestion of the intermediate nodes, link breaks are less in Enhanced-Ant-AODV. So buffering of packets is less and hence the packets delivered per second are more in case of highly mobile scenario.

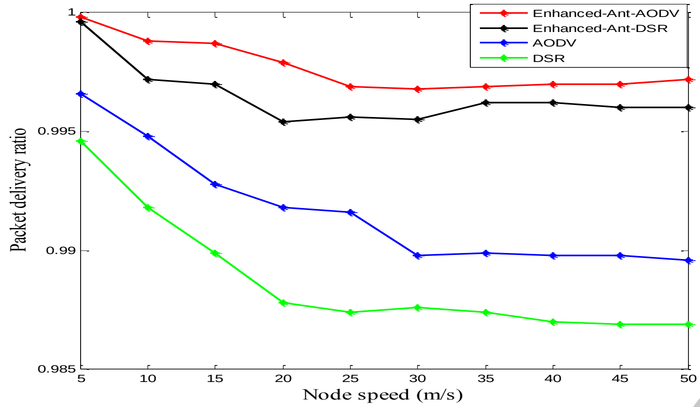


Figure 19: Effect of Node speed on Packet Delivery Ratio.

Figure 19 shows that packet delivery ratio in case of all the protocols decreases with increasing node speed. As node speed increases more route breakages will occur because of frequent node movement. This causes dropping of more packets. Since the proposed scheme considers received signal strength as one of the factors for route selection, the selected route will not break till the node moves far away from its previous position. Therefore, the route will not break frequently and packet delivery ratio remains higher compared to other protocols as node speed increases

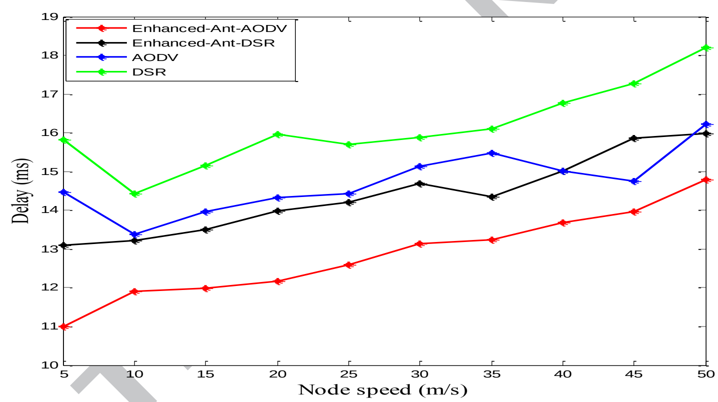


Figure 20: Effect of Node speed on Average end to end delay.

Figure 20 shows that with the increasing node speed end to end delay also increases in cases of all the protocols. Due to increase in node speed routes will break frequently causing longer waiting time of the packets in the queue. In the proposed scheme, stable route are selected. So, route breakages will be less and the scheme performs better than the other protocols as the node speed increases.

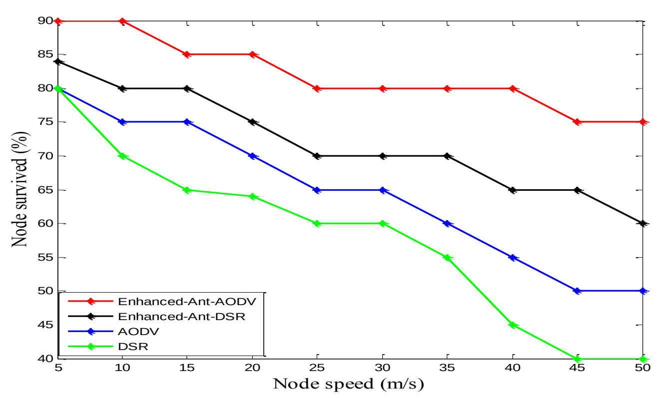


Figure 21: Effect of Node speed on Percentage of node survived.

Figure 21 shows that as the node speed increases, percentage of nodes survived after simulation time decreases in case of all the protocols. Routes will break frequently because of node movement. This results in more message transmission for route setup. More message transmission causes higher loss of residual energy. Therefore, the battery of the nodes will be exhausted and lesser number of nodes will survive as node speed increases. In proposed scheme since residual energy is considered as one of the factors for optimal route selection, more percentage of nodes survive at the end of simulation compared to other schemes.

5.3.3. Effect of data rate

Figure 22, 23, 24 and 25 show the effect of varying data rate on throughput, packet delivery ratio, average end to end delay and percentage of node survived respectively. In these cases data rate is varied from 4 Kbps to 2048 Kbps such as 4, 8, 16, 32, 64, 128, 256, 512, 1024 and 2048. Node number is taken as 20 and node speed is taken as 10 m/s. Maximum number of CBR traffic connection is taken as 10.

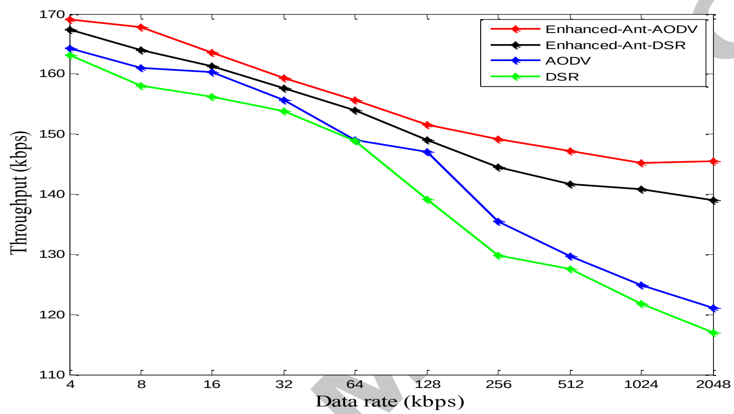


Figure 22: Effect of Data rate on Throughput.

Figure 22 shows that with the increasing data rate the throughput of all the scheme decreases. This is because of congestion caused by higher data rate. In proposed Enhanced-Ant-AODV scheme, congestion is considered as one of the factors for selecting the intermediate nodes. Therefore, with increase in data rate throughput of the proposed scheme decreases but does not decrease much.

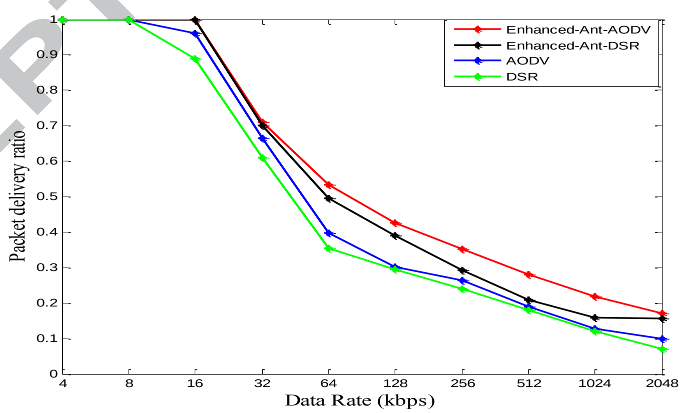


Figure 23: Effect of Data rate on Packet Delivery ratio.

Figure 23 shows that with increasing data rates the packet delivery ratio decreases for all the protocols. In Enhanced-Ant-AODV congestion has been considered as one of the factors for route selection. Therefore, the proposed scheme selects less congested path and packet delivery ratio remains better compared to the other schemes as data rate increases.

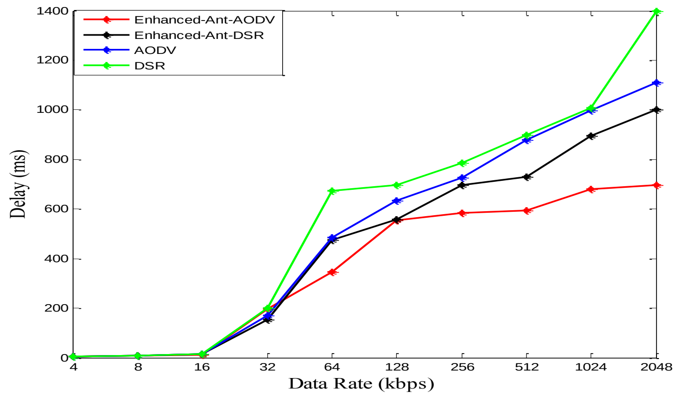


Figure 24: Effect of Data rate on Average end to end delay.

Figure 24 shows that end-to-end delay increases after certain point in case of all the protocols with the increase in data rate. This is because of congestion. Since the proposed scheme considers congestion for counting the pheromone count, it's end-to-end delay remains less compared to other schemes as data rate increases.

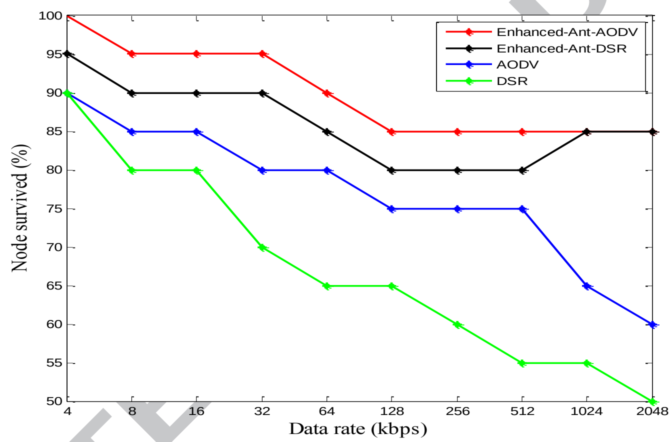


Figure 25: Effect of Data rate on Percentage of node survived.

Figure 25 shows that, as the data rate increases percentage of node survived after simulation time decreases. Congestion increases as data rate increase. This causes retransmission of packets and increase in battery power consumption of the nodes. So, lesser number of nodes survives after simulation time. In the proposed scheme since residual energy is considered as one of the factors for route selection, the scheme performs better than the other schemes as data rate increase.

VI. CONCLUSSION AND FUTURE WORK

In this paper, a routing scheme named Enhanced-Ant-AODV has been proposed for MANET. The performance of the proposed scheme along with three other reactive protocols AODV, DSR and Enhanced-Ant-DSR has been evaluated. From the simulation results, it can be said that Enhanced-Ant-AODV provides better results compared to Enhanced-Ant-DSR, AODV and DSR in terms of packet delivery ratio, throughput, average end to end delay and percentage of node survived.

The performance analysis of the proposed scheme with respect to packet loss ratio, energy consumption and jitter remains as future work. Performance comparison of Enhanced-Ant-AODV with ANT/AODV (Abdel-Moniem et al., 2010), Ant-DSR (Aissani et al., 2007) and Ant/Dymo (Martins et al., 2010) can also been done in future. Moreover, available bandwidth of the links can also be used as one of the path selection parameters to ensure bandwidth availability in advance. The protocol should also consider the sub-optimal path for exploiting new routes if route error occurs. The proposed technique can be applied in Vehicular Ad-hoc Networks (VANET) (Al-Sultan et al., 2014). Node positions are known in VANET since it is a GPS based network. So, link reliability can be measured considering distance rather than received signal strength. This will cut down the computation burden of nodes.

Acknowledgement

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