Performance Enhancement of Routing Protocol in MANET by implementing Ant Colony Optimization

Himanshu Sharma

Abstract—**Mobile Ad hoc network (MANET) is dynamic in nature. In MANET routing becomes challenging for certain Quality of services (QoS). In this paper an enhanced version of Dynamic source routing protocol (DSR) is proposed that is based on Ant colony optimization (ACO) algorithm. The proposed algorithm result shows high data packet delivery ratio, low end to end delay, low energy consumption and low routing overhead. The proposed algorithm calculated the best route according to the congestion, number of nodes and end to end path reliability of the route. To deliver a data packet the route with the highest pheromone count will be selected. For route maintenance in the network a pheromone decay technique is also introduced in this algorithm. Simulated results illustrates that this Improved-Ant-DSR(IAnt-DSR) performs better than the other ACO based routing protocol and DSR routing protocol.**

Index Terms—**Mobile Ad hoc Network (MANET), Ant colony optimization (ACO), Quality of Service (QoS), Request Ant packet (Req.Ant), Reply Ant packet (Rep. Ant).**

I. Introduction

MANET is growing in popularity day by day as it provides reliable wireless networking to the mobile devices. It is an infrastructure less network. In MANET nodes need to create a network and to cluster together that can support several services like file sharing, resource sharing and messaging. The primary goal of MANET is to efficiently and quickly establish unicast or multicast reliable end-to-end route between the nodes so as to support for reliable connection establishment. The routing algorithm should provide less energy consumption because battery power of a node is limited.

Routing in MANET faces various challenges [1]. MANET is dynamic in nature so network topology changes very rapidly. There should be a reliable protocol for routing. There are limited solution available which can select the best route based on different parameters as congestion, load and route length. Asingle node cannot work as a centralized manager becauseevery node have limited processing capabilities and limitedenergy. So, the challenging issue in MANET is routing.

The DSR [2] routing protocol has certain drawbacks: high end to end packet delivery, it consumes more energy, low data packet delivery ratio due to frequent link breakage and high routing overhead due to insufficient route discovery mechanism. The proposed algorithm improved DSR protocol by proposing a route maintenance and route discovery approach.

ACO algorithm was developed by [3] to search an optimal route in the network. This algorithm was based on harvesting ant seeking route for a source of food. As shown in Fig.(1), Ants communicates and exchange information with each other by pheromone value. In search of food ants go in random directions from their nest. On the path back to the nest, Ant deposit pheromone on their trajectories to acknowledge their fellow ant for food and thus augmenting the pheromone on their path. In this process there are a number of paths from source node to destination node.

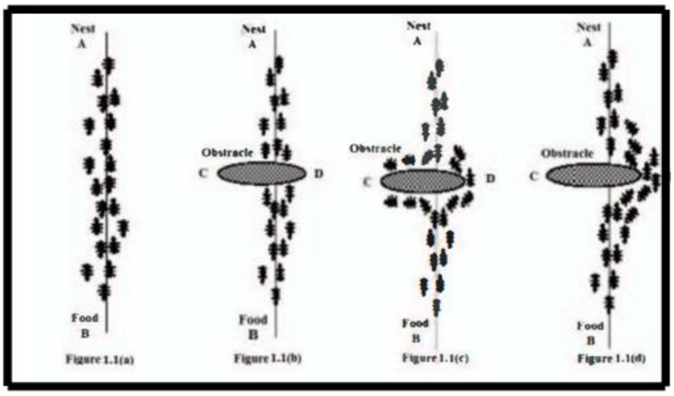

Fig. 1 Ant's Behavior [24]

The important factor of this process is less end to end travel time with shortest path. But if a path is broken than alternate shortest path with highest pheromone count will become the next option. After some time, pheromone slowly evaporates. It helps ants to adapt changes in the environment. In DSR protocol, the concept of ACO algorithm is to maintain and discover the best path among the nodes. It can provide effective routing. It update the routing table periodically.

This paper proposed an innovative Ant Colony optimization based routing algorithm (IAnt-DSR) which considers the route discovery, route selection, reliability of a link, pheromone decay approach for route maintenance. The proposed scheme is quite effective in comparison to the various other schemes with respect to the selected parameters in NS2 environment.

The next section provides an overview of the related works in detail. Section 3 covers proposed approach in adequate details.

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Section 4 covers simulated results and its discussions. Section 5 concludes all the discussions made earlier.

II. Related work

Several MANET routing algorithms are developed in recent years [4]. Routing protocols are of three types proactive, reactive and hybrid protocols. In proactive routing protocol all nodes maintain a routing table which stores the route information from other nodes. The problem with this protocol is low end to end delay, maintenance and control packets increase the routing overhead (increase the load and congestion in network). In reactive routing protocol the routes are established on demand. This scheme do not store any routing table. By this approach the routing overhead decreases but it also increases end to end delay of data packet delivery. In hybrid routing protocols the advantages of both proactive and reactive protocols are combined. In this protocol, the network is divided into different group of nodes (zones) i.e. Intra-zone routing (proactive) and inter-zone routing (reactive), but in these zones the energy consumption of each node is very high.

In ANT-AODV [5], [6] ACO is utilized to continuously make routes between nodes without any demand i.e. proactively and AODV is utilized to find routes on demand i.e. reactively. The proactive routing approach lessens the end-to-end delay for data packet delivery. However, as other proactive approaches, Ant/AODV also suffers in high routing overhead which stimulates congestion in the system. This routing overhead issue additionally happens in Ant-DSR proactive routing approach [3]. In Ant-DSR, three ant agents are utilized: broadcast ant agent, unicast ant agent, and hello ant agent. Hello ant agents are utilized to distinguish the neighbors in the beginning. Unicast ant agents proactively discover the routes and stores in the cache. Broadcast ant agents are used to identify the present neighbors. The reliability of a route is measured by Euclidian distance i.e. number of hopes.

In Ant/Dymo, three distinctive control packets are utilized EANT (Exploring Ant), RREP and RREQ [7]. EANTs are utilized to proactively search for the routes and the relating Pheromone table. When a node wants to send a packet, it checks the proactive routing table. When no routes are known, it sends the RREQ message to find the route. This RREQ propagates through the network and estimate the pheromone level of the route. On getting this RREQ, the destination node sends back RREP to the source node. The proactive route discovery by EANT messages, significantly builds the routing overhead and the energy consumption of the individual nodes. It cannot guarantee end to end path reliability because of intermediate disconnection in a high mobility situation. Pheromone count scheme was applied to select the best route.

In AntHocNet, the G Di Caro, F Ducatelle and L M Gambardellaapplied reactive forward ant and backward ant for route discovery and once the data session is begun proactive forward ant is then utilized to measure the nature of the path being used and to investigate new paths [8]. Along with these control packets, a "Hello" message is broadcasted at periodically to identify the broken connections. This plan suffers in high routing overhead. Additionally intermediate link breakage will restrict the data packet delivery.

An intelligent algorithm is proposed by G.S. Abkenar, A. Dana and M. Shokouhifar [9], in which two distinctive ant routing protocols (ARA) [10], and ARAMA [11] utilized four unique situations. An alternate approach had been taken in HOP NET [12] and ADZRP [13] where ACO driven zone based hybrid routing protocols are proposed. In this technique, they proactively keep up the intra-zone routing table and apply ACO for Inter-zone reactive routing. Like ZRP, these routing schemes results in a high energy consumption. Among Reactive, Proactive or Hybrid, none of these routing algorithms could produce high data packet delivery as they don't take a specific measure to avoid congestion or intermediate link breakage which is extremely regular incidence in a dynamic condition like MANET [14].

Another approach Enhanced multi-path dynamic source routing algorithm (EMP-DSR) was discovered by E.K. Asl, M. Damanafshan, M. Abbaspour, M. Noorhosseini and K. Shekoufandeh in which few routing schemes was considered for link reliability as an earlier component for route selection. [15]. Authors have proposed an enhanced multi-path dynamic source routing algorithm (EMP-DSR) which is an upgraded version of MP-DSR. In EMP-DSR, the path is chosen in view of two parameters: link reliability and the time required by forward ant to find the route. In any case, aside from path reliability and delay, congestion in a route assumes an important part for packet delivery. The reliable routes gets congested and because of high congestion the data packet delivery got effected. Due to high congestion, a node may get dropped because of broken and invalid route. Thus, the congestion avoidance routing protocol [16], suffers in low data packet delivery due to intermediate link breakage in the current routes. These congestion avoidance routing schemes attempt to quantize the congestion of the individual nodes. Therefore, the route of lowest congestion and smallest length is chosen.

In another technique [17], authors proposed an energy aware ARAMA algorithms whereas in [18] an energy aware ZRP protocol has been exhibited. The battery energy of the intermediate nodes of a route is also considered by the authors [9], [19] as earlier component for route selection. Also, these energy-aware techniques do not consider congestion/link reliability as an element for route selection and therefore suffers in low data packet delivery.

S. Surendran and S. Prakash [20]proposed a QoS constrained fault tolerant ant look ahead routing algorithm which attempts to identify valid route and look-ahead route pairs which might help in choosing the alternate path in case of valid route failure.

In [21] the authors proposed an ant colony algorithm based on smell factor, SUMACO, for delay-constraint multicast routing applications. Simulation results verify the speed of proposed algorithm to find the final tree of multicast routing.

S. Rathore and M. R. Khan[22] proposed an ACO algorithm to improve the load balancing by providing the required queue size to each node in network. Due to that the processing capability of nodes are also utilized for maximum data forwarding to next neighbor and receiving from neighbor or sender.

In [23] the authors analyzed an AntHocNet and Ant Colony Optimization Routing (ACOR) algorithm. In this paper some steps in the designing of the ant based routing protocol for ad hoc networks are presented. The routing protocol is based on the Anthocnet routing protocol.

Therefore there is a need to develop a routing protocol that can satisfy all the fundamental quality of service requirements such as low energy consumption, low routing overhead, low end to end delay, and high data packet delivery ratio.

This paper shows an improved dynamic source routing protocol that overcomes the short comings of previous techniques.Table I shows the comparison of different routing protocols:

Table I(Comparison of routing protocols)

Protocol	DSR	ANT-AODV	ANT-DSR	ADZRP	IAnt-DSR
Routing type	Reactive	Reactive	Proactive	Hybrid	Multipath Reactive
Types of ANT	None	Forward ANT	Forward and backward ANT	Internal and Explora-tory	Forward ANT and Backward ANT with maintenance
Route repository	Route cache	Pheromon-e Count	Pheromon-e Count	Intra RT	Pheromone count
Path type	Multiple	Multipath	Broadcast	Multica-st	Broadcast

III. THE IMPROVED-ANT-DSR ALGORITHM

A. Proposed algorithm

Improved-Ant-DSR algorithm for MANET, is a self-arranging multi-path reactive routing protocol. This section deals with the proposed algorithm in which the packet format of two control packets i.e. Req.Ant and Rep. Ant and the techniques for measuring the congestion and the reliability of a link describes in detail. Finally the related route discovery, route selection and route maintenance strategies are discuss in detail.

B. Packet format of Req.Ant and Rep.Ant control packet

The two control packets Req.Ant and Rep.Ant execute dissimilar functions nevertheless they share a common data structure as illustrates below.

<table>
<tr><td colspan="4">Source node address</td></tr>
<tr><td colspan="4">Destination node address</td></tr>
<tr><td>Hops</td><td>Congestion Metric</td><td>Link Metric</td><td>Type</td></tr>
<tr><td colspan="4">Stack of node visited
Node 1
Node 2
.
.
.
Node j</td></tr>
</table>

The Hops field indicates the number of hops required in a route i.e. the length of the route. When the sender node propagates the Req.Ant packet sets this field as zero. As the packet sends through the network, each intermediate node increases this Hops field by one. The Congestion Metric field stores the congestion metric value of the route and the Link Metric field stores the connectivity level of the intermediate links of the route. The Type field shows the category of Ant (for Req.Ant Type= 1 and for Rep.Ant Type = 0). Stack of node field stores the addresses of all the intermediate nodes as the Req.Ant propagates through the network.

C. Measurement of the congestion level

In [20] the congestion level of a route was calculated, where each node calculates a Node Congestion Metric relying on packet drop rate, channel load value and buffer occupancy. The nonlinear node congestion metric (NNCM) is developed as,

$$NNCM = \{1 - (1 - LNCM^2)\} \quad (1)$$

Where NNCM represents the Nonlinear node congestion metric and LNCM represents the linear node congestion metric. Each Req.Ant packet has its own Congestion Metric (CM) field. When the packet transmits through the system then at each intermediate node it multiplies its congestion metric value with the individual NNCM value. As it reaches the destination, the CM field of the packet indicates the total congestion level of the route.

$$\text{Congestion metric value} = [1 \times \text{NNCM1} \times \text{NNCM2} \times \text{NNCM3} \times \ldots\ldots\ldots.NNCM_n] \quad (2)$$

WhereNNCM_n represents the Node Congestion Metric value of the n-th node.

D. Measurement of the connectivity level of a route

The proposed approach predicts the link breakage before it happens. To envisage the connection breakage, we set the value of RSSM (Received Signal Strength Metric), for each connection between the nodes based on their Received Signal Strength that shows the possibility of connection breakage, i.e. the connectivity level of the link. Here, during connection setup, each node antenna transmits an ECHO packet. The structure of the ECHO packet illustrates as follows:

Source Address	Congestion Metric	Antenna Gain	Maximum Transmitting Power	Maximum Speed Limit

When a node gets an ECHO packet from different nodes, it stores the connection by the source address and the relating Antenna Gain, Maximum Transmitting Power of node antenna and Maximum speed limit of that node in its cache to determine the Received Signal Strength Metric (RSSM). It also stores the congestion level of the connection. The received signal strength RSS_{jd} of neighbor node j from a distance d can be expressed as,

$$RSSjd = \frac{G_{Rec} \times G_{Trans} \times P_t}{(4\times\pi\times d/\lambda)^2} \quad (3)$$

Where λ is the wavelength, G_{Rec} is the receiving antenna gain, G_{Trans} is the transmitting antenna gain and P_t is the maximum Transmitting power of antenna. This approach set a threshold value (Th_j) of the received signal strength of j^{th} neighbor node as,

$$Th_j = \frac{G_{Rec} \times G_{Trans} \times P_t}{(4\times\pi\times 0.9054R/\lambda)^2)} \quad (4)$$

Here R is the coverage range of the antenna. A receiving node recognizes its own coverage range (R), antenna gain (G_{Rec}), wavelength used in MANET (λ) and after the broadcasting step is finished, the transmitting antenna gain (G_{Trans}) and the maximum transmitting power P_t of neighbor node antennas. A node calculates Received Signal Strength Metric (RSSM) for each of its links as,

$$RSSMj = \begin{cases} 0, & if\ RSS_{jd} < Th_j \\ \left(1 - \frac{Th_j}{P_{jd}}\right), & if\ RSS_{jd} \geq Th_j \end{cases} \quad (5)$$

The link, whose RSSM is zero, is quickly removed from the cache. The link with nonzero RSSM is kept in the node cache with their relating RSSM value, as illustrated in Fig. 2. A node has two cache memories i.e. (i) RSSM cache that stores the connection and corresponding RSSM and NNCM value and (ii) Route cache that stores the route to various nodes in the network.

Link	Frequency (GHz)	Threshold Value	Received signal strength	RSSM	NNCM
1	2-2.6	63	115 dBm	0.447	0.35
2	1.3-2.2	55	92 dBm	0.382	0.54
3	1.7-2.1	62	101 dBm	0.283	0.47
4	2.4-3.1	73	97 dBm	0.236	0

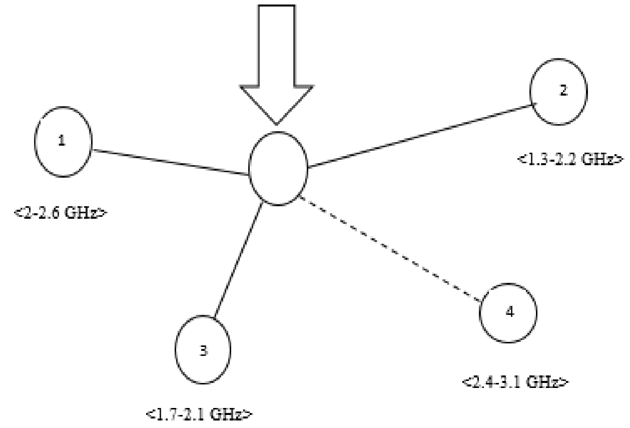

Fig. 2 (RSSM values during connection setup, threshold value for each link and the frequency range of the neighbor)

As the network configuration varies in every second, it is essential to update the RSSM value and NNCM value of the connections. In a network, a time interval β is defined as:

$$\beta = \frac{0.946 \times R}{S_{Host} + S_{Neighbor}} \quad (6)$$

Where R is the range of node reception antenna, S_{Host} is the maximum speed limit of the node, and $S_{Neighbor}$ is the maximum speed limit of the neighbor node.

To predict the link breakage, a specific threshold value (Th_j) is set for the received signal strength of a specific link. When a node gets an ECHO packet from its neighbor node of signal strength RSS_{jd}, which is more than or equivalent to this threshold level Th_j, then that connection is trustworthy. It will set the RSSM value for that connection as $(1 - \frac{Th_j}{RSS_{jd}})$. If the signal strength is less than the threshold level then that link might be broken quickly. For that link the RSSM value will be zero. As the node positions may change very rapidly, it is essential to update the RSSM value of the links, periodically, after every β time interval where $t \geq \beta$. If $t < \beta$, a reliable link may break inside this time interval β and the node being uninformed about this broken link, may attempt to utilize that link for packet sending.

Let the threshold value Th_j of the signal strength for a specific neighbor node is set as the signal strength received from that node antenna placed at a distance of $d * R$ (where d varies between 0 and 1) from the node. Thus, if that neighbor node is $d*R$ distance apart from the node and two of them begins to move far from each other in opposite direction with their maximum speed, S_{Host} and $S_{Neighbor}$, respectively, then they could maintain their link up to $\frac{(1-d)R}{S_{Host} + S_{Neighbor}}$ time i.e. the minimum value of t ($t_{Minimum}$) is $\frac{(1-d)R}{S_{Host} + S_{Neighbor}}$. Consequently the value of β is $\frac{(1-d)R}{S_{Host} + S_{Neighbor}}$. Within this time interval β, a node can depend on every one of the links whose RSSM value is more than zero. After this β time, ECHO packet is transmitted and reliability metrics (RSSM) are updated.

The antenna coverage area of range R can be measured as a circular area of radius R. The distance between two mobile nodes in a circular region of radius R is $0.9054R$ [25]. Here we set this distance as the threshold value. Thus, the threshold value of the signal strength is set as the signal strength received from a node antenna kept at a distance of $0.9054R$ from the node and corresponding time interval β is $\frac{0.0946R}{S_{Host} + S_{Neighbor}}$ time.

Consider the maximum speed limit of the nodes for determining the minimum value of time interval β. Speed used in ECHO packet may vary in every second. If the β is calculated based on that value, than it can give an error. So the β will be calculated by taking maximum speed limit of a node, to avoid this error. So, the RSSM value of the j-th link demonstrates the connectivity level of the link. It changes between 0 (less connectivity) and 1 (high connectivity). The RSSM of a link is constantly under 1 as a node cannot send the packet to itself (i.e.$RSS_{jd} = \infty$).

Every Req.Ant packet has its own Link Metric (LM) field. The sender node sends the Ant, setting this LM field as 1 (high connectivity). When the packet transmits through the network, each intermediate node multiplies its LM with the RSSM value of the link through which it came. Accordingly, when it reaches at the destination, the LM field of the packet demonstrates the network level of the route.

$$RSSM\ Value = 1 \times RSSM_1 \times RSSM_2 \times \dots RSSM_j \dots \times RSSM_k \quad (7)$$

Where $RSSM_j$ is the RSSM value of the j-th link and $RSSM_k$ is the RSSM value of the k-th link. In the earlier algorithm (AntHocNet [26], to acquire the data of the neighbor node, a control packet (Hello message) is periodically (at each t_{HELLO}) transmitted by the nodes. As a node receives Hello message from a neighbor, it includes that link in its cache. If it does not receives notification from an enlisted link for a specific time ($2 \times t_{HELLO}$) then it deletes that link from the cache. This method has two disadvantages: First, the time interval (t_{HELLO}) is picked randomly.

In the proposed approach, the time period β is selected in such a way that because of random movement of the nodes, there is no probability of breakage in a reliable link, within the time interval β. After each β time interval the RSSM values are updated. For efficient utilization of the cache, the links with zero RSSM value are excluded from the cache.

Secondly, no reliability measurement is taken for the intermediate link. In the proposed approach this disadvantage is overcome by measuring the reliability measurements of the intermediate links. The LM field in the Req.Ant demonstrates the reliability of that route. Therefore the sender can select the route after knowing the end to end reliability of that route.

Few authors proposed some reliability measurement techniques, where they probably envisage the node position based on its present location and velocity [27], [28] or utilize GPS (Global Positioning System) to find the nodes [29] and envisage the link reliability. But, GPS may not be accessible in MANET. There is a probability that this procedure may create an error in a high mobility situation. The proposed approach do not require any probability of expectation or GPS to quantize the reliability.

E. Route discovery

The route detection is taken in two different situations such as, when there are less number of nodes and when there are more number of nodes. For less number of nodes, most of the earlier techniques (DSR [2], Ant-DSR [27] apply blind flooding strategy where the sender node broadcasts the RREQ message and each node after receiving the RREQ message, rebroadcasts it to all available links irrespective of their reliability. But, if there are more number of nodes, then this method increases the end to end delay and the routing overhead to a significant amount and may prompt broadcast storm problem [30]. The proposed approach applied blind flooding scheme with reliability for less number of nodes. For more number of nodes, the intermediate link will forward the packet through the best link only. This approach firstly broadcast the Req.Ant packets and afterwards the nodes who get this packet will forward it through the best link, rather than rebroadcasting it. Therefore, this method can discover the efficient routes by consuming less amount of time, bandwidth and energy.

There are no specific measures being taken for infinite loop conflict and void region conflict. A common procedure is proposed for looping situation by setting a maximum node limit for the RREQ packet i.e. RREQ packets keep on traveling in the loop until the Hop Count field achieves its highest limit. Then the packet is dropped. But, this procedure unnecessarily possesses the accessible bandwidth and increases the load of the network. Likewise, to overcome void region conflict, certain reinforcement methods (e.g., face routing [31]) is proposed. Unfortunately, with current reinforcement methodology, packets frequently got in a loop and are dropped. The proposed approach effectively overcome these two clashes by intelligently diverting the path of the Req.Ant.

F. Route selection

Between the source and the destination node numerous routes are exist. Thus there is a need to trace the best route that depends on the length of the route (Hop Count), congestion along the route (CM) and the connectivity level between intermediate links (RSSM).

The source node determines the pheromone level of each route, as follows,

$$Pheromone\ count = \frac{LM}{Hop\ count * CM} \tag{8}$$

The sender node gets the route information from the Rep.Ant packet. With the help of Eq. (8) the pheromone level is determined and selects the route of the highest pheromone count to send the data packet through that route. Therefore good routes such as lower length, lower congestion and higher connectivity level have higher priority of being selected while other routes are still kept new. These additional routes are kept for emergency (if the best route gets overloaded or goes down due to a defective node).

First come first serve method is used to decrease the end to end delay. When another Rep.Ant is received, then it looks at the pheromone count between these two routes and the best one is chosen. This procedure proceeds until it gets the last Rep.Ant from that specific destination. Thus, the route selection is done.

The stack of node field of the Rep.Ant (i.e. the path) is attached with the data packet before sending the data packet. Data packet monitors the route as given in the stack of node field. An ACK (acknowledgement) message with least overhead is sent by the destination node when it gets a data packet, also it gives a guarantee that it has effectively received the data packet.

Another route from the cache will be selected if the sender node does not get any ACK message inside a fixed time interval ($\mathcal{T}$), where $\mathcal{T}$ is a small value (in ms).

G. Route Maintenance

In MANET, route maintenance plays a vital role. Due to dynamic changes in the network, the good routes may turn to be bad because of congestion or intermediate link breakage. In harvesting ant situation, the pheromone concentration illustrates the route efficiency. The pheromone level of unused routes slowly evaporates away. The proposed approach implement a pheromone decay method for each route as follows,

$$\wp = \wp * e^{\frac{t * S_{avg}}{N_{ack}}} \tag{9}$$

Where t is the time in seconds. After discovering the routes the time count starts, N_{ack} is the number of ACK received up to t sec, and S_{avg} is the Average of the maximum speed limit of the nodes in MANET.

Primarily (at $t = 0$),N_{ack} is set as 1 (considering Rep.Ant packet as an acknowledgment message). Currently, the sender node, for getting each ACK message from the destination node (i.e. effective data transmission), increases this N_{ack} by 1. Hence when a route is effectively utilized for sending the data packets, the pheromone value related with that route is increased. Then, the pheromone values for the unused or invalid routes are slowly reduced. When the pheromone value of a route reduces to a specific small value, say η (predefined), that route is quickly expelled from the route table.

The pheromone level of the routes will decrease more rapidly when the average maximum speed of the nodes is high. In a high mobility condition, a route cannot exist for a long time period. When a data packet transmitted through a broken route, then the data delivery will fail and increasing the routing overhead. Thus the memory occupancy of the nodes will increase due to these broken routes. Therefore, a pheromone level is defined that depends on the node portability which is more efficient than the past route maintenance methods.

H. Analysis of Energy consumption in IAnt-DSR

This section deals with the development of an expression for the energy consumption of the individual nodes. Firstly, the energy consumed during the route discovery process ($\tilde{E}_{RD}$) is found out. Afterwards, the energy consumed during data transmission ($\tilde{E}_{Data}$) is ascertained. Additionally, the energy consumed for ECHO message broadcast ($\tilde{E}_{Echo}$) is calculated. So, the aggregate energy can be given as,

$$\tilde{E}_{Total} = \tilde{E}_{Echo} + \tilde{E}_{RD} + \tilde{E}_{Data} \tag{10}$$

The average number of associated neighbor node can be given as [32],

$$T_{Avg} = \mu\pi R^2 - 1 \tag{11}$$

Here μ is the node density and R is the transmission range of antenna. Thus, the average number of associated node inside the threshold region i.e. within 0.9054R can be given as:

$$T_{RSSM} = \mu(0.9054R)^2 - 1 \quad (12)$$

Here T_{RSSM} is the number of links or neighbor node addresses stored in the RSSM cache of a node.

The node density in a rectangular area of $Q*R$ having absolute T_N number of nodes can be given as

$$\mu = \frac{N}{Q*R} \quad (13)$$

So, the energy related with the Req.Ant broadcasting procedure can be given as:

$$\tilde{E}_{Broadcast} = T_{RSSM} * S_{REQ} * U_T \quad (14)$$

Here S_{REQ} is the size of the Req.Ant packet and U_T is the energy required to transmit a bit.

In the worst scenario, no intermediate node determines the path to the destination. When there are more number of nodes, than each of these associated nodes of the sender node, will forward the packet to one of its neighbor nodes. This single node will forward the packet to another node. Thus the route discovery will continue as appeared in Fig. 3.

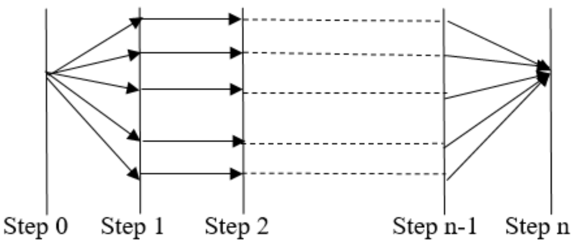

Fig. 3. Propagation of Req.Ant in more number of nodes

As illustrated from Fig. 3, there are $(n-1)*T_{RSSM}$ number of intermediate nodes for step = 0 to n. Now, for route selection, only a single link will be selected from the accessible links in each step. In a selected route for total ∂ number of hops, we can state that,

$$n = \partial \quad (15)$$

Thus, for total ∂ number of hops, total intermediate node is:

$$T_{INTERMEDIATE} = T_{RSSM}(\partial - 1) \quad (16)$$

In case of less number of nodes, each of these associated nodes of the sender node, will forward the packet to all links exists in the RSSM cache, except the link it has come through number of links ($T_{RSSM} - 1$). Each node will forward the packet to another ($T_{RSSM} - 1$) number of links, as illustrated in Fig. 4. From step = 0 to 1, there are T_{avg} number of intermediate nodes. From step = 0 to 2, there are $T_{avg} \times (T_{RSSM} - 1)$ number of intermediate nodes, as there is no overlapping because of less number of nodes, there is less chance that a node is in the threshold region of at least two or more number of neighbor nodes. Additionally, from step = 0 to 3, there are $T_{avg} \times (T_{RSSM} - 1)^2$ number of intermediate nodes. In this path, from Fig. 4, for step = 0 to n, there are $T_{avg} \times (T_{RSSM} - 1)^{(n-2)}$ number of nodes.

As shown from Fig. 4 and Eq. (15), in worst scenario (no overlapping) the total ∂ number of hops in the selected route for intermediate nodes is,

$$T_{Intermediate} = T_{RSSM} \times (T_{RSSM} - 1)^{(\partial-2)} \quad (17)$$

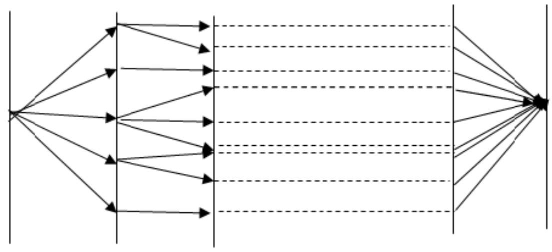

Fig.4 (Req.Ant propagation in less number of nodes)

During data packet forwarding in between source and destination, the average number of hops are as

$$\partial = \frac{\mathfrak{D}}{d_{avg}} \quad (18)$$

Here $\mathfrak{D}$ is the average distance between a sender node and a destination node and d_{avg} is the average distance covered in one hop. $\mathfrak{D}$ can be given in a rectangular area of G × H, as [25],

$$\mathfrak{D} = \frac{1}{15}\left[\frac{G^3}{H^2} + \frac{H^3}{G^2} + \sqrt{G^2 + H^2}\left(3 - \frac{G^2}{H^2} - \frac{H^2}{G^2}\right)\right] + \frac{1}{6}\left(\frac{H^2}{G}\sqrt{\frac{G^2+H^2}{H}} + \frac{G^2}{H}\sqrt{\frac{G^2+H^2}{G}}\right) \quad (19)$$

Average hop length d_{avg} for a transmission range R, is 0.9054R. Subsequently from Eq. (18), the average number of hop in a route will found out. From Eq. (16) and (17) the aggregate number of intermediate nodes for Req.Ant propagation between random source destination pair is also calculated. Presently, for each of the associated node of the sender node, the Req.Ant packet will propagate through $T_{Intermediate}$ number of nodes. Thus the energy consumption in Req.packet propagation can be specified as, energy consumed for receiving and sending the Req.Ant packet by $T_{Intermediate}$ number of nodes,

$$\tilde{E}_{Propagate} = T_{Intermediate} \times S_{REQ} \times (\tilde{E}_r + \tilde{E}_t) \quad (20)$$

Here $\tilde{E}_r$ is the energy consumed to receive one bit. At receiving end, the receiver node gets the packet from its neighbor and response back through each of them. Thus, energy consumed at receiver node is,

$$\tilde{E}_{Receiver} = T_{RSSM} \times S_{REQ} \times \tilde{E}_r \quad (21)$$

The receiver replied by the Reply Ant to its neighbors and the Reply Ant transmits through the intermediate node, till it reaches to the sender node. Therefore, the energy consumed in Rep.Ant is,

$$\tilde{E}_{Reply} = T_{RSSM} \times S_{REP} \times \tilde{E}_t + \left(T_{Intermediat\ e} \times S_{REP} \times (\tilde{E}_r + \tilde{E}_t)\right) + T_{RSSM} \times S_{REP} \times \tilde{E}_r \quad (22)$$

Here S_{REP} is the span of the Rep.Ant packet. Presently the sender node will calculate the pheromone value and afterward selects the best route. The energy consumed to perform these task is less and can be ignored. Clearly the n number of data packets of size S_{data} will be sent through the selected route. For average number of hop count ∂, energy required to transmit data is,

$$\tilde{E}_{Data} = \partial \times n \times S_{Data} \times (\tilde{E}_r + \tilde{E}_t) \quad (23)$$

The energy associated with the broadcasting the ECHO Packet can be given as,

$$\tilde{E}_{Echo} = \frac{\alpha}{T} \times T_{Average} \times S_{Echo} \times \tilde{E}_t \quad (24)$$

Here S_{Echo} is the size of the ECHO packet, α is the time interval of broadcasting ECHO message and T is total time the node is alive in the network. The total energy consumed by the routing protocol can be calculated as,

$$\tilde{E}_{TOTAL} = \tilde{E}_{Echo} + \left(\tilde{E}_{Broadcast} + \tilde{E}_{Propagate} + \tilde{E}_{Receiver} + \tilde{E}_{Reply}\right) + \tilde{E}_{Data} \quad (25)$$

The energy consumed by a sender node *($\tilde{E}_{Sender}$),* receiver node ($\tilde{E}_{Receiver}$), and the intermediate nodes *($\tilde{E}_{intermediate}$) can be given as,*

$$\tilde{E}_{Sender} = \tilde{E}_{Broadcast} + \tilde{E}_{Echo} + T_{RSSM} \times s_{Reply} \times \tilde{E}_r + n \times s_{Data} \times \tilde{E}_r \quad (26)$$

$$\tilde{E}_{Inermediate\ \ Node} = \tilde{E}_{Echo} + S_{REQ} \times (\tilde{E}_r \times 2 \times \tilde{E}_t) + S_{Rep} \times (\tilde{E}_r + \tilde{E}t + n \times SData \times \tilde{E}r + \tilde{E}t \quad (27)$$

$$\tilde{E}_{Receiver} = \tilde{E}_{Echo} + T_{Avg} \times \left(S_{REQ} + S_{Rep}\right) \times (\tilde{E}_r + \tilde{E}_t) \quad (28)$$

The base energy required for a node is,

$$\tilde{E}_{node} = maximum\ of \{\tilde{E}_{SENDER\ NODE}, \tilde{E}_{INTERMEDIATE\ NODE}, \tilde{E}_{RECEIVER\ NODE}\} \quad (29)$$

IV. EXPERIMENTAL RESULTS

This section evaluates the performance of proposed approach through simulation using NS2. The execution of IANT-DSR algorithm is compared with some other algorithms developed in recent years, such as DSR [2], ACO based Ant-DSR [27] and AD-ZRP [33]. The performance of these algorithms is evaluated for 200 nodes network.

Table II (Simulation Parameters)

Simulation Parameter	Values
Node antenna range	35m
Dimension	11000 m2
MAC protocol	MAC/IEEE 802.11
Traffic Type	CBR
Initial Energy for each node	120 jule
Maximum speed limit of a node	15 m/s
Time for each duplicate packet	55 ms
Data Packet size	64 bytes
Timer value for receiving ACK message from the destination	100 ms
Required Energy to Transmit/Receive a bit	0.06 Jule/bit
Simulation Time	0 to 100 s
Minimum pheromone level $\wp$	0.0001
Mobility Model	Random waypoint

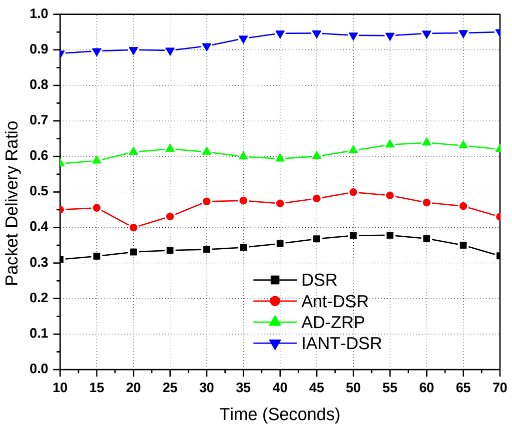

Fig. 5 (Packet Delivery Ratio)

Fig.5 illustrates the Packet Delivery Ratio of the system, IAnt-DSR results in high throughput value than other protocols. It was observed that IAnt-DSR shows better results than other protocols.

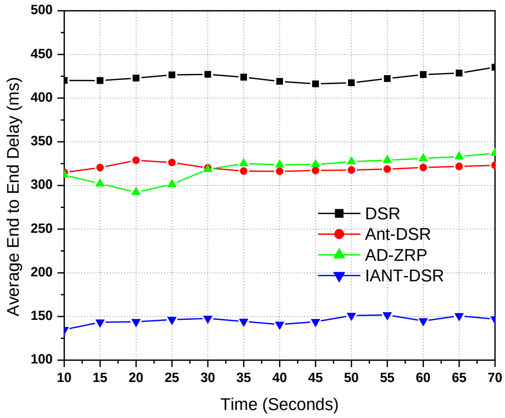

Fig. 6 (Average End to End Delay)

Fig.6 illustrates the end to end delay of IAnt-DSR in comparison with other protocols. IAnt-DSR lessens the end to end delay by applying novel route discovery and route maintenance approach. If the routes are not appropriately maintained then the intermediate node may inform the broken path to the sender node which will hamper the Data packet delivery process and expands end to end path delay.

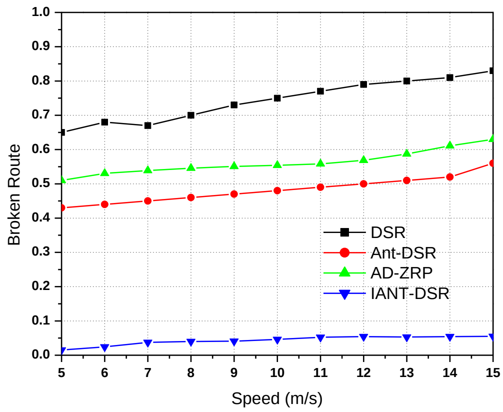

Fig. 7 (Broken Route)

Fig.7 illustrates the results of broken routes in MANET, AD-ZRP tends to create fundamentally good results (i.e. less number of broken routes). IAnt-DSR shows better results over AD-ZRP.

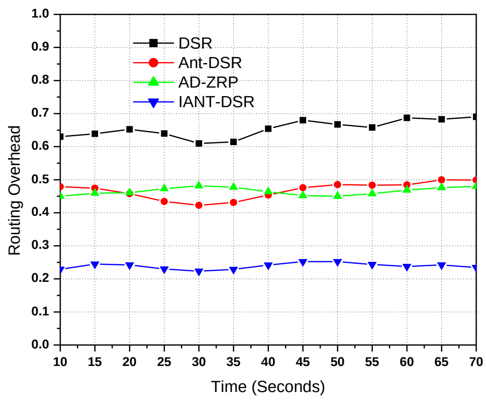

Fig. 8 (Routing Overhead)

Fig.8 illustrates the correlation between the protocols for routing overhead. The DSR protocol demonstrates highest overhead because of blind flooding in route discovery process.

IAnt-DSR protocol demonstrates lower routing overhead than other protocols.

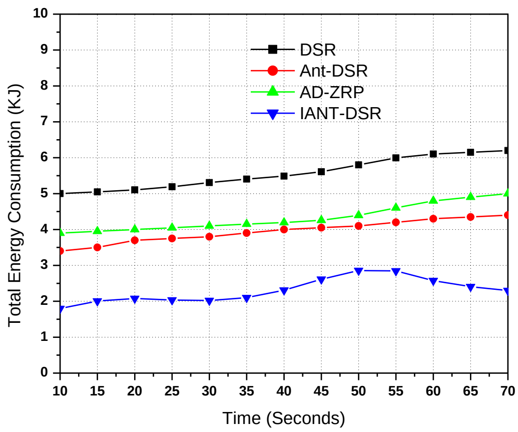

Fig. 9 (Total Energy Consumption)

Fig.9 illustrates the total energy consumption of the protocols in MANET. It is shown that, IAnt-DSR demonstrates better outcome in terms of energy consumption.

V. Conclusion

In this paper, IAnt-DSR protocol is explained and executed. The primary focus is on efficient routing by avoiding link breakage and congestion avoidance phenomena. This approach also shows the significant energy consumption. The proposed algorithm is compared with other algorithms and obtained up to 30% better results in terms of total energy consumption, packet delivery ratio, broken route, average end to end delay and routing overhead. The proposed algorithm can be extended to other ad hoc networks (e.g. Vehicular Ad-Hoc network). This scheme can further support to some other quality of services requirement like privacy and security.

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