Reinforcement Energy Efficient ant Colony Optimization of Mobile Ad Hoc Multipath Routing Performance Enhancement

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Abstract: *The Mobile Ad hoc Network (MANET) is a collection of mobile nodes that operates without infrastructure and is self-administrative. It often changes the topology called dynamic network. The nodes are in the dynamic network spending more energy on path finding that resultant the node quickly draining and being inactive in the network. To overcome this issue, propose an Improve Energy Capability Backup Route ant colony optimization (IEC-BR) algorithm for reducing energy usage, enhancing network lifetime, improving packet delivery, and decreasing end-to-end delay. The algorithm uses a backup route for minimizing the route researching and node energy preservation. Stability factors and Quality of Services (QoS) parameters help to enhance the network lifetime and QoS. The stability factor uses the node residual energy and the link lifetime. Hop count and bandwidth are used for the QoS parameters. The simulation result has proved the proposed IEC-BR technique improves packet delivery, node lifetime by 31% and reduces the network delay compared to the traditional Ad hoc On-demand Distance Vector (AODV) and Multi Objective Ad hoc On-demand Distance Vector (MOAODV) routing protocols.*

Keywords: *QoS, MANET, energy efficient, routing, ACO.*

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1. Introduction

The collection of mobile nodes combines to form a momentary network is a Mobile Ad hoc Network (MANET). It is a multi-hop short term network without using centralized administration and infrastructure. Numerous applications use MANET because of its ability to form a network anywhere and anytime. The major challenge in MANET is to provide efficient routing and the quality of services. The frequent topology changes affect the routing and the battery power of the nodes. The quality of service path is providing reliability, less delay time in data delivery, and less packet loss.

The resource-consuming applications affect the mobile ad hoc network's quality of service. These applications are multimedia, real-time streaming, and others that are primarily required minimal resource to deliver the data. The network dynamic nature affects the route search with minimal resources. The resultant path that satisfies the set of services and resources required by the application called Quality of Services (QoS) [7]. Providing the quality of services is hard in the mobile ad hoc network due to its dynamic topology.

The traditional routing protocol helps to find a path without QoS. Enabling QoS in the path, an algorithm uses QoS metrics like bandwidth, delay, hop count, cost [3]. Hop count is an additive metric that all nodes in the path help to reach their destination [6]. The other metrics are node energy and link stability used to select the next-hop among nodes to forward the data to the destination.

A novel approach named the IEC-BR ACO routing algorithm is proposed for enhancing network lifetime and reducing node energy consumption in MANET. For energy conservation, the algorithm uses a backup route and Ant Colony Optimization (ACO) [9] for avoiding path research. ACO uses two agents for collecting the QoS parameters' values, one is Forward Ant (FANT), and another one is Backward Ant (BANT). The proposed algorithm combines three approaches to achieve high packet delivery and increase the lifetime of the node.

The first approach is to calculate the stability factor using the node's residual energy and link lifetime.

The second approach is to collect the quality-of-service parameters for calculating the shortest path using ant agents.

The third approach is minimizing energy usage and increasing the lifetime of the node. In ACO, forward ants traverse the network and form the pheromone on its path. The backup pheromone table at each node is used to minimize the node residual energy usage by avoiding the same path search again. NS3 simulator is used to accomplish the simulation of our algorithm (IEC-BR ACO) Improving Energy Capability Backup route Ant Colony Optimization with Ad hoc On-demand Distance Vector (AODV) [16] and Multi Objective Ad hoc On-demand Distance Vector (MOAODV).

2. Related Works

This research concentrated on addressing the problems of single path routing protocols. Existing routing protocol using minimum hop count for the route destination, the other factors energy, bandwidth, and delay are not considered. EE-AODV [11] using Energy Consumption (ECR), is calculated using Residual Energy (RE) and Current Energy (CE) of the node. Finally, the route is weighted by the number of hops and the energy. EE-AODV using the route search process again for path failure. Hybrid modeling [12] uses the predicted position for routing decisions. prediction is based on location not used by past information. It uses the polynomial regressing (P_{ti}) is position and time, and speed is calculated (s). Bat Optimized Link State Routing (BOLSR) [14] is improved the energy usage in (OLSR) using Bat Algorithm (BA) with velocity (v_i) and frequency (f_{min}). The route selection is used Objective Function (OF) that calculated from overhead, energy variance, and PDR. MANET [1] contains many on-demand routing protocols like DSR and AODV. Addressing the problems for enabling the QoS in on-demand routing protocols, Ant Colony Optimization (ACO), and multipath routing. MANET protocols in which some significant Are ad hoc On-demand Multipath Distance Vector (AOMDV) [20] that assures loop less and discontinues of an alternate route. It is using the ($advertisedhopcount_i^d$) which is calculated using hop count, next hop and route list. The Split Multipath Routing (SMR) [17] uses two routes for each session, the first one is the quickest path, and the other is a disjointed route. Temporally-Ordered Routing Algorithm (TORA) [23] remains scalable for broad and dense networks. Multipath DSR (MDSR) [22] signifies to lessen the path query flooding. AODV Backup Routing (AODV-BR) [18] creates a mesh network and provides many equivalent routes to its destination. The Lifetime-Aware Multipath Optimized Routing (LAMOR) [26] depends on node residual energy and current transit states. Energy Drain Rate is calculated (DR) by total Energy Consumption (EC) in seconds (T). (NDMLNR) [27] considers connection and node establishment for multipath routing, The (OLSR)[4] protocol using bandwidth and delay QoS metric for the performance improvement. Ant colony based Multi-path QoS-aware Routing (AMQR) [19] provide QoS using swarm intelligence and disjoints multipath routing. Improved Ant Colony Optimization (I-ACO) [28] employs a pair of models, one for obtaining the position of the next node named transition probability, the next one is a directional probability that serves to locate the subsequent node towards the destination. QoRA [2], a QoS enabled routing protocol using ant colony optimization that holds two parts, the first part is path selection based on the QoS requirement, and the next part is the SNMP component. AODV Reliability (AODV-R) [25] routing protocol uses ant colony optimization, the protocol reduces the link damage chances by selecting the most reliable path in the dynamic network. Reactive Congestion aware multipath Routing Protocol (RCRP) [21] selects the path based on the Energy Reduction Rate (ERR) and Packet Delivery Time (PDT).Position based routing algorithm [15] uses a robust path in which disconnection rate is very less in the GPS enabled mobile nodes in the ad hoc network. Simple Ant colony Routing Algorithm (SARA) [8], the routing process is optimized by using controlled neighbor broadcast. Ant HocNet [10] routing algorithm setup multiple paths to improve the routing process using heuristic probability. This probability value is increased or decreased based on the pheromone deposition. ARA and PERA [5] are reactive routing protocols used in wireless networks. Clustering Head (CH) is used for energy fairness and equal traffic in all cluster [24].

3. IEC-BR ACO System Model

A distinct approach that is an IEC-BR ACO routing algorithm is introduced for enhancing the network lifetime by minimizing the node energy consumption, improving packet delivery, and reducing end-to-end delay. The next-hop is important for reducing the node's power expenditure in the network. The next-hop possibility is calculated by

$$NH = \text{node power} X \text{ connection durability} \quad (1)$$

NH is computed by considering nodes power and link durability. Link durability is the availability of the link. Table 1 shows the various acronyms used in this and its meaning.

Table 1. Notation table.

Signs	Information
C(a,b)	The power dissipated by a node for a packet transmission
R_{lt}	The remaining life of nodes
E_i	The power of a node
r_i	The node power consumption per unit time
E_c	The node power cost

3.1. Hop Count

The hop count is one of the significant quality metrics in the network. It is the additive metric. The source node assigns the destination address, and the network protocol returns a path to the destination. To reach the destination, the packets are forwarded through the intermediate node in the path. The intermediate nodes are called a hop. Hop is the measurement of counting the number of nodes between source and destinations. In terms of quality, Less hop count is selected for reliable communication between source and destination since the total processing delay is less compared to the more number of hops path.

$$Hop\ count\ (path\ (s,d)) = \sum_{s}^{d} nodevisited \quad (2)$$

The hop count is a summing up of each node that visited during the pathfinding between the source and the destination.

3.2. Band Width

Bandwidth is the next significant metric in QoS. It is a concave metric that has been estimated by taking a minimal bandwidth available between links from source to sink. Minimum bandwidth helps to reduce congestion.

$$BW\ (route\ (s,d)) = min\ \ \{bandwidth(n)\}\, n \in p(s,d) \quad (3)$$

3.3. MANET Model

Figure 1 shows a joined directionless MANET graph G= (V, E) comprising n nodes. In that v denotes the nodes $v_i \in V$ here i=0, 1, 2...n-1 and E is an associated path between the nodes

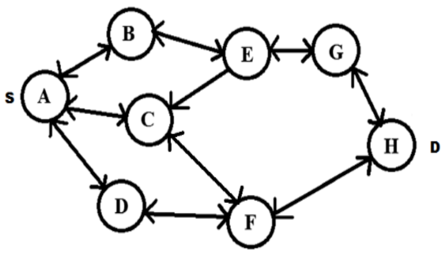

Figure 1. Network model.

3.4. Residual Life Time of Node

The node's remaining energy calls a residual lifetime. It is the power used through the node for sending and receiving the data throughout the communication. $E_r(V)$ is the existing node energy (v). The power needed to transport the data between node a and b, in that $c(a,b)\epsilon V$. Let $P(v_{i\ldots n})$ be the energy cost of the path, in an idle scenario is

$$E_c(P(v_{i\ldots n})) \quad (4)$$

that is determined

$$E_c(P(v_{i\ldots n})) = c(v_0,v_1) + c(v_1,v_2) + \cdots + c(v_{n-1},v_{n2}) \quad (5)$$

$$E_c(P(v_{i\ldots n})) = \sum_{i=0}^{n-1} c(v_i,v_{i-1}) \quad (6)$$

Remaining power path, $r(P(v_0,v_n)$ described as

$$r(P(v_0,v_n) = \min(E_r(v_i) - c(v_i,v_{i+1}))\ 0 \le i \le k \quad (7)$$

The power of a node determined by

$$E_i(t) = E_i\,(t) - c(v_i,v_{i+1}) \quad (8)$$

The remaining life of node i as

$$R_{it} = E_i/r_j \quad (9)$$

r_i describe the power dissipation of the node per unit time.

3.5. Link Stability

Link durability among the nodes needs an action parameter and open space propagation. The pair of nodes remains in the same communication area, let (x_1, y_1) and (x_2, y_2) discuss the node position. v_1 and v_2 designate the node speed by the direction of θ1 and θ2. Link durability is measured by

$$LS = (-(mn+cd) + \sqrt{(m^2+c^2)r^2 - (md-cn)^2})/m^2 + c \quad (10)$$

Where $m = v_1 \cos\theta_1 - v_2 \cos\theta_2$, $n = x_1 - x_2$, $c = v_1\, sin\theta_1 - v_2\, sin\theta_2$ and , $d = y_1 - y_2$

4. IEC-BR ACO: Improved Energy Efficient Ant Colony Optimization Protocol for MANET

The IEC-BR ACO is a QoS-enabled multipath routing protocol constructed by the ant colony. The reactive ant agent FANT is used to get the paths to the destination the other agent BANT is used to establish the return path to the source. The ant uses a pheromone table to maintain the paths and their features. A trusted neighbor node serves to get the route between the source and its destination.

Both the Next-Hop (NH) and QoS metrics are used to compute the trusted neighbors. The remaining energy and link durability are applied for the next hop, and QoS metrics are measured in the network. The node measured value is greater than the threshold value then it is a trusted neighbor. The source node uses the FANT packet to search the path to the destination through a trusted neighbor to control the routing overhead in the network.

The FANT packet keeps the path information in the path field for avoiding a loop in the middle node. The middle node receives the FANT packet and examines its presents in the path field. If path field contains its address, the FANT packet is discarded otherwise it appends in the path field and broadcast to the trusted neighbors. In the route search process, the FANT obtains hop count and bandwidth. Figure 2 denotes the FANT packet structure.

The destination calculates the path preference after arriving the FANT packets. The path preference uses the QoS metrics that compare with threshold values, if it satisfied then BANT produces. Figure 3 shows the BANT packet structure. The destination node unicast the BANT packet to reach the origin node by applying path fields stack knowledge.

S.A	D.A	Seq.No	BW	HC	Time Stamp	Path

Figure 2. FANT structure.

The intermittent node receives a BANT packet by using the path field during the traverse of BANT packet towards origin. The origin node gets many BANT packet that has created at the initial. To select the optimal path from multiple routes, source uses a high pheromone value link.

D.A	Actual S.A	Time Stamp	Path preference

Figure 3. BANT structure.

The link pheromone value is decayed if the data not transferred in a specified time period α from the source to its destination. The decayed element $\sigma$is described as:

$$\alpha_{s,d} = \begin{cases} (1-\sigma), & if(1-\sigma) \leq 1 \\ 1, & if(1-\sigma) \geq 1 \\ 0.1, & Otherwise \end{cases} \tag{11}$$

The neighbor association between the nodes is managed by using a hello message. Node announcing hello messages to its neighbor and assigned pheromone value as 0.1 to that link. Assigned pheromone value as zero for the link If the node is not having any neighbor that updated it in the pheromone table. The node keeps the neighbor relation only if the node is available. The node unavailable occurred due to the movement or remaining power of the node.

4.1. Path Preservation

The pheromone value helps to select an optimal path from multiple paths in the network. The higher pheromone value link is the aspired path for sending data. The node in the decided route is overloaded due to the reliable and better power that creates a delivery delay, decreases bandwidth, and deficiency of energy. Overloaded route NH is refreshed in the pheromone record and chooses the secondary next hop of a pheromone table for reliable delivery from source to destination.

5. IEC–BR ACO

IEC-BR ACO is an improved energy-efficient backup route ant colony optimization algorithm introduced to minimize the energy usage in the nodes. The pheromone value is used for selecting a path from various paths. The same path is frequently used the pheromone value of the link is updated and maintain. No ants using the link for some time then the pheromone begins to evaporate. The source node wants to transfer the data to the same destination, the node starts searching process that consumes additional node energy. The proposed IEC-BR ACO is used to minimize the searching process and reduce energy consumption by using the backup pheromone table value.

5.1. Measurement of Node Energy Consumption in a Model

Designing an energy efficient protocol is a highly important because energy is a limited resource in the mobile ad hoc network. The energy consumption of such a protocol requires proper modeling. Four energy consumption states are in the node like receive, transmit, sleep, and idle. The first and second states used for receiving and transmitting packets in the communication, the sleep is a low power state that consumes little power, the node idle state neither receives nor transmit.

Every node spends the energy for processing the data from the source to its destination. Intermediate nodes are acting as a relay to forward the data between nodes. In the network model, the node is competing in the communication or not, it may receive the information from the adjacent node and processing it. That consumes the node energy for further process. Figure 1 shows the network model, the node *C* concerned or not in the flow of communication that influences by node *E*. The energy use at node *C* calculated as follows

$$E_{C/E} = \alpha_{c>0}(\alpha_{C=E}E_{tac} + \alpha_{C\neq E}E_{rac}) + \alpha_{e>0}\big(\alpha_{C=E}E_{tdp} + \alpha_{C\neq E}E_{rdp}\big) \tag{12}$$

Where

$E_{C/E}$ =energy used at node C due to node E

E_{tac}=energy used for acknowledgement packet transmission

E_{tdp}= energy used for one data packet transmission

E_{rac}=energy used for acknowledgement packet reception

E_{rdp} =energy used for one data packet reception

5.2. Energy Calculation for Transmission and Reception

The energy required to transmit and receive the data packets are calculated by

Default MTU Packet length=1500 bytes

Default high quality bit rate=250 kbps (20.8 packets/sec =250000/ 8*1500)

Default value of IEEE 802.11b DQPSK modulation,

Packet total size = size of (preamble+PLCP header + Media Access Control header+Internet Protocol header +data)=(144 + 48 + 28x8 + 20x8 + 1500x8) (13)

The single packet transmission time is 1.143 ms

The energy required to transmit and receive for Acknowledgement packet is

Packet size=14 bytes

Bit rate=250kbps

Packet total size = size of (preamble + PLCP header + ACK) (14)

ACK packet size=144+48+14x8

So, the single acknowledgement packet transmission time is 0.027 ms

Energy Calculation

The transmission power used is 1.3 W, and reception power used is 0.9 W [13], then the energy cost for the various components is

E_{tdp} =1.3x1.143x10^{-3} =1.485 mJ
E_{rdp} =0.9x1.143x10^{-3} =1.028 mJ
E_{tac} =1.3x27 x10^{-6} =0.035 mJ
E_{rac} =0.9x27x10^{-6} =0.243 mJ

Thus, the energy required to flow the data from one node to other is required 1.52 mJ. In the proposed technique, the energy required to transfer FANT packet is as follows

Packet size =24 bytes
Bit rate =250kbps

Total packet size =size of (preamble + PLCP header + FANT) (15)

FANT packet size=144+48+24X8
The single FANT packet transmission time is 0.034 ms
E_{tfa} =1.3 x 34x10^{-6} =0.442 mJ
E_{rfa} =0.9 x 34x10^{-6} =0.306 mJ

The total energy required to process single FANT packet is 0.748 mJ

The energy required to transfer the BANT packet is
Packet size 16 bytes
Bit rate =250kbps

Total packet size = size of (preamble +PLCP header + BANT) (16)

BANT packet size=144+48+16x8
The single BANT packet transmission time is 0.029 ms

E_{bta} =1.3 x 29 x10^{-6} =0.377 mJ
E_{bra} =0.9 x 29 x10^{-6} =0.261 mJ

Path with energy consumption from source to destination

Table 2. End-to-end energy consumption.

Source Node	Destination Node	Possible Path	Energy consumed (mJ)
A	H	A-B-E-G-H	5.564
A	H	A-C-E-G-H	5.564
A	H	A-C-F-H	4.178
A	H	A-D-F-H	4.178

The above table shows four different possible paths available between the source and its destination with total energy consumed by the FANT and BANT packets. The energy consumption of the node is considering the pathfinding between source and destination with no additional constraints.

Figure 7 shows IEC-BR node energy consumption that compare with ACO and IEC-BR. The route fails or pheromone evaporated in the path, the ACO seeks a new path from the source to its destination. That requires energy to process at each node to reach its destination. IEC-BR uses a backup pheromone table that helps to reuse the same path without spending additional energy of 1.443mJ for pathfinding.

- *Scenario* 1

The source node uses the pheromone table to transmit the data to its destination. The backup of the pheromone table keeps at each node for the reference. If the pheromone evaporates, the link information is not available, the node checks the backup pheromone table for the path to transmit the packet to its destination. That saves 4.178 mJ of energy of the entire path and each node is saving a minimum of 0.706 mJ of energy using IEC-BR algorithm. This helps to increase the node lifetime.

- *Scenario* 2

The source node selects the path A-C-F-H for data transmission in the network. Due to the dynamic nature of the network, node F is not present in the path that resultant route breaking. The traditional protocol uses a path researching process it consumes energy, but the IEC-BR algorithm uses the node C backup pheromone table for selecting the alternate path to the destination from node C. That saves energy consumption and reduces the processing overhead of the node.

6. Performance Analysis

The proposed QoS protocol IEC-BR ACO is compared with AODV [8] and MOAODV [25] routing protocols. The specification shown in Table 2 and QoS metrics are used for the simulation. The result is compared using the listed parameters between AODV, MOAODV and IEC-BR ACO.

a. Routing overhead.
b. Packet delivery ratio.
c. Packet delivery ratio with node.

Table 3. Simulation environment.

Parameters	Values
Nodes	50
Traffic Pattern	CBR
Simulation time	300s
QoS metric	bandwidth, energy, hop count
Threshold value	Hop count (max 15) Bandwidth (min 3 Mbps) Energy (min 30%)

Figure 4 shows the routing overhead of the network it is based on node mobility. In the MANET, nodes are freely moved in any direction if node mobility is high, the network topology changes are also high. The topology changes initiate a route-finding process due to the inaccessible path. That leads to increase routing overhead in the form of route-finding packets.

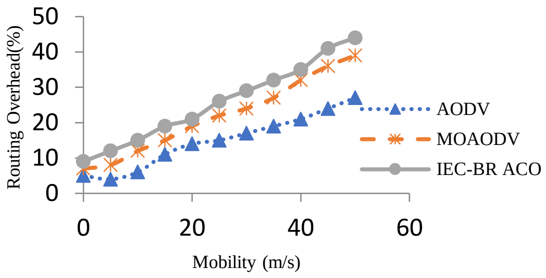

Figure 4. Routing overhead.

The pathfinding uses control packets that is used for searching and monitoring a route between nodes, and the path between source and the destination. The proposed algorithm IEC-BR ACO is periodically updating the nodes for maintaining the path that causing more packet generation and increases routing overhead. Figure 4 shows, IEC-BR is used more routing overhead packets comparatively other protocols because of the FANT and BANT used in the network. The node movement is also increased the routing overhead due to the pathfinding.

The Packet Delivery Ratio (PDR) is another significant metric that shows the throughput of the network. The network application may need a different throughput. Figure 5 shows the packet delivery ratio of different protocols. The result exposes, the increasing of node speed resultant the decreasing of packet delivery.

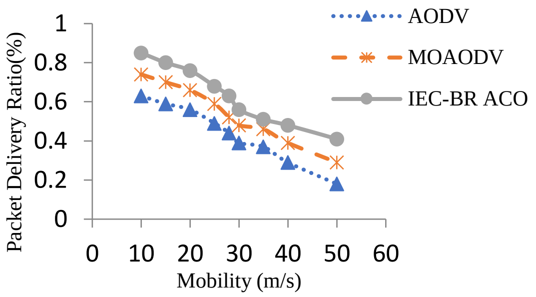

Figure 5. Packet delivery ratio with mobility.

A probability of link failure in the network is due to node mobility. Increasing node mobility creates link failure in the network since the node is away from the signal coverage area. It causes packet drops in the network. Figure 6 shows the packet delivery ratio is decreased with node mobility

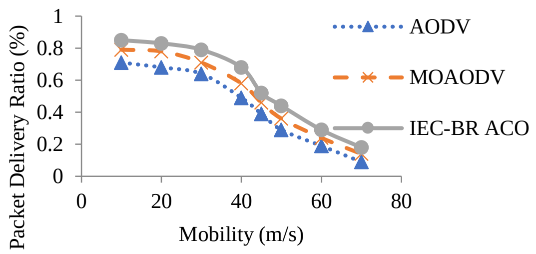

Figure 6. Pacsket delivery ratio with node.

Based on the performance analysis, the QoS achievement of IEC-BR ACO is superior compared with MOAODV and AODV.

Energy consumption is another significant QoS metrics in the ad hoc network. The node frequently moves from one position to another in infrastructure less network that often change the topology.

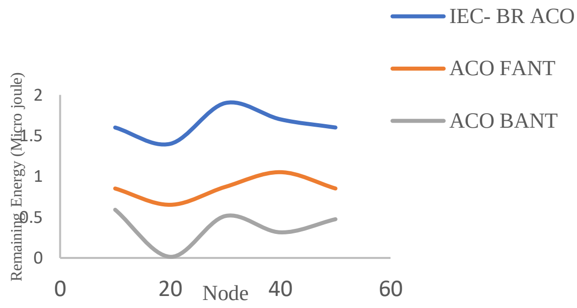

Figure 7. Energy consumption.

It resultants a frequent route-finding process is initiated for forwarding the packet. The Route finding uses nodes energy for building the pheromone table in the ant colony optimization.

Figure 7 describes the remaining energy of the node with two different techniques. The backup route algorithm helps to save the node energy and minimize the processing overhead of the node.

Table 4. Node remaining energy.

Node	IEC-BR ACO (mJ)	ACO FANT (mJ)	ACO BANT (mJ)
A	1.6	0.852	0.591
C	1.4	0.652	0.014
E	1.9	1.152	0.514
G	1.7	0.952	0.314
H	1.6	0.852	0.475

Table 4 shows the energy consumption of five different nodes using two techniques. In that IEC-BR ACO remains with the same node energy when the route to the destination is not available. It uses the alternate path from the backup pheromone table instead of searching the new route. But the tradition ant colony optimization starts route searching immediately when the path is not available to the destination

7. Conclusions

A proposed routing algorithm IEC-BR ACO is taken a backup of pheromone table at each node for avoiding a node energy usage. The route is not available, the node checks the route in a backup table for the destination. The simulation result is proved that proposed IEC-BR ACO consumes less energy to attains a high packet delivery ratio in a dynamic network. IEC-BR ACO is used the QoS metrics and stability factor for improving the performance. Bandwidth and hop count used as QoS metrics to predict the many disjoint paths from source to destination with QoS constraints. Residual energy and link stability used as a stability factor to predict the next hop from many disjoint paths. It helps to increase the network lifetime. ACO is used for path optimization during the route discovery. It is proved that the IEC-BR is using a lesser node energy consumption and increase the lifetime of the node.

References

[1] Abolhasan M., Wysocki T., and Dutkiewicz E., "A Review of Routing Protocols for Mobile Ad Hoc Networks," *Ad Hoc Networks*, vol. 2, no. 1, pp. 1-22, 2004.

[2] Al-ani A. and Seitz M., "QoS-Aware Routing In Multi-Rate Ad Hoc Networks Based on Ant Colony Optimization Network Protocol Algorithms," *Journal of King Saud University-Computer and Information Sciences*, vol. 7, no. 4, pp. 1-25, 2016.

[3] Asokan R., Natarajan A., and Nivetha A., "A Swarm-Based Distance Vector Routing to Support Multiple Quality of Service (Qos) Metrics in Mobile Ad Hoc Networks," *Journal of Computer Science*, vol. 3, no. 9, pp. 700-707, 2007.

[4] Badis H. and Agha K., "Quality of Service for Ad Hoc Optimized Link State Routing Protocol (QOLSR)," http://www.ietf.org/rfc/rfc3561.txt, IETF, RFC draft 01, 2005.

[5] Baras J. and Mehta H., "A Probabilistic Emergent Routing Algorithm for Mobile Ad Hoc Networks (PERA)," *in Proceedings of WIOpt'03: Modelling and Optimization in Mobile*, Tokyo, pp. 23-24, 2003.

[6] Chakeres I. and Belding E., "AODV Routing Protocol Implementation Design," *in Proceedings of 24th International Conference on Distributed Computing Systems Workshops*, Tokyo, pp. 698-703, 2004.

[7] Chen S. and Nahrstedt K., "An Overview of Quality of Service Routing for Next-Generation High-Speed Networks Problems and Solutions," *IEEE Network*, vol. 12, no. 6, pp. 64-79, 1998.

[8] Correia F. and Vazao T., "Simple Ant Routing Algorithm Strategies for a (Multipurpose) MANET Model," *Elsevier-Ad Hoc Networks*, vol. 8, no. 8, pp. 810-823, 2010.

[9] Di-Caro G., "Ant Colony Optimization and its Application to Adaptive Routing in Telecommunication Networks," PhD Thesis, Faculte´desSciences Applique´es, Universities Libre de Bruxelles, Brussels, Belgium, Forthcoming, 2004.

[10] Di-Caro G., Ducatella F., and Gambardella L., "AntHocNet: An Ant-Based Hybrid Routing Algorithm for Mobile Adhoc Networks," *in Proceedings of International Conference on Parallel Problem Solving from Nature*, Switzerland, pp. 461-470, 2004.

[11] Er-rouidi M., Moudni H., Mouncif H., and Merbouha A., "A Balanced Energy Consumption in Mobile Ad hoc Network," *Procedia Computer Science*, vol. 151, pp. 1182-1187, 2019.

[12] Farheen N. and Jain A., "Improved Routing in MANET with Optimized Multi Path Routing Fine Tuned with Hybrid Modeling," *Journal of King Saud University-Computer and Information Sciences*, 2020.

[13] Feeney L., "Energy Efficient Communication in Ad Hoc Wireless Networks," *Mobile Ad Hoc Networking*, pp. 301-327, 2004.

[14] Kadono D., Izumi T., Ooshita F., Kakugawa H., and Masuzawa T., "An ant Colony Optimization Routing Based on Robustness for Ad Hoc Networks with GPSs," *Ad Hoc Networks*, vol. 8, no. 1, pp. 63-765, 2010.

[15] Jubair R., Mostafa A., and Muniyandi A., Mahdin H., Mustapha A., Hassan M., Mahmoud M., Al-Jawhar Y., Al-Khaleefa A., and Mahmood A., "Bat Optimized Link State Routing Protocol for Energy-Aware Mobile Ad-Hoc Networks," *Symmetry*, vol. 11, no. 11, pp. 1409, 2019.

[16] Krco S. and Dupcinov M., "Improved Neighbour Detection Algorithm for AODV Routing Protocol," *IEEE Communications Letters*, vol. 7, no. 12, pp. 584-586, 2003.

[17] Lee S. and Gerla M., "Split Multipath Routing With Maximally Disjoint Paths in Ad Hoc Networks," *in Proceedings of IEEE International Conference on Communications Conference Record*, Helsinki, pp. 3201-3205, 2001.

[18] Lee S. and Gerla M., "AODV-BR: Backup Routing in Ad Hoc Networks," *in Proceedings of IEEE Wireless Communications and Networking Conference. Conference Record (Cat. No.00TH8540)*, Chicago, pp. 1311-1316, 2000.

[19] Liu l. and Feng G., "A Novel Ant Colony Based Qos-Aware Routing Algorithm for Manets," *in Proceedings of International Conference on Natural Computation*, Changsha, pp. 457-466, 2005.

[20] Marina M. and Das S., "On-demand Multipath Distance Vector Routing in Ad Hoc Networks," *in Proceedings 9th International Conference on Network Protocols*, Riverside, pp. 14-23, 2001.

[21] Misra S., Dhurandher S., Obaidat M., Verma K., and Gupta P., "Using Ant-Like Agents for Fault-Tolerant Routing in Mobile Ad-Hoc Networks," *in Proceedings of IEEE International Conference on Communications*, Dresden, pp. 1-5, 2009.

[22] Nasipuri A. and Das S., "On-Demand Multipath Routing for Mobile Ad Hoc Networks," *in Proceedings 8ht International Conference on*

Computer Communications and Networks, Boston, pp. 64-70, 1999.

[23] Park V. and Corson M., "A Highly Adaptive Distributed Routing Algorithm for Mobile Wireless Networks," *in Proceedings IEEE 16th Annual Joint Conference IEEE Computer and Communications Societies, INFOCOM'97*, Kobe, pp. 1405-1413, 1997.

[24] Ramakrishnan S., Sevalaiappan L., and Ravichandran S., "Traffic-Aware Clustering Scheme for MANET Using Modified Elephant Herding Optimization Algorithm," *The International Arab Journal of Information Technology*, vol. 18, no. 5, pp. 694-703, 2021.

[25] Singh H. and Singh P., "Enhanced New Clustering Ant Colony Optimization Based Routing Protocol AODV-R," *International Journal of Computer Applications*, vol. 160, no. 9, pp. 24-27, 2017.

[26] Tan L., Xie L., Ko K., Lei M., and Zukerman M., "Lamor: Lifetime Aware Multipath Optimized Routing Algorithm for Video Transmission over Ad Hoc Networks," *in Proceedings of IEEE 63rd Vehicular Technology Conference*, Melbourne, pp. 623-627, 2006.

[27] Upadhayaya S. and Gandhi C., "Quality of Service Routing in Mobile Ad Hoc Networks Using Location and Energy Parameters," *International Journal of Wireless and Mobile Networks*, vol. 1, no. 2, pp. 138-147, 2009.

[28] Yadav M., Arya K., and Rishiwal V., "Improved Ant Colony Optimization Technique for Mobile Adhoc Networks," *in Proceedings of International Conference on Computer Science and Information Technology*, Bangalore, pp. 1-13, 2011.

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