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Energy-Efficient Perspicacious Ant Colony Optimization Based Routing Protocol for Mobile Ad-Hoc Network

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Abstract – **Mobile Ad-hoc Networks (MANETs) are a special kind of network that organize by itself, and they provide high-quality service despite the cost of routing. In MANET, there exist no option to reach other hosts in a single-hop where it needs multi-hop. Many intermediary hosts relay packets transmitted by the source host before reaching the destination host in a multi-hop situation. The level of energy at each node plays a significant role in MANET. Routes are frequently broken, and new routes are discovered in MANETs because of node mobility. In this paper, Energy-Efficient Perspicacious Ant Colony Optimization Based Routing Protocol (EEPACORP) is proposed to determine the optimum route to transfer the data to reduce energy spent by each node for data transmission. EEPACORP is based on the ant's inherent disposition to seek for food. EEPACORP is inspired from genetic character of ant towards finding its food. Pheromone concentration are modified in EEPACORP to find the most appropriate route. The performance of EEPACORP is analyzed in NS3 using standard network metrics. EEPACORP's studies demonstrate that it reduces delays and energy consumption better than the present routing methods.**

Index Terms – **Optimization, Routing, ACO, Delay, MANET, Energy.**

1. INTRODUCTION

Mobile Ad-hoc Networks (MANETs) are a form of a network where the mobility of nodes is relatively high, making them ideal for mobile applications. In MANETs, nodes can move about quite a bit, which is why they're referred to as "moving networks". There is no set infrastructure in MANETs[1], [2]. Thus, nodes can come and go as they want. In theory, the computing power of each node should be equal. For a network to function correctly, mobile devices must work together to find and maintain routes for packets as they travel between them and their intended destinations. With mobile nodes, routes are constantly changing and need to be updated.

This necessitates complicated routing algorithms. Since MANETs are dynamic, maintaining routes is challenging[3]. When it comes to routing, it's all about finding the best way for data packets to go across a network. Routing information is critical to network communication's throughput, reliability, and congestion characteristics. One of the essential aspects of an optimal routing algorithm is how quickly it can get a packet to its final destination. A network node updates its routing table by sharing information with other network nodes[4].

There are three types of MANET routing protocols categorized as proactive, reactive, and hybrid. System wide broadcasts are required for proactive protocols developed from static networks, as they need periodic routing information with neighbor nodes. These protocols refer to storing a routing entry for every possible network destination[5]. A reactive routing protocol builds a route when a network node connects with another node. Node-to-node route discovery occurs anytime a node wishes to go to another location. This approach saves the route when the destination is no longer accessible by all possible routes from the source or if the route is no longer wanted. Routers that use a hybrid protocol have both proactive and reactive features[6].

Ant Colony Optimization (ACO) algorithms may be used to solve a wide range of combinatorial optimization issues. For the first time, an ant colony optimization metaheuristic was introduced by Marco (1992)[7]. Giving the approach its name was based on observations of "actual" ant behavior. Ant colonies can determine the most efficient route to food by depositing and responding to the pheromone trail, which helps future ants locate the best routes to the food source[8]. While the pheromone on unfavorable pathways dwindles with time, the pheromone on more favorable pathways strengthens. A

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new route is established back to the nest of origin, which is biased by the pheromones deposited on the less-distant path by the ants once they have arrived at their objective[9].

1.1. Problem Statement

MANET is always limited to energy leading to have shorter network lifetime. Every node may act as a source, a destination node, or a router, directing messages to their desired destinations. To transfer data, a node's energy is used heavily. In the event that a number of network nodes or connections fail, the network will be partitioned. Finding a new route after discovering a failed route causes additional delay and consumes a large amount of energy. The life span of mobile nodes is limited by their battery capacity, which necessitates using an energy-efficient routing protocol.

1.2. Objective

This paper aims to build an "Energy-Efficient Perspicacious Ant Colony Optimization Based Routing Protocol" that uses the inherent qualities of ants in their quest for food to reduce energy usage during data transmission.

1.3. Organization of Paper

The current section of the paper has briefed the MANET, Routing Protocols, problem statement and objective. Relevant works of literature related to the problem statement are discussed in Section 2. Section 3 proposes the routing protocol to MANET to reduce energy consumption. Section 4 provides the details of the setting used for simulating the proposed protocol against the existing routing protocol. Section 5 describes the metrics used for evaluation. Results and discussion are provided in Section 6. Section 7 concludes the paper with future research dimensions.

2. LITERATURE REVIEW

This research work has selectively chosen the literature related to the consumption of more energy leading to network failure among different available works of literature.

"Two-Hop Relay Algorithm"[10] is proposed for exploring the delivery of packets in 3D MANET. Markov chain theoretical architecture models the framework and expressions in a closed-form derived from relative standard deviation and mean for packet delay delivery issues. The packet is transmitted from source host to destination host with the proper setting. "Optimized Power Control"[11] is proposed for determining the power transmission to nodes in an optimal manner. The modified version of the Gabriel Graph Algorithm is applied to verify the network's transmission power, energy consumption, and delay performance. The network parameters were confirmed using Local Tree-based Reliable Topology and Distributed Power Management. "Bottlenecks Detection" [12] is proposed for detecting the nodes with bottlenecks, and the fluctuations in

the topology are reduced. Overhead of the network is reduced, and a simulation tool is used to validate and detect different attacks in the network. Other paths were determined for passing the data, and the linear cost was provided.

"Three-Dimensional Clustered Overlay Routing" [13] is proposed for efficient operations in MANETs. Maximum lookup latency, computation, and control overhead and maintenance were analyzed over MANET. Routing overhead, path-stretch ratio, file discovery delay and false-negative ratio were reduced in a high mobility environment. "Secure Multi-Path Reactive Protocol"[14] is proposed for secure routing in IoT devices. A secured routing structure is incorporated for enabling multi-path routing and trust in the network. Two different events, namely, uncooperative nature and mobility, were detected, and conventional techniques called DMRP and SMORT were compared to prove its scalable performance.

"Mobility models based Content Discovery" [15] is proposed to evaluate the internet performance based upon content delivery methods. Direct and derived mobility metrics were fused, assessing their impact on content dissemination and delivery. The scalability of the network is also determined, and the non-modelled protocol's resilience for content evolution is presented. "Smart Geographical Routing" [16] is proposed for minimizing the packet delay and loss. Multimedia packets were transmitted by selecting better throughput paths, and the shortest route to the sink was selected. Network void bypass is chosen to solve network holes and enhance the network's reliability. The lifetime of the sensor is extended by reducing the transmission range to the nodes in the sensor, which enables load balancing.

"Thresholds QoI based Routing"[5] is proposed to design the framework for delivering the performance threshold to the user. The performance value is modified as a ratio, and a correctness measure is used to determine every source's scores. In addition, the optimal information source is picked, and the performance is tested using simulation software. "Quantum-Genetic based Routing"[17] is proposed for distribution control of routing in MANET. Multi-Point Relay is fused with OLSR (Optimal Link State Routing), and the MPR sets were selected by grouping the augmented Q-Learning algorithm.

The network topology control is reduced along with end-to-end packet transmission, and the delivery rate of packets is improved. "Fuzzy-based Cooperative Secure Communication"[18] is proposed for exploring the different disruptions in IoT networks by handling the attacks in the nodes at the edges. A Fuzzy-based environment is selected to decrease the attacks and malicious attacks in the detected nodes. The bandwidth usage and latency are reduced, and the malicious node is isolated. Reaction-based trust evaluation is performed by re-analyzing the nodes using their reputation range of values.

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"Artificial Immune System based Routing" [19] is proposed to identify the selfish nodes in MANET. The strategy of the Human Immune System is mimicked based upon the principle of Artificial Immune Systems (AIS). Trust models were built to differentiate the selfish and genuine nodes for which simulation-based results are generated. "Hybrid Secure Routing cum Monitoring Protocol" [20] is proposed to discover and prevent IoT issues. The complex symmetric essential approach is used to hide the sensor guard nodes. The parameters of Ad-hoc On-demand Multipath Distance Vector and Optimized Link State Routing were selected using a secured routing protocol. The authentication and Encryption Model are used for designing the framework, and Eligibility Weight Function selected the sensor nodes.

"Secured Data Communication Scheme" [21] is proposed for enhancing the throughputs using end-to-end communication in a secured manner for MANETs. Optimal links were selected from the queue of transmission links that are available and are safeguarded by authentication. Secret-key-based encryption enhances interaction among nodes, and the malicious nodes were presented in the source and destination paths. "Coalition Game Model-based Routing" [22] is proposed for mitigating the modifications in the topology of the ad-hoc network. The cooperation process is evaluated for its scalability in different network environments. OLSR, a routing protocol, is used for assessment, and the network stacks were simulated with varying densities of node, deliverability, and control overhead. Optimization [23]–[28], [29] plays a vital role in MANET to find the best route.

"Affinity Propagation-Driven Routing Protocol (APDRP)" [30] is proposed for clustering in MANETs. Local optima logic is used, and mapping evolution is performed for network topology. Gauss Markov (GM) is used to detect the node's movement structure and is optimized using a modified Affinity Propagation technique. An analytical model elaborates the propagation technique with different nodes and their timelines.

"Multi-Adaptive Routing Protocol (MARP)"[25] is proposed to determine the most efficient path to the destination in an ad-hoc network. Based on fish's natural tendency to look for food in groups, MARP is designed to do the same for identifying the best route. When a node's priority changes or fails, MARP focuses on finding the most efficient and effective method to get the node back up. Before transmitting a data packet, multi-adaptive routes verify the network's connection and functionality.

All the above discussed protocols face the issue of consuming more energy for data transmission, leading to node failure and network failure. Hence, there is a need for an optimization-based routing protocol to find the better route that reduces delay and saves more energy.

3. ENERGY-EFFICIENT PERSPICACIOUS ANT COLONY OPTIMIZATION BASED ROUTING PROTOCOL (EEPACORP)

EEPACORP is a novel routing protocol for calculating the distance between two nodes. Every node that requires a GPS facility is the basic assumption used to modify traditional ACO. Every moving node's physical position (M_Z) may be dynamically identified using GPS. EEPACO takes into account the present physical location (UM_Z), propagation delay, and node velocity (r). In $EEPACO$, all nodes send beacons to their one-hop neighbours(G) to calculate the distance between themselves and their one-hop neighbours. G is then placed in the node's routing table when it has been calculated. The calculated G is utilized to determine the cost of the node's edge. Beacons will warn other nodes if any node speeds up or slows down in the future. G is calculated and saved in the node routing table when the modifications are made. To start cost to pathways, $EEPACO$ is applied.

Furthermore, the given expenses are considered as parameters while implementing modified ACO. Because MANETs are dynamic, the path's cost is also subject to quick change. The $EEPACO$'s primary goal is to cut down on communication and routing overhead. Modified ACO is started after determining the distance between nodes. The ACO's major goal is on-demand path discovery, which means it seeks the most direct route from the source to the final destination. The improved ACO reduce communication costs by reducing route length, node overhead, and connection expenses. The long journey between the source and the destination may result in high communication costs, increased network overhead, and frequent connection failure. The next stage is to transmit data from source to destination after identifying the shortest route using modified ACO. An $EEPACORP$ for $MANET$s that addresses the shortcomings of current approaches is proposed in this context.

$EEPACORP$ deploys nodes in random order at first. There are "t" nodes in the topology. The $EEPACORP$ uses internode distances to allocate costs to edges. Based on cost, the modified ACO places a pheromone on each edge. Pheromone levels are monitored at each edge using the pheromone updating model. The probability and decision models are utilized to choose the data transmission route. A directed graph is a topology made up of edges and vertices. Eq.(1) is applied in $EEPACORP$ to depict the graph.

$$J = (R, H), \tag{1}$$

Where R represents the vertices set and H indicates the graph J's edges.

Eq.(2) represents the shortest route (SR) determined utilizing ACO.

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$$EM = \{R_1, R_2, \ldots, R_t\}, \tag{2}$$

Where nodes are represented as $R_1, R_2, \ldots, R_t$ in Eq.(2).

3.1. Inter-Distance-Based Approach

$EEPACORP$ uses the propagation delay, velocity ($speed$) and the current physical location (UM_Z) of nodes to determine the distance between one node and another. All of the nodes in $EEPACORP$ use GPS to locate their first UM_Z. The edge rate (ER) is determined by the internode distance (G). The G is precisely proportional to the node's ER, as shown by Eq.(3).

$$G \propto UKH \tag{3}$$

Eq.(4) shows that the node's inter-distance (G) is proportional to velocity (r) and the propagation delay (F_M) of the node. The G is proportional r and F_M. The distance is affected by changes in the node's velocity and propagation delay (G).

$$G \propto F_M * r \tag{4}$$

Consider two nodes, A and B, moving at r_1 and r_2 velocities, respectively. At time F_0, node A broadcasts its initial current physical position (UM_Z) and velocity (r) or speed as a beacon message, which is received by node B at time F_1. The source generates a sequence number for the identified route, and E_{num} reflects that number. In a beacon message, E_{num} is used to prevent duplicate messages from being sent.

At time F_0, node v's current location is shown in G_2 as a distance from A's current position. The information regarding the propagation delay is computed as $(F_1 - F_0)$ sent via control codes. Eq.(5) shows how G_2 is determined. Eq.(6) illustrates the node A's travel distance in time $(F_1 - F_0)$ as given by G_1. Based on the received message, node B estimates the inter-node distance using Eq.(7).

$$G_2 = r_2 * ((F_1 - F_0) \tag{5}$$

$$G_1 = r_1 * ((F_1 - F_0) \tag{6}$$

$$G = G_2 - G_1 \tag{7}$$

Each node that receives a message saves the T_e and UM_Z and of the next node and calculates G using Eq.(7). When two nodes calculate G, the computed node unicasts G to the other node. In the same way, all nodes determine their distance from other nodes and the G's traded between them.

Immediately after exchanging calculated distances, the nodes' routing tables are updated.

During the time period $F_1 - F_0$, each node has a physical region that it may cover. If the node detects a speed change, it will send out beacon signals. After receiving these messages, the intermediate nodes will update their routing database (i.e., table) by calculating new distances. The routing table is instantaneously updated as soon as a parameter value is altered.

EEPACORP relies heavily on the computation of inter-node distances. The internode distance, or the distance between nodes, is the first thing EEPACO is utilized for. The time of arrival (ToA) notion is used to calculate the internode distance. Using ToA in EEPACOs is a common practice. ToA is a distance-velocity-propagation-delay relationship. Let A and B be two points with velocities of r_1 and r_2 respectively. The internode distance computation approach uses node A as a beacon node and node B as a neighbour node to determine the distance between the two. The transmitting node or beacon node sends a beacon message at the time F_0, and the receiving node or neighbour node receives it at the time F_1, at which point the neighbor node B uses the time differential between receiving and sending to determine the distance G between itself and the node A. (r). Eq.(5), Eq.(6), and Eq.(7), provide the process of this action.

In the same way, each node calculates its own G-distance from all the others. As a beacon node emitting beacon messages or a neighbour node doing distance calculations, each node in the network serves a dual purpose. Allows nodes to calculate the distance between themselves and the rest of the network. As a result, all beacon nodes and their neighbors are assigned the same amount of processing power. To calculate internode distance, the calculated internode distance G is utilized as a RE that connects two nodes. In $EEPACORP$, ants begin searching for a destination by traversing any network's nodes. Ants use the node's routing database to determine the cost of a journey between two points. Depending on the available resources, the ant deposits pheromone. Costs are allocated based on the distance travelled. $EEPACORP$ sees the RE as laying the groundwork for the future.

3.2. Modified ACO

To determine a route from the nest to the food supply, ants might begin their trip randomly. As a result, a greater number of ants are forced to use other routes in search of food. This "pheromone-like" material is released by the ants known as forwarding ants ($FWRD_{ant}$) as they move, other ants of the same nest also release it to improve the route to a food source and attract other ants to follow suit. In the case of a "pheromone" deposit, it may be used to locate the nest by an ant termed a "backward ant" ($BWRD_{ant}$). Other backward

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ants may use pheromone traces to find their way back to the nest after foraging for food in the same way. The quantity of pheromone released along a given route grows when more ants from the same nest follow the same path. The path's high concentration of pheromone encourages other ants to follow it. An ant returns to its nest with food as soon as it finds a new food source. For example, it's well known that ants use shortcuts to get to their colony in the shortest time possible. Ants from the same nest will engage in the search for a food source at random. The ants come back to the nest at various periods throughout the day. The shortest route is found in the minor time period. This method is used to direct the remaining workers. The "pheromone" amount guides ants. On the journey, the amount of pheromone is determined by how much food is available and how well it's prepared. In order to find the quickest route between the food source and their colony, the other ants follow this scent trail. As time goes on, the pheromone compound begins to evaporate; this evaporation diminishes the "pheromone" deposited by the same nest. An automatic reduction in "pheromone" in the route causes the path to be broken. Using the likelihood ratio of evaporation, regular journey ants must spread "pheromones" to overcome this issue.

In $EEPACORP$, the ant begins the tour and travels from node to node for each algorithm iteration. The ants locate the RE and deposit pheromones depending on edge cost as they move. When iterations are repeated, the value of the maximum iterations (MI) is utilized. Eq.(8) is used to calculate MI.

$$MI = TNA * TNN, \qquad (8)$$

Where TNA indicates the $total-number-of-ants$ that have started a tour and TNN denotes $total-number-of-nodes$ in MANET.

The significant components of EEPACORP are (i) deposit of pheromone, (ii) update of pheromone, (iii) probabilistic prediction, (iv) decision-making, and (v) data transferring.

3.3. Deposit of Pheromone

In the modified ACO method, an ant is merely a computational agent. In order to find the shortest route between two points, an ant uses iteration. To go from one vertex to another in the iterative model, the ant uses the edge that connects "a" and "b". An ant calculates the RE of "a" and "b" before making any movement, and this pheromone deposit is used to keep the colony alert. Deposit of pheromone can be made in three methods: (i) constant rate depositing, (ii) depending on the edge quality, and (iii) depending on the RE. The probability-based strategy is needed for the first method. The average rate of pheromone deposition at the margins may be calculated using this model. In the second method, the

pheromone is applied to edges depending on quality here. The connection quality gets fluctuate or becomes dependent on the quality of food source available (i.e., destination). In the third method, pheromones are deposited based on the RE value.

EEPACORP follows the third method for pheromone deposition. Chemical substances (i.e., pheromones) are deposited on the graph using a mathematical model shown in Eq.(9).

$$\Delta\beta_{d,v}^A = \begin{cases} \dfrac{1}{u}, A^{th} ant\ travels\ between\ edge\ d,v \\ 0 \qquad\qquad\qquad\qquad otherwise \end{cases}, \qquad (9)$$

Where d, v represents the edges that connect the nodes. $\Delta\beta_{s,w}^A$ represents the deposit of pheromone by A^{th}ant while it travels from d node to v node. U indicates the cost spent for finding the path by the ant A. If $\Delta\beta_{d,v}^A \neq 0$, then the pheromone is deposited by the ant A, else $\Delta\beta_{d,v}^A = 0$, which means that the pheromones are not deposited by ant A on edge.

$$\Delta\beta_{d,v}^A \neq 0$$

Eq.(9) computes the level of pheromone that is to be deposited on edge vertices by every ant. More pheromone is deposited when more ants move along the same edge.

3.4. Update of Pheromone

There are two ways to update pheromone levels: by evaporation and through a pheromone update model that regularly deposits the same or different amounts of pheromone. The pheromone updating model's objective is to raise pheromone values as much as possible. Eq.(10) is applied to illustrate the updating process.

$$\beta_{d,v}^A = (X - \varphi)\beta_{d,v} + \sum_{a=1}^{t} \Delta\beta_{d,v}^A, \qquad (10)$$

Where "X" represents the link's former pheromone value. "φ" indicates the rate of evaporation. No evaporation occurs if $\varphi = 0$. If evaporation happens at $\varphi = 0$, then $\sum_{a=1}^{t} \Delta\beta_{d,v}^A$ represents the RE, and $\beta_{d,v}^A$ indicates the deposit of new pheromones by ants.

3.5. Probabilistic Prediction

To predict the quality of the route, all edges probability values are analyzed. Eq.(11) is applied to find the probabilistic value.

$$M_{d,v} = \frac{(\beta_{d,v})^d}{\sum(\beta_{d,v})^d}, \qquad (11)$$

Where the level of pheromone present at every edge is indicated as $(\beta_{d,v})^d$. Coefficients that are used for controlling

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the pheromones are represented as d and v. $\frac{(\beta_{d,v})^d}{\Sigma(\beta_{d,v})^d}$ influences the likelihood of selecting the "d" or "v". Edges probability values are indicated using $M_{d,v}$. $\Sigma(\beta_{d,v})^d$ indicates the combination (or product) of "d" and "v".

3.6. Decision Making

Choosing the shortest route is a part of the decision-making process. Using the roulette wheel principle, $EEPACORP$ choose the shortest route out of many possible ones. Proportional Selection for Fitness (PSF). To accomplish selection operations, PSF is often employed as a general operator in genetic algorithms. In PSF, the fitness function assigns fitness values to probability values to select the best one. Values with higher scores have a greater likelihood of being selected. Each number on the roulette wheel is given a certain value. Fitness value calculation is expressed mathematically as Eq.(12).

$$M_s = \frac{G_s}{\sum_{W=1}^{t} Gw},\qquad(12)$$

Where fitness value of every s is indicated as G_s, rate of probability for s is indicated as M_s, count of overall values are denoted as t, the summation of t is represented as $\sum_{W=1}^{t} Gw$. A roulette wheel with all fitness values should be spun many times to choose the best route randomly. Those with a high fitness value will have an advantage of the minimum delay and higher delivery of packets.

3.7. Data Transferring

Each node will have a high fitness value edge chosen to transport data. Many factors contribute to high fitness value edges, such as low cost for communication and high value for pheromone. An advantage that has minimal communication costs is the "shortest path."

3.7.1. Handling Link Failure

Failure handling is responsible for identifying an alternate route if an existing route fails to function properly. Mobility and floods are two potential causes of link failure. When a message is sent, the source waits for a response before moving on. An error occurred while transmitting the packets. Only packets received by the destination are acknowledged by the destination and sent back to the source. It is assumed by the source that the established path is severed if the acknowledgement is not received. The source node utilizes the route discovery procedure to locate an appropriate path to send the packets. N2N communication is taken into account in EEPACORP. There is a forward movement of the source and destination nodes in N2N. Nodes in the routing process (transfer of data) or source are valid until the radio communication link is maintained with the intermediary

nodes. When node departs from the predetermined path, the legitimacy of the node starting point and ending point is nullified. The pseudocode of EEPACORP is provided in Algorithm 1.

1. Initialize random number of nodes in a random location

2. Set node mobility speed for an individual node

3. Identify velocity and location of individual nodes

4. Apply the unicast concept to direct neighbor nodes

5. Set $U = G$

6. Update routing table with U

7. Parameter Initialization

8. Identify U t initiate traveling of ant

9. Forward

   a) $Iter = 0$;

   b) Do

   c) {

   d) Ant_s travel between $T_s \& T_w$

   e) Estimate cost

   f) Deposit pheromone according to estimation

   g) $Iter + +$;

   h) }

   i) While ($Iter <= Maximum\ Iter$)

10. Backward

   a) Ant travel to a destination with ACK using the same route

11. Pheromone Updation

   a) Set Interval of time to update pheromone deposit

   b) Identify U

   c) Identify the current state of pheromone deposited previously X

   d) Set Evaporation rate for pheromone (φ)

   e) Perform pheromone deposition depending on $(X - \varphi)$ and U

12. Identification shortest route

13. Transfer data to using the shortest route

14. Handle route failure either using the existing or alternate route

Algorithm 1 EEPACORP

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4. SIMULATION SETTING

A description of utilizing NS3 simulations to assess the EEPACORP is discussed in the present section. Multiple simulators are available to evaluate routing protocols of MANET. This research work has chosen NS3 to evaluate the proposed EEPACORP against the existing routing protocols. MANET's protocol simulation and implementation specifics for different environments, particularly its performance, are always a mystery to researchers. A comparison between EEPACORP and existing routing protocols is made in this research. C++ is the preferred language for the NS3 simulator in this research. Table 1 depicts the simulated environment in which the suggested approach was tested.

Table 1 Simulation Settings and Parameters

Parameters	Values
Simulator	Network Simulator version 3
Number of nodes	250
Area Size of Simulation	1250×1750 m^2
Mobility Speed	5 m/s to 32 m/s
Packet Size	256 kb
Initial level of Energy	12 Joules
Range of Transmission	480 m
Traffic Type	CBR
Channel Type	Wireless
MAC	802.16
Model of Mobility	Randomway Point

5. PERFORMANCE METRICS

The following metrics are used in this research work to compare the performance of the proposed protocol EEPACORP against current routing protocols.

- ✓ Packet Delay (PD)is referred to the length of time consumed by a packet to reach the destination node travel from the source node.

- ✓ Packet Delivery Ratio(PDR) measures how many packets were successfully delivered concerning the total number of packets that were originally sent.

- ✓ Packet Loss Ratio(PLR) measures how many packets were lost compared to how many were transmitted.

- ✓ Throughput(TP) denotes the quantity of data transferred in a given length of time.

- ✓ Energy Consumption (EC)denotes the amount of energy taken by a packet while travelling to a destination from the source.

6. RESULTS AND DISCUSSION

6.1. Packet Delay (PD) Analysis

Figure 1 compares EEPACORP's packet delay against the APDRP and MARP. From Figure 1, it is clear that EEPACORP faces minimum delay than the existing routing protocols APDRP and MARP. EEPACORP identify the routes based on the inter-distance rather than simply identifying the available routes. APDRP and MARP find the available routes and send data that results in route and packet retransmission failure. This makes them face more and increasing delays when the number of nodes increases. It is also worth noting that, PD all protocols get drastically increased when the count of nodes gets increased. Table 2 provides the result values of Figure 1. Table 3 provides the average delay faced by the protocols.
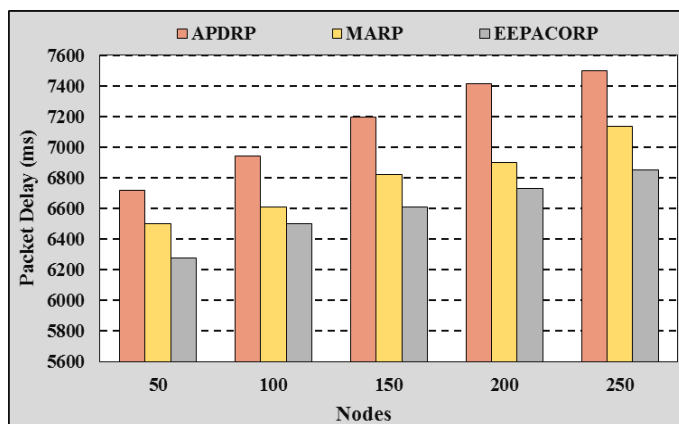

Figure 1 Packet Delay (PD) Vs Protocols

Table 2 Result Values of Packet Delay (PD) Analysis

Nodes	APDRP	MARP	EEPACORP
50	6721	6498	6278
100	6942	6607	6502
150	7198	6820	6607
200	7413	6899	6732
250	7499	7135	6851

Table 3 Average Packet Delay (PD)

Routing Protocols	AveragePD
APDRP	7154.6
MARP	6791.8
EEPACORP	6594.0

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6.2. Packet Delivery Ratio (PDR) and Packet Loss Ratio (PLR) Analysis

Figure 2 and Figure 3 discusses the *PDR* and *PLR* of *EEPACORP* against APDRP and MARP, which are the existing routing protocols. From Figure 2 and Figure 3, it is easy to make an understanding that *EEPACORP* is better in terms of delivering packets to the destination and having a minimum level of PLR than APDRP and MARP. Pheromone deposit update and probabilistic prediction lead the way for *EEPACORP* to face higher *PDR* and lower *PLR*. APDRP and MARP focus only on finding the shortest route in a short duration without checking its quality and its issues. It is significant to note that *PDR* of all routing protocols gets decreased when the count of nodes gets increased. Hence, vice-versa in *PLR*. Table 4 provides the result values of Figure 2 and Figure 3. Table 5 illustrates the average *PDR* and *PLR* of protocols.
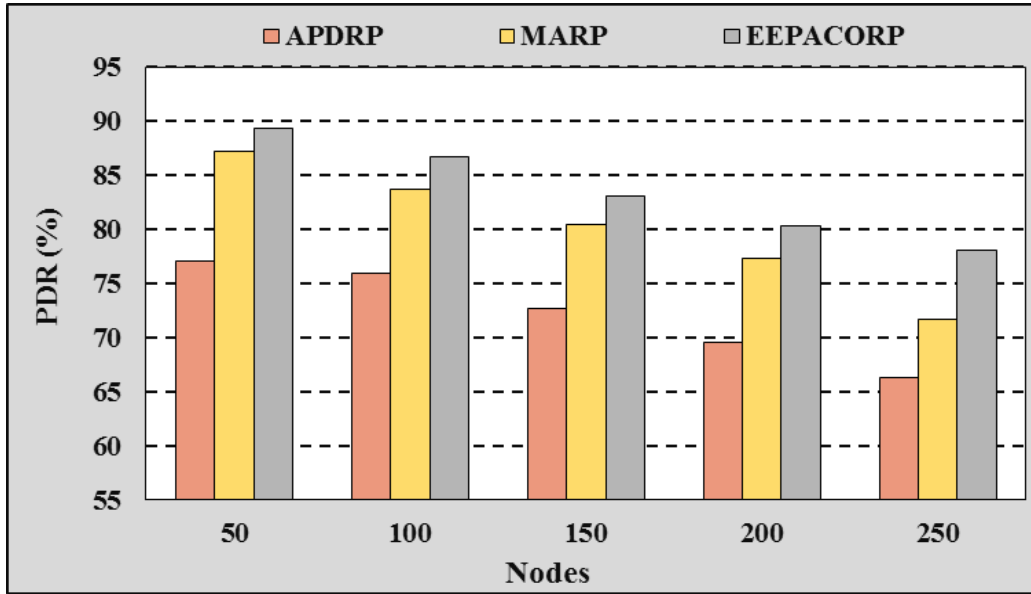

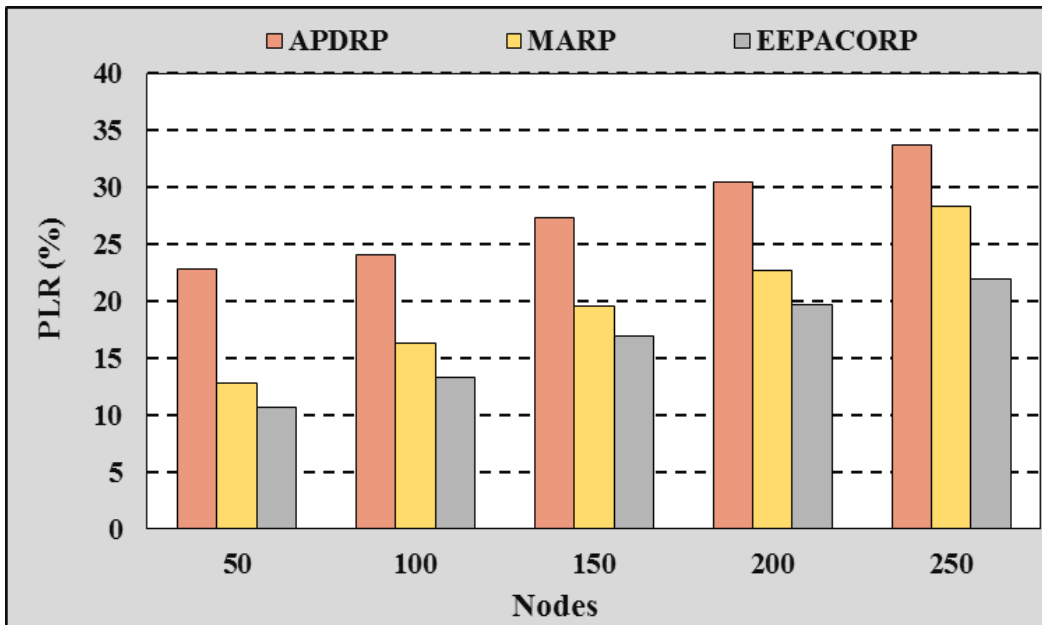Figure 2 Packet Delivery Ratio (PDR) Vs Protocols

Figure 3 Packet Loss Ratio (PLR) Vs Protocols

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Table 4 Result Values of Packet Delivery Ratio (PDR) Analysis

Nodes	*PDR*			*PLR*		
	APDRP	MARP	EEPACORP	APDRP	MARP	EEPACORP
50	77.119	87.177	89.356	22.881	12.823	10.644
100	75.955	83.697	86.684	24.045	16.303	13.316
150	72.701	80.420	83.091	27.299	19.580	16.909
200	69.589	77.265	80.356	30.411	22.735	19.644
250	66.248	71.732	78.083	33.752	28.268	21.917

Table 5 Average Packet Delivery Ratio (PDR) and Packet Loss Ratio (PLR)

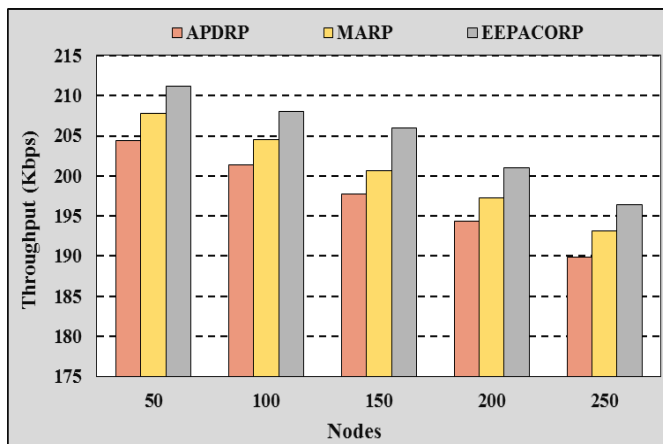| Routing Protocols	Average *PDR*	Average *PLR*
APDRP	72.322	27.678
MARP	80.058	19.942
EEPACORP	83.514	16.486

6.3. Throughput (TP) Analysis

Figure Throughput (TP) Vs Protocols

EEPACORP relies on the computation of the distance between inter-node, which provides the highest throughput. From Figure 4, it is clear that *EEPACORP* provides the highest throughput than APDRP and MARP with the different number of nodes highest throughput. Sending data only on the shortest route won't increase the throughput in *MANET,* which is followed by APDRP and MARP. *EEPACORP* identifies the route based on the optimization strategy and probabilistic calculation, and hence the route identified gives better lifetime and achieve better throughput than APDRP and MARP. Table 6 provides the result values of Figure 4. Table 7 provides the average throughput of *EEPACORP* and existing routing protocols.

Table 6 Result Values of Throughput (TP) Analysis

Nodes	APDRP	MARP	EEPACORP
50	204.372	207.804	211.180
100	201.395	204.478	208.031
150	197.697	200.695	205.945
200	194.332	197.264	201.027
250	189.876	193.191	196.421

Table 7 Average Throughput (TP)

Routing Protocols	Average *TP*
APDRP	197.534
MARP	200.686
EEPACORP	204.521

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6.4. Energy Consumption (EC) Analysis

Figure 5 highlights the energy consumed by EEPACORP, APDRP and MARP during the entire simulation period. Figure 5 demonstrates that all routing protocols consume more energy when the number of nodes increases. It is noted that EEPACORP has consumed low energy for data transmission than other routing protocols. Identification of shortest route via optimization leads to the route success rate for lengthier time in EEPACORP. The routes found without optimization by APDRP and MARP face more congestion due to the failure of the route that results in packet retransmission and more energy consumption. Table 8 provides the result values of Figure 5. Table 9 provides the average energy consumption of *EEPACORP* and existing routing protocols.
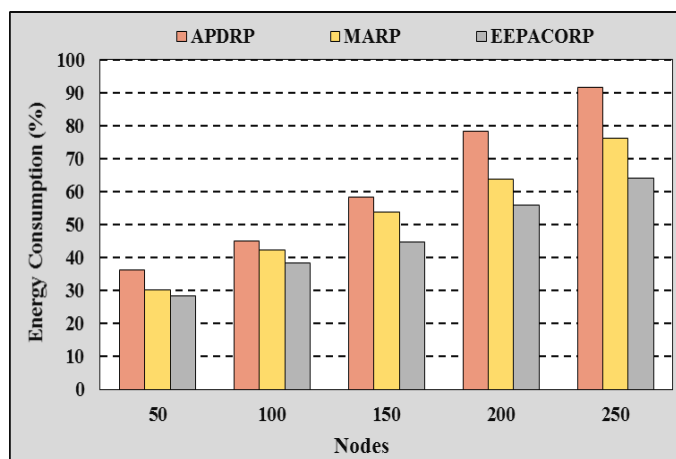

Figure 5 Energy Consumption (EC) Vs Protocols

Table 8 Result Values of Energy Consumption (EC) Analysis

Nodes	APDRP	MARP	EEPACORP
50	36.175	30.262	28.395
100	45.014	42.381	38.336
150	58.442	53.686	44.725
200	78.427	63.935	55.971
250	91.789	76.119	64.039

Table 9 Average Energy Consumption (EC)

Routing Protocols	Average *EC*
APDRP	61.969
MARP	53.277
EEPACORP	46.293

7. CONCLUSION

Energy-Efficient Perspicacious Ant Colony Optimization Based Routing Protocol (EEPACORP) is proposed in this paper to minimize the delay and energy consumption in MANET. EEPACORP is designed based on the natural characteristics of ants towards classifying and identifying the best route to the destination. The concentration level of pheromone is modified in EEPACORP to enhance the route's lifetime, resulting in better network lifetime. NS3 simulation is done to evaluate EEPACORP against existing routing protocols. EEPACORP consumes 46.293% less energy than the existing routing protocols APDRP and MARP, which spend 61.969% and 53.277%, respectively, according to the results. The future direction of EEPACORP can be focused on ensembling different bio-inspired strategies to reduce energy utilization even more.

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