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Research Article

Efficient Routing Protocol (ERP) for MANETS-IoT Systems

Dr.R. Suganthi[1], Dr. Mesith Chaimanee[2], Dr. Mithileysh Sathiyanarayanan[3]

[1]*Postdoctoral Fellow Researcher, Shinawatra University, Thailand, sugimanicks@gmail.com*
[2]*Faculty of Engineering, Department of IT, Shinawatra University, Thailand, mesith.c@siu.ac.th*
[3]*Faculty of Engineering, Department of IT, Shinawatra University, Thailand, mithileysh@mitsquare.com*

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ABSTRACT

An Internet of Things (IoT)-integrated mobile ad hoc network (MANET), referred to as MANET-IoT systems, consists of interconnected mobile and IoT devices, often operating with limited battery capacity. In such systems, existing routing protocols consume significant energy and time for path identification, which impacts the overall system performance. The purpose of this paper is to suggest a new Efficient Routing protocol (ERP) Protocol for MANET-IoT systems to enhance network performance by efficiently selecting intermediate forwarding nodes according to the Position details about the destination node. This approach reduces the path searching process, thereby lowering overall energy consumption. Simulations are conducted using the ns-2 simulator. The proposed protocol is simulated using wireless nodes and IoT devices and compared with existing Position-based protocols, LAR and EELAR. The experimental results demonstrate that the ERP protocol significantly reduces total energy consumption, routing overhead, and transmission delay, while also extending the lifetime of devices. The outcomes of the simulation confirm The improved functionality of the suggested protocol in MANET-IoT systems.

Keywords: MANET-IOT, ERP, Efficient parameter (EP), Destination Position Request Message (DPRQ), Destination Position Reply message (DPRP).

INTRODUCTION

An Internet of Things (IoT)-integrated mobile ad hoc network (MANET, referred to as MANET-IoT systems, consists of mobile and IoT devices interconnected through wireless communication links without pre-established infrastructure or centralized control. During the deployment of MANET-IoT systems, several challenges must be addressed, such as restricted bandwidth, route with multiple hops, dynamic topology, abrupt link failure, limited battery capacity or energy, and security issues. Among these, efficient energy usage and minimizing transmission loss are critical, as the devices are often battery-operated, and communication links can break suddenly due to mobility and varying environmental conditions. The durability and dependability of the MANET-IoT system are improved by effective energy use and decreased transmission loss.

A mobile node's energy loss impacts its operation and, consequently, the network's lifespan. The performance of the network is further impacted by frequent packet loss brought on by mobility. To extend the lifespan of the network, it is necessary to consider the lifetime of each node.

All of the accessible nodes should share the load equally. Load balancing diminishes the likelihood of individual node failure, hence extending the network's longevity. Efficient Network lifespan can be increased and energy usage significantly decreased with minimal energy routing strategies [1],[2],[3]. There are three major categories of routing protocol. They are proactive, reactive and hybrid protocols. Routing tables are first maintained by the proactive routing protocol. They get information from the table's merchants and neighbors on a regular basis. A number of proactive routing techniques are covered in [2] and [4]. For small networks, the proactive routing protocol works well. Due to the significant routing overhead and challenging table maintenance, it is not appropriate for big networks. It uses more electricity and bandwidth [5]. The second is the protocols that are reactive, which do not keep the routing table up to date. When necessary, it initiates the route search procedure. The Origin node broadcasts the request packet to every neighbor that is available during discovery [4]. The path

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between the Origin and destination nodes is included in the reply sent by the destination node. It will transmit the data along the chosen path after determining the route [2],[5]. In contrast to the proactive routing protocol, this causes a decrease in routing overhead and an increase in delay.

Reactive protocols include Ad-hoc on Demand Distance Vector (AODV) [7], [8] and Dynamic Source Routing (DSR) [6]. The third routing protocol is hybrid, which combines the benefits of reactive and proactive protocols. Two zones are defined by each node. There is an outside zone and an interior zone. As a result, the hybrid protocols function as reactive protocols outside and proactive protocols within. One type of hybrid routing system is the Zone Routing system (ZRP) [9], [10].

In this work, a novel Efficient Routing (ERP) Protocol is proposed for MANET-IoT systems. The ERP protocol minimizes the path searching process by identifying The destination node's position (DN) and appropriately selecting the most appropriate node to transmit data. This approach reduces routing overhead, thereby improving the overall efficiency and performance of the MANET-IoT network.

RELATED WORK

Here, a few of the routing protocols are examined.

Flooding

Many routing protocols, including DSR and AODV, use the fundamental route finding method to determine a path between the Origin and the destination. This process often relies on flooding, which involves every network node during path identification. However, Flooding reduces the overall lifespan of the network by using up the energy of all participating nodes [4].

Location-Aided Routing (LAR) protocol

A distributed location service provides the location data needed by the Location-Aided Routing (LAR) protocol. By utilizing location data, LAR minimizes the search space for route discovery [11], [12], [13] Both the sender and the recipient are included in this search area, which is a tiny rectangular area. A message requesting a route is broadcast by the Origin node inside this rectangle, and the destination node responds via the intermediary nodes. The reply message contains the addresses of these intermediate nodes. Subsequently, the Origin transmits data along the identified path. This approach conserves energy by excluding nodes outside the defined search area, thereby extending the network's lifetime. However, the nodes within the rectangle experience increased energy consumption due to their repeated involvement in communication [14], [15].

Energy Efficient Location Aided Routing (EELAR) Protocol

EELAR [10], [12], [17] was introduced as an enhancement of the LAR protocol. By limiting the route finding process to a narrower search zone, it saves a substantial amount of energy for mobile nodes. Unlike LAR, which uses a rectangular search region, EELAR reduces the search area to one-third of the rectangle. All nodes can access the location data of mobile nodes, which is maintained by a reference wireless base station. A route request is started by the Origin node. within the defined search region, and the destination responds with a reply containing the addresses of intermediate nodes. The Origin then transmits data through these intermediate nodes. EELAR reduces energy consumption and routing overhead compared to LAR. Direct transmissions take place inside a zone, while inter-zone transmissions are routed via the base station, adding to the base station's workload.

Minimum Energy Routing (MER) Protocol

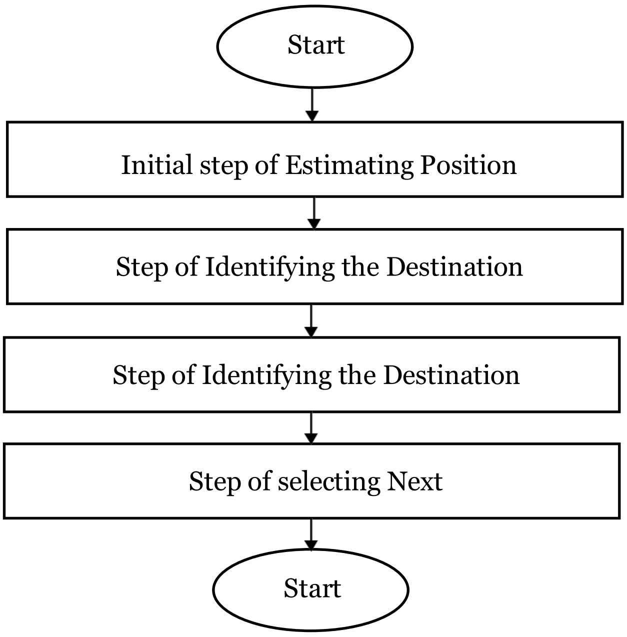
Minimum Energy Routing (MER) [18], [16] focuses on transmitting data packets along an approach that requires the least quantity of energy. Determining the energy usage for route finding and data transfer across all accessible paths is required to do this [19]. However, this calculation process increases network overhead. Consequently, When determining the most energy-efficient route, MER leads to increased routing overhead and energy usage.

PROPOSED WORK

The ERP combines both proactive and reactive concepts along through the Position info. For large network, the Position information is used. This protocol is used to safeguard energy and thus improves the network lifespan.
It makes advantage of the destination's position, "D". Based on the Position, it chooses the optimal intermediate node. It does not send any route requesting message. But it sends the Position requesting message. The Origin 'O'

directly transmits data through the selected intermediate nodes. The leftover nodes do not participate in the communication, so their energy is retained. The 'O' uses the parameter which is named as Efficient Parameter (EP) to choose its neighbor node as the following hop for dispatching the data to the data terminating node. The node parameters like residual energy, distance, velocity of that node are utilized to compute the Efficient Parameter. The maximum value of the EP represents that the node is best for communication.

The work flow of ERP protocol



Initial step of Estimating Position

Each individual node utilizes a GPS positioning system to determine its Position, represented by coordinates (X, Y) [20], [21]. All nodes' Position data in a Position table must be kept up to date by a Central Node (CN). To update this information, each node periodically transmits a Beacon signal to the Central Node. Figure 1 illustrates the Beacon signal.

Node Number	X Coordinate	Y Coordinate

Figure 1: The Beacon Signal format

The table 1 shows the Position table which is maintained in CN. The nodes are represented by their numbers like n1, n2, n3.....nN. N represents the total quantity of current network nodes. The value (X1,Y1) is the Position coordinate of the first node n1. The value (X2,Y2) is the Coordinate of position of the second node n2.

Table 1: The Position table in the CN

S.No	Node Number	X Coordinate	Y Coordinate
1	n1	X1	Y1
2.	n2	X2	Y2
....			
N	nN	XN	YN

There is a circular transmission range for every node. The figure 2 shows The node's transmission range which is circular and with a collection of Neighbor Nodes (NN). Both the transmission power level and the antenna utilized in the node affect the range of transmission. Within the range of transmission, the neighbor nodes are accessible.

Edge Nodes (EN) are the nodes that are located within the transmission edge. All of its NN and EN can establish direct contact with the node. To communicate with people outside of the transmission range, use the edge nodes.

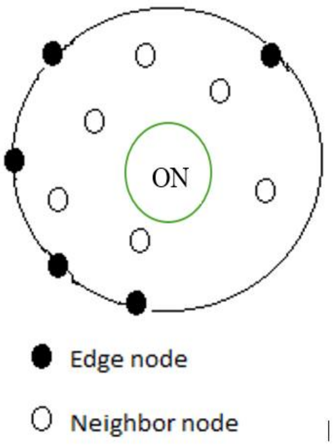


Figure 2: The Origin Node surrounded by Edge and Neighbour Nodes

The table 2 displays the Neighbor Table for a specific node. Every node keeps track of data about all of its neighbors in a Neighbor Table (NT).

Table 2: The Neighbor Table in each node

S.No	Node number	Time stamp	X coordinate	Y coordinate	distance	energy	Velocity	Status of movement
1	N_1	T_1	X_1	Y_1	D_1	E_1	V_1	Inwards
2	N_2	T_2	X_2	Y_2	D_2	E_2	V_2	Outwards
3	N_3	T_3	X_3	Y_3	D_3	E_3	V_3	Not moving
4	N_4	T_4	X_4	Y_4	D_4	E_4	V_4	First entry

Nodes periodically transmit beacon signals, allowing each node to identify its own set of neighbors. Upon receiving a beacon signal, a node checks its table for an existing entry for the transmitting node. If no entry is found, a new entry is created, recording the X coordinate, Y coordinate, timestamp, and energy of the neighboring node. The distance (D) and velocity (V) are then calculated using the provided formulas using equations 1 , 2 and stored. Here, (X_{ON}, Y_{ON}) represents the origin node's (ON) coordinates, and (X1, Y1) represents the coordinates of its neighbor [15].

$$D= \sqrt{((Y_1 - Y_{ON})^2 + (X_1 - X_{ON})^2)} \qquad (1)$$

$$V= (D_2-D_1) / (T_2-T_1) \qquad (2)$$

If an entry for the same node already exists in the Neighbor Table (NT), the node updates the Position coordinates (X, Y) and recalculates the distance and velocity. It then compares the new distance with the previous one. If the new distance is greater, it records that the node is moving away. Conversely, if the new distance is smaller, it records that the node is moving closer. In Table 2, there are four entries: Node 1 is moving closer to the origin node (ON), Node 2 is moving away from the ON, Node 3 remains stationary (as two consecutive beacon signals show the same Position), and Node 4 has newly entered the ON's coverage area.

Step of Identifying the Destination Position

The origin node (ON) transmits a Position Request message to the central node (CN). Figure 3 illustrates the Position Request message, where "R" indicates that it is a request message. The message's destination node's (DN) address is included by the ON.

R	Destination Node address	Central Node address

Figure 3: The Position Request message

The central node (CN) responds to the origin node (ON) with a Position Reply message, including the destination node's (DN) Position information (X coordinate, Y coordinate). The CN retrieves this information from the Position table before sending the reply. Figure 4 depicts the Position Reply message, where "r" indicates that it is a reply message. The ON extracts the DN's Position details from the reply message.

r	Destination node Address	X coordinate value	Y coordinate value

Figure 4: The Position Reply message

Step of Identifying the Destination Region

During this stage, the destination node's (DN) region is determined by the origin node (ON). Among all the available Edge Nodes, the ON selects just one. To streamline the process of selecting the Edge Node, the Four separate regions make up ON's transmission range. The division of the node's transmission range into these four Regions is shown in Figure 5.

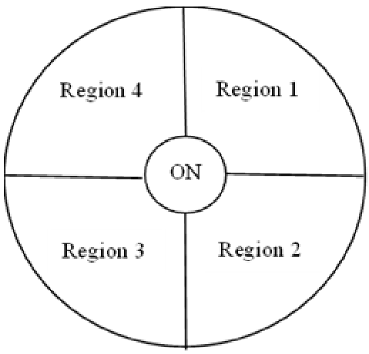


Figure 5: The Origin Node transmission range is parted into four regions

The origin node (ON) first checks if the receiver is one of its neighbors. If the receiver is a neighbor, the origin sends the data directly. However, if the receiver is not a neighbor, one of its edge nodes is selected by the ON as the subsequent hop. The ON determines the Region and only considers the edge nodes in that selected Region, excluding the other three Regions.

Pseudo code to select the Target Segment

//Origin Node Position (X_O, Y_O)

//Destination Node Position (X_D ,Y_D)

//Origin node finds the region of 'D'

If X_O is less than X_D, and Y_O is less than Y_D, 'O'chooses the region 1 as 'D' region

ElseIf X_O is less than X_D, and Y_O is greater than Y_D, 'O' chooses the region 2 as 'D' region

ElseIf X_O is greater than X_D, and Y_O is greater than Y_D, 'O'chooses the region 3 as 'D' region

ElseIf X_O is greater than X_D, and Y_O is less than Y_D, 'O' chooses the region 4 as 'D' region

End

Step of selecting Next

The best edge node is selected in this stage to transfer the data to the following hop. Once the Region is selected, the origin node (ON) picks the next hop node within that Region. The ON evaluates all the edge nodes by calculating their Efficient Parameter (EP). The node with the greatest EP value is subsequently chosen to be the packet's next hop. The formula for calculating the EP value is provided as follows:

$$EP_i = \frac{E_i}{d_i V_i} \quad / \textit{ If } V_i \neq 0 \qquad (3)$$

$$EP_i = \frac{E_i}{d_i} \quad / \textit{ If } V_i = 0 \qquad (4)$$

with EP_i standing for the ith neighbor node's efficient parameter.

E_i stands for Energy Left in That Node.

d_i= The separation between the neighbor node and the DN

V_i is the ith neighbor node's movement velocity.

Equation 3 provides the formula for calculating the EP value when the velocity is non-zero, while Equation 4 outlines the formula for the EP value when the velocity is zero.

Three parameters are used to calculate the EP value: The distance between a node and its destination (DN), its velocity, and its leftover energy. It is essential to choose the node with the largest residual energy since data will be lost if a node's energy runs out while it is being transmitted. A higher EP value indicates a node with more energy. Next, the node's velocity is considered. Data loss could occur if a node traveling quickly leaves the transmission range before getting the data. Therefore, selecting a stable or slower-moving node is preferred. For a stable node, the velocity is zero, and in such cases, the ON does not factor in velocity. A higher EP value suggests the node is moving slower. If two edge nodes have the same energy and velocity, the node closer to the destination is selected. A higher EP value in this case signifies the node's proximity to the destination.4. Hardware Implementation.

SIMULATION AND RESULTS

To evaluate the ERP's performance, the Network Simulator-2 (NS-2) has been used. 100 nodes are used. Initially, the nodes were located arbitrarily in the indicated area. The opening energy of each node is taken as 2J. The Rate of Data is set to 5 Mbps. IEEE 802.11's distributed coordination feature is selected as the MAC layer protocol. The simulation has been carried for 100 seconds. The NS 2 simulator is employed to model the suggested protocol, and the simulation outcomes are compared to those of the current protocols, LAR and EELAR.
The procedure followed in simulation

Writing TCL script (.tcl Extension file)
Executing TCL script
Generating Trace and NAM file.
Executing AWK script for performance evaluation.

Figure 6 displays a screenshot of the output from the NS2 simulation.

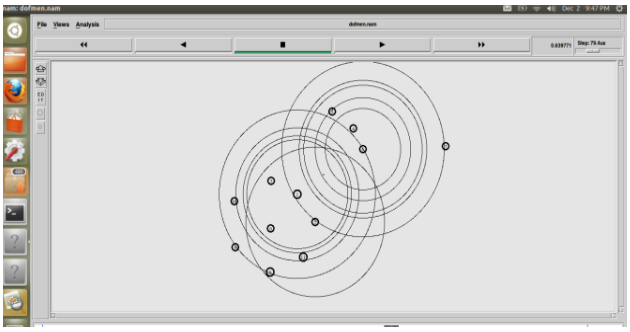


Figure 6: The Screenshot of ns2 simulation

Performance Metrics

Three performance metrics are utilized in the performance analysis of the proposed protocol.

Routing Overhead

The whole amount of routing packets which are used for route establishment is divided by the complete sum of data packets that were delivered gives the metric is named as the routing overhead ratio.

Routing overhead = (No of routing packets / (No of routing Packets +No of data packets sent)) (5)

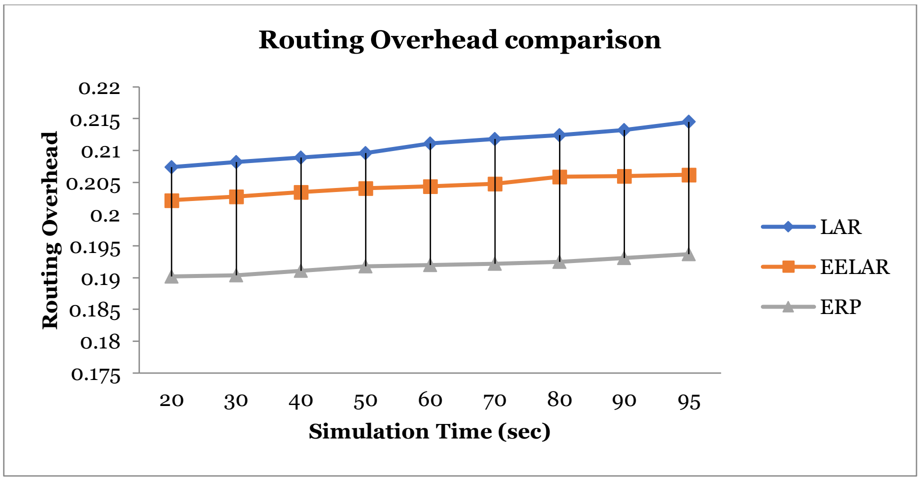


Figure 7: Routing Overhead Comparison

Figure 7 displays the comparison of the Routing Overhead of the ERP protocol, and routing overhead of the existing protocols. The ERP has reduced Routing Overhead. For LAR routing, the complete set of nodes in the request zone play a part in the flooding, and this increases the routing overhead. For EELAR routing, the routing zone is reduced, and hence the routing overhead is also decreased. For ERP the flooding is not happening there. Based on the forwarding node's attributes and the destination node's direction, the Origin node chooses the forwarding node directly to transmit the data. Hence the routing overhead has been reduced much. The observed thing from the simulation is that the routing overhead increases for all considered protocols when simulation time increases. Over large simulation time, the possibility of link breakage, and data loss increases.

Throughput

Network throughput is the charge of fruitful communication message deliverance through a communication channel. how many packets are successfully received in a certain amount of time. Average Throughput is the number of bytes successfully received, and is calculated by Equation (6).

Throughput= (Number of bytes received*8) / (Simulation time x 1000) kbps (6)

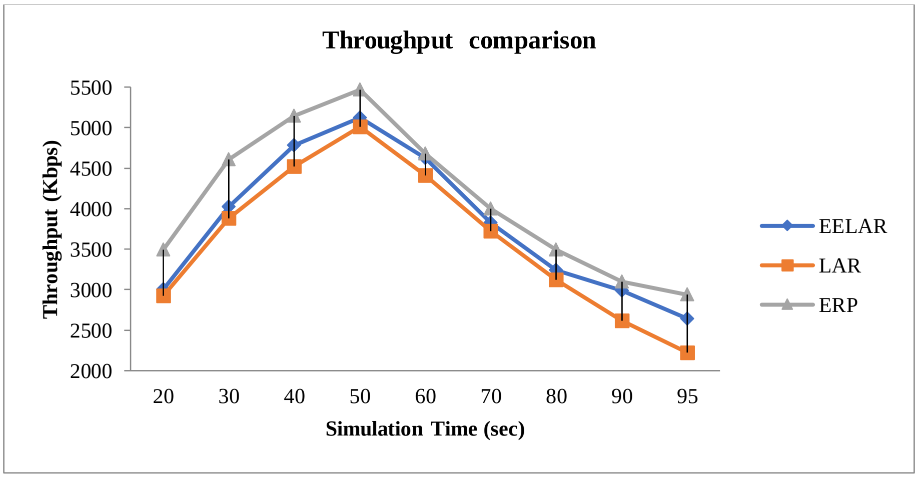


Figure 8: Throughput comparison

The Figure 8 shows that The ERP protocol increases the throughput. The throughput value increases with an increase in simulation time. But after 60 seconds the random movement of nodes is introduced. The nodes are moving, hence the link break occurs, and thereby the throughput value has been reduced for all the protocols.

Total Energy Consumption

During simulation, the energy of the nodes is reduced for data communication, and other processing. The reduced amount of energy is called as energy consumption. At the beginning of the simulation, the opening energy is defined. During simulation the energy value is gradually decreased. At the termination of the simulation, the remaining energy value is calculated, and is factored with respect to the initial value. The Equation 7 will produce the value of total energy ingestion.

Total Energy ingestion= (Total amount of energy spent over the Transmission of all the packets) (7)

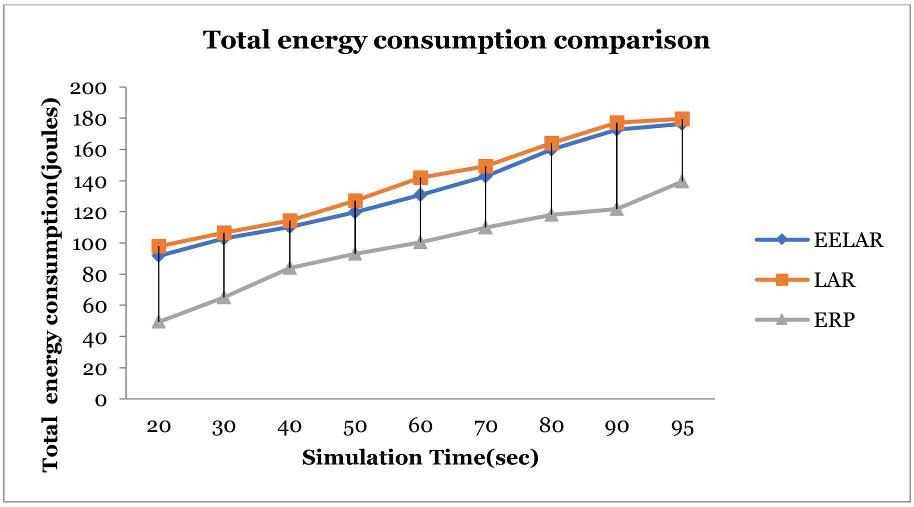


Figure 9: Total energy consumption comparison

Figure 9 shows a comparison between the ERP's overall energy consumption and that of the current protocols The total energy intake is lower in ERP procedure. All of the network's nodes have well-adjusted energy reduction. The network's lifespan is now longer than it was previously.

Packet Delivery Ratio (PDR)

The PDR is the fraction of the data packs that were conveyed to the destination node to the data packs that were generated by the Origin. PDR is determined in this manner using the Equation (8).

Packet Delivery Ratio=Total number of packets successfully received/Total number of packets transmitted (8)

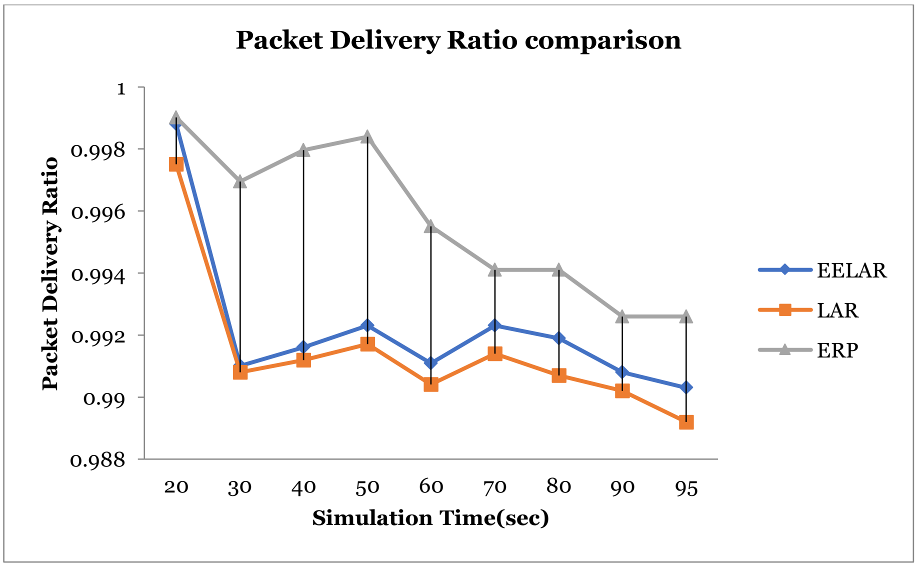


Figure 10: Packet Delivery Ratio comparison

Figure 10 compares the PDR of ERP, EELAR, and LAR protocols under various simulation times. It displays that the protocol ERP has better packet delivery ratio as compared with LAR, and EELAR. In LAR and EELAR protocols the data packet is transmitted via the chosen path. The path is taken from the route replying message. But those two protocols do not consider the mobility, and leftover energy of the selected forwarding nodes. The route reply from the destination node to the Origin node identifies the whole path. But actual data transmission is taking place after some time. Hence the possibility of link breakage is there. Some packets are lost. The PDR is reduced. But in ERP each node selects the next forwarding node based on their energy value, and mobility on time. After selecting the forwarding node, it will immediately transmit the data. Hence the possibility of link breakage, and data loss is less. The PDR is raised in the proposed ERP protocol.

CONCLUSION

In this paper, we initially talked about the Position based routing protocols. We proposed Efficient Routing Protocol (ERP) protocol for MANET-IOT systems that improves the network performance by reducing network routing overhead, end-to-end transmission delay and total power consumption. With the aid of position data, it chose a single edge node with highest EP value as its subsequent hop. The node that was chosen moves slowly, has more left over energy, and is the furthest away from the origin node. By distributing the load evenly across all nodes according to their remaining energy, it extended the network's lifespan. From the conducted experiment it has been observed that ERP protocol outperforms than the existing Position based routing protocols LAR and EELAR.

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