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IEEHR: Improved Energy Efficient Honeycomb based Routing in MANET for Improving Network Performance and Longevity

[1]Dr. J. Martin Sahayaraj, [2]Dr. N. C. Sendhil Kumar, [3]Dr. P. Mukunthan, [4]Dr. N. Tamilarasan, [5]S. Jaya Pratha
[1-4]Professor, [5]Assistant Professor,
[1-5]Department of ECE, Sri Indu College of Engineering and Technology,
Hyderabad-501510, T.S,India
[1]phdresearchmail2018@gmail.com, [2]ncsendhilkumar@gmail.com, [3]mukunthanece@gmail.com, [4]neithalarasu@gmail.com,
[5]jayapratha109@gmail.com

Abstract— In present scenario, efficient energy conservation has been the greatest focus in Mobile Adhoc Networks (MANETs). Typically, the energy consumption rate of dense networks is to be reduced by proper topological management. Honeycomb based model is an efficient parallel computing technique, which can manage the topological structures in a promising manner. Moreover, discovering optimal routes in MANET is the most significant task, to be considered with energy efficiency. With that motive, this paper presents a model called Improved Energy Efficient Honeycomb based Routing (IEEHR) in MANET. The model combines the Honeycomb based area coverage with Location-Aided Routing (LAR), thereby reducing the broadcasting range during the process of path finding. In addition to optimal routing, energy has to be effectively utilized in MANET, since the mobile nodes have energy constraints. When the energy is effectively consumed in a network, the network performance and the network longevity will be increased in respective manner. Here, more amount of energy is preserved during the sleeping state of the mobile nodes, which are further consumed during the process of optimal routing. The designed model has been implemented and analyzed with NS-2 Network Simulator based on the performance factors such as Energy Efficiency, Transmission Delay, Packet Delivery Ratio and Network Lifetime.

Keywords- Honeycomb, Location-Aided Routing, Energy Efficiency, Optimal Routing, MANETs.

I. INTRODUCTION

The MANET is formed with the group of mobile nodes and the ad hoc model is stated as a dynamic multi-hop wireless network, which does not have an infrastructure or central control. The Mobil ad-hoc network can be organized faster, since there is no defined and expensive design model. This nature makes the network effectively applicable in various military and rescue management operations [1]. Because of the node mobility, efficient routing is a challenging part in MANET, which required proficient methodologies. In general, the Mobile Ad-hoc Networks are self-configuring and self-directional in nature [2].

For providing data communications and node mobility, battery resources are used in MANET. So, it has limited energy resources, which has to be consumed effectively with efficient protocol design for routing and data forwarding. The basic infrastructure less MANET network is given in Figure 1, in which the mobile nodes are connected without any central admin. Moreover, it is to be stated that the nodes in the network can be connected or disconnected dynamically at any time [3]. Because of the flexible nature of the mobile ad-hic network, it has been adopted in many applications such as, habitat and ocean monitoring, target tracking, social networking, etc [4], [5], [6] and [7].

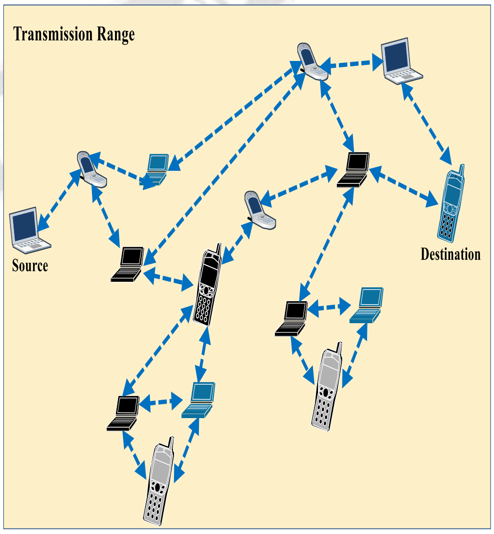

Figure 1. Basic MANET Architecture

The general classification of Routing Protocols of MANET is given in the Figure 2. The MANET routing protocols are broadly classified into,

- Geographic Routing Protocols
- Topology Based Routing Protocols

A Geographic based Routing Protocols:

It can also be termed as Position based Routing Protocols, in which nodes are not required to maintain the network topology based information, since they are topology free model. Instead, they only rely on the location information of nodes for packets forwarding. In general, nodes are needed to have knowledge about its own geographic positions and also the locations of their neighbours and the position of the destination nodes in which the packets are required to send. Based on the location information, routing is established by sending packets hop by hop till it reaches the destination.

B Topology Based Routing Protocols:

Topology based routing protocol can also be termed as the table-based routing that depends on the current topology of MANET. Further, the topology based routing can be classified into,

- Proactive Routing Protocols
- Reactive or On-demand Routing Protocols
- Hybrid Routing Protocols

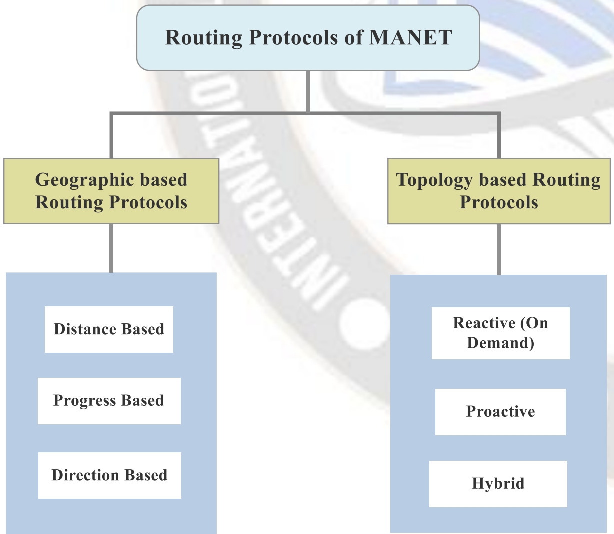

Figure 2. Routing Protocols of MANET

In the several types of routing protocols, Location Aided Routing protocol comes under the Reactive source routing that is operated through Global Positioning System (GPS). The protocol is used for utilizing the position information to enhance the efficiency of the route finding process, in which it is constrained with request zone that comprises the source node location and expected region [8]. For efficiently evaluation the energy utilization over nodes, Honeycomb based model has widely studied and incorporated in this paper. Such kind of bionic algorithms can pretend to be the operational activities of the living beings on land. Moreover, this model has been included for pervading simple heuristic rules into the expanded operations [9]. With that concern, the honeycomb algorithm is a kind of novel heuristic algorithm for solving the problems over combined optimization methodologies. Since, it has the characters like distributed processing, giving positive feedback and adaptive functionalities, the approach has more advantages to be integrated with energy efficient routing model in Mobile Ad-hoc Network [10]. Furthermore, energy preservation of nodes can be properly handled with the LAR protocol. The Geographic Adaptive Fidelity (GAF) can be used for conserving the power during the offline modes also. In that, honeycomb model provided zero data packet loss when compared with other algorithms. Typically, each cells of honeycomb covers the all edges of possible cells that are adjacent (with unit maximum distance). Hence, the cells at the next-hops are uniformly reachable to the defined cell. For that wide and easy coverage, the techniques of honey comb model is infused with the LAR for energy preservation in the MANET.

The remainder of the paper is organized as follows: Section 2 deliberates the existing models and functionalities for efficient routing in MANET. Section 3 presents the research background details that includes the operations in LAR and typical honeycomb structure. Section 4 describes about the work process involved in the proposed Improved Energy Efficient Honeycomb based Routing (IEEHR) model. Simulation results and comparisons are given in the section 5 and finally, section 6 concludes the paper with ideas to future enhancement.

II. RELATED WORKS

The Zone based routing (ZCG) has been given in [12] using the collision broadcasting protocol. The model has utilized lower energy in avoiding repeated transmission of data packets and attained maximum reachability of transmission region. Moreover, in this model, the region has been divided into number of zones, which comprise efficient leaders accordingly. In [13], an Optimal Path Selection Model (OPSM) has been developed for disaster management applications in MANET. In OPSM, the route selection process was worked on the basis of link lifetime and the power rate of nodes. The links that were having maximum probability of failure would not be considered for the process of routing. Further, residual energy of the links were considered for route maintenance.

In [14], Enhanced Proactive Source Routing (EPSR) has been presented for developing multipath routing. Multipath routing has been performed by an efficient multipath routing. In another work [15], for reducing the consumption rate of energy, lossy and loss-less data aggregation model has been proposed for efficient data transmission. In [16], the authors have presented a bi-objective optimization technique. The stability of the links between nodes and energy utilization rates of each node are considered for the process of optimal route discovery process in MANET.

Distance based Sleep Scheduling has been developed in [17], for handling the topological changes in MANET. The model has also been developed in such a way to reduce the energy consumption of the overall network and thereby, increasing the network longevity. Moreover, in this protocol, the farthest mobile nodes are given with more priority for routing. Energy utilization in this model has been reduced by the smaller group of nodes. Then, the overall network energy utilization has been reduced by implementing the sleep based model, which makes the idle nodes to sleep, thereby reducing the energy wasted by those nodes. In [18], it has given that the Dynamic Source Routing model has been developed for energy preservation with multipath routing. The varied traffic patterns have been examined along with the energy preservation.

Energy efficiency based multipath routing on the basis of Particle Swarm Optimization (PSO) has been presented in [19]. The model developed on the basis of Recurrent Neural Networks for training. Moreover, the communication cost, energy efficiency, traffic based issues and optimal route discovery. Mobility aware route discovery model was given in [20] based on clustering nodes. Cluster based routing has been used for enhancing the network throughput, reducing transmission delay and routing overhead. GAF techniques have been infused in [10] with WSN for power conservation, but the GAF model have some unreachable corners. A new routing model called Adaptive Energy and Location Aware Routing (AELAR) was given in [21] for effectively managing the energy conservation and reducing transmission delay. Moreover, the region has been divided into zones for providing optimal data discovery between the end nodes.

Permutation based K-means Clustering (PKMC) was developed in [22] for preserving energy in MANET routing. Based on k-mean clustering, clusters are formed on the basis of permutation technique during data communication. Energy optimization has been effectively handled in [23]. In addition to that, the node position data and energy management model has been used to optimize the energy utilization of each node and increase the network longevity. Moreover, the network identified the unused bandwidth and allowed the user, required additional bandwidth to use that resource to transmit the data packets.

In [24], mobility based topological structure has been discussed. The model used the 1-hop neighbour's node position in the communication region. But, the reliable communication was lack in the model and also cost effective. In [28], a model for secure routing in large scale MANET has been developed. Moreover, the model has been utilized for efficient resource sharing among the mobile nodes in the network.

It is observed from the analysis of related works; it is complicated to integrate the stability in path determination due to the mobility of nodes and packet loss. For enhancing that, Honeycomb model is integrated with LAR. Hence, the model used to cover all the edges of the transmission area using the IEEHR model.

III. BACKGROUND OF RESEARCH

C Location Aided Routing in MANET:

In MANET, the LAR protocol comes under the reactive or on-demand routing protocol. In the work process, the protocol uses the data about the location of the node for broadcasting the route_request packet towards the destination node only in the request region, instead of flooding it to the complete network. Moreover, the protocol selects the request region on the basis of the location of source_node and the destination_node respectively, whereas the anticipated or expected region is determined with respect to the location of the destination_node. The expected region is considered to in circular area, which is framed on the basis of the most recent information about the location of the destination_node (DN), with respect to the corresponding X and Y axis, as (Xdn, Ydn), the time_instant of the location (tm0), mobility speed of the DN as (MS) and the present time (tm1). With this location information, a radius for circle area is created as Rc=MS(tm1 - tm0) positioned at (Xdn, Ydn). Further, the request region is in rectangular structure, in which the corners are denoted as A, B, C and D. The source_node SN is at the corner A, at the position (Xsn, Ysn), with respect to the x and y axis. When there is a neighbour node of SN finds the source_node is at the area of request region, the route_request (R_REQ) packet is transmitted to that. As in typical, handshaking process, when the node DN receives the R_REQ, a route_reply (R_REP) packet is forwarded as a reply. In a case, when the node SN does not have the prior location information of DN, the complete network of the designed MANET is considered to be the expected region of the process [25] and [26].

Based on the reception of R_REQ packet, the nodes in between the SN and DN are involved in forwarding the R_REQ to the entire nodes in request region. When there is a need of re-forwarding the R_REQ packets, only the nodes in the request region can perform the action, thereby effectively reducing the number of messages to be transmitted. This may

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also pave a way for efficient energy utilization and also involves in reducing the routing overhead. The size of the request region is directionally proportional to the average mobility speed of nodes and the elapsed time, which are given as (MS) and (tm1 - tm0) respectively. The Location Aided Routing technique can be effectively implemented, when there are a large number of data packets to be forwarded through the network effectively. The typical demonstration of LAR mechanism is given in the Figure 3.

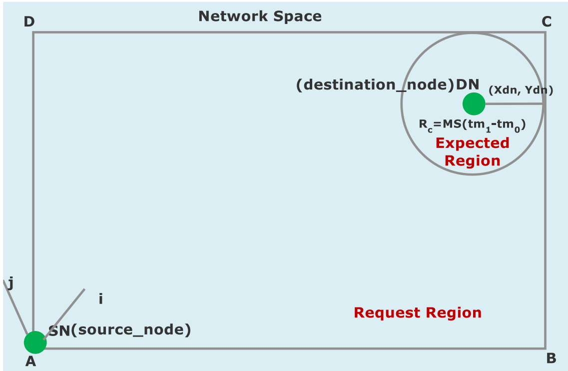

Figure 3. LAR Mechanism

D Honeycomb Structure:

In Honeycomb architecture, the hexagonal grid structure is used to cover all areas in the cell efficiently [27]. In typical GAF structure, square grid structure is used, where as in honeycomb structure, it is replaced with the hexagon cells. In the figure 3, it is shown that the cell A has 6 neighbors, covers the region from all directions. In case of square cell structure, it has 8 neighbors comprises, 2 vertical edges, 4 diagonals and 2 horizontal edges. Among that, only four edges are covered with the next hop link, while in honeycomb structure all possible six edges are covered for communication with one-hop distance because of it symmetric nature. Hence, all the next-hop cells for the hexagonal cell A are evenly reachable.

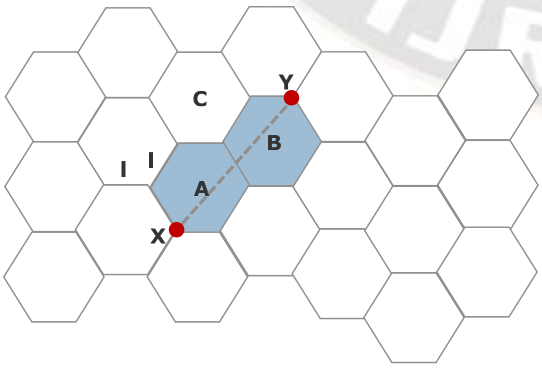

Figure 4. Honeycomb Structure

From the Figure 3, ‘l’ is considered to be the length of each edge, then, the longest distance between the two neighbour cells, here A and B, is demonstrated by the line (X, Y),

$$Dist_{(X,Y)} = \sqrt{13}\, l \quad (1)$$

The maximum value for the edge length (l) is formulated as,

$$r_{max} = {}^{L}/_{\sqrt{13}} \quad (2)$$

Following, the area of each hexagonal cell (HC) is given as,

$$HC = 3\sqrt{3}\ {}^{L^2}/_{26} \quad (3)$$

When the size of the network is taken as S with ‘n’ nodes, then, the number of nodes per HC will be calculated as follows,

$$NN_{HC} = 3\sqrt{3}\, n\ {}^{L^2}/_{26}\, S \quad (4)$$

Hence, incorporating the honeycomb structure in MANET with LAR, helps in covering all the unreachable edges of the cell in MANET communications.

IV. Work Process of Improved Energy Efficient Honeycomb Based Routing (IEEHR)

In the proposed Improved Energy Efficient Honeycomb based Routing (IEEHR), the effectiveness of utilizing honeycomb structure is incorporated in Location Aided Routing concept for framing an energy efficient routing model in MANET. The pictorial representation of the LAR implementation with Honeycomb structure is given in Figure 4. The methodology also includes energy derivation model for computing the Energy Consumption Rate (ECR) and the Residual Energy (RE) of each node.

E Energy Derivation Model:

In IEEHR, the energy levels of nodes are to be computed in every instant of processing packet transmission. Here, the Energy Consumption Rate (ECR) for a mobile node (MN) at an instant ‘Tm’ is derived as follows,

$$ECR_{Tm} = PT_t * u + PT_r * v \quad (5)$$

From the above equation, the ECR at time ‘TM’ is computed, using, ‘PT_t’ denotes the packet transmission amount transmitted by an MN and ‘PT_r’ denotes the amount of data packets received by a node MN at time ‘Tm’. Moreover, ‘u’ and ‘v’ are the energy efficiency constants, those values are between 0 and 1. When the initial energy of each node is considered as, EYinit, then, the remaining (residual) energy of an MN is calculated as follows:

$$EY_{resi} = EY_{init} - ECR_{Tm} \quad (6)$$

Based on this energy derivation model, the optimal route establishment process of IEEHR model is developed.

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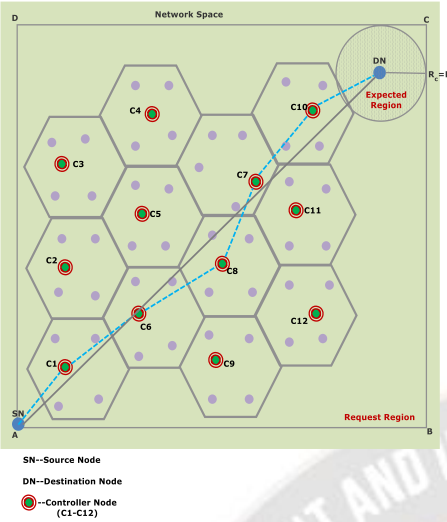

Figure 5. LAR Implementation with Honeycomb Structure

F Working Procedure:

The process of IEEHR comprises two phases and the working procedure steps are as follows.

Initially, the source_node SN is required to locate the destination_node DN, within the range of expected region, in the circle_radius Rc=MS(tm1 - tm0) and also with the assumption that the SN and DN, both are within the range of request region.

The request region that lies between the source and destination nodes is framed into hexagonal cells, within the range of network communication.

A path line has been framed between the SN and DN.

In each Hexagonal Cell (HC), there are many nodes presented. Among all, one controller node (c) has to be selected in each HC for forwarding the data packets in the network. Other than 'c', the remaining nodes are in sleep mode, to conserve the energy effectively. In the Figure 4, there are 12 hexagonal cells are considered between SN and DN, in that there are {c1, c2, c3, c4, c5, c6, c7, c8, c9, c10, c11and c12) controller nodes are used for data forwarding.

The Controller node can be selected on the basis of their energy levels, which can be computed as explained in the section 4.1.

The node 'c' can be switched among hexagonal cells, in accordance with their residual energy.

After the Source_node, the next-hop node can be selected on the basis of the distance of an MN from the base path line, as in LAR model. The distance is measured as the perpendicular line between the controller node and the path line. The node having minimal distance is selected as the next-hop node for data forwarding.

The process is repeated till the route path reaches the DN, which is in the request region.

In this process, the controller nodes are the active nodes, whereas the remaining nodes are considered to be at sleep for energy preservation in the network. This can increase the network longevity by reducing the energy depletion rate of each node. The solid line (Figure 4), which is drawn between the source and destination is the path line, referencing that line, the optimal routes are framed from SN to DN. The two phases of working procedure is presented in the Figure 5.

In the first phase of work, the request region and the expected region in the network space are considered to frame the model. The step by step work process is portrayed in flow diagram, in which the control nodes are selected to save the energy, which can be effectively utilized in the process of route establishment. For Optimal route discovery, the R_RED packet is forwarded from the SN to the next-hop node, which can be selected on the basis of the perpendicular distance of that MN from the path line drawn between SN and DN. This process is repeated till the destination node is reached. After the path determination, the confirmation has been given by forwarding a R_REP message from the source to the destination. Hence, optimal route has been established for packet forwarding, which increases the network lifetime and packet delivery ratio and, decreases the transmission delay effectively.

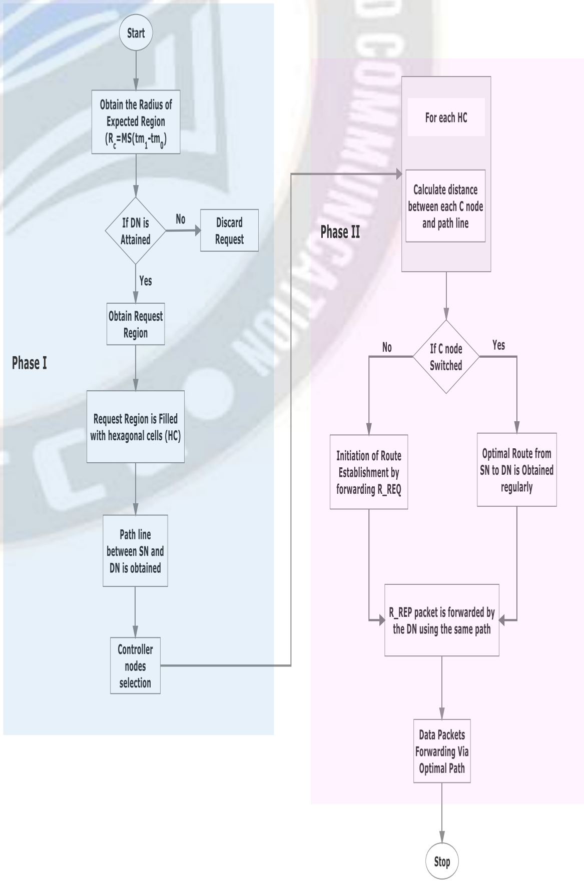

Figure 6. Working Process of IEEHR

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V. RESULTS AND DISCUSSIONS

The proposed IEEHR is simulated and evaluated using Network Simulator NS-2.34 and the results are compared with the existing protocols of MANET such as Optimal Path Selection Model (OPSM) and Adaptive Energy and Location Aware Routing (AELAR). Moreover, the network setup ranges from 20 to 40 mobile_nodes with the distribution area 1000×1000 m2. The evaluation has been done on the basis of decisive factors such as packet delivery ratio, Energy Consumption Rate, end-to-end delay and Network Longevity. The simulation has been executed for the developed IEEHR, OPSM and AELAR with some pre-defined simulation parameter values that are given as in Table 1. Moreover, the values of ‘u’ and ‘v’ are taken as 0.5 and 0.6 respectively, for energy derivation.

TABLE 1: SIMULATION PARAMETERS AND INITIAL VALUES

PARAMETERS	INITIAL VALUES
Simulator	NS-2.34
Terrain area	1000m x 1000m
Simulation Time	800 s
No. of nodes	Varies from 20-40
Simulation End Time	50.0
Mobility Model	Random Waypoint
MAC type	IEEE 802.11
Propagation Model	Two Way Ground
Traffic type	CBR
Traffic Rate	1-6 Mbps
Mobility speed	0-5 m/sec
Payload Size	512 bytes
Transmission Range	250 m
Initial Energy	5Joules per Node
Frequency	9 Mhz

In general, the network lifetime is defined as the total time, which the network activity extends or the time taken for half of the nodes in the network are to become inactive because of energy depletion. The chart presented in figure 6 portrays the number of nodes that are exhausted during the process of data forwarding in MANET. It is explicit from the figure that the nodes in the proposed routing model lose minimal energy, when compared to the other models. This is mainly because of using the controller nodes in the hexagonal cell to be active and making other nodes in sleep mode. In this process, the network lifetime can be improved for about 22% by efficient energy consumption of nodes in the HCs.

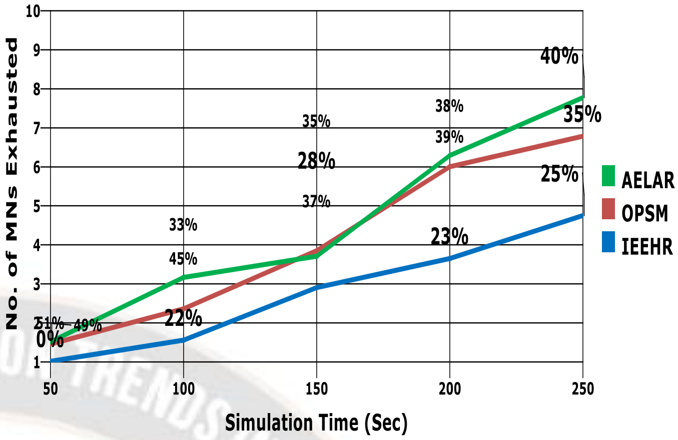

Figure 7. Simulation Time Vs Exhausted MNs

Energy Consumption Rate (ECR) is the significant factor to be analyzed and the calculation process is provided in the section 4.1. The figure 7 shows the results based on Energy Consumption Rate with increasing simulation time. The Energy consumption rate is considerable reduced in the proposed model, when compared with others.

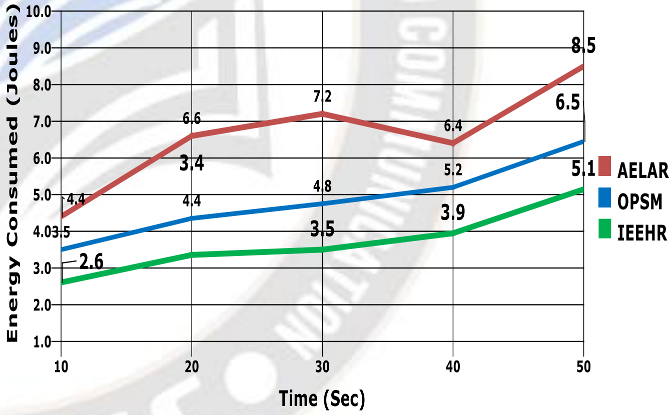

Figure 8. ECR Vs Simulation Time

Packet Delivery Ratio (PDR) is defined as the ratio of successful reception of data packets to the destination. Furthermore, the factor estimates the protocol efficiency. The Figure 8 and Figure 9 demonstrate the PDR values attained by the proposed model IEEHR, with respect to the number of nodes and the mobility speed of the nodes, respectively. The analysis has been made with standard pause time with varying number of MNs, from 25 to 40 and varying mobility speed that ranges from 5 to 25 m/s. The results of the analysis show that the proposed model provides higher rate of packet delivery ratio in both cases. In case of PDR analysis based on the mobility speed of nodes, the PDR value decreases when node velocity increases. Still, the PDR values of the proposed

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model is higher than the others, proves the efficiency of the proposed IEEHR.

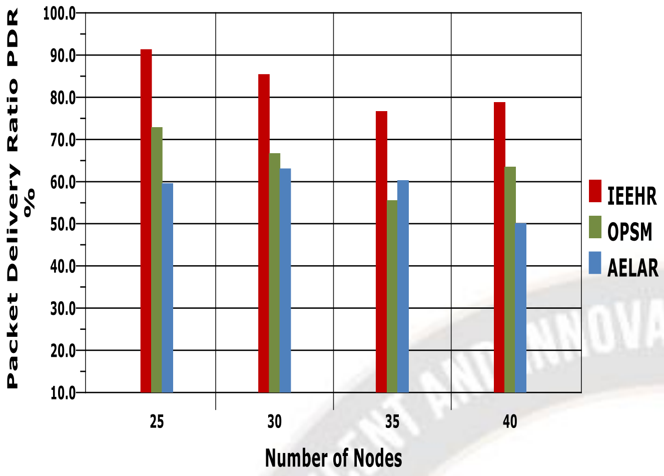

Figure 9. Packet Delivery Ratio Evaluation

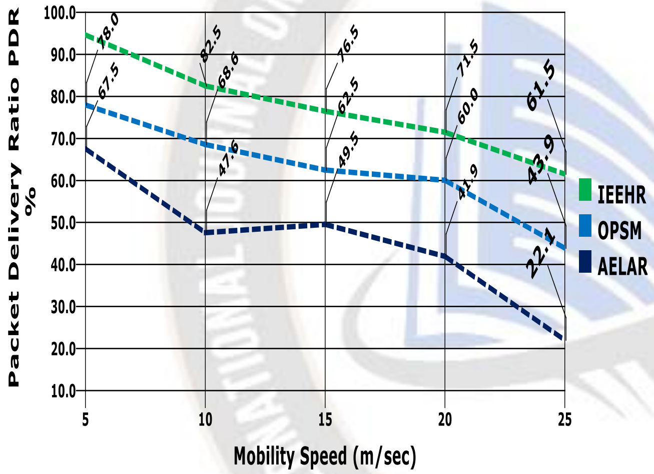

Figure 10. PDR Vs Mobility Speed

End-to-End delay is defined as the average time taken by the node to forward the data packets from the SN to DN through the optimal route. The results of End-to-End delay are presented in the Figure 10. It can be shown in the figure that, when there is an increase in mobility speed of the MNs, there is a slight increase in the delay. However, the proposed model produces lesser delay than others. This can be achieved by reducing the search area of destination, which also reduces the overall time taken for optimal route establishment.

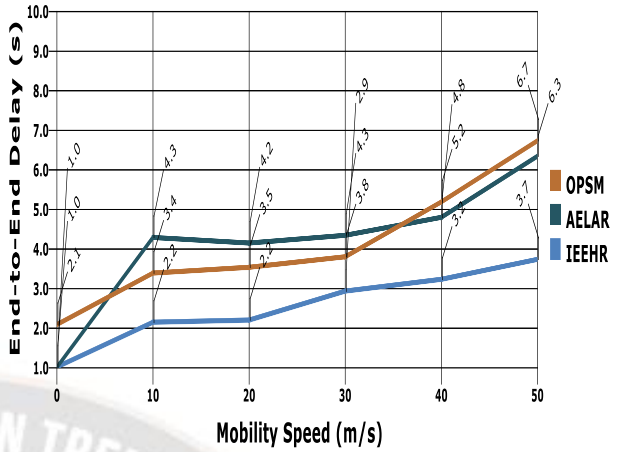

Figure 11. End-to-End Delay Analysis with Varying Node Mobility Speed

VI. CONCLUSION AND FUTURE ENHANCEMENT:

In this paper, Improved Energy Efficient Honeycomb based Routing (IEEHR) model has been proposed and analyzed. The model utilizes Location Aided Routing protocol with the honeycomb structure for efficiently developing a routing model, which covers all the edges in coverage area. Moreover, the optimal route between the source and the destination has been achieved by referring the path line that lies in between. The controller nodes are selected based on the obtained ECR and Residual Energy rates of all nodes. On the process of data forwarding, the mobile nodes other than the controller nodes are in sleep mode, which helps in energy conservation of nodes. This also enhances the network lifetime. The simulation results are provided based on the parameters such as PDR, End-to-End Delay, Energy Consumption Rate and Network Longevity. In the evaluation, the proposed model provides evidences for its efficiency by producing better results than the existing models and, makes that the IEEHR protocol provides reliable communication in MANET.

The work can be enhanced with some other bionic or evolutionary algorithms to improve the energy efficiency and communication reliability in advanced manner.

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