Energy Efficient Power Aware Routing Algorithm (EEPARA) For Mobile Ad Hoc Network (MANET)

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ABSTRACT

Currently, one of most innovative topics in computer communications is wireless networking. One area in wireless networking is ad hoc networking. The concept of ad hoc networking is based on the fact that users can communicate with each other using a mobile wireless network, without any form of centralized administration. Mobility with potentially very large number of mobile nodes, and limited resources (like bandwidth and power) make routing in ad hoc networks extremely challenging. Routing protocols for wireless ad hoc networks have to adapt quickly to the frequent and unpredictable changes of routing topology and must minimize the generated overall network overhead. To deal with these issues a large number of different routing protocols for ad hoc networking are developed, each with their own features and characteristics.

In a mobile ad hoc network, nodes are often powered by batteries. The power level of a battery is finite and limits the lifetime of a node. Every message sent and every computation performed drains the battery. One solution for power conservation in mobile ad hoc network is power awareness routing. Which select the routes with lower reluctance values, on average and with time, leads to better utilization of the energy resources of the devices in the network. This means that routing decisions made by the routing protocol should be based on the power-status of the nodes. Nodes with low batteries will be less preferably for forwarding packets than nodes with full batteries, thus increasing the life of the nodes. A routing protocol should try to minimize control traffic, such as periodic update messages to improve the lifetime of the nodes and network. However, not every routing protocol is suitable for implementing power awareness routing and different approaches on power awareness routing can be followed.

Our main contribution in this paper is energy efficient routing protocol. It addresses energy aware link cost computation and route discovery. The link cost is derived based on energy aware parameters such as transmission power between the nodes, the residual battery energy of nodes, receiving power and. The routing mechanism also addresses delay forwarding to minimize broadcast storm. This energy efficient routing protocol is named Energy Efficient Power Aware Routing Algorithm for Mobile Ad Hoc Network. Our goal in this paper is to propose Active Communication Energy Efficient routing mechanisms and protocols, satisfying less energy consumption from the viewpoints of nodes and network and select the shortest path from source to destination such that each node remains healthy after completing the data transmission. Power Awareness Routing is implemented using NS2 software.

Keywords

Ad-Hoc networks, Energy Efficient Power Aware Routing Algorithm (EEPARA), and Ad-Hoc on Demand Distance Vector Protocol (AODV), Mobile Ad-Hoc Network (MANET).

1. INTRODUCTION

A mobile Ad-Hoc network (MANET) [1] is an autonomous system of mobile nodes (and associated hosts) connected by wireless links. Mobile Ad-Hoc Network (MANET) is a wireless network without any fixed infrastructure or centralized control; it contains mobile nodes that are connected dynamically in an arbitrary manner. Based on infrastructure, the wireless networks broadly classified into two types, first type infrastructure networks contains Base stations. The second type is called Mobile Ad-Hoc Networks enable users to communicate without any physical infrastructure regardless of their geographical location. Each node operates not only as an end-system, but also as a node to forward the packets. The nodes are free to move about and organize themselves into a network. The main application of mobile Ad-Hoc network is in emergency rescue operations and battlefields. This paper addresses the problem of secure power awareness routing to increase lifetime of overall network. Since nodes in mobile Ad-Hoc network can move randomly, the topology may change arbitrarily and frequently at unpredictable times. Transmission and reception parameters may also impact the topology. Therefore it is very difficult to find and maintain an optimal power aware route. In general the main security requirements for any system will be confidentiality, authentication, integrity, non-repudiation, availability, and access control. Confidentiality ensures that eavesdroppers will not be able to read the information sent through the network which may be achieved by encrypting data and control packets. Authentication prevents impersonation and verifies the identity of the nodes. Integrity will insure that packets will not be modified or altered by an adversary [2]. Rest of the paper is organized as follows: Section 2 discusses the study on the related work. In section 3 working of the proposed (EEPARA) scheme have been given in detail. Section 4 simulation framework and results and Section 5 concludes the paper.

2. RELATED WORK

Prior to propose algorithm, many researcher's has proposed number of algorithm. In this section the work done by them has been discussed.

"Rishiwal" etal[3] has proposed an efficient algorithm, which maximizes the network lifetime by minimizing the power consumption during the route establishment from source to destination. During the threshold time, destination node calculate link status ratio of every request route. Finally energy consumption of node after time 't' is calculated. Path with minimum energy consumption is selected. In proposed EARQ algorithm by Junyoung Heo Jiman Hong, and Yookun Cho, [4] every node estimates the energy cost, delay and reliability of a path based only on information from neighbouring nodes and select the path with lower energy cost and has high throughput. But, the path selected sends a redundant packet via an alternate path that increases the power consumption. Longbi Lin and Xiaojun Lin proposed the algorithm based on optimizing power control, link scheduling, and routing. They developed **a** low-complexity and distributed algorithm that is power-efficient, especially under the node-exclusive interference model and with suitable assumptions on the power-rate function.

Jiayu Gong and Xiliang Zhong simulated a reward-based packet scheduling problem in wireless environments. They considered single transmitter communicating with multiple receivers periodically. For guaranteed transmission of data they associated each packet with a delay constraint. Since periodic data stream has different data size and power functions, transmitter obtains more reward as it transmits more data. They developed scheme that selectively transmits data stream of different data size at different transmission rates so that transmitter reward can be maximized for given time and energy constraints. [5]

There are some algorithms that select the path based on the accumulated energy of all nodes in the path. One of them has algorithm that compressed the data before delivering and use low power efficient scheme for transmission. [6]

In self-organizing routing algorithm providing topological adaptation in an energy-aware context at the network level have been proposed by Cesare Alippi, Romolo Camplani, and Manuel Roveri in their paper [7]. In which they suggested k-level hierarchical extension of the Low-energy Localized Clustering (LLC) algorithm that takes into account the estimate of the residual energy of nodes, the aggregation degree, and uniform coverage level of the monitoring area as well as extended lifetime for the network nodes.

ENERGY EFFICIENT POWER AWARE ROUTING ALGORITHM:

In proposed algorithm, after preparing the packet by adding appropriate information in the header, we calculate the distance from each of its neighbors to the destination and also calculate the minimum energy required for sending a packet. We find the paths which have highest energy by comparing available residual energy and minimum energy required. If the available energy is less than the minimum energy required we append the residual energy of that node the move to the next node. In this way after reaching the destination, we find the total route request packet reach at the destination. The destination will choose the path for route reply that has highest energy. The distance between two points on the earth surface can be calculated by using its latitude and longitude coordinates. In this way we had tried to improve life time of network, throughput by keeping the participant node healthy after the completion of data transfer.

2.1 Design Functions

Following functions are considered while designing the proposed algorithm.

3.1.1 Energy-based routing cost computation:

Energy cost of a link in a route must be taken into account in Energy Efficient routing protocols during the route selection. There are different methods to calculate it depending on the objectives of the routing protocol. The important parameters such as power aware, cost aware and cost and power aware routing can be included during the calculation of link cost, where

- ✓ **Power aware routing:** In this, the routing decisions are based on the transmission power and the transmission power depends on the distance between the source and the destination.
- ✓ **Cost aware routing:** In this, the remaining life-time of nodes is used as a metric for decision making.
- ✓ **Combining power and cost aware metrics:** In this, the transmission power and the node life-time are combined as a metric to calculate link cost. There are two ways to combine them. [9 the. sam.]

i) Power*cost:

$$\text{Power-Cost}(B, A) = f(A) * u(r) \quad (1)$$

Where A and B are source and destination nodes

'r' is the distance between B and A

f(A) life-time of node A

u(r) transmission power require at a distance r

ii) Power + Cost

$$\text{Power-Cost}(B, A) = \alpha u(r) + \beta f(A) \quad (2)$$

Where α and β weighting factors for transmission power metric and node life-time metric

3.1.2 Energy aware route discovery:

By taking energy aware parameters Energy Efficient routing protocols compute the link and route cost. Energy Efficient routing protocols use min-max route selection technique. In traditional route discovery methods initiate the route discovery by broadcasting request and it is assumed that it is heard by the neighboring nodes, all these nodes than rebroadcast the packets. These rebroadcast packets are again heard by all. A node that has already rebroadcasted the request ignores it. And finally the destination node replies back to the request it has heard from. But during this complete process the energy efficient route is not discovered. Therefore, the route discovery mechanism of these protocols must be customized to be energy efficient.

3.1.3 Energy Aware route maintenance:

In general route maintenance is carried out only when the links are broken by the use of route error packets. There is no mechanism to indicate change in the quality of a link, change in the energy cost requirements due to node mobility. The changes in the energy costs of the links must be tracked regularly so that the energy expended is as close to the minimum value as possible. As per the movement of nodes the transmitting power must change. It must decrease when nodes move closer to increase energy saving and must be increase to maintain the link if it moves away. So these changes in the energy cost must be conveyed to the source node, so that it can choose other lower energy cost routes as required. Hence an energy efficient routing protocol must have a mechanism for tracking the link energy cost changes.

3.1.4 Energy Aware Load Balancing:

The main goal of Energy Aware Load balancing is to maintain the energy usage of all mobile nodes by selecting a route with underutilized nodes instead of the shortest route. This may give the longer routes but the packets are routed through energy-rich intermediate nodes. Protocols based on this approach may not give the lowest energy route, but it will prevent certain nodes from overloading and so increase the network life time.

3.2 Design Parameter:

Proposed algorithm is design considering following parameters. Same parameters are used for comparing the two different setups and validating the result.

3.2.1 Packet Delivery Fraction (PDF):

It is the ratio of total number of packets successfully received by the destination nodes to the number of packets sent by the source nodes. PDF is very important metric as it describes the loss rate i.e. it gives the maximum throughput that the network can support. There are many reasons such as packet collisions in 802.11 layer, network partitions, routing loop and interface queue drop due to which packets may not be delivered to the destination. PDF is given as,

$$\mathrm{PDF} = \frac{\text{Number of packet Recived by the Destination}}{\text{Number of packets send by Source}} \qquad 3$$

A high value of PDF indicates that most of the packets are being delivered to the higher layers and is a positive sign of the protocol performance.

3.2.2 Energy Consumed per Successful Data Delivery:

It is represented by ECSDD. It is the ratio of total network energy consumption to the number of data packets successfully delivered to the sink. The network energy consumption includes all the energy consumptions except MAC layer controls**.**

$$\mathrm{ECSDD} = \frac{\sum_{k=1}^{N}(E_{ik} - E_{rk})}{\text{Total number of packet recived}} \qquad 4$$

Where Ei_k- is initial energy of node k

Er_k- is remain energy level of node *k* at the end of simulation

N- is the number of nodes in the network

A less value of ECSDD means that most of that packets being delivered with less energy and is an achievement sign of protocol on energy efficiency.

3.2.3 The Variance of Residual Battery Energy in Joules (VRBE):

It is a simple indication of energy balance and can be used to extend network lifetime. The value calculated indicates whether the routing scheme has overused any number of nodes or not. This is a very important performance metric because it is a measure of protocol fairness. Therefore, the sought value for this metric is one that is as close as possible to zero. The smaller ***VRBE*** indicates that all nodes in the network are equally important and no one node must be penalized more than any of the others. It is given as,

$$V_{RBE} = \frac{\sum_{k=1}^{N}(E_{rk} - \mu)^2}{N} \qquad 5$$

Where $\mu = \frac{\sum_{k=1}^{N} E_{rk}}{N}$

E_{rk} --is the residual energy of node k

3.2.4 Network Lifetime (NL):

It is one of the important metrics used to evaluate the energy efficiency of the routing protocols withrespect to network partition. In wireless Ad Hoc networks, especially where the nodes are distributed densely, the death of the first node seldom leads to the total failure of the network. Network gets partitioned with increased number of dead nodes. It is still possible to have end-to-end transmissions even if there is partitioning of network if there exists at least one pair of adjacent nodes working, since they could transmit to each other and keep the network alive. So, NL can be defined in the following ways

- ✓ It may be defined as the time taken for K% of the nodes in a network to die.
- ✓ The *lifetime of the network* under a given flow can be the time until the first battery drains-out (died)

- ✓ It can also be the time for all nodes in the network to die.

We adopt the second definition for analysis of this paper. Here, a node with less than 10% of its full battery capacity is considered as a dead node.[108]

2.2 Explanation of Methodologies EEPARA

The main objective of this algorithm is to improve the active communication energy efficiency of the routing protocols. The energy efficient routing protocols must be designed on the view point of the nodes and the network. The network lifetime is directly influenced by the nodes' lifetime in the network because the nodes act in the network as router and host. The energy consumption can be reduced by designing routing protocols those select routes with less energy consumption for end-to-end packet transmission. Even if such type routing protocols save significant amount energy, they don't guarantee to prolong the network lifetime. Sometimes these protocols may shorten the network lifetime since they use specific routes repeatedly by considering of the end-to-end energy consumption. It is clear that the network lifetime is not only depending on the minimum energy consumption for packet but also energy aware load balance. We design energy efficient routing protocol of MANETs that discovers the route based on energy aware metrics.

1. Proposed work will be start with understanding current work on Power-Aware algorithm. Consideration of various parameter such as status of battery lifetime, type of data to be transfer, cost function, available bandwidth, propagation delay, and transmission power require is an important for developing required algorithm.
2. Development and Simulation of basic Network model with NAODV protocol for MANET to implement proposed power-aware algorithm will be done. It will include selecting energy efficient route by selecting path that has all healthy nodes and they remain healthy at the end of complete data transfer.
3. It includes calculation of energy consumption of node.
4. It bypasses energy-poor and highly queued nodes and at the same time picks a route that will consume less energy by selecting shortest route.
5. Simulation will be carried out using Network Simulator-2 (NS2).

Performance comparison between existing and proposed algorithm of Power-Aware routing for MANET will be done and so the result will be validate.

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3.2.1 Explanation of Design methodology EEPARA

Step 1: Initially every node has some energy level, after transmitting packet it reduces its energylevel.

Step 2: Along with the RREQ, source will send the total volume of data.

Step 3: Node will calculate the energy required to transmit the volume of data as,

Energy required = (total time * power required to transmit a packet *0.9)

Step 4: Then node will estimate its battery status, after transmitting the complete data.

Step 5: If found the energy level below the minimum require to survive, the path be discarded by blocking the RREQ.

Algorithm

If

$E_{xM} > E_M$

Then proceed

Else

Select alternate route.

Step 6: After finding the node with sufficient energy, algorithm will follow

If

Distance between Source and Destination is less than 200mthan, agent is attached and data transmission starts.

Else

Node having node angle less than sink angle is selected as next hop, routing table is updated and from step no2 the procedure is repeated till the destination is reached.

3.2.1 Algorithm

1. Create simulator instance
2. Create nam and trace files
3. Set configuration for nodes
4. Create node
5. Set initial positions of all nodes
6. Decide the source node and destination node
7. Calculate the total time of flow with the following formula
   Total time = stop time – start time
8. On the basis of total time of flow, calculate energy required to transmit all packets within that flow. For this calculation we use the energy model which shows that the energy expended in sending data-packet of size D bytes at a transmit power of p_t can be expressed as

$$E(D, p_t) = (k_1 \times p_t \times D) + k_2 \qquad 6$$

Where the typical values fork_1 and k_2 in two frame exchange 802.11 MAC environment at full power (280mW) and 2 Mbps bit rate are 4µs/byte and 42µJoules respectively.

9. Calculate the distance between source node and sink node, and check energy levels of both.
10. After setting the source and destination, quadrant is formed by taking source node as origin.
11. Calculate the distance between source and destination node. If distance is less than 200m & both have sufficient energy to transmit all packets, then attach agents to the node, create routing table for each node in this flow and start sending data
12. If distance between source and sink node is greater than 200m & both have sufficient energy to transmit all packets then following will take place
    - i. take the source node as origin and draw a quadrant
    - ii. On the basis of this quadrant calculate the angle of line joining the source and sink (call this angle as sink node angle) with respect to positive X-axis
    - iii. Calculate the node angle (angle of a line which joins the source node and current node) of each node with respect to positive X-axis
    - iv. Calculate the difference between sink node angle and node angle for each node
13. On the basis of energy level of node & minimum angle difference, source node will select next node(node1) to form route
14. Node1 will check whether sink node is its neighbor node or not
15. If sink node is a neighbor node of node1 then form the route , attach agents to the node and start sending data
16. If sink node is not a neighbor node of node1 then step 12 & 13 will be repeated till the destination node

The algorithm and flowchart describe this decision:

3.2.3 Flowchart:

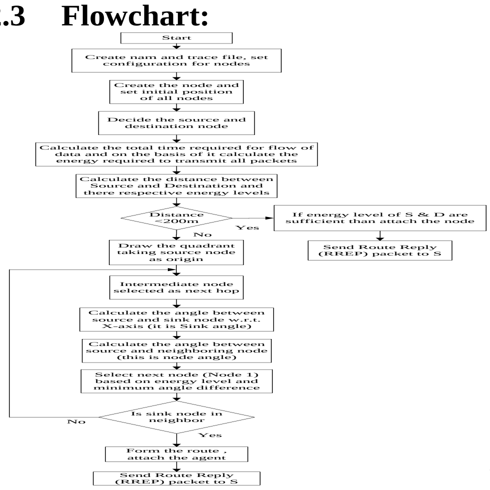

Figure 1: Flowchart for EEPARA

Without a fixed infrastructure, ad hoc networks have to rely on portable, limited power sources. In that node has to relay messages for other nodes in the same network. Hence the issue of energy-efficiency becomes one of the most important problems in ad hoc networks. Energy can be consumed during processing and communication. The energy consumed during communication is more dominant than the energy consumed during processing. So, the communication system should be energy efficient by optimizing the energy consumption at different states of the communication.

3.2.4 Energy consumption model:

The following sections gives the mathematical model to design energy efficient routing protocols related with transmission power.

The total time required for flow is calculated with the help of following formula

Total time = stop time – start time

Or in case of 802.11 MAC environments at full power (280mW) and 2 Mbps bit rate time required is 4μs/byte.

To calculate the energy consumption for sending data packet of size D bytes at transmit power p_t we use equation 6 as describe above

$$E(D, p_t) = (k_1 \times p_t \times D) + k_2$$

With typical values for k_1 and k_2 in two frame exchange 802.11 MAC environment at full power (280mW) and 2 Mbps bit rate are 4μs/byte and 42μJoules respectively. We focus on the energy consumption related to data packet. This includes the network layer related packets (RREQs and RREPs). Since the MAC layer related packets (CTS, RTS, ACK) are very smaller in size compared with the size of a data packet, we ignore the energy consumption related to MAC layer packets in our model.

3.2.5 Distance calculation:

To make the list of neighboring nodes the distance between nodes are calculated using the formula of Pythagoras Theorem. It is shown in the formula given below.

$$R^2 = X^2 + Y^2 \qquad 7$$

3.2.6 Quadrant equations:

After calculating the distance and listing the neighboring nodes having sufficient energy, angle between router node and source node called node angle and angle between source and destination node called source node angle is calculated with the following equation. Both angles are measured w.r.t. positive X-axis.

$$\text{Angle} = \text{Sin}^{-1}(\text{opposite/hypotenous}) \qquad 8$$

$$\text{Angle} = \text{Cos}^{-1}(\text{Adjacent/hypotenous})$$

4. SIMULATION AND RESULT

4.1 Simulation Environment

The proposed scheme is simulated using ns-2 simulator. Setup includes wireless scenarios. Modification is required to run the simulation for the proposed algorithm and that was done in the files in **"mobilenode.cc"** and **"mobilenode.h"** files to get feedback of energy. /this was done by using patch

NOAH (No Ad-hoc Routing protocol) installed in ns-2 simulator.

The setup consists of a test bed of 50 nodes confined in a1800 x 840 Sq.m in rectangular area. The initial energy of each node is 1000.0J. We use TwoRayGround because it is more liked realistic. The length of each simulation time is as per requirement.The scenario is evaluated with respect to the number of connections (25-50 number of source-to-destination connections in interval of 5 ms).

Traffic is generated using constant bit rate (CBR).The The size of each packet is 512bytes. The network size and the number of nodes are kept constant while varying the number of sources-destination pairs within the network for each scenario. Table 1 shows the simulation parameters used.

Table 1: Simulation Parameter

Parameter	Value
Number of nodes	25, 30, 40, 50
Channel type	Wireless Channel
Radio-propagation Model	TwoRayGround
Antenna type	Omni Antenna
Interface queue type	Drop Tail/Pri Queue
Maximum packet in Queue	100
Network interface type	Phy/Wireless Phy
MAC type	802_11
Topographical Area	1800 x 840 Sq. m
Tx Power	1.00W
Rx Power	1.00W
Total simulation Time	As per requirement
Initial energy of a Node	1000.0 Joules
Routing protocols:	EEPARP (Energy Efficient Power Aware Routing Protocol)
Traffic Model	FTP
Packet Size	1060 Bytes

The simulation eases the analyzing and the verification of the protocols, mainly in large-scale systems.

4.2 Results Analysis

Initially scenario has been setup for the nodes network as shown in below.

4.2.1 Setup-1

In the first setup the number of nodes selected is 25 and the pause time is 25 ms and numbers of packets in queue is 100 and size of each packet is 1060 Bytes other parameters are shown in table 1. The graph for average delay, PDR, throughput and remaining energy is plotted by running the simulation. Figure 2 shows the normal view snapshot of the nodes location for setup-1 having 25 nodes.

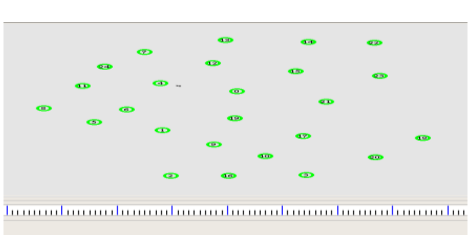

Figure 2 Simulation Snapshot for 25 Nodes

4.2.1.1 Average End-to-End delay Vs Pause time

Figure 3 shows the graph for average delay Vs pause time. Average End to End Delay signifies the average time taken by packets to reach one end to another end (Source to Destination). Graph is shown for the first flow because delay will be same for all other flow.

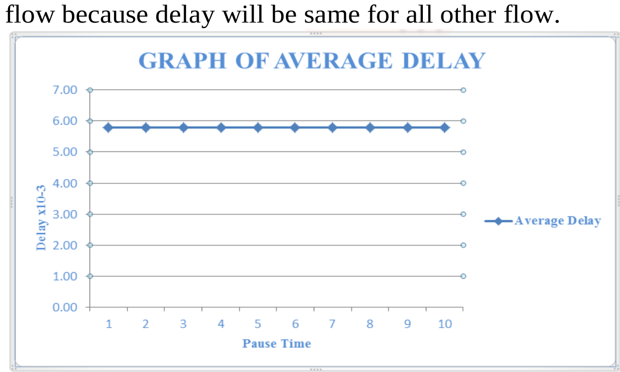

Figure 3 Graph of Average End-to-End delay Vs Pause time

From the above graph it is found that, once the path is set the delay remains constant. There is no change in the delay.

4.2.1.2 Packet delivery ratio Vs Pause time

Figure 4 shows the graph of Packet Delivery Ratio for 25 nodes simulation setup. It is seen that PDR for 25 node setup is 93.7%. PDR is quit high.

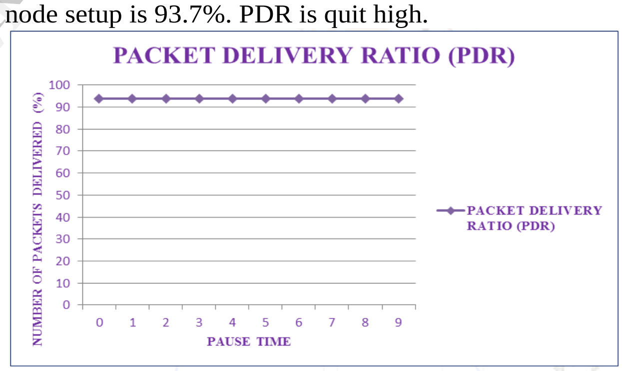

Figure 4 Graph of Packet Delivery Ratio V_s Pause time

4.2.1.3 Remaining Energy Graph

Figure 5 shows the remaining energy of nodes that are participating in the routing. After transmitting the required data energy of all the participating nodes is in between 978.675J &986.0702J. Graph shows that remaining energy level of all the nodes is sufficient at the end of the transmission of all the packets. This means that nodes remain healthy at the end of transmission, which is one of the objectives of our paper.

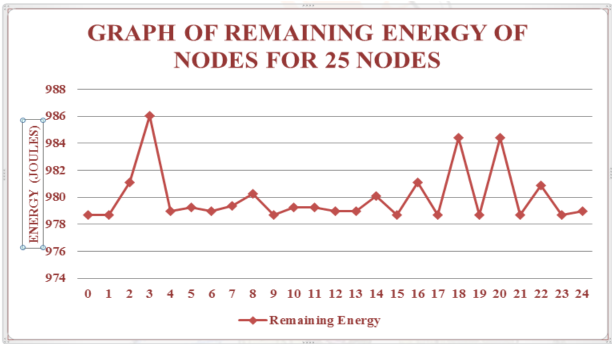

Figure 5 Graph of Remaining Energy of Nodes

4.2.1.4 Throughput Vs Pause time

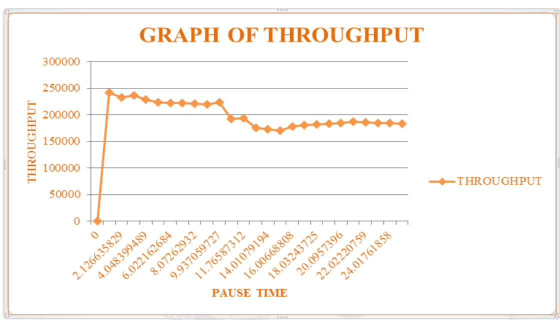

Figure 6 Graph of Throughput Vs Pause time for 25 nodes simulation setup

Throughput is the measure of number of packets sent against received so it identifies the efficiency of the routing algorithm. Figure 6 shows the graph for throughput Vs pause time respectively. It is seen that initially throughput increases with the pause time since initially the utilization of channel capacity is only for path setup but as the pause time increases it get settle and used the channel capacity to its full capacity. The graph shows that the algorithm can be used for higher density setup.

4.2.2 Setup-2

In the first setup the number of nodes selected is 50 and the pause time is 25 ms. and number of packets in queue is 100 and size of each packet is 1060 Bytes other parameters are shown in table 1. The graph for average delay, PDR, throughput and remaining energy is plotted by running the simulation. Figure 7 shows the snapshot of the nodes location for setup-2 having 50 nodes.

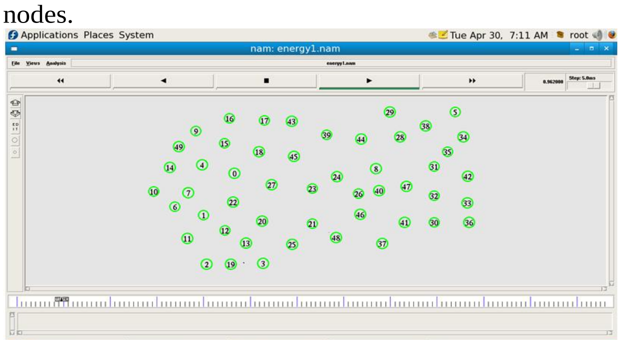

Figure 7 Simulation Snapshot for 50 Nodes

4.2.2.1 Average End-to-End delay Vs Pause time

Figure 8 shows the graph for average delay Vs pause time. Average End to End Delay signifies the average time taken by packets to reach one end to another end (Source to Destination). Graph is shown for the first flow because delay will be same for all other flow. It is more compare to that of 50 nodes setup.

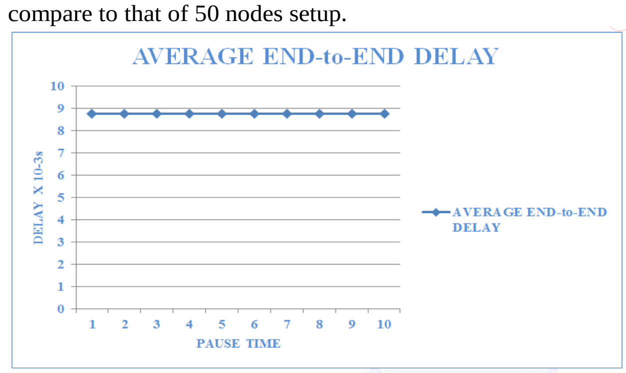

Figure 8 Graph of Average End-to-End delay Vs Pause time

From the above graph it is found that, once the path is set the delay remains constant. There is no change in the delay.

4.2.2.2 Packet delivery ratio Vs Pause time

Packet delivery ratio signifies the number of packets delivered/ forwarded against number of packets received. Higher PDR ratio is desired in the routing algorithm. Figure 9 shows the graph of Packet Delivery Ratio for 50 nodes simulation setup and table 4.11 shows the data for the graph. It is seen that PDR for 50 node setup is 97.3%. Almost same as that of setup for 50 nodes

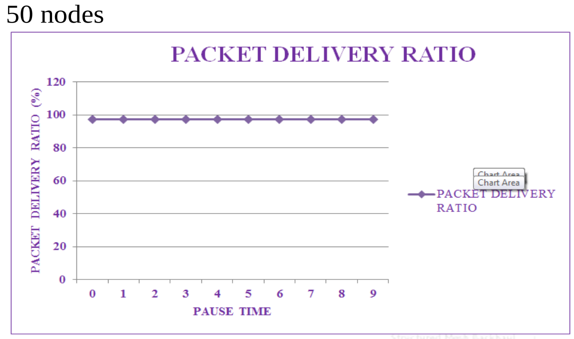

Figure 9 Graph of Packet Delivery Ratio Vs Pause time

4.2.2.3 Remaining Energy Graph

Figure 10 shows the remaining energy of nodes that are participating in the routing. After transmitting the required data energy of all the participating nodes is in between 976.977J & 995.789J. Graph shows that remaining energy level of all the nodes is sufficient at the end of the transmission of all the packets. This means that nodes remain healthy at the end of transmission, which is one of the objectives of our paper.

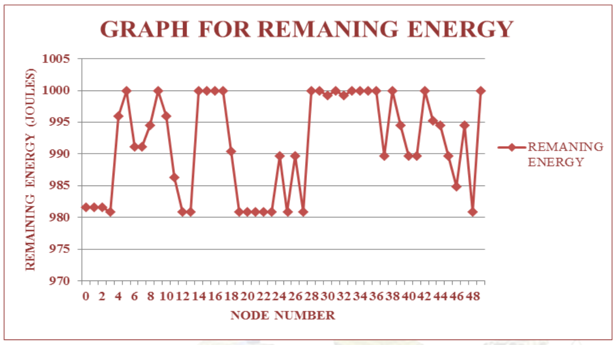

Figure 10 Graph of Remaining Energy of Nodes

4.2.3.4 Throughput Vs Pause time

Figure 11 shows the graph for throughput Vs pause time. It is seen that initially throughput increases with the pause time since initially the utilization of channel capacity is only for path setup but as the pause time increases it get settle and used the channel capacity to its full capacity. The graph shows that the algorithm can be used for higher density setup.

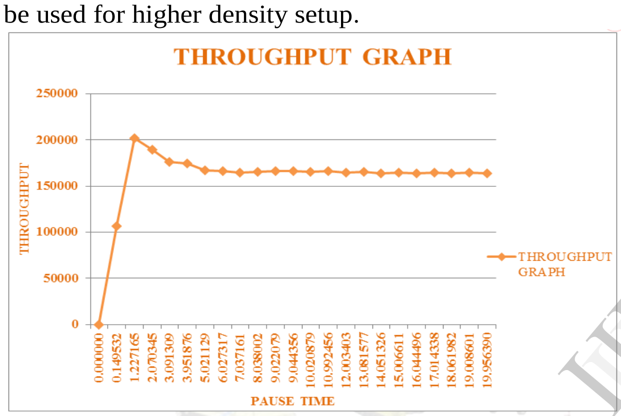

Figure 11 Graph of Throughput Vs Pause time for 50 nodes simulation setup

4.3 Comparison

In this section we have compare the Energy Efficient Power Aware Routing Algorithm for different number of nodes. For comparison we have taken three simulation setups of 25 and 50 nodes.

4.3.1 Comparison of Average End-to-End delay of EEPARA

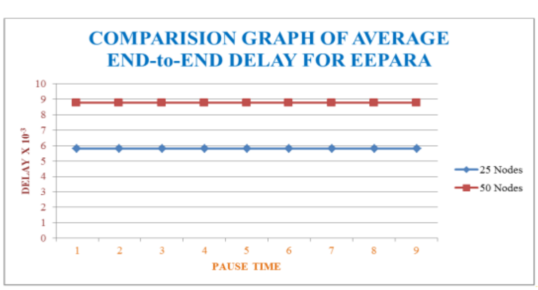

Figure 12 Comparison graph of Average End-to-End delay

From graph it is found that the delay of both setups is different but they are constant throughout the simulation. It is lower for 25 nodes setup and high for 50 nodes setup. It can be concluded that for less number of nodes delay is less.

4.3.2 Comparison for Packet Delivery Ratio of EEPARA

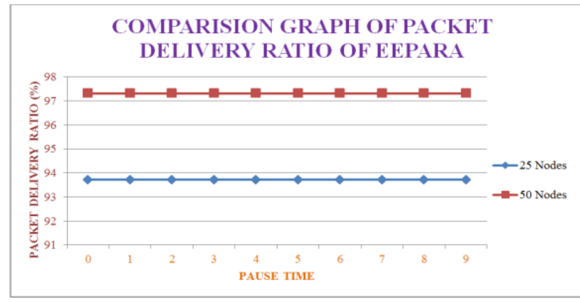

Figure 13 Comparison graph for Packet Delivery Ratio of EEPARA

Graph shows that PDR is almost same and highest for setup of of 50 nodes. Drop in packets are due to the transition in source and destination after 10, 15, 20 and 25mS. So from graph it can be concluded that, algorithm can be used at higher node capacity scenario.

4.3.3 Comparison for Remaining Energy of nodes of EEPARA

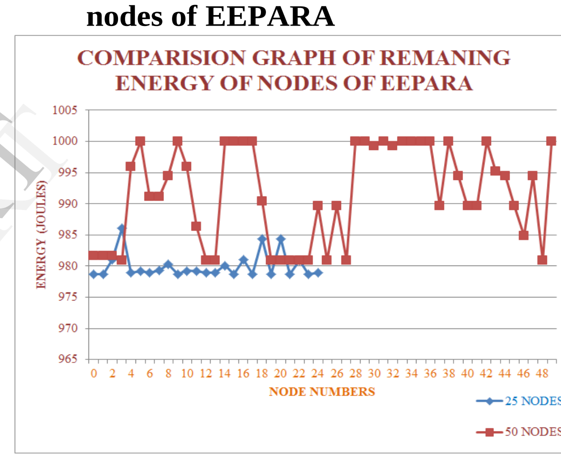

Figure 13 Comparison graph for remaining energy of Nodes

Comparison graph of remaining energy for 25and 50 nodes setup is shown in figure 13. It is observed from the graph that energy consumption of node is almost same. It can be concluded that energy consumption do not depends on the density of nodes in the setup, it depends on length of path.

4.3.4 Comparison for Throughput of EEPARA

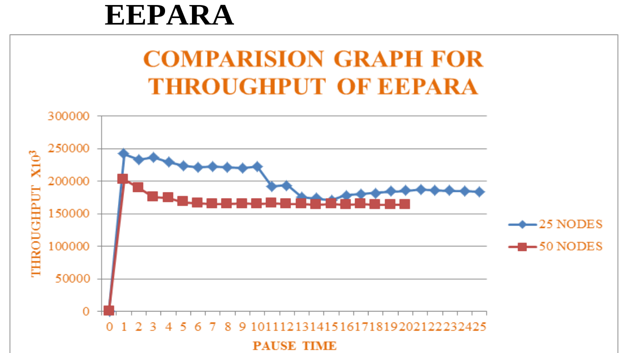

Figure 14 Comparison graph of throughput for EEPARA

Comparison of throughput for setup of 25 and 50 node shows that it is high for 25 nodes setup. Comparison graph shows that algorithm has good throughput for 50 node setup. We can conclude that, optimally algorithm can be used with good throughput at 50 node setup.

4.3.5 Conclusion of comparison:

From the comparison of the four parameters for two different scenarios, it can be concluded that: Proposed algorithm will give good result when used for 50 node setup. Because 50 nodes setup has higher PDR, throughput near to the maximum and also energy consumption is less i.e. nodes remain healthier at the end of data transfer as compare to 25 node setups. Only 50 nodes setup has average delay more compare to 25 setup.

5 Validation

To validate our work we had compare our algorithm with AODV, NAODV and proposed algorithm EEPARA for Average End-to-End delay, Packet Delivery Ratio and Throughput. We cannot compare the remaining energy parameter since other two do not have energy aware algorithm.
The data for AODV and NADOV has been taken from the research paper published.

5.1 Average End-to-End delayvs Pause time

Using the above available data after simulation, graph has been plotted as shown in figure 15. It shows that average End-to-End delay is highest for AODV and lowest for proposed algorithm which is implemented in NAODV protocol. So by implementing proposed algorithm the delay has been reduced.

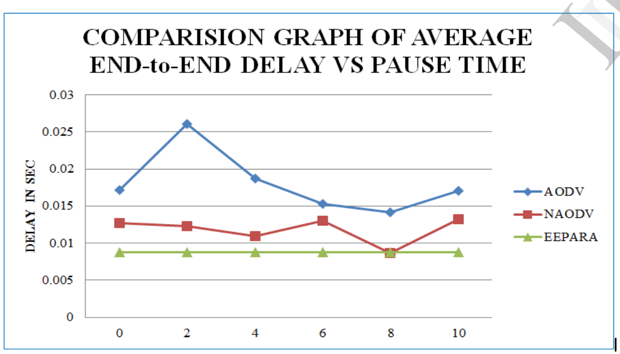

Figure 15 Comparison graph of Average End-to-End delay

5.2 Packet Delivery Ratio (PDR)vs Pause time

Figure 16 shows the comparison graph for Packet Delivery Ratio. It is found that, proposed EEPARA algorithm gives highest and constant PDR throughout the simulation compare to AODV and NAODV. This is because the path selected has all healthy nodes and they remain healthy after complete data transfer. So there is no link breakage which ensures maximum packet delivery to the destination. It is also observed that by using NAODV PDR increases as compare to AODV and also become almost constant by making modification in original AODV protocol. After implementing the proposed algorithm the PDR increases and become constant.

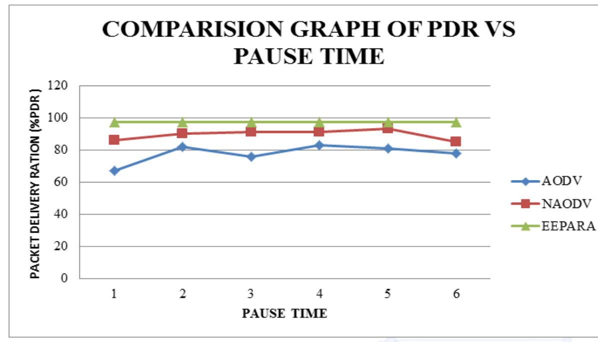

Figure 16 Comparison graph of Packet Delivery Ratio vs Pause time

5.3 Throughput vs Pause time

Comparison graph shown in figure 17 is for throughput. NAODV has highest throughput and drops slightly with the time. Throughput of proposed algorithm is less than AODV and NAODV. It can be concluded that proposed algorithm is suitable for medium density setup. In proposed algorithm we had set four flows i.e. we had set four different source and destination which will be changing after every 10 milli second, with total simulation time is 40 milli second. This may be one of the reasons for the drop in throughput, since at the time of change in source-destination some of the packets get drop.

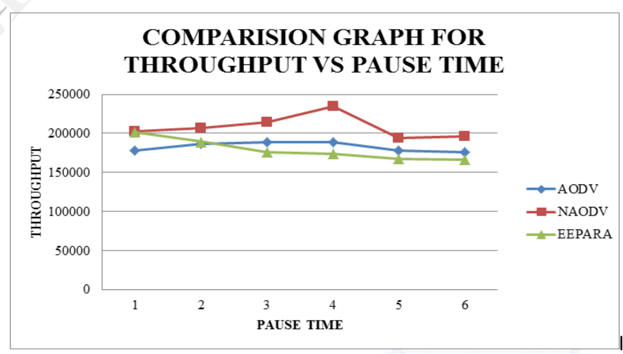

Figure 16 Comparison graph of Throughput vs Pause time

From the comparison graph of 25 and 50 node setup of EEPARA it is found that algorithm has constant delay and PDR. Algorithm has higher throughput which means that algorithm is suitable for higher density network.
Comparison with AODV and NAODV shows that, proposed algorithm has lower delay and higher PDR than other two, while throughput is on the lower side as compare to AODV and NAODV.

6.0. Conclusion

Due to special type network, MANETs is increasingly adopted for research work in recent years. In recent years, rapidly deployed and dynamic military and civilian systems MANETs is used for communication purpose due to ease in installation, no infrastructure requirement and many other advantages. Due to rapid change in network topology in MANETs with time, new challenges are there for routing protocols in MANETs since traditional routing protocols may not be suitable for MANETs. For example, there is one assumption that a node can receive any broadcast message sent by others in the same subnet. However, this may not be true for nodes in a wireless mobile network due to limited bandwidth. Thus, this network model introduces great challenges for routing protocols. Moreover, some protocols cannot efficiently handle topology changes. Researchers are designing new MANETs routing protocols, comparing and improving existing MANETs routing protocols before any routing protocols are standardized using simulations. Apart from above challenges another one which is as important as above is network life time, which solely depends on the battery life and consumption of that particular node. The main question that was to be answered in this paper was:

Can we developed an algorithm which will select the path that has all healthy node and they remain healthy at the end of the data transfer, keeping delay as minimum as possible and keeps throughput high.

We have shown through simulation that by having energy feedback from node which provides the information regarding availability of node in setting the path to destination. Feedback is send to requesting node, after comparing the available battery life and the energy required for data transfer. This algorithm ensures the path setting which has nodes capable of transferring the data without getting dead. For this we had adopted Non Ad hoc routing protocol which makes the modification in the traditional AODV routing protocol by having patch.

Our contribution includes the presentation of a new Energy Efficient Power Aware Routing Algorithm for routing in mobile ad hoc networks. It is an algorithm, combining the path selection based on sufficient energy level of node battery with shortest path to the destination by calculating the quadrant angle.

Our simulation setup analysis shows that EEPARA algorithm is suitable for mobile ad hoc networks. These EEPARA algorithms illustrate different reasons about why this kind of algorithms could perform well in mobile ad hoc networks. Firstly, the EEPARA algorithm select the node in the path only when it insure that it will survive till the end of data transfer by calculating the energy consumption ratio. This ensures that the path set between source and destination will survive without death of any node due to energy exhaust. Secondly algorithm selects the shortest route by calculating the angle between requesting and replying node. This ensures that the energy of the node is utilized efficiently. Because, of the energy consumption of node depends on the distance between nodes.

We have implemented this routing algorithm using simulation, and compared its performance to that of AODV and NAODV without Energy Aware algorithm in a simple network scenario.

We can summarize our final conclusion from our experimental results as follows:

Increase in the density of nodes results in increase in the average End-to-End delay.

Increasing or decreasing the pause time has no effect on mean End-to-End delay.

There is significant effect on the delay between setup for 25 and 50 nodes.

Increasing in the number of nodes will cause increase in the number of nodes that will have their energy unutilized.

Our proposed EEPARA algorithm results in a considerable reduction in the mean End-to-End delay for 50 nodes setup when compared with AODV and NAODV.

Our proposed EEPARA algorithm results higher Packet Delivery ratio for 50 nodes setup when compared with AODV and NAODV.

Our proposed EEPARA algorithm results in a lower throughput for 50 nodes setup when compared with AODV and NAODV.

Energy consumption graph of our proposed EEPARA algorithm shows that at the end of the data transfer, the node participating in the path from source to destination remains healthy.

Finally we can conclude that, the proposed EEPARA algorithm has longer life of network compare to AODV and NAODV with less delay, higher PDR with lower throughput. Proposed algorithm is suitable for the network which requires longer life time.

7.0 Future Work

We identify the following areas of future research: Study the operation of our proposed algorithm under heterogeneous network with exact battery consumption of each type of nodes. We have discussed the behavior of our proposed algorithm without mobility models. In an ad hoc network, there are many other situations where it is necessary to model the behavior of MNs as they move together. One of our future research studies is the study of the behavior of our proposed algorithm with simple mobility model of nodes and then other mobility models such as Reference Point Group Mobility (RPGM) model which represents multiple MNs moving together. And then we can compare between these different mobility models to show its effects on the performance of our EEPARA proposed routing algorithm. Create more realistic scenario for movement models by incorporating obstacles. These obstacles are utilized to both restrict node movements as well as wireless transmissions. The aim of this study is to show how the obstacles have a significant impact on the performance of our proposed EEPARA routing algorithm for ad hoc networks. To study different traffic scenarios such as using multiple source nodes and multiple destination nodes in order to show the general applicability of our proposed EEPARA routing algorithm. Compare the performance of our proposed EEPARA routing algorithm with one of the proactive (table driven) routing protocols such as Destination Sequenced Distance Vector (DSDV) routing protocol.

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