An Energy Efficient Path Routing Protocol based on AODV Routing Protocol for Mobile Adhoc Networks

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***Abstract* - Mobile Adhoc Networks (MANETS) have become useful means for delivering the benefits of wireless voice and data networking to military users specially those operating in battlefield environment and along borders, beyond the reach of a fixed network. However, mobile nodes in MANETS are battery driven which suffer from limited energy level problems and are difficult to replace/recharge. Due to the critical operations requirement the outage of even a few of the nodes due to power exhaustion might cause disconnect of services in the entire MANET. In MANETS, energy efficiency is an important challenge which leads to the proposal of an 'energy efficient path routing' (EEPR) protocol, that reduces the variance in residual energies of nodes and thus increases the net-work lifetime of MANET. In addition, it is also proposed to include a link stability parameter while selecting the routing path to further improve the energy efficiency. Using a min-max formulation for highest residual energy path and link stability parameter, EEPR selects the path that is most energy efficient and with highest stability/reliability.**

Keywords — ***MANETS, Routing, Energy Efficiency, Link Stability, EEPR***

I. INTRODUCTION

A Mobile Adhoc Network (MANET) is group of mobile nodes that form an adhoc network. MANETS support tactical network for military communications and automated battlefield environment. Indian Army, as part of the modernization of its forces has undertaken projects for Battlefield Management System which try to integrate various elements on ground with mission-oriented equipment integrated with the command and control centres for quick decision making e.g. C4ISTAR which represents C4 (command, control, communications, computers) and ISTAR (intelligence, surveillance, target acquisition, and reconnaissance) system. It envisions various teams of soldiers/fire units/reaction teams connected on a network which is fed with information from various sensors/surveillance devices, controlled by a control centre for decision making and passing orders for appropriate action by a particular team, by assessing situation on the battlefield. The information is shared/ passed on palmtop/notebook computers held with the teams, which act as nodes. Such a battlefield scenario which has mobile elements forming an adhoc network, helping in passage/flow of in-formation with a requirement of moving from one place to another based on task assigned, represents a MANET.

Mobile nodes in MANETs are battery driven and thus they suffer from limited energy level problems. Moreover, due to deployment of troops in the inhospitable mountainous/ desert/jungle terrain in far flung areas along the borders, with the requirement of being self-contained for several days altogether, recharging/replacing of batteries is difficult and at times not possible. Since, these battery operated mobile devices which act as nodes deployed in the battlefield environment/Border Management Posture, perform the routing function for establishing communication among different mobile nodes, the outage of even a few of the nodes due to power exhaustion might cause disconnect of services in the entire MANET. Thus, devising means for extending the battery lifetime of these mobile devices/nodes in a MANET has become an important aim and most of the researchers have recently started to consider development of energy efficient protocols for MANETs. Also, the nodes in the network are moving, so if a node moves out of the radio range of the other node, the link between them is broken. Thus, in such an environment there are two major reasons of a link breakage i.e. firstly, a node dying of energy exhaustion and secondly, a node moving out of the radio range of its neighbouring node.

The energy-efficient routing protocol in MANET tries to reduce energy consumption by means of an energy-efficient routing metric, used in the routing table computation instead of the minimum-hop metric. This way, a routing protocol can easily introduce energy efficiency in its packet forwarding. However, it does not take into account a node moving out of the radio range of its neighbouring node. Thus, an additional metric for link stability can be added as a routing metric, and used in conjunction with energy-consumption metric to compute the routing table, thus increasing the overall energy efficiency of the network and increasing the network lifetime.

II. RELATED RESEARCH WORK

Charles E Perkins, 'Adhoc Networking', in text [1] of 2000, gives a broad understanding to the working of MANETS and also discusses a military perspective on MANETS. It discusses in detail the working of important routing protocols like DSDV, AODV, DSR and ZRP and provides help in understanding them in detail.

Kartik Chawda and Deepmala, in paper [2] of 2015, carry out a survey of energy aware routing protocols to assist researchers, application developers and academic students in selecting appropriate routing protocol for their work.

Charles E Perkins, in paper [3] of 2003, explains the functioning of AODV routing protocol. AODV is a reactive or on-demand protocol that can handle both unicast and multicast routing. It uses the concept of shortest path algorithm. In AODV no counting-to infinity problem arises as compared to other protocols like DSDV. Network remains silent until some node in the network want a connection to broadcast the message. The paper gives in-sight in to the Route Discovery and Route Maintenance procedures used in AODV using Route request, Route Reply and Route Error messages.

DB Johnson, DA Maltz and YC Hu, in paper [4], explain the functioning of DSR protocol. Like AODV it is also a reactive or on-demand routing protocol. It uses source rout-ing in spite of depending upon the routing table. In source routing the route packets contain the address of each device and also track which packet will have been traversed. This causes more overhead in defining long paths or large addresses such as IPV6 as compared to AODV. The paper also gives insight in to the Route Discovery and Route Maintenance procedures used in DSR and use of route caches to store routing information.

Hannan Xiao, in paper [5], proposes a set of performance metrics in evaluating energy efficiency in MANETs, and studies the energy consumption of MANET from a variety of aspects: at different network layers including application layer, network layer and MAC layer, at different operation mode including idle, transmit and receive, and with different routing protocols including DSR, DSDV and AODV.

Vidyarthi SS, Vijayalakshmi S, Simha GAV and Shekar, in paper [6] of 2011, propose a new protocol called Enhanced-AODV (E-AODV) protocol. They bring out that the conventional broadcast scheme that broadcasts packets omni-directionally suffers from several drawbacks like excessive amount of redundant traffic, exaggerated interference or contention among neighbouring nodes and limited coverage. The prevalent well known AODV and DSDV protocols used for routing in such networks use the conventional broad-cast scheme and thus suffer from these drawbacks as well. Such problems in adhoc networks can be alleviated with the use of directional antennas. Compared to the omni-directional scheme E-AODV uses minimum number of control packets and with lower broadcast redundancy E-AODV is more bandwidth and energy efficient.

Utkarsh, M Mukesh and S Chinara, in paper [7] of 2012, state that a Reactive Energy Saving Adhoc Routing (ESAR) algorithm gives long life time network. In ESAR the packet is delivered through that selected path until the node reaches at the threshold value and at this time another alternate path is selected for packet deliver. ESAR increases the network lifetime by the applying the threshold concept in the entire available path. ESAR performance is better than AODV and Energy Efficient Adhoc On-Demand Routing proto-col (EEAODR) because ESAR uses many alternate path while in AODV and EEAODV repeated use of same path reduces the network lifetime.

Shivashankar, HN Suresh and GVaraprasad, in paper [8] of 2013, propose an efficient algorithm for MANETs, which maximises the network lifetime by minimising the power consumption while establishing path with the help of modified DSR. The proposed work minimises the energy consumption per packet and maximises the network lifetime. The design objective of modifying DSR is to select energy-efficient paths. The main features of modified DSR are to minimise energy consumed per packet, maximise network lifetime for network and minimise maximum node cost.

III. ENERGY EFFICIENT ROUTING IN MANETS

An approach to improve the energy efficiency by using an 'Efficient Energy Path Routing' (EEPR) is discussed in this paper that increases the network lifetime of MANETS. For MANETS deployed in battlefield scenario/border management posture, reliability, survivability and self-sustenance of the network is of utmost importance. In such an environment there are two major reasons of a link breakage i.e. firstly, a node dying of energy exhaustion and secondly, a node moving out of the radio range of its neighbouring node. The proposed energy efficient routing protocol for MANETS tries to reduce energy consumption by means of an energy efficient routing metric, used in routing table computation instead of the minimum-hop metric. This way, a routing protocol can introduce energy efficiency while selection of routes. However, energy metric does not take a node moving out of radio range while making its calculation into consideration. Thus, it is further proposed to use an additional metric that takes stability/availability of a particular link in to account. The proposed approach in the project adds two extra fields in the packet header as routing metrics which are 'Energy Model' and 'Link Stability Parameter' and both of these metrics are used in routing table computation.

A. Energy Model

The energy model calculates the residual energy of a node by subtracting energy consumed by a node for various routing decisions and for all packets sent, received, forwarded and dropped while traversing from source to destination node. This residual energy of the node is added as a routing metric in the packet header and is used towards selection of an energy efficient path from the source to destination node. It is noted that this selected path may not be the minimum energy path but the path having maximum residual energy of the nodes since routing to maximize the lifetime of the network is different from minimum energy routing. Minimum energy routes attract more traffic flows, and the nodes along these routes suffer battery exhaustion and die very soon; hence causing a complete network failure. However, routes selected based on maximum residual energy results in increased network lifetime by balancing load through all the routes and nodes globally within a network.

B. Design Objective and Proposed Algorithm

While considering a design objective and a new approach it should be understood that the two objectives of routing i.e. minimum total energy consumption and lifetime of the network can be mutually contradictory. Consider a case, when a common node lies on several paths from various nodes, then the battery power of this node quickly runs into depletion. As a result this particular node may die of battery exhaustion very soon, eventually shortening the network lifetime. When choosing a path, the existing routing protocol implementation chooses the path with the minimum number of hops. For EEPR, however, the path is chosen based on energy. First, we calculate the residual energy level for each node, and find the lowest residual energy of a node on a particular path. Then the selection is made by choosing the path with the maximum lowest residual energy. For example, consider a scenario as given in Figure1, in which there are three paths to choose from. The first path contains three hops with node residual energy values 80, 90, 30, and 70, and the second path contains three hops with energy values 80, 60, 40, and 70 and the third path contains four hops with energy values 80, 60, 40, 30 and 70. The minimum residual energy for the first and third path is 30, while the minimum residual energy for the second path is 40. Since 40 is greater than 30, the second path would be selected.

To find the residual energy of a node we first calculate the total amount of energy consumed at a node in sending, receiving, forwarding and dropping packets over a hop. The energy consumed at one node is calculated by the equation:-

$$Ec_i = E_s(n_i) + E_r(n_i) + E_f(n_i) + E_d(n_i)$$

where, Ec_i denotes the energy consumed at node i and E_s, E_r, E_f, E_d denote the energy consumed in sending, receiving, forwarding and dropping at node i, respectively.

We then subtract this consumed energy from the initial energy of the node to get the residual energy:-

$$E_{residual} = E_{initial} - Ec_i$$

In Figure.1, a typical on-demand routing protocol has an option of selecting the shortest path out of three possible routes i.e. ABCD, AEFD or AEFCD. The proposed EEPR selects the path AEFD only, because that selected path consists of the node with minimum residual energy higher than that of nodes on the other paths. This protocol favours the path whose lifetime is maximum and thus increases the network lifetime of the MANET. The objective function for EEPR is as follows:-

$$\text{Max } E_k(t) = \text{Min } E_i(t) \qquad i \in k$$

where, $E_k(t)$ = residual energy of path and

$E_i(t)$ = residual energy of node i in path k

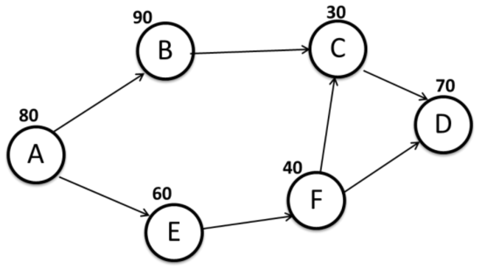


Figure 1. Route selection in EEPR

We calculate the path with maximum minimum residual energy in Figure1, as follows:-

Path 1 (A-B-C-D):-

$E_k(0) = \text{Min } E_i(0) = \text{Min}(E_A(0), E_B(0), E_C(0), E_D(0)) \quad i \in k$

$E_k(0) = \text{Min } E_i(0) = \text{Min } (80, 90, 30, 70) = 30$

Path 2 (A-E-F-D):-

$E_k(0) = \text{Min } E_i(0) = \text{Min}(E_A(0), E_E(0), E_C(0), E_D(0)) \quad i \in k$

$Ek(0) = \text{Min } E_i(0) = \text{Min } (80, 60, 40, 70) = 40$

Path 3 (A-E-F-C-D):-

$E_k(0) = \text{Min } E_i(0) = \text{Min}(E_A(0), E_E(0), E_F(0), E_C(0), E_D(0)) \ i \in k$

$E_k(0) = \text{Min } E_i(0) = \text{Min } (80, 60, 40, 30, 70) = 30$

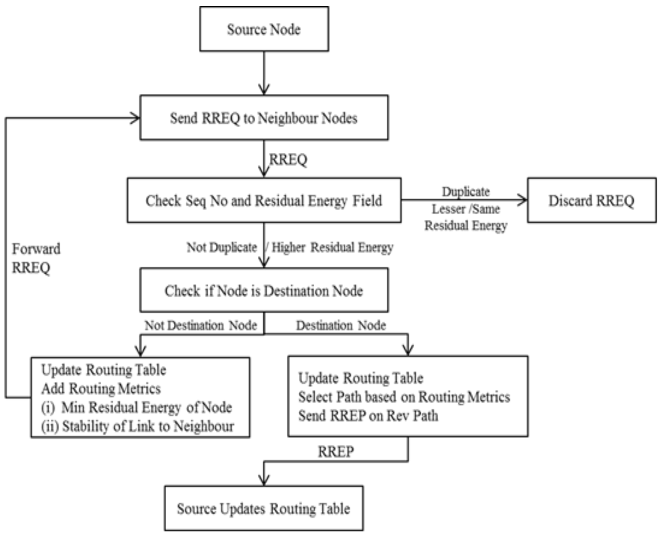
Hence selected path is :-

$\text{Max } E_k(0) = \text{Max } (30, 40, 30) = 400 \rightarrow$ **Path 2 (A-E-F-D)**.

The main objective of energy metric is to achieve energy efficiency by minimizing the variance in the residual energies of all the nodes and thus improve the network lifetime. This approach follows a load balancing approach that avoids power/traffic congested paths and chooses paths that are lightly loaded. This helps EEPR achieve less variance in energy levels of different nodes in the network and thus maximizes the network lifetime.

C. Flow Chart

The routing mechanism of EEPR protocol is summarized in using a flow chart below:-



IV. SIMULATION AND RESULTS

Network Simulator version2 (NS2) software has been used to carry out all the simulations for DSDV, DSR, AODV and the proposed EEPR routing protocol which is a modification of AODV protocol.

A. Simulation Layout

Simulation has been carried out for a typical MANET deployment along border areas/battlefield scenario, with sensor/source nodes deployed at the edge of network (border) sending information to a control headquarters through various mobile nodes (number of nodes ranging from 30 to 60) forming the MANET. The simulation layout is given at Figure2.

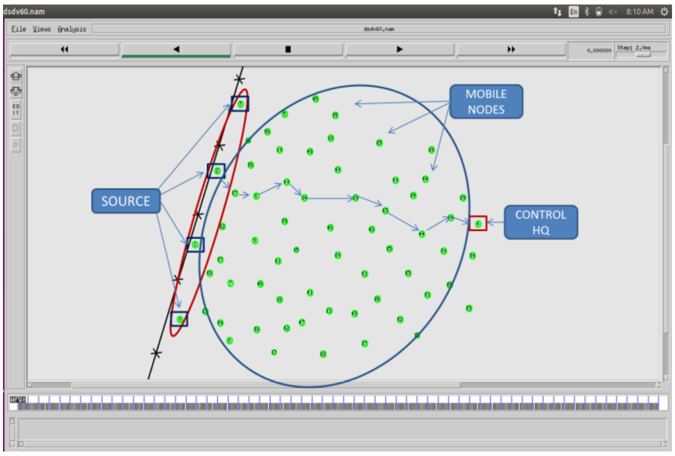


Figure 2. Simulation Network Layout

B. *Simulation Parameters*

Parameters used for simulation are given in Table 1.

Parameter	Value
Channel	Channel/Wireless Channel
Propagation	Propagation/Two Ray Ground
Antenna	Antenna/Omni Antenna
Terrain Area	1500 m x 1500 m
Simulation Time	60 s
MAC Type	802.11
Application Traffic	CBR
Routing Protocol	DSDV, AODV, DSR, EEPR
Data Payload	512 Bytes/Packet
Number of Nodes	40, 50, 60, 70
Number of Sources	4
No of Destination/Control Nodes	1
Initial Energy of Nodes	100.00 Joules
Transmit Power	2.0 Watts
Receive Power	1.0 watts
Idle Power	0.5 Watts

Table 1. Network Parameters for Simulation

The energy consumption evaluation during simulation using DSDV, DSR, AODV and EEPR routing protocols was carried out for typical MANET deployed for military scenario for 30, 40, 50 and 60 nodes.

C. *Results*

Figures 3-6. show the energy consumption comparison for the various protocols i.e. DSDV, DSR, AODV and EEPR.

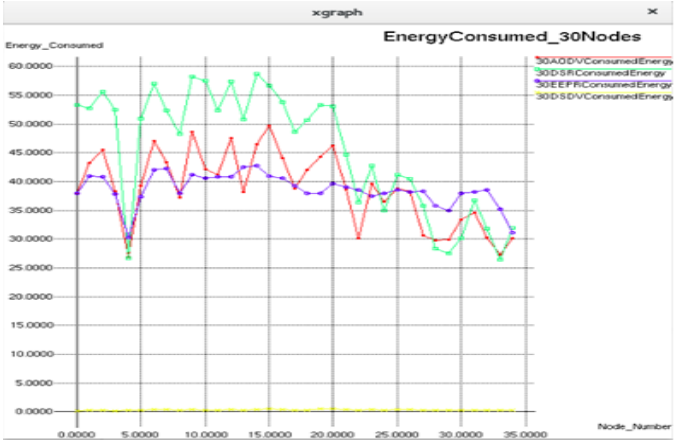


Figure. 3 Energy Consumed for 30 Nodes

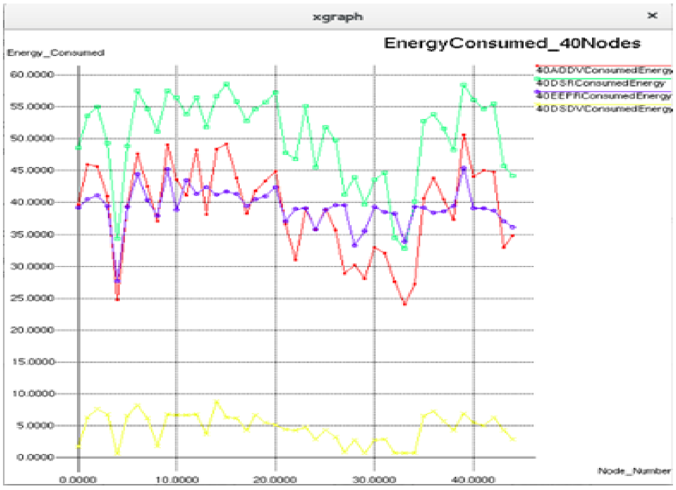


Figure. 4 Energy Consumed for 40 Nodes

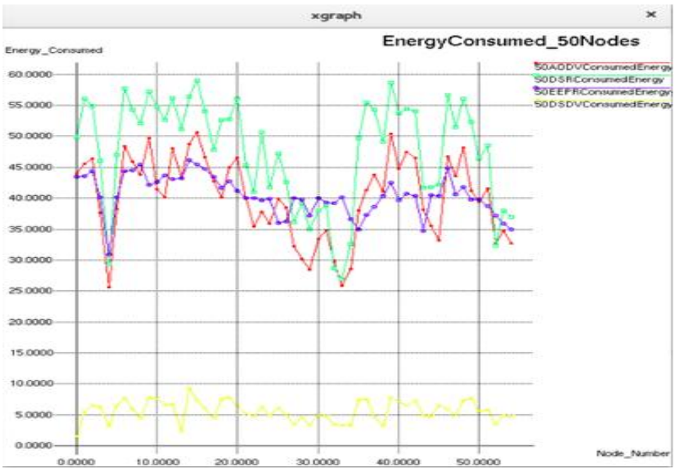


Figure. 5 Energy Consumed for 50 Nodes

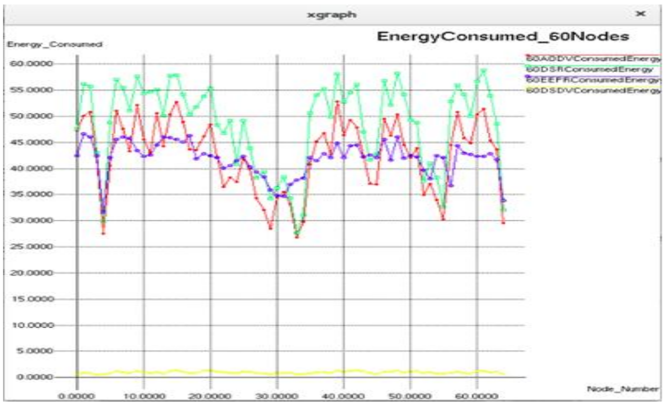


Figure. 6 Energy Consumed for 60 Nodes

From the graphs it was found that energy consumption using DSDV protocol is the least, however that is due to poor throughput and thus under-utilization of resources. The energy consumption using AODV and DSR protocol is comparable, however average energy consumption of AODV protocol is lesser than that of DSR (Figure7.) EEPR, which has introduced energy metric in AODV algorithm reduces the variance in energy depletion of various nodes and also reduces the average energy consumption in the network and thus proves to be more energy efficient.

D. Performance Comparison

The performance of routing protocols DSDV, DSR, AODV and EEPR was compared after plotting the graphs using xgraph, as shown in Figures 7-10.

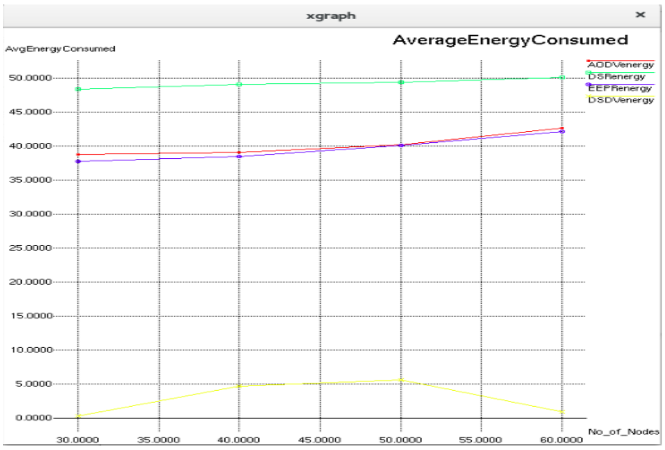


Figure 7. Average Energy Consumption

The comparison of average energy consumed is given in figure 7. The energy consumption of DSR is maximum while EEPR offers an improvement in energy efficiency when compared to AODV.

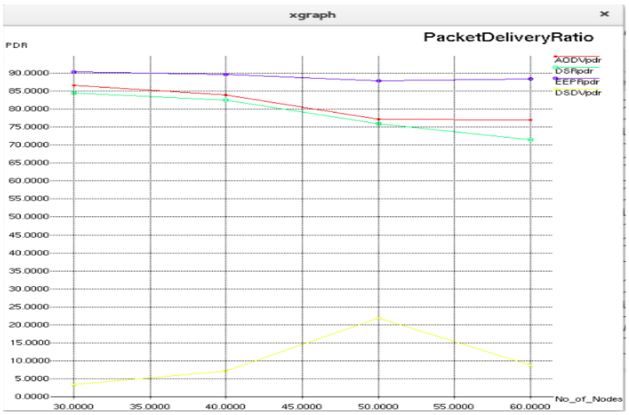


Figure 8. Packet Delivery Ratio

The comparison of packet delivery ratio (PDR) is given in figure 8. The PDR of DSDV and DSR is the least while EEPR offers an improvement in packet delivery ratio when compared to AODV.

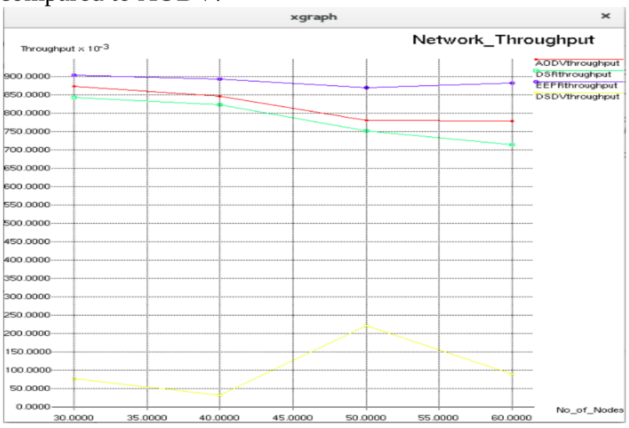


Figure 9. Network Throughput

The comparison of network throughput is given in figure 9. The throughput of DSDV followed by DSR is minimum while EEPR offers better network throughput when compared to AODV.

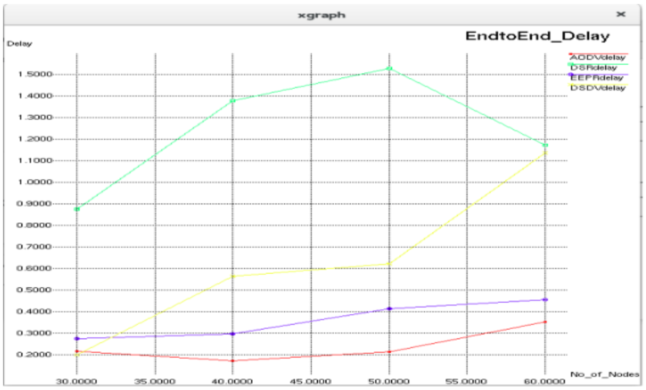


Figure 10. End-to-end Delay

The comparison of end-to-end delay, given in figure 10, shows that the delay for EEPR as compared to AODV is more, which is due to selection of path based on residual energy rather than number of hops.

The performance comparison of the protocols reveals that the packet delivery ratio and throughput of DSDV is the worst while that of AODV and DSR are comparable. EEPR which is a modification of AODV algorithm improves the PDR and throughput of the network however it causes an increase in end-to-end delay since energy metric is used for routing rather than distance metric.

V. CONCLUSIONS

The proposed algorithm aims at addressing the problem of improving the energy efficiency and thus maximizing the network lifetime of a MANET deployed in a typical military scenario. The proposed EEPR routing protocol selects a path based on max-min formulation for finding the ideal residual energy path for reducing the variance in energy consumption/residual energy of the nodes. As a result, the network lifetime of a MANET is also increased. As a future work, the reliability factor by using a link stability parameter to prevent unstable links from participating in route discovery procedure can be implemented to further improve the energy efficiency, as it would reduce link breakages which cause generation of route error messages leading to fresh route discovery procedures.

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