RESEARCH ARTICLE

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Formulation and Implementation of Energy Efficient Routing Algorithm for MANET along with Performance Analysis

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Abstract

Mobile adhoc network (MANET) is composed of wireless mobile nodes/devices which are moving randomly in infrastructure-less adhoc environments. Topology among mobile nodes is dynamic in nature and keeps on changing regularly. The adhoc environment is open to all the genuine users as well as intruders/attackers. Moreover, the wireless connection between mobile nodes can break at any time on account of mobility of nodes. Also, the mobile notes depend on their battery power, which may go down because of exhaust of battery power. Hence, it is a very complex task to implement energy efficient routing over MANET. While handling energy efficient routing, the optimum utilization of batter power is required. In this research paper, efforts have been carried out to formulate an algorithm for energy efficient routing over MANET. Its performance has been studied through network simulator. The simulations have been carried out by writing self created network scenarios with 20, 60 and 100 mobile nodes. Moreover, analysis of the proposed energy efficient routing protocol has been done with AODV routing protocol by using various performance evaluation metrics viz. packet delivery ratio, normalized routing load, average end to end delay, packet loss, throughput, average energy consumed and average energy left. It was derived from the performance analysis that proposed protocol provides energy efficient routing over MANET and also gives better or almost same performance in comparison to AODV.

Keywords: AODV, EER, Energy, MANET, Protocol, Routing.

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Introduction

MANET[1] is collection of mobile devices which are adaptive in nature, self-organizing and requires no fixed infrastructure. This network can be deployed without any infrastructural support where routes are mainly multi-hop because of the limited radio propagation range. Applications of MANET can be seen in the fields of virtual classrooms, defence communication, rescue operations, communications setup in seminars & conferences, sharing of files among users etc. and much more. Unlike wired networks with dedicated routers, each mobile device in an adhoc network may act as a router and host and forward packets for other peer nodes. Major hurdle in communication over MANET is mobile device battery[2] limitations.

To route a packet from a source to a destination involves a sufficient number of intermediate nodes which are battery operated. Optimum utilization of battery power of mobile device is required to avoid early termination of network. One distinctive trait of Energy Efficient Routing Protocol is efficient use of battery power. Given the choice between two routes to a destination, a requesting node is required to select one with better batter power status. A new scheme has been proposed to incorporate energy efficient routing over MANET. Efforts have been made to modify AODV protocol by incorporating energy efficiency.

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Literature Review

The energy efficiency of a node is defined by the number of packets delivered by a node in a certain amount of energy. Life of a mobile node can be increased by means of efficient battery management,[3,4] transmission power management[5,6] and system power management.[7] Energy control algorithms[8,9] have been studies in which the available bandwidth is shared among all the users. Reduction in transmission power increases frequency reuse, which leads to better channel reuse. Developing battery efficient systems with low cost and complexity still remains a crucial issue. Efficient power aware routing protocol is the need of present situations. The design objective of energy aware protocols is to select energy efficient routes and simultaneously minimize the overhead incurred in selecting the routes. Some routing algorithms given by Li P. *et al.*[10] and Chang J. H. *et al.*[11] can optimize the energy use with a global perspective. But these algorithms incur expensive overheads for gathering, exchanging and storing the state information. These algorithms can be improvised in order to make them scalable. Some algorithms Xue Y. *et al.*[12] and Domingo M.C. *et al.*[13] work without assuming any topological knowledge at nodes and they can avoid the proactive overheads required for topological information. These kind of on-demand approaches are required for energy efficient paths.

An energy and delay constrained routing in MANETs have been proposed by Laura *et al.*,[14] in which energy saving and timely delivery of data packets is incorporated into the route discovery phase to select paths with lower cost. Chen *et al.*[15] have proposed an Energy Efficient AODV for Low Mobility Ad hoc Networks, in which the node energy consumption of the overall network is reduced by dynamically controlling the transmission power by utilizing a novel route cost metric. Three extensions to the traditional AODV protocol, named Local Energy Aware Routing, Power Aware Routing and Lifetime Prediction Routing have been proposed by Senouci S. M. *et al.*[16] for balanced energy consumption in MANETs. Li *et al.* [10] have proposed an algorithm to maximize the network life time by balancing the energy draining rates among nodes using precise global state information. Narayanaswami *et al.*[17] have designed an approach named COMPOW, which works to find the minimal common value of node transmission range to maintain the network connectivity. COMPOW attempts to satisfy three major objectives of increasing the battery lifetime of all the nodes, increasing the traffic carrying capacity of the network and reducing the contention among the nodes. It has been proved by Kawadia *et al.*[18] that the COMPOW protocol works only in a network with a homogeneous distribution of nodes. CLUSTERPOW is an extension of COMPOW for non-homogeneous dispersion of the nodes. Energy Aware Routing Scheme (EAR) has been proposed by Nayak P. *et al.*[19] Energy efficient design of the protocol was generated by varying the transmission range of the nodes. Variable transmission range means controlling the power level for each packet in a distributed manner at each node, thus affecting energy consumption of the network. Choosing a higher transmission range reduces the number of nodes needed to reach the destination but creates large interference, whereas reducing the transmission range demands more number of forwarding nodes leading to less energy utilization.

Each node communicates with the neighboring nodes during route discovery phase. Once the route is known, each individual node controls the transmission range as per the distance between source and destination node, so optimum energy is utilized for packet transmission. Taha, A. *Et al.*[20] highlights the energy consumption in MANET by applying the fitness function technique to optimize the energy consumption in ad hoc on demand multipath distance vector (AOMDV) routing protocol.

Anand, M. *et al.*[21] discusses an algorithm that improves the network's lifetime by discovering a path based on path trust, residual node energy, and path distance. It not only considers the energy-efficient secure routing but also considers the route maintenance. D.S.Jayalakshmi *et al.*[22] proposes the energy efficient routing protocol based on efficient route failure detection. The routing algorithm focuses on three important parameters viz. channel calibre, connection calibre and node's residual energy to find out the path that ensures authentic communication. The research study carried out by S. Pariselvam *et al.*[23] compares several energy efficient routing techniques to determine node fidelity and mobility characteristics of cellular nodes.

Objectives of Study

The objectives of this study are as follows:-

- To formulate an algorithm for energy efficient routing over MANET and study its performance through simulator.
- To compare the proposed energy efficient routing protocol with AODV routing protocol through simulation by using various performance evaluation metrics viz. packet delivery ratio, normalized routing load, average end to end delay, packet loss, throughput, average energy consumed and average energy left.

Performance Metrics

The following performance metrics[24] have been used during analysis of EER protocol:-

Packet Delivery Ratio: The packet delivery ratio is defined as the ratio of number of data packets received at the destinations over the number of data packets sent by the source.

$$\text{Packet Delivery Ratio} = \frac{\text{Total Data Packets Received}}{\text{Total Data Packets Sent}} \text{ X } 100$$

Normalized Routing Load: The normalized routing load is defined as the fraction of all routing control packets sent by all nodes over the number of received data packets at the destination nodes.

$$\text{Normalized Routing Load} = \frac{\text{Total Routing Packets Sent}}{\text{Total Data Packets Received}}$$

Average End-to-End Delay: This is the average time involved in delivery of data packets from the source node to the destination node.

$$\text{Average End to End Delay} = \frac{\sum (\text{Time Received} - \text{Time Sent})}{\text{Total Data Packets Received}}$$

Packet Loss: It is defined as the number of packets dropped by the routers during transmission.

Packet Loss = Total Data Packets Dropped= Total Data Packets Sent - Total Data Packets Received

$$\text{Packet Loss (\% age)} = \frac{\text{Total Packets Dropped}}{\text{Total Data Packets Sent}} \text{ X } 100$$

Throughput: A network throughput is the average rate at which message is successfully delivered between a destination node and source node. Throughput can be measured as bits per second (bps), packets per second or packet per time slot. The higher network throughput means better efficient routing protocol.

Average Energy Consumption: Total energy consumption metric gives the energy consumption in the network due to routing packets. Total energy consumed by each node is calculated as sum of transmitted and received energy for all control packets. However, Average energy consumed is the ratio of total network energy consumption to the number of data packets successfully delivered to the sink.

$$\text{Average Energy Consumed} = \frac{\sum_{k=1}^{n} (\text{Eik} - \text{E}rk)}{\text{Total Number of Packets Received}}$$

Where Eik is initial energy of node k, Erk is remain energy level of node k at the end of simulation and n is the number of nodes in the network. A less value of average energy consumed means that most of the packets have been delivered with less energy and it represents better energy efficient routing protocol.

Average Energy Left: Average Energy Left is defined as difference between initial energy of network and average energy left.

Average Energy Left = Initial Energy – Average Energy Consumed

Proposed Method/Algorithm

The following algorithm is proposed for energy efficient routing over MANET:-

Algorithm - EER (Energy Efficient Routing)

Step 1 (Source Node): The source node broadcasts Route REQUEST message containing threshold value of energy. The neighbouring node receives and forwards the same on available active route till the Destination Node is achieved.

Step 2 (Neighbouring Node): If the Energy of Neighbouring Node is greater than Threshold Energy, A REPLY message is sent to the source node otherwise NO REPLY message is sent to source node. Threshold has been added in route table and is used in REPLY phase, not in REQUEST phase.

Step 3 (Source Node): All the reply messages are scanned at source node. The neighbouring node with shortest active route/optimal route (depending upon energy level of node) is chosen for transmission of data and other neighbouring nodes are stored as alternate nodes that can be used at the time of link failure.

Note:- The algorithm do not always consider shortest path rather lifetime/energy level of each node is also considered depending upon the prevailing situation. Thus optimal path is chosen instead of shortest path in this step.

Step 4 (Destination Node): After the destination node is found, it sends back Route REPLY on the reverse path. Whenever Source Node receives Route REPLY, it means that route is established and the data is forwarded over the established route.

The assumption taken into consideration is that the nodes in the process of route creation are in the moving state and are within the radio range of each other. The key features in modified AODV routing protocol/algorithm depicting Energy Efficient Routing (EER) is as follows:-

1) Following AODV mechanism, routing is imitated using Source Node 'S'. This is performed as per AODV functionality for route creation. Added concept in EER protocol is that it also contains threshold value in the route table, termed as Th.

2) Now at the node with one hope distance called 'N'

If Pn > Pth && TT – TT(N) < DESTs then

A reply message will be sent which will contain the route information

Else if Pn < Pth then

A null Reply is sent

Where Pn is the node energy level, Pth is threshold energy level that is actually predefined, TT & TT(N) are the current time and the time when last packet had been forwarded to Dest through 'N' respectively and DESTs is the current estimated hop distance of the node from the destination.

3) As per RREP phase of AODV, 'S' acting as source node, gets all active REPLY messages. These messages are saved in the Route table for selection of active route.

4) To find out number of packets loss, packet delivery ratio is calculated. Other Performance Metrics are also considered for analysis purpose.

5) In case of link failure, If one intermediate node gets depleted in energy and breaks down, check is made for Destination node, and if the said down node link is closer to the destination than source, a scheme called Link local repair is carried out.

6) In most protocols for faster transmission, shortest path is selected. In the proposed energy efficient routing protocol, this practice is sacrificed in few cases depending upon the energy left in the node. Efforts are not to always consider shortest path rather lifetime/energy level of each node is important which is tabled and then optimal path is chosen.

Table 1: Simulation Parameters

Simulator	*NS-2.34*
Network Interface	WirelessPhy
Channel	WirelessChannel
Antenna type	OmniAntenna
Propagation	TwoRayGround
MAC Type	802.11
Mobility Model	Random Waypoint
Transmission Power	1.65 W
Reception Power	1.1 W
Transition Power	0.6 W
Idle Power	1 W
Sleep Power	0.001 W
Initial Energy of Node	1000 Joules
Data Rate	1 mbps
Protocols	AODV and EER
Data Packet size	512 byte
Transmission Range	200 meter
Number of Nodes	20, 60, 100
Pause Time (Max.)	500 Seconds
Queue Length	150
Area	750 × 750, 1000 × 1000, 1500 × 1500
Speed	7 meter per second (fixed)
Traffic Agent	UDP
Traffic Model	CBR

Simulation Framework

The simulation analysis of proposed Energy Efficient Routing (EER) Protocol for MANET had been done w.r.t AODV protocol. The TCL scripts implementing EER algorithm have been executed over network simulator and results have been derived by analyzing TRACE and NAM files. Table 1 depicts prominent simulation parameters used during analysis of network traffic:-

As an illustration, Figure 1 and 2 depicts layout of TRACE and NAM files generated through network simulator:-

As an illustration, Figure 3 and 4 depicts visual representation of NAM files at two different times using network animator:-

Simulation Results and Analysis

The performance of Energy Efficient Routing (EER) Protocol has been evaluated w.r.t AODV Routing Protocol for varying number of devices/nodes i.e. 20, 60 & 100 nodes. The simulation parameters considered during performance evaluation have been given in table 1. All nodes are in moving state and the topology of the network keeps on changing. The performance evaluation metrics used are packet delivery ratio, normalized routing load, average end to end delay, packet loss, throughput, average energy consumed and average energy left. Figure 5 to 25 depicts various types of performance evaluation metrics w.r.t pause time. It is pragmatic that the speed and pause time defines mobility of nodes and both are inversely proportional to each other.

It has been observed from the simulation results (Figure 5 to 25) that most of the times EER protocol gives better or almost equal performance in comparison to AODV routing protocol for varying pause time from 100s to 500s.

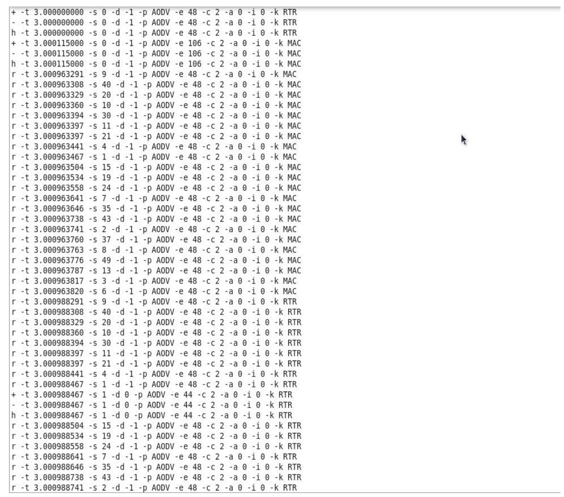

Figure 1: NAM File

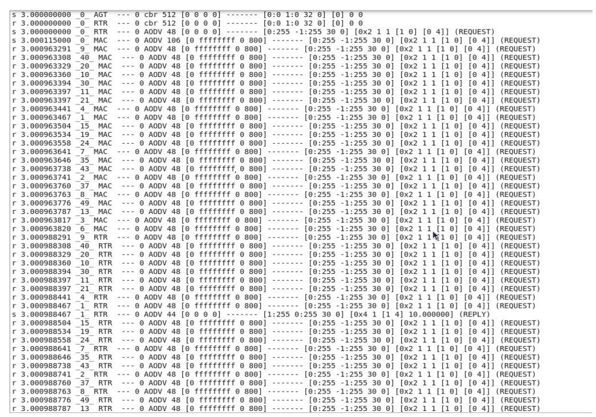

Figure 2: TRACE File

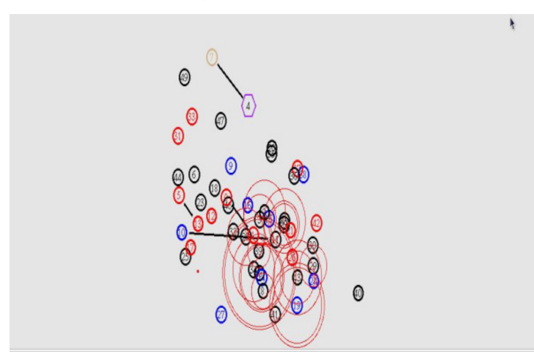

Figure 3: Visual representation of NAM file (Time=t_1)

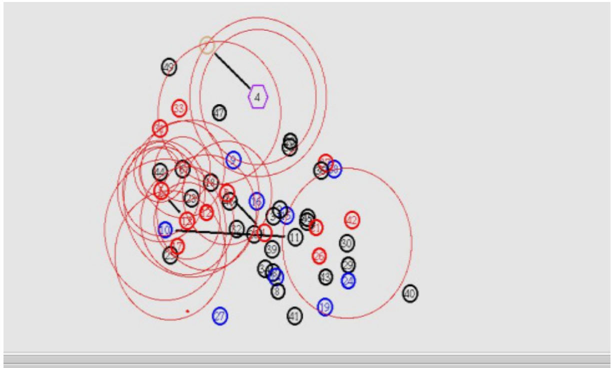

Figure 4: Visual representation of NAM file (Time=t_2)

Results for 20 Nodes

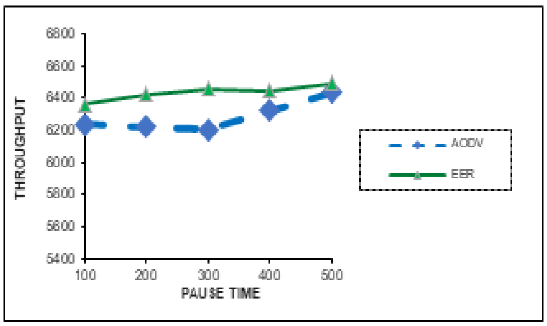

Figure 5: Packet Delivery Ratio versus Pause Time

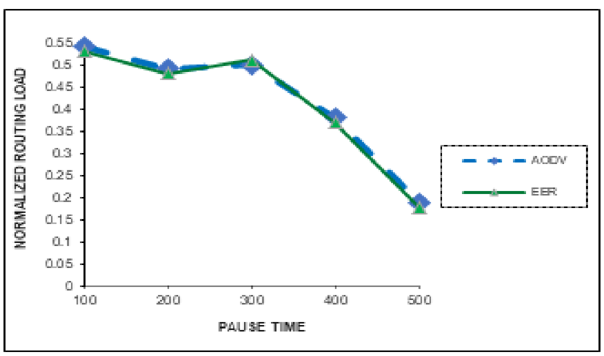

Figure 6: Normalized Routing Load versus Pause Time

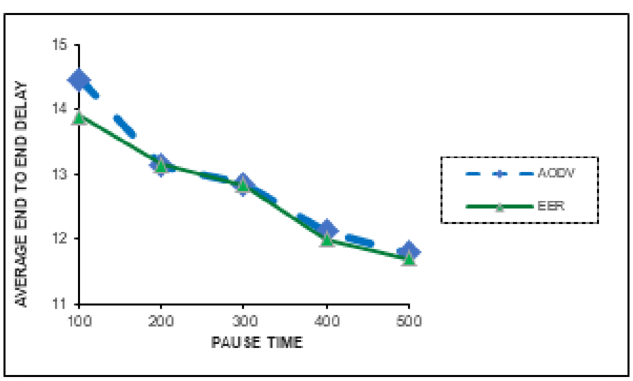

Figure 7: Average End to End Delay versus Pause Time

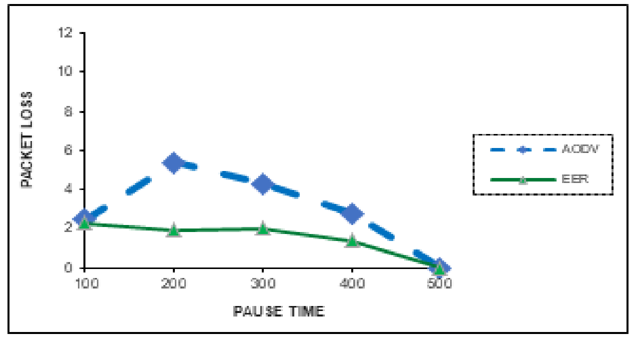

Figure 8: Packet Loss versus Pause Time

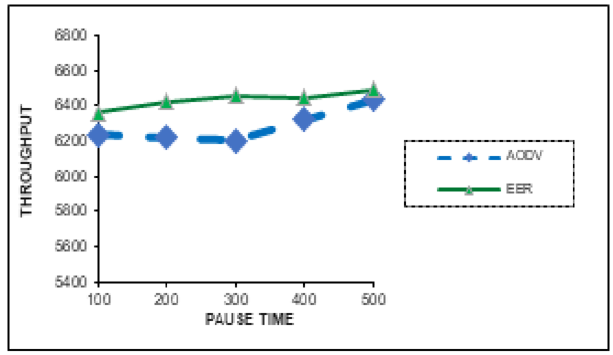

Figure 9: Throughput versus Pause Time

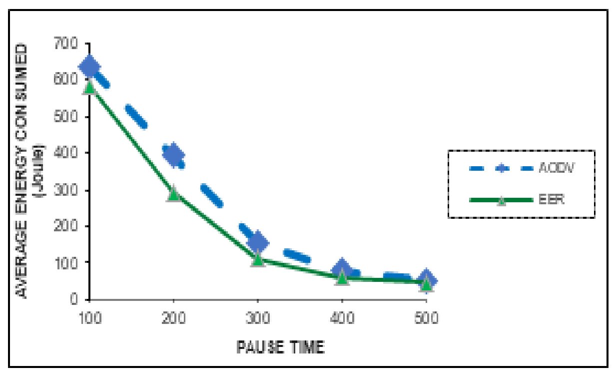

Figure 10: Average Energy Consumed versus Pause Time

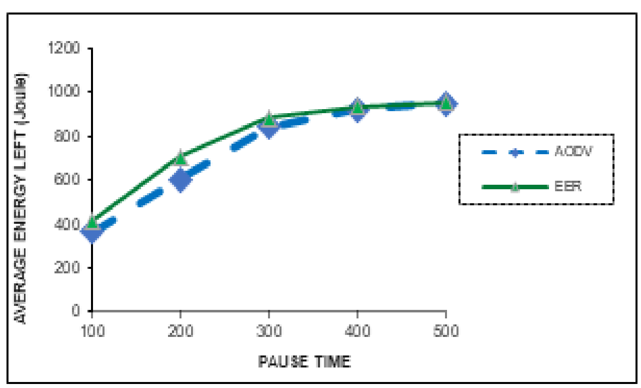

Figure 11: Average Energy Left versus Pause Time

Results for 60 Nodes

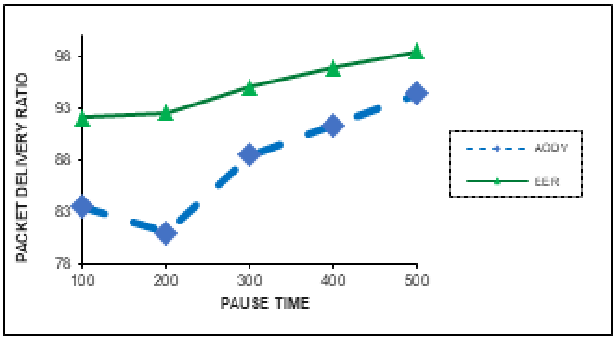

Figure 12: Packet Delivery Ratio versus Pause Time

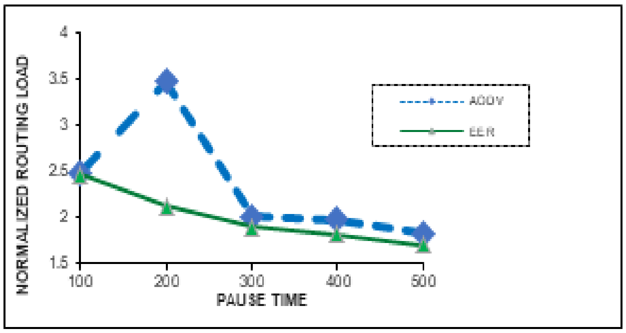

Figure 13: Normalized Routing Load versus Pause Time

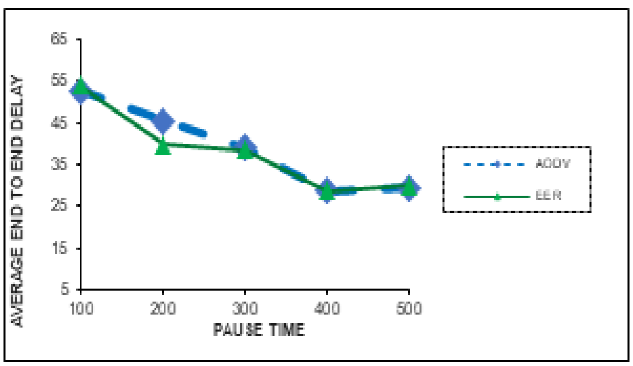

Figure 14: Average End to End Delay versus Pause Time

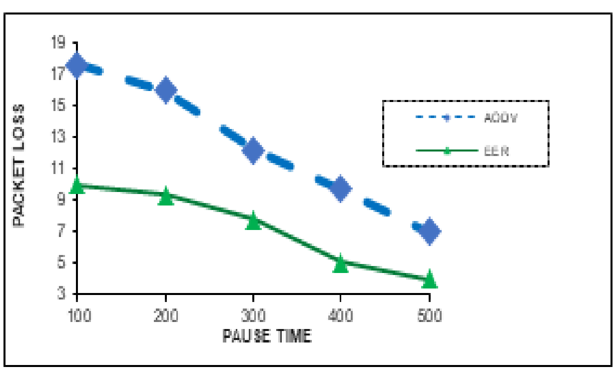

Figure 15: Packet Loss versus Pause Time

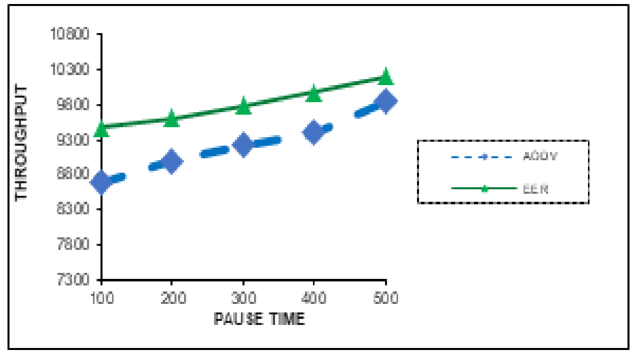

Figure 16: Throughput versus Pause Time

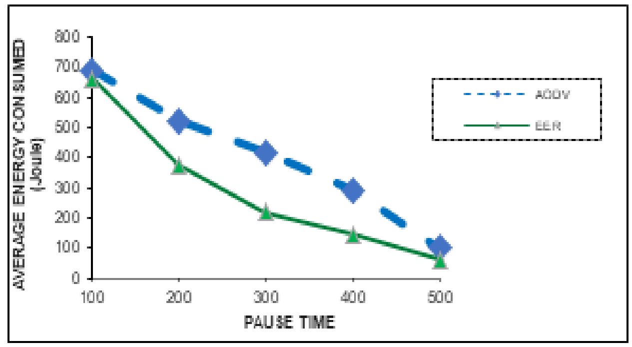

Figure 17: Average Energy Consumed versus Pause Time

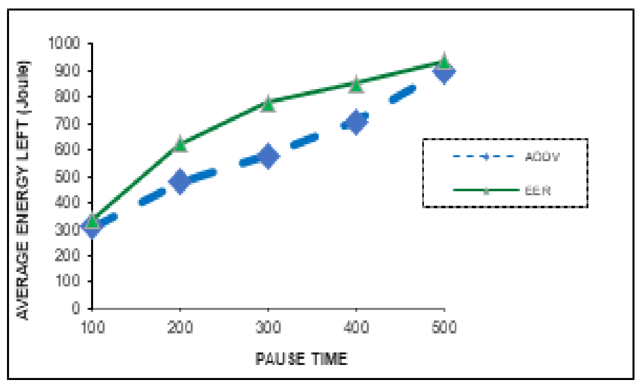

Figure 18: Average Energy Left versus Pause Time

Results for 100 Nodes

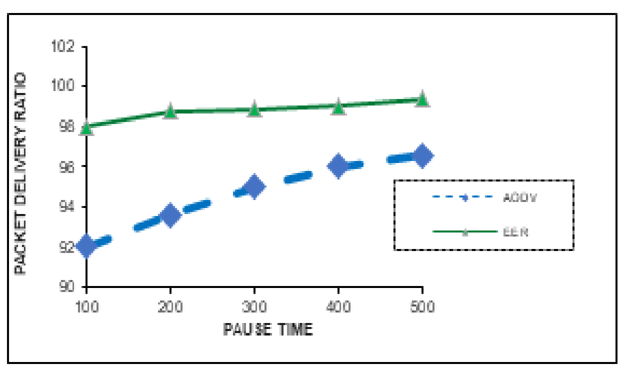

Figure 19: Packet Delivery Ratio versus Pause Time

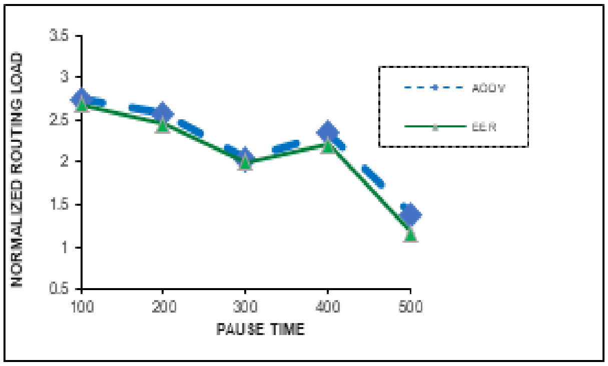

Figure 20: Normalized Routing Load versus Pause Time

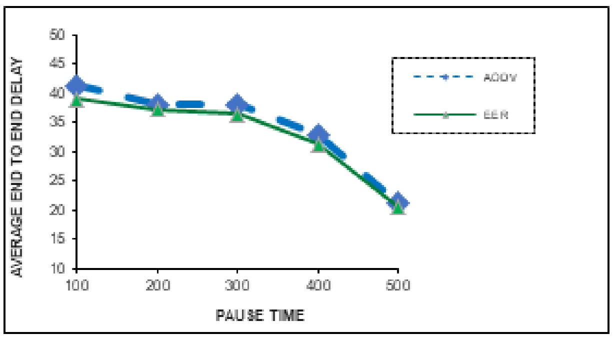

Figure 21: Average End to End Delay versus Pause Time

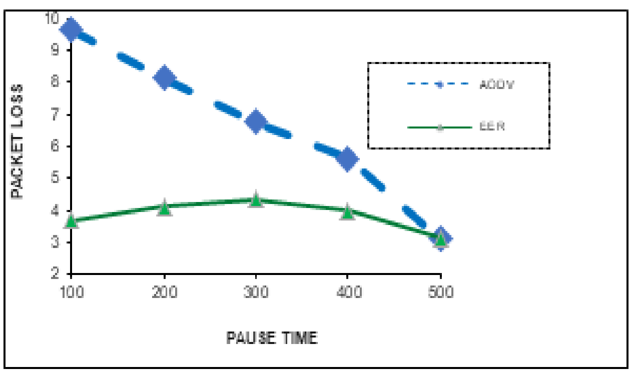

Figure 22: Packet Loss versus Pause Time

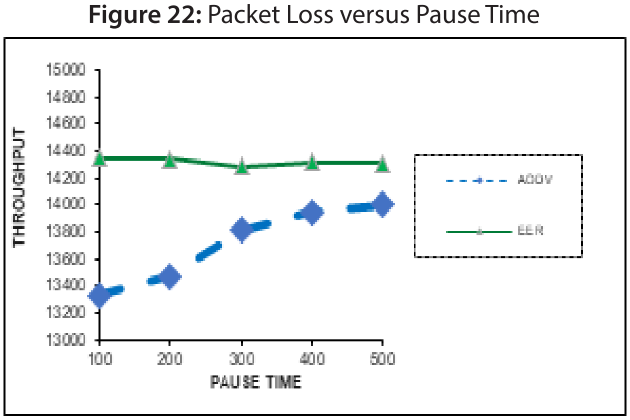

Figure 23: Throughput versus Pause Time

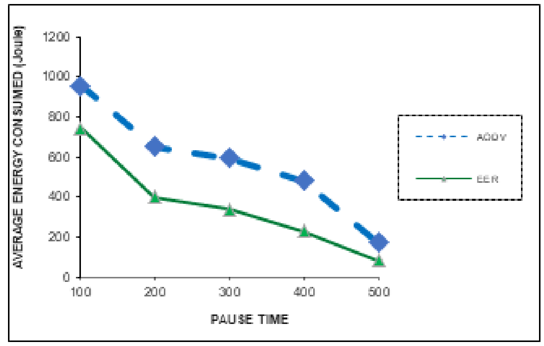

Figure 24: Average Energy Consumed versus Pause Time

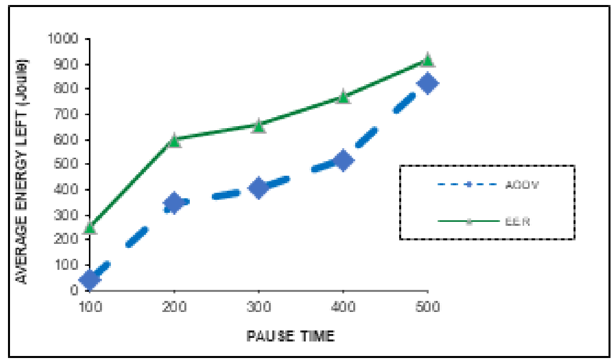

Figure 25: Average Energy Left versus Pause Time

Conclusion & Future Scope

Results have been derived by writing series of TCL scripts and executing the same over Network Simulator NS-2.34. It has been concluded that the proposed protocol named as EER provides energy efficient routing over MANET in an efficient manner. The protocol assumes that all the mobile devices/nodes dynamically adjust the transmission power over communication network. However, the proposed algorithm makes efficient use of battery power of mobile devices in order to avoid early depletion of communication network. The route selection for transmission of packets from source node to destination node is done on the basis of efficient battery power management. The results have been derived by creating different scenarios and varying number of mobile nodes. The performance has been evaluated for varying pause time using various performance evaluation metrics viz. packet delivery ratio, normalized routing load, average end to end delay, packet loss, throughput, average energy consumed and average energy left. The proposed protocol proves to provide energy efficient routing with best packet delivery under a variety of network conditions. Whenever a portion of the communication network gets down, the proposed protocol selects the best alternative path. The protocol quickly and accurately adapt to a variety of network conditions. There is ample number of possibilities of further extensions in the research work. The protocol can be extended to cover metropolitan area wireless adhoc network. Present research work has been carried out using UDP agents/ connections and this work can be extended for TCP agents/

connections. The proposed protocol can also be tested for fixed network. The protocol can also be further extended by introducing malicious network traffic with increase in number of mobile devices.

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