# Integrated Energy-Aware Mechanism for MANETs using On-demand Routing

M. Tamilarasi, T.G. Palanivelu

***Abstract*****—**Mobile Ad Hoc Networks (MANETs) are multi-hop wireless networks in which all nodes cooperatively maintain network connectivity. In such a multi-hop wireless network, every node may be required to perform routing in order to achieve end-to-end communication among nodes. These networks are energy constrained as most ad hoc mobile nodes today operate with limited battery power. Hence, it is important to minimize the energy consumption of the entire network in order to maximize the lifetime of ad hoc networks. In this paper, a mechanism involving the integration of load balancing approach and transmission power control approach is introduced to maximize the life-span of MANETs. The mechanism is applied on Ad hoc On-demand Vector (AODV) protocol to make it as energy aware AODV (EA_AODV). The simulation is carried out using GloMoSim2.03 simulator. The results show that the proposed mechanism reduces the average required transmission energy per packet compared to the standard AODV.

***Keywords*****—**energy aware routing, load balance, Mobile Ad Hoc Networks, MANETs ,on demand routing,transmission power control.

## I. INTRODUCTION

MANET is a temporary wireless network formed by a group of mobile nodes which may not be within the transmission range of each other. The nodes in MANET are self-organizing, self-configuring, self-maintaining and characterized by multi-hop wireless connectivity and frequently changing topology [1]. MANET usually consists of battery-operated computing devices which cooperate with each other to transmit packet from a source node to a destination node. The availability of each node is important for the enforcement of such cooperation. The failure of a single node can greatly affect the network performance. Since mobile nodes are usually battery-operated, one of the major reasons of node failure is battery exhaustion. In order to maximize the life-time of a mobile node, it is important to reduce the energy consumption of a node while transmitting packet. There are many strategies proposed in literatures to minimize the required active communication energy. C. K. Toh [2] has proposed a conditional max-min battery capacity routing (CMMBCR) to choose a shortest path among all paths in which every node has a battery capacity above a predefined threshold value in order to extend the lifetime of nodes in the network. Sheetalkumar Doshi and Timothy X Brown [3] have applied minimum transmit power control on Dynamic Source Routing (DSR) protocol. For sensor networks, Frederick J. Block, Carl W.Baum [4] have presented a set of routing metrics that utilize an estimate of the remaining lifetime of each node. Qun Li et al[5] have developed few distributed power aware routing protocols for sensor networks. Mohammed Tarique et al [6] have applied transmission power control and load sharing approach in DSR in which the minimum energy of node in the discovered path to transmit power ratio has been used as the parameter for selecting a route. In our paper, the load balancing approach is based on the remaining energy at every node which is the resultant energy after deducting the required energy for transmitting a packet from the available energy at every node. In this paper, we are integrating the transmit power control and load balancing approach as a mechanism to improve the performance of on-demand routing. We applied this integrated mechanism on AODV to make it as Energy Aware AODV (EA_AODV). The rest of the paper is organized as follows: Section II describes the load balancing approach and transmission power control approach applied on AODV to get EA_AODV. Section III presents the simulation results and conclusions are given in Section IV.

## II. EA_AODV PROTOCOL

It is important to maximize the lifetime of power constrained MANETs by reducing the energy consumption of every node, as the nodes operate with limited battery power. Energy efficient routing is one among the many ways of efficient battery energy utilization. In this paper, we proposed an energy aware mechanism for on-demand protocols which is a combination of load balancing approach and transmission power control approach. As per the load balancing approach on-demand protocols select a route at any time based on the minimum energy availability of the routes and the energy consumption per packet of the route at that time. As per the transmission power control approach once a route is selected, transmission power will be controlled on a link by link basis to reduce the power consumption per node. In this paper, energy aware approach is applied on AODV to make it as Energy Aware AODV (EA AODV)[7].

Manuscript received on July 23, 2007.

M. Tamilarasi is with the Department of Electronics and Communication Engineering,Pondicherry Engineering College,Puducherry-605 014, India (phone: 91-0413-2655392; fax: 91-0413-2655101; e-mail: tamilarasim@gmail.com).

T.G. Palanivelu Author is with the Department of Electronics and Communication Engineering,Pondicherry Engineering College,Puducherry-605 014, India. (e-mail: principal@pec.edu).

### *A. Overview of Route Discovery Mechanism in AODV*

In AODV, a source node that wants to send a message to a destination for which it does not have a route broadcasts a Route Request (RREQ) packet to its neighbors. The RREQ contains the source node's address, broadcast ID, destination node's address and current sequence number as well as the destination node's most recent sequence number. All nodes receiving this packet update their information for the source node. A node that receives a RREQ can send a Route Reply (RREP) if it is either the destination or has a route to the destination with a corresponding sequence number greater than or equal to the sequence number that RREQ contains. In the latter case, the node returns a RREP to the source with an updated sequence number for that destination; otherwise, it rebroadcasts the RREQ. Nodes keep track of the RREQ source address and broadcast ID, discarding any RREQ they have already processed. As the RREPs propagates back to the source, nodes receiving these RREPs set up entries to the destination in their routing tables. The route is established once the source node receives the RREP[2].

### *B. Load balancing approach*

Route discovery mechanism in EA_AODV is illustrated in Fig 1 in which node 1 is the source and node 5 is the destination. Assume that all nodes have empty caches. At time t, when the source initiates a route discovery, the available energy levels of the nodes and their current required transmit power levels are as shown in Fig 1. The source initiates a route discovery by broadcasting the RREQ packet. Node 2 and node 4 are within the transmission range of node 1. Since intermediate nodes 2 and 4 are not the destination, these two nodes add their own node ids in the request packet and rebroadcast that RREQ. Once the destination 5 receives the RREQ packet, it sends a reply to the source by reversing the path through which it receives the RREQ packet.

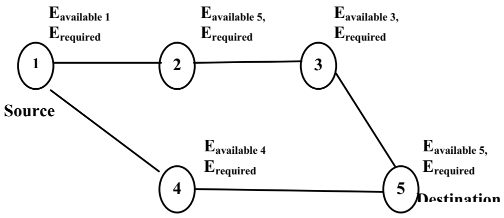


Fig. 1 Routing In EA AODV

Let us assume that destination 5 replies back to the source using the route 5 − 3 − 2 − 1. When the intermediate node 3 receives the RREP packet it estimates its remaining battery energy using the available energy of node and the required transmit power of a packet at that node and let this value be 'x'. Node 3 records this value in that RREP packet and forwards the RREP to next hop towards source which is node 2. Node 2 estimates its remaining battery energy in the same way. Let us assume this value be 'y'. It also reads the value 'x' recorded in the RREP packet and compares 'x' with 'y'. Node 2 will replace 'x' by 'y' only if 'y' is less than 'x' or else, 'x' will be retained in RREP. Let us assume that 'y' is less than 'x'. Thus the RREP carry the value of the minimum remaining battery energy 'y' of the path 1 − 2 − 3 − 5. So the source 1 records this path in the cache along with value 'y'. Let us assume that source 1 discovers another path 1−4−5 which has minimum battery energy of the path as 'z'. If 'y' is greater than 'z', the source then selects the path 1 −2−3−5 because that path has higher minimum battery energy than the shortest path 1−4−5. Thus, in EA_AODV, the mobile nodes which are very likely to drain out batteries are avoided in the route discovery phase.

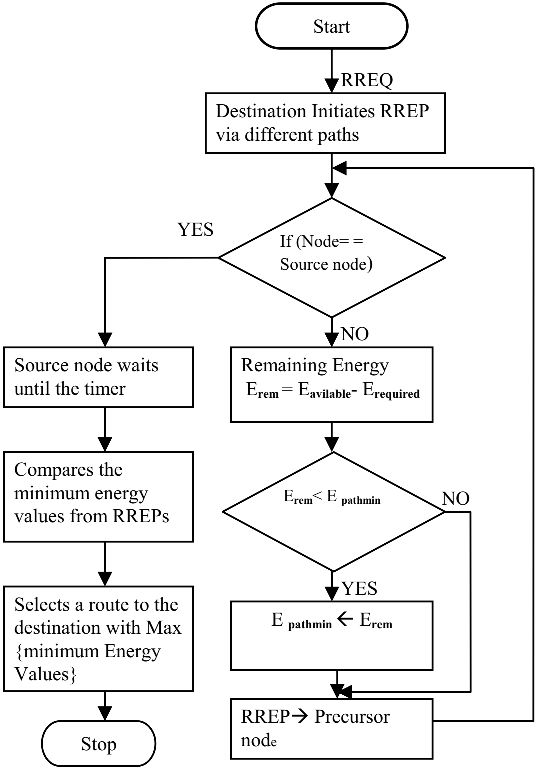


Fig. 2 Flowchart for selecting the highest minimum energy route

The available energy level and the required transmit power level of a node are taken into account while making routing decision. The subtraction of current available energy levels and the required transmit power levels of nodes indicate how likely these nodes will deplete battery energy. In order to do that a source node finds a minimum energy route at time t such that the following cost function is maximized.

$$C(E, t) = \max \{E_{rem}\} \tag{1}$$

$$E_{rem} = E_{available}(t) - E_{required}(t) \tag{2}$$

Where, Erem is the remaining energy of node, $E_{available}(t)$ is the available energy of node, $E_{required}(t)$ is the required transmit power of a packet at node. The energy required in sending a data packet of size D bytes over a given link can be modeled as

$$E(D) = K_1 D + K_2 \tag{3}$$

$$K_1 = (P_t^{\text{Packet}} + P^{\text{back}}) \times 8/BR \tag{4}$$

$$K_2 = ((P_t^{\text{MAC}} D^{\text{MAC}} + P_t^{\text{packet}} D^{\text{header}}) \times 8/BR) + E^{\text{back}} \tag{5}$$

Where, $P^{back}$ and $E^{back}$ are the background power and energy used up in sending the data packet, $P_t^{MAC}$ is the power at which the MAC packets are transmitted, $D^{MAC}$ is the size of the MAC packets in bytes, $D^{header}$ is the size of the trailer and the header of the data packet, $P_t^{packet}$ is the power at which the data packet is transmitted and BR is the transmission bit rate [8]. Typical values of K1 and K2 in 802.11 MAC environments at 2Mbps bit rate are 4μs per bytes and 42μJ respectively. Flow chart for load balancing approach is given in Fig. 2.

### C. *Algorithm for Transmission Power Control Approach*

*Step 1:* Transmit power is recorded in the data packet by every node lying along the route from source to destination and it is forwarded to the next node.

*Step 2:* When the next node receives that data packet at power $P_{recv}$, it reads the transmit power $P_{tx}$ from the packet, and recalculates the minimum required transmit power $P_{min,}$ for the precursor node.

$$P_{min} = (P_{tx} - P_{recv}) + P_{threshold} + P_{margin} \tag{6}$$

Where $P_{threshold}$ is the required threshold power of the receiving node for successful reception of the packet. The typical value of $P_{threshold}$ in LAN 802.11 is $3.652^{-10}$watt. To overcome the problem of unstable links due to channel fluctuations, a margin $P_{margin}$ is included. Because the transmit power is monitored packet by packet, in our work, we maintain a margin of 1dB.

*Step 3:* The recalculated minimum required transmission power, $P_{min}$ is sent to the precursor node through acknowledgement (ACK).

*Step 4:* When the ACK packet is received by the precursor node, it records the modified transmit power in the power table and transmits the remaining packets with $P_{min}$.

*Step 5:* When a node can not find a record in the power table for a particular node, which will be the case when two nodes never exchanged packet before, it transmits with default power level of 280mW.

In MANETs using the energy aware on demand routing protocol, a source initiates route discovery mechanism every time, after a break period, when it wants to send packets for a destination. It selects a route based on the load balancing approach in order to balance the depletion of battery energy and applies the transmission power control approach while transmitting the data packets. EA_AODV integrates the load balancing approach and transmission power control approach.

## III. PERFORMANCE EVALUATION

### A. *Simulation Scenario*

The following scenario has been simulated in GloMoSim [8] simulator for comparing the performance of EA_AODV with AODV. The total number of nodes participate in the network is fixed at 50 for the simulation. The nodes move inside a simulation area of (1500×300) m².The simulation time is kept at 900 seconds. The nodes move with a maximum velocity of 20m/s and in accordance with the random waypoint mobility model. In this model, a node randomly chooses a speed and a point in the simulation area for the next move. The speed is uniformly distributed between zero velocity and the maximal velocity. Subsequently, the node drives to the selected point at a constant speed. After arriving at the end point the node remains there for a certain time. Subsequently, the node repeats the operation by selecting a new end point and a new speed. The default transmit power is fixed at 15-dBm. The simulation is performed for three runs using different source destination pairs, with various number of CBR connections.

### B. *Performance Metrics*

The following four key performance metrics are evaluated:

(i) *Capacity* is the total number of useful data packets reached the destination at the end of simulation. Capacity indicates the throughput of the network.

(ii) *End-to-End Delay* is the total delay that a packet experiences as it is traveling through the network. This delay is built up by several smaller delays in the network that adds together.

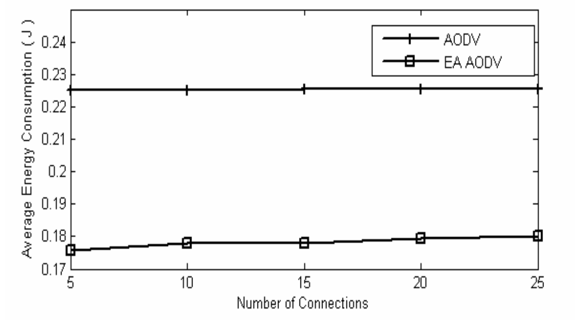
(iii) *Energy Consumption per packet* is the ratio of the total energy consumed by all nodes in the network to the number of packets successfully reached the destination.

(iv) *Average Energy Consumption per node* is the ratio of total energy consumed by all nodes in the network to the total number of nodes.

### C. *Performance Comparison of EA_ AODV and AODV*

The average energy consumption per node has been evaluated as a function of traffic connections for comparing the performance of EAAODV with that of AODV. Traffic connection refers to the source-destination pair participating in communication. . From Fig 3 it is observed that EAAODV gives 20% less average energy consumption per node compared to the conventional AODV. This is mainly attributed to the energy aware approach.

The other three performance metrics listed in section *B* namely energy consumption per packet, capacity and average end-to-end delay have been evaluated as a function of varying terrain dimensions for comparing the performance of EAAODV with that of AODV. Number of source-destination pairs has been fixed as 25. From Fig 4 it is observed that energy consumption per packet of EAAODV is much less than that of AODV and it is also observed that energy consumption per packet of both AODV and EA AODV is increasing slightly as the terrain dimension is increasing.



. Fig. 3 Average Energy Consumption per node

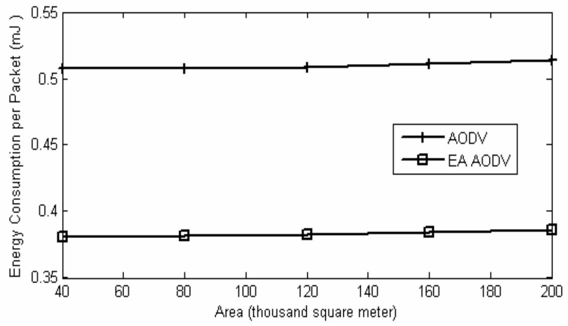


Fig. 4 Energy Consumption per packet for varying terrain area.

When the terrain area increases energy consumption per packet also increases, because packets may nave to travel via many more hops in larger network area than the smaller area. It is observed from Fig.4 that the EA_AODV protocol can save 20% of energy compared to standard AODV.

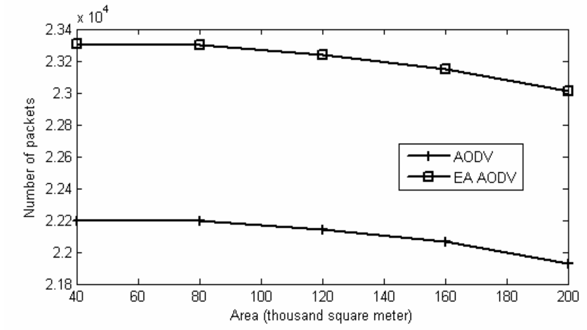


Fig. 5 Total number of packets reached the destination as a function of terrain area

Fig 5 shows that the capacity of EA_AODV is higher compared to the basic AODV. The reason for the lower capacity of AODV is that more number of nodes being out of sufficient battery power during the simulation and hence they could neither forward any more packets to a destination, nor could they transmit their own packets. But in EA_AODV, as the nodes have longer lives, they are capable of transmitting their own packets as well as forwarding packets of other sources, for a longer period of time.

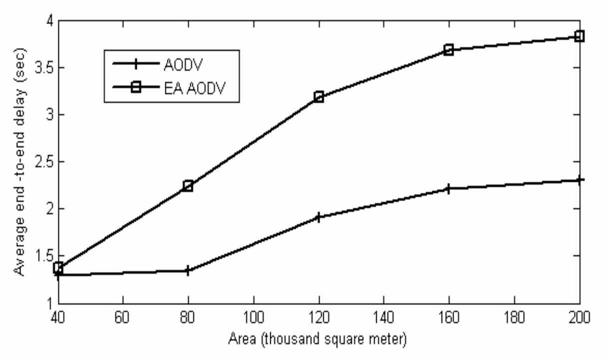


Fig. 6 Average end-to-end delay as a function of terrain area

The price being paid for the improved energy efficiency and capacity in EA_AODV is shown in Fig 6 which reveals that the average end-to-end delay experienced by the packets is more in the case of EA_AODV compared to AODV due to the inclusion of extra information such as remaining battery energy, packet transmission power in the packet header. This in turn changes the packet structure and increases the packet size. Moreover packets are not always sent via minimum hop path. Hence, average end-to-end delay is 5% higher in EA_AODV compared to the standard AODV.

However, simulation results indicate that the application of energy aware mechanism on AODV improves its performance by reducing the per-node as well as per-packet energy consumption and increases the throughput.

## IV. CONCLUSION

Energy management born out of limited battery capacity of wireless nodes is a challenge to be tackled in MANETs. In this paper, a mechanism is proposed for MANETs using on_demand routing protocols in order to maximize the lifetime of the network. This mechanism integrates two different approaches namely the load balancing approach and the transmission power control approach. The mechanism applied on standard AODV resulted in EA_AODV. From simulation results it is learnt that the EA_AODV reduces on an average the energy consumption per node by 20%, the energy consumption per packet by 20% and increases the capacity by 5%. The price paid for the improvement in these performance parameters is the 5% increase in average end-to-end delay due to the inclusion of extra information in the packet header. Though, in this paper the energy aware mechanism is applied only on AODV, it could be applied for any on demand routing protocol to get energy efficiency with improved performance.

## REFERENCES

[1] C.E. Perkins and E.M.Royer, “Ad HocOn Demand Distance Vector Routing”, in proceedings of the 2nd IEEE Workshop on MobileComputing Systems and Applications, pp. 90-100, February 1999.

[2] C.K.Toh, “Maximum Battery Life Routing to Support Ubiquitous Mobile Computing in Wireless Ad Hoc Networks”, IEEE Communications Magazine, pp 138-146, June 2001.

[3] Sheetalkumar Doshi, Timothy X Brown, “An On Demand Minimum Energy Routing Protocol for a Wireless Ad Hoc Networks”, Proceedings of ACM SIGMOBILE Mobile Computing and Communication Review, Vol. 6, Issue.3, pp. 50-66, July 2002.

[4] Frederick J. Block, Carl W.Baum, “Information for routing in energy-constrained ad Hoc networks”, Ad Hoc Networks 4 (2006), pp 499-08. URL:http://www.elsevier.com/locate/ad hoc

[5] Qun Li, Javed Aslam, and Daniela Rus,“Distributed Energy-Conserving Routing Protocols,” *proceedings of the 36th Hawaii International Conference on System sciences, IEEE2002*

[6] Mohammed Tarique, Kemal E. Tepe, and Mohammed Naserian, “Energy Saving Dynamic Source Routing for Ad Hoc Wireless Networks”, IEEE international Conference on Modeling and Optimization in Mobile Ad hoc and Wireless Networks, pp 305-310, December 2005.

[7] C.E.Perkins, E.M.Royer, S.R.Das, Ad hoc On-Demand Distance Vector (AODV) Routing”, *Internet Draft, draft-ietf-manet-aodv-12.txt*, 15, November 2002. URL:http://www.ietf.org/internetdrafts/draft-ietf-manet-aodv-12.txt

[8] Jorge Nuevo, “A Comprehensible GloMoSim Tutorial”, University of Quebec, September 2003

**M. Tamilarasi** did her B.E at Government College of Technology, Coimbatore, India and received her B.E. degree in Electronics and Communication Engineering from Bharathiar University, India and M.E. degree in Electronics from Madras Institute of Technology, Anna University, India. She is currently working as an Assistant Professor in the Department of Electronics and Communication Engineering at Pondicherry Engineering College and doing her Ph D in QoS Routing protocols in MANETs on part time basis at Pondicherry University, India. Her research interests include wireless communication, Data Networking, and MANETs.

**T.G. Palanivelu** received his B.E. and M.E. degrees in Electronics and Communication Engineering from Anna University, India in 1971 and 1973 respectively. He obtained his Ph.D. in Electronics and Communication Engineering from Indian Institute of Science, Bangalore, India in 1981. He joined the faculty of Department of Electronics and Communication Engineering at National Institute of Technology, Tiruchirapalli, India as a Lecturer in 1973, and thereafter as an Assistant Professor in 1983. He joined the faculty of Department of Electronics and Communication Engineering at Pondicherry Engineering College affiliated to Pondicherry University, India in 1985. He is a fellow of Institute of Electronics and Telecommunication Engineers, India. His research area includes wireless communication, MANETs and network security.