Energy Efficient Multipath Routing Protocol for Wireless Mobile Ad Hoc Networks

May Cho Aye, and Aye Moe Aung

***Abstract*—**MANET has limited resources like bandwidth and energy. Due to limited battery power nodes die out early and affect the network lifetime. So, energy efficiency is one of the main problems in a mobile ad hoc network, especially designing a routing protocol. In this paper, we propose an efficient routing algorithm and we call it EEM-AOMDV. The proposed algorithm aims to increase the network lifetime and minimize the energy consumption during the source to destination route establishment. The algorithm which we propose considers two energy metrics in route selection and integrates these metrics into AOMDV. This system is implemented by using NS-2.34. Simulation results show that the proposed routing protocol can extend the lifetime of the network and can achieve higher performance when compared to conventional ad hoc on-demand multipath distance vector (AOMDV) routing protocol.

***Keywords*—**AOMDV, energy efficient routing, remaining energy, transmission power control.

I. Introduction

MOBILE Ad Hoc Network (MANET) is a collection of mobile nodes, which form a wireless network without the use of an existing infrastructure. MANETs are usually characterized by random mobility of nodes, nodes arbitrarily entering and leaving the network and variable transmission range of nodes. These characteristics make MANET links to be intermittent and the topology to be highly dynamic [1,2,3]. The nodes are the main components of the network and they can move freely at any time and can leave or join the network. Each node in addition to functioning as a host, also serves as a router that can receive and forward packets to the next node. MANETs are very attractive for tactical communication in the military and rescue missions. They are also expected to play an important role in the civilian fora such as convention centers, conferences, and electronic classrooms.

Many routing protocols for MANETs have been proposed. Depending on the time of route discovery MANET routing protocols are divided into two categories; table-driven (proactive) routing protocol and on-demand (reactive) routing protocol. The on-demand routing is the most popular approach in the MANET. Instead of periodically exchanging route messages to maintain a permanent route table of the full topology, the on-demand routing protocols build routes only when a node needs to send the data packets to a destination. The standard protocols of this type are the Dynamic Source Routing (DSR) [4] and the Ad hoc On-demand Distance Vector (AODV) [5] routing. However, these protocols do not support multipath. The several multipath on-demand routing protocols were proposed.

The Ad-hoc On-demand Multipath Distance Vector (AOMDV) [6] routing protocol is a multipath extension of the Ad-hoc On-demand Distance Vector (AODV) routing protocol. AOMDV has three novel aspects compared to other on-demand multipath routing protocols. Firstly, it does not have intermodal coordination overheads like some other protocols. Secondly, it ensures disjointness of alternate routes via distributed computation without the use of source routing. Thirdly, AOMDV computes alternate paths with minimal additional overhead over AODV. It does this by exploiting as much as possible already available alternate path routing information.

The main limitation of ad hoc system is the availability of power. The nodes in the MANET are typically powered by batteries which have limited energy reservoir. Sometimes it becomes very difficult to recharge or replace the battery of nodes; in such situation energy conservations are essential. The lifetime of the nodes show strong dependence on the lifetime of the batteries. Early “death” of some mobile nodes due to energy depletion may cause several problems such as network partition and communication interruption. Therefore it is required to limit the power consumption of mobile nodes, prolong the battery life and to maintain the robustness of the system. The conventional on-demand routing algorithms establish connections between nodes through the shortest paths and they do not consider energy of nodes while selecting routes. These algorithms may result in a quick depletion of the battery energy of the nodes along the most heavily used routes in the network. This paper attempts to modify the most popular on-demand multipath routing protocol (AOMDV). The goal of this work is to find the feasible path based on the combination of two energy metrics. The proposed protocol reduces the energy consumption of mobile nodes and increases the lifetime of the network.

The remainder of this paper is organized as follows: In section 2, we discuss the related works relevant to our paper. Section 3 provides a detail description of the proposed system. In section 4, we evaluate the performance of the proposed system through simulation experiments. Finally, we conclude to our work in section 5.

May Cho Aye is with the Faculty of Information and Communication Technology, University of Technology (Yatanarpon Cyber City), Pyin Oo Lwin, Myanmar (e-mail: maychoaye@gmail.com).

Aye Moe Aung is with the Faculty of Information and Communication Technology, University of Technology (Yatanarpon Cyber City), Pyin Oo Lwin, Myanmar (e-mail: ayemoeaung@gmail.com).

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II. Related Works

Mobile Ad Hoc Networks (MANETs) is a wireless infrastructure-less network, where nodes are free to move independently in any direction. The nodes have limited battery power; hence we require energy efficient routing protocols to optimize network performance. Energy conservation is a major issue in the ad hoc networks for saving network life time with limited battery power.

Ongoing research in power optimization in MANETs have targeted all the layers especially network layer. Various routing protocols for effective energy utilization have been proposed. Suresh Singh and C. S. Raghavendra [7] proposed the PAMAS protocol that uses two different channels to separate data and signaling. The Suresh Singh, Mike Woo and C.S. Raghavendra [8] presented several power-aware metrics that do result in energy-efficient routes. The Minimum Total Transmission Power Routing (MTPR) [9] was initially developed to minimize the total transmission power consumption of nodes participating in the acquired route. The Min-Max Battery Cost Routing (MMBCR) [10] considers the remaining power of nodes as the metric for acquiring routes in order to prolong the lifetime of network. C.K.Toh [10] presented the Conditional Max-Min Battery Capacity Routing (CMMBCR) protocol, which is a hybrid protocol that tries to arbitrate between the MTPR and the MMBCR.

In [11], Yumei Liu, Lili Guo, Huizhu Ma and Tao Jiang proposed a multipath routing protocol for mobile ad hoc networks called MMRE-AOMDV, which extends the Ad Hoc On-demand Multipath Distance Vector (AOMDV) routing protocol. The key idea of the protocol is to find the minimal nodal residual energy of each route in the process of selecting path and sort multi-route by descending nodal residual energy. Once a new route with greater nodal residual energy is emerging, it is reselected to forward rest data packets. It can balance individual node’s battery power utilization and hence prolong the entire network’s lifetime.

In [12], Seema Verma, Rekha Agarwal and Pinki Nayak proposed a new energy efficient scheme called optimized energy aware routing (OEAR). The proposed algorithm not only considers energy of the node while selecting the route but also takes into account the number of packets buffered in the node. The OEAR finds the most stable path out of the entire existing paths from source to destination using on-demand routing.

III. Proposed System

The proposed algorithm aims to increase the network lifetime and minimize the energy consumption during the source to destination route establishment. The algorithm which we propose considers two energy metrics in route selection and integrates these metrics into AOMDV. The two energy metrics which we consider are:

1) Transmission power
2) Residual energy

A. Transmission Power Control

In our proposed system, the transmission power is used as the energy metric in the path discovery and selection. This method requires that each node can record in a suitable packet format field the power level, P_{Txmax}, used to transmit that packet. Furthermore, it requires that the radio-transceiver can estimate the received power, P_{Rx}.

With the knowledge of P_{Txmax} and P_{Rx}, the generic node is able estimate the link attenuation. In particular, when a station receives a packet from a neighbor, the channel attenuation is simply computed as the difference of the transmitted power P_{Txmax} and the received power P_{Rx}. For the simple case of a symmetric channel, where we neglect possible channel time fluctuations and we assume the same interference power level, the attenuation affecting the transmission of that station towards that neighbor would be the same as measured [13]. Thus, the transmission power P_{Tx} can be calculated as follow:

$$P_{Tx} = P_{Txmax} - P_{Rx} + S_R + Sec_{th} \qquad (1)$$

Where S_R is the minimum power level required for correct packet reception and Sec_{th} (*Security Threshold*) is a power margin introduced to take into account channel and interference power level fluctuations, i.e., to make the transmission more reliable in view of the fact that the channel is not symmetric. The typical value of Sec_{th} in LAN 802.11 is 3.652^{-10} watt.

Assume that there are j feasible paths and each path includes i nodes, the value R can be defined as follows:

$$R = \max_j \min_i (RE \,/\, P_{Tx}) \qquad (2)$$

The optimum route is determined by using the value of R described above. Among all feasible paths, the path with the maximum value R is chosen as the optimal route for transmitting data packets. Here RE is the residual energy on the route and P_{Tx} is the transmission power.

B. Residual Energy Estimation

It is to be assumed that all nodes present in mobile ad hoc network are equipped with a residual energy detection device and know their physical node location. The energy consumption for transmitting and receiving a packet can be calculated as follows:

$$E_{Tx} = \frac{P_{Tx} \times 8 \times Packetsize}{Bandwidth} \qquad (3)$$

$$E_{Rx} = \frac{P_{Rx} \times 8 \times Packetsize}{Bandwidth} \qquad (4)$$

The node remaining energy or the residual energy is the energy left after the packet transmission (i.e.) residual energy RE is given by

$$RE = IE - TER \qquad (5)$$

Where RE is the residual energy, IE is the initial energy and TER is the total energy required.

C. Operation of EEM-AOMDV

Our energy efficient multipath routing protocol is based on AOMDV and we call it EEM-AOMDV. The main idea in EEM-AOMDV is to balance nodal energy consumption and increase the lifetime of the network. The EEM-AOMDV performs a route discovery process similar to the AOMDV protocol. The difference is to determine an optimum route by considering residual energy of nodes on the path and transmission power as energy metrics. The EEM-AOMDV protocol consists of three phases:

1. Route Discovery

Route discovery in this proposed system is an enhanced version of route discovery in AOMDV. In route discovery procedure, the EEM-AOMDV protocol builds a route between source to destination using a route request and route reply query cycle. When a source node wants to send a packet to destination for which it does not already have a route, it forwards a route request (RREQ) packet to all the neighbors across the network. In our algorithm, two additional fields are added in the RREQ header information such as residual energy RE and transmission power P_{Tx}.

The extended Route Request packet of EEM-AOMDV is shown in Fig. 1.

<table>
<tr><td>Type</td><td>Reserved</td><td>Hop Count</td></tr>
<tr><td colspan="3">RREQ ID</td></tr>
<tr><td colspan="3">Destination IP Address</td></tr>
<tr><td colspan="3">Destination Sequence Number</td></tr>
<tr><td colspan="3">Originator IP Address</td></tr>
<tr><td colspan="3">Originator Sequence Number</td></tr>
<tr><td colspan="3">Residual Energy (RE)</td></tr>
<tr><td colspan="3">Transmission Power (P_{Tx})</td></tr>
</table>

Fig. 1 Extended route request (RREQ) message

The source node initiates the routing discovery with the maximal transmission power to broadcast RREQ packet. Once the Route Request (RREQ) packet is received by the destination node, the node needs to produce Route Reply (RREP) packet and send back to the source node. So it calculates P_{Tx} according to Eq. (1) and the ratio of RE to P_{Tx}. Then it adds the values to the corresponding fields of RREQ and produces RREP. The values recorded in RREQ will be copied to RREP. Finally, it begins to send RREP to the source node. Otherwise, the RREQ packet will be received by the intermediate nodes within the range of wireless transmission. If these nodes are not destination and do not receive the RREQ with the same packet ID, they will calculate P_{Tx} according to Eq. (1) and continually forward the RREQ to the destination. When the RREQ message arrives at next node, the transmission power and residual energy is updated into the route list entries.

When the RREP is received by the source node, the process will be terminated. Otherwise, the intermediate node receives the RREP and then it calculates the ratio of RE and P_{Tx}. If the calculated value is less than that recorded in RREP, the record will be replaced. Then it continues to forward RREP to the source node.

2. Route Selection

Once the RREP is received by the source node, the feasible path is successfully established. The source node starts a timer and during the period RREPs are collected by the source node. Then the source node begins to calculate the value R based on the corresponding records in RREP according to Eq. (2) and choose the path with the maximum value R as the optimal route. Finally, data packets are sent through this path with the transmission power recorded in RREP.

3. Route Maintenance

When a node finds an error in forwarding a data packet, it will initiate a route error packet (RERR) and send it back to the previous node to indicate the route breakage. If node receives this RERR message, it informs to the source node. Then each node that receives the RERR packet would remove the corresponding item from routing table and switches to alternate path.

IV. Performance Evaluation

A. Simulation Model and Parameters

We evaluate the performance of EEM-AOMDV and AOMDV routing protocol using ns-2 [14]. We implemented the EEM-AOMDV protocol in ns-2.34. In our simulation, the channel capacity of mobile hosts is set to the same value: 2 Mbps. The simulated traffic is Constant Bit Rate (CBR). In the simulations, IEEE 802.11 distributed coordination function (DCF) is used as the MAC protocol.

The simulation settings and parameters are summarized in Table I.

TABLE I
Simulation Parameters

Parameter	Value
Simulator	NS-2.34
Channel Type	Wireless Channel
Radio Propagation Model	Two Ray Ground
MAC Type	802.11
Antenna Model	Omni-directional (unity gain)
Simulation Time	200 sec
Number of nodes	25,50,100,150,200,250
Simulation Area	1000 m * 1000 m
Routing Protocols	AOMDV, EEM-AOMDV
Traffic Type	CBR
Data Packet Size	512 Bytes
Initial Energy	100 Joules

B. Performance Metrics

The proposed EEM-AOMDV protocol is compared with the traditional AOMDV protocol. It is evaluated mainly the performance according to the following metrics.

1. Energy Consumption

Energy consumption is defined as the ratio between the sums of energy expended by each node to the total number of data packets delivered.

2. End to End Delay

It is a time required for packets to reach to destination node from source node.

3. Throughput

It is the average rate of successful message delivery over a communication channel. These data can be delivered over a physical or logical link. It is measured in bits per second.

C. Performance Results

The performance of the protocol is evaluated using energy consumption, end to end delay and throughput as the parameters. We compare the proposed protocol based on transmission power of nodes and residual energy with traditional AOMDV.

Fig. 2 shows that EEM-AOMDV has a better energy consumption compared to AOMDV even number of nodes are varied. In Fig.3, EEM-AOMDV has the lower average end-to-end delay compared to AOMDV with different number of nodes. It outperforms energy efficient communication. Fig.4 shows that EEM-AOMDV is better than AOMDV based on throughput. Throughput reduces when simulation time increases, even then throughput of EEM-AOMDV is higher for complete simulation duration.

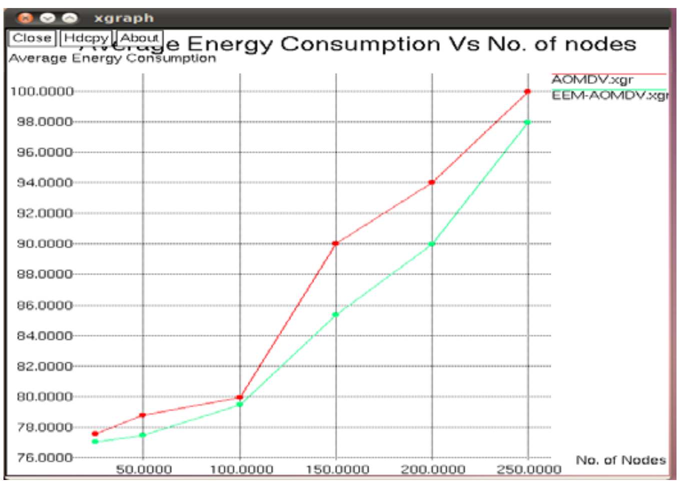

Fig. 2 Average Energy Consumption Comparison

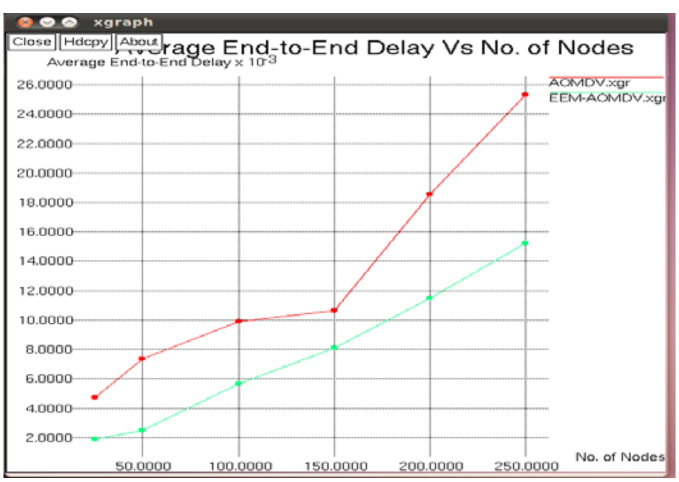

Fig. 3 Average End-to-End Delay Comparison

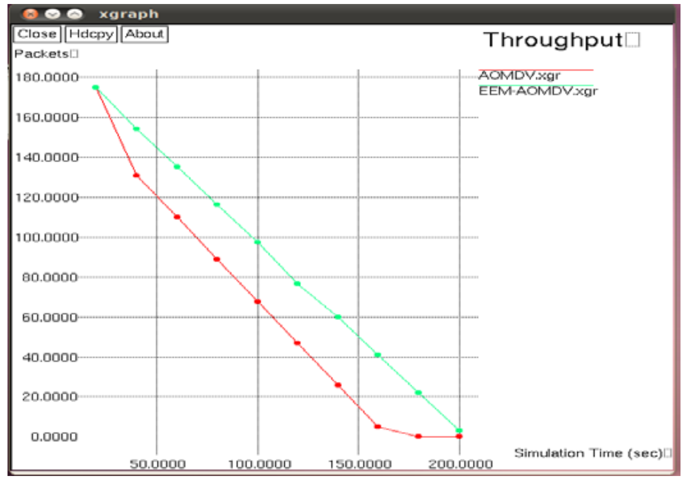

Fig. 4 Throughput Comparison

Overall, EEM-AOMDV gives much longer lifetime than AOMDV approach. EEM-AOMDV improves the network lifetime by about 20%. This justifies that EEM-AOMDV can balance the traffic load among different nodes and prolong the individual node's lifetime and hence the entire system lifetime. And also, EEM-AOMDV reduces energy consumption by 35% using our proposed protocol.

V. Conclusion

In this paper, we propose an efficient routing protocol based on a reactive and multipath routing. The proposed algorithm considers transmission power of nodes and residual energy to extend the network lifetime and reduce the energy consumption of mobile nodes. This system is provided to reduce energy consumption and end to end delay to improve the network lifetime and throughput. Hence, simulation results show that EEM-AOMDV has better throughput, end-to-end delay and energy consumption than AOMDV.

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References

[1] E. Royer and C-K Toh, "A Review of Current Routing Protocols for Ad-Hoc Mobile Wireless Networks", IEEE PCM, pp. 46-55, April 1999.

[2] S. Bhandare , "Energy Aware Implementation of an Ad Hoc Routing Protocol", ITD Masters Thesis University of Colorado, 2003.

[3] C. Jones, K. Sivalingam, P. Agrawal, J. Chen "A Survey of Energy Efficient Network Protocols for Wireless networks", Wireless Networks, 7(4):343--358, July 2001.
http://dx.doi.org/10.1023/A:1016627727877

[4] D. B. Johnson and D. A. Maltz, "Dynamic Source Routing in Ad hoc Wireless Networks," Mobile Computing, vol.353, pp. 153-181, Kulwer Academic Publishers, 1996.

[5] C. E. Perkins, and E. M. Royer, "Ad-hoc On-Demand Distance Vector Routing," Proc. of 2nd IEEE Workshop on Mobile Computing Systems and Applications, New Orleans, LA, pp. 90-100, 1999.
http://dx.doi.org/10.1109/MCSA.1999.749281

[6] Mahesh K. Marina, and Samir R. Das, "Ad hoc on-demand multipath distance vector routing," Wireless Communications and Mobile Computing, Vol 6, No. 7, pp. 969-988, November 2006.
http://dx.doi.org/10.1002/wcm.432

[7] Suresh Singh and C. S. Raghavendra, "PAMAS - Power Aware Multi-Access protocol with Signaling for Ad Hoc networks", in Proceedings of ACM SIGCOMM, Computer Communication Review, July, 1998.

[8] Suresh Singh, Mike Woo and C. S. Raghavendra, "Power-Aware Routing in Mobile Ad Hoc Networks", in Proceedings of Mobicom 98 Conference, Dallas, October 1998.
http://dx.doi.org/10.1145/288235.288286

[9] K.Scott, Bambos, "Routing and channel assignment for low power transmission in PCS", ICUPC, 1996.

[10] C.-K. Toh, "Maximum Battery Life Routing to Support Ubiquitous Mobile Computing in Wireless Ad Hoc Networks", IEEE Communications Magazine, June, 2000.

[11] L. L. Guo, H. Ma, and T. Jiang, "Energy Efficient on–demand Multipath Routing Protocol for Multi-hop Ad Hoc Networks," IEEE, 2008.

[12] Seema Verma, Rekha Agarwal, and Pinki Nayak, "An Optimized Energy Aware Routing (OEAR) Scheme for Mobile Ad Hoc Networks using Variable Transmission Range," International Journal of Computer Applications (0975-8887), Vol 45, No. 12, May 2012.

[13] P. Bergamo, "Distributed Power Control for Energy Efficient Routing in Ad Hoc Networks," Wireless Networks, pp. 29-42, 2004.
http://dx.doi.org/10.1023/A:1026236712926

[14] The VINT Project, "Network simulator _ ns2," http://www.isi.edu/nsnam/ns/.

Ms. May Cho Aye is an Assistant Lecturer at West Yangon Technological University (WYTU). She has received her B.E degree in Information Technology from Technological University (Taungoo), Myanmar in 2006 and M.E degree in Information Technology from West Yangon Technological University (WYTU), Myanmar in 2010. Currently, she is pursuing Ph.D degree in Information Technology from University of Technology (Yatanarpon Cyber City), Pyin Oo Lwin, Myanmar. Her research interests are Wireless Communications, Mobile Ad Hoc Networks and Wireless Sensor Networks.

Dr. Aye Moe Aung is with the Faculty of Information and Communication Technology, University of Technology (Yatanarpon Cyber City), Pyin Oo Lwin, Myanmar.