Energy Efficient Routing for MANETs using On-demand Multipath Routing Protocol

May Cho Aye, Aye Moe Aung

Abstract— **Energy efficient routing is very essential in MANET. Energy efficient routing techniques play a significant role in saving the energy consumption of the network. We decided to design an energy efficient routing protocol which reduces the total energy consumption in the network and thus maximize the life time of the network. We proposed an energy efficient routing protocol which is based on residual energy and transmission power of nodes for choosing energy efficient path. The goal of this work is to choose the best route based on these two energy metrics. The simulation is carried out using NS-2.34. The experimental results show that the proposed algorithm reduces the average energy consumption when compared to the standard AOMDV routing protocol.**

Index Terms—**AOMDV, energy efficient, residual energy, transmission power control.**

I. Introduction

A Mobile Ad-hoc Network (MANET) is a dynamic wireless network that can be formed without the need for any pre-existing infrastructure in which each node can act as a router. Mobile ad hoc network (MANET) is an autonomous system of mobile nodes connected by wireless links. Each node operates not only as a host, but also as a router to forward packets. The nodes are free to move about and organize themselves into a network. These nodes change position frequently. The rapidly changing of network topology makes it more difficult to make routing decision. It is a great challenge to maintain an efficient network performance while maintaining high energy efficiency in such environment [1].

Since MANETs are infrastructure-less, self-organizing, rapidly deployable wireless networks, they are highly suitable for applications involving special outdoor events, communications in regions with no wireless infrastructure, emergencies and natural disasters, and military operations, mine site operations, urgent business meetings and robot data acquisition [2, 3].

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. In table-driven routing protocols the routes are discovered and refreshed periodically. All routing related information is stored in routing tables at each node. Whenever a traffic source needs a route, it uses the route available in the routing table. In contrast to this, the traffic source initiates route discovery process when it needs route in case of on-demand routing protocols. The on-demand routing is the most popular approach in the MANET. 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 AODV routing protocol.

Deployment of ad-hoc network leads to many challenges such as limited battery power, limited bandwidth, multi hop routing, dynamic topology, security [7]. But, the major issue in MANET is energy consumption since nodes are usually mobile and battery-operated. Power failure of a mobile node affects its functionality thus the overall network lifetime. To prolong life time of the network, ad-hoc routing protocol should consider energy consumption. Efficient minimum energy routing schemes can greatly reduce energy consumption and extends the lifetime of the networks. In this paper, we propose an energy efficient algorithm which reduces the total energy consumption in the network and thus maximize the life time of the network. The algorithm which we propose considers the combination of residual energy and transmission power of nodes for choosing energy efficient path. We applied this system on AOMDV to make it energy aware and we denote as EER-AOMDV.

The remainder of this paper is organized as follows: In section 2, we discuss the related works relevant to our paper. Section 3 provides our proposed method and a detail operation of the proposed system is described in section 4. In section 5, we evaluate the performance of the proposed system through simulation experiment. Finally, we conclude to our work in section 6.

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.

Manuscript received May, 2014.
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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 [8] proposed the PAMAS protocol that uses two different channels to separate data and signaling. The Suresh Singh, Mike Woo and C.S. Raghavendra [9] presented several power-aware metrics that do result in energy-efficient routes. The Minimum Total Transmission Power Routing (MTPR) [10] was initially developed to minimize the total transmission power consumption of nodes participating in the acquired route. The Min-Max Battery Cost Routing (MMBCR) [11] considers the remaining power of nodes as the metric for acquiring routes in order to prolong the lifetime of network. C.K.Toh [11] 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 [12], 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 [13], 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 Method

In this paper, we propose an energy efficient routing algorithm which reduces the total energy consumption in the network and thus maximize the life time of the network. The algorithm which we propose considers the combination of residual energy and transmission power of nodes for choosing energy efficient path. We applied this system on AOMDV to make it energy aware and we denote as EER-AOMDV.

A. Residual Energy Estimation

It is to be assumed that 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:

$$E_{Tx} = \frac{P_{Tx} \times 8 \times Packetsize}{Bandwidth} \quad (1)$$

$$E_{Rx} = \frac{P_{Rx} \times 8 \times Packetsize}{Bandwidth} \quad (2)$$

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

$$RE = IE - TER \quad (3)$$

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

B. 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} [14]. Thus, the transmission power P_{Tx} can be calculated as follow:

$$P_{Tx} = P_{Txmax} - P_{Rx} + S_R + Sec_{th} \quad (4)$$

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:

$$R = \max_{j} \min_{i} (RE \;/\; P_{Tx}) \quad (5)$$

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.

IV. EER-AOMDV Protocol

In this paper, we propose an energy efficient routing (EER-AOMDV) based on AOMDV. The main idea in EER-AOMDV is to balance nodal energy consumption and increase the lifetime of the network. The EER-AOMDV performs a route discovery process similar to the AOMDV protocol. The difference is to determine an optimum route by considering residual energy of each mobile node and transmission power as energy metrics. The EER-AOMDV protocol consists of two phases:

1) Route Discovery

In route discovery procedure, the EER-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 EER-AOMDV is shown in Fig. 1.

<table>
<tr><td>Type</td><td>Reserved</td><td>Last Hop</td><td>Next Hop</td></tr>
<tr><td colspan="4">Broadcast ID</td></tr>
<tr><td colspan="4">Destination IP Address</td></tr>
<tr><td colspan="4">Destination Sequence Number</td></tr>
<tr><td colspan="4">Source IP Address</td></tr>
<tr><td colspan="4">Source Sequence Number</td></tr>
<tr><td colspan="4">Request Time</td></tr>
<tr><td colspan="4">Residual Energy (RE)</td></tr>
<tr><td colspan="4">Transmission Power (P_{Tx})</td></tr>
</table>

Fig. 1 Extended route request (RREQ) message format

The source node initiates the routing discovery with the maximal transmission power to broadcast RREQ packet. Once the RREQ packet is received by the intermediate nodes, they calculate RE and P_{Tx} and update the calculated values into the route list entries as shown in Table I and then continually forward the RREQ to the destination. Once the RREQ packet is received by the destination node, it calculates P_{Tx} 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.

When the RREP is received by the intermediate node, 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. Once the RREP is received by the source node, it 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 and choose the path with the maximum value R as the optimal route.

TABLE I
ROUTING TABLE ENTRIES FOR TRADITIONAL AOMDV AND EER-AOMDV

AOMDV	**EER- AOMDV**
Destination Address	Destination Address
Sequence Number	Sequence Number
Advertised-hop count	Advertised-hop count
Route List {(next hop1, hop count1), (next hop2, hop count2),.....}	Route List {(next hop1, hop count1, RE1, $\mathbf{P_{Tx}}$ 1), (next hop2, hop count2, RE2, $\mathbf{P_{Tx}}$ 2),.....}
Expiration time out	Expiration time out

1) 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.

V. PERFORMANCE EVALUATION

A. Simulation Parameters

We implemented the proposed protocol with NS-2.34 [15]. We tried to compare the performance of our proposed algorithm (EER-AOMDV) with AOMDV. The area in which the nodes are spread is 1000 X 1000 meters and there are 25, 50, 100, 150, 200 and 250 nodes which can move in a range of 250 meters in random directions. In this work we adapted CBR traffic model and each node uses the IEEE802.11 protocol in its MAC layer and the total simulation time is 200 seconds. Each of node has 100 Joules of energy at the start of every simulation.

The simulation settings and parameters are summarized in Table II.

TABLE II
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, EER-AOMDV
Traffic Type	CBR
No. of Traffic Connection	10
Data Packet Size	512 Bytes
Initial Energy	100 Joules

B. Result and Analysis

The proposed EER-AOMDV protocol is compared with the conventional AOMDV protocol for average energy consumption. Average Energy Consumption is the ratio of total energy consumed by all nodes in the network to the total number of nodes.

Fig. 2 gives the comparison between average energy consumption and number of nodes. Number of source-destination pairs has been fixed as 10. In this comparison, the proposed EER-AOMDV has a better energy consumption compared to AOMDV even number of nodes are varied. From Fig. 2 it is also observed that our proposed

EER-AOMDV reduces the total energy consumption in the network and thus maximize the life time of the network.

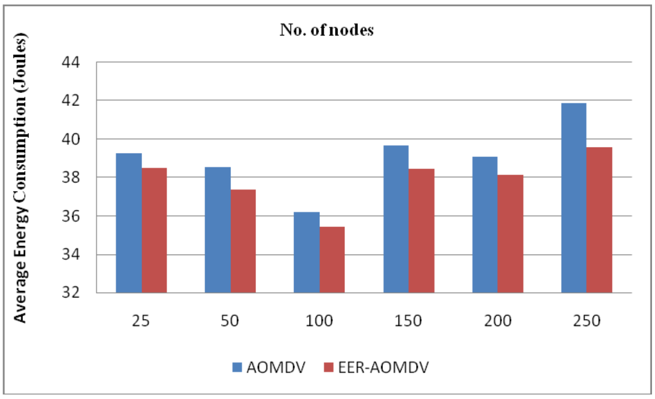

Fig. 2 Average energy consumption vs. no. of nodes

VI. Conclusion

In this paper, we proposed an energy efficient routing algorithm to reduce energy consumption in order to maximize the lifetime of the network. We considered the combination of residual energy and transmission power of nodes for choosing energy efficient path. In this paper, we analyzed our proposed routing algorithm EER-AOMDV with the standard AOMDV for average energy consumption. Simulation result shows that the proposed EER-AOMDV outperforms AOMDV in energy consumption and thus maximizes the network's lifetime. In our future work, we will analyze the performance of our proposed protocol with other parameters such as network lifetime, end to end delay and throughput.

Acknowledgment

The author would like to offer her deepest gratitude to supervisor, Dr. Aye Moe Aung, for her effective suggestion, willingness to share ideas and knowledge to attain her destination without any trouble. The author would like also to greatly thank Dr. Aung Win, Principal of University of Technology (Yatanarpon Cyber City), Pyin Oo Lwin, Myanmar for his support and guidance during this work.

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