Modified Energy Constraint AODV for Wireless Sensor Network

Hnin Yu Swe, and Soe Soe Khaing

Abstract—In wireless sensor network (WSN), an efficient utilization of resources is a very important issue as the nodes in the network depends on these scarce resources, such as battery power, bandwidth and so on. Energy efficiency and reliability are thus important issues in such network. Routing is one of the things that need to be enhanced to achieve a better network performance. Therefore, this paper enhances ad hoc on demand distance vector (AODV), which is one of the widely used reactive routing protocols, in order to reduce energy consumption and achieve the reliability of WSN. As AODV considers simple hop count metric to select the best path, it is not suitable for WSN. Therefore, the main purpose of this paper is to consider not only hop count but also energy metric and node lifetime when selecting the best path. The modified AODV, which is called EC-AODV, define energy threshold value to avoid inefficient node in data transmissions and it also consider energy factor and node lifetime metrics, in order to maintain the connectivity of the network as long as possible. Simulation results conducted in network simulator (NS-2) prove that the effectiveness of proposed system in terms of throughput, average end-to-end delay and energy consumption.

Keywords— AODV, EC-AODV, Energy Factor, Node Lifetime, WSN.

I. INTRODUCTION

A wireless sensor network (WSN) is a collection of nodes organized into a cooperative network. Each node consists of processing capability, multiple types of memory, an RF transceiver, a power source (e.g., batteries and solar cells), and accommodate various sensors. The features of the wireless sensor network are random deployment, self-organizing, cooperating and local computation. WSN has some characteristics unlike traditional wireless net, such as large number of nodes (versus ad hoc networks), densely deployed, prone to failure, frequent topological changes, broadcast communication (versus point-to-point), limited power computation, and memory, no global identification (ID). Many routing protocols have been proposed for wireless sensor network with different kinds of metrics according to application area.

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Routing protocols in wireless sensor network are subdivided into two basic classes as proactive routing protocols and reactive routing protocols. Destination-Sequenced Distance-Vector Routing Protocol (DSDV) is one of the proactive routing protocols, which performs well in static scenarios. On demand driven protocols offer a better performance in dynamically changing environments. Some examples of these protocols are DSR and AODV. In AODV, when a source node is wishing to send a packet but it has no valid route in its route table, it initiates a route discovery procedure. In route discovery, a source node broadcasts a route request (RREQ) to its neighbors. An intermediate node that receives a first RREQ sets up a reverse path to the source node if necessary. If the intermediate node has a valid route to the specified destination, or it is the intended destination, it returns a route reply packet (RREP) to the source node. Otherwise, the node will broadcast the RREQ to its neighbors. As the RREP travels towards the source, a forward path to the destination can be established. When the next hop link breaks, RERR packets are sent to a set of neighboring nodes that communicate over the broken link with the destination. The conventional on demand routing algorithms, such as DSR, AODV, that are being unaware of nodes' energy, establishes connections between nodes through the shortest path routes. These algorithms may result in a quick depletion of the battery power of the nodes along the most heavily used paths in the network. This paper attempts to modify the most popular on-demand routing protocol AODV. A number of parameters are added to AODV that balances the energy of nodes inside the network while selecting a route to the desired destination. The proposed system that considers the energy factor and node lifetime is able to increase the overall network performance by reducing the energy consumption.

The rest of the paper is organized as following. Section two describes related works and section three describes the proposed routing procedure. In section four and five, evaluating routing parameter and performance analysis are described. Finally, this paper draws the conclusion in section six.

II. RELATED WORKS

Enhanced Mobile Ad hoc Routing Protocol Using Cross Layer Design in Wireless Sensor Networks [7] proposes the new method based on AODV routing protocol to find the route using cross layer design on 802.15.4 standard. Energy Weight –AODV (EW-AODV) has used the cross layer design technique for routing layer to access the energy parameter from the lower layer. The Enhanced Fault-Tolerance Mechanism of AODV Routing Protocol for Wireless Sensor Network [2] creates a backup path for every node on a main path of data delivery. Choose the primary path from destination and all intermediate node create backup route by using request reply cycle. This may lead to message overhead in destination by request and reply message. Energy aware routing in Ad Hoc Networks [3] in which AODVEA routing protocol is proposed to choose a route with largest minimum residual energy and AODVM chooses a route with the large minimum residual energy and less hop count. Ad hoc On-demand Multi-path Distance Vector protocol (AOMDV) [4], which is an extension of AODV for discovering node-disjoint or optionally link-disjoint paths. It finds node-disjoint paths by exploiting a particular property of flooding. Energy Efficient Routing in Mobile Ad hoc Networks based on AODV Protocol [5] attempts to modify the popular on demand routing protocol AODV to make it energy aware. It uses total remaining energy and the transmission power is varies between two nodes as per their distance.

III. PROPOSED ROUTING PROCEDURE

Since 1999, KDD'99 [13] has been the most widely used This paper proposes modified AODV with energy metric, EC-AODV that considers the energy factor and node lifetime on the path for finding the optimal path between source and destination pairs. In this proposed system each node do not participate in route discovery and data forwarding process if residual energy is less than threshold value of energy. Otherwise the protocol works in two phrases like the AODV protocol as follows:

- Route Discovery
- Route maintenance

A. Route Discovery

In route discovery phrase each node checks its residual energy. If the residual energy of node is lower than threshold level, it does not participate in route selection to forward data traffic. When a source node has a data packet to send to an intended node in the network, it starts performing the following activities. Firstly, the source node checks whether it has already a route in its routing table. If the valid route exists in its routing table, it sends the packet to the destination on the specified route. Otherwise, it starts the route discovery procedure to find a route to that destination. EC-AODV function starts in the route discovery procedure. The source node prepares the RREQ packet with the destination IP address and there are newly added fields in the RREQ packets to find an optimal route. These fields are energy factor (EF) and node lifetime (NLT). Before sending a broadcast RREQ packet in the network, the source node initially calculates its EF and NLT and adds these values to the RREQ packet, and then broadcasts it.

After receiving the request packet by the intermediate nodes, they check their residual energy. If their energy is less than threshold value, they discard the route request. In contrast they calculate their EF and NLT and update their routing tables with a route that has a higher EF and NLT for the reversed path of RREP if their residual energy is greater than threshold value. Finally, the destination node receives the RREQ packet with EF and NLT. The best optimal path is updated in nodes' routing tables. EN-AODV considers not only the EF and NLT, but also hop count like AODV. Then it sends the reply back to the source with a route, in which a path that has higher nodes' lifetime and energy factor is selected.

B. Route maintenance

Route maintenance process comes to life when the link failure occurs. There are many reasons to cause the link failures, which are node mobility, power exhaustion, network congestion and so on. When a node detects that its neighbor nodes are not reachable by periodically sending HELLO packets, it sends RERR packet to its upstream node to reach to the source node. The nodes that receive the RERR packet flush their routing table entries regarding the fail nodes. When the source node receives RREP packet, it make the process of route discovery for a new route.

IV. EVALUATING ROUTING PARAMETERS

The proposed EC-AODV integrates two energy metrics into AODV in an efficient way so that the Ad hoc sensor network has a greater lifetime and energy consumption of each node across the network is reduced. The integration of two energy metrics is energy factor and node lifetime. The following steps are the calculation of energy factor.

$$\text{Energy} = \text{Power} \times \text{Time} \tag{1}$$

$$\text{Time} = 8 \times \text{packet\_size} / \text{Bandwidth} \tag{2}$$

When considering the nodes' energy in the network, it needs to calculate how much of energy is consumed by transmission and reception of packets, as well as nodes' current and initial energies. To calculate Energy Factor (EF) that we consider, the following equation is used.

$$EF = ER / Ei \tag{3}$$

where ER is residual or remaining energy and Ei is Initial energy of a node. Initial energy of a node is assigned when a node is initially created. ER is calculated as follow.

$$ER = Ec - (Et + Er) \tag{4}$$

where Ec is current energy of a node, Et and Er are transmission and reception energies of a node and calculated as follow.

$$Et = (Pt \times 8 \times \text{packet\_size}) / \text{Bandwidth} \tag{5}$$

$$Er = (Pr \times 8 \times \text{packet\_size}) / \text{Bandwidth} \tag{6}$$

where, Pt and Pr are the transmission and reception power of a node.

Node lifetime (NLT) is the ratio of residual energy of a node and draining rate (DR) of the node. Draining rate is the rate at which energy is consumed at a given node. In EC-AODV, all nodes need to calculate their predicted lifetime except destination. DR can be calculated by the following equation.

$$DR = (Ep - Ec) / (Tc - Tp) \tag{7}$$

where, Ep is previous energy of node and Ec is current energy, Tc is current time and Tp is the previous time.

To implement EC-AODV, there are some modifications of AODV's RREQ, RREP and routing tables of the nodes. The first two bits of reserved field in RREQ packet are used to access Ep and Tp and two new fields are added into RREQ and RREP packet to access energy factor and node life time. The modified RREQ and RREP packets are described in Fig.1 and Fig.2. Route Table Entries of EC-AODV are as follows:

- Destination IP Address
- Destination Sequence Number
- Next Hop
- Hop Count
- Energy Factor (EF)
- Node Life Time (NLT)
- TTL

Type	Ep	Tp	Reserve	Hop count
RREQ ID				
Destination IP Address				
Destination Sequence Number				
Originator IP Address				
Originator Sequence Number				
TTL				
Energy Factor (EF)				
Node Life Time (NLT)				

Fig.1. Modified RREQ packet

Type	Reserve	Hop count
RREQ ID		
Destination IP Address		
Destination Sequence Number		
Originator IP Address		
Originator Sequence Number		
TTL		
Energy Factor(EF)		
Node Life Time		

Fig.2. Modified RREP packet

During route discovery procedure, energy factor and node lifetime are calculated and added in RREQ packets. The destination or intermediate node creates reverse path according to hop count, energy factor and node lifetime and updates their routing tables.

V. Performance Evaluation of EC-AODV

Network simulator (NS-2) is used to evaluate the performance differences of AODV and EC-AODV. As the performance metrics, throughput, average end-to-end delay, packet delivery ratio, routing overhead and average energy consumption are measured.

- Throughput is the measure of the number of packets successfully transmitted to their final destination per unit time.
- Average end-to-end delay is the time delay between the application data packet sent at the source node to the destination node.
- Packet delivery ratio is the ratio of number of packets received by destination to number of packets sent by source. The PDR is varies between 0 and 1.
- Routing overhead is the sum of all types of control packets sent during route discovery and route maintenance during data transfer. It also includes RREQ, RREP, and RERR messages also.
- Average energy consumption is energy consumption per node calculated across the entire topology. It measures the average difference between the initial level of energy and the final level of energy.

Simulation is set up with 802.11 wireless channel and Random Waypoint mobility scenario. Simulations are run 300 seconds. The 20-tcp connections are randomly exchanging file transfer applications among 50 nodes that are moving at a speed of 3m/s. The initial energy of nodes is set to 500 joules. Fig.3 describes simulation parameters in detail. The output animation of simulation is shown in Fig.4.

Simulation Parameters	
Simulation area	670 x760
Channel type	Two Ray Ground
MAC type	IEEE 802.11
Antenna model	Omni-directional
Propagation	TwoRayground
Movement model	Random Waypoint Model
Average node speed	3 m/s
Node pause time	1 sec
Number of nodes	50 nodes
Simulation time	300 sec
Traffic model	TCP (20 connections)
Application	File transfer
Initial energy	500 Joules
Energy Threshold	2.5 Joules
Routing protocols	AODV and EN-AODV

Fig.3. Simulation parameters

The average energy consumption of nodes is firstly examined. The results are shown in fig.5. Energy consumption of each node in EC-AODV is more efficient than AODV according to simulation result. Moreover EC-AODV offers a better result in terms of quality of service parameters.

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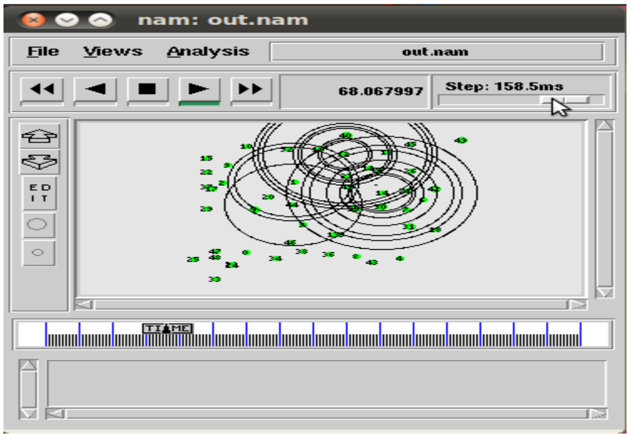

Fig.4. Network animator of output simulation

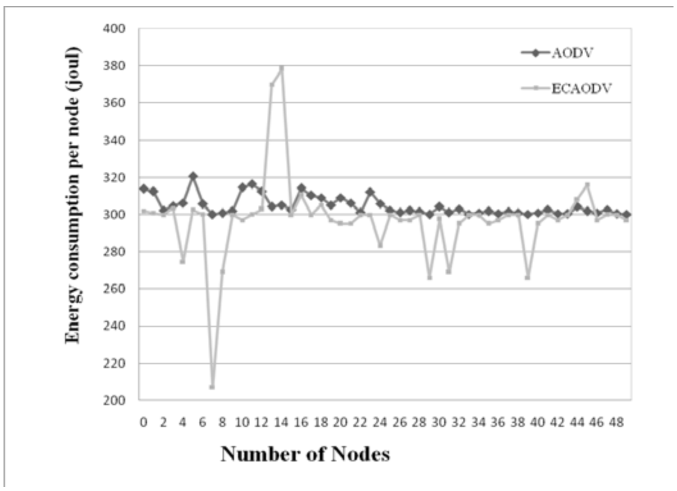

Fig.5. Energy consumption of node

Metric	AODV	EC-AODV
Throughput (bps)	728.39	983.74
Average end-to-end delay (sec)	459.86	74.31
Packet delivery fraction	0.9773	0.9958
Dropped packet ratio	2.98	0.36
Average energy consumption	308.73	301.86

Fig.6. Performance comparison of AODV vs EC-AODV

Other measured simulation results are shown in fig.6. EC-AODV outperforms 26% better in throughput, 83.8% better in average end-to-end delay, 1.86% better in packet reception rate or packet delivery fraction, 87.92% better in dropped packet ratio and 2.23% better in average energy consumption.

VI. Conclusion

The proposed system aims to provide the route, which has a higher energy factor from the source to the destination. WSN can suffer routing break problem during packet transmission due to power expiration. Energy efficiency and the reliability of packet transmission can be improved by choosing an optimal path, which has efficient energy resource. In EC-AODV, three parameters such as energy factor, node lifetime and hop count are considered in routing decision. EC-AODV achieves a better energy consumed and performance in QoS parameters than AODV. But EC-AODV is simulated with node 30 and it does not work well in larger network. EC-AODV still needs to be enhanced to work well in large network.

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