Throughput Analysis of Energy Aware Reactive Routing Protocol for Wireless Sensor Networks

P. Samundiswary, S. R. Anandkumar

Abstract*—Wireless Sensor Networks (WSNs) consist of thousands of small sensor nodes with sensing, computation and wireless communication capabilities. The main challenging task in WSN is routing. There are various types of routing protocols available for WSN. Ad hoc On-demand Distance Vector (AODV) routing protocol is one of routing protocols for mobile sensor networks. AODV avoids the counting-to-infinity problem of other distance-vector protocols by using sequence numbers on route updates, a technique pioneered by Destination Sequence Distance Vector (DSDV). This protocol utilizes the shortest route for communication between nodes. Hence, energy consumption and battery power of nodes is increased by using the same nodes with shortest route for communication several times. Energy efficient Ad hoc On-demand Distance Vector (EAODV) routing protocol is developed by incorporating energy aware algorithm along with the shortest route in the existing Ad hoc On-demand Distance Vector Routing protocol to reduce battery power and lifetime of WSN. In this paper, throughput performance of EAODV and AODV protocol has been examined and compared by varying packet size in CBR traffic, packet rate, coverage area and number of packets with the help of ns-2 simulator.

I. INTRODUCTION

Wireless Sensor Networks (WSNs) have several applications in different fields as military, surveillance and commercial applications such as environment monitoring, traffic control, remote patient monitoring and disaster relief applications[1-2]. Although WSN is used in many applications, it has many restrictions such as limited computation and limited communication abilities [3]. Hence various routing protocols have been developed for WSNs because the routing in WSNs is distinguished from other networks. First, due to the relatively large number of sensor nodes, it is impossible to build a global addressing scheme for the deployment of a large number of sensor nodes [4-5]. Thus, traditional IP based protocols may not be applied to WSNs. Second, sensor nodes are tightly constrained in terms of energy, processing, and storage capacities [6]. So they require careful resource management. Third, as node failure is occurred frequently in WSNs which results in unpredictable and frequent topological changes. So the routing protocol must adapt to frequent changes of the WSNs topology. AODV is one of the reactive routing protocols adapted for WSNs topology [7].

This protocol considers hop count to route the data to the required destination from the source. However, this protocol does not consider the energy consumption of the nodes to transfer the message from source to destination node. So the lifetime of the network is reduced by utilizing the same path and nodes. To extend the lifetime of sensor nodes, routing protocol with energy efficient is considered. And also it is desired to maintain the sensor nodes as long as alive as the sensor nodes are irreplaceable. Hence an attempt has been made to implement Energy aware Ad hoc On-demand Distance Vector (EAODV) by appending minimum residual energy along with minimum hop count in the Route REQuest (RREQ) message of the existing reactive routing protocol named AODV protocol. The throughput performance is evaluated for EAODV protocol and compared with AODV protocol by varying different criteria such as coverage area, packet rate and packet size in CBR traffic which is described in this paper. The remaining section of the paper is organized as below. Section 2 deals with the ad hoc on demand distance vector routing protocol. Energy aware ad hoc on demand distance vector routing protocol is described in Section 3. In section 4 routing performance namely throughput is analyzed and compared between EAODV and AODV. Finally, conclusions are drawn in Section 5.

II. AD HOC ON DEMAND DISTANCE VECTOR ROUTING PROTOCOL

The AODV [8] protocol is an on-demand routing protocol, which accomplishes the route discovery whenever a data transfer is requested between nodes. The AODV routing protocol searches a new route only by request of source nodes. When a node requests a route to a destination node, it initiates a route discovery process among network nodes [9]. Once a route is discovered in the AODV routing protocol, the route will be maintained in a table until the route is no longer used. Each node in the AODV protocol contains a sequence number, which increases by one when the location of a neighbor node changes. The sequence number can be used to determine the recent route at the routing discovery.

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The AODV protocol utilizes a similar routing discovery process as the DSR (Dynamic Source Routing) protocol but uses a different process to maintain and manage a routing table. The nodes of the DSR protocol maintains all routing information between source and destination but the nodes of the AODV protocol have path information in a brief routing table, which stores the destination address, destination sequence number and next hop address.

In AODV protocol, the flooding of RREQ messages is done as shown in Figure 1. Each entry of a routing table has a lifetime field which is set when its routing information is updated and changed. An entry will be removed from the routing table when its lifetime is expired. Moreover, to maintain a routing table, the AODV protocol periodically exchanges routing messages between neighbour nodes [10]. Such processes typically raise significant overhead and wastes available bandwidth.

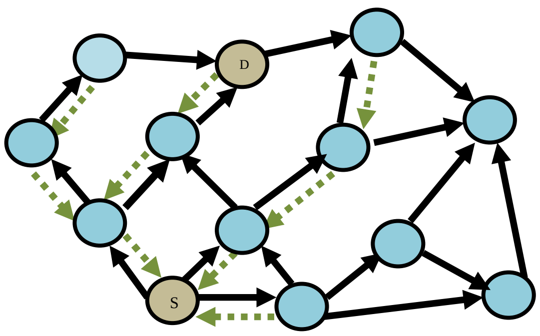

Figure 1: Flooding of RREQ messages

RREQ propagation
Reverse Route
S Source Node
D Destination Node

However, the AODV protocol reduces the latency time of the routing discovery and determines efficient routes between nodes. After flooding the RREQ messages in a network, a route is established between source and destination. The AODV routing protocol determines a least hop-count path between a source and a destination, thus minimizing the end-to-end delay of data transfer. Since the protocol uses the shortest route for end-to-end data delivery, it minimizes the total energy consumption.

However, if two nodes perform data transfer for long time on the specific path, nodes belonging in this path use more battery power than other nodes, resulting in earlier powering out of nodes [11-13]. The increase of power-exhausted nodes creates partitions in the wireless sensor network. The nodes belonging to these partitions cannot transfer any further data, thus killing the lifetime of the network.

In order to extend the lifetime of the network, one possible solution is to make equally balanced power consumption of sensor nodes. Since AODV routing mechanism does not utilize the residual energy of nodes at the routing setup, and since it considers only routing hop count as a distance metric, such unbalanced node energy consumptions occurs. Hence, energy efficient routing algorithm is developed [14] by considering both node hop-count and node energy consumption.

III ENERGY AWARE AD HOC ON DEMAND DISTANCE VECTOR ROUTING PROTOCOL

In EAODV protocol, residual energy of sensor nodes is considered along with the hop count to avoid unbalanced energy consumption of sensor nodes. Since, the protocol can make the node energy consumption balanced and extend overall network lifetime without performance degradation compared to the AODV routing algorithm.

The optimum route is determined by using the value of parameter α described in equation 1.

$$\alpha = \frac{Min - RE}{k.No - Hops} \quad \text{...........(1)}$$

Where
Min-RE is the minimum residual energy on the route
No-Hops is the hop count of the route between source and destination
k is the weight cofficients for the hop count

The destination node calculates the values of α for received routes and chooses a route that has the largest value of α. That is, the EAODV protocol collects routes that have the minimum residual energy of nodes relatively large and have the least hop-count, and then determines a proper route among them, which consumes the minimum network energy compared to any other routes.

The analysis of routing protocols

To understand the operations of the EAODV Routing protocol, the following operations are considered in the protocol
Case 1: A route with the minimum hop count between source and destination is chosen in AODV protocol
Case 2: A route with the large minimum residual energy and less hop count is selected. This methodology is used in EAODV routing protocol to achieve longest network lifetime.

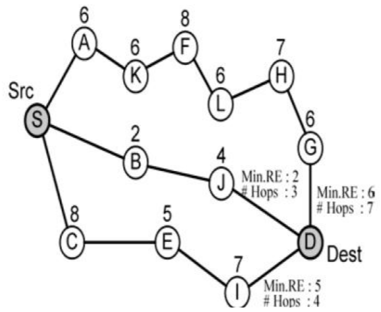

Figure 2: A sample network for establishment of routing paths

The operation of EAODV routing protocol is illustrated in Figure 2. Here a simple routing is considered to setup route from source node S to destination node D. The number written on a node represents the value of residual node energy. Since the Case 1 considers only the minimum hop count, it selects route <S-B-J-D> which has the hop count of 3. The proposed model considers the Case 2 to transfer the data from source to destination node. Thus route <S-C-E-I-D> is selected which has largest α value of 1.25. Case 1 selects the shortest path without considering residual energy of nodes, which is the same as the AODV routing algorithm. Case-2 improves the drawbacks of Case 1 by considering both residual energy and hop count. It extends network lifetime by arranging almost all nodes to involve in data transfer.

IV SIMULATION RESULTS

The model of wireless sensor network using AODV and EAODV protocol is simulated by using ns-2 [15]. The simulation model is performed for 50 nodes by considering the coverage area of 400×400(m^2) and simulation time of 20 seconds. The traffic model considered in the simulation is UDP/CBR traffic model. Size of data packet in CBR traffic is varied from 64 to 500 bytes, packet rate varies from 25 to 500k packets/sec and maximum no. of packets in queue is varied from 25 to 200 packets. Each sensor node in the network is assumed to have an initial energy level of 0.5 Joules. A node consumes the energy power of 175mW on packet transmission and energy power of 175mW on packet reception.

A) Throughput Performance under Different Packet Sizes

The packets size in CBR traffic is varied from 64 to 500 by considering 50 nodes for coverage area of 400x400 (m^2). Throughput analysis is studied through the simulation result shown in Figure 3. It is also observed from the same, that the throughput of energy aware AODV routing is higher than that of AODV routing of approximately 20%-50%. The improvement in throughput of EAODV is due to the delivery of more packets successfully from source to destination node by selecting the path based on energy levels of nodes along with the shortest route.

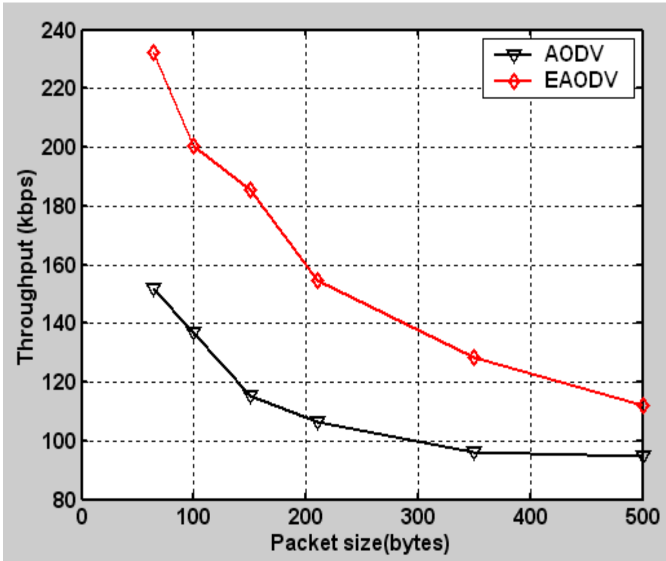

Figure 3: Throughput with respect to packet size in CBR Traffic for AODV and EAODV routing protocol

B) Throughput Performance under Different Packet Rates

The packet rate is varied from 25 Kbits/sec to 500 Kbits/sec for 50 nodes by considering the coverage area of 400x400 (m^2). The performance parameter namely throughput is determined and compared for AODV and EAODV protocol. It is verified through the simulation result illustrated in Figure 4 that the throughput of energy aware AODV routing is higher than that of AODV routing of approximately 54% at packet rate of 150Kbits/sec. The increased throughput obtained through EAODV is due to the fact that EAODV increases the forwarding rate of packets by selecting the neighbour nodes having minimum energy levels.

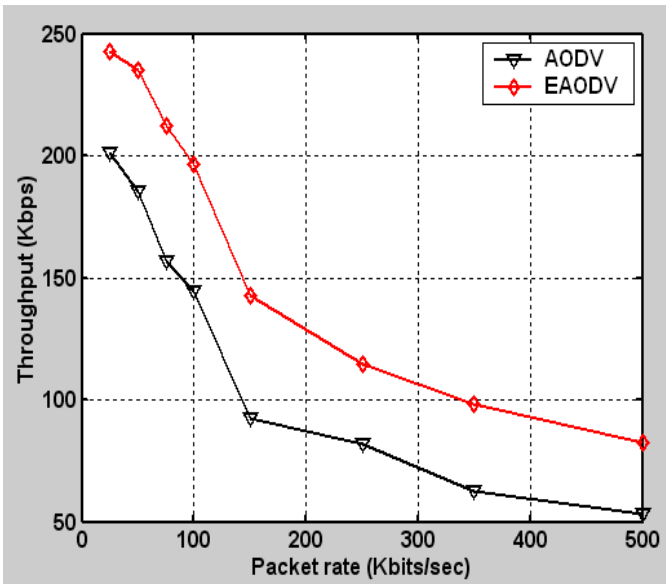

Figure 4: Throughput with respect to different packet rates for AODV and EAODV routing protocol.

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C) Throughput Performance under Different Coverage Area

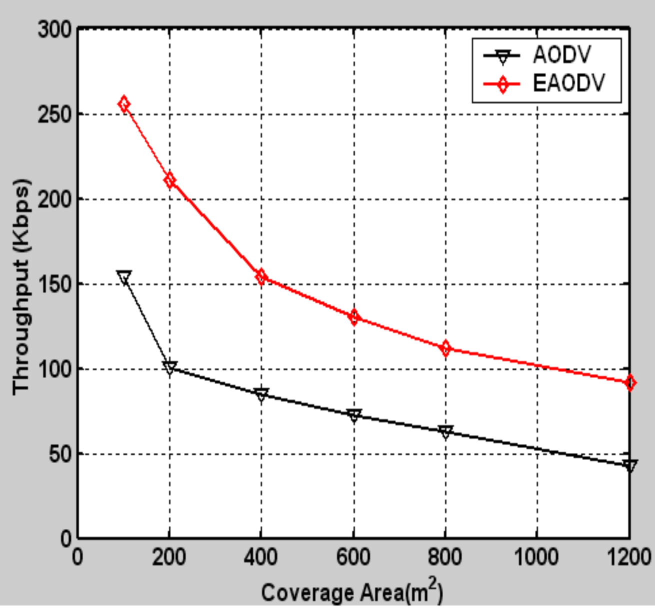

Figure 5: Throughput for various coverage areas of AODV and EAODV routing protocols with 50 nodes.

The throughput is evaluated for various coverage areas by considering 50 nodes. EAODV outperforms AODV by achieving higher throughput performance for 50 nodes as illustrated by figure 5. It is demonstrated through the same figure that EAODV provides higher throughput of approximately 85 % (average) for various coverage areas than that of AODV routing protocol. The throughput of EAODV and AODV is reduced for increased coverage area which is observed through figure 5. The reason is due to more random deployment of nodes in the larger coverage area.

D) Throughput Performance by varying number of packets in Queue Length

Throughput performance is examined by varying the no. of packets in queue length from 25 to 200 packets for 50 nodes with the coverage area of 400x400(m^2). Simulation result shown in Figure 6 demonstrates that EAODV achieves improvement in throughput of approximately 18%-30% compared to that of AODV. The increment in the throughput of EAODV is due to the fact that EAODV selects the neighbour node based on its residual energy level along with the hop count for the transmission of packets from source node to destination node.

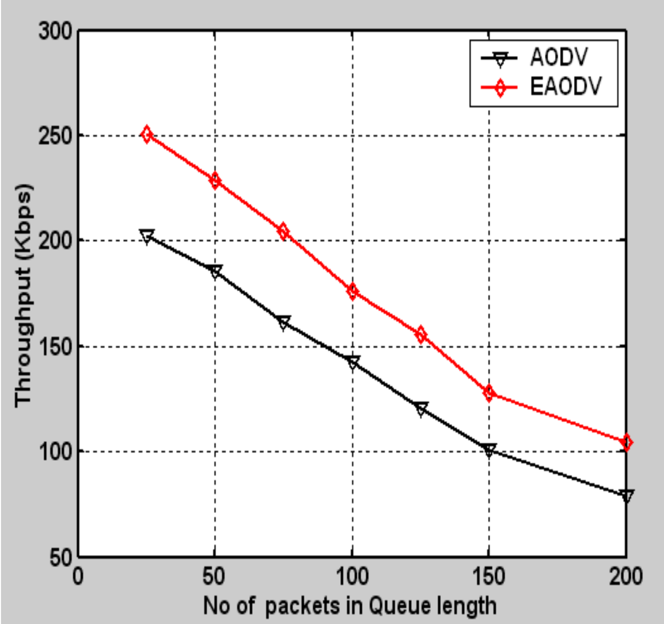

Figure 6: Throughput for different packets in Queue length of AODV and EAODV routing protocols with 50 nodes.

V. CONCLUSION

Energy efficient Ad hoc On-demand Distance Vector (EAODV) is thus a decentralized energy aware routing protocol which can be implemented for wireless sensor networks by using ns-2. EAODV uses the residual energy along with the hop count. It extends network lifetime by arranging almost all nodes to involve in data transfer. By varying the packet size, packet rate, coverage area and no. of maximum of packets in queue length and packet rate in the simulation, the throughput performance of WSN by using the AODV and EAODV is analyzed and compared for 50 nodes with the simulation time of 20 seconds and coverage area of 400x4400 (m^2). From the simulation results it can be concluded that the throughput performance of EAODV is much better than the AODV routing protocol. The throughput of the EAODV routing is 40-65% higher than the AODV routing. Thus EAODV can be implemented with the improved routing performance in terms of throughput

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