Energy-Aware Node Disjoint Multipath Routing Protocol for Wireless Sensor Networks

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***Abstract*— Single path routing protocols in WSN may lead to holes in the network, as only the nodes present in the single path are utilized for data transmission. Therefore, multipath routing protocols are recommended for WSN. Multipath routing protocols increases the network lifetime by distributing the traffic among multiple paths. Node disjoint multiple paths are selected for data transmission to spread the load among different nodes. In this paper we propose a sink initiated multipath search protocol to discover multiple node-disjoint paths between the source and the sink nodes. The performance of our protocol is compared to AOMDV and EENDMRP. The proposed protocol show better result in terms of energy consumption, packet delivery fraction, and end-to-end delay as compared to AOMDV and EENDMRP.**

***Keywords*— Wireless Sensor Network, Multipath Routing, Node-Disjoint, Energy Consumption.**

I. INTRODUCTION

Wireless sensor networks typically use batteries for supply of energy and often these batteries are non-chargeable. Thus, energy efficient communication is vital for prolonging the network lifetime. Recently, various routing protocols have been proposed for WSNs. Most of these protocols use single optimal path for data transmission. The optimal path is selected based on the metrics, such as minimum hop, high residual energy, minimum transmission cost etc. to route the data [1]-[4]. Although the single-path approach is simple and scalable, but selecting an optimal path and sending the data through that path may not increase the network lifetime [5]. Using multipath routing in wireless sensor networks can help in efficient energy usage, by evenly distributing the traffic load over the network, thus extending the network lifetime.

In [6], authors have proposed multipath routing technique to increase the resilience to node failure. Two different approaches for constructing multipath are considered. One is the classical node-disjoint multipath and the other approach is braided multipath that consists of partially disjoint alternate paths. Source node or an intermediate node selects one path from the available multiple paths to the sink on the basis of data delivery quality. On changes in network conditions, a node may change its primary path to another one. However, this mechanism is limited by the inherent delay to switch to and establish a new primary path in case of changes in network conditions.

In [7], authors have proposed an N-to-1 multipath routing protocol that finds multiple node-disjoint paths between the source and the sink nodes. The protocol is receiver-initiated (i.e., BS initiated) and finds every sensor node a set of node-disjoint paths to the BS simultaneously. However, the protocol does not take into account the node energy level during route construction phase. It also lacks an efficient load balancing mechanism to distribute the traffic in an efficient manner.

In [8], authors proposed an energy efficient routing protocol for WSN. During the route construction phase, the author proposes distributed multipath search algorithm which is capable to discover multiple-node disjoint paths. Also a load balancing algorithm is proposed that allows the sink node to distribute traffic over multiple paths based on path cost, which depends on energy level and hop distance of nodes along each path. However, the route construction and maintenance is costly in terms of energy due to high overhead.

In [9], authors have proposed a reactive multipath routing protocol. In the proposed protocol the assumption of common base station is eliminated and every node may act as a source and a sink node. The route discovery provides multiple paths between the source node and the destination nodes using shared nodes in the query and the search tree. Number of control messages used in the route construction phase is high in order to construct the query and the search tree. The query messages are sent from the sink nodes and search messages are sent from the source nodes. Both of these messages are broadcasted in the network.

In this paper, we propose an energy aware node-disjoint multipath routing protocol (EANDMRP). It is a sink initiated routing protocol. This protocol finds multiple paths between source and the destination based on the hop count and uplink neighbour nodes number. The rest of the paper is organised as follows. The network assumptions are discussed in Section II. We describe the proposed multipath data routing scheme in Section II. The energy aware node disjoint multipath routing protocol is presented in Section III. The comparisons with other protocols are presented in Section IV. Finally, conclusions are presented in Section V.

II. ASSUMPTIONS

The proposed protocol operates under the following assumptions:

1) The nodes are deployed randomly on the sensor network with one source and sink node.

2) As the nodes are deployed densely almost all the sensor nodes have two or more uplink neighbour nodes.

3) Nodes have no mobility.

III. ENERGY-AWARE NODE DISJOINT MULTIPATH ROUTING ALGORITHM

A. Building Network Topology

In the proposed protocol, the first phase is to build the network topology. The sink node starts the multipath route construction phase to generate its routing table. During this process BNTR (Build Network Topology Request) packets are exchanged between the nodes. BNTR packets are broadcasted by setting the hop count to 0, the sequence number to 1, and the BNTR sender address to itself. Sink node then broadcasts BNTR over the network. The hop count and the sequence number increases by 1 as the number of nodes that forward BNTR packet increases. The node checks the hop count from the sink node. If the increased hop count is less than the existing hop count, the node updates the uplink neighbour node list to the BNTR sender's information. If the hop counts are same, the node adds the sender's information to the existing uplink neighbour node list. If the existing hop count is lesser than the increased hop count, the node discards the packet.

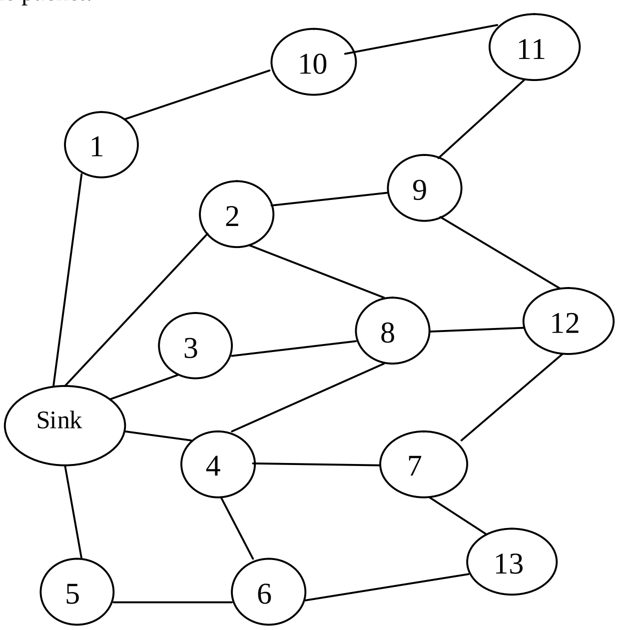

Fig. 1 Building Network Topology in EANDMRP

For example, the hop count of BNTR that node 6 received from node 1 is 2. Similarly, the hop count of BNTR that node 6 received from node 4 is also 2. Therefore, the uplink neighbour list of node 6 contains node 1 and node 4. However, the hop count of BNTR that node 6 received from node 7 is 4. Therefore, the BNTR packet received from node 7 is discarded because hop count 4 is larger than 2, which is the existing hop count. By setting up network topology based on the least hop count, the proposed protocol selects an optimal path that not only has the shortest length, but a path that also prevents packet loops from occurring. The proposed protocol guarantees multiple paths by adding the information of nodes that has same hop count. The intermediate node sends BNTP (Build Network Topology Reply) packets after a certain time with its hop count and uplink neighbour node lists to the sink. The sink node that receives BNTP compares the sequence number that the sink node finally broadcasted with the sequence number in received BNTP. When the two sequence numbers are the same, the sink node modifies the information of the BNTP sender on its routing table. This process continues until the sink node generates its routing table. Table 1 shows the routing table of the sink node in the case of Fig. 1

TABLE I
Sink nodes routing table

Node	**Available**	**Hop count**	**Uplink Neighbour Nodes**
1	T	1	Sink
2	F	1	Sink
3	T	1	Sink
4	T	1	Sink
5	F	1	1, 4
6	T	2	2, 4, 5
7	T	2	3, 5
8	T	2	3, 5
9	F	2	4
10	T	2	5
11	F	3	6, 9
12	T	3	7, 9, 10
13	T	3	8, 10

B. Data Transmission Phase

When the sink node has a message to send to the destination node, the sink node computes the entire route to the destination and then sends the data packet containing the computed route. Intermediate node are not required to maintain its routing table as the information on where to send the data packet is already contained within the packet itself. Thus, this proposed protocol can reduce routing message overhead and prevent looping since the intermediate node does not compute the route on where to send the packet. The proposed protocol uses the priority queue based on the hop count and uplink neighbour nodes count in order to find multiple nodes disjoint paths. If the hop count is larger, the priority to select that node as an uplink node is higher; while on the other hand if the hop count is same, the priority of the node that has smaller neighbour nodes is higher. Thus in this way the proposed protocol can find as multiple node disjoint paths.

IV. PERFORMANCE EVALUATION AND COMPARISON

We present in this section our simulation results for the performance study of our node disjoint multipath routing protocol. Our proposed protocol is compared with EENDMRP and AOMDV. We used NS-2 in order to implement our protocol and compare it with AOMDV and EENDMRP.

Our simulation environment consists of 100m by 100m containing 10 to 100 nodes randomly deployed. All the nodes are identical with transmission range of 15m. The sink node is situated on the left bottom corner and the source node is in the top right corner. The different protocols from different perspective such as end-to-end delay, packet delivery fraction and average energy spent are compared over different network sizes of 10, 20, up to 100 nodes.

A. Packet Delivery Fraction

The packet delivery fraction is the ratio of the data packets delivered to the destinations to those generated by the sources. Fig. 2 shows the PDF of the AOMDV, EENDMRP and EANDMRP for varying number of nodes. The packet drops in the proposed model is lesser as compared to AOMDV and EENDMRP due to the effective primary path selection. The proposed protocol uses the priority queue based on the hop count and uplink neighbour nodes number in order to find the optimal path which guarantees high PDF as compared to AOMDV and EENDMRP. In EENDMRP optimal path selection is based on path cost, whereas in AOMDV random path is selected for sending the data packets from the source node to the sink node over multiple paths. In the Fig. 2, when the number of nodes increases from 10 to 100, the PDF is 100% and 92% respectively in AOMDV; which is 100% and 97% in EENDMRP; whereas its 100% and 97.5% in EANDMRP.

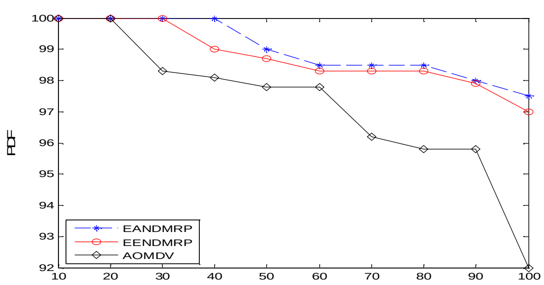

Fig. 2 Variation of PDF with number of nodes

B. Average End-to-End Delay

The average end-to-end delay includes all possible delays caused by queuing at the interface queue, buffering during route discovery latency, retransmission delays at the MAC, and propagation as well as the transfer times of data packets. The proposed protocol, i.e., EANDMRP can find the shortest, optimal route and can reduce the occurrence of congestion significantly by distributing the load weight on each node. The AOMDV model is reactive multipath routing protocol. When the source node has data to send, it starts the route discovery from the source to the sink node. Thus, the end-to-end delay is more due to its reactive nature. In EENDMRP is proactive multipath routing protocol where each and every node maintains its own routing table can result in high overhead. Thus the end-to-end delay is more because of its routing overhead. There is 4.5e4 ms and 6.8e4 ms end-to-end delay in AOMDV when the number of nodes is 10 and 100 respectively. End-to-end delay is 4.4e4 ms and 5.3e4 ms respectively in EENDMRP for 10 and 100 nodes. But, the end-to-end delay in EANDMRP is 3.6e4 ms and 4.9e4 ms when the number of nodes is 10 and 100 respectively. Fig. 3 shows the end-to-end delay for AOMDV, EENDMRP and EANDMRP.

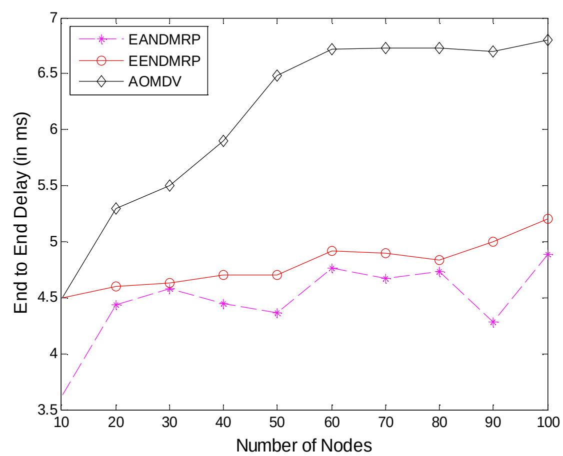

Fig. 3 Variation of end-to-end delay with number of nodes

C. Average Energy Spent

Fig. 4 shows the average energy spent by each node in the network. The average energy spent by each node in the EANDMRP model is less as compared to AOMDV and EENDMRP model. Intermediate nodes are not required to maintain its routing table which reduce routing message overhead drastically.

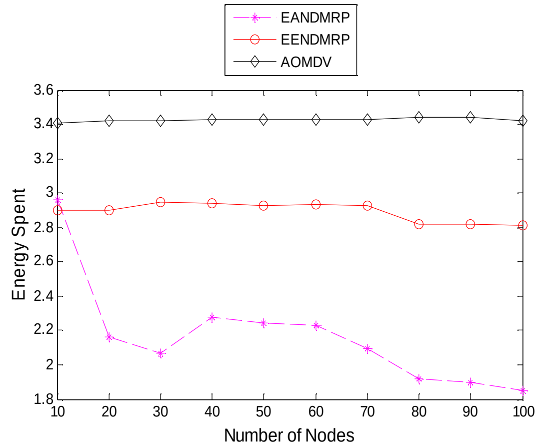

Fig. 4 Variation of energy spent with number of nodes

Thus energy spent on route discovery is greatly reduced. There is reduction of energy consumption in the EANDMRP model as compared to the AOMDV and EENDMRP model.

V. CONCLUSIONS

This paper proposes an energy aware multipath routing protocol to increase the network lifetime. It provides better reliability than AOMDV and EENDMRP. There is an improvement in reduction of end-to-end delay, improved packet delivery fraction and energy saving. This protocol is designed to support only text data and multimedia data routing is not taken into consideration.

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