Multi-Hop Optimal Position Based Opportunistic Routing for Wireless Sensor Networks

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***Abstract*—Wireless sensor network is a collection of a group of sensors connected to monitor an area of interest. Installation flexibility, mobility, reduced cost and scalability have given popularity to wireless sensor networks. Opportunistic routing is a routing protocol that takes the advantage of broadcasting nature of wireless sensor network for multi-hop communication. Considering the importance of communication between source-destination pairs in a wireless sensor network a Multi-hop Optimal position based Opportunistic Routing (MOOR) protocol is proposed in this paper. The algorithm chooses the path with minimum distance and number of hops between source and destination for transmission of data in the network. It is illustrated by simulation experiments that the proposed protocol has a good effect on End-to-End delay and lifetime of the network. In addition, it is observed that the average End-to-End delay is lesser for different simulation times when compared with existing EEOR protocol.**

Keywords—Delay; Energy Consumptio;, Opportunistic Routing; Routing Table; Wireless Sensor Network.

I. INTRODUCTION

Nowadays wireless sensor networks are used in all fields of life for communication. Wireless sensor node in a network senses an event in nature and reports it to the destination for the required action to be performed. Traditional wired networks have unlimited power, memory, fixed network topology, computational capability and large communication range. Whereas wireless sensor networks have limited resources like low bandwidth, fixed energy and short communication range. Varying topology due to signal fading and sensor failure make wireless sensor networks different from traditional networks. The challenges faced by sensor nodes in a wireless network are detecting and collecting data, assessing and evaluating the information, decision making and alarm functions. Node deployment, transmission media, connectivity, coverage, fault tolerance, scalability and quality of service are the design issues to be considered in a wireless sensor network.

The basic components of a sensor node are the sensing unit, power unit, processor, communication unit and memory unit. Sensor unit is a hardware unit that measures the physical parameter of an area of interest, converts it into electrical signals and transmits it to the processor for further processing. Memory unit is used for storing both the program code, and data sensed by the sensor unit. The power unit is responsible for delivering power to all the units of a sensor node. Processor includes analogue to digital converter, timer and other interfaces to do the processing tasks. Radio unit is the communicating unit that uses electromagnetic spectrum to convey information to the target node or the sink node.

Applications of wireless sensor networks can be classified into four classes, *viz,* Event detection and reporting, data gathering and periodic reporting, sink initiated querying and tracking based applications. Intruder detection, quality check at product line and detection of natural hazards fall into event detection and reporting class. Data gathering and periodic reporting include environmental monitoring, home/office smart environments and health applications. Biological attack detection and weather monitoring are included in sink initiated querying. Tracking based applications involve targeting in intelligent

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ammunition, tracking of animal in forest and tracking of people in commercial places.

The routing protocol has to be efficient for the node to have longer life. Based on the route selection, routing protocols are classified as proactive – route established before requirement, reactive – path established on demand, and hybrid – mix of proactive and reactive routing protocols. Based on architecture, routing protocols are classified as flat based, cluster based and location based routing protocols. It is a flat based reactive multi-hop routing protocol for wireless sensor networks. In opportunistic routing the source node forms the neighbors set, assigns priorities to them based on factors like hop count and energy level.

In this paper, propose Multi-hop Optimal position based Opportunistic Routing (MOOR) is proposed for optimizing the delay in information transmission between the pairs of source and destination and network lifetime in a wireless sensor network.

II. RELATED WORK

Amit and Anantha [1] proposed an operating system directed power management scheme to improve energy efficiency of nodes in a wireless sensor network by using sleep-state transitioning. Dynamic voltage scaling is used to reduce energy consumed by the processor activities. Bogdan Pavkovic, Fabrice Theoley re and Andrzej Duda [2] defined an opportunistic forwarding scheme that accepts Routing Protocol for Low power and lossy networks (RPL) with the possibility of forwarding packets with multiple paths. Opportunistic RPL is compared with basic RPL with respect to end-to-end packet delivery delay and network lifetime. Future scope of this scheme is to validate the scheme considering the limited packet buffers.

X.F. Mao, S. Tang, X. Xu, X. Y, Li, and H. Ma [3] proposed an Energy Efficient Opportunistic Routing (EEOR) protocol to improvise the packet loss ratio, energy consumed and delivery delay of a multi-hop wireless sensor networks. The protocol takes advantage of overhearing feature of sensor nodes in a network and proves to be better than ExOR Protocol. Ahmed E. A. A Abdulla, Hiroki Nishiyama, Jie Yang, Nirwan Ansari and Nei Kato [9] proposed Hybrid Multi-hop routiNg (HYMN) that is a hybrid of flat multi-hop routing and cluster based multi-hop routing architectures of wireless sensor networks. Through simulation it is shown that HYMN protocol improves the lifetime of the network as compared to flat based routing and cluster based routing individually.

Ying Liang and Yongxin Feng [5] proposed a new energy efficient routing protocol that is based on dynamic collaborative virtual antenna Multiple Input Multiple Output (MIMO) technology. Network node running time and average energy of node are analyzed against network operation time. The results show that the proposed dynamic collaborative virtual MIMO based routing protocol performance is better than that of Low Energy Adaptive Cluster Head protocol. Yu Gu and Tian He [6] implemented Dynamic Switch-based Forwarding (DSF) in low-duty-cycle wireless sensor networks to optimize the data delivery ratio, communication delay and energy consumption. DSF algorithm shows significant improvement in source-to-sink communication in sensor networks with unreliable radio links. Transmission between nodes arranged in concentric circles and a centrally placed sink can be considered in two parts: ring thickness and hop size.

Azad and Joarder Kamruzzaman [7] propose three schemes to optimize the ring thickness, hop size and sensor node duty cycles in the network to optimize the network lifetime. Results show that the proposed schemes are better in energy consumption compared to single hop, multi hop and hybrid routing. Xiaoli Ma, Min-Te Sun, Gang Zhao and Xiangqian Liu]8] discussed an efficient Path Pruning (PP) algorithm to reduce the number of hops in transmission of geographical routing protocols by using channel listening capacity of wireless nodes. The PP algorithm has low complexity of implementation and gives improved routing performance and delivery rate compared to Greedy Perimeter Stateless Routing (GPSR) and Greedy Other Adaptive Face Routing (GOAFR).

III. SYSTEM MODEL

A. Network Model

The network model used in this paper consists of 50 sensor nodes randomly deployed in an area of 500 m by 500 m. Each node is static and has a transmission range of 250 m. Each node generates a data packet of 1000 bytes per second and sends it towards the destination. Out of 50 nodes 9 pairs of source and destination are identified for the analysis of parameters of interest in the network.

B. Energy Model

Sensor nodes require energy for sensing, processing, receiving and transmitting. Each sensor node in the wireless sensor node is deposited with an initial energy. According to the activities of the network the sensor node consumes the required energy. Table I gives the list of components of energy deposited at and spent by a sensor node in the network. Let P_t be the number of packets transmitted, P_s be the number of packets received by a sensor node and N be the number of events in the network. Equation (1) is true for all the networks.

$$E \leq N\,E_s + P_t\;E_t + \;P_r\;E_r + I\,E_i \qquad (1)$$

where I is the total time spent by the sensor node in idle mode. Total energy consumed by the network is the sum of the energy spent by all the nodes in the network.

TABLE I. ENERGY MODEL OF A SENSOR NODE

Symbol	Description
E	Initial Energy
E_s	Energy used in sensing an event
E_t	Energy spent in transmitting a packet
E_r	Energy spent in receiving a packet
E_i	Energy spent in idle mode
E_{rs}	Residual Energy

C. Multi-hop Optimal position based Opportunistic Routing Protocol

In multi-hop wireless sensor networks the source has to send the packets to the destination through the intermediate nodes. The number and position of intermediate nodes affects the speed and reliability of transmission. Opportunistic routing selects a subset of neighbors of the source as members of forwarder list. EEOR chooses the nodes in the forwarders list as neighbors of source who are nearer to the source node. The proposed Multi-hop Optimal position based Opportunistic Routing protocol chooses the neighbors who are nearer to the destination node as the members of the forwarders list and chooses the node that is nearest to the destination to forward the packet from the source towards target. Choosing the forwarding node and forwarding the packet continues till the target node is reached.

The sensor node identifies its neighbours by broadcasting HELLO packets including the source address in the network. The nodes that receive the HELLO packets include the source as the neighbour in the routing table. All the sensor nodes will construct their routing tables in this way. Once the routing table is ready, the source node chooses the forwarding node as the neighbour whose distance to target is minimum to ensure that the packet is moving towards the destination. Once the packet reaches the destination it sends the acknowledgment to the source. MOOR chooses the path for acknowledgment packet opportunistically to balance the energy among the nodes in the network.

IV. SIMULATION ANALYSIS

This section provides simulation setup to demonstrate performance of Multi-hop Optimal position based Opportunistic Routing and the performance analysis of different parameters in the wireless sensor networks. 50 wireless sensor nodes are deployed randomly in a square area of 500m by 500 m, with uniform distribution. In these 50 nodes, 9 different source-destination pairs are chosen for one-hop, two-hop, and more than two-hop communications. The packet generation mode is Constant Bit Rate (CBR) and packets are generated at the rate of one packet per second. The buffer length at each of the nodes in the network is set to 10 packets.

The sensors nodes are deposited with an initial energy of 50 Joules. The energy spent by a sensor node in transmission of packet is a maximum of 0.38 Joules and in receiving is 0.36 Joules. The node consumes a minimum energy of 0.003 Joules, when it is in idle state. 1000 packets of 1000 bytes each are transferred between source and destination pairs. The acknowledgment packet size is 40 bytes in size. The behaviour of the network is observed for average End-to-End delay and network lifetime. The effect of varying the simulation time on average End-to-End delay is observed by varying simulation time from 25 seconds to 100 seconds. The performance of the wireless sensor network for Multi-hop Optimal position based Opportunistic Routing is analyzed for parameters network lifetime, End-to-End delay for different source-destination pairs.

A. Network Lifetime:

The *lifetime* of a sensor node is considered as the time from its deployment to the time up to the node has residual energy up to 90%. The node is said to be *alive* in this period. Beyond this period the node is said to be *dead*. *Network Lifetime* is the time between the inception of the network to the time up to which 10% of the sensor nodes are alive. Fig. 1 shows the network lifetime for both Energy Efficient Opportunistic Routing and Multi-hop Optimal position based Opportunistic Routing protocols plotted against network sizes 25 nodes, 50 nodes, 75 nodes and 100 nodes. The graph shows that the network lifetime is longer in the case of MOOR protocol as compared to EEOR protocol, irrespective of the number of nodes in the network.

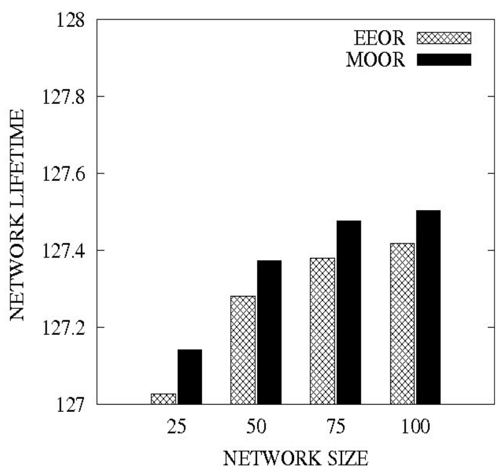

Fig. 1. Network Size versus Network Lifetime

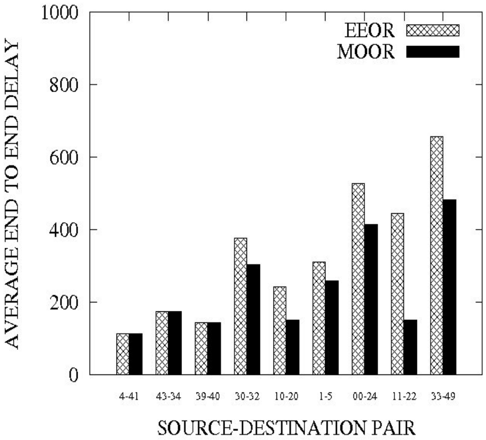

Fig. 2. Average End-to-End Delay for Different Source-Destination Pairs.

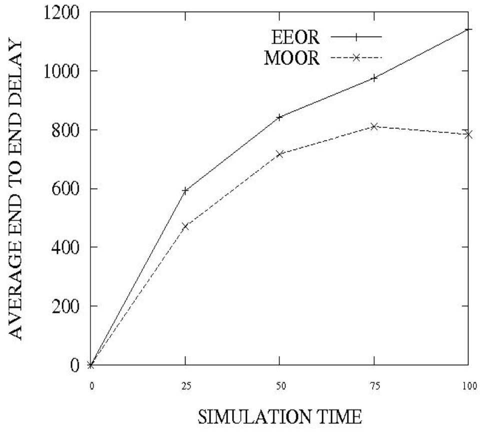

Fig. 3. Simulation Time versus Average End-to-End Delay.

B. Average End-to-End Delay:

The time elapsed between the source node sending the packet and the destination node receiving the packet is defined as *End-to-End delay*. The average of the End-to-End delay of all the packets transmitted between each of the pairs of source-destinations gives the *average end-to- end delay*. The average End-to-End delay is plotted against different pairs of source and destinations in Fig. 2. It is observed that for one hop networks, Multi-hop Optimal position based Opportunistic Routing does not show any improvement. As the number of hops increases, the reduction in delay is more compared to EEOR protocol. For two-hops and more than two-hop paths the delay is reduced up to a maximum of 90 ms for 10-20 source-destination pair and 295 ms for 11-22 source destination pair, respectively by using MOOR protocol.

C. Simulation time versus average End-to-End delay:

The time of the network simulation is varied from 25 seconds to 100 seconds in steps of 25 seconds without changing any of the network parameters and the corresponding average End-to-End delay is plotted in Fig. 3. The plot shows that as the simulation time is increased the average End-to-End delay is increased for both EEOR and MOOR protocols. The results show that the average End-to-End delay is reduced by a maximum of 30% when the network size is 100 nodes when MOOR protocol is used.

V. CONCLUSION

A novel routing protocol Multi-hop Optimal position based Opportunistic Routing (MOOR) protocol is presented in this paper, to reduce the packet transmission delay and to increase the lifetime of a multi-hop wireless sensor network. The forwarding node is chosen from the set of neighbours of the source node, based on its distance from itself and the target node. This technique decreases the average End-to-End delay between source and destination pairs compared to EEOR. The proposed Multi-hop Optimal position based Opportunistic Routing algorithm increases the lifetime of the network compared to EEOR by reducing the number of hops for data transmission and by choosing a opportunistic path for acknowledgment packet in multi-hop routing. Future expansion to this work is to analyse the network performance for mobile nodes in the network.

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