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Energy Based Multipath Routing Protocols for Wireless Sensor Networks

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Abstract - Wireless Sensor Networks (WSNs) consists of small nodes with sensing, computation, wireless communications capabilities have led to many new routing protocols specifically designed for sensor networks and enabling real time applications in Wireless Sensor Networks. Wireless Sensor Networks demands certain delay sensitive, bandwidth requirements and reliability, energy efficient not only this it also pose more challenges in the design of networking protocols. Energy Efficient and Quality of Services plays a vital role in wireless sensor networks. This paper describes an Energy Efficient and Quality of Service aware multipath routing protocol known as EQSR that maximizes the network lifetime through balancing energy consumption across multiple nodes, uses the concept of service differentiation to allow delay sensitive traffic to reach the sink node within an acceptable delay, reduces the end to end delay through spreading out the traffic across multiple paths, and increases the throughput rate to the other nearest path. Based on the concept of service differentiation the EQSR protocol employs a queuing model to handle both real time and non-real time traffic. By some simulation, evaluated and premeditated about the performance of the proposed routing protocol and compared it with other protocols. Simulation result shows that proposed routing protocol achieves lower average delay, higher packet delivery ratio and increases in energy consumption than other protocols.

Keywords: *Wireless Sensor Networks, Energy Consumption, Quality of Services (QOS), Multipath Routing.*

I. INTRODUCTION

Wireless sensor networks (WSNs) consist of densely deployed sensor nodes, which have limited computational capabilities, power supply, and communication bandwidth. The potential applications of sensor networks include environmental monitoring, industrial control, battlefield surveillance and reconnaissance, home automation and security, health monitoring, and asset tracking. Recently, various routing protocols have been proposed for WSNs. Most of them use a single path to transmit data. The optimal path is selected based on the metrics, such as the gradient of information, the distance to the destination, or the node residual energy level. Some other routing protocols that use multiple paths choose the network reliability as their design priority.

In wireless sensor networks, a lot of research has been done on some important aspects of WSNs such as architecture and protocol design, energy conservation, and locationing, supporting Quality of Service (QoS) in WSNs is still a largely unexplored research field. The key advantage of WSN is that the network can be deployed on the fly and can operate unattended, without the need for any pre-existing infrastructure and with little maintenance. Typically, sensor nodes are deployed randomly (e.g., via aerial deployment), and are

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expected to self-organize to form a multi-hop network. The sensor nodes may also perform data aggregation/compression to reduce the communication overhead in the network [1].

QoS protocols in sensor networks have several applications including real time target tracking in battle environments, emergent event triggering in monitoring applications etc.

Consider the following scenario: In a battle environment it is crucial to locate, detect and identify a target. In order to identify a target, we should employ imaging and/or video sensors. After locating and detecting the target without the need of imaging and video sensors, we can turn on those sensors to get for instance an image of the target periodically and send to the base station or gateway. However should deal with real-time multimedia data, which requires certain bandwidth with minimum possible delay, and jitter. In that case, a service differentiation mechanism is needed in order to guarantee the reliable delivery of the real-time data [2].

A. Challenges and issues in wsns

1. Energy consumption without losing accuracy

Sensor nodes can use up their limited supply of energy performing computations and transmitting information in a wireless environment. As such, energy- conserving forms of communication and computation are essential. Sensor node lifetime shows a strong dependence on the battery lifetime.

2. Fault Tolerance

Some sensor nodes may fail or be blocked due to lack of power, physical damage, or environmental interference. The failure of sensor nodes should not affect the overall task of the sensor network. If many nodes fail, MAC and routing protocols must accommodate formation of new links and routes to the data collection base stations.

This may require actively adjusting transmit powers and signaling rates on the existing links to reduce energy consumption, or rerouting packets through regions of the network where more energy is available. Therefore, multiple levels of redundancy may be needed in a fault-tolerant sensor network.

3. Quality of Service

In some applications data should be delivered within a certain period of time from the moment it is sensed, otherwise the data will be useless. Therefore bounded latency for data delivery is another condition for time-constrained applications. However, in many applications, conservation of energy, which is directly related to network lifetime, is considered relatively more important than the quality of data sent. As the energy gets depleted, the network may be required to reduce the quality of the results in order to reduce the energy dissipation in the nodes and hence lengthen the total network lifetime. Hence, energy-aware routing protocols are required to capture this requirement.

4. Scalability

The number of sensor nodes deployed in the sensing area may be in the order of hundreds or thousands, or more. Any routing scheme must be able to work with this huge number of sensor nodes. In addition, sensor network routing protocols should be scalable enough to respond to events in the environment. Until an event occurs, most of the sensors can remain in the sleep state, with data from the few remaining sensors providing a coarse quality.

II. RELEATED WORK

Quality of Service (QoS)-based routing in sensor networks is a challenging problem because of the scarce resources of the sensor node. Thus, this problem has received a significant attention from the research community, where many proposals are being made. QoS proposed a multi constrained multi-path routing (MCMP) protocol that uses braided routes to deliver packets to the sink node according to certain QoS requirements expressed in terms of reliability and delay. The problem of the end-to-end delay is formulated as an optimization problem, and then an algorithm based on linear integer programming is applied to solve the problem. However, the protocol always routes the information over the path that includes minimum number of hops to satisfy the required QoS, which leads in some cases to more energy consumption [3], [4], [5].

Energy constrained multi-path routing (ECMP) that extends the MCMP protocol by formulating the QoS routing problem as an energy optimization problem constrained by reliability, playback delay, and geo-spatial path selection constraints. The ECMP protocol trades between minimum number of hops and minimum energy by selecting the path that satisfies the QoS requirements and minimizes energy consumption. In our proposal, we combine different ideas from the previous protocols in order to optimally tackle the problem of QoS in sensor networks. In our proposal we try to satisfy the QoS requirements with the minimum energy [6] [7].

One of the early proposed routing protocols that provide some QoS is the Sequential Assignment Routing (SAR) protocol . SAR protocol is a multi-path routing protocol that makes routing decisions based on three factors: energy resources, QoS on each path, and packet's priority level. Multiple paths are created by building a tree rooted at the source to the destination. During construction of paths those nodes which have low QoS and low residual energy are avoided. Upon the construction of the tree, most of the nodes will belong to multiple paths. To transmit data to sink, SAR computes a weighted QoS metric and a weighted coefficient associated with the priority level of the packet to select a path. Employing multiple paths increases fault tolerance, but SAR protocol suffers from the overhead of maintaining routing tables and QoS metrics at each sensor node [8] [9].

SPEED also utilizes geographic location to make localized routing decisions. The difference is that SPEED is designed to handle congestion and provide a soft real-time communication service, which are not the main goals of previous location-based routing protocols. Moreover, SPEED provides an alternative solution to handle voids other than approaches based on planar graph traversal and limited flooding [10].

SPEED maintains a desired delivery speed across sensor networks by both diverting traffic at the networking layer and locally regulating packets sent to the MAC layer. It consists of the following components: An API, A neighbor beacon exchange scheme, A delay estimation scheme, The Stateless Non-deterministic Geographic Forwarding algorithm (SNGF), A Neighborhood Feedback Loop (NFL), Backpressure Rerouting, Last mile processing.

III. PROPOSED METHODOLOGY

Energy-aware QoS routing in sensor networks will ensure guaranteed bandwidth (or delay) through the duration of connection as well as providing the use of most energy efficient path. To the best of our knowledge, no previous research has addressed QoS routing in sensor networks. In this paper present an energy-aware QoS routing mechanism for wireless sensor networks. The proposed protocol extends the routing approach and considers only end-to-end delay. The protocol looks for a delay-constrained path with the least possible cost based on a cost function defined for each link. Alternative paths with bigger costs are tried until one, which meets the end-to end delay requirement and maximizes the throughput for best effort traffic is found. The protocol does not bring any extra overhead to the sensors.

The EQSR routing protocol [11] performs routes discovery using multiple criteria such as energy remaining, remaining buffer size, signal-to-noise ratio, end to end delay.

A. Assumptions and Definitions

Assume N identical sensor nodes are distributed randomly in the sensing filed. All nodes have the same transmission range, and have enough battery power to carry their sensing, computing, and communication activities. The network is fully connected and dens (i.e. data can be sent from one node to another in a multi-hop bases). Each node in the network is assigned a unique ID and all nodes are welling to participate in communication process by forwarding data. Furthermore, we assume that the sensor nodes are stationery for their lifetime. Additionally, at any time, we assume that each sensor node is able to compute its residual energy, and its available buffer size, as well as record the link performance between itself and its neighboring node in terms of signal-to noise ratio (SNR). By examining recent link performance data, predications and decisions about path stability may be made. Here, going to find out the cost of every link, have to discovery the path, and finally the select the path through which have send the messages.

B. Link cost function

The link cost function is used by the node to select the next hop during the path discovery phase. We use a cost function such as presented in with some changes. Let Nx is the set of neighbors of node x. Then our cost function includes an energy factor, available buffer factor, and interference factor with appropriate weights (α,β and γ):

Next hop= $\max_{y \,\varepsilon\, Nx} \{ \alpha E_{resd,\, y} + \beta B_{buffer,\, y} + \gamma I_{interference,\, xy} \}$,

Where, $E_{resd,\ y}$ is the current residual energy of node y, where y ε N_x, B_{buffer}, y is the available buffer size of node y, and $I_{interference}$, xy is the SNR for the link between x and y. In this cost function, we only consider the residual energy of node y but not x. Because node y consumes energy for data reception and transmission if it is selected as a next hop for node x. We do not consider node x, because whatever node y is, node x still needs to spend the same amount of energy on data transmission .

The total cost *(C_{total})* for a path *P* consists of a set of *K* nodes is the sum of the individual link costs $l_{(xy)i,\ i \in K}$ a long the path. Then we have:

$$C_{total,P} = \sum_{i=1}^{K-1} l(xy)_i$$

C. Path Discovery Phase

The proposed protocol employs the queuing model presented in to handle both real time and non real time traffic. Two different queues are used, one instant priority queue for real time traffic, and the other queue follows the first in first out basis for non real time traffic. The source node knows the degree of the importance of each data packet it is sending which can be translated into predefined priority levels. The application layer sets the required priority level for each data packet by appending an extra bit of information to act as a stamp to distinguish between real time and non real time packets. Based on the packet type, the classifier directs packets into the appropriate queue. The traffic allocation scheme first splits up the packets into a number of equal sized sub-packets (or segments), and then schedules sub-packets simultaneously for transmission across the available multiple paths. Before scheduling the sub-packets, the traffic allocation scheme adds error correction codes to improve the reliability of transmission and to increase the resiliency to paths failures and ensure that an essential portion of the packet is received by the destination without incurring any delay and more energy consumption through data retransmission. At the sink node, the parts are collected, reassembled, and the original message is recovered. The path discovery procedure is executed according to the following phases:

D. Initialization phase

Each sensor node broadcast a HELLO message through the network in order to have enough information about which of its neighbors can provide it with the highest quality data. Each sensor node maintains and updates its neighboring table during this phase. The neighboring table contains information about the list of neighboring nodes of the sensor node.

Source ID	Hop Count	Residual Energy	Free Buffer	Link Quality

Figure 1:

E. Primary Path discovery phase

After initialization phase each sensor node has enough information to compute the cost function for its neighboring nodes. Then, the sink node locally computes its preferred next hop node using the link cost function, and sends out a RREQ message to its most preferred next hop.

Source ID	Dest ID	Route ID	Residual Energy	Free Buffer	Link Quality	Route Cost

Figure 2:

F. Alternative Paths discovery phase:

For the second alternate path, the sink sends alternate path RREQ message to its next most preferred neighbor. To avoid having paths with shared node, we limit each node to accept only one RREQ message. For those nodes that receive more than one RREQ message, only accept the first RREQ message and reject the remaining messages.

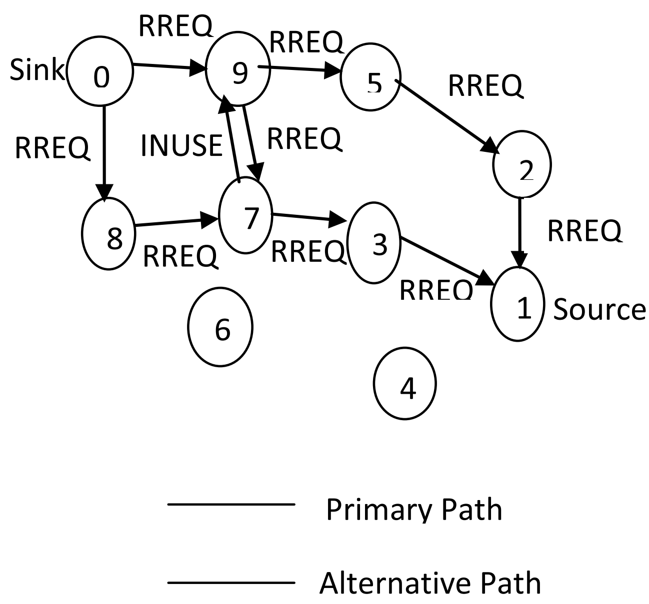

Figure 3:

Paths Selection

After the completion of paths discovery phase and the paths have been constructed, we need to select a set of paths from the N available paths to transfer the traffic from the source to the destination with a desired bound of data delivery given by α. To find the number of required paths, we assume that each path is associated with some rate *p*i (i=1,2, .. N) that corresponds to the probability of successfully delivering a message to the destination.

$$k = x_\alpha \sqrt{\sum_{i=1}^{N} Pi\ (1 - Pi)} + \sum_{i=1}^{N} pi$$

IV. PERFORMNACE EVALUATION OF EQSR PROTOCOL

The performance of the EQSR protocol is better than the MCMP protocol in a multi-hop network topology and impact of changing the packet arrival rate based on end-to-end delay, packet delivery ratio, and energy consumption.

A. Average End-to-End Delay

The average end-to-end delay is the time required to transfer data successfully from source node to the sink node.

B. Packet Delivery Ratio

The average delivery ratio is the number of packets generated by the source to the number of packets received by the sink node.

C. Average Energy Consumption

The average energy consumption is the average of the energy consumed by the nodes participating in message transfer from source node to the sink node.

V. CONCLUSION

An energy efficient and quality of service based mutli-path routing protocol designed specifically for wireless sensor networks to provide service differentiation by giving real time traffic absolute preferential treatment over the non real time traffic. The proposed protocol uses the multi-path paradigm together with a Forward Error Correction (FEC) technique to recover from node failures without invoking network-wide flooding for path discovery. This feature is very important in sensor networks. since flooding consumes energy and consequently reduces the network lifetime.

EQSR protocol uses the residual energy, node available buffer size, and signal-to-noise ratio to predict the next hop through the paths construction phase. EQSR splits up the transmitted message into a number of segments of equal size, adds correction codes, and then transmits it over multiple paths simultaneously to increase the probability that an essential portion of the packet is received at the destination without incurring excessive delay.

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