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Analysis of Defensive Data Transmission with Reduced Energy Expenditure in Wireless Sensor Network

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Abstract - In this to propose a distributed traffic-balancing routing algorithm for multi-sink wireless sensor networks that effectively distributes traffic from sources to sinks. The proposed algorithm considers the traffic being faced by surrounding neighbors before for-warding packets to any sink using gradient search for routing and providing a balance between optimal paths and possible congestion on routes toward those sinks. Extensive simulations conducted to evaluate the performance of the proposed scheme indicate that it effectively reduces the overall packet delay, energy consumption and improves the packet delivery ratio under heavy traffic.

KeyWords: Wireless Sensor Networks, IDDR, distributed traffic-balancing routing algorithm, multi-path dynamic routing algorithm

I. INTRODUCTION

In large-scale applications of wireless sensor networks (WSNs) such as environment monitoring or agricultural scenarios, several hundreds of sensor nodes are deployed over a large covered-area. The large numbers of nodes becomes active and transmit data traffic, leading to congested areas. Congestion increases packet delay and energy consumption due to retransmissions thus limiting the network's lifetime and efficiency. Additionally, the traditional centralized approach in which data traffic from sensor nodes gather toward a unique sink is not efficient in terms of energy consumption or packet delays, and may even be impossible due to limited network capacity. Therefore, the use of multiple sinks is proposed as a more feasible scheme for such networks. This approach balances traffic load and increases network utilization efficiency. Data traffic from a source to a final destination needs an optimal routing protocol that utilizes the limited power, memory, and processing resources of nodes effectively. Among the current solutions for routing in WSNs, gradient-based routing has been standardized by Internet Engineering Task Force (IETF) working group as an appropriate protocol for low power and lossy networks (LLNs) for which existing routing protocols such as OSPF, AODV, and OLSR cannot meet the requirements.

In event-driven sensor networks, e.g., those used in detection and monitoring applications, nodes normally operate under low or idle load states. When events occur, these nodes suddenly become active, resulting in a part of the network becoming overloaded and causing congestion in some areas. Many studies have been conducted with the aim of using gradient search to solve routing problems in WSNs.

On the basis of observations of the gradient search scheme, we propose a traffic-balancing routing algorithm for multi-sink WSNs to route packets around congested areas made by other paths toward the sinks. Our proposal exploits two-hop information and enhances congestion detection ability owing to its monitoring of the buffer size at a node. The underlying concept of our algorithm is the construction of gradient field using three factors: number of hops, number of packets at one-hop neighbors and the minimum number of packets at two-hop neighbors. The number of hops (distance cost) is built conventionally as in other gradient-based routing protocols that find the shortest paths for packets. The second and third factors address the queue length at neighboring nodes that may become the next forwarder.

Once the queue length, changing with network traffic exceeds a threshold, it means that there is congestion at a node in the path toward a specific sink. The node asks its surrounding nodes to increase (or decrease) their gradient field so that packets can flow along other paths. Thus, this method leads to a trade-off between shortest paths and packet delays caused by congestion at overloaded nodes.

II. RELATED WORK AND MOTIVATION

Most QoS provisioning protocols proposed for traditional ad hoc networks have large overhead caused by end-to-end path discovery and resource reservation. Thus, they are not suitable for resource-constrained WSNs. Some mechanisms have been designed to provide QoS services specifically for WSNs. Here we mainly focus on the metrics of delay and reliability.

RAP exploits the notion of velocity and proposes a velocity-monotonic scheduling policy to minimize the ratio of missed deadlines. However, the global information of network topology is required. Implicit Earliest Deadline First (EDF) mainly utilizes a medium access control protocol to provide real-time service. The implicit prioritization is used instead of relying on control packets as most other protocols do. SPEED maintains a desired delivery speed across the network through a novel combination of feedback control and non-deterministic QoS-aware geographic forwarding. In, a two-hop neighbor information-based gradient routing mechanism is proposed to enhance real-time performance. The routing decision is made based on the number of hops from a source to the sink and the two-hop information.

Adaptive Forwarding Scheme (AFS) employs the packet priority to determine the forwarding behavior to control the reliability. ReInforM uses the concept of dynamic packet states to control the num-ber of paths required for the desired reliability. However, both of AFS and ReInforM require to know the global network topology. LIEMRO utilizes a dynamic path maintenance mechanism to monitor the quality of the active paths during network operation and regulates the injected traffic rate of the paths according to the latest perceived paths quality. However, it does not consider the effects of buffer capacity and service rate of the active nodes to estimate and adjust the traffic rate of the active paths.

MM-SPEED extends SPEED for service differentiation and probabilistic QoS guarantee. It uses the same mechanism as SPEED to satisfy the delay requirements for different types of traffic, and uses redundant paths to ensure reliability. The MAC layer function is modified to provide prioritized access and reliable multicast delivery of packets to multiple neigh-bors. However, when the network is congested, all the source nodes still continuously transmit packets to the sink along mul-tipaths without taking some other mechanisms, such as caching packets for some time. This not only deteriorates reliability but also retards the delay-sensitive packets. Energy-Efficient and QoS-based Multipath Routing Protocol (EQSR) improves reliability through using a lightweight XOR-based Forward Error Correction (FEC) mechanism, which introduces data redundancy in the data transmission process. Furthermore, in order to meet the delay requirements of various applications, EQSR employs a queuing model to manage real-time and non-real-time traffic. DARA considers reliability, delay and residual energy. But it only differentiates the applications into two classes: critical and non-critical. The neighbor sets of a node for the two kinds of applications are different and all the packets belonging to the same category will be forwarded to the next hop computed by the same function. Obviously, two classifications of the applications in WSNs are not enough.

III. PERFORMANCE ANALYSIS

ON-DEMAND MULTIHOP LOOK-AHEAD-BASED REAL-TIME ROUTING PROTOCOL

OMLRP considered the following assumptions for real time routing which is followed from [22], [23]. The assumptions are as follows: Homogeneous sensor nodes are deployed in the network.

- Global Positioning System (GPS) is used by each sensor
- node to aware of its location in the field. One of them initiates to generate packets that became the
- source node.

This approach performed multi hop look ahead around the paths from the source to destination within an elliptical region. It selects an optimal path among multiple paths within the elliptical region. In that on demand Multi-hop information based Multipath routing with in elliptical region with K hop = 4. A multipath algorithm is obtained from that select multiple routes from source to destination within elliptical region with high link quality and low latency. In this, a node sends its packets to neighbors through multiple alternative paths. Optimal path is selected for data transmission from source to destination. If a problem occurred in selected path, it select next available shortest path for forwarding data to destination. The elliptical region is restricted the look ahead around the packet forwarding path for reliable routing. The elliptical region is calculated using location information of the source and the destination from GPS systems. When the source node starts for forwarding the packet to the destination, the multi hop look ahead is triggered within the restricted elliptical region. The elliptical region is calculated by using location of the source node s (xs , ys) and destination node d (xd, yd.) from Equation

$$D(s,d)=\sqrt{(x_d-x_s)^2+(y_d-y_s)^2} \quad \textbf{(1)}$$

where D(s, d) is a distance between source node s and destination node d.

LOOK AHEAD ALGORITHM

As A sensor node can distinguish whether it is within the elliptical region determined by the function (4). Look ahead algorithm is used to found out each sensor node located within elliptical region.

Algorithm:

Sensor node Na determine its location (xa, ya)

X=Xa cosΦ + Ya sinΦ (4)

Y=- Xa sinΦ + Ya cosΦ (5)

Na calculates f (x, y) from (4) and (5)

If the f (x, y) > 0

Na is located at out of the elliptical region.

If the f(x, y) <= 0,

Na is located within the elliptical region.

This algorithm provides an effective way to retain the energy efficiency and scalability. A hybrid metrics such as link quality and latency are used as the criteria for optimal path selection. Look ahead message mechanism is used which includes five tuples (Khop, s(xs , ys), d(xd , yd), Hellipse, R).

where Khop indicates no of look ahead hops; s(xs , ys), d(xd, yd) – indicate location of source and destination nodes respectively; Hellipse - elliptical region from (6).

$$H_{ellipse}=\frac{D(s,d)}{2}\times\frac{1}{h},h\geq 1 \quad \textbf{(2)}$$

where D(s, d)/2 is the semi axis of the elliptical region and h is the size of the elliptical region.

It calculates average speed of every path from the source to the destination until Khop for selecting optimal path. R is a selected optimal path among multiple paths from source to destination within the elliptical region based on multi hop look ahead mechanism. Fig. 2 noticed that the on demand Multi hop information based Multipath routing with in elliptical region with K hop = 4. If Khop = 4, every node in an elliptical region maintains location until four hop neighborhoods. From Equation (6), if h is 1, the elliptical region is a circular region between s (xs , ys) and d (xd, yd) and h value may be dynamically determined by system. The traffic load balancing is performed in the previous real time protocols [28]. Source and forwarding node can deliver data to a destination using selected optimal path that satisfy a desired speed and also perform traffic load balancing which make even energy consumption by all nodes.

ENERGY DISSIPATION RADIO MODEL

This paper, a radio hardware energy dissipation model was used where the transmitter dissipates energy to run the radio electronics and the power amplifier, and the receiver dissipates energy to run the radio electronics. Thus, to transmit a k-bit of message and distance d, the radio expends

$$E_{TX}(k,d) = E_{TX\_elec}(k) + E_{TX\_amp}(k,d) \quad \textbf{(3)}$$

To receive k-bit message, the radio expends

$$E_{RX}(k,d) = kE_{TX\_elec} \quad \textbf{(4)}$$

Where, ETX_elec - electronics energy for receiving k bit message, ETX_amp - amplifier energy depends on the distance to the receiver.

DISTRIBUTED TRAFFIC-BALANCING ROUTING ALGORITHM

Traffic information is interchanged between sensor nodes through advertising packets. Each node, including sinks periodically broadcasts an ADV packet to all neighbors. This time is set in a trade-off between the effects of updating information and the use of network resource. Assume that all sensor nodes have the same queue capacity. Each ADV packet contains the hop count to reach a specific sink and the queue length field constructed in the previous section. Algorithm 1 outlines the processes for building the table of gradient values at each node and then updating and rebroadcasting traffic information according to each sink under dynamic network conditions.

At first, each node builds by itself the distance and traffic cost fields, respectively, on the gradient table Gfor all neighbors in response to sinks, and initializes all fields to infinity. When an ADV packet arrives, the node checks whether the sink and source addresses. At first, the table is null, i.e., at the initial time there is neither connection status nor network information relating to sinks and neighbors. Then, the node will

add these addresses and consider them as parents following that sink address. Conversely, it uses distance cost to classify source nodes into lists of parents, siblings, and children corresponding to a specific sink. In addition, the queue length field from the ADV packets is updated into traffic cost fields on G with each neighbor. The node then employs newly updated information to broadcast for its neighbors through ADV packets in the update period.

TIME FOR UPDATE INFORMATION

The time for updating routing information relies on the buffer’s threshold. The update operation follows the fol-lowing two cases:

Normal case (light traffic)

If the data in the buffer is lower than the threshold, a node includes its traffic metric in the data message or broadcasts an ADV packet to its neighbors after a period of time.

Congestion (heavy traffic)

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When the number of packets in the buffer reaches a predefined threshold, it means that congestion has occurred. The neighbors should therefore choose paths that exclude this node. After a small period of time, an ADV packet is sent to all neighbors informing them of this congestion. However, the problem herein is that this technique only denotes local information. Thus, an effective routing technique that can obtain information and detect the congested area in view of global information is required. In distributed gradient-based routing techniques, it is difficult to obtain global information due to the dynamic properties of the network.Our proposal attempts to improve the local metric using two-hop information. If a node is in a congested state, it sends an ADV packet to inform its neighbors about this event. Its one-hop neighbors then forward this event to the next one-hop neighbor over time.

IV. PERFORMANCE METRICS

Packet delivery ration

Packet loss can be caused by network problems such as signal degradation over the network medium, channel congestion, and overflowed buffers due to routing schemes. Lost or dropped packets can significantly affect network applications. In this section, we evaluate the effect of the proposed scheme on packet losses representing packet delivery ratio in the network operation in various traffic scenarios. The packet delivery ratio (PDR) is defined as the ratio between the received packets at sinks and the total packets sent at all sources.

Energy consumption

In this section, we evaluate the average energy consumption per bit which is needed to transmit a packet to the final destination (one of the sinks) successfully, i.e., the ratio between total consumed energy at all nodes to send or transmit all packets and total bits in data packets which are received at the sinks. The energy consumption is involved in transmitting and receiving all packet types including data, acknowledgement (ACK), and ADV packets.

V. SIMULATION RESULTS

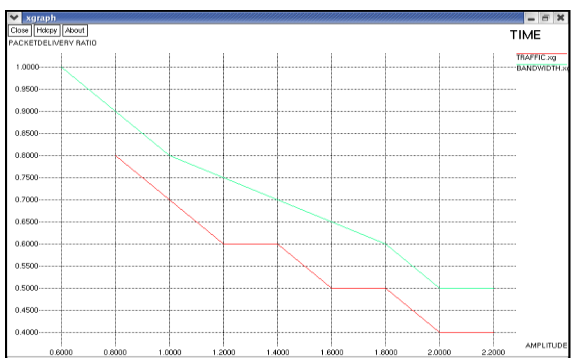

Figure 1. Packet delivery ratio

We implement this by enforcing a balanced energy consump-tion for all sensor nodes so that all sensor nodes will run out of energy at about the same time. This design guarantees a high message delivery ratio until energy runs out from all available sensor nodes at about the same time. Then the delivery ratio drops sharply. This has been confirmed through our simulations.

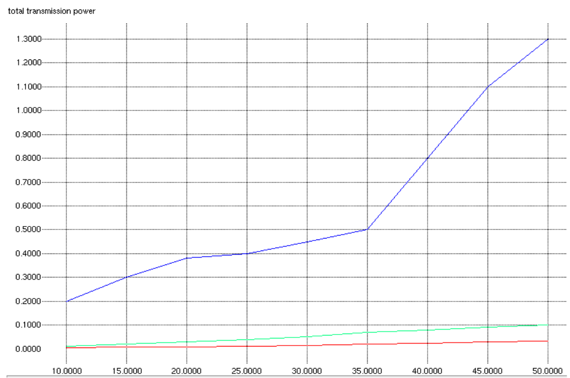

Figure 2.Total transmission power

In this scheme, the parameter ↵can be adjusted to achieve the expected efficiency. As↵increases, better energy balance can be achieved. Meanwhile, the average number of routing hops may also increase. Accordingly, the overall energy consumption may go up. In other words, though the energy control can balance the network energy levels, it may increase the number of routing hops and the overall energy consumption slightly. This is especially true when the sensor nodes have very unbalanced energy levels.

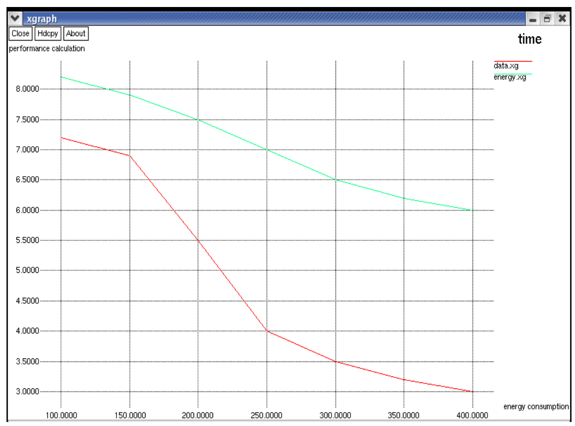

Figure 2. Performance calculation

In this section, we will analyze the routing performance of the proposed protocol from four different areas: routing path length, energy balance, the number of messages that can be delivered and the delivery ratio under the same energy consumption.

VI. DISCUSSION

This project presented a routing algorithm based on gradient search with the objective of reducing overall packet delay in multi-sink WSNs. The key concept herein is to utilize the number of hops and the current queue length at one-hop and two-hop next neighbors to make routing decisions. The proposed scheme reduces the number of packet retransmissions and packets dropped by preventing nodes with overloaded buffers from joining in routing calculation.

The proposed algorithm is strictly affected by the weighted factors that decide the ratio/relative as well as the importance between distance cost and traffic cost one and two-hop away before forwarding a packet depending on the application requirements. Traffic information is interchanged between sensor nodes through advertising packets. Advertising packet (ADV) containing information about node’s height and buffer size is generated after an update time to inform neighbor nodes about congestion. Each node, including sinks periodically broadcasts an ADV packet to all neighbors. The node, first checks the table of surrounding nodes, and then calculates gradient fields in response to each neighbor

We evaluate the performance of our proposed algorithm under two kinds of traffic: constant bit rate and exponential distribution in which the incoming time between packets follows a Poisson process used in practical traffic generation models. The simulation results are compared with the shortest path first routing algorithm (SPF), GRATA, and GLOBAL to show the improvement in network performance with varied traffic rates

VII. CONCLUTION

This project presented a routing algorithm based on gradient search with the objective of reducing overall packet delay in multi-sink WSNs. Proposed system is distributed traffic-balancing routing algorithm for multi-sink wireless sensor networks that effectively distributes traffic from sources to sinks. The proposed algorithm considers the traffic being faced by surrounding neighbours before for-warding packets to any sink using gradient search for routing and providing a balance between optimal paths and possible congestion on routes toward those sinks. Extensive simulations conducted to evaluate the performance of the proposed scheme indicate that it effectively reduces the overall packet delay, energy consumption and improves the packet delivery ratio under heavy traffic.

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