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A Lightweight & Novel Approach for In-Network Aggregation in Wireless Sensor Networks

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Abstract: ***Wireless sensor networks (WSNs) have sensing, computation and communications capabilities. Energy conservation is a key issue in WSN. Redundant data can be aggregated at intermediate nodes which can reduce the size and number of exchanged messages. This decreases communication cost, energy consumption and increases the lifetime. For this purpose a modified novel Data Routing for In-Network Aggregation (DRINA) algorithm is proposed for setting up a routing tree and high aggregation rate. To find the shortest path for routing, instead of hop count, distance parameter is considered to reduce the energy consumption, delay, communication cost, and increase the lifetime. Results indicate clearly that with the increase of number of nodes, throughput & lifetime increases and simultaneously delay, energy consumption, and tree cost decreases. Extensive simulations in Network-Simulator 2 show that our protocol outperforms the existing protocols in terms of various performance metrics. Thus the modified DRINA provides the best aggregation quality with respect to other algorithms.***

Keywords: Wireless sensor network, routing protocol, in-network aggregation.

1. Introduction

Current research in the areas of wireless communications, micro-electromechanical systems and low power design is progressively leading to the development of cost effective, energy efficient, multifunctional sensor nodes. Sensing, communication, processing and battery units are the primary components of a sensor node. Individual sensors have the capacity to detect events occurring in their area of deployment. A large number of tiny sensor nodes can be organized to form a distributed network where nodes collaborate to perform application specific functions.

Wireless sensors measure ambient conditions then transform these measurements into signals that can be processed to reveal some characteristics about phenomena located in the area around these sensors. WSN contains sensors that have the ability to communicate either among each other or directly to an external base station. In-network data aggregation refers to the different ways intermediate nodes forward data packets toward the sink node while combining the data gathered from different source nodes.

Routing in WSNs is very challenging due to the inherent characteristics that distinguish these networks from other wireless networks. These networks have several restrictions. The design of routing protocols in WSNs is influenced by many challenging factors like node deployment, energy consumption without losing accuracy, data reporting method, fault tolerant, scalability, network dynamics, data aggregation, QoS. These factors must be overcome before efficient communication can be achieved in WSNs.

In order to overcome these challenges the existing DRINA algorithm is modified and the result clearly shows that with the increase of number of nodes, throughput & lifetime increases and simultaneously delay, energy consumption, and tree cost decreases due to better aggregation technique.

2. Literature Survey

A comprehensive review of the existing literature on techniques and protocols for in-network data aggregation in wireless sensor networks is discussed in [1].

In this article, data aggregation has been added to the conventional technique in SPEED algorithm. The idea involves virtual configuration of sensors and specification of an individual ID to the created data by the sensors in each region, then data aggregation in relay node is done by this ID, resulting in less energy consumption, lower traffic and repeated data, an increase in network lifetime and better quality of service [2].

In [3] Dynamic Data-Aggregation Aware Routing Protocol (DDAARP) for wireless sensor networks is presented. This novel protocol builds dynamic routes, which improves the cost and quality of final routing tree. It also reduces the number of messages necessary to set up a routing tree, maximize the number of overlapping routes, selects routes with the highest aggregation rate, and performs reliable data aggregation transmission. The author described many applications of wireless sensor networks; a sensor node senses the environment to get data and delivers them to the sink via a single hop or multi-hop path. This paper studies the problem of maximizing the lifetime of data aggregation trees, which are limited to shortest path trees. This approach greatly improves the lifetime of the network and is more competitive when it is applied in a dense network [4].

The author presents an energy-aware spatial correlation mechanism (ESC) where nodes that detected the same event are clustered. Each cluster is divided into correlated regions and each correlated region has just one representative node. Also, the correlated regions can be changed dynamically in order to improve the accuracy of the sensed information [5].

The author presented how a compromised node can corrupt the aggregate estimate of the base station, keeping the focus

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on the ring-based hierarchical aggregation algorithms. To address the problem of false aggregate, they presented a lightweight verification algorithm which would enable the base station (BS) to verify whether the computed aggregate was valid [6].

The author described that the packets from different applications cannot be aggregated. To make data aggregation more efficient, author introduced the concept of packet attribute, defined as the identifier of the data sampled by different kinds of sensors or applications, and then propose an attribute-aware data aggregation (ADA) scheme consisting of a packet-driven timing algorithm and a special dynamic routing protocol [7].

The authors proposed a novel Data Routing for In- Network Aggregation, called DRINA, that has some key aspects such as a reduced number of message for setting up a routing tree, maximized number of overlapping routes, high aggregation rate, and reliable data aggregation and transmission. But here next node is selected by considering hop count which increases the transmission time and delay [8].

A Hybrid Routing Protocol (GHRP) based on Genetic Algorithm (GA) is proposed to support the metrics such as end-to-end delay, bandwidth and hop count. Through the simulation results, it has been showed that GHRP fabricates better performance than hybrid routing protocols ZRP (Zone Routing Protocol) [9].

3. Proposed Work

Modified Data Routing for in-Network Aggregation For Wsns

The algorithm is used to build a routing tree with the shortest paths that connect all source nodes to the sink while maximizing data aggregation. The model has certain terms which are as follows:

- **Collaborator:** A node that detects an event and reports the gathered data to a coordinator node.
- **Coordinator:** A node that also detects an event and is responsible for gathering all the gathered data sent by collaborator nodes, aggregating them and sending the result toward the sink node.
- **Sink:** A node interested in receiving data from a set of coordinator and collaborator nodes.
- **Relay:** A node that forwards data toward the sink.

The working of model is divided into following phases:

1. First step is to calculate the distance from the sink node to other nodes of the network.
2. At the first event, cluster head is selected which is closer to sink node and it is called as coordinator and the remaining node that detect the same event are named as collaborator.
3. The routes are created by choosing the best neighbor which is at minimum distance from sink node and accordingly distance from sink node is updated
4. Route repair mechanism: Here if the sender node receives ACK from the node within the pre-determined timeout, it will assume that the node is alive else new node is selected.

4. Calculating the Distance from Sensor Node to Sink Node

In this phase, the distance from the sink to each node is computed using distance formula. This phase is started by the sink node sending, by means of a flooding, the Hop Configuration Message (HCM) to all network nodes. The HCM message contains two fields: ID and HopToTree, where ID is node identifier that started or retransmitted the HCM message and HopToTree is the distance, in hops, by which an HCM message has passed. Also distance from sink node to other nodes of network is calculated using distance formula.

5. Cluster Setup Phase

For this election, all sensing nodes are eligible. If this is the first event, the leader node will be the one that is closest to the sink node. Otherwise, the leader will be the node that is closest to an already established route. In case, two or more concurrent nodes have the same distance to the sink, the node with the smallest ID maintains eligibility. Another possibility is to use the energy level as a tiebreak criterion. At the end of the election algorithm only one node in the group will be declared as the leader (Coordinator). The remaining nodes that detected the same event will be the Collaborators.

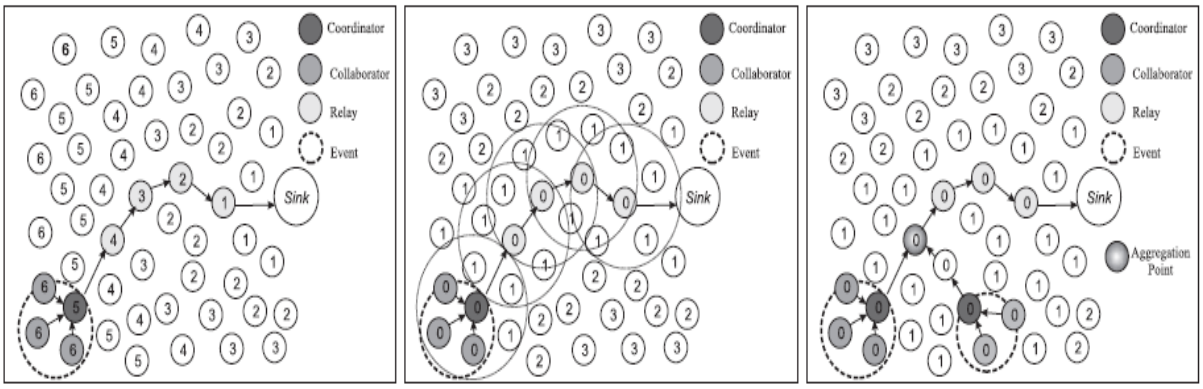
6. Inter Cluster Routing and Hop Tree Update

The routes are created by choosing the best neighbor at each hop. The selection for the best neighbor is classified in two ways firstly when the first event occurs, the node that leads to the shortest path to the sink is chosen figure 1(a)[8], and secondly after the occurrence of subsequent events, the best neighbor is the one that leads to the closest node that is already part of an established route figure 1(c) [8]. This process tends to increase the aggregation points, ensuring that they occur as close as possible to the events. The resulting route is a tree that connects the Coordinator nodes to the sink. When the route is established, the hop tree updating phase is started.

7. Route Repair Mechanism

It is responsible for both setting up a new route for the reliable delivering of packets and updating the hop tree. It consists of detection of failure node and selection of a new Node. When a node needs to forward data to the sink, it simply sends the data packet, sets a timeout, and waits for the ACK message. If the sender node receives ACK from the node within the pre-determined timeout, it will assume that the node is alive .If not, it considers the node as offline and another New node selected. After this repair mechanism, a newly reconstructed path is created & proceeding with forwarding aggregated data towards sink. This mechanism also provides secured data aggregation.

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(a)Example of routing event (b) Update of hop tree (c) Example of routing tree to event
Figure 1: Example of establishing new routes and updating the hop tree

8. Performance Evaluation

The performance evaluation is achieved through network simulator (NS-2). The default simulation parameters are presented in Table 1. For each simulation set, a parameter shown in Table 1 will be varied as described in the scenario. The evaluated algorithms used periodic simple aggregation strategy in which the aggregator nodes transmit periodically the received and aggregated information. The following metrics were used for the performance evaluation.

Table 1: Simulation parameters

Parameters	*Value*
Simulator	2.34
Number of nodes	30-50
Sink node	1
Network size (m^2)	1000
Radio range	250
Traffic source	CBR
Sensor field(m^2)	500 x 500
Packet size	512 bytes
Packet interval (µs)	2

Simulation is carried out in 500 x500 m^2 rectangular region with 30-50 numbers of nodes. All nodes have transmission range is 250 meters.

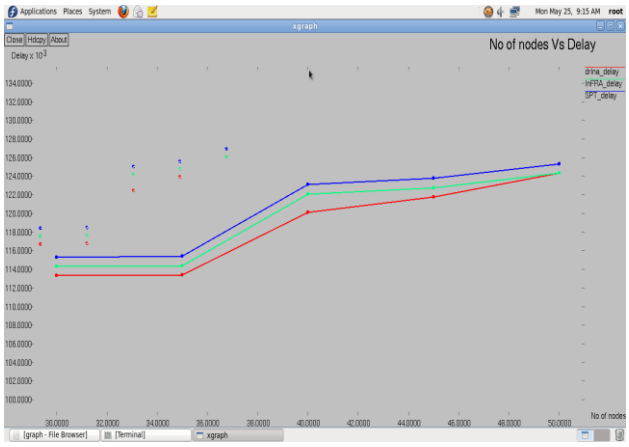


Figure 2: No. of Nodes vs Delay

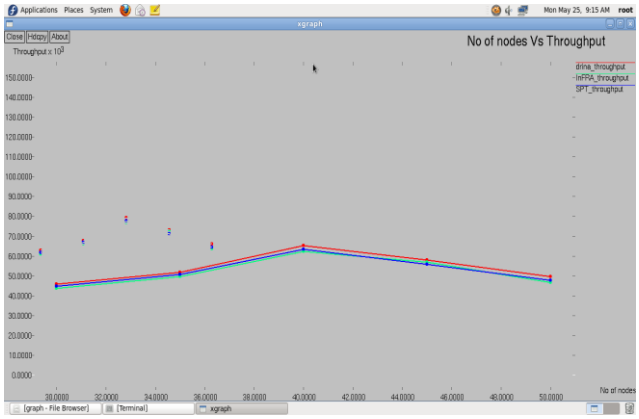


Figure 3: No. of Nodes vs Throughput

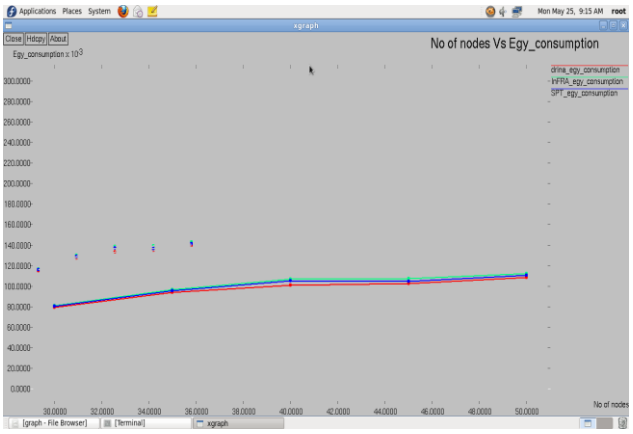


Figure 4: No. of Nodes vs Energy Consumption

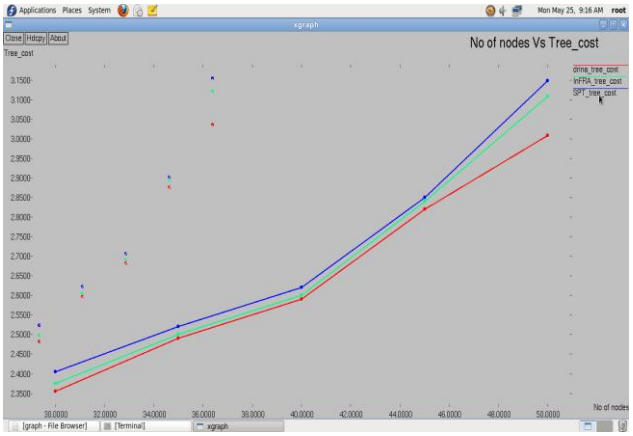


Figure 5: No. of Nodes vs Tree Cost

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Extensive simulations in Network-Simulator 2 show that our protocol outperforms the existing protocol Shortest path tree (SPT) & Information Fusion-based Role Assignment (InFRA) in terms of various performance metrics. These graphs shows the variation of y-axis with respect to x-axis & it is observed that as the number of node increases throughput, lifetime, & overhead increases and simultaneously delay, energy consumption, and tree cost decreases.

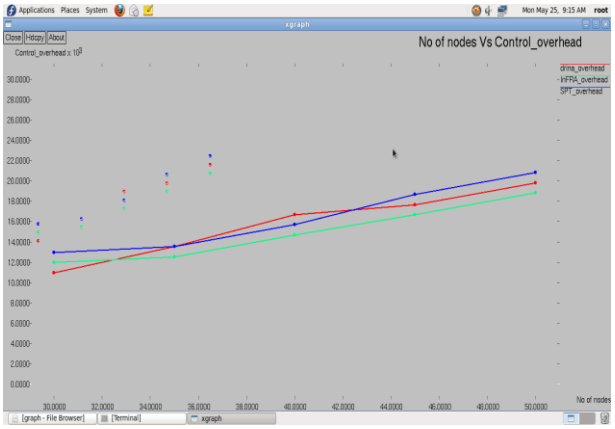


Figure 6: No. of Nodes vs Control Overhead

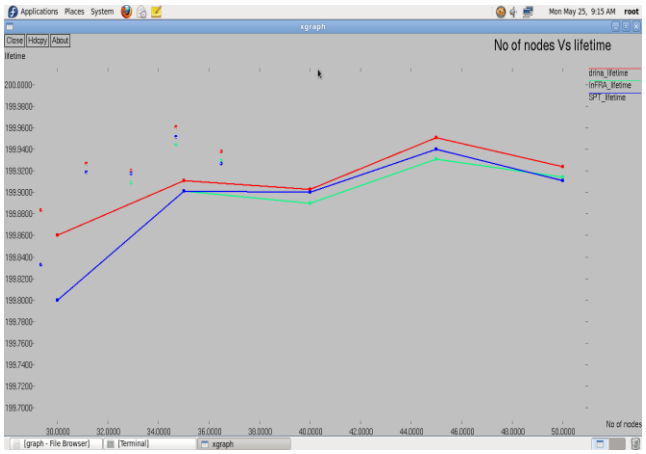


Figure 7: No. of Nodes vs Lifetime

9. Conclusion

The key aspect of the algorithm is to reduced number of messages for setting up a routing tree, high aggregation rate, and reliable data aggregation and transmission. In the modified DRINA algorithm cluster head is responsible for aggregating the data of all its neighbour nodes and transmit it through the shortest and energy efficient reliable path, which results increase in throughput, lifetime, and control overhead. Thus modified DRINA provides the reliable routing, with increased throughput, lifetime and decreased delay, energy consumption, tree cost.

10. Acknowledgment

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