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Prediction Algorithms for Improving Network Lifetime in WSNs

P. Ramya, K. Sangeetha and V. Venmathi

Department of Electronics and Communication Engineering,
SNS College of Engineering, Coimbatore, India

Abstract: The localized, self organizing, robust, scalable and energy-efficient data aggregation tree approaches for sensor networks, is called as Localized Power-Efficient Data Aggregation Protocols (L-PEDAPs). L-PEDAPs are based on LMST and RNG topologies, which can be estimated minimum spanning tree and can be computed efficiently using only position or distance information of one-hop neighbors. In order to use the sensor networks for long duration an efficient utilization of energy is essential because the sensor nodes are battery driven. The routing tree is constructed over these topologies and also considers different parent selection strategies. Then compare each topology and parent selection strategy and conclude that the best among them is the shortest path strategy over LMST structure. To reduce data traffic inside sensor networks, reduce the amount of data that need to send to base station. The main goal of data aggregation algorithms is to gather and aggregate data in an energy efficient manner so that network lifetime is enhanced. To propose a new algorithm to evaluate the node lifetime and the link lifetime utilizing the dynamic nature, such as the energy drain rate and the relative mobility estimation rate of nodes. The proposed solution is furthermore adapted to consider the node lifetime and link lifetime prediction algorithm in order to increase the network lifetime.

Key words: Minimum Spanning Tree (MST) · Local Minimum Spanning Tree (LMST) · Relative Neighborhood Graph (RNG)

INTRODUCTION

Many applications would require energy efficient routing scheme in wireless sensor networks nowadays. However to reduce the communication overhead and energy consumption of sensors while gathering, the received data can be combined to reduce message size. A simple way of doing that is aggregating the data. For gathering all data at the sink periodically so that the lifetime of the network is prolonged as much a possible.The lifetime can be expressed in terms of rounds where a round is the time period between two sensing activities of sensor nodes. The algorithm must also be scalable. The message and time complexity of computing the routing paths must scale well with increasing number of nodes[1]. Another desirable property is robustness, which means that the routing scheme should be resilient to node and link failures. Hence a localized version of PEDAP is proposed, which tries to combine the desired features of MST and shortest weighted path-based gathering algorithms. So the name of our new approach is localized power-efficient data aggregation protocol (L-PEDAP).

A wireless sensor network (WSN) consists of spatially distributed autonomous sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants[1].

All sensor nodes in the wireless sensor network are interacting with each other or by intermediate sensor nodes. A sensor nodes that generates data, based on its sensing mechanisms observation and transmit sensed data packet to the base station (sink) [2]. This process basically direct transmission since the base station may locate very far away from sensor nodes needs. More energy to transmit data over long distances so that a better technique is to have fewer nodes sends data to the base station. These nodes called aggregator nodes and processes called data aggregation in wireless sensor network [3].

Corresponding Author: P. Ramya, Assistant Professor, Department of Electronics and Communication Engineering, SNS College of Engineering, Coimbatore, India.

System Model and Problem Statement

Problem Definition: The sensor nodes are homogeneous and energy constrained. Sensor nodes and sink are stationary and located randomly [4]. Every node knows the geographic location of itself by means of a GPS device or using some other localization techniques. Every node senses periodically its nearby environment and has data to send to the sink in each round [3]. The nodes have a maximum transmission range denoted by R. Sensor nodes are thus normally not in direct communication range of each other.

The problem is to find an energy-efficient routing plan which maximizes the network lifetime. The routing plan determines for each node the incoming and outgoing neighbors for data forwarding and aggregation. In other words, a tree spanning all the nodes must be found as the routing plan [4]. The routing scheme should also include mechanisms to handle node failures and support new node arrivals.

Routing Protocols: Two elegant protocols called LEACH and PEGASIS have been proposed to maximize the lifetime of a sensor network [5]. A new minimum spanning tree based protocol called PEDAP (Power Efficient Data gathering and Aggregation Protocol) and its power-aware version [6]. PEDAP prolongs the lifetime of the last node in the system while providing a good lifetime for the first node, whereas its power-aware version provides near optimal lifetime for the first node although slightly decreasing the lifetime of the last node.

Each node builds its local minimum spanning tree independently and only keeps on-tree nodes that are one-hop away as its neighbors in the final topology several important properties of LMST: (1) the topology derived under LMST preserves the network connectivity (2) the node degree of any node in the resulting topology is bounded by 6 and (3) the topology can be transformed into one with bi-directional links (without impairing the network connectivity) after removal of all uni-directional links we propose a Minimum Spanning Tree (MST) based topology control algorithm, called Local Minimum Spanning Tree (LMST), for multi-hop wireless networks with limited mobility.

Power-efficient Topologies: There are many topologies proposed in the literature which can be efficiently computed using the location information of one-hop neighbors. However, the comparison did not consider the effect of data aggregation. An important advantage of using structures like RNG and LMST is that they can be constructed very efficiently in a localized manner [5]. Node deletions and additions do not globally change the structure. Only local changes in the structure are required and they can be efficiently computed when a node fails or when a new node is introduced to the network [6].

Topology Construction: In this phase, we aim to construct a sparse and efficient topology over the visibility graph of the network in a distributed manner [7]. We have different alternatives for sparse topologies that can be efficient for energy-aware routing. In this work, we choose to investigate the use of RNG and LMST and compare their relative performance [8]. We expect that LMST performs better than RNG because it is sparser. However, there are some aspects that make RNG and LMST comparable. First, the computation of RNG is more efficient than LMST. RNG needs only the location information of one-hop neighbors, whereas LMST needs a second message for informing about the LMST neighbors. This second message contains the local MST neighbors of the nodes and hence, it is larger in size compared to the first message which contains only the location information. One advantage of LMST is that it can approximate MST well especially when the density is high. In both topologies, we can also use the power-aware cost functions and consequently, we can efficiently approximate PEDAP-PA [9].

Routing Tree Computation: There are several methods for obtaining a tree structure (spanning all the nodes) given a graph. In this work, we use a flooding-based tree construction algorithm [6]. A special route discovery packet is broadcasted by the sink and when a node receives that packet, it decides its parent according to the information in the packet. After selecting the parent, it rebroadcasts the packet. Here, we investigate the efficiency of three different methods: first parent path method (FP), nearest minimum hop path method (MH) and shortest weighted path (i.e., least cost) method (SWP)[8]. The FP method is the simplest among the three. In this method, a node will set its parent as the first neighboring node from which the special route discovery packet was received.

The proposed routing scheme, at any time, each sensor node has to know its all one-hop neighbors and their locations, the neighbors on the computed topology, the parent node that it will send the data to in order to reach the sink and the child nodes that it will receive the data from before it sends the fused or aggregated packet to its parent node[7]. Our solution consists of three parts: Route Computation, Data Gathering and Route Maintenance.

System Implementation

Algorithm: The proposed routing scheme, at any time, each sensor node has to know it's all one-hop neighbors and their locations, the neighbors on the computed topology, the parent node that it will send the data to in order to reach the sink and the child nodes that it will receive the data from before it sends the fused or aggregated packets to its parent node. Our solution consists of three parts: Route Computation, Data Gathering and Route Maintenance.

Topology and Route Computation: The route computation is done via a broadcasting process which starts at the sink node. The sink initiates a ROUTE-DISCOVERY packet in order to find and set up the routes from all sensor nodes toward it. When a sensor node receives a ROUTE-DISCOVERY packet, it broadcasts the packet to all its neighbors on the computed topology if it updates its routing table [6].

The packet is sent by a power just enough for reaching all the neighbors on the sparse topology instead of using the maximum power [5]. Each ROUTE-DISCOVERY packet has three fields: a sequence ID which is increased when a new discovery is initiated by the sink, an optional distance field which shows the cost of reaching the sink and an optional neighbor list field which is the list of the neighbors of the sending node in the chosen topology. Only overhead is the size of the ROUTE-DISCOVERY packet [9]. Upon receiving a new ROUTE-DISCOVERY packet, the sensor node ignores the packet if it is not coming from a direct neighbor, in order to ensure using only the edges in the computed topology. And finally, if the SWP is chosen, the node updates its parent only if the path using the sender node is advantageous in terms of total energy consumption [8].

Data Gathering: After the parent and child nodes for an individual sensor node are determined, the node can join the data gathering process. In data gathering phase, each sensor node periodically senses its nearby environment and generates the data to be sent to the sink. However, before sending it directly to the parent node, it will wait all the data from its child nodes and aggregate the data coming from them together with its own data and then, send the aggregated data to the parent node [3]. Thus, at the beginning of data gathering step, only leaf nodes can transmit their data to their corresponding parent nodes. The reason for waiting to receive data from child nodes is to use the advantage of the aggregation[5]. In this way, each sensor only transmits once in a round and as a result, saves its energy.

Route Maintenance: After setting up the routes, three events can cause a change in the routing plan: route recomputation, node failure and node addition. Recomputation of the aggregation tree is required when power-aware (dynamic) cost functions are used. In power aware methods, the tree must be recomputed at specified intervals. Since the computation depends on the remaining energy of nodes, each time the computation takes place and a different and more power-efficient plan is yielded [10]. In this case, broadcasting a new ROUTE-DISCOVERY packet with a new sequence ID. Apparently, in order to utilize the power-aware methods, each node must know the remaining energy levels of its neighbors. In order to exchange the remaining energy levels, we use HELLO messages [9]. So, at the beginning of each recomputation phase, the nodes advertise their remaining energy levels. After that, ROUTE-DISCOVERY packet with a new sequence ID can be broadcasted by the sink.

When a node's energy reduces below a threshold value, the node broadcasts a BYE message using the maximum allowed transmit power. All nodes receiving the BYE message will immediately update their local structure [6]. In our solution, this is handled in a localized manner as follows: The child nodes of the failed node that receive the BYE message reset their routing tables and enter the parent-discovery phase by broadcasting a special message PARENT-DISCOVERY to its neighbors on the structure. According to the receiver of that special message, if the sender is its own parent on the way to the sink, the receiver also resets its routing table and broadcasts the packet to its neighbors. In this way, all the nodes that should enter the parent-discovery phase will be reached.

Simulation Results

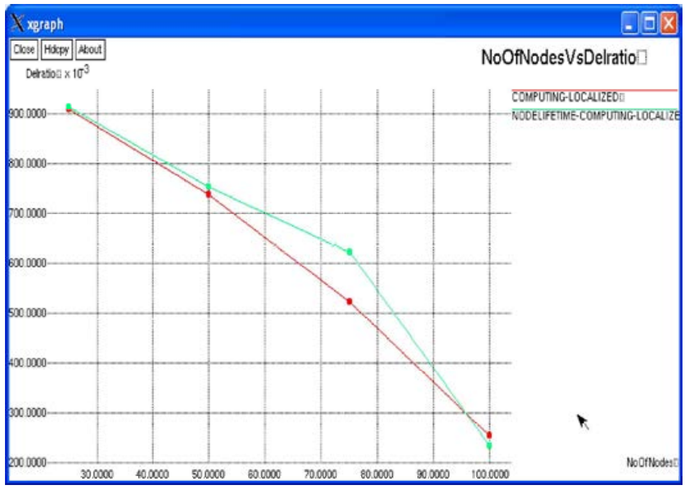

Fig. 1: Delivery Ratio

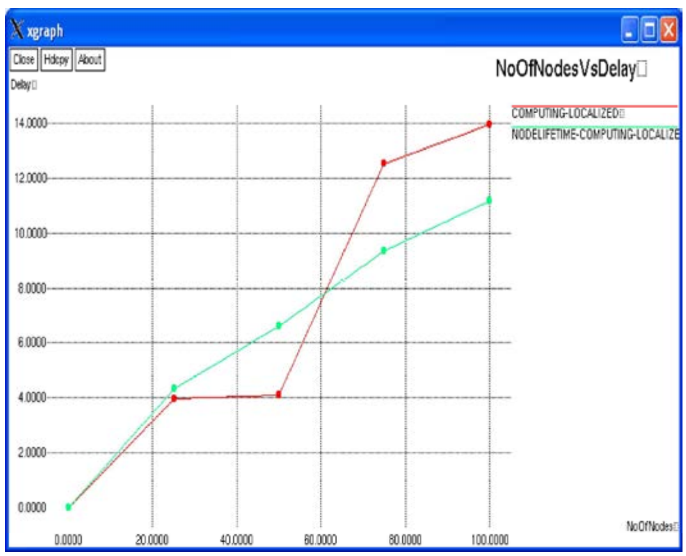

Fig. 2: Delay

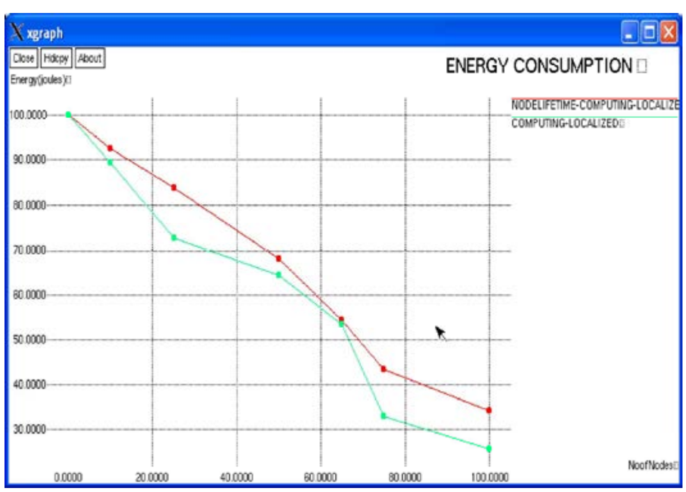

Fig. 3: Energy Consumption

CONCLUSION

Here in this work, a new energy-efficient routing approach that combines the desired properties of minimum spanning tree and the shortest path tree-based routing schemes. The proposed scheme uses the advantages of the powerful localized structures such as RNG and LMST and provides simple solutions to the known problems in route setup and maintenance because of its distributed nature. It is robust, scalable and self-organizing. All the nodes are not in direct communication range of each other. This means that dynamic methods can balance the energy expenditure among the nodes. By ignoring this cost, able to conclude that our localized solutions perform better than centralized and with over 90 percent upper bound.

This system can again be improved by using node lifetime prediction algorithm, link lifetime-prediction algorithm. Node lifetime is based on its current residual energy and its past activity solution that does not need to calculate the predicted node lifetime from each data packet. The connection lifetime in a route from two nodes of a stable connection is within the communication range of each other, the connection lifetime may last longer. If the received signal power strength is lower than a threshold value, then this link as an unstable state and then calculate the connection time. LLT (Link Lifetime) prediction algorithm requires only two sample packets and thus, it does not increase time complexity.

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