Flow Based Layer Selection Algorithm for Data Collection in Tree Structure Wireless Sensor Networks

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Abstract
The problem of data collection in tree structure wireless sensor networks has been studied in several articles and has many issues in data collection. Our earlier method performs data collection using layer based approach which performs layer selection in round robin approach. Also the existing method has the problem of channel utilization and to overcome the issue, this paper proposes a novel flow based layer selection algorithm for data collection in wireless networks. The proposed method maintains trace of data rate received from different layers at each cycle and using the trace available, the method performs flow estimation about how much byte of information has been received from each layer and number of nodes present in each layer, number of supporting nodes in wakeup mode in the neighboring layer, amount of energy depletion. Based on all these factors the method computes the channel utilization and data collection rate, based on which the method selects the any layer for data collection. Also the method triggers a set of supporting nodes of neighbor layers based on the data rate only. The proposed method improves the performance of data collection and increases the lifetime and channel utilization efficiency.

Keywords: Wireless sensor Networks, Data Collection, Tree Structure, Flow Based Approach, Layer Selection.

Introduction
The wireless sensor networks are the collection of sensor nodes located in different geographical region of the network. The nodes of network can be flooded or distributed throughout the region and each node has transmitter and receiver to perform sense and relay. The nodes can send and receive data packets towards any base station or sink node. The wireless sensor networks have much application and have the ability to be deployed in rapid manner. They can be deployed in minutes and in most cases the WSN are useful in performing data collection. For example, in war field conditions, the wireless sensor networks can be deployed to perform data collection. There will be huge requirement for the data collection about the troops and medicines or to receive information about enemy troops. So in order to collect such information from the war field there is a huge requirement of deployment of wireless devices, which is solved by the deployment of wireless sensor networks.

The deployment of wireless sensor network may be easier but the data collection has many challenges. In general in wireless topology the data collection can be performed using different routing protocols. All the information available in the data nodes has to be updated to a specific sink node, so in order to forward the information to the sink node the data packets has to be routed through some of the other nodes. In wireless sensor network the nodes of the network performs both sense and relay which supports cooperative routing. The problem is how the data collection is performed in a tree structure wireless sensor networks. If the nodes of the wireless sensor networks are arranged like a tree then the nodes present in the bottom layer has to transmit the data packets to the sink through the upper layers. So that the packet has to travel through the nodes of different layers to reach the sink. The nodes of the network are bounded with limited energy, so that they work on different modes. Whenever the nodes have data packets to be transmitted they work on wakeup mode otherwise they switch to the idle mode to save energy. Also the communication protocol used in wireless sensor network has different issues, the medium cannot be accessed by all the nodes simultaneous manner. So that the application of MAC protocol is there which enables the data communication and the protocol assigns the token for the nodes to perform data transmission. The nodes which has assigned with the MAC control only can send data through the network. Also if any of the node wants to transmit the data packets then the support from some of the other nodes also necessary.

In a tree structure network not all the layer nodes can perform data transmission at a time, only single layer nodes can perform data transmission at any point of time. Also the neighbor layer nodes also have to support the data transmission. The layer selection is the challenge here, because not all the nodes of any layer may have data packets to be transmitted and there will be a condition that multiple layer nodes might have data packets to be transmitted at any point of time. If the channel assignment is performed in round robin or time division method, the channel utilization may not be guaranteed. The selection of layer can be performed in several methods, but considering the data rate, energy depletion, and channel utilization would help to improve the performance of data collection and to improve the lifetime of the network. To achieve this an flow based layer selection algorithm has been discussed in this paper.
Related Work

There are number of methods has been discussed for the problem of data collection in wireless sensor networks. We discuss some of the method here in this section.

Energy Efficient Data Collection for Mobile Users in Wireless Sensor Networks Using SCFT Protocol [1], the sink node broadcast the message to all sensor nodes in the network to form the route path from the sensor to sink. To form the route path the proposed system incorporate the method of Self Centered Friendship (SCF) that means each node will consider itself as root node and appends the nodes that are connected to them by one hop. After the basic formation of SCF Tree the system moves forward with help of CRT for splitting the packets. The Chinese Remainder Theorem (CRT) is characterized by a simple modular division between the integers. Finally the system simply forwards the subpackets towards the sink which broadcast the message for data. Once all sub packets (called CRT components) are received correctly the sink node will recombine them using mask.

Energy-Aware Distributed Intelligent Data Gathering Algorithm in Wireless Sensor Networks [2], constructs a minimum connected dominating set (MCDS) based on maximal independent sets (MISs) in distributed and localized manner, and the node with more power is selected to be the cluster head in turn to prolong the network lifetime. In path formation phase, a path formation optimized algorithm (PFOA) is proposed to resolve the path formation NP problem with dynamic requirements. Then DIDGA uses the cluster head relay mechanism for planning the data gathering path. Compared with existed algorithms, detailed simulation results show that the proposed DIDGA can reduce average hop counts, average data gathering time, energy consumption, increase the efficiency of event detection ratio and prolong the network lifetime. An Energy Efficient Data Gathering in Dense Mobile Wireless Sensor Networks [6], constructs a data collection tree (DCT) based on the cluster head location. In DCT, data collection node (DCN) does not participate in sensing, which is simply collecting the data packet from the cluster head and delivering it into sink. CIDT minimizes the energy exploitation, end-to-end delay and traffic of cluster head due to transfer of data with DCT, cluster independent data collection tree (CIDT) provides less complexity involved in creating a tree structure, which maintains the energy consumption of cluster head that helps to reduce the frequent cluster formation and maintain a cluster for considerable amount of time. Capacity of data collection in arbitrary wireless sensor networks [7], first derive the upper and lower bounds for data collection capacity in arbitrary networks under protocol interference and disk graph models. We show that a simple BFS tree-based method can lead to order-optimal performance for any arbitrary sensor networks.

We then study the capacity bounds of data collection under a general graph model, where two nearby nodes may be unable to communicate due to barriers or path fading, and discuss performance implications. Finally, we provide discussions on the design of data collection under a physical interference model or a Gaussian channel model. An Energy-Efficient Data Collection Method for Wireless Multimedia Sensor Networks [9], propose an energy-efficient data collection method to extend the lifetime of networks that use a mobile sink. By using the neighborhood density clustering method and defining an optimal path for the mobile sink, the proposed method extends the life of the WMSN. Simulation results show that the proposed method increases the lifetime of WMSNs by up to 15 rounds, compared with LEACH. And data collection time is decreased owing to the predefined path for the mobile sink.

Efficient data collection in wireless sensor networks with path-constrained mobile sinks [11], propose a novel data collection scheme, called the Maximum Amount Shortest Path (MASP), that increases network throughput as well as conserves energy by optimizing the assignment of sensor nodes. MASP is formulated as an integer linear programming problem and then solved with the help of a genetic algorithm. A two-phase communication protocol based on zone partition is designed to implement the MASP scheme. We also develop a practical distributed approximate algorithm to solve the MASP problem. In addition, the impact of different overlapping time partition methods is studied. The proposed algorithms and protocols are validated through simulation experiments using OMNET++. Secure Data Aggregation Technique for Wireless Sensor Networks in the Presence of Collusion Attacks [14], demonstrate that several existing iterative filtering algorithms, while significantly more robust against collusion attacks than the simple averaging methods, are nevertheless susceptible to a novel sophisticated collusion attack we introduce. To address this security issue, we propose an improvement for iterative filtering techniques by providing an initial approximation for such algorithms which makes them not only collusion robust, but also more accurate and faster converging.

Data Collection in Multi-Application Sharing Wireless Sensor Networks [15], study the problem where each application requires a continuous interval of data sampling in each task. The proposed problem is a nonlinear nonconvex optimization problem. In order to lower the high complexity for solving a nonlinear nonconvex optimization problem in resource restricted WSNs, a 2-factor approximation algorithm whose time complexity is O(n^2) and memory complexity is O(n) is provided. A special instance of this problem is also analyzed. This special instance can be solved with a dynamic programming algorithm in polynomial time, which gives an optimal result in O(n^2) time complexity and O(n) memory complexity. Three online algorithms are provided to process the continually coming tasks. Both the theoretical analysis and simulation results demonstrate the effectiveness of the proposed.

All the above discussed methods has the problem of data collection error rate and more latency with poor channel utilization capacity.

Flow Based Layer Selection for Data Collection

The flow based layer selection approach computes the data reception rate at each layer and computes the number of nodes present in each layer. Based on these details the method computes the flow estimation and computes the channel utilization, energy depletion. Using all these information the method estimates the amount of data would be received from all the layers at each cycle of data collection. Based on the
computed measures a single layer will be selected for data collection and according to the data rate, the method selects random nodes to support data transmission to the upper layer. The entire process can be divided into different stages namely Flow estimation, Layer Selection and Random Neighbor selection. We explain each of the functional component in detail in this section.

**Flow Estimation:**
This stage takes input as the network topology and the network trace which is maintained. From the network trace the method identifies the number of layers present in the network. For each of the network the method computes the number of nodes present and extracts the data received from each of the nodes. For each time window the method computes the total bytes received from each node of the layer and computes the flow of data stream. Estimated flow factor will be used to perform layer selection at each cycle of data collection.

**Algorithm:**
The flow estimation algorithm computes the average byte stream sent by each layer nodes at each cycle and computes flow factor for each layer which will be used to perform layer selection in the next stage.

**Layer Selection:**
The layer selection algorithm use the flow factor computed in the previous stage and computes the bandwidth utilization and energy depletion rate for each of the layer. Based on computed measures the method computes the layer selection weight for each of the layer. Based on computed layer selection weight the method selects the top layer which can be used to perform data collection for the current cycle.

**Random Neighbor Selection:**
At this stage, the method computes the energy depletion rate of each nodes of layer $L_i$ and based on the energy depletion rate of the nodes and the flow estimation value of the bottom layer the method selects a small set of nodes with less energy depletion. Selected neighbors will be triggered for wakeup mode to support data transmission.

The above discussed algorithm performs random selection of neighbor nodes to support data transmission.
Results & Discussion
The proposed flow based layer selection approach has been implemented and tested for its efficiency using different scenarios. The method has produced efficient results in all the factors of data collection in wireless sensor networks.

Graph 1: Comparison of scheduling efficiency
The Graph 1, shows the comparison of scheduling efficiency and the graph shows that the proposed method has produced higher rate of scheduling efficiency than other methods.

Graph 2: Comparison of data collection efficiency
The Graph 2, shows the comparison of data collection efficiency of different methods and it shows clearly that the proposed method has produced higher data collection efficiency than other approaches.

Graph 3: Comparison of bandwidth utilization of different methods
The graph 3, shows the comparison of bandwidth utilization produced by different methods and it shows clearly that the proposed method has produced higher utilization than other approaches.

Conclusion
In this paper, we proposed a flow based layer selection approach for data collection in wireless sensor networks. The method starts with estimating the flow rate of streams at each layer and based on the flow of streams estimated the method performs layer selection to perform data transmission at current cycle. Once a single layer has been selected then the method performs the random neighbor selection based on the flow factor of the layer and the energy depletion factor of nodes of neighbor layer. According to computed values a small set of neighbors nodes will be selected and triggered to support the data transmission. The proposed method has produced efficient results in data collection in tree structure wireless sensor networks and increases the channel utilization and reduces the time complexity also.

References


