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Techniques to Improve Energy Efficiency in Wireless Sensor Networks: A Survey

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Abstract— In wireless sensor networks the nodes are deployed in different geographical conditions and the nodes may be left unattended for a long period of time. So to increase network lifetime the energy should be conserved. That is, an energy efficient wireless sensor network will last for a long time. To increase energy efficiency different methods like, data aggregation clusters, data aggregation trees, network coding, correlation dominating set, etc. can be used for correlated data environment. The effectiveness of these methods can be calculated in terms of network lifetime. In this paper explains different data gathering schemes used for prolonging network lifetime in wireless sensor networks.

Keywords— Wireless sensor networks; Energy efficiency; Data Gathering; Aggregation; Correlation dominating set

I. INTRODUCTION

A WSN consists of a set of distributed independent sensors which monitors physical or environmental conditions and it cooperatively transmit the data to a central location. The military applications encouraged the development of wireless sensor networks and now such networks are used in industrial applications, health monitoring, and so on. The sensor nodes mainly consist of three components to collect information about a supervised region. These three components of a sensor node are a processing unit with limited facility, atmospheric sensors and a short-range wireless transceiver. Using these components sensor nodes transmit the data about the observed region to the central node by forming a multi-hop wireless network [1]. The most important challenge of wireless sensor network is its restricted energy availability.

The collected critical data in WSN have to reach the sensor gateway as soon as possible. Different energy efficient methods in WSN must ensure a continuous network and reduced energy consumption. The replacement of the limited power sensors may be impossible or inefficient in almost all applications. As a result of that, the battery lifetime determines the lifespan of the sensor nodes and the network. In a multi-hop sensor network each node can act as a data originator and a router. So in WSN energy preservation and energy controlling have so much importance and it guided to the energy efficient methods and protocols. The methods used for data collection in an efficient way can be classified into different types. The classifications are cluster formation, aggregation trees, network coding, correlation dominating set, etc. [1]. In cluster formation method, different cluster heads are selected and the remaining nodes are combined to the cluster head. Cluster heads are responsible for forwarding the data to the base station. Many cluster formation methods are there and three methods are discussed in this paper. Aggregation is the process of combining data from different sources together. To aggregate the data in network aggregation trees can be formed and the correlated data collected by the sensor nodes can be aggregated and forwarded.

In network coding technologies in-network coding can be used for increasing energy efficiency. The data comes from one source can be encoded in the presence of another data. Different coding methods are there which will decrease the transmission cost.

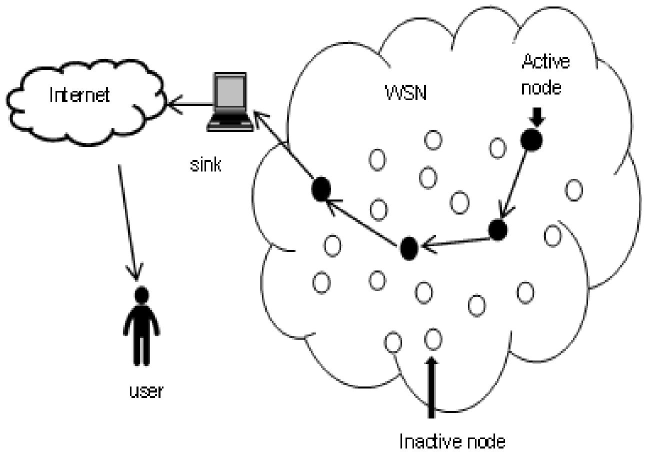

Fig. 1 Active nodes in a wireless sensor network

In correlation dominating set method some sensor nodes are activated so that they will sense the data. Remaining nodes are inactive and the active nodes will collect the data of those nodes using the correlation of the data collected by the nodes. The active nodes will form a tree and will send the data to the central node.

These different methods are explained in the following sections.

II. Data Gathering Schemes Based On Clustering

A. HEED (Hybrid and Energy-Efficient Distributed Clustering)

The HEED is a novel distributed clustering approach for durable ad-hoc sensor networks. It made assumptions only about the different energy levels in sensor nodes, but not about the occurrence of an infrastructure or about node capabilities. HEED chooses cluster heads based on two parameters in which the first one is the hybrid of node residual energy and the secondary parameter is the node closeness to its neighbours or node degree. Using suitable boundaries on node density and intra-cluster and inter-cluster communication ranges, HEED promises the connectivity of clustered networks. This approach is hybrid: cluster heads are probabilistically chosen based on their residual energy, and nodes join clusters such that transmission cost is reduced [2].

This approach is effective in extending the network lifetime and supporting scalable data aggregation, spends less energy in clustering, can provide features such as load-balancing and less overhead. It also should be noted that, it have repeated iterations so have complex algorithm. There is only small probability to decreases residual energy due to large number of iterations.

B. LEACH (Low-Energy Adaptive Clustering Hierarchy)

LEACH is an adaptive and self-configuring cluster formation method. In LEACH all non-cluster head nodes transmit data to their cluster head and when cluster head receives this data it performs signal processing functions on the data and transmits data to the BS. Nodes organize themselves into local clusters, with one node as cluster head. The cluster heads are selected based on residual energy of the nodes and the total system energy. The non-cluster head nodes sent join request to the selected cluster head. Two phases are there in LEACH, set-up phase and steady phase. In set-up phase the cluster head is selected and non-cluster head nodes are joined to the cluster head. In the steady phase the nodes transmit their data to the base station [3].

Advantages of this method are it outperforms conventional routing protocols, completely distributed, requiring no control information from the base station and nodes do not need global topology information. The disadvantages of this method are nodes must have data to send in the allotted time, limits the scalability of the network and exact correlation is assumed, which cannot be correct always.

C. CAG (Clustered Aggregation Technique)

CAG uses the correlation of sensed data. Using this correlation CAG decreases the number of transmissions and gives approximate results to aggregate queries. The result is guaranteed to be within a user-provided error-tolerance threshold. CAG arranges clusters based on the value the sensor node collects. When a query is given to the network, based on the correlation clusters are formed. Using mathematical models and simulations the efficiency correctness trade-off of CAG can be found. This technique contains two parts, Query phase and Response phase. In the query phase a tree is formed through which the data is forwarded. The cluster heads forward only one data to the next level after the aggregation and it is done in the response phase. Only cluster heads take part in the aggregation of the data in the network. The only parameter for cluster formation in the CAG method is its spatial correlation between the data sensed [4].

Advantages of this method are energy-efficient in-network aggregation, leveraging both spatial and temporal correlations, resilient to the packet loss and ensure confined approximation. Disadvantages of this method includes it uses a simple notion of correlation, where the edges of the forwarding tree constitute the correlations for the selection of cluster-heads and connecting sensor nodes and no hybrid clustering protocol.

III. Data Gathering Schemes Based On Data Aggregation Trees

A. MFST (Minimum Fusion Steiner Tree)

MFST uses the method of fusion for collecting the data in an energy efficient manner in wireless sensor networks. In the methods other than MFST the energy efficiency is achieved by reducing the transmission cost. But in MFST, other than transmission cost the cost for fusion of data in the network is also reduced. This is important for sensor networks with critical data and for security. In this method fusion cost for the correlated data is taken as another dimension to the space of routing optimization. A fusion function is used in this method and it can be used to determine the fusion cost using the input of the function, and is not similar to the transmission cost which is determined by the output of the fusion function. Some networks use complex functions for fusion, and in that the cost for fusion should be decreased. For data aggregation in one node, this method uses a step by step procedure, in which one input is fused to the existing fused set of inputs. It is because of the limited availability of resources and different arrival time of the inputs. The transmission cost depends on both the unit cost for transmitting data through the communication link and the amount of data being transmitted. Unlike transmission cost, fusion cost depends on the amount of data to be fused as well as the algorithm used for fusion [5].

For making conclusions for routing at the time of data combination, fusion cost plays a big role. The routing topology will be determined by the dissimilar fusion costs, which occurs due to the numerous combinations among the sensor nodes. Therefore, to get an energy efficient method for data transmission both transmission and fusion costs are calculated in this method.

B. Scale Free Aggregation

The proposed method is used to construct an efficient tree to transfer data from different sensor nodes to a central node which will be processing the data. If data from different sources go through a single node then those data can be aggregated in that node. The aggregation of data is done for reducing the number of bits to be transmitted. This method will reduce the transmission cost and will increase the lifetime of the network. In single sink aggregation method data comes from different sources will go through a single link and the total data through that link can be found by an aggregation function [6]. Single sink aggregation method focuses on the construction of a data aggregation tree which will work for all types of aggregation functions. This method contains two steps, matching step and selection step. Using these steps the aggregation tree and the single link can be found. The main advantage of this method is single tree can be used for all types of aggregation functions. This method is not good if, multiple sources and multiple sinks are present in the tree and when the aggregation function depends on the identity of the sources.

IV. DATA GATHERING SCHEMES BASED ON NETWORK CODING

A. Single Input Coding

This method uses the correlation between data to increase the energy efficiency. To aggregate data from different sources single input coding method must find the relationship between the data sensed by different sensors. Two types of coding are introduced here, foreign coding and self coding. For both of these different algorithms are used MEGA and LEGA respectively. In-network data processing is used here in which data from different sources will be aggregated as it goes from source to sink. Conditional coding is used in this method in which data from one source is aggregated in the presence of data from a different source. Single input coding can be applied to the asynchronous network, having no time considerations [7]. In self coding data is encoded in the originating node with the presence of side data from another node. In foreign coding data is encoded in a foreign node in the presence of its data.

B. On Network Correlated Data Gathering

In on network data gathering the transmission cost of data from source to sink is reduced using two coding strategies. First model is Slepian-Wolf model and second is joint entropy coding model. These two methods differ in terms of complexity of optimal coding and transmission optimization. In the case of Slepian-Wolf coding optimal coding complexity is high and the transmission optimization is simple. The data load in the nodes near the sink is high and nodes far away from the sink have a much lower rate. In joint entropy coding model the transmission optimization is complex and the optimal coding is easy. Here the large data rate is in the nodes far away from the sink and low data rate in nodes that are closer to the sink [8]. These methods are used when there is a correlation between the data sensed by different nodes. A combination of both these methods is more advantageous.

V. DATA GATHERING BASED ON CORRELATION DOMINATING SET

A. IAND (Iterative Active Sensor Node Determination)

This approach is to select a small subset of sensor nodes that may be sufficient to reconstruct data for the entire sensor network. Then, during data gathering only the selected active sensors need to be involved in the communication [1]. The selected active nodes must be connected, since they need to relay data to the data-gathering node. Both residual energy of the sensor nodes and the correlation between the data sensed by the nodes are the parameters used to determine the nodes which will take part in the transmission of data to the data gathering node.

VI. COMPARISON OF DIFFERENT DATA GATHERING SCHEMES

In this section the advantages and disadvantages of different data gathering methods are discussed and are listed in the table. The comparison of these methods is shown in table I. The comparison is done based on network lifetime, complexity, transmission cost and fusion cost.

TABLE I Comparison of Different Data Gathering Schemes

Method	**Advantages**	**Disadvantages**
HEED[2]	Prolong network lifetime, Scalable data aggregation, Load balancing	Complex algorithm
LEACH[3]	Completely distributed, Requiring no control information from the base station, Nodes do not need global topology information	Nodes must have data to send in the allotted time, Assumed perfect correlation might not be true
CAG[4]	Energy-efficient in-network aggregation, Leveraging both spatial and temporal correlations resilient to the packet loss, Ensure bounded approximation	No hybrid clustering protocol

MFST[5]	Varying network topology, fusion cost, correlation	Less robustness
Scale free aggregation[6]	Prolonged network lifetime, Efficient data aggregation, Decreases amount of data transmitted	Multi-commodity version of the problem, Aggregation depends not just on the number of sources, but also on the identity of the sources
Single input coding[7]	Efficient gathering of data	Assumes star topology, Only single input coding
On network correlated data gathering[8]	Reduce total transmission cost	Complex structure
Active node determination[1]	High performance, Increased network lifetime, High runtime efficiency	Only for static sensor network

VII. CONCLUSION

This paper is a study of different data gathering schemes used to increase the energy efficiency. To improve the energy efficiency of wireless sensor networks different methods can be used and these methods decrease the energy utilization for data transfer through the network. The different data gathering schemes are clustering, aggregation trees, network coding and correlation dominating set. The network lifetime can be increased to an extent using these methods.

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