ISSN:0975-9646

Load Balanced Data Aggregation Methods for Virtual Backbone in Wireless Sensor Networks

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ABSTRACT— **Data Gathering is a fundamental task in Wireless Sensor Networks (WSNs). Data gathering trees capable of performing aggregation operations are also referred to as Data Aggregation Trees (DATs). Currently, most of the existing works focus on constructing DATs according to different user requirements under the Deterministic Network Model (DNM). However, due to the existence of many probabilistic lossy links in WSNs, it is more practical to obtain a DAT under the realistic Probabilistic Network Model (PNM). Moreover, the load-balance factor is neglected when constructing DATs in current literatures. Therefore, it is focused on constructing a Load-Balanced Data Aggregation Tree (LBDAT) under the PNM. More specifically, three problems are investigated, namely, the Load-Balanced Maximal Independent Set (LBMIS) problem, the Connected Maximal Independent Set (CMIS) problem, and the LBDAT construction problem. LBMIS and CMIS are well-known NP-hard problems and LBDAT is an NP-complete problem.**

***Keywords*—Wireless sensor networks, PNM, data aggregation tree,load balanced data aggregation tree, LBMIS, CMIS.**

I.Introduction

In Wireless Sensor Networks (WSNs), sensor nodes periodically sense the monitored environment and send the information to the sink, at which the gathered/collected information can be further processed for end-user queries. In this data gathering process, data aggregation can be used to fuse data from different sensors to eliminate redundant transmissions, since the data sensed by different sensors have spatial and temporal correlations.[1] Hence, through this in-network data aggregation technique, the amount of data that needs to be transmitted by a sensor is reduced, which in turn decreases each sensor's energy consumption so that the whole network lifetime is extended.

For continuous monitoring applications with a periodical traffic pattern, a tree-based topology is often adopted to gather and aggregate sensing data because of its simplicity. Compared with an arbitrary network topology, a tree-based topology conserves the cost of maintaining a routing table at each node, which is computationally expensive for the sensor nodes with limited resources.

A .Problem Definition

Data gathering process, data aggregation can be used to fuse data from different sensors to eliminate redundant transmissions, since the data sensed by different sensors have spatial and temporal correlations. Hence, through this in-network data aggregation technique, the amount of data that needs to be transmitted by a sensor is reduced, which in turn decreases each sensor's energy consumption so that the whole network lifetime is extended. For continuous monitoring applications with a periodical traffic pattern, a tree-based topology is often adopted to gather and aggregate sensing data because of its simplicity[10].

The investigated problem is distinguished from all the prior works in three aspects. First, most of the current literatures investigate the DAT construction problem under the DNM, whereas the proposed work is suitable for both DNM and PNM. Second, the load-balance factor is not considered when constructing a DAT in most of the aforementioned works. Finally, the DAT construction problem is our major concern, whereas the prior works focus on the aggregation scheduling problem. DAT construction problem is explored under the PNM considering balancing the traffic load among all the nodes in a DAT. To be specific, in this paper, we construct a Load-Balanced DAT (LBDAT) under the PNM in three phases[3].

B. Existing System

Data Aggregation Trees (DATs)-Due to the dense sensor deployment, many different DATs can be constructed to relay data from the monitored area to the sink. DAT related works can be classified into three categories: Energy-Efficient Aggregation Scheduling, Minimum-Latency Aggregation Scheduling and Maximum-Lifetime Aggregation Scheduling.

Probabilistic Network Model (PNM)-To well characterize WSNs with lossy links, a more practical network model is the Probabilistic Network Model (PNM). Under this model, there is a transmission success ratio associated with each link connecting a pair of nodes vi and vj, which is used to indicate the probability that a node can successfully deliver a package to another.

C. Proposed System

To identify and highlight the use of lossy links when constructing a DAT. Moreover, in order to measure the load-balance of the nodes in a DAT under the PNM, we define two new metrics potential load, and actual load. The LBDAT construction problem is an NPcomplete problem and we solve it in three phases. First, we propose an approximation algorithm by using the linear relaxation and random rounding techniques to solve the LBMIS problem, which is an NP-hard problem. Theoretical analysis shows that this algorithm yields a solution upper bounded by $O(\ln(n)opt_{LBMIS}$, where opt_{LBMIS} is the optimal result of LBMIS, and n is the number of sensors in a WSN. Subsequently, a minimum-sized set of nodes are identified to make the LBMIS connected. Finally, to solve LBDAT, we present a randomized approximation algorithm to find an LBPNA. The approximation algorithm produces a solution in which the actual traffic load on each intermediate node is upper bounded by $O(\ln(n))Opt_{LBPNA}$, where opt_{LBPNA} is the optimal result.

To explore the DAT construction problem under the PNM considering balancing the traffic load among all the nodes in a DAT.

To construct a Load- Balanced DAT (LBDAT) under the PNM in three phases.

To investigate how to construct a Load-Balanced Maximal Independent Set (LBMIS).

To find a minimum-sized set of nodes called LBMIS connector set C to make this LBMIS M connected, which is called the Connected MIS (CMIS) problem.

To seek a Load-Balanced Parent Node Assignment (LBPNA).

After an LBPNA is decided, by assigning a direction to each link in the constructed tree structure, to obtain an LBDAT.[8]

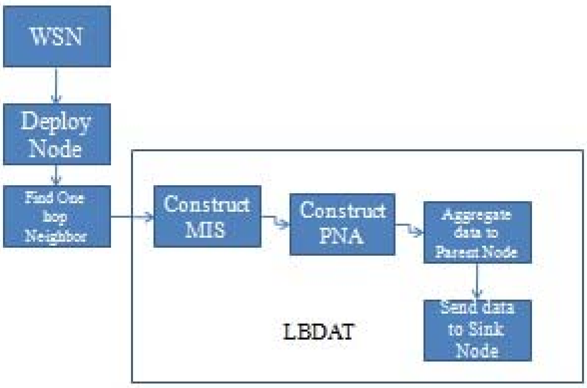

Fig. 1 System Architecture

II.METHODOLOGY

It contains following steps: Network model,One hop neighbor detection,Load-Balanced Maximal Independent Set (LBMIS) and Load-Balanced Parent Node Assignment (LBPNA).

A.Network Model

We assume a static connected WSN with the set of n nodes $V_s=\{v_1, v_2, . . .v_n\}$ and one sink node v0. All the nodes have the same transmission range. The transmission success ratio associated with each link connecting a pair of nodes vi, vj is available, which can be obtained by periodic Hello messages, or be predicted using Link Quality Index (LQI). It is also assumed that the transmission success ratio values are fixed. This assumption is reasonable as many empirical studies have shown that LQI is pretty stable in a static environment. Furthermore, no node failure is considered since it is equivalent to a link failure case. No duty cycle is considered neither. It is assumed that the n nodes monitor the environment in the deployed area and periodically report the collected data to the sink node v0 along the LBDAT [4].

Every node produces a data package of B bits during each report interval. Moreover, an intermediate node can aggregate multiple incoming B-bit packets, together with its own package into a single outgoing B-bit package. Furthermore, we assume the data receiving rate of each node vi is γi, and R denotes the maximum data receiving rate of all the nodes. Finally, the degree of a node vi is denoted by di, whereas δ/D denotes the minimum/maximum node degree in the network.

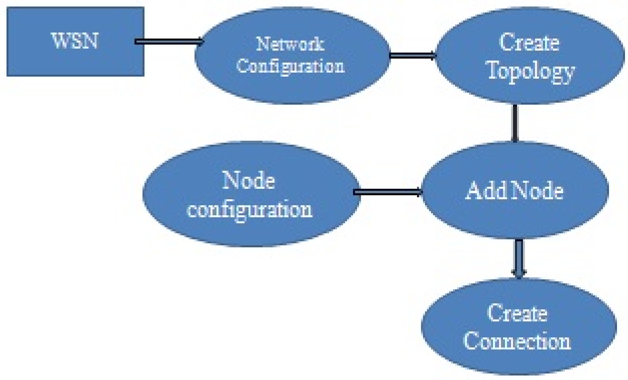

Fig.2 Module Diagram – Network Model

B.One Hop Neighbor Detection

A sensor network with a graph G(k)= (V(k),e(k)), whose node set V(k) represents the sensor nodes active at time k and the edge set e(k) consists of pairs of nodes (u,v) such that nodes u and v can directly exchange messages between each other at time k. By an active node we mean a node that has not failed permanently. All graphs considered are undirected, i.e., (i, j) =(j,i). The neighbors of a node i is the set Ni of nodes connected to i, i.e., Ni. The number of neighbors of i, is called its degree, which is denoted by di(k). A path from i to j is a sequence of edges connecting i and j. A graph is called connected if there is a path between every pair of nodes. From source node to destination node, neighbors of a source node are taken and all possible paths are created.[6]

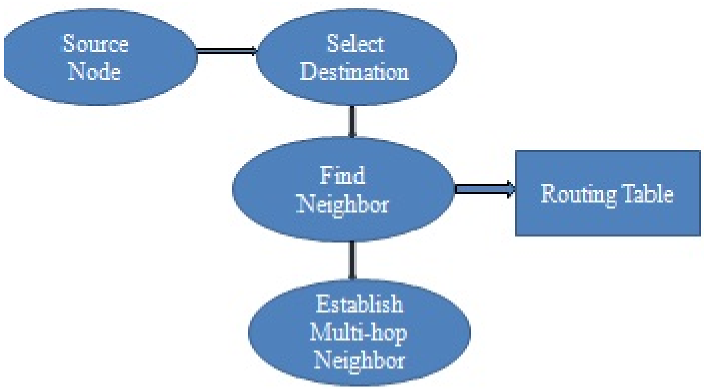

Fig.3. Module Diagram – Multipath Creation

C.Load-Balanced Maximal Independent Set (Lbmis)

All aggregated data are reported to the sink node, hence the sink node is deliberately set to be an independent node. Since an MIS is also a DS, we should formulate the DS constraint for the LBMIS problem first. The DS property states that each non independent node must reside within the 1-hop neighborhood of at least one independent node. Taking the load-balance factor into consideration, we are seeking an MIS in which the minimum potential load of the nodes in the constructed LBMIS is maximized. In other words, the potential traffic load on each node in the LBMIS is as balance as possible.

Approximation Algorithm to search for an LBMIS

Step 1: Sort sensor nodes by the w_i value (where 1 <= i <=n) in the decreasing order.
Step 2: Set the sink node to be the independent node, i.e., w_0=1.
Step 3: Set all w_i to be 0.
Step 4: Start from the first node in the sorted node array A.
If there is no node been selected as an independent node in v_i's 1-hop neighborhood, then let w_i=1 with probability p=w_i.
Step 5: Repeat step 4) till reach the end of array A.
Step 6: Repeat step 4) and 5) for v, w_i>0 times.

D.Load-Balanced Parent Node Assignment (LBPNA)

The node ID is used to break the tie (small-ID with higher priority). After applying the above parent node assignment scheme to all the non-leaf nodes, v_i ЄD, its parent node is decided. Furthermore, for each v_i Є D, the traffic load of v_i introduced by its non-leaf child nodes is denoted by ψi. Considering that for v_iЄ D, it can has as many as O(n) leaf children. A tree structure is decided after the Load-Balanced Parent Node Assignment (LBPNA) A is produced, which includes LBPNA for non-leaf nodes and leaf nodes. By assigning a direction of each link in the constructed tree from the children node to the parent node, an LBDAT is obtained [7].

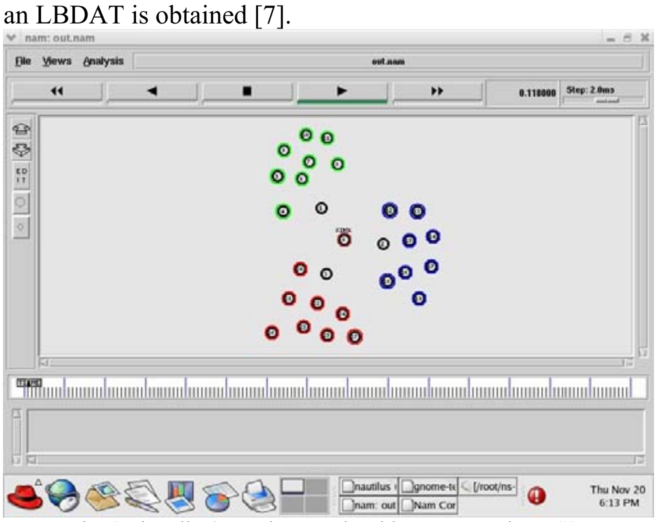

Fig. 4 Virtually Created Network With LBDAT Using NS2

III.CONCLUSION

The fundamental problems of constructing a load-balanced DAT in probabilistic WSNs were studied. In the first part, it finds the optimal MIS such that the minimum potential load of all the independent nodes is maximized. To this end, a near optimal approximation algorithm is proposed. Then the minimum-sized set of LBMIS connectors are found to make the LBMIS connected. The theoretical lower and upper bounds of the number of non-leaf nodes are analyzed as well. LBDAT construction problem is studied and proposed an approximation algorithm by using the linear relaxing and random rounding techniques. After an LBPNA is decided, by assigning a direction to each link, an LBDAT is obtained. The simulation results show that the proposed algorithms can extend network lifetime significantly.

The next step is to come up with a sophisticated model to integrate the aforementioned three phases together and analyze the overall performance of the LBDAT construction problem. This is because three phases algorithm might lead to performance loss/improvement since which did not investigate the correlations among them. Another direction is to design distributed algorithms for the LBDAT construction problem under both DNM and PNM. As to simulation, since the shape of the monitoring area has great influence on the performance of proposed solution, we will conduct more simulations b changing the shapes of the monitoring area in the future.

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