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Efficient Load-Balanced Data Aggregation Trees In Probabilistic Wireless Sensor Networks

B. Dhanalakshmi[1], R. Ilayaraja[2]
II-ME (CS) [1], Associate Professor/ECE[2], Dhanalakshmi Srinivasan Engineering College, Perambalur

Abstract-The data gathering process, data aggregation can be used to fuse data from different sensors to eliminate redundant transmissions. Currently, most of the existing works focus on constructing DATs according to different user requirements under the Deterministic Network Model (DNM).due to the existence of many probabilistic lossy links in WSNs so the current work which spend lots of efforts on aggregation, so we mainly focus on DAT construction problem. The proposed, we focus on constructing a Load-Balanced Data Aggregation Tree (LBDAT) under the PNM, we define two new metrics potential load, and actual load. First we solve LBMIS and connected MIS (CIMS). Finally, we 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, we obtain an LBDAT. Comprehensive performance ratio analysis is presented as well.

Index Terms—Probabilistic wireless sensor networks, data aggregation tree, maximal independent set, linear programming, load-balance, integer programming, random rounding, minimum-sized connected dominating set.

I. INTRODUCTION

A **Wireless Sensor Network** (WSN) is a computer network consisting of spatially Distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations. The development of wireless sensor networks was originally motivated by military applications such as battlefield surveillance. However, wireless sensor networks are now used in many civilian application areas, including environment and habitat monitoring, healthcare applications, home automation, and traffic control. In addition to one or more sensors, each node in a sensor network is typically equipped with a radio transceiver or other wireless communications device, a small microcontroller, and an energy source, usually a battery. The size a single sensor node can vary from shoebox-sized nodes down to devices the size of grain of dust. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and bandwidth. 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. 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. There are various models for sensor networks. In this work we mainly consider a sensor network environment where:

- Each node periodically senses its nearby environment and would like to send its data to a base station located at a fixed point.
- Sensor nodes are homogeneous and energy constrained.
- Sensor nodes and base station are stationary.

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
Adapted to gather and aggregate sensing data because of its simplicity. 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 Gathering is a fundamental task in Wireless Sensor Networks (WSNs). 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).

Most of the existing DAT construction works are based on the ideal Deterministic Network Model (DNM), where any pair of nodes in a WSN is either connected or disconnected. Without considering balancing the traffic load among the nodes in a DAT, some heavy-loaded nodes may quickly exhaust their energy, which might cause network partitions or malfunctions. The criterion to assign a parent node, to which data is aggregated for each node on a DAT, is also critical to balance traffic load on each intermediate node. However, unlike most of the existing works which spend lots of efforts on aggregation scheduling, we mainly focus on the DAT construction problem.

C. Proposed System

We 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 NP –complete problem, 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. 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 loads on each intermediate node optimal result. After LBPNA is decided, by assigning a direction to each link in the constructed tree structure, we obtain an LBDAT. The proposed system results are comparing with existing to extend the network lifetime significantly.

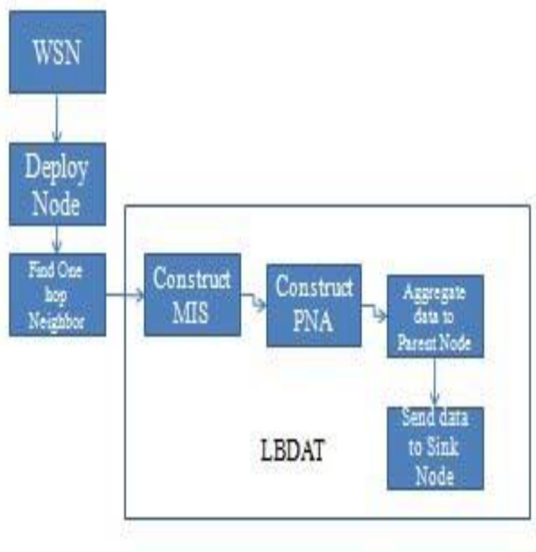


Fig.1.1 System Architecture

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 Vs= {v1, v2, vm} 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. 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.

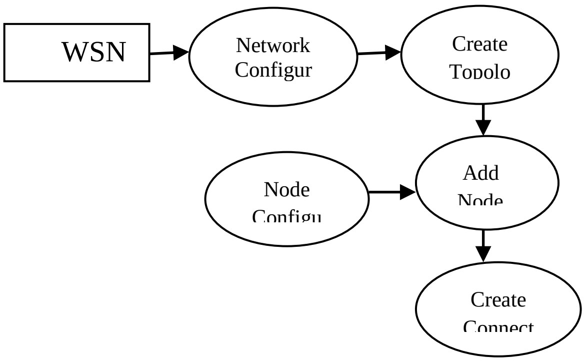


Fig.2.1 Module Diagram – Network Model

B. Load-Balanced Maximal Independent Set

The LBMIS problem is an Integer Nonlinear Programming (INP). Integer Nonlinear Programming (INP) first formulate Dominating set (DS) property constraint states that each non independent node must reside within the 1-hop neighborhood of at least one independent node. Next formulate Independent Set property indicate that no two independent nodes are adjacent. Subsequently, obtain to approximation solution by using Linear Programming (LP) relaxation techniques finally construct LBMIS.

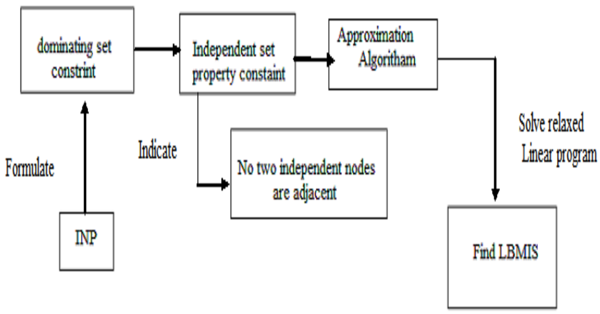


Fig.2.2 Load-Balanced Maximal Independent Set

C. Connected Maximal Independent Set

LBMIS construct process is finish go to next process is find connected node in MIS. After CMIS is constructed, we dedicate to find an LBPNA for non-leaf nodes.

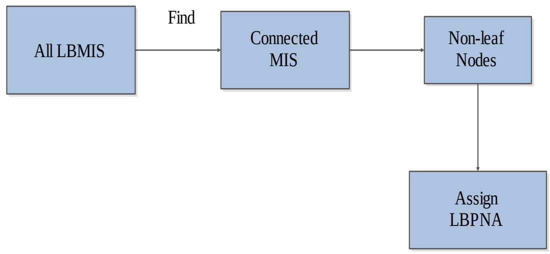


Fig.2.3 Connected Maximal Independent Set

D. Construct LBDAT

We already find a parent node assignment for non-leaf nodes. Hence, this module leaf-nodes formulate the LBPNA and using Integer Linear Programming (ILP).Then we, present a Randomized Approximation Algorithm technique. Finally we exploit to build LBDAT

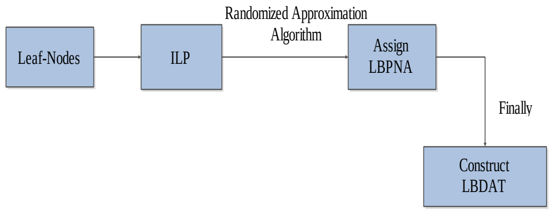


Fig.2.4 Construct Load-Balanced Data Aggregation Tree

E. 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, vi ЄD, its parent node is decided. Furthermore, for each vi Є D, the traffic load of vi introduced by its non-leaf child nodes is denoted by ψi. Considering that for viЄ 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].

III. Algorithm

Approximation Algorithm:

Due to the relaxation enlarged the optimization space, the solution of LPLBMIS corresponds to an upper bound to the objective of INP_{LBMIS}. Given an instance of LBMIS modeled by the integer nonlinear programming INP_{LBMIS}, we propose an approximation algorithm as shown in Algorithm 1 to search for an LBMIS.

The basic idea of Algorithm 1 is as follows: first, solve the relaxed linear programming LP_ LBMIS to get an optimal fractional solution. The Complexity of the first step (line 2 in Algorithm 1) since it is a sorting process. The time complexity of the random rounding procedure (line 7 to line 14 in Algorithm 1) Next, the correctness of our proposed approximation algorithm (Algorithm 1) is proven, followed by the performance ratio analysis. Before showing the correctness of Algorithm1, two important lemmas are given as follows.

Lemma 1: For a probabilistic WSN represented by G= (V, E, P (E)), if a subset S ≤V is a DS and meanwhile subset S is an MIS of G.

Lemma 2: The set M = {vi\ωi^ = 1, $0 \leq i \leq n$}, where ωi^ is derived from Algorithm 1, is a DS.
Approximation Algorithm to search for an LBMIS

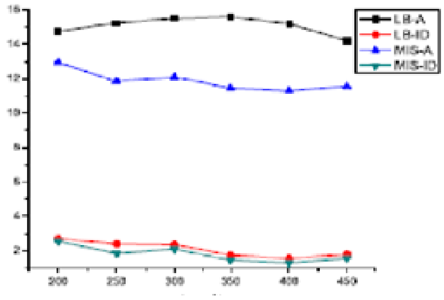
Step 1: Sort sensor nodes by the wi value
(where 1 <= I <=n) in the decreasing
order.
Step 2: Set the sink node to be the independent
Node, i.e., w0=1.
Step 3: Set all wi to be 0.
Node array A.
Step 4: Start from the first node in the sorted If
There is independent no node been
Selected as an node in vi's 1-hop
Neighborhood then let
wi=1
with
Probability p = wi.

Step 5: Repeat step 4) till reach the end of
array A.
Step 6: Repeat step 4) and 5) for v, wi >0
times.

Randomized Approximation Algorithm

Given an instance of LBPNA modeled by the integer linear programming ILPLBPNA, the sketch of the randomized approximation algorithm.

Hence, Algorithm 2 yields a solution upper bounded by$O(\log(n))\text{opt}_{LBPNA}$. Moreover, this bound can be verified in polynomial time. After A* is decided, a tree can be obtained by assigning each link a direction from the children to the parent.



IV. CONCLUSIONS AND FUTURE WORK

In this paper, The CMIS problem, which is NP-hard, is solved in two phases. In the first phase, find the optimal MIS such that the minimum potential load of all the independent nodes is maximized. In the second phase, the minimum-sized set of LBMIS connectors are found to make the LBMIS connected. After an LBPNA is decided, by assigning a direction to each link, we obtain an LBDAT.The simulation results show that the proposed algorithms can extend network lifetime significantly. Our 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 we 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 our proposed solution, we will conduct more simulations b changing the shapes of the monitoring area in the future.

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