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RESEARCH ARTICLE

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ENERGY CONSUMPTION FOR INDEPENDENT NODE AND DATA AGGREGATION WITH RELAY NODES IN WSN

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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). 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) and 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. In our present work is data aggregation with relay nodes and Energy consumption on Independent Node. Minimum Energy-Cost Aggregation Tree with Relay Nodes Technique used in this study, Independent node gets the data from all of its child nodes then transmits them to connecting node as single hop count. So we compared to previous our work is Minimum Energy-Cost Aggregation Tree with Relay Nodes (MECAT RN). Finally, our simulation results show that the proposed algorithms outperform the existing state-of-the-art approaches significantly

Key Words—Probabilistic wireless sensor networks, data aggregation tree, maximal independent set, linear programming, load-balance, integer programming, random rounding, minimum-sized connected dominating set, Minimum energy-cost aggregation tree with relay nodes.

1. INTRODUCTION

In many applications, sensors are required to send reports to a specific target (e.g. base station) periodically [1]. In habitat monitoring [2] and civil structure maintenance [3], it is a basic operation for the sink to periodically collect reports from sensors. Since the data gathering process usually proceeds for many rounds, it is necessary to reduce the number of the packets, which carries the reports, transmitted in each round for energy saving. In this paper, we undertake the development of data gathering in wireless sensor networks. Data aggregation is a well-known method for data gathering, which can be performed in various ways. In [1], a fixed number of reports received or generated by a sensor are aggregated into one packet. In other applications, a sensor can aggregate the reports received or generated into one report using a divisible function (e.g. SUM, MAX, MIN, AVERAGE, top-k, etc.) [4]. Data compression, which deals with the correlation between data such that the number of reports is reduced, is another method for data gathering [5], [6]. In many applications, the spatial or temporal correlation does not exist between data (e.g. status reports [1]), and data aggregation is a more suitable method for data gathering. The effectiveness of data aggregation is mainly determined by the routing structure. In many data aggregation algorithms, a tree is used as the routing structure [7], [12], especially for the applications that have to monitor events continuously. The reason is that sensors, which usually have limited resources, can save relatively high computational costs for maintaining routing tables if sensors route packets based on a tree. While several papers target at the maximization of the network lifetime [7], [8], the problem of minimizing the total energy cost is also well studied in the literature [13], [14]. Moreover, for some indoor applications, sensors may have AC power plugs. For example, the sensor of Octopus wireless sensor network, Minimizing energy Consumption and size are important research topics in order to make wireless sensor networks (WSN) deployable. As most WSN nodes are battery powered, their lifetime is highly dependent on their energy consumption Due to the low cost of an individual node, it is more cost effective to replace the entire node than to locate the node and replace or recharge its battery supply.

Our contributions are described below:

• We prove the problem of constructing a data aggregation tree with minimum energy cost, termed MECAT, is NP-complete and provide a 2-approximation algorithm.

• We study the variant of such a problem, in which the relay nodes exist, termed MECAT RN. We show the MECAT RN problem is NP-complete and demonstrate a 7-approximation algorithm.

• We show any _-approximation algorithm of the Capacitated Network Design (CND) problem [16] can be used to obtain a 2_-approximation algorithm of the MECAT RN problem.

II. NETWORK MODEL AND PROBLEM DEFINITION

We first illustrate the network model. Subsequently, our problem is described and shown to be NP-complete in Section.

A. The Network Model

We model a network as a connected graph G = (V,E) with weights s(v) ∈ Z^+ and 0 associated with each node v ∈ V \ {r} and r, respectively, where V is the set of nodes, E is the set of edges, and r ∈ V is the sink. Each node v has to send a report of size s (v) to sink r periodically in a multi-hop fashion based on a routing tree. A routing tree constructed for a network G = (V, E) with sink r is a directed tree T = (VT, ET) with root r, where VT = V and a directed edge (u, v) ∈ ET only if an undirected edge {u, v} ∈ E. A node u can send a packet to a node v only if (u, v) ∈ ET, in which case u is a child of v, and v is the parent of u. For the energy consumption, we only consider the energy cost of the radio. Let T x and Rx be the energy needed to send and receive a packet, respectively. While routing, a hop-by-hop aggregation is performed according to the aggregation ratio, q, which is the size of reports that can be aggregated into one packet. Because it would be meaningless if the aggregation ratio is set to a non-integer, the aggregation ratio is assumed to be an integer through this paper. It is noteworthy that we implicitly assume that the transmission energy and the receiving energy of a packet are constants. In [17], the authors observe that in a wireless sensor network with a small packet size, the startup energy cost, that is, the energy consumption in the state transition from sleep to idle, exceeds the transmission cost. Thus, we can view Tx(Rx) as the sum of the transmission cost (receiving cost) and the startup energy cost. Then, as long as the packet size is small, T x and Rx are approximately constants.

B. The Problem and Its Hardness

We first describe our problem in the following.

Problem 1: Given a network G = (V, E) with weights s (v) ∈ Z+ and 0 associated with each node v ∈ V \{r} and r, respectively, a sink r ∈ V, an aggregation ratio q ∈ Z+, energy costs T x ∈ R+ and Rx ∈ R+ for transmitting and receiving a packet, respectively, and C ∈ R+, the **M**inimum **E**nergy-**C**ost **A**ggregation **T**ree (**MECAT**) problem asks for a routing tree T = (VT, ET) with root r and VT = V, such that the total transmission and reception energy consumed by all sensors is not greater than C. In addition, MECAT (G, r, q, T x, Rx, C) denotes an instance of the MECAT problem, and COST (T) denotes the energy cost of a routing tree T. Next, we prove that the MECAT problem is NP-complete by showing a polynomial-time reduction from the Load-Balanced Semi-Matching problem, an NP complete problem, as described below.

Definition 1: A **semi-matching** in a bipartite graph G = (U ∪ V, E) is an edge set M ⊆ E, such that every node in U incident to exactly one edge in M. Given a semi-matching M and v ∈ V, Adj M (v) denotes the set of nodes u with {v, u} ∈ M.

Problem 2: Given a bipartite graph G = (U ∪ V, E) with a weight w(u) ∈ Z^+ associated with each node u ∈ U and k ∈ Z+, the **L**oad-**B**alanced **S**emi-**M**atching (**LBSM**) problem asks for a semi-matching M such that $k \geq \max_{v\in V} \sum_{Vpu\in AdiM(v)} w(u)$.

Furthermore, LBSM (G, k) denotes an instance of the LBSM problem.

Theorem 1: *The MECAT problem is NP-complete.*

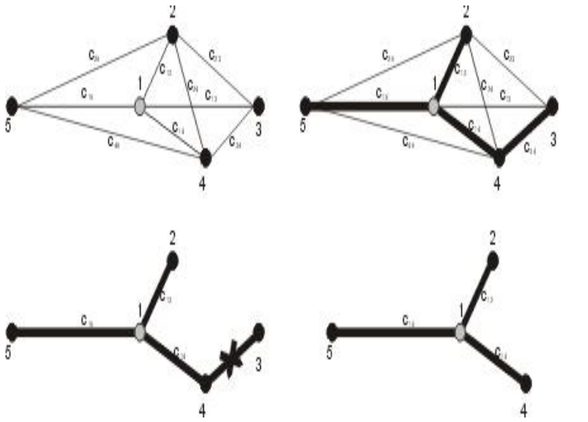
The high-level idea of the proof is to show that finding an aggregation tree such that every node sends only one packet, which is a special case of the MECAT problem, is NP-complete.

Proof: First, the MECAT problem is clearly in NP, since we can verify in polynomial time if a candidate solution is a tree and satisfies the energy cost constraint. Next, we prove that the MECAT problem is NP-hard by showing a polynomial-time reduction from the LBSM problem to the MECAT problem.

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. We conduct several simulations to evaluate the performances of the proposed algorithms. We apply shortest path algorithm to find optimal spanning tree rooted at the given node



The nodes that immediately follow the root node constitute the minimum neighborhood of the root node. The minimum cost routes are contained in the minimum neighborhood Each node considers just its min. neighborhood.

COST (TSPT) < 2 · COST (TOPT).

IV. DATA AGGREGATION WITH RELAY NODES

To improve the network connectivity or survivability, the relay node placement problem in a wireless sensor network has been extensively investigated. These relay nodes, which do not produce reports, are used to forward the packets received from other nodes. In this section, we study the problem of constructing a data aggregation tree with minimum energy cost in the presence of relay nodes.

A. The Problem and Its Hardness

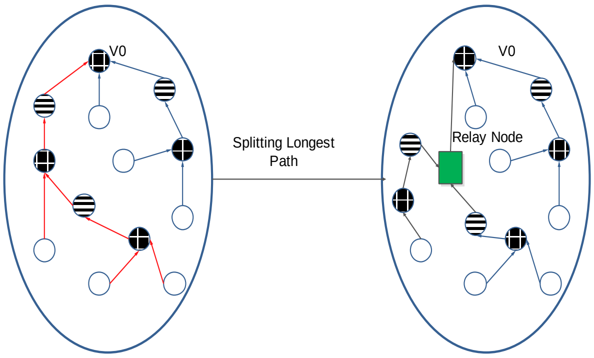
Here, a routing tree only needs to span all non-relay nodes. For the convenience of description, we assume every relay node has a zero-sized report. In the following, the problem is described and shown to be NP-complete.

Theorem 3: *The MECAT RN problem is NP-complete even if* q < |U| *and some relay nodes have degree more than two in the original graph*.

Modules:

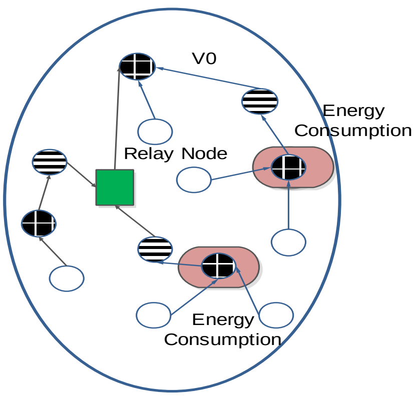
Data Aggregation with Relay Nodes

To improve the network connectivity or survivability, the relay node placement problem in a wireless sensor network has been extensively investigated in the literature. These relay nodes, which do not produce reports, are used to forward the packets received from other nodes. In this section, we study the problem of constructing a data aggregation tree, with minimum energy cost in the presence of relay nodes. Observe that while sending a packet to the sink, the longer the tree path is, the greater the energy cost .So we split the tree and set the relay node. The each group of information collects the relay node send the sink node. So the energy cost is reducing.



Energy consumption on Independent Node:

Generally independent node has heavy load when it contains more than one child node. So it needs more energy to balance the load. Hence in this study, proposed techniques to reduce the energy used by the independent node. Technique used in this study: Independent node gets the data from all of its child nodes then transmits them to connecting node as single hop count.



B. Approximation Algorithm

A Steiner tree algorithm and a shortest path tree algorithm provide solutions with minimum number of edges and minimum average hop distance from sources to the sink for the MECAT RN problem, respectively. However, both of them have bad approximation ratios, as described in Theorems 4 and 5. Their proofs are given in the appendix.

Theorem 4: *The approximation ratio of a Steiner tree algorithm is at least _* (|U|).

Theorem 5: *The approximation ratio of a shortest path tree algorithm is at least _* (|U|).

Algorithm 1: Salman's Algorithm for the CND Problem

Input: G, U, r, C

Step 1: Construct a complete graph G′ with node set U ∪ {r}.

Step 2: Set the weight of each edge (u, v) in G′ to the length of the shortest path from u to v in G.

Step 3: Compute a (3, 2)-LAST TL in G′.

Step 4: Let (u, u1, UN, r) be the shortest path from u to r in TL. Then, the concatenation of paths Pu, u1, Pu1, u2. , and Pun, r is the output path from u to r, where Px, y denotes the shortest path from x to y in G.

Step 5: Return the output path from u to r for each u ∈ U.

Algorithm 2: Our Algorithm for the MECAT RN Problem

Input: G, U, r, T x, Rx, C

Step 1: Construct a complete graph G′ with node set U ∪ {r}.

Step 2: Set the weight of each edge (u, v) in G′ to the hop distance from u to v in G.

Step 3: Compute a (3,2)-LAST TL in G′.

Step 4: Compute G″ = (V″, E″),

where V″ = {w|w ∈ Pu, v for some (u, v) ∈ TL}, E″ = {{x, y}|{x, y} ∈ Pu, v for some (u, v) ∈ TL}, and Pu, v is the shortest path from u to v in G.

Step 5: Construct a shortest path tree TSPT rooted at r and spanning U in G″.

Step 6: Return TSPT.

Algorithm 3: CND-Based Algorithm for the MECAT RN Problem

Input: G, U, r, q, T x, Rx, C, A

Step 1: Obtain a graph G′ from G by setting the weight of each edge in G to T x + Rx.

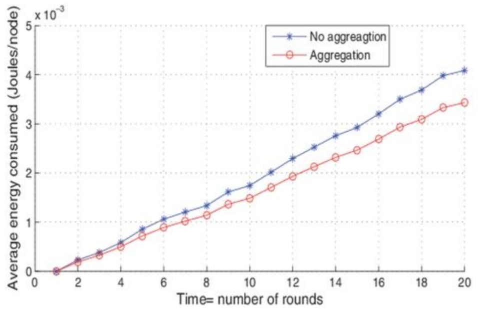
Step 2: Execute A with inputs G′, U, r, q, and C to obtain Pu, r, the path from u to r in G′, for each u ∈ U.

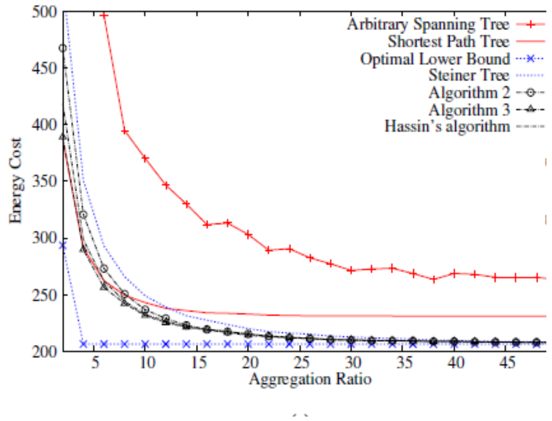
Step 3: Compute G″ = (V″, E″), where V″ = {w|w ∈ Pu, r} and E″ = {{x, y}|{x, y} ∈ Pu, r}.

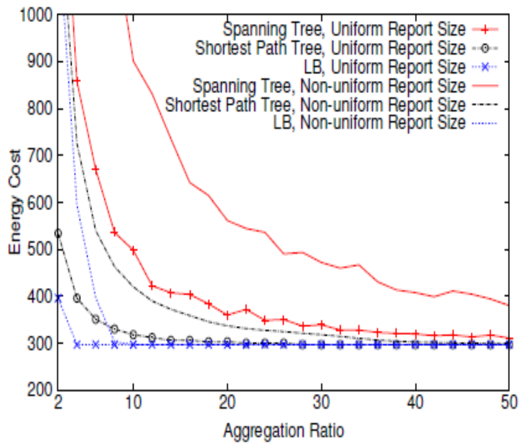
Step 4: Construct a shortest path tree TSPT rooted at r and spanning U in G″.

Step 5: Return TSPT.

Simulation result:







V CONCLUSIONS AND FUTURE WORK:

We address the fundamental problems of constructing a load-balanced DAT in probabilistic WSNs. We first solve the CMIS problem, which is NP-hard, in two phases. In the first phase, we aim to find 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. In the second phase, 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. Subsequently, we study the LBDAT construction problem and propose an approximation algorithm by using the linear relaxing and random rounding techniques. 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 but not consider the energy cost significantly. So we are improving the performance for using Minimum Energy-Cost Aggregation Tree with Relay Nodes (MECAT RN).

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