

A Data Aggregation Method for Balancing Load under Probabilistic Network Model (PNM)

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Abstract— Data aggregation is a very crucial technique in WSNs. Data aggregation helps in reducing the energy consumption by eliminating redundancy. 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). 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. Under this model, any specific pair of nodes are neighbors if their physical distance is less than the transmission range, while the rest of the pairs are always disconnected. However, in most real applications, the DNM cannot fully characterize the behaviors of wireless links due to the existence of the transitional region phenomenon. The load-balance factor is also neglected when constructing DATs in current systems. And most of the current literatures investigate the DAT construction problem under the DNM. In this paper we are discussing on load balancing factor and also on construction of DAT using Probabilistic Network Model (PNM). 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— Data aggregation, WSN, Network load balancing, Data Aggregation Trees (DATs), Load-Balanced Data Aggregation Tree (LBDAT), Deterministic Network Model (DNM), Probabilistic Network Model (PNM)

INTRODUCTION

Wireless sensor networks (WSNs) consist of sensor nodes. These networks have huge application in habitat monitoring, disaster management, security and military, etc. Wireless sensor nodes are very small in size and have limited processing capability and very low battery power. This restriction of low battery power makes the sensor network prone to failure. Data aggregation is a very crucial technique in WSNs. Data aggregation helps in reducing the energy consumption by eliminating redundancy. 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).

Data aggregation is the process of collecting and aggregating the useful data. Data aggregation is considered as one of the fundamental processing procedures for saving the energy. In WSN, data aggregation is an effective way to save the limited resources. The main goal of data aggregation algorithm is to gather and aggregate data in an energy efficient manner so that network lifetime is enhanced. Wireless sensor networks have limited computational power, limited memory and battery power, hence increased complexity for application developers which results in applications that are closely coupled with network protocols. In Wireless Sensor Networks (WSNs), sensor nodes periodically sense the monitored environment and send the information to the sink (or base station), 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.

Many practical applications like environmental monitoring, military applications, scientific research etc., are exploring the use of WSNs. Such applications require transferring a huge amount of relevance, sensed data from one point of the network to another. Since WSNs are mostly equipped with low power batteries, battery life is a major constraint in any real-time application. This necessitates the use of energy efficient data dissemination protocols for aggregation of the sensed data. Nodes of a WSN in close proximity usually hold similar data due to a property called spatial correlation. A data aggregation scheme is energy efficient if it maximizes the functionality of the network. If we assume that all sensors are equally important, we should minimize the energy consumption of each sensor.

For clarification [1], data gathering trees capable of performing aggregation operations are also referred to as Data Aggregation Trees (DATs), which are directed trees rooted at the sink and have a unique directed path from each node to the sink. Additionally, in a DAT, sensing data from different sensors are combined at intermediate sensors according to certain aggregation functions including COUNT, MIN, MAX, SUM, and AVERAGE. Due to the dense sensor deployment, many different DATs can be constructed to relay data from the monitored area to the sink. According to the diverse requirements of different applications, the DAT related works can be roughly classified into three categories: Energy-Efficient Aggregation Scheduling [3], [4], [5], Minimum-Latency Aggregation Scheduling [6], [7],[8], and Maximum-Lifetime Aggregation Scheduling[9],[10], [11], [12]. It is worth mentioning that aggregation scheduling attracts a lot of interests in the current literatures. However, unlike most of the existing works which spend lots of efforts on aggregation scheduling, we mainly focus on the DAT construction problem.

Key Points in data aggregation are as follows:

- i. Nodes sense attributes over the entire network and route to nearby nodes.
- ii. Node can receive different versions of same message from several neighboring nodes.
- iii. Communication is usually performed in the aggregate.
- iv. Neighboring nodes report similar data.
- v. Combine data coming from different sources and routes to remove redundancy.

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. Under this model, any specific pair of nodes are neighbors if their physical distance is less than the transmission range, while the rest of the pairs are always disconnected. However, in most real applications, the DNM cannot fully characterize the behaviors of wireless links due to the existence of the transitional region phenomenon. The load-balance factor is also neglected when constructing DATs in current systems. And most of the current literatures investigate the DAT construction problem under the DNM.

In this paper we are discussing on load balancing factor and also on construction of DAT using Probabilistic Network Model (PNM). 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.

The main contributions of this paper are summarized as follows:

- i. Analysis of Data aggregation technique
- ii. Constructing a Load-Balanced Data Aggregation Tree (LBDAT) under the PNM
- iii. Investigation of three problems namely, the Load-Balanced Maximal Independent Set (LBMIS) problem, the Connected Maximal Independent Set (CMIS) problem, and the LBDAT construction problem
- iv. Simulation using NS-2.34 under Fedora Linux environment

METHODOLOGY

A. Data Aggregation overview

Data aggregation is the process of collecting and aggregating the useful data. Data aggregation is considered as one of the fundamental processing procedures for saving the energy. A data aggregation scheme is energy efficient if it maximizes the functionality of the network. If we assume that all sensors are equally important, we should minimize the energy consumption of each sensor. As soon as a query is sent by the BS to a sensor, the first step followed is to handle the query. This is followed by data collection from sources and aggregation of that data.

Network Data aggregation is of two types:

- a. Address-centric (AC) and
- b. Data-centric (DC)

a) Address-centric (AC)

In AC routing protocol [2], query is routed to a specific address or a given sensor based on the address specified in the query. Each source independently Address Centric Routing sends data along the shortest path to sink ("end to-end routing"). Data is then sent from this specific location to the BS(Base Station). The source with the address specified in the query, sends its data directly to the BS.

b) Data-centric (DC)

However, in DC routing [2], based on the condition specified in the query, all sensors satisfying that condition, need to respond and therefore, the query is broadcast to all the nodes (within range) in the network.

B.Proposed Method

We solve the LBDAT construction problem in three phases in this paper. First, we construct a Load-Balanced Maximal Independent Set (LBMIS), and then we select additional nodes to connect the nodes in LBMIS, denoted by the Connected MIS (CMIS) problem. Finally, we acquire a Load-Balanced Parent Node Assignment (LBPNA). After LBPNA is determined, by assigning a direction to each link in the constructed tree structure, we obtain an LBDAT. In this subsection, we formally define the LBMIS, CMIS, LBPNA, and LBDAT construction problems sequentially. The proposed method can be implemented using following flow(Fig.1).The simulation parameters are shown in table 1.And data aggregation for different network based schemes[1] are shown on Fig.2.

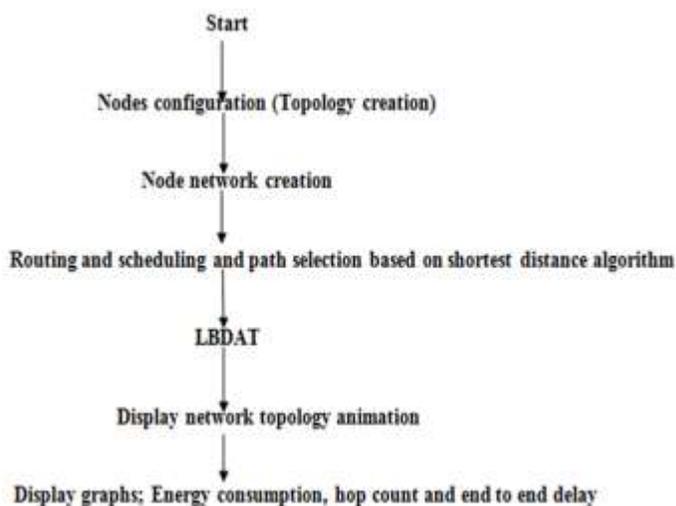


Fig.1.Proposed Flow

TABLE1
Simulation Parameters

Parameter/Specification	Details
No. of Nodes	50
Topology (Area)	500x500
NS2 version	NS2.34
Simulation Time	100 sec
Maximum Packet sent per second	1000
Energy threshold	0.3dbm

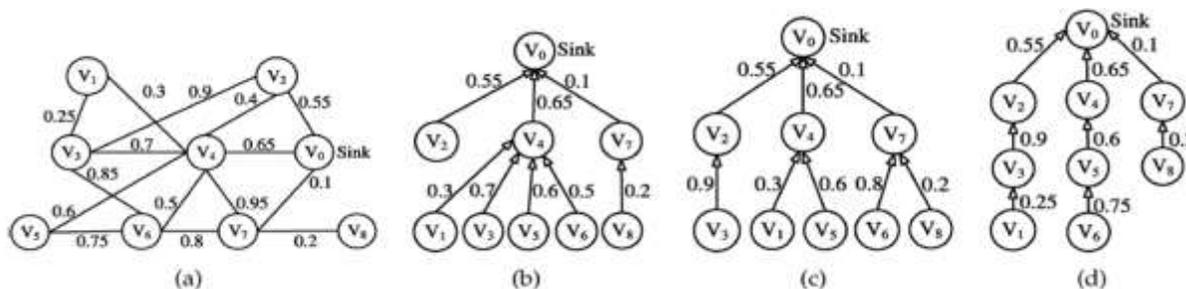


Fig.2.Data aggregation: Probabilistic WSN(a), DATs(b and c), and an LBDAT(d)

In this paper, 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.

SIMULATION RESULTS

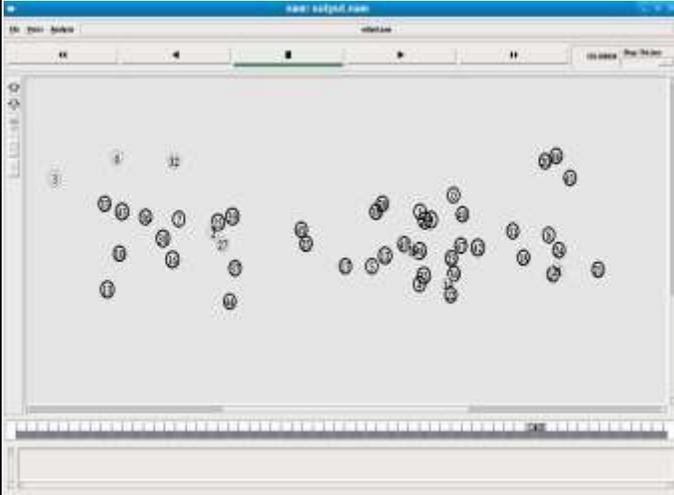


Fig.3.NS2 animation scenario

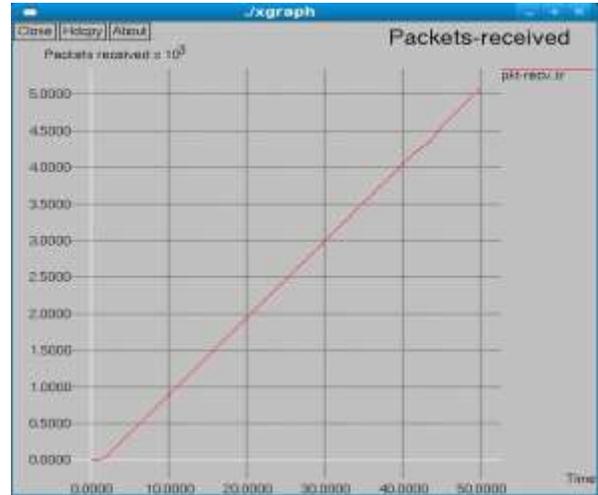


Fig.4.Packet received graph



Fig.5.PDR graph

TABLE 2
 PDR Values

SNO	NODES	PDR	PACKET SENT	PACKET RECEIVED
1)	10	0.8091	4725	3823
2)	20	0.9011	4725	3928
3)	30	0.7885	4725	4258
4)	40	0.6048	4725	3726
5)	50	0.6048	4725	2858

CONCLUSION

We are studying the WSN and data aggregation in WSN. In this paper we concentrated on load balancing factor and also on construction of DAT using Probabilistic Network Model (PNM). 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 (LB MIS) problem, the Connected Maximal Independent Set (CMIS) problem, and the LBDAT construction problem. LB MIS and CMIS are well-known NP-hard problems and LBDAT is an NP-complete problem. LBDAT will be NP-Complete and will be constructed in three steps: Load-Balanced Maximal Independent Set (MDMIS), Connected Maximal Independent Set (CMIS) and Load-Balanced Parent Node Allocation (LBPNA). Approximation algorithms and performance ratio analysis will also be covered.

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