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AN INTEGRATED DATA COLLECTION AND BANDWIDTH SCHEDULING FRAMEWORK FOR WSN

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Abstract

Mobile Data Gathering (MDG) schemes are used to collect sensor node data values in WSN. Mobile data collection framework is divided into three-layers such as sensor layer, cluster head layer and mobile collector (SenCar) layer. Mobile data collection is carried out using distributed load balanced clustering and dual data uploading (LBC-DDU) method. Distributed load balanced clustering (LBC) algorithm is used to construct clusters with sensor nodes. Dual data uploading is performed with the support of multiple cluster heads. Connectivity ranges are used to manage the inter connectivity between the clusters. Cluster head information is forwarded to SenCar for its moving trajectory planning. SenCar is equipped with two antennas two enable the cluster heads simultaneously upload data to SenCar . The data upload process utilizes multi-user multiple-input and multiple-output (MU-MIMO) technique. Polling points are selected for each cluster to utilize dual data uploading benefits. The SenCar collects the data by visiting the polling points in the trajectory and transfer the data to the static data sink. The system is constructed with initialization, status claim, and cluster formation, receives packets and cluster heads algorithms. Cluster head pair selection is improved with node property values. Discretization method is integrated with the system to select optimal polling point for the clusters. The Distributed Load Balanced Clustering with Dual Data Upload (LBC-DDU) scheme is enhanced to manage the overall spatial coverage. The MIMO scheduling is enhanced to support multiple cluster based transmissions.

1. Introduction

Sensor networks are usually deployed in areas that are dangerous or even unreachable to humans, such as volcanos, outer space, the seabed and so on. In such environments, human beings may not move close to the sensing field. A mobile observer, or SenCar, will be sent out to gather data from sensors periodically. Since the network may contain a large number of nodes, each tour may take a long time. In order to save energy, sensors may turn on their transceivers only when they need to send or relay packets. Except for the transmission period, the transceivers of sensors could be turned off.

The entire sensor network can be divided into several clusters, where sensors in each cluster must be connected to SenCar while it is moving through the cluster. When SenCar moves close to the cluster, all sensors belonging to the cluster will be woken up and will prepare to send packets. Sensed data can be collected by SenCar while it is traversing the cluster. To make this scheme work, two issues must be resolved here. The first issue is how

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the user can wake up and turn off sensors only when needed. A radio wakeup scheme allows the transceivers of sensors to be deactivated when they are idle.

2. Related Work

The energy-efficient data gathering problem in sensor networks has been extensively investigated using the traditional communication scheme (SISO). For many monitoring applications with a periodic reporting pattern, a tree-based topology was adopted due to its simplicity and energy efficiency, which were two important factors to consider in resource-constrained networks. In fact, a number of studies had investigated tree construction for data gathering under the traditional communication scheme [4]. In general, the traditional methods usually performed short-range transmission instead of long-range transmission to reduce the energy cost of data gathering in wireless sensor networks.

Virtual MIMO transmission has become a promising technology for next-generation wireless networks. This technology has been applied to save the energy consumption of multi-hop routings [9], [6]. Moreover, data gathering using vMIMO has also been studied. The vMIMO transmission on a cluster structure. As LEACH was an efficient cluster construction protocol, Yuan et al. proposed a vMIMO scheme for LEACH clusters, namely MIMO-LEACH, which is hereafter referred to as LMIMO for short. An approach that combined vMIMO and data gathering with fusion was presented analyzed the effect of long-haul distance on the energy efficiency of wireless transmissions.

The work [3] constructed a topology for data gathering with fusion based on the SISO and MISO modes. Another work [10] adopted vMIMO to improve energy-efficiency of data gathering with fusion in a cluster-based wireless sensor network. Generally speaking, the above works largely ignored the impact of topology structures on the energy consumption of vMIMO-based data gathering, and did not consider the joint optimization of topology construction and vMIMO communications. None of the previous works guarantees the approximate performance for the vMDG problem. To the best of our knowledge, our work presented in this paper is the first such work that jointly optimizes vMIMO and data gathering by 1) taking the unique vMIMO features into consideration when constructing an appropriate topology and 2) fully explore different vMIMO communication modes. As a result, it can guarantee (in terms of having an O(1) approximation ratio) a high energy-efficiency in wireless sensor networks.

3. Mobile Data Gathering in WSN

The proliferation of the implementation for low-cost, low-power, multifunctional sensors has made wireless sensor networks (WSNs) a prominent data collection paradigm for extracting local measures of interests. In such applications, sensors are generally densely deployed and randomly scattered over a sensing field and left unattended after being deployed, which make it difficult to recharge or replace their batteries. After sensors form into autonomous organizations, those sensors near the data sink typically deplete their batteries much faster than others due to more relaying traffic. When sensors around the data sink deplete their energy, network connectivity and coverage may not be guaranteed. Due to these constraints, it is crucial to design an energy-efficient data collection scheme that consumes energy uniformly across the sensing field to achieve long network lifetime. Furthermore, as sensing data in some applications are time-sensitive, data collection may be required to be performed within a specified time frame. Therefore, an efficient, large-scale data collection scheme should aim at good scalability, long network lifetime and low data latency.

Several approaches have been proposed for efficient data collection in the literature, see, for example, [5], [2]. Based on the focus of these works, we can roughly divide them into three categories. The first category is the enhanced relay routing [7], [8], in which data are relayed among sensors. Besides relaying, some other factors, such as load balance, schedule pattern and data redundancy, are also considered. The second category organizes sensors into clusters and allows cluster heads to take the responsibility for forwarding data to the data sink [12]. Clustering is particularly useful for applications with scalability requirement and is very effective in local data aggregation since it can reduce the collisions and balance load among sensors. The third category is to make use of mobile collectors to take the burden of data routing from sensors (as shown in Fig. 1b) [11].

Although these works provide effective solutions to data collection in WSNs, their inefficiencies have been noticed. In relay routing schemes, minimizing energy consumption on the forwarding path does not necessarily prolong network lifetime, since some critical sensors on the path may run out of energy faster than others. In cluster-based schemes, cluster heads will inevitably consume much more energy than other sensors due to handling intra-cluster aggregation and inter-cluster data forwarding. Though using mobile collectors may alleviate non-uniform energy consumption, it may result in unsatisfactory data collection latency. Based on these observations, in this paper, we propose a three-layer mobile data collection framework, named Load Balanced Clustering and Dual Data Uploading (LBC-DDU). The main motivation is to utilize distributed clustering for scalability, to employ mobility for energy saving and uniform energy consumption and to exploit Multi-User Multiple-Input and Multiple-Output (MU-MIMO) technique for concurrent data uploading to shorten latency.

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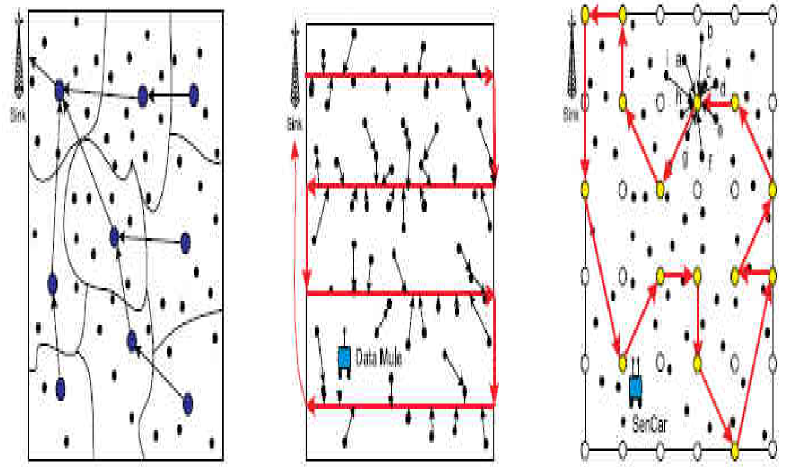

(a) Sensor clustering: achieving scalability and facilitating in-network aggregation and processing.

(b) Data Mule: taking over the routing burden from sensors to reduce the energy cost at sensor side.

(c) SenCar: optimizing on data collection tour for mobile collectors and minimizing relays at the sensors.

Fig.1. Some Examples of Efficient Data Collection Mechanisms in Wireless Sensor Networks

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The main contributions of this work can be summarized as follows. First, we propose a distributed algorithm to organize sensors into clusters, where each cluster has multiple cluster heads. In contrast to clustering techniques proposed in previous works, our algorithm balances the load of intra-cluster aggregation and enables dual data uploading between multiple cluster heads and the mobile collector. Second, multiple cluster heads within a cluster can collaborate with each other to perform energy efficient inter-cluster transmissions. Different from other hierarchical schemes in our algorithm, cluster heads do not relay data packets from other clusters, which effectively alleviate the burden of each cluster head. Instead, forwarding paths among clusters are only used to route small-sized identification (ID) information of cluster heads to the mobile collector for optimizing the data collection tour. Third, we deploy a mobile collector with two antennas to allow concurrent uploading from two cluster heads by using MU-MIMO communication. The SenCar collects data from the cluster heads by visiting each cluster. It chooses the stop locations inside each cluster and determines the sequence to visit them, such that data collection can be done in minimum time. Our work mainly distinguishes from other mobile collection schemes [1] in the utilization of MUMIMO technique, which enables dual data uploading to shorten data transmission latency. We coordinate the mobility of SenCar to fully enjoy the benefits of dual data uploading, which ultimately leads to a data collection tour with both short moving trajectory and short data uploading time.

4. Problem Statement

Mobile Data Gathering (MDG) schemes are used to collect sensor node data values in WSN. Mobile data collection framework is divided into three-layers such as sensor layer, cluster head layer and mobile collector (SenCar) layer. Mobile data collection is carried out using distributed load balanced clustering and dual data uploading (LBC-DDU) method. Distributed load balanced clustering (LBC) algorithm is used to construct clusters with sensor nodes. Dual data uploading is performed with the support of multiple cluster heads. Connectivity ranges are used to manage the inter connectivity between the clusters. Cluster head information is forwarded to SenCar for its moving trajectory planning. SenCar is equipped with two antennas two enable the cluster heads simultaneously upload data to SenCar . The data upload process utilizes multi-user multiple-input and multiple-output (MU-MIMO) technique. Polling points are selected for each cluster to utilize dual data uploading benefits. The SenCar collects the data by visiting the polling points in the trajectory and transfer the data to the static data sink. The system is constructed with initialization, status claim and cluster formation, receives packets and cluster heads algorithms. The drawbacks are identified from the existing system.

- Polling point selection and cluster head pairing operations are not integrated
- Polling point selection is not optimized
- Spatial coverage properties are not considered
- Multiple cluster based MIMO scheduling is not provided

5. Integrated Data Collection and Bandwidth Scheduling Framework

Cluster head pair selection is improved with node property values. Discretization method is integrated with the system to select optimal polling point for the clusters. The Distributed Load Balanced Clustering with Dual Data Upload (LBC-DDU) scheme is enhanced to manage the overall spatial coverage. The MIMO scheduling is enhanced to support multiple cluster based transmissions. Mobile collector (SenCar) based data collection scheme is constructed to perform data gathering operations in WSN. Network coverage analysis is adapted to identify the missing data collection regions. The data transfer process is improved with cluster based channel allocation mechanism. The system is partitioned into four modules. They are Sensor Layer, Clustering Process, Polling Point Selection and Band width Scheduling.

5.1. Sensor Layer

The wireless sensor nodes are installed to capture the data from environment. Sensor node deployment operations are carried out under the sensor layers. Node properties are collected and updated under sensor layers. The initialization phase is applied to collect the residual energy and coverage details of the neighbor nodes.

5.2. Clustering Process

The clustering process is designed to group the nodes with the resource details. Residual energy, sensing coverage and transmission coverage factors are considered in the clustering process. Status claim algorithm is used to update the node status as member or cluster head. Distributed Load Balancing Cluster (LBC) algorithm is adapted for the cluster formation.

5.3. Polling Point Selection

Cluster head pairs are analyzed for polling point selection process. Polling point identification is improved with Discretization method. Polling points are assigned to the clusters using Optimal polling point selection algorithm. Cluster head coverage is used in the polling point selection process.

5.4. Band width Scheduling

Channel assignment process is carried out to schedule the Dual Data Upload (DDU) process. Multi User Multi Input and Multi Output (MU-MIMO) technique is adapted for the data uploading process. The MU-MIMO scheme is enhanced to manage multi cluster environment. The Virtual Multi Input Multi Output (V-MIMO) scheme is applied to schedule the bandwidth for data upload process.

6. Conclusion

Sensor data gathering is performed using mobile collectors. The Distributed Load Balanced Clustering with Dual Data Upload (LBC-DDU) scheme is employed for the data collection process. LBC-DDU scheme is enhanced with optimal polling point selection and spatial coverage management features. The Multiple Input and Multiple Output (MIMO) scheduling is improved to support multiple cluster model. Wireless sensor network data collection process is handled with energy and network lifetime management factors. Traffic level and mobile collector movement are controlled with Optimal polling point selection mechanism. Spatial coverage analysis is carried out to verify the network coverage achievement. The system reduces the computational and communication load in the data collection process.

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