SAJET

South Asian Journal of Engineering and Technology Vol.2, No.15 (2016) 192–199

ISSN No: 2454-9614

Multiple Cluster MIMO Scheduling and Spatial Coverage Optimization for Data Distribution over WSN

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Received: 20/11/2015, Revised: 22/12/2015 and Accepted: 10/03/2016

Abstract

Data distribution schemes are constructed to transfer the sensed data values to the queried nodes. Delay and network lifetime factors are focused in the data distribution schemes. Energy levels are adapted to estimate the network lifetime values. Cluster based scheme, routing scheme and mobile objects based schemes are adapted in the data collection process. Routing schemes are applied to identify the data transfer path. Data transmission under cluster scheme is carried out through the cluster head nodes. Mobile objects are employed to handle the data distribution operations. Sensor data distribution tasks are handled using data distribution methods. Sensor layer, cluster head layer and mobile collector (SenCar) layer are used for the data distribution process. Distributed load balanced clustering and dual data uploading (LBC-DDU) method is applied for the data distribution process. Cluster construction tasks are carried out using Distributed load balanced clustering algorithm. Simultaneous data distribution is managed with Dual Data Uploading (DDU) scheme .The clustering scheme is reconstructed with pair selection and feasible polling point selection methods. Spatial coverage schemes are adapted to monitor the data capture area. Virtual MIMO scheme is adapted to support multi cluster transmission operations.

Keywords: Data Collection, Mobile Data Gathering, Wireless Sensor Network, Mobility Control, Energy Efficiency.
Reviewed by* **ICETSET'16 *organizing committee*

1. Introduction

Wireless sensor networks (WSNs) recently have been deployed and used for a large variety of critical applications, such as environmental monitoring, field estimation, field reconstruction and precision agriculture. In many applications, more than one physical attribute of a sensor field need to be sensed simultaneously. WSN deployed in a greenhouse for precision agriculture, where the soil temperature, moisture and fertility need to be measured for farmers to control the growth of crops with greater precision. These applications normally have strict coverage requirements for the deployed WSNs.

Coverage, which reflects how well a sensor field is monitored, is a critical factor for the success of a WSN. The coverage problems are highly dependent on the coverage model of individual sensor. The sensor coverage model is used to reflect sensors' sensing capability and capacity and is subject to a wide range of interpretations due to a large variety of sensors and applications. Most of the current studies on the coverage problem are based on the disk model, which defines a disk centred at the sensor with the radius of its sensing range. The disk model is too simple and idealistic to be applied in many real-world applications. Based on a simple single-value parameter, some new sensor coverage models have been proposed according to some signal processing technologies for WSNs. They are not enough in some applications that need to reconstruct field physical characteristics, such as the temperature and moisture in precision agriculture.

Motivated from the precision agriculture applications and based on the ordinary kriging a coverage model is proposed, in our previous study from the perspective of field reconstruction. Field reconstruction is to estimate some spatially distributed physical attributes with a given reconstruction quality for the whole sensor field. Network lifetime is another fundamental criterion for evaluating a WSN, which defines how long the deployed WSN can function well to its designed service requirements. Since the nodes are powered by non-rechargeable batteries and in many cases, sensor nodes are scattered in a hazardous environment, which is unpractical to recharge or replace their battery, how to improve the energy efficiency and prolong the network lifetime is a significant issue in WSNs. As in many previous studies, the lifetime of a WSN in this paper is defined as the time span from the network deployment to the time when the network coverage requirement cannot be satisfied.

2. Related Work

Existing literature in the realm of TDMA based interference aware link scheduling can be classified with respect to their objective functions. In some works like **[7],** the objective is to increase throughput and minimize delay without any consideration for the energy consumption, while studies in **[9], [10]** aim at minimizing the energy consumption by minimizing the energy wasted during sleep-wake up transitions **[3].**

With stronger processors, more memory on board and availability of higher bandwidth, sensor nodes are more equipped and are widely deployed to perform extensive computation tasks. Thus task scheduling should be given explicit consideration. But the solution approach of all the studies mentioned above do not take into account the computation task scheduling performed by each node.

Prior work on joint scheduling of computation and communication subsystems is presented in **[2].** The objective is maximizing the number of clients that can be scheduled with limited processor capacity and link capacity. In **[2]** the interference issues are not taken into account. An energy aware computation communication scheduling is studied where DVS is used for computation energy reduction. They consider a very simplistic model of one-hop network, ruling out parallel transmission and interference. They only leverage the energy-delay trade-off for computation tasks using DVS, as opposed to our scheme which uses a combination of DVS and DMS. Their approach to reduce energy consumption by slack reclamation using DVS equally scales down the CPU speed of all the sensors. This approach will yield poorer results when applied to a system where both DVS and DMS are available.

This is because any two processors will yield the same energy savings when scaled down equally that is from a frequency level f1 to f2. But two messages might differ in their energy savings when scaled down from same modulation levels m1 to m2 owing to different distances that these messages need to be transmitted over. So a combination of DVS and DMS needs an iterative scheme to yield better energy savings.

Additionally, the precedence and interference conflicts present among the scheduled entities prevent the optimal allocation of resources in order to reduce energy consumption. The main contributions of this paper are:

1. We formulate the Interference-aware Energy-aware Joint Scheduling (IEJS) problem. Constructing an energy-aware schedule which minimizes energy consumption, considering the convex nature of the energy-time trade-off curve and the various conflicts present is an NP-hard problem. It can be shown that the Multiple Choice Knapsack Problem (MCKP) can be polynomials reduced to the energy-aware scheduling problem.

2. We take the nature of the energy-delay curve into consideration before allocating slack to messages. Incremental slack allocation is not always energy efficient for messages. Further, when tasks and messages are jointly considered, there are two types of entities contending for the available slack. These two entities differ in the way they interfere with objects of their same type. Two message transmissions can interfere with each other due to spatial proximity of the involved transmitters and receivers. But that is not the case with tasks. Any two tasks can be simultaneously scheduled as long as there is no precedence relation between the two.

3. We present a mixed integer linear programming (MILP) formulation of our problem. The optimal solution of the problem can be obtained by using a commercial software package such as **[6],** though it is computationally very expensive. We develop a polynomial time algorithm for joint scheduling of tasks and messages in a variable TDMA setting. Our method takes into consideration the interference and precedence constraints and the varying nature of tasks and messages.

3. Data Collection under Mobile Sensors

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.

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.

4. Virtual MIMO Technique

The research discovers some issues on data gathering using the vMIMO technology, there are three main limitations we aim to overcome. First, the work in **[8]** used the vMIMO transmission on a fixed topology. It would be more beneficial if, in conjunction with the use of vMIMO, one constructs a suitable topology and designs energy-efficient routing protocol for data gathering. Second, the works in **[5],** did not fully explore the advantages ofvMIMOsince only the SISO and MISO communication modeswere employed. Finally, none of the works obtained any approximate performance guarantee for the data gathering problem in sensor networks.

An energy-efficient data gathering method is applied using vMIMO for wireless sensor networks. We first define the joint vMIMO and data gathering (vMDG) problem and formally prove that this problem is NP-Hard. As the problem is difficult to solve optimally due to its high computational complexity, we propose a distributed and heuristic algorithm called D-vMDG, which consists of two steps **[1].**

The first step selects a set of cooperative node pairs and constructs a tree-like topology by taking the unique features of vMIMO into consideration. Then, an energy-efficient routing protocol based on dynamic programming is proposed for the constructed topology. Our theoretical analysis shows that the proposed algorithm can achieve a constant approximation guarantee for the vMDG problem with respect to the optimal performance **[7].** Our simulation results illustrate that the proposed D-vMDG algorithm decreases the energy consumptions by about 81 and 36 percent compared with the well-known MDT and MIMO-LEACH algorithms respectively.

5. Scheduling and Spatial Coverage Optimization for Data Distribution over WSN

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.

Sensor node deployment operations are carried out under sensor layer module. Clustering process is designed to group the sensor nodes with resource details. Polling point selection module is designed to assign data collection points. Mobile collector movements are planned using scheduling process. MIMO scheduling operations are carried out under Channel assignment process. Network coverage is verified under spatial coverage analysis.

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. Mobile collector moves across the network area to perform data collection. The data collection is initiated under the polling points. Cluster head information is used to schedule the moving trajectory for mobile collectors. Mobile collector fetches the data from the cluster head pairs.

6. Proposed System

The wireless Sensor Network (WSN) is deployed to monitor the environment. The sensor device captures the data values and updates it into the local storage. Data gathering methods are adapted to fetch the data sensed by the nodes. The mobile collector (Sencar) is used to collect the sensor data values. The network area is monitored with the movement of mobile collector.

The sensor nodes are grouped as clusters. The system uses cluster head pairs to handle the data upload process. A cluster head pair collects the data values from the sensor nodes and uploads the data values to the mobile collector. All the data collection operations are carried out on the polling points. Multiple receiver based data collection is performed in the mobile collector.

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.

Sensor activity scheduling is an effective way to prolong network lifetime while maintaining the network coverage requirement in a densely deployed WSN.

If the area covered by a sensor is also covered by other sensors, then this sensor can go into an energy saving sleep state without loss of network coverage. We can divide the time line into intervals and schedule different sensor sets to guarantee network coverage in different intervals.

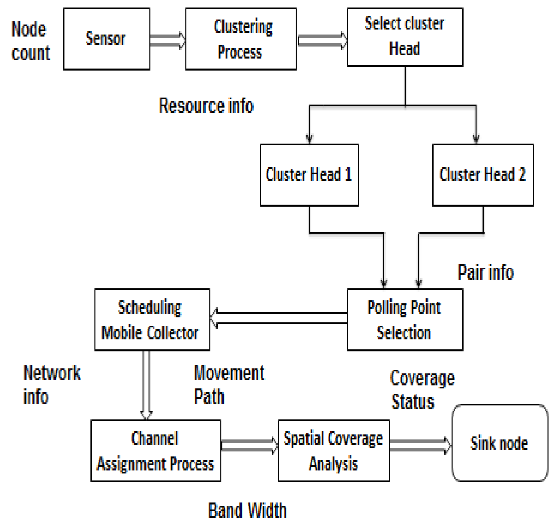

Fig 1.MIMO scheduling and Spatial Coverage Optimization.

7. Conclusion

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 six modules. They are Sensor Layer, Clustering Process, Polling Point Selection, Scheduling Mobile Collector, Channel Assignment Process and Spatial Coverage Analysis. Sensor node deployment operations are carried out under sensor layer module. Clustering process is designed to group the sensor nodes with resource details. Polling point selection module is designed to assign data collection points. Mobile collector movements are planned using scheduling process. MIMO scheduling operations are carried out under Channel assignment process. Network coverage is verified under spatial coverage analysis

7.1 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 neighbour nodes.

7.2 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.

7.3 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.

7.4 Scheduling Mobile Collector

Mobile collector moves across the network area to perform data collection. The data collection is initiated under the polling points. Cluster head information is used to schedule the moving trajectory for mobile collectors. Mobile collector fetches the data from the cluster head pairs.

7.5 Channel Assignment Process

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.

7.6 Spatial Coverage Analysis

Network coverage verification is performed in the spatial coverage analysis. Node coverage and proximity details are analyzed to estimate the cluster coverage. Cluster coverage details are summarized to estimate the data sensing coverage for the network. Network coverage and data collection regions are compared to identify the coverage missing area.

8. 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. The system reduces energy consumption in sensor node and cluster head level. 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.

References

[1] HongliXu, Liusheng Huang, ChunmingQiao, Weichao Dai and Yu-e Sun, "Joint Virtual MIMO and Data Gathering for Wireless Sensor Networks", IEEE transactions on parallel and distributed systems, vol. 26, no. 4, April 2015

[2] B. Fateh and G. Manimaran, "Energy-aware joint scheduling of tasks and messages in wireless sensor networks," in Proc.IPDPSW IEEE, Atlanta, GA, USA, 2010.

[3] Benazir Fateh and Manimaran Govindarasu, "Joint Scheduling of Tasks and Messages for Energy Minimization in Interference-Aware Real-Time Sensor Networks", IEEE Transactions On Mobile Computing, Vol. 14, No. 1, January 2015

[4] G. S. A. Kumar, G. Manimaran, and Z. Wang, "End-to-end energy management in networked real-time embedded systems," IEEE Trans. Parallel Distrib. Syst., vol. 19, no. 11, pp. 1498–1510, Nov. 2008.

[5] H. Xu, L. Huang, Y. Zhang, H. Huang, S. Jiang, and G. Liu, "Energy-efficient cooperative data a ggregation for wireless sensor networks," J. Parallel Distrib. Comput., vol. 70, no. 9, pp. 953–961, Sep. 2010

[6] S. C. Ergen, P. Varaiya, "TDMA scheduling algo for wireless sensor networks," Wireless Net., vol. 16, no. 4, pp. 985–997, May 2010.

[7] Y. Gai, L. Zhang, and X. Shan, "Energy efficiency of cooperative MIMO with data aggregation in wireless sensor networks," in Proc. IEEE Wireless Commun.Netw.Conf., Mar. 2007, pp. 792–797.

[8] Y. Wu, X. Li, Y. Liu, and W. Lou, "Energy-efficient wake-up scheduling for data collection and aggregation," IEEE Trans.Parallel Distrib. Syst., vol. 21, no. 2, pp. 275–287, Feb. 2010.

[9] J. Ma, W. Lou, Y. Wu, X. Li, and G. Chen, "Energy efficient TDMA sleep scheduling in wireless sensor networks," in Proc.INFOCOM, Rio de Janeiro, Brazil, 2009.