Available Online at www.ijcsmc.com

International Journal of Computer Science and Mobile Computing

A Monthly Journal of Computer Science and Information Technology

ISSN 2320–088X

IJCSMC, Vol. 4, Issue. 4, April 2015, pg.172 – 178

RESEARCH ARTICLE

The Exact and BD Algorithm for Data-Gathering Cluster-Based Wireless Sensor Network

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Abstract— Wireless sensor networks provide the facility for collecting diverse types of data at frequent intervals, even multiple times per second and over large areas. Data-gathering wireless sensor networks (WSNs) are operated unattended over long time horizons to collect data in several applications such as those in climate monitoring and a variety of ecological studies. The proposed system considers a LEACH model to optimally determine the sink and CH locations as well as the data flow in the network. This model effectively utilizes both the position and energy-level aspects of the sensors while selecting the CHs and avoid the highest-energy sensors that are well-positioned sensors with respect to sinks being selected as CHs repeatedly in successive periods. The current work focuses on the development of an effective Benders decomposition (BD) approach that incorporates an upper bound heuristic algorithm, strengthened cuts, and an optimal framework for accelerated convergence for LEACH model. Computational evidence demonstrates the efficiency of the BD approach and the heuristic in terms of solution quality and time.

Keywords— Benders Decomposition, LEACH, Cluster Head, Wireless Sensor Network

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I. Introduction

A **Wireless Sensor Network** are spatially distributed autonomous sensors to *monitor* physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location. Sensor node normally senses the physical event from the environment. A group of sensors communicating in a wireless medium form a wireless sensor network for the purpose of gathering data and transmitting it to a user (sinks). The main purpose of the WSN is to monitor and collect data by the sensors and then transmit this data to the sinks. Clustering is a key technique used to extend the lifetime of a sensor network by reducing energy consumption. Scalability of network increases with the help of clustering techniques. This paper considers time-driven sensor network applications such as environmental sensor networks for monitoring ecological habitats. WSN gives a great opportunity for monitoring ecology that was not possible before due to the remoteness of areas of interest and/or infeasibility of in-person attendance in data collection. Use of WSNs does not only make eco-monitoring possible, but also facilitates more frequent data collection. In addition, as habitat monitoring can be very sensitive to human presence, an unattended WSN provides a non-invasive approach to obtain real-time environmental data. The network operations of general framework of WSN of our interest can be outlined as follows. Initially, a set of sensors, which are equipped with limited energy resource (e.g., battery) as well as sensing, processing, and communication capabilities, is deployed in a geographical region. Data collected by the sensors are forwarded to specially designated sensors, called cluster heads (CHs), which conduct some processing to aggregate their received data. CHs then forward the data to specific locations, called sinks, either directly or through other CHs. In this underlying setting which is depicted in Fig. 1, design of the network refers to the determination of CH and sink locations, while the operation decisions refer to the routing of data from the sensors to the sinks in that network.

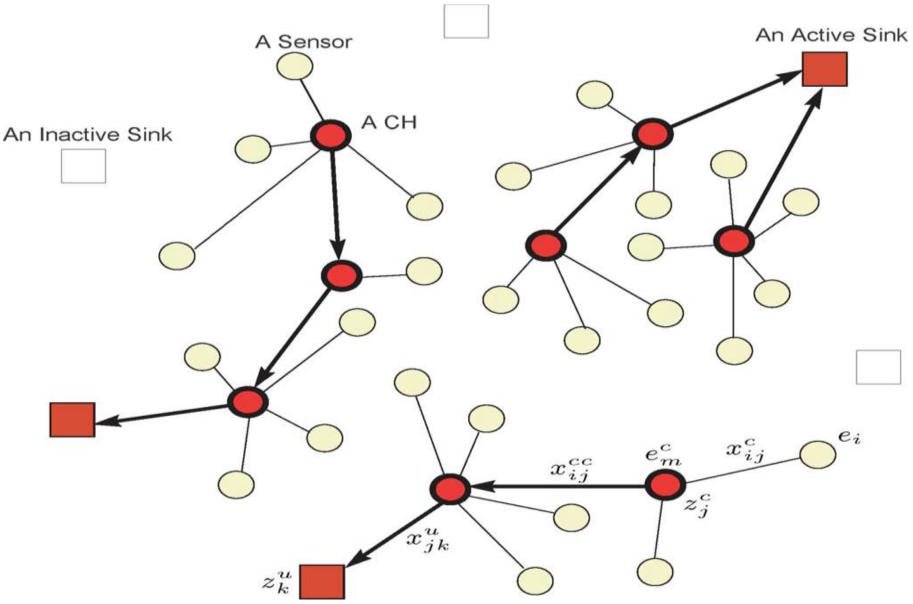

Fig. 1. Sample network, data flow, and notation

In many applications of WSNs network lifetime is one of the main concerns in network design and operation. Sensor redeployments may be needed due to several reasons, e.g., having less than a critical number of operational sensors with enough remaining energy in the network. Typically, the lifetime is assumed to be divided into periods of uniform length. For each period, network design and operations decisions are made in a way that the number of periods in a deployment cycle is maximized. Consequently, the network lifetime is defined as the number of periods that can be achieved with a deployment. Topology control and routing are two fundamental problems in effective design and operation of WSNs. The close relationship between these decisions and their relation to network lifetime are especially underlined by the WSN specific design include energy efficiency and computation communication trade-off. Energy efficiency is a major concern since each sensor has finite and non-renewable energy resource.

Communication computation trade-off refers to the fact that communication consumes more energy than performing computations on board sensor. This is critical as it relates to the energy efficiency. Although the direct communication of a sensor with a sink is suitable for the whole network, this is practically impossible or may require excessive energy may the network lifetime get reduced. Therefore, routing schemes where the data size is decreased by in-network data aggregation where energy is used for computation rather than communication along the paths from sensors to a sink (user) are usually preferred.

II. Literature Survey

Clustering of sensors has been shown effectiveness in improving sensor network lifetime in the literature. The principle is to organize WSNs into a set of clusters, and within each cluster, sensors transmit the collected data to their CHs. Each CH collects its received data and forwards it to the sink either directly or via relaying through other CHs.

This is beneficial in three ways in terms of energy efficiency such as

1) Hierarchical structure provides facility to eliminate the quick energy drainage at the sensors that are away from the sink by a multi hop sensor-to-sink data transfer scheme;

2) To reduce data redundancy the data aggregation is performed at the CHs so that energy in savings communications are realized;

3) At frequent intervals re clustering can balance the energy consumption by reassigning the CHs and the sinks and adjusting the routing in the network. This project discusses the works that are more closely related to this research in the context of network topology and data routing.

Heinzelman et al. develop a data aggregating cluster-based routing protocol Low Energy Adaptive Clustering Hierarchy (LEACH). In LEACH, they assume a single-hop CH-to-sink connection and adopt the randomized rotation of CHs to ensure balanced energy consumption. But such assumptions may not guarantee network connectivity. The LEACH algorithm proceeds in rounds. In each round, each sensor node independently decides whether or not to become a CH according to a probability function. On average, this function makes each node become a CH for a similar period of time, assuring fair balancing of energy consumption among all nodes. Although LEACH performs local data fusion to compress the cluster information, it does not consider data correlation when forming optimal-sized clusters. Moreover, since the probability of becoming a CH is fixed, LEACH results in clusters that are on average of the same size throughout the entire network.

Younis and Fahmy et al. propose a hybrid energy-efficient distributed clustering routing (HEED) protocol where the CHs are probabilistically selected based on their remaining energy and the sensors join clusters such that the communication cost is minimized. HEED assumes a multihop connection between the CHs and to the sink and assumes all nodes are of same important.

In EAP, each CH is probabilistically selected based on its ratio of the remaining energy to the average remaining energy of all the adjacent sensors within its cluster range. This is in contrast to HEED that only selects CHs based on a sensors' own remaining energy. For further improvement in network lifetime, EAP introduces the idea of intra cluster coverage‖ that allows a partial set of sensors to be active within clusters while maintaining an expected coverage.

Specifically, in a multi hop cluster-based WSN, the CHs closer to the sink may have quick drainage due to their heavy load in forwarding data to the sink. It notes that most of the above-mentioned studies do not explicitly take this factor into account. To ensure balanced energy consumption, there are some studies, that consider an unequal cluster-based routing scheme, i.e., CHs closer to the sink have smaller cluster sizes than those farther from the sink.

III. System Design

In this paper the main purpose is to address the optimum design and operation of a WSN for a period within a deployment cycle. This scheme consider an optimization approach to effectively integrate topology control and routing decisions in a cluster-based hierarchical network structure in which in-network data aggregation is facilitated for better energy efficiency.

Specifically, proposed system considers two important extensions of this model.

1) First, in the model context, it incorporate a total fixed cost term associated with CH selection into the objective function. By setting a higher fixed cost of usage for a sensor with low energy, the model try to avoid some well-positioned sensors from being selected as CHs repeatedly in successive periods and to protect these sensors from quick energy depletion. This approach also facilitates a uniform energy consumption profile at the sensors across the network. This is important because in a hierarchical setting, where data flow from sensors to the sinks occurs via CHs, a CH not only functions to capture information in its vicinity, but also as an aggregator/relay node to process and transfer the data generated by other sensors to the sinks. Thus, CHs consume more energy than regular sensors, while the whole network operation enjoys taking advantage of the computation– communication trade-off.

2) Second, observing that the model is amenable to exact solution via Benders decomposition (BD), in the methodological context, we focus our efforts on devising an efficient BD Algorithm as a solution method. In particular, we develop a solution approach that incorporates an effective. Heuristic algorithm and strengthened Benders cuts in an optimal BD framework. Computational evidence demonstrates the efficient performance of the approach in terms of solution quality and time.

This heuristic algorithm provides a good initial upper bound and facilitates the generation of initial Benders cuts, while the strengthened Benders cuts and optimal framework accelerate the convergence of the BD algorithm.

In each iteration of Benders algorithm, the master problem is resolved to optimality with the addition of a Benders cut. This gives a lower bound for the original problem, and values for the integer variables are then substituted into the sub problem. The dual sub problem is then solved to produce an upper bound for and a set of dual variables values that are used to generate a new Benders cut for the master problem in the next iteration. This process is repeated until a termination condition, usually a small optimality gap between the lower bound and the upper bound, is met. In Benders approach, it is known that if the iterations are allowed to continue long enough, an optimal solution is obtained as the Benders cuts recover the complete feasible polyhedron of the overall problem.

A. Network Model

In our problem of interest, sensors are deployed in a two-dimensional field, and the forwarding from a sensor to its CH. This scheme considers a multilayer hierarchical setting where data flows from sensors to the sinks either directly or through other CHs as depicted. It assume that sensors are equipped with a dynamic transmit power level control that they utilize to achieve topology control based on the solutions obtained candidate sinks, which have no energy limitations, are located around the periphery of the sensor field. In the beginning of a deployment cycle each sensor is assumed to communicate its position, obtained via triangulation to the user. As sensors collect data, they form packages to forward to their CH based on a schedule.

B. Communication Model

This scheme assumes that a sensor can communicate with any sensor or sink within its vicinity that is assumed to be a disk centered at that sensor. It defines the radius of such a disk as the transmission range. Although this model is widely used in the routing and topology control literature, it does not represent actual hardware capabilities in real applications. More importantly, the model makes the assumption that a sensor can reliably communicate with any sensor within its transmission range. This paper further observe an implication of link reliability on network performance is loss of data and/or delayed transmission of data, which cause additional energy consumption due to changes in data transfer schedules and resends. While the link reliability issues in the context of a data-gathering WSN can also be addressed through deployment of dense networks with some level of redundancy. This comes at the expense of increased problem sizes as well as more involved operational planning due to concerns such as interference, data aggregation, scheduling, etc.

C. Energy Consumption Model

This scheme employs a simple energy dissipation model that reflects the operational network characteristic of interest. To estimate the energy dissipation for transmitting (bits) of data from node to node. To calculate the power requirement at a receiver node, it use the model where (J/bit) is a constant. Therefore, transmitting (bits) of data from node to node dissipates, and receiving the same amount of data dissipates. It assume that the radio dissipates n J/bit to run the transmitter or receive circuitry and p J/bit/m for the transmit amplifier. In addition, it employs a dissipation rate of p J/bit for data aggregation/processing efforts at a CH. A higher value is more appropriate to account for interference in uneven terrain, for computational purposes, this assume a value which represents the ideal case in terms of the efficiency of communications. With higher values, energy consumption levels are expected to increase due to increased path loss and, in turn, a reduced network lifetime is expected.

IV. Results

A framework of Network has been Created. In this network we are creating the number of nodes, number of cluster head, number of sinks, Range of the network. We are sending the data from node to sink cluster head.

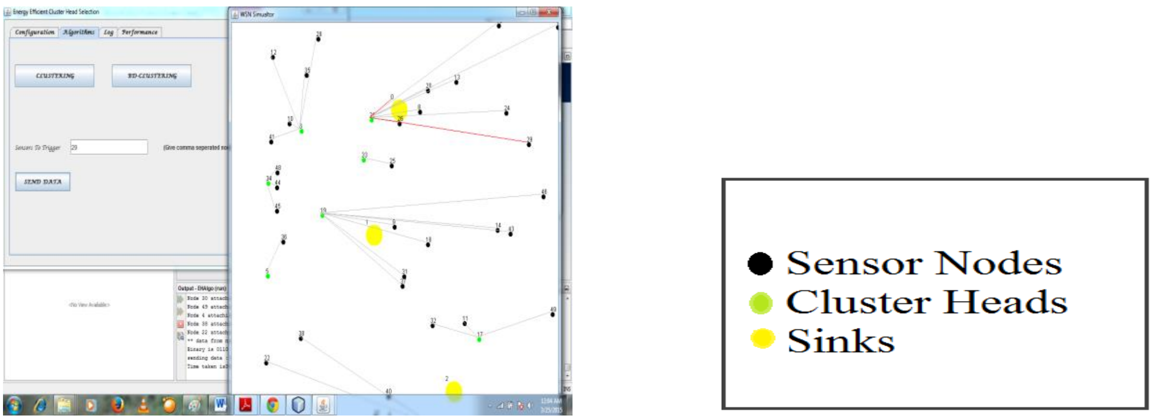

Fig. 2 creation of network

In fig 2 represents the number of nodes, cluster head, sinks deployed in the network. Cluster head selection by using bendor decomposition algorithm & also sending data from node to cluster head then sink.

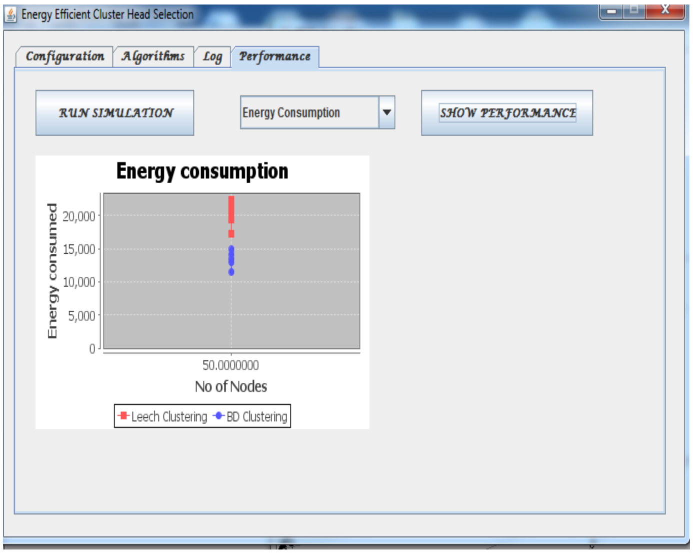

Fig 3. Energy consumption

In fig 3 represents the how much energy consumed by using LEACH & BD Clustering Algorithm.

V. Conclusion

The CHs this scheme propose a new objective as the minimization of a weighted sum of the average energy usage, the range of remaining energy distribution and the energy-based fixed cost. By doing so, this model avoids some well-positioned sensors being selected as CHs repeatedly in successive periods to protect low-energy sensors from quick energy depletion while facilitating a uniform energy consumption profile in the network. This scheme develops an effective –optimal BD approach that incorporates an upper bound heuristic algorithm and strengthened cuts. Specifically, it devises a feasible heuristic algorithmic solution so as to facilitate the generation of an initial Benders cut.

This study can be improved in several directions. One extension of this work is to incorporate the coverage problem into the integrated topology control and routing problems with the high spatial redundancy of sensors by only allowing a subset of sensors active for a given period of time, whereas all other sensors save energy being in inactive state. Since it currently focuses on time-driven sensor networks applications pertaining to continuously monitoring ecological habitats such animals, plants, micro-organisms, another interesting extension in the future is to reformulate the models to suit for the time-critical applications

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