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Solution of Energy-Efficiency of sensor nodes in Wireless sensor Networks

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Abstract: The large-scale deployment of wireless sensor networks (WSNs) and the need for data aggregation necessitate efficient organization of the network topology for the Purpose of balancing the load and prolonging the network lifetime. The past few years have witnessed increased interest in the potential use of wireless sensor networks (WSNs) in applications such as disaster management, combat field reconnaissance, border protection and security surveillance. In this paper, we study the clustering methods in WSN which improve energy-efficiency and discuss the design rationale of the different clustering approaches, classify the proposed approaches based on their objectives and design principles. We further discuss several key issues that affect the practical deployment of clustering techniques in sensor network applications.

Keywords: Wireless sensor networks, Cluster Head, energy efficiency, LEACH, EEPSC

I. Introduction

Wireless sensor network is a collection of sensor nodes interconnected by wireless Communication channels. Each Sensor node is a small device that can collect data from its surrounding area, carry out simple computations, and communicate with other Sensors or with the base station (BS).Recent years have witnessed an increasing interest in using wireless sensor networks (WSNs) in many applications, including environmental monitoring and military field surveillance. In these applications, tiny sensors are deployed and left unattended to continuously report parameters such as temperature, pressure, humidity, light, and chemical activity. Reports transmitted by these sensors are collected by observers (e.g., base stations).The dense deployment and unattended nature of WSNs makes it quite difficult to recharge node batteries. Therefore, energy efficiency is a major design goal in these networks. Several WSN applications require only an aggregate value to be reported to the observer. In this case, sensors in different regions of the field can collaborate to aggregate their data and provide more accurate reports about their local regions. For example, in a habitat monitoring application, the average reported humidity values may be sufficient for the observer. In military fields where chemical activity or radiation is measured, the maximum value may be required to alert the troops. In addition to improving the fidelity of the reported measurements, data aggregation reduces the communication overhead in the network, leading to significant energy savings [2], [3]. In order to support data aggregation through efficient network organization, nodes can be partitioned into a number of Small groups called clusters. Each cluster has a coordinator, referred to as a cluster head, and a number of member nodes. Clustering results in a two-tier hierarchy in which cluster heads (CHs) form the higher tier while member nodes form the lower tier. Fig 1 illustrates flow in a clustered network. The member nodes report their data to the respective CHs. The CHs aggregate the data and send them to the central base through other CHs. Because CHs often transmit data over longer distances, they lose more energy compared to member nodes. [3] The network may be reclustered periodically in order to select energy-abundant nodes to serve as CHs, thus distributing the load uniformly on all the nodes. Besides achieving energy efficiency, clustering reduces channel contention and packet collisions, resulting in better network throughput under high load.

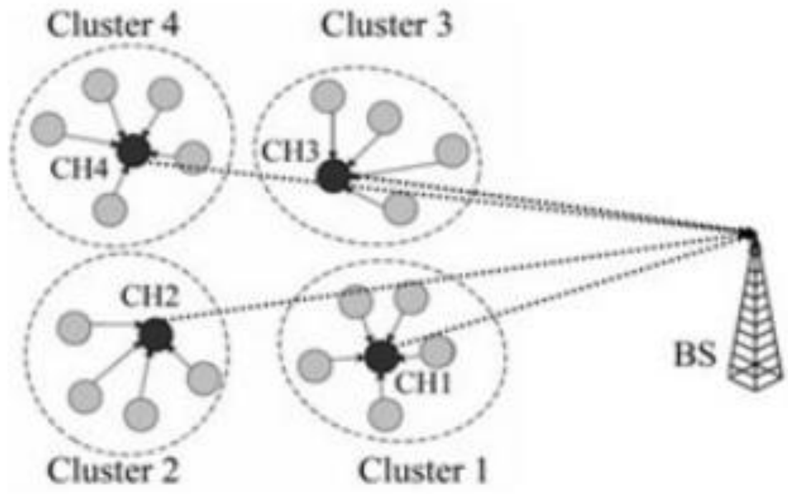

Fig.1 The LEACH Clustering Communication hierarchy

Clustering has been extensively studied in the data processing and wired network literatures. The clustering approaches developed in these areas cannot be applied directly to WSNs due to the unique deployment and operational characteristics of these networks. Specifically, WSNs are deployed in an ad hoc manner and have a large number of nodes.

II. Objective Of Clustering

Many protocols have been proposed for energy-efficiency in WSN in the last few years. Clustering based schemes are believed to be the most energy efficient routing protocols for wireless sensor networks. As defined previously, Clustering is grouping of similar objects or the process of finding a natural association among some specific objects or data [5]. The structure of a general cluster scheme is shown in the following Figure1. In each cluster, one node is elected as the cluster-head (CH) while the rest of the nodes are member nodes. Member nodes in their respective clusters sense the ambient conditions in the environment and transmit the measured data to their corresponding cluster-head. Cluster-heads handles the responsibilities to collect data from their member nodes, to aggregate them, and finally to forward the aggregated data either to neighboring cluster- head (multi hop) or directly (single hop) to sink/base station. Clustering leverages the advantages of small transmit distances for most of nodes, requiring only a few nodes to transmit far distances to the sink/base station [7].Thus clustering along with the reduction in energy consumption improves the network life-time. Along with clustering, the concept of hierarchical clustering also plays a very important role in developing energy efficient schemes for WSN. We classify the clustering techniques based on two criteria:

1. The parameter(s) used for electing CHs
2. The execution nature of a clustering algorithm (probabilistic or iterative)

III. Clustering Methods

Many clustering algorithms have been proposed for wireless sensor networks in recent years. We review some of the most relevant papers. In LEACH [2], each node has a certain probability of becoming a cluster head per round, and the task of being a cluster head is rotated between nodes. In the data transmission phase, each cluster head sends an aggregated packet to the base station by single hop. In PEGASIS [3], further improvement on energy-conservation is suggested by connecting the sensors into a chain. Each cluster member searches for a neighbor closer than the cluster head within the cluster to set up an energy-saving and delay- adaptive data relay link. HEED [4] extends LEACH by incorporating communication range limits and intra-cluster communication cost information. The initial probability for each node to become a tentative cluster head depends on its residual energy, and final heads are selected according to the cost. In the implementation of HEED [4], multihop routing is used when cluster heads deliver the data to the data sink. All these methods require re-clustering after a period of time because of cluster heads' higher workload. The main goal of cluster-based routing protocol is to efficiently maintain the energy consumption of sensor nodes by involving them in multi-hop communication within a cluster and by performing data aggregation and fusion in other to decrease the number of transmitted messages to sink and transmission distance of sensor nodes. Some popular cluster-based routing schemes towards achieving the required goal of energy efficiency to prolong network lifetime are discussed here in brief:

1. LEACH-Distributed

Low-Energy Adaptive Clustering Hierarchy (LEACH) is one of the most popular distributed cluster-based routing protocols in Wireless sensor networks. LEACH randomly selects a few nodes as cluster heads and rotates this role to balance the energy dissipation of the sensor nodes in the networks. The cluster head nodes fuse and aggregate data arriving from nodes that belong to the respective cluster. And cluster heads send an aggregated data to the sink in order to reduce the amount of data and transmission of the duplicated data. Data collection is centralized to sink and performed periodically.

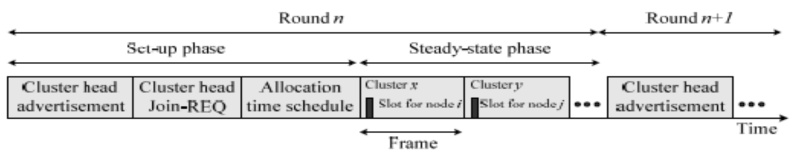

Fig2.Time line of LEACH protocol

The operation of LEACH is generally separated into two phases, the set-up phase and the steady-state phase, as shown in Figure2. In the set-up phase, cluster heads are selected and clusters are organized. In the steady-state phase, the actual data transmissions to the sink take place. After the steady- state phase, the next round begins. During the set-up phase, when clusters are being created, each node decides whether or not to become a cluster head for the current round. This decision is based on a predetermined fraction of nodes and the threshold T(n). The threshold is given by where p is the predetermined percentage of cluster heads (e.g., p = 0.05), r is the current round, and G is the set of nodes that have not been cluster heads in the last 1/p rounds.

T=p/(1-p*mod(r,1/p)---------------------(1)

Using this threshold, each node will be a cluster head at some round within 1/p rounds. After 1/p rounds, all nodes are once again eligible to become cluster heads. In LEACH, the optimal number of cluster heads is estimated to be about 5% of the total number of nodes. Each node that has elected itself a cluster head for the current round broadcasts an advertisement message to the rest of the nodes in the network. All the non-cluster head nodes, after receiving this advertisement message, decide on the cluster to which they will belong for this round. This decision is based on the received signal strength of the advertisement messages [6]. After cluster head receives all the messages from the nodes that would like to be Included in the cluster and based on the number of nodes in the cluster, the cluster head creates a TDMA schedule and assigns each node a time slot when it can transmit. During the steady-state phase, the sensor nodes can begin sensing and transmitting data to cluster heads. The radio of each non cluster head node can be turned off until the node's allocated transmission time. The cluster heads, after receiving all the data, aggregate it before sending it to the sink [8]. Each cluster head communicates using different CDMA codes in order to reduce interference from nodes belonging to other clusters.

2. EEPSC(Energy-Efficient Protocol with Static Clustering)

EEPSC [1], a hierarchical static clustering based protocol, partitions the network into static clusters eliminating the overhead of dynamic clustering as employed in LEACH [5] and utilizes temporary-cluster-heads to distribute the energy load among the high power sensor nodes; thus prolongs the network lifetime. The main differences between EEPSC and LEACH are described below:

1. EEPSC benefits a new idea of using temporary-cluster- heads and utilizes a new setup and Responsible node selection phase.
2. EEPSC utilizes static clustering schemes therefore eliminates the overhead of dynamic Clustering.
3. EEPSC is a self-organizing, static clustering method that forms clusters only once during the Network action.
4. The operation of EEPSC is broken up into rounds where each round consists of setup phase, responsible node selection phase and steady-state phase.

IV. Execution Of Clustering Schemes

The execution of a clustering algorithm can be carried out at a centralized authority (e.g., a base station) or in a distributed way at local nodes. Centralized approaches require global. The performance of the schemes is evaluated considering network lifetime as a parameter which is defined as the time until the last node dies in the network. Network lifetime is measured using two different yard-sticks:

1. Number of nodes alive in the network—more number of nodes alive implies network lifetime lasts longer.

2. Number of messages received at BS—more number of messages received at BS implies more number of nodes is alive in the network leading to longer network lifetime.

Simulation Results and Discussion

To validate the performance of LEACH and EEPSC Clustering, for our experiments, we used a 100-node network where nodes were randomly distributed between(x=0, y=0) and (x=100, y=100) with the BS at location(x=50, y=175). The bandwidth of the channel was set to 1 Mb/s, each data message was 500 bytes long, and the packet header for each type of packet was 25 bytes long.

We assume a simple model for the radio hardware energy dissipation where the transmitter dissipates energy to run the radio electronics and the power amplifier, and the receiver dissipates energy to run the radio electronics. In these experiments, each node begins with only 2 J of energy and an unlimited amount of data to send to the BS. Each node uses the probabilities to determine its cluster head status at the beginning of each round, and each round lasts for 20 s.6 we tracked the rate at which the data packets are transferred to the BS and the amount of energy required to get the data to the BS. When the nodes use up their limited energy during the course of the simulation, they can no longer transmit or receive data. For these simulations, energy is consumed whenever a node transmits or receives data or performs data aggregation. Using spread-spectrum increases the number of bits transmitted, thereby increasing the amount of energy dissipated in the electronics of the radio.

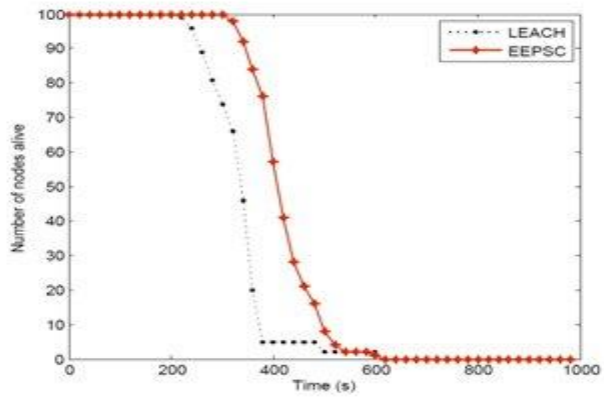

Fig3. Number of nodes alive over time

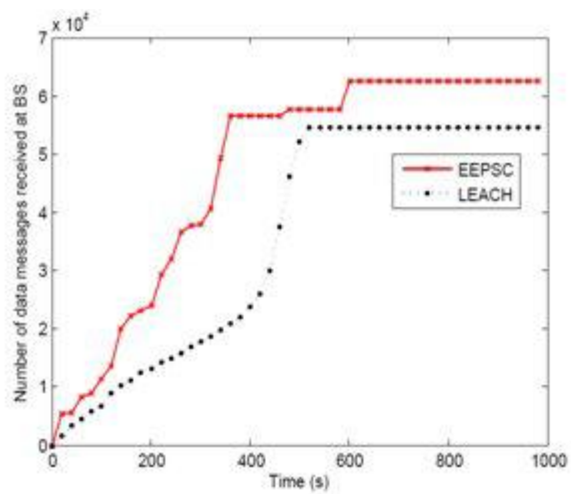

Fig4. Number of data messages received at base station over time

The improvement gained through EEPSC compared to LEACH is further illustrated by Figs. 3-4 which indicates the lifetime of network is extended and the overall number of messages received at base station is increased. With LEACH, all nodes remain alive for 220 seconds before the first node dies, while in EEPSC, all nodes remain alive for 320 seconds; which is 45% more than LEACH. Figs. 3 and 4 show that, the total number of data messages received at base station at the end of network lifetime is greater for EEPSC. Figs.3 and 4 clearly indicate the advantages of EEPSC over LEACH in terms of network lifetime.

VI.Conclusion

Clustering is a useful topology-management approach to reduce the communication overhead and exploit data aggregation in sensor networks. We have classified the different clustering approaches according to the clustering criteria and the entity responsible for carrying out the clustering process. We have focused on distributed clustering approaches, which are more suitable for large-scale sensor networks. We highlighted some of the basic challenges that have hindered the use of clustering in current applications. We surmise that the most compelling challenges are how to schedule concurrent intra cluster and inter cluster transmissions, how to compute the optimal cluster size, and how to determine the optimal frequency for CH rotation in order to maximize the network lifetime. Finally it is concluded from the survey that, still it is needed to find more scalable, energy efficient and stable clustering scheme, for data gathering in wireless sensor networks.

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