TREE-CLUSTERED DATA GATHERING PROTOCOL (TCDGP) FOR WIRELESS SENSOR NETWORKS

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ABSTRACT

Wireless Sensor Networks (WSNs) consist of numerous low cost, low power, low volume, and short-distance transmitting nodes. As sensor nodes are deployed in a sensing field they can help people to monitor and aggregate data. Researchers also try to find more efficient ways of utilizing limited sensor node energy to provide longer WSN lifetime. Therefore, finding a method to reduce node data transmission energy consumption has become a very important issue. The multi-hop routing protocol is well known for power saving in data gathering. Recently, several researchers have used cluster-based (e.g., LEACH), chain-based (e.g., PEGASIS), and tree-based (e.g., TREEPSI) methods to establish energy efficient routing protocols. In this paper, we propose a tree-clustered data gathering protocol (TCDGP) to improve upon the LEACH and TREEPSI methods. This novel protocol can preserve the advantages of the LEACH and TREEPSI methods and further reduce power consumption. The simulation results show that our proposal gives better performance than other methods.

Key Words: wireless sensor networks (WSNs), energy-efficient, multi-hop routing protocol.

I. INTRODUCTION

Micro electro-mechanical system (MEMS) have made remarkable advances in recent years. Wireless Sensor Networks (WSNs) have also grown rapidly due to the development of low power wireless communications. Miniature wireless sensors have been widely used for wireless communications and data processing. To create these types of applications, WSNs need a huge number of low cost, low power, low volume, and short-distance transmitting nodes.

Generally speaking, the more sensors close to the point of interest, the more precise the sensed information. For this reason, sensor nodes are always dispersed densely in the sensing field. This is also why traditional expensive macro-sensors cannot achieve good information. A growing number of technologies are now available to produce sensor nodes with volume limited to a few cubic centimeters, which are easy to embed in the environment. Nodes can be dispersed in the environment that are not easily detected yet are suitable for long term observations. Through collaborative effort, sensor nodes send many kinds of information from the environment to remote sinks. After a sink aggregates and computes the data, the sink will convey the data to an external network through the internet or a satellite network. There is a general consensus on WSN power consumption that it is not easy to supply a great amount of power to sensor nodes because the battery size is restricted by the node volume, therefore MANETs routing protocols are suitable directly for WSNs. Numerous routing protocols have been written to improve the power consumption in wireless sensor networks. (Akkaya and Younis, 2005; Akyildiz et al., 2002; Han et al., 2006; Min et al., 2001; Muruganathan et al., 2005; Rabaey et al., 2000; Satapathy and Sarma, 2006; Wesnarat and Tipsuwan, 2006).

In this paper, we will investigate the problems that occur in the LEACH (Heinzelman et al., 2006)
and TREEPSI (Sohrabi et al., 2000) environments and propose solutions. We propose a new energy efficient tree based routing protocol for data aggregation (TCDGP) to improve upon the LEACH and TREEPSI methods. The proposed method preserves the advantages of the LEACH and TREEPSI protocols and further reduces power consumption. We can shorten the transmission distance between nodes and prevent the root nodes from dying quickly.

The remainder of this paper is organized as follows: In Section II, we introduce the radio module environment characteristics in WSNs. Section III describes related research on decreasing the power consumption in WSNs. Section IV discusses our routing assumptions, and environmental framework, and explains how our proposal works. Section V shows the simulation results. The last section presents our conclusion and discusses future work.

II. WIRELESS SENSOR NETWORKS (WSNS)

1. Network Architecture

The WSN network architecture is shown in Fig. 1. WSNs consist of a large set of autonomous wireless sensing nodes. (Akyildiz et al., 2002) These sensor nodes are randomly deployed in the sensing field. Each sensor node has the ability to detect the target signal, process data, and communicate with other nodes. The nodes transmit their data to the sink, which collects this data periodically. After a predesignated period, the sink will transfer the collected data to the end users via a Local Area Network, the internet, or satellite network.

The sensor node hardware consists of four main components. These are the sensing unit, processing unit, communication unit, and power unit. The Analog digital converter (ADC) is a translator that tells the processing unit what the sensor unit has sensed and also informs the sensor unit what to do. The communication unit task is to receive commands or queries. It is also in charge of all communications between the sensor node and sink. The processing unit is responsible for executing the pre-stored program code or coded instructions announced by the sink. It can start up, control, and coordinate the different units in the inner component.

2. Radio Module for Energy Dissipation

Much research has been conducted in the low power radio area. Previous research provides assumptions about the radio characteristics and describes the advantages of different protocols and applications. Some research used first order radio modules, in which a fixed dissipating energy, $E_{elec}$, is spent in transmitting and receiving a packet of signals. The extra cost is proportional to $d^2$ and is spent on the amplifier $\epsilon_{amp}$, in transmitting a packet. The equations used to calculate the transmission and receiving costs to transmit a $k$ bit message for a distance $d$ are shown in the following.

**Transmitting:**

$$E_T(k, d) = E_{Tx-elec}(k) + E_{Tx-amp}(k, d)$$

$$E_T(k, d) = E_{elec} \cdot k + \epsilon_{amp} \cdot k \cdot d^2$$  \hspace{1cm} (1)

**Receiving:**

$$E_R(k) = E_{Rx-elec}(k)$$

$$E_R(k) = E_{elec} \cdot (k)$$  \hspace{1cm} (2)

In this paper, we assume LEACH, PEASIS, and TREEPSI use the same radio model as shown in Fig. 1. (Heinzelman et al., 2000; Lindsey et al., 2002; Sohrabi et al., 2000) The radio characteristics have two power dissipation modes: transmit and receive.

The transmission distance will affect the power consumption when the sensor nodes transmit data. Differences in consumption results can be observed for different communication modules. To improve the critical factor and distance, traditional routing protocols modify the mechanism to give priority to using the shortest path or add a different management mechanism to produce new and different routing protocols, such as a cluster-based protocol, chain-based protocol, or tree-based protocol.

As shown in Table 1, this model assumes the radio dissipates $E_{elec} = 50 \text{nJ}/\text{bit}$ for the Transmitter and Receiver electronics. The Transmit Amplifier dissipation is $\epsilon_{amp} = 100 \text{pJ}/\text{bit}/\text{m}^2$. There is a cost of 5 nJ/bit/message for $k = 2000$ bit messages in data fusion. It also assumes that the radio channel is
symmetrical. This means that the energy required to transmit a message from node \( a \) to node \( b \) is the same as the energy required to transmit a message from node \( b \) to node \( a \) for a given signal-to-noise ratio (SNR). The greater the communication power, the greater the SNR and a typical SNR value is 10dB.

### III. RELATED WORKS

In general, Wireless Sensor Networks (WSNs) can gather the sensed information from hundreds or even thousands of sensing nodes and transmit them to the sink. A network sometimes uses the simplest methods, the sensor nodes to transmit the sensed data to the sink directly. This method is very simple, but it can cause a serious problem in that the network will spend more energy in transmitting data from a node that is farther away than on a node that is closer. Therefore, it is desirable to make these nodes as energy-efficient as possible and to rely on their large numbers in order to obtain high quality results. Likewise, the sensor network routing protocols must be designed to achieve fault-tolerance in the presence of individual node failures while also minimizing energy consumption. Moreover, since the limited wireless channel bandwidth must be shared by all the sensor nodes in the network, routing protocols for these networks should be able to perform local collaborations in order to reduce the bandwidth requirements. Eventually, the data being sensed by the nodes in the network must be transmitted to a control center (i.e., the sink) or base station where the end sensor nodes can access the data. There are many routing methods in WSNs (Akkaya and Younis, 2005; Cheng and Jia, 2005; Han et al., 2006; Jiang and Manivannan, 2004; Liang and Yu, 2005; Martirosyan et al., 2008). A comparison of various routing methods is shown in Table 2 and a description of each method follows:

#### Diffusion-based aggregation

The diffusion process mainly utilizes the flooding mechanism as common routing. Consequently, it needs to broadcast constantly in order to transmit data.

#### Cluster-based aggregation

The main idea is to divide the sensor nodes into several clusters in the sensed area. Each cluster will choose a cluster head automatically.

#### Chain-based aggregation

This idea is the formation of one to several chains. All chains will select chain-heads to help gather data. Sensor nodes send the data to two neighbor nodes. Thus, the neighbor nodes forward it to the chain head after fusing it with their data. Each sensor node will do its job in the same way until the chain head aggregates the data. Finally, the chain heads transmit the aggregated data to the sink directly.

#### Tree-based aggregation

The main idea is the formation of a tree-like routing architecture in a WSN. At the initial phase, the sink will build a tree according to the sensor node information. Thus, a root node helps the sink to aggregate the data and then transmit data to the sink behind the WSNs.

### 1. Leach

In (Heinzelman et al., 2000), the authors proposed a Low-Energy Adaptive Clustering Hierarchy (LEACH) protocol. LEACH is representative of a cluster-based routing protocol and was the first protocol proposed for WSNs to reduce power consumption and avoid direct communication between the sink and sensor nodes. In a sensor field, sensor nodes sense data and send it to the sink called a “round”. The working procedure for LEACH will be finished in a single round. Before gathering the sensed data for each round, the large number of sensor nodes is divided into several clusters. A cluster head is randomly chosen through self-organization. Each cluster head is in charge of gathering the sensed data from the sensor nodes in the cluster. The cluster head will aggregate the received data and send it directly to the sink. After the sink has received all of the data from the cluster heads a round has ended. There are two phases in each round in the LEACH protocol: the setup phase and the steady-state phase.