Tree-Clustered Data Gathering Protocol (TCDGP) for Wireless Sensor Networks

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Abstract

Wireless Sensor Networks (WSNs) consists of plenty nodes which are low cost, low power consuming, small volume and short-transmitting. As sensor nodes are deployed in sensing field, they can help people to monitor and aggregate data. Researchers also try to find more efficient ways of utilizing limited energy of sensor node in order to give longer life time of WSNs. Therefore, how to reduce node's energy that is consumed in transmitting data has became a very important issue. From many kinds of paper, multi-hop routing protocol is well known for power saving in data gathering. Recently researches uses such types of the cluster-based (e.g., LEACH), the chain-based (e.g., PEGASIS) and the tree-based (e.g., TREEPSI) to establish their energy-efficient routing protocol. In this paper, we propose tree-clustered data gathering protocol (also called TCDGP) to improve the LEACH and TREEPSI. The novel proposed protocol can preserve both advantages and improve the power consumption further. Finally, simulation results show that our proposal has better performance than before.

Keywords: *Wireless Sensor Networks (WSNs), energy-efficient, multi-hop routing protocol*

1. Introduction

The micro electro mechanical system (MEMS) has made remarkable advances in recent years. Wireless Sensor Networks (WSNs) is also rapid growth due to the development of low power wireless communications. The miniature wirelessly sensors have been widely used for the sensor, wireless communication and data processing ability. In order to create such types of applications, WSNs need a huge number of low cost, low power consuming, small volume and short-transmitting nodes. [1] [2] [3]

Generally speaking, the more sensors close to circumstance, the more sensed information is precise when sensor are sensing events. For this reason, sensor nodes always are disposed plenty and densely in the sensing field. This is also why the traditionally expensive macro-sensor cannot achieve the goals. A growing number of technologies are now available to produce a sensor node whose volume is limited in few cubic centimeter. It is more and more easy to embedded in the environment. Nodes can be deposed in the environment that people cannot easier arrive or suitable to observe for a long time. Sensor nodes through the collaborative effort, sending the many kinds of the environment information to the remote Sink. After Sink aggregating and computing data, Sink will convey data to external network by way of Internet or satellite network. There is a general consensus on power consumption of WSNs field consists of. It is not easy to supply large power to sensor node because the battery is restricted on the nodes volume and it does not have the problem in MANETs. Therefore, the traditional MANETs routing protocols are suitable directly for WSNs. For above-mentioned reasons, a lot of routing protocols are purposed to improve the power consumption in wireless sensor networks.[8]

In this paper, we will investigate into the environment with the problems that LEACH and TREEPSI want to solve it. And then, we propose a new routing protocol, tree based energy-efficient for data gathering protocol (also called TCDGP), to improve the LEACH and TREEPSI. It preserves both advantages in LEACH and TREEPSI protocols and improves the power consumption further. One of above advantages we used is that we can shorten the transmission distance between nodes. And the root nodes will not die so soon.

The remainder of this paper is organized as follows. In Section 2, we first introduce the characteristic of environment and radio module about Wireless Sensor Networks. Section 3, describes the related researches about how to decrease the power consumption in the similar wireless sensor network. Section 4, discusses our routing assumption and environment framework and explains how to work about our proposal. Section 5, show the simulation results. Finally, the last section gives the conclusion and future works.

2. Wireless sensor networks (WSNs)

2.1. Network architecture

The network architecture of WSNs is shown in Figure 1. Wireless sensor networks (WSNs) consist of a large set of autonomous wireless sensing nodes.[8] These sensor nodes are randomly deployed in the sensing field. Each sensor node has the abilities of detecting sensors, processing of data and communication with other nodes. They have to transmit data to the sink. Sink acts as an important role in collecting data periodically. After, the sink will transfer collected data to end users via Local Area Network, Internet, Satellite networks, etc.

Hardware of sensor node consists of four main components. There are sensing unit, processing unit, communication unit and power unit. Analog digital convertor (ADC) is a translator that tells the processing unit what the sensor unit has sensed, and also informs the sensor unit what to do. Communication unit task is to receive command or query from, and it is in charge of all communications between sensor node and sink. Processing unit is responsible to execute the program code that has been storage in advance, or announced by sink. It can start up, control and coordinate the difference units in the inner component.

2.2. Radio module for energy dissipation

There are many researches in this area of low power radio. Previous researches provide assumptions about the radio characteristics will change the advantages of different protocols and applications. Some researches use the first order radio module currently. A fixed dissipating energy, E_{elec}, is spent in transmitting and receiving a packet of electronics. A extra cost is proportional to d^2 is spent for amplifier, ε_{amp}, in transmitting a packet. In order to transmit a k bits message for a distance d, the equations used to calculate transmission and receiving costs shown in the following.

Transmitting:

$$E_{Tx}(k,d) = E_{Tx\text{-}elec}(k) + E_{Tx\text{-}amp}(k,d)$$
$$E_{Tx}(k,d) = E_{elec} * k + \varepsilon_{amp} * k * d^2 \quad \text{(eq: 1)}$$

Receiving:

$$E_{Rx}(k) = E_{Rx\text{-}elec}(k)$$
$$E_{Rx}(k) = E_{elec} * k \quad \text{(eq: 2)}$$

In this paper, we assume LEACH, PEASIS and TREEPSI use the same radio model, like Figure 1. [4][5][6] The radio characteristics have two modes, transmit and receive, in power dissipation.

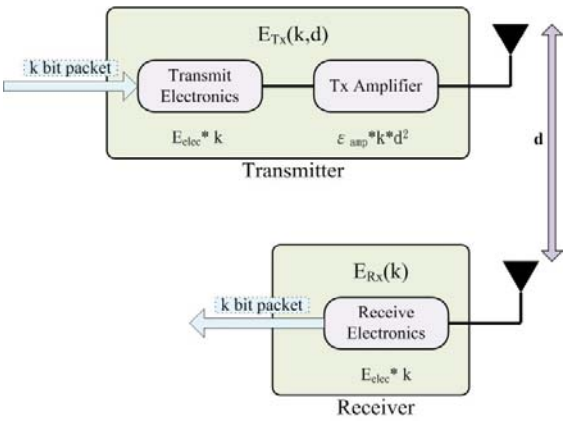

Figure 1. First order radio model

The transmission distance will affect the power consumption when sensor nodes want to transmit data. Especially for different communication modules, the consumption results could be observed obviously. In order to improve the critical factor, distance, so traditional routing protocols has priority in using the shortest path to modify the mechanism. Or adding the different management mechanism to produce a new and different routing protocols, such as cluster-based protocol, chain-based protocol, tree-based protocol and so on.

As shown in Table 1, this model assumes the radio dissipates E_{elec} = 50 nJ/bit for the Transmitter and Receiver Electronics. The Transmit Amplifier dissipating is ε_{amp} = 100 pJ/bit/m^2. There is a cost of 5 nJ/bit/message for k = 2000 bit messages in data fusion. It also assumes the radio channel is symmetric. It 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 more communication power is great, the more the SNR is large, typically 10dB.

Table 1. Radio Characteristics

Operation	Energy Dissipated
Transmitter Electronics($E_{Tx\text{-}elec}$)	50 nJ/bit
Receiver Electronics($E_{Rx\text{-}elec}$) ($E_{Tx\text{-}elec} = E_{Rx\text{-}elec} = E_{elec}$)	50 nJ/bit
Transmit Amplifier(ε_{amp})	100 pJ/bit/m^2

3. Related works

In general, Wireless Sensor Networks (WSNs) can gather the sensed information by hundreds or even thousands of sensing nodes and transmit them to the sink. It uses the easiest way that sensor nodes transmit the sensed data to sink directly. Using this way is very simple, but it will have a serious problem. When a farther sensor node transmits the data, it will spend more energy than the closer one. 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 sensors 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. At present, there are many routing methods in the wireless sensor networks. [9] The primary three types will be introduced as following Table 2.

Table 2. Comparison of protocol types

Protocol Type	Characteristic
Cluster-based	Nodes divided several clusters for cluster head sending
Chain-based	Nodes forming a long chain for chain head fussing
Tree-based	Building a tree like path for root node aggregating

3.1. LEACH

In [5], authors proposed a Low-Energy Adaptive clustering Hierarchy (LEACH) protocol. LEACH is representative cluster-based of routing protocols. It is also the first proposed in wireless sensor network and can reduce power consumption on avoiding the communication directly between sink and sensor nodes. In a sensor field, sensor node senses data and sends data to the sink that called “round”. The working procedure for LEACH will be finished in a round. Before gathering the sensed data at each round, the huge number of sensor nodes will divide into several clusters and choose a cluster head randomly by self-organization. Each cluster head is in charge of gather the sensed data from the sensor nodes in the cluster. The cluster head will aggregate the received data, and then send to the sink directly. After sink received all the data from cluster heads, a round will be ending. There are two phases in each round about LEACH, Set-up phase and Steady-state phase.

3.2. PEGASIS

In [6][7], authors proposed a Power-Efficient Gathering in Sensor Information Systems (PEGASIS). PEGASIS is based on chain–based protocol and differ from LEACH. This proposal is building all sensor nodes to form a chain according to Greedy algorithm that the sum of edges must be minimum in wireless sensor networks. At the initial phase before each round, they must choose a chain head. The N represents the number of nodes and all the nodes use the natural number from 1 to N. Then WSNs utilize the $i = j \bmod N$ to choose chain head. If i is equal to zero, then choose N. The two end-point of the chain will start send sensed data to the parent’s nodes for forwarding data to the chain head. All the nodes in the chain only transmit data to its neighbor. Each edge only send or receive data one time. In [6], after the chain head received the two children nodes, it will aggregate the data and transmit the collecting data to sink directly.

3.3. TREEPSI

In [4], authors proposed a Tree-based Efficient Protocol for Sensor Information (TREEPSI). TREEPSI is tree-based protocol that is different from above-mentioned protocols. Before data transmission phase, WSNs will select a root node in all the sensor nodes. Set the root identify id=j . There are two ways to build the tree path. One is computing the path centrally by sink and broadcasting the path information to network. The other can be the same tree structure locally by using a common algorithm in each node. At the initial phase, root will create data gathering process to the children nodes using any standard tree traversal algorithm. The go into the data transmission phase after building the tree. All the leaf nodes will start sending the sensed data towards their parent nodes. The parent nodes will collect the received data with their own data. Then send the collected data to their parent. The transmission process will be repeated until all the received by the root node. After root node aggregating data, it send collecting data to sink directly. The process will go around until the root node dead. WSN will re-select a new root node. Root id number would be j+1. Then do the initial phase again like above. The tree path will not change until the root node dead. TREEPIS and PEGASIS are using the same way to