Improvement in Energy Efficiency of Wireless Sensor Network

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ABSTRACT

Clustering in wireless sensor network is important to increase the lifetime of sensor network. LEACH protocol is one of the clustering routing protocols in wireless sensor networks. In LEACH each node has the equal probability to be a cluster head, due to which the energy dissipation of every node is balanced. In LEACH protocol, time is divided into many rounds and in each round, all the nodes wishes to be cluster head according to a predefined criterion. This paper focuses on the approach that how could the number of cluster heads are limited in the network, if we limit the number of cluster head to a percentage of total nodes in the network, we can increase the lifetime of the network and decrease the energy dissipation per node. These functions can be used to enhance the performance of cluster-based wireless sensor networks in terms of lifetime and throughput.

Keyword

LEACH, wireless sensor networks, clustering, energy dissipation, lifetime.

1. INTRODUCTION

Sensor nodes, sink node and management node are the three main componenets of wireless sensor network. In wireless sensor network a large number of sensor nodes are deployed in the monitored area, and wireless sensor network have the property of network through the way of self-organization. The data is monitored by sensor nodes transmitted along other nodes one by one, that will reach the sink node after a multi-hop routing and finally reach the management node through the wired and (or) wireless Internet[10]. The energy, the ability of signal process, storage capacity and communication capability of sensor nodes are very limited. A primary design goal for wireless sensor networks is to use the energy efficiently [6]. Cluster-based routing algorithm has a better energy utilization rate compared with non-cluster routing algorithm [7].

I.1 FEATURE OF SENSOR NETWORK

Wireless Sensor Networks have many benefits over the traditional network. In this section we are going to outline some features of WSNs.

1.1.1 Collaborative Objective

The objective is the most important aspect of WSN that make it different from other wireless networks [8]. Normally the main objective of wsn network is sensing an event in the environment and then this sensed event is reported to the base station. The sensor nodes collaborate to achieve the certain goal of their deployment.

1.1.2. Network Scale

Although some applications involve a small number of sensors (10-20), other applications may involve a large number of sensor nodes (100-1000) [4]. Due to recent researches in integrated circuit design technology that make the mass production of sensor devices relatively inexpensive and this make WSNs with large number of nodes common. Redundancy makes the network more robust to routing and node failures where each node has many alternative paths to reach the sink. This is another point that makes WSNs different from other network in terms of scalability.

1.1.3. Many-to-one Communication Paradigm

The objective of sensor node is to monitor signal of interest. The events will be reported by the sensor nodes to the base station where the next action will be decided by which. Thus the data flows in upstream (many-to-one); sensor nodes send their reports to the sink, and in downstream (one-to many); the sink sends queries or control messages to the sensor nodes. This is unlike internet where the traffic flows from a single server to many clients and unlike a peer-to-peer network where the traffic flows between any two nodes of the network.

1.1.4. Nodes with limited capabilities

The hardware component of sensor node is is restricted by a battery which is limited in energy and usually cannot be replenished (typically a small lithium battery rated at a few hundred mAh), slower computing speeds (about 4MHz), small memory (about 8KB flash memory and 512 bytes of RAM), low data rates (up to 20 Kbps) and limited communication range (10-100 feet) [2]. When designing the protocols at different layers, all these limitations that have a direct impact on the functioning of the network must be taken into account.

1.1.5. Clustering for Scalability

WSNs consist of large number of nodes. So, for gathering data and arbitrating the access to the wireless channel are needed. These protocols are required be scaled well even if the number of nodes has been increased. To achieve this, sensor nodes are organized in smaller sub network called clusters which helps in lower routing overheads. The clusters could consist of nodes with different hardware capabilities. In each cluster there is cluster head which receives and aggregates the data sent to it by member nodes.

2. CLUSTERING AND ROUTING

The WSNs are usually densely deployed and this feature makes WSNs different from other traditional networks [9]. Clustering has some advantages like coverage and connectivity on one hand, and disadvantages of collision and overhead in the other hand. One of the major problem of WSNs is the scalability . Accordingly, the recent developments have witnessed in WSN made it interested in the applications that need high-deployment, i.e. environmental monitoring applications, where the sensor nodes are left unattended in order to report the parameter of interest like humidity, temperature, light, etc. [7]. WSN face difficulty of recharging batteries of node in the case of such deployment, the energy efficiency became a major design goal in WSNs. Because the sensor networks are usually deployed in the area where recharging or replacement of battery is not possible. In clustering the nodes are partitioned into smaller groups called clusters. A cluster consists of a number of nodes called cluster members and a coordinator node called Cluster Head (CH), which aggregates the collected data by cluster members and send it to the sink, hence, more energy conservation.and cluster heads work as a coordinator, hence the number of nodes that access the channel are limited.

2.1 Advantages of clustering in WSNS

- scalability: Since the transmission numbers among the nodes are limited, the number of deployed nodes in the network could be high.
- Collision reduction: Because the CHs work as a coordinator, number of nodes that access the channel is limited.
- Energy efficiency: Because of the periodic re clustering in the network, the duties of CH, which consumes more energy, are distributed to the other nodes.
- Local information: Due to local communication between cluster members and respective CH, the situation of both local network and phenomenon are summarized at the CH [5].
- Routing backbone: As the CH aggregates the collected data by its cluster members and sends it to the sink, efficient routing backbone in the network can be built.

3. LEACH PROTOCOL:

LEACH is an adaptive clustering routing protocol proposed by Wendi B. Heinzelman, et al. The implementation process of LEACH includes many rounds. Each round consists of the setup phase and the steady data transmission phase. In the set-up phase, the cluster head nodes are randomly selected from all the sensor nodes and several clusters are constructed dynamically. In the steady data transmission phase, member nodes in every cluster send data to their own cluster head, the cluster head compresses the data that received from member nodes and sends the compressed data to the sink node. LEACH protocol periodically elects the cluster head nodes and re-establishes the clusters according to a round time, which ensures energy dissipation of each node in the network is relatively evenly. This protocol is divided into rounds; each round consists of two phases;

(1) Set-up Phase

- Advertisement Phase
- Cluster Set-up Phase

(2) Steady Phase

- Schedule Creation
- Data Transmission

(1) Setup Phase

Steps performed during Formation of clusters and election of cluster head Phase where, during an election phase, clusters are created using a threshold function as given in (8).

$$T(n) = \frac{p}{1 - p\left(r \ mod \frac{1}{p}\right)}, \forall n \in G \quad (1)$$

p is the difference of the desired percentage of the cluster heads.

pr is percentage of retained clusters, Initially pr is 0, as there are no clusters in the network.

r is the current round

G is the set of nodes that have not yet become head-set members for the last 1/p rounds.

1) First, each node generates a random number, which is between 0 and 1. If the random number is less than T (n), the node becomes a head-set member and acts as a CH for this election phase.

2) Each selected CH broadcasts a short-range advertisement. The sensor nodes may receive advertisements from one or more CHs.

3) Each sensor node chooses its CH on the basis of the signal strengths of the received advertisements.

4) The sensor nodes transmit short-range acknowledgments to inform their CHs about their decision. At this stage, the clusters for the current round are determined and each head-set has one associate member.

5) The CHs that have relatively large cluster sizes select a pre-defined number of additional head-set members for their clusters; the additional head-set members are chosen based on the signal strength of the acknowledgment messages. The selected head-set members cannot become head-set members until all the remaining nodes have become CHs. Iteration is defined as a duration in which all the nodes have become CHs.

6) Each CH creates a TDMA schedule for the head-set members, as well as the remaining cluster members. Seventh, CHs broadcast their TDMA schedules to their members. At the end of election phase, each head-set member checks if it has sufficient energy for next round. If the energy of any head-set member falls below the given threshold value, it is removed from the head-set; the remaining head-set members update their schedules accordingly.

(II) Steady-state phase:

Data transmission begins; Nodes send their data during their allocated TDMA slot to the CH. This transmission uses a minimal amount of energy (chosen based on the received strength of the CH advertisement). The radio of each non-CH node can be turned off until the nodes allocated TDMA slot, thus minimizing energy dissipation in these nodes. When all the data has been received, the CH aggregate these data and send it to the BS.

4. PROBLEM STATEMENT:

We suppose that the time of set-up phase is α , and the steady data transmission time is t , then the time length of every round is $t_r = (\alpha + t)$. For simplicity, we define the time when the first sensor node dies as the lifetime of the network, which is denoted as t_{fdn} . It is noted that the following analysis can be easily extended to other definition of lifetime.

$$t_{fdn} = n \cdot (\alpha + t) \quad (2)$$

According to LEACH protocol, there are *m* frames in the time *t*, so

$t_{frame} = mT$

here T_{frame} is the time length of each frame. Therefore,

$$t_{fdn} = n \cdot t_r = (\alpha + m \cdot T_{frame}) \quad (3)$$

Given the initial energy E_0 of sensor node, the t_{fdn} can be deduced according to the energy dissipation in cluster set-up phase and data transmission phase

4.1 ASSUMPTIONS:

(1) We define lifetime of sensor network as the time when the first sensor node dies which is denoted as t_{fdn}.
(2) We assume N nodes are evenly distributed in $M \times M$ area, the coordinate of the sink node is (Xsink, Ysink), the initial energy of each node is E_0, the length of data message is L bits, and the length of control message is P bits.
(3) The average distance from cluster head to the member nodes is equal to the distance from member nodes to the cluster head.
(4) Network lifetime is the product of the number of rounds (n) and the time length (t_r) of each round.
(5) A simple model for the radio hardware energy dissipation is adopted [1][3]. The transmitter dissipates energy to run the radio electronics and the power amplifier. The receiver dissipates energy to run the radio electronics.
(6) The sensor nodes are static.
(7) The number of cluster head is five percent of total number of cluster head.
(8) After the algorithm runs, nodes in the network should be uniquely identified, or cluster head, or ordinary node.
(9) We have tried to deduce the reasonable number of frames in a LEACH round is deduced to prolong the lifetime and increase the throughput.
In this thesis, we define the throughput Q as the amount of data packets transmitted from cluster head nodes to the sink node during lifetime. In the steady data transmission phase of LEACH protocol, every cluster head receives (N/ k −1) packets from its member nodes in each frame, compresses the (N / k −1) packets into one packet, and then sends the aggregate packet to the sink node. So a cluster head sends one packet to the sink node per frame. If there are m frames in the steady data transmission phase and k clusters in the network, the amount of data packets that all the cluster head nodes send to sink node is:
Q = k . n .m
As n is the function of m, so Q can be expressed as the function of m that determines the time length of round.
In this paper, we deduce the optimal k to minimize the energy consumption in a round (E). E includes the energy dissipation in both the set-up phase and steady data transmission phase.
So we have defined optimal k as:
k= arg min(k.e)
i.e. we need to find the desired value of k for which the value e is minimized, which results in increase in the lifetime.

4.2 Simulation and results

Simulation parameter are taken as same **[1]** except the initial energy of node.

Simulation parameters:

Coordinates of sink node	(50,175)
Initial energy of node	5J
Eelec	50nJ / bit
ε_{fs}	10pJ/ bit/m^2
ε_{mp}	.0013 pJ/ bit/m^4
E_{DA}	5nJ / bit / signal
Nodes	100
Network size	100x100
Data size	6400 bytes

Table1: shows the simulation parameters

Table 1 shows the simulation parameters, as our approach is if the cluster heads in the network is five percent of the total nodes in the network the life time of the network is increased considerably as shown in the following figure:

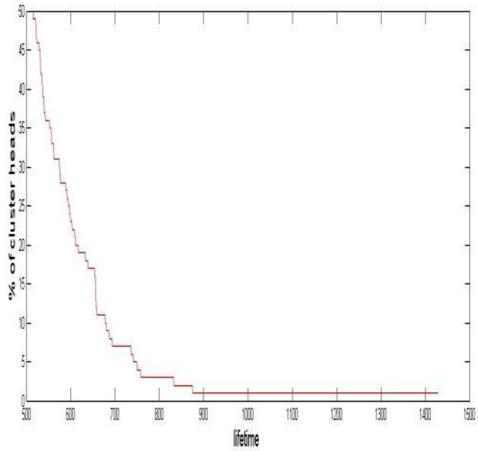

Figure1 : shows the graph between %of CH and lifetime
Results (figure1) have shown that if the cluter heads are 5% of total nodes there is increment in lifetime upto 700 secs if we compared the lifetime with previous approaches.

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