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Energy Efficient Cluster-based Routing Algorithm for Prolonging the Lifetime of Wireless Sensor Networks

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Abstract: Clustering algorithm has an important effect on the performance of wireless sensor network. In this paper, energy efficient cluster-based routing (EECR) algorithm is proposed to prolong life time of wireless sensor networks. EECR selects the cluster-heads according to the two parameters remaining energy and node degree. Also cluster-heads select its members according to the two parameters of sensor remaining energy and the distance to its cluster-head. EECR is done in three phases quickly. Simulation results show that the proposed algorithm, increase the network lifetime more than 18 percent in compare of LEACH protocol.

Keywords: Clustering; cluster head; lifetime; wireless sensor network; Routing.

INTRODUCTION

With recent advances in micro-sensors, VLSI technologies and wireless communications fields another kind of wireless network as a wireless sensor networks has been created[1]. They are usually made up with wireless sensor nodes; small, cheap, resource limited devices sensing the environment and communicating with each other[2]. Wireless distributed microsensor systems will enable the reliable monitoring of a variety of environments for both civil and military applications[3].

These networks have many limits in the network lifetime such as processing power, memory and transmitter power. Energy conservation has been identified as the key challenge in the design and operation of these networks[4]. The essential operation in clustering is to select a set of cluster heads from the set of nodes in the network. Cluster heads are responsible for coordination among the nodes within their clusters and aggregation of their data (intra-cluster coordination), and communication with each other and/or with external observers on behalf of their clusters (inter-cluster communication)[5].

In clustering, all sensors in network divided into clusters that each of these clusters has a sensor as cluster-head (CH). These sensors are homogenous and have same capability of processing, memory and power consumption. Function of cluster-head is cluster management, data collection from cluster members and sends them to the base station (BS). In recently years, multiple algorithms have been presented for clustering in wireless sensor network that in section 2, we describe LEACH [3], LNCA[4] and HEED[5] and other protocols[6-9].

RELATED WORKS

LEACH protocol [3] is one of known protocols in the clustering field. Each sensor decides whether become a cluster-head for the current round. This decision is based on the recommend percentage of cluster-heads for the network (p) and number of times the sensor has been a cluster-head so far. Each sensor chooses a random number between 0 and 1. If the number is less than a threshold T(n), the sensor becomes a cluster-head for the current round. The threshold is set as in

$$T(n)=\begin{cases}\dfrac{p}{1-p(r \bmod (1/p))} & n\in G\\ 0 & others\end{cases} \tag{1}$$

Where r is the current round and G is the set of sensors that have not been cluster-heads in the last 1/P rounds.

LNCA[4] (Local Negotiated Clustering Algorithm) present a novel clustering algorithm, which employs the similarity of nodes' readings as an important criterion in cluster formation. LNCA greatly reduces the data-reporting related traffic with reasonable clustering cost. HEED[5] periodically selects cluster-heads according to a hybrid of the sensor residual energy and a secondary parameter, such as node proximity to its neighbors or node degree.

HEED set an initial percentage of cluster-heads among all n nodes (C_{prob}), assuming that an optimal percentage cannot be computed a priori. C_{prob} is only used to limit the initial cluster-head announcements, and has no direct impact on the final clusters. Before a node starts executing HEED, it sets its probability of becoming a cluster-head, CH_{prob}, as in[5]

$$CH_{prob}=C_{prob}\times\frac{E_{residual}}{E_{\max}} \tag{2}$$

Where $E_{residual}$ is the estimated current residual energy in the node and E_{max} is a reference maximum energy, which is typically identical for all nodes. In EE_SPEED [8], clustering routing is based on a weight function, which is a combination of the three factors: Delay, Energy and Speed. MCBT [9] propose a distributed algorithm to create a stable backbone by selecting the nodes with higher energy or degree as the cluster heads.

NETWORK MODEL

Network model of my proposed algorithm as follows:

- Set of n sensors are spread in environments non-uniformly. Considering that clustering is multi-hop, density of sensors near base station is higher.
- All sensors have same capability.
- Base station and sensors location are fixed.
- Each sensor has a unique ID.

Communication between sensors and its cluster-heads is single-hop and communication between cluster-heads and BS is multi-hop.

ENERGY MODEL

In this section we introduce used energy model for transmission and receiving data packets. For transmit k-bit data to distance d, consuming energy is calculated as [3]:

$$E_{Tx}(k,d) = E_{elect} \times k + E_{amp} \times k \times d^2 \quad (3)$$

Also consuming energy to receive k-bits data is calculated as in[3,5]:

$$E_{Rx}(k) = E_{elect} \times k \quad (4)$$

PROPOSED ALGORITHM

In this paper, energy efficient cluster-based routing (EECR) algorithm is proposed to prolong lifetime of wireless sensor networks. In EECR, sensor is selected as cluster head according to the two parameters remaining energy and node degree. Also cluster-heads select its members according to the two parameters of sensor remaining energy and the distance to its cluster-head.

EECR is done in three phases, Initial, hierarchical and final phases. This algorithm perform initial phase only in beginning of network clustering and final phase in after finishing of network clustering. However, algorithm repeat hierarchical phase from first level until last level hierarchically that finish clustering of entire network. In data collection phase, sensors compare gathered environmental data with its neighboring data. If data was similar[4], sensor store ID of messages sender in the list of its neighbors and count number of neighboring and set to N_i variable.

Initial Phase

At beginning of clustering, BS that as a cluster-head of first level, transmit a "Start" message in transition range of sensors, and tell starting of clustering to all. Only sensors that are close to BS, receive this message.

Hierarchical Phase

This phase is done in four steps hierarchically that whole sensors of network can clustered.

Step 1:

In this step, the sensors that received "Start" massage (whether from BS at first or other sensors), compute the value of T for themselves. Value of T calculated based on two factors of sensor remaining energy (E_r) and number of neighbors (N_a) that as in:

$$T = \frac{E_r}{E_i} + N_a \quad (5)$$

In (5), E_i is initial energy of sensor. After the computing value of T, Sensors send it to their neighbors. Sensors receive value of T from neighbors and compare it with themselves T value. Each sensor which has largest T value, selects itself as a cluster head and selects sender of "Start" message as a its high level cluster-head.

Step 2:

After that EECR selects cluster-heads, cluster-heads must select its members. In this step, cluster-heads send a "join to me" message to all nodes in its range. Every sensor node that receive this messages from cluster-heads, calculate value of T_{CH} for them. Value of T_{CH} calculated based on two factors of sensor remaining energy (E_r) and the distance to its cluster-head (S_r) that as in

$$T_{CH} = \frac{E_r}{E_i} + \frac{S_r}{S_c} \quad (6)$$

In (6), E_i is initial energy of sensor and S_c is maximum strength of received signal.

After T_{CH} computing, sensors select sender of highest T_{CH} as its cluster-head and send a "join to you" message to it.

Step 3:

In this step, cluster-heads create a TDMA scheduler according to cluster members that receive "join to you" message from them and send TDMA to all.

Step 4:

In this step, cluster-heads transmit “Start” massage in itself radio range for selecting clusters of next level and step1 repeated hierarchically that entire network be clustering.

Final Phases

Data collected by sensors from environment and delivered to BS by cluster-heads. This work performed by members and cluster-heads as below:

- Member sensors gather data from environment and send to itself cluster-head in its scheduled transmission time. The radios transmitter of other sensors is turned off until their allocated transmission time to save the energy.
- Cluster-heads receive data packets from its members and also receive from low levels cluster-heads. Then they perform data aggregation on received data and transmit to its high level cluster-head.

SIMULATION AND PERFORMANCE EVALUATION

We simulate EECR and LEACH protocols by MATLAB software and compare efficiency of them. Proposed algorithm is simulated in 300*300 field. Simulation results averaged after 20 times running. The assumptions for simulation are considered as is Table I. In Table I, E_{DA} is required energy for data aggregation.

Fig. 1 shows number of dead sensors because of finish batteries during the rounds in EECR and LEACH protocols. Comparing of two graphs of Fig. 1 implies the network lifetime of EECR will be increase further than LEACH protocol.

Table I. Simulation assumptions

Parameter	***Value***
Field	300*300
BS location	(0 , 150)
numbers of Sensors (n)	50
Sensor Range	150 m
E_r	1.5 J
E_{elec}	50 nJ
E_{amp}	100 pJ
E_{DA}	5 nJ
Package length	1000 bit

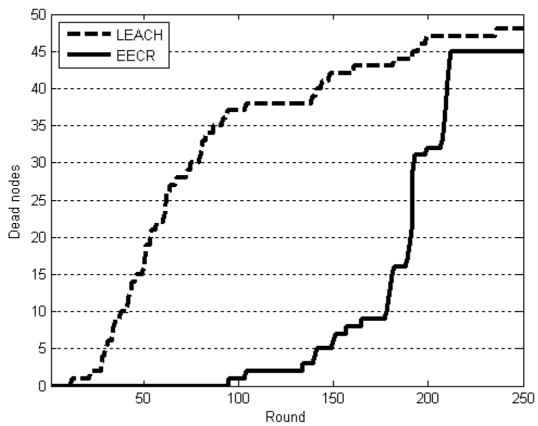

Figure 1. Number of dead nodes.

This variation was created due to EECR being multi-hop versus LEACH. When half nodes of network die, almost efficiency of network is low. In mean state, EECR improve this time more than four times. Also it improve dead time of last node (e.g. network life time) 18%.

Fig. 2 shows total energy of nodes in network during the rounds in EECR and LEACH protocols.

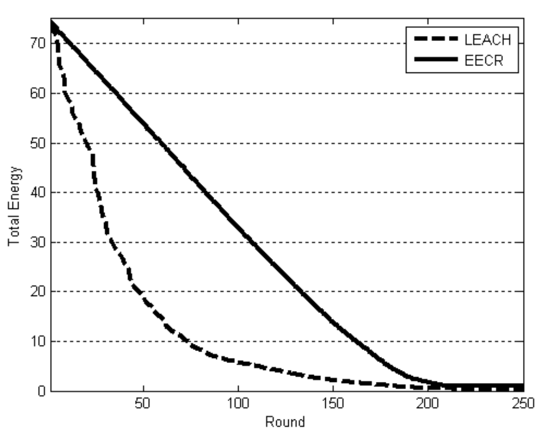

Figure 2. Total Energy of nodes in Network.

Fig. 1 indicates the energy consumption of nodes in LEACH is more than EECR.Fig. 3 and Fig. 4 show status of nodes in round 170 of networks in EECR and LEACH protocols.

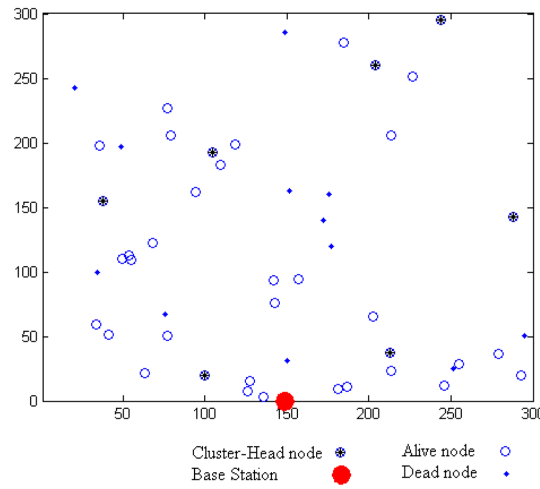

Figure 3. Status of nodes in EECR.

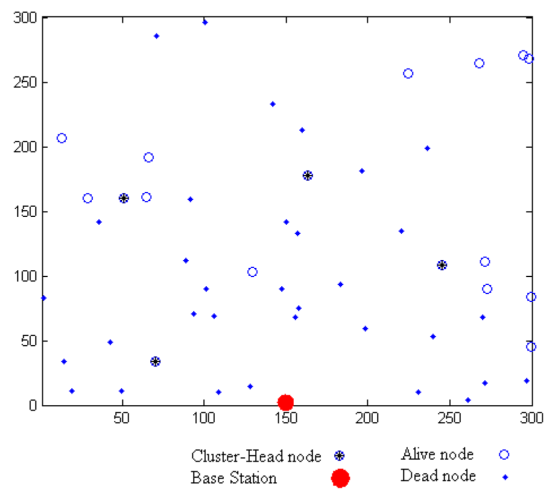

Figure 4. Status of nodes in LEACH.

Fig. 3 and Fig. 4 indicate the number of dead nodes in LEACH is more than EECR.

CONCLUSIONS

For extending lifetime of wireless sensor networks, in this paper an energy efficient cluster-based routing algorithm is proposed to increases life time of wireless sensor networks.

EECR selects the cluster-heads according to the two parameters remaining energy and node degree. EECR is done in three phases quickly. Also members join to cluster-heads according to two factors, maximum energy and the distance to cluster-head. Then we simulate EECR and LEACH protocols and compare efficiency of them. Simulation results show that EECR prolong life time of network 18% nearly. EECR has a good scalability and network life time prolong further with increasing scale of network.

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