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Energy-Efficient Routing in Wireless Sensor Networks to Improve the Life Time of Sensor Nodes

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Abstract-Energy-efficient routing is a critical problem in multihop WSN due to the severe power consumption of wireless nodes, the research on routing algorithm is pivotal in the architecture of WSN. This paper analyzes the implementation and existing issues in LEACH. Specifically for node energy and the network lifetime, it proposes an energyefficient routing algorithm based on cycle-switching cluster head. It improves node energy efficiency, balances energy consumption of all sensor nodes, enhances reliability of data transmission and increase network lifetime in comparison to LEACH. Simulation results showed that the algorithm is efficient. Moreover, the protocol increases the balance of energy dissipation, scalability and reliability of WSN.

Keywords: routing protocol; clustering; network lifetime; minimum cost

I. INTRODUCTION

Sensor networks have emerged as a promising tool for monitoring (and possibly actuating) the
physical world, utilizing self-organizing networks of battery-powered wireless sensors that can sense, process and communicate. In sensor networks, energy is a critical resource, while applications exhibit a limited set of characteristics. Thus, there is both a need and an opportunity to optimize the network architecture for the applications in order to minimize resource consumed. The requirements and limitations of sensor networks make their architecture and protocols both challenging and divergent from the needs of traditional Internet architecture. A sensor network is a network of many tiny disposable low power devices, called nodes,which are spatially distributed in order to perform an application-oriented global task. These nodes form a network by communicating with each other either directly or through other nodes. One or more nodes among them will serve as sink(s) that are capable of communicating with the user either directly or through the existing wired networks. The primary component of the network is the sensor, essential for monitoring real world physical conditions such as sound, temperature, humidity, intensity, vibration, pressure, motion, pollutants etc. at different locations.

The tiny sensor nodes, which consist of sensing, on board processor for data processing, and communicating components, leverage the idea of sensor networks based on collaborative effort of a large number of nodes**.**

Applications of Sensor Networks

In the recent past, wireless sensor networks have found their way into a wide variety of applications and systems with vastly varying requirements and characteristics [6][8]. The sensor networks can be used in Disaster Relief, Emergency Rescue operation, Military, Habitat Monitoring, Health Care, Environmental monitoring, Home networks, detecting chemical, biological, radiological, nuclear, and explosive material etc. as summarized in table 1.

Table 1: Some applications for different areas.

Area	Applications
Military	Military situation awareness[6]. Sensing intruders on basis. Detection of enemy unit movements on land and sea [4]. Battle field surveillances [5].
Emergency situations	Disaster management [9]. Fire/water detectors [2]. Hazardous chemical level and fires [4].
Physical world	Environmental monitoring of water and soil [7]. Habitual monitoring [7]. Observation of biological and artificial systems [7].
Medical and health	Sensors for blood flow, respiratory rate , ECG(electrocardiogram),pulse oxymeter, blood pressure and oxygen measurement [10]. Monitoring people's location and health condition [5].
Industrial	Factory process control and industrial automation [6]. Monitoring and control of industrial equipment [2].
Home networks	Home appliances, location awareness (blue tooth [2]). Person locator [17].
Automotive	Tire pressure monitoring [2][3]. Active mobility [8]. Coordinated vehicle tracking [6].

II. ANALYSIS OF LEACH

A. The Algorithm of LEACH

LEACH(Low Energy Adaptive Clustering Hierarchy) was the first sub-cluster-style routing protocols in WSN. Most of the subsequent sub-cluster routing protocols are developed on the basis of LEACH.LEACH conserves energy because it uses data compression techniques and sub-cluster dynamic routing technology. With the nodes set to cluster head node in random, it balances the load of the network and prevents the rapid death of cluster head nodes [2]. The process implementation of LEACH is cyclical. The round circle is divided into clusters of the establishment phase and stable data communication phase. In the stage of the cluster establishment, it randomly generates cluster head; in the stage of data communication, cluster nodes sent data to the cluster head, cluster head performs data, and the results will sent to the sink node. The cluster head selection process of LEACH is as follows: the nodes generate a random number between 0-1, if this number is less than the thresholds *T(n),* then it publish a notice that they are cluster head messages. In each round of circulation, if the node has been selected as cluster head, *T(n)* is set to 0, so that the node does not re-selected as cluster head[3]. When the node is not selected, it will be the selection of probability *T(n)*; With the increasing number of unselected nodes, the threshold *T(n)* of the remaining selected cluster head is even greater, the node produces the probability of the random number which is less than *T(n)* will be even greater, so the probability of cluster head node will increases. *T(n)* can be expressed as:

$$T(n) = \begin{cases} \dfrac{P}{1 - P * (r \bmod \frac{1}{P})} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases}$$

P is the cluster head in the percentage of all nodes, r is the number of selection rounds, *r* mod (*l/P*) is selected the number of cluster head nodes in a cycle, *G* is not selected cluster head node set.

B. The Deficiency of LEACH Algorithm

From the formula, the short-comings of LEACH are analyzed:

1. From the *T(n)*, the cluster head node which is selected will not become a cluster head in the next *1/P* recycling round. The threshold value *T(n)* of the remaining node will increase. The node produces the probability of random numbers which is less than *T(n)*, the probability of the selected cluster head will increases. The value of *P* determines the number of cluster head in each round. However, how to determine the best value P is very difficult in practical applications because it relates with the size and density of the network [4].
2. *T(n)* does not consider the energy factor. This algorithm must be based on two assumptions in order to achieve the average energy consumption target: (1) the initial energy of each node is equal ;(2) the energy consumption is equal when each node is selected as a cluster head. However, the size and distance from the cluster head to the base a station is different.
3. As the first round after the establishment of a fixed cluster head, this cluster head makes much more energy. The algorithm selects cluster head frequently and changes the network layer structure, so it increases energy costs [5].

The deficiencies of the formula *T(n)* in LEACH, the algorithm takes the energy into account, the formula of *T(n)* is improved.

$$T(n)_{new} = \frac{P}{1 - P \times (r \bmod P^{-1})} \frac{E_{n\_current}}{E_{n\_max}}$$

Where $E_{n\_current}$ is the current amount of energy and E_{n_max} is the initial amount of energy

En_current is current energy of the node, *En_max* is initial energy. Formula (2) is improved, so that a lower proportion of energy consumption is selected as cluster head node priority [6].

Experimental results show that the node selection based on LEACH can effectively improve the network life cycle of 20%. However, the formula (2), there is a defect of this improvement. When the network is running quite a long period of time, all the current energy nodes have become low, then the threshold *T(n)* will be smaller, the probability of all nodes selected as a cluster greatly reduces, each of the selected cluster head reduce, eventually network energy consumption is not balanced, the life cycle of network becomes shorter. So the calculation of *T(n)* is improved. *rs* is the selected cluster head rounds. Once cluster head is selected, *rs* resets to 0.

Pseudo-code for leach protocol:-

BEGIN

1: Specify the probability (*pset*), number of nodes (n);
2: Einit(s)=E0, s=1,2, …, n;

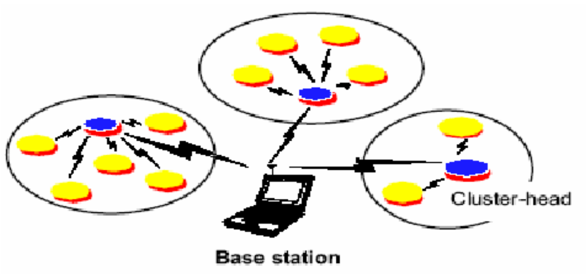
(I) PREPARATION PHASE

1: **if** (Einit(s)>0 & rmod(1/pset)≠0) **then** //pset can set≥0.5
2: r<-random(0,1) and compute T(s); //given by (1)
3: **if** (r < T(s)) **then**
4: CCH{s}=TRUE; //node s be a candidate CH
5: **else**
6: CCH{s}=FALSE; //node s not be a candidate CH
7: **end if**
8: **end if**
9: SendToBS(IDu, (xu,yu), CCH(u)) <-All nodes send messages to BS;
10: GAinBS(*popt*)<-Optimal probability is determined;
11: BC (*popt*) <-BS broadcasts a message back to all nodes;

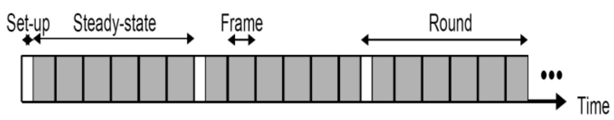
(II) SET-UP PHASE
1: **do** { //repeat for r rounds
2: r<-random(0,1);
3: **if** (Einit(s)>0 & rmod(1/popt)≠0) **then**
4: compute T(s); //given by (1)
5: **if** (r < T(s)) **then**
6: CH{s}=TRUE; //node s be a CH
7: **else**
8: CH{s}=FALSE; //node s not be a CH
9: **end if**
10: **end if**
11: **if** (CH{s}=TRUE) **then**
12: BC (ADV)<-broadcast an advertisement message;
13: Join(IDi); //non-cluster head node i join
into the closest CH
14: Cluster(c); //form a cluster c;
15: **end if**

(III) STEADY-STATE PHASE
1: **If** (CH(s)=TRUE) **then**
2: Receive(IDi, DataPCK) //receive data from members;
3: Aggregate(IDi, DataPCK) //aggregate received data;
4: TansToBS(IDi, DataPCK); //transmit received data;
5: **else**
6: **If** (MyTimeSlot=TRUE) **then**
7: TansToCH(IDi, DataPCK); //transmit sensed data;
8: **else**
9: SleepMode(i)=TRUE; //node i at a sleep state
10: **end if**
11: **end if**
12: } // one round is completed
END

LEACH-Architecture



Phase Life of Leach Protocol



Timeline showing LEACH operation
Each Leach operation ***round*** consists of Set-up phase (*clusters are organized*).

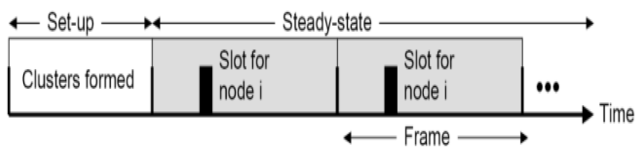
1. Cluster Head Selection.
2. Cluster Formation.

Steady state Phase (*data transmission*).

Setup phase

At the beginning of each round, each node advertises it probability, (depending upon its current energy level) to be the Cluster Head, to all other nodes. Nodes with higher probabilities are chosen as the Cluster Heads. Cluster Heads broadcasts an advertisement message (ADV) using CSMA MAC protocol. Based on the received signal strength, each non-Cluster Head node determines its Cluster Head for this round (random selection with obstacle). Each non-Cluster Head transmits a join-request message (Join-REQ) back to its chosen Cluster Head using a CSMA MAC protocol. Cluster Head node sets up a TDMA schedule for data transmission coordination within the cluster.

Steady-State Phase



Timeline showing LEACH operation

TDMA schedule is used to send data from node to head cluster. Head Cluster aggregates the data received from node cluster's. Communication is via direct-sequence spread spectrum (DSSS) and each cluster uses a unique spreading code to reduce inter-cluster interference. Data is sent from the cluster head nodes to the BS using a fixed spreading code and CSMA.

Assumptions

Nodes are all time synchronized and start the setup phase at same time.

1. BS sends out synchronized pulses to the nodes.
2. Cluster Head must be awake all the time.

To reduce inter-cluster interference, each cluster in LEACH communicates using direct-sequence spread spectrum (DSSS). Data is sent from the cluster head nodes to the BS using a fixed spreading code and CSMA.

B. The Cluster Head Competition

After acquiring the network parameters, cluster head is generated by rotation approach [7]. In order to balance the node energy consumption, the radius of all nodes is determined by non-linear way and the hops of the node to the sink.

C. Cluster Formation

Cluster formation includes cluster generation and cluster migration. Based on the feedback between the adjacent nodes each node operates independently the algorithm, resulting in two logical parts of cross-iteration to form clusters.

Algorithm is running, the node is divided into three kinds of state：unclustered, clustered and the cluster-head. Unclustered node does not join any cluster, clustered node has become a member of one or more clusters. In each round of iteration cycle, the nodes run different algorithm according to different state. When all nodes have been completed after the iterative algorithm, there are not be covered by a small amount of nodes, so it finally need to conduct a "clean-up" iteration, the clusters do not occur in the process of migration, all the nodes are not covered by a cluster head or through a neighbor node to other cluster members of the multi-hop node.

D. Data Transfer Phase

When the cluster head receives "report" message from the members of other node. Nodes will produce TDMA (Time Division Multiple Access) scheduling table. Once the network has been formed in the cluster, and the TDMA scheduling table has also been set down, it began sending the data [8]. In the sending phase, their own time slot does not come; the members of the node will shut down the transceiver in order to save energy. The receiver of cluster head node must always be turned on to receive data from different node. When a data transfer has been completed, Cluster head will receive data, the received data will be fused into a new data. In order to avoid the impact of this situation, different cluster uses the mechanism CDMA (Code Division Multiple Access, Code Division Multiple Access).In this method, the cluster within the other cluster signals will be finished.

IV. SIMULATION RESULTS AND ANALYSIS

Using object oriented modeling technique to emulate this new algorithm based on MATLAB7.1 platform, the results are compared with LEACH and MA. The network consists of 100 nodes randomly distributed in the area 100m*100m. Table1 shows a simulation of a specific environmental parameters setting. From Fig.1, it can be seen: the first node in a data transmission time of death rounds the algorithm is superior to LEACH algorithm. with node energy consumption and the increase number of deaths, the algorithm consumes more energy than LEACH in clustering process, it prolong the lifetime of a sensor network by 30%~36% over that of LEACH in different scenes while still maintaining the simplicity of LEACH[7].

Table- System Parameters

Parameters Value

TABLE I. SYSTEM PARAMETERS

Parameters	Value
E_o	1.0J
E_{elec}	50e-009J/bit
ε_{fs}	10e-012J/bit/m^2
ε_{mp}	1.184e-018J/bit/m^4
E_{DA}	5e-009J/bit/signal
C	200bits
D	4000bits

From Fig.2, it shows two kinds of algorithms and LEACH about the total energy of the network data transmission rounds. When transmission rounds in the same amount of data, the residual energy of network means that algorithm is more energy, the survival of the network longer.

Compared with LEACH algorithm, the algorithm saves energy more than LEACH. The node life-cycle is cycle is almost increased with the initial energy increases linearly related. Simulation results show that the proposed strategy can save node energy, prolong the network lifetime, and increase network reliability.

V. CONCLUSION

This paper proposes an energy-efficient routing algorithm based on cluster-head prediction and power control. It uses energy and distance parameters to predict the cluster head. Meantime, the mechanism of power control is introduced to sub-cluster routing and data transmission process. Using nonlinear methods to dynamic sub-cluster node, cluster-head nodes forward the data to balance energy consumption. The analysis and experiment results show that, compared with leach, the proposed protocol considers the influence to route mechanism from the route hop number, node position, and energy consumption of each node. Furthermore, it can reduce the delay of data forwarding and satisfy the demand of WSN application.

Fig 2

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