Energy-efficient Transmission based on Hierarchical Routing Protocol for Wireless Sensor Networks

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ABSTRACT
In wireless sensor networks (WSN) energy consumption is the most critical problem because each sensor node has limited batteries. In order to reduce energy consumption and to optimize the network life-time of this kind of networks clustering algorithms have been widely used. LEACH is the most popular clustering algorithm, which used an interesting technique to select a cluster head alternately and to build cluster. In this work, we propose a new scheme to select cluster head according to the residual energy of nodes. The simulation results show that proposed algorithm achieve longer stability period and network life-time by comparison to other clustering approaches i.e. LEACH, ALEACH, LEAHC-DCHS and LEACH-SWDN.

Keywords
Wireless sensor networks; energy consumption; clustering; homogeneous; life-time, stability period

1. INTRODUCTION
Many advanced work have been done in WSN which is used in many applications as home security, healthcare applications, intrusion detection, sensing ambient conditions such as sound, pressure, gas concentration and temperature [1, 2]. A wireless sensor network has characteristics of self-organization and energy constraints [3, 4].

A WSN consists of a large number of sensor nodes that deployed in an area of interest (general inaccessible areas). All sensor nodes should collaborate with each other in order to transmit their sensed data to the base-station (BS) and finally accomplish the sensing and communication task. In these kinds of network wireless transmission is the most energy consuming operation and sensors nodes are limited battery. Therefore, energy efficiency is a very crucial issue [5-6] and energy consumption transmission protocol is required to maximize network lifetime.

Energy consumption is more studied and modeled to generate protocols and models for improvement of the performance as particularly a lifetime of WSN which is extremely important [5-14]. Clustering algorithms were most used [8-15]. The principle is to divide the network into clusters. For Each cluster a CH node is designated. The member nodes send data to the CH that will route them to the BS after aggregation.

LEACH [8] is the best-known clustering algorithm for wireless sensor network. The good idea of this algorithm has allowed several researchers to do an improvement and even draw inspiration for new algorithm for better control and energy conservation in WSN as the protocols: LEACH-DCHS [9], ALEACH [10], LEACH-SWDN [11]. LEACH is based on weighted election probabilities assigned to each node to become CH without taking account to their residual energy. Some nodes are more frequently becomes CHs and spend most of energy. It may happen after some rounds the energy of this nodes becomes less than other nodes and the network becomes heterogeneous on energy. To overcome this drawback, this work presents, a new CH selection scheme tacking account residual energy of each node and the threshold energy of live nodes. By using these criteria, we hope increases stability and lifetime of network.

2. LEACH PROTOCOL
LEACH is the first adaptive hierarchical clustering routing protocol [8,12]. The idea of LEACH is to organize WSN into clusters. Each cluster has a CH whose using as local routers to the BS: Each node transmits sensed data to its closest CH. The CH for each cluster after receiving all the data from cluster members performs aggregation and then transmits both an aggregated packet to the BS through a single-hop relay in order to reduce the amount of information transmitted to the base station.

LEACH consists of two phases: the set-up phase, and the steady-state phase. In setup phase, a few nodes are selected randomly as cluster heads (CHs) and nodes are organized into clusters and in the steady state, the time slot scheduling is creating and the data transmission to the BS is held.

CHs has to consume more energy as compare to member nodes, in order to balance the energy of the network LEACH operates in several rounds, each consisting of a set-up and a steady-state phase.

In the set-up phase one node is selected as CH based on the threshold T(i) given by eq. 1 and the generated random number. The threshold T(i) is defined as follows [8]:

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

Where p is the cluster head probability, G is the set of nodes that have not been cluster heads in the last 1/p rounds and r is the current round.

In LEACH each node becomes a cluster head only for a single time for $r = \dfrac{1}{p}$ rounds. In the beginning of each rounds every node belong to G generates a uniform random number in the interval [0, 1]. The node is selected as a cluster head for the current round if the random number is less than the T(i) otherwise the node is expected to join the nearest cluster head in its neighborhood.

3. THE PROPOSED MODIFIED LEACH PROTOCOL

LEACH randomly selects a cluster heads and there are no restrictions on their distribution and on their energy level as showing in eq. 1. This is meaning that nodes with low residual energy may be selected as cluster head with the same probability of those with high residual energy. As mentioned above LEACH let every node to become CH one in every $\frac{1}{p}$ rounds. With a paste round, it is obvious that all the nodes do not the same residual energy. So, if the period 1/p which one node can become CH is kept equal for all nodes as in LEACH the energy is not uniformly distributed and nodes having low energy can be CH and die quickly before nodes with high energy. Therefore, the level of the residual energy of the nodes should be considered in order to making nodes with higher residual energy level have the bigger probability to elect itself to be cluster head. In order to take account, the residual energy, the average probability for cluster head must be depending to residual energy and can be given as:

$$pi = po\frac{E_r(i)}{Eo} \qquad (2)$$

The threshold value for each node to become a cluster head during each round becomes:

$$T(i) = \frac{pi}{1 - pi * (r \bmod \frac{1}{pi})} \quad \text{if } s \in G \qquad (3)$$

Doing this, the nodes with higher energy have more chance to become CH. With this approach, it is more likely to ensure energy balance of the entire network, prolong the network stability period and lifetime.

3.1 Algorithm Description

In each round nodes decides to become CH based upon pi and threshold T(i) given in eq. 2 and eq. 3 respectively. Indeed, each node having residual energy great or equal Ev generates a uniform random number in the interval [0,1], if this number is less than the threshold T(s), then this node is candidate to become a cluster head. The proposed algorithm comports two phases: set-up phase and steady-state phase as follows:

```
BEGIN
//Set-up phase :

      specify po, a,rmax
      Er(i)=Eo, i=1, …,n
    if (rmod(1/pi) !=0 &&  Er(i)>=Ev)
       then
        temp ← random(0- 1)
         compute T(i)  // given by (2)
         if (temp <T(i) ) then
              node(i) ←CH; //node be a CH
              number CHs←number CHs+1
         else
               node(i) ←normal node;
         end if
      endif
      if (node(i)=CH) then
        CHs broadcast CH-status;
            non-CH send join-request message to
            closest-CH
             Clusterss(c); //form a cluster c
        end if
  // Steady-state phase: Similar than LEACH
        if (node(i)=CH) then
             Receive data from members;
             Aggregate and transmit received data to
              BS;
        else
            if (TimeSlot) then
                transmit data to associate CH;
            else
               node i at a sleep state;
             end if
        end if
 END
```

4. RADIO DISSIPATION

The energy required by the transmit amplifier $T_{Tx}(l,d)$ to transmit l bit message between a transmitter and receiver over a distance d is [8-12]:

$$T(i) = \begin{cases} l \times E_{elec} + l \times \varepsilon_{fs} \times d^{2} & \text{if } d \le d_0 \\ l \times E_{elecs} + l \times \varepsilon_{mp} \times d^{4} & \text{if } d \ge d_0 \end{cases} \qquad (4)$$

Where $d_0 = \sqrt{\varepsilon_{fs} / \varepsilon_{mp}}$ is the threshold distance, Eelec represents the energy consumption in the electronics for sending or receiving one bit. The terms $\varepsilon_{fs} \times d^2$ and $\varepsilon_{mp} \times d^4$ represent respectively the amplifier energy consumptions for a short and long-distance transmissions .

5. SEMULATIONS AND RESULTS

This section evaluates the performance of proposed protocol using MATLAB. We will interest about network lifetime (N.L.T: time period from the start of the network until the death of the last node), period stability (PS: time period from the start of the network until the death of the first node) and energy consumption.

The Lifetime of a network refers to the time period from the start of the network until the death of the last node.

We consider a WSN with 100-node sensor randomly deployed inside 100m×100m (Fig. 1). The BS is located at coordinate (50,175).

The simulation parameters used are listed in Table 1 according to the radio basic energy dissipation model [7-10].

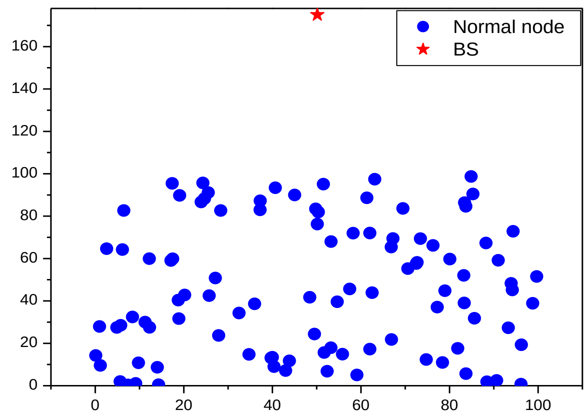

Fig. 1: Random deployment of sensors nodes (100 nodes, 100m x100m).

Fig. 2 show comparison between the proposed protocol and other clustering approaches i.e. LEACH, ALEACH, LEAHC-DCHS and LEACH-SWDN regarding number of a live nodes. It can be seen that the proposed protocol prolonged lifetime network significantly compared with all other protocol. In our case the network remains alive almost up to 3000 rounds assuring network life-time to be more optimized. Moreover, it is also obvious that stability period is also improved i.e., first node dies around 1740 rounds whereas, in schemes like LEACH, ALEACH, LEAHC-DCHS and LEACH-SWDN this value is much lower.

Table 1: Simulation parameters

Parameters	values
Number of nodes	100
Field simulation	100m x 100m
Base station position	(50,175)
Initial energy (E0)	0.5 J
Transmitter Electronics (Eelec)	50 nJ/bit
Receiver Electronics (Eelec)	50 nJ/bit
Length of data packet (Bytes)	3000
Transmitter Amplifier (ε_{fs}) (If $d < d_0$)	10 pJ/bit/m^2
Transmitter Amplifier (ε_{mp}) (If $d > d_0$)	0.0013 pJ/bit/m^4
Probability of CH	0.05

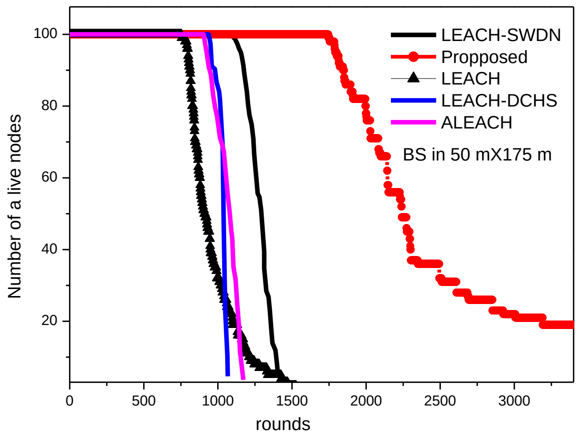

Fig. 2: Wireless Sensor Network lifetime (BS in 50m x175 m)

Table 2: Comparison of network parameters

	LEACH	ALEACH	LEAHC-DCHS	LEACH-SWDN	proposed
S.P	750	900	950	1115	1740
N.L.T	1750	1066	1172	1400	>3000

Table 2 show comparison of network parameters ie. network lifetime (N.L.T) and stability period (S.P). From table 2 it is clear that the proposed protocol performs quiet well comparing with LEACH,ALEACH, LEAHC-DCHS and LEACH-SWDN.

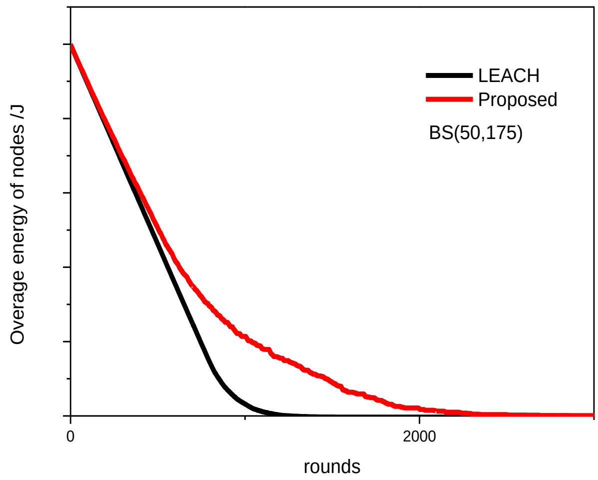

Fig.3 The energy consumption

Fig. 3 compared the energy consumption between the LEACH and our protocol during the simulation time. Dissipation of energy is due to the operations performed, such as sensing operations, data processing and communication. It is shown clearly that our protocol consumes less energy than LEACH.

6. CONCLUSION

In this paper, we proposed an algorithm based on LEACH to improve WSN lifetime. In the proposed routing protocol, we consider the residual energy to select CH nodes. Presented simulation results shows that the improved algorithm can balance the network energy consumption, prolong the network lifetime and increase the stability period. As future work, study of proposed protocol is envisaged, in the case of a network with sensor nodes heterogeneous.

7. REFERENCES

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