A Novel Approach for Energy-Efficient of WSN Using PEGASIS Protocol

Mohammed KADDI[1] *, Yamina MALOUKI[2], Moamen Adel Abdelfattah Alnatoor[1]

[1]LDDI Laboratory, University of Adrar Adrar, Algeria
[2]Mathematics and Computer Science Department, Faculty of ST, University of Adrar, Algeria
*Corresponding author: kaddimohammed1983@univ-adrar.edu.dz

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ABSTRACT

Wireless Sensor Networks (WSNs) have hardware and software limitations and are deployed in hostile environments. The problem of energy consumption in WSNs has become a very important axis of research. To obtain good performance in terms of the lifetime of the WSN, several routing protocols have been proposed. We present in this article a new approach for the energy efficiency of WSN by using the PEGASIS (Power Efficient Gathering In Sensor Information Systems) routing protocol in order to reduce sensor energy consumption and to achieve good performance in terms of the lifetime of the network in WSN. The simulation results have shown that our proposed protocol excels regarding energy consumption in wireless sensor networks, resulting in an extension of a lifetime for the network. We simulated the proposed technique compared with traditional LEACH (Low-Energy Adaptive Clustering Hierarchy) protocol using MATLAB environment.

I. Introduction

Many micro-sensors are deployed in nature to create a network of sensors for both control and monitoring purposes. Wireless Sensor Network (WSN) is generally composed of a large number of low-cost, low-power, and multifunctional sensor nodes that are randomly deployed in an area of interest for various types of applications such as civil, military, commercial, industrial, healthcare, security, and emergency surveillance. These sensors collaborate and relay the information from node to node in multi-hop mode and via a wireless connection to the base station (BS).

However, this communication scheme is expensive in terms of energy because any node plays the role of a relay node since it sends back the information received for the first to its neighbors. This communication process repeats until the arrival of the information at the BS. Consequently, to remedy this drawback, several routing protocols have been proposed in the literature, on the one hand, to transfer the information quickly to the base station at a lower cost. Routing protocols based on the network structure can be classified into two categories: flat protocols and hierarchical protocols.

In a flat topology, all sensor nodes have the same role and collaborate to accomplish the routing task. Flat networks are characterized by: the simplicity of the routing protocols, high fault tolerance, and the ability to construct new paths following changes in topology. However, the nodes close to the base station participate more than the others in the routing process. In addition, the performance of these networks decreases in the case of highly dense networks [1]. This consideration has driven to data-centric routing [2], where the base station sends requests to some region and waits for data to be sent from that specific area. Since data are being requested through queries, attribute-based naming is necessary to specify the properties of data. This category includes Directed Diffusion [3], SPIN [4], Rumor Routing [5], and EBRP [6].

In a hierarchical topology, the nodes have different roles. Indeed, some nodes are selected to perform particular functions such as data aggregation and data routing. One of the most commonly used methods in this topology is clustering. It consists of partitioning the network into clusters. A cluster consists of a cluster head (CH) and its members. Depending on the architecture adopted, members may be direct neighbors of the cluster head or not. This topology helps save bandwidth through the aggregation of data collected by cluster heads and great scalability. Its major disadvantage is the overloading of the cluster heads which induces an imbalance of the energy consumption in the network. To remedy this problem, cluster heads can be selected according to their energy capabilities and their election should be periodic [1]. In this group, there are some routing protocols such as LEACH [7] and PEGASIS [8].

In this paper, in order to extend a wireless sensor network’s lifetime, we present an energy-efficient clustering scheme based on a hybrid between our proposed technique and the LEACH protocol. This proposed protocol is an improvement of the PEGASIS protocol. We note that the proposed protocol is centralized because the data path construction between the CHs is done by the BS.

The rest of this paper is organized as follows. In Section II, the related work is discussed. Section III explains the approach. In Section IV, we give a performance evaluation of the proposed method via simulations and compare the results with the LEACH protocol. Finally, Section V concludes the paper, and future work is pointed out.

II. Related Work

Electricity production as in [9] and energy-saving as in [10] are two important current challenges in the field of research. In the literature, there are several protocols and energy-efficient cluster-based routing algorithms have been proposed to save energy and therefore extend the network lifetime. We quote in this paper some of the algorithms related to our work, among which we quote the following:

Low-Energy Adaptive Clustering Hierarchy (LEACH) [7] is one of the most popular distributed cluster-based routing protocols. The idea of LEACH consists in forming a cluster of sensor nodes based on the amplitude of the received signal and using the CHs elected as routers. Based on time division multiple accesses (TDMA), the sensor nodes transmit data to the CHs. These cluster heads collect data from all cluster members; fuse and aggregate data gathered by merge procedures, and transmit this data directly to the BS. Data collection is periodically sent to a central sink. LEACH protocol is executed in rounds of two phases: construction and communication. The duration of the communication phase is longer than that of the construction phase in order to minimize the overhead.

PEGASIS (Power-Efficient GAthering in Sensor Information Systems) [8] an extension of LEACH. It is a chain-based protocol. The basic idea of this protocol is that the nodes will be organized in a chain so that the nodes transmit and communicate only with their nearest neighbors. The only node that sends data from the chain directly to the BS is the leader.

Directed Diffusion [3] is a data-centric routing protocol allowing multiple paths to be used for routing information. It consists of various elements: interests, gradients, data messages, and reinforcements (positive and negative). Interest is a request, in which it specifies the desired data, sent by the base station (sink node) to the sensor nodes. The principle of the DD protocol is as follows: The "Sink" node begins sending, to all the nodes, an interesting message to start a specific application. This packet will be acknowledged by another called gradient. A gradient is a response link on the part of the neighbor receiving the interest. Using the interests and gradients, several paths can be established between the sink and the source. One of these paths is selected by reinforcement. If this path fails a new or alternate must be identified.

SPIN (Sensor Protocols for Information via Negotiation)[4] is one of the adaptive protocols proposed to overcome the resource ignorance problem faced in the flooding technique by using negotiation and adaptation to available resources. It is based on a data-centric routing, where the nodes of the sensors broadcast an advertisement for the available data and await a request from the wells concerned. It is designed to remedy the deficiencies of conventional flooding by negotiating and adapting resources. SPIN uses three types of messages: ADV, REQ, and DATA. Before sending a DATA message, the sensor node sends an ADV message that contains the descriptor, that is, the metadata of the DATA. If a node wishes to receive this data, it sends a REQ message so that the DATA is sent to this node of the neighboring sensor. The node of the neighboring sensor then repeats this process. Thus, in this way, only the sensor nodes in the whole sensor array that are interested in the data of the transmitted message will have a copy.

The authors in [11] have proposed a new optimization technique for energy saving for wireless sensor networks called Tree-Correlation (Tree-Corr) using the tree structure as a routing protocol to reduce the data transmission distance of nodes at the base station. They proposed three scenarios for our approach according to the method of deploying nodes in the area of interest. The simulation results show that the first scenario which took into account the number of sensors in each level during the deployment of the sensors, in particular, the number of sensors deployed at level n + 1 greater than the number of sensors deployed at level n offers energy efficiency compared to the other two scenarios.

Several works have used metaheuristic methods for different purposes such as the works cited in [12],[13], [14]. Sweta Potthuri et al. [15] proposed a hybrid DE and simulated annealing (DESA) for clustering operation and cluster leader selection. The energies of the nodes and the distance between the nodes and the CH are the two factors taken into account by the proposed fitness function to determine the different clusters and to select the heads of the clusters. Simulation results show that DESA increases the network life cycle compared to other algorithms.

III. Proposed Approach

III.1. System Model

1) Network Model

In this paper, we use the same sensor network as the WSN model used in [16]. In our model, the nodes N are uniformly distributed randomly or manually in an area that has a dimension N*M. During the deployment of the nodes, we took into account the following criteria:

- All sensor nodes and the BS are immobile,
- The coordinates of the sensor nodes must be found by an automatic position detection mechanism,
- All nodes have the same initial energy,
- The BS has a huge capacity in terms of computing power, energy, memory, and storage,
- The energy required to transmit a data packet from the sensor node to the other is the same as to transmit a packet in the opposite direction,
- The technique used to decrease the amount of data sent is the data fusion technique.

2) Consumption Model

We use the same simple model shown in [16] for the radio hardware energy consumption where the transmitter dissipates energy to run the radio electronics and the power amplifier, and the receiver dissipates energy to run the radio electronics. Both the free-space channel (energy dissipation of d2) and the multi-path channel (energy dissipation of d4) are used according to the distance between the transmitter and the receiver. Thus, the energy consumption for the transmission of a packet of 1 bit at a distance d is given by the following equation:

$$E_{TX} = \begin{cases} L * E_{elec}(L,d) + L * \varepsilon_{fs} * d^2, d < d_0 \\ L * E_{elec}(L,d) + L * \varepsilon_{mp} * d^4, d \geq d_0 \end{cases} \quad (1)$$

Where;

- E_{TX} is the energy dissipated by the transmitter to transmit a message of size L bits for a distance of d meters,
- $E_{elec}(L,d)$ is the energy required for the transmission / the reception operation of a single bit for 1 meter,
- L is the packet size to be transmitted,
- ε_{fs} and ε_{mp} is the energy of amplification that depends on the transmitter amplifier model,
- d_0 is the threshold distance for which the amplification factors change in value.

The distance d_0 is given by:

$$d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \qquad (2)$$

In order to receive a packet of L bits, the receiver consumes [16]:

$$E_{RX}(L) = L * E_{elec} \qquad (3)$$

III.2. Proposed Algorithm

Our proposed approach is a chain structure-based approach for a hierarchical network architecture based on a greedy algorithm. Each node only communicates with the nearest neighboring nodes. Our approach is an improvement of the PEGASIS protocol [8]. The main idea of our approach is that the nodes are formed in a chain where each node receives and transmits only to the nearest neighbor. The distance between transmitter and receiver as well as the amount of transmission energy is reduced. To form the communication chain, the furthest node from BS is chosen as the first member of the chain. The nearest neighbor of the first member of the chain is elected as the second node in the chain. Nodes receive data packets from the previous chain member and merge their data signals into the received data packet to form a single packet. This process continues until the chain gets its last member node closest to BS. The data collection cycle may be initiated by synchronization with a BS beacon packet. A token can be passed between nodes in the chain to indicate the turn of data transmission. Figure 1 below shows the architecture of our approach.

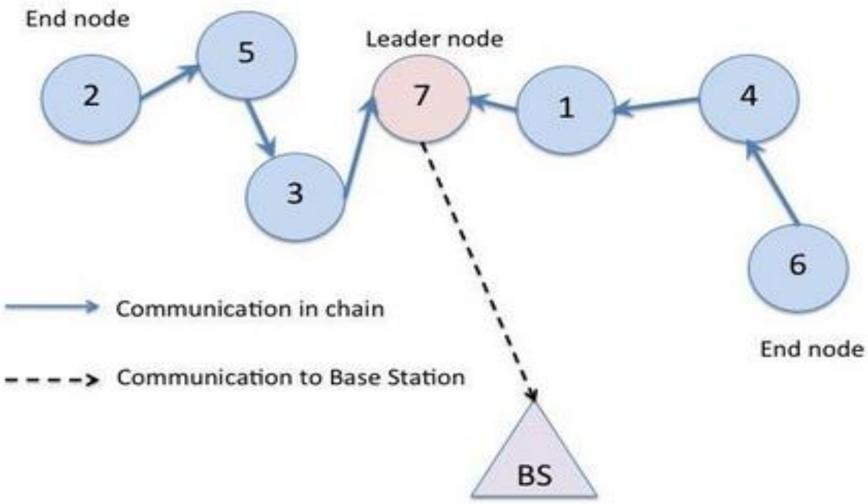

Figure 1. Our approach architecture.

To implement our approach we proposed the following algorithm:

1. Input

$\boldsymbol{N}$: ***initial number of nodes***, $\boldsymbol{E_i}$: *initial energy of each node, R: number of rounds,* $\boldsymbol{E_R}$: *residual energy in the network, D: number of dead nodes,* $\boldsymbol{D_{R-1}}$: *previous number of dead nodes, Data: number of sent data to the base station,*

2. Initialization

$D \leftarrow 0;\ \boldsymbol{S_{deads}} \leftarrow D$
$\boldsymbol{S_{alives}} \leftarrow N - \boldsymbol{S_{deads}}$;
$R \leftarrow 0$;
$\boldsymbol{D_{R-1}} \leftarrow 0;$

```
Data ← 0;

3. Main process

while (S_alives <> 0) do
begin
if (R = 0 or D <>D_{R-1}) Then    /* Condition to rebuild the chain build the chain */
  for i From 1 To N do
  begin
  E_i ← E_i - Consumed Energy during chain construction;
        if (E_i =0) then
        State (i) ← Dead;  /* node state is dead*/
        D ← D + 1; /* Increasing number of dead nodes*/
        endif;
  endfor;
endif;
Leader ← R mod N;   /* Select the chain leader*/
send the data to the leader;
sending leader data to the base station;
E_leader = E_leader – Energy consumed by the leader in the transmission and reception operations;
Data ← Data + 1; /* Increment number of sent data to the BS*/
  for i from 1 to N do
  begin
  E_i  ←  E_i - Energy consumed of data sending;
        if (E_i == 0) Then
        State (i) ← Dead;  /* Even if the node is the leader*/
        D ← D + 1;
        endif;
  endfor;
  for i from 1 To N do     /* calculating the residual energy in the current iteration */
  begin
  E_R ←  E_R + E_i;
  endfor;
R ← R + 1;
endwhile;
```

IV. Simulation & Results

IV.1 Simulation settings

To validate the performance of our proposed protocol both LEACH and our approach are simulated using MATLAB as a simulation environment.

First, we must introduce all the simulation parameters: we specify the dimensions of the simulation zone, the position of the base station, the number of nodes to be distributed in the zone, the two energy parameters ($E0$, EDA), the different factors influencing both transmission and reception operations ($ETX, ERX, \varepsilon fs, \varepsilon mp$), packet size and the maximum number of iterations without improvement of the current solution. Then, we run the simulation. Finally, we show the simulation results.

The simulation parameters taken in this simulation are as follows:

Table 1. Simulation parameters

Parameters	Values
Area of simulation	100 x 100 m^2
Number of nodes	200
Position of the base station	(50,50)
Initial energy ($E0$)	0.5 J/node
Transmitter Electronics (ETX)	50 nJ/bit
Receiver Electronics (ERX)	50 nJ/bit
Size of the data packet	4000 bits
The amplifier of the transmitter (εfs) if $d \leq d0$	10 pJ/bit/m^2
The amplifier of the transmitter (εmp) if $d \geq d0$	0.0013 pJ/bit/m^4
The Energy of Data Aggregation EDA	50 nJ/bit

IV.2 Results of simulation

The results obtained are shown in the following figures:

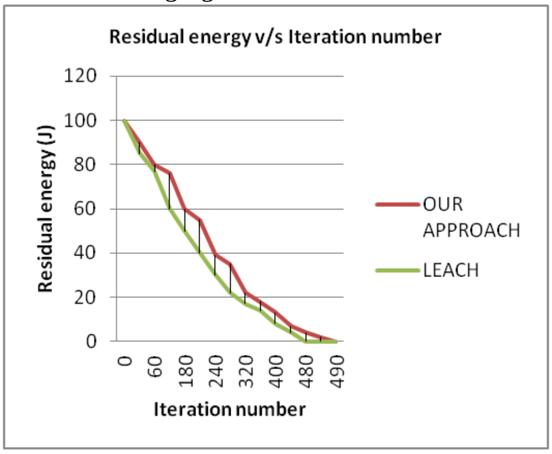

Figure 2. Residual energy v/s Iteration number.

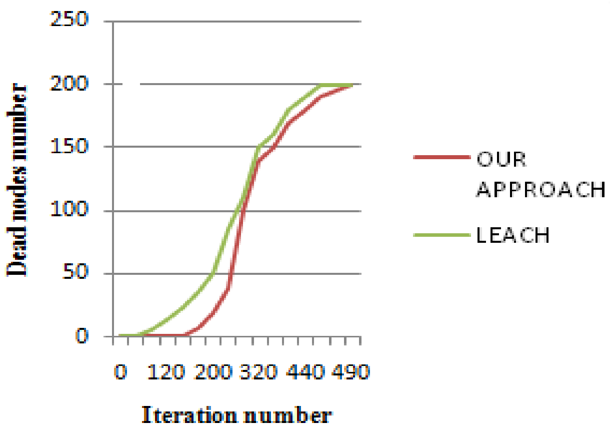

Figure 3. Dead nodes number v/s Iteration number.

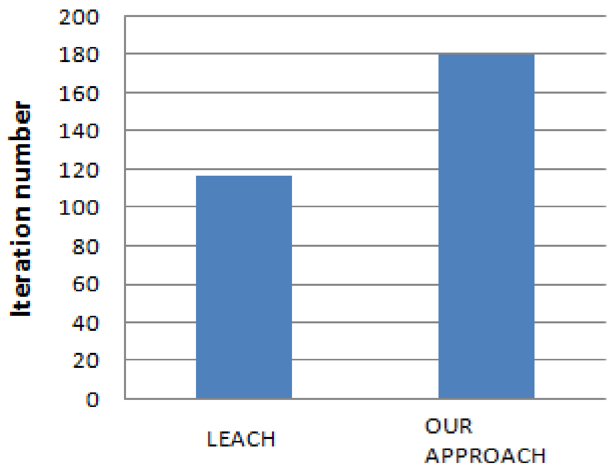

Figure 4. Iteration number in which the first node dead v/s Protocol type.

IV.3 Results Analyses

It is observed from the graph in the figure. 2 that the approach consumes less energy than the LEACH. From figure.3 it can be observed that the number of dead nodes number increases slowly in our protocol compared to that in LEACH. It can also be seen from figure.4 that the first node exhausts its energy after 117 iterations in LEACH, whereas in our approach, the first node exhausts its energy after 180 iterations.

We can deduce from these results that our protocol is efficient in terms of saving energy in the WSN, this is due to the presence of the chain that connects all CHs which reduces the transmissions to the BS.

V. Conclusion

In this paper, we offered a novel energy-efficient clustering protocol in WSN by proposing a new algorithm that is based on the principle of the PEGASIS protocol. Results of simulation show the efficiency of our proposed approach compared with the LEACH protocol which is the well-known clustering protocol. As future work, we quote the following points: Compare our approach with other approaches and other protocols, including other parameters of the simulation and test our approach in mobile networks.

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