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Consumption of Energy and Routing Protocols in Wireless Sensor Network

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Abstract

Extend the life of a wireless sensor network (WSN) is a fundamental challenge, as they have a limited supply. Multiple protocols and approaches have been proposed to minimize power consumption. Routing protocols and especially the hierarchical approach is one of the techniques used to minimize energy consumption and to improve the duration of network life. In this paper we propose a new approach to transfer and select the CH (Cluster Head). ART-LEACH (Advanced Routing Transfer- Low-Energy Adaptive Clustering Hierarchy) is a self-organizing protocol based on clustering. Our approach is to use energy more evenly the selected nodes as CH. We evaluated the performance of LEACH (Low-Energy Adaptive Clustering Hierarchy) and IB-LEACH (Improved and Balanced Low Energy Adaptive Clustering Hierarchy) protocol with the proposed new approach using MATLAB as a simulation tool. The simulation results showed that our proposal provides a reduction in energy consumption and increase the duration of network life.

Keywords : wireless sensor networks, routing protocol; clustering techniques LEACH; IB-LEACH; energy optimization.

1. Introduction

Wireless sensor networks (WSN) consist of a set of very small devices, called sensor nodes, ranging from tens of elements to several thousand. In this type of network, each node is able to react in case of need by sending the information collected in one or more collection points, using a wireless connection.[1] [2] [3]. The sensor is provided with an energy source to power its components. However, due to its small size, energy resources at its disposal is limited and generally irreplaceable. To prolong the life of the network, several routing approaches have been proposed.

In this article we study the different routing protocols and existing improvements in a first section. In Section 2 we present a comparative study of different protocols. In Section 3, we present the existing improvements. In Section 4 we will detail the proposed improvement and results. Finally, Section 5 ends with a conclusion.

2. Routing Protocols in Wireless Sensor Networks

Routing protocols are actually split into three families: the routing protocols given central, hierarchical or geographical. In what follows, we cite a set of hierarchical routing protocols most widespread in applications of wireless sensor networks. It gives a brief overview on the principle of each:

2.1 TEEN: Threshold-sensitive Energy Efficient sensor Network protocol:

The network architecture is based on a hierarchical grouping several levels where the nearest nodes form clusters. Then this clustering process proceeds to the second level until the base station is reached [4,11].

2.2 APTEEN: Adaptive Threshold-sensitive Energy Efficient sensor Network protocol

It is a hybrid protocol that changes the frequency and threshold values used in TEEN according to user needs and the type of application [5].

2.3 HEED: Hybrid, Eenergy-Efficient, Distributed approach

HEED selects the cluster-heads in a hybrid test involving the remaining energy of the nodes and a second parameter such as the degree of the nodes. It aims to achieve a uniform distribution of cluster-heads in the network and to generate clusters balanced in size [6].

2.4 LEACH protocol: Low-Energy Adaptive Clustering Hierarchy

Form clusters to minimize power dissipation [7]

2.5 IB- LEACH protocol: Improved and Balanced Low Energy Adaptive Clustering Hierarchy

Uses gateways to reduce the cluster-head of energy consumption [8].

3. Comparison of hierarchical routing protocols

3.1 The comparison criteria

- **Efficiency**: Balance the load between the nodes of the network, improves the energy efficiency of sensor nodes, extend the life of networks and improve communication efficiency, which increases the period of stability and duration of network life. [8,3]
- **Scalability**: Scalability is an important factor in wireless sensor networks. A network zone is not always static, it changes according to the needs of users. All nodes in the area of network must be scalable and be able to adapt to changes in the structure of the network depending on the user. [9,2]
- **The stability of clusters**: The effectiveness of a clustering algorithm is evaluated in terms of the number of clusters formed and stability of the clusters according to the node mobility. The clustering process is mainly to optimize the maintenance information of the network topology and reduce the overhead of broadcasting for the discovery of paths. [10,11]
- **Load Balancing**: the main function of a WSN is to collect relevant information from an area of interest. Some applications, such as environmental control, need the WSN works as long as possible. Thus, the extension of the life of the WSN is important objective of each routing protocol. A poor load balancing will result in the rapid depletion of energy of some sensor nodes, as a result of a short lifetime of the WSN. A good routing protocol should ensure energy balancing to prolong the lifetime of WSN. [12]

3.2 The comparative table

Table 1 shows the classification of proposed protocols for WSNs, according to four criteria has been described previously (Energy efficiency, scalability, stability clusters, load balancing) [13,14].

Table 1 : Comparison of different hierarchical routing protocols in WSNs

Protocols	Energy Efficiency	Stability clusters	Load Balancing	scalability
TEEN	high	high	acceptable	low
APTEEN	Moderate	Low	Very Low	Moderate
HEED	moderate	moderate	high	low
LEACH	High	moderate	moderate	strong
IB-LEACH	High	moderate	moderate	Strong

3.3 Advantages and disadvantages

Table 2 shows the advantages and disadvantages of routing protocols in WSNs.

Table 2 : Advantages and Disadvantages of routing protocols in WSNs

Protocols	Advantages	Disadvantages
TEEN	-Energy consumption in this protocol is lower than in proactive protocols or those that transmit data periodically[15,1]	-If the thresholds HT and ST are not received, the nodes will never communicate, and no data will be transmitted to the user and the base station does not know which nodes have exhausted their energy - TEEN is not suitable for applications that require periodic mailings data
APTEEN	-Provides flexibility that allows the user to select the CT time interval, and threshold values HT and ST so that the power consumption is controlled by the variation of these parameters	- Requires additional complexity to implement functions of thresholds and time periods CT. -The additional cost and complexity associated with the formation of clusters at several levels are quite high [16]
HEED	- Ensures that all sensors are part of a single cluster, and the cluster heads are well distributed - Extends the life of the nodes within the network - Creates widespread clusters	- The Total evaluation presents some difficulty, because of the absence of any central control - Does not specify a particular protocol to be used for communication between cluster-heads and the base station - Clustering topology does not achieve minimum energy consumption in the intra-cluster communication -The clusters generated are not balanced in size.
LEACH	-It Provides scalability in network by limiting most communications within the different clusters. -The Cluster-heads aggregate or merge the information gathered by sensor nodes, which helps to limit the traffic generated in the network. -The Role of the distributive property of CH between cluster members.	-This Significantly based on CHs rather than members of the cluster nodes to communicate with the base station. Thus, he incurs robustness problems such as failure of CHs. -The CHs farthest from the base station quickly die with respect to those are close to the station. -We Can not be CH during a round if the random numbers generated by all network nodes are higher than the probability T (n). [17]
IB-LEACH	- Balanced energy dissipation - Lifetime of network is extended - More stable region that LEACH - The use of the bridge and CH reduce the phenomenon of the rapid death of CH caused by excessive energy consumption	- Random Location bridges does not ensure an efficient energy balance. - The sensor node sends its data at the same CH if it is closer to the base station or gateway. - The choice of the bridge is based solely on energy without counting the distance which affects energy consumption

The study and analysis of the major routing protocols for WSNs, allowed us to offer our own routing protocol based on the assumptions of IB-LEACH whose main objective is the extension of the lifespan the network and the effective management of energy consumption.

4. Improvements proposed

4.1 Network Architecture

ART-LEACH (Advanced Routing Transfer- Low-Energy Adaptive Clustering Hierarchy) is our protocol is a self-organizing protocol based on clustering as shown in Figure 1, which is to partition the network into groups (clusters). The nodes send their data to the cluster-heads (CH), which in turn send the data to the base station (BS) via the gateway level 1 and 2.

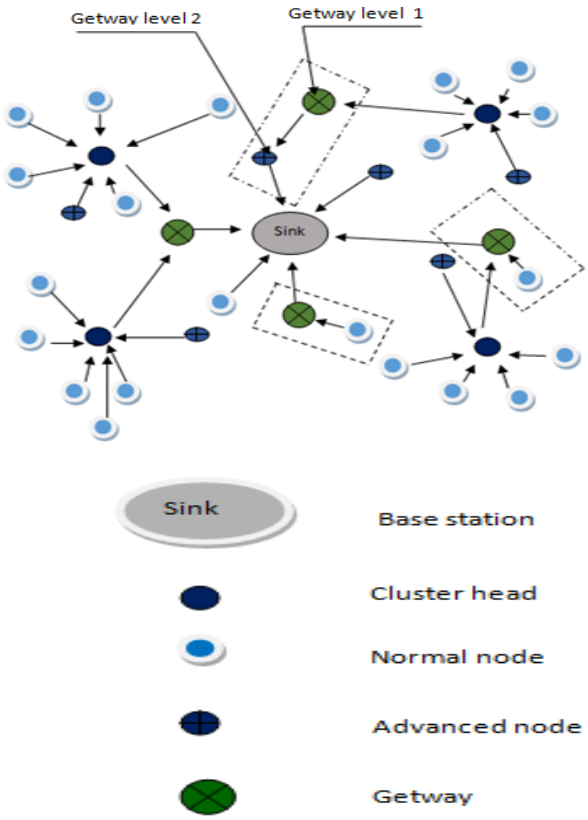

Figure1 : Network Model with ART-LEACH

The aim is to promote the nodes with more energy and close to the SB and belong to a well-defined zone (the zone gateways) to become level 1 gateways and seek advanced node that is located between the gateway level 1 and SB to become a level 2 gateway

4.2 Election of gateways level 1

Both parameters were combined (energy and distance) for calculating a threshold according to which the selected gateway level 1.

This threshold is calculated as follows:

$$threshold = E / d \qquad (1)$$

Where **E** is energy current node and **d** is the distance between the node and the base station. The nodes having the highest threshold and belong to the gateway area choose to be gateways level 1.

4.3 Election gateways Level 2

To select gateways level 2 requires that the nodes are developed and located between the base station and the Gateway Level 1 as it is shown un Figure 2.

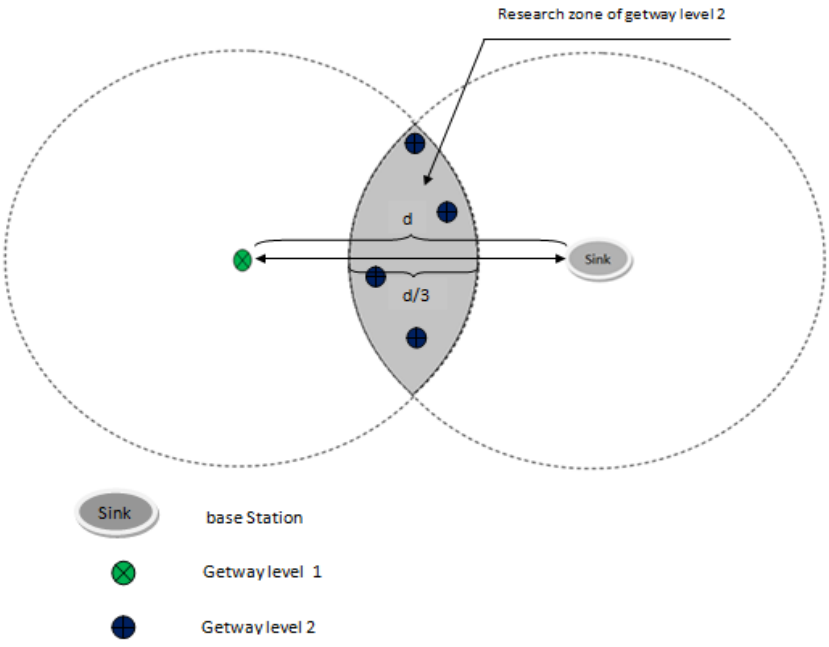

Figure 2 : Zone gateways Level 2

Nodes having more energy are more likely to become second gateways. They send their ID and their energy to gateways level 1 and later it selects those with more energy to become gateways Level 2.

4.4 ART-LEACH protocol operation

The operation of ART-LEACH protocol is as follows:

The sensor nodes elect themselves to be gateways level 1 at one time with a certain probability. The base station confirms that if these nodes are suitable for bridges. As against the last take responsibility to elute the gateways level 2 with some restraint. The non-gateway nodes elect themselves for CH with a certain probability. Each node that will be designated CH or gateway for the current turn broadcasts a greeting message (ADV) to the rest of the nodes surrounding it.

The other nodes must keep their receivers tuned to hear the messages broadcast by the CHs and gateways, and each of these nodes decide which group to join for the current round

by choosing the cluster-head or gateway, which requires minimum communication energy and sends a REQ-JOIN message notifying him of his membership. If a sensor node is very close to the base station, they will be directly connected.

After all the sensors are positioned, each CH creates a schedule for the nodes of the cluster. This allows the radio components of each sound cluster node to be deactivated at any time, except for its transmission time, which reduces the energy dissipated in the individual sensors.

The operation of the base station is shown in Figure 3.

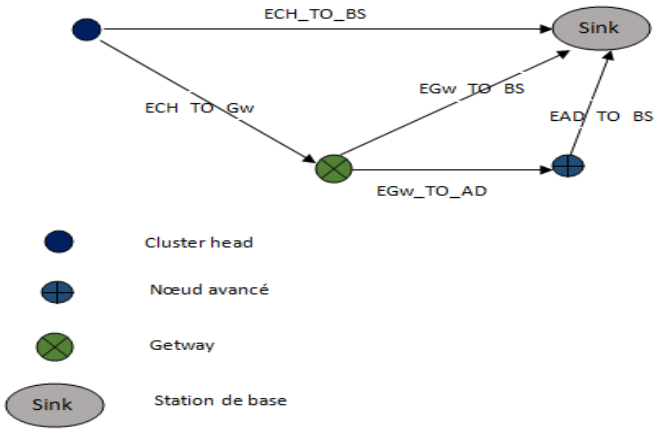

Figure 3 : Operation of the base station

Once the CH has all the data from their cluster members, it transmits them to:

- **The base station if** ECH _TO_ BS ≤ ECH _TO_ Gw + E Gw _TO_BS
  - ECH _TO_ BS: the total energy dissipated to send the cluster-head data to the base station.
  - E CH _TO_ Gw: the total energy dissipated to send the cluster-head data to the gateway.
  - E Gw _TO_BS: the total energy dissipated to send the gateway data to the base station.
  - EGW _TO_ AD: the total energy dissipated to send data gateway node to advanced (level gateway 2).
  - EAD _TO_BS: the total energy dissipated node to send data to the advanced base station.
- **The gateway level 1 if** ECH _TO_ BS > _TO_Gw + E Gw _TO_BS

  The gateway Level 1 subsequently transmits the data
- **The base station if** EGW _TO_ BS ≤ EGw _TO_ AD + EAD _TO_BS
- **The gateway level 2 if** EGW _TO_ BS > EGW _TO_ AD + EAD _TO_BS

The individual sensors nodes send their data

- **The gateway level 1 if** EN_TO_Gw < EN_TO BS **and** EN_TO_Gw < EN_TO_CH
- **The base station if** EN_TO BS < EN_TO_Gw **and** EN_TO BS < EN_TO_CH
- **The cluster-head if** EN_TO_CH < EN_TO_Gw **and** EN_TO_CH < EN_TO _BS

The operation of the gateway level 2 is shown in Figure 4.

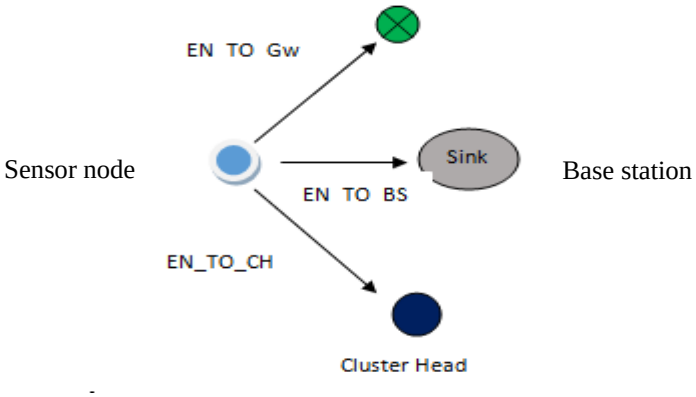

Figure 4 : Operation of gateway level 2

5. Experimentation and results

To evaluate the performance of ART-LEACH protocol was used MATLAB simulation, the parameters of our simulation are summarized in table 3:

Table 3. Simulation parameters

Settings	Definition	Value
(x,y)	Location of the base station	(50,50)
N	The number of nodes	100
E0	initial Energy	0.5 J
E elec	Energy required to activate the electronic circuits	50.10-9J
EDA	Energy required for data processing	5.10-9J
K	The packet size	4000 bits
εfs	free space model of the amplifier of the transmitter	10.10-12J
Emp	Model multi-path of the amplifier of the transmitter	13.10-15J
D0	Threshold distance	D0 = √ εfs / εmp

Two parameters are chosen to evaluate the ART-LEACH protocol, which are the energy consumed and the number of dead nodes. In order to prove its effectiveness, we kept the same location nodes and conducted simulations of the three routing protocols LEACH, IB-LEACH and ART-LEACH.

5.1 Evaluation of the energy consumed

From the results of Table 4, we see that the protocol ART-LEACH consumes less power that the protocols LEACH and IB-LEACH. In LEACH CHs directly transmit the data packets to the base station and IB-LEACH they go through a gateway. The CHs that are far from the base station or gateway so will quickly deplete their energy reserves, which involves frequent reelections of CHs followed reconfigurations clusters. This results in a large consumption of energy of the entire network. ART-LEACH alleviates this problem with the presence of gateway level 2 which reduces the transmission distance from the leader nodes (last nodes) to the base station.

Table 4. Remaining power over time

Tours / Energy/Protocol	1	200	400	600	800	1000	1200	1400
LEACH	60	51.606	43.181	34.749	26.321	17.891	10.181	6.415
IB-LEACH	60	52.121	44.09	35.983	27.826	19.589	11.862	8.6508
ART-LEACH	60	52.037	44.43	37.297	30.521	24.126	18.225	13.04

The improvement provided by ART-LEACH is further confirmed by the results in Figure 5. The latter shows the average power dissipation of all nodes by the three protocols over time. As it is clearly seen, ART-LEACH optimizes energy expenditure that LEACH and IB-LEACH.

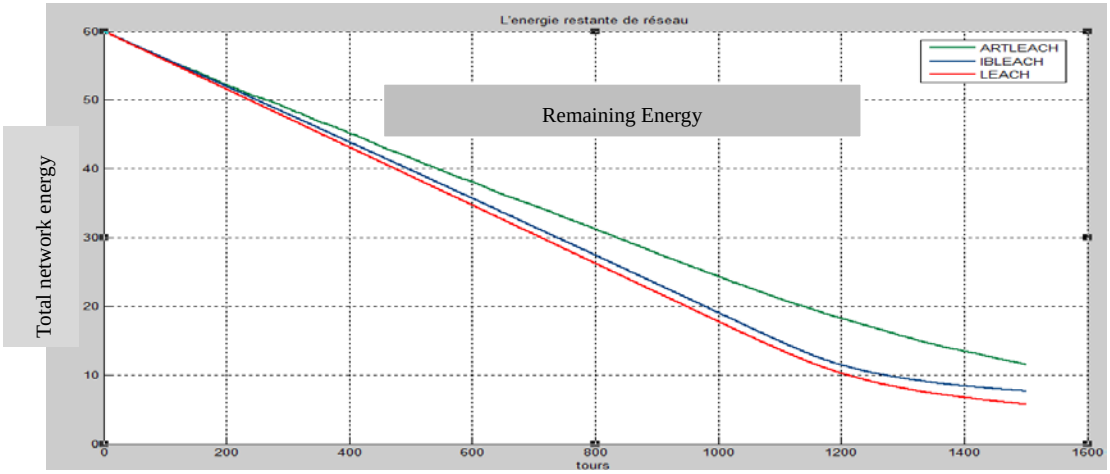

Figure 5 : Residual Energy vs rpm

5.2 Evaluation of number of dead nodes

Table 5 summarizes the number of dead nodes obtained in each protocol as a function of the number of tours.

Table 5. Number of dead nodes /protocol

Tours / Dead Nodes / Protocol	1	200	400	600	800	1000	1200	1400	1500
LEACH	0	0	0	0	0	0	29	75	79
IB-LEACH	0	0	0	0	0	0	27	77	79
ART-LEACH	0	2	4	7	10	17	22	41	60

In Figure 6, we compared the number of dead nodes in the three protocols. The first node of the protocol LEACH die after 1050 tours , like the IB-LEACH protocol, while the first node of the protocol ART-LEACH dies after 200 tours , but after 1200 tours it is clear that the number dead nodes in the protocols LEACH and IB-LEACH is higher than that of ART-LEACH which means the network operates as long as that is to say that we managed to extend the life network 40%, this is an interesting result since in WSN all nodes must work together to accomplish a definite goal.

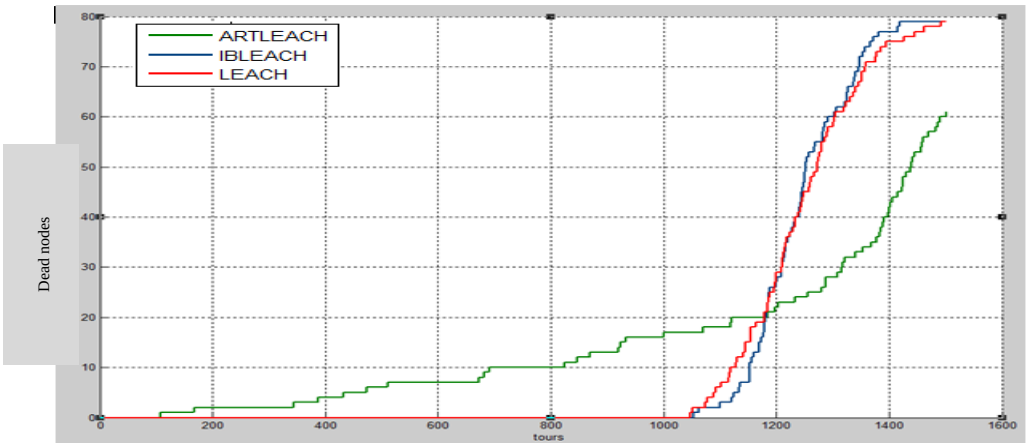

Figure 6 : Number of dead nodes vs number of tours

6. Conclusion

We studied the different routing protocols and respectful improvements proposed to extend the duration of life of WSN. In addition we proposed an improvement that takes into account nodes with maximum power and minimum distance from the base station belonging to a well-defined area (the bridge area) to become level gateways 1 and seek advanced node

that is between the gateway level 1 and SB to become a gateway level 2. We conducted also experiments to assess in terms of the various improvements of the performance lifetime of the network. Based on simulation results, it was demonstrated that the ART-LEACH protocol improves power dissipation and increases the energy gain, as it extends the life of the network by 40% compared to LEACH protocol and IB-LEACH.

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