Analysing Study of a Contribution to Minimize the Energy Consumption and Improve the Performance of Wireless Sensor Networks

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***Abstract*— Improving performances of a wireless sensor network and prolonging its lifetime is a fundamental challenge in their design. There are still many mechanisms to minimize power consumption and improve lifetime of our system. The hierarchical approach is one of the most used technologies. In this paper we propose a literature survey of different optimization techniques in energy consumption in wireless sensor networks focusing on hierarchical routing method. Thus, an analysis of its basic algorithm and a brief description of these extensions and improvements have shown that this technique allows a reduction in energy dissipation and a larger network lifetime.**

Keywords- Wireless Sensor Networks; Clustering; routing; Zigbee; Energy consumption; Media Access Control.

I. INTRODUCTION

The general function of wireless sensor networks is the detection of information in the most hostile environments. The sensors are autonomous; therefore their lifetime is that of their battery. The design of sensor networks is influenced by several constraints whither energy remains central to all concerns on these sensors. Experimental measurements have shown that the transmission of data is the largest consumer of energy, calculations consume very little, and on the other hand the energy consumption of the detection module depends on the specificity of the sensor. There are many mechanisms to reduce this energy consumption, such as specific communication protocols, Data compacting, ZigBee communication protocol and optimization of energy consumption by the MAC layer.

In this document, we cite the various techniques to improve network performance and minimize energy consumption in order to have a full operability of these mechanisms, we concern ourselves specifically in the hierarchical routing protocol mechanism that uses the random rotation of local Cluster-Heads within these clusters in order to uniformly distribute the load of energy between the sensors throughout the network. This technique is well known and more effective by being the economical at the energy level compared to other approaches [1]. This allows us to implement more complex algorithms for better performance.

In the following sections, we will present a model of energy consumption for wireless sensor networks, with a brief analysis of various energy optimization techniques. Then, we examine an efficient energy routing approach, adapting its basic algorithm. At the end, we show, in the form of synthesis some validation improved this technique and these extensions. We draw the conclusion and our perspectives in the final section.

II. ENERGY CONSUMPTION MODEL FOR COMMUNICATIONS

The sensor nodes are designed to operate for years. Thus, their energy capacity must be used efficiently in order to maximize network lifetime. It should be noted that once sensor node has exhausted its energy, it is considered as failed. The energy consumed by a sensor node is mainly due to the following operations: Capture Energy, processing and communication of data [2].

- Capture: The capture energy consumed is not very important. In general, it represents a small percentage of the total energy consumed by a node. It varies depending on the phenomenon and performed monitoring type.
- Processing: The energy consumed for the operations of calculations and processing is much lower compared to that of communication. It is divided into two parts: the switching power and leakage energy. An example is cited in [2].
- Communication: the communications consume much more energy than other tasks. They cover communications in transmission and reception.

Heinzelman and al [3] proposed an energy consumption model and the radio power consumption associated rules (see Fig. 1). Thus, the energy necessary to transmit $E_{Tx}(s,d)$ and receive $E_{Rx}(s)$ messages is given by:

- To transmit a ***(s)*** bit message to a receiver far away from ***(d)*** meters, the transmitter expends:

$$E_{Tx}(s,d) = E_{Tx\_elec}(s) + E_{Tx\_amp}(s,d)$$

$$E_{Tx}(s,d) = (E_{elec} * s) + (E_{amp} * s * d^2) \quad (1)$$

- To receive a ***(s)*** bits message, the receiver consumes:

$$E_{Rx}(s) = E_{Rx\ elec}(s)$$

$$E_{Rx}(s) = E_{elec} * s \quad (2)$$

E_{elec} and E_{amp} are respectively the electronic energy of transmission / reception and amplification energy.

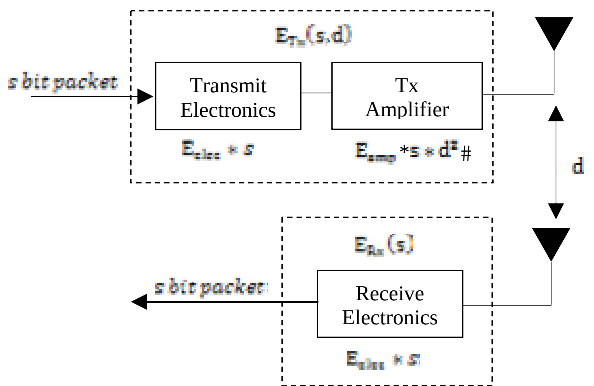

Figure 1. Energy consumption model for communications[3].

TABLE I. RADIO CHARACTERISTICS

Operation	Energy Dissipated
Transmitter Electronics ($E_{Tx\ elec}$) Receiver Electronics (($E_{Rx\ elec}$) ($E_{Tx\ elec} = E_{Rx\ elec} = E_{elec}$)	50 nJ/bit
Transmit Amplifier	100 pJ/bit/m^2

For these parameter values, receive a message is characterized by a low-cost operation, whither the protocols should therefore try to minimize not only the emission distances, but also the number of transmit and receive operations for each message.

The design and implementation of wireless sensor networks are influenced by several parameters, such as the state of the radio module, because it is the component of the sensor node that consumes the most energy, since it provides communication between the nodes. Other constraints are necessary, such as limited resources, limited bandwidth, dynamic topology, scalability, etc. These factors are used as guidelines for the development of algorithms and protocols that are dedicated to wireless sensor networks.

III. TECHNIQUES TO MINIMIZE ENERGY CONSUMPTION

To reduce energy consumption in these wireless sensor networks and determining the lifetime of the network, in order to evaluate the performances of our network, there are many mechanisms, such as:

- Data compression: It is obvious that the early to reduce the amount of data to be transmitted saves energy in an efficient manner, as the radio transceiver is the component that consumes the most energy. But sometimes the data compression techniques used have a very high energy cost, especially when it comes to compressing images or videos. We must therefore develop several compression algorithms that are energy efficient and have a good debit-distortion ratio.
- Zigbee communication protocol: a protocol that allows radio communications with low energy cost between sensor nodes. It is characterized by a range between a few meters to several hundred meters and a very low debit. ZigBee nodes require between 2% and 10% of the code necessary to implement Bluetooth nodes [4]. This feature will allow ZigBee nodes occupies less memory and less energy space compared to traditional wireless networks. Among the weaknesses of this technology, we find that its protocol is very slow on which the radius of action is relatively low, thus an incomplete battery with a bad interface.
- Optimization of energy consumption by the MAC layer: Media Access Control is the software layer that allows organizing and controlling access to multiple medium, it is the communication channel. MAC protocols based on TDMA method (Time Division Multiple Access) offer an implicit solution [5], which each network node doesn't exchange messages at (slots) time intervals reserved to it, it must keep its transceiver off for the rest of slots for saving energy.

These methods are mostly hardware mechanisms managed by the higher-level software. But among all those technical considerations, the most optimum method in terms of energy consumption and the researchers is that adapts specific routing protocols for wireless sensor networks.

Among the best known and most effective, it cites the LEACH protocol with these extensions (Low Energy Adaptive Clustering Hierarchy), which is a hierarchical routing protocol. It is this technique that we will detail in the next section.

Other routing protocols exist in the literature [6], for example SPIN SPEED, TEEN, APTEEN, PEGASIS, UCS, etc. But the choice of suitable routing protocol depends on several parameters including the nature of the application, the density of the network, the platform used, and the quality of service requested.

IV. HIERARCHICAL ROUTING METHOD

In this section, we explain the communication architecture, the operating principle of this technique for routing, and an analysis of the basic algorithm.

A. *Architecture and operating principle of the method*

LEACH is a hierarchical routing protocol that divides the network into zones and clusters in a distributed manner, Cluster

Head nodes (CH) consist then used as relays to reach the Base Station by optimizing energy consumption according to an algorithm that uses the rotation of the head group CH to fairly distribute the energy load between network nodes [7].

A node decides which cluster to join based on the strength of received signals. The following figure shows the communication protocol architecture.

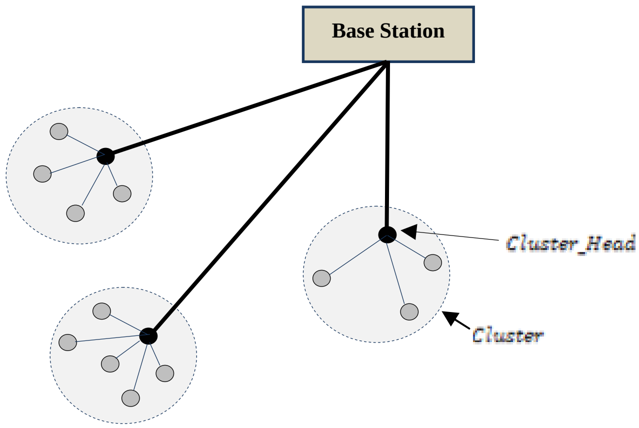

Figure 2. LEACH communication architecture.

The idea is to train cluster nodes sensors based on the received signal, and using the Cluster-Heads to deliver local messages to the base station by increasing the overall lifetime of the system.

Forming these groups, all non-CH nodes transmit their data at the head of the group. When the Cluster Head receives the data of all members of the group, it performs processing functions on the data and transmits them to the base station using a unicast communication Single-Hop.

B. Cluster Head selection algorithm

The basic algorithm of the protocol proceeds in rounds, where each cycle begins with one Set-up Phase followed by Steady Phase.

We want to have a number of Cluster-Heads, these, which is denoted ***K*** is fixed and it is unchanged for all rounds. During the first phase, the nodes self-elect to be Cluster-Heads. They are based on the percentage of desired Cluster-Heads in the network and the number of iterations in which a node has taken the role of the Cluster Head. Every ***i*** node generates a random number between 0 and 1. If this number is less than a probability $P_i(t)$ the node declares Cluster-Heads [8].

$P_i(t)$ is calculated a function of ***K*** and ***r*** round:

$$Nombre(CH) = \sum_{i=1}^{N} Pi(t) = k \qquad (3)$$

Whither ***N*** is the total number of nodes in the network. If there are ***N*** nodes and ***K*** Cluster-Heads, so, must be ***N/K*** rounds during which one node should only be elected once as much as Cluster Head before the round is reset to 0.

The probability of becoming Cluster Head for each ***i*** node is:

$$Pi(t) = \begin{cases} \dfrac{K}{N - K * (r mod \frac{N}{K})}, & Ci(t) = 1 \\ 1 & Ci(t) = 0 \end{cases} \qquad (4)$$

Where ***r*** is the current iteration, $C_i(t)$ equal to 0 if the ***i*** node has already been Cluster-Heads in one of ***(r mod N/K)*** previous iterations, and it is equal to 1 otherwise. This probability is based on the assumption that all nodes are initially homogeneous and starts at the same residual energy quantity and die approximately the same time [9].

Then, each Cluster-Head inform the other non-CH nodes of its election using the CSMA MAC protocol to avoid collisions between the Cluster-Heads. Each node selects the Cluster-Head closest based on the amplitude of the received signal, whence Cluster Head having the strongest signal will be selected. After the formation of clusters, each CH acts as a local command center to coordinate the transmission of data within its group [8]. It creates a scheduler TDMA (Time Division Multiple Access) and assigns each member node a time slot during which it can transmit its data.

To prevent interference between messages clusters that are close, each CH randomly selects a code in a code list CDMA (Code Division Multiple Access) and passes it to the nodes belonging to the group for use during transmission.

The transmission phase is longer than the previous phase (Fig. 3), and allows the collection of sensor data. Using TDMA scheduler, members transmit their data captured during their own slots. This allows them to turn off their communication interfaces outside their slots to save energy. These data are then aggregated by the Cluster Heads that merge and compress, and send the final result to the well node.

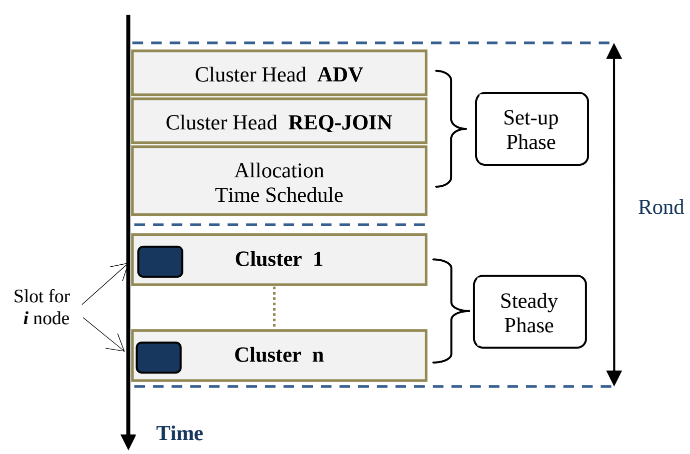

Figure 3. Distribution of time and different phases for each round

After a predetermined time, the network will switch to a new round. This process is repeated until all network nodes will be elected CH, once, throughout the previous rounds. In this case, the round is reset to 0.

V. Extensions And Improvements: Synthesis

LEACH, is among the first to adopt the protocols Clustering as a solution to the problem of energy consumption in wireless sensor networks, this technique allows to reduce considerably the energy consumption compared to other techniques, subdividing the global network into several networks, where each is represented by a single Cluster Head who deals with the dissemination of data to the base station, while the other nodes in the cluster enable a local data dissemination to the cluster Head. It adopts a data aggregation at the Cluster Heads to reduce the size of data transmitted to the base station, and therefore, it will use less energy.

However, overcharging Cluster Heads by aggregating data in addition to the direct communication with the base station and the stability problems, as well as other features rapidly depleted their energy and create a bad distribution of the consumption of energy within the network. Therefore, many derivatives protocols LEACH algorithm have been proposed and improved by many researchers, including C-LEACH [9], V-LEACH [10], Q-LEACH [11], and MODLEACH [12].

In [9], the authors proposed a hierarchical protocol called LEACH-C. It was designed to improve the performance of LEACH. This uses a centralized architecture for selecting clusters Heads while involving the base station and the sensor location information. However, it significantly increases the network overhead since all sensors will send their location information to the base station simultaneously for each Cluster Head of election phase.

Another variant of LEACH called V-LEACH is proposed. The difference between this extension and our basic protocol is the selection criterion level of the Cluster Heads. This approach will improve the lifetime of the global network by replacing the Cluster Heads of other particular nodes. The idea is to have another node (Vice-Cluster Head) which will take the role of primary Cluster Head when it dies.

Q-LEACH another derivative LEACH protocol that optimizes network performance is improving the period of stability and consolidation process, as well as the network lifetime. The operating principle of this approach is to partition the network into four equal quadrants, which will allow better coverage of the entire system. Therefore, the burden of the transmission of the other nodes in Cluster Head will be reduced.

With the same objective, which is also MODLEACH based LEACH minimizes energy consumption per group. When the energy of Cluster Heads decreases below a certain threshold, they will be replaced, minimizing the load on the routing protocol. Therefore, the replacement procedure involves the Cluster Heads residual energy cluster Heads at the beginning of each turn.

The main objective of this hierarchical routing protocol and all the improvements which have been proposed is to minimize the power consumption and extending the life of the wireless sensor networks. However, after an analysis that is performed on the vector LEACH protocol and these derivatives protocols, it was found that the Cluster Heads farthest from the base station quickly die relative to those near the station, so communications that take place over small distances. Also, it was observed that there was no intergroup communication in the network, since the Cluster Heads communicate directly with the base station. This process requires a wide range of transmission power in the network. Our future works focus on the improving of these points with an overall security of the entire network against parasites without degrading the performance of our system.

VI. Conclusion

Wireless sensor networks open the way for various applications in many fields, it has a considerable interest and it is considered as a new step in the evolution of information and communications technology. But, the use of these sensor networks is complex at the energetic level.

In this survey, an analysis of different methods was made, whose main objective is the effective management of energy consumption and the extending of sensors lifetime. Afterwards, we discussed the classic hierarchical routing protocol that has better performance in terms of reliability, durability and energy conservation. At the end, it was concluded by a synthesis of the various proposed improvements and derived from that protocol. In outlook, we will deliberate the study of other techniques that will be reliable and efficient, with the implementation of other algorithms to compare the results in terms of consumption and energy dissipation.

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