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Lifetime optimization of wireless sensor network by a better nodes positioning and energy distribution

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Abstract. The purpose of this paper is to propose a method of energy distribution on a Wireless Sensor Network (WSN). Nodes are randomly positioned and the sink is placed at the centre of the surface. Simulations show that relay nodes around the sink are too much requested to convey data, which substantially reduces their lifetime. So, several algorithmic solutions are presented to optimize the energy distribution on each node, compared to the classical uniform energy distribution. Their performance is discussed in terms of failure rate of data transmission and network lifetime. Moreover, the total energy distributed on all nodes before the deployment is invariable and some non-uniform energy distributions are created. Finally, simulations show that every energy distributions greatly improve the WSN lifetime and decrease the failure rate of data transmission.

1. Introduction

The WSN gradually intrude into our lives and revolutionizing the way we live and work. They are found in the fields of industry, health, transportation. The sensor nodes are able to collect, process and relay a variety of data types [1]. Communication between nodes can become impossible in a certain region and this region is called a hole. Different kinds of holes are presented in [2]. In this case, the hole is caused by energy depletion among nodes around the sink. Relay nodes always do higher data transmission and thus consume more energy than the other nodes. Some papers deals with this problem and gives some possible solutions [3], [4].

This paper focuses on a way to extend the lifetime of the WSN by applying different energy distribution laws to the sensor nodes before the deployment and by proposing a way to randomly distribute nodes on the monitoring surface. The data routing protocol used are the GPSR and HEED algorithms [5], [6], [7]. Using each routing protocol, the simulations show that the energy distribution on nodes batteries and its position play a determining role in the WSN lifetime. Therefore, the failure rate of data transmission from the source node to the destination node is reduced by modifying these parameters. Our goal is to extend the network lifetime and reduce the failure rate of data transmission τ by a better nodes positioning and by selecting the better energy distribution on each node.

The paper is organized as follows: network model and routing models are presented in section 2. The Uniform Energy Distribution and the related results are discussed in section 3. The energy optimization is provided in section 4. Section 5 concludes our work.

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2. Network model and routing models

2.1. Network topology model

The nodes are positioned in a random way around several rings of which the shared centre is the sink. This ring-shaped topology is most often used and well-adapted for the hierarchical WSN. The expected number of rings N_a and number of nodes N are fixed for a given WSN. Firstly, each node is placed in a random and equiprobable way on a ring. Then, the exact position of the node is determined by using a Normal distribution law $\aleph(R,\sigma)$ of which the centre is the ring radius.

2.2. Channel model and node model

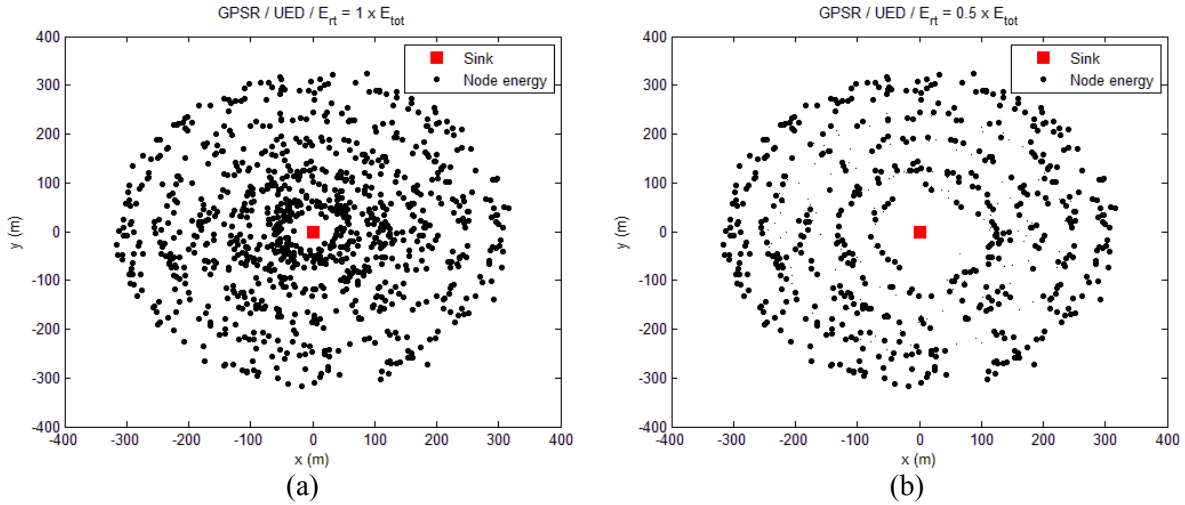
A traditional energy model is used here, known as first order radio model. The energy consumption for transmitting E_{tx} is given by the equation below.

$$E_{tx}(\mathrm{d}) = \mathrm{E}_{elec} + \varepsilon_{amp} \times d^2 \quad (1)$$

with E_{elec} the energy dissipation to run the radio, ε_{amp} the energy dissipation to run transmit amplifier and d the node transmission range. Besides, the energy consumption for receiving and the energy consumption for processing are considered to be constant. For each simulation, the Telos B node parameters are used [8]. The simulations are then done with real parameters.

2.3. Routing models

One node detects an event in a random and equiprobable way. Nodes always transmit the measured information to the sink with the help of the other nodes used as relays. A transmission data cycle begins since a node detects an event and finishes when this piece of information has reached the sink, or when it is no more transmitted, otherwise the transmission can be stopped when there is a loss of radio link, if the relay node is dead or even a bad data routing. Concerning the routing strategies, two protocols have been chosen to transmit the data. The Greedy Perimeter Stateless Routing (GPSR) [5] transmit data with the help of the neighbouring nodes until reaching the sink. The Hybrid, Energy-Efficient, Distributed Clustering Approach (HEED) [6] makes up clusters within the WSN. The data detected by a node is transmitted to its Cluster Head (CH), which then transmit the data to other CHs in order to reach the sink node.



(a) (b)

Figure 1. Evolution of the nodes remaining energy using the GPSR protocol and the UED when no energy has been consumed (a) and when 50% of the network total energy (E_{tot}) has been consumed (b). The point size is proportional to the remaining energy level in the node battery.

3. Results and discussion using the uniform energy distribution

The GPSR and HEED protocols have been used on the network and both protocols leads to an energy hole issue when the Uniform Energy Distribution (UED) is used. As illustrated in figure 1, when 50% of the network total energy has been consumed, there are few nodes with sufficient energy close to the sink. The problem is that there is still a great amount of energy available on the nodes far from the sink.

4. Energy optimization

Three energy distributions are presented here to optimize the WSN energy consumption. The main idea of these distributions is to give more energy on the nodes located close to the sink in order to avoid the energy hole issue. The simulations results are presented and discussed in section 4.2.

4.1. Energy distribution

First, the ideal case is considered in which a node would transmit directly to a node located on the adjacent ring. The Ring-shaped Energy Distribution (RED) consists of giving a different amount of energy to the nodes depending on which ring they belong. The energy proportion between the rings is calculated by considering the data transmission between nodes from one ring to another. In this scenario, 5 different levels of energy is created for the nodes.

The Optimal Energy Distribution (OEDN) is an optimal algorithm a posteriori. It distributes different amounts of energy on each node. The needed amounts of energy are computed by making several simulations of the WSN with the calculation of the nodes energy consumption.

The last distribution is a suboptimal algorithm of OEDN. The Staircase-shaped Energy Distribution (SED) calculates the average amount of required energy for different intervals of nodes distance from the sink. This distribution is quite similar to the RED if we consider the intervals like virtual rings.

4.2. Simulation results and discussion

A simulation of the identical WSN using the four energy distributions (UED, RED, NCOED and SED) has been done. Figure 2 shows the evolution of remaining total energy E_{rt} and the failure rate of data transmission τ for the GPSR and HEED protocols. The network is considered dead when τ is equal to 10% and the network lifetime is represented by the number of cycles in the graphs. It illustrates the fact that the OEDN is the most efficient distribution whatever the routing protocol. Otherwise, the RED and the SED are relatively efficient since they remarkably improve the lifetime of the WSN. In fact, the OEDN allows the network to consume almost the totality of its initial energy using the two routing protocols. This improvement is quite significant since the WSN lifetime and consumed energy are more than doubled compared to the traditional UED.

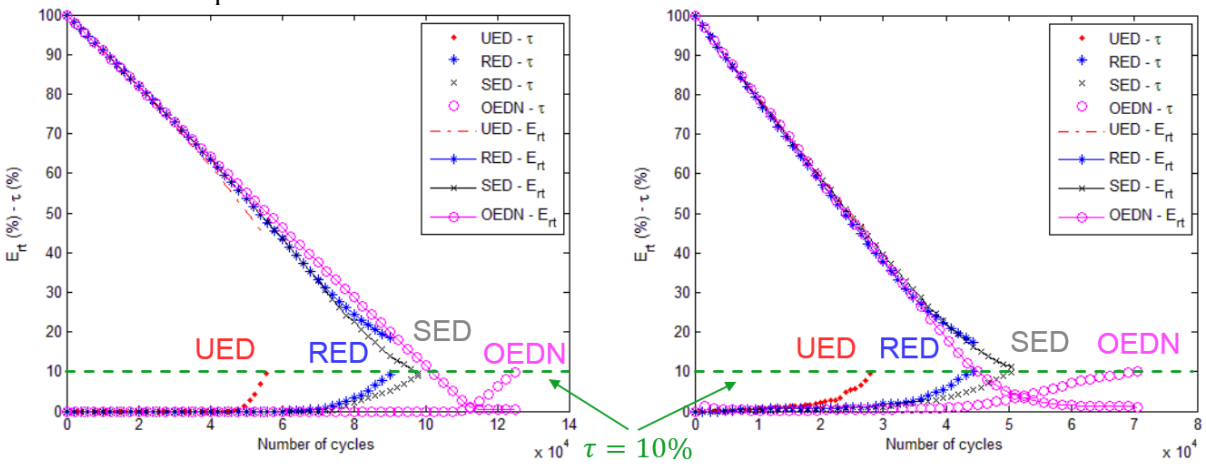


Figure 2. Evolution of the remaining total energy E_{rt} and the failure rate τ using the UED, RED, SED and OEDN distributions, with the GPSR (a) and the HEED (b) protocols.

The lifetime improvement of the different energy distributions compared to the UED has been presented in the table 1. Both protocols provide similar results regarding the lifetime improvement with a particular energy distribution. Indeed, the network lifetime has been improved by about 60% using the RED and by almost 80% using the SED, still compared to the UED. These values could be considered quite low compared to the ones obtained with the OEDN, which allows the network to work more than twice longer. However, the OEDN distributes an optimal amount of energy on each node and this distribution is quite difficult to set up in a realistic scenario. In order to avoid this issue, the SED is more interesting and efficient enough to greatly improve the network lifetime. The RED also presents good results since the algorithm is simpler than the SED. Therefore, the network lifetime is significantly improved by using the new energy distributions.

Table 1. Summary of the results obtained with each distribution.

Routing protocol	Energy distribution	Lifetime improvement compared to the UED
GPSR	RED	+ 64 %
	SED	+ 78 %
	OEDN	+ 127 %
HEED	RED	+ 55 %
	SED	+ 79 %
	OEDN	+ 147 %

5. Conclusion and perspective

This article presented the energy hole issue while using a UED over the WSN. Different energy distributions have been proposed to avoid this energy hole and increase the network lifetime. The main idea of theses distributions is to distribute more energy on nodes located close to the sink. An optimal distribution has been proposed even if it is difficult to set up in a real network. Indeed, the OEDN extremely improves the reliability of the network while consuming almost the totality of the WSN energy. Besides, an a priori algorithm of energy distribution has been proposed and the RED multiplied by around 1.6 the lifetime of the WSN. Finally, the SED multiplies by 1.8 the network lifetime compared to the traditional UED. However, all these distribution algorithms prove that the WSN lifetime can be improved significantly by modifying the energy distribution.

In future works, the same study can be done to other network topologies by eventually proposing new energy distributions. Finally, the implementation of this study on a real network would be interesting too.

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