A SURVEY ON DISTRIBUTED ENERGY-EFFICIENT AND POSITION-AWARE ROUTING PROTOCOL FOR HETEROGENEOUS WIRELESS SENSOR NETWORK

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Abstract

Wireless Sensor Networks consist of tiny and low power devices called sensors that are usually scattered in geographically isolated areas. One of the fundamental challenges in their design is to maximize their lifetime because they have a limited power supply. Clustering algorithm is the main method used in this regard. In this paper, we present and evaluate a Distributed Energy-Efficient and Position-aware routing protocol for heterogeneous Wireless Sensor Networks. In this respect, cluster-heads are elected using the same probability threshold used in LEACH-E. Moreover, it uses an extra hierarchical level by selecting the most powerful to be as a gateway node for data transmission to the base station. Furthermore, impose the position of the powerful cluster head to be in a position as close as possible to the base station in order to reduce transmission costs. Simulation results demonstrate that our proposed protocol outperform LEACH-E and extend the overall network lifespan.

Keywords: Wireless sensor networks , Network lifetime, Clustering algorithms.

1.Introduction

Recent advances in MEMS (Micro-Electromechanical Systems) have enabled the development of tiny, low-cost, low-power, multifunctional sensors able to communicate in short distances. A wireless sensor network (WSN) is made of a large number of micro-sensors spatially dispersed over a geographical area in order to sense, measure and monitor physical parameters such as temperature, humidity and pressure, then observe and react to phenomena in the environment. Wireless Sensor Networks provide several applications from military applications such as battlefield mapping and target surveillance to creating smart homes and environment monitoring. In most of the applications [1-4], sensors are brought to collect data in a remote environment in order to detect an event and then communicate the collected information to a distant base station (BS) from where it's made available for the end-user.

Energy of sensors is usually limited since harsh conditions and remote applications area make it quite impossible to recharge or replace their batteries. Energy of sensor nodes is consumed by sensing, processing and communicating the data and also in other operations performed by nodes. Communication is the most greedy part, in fact it consumes the largest amount of energy as illustrated in Fig. 2.

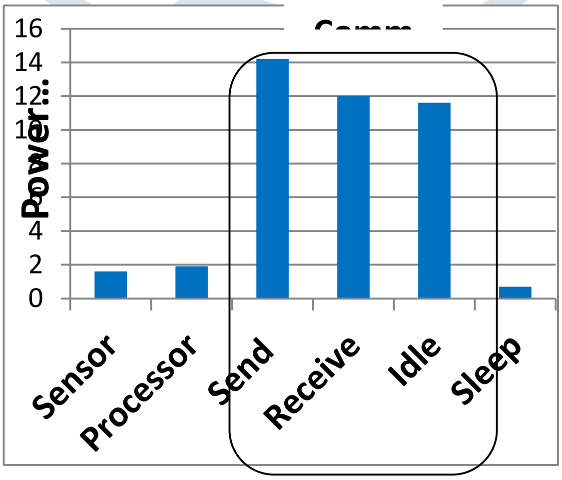


Fig. 2. Energy consumption in WSN

As energy is a major constraint, the main idea behind WSN is to develop energy efficient algorithms that optimize energy consumption. In this respect, Clustering [5-9] is the most used method to optimize energy consumption in WSN. It consists of separating sensors into hierarchical groups. In fact, by dividing them in two group: the normal sensors and the cluster heads (CH). Normal nodes send collected data to their respective CH, this latter then send the collected data to the BS after aggregation and compression. Since only some nodes are needed to transmit data over a long distance to the BS, more energy is saved and the overall network lifespan is increased. We recognize two kinds of hierarchical schemes. The homogeneous clustering schemes which are used in homogeneous systems in which all sensor nodes have the same amount of energy such as LEACH [10], HEED

[11], and PEGASIS [12]. The heterogeneous clustering schemes are used in heterogeneous systems where all the sensor nodes have different amount of energy, such as SEP [13], LEACH-E [14] and DEEC [15]. Based on LEACH-E protocol, we develop and validate a Distributed Energy-Efficient and Position-Aware (DEEP) routing protocol for heterogeneous wireless sensor networks. This protocol is intended to increase the overall network lifespan of heterogeneous WSN. In DEEP we add an extra hierarchical level following two criteria : the position and energy level of the CH. This method improves and optimizes the use of the energy dissipated in the network. The use of an extra hierarchical layer for data transmission to the base station takes advantage of multi-hop and small distance transmissions and reduces number of redundant messages. As a consequence, only one CH, the most powerful one which we call master cluster head (MCH) is required to transmit data over faraway distance to the BS. This allows a better energy utilization through the sensor network and increases the network lifespan accordingly. The remainder of this paper is organized as follows. Section II presents the heterogeneous WSN model. Section III exhibits the details and analyzes the properties of DEEP. Section IV evaluates the performance of DEEP trough simulations and comparison of results with LEACH-E protocol. Finally, Section V gives concluding remarks and some perspectives.

2. Heterogeneous network model

The main goal of cluster-based routing protocol is to efficiently maintain the energy consumption of sensor nodes by involving them into multi-hop communication and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the BS. In this section, we make a few statements and assumptions about the network scheme and introduce the network and energy model used in this work. In this study we suppose that there are N sensor nodes, which are consistently dispersed over a M x M square area as illustrated in Fig. 3. These sensors have always information to transmit to the BS which is located far from the sensing zone. This kind of WSN setting can be used in various fields such as space exploration, environment monitoring and some military applications.

o (simple node) + (advanced node) * (cluster head)

Normally CHs transmit collected data directly to the BS. We suppose that sensor nodes are stationary as assumed in [14]. In the two-level hierarchical WSN, there are two kinds of sensor nodes, the advanced nodes and normal ones. E_0 is the initial energy of normal nodes, and m is the fraction of advanced nodes, which have a times more energy than the normal ones. Therefore, there are $(N \times m)$ advanced nodes fit out with $E_0(1+a)$initial energy, and $N(1-m)$ normal nodes fit out with same initial energy. The total initial energy of the two

Where E_{elec} is the energy dissipated per bit to run the transmitter E_{Tx} or the receiver E_{Rx} circuit, and $\epsilon_{amp} d^4$ depend on the amplifier model used and d is the distance between the sender and the receiver. We will fix the value of d_0 at 87.7 meters. In most WSN, sensor nodes have limited power supply since they are usually powered by batteries. Energy plays an important role in their design. One of the drawbacks of LEACH-E is that CH communicate directly to the BS as shown in Fig. 4, this can lead high energy consumption. Moreover, All CHs send data to the BS, this can cause redundant and unnecessary information transmitted to the BS.

In this respect, we develop a Distributed Energy-Efficient and position-aware routing protocol (DEEP) for heterogeneous wireless sensor networks. Based on LEACH-E probability threshold to elect CHs, DEEP achieves a large reduction in the energy consumption and increases the WSN lifespan by adding an new hierarchical layer for data transmission to the BS. In next section, we describe the DEEP protocol in more details.

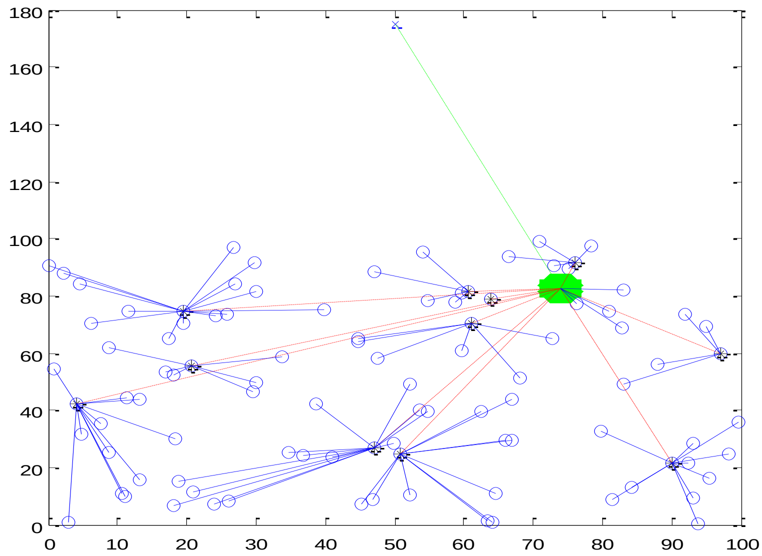
3. Our DEEP protocol

DEEP protocol uses the same probability formula as in LEACH-E. In order to optimize energy consumption, we add a second hierarchical layer for data transmission to the BS. Furthermore, we set a condition about the position of the CH which act as relay between all CHs and the BS. We select the most powerful CH that we call MCH as intermediate hierarchical level between CHs and the BS. The MCH is chosen based on its energy level and its position to be close to the BS. In fact, by using this method we reduce the number of far distance transmissions since the nodes will only have to make short distance communications while the MCH will handle far distance transmissions to the BS. The main characteristics of DEEP protocol are :

- All nodes in the network are heterogeneous and have limited energy.
- All nodes are able to communicate with CHs.
- CHs perform data compression and aggregation.
- CHs communicate to BS trough the MCH.
- The MCH is chosen among all CHs.
- The MCH is the CH having the highest energy level and position close to BS.
- The BS is immobile and located far from the sensing area.

We assume that the N nodes in the network are distributed over a M×M square zone and that the network topology stay the same over time and the BS is situated in (x = 50, y = 175) as shown in Fig. 5.

Normal node Master Cluster Head Cluster head



Based on the position of coordinates and the broadcasted message, the CHs elected can select the MCH. Consequently, the CH with the highest energy level and close to the BS will be chosen as MCH in this round. This last node gather all data coming from all CHs, compress it into a single signal and send it directly to the BS. We have chosen the MCH as intermediate hierarchical level, because only this latter will grant transmission in long distance. In fact, other nodes will not have to dissipate energy by performing long distance transmission to the BS since they will be involved in multi-hop and short distance transmissions.

4. Simulations : Results and Discussion

In this section, we put in evaluation our proposed DEEP protocol using MATLAB. We consider a WSN with N = 100 nodes randomly distributed over a area of 100 m × 100 m. We compare the performance of DEEP with LEACH-E protocol. For that, we create several scenarios to examine the following metrics. We assume that, energy is reduced whenever a node transmits or receives data and whenever it performs data aggregation. A sensor node is dead when it runs out of energy, and can no longer transmit or receive data. First, we examine the stability period of our DEEP protocol and compare it to that of LEACH-E. We will analyse the performance of LEACH-E and DEEP routing protocols using the simulation parameters listed in Table 1

Firstly, we calculate the number of nodes alive over time. Fig. 6. shows the results in the case with m = 0.1 and a = 5. This metric is important because it gives the end user reliable information of the sensing area. It is obvious in Figure 7 that the stability period of DEEP is larger compared to that of LEACH-E. It is observed that DEEP performs better than LEACH-E in terms of the number of alive nodes : all nodes remain alive until 1722 rounds for DEEP, while the corresponding number for LEACH-E is around 900 rounds.

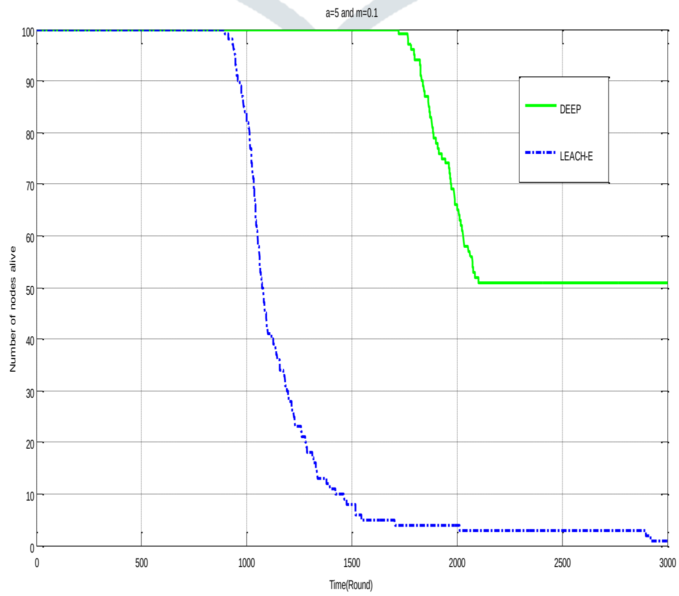


Fig. 6. Number of nodes alive over time

We can clearly see that the period of stability of DEEP exceeds considerably that of LEACH-E. We can also note that more than 50% of nodes remain alive up to 2102 rounds, this result is very important especially for non-critical applications such as in agriculture applications. The results show that DEEP is more efficient than LEACH-E and performs better in terms of stability and availability. Furthermore, we calculate the First Node Died (FND) and the Half Node Died (HND) for DEEP and LEACH-E and we get the number of nodes alive in 3000 rounds. The results are summarized in Table 2.

Secondly, we compute the number of messages received at the BS over time for DEEP and LEACH-E. The results of Fig. 7 shows that the messages delivered to the BS by DEEP are much higher than those of LEACH-E. This means that DEEP is a more efficient protocol an can offer a better reliability and scalability.

Lastly, we compute the number of nodes alive over number of messages received at the BS. It is clearly illustrated in Fig. 8 that the number of nodes alive for DEEP far exceeds those of LEACH-E.

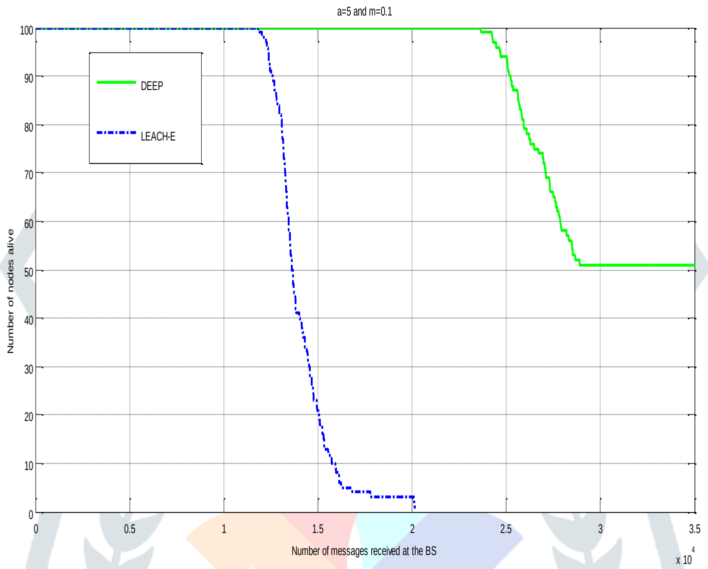


Fig. 8. Number of node alive over Number of messages received at the BS

5. CONCLUSION

Most of existing clustering protocols aims to maximize lifetime of the sensor nodes in wireless sensor networks. In this paper we propose a Distributed Energy-Efficient and Position-aware (DEEP) protocol for heterogeneous wireless sensor networks. In DEEP, We select the most powerful CH in a position close to the BS which Master Cluster Head (MCH) to act as gateway between the cluster heads and the base station. The simulation results shows that DEEP outperforms LEACH-E in terms of network lifetime and number of messages received at the BS. As perspective, we aim to extend our work by adding more master cluster head in large geographical region in order to evaluate scalability in multi-level energy WSN.

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