Novel approach to maximise the lifetime of Wireless sensor networks

Hierarchical protocols LEACH and PEGASIS

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ABSTRACT. The hierarchical routing of data in WSNs is a specific class of routing protocols it encompasses solutions that take a restructuring of the physical network in a logical hierarchy system for the optimization of the consumption of energy. Several hierarchical routing solutions proposed, namely: the protocol LEACH (Low Energy Adaptive Clustering Hierarchy) consist of dividing the network in distributed clusters at one pop in order of faster data delivery and PEGASIS protocol (Power-Efficient Gathering in Sensor Information Systems) which uses the principle of constructing a chain's sensor node. Our contribution consists of a hierarchical routing protocol, which is the minimization of the energy consumption by reducing the transmission distance of data and reducing the data delivery time. Our solution combines the two hierarchical routing approaches: chain based approach and the cluster based approach. Our approach allows for multi-hop communications, intra- and inter- cluster, and a collaborative aggregation of data in each Cluster, and a collaborative aggregation of data at each sensor node.

KEYWORDS: Hierarchical routing, LEACH, Optimization of energy, PEGASIS, WSNs

1. Introduction

Wireless sensor networks (WSN) consist of a large number of devices known as sensors. These are equipped with the ability to collect physical quantities such as temperature, pressure, pH, etc. in a study area. Then, they perform a processing on the collected data before they cooperate among them to route it to a control center called base station. Due to the small size of the sensors and their low cost of production, WSN offer numerous practical applications; these applications may be sensitive especially in the military, medical, environmental, etc. [1].

Due to the miniaturization constraints [2], the nodes typically have very limited resources in terms of computing capacity, data storage space, transmission and energy flow. These limits are part of the research questions in the field of wireless sensor networks. In particular, the constraint linked to energy is a fundamental problem. Indeed, all elements need energy to operate; the control of energy consumption of a node remains a major problem for maximizing its lifetime [3, 4, 5].Hierarchical routing is considered as a powerful tool as regards to the minimization of the energy consumption compared to other types of routing. Our contribution is to propose a new hybrid approach based on hierarchical protocols [6, 7, 8, 9]. Hierarchical routing is considered a powerful tool for minimizing power consumption compared to other types of routing. Our contribution consists to propose a new hybrid approach based on hierarchical protocols. The rest of this article is structured as follows:

In the next section, we presented the energy consumption model. Then we present our hybrid approach in section 3. Finally we evaluate the performance of our approach in section 4, before concluding and presenting the perspectives of this work.

2. Model of Energy Consumption

The sensor node consumes energy to perform three main tasks: detecting, communication and data processing. The energy used for the detection of physical phenomena is not very important. As well as the one used for the treatment is lower than the energy of communication. For example, the necessary energy to transmit 1KB over a distance of 100m is approximately equivalent to the energy needed to run 3 million instructions with a speed of 100 million instructions per second. While the necessary energy for processing the data is calculated by applying the following formula :

$$E_{DA} = 5\,\text{nanojoule}/\,1\,\text{bit} \quad (1)$$

Since communications dissipate much more energy than other tasks, a power radio's consumption model is proposed by Heinzelman et al. [10] Thus, the necessary energies to emit E_{tx} and receive E_{rx} messages are given by:

To send a message of k bits over a distance of d meters, the transmitter consumes:

$$\begin{aligned} E_{tx}(k,d) &= E_{tx-elec}(k) + E_{tx-amp}(k,d) \\ &= k.E_{elec} + k.E_{fs}.d^2 \quad si\ d < d_0 \\ &= k.E_{elec} + k.E_{amp}.d^4 si\ d \geq d_0 \end{aligned} \tag{2}$$

To receive a message of k bits, the receiver consumes:

$$E_{rx}(k) = k.E_{elec} \tag{3}$$

Where $E_{tx-elec}(k)$ It is the energy transmission, $E_{tx-amp}(k,d)$ it is the amplification energy E_{elec} is the amount of energy consumed by a bit and E_{fs} is the signal amplification in a lower distance to the threshold distanced$_0$. If the distance transmission is superior to d_0 the amplification E_{amp} is used Such as:

$$d_0 = \sqrt{\frac{E_{fs}}{E_{amp}}} \tag{4}$$

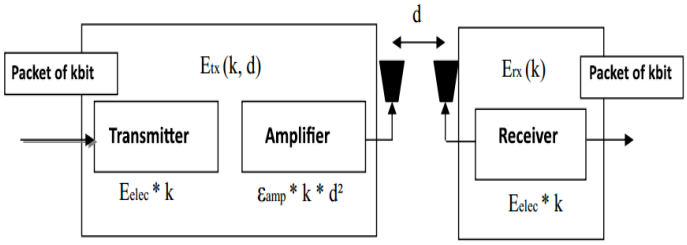

Figure 1. *A model of energy consumption*

3. Hybrid approach proposed

After analyzing the two algorithms (LEACH and PEGASIS) [3,6], we noticed that we can improve the first protocol (LEACH) by applying the concept of the second protocol (PEGASIS) within groups (cluster) and at the level of cluster heads, this leads us to propose a new hybrid protocol which combines the advantages of two broad approaches which are (clustered approach) and (chained approach).

3.1. Basic Concepts of our protocol

The proposed algorithm consists of combining the two protocols PEGASIS and LEACH according to two major steps:

Step 1: Application of PEGASIS within the cluster

The organization of the nodes those belong to the same group (cluster) in a chain can improve and regulate the energy dissipation, which reduces the load into cluster-head. Actually, the nodes communicate only with their close neighbors and not directly with their cluster-head, which saves the energetic consumption and offers better use of the bandwidth. The aggregation of data at each node between nodes and cluster-head, this is the consequence of preserving energy reserves in the nodes and cluster-head.

The figure below shows how the nodes are organized in groups (clusters), the C0 node transmits its data to its nearest neighbor C1, C1 aggregates the data received with its own and transmits them to its neighbor until they reach the leader node which transmits them to the CH(cluster-head). So in this first organizational step (chain group), all nodes in the cluster will transmit their data collected in their respective CHs (cluster-heads) by connecting them through the chain, while each CH receive the collected data by the leader node (the nearest node CH) of the chain.

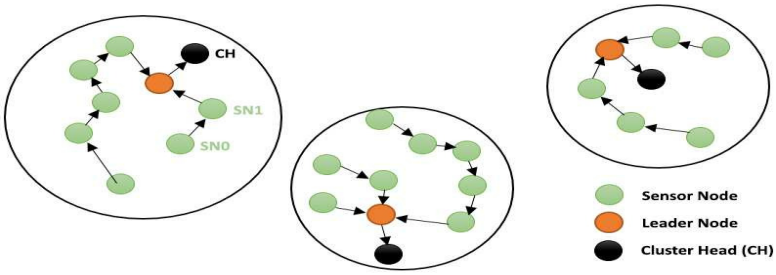

Figure 2. *Organization of nodes of a cluster as chain*

Step 2: Application of PEGASIS at Cluster heads level

The principle of this second step is to organize cluster head nodes as a closely neighbor chain. In order to prevent the farthest cluster-heads from the base station to die quickly, thereby, aggregating the data at each cluster-head reduces the number of transmissions to the base station to a single transmission carried out by the cluster-head leader of the chain, which also reduces the load on the base station. This allows to save and to regulate the energy consumption by cluster-heads.

The below figure shows how the cluster-heads nodes will be organized, the node CH_0transmits its data to its nearest neighbor CH_1, CH_1 aggregates the data received with its own and transmits them to its neighbor until the cluster-head leader which transmits them to the base station. So in this first organizational step (chain group), all cluster-heads nodes will transmit their collected data respectively to the base station by being connected to the chain, while the base station must receive the data collected by the leader node (the closest node base station) in the chain.

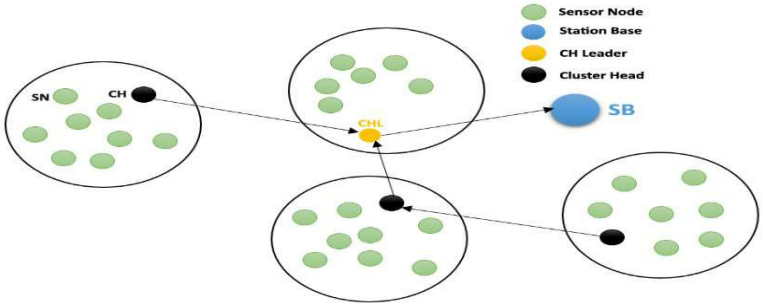

Figure 3. *Organization of cluster heads as chain*

To summarize, our approach is used to improve the LEACH protocol by using basic concepts of PEGASIS protocol, this improvement can change in the LEACH's topology as shown in the figure below :

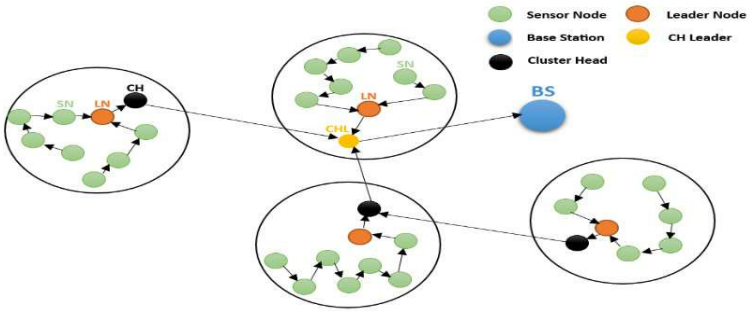

Figure 4. *Topology of our hybrid approach*

3.2. Major steps of our algorithm

The progress of our hybrid protocol is divided into several execution cycles (Figure 11). Each cycle begins with an initialization phase in which the chain clusters are formed. The CHs are elected and the CH chain is formed, followed by a transmission phase where the collected data is transferred through the chains to the CHs which in turn transmit them to the control center through the CH chain. Nodes must all be synchronized to participate in the initialization phase at the same time

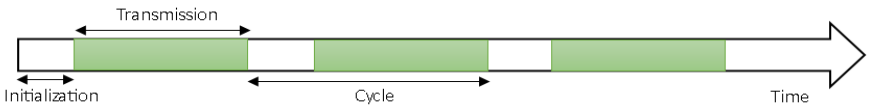

Figure 5. *Stages of execution of our hybrid approach*

3.2.1. Initialization step

The initialization step begins with the creation of the groups in which we adopt the same approach used in centralized LEACH-C, where the base station uses the simulated success to form groups. This approach provides a better result compared to the distributed approach, used in LEACH, in terms of forming groups and energy conservation. After the formation of groups, cluster-heads are selected in a simplified way where only the node that has the largest reserve of energy among the nodes of the same group, is elected. Then we approach the construction of two chains, chain linked the same cluster member nodes and other nodes linked the cluster-heads where a centralized method is followed in which the base station uses the information sent by the nodes to form chain using the chain forming algorithm proposed by PEGASIS algorithm.

3.2.2. Transmission step:

The transmission step is divided into several iterations in which nodes will transmit their collected data, through the chain, to the cluster-heads. In addition, these cluster-heads transmit in turn, their data through the chain they form to the base station. In each iteration, a node transmits at least one data packet during its time slot previously allocated by the base station. Knowing that the time slot allocated to each node is constant, the time for each iteration of transmission will obviously depend on the number of existing nodes in each cluster and the number of cluster-heads.

The transmission phase in our approach is divided into two stages: the first stage concerns the intra_cluster transmission and the second stage concerns the inter-cluster transmission. In the first stage, the members of each cluster node transmit their collected data through the chain to their cluster-head. After the cluster-heads receives data, the

transmission process proceeds to the second step of transmitting the collected data by the cluster-heads through the channel to the base station. We can summarize this phase by the following:

- Data collected through the sensor nodes.
- Transfer of aggregated and collected data from neighboring nodes through the chain to cluster-heads.
- The cluster-heads transmit the received data from the closest neighbor through the chain to the base station.

4. Evaluation of our approach

The simulation of our hybrid algorithm is the most important stage in our work since we can prove the improvements made in terms of energy savings and overall lifetime of the network using the results provided. The performance analysis of our hybrid routing algorithm is evaluated using MATLAB. The results from the simulation are compared with LEACH algorithms and PEGASIS in terms of network lifetime.

To compare the lifetime of the network between the two algorithms LEACH and PEGASIS and our algorithm, we measured the residual energy of sensor nodes for each iteration to determine the number of communication rounds when 1%, 20%, 50% and 100% of nodes die, we reused and reconfigured according to our parameters, simulation information LEACH and PEGASIS protocols provided in [11] and [12], and compared with the results of our simulation, the result is given as a graph in below Figures:

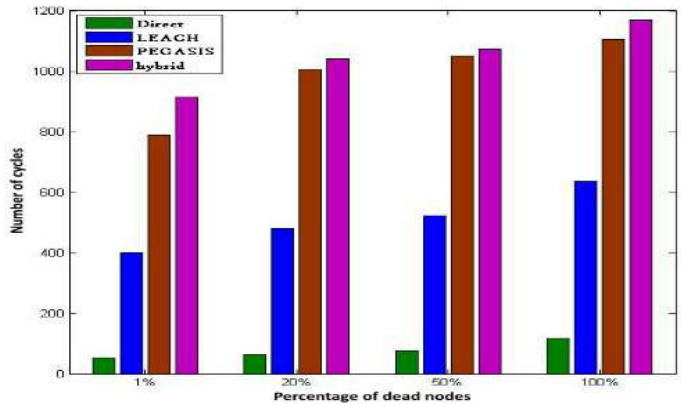

Figure 7. *The performance results of a network of 50m x 50m with an initial energy of 0.25j / node*

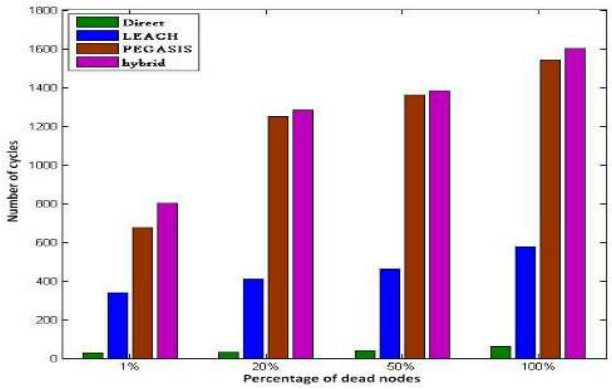

Figure 8. *The performance results of a network of 100m x 100m with an initial energy of 0.5J / node*

Based on simulation results, we have shown that our hybrid algorithm improves the energy dissipation inside and outside clusters, increases energy gain, and extends the lifetime of the network from 50% to 75% compared to the LEACH protocol and from 10% to 17% compared to PEGASIS protocol.It remains to be noted that our algorithm provided the best value, since it increases the lifetime of the network compared to LEACH protocol, and significantly reduces the extreme latency introduced by the protocol PEGASIS.

5. Conclusion

Motivated by the extreme latency introduced by the long nodes chain in the PEGASIS protocol and poor energy dissipation in the LEACH protocol, where cluster heads and farthest nodes die faster than others nodes, we tried to propose a new algorithm that combines the benefits of both protocols in order to reduce their disadvantages and provide a best value life / latency. To validate the improvements made by our protocol in terms of extending the network lifetime and the effective management of energy consumption, we simulated the operation of our algorithm with MATLAB and compared the results with those provided protocol LEACH and PEGASIS.

The results from the simulation show that our protocol offers better power management compared to LEACH and PEGASIS protocols. In addition, the degree of latency caused by the long chain in the PEGASIS protocol is significantly reduced.

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