Improving the Hierarchical Routing Protocol to Enhance the Lifespan of Wireless Sensor Networks

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Summary
Wireless sensor networks are a group of small sensor nodes that can monitor and sense the surrounding area and transmit data to a main station. The serious challenge for sensor networks is the restrictions on energy in the nodes, which sometimes affects the networks survival. As a result one major issue to consider in designing these networks is the development of protocols and algorithms that make the best use of limited sources, especially energy sources. One very important algorithm is the routing algorithm which is directly connected to the energy consumption and network lifespan. Among the routings offered for these networks, hierarchical routing protocols turn out to save a great deal of energy. In these protocols, the present nodes with higher energy can be used to gather data and routing information. In this paper, a clustering approach is proposed based on a three-way method to increase the network lifespan. The efficiency and performance of the proposed algorithm has been tested using simulation tools in different scenarios. Final results show an overall improvement in the network performance including network lifespan and some more basic criteria in compare to other algorithms.

Keywords:
Hierarchical wireless sensor networks, Routing algorithm, network lifespan, Node energy consumption

1. Introduction

Technological Advances in Telecommunications and Electronics in recent years lead to the construction of small inexpensive sensors that manage to establish a wireless communication. These sensors are called wireless sensor networks which are great tools for monitoring and collecting data in the physical conditions of the environment. These networks are increasingly and steadily used in many industrial, military and consumer applications. A big challenge in these networks is the Energy sources and the limited capacity of energy. Therefore, researches tend to provide efficient groups of algorithms and methods that increase the lifespan of nodes and consequently that of sensor networks (1,2). In order to increase the network lifespan, an algorithm is proposed in this paper according to the HHCA algorithm. However, one problem with this algorithm is that nodes choose their cluster header according to LEACH algorithm. Besides, the node energy does not have a place in choosing cluster header and gridding.

In this paper, we present an energy-aware algorithm for packet routing in a hierarchical network. Since in the proposed algorithm, the selection of cluster headers is based on the parameters like the remaining energy and distance, energy is ultimately distributed in a more organized way. As a result we would have a lengthier network lifespan. And the simulation would show a decrease in energy consumption as well as an increase in network lifespan. The simulation also indicates that the proposed algorithm works more efficiently.

The rest of this paper is as follows: The second section, discusses the HHCA routing protocol. In Section 3, the proposed algorithm is discussed. The fourth section displays the simulation results. Finally, in the fifth section a conclusion and review of the material is delivered.

2. Theoretical Consideration

One of the most important methods in increasing the network lifespan is the efficient consumption of energy. In this paper, the disadvantages of the HHCA[1] algorithm are considered, in which the nodes select their cluster header using the LEACH algorithm, and the cluster grid selection is made according to equality(3) without taking into account the node energy. In this method which is based on a three-way method, a clustering approach is suggested. This approach combines the gridding for high-level header and distributed clustering for selecting a lower head level. In this algorithm, the header grid is located in the second layer, the cluster header in the first layer and sensor nodes are located in the zero layer. Sensor nodes send data from the zero layer to the first layer of the cluster, then to the second layer of grid header and finally to the central station. Figure (1-2) displays an overview of three-way hierarchical clustering. Our proposed algorithm

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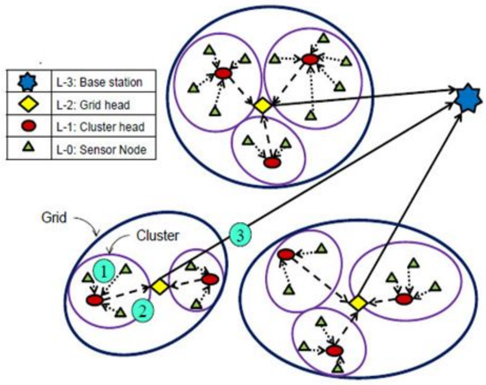
consists of four stages, which are discussed in detail in the following section.



(1-2)

Figure 1 An overview of three-way hierarchical

Stage 1: Formation of the Cluster
In the first part, after the random distribution of sensor nodes in particular areas, the network starts running while each sensor node sends the Hello message to the central station. This message contains the identification number, location and energy of each node.
After the central station receives the Hello message, T (p) is measured in the equation 4, and the right node will be selected as the cluster header.

$$T(p) = \alpha e_i + \beta\left(\frac{1}{dt_i}\right) + e^{\gamma e_i}$$

α, β, γ

refer to the random numbers between 0 and 1.
On the condition that: $\alpha + \beta + \gamma = 1$
e_i shows the remaining energy of the node, dt_i stands for the distance between cluster header and central station. e^{e_i} calculates the exponential function of the remaining energy of the cluster header.

Stage 2: Formation of Clusters
At this stage, it must be decided which node belongs to which cluster header. Each cluster header transmits the CH-message in the network and waits for the JOIN-REQ message from the cluster nodes. The cluster node with the highest energy and the least distance is selected as its cluster header**.**
Stage 3: Selection of the Cluster Header
Then each cluster header chooses the two clusters with the least distance and compares the remaining energy of the nodes with each other. The node with the highest energy level will be selected. If both nodes have the same level of energy, the node with the less distance will be picked. Since the sensor network nodes work with energy, the node with the less energy may be selected. Sometimes the nodes in the cluster might be further than the cluster header. In this case the nodes lose much more energy and deteriorate much sooner than other nodes in the cluster. In choosing the cluster header, a node might have less distance to the cluster header, but it also might have much less energy. Therefore, by evaluating the node energy and its distance from the cluster header, we can choose the clusters and grid headers with the higher energy nodes in routing and hence a more network lifespan.

Stage Four: Data Transfer
Once the clusters are formed, after a defined period, every cluster header runs the TDMA program. Then, each node sends its own data to its cluster header. At this point, the cluster header receives all the sensor data and sends them to its grid header. The grid header transmits the receive packets to the central station based on the TDMA.

3. Experimental Consideration

In this section, the simulation results of the proposed algorithm will be compared with the LEACH, HHCA algorithms: the number of alive nodes, total energy consumption of all nodes, and the amount of packet received at the central station will be analyzed.

3.1 Simulation parameters

In order to send and receive the data packets, an amount of energy will be extracted from the energy source of the sensor. The required amount of energy for sending and receiving the packets are as follows. The energy consumption for transmitting a K bit message to d, will be estimated according to equation (5).

$$E_{TX}(k,d) = \begin{cases} E_{elec} * (K) + \varepsilon_{fs} * (K * d^2) & if\ d < d_0 \\ E_{elec} * (K) + \epsilon_{amp} * (K * d^4) & if\ d \geq d_0 \end{cases}$$

In this model, in order to receive a k bit message, E_{rx} energy will be consumed. Equation (6) shows the calculation of E_{rx} .
(8)
$$E_{rx}(k) = E_{elec} * (K)$$

In Equation 6, 5: E_{elec} is the base energy required for transmitter and receiver circuits [8,9,10]. In table 1, the primary values of common simulation parameters for wireless sensor networks are presented.

Table 1: The conditions for simulation

Parameters	Value
Area of simulation area	100×100square meters
E_{elec}	50 nj/bit
ε_{fs}	10 pj/bit/m^2
ε_{mp}	0.0013pj/bit/m^4
Primary energy of the node	0.5
Data packet	500 bytes
Header packet	20 bytes
Number of sensor nodes	100
Simulation period	20m

3.2: Comparing network lifespan with total energy consumption

Since the end of energy in a node would also mean the death of that node, one of the most important parameters of the optimization lies in studying the lifespan of the nodes in the wireless sensor network. Therefore, in order to show the parameter of the number of alive nodes in the sensor network, we calculate the nodes present at the beginning of the energy network and, by continuing to simulate, we would know the energy loss rate. As the simulation results suggest, the node's loss rate is the same as the loss of nodes over time. Figure 2 shows the network lifespan. As it displays, the proposed algorithm has a better performance in the network lifespan than the LEACH, HHCA algorithms. In the LEACH algorithm, the death of the first node occurs in 156, and in the HHCA algorithm the death of the first node is in 503, while in the proposed algorithm the death of the first node comes about in the 763rd round. This all indicates the better performance of the proposed algorithm.

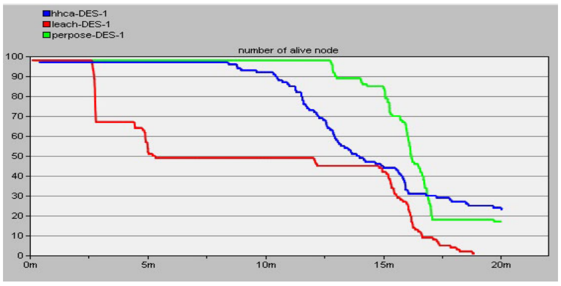


Figure 2: Network lifespan

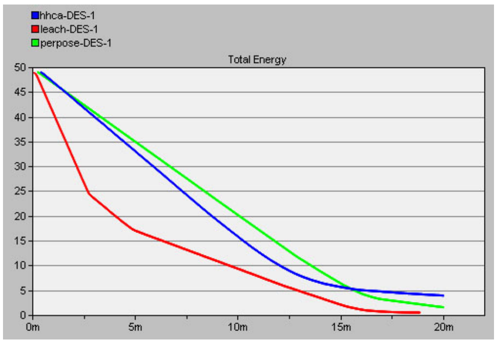


Figure 3: The whole energy consumption of the nodes

Another optimal parameter in the wireless sensor network is the analysis of the energy consumption in the nodes. To meet this objective, we calculate the total energy consumption of all nodes in the sensor network. As shown in Fig. 3, the total energy consumption of the all network nodes in the proposed algorithm has been significantly improved comparing to the LEACH, HHCA algorithms, and the simulation results show better behavior of the proposed algorithm.

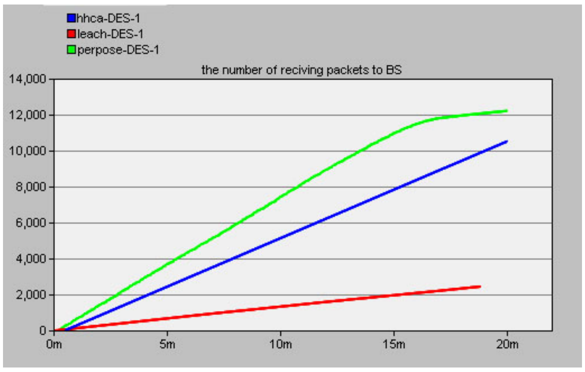


Figure 4: The number of data packet sent to the central station

3.3: Comparing the number of packets sent to the central station

Figure 4 shows the number of packets sent to the central station. The amount of packets received in the proposed algorithm is more than the ones received in the LEACH, HHCA algorithms. Since in the proposed algorithm the route selection is designed in a way that the death of the nodes occurs later, the central station receives more packets. According to the simulation results, the efficiency of the hierarchical sensor network is due to the optimality of the proposed algorithm in the number of packets sent to the central station.

4. Conclusion

The wireless sensor network creates an intelligent environment which gathers data from the coverage area and sends information to the base station. The optimal energy consumption in these sensors plays an effective role in the networks survival. From all the protocols proposed to increase the network lifespan by creating a balance in energy consumption, hierarchical routing protocols prove to save a great deal of energy. In this paper, due to the weaknesses of the HHCA, an algorithm was proposed to provide a more coherent distribution of energy and thus an increase in the network lifespan. This aim was carried out by finding the best cluster header in terms of remaining energy and distance parameter. Due to simulation results, the proposed algorithm has been able to increase the lifespan of the hierarchical network by decreasing the energy consumption.

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