Improved Grouping Protocol of Homogeneous Wireless Sensor Network for Smart Environment

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Abstract. Smart environment is widely applied and it is the most important application of wireless sensor networks. Reduction of the energy consumption problem is the key to developing WSN. In the cluster based of energy-efficient method, the fixed cluster head number, the energy of node and the transmission distance are the keys to extending the network lifetime. We propose an improved grouping protocol to make the cluster head number the same with expectancy. The total energy of a group and the distance between node and BS are both used to generate the group. The proposed method is compared with previous works by simulation to evaluate the performances.

Keywords: wireless sensor network, energy consumption, smart environment.

1 Introduction

Smart environment shows a great promise in the health care, environment monitoring, and ubiquitous computing applications. It combines the sensing, machine learning, pervasive computing, and communication technologies, assisting human with valuable functions [1]. Smart environment is also the most important application of wireless sensor networks (WSN) [2]. A WSN consists of a large number of sensor nodes, which have small volume, low-cost, limited computation and limited power capacity [3]. Each node is used to sense and to transmit the sensed data to the base station (BS) for application.

Since sensor nodes are small size and the energy carried by the battery is limited, to develop the energy efficient method for increasing the network lifetime becomes an important issue [4]. To reduce the energy consumption, we can enhance the hard ware efficiency or improve the network performance. There are many proposed network routing protocols [5-11]. The most common routing protocol is the cluster-based protocol [12]. In the cluster-based protocol, the nodes transmit the sensed data to the cluster head. Cluster head forwards the received data to the BS [13]. The most popular of the cluster-based methods is LEACH (Low-Energy Adaptive Clustering Hierarchy) [12]. However, LEACH is designed for one-level wireless sensor network.

In order to apply cluster-based method in multi-level WSN, SEP (stable election protocol) [7] and DEEC (distributed energy-efficient clustering) [9] are proposed. LEACH, SEP, and DEEC are similar in that they are divided into the clustering stage
and the data transmission stage. During the clustering stage, the cluster heads are generated by probability. Data transmission operation is broken up into rounds. Each node sends the sensed data during each round. Compare with LEACH, the difference between SEP and DEEC is that they consider the residual energy in the probability of the cluster head selection. However, the random selection makes the number of cluster heads is not fixed.

The SGCH protocol (Steady Group Clustering Hierarchy) is proposed to fix the random selection [14, 15]. SGCH is divided into the grouping stage and the data transmission stage. In the grouping stage, all sensor nodes are uniformly divided into groups where the number of groups is equal to the expected number of clusters. In each round, the node with the maximum energy remaining in a group is selected as the cluster head. However, the residual energy of sensor node is not considered in the SGCH.

To make the energy efficient, we have to fix the number of the cluster heads and consider the energy of nodes. Since the energy consumption depends on the transmission distance, the distance should also be considered. In this paper, we propose an improved grouping protocol based on SGCH to make the cluster head number the same with expectancy. The total energy of a group and the distance between node and BS are both used to generate the group. The proposed method is compared with LEACH, SEP, DEEC by simulation to evaluate the performances.

2 Proposed Method

The proposed method is based on SGCH protocol. We call the proposed method Improved Grouping Protocol (IGP). It is divided into the grouping stage and the data transmission stage. In the grouping stage, the sensor nodes are divided into several groups. Data transmission operation is broken up into rounds. Each round begins with a cluster setup phase followed by a steady-state phase. The clusters and cluster heads are formed in the cluster setup phase. The data are transmitted to the BS in the steady-state phase. Comparing with the SGCH, the main difference of the proposed method is the grouping stage. The following summarizes the details of grouping stage of the proposed method.

In the grouping stage, the distance ratio of each group and BS will be computed. The distance ratio is used to calculate the total energy of each group. We expect the amount of clusters and groups to be the same. The distance ratio is set as

$$ \text{GD}_i = \frac{D_{\text{farthest}} - D_{\text{nearest}}}{D_{\text{nearest}} + D_{\text{farthest}}(k-i)} $$  

where GD$_i$ is the distance ratio of group $i$ and base station, $D_{\text{nearest}}$ is the shortest distance of sensing area to base station, $D_{\text{farthest}}$ is the largest distance of sensing area and base station, and $k$ is the group number (it is also the cluster number). BS calculates the total energy, $E_{\text{total}}$, of all sensor nodes and allots the energy to each group. The designed total energy for each group is
\[ G E_i = \frac{E_{\text{total}}}{\sum_{j=1}^{i} G D_j} \]

where \( GE_i \) is the allotted energy of the group \( i \). We assume that there are \( m \) sensor nodes denoted as \( N_1 \ldots N_m \). The timing diagram of the group stage is shown in Figure 1, and the step flow is summarized as follows.

**Step 1.** BS broadcasts the group header request (GHR) message to all nodes.

**Step 2.** Every node returns the ACK message to the BS when the node receives the GHR. The ACK contains the ID and the initial energy of the node.

**Step 3.** BS assigns a serial number of the nodes in order of the received ACK messages. BS then uses equations (1) and (2) to calculate the total energy of all sensor nodes and the energy of each group.

**Step 4.** BS selects the node with the largest serial number to be the head of the first group. The first group head is denoted as \( GH_1 \), and the first group is set as \( G_1 \). BS sends the group head (GH) message which contains the calculated total energy of \( G_1 \) to \( GH_1 \). We use \( GH_i \) to denote the \( i \)th selected group head.

**Step 5.** When \( GH_i \) receives GH message, it broadcasts group request (GR) message.

**Step 6.** On receiving the GR message, the node returns an ACK (which includes ID and the initial energy of the node) to \( GH_i \) if the node does not belong to any group.

**Step 7.** \( GH_i \) accumulates the energy while receiving the ACK messages. When the summed energy is equal or larger than the designed energy of \( G_i \), the accumulation is terminated, and the accumulated nodes are set to be the members of the group \( G_i \).
Step 8. GH\textsubscript{i} broadcasts group agreement (GA) message to the group members and the BS. The BS records the G\textsubscript{i} and its members.

Step 9. BS selects a node which does not belong any group and with the largest serial number to be the next group header. The selected group head is set as GH\textsubscript{i+1} and the group is set as G\textsubscript{i+1}. BS sends GHR messages to GH\textsubscript{i+1}.

Step 10. Steps 5 - 9 are repeated until \( i = k \).

Step 11. The last group head, GH\textsubscript{k}, broadcasts the last group (LG) message. On receiving LG, the node which does not belong to any group is set to be member of the group G\textsubscript{k}. When the BS receives the LG message, it broadcasts to all sensor nodes that the grouping stage is terminated.

3 Simulations

In the simulations, MATLAB is used to compare the proposed method and the previous works, i.e. LEACH, SEP, DEEC and SGCH. We compare the network lifetime and the amount of packets received of BS. The time variance of the node death is recorded to analyze the performance. We set a 100m×100m sensing area with randomly deployed 100 sensor nodes. Each sensor node has the same initial energy, E\textsubscript{0}. In other words, a homogeneous wireless sensor network is set to simulate the smart environment sensing. The number of clusters (or the groups) is five. The BS is located outside the sensing area (50m, 175m).

After grouping stage, the grouping results of SGCH and the proposed method are shown in Figures 2 and 3, respectively. In Figures 2 and 3, G\textsubscript{1}, G\textsubscript{2}, G\textsubscript{3}, G\textsubscript{4} and G\textsubscript{5} are denoted as □, ◇, ●, × and ☆, respectively. In the grouping result of SGCH, most nodes of G\textsubscript{5} (☆) lie on the left-top corner and there are two nodes of G\textsubscript{5} that lie on the right-top corner. Since we improve the grouping protocol, the grouping result of the proposed method makes the nodes of G\textsubscript{5} gather at the same side.

The average number of nodes alive over simulation rounds is shown in Figure 4. We can see that the time interval before the first node dies of the IGP is the longest.
Figure 5 shows the average number of messages received in the BS. The proposed method is obviously more efficient than the others.

We deploy random network topology 10 times. In each topology, we evaluate the performance. We record the death rounds of the sensor nodes. The average and the variation of the node death rounds are shown in Figure 6 and 7, respectively. We can see that the performance of the proposed method is higher than that of the others.

![Fig. 4. The number of nodes alive over round.](image)

![Fig. 5. The number of messages received in the BS](image)

![Fig. 6. The average nodes dead rounds.](image)

![Fig. 7. The variation node death rounds](image)

4 Conclusions

Smart environment is one of the most important applications of wireless sensor networks. Since the sensor node battery power is not sufficient, to reduce the energy consumption for prolonging WSN lifetime becomes a key challenge. In this paper, an improved grouping protocol is proposed. The proposed method considers the distance while allotting the energy for the grouping stage. In the simulations results, the homogeneous wireless sensor network is set to show the performance. The performance of the proposed method is better than that of the previous works. The
proposed method is suitable for smart environment created by the homogeneous wireless sensor network.

References

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