March - April 2020
ISSN: 0193-4120 Page No. 4234 - 4240

Probability of Cluster Header Suitability in Wireless Sensor Networks

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Abstract
Background/Objectives: Clustering techniques for wireless sensor networks are one of the technical methods for efficient energy management and regional distributed network management. The most basic approach to clustering is how to organize headers and members.

Methods/Statistical analysis: In this paper, the probability of cluster header suitability was calculated based on the coordinate value of sensor node, header candidate node and sink node. Based on this probability value, a method was proposed to be a cluster header and to form a distance-based member within the communication radius of the cluster header.

Findings: The selection and configuration of cluster headers and members was confirmed through distance-based C# simulations, and the connection to sink nodes was confirmed through cluster headers. This experiment selected cluster head with high probability of header suitability as a path close to the sink node, and formed cluster members around the cluster header. By adjusting the probability values when configuring a cluster member, the experiment confirmed that the network could form a cluster closer to a straight line. In addition, the higher the probability of cluster head suitability limit when configuring a cluster, the shorter the path from the sensor node to the sink.

Improvements/Applications: The method proposed in this paper can form a cluster independently by calculating each sensor node's probability value of header suitability based on coordinate value, and can transmit data at a short distance to sink node based on distance.

Keywords: *Clustering, Cluster Header, Cluster Member, Routing, Wireless Sensor Networks*

1. Introduction

Wireless sensor networks are the networks that future societies need. Along with artificial intelligence and IoT, it is one of the technologies to enrich human life. Society of the future will handle many things that people have not done before with the technology of intelligent machines and networks. Wireless sensor networks are evolving day by day with the development of sensors and the technology of wireless networks, but the problem of batteries still remains unresolved [1-3]. Because batteries in individual sensor nodes are so closely correlated with the life of the entire network, many studies are being conducted to efficiently manage energy in the wireless sensor network [4-6]. Typically, we have studied a number of ways, such as not sending data directly to sink node, but rather through sensor nodes or forming a cluster.

LEACH is a representative clustering technique and many comparable techniques were proposed [4]. In this technique, the headers were selected as a probability-based distributed method considering the amount of energy remaining and neighboring nodes to select the headers. Since then, in many papers, this technique has been basically applied and many versions and various methods have been proposed [5-7].

The reason for the cluster configuration is that it can be sent by gathering rather than sending data individually, and regional distributed tasks through cluster headers can be more efficient. In many clustering techniques that have been studied so far, issues regarding the selection of cluster headers and the composition of members have been considered. There have also been many studies on whether cluster configurations should be centralized or distributed locally. A number of studies have also been proposed on how to route the data received from the cluster header to the sink node [3,8,9].

In this paper, the composition of the cluster is not constructed within the transmission radius of the center of the cluster's header, which has been performed in many traditional ways, but rather in the form of a fan shape with the header on the line of the sink node. This is a method to minimize the length of data transfer, as described in a previous study [10]. In this study, rather than angle, three length information was used to construct cluster members: distance between sensor node and sink node, distance between header node and sink node, distance between sensor node and header node. The formula was much simpler and could have a similar effect as using angles. Limiting the result value of the formula allows the headers and member nodes to be configured closer. In addition, the data transfer routing from the cluster header to the sink node was hop-by-hop through the cluster headers to which the header belonged in the same way. In a network that does not have many sensor nodes, connectivity between cluster headers may not be a hop, but in most cases, connections to sink were guaranteed in a hop by hop manner.

The composition of this paper is as follows. There is a description of clustering techniques and routing proposed in this paper in Chapter 2, and Chapter 3 shows simulation data and results. Finally, we conclude in Chapter 4.

2. Probability of Cluster Header Suitability

A wireless sensor network can largely separate the transmission of data into two forms. Broadcasting data from the sink node to the sensor node, and data transfer from the sensor node to the sink node. It can be limited to the transfer of data between the sink node and the sensor node, not to each independent data transfer between the sensor nodes. Many clustering and routing techniques have been considered in the study of how sensor nodes that detect events are intended to deliver data to sink nodes. In fact, data transmission on a regular wireless network is done over a base station, and data transmission to a base station is direct. For wireless sensor networks, there are geographic limitations to the nature of the network as well, and due to limitations in battery use on sensor nodes, direct transmission of long distances can be avoided. In addition, for efficient energy management, each sensor node transmits data using clustering techniques rather than directly.

In the previous paper, the selection of headers and the selection of members as clustering techniques were proposed using distance and angle from sink node [10]. In this paper, we want to construct the cluster using distance information between member node and header node and sink node. In this method, clustering was constructed based on two facts:

- Cluster headers should not be farther to sink nodes than cluster members.

- When selecting a router, select the sensor node that is the farthest within a hop and the shortest to sink node as the router node.

March - April 2020
ISSN: 0193-4120 Page No. 4234 - 4240

When configuring a cluster, there are many studies where cluster headers even perform the role of routers and separately configured routers. The transfer of data through cluster headers simplifies the preparation requirements for routing. However, in terms of efficiency, it is more optimal to configure a router separately. However, additional preparation for router configuration is required. A network with many sensor nodes uses a cluster header as a router, where the header node belongs the other cluster as member node. This ensures routing by clustering alone without the need to configure additional routers.

For sensor nodes, the final destination for the transfer of data is sink node. When configuring clustering, it is more efficient to position the header in the direction of progress to the sink node. Each sensor node calculates the probability of its own header suitability so that the most appropriate header node among the sensor nodes present in the direction of progress can be selected. The more likely the suitability of this header node is, the more likely it is to become a header. The selection of headers is chosen as probability values because it is more efficient in the nature of the network to select them in a distributed and autonomous manner. If the cluster headers are selected within the transmission range from the sensor node position as shown in the figure 1, the sensor nodes that are located on the direct way to the sink node would be best suited. And it would be better for the sensor node that is the shortest away from sink node within transmission radius. The first figure shows a header candidate node within the transmission radius of sensor node. The second figure is a separate representation of the neighboring nodes that sensor node considers when calculating the probability of header suitability. Each sensor node calculates its probability of header suitability as follows.

$$\frac{\sum_{i=1}^{N} \frac{\text{Distance between neighbor node } i \text{ and sink} - \text{Distance between sensor node and sink}}{\text{Distance between neighbor node } i \text{ and sensor node}}}{\text{Number of neighbor sensor nodes}(N)} \quad (1)$$

Each sensor node receives location information from neighboring nodes within the communication radius. The probability of header suitability for each sensor node are calculated in relation to the distance between each neighboring sensor node. The more a header candidate node is located close to a straight line between sensor node and sink node, the higher the probability value. The closer the header candidate node is to the sink node than the sensor node, the higher the probability value. The probability of header suitability is the probability that header exists close to the sink node in the position of the sensor node that wants to send the data. In addition, when configuring clustering, this probability can be restricted to select a more appropriate header. In Figure 1, the candidate header nodes are shown in the position of the sensor nodes, the best of which is indicated in red.

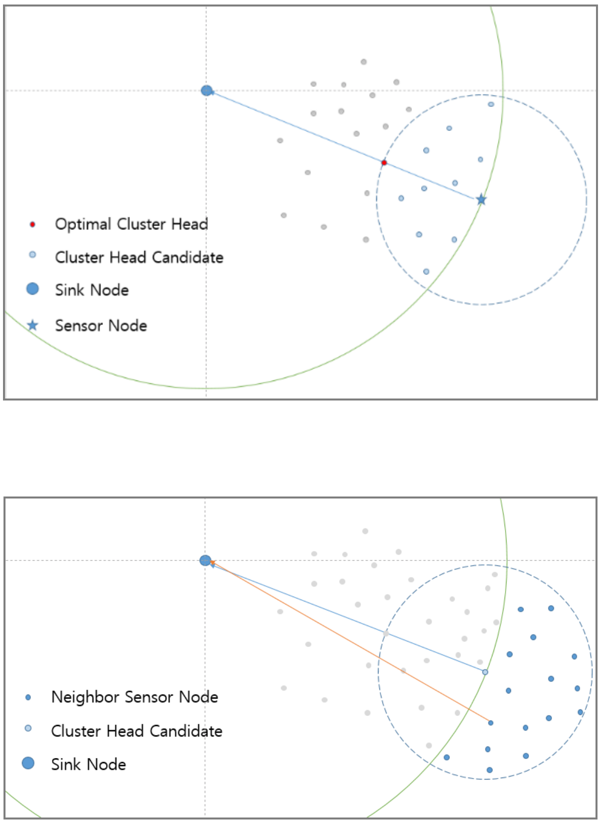


Figure 1. Cluster Header and Cluster Member

TEST Engineering & Management
March - April 2020
ISSN: 0193-4120 Page No. 4234 - 4240

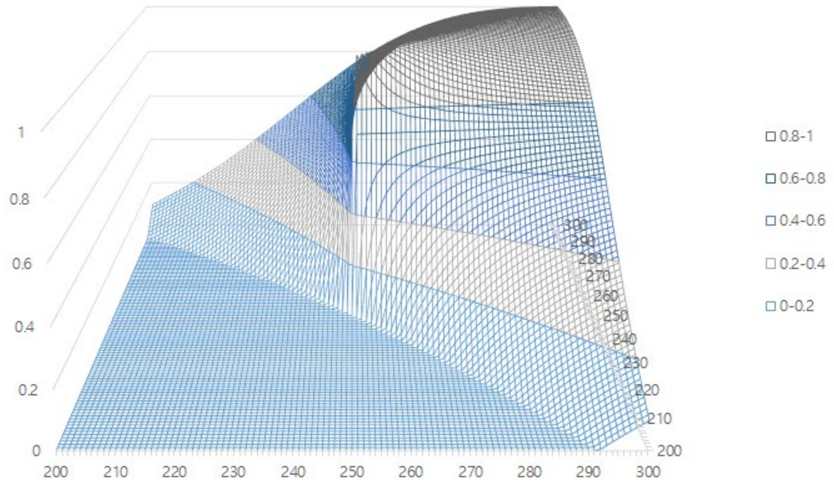


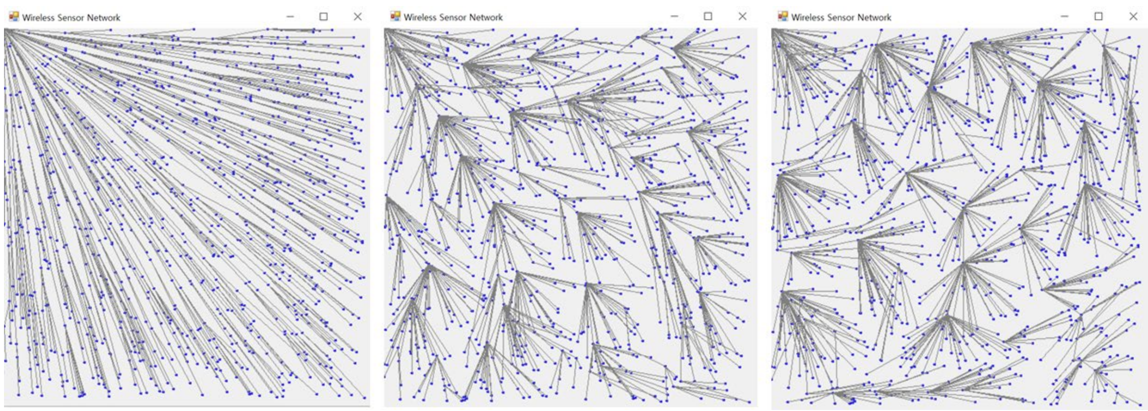
Figure 2. Probability of Header Suitability with Sensor Node (250, 250)

Each sensor node calculates its own probability of header suitability using information from its neighbor nodes. Figure 2 shows a graph of the conformity of the header with the surrounding nodes around the (250,250) node in the 500 * 500 network. A graph shows the individual probability of header suitability calculated between each sensor node and a header candidate node located in (250,250). This graph shows that distance-based cluster configuration is possible.

When the header node declares, the sensor node listening to the broadcast within transmission range will be a member of the header node with the highest probability value. The selection of the header node periodically takes into account the residual energy. This increases the network's life time. The header node transmits data to the sink node with the cluster header node to which it belongs as a member.

3. Simulation

In this paper, C#-based simulations were carried out, no consideration was given for the amount of energy, and distance-based comparisons were carried out. A simulation was conducted to compare the performance of the methods proposed in this paper. The default values used for the experiment are as follows. The network size is 500 by 500. The sink is located at (0,0). Each sensor node has a communications radius of 100. There are 1000 sensor nodes randomly placed in the network.

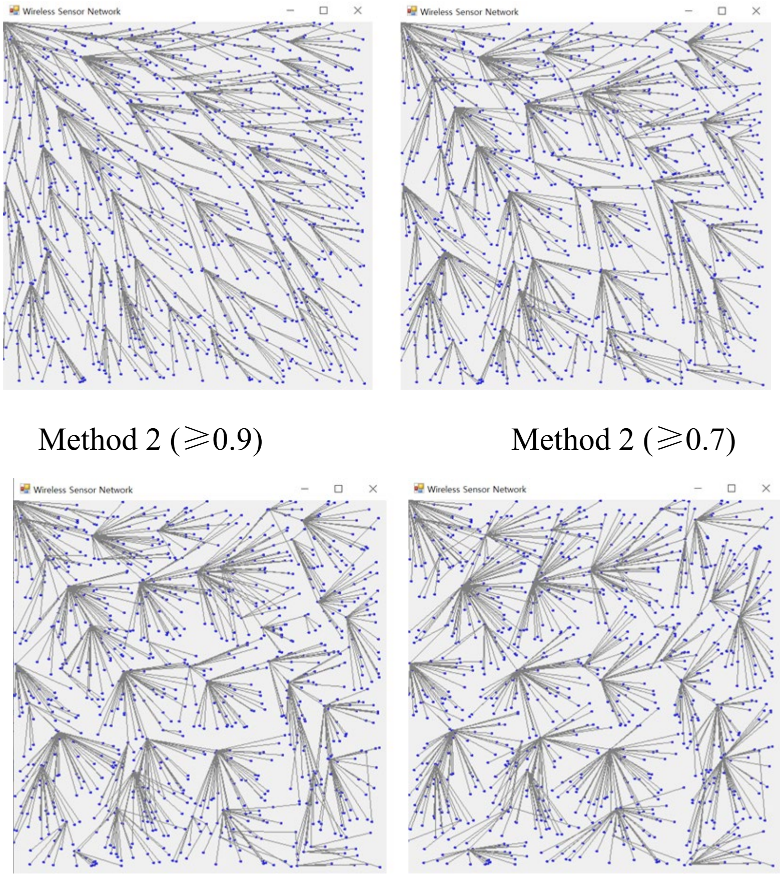


Method 1 Method 2 (⩾0.7) Method 3

Figure 4. Cluster Formation

March - April 2020
ISSN: 0193-4120 Page No. 4234 - 4240

Figure 3 shows the cluster header node located at (250,250) and the cluster member nodes which are selected by the restricted probability of header suitability. In the figure 3, the distribution plot is divided into a probability value of 0.7 or higher and a probability value of 0.5 or more. Increasing and limiting the probability values can result in a stronger bond relationship.



Method 2 (⩾0.9) Method 2 (⩾0.7)

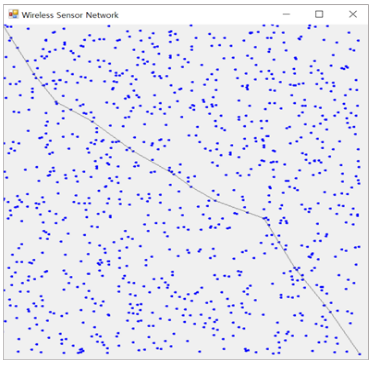
Method 2 (⩾0.5) Method 2 (⩾0.0)

Figure 5. Cluster Formation Method 2 with Different Restriction

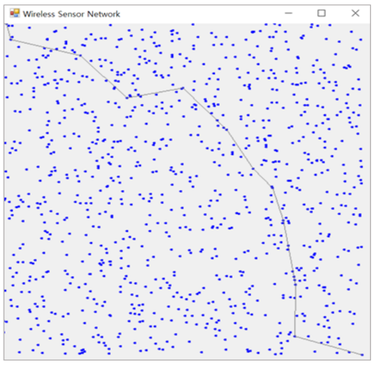
⩾ 0.7 ⩾ 0.5

Figure 3. Cluster Header and Member with Probability of Header Suitability

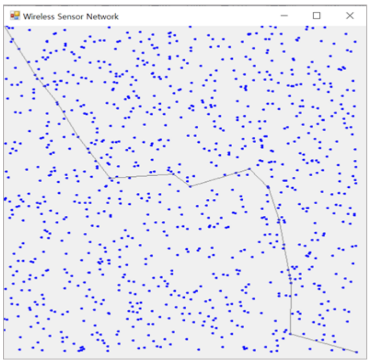
March - April 2020
ISSN: 0193-4120 Page No. 4234 - 4240



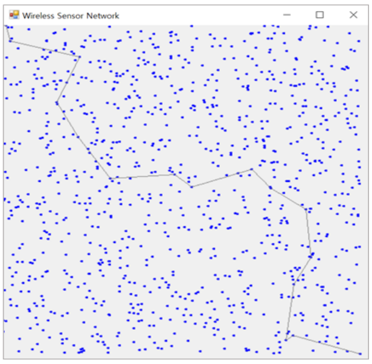
Method 2 (⩾0.9)



Method 2 (⩾0.7)



Method 2 (⩾0.5)



Method 2 (⩾0.3)

Figure 6. Path from Sensor Node (500,500) to Sink with Method 2

Figure 4 (a) shows Method 1 that is a selection of neighbor sensor node with the highest header probability to each sensor node, and Figure 4 (b) shows Method 2. In Method 2, each sensor node averages the probability of header suitability against the neighbor sensor nodes, and sensor nodes with high probability are selected as headers, and within transmission range, header compose members. Figure 4 (c) of Method 3 shows that each sensor node calculate the averaging of probability of header suitability, and each sensor node has the largest probability value of any of the neighbor sensor nodes as a header. Our proposed approach is Method 2 and can be restricted with the probability values.

Figure 5 shows the difference of the limiting in Method 2. The larger the limiting probability of header suitability, the narrower the angle it contains and the closer the entire path to a straight line.

Figure 6 shows a graph of the path of data transfer to the sink node by connecting the header nodes. The figure 6 shows the path of a sensor node located in (500,500) to the sink node through the header nodes. If the probability of header suitability was increased, the entire path would be more accessible to the straight shape of the sink node.

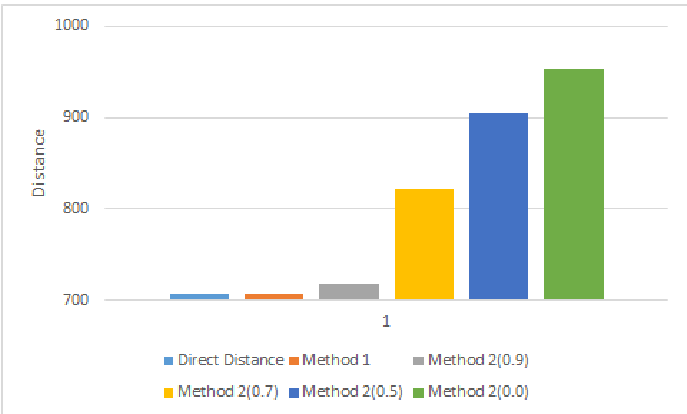


Figure 7. Path Length from Sensor Node (500,500) to Sink

Figure 7 shows the length of the path that the sensor node located in (500,500) connects to the sink node. Path length of routing through cluster headers at sensor nodes, and the path length value of routing according to the limits of header compatibility probabilities presented in this study was compared. The smaller the limit, the wider the range of members included in the header, and the longer the distance was seen. Increasing the value of the limit shows no significant difference from the direct connection.

4. Conclusion

Clustering is one of the ways for efficient energy management in sensor networks. To construct a cluster by communicating the detected data in the wireless sensor network to the sink node, the cluster headers and members were configured based on the coordinate based on the probability of header suitability. It also connects the header and header to the routing path through the cluster header and passes data to the sink node. Experiments have shown that the path becomes shorter by increasing the probability of header suitability in cluster configuration. This paper only took into account the length of the path, and in the next paper, we will study the method for prolonging the life of the network in consideration of energy etc.

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