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Fan-Shaped Flooding in Wireless Sensor Networks

EunHwa Kim
Department of AI, YongIn University, Republic of Korea

*__Correspondence:__ EunHwa Kim; ehkimanna@yongin.ac.kr

ABSTRACT: In a wireless sensor network, data flows in two main directions. There are flooding that transfers data from the sink node to the entire node and routing that transfers data sensed by each sensor node to the sink node. Transferring data from the sink node of the wireless sensor network to the entire sensor node is called flooding. In an energy-constrained environment, a more efficient method has been developed, because the most basic flooding technique contains a lot of data redundancy. In this paper, the combination of the distance-based approach and the neighboring node information method is proposed as a more energy-efficient method. Flood data can be transmitted by adjusting the angle of the transmission line within the transmission radius to the shape of a fan and limiting the distance within the communication radius. The redundancy and connectivity of data were compared and examined according to angle and distance values, and the experiment proved that the proposed method can provide connectivity to the entire sensor node while reducing data redundancy. It was confirmed that the optimal angle and distance could change according to the density and communication radius of the network. Additional research will be needed, such as a method that can dynamically calculate the optimal angle and distance while taking into account factors like network density and communication radius.

Keywords: Flooding, Clustering, Energy Efficiency, WSN

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1. INTRODUCTION

Wireless sensor networks are becoming indispensable elements in our lives with the development of AI and the Fourth Industrial Revolution. With the extension of mechanical engineering and battery life, it has become possible to develop small and flexible wireless sensor nodes. As a result, the diversity that can be used in many application areas is expanding [1,5]. The role in disaster areas that are difficult to access by people, in particular, will have a significant impact on human lives [7].

In a wireless sensor network, the direction of data delivery is largely divided into two. There is flooding in which data is delivered from the sink node to the entire sensor node of the network, and there is a method in which individual sensor nodes detect events and transfer data to the sink node. In the case of flooding, it is also used to recognize neighboring nodes for topology configuration at the beginning of the network, and to transfer data from the sink node to the entire network. It is feasible to use the whole flooding in topology configuration, but when it comes to data transfer, the rate of overlapping data increases, and energy efficiency suffers.

Many studies have been conducted on many factors for efficient energy management in wireless sensor networks [2,3,8,17,18]. In the topology configuration of the wireless sensor network, it is important to configure an appropriate network that satisfies both coverage and connectivity. In a wireless sensor network with a relatively high density due to difficulty in charging energy, the network must satisfy coverage capable of sensing the entire network area and consider connectivity between nodes for data transfer of sensor nodes [19]. Furthermore, numerous studies are being done to improve the efficiency with which sensed data is transferred. Clustering-based methods are examples of representative methods.

In this paper, a limited flooding method is proposed to manage the data redundancy of flooding. Data transfer in flooding is based on the part that the sink node sends toward the sensor nodes of the entire network. Considering that each sensor node receives data directly from the sink node, the directionality is determined. Based on this direction, the angle is adjusted to determine the data transfer range in a fan shape.

Depending on the density of the sensor node of the network, connectivity that may reach the entire node according to this angle may vary. In this paper, connectivity and redundancy were tested while varying the density and angle. In the case of high density, it was confirmed that the narrower the angle, the lower the redundancy of data while maintaining connectivity.

The following is the content of this paper: *Section 2* briefly summarizes the studies related to flooding, *Section 3* explains the fan-shaped flooding proposed in this paper, *Section 4, 5* shows the experiment and results, *Section 6* presents the discussion and *Section 7* shows the conclusions.

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2. RELATED WORKS

In a wireless sensor network, simple flooding occurs during a broadcast storm [15]. Simple flooding occurs when a sensor node receives data and sends it to all surrounding sensor nodes limited by the communication radius, resulting in data redundancy at the receiving node and data loss or delay due to channel competition within the overlapping communication radius.

In this paper, we intend to compare flooding using two metrics-data redundancy and connectivity. The data redundancy rate refers to the number of times a sensor node receives the same data in duplicate from several neighboring sensor nodes, and connectivity refers to the rate at which data transmitted from the sink node is finally received to each sensor node through several sensor nodes. This connectivity is also called the arrival rate of data. The higher the data redundancy rate, the stronger the connectivity, and the lower the redundancy rate, the lower the connectivity. The most optimal flooding technique would be a method of maximizing connectivity while lowering this redundancy rate.

In order to overcome the problems of simple flooding, various flooding methods have been proposed and compared [4,9]. Representative methods include probability-based methods and counter-based flooding, distance-based flooding, location-based flooding, and neighbor node information-based flooding [14]. In probability-based flooding, each sensor node determines whether to retransmit based on a predetermined probability value. This probability value can adjust the retransmission ratio across the entire network. This optimal ratio value determines connectivity and data redundancy. Counter-based flooding increases the counter value each time each sensor node receives redundant data and does not retransmit when this value exceeds a predetermined threshold [11]. This threshold determines the redundancy and connectivity of data [10]. In distance-based flooding, data is received for a predetermined time, and retransmission is not performed if the minimum distance value among the transmission sensor nodes of the received data is less than a predetermined threshold. The distance can be measured by the strength of the signal. Even in this method, the redundancy and connectivity of data vary depending on the optimal value of the predetermined threshold.

In the neighbor node information-based flooding, optimal flooding is performed using neighbor node information up to 2-hop [12,13]. Connectivity can be increased while reducing the data redundancy rate compared to previous methods. However, the part where information up to 2-hop must be stored can be a disadvantage.

The flooding technique proposed in this paper attempts to reduce data redundancy by using 1-hop neighboring node information in a way that transforms distance-based flooding.

3. METHODS

Flooding is the process of sending data from a sink node to the entire network in a wireless sensor network. Whole broadcasting is the most fundamental way of delivery. Since there are numerous overlapping data transfers in this situation, this paper proposes Fan-Shaped Flooding as a more energy-efficient solution.

In Fan-Shaped flooding, as shown in Figure 1, each sensor node delivers data in a fan shape away from the sink node, rather than all sensor nodes limited by the communication radius. Sensor node receiving the flooding information is determined by the location of the sink node and the transmitting sensor node.

Figure 1 is a diagram in which neighboring nodes within a 300-communication radius are connected around a sensor node located in 100 and 100. In addition, based on the sink node located at (0,0), the angles of the data transfer direction are changed to 360, 180, 120, 60, and 30.

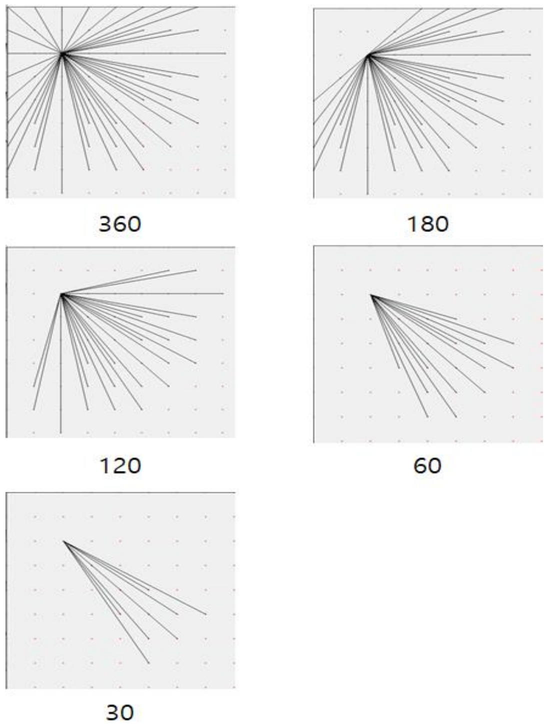

Figure 1: Fan-Shaped Flooding

Flooding, as used in this paper, is a method for restricting the number of neighboring nodes that can deliver data. Since flooding is started from the sink node to the entire network, each sensor node transfers data in the opposite direction with its back to the sink node. It is intended to adjust the width of the transmission direction to an angle, and as this angle increases, the number of neighboring sensor nodes to be transmitted increases, and a lot of overlapping data is generated. Conversely, the narrower the angle, the less redundancy of the transmitted data may be, but the connectivity of data transmission may decrease. The optimal angle is closely related to the density of sensor nodes in the entire network.

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In addition, data redundancy can be reduced by limiting the length of the transmitted radius as well as the angle. As for the length limit of this radius, the smaller the allowable length, the smaller the connectivity of the data, and the smaller the redundancy. The optimum value of the radius length may also vary depending on the density of the sensor node of the network. Figure 2 shows neighboring sensor nodes according to the length limit of the communication radius. This figure is an example of a case where the communication radius is 300 and the flooding angle is 120 around the sensor node located in (100, 100). The first figure depicts neighboring nodes across the entire radius, whereas the second depicts only those nodes that are within 0.5 of the communication radius. The final figure depicts a communication radius of 0.8 or greater. Naturally, as the limitation of the communication radius increases, the number of neighboring sensor nodes decreases and the redundancy decreases. However, since the range of neighboring nodes delivered by these neighboring sensor nodes also decreases, sensor nodes that do not receive data occur, resulting in reduced connectivity.

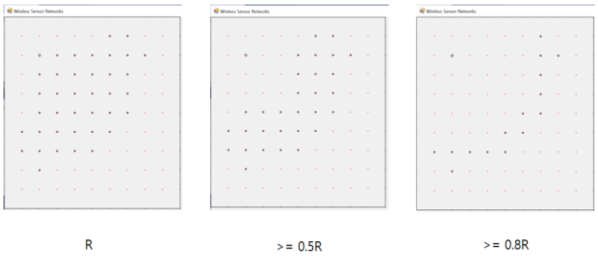

Figure 2: Neighboring sensor nodes according to communication radius limitations

Flooding requires connectivity to cover all sensor nodes in the entire network. Connectivity must be satisfied while minimizing data redundancy. Assuming that the density of the network is very high, the optimal angle in fan-shaped flooding depends on the communication radius. As the communication radius increases, the angle must increase to satisfy connectivity.

4. EXPERIMENT

A c#-based simulation was conducted to analyze the performance of fan-shaped flooding in the method proposed in this paper. The data variables used in the experiment are as follows.

- The network size is 500 by 500.
- The sink node is located at the upper left (0, 0).
- Sensor nodes are deployed randomly on the network.
- The number of Sensor nodes changed between 100 and 500.
- The communication radius is set to a value between 50 and 100.
- The flooding angle of sensor node changed from 30 to 180

Referring to the measured values of this experiment in *Fig. 3*, 200 sensor nodes were randomly arranged, and an angle of 30 degrees was formed around a straight line formed by each sensor node and sink node. That is, sensor nodes in the fan-shaped area of 60 degrees from the transmitting sensor node were configured as neighboring nodes. With only these neighboring nodes, the number of unconnected nodes is expressed to see the connectivity connected from the sink node to each sensor node. In *Figure 3*, the average number of neighboring nodes is 3.295, and out of the total 200 sensor nodes, the number of sensor nodes that are not connected from the sink node is 14.

Figure 3: Sensor Network Connectivity with flooding angle

Data redundancy was measured while changing the flooding angle of sensor nodes. As shown in *Figure 4*, as the angle increases, the number of neighboring sensor nodes increases, and each sensor node increases the number of neighboring sensor nodes receiving data, resulting in greater data redundancy. On the other hand, as the angle decreases, the number of neighboring sensor nodes decreases, and the redundancy of data decreases, but as sensor nodes not connected from sink nodes increase, the connectivity of data decreases.

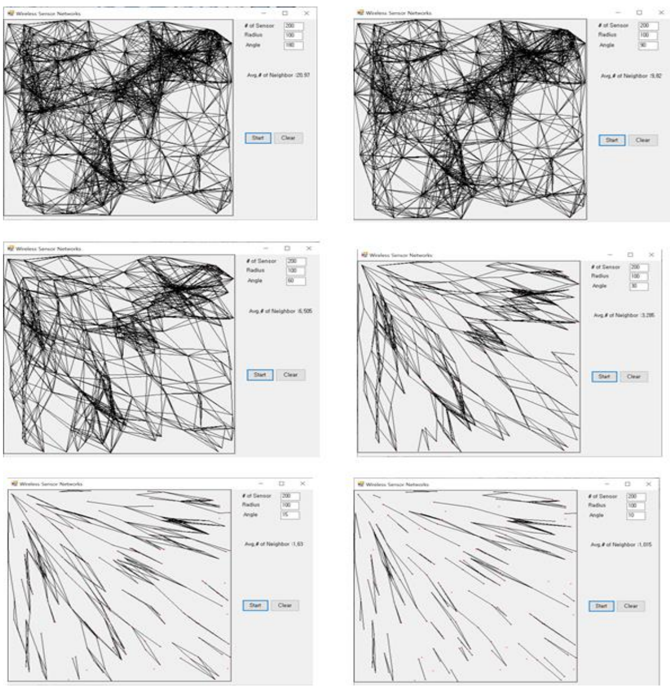

Figure 4: Sensor Network with various flooding angle

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Figure 5 shows the results of an experiment in which sensor nodes that receive flooding information within a communication radius are limited according to the distance ratio. The number of sensor nodes is 200, the communication radius is 100, and the flooding angle is 60. In case of neighboring nodes with a distance of 0.3 or more of the communication radius were connected, one sensor node was not connected, four sensor nodes were connected for 0.5 or more, and 100 sensor nodes were not connected for 0.8 or more. As the distance limit increases, the number of sensor nodes that are not connected increases. However, it can be seen that even if the adjacent sensor nodes are excluded from flooding, it does not significantly affect the connectivity.

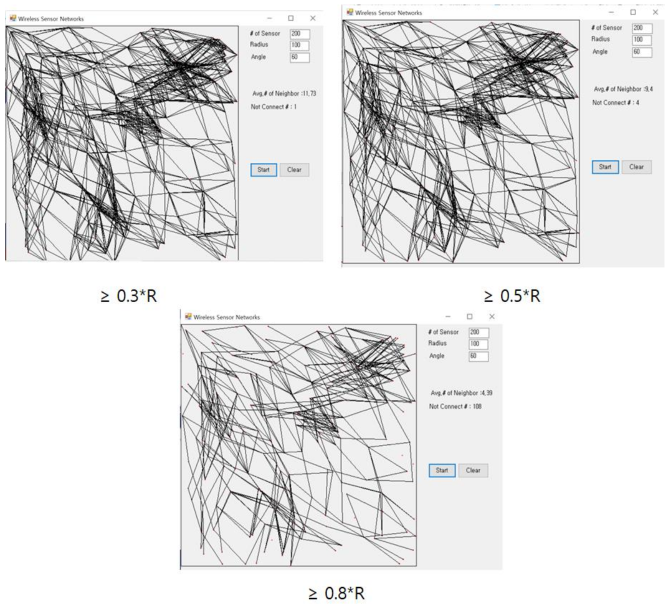

Figure 5: Sensor Network with limited distance

5. RESULT

Figure 6 represents the average number of neighboring nodes measured while changing the flooding angle of the sensor node under the same condition. Reducing the angle reduces the number of neighboring nodes, reducing redundancy. Without limiting the floating angle, the average number of flooding sensor nodes is 21.02. The higher the average number of neighboring nodes, the higher the data redundancy.

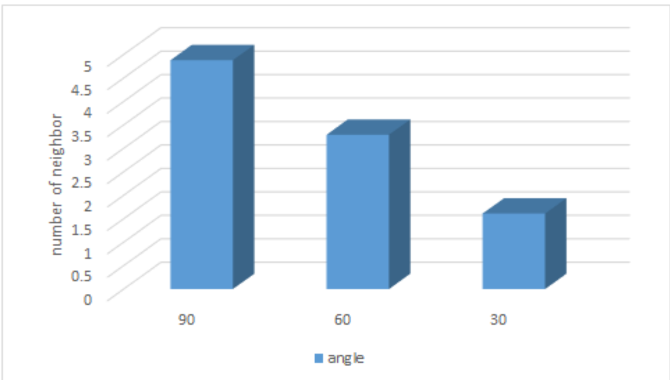

Figure 6: Number of neighboring sensor nodes

The connectivity according to the flooding angle of the sensor node was measured. Figure 7 shows the number of nodes not connected to the sink node measured while changing the floating angle of the sensor node. Flooding is a data delivery method in which a sink node transmits data to the entire network, and if this connectivity is poor, it becomes meaningless. The smaller the angle, the lower the redundancy of the data, but the relatively less connectivity. It is necessary to find an optimal angle that satisfies connectivity and redundancy, and this value should reflect various factors such as network density and sensor node transmission radius.

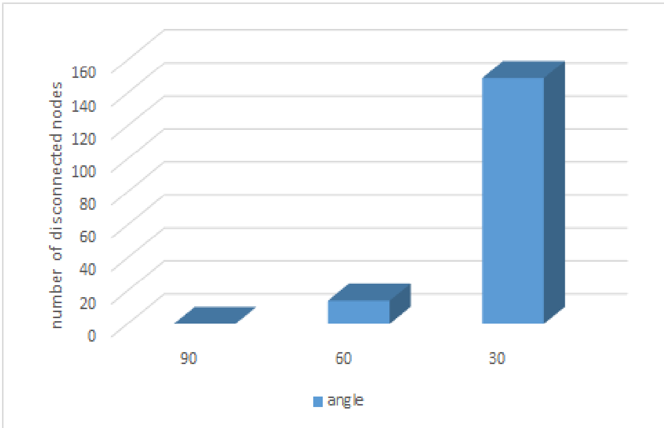

Figure 7: Disconnectivity of sensor nodes (total 200 sensor nodes)

6. DISCUSSION

It was confirmed through experiments that the redundancy of neighboring nodes transmitted by adjusting the angle of flooding and the transmission radius can be reduced. As the angle is reduced, the redundancy is reduced, but the connectivity of the entire network is also reduced. It is necessary to verify the factors for determining the appropriate angle size. This is related to the sensor node density of the network as well as the size of the angle and the range of the transmission radius. Further research will be needed to find the optimal solution to satisfy connectivity and redundancy.

7. CONCLUSION

In this paper, we proposed and simulated an efficient flooding technique for wireless sensor networks. Flooding can only be delivered to sensor nodes of limited angles in the opposite direction of the sink node in a wireless sensor network with many energy constraints to limit the scope of overlapping flooding. Through simulation, it was confirmed that the proposed method can reduce the redundancy of the data delivered and flow energy efficiently. We will provide energy-efficient flooding and connectivity in the upcoming paper by adjusting the angle according to the transmission radius size.

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