March - April 2020
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Distance-Based 2-Hop Clustering Algorithm in WSNs (Wireless Sensor Networks)

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Abstract

Wireless sensor networks (WSNs) with huge sensor nodes are randomly deployed over a wide area and sensors node have to transfer aggregated data to other node under power constraints. Multi-hop routing and distance-based clustering method have proposed to improve the lifetime of sensors in the network. LEACH (Low Energy Adaptive Clustering Layer) scheme is a proposed clustering algorithm to improve energy efficiency by evenly distributing the energy of sensors in WSN. This article proposes a single unit distance based two-hop clustering method for clustering and analyzes the energy persistence of sensor nodes in the formed clusters. Distance-based formation has physical distance limit between sensor nodes when forming a cluster, and hop-based cluster formation has logical distance between sensor nodes. By taking advantage of these two clustering, energy efficiency between sensors can be increased.

System: As members forming clusters, sensor nodes are recruited based on physical distances. However, this method has many limitations in recruiting cluster members due to the limitation of the distance between cluster members and the transmission energy. At this time, duplicate nodes between cluster groups occur. To overcome this limitation and duplication, hop-based clustering can be applied. When a cluster is formed, members based on distance can be recruited first. After then, hop-based members can be recruited from the first recruited member, eliminating duplicate nodes between cluster groups. That is duplicated member nodes between cluster groups must be registered in only one group, so it can limit to two-hop to eliminate duplicate registration. If the cluster head and the gate node are selected after removing the duplicate node in the cluster, and then cluster formation is completed. The proposed cluster formation method can improve energy efficiency when transfer node data in a hop-based network.

In this paper, we propose a clustering technique that applies distance-based and hop-based applications. The proposed cluster formation method can efficiently manage the operating energy when the gate node transfers data received from the cluster head to the next cluster head.

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1. Introduction

The wireless sensor networks (WSNs) consists of large-scale sensors for the accuracy of sensor data collection and the scalability of the sensing area. In the field of WSNs, they have been adapted to a wide range of applications due to significant progress over a long period of time. Due to the development of semiconductor technology has accelerated the development of wireless communication networks, especially micro electro

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March - April 2020
ISSN: 0193-4120 Page No. 4299 - 4306

mechanical system (MEMS)-based sensor technology, which has led to the development of cheaper wireless sensors.[1,2] Advances in MEMS have made sensor functions smaller and smaller, and these hundreds or thousands of smaller sensors are applied to wireless networks, allowing them to operate more reliably and longer, maintaining network continuity. Although advances in sensor technology have made network implementation easier and improved maintenance, paradoxically, it is more important to ensure the stable operation of sensor nodes and maintain the persistence of data transmission.[3,4]

In a WSNs environment consisting of large-scale sensors, self-organizing ability of clustering to adapt to dynamic situation and cooperative information transfer between nodes are required. In order to transfer the detected information from the sensors to the collecting node, power efficiency must be secured to maintain the lifetime of the sensor node for a long time under the limited power situation.[5] Thus, WSN is a form of Ad-hoc network with autonomous configuration capability of multi-hop that maximizes energy efficiency.[6] Multi-ad hoc network have a flat network structure in which each node finds a path by itself and reaches a destination via another node, and there is a hierarchical network structure in which clusters are formed so that data is transferred to the destination by communication between cluster head nodes. When transferring data from each node, a hierarchical network structure that is centralized to perform main control and processing functions in the cluster head is appropriate in terms of energy efficiency. In the hierarchical network, a cluster head is elected from the plurality of nodes, and the selected node registers and controls the sensor nodes in a certain area as member nodes. The WSN consists of the plurality cluster groups consisting of member nodes and cluster heads. The collected data from the sensor node is transmitted to the cluster head, and this information is transferred between clusters and finally reaches the base station. There are member nodes that can register as a duplicate node between adjacent cluster groups during cluster formation, and a complex algorithm is applied to remove duplicate registration of the member nodes. For this reason, additional work occurs between the member node and the cluster head, this lead to a decrease in energy efficiency.

In this paper, we propose a clustering method that forms a member node when forming clustering and elects a cluster head from it, and removes duplicate member node registrations between cluster groups from duplicate nodes between cluster groups, and facilitates gate node configuration. The proposed method is a distance based clustering method that forms a member node when forming clustering. And we applied two-hop based clustering when selecting the cluster head. Also, the proposed clustering method removes duplicate member node registrations between cluster groups and facilitates gate node configuration.

2. WSN structure and characteristics

Sensors are multi ad-hoc networks consisting of thousands of sensor nodes and aggregate nodes to monitor a wide range of natural environments under harsh natural and limited power conditions. The aggregating node collect information and manages various phenomena in the sensor network in its own area, and when an external user requests specific data, the aggregating node directly transmits data to the user or requests a specific data to the sensor node. On the other hand, sensor nodes are responsible for sensing various information in a responsible area and transmitting the result to the collecting node periodically. In addition, sensor nodes operate under limited power conditions, so communication protocols must be designed to maximize energy efficiency. Representative methods for constructing a large-scale wireless communication network include a plat topology and a hierarchical topology.

The flat topology is based on point-to-point communication, for this purpose, a path must be established through the exchange of mutual control messages immediately before actual data communication. Therefore, communication between nodes is achieved through contention-based control methods such as CSMA/CA. As long as the routing is established between nodes to construct a large-scale wireless network, the network approach is performed by a competitive method regardless of the network size. Representative approaches considering flat topology WSN include Directed diffusion[7] and S-MAC[8]. The flat structure, which forms a single hop structure, is simple to establish and easy to control, making it suitable for small areas WSNs. The communication protocol of the flat structured network must be prepared to receive data not only in transmitting data from the sensor node but also in case another node sends data to itself. For this reason, the flat structured single-hop networks decrease energy efficiency in a wide area WSNs.[9]

In the hierarchical network, the cluster group in which each sensor node is registered as a member is formed. Each cluster group has a cluster head node elected from the member nodes, and aggregate data from the sensor node, and transmits and controls the data to the head node of another cluster group. The architecture of a wireless sensor network is shown in Figure 1. The cluster head which is a representative node is elected in the cluster group, thereby performing dynamic resource reservation and allocation. Each member node in the cluster group has an advantage of improving energy efficiency by transmitting/receiving data allocated to member node itself and maintaining a sleep state for other times.[9-11]

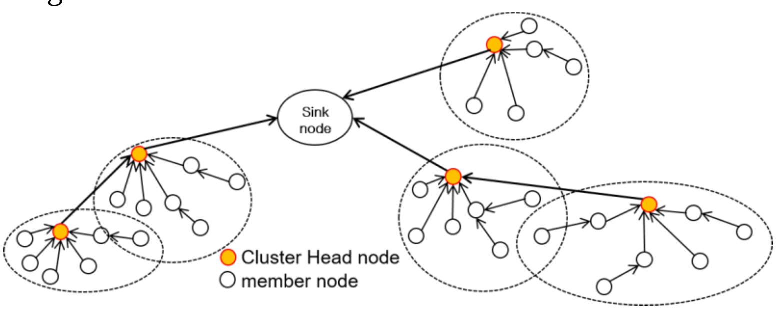


Figure 1. Hierarchical Wireless Sensor Network

2.1. Radio Channel Modeling

The LEACH method adopted a simplified the radio model for the operation of the transmitter and receiver devices.

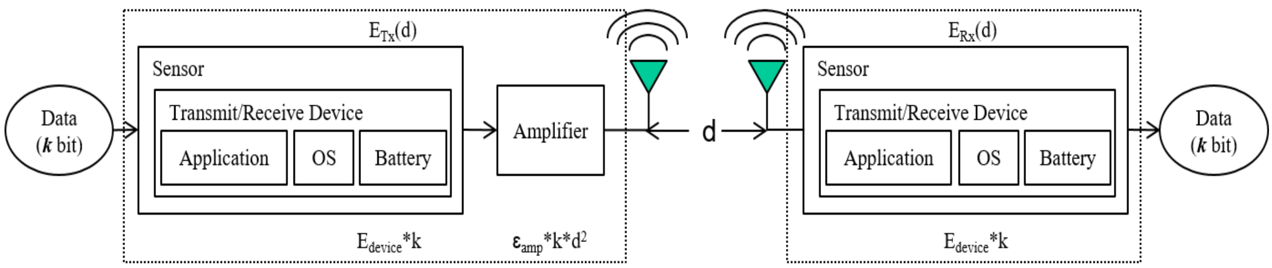


Figure 2. Radio energy model in Wireless Sensor Network

March - April 2020
ISSN: 0193-4120 Page No. 4299 - 4306

As shown in Figure 2, the device uses The LEACH method adopted a simplified the radio model for the operation of the transmitter and receiver devices. As shown in Figure 2, the device uses E_{device} = 50 nJ/bit with ϵ_{amp} = 100 pJ/bit/m^2. [12]

The radio model to transmit a k-bit message at distance d is as follows:

$$E_{Tx}(k,d) = E_{Tx-device}(k) + E_{Tx-amp}(k,d)$$

$$E_{Tx}(k,d) = E_{device} * k + \epsilon_{amp} * k * d^2 \quad (1)$$

The radio model to receive a k-bit message from the transmit node is as follows [13] :

$$E_{Rx}(k,d) = E_{Rx-device}(k)$$

$$E_{Rx}(k,d) = E_{Rx-device}(k) \quad (2)$$

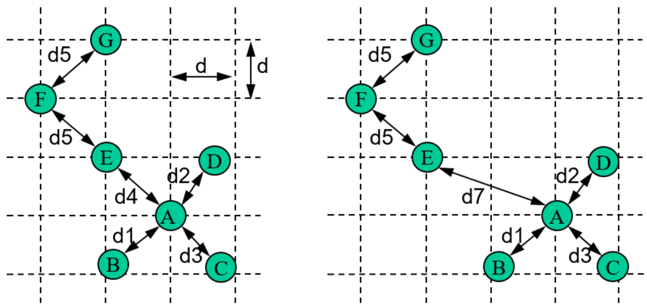
From the previous assumptions, we can guess a message receiving is important cost of network implementations. Therefore, the protocol should be implemented to minimize message transmit and receive.

3. Clustering Algorithm

In this paper, initially, to form a cluster group, sensor nodes located at adjacent distances communicate with each other to form a cluster. We call it distance-based clustering. After then, member nodes within the cluster group elect the cluster head(CH) and the gate node(GW) to complete the cluster formation. Once a cluster group is formed, there are nodes that overlap between the groups and we need to make sure that these nodes are not registered in both cluster groups. In order to avoid duplicate registration in both groups, this paper proposed a two-hop based selection method.

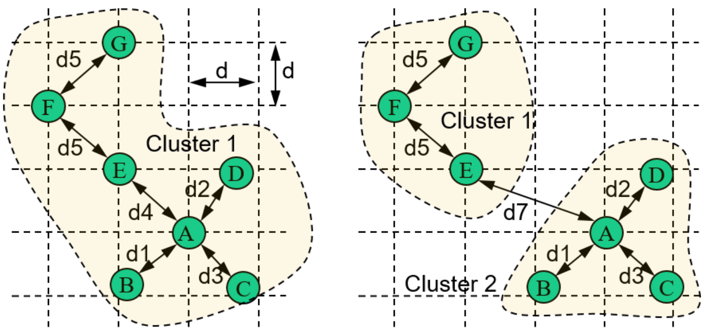
3.1. Distance-Based Initial Clustering

Assume that the distance between nodes is di(i=1,2,…,6), and assume that each node is arranged as shown in Figure 3. The unit distance is d. All distances d1 ~ d6 between member nodes are as shown in (a) of Figure 1 when they are less than unit distance d.



(a) (b)

Figure 3. Cluster member registration for initial clustering



(a) (b)

Figure 4. Cluster group separations

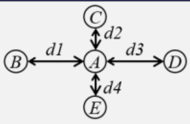
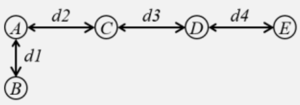
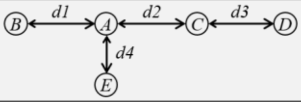
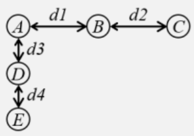
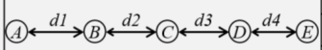
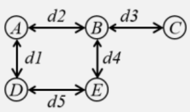
March - April 2020
ISSN: 0193-4120 Page No. 4299 - 4306

3.2. Cluster Formation

In the initial stage of cluster formation, it can be determined according to the strength of mutual tension between neighboring sensor nodes. Figure 5 shows the magnitude of mutual tension according to the distance between two nodes. When the distance between node A and node B is d2, the mutual force expressed as fAB, and since the mutual force is inversely proportional to the distance, fAB = 1 / d2. Therefore, fAC = 1 / d1 and fCB = 1 / (d1 + d2). Table 1 is show the expanded cases of the mutual force according to the distance between nodes in Figure 5.

Figure 5. Mutual distance between nodes

Table 1: The extended cases of mutual force between nodes

Case		force (node A to node B) : f_{AB}
1		$f_{AB} = 1/d1$, $f_{AC} = 1/d2$, $f_{AD} = 1/d3$, $f_{AE} = 1/d4$
		$f_{BC} = 1/(\sqrt{d1^2 + d2^2})$, $f_{BE} = 1/(\sqrt{d1^2 + d4^2})$
		$f_{CD} = 1/(\sqrt{d2^2 + d3^2})$, $f_{DE} = 1/(\sqrt{d3^2 + d4^2})$
2		$f_{AB} = 1/d1$, $f_{AC} = 1/d2$, $f_{CD} = 1/d3$, $f_{DE} = 1/d4$
		$f_{AD} = 1/(d2+d3)$, $f_{CE} = 1/(d3+d4)$, $f_{AE} = 1/(d2+d3+d4)$,
		$f_{BC} = 1/(\sqrt{d1^2 + d2^2})$, $f_{BD} = 1/(\sqrt{d1^2 + (d2 + d3)^2}$ $f_{BE} = 1/(\sqrt{d1^2 + (d2 + d3 + d4)^2}$
3		$f_{AB} = 1/d1$, $f_{AC} = 1/d2$, $f_{CD} = 1/d3$, $f_{AD} = 1/d4$
		$f_{BE} = 1/(\sqrt{d1^2 + d4^2})$, $f_{CE} = 1/(\sqrt{d2^2 + d4^2})$, $f_{DE} = 1/(\sqrt{d4^2 + (d2 + d3)^2}$
4		$f_{AB} = 1/d1$, $f_{BC} = 1/d2$, $f_{AD} = 1/d3$, $f_{DE} = 1/d4$
		$f_{AC} = 1/(d1+d2)$, $f_{AE} = 1/(d3+d4)$
		$f_{BD} = 1/(\sqrt{d1^2 + d3^2})$, $f_{CD}= 1/(\sqrt{d3^2 + (d1 + d2)^2}$, $f_{BE}= 1/(\sqrt{d1^2 + (d3 + d4)^2}$, $f_{CE}= 1/(\sqrt{(d1 + d2)^2 + (d3 + d4)^2}$
5		$f_{AB} = 1/d1$, $f_{BC} = 1/d2$, $f_{CD} = 1/d3$, $f_{DE} = 1/d4$
		$f_{AC} = 1/(d1+d2)$, $f_{BD} = 1/(d2+d3)$, $f_{CE} = 1/(d3+d4)$
		$f_{AD}= 1/(d1+d2+d3)$, $f_{BE}= 1/(d2+d3+d4)$, $f_{AE}= 1/(d1+d2+d3+d4)$
6		$f_{AB} = 1/d2$, $f_{BC} = 1/d3$, $f_{AD} = 1/d1$, $f_{BE} = 1/d4$, $f_{BC} = 1/d3$
		$f_{AC} = 1/(d2+d3)$
		$f_{AE} = 1/(\sqrt{d2^2 + d4^2}) = 1/(\sqrt{d1^2 + d5^2})$, $f_{BD} = 1/(\sqrt{d1^2 + d2^2}) = 1/(\sqrt{d4^2 + d5^2})$, $f_{CE} = 1/(\sqrt{d3^2 + d4^2})$
		$f_{CD} = 1/(\sqrt{d1^2 + (d2 + d3)^2}$

Therefore, nodes of adjacent distances can register with each other to form the same cluster through communication between member nodes.

3.2. Cluster Head Election

After the initial cluster configuration is complete by distance-based, cluster head election step starts between member nodes of the cluster group. The cluster head is elected from the member nodes which registered the largest number of member node from the communication between member nodes. In the case of Cluster 1 in Figure 5 (a), node A is elected the cluster head because it registers the largest number of member node as adjacent nodes. In the case of Cluster 1 in Figure 6 (a), node F is elected and Cluster 2 in (b) is elected the cluster head as node A because it registers the largest neighboring nodes.

March - April 2020
ISSN: 0193-4120 Page No. 4299 - 4306

3.4. Overlap Node

When cluster group is formed at first, some member nodes are registered duplicate between cluster groups. Figure 6 shows the case of overlapped member nodes between cluster groups. In the figure, the cluster group 1 consists of member nodes as A, B, C, D, E, F, G, H, and I. And the Cluster group 2 consists of member nodes as H, I, J, K, L, M, and N. Figure 6 is the case when the member node H and I are duplicated registered in cluster groups 1 and 2. To avoid such duplicate registrations, a limited number of hops can be applied to duplicate member nodes.

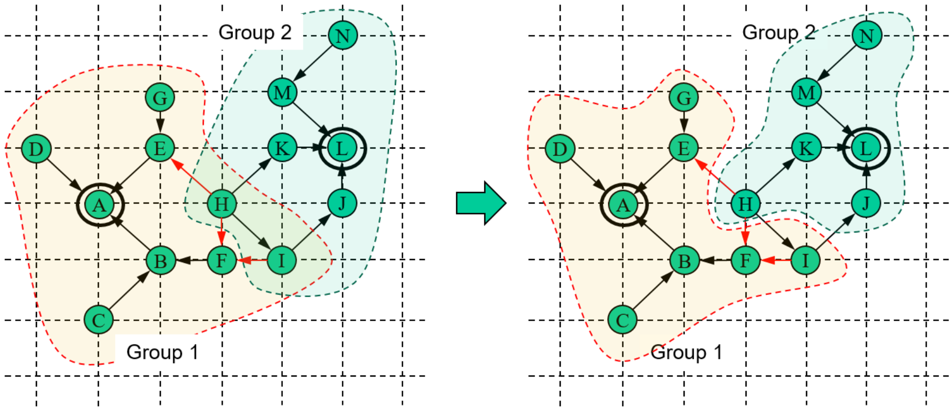


Figure 6. Overlapped member nodes between Cluster Group

If two-hop limit is applied to node H and I, node I registered as a member node of cluster group 2 that satisfies two hops. Even though this node has a strong mutual force with cluster group 1, but it has more than two hops. And Node H is registered as a member node in the cluster group 1 since the mutual force from cluster group 1 is larger than cluster group 2. Also, it satisfied within two-hop away.

3.4. Re-elect Cluster Head

If the CH(Cluster Head) has a shorter lifetime than other member nodes during the data collection and transfer operation after cluster group completion, the cluster head must be re-elected among other member nodes in the cluster group. Initially, assume that all of the node has an energy level 1 and the energy level is reduced by 0.1 for data collection and transmission. The member node should only transmit data to the cluster head node, and the cluster head should transmit the collected data from the sensor node to the base station. CH node consumes much more energy than sensor node. Table 2 shows the energy consumption simulation results.

Table 2: Energy consume calculation between sensor and CH node

	step 1		step 2		step 3		step 4		step 5	
	collect	trans-mit	collect	trans-mit	collect	trans-mit	collect	trans-mit	collect	trans-mit
Sensor node	0.9	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.5	0.5
CH node	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0

4. Results and Discussion

Figure 7 shows the simulated results of clustering by proposed method, for about 1000 random nodes. The simulation results show that member nodes are connected by lines and exist within a cluster.

March - April 2020
ISSN: 0193-4120 Page No. 4299 - 4306

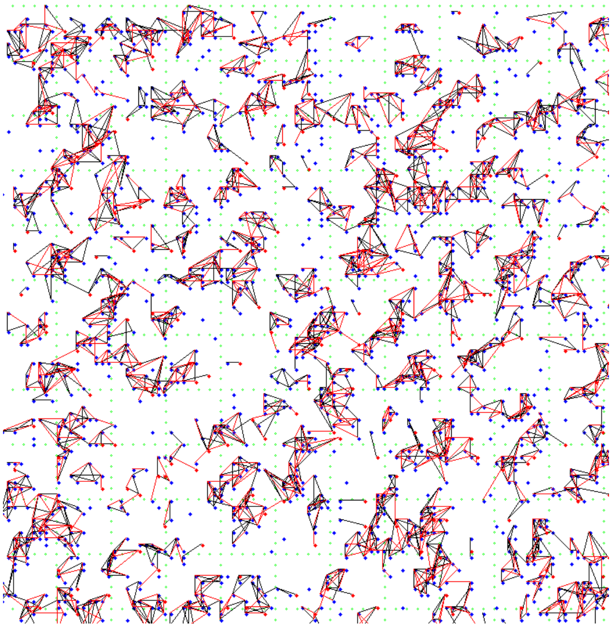


Figure 7. Simulation results showing example of clustering

5. Conclusion

This paper proposed clustering algorithm which is based on distance and 2-hop between node within the cluster group. In this paper, initially, to form a cluster group, adjacent distances sensor nodes communicate each other. Figure 4 show the principle of clustering group. And member nodes elect the cluster head(CH) to complete the cluster formation. We defined in the table 1 the cases of mutual force between nodes. And there are nodes that overlap between the groups and we showed method of avoid of duplicated node between cluster group which is based on 2-hop. Figure 7 shows the clustering simulation results for 1000 random nodes. The proposed clustering method makes it possible to distribute members evenly by applying distance between cluster groups and 2-hop base. In order to extend the life of the cluster group, the CH node is re-elected in the cluster so that the CH node can be replaced with another member node when the life of the CH node is reduced.

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