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An Adaptive Clustering Scheme Related to the Sink Position for Sensor Networks

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Abstract. Most existing clustering protocols have been aimed to provide balancing the residual energy of each node and maximizing life-time of wireless sensor networks. In this paper,[1] we present the adaptive clustering strategy related to sink position for clustering protocols in wireless sensor networks. This protocol allows networks topology to be adaptive to the change of the sink position by using symmetrical clustering strategy that restricts the growth of clusters based on depth of the tree. In addition, it also guarantees each cluster the equal life-time, which may be extended compared with the existing clustering protocols. We evaluated the performance of our clustering scheme comparing to LEACH and EEUC, and observe that our protocol is observed to outperform existing protocols in terms of energy consumption and longevity of the network.

Keywords: sensor networks, clustering

1. Introduction

The wireless sensor network consists of hundreds or even thousands of sensor nodes deployed in a remote region to sense events. The sensor nodes communicate with each other to transmit their sensed data to the sink node (or base-station). Then, the sink node transfers the data to the human director, letting him know events taking place in the remote region. In the sensor networks, wireless transmission is the most energy consuming operation. In addition, each sensor node has very limited batteries, and it is very hard to recharge them[1]. Therefore, energy-efficient transmission protocol is required to maximize network lifetime of the entire sensor networks.

Many kinds of efforts have been done on developing energy-efficient transmission protocols for wireless sensor networks. Those can be categorized into routing, and clustering protocols. Particularly, the clustering protocols can significantly reduce energy consumption by aggregating multiple sensed data to be transmitted to the sink node. However, every existing clustering protocol assumes the sink node is fixed, and they only consider 'How can we configure clusters more energy-efficiently by size and/or count of clusters?' without concentrating on adaptive clustering related to the position of the sink node. Because the change of the sink node position is not considered, the existing networks topology might cause the residual energy of clusters out of balance. It is possible to configure network topology using simple clustering methods when the sink node that collects data is fixed. However, if the sink node is not fixed and dynamically changed, cluster

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reconstruction and cluster head selection must change according to the distance to the sink node. In this paper, we present an adaptive clustering strategy related to the sink position for clustering protocols in wireless sensor networks. This protocol allows networks topology to adaptive by symmetrical clustering that restricting the growth of clusters based on depth of the tree, and this protocol guarantees the lifetime of the entire networks can be extended compared with the existing clustering protocols.

2. Related Works

In this section, we briefly present the existing works related to our scheme. Many kinds of data aggregation protocols have been proposed for wireless sensor networks. These can be categorized into two classes; hierarchical clustering protocols and chain-based aggregation protocols. LEACH[2] is a well known clustering protocol for wireless sensor networks. LEACH includes distributed cluster formation, local processing to reduce global communication, and randomized rotation of cluster-heads. Together, these features allow LEACH to achieve the desired properties. However, there is no guarantee that nodes selected as cluster head are evenly dispersed throughout the network because procedure to select cluster head is based on the random cluster formation method with local probability. To solve this problem, an improved version of LEACH was proposed, named LEACH-C[3]. In LEACH-C, cluster formation is made by a centralized algorithm at the base station. In 2005, Li et al. proposed EEUC[4], which is an energy-efficient unequal clustering protocol. In EEUC, nodes are partitioned into different-sized clusters; clusters closer to the base station have smaller sizes than those farther away from the base station. Thus cluster heads closer to the base station can preserve energy for the inter-cluster data forwarding.

Chan and Perrig proposed an ACE[5] algorithm. It forms clusters based on connectivity information of each node. A node which has the highest connectivity becomes cluster head. If multiple nodes have the highest degree of connectivity, a node which has low unique identifier will be selected as a cluster head. The cluster formation based on the connectivity of nodes is not an appropriate way, because every node must maintain connectivity each other and wireless sensor networks consist of too many nodes. HEED[6] considers limitations of communication distance of wireless network and intra-cluster communication value and expands the notion of LEACH. In each node, the probability to be a temporary cluster head is based on residual energy possessed by each node and every temporary cluster head competes to be the last cluster head. The last cluster head is decided by intra-cluster head communication value. TEEN[7] is similar to LEACH except that sensor nodes do not have data being transferred periodically. In TEEN, each sensor node decides to transmit their sensed data using a threshold value. Cluster heads broadcast the value, and if a sensed data is bigger than the threshold value, each node transmits data. LEACH has a feature which is appropriate for proactive sensor network, but TEEN is appropriate for reactive sensor network. APTEEN [8] provides hybrid network which minimizes the uppermost limit of proactive sensor network and reactive sensor network and combines merits of both sensor networks. In APTEEN, sensor nodes can periodically transfer data and well respond to sudden change of an attribute value of measured data.

3. Adaptive Clustering Protocol based on Sink Location

3.1. Impact of clustering protocol on energy consumption

The degree of energy consumption on each sensor node changes according to the distance between cluster head and sink node, and transmission method by multi-hop or by single-hop. In case of single-hop(e.g. LEACH), because cluster head transmits data to sink node directly, the degree of energy consumption vary whether the cluster is the nearest to the sink node or the farthest away from the sink node. Generally, the farthest cluster away from sink node consumes more energy than other clusters. In case of multi-hop, because of the data transmitted from all clusters by relay, the cluster nearest to the sink consumes large amount of energy.

Consequently, in cluster tree topology, the degree of energy consumption vary based on the roles of sensor nodes, thus, cluster head which need large amount of power must be distributed for energy-efficient networks. Fig. 1 and 2 show intra-cluster and inter-cluster range.

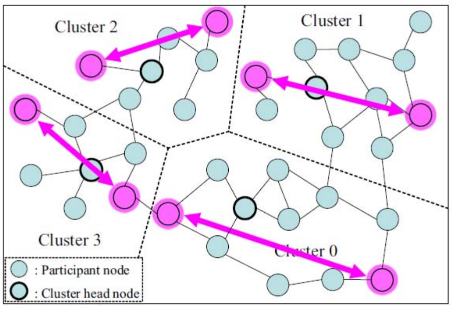

Fig. 1: Maximum distance between member nodes

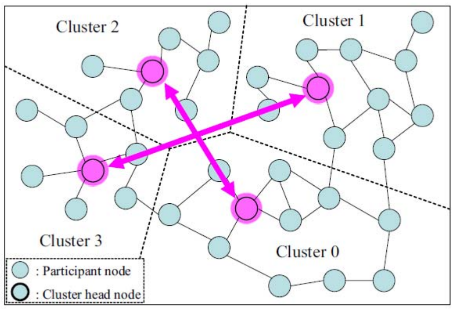

Fig. 2: Maximum distance between cluster heads

The FND means the time the first node died and LND means the time the last node died [9]. The FND and LND can be used to represent the barometers of energy-efficient network, because the infection of withdrawn arbitrary node spreads out to whole network. Consequently, the interval between FND and LND time must be minimized to be the greatest energy-efficient network.

If the position of the sink node is fixed, cluster construction related with the distance from the sink node. Otherwise, it needed further study for clusters to construct energy-efficiently. We have researched focusing on this point.

3.2. Symmetric clustering based on the location of the sink

In the hierarchical cluster tree, the cluster near the sink is the top level cluster. Because an upper cluster must transmit the data from a lower cluster to the sink, more energy is required. When we assume the level of the cluster tree is *L*, the forwarding energy consumed by the cluster head of the corresponding level can be presented as Formula 1. In this formula, N is the number of all nodes and k is the number of clusters. The other parameters are the values from [2][3].

$$E_{fw} = lE_{elec}\left(\frac{N}{k}-1\right)+lE_{DA}\frac{N}{k}+lE_{elec}+l\varepsilon_{fs}\left(\frac{d}{L}\right)^{2} \tag{1}$$

The total forwarding energy consumption by the *L* level cluster is:

$$E_{totalfw} = E_{fw}\cdot\sum_{i=0}^{L-1}(L-i)\cdot\left(2^{L-i}\right) \tag{2}$$

The extent of the forwarding energy consumption for each level in the cluster tree is:

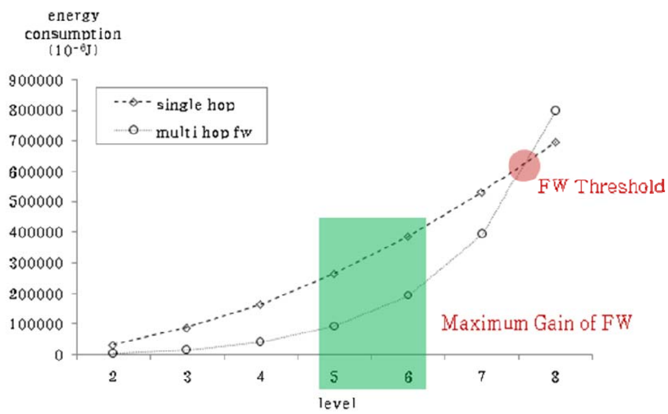

Fig. 3: Forwarding Energy Consumption Trend for Each Cluster Tree Level

Comparing the case that a cluster directly transmits data to the sink with the forwarding energy consumption according to the tree level change as shown in the figure above, big differences are found in 5 and 6 tree levels. If the level is 7.5 or above, the forwarding energy consumption gets more than the other case.

If it is assumed that each node has the same initial energy and all nodes are distributed with equal spacing, in order for a certain cluster to have much more energy than the other cluster, the cluster size must be bigger. When the cluster size is calculated considering the energy consumption for data forwarding (Fig. 3), the result is the following (Fig. 4).

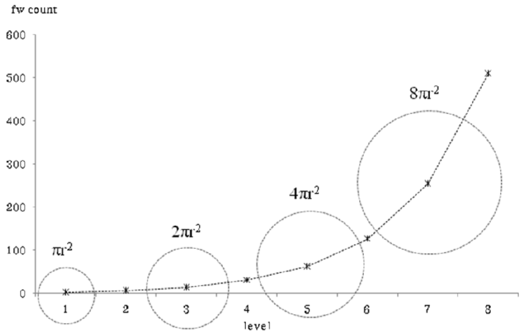

Fig. 4: Cluster Size for Each Level

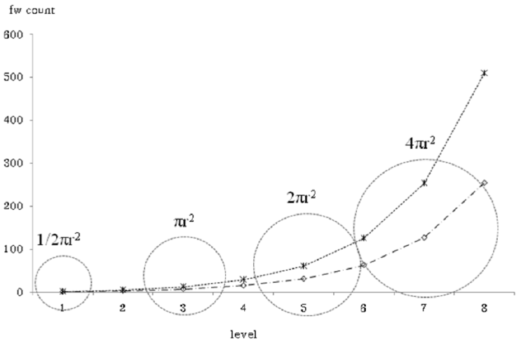

Fig. 5: Two-tiered Cluster Trees

As shown in Fig. 4, the cluster size increases 1.4 times as the level increases. In this case, the difference between the top level cluster and the lowest cluster steeply increases. The size of the top level cluster is too big so adequate clustering is difficult. Accordingly, when the level of the cluster tree increases over the specified amount, the trees can be divided into two or more to restrict the top level cluster size. Fig. 5 shows the change of cluster size when the cluster tree is split into two to restrict the top level cluster size.

To meet the requirement for the optimal number of clusters that is calculated in LEACH. However, it is based on the distance between each cluster and the sink so it is not appropriate in the symmetric clustering that uses the multi-hop forwarding. The symmetric clustering must calculate the optimal number of clusters considering how many hops are used for data transmission from each cluster to the sink.

$$E_{total} = k \cdot E_{cluster} + E_{fw} \cdot \sum_{i=0}^{L-1} (L-i) \cdot (2^{L-i}) \tag{3}$$

In Formula 3, the optimal number of clusters can be calculated. It makes the total energy E_{total} 0.

$$k_{opt} = \frac{N(E_{elec} + E_{DA})}{\varepsilon_{fs} \cdot \left(\frac{d}{L}\right)^2 \cdot \sum_{i=1}^{L-1} (L-i)(2^{L-i})} \tag{4}$$

The trend graph in Fig. 6 shows the trend of the cluster tree level and the number of clusters.

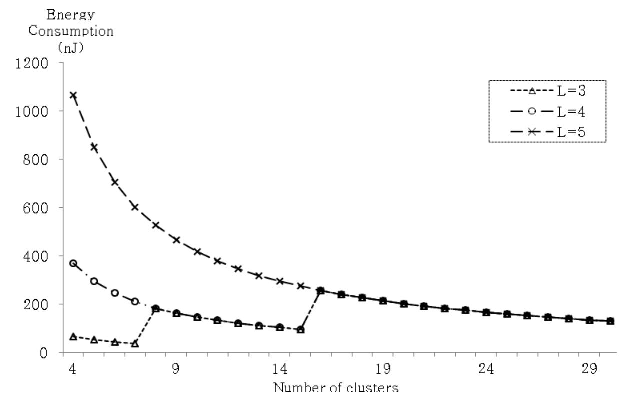

Fig. 6: Energy Consumption based on Cluster Tree Level and Number of Clusters

When the cluster tree level is 3 as in Fig. 6, the lowest energy consumption is presented in case the number of clusters is 7. With level 4, the lowest energy consumption is implemented in case the number of clusters is 15. When the number of clusters exceeds (2^L-1), the tree level increases. At this time, the forwarding energy consumption steeply increases.

When same-sized clusters are constructed, the cluster further away from the sink requires more energy for forwarding data to the sink. Thus, when compared with the clusters near from the sink, its life span gets shorter. Meanwhile, when the symmetric cluster tree is constructed as in Fig. 7, its simulation result is shown in Fig. 8.

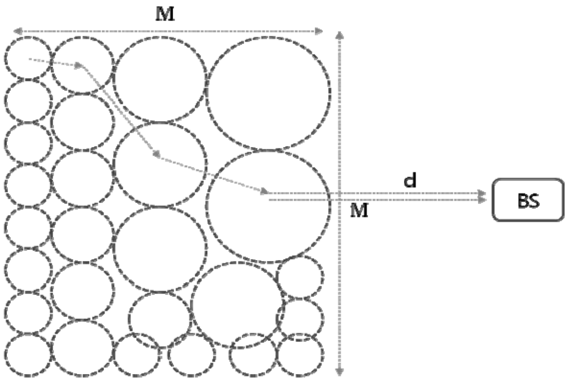

Fig. 7: Symmetric Clustering

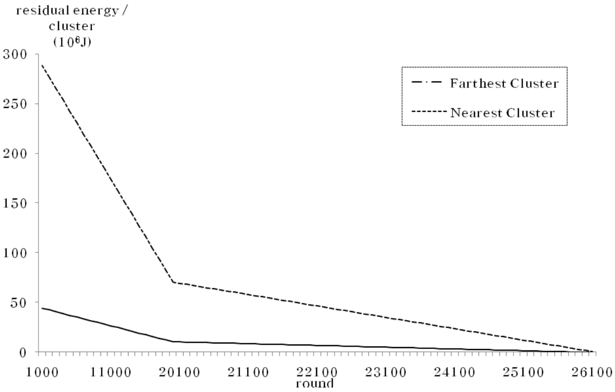

Fig. 8: Energy Consumption Trend based on Distance to Sink for Symmetric Clustering

Fig. 7 shows that the cluster farthest from the sink consumes energy in the same time as in the cluster nearest from the sink. In addition, the energy consumption time for each cluster increases by about 5,000.

3.3. Symmetric clustering based on the location of the sink

The proposed adaptive clustering protocol, unlike the EEUC, constitutes a larger configuration of the clusters near to the sink, which helps reduce the change of the routing path according to the movements of the sink.

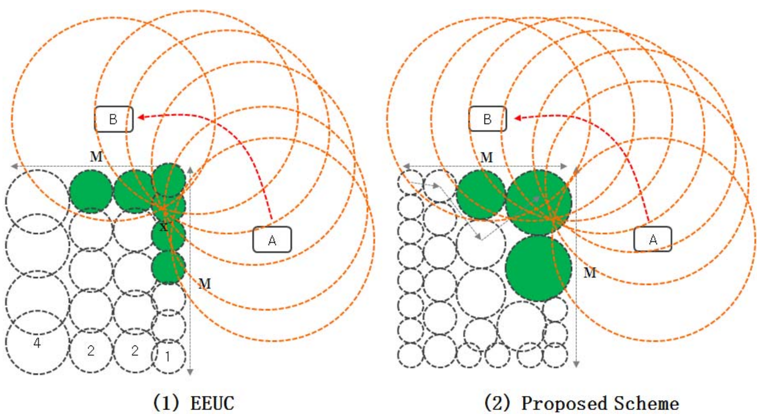

Fig. 9: Change of the nearest clusters related to the sink position

In Fig. 9, (1) shows clusters of EEUC, and (2) shows the configuration of the cluster based on the clustering technique proposed by this paper. Fig. 9 shows the changes of adjacent clusters when the location of sinks moves from A to B.

How often the adjacent clusters change affects the routing table update time each cluster need to transfer data. The radius of the clusters near to the sink is assumed to be *r* in Fig. 10 (1) and the radius of the clusters is assumed to be *2r* in Fig. 10 (2). When the sink moves from $A\ (p_1, q_1)$ to the $B\ (p_2, q_2)$ along the function of $x^2 + y^2 = R^2$, in the EEUC of the (1), the time of the routing table is updated at about 8% earlier times compared with the routing protocol proposed by this paper. In addition, if the size of the clusters near to the sink is changed according to the movement of the sink, clusters need to be reconstructed. The renewal of the routing table and reconfiguration of the clusters requires energy consumption. The more repetition is, the less the lifetime of the network is.

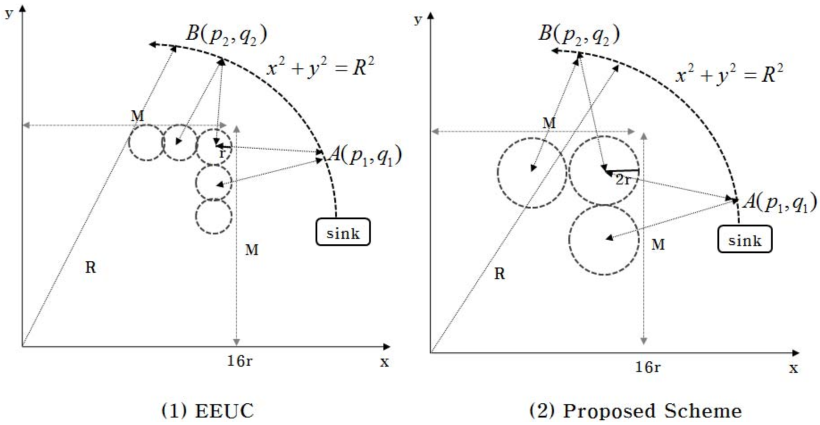

Fig. 10: Difference of routing table update time

4. Conclusions

While many studies are in progress in the hierarchical clustering techniques for the optimal sensor network environment, this paper showed the study on adaptive clustering method to minimize energy consumption and guarantee the same life span for all sensor nodes considering the change of sensor location. Because the forwarding energy consumption is concentrated at the cluster nearest from the sink, the clustering has to be implemented considering the forwarding energy consumption. Because all clusters are constructed in hierarchical trees, the tree level has to be set considering the cluster size to prevent the cluster size from getting bigger and to block concentrated energy consumption in a specific cluster. For an ideal clustering mechanism considering the sink location change, relating to the time cycle to detect the change of the sink location, the cluster resetting interval and the energy consumption required to reconstruct clusters must be additionally considered.

5. Acknowledgements

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6. References

[1] Karl, H., & Willig. A. Protocols and architecture for wireless sensor networks. New York, Wiley, 2005.

[2] W. B. Heinzelman, A. P. Chandrakasan, and H. Balakrishnan, Energy-Efficient Communication Protocol for Wireless Microsensor Networks. *Hawaii International Conference on System Science*. 2000.

[3] W. B. Heinzelman. An Application-Specific Protocol Architectures for Wireless Networks. *IEEE transactions on wireless communications*, 2002, 1(4).

[4] G. Chen C. Li, M. Ye and J. Wu. An energy efficient unequal clustering mechanism for wireless sensor networks. *In. Pmc. of MASS*. 2005.

[5] H. Chan, A. Perrig. ACE: An Emergent Algorithm for Highly Uniform Cluster Formation. *In 2004 European Workshop on Sensor Networks*. 2004, pp. 154-171.

[6] Ossama Younis and Sonia Fahmy. Distributed Clustering in Ad-hoc Sensor Networks: A Hybrid, Energy-Efficient Approach. *Proceedings of IEEE INFOCOM.* 2004, pp. 366-379.

[7] A. Manjeshwar and D. P. Agrawal. TEEN: a routing protocol for enhanced efficiency in wireless sensor networks. *Proc. of 15th International Conference on Parallel and Distributed Processing Symposium*. 2001, pp. 2009-2015.

[8] A. Manjeshwar and D. Agrawal. APTEEN: A Hybrid Protocol for Efficient Routing and Comprehensive information Retrieval in Wireless Sensor Networks. *International Parallel and Distributed Processing Symposium: IPDPS 2002 Workshops*. 2002, pp. 195-202.

[9] Handy, M. J., Haase, M., & Timmermann, D. Low energy adaptive clustering hierarchy with deterministic cluster-head selection. *In 4th IEEE International Conference on Mobile and Wireless Communications Networks*. 2002.