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Energy Efficiency Improvement of the of a Cluster Head Selection for Wireless Sensor Networks

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Abstract

Sensor Networks can perceive the extensive area by application of many sensor nodes because the size of sensor nodes is small and cheap. Sensor nodes can transfer multi hop data to sink nodes which is far away than sending and receiving distance. Many routing methods are proposed in order to raise energy efficiency in sensor networks filled. There is a routing method based on structure as a composing method of network by cluster. Cluster technology consisting and maintaining network topology based on cluster is mostly studied in routing protocol. There are demerits that LEACH, EACHS shall be rest energy of all nodes and HEED can't guarantee the number of cluster head. The proposed energy efficiency of selected cluster head guarantees the number of cluster head which is a demerit of HEED and minimizes the node of DEAD.

Keywords: *Wireless Sensor Network, Clustering, Cluster Head, Energy Models ction*

1. Introduction

CUSN (Ubiquitous Sensor Network) is an information infrastructure that every person can access to the recognition, storage, manufacture and fusion from collected context information of various sensor nodes in anywhere and anytime. In other words, USN is an important technology to actualize the era of ubiquitous and many researches has been studied continuously. And regarding to this development of ubiquitous system, the needs of a sensor network technology for cushier collection on require data has been came to the fore.

Sensor Networks can perceive the extensive area by application of many sensor nodes and the size of sensor nodes is small and cheap. Also, the sensor network is generally consisted with sensor nodes that are deployed in jurisdiction area to identify any phenomenon and to transmit the recognized and generated data from the sensor nodes and for this purpose, a wireless transceiver is used. However, as it has short distance in transmission between the sensor nodes and sink node that is placed in distance, a sensor should be arranged for identification function as well as retransmit function to transmit the data. Generally, it is difficult to store large amount of energy as sensor nodes are formed into very small nodes. In

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addition, thousands of nodes do not have capability to charge itself in sensor network, so when many nodes have energy depletion, there are difficulties for replacement on each node.

The lifetime of sensor node has depends on each sensor's energy consumption so if possible, it is aimed to save energy consumption to extend the lifetime of the entire network. In the field of sensor network, many routing technology have been proposed to improve the energy efficient of the sensor node. Among many methods, a structure-based routing technology is formed on network using cluster.

Many cluster technologies has been studied to configure and maintain the cluster based network topology in routing protocol [4]. As the energy efficiency is important for the clustering technology in wireless sensor network and this technique transmits Sink by combines the cluster head node and the date of cluster member nodes to reduce the amount of communication between nodes. And inside cluster, by adjusting the schedule of the cluster head under TDMA (Time Division Multiple Access) schedules will extend the sleep type of the node.

In clustering algorithm, every node must belong to a cluster head or to only one cluster after clustering [8]. To minimize the energy consumption, energy of the sensor network node needs to be used more efficiently. The energy efficiency of selected cluster head guarantees the number of cluster head and made the initial energy of the node to a variable to signify common node and advance node. This paper studied the advance nodes that allow vary in the initial energy ratio to minimize the DEAD nodes. The paper is organized as introduction, cluster head selection algorithm, suggesting methods and simulation and it is concluded in the last.

2. Cluster Head Selection Algorithm

The sensor used in wireless sensor network usually operates in a tough environment where people cannot approach or even in dangerous places and many sensor nodes are installed to form a sensor network. Moreover, the energy consumption and data processing capability of sensor nodes are limited. Flat routing protocol and hierarchical routing protocol are applied. However, as these techniques have limited energy it is more efficient than selecting a cluster head. First of all, let's take a close look on LEACH (Low Energy Adaptive Clustering Hierarchy) in algorithm for a cluster head selection.

2.1. LEACH (Low Energy Adaptive Clustering Hierarchy)

The application field of sensor network is the environment observation and location tracing. In such an environment, the end-user does not need any repeated data as each node of the data is not related to each other. The role of LEACH (Low Energy Adaptive Clustering Hierarchy) is to merge repeated date by cluster head and sent to sink. Hence, any repeated data is not sent to the sink.
The LEACH assumptions are as follows.

- All nodes have enough energy to send data to the sink and can adjust transmission energy.
- All nodes have data to send at anytime and close nodes have data associated with each other.

The main objective of routing protocol for routing is transferring data from transmit node to object node and find the most suitable path with accuracy. Thus, with limited shared resources, energy consumption needs to be minimized on transmission

bandwidth in the network overhead or between the nodes. For this matter, the sensor network avoid duplication of data among the adjacent sensor nodes by clustering, simplify routing and energy consumption can be managed efficiently. The clustering technology is a similar data collection process by forming local clusters in the adjacent area. The sensor network using LEACH protocol is consisted with numerous clusters and each cluster is organized as upper layer node called cluster heads or normal nodes.

LEACH makes even energy consumption between the nodes in the network. And to do so, the cluster head (CH) is randomly replaced on the probability based. At the start of each round, probability value of $P_i(t)$ decides whether to work as cluster head. The number of cluster head k of $P_i(t)$ value on each round, in other words, when N is the total number of nodes in network based on the number of clusters, equation (1) is given as below. On average, each node should be set as the cluster head once every N/k in order to guarantee the same number of cluster head in every node.

$$\mathrm{B[CH]} = \sum_{i=1}^{N} P_i(t) \times 1 = k \tag{1}$$

From the selection process of the cluster in LEACH protocol, each node follows equation (2) to obtain the selected probability of the cluster head, where $C_i(t)$ is a control function, and when, during recent r mod (N/k) round has cluster head in relevant node is then, 0 , if not 1. In consequence, if it had been head for at least once, there is no chance to be selected again during the recent r mod (N/k) round.

$$P_i(t) = \begin{cases} \frac{K}{N - k * (r \bmod \frac{N}{k})}, & C_i(t) = 1 \\ 0 \quad , & C_i(t) = 0 \end{cases} \tag{2}$$

According to equation (2), I stands for the node identifier, t is the time, N is the total number of nodes, k is the number of clusters and r represents the round. The head node selection gives equal probability from random nodes during one round as it exclude the nodes that has been selected in the previous round. Therefore, the value of $P_i(t)$ simply rises as the round increases. And since this pattern is iterated every N/k, all nodes have equal probability of being selected to be the head node.

The probability function of equation (2) lets to select more often on nodes that has not been chosen as the cluster node in latest time, where the node which has not been selected in the recent time, it comprises more energy. All nodes are assumed to transmit data at any time. Due to the probability function of equation (3), this additional probability function is considered that a node with greater energy is to be selected more frequently as the cluster head.

$$P_i(t) = \min\left\{\frac{E_i(t)}{E_{total}(t)} k, 1\right\} \tag{3}$$

The $E_{total}(t)$ represents the sum of the current energy on all nodes and $E_i(t)$ represents the current energy of node I. By applying this probability function, node with greater energy is to be selected as the cluster.

2.2. EACHS (Energy Adaptive Cluster-Head Selection for Wireless Sensor Networks)

ALEACH's cluster head selection algorithm has the disadvantage and EACHS supplemented them which has the following features [10].

- Arrangement of the sink apart from the sensor nodes.
- Sensor nodes are the same type of nodes and consume energy.
- Sensor nodes have no mobility.
- Sensor nodes do not have their own location information.
- All sensor nodes can reach the sink.
- Symmetric radio channel is used.

EACHS did not consider the weakness of LEACH which is the communication distance between the nodes. The cluster heads or normal nodes that are far apart from the sink or the cluster head consume larger energy to transmit the data due to the distance and so, it shorten the life expectancy of network. Figure 10 illustrates the distance between the sensor nodes and the sink.

The cluster head selection algorithm in LEACH does not select the cluster head by considers the energy of nodes. Thus, the entire network nodes do not have equal balance on the energy consumption. In order to evenly balance the energy consumption on nodes, EACHS selects the residual energy of the node as the cluster head.

$$\mathrm{T(n)} = \frac{p}{1-p\left((r+1)\ mod\ \frac{1}{p}\right)}\left[\frac{E_{r\_residual}-E_{r\_dissipate}}{E_{r\_average}-E_{r\_dissipate}}\right] \quad (4)$$

The cluster head will be selected from the distributed nodes by the probability function of equation (4). $E_{r\_residual}$ is the residual energy of the node and $E_{r\_average}$ is the average energy of all the nodes.

If there are larger numbers of residual energy of nodes, it has higher probability to be selected as the cluster head by equation (4). We can assign parameter $E_{r\_dissipate}$ and if the energy consumption is greater in the final round it has higher possibility to be a cluster head and if the energy consumption is smaller in the final round, it has lower possibility to be a cluster head.

2.3. HEED Clustering Approach for Ad Hoc Sensor Networks

A HEED (Hybrid Energy-Efficient, Distributed Clustering Approach for Ad Hoc Sensor Networks) has a complement the shortcomings of the cluster head election algorithm in LEACH. HEED has the following features.

- Sensor nodes are the same type of nodes and consume energy.
- Sensor nodes have no mobility.
- Sensor nodes do not have their own location information.

LEACH requires identifying all the node, however, HEED does not require to recognize every node. It utilizes their own to be selected as a cluster head.

$$CH_{prob} = C_{prob} \times \frac{E_{residual}}{E_{max}} \quad (5)$$

The cluster head will be selected from the distributed nodes by the probability function of equation (5). From the above equation, C_{prob} represents the comprised ratio of the cluster

head in entire network, E_{max} is the initial energy of the nodes and $E_{residual}$ is the residual energy of the node.

3. Suggesting Methods and Simulation

LEACH has the fixed function to select a cluster head so that all energy nodes have equal consumption and only the cluster head has imbalanced energy consumption due to the transmission of date or message to the sink. EACHS has a disadvantage that it requires to identify residual of all the nodes. Where HEED uses own nodes to be the cluster head and cannot grantee the number of the cluster. Therefore, the proposed algorithm is aimed to guarantee the number of the cluster head and minimize the DEAD nodes.

The proposed algorithm as a function of the initial energy value is to ensure the number of cluster head nodes and minimize DEAD nodes. The sensor nodes are made as normal nodes and advance nodes called (a), which have the greater energy consisted than the normal nodes. In addition, there is an initial energy ratio and these nodes have greater energy consisted up to ratio value of (m) between the advance nodes. In the following experiment is the comparison of nodes in the cluster heads and DEAD nodes by vary the advance node (a) and the initial energy ration (m).

The distance restraint and situation defense occur in actual communication situation. For this issue when comparing between the given value with the same initial energy and changed value in the initial energy, more cluster heads are guaranteed and have higher possibility to be selected when the initial energy value is changed. In this paper, the proposed method is to minimize DEAD node and guarantee the number of cluster head. To ensure the proposed method, previously suggested model of energy consumption is used to compare and used MATLAB to simulate.

The energy model is considered for transmitting and receiving one of data in accordance with LEACH energy model. Assume that the distance between a transmitter and a receiver is d in energy model [11].

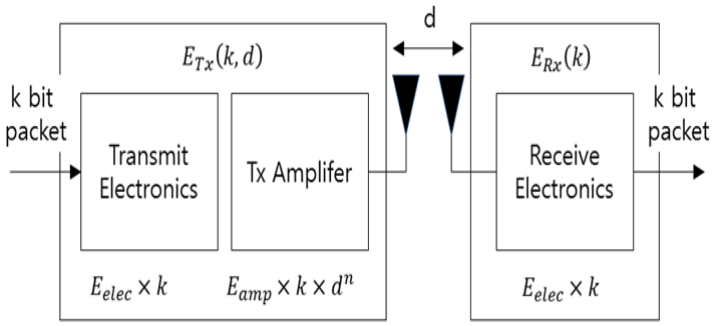

Figure 1. Radio Energy Model

If d is larger than d_0, the multi-path model (with less path coefficient 4) is used otherwise open space model (with less path coefficient 2) is used. Therefore, to transceiver energy between L and B in bit message, $E_{Tx}(l.d)$ and E_{Rx} are the energy consumption in transmission and reception as in equation (6) and (7).

$$E_{Tx}(l.d) = f(x) = \begin{cases} L \cdot E_{elec} + L \cdot E_{fs} \cdot d^2, & d \le d_0 \\ L \cdot E_{elec} + L \cdot E_{amp} \cdot d^4, & d > 0 \end{cases} \quad (6)$$

$$E_{Rx} = L \cdot E_{elec} \quad (7)$$

where $E_{elec}$is the energy spent to operate the transceiver circuit and depends on factors such as the digital coding, modulation, filtering, and spreading of the signal. Amplifier energy, $E_{amp} \cdot d^4$ or $E_{fs} \cdot d^2$are the energy expenditure of transmitting one bit data to achieve an acceptable bit error rate and is dependent on the distance of transmission in case of free space model and multipath fading model. In simple term, this depends on the distance to the receiver and the acceptable bit-error rate. Value of threshold distance d_0 is given by $d_0 = \sqrt{\frac{E_{fs}}{E_{amp}}}$.

In equation (8), the E_{CH} and $E_{nonCH}$are the energy consumption of a cluster head nodes and non-cluster head nodes during a round.

$$\begin{aligned} E_{CH} &= \left(\frac{n}{k} - 1\right) LE_{elec} + \frac{n}{k} LE_{DA} + LE_{elec} + LE_{amp} d^{4BS} \\ E_{nonCH} &= LE_{elec} + LE_{fs} d^{2CH} \end{aligned} \quad (8)$$

The equation (9) is the energy consumption of both, in a cluster head nodes and non-cluster head nodes in cluster.

$$E_{cluster} = E_{CH} + (\frac{n}{k} - 1) \cdot E_{nonCH} \quad (9)$$

Therefore, all the energy consumed in the network is the equation (10).

$$E_{total} = L\{2nE_{elec} + nE_{DA} + E_{fs}(kd^{2BS} + nd^{2CH})\} \quad (10)$$

The variables of the energy consumption model in sensor network are in Table 1.

Table 1. Sensor Networks, Energy Consumption Model Variables

Variable	Instruction	Variable	Instruction
L	Bit message	Eelec	Circuit energy consumption
EDA	Aggreation	Efs	Free-space loss
d0	Distance threshold value	Eamp	Multi-routing loss
k	Number of cluster head	n	Number of node type

When we compare the number of the proposed cluster heads and LEACH then Table 2 can be used variables as follows to minimize the DEAD nodes.

Table 2. Simulation Variables

Variable	Value	Variable	Value
No. of node	100	P	0.1
M	100m*100m	Efs	10pJ/bit/m^2
SINK	(50,50)m	Eamp	0.0013pJ/bit/m^4
Initial energy	0.5J	Eelec	50nJ/bit
Message length	4000bit	EDA	50nJ/bit

Where the initial energy is different, changes of ratio in advance nodes to make it even and guarantee the number of a cluster heads as well as comparing with DEAD nodes and compared data is as Table 3.

Table 3. The Advance Node the Initial Energy Change

	First DEAD node found	DEAD node 50%	DEAD node 100%
m=0.1 a=1	969	1241	4311
m=0.1 a=2	969	1241	6368
m=0.1 a=3	969	1241	8944

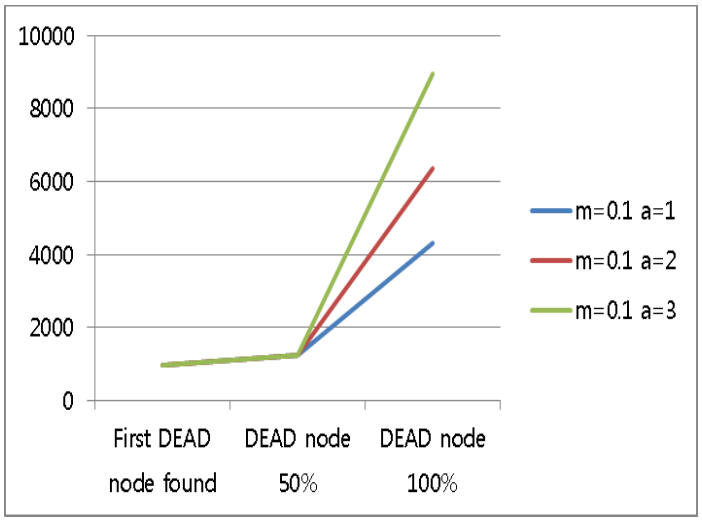

Figure 2. The Advance Node the Initial Energy Change

According to the comparison result, the round where the first DEAD node is found was not that, higher number of the initial energy does not show slower detection on the DEAD node. Nevertheless, it can slower where it detects 100% on the DEAD nodes. The following DEAD node comparison is completed in same environment but in varies on the initial energy by changing the ratio of advance nodes in Table 4.

Table 4. The Initial Advance Node Rate of Energy Change

	First DEAD node found	DEAD node 50%	DEAD node 100%
m=0.1 a=2	969	1241	6368
m=0.2 a=2	1051	1273	X
m=0.3 a=2	969	1325	X

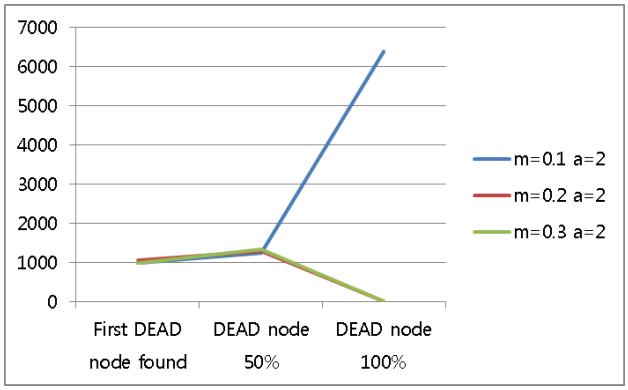

Figure 3. The Initial Advance Node Rate of Energy Change

After the trial, the experiment held in the same condition until the round of 9999. In Table 3, it showed the DEAD nodes with 100% however in Table 4, the DEAD nodes were not found at all. As a result, it proved that rather than varying the initial energy of the node, the changes on the initial energy ratio of nodes has higher probability to extend the life expectancy on network.

LEACH had fixed function equation to select the cluster head and that has imbalanced energy consumption. When the cluster head has been selected, high energy consumption takes to transmit the data or message to the sink. For this reason, the DEAD nodes will occur quickly.

4. Conclusion

The cluster-based wireless sensor network to configure and maintain the network topology in the routing scheme and the cluster are used also to configure the network LEACH, EACHS, HEED methods are observed. LEACH had fixed function equation to select the cluster head and that has imbalanced energy consumption. EACHS has a disadvantage that requires identifying the residual energy of nodes and HEED has defect that it cannot guarantee the number of the cluster head. Due to these problems, imbalanced energy consumption has been occurred and the DEAD nodes were found quickly. In this paper, by selecting the cluster head more efficiently in wireless sensor network to guarantee the number of the cluster head and with varying the initial energy, it presents the normal nodes and advance nodes. Through the simulation, it confirmed that in order to minimize the DEAD node is by varying the initial energy ratio among the advance nodes. In simulation, comparing between when it has the same value of the initial energy and when it has various value of the initial energy, the result verified when it has various value of the initial energy more cluster heads were selected by the initial energy variable. And again, the initial energy ratio has been

changed when the changes of the initial energy. For that consequence, 100% of the DEAD nodes were found when varying the initial energy at 9999 rounds. Nevertheless, when changing the initial energy ratio, there were no DEAD nodes with 100%. This verified that the change of the initial energy ratio is efficient in wireless sensor network field. Therefore, this proposed method can extend the life expectancy of the entire network.

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