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The New Clustering Algorithm for Sensor Nodes' Mobility and Variability

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Abstract

Wireless sensor networks are making the secure monitoring a various environments. Many researches have been done for extending the network lifetime. In this paper we are looking at routing protocols, especially LEACH protocol. LEACH protocol is a representative routing protocol and improves overall network energy efficiency by allowing all nodes to be selected to the cluster head evenly once in a periodic manner.

However, there is a problem that the data transmission success rate decreases when nods move because movement of nodes is not considered. The LEACH-Mobile protocol improves the data transmission success rate by considering the mobility of nodes. But energy consumption increased because it consumes more energy to recognize which nodes moves and re-transfer data. LEACH-Mobile didn't consider the situations where the number of total nodes is variable within sensor field.

In this paper we propose LEACH-VMN (Variable Mobile Nodes) protocol considering nodes' mobility and variability. In order to verify the performance of the proposed protocol, a scenario I considering only nodes' mobility and a scenario II considering nodes' mobility and variability simultaneously are simulated and compared with the LEACH-Mobile protocol.

Keywords: Wireless sensor network (WSN), Mobile nodes, LEACH, LEACH-Mobile, LEACH-VMN

INTRODUCTION

Wireless sensor networks are the core technology of ubiquitous networks. Wireless sensor networks are classified into two, the fixed and the mobile networks depend on whether the nodes have been moved. The fixed sensor networks mean that the positions of nodes do not change and occasionally are used in such as vibration detection of bridges and earthquake detection of buildings. The mobile sensor networks consist of mobile nodes which are changing the locations of nodes, used to detect the earthquake of the seabed (earthquake, heavy rain, tsunami, and typhoon etc.) and to monitor the patient conditions with body sensors attached to the patient.

The routing protocol of wireless sensor networks are classified into the plane routing, location-based routing, and hierarchical routing [1] [2] [3] [4]. The routing protocol used in this paper is the LEACH protocol. The LEACH protocol is the representative protocol among the hierarchical routing protocols [5]. The LEACH protocol improved the energy efficiency of network by clustering method but does not consider the situation of nodes movement. Therefore, if nodes move, data transmission success rate is low.

The LEACH-Mobile protocol is a protocol that improves the problem of movements of nodes[6]. In LEACH-Mobile protocol, the node moved and failed to transfer data, the problem was solved by making the failed node join the re cluster and re transmitting the data. However, energy is consumed additionally for recognition of the moved node and energy consumption is larger than LEACH protocol.

In this paper, propose LEACH-VMN protocol considering mobility and variability in sensor field for problem solving. LEACH-VMN protocol considers mobility by transmitting the location information of the node to the base station. And cluster head is selected based on the residual energy, so that when a new node comes in, the cluster head is selected based on the new node to consider the variable number of nodes. In order to verify the performance of the proposed protocol, a scenario I considering only node mobile and a scenario II considering node mobile and variable number of nodes are simulated and compared with the LEACH-Mobile protocol.

RELATED RESEARCHES

LEACH Protocol

LEACH (Low Energy Adaptive Clustering Hierarchy) protocol is a clustering-based hierarchical routing protocol proposed by Wendi B. Heinzelman [6]. The process of the LEACH protocol consists of a set-up phase and a steady-state phase. In the set-up phase, cluster heads are selected and

clusters are formed. A cluster consists of a cluster head and a number of member nodes.

$$T(n) = \begin{cases} \dfrac{p}{1 - p(r \bmod \frac{1}{p})} & if \quad n \in G \\ 0 & otherwise \end{cases} \qquad (2.1)$$

In the steady-state phase, member nodes transmit the sensing/collected data to the cluster head which he belongs to according to the TDMA scheme which was set in set-up phase. And each cluster head aggregates the received data from the member nodes and sends them to the base station.

LEACH-Mobile Protocol

The LEACH-Mobile protocol has been proposed to increase the data transmission success rate, taking into account the movements of nodes within a sensor field [7]. Sensor nodes move randomly at a specific rate within a sensor field. The cluster heads confirm whether the moved node(s) participate in their cluster every round.

The set-up phase of the LEACH-Mobile protocol is equal to that of LEACH protocol and only data transmission scheme of the steady state phase is different from that of LEACH. The cluster heads send a request message to their member nodes to send the collected data. The member nodes which received the transmission request message transmit acknowledgement message to the cluster head and then transmit the data.

If all the member nodes succeed in transmitting data to the cluster head, the next round proceeds. But if the cluster head doesn't receive acknowledgement message from member nodes, the cluster head assumes that the corresponding member nodes have moved out of the cluster and are not present in the cluster. Then adding the corresponding nodes to the transmission failure list and all cluster heads broadcast to the nodes "cluster join request message". The moved nodes which were fail to transmit data join the cluster and transmit collected data to the new cluster head.

PROPOSED ALGORITHM

Cluster Head Selection

The cluster heads selection in the LEACH protocol is performed through Equation (2.3). To select the cluster heads among nodes, the proposed algorithm basically uses equation (2.3) and adds to consider two rules: 1) the residual energy of the sensor nodes. The more residual energy nodes have, the more elected as cluster head. 2) The number of cluster heads per round is constant. The method to select cluster heads with newly added two rules shows in Figure 2.

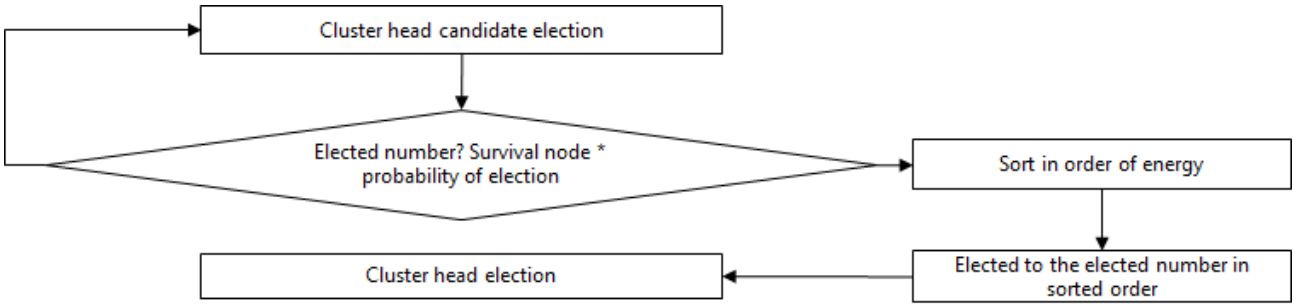


Figure 2. Cluster heads selection.

Mobility and Variability

The proposed LEACH-VMN protocol considers both the mobility of sensor nodes' within sensor field and the variability of sensor nodes' numbers without restriction on sensor field. In order to consider two conditions, 1) nodes randomly moves and 2) new nodes are introduced in during specific rounds and some of existing nodes are leaked out of sensor filed. Therefore the newly added nodes are likely to become cluster headers because of larger residual energy. For convenient of simulation, the movements of nodes happen in set-up phase and the variability of sensor nodes' numbers occurs in steady-state phase.

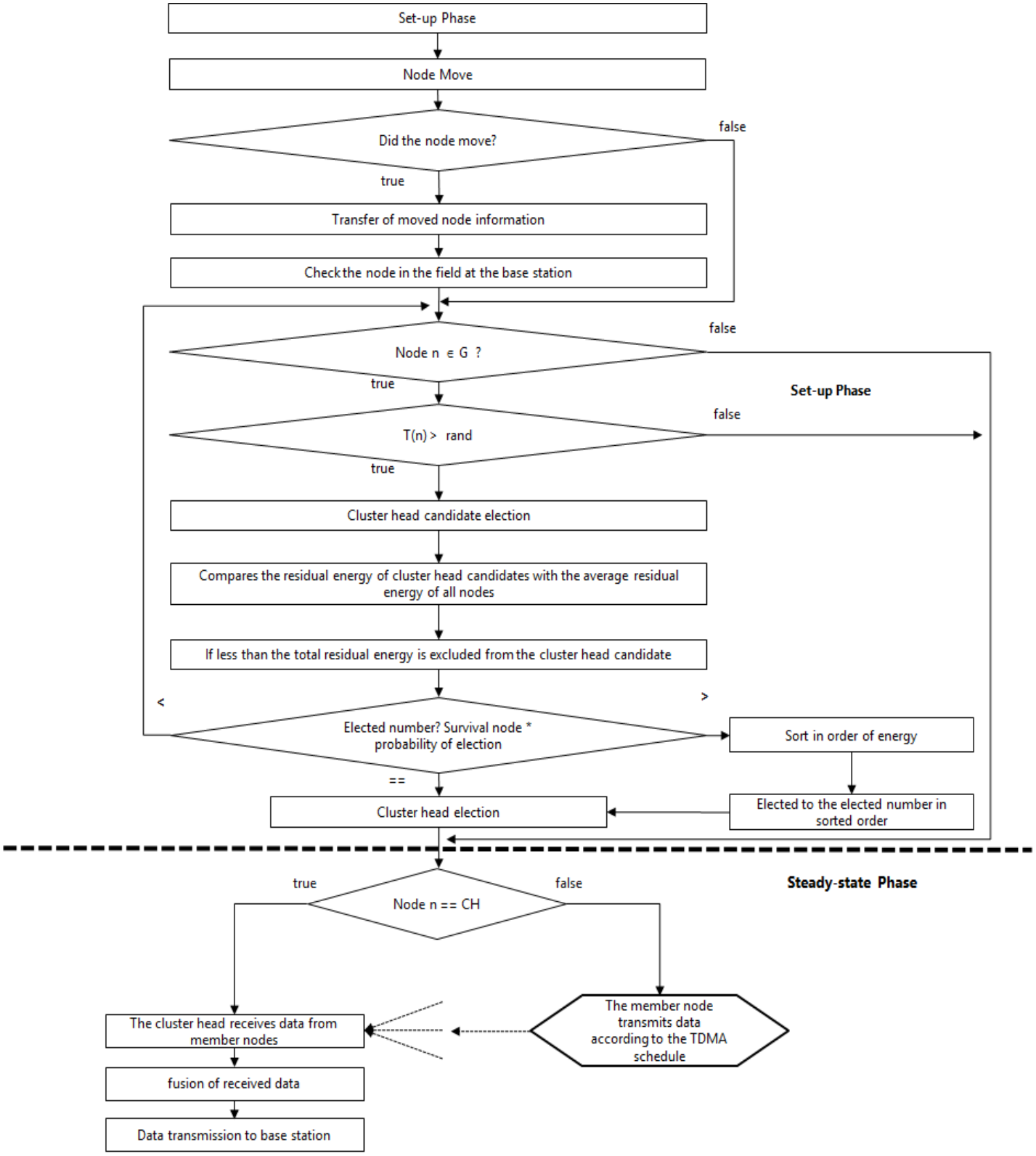


Figure 3. LEACH-VMN Flowchart.

The steady-state phase is the same as the data transmission of the LEACH protocol. Unlike the LEACH-Mobile protocol, the LEACH-VMN protocol does not need the transmission failure list-up operation and the re-transmission of the moved sensor nodes. As a result, the energy consumption of the nodes will be smaller than the energy consumption of the LEACH-Mobile protocol.

SIMULATION RESULT

In order to compare the LEACH-VMN with the existing LEACH-Mobile protocol, we simulated two scenarios. Overall simulation parameters are described below Table 1 and Table 2. All simulations was performed 10 times to make sure the accuracy of each simulation and averaged the results.

Table 1. Radio model parameters

Parameters	*Control Variables*
Node initial energy	0.5J
Message size	2000bit
E_{elec}	50nJ/bit
ε_{fs}	10pJ/bit/m^2
ε_{mp}	0.0013pJ/bit/m^4

Table 2. Simulation parameters

Parameters	*Control Variables*
Field size(m)	100(m)*100(m)
Base station location	(50(m),150(m))
scenario Ⅰ Initial node count	100
scenario Ⅱ Initial node count	50
Location updating GPS data	16 byte
Cluster selection probability (p)	10%

Scenario I

Scenario 1 is only for taking account of the movement of sensor nodes. We simulated 10% increments from when no nodes move (0%) to when all nodes move (100%).

Figure 4 shows the simulated results of FND, HND, and LND of the LEACH-Mobile protocol and the LEACH-VMN protocol. In case of node movement ratio is low, there is a slight difference in network life between two protocols. However, as the node mobility ratio increases, the results show that the network lifetime of the LEACH-VMN protocol is longer than that of the LEACH-Mobile protocol.

Figure 5 shows the FND attenuation ratio according to the movement ratio of sensor nodes. The proposed protocol reduces the FND attenuation rate from 2.2% to 0.8%. The LEACH-Mobile protocol is attenuated from -0.2% to 8.1%. As the nodes' mobility increases, the attenuation ratio of the LEACH-Mobile protocol is irregular but the LEACH-VMN protocol attenuates to some extent. This result means that the proposed protocol is more stable than LEACH-Mobile protocol.

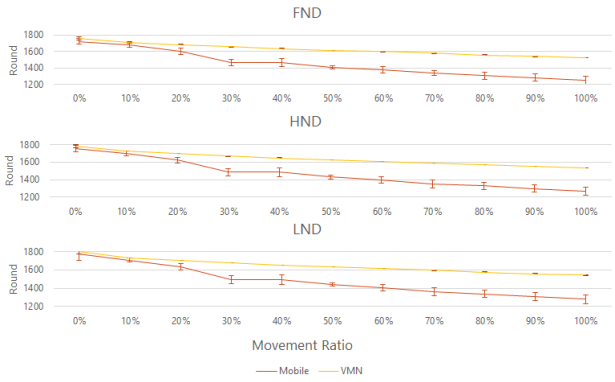


Figure 4. LEACH-VMN Flowchart.

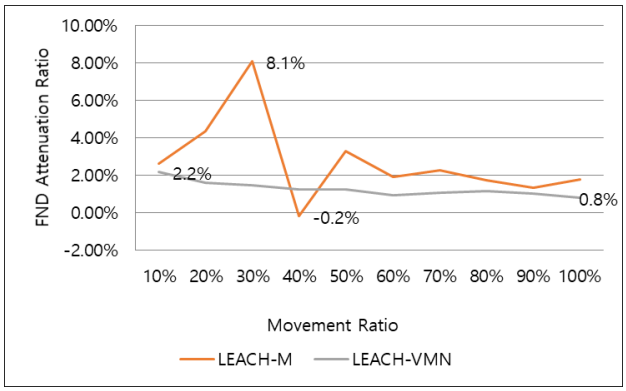


Figure 5. LEACH-VMN Flowchart.

Scenario II

In Scenario II, we take account of the movement of nodes' and the variability of nodes' number at the same time. The movement ratio of nodes is the same as Scenario I. Number of nodes in each round is shown in Table 3. In table 3, + means that new nodes are added and – means the outflow of nodes out of sensor field. Every 100 rounds, sensor nodes repeatedly flows in and out. And nodes which go out of field can re-enter the sensor filed with 50% of probability. The simulations in Scenario II was performed until the FND occurred. The reason why we didn't check HND and LND is that nodes' number variability can mislead the results.

Table 4. Number of nodes in each round

Round	*Node Count*
0~100	50
101~200	80 (+30)
201~300	60 (-20)
301~400	90 (+30)
401~500	70 (-20)
501~600	100 (+30)
…	…

Figure 6 is showing the lifetime of two protocols, FND. It can be seen that the lifetime of the network is linearly damped by the movement ratio. This simulated results indicate that the lifetime of LEACH-VMN protocol is longer than that of the LEACH-Mobile protocol and the proposed LEACH-VMN protocol is more reliable than the LEACH-Mobile protocol. Figure 8 is showing the FND Attenuation Ratio of two protocols. This also shows that the proposed protocol is more stable.

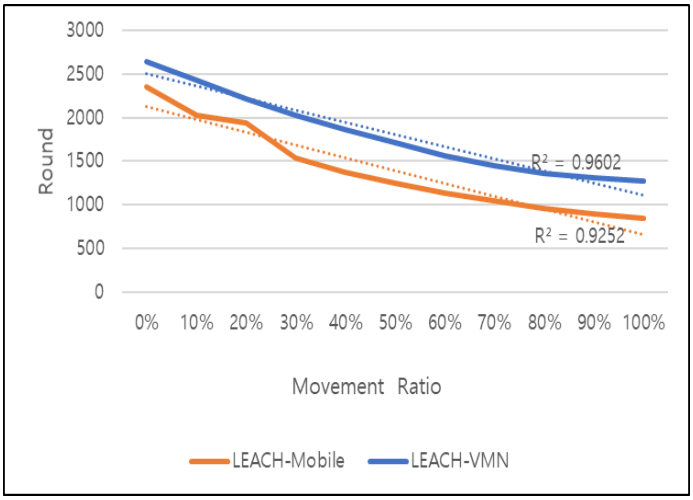


Figure 6. Network lifetime(FND).

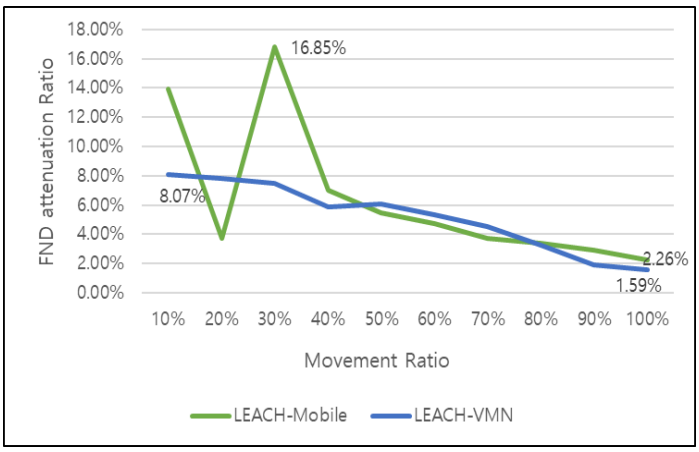
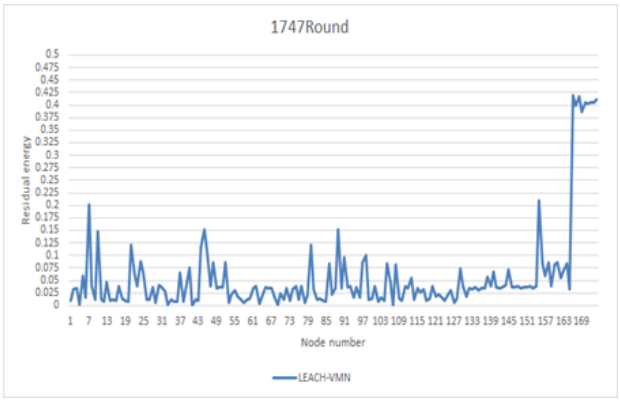
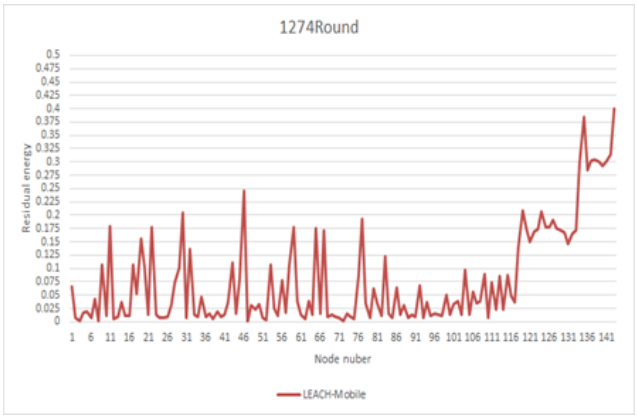


Figure 7. FND Attenuation Ratio.

The residual energy of the sensor nodes in sensor field is compared. The residual energy of all nodes in both protocols show when the FND occurs in Figure 8. This figure indicates that the LEACH-VMN protocol is consuming evenly than the LEACH-Mobile protocol at the 50% of nodes movement.



(a) LEACH-VMN



(b) LEACH-Mobile

Figure 8. Movement Ratio 50%.

CONCLUSION

In this paper, we propose a LEACH-VMN protocol considering nodes movement and nodes number variation. In order to consider the movement and variation of nodes, the moved nodes transmit the location data to the base station and select cluster headers based on residual energy of nodes regardless of newly added nodes and existing nodes.

Compared to the existing LEACH-Mobile protocol, the network lifetime of the LEACH-VMN protocol improves FND by more than 2% up to 22% when considering only node movement. HND and LND are improved by at least 1% up to 21%.

The standard deviation of FND of the proposed LEACH-VMN protocol is less than 0.5% as nodes movement ratio increases. This means that the proposed LEACH-VMN protocol is a stable protocol. The FND attenuation ratio is irregular in the LEACH-Mobile protocol, but the proposed LEACH-VMN protocol is attenuated within a certain range and is more stable.

With all simulated results, the proposed LEACH-VMN protocol has more network lifetime and more stable than the LEACH-Mobile protocol.

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