

Cluster Head Selection Scheme for Minimizing the Changes of the Cluster Members considering Mobility in Mobile Wireless Sensor Networks

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Abstract— In Mobile Wireless Sensor Networks (MWSNs), selecting a node with different mobility as a cluster head causes frequent changes of the members. According to TDMA schedule based on LEACH, all sensor nodes can send data at just a specially assigned slot in the next round after a certain period of time. Therefore, the allocated slots to the node which moved away from their cluster head will be discarded. Also it has to spend more energy to keep in touch with the current cluster head. Hence, we propose a cluster head selection scheme for minimizing the changes of the cluster members in MWSNs. The cluster heads are elected by calculating the waiting time for themselves. The criteria for cluster head selection are an energy level and the similarity of movement. To support the mobility, we propose a dynamic slot allocation for reducing the unused slots based on the predicted residence time between the cluster head and the members. Results from experimental implementations have demonstrated that the proposed clustering scheme prolongs the network lifetime and reduces the number of leaving nodes.

Keywords— Mobile Wireless Sensor Networks, Cluster head selection

I. INTRODUCTION

Recently, with the advancements of Micro Electro Mechanical Systems (MEMS) technologies, Mobile Wireless Sensor Networks (MWSNs) have opened up new vistas for a wide range of application domains. These sensor nodes can self-organize to form a network and can communicate with each other using their wireless interfaces and transmit to the destination as multi-hop. They are especially useful in extremely hostile environments, such as near volcanically active sites, inside a dangerous chemical plant or in disaster area with a nuclear reactor.

However, the deployment of MWSNs still requires solutions to a number of technical challenges that stem primarily from the constraints imposed by simple sensor devices: small storage capacity, low processing power, limited battery lifetime and short radio ranges [1].

To help solve some of those constraints, various clustering techniques have been proposed by grouping sensors into clusters and assigning specific tasks to the sensors in the clusters. Cluster-based architectures in wireless sensor networks (WSNs) have the advantage of providing scalable and resource efficient solutions [2]. For WSNs or MWSNs,

some cluster based energy efficient schemes have been investigated in many ways [3]–[5]. The Low-Energy Adaptive Clustering Hierarchy (LEACH) scheme presented in [6] is the very first protocol that uses clustering for extending the network lifetime in WSNs.

Applying LEACH-based clustering, which is considered to be a fundamental clustering scheme in fixed sensor networks, to MWSNs requires a design which takes into account the mobility of all the sensor nodes. Above all, the number of leaving nodes that moves away from the current cluster head before the next new cluster head selection process affects the network lifetime and causes transmission delays for the collected information.

The transmission delay and unnecessary energy consumption may occur to each sensor node as the result of searching for a new cluster head and being allocated a slot for data transmission. For example, if a cluster head has different mobility from its members, a number of member nodes will move away from their cluster head. Consequently, this can lead to unstable clustering for nodes to frequently move between cluster heads. A leaving node is defined as a node that moves away from its parent cluster head before the process of a new cluster head election. The leaving rate means a probability that the number of nodes move away from their cluster head given a certain amount of time.

Figure 1 shows the reason that the process of selecting a cluster head should take into consideration the mobility. For example, assume that there are n mobile sensor nodes dispersed in a specific area, as shown in Figure 1.

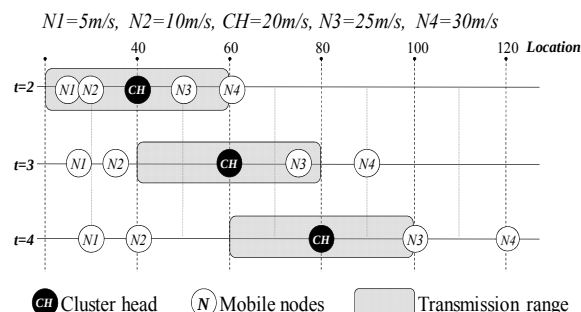


Figure 1. Location of the members as time passed

If a cluster head moves 20m/s and the member nodes move rapidly or slowly, a significant number of nodes become disjointed from the current cluster head shortly after. Consequently, if a node with different mobility is elected as a cluster head without considering the mobility such as their, the leaving rate is increased.

Hence, in a mobile environment, it is desirable that a sensor node which has a similar mobility with their members and has high energy should be selected as a cluster head to reduce the number of leaving nodes and prolong the network life time. Therefore, in this paper, we propose a cluster head selection scheme for minimizing the changes of the cluster members which once belonged to one cluster.

In our proposed scheme, there are two steps in the clustering process: the cluster head election step and the cluster formation step. At the beginning of each round, a sensor node that has a smallest deviation of mobility with its neighbors and has a relatively high residual energy is selected as a cluster head. The rest of sensor nodes then join a proper cluster head that consumes less energy for data transmitting and has a long link connection time. Results from the experimental implementations have demonstrated that the proposed cluster head selection scheme prolongs the network lifetime and shows the highly similar mobility between cluster head and their members.

The rest of this paper is organized as follows. In Section 2, we review some clustering schemes. Section 3 presents our clustering scheme. Next, in Section 4, we present some simulation results in order to evaluate the proposed scheme. Finally, we conclude our paper in Section 5.

II. RELATED WORKS

A number of previous investigations have explored a variety of ways to improve the problems that might occur from applying LEACH based clustering schemes to MWSNs [6]–[9].

In LEACH, cluster heads are randomly elected by turns with a certain probability consider the remaining energy in order not to drain the battery of a single sensor node. Basically, in the LEACH based protocol for MWSNs, each round is divided into a setup phase and a steady state phase as shown in Figure 2.

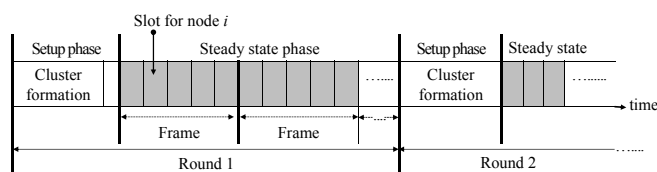


Figure 2. Time line showing LEACH based clustering protocol

Each round begins with a setup phase when the clusters are organized followed by a steady state phase. During the setup phase, some nodes are elected as cluster heads according to a variety of criteria for selection and the rest of the nodes are organized into clusters. In the steady state phase, the cluster heads set up a time division multiple access (TDMA) schedule

and transmit this to their members as shown in Figure 2. Members send data to their cluster head only during assigned slots according to the TDMA schedule and each cluster head sends the aggregated data to the sink directly.

Although LEACH improves the performance in terms of evenly energy dissipation, its applications are limited on fixed sensor nodes without considering mobility. Once cluster is organized, all sensor nodes can send data at just a specially assigned slot in the next round after a certain period of time. According to TDMA schedule, the allocated slots to the node which moved away from their cluster head will be discarded. In addition, the nodes which move in their cluster head have to wait until the newly elected cluster head assigns a slot to them at the next round. At this time, a transmission delay occurs. Therefore, the transmission delay can be reduced by allocating the slot considering the mobility. As the LEACH protocol does not take into account the mobility of sensor nodes after the setup phase for cluster head selection within a round, the LEACH protocol is accompanied by serious data losses in MWSNs [7]–[8].

The LEACH-Mobile (LEACH-M) has been introduced to support the mobility by adding membership declaration to the existing LEACH protocol. LEACH-M uses the same setup procedure of the LEACH protocol. The basic idea in LEACH-M is to confirm whether a mobile sensor node is able to communicate with a specific cluster head, as it transmits a message which requests for data transmission back to mobile sensor node from cluster head within a time slot allocated in TDMA schedule of a cluster head [8].

Cluster head election in LEACH-M has been improved by the LEACH-Mobile enhanced (LEACH-ME) as proposed in [7] whereby the sensor node with minimum mobility factor is elected as cluster head.

Cluster-based Energy-efficient Scheme (CES) has been proposed in [1] for MWSNs was designed based on the LEACH protocol. The CES relies on the weighing k-density, residual energy and mobility parameters in a cluster head election [5].

III. PROPOSED SCHEME

We consider that sensor nodes are randomly placed over the two-dimensional field with following assumptions:

- The sensor nodes are mobile but the sink is immobile outside of the network field.
- The sensor nodes with global positioning system (GPS) devices can be aware their location using a localization mechanism [10] and exchange their information with their neighbors periodically.
- They can aware the speed, movement direction and the amount of their residual energy.
- All nodes have identical processing and communication capabilities.

In our proposed scheme, all sensor nodes calculate the weighting time to decide whether the node itself should be a cluster head or not for themselves. The criteria for cluster head selection are an energy level and the similarity of movement.

All nodes have to wait before transmitting cluster head announcement messages to avoid severe collision and contention among the nodes. During the setup phase of each round for cluster formation, each node calculates its waiting time using the amount of residual energy and the similarity of movement.

The waiting time (WT) for node is calculated as follows:

$$WT = WT_{Max} * \alpha \left(1 - \frac{E_{Residual}}{E_{Initial}} \right) * \beta \left(\left| Avg(\vec{v}_i^k) - \vec{v}_n \right| \right) \quad (1)$$

where WT_{max} is a predefined maximum waiting time. $E_{Residual}$ and $E_{Initial}$ mean the amount of residual energy of a node and the amount of initial energy, respectively. $Avg(\vec{v}_i^k)$ and $\vec{v}_n$ indicate the average velocity of the surrounding nodes and the velocity of each node.

As a result of our scheme represented above in Eq.(1), a higher residual energy node with the smallest deviation is likely to be a cluster head because its waiting time is shorter. The rest of nodes which received cluster head announcement packets give up rebroadcasting to prevent broadcast storms and they then select the best cluster head. By selecting the cluster heads with the smallest movement deviation, the changes of the members can be minimized.

To increase the slot utilization, each cluster head determines the number of their members through the request and acknowledgement sections as shown in Figure 3. During the request period (R), a sink broadcasts its location, velocity and the amount of energy. Each node received the request messages sends an acknowledgement to the sink.

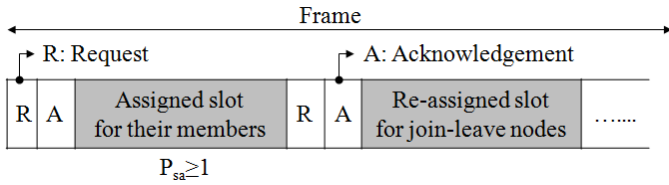


Figure 3. The slot assignment scheduling

The slot allocation is based on the predicted residence time (PRT). A predicted residence time means the link connection time between the cluster head and the members. The factor PRT has been proposed in [11].

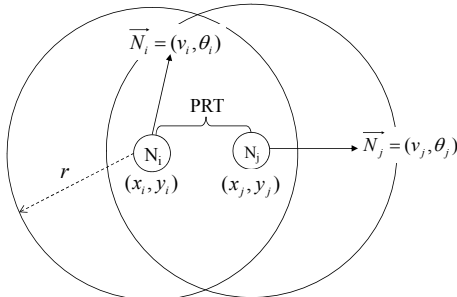


Figure 4. Predicted Residence Time(PRT) between two moving nodes

During the PRT, two mobile nodes will remain connected within transmission range of each other as shown in Figure 3. Let (x_i, y_i) be the coordinates of a mobile sensor node N_i and (x_j, y_j) be that of mobile sensor node N_j . Also N_i and N_j move to the movement angel θ_i and θ_j with speed v_i and v_j , respectively.

The PRT can be predicted using the mobility of node such as the speed and the movement direction as below in Eq.(2) [11], [13].

$$PRT = \frac{-(ab+cd) + \sqrt{(a^2+c^2)r^2 - (ad-bc)^2}}{a^2+c^2} \quad (2)$$

where $a=v_i \cos \theta_i$, $b=x_i-v_j \cos \theta_j$, $c=v_i \sin \theta_i$, $d=y_i-v_j \sin \theta_j$ and $d=y_i-y_j$. If two nodes have zero relative velocity, i.e., $v_i=v_j$ and $\theta_i=\theta_j$, the link will remain forever as PRT will be ∞ .

As shown in Figure 4, if the probability of slot allocation (P_{sa}) is greater than 1, cluster head assigns the slots to the node. The probability of slot allocation is calculated based on the PRT as follows:

$$P_{sa} = INT \left(\frac{PRT}{Round\ time} \right) \quad (3)$$

By assigning the same number of slots to their members, the unused slots can be reduced. In addition, through the rescheduling, the cluster head removes the slots which are assigned to the left node and re-allocates the slot to the newly join node.

After finishing process of electing cluster head, the rest of the nodes that are not elected as cluster heads join the best effective cluster head by considering the link connection time and energy consumption parameters.

Each node selects its parent cluster head according to its energy consumption and predicted residence time. Once cluster is organized, all the sensor nodes can send data at just a specially assigned slot in the next round after a certain period of time. Frequent disconnection from the cluster head can causes the packet losses and a transmission delay. Therefore, each node should select a cluster head that consume less energy for data transmission to prolong the network lifetime. In addition, for minimizing the changes of the members, the predicted residence time between the sensor node and the cluster head should be longer. Each node determines the new cluster head using above two metrics, as follows:

$$\frac{PRT}{Round\ time} * \frac{E_R}{E_C} \quad (4)$$

where E_C and E_R mean the amount of energy consumed for transmission and the amount of residual energy of each node, respectively. A node with a long PRT and high residence time is selected as their new cluster head.

IV. PERFORMANCE EVALUATION

For our experiments, we used a network topology and energy consumption for the simulation which was based on

some numeric parameters obtained from [6], [9]. TABLE 1 lists the main simulation parameters.

TABLE 1. SIMULATION PARAMETERS

Parameter		Values
Network area		100*100(m)
Sink location		50, 175
Number of nodes		100
Radio transmission range		15m
Data	Data packet size	500bytes
	Packet header size	25bytes
Mobility	Model	RPGM
	speed	2, 4, 10(m/s)

We use the Reference Point Group Mobility (RPGM) model. The RPGM model was used for the motion of sensor nodes. The RPGM model represents the random motion of a group of mobile nodes as well as the random motion of each individual mobile node within the group [12]. Group movements are based upon the path traveled by a logical center for the group.

Figure 5 shows that our proposed scheme survived longer than the LEACH. In Figure 5, the x-axis represents simulation time and the y-axis represents the number of nodes alive per round. LEACH selects the cluster heads randomly without considering the location of sensor nodes.

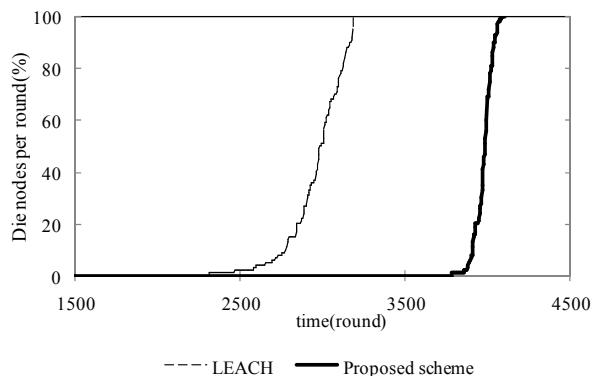


Figure 5. Lifetime of sensor nodes

In our proposed scheme, it takes longer time for nodes to die. Also, the distance from member nodes to cluster head is not changed significantly because the mobile pattern between a cluster head and member nodes is the same in our proposed scheme. Therefore we can see that our scheme is a more effective scheme in terms of prolonging the sensor node lifetime, which is one of the most important factors in wireless sensor networks.

Figure 6 shows the average number of nodes which has a similar movement with a cluster head per round. Moving with similar movement means that they move with the differences of the speed and the movement angle within the ± 10 percentage points. Overall, we can see that the number of nodes that move the same direction with a cluster head is decreased as the sensor nodes move rapidly.

In proposed scheme, the similarity of the movement is high compare with LEACH. If a cluster head and its member move with similar movement, it can reduce the cost for node to join a new cluster head. Hence, it demonstrates that our scheme can configure a stable clustering.

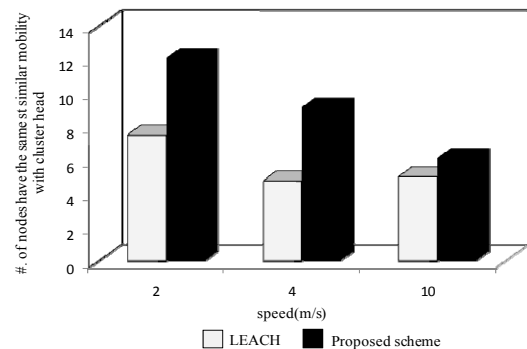


Figure 6. the similarity of the movement with a cluster head

V. CONCLUSION

In MWSNs useful in extremely hostile environment, one of the critical issues is an extending the lifetime of sensor nodes. In addition, a clustering-based architecture is effective in terms of scalability and requires a design considering the mobility of all the sensor nodes as well. The similarity of movement between cluster head and member nodes affects the network lifetime.

In this paper, we propose a cluster head selection scheme for minimizing the changes of the cluster members considering the amount of energy and the similarity of movement. Also, we propose a dynamic slot allocation based on the predicted residence time between the cluster head and the members to increase the slot utilization. The simulation experiment shows that the proposed scheme outperforms LEACH in energy consumption by selecting considering the similarity in the mobility and the energy.

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