

A Density and Distance based Cluster Head Selection Algorithm in Sensor Networks

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Abstract— Sensor Networks consist of massively distributed, small devices that have some limited sensing, processing, and communication capabilities. Due to the design of the topology of Sensor Networks, supporting energy-efficient routing protocol in the sensor networks is a challenging task. In this paper, we propose a Density and Distance based Cluster Head Selection (DDCHS) algorithm. The proposed algorithm divides cluster area into several perpendicular diameters, and then selects cluster head by the density of member nodes and the distance from cluster head. The simulation experiments shows that DDCHS algorithm has improves the network lifetime about 50% better than LEACH and about 10% better than HEED. From the results, considering node density and the distance from cluster head in sensor networks can be more energy-efficient than considering only the distance between nodes in energy usage of Wireless Sensor Networks.

Keywords— Sensor Networks, energy aware, energy efficiency protocol, cluster-head selection, density and distance

I. INTRODUCTION

A Sensor networks is a wireless network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions[1]. Sensor networks consist of large number of small, relatively inexpensive and low-power sensors that are connected to the wireless network. Since each node only has limited energy resource and the battery recharge or replacement is impractical, sensor networks with a energy-aware design becomes important to achieve the desired lifetime performance. The mean of energy-aware is that the energy spent on delivering packets from a source to a destination is minimized [2].

Recently, various clustering technique to reduce an energy consumption of sensor nodes have been developed. One of the most well-known clustering approaches is LEACH (Low-Energy Adaptive Clustering Hierarchy) [3] a clustering-based protocol that utilizes a randomized rotation of local cluster head to evenly distribute the energy load among the sensors in the network. But, since node has different communication distance and remainder energy, LEACH can not have chance to cluster head and consume their energy evenly with only probability. In addition, when the cluster

head select, the cluster head causes on additional overhead to estimate the sum of the current energy.

Unlike LEACH, where nodes self-configure themselves into clusters, LEACH-C (LEACH-Centralized) [4] utilizes the base station for the cluster formation. During the setup phase of LEACH-C, the base station receives information regarding the location and energy level of each node in the network. Using this information, the base station finds a predetermined number of cluster heads and configures the network into clusters. The cluster groupings are chosen to minimize the energy required for non-cluster head nodes to transmit their data to their respective cluster heads. But, at the beginning of each round, LEACH-C causes on additional overhead to receive information from each node about their location and energy level for the centralized cluster formation algorithm.

HEED (Hybrid Energy-Efficient Distributed clustering) [4], that periodically selects cluster heads according to a hybrid of the node residual energy and a secondary parameter, such as node proximity to its neighbors or node degree. HEED terminates in iterations, incurs low message overhead, and achieves fairly uniform cluster head distribution across the network. But, HEED does not guarantee the number of selected cluster head. If the energy of all nodes is similarly low, most nodes can become cluster head.

In this paper, we propose a Density and Distance based Cluster Head Selection (DDCHS) algorithm in the sensor networks. The proposed scheme is dividing cluster area into two perpendicular diameters to get four quadrants, then in each quadrant, selects following cluster head by group's node density and distance from cluster head. First, we outline the basic DDCHS scheme. Then, we describe our DDCHS scenario.

II. THE BASIC DDCHS SCHEME

In this section, we describe an overview of the basic DDCHS scheme for sensor networks. The proposed algorithm divides cluster area into two perpendicular diameters, and then selects cluster head by the density of member nodes and the distance from cluster head.

A. Network model

During the phrase of cluster initialization, the sensed zone is divided into several virtual hexagons which it can avoid the overlapping nodes of circular cluster. Furthermore, we make

some sub-circle in the formatted virtual hexagon base on the average distance between the common nodes and the cluster center.

Consider a set of sensors disperse in a field. We assume the following properties about the sensor networks.

- The sensor nodes are quasi-stationary.
- All nodes have similar capabilities and can communicate using the same transmission power, but energy consumption is not uniform.
- Nodes are location-aware, i.e. equipped with GPS-capable antennae.

B. The DDCHS Algorithm

The each steps of proposed DDCHS algorithm are described as follows.

- [step1]**Local Grouping** divides cluster area into two perpendicular diameters to get four quadrants.
- [step2]**Compare the node density** that is the number of cluster members in each quadrant and select candidate quadrants.
- [step3]**Compare the node distance** that is from the nearest cluster head in candidate quadrants and select following cluster head.

Following cluster head determination, the nodes that are picked as cluster heads advertise their status to their immediate neighbors, i.e., each cluster head communicates with neighboring devices by transmitting a signal identifying the particular node as a cluster head and inviting these neighbors to join in the cluster. Other nodes may also participate in the advertising process. Hearing these advertisement messages, each sensor node chooses the nearest cluster head and registers itself as a cluster member leading to the formation of clusters.

In sensor networks, figure 1 shows the DDCHS algorithm for cluster head selection from cluster area.

Cluster head selection algorithm

Process 1. Initialize

```

Setmem ← {u : lies within my cluster range}
If (is_exist_CH == True)
    my_cluster_head = nodeID
    Setgrp ← set grouping by divide cluster area
else
    Compute and broadcast cost to ∈ Setmem
    SetCH ← max(energy)
    my_cluster_head = nodeID
    Setgrp ← set grouping by divide cluster area
end if

```

Process 2. Repeat

```

If (is_exist_CH == False)
    Goto Process 1
else
    If (Setgrp == False)

```

Go to Process 1

else

Compute and broadcast cost to ∈ Setgrp

CHgrp ← max(density)

Compute and broadcast cost to ∈ CHgrp

SetCH ← min(distance)

my_cluster_head = nodeID

Cluser_head_msg(nodeID, position)

end if

end if

Figure 1. Cluster head selection algorithm

Figure 2 illustrates the Local Grouping that is divide cluster area into two perpendicular diameters at position of initial cluster header. M is a size of sensor field, R is a communication radius of initial cluster head, C(x,y) is a position of initial cluster header, C'(x',y') is a center of inscribed circle.

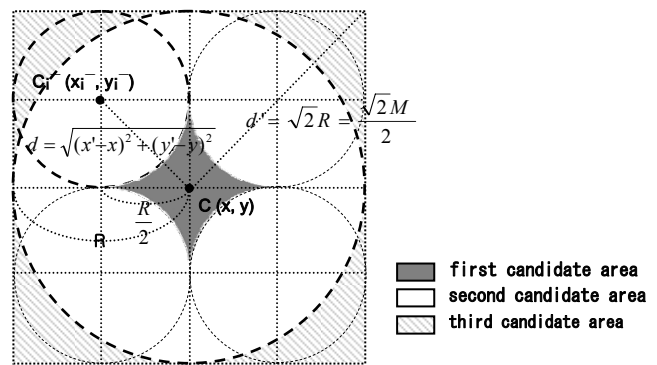
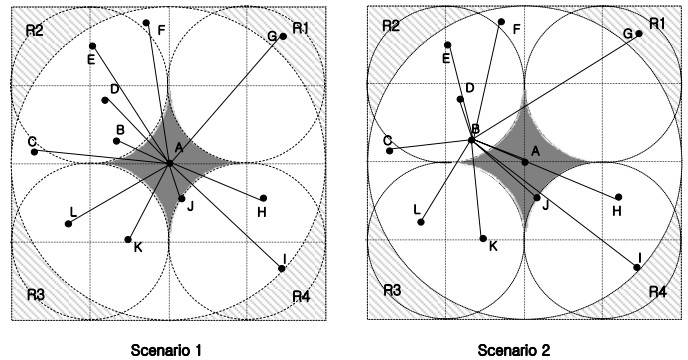


Figure 2. Local Grouping by divide cluster area

In figure 2, dark area is highest priority candidate area for next cluster head selection according to DDCHS algorithm. Since third candidate area is far distance from initial cluster head, avoid candidate area for next cluster head selection.

III. APPLICATION SCENARIOS

Figure 3 illustrates four cluster head selection scenarios by DDCHS algorithm, in which the energy consumption for communication between cluster head and member node is different by giving change in header position. Starting from a simple scenario, we describe our scheme how DDCHS algorithm can select following cluster head to support sensor application and inter-working.



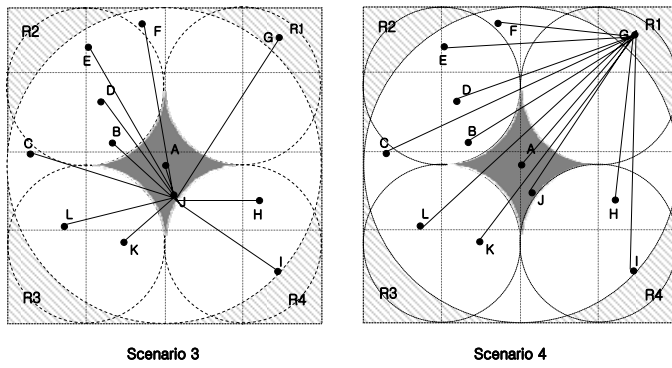


Figure 3. Application scenarios for cluster head selection

Scenario 1 is an example that creates a group within the radius of the first cluster header. It is the ideal form as control groups that set the initial cluster header in the center of the radius. In this scenario, node A is a cluster head.

Scenario 2 is an example that changes the cluster head according to the DDCHS algorithm. In the R2 area, which has the most nodes of the cluster area (thus density is high), the node B that is nearest to the initial head selects the next cluster head. In this scenario, node B is a cluster head.

Scenario 3 is an example that changes the cluster head according to the HEED algorithm that selects the head by only considering communication distance and the remainder energy. In this scenario, node J is a cluster head.

Scenario 4 is an example that changes the cluster header according to the LEACH algorithm that selects the cluster head by only probability without consideration about cluster form. In this scenario, node G is a cluster head.

IV. EVALUATION

A. Evaluation Metrics

In this subsection, we prove that our algorithm can reduce overheads and provide more energy-effective through simulation experiments. First, we assume that cluster member nodes N_k ($k = 1 \dots n$) be in the communication range of R in which there are no packet loss by attacks from inside or outside the network, and network bandwidth is sufficient for all requirements. Sensor nodes have power control so that they can transmit their data directly to the cluster head or to any other nodes in the network.

The basic constraints of sensor networks are: limited power/energy, limited storage and working memory. So in order to evaluate the performance of cluster head selection, we have compared the communication cost and energy consumption. To evaluate the performance of the proposed scheme, we assume that simulation environments are a congestion-free MAC layer and an error-free communication.

We simulated the performance metrics with the parameters of the system and network parameter listed in Table 1.

Table 1. The system and network parameter

Network grid	(0,0)~(100,100)
Radius of the region, R	25m
Length of each packet, l	500/1,000bits
Electronics energy, E_{elec}	50nJ/bit
Transmitter energy, ϵ_{fs}	10/20pJ/bit/m ²
Amplifier energy, ϵ_{ms}	0.0013pJ/bit/m ⁴
Initial energy per node	2J

B. Performance Evaluation

We adopt the energy consumption model given in [5] for transmitting and receiving data with length l bits when x is the distance between transmitter and receiver. For transmission over a distance less than d_0 will use the free space model and else use the multi-path fading model.

$$E_{Tx}(l, d) = \begin{cases} l \times (E_{elec} + \epsilon_{fs} x^2) & x < d_0 \\ l \times (E_{elec} + \epsilon_{mp} x^4) & x \geq d_0 \end{cases} \quad (1)$$

$$E_{Rx}(l) = l \times E_{elec} \quad (2)$$

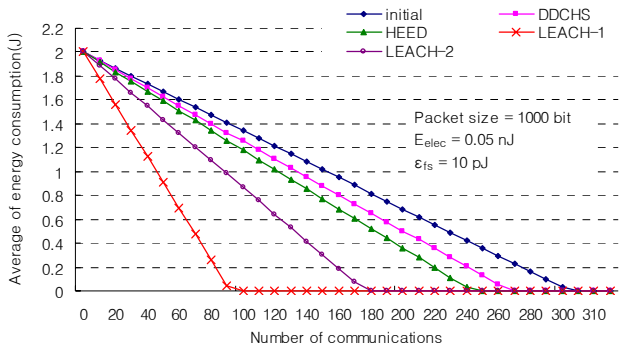
In order to calculate the energy consumption, we compare the different clustering protocols. When the packet size is 1000bits and the E_{elec} is 0.05nJ and the ϵ_{fs} is 10pJ, table 2 shows the energy consumption due to communication cost of once between the whole node and cluster head by position of cluster. From the result, except scenario A that uses to control group, we can show that the energy consumption of the proposed algorithm is most efficient. It is observed that the DDCHS protocol has a much better performance than the HEED and LEACH protocols.

Table 2. Energy consumption for communication of once

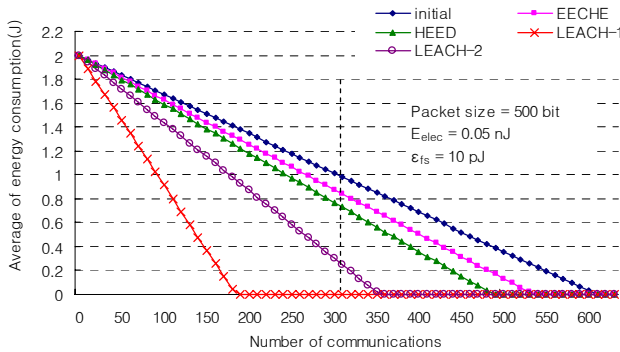
Header	A	B	J	G	K
Protocol	initiate	DDCHS	HEED	LEACH	
A	0	1.96	3.84	15.68	4
B	1.69	0	3.24	20.07	5.29
C	9	3.39	11.7	39.94	8.41
D	4	1.04	8.64	19.01	10.5
E	9.24	4.84	15.05	19.01	19.71
F	9.73	7.84	15.68	9.99	25
G	14.75	20.79	18.49	0	35.28
H	5.29	12.82	3.84	13.99	10.5
I	12.96	23.23	8.76	29.16	12.67
J	0.71	4	0	18.32	2.56
K	4.16	5.02	2.56	34.11	0
L	7.29	4.84	6.66	41.99	1.85
TOTAL	78.82	89.77	98.46	261.27	135.77
AVG	6.57	7.48	8.21	21.77	11.31

Figure 4 shows that the average of energy consumption between the whole node and cluster head by position of cluster. In evaluation metrics, we assumed that the initial energy per node is 2J. Through the above experiment results, we also can calculate the energy consumption for communication of once.

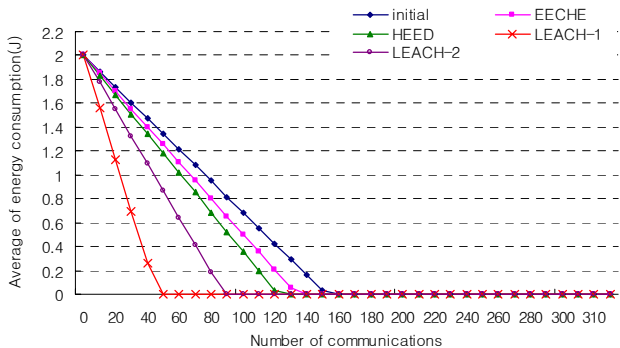
Therefore, we can estimate the count of communication on the network lifetime.



(a) energy consumption (packet size=1000bit, $E_{elec}=0.05nJ$, $\epsilon_{fs}=10pJ$)



(b) energy consumption (packet size=500bit, $E_{elec}=0.05nJ$, $\epsilon_{fs}=10pJ$)



(c) energy consumption (packet size=1000bit, $E_{elec}=0.05nJ$, $\epsilon_{fs}=20pJ$)

Figure 4. Energy consumption per number of communication

The based on the results of Figure 4 (a), when the packet size is 1000bits and the E_{elec} is 0.05nJ and the ϵ_{fs} is 10pJ, we found that initiate as control groups takes about 305 rounds, LEACH takes about 92 rounds and 177 rounds respectively to die, while HEED takes about 244 rounds, DDCHS takes about 268 rounds. And the DDCHS is energy-efficient more than about 10% than HEED, and more than about double or triple times than LEACH in some cases.

In addition, the lifetime of all nodes is affected by the transmit packet size and the transmitter energy. The based on the results of Figure 4 (b) and (c), when the transmit packet size and the transmitter energy is reduced by half, the lifetime of all nodes increases about 2 times.

Through the simulation experiments, we showed that the DDCHS algorithm has improves the performance of cluster head selection and provide more energy-efficient comparing to the above two protocols. The Length of each packet and the selectronics energy that use in an experiment is 1,000bits and 50nJ, respectively. But if packet size and transmission power grows, this difference differential may great more.

V. CONCLUSIONS

In this paper, we propose an DDCHS algorithm which improves the performance of clustering. The proposed algorithm divides cluster area into two perpendicular diameters, and then selects cluster head by the density of member nodes and the distance from cluster head.

In order to evaluating the performance of proposed scheme, we have compared the communication cost and energy consumption. Through the simulation experiments, we showed that the DDCHS algorithm is energy-efficient more than about 10% than HEED, and more than about double or triple times than LEACH in some cases.

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