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Dual Cluster Head Algorithm for Proficient Routing in Wireless Sensor Networks

R. Ananth* and S. Karthikeyan

Sathyabama University, Agni College of Technology, Chennai – 600130, Tamil Nadu, India;
abv1984@gmail.com, karthijoy1@gmail.com

Abstract

Objectives: In cluster based algorithms, the group head needs to do the transmission, gathering, aggregation, collection and the timing administration. Due to this the head of the cluster will lose its energy rapidly and another head ought to be found. A new election process creates unwelcome control message movement in that particular network. The main objective is to reduce the number of elections hence the wastage of energy can be minimized. **Methods/Statistical Analysis:** To reduce the number of election we propose our model Dual Cluster Head Protocol (DCH). The key idea is to have a group head and sub group head, where the work load will be shared between them. The sub head will perform the information gathering and aggregation inside the cluster and it will report just to the main cluster head. The clusters will be managed by the Sub-Cluster Head (SCH) node, but the session management will be carried out by the cluster head. All the outward communications will be carried out by main cluster head; also it relays the information from other heads. **Findings:** Our algorithm uses lesser amount of control messages than other conventional algorithms since the number of cluster head re-elections is reduced. The performance of the algorithm matches with protocols like LEACH and SEECH. We have used 3 scenarios for testing the protocol; in the first scenario with 100 nodes DCH protocol performed 31% better than SEECH and 86% better than LEACH. In second scenario with 400 nodes DCH protocol performed 6% better than SEECH and 20% better than LEACH. In third scenario with 1000 nodes DCH protocol performed 38% better than LEACH but fell short of 45% when compared with SEECH. **Application/Improvements:** Right now the algorithm performs well in low and medium density sensor fields. It can be improved to work efficiently in high density sensor fields. The comparison can be made with newer protocols like HEED

Keywords: Aggregation, Clustering, Dual Cluster Head, Routing

1. Introduction

A Wireless Sensor Network (WSN) is an astute and low cost arrangement that empowers the effectiveness and unwavering improvement of numerous applications. The WSNs for most part comprises of countless low-power nodes which are smaller in size, some as small a coin. These sensor hubs can act as independent devices and be deployed in different sorts of situations. One of the primary concerns to the WSNs is to enhance their lifetime. They are utilized to observe various physical situations with number of battery-controlled sensor nodes that restricts the lifetime of a network. It is hard to replace the batteries for these nodes[1]. Furthermore, the sensor hubs have limited abilities for detecting, communication, processing, and portability because of the hardware constraints. There are numerous strict restrictions in the design of WSNs, like, little size, light weight, low energy utilization and cheaper. The success of the WSNs lies in their detecting quality, adaptability, effective energy

**Author for correspondence*

utilization, portability etc. WSNs are actually the best choice in remote and perilous environments[2]. A definitive objective of such WSNs in the vital situations is to frequently convey the detecting information from sensor nodes to sink node. Every node is equipped for gathering and handling the information, and can forward to one or more sink hubs utilizing their transceiver. They are multihop devices, where the information will take various hops on diverse nodes before it reaches the sink. The base station or sink is a stationary hub and will be far away from the detecting field[3]. Just about 70% of the energy of a sensor will be utilized for transmission and gathering purposes. BS or sink will be the control center and analysis of sensed data by the user can be done. It may be difficult for all nodes to have direct link with the sink node all the time. Likewise the sensors elements far away from the sink node will have to shed more energy if the communicate directly. This will influence the lifespan of the node and in increasing the lifetime of the network. To prolong the network durability the geographically closer sensor devices are grouped together to form a Cluster[4]. Every group is made of member nodes named as Group Member (GM) or Cluster Member (CM) and a Group Head (GH) or Cluster Head (CH).

Sensor systems gather vast information for a sink to handle. This information may be ambiguous, since same event can be documented by two or more nodes. Along these lines, to compress and analyse the information naturally data aggregation is needed. Cluster heads are the pioneer of a group, and are in charge of gathering and aggregating data from the members. The aggregated data is sent to the Base Station (BS) straightaway if the BS is closer to the CH else it will be directed through numerous other CH[5]. Clustering empowers us to diminish the transmission bandwidth and subsequently we can enhance the capacity of the system. Likewise it helps us to build the system lifetime by having effective utilization of power. Routing between the groups can be direct or multihop corresponding to the separation between them. Energy consumption is directly proportional to the separation between them; more the separation more the node transmits and more rapidly it depletes.

Topology and routing are two foremost issues in effective planning and operation of WSNs. The cozy relationship between these and their link to network lifetime are particularly underlined by the energy efficiency and computation–communication trade-off. Despite the fact that the direct transfer of data from a sensor to a sink is ideal, this is unrealistic and prompts huge energy consumption thereby decreasing the life of the entire network. Communication–computation trade-off indicates that communication uses more energy than performing processing on board a sensor. Hence routing mechanisms will reduce the size of data by using data aggregation.

Network topology can be classified on the basis of data gathering and by the sensor arrangements[6]. The various types are: 1. Flat Topology, 2. Tree Based Topology, and 3. Cluster Based Topology.

1.1 Flat Topology

Flat Topology is a simple technique to accumulate the information from the remote area to sink, since it uses flooding, gossiping and direct transfer, etc. Here, every sensor node enjoys similar hierarchy and forwards the information packets to the one-hop separation neighbour nodes. Since, FT lacks a predefined topology it is utilized in networks where topology does not exist and does not have any energy constraints.

1.2 Tree Based Topology

In Tree Based Topology all the installed sensor nodes can build a consistent tree. Here, the whole information goes from child node to the parent nodes. The data from all sensor nodes will be transferred to the sink. Since flooding is not necessary tree topologies utilizes unicast rather than broadcast. Along these lines, tree topology should guzzle less power than flat topology. Tree arrangement for the entire network is a tedious and excessive operation. It can't endure when intermediate nodes die and the energy utilization is uneven over the system.

1.3 Cluster Based Topology

Clustering is a broadly utilized method because of adaptability to hundreds or a huge number of nodes. It can perform administration, data aggregation, load balancing, etc. It contains two stages namely set-up stage and the other being steady state stage. In set-up stage, group head election is a critical task, which can be accomplished by strategies like centralized or distributed.in centralized methods the base station will assign the cluster head, but in distributed methods we may have election phase, probability based or residual energy based methods. All the group heads are attached with the sink by direct communication or multi-hop connection[7]. The steady state stage can be started to forward the information packets from the member nodes to sink.

In clustering protocols a head gets all data and it aggregates as a packet. Instinctively, intracluster energy relies on upon two components cluster size and centrality. In huge sized clusters there is all the more high power correspondences since the energy utilization in node is connected to the distance separation and keeping the group head in the midpoint of cluster. The cluster head kept at the middle will diminish the squared average distance between group head and individuals which leads to less intra-group energy. In sensor fields with irregular node distribution node density influences the intracluster energy. After data aggregation the relay nodes takes data packet from cluster head and transmits it to the information sink. It is done by means of single jump or multi jump correspondence. In both schemes the energy to transmit packets to sink will definitely increase if number of clusters is expanded[8].

In almost all the clustering procedures in literature, every group head also doubles as a relay node all the while and the other way around. This may not be ideal because of a few reasons; few head nodes can't be in the midpoint of a group due to the position. Hence utilizing such nodes as group head will create unwanted energy wastage. Second, in many cases information sink is a bit too long away from the network. Keeping in mind the end goal to build up small hop distance transmission the closer nodes can be used as transfer nodes or relay nodes. Third, the nodes which are engaged in transmission and reception consume more power than idle nodes.

LEACH proposed in one of well-known clustering processes for WSNs. It has no knowledge about the network and is a distributed algorithm. The group formation and cluster head selection is taking into account the signal quality and threshold value. Ideally for an effective network 5% of the entire number of sensor elements can be used as cluster heads. Every node in the network has an opportunity to go about as a cluster head for a specific time in order to regulate the energy consumption of the nodes. It is accomplished by the sensors choosing an arbitrary number somewhere around 1 and 0. The sensor nodes deplete gradually, haphazardly and dynamic clustering enhances the lifespan of the sensor arrangement. LEACH uses one hop communication and it is not appropriate to large mobile WSNs.

SEECH: Scalable Energy Efficient Clustering Hierarchy Protocol has three phases[9]: 1. In start phase each node analyses some essential info such as its distance from sink and the number of available neighbours within a radius RNG and each node is assigned a degree $deg_i = n_i / max \{n_1, n_2, \ldots, n_N\}$, 2. The cluster heads and the apt relay nodes are identified in the *setup* phase. In addition the path between the entire clusters and the sink node is determined, and 3. In *steady-state* phase, the data is collected from the member nodes and it is forwarded to the base station depending on the topology used. Like numerous other clustering algorithms high level energy nodes are chosen as group heads and they are cyclically replaced by taking into account of the location of nodes thereby reducing the intra cluster energy wastage.

In SEECH the nodes to be selected as cluster head is chosen from neighbours in a clear radius $n_{i.}$ By and large, nodes with bigger degrees are more proper choices for group head. The benefit of this technique is that number of nodes may be connected by fewer group heads utilizing low power exchanges. In group head selection first a portion of the nodes are chosen as provisional group head by a distributive system. Then other nodes acquaint themselves with the network, these nodes are potential group head contenders while other member nodes go to sleep mode. A short time later, all contenders execute a straightforward calculation with the goal that group heads could be chosen depending on their degree and location.

2. Dual Cluster Head Theory

Usually the group head will perform information gathering, aggregation, authentication, directing of accumulated data to the BS. In addition to this some cluster heads are known to do session and energy management among the member nodes. Topology control can be an additional task assigned in some advanced algorithms. These activities are tiresome and will spend vast measure of energy, and generally the group head is the first to get drained. Therefore after certain lower energy limit another cluster head determination procedure is started to find a suitable head. Be that as it may, this procedure again makes undesirable control message movement in the network which is of no meaning relating to the data. We do not have choice to stop this unless we figure out how to extend the lifetime of our current cluster head.

The Figure 1 describes all the components of the sensor network and in Figure 2 we have the detailed description of a single cluster. Thus we introduce two group head algorithm which will enhance the group head's lifespan which thus will enhance the life of the system. The additional head is called as sub cluster head or SCH. The SCH is a unique node which will interconnect to the CH node and will deal with information accumulation, gathering and compression. This will considerably decrease the workload of CH. At the moment all the cluster individuals will look up to the SCH node and SCH will oversee the operations in the cluster and will aggregate the total information. It will deal message integrity check, segmentation and sequence control. The sub head node will forward the data just to its CH pair and all the communication with the external system is done by the CH. Both nodes will function as a team in conveying the data to the sink node. When the sink node is far from the head node, the data will be steered through the neighboring CH nodes. Subsequently the CH nodes will have dynamic communication for majority of the times. Therefore the cluster heads will lose energy faster than normal nodes. But this work sharing process will improve the lifespan of the heads than the clustering procedure like LEECH, PEGASIS, SEECH, HEED and etc.

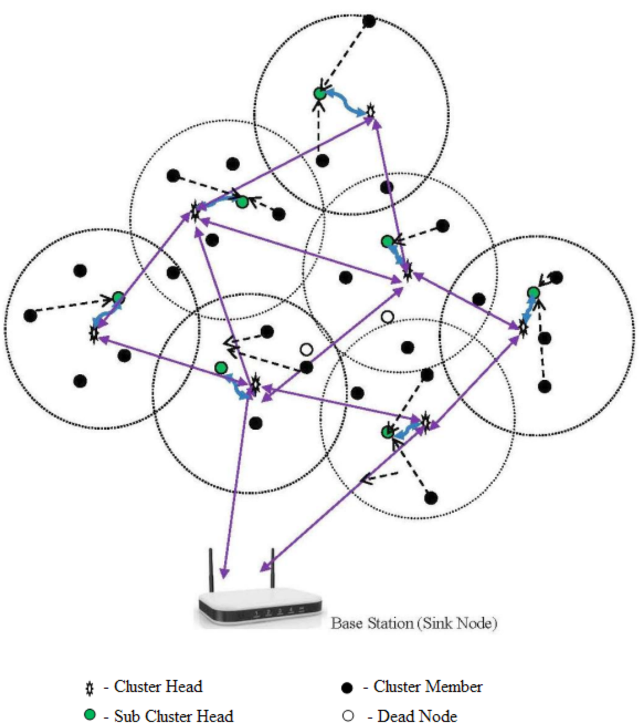

Figure 1. Cluster structure.

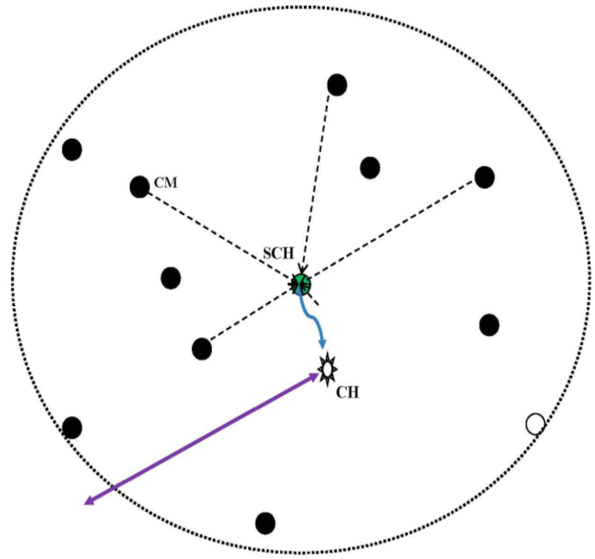

Figure 2. Single cluster.

The CH selection starts setup stage, where first the nodes will identify its neighbours and finds the location of sink node. It is started by the sink by transferring a Hello packet. This data comprises of Euclidean distance, Source Id and incremental Hop-tally (H_1) to the destinations like the sink node and the sender. Hop-count (H_1) and Euclidean separation are utilized to ascertain the separation from the Base Station (BS). The nodes which get the "Hello" will update the sender as its neighbour and will upgrade the Sender Id, Hop-tally and position, and after that resend a "Hello" reply packet to the sending node[10]. Every node receiving the Hello Packet will likewise forward by revamping its id as Sender Id, locality factor. The group size is constrained to one hop separation from the head node[11]. This empowers us to have a controlled cluster and thus the measure of data created won't surpass out of hand.

The group head is decided to be the node which has the highest energy at the given time, while the SCH node is the node with second highest energy level. Attention ought to be taken to verify that the separation between the two head nodes is kept as little as it could be allowed. When neighbour identification is done next is the procedure of determination of Group Head and its Sub-Cluster Head. To begin with every one of the nodes in the field will display its energy level to the neighbouring nodes. Then the nodes will compare the energy levels of the other node with its own energy level. The hello packet will also have information about the power level of the transmitting node. By reading this any node can identify the power level of other nodes. Nodes with lesser energy will reset its clock and will turn out to be a group member. Subsequently two nodes with the best energy will be picked as CH and SCH. Off chance if the energy level of more nodes is equal, a pair of nodes which is closer to each other is chosen as head nodes. The separation between the CH and SCH is a discriminating parameter in outlining the routing algorithm, since if the SCH and CH is far away it will cost us extra power wastage. When the energy level of any of one node drops beneath the threshold; it will show a Dead message to other sensor nodes before dying. The neighbours react to the Dead Message by overhauling their routing table. In LEECH when the group head node passes on a re-clustering is started. This procedure will needlessly dissipate some energy so in LEECH-C the re-grouping procedure is obstructed and the same group is kept up, with another node as group head. So in our method also the same cluster will be kept up and just the CH and SCH nodes will be different. At the point when the energy level of cluster head pair drops beneath the preset level a new selection procedure will be started inside of the same group. The re-election will be started if any of one node's energy levels drops. By all accounts it may seem to be absurd to change the SCH if CH fails or to change the CH if SCH fails horrendously. Regardless, changing the pair will give perfect execution in light of the fact that in spite of the way that the node has some energy leftover, it is in line to be depleted sooner rather than later. Exactly when that happens another selection will be started with "Hello" exchanges. This will make a surge of routing information in the system. With each message the lifespan of the system is decreased. So on deposing both CH& SCH pair will give lesser coordinating messages in the system.

The sub-group node SCH collects the information, then aggregates it and compresses it to reduce size. Of these three, aggregation of information is the premier task of a SCH node. In a heavily congested system there will be regularly numerous nodes detecting the same data. Aggregation will separate the useful data from the entire sensed information. Data aggregation enhances the lifetime of sensor system by wiping out repetitive information[12]. Clustering and data aggregation is used where each node sends data to the SCH node and the sensed data is analysed, compressed and after that sent to the main cluster head CH which will forward the packets to the base station through other head nodes. Thus a suitable data aggregator will improve the capability and drops the energy wastage.

3. Comparative Analysis

The comparative analysis of various protocols is performed using the simulator ns-2 with the assistance of Nam and X graph. Table 1 has the detailed design parameters; the starting energy of all nodes is set to 1 J/node. Node uses *50 nJ/bit* energy for an active communication involve the node's transceiver. The amplifier will use $E_{amp} = 100\ pJ/bit/m^2$ and the initial network is 100m x 100m with the base station (sink) is at (10, 0). We will use three scenarios with respect to the number of nodes (N), i.e. N = 100, N = 400 & N = 1000. The data frames transmitted will be of 1kB in size.

Table 1. Design parameters

Sl. No	Parameters	Values (Test 1)	Values (Test 2)	Values (Test 3)
1.	Number of Nodes	100	400	1000
2.	Initial Energy	1 J/ Node	1 J/ Node	1 J/ Node
3.	Sensor Field	100 × 100m	100 × 100m	200 × 200m
4.	Size of each Packet	1000 Bits	1000 Bits	1000 Bits
5.	Transmitting energy per bit	50 nJ	50 nJ	50 nJ
6.	Receiving energy per bit	50 nJ	50 nJ	50 nJ
7.	Amplification	100 pJ/bit/ m^2	100 pJ/bit/ m^2	100 pJ/bit/ m^2
8.	Average cluster radius	30m	30m	30m
9.	Base Station location	10,0	50,100	200,190

For analysis of the protocols we use three factors namely First Node Dead (FND), Average Node Dead (AND) and Last Node Dead (LND). The lifetime of a network is measured by means of FND value of Table 2, from the analysis in Figure 3 specifies the time when the first node loses its energy. The AND value in Table 3 and plotted in Figure 4 can be the average life of all nodes and LND value in Table 4 and plotted in Figure 5 specifies the time when the last node depletes. The simulation is done with new sets of node every time so that the network starts with full energy. For the Test 1 we used 100 nodes which are quasi-stationary. LEACH is the first protocol to lose out a node, followed by SEECH, the lifetime of network when using DCH is 31% better than SEECH and 86% better than LEACH. It is evident for lesser number of nodes the performance is remarkable. During the second test the number of nodes is increased to 400 with similar sensor field. Now there is a hike of 20% average lifetime of nodes when

Table 2. Network lifetime

Tests	Protocol	Rounds before FND
Test 1 N = 100	LEACH	726
	SEECH	1028
	DCH	1356
Test 2 N = 400	LEACH	685
	SEECH	1015
	DCH	1183
Test 3 N = 1000	LEACH	672
	SEECH	1587
	DCH	1091

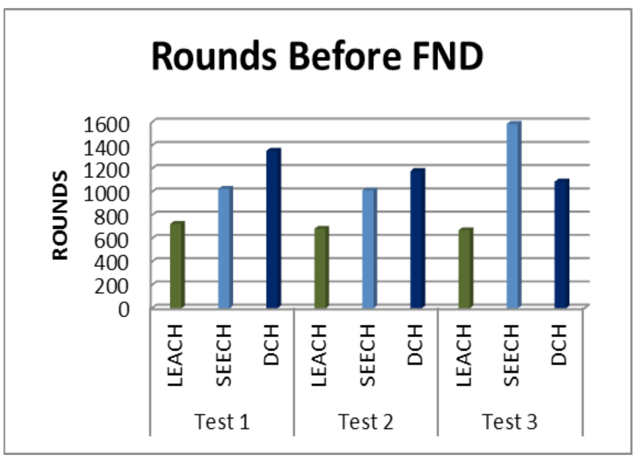

Figure 3. Lifetime graph

Table 3. Average lifetime

Tests	Protocol	Rounds before AND
Test 1 N = 100	LEACH	929
	SEECH	1054
	DCH	1121
Test 2 N = 400	LEACH	902
	SEECH	1093
	DCH	1108
Test 3 N = 1000	LEACH	903
	SEECH	1810
	DCH	1507

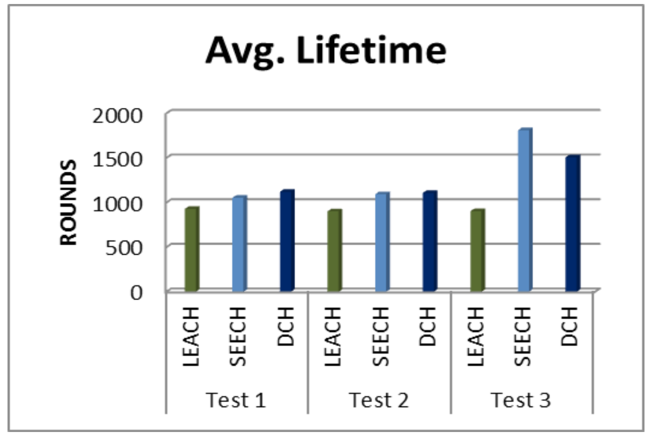

Figure 4. Average lifetime of nodes

Table 4. Total rounds

Tests	Protocol	Rounds before LND
Test 1 N = 100	LEACH	1209
	SEECH	1099
	DCH	1248
Test 2 N = 400	LEACH	1274
	SEECH	1140
	DCH	1231
Test 3 N = 1000	LEACH	2014
	SEECH	2202
	DCH	2186

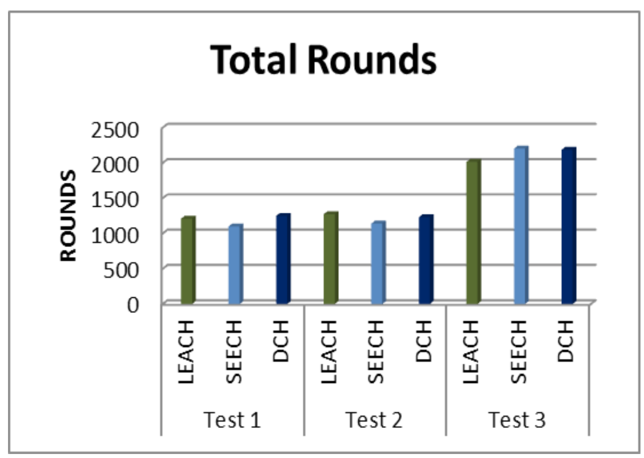

Figure 5. Total number of rounds

Comparing Leach and DCH and 6% hike when comparing SEECH and DCH. Finally when the number of nodes is 1000, we can see that the SEECH is out performing other protocols. It shows that SEECH is built for large network, still DCH is performing nearly similar to SEECH.

4. Conclusion

We have proposed an algorithm which can perform clustering and data aggregation effectively by using two heads within a cluster. This methodology assisted us to elongate the lifecycle of the cluster heads and we could reduce the routing messages traffic in the network. DCH is compared with other similar protocols and analysis was done to ascertain the performance. It performed well in low and medium density networks and marginally in high density network.

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