

# Density Based Clustering Protocol for Optimizing Energy Consumption in Wireless Sensor Network

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**Abstract:** This paper proposes density based clustering protocol for optimizing the energy consumption in Wireless Sensor Network. There are many approaches in the literature; which are differ in the method and frequency of cluster head selection. This paper proposes a new method of cluster head selection. The nodes of the network are categorized as interior and exterior nodes based on the density of other nodes in the surrounding. The ratio of interior type of neighbors to exterior type of neighbors of a node is used to decide the level of a node. This level in combination with distance of a node from the base station is used to decide whether it will act as a cluster head or not. As the energy of nodes depletes, some neighbors may die thus changing the level of the node. At this point, new cluster heads are selected. Due to this the energy of network is consumed in a balanced manner. Simulation experiments are designed to compare the proposed method with other popular clustering algorithms. Overall impression of results is that the proposed method gives a longer network life due to properly distributed energy consumption throughout the network.

**Keywords:** Wireless Sensor Network, Sensor Node, Cluster Head, Interior Node, Exterior Node

## 1. INTRODUCTION

In wireless sensor network, every node is interconnected to another node. They communicate with each other and transfer data from one node to another node. Every node contains transceiver, battery, microcontroller, antenna and transducer. The transducer converts the physical signal to the electrical signal and transmit it. The microcontroller is used for storing the output of the sensor. Transceiver connected to the control computer of the sensor by wire or wireless. It receives the data from the sensor and then it transmits/sends the data to the control computer [1].

For working of the sensor node, component power is received from the battery source. Sensing and monitoring tasks require tools that can efficiently perform the task and return desirable results. Using Wireless Sensor Networks (WSNs)

for the same has been proved to be a boon since last 10 years [2]. WSNs can be defined as a network of nodes that are distributed specifically or autonomously in a given area, also called the Region of Interest (RoI). Each of the nodes performs three tasks: sensing, processing and communicating with the base station. Sensing implies monitoring the given area or a part thereof depending upon the range of a node. Processing implies local computations on the sensed data according to the application requirements. The communication phase then involves communication between the nodes and the base station to send the sensed processed data from the nodes to the base station. The sensing process ends with the transfer of the sensed data to the base station. As successful and simple as these networks seem, they too have certain performance issues to cope with, in terms of memory, bandwidth, processing and most important of all energy.

### 1.1 Applications of Wireless Sensor Networks

The WSNs are considered to be the spatially dedicated and dispersed sensors group for recording and monitoring the physical conditions of environment and further by organizing entire collected data (information) at the central location. The applications of wireless sensor networks [3-7] are as follows:

**Area Monitoring:** In an area monitoring, a collection of sensor nodes are organized in the region where maximum phenomenon can be monitored. In military area, the sensors are used to detect the enemy intrusion.

**Health Care Monitoring:** There are two types of medical applications: (1) Wearable and (2) Implanted. The wearable devices are usually on human body surface or at the close proximity of a user. The medical devices which are inserted in the human body are called as the implantable medical devices. As well there are too many different applications body, for example, person location and

position measurement, an entire ill patients monitoring in the hospitals as well as at homes. The Body-Area Networks may collect the data about individual's energy, fitness, and health expenditure.

**Air Pollution Monitoring:** The WSNs have been organized in the several cities (Brisbane, London and Stockholm) in order to monitor a concentration of the dangerous gases for the citizens. These may take the ad hoc wireless links advantages rather than the wired installations that used to make them extremely mobile for the purpose of testing readings in various areas.

**Forest Fire Detection:** The Sensor Node Networks may be installed in the forest in order to sense when the fire get started. The nodes may be equipped with the sensors in order to measure the gases, humidity and temperature that are created by the fire in vegetations and trees. The timely detection is important for the successful firefighter's action; Now a days, with the use of wireless sensor networks, we are able to know the starting time of fire, and the how it's spreading.

**Landslide Detection:** A system of landslide detection makes the use of Wireless Sensor Network in order to detect the soil movements and changes in the numerous parameters which may occur during or before a landslide. Through gathered data, it may be suitable to know the landslides occurrence long before that it happens actually.

**Water Quality Monitoring:** It includes analyzing of water properties in the oceans & lakes, rivers and dams as well as the underground reserves of water. The utilization of number of wireless (remote) distributed sensors allows the accurate map creation of the status of water status, and permits the permanent monitoring stations deployment in difficult access locations, without the required retrieval of manual data.

**Natural Disaster Prevention:** The WSNs are efficient enough to act in order to prevent consequences of the natural disasters, such as floods. The wireless nodes have been successfully deploying in the rivers where water level changes have to be observed in the real time.

### *1.2 Issues in Wireless Sensor Networks*

There are many challenges and issues in wireless sensor networks. However, the energy issue is the most researched topic in the field of WSNs [8]. The nodes rely on a limited battery life for energy. Batteries are irreplaceable and cannot be recharged and that adds to complication especially in situations when all or some nodes fail in the middle of sensing. Another issue is related to the way the nodes are deployed; if they are deployed randomly,

then the nodes may continuously focus only one part of the region of interest and not having other nodes location information and thereby leading to energy wastage and increased energy consumption.

Due to the limited bandwidth of each node, extended energy is consumed when distance from a node to the base station is large. A reliable solution to the problem is multi-hop communication, but the intermediate nodes behaving as hops in this case have increased energy consumption due to high probability of them getting exhausted earlier than usual. Any of the two discussed issues: random deployment and multi-hop communication, in addition, bring about an uneven energy distribution in the network. The network has to be re-routed or re-organized can be considered as plausible solutions but do not necessarily guarantee success. Another challenge to solve is the environment or the type of network. In a dynamic environment, the nodes regularly change their positions which add to the usual energy consumed, reason being the additional requirement of updating location information regularly.

### *1.3 Optimizing Energy Consumption using Clustering*

One possible solution to the various issues discussed is to aggregate data and transfer the data to the base station via nodes serving as local base stations. These local base stations get the sensed data from each of the nearby nodes, process/aggregate it and transfer the aggregated data to the base station. The local base stations serve as Cluster Heads (CH) when talked in terms of clustering. Inherently, marking of such nodes is similar to finding cluster centers/representatives with exactly one cluster formation in one sub region. Advantages of clustering in WSNs are numerous, some of which are discussed below:

- Load balancing: The overall load is distributed within the cluster heads (processing and communication) and member nodes (sensing).
- Preventing redundant message exchange: Limit is placed on the messages exchanged between individual nodes. Each node directly communicates to its respective CH. This in turn reduces the message and the communication complexity of the network.
- Collision reduction: The limited resources in the network within a large set of nodes communicating with each other may lead to collisions. Reduced communication results in reduced collisions and in return, reduced latency.
- Reduced failure chances: With cluster heads, even in cases when the individual nodes die

between the sensing tasks, the network does not fail since the cluster heads continue the process. Also, the cluster heads are selected repeatedly so as to not overload the initially selected CHs. CHs, as is clear, has more responsibilities to fulfill in the sensing task and therefore require more energy.

The rest of paper is organized as follows: Section 2 presents the literature review of existing work. Section 3 discusses the proposed protocol. Section 4 explains the implementation results. Finally conclusion and future work is presented in the section 5.

## 2. LITERATURE SURVEY

Clustering in Wireless Sensor Networks has found wide acceptance both by researchers and practitioners. The most primitive of clustering algorithms for WSNs that provide energy efficiency and good quality results is the LEACH (Low Energy Adaptive Clustering Hierarchy) protocol by Heinzelman et al [9]. The aim of the protocol is to help organize the nodes in a clustering hierarchy with each cluster having a cluster head or precisely, a local base station. The nodes after sensing and processing phases have to pass the sensed data to these local base stations which then pass the same to the main base station.

The researchers designing and developing clustering protocols since then have a somewhat same methodology as of LEACH: selecting CHs, announcement of CHs, assignment of nodes to these CHs, sensing, processing, transfer of data to BS, reselection of CHs and repeating the process till a specific criterion is met. There are observed certain scopes of improvements in the LEACH protocol which later became the center of researches of many energy aware clustering protocols. The limitations of LEACH were improved up to a great extent in HEED (Hybrid Energy – Efficient Distributed) clustering protocol [10]. The improvements are done in the direction of single hop routing problem, non-consideration of energy for CH election and uneven distribution of CHs in the network. The HEED protocol was further improved by Ding et al. in their proposal Distributed Weight-based Energy-efficient Hierarchical Clustering (DWEHC) Protocol [11]. HEED protocol works on distributing clusters evenly but these clusters have unbalanced energy consumption. Another improvement to the LEACH protocol is proposed by Kim and Byun with D-LEACH [12]. The underlying objective behind their proposal is to not involve all the nodes of the network in the clustering process and leave them in sleep mode till other nodes proceed with their

sensing tasks. This can lead to overall low energy consumption and a maximized network lifetime. Ellatief et al. proposed the EED (Energy Efficient Density-based clustering) [13] protocol. The proposed protocol is based on the concept of density and neighborhood. Neighbors of a node are classified as interior or border. Interior neighbors are the ones with comparatively high density than the node and border neighbors have lower density relatively. Baranidharan and Santhi proposed the DUCF (Distributed load balancing Unequal Clustering in wireless sensor networks using Fuzzy approach) protocol [14]. The authors used a fuzzy approach to balance the energy consumption between the CHs. Hence, unequal cluster formation is done in the proposal. LEACH-C is an improvement of LEACH protocol which uses a combination of central clustering algorithm and LEACH phases together. Another improvement of LEACH algorithm is presented that known as V-LEACH. In this method there is a candidate CH node in each cluster in addition to CH nodes. This node acts like a CH to transmit information to the base station to avoid disconnection for when the CH node dies and no need to selects a new CH. This will increase the network lifetime and the problem of uneven distribution is solved in V-LEACH.

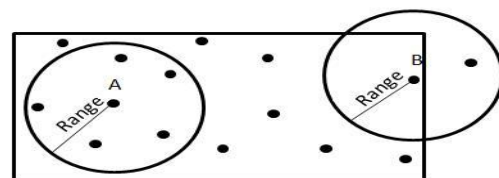


Figure 1: Illustration of interior and exterior nodes

## 3. PROPOSED PROTOCOL

This section describes the proposed protocol for clustering, in which density of nodes is used to decide category of a node. Then some criteria are set for a node to be selected as cluster head.

### 3.1 Interior and Exterior Nodes

A node is categorized as an interior or an exterior node. This categorization is done based on the number of neighbors of each node. By neighbors, we mean the nodes that lie within the transmission range of the sensor nodes. The minimum number of neighbors that make a node as an interior node is 4. The same criterion is used in the dissertation. The nodes that are not interior are the exterior nodes. The concept of interior and exterior neighbors is illustrated in fig. 1. Node A is an interior node because of more than 4 points within the range of the node. Likewise, node B fails to fulfill the

criterion of interior nodes with only one neighbor and is therefore an exterior node.

### 3.2 Cluster Head Selection Criteria

The CHs are selected based on the following criteria.

**Levels of density:** The levels for any node are decided based on the percentage of interior nodes of any node. If all the neighbors to a node are interior or say the percentage is 100%, the node lies in level 1. The nodes in level 1, therefore, lie in the dense region because of all neighbors being interior. Levels 2, 3 and 4 correspond to 75%, 50% and 25% of interior neighbors to a node. The levels indicate the density of nodes.

**Distance of a node from BS:** Distance of a node from the base station should be less than  $2 \times$  transmission range of a node. This means that the messages from the CHs to the BS should reach within 2 hops to have a reduced communication complexity. The importance is therefore given to those nodes that are nearer to the base station through this criterion.

**Frequency of CH selection:** Once the CHs are selected in the initial stage based on the proposed criteria, the residual energy of the CHs is checked. If the residual energy of any CH is less than 15% of the initial energy, then the entire CH selection process is repeated.

- Step 1:** Calculate the number of neighbors for each node.
- Step 2:** For every node, if number of neighbors is less than 4, the node is interior otherwise exterior.
- Step 3:** For every node, calculate the number of interior and exterior neighbors.
- Step 4:** Decide the level of each node
- Step 5:** Select cluster heads depending on level and distance to base station
- Step 6:** Repeat the entire process if for any CH, residual energy is less than 15%.

Figure 2: Proposed Clustering Protocol

### 3.3 Formal Description of Protocol

The entire process can now be understood as a sequence of steps as listed in Fig. 2. At the time of setup, every node discovers its neighboring nodes i.e. nodes which are within its single hop communication range. The neighbor discovery is done using hello packets and received signal strength indicator. The nodes are then classified as interior or exterior depending on the number of neighbors. Accordingly numbers of interior and

exterior neighbors of a node are computed. This is the setup phase and is required to be done only once. The steps 1 and 2 in algorithm of Fig 2 consist of the setup phase. In step 3, whenever a neighboring node is dead, the number of interior or exterior neighbors gets changed. Hence, it is executed whenever a neighbor node is dead. Step 4 decides the level of a node based on the number of its exterior and interior neighbors. The level remains unchanged unless a neighboring node dies. Thus, steps 3 and 4 are not executed at every round, rather only when a neighboring node has died. CHs are elected in Step 5 according to the level and distance from BS. Those nodes, who have not been elected as CH, join their nearest CH as member. The CHs remain fixed until energy of any CH has fallen below a set threshold. We have set threshold as 15% of the initial energy. These nodes can now not be selected as CH in any further round.

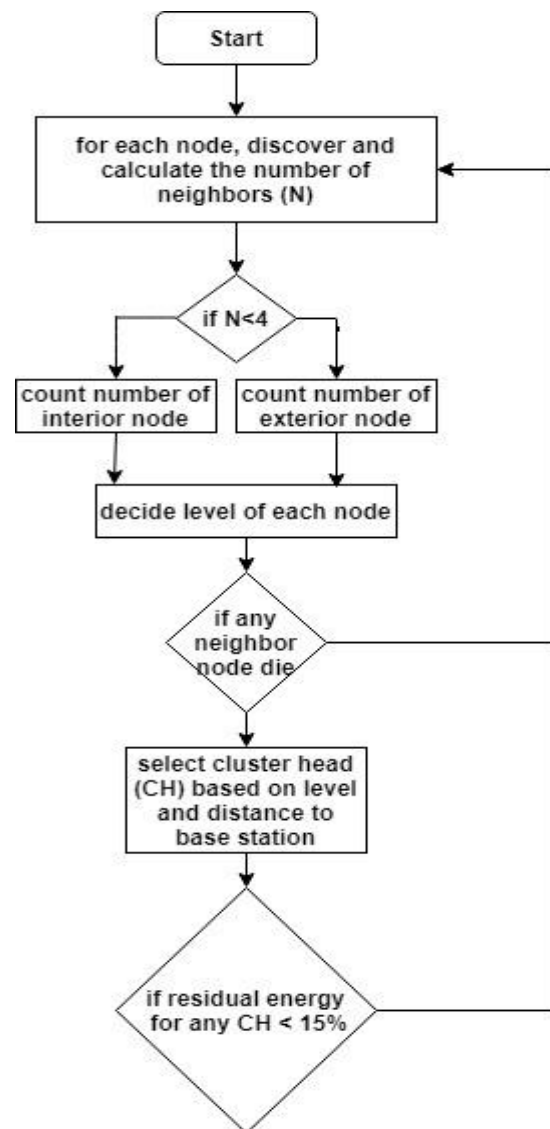


Figure 3: Flow chart of proposed approach

With the progress of the protocol, some nodes might exhaust of energy and hence, do not participate in the network. These nodes should now, therefore, not be considered as neighbors of any node anymore. Thus, the network gets reduced over time and the degree of the node changes.

This indirectly might change the category of a node from interior to exterior. Hence, when the energies are reduced to such levels, entire process should be repeated. Yet, the frequency of execution of any step of the protocol is very less as compared to any previous suggested protocols. This saves the processing energy of nodes. Fig 3 shows the flowchart of proposed approach.

### 3.4 Formal Description of Protocol

The connectivity of the network is maintained only when the crucial nodes which lie in the routing path towards the base station do not die earlier. The proposal uses a seemingly contrasted condition by selecting the nodes closer to BS as CHs and depleting their energy faster. Yet, when the energy of such nodes falls below 15% of initial, they are not selected as CH. This leaves such nodes with sufficient energy to serve routing purposes. Hence, connectivity to the BS is maintained. One more aspect is the density of nodes around a 'crucial' node. If a node is more crucial, it means there are no other nodes around it to route information towards BS. Since this 'crucial' node has very less neighbors, it will never be selected as CH. Hence, its energy will not get reduced soon.

## 4. SIMULATION RESULTS

The experiments on the proposed clustering protocol have been conducted on MATLAB computing platform on an Intel (R) Core (TM) i3-2130 CPU with 64-bit Windows 8.1 Operating System. Version 2007B of MATLAB is used. Table 4.1 shows the values and descriptions of the simulation parameters.

The efficiency of the proposed clustering scheme is tested by comparing it with similar popular clustering algorithms. Implementation of the proposal and the protocols to be tested is done on a popular computing environment. Testing is done by varying the number of nodes and the deployment area and on the basis of certain criteria. Results of the experiments through exact results and visualized outputs give a better understanding of the performance.

The performance of the proposed clustering protocol is tested against the popular LEACH, DEGRA and EED protocols on the basis of the following criteria.

**Table 1 :** Simulation Parameters

Simulation Parameters	Description	Values
Initial node energy	Initial Node Energy	0.5j
Eelec	Energy consumption by node circuits for data transmission	50pJ/bit
EFX	Energy consumption for short distance by amplifier	10 pJ/bit/m <sup>2</sup>
ETrip	Energy consumption by amplifiers for large distances	0.0013pJ/bit/m <sup>4</sup>
EDA	Energy consumption by nodes for aggregating sensed data before transfer to the BS	5nJ/bit/signal
Packet size	Packet size	1000 bytes

- **Total Residual Energy:** This factor corresponds to the amount of energy left in the network at any given instant.

- **Time consumption per round:** It denotes the time (in seconds) consumed by the network per round of the protocol.

- **Network lifetime:** Network lifetime here refers to the number of rounds a protocol takes to execute the sensing task till the node drop count reaches 75%.

The fall or rise in the performance of the protocol is judged by varying the number of nodes and the simulation area on the basis of the above discussed criteria. The first set of results depicts the effect of varying nodes on the protocol and the second set evaluates its performance by varying simulation area.

Based on the observations, it can be clearly concluded that inspite of the increasing nodes and area, the proposed protocol seems to return the best performance as compared to LEACH, DEGRA and EED protocols. The fall in energy is observed to be the slowest in the case of the proposed protocol with rounds. Slowest decrease indirectly corresponds to a maximized lifetime which is clearly visible through the number of rounds the protocol takes to execute. More the number of rounds, more is the lifetime of the network. Also, the time consumption per round is observed to be least in case of the proposal. This leads to faster execution adding to the performance of the protocol. The only difference spotted in the two results is the fact that increasing area leads to lesser number of rounds due to which performance is not perceived that clearly.

## 5. CONCLUSION

In this paper, we have proposed density based clustering protocol for optimizing energy consumption in wireless sensor networks. The proposed criteria for selection are based on density levels and the distance of a node from the base station. The efficiency of the proposed proposal is evaluated and compared with popular clustering algorithms like LEACH, DEGRA and EED. The performance evaluation is done in terms of total residual energy, network lifetime and time consumption per round of the protocols. The experiments analyze the performance by varying the number of nodes and the simulation area of the network. A maximized lifetime with faster execution and slowest decrease in the energy of the network makes the proposed improvement visible and the proposed protocol provides better results than the existing protocols.

In this research work, we have considered the static environment with homogeneous settings and the sensor nodes are distributed autonomously, not specifically in the region of interest. Extension of the proposal can be tested in heterogeneous settings, dynamic environment with nodes placed at specific targets.

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