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Research Article

A Multi-Parameter-Based Clustering Protocol For Heterogeneous Wireless Sensor Networks

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ARTICLE INFO	**ABSTRACT**
	Wireless sensor network can be for the urbanization of the modern civilization. Our all over growth critically depends on the development in of agriculture. Thus, we have deployed the wireless sensor network for smartification of the cultivation. In this work to collect data we have deployed sensors in the field. We have considered a heterogeneous environment where each sensor has varying computational power, storage capacity and residual energy. In such heterogeneous environment to prolong the lifespan of the sensors we have proposed a Clustering algorithm. In our protocol we have considered various parameters of the sensor such as residual power, storage and computational capacity. Considering multiple parameter is shows the novelty of our work. Our deployed system is scalable with hundreds of sensors.
	Keywords: WSN, sensor, cluster, cluster head, energy.

1 Introduction

A wireless sensor network (WSN) is a network made up of numerous sensors with limited resources and a base station that communicates with one another over a wireless communication channel. These sensors self-organize to create a distributed autonomous system that can be applied to many different situations. Due to their enhanced performance, simplicity of use, and low cost, wireless sensor networks (WSNs) have been employed for a variety of applications, including smart homes [1], air purifiers [2], monitoring of fire and disasters [3], environmental monitoring and management [4], medical and health care services [5], positioning and tracking [6], localization, logistic etc.
Sensors are energy efficient constraint, multi-functional wireless device. Sensors are frequently required in industrial applications. To achieve certain application goals, a group of sensors gathers the information from the surroundings. To achieve the best performance, individual sensors are connected to one another. Sensors use transceivers to communicate with one another. The number of sensor nodes in WSN might range from hundreds to thousands.

1.1 Components of Wireless Sensor Network (WSN)

The components of WSN system are sensor node, cluster head, gateway and base station.

Sensor Node:

A node capable of carrying out data processing, data gathering, and communication with other network nodes that are connected with it. An individual sensor node has a 4–8 MHz frequency range, 4 KB of RAM, 128 KB of flash memory, and preferably 916 MHz of radio frequency.

A Sensor Node in a WSN consists of the following fundamental units:

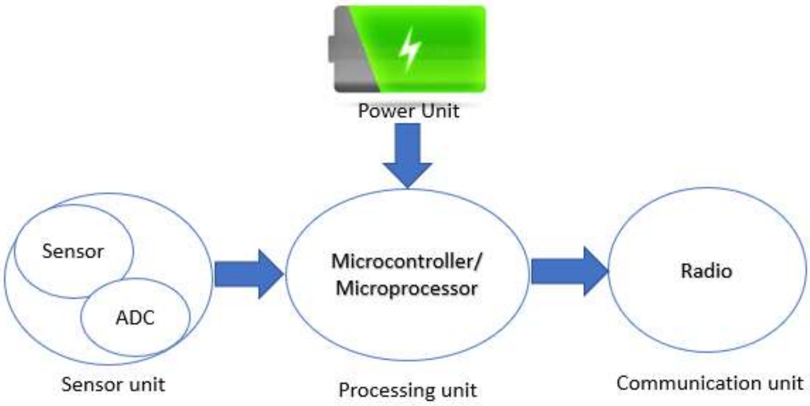


Fig.1: Fundamental Units a Sensor

- **Sensor**: The sensor gathers the analog data like temperature, humidity and pollution percentage from outside environment and the built in Analog to Digital Convertor (ADC) within the sensor converts this data to digital form.
- **Processing Unit:** Each sensor none has a microprocessor or microcontroller serves as the primary processing unit and handles intelligent data processing and manipulation. The computational capacity of each node is limited but sensors are very efficient in real life data collection with collaboration with each other.
- **Power Supply**: Since every component is a low-power gadget, the system is powered by just one tiny battery.

Communication System: A short-range radio is used in the communication system for data transmission and receiving.

Cluster Head:
In some WSN topologies are hierarchical where some node act as cluster head or zone head. As we discussed a WSN may consists of hundred to thousands of sensor nodes, in such scenario to achieve scalability the entire network is divided into smaller cluster. A single node or multiple node play the role of cluster head depending on the applications and system requirements. A distinct cluster head processor is 4–8 MHz, with 512 KB of RAM, 4 MB of flash memory, and operates at 2.4 GHz. All of the sensor network's nodes place a great degree of trust in this node, which is also very secure.

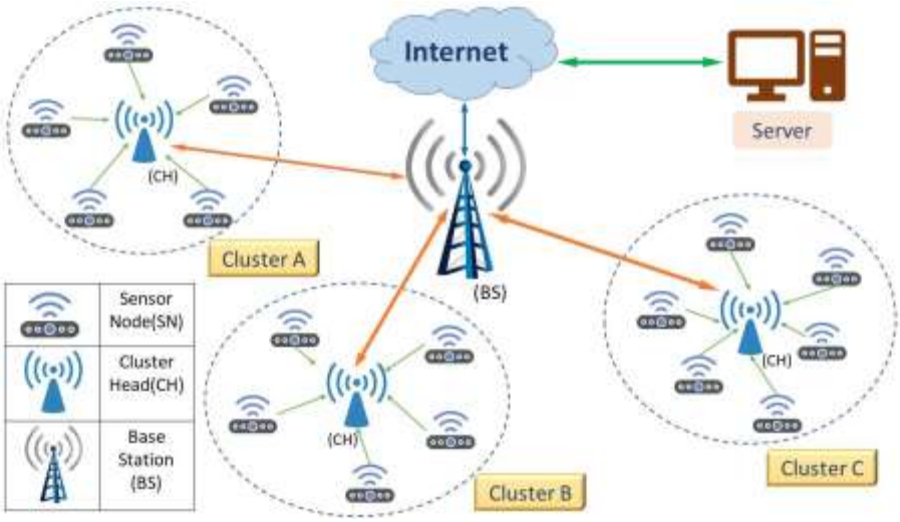
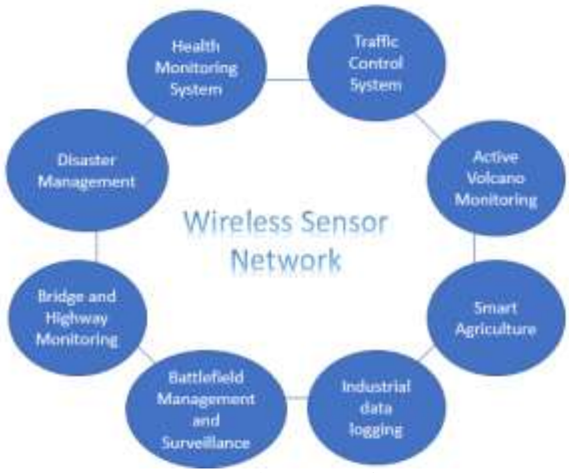


Fig.2: Wireless Sensor Network

Base Station:
The base station is often connected to better energy sources than batteries and has far more processing power and memory. The base station can be viewed as the point of entry into the WSN, and its main objective is to collect sensed data from the WSN's sensor nodes. Base station is also responsible for inter communication between different WSNs. Data visualization and data analysis are also two main objectives of base station.

1.2 Application of Wireless Sensor Network:

WSNs are widely used in a variety of applications as a result of their rapid growth. Some of the applications are



Fig, 2: Application of WSN

- **Health Monitoring System:** Using different types of bio sensors we can continuously monitor the health parameter such as temperature, oxygen saturation point, pulse rate and heart beat of a patient under monitor.
- **Traffic Control System:** WSNs can be used for monitoring traffic signals [7] and for implementation of smart parking sensors are widely used.
- **Active Volcano Monitoring:** A WSN system can proactively measure a number of warning indications before a volcano erupts in order to alert surrounding residents to the eruption.

We have proposed here a data collection scheme from agriculture field through WSN. In this paper, we proposed a clustering protocol to increase the lifespan of the sensors. In section 2 we have done an exclusive literature study in this domain. The system model is discussed in the section 3. Section 4 describes the clustering methodology and all the proposed algorithms are included in section 5. Case study of the research have been shown in section 6. Finally, the paper is concluded in section 7.

Related Work

WSN has become a lucrative area of research now a days because of its wide applicability in the medical domain, environment monitoring and commercial market. In [10-12] WSNs are used for monitor the Environment as well as Alarm-Net [13] and Code-Blue [14] WSN is deployed for medical area. WSNs also play an important role in, smart cities and smart agriculture [15]. For collecting data periodically, a schedule-based data collection technique using WSN [16] has been proposed by the authors. In this paper, authors have presented an innovative schedule-based data collection algorithm with a limited data collection time and high fault tolerance rate. Opportunistic data mules have been used for data collection in [17].

A Wireless Sensor Network (WSN) may consists of hundreds to thousands of resource constraint sensor nodes. These sensors are capacity and energy wise heterogeneous in nature. If we want to collect sensory data from individual sensors, then it will not be a good solution as they have limited energy. So instead of collecting data from all sensors, we can go for a hierarchical solution. The area of interest can be divided into small zones or energy efficient clusters [18]. Each of the cluster is represented by a superior node known as cluster head [19] [20]. The layered architecture of clustering is very much adaptive in WSN because it reduces the energy consumption of all sensors as well as routing overhead.

Clustering methods are subdivided into two groups- Static and Dynamic clustering method. Unlike dynamic clustering algorithms, which produce new clusters periodically with different communication trials, static clustering algorithms only construct clusters once at the initiation of the network and keep the same set of clusters throughout the network's existence. Some of the well-known dynamic clustering algorithms are hybrid unequal clustering with layering (HUCL) protocol [21], unequal cluster-based routing (UCR) protocol [22], scalable energy efficient clustering hierarchy (SEECH) protocol [23], Low-energy adaptive clustering hierarchy (LEACH) [24], energy-efficient clustering strategy in wireless sensor networks (EECS) [25] and topology-controlled adaptive clustering (TCAC) [26]. In contrast, a static clustering algorithm was proposed by the authors in [27].

This research proposes a hierarchical clustering-task scheduling (HCSP) Protocol to minimize the clustering energy cost and increase WSN lifespan. Another clustering approach that exploits wireless communication's inherent overhearing properties to cut down on clustering costs is PEACH [28]. As a result, PEACH uses a completely different approach than HCSP for scheduling the clustering operation. The clustering method in EDIT [29] uses the fewest possible communications that must be transmitted back and forth between sensor nodes.

System Model

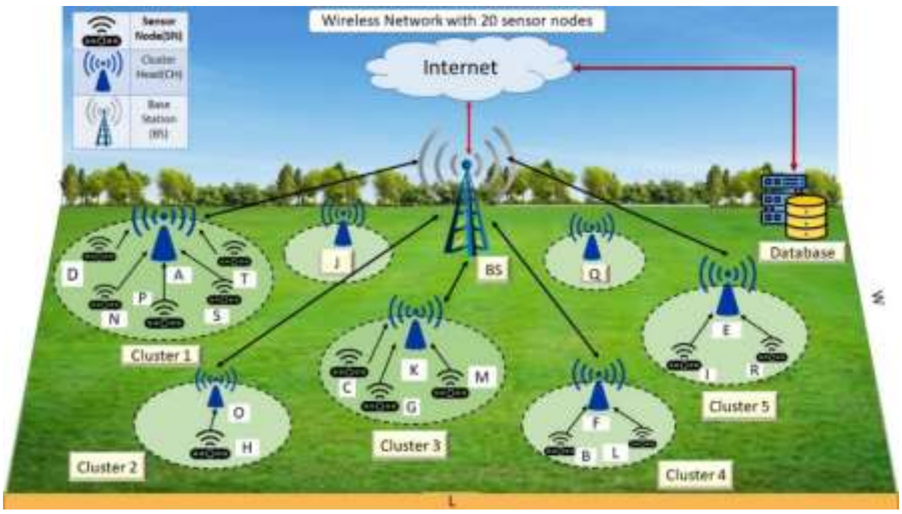
So far, we have discussed about the wide range application of WSN in diverse area such as smart agriculture, health care, military applications, disaster management and many more. The economic development of any civilization extensively depends on agricultural growth of that area. So, migration towards smart agriculture is extremely necessary now a days. That's why, in this proposed work, we have deployed different types of sensors in agriculture field to monitor different environmental parameters such as temperature, moisture of the soil, different chemical components of soil, water level within the field and air permeability etc.

We consider a WSN of N no of sensors deployed in area of length L and width H . Each of the sensor is installed in a unique location denoted by its co-ordinate. A graph
$V = \{V_i | 1 \leq i \leq N\}$ homogeneous sensors are deployed in the region, where each sensor V_i has a unique location, denoted by $(x_{i,} y_i)$. As we could denote each of the sensor by their unique axial points, a graph G is formed considering the Euclidian distance between the sensors.

$G = (V, E| \, e_{ij})$ is an edge between v_i and v_j
The Euclidian distance between each pair of sensors is computed to deploy the overall topology of the network for an instance of time. If Euclidian distance between $v_i v_j$ is less than the transmission range of the sensors then v_i then v_j is inserted in the *neighboring set* of v_i. Thus, the *neighboring set* of each sensor is created individually.
Here we have considered a heterogeneous environment where nodes are capable to sense temperature, moisture and chemical composition of the soil. In such diverse environment, sensors have varying amount of storage, power supply, computational capacity as well as transmission bandwidth. Some sensors are extremely resource constraint though they are capable to sense data but unable to send huge data to the base station. That's why these nodes will send the sensory data to a nearby giant node (with adequate amount of resource). Thus, instead of collecting data we will collect the data from some selective node. And centering those giant nodes the entire network is divided into small groups called cluster.

Clustering Methodology

As the environment is heterogenous with diverse capacity of sensors, all nodes are not able to transmit the data the distant base station. Thus, to improve the lifespan of the sensor clustering is the best solution for such environment. The resource constraint nodes will sense the data from the surroundings and transmit the sensory data to the nearby resource wealthy sensor nominated as cluster head.
To divide the network into clusters we took reference from a schedule-based protocol LEACH [29]. Former work while choosing the cluster head authors have considered the available residual energy in the sensor. But our proposed cluster head selection criteria are not solely depended on residual energy of the sensor. Instead we have considered the available bandwidth as well as store capacity of a sensor along with its residual energy as our environment is heterogeneous in nature.



Fig, 3: System Model

Among all the sensors those have energy, bandwidth and storage capacity more than the threshold value of these parameters become a cluster head. We have considered computational capacity, transmission capacity as well as storage capacity altogether for the selection criteria of the cluster head which is definitely a better solution over our referred protocol.

After selecting all the cluster heads, we divided the entire network into smaller groups, called cluster. Within a cluster all node sensed data from the environment. Then instead of transferring data to the base station forward the data to the cluster head which reduces the bandwidth consumption of a resource constraint node. The cluster head collects data from all the members of that cluster and then transmitted the collected data along with its own sensed data to the base station.

Proposed Algorithm

Our proposed work consists of 3 units- formation of the overall topology then selecting the cluster heads and finally based on the cluster head creation of the clusters. Thus, we have proposed three algorithms. Algorithm 1 depicts the Graph Creation, Algorithm 2 selects some nodes as a cluster head depending upon some criteria and last Algorithm distributed the entire topology into different clusters based on the selection of cluster heads. The following table shows the symbols that we have used in these algorithms-

Table 1. Symbol Table

Symbol	**Description of the symbol**
L	Length of the area of interest
W	Width of the area of interest
t_r	Transmission range of sensors
G	The entire topology
v_i	ith sensor
(x_i, y_i)	x and y coordinate of v_i
CH	Set of Cluster Head
$threshold_{battery}$	Minimum energy requirement of a CH
$threshold_{BW}$	Minimum bandwidth requirement of a CH
$threshold_{Memory}$	Minimum storage requirement of a CH
$battery_i$	Residual Energy of v_i
BWi	Residual Bandwidth of v_i
$avail_{memory_i}$	Residual Storage capacity of v_i
Ed_{ij}	Euclidean distance between two sensors v_i and v_j
e_{ij}	Edge between v_i and v_j
$Neighbr_i$	1 hop Neighbors set of v_i
$Cluster_j$	j^{th} cluster

The first algorithm deals with overall graph creation with N no of sensors.

Algorithm 1: Graph Creation Algorithm

Input: No of Sensors, L, H, $\boldsymbol{t_r}$, $threshold_{battery}$, $threshold_{BW}$, $threshold_{Memory}$ for CH.

for all sensors **do**
Randomly initialize
    Sensor name, Co-ordinate, $battery_i$, BW_i and $avail_{memory_i}$.

// Initialize the Graph topology
for each sensor v_i **do**
    $\forall$ $\boldsymbol{v_j}$ $\boldsymbol{except}$ $\boldsymbol{v_i}$ do
        Calculate $Ed_{ij} = Euclidn\_dis(v_i, v_j)$
            if $Ed_{ij} < t_r$ then do
                include e_{ij} in the Graph G && $Neighbr_i \leftarrow v_j$
    goto next v_j
goto next v_i

After creating the graph, we have selected some of the nodes as a cluster head having energy, bandwidth and storage capacity more than threshold value.

//Cluster Head Selection
$\forall v_i \in G$ do
if $battery_i > threshold_{battery}$&&$BW_i > threshold_{BW}$ &&$avail_{memory_i} > threshold_{memory}$
    then do $CH \leftarrow v_i$

Algorithm 2: Cluster Head Selection Algorithm

The clusters are created by observing the neighbor list of the cluster head.

Algorithm 3: Cluster Formation Algorithm

// Formation of Cluster

  $\forall v_j \in CH$ do
    $\forall v_i \in Neighbr_j$do
        if $v_i \notin any\ cluster$
            $Cluster_j \leftarrow v_i$
    goto next v_i
  goto next v_j

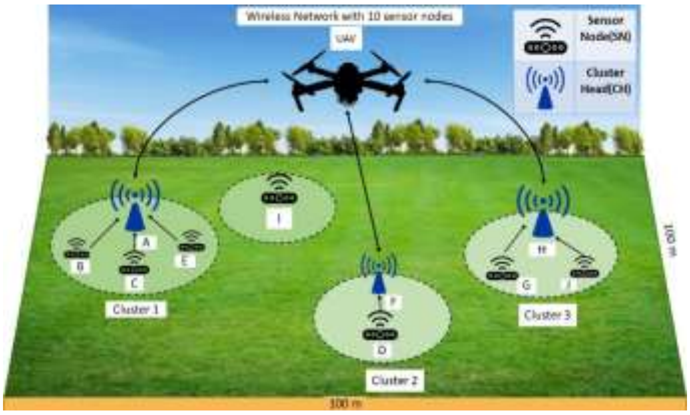
6 Case study

We have simulated the entire environment using c++ code. A bi- directional graph has been plotted with random number of sensors. Our proposed algorithm has been implemented through the code. The overall topology is deployed successfully with more than 100s of sensors through the implementation of Algorithm 1. Then a set *CH* is created that contains only cluster heads by using Algorithm 2. Through implementation of Algorithm 3 clusters are created. We have considered two cases here

Case 1: We have run the simulation with 10 sensors and our program created 4 clusters. The following is the corresponding figure of that execution of the simulation. We have also included the diagram that graphically represent this figure.

```
Enter Number of Sensor: 10
Fomatted Cluster...
A --> [B --> C --> E]
F --> [D]
H --> [G --> J]
I --> []
```

Fig, 4: Instance of Cluster Formation with 10 sensors



Fig, 4: Graphical Representation of Cluster Formation

Case 2: We have run the simulation with 20 sensors and our program created 5 clusters. The following is the corresponding figure of that execution of the simulation. We have not included the graphical representation in this case as the diagram will be crowded with too many sensors.

```
Enter Number of sensor: 20
Formatted Cluster...
A --> [D --> N --> P --> S --> T]
E --> [I --> R]
F --> [B --> L]
J --> []
K --> [C --> G --> M]
O --> [H]
Q --> []
```

Fig, 6: Instance of Cluster Formation with 20 sensors

7 Conclusion

The proposed Clustering protocol out performs among the other algorithm available in the literature because we have considered different parameters while selecting the cluster head. Our system is scalable with more than hundreds of sensors deployed in the monitoring area. While running the simulation with large number of nodes some of the sensors are not included in any of the cluster. Unmanned Arial Vehicles (UAVs) are prominent domain of research now. We include this new technology as an extension of this research by excluding the installation of a permanent base station.

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