A Review of Clustering Algorithms for Indoor Wireless Sensor Networks

Bhavna Pandole
acro.bhavna@gmail.com

Amit Thakur
amitthakurbist@gmail.com

Abstract – Wireless sensor network (WSN) consists of large number of sensor nodes or devices that are distributed spatially and communicates using radio signals. These sensor nodes are usually placed in the geographical area to gather information from the surroundings. Once the sensor nodes are deployed they are typically unapproachable to the humans. Sensor nodes in WSN sense the data from the environment and send it to the base station or sink node where this data is analysed. This paper presents a review on sensor networks on Smart Grids, in conjunction with an appropriate management methodology that allows us to analyze the behaviour of these wireless networks in an indoor environment, within a smart home.

Keywords – Base Station, Cluster Head, Global Positioning System, Indoor Wireless Sensor Networks.

I. INTRODUCTION

The most popular network used today is wireless sensor network (WSN). Wireless sensor network is an emerging technology and is gaining popularity today, as user preferred wireless connectivity over wired connection. WSN consists of large number of autonomous sensor nodes that are responsible for observing the physical or environmental conditions and changes occur in them such as temperature, humidity, sound, pressure, motion, vibration etc. of a target area and send or transmit this data to the base station or sink node where this data can be observed and analyzed.

Usually, the base station has higher computation and communication capability. A base station acts as an interface between sensor network and the users. One can retrieve required information from the network by sending inquiry messages and gathering results from the sink. Typically a wireless sensor network consists of thousands of sensor nodes or devices these sensor nodes are distributed spatially which communicates using radio signals [1]. Sensor nodes are small in size and consume very low energy and are operated in high volumetric densities. The spatial density of sensor nodes in the field may be as high as 20 nodes/ m³. As wireless sensor nodes are typically very small electronic devices, they can only be equipped with a limited power source.

Each node in a wireless sensor network (WSN) is resource constrained: node have limited power, speed of processing, capacity to store data, and communication bandwidth. After their deployment in the target area they are responsible for self-organizing an appropriate network infrastructure. Global Positioning System (GPS) and local positioning algorithms are used to obtain location of the sensor nodes [1].

![Wireless Sensor Network](http://jiseat.com)

Wireless Sensor Network nodes are densely deployed in the target area and the power is provided to them via battery which is the only source of energy for most of the sensor nodes. Sometimes this target area is not reachable by the humans so it is impractical to replace a battery therefore once energy or computational resources are consumed, immediate recovery of these resources is a complex task. This is the reason why a large part of the research in WSN focuses on the development of energy efficient or economical method for WSN [2]. When these sensor nodes transmit gathered data to the sink they consume the energy of a battery. Each time sensor sends or receives data from the base station or from other sensor nodes it consumes some
amount of energy which increases the energy consumption of the network. Therefore energy efficient routing protocol or energy efficient clustering methods are used [3]. Figure 1 shows the sensor nodes deployed in the target area. Each sensor node has certain area of coverage for which it can reliably and accurately report the particular quantity that it is observing or monitoring. Several sources of power consumption in sensor nodes are signal sampling and conversion of physical signals to electrical, signal conditioning and analog-to-digital conversion. There are three categories of sensor nodes:

- **Passive, Omni Directional Sensors:** By active probing passive sensor node senses the environment without manipulating it. The energy is needed only to amplify their analog signals in this case. In measuring the environment there is no perception of “direction”.

- **Passive, Narrow-beam Sensors:** These sensors are passive and while sensing the environment they are concerned about the direction.

- **Active Sensors:** These sensors actively probe the environment.

Since a sensor node has limited sensing and computational capacity, communication performance and power. A large number of sensor nodes and devices are distributed in a target area for collecting information from that area. These nodes can communicate with each other for sending or receiving information directly or via other intermediate nodes so each node in a sensor network acts as a router which routes the data from source to destination inside the network. In direct communication i.e. single-hop, each sensor node communicates directly with sink or Base Station (BS) and sends gathered information. The base station is fixed and located far away from the sensors. Base station or sink can communicate with the end user either directly or through some existing wired network. In direct communication the distance between the sensor nodes and base station is large hence they consume energy quickly.

In another approach which is multi-hop communication, data is sent to the base station using intermediate nodes and thus saves sending node energy. In multi-hop communication intermediate nodes act as a relay node and the nodes having data to send to the base station or sink they first send that data to the relay node in particular time slot controlled by global clock after that relay node aggregates the data coming from the nodes and then transmit that data to the base station or sink node.

II. **INDOOR WIRELESS SENSOR NETWORKS**

The diagram of a wireless sensor network that has access points, which should cover the sensors located within the residence. It also has an intelligent meter, which can act as an actuator to have a bidirectional connection with the companies that are responsible for supplying the electric power service. It refers to the architecture that can be provided by a bidirectional system of intelligent networks, in which energy management systems and data management systems are included.

![Figure 2: Wireless sensor network for indoor infrastructure](image)

Figure 2: Wireless sensor network for indoor infrastructure [4]

Figure 3 shows an Indoor wireless sensor network, that is, a network of household areas, the same ones that allow us to automate homes in an appropriate way, taking into account the comfort of the users. These networks, being made up of different sensors that are sending data in real time, allow us to control many aspects of the electronic devices of homes, and even on some occasions we can get to have a total automation of residential homes [5].

Home automation is closely related to the different wireless networks that have been appearing in recent years, especially with wireless sensor networks. For this type of technology different types of sensors are implemented; among the most important we have those that allow us to control lighting [6]. It should also be emphasized that one of the advantages offered by the new electrical devices, which are designed to adapt to this type of network, is that they can be programmed according to our needs, in order to avoid excessive waste of electricity, that is, they can be configured to start working when the user wants. This could greatly improve the efficiency of households; In addition, it is possible to generate
great savings because these devices consume a large amount of energy and could operate at times when there is low demand. For this reason, the implementation of this type of networks is sought, which besides making our system efficient would provide greater stability to it.

Figure 3: Indoor wireless sensor network for advanced measurement infrastructure [4]

III. CLUSTERING IN WIRELESS SENSOR NETWORK

WSN consist of large number of sensor nodes and they are limited with a battery power so to make efficient use of battery power clustering is a good idea. Clustering is the process of dividing the sensor nodes in WSN to form groups these groups of nodes are called as clusters. Clustering helps in providing scalability and improving life time of network [7]. In each cluster a head or leader node is selected named as cluster head (CH). Cluster head is either selected by the nodes in the cluster or pre-assigned by the network designer. The nodes in the cluster are named as member node. All the member send their sensed data directly to the cluster head which gather all this data coming from the member nodes of the cluster and then send it to the base station or sink node [8]. The key attributes that have to be considered before designing clustering.

- **Number of Clusters:** In some protocols number of clusters is depend on the area and connectivity of the WSN while in some protocols the number of clusters is predefined.

- **Intra-cluster Communication:** Nodes in the cluster or member nodes can communicate directly to the cluster head that is in single hop or by multi-hop communication.

- **Mobility of CH node:** If sensor nodes in the cluster are static than they provide stable structure on the other hand if they are mobile nodes then the topology of the network changes dynamically.

- **Nodes type:** There are two types of nodes homogeneous and heterogeneous.

- **Cluster head selection:** Cluster heads are pre-assigned in heterogeneous network while in cluster heads are selected on the basis of some defined parameters in homogeneous network.

- **Overlapping:** Protocol designed should not overlap the clusters.

The main advantages of using clustering in WSN is that they reduce the energy consumption by reducing the communicating distance because the nodes send data only to their cluster head and also
the amount of data sent to the base station or sink is reduced which also reduce energy consumption [9]. In the process of cluster formation the cluster heads will broadcast request packet to the sensor nodes within its range (or neighbours) to form clusters. In single-hop communication the nodes send their data to the cluster head directly. In multi-hop communication the nodes send their data to neighbouring nodes which then forward the data to cluster heads. Cluster head assigns a time slot to all the member nodes using a TDMA schedule. All member nodes send their data in a particular time slot.

The cluster head transmit the aggregated data directly to the base station or through other cluster heads. The clustering and cluster head selection process can be done by using existing protocol such as LEACH, PEGASIS. The cluster heads can also be selected on the basis of following parameters:

1. Highest residual energy.
2. Maximum number of neighbouring nodes.
3. Smallest distance from the base station or sink.

The cluster heads performs following operations:

1. Create a TDMA schedule through which all the sensor nodes receive a time slot for transmitting their data.
2. Gather all the sensed data coming from the sensor nodes and aggregate the data to remove the redundancy among correlated values.
3. Transmit the aggregated data to the base station or sink directly or to a nearby cluster head.

There are mainly two types of clustering methods. The first one is centralized clustering in which the clusters are formed by a centralized authority and it also select the cluster node from all the sensor nodes. The second method is distributed clustering in which each node run their own algorithm and takes decision of becoming a cluster head. Sometime hybrid method is also used which combines the operation of both centralized and distributed method.

In clustering all the data of the member nodes are first sent to the cluster head so the cluster head will consume more energy as compared to the member nodes of the cluster and due to this reason cluster head will consume energy quickly to overcome this problem the cluster head will be powered with more energy as compared to other nodes or this can also be overcome by distributing the task of cluster head equally among the sensor nodes by selecting each node of the cluster as a cluster head one by one.

As shown in Figure 4 the sensor nodes are grouped together to form clusters each cluster has 6 sensor nodes in it in which one is a head node. All the member nodes send data to their concerned cluster head and all the cluster head send the aggregated data to the base station or sink as shown in Figure 4.

IV. PROPERTIES OF CLUSTER

The properties of cluster are as follows:

- **Cluster Count**: The number of clusters formed in a round is called as cluster count. As the number of cluster increases the size of the cluster decreases which reduces the energy consumption.

- **Cluster Size**: The maximum path length among the non-cluster nodes from cluster head is called as cluster size. Cluster with small size have reduced transmission distance and load of cluster which also improves energy. When cluster are fixed throughout the life time the size of the cluster is also fixed otherwise it is variable for each cluster.

- **Cluster Density**: The number of cluster member nodes in the cluster and cluster area is the density of the cluster. In dense clusters there is big challenge to reduce the energy consumption of cluster heads. Fixed clustering always has sparse density of cluster use, but cluster density is variable in dynamic clustering approaches.

- **Message Count**: The number of message transmission required for cluster head selection is called as message count. For cluster head
selection process more number of message transmission lead to more energy consumption.

- **Stability:** Clustering schemes are said to be adaptive if the members of a cluster are not fixed else it is fixed because the cluster count are not varied throughout the clustering process. The fixed cluster count increases the stability of a sensor network.

- **Inter-cluster Head connectivity:** It indicates the capabilities cluster heads communication to base station. If the range of the cluster head is not enough to reach to base station or sink node then it has to ensure some intermediate provision of routing to base station.

- **Intra-cluster Topology:** Topology indicates the type of communication within the cluster i.e. single-hop or multi-hop. This communication depends on the range of the sensor nodes. This limited range bounded the cluster head count.

### V. Literature Review

N R Wankhade and D N Choudhari, in their paper “Advanced Energy Efficient Routing Protocol for Clustered Wireless Sensor Network: Survey” [10], Due to the characteristics that differentiate sensor network from contemporary communication and wireless Ad-hoc Network the routing in sensor network is a challenging one. To deploy the large number of sensor nodes it is not possible to build a global addressing scheme so the classic IP-based protocols can’t be used for sensor network. Secondly, to a specific sink or destination node the sensor network applications require sensed data flow from many regions or sources which is in contrary to typical communication network. Thirdly, as multiple sensors can generate similar data within near a phenomenon the generated data traffic contains redundancy so to improve energy and bandwidth use routing protocols must use it. Fourthly, sensor nodes need proper resource management because they are highly constrained regarding transmission power, process capacity, on-board energy, and storage.

You-Chiun Wang, Wen-Chih Peng and Yu-Chee Tseng, in their paper “Energy-Balanced Dispatch of Mobile Sensors in a Hybrid Wireless Sensor Network” [11], considered a hybrid wireless sensor network with static and mobile nodes. Monitoring the environment and reporting the events occurring in the targeted area are done by Static sensors. The overall lifespan is maximized because they schedule the mobile sensors traveling paths in an energy balanced way and shows that it has been a NP-complete problem. To schedule mobile sensors traveling paths they proposed a centralized and a distributed heuristics which allows arbitrary number of mobile sensors and event locations in each round having an energy-balanced concept in mind. The centralized heuristic tries to minimize the energy required in moving mobile sensors while keeping their energy consumption balanced.

Gerard Chalhoub and Michel Misson, in their paper “Cluster-tree Based Energy Efficient Protocol for Wireless Sensor Networks” [12], proposed a time segmentation approach which improves the overall network performance, saves energy and enables quality of service in terms of guaranteed access to the medium. By synchronising nodes activity using tree based topology the time segmentation is achieved. Collision free beacon propagation along the cluster-tree is guaranteed by synchronization period. In order to improve the energy efficiency of the network and its performance they propose a data collection period. Finally, to improve further more the network performance and guarantee and end-to-end delay they add relay time intervals between coordinators. With respect to a cluster tree configuration the overall estimated energy consumption is reduced in their results also there is increase of 20% to 40% in the received frames and in most cases the average number of collisions is divided by 2.

Rathna R. and Sivasubramanian A., in their paper “Improving Energy Efficiency in Wireless Sensor Networks through Scheduling and Routing” [13], proposed an environmental monitoring application of wireless sensor network. The more attention is given to the two areas i.e. clustering and routing. Their work is an attempt to reduce the power consumption of the sensor nodes, by concentrating on the radio. The Cluster based sleep/wake-up scheduling method is proves to be efficient after testing in a simulated WSN. For simulation they use Network Simulator (NS2). Shortest Hop path Tree (SPT) and Minimum Spanning Tree (MST) forms the tree structures and by applying clustering techniques to these structures WSN is simulated. In MST the clustering of nodes gives best results. The scheduling algorithm proposed in it is based on TDMA completely. Reducing a number of times a node has to wake up during a time slot to be in active mode helps in reducing energy consumption. Their main purpose is to use energy efficiently.

Mohammad Soleimani, Mohammad Ghasemzadeh and Mehdi Agha Sarram, in their paper “A New Cluster Based routing Protocol for Prolonging...
Network Lifetime in Wireless Sensor Network” [14], presents a routing protocol based on cluster with considering the low energy consumption in wireless sensor network. The energy load among the sensor nodes is balanced by this protocol. The nodes which are close to each other have more overlap and cause a waste of energy by generating repetitive data because they sense the same data from environment. In the proposed protocol, a certain number of nodes are specified in each round; the nodes which have at least one neighbouring node at a distance less than the threshold. Then, to go to sleep mode the nodes with their neighbours have been chosen. Also, by integrating the distance of nodes from the base station the energy imbalance among sensor nodes is reduced. This method increase the lifetime of the network and can prevent wasting of energy.

Sanjay Waware, Nisha Sarwade and Pallavi Gangurde, in their paper “A Review of Power Efficient Hierarchical Routing Protocols in Wireless Sensor Networks” [15], presented some of the major power-efficient hierarchical routing protocols for wireless sensor network. In a hierarchical architecture, to process and send the information the nodes with higher energy can be used while to perform the sensing task in the targeted area the nodes with low energy can be used. The overall system scalability, energy efficiency and lifetime of the network will be improved by creating clusters and assigning special tasks to cluster heads. To decrease the number of transmitted messages to the BS data aggregation and data fusion has been done to reduce the energy consumption within the cluster in hierarchical routing having two layers in which one is used to select the cluster head and other is used for routing.

Sunita Rani and Tarun Gulati, in their paper “An Improved PEGASIS Protocol to Enhance Energy Utilization in Wireless Sensor Network” [16], Wireless sensor network is an ad hoc network. Each sensor has limited energy to monitor the physical or environmental condition such as sound, vibration, temperature at different locations. The wireless sensor nodes are deployed into the network. The protocols play an important role in minimizing the delay while offering high energy efficiency and increase network lifetime. One of such protocol is PEGASIS which is based on the chain structure, each chain have one cluster head. The large amount of energy is consumed by cluster heads and the times of every round increasing. The advantage of PEGASIS is node sends data to its closest neighbor, it increase the lifetime of the network by saving the battery energy for WSN. The proposed work is to select the next neighboring node reliably.

Samia A. Ali and Shreen k. Refaay, in their paper “Chain-Chain Based Routing Protocol” [17], proposed an efficient routing protocol called CCBRP (Chain-Chain based routing protocol). It achieves both reduced energy consumption and reduced delay. Using greedy algorithm the CCBRP protocol divides a WSN into a number of chains and runs in two phases. In the first phase, the data is transmitted to the chain leader in each chain by the sensor nodes in parallel. In the second phase, all chain leader nodes form a chain and data is sent to the leader node chosen randomly by the chain leader nodes than data fusion is performed by the randomly chosen node and after that this fused data is forwarded to the BS or sink node. The delay of the proposed CCBRP is same as LEACH and CCM but 75% less than that of PEGASIS.

Lathies Bhasker, in his paper “Genetically Derived Secure Cluster-based Data Aggregation in Wireless Sensor Networks” [18], proposed a genetically derived secure cluster-based data aggregation in WSN which Initially, based on the node connectivity the CHs were selected, which acts as a data aggregator. Then, using the genetic algorithm the clustering process was executed. A data encryption technique is employed that offers authenticity, confidentiality and integrity when a cluster member wants to transmit the data to aggregator or a cluster head. The proposed technique reduces the energy consumption, ensured data security and reduced the transmission overhead.

Stephanie Lindsey and Cauligi Raghavendra, in their paper “Data Gathering Algorithms in Sensor Networks Using Energy Metrics” [19], presented three new protocols for wireless sensor network. PEGASIS is one of these protocols it is a greedy chain protocol that is near optimal for sensor network having data-gathering problems. By minimizing the distance, eliminating the overhead of dynamic cluster formation, limiting the number of transmissions and receptions among all the nodes and using only single transmission to the BS per round PEGASIS out-performs LEACH. The simulation shows that when 1%, 25%, 50%, and 100% of nodes die for different topologies and network sizes the PEGASIS performs better than LEACH by about 100% to 200%. Compared to LEACH-C, which doesn’t have the cluster formation over-head in each round, the improvements will be slightly lesser. As the size of
the network increases PEGASIS shows an even further improvements.

Ouadoudi Zytone and Driss Aboutajdine, in their paper “A Lifetime Extension Protocol for Data Gathering in Wireless Sensor Networks” [20], presented a new algorithm in WSN for gathering. This is based on chain formation using greedy algorithm. Its primary focus is to distribute the energy load equitably over the whole network nodes. To avoid dying of nodes quickly, the role of leader node is better distributed over nodes based on their energies required to transmit to the sink. Thus, all the network nodes would have the same lifetime and then as result, the lifetime of the network will increase. In the proposed algorithm the transmission energy over the whole network nodes is balanced correctly which increase the network lifetime. The result of simulation shows that as compared to the well-known protocol for chaining in wireless sensor network this technique provides improvement.

Razieh Sheikhpour, Sam Jabbehdari and Ahmad khademzadeh, in their paper “A Cluster-Chain based Routing Protocol for Balancing Energy Consumption in Wireless Sensor Networks” [21], Presents an Energy Efficient Cluster-Chain based Protocol (ECCP) for wireless sensor network that aims at maximizing stability period, network lifetime, and balancing the energy consumption among sensor nodes. Using multiple metrics sensor nodes are organized into cluster in ECCP and within the cluster a chain is constructed among the sensor nodes so they can receive data from previous neighbours and transmits to a next neighbour. In ECCP chain based data transmission mechanism is also used to send data packets to base station from the cluster heads. ECCP offers an advantage of small transmit distance by chaining the nodes in each cluster and by conserving their energy ECCP help them to be operational for longer time period. The result of simulation shows that in term of network lifetime, stability and instability period and balancing the energy consumption among the sensor nodes ECCP is more efficient as compared to CBRP, LEACH and PEGASIS.

Cong Wang and Cuirong Wang, in their paper “A Concentric Data Aggregation Model in Wireless Sensor Network” [22], proposed a concentric data aggregation model. The main purpose of this model is to consider the base station location, and divide the whole WSN into several hierarchical and concentric zones refer to the base station’s location, each zone is also divided into some areas and nodes are organized as PEGASIS in every area. Sensor nodes collects the data which goes through proper areas belong to different level zones towards the base station and in each hop that data is aggregated. The aggregated data is transmitted to the base station by the head on the last area which is the nearest node of the base station. The simulation results shows that in transmission delay and energy efficiency it performs better it also avoids data, gathering latency and reduce energy consumption.

Tumer et al. proposed an EELP (Energy Efficient LEACH Protocol) routing protocol based on LEACH. LEACH (Low Energy Adaptive Clustering Hierarchy) is seminal work in the area of clustering-based protocol, proposed by W.B. Heinzelman. In EELP, all nodes are organized sequentially in the rooms of the apartments of a multi-story building. In this protocol, cluster head (CH) selection is determined as the highest energy by the base station. Simulation results demonstrated that our protocol is more energy-efficient than the LEACH protocol [23].

VI. CONCLUSION

With the technological advancements wireless sensor networks found enormous applications in various fields such as rescue operations, military fields etc. these networks are usually deployed in hostile areas or adverse environmental conditions where human involvement is not possible. Furthermore these sensor nodes are usually operated by battery which is normally not easy to replace. Hence energy efficiency is of prime need in wireless sensor networks. Clustering is the key technique for diminishing energy dissipation in the network and enhancing the network stability. This paper presents theoretical framework of Indoor Wireless Sensor Networks and review of various clustering approaches.

REFERENCE


