A Survey: Heterogeneous Clustering Approach In Wireless Sensor Network

DIVYA Jain[1], Dr. Tasneem Bano Rehmaan[2]
[1] Student of M. Tech, [2]Associate Professor, Computer Science and Engineering (CS department.),
[1,2]Shri Ram Institute of Science and Technology, Jabalpur (R.G.P.V. University Bhopal)

Abstract

In Wireless Sensor Networks (WSNs) energy is one of the most important factors. Maximum utilization of energy of every node is a critical factor. In routing the main purpose is to optimize the network architecture for various applications and maximize the utilization of all resources. The framework and architecture of every wireless sensor networks are different based on the application. This paper presents a survey about the clustering and routing techniques for wireless sensor network (WSN). Various protocols are also comparing, this comparison reveals the important features which are to be kept in mind while designing new protocols for clustering sensor network.

Keywords

WSN, Sensor nodes, Routing, Clustering.

1. Introduction

Wireless Sensor Networks (WSNs) are highly distributed wireless networks of small, lightweight sensor nodes which is deployed in large numbers. Wireless Sensor Networks mainly consist of low power, limited memory and smaller size sensor nodes, used for sensing, processing and communicating the data over the wireless sensor network. Sensor node is made with various components like sensing unit (sensor and ADC), processing unit (processor and storage), power unit, transceiver (antenna), mobilize and location finding system as shown in figure 1.

Sensor node deployment is basically dealing with the connection and organization of various nodes over the sensor field. It deals with physical connectivity of nodes. Topology is basically depends on the deployment of nodes over the network. Deployment of nodes can be in random location or at the specific fixed location. The number of nodes in the network can also be fixed or variable depending upon the application, routing protocol and node properties. There are three kinds of deployment present in WSNs [1].

- **Pre-deployment or deployment phase:** In this deployment phase sensor node can be placed in mass or placed one by one in the sensor network region [1].
- **Post-deployment phase:** When a sensor node is deployed over the network region, it may be changed due to various reasons like low power, data calculation, scalability or failure [1].
- **Redeployment phase:** After the deployment of sensor node in network if some additional nodes are added than sensor node and the network is redeployed or re-arranged. Organizing the network is based on the addition of node, failure of any existing node, routing and application requirement [1].

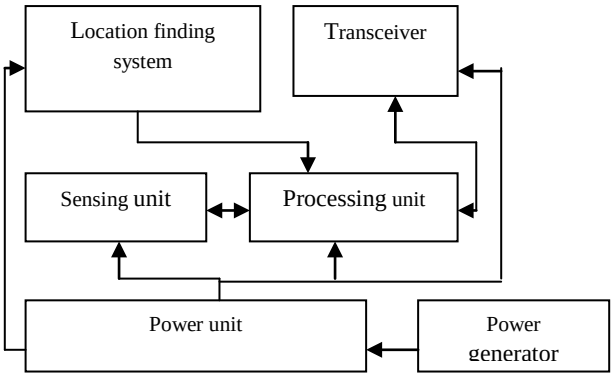

Figure 1: Sensor node components

WSN is classified, based on nodes and application. WSN based on node are further divided into two parts homogeneous nodes and heterogeneous node. WSN based on the application are also classified in two parts reactive and proactive.

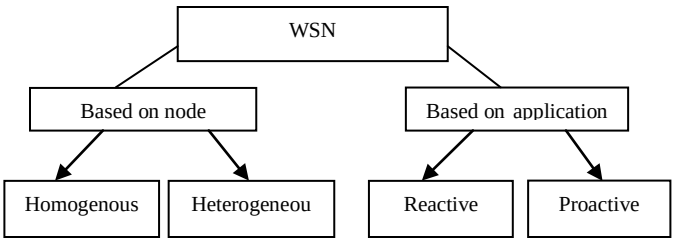

Figure 2:Types of Wireless sensor networks

In homogeneous, all nodes are same in property they have same energy, power, etc. When the wireless sensor network consists of all homogeneous sensor nodes, then some cluster heads, which is far from the sink node die before the other sensor nodes because they are overloaded with data and take a large amount of energy at the time of transmission to the sink node. All cluster heads are directly connected to the sink node in homogeneous network. Whereas, in heterogeneous, all sensor nodes have the different properties such as battery energy, hardware complexity, etc. In this cluster head is selected based on the better battery energy. Cluster head creates the cluster and aggregate the data which is received from the neighbour nodes and transfer to sink node.

In Reactive protocol nodes send data immediately to base station when any drastic change occurs in the network. Reactive protocol is used in those applications where time is critical factor like military field. In Proactive protocol we get the alert at the particular time, so if any activity done, then we not get the alert at the time. It does not transfer data continuously to the base station over the network.

There are various applications of sensor networks, where sensor nodes play an important role for measure changes in the different applications, some applications are Military, Health, Home, Environment, Commercial areas, etc.

1.1. Information flow in wireless sensor networks

The information flow in wireless sensor networks is categorized in three ways.

- One way information flow
- Two way information flow
- Multi-way information flow

In single way, information flow between the source and destination only and no intermediate is used. In two ways, information flow in both directions from cluster node to sink node as well as a sink node to cluster nodes. It is used for communication between source to destination and vice versa. Sink node only sends the control information to cluster nodes. In multi-way, information flow in between the number of sources and there is only one destination. It is mainly used for multimedia data transfer over the network. Multi-way communication require a large amount of resources and energy for data calculation and data transferring.

1.2. Routing Techniques

Routing techniques are based on the network structure and protocol operation. The network structure is classified into three categories: flat, hierarchical, and location based routing. While the protocol operation is classified into following categories: multipath based, query based, negotiation based, QOS based and coherent based. Routing in WSNs has become an important factor due to the intrinsic characteristics that discriminate these networks of other wireless networks. To maintain the sensor node ID is not easy because there are a large number of sensor nodes are deployed, that's why the global addressing scheme for nodes are not possible. To minimize the energy consumption routing techniques proposed well known routing scheme as well as special approach is data aggregation, clustering, data centric method.

A detailed overview of the routing protocol in WSNs [4] shown in figure 3.

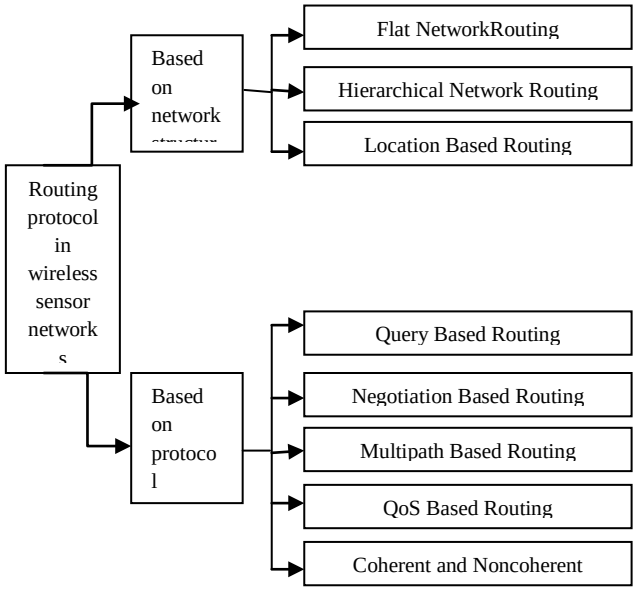

Figure 3:Routing protocols in wireless sensor network

In network structure based protocols, there are three categories listed below.

- Flat network routing
- Hierarchical network routing
- Location based routing

1.2.1. Flat networks routing

This is the multi-hop flat routing protocol. In flat routing protocol each sensor node performs the same task and sensor nodes combine together to perform the sensing task. Each node is not assigned by global identifier because of the large number of nodes. This deliberation has led to the data centric routing, where query sends by the base station to definite regions and waits for data from the sensors located in the selected regions. SPIN and Direct Diffusion protocol are based on this routing protocol which is used for saving energy.

1.2.2. Hierarchical routing

The advantage of hierarchical routing is scalable and efficient communication. The concept of hierarchical routing is also used to perform energy-efficient routing in wireless sensor networks. There are two types of nodes in hierarchical architecture which is advance node and normal node. Advance node has the high energy level in comparison to the normal node energy level. Advance node is used to pass the aggregate data to the BS where normal node is used for sensing the activity and send the data to the advance node. Advance node is known as cluster head. The formation of cluster head improves the scalability, lifetime and energy utilization of the WSNs.

There are two layers in hierarchical routing in which one layer is used to select the cluster heads and another layer is used for routing. There LEACH, PEGASIS, TEEN, Self Organizing Protocol (SOP) are some protocols which falls under the hierarchical routing protocol.

1.2.3. Location based routing protocol

In this protocol sensor nodes are addressed by means of their location. Incoming signal strength estimates the distance between the neighbouring nodes. Some location based schemes demand that if there is no activity done, then the sensor nodes are falling into a sleep state. Geographic adaptive fidelity (GAF), Geographic and energy aware routing (GEAR), SPAN are location based routing protocol.

Routing protocols based on protocol operation: There are some protocols which differ in routing functionality and some protocols are hybrid in nature. There are different category, such as mobility, position awareness, power usage, negotiation based, data aggregation, localization, QoS, state complexity, scalability, multipath and query based on which different routing protocols are fit and in the base of this category, comparison of different routing protocols is done [4].

1.3. **Routing model in wireless sensor network** The existing routing protocol in wireless sensor network uses a different model for data delivery. Following are three routing models used by routing protocols [2].

- One hop model
- Multi-hop model
- Hierarchical/Clustering model

1.3.1. One - hop model

In these networks each and every sensor node transmits directly to the base station. This mode of communication is not only costly in terms of energy consumption, but also it is impractical because each node has restricted or limited transmission and sensing range. Therefore, direct communication is not a feasible model for routing [2].

1.3.2. Multi-hop Model

In Multi –hop model, a node transmits to the base station by redirecting its data to one of its nearest neighbours, which is near to the base station. The latter then passes on its neighbour that is even closer to the base station. The information travels from source to destination through hop by hop from one node to another until it reaches the base station or sink. Considering the energy and the transmission range node restrictions, this multi-hop planar model is a feasible approach. In a network composed of thousands of sensors, this model will exhibit high data dispersion latency due to the long time needed by the node information to arrive to the base station [2].

1.3.3. Clustering-based Hierarchical Model

A hierarchical approach for the network topology splits up the network into a number of areas called clusters. Nodes are assembling depending on some parameter into clusters with a cluster head, which has the province of dispelling the data from the cluster to another cluster head or base stations. The data still hop from one node to another node, because it hops from one layer to another layer, it covers larger distances and moves the data faster to the base station than in the previous multi-hop model [2]. The reaction time in this model is theoretically much less than in the multi-hop model. Clustering brings out built-in optimization potentialities at the cluster heads. This model is more suitable than the one-hop or multi-hop model.

In the clustering-based hierarchical model, all data is aggregated in the cluster and send to cluster head node to a higher-level cluster head, thus travelling larger distances as compare with both models explained and reducing time and latency of data flow in the network. Therefore, the

clustering-based model is more suitable for time-critical applications where the data are used in defining time or at regular interval. Nevertheless, this model has one drawback since as the spent energy is directly proportional to the square of the distance between two clustering levels. If the distance increased than the energy utilization also increased [2]. Due to this the energy utilization is increased. Despite this drawback, this clustering model offering a better approach to routing for wireless sensor networks [2].

2. Clustering in Wireless Sensor Network

In the study of clustering, the WSNs, nodes are heterogeneous which have different properties and different energy level then it becomes necessary to divide the network into smaller units and in each small unit there is a cluster head which is selected by different ways. Where the cluster head communicates with other non-cluster head (normal nodes). The energy or power of the cluster head is more than the other sensor nodes. When the energy of the one node is maximum then the other node, then that node is selected as a cluster head and after that cluster head form the cluster in which sensor node of the small unit is connected to the cluster head. Cluster head is also selected on the basis of distance means when the distance between the node and the base station is less, than the particular node becomes the cluster head [5].

Cluster head collects the data from the other sensor nodes of our region and aggregate all data and then pass to the base station, that time rest nodes are sleepy. In the below subsection 2.1, 2.2 are two types of networks discussed that is homogeneous and heterogeneous network.

2.1. Homogeneous network

A homogeneous sensor network consists of identical nodes that is all the sensor nodes have same hardware complexity, battery energy and sensor range.

In a homogeneous network, it is noticeable that the cluster head nodes will be over-burden with the long range transmissions to the re-mote base station, and the extra processing mandatory for data aggregation and coordination of protocol. As a result the cluster head nodes expire before other nodes. However, it is desirable to ensure that all the nodes run out of their battery at about the same time, so that very little residual energy is exhausted when the whole system expire [11].

Using a homogeneous network and role rotation, all the nodes should have the capability of acting as cluster heads, and all the nodes possess the mandatory hardware capabilities and other characteristics. With the advancement in the wireless sensing networks (WSN) various kinds of application specific routing protocols have been developed [11].

2.2. Heterogeneous network

In Heterogeneous wireless sensor network (heterogeneous WSN) different sensor nodes have different computing power and sensing range and therefore provide more flexibility in deployment. For example, if there are two types of sensor nodes: the high-end ones have higher process throughput and longer communication or sensing range; the low-end ones are much cheaper and with limited computation and communication or sensing abilities. A mixed deployment of these nodes can achieve a balance of performance and cost of wireless sensor network [12]. As compared to homogeneous wireless sensor network, deployment and topology control are also more complex in heterogeneous wireless sensor network.

Deployment of node in heterogeneous WSN has to contemplate the topology control between non-uniform types of sensor nodes. For example, to maintain a symmetric communication, the communication distance between high-end nodes and low-end sensor nodes cannot be larger than the maximum communication range of the low-end sensor nodes [12]. Also, if the sensor nodes have different detection and communication range, the coverage area of low-end nodes cannot be fully covered by the high-end node [12].

In a Heterogeneous sensor network, two or more different types of nodes are having different battery energy, range and functionality for various purposes. The motivation being that the more efficient hardware, long range of communication and the extra battery energy can be inserted in few cluster head nodes, thereby reducing the hardware price of the rest of the network. However, fixing the cluster head nodes means that role rotation is no longer possible. When the other sensor nodes use single hopping to reach the clustering head, the nodes that are far away from the cluster heads always utilized more energy than the nodes that are nearer to the cluster heads. On the other hand, when nodes use multi-hopping to reach the cluster head, the nodes that are nearest to the cluster head has the highest energy load due to relaying. Consequently, there always exists a non-uniform energy drainage pattern in the entire network [13].

In Heterogeneous sensor network architecture, there are two types of sensors used first one is line-powered sensors which have no energy restriction, and the other one is battery-powered sensors having a restricted lifetime of energy [13]. With the help of heterogeneity in wireless sensor networks the network lifetime can be extended.

Heterogeneity in wireless sensor network is classified into three categories computational heterogeneity, link heterogeneity and energy heterogeneity [6].

In computational heterogeneity the lifetime of heterogeneous nodes is more in WSNs than the normal node. Heterogeneous nodes consist of powerful microprocessor and more energy. Long term storage and processing of complex data are provided by heterogeneous node.

In link heterogeneity, the heterogeneous node has the two property bandwidth is high and far distance network transceiver. While the normal nodes do not consist in this property. Data transmission is more reliable in link heterogeneity. In energy heterogeneity, replacement of the battery is possible. It consumes less energy [6].

3. Related work

There are many algorithms designed to select the cluster head in ad-hoc network and wireless sensor network. Selection of cluster head is based on some criteria such as highest degree, lowest-id, highest-id, node weight, residual energy and probability. Clustering technique can also be classified based on cluster size, namely single hop and multi-hop. In the following subsection 3.1, 3.2, 3.3, 3.4, 3.5 are various protocols which are proposed for the cluster head selection. In the subsection clustering algorithm for the heterogeneous model has been discussed.

3.1. HEED: Hybrid Energy-Efficient Distributed clustering protocol

A distributed, energy efficient clustering approach for ad-hoc sensor networks is presented in this protocol. In HEED protocol a cluster head is selected on the basis of the combination of the residual energy and nodes join the cluster. In this quasi-stationary networks are assuming where nodes location is unaware and have equal significance. It exploits the availability of multiple transmission power levels at sensor nodes. HEED is effective in increasing the network lifetime and supporting scalable data aggregation. There are four primary objectives in HEED, increase network lifetime by distribution of energy consumption, to end the process of clustering within a constant number of iterations, minimizing control overhead and generate cluster heads [7].

3.2. PEGASIS: Power Efficient Gathering in Sensor Information System-

It is the improvement of LEACH. PEGASIS protocol is based on the optimal chain based protocol. When a node is dying, then the chain is reconstructed. The basic idea of this protocol is that in order to increase the lifetime of the network, nodes needs only communicate with their closest neighbours and they are communicating with the base station. PEGASIS all nodes maintain a complete database about the location of all other nodes in the network. In this energy load is distributed to nodes to increase the lifetime and network quality [8].

3.3. DBCHSA: Distance Based Cluster Head Selection Algorithm for wireless sensor network

There are many algorithms developed for the cluster head selection, this is the one where on the basis of distance, selection of cluster head is done. This algorithm improves the lifetime of the sensor network. Distance based method is used for the selection of cluster head. Data aggregation and balancing of load is provided by clustering technique. The algorithm for the selection of cluster head is as follows:

i) Placing sensor nodes

ii) Process of clustering

iii) Selection of cluster head

iv) Rest of the nodes select as their neighbours

v) Sensing information from the rest of the nodes and send to corresponding cluster head and information transferred to the base station.

The aim of this technique is to increase the lifetime of the network and increase the nodes in a sensor network, which will alive for the maximum time period [5].

3.4. EACP: Energy aware clustering protocol for heterogeneous wireless sensor networks

In this paper they proposed an energy aware clustering protocol for heterogeneous WSNs. In this protocol two types of nodes are used normal node and advanced node. Cluster head selection is done on the basis of the average energy and residual energy of the normal nodes. With the help of simulation, it has been found that EACP extends the network life, throughput and stable region of the WSNs. This protocol is used to maximize the lifetime of the network. A novel technique is used for the cluster head selection and the concept of gateway is used for cluster head to transfer the aggregated data to the base station. A sleep state is also introducing for some sensor nodes to save energy. It is two level heterogeneous networks. System energy is increased with heterogeneous nodes [9].

3.5. NTCT: A Novel Trajectory Clustering technique for selecting cluster heads in WSNs

In Novel Trajectory clustering technique, cluster head is selected in WSNs. Cluster head is selected on the basis of the traffic and rotates periodically. They provide the first trajectory based technique of clustering to select the cluster heads."Trajectory" means the path which is followed by the sensor nodes to transfer data to the base station. They proposed the novel trajectory clustering algorithm for clustering such paths and obtained representative trajectory is used to assign the cluster heads. In the Trajectory clustering algorithm, sensor nodes are able to reduce packets of data by data aggregation. In this technique the concentration on cluster head rotation among all sensor nodes to improve the lifetime of the network which is based on traffic density [10].

4. Comparison of clustering algorithms for heterogeneous wireless sensor network

With recent advancements in the routing of wireless sensor network it is observed that network is by heterogeneous nature. It is of prior importance to consider the heterogeneity of the network so to have high energy conservation and network lifetime in wireless sensor network. As discussed in the related work there are many heterogeneous approaches for wireless sensor network. The performance of these algorithms has been observed on following performance parameter:

- Stability period-The time limit for which sensor network remains constant.
- Network lifetime- It is the time amount that a wireless sensor network would be fully operational.
- Scalability- It is the ability of the network to handle a growing amount of work in a capable manner.
- Throughput- It is the total rate of data sent over the network.
- Energy efficiency- It is a way of managing and restraining the growth in energy consumption.

Parameters of protocols are classified into different grades: (50%-60%) Better, (60%-70%) Good, (70%-80%) Very good, (80%-90%) Best and (90%-100%) Excellent.

Figure 4:Table of comparison of protocols

Protocols	Stability period	Lifetime Network	Scalability	Throughput	Energy efficiency
PEGASIS	V. Good	Good	Good	Good	V. Good
HEED	V. Good	V. Good	Good	Good	V. Good
DBCHSA	Better	Better	Better	Better	Better
EACP	Better	Better	Good	Good	Better
NTCT	Good	Good	Better	Better	Good

5. Conclusion and future scope

The main aim of heterogeneous approach is to consider the heterogeneity of wireless sensor network nodes with varying battery power. As now a days there are multivendor nodes deployed and it become difficult to have a homogeneous nature of the network. The common objective of these approaches is to have low battery consumption and high network lifetime. Various heterogeneous clustering approaches have been studied on parameter like stability, network lifetime, scalability, throughput and energy efficiency. It has been observed that these heterogeneous clustering approaches have good performance, but can even outperform with respect to throughput, scalability and network lifetime. In future a novel approach can be proposed to have a secure and fault prove heterogeneous clustering approach with high scalability, throughput and network lifetime.

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