Scientific Journal Impact Factor (SJIF): 1.711
International Journal of Modern Trends in Engineering and Research
ISSN (ONLINE) : 2349 - 9745
ISSN (PRINT) : 2393 - 8161

A Survey on Cluster Based Routing Protocols in Wireless Sensor Networks

Asia Sultana[1], Sayyada Hajera Begum[2]
[1]*Information Technology Department, MJCET*
[2]*Information Technology Department, MJCET*

Abstract - Wireless sensor network (WSN) consists of a large number of tiny, cheap, resource-constrained, smart devices called sensors that can be deployed inside or near a physical area that is to be observed. They are networked through wireless links and the Internet, and provide unprecedented opportunities for a variety of military and civilian applications like environmental monitoring, battle field surveillance, and industry process control. The performance of WSN depends mainly on the routing protocol. Routing protocols are broadly categorized as - Data centric or negotiation based protocols, Hierarchical or Cluster based protocols and Location based protocols. The most important challenge in WSN is energy conservation and one of the most popular methods of making WSN energy-efficient is clustering. Clustering routing protocols in WSNs have a number of advantages such as better scalability, efficient consumption of energy and increased lifetime. In this paper, we first discuss the system architecture of the WSN, design and routing challenges of WSN, classification of routing protocols, Clustering concepts and then the Clustering routing protocols. We survey different clustering routing protocols, highlighting their objectives, advantages and disadvantages. Finally, we compare, and conclude the paper.

Keywords - Wireless sensor networks, Clustering, Cluster Head, Scalability, Routing protocol

I. INTRODUCTION

WSN is a collection of huge number of tiny, smart, untethered, low cost, low power electronic devices called sensors which have the ability of sensing information, performing computations, self-organizing and communicating the sensed/processed information to the other nodes or to the sink/ base station. WSNs are suitable for various applications such as calamity (earthquake, tsunami) management ,controlling offices and homes, ships and aircraft safety ,military target tracking and surveillance , security surveillance, environment monitoring (temperature, pressure, light, humidity), traffic surveillance, inventory tracking ,habitat monitoring, health monitoring, highway monitoring etc. The sensor nodes have limited resources e.g., limited battery power, limited memory, restricted processing ability, limited bandwidth. The major concern of the sensor network is to increase the lifetime of the network by reducing /optimizing energy consumption of the sensor nodes. Power efficiency in WSNs is usually accomplished in three ways:

1. Low-duty-cycle operation.
2. Local/in-network processing to reduce data volume and hence transmission time
3. Multihop networking

WSNs are analogous to MANETs in some ways (ex: multi-hop communication) but are dissimilar in several ways:

1. WSNs are based on multicast or broadcast communication, whereas most MANETs depend on point-to-point communication.
2. In most cases, the sensors are not mobile but in MANETs nodes are mobile.
3. Energy is a major limitation in WSNs and hence it has to be consumed very efficiently; but this is not the case in MANETs, where the interconnecting devices can be changed or recharged

frequently. The sensor nodes may be left unattended for lot of time which infers that energy resources have to be utilized very carefully, which in turn, prevents high-data-rate transmission

4. The number of sensor nodes in a WSN can be numerous than the number of nodes in a MANET. Hence the routing protocols which have been proposed for MANETs are not appropriate for WSNs, and hence several alternatives have been suggested.

A. Issues of Sensor Nodes

Sensors	Size : Small, medium ,large Mobility : Stationary, mobile Type: Passive or active
Operating environment	Monitoring requirement :distributed or localized Coverage : Dense, sparse Deployment : Fixed and planned or adhoc Composition : Homogeneous or heterogeneous Nature : Cooperative or non-cooperative
Communication	Networking : Wired or wireless Bandwidth : High or low
Processing architecture	Centralized, distributed , in-network or hybrid

II. WIRELESS SENSOR NETWORK ARCHITECTURE

WSN consists of hundreds and thousands of wireless sensor nodes which collect the information from their surrounding environment and send their sensed data to base station or sink node. The figure 1 shows a typical sensor node which consists of the four components: sensor unit, central processing unit (CPU), power unit, and communication unit [1]. The sensor unit consists of sensor and ADC (Analog to Digital Converter) and is responsible for collecting information as the ADC requests, and returning the analog data it sensed. ADC is a translator that tells the CPU what the sensor unit has sensed, and also informs the sensor unit what to do. Communication unit transmits the data from CPU to the outside world and is the most complex unit. It interprets the command from ADC, monitors and controls power if necessary, processes received data, computes the next hop to the sink, etc. Power unit supplies power to sensor unit, processing unit and communication unit. Each node may also consist of the two optional components namely Location finding system and Mobilizer. If the user requires the knowledge of location with high accuracy then the node should pass it to Location finding system and Mobilizer may be needed to move sensor nodes when it is required to carry out the assigned tasks.

The ideal wireless sensor network is scalable, fault tolerant, consume very little power, smart and software programmable, efficient, capable of fast data acquisition, reliable and accurate over long term.

Volume 02, Issue 08, [August– 2015] ISSN (Online):2349–9745 ; ISSN (Print):2393-8161

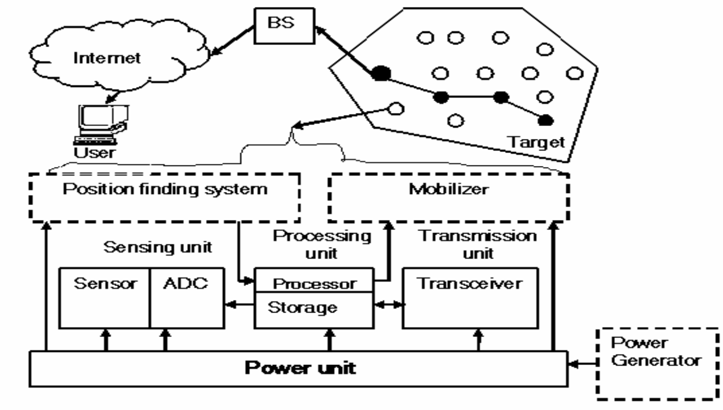

Fig 1 WSN Architecture [3]

A. Design Challenges of WSN

1. Limited resources
2. Adhoc deployment
3. Unattended operation and self-configurability
4. Dynamic topology and adaptability
5. Scalability
6. Node size
7. Node costs and its distribution
8. Environmental factors
9. Transmission channel factors
10. Data traffic models
11. Application-dependent quality of service requirements.
12. Untethered
13. Reliability [4,5,7]

B. Routing Challenges in WSN

Routing is finding a path or route from source to a destination. Routing protocols in WSN are required to reduce energy consumption, and increase lifetime of the sensor network. Hence, it is essential that the routing protocol be designed to transmit sensed data efficiently, reliably and with optimal utilization of energy. Routing in WSN is challenging due to some reasons: One reason is that the resources are restricted, and hence vigilant resource utilization is required. Secondly, since data gathered by many sensors relies on a common phenomenon, there is a possibility that they may generate redundant data. Redundancy needs to be addressed by the routing protocols to ensure efficient energy utilization. Thirdly, global IP addressing mechanism is not applicable to WSN due to large number of sensor nodes involved (which may increase the overhead of ID maintenance). Fourth, sensor networks are application specific i.e., design requirements of a sensor network change with application [7]. Fifth, the network may have homogeneous or heterogeneous nodes, stationary or mobile, manually or randomly deployed nodes. Different issues of sensor nodes and design challenges of WSN also needs to be addressed by the routing protocols. Because of these challenges, many novel algorithms have been suggested for routing data in sensor networks.

III. CLASSIFICATION OF ROUTING PROTOCOLS IN WSN

The routing protocols can be subdivided into two broad categories, network architecture based routing protocols and operation based routing protocols [6].

Network Architecture based routing protocol classification:
Protocols are divided according to the structure of network. These protocols are:
- Flat-based routing
- Hierarchical-based routing
- Location-based routing

Operation Based Routing Protocol classification:
WSNs applications are categorized according to their functionalities. Protocols classified according to their operations are:
- Multipath routing protocols
- Query based routing
- Negotiation based routing
- QoS based routing
- Coherent routing [12]

A. Clustering Preliminaries

Clustering
In hierarchical or cluster based routing, sensor nodes are grouped into clusters and every cluster has a leader known as the Cluster head (CH). A CH may be elected by the sensors in a cluster or pre-assigned by the network designer. A CH may also be just one of the sensors or a node that is richer in resources [11]. The sensor nodes or regular nodes sense the field, generate the data, and send them to their associated CH. The CHs receive these data and after performing some processes like aggregation/fusion, transmit it to the BS [10].

Advantages and Objectives of Clustering
Clustering routing protocols in WSNs have a number of advantages when compared to flat routing protocols such as better scalability, efficient consumption of energy, increased lifetime, less load, and more robustness. In this section, advantages as well as the objectives of WSN clustering are summarized:

More Scalability: As the number of nodes and the size of the network increases, cluster based network architecture is an efficient approach of managing scalability. Clustering topology can localize the route set up within the cluster and thus reduce the size of the routing table stored at the individual node [8].

Data Aggregation/Fusion: Data aggregation/fusion is the process of accumulating the data from multiple sensor nodes and providing the fused data to the BS. It is an efficient means of eliminating redundant transmission and consequently saves energy utilization

Less Energy Consumption: Data aggregation process reduces transmission data and saves energy. In addition, only CHs perform the task of data transmission in clustering routing scheme, which can save a great deal of energy consumption [9].

More Robustness: Clustering routing scheme is robust to network topology changes which can be due to node mobility, node failures, addition of new nodes, etc. within individual clusters and thus the entire network becomes easily manageable.

Load Balancing: Load balancing needs to be considered for increasing the lifetime of WSN network. In general, constructing equal-sized clusters is adopted for prolonging the network lifetime since it prevents the premature energy exhaustion of CHs. Besides, multi-path routing is a method to achieve load balancing. [9]

Fault-Tolerance: WSNs usually operate in harsh, unattended, untethered environment and hence may suffer from hardware malfunction, physical damage, energy depletion and so on. WSNs have to be fault-tolerant to ensure there is no loss of significant data. Rotation of CH, re-clustering and CH backup are different schemes employed for making sensor network fault tolerant.

Maximization of the Network Lifetime: Since sensor nodes are resource-constrained, efficient utilization of resources is needed to increase the lifetime of the sensor network. Motes that are near to most of the sensor nodes in the clusters should be selected as CHs. Additionally, the aim of energy-aware idea is to select those routes that are expected to prolong the network lifetime in inter-cluster communications, and the routes composed of nodes with higher energy resources should be preferred. [9]

B. Characteristics of Clustering

The clustering protocols of WSNs have been compared based on some Clustering characteristics – Cluster properties and Cluster-Head properties. Taxonomy of Clustering characteristics is specified in Fig. 2

Cluster Properties

The number of Clusters: The number of formed clusters can be either constant (preset) or variable [10]. When CHs are preset, the number of clusters is fixed and if CHs are selected randomly from among the sensor nodes or if the selection is based on some rules then the number of clusters are variable.

Cluster Sizes: The size of each cluster may be same or may be different. Clustering with different cluster sizes can achieve more uniform energy consumption.

Intra-Cluster Communication: Communication between the CH and the sensor nodes can be either by single hop or multi-hop .When the size of the cluster is large, the number of CHs is small, and when the sensor's communication range is restricted, then multi-hop communication may be required.

Inter-cluster communication: Some applications of WSN assume that the communication between CH and the BS is direct (usually in small scale networks and traditional approaches), [10] otherwise multi-hop.

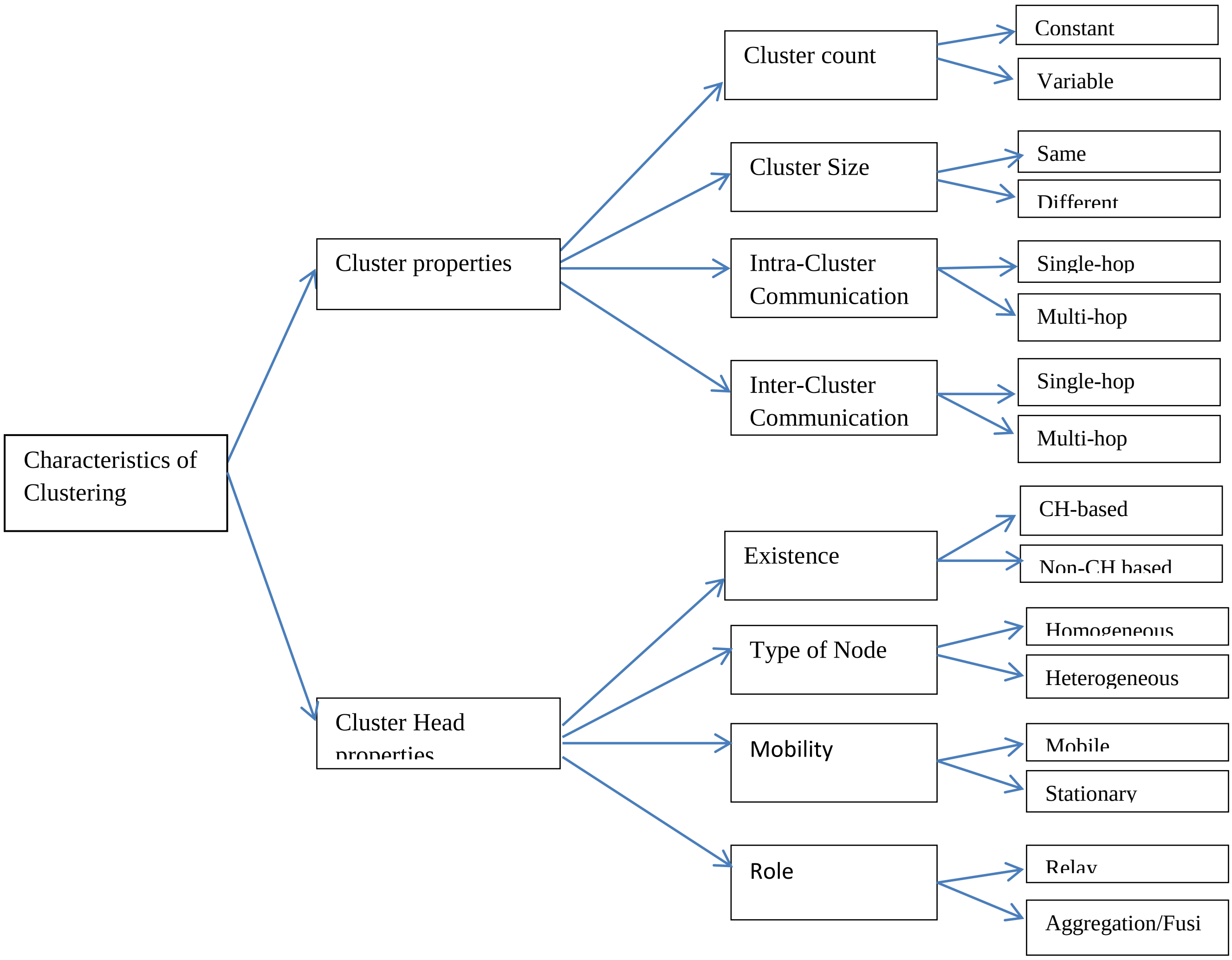

Fig.2 Taxonomy of clustering characteristics

Cluster Head Properties

Existence: A cluster may have at least one CH within it or may not have any CH (chain-based clustering algorithms)

Type of node: The sensor network can be homogeneous or heterogeneous. In homogeneous network, all the sensor nodes have same capabilities and resources .CHs, in such networks are selected either randomly or based on some criteria. In heterogeneous network, all the sensor nodes have different capabilities and resources. In such networks, nodes which are superior in resources and capabilities are selected as CH

Mobility: The CHs can be either stationary or mobile [10] .If a CH is mobile, then clusters don't remain stable and need to be maintained constantly (overhead). If CHs are stationary, then clusters remain stable and are easy to manage. Sometimes, CHs can travel for limited distances to reposition itself for better network performance [11].

Role: A CH can simply act as a relay for the traffic generated by the sensor nodes in its cluster or perform aggregation/fusion of collected information from sensor nodes in its cluster. Sometime, a cluster head acts as a sink/BS that takes actions based on the detected phenomena or targets [11].

IV. CLUSTERING PROTOCOLS

A. LEACH - Low-Energy Adaptive Clustering Hierarchy

It is a most popular cluster-based routing protocol designed to collect and deliver data to the data sink, typically a base station. The main objectives of LEACH are:

1. Network lifetime Extension
2. Reduction in energy consumption by each network sensor node
3. Data aggregation to reduce the number of communication messages

LEACH organizes the network into a set of clusters and each cluster is managed by a selected cluster head, CH. The operation of LEACH is organized into two distinct phases. The first phase is the setup phase, which consists of two steps, formation of clusters, and CH selection. The second phase is the steady-state phase. In this phase, sensor nodes sense and transmit the data to the CH, which in turn aggregates it (to remove redundancy) and then transmits it to the base station over a single hop. TDMA/CDMA MAC is used to reduce inter-cluster and intra-cluster collisions [12].

At the beginning of the setup phase, a round of CH selection begins. The role of CH is rotated among sensor nodes, to distribute consumption of energy evenly across all network nodes.

To become a CH, a node, n, generates a random value, v, between 0 and 1.It then compares ‘v’ to the CH selection threshold, T(n) and if it is less than T(n), then the node becomes the CH.The CH selection threshold ensures with high probability that a predetermined fraction of nodes, P, is selected as CH’s at each round and also that nodes which served in the last 1/P rounds are not selected in the current round.

The threshold T(n) of a competing node n can be expressed as follows:

$$T(n) = 0 \qquad \text{if } n \notin G$$
$$= P / 1- P(r \bmod (1/P)) \qquad \text{if } n \in G$$

The preset parameter, P, represents the CH probability. The variable G denotes the set of nodes that have not been selected to become CH’s in the last 1/P rounds, and r denotes the current round. After the selection of the CH, every CH advertises itself to the rest of the nodes in the network. On receiving the CH advertisements, the remaining or the non-cluster head nodes selects a cluster to join based on strength of the received signal. The nodes then acknowledge their respective CH’s of their interest in joining their cluster. After clusters are formed, each CH creates and broadcasts the TDMA schedule, which specifies the time slot each node of the cluster is allocated for transmitting the sensed data. Each CH also chooses a CDMA code, which is also circulated among all members of the cluster to reduce inter-cluster interference. During the steady phase, sensor nodes gather information periodically and use their allocated slots to transmit the data collected to the CH.

Advantages of LEACH:

1. The rotation of CH’s among the sensor nodes achieves balanced energy consumption
2. Use of CDMA code/TDMA schedule prevents collisions

3. Sensor nodes can open/close communication interfaces based on their assigned time slots and thereby reduce energy consumption
4. CH can reach the base station in a single hop
5. Data aggregation by the cluster reduces the number of transmitted messages and hence reduces consumption of energy as nodes need not send their information directly to the base station.
6. LEACH is based on a distributed algorithm and requires no control information from the base station. The cluster management is done locally, which eliminates the need for global network knowledge.

Drawbacks of LEACH:

1. LEACH allows single-hop inter and intra cluster routing where each node can communicate or transmit directly to the CH and then to the base station. Long-range communication between CH and the base station can lead to excessive energy consumption. Hence, it is not a practical approach and also not suitable to networks deployed in large regions.
2. The dynamic clustering concept (rotation of CH, advertisements) of the algorithm is an overhead which may increase the energy consumption of the nodes.
3. Since the selection of CH is done randomly, it is possible that a low energy node gets selected as CH and number of CH's may become intense in a particular area.
4. The protocol assumes that all nodes begin with the same amount of energy capacity in each election round, assuming that being a CH consumes approximately the same amount of energy for each node [12].

B. PEGASIS – Power-Efficient Gathering in Sensor Information Systems

PEGASIS is an enhancement of LEACH protocol. The main objectives of PEGASIS are:

1. First, the protocol targets at extending the network lifetime by ensuring high level of energy efficiency and uniform energy consumption across all network nodes.
2. Second, the protocol attempts to decrease the delay that data experience on their way to the base station.

In this protocol, the sensor nodes are supposed to have global knowledge about other sensors' positions. Furthermore, they have the capability to control their power to cover arbitrary ranges. The nodes' responsibility is to gather and deliver data to a sink. Contrary to other protocols, which depend on cluster-based hierarchical organization of the network for data gathering and dissemination, PEGASIS uses a chain structure. Based on the chain structure, nodes communicate with their closest neighbors and also each node gets a chance to be the chain leader for transmission of aggregated data to the sink. The chain is constructed with the farthest node from the base station. Network nodes are added to the chain gradually, starting from the closest neighbor to the end node in a greedy fashion. To find out the closest neighbor, a node utilizes the signal strength to measure the distance to all its adjacent nodes and then adjusts the signal strength so that only the closest node can be heard. Nodes take turns in transmitting aggregated data to the sink, and node number i mod N (N denotes the number of nodes) transmits to the sink in round i. A node within the chain is selected to be the chain leader and it is the responsibility of the chain leader to transmit the aggregated data to the sink. Data aggregation is done along the chain where each node receives data from one neighbor, fuses with its own data, and transmits to the other neighbor on the chain. First, the chain leader issues a token to the last node in the right end of the chain. Upon receiving the token, the end node transmits its data to its closest neighbor in the chain towards the leader. The neighboring node fuses the data with its own and sends the aggregated to its downstream neighbor and this process continues until the aggregated data reaches the chain leader. Upon receiving the data from the right side of the chain, the leader repeats the same aggregation process for the left end of the chain. Upon receiving the data from both sides of the chain, the leader aggregates the data and transmits it to the data sink.

Advantages of PEGASIS:

1. PEGASIS does not have the overhead of cluster formation, advertisements and also reduces the data transmissions through data aggregation performed in chain communication.
2. Since each node in the chain is allowed to transmit data per round ,energy consumption is uniformly distributed among the nodes
3. It can efficiently handle different network scales using the multi-hop, chain-based approach among the nodes [10].

Drawbacks of PEGASIS:

1. It is not practical for all the nodes to have global knowledge of the network topology especially for large scale networks.
2. The single chain approach diminishes the network reliability such that if a node in the chain dies the nodes are disjointed [10].
3. It leads to excessive delays for nodes which are at a great distance from the sink and such nodes may consume lot of energy for communication with the sink.
4. Single chain leader approach may sometimes lead to a bottleneck.

C. HEED - Hybrid Energy-Efficient Distributed Clustering

It is a popular, hybrid, energy - efficient and distributed clustering protocol and has following four objectives:

1. Increasing lifetime of the sensor network by distributing energy consumption
2. Bring an end to the clustering process within a finite number of iterations
3. Reducing control overhead
4. Constructing well – distributed CH's and compact clusters.

HEED periodically selects CH's based on a hybrid of two parameters: The first or the key parameter is the residual energy of each sensor node and the second parameter is the intra-cluster communication cost . The first parameter is used to select an initial set of CH'swhile the second parameter is used for breaking ties. The clustering process at each sensor node involves several rounds. An initial percentage of CH's in the network, C_{prob} ,is predefined and is used to limit the initial CH announcements. Each mote sets the probability $CH_{prob}$of becoming a CH as follows:

$CH_{prob} = C_{prob}.E_{residual} / E_{max}$,

Where $E_{residual}$ is the current residual energy in the node and E_{max} is the maximum energy or the initial energy of the node (fully charged battery), which is identical for homogeneous sensor nodes. The CH_{prob}value must be greater than a minimum threshold p_{min} . A CH is either a tentative CH, if it's CH_{prob} is less than 1, or a final CH, if its CH_{prob} has reached 1. During each round of the protocol, every mote that never heard from a CH, elects itself as CH with probability CH_{prob} .The newly chosen CH's are added to the current set of CH's. If a sensor node is chosen to be a CH, then it broadcasts an announcement message as a tentative CH or a final CH. A sensor node hearing the CH list selects the CH with the lowest cost from this set of CH's. Every mote then doubles its CH_{prob} and proceeds to the next step. If a node completes the HEED execution without electing itself to become a CH or joining a cluster, it declares itself as a final CH .A tentative CH can become a normal node at a later iteration if it hears from a lower cost CH.A node can be selected as CH at successive clustering intervals if it has higher residual energy with lower cost.

Advantages of HEED:

1. Distribution of energy extends the lifetime of all the motes in the network, thus preserving the stability of the neighbor set.
2. Nodes communicate in a multi-hop fashion thus promoting more energy conservation and scalability in the network.
3. The protocol improves network lifetime since CH's are not selected randomly ,but are chosen based on 2 parameters
4. The CH's are well distributed across the network leading to balanced load in the network and the communication cost is also less.

Drawbacks of HEED:

1. The protocol involves iterative based clustering methodology which imposes lot of overhead in CH selection causing extra energy consumption leading to decrease in lifetime of the network.
2. The selection process of CH's may generate more CH's than expected leading to unbalanced energy consumption in the network.
3. Number of clusters formed is more, leading to excess energy consumption

D. EEHC- Energy - Efficient Hierarchical Clustering

It is a distributed, randomized, k- hop hierarchical clustering algorithm with the following objectives:

1. Maximizing the lifetime of the network.
2. Addressing the limitations of one-hop random selection algorithms by extending the cluster architecture to multiple hops.
3. Improving the scalability of the network.

The EEHC algorithm organizes the sensors in a network into hierarchy of layers andCH's. The CH's gather the information from the sensors within their clusters and send an aggregated report through the hierarchy of CH's to the sink. The algorithm involves two - stage clustering: single - level clustering and multilevel clustering. At the single - level clustering stage, each sensor node becomes a CH with a predefined probability p and announces itself as a volunteer CH to the neighboring nodes within k - hops communication range. Any node that receives such an announcement message and isn't itself a CH, will become a member of the closest cluster. Those nodes that are neither CH's nor belong to a cluster will become forced CH's. If the announcement messages don't reach a node within a time interval t which is preset, the node becomes a "forced" CH assuming that it is not within k hops of all volunteer CH's. The energy required for sending the information gathered by the sensors to the processing center depends on the parameters p and k .The same mechanism is extended from bottom-up to multilevel clustering at the second stage. Assuming that there are h levels in the clustering hierarchy, the information gathered at all sensor nodes is first sent to level - 1 CH's. , then the level - CH's aggregate the information and forward it to the level – 2CH's, and so on. Finally, the level - h cluster heads send the aggregated report to the base station.

Advantages of EEHC:

1. It improves the lifetime and stability of the network
2. It makes WSNs more scalable because of its hierarchical architecture.
3. It is suitable for use in WSNs with a large number of nodes

Drawbacks of EEHC:

1. Data aggregation in multi-layered clustering increases the delay since the data should be stored in intermediate nodes until other data arrive and then are aggregated and transmitted to the sink.
2. Energy consumption for network operations depends on the optimization of the parameters p and k.

E. DWEHC - Distributed Weight-based Energy-Efficient Hierarchical Clustering

Distributed weight - based energy - efficient hierarchical clustering (DWEHC) is a distributed clustering algorithm with the following objectives:

1. Achieving balanced cluster sizes
2. Optimizing intra-cluster topologies
3. Maximizing the lifetime of the network.
4. Improving the scalability of the network.

The DWEHC algorithm assumes that the motes are location aware and transmit at the same fixed power levels. The cluster radius, which is the farthest transmission distance from one cluster member node to its CH is fixed for the whole network. After running seven iterations on each node, the algorithm generates a multihop intracluster structure in which a CH is at the root and member nodes are in breadth - first order. TDMA i.e. Time division multiple access is used for intracluster communication and the CH's compete for the channel using the 802.11 protocol to send data to the sink. Each sensor node, after locating the neighboring nodes in its area, calculates its weight as follows:

$$W_{weight(s)} = E_{residual(s)} / E_{initial(s)} \times \sum (R - d) / 6R$$

Where $E_{residual(s)}$ is the residual energy of node s, $E_{initial(s)}$ is the initial energy of node s, R is the cluster range which is fixed for the entire network and d is the distance from node s to neighbor node. The node having the largest weight in the neighborhood becomes a temporary CH and a temporary CH becomes a real CH only if a given percentage of the neighbors elect it as their CH.

At this stage, the neighboring nodes are treated as the first - level child members with respect to the CH. A node gradually adjusts such membership for reaching a CH using the least amount of energy. Each node checks with its non –CH neighbors to find out the least cost for reaching a CH and then decides if it is better to stay as a first - level member or become a second - level one; that is, reaching the CH over a 2 - hop path. It is likely that the node may move to a new CH leaving the original one. This process goes on until all nodes settle on the most energy - efficient intracluster topology.

Advantages of DWEHC:

1. Each cluster has minimum - power topology and each parent node contains limited number of child nodes, which improves scalability of the network.
2. The algorithm achieves good load balance per node, thus prolonging the lifetime of a CH.
3. Clusters are more balanced and the algorithm achieves considerably lower energy consumption in intra-cluster and inter-cluster routing than HEED.
4. The clustering process completes within a few iterations, and does not depend on network topology or size.

Drawbacks of DWEHC:

1. Multi-hop intra-cluster communication increases the total energy consumption in the network and hence the algorithm may not be applicable to large-region networks

2. The iterative nature of the algorithm during cluster formation produces a relatively high control message overhead compared to other protocols.

F. TEEN - Threshold Sensitive Energy Efficient Sensor Network Protocol

TEEN is a clustering communication protocol with the following Objectives:

1. It targets a reactive network and enables cluster heads to impose a constraint on when the sensors should report their sensed data.
2. It gives the trade – off between energy efficiency, data accuracy, and response time dynamically.

TEEN uses hierarchical clustering, which groups sensors into clusters which are led by a cluster head and all the sensors within a cluster report their sensed data to their cluster head. The cluster head then sends the collected data to the higher level cluster heads until the data reaches the sink [13].

Once the cluster heads are decided, each cluster head broadcasts to its members a value, called hard threshold (HT), for the sensed attribute in which the user is interested, beyond which a sensor should turn its transmitter on to report its sensed data to its cluster head. In addition, a cluster head broadcasts another value, called soft threshold (ST), which indicates a small change in the value of the sensed attribute, which triggers a sensor to turn on its transmitter and send its sensed data to the cluster head. In addition, nodes store the current sensed value (SV) of the sensed attribute [15].

The nodes keep sensing their surroundings continuously and transmit the sensed data based on the values of the hard and soft thresholds. A sensor transmits its sensed data only if its value is higher than HT and the difference between the current value and the previously stored value SV is $\geq$ ST. When a sensor sends its sensed data, it updates SV with the current value of its sensed attribute [14].

The hard threshold helps the sensors to transmit only significant information while the soft threshold further reduces the number of transmissions for sensed data. Thus, the sensors will send only sensed data based on the hard threshold value and the change with respect to the previously reported data.

Advantages of TEEN:

1. TEEN performs much better than LEACH.

Drawback of TEEN:

1. TEEN is not suitable for sensing applications which require sensors to report their data on a regular basis as the sensors may not be able to transmit at all for some value of the hard threshold.

G. APTEEN - Adaptive Periodic TEEN

Adaptive Periodic TEEN (APTEEN) overcomes the shortcomings of TEEN and has the following objectives:

1. It combines the features of both TEEN (time - critical data) and LEACH (periodic sensed data transmission).
2. It is a hybrid clustering scheme that allows the sensors to sense data periodically and report any sudden change in the value of the sensed attribute to their cluster heads [13].

After the clusters are formed, a cluster head broadcasts the sensed attributes, the hard and soft thresholds, a TDMA schedule that assigns a slot to each sensor, and a maximum time interval between two successive slots sent by a sensor, called count time (TC). This count time is used when sensors have to report their sensed data periodically to the sink. APTEEN can handle three types of queries: it can answer historical queries by extracting historical data associated with the events that occurred in the past. It can also respond to one - time queries that give a snapshot view of the network. Moreover, it can reply to persistent queries that allow monitoring the network within a time interval with respect to some sensed attributes.

Advantages of APTEEN:

1. APTEEN guarantees lower energy dissipation and a larger number of sensors alive. In LEACH sensors transmit their sensed data continuously to the sink, in APTEEN sensors transmit their sensed data based on the threshold values.

Drawback of APTEEN:

1. Performance of APTEEN in terms of energy consumption and network lifetime lies between those of LEACH and TEEN.

H. EECS - Energy Efficient Clustering Scheme

EECS extends the LEACH algorithm and has the following objectives:

1. It dynamically sizes the clusters based on the cluster distance from the base station.
2. It's a competition based clustering scheme where the network is partitioned into several clusters and a single-hop communication between the CH and the BS is performed.

In every cluster the candidate nodes compete to become cluster heads by broadcasting the status of their residual energy to all the neighboring nodes within a competitive range. The competing nodes then wait for the other nodes to announce their residual energy [10]. If a competing node does not find a node with more residual energy, it becomes the cluster head.

This scheme shows that the clusters present at a larger distance from the BS requires more energy for transmission than those present closer which improves the distribution of energy in the network resulting in extended lifetime of the network [16].

Advantages of EECS:

1. Based on energy and distance, EECS constructs balancing point between intra-cluster energy consumption and inter-cluster communication load [9].

Drawbacks of EECS:

1. The communication with the BS is direct in EECS, thus long-range transmissions directly from CHs to the BS can lead to much energy consumption. Hence it is not suitable for large-range networks.
2. EECS produces much more control overhead complexity because all nodes must compete for becoming CHs.

I. EARP - Energy Aware Routing Protocol

EARP is proposed for 3-tier architecture based clustered sensor networks with the following objective:

1. It works by grouping Sensors into clusters prior to the network operation.
2. The algorithm employs cluster heads, namely gateways, which are less energy constrained than sensors and assumed to know the location of sensor nodes.

A TDMA based MAC is used by the nodes to send data to the gateway. Gateways maintain the states of the sensors and sets up multi-hop routes for collecting sensors data. The gateway informs each node about slots in which it should listen to the other nodes transmission which the node can use for its own transmission [8]. The command node or sink communicates only with the gateways. The sensor nodes are capable of operating in an active mode or a low-power stand-by mode. In addition, the sensing and processing can be powered on and off.

The sensor nodes in a cluster can be in one of the four states: Sensing, Relaying, Sensing-Relaying and Inactive. In sensing state, the nodes probe the surroundings and generate data at a constant rate [17]. In relaying state, the node does not sense the target but relays data from other active nodes. In sensing-relaying state, the node is both sensing and relaying messages from other nodes. In Inactive state, the nodes neither sense nor relay messages from other nodes by turning off its communication circuit.

Advantages of EARP:

1. EARP consistently performs well with respect to both energy-based metrics such as network lifetime, as well as contemporary metrics such as throughput and end-to-end delay.

Drawbacks of EARP:

1. The algorithm constrains the minimum transmission range.
2. Requires the deployment of many gateways to ensure high sensor coverage.

J. EEUC - Energy Efficient Uneven or Unequal Clustering Protocol

EEUC is the clustering protocol with the following objectives:

1. EEUC solves the hot spot problems in the network.
2. It balances the energy consumption among the sensor nodes in the network by partitioning the whole network into clusters of unequal sizes.

During the process of CH election, each node becomes a tentative CH by broadcasting compete message within a competitive range which is determined by its distance to the BS [9]. The node's competition range decreases as its distance to the BS decreasing. Thus, the cluster closer to the BS has smaller size and consumes lower energy during the intra-cluster communication, and preserves more energy for the inter-cluster processing. Then, tentative CHs in local regions compete in order to become a real CH.

EEUC works in 3 phases: Cluster Set-up phase, Steady State phase and Routing phase. In Cluster set-up phase the Base Station gathers the node information such as node ID, location and energy information and based on this information it creates clusters of unequal sizes and the information is then broadcasted into the network. In Steady State phase nodes in the cluster are given CH sequence number and the cluster ID. If the node's CH sequence number is 1, the node become CH for the first round, if 2, it is CH for second round and so on. In Routing phase the CH node performs data gathering and aggregation of all the received data which is then transmitted to the BS using multi-hop communication.

Advantages of EEUC:

1. Unequal clustering mechanism solves the hot spot problems by balancing the energy consumption among CHs.
2. Saves more energy via inter-cluster multi-hop routing mechanism.
3. Increased network lifetime compared to LEACH and HEED.

Drawbacks of EEUC:

1. Performing clustering in each round imposes overhead in the network.
2. The global data aggregation results in more overhead for all nodes and can deteriorate the network performance.
3. The routing scheme can result in new hot spots.

V. COMPARISON

The different clustering routing protocols for WSNs have been compared based on Clustering characteristics and the figure for the same is specified in Fig. 3.

Clustering Routing protocol		LEACH	PEGASIS	HEED	EEHC	DWEHC	TEEN	APTEEN	EECS	EARP	EEUC
Cluster Properties	Cluster count	Variable	Variable	Variable	Variable	Variable	Constant	Variable	Variable	Variable	Variable
	Cluster size	Same	Same	Same	Same	Same	Same	Same	Different	Same	Different
	Intra-Cluster Communication	Single-hop	Multi-hop	Single-hop	Multi-hop	Multi-hop	Single-hop	Single-hop	Single-hop	Multi-hop	Single-hop
	Inter-Cluster Communication	Single-hop	Single-hop	Multi-hop	Multi-hop	Single-hop	Multi-hop	Multi-hop	Single-hop	Multi-hop	Multi-hop
Cluster-Head Properties	Existence	CH based	non-CH based	CH based	CH based	CH based	CH based	CH based	CH based	CH based	CH based
	Type of node	Homogeneous	N/A	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous
	Mobility	Stationary	N/A	Stationary	Stationary	Stationary	Stationary	Stationary	Stationary	Stationary	Stationary
	Role	Relay /Aggregation	N/A	Relay /Aggregation	Relay /Aggregation	Relay /Aggregation	Relay /Aggregation	Relay /Aggregation	Relay /Aggregation	Relay /Aggregation	Relay /Aggregation

Fig. 3 Comparison of different clustering routing protocols in WSNs

VI. CONCLUSION

Wireless sensor networks (WSNs) have received tremendous attention from both academia and industry over the past few years. In near future, WSNs will revolutionize the way we live, work, and interact with the physical world. Lot of research has been carried out to explore and solve different design and application issues, and major advances have been made in the development and deployment of WSNs, and they can be employed in a wide range of applications. The design of robust, efficient and scalable routing protocols for WSNs is a challenging task. Clustering has been widely pursued by the research community since clustering routing protocols can well match the challenges and constraints of WSNs. Hence, significant efforts have been made in designing effective and efficient clustering routing protocols for WSNs. In this paper, we have presented a survey of few clustering routing protocols in WSNs highlighting their objectives, advantages and disadvantages.

REFERENCES

[1]. Neetika & Simarpreet Kaur, Review On Hierarchical Routing In Wireless Sensor Networks [2]. Wei Li, Wireless Sensor Networks.

[3]. Rajashree.V.Biradar, V.C. Patil, Dr. S. R. Sawant, Dr. R. R. Mudholkar, Classification and comparison of routing protocols in wireless sensor networks.

[4]. Neha Upadhyay, Vikram Jain, node and sink mobility supported routing protocol in wireless sensor network with improved energy efficiency, International Journal of Computer Science and Mobile Computing, IJCSMC, Vol. 2, Issue. 6, June 2013, pg.267 – 273, ISSN 2320–088X

[5]. Santar Pal singh,S.C. Sharma, A Survey on cluster based routing protocols in Wireless sensor networks, International conference on Advanced computing technologies and applications (ICACTA -2015)

[6]. GarcíaVillalba, L. J., Sandoval Orozco, A. L., Triviño Cabrera, A., &Barenco Abbas, C. J. (2009). Routing protocols in wireless sensor networks. Sensors, 9(11), 8399-8421

[7]. Jamal N. Al-Karaki Ahmed E. KamaL, Routing Techniques in Wireless Sensor Networks: A Survey, CUBE initiative of Iowa State University, Ames, IA 50011.

[8]. K. Akkaya, M. Younis, A survey on routing protocols for wireless sensor networks, Elsevier Journal of Ad Hoc Networks 3 (3) (2005) 325–349
[9]. Liu X. A survey on clustering routing protocols in wireless sensor networks.Sensors 2012;12:11123–53.
[10]. M. Mehdi Afsar, Mohammad-H.Tayarani-N, Clustering in sensor networks: A literature survey, Journal of Network and Computer Applications 46(2014)198–226
[11]. Abbasi, A.A.; Younis, M. A survey on clustering algorithms for wireless sensor networks Comput.Commun.2007, *30*, 2826–2841.
[12]. VishakhaSinghal and ShrutikaSuri ,Comparative Study of Hierarchical Routing Protocols in Wireless Sensor Networks ,International Journal of Computer Sciences and Engineering Open Access Review Paper 2014 ,Volume-2, Issue-5 E-ISSN: 2347-2693
[13]. Jun Zheng, Abbas Jamalipour, Wireless Sensor Networks – A Networking Perspective.
[14]. Saewoom Lee, Youngtae Noh, and Kiseon Kim, Key Schemes for Security Enhanced TEEN Routing Protocol in Wireless Sensor Networks, Hindawi Publishing Corporation International Journal of Distributed Sensor NetworksVolume 2013.
[15]. Arati Manjeshwar and Dharma P. Agrawal, TEEN: A Routing Protocol for Enhanced Efficiency in Wireless Sensor Networks.
[16]. Ankita Joshi, Lakshmi Priya.M, A Survey of Hierarchical Routing Protocols in Wireless Sensor Network.
[17]. Sanjay Waware, Dr. NishaSarwade , PallaviGangurde, A Review of Power Efficient Hierarchical Routing Protocols in Wireless Sensor Networks, International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622, Vol. 2, Issue 2,Mar-Apr 2012, pp.1096-1102.

Ms. Asia Sultana is currently working as Associate Professor in I.T.D in Muffakham Jah College of Engineering and Technology, Hyderabad, India. She received her Master degree in Computer Science and Engineering from Jawaharlal Nehru Technological University, Hyderabad, India. Her areas of interest include Computer Networks, Wireless Sensor Networks, Mobile Computing Data Structures, Database management systems. She is a life member of CSI.

Ms. Sayyada Hajera Begum is currently working as Assistant Professor in the Dept of IT, Muffakham Jah College of Engineering and Technology, Hyderabad, India. She received her M.Tech degree in Software Engineering from Jawaharlal Nehru Technological University, Hyderabad. She is a member of Association for Computer Machinery (ACM). Her areas of interest include WSN, Network Security, Database Management System and Compiler Construction.