Comparison of Clustering Algorithms and Clustering Protocols in Heterogeneous Wireless Sensor Networks: A Survey

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Abstract:-Wireless sensor networks (WSNs) have received tremendous attention in recent years because of the development of sensor devices, as well as wireless communication technologies. It is usually deployed in inaccessible terrains, disaster areas, or polluted environments, where battery replacement or recharge is difficult or even impossible to be performed. For this reason, network lifetime is of crucial importance to a WSN. Clustering is a key technique to improve the network lifetime, reduce the energy consumption and increase the scalability of the sensor network. This paper surveys the different clustering algorithm for heterogeneous WSN and compares these protocols on various points like, location awareness, clustering method, heterogeneity level and clustering Attributes.

Keywords - WSN, Clustering Algorithm, Protocols.

I. INTRODUCTION

A collection of mobile or static nodes which are able to communicate with each other for transferring data more efficiently and autonomously can be defined as wireless sensor network. A lot of applications of wireless sensor network can be found in different field such as events, battlefield surveillance, recognition security, drug identification and automatic security [1].The sensor nodes can be homogeneous or heterogeneous. WSN sensor nodes are typically operated by batteries, which are limited in energy capacity, and difficult or even impossible to be replaced or recharged. For this reason, power control is needed to efficiently make use of the limited energy resources in order to minimize the energy consumed by the sensor nodes and thus prolong network lifetime. For this purpose, energy efficiency must be considered in every aspect of network design and operation, not only for individual sensor nodes, but also for the communication of the entire network. Clustering is a key technique to improve the network lifetime, reduce the energy consumption and increase the scalability of the sensor network. A scalable sensor network is obtained by means of clusters.

Advantages of clustering

a) Reduces the size of the routing table by localizing the route setup within the cluster.
b) Conserves communication bandwidth.
c) Prolonged battery life of individual sensor.
d) No topology maintenance overhead.
e) Reduce rate of energy consumption.

II. HETROGENEOUS MODEL FOR WIRELESS SENSOR NETWORKS

A) Type of Resource Heterogeneity

There are three common types of resource heterogeneity in sensor nodes:

1) **Computational heterogeneity**: - Means that the heterogeneous node has a more powerful microprocessor and more memory than the normal node. With the powerful computational resources, the heterogeneous nodes can provide complex data processing and longer-term storage.
2) **Link heterogeneity**: - Means that the heterogeneous node has high-bandwidth and long-distance network transceiver than the normal node. Link heterogeneity can provide a more reliable data transmission
3) **Energy heterogeneity**: - Means that the heterogeneous node is line powered or its battery is replaceable.

Among above three types of resource heterogeneity, the most important heterogeneity is the energy heterogeneity because both computational heterogeneity and link heterogeneity will consume more energy resource.

B) Impact of Heterogeneity on Wireless Sensor Networks

If we place some heterogeneous nodes in sensor network it shows the following benefits:

1) **Response-time**:-Computational heterogeneity can decrease the processing latency in immediate nodes

and link heterogeneity can decrease the waiting time in the transmitting queue. Fewer hops between sensor nodes and sink node also mean fewer forwarding latency.

2) **Prolonging network lifetime**:-The average energy consumption for forwarding a packet from the normal nodes to the sink in heterogeneous sensor networks will be much less than the energy consumed in homogeneous sensor networks.
3) **Improving reliability of data transmission: -** It is well known that sensor network links tend to have low reliability. And each hop significantly lowers the end-to-end delivery rate. With heterogeneous nodes; there will be fewer hops between normal sensor nodes and the sink. So the heterogeneous sensor network can get much higher end-to-end delivery rate than the homogeneous sensor network.

C) Performance Measures

Some performance measures that are used to evaluate the performance of clustering protocols are listed below.

1) **Network lifetime: -** It is the time interval from the start of operation (of the sensor network) until the death of the first alive node.
2) **Number of cluster heads per round:-** Instantaneous measure reflects the number of nodes which would send directly to the base station, information aggregated from their cluster members.
3) **Number of nodes per round**: - This instantaneous measure reflects the total number of nodes and that of each type that has not yet expended all of their energy.
4) **Throughput: -** This includes the total rate of data sent over the network, the rate of data sent from cluster heads to the base station as well as the rate of data sent from the nodes to their cluster heads.

III. CLASSIFICATION OF CLUSTERING ATTRIBUTES

3.1 **Cluster properties:**

1) **Cluster Count: -** Cluster heads are predetermined in some of the approaches. Thus, the numbers of clusters are preset. Cluster head selection algorithms generally pick randomly cluster heads from the deployed sensors hence yields variable number of clusters.
2) **Intra-cluster Topology**: - Some clustering schemes are based on direct communication between a sensor and its designated cluster head, but sometimes multi-hop sensor-to-cluster head connectivity is required
3) **Connectivity of CH to BS: -** Cluster heads send the aggregated data to the base station directly or indirectly with help of other cluster head nodes. It means there exists a direct link or a multi-hop link.

3.2 Cluster head Capabilities:

1) **Mobility**: - CH can be stationary or mobile. But movements are limited within the region for better network performance.

2) **Node Types**: - Deployed sensor nodes equipped with more computation and communication resources are selected as CHs [6].

3)**Role**:- The role of cluster heads in the sensor networks can act as a relay for the information generated by the cluster members or perform the task of aggregation or fusion of data.

3.3 CH Selection Based on:

1) **Initial Energy**: - This is an important parameter to select the cluster head. When any algorithm starts it generally considers the initial energy.
2) **Residual Energy: -** After some of the rounds are completed, the cluster head selection should be based on the energy remaining in the sensors
3) **Energy Consumption Rate**: -This rate is defined as

$$Vi(t) = [Initial – Ei(t)] / r$$

Where Initial is the initial energy, Ei(t) is the residual energy and r is the current round of CH Selection.

4) **Average Energy of the Network: -** The average energy is used as the reference energy for each node. It is the ideal energy that each node should own in current round to keep the network alive [5, 2].

IV. CLUSTERING ALGORITHMS AND PROTOCOLS FOR WSN

There are several different ways to distinguish and classify the clustering algorithms used in WSN. Most of the known

clustering algorithms for WSNs can be distinguished on the basis of cluster head selection process.

4.1. Popular Probabilistic Clustering Protocols

Energy-Efficient Communication Protocol for Wireless Micro sensor Network (LEACH)

W. B. Heinzelman et al. [8] proposed first well known clustering protocol LEACH for wireless sensor networks. In this sensors are organized into clusters and randomly select a few nodes as cluster head with a certain probability of becoming a cluster heads per round. The task of being a cluster head is rotated between nodes. The rotation role balances the energy dissipation of the nodes in the networks. LEACH is a distributed algorithm but cluster count (cluster head) is not fixed in each round per epoch. Due to distributed algorithm each node is capable to select itself as a cluster head by choosing random number. There is possibility that each node choose same number for cluster head selection, due to randomness property of random number generator. So cluster head count is varying in each round.

An application-specific protocol architecture for wireless microsensor networks (LEACH-C)

W. B. Heinzelman et al. [9] this protocol uses a centralized approach where the information of node location and energy level was communicated to base station. The base station decides about the cluster head selection and cluster formation. In this protocol the selection of cluster heads is random and the cluster head number is limited. The base station sure those nodes have less energy than it cannot become a cluster head. This protocol is not suitable for large scale network because there is a problem to send the status of a node which are far from the base station. The cluster head role rotates every time so it is not feasible to send information every time in a quick time. It increases the latency and delay.

A Stale Election Protocol for Clustered Heterogeneous Wireless Sensor Networks (SEP)

Georgios S. et al. [10] introduces the heterogeneity that prolongs the time interval before the death of first node called stability period. This protocol is based on the weighted election probabilities of each node to become cluster head according to the remaining energy in each node. In this there are two types of nodes was considered as normal and advanced. This protocol does not require global knowledge of energy at every round to select cluster heads. Authors extended the LEACH protocol except the heterogeneity awareness. Cluster count is variable in this algorithm and also unstable period is not good.

Hybrid Energy-Efficient Distributed Clustering (HEED)

O. Younis et al. [11] improves the LEACH protocol by using residual energy, node degree or density as a main parameters for cluster formation to achieve power balancing. This protocol was proposed with three main parameters: First parameter is to enhance network lifetime by distributing energy consumption, second clustering terminates within a fixed number of iterations third minimum control over head and fourth the cluster heads was well distributed. The algorithms proposed in this protocol periodically selects cluster heads based on the two basic parameters. The first primary parameter is the residual energy of each node; second parameter is the intra-cluster communication cast as a function of cluster density or node degree. The primary parameter selects initial set of cluster heads probabilistically which secondary parameter is breaking ties. HEED is not able to fix the cluster count in each round and it is also not aware of heterogeneity.

Distributed Energy Efficient Hierarchical Clustering for Wireless Sensor Network (DWEHC)

P Ding et al. [12] proposed a distributed weight based energy efficient hierarchical clustering protocol which aims at high energy efficiency by generating balanced cluster sizes and optimizing the intra cluster topology. Each sensor node calculates its weight after finding the neighboring nodes in its area. The weight is a function of the sensors residual energy and the proximity to the neighbors. In a neighborhood, the node with largest weight would be elected as a cluster head and the remaining nodes become members. At this stage the nodes are considered as first level members because they have a direct link to the cluster head. A node progressively adjusts such membership to reach a cluster head using the least amount of energy. Basically, a node checks with its non-CH neighbors to find out their minimal cost for reaching a cluster head. Given the node's knowledge of the distance to its neighbors, it can reach the cluster head over a two-hop path. The protocol is not performing well in term of stability period due to huge amount of energy consumed in neighbors finding.

Distributed Energy Efficient Clustering Algorithm for Heterogeneous Wireless Sensor Networks (DEEC)

Li Qing et al. [13] proposed a distributed multilevel clustering algorithm for heterogeneous WSN. In DEEC the cluster heads are selected by a probability based on the ratio between residual energy of each node and the average energy of the network. The approach of being cluster heads for nodes are different according to their initial and residual energy. The authors have assumed that all the nodes of the sensor network are equipped with different amount of energy. Two levels of heterogeneous nodes are considered in the algorithm and after that a general solution for multi-level heterogeneity is obtained. To avoid that each node needs to know the global knowledge of the networks, DEEC estimates the ideal value of network life-time, which is used to compute the reference energy that each node should expend during a round. Cluster count is variable in this approach lead to uneven clusters.

Distributed Energy Balance Clustering Protocol for Heterogeneous Wireless Sensor Networks (DEBC)

Changmin D et al. [14] proposed a protocol for heterogeneous wireless sensor network. The selection of cluster heads depends on the probability based on radio between residual energy of node to the average energy of network. The high initial and residual energy nodes have more chances to become cluster heads then the nodes have low energy. This protocol improves the LEACH and SEP protocol by considering two level heterogeneity and extending upto multi hop heterogeneity.

An unequal cluster-based routing protocol in wireless sensor networks (UCR)

Guihai chen. et al. [15] proposed a protocol for mitigating the hot spot problem in WSNs. It is designed for source driven sensor network applications, such as detection of periodical data from environment. It is a self organized competition based algorithm, where selection of cluster heads based on local information as residual energy of neighboring nodes. The cluster heads closer to base station are expected to have smaller cluster sizes, than those for their from the base station, thus the cluster heads will consume lower energy during the intra cluster data processing and can presume some more energy for the inter cluster relay traffic. The protocol is accomplish the cluster head selection procedure in two phase, which is time consuming and cluster size is uneven due to variable cluster count.

Cluster-based Service Discovery for Heterogeneous Wireless Sensor Networks (C4SD)

R.S. Marin et al. [16] developed a protocol (C4SD) for heterogeneous WSNs that rely on a clustering structure that offers distributed storage of service descriptions. In this protocol, each node is assigned a unique hardware identifier and weight. If any node has higher capability must be selected for cluster head role. These nodes act as a distributed directory of service registrations for the nodes in the cluster. The basic structure ensures low construction and maintenance overhead, reacts rapidly to topological changes of the sensor network by making decisions based only on the 1-hop neighborhood information and avoids the chain reaction problems. A service lookup results in visiting only the directory nodes, which ensures a low discovery cost.

An Improved LEACH protocol for application specific wireless sensor network (Improved LEACH)

Chong Wang et al. [17] suggested a protocol to save energy cost induced due to redundant nodes and balancing the energy consumption among sensor nodes by splitting large cluster into smaller ones. According to author large clusters are split into smaller ones using the mechanism sub cluster head. By using this, the data frame will be smaller, thus the number of frame received by BS will be increasing during the same time. Another make improvement in redundant nodes keeps asleep for most of time. In other words, only one node of them is needed which the others can keep asleep until the first one exhaust with the energy. In such a way the network lifetime is extended. The proposed protocol leads to unequal sized cluster due to variable cluster count.

Energy Efficient Heterogeneous Clustered Scheme for Wireless Sensor Networks (EEHC)

D. Kumar et al. [18] proposed a distributed cluster head election scheme for heterogeneous WSNs. The election of cluster heads is based on different weighted probability. The cluster's member nodes communicate with the elected cluster head and then cluster heads communicate the aggregated information to the base station. The authors have considered three types of nodes. Authors have proposed the different threshold for each type of nodes. This guarantees that each type of node become cluster head according to their weighted

probability. The proposed protocol leads to unequal sized cluster due to variable cluster count.

Stochastic Distributed Energy Efficient Clustering for Heterogeneous Wireless Sensor Networks (SDEEC)

B. Elbhiri et al. [19] extended the DEEC protocol as the stochastic strategy is the key idea where the number of transmission intra clusters is reduced. This strategy is used when the objective is to collect the maximum or minimum data values like temperature, humidity etc in a region of the network. Thus the cluster head selects pertinent information between those received and send it to the base station. In this case, if the clusters head receives only from nodes with significant information and the others node must be in sleep mode. It is an application specific protocol.

Stochastic and Balanced Distributed Energy Efficient Clustering (SBDEEC)

Elbhiri Brahim et al. [20] proposed a protocol that permits to balance the cluster head selection overall network nodes following their residual energy. So, the advanced nodes are largely solicited to be selected as cluster heads for the first transmission rounds, and when their energy decreases sensibly, these nodes will have the same cluster head selection probability like the normal nodes. The other key idea in of this protocol is to better reduce the intra clusters transmission when the objective is to collect the maximum or minimum data values in a region like temperature humidity etc.

Distributed Cluster Head Election Scheme for Improving Lifetime of Heterogeneous Sensor Network and Applications (DCHE)

Dilip Kumar et al. [21] proposed a distributed cluster head election scheme for heterogeneous WSNs. The election of cluster heads is based on different weighted probability. The cluster's member nodes communicate with the elected cluster head and then cluster heads communicate the aggregatedinformation to the base station. Authors have considered three different types of nodes and all have different threshold. The weight assigned to each node will decide the selection of cluster head for each type. Simulation results show that the DCHE scheme offers a better performance in terms of lifetime and stability than LEACH, DEEC and Direct Transmission.

Energy Efficient Scheme for Clustering Protocol Prolonging Lifetime of Heterogeneous Wireless Sensor Networks (TDEEC)

Parul Saini et al. [22] proposed an energy efficient cluster head election scheme for heterogeneous WSNs. The author have adjusted the value of the threshold, according to which a node decide to become a cluster head or not, based on the ratio of residual energy and average energy of that round in respect to the optimum number of cluster heads. Two level and three levels of heterogeneous nodes are considered in the algorithm and after that a general solution for multilevel heterogeneity is proposed. It requires the average network energy for cluster head selection, which is more energy consumable.

Developed Distributed Energy-Efficient Clustering for Heterogeneous Wireless Sensor Networks (DDEEC)

Elbhri et al. [23] proposed a developed distributed energy efficient clustering scheme for heterogeneous WSNs. DDEEC is based on DEEC scheme, where all nodes use the initial and residual energy level to define the cluster heads. In this protocol each node needs to have the global knowledge of the networks, DDEEC like DEEC estimate the ideal value of network lifetime, which is used to compute the reference energy that each node should expend during each round. In this scheme, the network is organized into a clustering hierarchy, and the cluster heads collect measurements information from cluster nodes and transmit the aggregated data to the base station directly. Moreover, the authors have supposed that the network topology is fixed and no-varying on time. The difference between DDEEC and DEEC is localized in the expressions which define the probability to be a cluster head for normal and advanced nodes.

Energy Efficient Clustering Scheme for Self-Organizing Distributed Wireless Sensor Networks (EECS)

Kyung Tae Kim et al. [24] developed an energy efficient clustering scheme based on the concept of weighted probability function for the election of cluster head. In this probability function three parameters are considered. The first parameter is the energy possession rate which is the initial energy Vs current energy. The second one is the individual round which is the time, it takes for the cluster head to be selected and the cluster head aggregate the received data from the member nodes and then transmit the fused information to the base station. Third one is the count

that the node had been selected as the cluster head. It mitigates the problem of the decrease in remaining energy of the node as time process by using the above parameters. The proposed protocol take more time for clustering and unequal sized clusters is formed in sensing area.

Mobile Nodes Based Clustering Protocol for Life Time Optimization in Wireless Sensor Network: (MNCP)

Babar Nazir et al. [25] proposed an algorithm that uses mobile nodes to fill the gap formed by any energy hole or hot spot. The mobile nodes can move any where if any cluster is suffering from the cluster head selection problem due to low residual energy. Any cluster that has the problem of cluster head selection send a message for mobile node in the nearly area. Any nearest mobile node of maximum energy will be activated and move to that reignited cluster. In that way we can use the energy in a balanced way through the network and increase the lifetime of the sensor network.

Improved and Balanced LEACH for Heterogeneous Wireless Sensor Networks (IBLEACH)

Ben Alla Said et al. [26] proposed an improved and balanced LEACH which is a self-organizing, adaptive clustering protocol that uses randomization to distribute the energy load evenly among the sensors in the network. In the scheme, some high energy nodes called NCG nodes (normal node/cluster head/gateway) become cluster heads to aggregate the data to their cluster members and transmit it to the chosen gateways that requires the minimum communication energy to reduce the energy consumption of cluster head and decrease probability of failure nodes.

Energy Consumption and Lifetime analysis in Clustered Multi-hop Wireless Sensor Networks Using the Probabilistic Cluster-Head Selection Method (ECLCM)

J. Choi et al. [27] developed an energy model to estimate the energy consumed in a multihop WSN clustered with probabilistic cluster head selection. Each sensor node selects itself as a cluster-head with a predefined probability without any information exchange with other nodes. Each cluster-head advertises itself as a cluster-head to other nodes within its radio range. Each node receives advertisements during a certain period from the arrival of the first received advertisement, and then chooses a cluster-head with the smallest number of hops from it and advertises its cluster-head to other nodes within its radio range. If cluster heads with the smallest number of hops from a sensor node are more than two, then the node randomly selects one of them. This repeats until each node selects its cluster-head or become a cluster-head. All nodes communicate according to TDMA schedules organized by the cluster-heads or the sink node. Thus, data collision can be prevented. The proposed protocol leads to unequal sized cluster due to variable cluster count. Multi hopping lead to network holes near to base station.

Weighted Election Protocol for Heterogeneous Wireless Sensor Networks (WEP)

Md. G. Rashed et al. [28] developed an energy efficient protocol (WEP) to enhance the stability period of sensor network. Author introduces a clustering scheme with a chain routing algorithm to enhance the energy and stable period constraints. In this a weight is assigned to the optimal probability for each node. This weight must be equal to the ratio between initial energy of each node to the initial energy of the normal node. After assigning weighted probability, the cluster heads and cluster number are selected in the same way as in LEACH protocol. By using the algorithm a chain among the selected cluster heads have been constructed. After this from the selected cluster heads, a chain leader is selected randomly. All non cluster head nodes send their data to their respective cluster head nodes. The cluster head nodes in each cluster then fused the data and send it to base station.

Energy Efficient Cluster Based Data Aggregation for Wireless Sensor Networks (ECBDA)

Siva R. et al. [29] propose a data aggregation method to enhance the network lifetime. In ECBDA cluster formation phase is used to split the network into set of cluster. *K* clusters are formed in each layer then each layer is divided into a set of clusters. In Cluster Head election process, one node is selected as cluster head from each cluster by using its residual energy and the communication cost factor. Once a node is elected as a cluster head, it broadcasts the cluster head message to its cluster members, other cluster heads and base station. Data forwarding is performed in the third phase. In the Data aggregation phase, all cluster members send its sensed data during its allotted time slot. The cluster head waits until its TDMA frame ends. After receiving its data from its entire cluster member, cluster head starts the aggregation process. Each cluster head eliminates the duplicates and forwards the packet to BS via the forwarding nodes. Maintenance phase checks the cluster head's residual

energy at each round. If the residual energy is less than the required threshold value, a new cluster head is elected from the same cluster. Re-clustering is also performed in the maintenance phase. The proposed protocol leads to small sized cluster which lead to more amount of data transfer form cluster head to base station it is energy consumable.

A Density Control Energy Balanced Clustering Technique for Randomly Deployed Wireless Sensor Network (DCEBC)

Sanjeev Kumar Gupta et al. [30] developed a protocol to enhance the life time of heterogeneous wireless sensor networks. In this paper authors select cluster heads based on probability threshold and current energy level. Authors also work on redundant node identification and deactivation. DCEBC achieves longer lifetime and stability period.

4.2. Popular Non Probabilistic Clustering Protocols

Designing Efficient Routing Protocol for Heterogeneous Sensor Network (HSR)

Xiaojiang Du et al. [31] Considers heterogeneous sensor networks by deploying a small number of powerful high end sensors with large number of low end sensors. In this each sensor node is static and aware of its own location. As both types of sensors are uniformly and randomly distributed in the network. In cluster formation process nodes select the cluster heads based on the signal strength. The cluster heads send the data to the sink via multi hop transmission over cluster heads. The proposed approach is static which will not suitable for many applications.

Traffic Based Clustering in Wireless Sensor Network (TBC)

Vijay Kr. Chaurasiya et al. [32] proposed an approach to create a system which will adopt a topology (size of cluster and number of hierarchal level) in accordance with the traffic patterns and density of sensor nodes deployed in a given area of interest. In multi hopped network load on the cluster head near the base station will be more as compared to farther cluster heads as the proximity cluster head have to do the dual work of collecting data from its own cluster and also to forward data from distant cluster heads. Therefore this situation may result in dying out of nearest cluster heads sooner than distant cluster heads. It will result in failure of sensor network as a whole. Therefore, authors have suggested that to construct a network topology based on the node density in different regions of the overall area covered by the network. This will avoid bottleneck problem and may result in long life of the network by proper load balancing. The proposed protocol degrades the energy of long distance sensor nodes early than nearer sensor nodes.

A probability Driven Unequal Clustering Mechanism for WSNs (PRODUCE)

Jung-Hwan et al. [33] proposed a distributed and randomized clustering algorithm that organizes the network with unequal sized clustering. It determined with localized probabilities and multihop routing based on stochastic geometry. In this algorithm, distance clusters which are far from the BS have larger cluster sizes and closer cluster have smaller cluster sizes. For the selection of cluster head in cluster a different probability assigned on each level. The proposed protocol leads to unequal sized cluster due to variable cluster count.

Energy and Distance Based Clustering: An Energy Efficient Clustering Method for WSN (EDBC)

Mehdi Saeidmanesh et al. [34] proposed a protocol which considers the residual energy and distance from the base station of each node in the cluster head selection process. If all sensor nodes are distributed in large area some clusters are far from the base station and others are close to base station. This can lead a great difference in transmission energy dissipations that the nodes use transmits data to base station. In this author has divided the whole of the network terrain into concentric circular segments around the base station. The number of cluster heads in each segment is different from the other segments in terms of distance from the base station. The cluster head election probability in closer segments is more than distant segments and the number of cluster heads in these segments is more.

Distributed Clustering Algorithms with Load Balancing in Wireless Sensor Network (DCLB)

Farruh Ishmanov et al. [35] evaluated distributed clustering with load balancing for forming cluster efficiently and balancing load in inter cluster communication cluster. Size (range) is important in terms of energy efficiency and balancing load in multi hop communication of cluster heads. Since it determine data volume in every step of clustering to avoid energy inefficiency and balanced load of cluster. It forms cluster with different sizes in each step. The proposed

protocol leads to unequal sized cluster due to variable cluster count.

A Density and Distance Based Cluster Head Selection Algorithms in Sensor Networks (DDCHS)

Kyounghwa Lee et al. [36] proposed an algorithm to elect the cluster head based on density and distance of sensor nodes in the sensor network. In this the cluster area is divided into two perpendicular diameters to get four quadrant, then in each quadrant, select following cluster head by group's node density and distance from the cluster head. Author have compared with LEACH and HEED protocols by calculating the energy consumption for communication of once between whole nodes and cluster head by position of cluster. This protocol shows better performance than LEACH and HEED.

Energy Efficient Clustering Scheme with Self-organized ID Assignment for Wireless Sensor Networks (EECSIA)

Qingehao Zheng et al. [37] proposed a distributed clustering scheme that considers both energy and topological features of a WSN. EESCIA enables an efficient solution to handling large-scale networks in assigning unique IDs to sensor nodes, reducing communication expenses and extending the network lifetime. EECSIA is fast and locally scalable, and it achieves a good distribution of cluster heads within the networks. Further-more, as nodes are energy constrained, frequently receiving data from common nodes and forwarding them to base station will consume a large amount of energy on cluster heads. EECSIA has avoided this problem, and it can achieve re-clustering within constant time in a local manner. Message communication is very large for cluster head selection which is more energy consumable.

Fault Tolerant Energy Efficient Distributed Clustering for WSN (FEED)

M. Mehrani et al. [38] proposed an energy efficient clustering method, which select suitable cluster heads by using energy, density, centrality and the distance between nodes for making cluster. Authors have taken a supervisor node for every cluster head which is to be its replacement when the cluster head fails. This property causes an increase in network lifetime and also helps the network to be fault tolerant. It requires the global position of sensor nodes and message communication is very large in cluster head selection, which is costly and energy consumable respectively.

A location Based Clustering Algorithm for Wireless Sensor Networks (LBS)

Ashok Kumar et al. [39] proposed a protocol to prolong the lifetime of sensor network. The clusters are formed only once during the lifetime of sensor network. Cluster heads rotation depends on the residual energy of a cluster heads. The rotation frequency timing of cluster head is based on energy consumption of sensor nodes for various tasks performed by them during the lifetime of sensor network. This ensures balanced energy consumption of all sensor nodes present in a cluster, resulting in prolonged network lifetime. The proposed protocol is static in nature, cluster head selection procedure is not well in term of energy consumption. Load balancing is unevenly distributed, so all these lead to poor stability period.

Node degree based clustering for WSN.

Sanjeev Kumar Gupta et al. [38] propose Node Degree Based Clustering (NDBC) for enhancing life time of heterogeneous WSNs. In this paper, authors use two types of sensor nodes, i.e., advanced and normal nodes. Advance nodes are having more energy than normal nodes. The advanced nodes are selected as cluster head based on its energy and node degree in the network. Using NDBC authors have reduced communication cost among sensor nodes used for transmitting and receiving the messages for cluster head selection.

V. CONCLUSION

The life time and reliability of the network can be improved by heterogeneity in wireless sensor networks. Clustering is a good technique to reduce energy consumption and to provide stability in wireless sensor networks. To operate under heterogeneous wireless sensor networks, several protocols are proposed. Most of the recent energy efficient protocols designed for heterogeneous networks are based on the clustering technique, which are effective in energy saving for wireless sensor networks.

Table1. Comparison of the Clustering Protocols for Wireless Sensor Networks

Clustering Approach	Clustering Method(Distributed(D),Centralized (c), Hybrid(H)	Location Awareness[Yes(Y),No(N)]	Heterogeneity Level	Cluster head Mobility [Fixed(F),Mobile(M)]	Connectivity of CH to Bs	Intra-Cluster Topology	Cluster Count [Variable(V), Fixed(F)]	Pure Probability(Y/N)	Neighbor(Y/N)
LEACH	D	N	-	F	Direct Link	Single Hop	V	Y	-
LEACH-C	C	N	-	F	Direct Link	Single Hop	V	Y	-
SEP	D	N	Two	F	Direct Link	Single Hop	V	-	-
HEED	D	N	-	F	Direct Link	Single Hop	V	Y	-
DWEHC	D	N	-	F	Direct Link	Single Hop	V	-	-
HSR	D	Y	Two/Multi	F	Multi Hop	Multi Hop	V	-	-
DEEC	D	N	Two/Multi	F	Direct Link	Single Hop	V	-	-
DEBC	D	N	-	F	Direct Link	Single Hop	V	-	-
UCR	D	N	Multi	F	Multi Hop	Single Hop	V	Y	-
C4SD	D	Y	-	M	Multi Hop	Multi Hop	V	-	-
TBC	D	Y	-	F	Multi Hop	Multi Hop	V	-	Y
PRODUCE	D	Y	-	F	Direct Link	Single Hop	V	-	-
EDBC	D	Y	-	F	Direct Link	Single Hop	V	-	-
DCLB	C	Y	-	F	Multi Hop	Single Hop	V	-	Y
Improved LEACH	D	N	-	F	Direct Link	Single Hop	V	Y	-
EEHC	D	N	Three	F	Direct Link	Single Hop	V	-	-
SDEEC	D	N	Two	F	Direct Link	Single Hop	V	-	-
SBDEEC	D	N	Two	F	Direct Link	Single Hop	V	-	-
DCHE	D	N	Three	F	Direct Link	Single Hop	V	-	-
TDEEC	D	N	Two/Multi	F	Direct Link	Single Hop	V	-	-
DDEEC	D	N	Two	F	Direct Link	Single Hop	V	-	-
DDCHS	D	Y	-	F	Direct Link	Single Hop	V	-	Y
EECS	D	N	-	F	Direct Link	Single Hop	V	-	-
MNCP	D	N	-	M	Direct Link	Single Hop	V	-	-
IB-LEACH	D	N	-	F	Direct Link	Single Hop	V	Y	-
EECSIA	D	N	-	F	Direct Link	Single Hop	V	-	Y
FEED	D	N	-	F	Direct Link	Single Hop	V	-	Y
ECLCM	D	N	-	F	Multi Hop	Multi Hop	V	Y	-
WEP	D	N	Two	F	Direct Link	Single Hop	V	-	-
LBC	C	Y	-	F	Direct Link	Single Hop	F	-	-
ECBDA	H	N	-	F	Multi Hop	Single Hop	V	-	-
DCEBC	D	N	Two	F	Single Hop	Single Hop	V	-	Y
NDBC	D	N	Two	F	Single Hop	Multi Hop	F	-	Y

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