

A Survey on Clustering Algorithms for Heterogeneous Wireless Sensor Networks

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ABSTRACT

Potential use of wireless sensor networks (WSNs) can be seen in various fields like disaster management, battle field surveillance and border security surveillance since last few years. In such applications, a large number of sensor nodes are deployed, which are often unattended and work autonomously. Clustering is a key technique used to extend the lifetime of a sensor network by reducing energy consumption. It can also increase network scalability. Sensor nodes are considered to be homogeneous since the researches in the field of WSNs have been evolved, but some nodes may be of different energy to prolong the lifetime of a WSN and its reliability. In this paper, we study the impact of heterogeneity of nodes to the performance of WSNs. This paper surveys different clustering algorithms for heterogeneous WSNs by classifying algorithms depending upon various clustering attributes.

Keywords - Clustering, Sensor nodes, Energy efficiency, Homogeneous, Heterogeneity, Stability, WSN.

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1. Introduction

With the advances in the technology of micro-electromechanical system (MEMS) and developments in wireless communications, wireless sensor networks have emerged [1]. In past few years, wireless sensor networks (WSNs) have become one of the most interesting areas of research. A WSN is composed of a number of wireless sensor nodes which form a sensor field and a sink. These large numbers of nodes with low-cost, low-power, and capable of communication at short distances perform limited computation and communicate wirelessly from the WSNs [2]. Specific functions such as sensing, tracking and alerting [3] can be obtained through cooperation among these nodes. These functions make wireless sensors very useful for monitoring natural phenomena, environmental changes [4], controlling security, estimating traffic flows, monitoring military application [5], and tracking friendly forces in the battlefields. These tasks require high reliability of the sensor networks. To make sensor networks more reliable, the attention to research on heterogeneous wireless sensor networks has been increasing in recent past [6-9].

Clustering is a key technique used to extend the lifetime of a sensor network by reducing energy consumption [10]. A sensor network can be made scalable by forming clusters. Leader of the cluster is often referred to as the cluster-head (CH). A CH may be elected by the sensors in a cluster or pre-assigned by the network designer. Various clustering algorithms have been specifically designed for WSNs for scalability and efficient communication. The concept of cluster based routing is also utilized to perform energy-efficient routing in WSNs. In a hierarchical architecture, higher energy nodes (cluster heads) can be used to process and send the information while low energy nodes can be used to perform the sensing. LEACH [11], PEGASIS [12], TEEN [13] and APTEEN [14] are some of the clustering algorithms.

Clustering Advantages

1. Clustering reduces the size of the routing table stored at the individual nodes by localizing the route set up within the cluster [15].
2. Clustering can conserve communication bandwidth since it limits the scope of inter-cluster interactions

to CHs and avoids redundant exchange of messages among sensor nodes [16].

3. The CH can prolong the battery life of the individual sensors and the network lifetime as well by implementing optimized management strategies [16].
4. Clustering cuts on topology maintenance overhead. Sensors would care only for connecting with their CHs [17].
5. A CH can perform data aggregation in its cluster and decrease the number of redundant packets [18].
6. A CH can reduce the rate of energy consumption by scheduling activities in the cluster.

Sensor nodes are considered to be homogeneous since the researches in the field of WSNs have been evolved, but in reality, homogeneous sensor networks hardly exist. Even homogeneous sensors have different capabilities like different levels of initial energy, depletion rate, etc. In heterogeneous sensor networks, typically, a large number of inexpensive nodes perform sensing, while a few nodes having comparatively more energy perform data filtering, fusion and transport. This leads to the research on heterogeneous networks where two or more types of nodes are considered. The life time and reliability of the network can be improved by heterogeneity in wireless sensor networks. Heterogeneous sensor networks are very much useful in real deployments because they are more close to real life situations [19, 20].

Most of the recent energy efficient protocols designed for heterogeneous networks are based on the clustering technique, which are effective in scalability and energy saving for WSNs. In this paper, we provide a complete survey of literature on heterogeneous wireless sensor networks (HWSNs). We also summarize and categorize clustering algorithms, stating their features and shortcomings.

Rest of the paper is organized as follows. Section 2 and Section 3 describe the heterogeneous model for wireless sensor networks and classification of clustering attributes respectively. In Section 4 we present a survey of clustering algorithms for heterogeneous wireless sensor networks with comparison among them and classify depending upon clustering attributes described in section 3. Lastly, Section 5 concludes the survey work.

2. Heterogeneous Model for Wireless Sensor Networks

This section presents a paradigm of heterogeneous wireless sensor network and discusses the impact of heterogeneous resources [21].

2.1 Type of Resource Heterogeneity

There are three common types of resource heterogeneity in sensor nodes: computational heterogeneity, link heterogeneity and energy heterogeneity.

- **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.

- **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.

- **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.

2.2 Impact of Heterogeneity on Wireless Sensor Networks

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

2.2.1 Response time: Computational heterogeneity can decrease the processing latency and link heterogeneity can decrease the waiting time, hence response time is decreased.

2.2.2 Lifetime: The average energy consumption will be less in heterogeneous sensor networks for forwarding a packet from the normal nodes to the sink, hence life time is increased.

Further, it is also known that if in a network, heterogeneity is used properly then the response of the network is tripled and the network's lifetime can be increased by 5-fold [21].

2.3 Performance measures

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

2.3.1 Network lifetime: It is the time interval from the start of operation (of the sensor network) until the death of the first alive node.

2.3.2 Number of cluster heads per round: Instantaneous measure reflects the number of nodes which would send directly to the sink, information aggregated from their cluster members.

2.3.3 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.

2.3.4 Throughput: This includes the total rate of data sent over the network, the rate of data sent from cluster heads to the sink as well as the rate of data sent from the nodes to their cluster heads.

3. Classification of Clustering Attributes

Network architectural parameters like in-network data processing, node deployment and capabilities are best described in [22]. Clustering objectives like load balancing and fault-tolerance, increased connectivity, reduced delay, minimum cluster count, maximal network longevity are also described with reference to the homogeneous wireless sensor networks. Abbasi *et al.* [22] also presented a classification of clustering attributes as clustering properties, cluster head capabilities and clustering process. Our survey of heterogeneous clustering algorithms is also based on some of the attributes described in [22].

Here we summarize the set of attributes that can be used to categorize and differentiate clustering algorithms of HWSNs.

3.1 Cluster properties

Quite often, clustering schemes strive to achieve some characteristics for the generated clusters. Such characteristics can be related to the internal structure of the cluster or how it relates to others. The following are the relevant attributes:

- **Cluster Count:** CHs are predetermined in some of the published approaches [23, 24, 27, 29], thus, the number of clusters is preset. CH selection algorithms generally pick randomly CHs from the deployed sensors hence yields variable number of clusters.
- **Intra-cluster Topology:** Some clustering schemes are based on direct communication between a sensor and its designated CH, but sometimes multi-hop sensor-to-CH connectivity is required.
- **Connectivity of CH to BS:** CHs send the aggregated data to the BS directly or indirectly with help of other CH nodes. It means, there exists a direct link or a multi-hop link.

3.2 Cluster-head Capabilities

The following attributes of the CH node are differentiating factors among clustering schemes:

- **Mobility:** CH may be stationary or mobile. In most cases, they are stationary. But sometimes, CHs can move within a limited region to reposition themselves for better network performance.
- **Node Types:** Generally sensor nodes among the deployed sensors are designated as CHs, but sometimes sensor nodes equipped with significantly more computation and communication resources are selected as CHs.

- **Role:** Some of the main roles of the CHs are simply relaying the traffic, aggregation or fusion of the sensed data.

3.3 CH Selection Criteria

- **Initial Energy:** This is an important parameter to select the CH. When any algorithm starts it generally considers the initial energy.
- **Residual Energy:** After some of the rounds are completed, the cluster head selection should be based on the energy remaining in the sensors.
- **Energy Consumption Rate:** This is another important parameter that considers the energy consumption rate $V_i(t)$ based on following formula:

$$V_i(t) = \frac{E_{initial} - E_i(t)}{r - 1}$$

Where $E_{initial}$ and $E_i(t)$ are the initial energy and residual energy of each node respectively and r is the current round.

- **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.

The above listed clustering attributes are used to classify the clustering algorithms in the next section.

4. Clustering Algorithms for HWSNs

A WSN is composed of hundreds of sensor nodes distributed randomly. Clustering is one of the best ways to extend the lifetime of a sensor network by reducing energy consumption. It can also increase network scalability and lifetime. In this section, we present a literature survey of distributed algorithms for clustering in WSNs. Clustering algorithms for HWSNs should be energy efficient to take the advantages of node heterogeneity. Clustering algorithms in this paper are classified based on two main criterions: according to the stability and energy efficiency. Selection of cluster head in energy efficient techniques generally depends on the initial energy, residual energy, average energy of the network, or energy consumption rate or combination of these. The stable election protocols for clustered HWSN prolong the time interval before the death of first node i.e. stability period.

4.1 Stability-Oriented Clustering Protocols for HWSNs

The protocols discussed below increase the stability period of wireless sensor networks. Stability period is actually the time interval before the death of the first node. It is very important for the applications where the response from the sensor nodes must be reliable. Protocols surveyed in this category are: SEP [25],

EDFCM [26], Base-station initiated clustering [27], and ZREECR [29].

Stable Election Protocol for Clustered HWSNs: Smaragdakis G. *et al.* [25] describe the impact of heterogeneity on the heterogeneous-oblivious protocols and instability of the protocols like LEACH, in the presence of heterogeneity, once some nodes die. The authors describe the problems that can occur due to heterogeneity of nodes. They propose Stable Election Protocol (SEP) [25], a heterogeneity-aware protocol. It does not require energy knowledge sharing but is based on assigning weighted election probabilities of each node to be elected cluster head according to their respective energy. By using this approach, authors ensure that the cluster head is randomly selected based on the fraction of energy of each node; this assures that each node's energy is uniformly used. In SEP, two types of nodes (normal and advanced) are considered. It is based on weighted election probabilities of each node to become cluster head according to the remaining energy in each node. This prolongs the stability period i.e. the time interval before the death of the first node.

The problem that arises with the heterogeneity-oblivious protocols is that if the same threshold is set for both normal and advanced nodes then there is no guarantee that the number of cluster heads per round per epoch will be $n \times p_{opt}$. SEP uses the following characteristic parameters of heterogeneity, namely the fraction of advanced nodes (m) and the additional energy factor between advanced and normal nodes (α). SEP talks about the fairness constraint on energy consumption i.e. advanced node get the chances to become the CH more often than the normal nodes.

The solution of SEP is more applicable compared to any solution which assumes that each node knows the total energy of the network in order to adapt its election probability to become a cluster head according to its remaining energy. In this approach, a weight is assigned to the optimal probability p_{opt} . This weight must be equal to the initial energy of each node divided by the initial energy of the normal node. Let p_{nm} and p_{adv} be the weighted election probability for normal nodes and the advanced nodes respectively. In order to maintain the minimum energy consumption, the average number of cluster heads per round per epoch must be constant and equal to $n \times p_{opt}$.

Virtually, there are $n \cdot (1 + \alpha \cdot m)$ nodes with energy equal to the initial energy of a normal node. In the heterogeneous scenario, the average number of cluster heads per round per epoch is equal to $n \cdot (1 + \alpha \cdot m) \cdot p_{nm}$. The weighed probabilities for normal and advanced nodes are, respectively:

$$P_{nm} = \frac{P_{opt}}{1 + \alpha \cdot m}$$

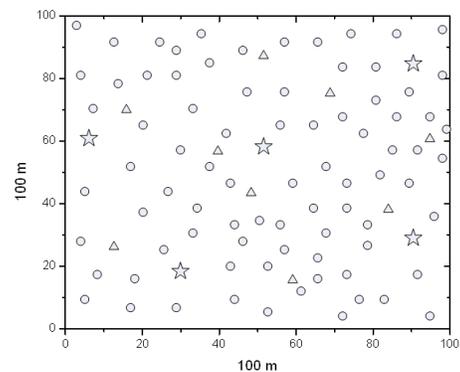
$$P_{adv} = \frac{P_{opt}}{1 + \alpha \cdot m} (1 + \alpha)$$

With help of these weighted probabilities thresholds for normal nodes and advanced node can be calculated.

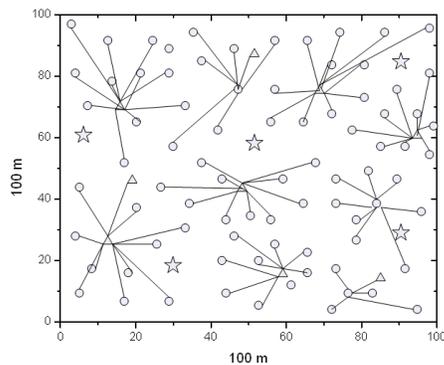
In most rounds, no cluster head is selected by SEP. In such rounds where no CH is selected, the data packets cannot be transmitted to the base station. This is a great disadvantage to the reliable transmission in the networks, especially for some important real-time transmission tasks.

Novel Stable Selection and Reliable Transmission Protocol for Clustered HWSN: H. Zhou *et al.* [26] propose a model of energy and computation heterogeneity for heterogeneous wireless sensor networks. They also propose a protocol named Energy Dissipation Forecast and Clustering Management (EDFCM) for HWSNs. This algorithm balances the energy consumption round by round, which will provide the longest stability period for network. The heterogeneous model they consider is composed of three types of nodes including Type_0, Type_1 and some management nodes as shown in Fig. 1. Type_0 and Type_1 nodes vary in capabilities of sensing, energy and software. They have the responsibility of sensing events, while the management nodes perform management of both types of nodes during cluster formation. EDFCM is specially proposed for heterogeneous networks to provide the longer lifetime and more reliable transmission service.

Unlike the other energy efficient protocols, the process of cluster head selection in EDFCM is based on a method of one-step energy consumption forecast. It uses the average energy consumptions of the two types of cluster heads in previous round for this purpose. The more remaining energy in a node after the operation of next round, higher the chances of node to be selected as a cluster head.



(a) Network Structure.



(b) Clustering in EDFCM [26].

Fig. 1. Type 1 and Type 2 nodes are shown by circle and triangle respectively and management nodes by star.

In EDFCM protocol, the operation of network can be divided into two phases: cluster formation phase and data collecting phase. Cluster formation phase of EDFCM is very similar to that of LEACH, but there are two differences:

- (i) The selection probability is a weighted function.
- (ii) It guarantees a stable number of cluster heads each round.

Base Station Initiated Dynamic Routing Protocol: S. Verma *et al.* [27] propose a routing protocol that is based on clustering and uses heterogeneity in nodes to increase the network lifetime. In this scheme, some nodes which are stronger than other nodes in terms of power, computational capability and location awareness, work as the cluster heads. They forward information to their parents, towards the base station by aggregating all the information from their clusters members.

Following assumptions are considered in this scheme: all nodes are deployed uniformly in the field and CHs will be assumed dead only when their energy is very less. There is no collision between inter cluster and intra cluster communication. Transmission power of the CH is adjusted in such a way that only single hop broadcast is possible. In this algorithm, how far a CH is from the BS, is defined as level. Low level means that CH is near to the BS and if level is high it means CH is away from BS accordingly. Data flow will be always from higher level to lower level. Decision of levels by base station is based on the range of the CH and normal node. Ranges of all the nodes are enough to ensure the connectivity and coverage.

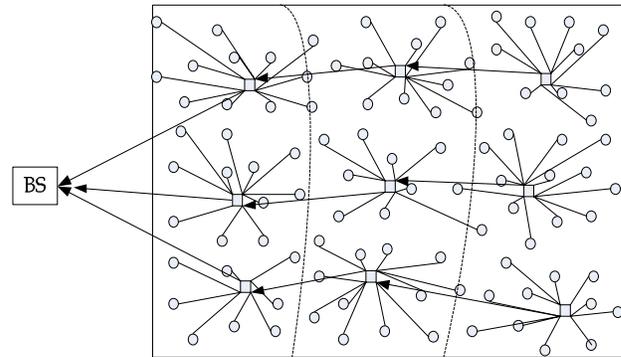


Fig. 2. Cluster hierarchy in sensing field [27].

Structure of the network considered in this approach is shown in Fig. 2. BS sets its level to zero and broadcasts a packet to initiate the scheme. Base station mentions that this packet is only for CHs. Since the CHs have different signal strength from normal nodes, they receive the packet and set their levels accordingly. When the CHs of first level are selected, they broadcast their level. CHs at lower level receive the packet according to the signal strength. They choose their parent from upper level CHs only. This process is repeated again and again until all CHs are connected. CH now broadcast a message that all sensor nodes should join the CH according to the RSS (Radio Signal Strength). Communication between CH and sensing nodes is single hop, while communication between different CH is multiple hops. All CHs send their position, level and energy consumption to the BS at the end of the round. BS then analyzes the energy consumption of different CH at the same level.

Routing Protocol for Balancing Energy Consumption in HWSN: Li X. *et al.* [29] developed and analyzed a protocol based on residual energy and energy consumption rate (REECR). This protocol is an improvement of the previous work by the same authors [28]. They presented the protocol based on the REECC rather than periodic rotation and stochastic election. REECC protocol was not perfect in balancing the energy and stability of network, so they proposed a zone based improvement of this REECC protocol, naming ZREECC [29] (Zone-Based Residual Energy and Energy Consumption Rate). This protocol improves the stability period. The problem that is considered in this work is that the cluster head may be very near or very far from BS. In such a case, balancing the energy consumption is a very tough task and leads to instability.

To solve this problem, the authors propose a zone based solution named ZREECC. This protocol divides the network into fixed-size zones, depending upon distance and orientation from base station as shown in Fig. 3. There are 12 fixed size zones that are shown in the Fig. 3. It is expected that clusters near to the BS have smaller cluster sizes because CHs have to relay the data from the

farther CHs to the BS. In this way CHs will save some significant amount of energy in intra-cluster data processing as well as inter-cluster relay traffic.

The heterogeneous model of the network considers two type of node varying in energy; type_0 and type_1. In the first round the CHs are selected at geometric centers of the zones.

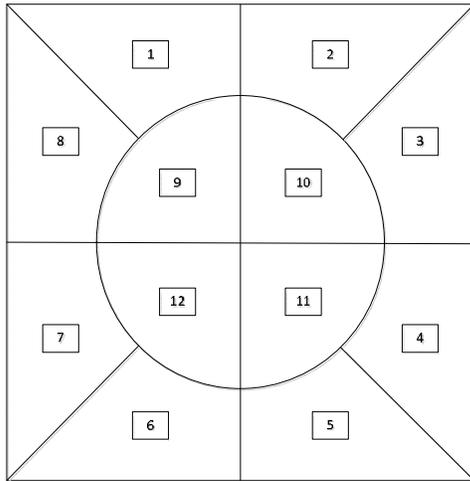


Fig. 3. A schematic diagram of different size zones [29].

This avoids the situation of the very near and very far node to become CH. But in the second round the selection of the CH in each zone based on residual energy and energy consumption rate as follows:

$$P_i(t) = \frac{E_i^\alpha(t)}{V_i^\beta(t)}$$

Where $P_i(t)$ is the possibility of each node to be selected as a cluster-head in each zone, and α are β weight coefficients. $E_i(t)$ is the current residual energy of each node and $V_i(t)$ is the energy consumption rate of each node. CHs collect the data from all sensor nodes in the network, aggregate it and send it to the BS. While forwarding the data to the BS every CH selects the closest CH in the direction of the BS.

Although the authors presented an improvement in their work but this protocol is not energy efficient, compared to the previous one because the selection of the CH is done locally on zone level, and not on the network level; but on the other hand it is more stable than REECR.

4.2 Energy-Efficient Clustering Protocol for HWSNs

The concept of cluster based routing is also utilized to perform energy-efficient routing in WSNs. Efficient organization of sensor nodes into clusters is useful in reducing energy consumption in WSNs. Many energy-efficient routing protocols are designed based on the clustering structure of HWSNs [30-33]. Each clustering algorithm has mainly two phases: the cluster setup phase and steady state phase. For heterogeneous WSNs, a very critical task for clustering protocols is to select the cluster head so that least energy is consumed, and hence prolong

the lifetime. In this section, we look into various energy-efficient cluster head selection protocols for HWSNs like EEHC [34], DEEC [36], SDEEC [37], DBEC [38] and C4SD [39].

Energy Efficient Heterogeneous Clustered Scheme: Dilip and Patel [34, 35] proposed an energy efficient clustered scheme for HWSNs based on weighted election probabilities of each node to become cluster head. It elects the cluster head in distributed fashion in hierarchal WSN. This algorithm is based on LEACH (Low Energy Adaptive Clustering Hierarchy) [11], the most popular clustering protocol in WSN. In the LEACH algorithm, there is an optimal percentage p_{opt} of nodes that has to become cluster head in each round. This algorithm works on the election processes of the cluster head in presence of heterogeneity of nodes. Fig. 4. shows heterogeneity of the network, the snapshots when all nodes are alive and how the normal nodes die after some rounds.

Distributed Energy-Efficient Clustering Algorithm for HWSN: Qing, Zhu, and Wang [36] proposed DEEC; a distributed multilevel clustering algorithm for heterogeneous wireless sensor networks. DEEC selects the cluster-heads with the help of probability based on the ratio between residual energy of each node and the average energy of the network. How long different nodes would be cluster-heads, is decided according to the initial and residual energy. The authors assume that all the nodes of the wireless sensor network are equipped with different amount of energy, which is a source of heterogeneity.

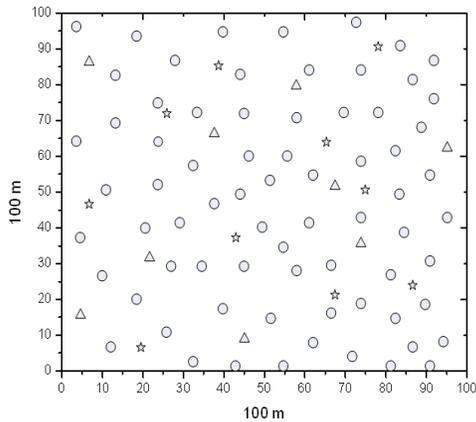
DEEC is also based on LEACH; it rotates the cluster-head role among all nodes to expend energy uniformity. Two levels of heterogeneous nodes are considered in this algorithm and after that a general solution for multi-level heterogeneity is obtained.

Working of DEEC is as follows: all the nodes need to know the total energy and lifetime of the network. Average energy of the network is used as the reference energy. Thus, DEEC does not require any global knowledge of energy at every election round. When a new epoch begins, each node s_i computes the average probability p_i by the total energy E_{total} , while estimate value R of lifetime is broadcasted by the base station. Now p_i is used to get the election threshold $T(s_i)$. This threshold decides node s_i to be a cluster-head in the current round.

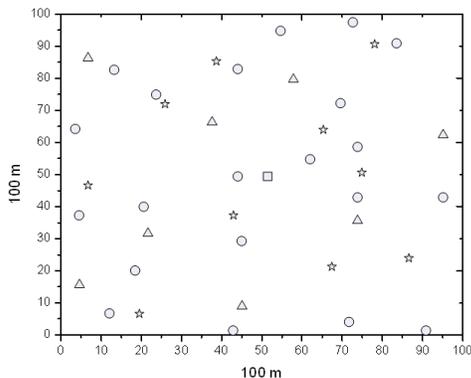
An improvement of this algorithm is proposed as Stochastic DEEC [37] by Elbhiri, Saadane, and Aboutajdine. The cluster head selection in overall network is based on nodes' residual energy in the Stochastic Energy-Efficient Clustering (SDEEC). This protocol is based on DEEC with new strategies. The Stochastic strategy is the key idea where the intra-clusters transmission is reduced. Like DEEC, this

approach considers the two-level heterogeneity, but it conserves energy by making non-CH nodes sleep, unlike DEEC. This protocol divides the network into dynamic clusters.

According to the protocol, all non-CH nodes send data to respective CHs in their allocated transmission time. The CH node must keep its receiver on, in order to receive all the data from the nodes in the cluster. Some signal processing is performed by CH to compress the data into a single signal when all the data is received. After this phase, each CH sends the aggregated data to its prime CH. Each non-CH can turn off to the sleep mode to conserve the energy. The drawback in the protocol is that if non-CH nodes turn off to the sleep mode when CH is performing aggregation, how they will come to know about the next round of CH selection.



(a) Network Structure.



(b) Network after some rounds.

Fig. 4. Normal, advanced and super nodes are shown by circle, triangle and star respectively [34].

Distributed Energy Balance Clustering Protocol for HWSNs: In Distributed Energy-Balance Clustering algorithm (DEBC) [38], a probability based clustering algorithm was proposed by Changmin Duan and Hong Fan. DEBC elects cluster heads based on the knowledge of the ratio between remaining energy of node and the average energy of the network. This protocol also considers two-level heterogeneity and then it extends the results for multi-level heterogeneity. DEBC is different from LEACH, which make sure each node can be cluster head in each $n_i=1/p$ rounds. DEBC chooses n_i according to the node i and remaining energy E_i^k in round k . p_i denotes the probability of node i being cluster head in each n_i rounds. With the help of p_i probabilities for advanced and normal nodes to be CH can be calculated and this can be further extended to multi-level heterogeneity.

Cluster-Based Service Discovery for Heterogeneous Wireless Sensor Networks: Marin *et al.* [39] proposed an energy efficient cluster-based service discovery protocol (C4SD) for HWSNs. The problem addressed in this paper is to design a service discovery protocol that is suitable for heterogeneous WSNs and reduces the workload of the resource constrained devices. Authors proposed a cluster based solution, where a set of nodes are selected, based on their capabilities. In this algorithm each node is assigned a unique hardware identifier and weight (capability grade). Higher the capability grade more suitability for CH role. These nodes act as a distributed directory of service registrations for the nodes in the cluster. Since the service discovery messages are exchanged only among the directory nodes and the distribution of workload according to the capabilities of the nodes, the communication costs are reduced. The proposed clustering algorithm reacts rapidly to topological changes of the sensor network by making decisions based only on the 1-hop neighborhood information, avoids chain reactions and constructs a set of sparsely distributed CHs. The clustering algorithm is simulated and compared with distributed mobility adaptive clustering (DMAC) [40]. The result shows that it outperforms DMAC.

Table I compares the various clustering algorithms discussed above on various points like energy efficiency, location awareness, cluster stability, clustering methodology, heterogeneity level and balance clustering. Table II classifies the algorithms based on clustering attributes discussed in section 3.

TABLE I
 Comparison of the Clustering Algorithms for HWSN

Clustering Approach	Energy Efficient	Location Awareness	Balanced Clustering	Cluster Stability	Heterogeneity Type	Clustering Methodology	Heterogeneity Level
SEP [25]	Low	No		Good	Energy	Distributed	Two
EDFCM [26]	Low	Yes	Yes	Very Good	Computational and Energy	Distributed	Three
BS Initiated Clustering [27]	Low	Yes	OK	Good	Computational and Energy	Centralized	Two
ZREECR [29]	Low	Yes	Yes	Good	Computational and Energy	Centralized	Two
EEHC [34]	High	No	Yes	Moderate	Energy	Distributed	Three
DEEC [36]	High	No	Yes	Moderate	Energy	Distributed	Two
SDEEC [37]	High	No	Yes	Good	Energy	Distributed	Two
DEBC [38]	High	No	Yes	Good	Energy	Distributed	Two/Multi
C4SD [39]	High	Yes	No	Moderate	Energy and Link	Centralized	Multi

TABLE II
 Classification of Surveyed Algorithms Based on Clustering Attributes

Clustering Approach	Clustering Properties			Cluster Head Capability			CH Selection based On			
	Cluster Count	Intra-cluster Topology	Connectivity of CH to BS	Mobility	Node Type	Role	Initial Energy	Residual Energy	Energy Consumption Rate	Average Energy of Network
SEP [25]	variable	Fixed(1-hop)	Direct Link	Fixed	Sensor	Aggregation	X	√	X	X
EDFCM [26]	variable	Fixed(1-hop)	Direct Link	Fixed	Sensor	Aggregation	X	√	X	X
BS Initiated Clustering [27]	Fixed	Fixed(1-hop)	Multi-hop	Fixed	Resource rich	Aggregation, Compression	√	X	X	X
ZREECR [29]	Fixed	Fixed(1-hop)	Multi-hop	Fixed	Sensor	Aggregation	X	√	√	X
EEHC [34]	variable	Fixed(1-hop)	Direct Link	Fixed	Sensor	relaying	X	√	X	X
DEEC [36]	variable	Fixed(1-hop)	Direct Link	Micro-mobile/fixed	Resource rich	Aggregation	X	√	X	√
SDEEC [37]	variable	Fixed(1-hop)	Direct Link	Micro-mobile/fixed	Resource rich	Aggregation	√	√	X	X
DEBC [38]	variable	Fixed(1-hop)	Direct Link	Micro-mobile/fixed	Resource rich	Fusion, relaying	X	√	X	√
C4SD [39]	variable	Multi-hop	Multi-hop	Mobile	Resource rich	Relaying	√	X	X	X

5. Conclusion

Wireless sensor networks are not always homogeneous, they may be heterogeneous too. This paper surveys research protocols for clustering in heterogeneous wireless sensor networks. Clustering is a good technique to reduce energy consumption and to provide stability in wireless sensor networks. We classified all protocols according to stability and energy efficiency of network. We summarize a number of schemes, stating their strengths and limitations. Finally on the basis of survey work, we conclude that the heterogeneous wireless sensor networks are more suitable for real life applications as compared to the homogeneous counterpart.

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