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REVIEW ARTICLE

Systematic Review of Stable Election Protocols Variants

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ABSTRACT

Energy management is one of the critical parameters in large scale WSN. If an individual node in the network communicates and forwards its data directly to BS, there is a maximum probability of network congestion and data collisions. As the sensor nodes have limited battery power, it will result in energy depletion faster and will degrade the overall network lifetime. To optimize the network life and management strategies certain goals like, prolonged network lifetime, scalability, coverage and network simplicity are desirable. To achieve these goals, it is essential to propose an efficient and scalable network layer protocol. To address the above-mentioned issues clustering protocol has been proposed by various researchers. Clustering protocols provide the solution to utilize the network energy uniformly to enhance the network lifetime, maximize the packet delivery ratio and throughput as well clustering of nodes avoids long-distance communication of nodes to BS. Many novel techniques have been proposed by the researchers related to heterogeneous sensor networks and have made their best efforts to overcome the challenges and obstacles but somewhere these theoretically proposed protocols lack deficiencies. In this paper, we have investigated a different variant of Stable Election Protocol which was proposed by various researchers in terms of stable and unstable regions and the number of cluster heads per round.

Keywords: HWSN, Energy, Clustering, Heterogeneous, Cluster Head, Residual Energy

Author`s Contribution	Address of Correspondence	Article info.
[1,4]Manuscript writing, Data Collection Data analysis, interpretation, Conception, synthesis, planning of research, and discussion	*Shahzad Hussain shassan.buic@bahria.edu.pk*	*Received: Nov 17, 2018 Accepted: April 27, 2019 Published: June 30,2019*

Cite this article: *Hassan S,Ahmad M. Systematic Review of Stable Election Protocols Variants .J. Inf. commun. technol. robot. appl.2019; 10(1):19-34.*

Funding Source: *Nil*
Conflict of Interest: *Nil*

INTRODUCTION

WSNs have expanded incredible increase in the previous era and they implemented numerous features of wireless ad hoc networks such as infrastructure-less deployment, and self-organization able and self-healing. These features are suitable where the situation for an immovable infrastructure network is not feasible. However WSNs have evolved to be attractive and they clutch countless potentials for our forthcoming, several trails are essential to be addressed. A couple of the well-known trials are accredited to issues relating to QoS, computation, coverage area, deployment, energy efficiency and scalability [1].

Wireless sensor networks are composed of small sensor nodes with limited battery power which senses the data and forwards it to the base station (BS) for further processing. The WSNs comprises a couple of hundreds to thousands of nodes spread randomly or statically in a specified area. The data transmission and reception are done over a wireless channel by using a built-in dedicated radio. Most of the energy of the nodes is utilized in transmitting or receiving data. In certain applications, the WSN the nodes are organized in harsh and hostile environments and remain unattended and it is desired that the network must be able to function for extended period of time which makes the energy utilization of both the overall network and network nodes more significant thus the energy consumption of WSN is a crucial issue. Numerous popular methods have been suggested to consume network energy efficiently [2, 3].

The clustering method is among them [4-7]. In clustering protocol Cluster Head (CH) plays the key role. The CH is selected among the existing sensor nodes and the eligibility conditions of CH differ from algorithm to algorithm but all researchers aim to diminish the energy consumption and prolong the network lifetime. Generally, the CH interconnects with its members with the same cluster for data transmission and then forwards the aggregated data to the base station (BS) [12-13].

Clustering has been extensively adopted by the investigators whether it is geometric routing [8], grid-based routing [9], homogenous routing [10] or heterogeneous routing [11]. In [16] has introduced energy heterogeneity to prolong stability period before the expiry of the first network node, which plays a critical role for certain applications in which the response from the network must be consistent. In SEP the cluster head selection is centered on the weighted probability of individual nodes related to remaining energy. The downside of SEP is advanced nodes. Advanced nodes have extra energy and their probability to be selected as CH is higher concerning the normal node which results in higher energy depletion and at a certain stage the energy of them becomes equal to the normal nodes but still, the probability of advance nodes to be elected as CH is maximum. In [17] the author has proposed a horizontal intra-layer and vertical inter-layer optimization technique to find the global minima, which involves a minimized number of repetitions as compared to traditional single-layer realization of HWSN. Additionally, cooperation amongst nodes is considered transmitting data to the fusion Center receiver to improve transmission reliability in variable transmission channel conditions.

A dynamic cluster head selection method is presented in this article which minimizes the overhead within the intra-cluster communication and reduces the non-uniform energy utilization. Subsequently, the proposed article delivers an energy effective solution for HWSNs to boost the life-time of the network. In [62] the author proposed a hybrid two-level protocol heterogeneous protocol. The protocol adopts the best features of [63] and [64] Protocols. Singh et al. discuss a novel energy-efficient clustering protocol (NEECP) for increasing the network lifetime in WSNs [21-65]. This technique effectively selects the cluster heads with an adjustable sensing range and performs data aggregation using a chaining approach. It also avoids the transmission of redundant data by using a redundancy check function for improving the network lifetime. It is implemented by considering the data with aggregation and without aggregation.

In [27-66] the author has adopted a hierarchical agglomerative clustering (HAV) protocol for cluster head selection. It is the two-step process the cluster is formed by implementing HAC on the network nodes and Euclidean distance amongst nodes. The election of the CHs is based on the closeness with a virtual node representing the optimum head site concerning energy ingesting. The protocol is re-executed after each round to balance the energy utilization of the network nodes. on lifetime maximization of HWSN with the multi-layer realization [25-67]

A dynamic cluster head selection method is presented in this article which minimizes the overhead within the intra-cluster communication and reduces the non-uniform energy utilization. Subsequently, the proposed article delivers an energy effective solution for HWSNs to boost the life-time of the network.

Heterogeneity might be a consequence of stimulating the network by adding additional nodes equipped with high energy to boost the lifetime of the network. Nodes in existing routing algorithms cannot expend their energy uniformly due to various reasons e.g. due to intra-cluster communication, etc. The lifetime of the proposed protocols changes by altering changing the cluster head selection criteria. The response of every protocol changes with changing heterogeneity parameters. The performance comparison has been presented at the end of some selected protocols with respect to the cluster head selection this paper we have analyzed different variants of SEP protocols which are VCHSEP, SEP-E,

DB-SEP, T-SEP, H-SEP, SEP-FL, M-SEP, ECR-SEP, MSE, A-SEP, EM-SEP, K-SEP, SEP-E (RCH),G-SEP, ZSEP, ELBSEP, DSEP-FL, BEECP, DTRE-SEP, ZBHCF, DEEC, DDEEC, TDEEC, EDEEC and EESA

CLUSTRING OBJECTIVES

2.1. **Load Balancing Partition:** the network into equal size of the cluster can greatly improve the time-period. Due to the unbalance size of the cluster, the network performance can be degraded. Since the CH performs multiple tasks and data aggregation due to which the energy of the CH is depleted rapidly as compared to other nodes. It is very important to balance the load between them to achieve the desired performance objectives. Load balancing is a critical factor in clustering [14], where CH is randomly selected from the network nodes [10]. Besides load, balancing the rotation of CH also helps in fault tolerance [8].

2.2. **Fault Tolerance:** In certain applications, nodes are organized in a harsh environment due to which the nodes are exposed to malfunction or physical damage. To avoid the data loss, fault tolerance property of CH is desired in some applications. The most common method is to re-cluster the network, but due to excessive resource utilization, this method is not very encouraging. Another approach to overcome the cluster failure is by adding a backup or secondary CH and the function of the secondary or back CHs varies. By, round rotation of CHs between the network nodes provide additional benefit employing fault tolerance [15].

2.3. Guaranteed Connectivity: This objective of minimal cluster count is mostly mutual when some CHs are particular is node is equipped with more resources, processing, and computational power as compared to normal CHs [16]. Due to their size, cost and vulnerable nature, network designer tends to deploy a minimal number of these nodes

2.4. **Enhancing Network Lifetime**: When cluster heads are highly equipped as compared to other network nodes, it is very vital to decrease the intra-cluster communication energy [17] and the distance amongst the CH and member nodes should be kept a minimum.

2.5. The number of Cluster Head: The number of CHs in the network should be optimal. When the node is selected as CH, it depletes additional energy as compared to its member nodes. If the number of CHs in a network is not optimal. It will reduce the network lifetime as the rate of energy consumptions at CHs is higher [18].

CLUSTRING ATTRIBUTES

3.1. Clustering Approach: To consume the network energy effectively and limit the correlated data, data aggregation and sensor fusion many novel techniques have been proposed by the researchers [8]. To consume the network energy uniformly and enhance the lifetime of the network clustering has gained much attention in WSN due to their CH selection and data aggregation. In the clustering technique, the nodes are partitioned into groups known as clusters. In general, one CH is selected from the clusters and other cluster members connect with the cluster head. The cluster members communicate only with the cluster head and forward the senses data to CH. The CH then performs data aggregation and data fusion on the data obtained by the cluster members and transmits the fused data to the BS for further end-user processing. Clustering-based techniques play an important role in enhancing energy efficiency and guaranteed to prolong network lifespan, for reusing the bandwidth and data gathering [19] and target tracking [20], single-hop or multi-hop communications, routing [8,21,22-24], etc. Clustering is predominantly suitable for a large type of network comprising a hundred or thousand nodes that requires scalability. Scalability in those network environments which involves load balancing, well-organized resource exploitation, and data aggregation [25].

3.2. Clustering Elements Commonly: The cluster comprises three main elements, i.e. Cluster Heads, Member Nodes, and the Base Station (BS) [26].

Cluster Head: Generally, the cluster head is selected from the network node based on different approaches. The CH gathers the data from the cluster members and performs data aggregation on it and also eliminates the correlated data. The CH plays multiple roles besides data aggregation it also acts as a gateway between nodes and the base station.

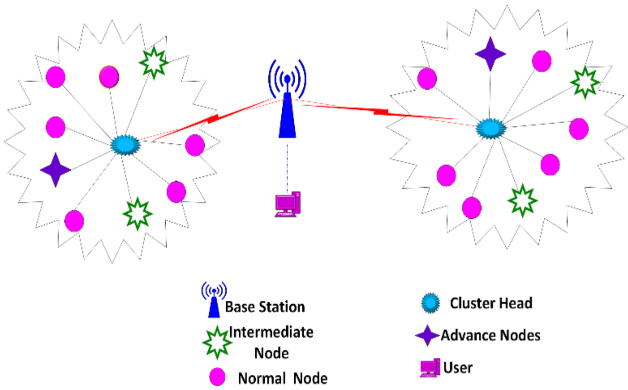

Figure 1. Clustering Element

Member Nodes: The cluster member nodes or network nodes are those are not elected as CH during the clustering selection phase. After the cluster selection phase, the nodes join the nearest CH forming a cluster. Due to the random placement of the nodes, sometimes the nodes are deployed very near to each other and their sensing region overlaps with others which results in highly correlated data. The cluster member senses or monitor the area within their sensing range and transmits it to the CH. The HWSN is equipped with multi-level energy i.e., are normal, intermediate and advance nodes. The advance nodes are more energized as compared to normal nodes and intermediate nodes while the energy of the intermediate nodes is equal to the average energy of advance and normal nodes.

Base Station: The BS performs further desired computation on the data forwarded by the CHs for end-user requirements. Usually, the base station is static but in some desired application it can be mobile too. The static base station is deployed at a distance from the nodes while in the case of the mobile base station it follows a fixed trajectory.

3.3. Cluster Head Capabilities: As argued above the network design affects the clustering method; mainly the node abilities and the choice of the in-network handling. Attributes of the CH nodes are discussed as [27].

Static or Mobile: In most of the researches the CH are static while In some applications the CHs are mobile and due to their mobility the membership of the clusters changes dynamically which results in continuous cluster management. In the case of static clustering, the cluster formation is steady. In some scenarios, the CH can be relocated to a new location to maximize the coverage.

Node Types: In some applications, the nodes are equipped with more processing and computation power as compared to other CHs which is discussed later in this chapter.

Role: A CH performs the task like network outer. The CH performs data aggregation and forwards the data to BS and also communicates with the member nodes and the BS.

CLUSTRING PROCESS

4.1. Clustering Process Designing of the clustered network is on the most crucial step for effectively utilizing the network energy. During the designing issue, certain aspects should be considered; like optimal cluster head size, CHs selection criteria, etc. The clustering establishment process can be divided into three main phases' i.e. (i) cluster head selection (ii) cluster formation and (iii) data transmission phase. Various research has been proposed to implement each of these phases (26).

4.2. Cluster Head Selection CH selection can be classified into three categories, centralization by the BS, decentralization by the nodes or hybrid selection and some by the nodes themselves.CH selection is a major challenge to prolong energy efficiency and network's lifetime. The CH is selected among the existing sensor nodes and the selection measures of CH vary in the suggested research but the key intention these studies is to decrease the energy consumption and prolong the network life span [28]. To minimize the routing complexity and make the network more energy efficient it is necessary to decide the optimum number of CH, which will minimize the overhead while maintaining the network connectivity in case of topology changes occur. Researchers have proposed different mechanisms to select the cluster head but still its open research problem.

HSWSN are generally two-level protocols equipped with normal nodes having the initial energy of E0 and my advance nodes having extra energy α as related to normal nodes. The total energy of the network is increased to "(1+m.α)" times. So, the whole initial energy of the network develops to:

$$E_{TOT} = nE_0(1 + m\alpha) \quad (1)$$

The probability of normal nodes (PNS) and advance nodes (PAS) to be elected as CHs becomes [11]:

$$P_{NS} = \frac{P_{opt}}{(1 + \alpha * m)} \quad (2)$$

$$P_{AS} = \frac{P_{opt}}{(1 + \alpha * m)} * (1 + \alpha) \quad (3)$$

The CHs is election is based on threshold value which is set between 0 and1. If the computed value is higher than the previous one, CHs are selected. The threshold value for normal nodes and advance nodes is:

$$T_{(S_{NS})} = \begin{cases} \frac{P_{NS}}{1 - P_{NS} * (r * \mathrm{mod}(\frac{1}{P_{NS}})} & \text{if } S_{NS} \in X' \\ 0 & \text{otherwise} \end{cases} \quad (4)$$

$$T_{(S_{AS})} = \begin{cases} \frac{P_{AS}}{1 - P_{AS*} * (r * \mathrm{mod}(\frac{1}{P_{AS}})} & \text{if } S_{AS} \in X'' \\ 0 & \text{Otherwise} \end{cases} \quad (5)$$

Where r is the present round, X' and X'' are nodes that are not selected as CH with in the last round.

4.3. Cluster Formation: In cluster formation or set-up phase the cluster formation takes place. The CHs declare their selection to network nodes by broadcasting advertisement messages and each network node responds by sending a join message to the CH. For N number of network nodes, a certain number of clusters are formed during each round. The energy consumed by the CH in a certain round is computed by the following equation [11].

$$E_{CH} = P.E_{Ckt}\left(\frac{n}{C} - 1\right) + P.E_{AD}\frac{n}{C} + P.E_{Ckt} + P.\epsilon_{fs} d_{TX}^2 \quad (6)$$

Where C is the sum of clusters, EAD aggregated data and d_{TX} is the distance amongst the CH and BS. The energy utilized by a non-CH is as follow

$$E_{NCH} = \begin{cases} P.E_{Ckt} + P.\epsilon_{fs}.d_{CH}^2 & \text{if } d_{CH} < d_{BS} \\ P.E_{Ckt} + P.\epsilon_{mp}.d_{BS}^2 & \text{if } d_{CH} > d_{BS} \end{cases} \quad (7)$$

Where d_{CH} is the distance between the member node and the CH and its average value can be computed by "$d_{CH}=M/(\sqrt{2\pi})$". d_{sk} is the distance amongst the nearest node and the BS.

4.4. Data Transmission: In data transmission or steady-state Phase the cluster member forwards sense data to CHs, and the CH performs data aggregation and forwards it to the BS. The total energy consumed in the network is equal to

$$E_{TOT} = P.\left(2nE_{Ckt} + nE_{AD} + \epsilon_{fs}\left(C.d_{TX}^2 + n\frac{M^2}{2\pi C}\right)\right) \quad (8)$$

TYPES OF CLUSTERING

Commonly the clustering can be group into two types' homogeneous or heterogeneous clusters' and static or dynamic clusters. In formal type is the clusters are established on the function of the nodes within the cluster while the earlier deals with cluster formation [27].

5.1 Homogenous Clustering: In the homogenous type of clustering the network nodes have the same initial energy, processing capabilities, and sensing range. The homogenous networks require high hardware cost. To overcome the limitation of homogenous networks heterogeneous networks were proposed in which two types of sensor nodes were introduced (29).

5.2 Heterogeneous Clustering Generally: The heterogeneous network has two types of nodes having different energy levels termed as high energy or advance node and low energy or normal nodes. The advance nodes have maximum energy than the normal nodes. Depending on node heterogeneity the heterogeneous network can be classified into categories such as two-tier or multi-tier heterogeneous networks [13].

NODE HETEROGENEITY IN HETEROGENEOUS WIRELESS SENSOR NETWORKS

Based on numerous parameters on which HWSN can be categorized. For the enhancement of network life-time, node heterogeneity is exploited in many research areas. In heterogeneous sensor networks, the nodes are equipped with different capabilities such as different energy levels, sensing range and computational power which are dependent on the application. The node heterogeneity benefits the HWSN in many ways e.g. decreases the latency, maximizes throughout, a minimal number of hops and end to end delivery is far greater with respect to homogeneous WSNs [27]. Node heterogeneity can be divided into three kinds, i.e. Link heterogeneity, Energy Heterogeneity, and Computational heterogeneity.

6.1. Energy Heterogeneity: In energy heterogeneity, the nodes have multiple energy levels. Usually, there two types of nodes in the networks with respect to the energy, normal nodes, and advance nodes and are termed as two-tier HWSN protocols [9]. The advance nodes are more energized as compared to normal nodes and more probability is given to advance nodes to be elected as CH.

In some research, the nodes operate in three-level energy heterogeneity i.e. normal, intermediate and advance nodes and are termed as three-tier HWSN protocols [30]. The intermediate nodes perform as a channel between the normal nodes and advanced nodes and their energy is kept between the advance and normal nodes.

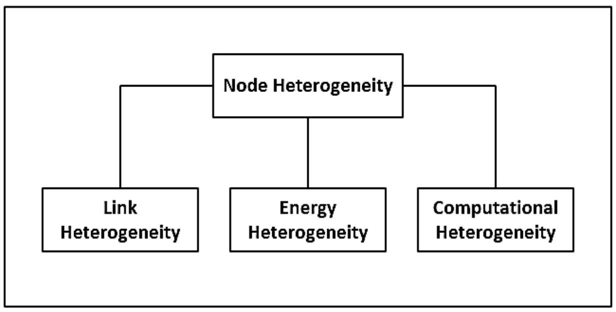

Figure 2. Node Heterogeneity

6.2. Computational Heterogeneity: Computational heterogeneity refers that the heterogeneous nodes are equipped with a powerful processor, high memory and can compute complex data which ultimately reduces the processing latency, as a result, a maximum end-to-end delivery rate is achieved as compared to homogeneous sensor networks [31].

6.3. Link Heterogeneity: Link heterogeneity accounts for the reliable transmission distance between two nodes. To ensure reliable data transmission, link heterogeneity was implemented to meet the condition of maximum bandwidth and communication over long haul distance [32].

HETEROGENEOUS WSN MODEL

The Heterogeneous WSN model contains N number of sensor nodes distributed in the MxM area. Usually, in most of the heterogeneous models, there are binary or three types of sensor nodes equipped with dissimilar energy levels but in few cases, the types of nodes used are more than three and are named as two, three and multilevel heterogeneous WSN model.

THE NETWORK MODEL

In almost all of the related SEP variants research, an arbitrary radio model [29] has been presented with the assumed parameters radio dissipation energy is chosen to be 50 EenJ/bit to make the transmitter or receiver operational and 100 pJ/bit/m2 is introduced into the model to adjust the SNR of the channel. To transmit a data "L" at a distance "d", the energy consumed by the network is given below,

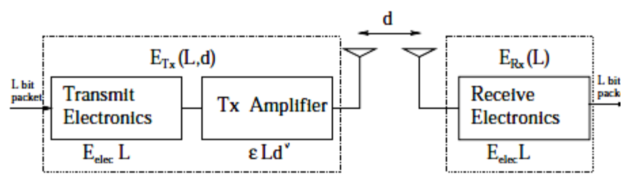

Figure 3: Energy Consumption Model

$$E_{Tx}(l, d) = \begin{cases} L.E_{elec} + L.\varepsilon_{fs}.d^2 \text{ if } d < d_o \\ L.E_{elec} + L.\varepsilon_{mp}.d^4 \text{ if } d \geq d_o \end{cases} \quad (9)$$

Where E_{elec} is the energy utilized to operate the transmitter or the receiver, free space (εfs) and multipath (εmp) losses, and d is the distance among the transmitter and receiver. By comparing the two terminologies at d = d_0, we have

$$d_o = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \quad (10)$$

Furthermore, the deployment of nodes is a key issue, another assumption has been made that the wireless channel is symmetric i.e., the identical volume of energy is required to communicate a k-bit message from sensor nodes A to B [11] which is not true, the nodes are remotely deployed on a terrain which may have many variations e.g. the surface of the ground may not be uniform so in this case the variation in antenna height greatly affects the transmission between two nodes.

Another key factor ignored in this model is receiver sensitivity. To receive a L−bit data the radio spends [11].

$$E_{Rx=}L.E_{elec} \quad (11)$$

SEP

SEP [11] is a HWSN protocol to extend the stability period before the death of the first node, which plays a critical role for certain applications in which the response from the network must be consistent. In SEP the CH election is founded on the weighted probability of the node according to remaining energy. SEP is two-tier protocols that contain normal and advanced nodes. Advanced nodes are armed with additional energy than the regular nodes. SEP protocol claims to rise the stable area which as a result minimizes the unstable area and the protocol claims to improve the feedback of Clustered WSN in the presence of heterogeneous nodes.

The downside of SEP is advanced nodes. Advanced nodes have extra energy and their likelihood to become CHs is higher than the normal nodes. But at a certain stage, the energy of the advance nodes becomes identical to the normal node nevertheless preference is given to advance nodes to become CHs. The simulation results showed that SEP expressively improved the stable region by 26% as related to LEACH.

COMPARATIVE ANALYSIS OF SEP VARIANTS

The following section provides a brief overview of SEP Variants.

10.1. VCHSEP [33] is founded on the virtual CHs (VCH) selection, which further explores the energy ingesting of the normal nodes, CHs and VCH nodes. The cluster construction is a two-step method the creation of clusters and cluster partition, contrasting SEP [11] in which each node is equipped with different volumes of energy.

The cluster members (CMs) nodes transmit their gathered data to the CH and after data transmission, the member's nodes enter into sleep mode to save the energy. The CH transmits the data to VCH. After encoding the data, the VCH transmits data to the base station (BS). In VCHSEP the energy consumption of individual nodes is calculated i.e. member nodes, CHs, and VCH Unlike other protocols [11, 14], which have an acceptable signal to noise ratio for spreading data at a distance. In this protocol, the author has investigated the power consumption of the circuit block [33] and focuses more on the power consumption within the circuit and transmission. Simulation results reflect that VCHSEP increased the stability period by 17% as compared to SEP, but overall the network life is decreased as compared to SEP

10.2. SEP–E [34] is a tri-level protocol. SEP-E is an improved version of SEP that shows prolong the network lifetime. SEP-E has introduced a supplementary node named as an intermediate node which acts as a link between the advance and normal nodes, with an aim to house and provides for multi-nodes diversity. The energy level of the intermediate node is amid the advanced node and the normal node.

The limitations of SEP-E are, the selected CHs may be very near each other since SEP-E hinge on the probability. SEP-E does not reflect the energy leftovers of the individual node so the nodes that have relatively small energy remains can be the cluster-heads. This makes the network life-time be reduced. The stability period of SEP-E is somewhat improved than SEP, and the instability is ample lesser than SEP

10.3. DB-SEP [35] is grounded on the preliminary energy of nodes and the distance amongst them and the BS to control nearby nodes and distant nodes in order to give additional chance to adjacent nodes to be CHs by adjusting the selection probability value for each sort of nodes. The network is prearranged into a clustering scheme, and the CHs performs data fusion function to cut associated data transmitted by the member nodes within the same clusters.

In DB-SEP, each node autonomously picks itself as a CH on the basis of its initial energy and the distance to the BS. Thus, nodes near to the BS having additional energy as compared to other nodes have an extra chance to be nominated as a CH for the current round. Just like [11], in DB-SEP the nodes which are closest to the BS will have more chance to become CH as compared to nodes which are far-off from the BS, the drawback is that the energy of the nodes will drain out quickly and will die first which will cause instability in the network. Another drawback is the elected CH is near from the sink but maybe it is far from it's nodes due to this reason the farthest node will utilize more energy to transmit the signal to the associated CH.

10.4. T-SEP [36] is a hybrid algorithm that has assumed the top features of [34] and TEEN [37] protocols. T-SEP a reactive protocol and it has tri energy levels.

CH selection is based on the threshold value set between 0 and 1. In T-SEP frequent data, the transmission is limited by threshold value and the transmission is performed only in set conditions are met. To prolong the network lifetime TSEP has used the features of [37] in which two levels of the threshold have been used, i.e.

The drawbacks of the T-SEP are, CHs are selected on the basis of nodes probability, not energy, CH is still probability based in T-SEP protocol. T-SEP is Time-critical, the downside of this scheme is that if set threshold value is not reached, no data transmission will occur and end-user will not receive any info from network, and even if one node or all nodes die out and the system will remain unaware so TSEP is not suited for those applications where data transmission is required continuously

10.5. H-SEP [38] uses two levels of energy and the election of nodes depends upon the weighted probabilities of initial energy compared with the other nodes in the network. To diminish the transmission cost a new clustering scheme has been proposed which uses two kinds of CHs, the primary and Secondary CHs. The election of Secondary CHs is probability-based which are elected from the existing primary CHs pool and only primary CHs select the secondary CHs.

The transmission energy is directly proportional to the distance among transmitting CHs and the BS, as the distance between them increases the consumption of transmission energy also increases in process of data transmission. The Primary CHs scans the distance between the secondary CHs and then transmits the aggregated data to the Secondary CH which further forwards aggregated data to BS, thus minimizing the transmission distance and minimizing energy consumption.

Like other protocols, the election of the process of CHs is probability-based and advance nodes have more probability to be elected as CH. The secondary CHs are elected from the existing primary CHs by the primary CHs. The limitation of the HSEP is that the primary CH elects the closet the secondary CH to transmit the aggregated data but the elected secondary CHs already elected as primary CH which is also involved in the data aggregation. So, it means a single CH is responsible for data aggregation and performs transmission as well. So, there is a probability that the CH will die out at a faster rate. And the extra overhead is also used in the election of secondary CHs and transmitting the data to them as well. The simulation results showed that HSEP increased the stable region by 9% as compared to SEP

10.6. SEP-FL Fuzzy logic requires little computation competencies and it is able to provide decision construction methods to expand efficiency while prolonging the total network life-time. Fuzzy-logic emulates the logic of human reasoning, which is much less rigid than computer computation [39].

In [40] the author presented the SEP-FL (Fuzzy logic) method to improve the network lifetime in clustered HWSN. The protocol is founded on dual deterministic principles: the residual energy of each node and the distance from the BS. The fuzzy interference system (FIS) consists of twofold sets one for the advance and the other for normal nodes. Each scheme is based on four sets fuzzifier, rule base, inference machine, and fuzzified.

In this SEP-FL model, two parameters are considered i.e. Energy and distance to the BS of each member node. To further analyze the lifetime of the network these parameters are further divided into a linguistic variable that is used to represent these parameters into tri-levels. For energy “low level”, “medium level” and “high level” are selected and “close, medium and far” for the distance between the BS. The two parameters are divided into three levels each thus resulting in 32=9 possible chance values. By using defuzzification1 methods i.e. centroid the aggregated chance value results are obtained. IF-THEN rules are used in every round to calculate the chance of CH election between advance and normal node. The number of maximum chances is compared with the threshold value for the node; if the maximum chance is fewer than the specified threshold value then the nodes become CH.

10.7. M-SEP. The other variant of SEP is M-SEP [41] which uses two aggregators are introduced and their position changes with respect to nine energy levels and in each case the network life-time and efficiency are compared.

In M-SEP the CHs heads to send the data received from the node either to the sink or to the aggregator on basis of minimum distance or we can say the CH sends the data to the nearest BS or to the data aggregator. The aggregators are equipped with infinite energy.

In M-SEP nine different levels of heterogeneity have been used and in each case, the number of nodes equipped with higher energy is 10. In two levels the number of advance nodes will be 10, the three-level the number of the advance node will 10 and as well the super-nodes will be 10 and so on. It has been observed that by changing the data aggregator position greatly affects the network lifetime.

The selection of higher energy nodes is again probability-based and at each level, the nodes with higher energy will tend to become CHs more often. The network prolongs lifetime and efficiency is achieved by using nine levels of heterogeneity. In this paper, the author did not mention the initial energy dissipated values for the operation of transmitter and receiver and data aggregators. As we can perceive that the sum of high energy nodes increases with the level of heterogeneity so in the case the in the ninth level there will be only 10 normal nodes. And normal nodes will have the very least probability to become CH.

10.8. SCR-SEP. The author proposed ECR-SEP [42] is based on weighted probabilities and the election of CH based on the Energy Consumption Rate (ECR).

The selection of CH depends on the previous round; the node having less ECR is selected as CH in the next round. The CH selected in the present round has fewer chances to be elected as CH in following round because of more ECR as compared to other nodes, so a node having high ECR has more chances of becoming CH node.

10.9. MSE. The author proposed another improved version of SEP which is mobile sink based and the distribution of nodes is non uniform. The mobile sink travels back and forth on a pre defined route to collect the data from the CHs [43]. The election of CHs is performed in two ways i.e. first preference is given to advance nodes which are equipped with additional energy and in the next step, the selection is based on residual energy. Besides data aggregation, the CHs also perform the shortest path route discovery between the sink trajectory and the advance nodes. If the distance between the normal CH and trajectory is maximum as compared to the distance between the advances CH. In this case, the normal CH will transmit its data to the advance CH. Once the CH obtains all data from its respective node, it fuses the data into a single packet before transmission to the mobile sink and after performing data transmission the CH enters into sleep mode.

At a certain point the advance CH may die out which will cause failure in the network, and the normal CH will lose its connectivity with it which will result from the destination to infinity which will lead to loss of data. To overcome this issue, the residual energy of the CH is calculated, if it not adequate for the data transmission, the advance CH will delete itself from the network and will send a halt message to normal CH. Once the advance CH dies out the normal CH will again perform the distance calculation to connect with nearest advance CH and meanwhile, the normal CH will directly transmit the gathered data to the mobile sink.

Like other protocols, the author has not focused on the instability of the network. The network will become more unstable as the advance node CHs become inactive or die out because in this case the normal CH perform again distance calculation for the new trajectory and will transmit the data directly to the mobile sink. As the sink is mobile so may the distance calculation may not accurate and if the mobile sink is far away from the normal CH, it will require more energy to transmits the data. So, there is extra overhead consumed for a new trajectory path and advance CH. Lastly, the trajectory model used is fixed and will remain unstable during topology changes and in real-world implementation, the mobile sink may not follow the determined trajectory due to obstacle ahead.

10.10. A-SEP. The ASEP [44] has been proposed which is grounded on SEP. It alters the probability density function of the [11]. The advance nodes are energized with extra energy but after every round the energy of advance node decrease and at a certain stage the energy of advance node becomes equivalent to normal node but as the probability of advance node is higher than the normal so they will be selected more than the normal nodes due to which the energy ingesting will be maximum and the network lifetime will be decreased.

To overcome this problem, ASEP modified the existing protocol. At a certain stage when the energy of both nodes becomes equal so they will have the same probability of selection as CH.

10.11. EM-SEP [45] is another improved version of (11) which prolongs the stability region of the network by uniform energy consumption. The nodes are equally distributed in the clusters. Furthermore, another enhancement is, if there is more than one node available to become a CH in a given round, the node equipped with higher energy is elected is CH. These factors help to prolong the stability of the network.

10.12. K-SEP It is another improved version of SEP, in which the election of CHS is based on the residual energy and the distance [46]. Cluster member node always transmits data to the associated CH. But in fact, it not true, the nodes closed to each other may have correlated data, so it is not necessary to transmit the data in the specified time slot.

In K-SEP the member node transmits data randomly at report time to the CH with some probability and if there is no data to transmit the member node enters into sleep mode which helps to prolong the network lifetime. Throughout each pass of the algorithm, the data is allocated to the adjacent partition based upon roughly similar parameters. Subsequently the completion of every consecutive pass, the data might change partitions, thus shifting the values of the original partitions-Means clustering algorithm is an unsupervised algorithm that is used to resolve the clustering problem. The standard K-Mean algorithm is based on various steps [47].

K-SEP protocol expands the clustering and CH selection process. Initially, the K-Means algorithm is used for uniform clustering and after that, the CH is elected on the basis of Euclidian distance from the middle of cluster and higher residual energy. In the initial round of communication, in the setup stage, the K-means algorithm is used for cluster construction, which guarantees even clustering. The cluster construction by K-means algorithm confirms the finest clustering and election of CH is based upon the Euclidian distance amongst the CH and sink and maximum residual energy.

The drawback of the proposed protocol is that the outcome of clustering dependent on the initially elected centroids. K-Means does not perform spherical data sets efficiently and only numerical values attributes can be clustered.   In K-means protocol clustering is performed when 50% of the nodes die out and after that random clustering is performed.

10.13. SEP(RCH) To balance the network load and prolong the network lifetime, a new protocol SEP-E (RCH) [48] based on improved redundant CH selection has been developed. There are two types of CHs heads used in this protocol i.e. Initial CH (ICH) and initial redundant CH (RCH). The protocol uses conditional probability to select CH among ICH or RCH, the node having higher residual energy and mean distance for the current round is elected as CH and the other node performs as redundant CH. Due to extra redundant CH, the reliability and security of the have been enhanced in case of CH failure and damage by invaders.

The limitation of the protocol is that it considers the residual energy of the CH and it does not account for the location and data transmission between the node and the CH. If the node has far away from the cluster, it will require more energy to transmit its data to the CH. Extra overhead energy is used in each to broadcast status information between normal nodes, ICH and RCH by flooding. The redundant CH carries the same info as ICH and utilize energy in doing so, so there might be less chance for the RCH to become ICH in the next round.

10.14. G-SEP [49] is constructed on the "weighted probability" of the initial energy of nodes comparative to other network nodes. The protocol increases the lifetime of the network by the addition of rechargeable gateways in the system which is deployed at the edges of the sensing region. The number of gateway nodes used depends on the formation of the CH, so that each CH could send its data to the nearest gateway node which results in minimized time consumption and traffic load. The gateway nodes perform data aggregation and transmit the data to the BS. And the multiple uses of gateway nodes increase the network reliability in the sense if the one gateway node fails due to some reasons the sensor nodes reroute their data to the nearest gateway node.

Again, the election of CH is based on the weighted probabilities and conditional threshold values. The nodes having higher energy will have more chances to become CH. In the case of a gateway node failure, the sensor nodes associated with it will again compute for the nearby gateway node, which will increase instability in the system

10.15. Z-SEP. The Z-SEP [50] is based on zone partitioning. The regions are separated into various zone explicitly zone 0, 1, and 2. The normal nodes are equipped with less energy so they are placed in zone 0 which is nearer to the Sink and the advance node having higher energy are deployed in zone 1 and 2 which are far-off from the BS. The reasons behind this. The normal nodes do not take part in the clustering and directly transmit their data to the sink, whereas cluster formation takes place only in the advance nodes which is probability-based.

The limitation of this protocol is that, that the advance nodes are deployed far away from the sink, so the CHs will require more energy to transmits data to BS and they will die out sooner as compared to previous protocols. Secondly, the normal nodes do not take part in the CHs formation and therefore data aggregation is not performed in them. The nearby normal nodes will have redundant data and sink will receive numerous redundant data which will increase the computation of data in the sink

10.16. ELB-SEP The CHs communicates with other to transmits the data to sink, CHs closer to the sink performs more data transmission tends to die out first leaving areas of the network regions uncovered and causes network portioning, unlike previous protocols the election of CH was probability base which results in the election of CH having less residual energy ignoring the one having high residual energy. To address this problem ELB-SEP [51] was proposed which is based on the nodes residual energy l estimation of sensor nodes and it has implemented the best features of [34], three-level heterogeneity and T-SEP (36), threshold level estimation.

The formation of CH is based on an unequal clustering mechanism [52] in which the nodes are portioned into unequal size, the nodes closer to the sink will form small clusters and the nodes away from the sink will form large clusters. So, in this way, the nodes closer to the bs saves significant energy from inter-cluster data routing.

The limitation of ELBSEP is that if the threshold value is not touched, the BS will not receive any data from network nodes and even all the network nodes die out, the system will be unknown about these limitations. So, ELBSEP is not suitable for those sorts of applications where a sensed data is required frequently and nonstop

10.17. DSEP-FL This paper [53] suggests a novel protocol DSEP-FL that expands D-SEP by means of the Fuzzy Logic method. Fuzzy logic takes real-time verdicts with the incorrect info. The BS picks the node as CH having higher energy by means of four parameters that are nodes energy level, distance from BS, the concentration of network nodes, and criticality w. r. t. the whole CH. This article investigates the DSEP protocol using DSEP-FL CH by taking into account four parameters such as energy, centrality, concentration, and distance to BS.

10.18. DTRE-SEP. In DTRE-SEP [54] the CH selection criteria are both probability and residual energy-based. At a certain stage when the energy of both normal and advance nodes becomes equal, at this point the CH selection criteria become equal for both types of nodes. It also takes the advantage of direct transmission, if the node is located close to the base station as compared to the CH, the node will forward its data to the BS.

10.19. BEECP. In this article [55], a new approach for CH selection in HWSNs founded on biogeography-based optimization (BBO) (16) has been anticipated. BBO is a famous evolutionary algorithm used to resolve numerous composite real-world problems. BBO defined three key operators namely “elitism, migration, and mutation”. In the investigated approach, “the fitness function” for BBO has been altered on the root of cluster density and the distribution of CHs in the network region. The density must be diminished in order to make compressed clusters so that each member node can transmit data to its respective CH node with minimum distance while the distribution of CHs must be greater in order to cover the overall network area in an effective way.

10.20. ZBHCP In [56] the author has proposed a zone-based protocol to enhance the network lifetime by the partitioning the region in different zones. The aim of the protocol is to increase the network lifetime by decreasing the intra-cluster and inter-cluster communication distance by computing the transmission distance between the cluster member node and the base station and as selecting the cluster heads from their respective zones.

10.21. EESAA. In [57] the author presented the idea of coupling among the nodes of identical application which are organized closed to each other will create a pair for communication and transmission. The only single member of active couple nodes will take part in communication while other member goes in sleep mode in order to reserve energy. The disadvantage of this technique is that some of the nodes leftovers were unpaired and remain active throughout the lifetime of the network and their energy is exhausted at a higher rate which reduces the network stability, while the coupling nodes alternatively on/off their radio.

10.22. DEEC [58] is a multi-level distributed clustering protocol which also can also be implemented in two-level HWSN. The election of CH is based on the ratio of residual energy of individual nodes and network average energy. The drawback of this prior calculation utilizes additional energy to share the info among the nodes

10.23. DDEEC [59] is an enhanced version of [58] protocol, in which individual network node computes the initial and residual energy for the CH election. Each node in the network needs the global knowledge of the network to calculate the reference energy which will be consumed by each individual node in a current round.

10.24. TDEEC [60] adopts the same cluster head election criteria and average energy consumption as proposed in [58] DEEC. TDEEC protocol implements different threshold values for CH selection in order to enhance network lifetime. In (60), the threshold value is balanced and set between 0 and 1 select node for CH selection based on residual energy and average energy of the current round.

10.25. EDEEC [61] is an enhanced version of [58] which is a three-level heterogeneous protocol. It comprises three sorts of nodes, i.e. normal nodes, advanced nodes and super nodes based on initial energy. The CH election criteria are based on the [58].

SIMULATIONS AND DISCUSSIONS

11.1. Performance Measures

The selected protocols are validated against the following performance measure.

Stable Region. Stable Region is defined as when the network becomes operational and the first network node drains out its energy.

Instability Region. It is defined as when the last network node drains out its energy.

Network Lifetime. It is the measure of the time period since the network becomes operational until the last network node drains out its energy.

Active Nodes. It is the total number of nodes that are part of the network and active in transmission.

Dead Nodes. It is the total number of dead nodes that have expanded their energy totally.

Throughput. It is the total sum of packets transmitted from CH and the nodes transmitting directly to the BS.

A number of Cluster Heads per Round. It this the total number of nodes that are selected as cluster heads per round.

11.2. Simulations

To further examine the performance of the above the debated protocols we have selected a couple of protocols for simulations. To carry out simulations, 100 nodes are randomly deployed in the 100*100 area. The simulations are performed for each protocol individually. Rest of the parameters is listed in Table 1

Table 1.Network Parameters

Parameter	Value
Area	100*100
nodes	100
E_{Ckt}	50nJ/bit
E_{AD}	5nJ/bit/message
E_0	0.5J
Packet Size	4000
P_{opt}	0.1
εfs	10pJ/bit/m^2
ε_{mp}	0.0013pJ/bit/m^4
d_{NS}	87.70

From figure (4) represent the stable region of the protocols DDEEC, DEEC, EDEEC, TDEEC, TSEP, SEP, ZBHCP, ZSEP, DTRE-SEP, and EESAA. The stable region plays a critical role in the enhancement of network life-time. When the first network nodes drain out its energy completely, the networks become unstable. It can be verified from the simulations that TSEP outperforms all other protocols in terms of stable region. The reason behind this that TSEP is a reactive protocol and reacts only when certain conditions are met. Moreover, TSEP is a tri-level heterogeneous clustering protocol that takes advantage of additional nodes termed as intermediate nodes. With respect to a stable region, ZBHCP stands in the second position. The ZBHCP enhances the network lifetime by dividing the network area into four different zones and the CHs are selected from each respective zone only thus minimizing the overall intracluster and inter-cluster transmission distance to preserve the excess amount of energy wasted in long haul transmission. DDEEC, DEEC, EDEEC, TDEEC, and ZSEP significantly enhances the stable region of the network as compared to SEP, ESSA, and DTRE-SEP. In Z-SEP the CHs are selected only from the advance nodes which are deployed near the base station while the energy of the normal nodes depletes at a much higher rate due to direct transmission and as a result vast area of the networks remains uncovered. The stable region of the SEP protocol is very minimum because SEP is a weighted probability-based protocol in which priority is given to advance nodes to be selected as CHs even if the energy of the advance nodes falls below the energy of the normal node.

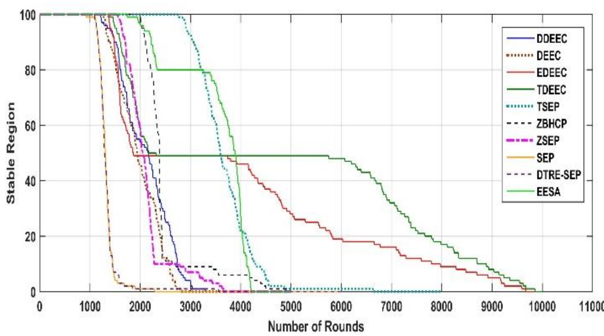

Figure 4. Active Nodes Per Round

Figure (5) illustrates the unstable region of the protocols, DDEEC, DEEC, EDEEC, TDEEC, TSEP, SEP, ZBHCP, ZSEP, DTRE-SEP, and EESAA. The unstable stable region of the EDEEC, TDEEC and TSEP protocols is significantly larger as compared to two-tier protocols. The reason behind this that three-tier clustering protocols are equipped with additional intermediate nodes due to which the overall network energy is increased and the intermediate nodes act a bridge between normal and advance nodes. TDEEC outperforms all other protocols in terms of an unstable region. Like TSEP, TDEEC is also a threshold sensitive protocol. The unstable of ZBHCP is quite encouraging being a two-tier protocol. The ZBHCP takes advantage of zone partitioning and inter and intracluster communication distance which ultimately increases the unstable region of the network. The unstable region of DDEEC, DTRE-SEP, and ZSEP is considerably higher than the SEP, EESA, and DEEC.

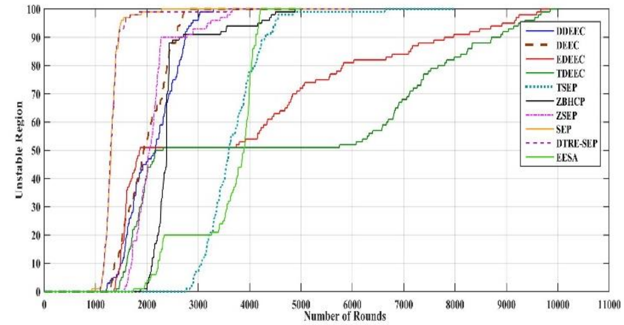

Figure 5. Dead Nodes Per Round

Figure (6) demonstrate the overall throughput of the under-discussion protocols. TDEEC and EDEEC have maximum throughput among all the protocols. The throughput of ZBHCP, DTRE-SEP, and TSEP is significantly higher while the packets transmitted to BS from DEEC, DDEEC, ZSEP, and SEP has approximately equal since the probability of CH selection is the same.

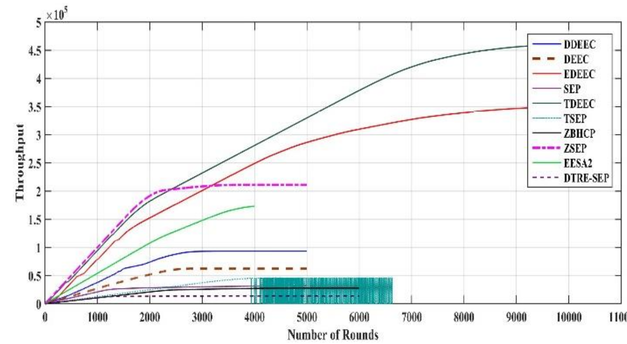

Figure 6. Packets Transmitted to BS Per Round

Table (2) states the number of rounds in which the first and last network node drains out their energy completely. It can be concluded that in protocols, TSEP, ZSEP, and ZBHCP energy is distributed more uniformly with respect to the other protocols. The first node in TSEP, ZBHCP, and ZSEP drains out their energy in 2749th, 1878th and 1559 rounds respectively. As discussed above the TDEEC EDEEC and TSEP takes the advantage of additional nodes being added to the network, the last nodes of the TDEEC EDEEC and TSEP drain out their energy completely in 9849th, 9666th and 6633 rounds.

Table 2. Stable and Unstable Region		
Protocol	1st Node	Last Node
SEP	926	2283
DTRE-SEP	1088	3553
DDEEC	1213	3294
DEEC	1271	2811
TDEEC	1401	9849
EDEEC	1364	9666
TSEP	2749	6633
EESA	862	2564
ZSEP	1559	3661
ZBHCP	1878	4889

Table (3) shows the maximum number of elected CHs in a specific round. It can be verified from the table (3) that none of the proposed protocols full fills the criteria of the optimal number of CH per round that should be around 10 [11] in a given round. The number of CH in ZSEP is only two, this is because the CH is selected from the fraction of advance nodes only. From figure (5) it can also be concluded that the stable region becomes unstable when the first node dies out due to which the optimal number of CH selection is disturbed.

Table 3. Number of CHs	
Protocol	CHs
SEP	40
DTRE-SEP	40
DDEEC	93
DEEC	40
TDEEC	40
EDEEC	40
TSEP	40
EESA	40
ZSEP	2
ZBHCP	40

OPEN ISSUES

This article analyzes the performance of some selected heterogeneous protocols in terms of, energy efficiency, cluster head selection parameter, data transmission, network lifetime, stable region and unstable region Though the existing protocols have successfully enhanced the network lifetime but still there are open issues which need to be addressed, i.e., Optimal Cluster Head Selection Per Round, node deployment and CH head distance from the BS.

CONCLUSIONS AND FUTURE WORK

Uniform Energy Consumption is one of the vital parameters in WSNs with limited power supply. It is vital to decrease the energy depletion of the nodes to increase the network lifetime. This article investigates various clustering protocols to enhance the network lifetime in the context of HWSN. In HWSN, cluster heads selection plays a vital role in the enhancement of the network lifetime. If the number of cluster heads are not optimal per rounds, the network energy will deplete faster due to which the network life will be minimized, and it was observed in some rounds that number of cluster heads per round was not optimal and even in some round no cluster head was elected which shows that no communication took place that rounds.

REFERENCES

1. Misra, Sudip, Woungang, and Isaac, “Guide to Wireless Sensor Networks” Springer: (2009).
2. F. Akyidiz , Y. Sankarasubramaniam, W. Su, and F. Cayirci, “A survey on sensor networks”, IEEE Commun, Vol. 40, No. 8, pp.102-114 (2004)
3. JN. Al-Karaki and AE. Kamal, “Routing techniques in wireless sensor networks: a survey”, IEEE Wireless Communications, Vol.11, No.6, pp.6-28 (2004).
4. PNH. Vaidya, M. Chatterjee, and D. Pradhan, “A cluster-based approach for routing in dynamic networks”, ACM SIGCOMM Computer Communication Review Vol.27, No.2, pp.4965 (1997)
5. B. McDonald and T. Znati, “Design and performance of a distributed dynamic clustering algorithm for Ad hoc networks,”, Simulation Symposium Proceedings pp.27–35(2001)
6. Ni. Sze-Yao, T. Yu-chee, CH. Yuh-shyan and S. Jang-ping, “The broadcast storm problem in a mobile Ad Hoc network”, in: Proceedings of the Annual ACM/IEEE International Conference on Mobile Computing and Networking Vol.8, No 23, pp.153–167(2002)
7. D. Estrin, R. Govindan, J. Heidemann, and S. Kumar, “Next century challenges: scalable coordination in sensor networks”, in: Proceedings of the 5th Annual ACM/IEEE International Conference on Mobile Computing and Networking (MobiCom99) (1999)
8. E. Kranakis, H. Singh, & J. Urrutia. “Compass routing on geometric networks”, in: Proc. 11th Canadian Conf. on Computational Geometry, Vancouver, Canada, pp. 51–54(1999)

9. H. Yung-Fa, Y. Li-Chu and L. Jen-Yung, "An Efficient Energy Data Gathering Based on Grid-Chain for Wireless Sensor Networks", IEEE Awareness Science and Technology (iCAST) (2012)
10. W. Heinzelman. A.P. Chandrakasan and H. Balakrishnan, "An application-specific protocol architecture for wireless microsensor networks", IEEE Transactions on Wireless Communications, Vol. 1, No. 4, pp.660-670, (2002).
11. Smaragdakis, I. Matta and A. Bestavros, "SEP: A Stable Election Protocol for clustered heterogeneous wireless sensor networks", in: Second International Workshop on Sensor and Actor Network Protocols and Applications, (2004)
12. V. Mhatre, C. Rosenberg, D. Kofman, R. Mazumdar, and N. Shroff, "Design of surveillance sensor grids with a lifetime constraint", in: 1st European Workshop on Wireless Sensor Networks (EWSN), (2004)
13. A. Abbasi, and M. Younis, "A survey on clustering algorithms for wireless sensor networks", Computer Communications, Vol.30, No.14, pp.2826-2841(2007)
14. M. Younis, K. Akkaya, and A. Kunjithapatham, "Optimization of task allocation in a cluster-based sensor network", in: Proceedings of the 8th IEEE Symposium on Computers and Communications (2003)
15. F. Deniz, H. Bagc, I. Korpeog, and A. Yazıcı, "An adaptive, energy-aware and distributed fault-tolerant topology-control algorithm for heterogeneous wireless sensor networks", Ad Hoc Networks, Vol.44, pp.104-117 (2016)
16. Li. Xiaolong, C. Jun and Z. Zhang, "Topology Control for Guaranteed Connectivity Provisioning in Heterogeneous Sensor Networks", IEEE Sensors Journal, Vol.16, No.12 (2016)
17. S. Halder and S. Das Bit, "Enhancement of wireless sensor network lifetime by deploying heterogeneous nodes", Journal of Network and Computer Applications archive, Vol.38, pp.106-124 (2014)
18. M.S. Fareed, N. Javaid, M. Akbar, S. Rehman, U. Qasim, Z.A. Khan, "Optimal Number of Cluster Head Selection for Efficient Distribution of Sources in WSNs", Seventh International Conference on Broadband, Wireless Computing, Communication and Applications (BWCCA) (2012).
19. WP. Chen, J. C. Hou and L. Sha "Dynamic Clustering for Acoustic Target Tracking in Wireless Sensor Networks", 11th IEEE International Conference on Network Protocols (ICNP'03), pp.284-294 (2003)
20. J.N. Al-Karaki and A.E. Kamal, "Routing Techniques in Wireless Sensor Networks, A Survey", Department of Electrical and Computer Engineering, Iowa State University, (2004).
21. A. Manjeswar , Agrawal, "TEEN A protocol for enhanced efficiency in wireless sensor networks". In Proceedings of 1st International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing, San Francisco, CA, USA, pp.189 (2001).
22. C. Liu, K.Wu and J.Pei, "A Dynamic Clustering and Scheduling Approach to Energy Saving in Data Collection from Wireless Sensor Networks", Second Annual IEEE Communications Society Conference on Sensor and Ad Hoc Communications and Networks (SECON 05) (2005).
23. Aurenhammer F. and Diagrams V. "A Survey of a Fundamental Geometric Data Structure", ACM Computing Surveys, pp.345- 405(1991).
24. L.M.C. Arboleda and N. Nasser, "Comparison of Clustering Algorithms and Protocols for Wireless Sensor Networks", Proc. Canadian Conf. Electrical and Computer Eng., pp.1787-1792, (2006).
25. Liliana M.C. A, and Nasser N. "Comparison of Clustering Algorithms and Protocols for Wireless Sensor Networks", Electrical and Computer Engineering, CCECE '06. Canadian Conference on, pp.1787 – 1792, (2006).
26. S. Tanwara, N. Kumarb, and J.P.C. Rodriguesc, "A systematic review on heterogeneous routing protocols for wireless sensor network", Journal of Network and Computer Applications Vol. 56, pp.39-56 (2015).
27. H. Zhou, Y. Wu, Y. Hu and G. Xie, "A novel stable selection and reliable transmission protocol for clustered heterogeneous wireless sensor networks", Journal of Computer Communications, Vol.33, No.15, pp.1843-1849 (2010)
28. D. Gupta and R. Verma, "An enhanced cluster-head selection scheme for distributed heterogeneous wireless sensor network", International Conference on Advances in Computing, Communications, and Informatics (2014)
29. W. Heinzelman, A. Chandrakasan, and Balakrishnan H. "Energy-Efficient Communication Protocols for Wireless Microsensor Networks", In Proceedings of Hawaiian International Conference on Systems Science (2000).
30. T.N.Qureshi, N.Javaid, N, M. Malik, U. Qasim, and Z. Khan, "On Performance Evaluation of Variants of DEEC in WSNs", IEEE Seventh International Conference on Broadband, Wireless Computing, Communication and Applications (BWCCA), (2012).
31. P. Samundiswary, P. Priyadarshini and P. Dananjayan, "Performance Evaluation of Heterogeneous Sensor Networks", International Conference on Future Computer and Communication, pp.264 – 267(2009)
32. C.Maurice, H. Horst, and Z. Feng, "Scalable information-driven sensor querying and routing for ad hoc heterogeneous sensor networks", International Journal of High Perform Computer Application (2002).
33. C. Long, L. Li and W. Wu "An Improved Scheme of SEP in Heterogeneous Wireless Sensor Networks", IEEE Pacific-Asia Workshop on Computational Intelligence and Industrial Application (2008).
34. F. Aderohunmu and J. Deng, "An Enhanced Stable Election Protocol (SEP) for Clustered Heterogeneous WSN", Department of Information Science, University of Otago, New Zealand.
35. S. Benkirane, M.L. Hasnaoui, A. Benihssane, and M. Laghdir, "Distance-based Stable Election Protocol (DBSEP) for Heterogeneous Wireless Sensor Network", International Journal of Computer Applications, 58(2012)

36. A. Kashaf, N. Javaid, Z.A Khan and I.A. Khan, TSEP: Threshold-Sensitive Stable Election Protocol for WSNs, 10th International Conference on Frontiers of Information Technology (FIT) (2012).
37. A. Manjeswar , Agrawal and D.P. TEEN, "A protocol for enhanced efficiency in wireless sensor networks", In Proceedings of 1st International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing, San Francisco, CA, USA, pp.189, (2001).
38. A. Khan, N. Javaid, U. Qasim, Z. Lu and Z.A. Khan, "HSEP: Heterogeneity aware Hierarchical Stable Election Protocol for WSNs", Seventh International Conference on Broadband, Wireless Computing, Communication and Application, Victoria, Canada, pp.373(2012)
39. A. Ortiz, F. Royo, C. Castillo and J. Pedro, "Fuzzy-logic based routing for dense wireless sensor networks", Telecommunication Systems (2011)
40. B. Mostafa, C. Saad, and H. Abderrahmane, "Fuzzy Logic Approach To Improving Stable Election Protocol For Clustered Heterogeneous Wireless Sensor Networks", Journal of Theoretical and Applied Information Technology, Vol.53, No.3(2013)
41. G. Arya and D. Chauhan, "Modified Stable Election Protocol (M-SEP) for Hierarchical WSN", International Journal of Computer Applications, pp.0975 – 8887, Vol.79, No.16 (2013)
42. O. Rehman, Z. Javaid, B. Manzoor, A. Iqbal, M. Ishfaq and A. Hafeez, "Energy Consumption Rate Based Stable Election Protocol for WSNs", Journal of Computer Science, Vol.19, No.4, pp.932–937 (2013)
43. J.Wang , Z. Zhang J.Shen, F. Xia and S Lee, "An Improved Stable Election based Routing Protocol with Mobile Sink for Wireless Sensor Networks", IEEE International Conference on Green Computing and Communications and IEEE Internet of Things and IEEE Cyber, Physical and Social Computing, Beijing, China, pp.945-950 (2013)
44. M Singh and N Sidhu, "Advance Stable Election Protocol in Wireless Sensor Networks", International Conference on Communication, Computing & Systems (2014).
45. A.A. Malluh, M.K. Elleith, Z. Qawaqney, and J.R. Mstafa "EM-SEP: An Efficient Modified Stable Election Protocol", Proceedings of IEEE American Society for Engineering Education (ASEE), Bridgeport, Connecticut, USA, pp.1-7(2014)
46. B. Kandari and R. Singh "K-SEP: A more stable SEP using K-Means Clustering and Probabilistic Transmission in WSNs", International Journal of Current Engineering and Technology, Vol.4, No.4(2014)
47. M. Queen, "Some methods for classification and analysis of multivariate observations", Fifth Berkeley Symposium on Mathematics, Statistics and Probability,pp.281-297(1967)
48. R. Pal, R. Sindhu, and A. Sharma, "SEP-E (RCH): Enhanced Stable Election Protocol Based on Redundant CH Selection for HWSNs", 9th International Conference on Quality, Reliability, Security, and Robustness in Heterogeneous Networks, Vol.115, pp.104-114(2013)
49. J. Pand and H. Kaur, "Gateway Based Stable Election Multi-Hop Routing Protocol for Wireless Sensor Networks", International Journal of Mobile Network Communications & Telematics (IJMNCT), Vol.4, No.5 (2014)
50. S. Faisal, N. Javaid, A. Javaid, M.A. Khan, S.H. Bouk and Z. Khan, "A. Z-SEP: Zonal-Stable Election Protocol for Wireless Sensor Networks", Journal of Basic and Applied Scientific Research (JBASR), (2013).
51. Mishra Y, Singhadi A and Pandey R. "Energy Level Based Stable Election Protocol in Wireless Sensor Networks", Engineering Trends and Technology (IJETT), Vol.17, No.1, (2014).
52. C. Li, M. Ye, G. Chen and J. Wu, "An energy-efficient unequal clustering mechanism for wireless sensor networks", IEEE International Conference on Mobile Adhoc and Sensor Systems Conference Improved LEACH Protocol for Wireless Sensor Networks, pp.8-604(2005).
53. S. Kaur, H. Singh, and V. Khullar, "Performance Analysis of Deterministic Stable Election Protocol Using Fuzzy Logic in Wireless Sensor Networks", International Journal of Computer and Information Engineering; Vol.11, No.7 (2017)
54. S. Hassan, M.S. Nisar, and H. Jiang, "DTRE-SEP: A Direct Transmission and Residual Energy-based Stable Election Protocol for Clustering Techniques in HWSN", International Conference on Communication Software and Networks(ICCSN), pp.266 – 271(2015)
55. R. Pal, H.M.A. Pandey, and M. Saraswat, "BEECP: Biogeography optimization-based energy-efficient clustering protocol for HWSNs", Ninth International Conference on Contemporary Computing (IC3), (2016)
56. S. Hassan, M.S. Nisar, H. Jiang, "Energy Preservation in Heterogeneous Wireless Sensor Networks through Zone Partitioning," Indonesian Journal of Electrical Engineering and Computer Science, Vol.2, No.2, pp.390-395(2016).
57. T. Shah, J. Nadeem, T.N. Qureshi TN. "Energy Efficient Sleep Awake Aware (EESAA) Intelligent Sensor Network Routing Protocol", 15th International Multitopic Conference (INMIC),(2012)
58. Q. Li, Z. Qingxin and W. Mingwen, "Design of a distributed energy-efficient clustering algorithm for heterogeneous wireless sensor networks", Computer Communications, Vol.29, No.12, pp.2230-2237(2006)
59. Elbhiri B., Saadane R., Fkihi E, and Aboutajdine D. "Developed Distributed Energy-Efficient Clustering (DDEEC) for heterogeneous wireless sensor networks", I/V Communications and Mobile Network (ISVC), (2010)
60. P. Saini and A.K. Sharma, "Energy Efficient Scheme for Clustering Protocol Prolonging the Lifetime of Heterogeneous Wireless Sensor Networks", International Journal of Computer Applications, Vol.6, No.2(2010)
61. P. Saini and A.K Sharma, "E-DEEC- Enhanced Distributed Energy Efficient Clustering Scheme for heterogeneous WSN", 1st International Conference on Parallel, Distributed and Grid Computing, (2010)