

A Survey on Energy Efficient Strategies for Heterogeneous Wireless Sensor Networks

Rohit Gupta¹, Parveen Kumar², Vinith Chauhan³ and Yogesh Bhomia⁴

^{1,4} Nims University Rajasthan, Department of Electronics and Communication Engineering Jaipur, India
Email: 09.rohit@gmail.com

² Nims University Rajasthan, Department of Computer Science Engineering, Jaipur, India

³ Department of Technical Education, Uttar Pradesh, India
Email: pk223475@gmail.com, vinithchauhan@rediffmail.com, bhomia9yogesh@rediffmail.com

Abstract—Ongoing advancements in electro-mechanical, power electronics and wireless communications have made possible the use of wireless sensor networks in remote applications such as environmental conditions, forest fire protection and target monitoring in military applications. These unattended applications require a huge number of sensor nodes working efficiently together for a common goal. Since sensor nodes have limited energy resources, it is of vital importance to use them in an efficient manner to improve a network's lifetime. Clustering is one of the most effective ways to achieve this. Clusters are more efficient when they work together since nodes may not have the same amount of energy, making it even more vital for them to do so. Homogeneous and heterogeneous types of wireless sensor networks exist. Energy-efficient clustering strategies in heterogeneous wireless sensor networks are examined in this research. There are nodes in homogeneous wireless sensor networks that have equal resources, while there are nodes with different energy levels in heterogeneous wireless sensor networks that enhance the network lifespan.

Index Terms— Wireless sensor network (WSN), Energy Efficiency, Homogeneous, Heterogeneity and HWSN.

I. INTRODUCTION

Current research focuses on the development of new energy-efficient routing methods for wireless sensor networks (WSNs) [1]. A variety of models have been introduced and connected to WSNs in order to improve energy efficiency and lifetime of a network. They can be used to measure temperature, humidity, pressure and much more. There are a wide range of uses for WSN at the present time such as condition checking, medical monitoring, environmental monitoring, and even home security [2,3]. When compared to the sensor node driven ad-hoc network, the wireless sensor network (WSN) is data-centric. When it comes to asset-constrained sensor nodes, they're usually dumped into an unknown domain without a preconfigured foundation. For the sensor nodes to check their environment, they must be able to get themselves to the working area [4]. Meanwhile, the sensor nodes form a network. As a result of current improvements, sensor nodes have a very short lifespan despite the fact that low energy consumption is a primary aim. The sensing nodes are wireless, so they can be placed even in unreachable areas and hilly domains without any difficulty. There are a variety of routing approaches that are designed to build nodes uplifts energy compelling. A variety of clustering algorithms have

been proposed as a means to avoid these issues [5].

To reduce the energy consumption of the network, sensor nodes can be arranged in clusters [6]. As a result of this, the nodes in the system are sorted into several clusters, each of which has a cluster head (CH) and all the information is gathered within the cluster and after that it is send to base station(BS). It has been found that clustering has a lot of advantages due to which it has been widely used in WSNs to outline several energy-efficient strategies [7]. The clustering protocols include LEACH [8], DEEC [9], NEAP [10] and SEP [11].

All nodes in the cluster communicate with the CH, which collects data from all of them and sends to base station [12]. As an alternative, a small number of dissimilar sensor nodes can be used to extend the network's lifespan. Fig. 1 shows the process of clustering in WSN.

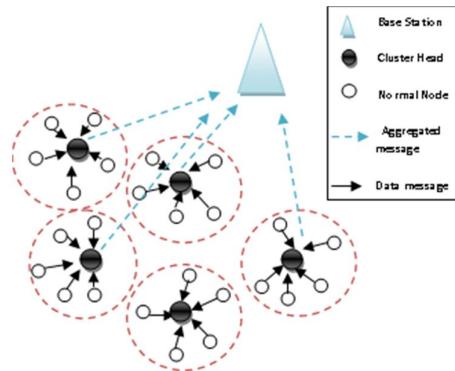


Figure 1. Clustering of Network

Node data can be collected using a variety of strategies, such as LEACH, which uses homogeneous types of nodes throughout the network. This type of environment provides nodes with the same capabilities, such as energy and computing power. Because of this, it is difficult to save energy in a homogeneous network. As a result, heterogeneous networks come into play in order to solve these difficulties. Heterogeneous wireless sensor networks (HWSNs) are incorporated in the study in order to increase the network's reliability. The heterogeneous network consists of a variety of sensor nodes that measure power and range. As a result of their closeness to real-life conditions, they are very useful.

There are a number of clustering procedures that are developed with heterogeneity. Based on its energy and data collection capacities, the WSN is divided into homogeneous and heterogeneous types of networks. Protocols such as the SEP and DEEC are examples of the heterogeneous network. Wireless sensor networks (WSNs) with heterogeneous nodes have greater and lower energy levels. The lower nodes have a shorter range of connectivity and smaller computational power. When it comes to communication range and computing power, high-energy nodes have the upper hand. Cluster heads are usually chosen from the nodes with the highest energy (CH). As a result of the cluster heads' ability to aggregate data, significant energy savings are achieved. Hardware as well as surplus energy stored in the battery is built into each node in HWSN. As a result of HWSN's use, complicated hardware and extra energy in the battery are integrated into the node; as a result, the costs associated with having a larger number of lower-energy nodes are eliminated.

There are various advantages of clustering that includes: (1) It optimizes routing table storage space at each node by localizing the route set-up within the cluster (2) conserves bandwidth (3) sensors with a longer lifespan (4) Clustering reduces the need for topology maintenance. Sensors would only be interested in connecting to their CHs (5) CHs aggregate their data and reduce the number of duplicate packets (6) Scheduling activities in a cluster can help to reduce energy consumption.

The paper in section 2 consists of the history of heterogeneous wireless sensor nodes. Section 3 discusses the H-model for wireless sensor network which includes types of resource heterogeneity and impact of heterogeneity on WSN and its performance measures. Section 4 and section 5 presents the architecture of sensing node and the energy model utilized. Clustering algorithms for heterogeneous wireless sensor network is described in section 6. At last section 7 concludes the survey paper.

II. HISTORY

To conserve energy and increase network lifespan, sensors should be clustered into small groups. High-power nodes are used as cluster heads (CHs) in clustering to increase energy efficiency, reducing the likelihood of

nodes running out of energy [13]. Utilizing clustered approach in routing protocols achieves energy efficiency. Sensing nodes collect data and transfers it to the cluster head which aggregates the data, processes it and delivers the collected data further to the base station [14, 15]. LEACH (Low - energy adaptive clustering hierarchy), HEED (Hybrid Energy-Efficient Distributed Clustering), PEGASIS (Power Efficient Gathering in Sensor Information System), EECS (Energy Efficient Clustering Scheme) and WCA (Weighted Clustering Algorithm) are some of the protocols that are used in homogeneous wireless sensor networks. Clusters in LEACH are formed on the basis of minimum distance from the sensing nodes to cluster heads [16]. By expanding LEACH, the EECS protocol was created. The distance between clusters and the base station decides the dynamic size of cluster in EECS [17]. When compared to LEACH, the throughput of EECS is improved. WSNs with homogenous topologies can benefit from HEED, which is a multi-hop clustering technique. CH is selected by HEED depending on the distance between the nodes. HEED extends the lifespan of a network in comparison to generalized LEACH. PEGASIS is a WSN protocol that collects data in a homogenous manner. PEGASIS networks are chain-based structure from sensor nodes to base stations. Only one sensor node can transmit data at a particular time slot in PEGASIS. Although the network lifespan in PEGASIS is improved but suffers from issues like scalability and reliability. A sensor node's weight is used in WCA. There are several factors like energy, mobility, node degree that are considered in determining the weight of a node. WCA is scalable and versatile. The load is efficiently balanced in WCA. According to [18], WSNs can be modelled using a modified LEACH technique. The cluster head selection is based on energy and distance. The energy efficiency of modified LEACH is improved when clustering is only allowed for distant nodes. Various LEACH follow-up protocols, such as [19-27], have been proposed as part of the so-called LEACH family.

Networks that are heterogeneous differ in their energy levels. With regard to network lifespan, LEACH and its family members HEED, EECS, PEGASIS, and WCA perform poorly in HWSN. Some of the most essential routing protocols for heterogeneous wireless sensor networks include: SEP (Stable election protocol), DEEC (Distributed energy-efficient clustering), DDEEC (Developed distributed energy-efficient clustering), ED-DEEC (Enhanced developed distributed energy- efficient clustering), S-DEEC (Stochastic DEEC), EDAL (Energy-Efficient, Delay-Aware, and Lifetime- balancing Data Collection Protocol), Het-DEEC (Heterogeneous DEEC), BEENISH (Balanced energy efficient network-integrated super heterogeneous protocol), SEEC (Stable and energy efficient clustering), CEEC (Centralized Energy Efficient Clustering), ML-HEED (Multilevel Hybrid Energy-Efficient Distributed Clustering), EDCF (Energy dependent cluster formation), DETSSEP (Distance based enhance threshold sensitive stable election protocol), TEAR (Traffic and Energy Aware Routing), ETSSEP (Enhance threshold sensitive stable election protocol), the improved cluster head selection methods SEP-T, EEHC, EESCP, EECPEP-HWSN, EEMHR, MCR. Different cluster head selection methods are used in these protocols to improve stability, throughput, and network lifespan in heterogeneous WSN.

III. H-MODEL FOR WIRELESS SENSOR NETWORK

A study of heterogeneous resources on heterogeneous wireless sensor networks is presented in this section (HWSN).

A. Types of Resource Heterogeneity- Resource heterogeneity include computational heterogeneity, link heterogeneity and energy heterogeneity.

Computational heterogeneity- Computational heterogeneity leads to quicker processing and greater memory on the heterogeneous node. Due to their enormous computational capacity, they are able to handle complicated data and store it for a lengthy period of time.

Link heterogeneity- Link heterogeneity refers to the fact that the heterogeneous node has a higher bandwidth and a longer distance network transceiver than the conventional node. When links are heterogeneous, data transmission can be more efficient and reliable.

Energy heterogeneity- This term refers to the replacement of battery.

As a result, much energy is utilized in computational heterogeneity and link heterogeneity, therefore energy heterogeneity is considered as the most significant resource heterogeneity.

B. Impact of heterogeneity on WSN- The advantages of deploying heterogeneous nodes in wireless sensor network are as follows:

Response time- Due to computational and link heterogeneity, responding time is reduced.

Lifespan- There will be a reduction in energy usage in heterogeneous sensor networks when a packet is forwarded from a node to the sink and as a result the lifespan of a node is increased. Hence, heterogeneity in a network can triple the network's response time and increase its lifespan by five times.

C. Performance measures- A list of some of the parameters are compiled that are used to evaluate clustering protocols.

Network lifespan- This indicates the period of time between the start of operation (of the sensor network) and the death of the first node that is still alive in the network.

Number of CH per round- Nodes that deliver aggregated data directly to BS are counted in the number of nodes in this column.

Numbers of nodes per round- Nodes that have not used all of their energy are counted here.

Throughput- It is the overall data rate send over the network which includes the rate of data send from CH to BS and the rate of data send from cluster members to CH.

IV. ARCHITECTURE OF SENSING NODE

Its architecture is displayed in Fig. 2 and includes a sensing and processing module, wireless communication (Transceiver) and actuator.

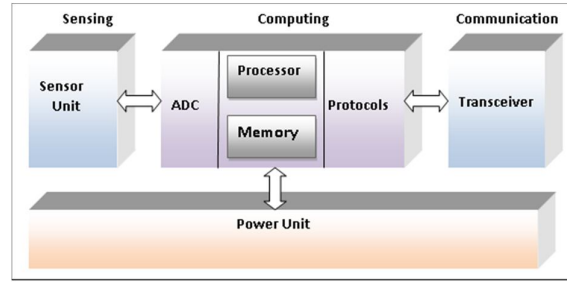


Figure 2. Architecture of sensing node

There is a power supply that powers all of the modules in the system. Sensing module sensors are used to gather information, while ADC converts the sensed data into digital bits.

Modulation/demodulation and sampling are also performed by the sensing module. Processing module comprised of a processor and a memory. Control of sensors, protocol-based data communication, data processing and storage are all responsibilities of this module. Data is transmitted and received through the antenna by the wireless communication module. Sensor nodes can be built with or without actuator and GPS.

V. ENERGY MODEL

Energy model of sensing node is illustrated in Fig. 3 that includes several parameters such as packet size, transmit and receive electronics.

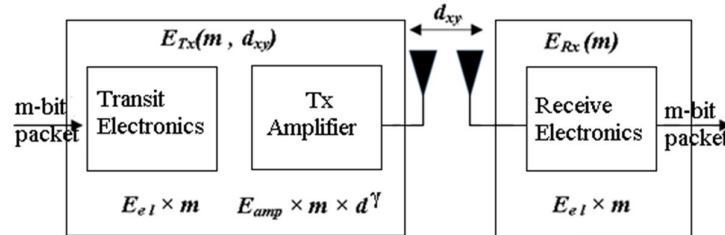


Figure 3. Energy model of a sensing node

The amount of energy consumed by the transmitter depends on how long it is in operation. Reducing the radio transmission time is one technique to boost the energy efficiency of the node. By transmitting more bits per symbol, the transmission time can be shortened. It is possible to mitigate the transmit/receive time by using M-ary modulation methods. The usage of energy-efficient protocols will reduce energy consumption and lengthen

the lifespan of the network. The energy model is comprised of two sections i.e. transmission and reception of data and these two sections are at a distance d_{xy} from each other [28]. The energy model used here transmits and receives m bits of data.

The energy needed to transmit m -bit data from x^{th} node to y^{th} node separated by the distance d_{xy} is-

$$\begin{aligned} E_{Tx}(m, d_{xy}) &= E_{Tx-el}(m) + E_{Tx-amp}(m, d_{xy}) \\ &= mE_{el} + mE_{amp}d^\gamma \\ &= \begin{cases} mE_{el} + mE_{fs}d^2 & \text{if } d_{xy} < \delta \\ mE_{el} + mE_{mp}d^4 & \text{if } d_{xy} \geq \delta \end{cases} \end{aligned} \quad (1)$$

$$E_{Rx}(m) = E_{Rx-el}(m) = mE_{el} \quad (2)$$

Where E_{Tx} denotes the energy transmitted and E_{Rx} is energy consumed in receiving of data. E_{el} is the energy used to transfer single bit, E_{fs} and E_{mp} are the amplification coefficient and m is the data bits.

VI. CLUSTERING PROTOCOLS FOR HETEROGENEOUS WIRELESS SENSOR NETWORK

The best significant way to extend the lifespan of a sensor network is by minimizing its energy consumption is by clustering the sensors together. As a result, the network's scalability and lifespan can be improved. A literature review of distributed techniques for clustering in WSNs is discussed in this paper. Clustering algorithms for heterogeneous WSN must be energy-efficient for the benefit of node heterogeneity. In this study, clustering algorithms are categorized based on two key criteria: stability and energy efficiency. The initial energy, residual energy, average energy of the network, or energy consumption rate or a combination of these determines the cluster head selection in energy efficient procedures. Various clustering protocols for heterogeneous wireless sensor networks are listed below-

A. Stability-Oriented Clustering Protocols for Heterogeneous WSNs

Wireless sensor networks are more stable when using the protocols outlined below. The stability period is the duration before the first node dies. There are applications where the sensor nodes' response must be trustworthy. This category includes protocols such as: SEP [29], EDFCM [30] and ZREECR [31].

Stable Election Protocol for Clustered HWSNs: Heterogeneity has an influence on protocols that are unaware of it and on protocols like LEACH, which become unstable if certain nodes die, according to Smaragdakis G. The problems due to heterogeneity of nodes are described by the author. SEP [29] is a protocol that takes heterogeneity into account. Instead of exchanging energy knowledge, it assigns a weighted election probability to each node based on their energy. Using this approach, a random selection of the cluster head is made based on the energy proportion of each node, ensuring that each node's energy is evenly distributed. There are two categories of nodes that are considered in SEP: normal and advanced. According to the remaining energy in each node, it uses weighted election probabilities for each node to become cluster head. This lengthened the stability period.

Energy Dissipation Forecast and Clustering Management for HWSNs: H. Zhou [30] suggested an energy and computation heterogeneity model for heterogeneous wireless sensor networks. Further, a protocol for HWSNs known as Energy Dissipation Forecast and Clustering Management (EDFCM) is also presented. When using this technique to balance energy usage, the network will be stable for the longest time possible. There are three sorts of nodes in the heterogeneous model that they are considering: Type 0, Type 1 and some management nodes. Nodes of Type 0 and Type 1 have different sensor, energy and software capabilities. They are in charge of sensing events, whereas the management nodes are in charge of managing both types of nodes throughout cluster formation. EDFCM has been designed specifically for heterogeneous networks in order to deliver a more dependable transmission service with a longer lifespan.

In contrast to previous energy efficient methods, EDFCM's cluster head selection is based on a one-step energy consumption forecasting algorithm. In order to do this, it takes the average energy of the two cluster heads from the previous round. Nodes with greater energy after the following round have a better chance of being picked as cluster head.

Routing Protocol for Balancing Energy Consumption in HWSN: There has been an analysis of a procedure based on the residual energy and energy consumption rate (REECR) [31]. According to the same authors, this approach is an improvement over the prior work in the same field. A REECR-based technique was provided instead of periodic rotation and stochastic election. There was a problem with the REECR protocol when it came to balancing energy and network stability; hence ZREECR (Zone-Based Residual Energy and Energy Consumption Rate) was presented as a zone-based upgrade of REECR. By implementing this protocol, the stability period was increased. The main issue of this work is the position of cluster head (may be very close to or very far from BS). Equilibrating the energy consumption in such a situation becomes hard and leads to instability. The authors suggest a zone-based method ZREECR to overcome this challenge. Based on distance and orientation from base station, this protocol divides the network into fixed-sized zones. Clusters near to BS are having smaller cluster sizes as the CHs have to transfer data from the distant CHs to the BS. The use of this technology will allow CHs to save significant amounts of energy in intra-cluster data processing as well as in inter-cluster relay traffic.

B. Energy Efficient Clustering Protocols for Heterogeneous WSNs

Cluster-based routing is also used in WSNs to achieve energy-efficient routing. WSNs can be made more energy efficient by arranging sensor nodes into clusters. Based on the HWSN clustering structure, many energy-efficient routing methods have been devised. It is important to note that each technique has two phases: the clustering setup phase and the steady-state phase. Clustering techniques for heterogeneous WSNs must select the cluster head in such a way that the least amount of energy is utilized, hence extending the lifetime of the network.

Energy Efficient Heterogeneous Clustered Scheme (EEHC): EEHC [32] is a heterogeneous wireless sensor network protocol that is used for selecting CH in distributed manner. Heterogeneity is used at three different levels in this system. In order to select the cluster head, weighted election probability (WEPs) is adopted. Using WEP, nodes compare their initial energy to that of other nodes in the network. Its network lifespan and stability is superior to LEACH.

Distributed Energy-Efficient Clustering Algorithm (DEEC): DEEC selects a cluster head using a probabilistic approach based on the ratio of residual energy to average energy of the node [33]. When it comes to CH, the higher-energy nodes have a better probability of being selected. They are aimed at extending the network's lifespan and stability. For the CH selection, it uses the probability model based on node energies. It uses the heterogeneous network concept where nodes have different energy levels, which helps to extend the network's lifespan. The drawback of this approach is that the nodes with more energy will quickly die when they meet other nodes with the same energy level.

Enhanced Distributed Energy-Efficient Clustering Algorithm (E-DEEC): In an effort to improve stability and lifespan, the author proposes an extended DEEC (EDEEC) [34] protocol that uses three levels of heterogeneity. Nodes in the network are categorized into three categories based on their energy level in the three-level model of heterogeneity. There are three different types of nodes that participate in the clustering process and the CH is picked among them based on the probability model. To determine the likelihood of CH selection, the average energy is used as input. Comparatively, this technique increases the lifespan of the network and stability over that of the DEEC protocol.

Developed Distributed Energy-Efficient Clustering (DDEEC): Here the CH selection is based on the amount of energy left in each node and the selection criteria for CH alter dynamically based on node's energy levels [35]. There is an efficient selection of the CH based on the node's residual and initial energy. A two-level heterogeneous model is used in this technique and the nodes with the highest energy levels are more likely to become CHs. A threshold residual energy value is used in order to avoid energy imbalance in the network. By adopting this strategy, all network members have an equal chance of becoming the CH and energy is used uniformly, increasing the network's lifespan.

Multi-hop Communication Routing (MCR): The data from sensing nodes in a cluster is routed to the base station using a multi-hop communication technique in MCR [36]. There is direct contact of sensing nodes with the cluster head and cluster head to base station.

Energy-Efficient multilevel heterogeneous routing (EEMHR): The EEMHR protocol partitions the network into multiple levels of service [37]. The cluster head selection in EEMHR is based on a variable threshold value. The number of active nodes in the current round is taken into account when determining the threshold value. A

cluster formation phase and a data transmission phase are required for the EEMHR for execution. EEMHR has a longer network lifespan than SEP.

Multilevel Hybrid, Energy-Efficient Distributed Clustering approach (ML-HEED): MLHEED [38] is made up of primary and secondary factors. First, primary factors indicate heterogeneity, whereas secondary parameters are depending on heterogeneity levels. MLEED is known as MLHEED-n when dealing with n-level heterogeneity. There are six levels of heterogeneity in MLHEED. Residual node energy and node density are taken into account while choosing a cluster head. MLHEED has a good distribution of clusters. About 5% of all nodes are chosen at random to be cluster heads. To join the cluster, each cluster head sends out a broadcast message to all the sensor nodes. According to the intensity of the received signal, each node selects which cluster it should join. The cluster head is notified by the nodes when they decide to join. In order for all sensor nodes to transmit data, each CH generates a TDMA schedule for them to follow. Each sensor node delivers data to the other in the allotted slots. Thus, the network's throughput, latency, energy consumption and traffic load are all reduced by a significant amount when MLHEED is used.

Energy efficient Heterogeneous DEEC protocol (Het-DEEC): As part of the CH selection, Het-DEEC takes into account the weighted election probability, threshold and residual energy of all nodes. Among heterogeneous networks, HetDEEC-1 is the most common, followed by HetDEEC-2 and HetDEEC-3, respectively. HetDEEC-1 is a homogenous network. Two types of energy nodes comprise HetDEEC-2 heterogeneous network and three types of energy nodes comprise HetDEEC-3 heterogeneous network. Low-energy nodes can be deployed in large numbers due to their low cost. The energy heterogeneities help to increase the network's energy and lifespan. While DEEC's total network energy increases by 100%, hetDEEC-3's network lifetime increases by 182.67 %. As compared to other DEECs, HetDEEC-3 has a longer stability period [39].

Threshold Balanced Sampled DEEC (T-DEEC): For estimating network energy, T-DEEC [40] is used which is similar to DEEC. DEEC includes multi-heterogeneity levels. When using T-DEEC, Cluster head is chosen based on the ratio between the residual energy of nodes and the network's average energy. T-DEEC outperforms DEEC in terms of network stability and lifespan.

Enhanced developed distributed energy- efficient clustering (ED-DEEC): ED-DEEC network comprises of normal nodes, advanced nodes, and super nodes [41]. For ED-DEEC's energy model, the radio environment is also taken into account. Because only advanced nodes are punished, DEEC and EDEEC are inefficient energy balancers. Dynamic cluster head probability modifications in ED-DEEC prevent this problem.

Stable and energy efficient clustering protocol (SEEC): Only one advanced node per cluster exists in SEEC [42] but normal nodes are distributed at random fashion in each cluster. Clusters and CHs remain the same throughout the network's lifespan. Data from each cluster member is processed and aggregated by each CH. Consequently, the network's energy consumption is lowered because routing is done exclusively through the more powerful and sophisticated nodes, which are more energy efficient. When it comes to sensing in SEEC, BS occupies a central position. Assume that n_1 is the total number of normal nodes and m_{an} is the total number of advanced nodes. So, $N = (n_1 + m_{an})$ gives the total number of nodes in the network. Thus high throughput and greater stability are provided by the SEEC protocol.

Centralized Energy Efficient Clustering (CEEC): There are three different types of nodes in CEEC [43]. CEEC uses three different kinds of nodes: the "super nodes", the "advanced nodes" and the "regular nodes". Network deployment planning is offered by CEEC. CEEC creates centralized clustering by using central control methods and the selection of cluster head is decided centrally. It is chosen centrally which nodes become cluster heads. Each node's location and its residual and initial energies are taken into account while choosing the cluster head.

Enhance threshold sensitive stable election protocol (ETSSEP): A three-level heterogeneity system is used by ETSSEP [44]. Normal, intermediate, and advanced nodes make up the three levels of nodes in the system. Based on the network's average energy, node's residual energy, and the appropriate number of clusters per rounds, the threshold value for selecting clusters is calculated. ETSSEP boosts network lifespan and stability by 37.79 % and 33.5 %, respectively, when compared to TSEP.

Energy efficient sector-based clustering protocol (EESCP): According to EESCP [45], the deployment area is divided into sectors. Each sector is made up of a cluster head (CH). Sectional node placement is determined by angle of arrival. Based on the greatest residual energy, cluster head (CH) selection probabilities for normal and

advanced nodes are calculated. EESCP is the result of update to SEP and LEACH. Parameters including throughput, network lifespan and energy consumption are analyzed by EESCP. EESCP extends the life of the network and increases throughput compared to ETSSEP and SEP.

Traffic and Energy Aware Routing (TEAR): By handling both energy and traffic heterogeneities with several random levels, the stability is improved using Traffic and Energy Aware Routing (TEAR) [46] protocol. TEAR's energy model uses multi-heterogeneity as well as multi-level traffic heterogeneity. A node's traffic requirements and its energy levels are considered when selecting a cluster head. TEAR has a longer stability period than existing algorithms like LEACH, SEP and DEEC. It accounts for traffic heterogeneity by raising the packet length of each node. Nodes with higher traffic for CH selection are not considered in TEAR. There are three factors that are considered by TEAR while selecting a CH i.e. initial energy, residual energy of the node and traffic at the node. In the future, TEAR will be used to create routing protocols for practical applications of WSN.

Balanced energy efficient network-integrated super heterogeneous (BEENISH) Protocol: HWSN protocol BEENISH [47] has four levels of heterogeneity. In this protocol, there are four different types of nodes and the nodes utilized in this protocol are referred to as ultra-super-nodes, super-nodes, advanced nodes, and regular nodes. Out of that the ultra-super nodes have more energy than other nodes. Based on WEP, network's average energy and residual energy, the cluster head is selected in BEENISH. In BEENISH, a similar approach is applied as it was in DEEC.

Energy-Efficient Multilevel Heterogeneous Routing protocol (E-BEENISH): The protocol E-BEENISH (Enhanced balanced energy efficient network integrated super-heterogeneous) [48], uses single hop communications for four-level heterogeneous WSNs to communicate. In addition, there are super-nodes, ultra-super nodes as well as normal and advanced nodes. Based on WEP, each node's residual energy and the distance from sink to node, E-BEENISH decides the selection of cluster heads.

TABLE I. COMPARISON OF ENERGY EFFICIENT HETEROGENEOUS ROUTING PROTOCOLS

Name of Protocol	Selection base for CH	Levels of Energy	Stability	Network Lifespan
SEP	Weighted election probability (WEP)	2-levels	Less but better than LEACH	Better than LEACH
DEEC	WEP, Residual energy of nodes & Average energy of the network	2-levels	Less but better than LEACH and SEP	Better than LEACH and SEP
E-DEEC	WEP, Residual energy of nodes & Average energy of the network	3-levels	Better than SEP and LEACH	20% more rounds than LEACH and 15% more than SEP
T-DEEC	Nodes with high energy	Multi levels	Better than SEP and DEEC	Better than DEEC
D-DEEC	WEP, Average energy of the network and threshold residual energy	2-levels	30% better than SEP and 15% better than DEEC	Better than DEEC and SEP
ED-DEEC	WEP, Average energy of the network and absolute residual energy	3-levels	Better than DEEC, DDEEC and EDEEC	Better than DEEC, DDEEC and EDEEC
SDEEC	WEP, Node's residual energy and Network's average energy	2-levels	80% times longer than DEEC and 110% longer than SEP	Better than DEEC and SEP
Het-DEEC	WEP, Threshold and Residual energy of nodes	3-levels	Better than SEP and DEEC	Better than SEP and DEEC. HetDEEC-3 is better than HetDEEC-2 & HetDEEC-1
MCR	Weighted election probability (WEP)	3-levels	Less but better than LEACH	Better than LEACH
EEMHR	Weighted election probability (WEP)	Multi levels	Better than SEP and MCR	Better than SEP and MCR
CEEC	Residual energy of nodes, Each Region's average energy, Node's Initial energy and its location	3-levels	It is about 40%, 70% and 100% better than DEEC, SEP and LEACH	Better than DEEC, SEP and LEACH
MLHEED	Residual energy of nodes and node density	6-levels	Increasing Heterogeneity levels increases Network lifetime (MLHEED-6 is better than MLHEED-5 and lower)	Increasing Heterogeneity levels increases Network lifetime (MLHEED-6 is better than MLHEED-5 and lower)

EESCP	WEP, Residual energy, Average distance of any nodes from Base station and distance to Base station from nodes.	2-levels	Better than SEP and ETSSEP	Better than SEP and ETSSEP
ETSSEP	WEP, Residual energy of nodes & Average energy of the network	3-levels	More than twice of the TSEP by 33.5%	Better than TSEP by 37.79%
TEAR	WEP, Residual energy, Initial energy and traffic at the node	2-levels & traffic heterogeneity	Better than LEACH, SEP and DEEC	Better than SEP and DEEC
SEEC	Only advanced nodes become cluster heads	2-levels	Better than LEACH	Better than LEACH
BEENISH	WEP, Residual energy of nodes & Average energy of the network	4-levels	Better than DEEC, DDEEC and EDEEC	Better than DEEC, DDEEC and EDEEC
E-BEENISH	WEP, Residual energy of node and distance from sink to the node	4-levels	Better than BEENISH, DS-BEENISH and DSE-BEENISH	Better than BEENISH, DS-BEENISH and DSE-BEENISH by 30%, 25% and 20% respectively

VII. CONCLUSION

A review of clustering techniques in heterogeneous wireless sensor networks is presented in this publication. In wireless sensor networks, clustering is a smart way to reduce energy consumption and offer stability. On the basis of network stability and energy efficiency, all protocols were categorized. Wireless sensor networks are primarily employed in distant places where battery replacement is not practical. To boost stability, dependability, throughput, and network lifespan, they demand energy efficient routing protocols. Routing protocols of HWSN have a high degree of variety which contributes to effective resource usage. HWSN protocols play a critical role in balancing the network's energy and ensuring its long-term stability. As a final conclusion, we found that heterogeneous wireless sensor networks are better suited for real-world applications than their homogeneous counterparts.

REFERENCES

- [1] Yick, B. Mukherjee, and D. Ghosal, "Wireless sensor network survey," *Comput. Networks*, vol. 52, no. 12, pp. 2292–2330, Aug. 2008.
- [2] M.A. Hussain, P. Khan and K. Kyung Sup, "WSN research activities for military application," published in 11th International Conference on *Advanced Communication Technology*, vol. 01, pp. 271–274, 2009.
- [3] Y. Zhu, J. Song, and F. Dong, "Applications of wireless sensor network in the agriculture environment monitoring," *Procedia Eng.*, vol. 16, pp. 608–614, Dec.2011.
- [4] P. Vishal and A. Ramesh Babu, "Firefly Algorithm for Intelligent Context-Aware Sensor Deployment Problem in Wireless Sensor Network," *J. Circuits, Syst. Comput.*, vol. 28, no. 06, p. 1950094, Jul. 2019.
- [5] A. Shokrollahi and B. Mazloom-Nezhad Maybodi, "An Energy-Efficient Clustering Algorithm Using Fuzzy C-Means and Genetic Fuzzy System for Wireless Sensor Network," *J. Circuits, Syst. Comput.*, vol. 26, no. 01, p. 1750004, Jan. 2017.
- [6] M. N. Cheraghloou and M. Haghparast, "A Novel Fault-Tolerant Leach Clustering Protocol for Wireless Sensor Networks," *J. Circuits, Syst. Comput.*, vol. 23, no. 03, p. 1450041, Mar. 2014.
- [7] N. A. Pantazis, S. A. Nikolidakis and D. D. Vergados, "Energy-Efficient Routing Protocols in Wireless Sensor Networks: A Survey," *IEEE Commun. Surv. Tutorials*, vol. 15, no. 2, pp. 551–591, 2013.
- [8] G. S. Arumugam and T. Ponnuchamy, "EE-LEACH: development of energy-efficient LEACH Protocol for data gathering in WSN," *EURASIP J. Wirel. Commun. Netw.*, vol. 2015, no. 1, p. 76, Mar. 2015.
- [9] S. Singh, A. Malik and R. Kumar, "Energy efficient heterogeneous DEEC protocol for enhancing lifetime in WSNs," *Eng. Sci. Technol. an Int. J.*, vol. 20, no. 1, pp.345–353, Feb. 2017.
- [10] S.-S. Wang and Z.-P. Chen, "LCM: A link-aware clustering mechanism for energy-efficient routing in wireless sensor networks," *IEEE Sensors Journal*, vol.13, no. 2, pp. 728–736, 2013.
- [11] F. Aderohunmu and J. Deng, "An Enhanced Stable Election Protocol (SEP) for Clustered Heterogeneous WSN," Jan 2009.
- [12] R. ELkamel and A. Cherif, "Energy-efficient routing protocol to improve energy consumption in wireless sensors networks," *Int. J. Commun. Syst.*, vol. 30, no. 17, p. e3360, Nov. 2017.
- [13] Sukhkirandeep Kaur and Roohie Naaz Mir, "Clustering in Wireless Sensor Networks- A Survey," *I.J Comp. Network and Inf. Security*, MECS, Jun 2016.
- [14] Wendi Rabiner Heinzelman, Anantha Chandrakasan and Balakrishnan, "Energy-Efficient communication protocol for wireless micro sensor networks", *Proceedings of the 33rd Annual Hawaii International Conference on System Sciences*,

vol.2, 2000.

- [15] V. Chauhan and S. Soni, "Energy Aware Unequal Clustering Algorithm with Multi-hop Routing via Low Degree Relay Nodes for Wireless Sensor Networks," *Journal of Ambient Intelligence and Humanized computing*, vol. 12, pp. 2469-2482, 2021.
- [16] J. Dechene, A. El Jardali, M. Luccini and A. Sauer, "A Survey of Clustering Algorithms for Wireless Sensor Networks", *OALib Journal*, 2006.
- [17] X. Liu, "A typical Hierarchical Routing Protocols for Wireless Sensor Networks: A Review," in *IEEE Sensors Journal*, vol. 15, no.10, pp. 5372-5383, Oct. 2015.
- [18] Atul Pratap Singh, Nishu Sharma and Nihar Ranjan Roy, "Residual Energy and Distance based Energy-Efficient Communication Protocol for wireless sensor network", *Int. Journal of Computer Applications*, vol. 74, no.12, Jul. 2013.
- [19] V. Loscri, G. Morabito and S. Marano, "A two-level hierarchy for low-energy adaptive clustering hierarchy (TL-LEACH), " in *Proc. IEEE 62nd Semiannu. Veh. Technol. Conf., Dallas, TX, USA*, pp.1809-1813, Sep.2005
- [20] Xiangning, S. Yulin, "Improvement on LEACH protocol of wireless sensor network," *Proc. Int Conf Sensor Tech. Appl., Valencia, Spain*, pp. 260-264, 2007.
- [21] X. Mo, "Study and design on cluster routing protocols of wireless sensor networks," Dissertation, *College Inf.Sci., Zhejiang Univ., Hangzhou, China*, 2006.
- [22] W. Yassein, M.B. Al-zoubi, A. Khamayesh, Y. Mardini, "Improvement on LEACH protocol of wireless sensor network (VLEACH)", *Int.J.Digital Conent Technol.Appl.*, vol.3, no.2, pp. 132-136, Jun.2009.
- [23] Ran, H. Zhang and S. Gong, "Improving on LEACH protocol of wireless sensor networks using fuzzy logic," *J.Inf.Comput.Sci*, vol.7, no.3, pp. 767-775, 2010.
- [24] H.M. Abdulsalam and L. K Kamel, "W-LEACH: Weighted low energy adaptive clustering hierarchy aggregation algorithm for data streams in wireless sensor networks," in *Proc.IEE Int.Conf. Data Mining Workshops,Sydney, NSW, Australia*, pp 1-8, Dec.2010.
- [25] J. Hong, J. Kook, S. Lee, D. Kwon and S. Yi, "T-LEACH: The method of threshold-based cluster head replacement for wireless sensor networks," *Inf. Syst. Fronteirs*, vol.11, no.5, pp. 513-521, Nov.2009.
- [26] L.B. Oliveira, "SecLEACH-On the security of clustered sensor networks," *Signal Process.*, vol.87, no.12, pp.2882-2895, Dec.2007.
- [27] V. Chauhan and S. Soni, "Mobile Sink-Based Energy Efficient Cluster Head Selection Strategy for Wireless Sensor Networks," *Journal of Ambient Intelligence and Humanized computing*, vol. 11, pp. 4453-4466, 2020.
- [28] M. Mirzaie and S. M. Mazinani, "Adaptive MCFL: An adaptive multi-clustering algorithm using fuzzy logic in wireless sensor network," *Comput. Commun.*, vol.111, pp. 56-67, Oct. 2017.
- [29] G. Smaragdakis, I. Matta and A. Bestavros, "SEP: A stable election protocol for clustered heterogeneous wireless sensor networks," In: *Proc. of the International Workshop on SANPA*, pp. 251-261, 2004.
- [30] Z. Haibo, W. Yuanming, H. Yanqi and X. Guangzhong, "A novel stable selection and reliable transmission protocol for clustered heterogeneous wireless sensor networks," *Computer Communications*, In Press, Corrected Proof.
- [31] X. Li, D. Huang and Z. Sun, "A Routing Protocol for Balancing Energy Consumption in Heterogeneous Wireless Sensor Networks," *MSN, LNCS 4864*, pp. 79-88, 2007.
- [32] Dilip Kumar, Trilok C.Aseri and R.B Patel, "EEHC: Energy efficient heterogeneous clustered scheme for wireless sensor networks," *Comput. Commun*, 2009.
- [33] S. Singh, A. Malik and R. Kumar, "Energy efficient heterogeneous DEEC protocol for enhancing lifetime in WSNs," *Eng. Sci. Technol. an Int. J.*, vol. 20, no. 1, pp.345-353, Feb. 2017.
- [34] P. Saini and A. K. Sharma, "E-DEEC-Enhanced Distributed Energy Efficient Clustering Scheme for heterogeneous WSN," Oct. 2010.
- [35] B. Elbhiri, R. Saadane, S. El fldhi, and D. Aboutajdine, "Developed Distributed Energy-Efficient Clustering (DDEEC) for heterogeneous wireless sensor networks," in *5th International Symposium On I/V Communications and Mobile Network*, pp. 1-4, 2010.
- [36] Dilip Kumar, Trilok C. Aseri and R.B Patel, "Multi-hop communication routing (MCR) protocol for heterogeneous wireless sensor networks," *International Journal of Information Technology, Communication and Convergence*, vol.1, no.2, 2011.
- [37] Sudeep Tanwar, Neeraj Kumar and Jian-Wei Niu, "EEMHR: Energy-efficient multilevel heterogeneous routing protocol for wireless sensor networks," *International Journal of communication Systems*, 2014.
- [38] Samayveer Singh, "Energy efficient multilevel network model for heterogeneous WSNs", *Engineering Science and Technology, an International Journal*, 2017.
- [39] Samayveer Singh, Aruna Malik and Rajeev Kumar, "Energy efficient heterogeneous DEEC protocol for enhancing lifetime in WSNs," *Engineering Science and technology, Elsevier*, 2017.
- [40] Parul Saini, Ajay 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.
- [41] Nadeem Javaid, Muhammad Babar, Rasheed, Muhammad Imran, Mohsen Guizani, Zahoor Ali Khan, Turki Ali Alghamdi and Manzoor Ilahi, "An energy-efficient distributed clustering algorithm for heterogeneous WSNs," *EURASIP Journal on Wireless Communications and Networking*, 2015.
- [42] Rawya Rizk, Fifi Farouk and Fayez W Zaki, "Towards Energy Efficiency and Stability in Heterogeneous Wireless

Sensor Networks,” *Springer* 2017.

- [43] M. Aslam, T. Shah, N. Javaid, A. Rahim, Z. Rahman, Z. A. Khan, “CEEC: Centralized Energy Efficient Clustering A New Routing Protocol for WSNs,” *9th Annual IEEE Communication Society Conference on sensor, Mesh and Ad Hoc Communications and Networks (SECON)*, 2012.
- [44] Shekar Kumar, Shashi Kant Verma and Awadhesh Kumar, “Enhanced threshold sensitive stable election protocol for heterogeneous wireless sensor networks,” *Wireless Pres Communication*, 2015.
- [45] Suniti Dutt, Gurleen Kaur and Sunil Agarwal, “Energy efficient sector based clustering protocol for the heterogeneous WSN,” *Proceedings of 2nd International conference on communication, computing and networking*, 2019.
- [46] Deepak Sharma, Amol P. Bhondekar, “Traffic and Energy Aware Routing for Heterogeneous Wireless Sensor Networks,” *IEEE Communications Letters*, vol.22, no.8, Aug. 2018.
- [47] T.N. Quershi, N. Javaid, A.H. Khan, A. Iqbal, E. Akhtar and M. Ishfaq, “BEENISH: Balanced Energy Efficient Network Integrated Super Heterogeneous Protocol for Wireless Sensor Networks,” *International Workshop on Body Area Sensor Networks(BASNet-2013)*, Elsevier, 2013.
- [48] Yinghui Zhang, Xiaolu Zhang, Shuang Ning, Jing Gao and Yang Liu, “Energy- Efficient Multilevel Heterogeneous Routing Protocol for Wireless Sensor Network,” *IEEE Access*, vol. 7, 2019.