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№ 3872

Energy Efficient Heterogeneous Routing Protocols for cluster based Heterogeneous Wireless Sensor Network (HetWSN) – Strategies and Challenges: A Review

Preeti Gupta, Sachin Tripathi and Samyaveer Singh

July 14, 2020

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Preeti Gupta[1*], Sachin Tripathi[2], Samayveer Singh[3]

[*1]Indian Institute of Technology (ISM) Dhanbad, Jharkhand, India
[2]Indian Institute of Technology (ISM) Dhanbad, Jharkhand, India
[3]National Institute of Technology, Jalandhar, Punjab, India
[*1]preetigupta216@gmail.com
[2]var_1285@yahoo.com
[3]samayaveersingh@gmail.com

Abstract

Regardless of the advancement in WSN (Wireless Sensor Network), efficient energy utilization is still essential to increase network lifetime. In real time applications, due to battery constraints of sensor nodes the network lifetime depreciates. To ameliorate the energy depletion problem, cluster based heterogeneous WSN (HetWSN) integrated with optimization techniques is one of the solutions. Technologies like IoT, machine learning, neural network could be of great importance for optimization. In this paper we address comprehensive literature review of cluster-based routing protocols along with their pros and cons for HetWSN, covering period of 2009-2019. In addition, we also briefly compare energy based and hybrid clustering algorithm for static and mobile HetWSN on the basis of various clustering attributes. As an outcome of our review, we present a statistical study of the survey which will give researchers a direction to propose novel energy efficient protocol in future. Finally, open issues in WSNs followed by some discussion and conclusion is presented in the paper.

Keywords: Heterogeneous WSN, Clustering, Mobility, Machine Learning, Internet of things.

1. INTRODUCTION

WSN has become one of the most attracted topics of research due to its ability to detect and monitor physical or dynamic environmental conditions over a time frame. How vital has wireless sensor network become now a days can be deciphered from the high volume of research being carried out related to it in past decade. Many sensor nodes combined to form a WSN. The sensor node in WSN has ability to gather information through sensing unit, process the collected data through computing unit and perform communication. Any physical or dynamic activity in the environment can be sensed by a sensor node in which they are installed. A sensor node encompasses components like a battery (acts as power source), sensing unit (sensors and analog-to-digital converters), transceiver, processing unit (Storage and processor). Other possible parts may be generator for energy, mobilizer to move sensor node whenever required and a system for finding a location with high accuracy. Source of power must be used proficiently in the sensor nodes because of extensive network structure the replacement of the embedded batteries in sensors is a quiet tough procedure once they have been deployed. In cluster based network, the collected data is transferred to the cluster head (CH) and then to the node from where data can certainly be sent to user either through a cables or wireless medium. In clustered WSN, cluster head makes the data ready to be used at the base station and further to be used by users. The set-up of sensor node in cluster based network can be done using static or mobile element.
Several applications in WSN such as environment monitoring [1], control system for pollution, operations of military, vehicle motion controlling, finding earthquake, target tracking system and surveillance system, monitoring system in medical [2] are of great significance. Efficiency of cluster based HetWSN can be examined through some parameters like sensor node deployment, Clustering properties, CH selection, mobility of nodes, network scalability, energy efficiency, connectivity between network, data delivery ratio at network layer etc.

1.1. Preliminaries

Clustering is the method in which samples are apportioned into sets with alike members, these groups are called clusters. It falls under one of the divisions of unsupervised learning. Cluster based HetWSNs can be classified according to the clustering techniques, clustering algorithm, Mobility and Node Heterogeneity. The purpose of the grouping nodes in a cluster is to ameliorate energy efficiency. However, grouping node in one cluster is a quiet challenging issue. Classification of cluster based HetWSN is presented in Fig.1.

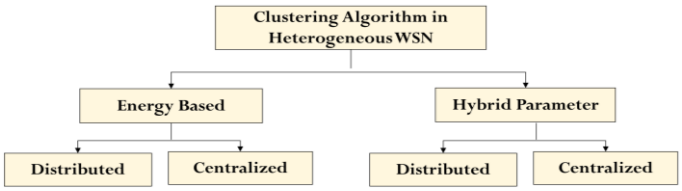


Fig. 1: Classification of clustering algorithm

1.1.1. Clustering Techniques

To differentiate the cluster-based networking protocols there are several parameters employing clustering Techniques for grouping nodes in a cluster depend on network structure, data processing and node deployment in HetWSN. Nodes placed in network area may have similar or different energy levels, processing capability or linking potential. Fig.2 shows the 2-level hierarchy of cluster member nodes. Furthermore, networks can be established on basis of hop (single/multiple) and number of sinks in the network. Cluster head nodes sends the gathered data to CH and collected aggregated data is sent to the sink (base station) respectively. The challenges for obtaining the best result in clustering come out from the process of clustering. The process of clustering includes cluster formation and cluster head (CH) selection algorithms like distributed, hybrid and centralized. Incorporating machine learning techniques, neural network or IoT could be effective in optimizing the clustering result [3][4][5].

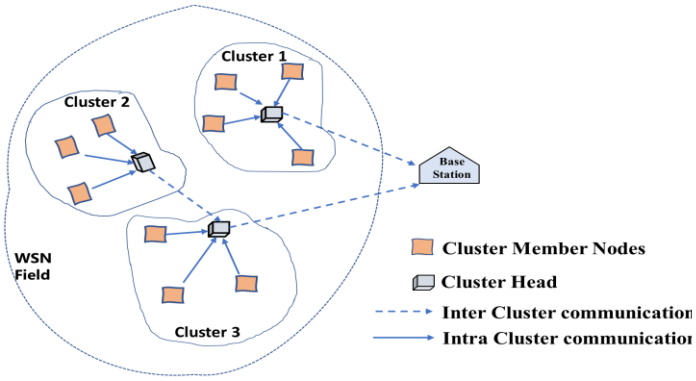


Fig. 2: Architectural design of cluster based HetWSN.

1.1.2. Clustering Algorithm in HetWSN

Sensing devices placed in network field may have similar or different energy levels, processing capability or linking potential. The Nodes with higher energy level has the greater probability to become a Cluster Head. Cluster based HetWSN protocols are either energy based or established with other parameters.

- Energy Based clustering algorithm: In this type of clustering the election of cluster head is based on total remaining energy of nodes and the energy consumed. Energy based clustering protocols in HetWSN can be further classified based on clustering topology.
- Hybrid clustering algorithm: In this type of clustering algorithm the communication between base station and member node of cluster decides selection of the head node in a cluster.

1.1.3. Mobility in Cluster based HetWSN

Mobility is one of the parameters that is also helpful in numerous of application based WSN. Mobility is significant generally in application based network and remarkably, for the IoT. The invention of the IoT (Internet of Things) has accelerated Avant grade protocols which ameliorate the lifetime of a network [6]. Mobility in WSN can be categorized on the basis of physical as well as architectural aspects. Fig.3 shows categorization of Mobility in a network for stationary or moving element.

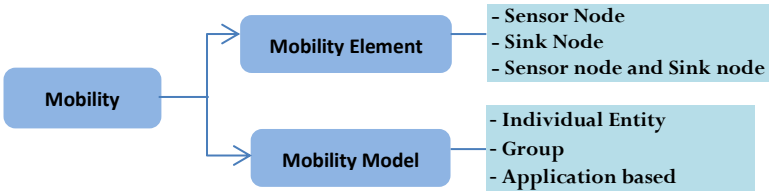


Fig.3 Classification of Mobility for stationary and moving element

1.1.4. Challenges in Clustering

The procedure of clustering includes cluster formation and election of a head node of a cluster. Difficulties in forming a cluster and selecting a cluster head is mentioned below

a. Challenges in formation of cluster are total number of clusters, type of communication (Inter/Intra), Load Balancing and cost.
b. Challenges in selecting Cluster Head (CH) are Energy efficiency, Connectivity, Load Balance amongst all sensor devices and node distance.

Though, various methods have been established for the appropriate grouping of node, but the sensors are clustered suitably or not still don't meet the accountability for answering that the clustering done is best or not.

1.2 Outline

Section 2 explains the work done on different Clustering routing protocols in the direction of achieving elongated lifetime for HetWSNs. Contributions and corresponding discussions which contains node deployment, cluster formation cluster head selection based on several parameters, node heterogeneity of various protocols is comprehensively discussed in section 3. Sector 4 presents statistical analysis of protocols in this review paper. Section 5 discusses about the persisting problems in this area. Conclusion of entire paper is reported in section 6. A little direction to the future work is also given along with the conclusion. Thereafter, the references in the proposed work are listed.

2. LITERATURE REVIEW

A Protocol Low- Energy Adaptive Clustering Hierarchy (LEACH) for WSNs efficiently utilized energy using clustering approach which in-turn increases network lifetime, W.R Heinzelman et al [7]. The issues associated due to random selection of CH in LEACH protocol are, (i) CH nodes are not permanent (ii) CHs distributed disproportionately in the zone where they are installed. These two issues can be solved by uniformly distributing the CHs throughout in the network. The same issues have been investigated and solved suing LEACH-C protocol and a Fixed LEACH protocol. Simulation and analysis of two-level hierarchical network (HWSN) done by Smaragdakis et al. [8] solve the problem of uneven CH uneven energy distribution. Election of CHs based on the left-over energy of every sensor node follows the procedures of weighted election probabilities per node. It gives reduced performance for multi-level HWSN.

A major effort for multi-level hierarchical network (HWSN) investigated by Qing et al. [9]. They proposed clustering algorithm DEEC (Distributed Energy Efficient Clustering) which provide high performance by saving energy of nodes and thus prolonged network life. Lindsey and Raghavendra [10]. Another extension of LEACH protocol is Hybrid energy efficient distributed (HEED) clustering protocol [11], which uses primary constraints and secondary constraint to choose the CHs. Overhead is less in relations to processing and exchange of message. Also, it does not presume any distribution of the nodes or location awareness.

Yazid et al [12] analyzed the routing protocols in an extensive manner based on clustering method. Comparing all those architectures, the design of TSEP and SEP were efficient than that of ZSEP and ESEP. Therefore, in order to enhance network lifetime and to save energy, TSEP architecture can be a decent preference for heterogeneous WSN. Several reviews of cluster-based routing protocols in heterogeneous WSN over the period of time are summarized in the Table 1.

Table 1: Several reviews of cluster-based routing protocols in heterogeneous WSN

Year and Author	Objective	Pros	Cons
2009 GM et al. [13]	Classification based on Energy efficiency, minimize bandwidth and latency	Efficacy and weak point of every protocol described	Comprehensive tabular analogy is not performed.
2010 Vivek et al. [14]	Research on different clustering algorithm for HetWSN. Protocols are categorized based on Energy efficiency, System stability.	Incorporated different heterogeneity types.	Few parameters selected for comparison
2010 Shio et al. [15]	Survey of Energy efficient Protocol based on category, System stability.	Grouping on the basis of various categories of routing- protocol	Tabular classification was missing
2011 Chunjuan et al. [16]	Design of accuracy-based 3D network and Duty cycled WSN.	Underlined Problems in clustering	Tabular classification was missing

2012 Kewei et al. [17]	Articulation of problems based on cluster size optimization and choice of proper communication mode	Qualitative review of protocols	Heterogeneity not considered while comparison
2012 Sahoo et al. [18]	Layout of protocols for Multi path infrastructure, energy efficiency, design and challenges in WSN	Inclusion of the concept of MAC protocol.	No tabular comparison.
2013 Sanjeev et al. [19]	Selection of optimal routing path, energy efficiency, network lifetime Cluster head selection	Tabular approach to explain categorization of routing protocols.	All heterogeneities not considered
2013 Tyagi et al. [20]	Grouping according to Cluster head selection, Security and Load balancing	Pictorial classification of each categories of routing protocols.	Types of heterogeneity not considered
2013 Zahariah et al. [21]	Aim to project protocols based on centralized topology management and Network lifetime.	Strategy of designing routing protocol along with performance evaluation encompassed.	Focused only on hierarchical routing protocols
2015 Sudeep et al. [22]	Comprehensive discussion on various protocols, to highlight the pros and cons with respect to some performance evaluation parameters.	Good and extensive research on heterogeneous protocols	Focused only on Energy Heterogeneity.
2015 Singh J et al. [23]	To describe the operations of WSN algorithms and to assess them based of several clustering features.	Brief review of protocols	Mobility of node in HetWSN is not discussed
2016 Jing et al. [24]	Categorize and brief discussion on persisting routing protocols into homogeneous or heterogeneous WSNs.	Tabular method for comparison of protocols.	Covered less protocols for comparison
2018 Ali et al [25]	Classification of clustering algorithms that are stability-oriented and energy efficient according to operation model and network architecture.	Good and extensive research on heterogeneous protocols	Not discussed much about mobility in Heterogeneous wireless sensor network.
2019 Bhagya Shri et al [26]	Current researches performed to obtain the result for less energy utilization and better network lifespan.	Good and extensive research on clustering protocols	Detailed description missing. Types of heterogeneity not taken into consideration.

From the survey of literature in Table 1, it can be seen that Hierarchy of sensor nodes, consumption of energy, redundancy in data, SNs size, consistency, safety, and

fault tolerance are some features exhibited by many of routing protocols, very few persisting researches have contemplated the node heterogeneity with respect to various parameters. In our work, we have defined classification of various heterogeneous protocols as well and focused more static and mobile Heterogeneous WSN.

3. CLASSIFICATION OF HetWSN

HetWSN consist of sensor devices having dissimilar level of energy. The processing, computing and linking capacity varies in the WSN area. Further classification in HetWSN could be done on the basis of mobile or static HetWSN. For clustering in HetWSN various cluster-based protocols can be distinguished based upon Centralized, distributed or Hybrid Clustering algorithms. Division of routing protocols on basis of mobility of node for heterogeneous wireless sensor network is illustrated in Fig.4.

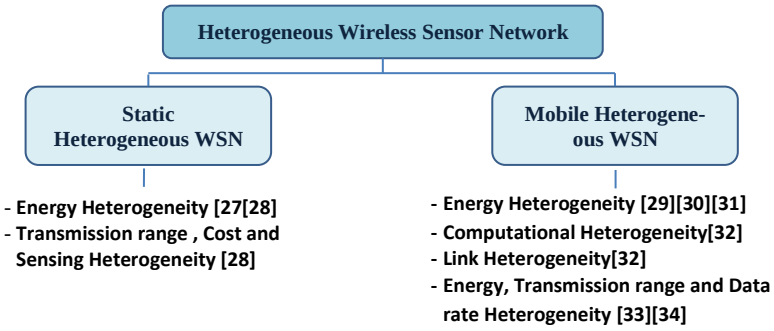


Fig. 4: Classification of energy-efficient Heterogeneous routing protocols based on Static and Mobile Environment

A comprehensive explanation of cluster-based protocols for Static and Mobile heterogeneous WSNs (HetWSN) centered on energy heterogeneity is provided in this paper. Employing node heterogeneity in the design of cluster based WSNs reduces the latency and enhance the data throughput transfer to the destination from the sink. Different types of heterogeneity are Energy Heterogeneity, Computational Heterogeneity, Link Heterogeneity and Hybrid category. Using heterogeneity concept in cluster base HetWSN can boost the energy efficiency of the network. Mobile nodes are useful to minimize the number of hops travelled by a data packet in a network using single or else multi-hop communication.

3.1 Static Heterogeneous WSN (HetWSN)

A network made up of the sensing devices in which the nodes are static in nature but have different processing capabilities. Sensor nodes with hierarchy of nodes supporting different level of energy helps gains improved network lifespan.

3.1.1. Energy based CH Selection Algorithms

ECDC [35] protocol used in coverage of area and a particular point in heterogeneous WSNs for improving efficiency in network lifetime. This protocol has three various divisions for sensor nodes in terms of the energy that are CH (cluster head), plain node and a cluster member. CH is selected based on coverage and residual energy which leads to even distribution of cluster size. Additionally, the lifetime of CH is decided from the starting time to the period when more than thirty percent of sensors are dead. The simulation yields depict the decreased energy consumption and improved coverage performance when compared with HEED and LEACH . This protocol is used where nodes are uniformly deployed.

S Chand et al proposed a protocol Heterogeneous HEED [36] for HetWSN in which three level hierarchy of sensor nodes is considered based on energy heterogeneity. Authors also incorporated distance factor also followed by Fuzzy logic implementation to elect the CHs. Incorporating Fuzzy logic system improved the network lifespan by many folds because a greater number of packets are forwarded to the sink with reduction in energy consumption. The simulation work of Heterogeneous HEED Protocol shows that there is increase in number of active sensor devices on increasing the energy heterogeneity level. Hence the network lifetime is improved at excessive level when higher energy heterogeneity is used.

A protocol Multi Level HEED proposed by S.Singh [37] considered 6 level heterogeneity in the experiment. The simulation result shows improved throughput and network lifetime with reduced aggregate delay. CH selection is based on total energy remaining in a node and node density. ECCR[38] is cluster based energy centric protocol proposed by A. S. M. Sanwar Hosen et al. the selection of cluster head is based on residual energy, distance from member devices.

Verma et al proposed IDHR (Improved Dual Hop Routing) and MEEC (Multiple data sink-based Energy Efficient Cluster-based routing) protocols [39] in HetWSN. Selecting a cluster head in IDHR and MEEC depends on parameters i.e energy, node density and distance between the sink and a node. There are three types of node namely super, advance and normal nodes. Although Network structure for MEEC and IDHR is different but cluster head selection and the network

Table 2: Brief comparison of Energy Based Clustering Protocols for Static HetWSN

Protocol and reference	Cluster Head Selection Constraints	Cluster structure	Data Transmission (Inter-Intra cluster)	Cluster Optimization Technique/Model	Node Hierarchy	Deployment strategy	Stability	Load balancing	Reliability
2014 ECDC [35]	Residual energy and coverage	Distributed	Single Hop- Single Hop	Radio energy model	3 Level (CH, Plain Node and Cluster member)	Uniform in square filed	-	-	-
2014 Heterogeneous HEED [36]	Residual energy and neighbor density of nodes	Distributed	Single Hop-Single Hop	Fuzzy Logic	3 Level	Random (Square filed)	-	Yes	Yes
2017 ML HEED [37]	Residual Energy and Node density	Distributed	Single Hop- Single Hop	Radio energy model	6 Level (n level)	Random (square area)	-	Yes	-
2018 ECCR [38]	Residual energy, No. of member nodes Distance from base station	Hierarchical	Multi Hop-Single Hop	First-order radio dissipation model	1 Level	Uniform and Random	Good	-	-
2019 MEEC [39]	Residual energy, Distance factor of node from sink, Node Density	Hierarchical	Single Hop- Single Hop	Radio Energy Model	3 Level (Normal advance and super node)	Uniform and Random	-	-	Yes
2019 IDHR [39]	Residual energy, Distance factor of node from sink, Node Density	Hierarchical	Dual Hop-Single Hop	Radio Energy Model	3 Level (Normal, advance and super node)	Uniform and Random	-	-	Yes
2020 HMGWO [40]	Residual energy, distance between the node and the BS	Hierarchical	Single Hop	Bio-Inspired	Muti-Level	Random	Very good	Yes	Yes

functioning is same for both the protocols. Probability of each node being alive is calculated once it's checked that residual energy of node is greater than threshold energy. Thereafter a random number is generated using following equation: $ARN_0 = \frac{N-D_N}{N} \times R_N$

If ARN_0 generated is greater in value than the threshold value for advance, super and normal node then respective node becomes a cluster head. MEEC reduces the energy-hole problem thereby enhancing the network lifespan. From the simulation results it is concluded that IDHR and MEEC individually outperform state of art protocols.
Xiaoqiang et al worked on Routing protocol in HEtWSN using bio-inspired optimization technique to propose a new protocol using modified GWO (grey wolf optimizer)[40]. Cluster Head is selected on the basis of remaining energy of a node and distance. Cluster is formed using various fitness functions for the nodes in HETWSN. The experimental results show signification improvement in network energy. Energy based clustering protocol has been compared in table 2.

3.1.2. Hybrid parameters based clustering algorithm

The authors of LEMHR (Lifetime Extended Multi-Levels Heterogeneous Routing) showed that improvement of energy of a network initially may not assure an improvement of energy for higher level nodes in the starting when compared with the nodes at lower level. EEMHR [41] uses k levels of vertical energy heterogeneity but LEMHR[42] uses k levels of horizontal energy heterogeneity. Because of energy heterogeneity it is noticed that the lifetime of a network using LEMHR nearly double up compared to EEMHR. LEMHR can be used in all the applications using smart grid.

S Singh et. al proposed a cluster based three level Heterogeneous DEEC protocol[43]. HetDEEC works on energy dissipation model. This protocol is location unaware because nodes are not equipped with any GPS. HetDEEC this cluster head is based on weighted election probabilities and threshold function. There isn't any cluster optimization technique used in the projected protocol. However the comparison of 1 level, 2 level and 3 level of DEEC with 1,2 and 3 level HetDEEC shows that there is improvement in network energy using HetDEEC protocol. Authors also proposed three-level HetSEP protocol [44] and compared the network energy with 3 level SEP protocol. There was 100% increase in network energy as compared to Stable Election protocol.

Sahoo et al. [45] proposed Enhanced Stable Routing Algorithm (ESRA) for HetWSN. Two-level node hierarchy is employed which not only increases the cluster head selection but improves the operation of node. For normal and advance nodes, a cluster head is selected using below equation: $P_{nrm} = \frac{P_{opt}}{(1+am)\times E_i n}$; $P_{adv} = \frac{P_{opt}}{(1+am)\times E_i n}(1+a)$.
Threshold value of normal node and advance node is calculated and then is compared with the random number generated by the respective node. If threshhold value is greater than the generated random number of respective node then that

particular normal and advance node will be chosen as cluster head otherwise it will remain as a normal node or member node respectively. However, cluster head selection has been categorised as NP-Hard problem in their work.

A nature inspired method GSA-DEEC in WSNs is introduced by Samayaveer Singh [46] which is effective in terms of communication and operating cost of the systems. An optimization technique Gravitational Search Algorithm inspired from nature is used for CH Selection. GSA DEEC offers balance stability among all the nodes deployed randomly in an area to perform for both HetWSNs as well as homogeneous WSN thereby making it efficient selection for CH.
A protocol [47] ECRCP proposed by M Zeng et al. is a cluster based heterogeneous protocol in which the cluster selection is based on maximum coverage ratio. The nodes deployed at fixed position and are equipped with global positioning system. Nodes have different transmission range and data range. The Energy model is established before clustering and then according to maximum coverage ratio cluster head is elected. To optimize cluster head selection it uses objective function in coverage control algorithm. It is observed from the experimental observations that ECRCP is energy efficient in terms of network energy. This protocol can be used for the applications where base station is located in the center of the WSN.
Raji pal et al. proposed a cluster based energy efficient weighted clustering method [48]. This protocol uses genetic algorithm technique to optimize cluster head selection and cluster formation. The objective function to elect cluster head is modified on the basis of density of nodes, distance between nodes and the number of CH. This protocol can be used in application of image segmentation, simulation, image compression, medical image processing etc. A cluster base dynamic energy aware routing protocol GCEEC (Gateway clustering energy efficient centroid) proposed by K.N. Qureshi et al. The cluster head selection is on the basis of centroid position of a sensor node in a cluster [49]. The data load of cluster head is reduced due to positioning of gateway node between cluster head and the base station. It is observed from the simulation that GCEEC outperform the state-of-the-art protocols and can be used in applications based on humidity or temperature monitoring and illumination in farming area.

Table 3 gives a brief description of several protocols highlighting Static Heterogeneous WSN where the cluster head selection is based on parameters like weighted election probabilities (WEP), Threshold function, Distance factor, coverage ratio, centroid position

Table 3: Brief comparison of Hybrid parameter Clustering Protocols for Static HetWSN

Protocol and reference	Heterogeneity/ WSN type	Cluster Head Selection	Clustering structures	Optimization Technique/ Model	(Inter-Intra Cluster) Data Transmission	Node Hierarchy	Deployment strategy	Stability	Load balancing	Reliability
2014 EEMHR [41]	Energy, HetWSN	WEP	Hierarchical	Radio Model	Multi Hop-Single Hop	Multi-Level (Normal and Advance Nodes)	Random	Good	-	-
2015 LE-MHR [42]	Energy, HetWSN	WEP	Hierarchical	Radio Free space/ Multi path model	Multi Hop-Single Hop	Multi-Level Normal node	Uniform	Good	-	Yes
2017 hetDEEC [43]	Energy, HetWSN	WEP and Threshold function	Distributed	Radio Dissipation model	Single or Multi Hop	3 Level	Random (square area)	-	Yes	-
2017 het-SEP [44]	Energy, HetWSN	WEP and Threshold function	Distributed	Radio Dissipation model	Single or Multi Hop	3 Level	Random (square field area)	-	Yes	Yes
2019 ESRA [45]	Energy, HetWSN	Distance factor of node from sink	Hierarchical	Radio Energy Consumption model	Multi-Hop- Single Hop	2 Level (Normal and advance node)	Random	Very Good	Yes	-
2019 GSA DEEC [46]	Energy, HetWSN/ Homogeneous	Fitness function, Distance factor of node from base station, Node Density	Distributed	Bio- Inspired	Multiple Hop or/and Single Hop	Multilevel for HetWSN	Random (Square filed)	Very Good	Yes	Yes
2019 E-CRCP [47]	Data & range transmission, HetWSN	Maximum Coverage ratio	Centralized	Energy Model	Single or Multi Hop	Multi-Level	Random	Good	Yes	-
2020 EEWC [48]	Energy, HetWSN	Weighted fitness Function	Distributed	Genetic Algorithm	Single Hop- Multi Hop	2 Level (Normal and advance node)	Random (Square filed)	Very Good	Yes	-
2020 GCEEC [49]	Data & range transmission, HetWSN	Centroid position	Centralized	Energy Model	Multi Hop- Single Hop	Multi-Level/ Single Hop	Random	Good	Yes	Yes

3.2. Mobile Heterogeneous WSN (HetWSN)

A network made up of the sensing devices in which the nodes are mobile in nature and also have different processing capabilities. A mobile wireless sensor network and heterogeneity may improve the network's efficiency.
In cluster based HetWSN sink or cluster head can be moving element. A mobile node is used to collect the sensed information by moving around the network. A mobile node can track various kinds of mobility designs in the sensor deployed area, such as controlled mobility, random mobility and fixed path (TO-FRO) or predictable mobility. Sink mobility plays significant role for data collection and energy efficiency strategies.
Fig.5 shows mobility scenario in heterogeneous WSN where sink is a mobile element. It is moving in To and Fro motion (Fixed mobility pattern) with the purpose to balance load among all the nodes in network. Sink Mobility method is categorized depending on the mobility patterns like fixed/predictable, controlled modalities and random. The path selection for the sink mobility can be optimized using techniques like bio-inspired protocols, mobility pattern.

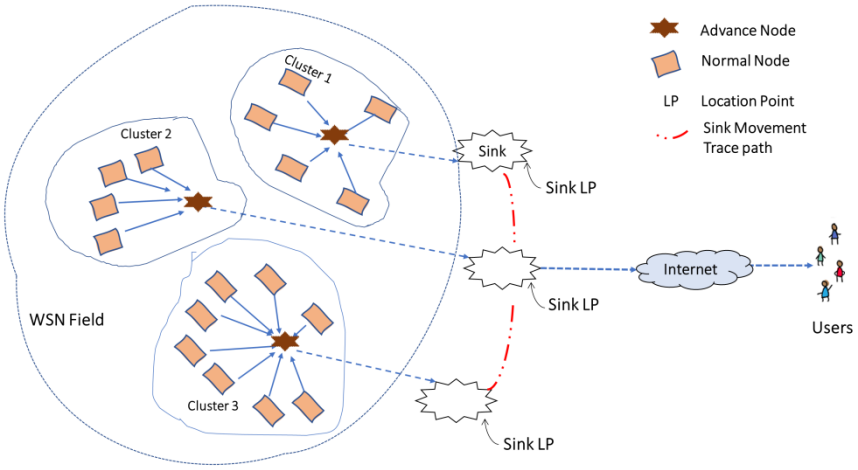


Fig. 5: Mobility Scenario in heterogeneous wireless sensor network

3.2.1. Energy based clustering algorithm

A cluster based hierarchical adaptive and reliable routing protocol proposed by F.J Atero et al [50]. In this 2-Level nodes are deployed in the network field where cluster head and member nodes are at one level whereas sink is at another level. The cluster head selection is based on residual energy. Another protocol s-Harp is introduced by the authors to optimize the cluster head selection. It uses novel threshold value which reduces the chance of a node to become CH which are at far distant from the base station and have low energy. Thus, protocol supports in maintaining efficient link and providing fault tolerance.

A.M Krishnan and P.G Kumar proposed an effective Clustering Approach with Data Aggregation Using Multiple Mobile Sinks for HetWSN. With the help of mobile sink CHs are elected. And the selection is based on residual energy and a threshold value. Mobile sink trajectory is a fixed predefined straight line inside the heterogeneous WSN field.[51]

In protocol EECDRA (energy-efficient cluster- based dynamic routes adjustment approach) [52] the sensor devices in the network field are distributed in a circular area uniformly and then partitioned in identical cluster heads and clusters. There are two movable sinks placed at the edge of the deployed area. Mobility of sink is fixed either clockwise or anticlockwise. It reduces the updating of path thereby enhancing the power efficiency and lifespan of a network. It also gives accountability for load balancing.

A nature inspired protocol using multiple mobile sink proposed by R. Vijayashree et.al [53]. The protocol MMABC (multiple mobile sink using artificial bee colony) can be used in applications with large WSN area. The cluster head selection is based on total remaining energy of nodes, threshold value and distance factor. For Mobility path optimization it uses bio- inspired artificial colony algorithm. Also mobile sink powered with more energy as compared to other nodes in the sensor network field. It is observed from the experimental analysis that MMABC not only optimize the sink path but also stabilize the cluster head selection.

S Zafar et. al proposed two cluster based and mobility aware protocols MCCA(Mobility-aware Centralized Clustering Algorithm) and MHCA (Mobility-aware Centralized Clustering Algorithm) [54]. Nodes are deployed randomly in network area and have different data rate processing data, energy and Transmission range. MCCA algorithm uses centralized clustering whereas MHCA uses hybrid clustering. The cluster head selection in both the protocol is based on residual energy and node velocity. Authors employed first order radio model for energy consumption in data transfer. Experimental results show that both the protocols help in reducing the loss and are energy efficient protocols. Table 4 gives a brief description of several protocols highlighting energy based mobile HetWSN.

3.2.2. Hybrid parameter based clustering algorithm

A mobile HetWSN protocol RAHMoN [55] distinguishes sensing devices as mobile and static. Cluster head is elected on the basis of Distance to the sink, mobility level and energy of node. Sink mobility is based on random waypoint model. There isn't any optimization technique used for clustering. But, the simulation work and performance calculation show that it is effective and adaptable in any kind of environment.

Table 4: Brief comparison of Energy based Clustering Protocols for Mobile HetWSN.

Protocol and Study reference	Heterogeneity/ WSN type	Mobility Node	Mobile Trajectory	Cluster Structure	Cluster Head Selection	Data Transmission	Node Hierarchy	Deployment strategy	Stability	Load balancing	Reliability
2011 s-HARP [50]	Energy, HetWSN	Mobile cluster head	Random	Hierarchical	Residual Energy	Multi-Hop	2 Level (Cluster Head and Normal Node)	Random	Good	Yes	Yes
2015 [51]	Energy, HetWSN	Multiple Mobile Sink	Fixed and Pre-defined	Distributed	Residual energy, threshold	Single Hop	2 Level	Uniform	Good	Yes	Yes
2017 EECDRA [52]	Data rate and Transmission range HetWSN	Mobile Sink	Clockwise or Anticlockwise to network boundary	Distributed	Residual energy	Single Hop	2 Level	Uniform (circular region)	-	Yes	-
2019 MMABC [53]	Energy, Homogeneous/ HetWSN	Multiple Mobile	Random	Distributed	Residual energy, threshold, distance factor	Multi-Hop	2 Level	Random (Square filed)	Good	Yes	Yes
2019 MCCA [54]	Energy, data rate and Transmission range, HetWSN	Mobile Nodes, Static base station	Random	Centralized	Residual energy, velocity	Single hop	3 Level	Random (Square filed)	Good	-	Yes
2019 MHCA [54]	Energy, data rate and Transmission range, HetWSN	Mobile Nodes, Static base station	Random	Hybrid	Residual energy, velocity	Single hop	3 Level	Random (Square filed)	Good	-	Yes

Table 5. Brief comparison of Hybrid based Clustering Protocols for Mobile HetWSN.

Protocol and Study reference	Heterogeneity/ WSN type	Mobility Node	Mobile Trajectory	Clustering Structure	Cluster Head Selection	Data Transmission	Node Hierarchy	Deployment strategy	Stability	Load balancing	Reliability
2012 RAH-MoN [55]	Energy, HetWSN	Mobile sink and cluster head, Static nodes	Random	Hybrid	Distance to the sink, Mobility Level and Energy of node.	Multi-Hop	2 Level (Mobile and static node)	Uniform	-	-	Yes
2013 HSN [56]	Energy, data rate and Transmission range, HetWSN	Mobile Sink	Random Way point	Hierarchical	High Energy Level node	Single Hop	3 Level (H-Sensor, L-Sensor, Sink)	Random and Uniform	-	Yes	-
2016 Heuristic Tour Planning Algorithm [57]	Transmission, Energy, HetWSN	One Mobile Sink, Static nodes	Random	Hybrid	Threshold Function	Single Hop	2 Level	Random	-	Yes	-
2019 EC-PSO [58]	Energy, Transmission range, HetWSN	Mobile data collector, Static nodes	Determined	Centralized	Node energy.	Multi Hop	2 Level	Random	Good	Yes	Yes

A mobile sink clustered HSN (Heterogeneous Sensor Network) protocol was proposed by Sudarmani et al. [56]. Network deployment consists of three-level hierarchical structure of nodes. HSN follows particle swarm optimization for movement of sink. It also demonstrated that the loss of data incurs when mobility in sink increases. Also, it is appropriate for large-scale wireless sensor network.

G Hie et al proposed cluster based Heuristic Tour Planning Algorithm in which cluster head is selected on the basis of threshold function. Mobility elements are the mobile nodes, mobile vehicle or a mobile robot powered with adequate energy. The energy consumption based on radio energy consumption model. It uses minimum spanning tree to solve the traveling salesman problem. The energy dissipation model is represented using below equations

$$ET_x(m,d) = E_{elec} * m + \varepsilon * m * d^n \quad ; \quad ER_x(m) = E_{elec} * m$$

Where, $ET_x(m;d)$ is the energy transmission, $ER_x(m)$ is the energy dissipation, E_{elec} and ε are the constants, 'm' is the number of bits and'd' is the distance [57]. EC-PSO is an Improved Routing Schema with Special Clustering proposed by J wang et. al [58]. Cluster head selection is based on node energy

Table 5 gives a brief description of several clustering protocols where CH selection is based on hybrid parameters for mobile HetWSN.

4. STATISTICAL ANALYSIS

In this section, we discuss the statistical study of recent research topics for routing protocols that are cluster-based in heterogeneous WSN. Comparative Analysis of energy base and other clustering protocols is shown in the graph (Fig.6).

We find that most of the researchers focus on Energy heterogeneity. In contrast to it, less research has been carried out by considering Transmission range and transmitting data rate. Static HetWSN protocols have been employed more in large area WSN. However, Mobile HetWSN outperforms in application specific protocols. Probabilistic parameter is most commonly used in the election of head node of a cluster. Residual energy and distance are next two most used parameters in CH selection.

Transmission and data rate heterogeneity are least explored area as compared to Energy heterogeneity. In our survey 76% of protocols are static in cluster base HetWSN which is 26% more than mobile HetWSN protocols. Altogether, protocols in both static and mobile HetWSN based on hybrid parameter provide better load balancing, stability and are more reliable.

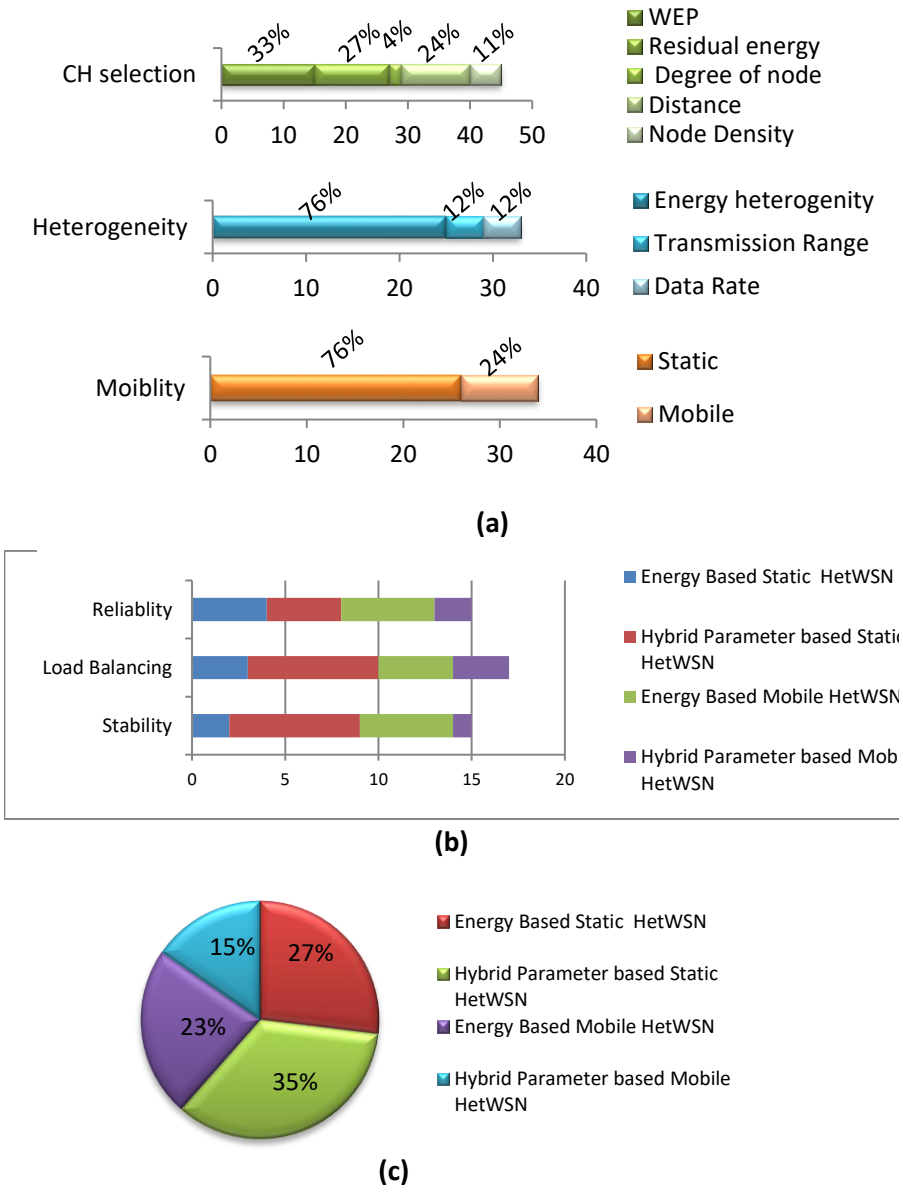


Fig. 6: a) Factors considered in protocols of cluster based Heterogeneous WSN, **(b)** Static and Mobile HetWSN comparative analysis on basis of stability, load balance and reliability, **(c)** Total percent of Cluster based Static and mobile HetWSN algorithms considered in survey.

5. CURRENT ISSUES AND DISCUSSION IN HetWSN

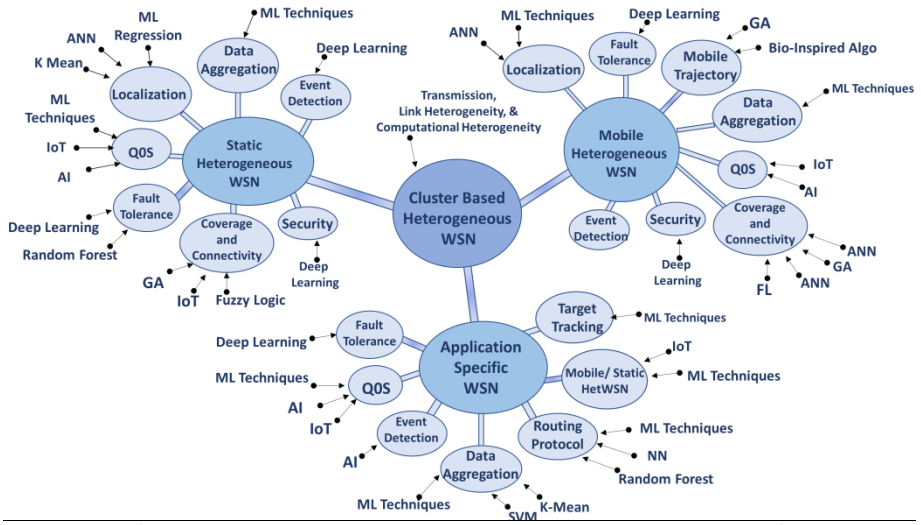
From the review and comparison of several protocols designed for heterogeneous WSN, we conclude that there are yet many open issues which needs to be explored

and a new direction of work may be designed. Fig.7 shows directions of research yet to be explored or least explored.

Energy efficiency is yet a challenging and important problem for WSNs. New Scholars or beginners can do research on Computational and Link heterogeneity as these are also significant in the design of WSN. Bio-inspired protocols are also one of the effective methods to inculcate sink movement. This reduces energy loss in election of cluster head and also improves in target tracking.

Application based clustered network requires exploring optimization techniques for sink movement. As of date routing protocol for specific applications also need attention beside hardware implementation. The state of the art protocols can be explored with invent of IoT. Incorporation of Internet of Things with cluster based HetNET could be great for topology management, ensuring reliability and high availability in application specific WSN. [59]

Machine learning algorithms could be of great importance in sensor readings, for large scale clustering, data aggregation, Target tracing and to optimize routing path for a cluster based routing algorithms [60]. Hybrid parameter clustering for mobile HetWSN is also less explored. Neural network can be useful as an effective tool in decreasing duty cycling, data driven and mobile oriented approach in cluster based heterogeneous wireless sensor network.



AI- Artificial Intelligence; ML- Machine learning Techniques; IOT- Internet of Things; GA- Genetic Algorithm; FL- Fuzzy Logic, ANN- Artificial Neural Network

Fig. 7: Open issues in Cluster Based Heterogeneous WSN

6. CONCLUSION

We have focused on cluster based routing protocols that are energy efficient for mobile and static heterogeneous wireless sensor networks (HetWSN) in this paper. Clustering protocols based on hybrid parameters are more reliable and provide better load balancing which improves the network stability. Mobility based protocols also outperform in many scenarios and ameliorates energy consumption in clustering process. Mobility plays a significant role in network longevity in most of the application based networks. We found that cluster based network incorporated with optimization techniques outperforms the state of art protocols in some cases. Hence incorporation of intelligent techniques with the clustering protocol is recommended for a cluster based HetWSN. Several directions in future work may include implementation of an efficient protocol using optimized clustering and incorporating node mobility for heterogeneous WSN.

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