

A Comparative Study of Distributed Clustering Algorithms in IoT based WSN

Vaibhav V. Deshpande¹ and Dr. Rajesh K. Shukla²

¹PhD Scholar, ¹⁻²Oriental University, Indore, MP 453555, India

Email: vdeshpande2074@gmail.com

Abstract— Wireless sensors are regarded as critical components in allowing effective IoT networking that has spread into a variety of real-time applications. One of the primary goals in constructing a wireless sensor network (WSN) is to increase network lifespan by minimizing total network energy usage. For accomplishing this, numerous strategies like clustering have been proposed to lengthen network lifespan. Distributed clustering is a significant strategy for reducing energy usage in a WSN as it enhances Packet Delivery Ratio and aids scalability. Each sensor node functions in a cluster alter to reduce energy usage, hence extending lifetime of network. Yet, despite the growing adoption of wireless sensor network-based applications, they are still struggling from restrictions such as memory and processing. This research does a literature evaluation with a focus on features of wireless networking for energy conservation and network lifetime enhancement, current cluster-based distributed routing algorithms, their characteristics and future works.

Index Terms— IoT, Wireless Sensor Networks, Clustering, Network lifetime enhancement

I. INTRODUCTION

A wireless sensor network (WSN) is a network field made up of numerous sensors deployed on hardware objects which are spatially scattered to gather data dependent on the activity. To provide information to the base station, the dispersed nodes might be organized into clusters. Sensor nodes are auto organized and capable of monitoring, interpreting and interacting [1]. Wireless sensor networks are employed in practically all remote access applications that entail sensing information from far places and relaying it wirelessly to the control base stations. It really has attracted broad significance and notice, particularly with the incorporation of the IoT which efficiently aids in the transfer of real-time data and digital information. Energy of networks is a key issue, particularly in the transmission of multimedia material because the power delivered to nodes is restricted in nature. As a result, proactive energy consumption for applications or on-demand transmission is required [2]. Data transmission uses greater energy in wireless communication than data processing. Several ideas and techniques for optimizing energy utilization in Wireless Sensor Networks have been presented in recent years. They are divided into clusters to collect information more effectively. As a result, one method for increasing network longevity is to consider routing and clustering [3]. The data collected from every sensor node may be analyzed jointly in a distributed or consolidated manner to assess performance measures towards enhancing our everyday lives [4]. The organization of nodes into clusters is a key method of collecting energy-efficient information in IoT. Clustering, as opposed to non-clustering algorithms, often eliminates energy loss due to passive listening, conflicts, and eavesdropping. In general, each cluster assigns a designated time slot to Member Modes (MNs) for delivering detected information

to the Cluster Head [5]. Clustering in WSNs is extremely advantageous for extending network lifetime and lowering node energy usage. It is demonstrated to enhance network lifespan to three times more than non-clustering systems. Lacking clustering, considerable quantities of energy are spent in data transmission, when nodes interface directly with the sink node, potentially resulting in excessive energy usage. The CH may save more energy by gathering data from nodes and sending it through the CHs to the sensor nodes. As a result, correctly picking the CH from nodes can conserve energy and extend the WSN's lifespan. Furthermore, the majority of the studies concentrated on Cluster head selection in grouping and cluster dependent routing [6]. Heterogeneous wireless sensor networks (HWSNs) are becoming increasingly popular in practice as node resources and network structure evolve. It is primarily concerned with energy heterogeneity. "Stable Election Protocol (SEP), Modified SEP (M-SEP), Prolong-SEP (P-SEP), an Improved version of the Energy Aware Distributed Unequal Clustering Protocol (improved-EADUC) and Distributed Energy-Efficient Clustering Algorithm (DEEC)" were proposed as HWSNs routing protocols with node energy heterogeneity [7]. There are several cluster-based scheduling protocols that use "periodic cluster head election and re-clustering". A majority of these strategies elect cluster heads either individually or through comparison of distinct weighting factors. After similar cluster forms, a joining message is sent, to the local cluster head or to a cluster head with a greater residual energy [8]. The primary contributions in this survey article are overview of distributed clustering algorithms, brief overview of the process involved in IoT-based wireless sensor networks, recent advancements done in the area of IoT-based wireless sensor networks, limitations and research gaps related to the performance enhancement in wireless sensor networks.

II. RELATED WORK

This section reviews existing research studies on distributed clustering mechanism objectives in IoT based wireless sensor network for network lifetime enhancement. For WSNs, a variety of energy-efficient techniques have been developed. Clustering has been incorporated to WSNs since it has shown to be an excellent method for improving data acquisition and sustainability in big WSNs. It also preserves the sensors' restricted energy resources. The cluster that has received the most attention is "low energy adaptive clustering hierarchy (LEACH)". It is one of the first routing methods designed for WSN improving energy efficiency. LEACH's primary idea is to manage energy usage by alternating the CH duty across nodes. Every node creates a number among zero and one. The node defines itself as a CH if the random number is smaller than a specific threshold [9] [10]. In [11] suggested a "sleep-wake energy-efficient distributed clustering method (SEED)" for wireless sensor networks. To accomplish equitable power distribution, it separates the detecting network into zones according to energy level. Only nodes with high residual energy in each area can become CHs in SEED. Unfortunately, it adds extra control packet burden which has a significant impact on network longevity. Furthermore, it doesn't consider the source node capacity and computing capabilities during the CH declaration procedure that might compromise network performance in heavy multimodal traffic scenarios. The SEP protocol distinguishes between developed and regular nodes by using distinct threshold calculations. As contrasted with standard nodes, advanced nodes have a larger possibility of being CHs that minimizes the residual energy variance between ordinary and advanced nodes, thereby extending the network's life cycle [12]. According to the M-SEP methodology, nodes with a high residual energy get a better chance to develop into CH. This approach increases the packet transmission rate and the network's lifespan [13]. "Threshold Sensitive Protocol for Reactive Networks (TEEN)" is a protocol based on the LEACH protocol. In this technique, the cluster head is chosen twice, the second time with a second level CH. The two-pronged method to CH selection assists in assessing how rapidly the perceived input data changes. It optimizes "data packet delivery ratio" by delivering crucial information only when a particular user requests it, making it excellent for time-sensitive applications [14]. In [15] suggested a clustering technique that is Hybrid, Energy-Efficient, and Distributed (HEED). CHs are chosen at frequent times in HEED depending on two criteria: "residual energy and intra-cluster communication cost". To transmit the data packet to the sink with the fewest hops, a clustering approach based on the gradient field was presented. First, each networked node collects its slope in order to discover the slope field that allows a data packet to reach the sink with the fewest hops [16]. In [17], a centralized clustering technique is the "saving energy clustering algorithm (SECA)". Candidate CHs are initially chosen based on their total residual energy. The "modified K-means method" that takes into account the position and residual energy is then used to identify the ultimate CHs. The algorithm is divided into two parts: "the setup phase and the steady-state phase". The centre position is determined during the setup phase to define the starting means of points in accordance with the position of the cluster members. In [18] proposed "Energy aware unequal clustering (EAUC)" that is a clustering technique based on fuzzy logic. The sensor field in EAUC is separated by multiple cluster system. Clusters near the sink have a lower size. The fuzzy logic framework is used for CHs choice and it takes into account all sensor parameters such as residual energy, location, and number of nodes. The

fuzzy logic system's output is the ability of selecting a sensor node as a CH. In [19], "EEUC (energy-efficient unequal clustering)" method is a clustering method with uneven weights. The size of every cluster in EEUC is determined by the distance between its associated CH and the sink. CHs are selected by contest and the contest range expands as distance increases. Clusters near the sink have fewer members when using this strategy and the energy consumed for cluster transmission is minimized. The "Sierpinski Triangle" is used to segment the network via the "energy degree distance unequal clustering method (EDUCA)". In general, the triangle on the outside of the sensor field seems to have more sensor nodes [20]. In [21] suggested a "distributed energy-efficient clustering (DEEC)" methodology. The paper developed a "cluster-head election" technique that relies on the proportion of a node's residual energy to the network's average energy. Although a regular cycle of cluster-head selection using different weight values is used in all of these clustering and routing approaches to introduce balanced power usage of nodes, neither of these algorithms can account for the "energy hole" problem in "many-to-BS data-gathering".

III. OVERVIEW OF DISTRIBUTED CLUSTERING ALGORITHMS

The technique of distributed clustering is one that lacks a fixed central CH and the CH varies across node to node depending on certain pre-determined variables. The key benefits of clustering are as follows: Clustering allows for the geographical reuse of inputs in order to boost system capacity. For example, if the clusters are not adjacent, they might share the same wireless frequency. Only other CH or cluster ports have access to a cluster's information of the network. This constraint minimizes the amount of transmissions required to disseminate routing information. More energy-efficient routing protocols have been devised by taking use of the clustering advantage. When a cluster pattern is employed in a WSN, local changes are not required to be mirrored throughout the whole network. This decreases the amount of data conveyed by sensor nodes and the amount of data retained in IoT devices [22]. Various clustering algorithms are presented below:

A. Low Energy Adaptive Clustering Hierarchy (LEACH)

It is a clustering method which spreads energy usage throughout its network with the network split into groups and CHs that are fully dispersed in nature, with the randomly selected CHs collecting information from nodes in their cluster. Each cycle of the LEACH protocol consists of four major steps: advertising, cluster formation, timetable generation, and data transfer. The eligible CH nodes will issue a notification to the nodes coming within them to apply as a cluster component in its cluster in the first stage, the advertisement phase. The nodes may agree to it according to the strength of the received signal. During the cluster initialization stage, the nodes would react to the CHs they have chosen. Once the CH gets reactions from the nodes, it must create a "TDMA scheme" and return it to its member nodes to notify all that they're required to provide the data to it. The data acquired by the separate sensors will be transmitted to the CH throughout respective time intervals during the data transmission stage. The major limitation is that once the data transmission throughout a specific slot is completed, the radios of the member nodes will be shut off to save energy. It has demonstrated significant progress, mostly in regards to energy effectiveness [23].

B. Hybrid Energy-Efficient Distributed Clustering (HEED)

It is a distributed algorithm that chooses the CH depending on leftover energy as well as data rate. HEED was suggested primarily to avoid the random assortment of CHs. Since the LEACH method is substantially more power saving than its ancestors, the fundamental disadvantage of this technique is the random choice of CH. In a worst-case event, the CH clusters could not be spread evenly amongst nodes which lead to adverse effect on data collection. This procedure is carried out in three stages: "the initialization phase, the repetition phase, and the finalization phase". As it enables heterogeneous sensors, battery charge may change depending on the activity and capability of the node. This phase was iterated until the CH node with the lowest transmission cost was discovered. Unless the node cannot locate the proper CH, the node in issue was chosen as the CH. The selection of CH was determined during the finalization process. In general, the preliminary CH node is now the finalized CH node. The major advantages are increasing the lifespan of the WSN by spreading energy usage equally, choosing cluster heads in a certain amount of repetitions, control overhead should be kept to a minimum and creation of cluster-heads with a uniform distribution and compressed clusters [24].

C. Energy Efficient Hierarchical Clustering (EEHC)

It is a WSN distributed stochastic clustering technique wherein CHs gather data on particular clusters and provide the consolidated result to the source. Their method is divided into two stages: "initial and expanded" [25]. The initial step also known as "single-level clustering" where every node broadcasts its own CH to the adjacent nodes within its transmission range with a probability. These CHs are referred to as voluntary CHs. Each node that gets such notifications but does not constitute a CH joins the nearest cluster. Forced CHs are networks that are neither CHs nor cluster members [26].

D. Linked Cluster Algorithm (LCA)

It is a distributed clustering approach that eliminates transmission collisions between nodes and employs "TDMA frames" for cross communication for every frame including a communication slot for each node in the network. Several studies proposing clusters and CH election methods focus on single-hop grouping and ensure that neither node is far more than a step away out from head. The LCA technique was primarily intended for usage in networks with fewer than hundred nodes. The latency between node communications is low in such tiny networks and may be tolerated [27] [28].

E. CLUBS

This technique takes use of data transmission to effectively group nodes into clusters, with the time it takes for completion related to node density. The clustering process in CLUBS is characterized by the following in order for the clusters to be beneficial for allocating resources and self-organization: To begin, each networked node must be a member of at least one cluster. Secondly, each cluster should have the same size. Finally, a cluster must have internal routing, that implies each node in the cluster must be able to connect with other nodes in the same cluster. With such a potential cluster dimension of 2 hops, the CLUBS algorithm produces overlapping clusters. The key advantage of CLUBS is that CH conflict is less likely [29].

F. Fast Local Clustering Service (FLOC)

It is a distributed clustering approach that generates non-overlapping and about equivalent clusters. It accomplishes locality: the impacts of data aggregation and errors may be felt in any portion of the network that is less than two units away. It uses a "dual-band wireless radio-model" for transmission. Also it accomplishes re-clustering in a local and constant time way. It also achieves locality in the sense that every node is only influenced by nodes in two units. These characteristics encourage this algorithm to be suited for massive WSNs [30].

G. Algorithm for Cluster Establishment (ACE)

It is a relatively uniform group development, self-organizing, effective distribution, less duplication, and emerging cluster formation technique for WSNs that is scale-independent and achieves in time related to node placement density irrespective of network size. It requires little geographical information and only a minor amount of transmission power. The fundamental idea behind ACE is to evaluate a cluster node's potential as a CH before becoming one and to step down if it is not the greatest CH at the time. The ACE method has two key steps: "spawning of new clusters and migration of existing clusters". ACE is quick, resilient to transmission errors and node failure and thus efficient in terms of transmission [31].

H. Distributed Weight-Based Energy-Efficient Hierarchical Clustering (DWEHC)

It is a well-distributed clustering technique that creates well-balanced groups and outperforms HEED significantly. The clustering operation is completed in $O(1)$ rounds and is not affected by topology of the network or volume. Every node identifies its peers first and then determines its weight depending on leftover energy and location to its neighbors. The neighborhood's highest weight node could develop into CH. Neighboring nodes will become member nodes of the clustered hierarchy. Because they have a direct connection to the CH, the nodes are regarded as 1st members at this point. In order to attain a CH with the least amount of energy, a node gradually adapts to certain membership. Essentially, a node checks including its non-CH neighbors to determine their lowest cost for accessing a CH. It exhibits significant improvements in both "intra-cluster and inter-cluster" energy usage [32].

IV. IOT-BASED WIRELESS SENSOR NETWORKS

Wireless Sensor Networks (WSN) is employed to detect and operate a wide range of household and business automation systems. A conventional WSN is composed of tiny gadgets known as nodes. In addition to nodes, those nodes feature a built-in processor, low latency, computing capability and smart sensors. Detectors and nodes are utilized to track the surroundings using these. There are other factors to consider including moisture, temperature, warmth and shaking. WSN is made up of a user, a spine, and a sensor center. The sensor centers connect with each other and send the managed information to the sink hub when distant communication is enabled. All centers send information to the sink center that is subsequently distributed to users over the web. The IoT is a system that enables computer networks to operate, connect, and collaborate with numerous physical objects. It is a type of information technology and Internet network change and development. Developing IoT products enable the development of low-cost WSN with internet connection. The convergence of IoT and WSN is headed towards genius technology. Bandwidth, transmission latency, transmission time, energy usage and security are all factors to consider in IoT dependent Wireless sensor networks. There are number of protocols for WSN. When used in

IoT-WSN-based automations, these protocols and existing research methodologies have both advantages and downsides. There are several sorts of WSNs accessible for various uses. They are “Mobile WSNs, Underground WSNs, Multimedia WSNs, Terrestrial WSNs and Underwater WSNs” [33].

A. Wi-Fi HaLow

This approach allows current "IEEE802.11 communication terminals" to function with a reduced data transfer rate. As a result, it may be employed in remote communications with wireless tower load dumping. Its relay type expansion is utilised for long-distance communication. It employs modulation techniques such as "Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), and Quadrature Amplitude & Phase Shift Keying (QAM)" [34].

B. IEEE 802.15.4 standard

This is the foundational standard for the "ZigBee, MiWi, ISA 100.11a, and WirelessHART" specifications. 3 frequencies are employed. It employs physical layers based on "Direct Sequence Spread Spectrum". The physical layers are restricted to 2 [35].

C. 6LoWPAN

This protocol is built on IPv6 with a "Low Power Wireless Personal Area Network" approach above top. The "Internet Engineering Task Force (IETF)" developed this protocol for use with limited devices operating in frequency spectrum. It can manage numerous small Internet-of-Things gadgets that IEEE 802.15.4 cannot. It is specifically developed for limited battery-powered gadgets that have modest data rates. As a result, it is commonly employed in private area networks and heterogeneous wireless networks for extended ranges [36].

D. IKEv2 authentication-dependent protocols

This protocol may improve connectivity between point-to-point nodes in a distributed network. It supports three primary forms of connections. These are protected edge router communication, secure portal routing and edge router portal tunnelling. IKEv6 supports many types of encryption processes to provide safe connection [37].

E. PMIPv6

This protocol is a popular networking protocol in IoT-dependent wireless sensor networks. A mobile node really isn't permitted to execute "IP-Layer signalling" under this transmission medium. They are permitted to operate using the regular protocol suite. The flexibility is allowed within a designated zone known as the "Localized Mobility Domain (LMD)". The network assigns the mobile node a unique IP address, and the network records the mobile node's travels. This protocol has two basic functional entities [38].

F. APHA

The goal of implementing APHA is to give underside security. Layered Authorization is employed to allow for multilevel relationships among two types of trustworthy nodes. A protocol stack may have several types of cluster members grouped in various hierarchical tiers dependent on their computational capabilities. The Layered Authorization performs the role of providing a secure means of communication between different hierarchical layers. Mutual Authentication safeguards random networks from invader nodes. It enables communication with unknown nodes through a shared diagnostic team. To maintain security, nodes that fail the verification test would be barred from further connection [39].

G. Edge Mesh

It is a new technology that has emerged in the aftermath of the cloud computing prototype. In many ways, edge computing is comparable to fog computing. To address the job scheduling problems, a "genetic algorithm with modified crossover and mutation operators" is developed. It is recommended for usage with applications like intelligent homes and construction automation, autonomous vehicles and smart biomedicine [40].

H. GTANS

It is aimed at improving wireless mobile network security. Since the primary platform of this study is just not directly related to IoT-based WSN, it is included in this discussion since "graph theory" is used to offer network security and IoT-based WSN can function as a subset of WSN. This study employs the "four-color Graph theorem". It addresses two challenges: no coverage sections eradication and varied channel allocation in cluster centers [41].

V. SURVEY ON RECENT ADVANCEMENTS FOR IOT BASED WIRELESS SENSOR NETWORKS

Wireless sensor networks (WSNs) have been created as a result of latest innovations in wireless infrastructure. WSN observes, records, and regulates operations or occurrences that occur in the environment. In these systems, data is sent via a number of routing mechanisms. The 4th industrial revolution, often known as "Industry 4.0", is described as the combination of sophisticated industrial automated systems comprised of equipment and gadgets linked by sensors and governed via software. It is done to improve operational efficiency and dependability. Because of industrial Internet of things, the notion of exploiting IoT technology in production, "Industry 4.0" is seen as a possibility. It provides a means of linking engines, electric grids, and sensing to the web in an industrial context [42]. WSN organization is critical in Workstation layout for scanning the area and data collecting. It investigates its use in a few areas, data capacity, and observation. "Acoustic Surveillance System", the first completely constructed WSN was known as "SOSUS". It was used to identify the threat presented by underwater submarines [43]. As most wireless sensor modules are budget restricted and run on batteries, communication burden and energy requirements are critical challenges to consider when designing WSNs. To handle these wireless sensor devices efficiently and unified, corporate officials must be capable of providing a network infrastructure that supports diverse WSN services and applications that ease the administration of "sensor-equipped real-world entities". A cross-layer architecture of portable and internet dependent Restful Web services is the essential approach for enabling effective and reliable administration of WSN inside such an infrastructure [44]. Wireless sensor networks (WSNs) provide a worldwide approach to the development of medical system infrastructure. This results in an e-health platform which offers an useful collection of data to all users, irrespective of their present location, in real time. Economic systems in this domain typically do not suit general patient demands, and those that do are often economically unsustainable due to high operations and development expenses. WSNs in medicine have emerged as a result of recent improvements in wireless networks and electronics [45].

VI. COMPARATIVE ANALYSIS

TABLE I. COMPARATIVE ANALYSIS OF EXISTING WORKS

References	Objectives	Applications	Results obtained	Future scope
[46]	To extend network life by lowering overall network energy consumption using clustering.	Load balancing in WSN	As compared to earlier presented techniques, this algorithm dramatically increases network longevity.	Can be improved in terms of user distribution
[2]	To enhance network lifetime by EMEER algorithm	Multimedia content transmission	Performs better than traditional clustering techniques	Cluster head selection can be optimized
[47]	To optimize energy in heterogeneous WSN by TOPSIS clustering mechanism	Large scale heterogeneous WSN	Reduces power consumption and increases total network lifetime compared to recent protocols.	Could be tested for more heterogeneous networks
[3]	To maximize network lifetime by Improved Grey Wolf Optimization Algorithm	Optimization of CH selection in WSN	When compared to a typical LEACH technique, the overall number of operating cycles has grown by 441.4% and 869.6%, respectively	Formation of CH can be improved.
[48]	To enhance lifetime in heterogeneous WSN using Fuzzy Logic-Based Routing Algorithm	Heterogeneous WSN	Performs best under heavy traffic load conditions	Should perform well at upper bound
[49]	To improve lifetime of network by cooperative data gathering and relaying algorithm	Cluster based WSN	Good latency, lifetime, and energy consumption and delivery rates	Should be cost effective
[50]	To make fault tolerant routing in WSN by EFT-PMD	Routing in WSN	Better throughput and packet delivery ratio	Fault tolerance should be achieved in heterogeneous networks
[51]	To tune network life time in terms of energy by three-tier clustering technique	IoT based WSN	Better performance than FUCARH, ABCSD, ETLHCM and EAMR	Link formation can be improved
[5]	To maximize network lifetime by optimal clustering	Wireless sensor networks	Increases network lifespan by 19% and improves energy balance by 18%	Should be considered for heterogeneous networks

VII. LIMITATIONS, CHALLENGES AND RESEARCH GAPS

Usually clustering techniques employ two techniques: choosing cluster heads with higher residual energy and shifting cluster heads on a regular basis to regulate the battery life of sensor nodes across the connection. The positioning of the base station is not taken into account by such clustering techniques. Hotspots are caused by this lack of care in inter wireless sensor networks. CH close to the access point die faster as they are subjected to deal with more broadcast traffic than cluster heads far away from the transmission center. Nevertheless, sensor networks are often distributed at random by tossing them into the target zone. As a result, in most circumstances, this strategy is not applicable to real-world situations. In the Wireless Sensor Network, several clustering algorithms make use of uncertainties. Generally, fuzzy clustering methods employ fuzzy logic to mix various clustering factors in order to select CH based on the "defuzzified output of fuzzy if-then rules". Regarding energy effectiveness, optimal clustering should reduce all overhead related not just with the CH selection process, but also with node attachment to their corresponding cluster heads.

VIII. CONCLUSION

It has been demonstrated through the study of various papers that there are various clustering methods exist in Wireless Sensor Networks, as well as various methods to improve the network's life span, conserve energy and efficient node selection for clustering the nodes. The IoT is a platform of interconnected computers or devices which can send and receive data over the internet. WSN is a network of sophisticated sensors that provide a low-cost integration of renewable energy space to IoT sensing instruments. As it is almost impossible to eliminate or replace the batteries in IoT devices, energy consumption is one of the key design issues for WSN. In a network with limited resources, algorithm clustering is critical for power conservation. Using a CH appropriately manages network demand, increasing energy use and boosting longevity. The analyses in this study may be useful for future research in this field.

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