A Short Review of Some of the Unequal Clustering Algorithms in Wireless Sensor Networks

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-----ABSTRACT------

Wireless Sensor Networks (WSNs) contains a large number of sensor nodes that can sense, compute data, communicate with each other, and monitor the physical condition of the environment surrounding. These sensor nodes have limited energy and storage capability. Therefore, energy optimization, to increase the network lifetime is one of the challenging topics in WSN. Other challenges are routing protocol design, Scalability, Selection of the sensor location, Cluster improvement, and security issues. To overcome these challenges to some extent, one of the effective ways is clustering, but it leads to an energy hole or hot spot problem. Unequal clustering is a solution to this problem. This paper provides a broad overview of various unequal clustering methods with its purpose, features.

Keywords - Energy Efficiency, Hotspot problem, Network lifetime, Unequal clustering, Wireless sensor networks.

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I. INTRODUCTION

Wireless sensor network (WSN) contains spatially distributed sensors intended for monitoring the physical conditions of the environment.

Components of sensor nodes [1]:

- 1. Micro-Controller-Also referred to as the processing unit. It is a computer on a chip that is very small in size. It can perform powerful tasks, including controlling the function of other devices connecting to it. It includes a microprocessor, RAM, and associated peripherals.
- 2. Sensing unit- It senses the physical condition of the environment. For instance, pressure, temperature, moisture, vibration, acoustic signal, vehicle transportation, infrared radiation, etc.
- 3. Transceiver-Also referred to as the communication unit. Transmitter and receiver, it is used for communication purpose by the nodes to send and receive processed information.
- 4. Power source-The sensor nodes are batterypowered nodes get the energy from the batteries.

Wireless sensor networks [37][38] are application-specific and can reach several thousand nodes. In a WSN, deployment of nodes can be done in two ways either by placing them at a calculated location or dynamically using any random deployment technique like scattered from a plane over unreachable areas where human intervention is difficult or impossible. The key features of sensor networks are self-organizing skill, limited battery power, the dynamic topology of the network, short-range data transmission, node portability, routing, and wide-ranging deployment capability. Because these features, WSN facilities include [36] of comprehensive war surveillance, environmental monitoring, industrial inventory control, disaster management, traffic control, and medical care monitoring.

Power consumption, bandwidth, and memory are considered crucial issues in WSN designs. Due to sensor nodes deployed in harsh environments, the energy of the sensor nodes depletes expeditiously, and the sensor nodes become lifeless, so re-charging or replacing the sensor nodes becomes difficult enough or impossible in often cases. Therefore, maintaining sensor node life to improve stability is a critical issue with WSNs. Thus, an energyefficient transmission approach is needed to transfer data to the BS from the sensor nodes to extend the useful life of the network. In this regard, clustering with WSN has shown significant progress in reducing the energy consumption of the sensor nodes.

Clustering in WSN is an adequate way to conserve energy and efficiently manage large numbers of nodes, which the researchers recommend. Clustering organizes sensor nodes into groups called clusters. Common nodes of the group/cluster are called cluster members, and from each group/cluster, a sensor node is to be the cluster head (CH). The selection of the right cluster head in WSN can be one more challenge. There is a much energy-efficient algorithm for selecting a cluster head.CH can be chosen based on the residual energy, the number of neighbours, and the distance of the node from the base station.

CH selection

CH in WSN can be selected in three ways: a probabilistic method, an attribute-based method, and a predefined class.

- 1. In the probabilistic approach, CHs are chosen arbitrarily without any prior thought.
- 2. Attribute-based methods use a variety of criteria to select CHs, such as residual or leftover energy of nodes, an order of nodes, the centrality of nodes, predictable remaining or residual energy, and distance to the base station.
- 3. For a pre-set type, prior to putting the sensor in a sensing range, CH is chosen.

Cluster members sense physical world parameters and pass detected values to.CH collects data from each cluster node and accumulates data to eliminate repetitive data, and transfers the accumulated data to the base station. As cluster members cannot relay data straightly to BS, therefore it forwards data to the Cluster head, and CH only transmits it to BS.

Data transmission can be done by:

1. Intra-cluster communication: {Data transfer within a cluster means the node sense data and communicates directly with the cluster head (CH) (single transition/single hop)

2. Inter-cluster communication: {The CH node communicates either directly to the external base station (BS) or through other CH nodes (multi-hop).

Cluster Properties

Clustering methods have several characteristics for cluster formation. Below are the attributes associated with the interior composition of the cluster.

1. Cluster count

It is the number of clusters to be created in one round. The larger the number of group/clusters formed, the smaller the cluster size, which is more suitable if taking energy expenditure into account. The number of formed

groups/clusters are either predetermined or varies depending on the requirements of the application. In some instances, the number of group/clusters formed is 5 % of the total count of distributed nodes. In some clustering methods, the selection of cluster heads is predetermined by distributed sensor nodes in a fixed cluster. While in several implementations, the count of groups/clusters

formed will change if CHs are randomly selected.

2. Cluster size

The cluster size is the maximal route length between cluster member nodes from the CH. Small clusters are

more helpful if considering energy expenditure as they minimize the transportation distance and the weight on the cluster head. Based on cluster size a cluster can be of equal size or uneven size clusters. In equal clustering, the cluster size in the network is the equivalent. For unequal clustering, the size of the cluster is determined based on the distance to BS.

3. Cluster Density

It is the ratio of the number of cluster members in a cluster to the area of a cluster. Reducing the power dissipation of cluster heads in compact clusters presents significant challenges. Some cluster ways that use a fixed clustering always have a low cluster density, but dynamic clustering uses a variable cluster density.

4. Message count

It is the number of messages communication needed to pick a cluster head. If messages sent are to be more, the cluster header selection procedure will consume more energy. Numerous protocols are non-probabilistic and need information transfer for cluster head choosing.

5. Stability

A clustering scheme is adaptive if the cluster members are not fixed or else, we can consider it as stable because the number of clusters does not vary during the clustering process. A fixed number of group/clusters can improve the stability of the sensor network.

Cluster-Head Capabilities

The ability of cluster heads in cluster designs in terms of stability and longevity of the sensor network affects the entire cluster process. Below are some attributes to distinguish between clustering schemes.

1. Role

The purpose of cluster heads in wireless sensor networks is to serve as a relay of information produced by the member nodes of a cluster or execute the charge of data accumulation of the collected sensor data.

2. Node Type

During deployment, some sensor nodes are pre-allocated as cluster heads based on higher energy, high transporting, and computing supplies.

3. CH selection

As mentioned in the above section. The Various advantages of clustering [2][35] are efficient network traffic management, improving energy consumption by better bandwidth usage, scalability, reliability, minimal delay, efficient load balancing, and reduced routing table

size when using routing for energy efficiency. CHs nearby BS uses more energy and also exhausts energy more rapidly than CHs faraway from BS. CHs nearer to BS are burdened with immense relay traffic because of the traffic from their cluster members inside the cluster in addition to data collection, and traffic between different clusters from other CHs to transmit data to the destination (BS). These results in network connections and network range problems in clusters near BS. This problem is called the hotspot problem or energy hole problem.



Fig. 1. Shows clustering in WSN with the following indication mentioned in Fig. 2.

ightarrow ightarrow Indicates members of the cluster

 \rightarrow Indicates the Cluster Head

(Red Line) → Indicates Inter- Cluster Communication

(Blue Line) →Indicates Intra-Cluster Communication

Indicates Base Station

Fig. 2. Indications

Unequal clustering is one of the most effective methods to solve hotspot problems because it can help to balance the load between CHs. Unequal clustering minimizes the size of the clusters nearby to BS and the size of the clusters far from the BS increments.

So, from this, we can get to know that the distance of the CHs from the base station is directly proportional to the size of the cluster.

Smaller clusters nearby the BS specify fewer cluster members and more limited traffic within the cluster. Thus, the smaller the cluster size, the more limited energy the intra-cluster traffic consumes, and the more it focuses on traffic between the clusters.

Likewise, the clusters with larger size and away from BS specify a greater number of cluster members, the less energy the inter-cluster traffic consumes, and the more it focuses on intra-cluster traffic.

Due to unequal clustering, all CHs can consume the equivalent amount of energy, which means CH near BS spends the same amount of energy as CH away from BS.

Therefore, unequal clustering abolishes hot spot problems through efficient load balancing between the CHs.





Clusters having

Medium Size

Clusters close to the

BS having Small Size

Many papers were published showing the use of clustering methods, but not many have surveyed unequal clustering approaches. Therefore, due to this lack of recently developed studies of unequal clustering incited us to write this paper. This survey paper describes in detail the purpose, characteristics, and classification of unequal clustering algorithms. The remainder of this paper is as follows: An outline of unequal clustering, including goals and features, is given in segment 2. Unequal clustering protocols are listed and described in Segment 3 and the comparison of approaches for better understanding in segment 4 and conclusion of the paper in Segment 5.

2 OUTLINE OF UNEQUAL CLUSTERING

This section provides a detailed overview of unequal clustering with purpose and properties.

2.1 Unequal clustering objectives

Nodes are clustered in WSN for various purposes depending on the requirements of the application. Conserving energy and resolving hot spot problems are the principal goals of unequal clustering or prolonging network lifetime. Description of Some of the secondary goals is below. **2.1.1 Load Balancing:** Load balancing is a way to balance the energy expenditure of all nodes. Unequal clustering in WSN ensures even load distribution, which helps to extend the lifetime of the network. In simple words, the lifetime of the WSN will not only rely on the life of weak nodes but will also depend on the survival of all nodes in the network.

2.1.2 Prolonging network Lifetime: There are many definitions for the lifespan of a sensor network that exists. Yet, the commonly accepted interpretation is when the network reaches a point where it is can no longer perform its desired function. It may not prolong when a large number of nodes die. The nodes of a network may no longer be able to communicate or if the network becomes out of coverage. Energy harvesting and the transfer of energy from a high-energy node to low-energy nodes are some latest techniques used to extend the life of sensor nodes and the network. Developing energy-efficient routing protocols and using better clustering methods can also be used to prolong the network lifetime.

2.1.3 Scalability: Scalability is an attribute that describes the ability of a network to grow and manage growing demand. If hundreds to thousands of sensor nodes are in a network, the design of the routing method should take into account the ability to process such a vast number of sensor nodes without affecting network performance.

2.1.4 Fault Tolerance: Fault tolerance is a crucial issue for reliable data delivery in WSN applications. In wireless sensor networks, loss of sensor nodes, communication lines, and data is inevitable. The WSN network fails due to several factors such as power outages, radio interference, environmental impact, asymmetric communication lines, sensor link breakdown, and collisions. In the event of an outage or error, it needs to ensure that the system is available. Many mechanisms have been proposed for fault tolerance to ensure reliability, increased savings, so on. redundancy-based mechanism, cluster-based The mechanism, and deployment mechanism are the three categories of all these methods of fault tolerance can be categorized. Clustering is one of the effective means to make a fault-tolerant WSN. The self-organizing WSN manages the failure by re-configuring/re-clustering the network. Many Energy-efficient re-clustering methods are there to select the best node in a cluster as a cluster head to increase the observing coverage area and to prolong the network's life.

2.1.5. Data Aggregation/Fusion: Data aggregation is an energy-efficient method in WSN. Data aggregation is the means of gathering and accumulating useful data. There can be many nodes that may sense the same phenomena and this can lead to redundancy in the data. Data aggregation can eliminate this redundancy of data. Data aggregation can also be done through signal processing known as data fusion. Data fusion combines certain signals and using some techniques eliminate signal noise, ultimately producing a faultless signal. Data aggregation

also reduces the number of transmissions and improves WSN throughput and energy use.

2.1.6. Topology control: Topology control here refers; we need to make a less complicated topology for the network. In every cluster, the CH is accountable for all topological modifications done at the cluster level and, if any alterations occur, for example, a node fails or relocates to a different cluster. Re-clustering will occur, effectively supporting the network topology. There are many optimization algorithms designed for topology control network and have many uses in the designing and implementation of WSNs. Such as Effective deployment of the sensor network, determining the best transmission range, Better simulation for energy-saving.

3 UNEQUAL CLUSTERING ALGORITHMS



Fig. 4. Types of Unequal Clustering in WSN

3.1 Unequal LEACH

Unequal LEACH [3] Low-energy adaptive clustering hierarchy (LEACH) is one of the foundational algorithms of WSN, presented by Heinzelman in 2000. The LEACH operation executes into rounds. Every round originates with a configuration period in which the cluster gets arranged, succeeded by a steady phase that performs numerous data blocks transportation from the sensor nodes to the cluster head and then to the BS.

In the configuration step, every node attempt to elect itself as the CH per the probabilistic model. Nodes advertise information after they get picked as a head cluster. All non-cluster head node defines a cluster to which it belongs, picking a cluster head node that needs the least interaction energy. Next, it necessarily notifies the cluster head node that it will be a member of the cluster.

In the steady-phase, the cluster head directs its receiver to receive complete data from the cluster member nodes. Once the cluster head gets all the data, it starts working on the data and later sends the resulting information from the CH to the base station. By the methods suggested preceding, after a specific period, the network enters the succeeding clustering process and continues till it meets the network's precise requirements. The steady-state period is lengthy compared to the configuration phase to minimize overhead installation costs.

A better LEACH with an added viable tuning step is proposed to overcome the practical difficulties of LEACH. Improved LEACH creates clusters depending upon Adaptive On-demand Weighting (AOW) that compromise residual or remaining energy with whole energy and competitive radius. Clusters are uneven in size, and CHs transmit data straightly to BS deprived of intermediary nodes. For the selection of cluster heads, the round-robin method is used, and the time intervals to rotate are predefined. At the steady-state stage, the members of a

cluster apply the TDMA program to send data to the CH, and the cluster head utilizes the CSMA program to send the acquired and aggregated data to the BS. After a while, re-clustering will occur. Advanced LEACH output provides a more stable topology for the network and the best service life in contrast to LEACH. This approach bypasses the problem of the hotspot and is suitable for wide-ranging WSNs with high node density.

The latest improved LEACH algorithm is the Node Ranked LEACH (NR-LEACH). The Cluster head in this algorithm is selected based on the rank of each sensor node. Each Node is ranked depending upon its distance from BS, remaining or residual energy, and connected links, and the highest rank node is designated as the cluster head. This algorithm reduces packet loss and has a better packet delivery rate than the previous versions of LEACH protocol, reducing the transfer of redundant data to the cluster head, and improves performance.

3.2 Energy Driven Unequal Clustering (EDUC)

EDUC [4] is a distributed algorithm that lessens power expenditure and overcomes problems with heterogeneous WSN hotspots. EDUC consists of two phases: the phase of cluster construction and data collection. The cluster construction phase includes the CH competition phase and the cluster formation phase, in which clusters of unequal sizes are constructed. Clusters closer to the base station have a smaller size versus the clusters distant from the base station to save energy when transmitting data over long distances. Due to unbalanced clustering, all CHs can exhaust the equivalent amount of energy which means CH near BS spends the same amount of energy as CH away from BS. EDUC includes unequal clustering algorithms and energy-driven adaptive CH rotation methods. Each node serves as CH just one time on the complete network, so the energy depleted during the CH rotation is minimized.CH transfers data straight to the BS. This hypothesis of a single transition is not feasible for several real-time applications, and this is the constraint of this algorithm that it is beneficial for single-hop WSN alone.

3.3 Improved version of the energy aware distributed unequal clustering protocol (EADUC)

To resolve hotspot problems in multi-hop wireless sensor networks, one of the protocols used often is EADUC [5]. In the improved version of EADUC, the additional parameter to choose the cluster heads is, taking into account the number of nodes in the vicinity along with the two clustering variables - location of the base station and leftover or remaining energy of EADUC. Improved EADUC uses a different method to calculate the competition radii taking into account the location of the base station and residual energy along with the additional parameter- the count of neighbourhood nodes. The cluster head sends the data packet to the BS either directly or through relaying. In improved EADUC, also, for the nexthop node selection, the relay metrics are determined in terms of energy consumption and not just the distance information used in EADUC. To further improve performance, in improved EADUC, the rotation of the cluster head does not occur in each round and, the clustering overhead reduces because once the cluster sets up, it lasts for several rounds. As a result, the power consumption of the network decreases, and its life extends.

3.4 Uniform Location Clustering Algorithm (LUCA)

Uniform Location Clustering Algorithm (LUCA) [6] a clustering algorithm with unequal cluster sizes. In LUCA, the sensor nodes are position-informed and, each sensor defines a cluster size based on its location. To address the hot spot issue, LUCA formulates clusters with small sizes nearby the BS and clusters with large sizes apart from the BS. LUCA uses a random delay time to generate CHs uniformly. LUCA's unequal clustering approach can alleviate the problem of equal clustering, but it is unsuitable for much real-time application as the nodes are location-aware and increase energy overhead.

3.5 HEED Based Clustering Algorithms

3.5.1. Hybrid, Energy-Efficient, distributed (HEED) [7] [8] is a clustering approach that creates clusters of similar sizes. In this protocol, the CHs are selected based on their node degrees and residual energy. Node degree helps to balance the load among the cluster heads.

Three phases in HEED form clusters:

1 Phase 1: Initialization-Each node is assigned a probability of becoming a tentative cluster head.

2. Phase 2: Iteration-Here, the nodes double their probability of becoming a cluster head if not covered by any cluster head in each iteration.

3. Phase 3: Finalization-Sensor nodes that did not choose a cluster head will grow one.

The end of the clustering process makes an entry of the network in the data transfer phase. To rotate the role of CH and thus balance the energy levels in the network, clustering reoccurs after some time.

In this finalization stage, All the sensor nodes that are members of the cluster transfers the data to its cluster head. This collected data at the cluster head is delivered finally to the base station in a multi-hop way (moving from one CH to another and at last to the BS).

The difficulty with this is that nodes closer to the BS drain their power very fast than that node farther away. This excessive traffic between clusters near the BS affects the nearby nodes that they begin to die prematurely, resulting in reduced network life.

3.5.2. UHEED [9] improves the HEED protocol by generating unequal sized clusters. It alleviates the hotspot problem for HEED protocol but can be further enhanced. Due to unequal sized clusters, the clusters near the BS have a smaller size and smaller competition radius compared to the clusters away from the BS that have a larger competition radius and the amount of intra-cluster communication near the base station is less compared to the traffic while data transfer between clusters or relay traffic, thus preventing the early death of the nodes.

3.5.3. RUHEED [10] betters UHEED with the initiation of cluster head rotation as energy can be saved better.

RUHEED consists of the following three steps: -

1. Cluster Phase-CHs selection uses the HEED algorithm.

2. Cluster Formation

3. Rotation Phase-Without running any election protocol in this stage, the CH chooses a specific member of its cluster as a current or new cluster head, and the node with the highest residual energy is designated as the cluster head.

This phase remains in progress till one of the WSN nodes fully exhausts its power and, whenever this appears, reclustering to be done using the clustering phase.

3.6 Unequal Cluster-based Routing (UCR)

Unequal Cluster-based Routing (UCR) [11] divides the nodes into clusters of unequal sizes. Clusters closer to the base station have a smaller size and smaller competition radius versus the clusters distant from the base station,

thus, preserving energy for relay traffic between the clusters. The CH is picked based on the remaining energy of adjacent or neigh boring nodes. The UCR protocol distributes CH using a competing radius with an election process and, the rest of the sensor nodes get the transmission from one or more than one CHs and compose an associative judgment based on the lowest transfer expense. However, this mechanism is not always efficient in networks with uneven distribution of nodes. As a result, due to the uneven distribution of nodes, higher power expenditure yet exists amidst the CHs closest to BS. Also, UCR randomly selects multiple tentative CHs to compete for the final CH. Therefore, the involvement of a few temporary CHs may come at the cost of another node that has more residual energy.

3.7 Advanced Energy Efficient Unequal Clustering Mechanism (AEEUC)

In this segment, the Advanced Energy Efficient Unequal Clustering mechanism in WSN has been brought forth and shown how AEEUC [12]is more reliable than UCR in lengthening the network life. We assume that the WSN compose of a BS and a collection of homogeneous sensor nodes that are scattered unevenly covering a limited area of importance. After the deployment, the sensor nodes and the BS are kept stationary. The base station is a node with limitless power and immense abilities, though the sensor nodes have restricted energy.

Due to unequal clusters, AEEUC enhances energy performance. It advances the distribution of CH nodes throughout the WSN. Also, AEEUC uses several criteria for cluster formulation to efficiently spread and regulate energy expenditure between CHs. Furthermore, AEEUC also considers delicate data control to lessen the number of transmissions. Also, AEEUC uses energy-efficient multiple hop routing policies for communication between the clusters.

AEEUC is better than UCR in the following ways:

(a) If using the AEEUC algorithm, all CH will go for the proximate CH having minimum link cost, higher residual energy, and few cluster members as the following hop to adjust the energy utilization amongst CH.

(b) The UCR protocol requires each node other than CH to send received information to CH per loop. In the AEEUC approach, all nodes have the freedom to examine their data before each transmission, though only a section of these nodes will forward their data to the cluster head. It

significantly lessens the energy dissipation during the transfer.

3.8 Improved fuzzy clustered routing algorithm (IFUC)

To address fuzzy performance, an improved fuzzy clustered routing algorithm (IFUC) [13] aimed at balancing and further improving network power consumption to extend the lifespan of the WSN.

IFUC prolongs the network life better when compared to LEACH and EEUC.

There are two phases:

(a) Initial Phase: The fuzzy logic part is adopted to manage uncertainties in the selection of cluster heads and the determination of cluster sizes.

The main idea of a clustering plan is to utilize the local knowledge such as

1. Remaining or Residual or Leftover energy of sensor nodes.

3. Node density.

This information is further used to discover an estimate of the likelihood that the tentative cluster head will become a cluster head and their competence radius. Like many other clustering approaches, the clustering operation is executed in rounds, which is characterized by the use of fuzzy logic. Tentative cluster heads are selected randomly at the starting of each iteration or round so that they can compete to become the final CH. Based on the local information, the tentative head calculates their chance to become the cluster head and competence radius, and the competition to become the CH begins. Every unconfirmed cluster head sends a COMPETECHMSG within its radius of competence.

The message includes the node ID and the probability that it will be a cluster head. As soon as the tentative cluster discovers that there is another tentative cluster with a high likelihood of becoming a Cluster Head, it withdraws from the competition by announcing QUITCOM-PETEMSG inside its competence. The unconfirmed cluster head with the highest probability in its range of competence becomes the CH in the end. When the election phase of the cluster head is over, each cluster head announces a message over the WSN and, normal sensor nodes join with the closest cluster in the range.

(b) Second Phase-In the second step, to achieve load balancing, ACO is used to obtain the most suitable routes from the cluster heads to the BS by taking into attention the inter-cluster traffic.

3.9 Energy Efficient Unequal Clustering (EEUC)

EEUC [14] is a distributed unequal clustering algorithm generally utilized for periodical data gathering applications in WSN. Each node has a pre-defined competitive range. The smaller size of the cluster adjacent to the BS helps in decreasing the loss of energy that happens due to intra-cluster traffic, resulting in saving ample energy to route the data from one cluster to another and at last to BS by multi-hop routing. EEUC protocol is additionally a stochastic clustering approach because, while every round of cluster creation, all node produces an arbitrary number between 1 and 0 to determine if to compete to become the cluster head or not. If the sensor node chooses to compete in the race, it becomes a tentative cluster head.

Finally, the Tentative cluster using localized or confined competition compete, and depending on the sensor node leftover energy, the final CHs are picked out. EEUC significantly lessens the consumption of energy and protracts the network lifetime contrasted with LEACH and HEED.

3.10 Energy Aware Fuzzy Unequal Clustering (EAUCF)

EAUCF [15] is a competitive distributed unequal clustering algorithm that is similar to EEUC. The primary distinction between these two, EEUC and EAUCF, is their methodology of computing the radius of competition. EEUC only considers the distance to the base station parameter into account for calculating the competition radius, while EAUCF uses both- length to reach the BS and the remaining sensor node energy. Also, EAUCF applies fuzzy logic to determine the radius of competition. EAUCF adopts a probabilistic model like CHEF and EEUC to elect the tentative CHs but, based on this model, the final CH cannot be chosen.

In EAUCF, to calculate the cluster head competition radius, the two fuzzy input variables are:

(a) The first fuzzy input variable is the distance of a specific tentative cluster-head to the base station.

(b) The second is the tentative cluster-head residual energy. There is only one fuzzy output parameter - the radius of competition of the tentative CH.

After the computation of the radius of competition by every tentative CH, the race to become the CH begins. Every tentative cluster head broadcasts a CandidateCH Message within its maximum cluster-head competition radius. The message includes the node ID, residual energy, and competition radius, with the prime parameter as the residual or remaining energy, in the cluster-head competition. As soon as the tentative cluster discovers that there is another tentative cluster with high residual energy, it withdraws from the competition by announcing Quit Election Message within its competence. That appropriate tentative cluster head becomes the final CH, which has the maximal energy grade amongst the tentative CHs from which it gets the CandidateCHMessage. When the election phase of the cluster head is over, the normal sensor nodes join with the closet cluster.

EAUCF is more stable than LEACH, EEUC, and CHEF considering two metrics:

(a) First Node Dies (FND)

(b) and Half of the Nodes Alive (HNA).

3.11Fuzzy Based Unequal Clustering (FBUC)

This segment contains an improved variant of the fuzzy energy-aware unequal clustering approach (EAUCF), termed as Fuzzy Based Unequal Clustering (FBUC) [16], an unequal clustering approach depending upon fuzzy logic. In this Algorithm, when calculating the radius of competition, an enhancement is presented by including another parameter, node degree. Here, the competition radius estimates the size of the cluster.

^{2.} The distance to reach the BS.

In EAUCF, after the final CH is selected, the non-cluster head nodes or member nodes connect to the cluster head, the one most approaching to them. Numerous algorithms are there that connect non-cluster head nodes or member nodes to cluster heads based solely upon distance parameter. In unequal clustering, Clusters nearby the BS possess a smaller size compared to the clusters farther than the BS. Hence, If the cluster is closer to the base station and has a higher number of nodes surrounding it, then the cluster head energy drains quickly as these nearby nodes connect to the CH. To resolve this barrier, the approach used in FBUC focuses on combining the nodes which are not in a cluster with the CH.

After the final CH is selected, using fuzzy logic. The cluster forms in the following way:

The non-cluster head member nodes connect to the CH depending upon the degree of cluster head and the length to reach the cluster head.

Cluster head Degree = the number of nodes in its competition reach / the entire nodes.

The main benefits of this approach are extended node life, reduced transmission delays, and decreased energy consumption.

3.12 Energy Conserved Unequal Clusters with Fuzzy logic (ECUCF)

This segment shows a new algorithm, ECUCF [17], that applies fuzzy logic in conjunction with unequal clustering. This protocol is an enhancement over Fuzzy Based Unequal Clustering (FBUC). In WSN, to prolong the network's life and improve the energy efficiency, sectors are formed in EUCF based on two prime parameters- the distance from the base station and the left-over energy of the node.

For the formation of sectors

(a) Fuzzy input variables - DistancetoBS, Leftover or Remaining or Residual energy, Node nearness or proximity.

(b) Fuzzy output variable -Sector formation

ECUCF segments the network into the nearest, center, and outer sectors from the BS depending upon distance.

For Cluster Head Selection: -

The fundamental idea of the LEACH algorithm is the base for picking the cluster head. Each sensor generates an arbitrary digit between 1 and 0. The sensor node becomes prime cluster head if the generated random digit is smaller than the default/predefined threshold (PT) and, the prime CH monitors the power level of its neighboring nodes to keep the sensor nodes in an awake or sleep state. If the energy of a node falls below a threshold, the prime-CH by force put the specific sensor node to sleep. In ECUCF protocol, the final selection of the CH and calculation of the competition radius depends on the principle of fuzzy applying fuzzy parameters mentioned before - the distancetoBS, node proximity, and the remaining energy of sensors.

ECUCF gives better performance across FBUC and LEACH by expanding the total number of active sensor nodes, incrementing the number of the clusters, and extending the node's lifespan in each round.

3.13 Genetic Algorithm (GA)

The Genetic Algorithm (GA) [18] [19] is one of the machines learning algorithms that provide an effective technique for optimization that produces many useful results in the _eld of engineering. This algorithm uses three genetic operators- selection, crossover, and mutation to manipulate the chromosome/solution.

Chromosomes: The possible initial solution to the problem is called chromosomes.

The workflow of the GA is:

(a) Generate initial population at random. These are chromosomes or geno-types.

(b) Evaluate the fitness of each chromosome.

(c) Now to select the parents based on the fitness, the selection operator is applied.

Selection operator: - In this, of all the random populations, two- parents are selected for crossing, expecting that their offspring give higher fitness value than their parents.

Techniques generally used in the selection operator-

- I. Roulette wheel selection
- II. Rank selection
- III. Boltzmann selection
- IV. Tournament selection
- V. Steady-State Selection
- VI. Elitism Selection.

Roulette wheel selection: -

It says based on the percentage contribution to the fitness value of the total population, the strings are selected to form the next generation by mating.

(d) After selecting the parents, the cross over operator is applied. The crossover selects two parent chromosomes and lets them exchange some of their genetic information with each other, producing the next generation of chromosomes.

The crossover operator indicates that it can be a crossover of one or two points.

In one-point crossover: -

In this, the pair of strings selected to form new strings pair need to be cut at random locations and, the segments obtained are modified or swapped to create a new strings pair.

Randomly the crossover point is selected.

For example, Parent 1: 101|11001 Parent 2: 100|01111 Offspring 1:10101111 Offspring 2: 10011001

In two-point, there will be 2 breakpoints. Randomly 2 places selected for crossover.

For example, Parent 1: 101|11|001 Parent 2: 100|01|111 Offspring 1: 10101001 Offspring 2:10011111

(e) The mutation operator applied to individual offspring after mating. In mutation, the bits are changed from 0 to 1 at the randomly chosen position of randomly selected strings.

Again, evaluate the fitness for these output strings after mutation. If optimal or good solution found stop and if not continue with the algorithm.

Genetic Algorithm can be applied in WSN to find the optimum number of cluster heads so that the energy consumed while the communication between the sensor nodes can be minimized and the life of the network can be prolonged.

3.14 Genetic Algorithm based Energy-Efficient Adaptive Clustering Hierarchical Protocol (GAEEP)

The GAEEP protocol [20] working undergoes many rounds. All-round starts with a

(a) Set-up step-in which the BS decides the positions of the CHs and allots the member nodes to each CH,

(b) Succeeded by a steady-state step, Inter-cluster routing from CH to Base Station happens throughout the steady-state phase.

In the first round, BS sent short awakening messages to all sensor nodes in the sensor area, requesting IDs, energy levels, and locations. Based on the acknowledgment obtained from the sensor node, the Base station applies a Genetic algorithm to find the ideal number and positions of CHs based on minimizing the power consumed in the communication process and then allocate the members nodes of each CH. If the node is more nearby to BS than any nearby CH, it can interact directly with the BS. Every CH adopts TDMA scheduling and allocates slots to all of its members to avoid conflicts because of communication within the cluster. Besides, to minimize interference between clusters, each CH chooses a unique code division multiple access codes and notifies its member within the cluster to use this spreading code to send data.

Furthermore, the GAEEP algorithm improves the clustering process performance as it extends the period of stability and narrows the instability time.

3.15 Ant Colony Optimization (ACO)

Ant Colony Optimization (ACO) [21] is a heuristic optimization approach that is well suited to dynamic and distributed environments and, one of the methodologies used to extend the capabilities of WSN. Swarm intelligence algorithms have been used for solving WSN problems. Swarm intelligence is a subcategory of artificial intelligence, inspired by the intelligent behaviour of groups in the natural ecological framework of social insects like ants, bees, wasps, and termites.

ACO is an approach of swarm intelligence, inspired by the foraging behaviour of ants that corporate to locate the shortest path between the food source and the nest. Looking for food, ants randomly roam in the environment. Once they find a food location, the ants return to the nest first, leaving back the traces of a chemical known as pheromones on their way which is helpful for indirect communication between ants for the selection of nodes. Routing and load balancing are some of the problems that an ACO algorithm can solve.

For routing, ACO algorithms are often used to use a metaheuristic approach to determine the best source-todestination route. In addition to determining the best path, the stagnation problem where most of the packets are attributed to the same sensor node leading to the node with a high workload can eventually be solved using the load balancing technique. This is because the use of global or local pheromone updates can change the optimal route from time to time. Although, ACO algorithm performance can be expanded further to acquire minimum latency, maximum throughput, the minimum energy consumption of sensor nodes, and the least stagnation issue, to adjust the whole sensor nodes and simultaneously to prolong the network lifetime of the WSN network.

3.16 Fuzzy and ant colony optimization based combined MAC, routing and unequal clustering cross-layer protocol for wireless sensor networks (FAMACROW)

FAMACROW [22] is a cross-layer approach that merges energy-saving hi-erarchical cluster routing and media access control routing. It employs a fuzzy-based cluster head election procedure for choosing nodes with a higher number of adjacent nodes, high residual energy, and high transmission link quality as cluster heads. It follows that clusters close to BS drain energy quicker than those a long way from BS, heading to critical problems with connectivity and network coverage in the area close to BS. To resolve this issue, FAMACROW organizes the network into clusters of different sizes, where clusters nearer to the BS are smaller in size than the farther away clusters. In addition to the smaller cluster size, there will be less communication within a cluster for the cluster heads close to the BS, thus saving energy for relay traffic.

Ultimately, for inter-cluster multiple hop routing of data from cluster heads to BS FAMACROW, applies the Ant Colony Optimization Approach.

It chooses cluster head to send forth the data to, considering the following:

(a) Its distance from the base station and the current CH (To save energy when clusters communicate).

(b) leftover energy

(c) queue length (To control data loss, as there can be congestion if the network fetches more information than it can manage)

(d) transmission probability (for secure and quality communication)

FAMACROW when, compared with IFUC, EAUCF, and UCR, shows that it has extended the life of the network by up to 63%, is up to 41% more energy-efficient, and receives up to 95% more data at BS.

3.17Swarm intelligence based fuzzy routing protocol (named SIF [23])

Clustering is a viable approach to deal with accomplishing energy performance in WSNs. The cluster-based routing protocol picks cluster heads from all the sensor nodes in the network, and later clusters are created by mapping all nodes to the most proximal cluster head. The fundamental disadvantage is that there are no restraints on how the cluster heads are to be distributed on the network. Apart from the unbalanced formation of clusters problem, most routing protocols are intended for a particular usage area and may not apply to all applications.

So, for these problems, the SIF protocol can be a solution. To aggregate all sensor nodes into balanced clusters, SIF uses the fuzzy c-means clustering algorithm followed by selecting the suitable cluster heads through the Mamdani fuzzy inference scheme. This procedure not just ensures the balancing of clusters throughout the coverage area but can also find out the exact number of clusters. To optimize the table of fuzzy rules in the SIF, it uses a combinative swarm information algorithm called annealing and fire- fly algorithm (FA-SA). Dissimilar to other protocols used for routing in the area of interest which, are intended for a specific application field, the fundamental goal of SIF methodology is to increase the useful life of the network dependent on the application's particularization.

3.18 Coverage aware and Unequal Clustering Algorithm (CUCA)

CUCA [24] algorithm extends network coverage area.

Main features of this algorithm:

(a) Nodes whose sensing area is fully covered by neighboring nodes have a higher priority for selection as cluster heads than partially overlapping sensor nodes.

(b) CUCA implements two CHs selection strategies:

- I. Target areas with very high node density are more likely to overlap sensing areas of sensor nodes. So those nodes are selected as CHs whose sensing area overlapped with its neighbors fully. As a result, the death of such a node does not violate the coverage area of the target area.
- II. In an area with sparse deployment, the node sensing area is less likely to have many overlaps. Thus, in such regions, the choice of CHs depends on the residual energy and the overlap area.

Due to unequal cluster size, the load among the CHs is balanced and distributed uniformly, avoiding the hotspot problem. The unequal size of clusters also helps in minimizing the communication energy of CHs.During the formation of the cluster, those non-CH nodes have cluster memberships whose residual energy is relatively higher than the others, and the non-CH nodes whose sensing region is thoroughly covered by its neighbors are put into rest mode to avoid energy loss and redundant data. CUCA performs better than CA and HEED in respect of coverage lifetime.

3.19 Energy- and Proximity based Unequal Clustering algorithm (EPUC)

EPUC [25] [26] chooses to achieve a spatial dispersal of clusters that balances the power consumption of all the CHs. In EPUC, the region around the base station is divided into several tracks which are, virtual. Nodes that are on identical track combine to form the same size clusters. After identifying tracks, the set of nodes independently chooses as a candidate for CH according to their energy remain.

Subsequently, irregular cluster sizes for the separate routes/tracks are monitored and defined based on two principles: -

(a) the distance from the BS and,

(b) the distance between the CCHs.

The purpose of choosing a CH is to form small size clusters near the BS and relatively large size clusters away from the BS. For CH selection in EPUC, nodes having the maximum remaining energy are designated as CH candidates. Then for the final set of CHs selection, the distance parameter is taken into consideration. EPUC eliminates hotspots problems and prolongs network service life more when contrasted to EEDC and UCR.

3.20Constructing Optimal Clustering Architecture (COCA)

COCA [27] is a scalable non-uniform distributed clustering design that explores the logical challenges of unequal clustering approaches in homogeneous networks. COCA builds an optimized clustering design with energyefficient routing and CH rotation to balance network power consumption. COCA adopts a procedure in which the quantity of clusters in a single region grows with decreasing distance to the base station. For multi-hop routing among clusters, it preserves energy, eliminating hot spot problems.

When selecting the CH, all nodes swap residual energy information among their neighbors. The maximum residual energy nodes confirm them to be the CH. Each CH selects multiple CHs randomly in the neighborhood cluster as the candidates to route data, and the CH with maximum remaining energy, chosen as the final CH for routing. This approach maximizes the network life two to three times when compared to UCR.

3.21Probability Driven Unequal Clustering Mechanism for WSN (PRODUCE)

PRODUCE [28] is a random, non-uniform clustering approach that fixes the hot spot problems. The network lifespan and coverage time of WSN increases as the density of nodes are higher. Coverage time is when the battery of the first CH gets a discharge, which leads to coverage problems, and the lifetime is the interval when all the network nodes stop working. It employs spatial probabilities to build unequal size clusters and probabilistic geometries for routing between clusters. Uneven clustering constructs small clusters close to the BS and large clusters far away from the BS. It reduces hot spots problem, allowing CHs located close to the BS to concentrate on relaying data between clusters and CHs remote from the BS for direct communication within the cluster. This unequal probability-based clustering scheme balances power consumption and maximizes network life and coverage time, especially in networks with high node density. Compared to EEUC, it provides more reliable outcomes in terms of network life.

3.22Energy Balancing Unequal Clustering Approach for Gradient based routing (EBCAG)

EBCAG [29] is a dispersed clustering method that prevents the network from hotspot problems through balancing the energy expenditure among all the CHs and, also, it lessens the energy dissipation of CHs. In this algorithm, each sensor node manages a gradient value, described as the minimum hop number to reach the BS. Based on the gradient value of its cluster head, the cluster size is determined, and, based on CHs descending gradients, the data collected by the members of the cluster forwards the data to the BS.

In this, tentative Cluster heads are selected randomly by a probability T (threshold value- Predefined) and, among the tentative Cluster heads, the CHs with the maximum residual energy, chosen as the final CHs. EBCAG balances energy between CHs well and significantly extends network life as compared to HEED and EDUC.

3.23Unequal Clustering Size Model (UCS)

Unequal Clustering Size Model [30] is a variable size cluster mode for wireless sensor networks. In UCS, CH position is pre-determined before deployment, which is why it is a preset algorithm. The sensing area is considered to be circular and divided into two layers. The shape and size of the clusters on the first layer are the same, but the shape and size of the clusters on the second layer are different. The UCS model solves the problem of unbalanced energy consumption. The CH is placed somewhere in the center of the cluster or near the center to minimize energy consumption. The region covered by the clusters in each layer can be modified by modifying the radius of a layer next to Base Station, thus changing the density of a specific cluster. This model functions better in homogenous networks and primarily balances energy utilization via an unequal clustering approach in the network that processes an abundance of data.

There are two main constraints to this approach:

(a) As the deployment of WSNs is usually random and the number of nodes can change widely, that's the problem of scalability.

(b) This approach also handles multiple layers, so the ideal number of cluster heads to each layer is another concern.

UCS can be extra useful in networks with enormous amounts of data transmissions. In UCS, there is a 10-30% improvement in data collection at the CHs when compared to the equal clustering approach.

3.24Particle Swarm Optimization (PSO)

WSN issues such as node distribution, data aggregation, localization, and energy-aware clustering are often considered optimization problems. Traditional optimized analysis methods are expensive in terms of processing, which grows exponentially as the size of the problem increases. Optimization techniques that require a moderate amount of memory and processing resources and still yield good results are needed, mainly when applied to a discrete sensor node.

Swarm Intelligence based algorithm is a fruitful computational alternative to analytical methods.

There have been a lot of different "Swarm Intelligence" innovations.

(a) Birds Flocking
(b) Ant Phenomenon
(c) Flower Pollination
(d) Bee Colonization
(e) Water Droplets
(f) River Formation
(g) Glowworm Swarming
(h) Cuttlefish Swarming
(i) Gravitational attraction

Among these all, when seeing PSO [31] [32], it is a common multidimensional optimization technique. PSO is a nature-inspired evolutionary and stochastic optimization technique to solve computationally complex optimization problems. This technique models the social behavior of a flock of birds, such as the movement and intelligence of swarms.

The PSO consists of a group/swarm of n particles (individuals), which covers the entire assumed solution space. In the solution space, each particle represents a separate solution, and each particle searches for the best solution. These particles interact directly or indirectly by using the search directions (gradients) or try to find a globally optimum solution. During the PSO iteration, each particle updates its position based on its prior experiences and those of its neighbors.

PSO is composed up of 3 vectors:

(a) The x-vector records the current location of the particle in the search space,

(b) The vector p (pbest) records the position of the best solution the particle has ever found.

(c) Vector v contains the gradient (direction) in which the particle will move if not disturbed.

All these vectors- the positions, the velocity, the best possible solutions (the global best, and the local best), they are all continually updated.

So, the main idea of PSO is, several particles cover the entire solution space and, each solution tries to move in a certain way to get the local best for its own and the global best for the whole group. So that finally it tries to get to the best possible solution as quickly as possible. If seeing PSO and Genetic Algorithm together, GA has the selection operator, but there are no selection operators in PSO. The PSO does not implement the most fittest or appropriate survival strategy. All individuals remain as members of the population throughout the PSO operation. The strengths of the PSO are quality solutions, convergence speed, ease of implementation, and computing efficiency.

Problems in PSO algorithm:

(a) It easily gets stuck in local optima, resulting in premature convergence.

(b) PSO has often been criticized for the fact that some particles can fly away from the search area.

3.25Effective bat algorithm for locating nodes in a distributed wireless sensor network

compared to humans, have better Bats, when eyesight/vision. They possess echolocation that makes it easy for them to navigate and catch prey at dark also. The bat emits a pulse as it moves and perceives the echoes returning to get a sound map of the surrounding. The bat can effortlessly calculate the time and distance needed to echo back the sound. One of the main problems with WSN is node localization. It plays a significant role in many areas, for instance, location service, network coverage, routing data, implementation purposes, and goal tracking. The main objective of localization is to find the positions of the nodes in a short period at low energy costs. Node localization is a multiple dimension space optimization problem.

The metaheuristic Bat algorithm [33] [34] is a potential tool for solving the Node localization problem. Dopeffbat is an improved and efficient Bat algorithm that solves the node localization problem. The effectiveness of this algorithm depends on adapting the velocity of bats through hybridization with the Doppler Effect.

This algorithm can be used with large WSNs with hundreds of sensors to provide good performance for node localization. Dopeffbat has higher accuracy and convergence compared to the Particle swarm optimization (PSO) and original Bat algorithm.

4. COMPARISON OF APPROACHES

The table below shows a comparison of the algorithms to get a clear and better understanding of the differences they have based on size of the cluster, connectedness, type of node and the awareness of the nodes about its location in the network.

Table 1. Comparison Table

Algorithms	Size of cluster	Connectedness	Method distribute	Type of Node	Location Info.
Unequal LEACH	Unequal	Single-hop	Yes	Homogeneous	Not Aware
EDUC	Unequal	Single-hop and Multi-hop	Yes	Heterogeneous	Not Aware
EADUC	Unequal	Single-hop and Multi-hop	Yes	Homogeneous	Not Aware
LUCA	Unequal	Single-hop and Multi-hop	Yes	Homogeneous	Aware
HEED	Equal	Single-hop and Multi-hop	Yes	Homogeneous	Not Aware
UHEED	Unequal	Single-hop and Multi-hop	Yes	Homogeneous	Not Aware
RUHEED	Unequal	Single-hop and Multi-hop	Yes	Homogeneous	Not Aware
UCR	Unequal	Single-hop and Multi-hop	Yes	Homogeneous	Not Aware
AEEUC	Unequal	Single-hop and Multi-hop	Yes	Homogeneous	Not Aware
IFUC	Unequal	Single-hop and Multi-hop	Yes	Homogeneous	Not Aware
EEUC	Unequal	Single-hop and Multi-hop	Yes	Homogeneous	Not Aware
EAUCF	Unequal	Single-hop and Multi-hop	Yes	Homogeneous	Not Aware
FBUC	Unequal	Single-hop and Multi-hop	Yes	Homogeneous	Not Aware
ECUCF	Unequal	Single-hop and Multi-hop	Yes	Homogeneous	Not Aware
GAEEP	Unequal	Single-hop and Multi-hop	No	Homogeneous	Not Aware
FAMACROW	Unequal	Single-hop and Multi-hop	No	Homogeneous	Not Aware
CUCA	Unequal	Single-hop	Yes	Homogeneous	Aware
EPUC	Unequal	Single-hop and Multi-hop	Yes	Homogeneous	Not Aware
COCA	Unequal	Single-hop and Multi-hop	Yes	Homogeneous	Not Aware
PRODUCE	Unequal	Single-hop and Multi-hop	Yes	Homogeneous	Not Aware
EBCAG	Unequal	Single-hop and Multi-hop	Yes	Homogeneous	Not Aware
UCS	Unequal	Single-hop and Multi-hop	Ves	Homogeneous and Heterogeneous	Aware

5. CONCLUSION

In this paper, we discussed clustering as an effective way to conserve energy and effectively manage large numbers of nodes in a network but, it suffers from hotspot problems that induce a higher energy depletion of the network and minimizes the network life.

Unequal clustering is a solution to this problem. It evenly distributes the load, eliminates hotspot problems, and prolongs the life of the network. Further, various unequal clustering protocols are reviewed, showing their contribution to enhancing the WSN life with their limitations. This paper also analysis some nature-inspired algorithms which, are a fruitful computational alternative to analytical methods and can solve difficult optimization problems.

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