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# Clustering Issues and Literature Review of Distributed Clustering Mechanisms in Wireless Sensor Networkswith its Real-World Applications

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***Abstract:*--To diminish the data transmission time and energy consumption, the sensor nodes are assembled into a number of little groups referred as clusters and the phenomenon is referred as clustering. Every cluster comprise of a leader which is known as cluster head. The cluster head will be chosen by the sensor nodes in the individual cluster or be pre-assigned by the user. The main advantages of clustering are the transmission of aggregated data to the base station, offers scalability for huge number of nodes and trims down energy consumption. Fundamentally, clustering could be classified into centralized clustering, distributed clustering and hybrid clustering. In centralized clustering, the cluster head is fixed. The rest of the nodes in the cluster act as member nodes. In distributed clustering, the cluster head is not fixed. The cluster head keeps on shifting form node to node within the cluster on the basis of some parameters. Hybrid clustering is the combination of both centralized clustering and distributed clustering mechanisms. In this paper, clustering issues and literature review of distributed clustering mechanisms in wireless sensor networks with its real-world applications has been elaborated. A literaturereview of different distributed clustering algorithms used in WSNs, based on few metrics such as cluster count, cluster stability, cluster head mobility, cluster head role, clustering objective and cluster head selection is carried out. The research work concludes with comparison of few distributed clustering algorithms in WSNs based on these metrics.**

***Keywords:*—Wireless sensor network, energy efficiency, scalability, sensor nodes, distributed clustering algorithm, clustering and network lifetime.**

## I. INTRODUCTION

Wireless sensor network is major and very interesting technology applied to different applications like monitoring the accessible conditions in specific areas. Each sensor node consists of a wireless transceiver, a microcontroller and a battery. The major advantages of these networks are self-organization, fault tolerance characteristics, energy efficiency, avoiding wiring problems and can be accessed through a centralized control. In order to decrease the data transmission time and energy consumption, the sensor nodes are grouped into multiple clusters. The grouping of sensor nodes is known as clustering. In cluster formation, every cluster has a leader which is known as cluster head. A cluster head is one of the sensor nodes which have advanced capabilities than other sensor nodes. The cluster head is selected by the sensor nodes in the relevant cluster and may also possible by the user to pre-assign the cluster heads. The cluster head is used to transmit the aggregated data to the sink or base station. The sensor-based military applications includes intrusion detection, perimeter monitoring, information gathering and smart logistics support in an unidentified deployed area, sensor-based personal health monitoring, location detection and movement detection using wireless sensor network. A typical wireless sensor networkapplication has been shown in figure 1.A WSN contains a group of spatially distributed sensor nodes which are connected without wires.

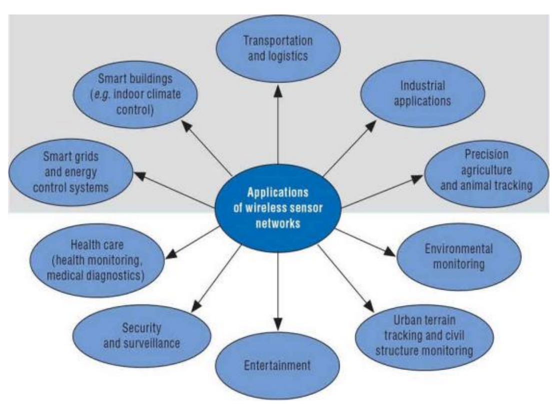


***Figure 1: Application of wireless sensor network***

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Each of the distributed sensor nodes characteristically consist of few sensing elements, a data processing unit, communication components and a power source which is generally a battery as depicted in figure 2. The sensed data is collected, processed and then routed to the preferred end user through a designated sink point, mentioned as base station (BS). WSNs are initially motivated for the use in military applications, such as border monitoring. Now it is chiefly focused on civilian applications such as environment monitoring,bio-medical applications, object tracking, gathering meteorological variables like temperature and pressure, disaster management, etc. The major benefit of WSNs is their capability to operate in unattended environments, where human life is infeasible. Given the enormous area to be enclosed, the short lifespan of the battery-operated sensors and the option of nodes to be destroyed while deployments, vast population of sensor nodes are expected in most of the wireless sensor network applications.

Researchers reveal that hundreds or even thousands of sensor nodes to be involved. These sensor nodes are energy constrained, thereby designing energy-aware clustering algorithms becomes a significant factor for lengthening the lifetime of sensors [8-12]. In order to provision data aggregation through efficient network organization, nodes can be separated into a number of small groups called clusters. This mechanism of grouping sensor nodes into clusters is named clustering as shown in figure 3. Every cluster would have a leader, usually referred to as cluster-head (CH). A CH may be elected by the sensor nodes in the cluster or may be pre-assigned by the network designer. A CH may also be just one of the sensors or a node that is normally richer in resources.

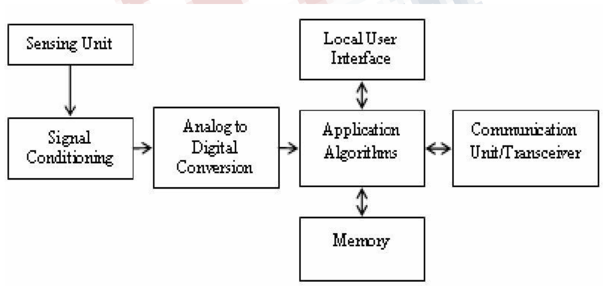


*Figure 2: Entire Components of a sensor node*

Moreover, clustering can stabilize the network topology at the level of sensors and thereby cuts on topology maintenance overhead. The CH can also implement optimized management policies to prolong the battery life of the individual sensors and to maximize the network lifetime [9, 10, 11]. The paper has been organized as follows. A crisp introduction to wireless sensor networks stating their features and applications have been entailed in Section 1. The various design issues in wireless sensor network have been entailed in Section 2. The prevailing real world applications of wireless sensor network has been elaborated in Section 3. A literature survey of different distributed clustering algorithms for wireless sensor networks with their features and limitations have been discussed in Section 4. Finally, the last section concludes the research work.

## II. DESIGN ISSUES IN WIRELESS SENSOR NETWORK

### *2.1 Resource constraints*

The implementation of sensor networks is mainly inhibited by resources like energy, memory and processing. Constrained by limited physical size, the sensor nodes have restricted battery energy. Similarly, their memories are also limited and have restricted quantity of computational capabilities.

### *2.2 Dynamic topologies*

The topology and connectivity of the sensor network might vary due to link failure and sensor node failure. Furthermore, sensors may also be subjected to interference, highly corrosive environments, large humidity levels, vibrations, dust or other situations that confront their performance. These inconsiderate environmental conditions and dynamic network topologies cause a portion of the sensor nodes to get broken down.

### *2.3 Quality-of-service (QoS) requirements*

A variety of applications visualized on wireless sensor network will have dissimilar quality of service requirements. The quality of service offered by these sensor networks refers to the accuracy between the data reported to the sink node and what is really happening in the sensing atmosphere. Data with long latency due to processing may be invalid and lead to incorrect decisions in the ensuing monitoring system.

### *2.4 Data redundancy*

Because of the high solidity in the network topology, sensor interpretations are seriously correlated in space domain. Additionally, the nature of physical happenings constitutes the temporal correlation between the consecutive observations of the sensor node.

### *2.5 Packet errors and variable-link capacity*

Compared with wired networks, wireless sensor network have the attainable capacity of each wireless links that depends on the interference level perceived at the receiver. Moreover, wireless links display widely changing characteristics over time and space due to noisy environments, thereby making quality of service provisioning to be a demanding task.

### *2.6 Security*

Security is an essential feature in the design of sensor networks, to make the communication safe from external denial-of-service (DoS) attacks and intrusion. Passive attacks happen by eavesdropping on transmissions including traffic analysis or exposure of the message contents. Active attacks constitute modification, fabrication and interruption which might include node capturing, routing attacks or flooding. In military applications, security plays a vital role during data communication.

### *2.7 Large-scale deployment and ad-hoc architecture*

Many sensor network have a multitude of sensor nodes (hundreds to thousands or even more), which might be spread arbitrarily over the deployment field. Furthermore, the lack of predetermined network infrastructure demands these networks to setup connections and upholds the network connectivity autonomously.

### *2.8 Integration with Internet and other networks*

It is of fundamental importance for the commercial development of sensor networks to provide services that permit the querying of the network to retrieve useful information. For this reason, these networks should be remotely accessible from the Internet and hence needed to be integrated with the IP architecture. The current sensor network platforms use gateways for integration between sensor network and the Internet.

## III. REAL WORLD APPLICATIONS OF WSN

Although the implementations of wireless sensors are enormous, there are few strange applications of WSNs which could be categorized under: military applications, ecological monitoring, profit-making or human centric applications and in robotics as documented by (Arampatzis et al 2005; Xu et al 2001).

### *3.1 Military and Surveillance Applications*

Military applications are very intimately related to the perception of sensor networks. In detail, it is very tough to say whether motes (nodes) were developed because of military and air defense needs or whether they were invented autonomously and were subsequently applied to army services. Regarding military applications, the area of attention ranges from information collection, generally to the enemy tracking or battlefield surveillance. The avoidance of intrusion will be the answer of the defense system. One example project is "A line in the Sand" and refers to the deployment of several nodes which are gifted for detecting metallic objects. The ultimate goal was the tracking and categorization of moving items with metallic content, and specially the tracking of vehicles and weapon-carrying soldiers. Other civilians were uncared by the system. The principle here is to coordinate with a number of this category of sensors in order to keep sensing the moving object, thereby diminishing any information gaps about the track that could arise. Peacetime applications of wireless sensor networks like homeland security, possession-protection, surveillance, border patrol, etc., are the actions that possibly the future sensor network will be taking on.

### *3.2 Environmental Monitoring Applications*

The ability of a wireless sensor node to sense temperature, light and indoor air pollution could be employed for indoor and outdoor environmental monitoring applications. A chief wastage of energy takes place through needless heating or cooling of buildings. Sensor nodes could be integrated with heaters, fans and other related equipment at an economic way, leading to healthier environment and greater level of comfort for the residents. Other environmental applications are the lessening of fire and earthquake damages. Fire and smoke detections are something widespread today in buildings, and in many countries it is forced by relevant regulations.

### *3.3 Wildlife Maintenance and their Conservation*

Maintaining the faunas in remote areas is one of the vital applications of wireless sensor network. Their lifestyle could be analysed by placing wireless sensor nodes on their bodies. Their migration in the areas where human intervention is merely impossible could be analysed and steps could be taken for their conservation. These sensor nodes will be grouped into dynamic clusters, and the collected information will be sent to the distantly located monitoring station.

### *3.4 Application in Logistics*

Management of precious assets like equipment, machinery and diverse stock or products could be predicament. The difficulty is extremely distributed as these companies increase all over the globe. A gifted technique to achieve asset tracking and cope with this crisis is believed to be with the employment of wireless sensor network. The application of wireless sensors in petroleum bunks refer to the storage supervision of barrels. The concept is that, the sensor nodes attached to these barrels will be able to position the nearby objects, detecting their content and alerting in case of impropriety with their own, etc.

### *3.5 Healthcare Applications*

Healthcare systems can also profit from the use of wireless sensors. Applications in this group comprise of tele-monitoring human physiological data, monitoring of patients within the hospital, monitoring drug administrator in hospitals, etc. Cognitive disorders possibly leading to Alzheimer's could be monitored and controlled at their premature stages with these wireless sensors. The nodes can be used to outline the recent actions, and thus remind the senior citizens, point out the person's real actions or detect a growing problem. A comparable approach employs Radio Frequency Identification (RFID) tags to examine the patient behaviour and customs by recording the frequency with which they touch particular objects. These applications include a display which will assist the care-giver with the exact information about the indisposed person unnoticeably and without hurting their mental feelings. Sensor nodes can also be used in order to study the behaviour of young children.

### *3.6 Robotic Applications*

The association of both static and mobile networks is accomplished with the help of mobile robots, which discovers the environment and deploys motes that operate as beacons. The beacons help the robots to explain the directions. The mobile robots can act as gateways into wireless sensor network. Examples of such tasks are satisfying the energy resources of the wireless sensor network indefinitely, configuring the hardware, perceiving sensor breakdown and suitable deployment for connectivity amid the nodes. This approach strives to answer the difficulty of unifying a network that is separated because of detached groups of sensor clusters. In all these cases, robots are the essential part of the sensor network. In the choice between robotics and medical applications is the virtual keyboard, which is an arrangement of wearable motes capable of sensing the acceleration. Motes are attached with a glove for every finger and at the wrist which is capable of recognition. Applications could be a wireless wearable keyboard or a pointing device, hand motion and gesture recognition for the disabled.

### *3.7 Landslide Detection Applications*

Landslide detection employs wireless sensors for forecasting the occurrences of landslides. One sole trait of these systems is that it combines numerous distributed techniques to contract with the complexities of a distributed sensor network environment where connectivity is deprived and power budgets are unnatural, while fulfilling the real-world safety requirements. These sensors prepare point measurements at different parts of the rock but formulate no effort in measuring the relative motion between the rocks. The approach is based on the uncomplicated observation that rock-slides takes place because of bigger strain in the rocks. Thus, by measuring the source of the landslide, the landslides could be foreseen as easily as if one would be measuring the budding relative movement of rocks. Also, wireless sensor technology can be used to offer advance warning of a looming landslide disaster, facilitating emigration and disaster management.

### *3.8 Forest fire Detection Applications*

Forest fires are wild fires happening in wild areas and become a reason for major damage to natural and human resources. Forest fires burns the infrastructure and might result in severe human death toll closer to urban areas. The universal causes of forest fires include lightning, human carelessness and disclosure of fuel to tremendous heat. It is known that in few of the cases, forest fires are part of the forest ecosystem and they are momentous to the life cycle of indigenous habitats. However, in many cases the losses caused by these fires to public safety and natural resources is intolerable, thereby untimely detection and suppression of fires deem crucial. Charge Coupled Device (CCD) cameras use image sensors which enclose an array of light sensitive capacitors or photodiodes. In case of fire or smoke action, the system alerts the local fire departments, residents and the industries.

### *3.9 Wireless Sensor-Cloud Applications*

Sensor-Clouds could be used for health monitoring applications by means of merely available sensors like accelerometer sensor, proximity sensor, temperature sensor and so forth to gather patient's health-related data for tracking the sleep activity pattern, body temperature and other respiratory conditions. These

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wearable sensor devices have the support of wireless interface for streaming the data and are linked wirelessly to any smart phone through this interface.

## IV. DISTRIBUTED CLUSTERING PROCEDURES FOR WIRELESS SENSOR NETWORKS

Distributed clustering is the mechanism in which there is no fixed central CH, and the CH keeps on shifting from node to node based on some pre-assigned parameters [1] (figure 3). In this section, a literature survey of several published distributed clustering algorithms for wireless sensor networks is presented, based on some advantages like efficient utilization of communication bandwidth within the clusters, localizing energy efficient route setup within clusters, avoiding redundant message transfer between sensor nodes and reduction in energy consumption [2, 4, 5].

### *4.1 Low Energy Adaptive Clustering Hierarchy (LEACH)*

LEACH is a clustering mechanism which distributes energy consumption all along its network, the network being separated into small clusters and CHs which are purely distributed in manner and the arbitrarily elected CHs, gather the information from the nodes which are coming under its cluster. The LEACH protocol involves four chief steps for each round: the advertisement phase, the cluster set-up phase, the schedule creation and the data transmission. During the first step, the advertisement phase, the eligible CH nodes will be delivering a notification to the nodes coming under them to become a cluster member in its cluster [13, 14]. The nodes will be accepting the offer based on the received signal strength (RSS). In the cluster set-up phase, the sensor nodes will be responding to their selected CHs. In schedule creation step, as the CH receives response from nodes it have to make a TDMA scheme and send it back to its cluster members to intimate them when they have to pass the information to it. In data transmission step, the data collected by the individual sensors will be given to the CH during their time intervals. The chief constraint here is that, the radio of the cluster members will be turned off to lessen the energy consumption after the data transmission during particular slot is finished. Here in LEACH clustering protocol, multi-cluster interference problem was solved by using single CDMA codes for each cluster. The energy drain is prohibited for the same sensor nodes which have been elected as the cluster leader using randomization, for each time CH would be changed. The CH is accountable for collecting data from the cluster members and fusing it. Lastly, each CH will be forwarding the fused data to the base station. LEACH shows a considerable improvement mainly in terms of energy-efficiency [3, 6, 7].

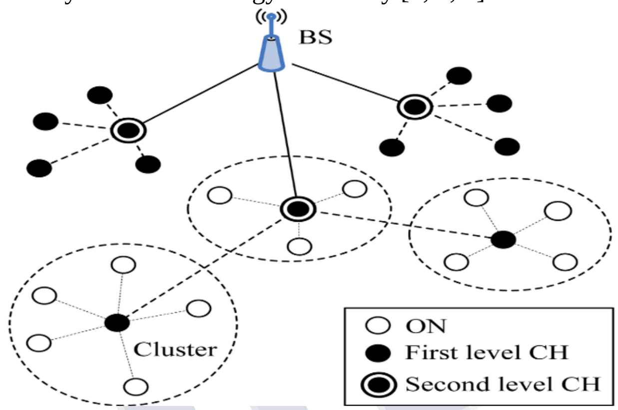


***Figure 3: Diagram of clustering mechanism***

### *4.2 Two-Level LEACH (TL-LEACH)*

A new version of LEACH called TL-LEACH is the clustering methodology in which the CH collects data from other cluster members as in original LEACH, but rather than shifting data to the base station directly, it uses one of the CH that lies between the CH and the base station. It has two levels of cluster heads (primary cluster head and secondary cluster head). The primary CH in each cluster communicates with the secondary CH, and the corresponding secondary CH communicates with their sub-cluster nodes. Data aggregation can be performed as in LEACH. Additionally, communication within a cluster is scheduled by means of TDMA time-slots. The association of a round comprises of first selecting the primary and secondary CHs using the same mechanism as in LEACH, with the probability of being raised to a primary CH lesser than that of a secondary node. Transmission of data from source node to the base station is carried out in two steps, and the secondary nodes gather data from nodes in their own clusters. Data aggregation could be done at this level. Primary nodes gather data from their corresponding secondary clusters. Data aggregation can also be applied at the primary CH level. The two-level arrangement of this algorithm decreases the number of nodes that need to transmit the data to the base station, thereby effectively reducing the total energy usage.

### *4.3 Fixed number of Clusters LEACH (LEACH-F)*

Heinzelman et al proposed a distributed clustering methodology LEACH-F, in which the number of clusters will be permanent all-through the network lifetime and the cluster heads are rotated within the respective clusters.

Steady state phase of LEACH-F is equivalent to that of LEACH. LEACH-F may or may not offer energy saving and does not offer flexibility to the sensor node mobility.

***4.4 Centralized LEACH (LEACH-C)***

Heinzelman et al carried out few alterations in the original LEACH protocol and was proposed as LEACH-C. The original LEACH cluster formation algorithm has the disadvantage of having no assurance about the number of cluster head nodes. As the clusters are adaptive, there is deprived clustering set-up during a round. Nevertheless, by using a central control mechanism to form clusters, can generate better clusters by distributing the cluster head nodes all-through the network, which forms the elementary concept behind LEACH-C.

***4.5 Balanced LEACH (LEACH-B)***

Depedri et al proposed a distributed clustering methodology LEACH-B which functions in the following phases: the cluster formation, the cluster head selection and the data transmission. Each sensor node chooses its cluster head by assessing the energy dissipated in the path between the last receiver and the node itself. It offers greater energy efficiency in comparison with LEACH.

***4.6 Energy Threshold LEACH (LEACH-ET)***

Lijun et al proposed a distributed clustering methodology LEACH-ET, where the clusters will alter only when one of the following conditions are fulfilled: energy consumed by any one of the cluster heads attains the Energy Threshold (ET) in one round, and every sensor node is supposed to have the idea of the energy threshold value.

***4.7 Energy LEACH (LEACH-E)***

LEACH-E offers improvement in the selection of cluster heads when compared to the LEACH protocol. It considers the residual energy of a node as the topmost factor which decides whether these sensor nodes turn into cluster head or not in the succeeding round. LEACH-E assists a large in the cluster head election practice.

***4.8 More Energy efficient-LEACH-L (ME-LEACH-L)***

Chen and Shenformulated ME-LEACH-L, which is an energy-efficient multi-channel clustering-routing protocol for wireless sensor network. With the purpose of controlling the size of every cluster and separating the cluster heads from backbone nodes, ME-LEACH-L supervises the channel assignment amid neighbouring clusters and co-operation among the CHs during data collection process.

***4.9 Adaptive Cluster Head election and Two Hop transmissions LEACH (ACHTH-LEACH)***

Guo et al proposed ACHTH–LEACH to overcome few of the insufficiencies of LEACH. The clusters are set up on the basis of Greedy k-means algorithm. The cluster heads are elected on the basis of residual energy of the sensor nodes, which might undertake two hop transmissions to decrease the energy spent while forwarding the data to the base station. The performance of ACHTH-LEACH could be furthermore enhanced if few parameters and the threshold values are optimized.

***4.10 Trust Based-LEACH***

The frequently employed security solutions based on cryptography and other conventional methods cannot answer the associated issues of internal attackers. To accomplish excellent security feature for wireless sensor network, the Trust-Based LEACH has been proposed. This protocol guarantees secure routing, while keeping the needed functionalities of the original LEACH protocol. The decision-making is based on the decision trust, which is assessed separately and adaptively for dissimilar decisions by the fundamental situational trust.

***4.11 Cluster Maintenance-LEACH-DCHS (LEACH-DCHS-CM)***

Liu et al formulated LEACH-DCHS-CM, for fulfilling the prerequisite of frequent formation of clusters. The algorithm chiefly focuses on the energy balance when certain extent of sensor nodes fails.

***4.12 Time Based-LEACH (TB-LEACH)***

TB-LEACH is an effectual protocol for cluster head selection based on time. The primary mechanism of TB-LEACH is the formation of fixed number of clusters. This algorithm builds clusters by using random-timer mechanism.

***4.13 Optical LEACH (O-LEACH)***

In O-LEACH, the arrangement of the network is composed of a Distributed Fiber Sensor (DFS) link and two detached wireless sensor network fields. The DFS link is located at the center of the sensor fields and can cover certain area. The two fields are occupied with randomly scattered nodes and these nodes can or cannot communicate with each other depending on the necessary applications. This O-LEACH algorithm displaysdecent energy efficiency, especially when two wireless sensor networks are not accessible to each other.

### *4.14 Multi-hop and Single-hop LEACH (MS-LEACH)*

MS-LEACH mainly emphases on the problem of energy consumption during single-hop and multi-hop transmissions within a cluster. A critical value of cluster area size is established. MS-LEACH is based on the critical value and this technique outperforms LEACH protocol in terms of network lifetime.

### *4.15 Heterogeneous-LEACH (LEACH-HPR)*

Hanproposed LEACH-HPR, which is an energy efficient cluster head election technique and uses the customized Prim's algorithm to construct an inter-cluster routing in heterogeneous wireless sensor network. LEACH-HPR is more operative in reducing and balancing the energy consumption and hence exhibits enhanced network lifetime [6].

### *4.16Hybrid Energy-Efficient Distributed Clustering (HEED)*

HEED is a distributed algorithm which chooses the CH based on both residual energy and communication cost. Fundamentally, HEED was suggested to avoid the random selection of CHs. Though LEACH protocol is much more energy efficient when compared with its antecedents (discussed above), the foremostdisadvantageof this method is the random selection of CH. In the worst case, the cluster head nodes may not be evenly distributed among the nodes and it will have its consequence on data gathering. The Hybrid Energy-Efficient Distributed Clustering protocol gets executed in three subsequent phases: the Initialization phase, the repetition phase and the finalization phase. In repetition phase, until the CH node was found with least transmission cost, this phase was iterated. Finalization phase, in which the selection of CH was finalized. In common, the tentative CH now becomes the final CH node.

### *4.17 Linked Cluster Algorithm (LCA)*

Linked Cluster Algorithm (LCA) is a distributed clustering algorithm that evades communication collisions among sensor nodes and uses TDMA frames for inter-node communication, with each frame having a time slot for each node in the network for communication. Suggesting cluster formation and CH election algorithms, numerous papers focuses on single-hop clustering and thereby guarantees that no node will be more than one hop away from leader. In LCA, every nodes necessitates 2n time slots, where n is the number of nodes in the network, to have awareness of all nodes in its neighborhood. If a node x has the maximum identity among all nodes within one wireless hop of it or does not have the maximum identity in its one hop neighborhood, but there occurs at least one neighboring node y such that x is the maximum identity node in y's one hop neighborhood, it convertsin to a cluster-head. Essentially, the LCA approach was designed to be used in the networks with less than 100 nodes. In such minor networks, the delay between the node transmissions is negligible and may be accepted.

### *4.18 CLUBS*

This algorithm uses the benefit of local communication to proficiently aggregate the nodes into clusters, in which the time reserved for convergence is proportional to the local density of nodes. In order that the clusters to be beneficial for resource allocation and self-organization, the clustering phenomenon in CLUBS is described by the following: First, every node in the network must fit to some cluster. Second, every cluster should be of identical diameter. Third, a cluster should have local routing, which means that every node within the cluster should be able to communicate with each other using only nodes within that same cluster. The CLUBS algorithm forms overlapping clusters, with the maximum cluster diameter of two hops. Every nodes starts competing to form a cluster by selecting random numbers from a fixed integer range [0, R]. Each node counts down from that number silently. If it touches zero without being interrupted, the node becomes a CH and recruits its local neighborhood in to its cluster by broadcasting the recruit message. The nodes that get recruited are normally called followers. Once a node has been recruited as a follower, it halts counting down and listens for extra recruit messages. In CLUBS the main distinguishing feature that should be remembered is that it provisions cluster overlap. If a node detects a collision while counting down, it assumes that more than one of the neighbors tried to recruit it at the same time and convertsas a follower. At the end of R steps, all nodes in the network are moreover leaders or followers.

### *4.19Energy Efficient Hierarchical Clustering (EEHC)*

EEHC is a distributed and randomized clustering algorithm for WSNs, in which the CHs gather the information about the individual clusters and forward the aggregated report to the base-station. Their method is based on two stages: initial and extended. The initial stage which is also namedas single-level clustering, in which each sensor node proclaims itself as a cluster head with a probability p to the neighboring nodes within its communication range. These CHs are named as volunteer CHs. All the nodes that are within k hops range of a CH receive this announcement either by direct communication or by forwarding. Any node that accepts that announcements and is not itself a CH becomes the member of the closest cluster. Forced CHs are sensor nodes that are neither CHs nor belong to a cluster. If the announcement does not reach to a node within the preset time interval t that is calculated based on duration for a packet to reach a node that is k hops away, the particular node will become a forced CH assuming that it is not within k hops of all volunteer CHs. In the second stage, the procedure is prolonged to allow multi-level clustering and generally builds h levels of cluster hierarchy. Thereby, the clustering method is recursively repeated at the level of CHs to form an additional tier. The algorithm guarantees h-hop connectivity between CHs and the base-station.

### *4.20Fast Local Clustering Service (FLOC)*

FLOC is a distributed clustering method that produces non-overlapping clusters and around equal-sized clusters. FLOC attains locality: effects of cluster formation and faults or changes at any part of the network within almost two units distance. FLOC displays a double-band structure of wireless radio-model for communication. A node can communicate reliably with the nodes that are in the inner-band (i-band) range and unreliable communication with the nodes in its outer-band (o-band) range. Hence, thei-band nodes suffer very minute interference communicating with the CH, thus it is a reliable communication. Messages from o-band nodes are unreliable during data communication and hence it has the maximum probability of getting vanished during communication.FLOC is fast and scalable, hence it attains clustering in O(1) time regardless of the size of the network. It also displays self-healing capabilities, since the o-band nodes can switch to i-band node in another cluster. It also accomplishes re-clustering within constant time and in a local manner. It also accomplish locality, in that each node is only influenced by the nodes within two units. These structures stimulate FLOC algorithm to be suitable for large scale WSNs.

### *4.21Algorithm for Cluster Establishment (ACE)*

ACE is a highly uniform cluster formation, self-organizing, lesser overlapping, efficient coverage and emergent cluster forming algorithm for WSNs, which is scale-independent and finishes in time proportional to the deployment density of the nodes irrespective of the overall number of nodes in the network. ACE necessitates no knowledge of geographic location and requires only minor amount of communication overhead.The key idea of ACE is to assess the potential of a cluster node as a CH before becoming a CH and steps down if it is not the best CH at the moment. The two rational steps in ACE algorithm is spawningof new clusters and migration of the existing clusters. Spawning is the process by which a node becomes a CH. During spawning, when a node agrees to become a cluster head, it broadcasts an invitation message to its neighbors. The neighboring nodes agree such invitation and become a follower of new CH. The chiefdistinguishing feature of ACE is that, a node can be a follower of more than one CH. During migration, best candidate for being CH is selected. Each CH will occasionally check all its neighbors to regulate which node is the best candidate to become a cluster head for the cluster. The finest candidate is the node which, if it were to become a cluster head, would have greatest number of follower nodes with lesser amount of overlap with the prevailing clusters. Once the best cluster head is determined by the current cluster head, it will promote the best candidate as the new CH and steps down from its CH position. Thus, the location of the cluster tends to migrate towards the new CH and some of the former follower nodes of the old cluster head are no longer part of the clusters while some new nodes near the new CH becomes new followers of the cluster. Each time that an action can be started for a node is called node's iteration.ACE is fast, robust against packet loss and node failure thereby effectual in terms of communication. It uses only local communication between the nodes and shows a decent demonstration of flexibility of emergent algorithms in large-scale distributed systems.

## V. CONCLUSION

Essentially, clustering could be classified into centralized clustering, distributed clustering and hybrid clustering. In centralized clustering, the cluster head is fixed. The rest of the nodes in the cluster act as member nodes. In distributed clustering, the cluster head is not fixed. The cluster head keeps on shifting form node to node within the cluster on the basis of some parameters. Hybrid clustering is the combination of both centralized clustering and distributed clustering mechanisms. In this paper, clustering issues and literature review of distributed clustering mechanisms in wireless sensor networks with its real-world applications has been elaborated. A literature review of different distributed clustering algorithms used in WSNs, based on few metrics such as cluster count, cluster stability, cluster head mobility, cluster head role, clustering objective and cluster head selection is carried out. The research work concludes with comparison of few distributed clustering algorithms in WSNs based on these metrics.

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