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Energy Efficient Routing Clustering Algorithms For Wireless Sensor Networks

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ABSTRACT

Wireless Sensor Networks have come to the forefront of the scientific community recently and it consists of small nodes with sensing, Communications and computing capabilities. The Wireless Sensor Network Systems can be applied to monitor different environments. In WSN, sensor nodes play the most prominent role. These sensor nodes batteries are replacing or recharging is impossible, it is essential to find energy efficient routing algorithm. In this paper, we survey the features / characteristics and different well-know energy efficient cluster routing algorithms for WSNs have been classified and presented based on their characteristics.

INDEX TERMS - **Wireless Sensor Networks (WSN), Clustering, Energy Efficiency, Distributed cluster routing algorithms, Centralized cluster routing algorithms, Uni-form distribution..**

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1 INTRODUCTION

Wireless Sensor Networks have recently emerged as a premier research area. They have great long term economic potential, capability to transform our lives, and pose many latest system-building challenges. Sensor networks also pose a number of latest abstract and optimization problems, some of these such as tracking, location and exploitation are most important issues, in that several applications rely on them for necessary information. Coverage in general, answers the questions about quality of service that can be provided by a particular sensor network. The integration of various types of sensors such as acoustic, seismic, optical, etc. in one network platform and the study of the overall coverage of the system also presents numerous interesting challenges.

Wireless sensors have become an excellent tool for military applications relating intrusion detection, perimeter monitoring, and information gathering and elegant logistics support in an unidentified deployed area. Some additional applications: location detection, sensor-based personal health monitor with sensor networks and movement detection [11].

Energy efficiency is necessary for this sensor network's effectiveness because sensor nodes batteries recharging or replacing is impossible. A large number of studies have been conducted in order to propose energy efficient routing algorithms for WSNs [2],[4]. The main issue of energy consumption for WSNs is their communications [5].

Clustering is one of the best techniques [1], [6] for lowering energy consumption. In a clustered Wireless Sensor Network, sensor nodes are grouped into a certain number of clusters, each of which consisting of a cluster head (CH) and some non-cluster head nodes (non-CHs). CH collects information from all the cluster nodes and then forwards to other CHs or base station (BS), while non-CHs nodes are responsible for sensing environment and transmitting information to the corresponding CH [3].

The researches have been conducted for achieving high energy efficiency in clustered algorithm WSNs [7], [8], [9], [10]. Existing methods can be largely divided into two categories: centralized clustering methods [12], [13], [14], [24], [26] and distributed clustering methods [20], [21], [22], [23]. Centralized cluttering methods typically request knowledge of the location of each sensor nodes or the location distribution of all the sensor nodes such that decisions can be make to achieve a certain kind of global optimization. Distributed clustering methods, on the other hand, make all decisions based on local information, typically with limited information exchanges between neighborhood sensor nodes. The distributed clustering methods help achieve improved scalability of networks, while the centralized clustering methods are useful where location of each sensor nodes or location distribution of all the sensor nodes is known to a central controller. Centralized clustering methods also serve as a good reference for sensor network pre-plan and a helpful benchmark for evaluating the performance of distributed clustering methods or methods based on inaccurate global information.

In this paper, we survey the different well-known energy efficient cluster routing algorithms for WSNs which have been projected by researchers so far.

Int. J. Advanced Networking and Applications
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II CHARACTERITICS /FEATURES OF WSNS

WSNs have different characteristics / features which can have an impact on designing efficient cluster routing algorithms. These features of WSN can be used to compare different protocols and algorithms. A number of WSN characteristics / features are as follows [1]:

- **WSNs vs Ad-hoc Networks:** WSNs is one form of an ad hoc wireless network, A sensor network is a collection of a large number of sensor nodes that are deployed in particular region. Since an ad hoc Wireless S Network does not rely on any fixed network entities, the network itself is essentially infrastructure less. Here is no need for any fixed radio base stations, any wires or fixed routers.

- **Sensor Positions are not Engineered or Predefined: In t**his characteristics / feature allows random separation of sensors in the environment. Thus, all sensor nodes, algorithm and protocols need to have self-organizing capabilities.

- **Data Gathering: All t**he sensor nodes have processing capacity. They can take simple data gathering and transmit only the essential and processed data to the next sensor node.

- **Homogeneous vs Heterogeneous Sensors:** Wireless Sensor Networks can be categorized into homogeneous and heterogeneous sensor networks. Homogeneous sensor networks, all sensor node that have same processing and communication capacities [16]. Heterogeneous networks, sensor node that have not similar processing, communication, or battery capabilities. In particular, their hardware design can be varied [17].

- **Mobile vs Stationary Sensors:** WSNs can be divided into two groups; static networks and dynamic networks. Static networks, all sensor nodes are arranged in fixed positions and each node can collect the related data within its sensing range. Dynamic networks, all sensor nodes can be attached to moving objects such as vehicles, animals [18].

- **Location-aware vs Location-unaware Sensors: All** Sensor nodes can be location-aware or location-unaware. Location-aware sensor nodes know their location in the sensor network using electronic device such as GPS antenna; location-unaware sensor nodes do not know their location in the network. Centralized cluster algorithms can be used for location-aware sensors, distributed algorithms can be used for location-unaware sensors [19].

- **Single-hop vs Multi-hop Networks:** WSNs can be further divided into single-hop network and multi-hop network. In a single-hop networks, sensor nodes directly deliver their sensed data to the BS(Base Station) or sink. In multi-hop networks, sensor nodes transmit their sensed data to the BS (Base Station) or sink using intermediate sensor nodes [41]. As shown figure(a) single-hop without clustering network, figure (b) multi-hop without clustering networks, Figures (c) single-hop with clustering network and figure (d) multi-hop with clustering networks.

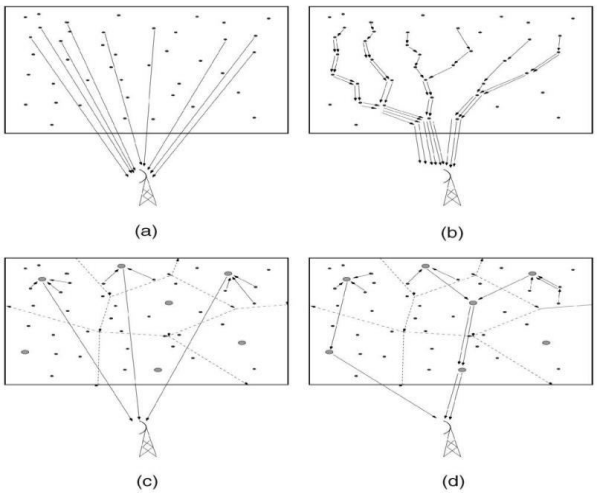

Fig.1: Single-hop vs Multi-hop Networks

- **Proactive vs Reactive Networks:** Sensor networks can be classified into proactive and reactive networks based on their target. The proactive networks monitor an area and sensed data send to the BS (Base Station)or sink. The reactive networks not only monitor an area but it also immediately react on any sudden changes to the sensed attributes. Reactive networks are well suited for real-time applications [31].

- **Scalability:** Wireless sensor networks are composed of hundreds to millions of nodes so routing protocols should work with this amount of nodes. Designing scalable routing protocols is essential for a wide range of WSNs. If compared Single-hop algorithms and multi-hop algorithms, the Single-hop algorithms a scalable then, because in multi-hop algorithms the number of hops increase by increasing the number of sensor nodes, and this leads to unacceptable latency for sending packets from sensor nodes to the base station or sink [1], [17].

Clustering algorithm of WSNs can be classified into Centralized or Distributed Clustering algorithm. These two classified algorithm are presented in the next two sections.

III DISTRIBUTED CLUSTERING ROUTING ALGORITHMS (DCRA)

DCRA can be used for location-unaware sensors nodes. These sensor nodes are not aware of their network location and based on their internal information all routing decisions to be made. Different distributed Clustering Routing Algorithm (DCRA) for WSNs are as follows:

Int. J. Advanced Networking and Applications
Volume: 10 Issue: 03 Pages: 3880-3887 (2018) ISSN: 0975-0290

1) Low Energy Adaptive Clustering Hierarchy (LEACH)

LEACH is such a well-know clustering algorithms for WSNs [2]. LEACH is first proposed by W.B.Heinzelman in [27]. Among the several clustering algorithms, LEACH is one of the first major improvements on conventional clustering algorithm in WSN. Many clustering algorithms [28], [29] are based on the LEACH, The process of LEACH is broken up into rounds, where each round start with a set-up phase, when the cluster-heads are organized, followed by a steady-state phase, when data transfer to the BS (base station). The steady-phase is longer compared to the set-up phase. In the set-up phase, every node decides whether or not become a cluster-head for current round**.** In the first round, each sensor nodes selects a random number between 0 and 1 and compares it to the threshold T(n) given in (1) and if the number is less than a threshold, the node becomes a cluster head.

$$T(n) = \frac{P}{1 - P * (r \bmod \frac{1}{P})} \; if n \in G, \;\; 0 \;\; otherwise \tag{1}$$

Where

Where p is the desired percentage of cluster heads,

r is the current round,

G is the set of nodes that have not been cluster heads in the last 1/p rounds.

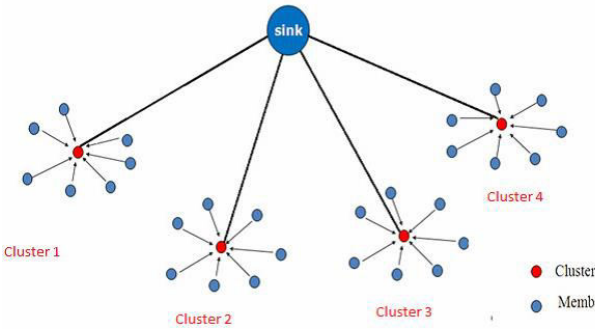

Fig.2: LEACH Protocol

2) Energy Efficient Clustering Scheme (EECS)

Energy Efficient Clustering Scheme (EECS) [41] is a clustering routing algorithm which better suitable the periodical data gathering applications. In EECS, a network is grouped into many clusters and data transmission is performing by single-hop communication between the cluster head and the BS (base station) or Sink. Furthermore, cluster head members compete for the capability to elevate to cluster head for a given round, and this competition is executed by members to transmit their residual energy to their neighboring members. If a given node can't find a node with extra residual energy, it becomes a CH (cluster head). In addition, EECS enlarge LEACH by dynamic sizing of clusters based on cluster distance from the BS (base station) or sink.

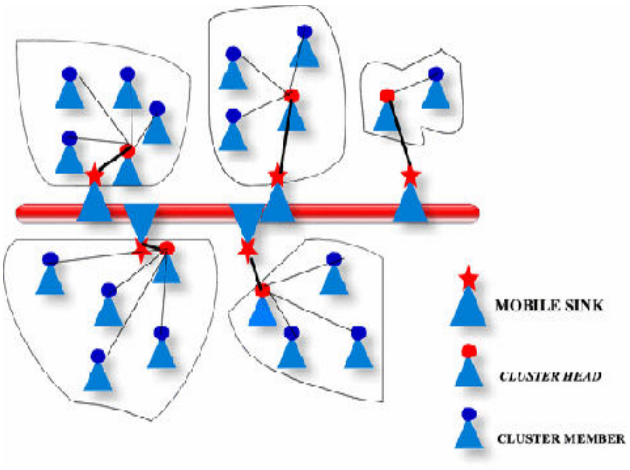

Fig.3: Energy Efficient Clustering Scheme

3) Power-Efficient GAthering Sensor Information Systems (PEGASIS) [32]

PEGASIS is another hierarchical routing algorithm for WSNs, which considered as an improvement over LEACH. PEGASIS, instead of forming clusters, forms a chain from sensor nodes into the BS (base station) or sink. The sensor node is executing a greedy algorithm in order to form a chain. All the sensor nodes send its sensed data to a close neighbor which is in the chain. All sensed data are aggregated in one node and only one node sends the aggregated data to the BS (base station) using long-distance transmission.

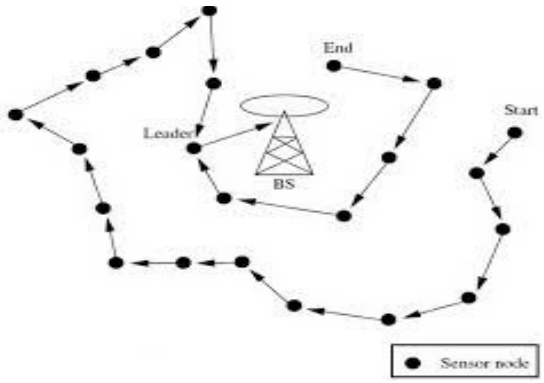

Fig.4: PEGASIS

4) Threshold sensitive Energy Efficient sensor Network (TEEN) [31]

TEEN is a new algorithm which is designed for reactive networks. The TEEN algorithm, an event is reported to the BS (Base Station) if it has interesting features. The TEEN algorithm recommends an efficient approach in terms of energy and it suitable for real time applications. It is not suitable for regular data gathering

Int. J. Advanced Networking and Applications
Volume: 10 Issue: 03 Pages: 3880-3887 (2018) ISSN: 0975-0290

applications. TEEN presents a trade-off between the accuracy and energy consumption applications.

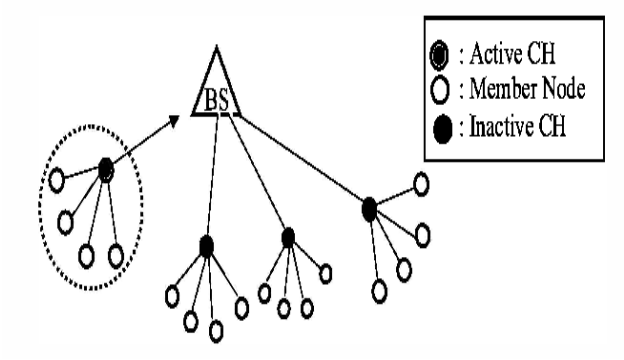

Fig.5: TEEN

5) Hybrid Energy-Efficient Distributed (HEED) [16]

HEED is one of the most effective distributed cluster-based routing algorithms in WSN. HEED has four primary objectives HEED has four primary objectives.

(i) Extending network lifetime by distributing energy consumption.

(ii) Terminating the clustering process within a constant number of iterations

(iii) Minimizing control overhead

(iv) Producing well-distributed cluster heads

The HEED two sensor nodes are considered as neighbour sensor nodes as long as they are within each others' power range. Therefore, two neighbouring sensor node would not be selected as CHs coincidently. The HEED is similar to LEACH, CHs form a single- hop routing protocol from CHs into the BS (Base Station).

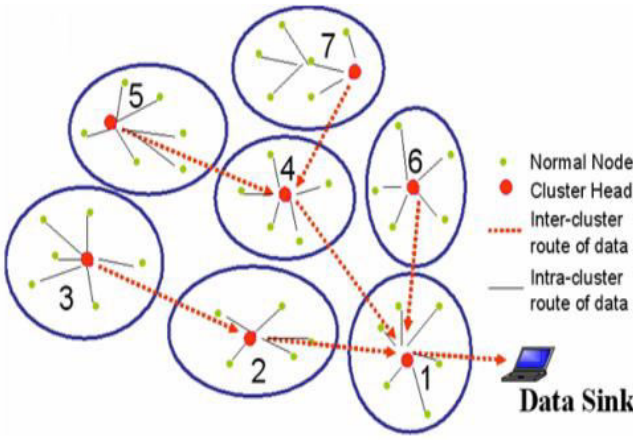

Fig.6: HEED

6) Distributed Weight-based Energy-efficient Hierarchical Clustering protocol (DWEHC) [30],

DWEHC is an extension of HEED. To improve HEED by building stability cluster range and optimize the intra-cluster topology using position awareness of the sensor nodes. The DWEHC create no assumptions on the size and the density of the network. furthermore, each sensor node implements DWEHC independently and the algorithm ends after some rounds that are executed by a distributed manner.

Two algorithms is DWEHC and HEED are related in many ways. Due to energy reserve during the process of cluster head selection, DWEHC creates extra well-balanced cluster heads distribution and it achieves significantly lower energy utilization in intra-cluster and inter-cluster routing than that in HEED. Moreover, The DWEHC does not depend on any network topology or size. But, position knowledge required by DWEHC is not always simple to be available, because it requirements specific hardware or equipment.

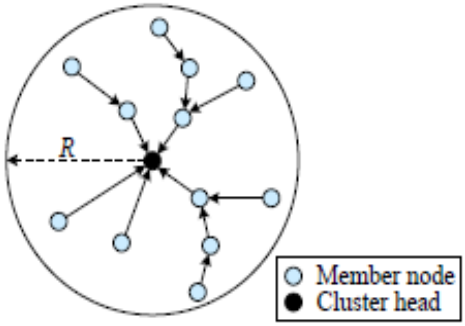

Fig.7: DWEHC

7) Self Organising Protocol (SOP) [33]

Considers (cluster head) CH-to-CH (cluster head) multi-hop data transmission from (cluster head) CHs to the BS (Base Station) in order to minimize the energy dissipation in the network. In SOP, once the clusters are shaped, CHs arrange a multi-hop backbone. Each sensor transmits its sensed data into its CH directly and each CH transmits its sensed data to the BS (Base Station) via a number of intermediary CHs. The SOP is more energy efficient than LEACH at the cost of bringing extra latency.

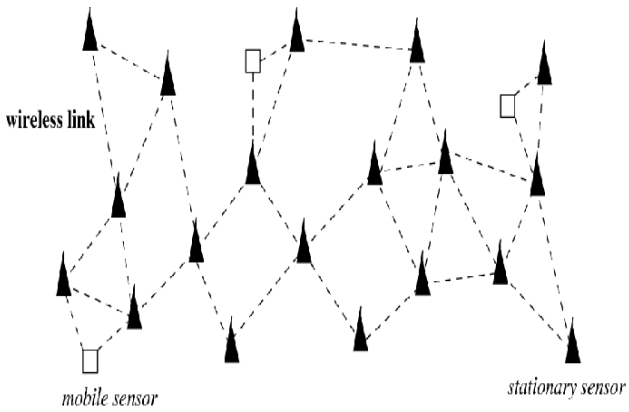

Fig.8: SOP

8) Stable Election Protocol (SEP) [21] and **powered by Ambient Energy Harvesting (HEAP)** [35]

Int. J. Advanced Networking and Applications
Volume: 10 Issue: 03 Pages: 3880-3887 (2018) ISSN: 0975-0290

There are two clustering algorithms which are designed for heterogeneous sensor nodes in the network. In the (**Stable Election Protocol)** SEP, the powerful sensor nodes have more of a probability of being selected as CHs and in the HEAP the super nodes are used as relay in order to execute a multi-hop routing from usual sensors into the BS (Base Station). In the (Stable Election Protocol) SEP the usual sensors have a smaller chance of being selected as the (cluster head) CHs, in the (**Powered by Ambient Energy Harvesting)** HEAP, they do not have any option and all of the routing task is performed by super nodes. These two algorithms of SEP and HEAP extend the stable-phase of the network depending on the percentage and initial energy of the powerful and super nodes.

9) Adaptive algorithm [36]

Adaptive algorithm is a distributed hierarchical clustering algorithm which benefits from a data passing technique in order to shape identical clusters. The adaptive algorithm, the data is exchanged between sensor nodes to find out their location across the network. The equal clusters are shaped by choosing proper CH (cluster Head) locations. Using figures showed cluster shapes before and after applying this algorithm Here, adaptive algorithm is compared with LEACH and LEACH-C in terms of the energy efficiency metric and shows outperformance of LEACH but not LEACH-C.

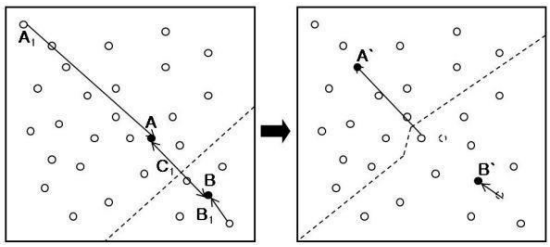

Fig.9 : **Adaptive algorithm**

10) Wireless Sensor Network Clustering with Artificial Bee Colony (WSNCABC) [37],

WSNCABC it is an algorithm in which a data transferring technique is used to find sensor nodes distances from each other. This information is transferred to the BS (Base Station) and the BS (Base Station) selects the CHs using Artificial Bee Colony method. The BS (Base Station) then broadcasts these CHs into the network and each node finds its nearby CH using the signal strength. WSNCABC outperformed the LEACH algorithm in terms of energy efficiency by up to 75% in their experiments in which the BS (Base Station) location was very near to the network edge. WSNCABC consist of a large amount of overhead in the set-up phase due to the large number of data passed between sensor nodes.

11) Bayesian algorithm [38]

Bayesian algorithm the energy efficiency optimization routing algorithm which uses the Bayesian game theory. In **Bayesian** algorithm, the network life time is divided into three steps including: initial step, CHs selection, and stable step. The initial step, the BS (Base Station) or sink transmits initial information to all of the sensor nodes. In the Cluster Head (CHs) selection step, each sensor node transmits some amount of its information such as its residual energy and its neighbors to other sensor nodes and also to the BS (Base Station) or sink. Then, all sensor nodes form a routing table containing its routing information. this algorithm does not seem efficient enough if the BS (Base Station) far away from the network

12) Avoid Near Cluster Heads (ANCH) [3]

ANCH is one of the latest distributed clustering routing algorithms designed for uniform distribution of Cluster Head (CHs) throughout the network region. This algorithm increases the number of potential Cluster Head (CHs) across the network using a regression method. Then, it removes a number of nominated Cluster Head (CHs) due to their close location to other Cluster Head (CHs) in order to meet the optimum number of Cluster Head (CHs). The ANCH algorithm is significantly more efficient than LEACH and HEED in terms of network energy utilization and network life time.

Both of its time and data complexities are $O(N^2)$, which is same to LEACH and better than HEED [15], [39].

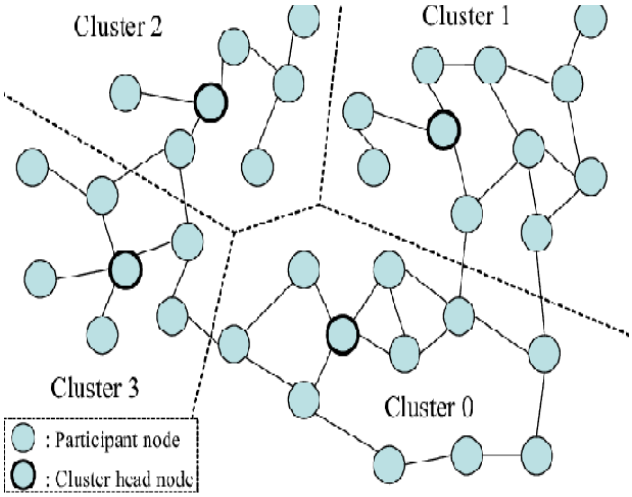

Fig.10: ANCH

IV CENTRALIZED CLUSTERING ROUTING ALGORITHMS (CCRA)

Centralized clustering routing algorithms (CCRA), this algorithms can be used for location-aware sensor nodes. That means all the sensor nodes that are aware of their network location and all the routing decisions can be taken in central locations such as the base station or sink. Different Centralized Clustering Routing Algorithm (CCRA) for WSNs are as follows:

Int. J. Advanced Networking and Applications
Volume: 10 Issue: 03 Pages: 3880-3887 (2018) ISSN: 0975-0290

1) A centralized version of LEACH, LEACH-C is proposed in [40].

The LEACH-C algorithm, All the sensor node knows its location in the network and the further operations of LEACH-C are equal to those of LEACH, the results presented in [40] showed a definite improvement over LEACH

2) Base Station Controlled Dynamic Clustering Protocol (BCDCP),

BCDCP is a centralized clustering routing algorithm for WSNs [42]. The clustering routing Algorithm called Base BCDCP, which consumed a high-energy base station or sink to set up clusters and routing paths, execute randomized rotation of cluster heads CH, and carry out other energy-intensive jobs. The key ideas in (BCDCP) are the development of balanced clusters where all cluster head CH serves an roughly equal number of member nodes to avoid cluster head CH overload, uniform placement of cluster heads CH throughout the sensor field, and consumption of cluster-head-to-cluster (CH-to-CH) routing to transfer the message to the BS (base station). BCDCP is a enhanced system lifetime and better energy savings over the LEACH, LEACH-C and PEGASIS clustering routing algorithm.

3) Power Efficient and Adaptive Clustering Hierarchy (PEACH) [43],

PEACH is a centralized multi-level clustering algorithm for WSNs. The PEACH algorithm can be used for both location-unaware and location-aware wireless sensor networks. The simulation results show that PEACH considerably minimizes energy utilization of each node and improve the network lifetime, compared with existing clustering routing protocols.

4) Optimised Lifetime Enhancement (OLE) [44],

OLE is an centralized algorithm which forms a chain from sensors into the BS Base Station) or sink. All the sensor nodes send its sensed data to a close neighbour which is in the chain. The OLE allows sensor nodes to direct communication with the BS (Base Station) or sink an unequal number of times based on their remaining energy. OLE should be executed in the BS (Base Station) Or sink and its results distributed into the network before starting the stable phase. In their experiments, OLE algorithm prolonged the network lifetime compared with PEGASIS.

5) Fuzzy Logic algorithms [45], [46]

Fuzzy logic algorithm based cluster head selection conducted in BS (base station). The BS(base station) or sink considers two election producer from sensor nodes which are energy level and distance to the BS (base station) or sink to select the suitable CH (cluster head) that will prolong the first node die (FND) time, data stream guaranteed for each round and also increase the throughput received by the sink or BS (base station) before FND. Here algorithm used three factor are sensors centrality, sensors density and sensors residual energy

V CONCLUSION

Wireless sensor networks are considered one of the best sources for monitoring remote fields and critical conditions which are out of range from human's perception. For optimal distribution of energy among sensor nodes, in order to improve network life time, suitable algorithms and applications should be developed. In this paper, survey of features/characteristics and energy efficient routing clustering algorithms is presented.

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Int. J. Advanced Networking and Applications
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