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Popular Protocols for Clustering in WSN: A Survey

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Abstract—The field of Wireless Sensor Network (WSN) has sought the attention of the researchers due to its plethora of applications, especially in the military. After the completion of the deployment of sensor nodes in the military scenario, it is difficult to retrieve/ replace the sensor. Thus, when the sensor node is designed, power consumption is the primary concern to be kept in mind with the specific end goal to prolong the network lifetime and functionality. Clustering is one of the most innovative mechanisms for ensuring energy efficiency in a WSN. In this paper, we have discussed & compared energy-efficient clustering protocols for typical sensor network.

Keywords—Clustering,Wireless Sensor Network(WSN), energy efficient clustering protocols, load balancing, cluster stability

I. INTRODUCTION

A WSN is a set of numerous sensor nodes in which a typical node can transmit, receive and sense the data as well as connect itself to its neighbouring nodes or with sink node [18]. WSN sensor nodes constitute of processing unit, in-built battery, transceivers & sensor interfaces. Once the sensor node is deployed in an environment it is unreachable to the user & hence is designed in such a way so that it can exist in a network for a considerable lifetime.

The base station transmits the information to the network or sink node of the network (sink may be the destination). The message is directed from the sensor on the cluster to the network. WSN architecture is shown in Fig. 1.

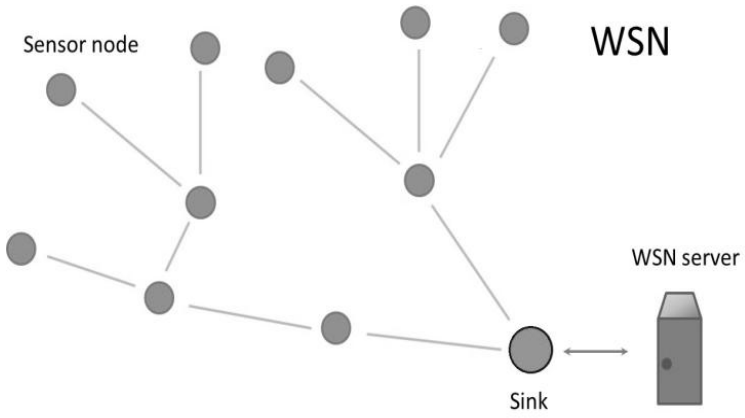

Fig. 1 An illustration of WSN

There are various mechanisms which can be utilized to economize energy utilization. The problem associated to the energy utilization can be tackled via various strategies like clustering algo, routing algo, data aggregation, enhancing the transmitter/ receiver power, reducing data size and local data processing.

In this paper, we consider the issues in cluster-based protocols along with the descriptive study of various clustering protocols and their advantages and comparisons.

II. CLUSTERING MECHANISM

To accomplish high scalability, energy efficiency & to improve the system lifetime the idea of forming clusters has been conceived i.e. making small bunches within the wireless sensor network environment. Fundamentally, a clustering scheme decides an arrangement of nodes that can enable the networking in a WSN.
Development of the clusters additionally includes assigning the nature of job to the node based on their perimeters. The coordinator of the cluster which is accountable for the processing, aggregation & transmission of the information to the base station (BS) is known as cluster head (CH) or the leader, though the remaining nodes which are accountable for the task of sensing & forwarding the congregated data to the CH are known as the member nodes. Fig. 2 [1] represents the basic hierarchy of clustering.

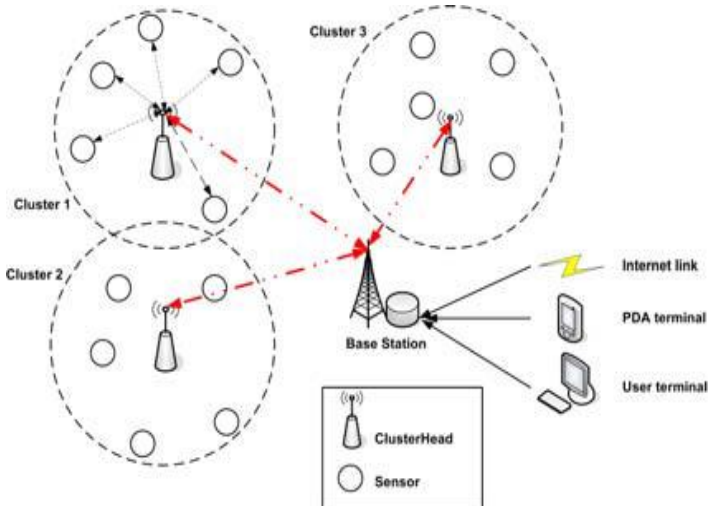

Fig. 2 An illustration of clustering

Advantages and objectives of Clustering

- Load Balancing
- Data Aggregation
- Fault Tolerance
- Reduced energy consumption
- Load Reduction
- Latency Reduction
- QOS
- Collision Avoidance

Load Balancing - For enhancing the lifespan of the system, the formation of equal sized clusters is fundamental since it prevents the use of the energy of a subgroup of cluster heads at a greater rate. Data delay is caused because of even allocation of sensor nodes. It is essential to have an identical number of sensor nodes in the clusters for the duration of data aggregation so that the full data information is prepared for further processing.

Data Aggregation - The strategy for collecting the data from numerous nodes to eradicate the redundant communication and provide the merged information to the BS is known as Data aggregation. It is effective for WSN network to save energy as mentioned by [2]. The widely known data aggregation technique is clustering data aggregation, in which every CH collates the gathered information & sends the data to the BS [3]. Usually, CHs resemble a tree structure while collecting information via multi hopping through various CHs which provides essential energy savings.

Fault tolerance –More often the sensor nodes need to work in a harsh and unfriendly environment and the risk of physical harm and separation is increased due to exposure. So, with the aim of ceasing the loss of data of the sensor nodes the let-down of cluster heads must be allowed. One approach to recuperate from the cluster head failure is to re-cluster the network & to permit reinforcement to CH. Rotation of the cluster head is likewise a decent method for addressing the issue of fault tolerance.

Lesser Energy Consumption - In clustering, data aggregation serves to decrease the data transmission and hence save energy. Moreover, communications without clustering can reduce the quantity of sensor nodes accomplishing the act of long-distance transmissions, accordingly permits to not economize energy spending for the whole system, on the other hand, the communication undertaken by the CH in clustering routing scheme saves a large quantity of energy.

Improved Connectivity and Lesser delay - If the cluster heads don't have long-range communication abilities then inter-cluster connectivity is required. This is fundamentally true when cluster heads are chosen from the sensor population.

Latency Reduction - When we partition the sensor network into groups, then only the cluster head implements the work of data transmissions out of the clusters which helps in avoiding collisions within the cluster and hence reducing the latency. In addition, data broadcast is performed hop by hop generally using flooding in flat routing scheme; however, only CHs do the job of data communication in cluster routing scheme, thus can decrease the quantity of hops from a data source to the BS subsequently decreasing latency in the network.

QOS - Clustering routing scheme makes the task of network topology control easier while it responds to the network changes, also accounting for node mobility and unpredicted failures, etc. A clustering routing scheme requires coping up with these changes within the individual clusters only and hence making the network more redundant. For sharing the duty, CH are usually rotated among all the sensor nodes to shun the possibility of a single point of failure in clustering routing algo.

Collision Avoidance - In wireless sensor networks the resources are generally managed by the individual nodes which reduce effectiveness in terms of resource utilization. Though in the multi-hop clustering model, a sensor network is isolated into clusters & the data correspondence among the sensor nodes is classified as intra-cluster for data collection & inter-cluster for data transmission. Therefore, the resources can be allocated orthogonally to each cluster to mitigate the possibility of clash among the clusters as briefed by [4]. Therefore, the multi-hop clustering model is the most effective model for upscaled WSNs.

III. LITERATURE SURVEY

S.No	Author	Problem Statement	Proposed Statement
1.	Indranil Gupta et al.[19]	Diminishing energy utilization & improving the system lifetime	Fuzzy logic based clustering to deal with cluster-head election
2	Ali Norouzi et al [20]	Investigated the enhancement strategy to increase the lifetime of Wireless Sensor Networks	The genetic algo(GA) is utilized as active method to figure out best states of sensor nodes.
3	Moslem Afrashteh Mehret et al [21]	To build the effectiveness of system	Dynamic clustering algo uses fuzzy logic & GA.
4	Bagger Zaire et al.[22]	To expand the system lifetime	Novel cluster-based routing protocol (CBRP) was introduced.
5	Stefanos et al.[23]	To enhance the system lifetime	Equalized CH election routing protocol (ECHERP) was introduced which pursue energy utilization via impartial clustering & gaussian elimination algo.
6	Golam Rashedet et al [24]	For energy effectiveness	Weighted election protocol along with standard LEACH algo is utilized to decide cluster & cluster heads.
7	Mainak Chatterjee et al.[25]	Enhancing the system lifetime	Introduced a MAC protocol utilizing on-demand weighted clustering algo.
8	Chuan-ming Liu & Chuan-hsiu Lee et al.[26]	To accomplish energy proficiency in remote sensor networks	Introduced another different algo for portability, random walk mobility model & random direction mobility model.

IV. CLUSTERING PROTOCOLS IN WSN

Clustering is a vital strategy for enhancing the network lifetime and network scalability in WSNs [5]. Clustering is a process in which sensor nodes are grouped together into disjoint clusters and cluster heads (CHs) are elected for all the clusters available in the network. Distinct routing protocols have been introduced to choose appropriate CHs. The categorization of cluster-based routing protocols in a WSN is shown in fig. 3.

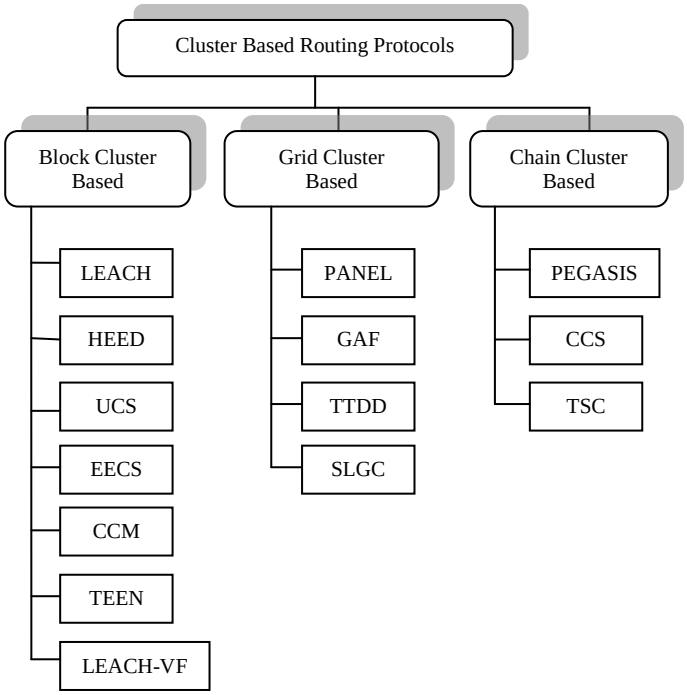

Fig. 3: Classification of Cluster Based Routing Protocol

A. Block Cluster Based Protocol

1. LEACH: In this protocol, the nodes cannot be elected as CH in subsequent rounds and hence load is shared between nodes [6]. Every node in a system has an alike opportunity to be a CH. To avoid collisions, it utilizes TDMA strategy. The main disadvantage of this protocol is that it cannot be used in a large-scale network due to single hop communication and since CHs are elected based on probability basis, thus load balancing is not ensured.

2. HEED: In this routing algo, there is a uniform distribution of CHs which ensures load balancing [7]. It involves multi-hop communication and thus scalability and energy efficiency is achieved. The limitation of this protocol is that a large number of nodes are elected as CH which results in unbalanced energy consumption.

3. UCS: This was the primary asymmetrical clustering model proposed by [8]. It involves two hops inter cluster communication and nodes in a cluster could vary in a bi-layered model. The main disadvantage of this routing scheme is that it does not take the residual energy of nodes into account and hence cannot be used in a large scale network.

4. EECS: It makes use of dynamic sized clusters and thus energy consumption of CHs is balanced [9]. This routing algo results in increased overhead as it requires global information for communication and there is more consumption of energy due to single hop communication.

5. CCM: This routing algo results in less consumption of energy as compared to LEACH protocol [10]. Disadvantage of this protocol is that it uses chain head selection criteria.

6. TEEN: It is mostly used for time critical applications wherein two thresholds namely hard and soft threshold are varied to reduce data communication [11]. Data communication is carried out only when the thresholds allow else CHs are not allowed to communicate with each other which may lead to loss of data.

7. LEACH-VF: This clustering-based algo allows some nodes to move to coverage inside a particular cluster [12]. The demerits of this algo are that load balancing is not achieved up to the mark and results in poor energy efficiency.

B. Grid Cluster Based Protocol

1. PANEL: This energy efficient routing algo helps in asynchronous applications & guarantees load balancing [7]. Limitations of this algo are that the clusters are predetermined and the geographic position information may require special inputs which might not be always available.
2. GAF: In this routing scheme the routing fidelity is maintained, and it extends the network lifetime by saving energy [13]. Its limitations are large traffic injection and unpredictable latency.

3. TTDD: This routing scheme resolves the numerous mobile sink and moving problem in large area network [14]. Disadvantage of this routing algo is large latency, less energy efficiency and requirement of stationary sensor nodes while being location aware.

4. SLGC: This routing algo involves less energy consumption compared to LEACH and thus extends network lifetime [14]. Disadvantage of this algo is that it involves large overhead due to complex data communication.

C. Chain Cluster Based Protocol

5. PEGASIS: In this clustering-based algo, energy load is distributed uniformly and involves less number of data transmissions [15]. It entails dynamic cluster formation and hence reduced overhead. Demerits of this algo are that it is not suitable for time varying topologies, network is not very scalable and long delays can cause bottlenecks.
6. CCS: In this clustering-based algo there is reduced data flow from a base station and hence less energy consumption [16]. The disadvantage of this algo is that there is unbalanced energy consumption and has a large delay due to the long chain.
7. TSC: It reduces the redundancy of data by the breakage of longer chains into smaller chains [7]. The disadvantage of this routing algo is non-uniform distribution.

V. ISSUES IN CLUSTER BASED PROTOCOLS

Much of the work has been done in clustering-based routing protocols in order to remove the respective drawbacks caused in clustering techniques as shown in Table I. There are some more issues in clustering that should be considered in future researches such as [17]:

A. Node Degree and CH Rotation

Deciding an optimum cluster size and an optimum node degree based on transmission range can be the future challenge for the researchers.

B. Scalability

Careful investigation is required to check the scalability of clustering techniques. It is usually required to enlarge the monitoring area amid new nodes, in a few large-scale deployments.

C. Redundancy Management

In order to build the trustworthy and competent relay backbone, the use of redundant nodes must be minimized. The aggregated data by CH relayed to BS must be investigated further.

D. Reliability

Transient fault management in clustering-based routing algo requires much more attention.

I. COMPARATIVE ANALYSIS OF CLUSTER BASED ALGOS

Here, we have compared different cluster-based routing protocols in light of energy efficiency, cluster stability & load balancing appeared in table 1 below.

TABLE 1: COMPARISION OF CLUSTERING ALGOS

Scheme Name	Energy Efficiency	Cluster Stability	Load Balancing
LEACH	Very Low	Average	Average
HEED	Average	High	Average
UCS	Very Low	High	Bad
EECS	Average	High	Average
CCM	Very Low	High	Average
LEACH-VF	Average	High	Average
TEEN	Very High	High	Good
GAF	Average	Average	Average
PANEL	Average	Low	Good
ITDD	Very Low	Very High	Good
SLGC	Average	Average	Average
PEGASIS	Low	Low	Average
CCS	Low	Low	Very Bad
TSC	Average	Average	Bad

VI. CONCLUSION

WSN is the area which requires lot of focus as it has a wide assortment of applications in near future. WSN requires many sensors which calls for evolved network management schemes and architectures. To resolve the issue of power management in a WSN, clustering is the mechanism which extends network lifetime while enhancing scalability. In this paper, we studied the different clustering protocols utilized in WSN & differentiated them on the basis of energy efficiency, load balancing & stability while giving scope for future research.

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