IJCSE International Journal of Computer Sciences and Engineering Open Access
Survey Paper Vol.-7, Issue-3, March 2019 E-ISSN: 2347-2693

# A Survey on Distributed Clustering Techniques for Wireless Sensor Networks

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DOI: https://doi.org/10.26438/ijcse/v7i3.404409 | Available online at: www.ijcseonline.org

Accepted: 05/Mar/2019, Published: 31/Mar/2019

***Abstract***— Wireless sensor networks (WSN) is an emerging technology in future. It consists of huge number of sensor nodes which are tiny, cost effective and easily deployable. Sensors execute the functions such as data gathering and data transmission which consequences in energy reduction and these effects the network lifetime. In this paper a brief survey on distributed clustering techniques for wireless sensor network, how to minimizing energy dissipation and maximizing network lifetime among the central concerns when designing applications and protocols for sensor networks. Clustering technique has been proven to be energy-efficient in sensor networks since data routing and relaying are only operated by cluster heads. This paper presents various distributed clustering algorithms based on Dynamic Hyper round policy (DHRP) techniques, HEF clustering, DERC, LCM, EDIT, I-LEACH and DHRP for large-scale WSNs to optimally determine the Energy-efficiency and Scheduling.

***Keywords***— Clustering, distributed algorithm, energy-efficiency, scheduling, wireless sensor networks.

## I. INTRODUCTION

The Wireless sensor network (WSN) has recently become promising network architecture and is widely used in many applications, including environmental monitoring, object detection, event tracking, and security surveillance [1]. A wireless sensor network can be defined as a network of devices that can communicate the information gathered from a monitored field through wireless links. The data is forwarded through multiple nodes, and with a gateway, the data is connected to other networks like wireless Ethernet. Due to the current developments in low powered tiny sensor technologies, the sensor nodes are used in wide range of applications in environmental monitoring [2]. It can hold potential to revolutionize segments of the economy and life. There could be one or few sink nodes and a fixed number of sensor nodes in Wireless Sensor Networks and all the sensor nodes have contact with the base station. A Wireless Sensor Network has been designed to perform the high-level of information processing tasks like detection, classification and tracking.

“Cluster based Wireless Sensor Network is used to reduce the network consumption and also the increase in energy efficiency. Clustering in WSN is done to minimize the energy consumption and also to reduce the data transmission over the network required to transmit the message to the BS, as the CH becomes responsible for communication, which results into prolonged network lifetime”.

Clustering of sensors has been shown effective in prolonging sensor network lifetime in the literature. The basic idea is to organize WSNs into a set of clusters, and within each cluster, sensors transmit the collected data to their CHs. Each CH aggregates its received data and forwards it to the sink either directly or via relaying through other CHs. This is beneficial in terms of energy efficiency in three ways: 1) Hierarchical structure facilitates a multi-hop sensor-to-sink data transfer scheme which eliminates the quick energy drainage at the sensors that are away from the sink; 2) data aggregation is performed at the CHs to reduce data redundancy so that energy savings in communication are realized; and 3) periodic re-clustering can balance the energy consumption by reassigning the CHs and the sinks and adjusting the routing in the network.

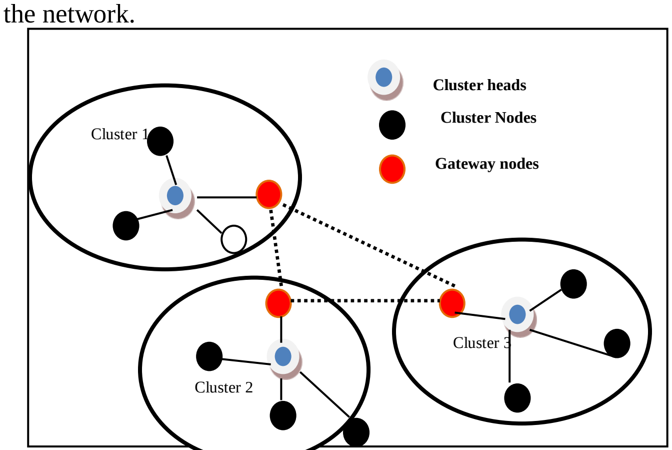


*Fig.1: Cluster based network model*

 

In distributed clustering of main challenge is to select proper nodes to act as cluster-heads and gateways. Previous researches have proposed many cluster-head election approaches for constructing clusters [3-6]. Each node in these approaches locally exchanges messages with the nodes in its communication range (i.e., neighbors) to determine whether it should become a cluster-head.

However, in distributed cluster-based WSNs, the network is divided into clusters. Each sensor node connections information only with its cluster head (CH), which transmits the aggregated information to the BS. Aggregation and fusion of sensor node data at the CHs because a significant reduction in the amount of data sent to the BS and so results in saving both energy and bandwidth resources. Once the clusters are constructed, each sensor node will be given an exclusive time slot; therefore, each sensor node knows when to transmit. Consequently, a node does not require being awake during the complete Time Division Multiple Access (TDMA) frame, but only during its specific time slot.

This survey paper explores strategies of Distributed Clustering-Task Scheduling for Wireless Sensor Networks Using Dynamic Hyper Round Policy model which schedules clustering-task to extend the network lifetime and reduce energy consumption.

Section I contains the introduction of cluster based wireless sensor networks, Section II contain the related work of distributed clustering algorithm for wireless sensor networks, Section III contain the survey on existing approaches of distributed and centralized clustering and Section IV concludes research work with future directions.

## II. RELATED WORK

**(***A. Chamam, and S. Pierre,* **2010 [7]**) proposed a "novel distributed clustering algorithm where cluster heads are elected following a three-way message exchange between each sensor and its neighbors. Sensor's eligibility to be elected cluster head is based on its residual energy and its degree. Their protocol has a message exchange complexity of O (1) and a worst-case convergence time complexity of O (N). Simulations show that algorithm outperforms EESH, one of the most recently published distributed clustering algorithms, in terms of network lifetime and ratio of elected cluster heads".

(*Bo-Chao Cheng, Hsi-Hsun Yeh, and Ping-Hai Hsu***, 2011 [8]**) developed a "High Energy First (HEF) clustering algorithm is chosen as a design reference model, which is proved to be an optimal clustering policy under certain ideal conditions. To address network lifetime predictability in practice, the network lifetime bounds and feasibility test for the HEF are developed via the worst-case energy consumption analysis. The network simulator 2 (NS2) is used to verify the proposed network lifetime predictability model, and the results show that the derived bounds of the predictability provide accurate estimations of the system lifetime".

(*Yichao Jin, et.al.,* **2011 [9]**) presented a "distributed re-clustering concept, which provides an energy-efficient re-clustering rate to conserve node energy while also equalizing the node energy consumption across the network". The re-clustering algorithm calculates the approximate amount of energy required to reorganize the clusters and to deliver the sensory data. By properly predicting the levels of the energy consumptions values, the appropriate frequency of performing
the re-clustering operation can be determined, which reduces control message overhead. To the best of their knowledge, this is the first work that analytically analyzes the overhead in re-clustering a WSN, groups re-clustering rounds to reduce this overhead, and simultaneously equalizes node lifetimes.

(*S. H. Kang and T. Nguyen*, **2012 [10]**) discussed a Distance Based Thresholds (DT) for Cluster Head Selection in Wireless Sensor Networks using distributed CH selection algorithm that takes into account the distances from sensors to a base station that optimally balances the energy consumption among the sensors. They proposed a Cluster Head (CH) selection algorithm LEACH-DT for sensor networks based on the node distance to the BS, in order to balance the energy consumption among the nodes. Simulations show that LEACH-DT outperforms the original LEACH with improved network lifespan over 10%.

(*H. Taheri, et.al.*, **2012 [11]**) illustrated an "energy-aware distributed dynamic clustering protocol (ECPF)" which applies three techniques: (1) non-probabilistic cluster head (CH) elections, (2) fuzzy logic, and (3) on demand clustering. The remaining energy of the nodes is the primary parameter for electing tentative CHs via a non-probabilistic fashion. A non-probabilistic CH election is implemented by introducing a delay inversely proportional to the residual energy of each node. Therefore, tentative CHs are selected based on their remaining energy. In addition, fuzzy logic is employed to evaluate the fitness (cost) of a node in order to choose a final CH from the set of neighboring tentative CHs.

(*A. Wang, D. Yang, and D. Sun*, **2012 [12]**) described a new method to improve Low Energy Adaptive Clustering Hierarchy (LEACH) by electing cluster heads according to the residual energy of the nodes dynamically. A sliding window is set up to adjust the electing probability and keep stable the expected number of the cluster heads using two parameters in this method, one is the initial energy information of the nodes and the other is the average energy information of those that have not already been cluster heads in the network. Meanwhile, the number of cluster heads which is fixed in the entire network lifetime in LEACH is modified to be a variable according to the number of the living nodes.

(*Sheng-Shih Wang and Ze-Ping Chen*, **2013 [13]**) proposed "a link-aware clustering mechanism", called LCM, to determine an energy-efficient and reliable routing path. The LCM primarily considers node status and link condition and uses a novel clustering metric called the predicted transmission count (PTX), to evaluate the qualification of nodes for cluster-heads and gateways to construct clusters. Each cluster-head or gateway candidate depends on the PTX to derive its priority, and the candidate with the highest priority becomes the cluster-head or gateway. Simulation results validate that the proposed LCM significantly outperforms the clustering mechanisms using random selection and by considering only link quality and residual energy in the packet delivery ratio, energy consumption, and delivery latency.

(*Ankit Thakkar and Ketan Kotecha*, **2014 [14]**) discussed a main objective of WSNs is to monitor physical phenomenon of interest in a given region of interest using sensors and provide collected data to sink. The WSN is made of a large number of energy, communication, and computational constraint nodes, to overcome energy constrains, and replacing or recharging the batteries of the WSN nodes is an impossible task, once they are deployed in a hostile environment. Therefore, to keep the network alive as long as possible, communication between the WSN nodes must be done with load balancing. To address this problem to provide a solution of routing algorithm is proposed by introduced Energy Delay Index for Trade-off (EDIT) to optimize both objectives—energy and delay. The EDIT is used to select cluster heads and "next hop" by considering energy and/or delay requirements of a given application. Their approach is derived using two different aspects of distances between a node and the sink named Euclidean distance and Hop-count, and further proves using realistic parameters of radio to get data closest to the test bed implementation.

(*Xuxun Liu*, **2015 [15]**) discussed a Hierarchical routing in wireless sensor networks (WSNs) is a very important topic that has been attracting the research community in the last decade. Typical hierarchical routing is called clustering routing, in which the network is divided into multiple clusters. Recently, some types of atypical hierarchical routing arise, including chain-based, tree-based, grid-based routing, and area-based routing. There are several survey papers that present and compare the hierarchical routing protocols from various perspectives, but a survey on atypical hierarchical routing is still missing. The authors first attempt to provide a comprehensive review on atypical hierarchical routing. To offer a classification of atypical hierarchical routing of WSNs and give detailed analysis of different logical topologies. The most representative atypical hierarchical routing protocols are described, discussed, and qualitatively compared.

(*B Y Kushal and M Chitra*, **2016 [16]**) discussed Wireless sensor networks (WSN) consist of large number of sensor nodes. These small and low-cost sensor nodes are deployed in monitoring region of interest. Since sensors perform multiple functions such as data gathering and data transmission results in energy depletion, these effects the network lifetime. The nodes having tendency to fail due to energy depletion is the critical issue in WSN. Due to wide number of applications of WSN, it is required to enhance the life time of entire network.

The authors proposed a method is aimed to optimize the energy dissipation by modifying the CH (Cluster Head) selection approach in LEACH (Low Energy Adaptive Clustering Hierarchy) algorithm and avoids the energy-hole problem considering mobility to the sink node which helps to prolong the lifetime of entire network.

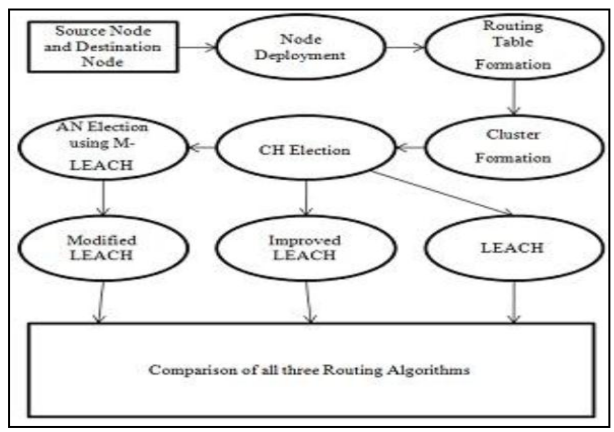


Fig.2: Architecture of LEACH system

(*Peyman Neamatollahi, Mahmoud Naghibzadeh, Saeid Abrishami, and Mohammad-Hossein Yaghmaee*, **2018 [17]**) discussed a Dynamic clustering (DC) of sensors into groups is a popular strategy to maximize the network lifetime and increase scalability. In this DC approach, to achieve the sensor nodes' load balancing, with the aim of prolonging lifetime, network operations are split into rounds, i.e., fixed time intervals. Clusters are configured for the current round and reconfigured for the next round so that the costly role of the cluster head is rotated among the network nodes, i.e., Round-Based Policy (RBP). This load balancing approach potentially extends the network lifetime. However, the imposed overhead, due to the clustering in every round, wastes network energy resources. The authors proposed a distributed energy-efficient scheme to cluster a WSN, i.e., Dynamic Hyper Round Policy (DHRP), which schedules clustering-task to extend the network lifetime and reduce energy consumption. Although DHRP is applicable to any data gathering protocols that value energy efficiency, a Simple Energy-efficient Data Collecting (SEDC) protocol is also presented to evaluate the usefulness of DHRP and calculate the end-to-end energy consumption.

## III. COMPARISION ANALYSIS

This survey paper aims to collect and consider papers that deal with Distributed Clustering-Task Scheduling for Wireless Sensor Networks Using Dynamic Hyper Round Policy techniques. The objective is not to undertake a conditions review, but quite to provide a broad state-of-the-art view on these related fields. Several existing approaches have been projected to assist distributed and centralized clustering, which has mentioned in a body of literature that is spread over a wide variety of applications.

**Table 1: SUMMARY TABLE FOR COMPARISON OF SHORTEST DISTANCES IN DYNAMIC GRAPHS TECHNIQUES**

| Title | Algorithm | Key-Idea | Techniques | Results | Performance |
|---|---|---|---|---|---|
| *A distributed energy-efficient clustering protocol for wireless sensor networks* (**2010**) [7] | Novel Distributed Clustering Algorithm | Wireless sensor networks Clustering Network lifetime Distributed Energy efficiency | Energy-Efficient Cluster Formation protocol (EECF) | EECF provides a better network lifetime and a better ratio ‘‘Number of CHs/Total number of sensors” than Energy-efficient Strong Head clustering (EESH). | EECF performs 90% cluster head ration of 100 sensor nodes. |
| *Schedule ability Analysis for Hard Network Lifetime Wireless Sensor Networks with High Energy First Clustering* (**2011**) [8] | High Energy First (HEF) clustering algorithm. | Cluster head selection, network lifetime, schedule ability, timing constraint, wireless sensor network. | Optimal cluster head selection technique. | HEF algorithm achieves significant performance improvement over LEACH, and HEF's lifetime can be bounded. | Cluster selection algorithms with the variance 0 has the longest network lifetime compared to that with a variance of 0.09 or 0.36. |
| *A Distributed Energy-efficient Re-Clustering Solution for Wireless Sensor Networks* (**2011**) [9] | Distributed Energy-efficient Re-Clustering algorithm (DERC) algorithm | To avoid high energy cost of too frequent re-clustering rounds, to determinate a suitable period of CH service time that ideally allows each node to act as a CH only once during the entire network lifetime. | Re-Clustering and Cluster energy consumption. | DERC outperforms EECS and EEHC in energy conservation. | For simulation of 800 round attains 0.29 coefficients Variation of node energy levels. |
| *Distance Based Thresholds for Cluster Head Selection in Wireless Sensor Networks* (**2012**) [10] | Distributed CH selection algorithm. | Cluster, Energy Consumption, Distance to base station. | LEACH protocol. | LEACH-DT outperforms other schemes with larger mean times. | Increase of lifespan by the LEACH-DT is greater than 10% over LEACH. |
| *LCM: A Link-Aware Clustering Mechanism for Energy-Efficient Routing in Wireless Sensor Networks* (**2013**) | LCM Cluster State Transition Algorithm. | Cluster State Transition and Procedure Contention. | Passive clustering (PC) technique. | LCM actually consumes less energy than the PC, PC-LQ, and PC-RE. | LCM improves the packet delivery ratio by an average of 13.85%, 5.16%, and 5.32% when |

 

| | | | | | |
|---|---|---|---|---|---|
| [13] | | | | | compared with the PC, PC-LQ, and PC-RE (Residual Energy). |
| *Cluster Head Election for Energy and Delay Constraint Applications of Wireless Sensor Network* (**2014**) [14] | Routing algorithm of Energy Delay Index for Trade-off (EDIT) | Cluster Head Election, Energy Delay Tradeoff and Multi-hop Routing. | Cluster Setup Phase and Steady State Phase. | Nodes have to transmit for a longer distance when Euclidean distance is used in EDIT protocol. | 10 Joules of initial energy to each node. |
| *Atypical Hierarchical Routing Protocols for Wireless Sensor Networks: A Review* (**2015**) [15] | Hierarchical Routing algorithm. | Atypical Hierarchical Routing, Chain-Based, Tree-Based, Grid-Based, Area-Based. | Hierarchical routing technique. | To provide a brief survey of logical topologies and hierarchical routing is provided. | |
| *Cluster Based Routing Protocol to Prolong Network Lifetime through Mobile Sink in WSN* (**2016**) [16] | Improved LEACH (Low Energy Adaptive Clustering Hierarchy) algorithm. | Multi Hop Routing and Data Aggregation. | Cluster head election, Agent node election and Route discovery using modified leach. | Mobile sink avoids the energy-hole problem and reduces energy dissipation. | Residual energy of the network after 20 iterations attains 3.52 mJ |
| *Distributed Clustering-Task Scheduling for Wireless Sensor Networks Using Dynamic Hyper Round Policy* (**2018**) [17] | CH Selection and Distributed algorithm. | Energy-efficiency and Scheduling. | Dynamic Hyper Round Policy (DHRP) | Using DHRP, SEDC outperforms popular and well-known clustering protocols, HEED and M-LEACH (which employ RBP), in terms of network lifetime and energy efficiency. | DHRP significantly reduces SEDC's re-clustering number to 50.28, resulting in the reduction of the clustering overhead. |

## IV. CONCLUSION

This paper presents the survey of the various clustering techniques for wireless sensor networks in the distributed environment. It also classifies HEF clustering, DERC, LCM, EDIT, I-LEACH and DHRP algorithm key ideas, techniques, result and the performance. To conclude the discussion on distributed clustering algorithms in wireless sensor networks framework by a comparative study with different categories, the strategies of distributed clustering task scheduling for wireless sensor networks Using Dynamic Hyper Round Policy techniques result in the reduction of the clustering overhead. The further work enhanced and expanded to DHRP presenting a centralized algorithm for small-scale wireless sensor networks to optimally determine the HR length policy.

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