DOI: https://doi.org/10.24113/ijoscience.v7i4.388

A Review on Energy Efficient Clustering Algorithms for IOT Applications

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Abstract

A large range of applications in different areas are available in wireless sensor networks (WSNs). The Internet of Things (IoT), which allows connections between various objects or devices through the internet, was one of the most recent emerging applications. However, as opposed to mobile ad-hoc networks, WSNs have a greater concern for battery capacity, which affects the network's durability. Therefore, numerous studies have focused on reducing the WSN's energy use. One of the many approaches to minimizing the energy of the WSNs is to design a hierarchical clustering algorithm. In this paper, an algorithm for IoT applications is presented that is based on energy-efficient clustering and the cluster head election process.

Keywords: *Wireless Sensor Network, Clustering Algorithm, Leach Protocol, IoT, Energy Efficiency.*

1. Introduction

A wireless network is a network of low cost, battery-operated, multifunctional, small-sized nodes. Wireless networks offer a great advantage in today's communication applications like environmental, traffic, military, and health monitoring. In such applications, there is a need for a reliable routing protocol. A large variety of Wireless sensor Network (WSN) applications encourage researchers to develop and improve protocols and algorithms for rising challenges. One of the objectives in WSN is to collect data from nodes and transmit them to the base station through the selected route but if there is no information about the route then it is quite difficult to find a path to the destination node. During data transmission, energy consumption is the main issue because sensor nodes have limited energy capacity. WSN needs load balancing algorithms that keep the use of the limited energy source to route the collected data to the receiving node [1].

A wireless network could be a collection of mobile/semi-mobile nodes with no pre-established infrastructure, forming a network, throughout those nodes communicate with each other via radio or infrared. In WSN there is no centralized architecture so every node act as a router [2]. Devices in WSN will communicate directly if each source and destination devices are in direct transmission range. Devices that are not in direct transmission range will communicate with the intermediate node that works as a router for forwarding packets, it means devices in WSN not solely works as end system however additionally as a router for forwarding route request, reply packets and data packets that help in communication. WSN reduces the cost and time of network setup and administration. This could have several applications particularly together with military and emergency services [3].

Various technologies and protocols are utilized in WSN. IEEE 802.11 meets all the wants to be used in wireless mode. Current Wi-Fi standards have a sufficient transmission speed and a high transmission speed. Future Wireless Local Area Network standards will reach previously inaccessible transmission speeds. However, even old standards like Bluetooth have ad-hoc features that will be useful for wireless data exchange [4].

2. Routing Protocols

A Wireless sensor network (WSN) is a collection of mobile sensor nodes forming either a particular infrastructure or maybe infrastructure-less where all nodes are free to move [5]-[9]. In WSN, each node behaves equally as a router as well as a host, although the topology of the network can also change quickly. Some of the algorithms are discussed below:

Classification of routing protocols based on functions:

- Proactive: In the proactive routing protocol, each node maintains a routing table to discover a route to destination nodes. For such a routing protocol, network information is periodically or regularly updated.
- Reactive: In a reactive routing protocol, the routing table is not maintained. Whenever route information is required, a dynamic route is discovered on the demand of the source node.
- Hybrid: Hybrid routing protocol have features or characteristics of both proactive and reactive routing which reduces the overall cost of the network. It first maintains a routing table for all available routes and further updates the routing table at the time of data transfer.

Table 1 describes some comparative parameters of different types of routing protocols.

Table 1: Routing Protocols

Protocol	Type	End to end delay	EC	Overhead
AODV	Reactive	Average	Average	Less
DSDV	Proactive	Less	More	Average
DSR	Reactive	Less	More	More
SPIN	Reactive	more	Less	Less
LEACH	Proactive	Less	Less	Less

Classification of routing protocols based on network structure

- Data-centric routing protocol
- Location-aware routing protocol
- Quality of service-based routing protocol
- Hierarchical routing protocol.

Data-centric routing protocol-

- Sink send queries to a certain region and waits for the data from sensor located region
- Here the data requested through queries.

Location-aware routing protocol

- Utilize the location information to transmit the data to the desired regions rather than the whole network
- It selects the next hops towards the destination based on the known position of the neighbors and the destination

Quality of service based pouting protocols

- QoS based protocols mean the quality of service required by the application.
- It could be the lifetime, reliability and energy-efficient, and location information

Hierarchical based routing protocol

- Groups different nodes as a cluster.
- High energy residual energy node is considered as cluster head.

The routing algorithm is designed to satisfy different Quality of Service parameters to provide better performance and to increase the lifetime of network consideration Wireless Sensor Networks challenges and issues.

3. LEACH Protocol

The routing protocol plays an important role in transmitting data from the source by forming a route to the destination via intermediate nodes and also helps to improve the performance efficiency of nodes when they are not in transmission mode. The LEACH protocol (Low Energy Adaptive Clustering Hierarchy) is a type of hierarchical routing protocol or cluster-based routing protocol. For structuring the network into distinct interrelated groups, they elect cluster heads using a cluster head selection algorithm. This protocol achieves a distributed process methodology by forming many clusters among a network.

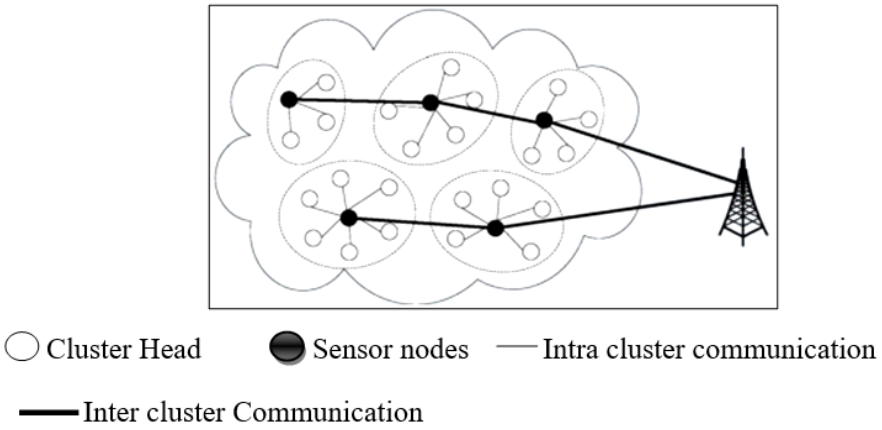

Fig. 1. Cluster-Based Routing Protocol

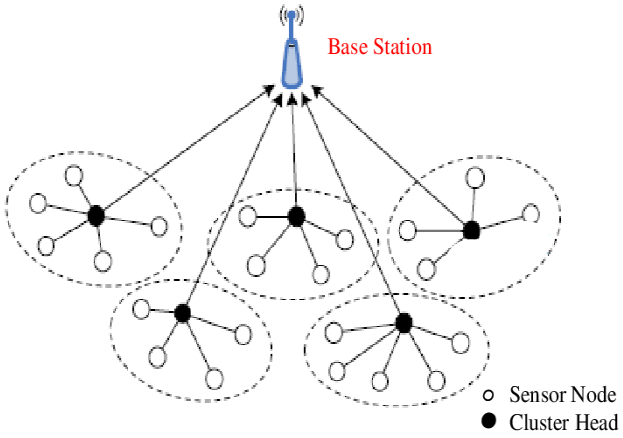

Fig. 2. Leach Protocol

LEACH protocol randomly selects certain sensor nodes as CH (cluster heads) and transforms its role to distribute the energy evenly across the network sensors [10][11]. In LEACH, CH nodes compression of nodes belonging to the group and transmission of an aggregate packet to the base station to decrease the usage of data should be sent to the ground station.

Clusters are grouped and CH (cluster head) channels are selected during the setup process, while data transmission to the base station occurs during the stationary phase. A default node fraction, p, is chosen CH (clusterhead) as follows during the installation stage. A sensor node chooses a random r from 0 to 1. The node becomes the group head for the current round when the random number is lower than T threshold (n). The threshold is determined using an equation that includes the optimal percentage of nodes to become cluster headers (p), the current round (r), and the set of nodes that have not been selected as the cluster header in the last one. (1 / P), annotated G [12].

It is given by:

$$T(n) = \frac{p}{(1 - p\left(r \; mod \left(\frac{1}{p}\right)\right))} \qquad \text{if n¢G}$$

Where G denotes the number of nodes participating in the CH (cluster head) election.

The use of multi-hop routing between cluster heads introduces a new problem of unbalanced energy consumption, according to a thorough study and review of clustering routing protocols by various researchers. Due to its many functions, including managing and controlling intra-cluster member nodes, gathering data from member nodes, implementing data fusion, and forwarding to the aggregation node, the cluster head node consumes a lot of resources. The cluster head node also transmits data from other cluster heads to the clustering routing protocol, which combines several hop routes between clusters, resulting in more heavy forwarding duties of the cluster heads nearer the sink node and face denser distribution. The problem is called the network's hot spot.

4. Literature Review

Ullah et al. [1] suggest a data collection framework based on the node clustering, which eliminates redundant and incorrect data effectively. In order to reduce the instability of the training process, the distance based radial function of Mahalanobis is applied in the projection step. The Kalman filter is also used before transmission to the cluster head to filter the data on every sensor Node.

Radhika et al. [2] introduced a new clustering methodology that subsequently removes the expense of clustering and exchanging messages to plan the grouping assignment. The network is grouped under the remaining sensor node energy. Clusters head nodes and ancillary nodes are decided by energy-based parameters and the Member Nodes are linked. Depending on the node states the roles of the head nodes of the cluster are interchanged. The recycling of nodes is achieved with the calculation of the update cycle using a fuzzy inference System to achieve minimum energy consumption.

In terms of overhead communication and communication among the end nodes, cluster heads and base stations, the focus was on the improvement of a dual-tier hierarchy for low energy-adaptive clustering hierarchy (TL-LEACH) protocol to ensure the most robust energy efficiency. Manzoor et al. [3]. In the course of this research, two major drawbacks of the TL-LEACH protocol were focused, most of which relate to the use and robust communication between nodes by using the protocol for WSN in large measure. To increase the TL-energy LEACH's efficiency, a new cluster-head selection mechanism was added, and the new version was dubbed Extended TL-LEACH (ETL-LEACH).

According to the satisfaction list, Madhumathy et al. [4] suggested an agent cluster-based routing protocol that divides the cluster into separate subgroups. Each of the independent subgroups has an agent node that can interact with the cluster leader. The proposed agent cluster-based routing algorithm was developed with the goal of reducing energy consumption while sending data from node to cluster head. The agent node is selected based on the satisfaction chart, which decreases the likelihood of agent node failure and thereby improves network stability and lifespan.

By adding a threshold limit for cluster head selection while simultaneously swapping the power level between the nodes, Behera et al. [5] updated the existing low-energy adaptive clustering hierarchy (LEACH) clustering protocol.

The suggested LEACH modified protocol exceeds the existing LEACH Protocol by 67 percent increase in output and by 1750 rounds of live nodes, which can be used to increase the lifetime of the WSN. The proposed algorithm is shown to work better in terms of stability and the life of the grid in various field, energy, and node-density scenarios in comparison with other energy efficient protocols.

In accordance with the radio parameters and channel conditions of the receiver Razzaq et al.[6] proposed the k-means clustering-based routing protocol and considers the optimal fixed packet size. This method will reduce an individual node's energy consumption while also extending the network's lifespan.

Wibisono et al [7] have integrated multi-hop routing protocols based on clusters and positions. The autonomous clusters are periodically formed when each node decides to become a cluster head (CH). To save energy and reduce the effect of overhearing transmission, direct long contact between a selected CH and a sink node is avoided. As a result, position-based routing is used in a multi-hop communication scheme. A wireless simulation platform was used to build and test the proposed approach.

According to the LEACH protocol, a new CH is elected in each iteration or round, which necessitates the creation of new clusters on a regular basis, according to Abidoye et al. [8]. Due to routing overhead, this may result in high energy consumption, which may not be appropriate for IoT devices. If a CH did not use a significant amount of energy in the previous round, a node with low energy has a decent chance of being CH in the next selection round. As a result, an effective CH replacement method was used to avoid wasting energy during cluster formation and transmission of advertising messages to cluster members.

By changing the primitive threshold formula, Xiong et al. [9] proposed Improved-LEACH based on the threshold. To optimize network sensing coverage, a coverage-preserving CH selection algorithm (CPCHSA) for the LEACH protocol is proposed. One of the protocols' drawbacks is that the number of CHs chosen in each round is unpredictable.

On the basis of LEACH, Peng et al. [10] suggested LEACH-B, an optimized protocol. Clustering and cluster head election methods are improved in this article. Firstly, BIRCH Algorithms can reasonably separate the whole area of the network into a number of sub-regions with great convergence and global optimization capacity. Then, in the sub-region, electing the cluster head when taking the residual energy factor into account.

Kandpal and Singh [11] suggested IL-LEACH, in which correlated information is sent to a virtual correlated cluster through a group of nodes, with only one node sending data. In recent years the LEACH Protocol also has been amended to reduce electricity consumption at various levels.

Siavoshi [12] proposed a new clustering strategy that divides the network into virtual circles to balance the load. The cluster size is dependent on the distance from the BS and varies from one cluster to the next. They discovered that as compared to the LEACH protocol, the network lifetime can be increased by nearly 73 percent. Sasikala et al. [13] suggested V-LEACH as a solution to this problem, with three types of nodes in the network: member node, CH, and vice-CH. When the original CH dies, the vice-CH actions take over the position of CH.

Mahapatra et al. [14] conducted a thorough examination of LEACH and its successors, taking into account four key factors: clustering process, data aggregation, mobility type, and scalability. The CHs are chosen at random by the LEACH protocol, and the BS has no knowledge of the network's residual energy.

Table 1 gives the comparative study of various methods for cluster-based routing protocols in Wireless Sensor Network.

Table 2: Comparative Study of Various Methods for Cluster-Based Routing Protocols WSN

Author	**Description**	**Results**	**Drawbacks**
Ullah et al. Springer 2020	Kalman filter is also used to filter the data at each sensor node before transmitted to the cluster head.	Testing accuracy is approx. 70-80%. Energy consumption is increasing steeply with increased round.	Data aggregation at the CH can be efficient only when similar data are grouped and processed together. Designed for fixed dataset. Designed for fixed and homogeneous clusters.
Radhika et al. Elsevier, 2019	Update cluster cycle using a fuzzy inference system.	The number of alive nodes to ~1500 rounds.	Energy consumption is more in mobile condition.
Manzoor et al. IEEE 2019	Enhanced two level LEACH protocol is proposed.	Processing space required is about 600 bytes and nodes alive for approx. 1200 seconds.	Not flexible for mobility
Madhumathy et al. IEEE 2019	Agent Cluster Based Routing Protocol for Enhancing Lifetime of Wireless Sensor Network	Robustness is increased.	Satisfaction list updation regularly. Which node to decide agent node. Computational complexity is high.
Behera et al., IET, 2018	Proposed an Energy-efficient modified LEACH protocol for IoT application	Outperforms as compared to the existing LEACH protocol with 67% rise in throughput and extending the number of alive nodes to 1750 rounds.	Energy Consumption is high.
Wibisono et al. IEEE 2018	Position-Based Scheme for Multi-Hop Routing Protocol in Cluster-Based Wireless Sensor Networks	Packet delivery ratio is about 90%	Not suitable for dynamic and heavy network.
Wenliang et al. IET 2017	Proposed improved LEACH clustering algorithm, considering the residual energy of the nodes and the factors of the long distance node.	Network is alive more than 1500 rounds. 80% survival rate.	Homogeneous scenario is considered and fixed nodes are taken.

Peng Li et al., Springer, 2017	LEACH-B algorithm is proposed. Effectively balance the network load and improve the utilization of energy, so as to extend the network life cycle.	The remaining energy of LEACH-B is always higher than LEACH protocol	Data fusion issue on cluster head node. Only focuses on residual energy of cluster head.
Liu et al., IEEE, 2012	Proposed the modified clustering algorithm reduces the setup time and the cluster head communication distance and balances the node energy consumption	Modified algorithm had efficiently reduced energy consumption of wireless sensor network nodes, and made survival time of network much longer than traditional LEACH algorithm.	Energy Consumption is high.
Boukerche et al. IEEE, 2006	QoS-aware routing protocol (QARP) is proposed. It uses packet prioritization scheme.	QARP performance evaluation shows better results for delivery rate and end-to-end latency for higher priority packets	It assumes that both the sensors and actors are static. Actor nodes are not used properly.

5. Conclusion

According to the clustering protocol, cluster head is elected in each iteration or round which requires the formation of new clusters regularly. This may lead to excessive utilization of energy due to routing overhead, which may not be acceptable for any mobile devices, especially in IoT devices. So, there is requirement of an energy-efficient CH replacement method that can be employed in order to avoid utilization of extra energy in cluster formation and transmission of advertisement message to cluster members. The unequal clustering routing algorithm is needed to be focused and improved for IoT applications with dynamic number of nodes as well as mobile nodes. This will lead to reduction of network energy consumption and extends the network life cycle with higher stability.

References

[1] Ihsan Ullah, Hee Yong Youn, "Efficient data aggregation with node clustering and extreme learning machine for WSN", The Journal of Supercomputing, Springer, 2020.

[2] S. Radhika, P. Rangarajan, "On improving the lifespan of wireless sensor networks with fuzzy based clustering and machine learning based data reduction", Applied Soft Computing Journal, 2019, 83.

[3] K. Manzoor, S. H. Jokhio, T. J. S. Khanzada and I. A. Jokhio, "Enhanced TL-LEACH routing protocol for large-scale WSN applications", Cybersecurity and Cyberforensics Conference (CCC), Melbourne, Australia, 2019, pp. 35-39.

[4] I. Banerjee and P. Madhumathy, "An Agent Cluster Based Routing Protocol for Enhancing Lifetime of Wireless Sensor Network", International Conference on Advanced Technologies in Intelligent Control, Environment, Computing & Communication Engineering (ICATIECE), Bangalore, India, 2019, pp. 265-268.

[5] Trupti Mayee Behera, Umesh Chandra Samal, Sushanta Kumar Mohapatra, "Energy-efficient modified LEACH protocol for IoT application", IET Wireless Sensor Systems, 2018, pp. 1-6.

[6] M. Razzaq, D. Devi Ningombam and S. Shin, "Energy efficient K-means clustering-based routing protocol for WSN using optimal packet size", International Conference on Information Networking (ICOIN), Chiang Mai, 2018, pp. 632-635.

[7] W. Wibisono, T. Ahmad and R. Anggoro, "Position-Based Scheme for Multi-Hop Routing Protocol in Cluster-Based Wireless Sensor Networks", International Conference on Wireless and Telematics (ICWT), Nusa Dua, 2018, pp. 1-6.

[8] Abidoye, A.P., Obagbuwa, I.C.: 'Models for integrating wireless sensor networks into the Internet of things', IET Wirel. Sens. Syst., 2017, 7, (3), pp. 65–72.

[9] Wu, W., Xiong, N., Wu, C.: 'Improved clustering algorithm based on energy consumption in wireless sensor networks', IET Netw., 2017, 6, (3), pp. 47–53.

[10] Peng Li, Wanyuan Jiang, He Xu1,Wei Liu, "Energy Optimization Algorithm of Wireless Sensor Networks based on LEACH-B", Springer, 2017.

[11] Kandpal, R., Singh, R.: 'Improving lifetime of wireless sensor networks by mitigating correlated data using LEACH protocol'. 2016 1st India Int. Conf. on Information Processing (IICIP), Delhi, India, 2016, pp. 1–6.

[12] Siavoshi, S., Kavian, Y.S., Sharif, H.: 'Load-balanced energy efficient clustering protocol for wireless sensor networks', IET Wirel. Sens Syst., 2016, 6, (3), pp. 67–73.

[13] Sasikala, A.S.D., Sangameswaran, N., Aravindh, P., et al.: 'Improving the energy efficiency of LEACH protocol using VCH in wireless sensor network', Int. J. Eng. Dev. Res., 2015, 3, (2), pp. 918–924.

[14] Mahapatra, R.P., Yadav, R.K.: 'Descendant of LEACH based routing protocols in wireless sensor networks', Procedia Comput. Sci., 2015, 57, pp.1005–1014.

[15] Yadav, L., Sunitha, C.: 'Low energy adaptive clustering hierarchy in wireless sensor network (LEACH)', Int. J. Comput. Sci. Inf. Technol., 2014, 5, (3), pp. 4661–4664.

[16] Liu Jun, Qi Hua, Li Yan, "A modified LEACH algorithm in wireless sensor network based on NS2", IEEE, 2012.

[17] A. Boukerche, R. Araujo, and L. Villas, ''A wireless actor and sensor networks QoS-aware routing protocol for the emergency preparedness class of applications,'' in 31st IEEE Conference on Local Computer Networks, 2006, pp. 832–839.

[18] Younis, O., Fahmy, S.: HEED: a hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks. IEEE Trans. Mob. Comput.,2004, 3(4), pp.366–379.