A Review on Optimization Algorithm based Cluster Head Selection in WSN

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Abstract: *Wireless sensor networks (WSNs) are used to record, collect and transmit information from the environment to the base station. For applications such as IoT and mobile WSN, intelligent routing is important to achieve better network quality of service (QoS) performance. Because the real-time scenario is dynamic and contains heterogeneous nodes (especially in terms of energy) for a longer duration of WSN. For such communication, the energy consumption of the sensor nodes is considered one of the important phenomena to be monitored. This article has focused on many approaches that are already energy efficient routing protocols using optimization algorithms. However, these algorithms need to be extended to work in dynamic, mobile and heterogeneous network scenarios..*

Keywords: WSN, Clustering, Mobility, Evolutionary Approach, Quality of Service (QoS)

I. Introduction

WSN is defined as a network of self-organizing small devices known as sensor nodes. To collect sensory data across the whole network field, all installed sensor nodes are scattered in a random manner based on ad-hoc architecture. Battery-powered sensor nodes are generally. Moreover, majority sensor network nodes are installed in hostile settings, making it impossible to refill or change their batteries [1]. To deal with this problem, extensive work has been done to save the most energy in order to use low energy radio communication hardware, power-aware media access control (MAC) protocols, etc. In traditional networks, routing protocols are meant to increase network results in terms of information transmission and network latency. WSNs, on the other hand, focus primarily on how to preserve energy while minimizing communication overheads [2]-[4]. Scalability, low costs, correctness, consistency, and ease of distribution are key advantages of WSN applications over traditional networking systems [5][6]. Energy utilization is a rare source in WSN situations [7] due to constrained limits, and it must be dealt with intelligently in order to improve lifetime of the network and routing efficiency. Because of the dynamic behavior of sensor nodes, traditional and single-tier routing techniques are not feasible for sensor-based applications. As a result, several researchers [8]-[10] have recently focused on the creation of adaptive and robust routing protocols for improving energy efficiency and discovering acceptable paths to destinations.

The sensor nodes are organized into separate clusters in cluster-based WSNs. A master node known as CH is in charge of each cluster. The nodes of a cluster are sending their data directly to the respective CH in this organisation. Rather it gathers information from its cluster member nodes and sends it to the sink directly or via other CHs. The following benefits are provided by the clustering of a WSN:

It enables data aggregation at the CH level, which can help save energy by removing unnecessary data.

Routing is simple to handle since only special nodes, such as CHs, need to keep the localized routing arrangement of other CHs and hence require just a limited amount of routing data. Furthermore, the network's scalability will be much improved.

It also saves communication capacity by allowing sensor nodes to communicate just with their appropriate CH, reducing the interchange of duplicated messages.

A CH, on the other hand, carries a substantial effort in the clustering approach by collecting information from cluster members and other CHs, data aggregation, and data transfer to the sink. The CHs are usually chosen from normal sensor nodes, making them even more difficult, as extra load nodes can rapidly die due to the energy usage of these nodes.

The information gathered by a nodes is sent to their associated CH, which aggregates the information and sends it to the sink node via single hop or multi-hop interaction [11]. There are two types of multi-hop model, flat model and cluster model. Every node in the multi-hop flat architecture shares the same information, resulting in substantial overhead and energy usage. While sensor nodes are low overhead and low energy use in the multi-hop clustering model, certain cluster heads aggregate and transmit data to the sinkhole. Wireless medium is also shared and managed by individual knots in the flat multi-hop model, resulting in low resource efficiency. In the multi-hop clustering paradigm, on the other hand, resources can be assigned orthogonally to each cluster to reduce cluster clashes and reused cluster by cluster. The multi-hop clustering model is therefore suitable for the network of sensors that are installed in remote, large areas. The communication channel is based on certain limitations that focus on minimizing network power consumption in order to increase the network span, which is the primary reason for clustering the nodes [12]. Clustering the sensor nodes has the following advantages: it reduces intra-cluster communication, achieves load balance throughout the network, and reduces update time by restricting sending/receiving signals in intra-cluster interactions. In addition, there are increased scalability [13]. For clustering the nodes, most clustering algorithms use the CH selection algorithm [14]. However, the current CH selection approach, LEACH, selects too many CHs at once or arbitrarily selects CHs far away from the BS without taking into account the nodes' remaining energy. As a result, some CHs deplete their energy early, lowering the WSN's lifespan. In particular, the main aim of the design of the protocols for routing is to ensure an energy-conscious WSN routing protocol which dictates the stronger communication protocol to reduce the WSN's energy consumption[15]. The optimal CHs are chosen using optimization techniques [16]-[22]..

II. WIRELESS SENSOR NETWORKS IN A NUTSHELL

Because the primary objective of a WSN is to gather data on environmental phenomena, and because the sensors are sometimes placed in difficult-to-reach locations, it is preferable that the network remain operational for as long as it takes. In order to do this, it is critical to limit wireless data communication. As a result, there are a variety of data reduction strategies available to reduce energy usage, including in-network processing, data compression, data prediction, and topology management. Clustering is specifically a very effective method for reducing the transmission of data between sensors and the Base Station (BS). Therefore the clustering organization, which structures the sensors in groups hierarchically and assign them as a cluster head (CH)[4], constitutes an efficient way of extending the lifetime of a WSN. Each head of each cluster is responsible for collecting and sending the data from its nearby sensors to the BS. The cluster-head option is especially important, because a sensor designated as CH will consume more battery than a standard sensor. The selection of the cluster head can simply be done to choose the sensor with a fully charged battery or greater remaining energy. While a single rule doesn't really absorb a considerable quantity of energy storage, such rules could not meet the specific demands of the network. In addition, the selection for the cluster heads depends for example on the nature of the network, tolerance for defects, scalability, load balance, expansion of coverage or network life expansion [2].

The graph G={S, C}, with S being the finite set of n sensors si, and the basic station sB, may represent a WSN. C is the finite set of m connections among the network sensors. The sensors must transmit the information collected directly to the base station (one-hop communication) or through other sensors (multi-hop communication). Therefore, we suppose:

- The sensors are strewn about in a two-dimensional Cartesian space at random.
- When deployed, the sensors remain static.
- The battery of the sensors cannot be recharged.
- All sensors have the same initial level of power; all sensors are equally capable of processing and communication;
- The sensors do not identify their own location or the location of the base station because the wireless communication channels are bidirectional.

We need an energy model that characterizes the key features of a WSN based, primarily, on the distance between sensors and their cluster heads, as well as the distance between cluster heads and the base station, when a sensor is picked as a cluster head and how this selection may extend the network lifetime.

Cluster head is selected using residual energy, distance and transmission range of each and every node in a cluster. Initially we estimate total energy expenditures (i.e. total energy used to acquire data, process data, transmit data as well as receive data) in the network.

$$TE = Ea + Ep + Et + Er \qquad \text{(i)}$$

Where, Ea = energy used to acquire n bits of data
Ep = energy used to process n bits of data
Et = energy used to transmit n bits of data
Er = energy used to receive n bits of data
Here, TE is used to find residual energy(RE).
So, RE is the residual energy at time t is calculated as below:
i.e. REi = TE (at initial condition) – TE(at time t at node i)
Finally, the Cluster Head Node transmits the data to the base station.

Finally, the Head Node of the cluster transmits the data to the station.
In a WSN, the main objective is to improve the process of data collection and therefore to increase network life. However, because actual lifetime is known when the network stops working, this particular objective cannot be directly evaluated. Although a network simulator can be used to predict this time, computer resources (both time and storage) are scarce, but it is not necessary to wait for the simulated data every time a cluster head is swapped. As a result, we can use proxy functions to significantly boost network lifespan. Examples include:

- Keeping the distance between cluster heads and the base station as little as possible.
- Keeping the distance between sensors and the cluster head as little as possible.
- Increasing the residual energy of the cluster heads.
- Increasing the load balance as much as possible. These goals can be optimized one at a time or all at once.

This article examines the importance of aims and concludes that only a few objectives are required to solve a particular situation. To put it another way, if we don't have any vital objectives, the Pareto optimum set is the same whether or not these objectives are included

III. Related Work

The proposed MLPGA algorithm, which ensures that the right chromosome to develop a near optimum network topology with master learning techniques and genetic algorithms, has been introduced by Yuchao Chang et al.[10]. The suggested algorithm provides a common K-means clustering algorithm of machine learning and proposes a clustering approach of providing energy to prevent overflowing CHs in order to create a 2-tier network architecture that is modelled into a chromosome. The proposed approach is shown to lead to optimal chromosomes both regionally and globally.

A new notion called hybridization of population initialization was developed by Shashi Bhushan [11]. A hybrid approach combining GA and K-means was used to cluster WSN. GA's initial population is seeded with K-means to ensure high-quality CHs. The fitness module is based on intra-cluster distance, inter-cluster distance, and cluster number, among other things. Depending on your preferences.

Sonam Lata [12] gave a quick overview on machine learning algorithms. Several difficulties like as location, routing, event detection, query processing, and energy harvesting are addressed when utilizing ML approaches in WSNs. Genetic algorithms have been found to be very effective in sensor node clusters and can increase the overall efficiency of WSN.

Using machine learning methods and a meta-heuristics algorithm, Jaewoong Kang et al. [13] suggest energy savings for the WSN system when environmental variables are taken into account. The researchers used a combination of machine learning and meta-heuristics to develop a new energy-saving method based on sensor distributing the information in this work.

The MOTCO (MultiObjective Taylor Crow Optimization), a combination of the Taylo series and the Crow Search algorithm, has been proposed by Rodrigues et al. [14]. (CSA). The suggested goal value is determined by the distance between cluster nodes, the power of the nodes, the cluster's traffic density, and the data packet transmission delay. The crafted optimal solution is set to a reasonable price and the cluster head is the optimum cluster head that corresponds to the reasonable level value of the objective function. In order to conduct the simulation, the WSN environment is divided into 50 and 100 nodes.

The Energy Cluster-based Routing Protocol (ECRP), proposed by MOUSSA et al., [15], not only in order to prevent frequent reclustering but also to adapt the topology of the grid, it is not only based upon the energy role of the Cluster Head (CH) around all cluster members. ECRP also implements a multi-hop routing algorithm to minimize and balance energy consumption. In order to cope with CH and relay node failures, a fault-tolerant mechanism is also proposed.

Qureshi et al. have presented [16] a Gateway Clustering Energy Efficient Routing Protocol (GCEEC-) which selects the cluster head from the center position and selects the gateways nodes for each cluster. The information burden from cluster head nodes is reduced by the gateway node, which sends information to the base station. In order to evaluate the proposed protocol with state of the art protocols, the simulation has been carried out. The research results show that the proposed protocol is performing better and that WSN-based temperature monitoring, humidity and lighting in the agricultural sector is easier to implement

IV. CHALLENGES AND FUTURE RESEARCH DIRECTION

Many current analyses or investigations on cluster routing protocols that use optimization methods are offered. The present surveys are mostly concerned with multi-objective optimization techniques for wireless sensor network scenarios. There has never been a comprehensive explanation of cluster lifespan prediction in a dynamic network setting. This section provides an overview of heterogeneity strategies as well as their limitations. This paper provides a quick overview of the challenges and concerns of clustering. The state-of-the-art reviews for the heterogeneous cluster-based routing protocol are listed in Table 1. This table summarizes all of the review aspects that have been offered in previous surveys.

Table 1. Basic Concepts and Limitations of Existing Algorithms

Ref	Technique	Limitations
[14]	Used taylor series and crow search algorithm to minimize the objective functions.	There is steep increase in dead node after 1000 rounds and throughput was also low.
[16]	Gateway nodes are created to optimize the CH overhead.	Not suitable for dynamic environment.
[18]	For optimal data forwarding path, GA is combined with ACO.	The network is stable but increases the algorithm complexity.
[19]	Modified k-mean algorithm was used to create cluster and ACO for best path selection for optimal transmission.	Doesn't support mobility.
[20]	Energy Heterogeneity are used to categorize sensor nodes. CH is selected using GA algorithm.	Doesn't support mobility and multiple sink nodes scenario.
[21]	To resolve hotspot problem, optimization is used. Sailfish optimization is used for CH selection.	Doesn't support mobility for dense WSN.
[22]	Used firefly algorithm to optimize energy level of CH by	intra cluster data aggregation was not considered.

V. CONCLUSION

Because technology advances at a rapid pace, WSN is becoming increasingly popular, and sensors are being employed in a variety of settings. Despite the fact that sensors are widely utilized, they are believed to be extremely sophisticated due to the restricted amount of energy and memory they can consume. Multiple ways have been used to make the energy efficient, but the methodology is not ideal for WSN due to the algorithm being sophisticated or very simple. The clustering routing protocol is widely used in WSN topologies because it improves the overall network's energy efficiency. However, it can cause issues like low QoS, load balancing, energy degradation under heterogeneous network conditions, node mobility, and security. The goals of future research in the field of clustering approaches for WSNs are summarized in this study. This paper proposes the construction of a multi-objective optimization algorithm for cluster lifetime prediction as well as optimal path selection for future research effort after studying the existing concerns and challenges of research activity.

REFERENCES

[1] Batra PK, Kant K (2016) LEACH-MAC: a new cluster head selection algorithm for Wireless Sensor Networks. Wireless Networks 22: 49–60.

[2] Yang M, Li Y, Jin D, Zeng L, Wu X (2015) Software-defined and virtualized future mobile and wireless networks: A survey. Mobile Networks and Applications 20: 4–18.

[3] Zhang XM, Wang EB, Xia JJ, Sung DK (2013) A neighbor coverage-based probabilistic rebroadcast for reducing routing overhead in mobile ad hoc networks. IEEE Transactions on Mobile Computing 12: 424–433.

[4] Zhang B, Tong E, Hao J, Niu W, Li G (2016) Energy Efficient Sleep Schedule with Service Coverage Guarantee in Wireless Sensor Networks. Journal of Network and Systems Management: 1–25.

[5] Jadoon R, Zhou W, Jadoon W, Ahmed Khan I (2018) RARZ: Ring-Zone Based Routing Protocol for Wireless Sensor Networks. Applied Sciences 8: 1023.

[6] Arya R, Sharma SC (2018) Energy optimization of energy aware routing protocol and bandwidth assessment for wireless sensor network. Int J Syst Assur Eng Manag 9(3):612–619 17.

[7] Ya L, Pengjun W, Rong L, Huazhong Y, Wei L (2014) Reliable energy-aware routing protocol for heterogeneous WSN based on beaconing. In: Proceedings of the 16th international conference on advanced communication technology. IEEE, Pyeongchang, pp 109–112.

[8] Mirzaie M, Mazinani SM (2017) Adaptive MCFL: an adaptive multi-clustering algorithm using fuzzy logic in wireless sensor network. Comput Commun 111:56–67.

[9] John, J., Rodrigues, P. MOTCO: Multi-objective Taylor Crow Optimization Algorithm for Cluster Head Selection in Energy Aware Wireless Sensor Network. Mobile Netw Appl 24, 1509–1525 (2019). https://doi.org/10.1007/s11036-019-01271-1.

[10] Yuchao Chang, Machine-Learning-Based Parallel Genetic Algorithms for Multi-objective Optimization in Ultra-Reliable Low-Latency WSNs, 2169-3536 (c) 2018 IEEE.

[11] Shashi Bhushan, Energy Efficient Clustering Protocol for Heterogeneous Wireless Sensor Network: A Hybrid Approach using GA and K-means, 978-1-5386-2874-4/18/$31.00 ©2018 IEEE.

[12] Sonam Lata, Machine Learning based Energy Efficient Wireless Sensor Network, 978-1-7281-3958-6/19/$31.00 ©2019 IEEE.

[13] Jaewoong Kang, Machine Learning-Based Energy-Saving Framework for Environmental States-Adaptive Wireless Sensor Network, VOLUME 8, 2020,IEEE.

[14] John, J., Rodrigues, P. MOTCO: Multi-objective Taylor Crow Optimization Algorithm for Cluster Head Selection in Energy Aware Wireless Sensor Network. Mobile Netw Appl 24, 1509–1525 (2019). https://doi.org/10.1007/s11036-019-01271-1

[15] Moussa, N., Hamidi-Alaoui, Z. & El Belrhiti El Alaoui, A. ECRP: an energy-aware cluster-based routing protocol for wireless sensor networks. Wireless Netw 26, 2915–2928 (2020).

[16] Kashif Naseer Qureshi, Muhammad Umair Bashir, Jaime Lloret, Antonio Leon, "Optimized Cluster-Based Dynamic Energy-Aware Routing Protocol for Wireless Sensor Networks in Agriculture Precision", Journal of Sensors, vol. 2020.

[17] M. Wu and M. Collier. A New Cluster-Based Evolutionary Routing Algorithm for Extending the Lifetime of Heterogeneous Sensor Networks. IEEE Intl Conference on Computational Science and Engineering (CSE) and IEEE Intl Conference on Embedded and Ubiquitous Computing (EUC) and Intl Symposium on Distributed Computing and Applications for Business Engineering (DCABES), 2016; pp. 185-188.

[18] Lakshmanan, L.; Jesudoss, A.; Ulagamuthalvi, V. Cluster Based Routing Scheme for Heterogeneous Nodes in WSN–A Genetic Approach. In Lecture Notes on Data Engineering and Communications Technologies; Springer, 2019; Vol. 26, pp 1013–1022. https://doi.org/10.1007/978-3-030-03146-6_117.

[19] Sahoo, B. M.; Pandey, H. M.; Amgoth, T. GAPSO-H: A Hybrid Approach towards Optimizing the Cluster Based Routing in Wireless Sensor Network. Swarm Evol. Comput. 2021, 60, 100772. https://doi.org/10.1016/j.swevo.2020.100772.

[20] Mehta, D.; Saxena, S. MCH-EOR: Multi-Objective Cluster Head Based Energy-Aware Optimized Routing Algorithm in Wireless Sensor Networks. Sustain. Comput. Informatics Syst. 2020, 28, 100406. https://doi.org/10.1016/j.suscom.2020.100406.

[21] Wang, Z.; DIng, H.; Li, B.; Bao, L.; Yang, Z. An Energy Efficient Routing Protocol Based on Improved Artificial Bee Colony Algorithm for Wireless Sensor Networks. IEEE Access 2020, 8, 133577–133596. https://doi.org/10.1109/ACCESS.2020.3010313.

[22] Bongale, A.M., Nirmala, C.R. & Bongale, A.M. Hybrid Cluster Head Election for WSN Based on Firefly and Harmony Search Algorithms. Wireless Pers Commun 106, 275–306 (2019). https://doi.org/10.1007/s11277-018-5780-8