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Incorporate ACO routing algorithm and mobile sink in wireless sensor networks

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ABSTRACT

Today, science and technology is developing, particularly the internet of things (IoT), there is an increasing demand in the sensor field to serve the requirements of individuals within modern life. Wireless sensor networks (WSNs) was created to assist us to modernize our lives, saving labor, avoid dangers, and that bring high efficiency at work. There are many various routing protocols accustomed to increase the ability efficiency and network lifetime. However, network systems with one settled sink frequently endure from a hot spots issue since hubs close sinks take a lot of vitality to forward information amid the transmission method. In this paper, the authors proposed combining the colony optimization algorithm ant colony optimization (ACO) routing algorithm and mobile sink to deal with that drawback and extend the network life. The simulation results on MATLAB show that the proposed protocol has far better performance than studies within the same field.

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1. INTRODUCTION

The WSN is divided into clusters, each cluster has a cluster head (CH). The sensors nodes within a cluster will transfer data to their CH. cluster heads (CHs) store the information then send the data to the sink (base station-BS) which can be either fixed or portable and can be recharged. However, the sensor nodes are limited in the ability to store and process the information [1], [2]. The further the sensor nodes are away from the sink, the more energy they will consume to forward data to the sink but the WSN still needs to maintain its life time. Therefore, to reduce the energy consumption, we will make the sink mobile to collect the data. Then, determine the path of the sink to the CHs [3]-[7]. The proposal presents an algorithm to balance the energy and optimize the life time of the WSNs by combining low energy adaptive clustering hierarchy cluster (LEACH-C) protocol with ACO algorithm that find the shortest path for mobile sink to CHs to collect information. The CHs will be selected based on the LEACH-C [8], [9]. After clustering, each cluster will have a CH (The coordinates of the sink and the CHs (xd, yd) are saved in an array). The simulation results show that the improved method extends the average life time of the sensor nodes thereby reduce the energy consumption of the system. The article includes the following sections: Section 1 introduction, section 2 related works, section 3 proposed algorithm, section 4 simulation and assessment of the performance of the proposed solution, section 5 conclusions.

2. RELATED WORKS

2.1. Routing in WSN

The sensor nodes in the network collect and transmit data to a sink by the method of direct transmission (single-hop) or visit an indirect (multi-hop). Direct transmission when the range of sensor nodes is near sink that is feasible. In contrast, the sensor nodes are distributed in large areas, this method will be more expensive, the nodes away from the sink will consume energy quickly and thus the life time of the network will be reduced. To minimize errors of this transmission method, the exchange between sensor nodes and sink is solved by the multi-stage indirect communication approach [10]-[16].

2.2. Some routing protocols in WSN

2.2.1. LEACH

Low energy adaptive clustering hierarchy (LEACH) [17], [18] is a low energy adaptive clustering protocol that deploys network nodes into multiple clusters, each cluster is managed by a CH. With the advantage of the LEACH is that no information of network configuration or data from the sink is needed once determinative the CH. so as for the nodes to possess just about constant energy, the flexibility to become CH of all nodes is that the same. However, in a round, the quantity of clusters could vary. As a result, there are a unit loops with multiple clusters being created, whereas others while not loops, leading to discontinuous information transfer to the sink. Choosing the CH doesn't take into account the placement of the detector node, therefore it's possible that overlapping or lying on the brink of one another between cluster heads affects network potency. At constant time, the CH doesn't care concerning the remaining energy of the node, that the CH is also rock bottom energy node.

2.2.2. LEACH-C

In order to overcome the disadvantages of traditional LEACH, LEACH-C [8], [9] was created and appreciated for its applicability. The selection of the cluster head at LEACH-C is done by the sink while LEACH chooses the cluster head randomly. With LEACH-C, the sink will rely on the information sent from nodes for clustering and cluster head selection. Moreover, the sink can add parameters, indicate the energy reserve of the node and use optimal algorithms to cluster and select the cluster head. The cluster is formed when the base station selects the appropriate cluster head which sends its ID to broadcast to nodes in the network. Each node will check if its ID is the same as the ID in the broadcast. If the same, the node will host the current cluster, otherwise will wait for broadcast information from the host. The clustering is more efficient, the energy is distributed evenly, the nodes in the network use the energy better. Through the location and information from the sensor nodes, cluster formation is more optimal. Collecting and transmitting data is performed continuously by controlling the number of clusters in the network. However, LEACH-C requires a large number of input parameters to select the cluster head, sending location information and energy status will consume a lot of energy if the distance from the nodes to the sink is quite large.

2.2.3. MSA

In WSNs, the sensor nodes are responsible for sensing, processing, and communicating. In particular, communication is the most energy consuming. To improve the life of the network, each protocol must have its own strategy, in which routing is one of the strategies that play an important role. Mobile sinks have been proposed with efficient extended simulations through the mobile sink assisted (MSA) algorithm [19]. Assuming that the sensor nodes are randomly allocated, the mobile sink can navigate the network to collect data and move to a fixed sink. Assuming a path for the portable sink, there are no obstacles and the communication range is high. Suppose that there is a fixed sink and four mobile sinks have infinite energy. For synchronized movement, the portable sinks move from the center to the four corners of the rectangular sensor area, where the mobile sink movements are determined by the fixed sink. For extended simulation results, the range of sensor buttons, initial energy, usable area, etc. can be changed. By using a mobile sink, the transmission distance is reduced, thereby significantly reducing the energy consumption on the line. However, the main drawback is that due to the probability CH selection, the energy level of the nodes when selecting the cluster is not considered. And this is the reason for the reduced performance of the MSA algorithm [20].

2.2.4. LEACH and a mobile sink in a fixed orbit

The sensor nodes are randomly deployed in the area. The portable sink starts at a fixed position and moves along a pre-scheduled static sink [21], [22]. How to choose a cluster head: the cluster head is selected based on the LEACH. The cluster head is responsible for collecting data from the cluster member nodes, saving data and transmitting data to the mobile sink within its range. How mobile sink moves*:* Based on the circular model of mobile sink in circular orbit similar to the idea of MECA algorithm [22], [23]. Let the mobile sink move in a clockwise or counterclockwise direction around the edge of the data field at a given velocity, fixed path, and predicted motion. Sink signals to inform all nodes of its current position with an explicit time and a radius from the middle of the sensor area R=100 m, 75 m, 50 m, 25 m, 15 m as shown in Figure 1.

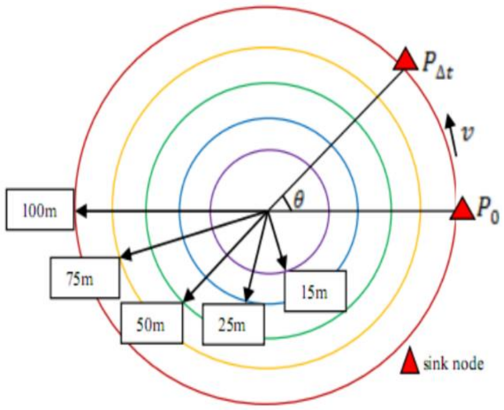

Figure 1. Sink moves in a fixed circular orbit

2.2.5. LEACH-C and a mobile sink

The objective of this protocol is to propose a hierarchical protocol based on the LEACH-C protocol by combining a mobile sink with K-mean clustering methodology to collect data to balance the consumption energy. A number of experiments have been carried out, the simulation results show that the power consumption decreases significantly and the amount of data received at the base station increases [24]. Power consumption: The purpose of the LEACH-CM mode is to reduce energy consumption to extend the life of the network. As a result, energy consumption is an important parameter during the test period, especially the average energy consumption of nodes. Network life: The author assessed the lifetime of the WSN in a specific context. This context adheres to the first node died (FND) index, which is the time elapsed until the first sensor starts to stop. The quality of the data received by BS.

2.2.6. Finding the shortest path for the sink movement

In this paper Ya-Qiong and Yun-Rui [25], the authors used the Dijkstra rule to seek out the shortest path from the CHs to the sink. This algorithm, reduces the formation of cluster heads, considers the distance to the BS base station, the distance to the cluster heads and also the energy of the nodes. At an equivalent time, presenting the shortest path between the cluster head and also the neighboring node, this ensures that this algorithm provides affordable communication and low power consumption owing to transmitted energy. Thus, the author has achieved the goal of reducing the energy consumption between sensor nodes in WSN.

2.2.7. Moving direction to save energy for sink mobility

In this paper [22]-[24], the author Ali *et al.* [26] studied to mix LEACH-C routing algorithm and Dijkstra algorithm to boost the energy consumption within the network. A mobile sink can move from the sink to CHs to retrieve information, the direction of the mobile sink's movement is set by the Dijkstra algorithm. The result's energy savings and increasing the network life time. The simulation results show that the proposed LEACH-CD is approximately the same as LEACH-C and superior to LEACH. But there is also a limitation when using the Dijkstra algorithm, which ignores some of the cluster head nodes and therefore some of the information collected is missing.

2.2.8. ACO

In 1991, Marco Dorigo introduced the ACO algorithm by observing, and drawing ideas from, the process of finding ant food sources. On the way to find food, they always leave signals to other ants to find the most effective way, the signal is the smell or pheromone. This odor may be lost or denser due to the choice of ant path. If the roads with the most ants pass, the odor concentration is highest, and the other roads the pheromones will evaporate. Finally, after a period of time they choose the path with the most pheromones are also the shortest way to move food to the nest [16], [27]-[31]. From the above behavior, the author has built artificial ant colonies, capable of leaving odors along the way, remembering the journey they have gone through and calculating the length of the path it chose. In addition to updating the smell, calculating, the ants can exchange information with each other. Thanks to this artificial colony, the author has built an ant system (AS) to solve the salesperson problem, compared to method of simulating natural simulated annealing (SA), genetic algorithm (GA), it effectively than through empirical and since then the author has developed, extensive application with common name ACO method [29], [32].

3. PROPOSED ALGORITHM

The author has presented some routing protocols such as LEACH, LEACH-C, MSA combined with mobile sink following the fixed orbital to improve the life time of WSNs and also point out the advantages and disadvantages of each method [24], [29], [33]-[38]. Then we proposed a new algorithm LEACH-CACO which is shown through the following main steps:

- The sensor nodes are randomly deployed in an area
- Clusters are formed from sensor nodes
- CHs for clusters are selected based on LEACH-C algorithm:

a. The sink receives the information about the remaining energy and current position of each node then calculates the average energy of WSN.
b. Choose the CH, compare the average energy of the network with the remaining energy of the sensor node
c. When the sensor nodes are within its communication limits, the CH is responsible for collecting and processing information from the cluster member nodes and transmitting data to the sink.

- Find the shortest path between sink and CHs:

a. After clustering, each cluster has a CH.
b. Use the ACO algorithm to seek out the shortest path from the sink to the CHs
c. The sink will move to the path to go over CHs and collect data

The simulation results of the proposal will be compared with other algorithms. The drawback of the LEACH-C associated with the Dijkstra algorithm to find the shortest path is that it ignores some cluster head nodes. Our proposal will address this matter to reduce the energy consumption and increase the lifetime of the network.

3.1. Flow chart of the proposed algorithm

Figure 2 shows the flowchart of the proposal. The direction of the sink's movement varies based on the algorithm that finds the shortest path from the sink to the CHs. Mobile sink has a certain time to stop to collect data.

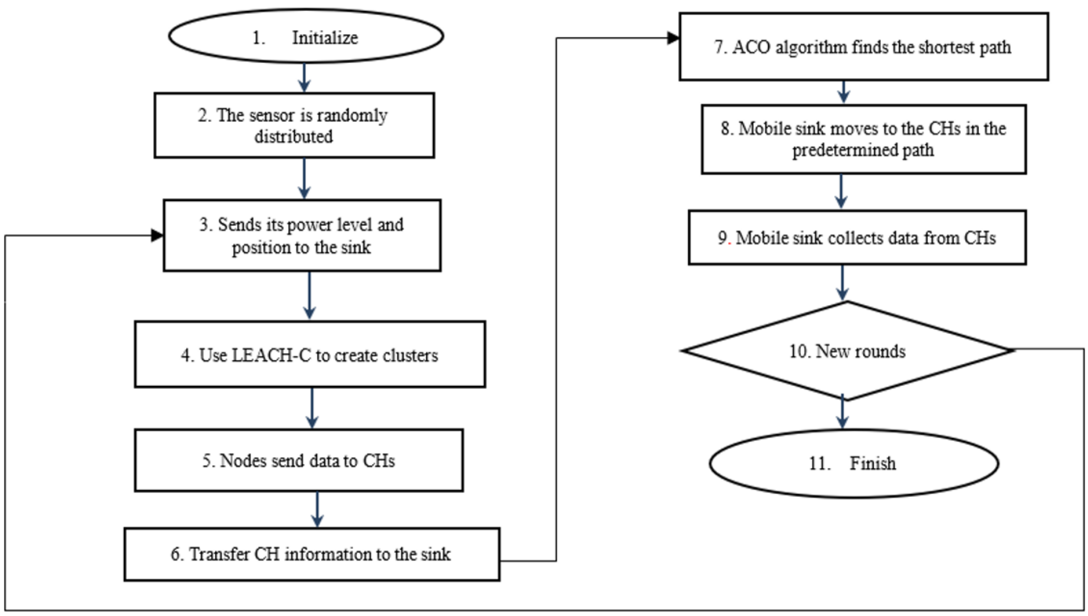

Figure 2. The flowchart of the proposal

4. RESULTS AND DISCUSSION
4.1. Simulation settings
To test and analyze the proposed solution, some simulations were implemented by MATLAB2014a. The simulation environment is designed with parameters as shown in Table 1.

Table 1. Parameter of WSN

Parameters	Value
Number of sensor nodes	100
Simulation area	100 m * 100 m
Sensor range	50 m
Initializing energy for each sensor E_O	0.1
Energy transmission E_{TX}	50 e^{-9}
Energy receiving E_{RX}	50 e^{-9}
The desired percentage becomes the CH in the total node of the network (P)	0.05
Transmission amplification factor E_{fs}	10e^{-12}

The evaluation of WSN focuses mainly on the number of alive nodes, the remaining energy in the network, and the average power consumption, because there is no electricity, there is no work for the sensor inside the network.
- Network lifetime: This is the number of cycles from the initialization of the network until all the nodes die.
- Number of alive nodes: The number of alive nodes at the time of the survey.
- Residual energy: This means the remaining energy of the network at the time of the survey.
- Average energy means the average energy of the network at the time of the survey.

4.2. Simulation results
4.2.1. Stability and network life
Table 2 and Figure 3 shows the quantity of alive and dead nodes throughout the network lifespan. The primary node for LEACH, LEACH-C, LEACH-CD, and proposed protocol dies at 119, 224, 268, and 308 rounds, the proposed protocol is more than range of rounds that the primary node dies. And all nodes die at 433, 499, 519, and 531 rounds, that is above of the quantity of rounds that the last node dies. As is seen from Figure 3, proposed protocol performs higher than the other selected existing protocols in terms of network life, stability amount. Thus, the proposed protocol consumes less energy that leads to not solely prolong network lifespan. However additionally prolong stability period as compared to the other protocols remaining energy.

Table 2. The network life time between the proposal and other algorithms

Protocol	First node to die (round)	Last node dies (round)
LEACH	119	433
LEACH-C	224	499
LEACH-CD	268	519
LEACH-CACO (Proposal)	309	531

Table 3 and Figure 4 shows that the data sent to the BS is more for proposed protocol as compared to the others protocols. The throughput for for LEACH, LEACH-C, LEACH-CD, and Proposed Protocol are 245, 423, 436, and 459. Proposed protocol is higher than the number of packets. LEACH identifies the cluster head supported random chance whereas LEACH-C, LEACH-CD and LEACH-CACO supported the position and energy info of all nodes within the WSN sent to the sink. Particularly, LEACH-CACO features a sink that moves to the cluster heads on the trail outlined by the ACO algorithm. Simulation results show that the amount of nodes alive and the remaining energy of the LEACH-CACO, is beyond LEACH, LEACH-C and LEACH-CD. This implies that the LEACH-ACO helped improve the network lifetime [39], [40].

Table 3. The energy consumption between the proposal and other algorithms

Protocol	Throughput (packets / loops)
LEACH	245
LEACH-C	423
LEACH-CD	436
LEACH-CACO	459

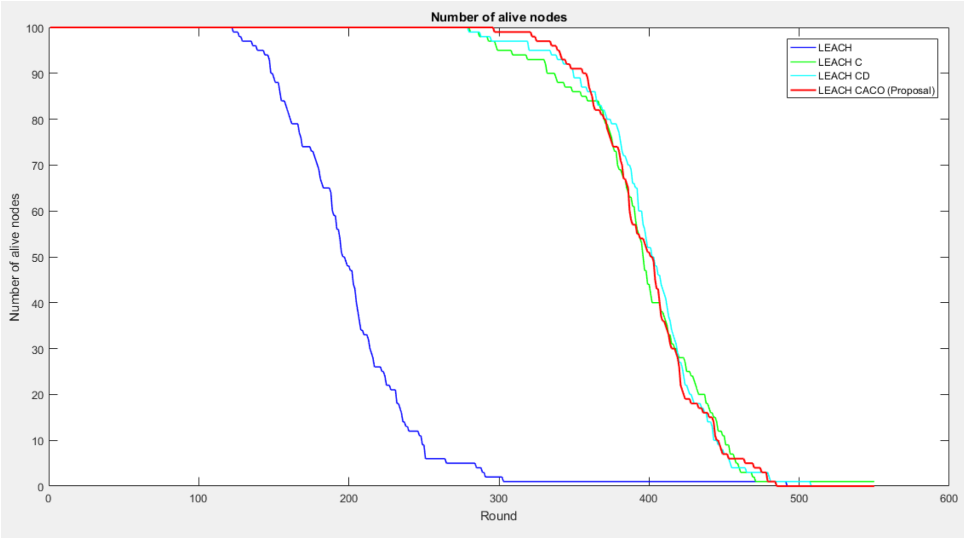

Figure 3. Number of alive nodes between the proposal and other algorithms

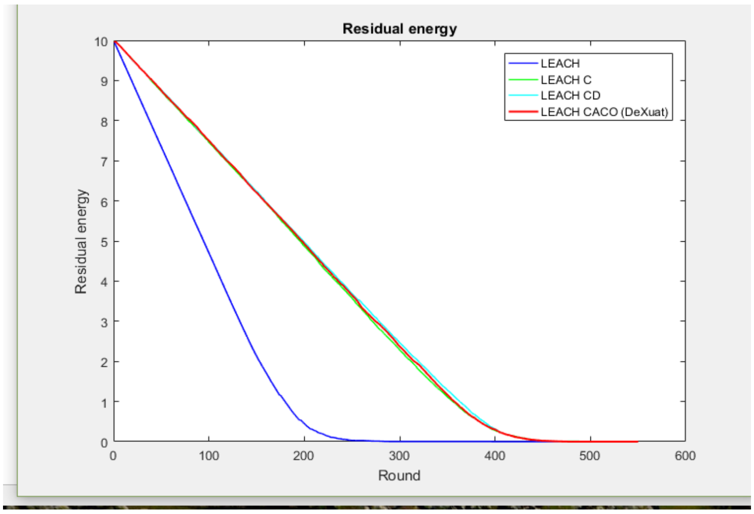

Figure 4. The energy consumption between the proposal and other algorithms

5. CONCLUSION

This paper presented a replacement algorithm LEACH-CACO to enhance the performance of WSNs. Through the proposed technique, it forms the sensor nodes into clusters by LEACH-C then combines with ACO algorithm to seek out the best path for the sink to maneuver over to gather information from the CHs. The simulation result shows that LEACH-CACO is better than LEACH, LEACH-C, and LEACH-CD in terms of the variety of nodes alive and also the quantity of energy consumed, therefore saving energy and enhance network lifespan. Within the future, we are able to attempt to add a lot of sinks or use different graph algorithm to seek out the simplest route for mobile sinks.

REFERENCES

[1] A. Singh and S. B. Rana, "Heterogeneous Routing Protocols in Wireless Sensor Network : A Survey," *International Research Journal of Engineering and Technology (IRJET)*, pp. 1014-1019, 2015.

[2] L. Li and D. Li, "An Energy-Balanced Routing Protocol for a Wireless Sensor Network," *Journal of Sensors*, vol. 2018, 2018, doi: 10.1155/2018/8505616.

[3] N. Ghosh and I. Banerjee, "Application of mobile sink in wireless sensor networks," *2018 10th International Conference on Communication Systems and Networks (COMSNETS)*, Bengaluru, India, 2018, pp. 507-509, doi: 10.1109/COMSNETS.2018.8328256.

[4] N. R. Zema, N. Mitton and G. Ruggeri, "A GPS-less on-demand mobile sink-assisted data collection in wireless sensor networks," *2014 IFIP Wireless Days (WD)*, Rio de Janeiro, Brazil, 2014, pp. 1-3, doi: 10.1109/WD.2014.7020847.

[5] A. K. P. R. Golash, “Design of Energy Efficient Multi-Sink and Mobile-Sink Routing Algorithms for Enhancing Network Lifetime for Consumer Home Networks,” *International Journal of Science and Research (IJSR)*, vol. 3, no. 4, pp. 783-788, 2014.

[6] F. Ahmed, Z. Wadud, N. Javaid, N. Alrajeh, M. S. Alabed, and U. Qasim, “Mobile sinks assisted geographic and opportunistic routing based interference avoidance for underwater wireless sensor network,” *Sensors,* vol. 18, no. 4, 2018, doi: 10.3390/s18041062.

[7] S. Basagni, A. Carosi, E. Melachrinoudis, C. Petrioli, and Z. M. Wang, “Controlled sink mobility for prolonging wireless sensor networks lifetime,” *Wirel. Networks*, vol. 14, no. 6, pp. 831-858, 2008, doi: 10.1007/s11276-007-0017-x.

[8] M. Omari and S. Laroui, "Simulation, comparison and analysis of Wireless Sensor Networks protocols: LEACH, LEACH-C, LEACH-1R, and HEED," *2015 4th International Conference on Electrical Engineering (ICEE)*, Boumerdes, Algeria, 2015, pp. 1-5, doi: 10.1109/INTEE.2015.7416826.

[9] A. Al-Shaikh, H. Khattab, and S. Al-Sharaeh, “Performance comparison of LEACH and LEACH-C protocols in wireless sensor networks,” *Journal of ICT Research and Applications*, vol. 12, no. 3, pp. 219-236, 2018, doi: 10.5614/itbj.ict.res.appl.2018.12.3.2.

[10] X. Liu, “A survey on clustering routing protocols in wireless sensor networks,” *Sensors*, vol. 12, no. 8, pp. 1113-11153, doi: 10.3390/s120811113.

[11] K. Latif, M. Jaffar, N. Javaid, M. N. Saqib, U. Qasim and Z. A. Khan, "Performance Analysis of Hierarchical Routing Protocols in Wireless Sensor Networks," *2012 Seventh International Conference on Broadband, Wireless Computing, Communication and Applications*, Victoria, BC, Canada, 2012, pp. 620-625, doi: 10.1109/BWCCA.2012.108.

[12] L. K. Le and A. M. Mahdy, “Routing in Wireless Sensor Networks : Improved Energy Efficiency and Coverage using Unmanned Vehicles,” *International Journal of Computer Networks (IJCN)*, no. 8, no. 2, pp. 27-41, 2016.

[13] M. M. Warrier and A. Kumar, “An Energy Efficient Approach for Routing in Wireless Sensor Networks,” *Procedia Technology*, vol. 25, pp. 520-527, 2016, doi: 10.1016/j.protcy.2016.08.140.

[14] S. Feng, L. Tang and J. Hao, "An energy efficient routing algorithm based on radar chart for wireless sensor networks," *2014 11th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD)*, Xiamen, China, 2014, pp. 840-844, doi: 10.1109/FSKD.2014.6980947..

[15] N. A. Pantazis, S. A. Nikolidakis and D. D. Vergados, "Energy-Efficient Routing Protocols in Wireless Sensor Networks: A Survey," in *IEEE Communications Surveys & Tutorials*, vol. 15, no. 2, pp. 551-591, Second Quarter 2013, doi: 10.1109/SURV.2012.062612.00084.

[16] L. K. Ketshabetswe, A. M. Zungeru, M. Mangwala, J. M. Chuma, and B. Sigweni, “Communication protocols for wireless sensor networks: A survey and comparison,” *Heliyon*, vol. 5, no. 5, 2019, Art. No. e01591, doi: 10.1016/j.heliyon.2019.e01591.

[17] M. Kowshalya and Sukanya, “Clustering Algorithms for Heterogeneous Wireless Sensor Networks - A Brief Survey,” *International Journal of Ad hoc, Sensor & Ubiquitous Computing (IJASUC)*, vol. 2, no. 3, pp. 57-69, 2011, doi: 10.5121/ijasuc.2011.2304.

[18] M. J. Handy, M. Haase and D. Timmermann, "Low energy adaptive clustering hierarchy with deterministic cluster-head selection," *4th International Workshop on Mobile and Wireless Communications Network*, Stockholm, Sweden, 2002, pp. 368-372, doi: 10.1109/MWCN.2002.1045790.

[19] D. V Jose and G. Sadashivappa, “Mobile Sink Assisted Energy Efficient Routing Algorithm for Wireless Sensor Networks,” *World of Computer Science and Information Technology Journal*, vol. 5, no. 2, pp. 16-22, 2015.

[20] A. Taleb, T. Alhmiedat, O. A. Hassan, and N. M. Turab, “A Survey of Sink Mobility Models for Wireless Sensor Networks,” *Journal of Emerging Trends in Computing and Information Sciences,* vol. 4, no. 9, pp. 679-687, 2013.

[21] K. Koosheshi and S. Ebadi, "An energy efficient new protocol for wireless sensor networks with multiple mobile sinks," *2017 International Conference on Information Science and Communications Technologies (ICISCT)*, Tashkent, 2017, pp. 1-6, doi: 10.1109/ICISCT.2017.8188592.

[22] J. Wang, Y. Yin, J. Kim, S. Lee and C. Lai, "A Mobile-Sink Based Energy-Efficient Clustering Algorithm for Wireless Sensor Networks," *2012 IEEE 12th International Conference on Computer and Information Technology*, Chengdu, China, 2012, pp. 678-683, doi: 10.1109/CIT.2012.142.

[23] R. Thomas, “An Energy Efficient Multi-sink clustering algorithm for Wireless Sensors Network,” *International Journal of Advanced Engineering and Global Techonlogy*, vol. 2, no. 4, pp. 647-653, 2014.

[24] D. Mechta and S. Harous, "Improving LEACH-C using sink mobility," *2016 IEEE 7th Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON)*, New York, NY, USA, 2016, pp. 1-6, doi: 10.1109/UEMCON.2016.7777901.

[25] Z. Ya-Qiong and L. Yun-Rui, “A routing protocol for wireless sensor networks using K-means and Dijkstra algorithm,” *International Journal of Advanced Media and Communication*, vol. 6, no. 2-4, pp. 109-121, 2016, doi: 10.1504/IJAMC.2016.080964.

[26] M. Ali, A. Iqbal, B. Nazir, N. Ul Amin, S. Mehmood, and K. Habib, “Energy Efficient Clustering Using Fixed Sink Mobility for Wireless Sensor Networks,” *International Journal of Advanced Computer Science and Applications*, vol. 7, no. 2, 2016, doi: 10.14569/IJACSA.2016.070266.

[27] Y. Sun, S. Zhang, H. Xu, and S. Lin, “New technologies and research trends for mobile wireless sensor networks,”

International Journal of Distributed Sensor Networks, vol. 2014, 2014, doi: 10.1155/2014/929121.
[28] C. University, "Application-Specific Protocol Architectures for Wireless Networks Chairman, Department Committee on Graduate Students," no. 1995, 1995.
[29] M. Hadjila, H. Guyennet, and M. Feham, "Energy-Efficient in wireless sensor networks using fuzzy C-Means clustering approach," *International Journal of Sensors and Sensor Networks*, vol. 1, no. 2, pp. 21-26, 2013, doi: 10.11648/j.ijssn.20130102.11.
[30] M. M. Umar, N. Alrajeh, and A. Mehmood, "SALMA : An Efficient State-Based Hybrid Routing Protocol for Mobile Nodes in Wireless Sensor Networks," *International Journal of Distributed Sensor Networks*, vol. 12, no. 2, p. 2909618, 2016, doi: 10.1155/2016/2909618.
[31] T. Shankar and A. Jadhav, "Whale Optimization Based Energy-Efficient Cluster Head Selection Algorithm for Wireless Sensor Networks," *arXiv preprint arXiv:1711.09389*, pp. 1-22, 2017.
[32] A. M. P. Amorim, P. A. C. Oliveira, and H. C. Freitas, "Performance evaluation of single- and multi-hop wireless networks-on-chip with NAS Parallel Benchmarks," *Journal of the Brazilian Computer Society*, vol. 21, no. 1, 2015, doi: 10.1186/s13173-015-0027-y.
[33] A. Kaur and H. Kaur, "Hybrid Approach Using Mobile Sink and Fuzzy Logic for Region Based Clustering in Wsn," *International Journal Of Computers & Technology*, vol. 16, no. 5, pp. 6933-6944, 2017, doi: 10.24297/ijct.v16i5.6264.
[34] J. Wang, Y. Gao, W. Liu, A. K. Sangaiah, and H. J. Kim, "Energy efficient routing algorithm with mobile sink support for wireless sensor networks," *Sensors*, vol. 19, no. 7, 2019, Art. No. 1494, doi: 10.3390/s19071494.
[35] N. Gharaei, K. A. Bakar, S. Z. M. Hashim, A. H. Pourasl, M. Siraj, and T. Darwish, "An energy-efficient mobile sink-based unequal clustering mechanism for WSNs," *Sensors*, vol. 17, no. 8, 2017, Art. No. 1858, doi: 10.3390/s17081858.
[36] D. Wei, Y. Jin, S. Vural, K. Moessner and R. Tafazolli, "An Energy-Efficient Clustering Solution for Wireless Sensor Networks," in *IEEE Transactions on Wireless Communications*, vol. 10, no. 11, pp. 3973-3983, November 2011, doi: 10.1109/TWC.2011.092011.110717.
[37] S. Siddiqui, B. Banarasi, D. Group, and O. Educational, "SPIN Protocol for transmission of data of mobile sink in Wireless Sensor Network," *SPIN*, vol. 7, no. 3, May 2017.
[38] C. Intanagonwiwat, R. Govindan, D. Estrin, J. Heidemann and F. Silva, "Directed diffusion for wireless sensor networking," in *IEEE/ACM Transactions on Networking*, vol. 11, no. 1, pp. 2-16, Feb. 2003, doi: 10.1109/TNET.2002.808417.
[39] Y. Yuan, C. Li, Y. Yang, X. Zhang, and L. Li, "CAF: Cluster algorithm and a-star with fuzzy approach for lifetime enhancement in wireless sensor networks," *Abstract and Applied Analysis*, vol. 2014, 2014, doi: 10.1155/2014/936376.
[40] B. Paul and M. A. Matin, "Optimal geometrical sink location estimation for two-tiered wireless sensor networks," *IET wireless sensor systems*, vol. 1, no. 2, pp. 74-84, 2011, doi: 10.1049/iet-wss.2010.0073.

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