ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 10, Spl Iss 1, 2021

Enhancing Wireless Sensor Networks with Energy-Efficient Hybrid K-Medoids and Sunflower Optimization Algorithm

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Abstract

Ensuring the prolonged energy endurance of sensor nodes within Wireless Sensor Networks (WSNs) is a paramount concern for their efficient operation. One viable strategy to achieve this goal is the incorporation of cluster heads (CHs) as pivotal energy sources to extend the overall longevity of WSNs. The effectiveness of CHs hinges on their ability to facilitate efficient communication within and between clusters, directly impacting the network's overall lifespan. However, determining the optimal energy allocation for WSNs and devising clustering algorithms presents significant challenges. Experimental results underscore the superiority of SFO-CORP when compared to existing protocols like LEACH, EECRP, FEEC-IIR, and CL-IoT. SFO-CORP achieves notable enhancements in various network performance metrics, including packet delivery ratio, energy consumption, end-to-end delay, network lifetime, and computational efficiency. These outcomes signify the potential of SFO-CORP as a promising solution for optimizing WSNs and ensuring their sustained energy-efficient operation.

Introduction

Energy efficiency is critical in WSNs, and clustering provides an effective means to achieve it. CHs facilitate communication between groups of sensor nodes and the BS [1]. Selecting optimal CHs is challenging, and various optimization techniques have been explored, such as fuzzy logic [2], ant colony optimization, genetic algorithms, particle swarm intelligence, and the harmony search algorithm [3]. This article proposes a hybrid approach using K-Medoids with SFO to address the CH selection problem. Additionally, an energy-efficient routing protocol is proposed, optimizing clustering and routing overheads through cross-layer optimization [4].

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3. Proposed Methodology

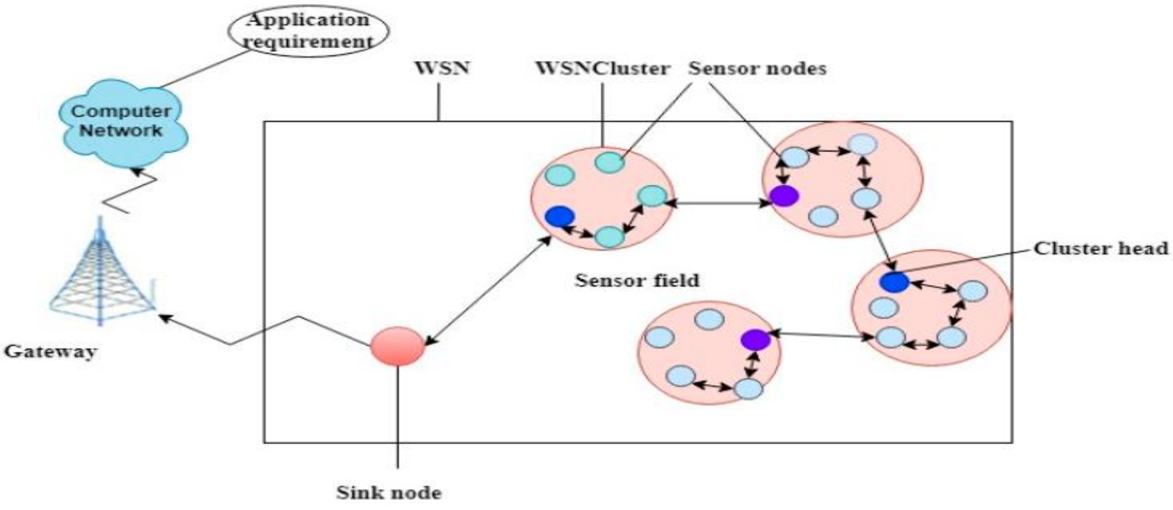

Figure 1. WSN architecture [25].

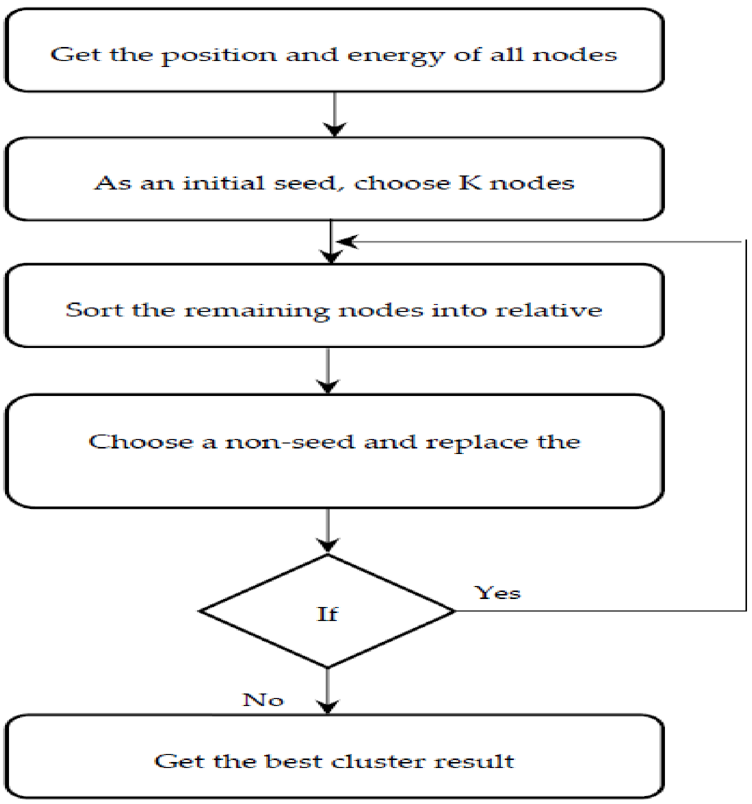

Figure 2. The Proposed K- Medoids-Based Clustering Algorithm.

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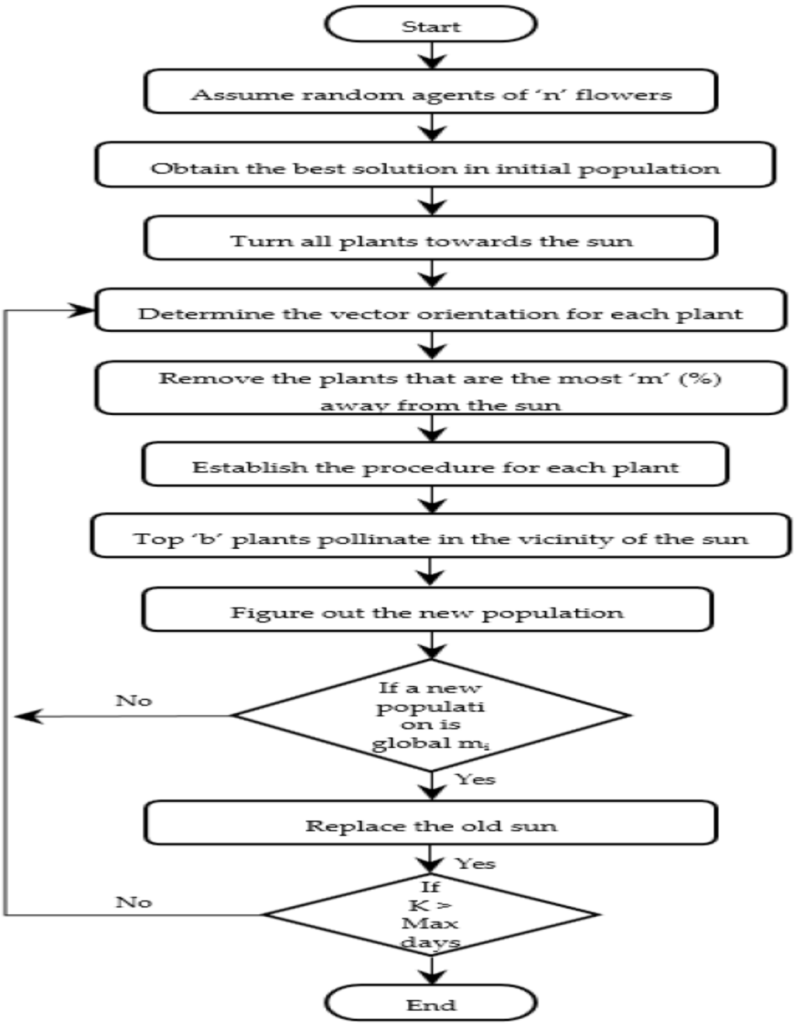

Figure 3. Sunflower Optimization Algorithm.

Table 1. Experimental Setup.

Parameter	Value
Area	1000 m^2
Nodes count	100
Initial energy	0.1 J
Bandwidth	20 kbps
Size of packets	500 bytes
Distribution of nodes	Random
Total nodes count	500

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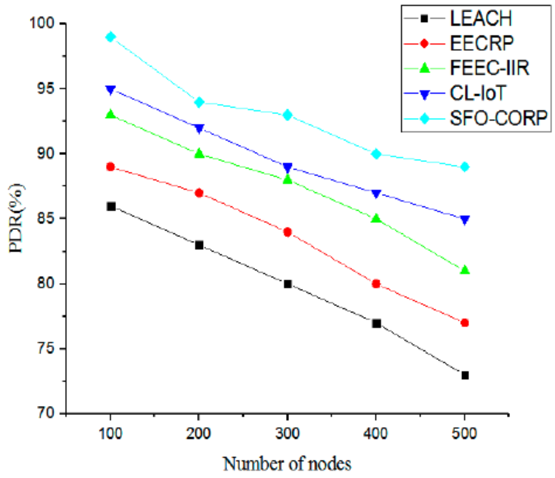

Figure 4. Comparison of PDR (%) for the various nodes.

Table 2. Comparison of PDR (%).

Node Counts	LEACH	EECRP	FEEC-IIR	CL-IoT	SFO-CORP
100	86	89	93	95	99
200	83	87	90	92	94
300	80	84	88	89	93
400	77	80	85	87	90
500	73	77	81	85	89

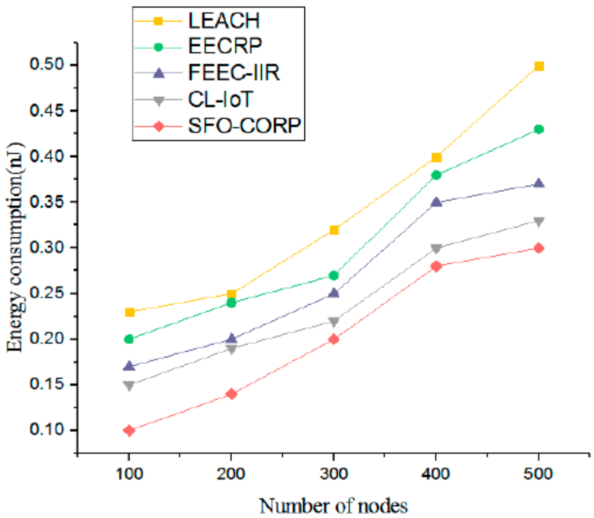

Figure 5. Node counts vs. energy consumption (nJ).

Table 3. Comparison of the Energy Consumption (nJ).

Node Counts	LEACH	EECRP	FEEC-IIR	CL-IoT	SFO-CORP
100	0.23	0.2	0.17	0.15	0.1
200	0.25	0.24	0.2	0.19	0.14
300	0.32	0.27	0.25	0.22	0.20
400	0.4	0.38	0.35	0.3	0.28
500	0.5	0.43	0.37	0.33	0.30

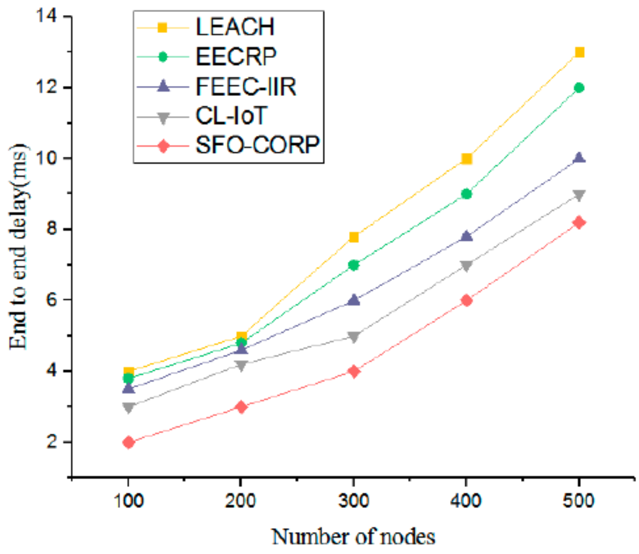

Figure 6. Node counts vs. E2ED (ms).

Table 4. Comparison of E2ED (ms).

Node Counts	LEACH	EECRP	FEEC-IIR	CL-IoT	SFO-CORP
100	4	3.8	3.5	3	2
200	5	4.8	4.6	4.2	3
300	7.8	7	6	5	4
400	10	9	7.8	7	6
500	13	12	10	9	8.2

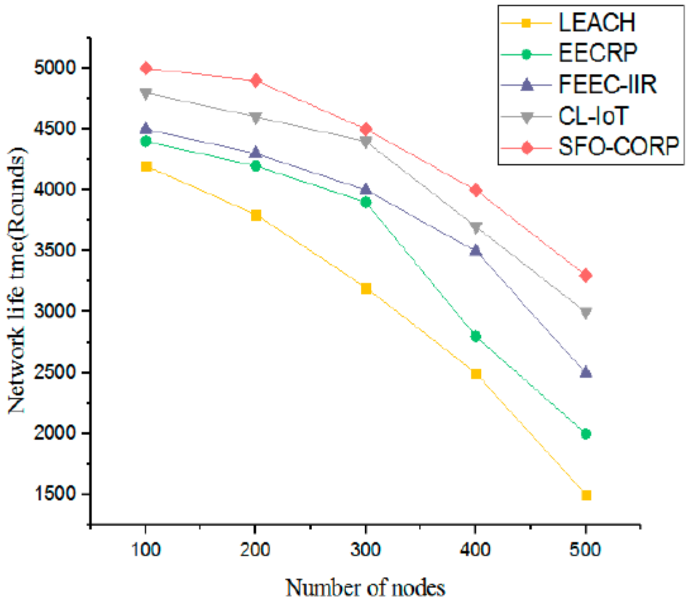

Figure 7. Number of nodes vs. network lifetime.

Table 5. Comparison of Network Lifetimes (rounds).

Number of Nodes	LEACH	EECRP	FEEC-IIR	CL-IoT	SFO-CORP
100	4200	4400	4500	4800	5000
200	3800	4200	4300	4600	4900
300	3200	3900	4000	4400	4500
400	2500	2800	3500	3700	4000
500	1500	2000	2500	3000	3300

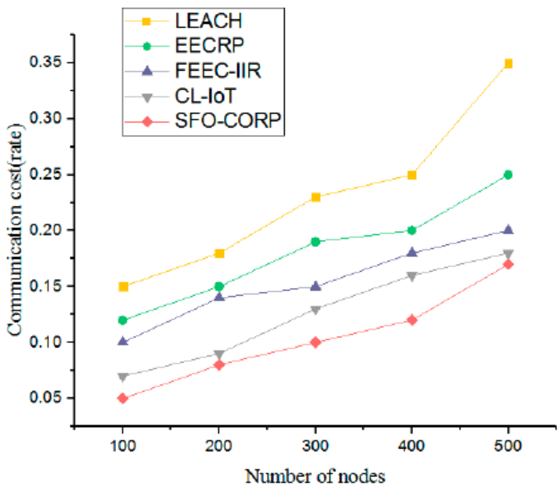

Figure 8. Number of nodes vs. communication cost (rate).

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Table 6. Communication Cost (rate).

Node Counts	LEACH	EECRP	FEEC-IIR	CL-IoT	SFO-CORP
100	0.15	0.12	0.1	0.07	0.05
200	0.18	0.15	0.14	0.09	0.08
300	0.23	0.19	0.15	0.13	0.10
400	0.25	0.2	0.18	0.16	0.12
500	0.35	0.25	0.2	0.18	0.17

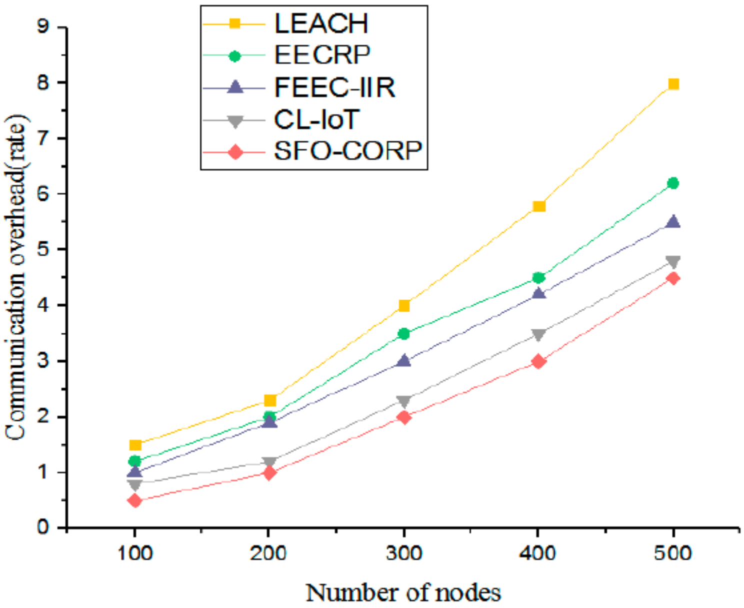

Figure 9. Number of nodes vs. communication overhead (rate).

Table 7. Communication Overhead (rate).

Node Counts	LEACH	EECRP	FEEC-IIR	CL-IoT	SFO-CORP
100	1.5	1.2	1	0.8	0.5
200	2.3	2	1.9	1.2	1.0
300	4	3.5	3	2.3	2.0
400	5.8	4.5	4.2	3.5	3
500	8	6.2	5.5	4.8	4.5

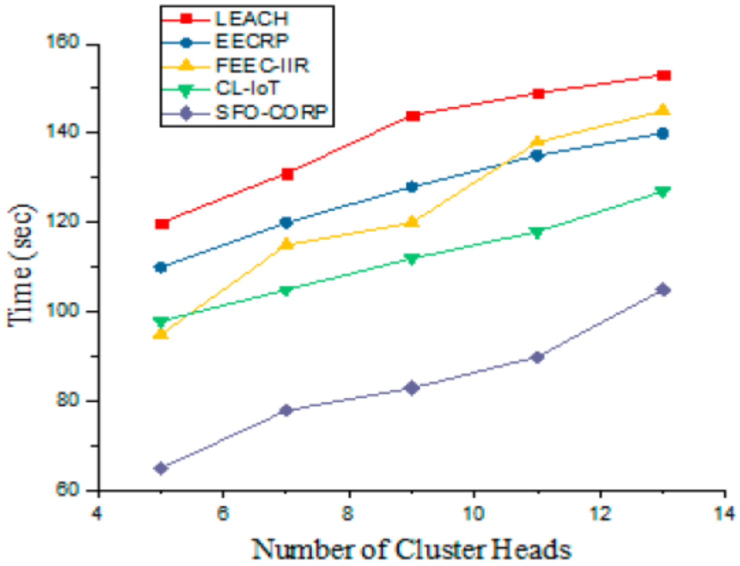

Figure 10. Number of cluster heads vs. time for CH selection.

Table 8. Timing analysis for CH selection.

Node Counts	LEACH	EECRP	FEEC-IIR	CL-IoT	SFO-CORP
5	120	110	95	98	65
7	131	120	115	105	78
9	144	128	120	112	83
11	149	135	138	118	90
13	153	140	145	127	105

5. Conclusions

The SFO-CORP protocol has demonstrated superior performance when compared to other existing protocols, particularly concerning the mentioned performance metrics. Notably, it has outperformed these protocols in terms of Packet Delivery Ratio (PDR), network lifetime, End-to-End Delay (E2ED), energy consumption, and computational efficiency. These results strongly suggest that the SFO-CORP protocol excels in energy efficiency and the selection of energy-efficient cluster heads, taking into account various critical factors like proximity and cost-effectiveness. Furthermore, it's evident that the development and evaluation of the SFO-CORP protocol have been a collaborative effort involving multiple authors and contributors.

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