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Optimizing Energy Efficiency in Indoor Wireless Sensor Networks: A Firefly Algorithm-Based Approach for Prolonged Network Lifetime

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ABSTRACT:

Sensor nodes in WSN are powered with a battery. Sensor nodes consume the battery power mainly in the tasks like data transmission, data reception and sensing. Sometimes it is impractical to replace a battery in WSN because humans can't reach. Therefore once energy or computational resources are consumed, immediate recovery of these resources is a complex task so it is necessary to make use of battery power efficiently to increase the lifetime of the sensor nodes that will also increase the lifetime of the whole network. This research focuses on Indoor Wireless Sensor Networks (WSNs) and proposes an effective management methodology for the internal analysis and verification of these networks. The primary objective is to enhance the energy efficiency of WSNs and extend their network lifetime. The research introduces an energy-efficient clustering algorithm, optimized by the Firefly Algorithm (FF). This algorithm aims to organize sensor nodes into clusters in a manner that optimizes energy consumption. The performance of the proposed approach is evaluated using key parameters such as Throughput and Network Lifetime, providing insights into the effectiveness of the algorithm in improving the overall efficiency and lifespan of indoor WSNs.

Keywords: Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), Wireless Sensor Networks, LEACH, Sensor Nodes, Wireless Sensor Networks.

1. INTRODUCTION

Wireless sensor network composed of numerous of sensor nodes which communicate with each other through wireless network. Each sensor node is required to be capable of sensing, processing and communicating the processed data to the neighbouring nodes to form a network. The data packets travel through these sensors nodes from source node to destination node via several intermediate nodes [2]. The data packets can uses long as well as short route to reach to the destination node. The long route may results in network delay and can take larger time while simulating it. On the other hand short route results in better network performance by consuming lesser energy and lowest network delay. Finally, the routing targets are oriented by the application, therefore different routing protocols have been offered for easily accessibility of those applications [3-4].

2. WIRELESS SENSOR NETWORK

Wireless sensor network also termed as distributed sensor nodes network in which each node are independent of each other and can perform transferring of data packets individually. A wireless sensor network is an accumulation of small randomly dispersed devices. Moreover in WSN, each node communicates with their neighbour node for transferring data from source node to sink node [4]. The size of sensor nodes may change from small grain size to large box according to the requirement of application. Networking topologies may also vary. In WSN assumption, a user may retrieve the information by sending query to the system and then getting the results accordingly [5].

3. ARCHITECTURE OF WSN

In wiresless sensor network there are two things, first is sensor node and other is sink node. The function of sensor node is collect data in real time whether is temperature or pressure or other thing. Then this data is send to sink node. Sink node has high energy and it perform the function of routing.

Following are the components of wireless sensor network:

A. Sensor Node: These are the main unit of main unit of sensor network. They sense all the required information from the area or environment and then transmit this to data to sink node continuously. Many sensor nodes can be deployed in an area.

B. Sink Node: Sink node has various functions they receive the data, and then process the data. It also store the data. The main purpose of sink node is data aggregation.

C. Sensor Field: It is simply an area where all nodes communicate with each other and send data to each other.

D. Task Manager: It can also be called as base station. It is centralised point in the network that gathers data from various source nodes and transmit them to sink node. The base station also function as a gateway for other network. It can also serve as entry point for various networks for the purpose of receiveing and transmitting data.

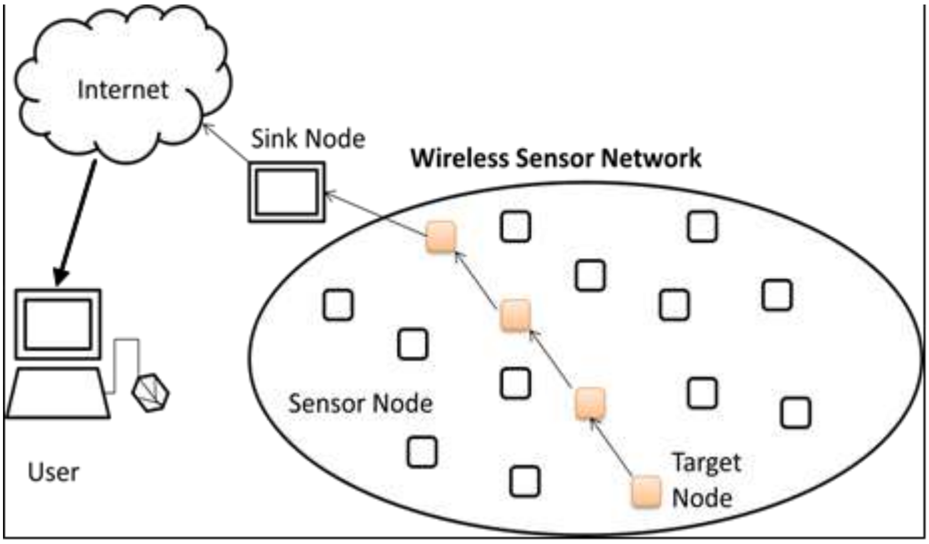

Figure 1: Architecture of Wireless Sensor network

4. CLASSIFICATION OF CLUSTERING ATTRIBUTES

Cluster Properties

Quite regularly, clustering techniques strive to accomplish a few qualities for the produced clusters. Such qualities could be identified with the interior structure of the cluster or how it identifies with others. The accompanying are the significant traits:

- Cluster Count: CHs are decided ahead of time in a portion of the distributed methodologies like [6-8], and [89], in this manner, the amount of clusters is reset. CH selection algorithms by and large pick haphazardly CHs from the sent sensors consequently yields variable number of clusters.
- Connectivity of CH to BS: CHs send the collected information to the BS specifically or by implication with help of other CH nodes. That is to say, there exists an immediate connection or a Multihop [9-14].

Cluster Head

- Capabilities: The accompanying properties of the CH node are separating components among grouping plans:
- Mobility: CH may be stationary or versatile. As a rule, they are stationary. Be that as it may here and there, CHs can move inside a restricted area to reposition themselves for better execution of network.
- Types of node: Generally sensor nodes among the conveyed sensors are assigned as CHs, however now and again sensor nodes outfitted with essentially more processing and correspondence assets are chosen as CHs.

CH Selection is Based On

- Initial Energy: This is a vital parameter to choose the CH. At the point when any algorithm begins it for the most part considers the initial energy.
- Residual Energy: After a portion of the rounds are finished, the cluster head choice ought to be focused around the energy staying in the sensors.
- Rate of Energy Consumption: This is an alternate vital parameter that considers the energy utilization rate $V_i(t)$ focused around emulating formula:

$$V_i(t) = \frac{E_{initial} - E_i(t)}{r-1} \quad (1)$$

Where $E_i(t)$ and $E_{initial}$ are the residual energy and initial energy of every node separately and r is the existing round.

5. LOW-ENERGY ADAPTIVE CLUSTERING HIERARCHY (LEACH)

During the configuration phase, randomly generated cluster head, the random number is selected in a range between 0 and 1 in each sensor node, if the selected number is smaller than some threshold $T(n)$, then the node is selected as the head of the cluster. Formulas of $T(n)$ as follows [16]:

$$T(n) = \begin{cases} \frac{p}{1-p(r \, mod \frac{1}{p})} & ,if \;\; n \in G \\ 0 & ,otherwise \end{cases} \quad (2)$$

Where, p is the percentage of the number of cluster headers and the total number of nodes in the network, r is the number of the current round, G is the set of cluster nodes except the cluster head of the last rounds $\frac{1}{p}$. Then, the header node of the cluster transmits the message that it is becoming a cluster head in the entire network, each node decides to join that cluster according to the intensity of the received information and responds to the corresponding cluster header. Then, in the next phase, each node uses the TDMA method to transmit data to the cluster header node, the cluster head sends the fusion data to the receiving node. Among the clusters, each cluster competes with the communication channel with the CDMA protocol. After a period of stable phase, the network enters the next round of the cycle again, continuous cycle [15-18].

The randomly selected group header method avoids excessive power consumption, improves network life, data fusion reduces traffic effectively, but the protocol still uses jump communication, although the transmission delay it is small, the nodes require high power communications, the expansion is deficient, it is not suitable for large scale networks; even in smaller networks, the nodes furthest from the receiving node communicating with each other at high power can lead to a shorter survival time; frequent selection of the cluster head will lead to the cost of energy traffic.

Proposed Method of WSN Cluster Head Election

The threshold formula given by Qian Liao et al. [18] is:

$$T(n) = \frac{p}{1-p^*\left(r\text{mod}\frac{1}{p}\right)} * \frac{E_{cur}}{E_0} \quad (3)$$

Where, E_0 and E_{cur} represent initial energy and current energy of the node respectively. The improvement in proposed protocol takes place using the increment in probability of high energy nodes, by which the nodes turn into the cluster-head. Although, this process causes an issue. The threshold $T(n)$ turn out to be small if the residual energy becomes very low resulting a reduction in nodes of the network. It will results the early death of nodes and finally the network lifetime will be less. Also, the threshold formula in equation (4) does not contains any impact of the distance between base station and nodes for cluster-head election.

Then the improvement in threshold is given as:

$$T(n) = \begin{cases} f(E_{cur}) * \left[\frac{(1-\alpha)p}{1-p^*\left(r\text{mod}\frac{1}{p}\right)}\right] & n \epsilon G \\ 0 & n \notin G \end{cases} \quad (4)$$

Where, $f(E_{cur})$ is the function related to the current residual energy of the node. It shows the impact of node energy on the election probability. It is given by:

$$f(E_{cur}) = \frac{E_{cur}}{E_{ave}} \quad (5)$$

E_{ave} is the average residual energy of entire nodes in the current round.

6. EVALUATION PARAMETERS

Throughput

It is the ratio of the total number of successful packets in bits received at destination in a specified amount of time.

$$\text{TH} = \sum \text{Transmission of Routing Packets} \quad (6)$$

Network Lifetime

The lifetime in a WSN is the time period throughout which the system constantly justifies the provision necessity.

7. SIMULATION RESULTS

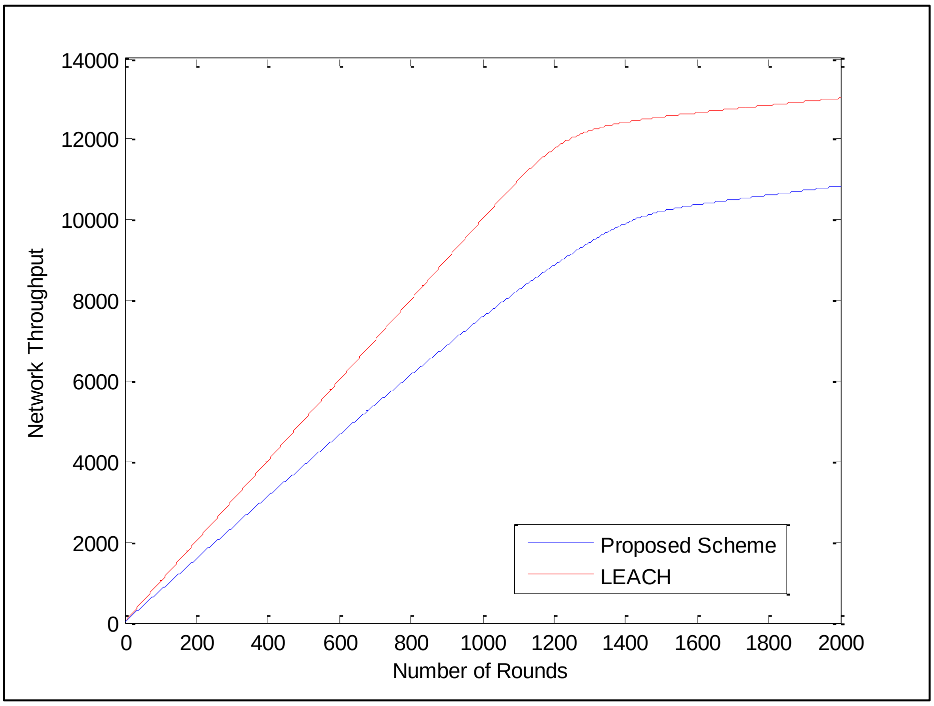

Figure 2: Network throughout comparison for proposed algorithm

Figure 2 shows the comparison of throughput for both the clustering algorithms. It can be noticed that the Firefly optimized approach gives better throughput as compared to LEACH.

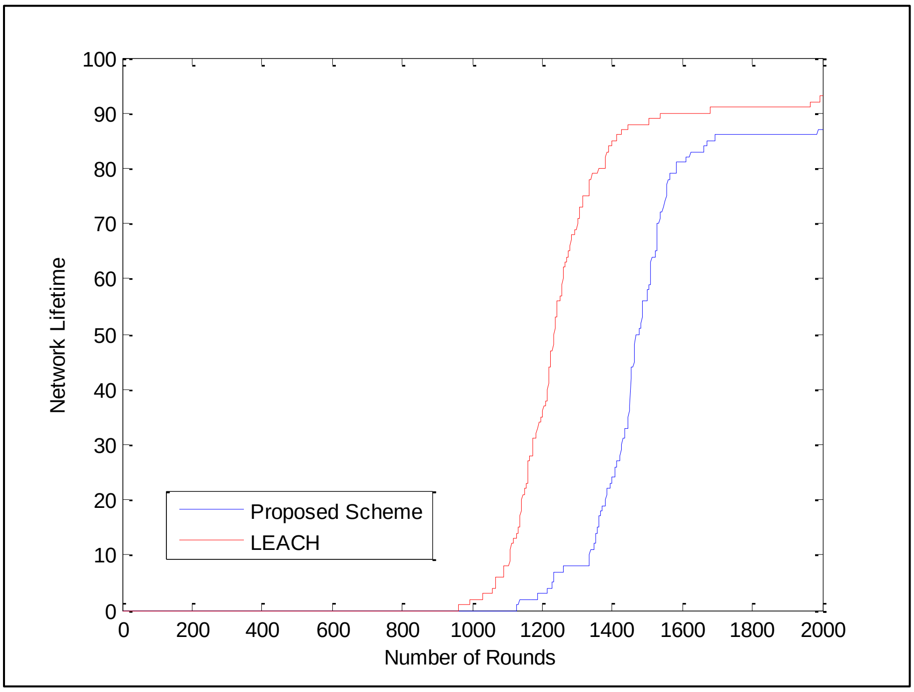

Figure 3: Network lifetime comparison for proposed algorithm

Figure 3 shows the comparison of Lifetime for LEACH and Firefly optimized proposed algorithm. It can be noticed that the Firefly optimized approach gives better results as compared to LEACH. At the end of round we are getting the minimum number of dead nodes in Firefly optimized approach as compared to LEACH.

8. CONCLUSION

This research work focuses on advancing the current state of proposed clustering algorithms, specifically addressing their power efficiency and reliability requirements. In the context of wireless sensor networks, the energy constraints of individual nodes play a crucial role in the design and implementation of any protocol. Additionally, the consideration of Quality of Service (QoS) metrics, such as delay, data loss tolerance, and network lifetime, unveils reliability challenges when devising recovery mechanisms for clustering methods. These essential characteristics often present a trade-off, as improvements in one aspect may negatively impact the other. The research aims to strike a balance, enhancing both the power efficiency and reliability of clustering algorithms in wireless sensor networks, thus contributing to the overall robustness and performance of the network. The Firefly Algorithm has gained prominence as a widely used technique for addressing optimization challenges in Wireless Sensor Networks (WSNs) due to its simplicity, high-quality results, rapid convergence, and minimal computational complexity. However, the iterative nature of the Firefly Algorithm raises concerns about its applicability in scenarios where real-time optimization is crucial and needs to be performed frequently. The algorithm's demand for substantial memory resources may pose limitations on its implementation, particularly for resource-constrained base stations. We have examined LEACH and Firefly algorithm based cluster-head election for heterogeneous WSNs containing different level of heterogeneity. Simulations prove that Firefly algorithm based cluster-head election performs well in all scenarios. It has best performance in terms of Network Throughput and Lifetime.

REFERENCES

1. Doherty, Lance, Jonathan Simon, and Thomas Watteyne. "Wireless sensor network challenges and solutions." *Microwave Journal* 55, no. 8 (2012): 22-34.
2. Zhan Wei Siew, " Fuzzy Logic Based Energy Efficient Protocol In Wireless Sensor Networks," ICTACT Journal On Communication Technology, December 2012, Volume: 03, Issue: 04, 2012
3. Mathieu Bourdeau. "A Wireless Sensor Network for Residential Building Energy and Indoor Environmental Quality Monitoring: Design, Instrumentation, Data Analysis and Feedback" Sensors 2023, 23(12), 5580; https://doi.org/10.3390/s23125580
4. Imad S. AlShawi, "Lifetime Enhancement in Wireless Sensor Networks Using Fuzzy Approach and A-Star Algorithm", IEEE SENSORS JOURNAL, VOL. 12, NO. 10, OCTOBER 2012.
5. Tsang-Chu Yu and et al. Wireless sensor networks for indoor air quality monitoring. Medical Engineering & Physics, Volume 35, Issue 2, February 2013, Pages 231-235.
6. S. Prasanna, Srinivasa Rao, "An Overview of Wireless Sensor Networks Applications and Security," International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, Volume-2, Issue-2, May 2012.
7. Yang, G.; Liu, S.; Li, Y.; He, L. Short-term prediction method of blood glucose based on temporal multi-head attention mechanism for diabetic patients. Biomed. Signal Process. Control 2023, 82, 104552.
8. Wang, Q.; Fan, Z.; Sheng, W.; Zhang, S.; Liu, M. Cloud-assisted cognition adaptation for service robots in changing home environments. Front. Inf. Technol. Electron. Eng. 2022, 23, 246–257.
9. Weerainghe, A.S.; Rasheed, E.O.; Rotimi, J.O.B. Occupant Energy Behaviours—A Review of Indoor Environmental Quality (IEQ) and Influential factors. In Proceedings of the 54th International Conference of the Architectural Science Association (ANZAScA) 2020, Auckland, New Zealand, 26–27 November 2020.
10. Pedersen, E.; Borell, J.; Li, Y.; Stålne, K. Good indoor environmental quality (IEQ) and high energy efficiency in multifamily dwellings: How do tenants view the conditions needed to achieve both? Build. Environ. 2021, 191, 107581.
11. De Boeck, L.; Verbeke, S.; Audenaert, A.; De Mesmaeker, L. Improving the energy performance of residential buildings: A literature review. Renew. Sustain. Energy Rev. 2015, 52, 960–975. [Google Scholar] [CrossRef]
12. Yang, J.; Santamouris, M.; Lee, S.E. Review of occupancy sensing systems and occupancy modeling methodologies for the application in institutional buildings. Energy Build. 2016, 121, 344–349. [Google Scholar] [CrossRef]
13.
14. M. Erol-Kantarci and H. T. Mouftah, "Wireless Sensor Networks for Cost-Efficient Residential Energy Manage- ment in the Smart Grid", *IEEE Trans. Smart Grid*, vol. 2, no. 2, pp. 314 -325, 2011.
15. L. Olivier, "Wireless Sensor Networking of Everyday Ob- jects in a Smart Home Environment", pp. 189-194, 2008.
16. D. Han and J. Lim, "Smart home energy management system using IEEE 802.15.4 and zigbee," *IEEE Trans. Consum. Electron.*, vol. 56, no. 3, pp. 1403–1410, Aug. 2010.
17. O. Asad, M. Erol-Kantarci, and H. Mouftah, "Sensor network web services for Demand-Side Energy Mana- gement applications in the smart grid," in *2011 IEEE Consumer Communications and Networking Conference (CCNC)*, 2011, pp. 1176–1180.

18. M. El Brak and M. Essaaidi, "Wireless sensor network in home automation network and smart grid," *Complex Syst. (ICCS), 2012 Int. Conf.*, pp. 1–6, 2012.
19. X. Hao, Y. Wang, C. Wu, A. Y. Wang, L. Song, C. Hu, and L. Yu, "Smart meter deployment optimization for efficient electrical appliance state monitoring", *2012 IEEE Third Int. Conf. Smart Grid Commun*, pp. 25-30, 2012.
20. K. Islam, W. Shen, and X. Wang, "Security and privacy considerations for Wireless Sensor Networks in smart home environments", *Proc. 2012 IEEE 16th Int. Conf. Comput. Support. Coop. Work Des*, pp. 626–633, 2012.