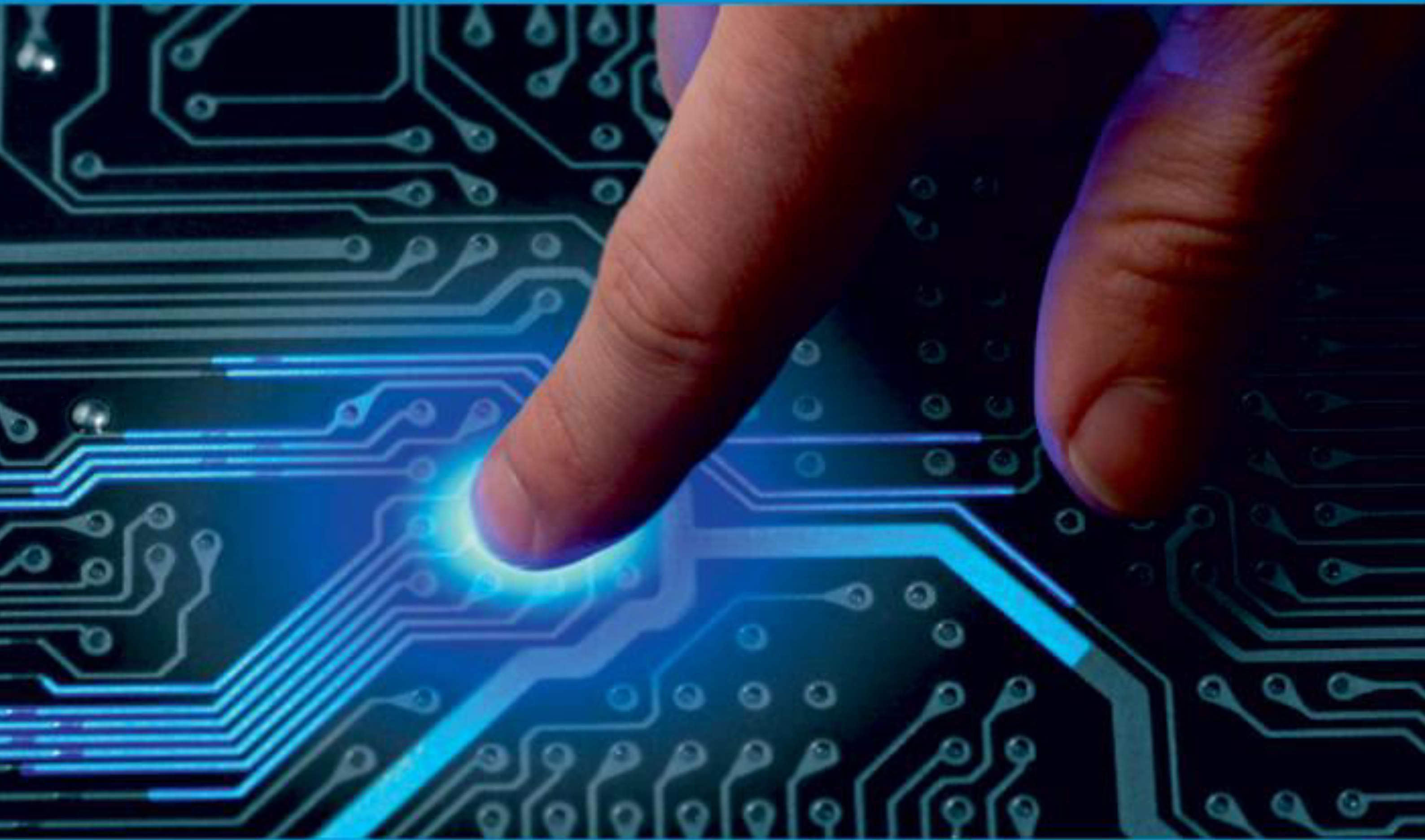
IJIRCCE

e-ISSN: 2320-9801 | p-ISSN: 2320-9798



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN COMPUTER & COMMUNICATION ENGINEERING

Volume 12, Issue 10, October 2024

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 8.625

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 8.625| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Enhanced Energy Efficiency and Stability in Wireless Sensor Networks Using Fuzzy Logic-Based Dual Cluster Head (FIS-DCH) Method

R.Manimuthu[1], A.Nagaraj[2], M.Parisa Beham[3], R.Tamilselvi[4]

PG Student, Sethu Institute of Technology, India[1]

Assistant Professor, Sethu Institute of Technology, India[2]

Professor, Sethu Institute of Technology, India[3,4]

ABSTRACT: The prime objective of this research is to compare the analysis of Fuzzy Logic-based Dual Cluster Head (FIS-DCH) method with the existing Fuzzy-based Cluster Head (FIS-CH) method in Wireless Sensor Networks (WSNs).It evaluates the performance by using NS2 simulator. In order to optimize the network efficacy and power sustainability, the FIS-DCH method demonstrates the dual cluster head method. This method is implemented in NS2 simulator. The simulation result shows that FIS-DCH method mitigates the cluster head modification's periodicity, optimized the packet delivery ratio which contributing the minimal energy consumption among the diverse network dimensions and results as more effective method. These final outcomes shows that FIS-DCH method make sure that offers an reliable data transfer and enhanced network connectivity period in dynamic system which presents a more sustainable and energy constrained method for WSNs.

KEYWORDS Wireless Sensor Networks, Fuzzy Logic Dual Cluster Head, Energy Efficiency Packet Delivery Ratio

I. INTRODUCTION

The Wireless Sensor Networks (WSNs) framework comprises of one sink Base Station (BS) and enormous Sensor Nodes (SN).This SN seems to be small with energy, transmission and memory constrained device. The sensor nodes are structured purposefully in the entire system to gather the vital data. An acquired data is then transferred by the SN to the nearby sink BS through multi hop channels or as a single hop directly.[1] WSNs is the most renowned and efficient method for transmitting the data from remote areas to the centralized servers. These SNs are having self organized capacity which develops a adaptive multi hop network that can transmit the compiled data to the base station.[2].Hence, the WSN's need has been increased and applied in a diverse domains like the healthcare industry, production, transportation, military, and environmental backgrounds. The Internet of Things (IoT) sector utilizes WSNs greatly in the recent days [3-8].

According to the specific competences and scenarios in these fields, the sensor node transmit the analyzed data to the BS via transmitter antenna. In WSNs processing the data transmission to the main BS by the specific node continuously which loss their energy promptly that results in node depletion or node failure. In order to address this issue, the routing method like cluster-based routing protocols is most often employed in this system. In this method, the network is partitioned into various clusters and each cluster has a specified Cluster Head (CH).The CHs plays a major role for routing the data transmission to the BS [9-10].In order to enhance the energy consumption and network lifetime, a novel optimization method should be established. In WSNs, the clustering is crucial component for energy management. This method is primarily mitigating the overhead because the BS is processing the data from fewer node. Since it is resource constrained, the WSN consume less energy effectively. WSN utilizes the clustering method for energy optimization .These models are classified by using centralized and distributed methods. In distributed systems, the clusters are produced using local data whereas the network global learning is needed to create the clusters in clustering algorithm.

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 8.625| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

II. RELATED WORK

The conventional clustering typically refers to hard clustering where each node is categorized into specific category and nodes solely dependent on single particular cluster that the cluster is independent of each other. Node has been grouped based on the various parameters especially residual energy and physical proximity [11].For example, K-means clustering is a progressive iterative distance based clustering algorithm where the CH is updated on the basis of the distance between the node to the cluster center [12].In WSNs, the Meta-heuristic algorithms is employed for their robust multi-criteria optimization skills. For instance, the CSO algorithm enhances the CH selection by emulating the tracking behavior of cat which includes the parameters like signal strength, residual energy, and intra-cluster distance. On considering the Indoor experiments using sensor nodes, a microcontroller, and a LabVIEW interface, it ensures that CSO enhances the network life time and lessens the computing time. But the performance of this algorithm is mitigated when handling the clusters with many nodes [13].The CH selection is optimized by the BOA (Butterfly Optimization Algorithm) in [14] which also integrates with the factors like remaining energy, range from BS and neighbors, node degree, and relevancy into the objective function. The optimal routing path from the source node to the BS through Cluster heads is calculated by the ACO (Ant Colony Optimization) in terms of factors like distance, energy, and node degree. When compared to conventional and existing methods, this approach enhances the network lifetime. In [14], the two-tier system is utilized in the THSI-RP protocol for clustering and routing. The CH selection is optimized by the first tier whereas the second tier demonstrates the routing tree to reduce the transmission distance. Some challenges raised in two-tier system when optimizing the network lifetime.

In [16],the two level genetic algorithm is employed to optimize the CH selection as well as multi-hop routing concurrently. In order to enhance the network lifetime, the energy consumption is considered in the routing method. Since the framework is highly sustainable, the result shows that the network lifetime is enhanced and performs in the same way when the GA is even replaced with other meta-heuristic algorithm. S. Jagadeesh et al. in [17] suggested the OAFS-IMFO protocol for clustering and routing process. OAFS offers an optimal CH selection based on energy and distance whereas the IMFO suggest the shortest route to the BS. The packet throughput has been enhanced in this protocol but with more energy consumption.

In [18], the hybrid DESA algorithm integrates the Simulated Annealing (SA) for global optimization with Differential Evolution (DE) for local search. The motivation of this integration is enhancing the network lifetime. But the CH selection is evaluated based on only the energy and distance which is also restricted. When SA is broadly used in WSNs ,it frequently results in local optima. As there is more improvement in Quantum technology, the quantum annealing is found to address the NP-hard problems in WSNs which provides better optimization compared to conventional SA.

The clustering motivation in [19] is restated as Quadratic Unconstrained Binary Optimization (QUBO) problem with involving two proposed encoding approach: one-hot encoding which is restricted by its inefficient utilization of quantum bits and binary encoding which uses the hierarchical representation of classes. The method depends on quantum annealing hardware and the classical solver "qbsolv" from D-Wave. In [20], the quantum encoding and the Hamiltonian of the Quantum Annealing (QA) algorithm is utilized to address the Traveling Salesman Problem (TSP)which is similar to the shortest route issue to mobile sink node which eventually reduces the overall energy issues.

In [20], the mobile sink node gathers the data from each nodes within in its communication limit in the organized route and return back to its beginning point on completion of single round. This task is similar to address the Traveling Salesman Problem (TSP). Quantum encoding technique is proposed by Zhijie Huang et al to denote the mobile path and utilizes the Hamiltonian of the Quantum Annealing (QA) algorithm to mange the quantum resolving gate which successfully addresses the entire energy issues.

Problem statement

- A conventional clustering methods in WSNs (e.g., FIS-CH) face challenges with:
  - Frequent cluster head changes.
  - High energy consumption.
  - Reduced packet delivery ratios
- these challenges contribute to shorter network lifetimes and reduced reliability.

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 8.625| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

- there is a need for a more robust, energy-efficient clustering method that adapts dynamically to network changes

Research Contribution and motivation

- The FIS-DCH method is introduced with dual cluster head method. Uses fuzzy logic for intelligent selection of primary and secondary cluster heads.
- Implementation through NS2 simulators which shows that FIS-DCH: Optimizes cluster head stability. Increases packet delivery ratio. Mitigates energy consumption.
- Offers an extensive analysis of FIS-DCH shows that it has capabilities to extend network lifetime and optimize performance. Increasing need for reliable, energy-efficient WSNs in crucial applications (e.g., environmental monitoring, healthcare, smart cities).
- The optimized solution is opted based on the existing clustering method's limitations. And targeting at solving the issue associated with maintaining network longevity and contant data transmission in dynamic environments.

III. PROPOSED METHODOLOGY

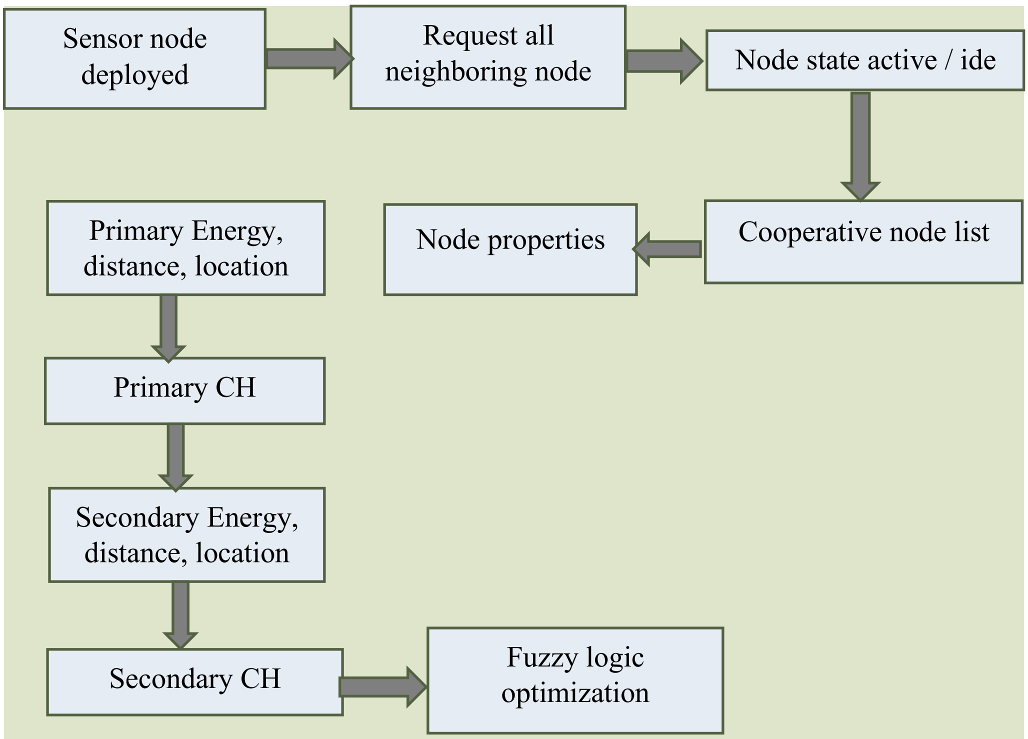


Figure 1 Proposed architecture

Figure1 illustrates the proposed framework in which the primary and secondary CH selection is performed in a Wireless Sensor Network (WSN) through fuzzy logic optimization. This process is essential for improving network performance especially in terms of energy efficacy and communication integrity.

1. **Sensor Node Deployment**

The initial process begins with deploying the sensor nodes in the target circumstances. These nodes are dispersed systematically to control the varied environmental attributes within their limited regions. Once done with the deployment, the nodes start to remain in active mode instantly and communicating with each other to generate a network.

2. **Requesting Neighboring Nodes**

Once finished deployment, each sensor nodes send a request to all neighboring nodes and collect data within its communication areas. This is very essential step to map the network topology which is crucial for selecting the following

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 8.625| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Cluster Heads (CHs).The communication range of every node demonstrates the quantity of neighbors ready to respond with and has impact on overall system framework.

3. Assessing Node State (Active/Idle)

Once the request done, the network determines the status of all neighboring nodes whether its is active or idle state. An active node is successfully functional and ready to assess in data communication whereas the node may be with less energy and temporarily not available is said to be idle node. This analysis is essential for identifying then node which is readily participating in the network and transmitting data.

4. **Compiling Cooperative Node List:**

Once identified the active nodes, they are consolidated in the cooperative node list. This list comprises of all nodes which are readily participating in the network which is having the capacity to become CHs or help in data relying. This stage assists in selecting CH which is capable of interacting and ready to take the responsibility rather than considering all applicant nodes.

5. **Evaluating Node Properties**

The next phase provides a cooperative list which consists of deep insight of node properties. The examined key properties are energy levels, proximity to other nodes, and geographical location. The CH selection is determined based on these properties of the nodes. Nodes with more energy and enhanced positioning is well suited to serve as CH.

6. **Selection of Primary Cluster Head (PCH)**

Through this evaluated properties, the Primary Cluster Head (PCH) is selected based on the node which shows the superior combination of energy, distance and location. This PCH role is to mange the data transmission within the cluster and sending the data to the central sink node. To make sure that selecting the PCH with great potential of managing the transmission load effectively.

7. **Selection of Secondary Cluster Head (SCH)**

The Secondary Cluster Head (SCH) selection process is initiated by following the PCH selection. In handling the task management in clusters, SCH assists the PCH and also acts as a backup. The SCH is also selected based on energy, distance, and location which aiming at it should be readily available to take charge and support the PCH when required.

8. **Fuzzy Logic Optimization**

Fuzzy logic Optimization method is applied in the last step. Fuzzy logic is applied to manage the inherent inconsistency and inaccurate in the node properties and also exact altering the SCH selection. This method improves the sustainability of the CH selction method which makes sure the network function effectively under varied circumstances.

Algorithm for Primary cluster head (PCH) and secondary cluster head (SCH)

Begin
{
Cluster formation ;
Choose PCH and SCH;
Elect PCH // primary cluster head
$Which\ node\ PCH = \left[\frac{Primary\ high\ (e)*low(d)}{high(communication\ time)};\right]$
PCH creates SCH //to improve the communication performance;
SCH monitor and PCH backup node;
Choose SCH
$SCH = \left[\frac{Secondary\ high\ (e)*low(d)}{high(communication\ time)};\right]$
PCH and SCH processing
Check the PCH processing time
$T_{int} = \left[\frac{I_{at}-P_t}{C_c}\right]$ // $I_a \rightarrow intial\ access\ time; P_t \rightarrow Processing\ time; C_c \rightarrow communication\ time$;
$For(S_n = 0; S_n < n; S_{n_t} + +)$;
If $(PCH(T_{int})(good) \rightarrow Packet\ processing\ is\ going\ on\ and\ storing\ the\ SCH)$ //
Els if
$(PCH(T_{int})(low) \rightarrow automatically\ SCH\ acts\ as\ PCH\ continues\ the\ packet\ processing)$*;*
Upcoming PCH and SCH decide by current_cycle;
Cluster with token list mapped by (PCH and SCH)
}

© 2024 IJIRCCE | Volume 12, Issue 10, October 2024| DOI: 10.15680/IJIRCCE.2024.1210012

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 8.625| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Experimental results

Parameter	value
Simulation time	200 s
Number of nodes	50
Simulation area	2500 × 2500 m^2
Mac Protocol	IEEE 802.11
Data rate	20 Mbps
Radio range	120m
Mobility model	Random waypoint model
Antenna	Omnidirectional antenna
Node speed	10-25 m/s
Packet size	512 bytes
Traffic type	Multicast constant bit ratio

Table 4: Simulation parameters

This method is simulated over a period of 200 seconds within the region of 2500 × 2500 m² with deploying 50 sensor nodes. These nodes communicate through IEEE 802.11 MAC protocol with a data rate of 20 Mbps and a radio range of 120 meters. The model's mobility is handled by using the Random Waypoint Model with speeds varying between 10 to 25 meters per second. All nodes are equipped with omnidirectional antenna and the network congestion is featured by multicast constant bit ratio, with a packet size of 512 bytes. This settings shows that the dynamic wireless system to evaluate performance in varying circumstances.

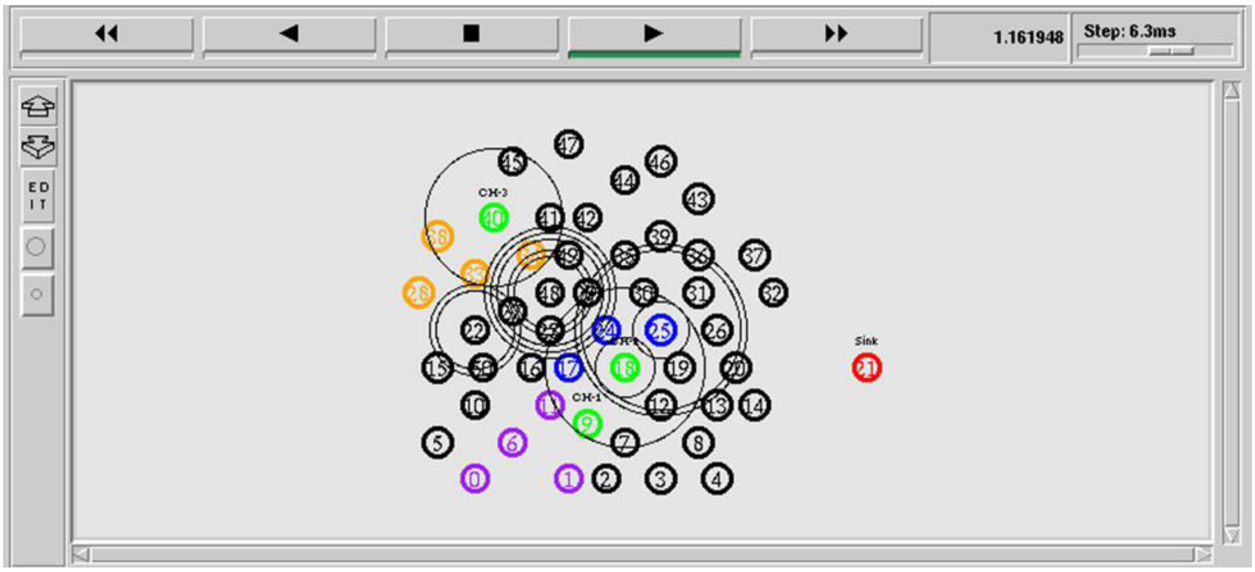


Figure 2 cluster formation

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 8.625| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Figure 2 shows the simulation representation of the Wireless Sensor Network (WSN).Each sensor node is denoted as black circle with a distinct number. Cluster Heads (CHs) is mentioned in various colors like green, blue, purple and orange and the surrounding circle represents the communication within the specified cluster. A central sink node is denoted in red color which collects the data transmitted by the CHs which accumulates the data and transmission process in the network.

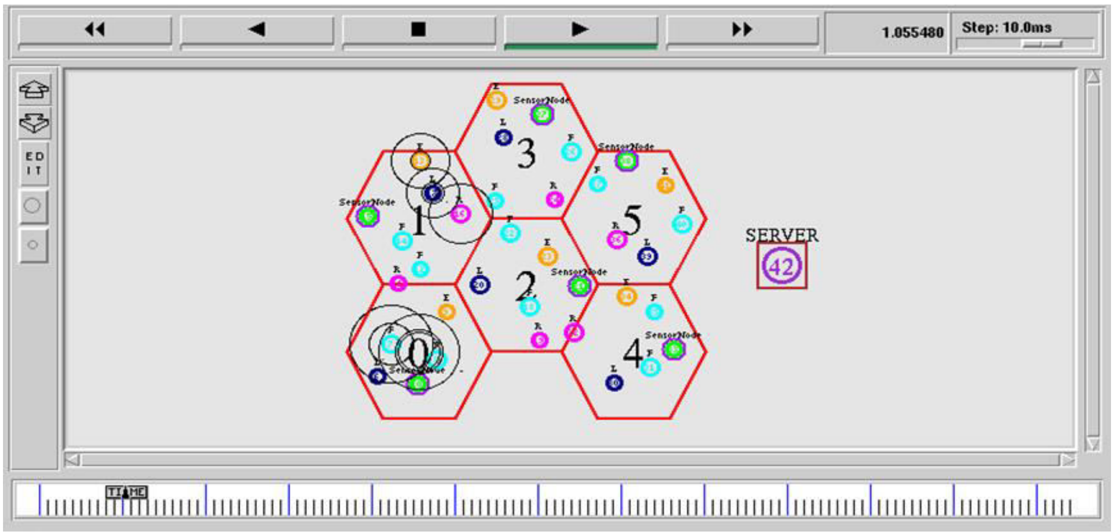


Figure 3 PCH and SCH election

In figure3,the Primary Cluster Heads (PCH) is represented in red nodes whereas the orange nodes indicate the Secondary Cluster Heads (SCH).The other nodes within the hexagonal cluster are normal cluster members. The PCH and SCH responsibilities fluctuating based on the attributes like energy levels, node mobility, and network demands as the network runs. This dynamic tuning enables the network to maintain efficient communication and data transfer. It make sure that selecting the optimized nodes as PCH and SCH at any period which results in enhancing the overall network performance and optimized network lifetime.

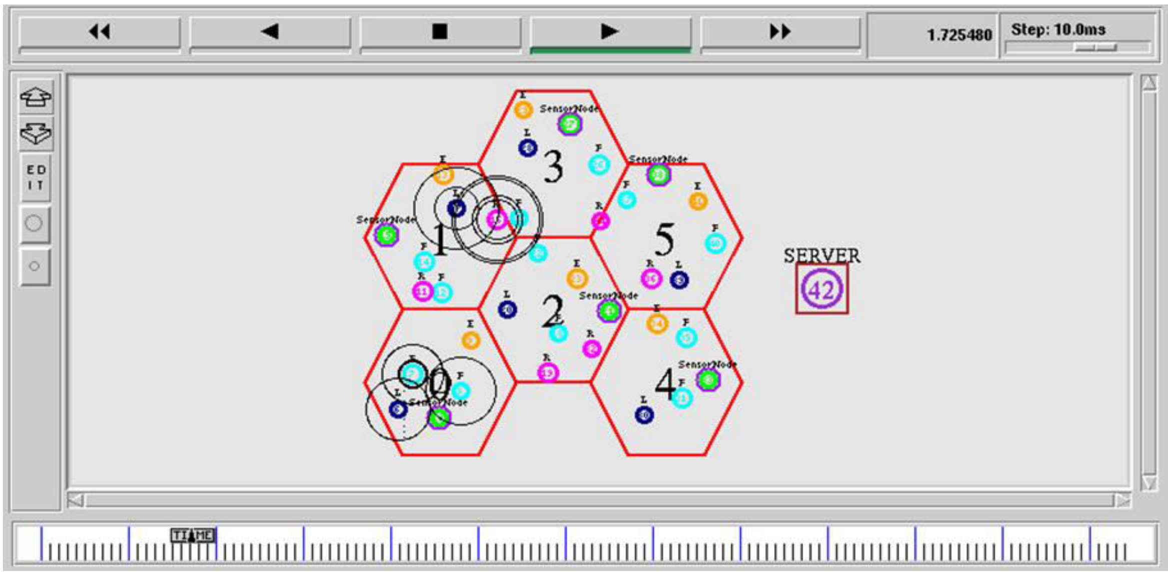


Figure 4 PCH and SCH

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 8.625| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Figure 4 shows a Wireless Sensor Network (WSN) where the positions of the Primary Cluster Heads (PCH) and Secondary Cluster Heads (SCH) has been dynamically altered compared to the prior configuration. The network is designed with six hexagonal clusters, each containing a group of sensor nodes. In this updated configuration, the PCH represented in green nodes which manages data collection and transmission within the clusters where the orange node denotes as SCH which acts as backup and supports PCH in data transmission. The other nodes are regular cluster members which collect and transmit to CHs. This image clearly shows the dynamic adjustment of PCH and SCH which implies the network's potential to adapt to varying conditions like fluctuating energy levels or nodes mobility. Hence, this flexible nature enables the network to maintain efficient performance, conserving energy and enhances the overall network lifespan. The central server, named "SERVER 42," acts as the primary data aggregation point for the overall system.

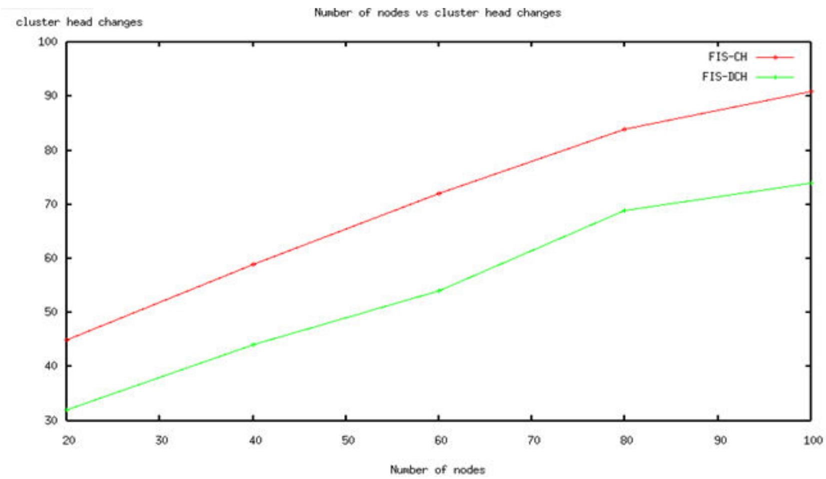


Figure 5 Number of node vs cluster head changes

A graphical representation in figure 5 shows that the proposed FIS-DCH method mitigates the cluster head changes when compared to the existing FIS-CH method. FIS-DCH method is mentioned in green line where existing FIS-CH denoted in red line. When increases the number of nodes, the existing FIS-CH method show a rise in cluster head changes steadily indicates its high instability and consuming more energy. Conversely, the proposed FIS-DCH remain in fewer changes which shows that its optimized stability and efficacy. This illustrates that proposed FIS-DCH method is more effective in cluster head changes which leads to superior performance and network lifespan.

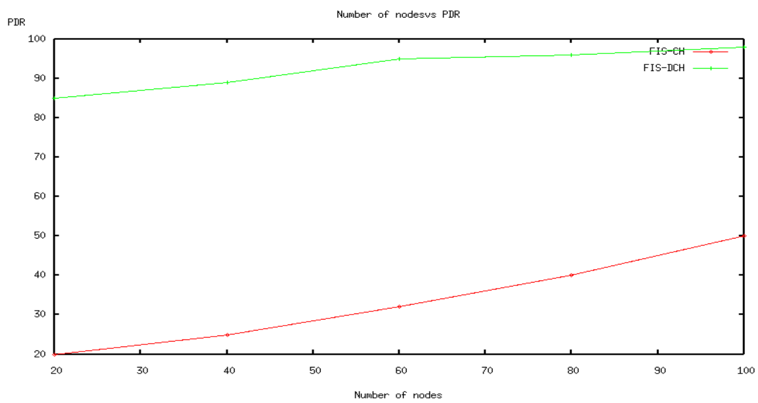


Figure 6 Number of node vs packet deliver ratio

Figure 6 represents the comparison analysis of the packet delivery ratio obtained between FIS-CH (existing Fuzzy-based Cluster Head) and FIS-DCH (proposed Fuzzy Logic-based Dual Cluster Head) when node count rises. The node count

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 8.625| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

is represented in X-axis where the Y-axis denotes the PDR value which the successful packet count is delivered within the network. The FIS-DCH method is denoted in green line which constantly rises the PDR near to 100% among various node counts which shows that its efficient and reliable packet delivery in larger networks too. On contrary, the FIS-CH method denoted as red line which delivers lower PDR, particularly as the number of nodes increases. This illustrates that FIS-DCH method performs better than the FIS-CH method which ensures that more reliable data transfer making it suited for large and dynamic wireless networks. FIS-DCH's significant performance of delivering high PDR shows its abilities to enhance the network stability and connection.

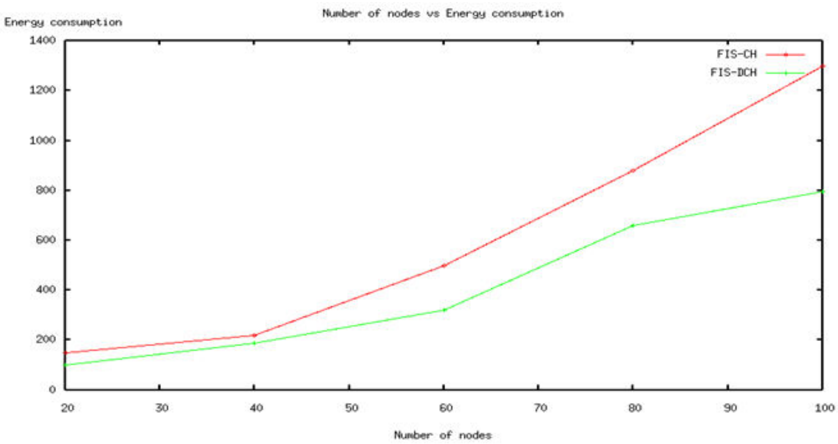


Figure 7 Number of node vs Energy consumption

A graphical representation in figure 7 shows the comparison of the energy consumption between two methods: FIS-CH (existing Fuzzy-based Cluster Head) and FIS-DCH (proposed Fuzzy Logic-based Dual Cluster Head) when increases the node count. The X-axis denotes the node count whereas the energy consumption in the network is denoted in Y-axis. The FIS-CH method is denoted in red line which has the energy consumption increases steadily as the node count rises, this indicates that this method is less energy efficient especially in larger networks. On contrary, the FIS-DCH method represents in green line shows the slight rise in energy consumption which highlighting its superior energy efficacy. This gap shows that the FIS-DCH method is more efficient in conserving energy which is well suited for larger networks where the energy management is crucial for network lifespan extension. This graph clearly explains about the effectiveness of FIS-DCH method in mitigating energy consumption with maintaining network performance.

IV. CONCLUSION

This comparative study using NS2 simulator concludes that the FIS-DCH method demonstrates superior performance than the conventional FIS-CH method in terms of various metrics like as cluster head stability, energy consumption and packet delivery ratio. The FIS-DCH method is not only offers more persistent and effective packet transmission but also mitigates the occurrence of cluster head changes and consume less energy effectively when handling larger networks. The future researchers should focused on the optimization of FIS-DCH by incorporating an adaptive algorithm to achieve efficient energy conservation and performance in dynamic and larger networks. Moreover, it is investigated in real time scenarios which leads to provide the detailed data in practical applications.

In future studies, they should focus on optimizing the FIS-DCH method by incorporating an adaptive algorithms to enhance the energy efficacy and performance in highly dynamic and large-scale Wireless Sensor Networks (WSNs).In addition to it, testing and deployment of the FIS-DCH method in real time cases is performed to evaluate the effectiveness and practicality in various circumstances which make sure that it satisfy the practical application demands.

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 8.625| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

REFERENCES

1. Bouarourou, S.; Zannou, A.; Boulaalam, A.; Nfaoui, E.H. Sensors Deployment in IoT Environment. In Proceedings of the International Conference on Digital Technologies and Applications, Fez, Morocco, 15–20 December 2022; pp. 276–283
2. Chand, S.; Singh, S.; Kumar, B. Heterogeneous HEED protocol for wireless sensor networks. Wirel. Pers. Commun. 2014, 77, 2117–2139. [CrossRef]
3. Qian, C.; Liu, X.; Ripley, C.; Qian, M.; Liang, F.; Yu, W. Digital Twin—Cyber Replica of Physical Things: Architecture, Applications, and Future Research Directions. Future Internet 2022, 14, 64. [CrossRef]
4. Hammood, D.A.; Rahim, H.A.; Alkhayyat, A.; Ahmad, R.B. Body-to-Body Cooperation in Internet of Medical Things: Toward Energy Efficiency Improvement. Future Internet 2019, 11, 239. [CrossRef]
5. Trakadas, P.; Simoens, P.; Gkonis, P.; Sarakis, L.; Angelopoulos, A.; Ramallo-González, A.P.; Skarmeta, A.; Trochoutsos, C.; Calvo, D.; Pariente, T.; et al. An artificial intelligence-based collaboration approach in industrial iot manufacturing: Key concepts, architectural extensions and potential applications. Sensors 2020, 20, 5480. [CrossRef]
6. Sam, A.J.; Mahamuni, C.V. A Wireless Sensor Network (WSN) Prototype for Scouting and Surveillance in Military and Defense Operations using Extended Kalman Filter (EKF) and FastSLAM. SSRN Electron. J. 2022. [CrossRef]
7. Ahmad, R.; Wazirali, R.; Abu-Ain, T. Machine Learning for Wireless Sensor Networks Security: An Overview of Challenges and Issues. Sensors 2022, 22, 4730. [CrossRef] [PubMed]
8. Bouarourou, S.; Boulaalam, A.; Nfaoui, E.H. A bio-inspired adaptive model for search and selection in the Internet of Things environment. PeerJ Comput. Sci. 2021, 7, e762. [CrossRef]
9. Kiran W, Smys S, Bindhu V (2020) Enhancement of network lifetime using fuzzy clustering and multidirectional routing for wireless sensor networks. Soft Comput 24(15):11805–11818
10. Sah DK, Amgoth T (2020) Renewable energy harvesting schemes in wireless sensor networks: a survey. Inf Fusion 63:223–247
11. Shahraki, A.; Taherkordi, A.; Haugen, O.; Eliassen, F. Clustering objectives in wireless sensor networks: A survey and research direction analysis. Comput. Netw. 2020, 180, 18.
12. Al-Khayyat, A.T.A.; Ibrahim, A. Energy optimization in wsn routing by using the K-means clustering algorithm and ant colony algorithm. In Proceedings of the 2020 4th International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT), Istanbul, Turkey, 22–24 October 2020; IEEE: New York, NY, USA, 2020; pp. 1–4.
13. Chandirasekaran, D.; Jayabarathi, T. Cat swarm algorithm in wireless sensor networks for optimized cluster head selection: A real time approach. Clust. Comput. 2019, 22, 11351–11361
14. Maheshwari, P.; Sharma, A.K.; Verma, K. Energy efficient cluster based routing protocol for WSN using butterfly optimization algorithm and ant colony optimization. Ad Hoc Netw. 2021, 110, 15
15. Yang, X.; Yan, J.Q.; Wang, D.S.; Xu, Y.G.; Hua, G. THSI-RP: A two-tier hybrid swarm intelligence based node clustering and multi-hop routing protocol optimization for wireless sensor networks. Ad Hoc Netw. 2023, 149, 22.
16. Kaedi, M.; Bohlooli, A.; Pakrooh, R. Simultaneous optimization of cluster head selection and inter-cluster routing in wireless sensor networks using a 2-level genetic algorithm. Appl. Soft. Comput. 2022, 128, 11. [CrossRef]
17. Jagadeesh, S.; Muthulakshmi, I. A novel oppositional artificial fish swarm based clustering with improved moth flame optimization based routing protocol for wireless sensor networks. Energy Syst. 2022, 1–21. [CrossRef]
18. Potthuri, S.; Shankar, T.; Rajesh, A. Lifetime Improvement in Wireless Sensor Networks using Hybrid Differential Evolution and Simulated Annealing (DESA). Ain Shams Eng. J. 2018, 9, 655–663. [CrossRef]
19. Kumar, V.; Bass, G.; Tomlin, C.; Dulny, J. Quantum annealing for combinatorial clustering. Quantum Inf. Process. 2018, 17, 14. [CrossRef]
20. Huang, Z.J.; Zhang, J.L.; Wu, M.Q.; Li, X.; Dong, Y.M. Evolutionary Method of Sink Node Path Planning Guided by the Hamiltonian of Quantum Annealing Algorithm. IEEE Access 2021, 9, 53466–53479

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN COMPUTER & COMMUNICATION ENGINEERING

9940 572 462 6381 907 438 ijircce@gmail.com

Scan to save the contact details

www.ijircce.com