Grenze International Journal of Engineering and Technology, January Issue

Network Deployment and Data Collection of Multi-Channel Cluster Tree using Optimization Algorithms

Kanchan[1] and Savita Bhosale[2]
[1]Department of Electronics and Telecommunication Engineering, Ramrao Adik Institute of Technology Nerul, 400706, Navi Mumbai, India
Email: kanchankmehtre@gmail.com
[2]Department of Electronics Engineering Ramrao Adik Institute of Technology, D Y Patil Deemed to be University, Nerul, 400706, Navi Mumbai, India
Email: savita.bhosale@rait.ac.in

Abstract— **ZigBee networks are more efficient when Hybrid Simulated Annealing Algorithms and Genetic Algorithm are used in a multichannel manner. Through the use of multi-channel technology interference mitigation approaches, this study aims to avoid the interfering between the channels and progress the network effectiveness of Zigbee networks. Wireless Sensor Networks (WSNs) with several channels can employ a cluster tree construction algorithm to transmit data reliably. Hybrid Simulated annealing algorithm Genetic algorithm to overcome the drawbacks and the problem of interference caused due to the presence of WLAN networks.**

Keywords— **Packet delivery ratio, Wireless sensor networks, Multi-Channel, ZigBee.**

I. INTRODUCTION

The creation of low-power, low-cost, multifunctional nodes that are trivial in size and interact unchained in small places should be made possible by recent advancements in MEMS (Micro-Electro-Mechanical Systems) equipment, digital electronics, and wireless communications. Based on the combined power of a vast number of these inconsequential WSNs (Wireless Sensor Networks), sensor nodes operate autonomously and without supervision. It is therefore widely used in the military, home-grow, health, atmosphere, and other lucrative fields [1]. Another standard called ZigBee is designed for low-cost approaches in automation, computer accessories, and home panels. It qualifies wireless networks for widespread deployment by using low-cost, low-power resolutions [2] [3]. The ZigBee Alliance has defined the low-rate wireless network, which is outlined in IEEE 802.15.4. In factories, workplaces, and businesses, the standard is intended to be a low-control, low-cost solution for schemes involving unapproved policy assembly. ZigBee has predictable applications in remote meter reading, security techniques, isolated control, and computer peripherals [2]. IEEE 802.15, which measures the whole gain of a powerful physical radio, is achieved by ZigBee. 4. To enable the practical potential of the principles to be recognised, ZigBee groups of companies were able to advance provisions covering the application profile layers and network [3][4]. wireless innovation. For ZigBee, the operating frequency is 2.4GHz. The coalition mission statement's main additions or modifications, as observed at ZigBee, are networked, low power and open standard. The POS (Personal Operating Space) and range of 10m are also stated in the standard 802.15.4, although it also highlights the likelihood of larger series at small data volumes [4].

Grenze ID: 01.GIJET.12.1.319

ZigBee should thus be widely employed in personal health care, building automation, PC & peripherals, consumer electronics, trade control, occupied/light, and viable controller because to its characteristics of ease of use, long battery life, interacting competences, low cost, and consistency [3]. The capacity of WSNs is restricted in terms of network bandwidth and are more prone to the problems such as noise, effect of interference and hidden terminals. The presence of noise and interference might mark the communication distance between sensor nodes. However, certain network configurations with hidden terminals use two or additional nodes for transmitting data simultaneously [13] [14].The clustering in Zigbee networks consists of base station and various profiles gives in Fig.1.Each profile or cluster group consist of cluster head or coordinator and cluster members.in one profile only one coordinator with several which contain same cluster value.

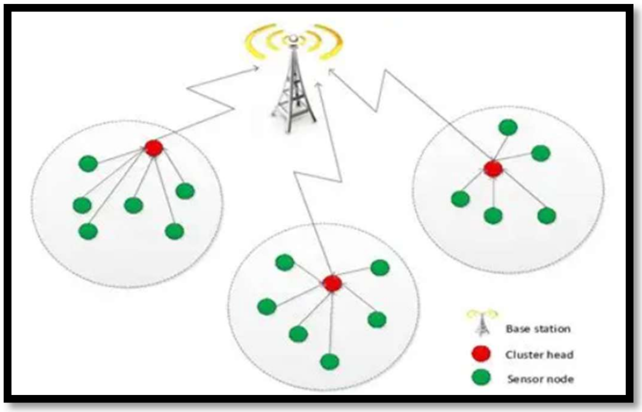

Figure 1. Cluster in wireless sensor network

II. LITERATURE REVIEW

A Nanoscale Wireless Sensor Network (NWSN) with a close sign loop is expected, inspired by the ZigBee kit. The ZigBee network layer and MAC layer are fully finished in the NWSNs, and a new node is taken into consideration that integrates the ZigBee module and WSN node organised, together with its hardware and software execution. The integrated WSN access obtained in this recognition demonstrated the ability to distribute data, manage collaboratively, and observe in real time. Simultaneously, the necessity of changing the switch scheme and records acquiring in industrial automation was also observed. On the other hand, industrial NWSNs' presentation and understanding still require a great deal of research and evaluation. The NWSNs will need a wide range of projections, however, as all the features have shown [5]. Using the ACA (Adaptive Cross Approximation) method, the Multi-Channel Cluster Tree (MCCT) protocol is enhanced to lessen hardware constraints and enable the use of multi-channel equipment in situations where Wi-Fi and ZigBee networks coexist. Additional study integrates more wireless strategies that are needed to advance the method's series [6]. After that, sensor nodes are powered by non-rechargeable batteries, and the network's lifespan is constrained. It is important to enhance capabilities such as communication protocol, routing, and access channel mechanism to progress energy convertible and promote network period. ZigBee performance is better with an adaptive WLAN interference mitigation technique than with another algorithm [8]. A multiple channel wireless network's adaptive channel system explains the channel's decision function [9]. As an alternative to adaptive routing, multiple channel communication is intended to reduce the impact of link and interference undercurrents in wireless sensor networks (WSN) [10]. Investigation of both multi-channel and single-channel messages via a direct channel in terms of maximal burst loss, frequency correlation of losses and temporal correlation of losses.

A wireless body area sensor network, or WBASN, is made up of a coordinator and a number of sensors to track organic signals. By employing the Interference Mitigation technique, it can be finished [11]. To reduce the number of intermediate wireless nodes and the imbalanced load on the gateway node, a two-layer topology consisting of WLAN and WPAN of the Zigbee network can be implemented [12]. Sensor-connected end nodes cooperatively provide the base station with the readings. The host PC is responsible for the database structure based on the sensor readings from the node [14].

Using wireless long-distance range and transmission, these two techniques are working together. For local electrical appliances, solar panels are quickly becoming more and more common in society, especially on top of

homes [24]. There are many small nodes connected by real ZigBee networks to form an adhoc wireless sensor indirect network [27]. The network's coordinator gathers temperature and humidity data wirelessly from many nodes that might provide personal information. Based on ZigBee/IEEE 802.15.4 standards, each sensor is made using an Arduino-based microcontroller, a ZigBee wireless module, and temperature and humidity sensor components. The ZigBee network works particularly well with modest data rates. Low consumption, low complexity, and low cost are characteristics of the ZigBee network, an innovative wireless technology [26].
Network services, communication protocols, and the internal and underlying operating systems are the three main areas of concern in WSN [25]. Endpoints, repeaters, and coordinators make up a Zigbee network; each component has unique specifications, such as temperature monitoring. Using the JN5168 development board, it is proven at less than 50 meters outdoors and less than 20 meters indoors [28]. By calculating the minimum length and number of nodes, the successful transmission of packets and the impact of bandwidth on the network are examined. The likelihood of dependence is calculated for both scenarios, i.e., when noise is present in the channel and when it is not. WSNs and Zigbee protocols have significantly improved their overall performance and energy efficiency since the advent of metaheuristic-based optimisation techniques [29]. This work also considers certain cases where the data packet transmits a sensitive message. Results of the tentative analysis display that the proposed approach covers different possible Wi-Fi traffic scenarios and the lightweight framework used in this research can maximize the performance by 4 times and 1.5 times for WISE and CII respectively. Specifically, for a Wi-Fi traffic of 4 Mbps, the performance is still above 90%. However, the energy consumption can be enhanced by employing more energy efficient protocols. A mathematical model for analyzing the operational process of Zigbee networks is proposed in [20].

III. PURPOSE METHODOLOGY

A. Genetic Algorithm (GA)

The Genetic Algorithm is a bio-inspired optimisation method that finds optimal or nearly optimal solutions by selecting, crossing over, and mutating a population of candidate solutions.
Use in ZigBee networks: GA is used to find effective routing routes that optimise Packet Delivery Ratio (PDR) while reducing energy usage and hop count.

Step 1: Encoding the Problem

- Consider each routeing path as a chromosome that connects the source and the destination.
- Every chromosomal gene corresponds to a node in the path.

Step 2: The First Population Development

- Initially, create a random population of viable routing routes.
- Every person in the population follows a unique route across the network.

Step 3: Assessment of the Fitness Function

- To assess each route's quality, define a fitness function.

The fitness function example is:

$$F = \alpha \times PDR + \beta \times \left(\frac{1}{Hop\ Count}\right) + \gamma \times LinkReliability - \delta \times Energy\ Consumption$$

Step4: Choosing
Choose parent routes by fitness level.

- Use methods such as:
- Roulette Wheel Selection Selection of the Tournament

Step5: Crossover (Recombination).

- One or more child routes can be created by combining two parent routes.
- Use Partially Mapped Crossover (PMX) or Order Crossover (OX) for pathways.

Step 6: A mutation

- To keep some child pathways diverse, make sporadic modifications.
- Different kinds of mutations
    - Exchange two nodes in between.
    - Add a node or remove it.
    - Utilising a local path finding technique, reroute a segment

Step 7: Replacement of Population

- Create a new population with:

- Elitism: Preserve the top k routes.
- Bring in new kids to replace the weakest performers.

Step 8: Revocation Standards

➢ Continue steps 3 through 7 until one of the following occurs:
  - The most generations (for example, 100)
  - The optimal fitness for n generations has not much improved.
  - Reached target PDR or network performance

Step 9: Provide the Best Path Output

➢ The chromosome with the highest PDR in the final population is chosen as the best routing path.

IV. Results and Discussions

A. Network Deployment

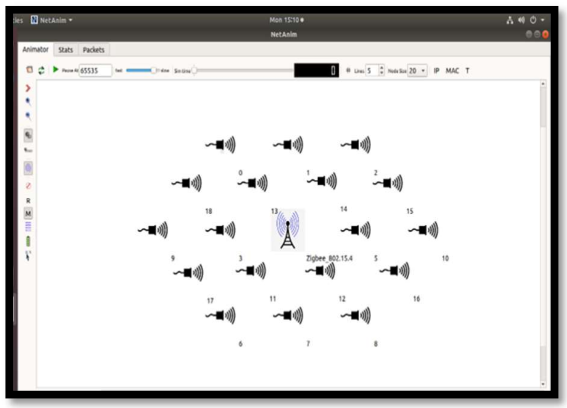

Figure 2. Network deployment

Fig.2 presents that we constructed 20 sensor nodes and multiple channels through Zigbee sensor 802.15.4 in this wireless sensor network deployment area using Netanim and NS3 simulator software. Each and every node placed in own location.

B. Channel Sensing for Communication

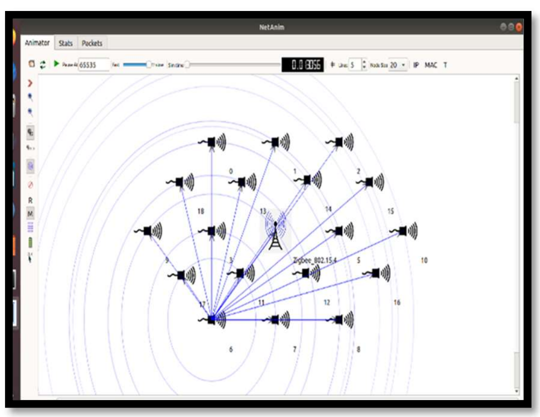

Figure 3. Channel sensing

Fig.3 presents that all the sensor node sensing the multiple channels for access the channel in this network. Here, hence channel is obtained, and communication started according to the channel availability for all the sensor nodes.to avoid the channel interfacing frequency division technique used.in this technique ISM band has 16 channels, and each channel is placed at 5MHz apart from each channel.

C. Data Collection

Fig.4 presents that Each and every sensor node collecting data from required sensing area in this network and communication details and results filtered through Wireshark data analysis tool.

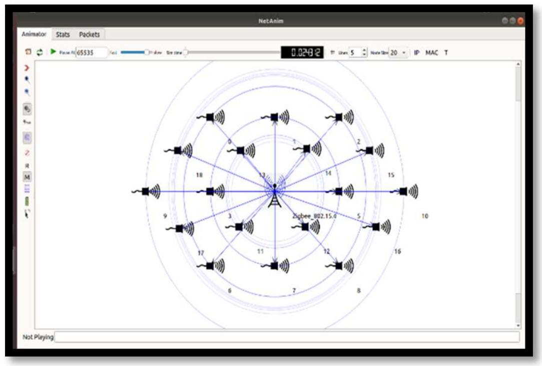

Figure 4. Data Collection

V. CONCLUSION

In this research, the algorithm is designed reduce interface between the nodes Simulation analysis was performed to confirm the effectiveness of the planned approach. the MCCT architecture used in this research is modified by implementing a non-beacon method with a hybrid Simulated Annealing algorithm to overcome the drawbacks and the problem of interference caused due to the presence of WLAN networks.

REFERENCES

[1] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, “Wireless sensor networks: A survey,” Computer Networks, vol. 38, no. 4, pp. 393–422, 2002.

[2] S. Ondrej, B. Zdenek, F. Petr, and H. Ondrej, “ZigBee technology and device design,” in Proc. Int. Conf. Networking, Systems and Mobile Communications and Learning Technologies, Apr. 2006, pp. 129–139.

[3] N. Baker, “ZigBee and Bluetooth strengths and weaknesses for industrial applications,” Comput. Control Eng. J., vol. 16, no. 2, pp. 20–25, Apr.–May 2005.

[4] S. Lin, J. Liu, and Y. Fang, “ZigBee-based wireless sensor networks and its applications in industrial,” in Proc. IEEE Int. Conf. Automation and Logistics, Aug. 2007, pp. 1979–1983.

[5] C. H. Cheng and C. C. Ho, “Implementation of multi-channel technology in ZigBee wireless sensor networks,” Comput. Electr. Eng., vol. 56, pp. 498–508, 2016.

[6] M. S. Kang, et al., “Adaptive interference-aware multi-channel clustering algorithm in a ZigBee network in the presence of WLAN interference,” in Proc. 2nd Int. Symp. Wireless Pervasive Comput., 2007.

[7] J. W. Chong, et al., “An adaptive WLAN interference mitigation scheme for ZigBee sensor networks,” Int. J. Distributed Sensor Networks, vol. 11, no. 8, p. 851289, 2015.

[8] W. Hassan and T. Farag, “Adaptive allocation algorithm for multi-radio multi-channel wireless mesh networks,” Future Internet, vol. 12, no. 8, p. 127, 2020.

[9] H. Liu, Y. Zhang, and M. Wen, “Wireless-powered communication networks for WSNs: Recent advances and challenges,” IET Wireless Sensor Syst., vol. 14, no. 1, pp. 1–15, 2024.

[10] P. Verma, S. K. Yadav, and V. Tiwari, “Energy-efficient wireless sensor networks in resource-constrained IoT environments,” Discover Internet Things, vol. 5, art. 152, 2025.

[11] M. Tolani, et al., “Two-layer optimized railway monitoring system using Wi-Fi and ZigBee interfaced wireless sensor network,” IEEE Sensors J., vol. 17, no. 7, pp. 2241–2248, 2017.

[12] V. Yadav, A. Jain, and A. Kumar, “Evolving landscape of wireless sensor networks: A survey of trends, timelines, and future perspectives,” SN Appl. Sci., vol. 7, art. 233, 2025.

[13] A. Saeedi, M. K. Rafsanjani, and S. Yazdani, “Energy efficient clustering in IoT-based wireless sensor networks using binary whale optimization algorithm and fuzzy inference system,” J. Supercomput., vol. 81, no. 1, pp. 1–49, 2025.

[14] J. Zhu, M. Yan, and Z. Hu, “Design of food situation monitoring system based on ZigBee and WinCC,” in Proc. 18th Int. Symp. Distributed Comput. Appl. Business Eng. Sci. (DCABES), 2019.

[15] Z.-q. Wang and Z.-h. Huang, “Wearable health status monitoring device for electricity workers using ZigBee-based wireless sensor network,” in Proc. 7th Int. Conf. Biomedical Eng. Informatics, 2014.

[16] B. Vijayalakshmi, “Patient monitoring system using wireless sensor based mesh network,” in Proc. 3rd Int. Conf. Comput., Commun. Networking Technol. (ICCCNT), 2012.
[17] Z. Qin, Y. Sun, J. Hu, W. Zhou, and J. Liu, “Enhancing efficient link performance in ZigBee under cross-technology interference,” Mobile Netw. Appl., vol. 25, pp. 68–81, 2020.
[18] A. Singh, et al., “Ventilation monitoring and control system for high rise historical buildings,” IEEE Sensors J., vol. 17, no. 22, pp. 7533–7541, 2017.
[19] E. K. Payne, et al., “Concept of designing thermal condition monitoring system with ZigBee/GSM communication link for distributed energy resources network in rural and remote applications,” Processes, vol. 7, no. 6, p. 383, 2019.
[20] X. Zong and H. Shao, “Design of cold chain logistics remote monitoring system based on ZigBee and GPS location,” AIP Conf. Proc., vol. 1820, no. 1, p. 1, 2017.
[21] R. P. N. Gomes, et al., “A hybrid sensor network for the real-time condition monitoring of rotating machinery,” in Proc. 6th IEEE Int. Conf. Distributed Comput. Sensor Syst. Workshops (DCOSSW), 2010.
[22] S. C. Folea and G. Mois, “A low-power wireless sensor for online ambient monitoring,” IEEE Sensors J., vol. 15, no. 2, pp. 742–749, 2014.
[23] H. Fitriawan, et al., “ZigBee based wireless sensor networks and performance analysis in various environments,” in Proc. 15th Int. Conf. Quality in Research (QiR): Int. Symp. Electr. Comput. Eng., 2017.
[24] S. Mahajan, L. Abualigah, A. K. Pandit, M. R. Al Nasar, H. A. Alkhazaleh, and M. Altalhi, “Fusion of modern meta-heuristic optimization methods using arithmetic optimization algorithm for global optimization tasks,” Soft Comput., vol. 26, no. 14, pp. 6749–6763, 2022.
[25] S. K. Gharghan, R. Nordin, and M. Ismail, “Energy-efficient ZigBee-based wireless sensor network for track bicycle performance monitoring,” Sensors, vol. 14, no. 8, pp. 15573–15592, 2014.
[26] E. Silveira and S. Bonho, “Temperature monitoring through wireless sensor network using an 802.15.4/802.11 gateway,” IFAC-PapersOnLine, vol. 49, no. 30, pp. 120–125, 2016.
[27] M. Alosofi, S. Alshamrani, S. Alrabaee, and M. Alazab, “Energy efficient routing protocol in sensor networks using genetic algorithm,” Sensors, vol. 21, no. 21, p. 7060, 2021.
[28] N. Sharma, B. M. Singh, and K. Singh, “QoS-based energy-efficient protocols for wireless sensor network,” Sustain. Comput. Informatics Syst., vol. 30, p. 100425, 2021.
[29] M. Yousaf, R. Bano, and A. Khan, “Future perspectives in energy-efficient wireless sensor networks: Exploring novel approaches,” ResearchGate Preprint, 2025.