SSRG International Journal of Electronics and Communication Engineering
ISSN: 2348-8549/ https://doi.org/10.14445/23488549/IJECE-V12I11P112

Volume 12 Issue 11, 146-154, November 2025

Original Article

Using Optimization Algorithm in a Multichannel Approach to Improve ZigBee Network Efficiency

Kanchan[1], Savita Bhosale[2]

[1]*Department of Electronics and Telecommunication Engineering, Ramrao Adik Institute of Technology, Nerul, Navi Mumbai, India.*
[2]*Department of Electronics Engineering, Ramrao Adik Institute of Technology, Nerul, Navi Mumbai, India.*

[1]*Corresponding Author : kanchankmehtre@gmail.com*

Received: 12 September 2025 Revised: 14 October 2025 Accepted: 13 November 2025 Published: 29 November 2025

Abstract *- A robust multichannel approach is presented in this paper for improving the efficiency of ZigBee networks. The objective is to increase the Packet Delivery Ratio (PDR) by applying a multichannel technique. Metaheuristic algorithms such as Simulated Annealing (SA) and Genetic Algorithm (GA) are used to implement the proposed multichannel approach. The operating frequency band for both ZigBee networks and Wireless LAN (WLAN) is 2.4 GHz, which is part of the industrial and scientific unlicensed band. This results in the problem of interference due to the presence of WLAN. This research aims to avoid the interference and improve the network efficiency of ZigBee networks to coexist with WLAN. Experimental evaluation is conducted by implementing a practical network, and the performance is evaluated in terms of different evaluation metrics such as packet transmission, computation time, transmission cycle time, PDR, and coexistence of ZigBee and Wi-Fi with optimization. New results display that the planned Hybrid GASA (Genetic Algorithm and Simulated Annealing) optimization approach significantly improved the PDR of ZigBee networks in the presence of interference from WLAN, compared to the existing Adaptive Channel Access (ACA) algorithm.*

Keywords *- Wireless communication, ZigBee Networks, Genetic Algorithm, Simulated Annealing, Packet Delivery Ratio, Multichannel.*

1. Introduction

A wireless sensor network is a network of electronic devices used to transfer information through many nodes that are connected over wireless links [1]. WSNs are characterized by their scalability, reliability, easy deployment, and their ability to operate on a globally available frequency band, license-free, which can be used for two-mode communications. Their operational flexibility makes them adaptable for establishing communication in various applications such as remote operation, monitoring water quality, military operations, and biomedical monitoring [2-4]. A robust WSN is cost-effective and has a lower data rate with minimum power consumption for accommodating multiple sensor devices.

Both hardware and software requirements of WSN are illustrated in the IEEE 802.15.4 [5] and the ZigBee configuration [6]. The network configuration in IEEE 802.15.4 can be in the form of a Peer-To-Peer (P2P), star configuration, or a cluster tree configuration [7]. However, the standard of the requirement based on the specific application does not provide information about the cluster tree formation algorithm.

Hence, the standards for constructing application-specific WSN might vary [8]. In addition, the sensor nodes in WSNs suffer from the problem of excess energy consumption, and this problem is critical since it is practically difficult to recharge the sensor nodes. Hence, it is crucial to minimize power consumption in WSNs, and several techniques have been proposed for designing an energy-efficient protocol for WSN [9]. In such configurations, the nodes are not aware of each other, and this results in the collision of data packets and causes packet loss. For instance, in IEEE 802.15.4 configurations, the network allows the implementation of several channels at the physical layer, but the MAC protocol is not designed for a multichannel environment and is suitable only for single channels. When implemented in a multichannel environment, MAC protocols do not work effectively. Hence, there is a need to develop an efficient multichannel protocol for WSNs for exploiting the advantages of parallel multichannel data transmission in wireless networks. Another prominent application is in industrial automation, where the nodes track the machine performance and help in detecting any kind of early faults [10], which leads to improving the overall production accuracy. The authors in [11] consider specific network configurations with hidden terminals that use two or more nodes for transmitting data simultaneously. In such configurations, the nodes are not aware of each other, and this results in the collision of data packets and causes packet loss. The ZigBee protocol is one such global, packet-based protocol that uses the fundamental 2.4 GHz band, commonly referred to as the medical, scientific, and industrial band [12]. The ISM band is basically used with Wireless LAN (WLANs) as mentioned in the IEEE 802.11 standard [13]. The WLANs are used in smart homes and smart electrical devices, such as personal computers, laptops, and smartphones, for achieving better connectivity. Although WLAN and ZigBee employ different channel access protocols, the demand for sharing the 2.4 GHz band affects the quality of the data transmission in ZigBee protocols. Even though different kinds of protocols have been developed and used in order to support the Wireless Sensor Networks (WSNs), ZigBee is becoming one of the most popular and widely used technologies [14].

This research designs a novel multichannel framework based on a metaheuristic optimization algorithm, with the ability to use multiple communications simultaneously within the same network environment. Various radio transceivers have already been used to realize the advantages of multichannel functionality. However, this research emphasizes the enhancement of the Packet Delivery Ratio (PDR) of wireless networks. The research motivations on the implementation of wireless networks in the time domain with an objective of avoiding interference, enabling the coexistence of WLAN and ZigBee protocols, and enhancing the PDR of ZigBee protocols. In wireless communication systems, noise and interference tend to influence the transmission distance among nodes; however, in environments that consist of unseen terminals, transmit data simultaneously using two or more nodes. Appropriately, single nodes are uninformed of each other; the resulting crash of data packets can lead to data loss. Most current protocols focus on single-channel clarifications, thus failing to take into account the conduct of multichannel transceivers. This kind of underutilization of the channels has introduced many problems. First, if all the nodes in the network use the same channel, it leads to an increase in the chances of data collisions and data overlap. Second, the existence of other technologies where the ZigBee-based networks are working. Because the other technologies also use the same kind of frequency band, this could easily disrupt the communication if the ZigBee-based networks are fixed to a single communication channel.

The significant contributions of this learning are as follows:

- A novel metaheuristic GA and SA-based optimization approach is implemented in a multichannel environment to mitigate the effect of interference and improve the network efficiency of ZigBee networks.
- The study evaluates the existence of Wi-Fi and ZigBee, applying optimization algorithms, to validate the use of the proposed Hybrid GASA, which combines Genetic Algorithms and Simulated Annealing Algorithms.
- The multichannel approach presented in this paper is designed to increase the PDR and reduce the computational time of ZigBee transmission in the presence of interference from WLAN.
- The routine of the proposed GA and SA-based multichannel approach is validated by comparing it with the existing Adaptive Channel Access (ACA) algorithm.

The paper is further structured as surveys: Section II discusses the existing works related to the interference mitigation and performance enhancement of ZigBee networks. Section III briefs the proposed research methodology, which includes network deployment and optimization. Section IV presents the effects of the experimental examination, and Section V concludes the paper through prominent study observations.

2. Literature Survey

Recently, there has been a tremendous increase in the adoption of multichannel approaches for improving the efficiency of the ZigBee networks [15, 16]. The authors in [17] proposed a novel Adaptive Packet Delivery (APD) algorithm for enabling ZigBee protocols to improve the efficiency in the presence of cluttered Wi-Fi traffic. The coexistence of other networks was analyzed before implementing the ADP algorithm, and it was observed that the Wi-Fi frame cluster experienced a uniform power distribution even with the increase in Wi-Fi traffic. Further, the analysis of PER is done to achieve a better probability of PDR. In addition, a new performance metric known as Channel Idle State Indicator (CISI) is employed for quantifying the quality of the channel. Based on the pre-analysis and the CISI value, the APD algorithm is constructed to direct the ZigBee nodes for swift data transmission. The ZigBee protocol is implemented for remote monitoring systems, and the mathematical model is designed based on the Markov chain apparatus. The novelty of the proposed mathematical model is that it considers the number of network components and all possible perturbations in the distributed data packets. And this is due to the effect of interference. The mathematical model formulated in this research is used to determine the prominent attributes of the wireless network systems, such as dependence parameters [18]. Two main dependence parameters are the dependence of the probability of successful packet transmission on the system load and the dependence of the bandwidth of the network. The successful packet transmission and the effect of bandwidth on the network are analyzed by determining the number of nodes and the minimum length. The probability of dependence is determined for both cases, i.e., the presence and absence of noise in the channel. With the emergence of metaheuristic-based optimization algorithms, there has been a significant improvement in the energy efficiency and overall performance of the WSNs and ZigBee protocols [19-21]. An Improved Wolf Prey Inspired Protocol (IWPIP) is proposed in [22] for identifying an optimized network path in dynamic environments such as a 5G-based thought radio adhoc network. The protocol identifies an optimized path based on the distance, number of hops, and reliability, which can reduce the power consumption in the wireless networks and improve the lifetime of the network. Before packet transmission, the paths identified are assessed by computing the fitness value, and the efficiency of the IWPIP protocol is determined by simulating the network environment, which shows that the proposed approach exhibits superior performance in terms of power consumption, drop ratio, PDR, and throughput.

The authors in [23] analyzed the efficiency of the mobility representations of the IEEE 802.15.4 ZigBee MAC using NS2.34 software. A hybrid algorithm that integrates the African Buffalo Optimization (ABO) and the Genetic Algorithm (GA) for optimizing the performance of the wireless network. The model is collectively called the HGAABO algorithm, which is used to select an optimal path in the WSN. The presentation of the proposed method is determined in terms of two main components, namely delay and energy. The HGAABO algorithm is implemented for identifying a set of optimal routes that can reduce the delay and find an efficient route using the proposed method. The presentation of the HGAABO algorithm is compared with the actual GA and GWO algorithms for validation. Results of the simulation show that the HGAABO achieves better results in terms of energy and delay compared to the GA and GWO algorithms. In a thorough analysis of security flaws in WSNs pinpoint important attack avenues as energy-draining, sinkhole, and Sybil attacks. The authors assess intrusion detection systems, trust models, and cryptographic approaches, highlighting the trade-off between energy efficiency and security. The authors in [24] provide an integration of AI, edge computing, and IoT platforms. With a clear roadmap of obstacles, including scalability, real-time limitations, and node failure recovery, this article divides WSN applications into four categories: smart cities, healthcare, industrial automation, and agriculture.

The authors provide a High-Secure Parallel Particle Swarm Routing Algorithm (HS-PPSRA). In addition to increasing security and throughput, this routing protocol seeks to lower latency, packet loss, and energy usage in WSNs. Results from simulations indicate that they perform better than more conventional methods like LEACH. The next-generation routing protocols, such as the Particle Swarm Optimization (PSO), Salp Swarm Algorithm (SSA), and Fuzzy Adaptive Learning Mechanisms (FALM). The study identifies fault tolerance, adaptive behavior, and energy efficiency as critical characteristics for sustainable WSN design. Enabling Examines performance parameters for ZigBee, including latency, packet loss, throughput, and RSSI.utilises conventional Wi-Fi channels 1, 6, and 11 to compare performance across ZigBee channels 11 to 26. Several ZigBee nodes were positioned in various Wi-Fi-equipped rooms of an apartment with Wi-Fi routers creating interference [25]. ZigBee signals are encoded into the unused subcarriers of adjacent Wi-Fi transmissions via a payload-encoding method. In order to minimize collisions and maintain complete compliance with IEEE 802.15, the technique successfully "hides" ZigBee data in low-energy gaps of the Wi-Fi using an SDR implementation [26]. The author in [27] presented a hybrid approach that combines a Fuzzy Inference System (FIS) and the Binary Whale Optimization Algorithm (BWOA). Their strategy sought to solve two major issues: the requirement for intelligent decision-making based on a variety of network factors and the binary nature of CH selection. The best set of CHs was found by adapting BWOA, which is based on humpback whale hunting tactics, for binary optimization. Unlike the wireless protocols, which heavily rely on high-speed and larger data, ZigBee mainly focuses on low-power consumption, low data rates, and maintaining stable communication over time. Unlike ZigBee, it is not able to transfer the data at high speed, but it prioritizes less data with lower power consumption, and also maintains network reliability, which is more important than transferring large amounts of information quickly [28]. This paper discusses the wireless sensor networks that demand security and energy efficiency. Mainly, it compares the different techniques, such as the multichannel MAC and cluster-based protocols. This paper evaluates the different allocation, clustering, and rotation of strategies and also proposes a hybrid framework that mainly integrates the dynamic resource allocation and adaptive clustering in order to further enhance the robustness, stability, and efficiency [29]. SINR effectively measures the interference; if the SINR value is above the specified value, then it aligns the multiple transmissions in the channel without affecting the reliability. In this way, SINR based slot reuse algorithm has allowed parallelism in the communication; this means the nodes that are available in the networks are able to send the data at the same time [30].

3. Proposed Multichannel Approach

This research selects the ZigBee network protocol as a standard protocol because of its easy configuration, better reach, and lower energy consumption in practical applications. The sensors are deployed in the selected network area based on the region of interest in such a way that the sensing can be carried out for a long duration. This research employs a Genetic algorithm and a hybrid simulated annealing algorithm to complement the existing algorithm and overcome the drawbacks of existing algorithms in terms of delay and reduced efficiency. In this approach, the GA generates different initial positions, and the Hybrid GASA integrates the advantages of both GA and SA algorithms.

3.1. Network Deployment and Channel Sensing

In this research, the Multichannel Cluster Tree (MCCT) architecture planned in [31] is modified to create a multichannel ZigBee WSN. The MCCT is a cluster tree communications protocol for constructing nodes in ZigBee beacon-enabled mode. The number of child nodes for a particular network coordinator is restricted to avoid collision, and each coordinator identifies a particular channel to transfer with its respective child nodes. Therefore, the nodes in the network send the data in the upward direction in the MCCT architecture through the channel, specifically to their parent node. Coordinators that interfere with other nodes are made to choose orthogonal channels to avoid beacon collisions. This multichannel transmission through orthogonal channels enables the MCCT communication protocol to increase the PDR, minimize delays, and improve the overall performance. As discussed previously, the MCCT architecture used in this research is modified by implementing a non-beacon method with a Hybrid GASA algorithm to overcome the drawbacks and the problem of interference caused by the presence of WLAN networks. The network deployment with sensor nodes is illustrated in Figure 1. The network environment is constructed with 20 sensor nodes and multiple channels through ZigBee sensor 802.15.4 in the WSN deployment area. Here, each and every node is placed in its own location. The channel sensing for communication is illustrated in Figure 2.

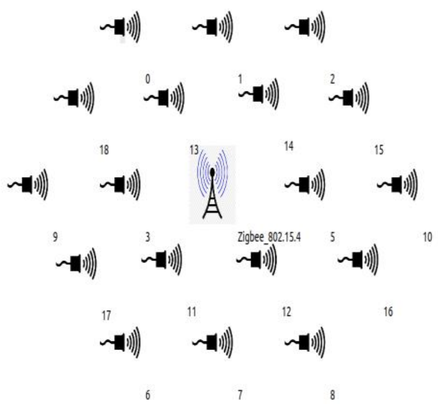

Fig. 1 Network deployment

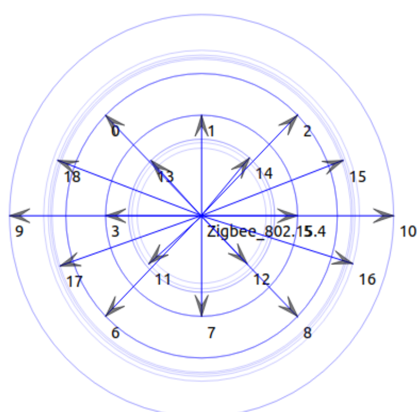

Fig. 2 Channel sensing

Figure 2 presents the schematic of the channel sensing in the wireless environment. Selecting an appropriate channel for the ZigBee network, when the network environment is congested, is highly challenging [32]. In this research, the communication channels are selected using the Hybrid GASA algorithm, which is discussed in the section below. Each and every sensor node collects data from the required sensing area in this network, and communication details are done using the ns3 simulator, and results are filtered through the Wireshark data analysis tool.

3.2. Hybrid GASA Algorithm

The Hybrid GASA algorithm combines the attributes of both genetic algorithms and simulated annealing algorithms. These algorithms have the ability to solve nonlinear problems and provide an optimized solution. The GA can provide an optimal solution in a broad searching area, while simulated annealing provides a solution in a narrow searching area. This research intends to explore the effectiveness of the hybrid algorithm in selecting an optimal channel for communication in ZigBee networks.

3.2.1. Genetic Algorithm (GA)

Genetic algorithm is an evolutionary algorithm effective for bio-inspired algorithms, which is mainly used for evaluating equally constrained and unconstrained optimization concerns based on the regular selection mechanism, which is similar to the thought of biological evolution. In GA, a set of initial populations (chromosomes) is generated, and the algorithm will detect one particle from the crowd of chromosomes and choose it as a parental chromosome. The parental chromosomes are responsible for generating the young through an extra process. This process continues until an optimal solution is obtained. In this way, the population is better after every iteration to achieve the best possible solution. There are three main steps involved in the creation of a new population, as shown in Figure 3.

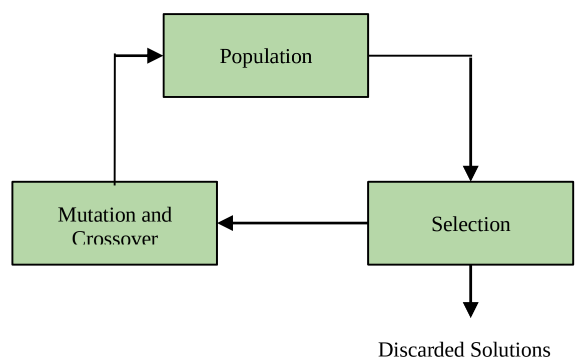

Fig. 3 Evolutionary cycle of GA

The operator in the algorithm selects the chromosomes from the swarm of population, which are called parent chromosomes. The parental chromosomes are responsible for generating the next population. The steps involved in the execution of the Genetic Algorithm are as follows.

Step 1: Initialization

In the initialization process, the primary swarm of chromosomes or particles is generated randomly in the search space.

Step 2: Objective function evaluation

After generating and initializing the population, the parent chromosomes generate offspring, which leads to the formation of newly generated offspring populations. Further, the objective function is formulated to ease the error function of the newly generated particles.

Step 3: Fitness evaluation

Based on the neutral function, the fitness value of an individual particle is evaluated. Particles that have a great fitness worth are designated for reproduction. Particles with the low fitness value are eliminated or not nominated for further methods. If two particles in the population have the least fitness value, then the finest solution among those particles is selected as the final solution of the genetic algorithm.

Step 4: Crossover process

For crossover, the parent elements are nominated for performing the crossover operation to produce a new population with newly generated offspring. The fitness rate of each newly formed population is planned, and the procedure in step 3 is repeated till all the elements with a high fitness worth are nominated.

Step 5: Reproduction

The reproduction method is a combination of two stages, namely mutation and crossover. The crossover procedure is discussed in the previous step, and the mutation method defines the changes that occur during the replication method with a very low probability score. In GA, the particles are selected based on the probability of mutation and crossover.

The pseudocode of the GA is discussed below:

Pseudocode:

Initialization:

Input: Dataset for initial population generation

Output: An optimal subset

Begin

for i = 1 to N do begin

Set the population P by casually selecting individuals from the examination space S Estimate the fitness value for everyone in the chromosome.

Select particles with the best fitness value from the population

Replication (until the stopping state is satisfied)

Perform crossover to produce new offspring

Mutation – according to the mutation probability, lately generated individuals are the changed $P_{new.}$

Update P ← P_{new}

Evaluate – calculate the fitness $f(x_i)$ for everyone in P

Return the particles with a great fitness rate from P

End

3.2.2. Simulated Annealing (SA)

The SA algorithm is another metaheuristic algorithm that simulates the melting and cooling process in metal processing tasks. Initially, a varying temperature value is set, which gradually cools after some time [33]. SA is employed for searching for an optimal solution in a smaller area. In some cases, SA performs better than GA [34]. The optimization process in the SA is like the mechanism involved in the annealing process, where the objective function is formulated to achieve the minimum value for a minimization problem. Cooling is carried out by calibrating the temperature based on the Boltzmann probability distribution theory. According to this theory, the probabilistic energy distribution in the thermal equilibrium is shown in Equation (1).

$$P(E)= \exp(-\Delta E/kT \tag{1}$$

Where, 'k' is the Boltzmann constant and exp is the Boltzmann coefficient. Equation (1) defines that the system achieves a uniform probability at high temperatures and vice versa. This process enables the SA algorithm to achieve faster convergence and reach a global minimum. Unlike GA, the SA algorithm has only one solution, and it searches for adjacent particles to obtain an optimum solution.

3.2.3. Hybrid GASA for selecting a communication channel

A Hybrid GASA algorithm helps to reach a balanced solution by letting GA explore a broader search space while SA explores local search areas. The SA algorithm initiates parameters randomly, and the best solution generated by GA is used as the initial configuration for SA. In response, the SA generates the population to obtain a primary solution. The GA picks two solutions from the initial solution generated by the SA. Further, GA performs crossover and mutation to obtain the best possible solution. Next, the SA algorithm identifies the solution based on the fitness value, and the position of the particles is updated with the previously obtained solution. The process is repeated until an optimum solution is obtained or until the stopping criteria are met.

In this research, the Hybrid GASA selects the optimum channel for communication. The coordinator in the multi-network architecture performs calculations for individual channel and ensures that each node in the network helps to select an optimal channel. The PDR for each channel is calculated, and the Hybrid GASA algorithm performs calculations that can help in selecting the optimal channel in the ZigBee network. For example, the nodes located deep in the network are least prioritized in terms of accessing the channel compared to the nodes located at a shallower depth. Decision variables, Total Interference, and PDR equations are shown in Equations (2)-(6). The steps below elucidate the working of Hybrid SAA: The network involves a 'group' of sensor nodes and is represented as,

$$N= \{1, 2, 3, 4 ...n\}$$

- The cluster heads are nominated from this set of nodes.
- All the nodes are attached to the cluster heads to form a cluster.

- The population vector is initialized using a set of random numbers that has a range of value from [0, 1].
- The succeeding step involves mutation tracked by crossover, and then the SA algorithm is used in the assortment process to select the next generation vectors.

We have:

- N = number of nodes
- C = number of available channels
- I=[Iij] = interference matrix, where Iij is the interference between node i and node j

Define decision variables:

$$x_i \in \{0,1,\ldots\ldots,C-1\} \text{ for } i = 1\ldots.N \quad (2)$$

Where x_i the channel is assigned to node i.

Objective Function

Total Interference:

$$F_{int}(X) = \sum_{i=1}^{N} \sum_{j=i+1}^{N} I_{ij}\delta(x_i, x_j) \quad (3)$$

Where

$$\delta(x_i, x_j) = \begin{cases} 1, & x_i = x_j \\ 0, & x_i \neq x_j \end{cases} \quad (4)$$

Packet Delivery Ratio (PDR):

$$PDR(X) = 1 - \frac{F_{int}(X)}{N.I_{max}} \quad (5)$$

Where Imax is the maximum interference value.
Combined objective (minimize interference, maximize PDR):

$$F(X) = F_{int}(X) - \lambda\, PDR(X) \quad (6)$$

λ is a weighting factor

- In the network, it is considered that the nature of the nodes is quasi-stationary.
- The consumption of energy by the sensor nodes depends on their distance to either the base station or the cluster head and is not the same for all the nodes.
- Network nodes are not aware of their own location.
- Every network node is of a similar kind.
- Network nodes organize themselves and require no monitoring once they are deployed.

4. Results Analysis

4.1. Simulation Setup

The performance of the Hybrid GASA algorithm has been evaluated with the Network Simulator (NS-3), and the Result metrics have been analyzed and filtered through the Wireshark analyzer tool. The number of data packets is transmitted from the Transmitter to the Receiver. The network utilizes the ZigBee IEEE 802.15.4 protocol. The simulation time of the algorithm has been set to 7 seconds. The Average packet size was taken in bytes, which contains multiple types of packets. Table 1 shows the simulation parameters used for the network. The computation time and interference for the proposed algorithm are calculated using a Python script.

Table 1. Simulation parameters

Measurement	Captured	Displayed
Packets	52	52(100%)
Time span, s	7.027	7.027
Average PPS	7.4	7.4
Average packet size, B	50	50
Bytes	2617	2617(100%)
Average bytes/s	372	372
Average bits/s	2979	2979

4.2. Performance Metrics and Simulation Results

This section deliberates the results of a replication which is conducted to confirm the productivity of the proposed multichannel approach. Result metrics have been analyzed and filtered through the Wireshark analyzer tool. Simulation is conducted to analyze the transmission of data packets for different time intervals, such as 1 second, 10 milliseconds, and 100 milliseconds, as presented in Figures 4-6, respectively.

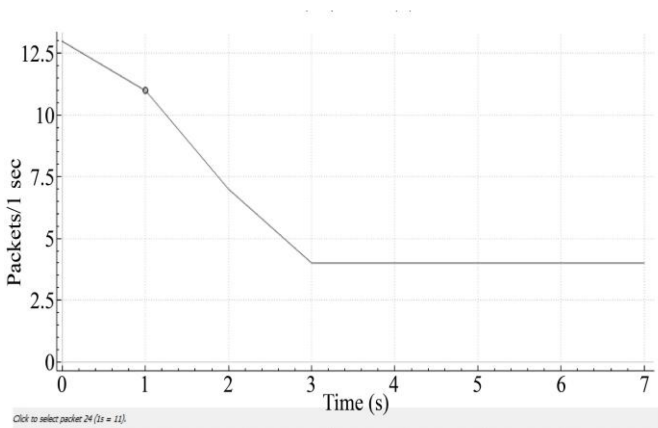

Fig. 4 Transmission packets vs Time (1 second)

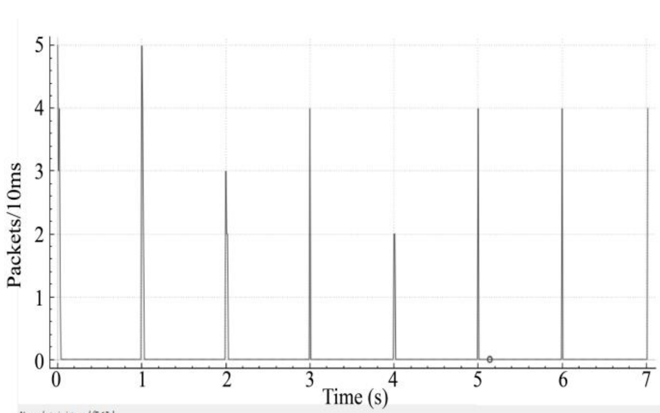

Fig. 5 Transmission packets vs Time (10 milliseconds)

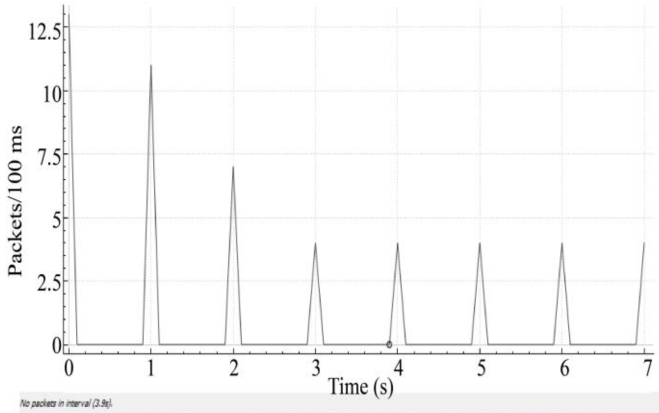

Fig. 6 Transmission packets vs Time (100 milliseconds)

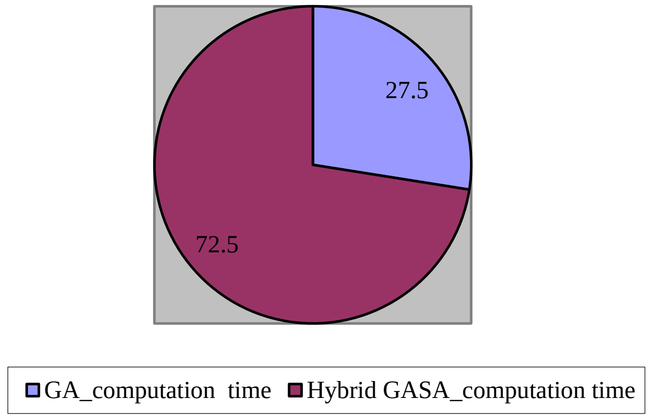

Fig. 7 Computation time taken by GA and Hybrid GASA

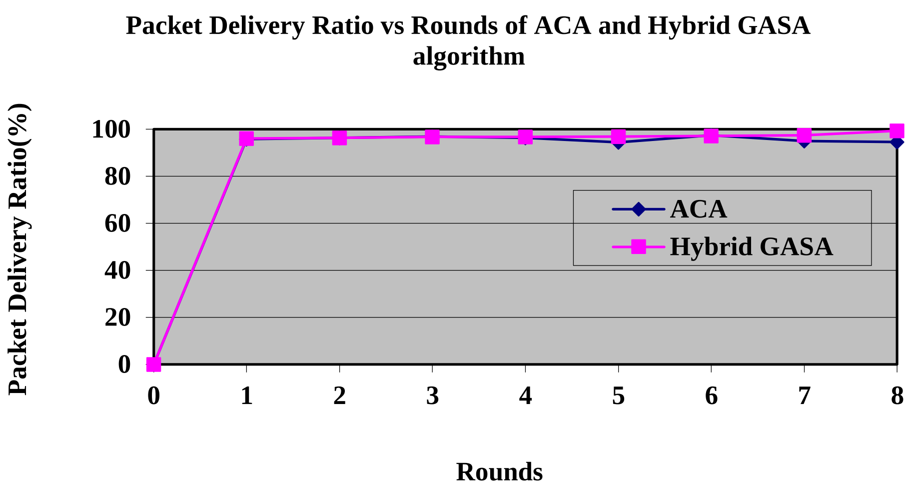

Fig. 8 Packet Delivery Ratio vs Rounds of ACA and Hybrid GASA algorithm

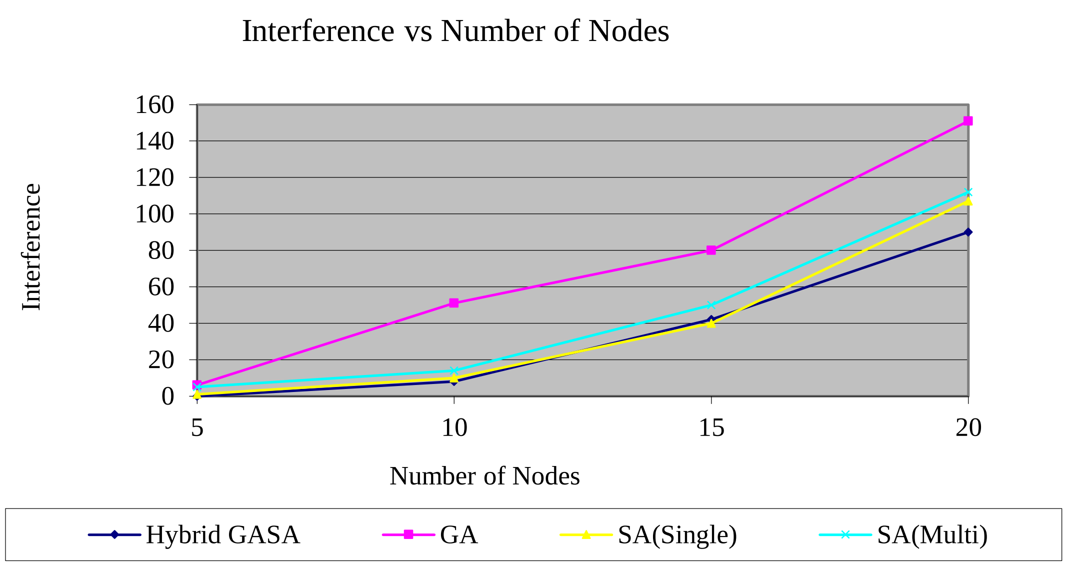

Fig. 9 Interference vs Number of Nodes

5. Comparison of the Proposed Method with Existing Methods

This section deliberates the Comparison results of the proposed algorithm with previous algorithms. The computation time taken by the GA and Hybrid GASA is evaluated and simulated as shown in Figure 7. It can be inferred from the simulation analysis that even though GA takes only 27.5% of the overall calculation time to reach faster convergence, in complex circumstances, it could lead to less-than-ideal channel allocations. Hybrid GASA provides better packet delivery, throughput stability, and interference reduction; however, it uses 72.5% of the computing time. GA for speed and Hybrid GASA for performance. In situations when speed and accuracy are required, a hybrid strategy that uses GA for the initial population and Hybrid GASA for refining is advised. An approach to minimize interference between overlapping wireless channels by intelligent allocation and planning. Algorithms like Hybrid GASA and GA are used to find optimal channel-node assignments that moderate interface overlaps and improve throughput. Interference score of the proposed method, the Hybrid GASA algorithm, is reduced compared to GA, SA single objective as interference, SA multi objective as interference, and PDR are illustrated in Figure 8. Hybrid GASA helps adaptively accomplish interference to retain PDR. Helps in adjusting channels to ease interference, especially when managing to refine GA - GA-produced solutions. The performance of the proposed Hybrid GASA approach is compared with the existing ACA algorithm in terms of PDR for different intervals. It can be inferred from the simulation results that the projected Hybrid GASA optimization algorithm increases the PDR of all nodes compared to the existing ACA algorithm. Correspondingly, the simulation results that define the coexistence of the ZigBee protocol and Wi-Fi with the optimization algorithm are illustrated in Figure 9.

6. Conclusion

This paper addressed the problem of coexistence between the ZigBee protocol and Wi-Fi in a multichannel environment using a GA and SA optimization algorithm. The study proposed a novel multichannel approach for avoiding the effect of interference in the wireless network caused by the presence of WLAN. The algorithm is designed to increase the PDR and improve the network efficiency. Several network parameters, such as computation time, PDR, transmission time, and coexistence, are used to determine the presentation of the proposed network location. Results display that the proposed method achieves better performance in terms of enabling the coexistence of ZigBee and Wi-Fi in the network environment.

References

[1] Diego V. Queiroz et al., "Survey and Systematic Mapping of Industrial Wireless Sensor Networks," *Journal of Network and Computer Applications*, vol. 97, pp. 96-125, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[2] S.R. Jino Ramson, and D. Jackuline Moni, "Applications of Wireless Sensor Networks — A Survey," *2017 International Conference on Innovations in Electrical, Electronics, Instrumentation and Media Technology (ICEEIMT)*, Coimbatore, India, pp. 325-329, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[3] Alexander T. Demetillo, Michelle V. Japitana, and Evelyn B. Taboada, "A System for Monitoring Water Quality in a Large Aquatic Area Using Wireless Sensor Network Technology," *Sustainable Environment Research*, vol. 29, pp. 1-9, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[4] Wichai Pawgasame, "A Survey in Adaptive Hybrid Wireless Sensor Network for Military Operations," *2016 Second Asian Conference on Defence Technology (ACDT)*, Chiang Mai, Thailand, pp. 78-83, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[5] Future 802.15 WSN WG Session Information, IEEE 802.15 Working Group for Wireless Specialty Networks (WSN). [Online]. Available: http://www.ieee802.org/15

[6] Building the Foundation and Future of the IoT, CSA. [Online]. Available: https://csa-iot.org/

[7] Nikumani Choudhury et al., "Beacon Synchronization and Duty-Cycling in IEEE 802.15.4 Cluster-Tree Networks: A Review," *IEEE Internet of Things Journal*, vol. 5, no. 3, pp. 1765-1788, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[8] Chia-Hsin Cheng, and Chung-Ching Ho, "Implementation of Multi-Channel Technology in ZigBee Wireless Sensor Networks," *Computers & Electrical Engineering*, vol. 56, pp. 498-508, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[9] Neelam Sharma, B.M. Singh, and Karan Singh, "QoS-Based Energy-Efficient Protocols for Wireless Sensor Network," *Sustainable Computing: Informatics and Systems*, vol. 30, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[10] Arash Heidari et al., "Assessment of Reliability and Availability of Wireless Sensor Networks in Industrial Applications by Considering Permanent Faults," *Concurrency and Computation: Practice and Experience*, vol. 36, no. 27, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[11] Xiaomin Ma et al., "A New Approach to SINR-Based Reliability Analysis of IEEE 802.11 Broadcast Ad Hoc Networks," *IEEE Communications Letters*, vol. 25, no. 2, pp. 651-655, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[12] A. Basir et al., "A Dual-Band Implantable Antenna with Wide-Band Characteristics at MICS and ISM Bands," *Microwave and Optical Technology Letters*, vol. 60, no. 12, pp. 2944-2949, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[13] Adnan Aijaz, and Parag Kulkarni, "Simultaneous Transmit and Receive Operation in Next Generation IEEE 802.11 WLANs: A MAC Protocol Design Approach," *IEEE Wireless Communications*, vol. 24, no. 6, pp. 128-135, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[14] Haorun Lv et al., "Design of Hybrid Topology Wireless Sensor Network Nodes Based on ZigBee Protocol," *Electronics*, vol. 14, no. 1, pp. 1-28, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[15] Shu Li et al., "A Survey of Energy-Efficient Communication Protocols with QoS Guarantees in Wireless Multimedia Sensor Networks," *Sensors*, vol. 19, no. 1, pp. 1-29, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[16] Ryota Kimoto et al., "MuCHLoc: Indoor ZigBee Localization System Utilizing Inter-Channel Characteristics," *Sensors*, vol. 19, no. 7, pp. 1-17, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[17] Zhenquan Qin et al., "Enhancing Efficient Link Performance in ZigBee Under Cross-Technology Interference," *Mobile Networks and Applications*, vol. 25, pp. 68-81, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[18] Khalim Khujamatov et al., "Markov Chain Based Modeling Bandwith States of the Wireless Sensor Networks of Monitoring System," *International Journal of Advanced Science and Technology*, vol. 29, no. 4, pp. 4889-4903, 2020. [Google Scholar]

[19] I. Jeena Jacob, and P. Ebby Darney, "Artificial Bee Colony Optimization Algorithm for Enhancing Routing in Wireless Networks," *Journal of Artificial Intelligence and Capsule Networks*, vol. 3, no. 1, pp. 62-71, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[20] Shubham Mahajan et al., "Fusion of Modern Meta-Heuristic Optimization Methods Using Arithmetic Optimization Algorithm for Global Optimization Tasks," *Soft Computing*, vol. 26, pp. 6749-6763, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[21] Essam H. Houssein et al., *A Review of Metaheuristic Optimization Algorithms in Wireless Sensor Networks*, Metaheuristics in Machine Learning: Theory and Applications, Springer, Cham, pp. 193-217, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[22] J. Ramkumar, and R. Vadivel, "Improved Wolf Prey Inspired Protocol for Routing in Cognitive Radio Ad Hoc Networks," *International Journal of Computer Networks and Applications (IJCNA)*, vol. 7, no. 5, pp. 126-136, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[23] N.R. Solomon Jebaraj, and H.R. Keshavan, "Hybrid Genetic Algorithm and African Buffalo Optimization (HGAABO) Based Scheduling in ZigBee Network," *International Journal of Applied Engineering Research*, vol. 13, no. 5, pp. 2197-2206, 2018. [Google Scholar] [Publisher Link]

[24] Amritesh Ojha, and Bharat Gupta, "Evolving Landscape of Wireless Sensor Networks: A Survey of Trends, Timelines, and Future Perspectives," *Discover Applied Sciences*, vol. 7, pp. 1-58, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[25] Biswajit Kumar Dash, and Jun Peng, "Zigbee Wireless Sensor Networks: Performance Study in an Apartment-Based Indoor Environment," *Journal of Computer Networks and Communications*, vol. 2022, pp. 1-14, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[26] Junmei Yao et al., "Enabling Cross-Technology Coexistence for ZigBee Devices Through Payload Encoding," *IEEE Transactions on Mobile Computing*, vol. 23, no. 8, pp. 8289-8306, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[27] Ahmad Saeedi, Marjan Kuchaki Rafsanjani, and Samaneh Yazdani, "Energy Efficient Clustering in IoT-Based Wireless Sensor Networks Using Binary Whale Optimization Algorithm and Fuzzy Inference System," *The Journal of Supercomputing*, vol. 81, pp. 1-49, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[28] Nagma Parveen et al., "Coexistence in Wireless Networks: Challenges and Opportunities," *Telecom*, vol. 6, no. 2, pp. 1-23, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[29] Sushma P. Pavale, and Purnima J. Patil, "A Comprehensive Analysis of Multi-Channel MAC Protocols and Cluster Protocols for Building Robust and Energy-Efficient Wireless Sensor Networks," *Robotics, Automation and Control Systems*, vol. 24, no. 3, pp. 828-855, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[30] Bo Zeng, Zhiqing Liang, and Chaofeng Zhao, "Sinr-Based Slot Reuse Algorithm for Multi-Channel Wireless Sensor Networks," *EURASIP Journal on Wireless Communications and Networking*, vol. 2025, pp. 1-16, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[31] Nazim Abdeddaim et al., "Multi-Channel Cluster Tree for 802.15.4 Wireless Sensor Networks," *2012 IEEE 23rd International Symposium on Personal, Indoor and Mobile Radio Communications - (PIMRC)*, Sydney, NSW, Australia, pp. 590-595, 2012. [CrossRef] [Google Scholar] [Publisher Link]

[32] Dong Yang, Youzhi Xu, and Mikael Gidlund, "Wireless Coexistence between IEEE 802.11- and IEEE 802.15.4-Based Networks: A Survey," *International Journal of Distributed Sensor Networks*, vol. 7, no. 1, 2011. [CrossRef] [Google Scholar] [Publisher Link]

[33] Tirana Noor Fatyanosa et al., "Hybrid Genetic Algorithm and Simulated Annealing for Function Optimization," *Journal of Information Technology and Computer Science*, vol. 1, no. 2, pp. 82-97, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[34] Belal Al-Khateeb, and Wadhah Z. Tareq, "Solving 8-Queens Problem by Using Genetic Algorithms, Simulated Annealing, and Randomization Method," *2013 Sixth International Conference on Developments in eSystems Engineering*, Abu Dhabi, United Arab Emirates, pp. 187-191, 2013. [CrossRef] [Google Scholar] [Publisher Link]