

A STUDY ON ZIGBEE ARCHITECTURE AND ITS IMPLEMENTATIONS IN REAL-TIME ENVIRONMENT

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ABSTRACT

Zigbee technology has emerged as a significant player in the realm of wireless communication protocols, catering to the expanding landscape of the Internet of Things (IoT) and smart device ecosystems. Designed to address the unique requirements of low-power, short-range communication, Zigbee offers a robust platform for establishing interconnected networks of devices. This abstract provides an overview of Zigbee technology, focusing on its key features, architecture, applications, and advantages.

Zigbee's distinguishing characteristic is its ability to enable low-power, energy-efficient communication between devices, making it an ideal choice for battery-operated sensors, actuators, and control systems. The protocol employs a mesh networking architecture, where devices can dynamically form self-healing networks, enhancing reliability and coverage. Zigbee operates in various frequency bands, including 2.4 GHz and 900 MHz, accommodating diverse regional regulations and minimizing interference with other wireless technologies.

In this abstract, we delve into Zigbee's applications across multiple sectors, such as home automation, industrial automation, healthcare, and smart cities. Zigbee-enabled devices facilitate seamless interaction and automation, enabling users to monitor, control, and optimize their surroundings remotely. This technology has found resonance in smart home ecosystems, where its low power consumption, scalability, and ability to support a multitude of devices have contributed to its popularity.

Additionally, the abstract outlines the advantages and considerations of Zigbee technology. Its low-power nature extends the operational life of battery-dependent devices, reducing maintenance demands. The mesh network topology enhances network resilience and

extends communication range. However, challenges include potential interference within the crowded 2.4 GHz frequency band and the need for proper network configuration to ensure optimal performance.

Keywords: Wireless, IoT, Smart device, Networks, Sensors, Actuators, Smart home ecosystem, Low power consumption, Scalability, Mesh network topology.

INTRODUCTION:

Zigbee technology has emerged as a key player in wireless communication protocols, offering a unique blend of features that cater to the growing demands of the Internet of Things (IoT) and smart device ecosystems [1] (Guo, S et al., 2015). One of its distinctive attributes is its emphasis on low power consumption, making it well-suited for applications involving battery-operated devices and energy efficiency [2] (Rojas, J. et al., 2019).

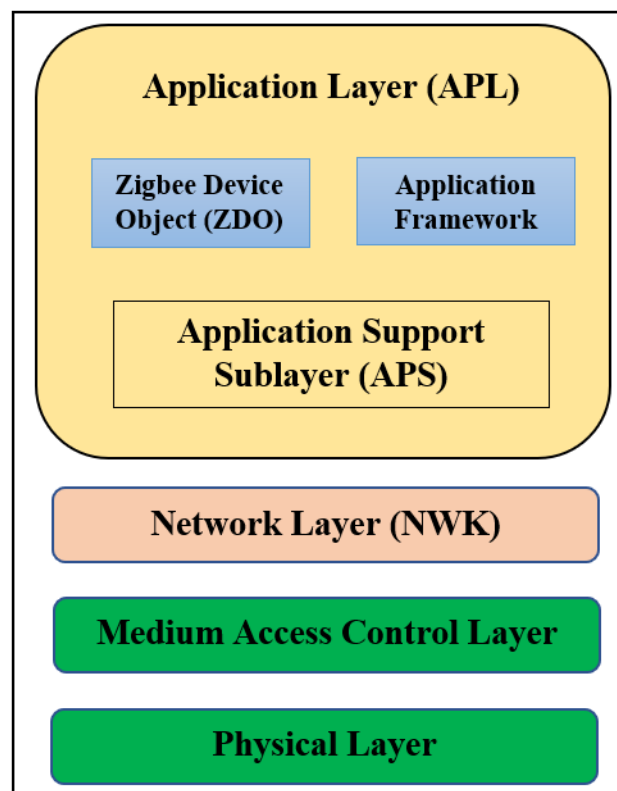


Fig (1). Zigbee Architecture

Application Layer: It defines various addressing objects including profiles, clusters, and endpoints.

Network Layer: It adds routing capabilities that allows RF data packets to traverse multiple hops (“Multiple devices”) to route data from source to destination.

MAC layer: Manages RF (Radio Frequency) data transactions between neighboring devices (Point to Point). The MAC includes services such as transmission retry and acknowledgement management and collision avoidance techniques.

Physical layer: It defines how devices are connected to make a network. It defines the output power, number of channels and transmission rate. Most Zigbee applications operate on the 2.4 GHz ISM band at a 250kbps data rate.

COMPARATIVE ANALYSIS BETWEEN WIFI AND ZIGBEE:

When comparing Wi-Fi and Zigbee devices, it is important to consider factors like the specific use case, required data rate, power consumption, coverage, and the number of devices in the network. Both technologies have their strengths and weaknesses, and the choice depends on the requirements of the application.

Wi-Fi:

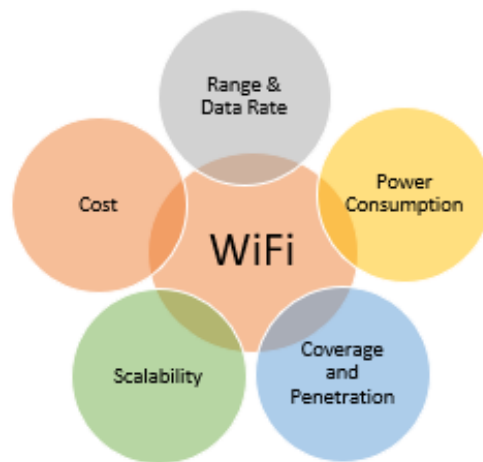


Fig (2). Features of Wi-Fi

1. **Range and Data Rate:** Wi-Fi typically offers higher data rates compared to Zigbee. It is suitable for applications that require high bandwidth, such as streaming video or large file transfers. However, Wi-Fi has a shorter effective range than Zigbee [3] (*Kaur, H., et al, 2017*).

- 2. Power Consumption:** Wi-Fi devices tend to consume more power compared to Zigbee devices. This makes Zigbee more suitable for low-power applications, as it is designed to maximize battery life in devices like sensors and actuators [4] (Hayes, J. P. 2019).
- 3. Coverage and Penetration:** Wi-Fi signals have shorter range and may struggle to penetrate obstacles like walls, especially in crowded environments. Zigbee's lower frequency and mesh networking capability can provide better coverage and penetration in such scenarios [5] (Bilgin, A., et al 2018).
- 4. Scalability:** Zigbee's mesh networking allows for easy scalability. Adding more Zigbee devices to a network often enhances coverage and reliability. Wi-Fi networks can become congested and less efficient with a high number of devices.
- 5. Cost:** Zigbee devices are generally less expensive to produce due to their simpler communication protocol. Wi-Fi devices often have more complex hardware, leading to higher costs.

Zigbee:

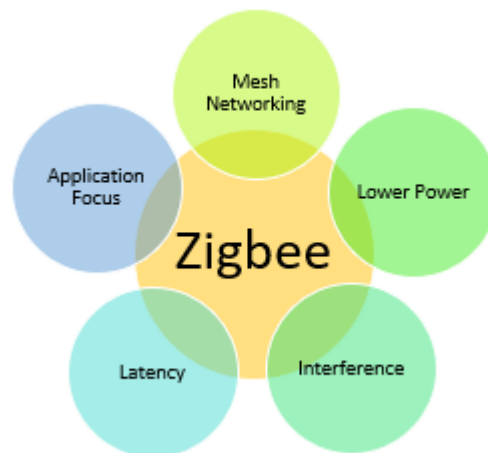


Fig (3). Features of Zigbee

- 1. Mesh Networking:** Zigbee devices can create mesh networks, where each device acts as a router, extending the network's range and robustness. Wi-Fi networks typically use a centralized architecture [6] (Ramakrishnan, N., et al 2018).
- 2. Low Power:** Zigbee is designed for low-power consumption, making it suitable for battery-operated devices with extended lifetimes.

3. **Interference:** Zigbee operates in the 2.4 GHz frequency band, which can be prone to interference from other wireless devices, including Wi-Fi. However, Zigbee can also operate in other frequency bands, such as 900 MHz.[7] (*Nguyen, H. T., et al 2017*).
4. **Latency:** Zigbee typically has lower latency compared to Wi-Fi, making it more suitable for applications that require quick response times, such as home automation.
5. **Application Focus:** Zigbee is commonly used in home automation, industrial automation, and IoT sensor networks. Wi-Fi is more versatile and is used for a wide range of applications beyond IoT [8] (*Garcia-Saavedra, A., et al 2013*).

IMPLEMENTATION OF ZIGBEE TECHNOLOGY IN REAL TIME:

Sno	Area of implementation	Description
1.	Home Automation	Zigbee extensively used in smart home applications, including controlling lights, thermostats, door locks, security systems, and home entertainment systems.
2.	Industrial Automation	Zigbee is employed for industrial monitoring and control, asset tracking, equipment condition monitoring, and remote sensing in factories and warehouses.
3.	Healthcare	Zigbee is used for patient monitoring, tracking medical equipment, managing medication inventory, and other healthcare-related applications.
4.	Smart Metering	Zigbee is utilized in smart meters for remote monitoring and management of utility consumption such as electricity, water, and gas.
5.	Retail	Zigbee-enabled solutions are employed in retail environments for inventory management, item tracking, and optimizing the shopping experience.
6.	Smart Agriculture	Zigbee-based sensors are used in agriculture for monitoring soil conditions, weather, and crop health.

7.	Logistics and Supply Chain Management	Zigbee devices can help track shipments, manage inventory, and monitor the condition of goods during transportation.
8.	Building Automation	Zigbee is used in commercial buildings for HVAC (heating, ventilation, and air conditioning) control, lighting management, and energy optimization.
9.	Automotive	Zigbee can be found in automotive applications for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication in smart transportation systems.
10.	Wireless Sensor Networks	Zigbee is widely used in creating wireless sensor networks for environmental monitoring, data collection, and research purposes.
11.	Smart Cities:	Zigbee can contribute to smart city initiatives through applications like smart street lighting, waste management, parking management, and environmental monitoring.
12.	Energy Management	Zigbee-enabled devices can be employed for home energy monitoring, load control, and demand response programs.

Table (1): Implementation of the Zigbee Technologies in various domain [9] Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications.

CONCLUSION:

In conclusion, Zigbee technology presents a compelling solution for creating interconnected networks of devices in IoT applications. Its focus on low-power communication, mesh networking, and adaptability to diverse contexts underpin its relevance in an increasingly connected world. As the IoT landscape continues to evolve, Zigbee's role in enabling efficient, reliable, and scalable wireless communication remains pivotal.

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