



Salient Features of protocols used for wireless communication

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Abstract –

In today's connected world wireless communication protocols are very essential. They enable efficient, reliable and secure transmission in the modern network. This research paper explores the key features of various protocols including Wi-Fi, Bluetooth, Zigbee, LoRa and 5G used in wireless communication mainly focus on operational principle and performance parameters like data range, energy efficiency, scalability and security. The study gives a comparative analysis based on the performance parameters and development for various applications. This paper also involves about the new trends like using AI, combining protocols and energy harvesting.

Keywords: Wireless communication protocol, operational principle

Introduction

Wireless communication protocols are the backbone of modern communication systems by enabling devices to communicate efficiently, reliably and securely. This protocol provides a facility to communicate without physical connections and helps in the exchange of data from personal area networks to global area networks.

In today's interconnected world understanding the features of protocols used in wireless communication networks are important. Each protocol gives a unique advantage in terms of data speed, range, energy consumption, security etc.

The goals are to provide a detailed analysis of these protocols mainly focus on their strengths and limitations. By analyzing the key features of these protocols, this study seeks to offer insights into optimizing wireless communication in different domains.

Related Work

Wireless communication protocols have seen significant advancement over the years. Deep research has been done on wireless communication protocols. Previous studies mainly focus on their design, performance and applications areas. For instance, Smith et al. [2] gives a detailed analysis of protocol advancement, focusing on Wi-Fi and Bluetooth. Tan et al. [4] examine the role of Zigbee and LoRa in IOT applications, highlighting their performance parameters like data range, efficiency, reliability, scalability. S. Patel [6] discussed about the evolution of 5G mainly emphasizing on its transformative potential for low latency and high-speed communication. Additionally, R. Kumar [7] reviewed about the emerging trends such as hybrid protocols and AI integration, predicting their impact on future networks. These studies help us understand the strengths and weaknesses of wireless communication protocols. They make it possible to compare different protocols effectively. By using this existing knowledge, our research aims to give a complete understanding of protocol features to help choose the right technology.

Overview of wireless communication protocol

1. Wi-Fi: - Wi-Fi is a widely used protocol for local area wireless communication. Wi-Fi operate based on the IEEE 802.11 standards, using radio waves to provide high speed internet and network connections, mainly operates in a 2.4 GHz and 5 GHz frequency bands. It is best suitable for indoor and residential network.

Salient Features: -

- Data Rate - Offers data rate up to 9.6 Gbps [1]
- Range - It has a moderate range up to 100 meters
- Applications – Mainly used in homes, offices and public hotspots and enterprise environment
- Security - Support WPA3 security for enhanced encryption and authentication [1]
- Interference – These signals are weakened by the physical barrier, electronics device and overlapping network. It can decrease speed up to 30 %.

2. Bluetooth: - Bluetooth is a most widely used communication protocol that uses a short wavelength UHF wave for short range communication, based on the IEEE 802.15.1, mainly operates in a 2.4 GHz. It primarily used for personal area networks. Bluetooth has improved over time. Bluetooth 5.0 allows speed up to 2 Mbps. The Bluetooth 5.2 has included new features for better sound quality.

Salient Features: -

- Data Rate – Offers data rate up to 2 Mbps [2]
- Range – The range of this protocol is effectively short as compared to other wireless protocol. Provide range up to 100 meters approx.
- Application – Mainly used in audio devices and ideal for personal area networks (PANs) like wireless headphones and smartwatches
- Energy Efficiency – Low power consumption with Bluetooth [3]
- Security – Bluetooth has a security features like pairing and encryptions. However, it has been attacked through methods like Bluejacking, Bluesnarfing, and BlueBorne.

3. Zigbee: - Zigbee is basically designed for low power, low data rate communication in a mesh network topology. Basically, operate on the IEEE 802.15.4 standard, mainly work in the 2.4 GHz frequency band, though it can also operate in 868 MHz and 915 MHz band in certain regions.

Salient Features: -

- Data - Zigbee support low data rate up to 250 kbps [4]
- Range - It has a range of 10-100 meters
- Applications - Ideal for IOT application like a smart home device, Industrial automation, sensor node
- Scalability - It supports large mesh network [4]
- Interference - Work in the 2.4 GHz band, it can experience interference from other wireless technology is like Wi-Fi and Bluetooth.

4. LoRa: - LoRa (Long Range) protocol widely used for wireless communication. It is a protocol for long- range, low power communication, often used in wide-area IOT network, operates on different frequency band like 415 MHz, 868 MHz, 915 MHz depending on the region.

Salient Features –

- Data Rate – Offer data rate up to 0.3 Kbps to 50 Kbps. [5]
- Range - It has a long range up to 15 km in rural areas.
- Applications – LoRa can be used in various application including agriculture, smart cities industrial monitoring and environmental quality monitoring.
- Energy Consumptions - It consume very less power, allowing battery operated device to last years.
- High Capacity - It has a capability to handle large number of devices, making them suitable for IOT applications.

5. **5G:** - The 5G protocol being several advanced features to wireless communication and is the latest cellular network standard, offering very high speed and low latency communication. It is especially designed to full fill the demands of current technological trends. 5G wireless technology will make current mobile internet service better and will also connect many devices and service in different industries like retail, education, and entertainment.

Salient Features –

- Data Rate – Offers data rate up to 10 Gbps. [6]
- Range – Mainly depend on deployment (milli meter wave for high speed, sub- 6 GHz for coverage).
- Applications - It support the emerging technology like AR/VR, autonomous vehicle and massive IOT setups.
- Energy Efficiency - 5G network use less energy, which help lower the power needed for connected device at the network itself.
- Enhanced Capacity – 5G can connect many devices at same time, making it perfect for crowded places and by IOT setups.

Comparative Analysis

Protocol	Data Range	Range	Energy Efficiency	Scalability	Security
Wi-Fi	Up to 9.6 Gbps	30-100 meters	Moderate	Limited to local networks	WPA3 encryption [1]
Bluetooth	Up to 2 Mbps	10-400 meters	High (BLE)	Limited to small devices	AES encryption [2]
Zigbee	Up to 250 Kbps	10-100 meters	High	Large mesh networks	AES encryption [4]
LoRa	Up to 0.3-50 Kbps	Up to 15 km	Very High	Wide-area networks	AES encryption [5]
5G	Up to 10 Gbps	Varies	Moderate	Massive device connectivity	Advanced Standards [6]

Emerging trends in wireless communication protocol

1. The era of wireless communication protocol is already being demonstrated with its new dimensions and trends. One of the new breakthroughs is the infusion of artificial intelligence (AI) and machine learning (ML)

that will make the system performance be better. Using AI and ML for adjusting the chip performance (adaptive optimization) can result to a better flexible communication system (protocol), and parameters like a code are adjusted to the clients to either increase throughput or reduce response time. In addition, bandwidth can be increased by a larger number of shorter frames and smaller feedbacks. Currently, if there is an early alert, the system will come up with the faster response to protect the data [7].

2. Another vital trend needed to mention is URLLC (ultra reliable low latency communication). Using 5G protocol URLLC is going to be the main instrument for autonomous vehicles, which is an example of mission-critical application in industry. URLLC is a promising innovation that can be the solution for better data-related needs in real time in countless areas [6].

3. Harnessing energy is of key importance of IOT networks. Using this measurement, it is important to innovate chip hardware, architectural design, and power management techniques to achieve the desired level of energy efficiency, thus improving efficiency of frontend chip I/O subsystems and microprocessors [5].

4. A great nearby future of data will be, that a link is made over all objects, not only humans but machines are included too. The magic should be infused into the man-machine communication for the operation to be transparent and effortless. The problem of power consumption associated with laser driver design has been solved using laser diode equalization and a quality power control (QPC) circuit. Designing suitable components and efficient means to couple power from the electromagnetic bandgap (EBG) structure to the rest of the IC, however, has been a challenge. [7]

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Applications and uses

1. Protocol such as Wi-Fi and Bluetooth are the key in the IOT world, offering reliable means for connecting various sensor wearable and smart device, facilitates seamless communication and data exchange among device, enabling efficient monitoring and control in IOT ecosystem.

2. Wi-Fi and Bluetooth protocols are two of the most important things in the world of the Internet of Things because they offer the most reliable ways of connecting a variety of wearable sensor devices and smart devices, thus, they enable seamless communication and data exchange between devices, which ultimately results in the efficient monitoring and control of the IOT ecosystem.

3. For smart City development all Municipalities should consider 5G & LoRa technologies in city infrastructure development.

4. In Industrial automation, Zigbee and 5G technologies are game changers. They facilitate the real time monitoring and communication between machines, increase efficiency and its productivity. These technology supports the automation of manufacturing process, creating smart factories with better decision making and less need for human involvement.

Conclusion

In summary, for effective usage of wireless communication protocols, all the intricacies of the fundamental characteristics of different wireless communication protocols should be known, which would make it possible to use them properly. This paper compares protocols to help Engineers and developers choose the best one based on their performance parameters. There are a plethora of distinct strengths and limitations of Wi-Fi, Bluetooth, Zigbee, LoRa, and 5G which make them apt for their applications.

Future research work will be integrating protocol concepts with energy harvesting techniques to improve the efficiency of the mechanism of wireless communication. Improvements are most likely to promote better innovations, connectivity between devices, and the ever-increasing demand for interconnected devices in different sectors. Further study and advancement of this protocol will lead towards establishing a substantially more robust, scalable, and energy-efficient wireless communication network.

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