

# Research on the applications of the wireless communication

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**Abstract.** Wireless communication transmits information, data, and signals across a spatial expanse without physical wired connections. The transmission of information is facilitated through the utilization of electromagnetic waves, which propagate through several mediums, including the air. The paper mainly examines the development process, the significant impact of wireless communication on individuals, the fundamental operating principles of wireless communication, and wide-used techniques and their applications in wireless communication. However, we also acknowledge the shortcomings and constraints of the existing wireless communication systems, and we are confronted with the challenge of identifying a viable approach to implement an improved and more comprehensive version of it. Luckily, it is anticipated that the future of wireless communication will yield promising prospects and contribute to notable progress in diverse fields. In conclusion, it is evident that despite the existing challenges in current wireless communication techniques, there is optimism for a promising future. This is attributed to the anticipated emergence of expanded applications and further enhancements facilitated by the continuous advancement and refinement of wireless communication techniques.

**Keywords:** wireless communication, electromagnetic waves, Internet of Things (IoT), Cellular Communication RFID (Radio-frequency identification), NFC (Near Field Communication).

## 1. Introduction

Wireless communication is a communication method that modulates electrical signals such as voice, text, information, and pictures that require to be transmitted on radio waves and transmits them through space and earth through wireless electromagnetic radiations.

The history of wireless communication spans centuries and is marked by significant developments and milestones in technology and communication. It mainly witnessed important progress as follows.

(1) 17th-19th century: early concepts and discoveries. In the 17th century, experiments regarding electricity and magnetism had already laid a solid foundation for the understanding of electromagnetic phenomena. Maxwell's theoretical prediction of electromagnetic has, in turn, fostered the development of wireless communication.

(2) Late 19th century: The invention of Radio. In the late 1800s, experiments conducted by famous inventors such as Nikola Tesla, Guglielmo Marconi directly contributed to the evolution of radio communication. Marconi's successful conveyance of wireless signals over the Atlantic Ocean marked a consequential milestone in long-distance wireless communication.

(3) Mid-20th century: Broadcast Radio, Microwave and Satellite Communication. The 1920s saw the rise of commercial broadcast radio, enabling the widespread dissemination of news, entertainment, and information. In the 1940s, the development of microwave technology allowed for high-frequency radio and transmission and also fostered the development of satellite communication. The first-ever artificial satellite was Sputnik 1, launched by Russia in 1957. Since then, satellites have become an essential part of our lives.

(4) 1960s-1970s: Mobile Communication and Early Computing. The development of cellular communication systems began in the 1960s, culminating in the launch of the first commercial cellular network in the 1980s. In addition, early computing and networking experiments laid the groundwork for packet-switched networks, which eventually evolved into the modern Internet.

(5) 1980s-Present: Digital Revolution and Beyond. The proliferation of personal laptops, mobile phones, and the internet revolutionized communication and information sharing on a global scale. As stepping into the 21st century, it consecutively brought about advancements such as Wi-Fi, Bluetooth, and 4G cellular networks. The ongoing development of 5G technology promises enhanced data throughput, decreased latency, and the ability to accommodate many interconnected devices [1].

It is obvious that the advancement of wireless communication also contributed to a profound and far-reaching influence on various aspects of society, technology, and everyday life. To start with, the invention of NFC (Near Field Communication) and RFID (Radio-frequency identification) have enabled instant communication across long distances, connecting people and businesses around the world in real-time [2]. Due to the rapid development of contemporary mobile networks, mobile phones and smartphones have become ubiquitous, providing individuals with continuous connectivity for voice calls, messaging, and internet access. Moreover, the advancement of wireless communication also made information more accessible. Wireless technologies like Wi-Fi and cellular networks have brought the internet to remote and underserved areas, democratizing access to information and knowledge and facilitating the rise of social media, online communities, and digital platforms for sharing content, opinions, and experiences. With regard to the transportation and logistics industry, wireless-enabled navigation systems and GPS technology have revolutionized transportation and logistics, making navigation more accurate and efficient. Currently, in the context of the epidemic, wireless communication supports online education platforms, enabling remote learning and access to educational resources. In a broader concept, it provides more access to digital libraries and educational materials, expanding learning opportunities for students of all ages. In a word, the influence of wireless communication is vast and has transformed nearly every aspect of modern life.

In the section 2, it mainly concentrates on wireless communication techniques. Initially, it elucidates the definition of wireless communication and explicates the bedrock of wireless communication. Then, it enumerates several classic instances and their possible applications to make the abstract concepts more comprehensible. The discussion reflected the deficiencies and limitations of current wireless communication and found a more comprehensive and ideal version. Eventually, it focuses on the possible enhancement and expansion of the current wireless communication technologies and ways to make them realizable.

## **2. The applications of wireless communication**

### *2.1. Definition of wireless communication*

Wireless communication alludes to the process of transmitting voice and data in the absence of physical cables or wires. Data transmission occurs through electromagnetic signals, which are disseminated from transmitting facilities to intermediate and end-user devices, thereby replacing the need for a physical link. The term "wireless" encompasses various technologies and devices, such as cellular communications, wireless networking connecting computers equipped with wireless connections, and wireless computer peripherals. Wireless communications rely on the transmission of electromagnetic waves via the atmosphere. The allocation of radio frequency bands within this spectrum is regulated by

the Federal Communications Commission (FCC) in order to mitigate issues related to congestion and ensure the reliable functioning of wireless devices and services [3].

## *2.2. Basic operating principle of wireless communication*

When it comes to how it works, it mainly undergoes four processes. Initially was wireless signal transmission, wireless signals are transmitted through electromagnetic waves generated by transmitting antennas. When transmitting data, the signal sender converts the data into an analog signal, and after modulation and signal amplification, the signal is transmitted through the antenna. The transmitted signal will propagate freely in space, a space propagation process. Since it is inevitable to encounter various interferences in the transmission process, such as multipath effects (that is, multiple signals caused by signal reflection and scattering during transmission), wireless communication technology uses frequency, coding, etc., to improve the stability and reliability of transmission. Then, by applying the antenna with the receiving function, the electromagnetic signal in the transmission is received back. After demodulation and other processes, it is restored to the original data that the receiver can obtain. Eventually, the received signal is decoded, denoised, and restored in digital signal processing so that the signal can be accurately identified and processed to achieve the ultimate communication purpose [4].

## *2.3. Common wireless communication techniques and their applications*

Specifically, typical wireless technologies include Wi-Fi (Wireless Fidelity), Bluetooth 5.0, Cellular Communication (GSM/2G/3G/4G/5G/LTE), RFID and NFC, etc.

*2.3.1. Wi-Fi.* To begin with, it is important to note that Wi-Fi encompasses a collection of wireless network protocols derived from the widely recognized IEEE 802.11 family of standards [5]. These protocols are extensively employed for the purpose of establishing local area networks among various devices, as well as facilitating internet connectivity. By utilizing radio waves, Wi-Fi enables the seamless data flow between digital devices in close proximity. The computer networks described herein are extensively employed globally, connecting devices within home and small office environments. Additionally, they facilitate connectivity to the Internet by establishing a wireless link between said devices and a router. Comparably, these networks are employed in common venues such as hotels, airports, and libraries, where wireless access points are strategically installed to provide guests with Internet connectivity for their portable devices. Wi-Fi refers to a wireless network technology that enables high-speed internet connectivity without needing physical connections or wiring. The smooth operation of a wireless network necessitates three critical components: radio waves, an antenna, and a router. Radio waves serve as essential components that enable the functionality of Wi-Fi networking. Utilizing a novel innovation has facilitated the incorporation of Wi-Fi compatibility into public networking. The compatibility of Wi-Fi can significantly reduce the burden on the company's cable television infrastructure, facilitating smoother internet browsing. Radio signals are transmitted from antennae and routers and afterward recognized by Wi-Fi receivers, such as computers and cell phones equipped with Wi-Fi cards. The computer promptly establishes a connection with the device when it receives signals from the router within 100-150 feet. The range of Wi-Fi is contingent on the surrounding circumstances, specifically the interior and outdoor settings. In addition, the Wi-Fi cards are capable of detecting and interpreting wireless signals, thereby establishing a connection to facilitate internet access for the user within the network. The speed of the device utilizing a Wi-Fi connection positively correlates with closeness to the main source, whereby a closer connection results in increased speed, while greater distance leads to decreased speed [6].

*2.3.2. Bluetooth.* Bluetooth is a wireless communication technology that facilitates short-range device-to-device communication, often within a range of around 10 meters. This technology enables the interchange of data between various devices, such as mobile phones, wireless Bluetooth headphones, computers, and associated peripherals. The utilization of the Bluetooth technology facilitates efficient communication between mobile communication terminals, simplifying the interaction between the

devices as well as strengthening their connectivity with the Internet. Thereby, data transmission becomes more rapid and efficient, as well as broadening the road for wireless communication. Currently, it has already been applied to the car HF system, which is one of the most typical car Bluetooth application technologies. The mobile phone can serve as a gateway to set up a connection between the car's hands-free system and itself. This connection can be generated automatically by activating the Bluetooth function on the mobile phone and the car's hands-free system. The mobile device has the capability to regulate both the microphone and the sound system within the automobile, leading to the establishment of full-duplex communication during phone calls without any interference. Furthermore, the utilization of Bluetooth technology is prevalent within the realm of industrial production. Bluetooth technology in CNC machine tools primarily manifests in wireless monitoring. By employing Bluetooth technology to install the appropriate monitoring infrastructure, users are afforded convenience in producing CNC machine tools while simultaneously upholding their safety. According to the carrier's statement, the technical personnel are responsible for continuous monitoring and management of machine tools, ensuring timely detection of any production issues pertaining to CNC machine tools. The wireless data link incorporates automatic monitoring features that can effectively intervene in specific situations, such as halting the spindle or initiating a system shutdown [7].

*2.3.3. Cellular Communication (GSM/2G/3G/4G/5G/LTE).* Throughout the development of the contemporary mobile network, it has already experienced five different generations, and at present, it is about to witness the birth of the 6G era. Let's just take the latest 5G technology, for instance, The previously mentioned wireless standard is a recent addition to the worldwide telecommunications landscape, succeeding the 1G, 2G, 3G, and 4G networks. Undoubtedly, the emergence of 5G technology has enabled the creation of a new network framework with the objective of connecting diverse entities, including individuals, machinery, objects, and numerous devices. The primary objective of 5G wireless technology is to provide significantly higher peak data speeds in the multi-Gbps range, reduced latency, improved dependability, expanded network capacity, increased availability, and an enhanced user experience for an expanding user base. The enhancement of performance and the optimization of efficiency contribute to the formation of novel user experiences and foster connections among expanding sectors. Broadly speaking, the utilization of 5G technology encompasses three main interrelated service categories: enhanced mobile broadband, mission-critical communications, and the vast Internet of Things (IoT). One of the key features of 5G technology is its inherent capacity for forward compatibility, which refers to its ability to adapt and accommodate forthcoming services that are presently unknown [8]. The implementation of 5G technology has the potential to revolutionize various industries by providing highly dependable, accessible, and low-latency connections. This can facilitate the remote management of essential infrastructure, cars, and medical procedures, enabling transformative services. Furthermore, the purpose of 5G technology is to establish a seamless connection between a vast array of embedded sensors in nearly all objects. This is achieved by the capacity to reduce data rates, power consumption, and mobility requirements, hence offering highly efficient and cost-effective connectivity options. Furthermore, 5G mobile technology can enhance our smartphones and introduce novel immersive experiences, such as Virtual Reality (VR) and Augmented Reality (AR). This advancement is facilitated by providing faster and more consistent data rates, reduced latency, and decreased cost-per-bit [9].

*2.3.4. RFID.* RFID is a wireless communication technology that utilizes electromagnetic or electrostatic coupling within the radio frequency range of the electromagnetic spectrum in order to establish a unique identity for a given thing, whether it be an object, animal, or individual. Radiofrequency technology is employed to conduct searches, identify, track, and establish communication with various objects and individuals. RFID is a technique employed for the purpose of remotely tracking or identifying an object through the utilization of radio transmission over the internet. The information is digitally encoded within an RFID tag and can be retrieved by the reader. This device functions as a tag or label that facilitates the reading of data from tags recorded in a database using a reader, in contrast to conventional

barcodes and QR codes. Passive or active RFID is frequently seen in contexts beyond visual perception. The utilization of RFID technology encompasses a diverse range of application domains, with one prominent illustration being the realm of local identification. If a reader is allocated to a certain location, it can probably monitor the current whereabouts of a uniquely identified item. Several logistics organizations and certain postal agencies have already included RFID-based functionalities in their tracking services. Likewise, the monitoring of the spatial placement of work items is being conducted in multiple manufacturing plants. The localization process involves reading RFID tags, which can be affixed to containers or commodities or used to identify the conveying vehicle. In addition to the advantage of delivering precise information, as opposed to the potential drawbacks of incomplete, delayed, or corrupted data resulting from manual data entry, the utilization of RFID tags obviates the need for a prolonged interruption in the transportation process, enhancing the efficiency of delivery. Furthermore, the localization of agricultural animals can be achieved with high efficiency by using RFID tags. Similarly, a comparable monitoring approach is employed in certain correctional facilities. Additional instances of location-specific applications can be envisioned by employing direction-selective readers. The objective of these methods is to accurately determine the precise positioning of a tag within a large geographical area, such as identifying the location of golf balls on a golf course [10].

**2.3.5. NFC.** NFC is a technology that has been developed by integrating wireless connectivity technology with non-contact RFID technology. The technology offers a secure and efficient means of communication for a wide range of electronic devices that are more prevalent in our everyday routines. The term "near field" within the context of NFC pertains to radio waves that are in close proximity to the electromagnetic field. Radio waves, being electromagnetic waves, adhere to Maxwell's equations. The process of propagating electric and magnetic fields from the transmitting antenna to the receiving antenna involves alternating energy conversion [11]. This conversion is characterized by the mutual enhancement of these fields, as observed in the operation of radios found in mobile phones. The transmission of the signal is facilitated by utilizing this fundamental concept, which is commonly referred to as far-field communication. Nevertheless, throughout a span of 10 wavelengths of electromagnetic waves, the electric field and the magnetic field exhibit a state of mutual independence. Currently, the electric field lacks significant significance, however, the magnetic field can be harnessed for the purpose of short-range communication, sometimes referred to as near-field communication. Integrating NFC technology and mobile communication technology in the business sector enables the implementation of several functionalities, including electronic payment, identity identification, ticketing, data interchange, anti-counterfeiting measures, and advertising. Integrating NFC services into mobile phones has also significantly improved their functionality, leading to a progressive shift in users' consumption behaviors towards electronic platforms [12]. This development has also created novel user consumption patterns and business models.

### **3. Conclusion**

Though the paper lists several widely used wireless communication technologies and their applications, we can hardly ignore the deficiencies and limitations of the current wireless communication technologies. To begin with, wireless signals possess a restricted coverage area and are susceptible to the influence of barriers, interference, and environmental factors. Chances are there could be poor or even no signal coverage in certain regions, particularly those remote or densely populated areas. Furthermore, the wireless communication bands can become crowded as the number of connected devices increases, especially with the growth of the Internet of Things (IoT). Likely, the security loophole could also be a knotty issue since wireless networks are easily susceptible to unauthorized access, data breaches, and cyberattacks if proper security measures are not implemented. Just take Wi-Fi, for instance. Public Wi-Fi networks can be particularly vulnerable to hacking and data interception [13]. Wireless communication based on data transmission over airwaves could also involve privacy concerns like data breaches. Moreover, wireless communication technologies operate within regulated frequency bands, and obtaining spectrum licenses and adhering to regulations can pose potential

challenges for further deployment and expansion. To conclude, a flawless and exhaustive version of wireless communication technologies still requires alteration, improvement, and refinement.

Fortunately, the future of wireless communication holds exciting possibilities and is expected to bring about significant advancements across various domains. While the exact developments may vary, we could anticipate some imminent upheaval. In the current era, 5G occupies a dominant theme. The rollout of 5G networks could promise ultra-fast data speeds, low latency, and support for many connected devices. Beyond 5G, researchers and engineers are exploring technologies that could deliver even higher speeds, greater capacity, and improved efficiency. Additionally, the Internet of Things (IoT) will continue to expand, with wireless communication enabling seamless connectivity for an increasing number of devices, sensors, and machines. And low-power, wide-area networks like NB-IoT and LoRa are expected to play a significant role in connecting billions of IoT devices [14]. With the breakthrough of future wireless communication, wireless networks will become more intelligent by integrating AI and machine learning algorithms. Thus, AI will optimize network performance, manage traffic, predict failures, and enhance security. Most importantly, wireless communication will see an increased focus on security and privacy, with advancements in encryption, authentication, and secure protocols to protect user data. The popularization of satellite-based communication systems could also promote ubiquitous connectivity even in remote or challenging environments.

Moreover, we may witness more expanded applications with the advancement of future wireless communication technologies. Firstly, autonomous vehicles and transportation may be diffusive as increasingly mature wireless communication technologies guarantee the crucial fundamentals of vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication for safer and more efficient transportation [15]. Relying on real-time data exchange and the latest wireless communication technologies, autonomous driving will surely boost its performance in various aspects such as navigation, avoiding obstacles, and optimizing traffic flow. What's more, advanced wireless communication will facilitate seamless remote work and collaboration by providing high-speed, low-latency connections for virtual meetings, file sharing, and real-time collaboration tools, thus definitely fostering remote work and collaboration. We may also witness industrial automation, and the arrival of the industry 4.0 age as wireless communication will enable advanced industrial automation, connecting machines, sensors, and robotics for efficient manufacturing processes and predictive maintenance. A new paradigm of wireless communication, the sixth-generation (6G) system, with the full support of artificial intelligence, is expected to be deployed between 2027 and 2030. With ultra-high data speeds, ultra-low latency, enhanced energy efficiency, advanced spectrum usage, and the application of integrated AI and machine learning, it will surely surpass and elevate the current mobile network [16]. Above all, as wireless communication technology continues to evolve, these expanded applications will reshape industries, improve connectivity, and contribute to the development of smarter, more interconnected societies.

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