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## A comparative analysis of wired vs. wireless data communication technologies

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### Abstract

Wired and wireless communication technologies are integral to modern data transmission across networks, each with unique benefits and challenges. This review presents a comprehensive analysis of wired and wireless communication technologies, focusing on their fundamental architectures, transmission mediums, bandwidth capacities, reliability, latency, and security. The paper explores existing literature and performance evaluations to offer insights into the roles these technologies play in various domains, including domestic, industrial, and commercial applications. This review concludes that while wired communication technologies maintain a competitive edge in reliability and security, the flexibility, scalability, and advancements in wireless technologies make them crucial for future network developments.

**Keywords:** Analysis wired, wireless data, communication technologies

### Introduction

Data communication has become an essential aspect of modern society, underpinning a wide range of activities from personal communications to complex industrial processes. The growth of digital technologies, the Internet, and the rise of the Internet of Things (IoT) have created an ever-increasing demand for fast, reliable, and secure data transmission systems. Wired and wireless communication technologies serve as the backbone of data transfer, each with distinct methods for moving data between devices. These technologies have evolved rapidly over the past few decades, responding to the growing need for higher bandwidth, lower latency, enhanced security, and greater mobility. Wired communication technologies, such as Ethernet and fiber optics, have been the cornerstone of data networks for decades, providing consistent, high-speed data transmission. Wired systems operate by transmitting data through physical mediums like copper cables, coaxial cables, or fiber optic lines. These technologies are known for their reliability, speed, and security, making them the preferred choice for environments where stable, high-performance connectivity is critical. For example, in data centers, financial institutions, healthcare facilities, and enterprises, wired networks ensure the integrity and consistency of data transmission, particularly in applications that are sensitive to latency and require uninterrupted connectivity. Despite the high performance, wired communication faces challenges in terms of scalability, installation costs, and limited mobility, which can make deployment complex in large-scale or dynamic environments. In contrast, wireless communication technologies have gained prominence in recent decades, thanks to the rapid expansion of mobile devices, IoT systems, and cloud-based services. Wireless systems, such as Wi-Fi, 4G, and the emerging 5G, transmit data using electromagnetic waves - typically radio frequencies or microwaves - over the air, eliminating the need for physical cables. The key advantage of wireless communication lies in its flexibility and mobility, allowing devices to connect to networks without the constraints of cables. This makes wireless technologies especially valuable in environments where mobility, scalability, and ease of deployment are essential, such as in smart homes, mobile workforces, and large public areas like airports or stadiums. However, wireless communication comes with its own set of challenges, including signal interference, security vulnerabilities, and limitations in bandwidth and latency compared to wired networks. The growing importance of network performance in today's digital economy has made this comparison highly relevant. Enterprises and consumers alike must decide which communication technologies to invest in, as these decisions can impact everything from operational efficiency to user experience.

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While wired communication has traditionally been seen as the superior choice in terms of performance, the continued development of wireless technologies - especially with the introduction of 5G and Wi-Fi 6 - has significantly narrowed the performance gap. As such, the analysis presented in this paper will consider both current technologies and future developments, offering insights into how wired and wireless communication systems may complement or compete with each other in the coming year.

### Main objective

The main objective of this paper is to conduct a comprehensive review of wired and wireless data communication technologies, comparing their performance, reliability, security, scalability, and suitability for different application environments, in order to provide a clear understanding of their respective advantages and limitations in modern networking systems.

### Wired Communication Technologies

Wired communication technologies rely on physical mediums, such as copper cables, coaxial cables, and fiber optics, to transmit data between devices. These technologies have been the foundation of modern networking for decades, with Ethernet being the most widely adopted standard for local area networks (LANs). Ethernet technology has undergone numerous advancements, improving its speed, reliability, and overall efficiency. Copper cables, typically used in earlier Ethernet versions (such as Cat5 or Cat6 cables), have given way to fiber optic cables in high-performance settings. Fiber optics use light to transmit data, offering unparalleled data transfer rates, reaching up to 100 Gbps and beyond, making it a preferred option in environments demanding large-scale, high-speed data transmission, such as data centers and enterprises. Wired communication is renowned for its reliability and stability. The physical medium of transmission is less susceptible to interference from environmental factors, such as electromagnetic interference or physical obstructions, which are common challenges for wireless systems. This high reliability makes wired communication essential for mission-critical applications where uninterrupted connectivity is vital, such as in banking, healthcare, and financial institutions. Studies, including those by Thompson *et al.* (2020) [2], have shown that wired networks maintain consistent performance even under high data load conditions, further reinforcing their role in high-demand environments. Security is another significant advantage of wired communication. Since data travels through physical cables, unauthorized access requires physical interaction with the network infrastructure, reducing the risk of cyberattacks like eavesdropping or signal interception. In contrast, wireless networks can be more vulnerable to such threats. Wired networks, however, are not immune to attacks, and physical security measures are still necessary to protect against threats like cable tapping. Despite this, numerous studies emphasize that wired networks generally offer better security by virtue of their closed, physical nature. Wired communication technologies are also known for their low latency, a critical factor in applications requiring real-time data processing. For instance, in sectors like high-frequency trading and online gaming, the delay between data transmission and reception needs to be minimal, making wired connections, especially fiber optics,

the go-to choice. Latency in wired networks can be as low as a few milliseconds, depending on the quality of the infrastructure and the distance between devices, with fiber optics providing even lower latency compared to traditional copper cables. Research by Smith *et al.* (2021) [3] supports the notion that wired technologies are still the leading solution in environments where minimal latency is crucial. Despite their benefits, wired communication technologies face challenges in terms of scalability and mobility. Expanding a wired network often requires significant investment in physical infrastructure, including cables, switches, and routers. This can be time-consuming and costly, especially in large or geographically dispersed environments. Additionally, wired connections limit device mobility, as devices must remain tethered to the network via physical cables, making them less practical for environments where frequent movement or flexibility is required, such as in modern offices or consumer applications. Studies exploring the cost-effectiveness of wired communication have found that while initial setup and maintenance costs are higher than wireless technologies, the long-term reliability and performance of wired networks often justify the investment in critical applications. Fiber optic networks, in particular, have shown remarkable longevity and are expected to support the growing demands of future networking needs without significant upgrades. Thus, wired communication continues to be a backbone for industries that prioritize reliability, security, and performance over flexibility and scalability. In summary, wired communication technologies remain a critical component of modern data networks, excelling in performance, security, and reliability. Although they face challenges related to scalability and mobility, they are indispensable in environments where stability and high data throughput are non-negotiable. The ongoing improvements in fiber optic technology, coupled with the need for secure, low-latency communication, ensure that wired systems will remain relevant in various industries, even as wireless technologies continue to evolve.

### Wireless Communication Technologies

Wireless communication technologies have revolutionized data transmission by eliminating the need for physical connections between devices. Utilizing electromagnetic waves, primarily radio frequencies or microwaves, wireless technologies enable the transmission of data over distances without relying on cables. This flexibility has led to the widespread adoption of wireless technologies in various domains, including personal devices, enterprise networks, and industrial applications. Common wireless communication standards include Wi-Fi (802.11), 4G, 5G, and Bluetooth, each serving specific needs based on speed, range, and application scenarios.

Wi-Fi, one of the most prevalent wireless technologies, has evolved significantly since its introduction, with the latest standard, Wi-Fi 6, offering faster speeds, lower latency, and greater capacity for handling multiple devices. Wi-Fi is essential in environments that require flexible connectivity, such as homes, offices, and public spaces. Research by Smith *et al.* (2020) [3] indicates that Wi-Fi 6 provides up to four times the capacity of its predecessor, making it suitable for dense environments like smart cities or Internet of Things (IoT) ecosystems. However, despite these advancements, Wi-Fi networks are still susceptible to

interference from physical obstacles, other electronic devices, and environmental factors, which can degrade signal quality and reduce performance.

Cellular networks, particularly with the advent of 4G and 5G technologies, have further expanded the capabilities of wireless communication. While 4G networks provide reliable high-speed mobile data, 5G is a significant leap forward in terms of both speed and reduced latency. 5G technology can theoretically reach speeds of up to 20 Gbps, with latency as low as 1 millisecond, making it a viable alternative to wired connections in certain scenarios. Studies by Ramesh *et al.* (2019) <sup>[4]</sup> have shown that 5G's ability to support massive device connectivity and its low-latency capabilities make it an ideal platform for real-time applications such as autonomous vehicles, telemedicine, and virtual reality. However, 5G also faces challenges, such as the need for dense network infrastructure and susceptibility to interference from physical objects, especially at higher frequencies.

One of the key advantages of wireless communication is mobility. Devices connected to a wireless network are not restricted by physical cables, allowing for continuous connectivity while on the move. This is particularly important in mobile computing, IoT applications, and large-scale environments where physical wiring would be impractical. For instance, in industrial IoT settings, wireless communication enables seamless data collection and communication between machines and control systems, facilitating automation and real-time monitoring. Wireless communication's ability to scale and adapt to a wide range of devices and environments has made it indispensable in many modern applications.

However, wireless communication also introduces challenges in terms of reliability and security. Unlike wired networks, which are generally stable and secure due to their physical nature, wireless networks are more prone to interference, signal degradation, and unauthorized access. Environmental factors such as walls, buildings, and atmospheric conditions can obstruct or weaken wireless signals, leading to reduced performance and inconsistent connectivity. Moreover, wireless networks are more vulnerable to security threats such as eavesdropping, signal jamming, and unauthorized access. To mitigate these risks, encryption protocols such as WPA3 have been developed to enhance wireless security, though they cannot entirely eliminate the inherent vulnerabilities of wireless transmission.

In terms of scalability, wireless networks are easier to expand than wired networks, as they do not require additional physical infrastructure. This makes wireless technologies ideal for large-scale deployments, such as public Wi-Fi networks, smart cities, and rural internet access. A study by Li *et al.* (2021) <sup>[6]</sup> demonstrated the cost-effectiveness of deploying wireless networks in rural and remote areas, where laying physical cables would be economically unfeasible. Wireless communication technologies enable rapid network expansion by simply adding more access points or cellular towers, making them highly adaptable to changing demands.

Power consumption is another consideration in wireless communication. Devices using wireless technologies often rely on battery power, and maintaining a constant wireless connection can be energy-intensive, especially in mobile devices and IoT sensors. Advances in wireless power

management, such as low-power wide-area networks (LPWAN) and energy-efficient Wi-Fi protocols, have made significant strides in reducing energy consumption. Nevertheless, power efficiency remains a challenge, particularly in large-scale IoT deployments where thousands of devices need to be continuously connected.

Overall, wireless communication technologies have transformed the way data is transmitted, offering unparalleled flexibility, scalability, and mobility. While they face challenges in terms of interference, security, and power consumption, ongoing advancements in technology are addressing these issues. With the rapid growth of 5G, Wi-Fi 6, and emerging wireless standards, wireless communication is poised to become even more integral to the digital infrastructure of the future, supporting a wide range of applications from personal devices to smart cities and industrial automation.

### **Wired vs. Wireless Communication Technologies**

Wired and wireless communication technologies represent two fundamentally different approaches to data transmission, each with distinct advantages and limitations. These differences are particularly evident when comparing factors such as bandwidth, latency, security, reliability, mobility, and scalability. The choice between wired and wireless communication technologies often depends on the specific application, environment, and performance requirements.

#### **A) Bandwidth and Data Transfer Rates**

One of the primary differences between wired and wireless communication technologies lies in bandwidth and data transfer rates. Wired technologies, particularly those using fiber optics, offer significantly higher bandwidth than most wireless options. Fiber optic cables can provide data transfer rates of up to 100 Gbps and beyond, making them the gold standard for high-performance environments such as data centers and enterprise networks. According to research by Chen *et al.* (2020) <sup>[1]</sup>, fiber optics not only provide high speeds but also maintain consistent performance over long distances without signal degradation.

In contrast, wireless technologies have lower theoretical maximum data rates. Wi-Fi 6, the latest wireless standard, offers speeds of up to 9.6 Gbps, but real-world speeds are typically much lower due to interference, distance from the access point, and network congestion. Similarly, 5G, the newest cellular technology, can theoretically reach speeds of up to 20 Gbps, but practical speeds vary significantly depending on the network infrastructure, environmental conditions, and user density. Studies by Ramesh *et al.* (2019) <sup>[4]</sup> indicate that while 5G networks can rival some wired technologies in terms of speed, they are still constrained by factors such as the availability of high-frequency spectrum and the need for a dense network of small cells to maintain signal quality.

#### **B) Latency**

Latency, or the delay between data transmission and reception, is another crucial factor in the wired vs. wireless comparison. Wired connections, particularly fiber optics, offer the lowest latency, often less than 1 millisecond (ms). This low latency is critical in applications such as financial trading, real-time gaming, and video conferencing, where even slight delays can impact performance. According to a



study by Thompson *et al.* (2020) <sup>[2]</sup>, wired Ethernet connections in corporate networks consistently deliver latency below 10 ms, making them ideal for environments that demand real-time responsiveness.

Wireless networks, however, generally experience higher latency due to signal propagation delays, interference, and the need to process data at various access points. For instance, 4G networks typically have latencies ranging from 50 to 100 ms, while Wi-Fi networks often exhibit latency between 20 to 30 ms, depending on network congestion and the quality of the connection. However, 5G networks have made significant strides in reducing latency, with potential latencies as low as 1 ms in optimal conditions. A study by Li *et al.* (2021) <sup>[6]</sup> found that 5G networks have reduced latency by up to 90% compared to 4G, making them competitive with wired networks in some scenarios. Nonetheless, wired connections remain the benchmark for ultra-low latency applications.

### C) Security

Security is a critical consideration when choosing between wired and wireless communication technologies. Wired networks are inherently more secure due to their physical nature. Data transmitted through cables requires physical access to the network for interception, making unauthorized access more difficult. In highly secure environments, such as government agencies, financial institutions, or data centers, wired networks are preferred due to the reduced risk of hacking and data breaches. Studies by Smith *et al.* (2020) <sup>[3]</sup> emphasize that physical security measures, such as restricted access to network infrastructure, significantly enhance the security of wired communications.

Wireless networks, on the other hand, are more vulnerable to security threats, including eavesdropping, data interception, and unauthorized access. Since wireless signals are broadcast through the air, attackers can potentially intercept data without physical access to the network. Wireless networks rely on encryption protocols such as WPA2 and WPA3 to secure transmissions. While these protocols provide a robust defense against most attacks, wireless networks remain more susceptible to vulnerabilities such as man-in-the-middle attacks or signal jamming. Research by Patel *et al.* (2019) <sup>[5]</sup> found that while WPA3 has improved wireless security, many networks still rely on older encryption standards that are more vulnerable to attacks.

### D) Reliability

Reliability is another area where wired communication technologies generally outperform wireless technologies. Wired connections are less prone to interference from environmental factors, such as walls, weather conditions, or electronic devices, ensuring a stable and consistent connection. In environments that require uninterrupted connectivity, such as hospitals or financial institutions, wired networks are preferred due to their high reliability. According to research by Thompson *et al.* (2020) <sup>[2]</sup>, wired Ethernet connections exhibit near-zero packet loss and minimal downtime, even in high-traffic environments.

Wireless networks, however, are more susceptible to signal interference and degradation. Obstacles such as walls, buildings, or even atmospheric conditions can weaken wireless signals, leading to reduced data rates, higher latency, and packet loss.

In addition, wireless networks are prone to congestion, especially in crowded environments where multiple devices compete for bandwidth. While advancements in wireless technology, such as multiple-input multiple-output (MIMO) and beam forming, have improved signal reliability, wireless networks still face challenges in maintaining consistent performance in environments with high interference.

### E) Mobility and Flexibility

Wireless communication technologies excel in mobility and flexibility, providing a distinct advantage over wired networks. Wireless networks allow devices to connect to the internet or local networks without the need for physical cables, enabling users to move freely within the coverage area. This is particularly important in mobile environments, such as smartphones, laptops, and IoT devices. Research by Zhang *et al.* (2021) <sup>[7]</sup> highlights the importance of wireless networks in enabling connectivity in smart cities, where large numbers of mobile devices need to connect to the network simultaneously.

Wired networks, in contrast, are limited by the need for physical connections, making them less practical in environments that require mobility or flexibility. While wired connections provide superior performance in terms of speed, reliability, and security, they are less suitable for environments such as modern offices, where users may need to move between workstations or connect multiple devices wirelessly. The fixed nature of wired networks also makes them less adaptable to changes in network topology or user demands, as expanding or reconfiguring a wired network often requires additional infrastructure and installation.

### F) Scalability and Cost

Scalability is another area where wireless technologies have an edge. Wireless networks can easily scale to accommodate a growing number of devices without the need for additional physical infrastructure. Expanding a wireless network typically involves adding more access points or upgrading existing equipment, making it a cost-effective solution for environments with a high density of connected devices. A study by Li *et al.* (2021) <sup>[6]</sup> found that wireless networks are particularly well-suited for rural or remote areas where laying physical cables would be prohibitively expensive.

Wired networks, while highly reliable, are more challenging and expensive to scale. Expanding a wired network requires laying additional cables, installing switches and routers, and often upgrading existing infrastructure to support higher bandwidth. This makes wired networks less flexible and more costly to expand, especially in large or geographically dispersed environments. According to a study by Patel *et al.* (2020) <sup>[8]</sup>, the cost of installing and maintaining a wired network can be up to three times higher than a wireless network in some cases, depending on the infrastructure required.

### Conclusion

The comparative analysis of wired and wireless communication technologies reveals that each has distinct strengths and weaknesses depending on the application and environment. Wired communication excels in terms of speed, reliability, security, and low latency, making it the preferred choice for critical infrastructure and environments where consistent performance is crucial. On the other hand,

wireless communication offers unmatched flexibility, mobility, and scalability, making it ideal for mobile applications, large-scale deployments, and environments requiring quick and easy setup. As wireless technologies such as 5G and Wi-Fi 6 continue to advance, the performance gap between wired and wireless communication is narrowing, particularly in terms of speed and latency. However, challenges related to interference, security vulnerabilities, and environmental factors still affect wireless systems. Meanwhile, wired technologies remain the standard for secure, high-performance, and stable connections, especially in sectors like healthcare, finance, and industrial settings. In conclusion, the decision between wired and wireless communication depends on the specific requirements of the network. A hybrid approach, combining the reliability and speed of wired networks with the flexibility and scalability of wireless systems, is likely to be the most effective solution for modern and future communication needs. This integration will allow both technologies to complement each other and meet the growing demands of digital ecosystems.

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