5G and WiFi-6 in industry 4.0 - A Review

[1]**Shashi Yadav**, [2]**Shivam Shukla**
Computer Science and Engineering,
Dr. A.P.J Abdul kalam Technical University (AKTU) Lucknow, Uttar Pradesh, India

Abstract: There is an increasing interest in integrating wireless technology in industrial applications. The Fourth Industrial Revolution is the on-going automation of traditional manufacturing and industrial practices, using modern smart technology such as AGVs and other mobile machines. The concern is that accessing wireless devices might be challenging in an industrial setting because there are several items that obstruct radio signals, such as walls, machines with metal components, etc. Both 5G and WiFi-6 technologies trying to address this problem. The goal of this paper is to evaluate and compare 5G with WiFi-6 technologies performance in an industrial environment.

Keywords: Industry 4.0, WiFi-6, 5G, Performance Evaluation, WiFi-6, 802.11, Wireless, Broadband, Internet.

1. Introduction

Manufacturers have traditionally considered wired infrastructure to be the more efficient, cost-effective and dependable solution. The pandemic has further strengthened the need for enterprises to be digitally agile. The enterprises already had an adoption plan of wireless networks in place, but CoVid-19 has further accelerated this shift. The factories of the future will be built of densely connected sensors, big data analytics and connectivity networks that will be able to detect their surroundings and communicate with each other, enabling them to make decentralized decisions. Industry 4.0, a technological strategy that originated in Germany in 2011 [1, 2] is predicted to grow by $ 310 billion until 2023 with an annual growth rate of over 27% and bring emerging technologies to 60% of global companies. It is also anticipated to drive the development of new services and activities in organisations and transform business and manufacturing processes [3].That expansion, therefore, would only be possible if such underlying network can deliver the bandwidth, real-time efficiency, range, privacy, and reliability that the Industrial IoT requires. Wi-Fi 6 and 5G Both technologies will vastly improve the wireless experiences for users and also hold the key to unlocking the power of the Industrial IoT for manufacturer.

5G will revolutionise how goods are manufactured and distributed in factories. With the help of 5G networks, businesses can create smart factories and fully utilise innovations like augmented reality for troubleshooting, automation, artificial intelligence, and the Internet of Things (IoT) [4]. The low latency, high reliability, and increased speed of 5G networks will help to support emerging technologies and their novel applications in industrial automation, such as process automation, remote monitoring and collaborative robot.5G technology will also allow for higher flexibility, lower cost and shorter lead times for factory floor production reconfiguration, layout changes, and alterations, which will result in significant improvements in terms of production.The adoption of 5G manufacturing seems to be a top goal for the telecoms industry, and also related technical domains, and has important impacts for productivity improvement while cutting prices.

Wi-Fi 6 will bring the added benefit to enabling Industry 4.0 use cases that need a robust, reliable, secure, and flexible Wi-Fi infrastructure. That includes things like production lines that are more automated and flexible, Real-Time Location Services (RTLS), condition monitoring, robotics, wearables, AR, and safety applications. Wi-Fi 6, which is the new common name given to 802.11ax, is packed with many technological advancements that enhance the performance of Wi-Fi networks. Wi-Fi 6 access points can be deployed in dense environments, such as stadiums and transportation hubs, to support more concurrently connected users and devices with diverse use cases. A range of technologies that optimise spectral efficiency, increase throughput and reduce power consumption make this possible. Wi-Fi 6 will still work in unlicensed (2.4 and 5 GHz) spectrum.

Wi-Fi 6 as well as 5G could very well be important for organisations presently adopting Industrial IoT solutions or prototyping such solutions at any extent, or wishing to create a network that also can satisfy both present and future needs. These technologies enable businesses to integrate more devices efficiently via wireless networks, in spite of their better speeds.This paper explores the technical and operational differences between Wi-Fi and 5G mobile networks in manufacturing industry and then reviews both to figure out which one is better and in what condition.

2. Background

For years, two different types of wireless technology have coexisted. Wi-Fi is a type of local area network (LAN) used primarily indoors, for example inside a home or workplace. Cellular networks, like the 4G LTE networks used by major operators, are a type of wide area network (WAN) used both indoors and outdoors, generally over long distances.

The next generation of Wi-Fi technology, Wi-Fi 6 is also known as 802.11ax and is based on the IEEE 802.11ax standard. It has been designed to enhance the speed and reliability of wireless networks. Simply put, what 5G cellular does for wide-area access, Wi-Fi 6 does for local access. Each Wi-Fi 6 access point reaches farther and covers a greater area, and can support many more devices at once. Wi-Fi 6 also delivers a dramatic boost in speed, plus a 50% improvement in battery life, a 4x increase in network capacity, and a 2x increase in bandwidth over previous generations of Wi-Fi [5].

5G is the name of the next-generation cellular data networks that will replace 4G LTE. 5G now being deployed by a growing number of mobile operators and is the latest generation of cellular communications. It will elevate mobile broadband experiences and support a host of new services, such as mission-critical communications, remote control of critical infrastructure, vehicles and the IIoT. 5G also will natively support all spectrum types, including licensed, shared and unlicensed, as well as all bands,operates in both the 28 GHz licensed mmWave spectrum and the 60 GHz unlicensed mmWave spectra.5G proponents claim that the technology has the potential to transform a wide range of industries, from automobiles to smart cities [6]. A growing number of use cases have emerged illustrating 5G's importance to the IIoT. For example, the German government is freeing up 100 MHz of licensed spectrum for industrial use. Using that spectrum, Volkswagen will deploy a private 5G network to support its manufacturing systems [7].Another example is the Finnish private LTE provider Ukkoverkot [8], which is setting up a private LTE network to bring connectivity, automation and intelligence to the Port of Kokkola in Finland.Some manufacturing companies are embracing 5G with both arms. For example, appliance maker Whirlpool recently announced it will replace its WiFi network with AT&T's 5G network. The first phase of Whirlpool's 5G rollout will cover 200,000 square feet in the center of its Ohio plant, and is intended to initially connect around 80% of the company's 100 driverless vehicles. Eventually Whirlpool plans to take over the management of the 5G network from AT&T, placing Whirlpool squarely in the growing "private network" trend. This will allowto go to truly autonomous vehicles throughout the entire plants, for maintenance, for delivery, for everything to support the manufacturing operations, doing so will save the company a significant amount of money.Whirlpool isn't alone. Samsung, Corning and Ericsson are among the companies that are evaluating 5G in a factory setting.

Much like Wi-Fi 6, 5G cellular networks will be faster than 4G LTE. Also just like Wi-Fi 6, 5G networks will bring greater bandwidth and capacity, meaning future cellular networks will be able to handle more users (and traffic). The 5G and Wi-Fi 6 transitions are about bringing sci-fi movie fantasy a reality, not really about uninterrupted streaming video or speedier downloads. Robots performing chores, automated driving, smart buildings, VR-based gaming experiences, remote treatments, telehealth, industrial automation, augmented reality, advertising campaigns, shopping online and cooperates will all undergo transformations far above imagination because of the 5G and Wi-Fi 6.

3. Technical features and advantages of 5G

The next generation of telecom networks, 5G has started hitting the market end of 2018 and will continue to expand worldwide. In addition to high speeds and low latency, the emergence of 5G cellular technology could put some pressure on the market prices of incumbent WAN connectivity.

Features of 5G for businesses.

- _Ultra High Speed:_With a data rate of up to 10 Gbps, 5G will bring a 10 times to 100 times improvement over the existing 4G LTE technology.

- _Ultra Low Latency:_5G's low latency, as low as 1 millisecond, will be the other key for WAN usage. Latency goes down From 200 milliseconds for 4G, to 1 millisecond(1ms) with 5G.

- _Ultra High Bandwidth:_Using shorter frequencies (millimeter waves between 30GHz and 300GHz) for 1000x bandwidth per unit area. This high-band 5G spectrum provides the expected boost in speed and capacity, low latency, and quality.

- _High Density:_ 5G density will enable up to 100 times more connected devices in the same physical area that 4G LTE operates today, while maintaining 99.999% availability and 100% coverage.

- _Reduction in power consumption:_An estimated 90% reduction in power consumption for devices means minor power savings at the smartphone level. But, from an infrastructure perspective, especially for IoT devices, the power savings could be significant.

- _Energy saver:_Up to 10-year battery life for low power IoT device.

- _Security:_ It is always a concern for mobile devices and IoT devices because the latter live on the edge of the corporate network. With 5G, stronger security than 4G LTE will be available for designers, including hardware security modules, key management services, over the air, secure element and others. This will help ensure that the data transmitted over the 5G network is secure while also hardening network endpoints.

Advantages of 5G

- 5G supports excellent mobility due to its roaming support.
- During the event of data congestion due to increased number of subscribers, 5G can offload traffic to indoor wi-fi networks.
- 5G offers 10x improvement in throughput, 10x reduction in latency, 10x improvement in connection density, 3x improvement in spectrum efficiency and 100x improvement in traffic capacity and network efficiency.
- Dynamic beamforming feature which helps in overcoming pathloss at higher mmWave frequencies.
- Higher bandwidth and data rates can be achieved using carrier aggregation and massive MIMO.

Because this network technology's reliability is so high and its latency so low, equipment can communicate wirelessly with back-end systems for time-critical operations in ways

that were not possible before. For the first time, this will combine fast production-line operations with the power of networked intelligence.

4. Technical features and advantages of Wi-Fi 6

Wi-Fi 6 expands the Wi-Fi band from 80 MHz to 160 MHz, doubling the channel width and creating a faster connection from router to the device. Wi-Fi 6 make it easy to enjoy 8K movies, large file downloads and uploads and responsive smart home devices that all without buffering.

Main features of Wi-Fi 6 (802.11ax)

- *The MU-MIMO technology (Multi User – Multiple Input and Multiple Output):* It allows information to be sent to several devices at the same time rather than to each device one after the other. In addition, MU-MIMO is being updated with Wifi 6. So far capable of communicating with 4 devices at a time, Wifi 6 will allow communication to 8 devices at the same time.

- *OFDMA (Orthogonal Frequency Division Multiple Access):* Wifi 6 also relies on OFDMA which not only speeds up data transfer but also reduces latency. This technology allows data to be transmitted to several devices in a single transmission. Each transmission will be therefore optimized to contain a maximum of information per shipment.

- *TWT (Target Wake-Up Time):* It is an intelligent standby mode to reduce the energy consumption of the access point, but also to limit interference with nearby devices.

Advantages of Wi-Fi 6

- Wi-Fi 6 provides 40% higher peak data rates and 4x improvement in network efficiency.
- Wi-Fi 6 based scheduling mechanism helps to reduce overhead and latency. Moreover multiple users can transmit simultaneously.
- Wi-Fi 6 client devices consume less power due to use of TWT (Target Wake Time) feature and hence it enhances battery life.
- Wi-Fi 6 offers higher security due to use of WPA3 protocol.
- Wi-Fi 6 uses long symbol duration outdoors and short symbol duration indoors.
- Co-channel interference is mitigated due to use of BSS color coding.

5. Comparing 5G and Wi-Fi 6

Wi-Fi technology has been a dominant technology in providing enterprise connectivity. However, mobile network operators are working on to present an option having greater prominence and unparalleled advantages. With dynamic leaps in the 5G cellular technology, private 5G compared to Wi-Fi will be eventually the key driver to support the connectivity in enterprises which includes dynamic spectrum sharing and network slicing.

Private 5G, the newest wireless standard, is a unique network that claims to offer 50x greater speed, 1000x more capacity, and 10x less latency. With this, more enterprise devices that can connect will be able to transmit more data, which was not conceivable in earlier networks. Additionally, with excellent connectivity, the transmission rate will be substantially faster and provide exceptional user experiences. Private 5G networks are built with small cells which mean short-range distribution radio network nodes are utilised to create indoor and outdoor 5G wireless framework. This enhances the overall network coverage providing 24x7 connectivity [9, 10]. Such type of implementation can be seen in manufacturing plants, mining, logistics companies, enterprise campuses, etc. Although the COVID-19 outbreak caused a delay in the 5G rollout timeline, mobile operators are continuing their preparations to expand their installations and add radio network nodes in new regions (cities, towns, and even rural areas).

Wi-Fi 6 will continue to be the access choice for low-cost network deployment: Low equipment, installation, and maintenance expenses of the Wi-Fi 6 network are the main reasons for Wi-Fi becoming the crux of a household network. It has been designed to enhance the speed and reliability of wireless networks. Wi-Fi networks can be operated by anyone and are mostly seen in homes, offices, and public places, connected to a single broadband network. If what is the difference between 5G and Wi-Fi is to be considered, then cost will be one of the major elements to point out the differences. While Wi-Fi access points for enterprise-based applications are expensive compared to home applications, it is still less expensive than getting the access points and licensing cellular technology for developing private networks. Hence, Wi-Fi 6 can be a cost-effective solution to serve small or mid-sized enterprises' wireless demands.

Following table uses various parameters between 5G vs Wi-Fi 6 and mentions the difference between 5G and Wi-Fi 6 technologies.

Specifications	5G	WiFi 6
Technology	Cellular	WLAN
Standard	3GPP Rel. 15 and beyond	IEEE 802.11ax
Operating frequency	Sub 1 GHz, 1 to 6 GHz, Greater than 6 GHz in millimeter wave range at 28 GHz and 40 GHz	2.4 GHz and 5 GHz both
Spectrum	Licensed	Unlicensed

Parameter	5G	Wi-Fi 6
Speed	Greater than 1 Gbps	Higher than 5G, About 600 Mbps with 80MHz/1 SS, About 9.6 Gbps with 160 MHz/8SS (11ac version gives about 7 Gbps with 160 MHz, 8 SS).
Range	5G small cells support 10-100 meters range based on their types such as femtocell, pico cell and microcell. 5G mmwave base station covers 2 meters (in indoor) and 300 meters (in outdoor).	Greater than 100 meters, Beamforming feature improves range by 4 times than 802.11ac (i.e. wifi5) version.
Maturity of the technology and its penetration	It is at nascent stages and will take few years to reach the current stage of 4G LTE deployments	It has already been matured and has deep penetration into our homes, enterprises, residential communities and commercial establishments
Cost of deployment	Expensive	Cheaper
IT administrators	Not required	Required as wifi networks are installed and managed by them
Security	5G cellular connections are more secure compare to unknown wifi connections. 5G users are exposed to security risks during process called wifi offloading. 5G will be as secure as 4G LTE today. 5G supports multiple authentication and key management features.	WiFi 6 supports WPA3 security protocols to provide high security.
Mobility	Higher	Lower than 5G
Application	Outdoors	Indoors

It's more about Wi-Fi 6 and private 5G complementing each other rather than evaluating private 5G vs Wi-Fi 6 as cellular technology is getting adjacent to Wi-Fi technology and vice-versa. This means that Wi-Fi will provide more flexibility and power in handling the available resources whereas 5G will enable high capacity to connect more devices.

Both Wi-Fi 6 and 5G are built from the same foundation: As the foundation for both Wi-Fi 6 and 5G is identical, Wi-Fi 6 vs 5G speed is of less prominence and significantly provides higher data rates to develop new applications and services. Internet of Things (IoT) applications can be connected in huge numbers associated with multiple users with minimal or no congestion in traffic. For example, machine-to-machine communication plays a key role in factory automation. While Wi-Fi 6 may work for a managed manufacturing operation, 5G may augment a large, campus-wide manufacturing environment. In some cases, Wi-Fi and 5G may be used simultaneously. For instance, a connected car may offer in-vehicle Wi-Fi for users' devices, while the car itself connects to a 5G cellular network. Because Wi-Fi has a lower cost to deploy, maintain, and scale—especially where access points need to serve more users—it will continue to be the predominant technology for home and business environments. This provides great support for dozens of data-hungry devices, like PCs, tablets, smartphones, streaming devices, TV sets, and printers, which must all connect to the network. Thanks to its longer range, 5G will be used for mobile connections, like smartphones. It will also be used for connected cars, smart city deployments, and even for large manufacturing operations.

Wi-Fi and 5G offer complementary functionalities. Where the user experience is concerned, 5G and Wi-Fi 6 can both achieve gigabit speeds and low latency. The explicit desire to leverage this combination is to unleash the potential of other emerging technologies such as IoT, cloud, Edge computing, big data analytics, VR, AR, robotics and more. 5G and Wi-Fi 6 together act as a transformative multiplier.

As indoor networks, Wi-Fi 6 offers low latency, high speed and greater device density compare to 5G. Moreover both 5G and Wi-Fi 6 have their unique features. We can conclude that both the technologies are going to exist together. There is no chance that one will replace the other. Both 5G and

wifi-6 technologies have their unique use cases. Moreover in certain use cases, 5G can complement with wifi-6.

6. Discussion and Conclusion

In short, Wi-Fi 6 and 5G will have a similar impact and provide similar improvements over current wireless and cellular networks. They are distinct, but complementary, technologies that will usher in a new era of device connectivity and network capacity.Wi-Fi 6 enables maximum efficiency of the wireless channel, which is what makes it possible to vastly increase the number of potential concurrent connected devices and speeds. They will co-exist and work simultaneously like an autonomous vehicle utilises the 5G cellular network and may offer in-vehicle Wi-Fi 6 for users' smartphones/tablets, or any other devices. While a manufacturing operation may be managed through the Wi-Fi 6 network, large-scale manufacturing processes may be executed under the private 5G campus network. Enterprises may choose an option for wireless access as per their business needs and still get the blazing speed, high-end capacity, and low latency to ensure devices can reliably share data in less time.Businesses should holistically estimate their data flow requirements and compatibility with their existing IT infrastructure. Undertake a cost-benefit analysis of 5G versus Wi-Fi 6 for the expected use cases. Only through a thorough analysis and with in-depth planning will enterprises be able to realise all the potential advantages that the Industrial IoT has to offer. This will ensure that their business processes are efficient, it fosters dynamic decision making, predicts maintenance needs and reduces downtime. It provides improved control of machinery, tracking assets and much more. The connectivity conundrum between Wi-Fi 6 versus 5G is not an easy decision to make.

Declaration of competing interest

There are no competing interests.

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