AT&T Business

# Will 5G replace Wi-Fi?

A perspective on the co-existence of 5G and Wi-Fi 6

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# Abstract

Wireless connectivity has reached the point that no matter where people are, they are usually connected. They often have come to depend on this connectivity for business and personal use, much like electricity, to enrich their lives. When traveling about, connectivity has typically been made possible by a cellular network (e.g., 4G LTE). When inside homes, offices, or other brick-and-mortar venues, connectivity has evolved from Wi-Fi networks to the next generation of wireless technologies – where the differences between Wi-Fi and mobile cellular networks are becoming more difficult to distinguish.

Underway is the evolution of the 4G LTE network to 5G, promising greater speeds, lower latency, and connectivity for many more devices. We are also seeing the next evolution of Wi-Fi to Wi-Fi 6 (also known as 802.11ax), promising greater speeds, higher device densities, and better battery life. Both technologies are poised eventually to deliver even better untethered experiences, enabling new applications not previously possible. Yet how can we know which technology is the right one for the right use? As these technologies gain momentum, hype about exciting, new capabilities can introduce confusion as well.

# “Is 5G poised to replace Wi-Fi”?

While that question is simple, the answer is not. Whether the mobile cellular network will replace Wi-Fi has been a discussion since the advent of 3G and early Wi-Fi. The answer lies in an examination of the two technologies, where they are different, and where they are the same. This paper is an exploration of 5G and Wi-Fi 6 from this perspective.

### Industry research

Given that these technologies are emerging, there is limited research on how they compare. This section is a review of eighteen industry documents covering 5G and Wi-Fi 6.  Key observations from those documents are also provided.

### Comparison and contrast of 5G and Wi-Fi 6

From the research, the two technologies are compared side by side. Armed with a deeper understanding of how Wi-Fi 6 and 5G compare, the differences between the two become clearer.

### Final observations

We conclude with observations from industry experts and an opinion about deploying 5G versus Wi-Fi 6 depending on the use case.

# Industry research

A survey of the industry was conducted for the purpose of building a knowledge base for this paper. The information can be clustered into three areas of research: content on 5G, content on Wi-Fi 6, and content on 5G versus Wi-Fi 6. Of the eighteen reference documents collected, the distribution across the three areas was: five documents on 5G, seven documents on Wi-Fi 6, and six documents representing a comparison of both technologies. The following represents a summary of findings from the research. Also, full citations for each document is listed in Reference Sources at the end of this paper.

# Observations from the research

**The International Telecommunications Union (ITU) 2020 vision**

When reviewing the research, one aspect seemed to resonate across the two technology domains. The goal of both technologies is to meet the requirements specified in the ITU's 2020 vision on the future of mobile connectivity. The vision is detailed in the ITU's IMT-2020 document.[1] Three key attributes for the vision are 1) enhanced mobile broadband, 2) ultra-reliable and low latency communications, and 3) massive machine type communications.

The research explicitly identifies three usage scenarios for 5G, and although Wi-Fi 6 usage scenarios were not explicitly stated, the usage scenarios seem to be the same. Given the overlapping objectives, this does make for an interesting point of comparison.

When we examine the suggested use cases, some are clearly meant for the 5G network. For example, self-driving cars can be envisioned as 5G capable (ultra-low latency). Other capabilities such as gigabit speeds can also be attributed to Wi-Fi 6. What is most important is that the reference model can be used as a point of comparison for the two technologies.

"When we examine the suggested use cases, some are clearly meant for the 5G network."

[1] IMT-2020. https://www.itu.int/dms_pubrec/itu-r/rec/m/r-rec-m.2083-0-201509-i!!pdf-e.pdf

# Future IMT

**Usage scenarios of IMT for 2020 and beyond**

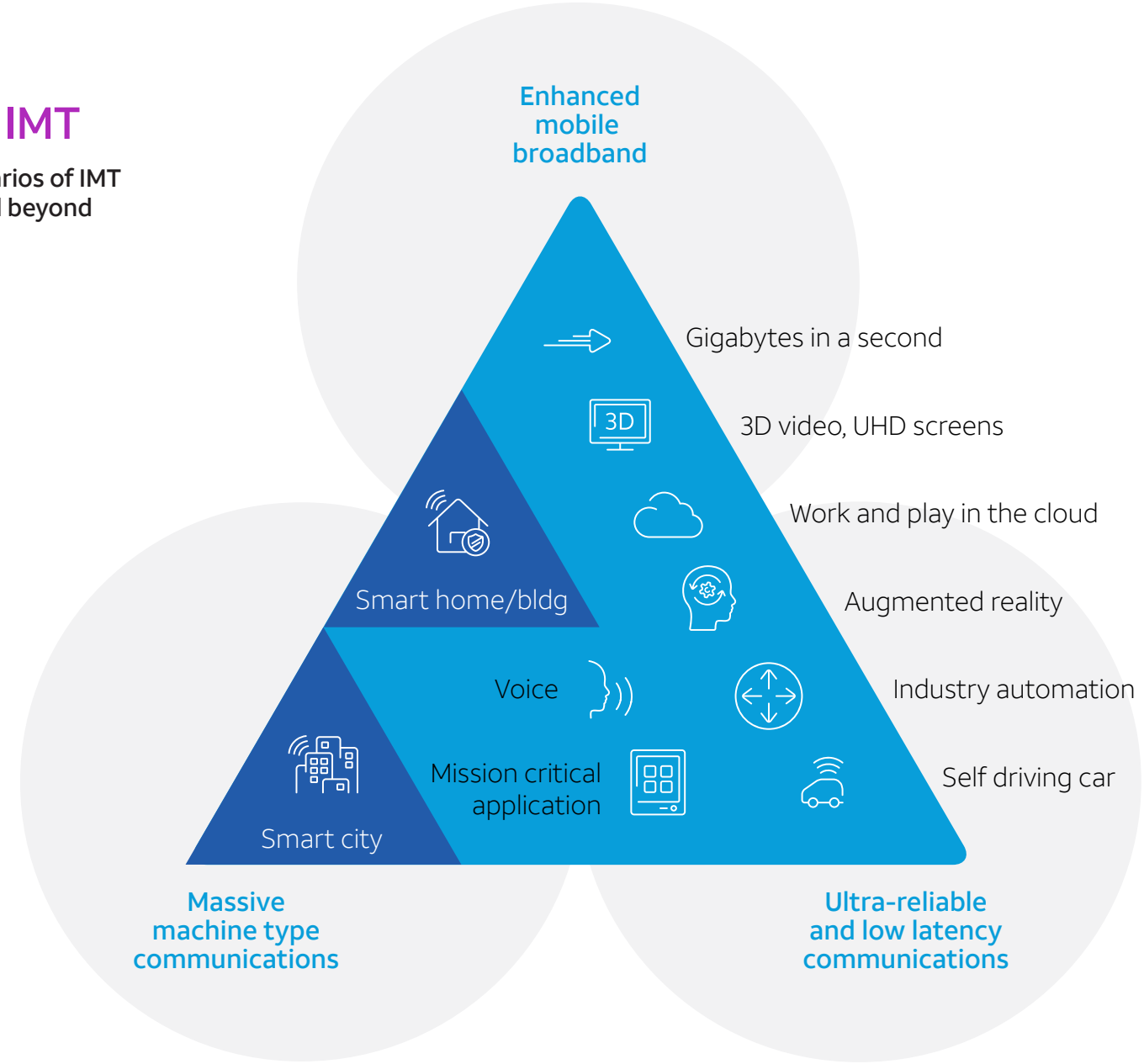


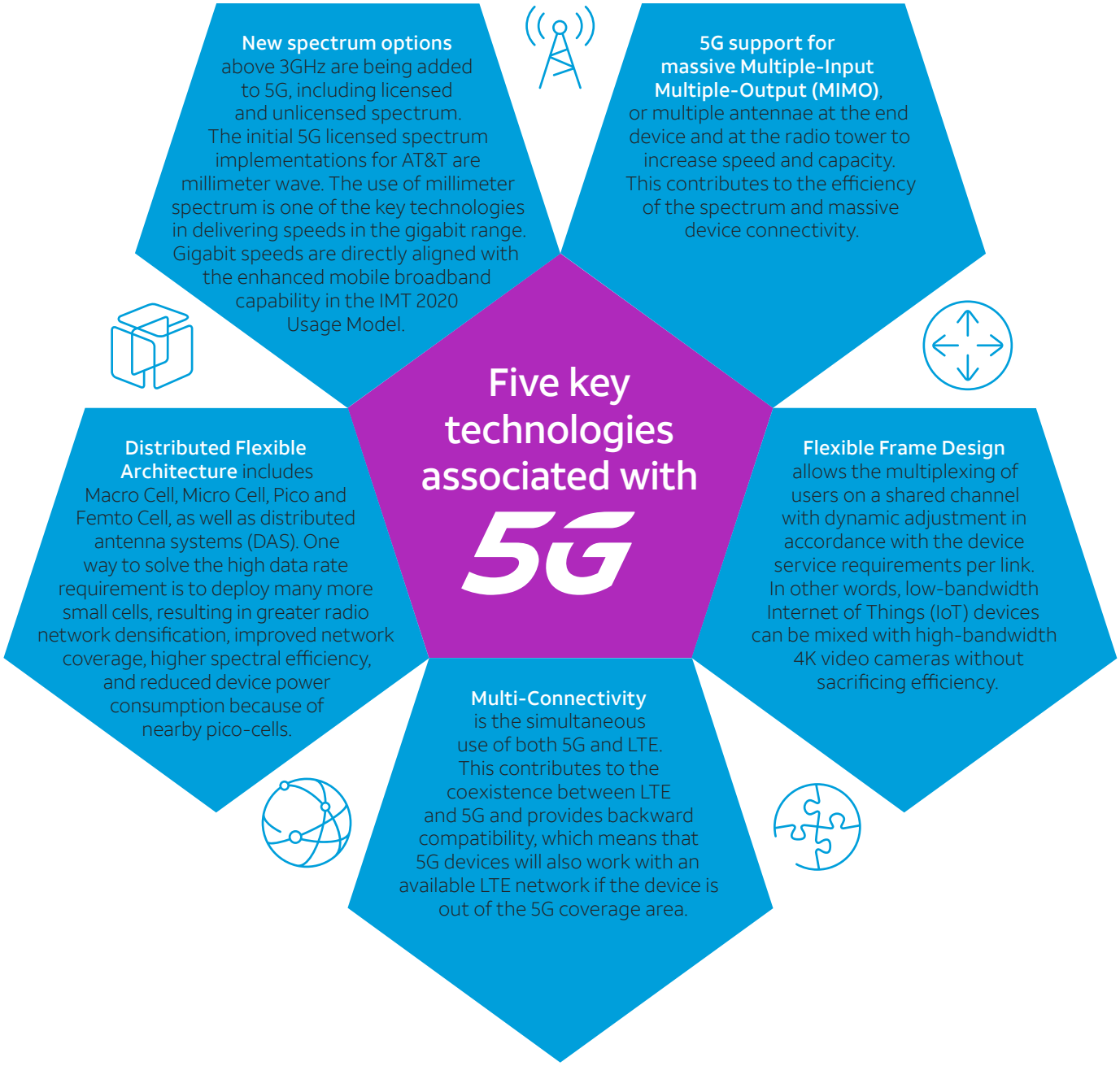

Diagram concept: courtesy of International Telecommunication Union (ITU)

# 5G: more than faster speeds

Most of the detailed information about 5G came from two primary sources: 5G Americas[2] and the 3G Partnership Program (3GPP)[3] organization. This research provided a detailed level of information on the standards and the 5G technologies.[4]

5G is an emerging standard which is set by the 3GPP organization. 3GPP follows the specifications defined in the ITU's IMT-2020 vision. Due to the complexity of the technology, coupled with the desire to deliver the technology quickly, the 5G standard was divided into two phases: Release 15 and Release 16. Release 15 was completed at the end of 2017 specifying a New Radio (NR) RAN interface with connectivity to an LTE enhanced packet core. The 5G devices will communicate with the 5G mobile radio network using NR. Historically, end-user devices generally become commercially available eighteen months after the completion of a standard. 5G has seen an acceleration of a few devices working in concert with carrier 5G release. The first commercial 5G smartphone devices were anticipated mid-2019. Release 16 specifies additional enhancements to Release 15, including a 5G packet core.

2 5G Americas. http://www.5gamericas.org/en/resources/white-papers/
3 3GPP. http://www.3gpp.com/
4 Wireless Technology Evolution: Transition from 4G to 5G-3GPP Releases 14 to 16. 5G Americas. (2018).


New spectrum options above 3GHz are being added to 5G, including licensed and unlicensed spectrum. The initial 5G licensed spectrum implementations for AT&T are millimeter wave. The use of millimeter spectrum is one of the key technologies in delivering speeds in the gigabit range. Gigabit speeds are directly aligned with the enhanced mobile broadband capability in the IMT 2020 Usage Model.
5G support for massive Multiple-Input Multiple-Output (MIMO), or multiple antennae at the end device and at the radio tower to increase speed and capacity. This contributes to the efficiency of the spectrum and massive device connectivity.
Five key technologies associated with 5G
Distributed Flexible Architecture includes Macro Cell, Micro Cell, Pico and Femto Cell, as well as distributed antenna systems (DAS). One way to solve the high data rate requirement is to deploy many more small cells, resulting in greater radio network densification, improved network coverage, higher spectral efficiency, and reduced device power consumption because of nearby pico-cells.
Flexible Frame Design allows the multiplexing of users on a shared channel with dynamic adjustment in accordance with the device service requirements per link. In other words, low-bandwidth Internet of Things (IoT) devices can be mixed with high-bandwidth 4K video cameras without sacrificing efficiency.
Multi-Connectivity is the simultaneous use of both 5G and LTE. This contributes to the coexistence between LTE and 5G and provides backward compatibility, which means that 5G devices will also work with an available LTE network if the device is out of the 5G coverage area.

# Wi-Fi 6: more than raw data rates

Wi-Fi 6 is essentially a rebranding of 802.11ax by the Wi-Fi Alliance™.[5] The key difference between 802.11ax and its Wi-Fi predecessors is that previous standards focused mainly on increasing raw data rates, whereas 802.11ax focuses on better efficiency, capacity, and performance. Even without a central fact source for Wi-Fi 6, the various companies comprising the Wi-Fi industry have thoroughly described the Wi-Fi 6 technology.

As a standard, 802.11ax is under the governance of the Institute for Electrical and Electronics Engineering (IEEE). Even though the standard was not ratified until 2019, it has been evolving since 2013, so equipment manufacturers have been making products available using 802.11ax chipsets. After ratification by the IEEE, the certification program sponsored by the Wi-Fi Alliance has been designed to ensure interoperability between Wi-Fi 6 radio networks and end user devices.

> Wi-Fi is estimated to carry approximately **60%** of the current wireless traffic, and that is expected to grow to **64%** by 2020.[6]

5 WiFi Alliance. www.wi-fi.org/wi-fi-certified-6. (2019).
6 *Wireless Global Congress 2018: Wi-Fi Injecting Itself Deeper into the 5G Mix with 802.11ax.* Global Data. Ed Gubbins. (2018).
7 *Unleashing the Power of Wi-Fi: Enterprise-Grade WiFi Forecast, 2019-2023.* Huawei. (2019).


Orthogonal frequency division multiple access (OFDMA) is new for Wi-Fi 6. It enables more users to simultaneously operate in the same channel, improving efficiency, latency, and data throughput.
Multi-user multiple-input, multiple-output (MU-MIMO) allows more data to be transferred at once, enabling an access point to handle a larger number of concurrent users. This contributes to the efficiency of the spectrum and massive device connectivity.
Wi-Fi 6 has five key technologies
Target wake time (TWT) allows devices to negotiate when and how often they will "wake up" to send or receive data. TWT increases sleep time and thus substantially improves battery life. IoT devices could potentially "sleep" for hours or days at a time, thereby conserving battery life. This makes Wi-Fi CERTIFIED 6 IoT devices more power efficient.[7]
Transmit beamforming improves signal power, resulting in significantly higher rates at a given range. This is particularly important when operating in the higher spectrum range to achieve higher speeds.
1024 quadrature amplitude modulation mode (1024-QAM) is a highly developed modulation scheme used in the communication industry in which data is transmitted over radio frequencies. Combined with other key technologies, QAM enables throughput increases by as much as 25 percent over Wi-Fi 5.

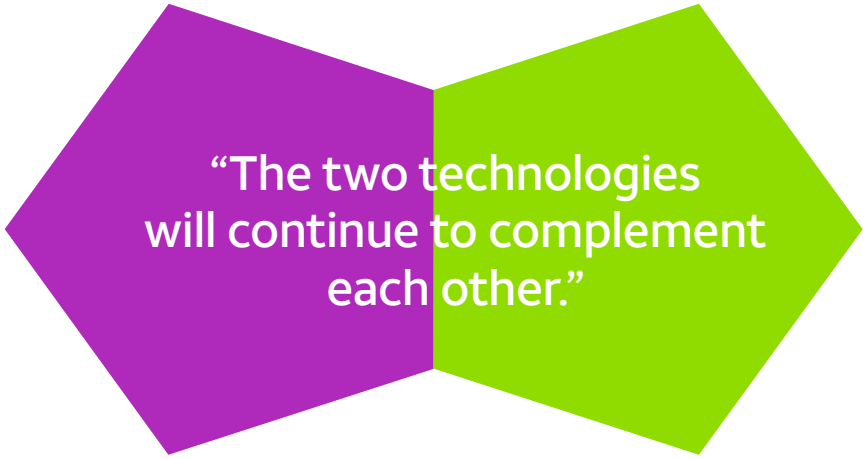
# 5G vs. Wi-Fi 6

While the key technologies for Wi-Fi 6 are somewhat different from 5G, an overlap exists. For example, 5G employs OFDMA, Multi-User MIMO, beamforming, and QAM.

Wi-Fi 6 and 5G are predicted to coexist much as the two technologies have done in the past.[8] Legacy Wi-Fi technologies have flourished in a local setting like the office, campus, or business venue, and Wi-Fi 6 is expected to do the same.

5G is the next evolution of 4G LTE and is primarily a wide-area technology that is deployed across cities and rural areas to support mobile connectivity. While 5G is in its early stages, the current 5G millimeter wave coverage is very limited.

Over time, coverage will expand, particularly with the use of additional spectrum bands such as sub-6 GHz. It is this key difference (LAN versus WAN) that leads to the conclusion that the two technologies will continue to complement each other. The consensus of this paper is that 5G will not replace Wi-Fi 6.




8 *5G or Wi-Fi 6 (802.11ax)?.* Qorvo. (2018). YES

# Comparison and contrast of 5G and Wi-Fi 6

## The similarities

There are many technologies within the Wi-Fi 6 and 5G ecosystems. For the context of this discussion, a few key technologies that are common between the two were selected for review.

> AT&T started deploying LTE-LAA services in 2017. And to date, AT&T has coverage in 24 markets.

### Spectrum

Unlicensed spectrum at 5GHz is common with both standards. Unlicensed 5GHz has been a mainstay of Wi-Fi technologies for years and it will continue to be part of the Wi-Fi portfolio with Wi-Fi 6. For the mobile cellular network, unlicensed 5GHz was added as part of the LTE 3GPP Release 13 which was finalized in March 2016.[9] This feature became known as LTE Licensed Access Assist (LTE-LAA) and allowed mobile cellular networks to combine licensed and unlicensed spectrum (carrier aggregation) to deliver greater speeds while ensuring fair coexistence with Wi-Fi. This put 4G LTE on the path to Gigabit services.

In the future, unlicensed spectrum at 6GHz is anticipated to be used with both Wi-Fi 6 and 5G. The FCC has proposed the expansion of unlicensed use of the 5.925–7.125 GHz band (6 GHz band) spectrum.[10] Additionally, the Wi-Fi Alliance and 3GPP have stated that 6GHz will be part of their respective standards after ratification.[11] [12]

## Quadrature Amplitude Modulation (QAM)

QAM is a modulation technique that is used to improve spectral efficiency and thus improve throughput. Wi-Fi 6 supports 1024 quadrature amplitude modulation mode (1024-QAM), and it enables throughput increases by as much as 25 percent over Wi-Fi 5.

3GPP Rel-15 (5G) supports 1024 QAM (from 256 QAM, which was introduced in LTE Rel-12), allowing 5G to achieve higher peak data rates and spectral efficiency in favorable scenarios.

The main motivations and target use cases for 1024 QAM are:

- Devices with high capacity connection and data requirements (e.g., a laptop or smartphone connected to a small cell, supporting video streaming, gaming, tethering, etc.)
- Stationary/nomadic intermediate devices (e.g., routers, IoT aggregation points, wireless backhaul gateways) and communicating with end users via other links

## Orthogonal frequency division multiple access (OFDMA)

OFDMA is a technique for transmitting large amounts of digital data over a radio wave. The technology works by splitting the radio signal into multiple smaller sub-signals that are then transmitted simultaneously at different frequencies to the

9 *3GPP & unlicensed spectrum*. http://www.3gpp.org/news-events/3gpp-news/1660-laa_ieee. 3GPP. Flynn, K. (Jan 2015). This is how it is on the Web Site.
10 *47 CFR Part 15*, [ET Docket No. 18–295, GN Docket No. 17– 183; FCC 18–147], (December 2018).
11 *The Next Generation Wi-Fi: The Future of Connectivity*. Wi-Fi Alliance. (2018).
12 *3GPP Commits to 5G NR in Unlicensed Spectrum in its next release*. https://www.qualcomm.com/news/onq/2018/12/13/3gpp-commits-5g-nr-unlicensed-spectrum-its-next-release. Qualcomm.

receiver. OFDMA significantly reduces contention (devices competing for network resources) and overhead (the extra traffic added by the system to manage the traffic flow), especially for short packets prevalent in many networks. It also enables more users to simultaneously operate in the same channel, and therefore improves efficiency, latency, and throughput. This supports the International Telecommunications Union (ITU) requirement for massive device support.

### Multi-user multiple input, multiple output (MU-MIMO)

MU-MIMO allows more data to be transferred simultaneously and enables an access point to handle a larger number of concurrent clients by increasing the number of antennas on a radio network. It is used for receiving and transmitting. This improves the overall capacity and increases the speed of the wireless connection.

# The differences

### Governing bodies

**Wi-Fi 6**

IEEE is the main body for maintaining and creating new standards for how radio frequencies are used to support Wi-Fi. A new standard is introduced every few years. The standard for 802.11ax (Wi-Fi 6) was slated for finalization in 2019. Since the 802.11ax standard has been in development since 2013, some equipment manufacturers have released products that use the unratified version of the standard.[13]

In addition to the IEEE, the Wi-Fi Alliance is a separate association of companies, including AT&T, concerned with regulating compliance with certain standards. Wi-Fi CERTIFIED 6™, an upcoming certification program from the Wi-Fi Alliance, will establish industry standards for devices based on Wi-Fi 6, or IEEE 802.11ax technology.[14]

[13] *802.11ax/Wi-Fi 6 Will Bring Speed, Efficiency to Enterprise WLANs, Especially Dense and IoT Environments (US44499118)*. IDC. Butler, B., Filkins, P., Mehra, R. (2018).
[14] Wi-Fi CERTIFIED 6: Next generation Wi-Fi. Wi-Fi Alliance.

## 5G

Standards for mobile wireless networks result from the efforts of two global institutions: ITU and 3GPP.

ITU is an agency of the United Nations (UN) whose purpose is to coordinate telecommunication operations and services throughout the world. Originally founded in 1865 as the International Telegraph Union, the ITU provides guidance, requirements, and recommendations that set the stage for the next generation of mobile wireless technologies. In the past, the ITU defined International Mobile Telecommunications-2000 (IMT-2000) for the Third Generation (3G), IMT-Advanced for the Fourth Generation (4G), and is now defining IMT- 2020 as the 5G specification expected by 2020.[15]

3GPP is a collaborative project aimed at developing globally acceptable specifications for the next generation mobile systems. The 3GPP caters to a large majority of the telecommunications networks in the world. 3GPP unites seven telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC), known as "Organizational Partners" and provides their members with a stable environment to produce the reports and specifications that define 3GPP technologies, such as 5G.[16] In support of IMT-2020, 3GPP defined a two-phased 5G work program starting with study items in Release-14, followed by two releases of specifications spanning Release-15 and Release-16, with the goal being that Release-16 includes everything needed to meet IMT-2020 requirements. Release-15 was completed in March 2018 and Release-16 was scheduled for 2019.

### Spectrum

## Wi-Fi 6

Many discussions about Wi-Fi 6 focus on improving the air efficiency of Wi-Fi networks, particularly in high-density situations. Wi-Fi 6 will continue to use unlicensed spectrum exclusively. Wi-Fi 6 works in the

15 *IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond.* International Telecommunications Union. (Sept 2015).
16 *Wireless Technology Evolution: Transition from 4G to 5G-3GPP Releases 14 to 16.* 5G Americas. (2018).

2.4 GHz and 5 GHz bands, which are the existing Wi-Fi bands. The use of unlicensed 2.4GHz spectrum remains unique to Wi-Fi 6.

Wi-Fi 6 also continues to operate in the 900 MHz band and 60GHz band. The 900Hz band (HaLow) offers longer range and lower power connectivity for low bandwidth IoT applications. The 60GHz band, in the millimeter wave region of spectrum, is well suited to deliver multi-gigabit speeds, but due to limited propagation, distance is shorter than the other frequencies in this standard.[17] The use of these bands is also unique to Wi-Fi 6 and previous Wi-Fi versions.

## 5G

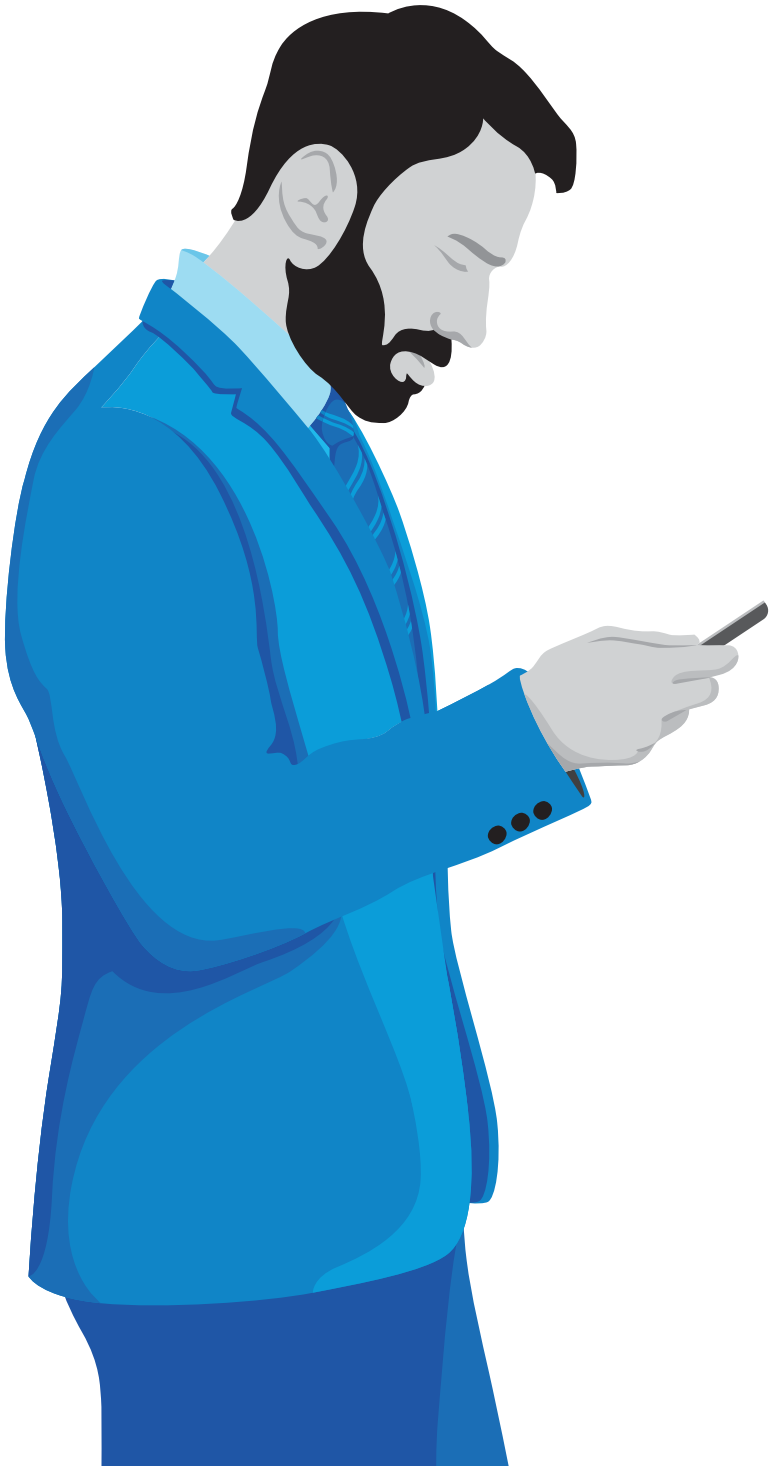
From 1G through 4G (LTE), licensed spectrum was exclusively used with the mobile cellular networks, which is a significant difference from the use of unlicensed spectrum for Wi-Fi. While each of the four main carriers in the U.S. have different spectrum portfolios, they all used licensed spectrum until recently. With the carryover of unlicensed 5GHz (LTE-LAA) and the planned inclusion of unlicensed 6GHz combined with licensed spectrum portfolio, 5G is differentiated from Wi-Fi 6. 5G now has the potential to carry traffic from both 5G mobile devices and Wi-Fi devices on the same radio network backbone.

The focus of the mobility carriers for the initial 5G offers has been on the high frequency spectrum, or millimeter wavelength bands.

This service is based on the 5G NR standard and uses 39GHz spectrum as an initial market entry. The long-term plan is to use spectrum from low, mid, and high band frequencies. Low band is less than 1GHz, mid-band is between 1GHz and 6GHz, and high band is everything else above 6GHz including the millimeter wave frequencies.

[17] *The Next Generation WiFi:* The Future of Connectivity. WiFi Alliance. (2018).

At the end of 2018, AT&T launched Mobile 5G services in parts of twelve cities, with another nine cities rolled out in 2019.[18]



[18] https://about.att.com/story/2018/att_brings_5g_service_to_us.html

# Conclusions

While 5G and Wi-Fi 6 have many differences and similarities, Wi-Fi 6 seems capable of being successful as a LAN technology and 5G is expected to realize success as a WAN technology. On a broad scale, the industry consensus is that 5G will not replace Wi-Fi 6 as a connectivity technology at the device level.

Many industry experts believe that Wi-Fi will coexist with 5G and be a key part of many 5G use cases.[19] However, there is a potential for the convergence of the two technologies into a single radio network backbone for campus, office, and business venues. Two key pieces of research indicate that the convergence of Wi-Fi 6 and 5G is poised to occur.

First, the 3GPP standards have announced the adoption of unlicensed spectrum at 6GHz,[20] which is also planned for Wi-Fi 6. This has the potential to create a distributed antenna system (DAS)

"Two key pieces of research indicate that the convergence of Wi-Fi 6 and 5G is poised to occur."

[19] Will 5G Replace Wi-Fi? https://www.sdxcentral.com/5g/definitions/will-5g-WiFi . SdxCentral.
[20] 3GPP Commits to 5G NR in Unlicensed Spectrum in its next release. https://www.qualcomm.com/news/onq/2018/12/13/3gpp-commits-5g-nr-unlicensed-spectrum-its-next-release . Qualcomm.

that supports both licensed and unlicensed spectrum, communicating with both Wi-Fi and mobile wireless devices. A common radio network for the work location, office, or venue could be the result.

Second, 3GPP published a feasibility study on LAN support for 5G.[21] The concept is that 5G LAN-type services provide LAN emulation capability that works with both Wi-Fi and mobile wireless networks, eliminating the need for a Wi-Fi backbone when the connectivity from Wi-Fi devices and mobile devices converge over the 5G network.

Imagine a future where there are Wi-Fi and mobility devices connecting to a single radio network. That radio network would be based on 5G, delivering extreme mobile broadband using licensed and unlicensed spectrum, massive device support for a multitude of connected devices, and ultra-low latency using premises-based edge computing devices.

Wi-Fi 6 and 5G each have characteristics that can be beneficial for connecting devices. The essence of the usage scenarios from the IMT-2020 vision is to execute a strategy that uses the separate technologies when appropriate and considers when the technologies can be converged.

[21] Feasibility Study on LAN Support in 5G (3GPP TR 22.821 V16.1.0 Release 16). 3GPP Organizational Partners. (2018).

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*5G or Wi-Fi 6 (802.11ax).* Qorvo. (2018).

*What's Best? Wi-Fi 6 (802.11ax) or 5g?.* https://www.qorvo.com/design-hub/blog/whats-best-Wi-Fi-6-80211ax-or-5g. Qorvo. (2018).

*Next Generation Wireless: What You Need To Know About 5G And Wi-Fi 6.* https://www.forbes.com/sites/riverbed/2018/10/18/next-generation-wireless-what-you-need-to-know-about-5g-and-wi-fi-6/ . Forbes. O'Farrell, P. Riverbed. (2018).

*FEDERAL COMMUNICATIONS COMMISSION, 47 CFR Part 15,* [ET Docket No. 18–295, GN Docket No. 17– 183; FCC 18–147]. (December 2018).

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