

The Future of Connectivity

TECHNOLOGY BRIEF

The year is 2024. You are sitting at home and enjoying new experiences like Metaverse - a graphically rich virtual space where you can work, socialize, shop, and play - slowly unfold over wireless infrastructure, as an example:

- Virtually attend live concerts across the globe.
- Virtual reality headsets for multi-player cloud gaming with players worldwide without latency challenges.
- Virtually trying out different dresses or glasses before buying, all done from the comfort of your home.

All this in addition to existing applications like whole-home surveillance using multiple video streaming cameras and video conferencing and telemedicine, which are now enhanced to default 8K or “multiple” 4K video streaming content.

Imagine a network that is able to support all these inherently different experiences simultaneously without lag.

Wi-Fi 7 is that network.



Wi-Fi Economic Impact

Global economic surplus value of Wi-Fi: US\$3.3T in 2021 to **US\$4.9T in 2025**.¹

4.4 billion Wi-Fi devices will ship in 2022. 18 billion Wi-Fi devices in use.²

More than **350 million Wi-Fi 6E devices** will enter the market in 2022.³

In 2021, global **connected devices** were set to hit **46 billion**.⁴

According to a 2021 survey from Deloitte, **the average US household has 25 connected devices** (up from 11 in 2019).⁵

More than **5 billion people around the world use the internet**. That's **63.1 percent** of the world's population.⁶

Just over the **past 12 months**, data shows that 192 million new users came online. The average global internet user spends almost **7 hours** online each day.⁶

¹ <https://www.wi-fi.org/discover-wi-fi/value-of-wi-fi>

² <https://www.wi-fi.org/news-events/newsroom/wi-fi-alliance-2022-wi-fi-trends>

³ <https://www.wi-fi.org/news-events/newsroom/wi-fi-alliance-2022-wi-fi-trends>

⁴ <https://www.juniperresearch.com/press/internet-of-things-connected-devices-triple-2021>

⁵ <https://www2.deloitte.com/us/en/insights/industry/telecommunications/connectivity-mobile-trends-survey.html>

⁶ <https://datareportal.com/global-digital-overview>

Connectivity today & tomorrow: Making efficient use of the spectrum

For over 20 years, the technology underlying much of today’s connectivity has been Wi-Fi – as developed by the IEEE 802.11 working group. Air is the “shared medium” of this wireless technology. You will hear the term “spectrum,” which refers to the invisible radio frequencies (the “air”) that wireless signals travel over. These signals enable us to connect to the world.

Wi-Fi operation works on this basic principle: Sense the medium before transmitting, and back off if there is an ongoing transmission. This will avoid most collisions on the network. Repeat the process when the current transmission ends.

With that in mind, to speed up wireless data transmission to each device, there is a continued need to: minimize the airtime consumption per device; and, maximize the channel usage while further increasing the network efficiency. Dense environments such as multi-dwelling units (MDUs) and homes with dozens of wireless devices need this optimization.

Wi-Fi 6 changed home connectivity evolving from a few devices with up to 150Mbps of peak throughputs to many devices with up to 4.8Gbps of peak throughputs. Wi-Fi 6 is marketed by the Wi-Fi Alliance as the sixth generation of the Wi-Fi. It is known in the IEEE 802.11 working group as 802.11ax or by its technical name “High Efficiency”.

The coming communications standard, Wi-Fi 7, is built on the IEEE 802.11be standard, technically referred to as “Extremely High Throughput (EHT)” and doubles the bandwidth to 320MHz versus Wi-Fi 6 at 160MHz. It creates multiple links between access point and clients allowing transmission of large amounts of data quickly. Wi-Fi 7 further optimizes the usage of the same limited spectrum while making the connection significantly robust.

Wi-Fi 7 is built to maximize overall network capacity, minimize latency, and increase speed to every device at home, including legacy devices. Wi-Fi 7 is built for the Metaverse, and much more.

This Technology Brief shares how technology innovation in Wi-Fi 7 delivers the most advanced connectivity to the consumer while ensuring optimal spectrum usage.

Wi-Fi 7: A more reliable, robust experience

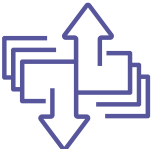
Over the years, Wi-Fi has become ubiquitous as the demand for data, video, and gaming has surged. That demand started to create a significant spectrum shortage; the “airways” became clogged with data. To alleviate the spectrum crunch, in 2021, several countries expanded the Wi-Fi spectrum by 1.2 GHz to a total of ~1.8 GHz. This was accomplished by using the 6 GHz (6E) spectrum band, adding to the previously existing 2.4 GHz and 5 GHz bands. (Note: Spectrum availability varies from country to country.)

For the first time in the industry, a standard is written that optimally uses all three bands: 2.4GHz, 5GHz and 6GHz of Wi-Fi.

Wi-Fi 7 brings the benefits of higher throughput, reduced latency, and enhanced robustness. New technologies make up the “toolkit” that gives a reliable, more robust Wi-Fi experience.


The Toolkit of Advanced Technology

Throughput




- 6GHz: 320MHz
- 4K QAM
- MRU

Latency Reduction

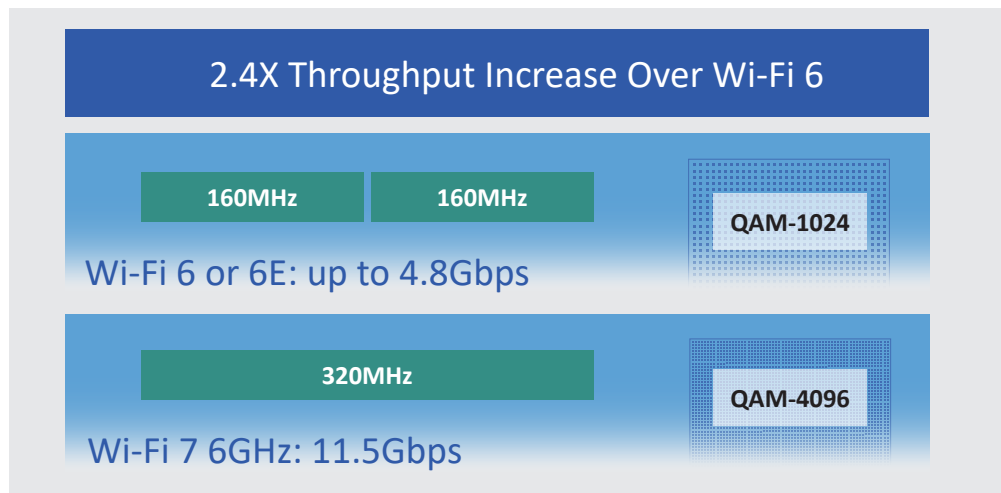


- Multi RU (MRU)
- Multi Link Operation (MLO)
- Restricted TWT

Enhanced Robustness



- MRU
- MLO

Throughput: Double the bandwidth to deliver more and faster content**Wi-Fi 7 makes the wireless pipe wider**

- Doubles bandwidth from 160MHz (as in Wi-Fi 6) to 320 MHz
- Increases modulation from 1K QAM to 4K Quadrature Amplitude Modulation (QAM)

Wi-Fi 7 equals faster uploads and downloads

- Improved peak throughput by a factor of ~x2.4
- Up to 11.5 Gbps of throughput on 6 GHz band

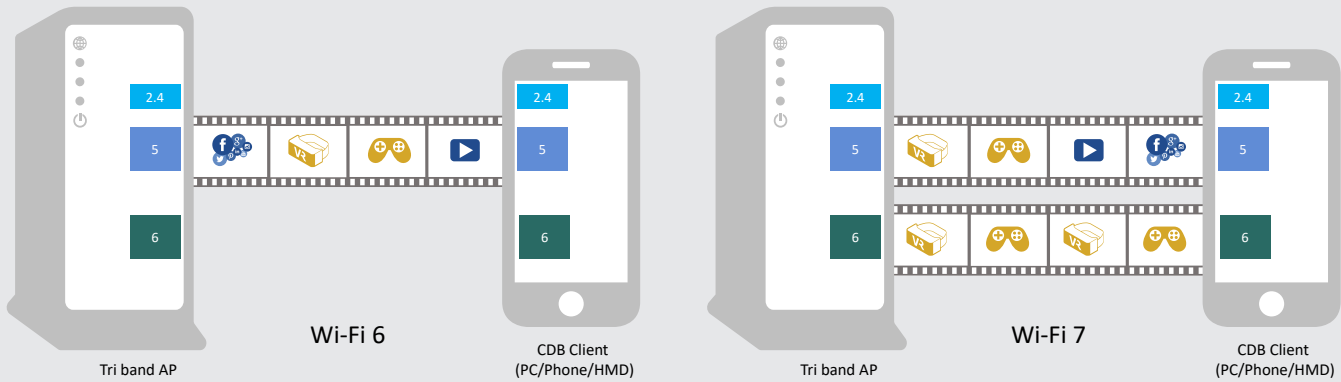
Beyond speed and feed: Reduce network latency and increase link robustness**Wi-Fi 7 decreases delays in transmission for time-sensitive applications such as gaming and the Metaverse**

Over the coming years, the Metaverse will gain momentum - while working or learning from home, people will use VR headsets to create enhanced virtual work environments. Immersive VR will exist where a real keyboard and computer screen overlay in the virtual environment.

Such applications have stringent criteria for throughput, latency, and jitter. This optimization is especially needed in dense environments such as Multi-Dwelling Units (MDU).

Features like Multi Link, Multi Resource Unit, and Restricted TWT are part of the Wi-Fi 7 toolkit which individually or in combination can improve next-gen experiences.

Multi-Link Operation (MLO)



Wi-Fi 6 allows only one link to be active between the router and the client. Depending on the level of interference, consumers who are gaming or using an XR experience may see a significant delay.

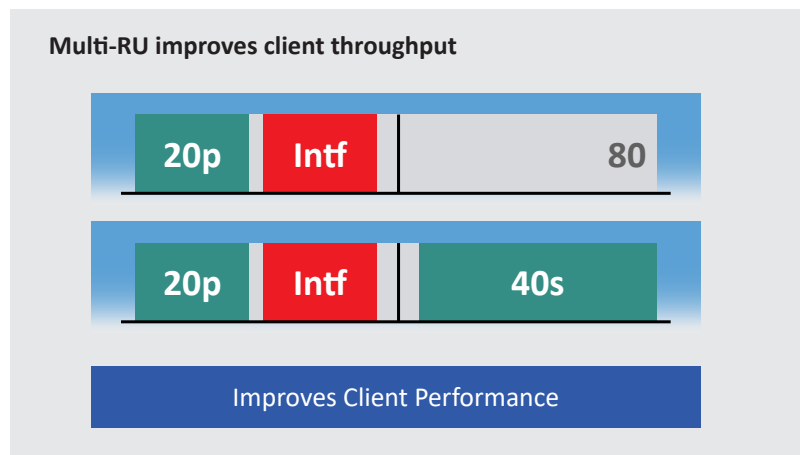
Wi-Fi 7 brings Multi-Link, a technology that enables an access point (AP) and a client to connect over multiple links. Aggregation of links can happen within the same band - (5 GHz: UNII1 and UNII3) or even within two different bands (2.4 GHz and 5 GHz, 2.4 GHz and 6 GHz, 5 GHz and 6 GHz). The gaming or XR connection is faster (at times doubling the throughput), and latency and jitter are reduced while improving network efficiency.

Multi-Link also provides robustness and reliability. In the presence of interference or congested environments, the traffic can switch between two “pre-established” links.

Multi Resource Unit (MRU) provides robustness too while improving client throughput: MaxLinear’s AdaptiveBoost

If there is an interference, radar on 5 GHz or an incumbent on 6 GHz, bandwidth and throughput to the client could sharply drop as shown in the figure below. If the client is operating in a radar channel in 5 GHz, it may even have to exit that channel.

Wi-Fi 7 allows puncturing the small section of bandwidth where the interference lies and using the remaining channel effectively. Using MaxLinear’s AdaptiveBoost technology paired with a smart scheduler, we could increase throughput to the client(s) by ~200% on 80 MHz and ~600% on 160 MHz channels.



Wi-Fi 7 is bliss for 2.4 GHz band

Like Wi-Fi 6/6E, all features of Wi-Fi 7 also work on 2.4 GHz.

2.4GHz offers a better range than 5 GHz and 6 GHz, providing better client mobility within the home without breaking the connection or triggering a new association and connecting to a different Wi-Fi channel. A client can seamlessly switch over from 6/5 GHz to 2.4 GHz with the Multi-Link feature. For Wi-Fi 7 clients, band steering application, which creates additional overhead and latency, is unnecessary.

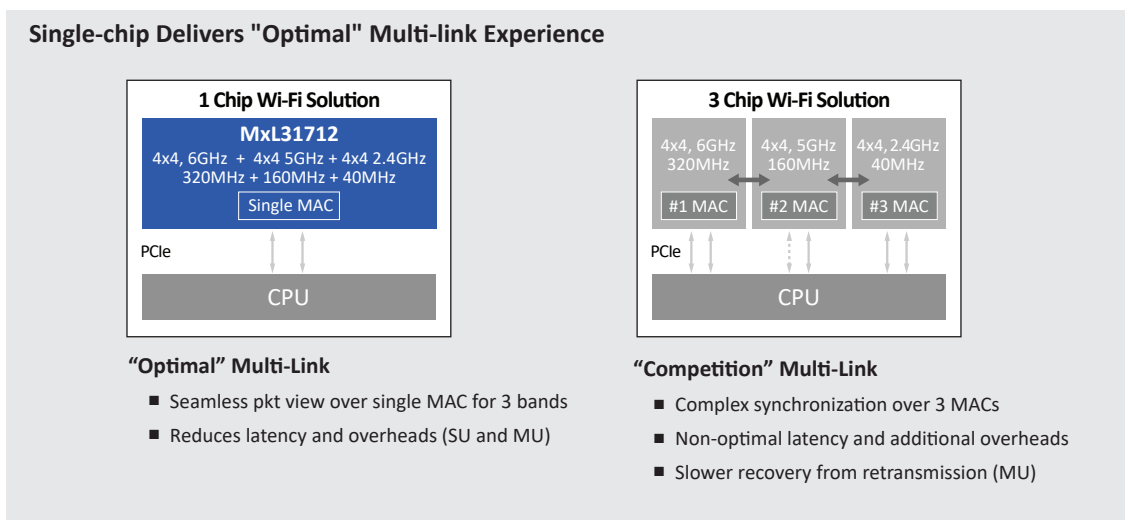
Clients supporting Wi-Fi 7 on 2.4 GHz will also have higher transmission rates improving the throughput and lowering the airtime, which makes legacy clients faster



MaxLinear’s single-chip SoC provides significant Wi-Fi 7 value

MaxLinear Wi-Fi 7 advantages include:

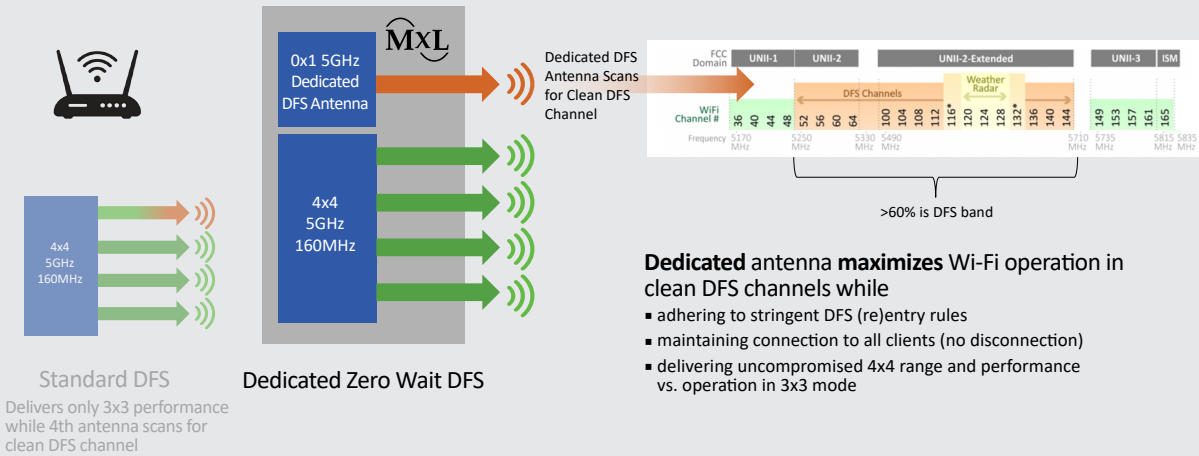
- **Lower total system cost and development time:** Single chip reduces total Bill of Material (BOM) and board complexity, with less time spent on thermal, mechanical, and PCB designs. Single chip also drives smaller form-factor which enables system integrators to build more elegant product designs.
- **Seamless, coordinated view of multi-bands for optimal MLO experience:** Single chip has one coordinated view of data flows across multiple channels in dual- and tri-band configurations for faster recovery from retransmissions during interference. This greatly improves link robustness and client efficiency, enables deterministic latency and higher throughput for demanding high-bandwidth applications in heavily congested environments like MDUs (Multi-Dwelling Units).



- **Enhanced network efficiency with “On-the-fly MAC”:** MaxLinear’s improved proprietary “on-the-fly MAC” architecture optimizes large and small packet scheduling and performance. It reduces overheads in the data path and enables quick recovery from data retransmissions during interference.
- **Reduced dead spots with dedicated chain for ZWFDS:** Provides seamless operations in DFS channels while adhering to stringent DFS (re)entry rules. Delivers uncompromised 4x4 range and performance reducing dead spots while offering best-in-class user experience.

Dedicated zero wait dynamic frequency selection (ZWDIFS)

Seamless DFS Operation



Maxlinear Wi-Fi used with Maxlinear’s gateway and access products, AnyWAN™, is highly optimized to deliver unparalleled performance, end-to-end quality of service, and line-rate throughputs inside and outside of the home.

Summary

A new study commissioned by the Wi-Fi Alliance predicts the rate of growth for the value of Wi-Fi will be a remarkable 150% between 2018 and 2025. The global economic surplus value of Wi-Fi will rise to a staggering US\$4.9 trillion by 2025. This evaluation includes contributions from the use of Wi-Fi by consumers, businesses, service providers, and more.

Wi-Fi’s success is based on continuous improvement and development. MaxLinear continues to invest in the technologies and innovation needed to advance Wi-Fi today and in the future.

Wi-Fi 7 enhances the performance of currently connected home use cases and is vital for advanced XR, gaming and the Metaverse – applications that are significantly impacted by latency, jitter and bandwidth-sensitive issues.

MaxLinear will deliver the complete Metaverse experience working with the client ecosystem. Beyond Wi-Fi, MaxLinear delivers on WAN technologies like MultiWAN, Fiber and Cable that connect the data pipe from operators to Wi-Fi inside the home, providing end-to-end quality of service required.



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