Pioneering the Future with Wi-Fi 8

Part Three: Always-On Connected

MediaTek Filogic White Paper

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Content

Key Insights

Wi-Fi 8 introduces:

- Improved connection quality when roaming among mesh network nodes
- Improved coverage via distributed-tone resource unit (DRU) and/or enhanced long range (ELR)
- Reduced power consumption, enhancing energy efficiency and always-on sustainability

Introduction

Since its standardization by IEEE 802.11 in 1997, Wi-Fi technology has become a cornerstone of global wireless network communication. By utilizing radio waves to transmit data between devices, Wi-Fi enables a wide range of devices—such as personal computers, smartphones, tablets, and other smart devices—to access the internet and communicate seamlessly without physical connections. Over the years, Wi-Fi has evolved through numerous iterations, starting with the initial 802.11b and advancing to the cutting-edge 802.11be (Wi-Fi 7), with each generation offering improvements in speed, coverage, and connection quality. This evolution has established Wi-Fi as one of the crowning technological achievements of the 21st century, transforming it from a basic, low-rate data wireless conduit into a robust, high-performance connectivity solution. These advancements have opened the door to innovative use cases and applications, revolutionizing the way we connect and interact with the digital world.

MediaTek Filogic – Pioneering Wi-Fi Innovation

The forthcoming Wi-Fi 8 aims to prioritize a pivotal aspect of wireless communication that has become increasingly critical: reliability. Recognizing the ever-growing quest for reliable wireless connectivity, the IEEE 802.11 Working Group has designated Wi-Fi 8 for Ultra High Reliability (UHR) and has formed the Task Group bn to spearhead this development. Industry experts from around the globe are contributing a wealth of potential features to this endeavor. MediaTek Filogic, as an active specification contributor and leading product provider for Wi-Fi solutions, is excited to share its technological vision through a series of white papers. These documents will dissect the myriad features under consideration, organized into four key categories:

1. Fast: Strategies to enhance the data throughput between access points (APs) and stations (STAs).

2. Reliable: Methods to bolster the reliability of wireless services.

3. Always-on Connected: Techniques to minimize service interruptions and maintain constant connectivity.

As we advance on this journey to the next frontier of Wi-Fi technology, MediaTek Filogic invites you to join in exploring the innovations that will define the future of wireless connectivity..

Wi-Fi 8 Overview and Trends

The parity of Wi-Fi and 5G

Wi-Fi has emerged as the most viable alternative to traditional wireline connectivity solutions such as Ethernet, fiber, and coaxial cables. It offers users the convenience of cable-free flexibility for many devices like laptops and televisions, without the constraints of physical connections. While the peak throughput of Wi-Fi often exceeds the requirements of many applications, users may sometimes experience intermittent jitter during streaming or video conferencing. This is indicative of Wi-Fi's susceptibility to environmental factors impacting signal quality and consistency. In many residential environments, cable-equivalent reliability remains a significant challenge for Wi-Fi technology.

In the current landscape, two prominent wireless technologies dominate the market: cellular 5G and Wi-Fi. While there have been debates about the potential for one to replace the other, it is inevitable that both will coexist in the foreseeable future due to several factors:

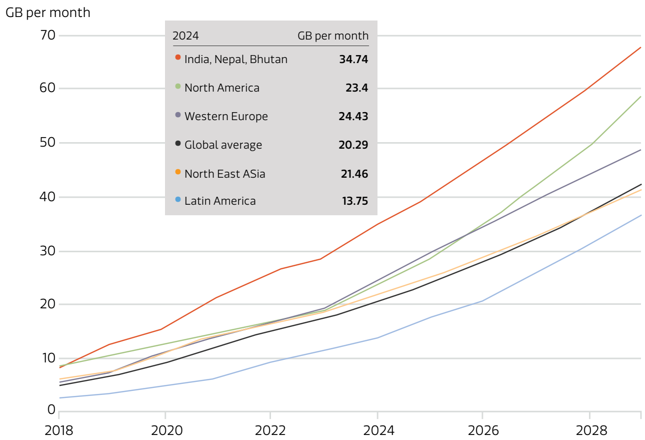
1. Cost considerations: the greater cost of 5G equipment and services compared to Wi-Fi, largely due to the expensive licensing fees associated with 5G spectrum allocation.

2. Device compatibility: most consumer electronics are equipped with Wi-Fi capabilities, whereas 5G / 4G connectivity is must less common. For instance, Wi-Fi-only tablets continue to dominate the tablet market.

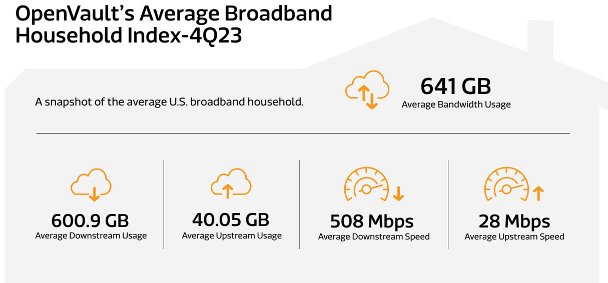
3. Data offloading: according to a study by Cisco, in 2022 over 50% of global mobile data traffic was offloaded to Wi-Fi networks, highlighting the significant role Wi-Fi plays in managing data traffic.

4. Data volume: data usage figures below illustrate the disparity in usage between the two technologies. In the United States, the average monthly data usage per person was approximately 23GB over 4G/5G, while broadband eclipsed this at 650GB, as shown in Figure 1, or 250GB per person, where most broadband data is carried by Wi-Fi. This indicates that Wi-Fi handles a much greater magnitude of data than 4G/5G. Projections for 2030 suggest that while 4G/5G may carry around 60GB per month, which is still far below the data carried by Wi-Fi. Based on the study, it will surpass 1TB per broadband subscription in 2028 or around 400GB per person.

These points highlight the complementary nature of 5G and Wi-Fi, with each serving distinct roles in the wireless ecosystem. Wi-Fi's significant data handling capacity, along with cost-effectiveness and widespread device integration, ensures its continued relevance amidst the expanding 5G infrastructure.



(a) Mobile data traffic per active smartphone by Ericsson



(b) A snapshot of the average US broadband household by OpenValut & Fierce network

Figure 1. Data consumption via cellular mobile, and household broadband per month

Evolution of Wi-Fi 8

Wi-Fi 8 is designated as Ultra-High Reliability (UHR), and aims to enhance effective and reliable communication. This generation of Wi-Fi shifts the focus to improving effective throughput, which refers to the actual data transfer rate experienced by users in real-world environments. For example, the flagship APs are equipped with three streams across each frequency band: 2.4GHz, 5GHz, and 6GHz. Most Wi-Fi clients typically support up to two streams and two bands. For smartphones and tablets, typically the channel bandwidth available to clients is less than the maximum defined by the standard. For instance, most iPhone models support 80MHz bandwidth on 5/6GHz bands, except for the latest models. The capabilities of these smartphones are well-suited for streaming, requiring 25Mbps for 4K video on Netflix, and 100Mbps for 8K video on YouTube. However, the latest chipsets for laptops, PCs and smart TVs, and sufficiently advanced IoT hardware are more capable, supporting the maximum bandwidth in the respective bands.

The table below summarizes the key features and parameters from Wi-Fi 4 through Wi-Fi 8. The concept of multiple AP coordination, introduced in Wi-Fi 7, was deferred to Wi-Fi 8 due to its complexity. The popularity of mesh networks has made multiple APs more common in homes, enhancing the Wi-Fi coverage. However, without effective coordination, these APs may contend and share common spectrum resources, often resulting in only one AP utilizing the spectrum at any given time. Thus, improving performance is a critical focus.

To address these challenges, dynamic sub-channel operation and non-primary channel usage have been proposed. These features are designed to optimize performance when there is a disparity in the number of streams and channel bandwidth among devices. For example, a BW320 (320MHz bandwidth) AP, when communicating with a BW80 (80MHz bandwidth) client, must limit itself to BW80, thereby losing 75% of its transmission capability. Dynamic Sub-Channel Operation (DSO) addresses this issue effectively. Non-Primary Channel Access (NPCA) aims to resolve scenarios where the primary channel is unavailable, allowing communication between the AP and the client to occur via a non-primary channel.

Mitigating interference and minimizing latency present formidable challenges in the realm of Wi-Fi services, particularly due to the inherent uncertainties involved. Wi-Fi 8 introduces a robust suite of features designed to address these issues effectively. Key among these features are In-Device Coexistence (IDC) mechanisms, TXOP preemption and HIP EDCA. These advanced capabilities are pivotal in delivering a more reliable and responsive Wi-Fi experience.

Ensuring comprehensive coverage remains a significant challenge, particularly in scenarios where users seek privacy or need to occupy less accessible areas, such as corners of a building. In such cases, the Wi-Fi service can become intermittent, leading to poor quality and unacceptable communication experience. To overcome these limitations and support voice and other low data rate applications at the network's edge, Enhanced Long Range (ELR) has been proposed.

Here is a comparative table highlighting the technology evolution from Wi-Fi 4 through Wi-Fi 8:

Feature	Wi-Fi 4	Wi-Fi 5	Wi-Fi 6 / 6E	Wi-Fi 7	Wi-Fi 8
Maximum Channel Bandwidth (MHz)	40	160	160	320	320
Frequency Bands (GHz)	2.4 and 5	5	2.4, 5 and 6	2.4, 5 and 6	2.4, 5 and 6
Max PHY rate	150Mbps * 4 600Mbps	866Mbps * 8 ~6.9Gbps	1200Mbps * 8 ~9.6Gbps	2880Mbps * 8 ~23Gbps[1]	2880Mbps * 8 ~23Gbps
Modulation	64 QAM	256 QAM	1024 QAM	4096 QAM	4096 QAM
Spatial Streams	4	8	8	8	8
MU-MIMO		DL only	UL & DL	UL & DL	UL & DL
Target Wait Time			Individual, broadcast	Restricted	Coordinated
OFDMA (# RU per STA)			Yes (single)	Yes (multiple)	Yes (multiple)
Multi-Link Operation				Yes	Yes
Multi-AP Coordination					Yes
DSO/NPCA					Yes
IDC					Yes
TXOP Preemption/HIP EDCA					Yes
Enhanced Roaming					Yes
Enhanced Power Saving					Yes
DRU					Yes
ELR					Yes
IEEE Standard	11n	11ac	11ax	11be	11bn

Wi-Fi service has become an integral part of daily life due to its convenience and flexibility. In the past, individuals commonly sought out Ethernet connections upon arriving at hotels; nowadays travelers almost exclusively check for Wi-Fi access instead. While cellular provides long range mobile access, it cannot fully replace the utility of Wi-Fi for most users. As indicated in the preceding section, the final leg of Internet connectivity is increasingly transitioning to Wi-Fi and cellular, with Wi-Fi maintaining a dominant position in this space.

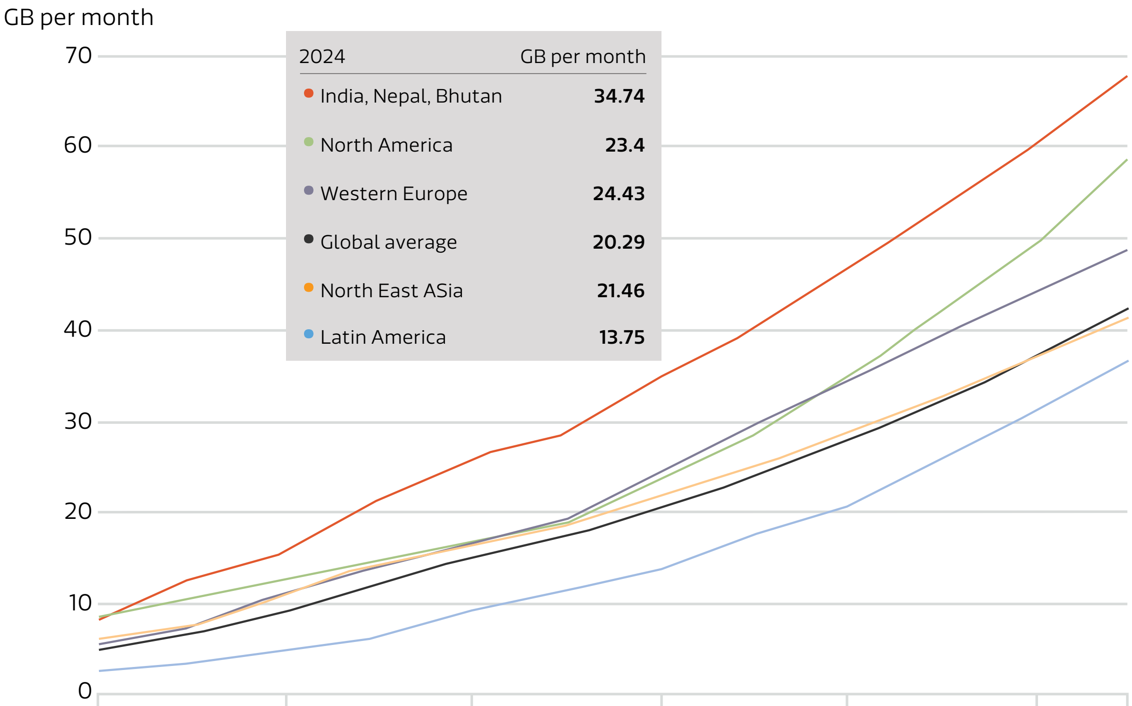


Figure 2. Value of Wi-Fi by the numbers.

Wi-Fi is also a key contributor to the global economy. The number of cumulative Wi-Fi devices shipped was 45.9 billion in 2024, with around 46% in active use based on the latest WFA study. In 2024, it was estimated that 4.1 billion devices were shipped, which represents a 7% annual growth. In these devices, around 30% are smart phones, and 6.5% are Wi-Fi 7 devices.

The global economic value provided by Wi-Fi reached $4.3 trillion USD in 2024 and will reach $4.9 trillion in 2025 based on the study conducted by WFA across 29 economies. United States and European Union lead the world with $1.6 trillion USD and $637 million USD, respectively.

Further analysis shows that growth in the EU region is primarily driven by the development of the Internet of Things (IoT), the use of Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), and eXtended Reality (XR), along with free wireless internet. Additionally, the EU's opening of 500 MHz of bandwidth in the 6 GHz band for wireless network use gives a significant boost.

The United States represents the most extensive use of wireless networks globally, where 85% of households with broadband have wireless network services, and 55% of mobile users access the internet via Wi-Fi networks rather than cellular. With the FCC granting the full 6 GHz band (1200 MHz of bandwidth) for Wi-Fi network use, the economic contribution of wireless networks will grow to $1.58 trillion in 2025.

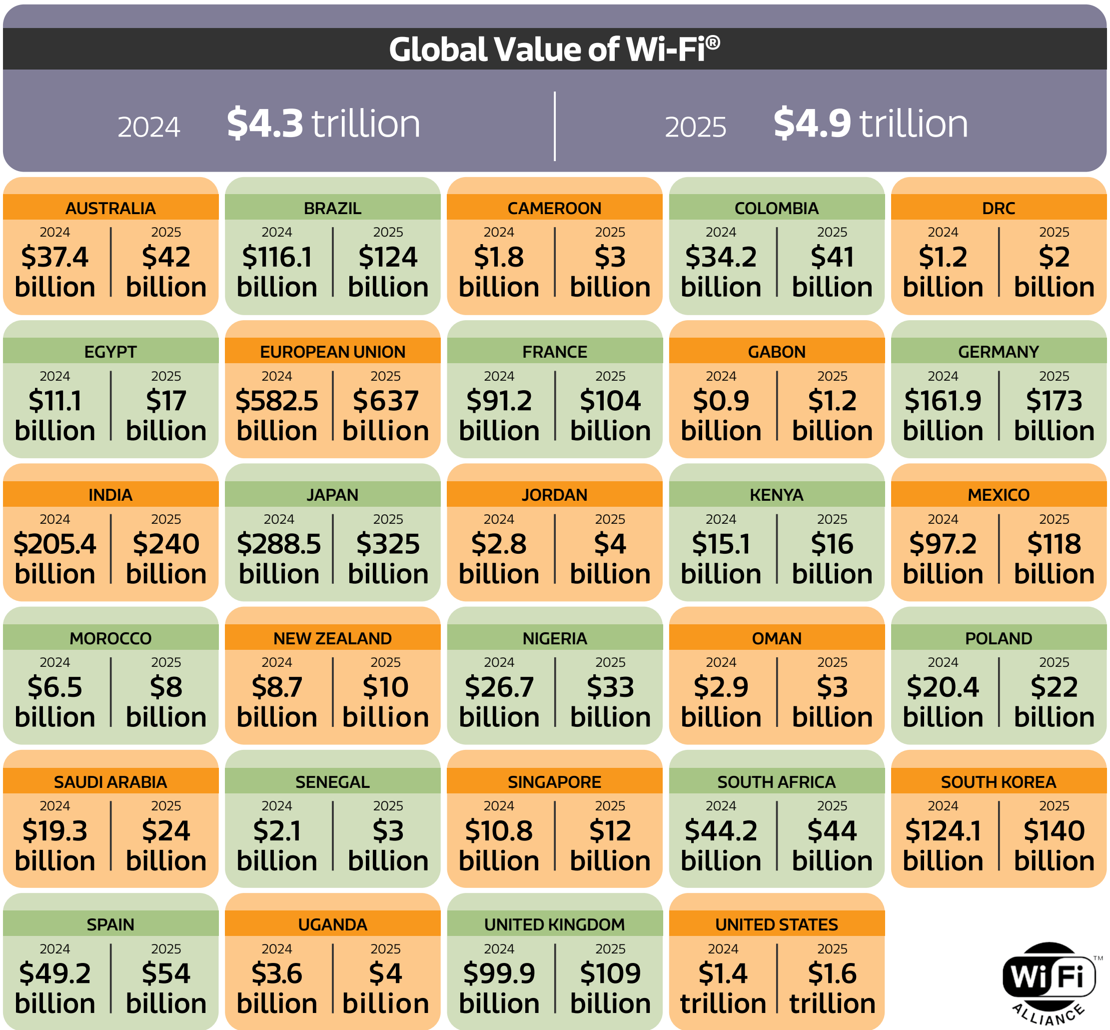


Figure 3. Global value of Wi-Fi

Among the 27 main economies, China has the largest Passive Optical Network (PON) deployment. There are more than 650 million broadband subscribers, where 28.6% have 1Gbps or above high-speed broadband access (mid-2024). The average connection speed is 487.6Mbps, which represented an annual growth of 17.9%. The three major operators shipped the most PON gateways; all of which had Wi-Fi available either via direct integration, or a separate / existing Wi-Fi AP.

With the number of Wi-Fi devices increasing per household, the demand for a better quality Wi-Fi experience is expected. The ever-growing number of wireless applications ensures Wi-Fi will continue to play a leading role enabling next generation use cases and applications since there is no replaceable technology in the foreseeable future.

The Focus of Filogic Wi-Fi 8

Wi-Fi 8 prioritizes reliability as its main objective, aiming to provide deterministic wireless services for applications such as XR, industrial automation, e-Health, and more. This focus on reliability is a significant shift from previous Wi-Fi standards, which primarily concentrated on increasing speed and throughput.

According to the IEEE 802.11 timeline, the target final approval date of IEEE 802.11bn, which encompasses Wi-Fi 8, is set for September 2028. The certification process for related products generally launches a year before the standard ratification. For instance, the first Wi-Fi 7 products were shipped in late 2023, with Wi-Fi certified Wi-Fi 7 products launching in early 2024, while the Wi-Fi 7 standard, 11be, is expected to be approved in September 2024, that is a 4-month delay from the original schedule. Based on this 4-year cadence, Wi-Fi 8 products are anticipated to hit the market in late 2027. That said, an exception to this cadence was observed in Wi-Fi 4, where the standardization process was prolonged, resulting in the pre-N products introduced approximately 3 years before the standard was officially finalized.

The development cycle for a Wi-Fi standard at IEEE is approximately 6 years, as illustrated in the figure below, however products often become available before the finalization of the standard due to manufacturers developing products based on draft versions of the standard. For example, even though Wi-Fi 7 is finally published in July 2025, Wi-Fi 7 devices have been in the market since the end of 2023. For Wi-Fi 8, the first products are expected to be available in early 2028, pacing for early adoption of the latest Wi-Fi technologies before the standard is officially completed. Any subsequent specification updates before the final approval need to be accommodated by certification or product update (firmware) to ensure interoperability.

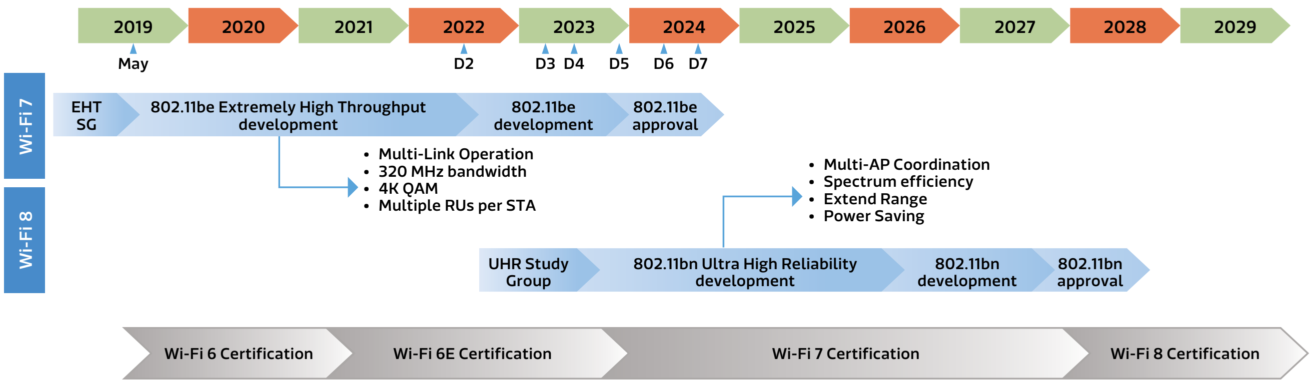


Figure 4. IEEE and WFA milestone about Wi-Fi 7 and Wi-Fi 8.

Each iteration of the IEEE 802.11 standards has progressively enhanced the capabilities of Wi-Fi. Wi-Fi 7 focused on maximizing peak throughput with innovations such as Multi-Link Operation, 320MHz bandwidth and 4K-QAM technology. Theoretically, the maximum Physical Layer (PHY) rate for a tri-band 4x4 Wi-Fi AP could reach around 19Gbps. When accounting for overhead, the actual peak throughput in a clean environment is approximately 80% of the PHY rate. Such pristine conditions are typically found only in a lab environment, rather than everyday scenarios.

The Wi-Fi 8 Advantage

With Wi-Fi access is becoming a staple of every household, interference is an inevitable challenge. The situation is further complicated by the deployment of multiple APs or mesh networks to ensure comprehensive home coverage, often sharing the same channel to minimize channel switching latency. Consequently, the throughput experienced by a user at any given moment may be significantly lower than the peak throughput. For instance, streaming a 4K video from Netflix requires 25Mbps, which is a fraction (less than 2%) of the peak throughput of a tri-band 4x4 Wi-Fi 7 AP. Despite this, users may still encounter jitter due to protocol overhead and random interference. This real-world throughput is referred to as effective throughput, which is the actual speed users can expect from their Wi-Fi connection. When effective throughput falls below 25Mbps, users may experience noticeable disruptions in their streaming quality. Wi-Fi 8 highlights the cooperation of multiple APs to minimize the interference and maximize the effective throughput.

Enabling Reliable, Actual Performance in Everyday Wi-Fi Environments

In this white paper we have divided our vision into several categories, with each category encompassing a set of features. It is important to note that this categorization is subjective, as each feature can contribute to multiple categories.

This chapter is dedicated to the exploration of the "Always-On Connected" category within Wi-Fi technology. The term "Always-On Connected" encapsulates the pursuit of improved Wi-Fi access availability, encompassing both the expansion of coverage areas and the extension of service uptime. Our aim is to delve into the tangible performance outcomes that users can depend on during their routine interactions with Wi-Fi networks. To this end, we have pinpointed a suite of cutting-edge technologies—namely, UHR roaming, power-saving features, distributed-tone resource units, and ELR. The subsequent sections will present real-world scenarios that exemplify the critical enhancements these technologies bring to Wi-Fi availability, thereby illustrating their impact on everyday connectivity experiences.

Enhanced Roaming

User scenario: Dylan and his friends live in a three-bedroom apartment that lacks Ethernet infrastructure. To ensure comprehensive Wi-Fi coverage throughout their home, they opted for a mesh network with Wi-Fi backhaul. The primary AP (AP1) is strategically located in the living room, connected directly to the internet via a Gigabit Passive Optical Network (GPON) connection, serving as the Mesh portal. The secondary APs, AP2 and AP3, act as Mesh Nodes and are positioned along the hallway, with one in the middle and the other at the end. One day, while Dylan was engaged in a conference call at the living room, he walked to the kitchen to grab some water. As he moved through the hallway, he noticed a sudden deterioration in audio quality during the call.

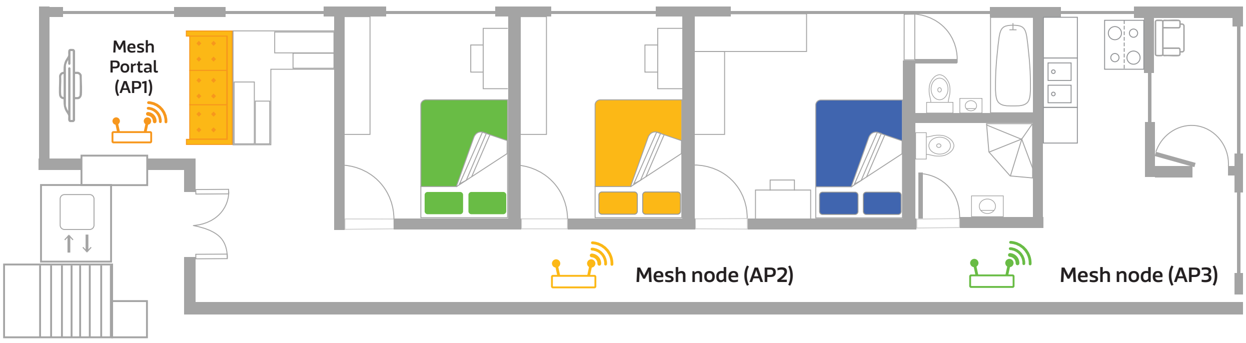


Figure 4. A mesh network is built with 3 APs

Issue: As Dylan moved from the living room to the kitchen, his phone switches Wi-Fi connection from AP1 to AP2, and subsequently to AP3. This handover, or roaming process, may have data received by the original AP after the phone switched to the next AP. Consequently, some data packets were dropped, adversely affecting the audio quality. This resulted in silent data loss for UDP and retransmissions for TCP, both of which impact the call quality and introduce additional latency.

Challenge: In traditional Wi-Fi roaming, disassociating from the current AP and reassociating with the target AP increases packet latency. This process also causes packet loss, as buffered data in the current AP are dropped after disassociation. The interruption in connectivity during the transition period leads to a temporary loss of network service. Consequently, users may experience degraded performance and interruptions in their network-dependent applications.

Technology: Wi-Fi 7 introduced Multi-Link Operation (MLO), enabling Multi-Link Devices (MLDs) to connect and transmit data across multiple frequency bands and channels simultaneously. In Wi-Fi 8, the roaming experience can be improved when a Non-AP MLD connects to different AP MLDs. To support this, the IEEE 802.11 architecture introduces the Seamless Mobility Domain (SMD) BSS Transition mechanism. SMD allows Non-AP MLDs to operate across multiple AP MLDs, with a Seamless Mobility Domain Management Entity (SMD-ME) handling authentication, association, and key management. This enables Non-AP MLDs to move between AP MLDs within the same SMD without reassociation, minimizing connectivity loss and ensuring a seamless user experience.

Two data path models between the non-AP MLD and the Distributed System (DS) are supported.

- Separate MAC Service Access Point (SAP) per AP MLD of the SMD (Figure 6a)
- One MAC SAP for the SMD (Figure 6b)

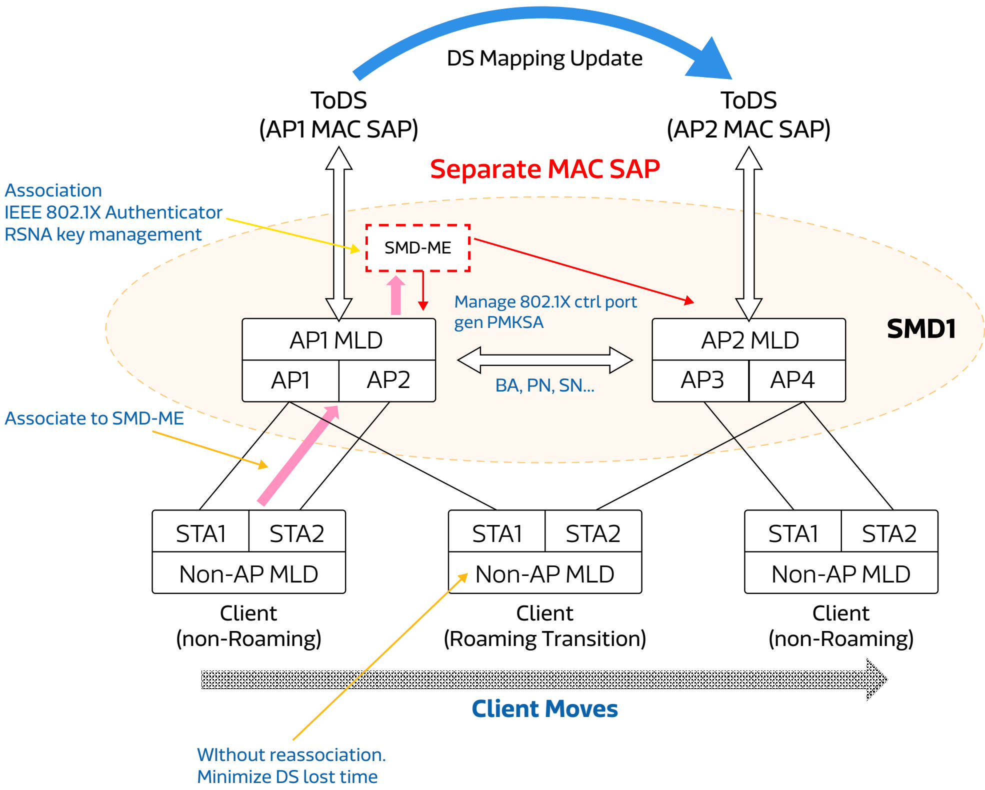


Figure 6a. SMD BSS Transition within Separate MAC SAP SMD

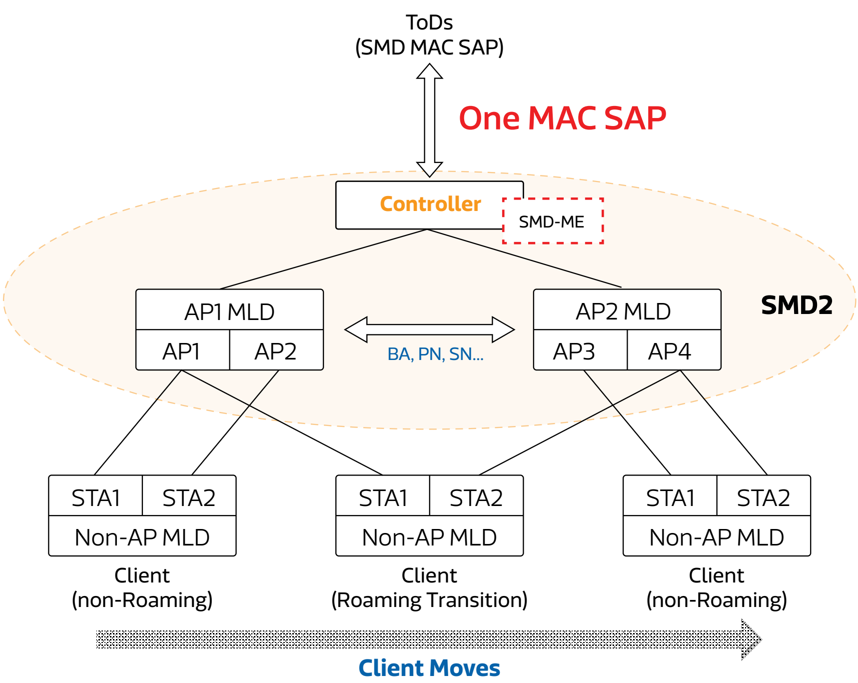


Figure 6b SMD BSS Transition within One MAC SAP SMD

SMD BSS Transition includes the following procedures:

- SMD BSS transition discovery:
  A Non-AP MLD discovers neighboring AP MLDs and their SMD support through active scanning, BSS transition management, or neighbor reports.
- Initial association to the SMD-ME:
  To perform SMD-level association, a Non-AP MLD authenticates and associates with the SMD-ME using the SMD Information element, during which an SMD-level Pairwise Master Key Security Association (PMKSA) and Pairwise Transient Key Security Association (PTKSA) are established based on the SMD Identifier.
- Target AP MLD selection:
  The STA may send a BSS Transition Management Query frame to its current AP, requesting recommendations for candidate target AP MLDs. The AP may also send an unsolicited BSS Transition Management Request frame to the STA, proactively recommending candidate APs for transition.
- SMD BSS transition preparation:
  The SMD BSS transition preparation involves transferring or renegotiating the Non-AP MLD's context with the target AP MLD and setting up the corresponding links. The non-AP MLD sends a separate preparation request to each candidate target AP MLD and, upon successful preparation, attempts the transition with one target at a time, retrying with another if the first attempt fails.
- SMD BSS transition execution:
  During an SMD BSS transition, the Non-AP MLD sends an execution request to either the current AP MLD or the target AP MLD to complete the transition, after which any required context are transferred between the current AP MLD and the target AP MLD. DS mapping and keys are updated as necessary.

With efficient context transferring and buffered data management, next-generation MediaTek Filogic solutions will ensure that users experience a continuous and seamless connected service while transitioning between APs. This advanced capability is pivotal in delivering a smooth and uninterrupted wireless experience, particularly in environments where users move frequently between coverage areas.

Enhanced Power Saving

Scenario: Stephen and his family are avid campers, but often require internet access during their outdoor adventures. Initially, Stephen utilized his smartphone as a Wi-Fi hotspot to allow his children to connect to the internet. However, this setup necessitated the use of additional power banks to ensure sufficient battery life for the duration of their trips. Seeking a more convenient solution, Stephen invested in a 5G CPE device to maintain internet access even when his phone was not available for his children. Despite this upgrade, he encountered a new challenge: the CPE's battery life was inadequate for all-day use. Stephen is now in search of a more robust CPE model that can reliably provide Wi-Fi access for an entire day without the need for recharging or supplementary power sources.

Figure 7. Stephen enjoyed camping with his family and surfing internet via a hotspot.

Issue: The primary issue stems from the fact that the AP operates in full capability mode continuously to ensure it captures all signals from both the internet and Wi-Fi clients. This mode of operation requires the AP to expend energy consistently, even when network traffic is minimal, leading to unnecessary power consumption.

Challenge: Minimizing power consumption in Wi-Fi Listen Mode. A significant challenge for Wi-Fi is managing power consumption. While the power used during active transmission or reception is considerable, it is typically short-lived. In contrast, devices spend a substantial amount of time in listen mode, which can contribute to over half of the total power consumption. Consequently, reducing power usage during this passive state is a critical objective for the advancement of next-generation Wi-Fi.

Technology: In the pursuit of energy efficiency, Wi-Fi 8 introduces a refined approach to power management during listen mode. APs and STAs can now operate at reduced receive capabilities, conserving energy when full power is not required. This low-power state is maintained until the device needs to actively process communication signals.

When it is time to transition from listen mode to active reception, the transmitter issues an Initial Control Frame (ICF) to the receiver. This frame prompts the receiver to send an Initial Control Response Frame (ICR), which signals the device to enhance its reception capabilities to accommodate the incoming data. The ICF and ICR exchange also facilitates the negotiation of critical packet parameters, including bandwidth, the number of spatial streams, and the highest Modulation and Coding Scheme (MCS) to be used.

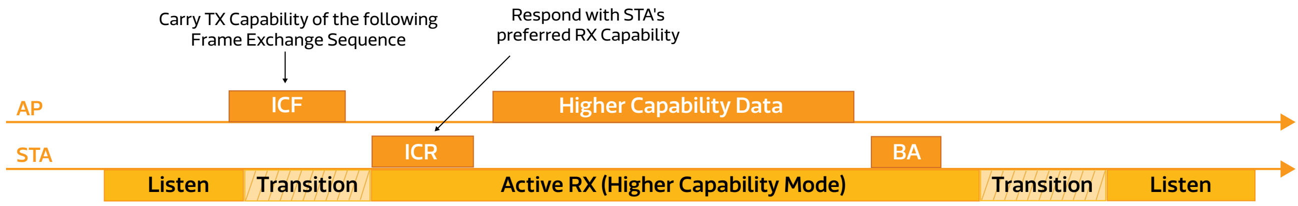


Figure 8. STA's Transition between Listen Mode and Active RX Mode

APs are generally in an always-on state to maintain uninterrupted communication with connected STAs, which results in substantial power consumption. However, with the latest advancements, APs can now be programmed to enter scheduled low-power intervals. During these intervals, APs may switch to Doze, Listen, or Lower Capability modes to save energy. Notably, in Doze mode, APs are not responsive to active scans from unconnected STAs, making this mode appropriate only under certain conditions, such as when an AP is part of an MLD setup and one of the links is not actively managing connections.

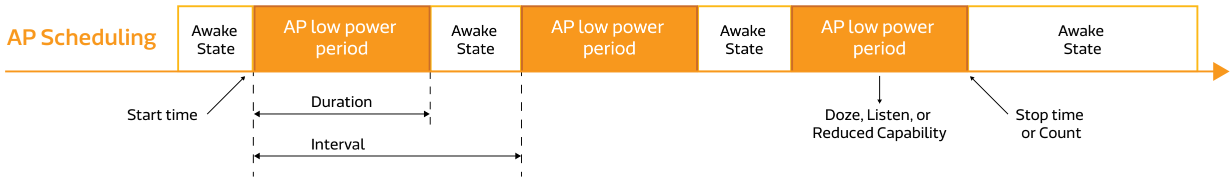


Figure 9. Scheduled Periodic AP Power Saving

MediaTek Filogic's next-generation solutions incorporate Enhanced Power Saving features, providing users with a prolonged always-on connected experience. This innovation is specifically engineered to minimize power consumption, enabling devices to maintain connectivity for longer durations without the need for constant recharging. MediaTek Filogic's intelligent power management system ensures that users can enjoy uninterrupted service, whether engaging in video streaming, web browsing, or other online activities, while also extending the battery life of their devices.

Distributed-tone Resource Unit (DRU)

Scenario: Katherine, Mason, and Bobby, along with several colleagues, were working in a room, each using a laptop computer. To minimize wireless interference, they opted for the 6GHz band, known for its clearer spectrum and higher bandwidth capabilities. Katherine positioned herself close to the AP, while Mason and Bobby were seated at the far end of the table. While downloading large files, Mason and Bobby noticed that their download speeds were approximately half of Katherine's. This discrepancy puzzled them, as they were all connected to the same Wi-Fi AP and were near one another.

Figure 10. Katherine and her colleague work with Wi-Fi in 6GHz

Issue: The root cause is the limitations of Power Spectral Density (PSD), where the transmission power of a Wi-Fi client is typically 6dB lower than that of an AP due to regulatory requirement. Consequently, Mason and Bobby are unable to achieve the highest Modulation and Coding Scheme (MCS) rate, leading to slower download speeds compared to Katherine, who is closer to the AP.

Challenge: Maximizing Uplink Coverage Range within PSD Constraints for Low Power Indoor (LPI) mode in the 6 GHz band. Exclusive to the 6GHz band, the new LPI mode is tailored for a wide array of indoor wireless products that seek to avoid the limitations of Automated Frequency Coordination (AFC) systems. While LPI mode offers a cost-effective solution for device operation within the 6 GHz spectrum, it comes with stringent Power Spectral Density (PSD) limitations that pose a challenge for network performance, particularly in uplink communications.

Technology: Enhancing Transmission Power within PSD Limitations Using Distributed-tone Resource Units. The Power Spectral Density (PSD) limitations in the 6 GHz band, particularly for Low Power Indoor (LPI) mode, are defined on a per MHz basis for each STA. These restrictions pose a challenge for maintaining robust uplink coverage due to the -1dBm/MHz PSD cap, which significantly limits the effective communication range of STAs. To navigate these constraints while aiming to boost transmission power, an innovative approach involves the strategic distribution of transmission tones across a broader spectrum. This method reduces the concentration of tones within any given 1MHz segment.

By dispersing the tones assigned to a small-size Resource Unit (RU) over a wider bandwidth, the transmission for each STA employs non-contiguous tones. This dispersion allows for each tone to be transmitted at a higher power level. For clarity, Resource Units defined in 802.11ax and 802.11be that use contiguous tones are termed regular RUs (rRU), while those utilizing distributed tones are referred to as DRU. This strategy effectively leverages PSD limitations to enhance transmission power, thereby improving spectrum efficiency and overall network performance.

The application of DRU is particularly advantageous in Uplink Trigger-Based Orthogonal Frequency Division Multiple Access (UL TB OFDMA) scenarios. When compared to employing rRUs of the same size, the use of DRUs allows all tones to benefit from increased transmit power, significantly boosting spectrum efficiency. Simulation results demonstrate a notable Range versus Rate (RvR) improvement, with a potential range extension of up to 40 meters when utilizing four distributed-tone RU242 STAs.

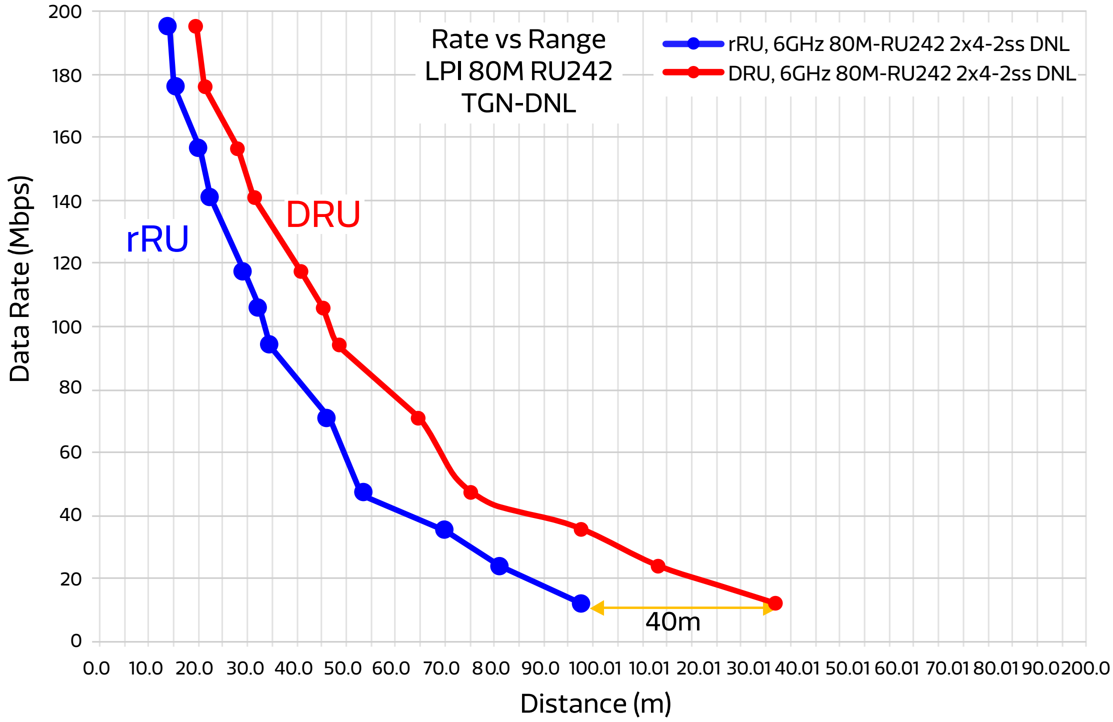


Figure 11. Significant RvR improvement achieved by DRU

The adoption of DRU technology not only facilitates a substantial increase in transmission power but also significantly enhances the efficiency of the 6GHz spectrum. When combined with AFC, DRU represents a complementary technology that bolsters the adoption and efficient utilization of the 6GHz band. Beyond its application for power enhancement in 6GHz LPI mode, DRU technology also holds potential for Very Low Power (VLP) operations within the 6GHz band, as well as in the 2.4GHz and 5GHz bands in specific regions subject to similar PSD constraints. This versatility underscores the value of DRU as a critical technology for optimizing spectrum usage across a variety of frequency bands and regulatory frameworks.

Enhanced Long Range (ELR)

Scenario: Samantha resides in an apartment adjacent to a park. She experienced limited Wi-Fi connectivity during a BBQ party in her backyard. The Wi-Fi AP is situated on the second floor of her apartment. While enjoying the gathering, she received a video call. Seeking privacy and a quieter space, she moved towards the park and sat on the grass, however, as she distanced herself further from the Wi-Fi AP the call disconnected. Samantha needs a way to sustain her Wi-Fi phone call while roaming at a moderate distance from her house in order to save on cellular data use.

Figure 12. Samantha steps away to talk privately while at a party

Issue: The primary limitation of Wi-Fi coverage is the transmission power constraints of connected devices. Environmental factors, such as wall attenuation and outdoor obstacles, further diminish the signal strength, necessitating that mobile devices stay relatively near to the AP. Wi-Fi APs typically have higher transmission power compared to non-AP STAs, so there is a critical need to enhance the uplink range to correct this imbalance.

Challenge: In general, APs transmit at higher power levels compared to STAs, which results in as much as 6 dB link budget difference between downlink and uplink. Consequently, uplink must be improved to address this imbalance, therefore we must enhance the uplink range.

Technology: To address these challenges, the Wi-Fi 8 introduces Enhanced Long Range (ELR), a technology designed to correct the imbalance, thereby increasing efficiency while maintaining a range comparable to the IEEE 802.11b standard.

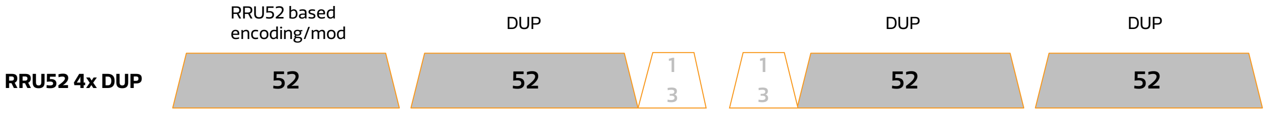
ELR Physical Layer Protocol Data Unit (PPDU) Composition:

1. Legacy Preamble: This segment includes the Legacy Short Training Field (L-STF) and Legacy Long Training Field (L-LTF), to ensure compatibility with legacy devices, both enhanced by a 3 dB boost to improve signal strength and reliability.

2. ELR Preamble: Mirroring the enhancements of the Legacy preamble, the ELR preamble features ELR-specific Short Training Field (ELR-STF) and Long Training Field (ELR-LTF), also amplified by 3 dB to support extended range capabilities.

3. ELR Data: For data transmission, ELR utilizes a 52-tone rRU coupled with 4x frequency domain duplication (rRU52 4x DUP). This method enhances signal redundancy and robustness, facilitating more reliable data transmission over extended distances.

To streamline the implementation of ELR, it is recommended to use a 20 MHz bandwidth and existing Modulation and Coding Schemes (MCSs). This approach ensures backward compatibility with legacy devices while providing the benefits of enhanced range and improved uplink performance, thereby addressing the current challenges in Wi-Fi connectivity.



ELR-MCS	Duplication	Modulation	R	Nbpscs	Nsd	Ncbps	Ndbps	Data rate (Mb/s)		
								0.8us GI	1.6us GI	3.2us GI
0	RRU52 4x DUP	BPSK	1/2	1	48	48	24	1.76	1.67	1.50
1	RRU52 4x DUP	QPSK	1/2	2	48	96	48	3.53	3.33	3.00

Figure 13. Two ELR-MCSs with rRU52 4x DUP

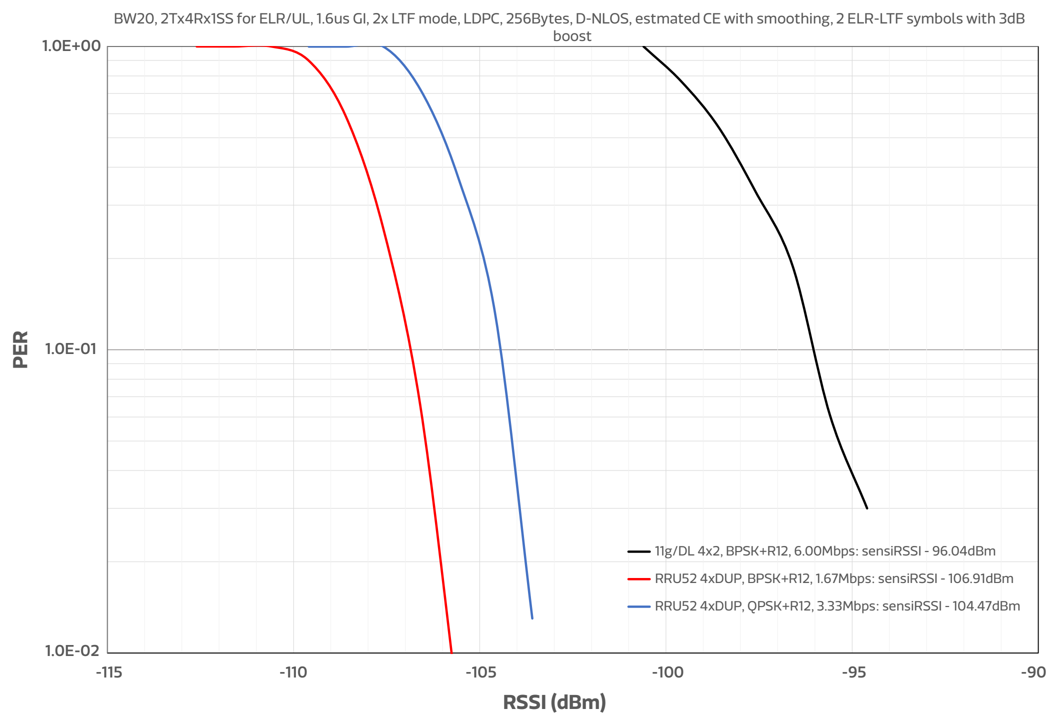


Figure 14. Sensitivity Comparison between ELR-MCSs and 802.11g 6Mbps

Our simulation results indicate a sensitivity gain exceeding 8 dB for the ELR uplink when compared to the downlink of 802.11g with a 6Mbps data rate. This comparison assumes a scenario with four antennas at the AP and two antennas at the STA operating in a typical office modeled by Model D in a Non-Line-of-Sight condition (D-NLOS) of TGn channel models.

The incorporation of ELR technology into MediaTek Filogic's Xtra Range offerings markedly improves long-range connectivity, thereby elevating the overall user experience. This integration ensures that users benefit from extended coverage and more reliable wireless communication, particularly in challenging environments where obstacles and interference are prevalent.

Conclusion

The evolution of Wi-Fi standards is being driven by the ever-increasing demand for faster, more reliable, and even more efficient wireless communications. Each new standard, from 802.11a to the latest 802.11be, has brought significant improvements in speed, capacity, and performance, enabling a wide range of applications and devices to connect seamlessly. As we continue to innovate and integrate more devices into our daily lives, the progression of Wi-Fi technology remains crucial, ensuring that our wireless networks can keep up with the growing needs of both consumers and businesses. The 802.11bn standard promises greater advancements, with the potential for higher effective speeds, lower latency, and more robust communications in increasingly crowded and diverse wireless environments.

Next-generation MediaTek Filogic will leverage several advanced technologies for enhancing communication efficiency across the various user scenarios:

- UHR roaming to enhance the quality and reliability of mesh networks
- DRU and ELR improve Wi-Fi coverage
- Reduced power consumption, enhancing energy efficiency and always-on sustainability

MediaTek in the Wi-Fi Industry

MediaTek is the world's largest supplier of Wi-Fi solutions, including standalone networking products such as routers, repeaters, and mesh access points, and devices with embedded Wi-Fi connectivity such as smartphones, tablets, TVs, IoT, smart home devices, PCs and laptops, games consoles, and many others.

Besides delivering high performance and low power integrated solutions to these platforms, MediaTek is actively participating in IEEE and Wi-Fi Alliance certification development to ensure top performance and industry interoperability. Some recent examples include selection of MediaTek's Filogic platforms as Wi-Fi 6E and Wi-Fi 6 R2 test bed devices. With Wi-Fi 7, and soon Wi-Fi 8, MediaTek continues to contribute technical expertise and knowledge of diverse market segment standards for improved Wi-Fi performance in daily applications.

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