Unveiling the **power** of

L4S & Wi-Fi 7

Sneak peek into Latest Wi-Fi 7 Trials at Excentis' Wi-Fi House

EXCENTIS

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Introduction

Are you fascinated by the latest advancements in network technology? Intrigued by the potential of L4S and Wi-Fi 7? Wondering how L4S would perform in real life? Your curiosity ends here!

As Wi-Fi 7 emerges as a catalyst for network enhancement, operators find themselves at a crucial juncture, ready to make strategic decisions that will define the trajectory of their networks.

This white paper acts as your starting point for jumping into evaluating the optimal access points for your forthcoming Wi-Fi 7 deployment.

At Excentis, we thrive on pushing boundaries in network innovation.
With our state-of-the-art testing tool "ByteBlower" we're not just observers; we're shaping the future of network technology. Join us on a journey of exploration as we delve into the intersection of L4S and Wi-Fi 7, leveraging ByteBlower to unlock new insights
and redefine your network experience.

Whether you're inclined towards pioneering announcements as an **early adopter** or prefer a cautious stance to **monitor industry developments.**

We've got you covered!

What's new with Wi-Fi 7

Wi-Fi 7, represented by the 802.11be standard, stands at the forefront of Wi-Fi innovation.

At Excentis, we're dedicated to exploring its capabilities, including revolutionary features like Multi-Link Operation (MLO) and operation in the 6 GHz band.

Wi-Fi 7 introduces 320 MHz wide channels, a major upgrade from previous generations.This wider bandwidth allows for faster data rates and increased throughput, much like upgrading **from a simple passenger train to a high-speed one.** While this advancement promises enhanced network performance and efficiency, challenges may arise in crowded Wi-Fi environments and with device compatibility. Nonetheless, the introduction of 320 MHz channels signifies a significant leap forward in wireless networking technology, offering users faster and more reliable connectivity.

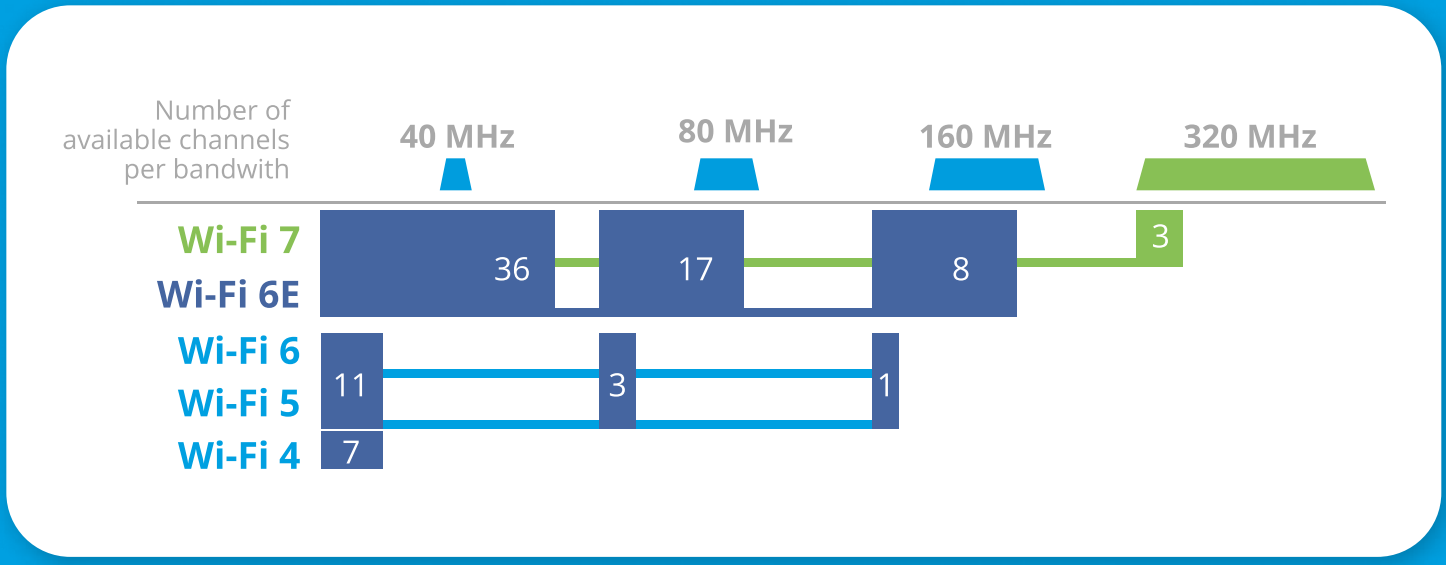
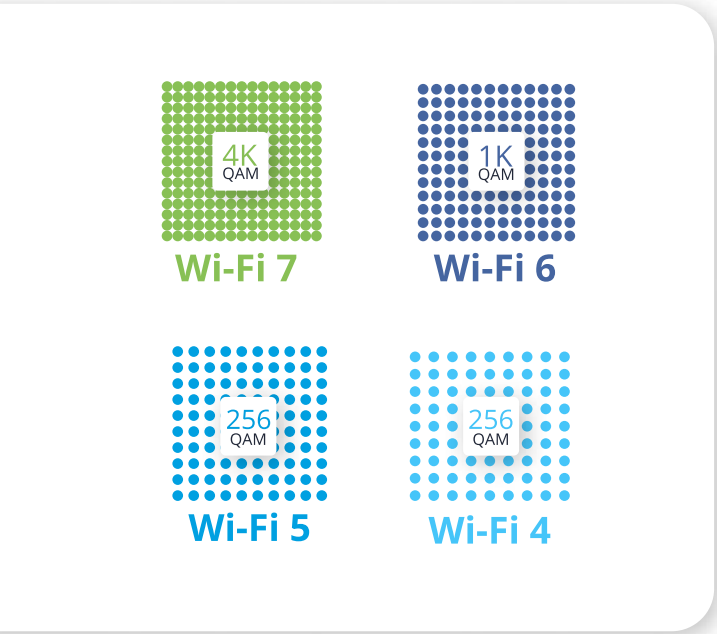


Image: Compares Wi-Fi bands and available channel bandwidths. Source[1]



Wi-Fi 7 boasts impressive throughput capabilities, potentially reaching up to 46 Gbps in theory, thanks to 4K QAM modulation, larger bandwidth, and increased antenna capacity.

Image: Illustrates Wi-Fi modulation and its evaluation. Source[1]

The Multi-Link Operation (MLO) feature lets you use the 2.4 GHz, 5 GHz, and 6 GHz bands all at once, making it great for various applications like AR/VR/XR and high-definition video streaming.

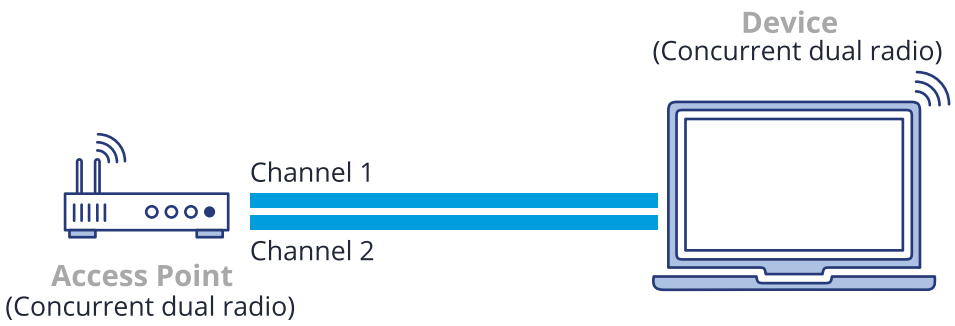
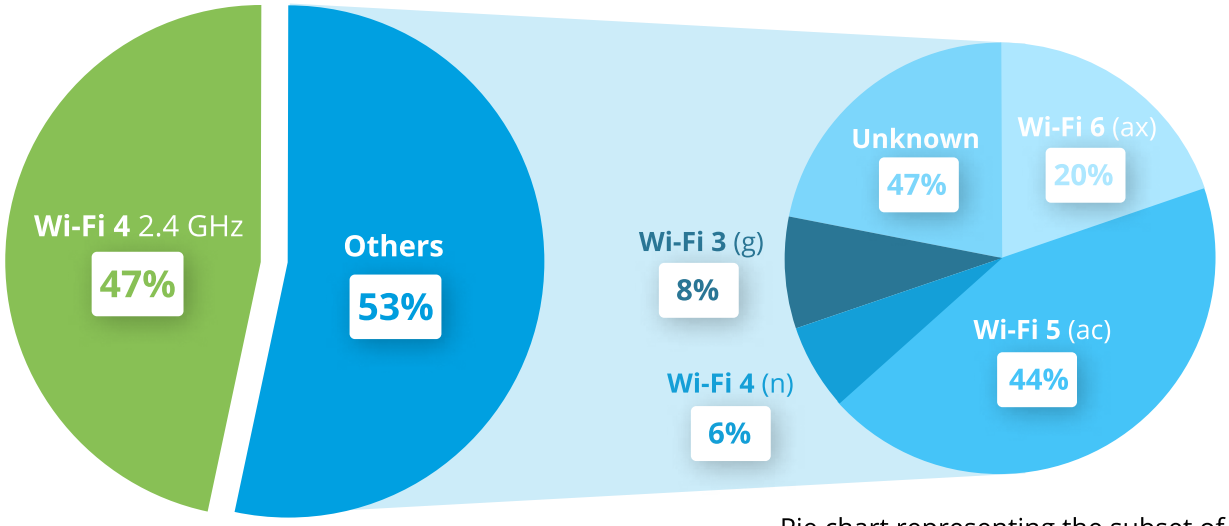


Image: Demonstrates MLO functionally between a laptop and a Wi-Fi 7 AP. Source[1]

With features like Quality of Service (QoS) and Time Sensitive Networking (TSN), Wi-Fi 7 caters to a range of use cases, from automotive to gaming. Leveraging ByteBlower's testing expertise, we deliver objective insights into Wi-Fi 7 performance and compatibility across All Access Networks.

Why today?

While Wi-Fi 7 was officially certified by the Wi-Fi Alliance as "Wi-Fi Certified 7". The alliance certifies products and started certifying Wi-Fi 7 compliant devices since January. Manufacturers and vendors are rapidly evolving their product lines. Despite this recent certification, the growing demand for data-intensive and low-latency applications, alongside the availability of Wi-Fi 7 devices, indicates that **it's not too early to start assessing the appropriate access points for your customer's needs.** This isn't just about early adopters; it's an opportunity to upgrade a significant portion of your customer base to Wi-Fi 7 and deliver an enhanced network experience. To illustrate, consider a dataset from an operator last year, which reveals a substantial number of devices still operating on 2.4 GHz Wi-Fi 4, primarily IoT and legacy devices, indicating the need for simultaneous backwards compatibility. Furthermore, approximately 20% of devices were already utilizing Wi-Fi 6 last year, indicating a rapid evolution in Wi-Fi technology adoption.



Pie chart representing the subset of "others"

Graph: Illustrates the division of client devices among different Wi-Fi bands.

Evolution of our Wi-Fi House

Testing Wi-Fi in real environments can be tricky. To assist our partners in selecting the optimal access points and assessing the latest Wi-Fi firmware and hardware, we've transformed a genuine household located in a remote area creating an unparalleled and static testing environment across the Wi-Fi spectrum. This unique setup allows us to accurately benchmark and replicate various Wi-Fi performance metrics and stability tests, providing you with precise data to make well-informed decisions.

Image: Real Wi-Fi house Excentis uses for Wi-Fi benchmarking.

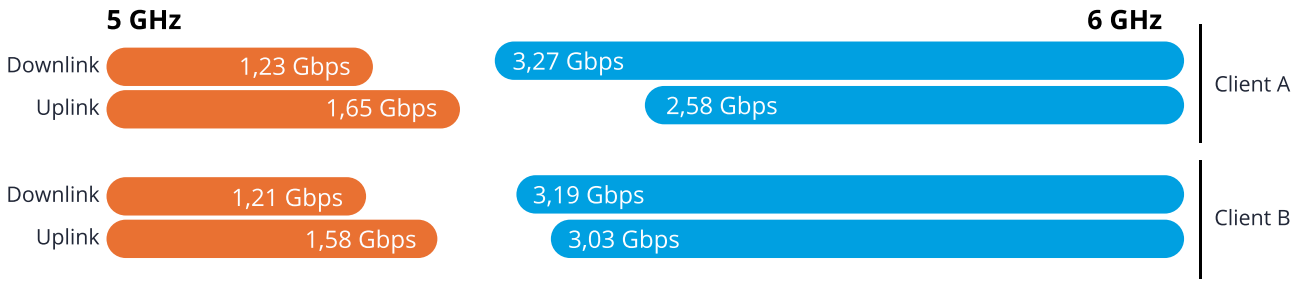
Recognizing the pressing need for Wi-Fi 7 testing in the evolving network, our **Wi-Fi House** enhanced with the latest **ByteBlower** testing tool, meets industry standards and provides unmatched testing capabilities, accuracy, and reliability, including **L4S testing** capability.

Insights from Wi-Fi 7 trials:

Armed with Wi-Fi 7 Access Points and client devices at the Excentis Wi-Fi house, we conduct thorough testing and comparisons with Wi-Fi 6/6E, highlighting its advancements. Our trials revealed fascinating insights into Wi-Fi 7 performance. While the promises made by Wi-Fi 7 are impressive, real-world scenarios paint a nuanced picture. Performance is significantly influenced by factors like band utilization and distance from the access point, underscoring the **crucial role of comprehensive testing methodologies.**

The magic of new wider channels in 6 GHz band

The 6 GHz band was introduced by the launch of Wi-Fi 6E. However, with Wi-Fi 7, we see the availability of new 320 MHz channels. This is twice as wide as the maximum channel bandwidth of 160 MHz with Wi-Fi 6E. To put this to test, in our initial analysis, we compared the throughput of Wi-Fi 7 in the 5 GHz and 6 GHz bands for a single client at a time. We conducted this experiment using a Wi-Fi 7 Access Point along with two different Wi-Fi 7 clients (Client A and Client B) positioned 1 meter away from the Access Point. We restricted the AP to 5 GHz only and then to 6 GHz only to see the impact of wider channels. To restrict the AP to a specific band, the Multi-Link Operation (MLO) was disabled for this test.



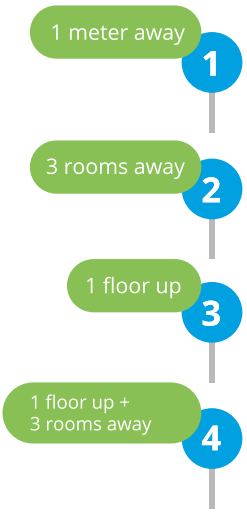
Graph: Illustrates the throughput for each client in both the 5 GHz and 6 GHz bands.

As anticipated, our findings revealed that a client can achieve larger bandwidth AND 4k-QAM modulation. This significant improvement can be attributed to the wider channel bandwidth of 320 Mhz, available in the 6 GHz band compared to the 5 GHz and 2.4 GHz bands. Furthermore, since the 6 GHz spectrum is relatively new for public use, it experiences less interference, resulting in less crowded channels and consequently higher throughput. It's important to clarify that these results demonstrate the throughput for a single Wi-Fi 7 client at a time. They should not be mistaken for the maximum throughput capacity of the Wi-Fi 7 access point.

The impact of Multi-Link Operation (MLO)

For this test setup, we utilized a Wi-Fi 7 Access Point along with two Wi-Fi 7 Clients (Client A and Client B) positioned at various positions within Excentis Wi-Fi House labelled as:

Positions within Excentis Wi-Fi House



Position 1: One meter away from AP

Position 2: Three rooms away from AP

Position 3: One floor up, exactly above the AP

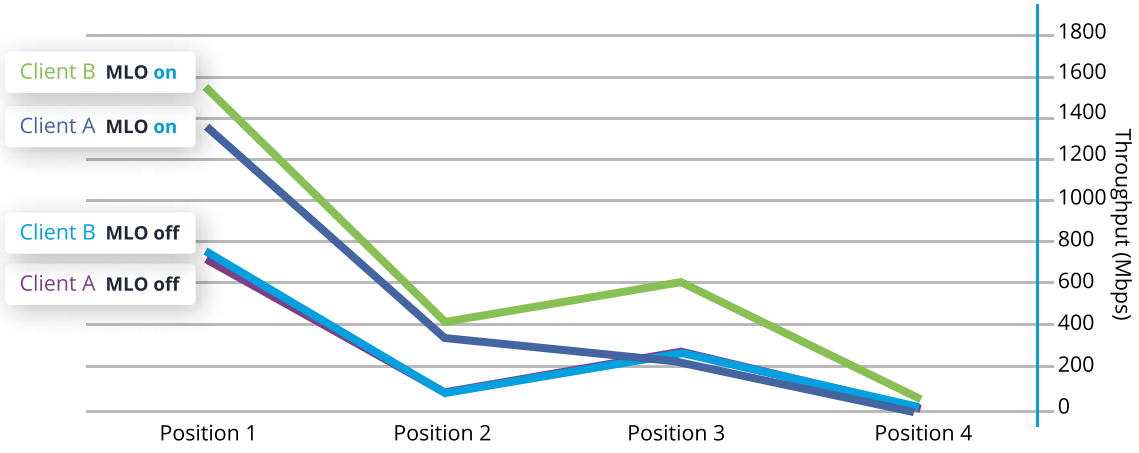
Position 4: One floor up, and 3 rooms away from the AP

Lower floor

Upper floor

Image: The Excentis Wi-Fi House floor plan with specific points where reproducible readings are taken.

We assessed the performance of the Wi-Fi 7 clients with Multi-Link Operation (MLO) both enabled and disabled across these different locations. The findings are outlined below.

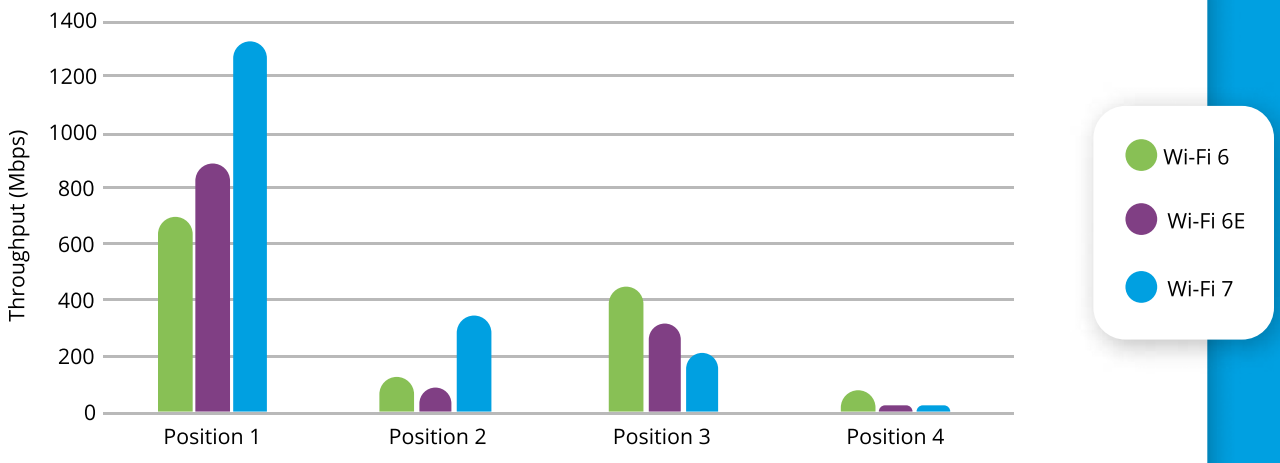


Graph: Illustrates the throughput for each Wi-Fi 7 client with both MLO enabled and disabled.

Let's delve into the performance comparison between Multi-Link Operation (MLO) enabled and disabled. At Position 1 and Position 2, both clients showed significantly improved performance with MLO enabled. However, an unexpected change occurred at the Position 3, highlighting potential inconsistencies in MLO behaviour. This suggests the need for fine-tuning algorithms for handover or band selection, especially as distance increases with the specific Access Point used in this test. Furthermore, at Position 4, one client lost connection to the Access Point, likely due to being out of range, while the other client experienced greatly reduced throughput with MLO enabled and no connection with MLO disabled. This underscores the potential value of MLO for maintaining stability in long-distance connections.

Comparing Wi-Fi 7 with previous standards

In our comparative analysis, we examined the performance of an early released Wi-Fi 7 Access Point (AP) against its predecessors, including Wi-Fi 6/6E APs. We utilized a variety of devices including a Wi-Fi 7 Access Point, Wi-Fi6E Access Point, Wi-Fi 6 Access Point, Wi-Fi 7 Client (Client A), Wi-Fi 6E Client, and Wi-Fi 6 Client. The objective was to assess the performance of Wi-Fi 7 Client A with Multi-Link Operation (MLO) enabled against Wi-Fi 6/6E Clients. Each device was tested individually across different locations within Excentis' Wi-Fi House.



Graph: Illustrates the throughput for a Wi-Fi 6, Wi-Fi 6E and Wi-Fi 7 client at different locations.

As anticipated, the Wi-Fi 7 client demonstrated better performance at Position 1 and Position 2 when compared to the Wi-Fi 6 or Wi-Fi 6E client. This could be a result of MLO and the wider 6 GHz band. However, we observed a reversal of performance at Position 3 and Position 4, likely influenced by the limitations of 6 GHz coverage. The shorter wavelengths of the 6 GHz band utilized by MLO and 4K QAM in Wi-Fi 7 make it less effective over longer distances or when obstructed by physical barriers, resulting in better performance for the Wi-Fi 6 and Wi-Fi 6E client in these scenarios. This analysis points towards a need for fine-tuning the decision-making ability of this specific Wi-Fi 7 Access Point to swiftly fall back to lower band in long range scenarios.

Considerations for adoption

Considering the upgrade to Wi-Fi 7 technology, it's essential to weigh factors beyond performance alone. Pricing and power consumption also play pivotal roles in determining the overall cost and sustainability of deployment. Our Wi-Fi house also offers valuable insights into these considerations, empowering you to make informed decisions tailored to your needs.

We tested the power consumption of three single Access Points—Wi-Fi 6, Wi-Fi 6E, and Wi-Fi 7. The power consumption results, with only one Wi-Fi client connected and operating at maximum throughput, are as follows:

Wi-Fi 6 Access Point: Approximately 6.0 Watts

Wi-Fi 6E Access Point: Approximately 9.4 Watts

Wi-Fi 7 Access Point: Approximately 16.3 Watts

Our tests on power consumption insights prompt a key question: Does the performance boost justify the rise in power usage?

Insights from the future: L4S and Wi-Fi 7 combined trials

Looking ahead, the evolution of Wi-Fi is inevitable as we stride into the future. In the coming times, Wi-Fi is bound to change as we move into the future. As networks progress, we're not just thinking about speed; we're also considering the important issue of latency, which is all about reducing delays in the network. Introducing L4S—an innovative breakthrough designed to minimize latency across networks, from client devices to application servers and back.

Recognizing the potential of L4S, Excentis embarked on a journey to explore and rigorously test its effectiveness.

Utilizing our testing tool, **ByteBlower**, we can now comprehensively **evaluate L4S across all access networks.**

Driven by curiosity, we decided to perform a combined test of these two groundbreaking advancements within the Excentis Wi-Fi House. Join us as we unveil the intriguing insights gleaned from this endeavour.

Testing with L4S disabled

To assess the impact of L4S, we first conducted tests in the absence of L4S functionality. For this evaluation, we utilized a set of Wi-Fi 7 Access Points creating a Wi-Fi mesh between ByteBlower and a client running ByteBlower Endpoint application.

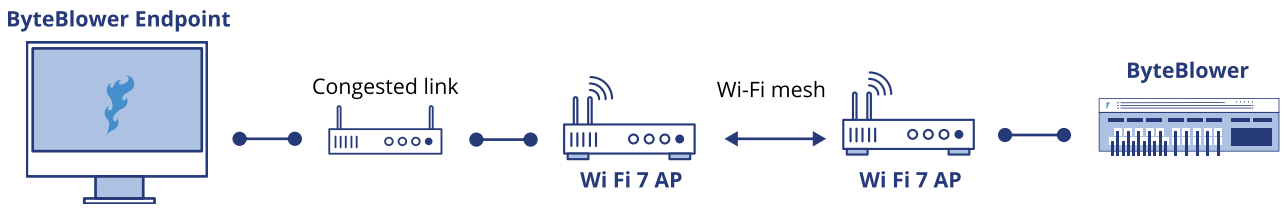


Figure: Illustrates a setup for L4S test run at Excentis Wi-Fi house

Initially, we initiated a UDP flow simulating a user (Person A) with a bandwidth of 600 Mbps. After 20 seconds, a TCP flow intended at 600 Mbps simulating another user (Person B) was introduced, continuing for the subsequent 20 seconds, thus concluding at the 40-second mark of the test.

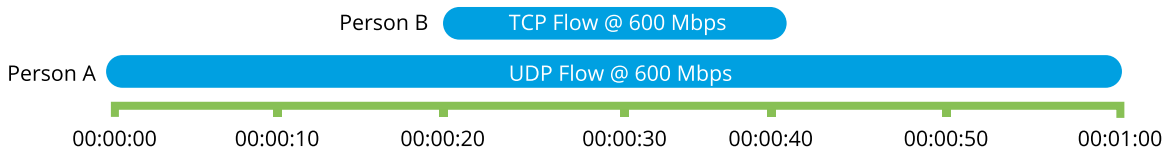


Figure: Illustrates the setup of flows during the test duration.

This led to bandwidth saturation for the client, causing TCP to adjust its speed due to its inherent congestion avoidance mechanism, resulting in retransmissions, as depicted in the graph in purple.

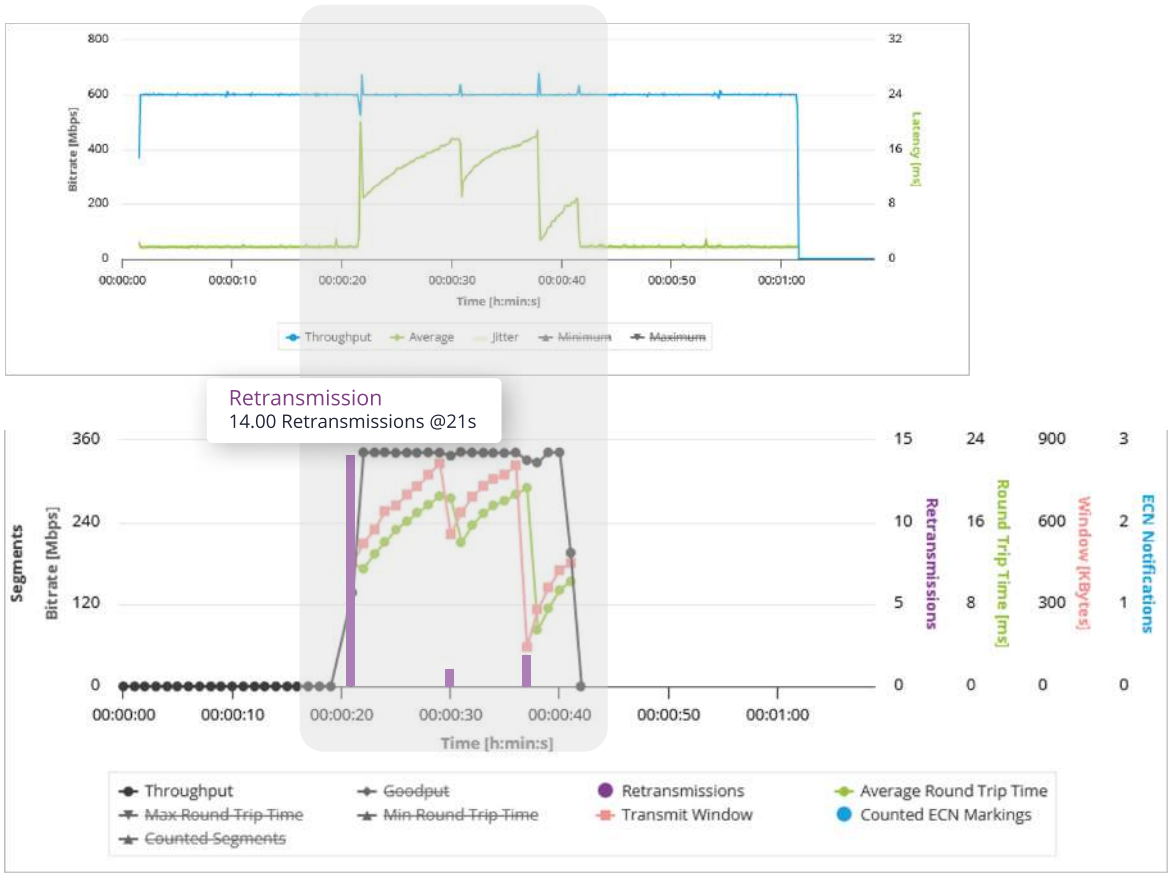


Figure: TCP and UDP flow measurements show an increase in latency between 20 and 40 seconds

Both UDP and TCP flows experienced congestion between 20 and 40 seconds, leading to increased latency and Round-Trip Time (RTT). Without L4S, Person A observed a significant latency jump from 3 ms all the way to 20 ms when Person B joined, impacting their experience. Person B encountered fluctuating latency around 16 ms as the TCP congestion avoidance is triggered by network buffer overflow, but this approach has limited effectiveness, resulting in sustained high latency.

Testing with L4S enabled client over Wi-Fi 7

Let's bring back the excitement. In the next phase, we repeated the scenario with L4S enabled. Let's see how both flows performed.

Figure: TCP and UDP flow measurements with L4S enabled show very stable latency readings

Notice the blue bursts in the graph above. This is the magic of L4S. Before reaching bandwidth capacity, L4S triggers ECN Marking (shown in blue). This alerts the sender about potential congestion at the receiver, prompting it to slow down. This not only prevents packet loss and retransmissions but also ensures no congestion, resulting in very low latency. Person A now experiences an average latency of less than 4ms during Person B's burst, almost 5 times lower than without L4S, due to the absence of network congestion. Such a minor latency increase goes unnoticed by User A. Similarly, User B also enjoys significantly reduced latency compared to before.

We tried this with various scenarios, combining different TCP and UDP flows. You can find the summary of our latency measurements below; they are in the same setup.

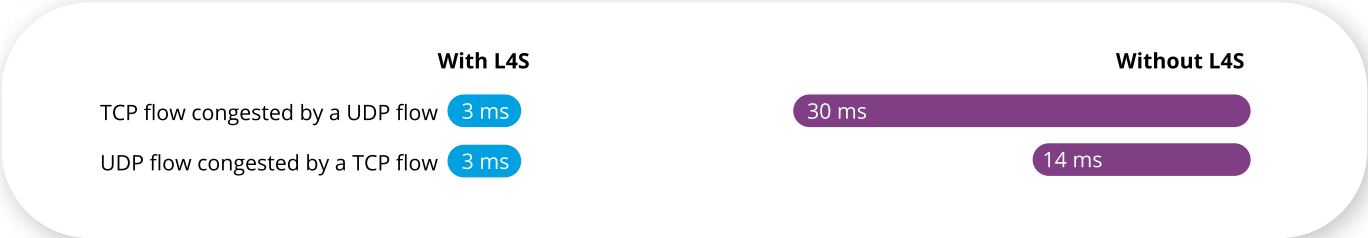


Figure: Compares impacts of L4S on reduction of latency in case of TCP and UDP flows

When congestion occurred in a UDP flow due to an increasing amount of TCP traffic, using L4S to avoid congestion reduced latency by a factor of five. In the reverse scenario, when a TCP flow was congested by a UDP flow, the impact of L4S was significant, reducing latency by one-tenth compared to congested traffic without L4S. This is because UDP doesn't naturally adjust its rate and lacks a feedback mechanism. L4S not only provides congestion feedback but also anticipates it, saving significant latency and frustration for latency-sensitive applications.

Looking ahead

The launch of the WiFi CERTIFIED 7 program heralds the beginning of the Wi-Fi 7 rollout, promising enhanced performance for future routers. However, verifying these improvements poses a significant challenge.

While Wi-Fi 7 and L4S are poised to revolutionize throughput and latency, assessing their efficacy, efficiency and performance requires examining various scenarios and real-world use cases. **Picture this: you've got tons of devices hooked up to a Wi-Fi 7 mesh node. Now, instead of just one device maxing out its bandwidth, the node itself or the whole mesh network could get jammed up. What happens then?** Luckily, L4S is also supposed to save the day in such a scenario but we are yet to find-out as soon as we get our hands on L4S ready Wi-Fi 7 Access Points.

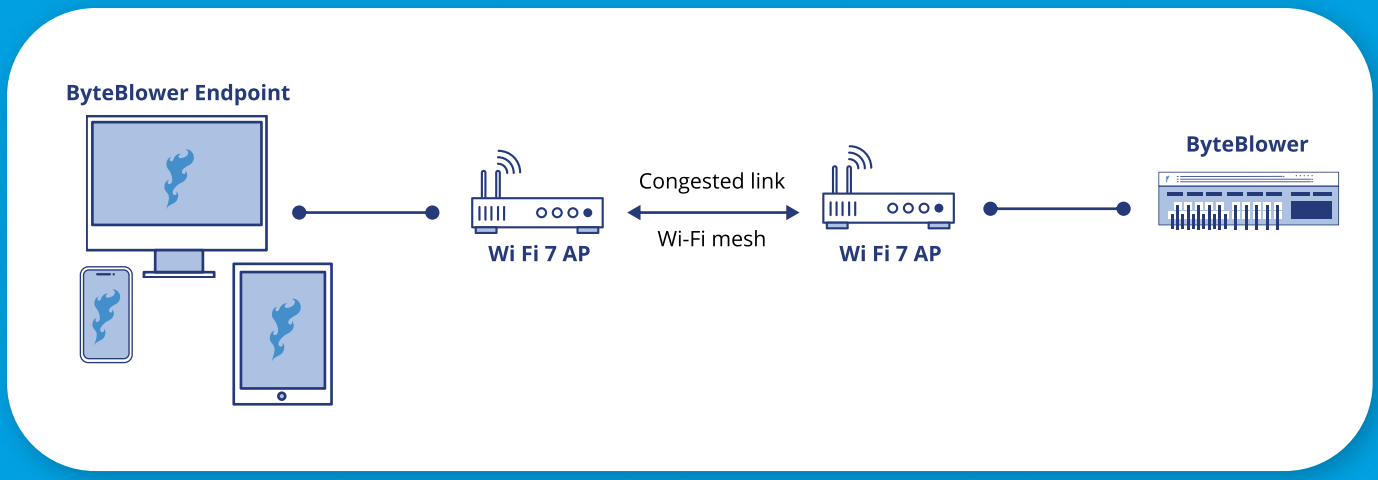


Figure: Demonstrate a setup for with congested Wi-Fi mesh link.

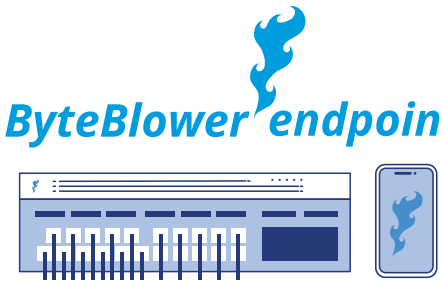
Excentis offers solutions to this challenge through real-world testing with its ByteBlower Endpoint solution, capable of running versatile performance tests on various devices, including new WiFi 7 devices.

EXCENTIS Leads the Way

Embark on an exhilarating journey with Excentis as we simplify your exploration of the latest technologies. Discover the power of L4S and Wi-Fi 7 at Excentis' Wi-Fi House, where real-world scenarios are meticulously replicated for precise testing. Utilizing ByteBlower, we've conducted extensive trials to evaluate L4S performance across diverse conditions, providing invaluable insights into its efficacy along with the Wi-Fi 7 landscape.

We are ready for Wi-Fi 7 and L4S?

Are you?



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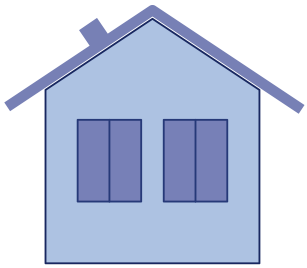

Wi-Fi House

Confidently select your next Wi-Fi 7 router or mesh.
Future-proof your investments.

Embark on a captivating technological journey with Excentis at the Wi-Fi House! Immerse yourself in the exploration of cutting-edge technologies like L4S and Wi-Fi 7, meticulously tested in real-world scenarios using the powerful ByteBlower. Our comprehensive services go beyond testing – they empower you to evaluate, compare, and confidently select your next Wi-Fi 7 router or mesh solution.

Leverage Excentis' expertise and choose from our tailored testing packages, ranging from Starter to Premium. Our seamless testing experience ensures unrivaled stability and advanced diagnostics, with features such as L4S integration, multi-client support, and Wi-Fi 7 standards compliance. This holistic approach guarantees that your testing journey is not only hassle-free but also future-proof.

Choose Excentis Wi-Fi House for superior testing tailored to your needs. With us as your guide, navigate the complexities of network technology and unlock new possibilities in connectivity.

Abbreviations and references

L4S: Low Latency, Low Loss, Scalable throughput

MLO: Multi-Link Operation

IoT: Internet of Things

QoS: Quality of Service

TSN: Time Sensitive Networking

References:

[1]https://www.intel.com/content/www/us/en/products/docs/wireless/wi-fi-7.html