TEST REPORT

Tolly.

#221110

February 2021

Commissioned by

Cambium Networks, Ltd.

Cambium Networks Wi-Fi 6 Access Points

TCO and Performance vs. Aruba, Meraki and Ruckus

EXECUTIVE SUMMARY

Wi-Fi 6 brings WLAN performance to a new level with aggregate throughput potential measured in Gigabits per second. The advent of Wi-Fi 6 also brings economics to a new level as higher performance and higher density impact price-performance and total cost of ownership (TCO) calculations.

Cambium Networks commissioned Tolly to benchmark the performance of its tri-radio XV3-8 (8x8/4x4 MU-MIMO) and XV2-2 (2x2 MU-MIMO) Wi-Fi 6 Access Points (APs) and comparable APs from Aruba, Meraki (Cisco) and Ruckus (CommScope). Performance tests encompassed low-client density and high-client density scenarios with various traffic types. Tolly Engineers also calculated price-performance and 5-year TCO. Cambium acquired Xirrus in 2019 and the current products combine technology from both companies.

The Cambium Networks XV3-8 price-performance was more than twice that of the nearest competitor while offering TCO that is an average of 38% lower than Aruba, Meraki and Ruckus. The XV3-8 averaged 47% higher bidirectional performance (in tri-radio mode) vs. competitive 8x8/4x4 APs and outperformed Meraki and Ruckus in the 100-client high-density test.

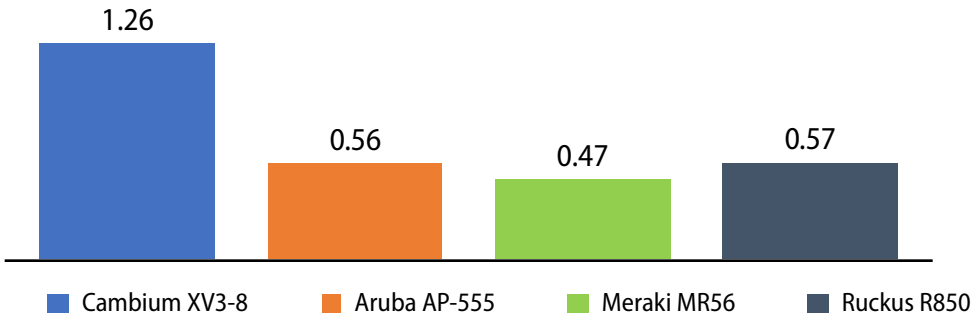
The Cambium Networks XV2-2 price-performance was twice that of the nearest competitor while offering TCO 35% lower than Aruba, 49% lower than Meraki and 44% lower than Ruckus. The XV2-2 outperformed the others in bidirectional and downstream throughput and delivered comparable or better performance in the 50-client high-density test.

THE BOTTOM LINE

Cambium Networks:

1. XV3-8 delivered average of 2.4X price-performance of competitors
2. XV3-8 had average of 38% lower TCO than Aruba, Meraki and Ruckus
3. XV3-8 delivered average of 47% higher bidirectional throughput in tri-radio mode than competitors
4. XV2-2 delivered average of 2X price-performance of competitors
5. XV2-2 had TCO 35% lower than Aruba, 49% lower than Meraki and 44% lower than Ruckus
6. XV2-2 outperformed competitors in bidirectional and downstream throughput

Wi-Fi 6 8x8/4x4 Access Points Price-Performance Ratio (Mbps/Dollar)



Note: Performance-price ratio = (maximum bidirectional throughput of the AP in the test with all available radios) / (AP list price + 5 years cloud management subscription list price). See Figure 2 chart 1 for detailed prices. See Figure 3 chart 1 for detailed throughput results.

Source: Tolly, December 2020 & January 2021

Figure 1

Background

Many deployments of Wi-Fi will include both high-performance 8x8/4x4 MU-MIMO APs and more general purpose 2x2 MU-MIMO APs, thus both are included in this evaluation. In addition to evaluating the maximum performance of a single AP of each type, engineers conducted high client density tests. For the 8x8/4x4 APs, the testing was run with 100 clients while for the 2x2 APs 50 clients were used.

The results of the single AP throughput tests were used to calculate price-performance where throughput was divided by cost. Finally, TCO for each AP was computed using hardware list price plus cloud management subscription cost.

Test Results

Price-Performance Ratio

Throughput charts make it easy to spot performance differences across APs but factoring in the cost of throughput can build a clearer picture of a vendor's value proposition.

Tolly engineers calculated the Mbps per dollar. For cost, the list prices were used plus five years of cloud management subscription costs.

For the 8x8/4x4 APs, Cambium XV3-8 price-performance (Mbps/Dollar) was 2.2X that of the nearest competitor, Ruckus. The Cambium XV3-8 price-performance was 2.25X that of Aruba and 2.68X that of Meraki. See Figure 1.

For the 2x2 APs, Cambium XV2-2 price-performance (Mbps/Dollar) was 1.84X that of the nearest competitor, Ruckus. The Cambium XV2-2 price-performance was 1.86X that of Aruba and 2.29X that of Meraki. See Figure 7 on Page 7.

5-Year TCO

TCO was calculated using AP list price and five years of cloud management cost. The Cambium XV3-8 total cost of $1,365, inclusive of hardware support, was 40% lower than Aruba and Meraki and 19% lower than Ruckus. The Cambium XV2-2 total cost of $665 was 35% lower than Aruba, 49% lower than Meraki and 31% lower than Ruckus. See Figure 2. For more details about hardware support differences, see Hardware Support - Additional Information section at the end of test results.

Cambium Networks, Ltd.

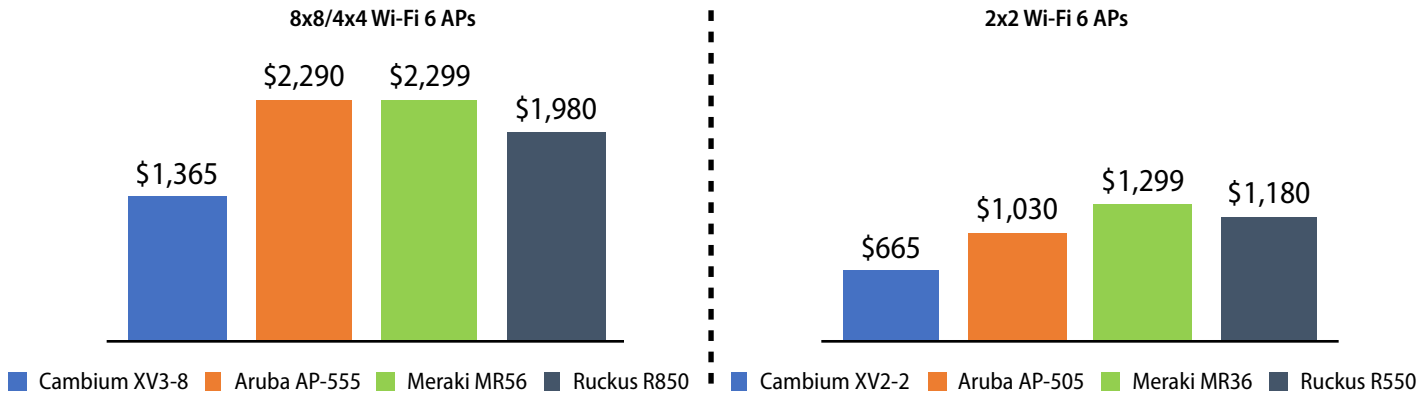
Wi-Fi 6 Access Points

TCO & Price-Performance

Tolly. Certified

Tested January 2021

Wi-Fi 6 Access Points 5-Year Total Cost of Ownership (TCO)
(Lower is better)



Note: TCO = AP list price + 5 years cloud management subscription list price. See Table 1 on Page 7 for detailed prices for each item.

Source: Tolly, December 2020 & January 2021

Figure 2

Maximum Throughput - 8x8/4x4 APs

These tests measured the maximum throughput of a single AP with separate tests run using bidirectional traffic, upstream-only, and downstream-only traffic profiles. Details of all tests can be found in the Test Setup & Methodology section of this report.

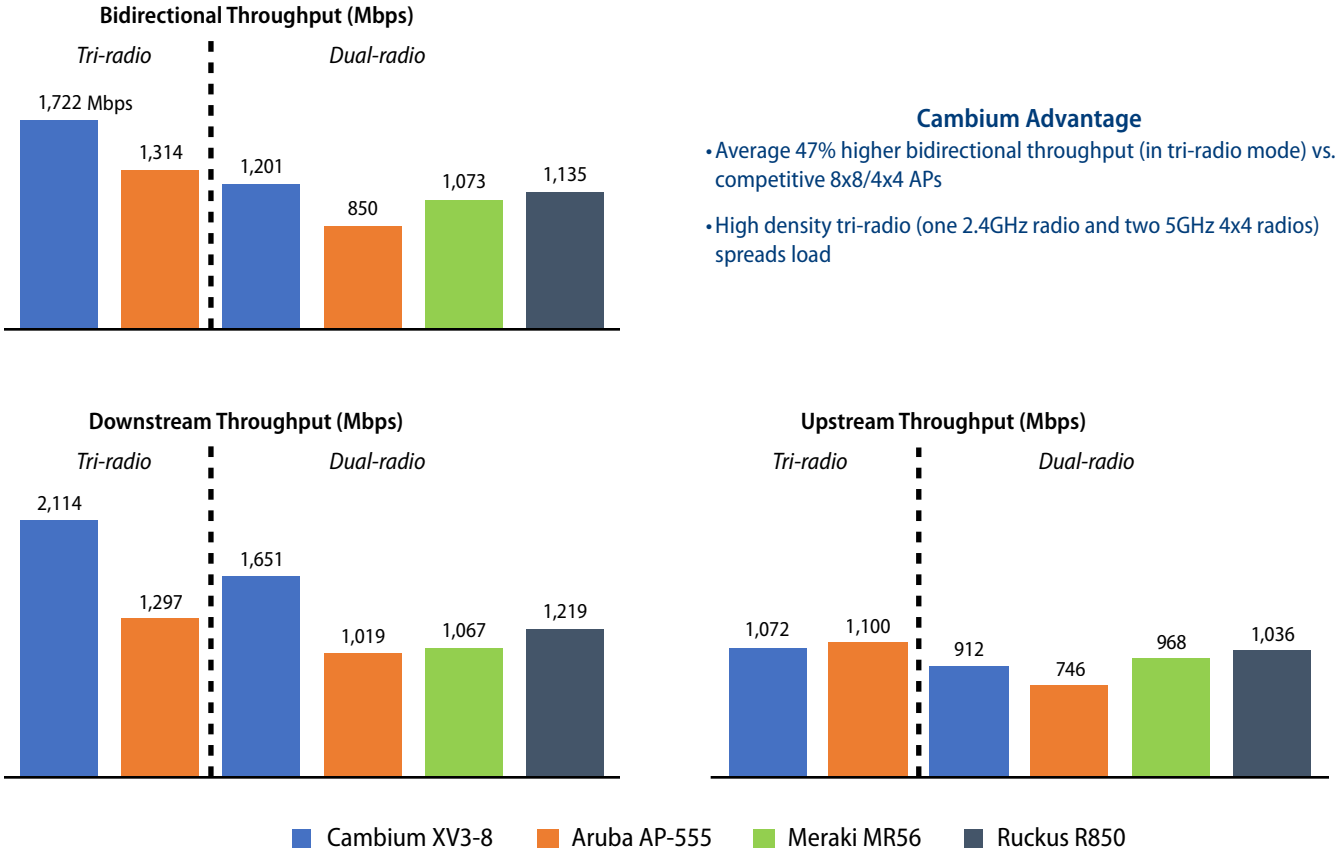
Of the four vendors tested, Cambium and Aruba provide the option to split the 8x8/4x4 radio into two 4x4 radios to provide a tri-radio solution. Tri-radio mode distributes the load across an additional radio thus generally providing higher aggregate throughput. Dual-radio mode provides one 2.4GHz radio and one 5GHz radio. Tests were run in both modes for Cambium and Aruba.

In the tri-radio tests, Cambium outperformed Aruba by 31% in the bidirectional test. In the downstream test Cambium was 63% higher than Aruba while in the upstream test Aruba was about 2.5% higher than Cambium. See Figure 3.

Cambium outperformed the other APs in all dual-radio tests save one. In the bidirectional tests, Cambium was 5.8% higher than the nearest competitor. In the downstream test, Cambium was 35% higher than the nearest competitor, where only Ruckus was higher in the upstream test by 14%.

When the best bidirectional throughput of all vendors across dual- and tri-radio is averaged, the Cambium tri-radio throughput is 47% higher.

Maximum Throughput - 8x8/4x4 APs



Note: Total of six IxChariot clients (2x2 Wi-Fi 6 Windows laptops) were used with two 2.4GHz clients and four 5GHz clients to evaluate performance of the AP. Bidirectional, downstream and upstream tests were tested separately as three different tests.

Source: Tolly, December 2020 & January 2021

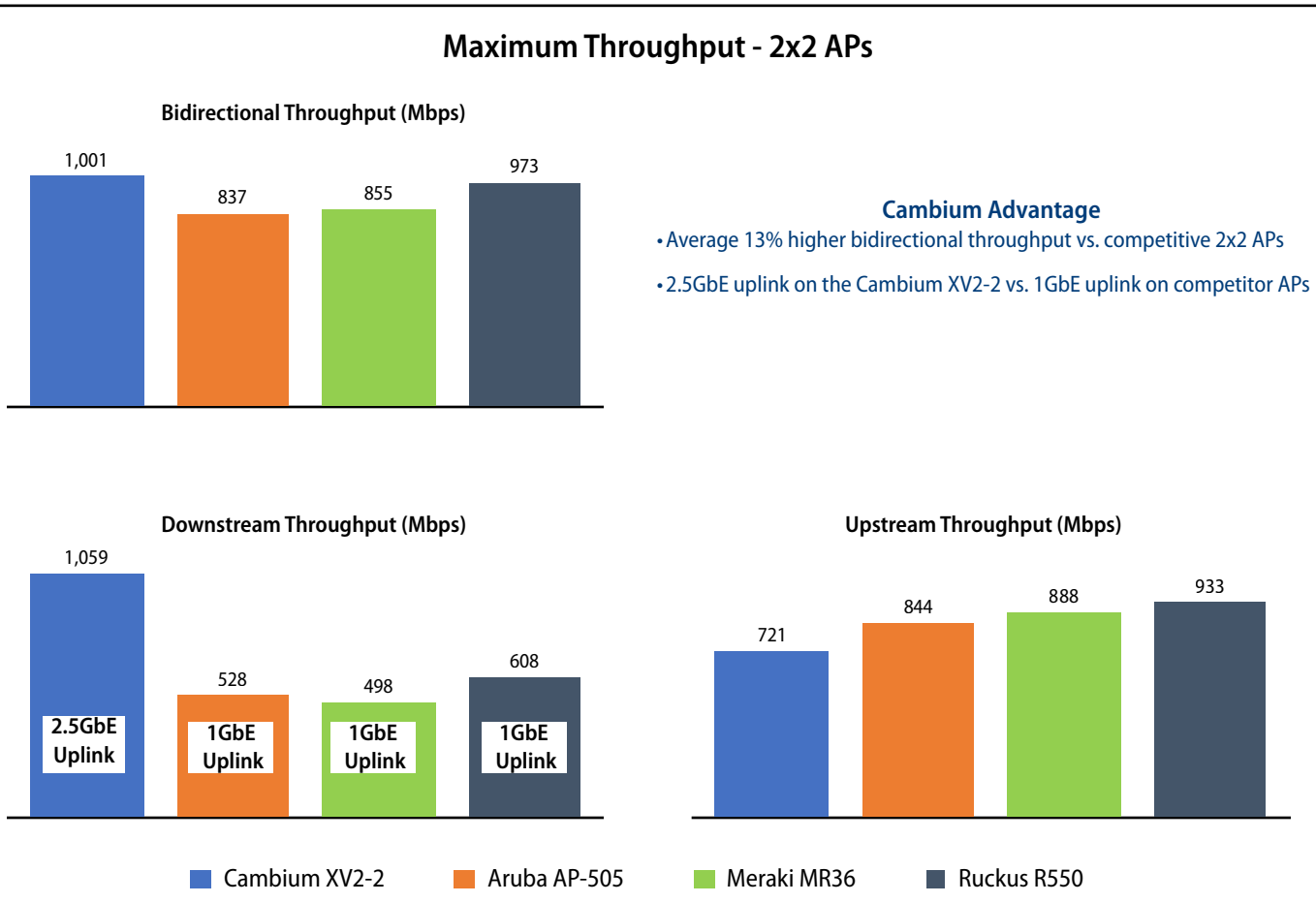
Figure 3

Maximum Throughput - 2x2 APs

Throughput tests were also run on each vendor's 2x2 AP. Only the Cambium AP provides a 2.5GbE uplink where the other APs offer only a 1GbE uplink.

For bidirectional throughput, Cambium ranged from about 3% to 20% higher throughput than competitors and 13% higher than the average of the three competitors. See Figure 4.

The downstream throughput tests illustrate the benefits of the 2.5GbE uplink. The Cambium throughput exceeded the capacity of a 1GbE link. The other APs would be unable to achieve >1Gbps performance due to the bandwidth limitation of their 1GbE uplink.



Note: Total four IxChariot clients (2x2 Wi-Fi 6 Windows laptops) were used with two 2.4GHz clients and two 5GHz clients to evaluate performance of the AP. Bidirectional, downstream, and upstream tests were tested separately as three different tests.

Source: Tolly, December 2020 & January 2021

Figure 4

High-Density Performance - 8x8/4x4 APs

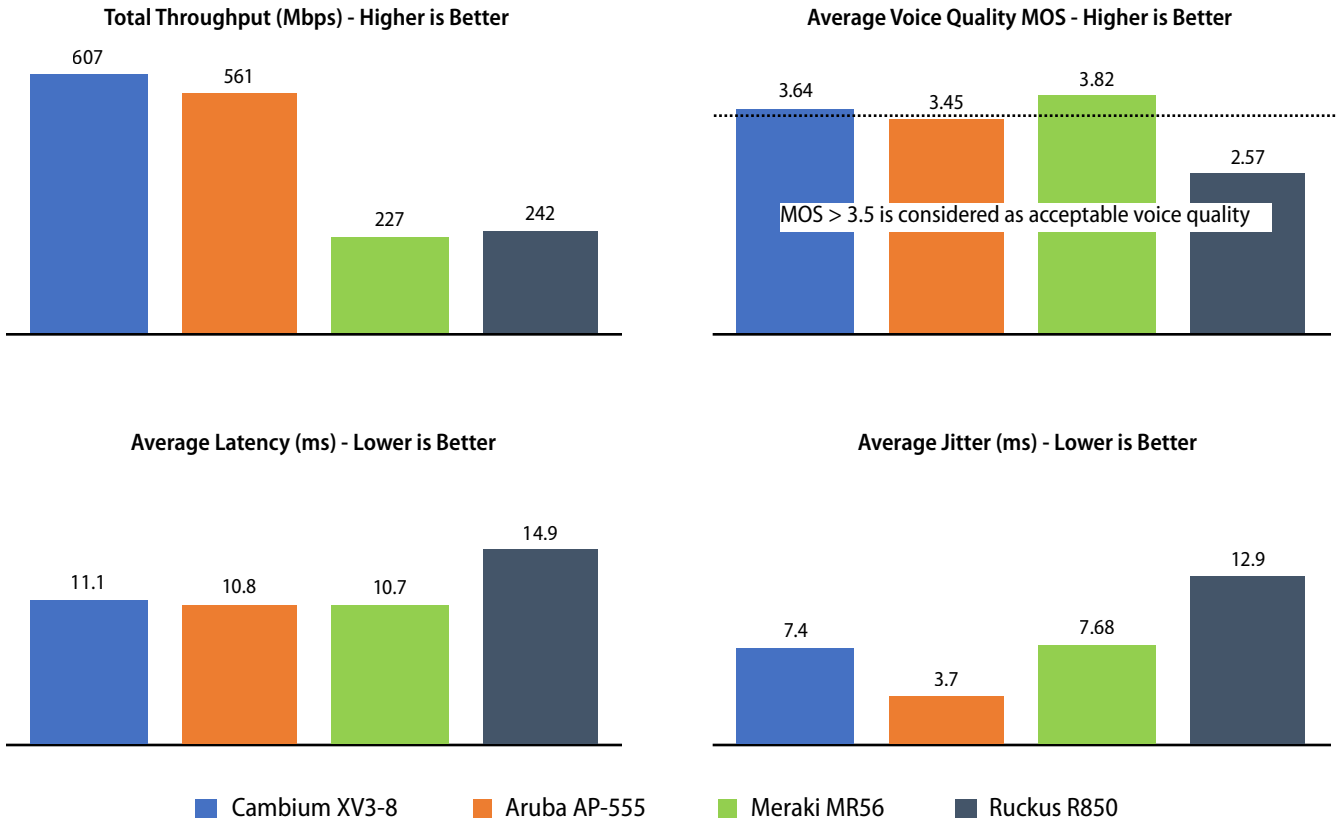
The high-density test was run with 100 clients consisting of a mix of client types to emulate real world environments. Ten percent of the devices consisted of Wi-Fi 6 laptops and all remaining devices were Wi-Fi 5 clients. Cambium and Aruba were configured in tri-radio mode while Meraki and Ruckus were run in dual-radio mode as neither supported tri-radio mode. Thus, the best performing mode was used for each AP.

This test ran a heavy traffic load mix of emulated video and voice traffic across all clients to create a challenging, congested environment. It measured total data throughput across all clients as well as the average voice quality across the 20% of clients that ran a simulated VoIP session.

Cambium delivered the highest throughput ranging from 8% to 167% higher than the competitors. See Figure 5.

Importantly, Cambium (along with Aruba and Meraki) had very low latency and jitter. This translated into good voice quality under high-density load.

High-Density (100 Clients) Performance - 8x8/4x4 Wi-Fi 6 APs



Notes: 1. Total 100 IxChariot clients (70 x Wi-Fi 5 laptops, 10 x Wi-Fi 5 Microsoft Surface Pros, 10 x Wi-Fi 5 Apple iPad Airs, and 10 x Wi-Fi 6 laptops) were used. In each test run, 20 clients ran downstream G711µ codec voice IxChariot traffic (QoS = control) and 80 clients ran downstream YouTube 4K video IxChariot traffic (QoS = Background). After the test run, IxChariot reports total throughput of all 100 clients, average MOS of each voice call, average latency and average jitter of traffic to each client.

2. The AP under test used one SSID for all radios. The AP under test distributed the clients to different radios with its default setting. The Cambium XV3-8 and Aruba AP-555 worked in tri-radio mode. The Meraki MR56 and Ruckus R850 only support two radios.

Source: Tolly, December 2020 & January 2021

Figure 5

High-Density Performance - 2x2 APs

This test modeled the prior test except that only 50 clients were used of which 20% were Wi-Fi 6 clients.

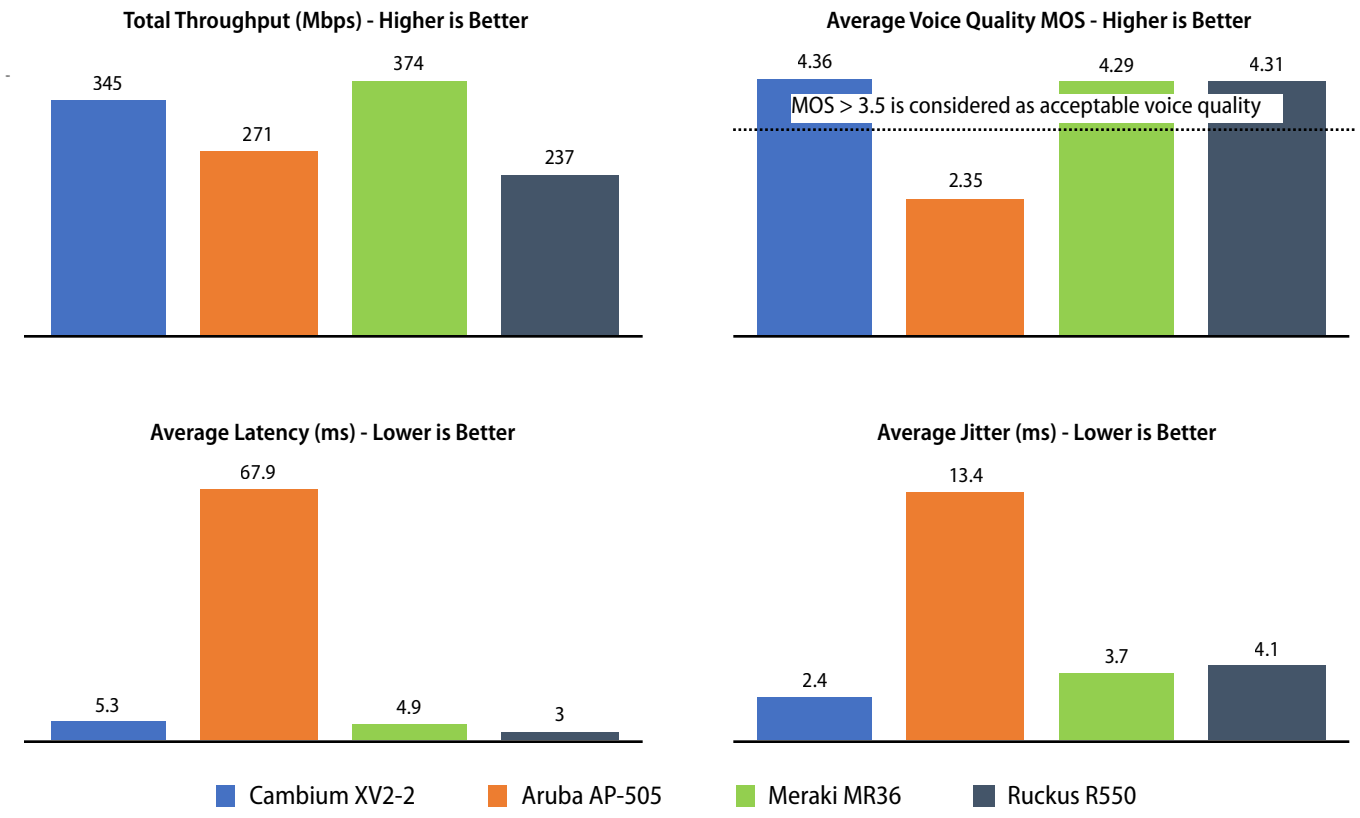
With respect to throughput, Cambium placed second after Meraki which had throughput 8% higher than Cambium.

In stark contrast to the 8x8/4x4 test, the Aruba AP exhibited very high latency and very high jitter compared with all three other APs.

Thus, the voice quality of the Aruba AP was unacceptably low. Cambium, Meraki and Ruckus all exhibited good quality voice MOS results under load.

Cambium and Meraki were the two vendors of the four that were able to provide good quality voice under load in both the 8x8/4x4 and 2x2 multi-client test scenarios.

High-Density (50 Clients) Performance - 2x2 Wi-Fi 6 APs



Notes: 1. Total 50 IxChariot clients (20 x Wi-Fi 5 laptops, 10 x Wi-Fi 5 Microsoft Surface Pros, 10 x Wi-Fi 5 Apple iPad Airs, and 10 x Wi-Fi 6 laptops) were used. In each test run, 10 clients ran downstream G711µ codec voice IxChariot traffic (QoS = control) and 40 clients ran downstream YouTube 4k video IxChariot traffic (QoS = Background). After the test run, IxChariot reports total throughput of all 50 clients, average MOS of each voice call, average latency and average jitter of traffic to each client.

2. The AP under test used one SSID for both radios. The AP under test distributed the clients to different radios with its default setting.

Source: Tolly, December 2020 & January 2021

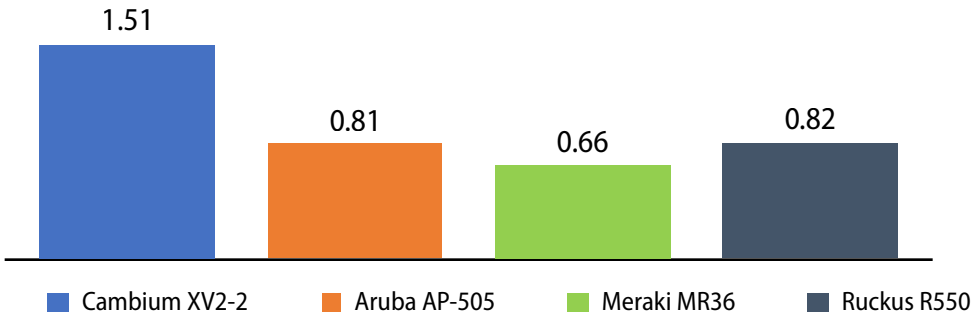
Figure 6

Hardware Support - Additional Information

Cambium, Aruba and Meraki default hardware support offerings with cloud (and without buying additional higher level support) are different but somewhat similar to each other in next business day (NBD) shipping. Ruckus' warranty only commits that the replacement product will be shipped out within 15 business days.

Cambium XMS-Cloud subscription includes the Cambium Care Advanced support which provides next business day (NBD) shipment of hardware replacement (delivery typically within 2 days). Aruba warranty also includes hardware support with NBD shipment (delivery typically 7-10+ days). Meraki advance replacement with NBD shipment is available with a call to Cisco Meraki technical support. Ruckus does not provide NBD shipment for free. The Ruckus 5-year advanced hardware replacement subscription costs $384 per AP on a public website.

Wi-Fi 6 2x2 Access Points Price-Performance Ratio (Mbps/Dollar)



Note: Performance-price ratio = (maximum bidirectional throughput of the AP in the test with all available radios) / (AP list price + 5 years cloud management subscription list price). See Figure 2 chart 2 for detailed prices. See Figure 4 chart 1 for detailed throughput results.

Source: Tolly, December 2020 & January 2021 Figure 7

Wi-Fi 6 Access Points Detailed Prices

8x8/4x4 Wi-Fi 6 Access Points				
	Cambium XV3-8 (8x8/4x4)	**Aruba AP-555**	**Meraki MR56**	**Ruckus R850**
List Price	$1,095	$1,990	$1,849	$1,695
5 Year Cloud Subscription List Price	$270	$300	$450	$285

2x2 Wi-Fi 6 Access Points				
	Cambium XV2-2	**Aruba AP-505**	**Meraki MR36**	**Ruckus R550**
List Price	$395	$730	$849	$895
5 Year Cloud Subscription List Price	$270	$300	$450	$285

Notes: 1. Aruba, Meraki and Ruckus list prices are from authorized online resellers: Aruba - https://www.securewirelessworks.com; Meraki - https://www.cloudwifiworks.com; Ruckus - https://www.ruckussecurity.com. Cambium list prices were provided by Cambium.

Source: Tolly, December 2020 & January 2021 Table 1

Test Setup & Methodology

In any given test, only one AP was online and under test.

Keysight IxChariot was used to generate traffic and measure throughput and voice quality scores.

Each 8x8/4x4 AP used one 5GbE wired uplink.

For the 2x2 APs, the Cambium XV2-2 used one 2.5GbE wired uplink. The Aruba AP-505, the Meraki MR36 and the Ruckus R550 only provides GbE interface, thus each used one GbE wired uplink. See Table 2 for all firmware levels.

Maximum Throughput - 8x8/4x4 APs

The 8x8/4x4 AP throughput test used one AP from each vendor as the DUT and six 2x2 Wi-Fi 6 laptops with Keysight IxChariot installed as the clients. Tests were run in a Faraday cage. The wireless clients were 4-5 feet from the AP under test. The dimensions of the Faraday chamber are 8' x 8' x 8'.

Cambium XV3-8 and Aruba AP-555 both support software-defined radios to support dual-radio mode with one 2.4GHz radio and one 8x8/4x4 5GHz radios or tri-radio mode with one 2.4GHz radio and two 4x4 5GHz radios. In tri-radio AP mode, two clients were connected to each radio. In dual-radio AP mode, two clients were connected to the 2.4GHz radio and four clients were connected to the 5GHz radio.

Meraki MR56 and Ruckus R850 only support dual-radio mode with one 2.4GHz radio and one 8x8/4x4 5GHz radio. In this test, two clients were connected to the 2.4GHz radio and four clients were connected to the 5GHz radio.

For all APs under test, each 5GHz radio used 80MHz bandwidth and each 2.4GHz radio used 20MHz bandwidth.

The bidirectional throughput test used one IxChariot up stream and one IxChariot down stream to each client except one 2.4GHz client. That 2.4GHz client only had one IxChariot down stream without up stream due to license limitation.

The downstream throughput test used two IxChariot down streams to each client except one 2.4GHz client. That 2.4GHz client only had one IxChariot downstream due to license limitation.

The upstream throughput test used two IxChariot up streams to each client except one 2.4GHz client. That 2.4GHz client only had one IxChariot up stream due to license limitation.

All radios used 10dB power. The IxChariot TCP High_Performance_Throughput script with modified window size as 256k was used for all tests.

Maximum Throughput - 2x2 APs

The 2x2 AP throughput test used one AP from each vendor as the DUT and four 2x2 Wi-Fi 6 laptops with Keysight IxChariot installed as the clients. Tests were run in a Faraday cage. The wireless clients were 4-5 feet from the AP under test. The dimensions of the Faraday chamber are 8' x 8' x 8'.

For all APs under test, the 5GHz radio used 80MHz bandwidth and the 2.4GHz radio used 20MHz bandwidth.

The bidirectional throughput test used one IxChariot up stream and one IxChariot

Test Equipment Summary

Vendor	Product	Web	
Keysight	**IxChariot**	https://www.ixiacom.com	ixia TESTED

Wi-Fi 6 Access Points Under Test

	Cambium XV3-8, XV2-2	Aruba AP-555, AP-505	Meraki MR55, MR36	Ruckus R850, R550
FIrmware Version	6.2-r14	8.6.0.4	27.5	200.9.10.4.212

Source: Tolly, December 2020 & January 2021 Table 2

down stream to each client. The downstream throughput test used two IxChariot down streams to each client. The upstream throughput test used two IxChariot up streams to each client.

All radios used 10dB power. The TCP High_Performance_Throughput script with modified window size as 256k was used for all tests.

High-Density Performance - 8x8/4x4 APs

Please see the note of Figure 5 for the test methodology. All radios used 12dB power. Each 5GHz radio used 80MHz bandwidth. Each 2.4GHz radio used 20MHz bandwidth. The wireless clients were placed in an oval pattern around the APs which were on shelves in a tower suspended. The clients were 10 to 30 feet from the AP under test. The overall dimensions of the room the test bed was located in were 25' x 70'.

Please note that all clients associated to the single SSID with all radios on the AP under test. The result may vary with different distributions of clients on different radios. Tolly engineers used the initial distribution when all clients connected to test.

High-Density Performance - 2x2 APs

Please see the note of Figure 6 for the test methodology. All radios used 12dB power. Each 5GHz radio used 80MHz bandwidth. Each 2.4GHz radio used 20MHz bandwidth. The wireless clients were placed in an oval pattern around the APs which were on shelves in a tower suspended. The clients were 10 to 30 feet from the AP under test. The overall dimensions of the room the test bed was located in were 25' x 70'.

Please note that all clients associated to the single SSID with all radios on the AP under test. The result may vary with different distributions of clients on different radios. Tolly engineers used the initial distribution when all clients connected to test.

About Tolly

The Tolly Group companies have been delivering world-class IT services for more than30 years. Tolly is a leading global provider of third-party validation services for vendors of IT products, components and services.

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