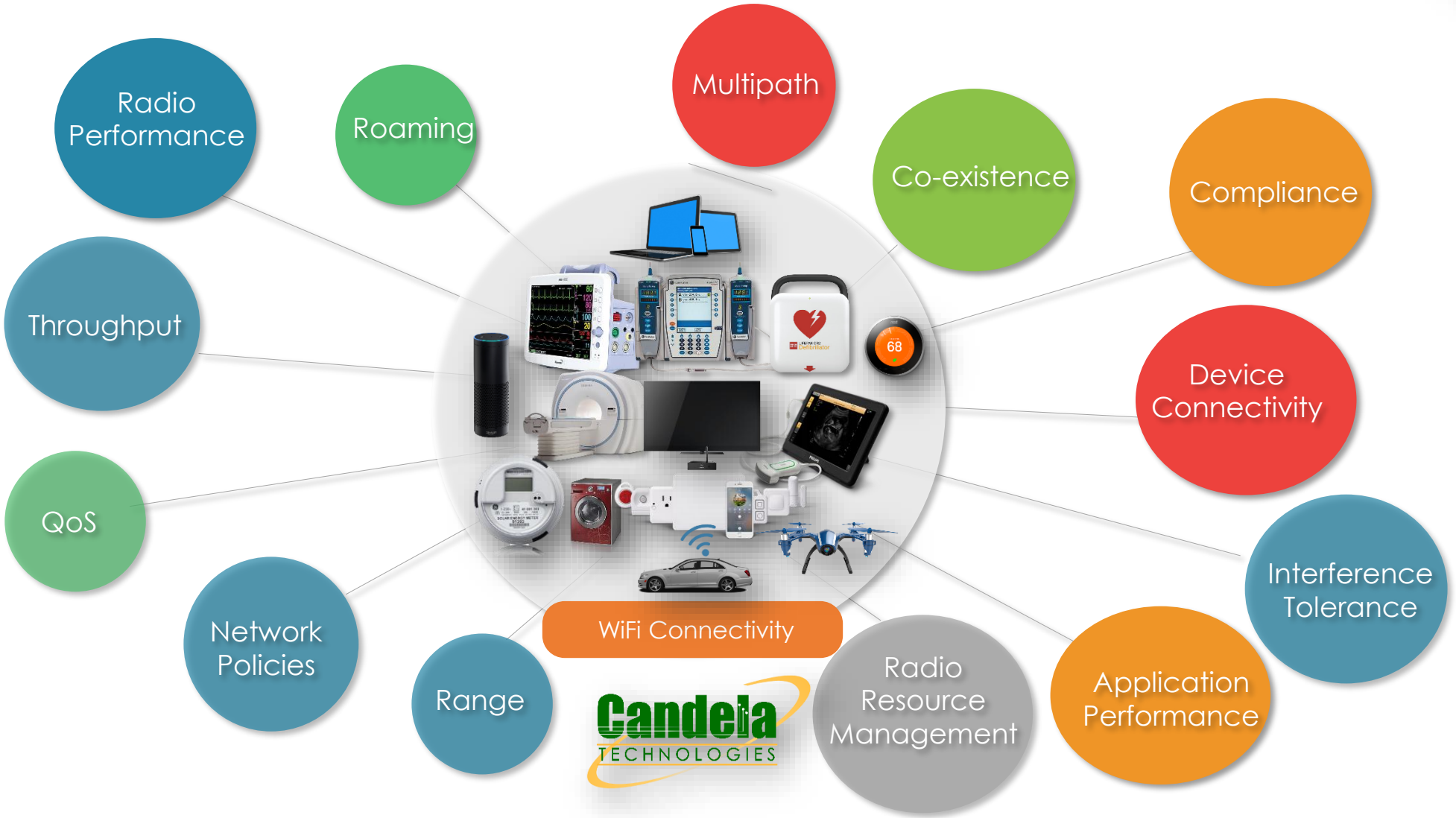
Network Testing & Emulation Solutions

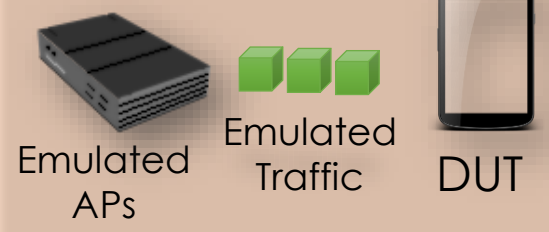
sales@candelatech.com
1-360-380-1618

Candela Station Device Test Solutions Overview

Station Device Testing Scenario



WiFi Client Testing Supported Options



Emulated APs / Emulated Traffic

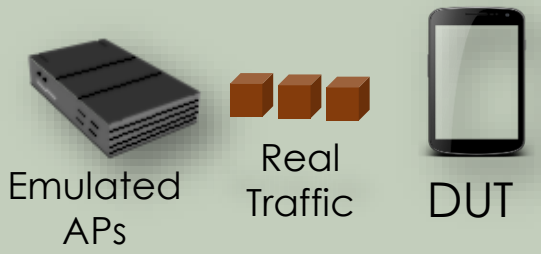
- Provides the most automated, repeatable, configurable and comprehensive test coverage.
- Ideal for early stage dev/QA, benchmarking and comparative testing

BENCHMARKING

Real APs / Emulated Traffic

- For interoperability testing with a known good golden AP from a partner.
- Still provides a high degree of test coverage and automation.
- Ideal for pre-deployment testing

INTEROPERABILITY



Emulated APs / Real Traffic

- Testing scenarios where emulated traffic cannot represent real-traffic.
- Can provide medium level of control but a higher level of realism
- Ideal for testing application specific devices

APP PERFORMANCE

Real APs / Real Traffic

- The most realistic way of testing
- Provides the least amount of control, automation and repeatability.
- Ideal for pre-deployment testing of application specific devices operating on vendor specific networks

END USER EXPERIENCE

Wi-Fi Client TEST REQUIREMENTS

Surveillance Systems

- ✓ Client Connectivity
- ✓ Stability Performance
- ✓ Range Performance
- ✓ Video Performance
- ✓ HD Video Quality
- ✓ Power-save
- ✓ WAN Impairments
- ✓ DFS testing
- ✓ Application Performance
- ✓ Battery Life
- ✓ Security
- ✓ Automation/Test Coverage

Healthcare

- ✓ Connection Reliability
- ✓ Mobility Performance
- ✓ QoS and consistent throughput
- ✓ Security
- ✓ Latency
- ✓ Coexistence on hospital Wi-Fi networks
- ✓ Location Services
- ✓ Proper Device/Network Management
- ✓ Test Services/Consulting
- ✓ Range

Peripheral & Office Equipment

- ✓ Client Connectivity
- ✓ Range Performance
- ✓ Application throughput
- ✓ Low Latency
- ✓ Security
- ✓ HD Video Quality for video conference
- ✓ Tolerance to Interference
- ✓ Proof of Concept /Vendor Selection
- ✓ Power-save
- ✓ Test Services/Consulting

Wearables

- ✓ Client Connectivity
- ✓ Different security, bands, bandwidth
- ✓ DFS/non-DFS channels
- ✓ Range – RvR, RvO
- ✓ Roaming
- ✓ Band steering
- ✓ Powersave
- ✓ Broadband speed (WANlinks)
- ✓ Video streaming
- ✓ Gaming
- ✓ Downloading apps

Consumer Electronics & IOT

- ✓ Client Connectivity
- ✓ HD Video Quality
- ✓ Zero Downtime
- ✓ Cellular and Wi-Fi Handover /Co-existence
- ✓ Range Performance
- ✓ Interference
- ✓ Interoperability
- ✓ Latency for Gaming
- ✓ Range & Roaming
- ✓ Mesh performance
- ✓ Automation
- ✓ DFS Testing

Retail /Industrial

- ✓ Zero Downtime
- ✓ Range Performance
- ✓ Application throughput
- ✓ Low Latency
- ✓ Security
- ✓ Location Services
- ✓ Cellular and Wi-Fi Handover /Co-existence
- ✓ Proof of Concept /Vendor Selection
- ✓ Test Services/Consulting

Wi-Fi Station Testing Scope

- ✓ The following testcases will be executed in Real Test-House and RF Enclosed Chambers based on the test scenario.
- ✓ Depending on the testcase scenario, either it will be executed in Real Test House or RF Enclosed Chambers or in both the environments.
- ✓ The test suite will be executed on Virtual and Real Access points. The commercially available APs will be used for the testing such as ASUS, TP Link, and NETGEAR…etc.
- ✓ Most of the analysis will be done using the Wireshark captures, and appropriate Candela testbed will be used for the testing.

Sr. No.	Test Suite/Test Case	Testcase Description	Pass/Fail Criteria
1	Connectivity Test	1. Connect the DUT to WiFi 6 and WiFi 6E APs. 2. Measure the 4-way handshake, DHCP time using the Wireshark. 3. Check the DUT connected to which SSID, BSSID, Channel, Band, and Bandwidth. 4. Check the Round-Trip Statistics, Link quality, Power level of the connection at the DUT dashboard. 5. Check the push button response time for various DUT operations.	**Pass**: DUT connects to WiFi 6 and WiFi 6E APs, handshake/DHCP completes, correct SSID/BSSID/Channel/Band/Bandwidth shown, round-trip/link stats are within acceptable range, push button responds within specified latency. **Fail**: Failure to connect, incorrect AP details, handshake/DHCP delay beyond threshold, missing or inaccurate metrics, slow/unresponsive button behavior.
2	Multi Band Test	1. Configure the AP to only 2.4GHz band and check the connectivity. 2. Configure the AP to only 5GHz band and check the connectivity. 3. Configure the AP with 2.4GHz and 5GHz with same SSID and authentication and check the connectivity. 4. Verify the statistics mentioned in the testcase 1.	**Pass**: DUT connects successfully to 2.4GHz and 5GHz individually (same SSID), correct band confirmed, metrics match expectations. **Fail**: Connection issues on any band, inability to handle same SSID on multiple bands, incorrect band report.
3	Multi SSID Test	1. Create Multiple SSID on same or multiple APs and check the connectivity. 2. Verify the statistics mentioned in the testcase 1.	**Pass**: DUT connects to all configured SSIDs, reports correct stats. **Fail**: DUT cannot distinguish between SSIDs or fails to connect.
4	Channel Test	1. Configure the AP with channel 1, 6, 11 in 2.4GHz and check the connectivity. 2. Configure the AP with UNII-1, UNII-2, UNII-2e, UNII-3 channels and check the connectivity. 3. Verify the statistics mentioned in the testcase 1.	**Pass**: DUT connects successfully to specified 2.4GHz and UNII channels, reports accurate metrics. **Fail**: DUT fails to connect on valid channels or shows incorrect stats.

Wi-Fi Station Testing Scope

Sr. No.	Test Suite/Test Case	Testcase Description	Pass/Fail Criteria
5	Bandwidth Test	1. Configure the 2.4GHz SSID to 20/40MHz BW and check the connectivity on each BW. 2. Configure the 5GHz SSID to 20/40MHZ BW and check the connectivity on each BW. 3. Verify the statistics mentioned in the testcase 1.	**Pass**: DUT connects on 20/40MHz for 2.4GHz and 20/40MHz for 5GHz, stats verified. **Fail**: Bandwidth setting mismatch or connectivity failure.
6	802.11 Security Test	1. Configure the 2.4GHz and 5GHz SSIDs to Open/WPA/WPA2 security with TKIP and AES encryption and check the connectivity on each security. 2. Verify the statistics mentioned in the testcase 1.	**Pass**: DUT connects securely using Open, WPA/WPA2 with TKIP/AES; metrics verified. **Fail**: Connection issues or failure under specific encryption types.
7	Country Code Test	1. Set the SSID country code to USA, India, and EU countries. Check the connectivity on different channels as per regulatory restrictions. 2. Verify the statistics mentioned in the testcase 1.	**Pass**: DUT connects under USA, EU, India settings, respects restrictions, channel/band compliance. **Fail**: Connection fails or out-of-bound channel usage.
8	Band Steering Test	1. Set the same SSID on 2.4GHz and 5GHz band, increase the distance between DUT and AP, and check the band steering happening when the RSSI changes. 2. Verify the DUT remains connected to AP when the Band steering happens. 3. Check the push button response time for various DUT operations.	**Pass**: DUT successfully steers between bands based on RSSI, maintains connectivity, button response within limits. **Fail**: Failed or delayed steering, disconnection, high button latency.
9	Roaming Test	1. Create roaming setup with 2-3 APs and roam the DUT between the APs. 2. Observe the DUT having the seamless operation while roaming between the APs. 3. Check reassociation request and responses, if de-authenticates, check the reason codes. 4. Check the push button response time for various DUT operations.	**Pass**: Seamless roaming with 2-3 APs, reassociation handled with proper reason codes. **Fail**: Delays, dropped connections, incorrect reassociation handling.

Wi-Fi Station Testing Scope

Sr. No.	Test Suite/Test Case	Testcase Description	Pass/Fail Criteria
10	Adjacent Channel and Co-channel Interference Test	1. Create adjacent channel and co-channel interference while the DUT is connected, check the response time of DUT operations when the interference is present. 2. Check the push button response time for various DUT operations.	**Pass**: DUT remains functional, button responds promptly under interference. **Fail**: Significant latency in the operations, dropped operations.
11	Range Test	1. Increase the distance between the DUT and AP by the step of 10, 20, 30, 40, 50 feet and check the stability of the connection between DUT and AP. 2. Verify the response time of DUT operations when the distance between AP and DUT is changes.	**Pass**: DUT remains connected up to 50 feet with proper DUT operations within the expected duration. **Fail**: Frequent disconnects or unresponsiveness for the DUT operations.
12	Home in a Box Test	1. Simulate various Near Medium Far traffic scenario on LANforge client in a Home in a Box testbed. 2. Check the check the stability of the connection between DUT and AP when the various traffic streams are simulating. 3. Check the push button response time for various DUT operations	**Pass**: DUT maintains connection under traffic load, button responds reliably. **Fail**: Connection drops or unstable under load.
13	Firmware Test	1. Test all the above tests with different firmware version which the customer would like to test.	**Pass**: All test cases pass consistently across firmware versions. **Fail**: Regression issues or test failures post firmware update.
14	Power save/suspend and wake reconnection validation	1. Verify that when a client device enters power-save or suspend mode and subsequently wakes, it can reliably re-establish the Wi-Fi connection without manual intervention. 2. Measure time to reconnect, ensure IP connectivity, and confirm no data loss or authentication failures.	**Pass**: DUT reconnects automatically, no manual intervention, no auth loss. **Fail**: Failure to reconnect or requires user action.
15	Hidden SSID behavior	1. Confirm that clients can successfully connect to a network with a hidden SSID (non-broadcast) by manually configuring the SSID. 2. Test both initial connection and reconnection scenarios. Ensure there is no intermittent disconnect once connected.	**Pass**: DUT connects and reconnects to hidden SSID without drop. **Fail**: Fails to connect or maintain connection.

Wi-Fi Station Testing Scope

Sr. No.	Test Suite/Test Case	Testcase Description	Pass/Fail Criteria
16	Long-term connection stability (soak test)	1. Connect the DUT to an access point. Make sure that the DUT is connected to power. 2. The suspend operation is disabled in the DUT. 3. The sleep and wake up operation is active. 4. Verify the connectivity for 24 hours	**Pass**: DUT remains connected with access point for 24 hours. **Fail**: Connection drops or operation not executable.
17	AP reboot and failover behavior	1. Simulate an access point reboot or outage. 2. Verify that a connected client seamlessly reconnects to another available AP or re-associates with the same AP post-reboot. 3. Measure failover time, authentication success, and packet loss.	**Pass**: DUT reconnects post-reboot seamlessly. **Fail**: Reconnect fails.
18	DHCP lease expiry and IP renewal	1. After the DHCP lease time expires, ensure the client properly renews or reacquires its IP address without disruption. 2. Check that there is no drop in connectivity during the lease renewal process.	**Pass**: DUT renews IP smoothly, no connectivity loss. **Fail**: IP renewal failure or service disruption.
19	Network congestion and its impact on button responsiveness	1. Under high network load, assess how congestion affects DUT responsiveness, such as when manually triggering SSID scan, reconnect, or other DUT operations. 2. The button operations should have minimum latency(≤200 ms latency).	**Pass**: DUT operations response remains within 200 ms . **Fail**: Latency exceeds 200 ms or becomes unresponsive.
20	Aggressive Roaming and Handoff Latency Under Load	1. Place the client in an environment with overlapping APs and heavy traffic. 2. Measure handoff performance (signal threshold triggers, time to reassociate) under load. 3. Validate roaming decision logic and ensure handoff latency is within spec (e.g., <50 ms).	**Pass**: Handoff latency < 50 ms; no drops. **Fail**: Delayed handoff, disconnects, or high latency.
21	DFS Channel Move Handling	1. On detection of radar signals requiring Dynamic Frequency Selection, verify that the AP migrates to a new DFS-compliant channel and the client automatically follows. 2. Measure reconnection delay and test no-traffic windows comply with regulatory limits.	**Pass**: DUT reconnects to DFS-safe channel with minimal delay. **Fail**: Loss of connection or failure to comply with DFS.

Wi-Fi Station Testing Scope

Sr. No.	Test Suite/Test Case	Testcase Description	Pass/Fail Criteria
22	International Channel Move Handling	1. Set the SSID country code to USA, India, and EU countries. Check the connectivity on different channels as per regulatory restrictions. 2. Verify the statistics on the DUT dashboard.	**Pass**: DUT connects under USA, EU, India settings, respects restrictions, channel/band compliance. **Fail**: Connection fails or out-of-bound channel usage.
23	High-Interference with Varying Client Density	1. Introduce RF interference and vary the number of clients connected to the access point. 2. Observe the DUT performance with various supported operations.	**Pass**: DUT performs all the operations in presence of interfence. **Fail**: DUT does not get proper airtime from the access point and operations delays.
24	Rapid SSID Switching	1. Switch the DUT rapidly between multiple SSIDs (e.g., every 30 seconds). 2. Ensure each reconnection is timely, secure authentication is successful, and the system remains stable over repeated transitions.	**Pass**: DUT reconnects quickly with secure auth in < 5s interval. **Fail**: Inconsistent behavior or auth failure
25	WiFi Beacon Loss / Micro Outages	1. Simulate short-term AP signal disruptions (e.g., 100 ms intervals). 2. Ensure the DUT remains associated or quickly recovers without user impact. Validate packet retransmission behavior and reconnection latency.	**Pass**: DUT remains connected or recovers within 1s. **Fail**: Drops connection or takes too long to recover.
26	Negative Test – Corrupted Beacon Frames	1. Simulate delivery of malformed or corrupted beacon frames to verify how the client handles invalid Wi-Fi management data using Virtual Access Point. 2. Confirm that the device does not crash, hang, or misbehave due to malformed headers or timing information.	**Pass**: DUT ignores corrupted frames, remains stable. **Fail**: Crashes, hangs, or malfunctions.
27	RF Storm Test (Noise Injection)	TBD	TBD

Wi-Fi Station Testing Scope

Sr. No.	Test Suite/Test Case	Testcase Description	Pass/Fail Criteria
28	Beacon Starvation + High Latency Combo	1. Simulate a scenario where beacon frames are severely delayed or lost due to congestion or interference, combined with high network latency. 2. Confirm the client continues to function or gracefully degrades and recovers post-impairment.	**Pass**: DUT sustains connectivity despite beacon delays. **Fail**: Disconnects or significant degradation.
29	Low-Level Frame Flooding / Management Frame Injection	1. Flood the Wi-Fi medium with excessive management/control frames (e.g., disassociation, Deauthentication, probe requests). 2. Confirm that the DUT properly authenticates legitimate messages, ignores spoofed ones, and maintains connectivity under attack. 3. The network flooding is feasible with the LANforge.	**Pass**: DUT filters spoofed frames, continues legitimate communication. **Fail**: Auth issues or DUT crashes.
30	(Optional) OTA update via WiFi	1. Need more inputs on the requirements	Need more inputs on the requirements

Peripheral & Office Equipment

Healthcare Devices

Smart Printers, Smart Scanners, Smart Projectors, Tablets, Conference accessories (speaker, projector)

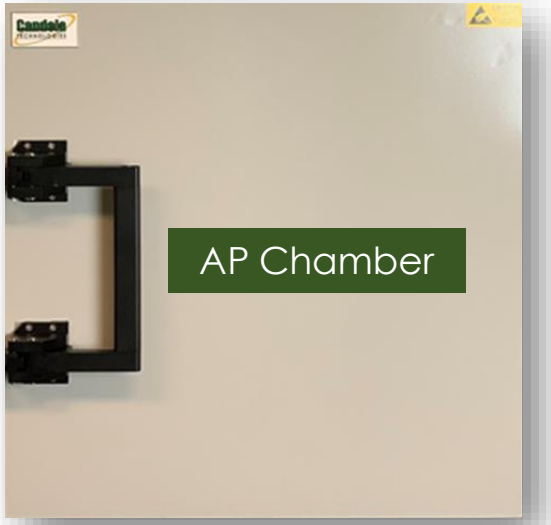
Tests:

- ✓ Basic Client connectivity
- ✓ Range Performance
- ✓ Long duration operation test
- ✓ Latency test
- ✓ Video Quality Tests
- ✓ ACI/CCI Test
- ✓ Interference test
- ✓ DFS Testing
- ✓ Performance with WAN Impairments

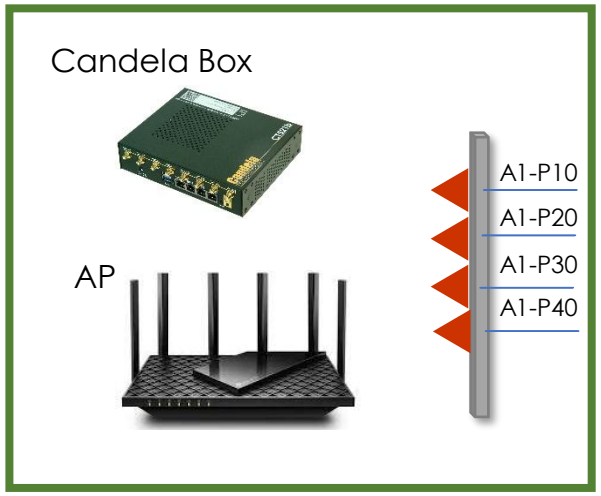
DUT: Smart Printer

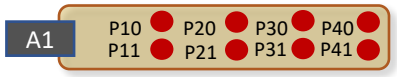
Parameter	Smart Printer	AP1	AP2	AP3
Model Name	-	ASUS ROG AX6000	NETGEAR INSIGHT	ADTRAN SDG8733
Wi-Fi Support	802.11 b/g/n	802.11ax	802.11ax	802.11be
Frequency Band	Only 2.4GHz	2.4GHz & 5GHz	2.4GHz, 5GHz & 6GHz	2.4GHz, 5GHz & 6GHz
NSS	1x1	4X4	4x4	4x4
Bandwidth Support	20MHz	160MHz	160MHz	320MHz
Vendor	Broadcom	Broadcom	Qualcomm	Mediatek

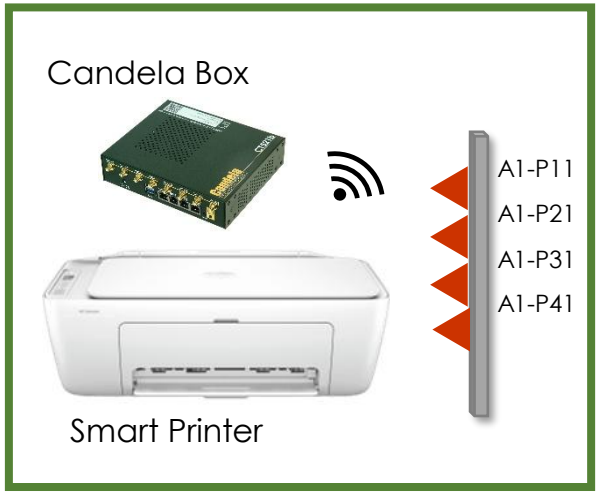
Testbed Topology



Programmable Attenuator







Printer Performance across different chipsets

Comparison of Printer Performance with various chipsets				
Testcase		**AP1 [Broadcom]**	**AP2 [Qualcomm]**	**AP3 [Mediatek]**
Client Connectivity	Open	648ms	806ms	626ms
	WPA/WPA2 Personal	663ms	899ms	729ms
	WPA2 Personal	824ms	884ms	790ms
	WPA3 Personal	1477ms	1467ms	1470ms
Performance w.r.t Range [Print command execution time]	Near	6.5s	8s	8s
	Far	15s	25s	12s
Performance w.r.t Congestion [Print command execution time]	Low	7s	8s	11s
	High	39s	43s	39s

- For the client connection test, the overall connection times were observed to be higher, as mentioned in the previous slide. Among the three APs, connection times were consistently higher with the Qualcomm (AP2) and Mediatek (AP3) APs compared to Broadcom (AP1).
- With Qualcomm (AP2), both the connection times and command execution durations were noticeably higher than with the other two chipsets.
- The printer exhibited better performance with Mediatek (AP3) under far-distance conditions, whereas Broadcom (AP1) showed optimal behavior at near distances.

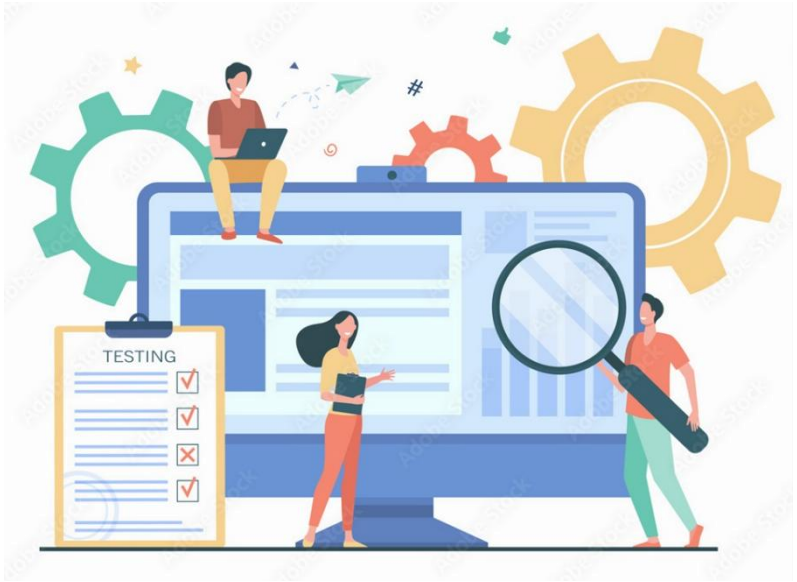
Client Connectivity

- The objective of this testcase is to verify if the smart printer can connect to any Wi-Fi network with different securities and measure the connection times.
- We verified client connectivity across different security modes - **Open, WPA/WPA2, WPA2 & WPA3** and recorded the connection times.
- Under ideal conditions, a connection time of less than 300 ms is generally considered a good result.
- We observed **quite higher connection times** across various security modes in ideal environment (no traffic/load). Below are the results with **AP1 [Broadcom]:**

S No.	Security Type	Connection Status	Connection time(ms) with AP1 [Broadcom]
1	Open	Associated with the AP and obtained IP address	648
2	WPA/WPA2 Personal	Associated with the AP and obtained IP address	663
3	WPA2 Personal	Associated with the AP and obtained IP address	824
4	WPA3 Personal	Associated with the AP and obtained IP address	1477

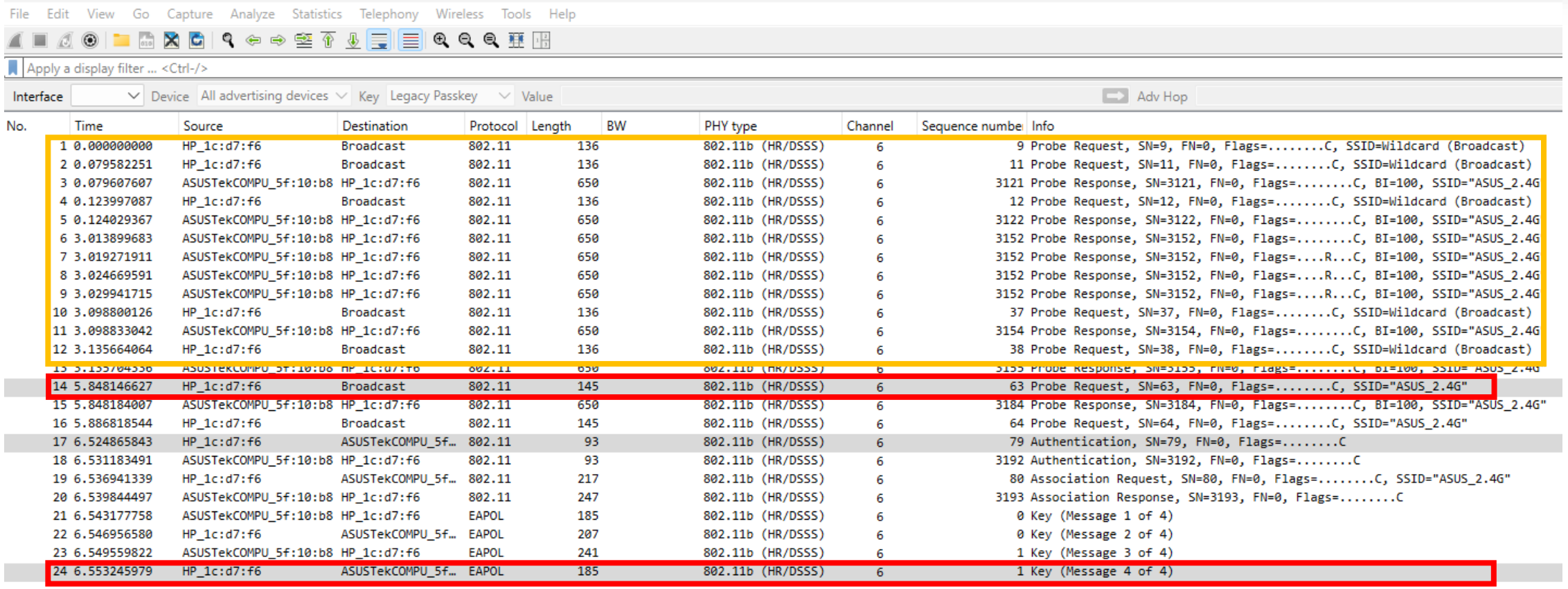
Client Connectivity – Higher connection times debug

S No.	Connection Process with AP1[Broadcom]	Time taken by Printer (ms)	Time taken by Candela client(ms)
1	Overall client connectivity	**705ms**	**119ms**
2	Probe request → Auth request	**676ms**	**44ms**
3	Auth request → EAPOL Message 4	29ms	76ms



- For the total 705ms client connectivity time, the time taken from probe request to authentication frame was observed to be around **676ms**.
- While the authentication request → EAPOL message 4 is completed within **29ms**.
- The Printer is taking some time to process the Probe Response frame and then send the Authentication request frame.
- This behavior is observed multiple times and with different APs.

Client Connectivity – Higher connection times debug



File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

Apply a display filter ... <Ctrl-/>

Interface Device All advertising devices Key Legacy Passkey Value Adv Hop

No.	Time	Source	Destination	Protocol	Length	BW	PHY type	Channel	Sequence numbe	Info
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2	0.079582251	HP_1c:d7:f6	Broadcast	802.11	136		802.11b (HR/DSSS)	6	11	Probe Request, SN=11, FN=0, Flags=........C, SSID=Wildcard (Broadcast)
3	0.079607607	ASUSTekCOMPU_5f:10:b8	HP_1c:d7:f6	802.11	650		802.11b (HR/DSSS)	6	3121	Probe Response, SN=3121, FN=0, Flags=........C, BI=100, SSID="ASUS_2.4G
4	0.123997087	HP_1c:d7:f6	Broadcast	802.11	136		802.11b (HR/DSSS)	6	12	Probe Request, SN=12, FN=0, Flags=........C, SSID=Wildcard (Broadcast)
5	0.124029367	ASUSTekCOMPU_5f:10:b8	HP_1c:d7:f6	802.11	650		802.11b (HR/DSSS)	6	3122	Probe Response, SN=3122, FN=0, Flags=........C, BI=100, SSID="ASUS_2.4G
6	3.013899683	ASUSTekCOMPU_5f:10:b8	HP_1c:d7:f6	802.11	650		802.11b (HR/DSSS)	6	3152	Probe Response, SN=3152, FN=0, Flags=........C, BI=100, SSID="ASUS_2.4G
7	3.019271911	ASUSTekCOMPU_5f:10:b8	HP_1c:d7:f6	802.11	650		802.11b (HR/DSSS)	6	3152	Probe Response, SN=3152, FN=0, Flags=....R...C, BI=100, SSID="ASUS_2.4G
8	3.024669591	ASUSTekCOMPU_5f:10:b8	HP_1c:d7:f6	802.11	650		802.11b (HR/DSSS)	6	3152	Probe Response, SN=3152, FN=0, Flags=....R...C, BI=100, SSID="ASUS_2.4G
9	3.029941715	ASUSTekCOMPU_5f:10:b8	HP_1c:d7:f6	802.11	650		802.11b (HR/DSSS)	6	3152	Probe Response, SN=3152, FN=0, Flags=....R...C, BI=100, SSID="ASUS_2.4G
10	3.098800126	HP_1c:d7:f6	Broadcast	802.11	136		802.11b (HR/DSSS)	6	37	Probe Request, SN=37, FN=0, Flags=........C, SSID=Wildcard (Broadcast)
11	3.098833042	ASUSTekCOMPU_5f:10:b8	HP_1c:d7:f6	802.11	650		802.11b (HR/DSSS)	6	3154	Probe Response, SN=3154, FN=0, Flags=........C, BI=100, SSID="ASUS_2.4G
12	3.135664064	HP_1c:d7:f6	Broadcast	802.11	136		802.11b (HR/DSSS)	6	38	Probe Request, SN=38, FN=0, Flags=........C, SSID=Wildcard (Broadcast)
13	3.135704536	ASUSTekCOMPU_5f:10:b8	HP_1c:d7:f6	802.11	650		802.11b (HR/DSSS)	6	3153	Probe Response, SN=3153, FN=0, Flags=........C, BI=100, SSID="ASUS_2.4G
14	5.848146627	HP_1c:d7:f6	Broadcast	802.11	145		802.11b (HR/DSSS)	6	63	Probe Request, SN=63, FN=0, Flags=........C, SSID="ASUS_2.4G"
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17	6.524865843	HP_1c:d7:f6	ASUSTekCOMPU_5f…	802.11	93		802.11b (HR/DSSS)	6	79	Authentication, SN=79, FN=0, Flags=........C
18	6.531183491	ASUSTekCOMPU_5f:10:b8	HP_1c:d7:f6	802.11	93		802.11b (HR/DSSS)	6	3192	Authentication, SN=3192, FN=0, Flags=........C
19	6.536941339	HP_1c:d7:f6	ASUSTekCOMPU_5f…	802.11	217		802.11b (HR/DSSS)	6	80	Association Request, SN=80, FN=0, Flags=........C, SSID="ASUS_2.4G"
20	6.539844497	ASUSTekCOMPU_5f:10:b8	HP_1c:d7:f6	802.11	247		802.11b (HR/DSSS)	6	3193	Association Response, SN=3193, FN=0, Flags=........C
21	6.543177758	ASUSTekCOMPU_5f:10:b8	HP_1c:d7:f6	EAPOL	185		802.11b (HR/DSSS)	6	0	Key (Message 1 of 4)
22	6.546956580	HP_1c:d7:f6	ASUSTekCOMPU_5f…	EAPOL	207		802.11b (HR/DSSS)	6	0	Key (Message 2 of 4)
23	6.549559822	ASUSTekCOMPU_5f:10:b8	HP_1c:d7:f6	EAPOL	241		802.11b (HR/DSSS)	6	1	Key (Message 3 of 4)
24	6.553245979	HP_1c:d7:f6	ASUSTekCOMPU_5f…	EAPOL	185		802.11b (HR/DSSS)	6	1	Key (Message 4 of 4)

- To further debug the high connection times, we analyzed the packet capture and observed that the client continued to send probe request frames even after receiving a probe response from the AP.
- As shown in the above snapshot, client connectivity time recorded with **AP1 [Broadcom]** in one iteration is **705ms**.

Client Connectivity under congestion

- The objective of this testcase is to verify if the smart printer can connect to an AP under congestion with different securities and measure the connection times. Below are the test results with AP1 [Broadcom].

S No.	Security	Channel Utilization	Connection Status	Connection time(ms) with AP1 [Broadcom]
1	Open	10%	Associated and obtained IP address	649
2		50%	Associated and obtained IP address	656
3		>90%	Associated and obtained IP address	675

S No.	Security	Channel Utilization	Connection Status	Connection time(ms) with AP1 [Broadcom]
1	WPA/ WPA2	10%	Associated and obtained IP address	671
2		50%	Associated and obtained IP address	679
3		>90%	Associated and obtained IP address	742

S No.	Security	Channel Utilization	Connection Status	Connection time(ms) with AP1 [Broadcom]
1	WPA2	10%	Associated and obtained IP address	705
2		50%	Associated and obtained IP address	711
3		>90%	Associated and obtained IP address	1076

S No.	Security	Channel Utilization	Connection Status	Connection time(ms) with AP1 [Broadcom]
1	WPA3	10%	Associated and obtained IP address	1548
2		50%	Associated and obtained IP address	1564
3		>90%	Associated and obtained IP address	1710

- In all the scenarios, the connection time is above 600ms and it was more than 1second for WPA3 security mode which is quite high.

Sample Test Results

- We verified print actions and print quality in two different conditions:
  1. Under various congestion levels: Low, High congestions
  2. At various distances: Near, Far

S No.	Parameter	Test Results with AP1 [Broadcom]		Test Results with AP2 [Qualcomm]		Test Results with AP3 [Mediatek]	
		Without congestion	With congestion	Without congestion	With congestion	Without congestion	With congestion
1	Channel Utilisation	7-10%	96%	15%	95%	10%	94%
2	Photo size	1.7MB	1.7MB	1.7MB	1.7MB	1.7MB	1.7MB
3	Print Type	Black & White	Black & White	Black & White	Black & White	Black & White	Black & White
4	Print command execution time	7s	39s	8s	43s	11s	39s

- Print command execution time is the time from tap 'print' to printer starting to pull paper.
- In the first subtest, initially the printer was connected to the wi-fi network and then congestion was then introduced by running TCP traffic from an additional client(candela station) traffic in the same environment.
- The printer performed well with both APs under ideal conditions (no congestion). However, when there is high congestion, command execution latency was significantly higher with AP1 compared to AP2.

Sample Test Results

Performance at Near and Far distances:

S No.	Parameter	Test Results with AP1 [Broadcom]		Test Results with AP2 [Qualcomm]		Test Results with AP3 [Mediatek]	
		At Near distance	At Far distance	At Near distance	At Far distance	At Near distance	At Far distance
1	Channel Utilisation	7-10%	96%	15%	95%	10%	94%
2	Photo size	1.7MB	1.7MB	1.7MB	1.7MB	1.7MB	1.7MB
3	Print Type	Black & White	Black & White	Black & White	Black & White	Black & White	Black & White
4	Print command execution time	6.5s	15s	8s	25s	8s	12s

- For this test, the distance is emulated using programmable attenuator and the performance is evaluated at near and far distances with all three APs.
- At Near distance, the command execution took almost same time with all APs with just 1.5s variation between AP1 and AP2, AP3.
- However, at far distance, the execution time increased to 15 seconds with AP1, 25 seconds with AP2 and 12s with AP3. AP2 [Qualcomm] exhibited quite higher responsive times at far distance.

Surveillance Systems

RvR

Wanlink

Interference

Roaming

Surveillance Systems

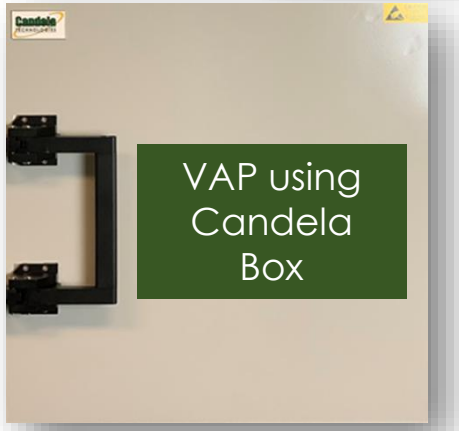
Indoor/Outdoor Surveillance Cameras, Smart Doorbell Keypads, Motion Sensors, Home Security Controllers

Tests:

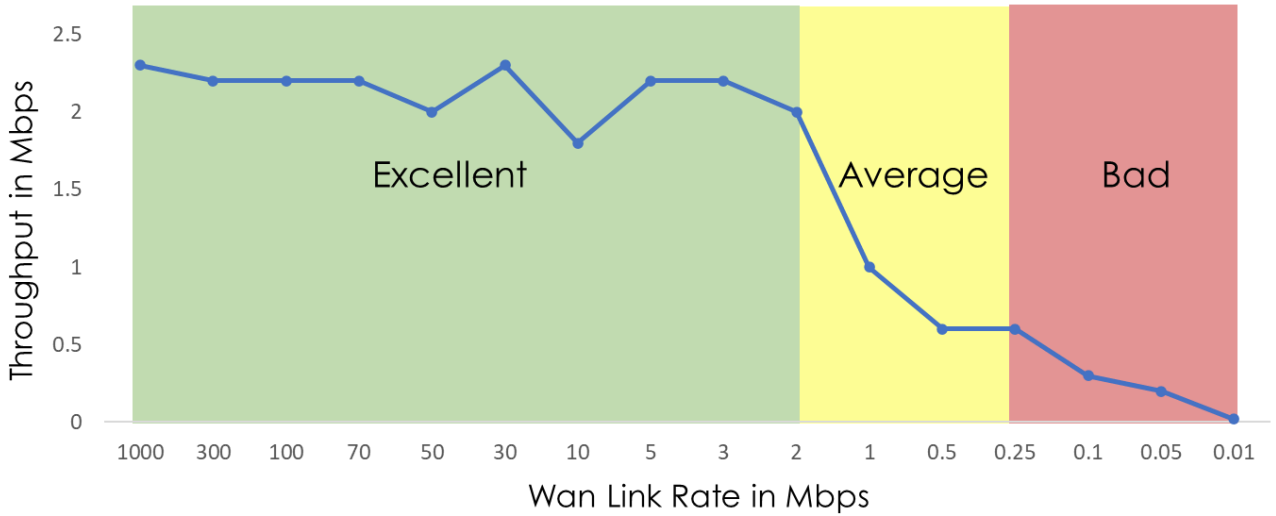
- ✓Long duration operation test
- ✓Stress testing with simultaneous motion and streaming
- ✓Connection times/failures.
- ✓Motion Detection testing and testing other triggers.
- ✓Power consumption profile (sleep, active, peak streaming)
- ✓Performance under limited or fluctuating bandwidth
- ✓Medium Streaming Performance and overall system performance in:
  - ✓Baseline ideal conditions
  - ✓Over distance
  - ✓With Wi-Fi interference
  - ✓With non- Wi-Fi Interference

Testbed Images

Attenuators shelf

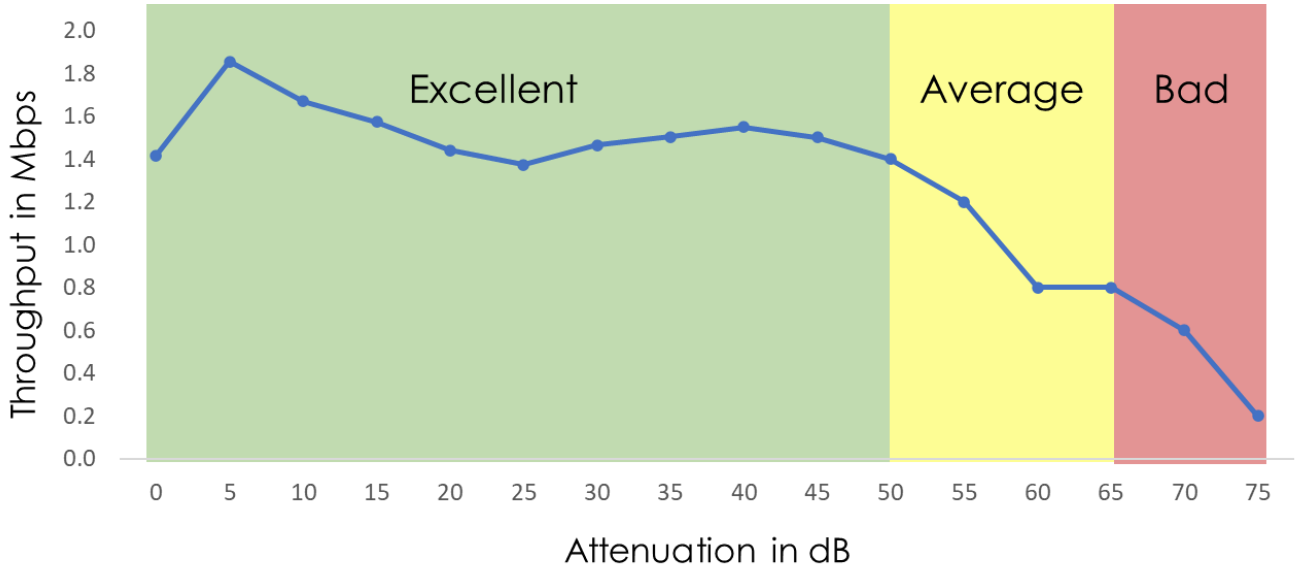


Sample Test Reports



User can have good experience till 2Mbps of link rate, post that there is a decline in throughput

User can have good experience till 50dB attenuation, post that there is a decline in throughput



Broadband speed - Video Observations

Camera 1

Link speed – 1Gbps (Avg)

Link speed – 100Mbps (Avg)

Link speed – 20Mbps (Avg)

Camera 2

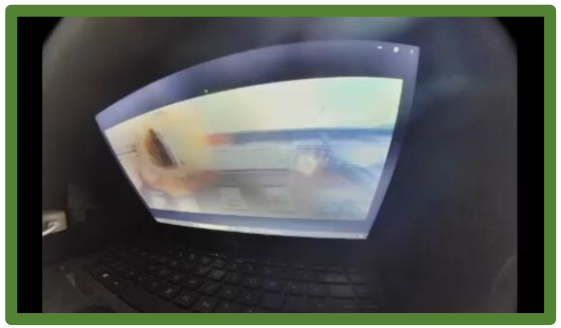
Link speed – 1Gbps (Excellent)

Link speed – 100Mbps (Excellent)

Link speed – 20Mbps (Excellent)

Camera 3

Link speed – 1Gbps (Excellent)



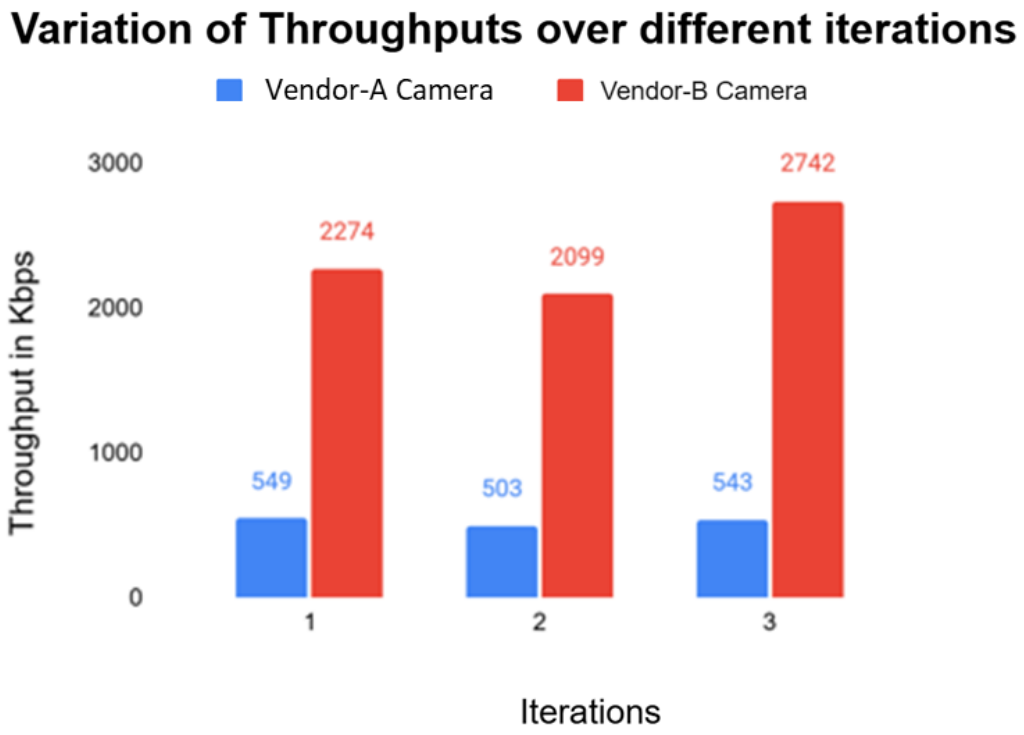
Link speed – 100Mbps (Excellent)

Link speed – 20Mbps (Excellent)

Throughput Test

In this test we have performed the below scenarios:

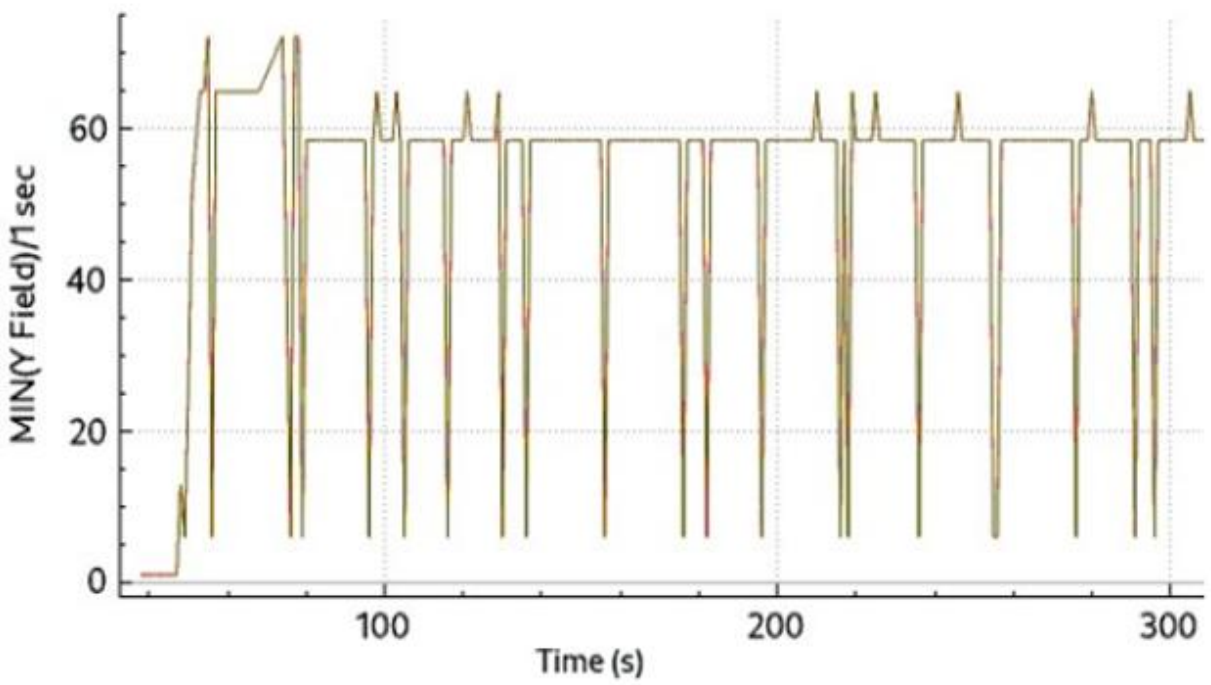
1. Run the live stream, evaluate the throughput for vendor-A and vendor-B cameras
2. Check the video quality and audio-video synchronisation.



- The achieved throughputs are higher with Vendor-B Camera when compared to Vendor-A camera.
- Audio and video synchronisation fails at times and the video playback is not smooth

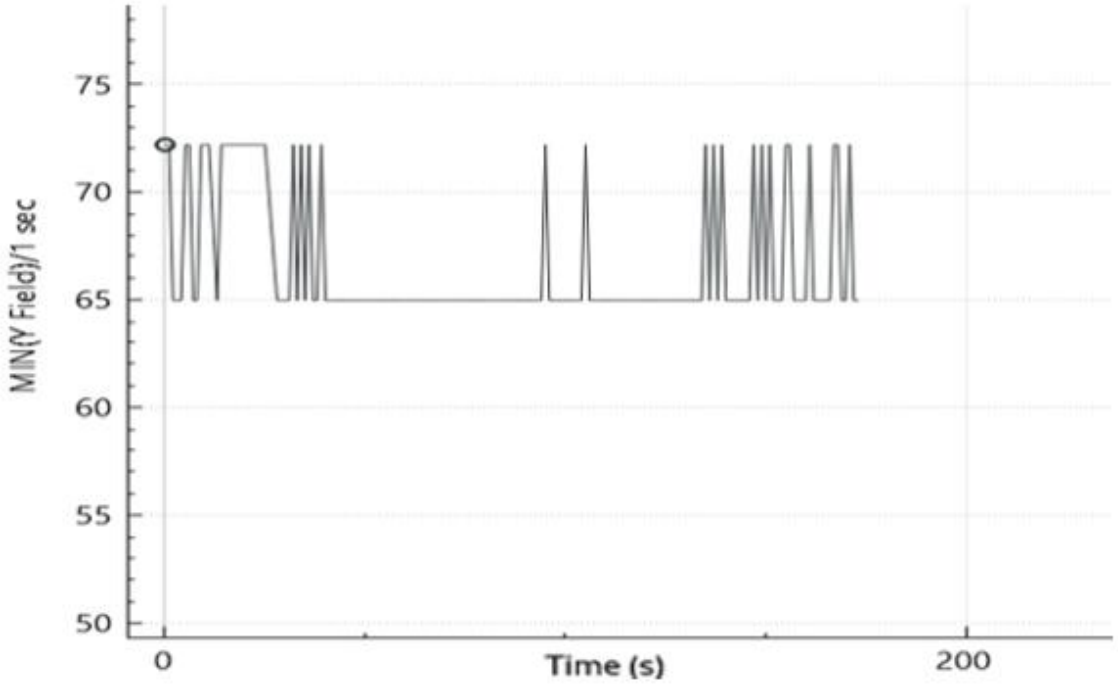
Throughput Test – Lower Throughput Observations

Vendor-A Camera



With the Vendor-A camera the variation of data rate is very high

Vendor B camera



With Vendor B Camera the variation of data rate is very less. The least data rate is around 65 Mbps

Live Video Streaming Test

Realtime scenario:

- In the myQ application we have the live video streaming option, in which we can check the current activity happening near the video keypad. This can be helpful to check if anyone is performing any activity in front of the camera.

Procedure:

- Here we have placed a Tablet in front of the video keypad, such that there will be a motion activity and actions happening near the camera line of sight.
- We also tried to add packet loss while doing the live video streaming to determine the performance of the video keypad.

Observations:

Sno	Packet loss	MCS		Data rate (Mbps)		Throughput (Kbps)		No of QoS frames		Amount of data transferred		Number of retries	
		Vendor-A	Vendor-B	Vendor-A	Vendor-B	Vendor-A	Vendor-B	Vendor-A	Vendor-B	Vendor-A	Vendor-B	Vendor-A	Vendor-B
1	0%	5	7	52	72.2	1529	1936	21072	24277	23MB	29MB	961	3898
2	5%	5	7	52	72.2	1125	2062	17044	25787	17MB	31MB	905	3758
3	10%	7	7	72.2	72.2	262	313	7446	5687	4MB	5MB	1734	837
4	15%	5	7	52	72.2	313	272	4374	6074	5MB	4MB	213	1024
5	20%	No stream	7	No stream	72.2	No stream	273	No stream	6208	No stream	4MB	No stream	986
6	30%		7		72.2		282		6407		4MB		951

Home in a Box Test

Observations with Wi-Fi Interference:

Sno	Channel Utilization	MCS		Data rate (Mbps)		Throughput (Kbps)		No of QoS frames		Amount of data transferred		Number of retries	
		Vendor-A	Vendor-B	Vendor-A	Vendor-B	Vendor-A	Vendor-B	Vendor-A	Vendor-B	Vendor-A	Vendor-B	Vendor-A	Vendor-B
1	20%	5	7	52	72	1322	1771	19427	17136	20MB	19MB	1713	727
2	50%	7	7	72	72	1311	1710	24053	17881	24MB	22MB	927	1049
3	95%	5	7	52	72	830	920	19347	10109	18MB	11MB	3292	1108

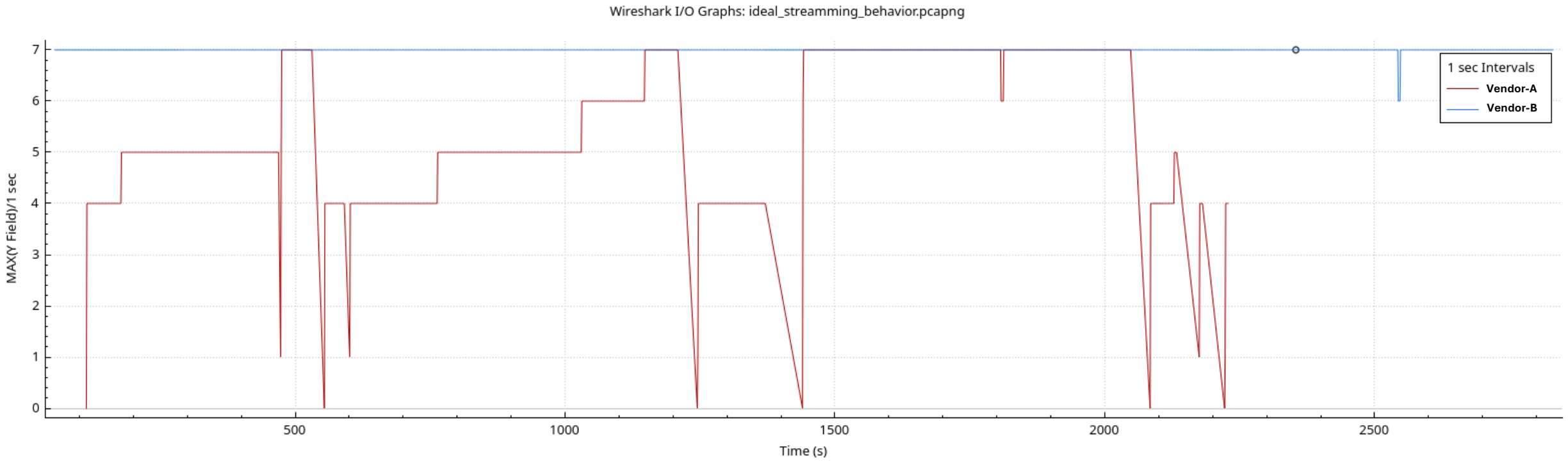
Observations with Zigbee and BLE Interference:

Sno	MCS		Data rate (Mbps)		Throughput (Kbps)		No of QoS frames		Amount of data transferred		Number of retries	
	Vendor-A	Vendor-B	Vendor-A	Vendor-B	Vendor-A	Vendor-B	Vendor-A	Vendor-B	Vendor-A	Vendor-B	Vendor-A	Vendor-B
1	5	7	52	72	1259	1747	15201	23401	17MB	27MB	256	906

- Here we can notice that the chamberlain device is having fluctuations in MCS rates even at 0% channel utilization and it is happening at random intervals.
- Also, the quality of the live streaming is getting dynamically adapted in the RING device due to which there is a better user experience.

Home in a Box Test

MCS Fluctuation with Vendor-A camera



Throughput Test – Lower Throughput Observations

The retransmissions are recorded high in the Vendor-A camera when compared to Vendor-B camera

Retransmissions recorded on the chamberlain device:

- **WLAN retries:** (25.5%)

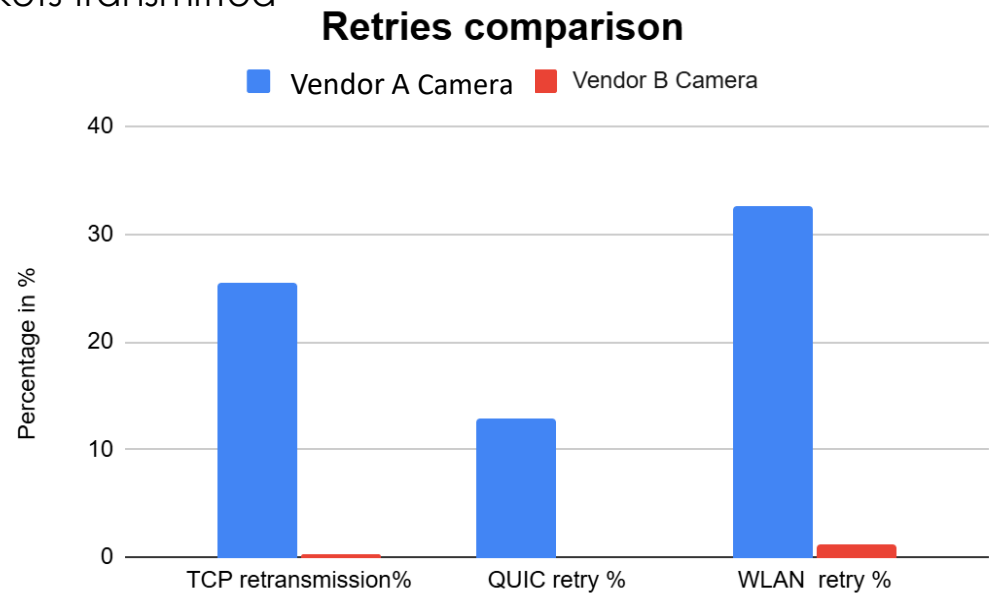
  Layer 2 retries account for 25% of the total data frames sent by the Vendor-A Camera
- **QUIC retries:** (12.9%)

  The video transmission occurs over the QUIC protocol, with retries recorded at approximately 12%.
- **TCP retries:** (32.06%)

  TCP retransmissions are the highest observed, constituting 32% of all TCP packets transmitted during the video session

Retransmissions recorded on the Vendor B Camera:

- **WLAN retries (0.31%) are an TCP retries are 1.18%.**
- Here QUIC protocol is not used for video audio transmission



Consumer Electronics

Consumer Electronics

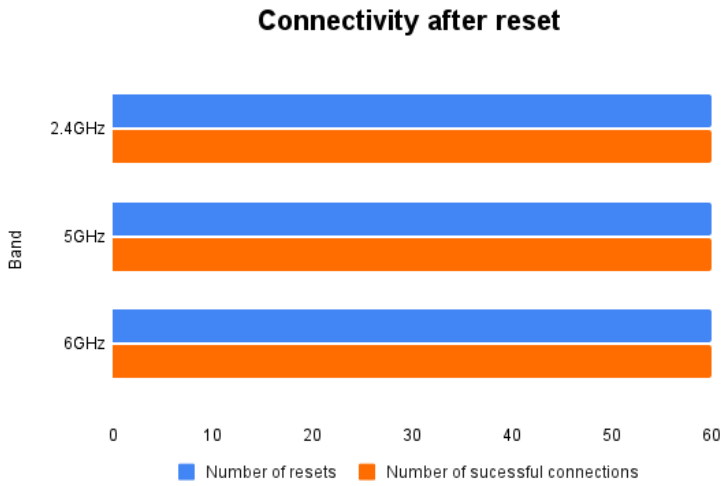
Smart TVs, Game consoles, Laptops, Smart Speakers, Smart Washing machines, Smart Refrigerators, Smart vacuum cleaners

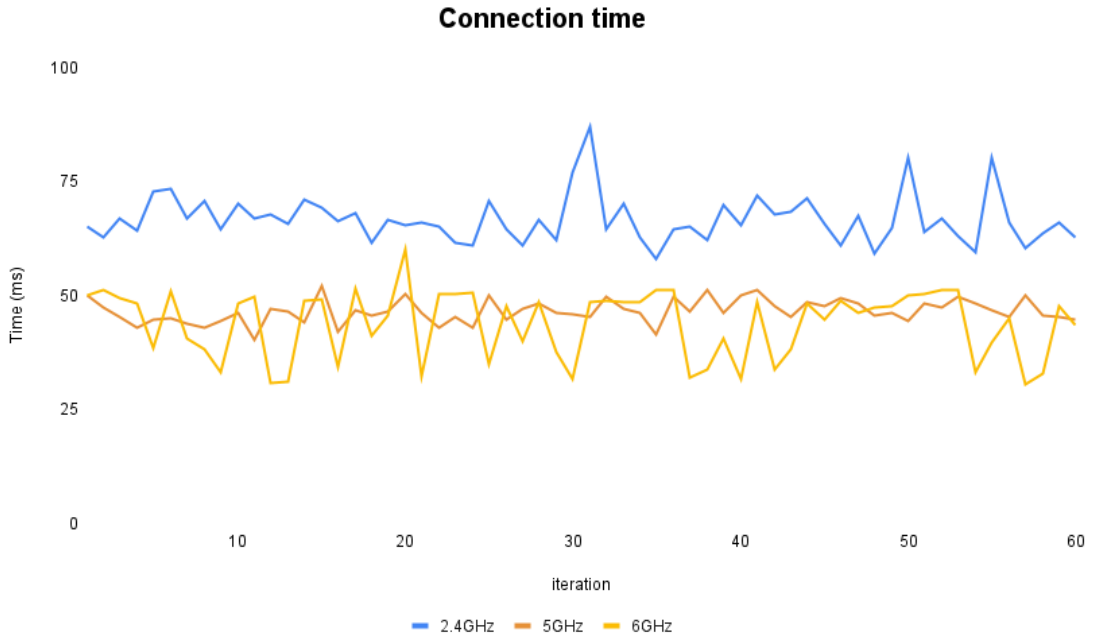
Tests:

- ✓Basic Client connectivity
- ✓Client connectivity with different security
- ✓Range Performance
- ✓Video Quality Performance
- ✓Long duration operation test
- ✓Interference test
- ✓Power consumption test
- ✓DFS Testing
- ✓Performance with WAN Impairments
- ✓Latency Test

Connectivity test

Objective: To verify the connectivity state and connection times of the device after resetting the Wi-Fi interface multiple times





Observation

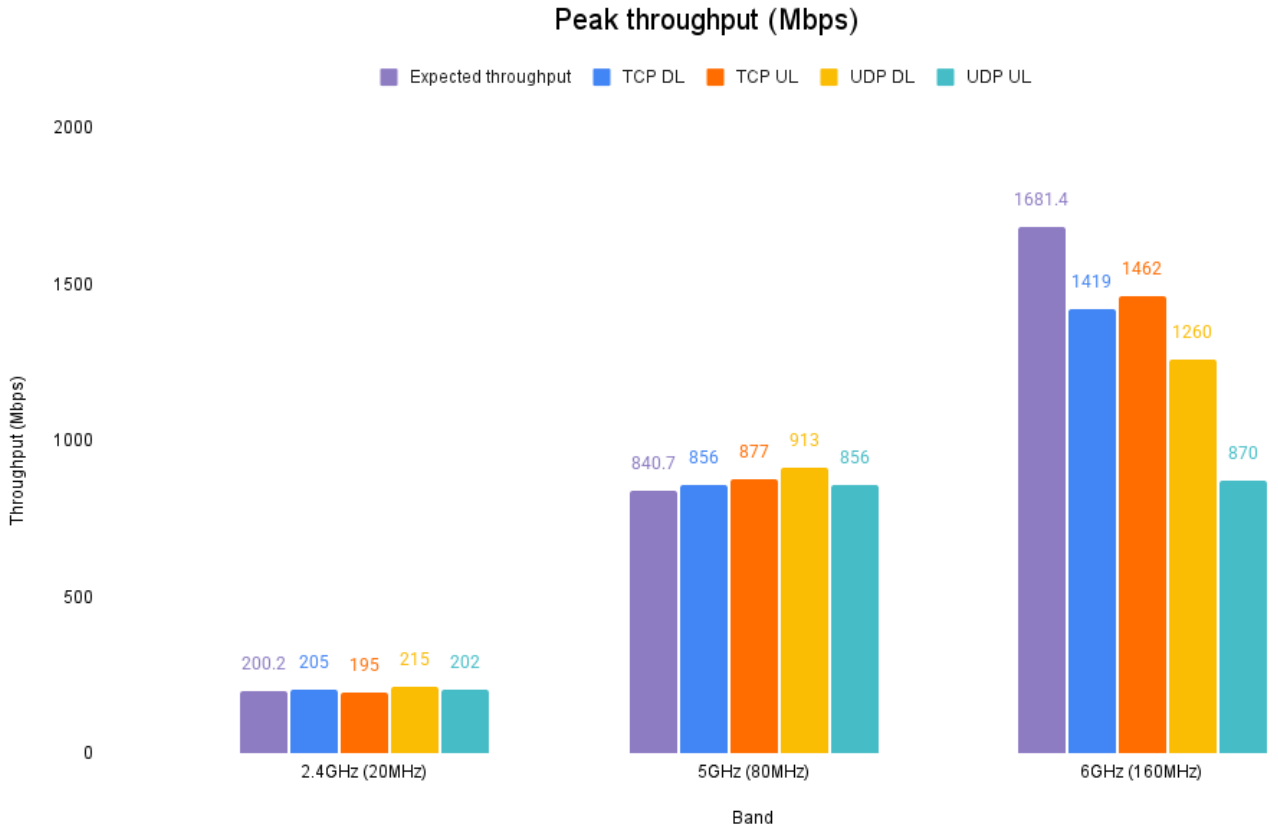
- Connected **successfully for all 60 iterations** across all bands
- Connection time on 2.4GHz is **slightly higher (around 10ms)** when compared to 5GHz and 6GHz

Note

- Connection time is measured from Probe request to EAPOL message 4

Peak performance test

Objective: To verify the maximum performance of the STA device in ideal RF conditions across multiple bands in different bandwidths

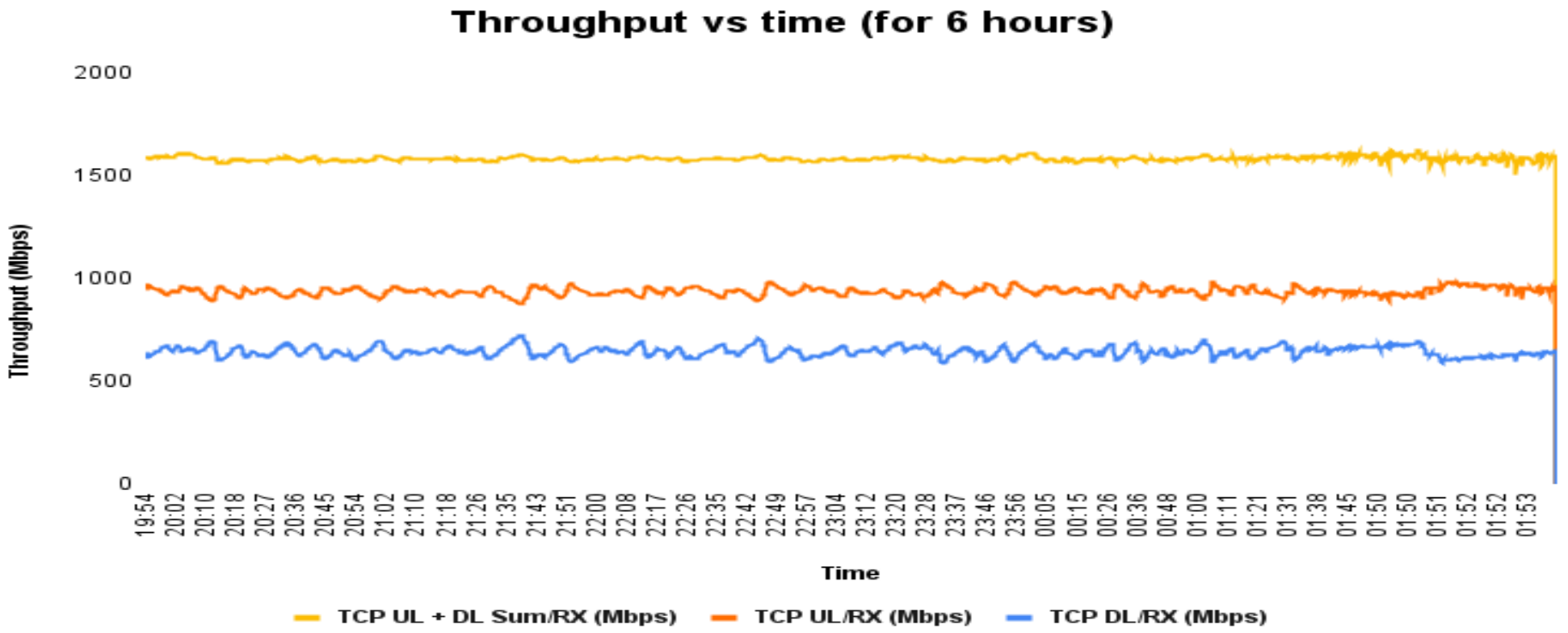


Observation

- Performance on **2.4GHz (20MHz) and 5GHz (80MHz) is good** as the device reached expected throughput value
- Achieved throughput is **less** when compared to expected throughput on **6GHz** band with 160MHz bandwidth

Stability test

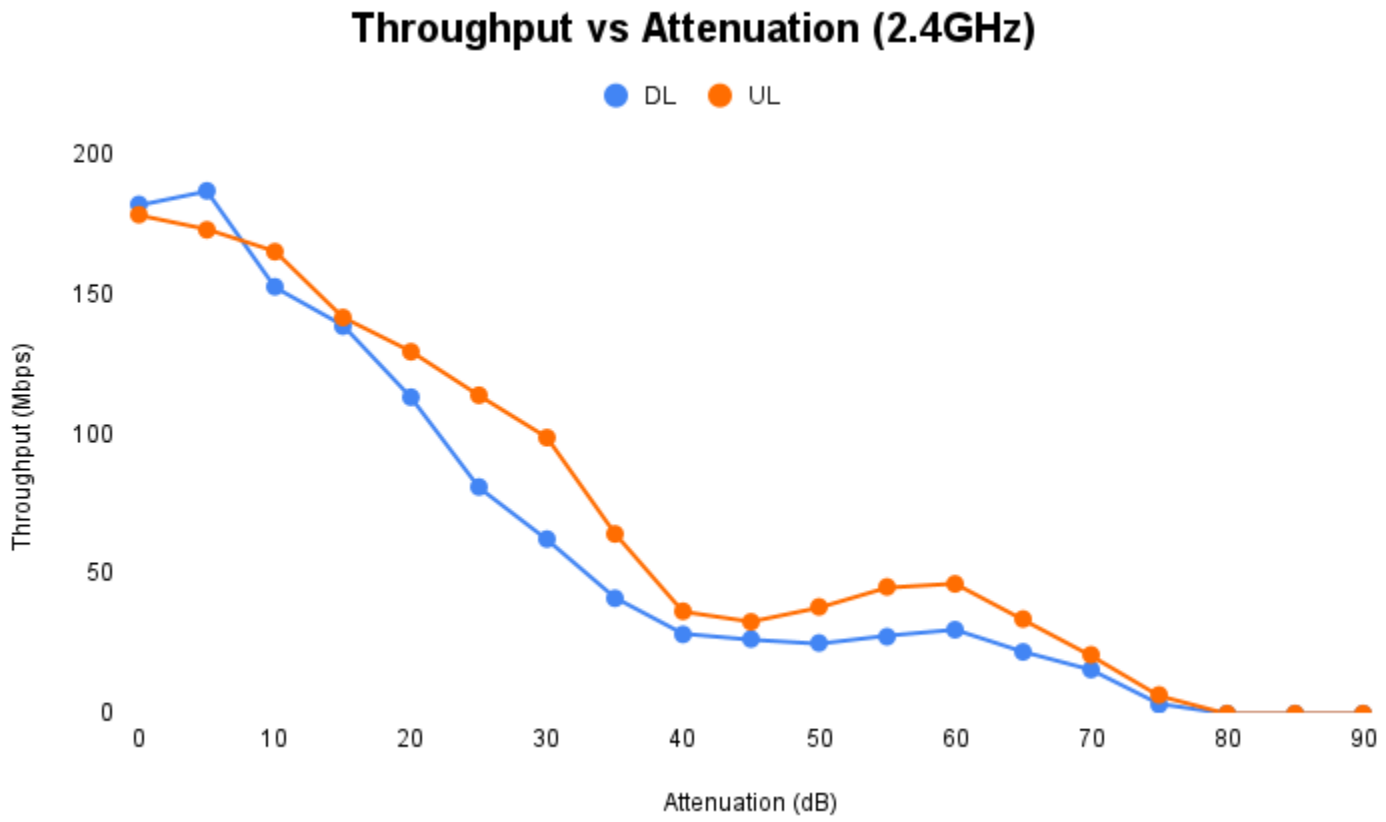
Objective: To verify the stability of the STA by running a throughput test for 6 hours and monitor for performance dips or crashes



Observation

- Device **exhibited good stability** with no performance dips or crashes

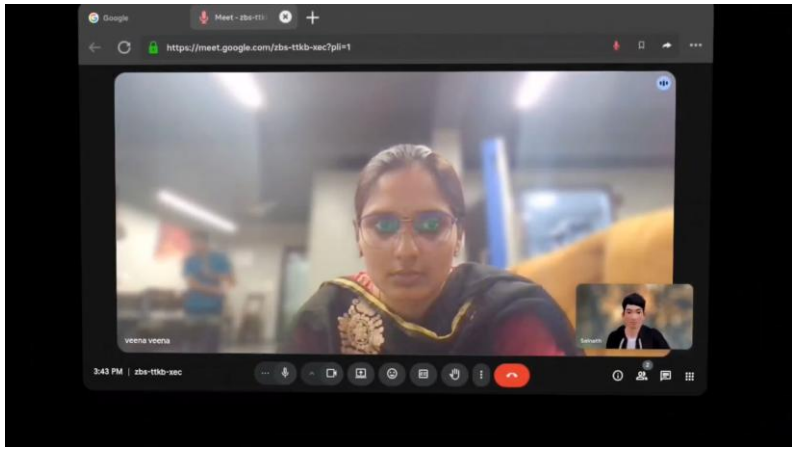
Rate vs Range test



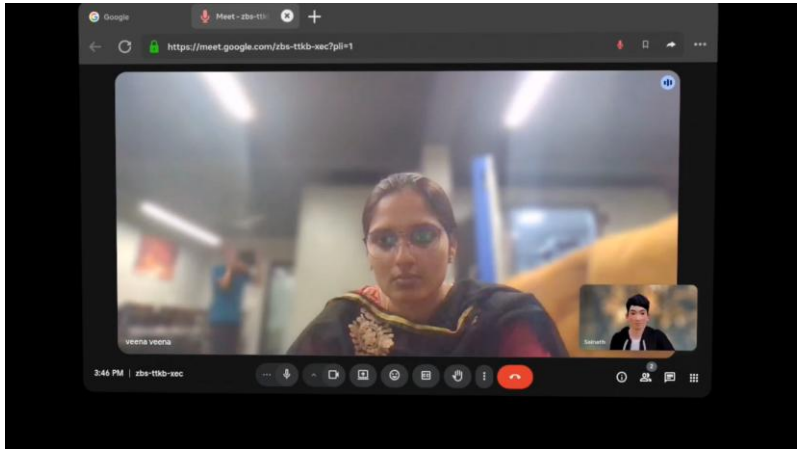
Observation

- Exhibited good range by staying connected till many attenuation levels
- At far distance **(-82dBm RSSI)**, the user experience went **bad** while having a google meet

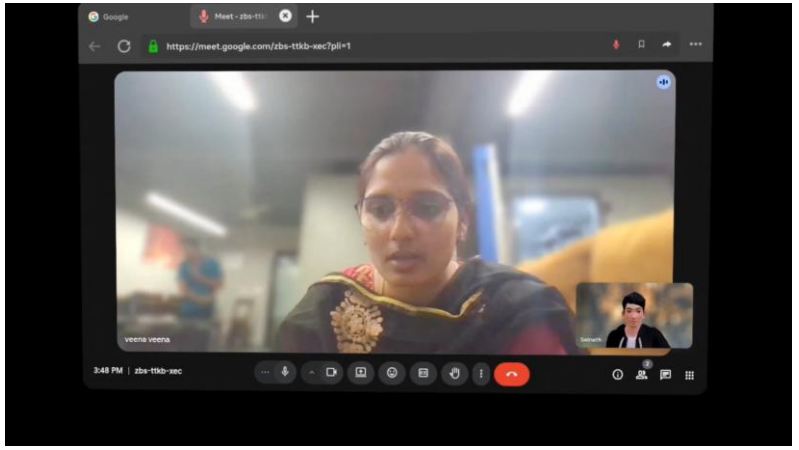
User experience – Rate vs Range



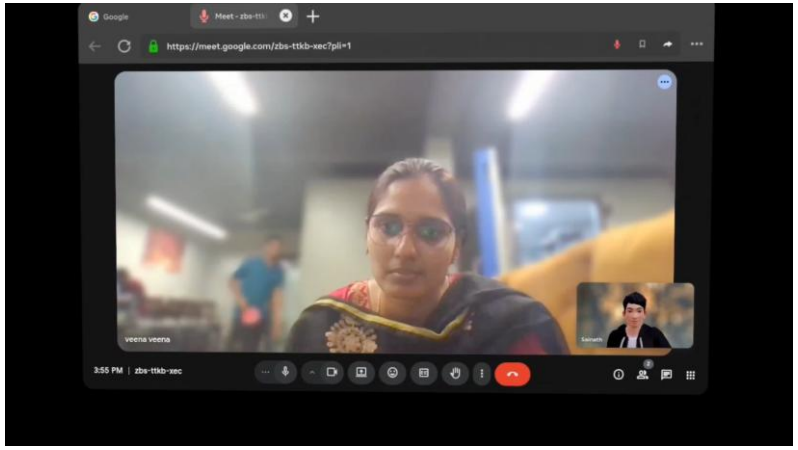
RSSI: -45dBm (excellent)



RSSI: -55dBm (excellent)



RSSI: -65dBm (good)

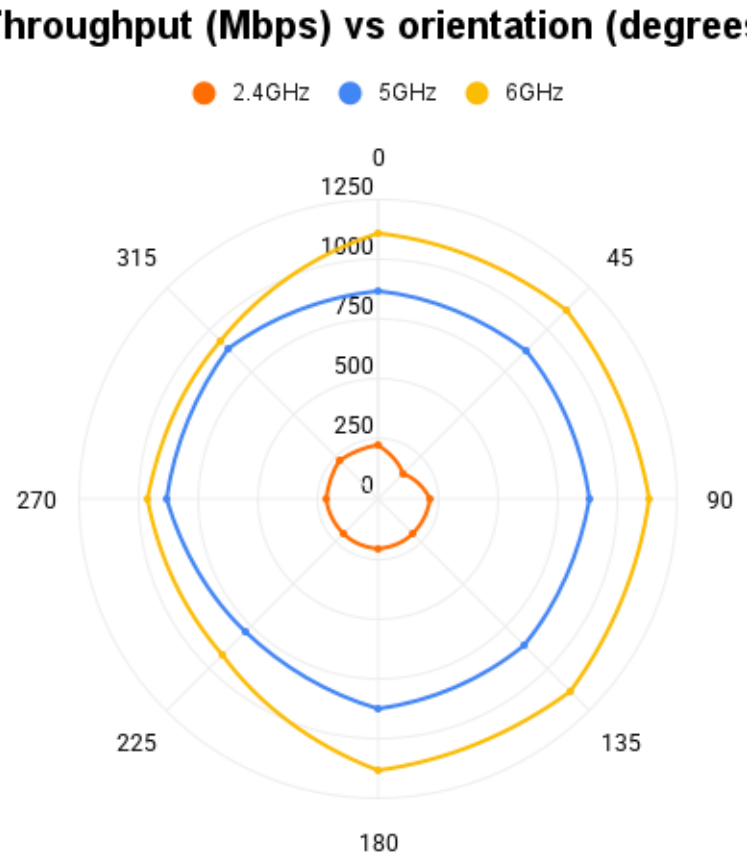


RSSI: -75dBm (average)

RSSI: -82dBm (bad)

Rate vs Orientation test

Objective: To verify the throughput behavior of the STA device at various orientations



Observation

- Slight throughput dips are seen at **45° for 2.4GHz** band and **225° for 5GHz, 6GHz** bands

User experience – Rate vs Orientation

0 degrees (excellent)

60 degrees (excellent)

120 degrees (excellent)

180 degrees (excellent)

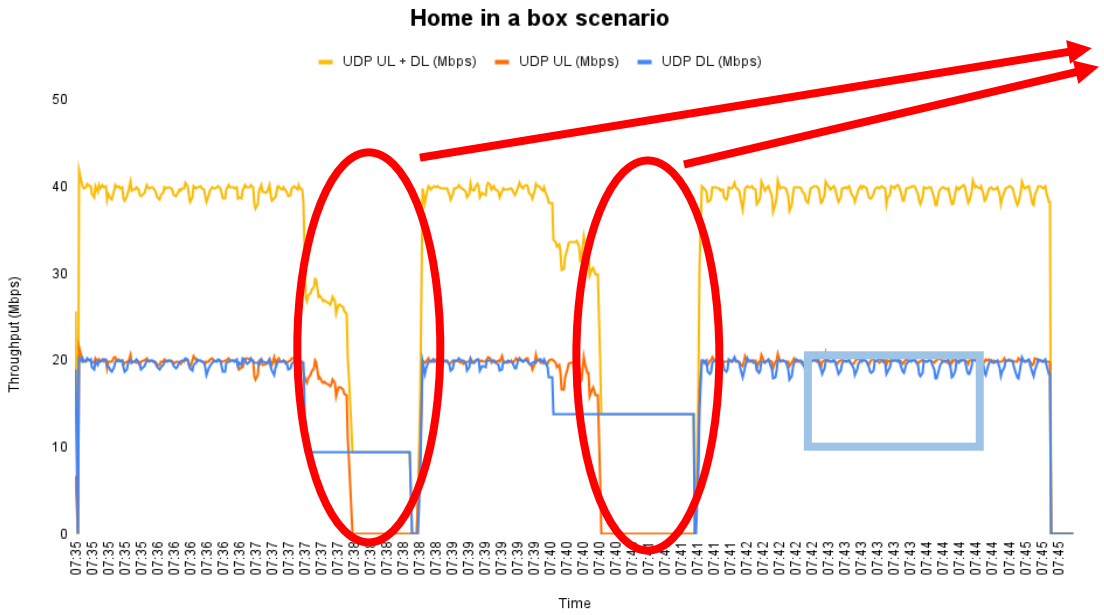
240 degrees (excellent)

300 degrees (excellent)

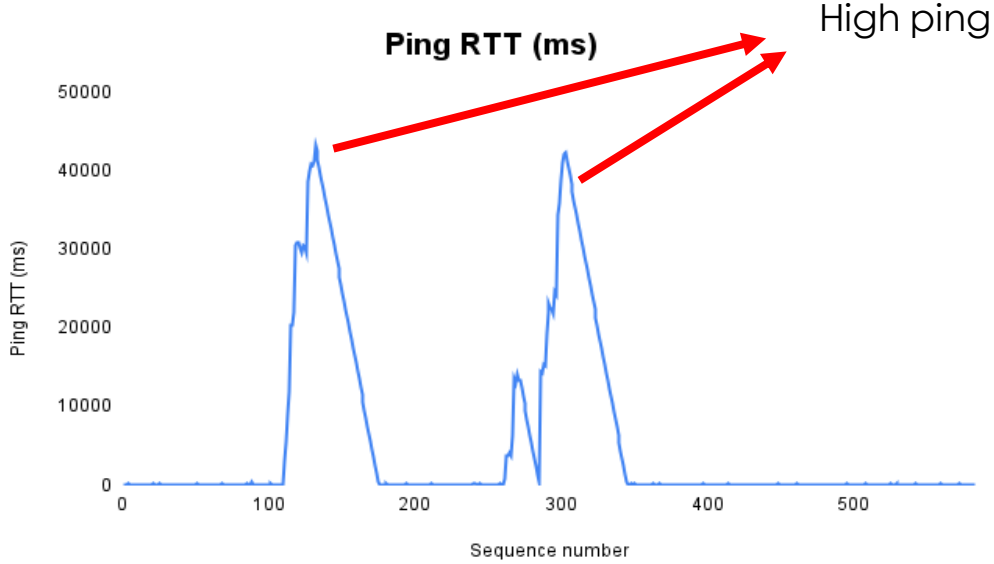
Observation

- Good user experience in all the above orientation points while watching 360° video on YouTube

Home in a Box test



Performance dropped when Home in a Box traffic profiles are active



High ping RTT

- Performance is **badly impacted** when Home in a Box traffic scenarios are active leading to dips in achieved throughput. The ping round trip time went to abnormally high values (beyond 40 seconds) when realistic home traffic profiles were running

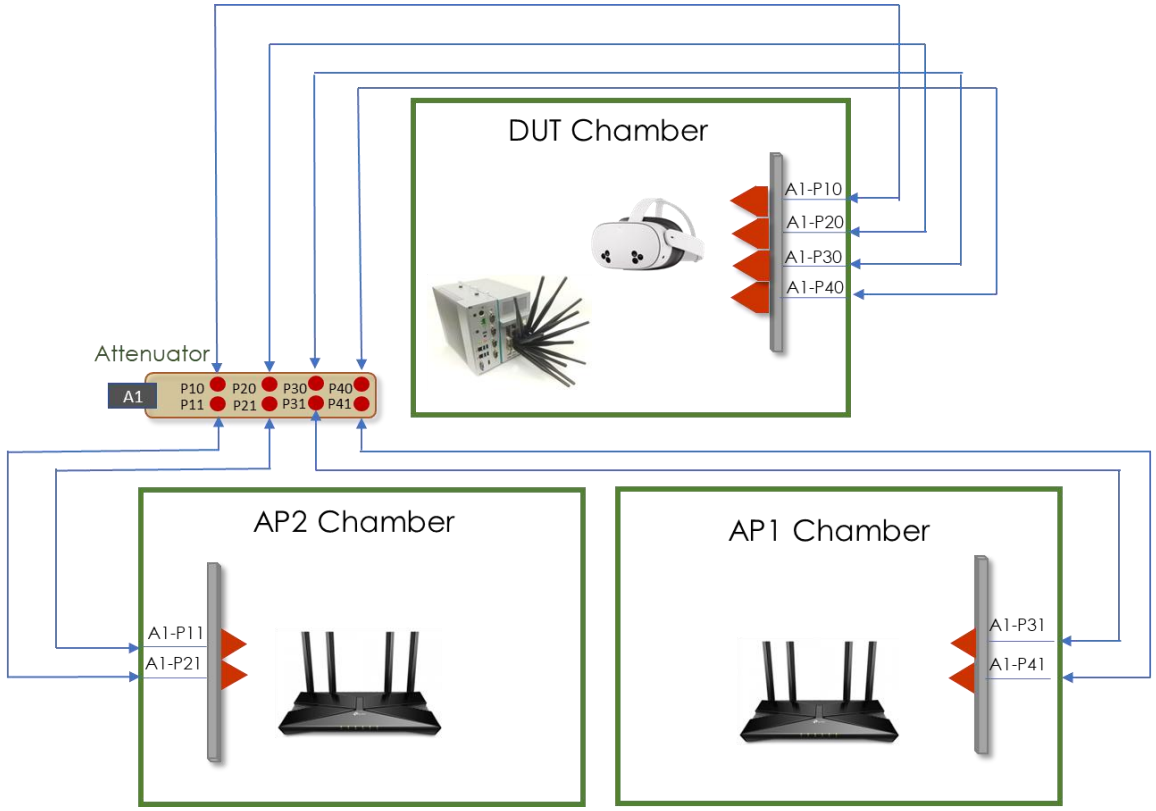
User experience – Home in a box

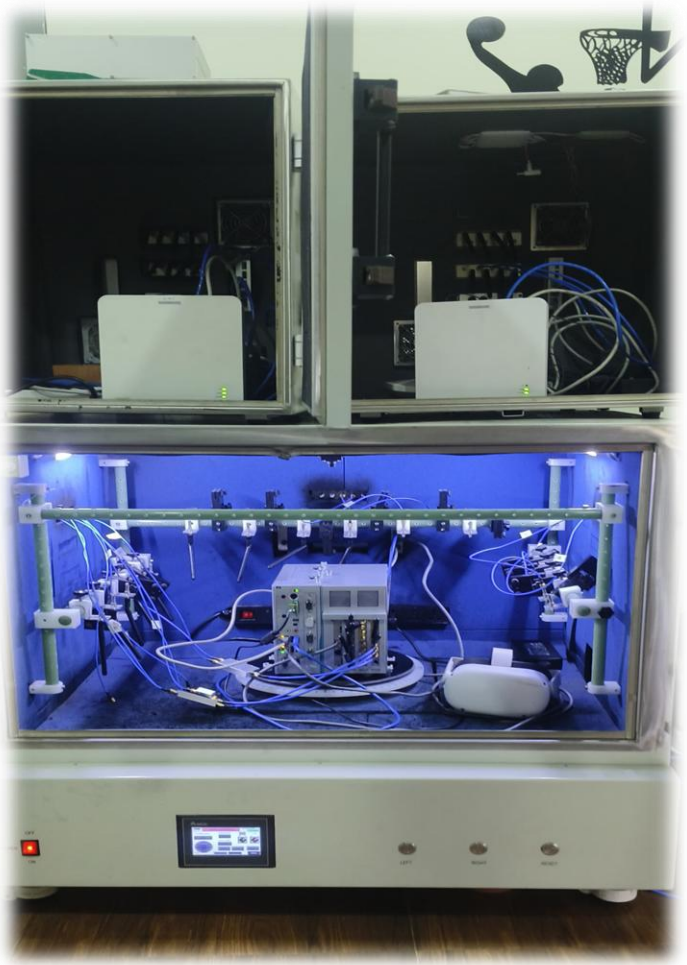
Observation

- The YouTube live video was interrupted and stopped playing when Home in a Box scenario is running leading to bad user experience

Roaming

Testbed topology:

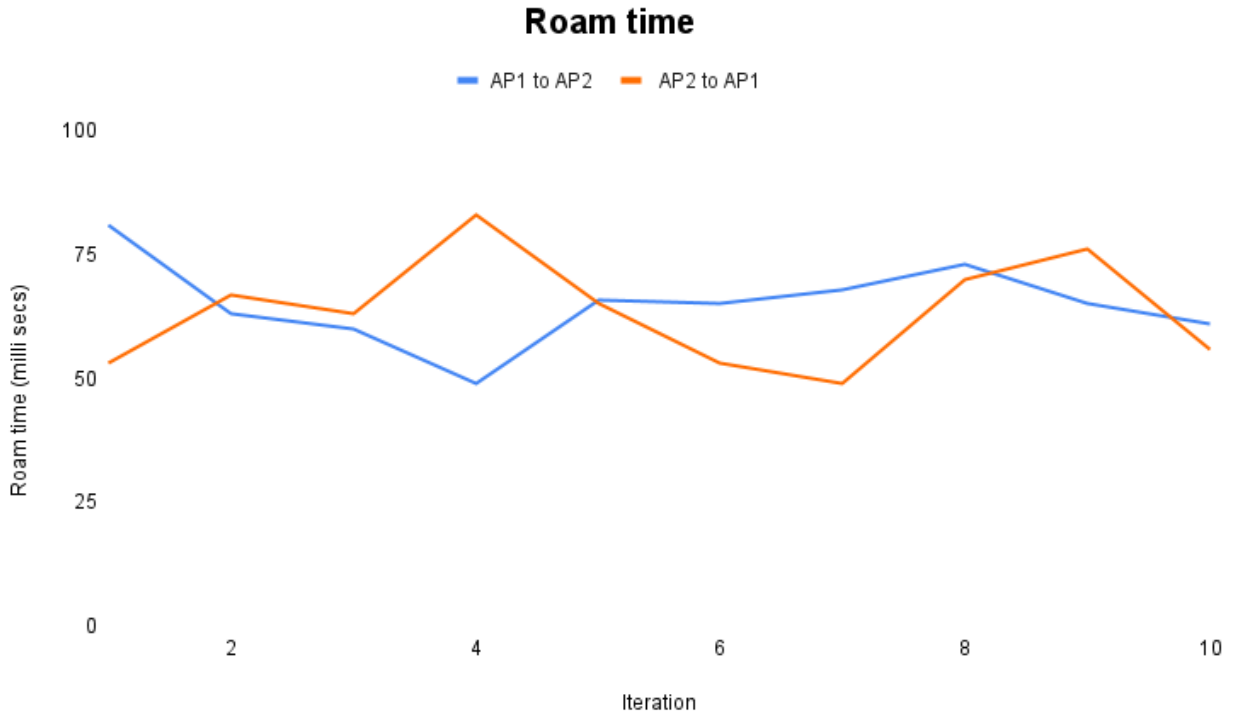




Roaming

Objective: To verify the roaming behavior of STA and analyze the roam times while roaming from AP1 to AP2 and vice-versa

Iteration	Roam Status (AP1 to AP2)	Roam Status (AP2 to AP1)
1	Success	Success
2	Success	Success
3	Success	Success
4	Success	Success
5	Success	Success
6	Success	Success
7	Success	Success
8	Success	Success
9	Success	Success
10	Success	Success



Observation

- Roaming is **successful** for every iteration and roam times are within 100ms

IoT Devices

IoT Devices

Smart Bulbs, Smart Switches, Smart Cameras, Smart extension box, Air purifiers, Smart plugs, Thermostat

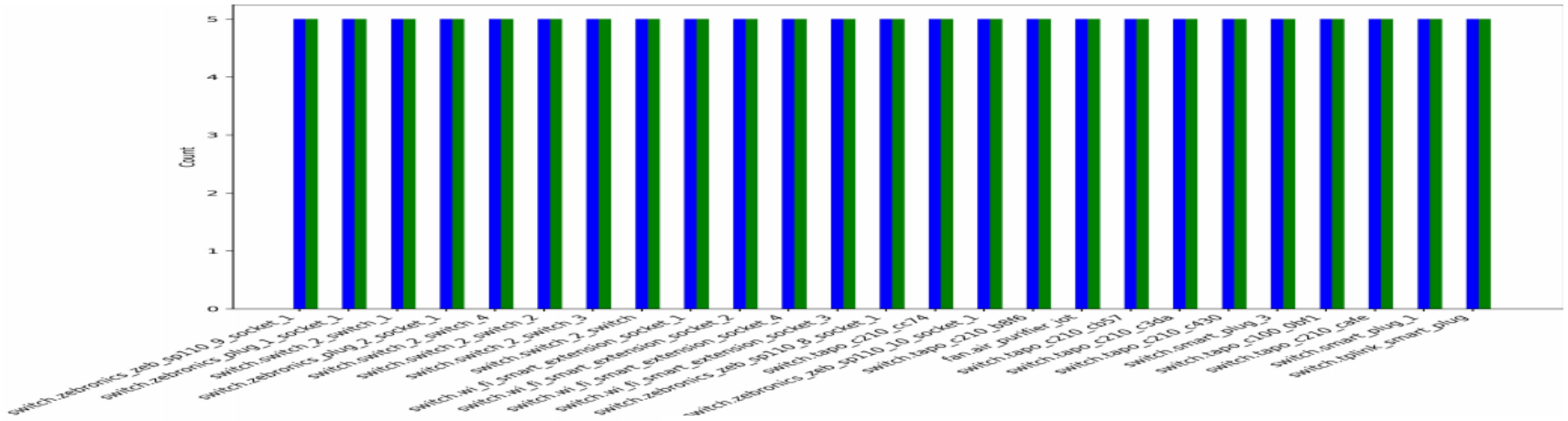
Tests:

- ✓ Basic Client connectivity
- ✓ Power consumption test
- ✓ Latency/Response Time test
- ✓ Functional Verification Test (Action successful/Unsuccessful)
- ✓ Range Performance
- ✓ Video Quality Performance
- ✓ Long duration operation test
- ✓ Interference test
- ✓ DFS Testing
- ✓ Performance with WAN Impairment

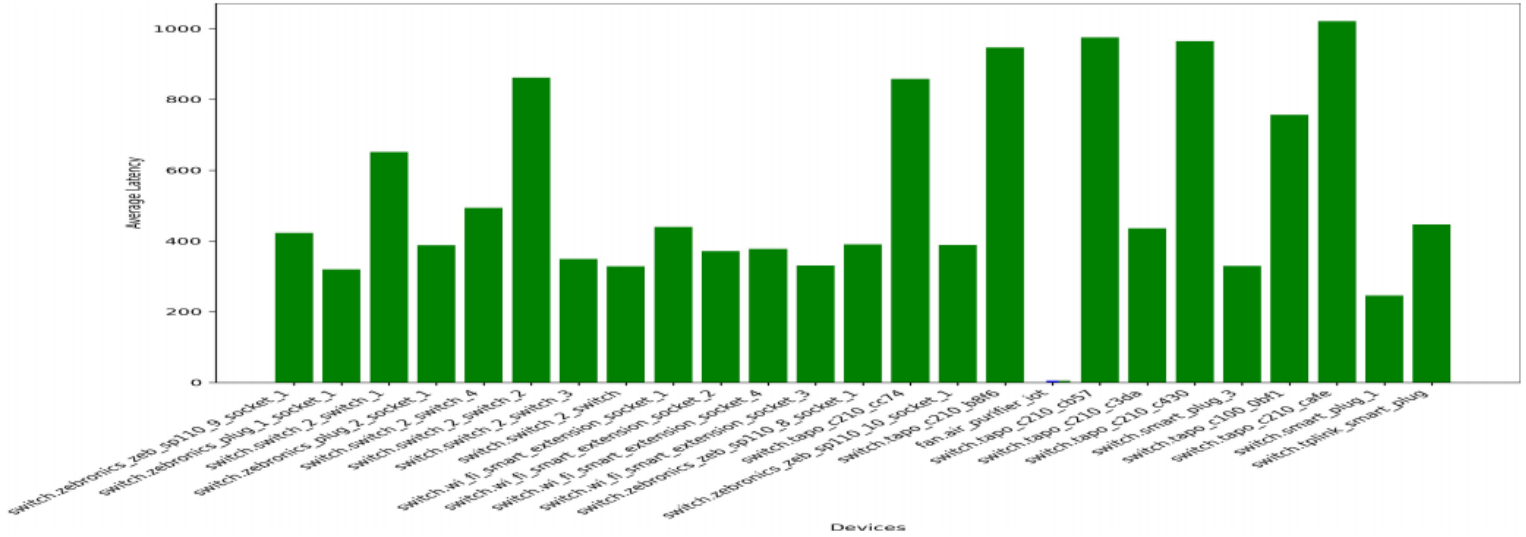
IoT Lab setup

IoT Test Report

Test Statistics



Request vs Average Latency (ms)



Healthcare

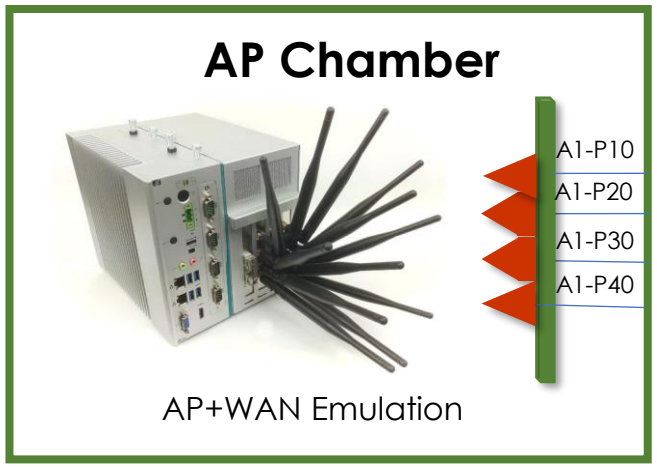
Healthcare Devices

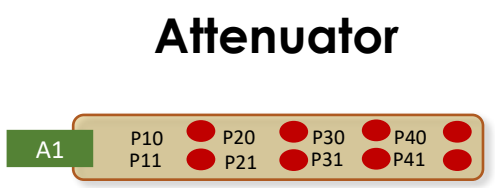
Infusion Pumps, Imaging Devices (MRI/CT), Wearable Health Devices, Tablets for Diagnostics

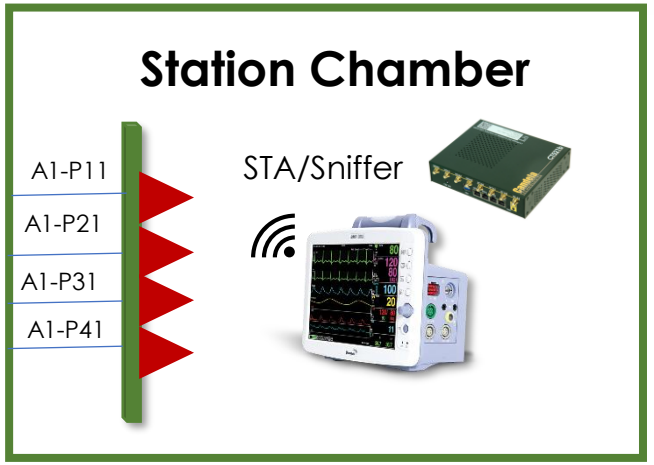
Tests:

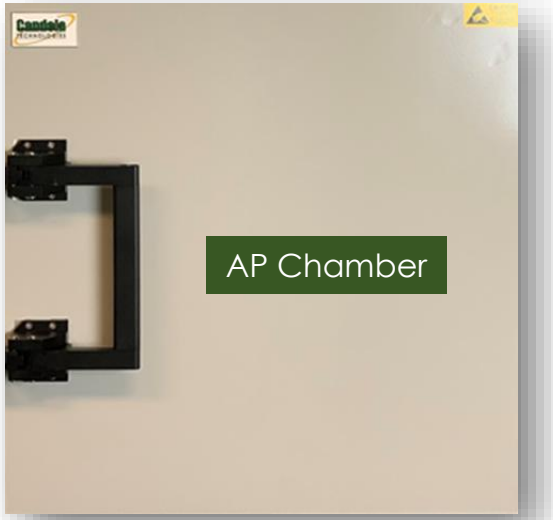
- ✓ Basic Client connectivity
- ✓ Latency test
- ✓ Latency under Load test
- ✓ ACI/CCI Test
- ✓ Range Performance
- ✓ Long duration operation test
- ✓ Interference test
- ✓ DFS Testing
- ✓ Performance with WAN Impairments
- ✓ Roaming

Testbed Topology

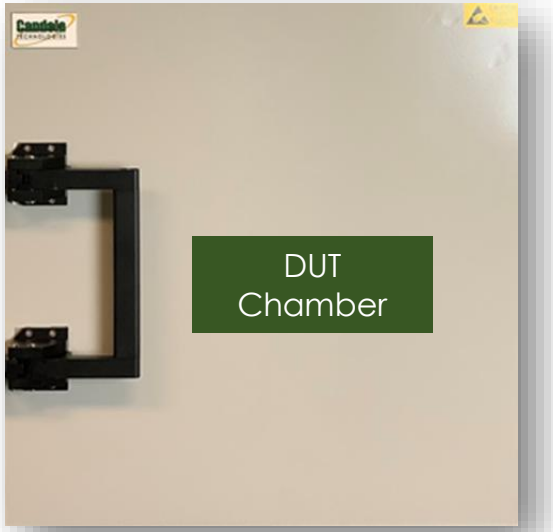




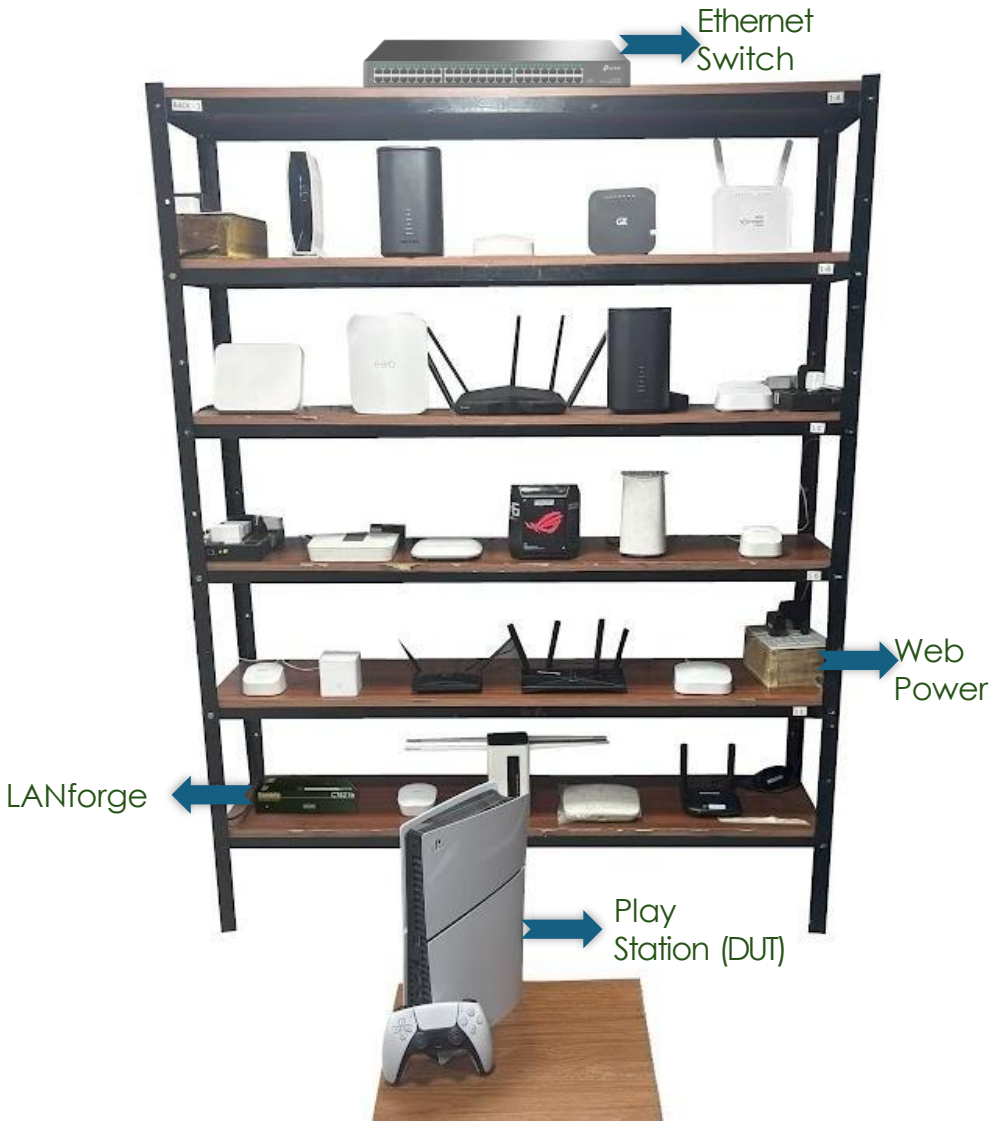




Attenuator



Wi-Fi Station & Router Lab Capabilities



- ✓ **Validate compatibility of diverse Wi-Fi stations**
  - Smart TVs
  - Gaming Consoles
  - Printers
  - Health Smart Devices, etc. with globally deployed routers and access points.
- ✓ **Test interoperability across router ecosystems**
  - Various Wi-Fi standards (802.11be/ax/ac/n)
  - Frequency bands (2.4 GHz, 5 GHz, 6 GHz)
  - Channel Bandwidths
  - Chipset vendors
  - Regional regulatory domains, and firmware versions.
- ✓ **Evaluate device behavior under various test conditions**
  - Client connectivity with Open, WPA, WPA2, and WPA3 security types
  - Performance testing with and without load
  - Interference scenarios involving co-channel and adjacent-channel overlap
  - Rate vs. Range analysis to measure throughput degradation over distance
  - Long-term stability across continuous association and roaming sessions

Wi-Fi Station Categories

Smartphones

Tablets

Laptops

Smart TVs

Gaming Consoles

Streaming Devices

Printers & Scanners

Smart Appliances

Smart Speakers

IoT Devices

Security Devices

Health Smart Devices

Wearables

Top Residential Wi-Fi Access Points by Region

North America
- Netgear Orbi RBE973S
- TP-Link Deco BE85 / BE63
- ASUS GT-BE98 Pro
- Amazon Eero Max 7
- ASUS RT-BE96U
- Netgear Nighthawk RS700S
- TP-Link Archer BE800
- Linksys Atlas Max 6E
- Ubiquiti UniFi U6-Pro
- Google Nest WiFi Pro

Europe
- AVM FRITZ!Box 7590 AX (Popular in Germany, Austria)
- TP-Link Deco BE85 / XE75
- Netgear Orbi RBE973S
- ASUS RT-BE96U
- Google Nest WiFi Pro
- TP-Link Archer BE800
- Ubiquiti UniFi U6+
- Huawei WiFi AX3
- D-Link Eagle Pro AI M32
- Tenda Nova MW6

Asia
- TP-Link Archer BE805 / BE800
- Xiaomi BE7000 (Wi-Fi 7)
- Huawei WiFi AX3 / AX6
- ASUS TUF AX6000
- TP-Link Deco XE75
- Netgear Nighthawk RS700S
- D-Link DIR-X5460
- Mercusys MR80X
- Tenda RX9 Pro
- JioAirFiber Router (India-specific)

South America
- TP-Link Deco XE75
- TP-Link Archer AX73
- ASUS RT-AX86U
- Netgear Nighthawk AX8
- TP-Link Deco X60
- D-Link EXO AX5400
- Mercusys Halo H80X
- Huawei WiFi AX3
- Xiaomi Mi Router AX1800
- Intelbras Twibi Giga

Africa
- TP-Link Deco X20 / X60
- TP-Link Archer AX20
- Tenda AC23
- Netgear Nighthawk AX1800
- Huawei WiFi AX3
- D-Link DIR-841
- TP-Link C6 v4
- Xiaomi Mi Router 4A
- Mercusys AC12G
- ZTE MF286C (LTE CPE with Wi-Fi)

Australia
- TP-Link Deco BE85 / XE75
- Netgear Orbi RBE973S
- ASUS GT-BE98 Pro
- Amazon Eero Max 7
- TP-Link Archer BE800
- Telstra Smart Modem Gen 3
- D-Link Eagle Pro AI M32
- ASUS RT-AX86U
- Ubiquiti UniFi U6-LR
- Google Nest WiFi Pro

This list is referred from Internet Source

List of Tests Supported.

Tests	All Station Types	Smart TVs	Streaming Devices	Security Cameras	Gaming Consoles	Printer
Client Connectivity	✓	✓	✓	✓	✓	✓
Open, WPA, WPA2, WPA3	✓	✓	✓	✓	✓	✓
Country Regulations, FCC USA, ETSI (Europe), India (WPC), Others	✓	✓	✓	✓	✓	✓
Frequency Bands - 2.4 GHz, 5 GHz, 6 GHz	✓	✓	✓	✓	✓	✓
Channel Bandwidths - 20 MHz, 40 MHz, 80 MHz, 160 MHz, 320 MHz	✓	✓	✓	✓	✓	✓
Channel Switch Behavior	✓	✓	✓	✓	✓	✓
Ping Performance – No Load on AP	✓					
Ping Performance – 30%, 50%, 70% Load on AP	✓	✓	✓	✓	✓	✓
Rate vs Range	✓	✓	✓	✓	✓	✓
Roaming – Daisy Chain, Star Topology	✓	✓	✓	✓	✓	✓
Short run test - 1 Hour	✓	✓	✓	✓	✓	✓
Long run test - 8 Hours	✓	✓	✓	✓	✓	✓
TCP & UDP Throughput (iPerf-Supported)	-	✓	✓	✓	✓	✓
Throughput vs different packet sizes (iPerf-Supported)	-	✓	✓	✓	✓	✓
Quality of Service (iPerf-Supported)	-	✓	✓	✓	✓	✓
4K Streaming and OTT application performance	-	✓	✓	-	-	-
Motion Detection	-	-	-	✓	-	-
Latency tests while playing games	-	-	-	-	✓	-
Latency tests while printing with different file sizes	-	-	-	-	-	✓

Router Performance Matrix Example

Brand	Model	Connectivity	Performance	Stability
Asus	Model-x	5	4	2
Tenda	Model-x	4	3	4
ipTIME	Model-x	5	5	3
Adtron	Model-x	3	4	5
D-Link	Model-x	4	3	1
TP-Link	Model-x	3	2	3
Vodafone	Model-x	5	1	4
Linksys	Model-x	4	3	4
TP-Link	Model-x	5	2	5
OPTUS	Model-x	3	5	1
Tenda	Model-x	3	5	1
Airtel Xtream Fiber	Model-x	5	2	4
Netgear	Model-x	5	4	5
GX	Model-x	4	1	1
Airtel	Model-x	4	1	1
Jio	Model-x	4	3	2
Eero	Model-x	5	4	3
Juniper	Model-x	4	4	5
Shasta	Model-x	4	3	1
Sky UK	Model-x	3	2	3

Brand	Model	Connectivity	Performance	Stability
Fortinet	Model-x	5	4	2
Ruckus	Model-x	4	3	4
EnGenius	Model-x	5	5	3
Technicolor	Model-x	3	4	5
Sagemcom	Model-x	4	3	1
Arcadyan	Model-x	3	2	3
Sercomm	Model-x	5	1	4
CommScope	Model-x	4	3	4
Actiontec	Model-x	5	2	5
Digisol	Model-x	3	5	1
Meraki	Model-x	3	5	1
Huawei	Model-x	5	2	4
ZTE	Model-x	5	4	5
Ubiquiti	Model-x	4	1	1
Orange	Model-x	5	3	4
Linksys	Model-x	4	3	4
Google	Model-x	5	2	5
Aruba Networks (HPE)	Model-x	3	5	1
Cisco	Model-x	5	4	3
Freebox	Model-x	3	5	1

Client Connectivity with Open, WPA2 and WPA3 Security

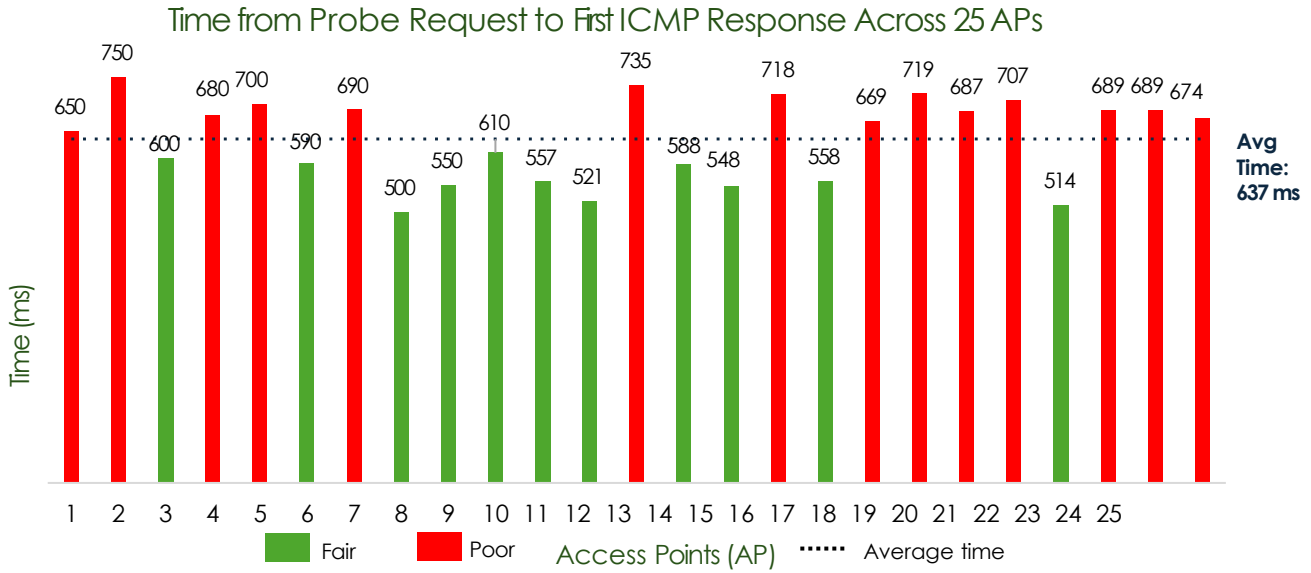
- ✓ To evaluate the connectivity performance of client devices (STAs) across multiple Access Points (APs) configured with **Open (unencrypted)/ WPA2/WPA3** security types.
- ✓ The evaluation is conducted over multiple iterations per AP, capturing key metrics including:
  - ✓ **Time taken from probe request to successful association**
  - ✓ **DHCP lease acquisition time**
  - ✓ **Time taken from probe request to first ICMP (ping) response**
- ✓ The results are then compared across various AP models to identify **variations in connection responsiveness and performance** under different security configurations.

Pass/Fail Criteria:

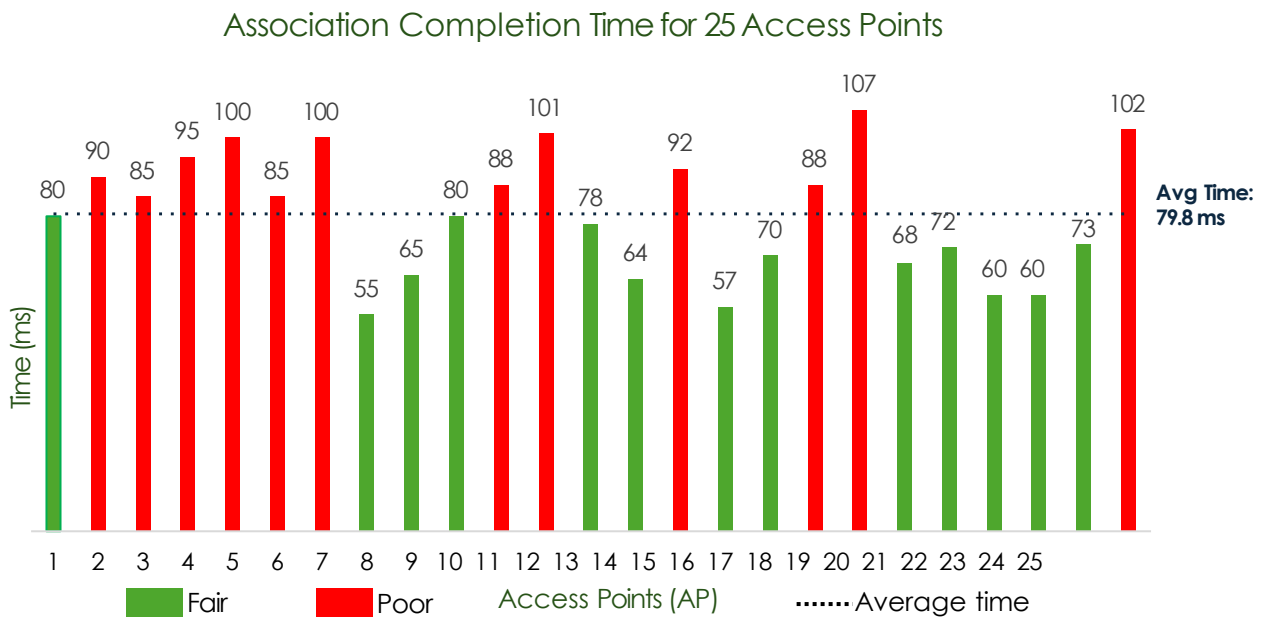
- ✓ If the STA does not connect to the AP, it is considered a **fail** for that particular AP.
- ✓ If the STA takes more time to complete any of the following steps: probe request to association, DHCP lease acquisition, or probe request to first ICMP response compared to the average time across all APs, it is considered poor performance.

Additional Info:

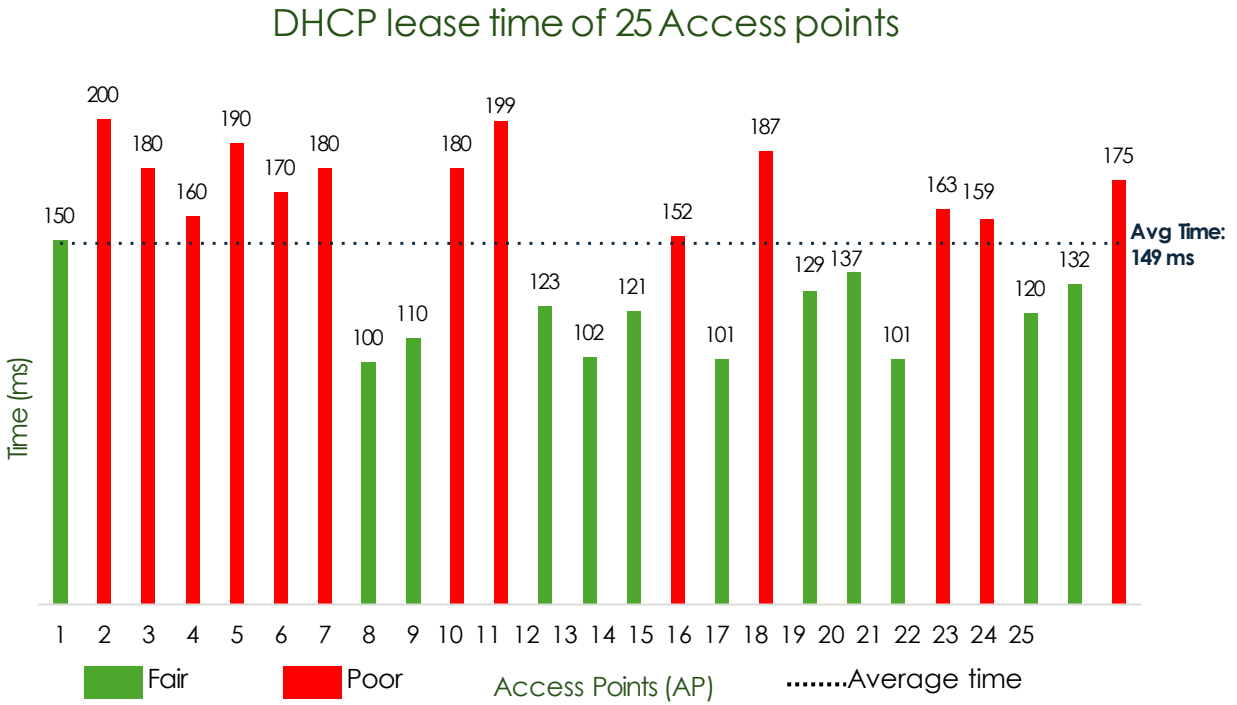
- ✓ A report will be generated in PDF or PPT format, along with corresponding CSV data



Client Connectivity with Open, WPA2 and WPA3 Security

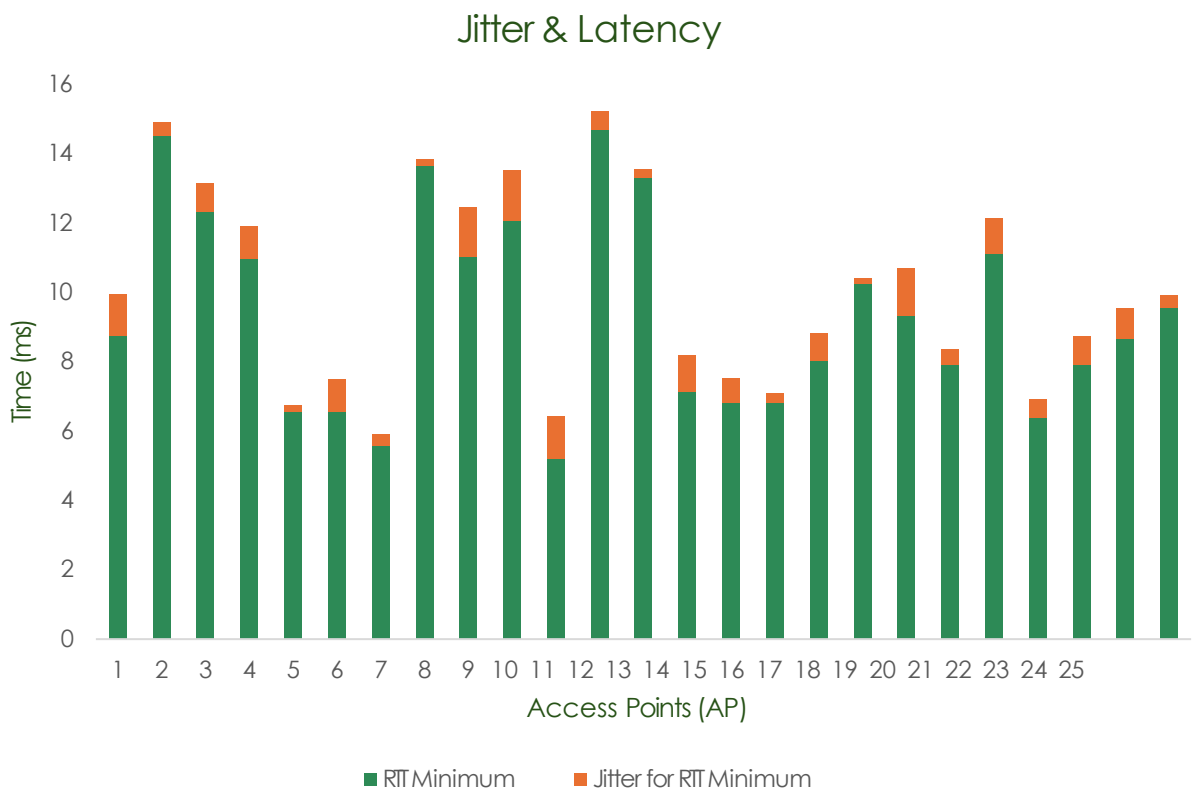


- The STA completed the probe request to first ICMP response in equal to or less than the average time (63.7 ms) on 11 out of 25 APs.
- On 13 APs, the STA completed the probe request to association in ≤79.8 ms.
- The STA completed the DHCP process in ≤ 149 ms on 12 APs.



STA Performance Under AP Load Conditions

- ✓ To evaluate the Wi-Fi performance of client devices (STAs) when other clients are already connected to the Access Point (AP) and generating active traffic, with channel utilization levels of 30%, 50%, and 70%, across multiple APs configured with WPA2 security.
- ✓ The evaluation is performed on each AP, capturing key metrics including:
  - **Round Trip Time (RTT):** Minimum, Maximum, and Average Latency
  - **Jitter (Packet Delay Variation)**
  - **Ping Success Rate (%)**
  - ✓ The results are compared across various AP models to identify variations in **connectivity** and **performance** under the WPA2 security configuration.
- ✓ Pass/Fail Criteria
- ✓ If the STA **disconnects from Wi-Fi** or consistently experiences **loss of 50 to 100 packets**, it is considered a **Fail** for that AP.
- ✓ If the STA shows **higher-than-average values** for any of the following:
  - **Maximum, Minimum, or Average Latency**
  - **Packet Loss**
  - **Jitter**
  - **Ping Success Rate (%)**
    compared to the average across all APs, it is considered **Poor Performance**.
- ✓ Additional Information
- ✓ A detailed report will be generated in **PDF or PPT format**, along with corresponding **CSV data**.



Rate vs Range

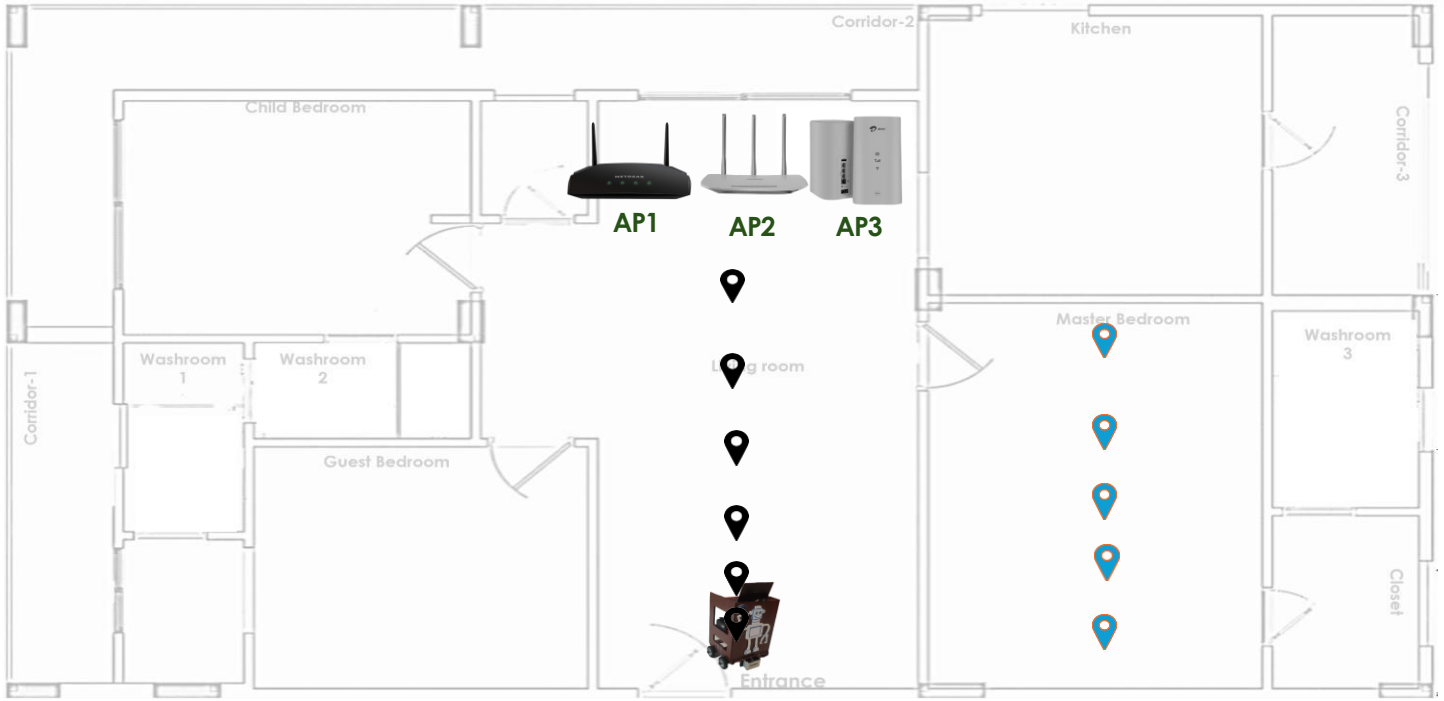
- ✓ Evaluate Wi-Fi performance of client devices (STAs) connected to multiple Access Points (APs) at distances of 3, 6, 9, 12, 15, and 18 feet under WPA2 security.
- ✓ For each AP and distance, the following metrics are measured:
  - **Round Trip Time (RTT):** Minimum, Maximum, and Average Latency
  - **Jitter (Packet Delay Variation)**
  - **Ping Success Rate (%)**
- ✓ Results are compared across APs to identify performance differences.
- ✓ Tests under both line-of-sight and non-line-of-sight conditions can be performed using different bands, bandwidths, and regulatory settings

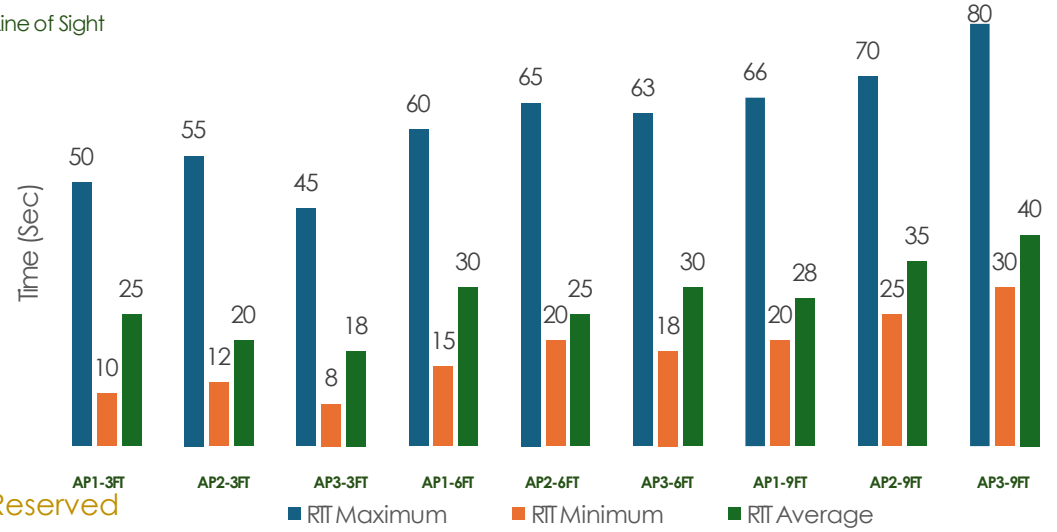
Pass/Fail Criteria

- ✓ **Fail:** STA disconnects or has 50–100 packet loss
- ✓ **Poor Performance:** Higher-than-average values in RTT, Jitter, Packet Loss, or Low Ping Success Rate (%)

Additional Info

- ✓ A detailed report will be provided in PDF/PPT format with CSV data.
- ✓ Device is placed on Robot.





Stability Test

- ✓ Evaluate the long-term Wi-Fi stability of client devices (STAs) connected to multiple Access Points (APs) over an extended duration (e.g., 1 hours) under WPA2 security.
- ✓ Monitor each STA-AP connection continuously and capture the following metrics:
  - **Connection Drops / Re-associations**
  - **Ping Success Rate (%) over time**
  - **Latency Trends (RTT - Min, Max, Avg)**
  - **Jitter Stability**
- **Packet Loss Events**

Pass/Fail Criteria

Fail: STA disconnects unexpectedly or frequently re-associates

Poor Performance:

- High jitter or latency drift over time
- Decreased ping success rate
- Sudden spikes in packet loss

Additional Info

Performance will be logged periodically, and the final repor will include time-based plots, summary charts, and comparison tables. Output formats: PDF/PPT with raw data in CSV.