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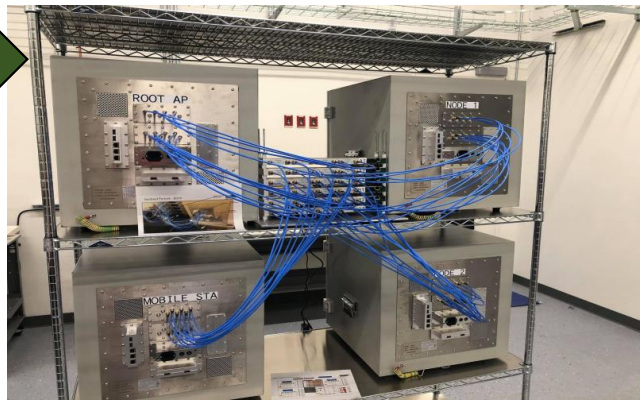
1-360-380-1618

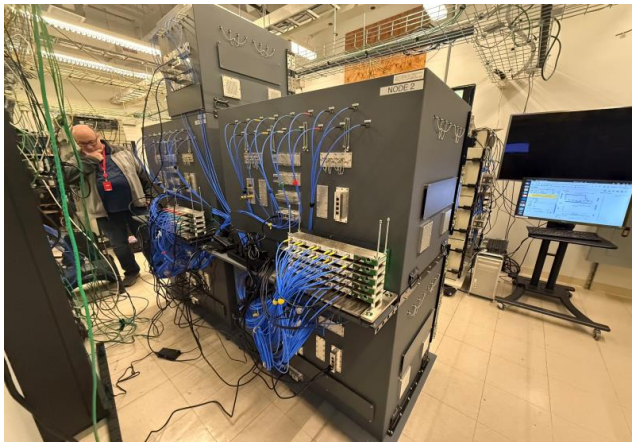
Network Testing & Emulation Solutions

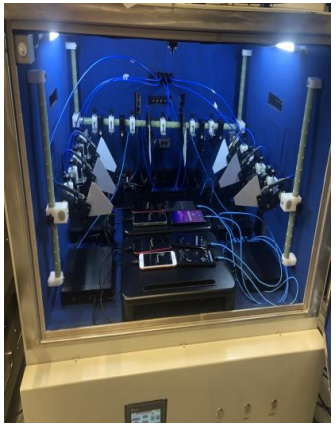
- Founded in 2000
- Focus on Network testing and Emulation Solutions
- WiFi test solutions since 2006
- Team of Networking Technologies and Firmware Experts
- Helping over 200 customers, design, develop and deploy high quality networking products

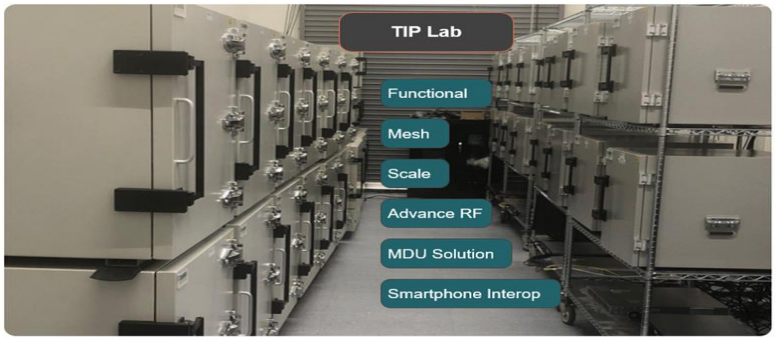
Candela Wi-Fi Test Solutions Overview

Our Testbeds at Various Customer Labs



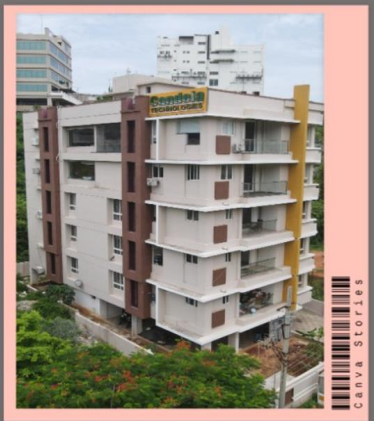




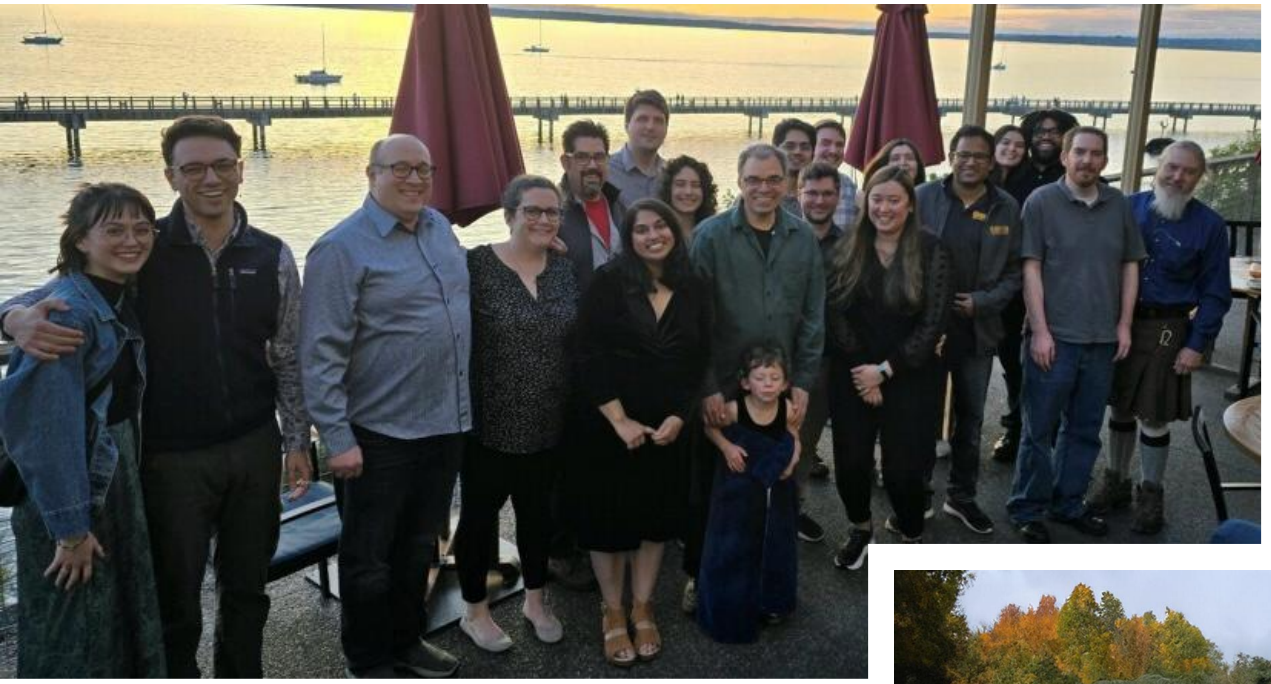


Candela-US (HQ) and Candela India – Visakhapatnam (HQ)

CT- VINSR



CT - PRIMA

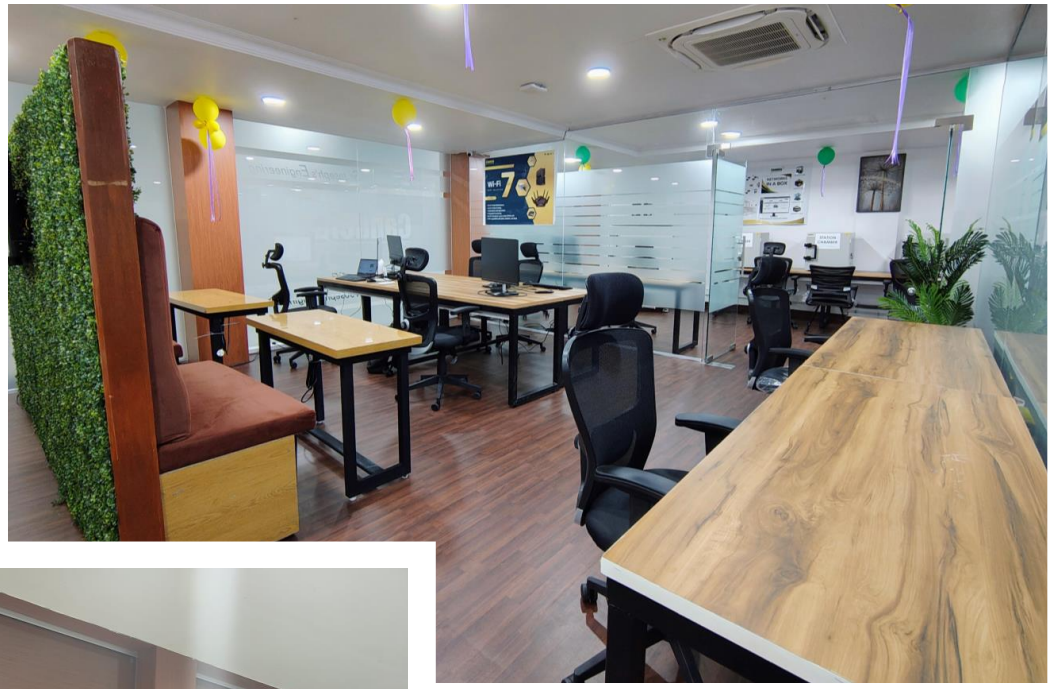


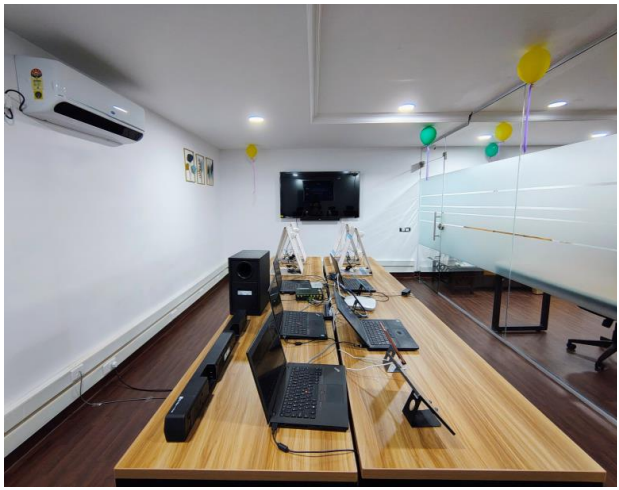
Candela-US and Candela India Teams - 100% Engineering organization

Candela India – Vizag Labs

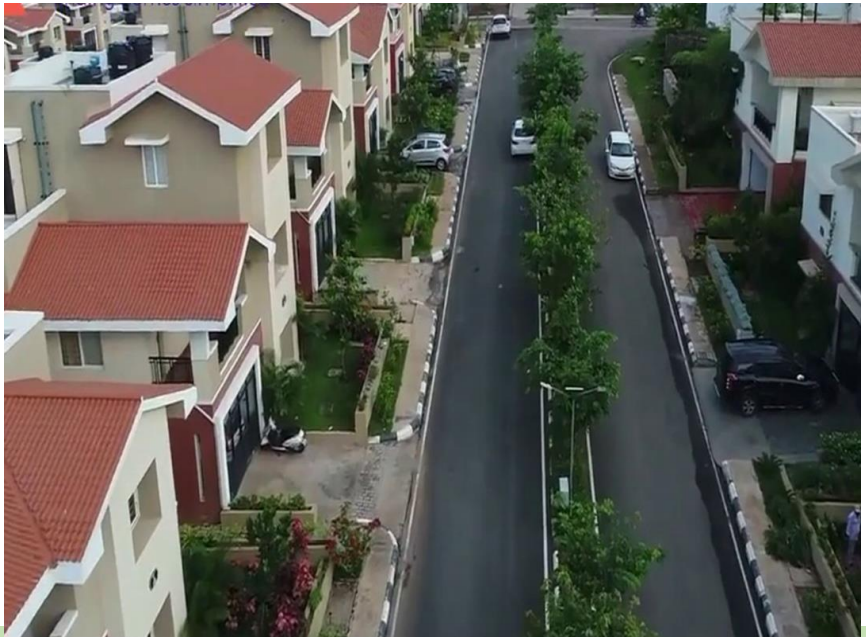
Candela India – Bangalore Lab

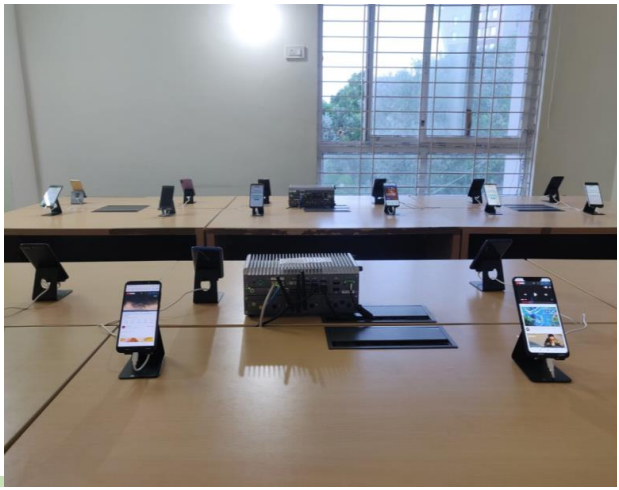
Candela India – Chennai Lab





Candela India – Test House Models





APs Tested in our India Lab

The 3-approaches for Wi-Fi AP/Router Testing

Lab Testing with Virtual Devices

Repeatability:
Scalability :
Automation :
Realism :

Lab Testing with Real Devices

Repeatability:
Scalability :
Automation :
Realism :

Real world Testing in Test House/Enterprises

Repeatability:
Scalability :
Automation :
Realism :

Staged Testing Catalog

Stage-1: Lab Testing with Virtual Clients		
Sl No.	Test Suite/Test Case	Estimated Days
1.1.0	Basic Testing	5
1.1.1	AP Capabilities & Power Cycle	1
1.1.2	Client Capacity with Open, WPA2/WPA3.	0.5
1.1.3	Single Client Throughput Test on 2.4, 5, and 6 GHz.	1.5
1.1.4	Single Client Throughput Test on 2.4, 5, and 6 GHz bands with different packet sizes	1
1.1.5	8-Hour Long Duration Stress Test	1
1.2.0	Advanced Testing	18
1.2.1	Client Connectivity with 802.1x	0.5
1.2.2	Multi/Max Client Throughput	2
1.2.3	Multi Band Throughput	1
1.2.4	Bi-Directional	0.5
1.2.5	Multicast Traffic	0.5
1.2.6	Quality of Service	0.5
1.2.7	FTP/HTTP	0.5
1.2.8	Auto Channel Selection	1
1.2.9	Air Time Fairness	0.5
1.2.10	OFDMA	0.5
1.2.11	MU-MIMO	0.5
1.2.12	Interference Testing ACI/CCI	1
1.2.13	Receiver Sensitivity	1.5
1.2.14	Rate vs Range	2
1.2.15	Rate vs Range vs Orientation	2
1.2.16	Band Steering	0.5
1.2.17	Dynamic Frequency Selection	3
1.3.0	More Advanced Testing	20
1.3.1	Validating Wi-Fi 7 Feature's.	3
1.3.1.1	Multi Link Operation	0.5
1.3.1.2	Preamble Puncturing	0.5
1.3.1.3	320 MHz, 4K QAM	0.5
1.3.1.4	BSS coloring	0.5
1.3.1.5	MU-OFDMA	1
1.3.2	TR-398 Issue2/3/4	10
1.3.3	Validating Mesh Features and Performance	4
1.3.3.1	Mesh Functionality – Mesh Discovery, Peering, Path Selection	1
1.3.3.2	Mesh Roaming with different topologies	3
1.3.4.0	Scale Testing - Connecting 500+ clients	3

Stage-2: Lab Testing with Real clients		
Sl No.	Test Suite/Test Case	Estimated Days
2.1.0	Features & Performance	27
2.1.1	Client Connectivity with Open, WPA2, with different OS types of Windows, Linux, MAC, iOS	2
2.1.2	Throughput with different types of Phones/Tablets/Laptops	2
2.1.3	Ping Test with different OS types of Windows, Linux, MAC, iOS	1
2.1.4	File Transfer Protocol	2
2.1.5	Video Browsing using Dash/Progressive/HLS Media	1.5
2.1.6	Web Browsing - Online & Offline Method	1
2.1.7	Multi Cast Traffic	1.5
2.1.8	QoS	2
2.1.9	RvR	3
2.1.10	Band Steering	2
2.1.11	Roaming with different topologies	3
2.1.12	Mixed Traffic (QOS, FTP, HTTP, PING, MULTICAST)	2
2.1.13	High Stress with different load, protocols for 8 Hours	2
2.1.14	Real Application Traffic like YouTube, Microsoft Team, Zoom and Real Browser Testing	2

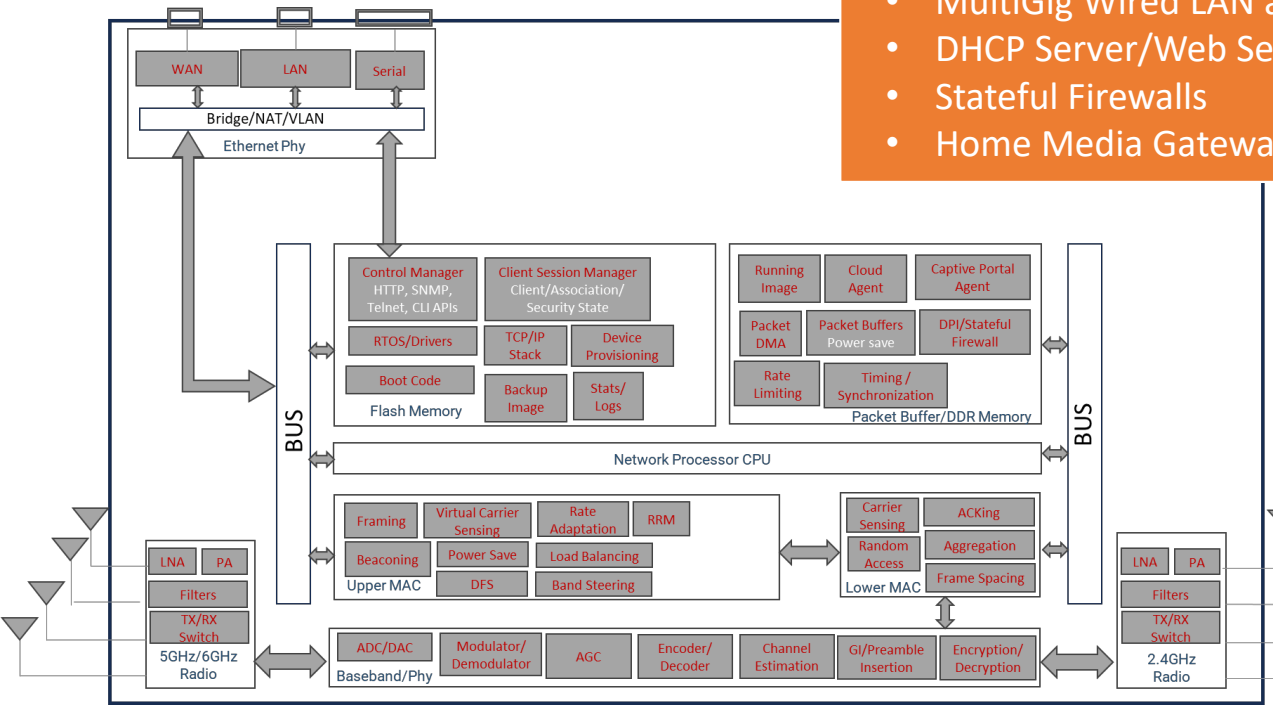
Stage-3: Test House Testing with Real Clients		
Sl No.	Test Suite/Test Case	Estimated Days
3.1.0	Coverage Testing	4
3.1.1	RSSI coverage Test in 2000+ sq ft Test House with single, two/three node	4
3.1.2	Throughput (TCP, UDP - UL, DL & Bi-Di) with single/two/three nodes	
3.2.0	Capacity	8
3.2.1	Client connectivity with 50+ devices spread across the floor	1.5
3.2.3	Throughput per Band	2.5
3.2.4	Throughput per Node	
3.2.5	Load Balancing	2.5
3.2.6	Band Steering	1.5
3.3.0	Mobility	7
3.3.1	Roaming with different topologies like Daisy Chain, Star with two or more nodes	3
3.3.2	802.11r Roaming with two or more nodes	2
3.3.3	Roaming with real application like Youtube, Teams	2
3.4.0	Interoperability	5
3.4.1	Throughput with different types of Phones/Tablets/Laptops	2
3.4.2	Performance over Distance	3

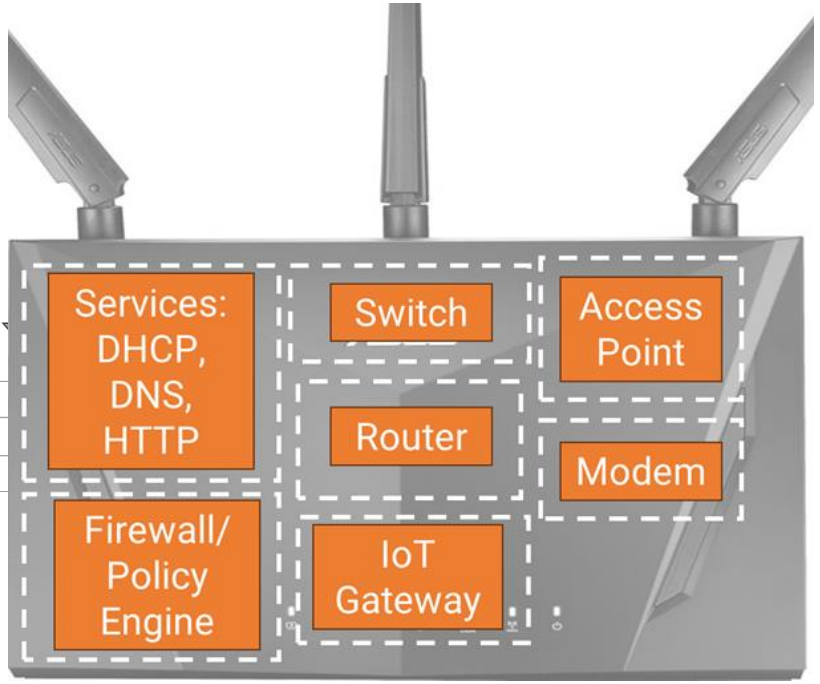

Station Emulation
Emulate 1000s of highly realistic wired and wireless LAN stations
AP Emulation
Emulate 100s of Access Points
Network Elements
DHCP servers, Virtual Bridges, Virtual Routers, SIP Servers, Radius Servers
WAN Emulation
Create network errors, delays, packet duplication, packet re-ordering
LANforge Hardware
Traffic Generation
Native LANforge traffic, VOIP, TCP, UDP, Real Application traffic, iPerf Integration
Monitoring
Real-time packet wired and wireless packet capturing and statistics
Signal Generation
Random noise, WiFi Packet Generation

Anatomy of a Modern Wi-Fi Router/Access Point

A Modern Wi-Fi Router has:

- At least 2 or 3 Wi-Fi radios
- MultiGig Wired LAN and WAN Ports
- DHCP Server/Web Servers
- Stateful Firewalls
- Home Media Gateway Functionality
- RF Spectrum Analysis
- Location Services
- Advanced Analytics
- Integration with Cloud
- VPN Integration





Testcases Summary

Testbed Type	Objective	Test Cases
Basic Testbeds	Run single AP functional/Performance Testing	• Client capacity/connection • Data plane throughput • Dual band performance • Airtime fairness
Advanced Testbeds	Full set of RF level and protocol level test cases on a single AP.	• Receiver sensitivity • Maximum connection / throughput • Airtime fairness, rate vs range • Spatial consistency • Multi STA performance • Downlink Mu-MIMO performance • AP co-existence
Mesh Testbeds	Full set of RF level and protocol level test cases on Mesh APs (Root + 2 Node configuration).	• Throughput per hop, client scale • Roaming, fail over scenarios • Performance over distance • Spatial consistency • Mesh Node Patterns
MDU Testbeds	Full set of RF level and protocol level test cases on a cluster of standalone APs in a high density/crowded environment deployments.	• Client scale • Large scale roaming • Large venue load patters • Traffic shaping/policy • Device profiling/analytics • Load balancing/band steering
WiFi 6E Testbeds	6GHz channels testing on WiFi 6E APs.	• 6 GHz RF performance • 6 GHz functional test cases • Triband Performance • 2.4/5GHz performance and functional tests on 6E APs

Access Point Testcases

Category	Sub-Category	Test Cases developed for
Command and Control	Firmware	Upgrades/Downgrades, AP boots/reboots, System resources
	Configuration & Communication	AP provisioning, ZTP, setting up networks/channels/profiles/APs, cloud connectivity, DHCP/Radius and other services, Alarms
	Operation Modes	Bridge/vlan/router modes,
	Physical & Virtual Interfaces	Basic functions of LAN/WAN/WLAN physical interfaces, indicators/LEDs, virtual interfaces (SSIDs/VLANs etc..)
	GUI/APIs	GUI settings (Read/Write) , API calls (Push/Pull)
Functional Testing	BSS Capabilities	Basic/Extended Capabilities, Security, QoS, RRM, DFS, 802.11a/b/g/n/ac/ax/k/v/r/i/u/w settings, reg domains etc..
	Connectivity & Security	Basic connectivity with all WPA/2/3 Personal/Enterprise, All EAP method, Passpoint. Captive Portal, WPS etc…
	Radio Resource Management	Load Balancing, Band Steering, Auto Channel Selection, DFS
	Smart WiFi	Role/User/Device/Network based policies, Traffic Shaping, Int Detection/Mitigation, DPI, threat detection, Location Services
	QoS & Mobility & Power Save	WMM, Fast Roaming, Open Roaming, Network assisted handoff, Legacy/WMM/MIMO Power Save
Performance Testing	Throughput Benchmark	Throughout for STA Modes/MIMO types/STA counts/BW settings/Traffic Types/Direction/Packet Sizes etc..
	Multiband Performance	Single/Dual/Tri band performance
	Mobility Performance	Rate vs Range, Rate vs Antenna Orientation, Roaming Delay, Roaming performance with different security types
	Radio Performance	Receiver Sensitivity, Transmitter Quality, Reg Domain TX power testing.
	Application Performance	VOIP Performance, Youtube/OTT Video Streaming, HTTP/FTP Performance, Social Media Apps performance
Stress and Endurance Testing	Day in Life Test	Mix of Stations/APs/SSIDs/Security Types/User Policies/Traffic/Device Load Patterns over time in a 10 hour day
	48-hour Stress Test	Full system load across all interfaces with maximum stations/traffic run for 48 hours
	Load Patterns #1,#2, #3	Various real world load patterns run over long durations.
Use Case Testing	Single AP SOHO	TR-398 or similar test plan for comprehensive single SOHO AP testing, Qualification/Badge Program
	SOHO Mesh	Throughput Per Hop, Mesh Failover, Roaming, Load Balancing, Qualification/Badge Program
	Med-Enterprise Network	Medium Size Enterprise Network Use cases, Qualification/Badge Program
	Multi Dweller Unit (MDU)	MDU Test plan with clear PASS/FAIL results , Qualification/Badge Program
	Campus Network/ LPV	Campus Network/Large Public Venue Test Plan/Operator Network, Qualification/Badge Program

802.11ac Access Point Test Plan - Overnight

Basic Client Connectivity

› Connect and Disconnect 20 clients each on 2.4Ghz and 5Ghz radios using Open, WPA-PSK, WPA-Enterprise methods, measure connecting times and connection drops.

Benchmark Throughput

› Run full line rate traffic with single client in 4x4 MIMO 80Mhz mode in 5GHz and 3x3 MIMO 40 Mhz in 2.4GHz. Measure and Benchmark maximum throughput.

Full System Performance

› Load all radios and ethnet interfaces simultaneously with full line rate traffic and measure the maxium achieved system throughput

Roaming Performance

› Create lots of clients and connect them to the AP and then cause lots of roams across various security types and measure romaing performance

Reciever Sensitivity

› Fix the MCS rates on the client and send traffic with same MCS rate but different transmit power values and measure receiver sensitivity at all power level. Run test at all MCS rates

Rate vs Range

› Measure performance over distance for various traffic types both Upstream and Downstream.

Client Capacity

› Run a throughput test with 1,2,5,10,20 and 40 clients. Repeat test on both 2.4GHz and 5GHz bands.

Mu-MIMO

› Create 3 STAs (1x 2x2 MIMO and 2x SISO) and measure the increase in troughput when Mu-MIMO feature is enabled.

Airtime Fairness

› Connect 1x 802.11ac client and 1x 802.11n client and 1x 802.11a client, run equal amount of traffic on all three clients and see if AP distributes airtime fairly.

QoS Performance

› Create different voice, video and data traffic streams with different DSCP settings and WMM settings and check to make sure the AP provides better throughput to high priority traffic.

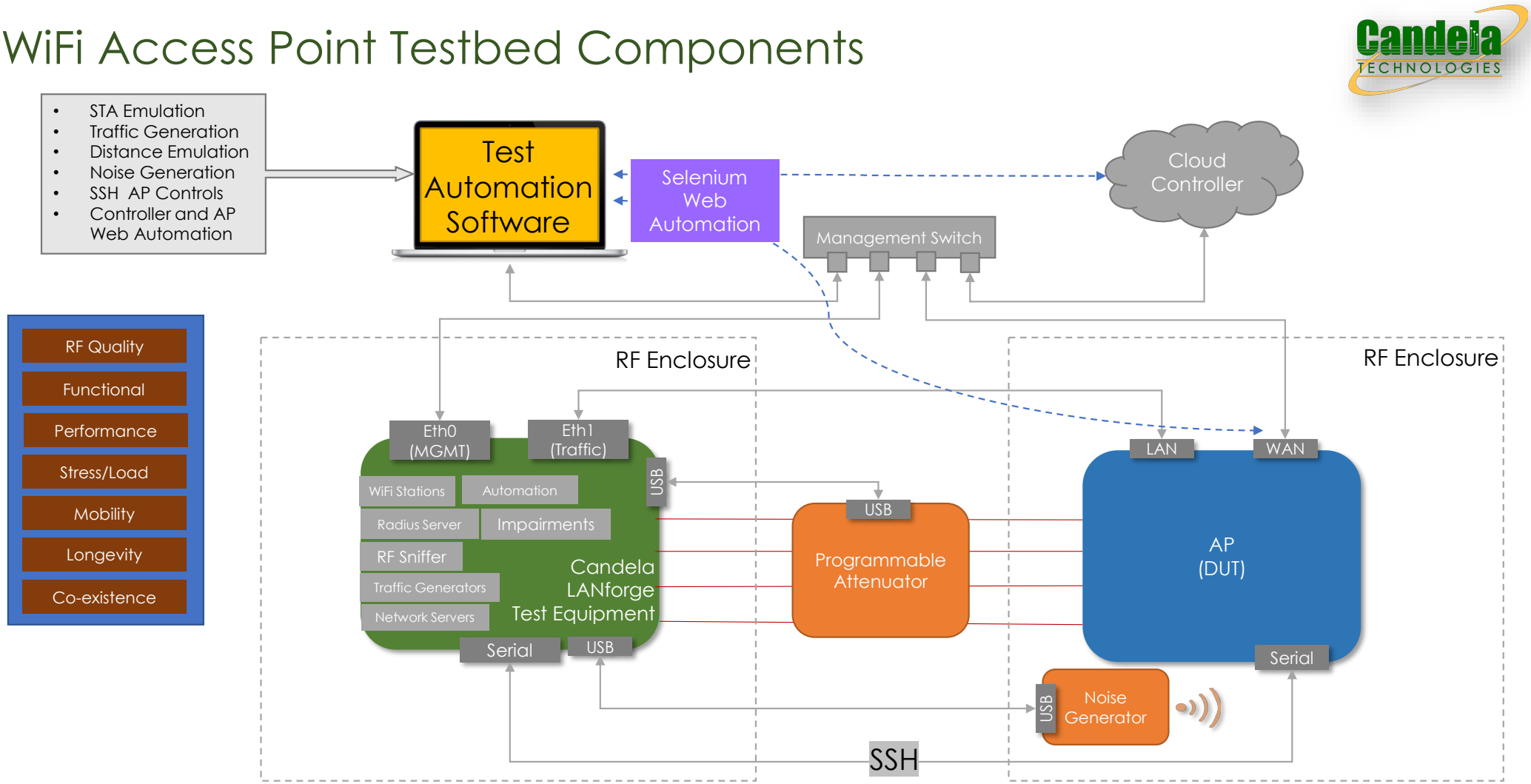
DFS Conformance

› Generate different types of Radar Pulses and make sure the AP can detect Radar and move to a differen channel and stay off channel.

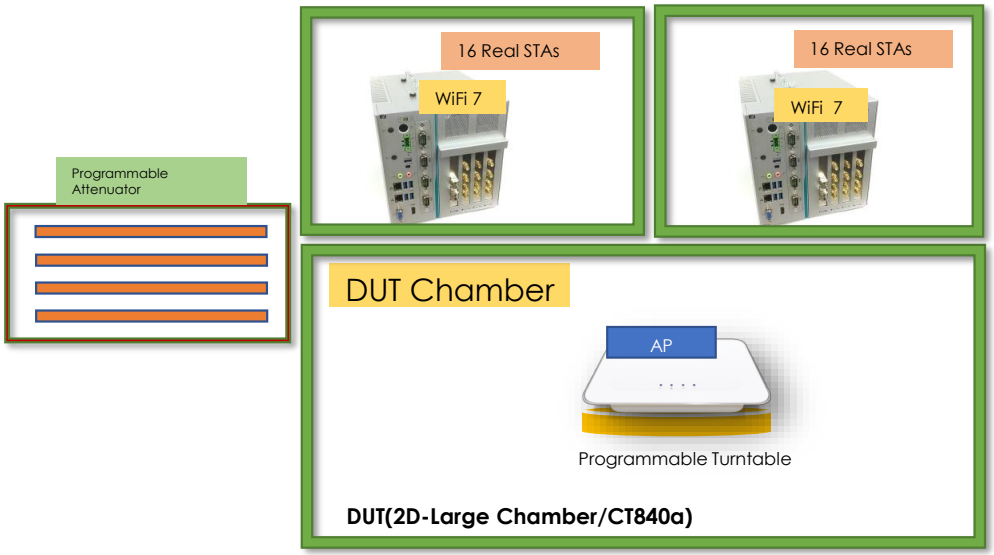
Lond Duration Stability

› Connect lots of clients and run traffic for a 24 hour period and look for any instability in the AP performance

WiFi Access Point Testbed Components



WiFi7 Test cases/Features Covered (802.11be):



Throughput Benchmark

This test gives the 6E performance with different packet sizes, channel BWs, traffic types, MIMO types.

Wider Bandwidth -320Mhz

Supports Bandwidth upto 320Mhz

Latency

This test intends to verify latency under low, high and maximum AP traffic load with multiple stations

Client Capacity

WiFi Capacity test is designed to measure performance of an Access Point when handling several 6E WiFi Stations.

Rate vs Range vs Orientation

This test measures the 6E performance over distance and different antenna orientation of the access point.

Airtime Fairness, QoS

Airtime Fairness Test intends to verify the capability of Wi-Fi device to ensure the fairness of airtime usage.

Near/Far Clients, Band Steering

Measure the performance and stability of the 6E clients based on low and high RSSI levels

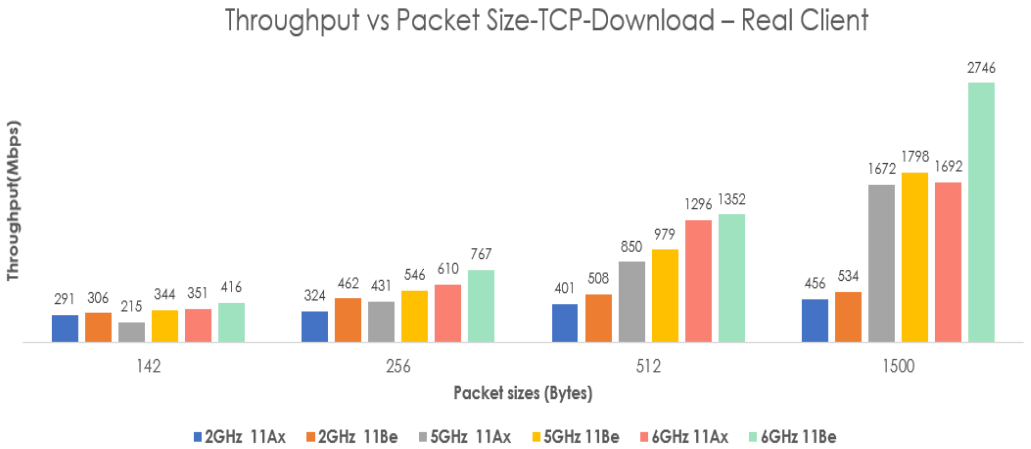
4096 QAM

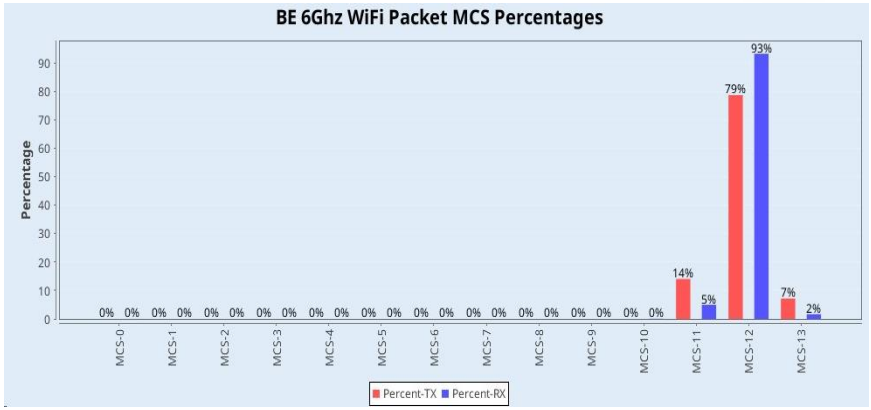
4096-QAM offers the potential for extremely high data rates, it also requires a high signal-to-noise ratio (SNR) for reliable communication

MLO (Not Supported for now)

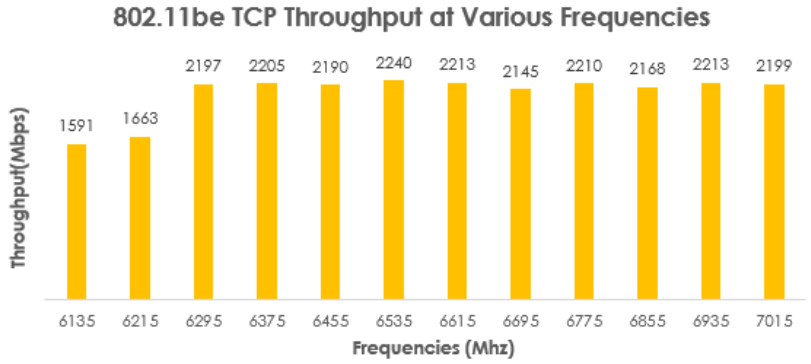
It enables devices to simultaneously send and receive data across different frequency bands and channels.

Wi-Fi 7 Throughput Benchmarking Test:

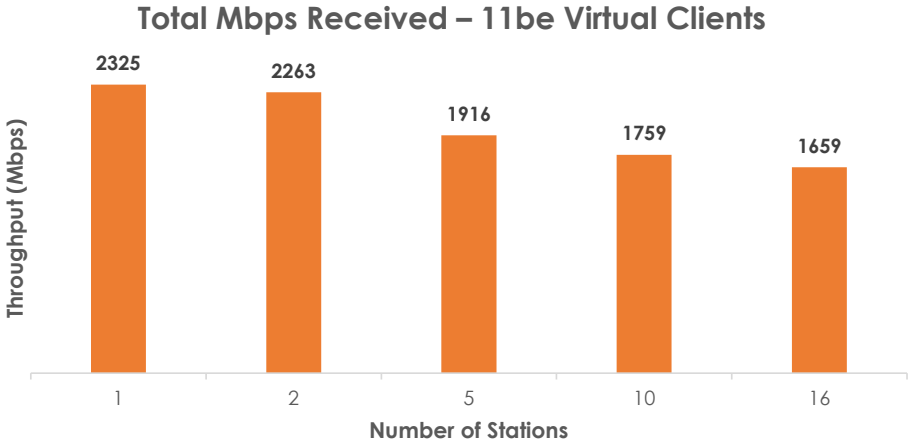


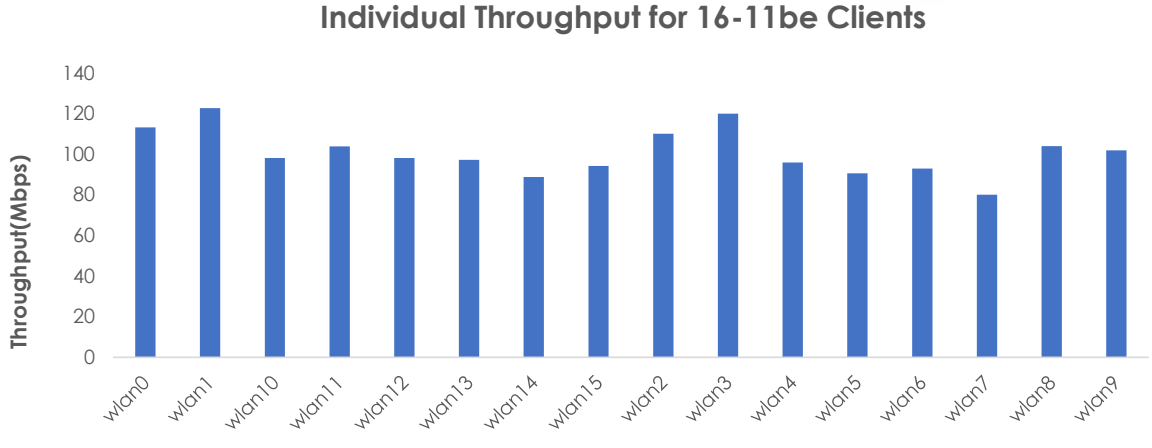


The Candela Wi-Fi data plane test is designed to conduct an automatic testing of all combinations of station types, MIMO types, Channel Bandwidths, Traffic types, Traffic direction, Frame sizes etc.... It will run a quick throughput test at every combination of these test variables and plot all the results in a set of charts to compare performance. The user is allowed to define an intended load as a percentage of the max theoretical PHY rate for every test combination. The expected behavior is that for every test combination the achieved throughput should be at least 70% of the theoretical max PHY rate under ideal test conditions. This test provides a way to go through hundreds of combinations in a fully automated fashion and very easily find patterns and problem areas which can be further debugged using more specific testing. The below chart shows the throughput with all the 6E channels.

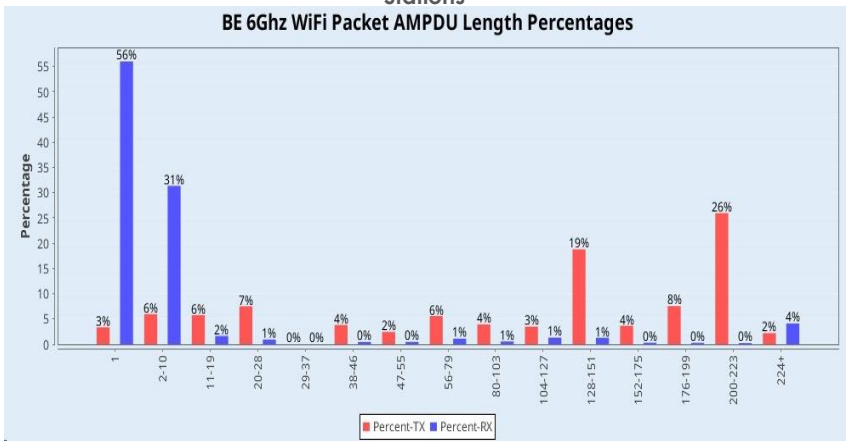


Wi-Fi 7 Client Capacity Test



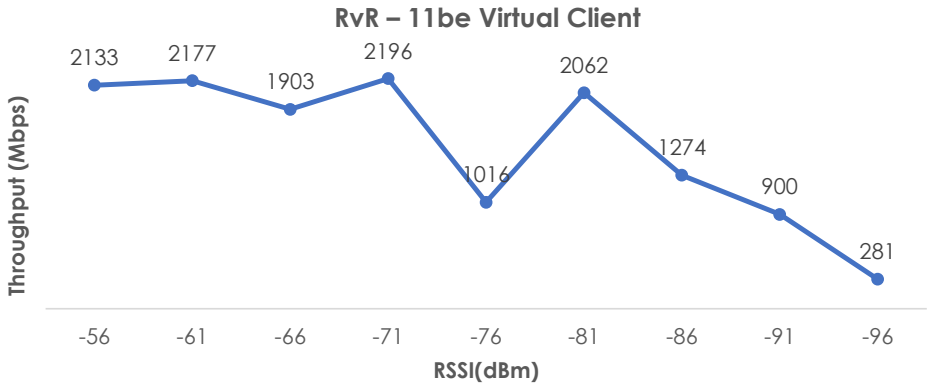


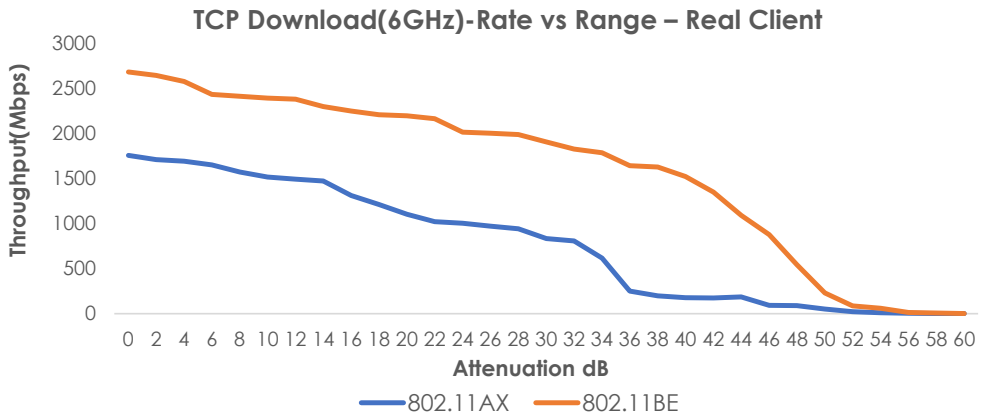
The Candela Wi-Fi Capacity test is designed to measure performance of an Access Point when handling several 6E Wi-Fi Stations. The test allows the user to increase the number of stations in user defined steps for each test iteration and measure the per station and the overall throughput for each trial. Along with throughput other measurements made are client connection times, % packet loss, DHCP times and more. The expected behavior is for the AP should be able to handle several stations (within the limitations of the AP specs) and make sure all stations get a fair amount of airtime both in the upstream and downstream.

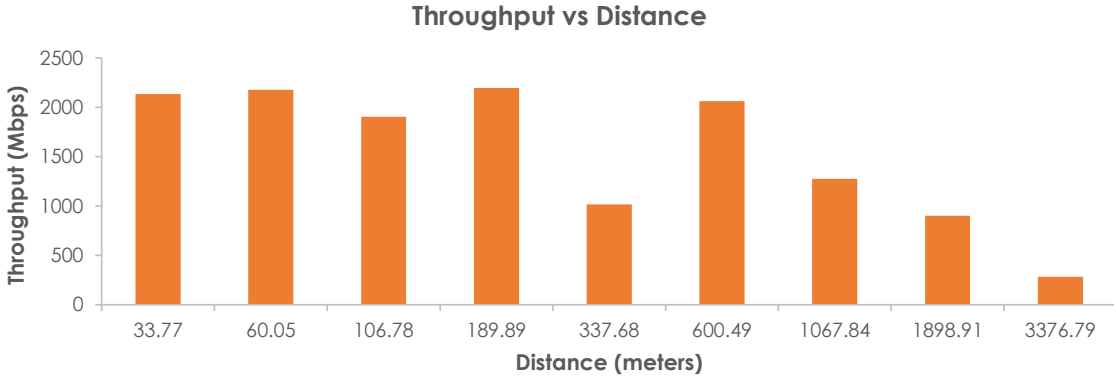


Wi-Fi 7 Rate vs Range Test:

This test measures the performance over distance of the Device Under Test. Distance is emulated using programmable attenuation and a throughput test is run at each distance/RSSI step and plotted on a chart. The test allows the user to plot RSSI curves both upstream and downstream for different types of traffic and different station types.

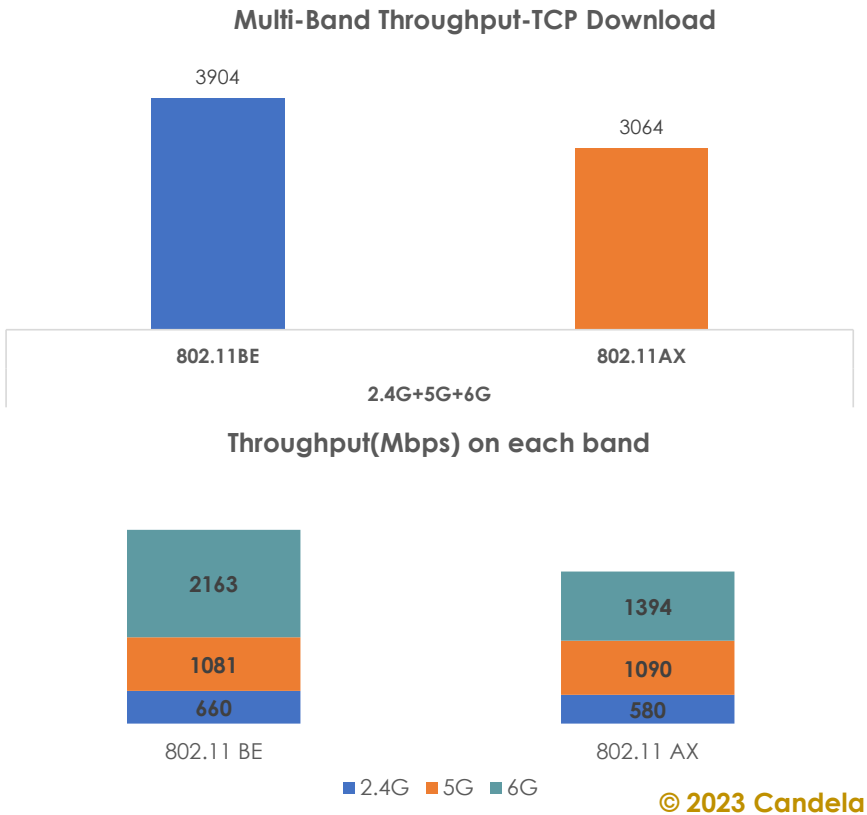


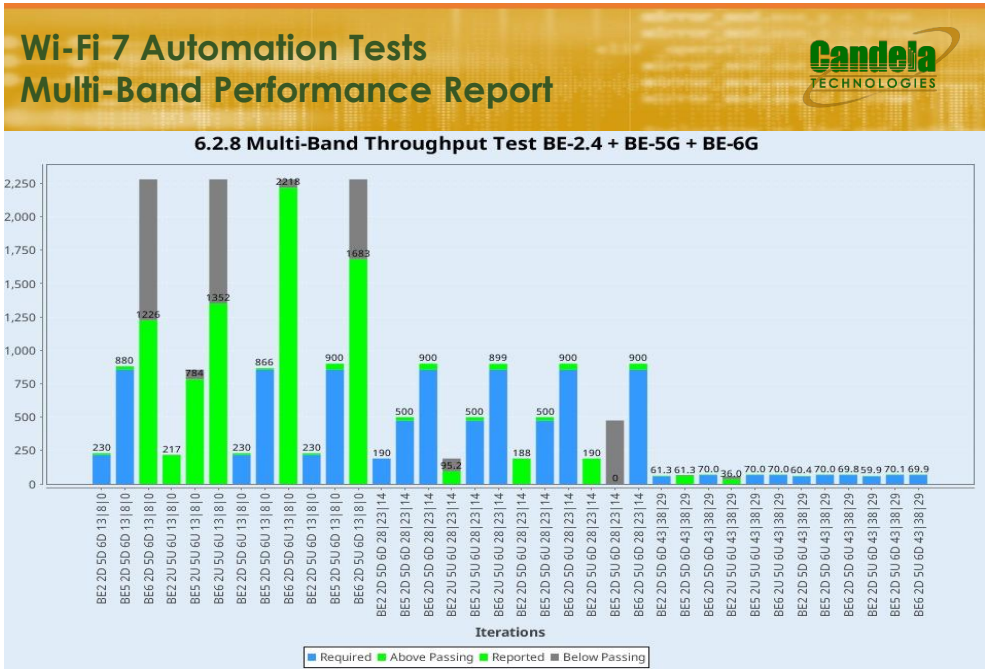




Wi-Fi 7 Multi-Band Throughput Test:

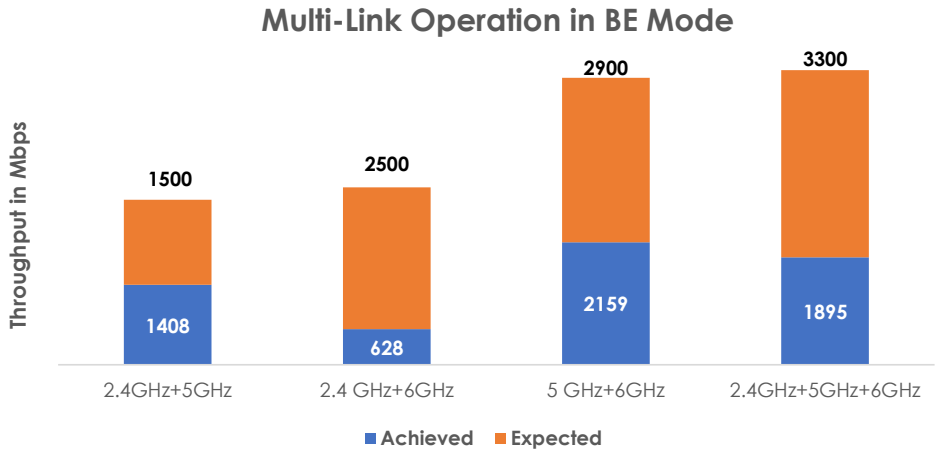
This test creates each client on 2.4, 5 and 6Ghz bands and run the traffic simultaneously. The Multi Band Performance test intends to verify that the Wi-Fi AP throughput with multiple bands active with a single station on each band. The configured speed will be 20% higher than the passing value for MTU sized frames in the throughput test. If the throughput test was skipped, then fixed values will be used.





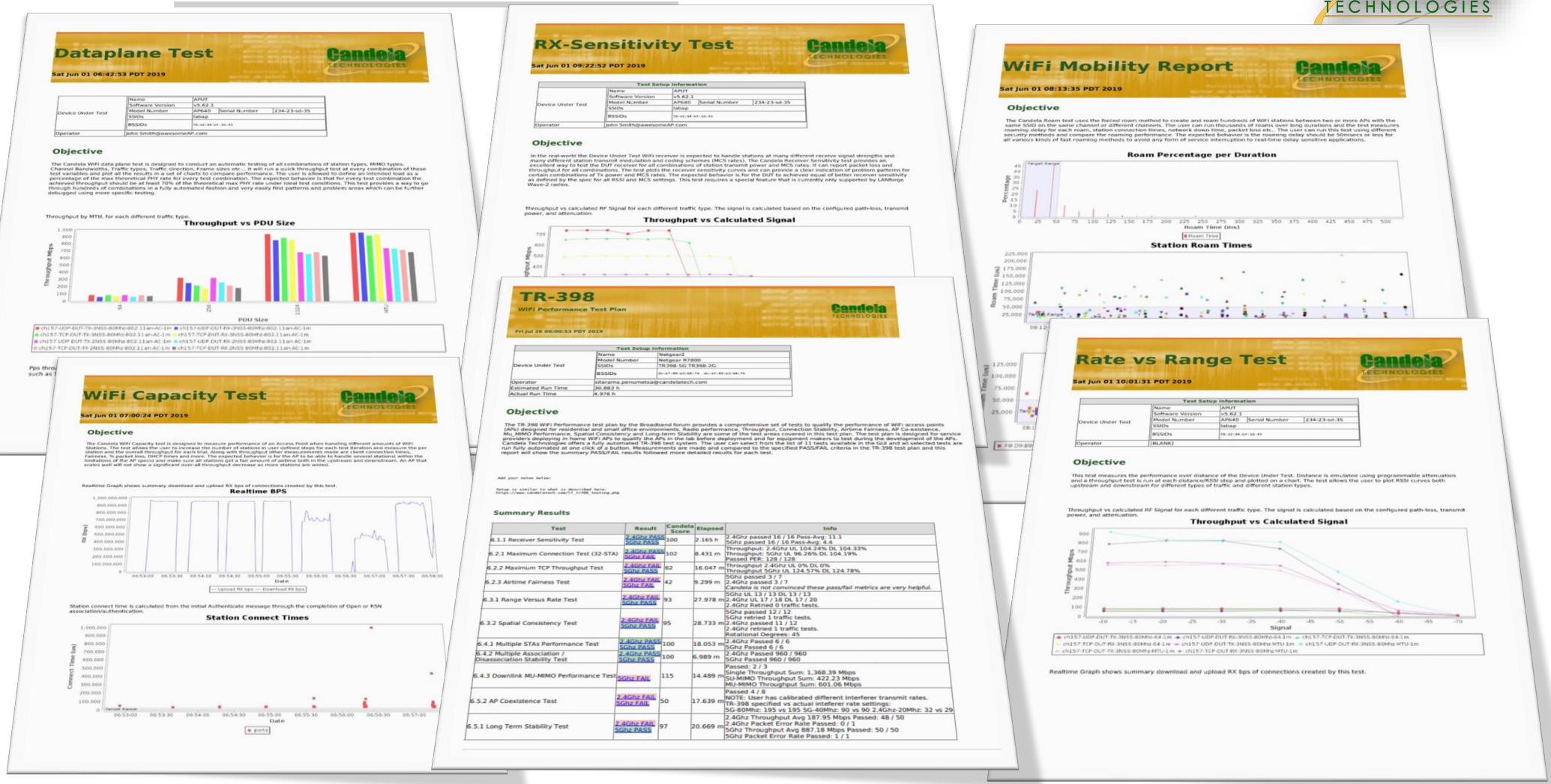
Multi-Link Operation:

It enables devices to simultaneously send and receive data across different frequency bands and channels. With MLO, Wi-Fi 7 supports establishing multiple links between the Station (STA, such as your phone) and Wi-Fi access point (AP, such as your router). Connecting to the 2.4 GHz, 5 GHz, and 6 GHz bands simultaneously increases throughput, reduces latency, and improves reliability. It is ideal for emerging applications like VR/AR, online gaming, remote office, and cloud computing.

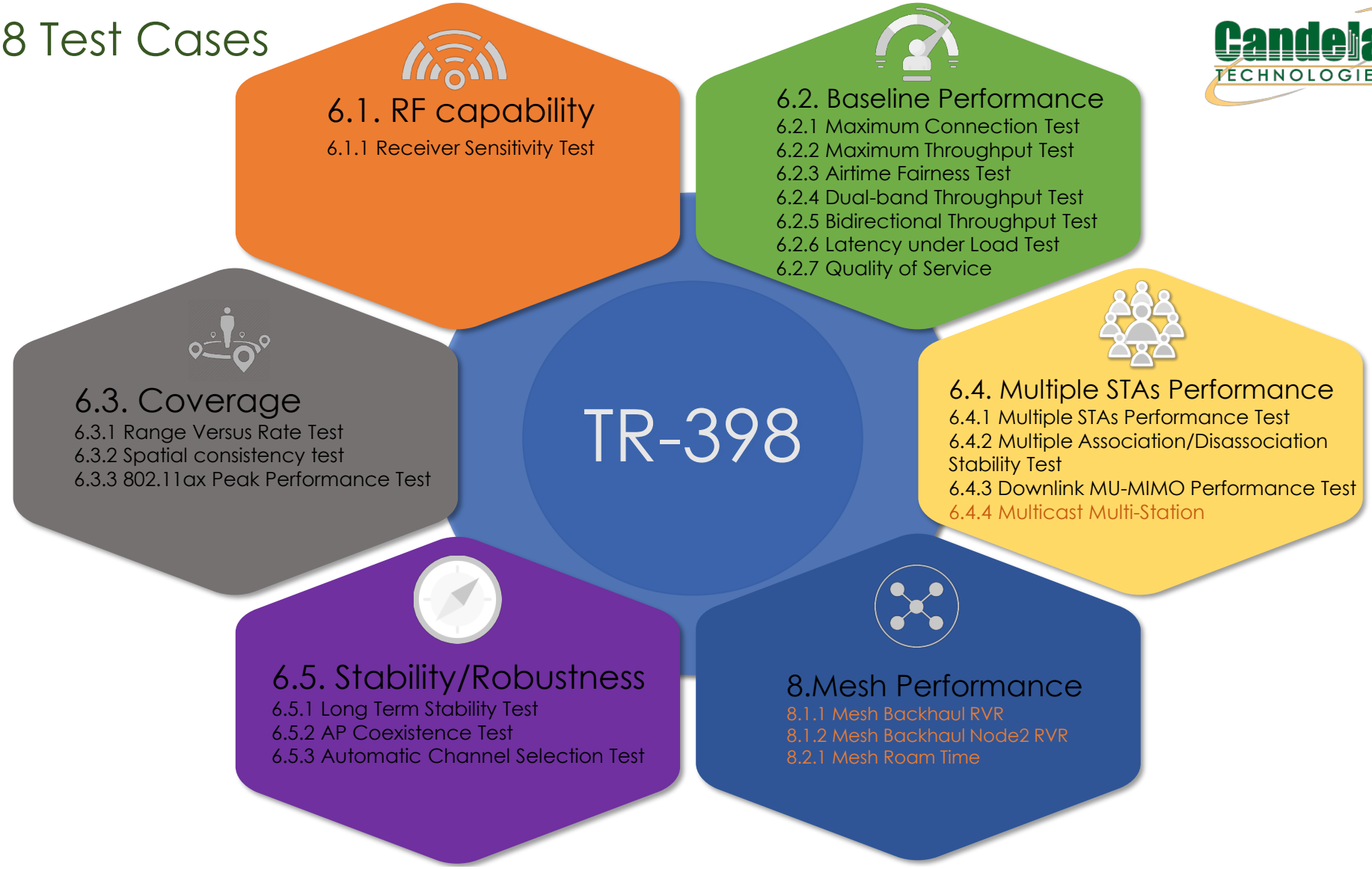


Band	Client Connected	MLO Enabled	MLO Working	Mode	NSS	MCS	Bandwidth	Channel	RSSI (dBm)	PHY-rate (Mbps)	TCP-DL Throughput (Mbps)	TCP-UL Throughput (Mbps)
2.4GHz + 5GHz	5GHz	Yes	Yes	BE	2	13	160	36	-30	2882	1408	1324
2.4GHZ + 6GHZ	2.4GHz, 6GHz	Yes	Yes	BE	2	9	320	1, 37	-19	1921, 3843	628	342
5GHz + 6GHz	5GHz	Yes	No	BE	2	12, 11	320	36	-29	5187, 4803	2.15 Gbps	2.43 Gbps
2.4GHz + 5GHz + 6GHz	6GHz	Yes	No	BE	2	13	320	1	-14	5764	1.89 Gbps	1.73 Gbps

PDF TEST REPORTS



TR-398 Test Cases

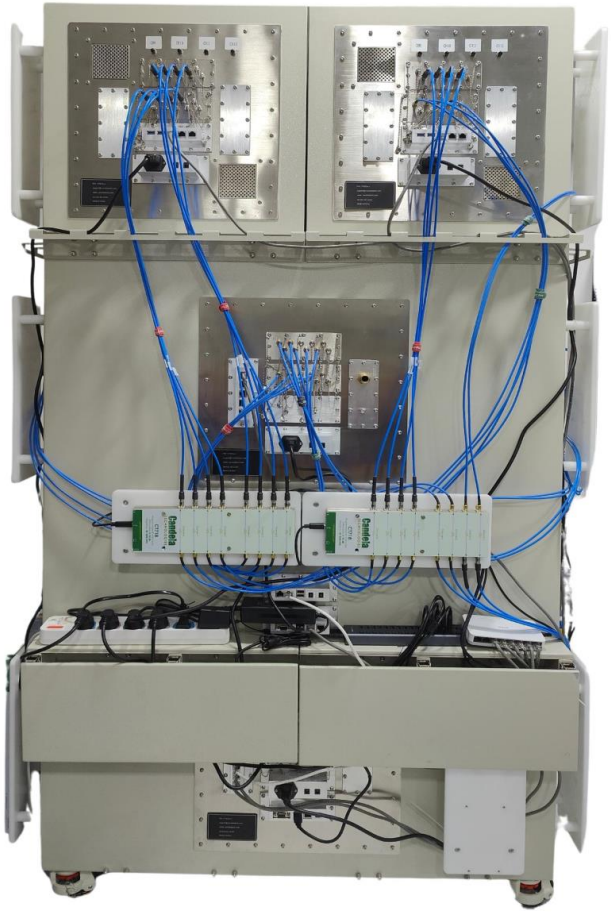


TR398 Issue 4

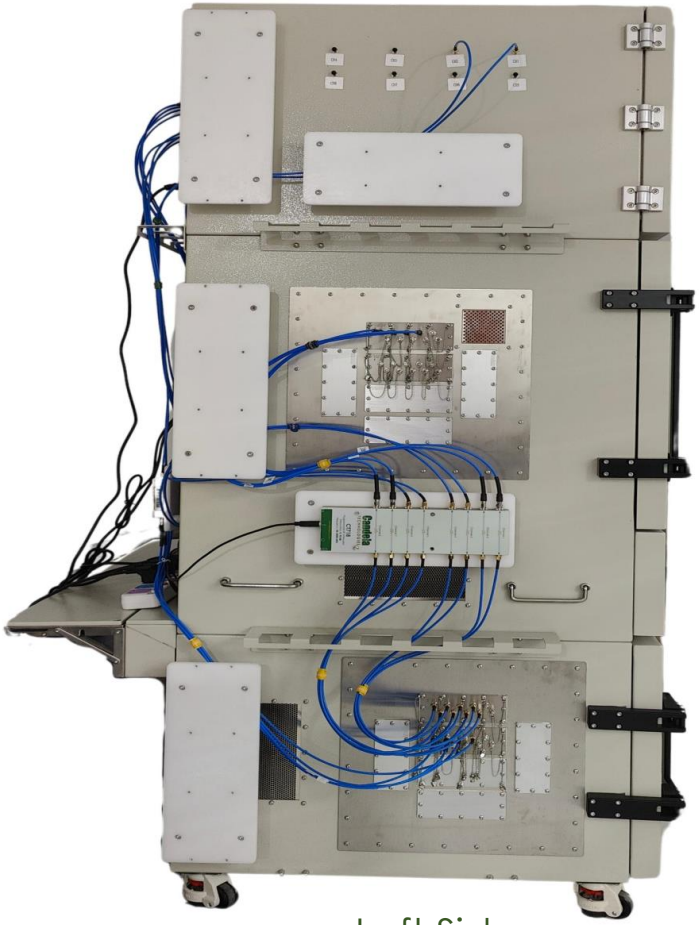
- 6.1. **RF capability**
  - 6.1.1 Receiver Sensitivity Test
- 6.2. **Baseline Performance**
  - 6.2.1 Maximum Connection Test
  - 6.2.2 Maximum Throughput Test
  - 6.2.3 Airtime Fairness Test
  - 6.2.4 Dual-band Throughput Test
  - 6.2.5 Bidirectional Throughput Test
  - 6.2.6 Latency under Load Test
  - 6.2.7 Quality of Service
  - 6.2.8 Muti-Band Throughput Test
  - 6.2.9 OFDMA Throughput
- 6.3. **Coverage**
  - 6.3.1 Range Versus Rate Test
  - 6.3.2 Spatial consistency test -
  - 6.3.3 802.11ax Peak Performance Test
- 6.4. **Multiple STAs Performance**
  - 6.4.1 Multiple STAs Performance Test
  - 6.4.2 Multiple Association/Disassociation Stability Test
  - 6.4.3 Downlink MU-MIMO Performance Test
  - 6.4.4 Multicast Multi-Station
  - 6.4.5 Uplink MU-MIMO Test
- 6.5. **Stability/Robustness**
  - 6.5.1 Long Term Stability Test
  - 6.5.2 AP Coexistence Test
  - 6.5.3 Automatic Channel Selection Test
  - 6.5.4 Puncturing
  - 6.5.5 MLO Performance Test
- 6.6 **Mesh Performance**
  - 6.6.1 Mesh Backhaul RVR
  - 6.6.2 Mesh Backhaul Node2 RVR
  - 6.6.3 Mesh Roam Time
- 7.1 **Parameter Accuracies**
  - 7.1.1 RSSI Accuracy
  - 7.1.2 Channel Utilization

TR-398 Issue 4 + Mesh Testbed Images

Front Side



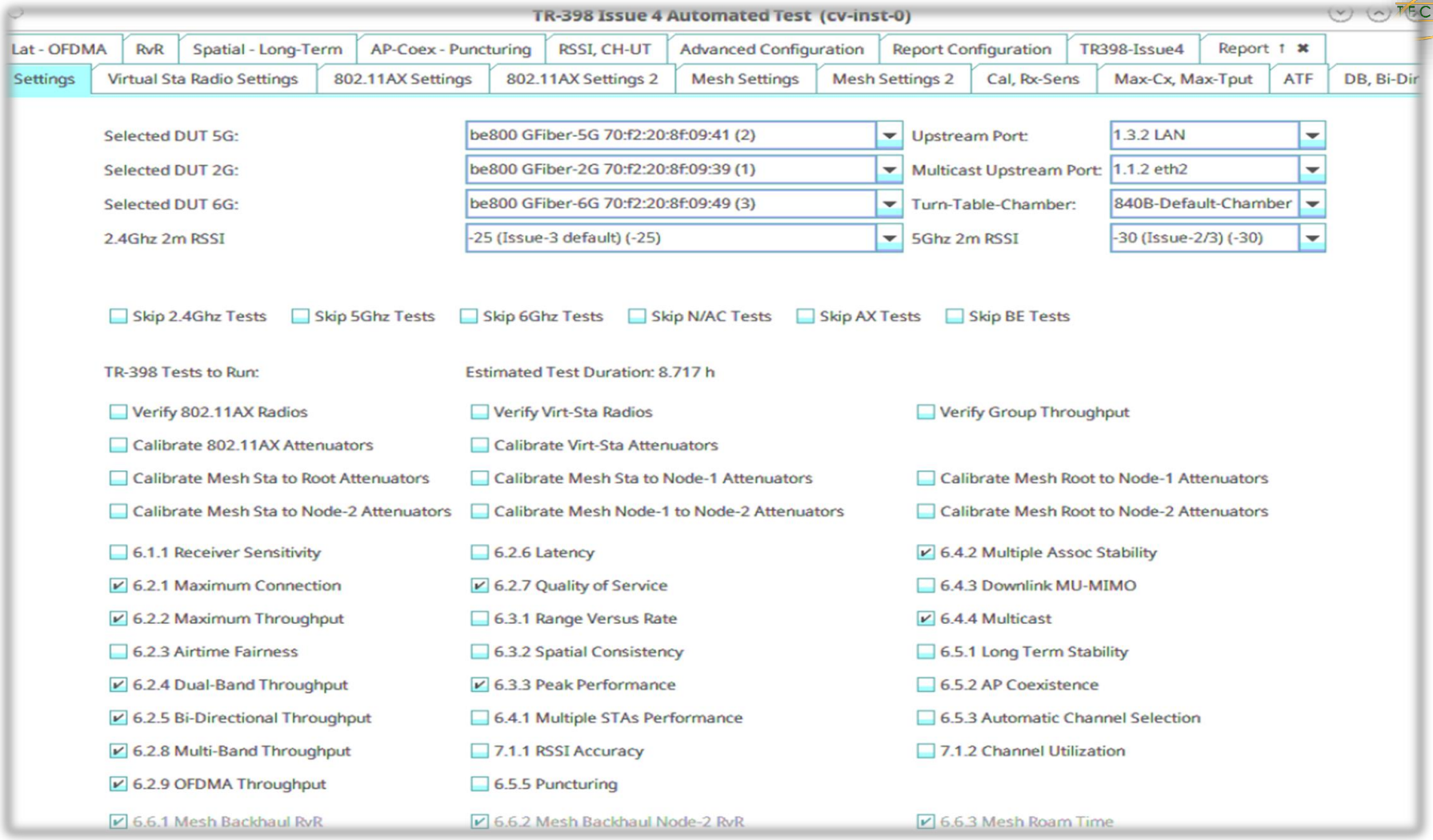
Back Side



Left Side


AP
CHAMB

TR398 Issue 4 Lanforge GUI



TR-398 Issue2 Test Report

TR-398v2

WiFi Performance Test Plan

Candela TECHNOLOGIES

Mon May 10 13:45:38 PDT 2021

Test Setup Information		
Device Under Test	Name	TR398-DUT-asus
	Software Version	3.0.0.4.386_42819
	Model Number	rtAX-88u
	SSIDs	asus11ax-2 asus11ax-5
	Passwords	hello123 hello123
	BSSIDs	3c:7c:3f:55:4d:60 3c:7c:3f:55:4d:64
	Notes	[BLANK]
Estimated Run Time	4.583 h	
Actual Run Time	3.929 h	

Objective

The TR-398v2 WiFi Performance test plan by the Broadband forum provides a comprehensive set of tests to qualify the performance of WiFi access points (APs) designed for residential and small office environments. Radio performance, Throughput, Connection Stability, Airtime Fairness, AP Co-existence, Mu_MIMO Performance, Spatial Consistency and Long-term Stability are some of the test areas covered in this test plan. The test plan is designed for service providers deploying in home WiFi APs to qualify the APs in the lab before deployment and for equipment makers to test during the development of the APs. Candela Technologies offers a fully automated TR-398v2 test system. The user can select from the list of 11 tests available in the GUI and all selected tests are run fully automated at one click of a button. Measurements are made and compared to the specified PASS/FAIL criteria in the TR-398v2 test plan and this report will show the summary PASS/FAIL results followed more detailed results for each test.

Summary Results

Test	Result	Candela Score	Elapsed	Info
Calibrate 802.11AX Zero Attenuation RSSI	2.4Ghz PASS 5Ghz PASS	100	5.389 m	Attenuator Calibration Step 2.4Ghz Passed 48 / 48 5Ghz Passed 48 / 48
Calibrate 802.11AC Zero Attenuation RSSI	2.4Ghz FAIL 5Ghz PASS	95	5.916 m	Attenuator Calibration Step 2.4Ghz Passed 44 / 48 5Ghz Passed 48 / 48
6.1.1 Receiver Sensitivity Test	Skipped	0	0	
6.2.1 Maximum Connection Test (32-STA)	2.4Ghz FAIL 5Ghz FAIL	90	17.126 m	Throughput: 2.4Ghz AC UL 103.56% DL 104.07% Throughput: 2.4Ghz AX UL 2.93% DL 101.93% Throughput: 5Ghz AC UL 103.96% DL 104.36% Throughput: 5Ghz AX UL 51.31% DL 103.29% Passed PER: 245 / 256
6.2.2 Maximum TCP Throughput Test	2.4Ghz FAIL 5Ghz PASS	118	9.953 m	Throughput N 2.4Ghz UL 93.02% DL 119.07% Throughput AX 2.4Ghz UL 114.48% DL 118.58% Throughput AC 5Ghz UL 118.25% DL 126.77% Throughput AX 5Ghz UL 130.26% DL 127.20%
6.2.3 Airtime Fairness Test	2.4Ghz FAIL 5Ghz PASS	89	16.709 m	AC 5Ghz passed 7 / 7 AX 5Ghz passed 7 / 7 N 2.4Ghz passed 7 / 7 AX 2.4Ghz passed 4 / 7
6.2.4 Dual-Band Throughput Test	2.4Ghz PASS 5Ghz FAIL	95	15.267 m	AC 12 / 12 2.4 AX 12 / 12 5Ghz AX 12 / 12
6.2.5 Bidirectional UDP Throughput Test	2.4Ghz FAIL 5Ghz FAIL	8	40.069 m	AC 5Ghz passed 0 / 3 AX 5Ghz passed 0 / 3 N 2.4Ghz passed 0 / 3 AX 2.4Ghz passed 1 / 3
6.3.1 Range Versus Rate Test	2.4Ghz FAIL 5Ghz PASS	82	1.217 h	AC 5Ghz UL 14 / 14 DL 14 / 14 AX 5Ghz UL 14 / 14 DL 14 / 14 N 2.4Ghz UL 7 / 17 DL 16 / 17 AX 2.4Ghz UL 10 / 17 DL 11 / 17
6.3.2 Spatial Consistency Test	Skipped	0	0	
6.3.3 AX Peak Performance TCP Throughput Test	2.4Ghz FAIL 5Ghz FAIL	80	4.821 m	Throughput AX 2.4Ghz UL 76.25% DL 79.06% Throughput AX 5Ghz UL 85.05% DL 83.01%
6.4.1 Multiple STAs Performance Test	2.4Ghz FAIL 5Ghz PASS	91	35.672 m	N 2.4Ghz Passed 6 / 6 AX 2.4Ghz Passed 4 / 6 AC 5Ghz Passed 6 / 6 AX 5Ghz Passed 6 / 6
6.4.2 Multiple Association / Disassociation Stability Test	2.4Ghz FAIL 5Ghz FAIL	99	11.192 m	N 2.4Ghz Passed 723 / 728 AX 2.4Ghz Passed 727 / 728 AC 5Ghz Passed 725 / 728 AX 5Ghz Passed 727 / 728
6.4.3 Downlink MU-MIMO Performance Test	Skipped	0	0	
6.5.2 AP Coexistence Test	Skipped	0	0	
6.5.1 Long Term Stability Test	Skipped	0	0	

Calibrate 802.11AX Zero Attenuation RSSI

Summary

Calibrate the Zero attenuation settings for 2.4 and 5Ghz

Test Procedure

These steps are done for 2.4Ghz and 5Ghz.

1. Create an /a/b/g (legacy) station on each radio (or optionally some other mode and NSS). Legacy mode is used because it is normally sent at full tx-power by the AP. Higher MCS frames are often transmitted below maximum power, especially when using multiple spatial streams.
2. Set all attenuators to 0.
3. Create download connections for each station and run them for 30 seconds.
4. Record Received Signal Strength (RSSI) for each station. This records a decaying average over the last few data frames received, not beacon RSSI.
5. Change attenuation to 8, 15, and 25 and re-run download test and record new RSSI.
6. Record the zero-attenuation RSSI, based on the average over all tested attenuations, in the TR-398v2 Automation setup window.

Pass/Fail Criteria

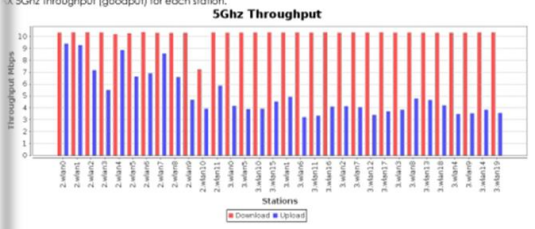
1. Ensure that relative RSSI is within 3 for each of the different attenuation values.

Candela Score

The Candela Score for Calibration Test is calculated as the percentage of passing sub-tests. As long as the score is 80 or higher and there are no bad outliers in the reported signal calculations the setup is probably working OK. Failures normally indicate a cabling problem or mis-configuration, or in rare cases, a hardware failure in the attenuator or LANforge radios. RF leakage inside of LANforge from adjacent radios

v_udp-2-2-3.wlan2--1.0.20-B	0 bps	1.182 Kbps	32,428	32,428	2,785	88.235
v_udp-2-2-3.wlan7--1.0.21-A	21.316 Kbps	0 bps	0	34,906	0	0
v_udp-2-2-3.wlan7--1.0.21-B	0 bps	787 bps	34,906	34,906	2,779	97.458
v_udp-2-2-3.wlan12--1.0.22-A	10.817 Kbps	0 bps	0	45,577	0	0
v_udp-2-2-3.wlan12--1.0.22-B	0 bps	1.379 Kbps	45,577	45,577	4,039	87.273
v_udp-2-2-3.wlan17--1.0.23-A	52.591 Kbps	0 bps	0	15,215	0	0
v_udp-2-2-3.wlan17--1.0.23-B	0 bps	588 bps	15,215	15,215	1,569	97.048
v_udp-2-2-3.wlan3--1.0.24-A	33.072 Kbps	0 bps	0	21,682	0	0
v_udp-2-2-3.wlan3--1.0.24-B	0 bps	1.968 Kbps	21,682	21,682	3,087	87.432
v_udp-2-2-3.wlan8--1.0.25-A	38.71 Kbps	0 bps	0	19,202	0	0
v_udp-2-2-3.wlan8--1.0.25-B	0 bps	592 bps	19,202	19,202	1,998	96.759
v_udp-2-2-3.wlan13--1.0.26-A	19.704 Kbps	0 bps	0	6,555	0	0
v_udp-2-2-3.wlan13--1.0.26-B	0 bps	394 bps	6,555	6,555	507	73.984
v_udp-2-2-3.wlan18--1.0.27-A	119.709 Kbps	0 bps	0	0	0	0
v_udp-2-2-3.wlan18--1.0.27-B	0 bps	0 bps	0	0	0	100
v_udp-2-2-3.wlan4--1.0.28-A	8.897 Kbps	0 bps	0	48,535	0	0
v_udp-2-2-3.wlan4--1.0.28-B	0 bps	2.756 Kbps	48,535	48,535	2,746	72
v_udp-2-2-3.wlan9--1.0.29-A	11.035 Kbps	0 bps	0	20,452	0	0
v_udp-2-2-3.wlan9--1.0.29-B	0 bps	197 bps	20,452	20,452	2,812	95.455
v_udp-2-2-3.wlan14--1.0.30-A	91.239 Kbps	0 bps	0	11,653	0	0
v_udp-2-2-3.wlan14--1.0.30-B	0 bps	4.72 Kbps	11,653	11,653	1,077	86.17
v_udp-2-2-3.wlan19--1.0.31-A	28.15 Kbps	0 bps	0	0	0	0
v_udp-2-2-3.wlan19--1.0.31-B	0 bps	0 bps	0	0	0	100

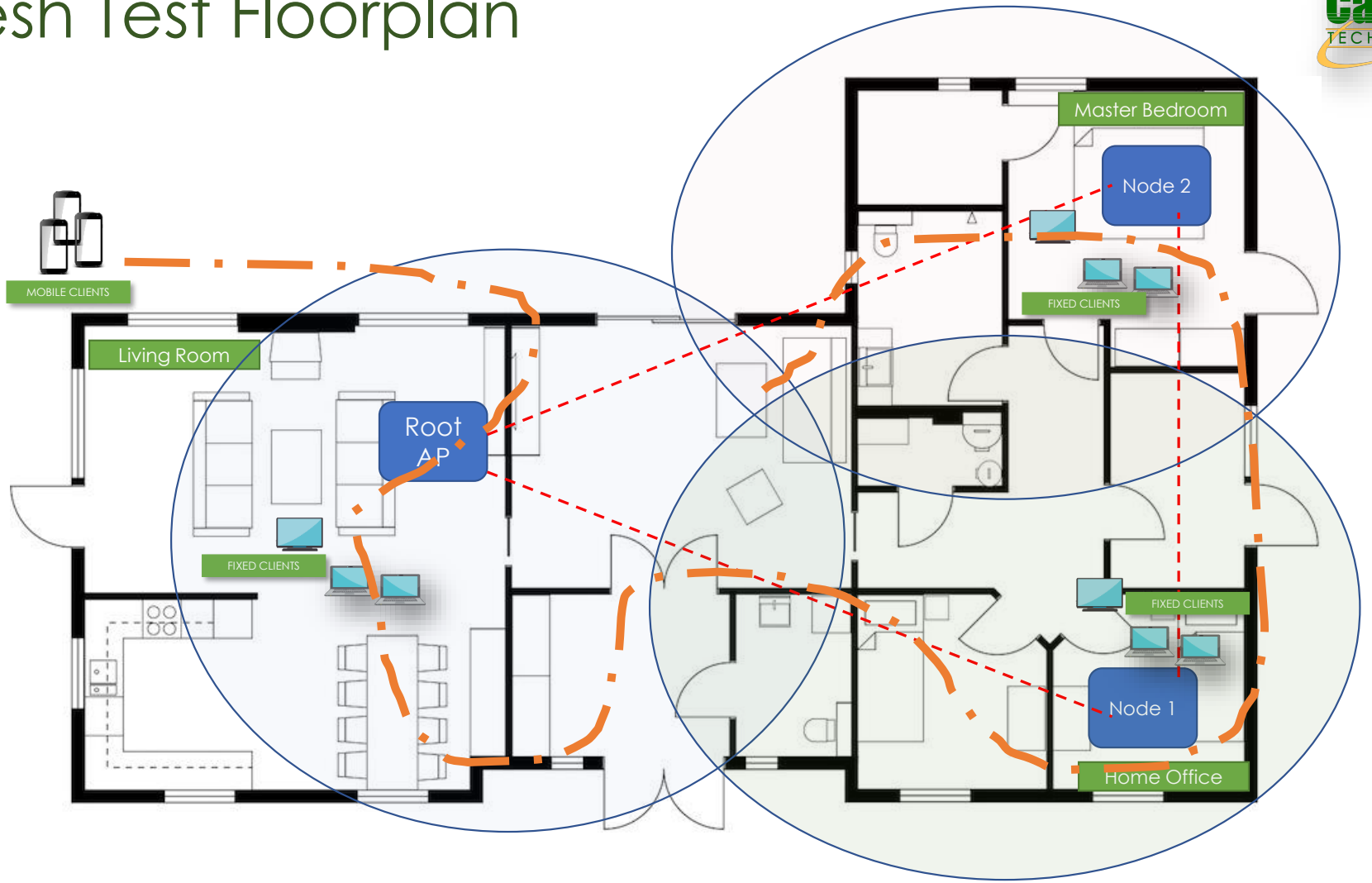
X 5Ghz Throughput (goodput) for each station.



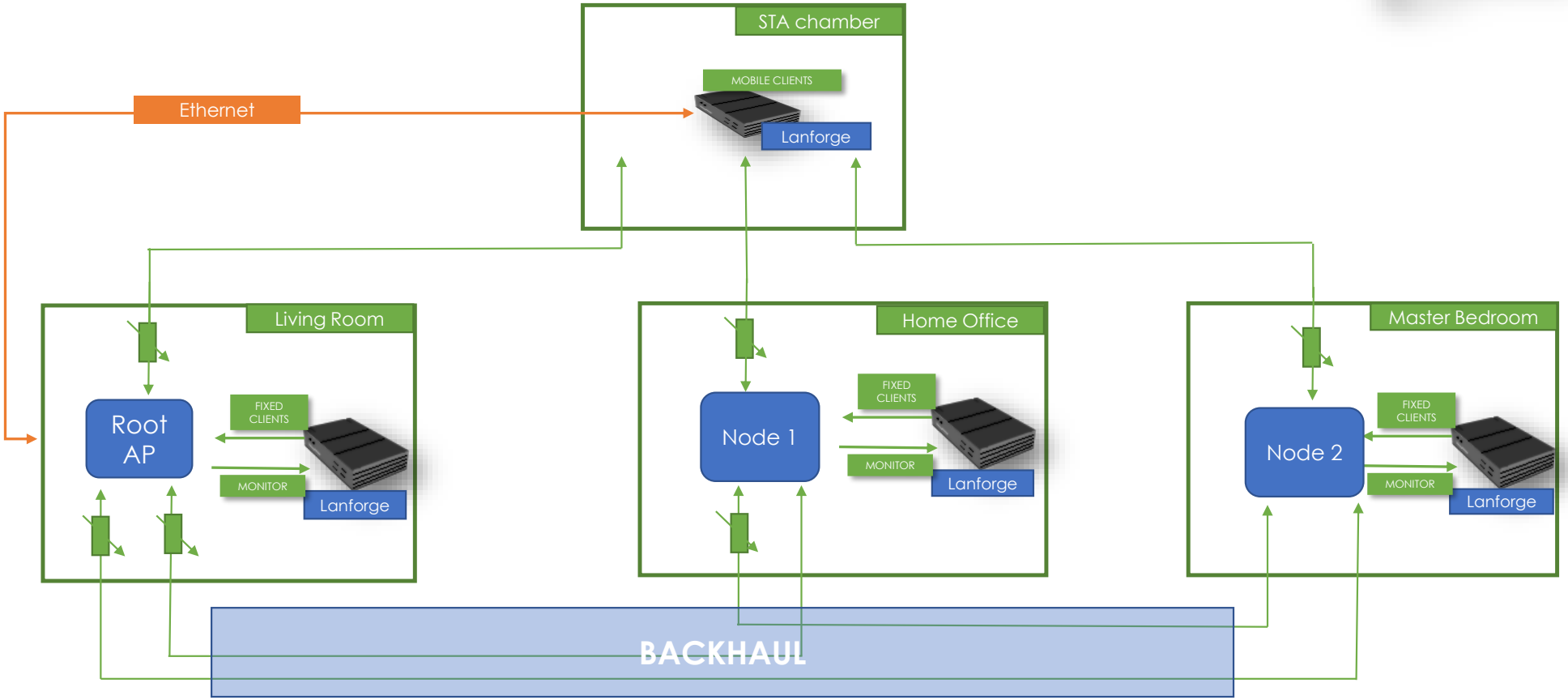
lax-Cx-Test: Snapshot AX 5Ghz Download

Port	Tx-Bps 1m	Rx-Bps 1m	Tx-Fail %	Tx-Link-Rate	Rx-Link-Rate	Mode	Channel	Last CX-Time(ms)	RSSI (dBm)	AP	IP	MAC
2.16 wlan0	25 bps	10.625 Mbps	0	245 Mbps	960.7 Mbps	802.11an-AX	36	251	-37	3C:7C:3F:55:4D:64	192.168.50.74	d8:f8:83:35:db:e9
2.17 wlan1	29 bps	10.641 Mbps	0	245 Mbps	540.3 Mbps	802.11an-AX	36	105	-36	3C:7C:3F:55:4D:64	192.168.50.186	d8:f8:83:35:ba:bf
2.18 wlan2	39 bps	10.65 Mbps	0	245 Mbps	1.201 Gbps	802.11an-AX	36	105	-37	3C:7C:3F:55:4D:64	192.168.50.25	d8:f8:83:36:54:f7
2.19 wlan3	29 bps	10.658 Mbps	0	245 Mbps	864.8 Mbps	802.11an-AX	36	306	-38	3C:7C:3F:55:4D:64	192.168.50.131	d8:f8:83:36:6b:d6
2.20 wlan4	39 bps	10.613 Mbps	0	245 Mbps	313.4 Mbps	802.11an-AX	36	419	-47	3C:7C:3F:55:4D:64	192.168.50.26	a4:6b:b6:3d:61:4
2.21 wlan5	29 bps	10.641 Mbps	0	245 Mbps	480.3 Mbps	802.11an-AX	36	478	-47	3C:7C:3F:55:4D:64	192.168.50.211	e8:14:08:21:96:84
2.22 wlan6	33 bps	10.676 Mbps	0	245 Mbps	1.201 Gbps	802.11an-AX	36	594	-48	3C:7C:3F:55:4D:64	192.168.50.188	a4:6b:b6:3d:d5:e
2.23	29	10.638		245	960.7	802.11an-						

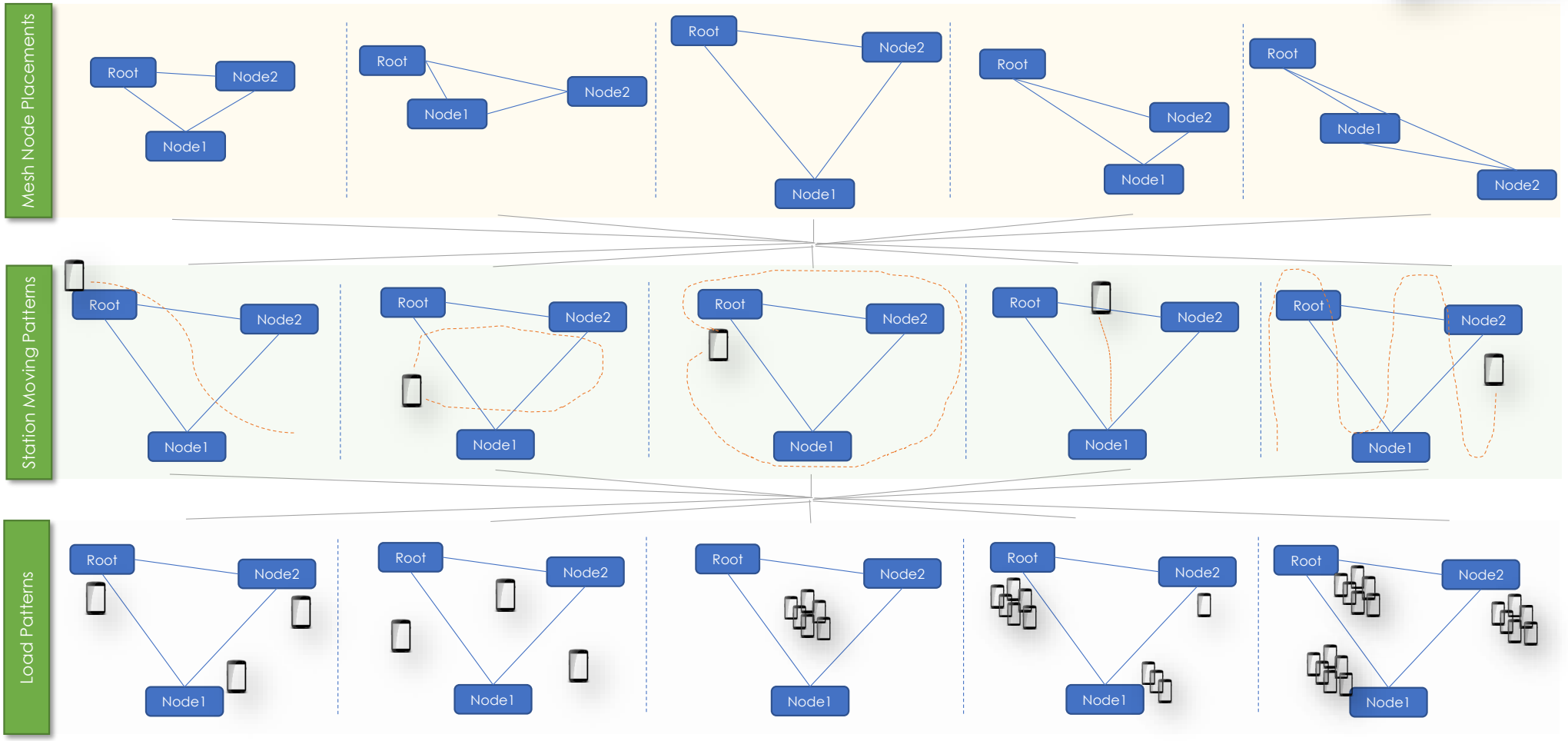
Mesh Test Floorplan



3 Node Testbed Example



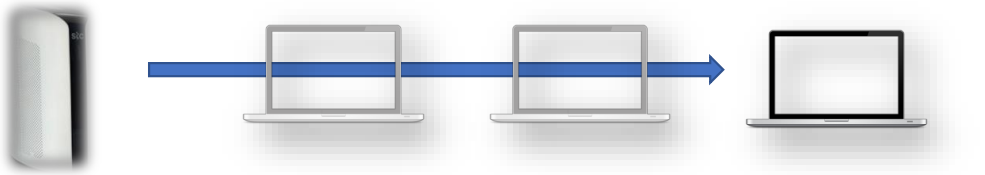
Test Automation Variables



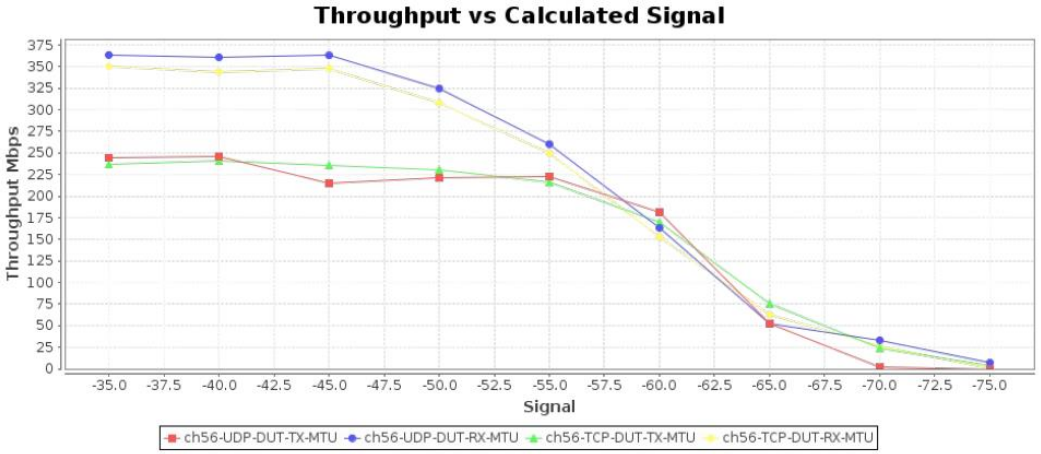
Mesh Testing Results Summary

	Tests	Rating	Tester Comments
1	Dataplane Throughput of Root AP	Average	Low performance was measured with smaller packet size traffic and in 80Mhz modes and also in 2x2 MIMO modes.
2	Multiband Performance of Root AP	Average	About 40% decrease in throughput was observed in the 5Ghz when running dual concurrent tests. 2.4GHz was doing fine
3	Performance over Distance of Root AP	Good	Downstream throughout was significantly lower but overall range was good. The range for 2.4GHz was better, as expected.
4	Long Duration Stability for Root AP	Good	System seems to stable and achieving good throughput over a 1 hour test run. In the middle of the test the AP downstream throughput started dropping
5	Mesh Client Connection Times per Hop	Excellent	Clients seem to connect just fine across all nodes with acceptable connection times. A small number of clients had long connection times
6	Mesh Throughput per Hop	Poor	A big variation in total throughout was found when tests were run with different numbers of clients on each node all running traffic at the same time. It was hard to find a specific pattern. More tests have to run in this key area.
7	Mesh Client Capacity Per Hop	Poor	Throughput dropped significantly when lots of clients were connected to Node1 and Node2 even though both the Nodes has good connectivity to Root AP
8	Mesh Roaming Performance	Average	The clients never roamed to Node1 and always had to connected to Node2. Lots of attempts by the clients to connect to neighboring APs have been ignored. Performance in the 2.4GHz band was a bit better than 5GHz

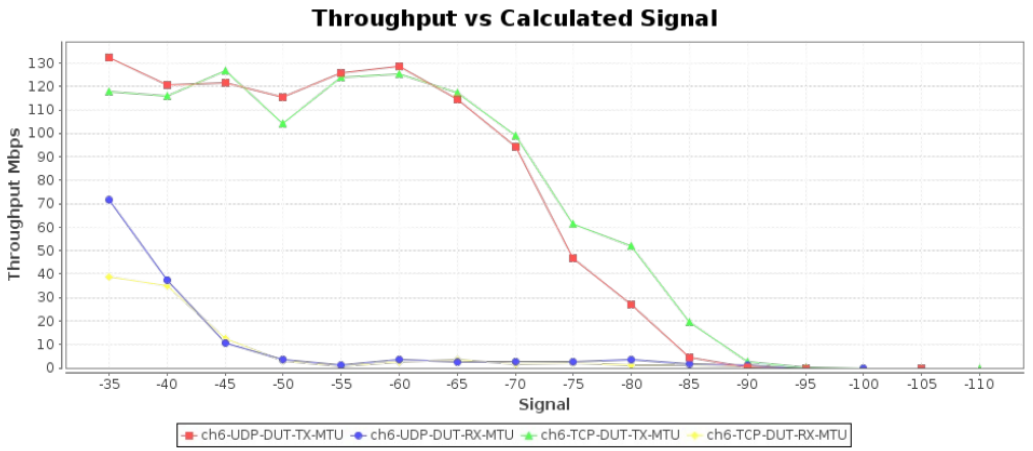
Root AP Throughput over Distance



Root AP



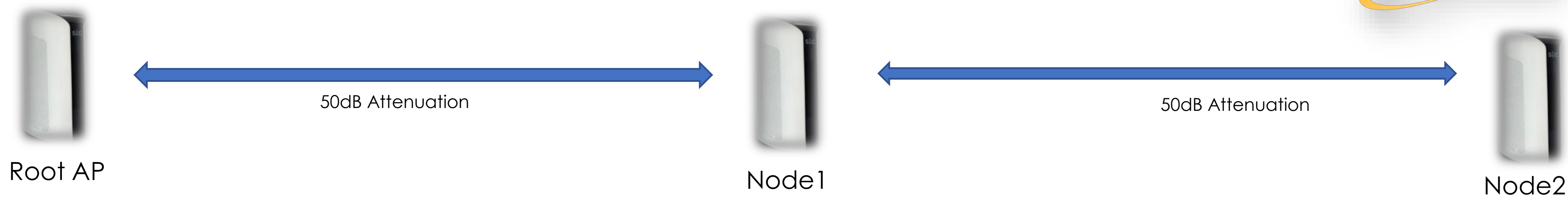
5 GHz

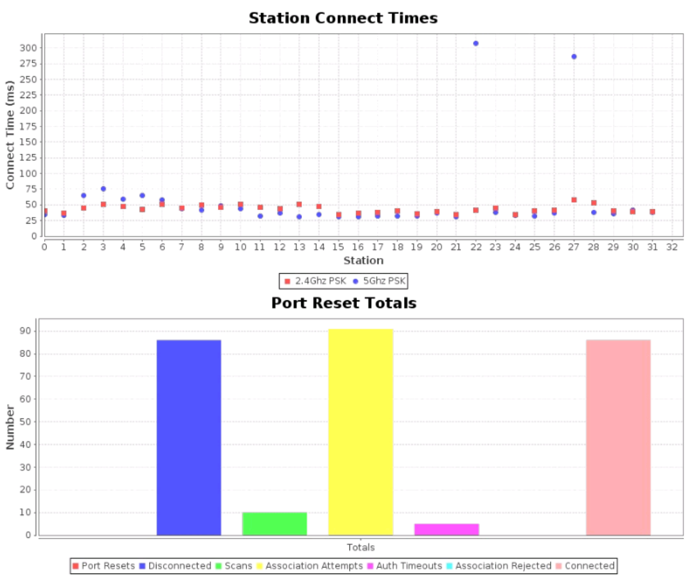


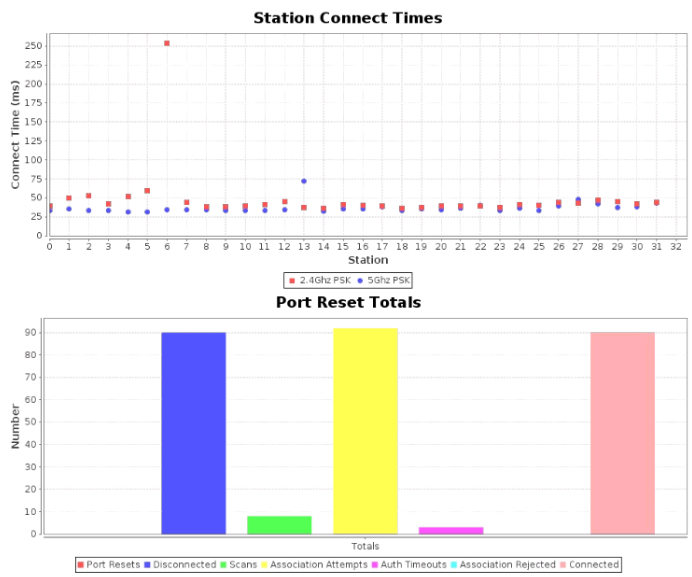
2.4 GHz

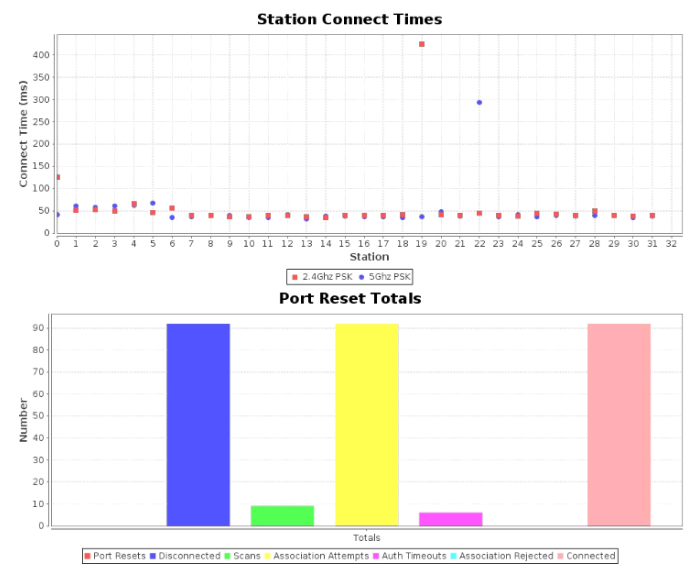
UDP/TCP, Upstream/Downstream throughput is calculated by increasing attenuation between the AP and the tester in 5dB steps programmatically.

Client Connectionn Times Test Per Hop





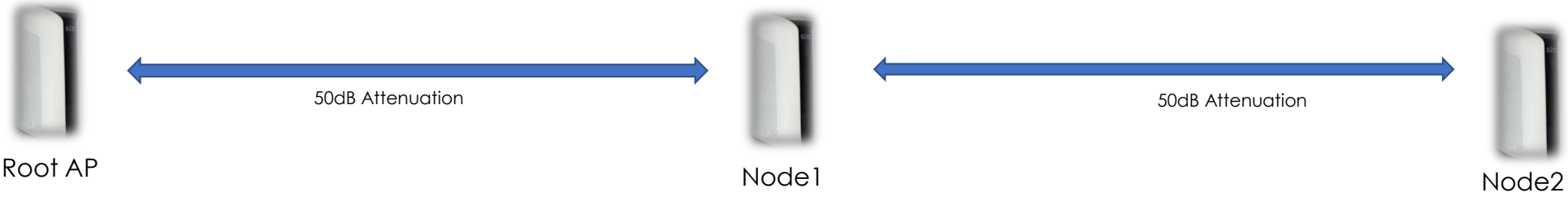


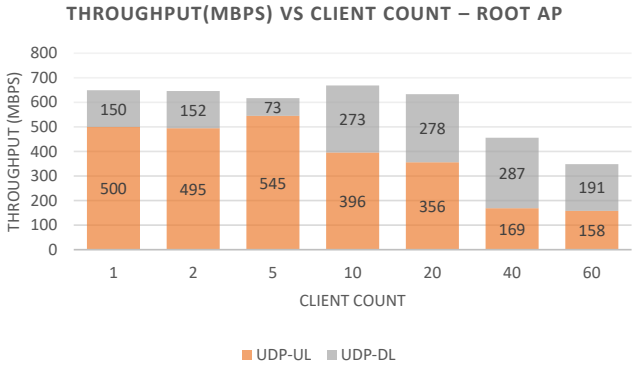


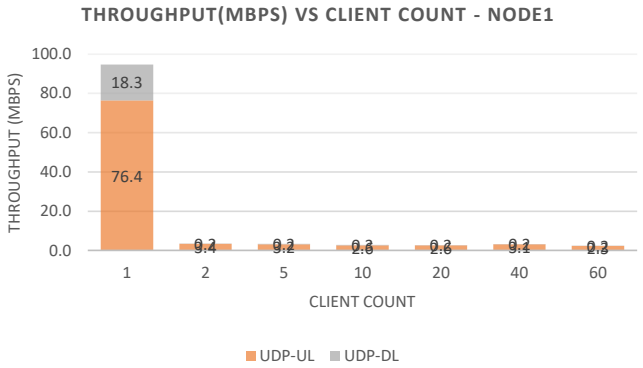
UDP System Throughput per Hop (5GHz)

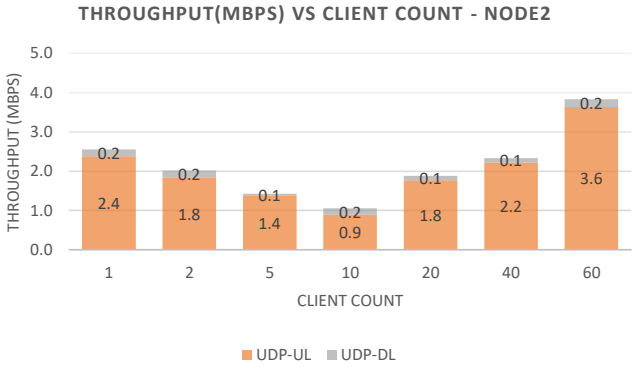
	Root AP	Node1	Node2	Total UL (Mbps)	Total DL (Mbps)	Total (Mbps)	% of Max Achieved
Number of Clients	1	0	0	306.5	296.3	602.8	85%
	0	1	0	27.6	111.4	139	20%
	0	0	1	0.09	23.3	23.39	3%
	1	1	0	108.6	129	237.6	34%
	1	0	1	108.4	43.7	152.1	22%
	0	1	1	2.4	7.6	10	1%
	1	1	1	109.4	47.3	156.7	22%
	5	0	0	397.6	308.7	706.3	100%
	0	5	0	88	0.6	88.6	13%
	0	0	5	1.1	32.4	33.5	5%
	5	5	0	491.8	144	635.8	90%
	5	0	5	494.2	140.2	634.4	90%
	0	5	5	56	31.7	87.7	12%
	5	5	5	498.1	99.1	597.2	85%
	10	0	0	366.8	199.1	565.9	80%
	0	10	0	137.3	3.3	140.6	20%
	0	0	10	0.04	0.427	0.467	0%
	10	10	0	388.3	189.3	577.6	82%
	10	0	10	490.1	90.3	580.4	82%
	0	10	10	11.868	32	43.868	6%
	10	10	10	496.6	87.5	584.1	83%

Client Capacity Test Per Hop (5GHz)

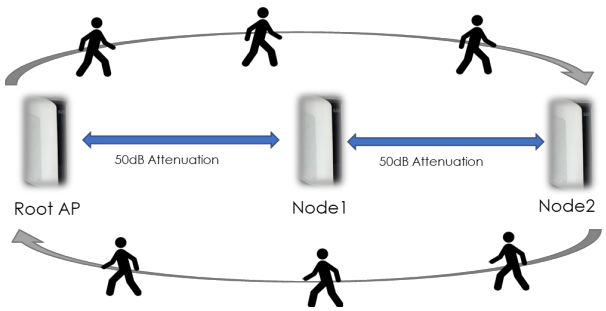


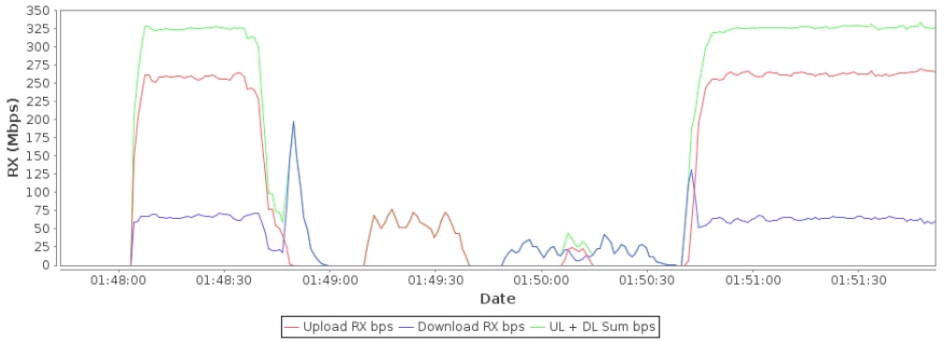




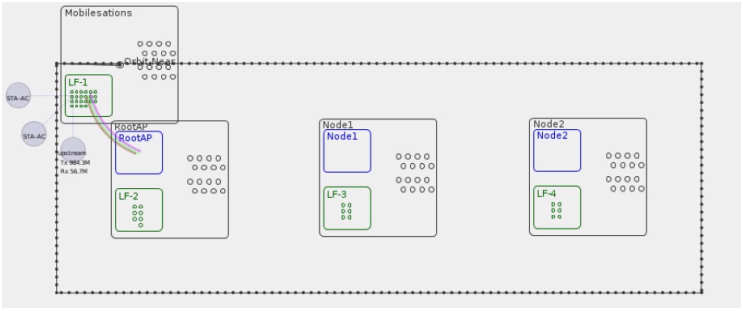


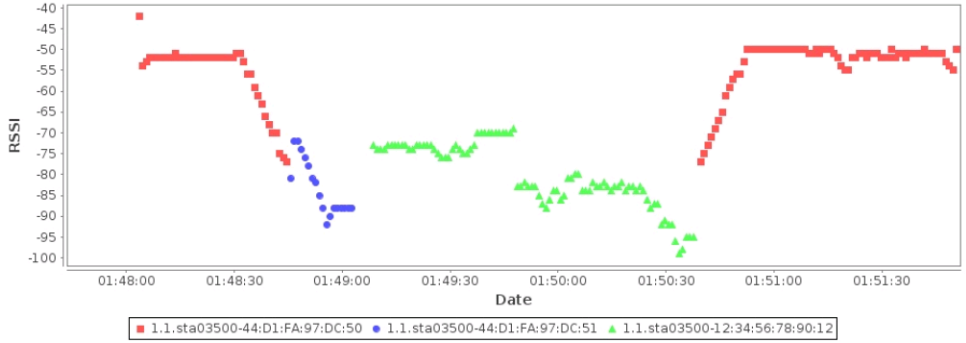
Single Client Mesh Roam Test – 5GHz



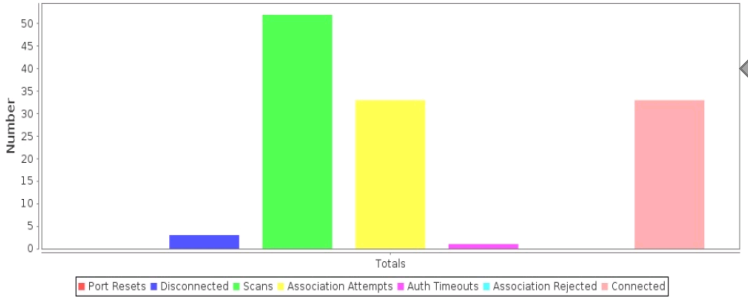


Throughput over the roam cycle



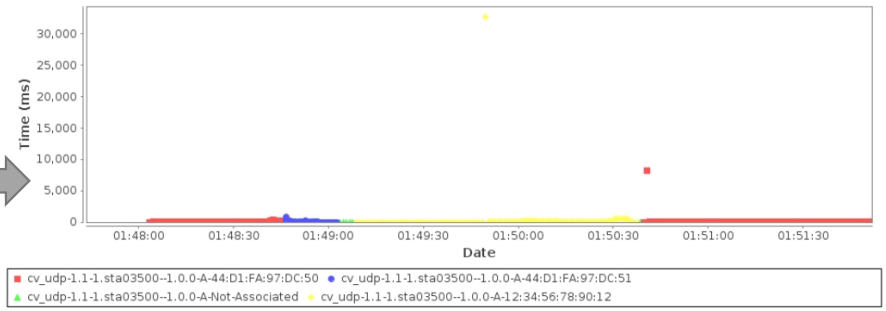


Client RSSI over the roam cycle

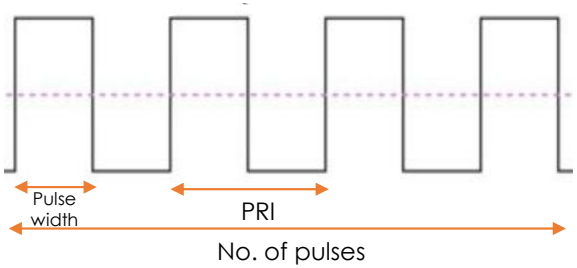


Client Events

Interpacket Gap during the roam cycle

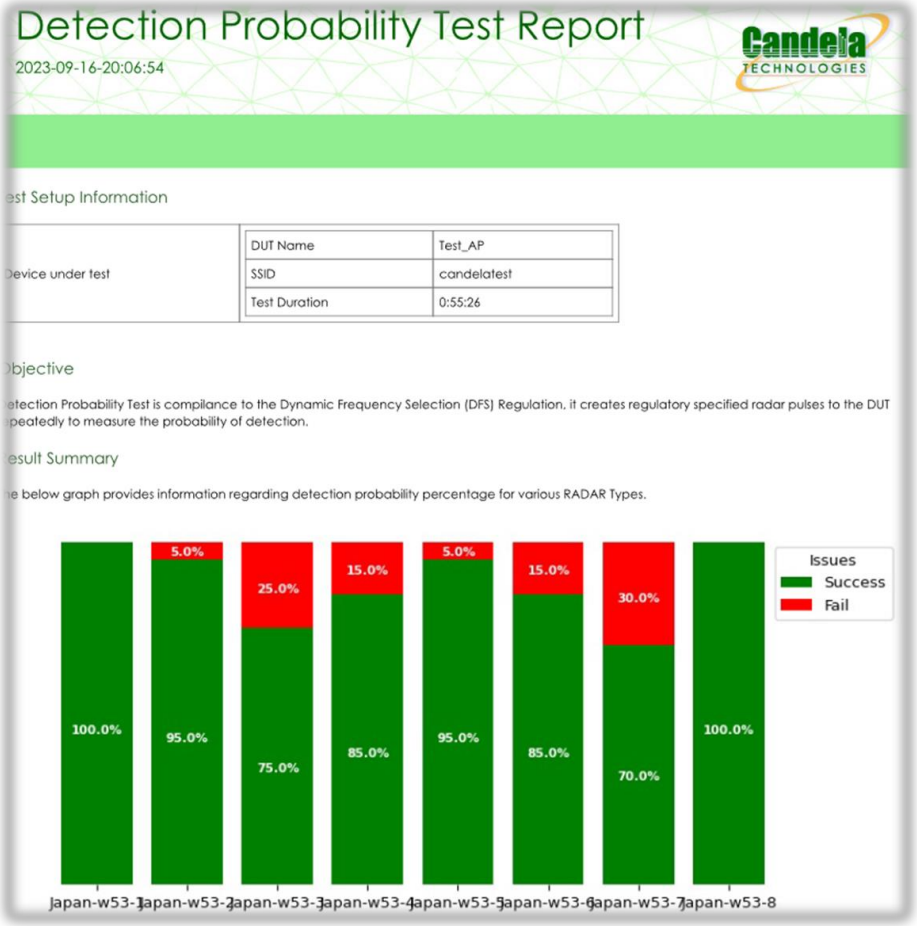


DFS Testbed Images



- We can generate various radar signals using an RF generator by adjusting the radar parameters.
- We can perform below test cases using candela LANforge
    1. The detection probability test
    2. The detection Bandwidth test

Sample Test Reports:



Detection Probability Test Report

2023-09-16-20:06:54

st Setup Information

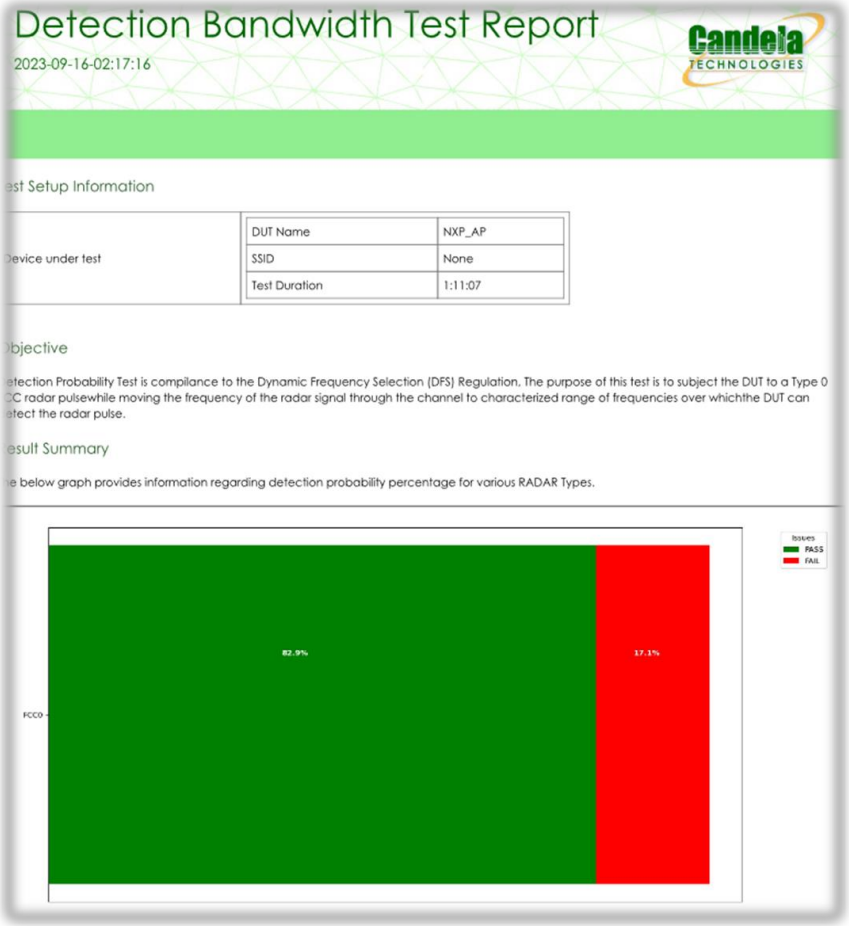
evice under test	DUT Name	Test_AP
	SSID	candelatest
	Test Duration	0:55:26

bjective

etection Probability Test is compilance to the Dynamic Frequency Selection (DFS) Regulation. it creates regulatory specified radar pulses to the DUT peatedly to measure the probability of detection.

esult Summary

e below graph provides information regarding detection probability percentage for various RADAR Types.



Detection Bandwidth Test Report

2023-09-16-02:17:16

st Setup Information

evice under test	DUT Name	NXP_AP
	SSID	None
	Test Duration	1:11:07

bjective

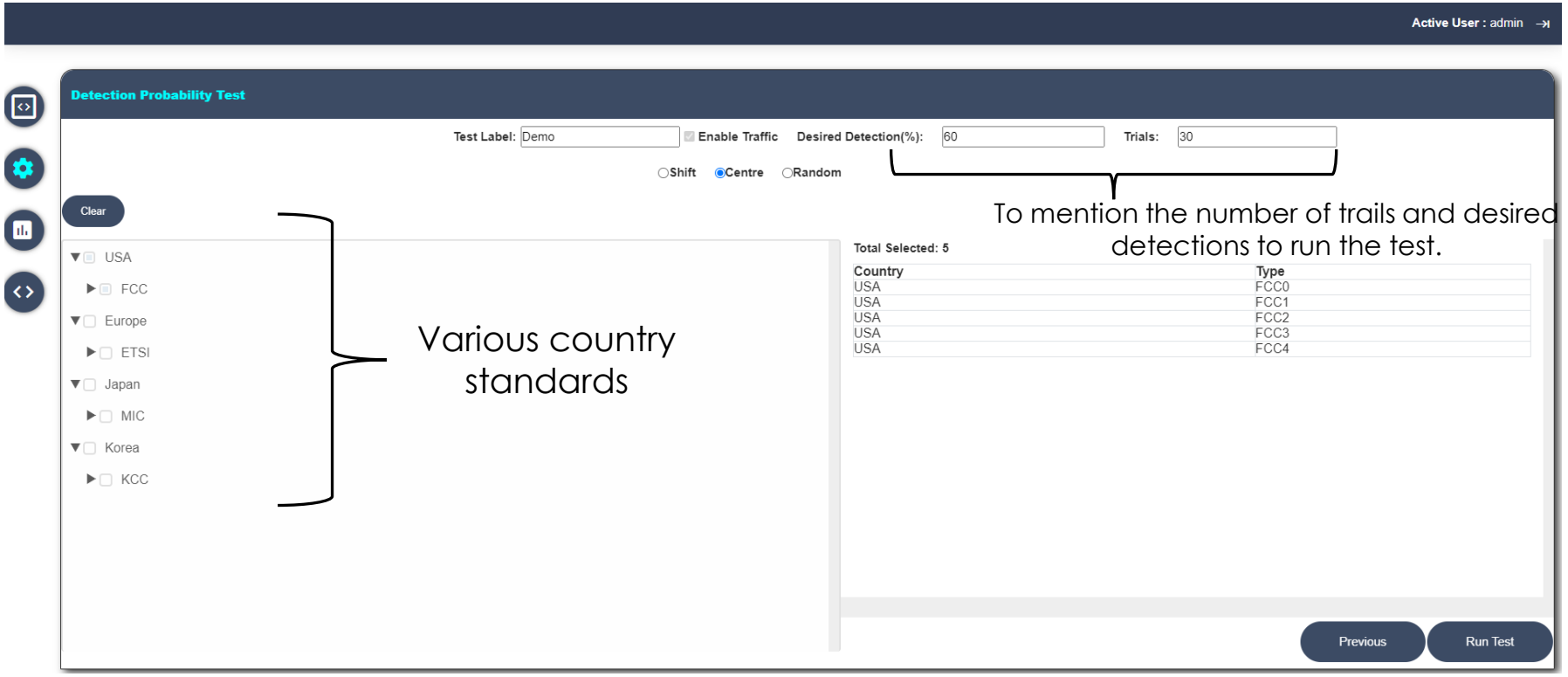
etection Probability Test is compilance to the Dynamic Frequency Selection (DFS) Regulation. The purpose of this test is to subject the DUT to a Type 0 C radar pulsewhile moving the frequency of the radar signal through the channel to characterized range of frequencies over whichthe DUT can tect the radar pulse.

esult Summary

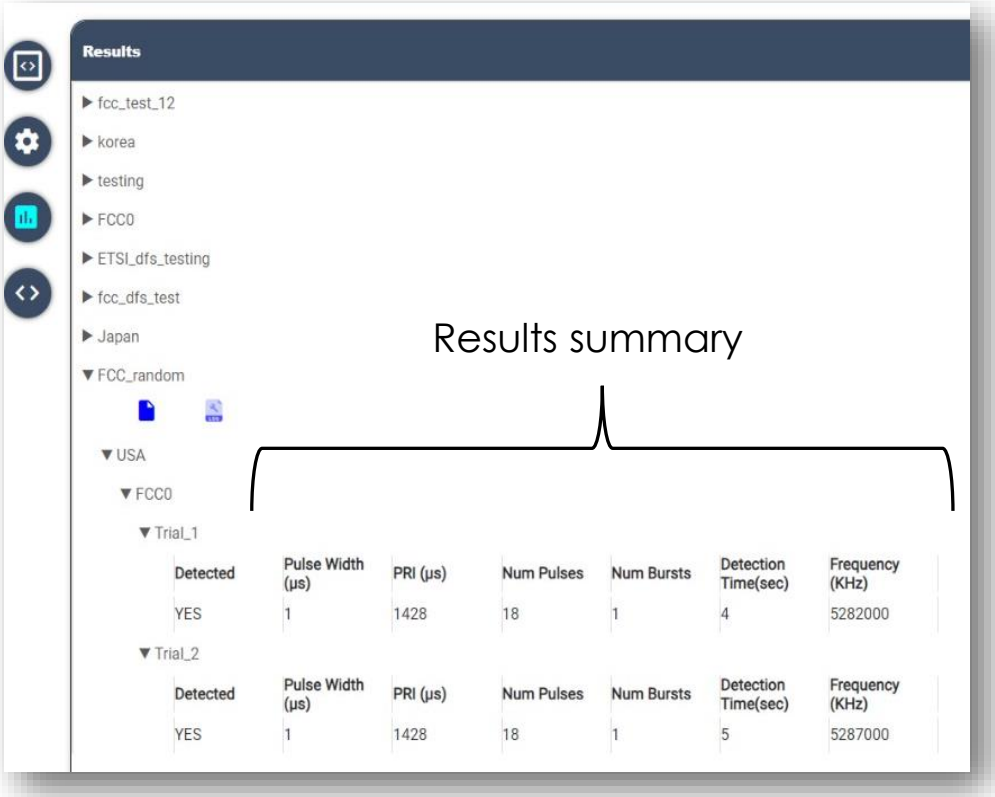
e below graph provides information regarding detection probability percentage for various RADAR Types.

DFS Web-UI:

DFS Web-UI has been designed to execute a wide range of test cases based on various country standards with just a single click, ensuring a user-friendly experience.



Sample WebGUI results:



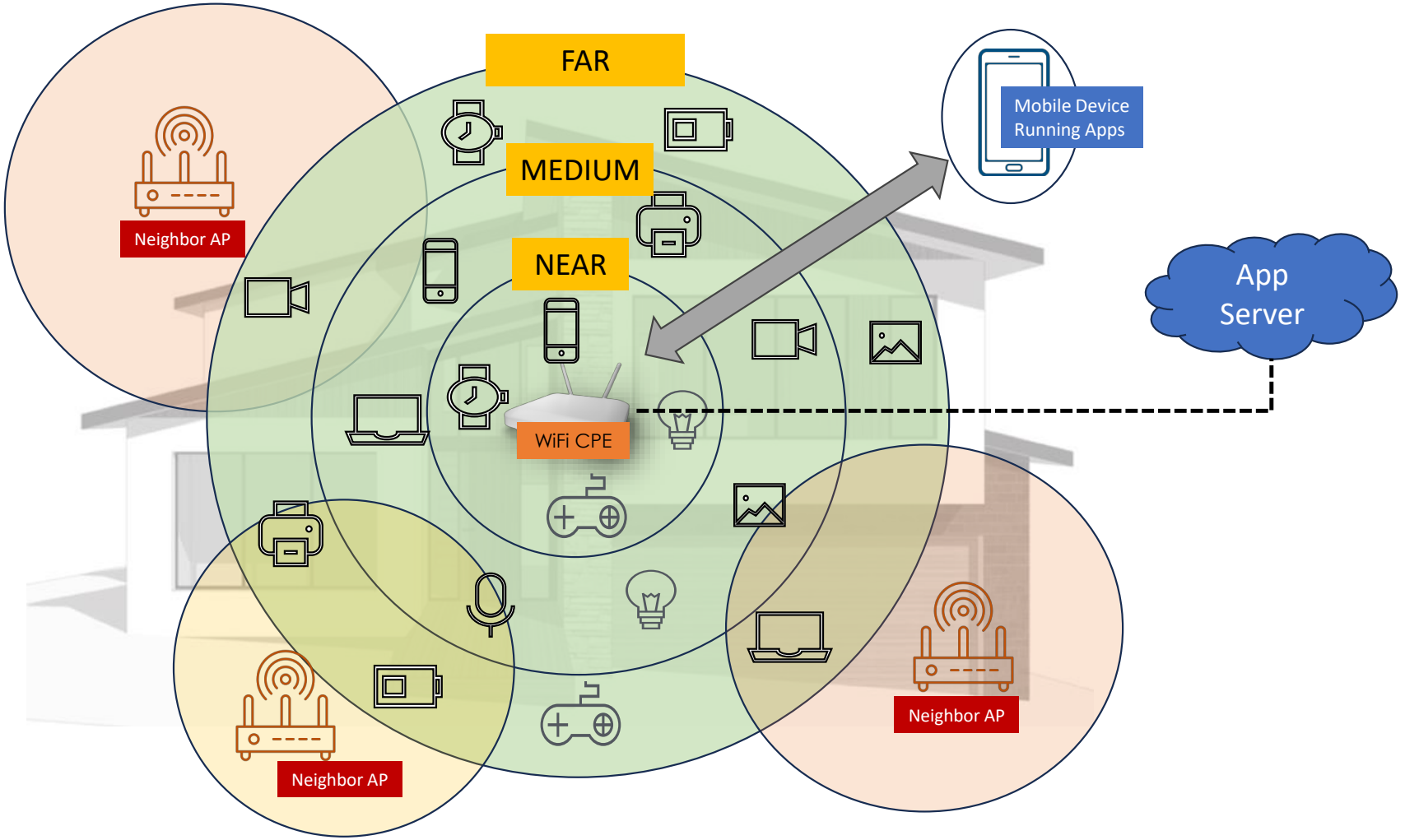
Results summary

Detected	Pulse Width (µs)	PRI (µs)	Num Pulses	Num Bursts	Detection Time(sec)	Frequency (KHz)
YES	1	1428	18	1	4	5282000

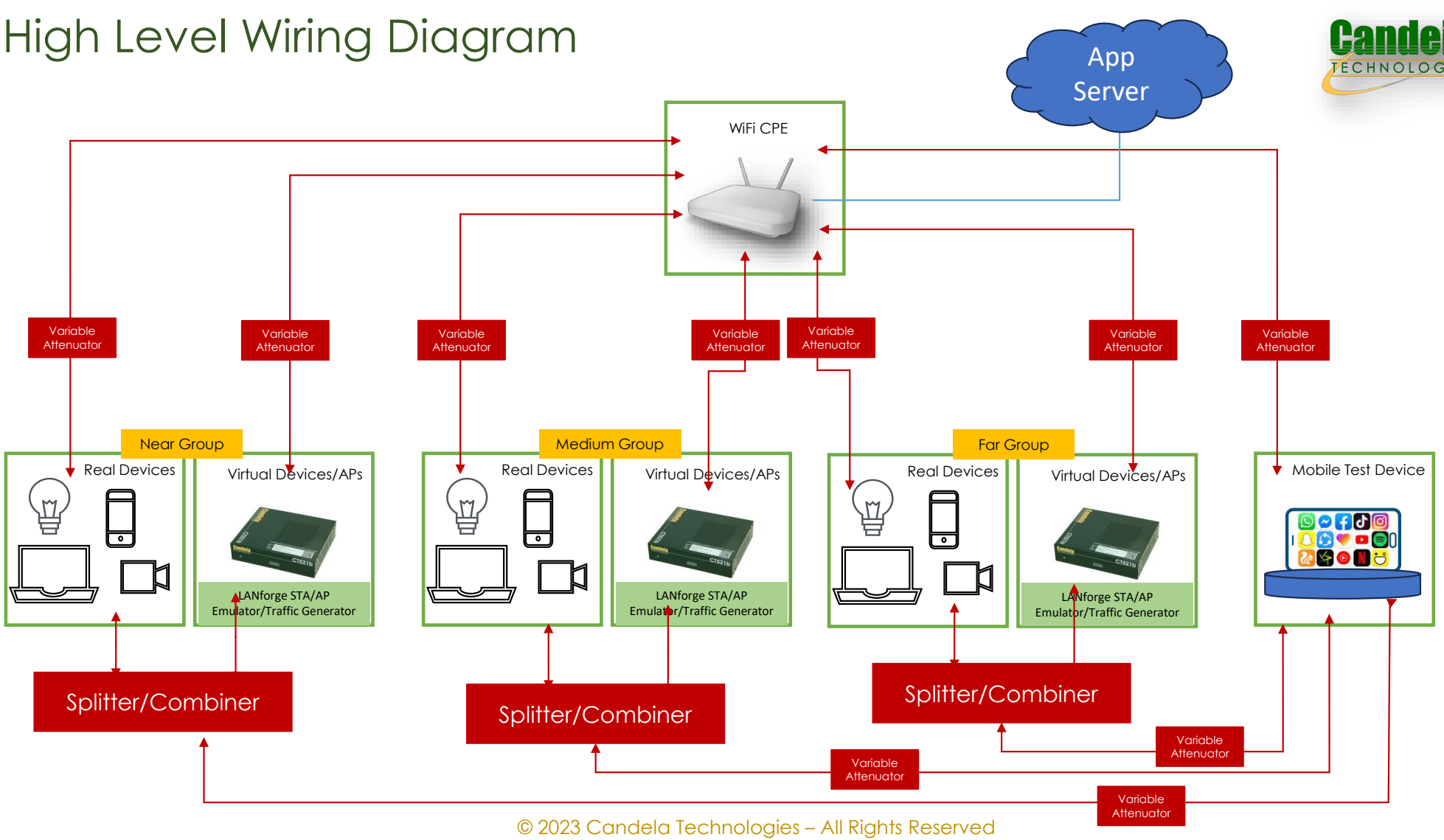
Detected	Pulse Width (µs)	PRI (µs)	Num Pulses	Num Bursts	Detection Time(sec)	Frequency (KHz)
YES	1	1428	18	1	5	5287000

```
INFO:root: stop_sniffer
INFO:paramiko.transport:Connected (version 2.0, client OpenSSH_8.8)
INFO:paramiko.transport:Authentication (password) successful!
INFO:root:pcap file name./pcap/dfs_csa_FCC0_Trial_1_channel56_2023-05-25-11-16.pcap
INFO:root:csa framepresent
INFO:root:csa frame  is present
INFO:root:radar detected
INFO:root:csa frame  time is May 25, 2023 11:17:02.316676222 IST
INFO:root:yes
INFO:root:csa timeMay 25, 2023 11:17:02
INFO:root:calculate detection time
INFO:root:detection time 0:00:04
INFO:root:detection time 4
INFO:root:{'FCC0': {'Trial_1': {'Burst': '1', 'Pulses': '18', 'Width': '1', 'PRI(US)': '1428', 'Detected': 'YES', 'Frequency(KHz)': '5280000
'Trial_7': None, 'Trial_8': None, 'Trial_9': None, 'Trial_10': None, 'Trial_11': None, 'Trial_12': None, 'Trial_13': None, 'Trial_14': None,
None, 'Trial_22': None, 'Trial_23': None, 'Trial_24': None, 'Trial_25': None, 'Trial_26': None, 'Trial_27': None, 'Trial_28': None, 'Trial_2
INFO:root:1
INFO:root:result data{'FCC0': {'Trial_1': {'Burst': '1', 'Pulses': '18', 'Width': '1', 'PRI(US)': '1428', 'Detected': 'YES', 'Frequency(KHz)
'Detected': None, 'Frequency(KHz)': None, 'Detection Time(sec)': None}, 'Trial_3': None, 'Trial_4': None, 'Trial_5': None, 'Trial_6': None,
'Trial_14': None, 'Trial_15': None, 'Trial_16': None, 'Trial_17': None, 'Trial_18': None, 'Trial_19': None, 'Trial_20': None, 'Trial_21': No
None, 'Trial_29': None, 'Trial_30': None}}
INFO:root:starting sniffer
INFO:py-scripts.lf_sniff_radio:channel: 56  frequency: 5280
INFO:root:generate radar
INFO:root:Current date and time :
INFO:root:time stamp of radar sendMay 25, 2023  11:17:15
INFO:paramiko.transport:Connected (version 2.0, client OpenSSH_8.8)
INFO:paramiko.transport:Authentication (publickey) failed.
INFO:paramiko.transport:Authentication (publickey) failed.
INFO:paramiko.transport:Authentication (password) successful!
INFO:root:lanforge
[sudo] password for lanforge:
starting

gr-osmosdr 0.2.0.0 (0.2.0) gnuradio 3.10.1.0
built-in sink types: uhd hackrf soapy redpitaya file
[0;32m[INFO] [UHD] [0;39mlinux; GNU C++ version 12.0.1 20220129 (Red Hat 12.0.1-0); Boost_107600; UHD_4.1.0.5
Using HackRF One with firmware 2023.01.1
UUUUstarted

stopping
```

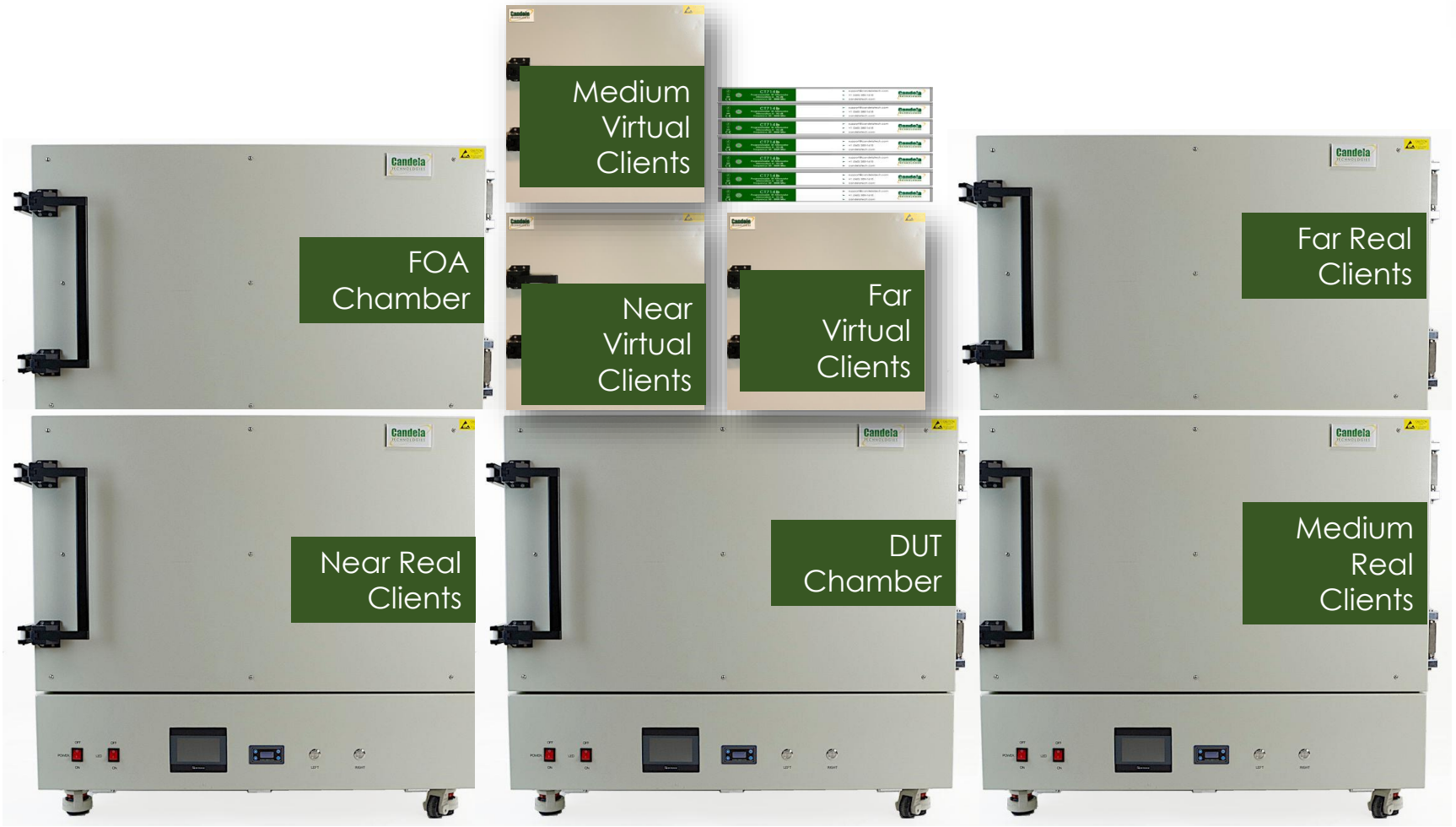
Home in a Box Testbed Topology – Single CPE:



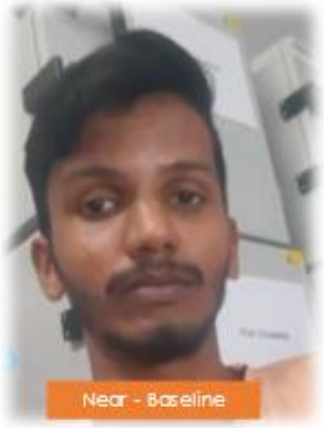
High Level Wiring Diagram



Home-in-a-Box Testbed Setup



Subjective Measurements of QoE of Real Video calling and OTT apps in various test conditions



Networks in a Box

Home in a Box

Office in a Box

Hospital in a Box

Stadium in a Box

Home in a Box

Select scenario

Create DUT

Simple Home | Condo | Multi-level | VILLA

Select DUT | NETGEAR | Duration | 1 hour | RUN TEST

Testbed View

AP
LF-1 LF-2

Near
LF-1 LF-2

Attenuator-1

Attenuator-1

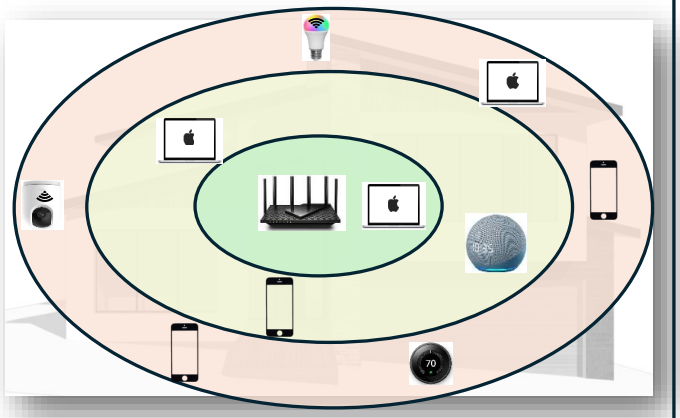
Medium
LF-1 LF-2

Far
LF-1 LF-2

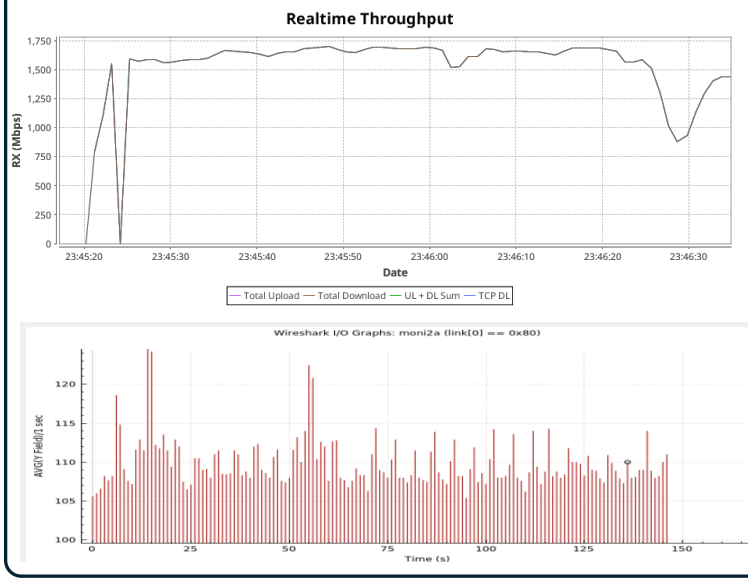
Client status

Zone view

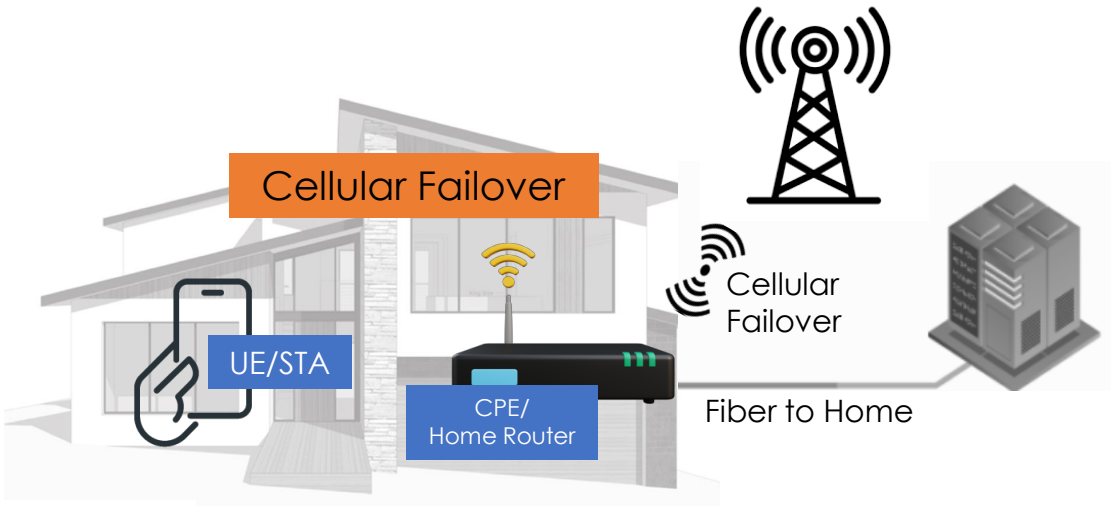
Table view

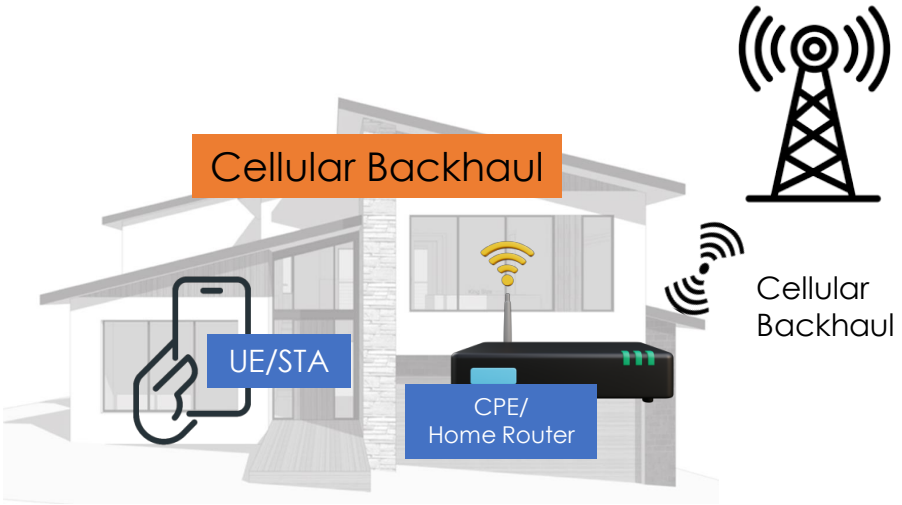


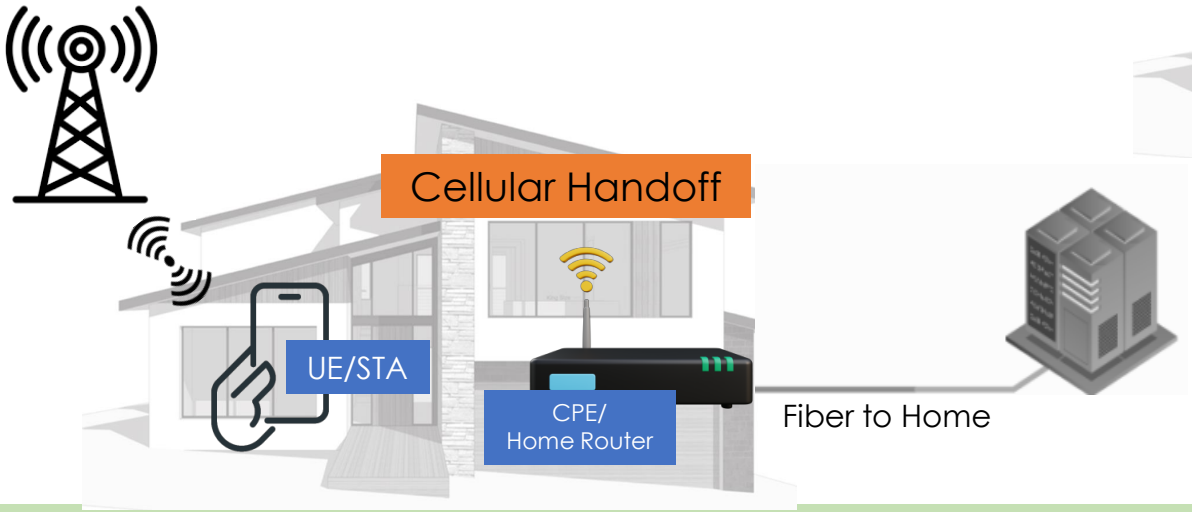
Client Report



Cellular + Wi-Fi Scenarios Testing

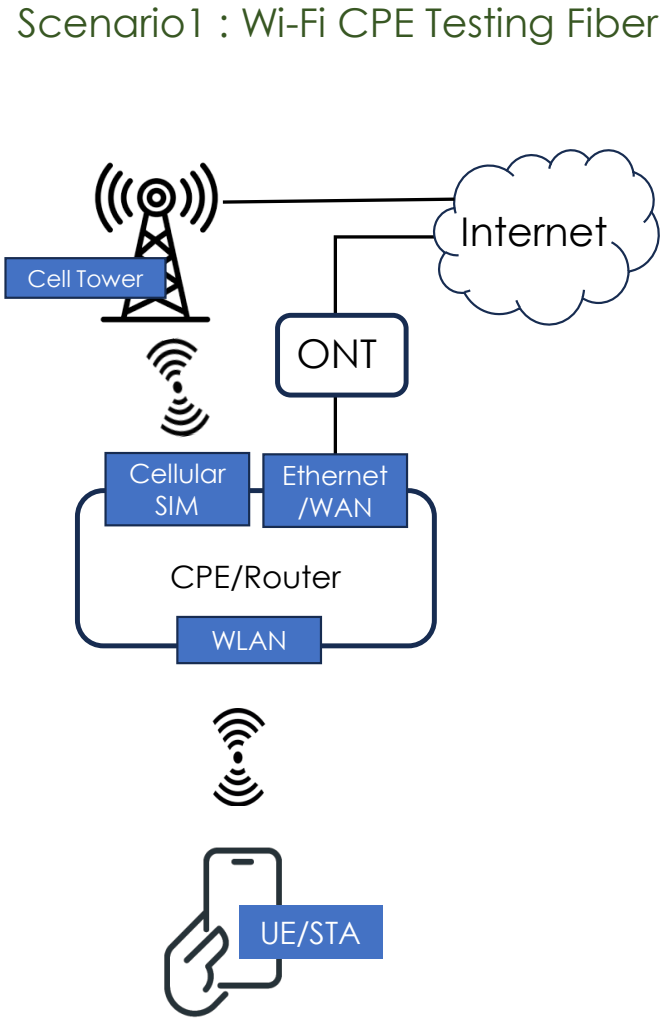


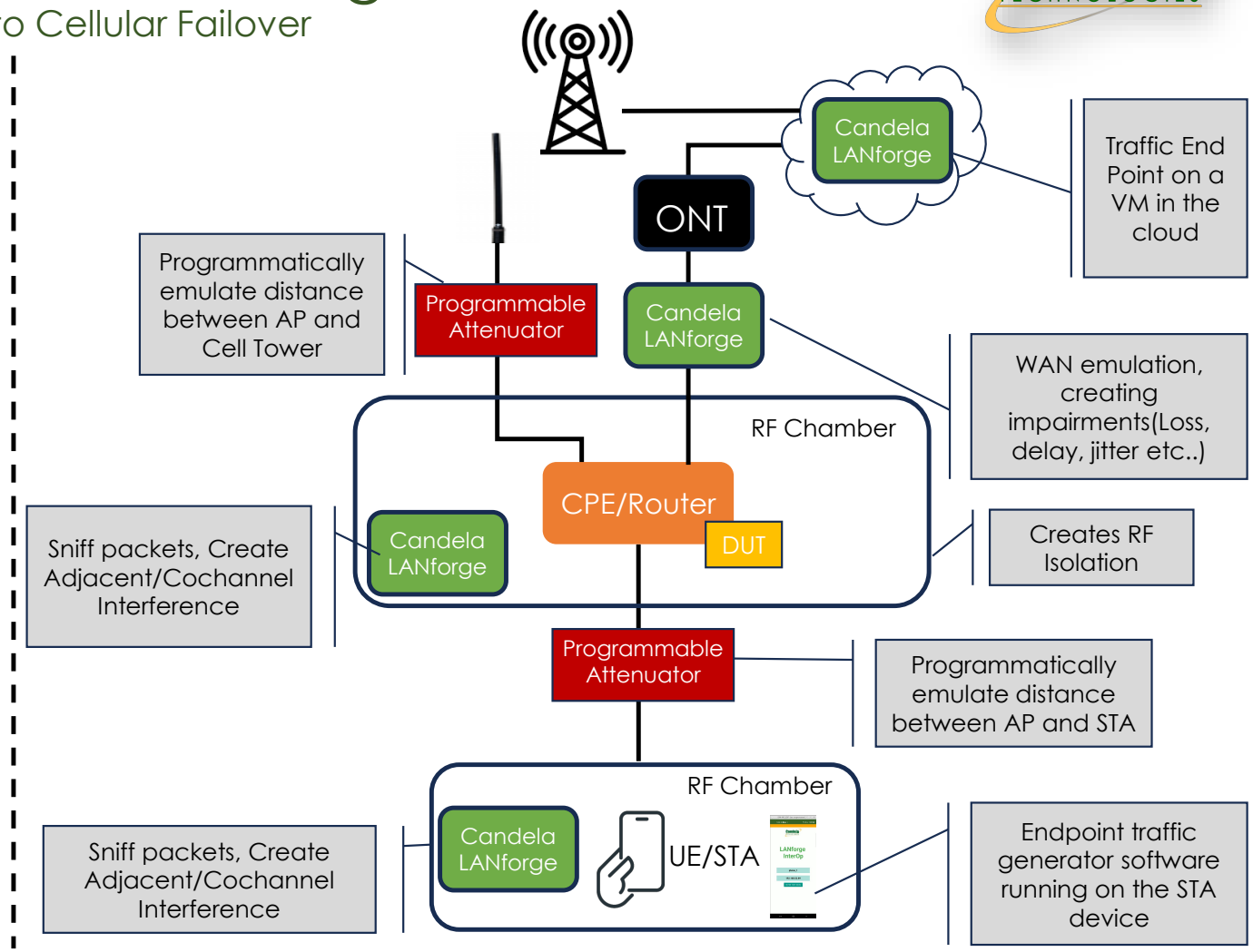




Cellular + Wi-Fi Scenarios Testing

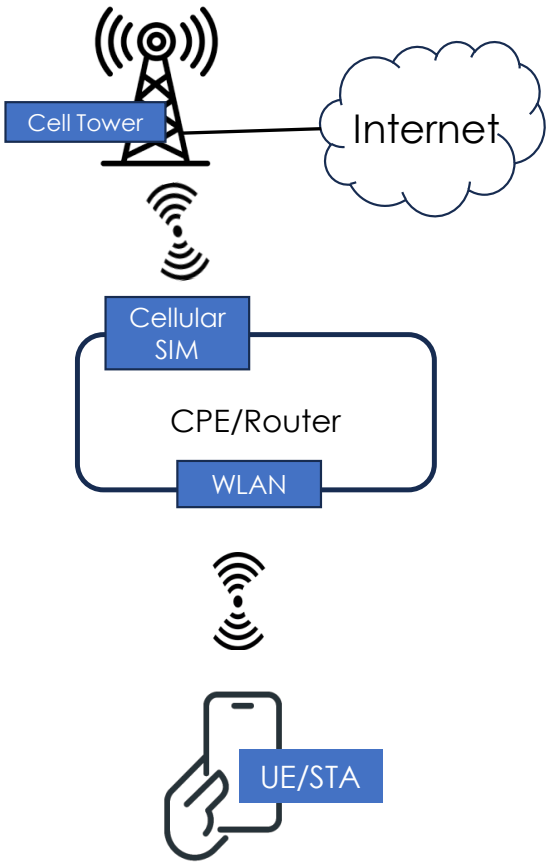
Scenario1 : Wi-Fi CPE Testing Fiber to Cellular Failover

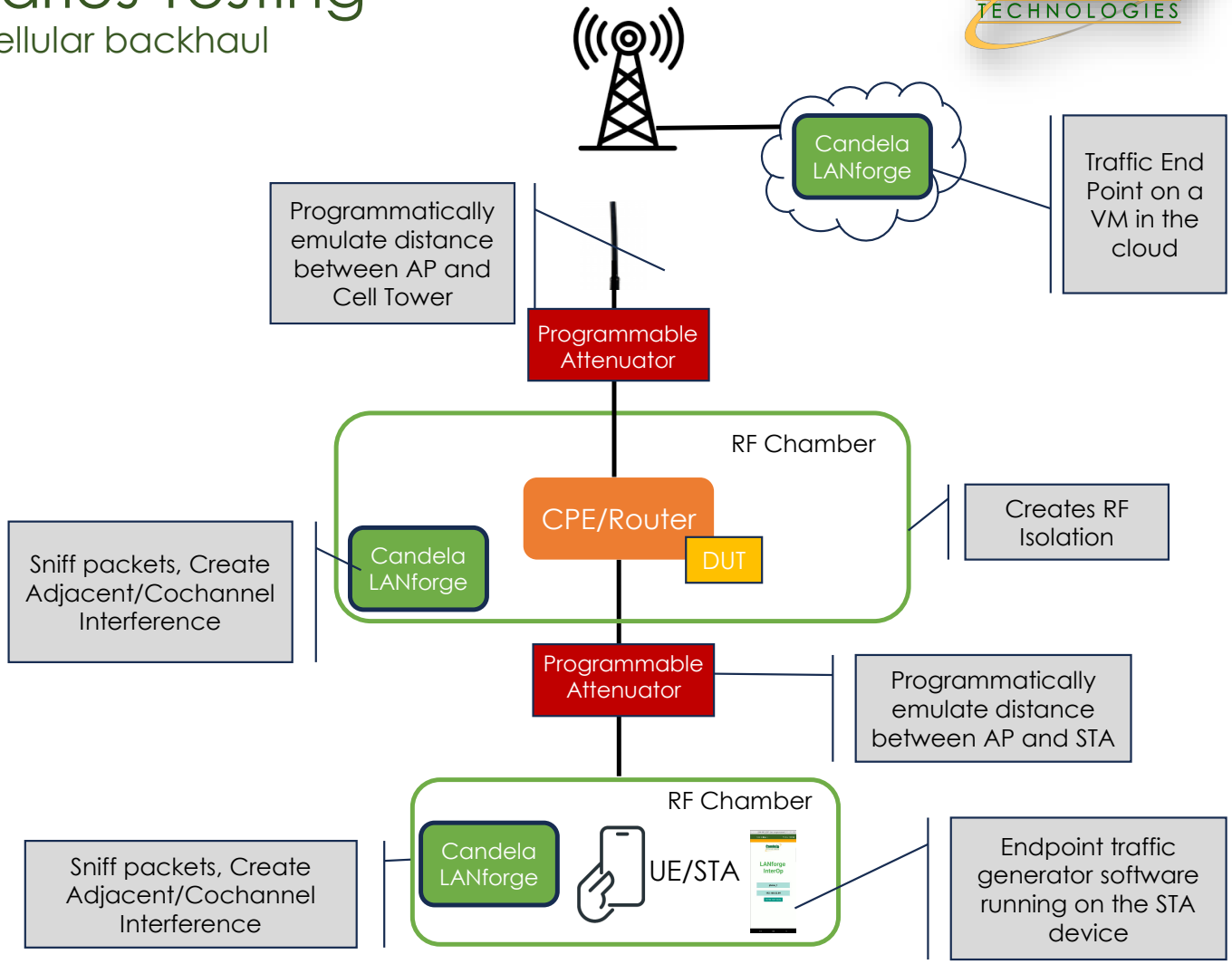




Cellular + Wi-Fi Scenarios Testing

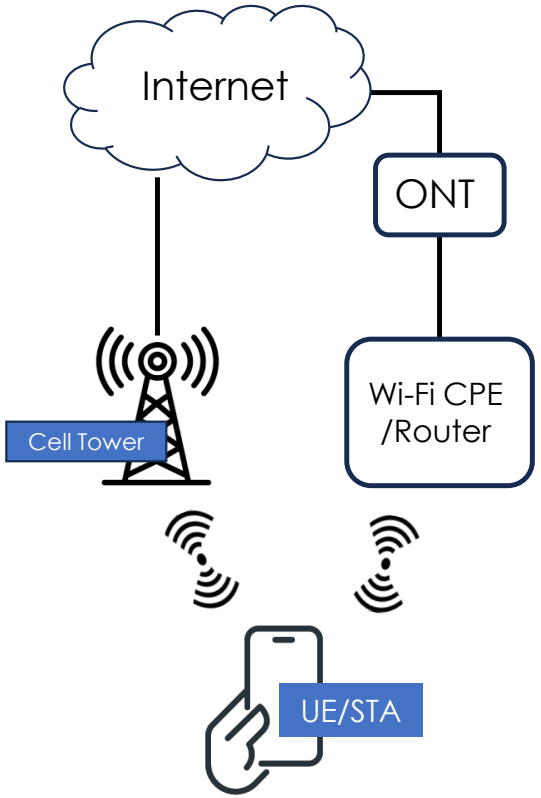
Scenario2 : Wi-Fi CPE Testing pure cellular backhaul

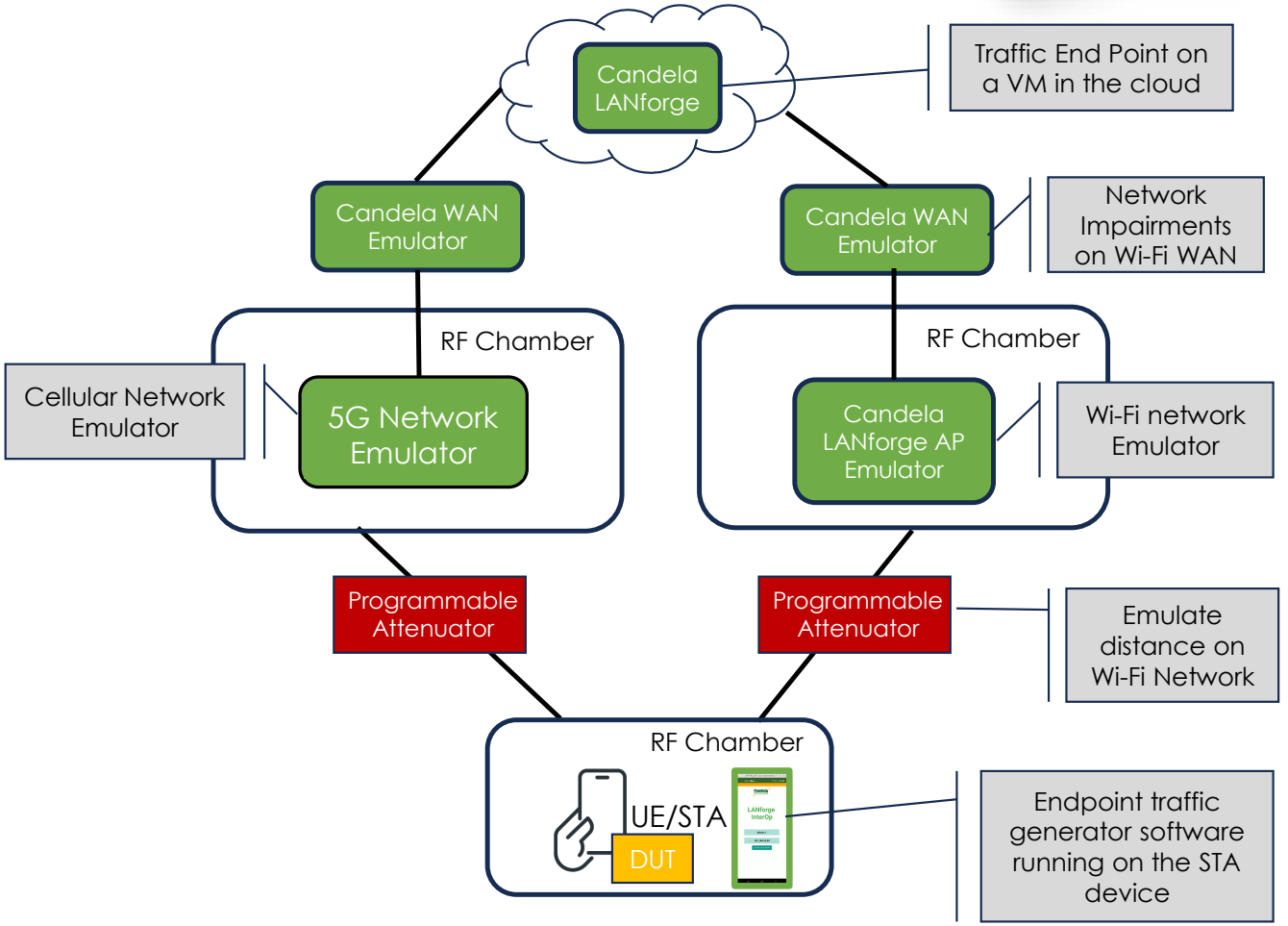




Cellular + Wi-Fi Scenarios Testing

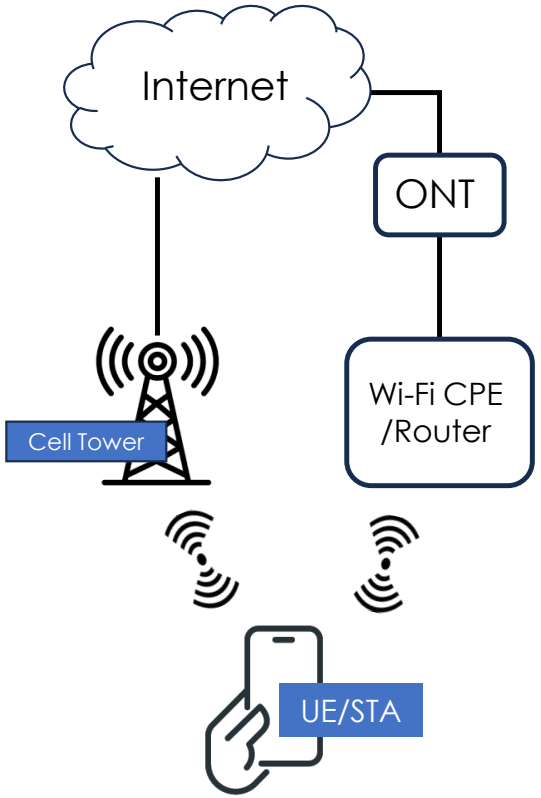
Scenario3a : Wi-Fi STA/UE Testing for Wi-Fi Cellular Handover – Emulated Networks

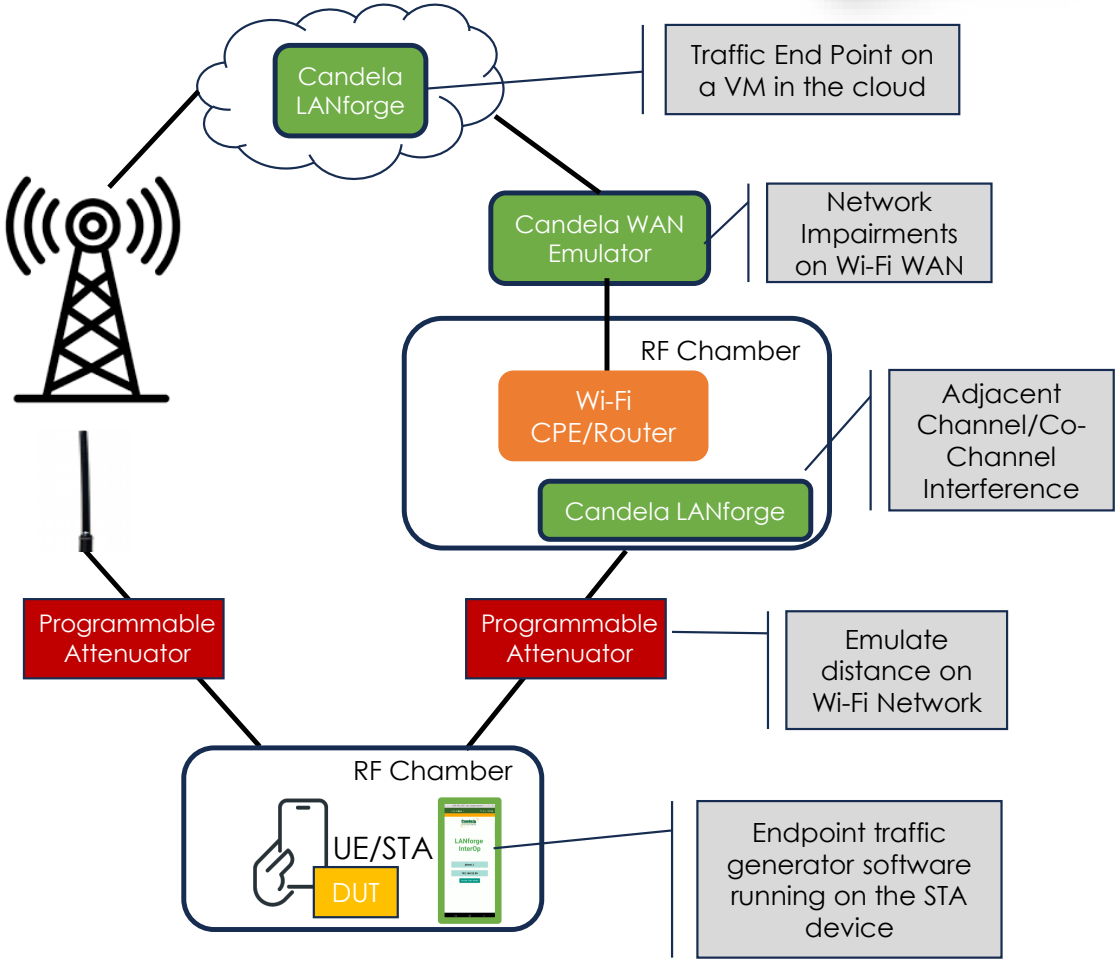




Cellular + Wi-Fi Scenarios Testing

Scenario3b : Wi-Fi STA/UE Testing for Wi-Fi Cellular Handover – Real Networks





Key Tests and Measurements

- End to End User Experience for Voice, Video and Data.
- CPE/Router Failover time and its effect on User Experience
- UE Handoff time between Cellular and Wi-Fi
- UE Handoff process (decision, initiation, execution) and its effects on user experience
- Performance over Distance for both access links and backhaul links when Wi-Fi is access and Cellular is backhaul.
- Connection time, security, seamless authentication, Open Roaming, Hotspot 2.0
- VoLTE over Wi-Fi testing.
- End to end call quality over Wi-Fi and cellular and during handover.

Candela Test Offerings

From Basic Manual Functional Testing to Full Lights Out CI/CD Automation and Everything in Between.

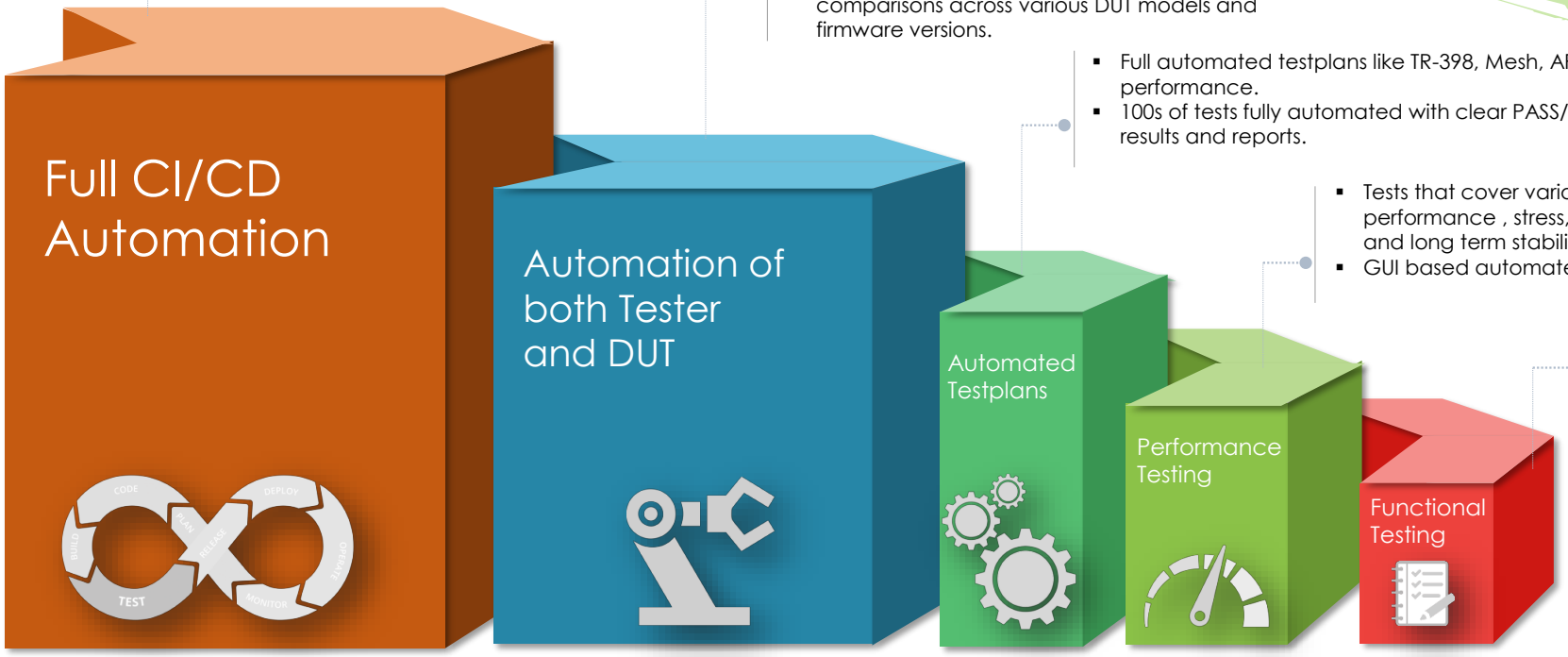
- Complete CI/CD Automation provides.
- Full automation to fetch and load builds on DUT, find the reserve testbeds, fetch and run test jobs, gather and analyze test results, export to result visualization tools.
- Integration with tools and platforms like Jenkins, Jira, GitHub, Testrail etc..

- Create 100s of fully automated test scripts that can automate both Tester and DUT controls.
- Create custom test reports and results comparisons across various DUT models and firmware versions.

- Full automated testplans like TR-398, Mesh, AP performance.
- 100s of tests fully automated with clear PASS/FAIL results and reports.

- Tests that cover various aspects of AP performance , stress, scale, real world scenarios and long term stability
- GUI based automated tests with test reports.

- Unit testing
- Test basic AP functions like connectivity, security, QoS, OFDMA, Mu-MIMO etc..
- Fully flexible GUI to create any type of test scenarios
- Ideal for Developer and early stage dev testing.



WiFi CI/CD Test Automation Framework

Command and Control

- Firmware
- Configuration & Communication
- Operation Modes
- Physical & Virtual
- Interfaces GUI/APIs

Functional Testing

- BSS Capabilities
- Connectivity & Security
- Radio Resource Management
- Smart WiFi
- QoS & Mobility & Power Save

Performance Testing

- Throughput Benchmark
- Multiband Performance
- Mobility Performance
- Radio Performance
- Application Performance

Stress and Endurance Testing

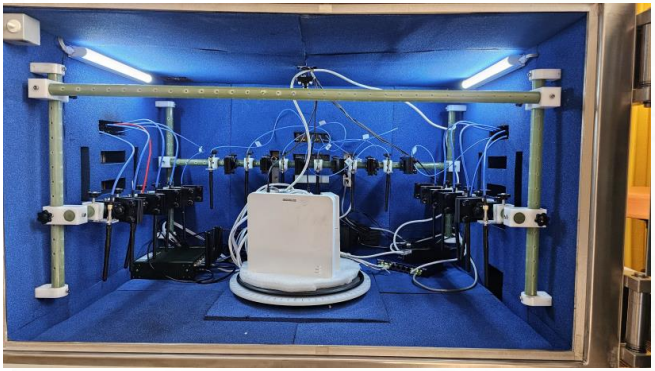
- Day in Life Test
- 48-hour Stress Test
- Load Patterns #1,#2, #3

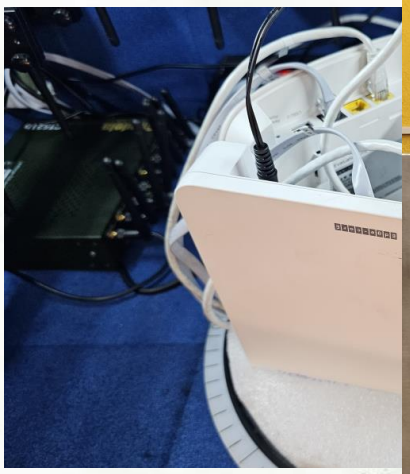
Use Case Testing

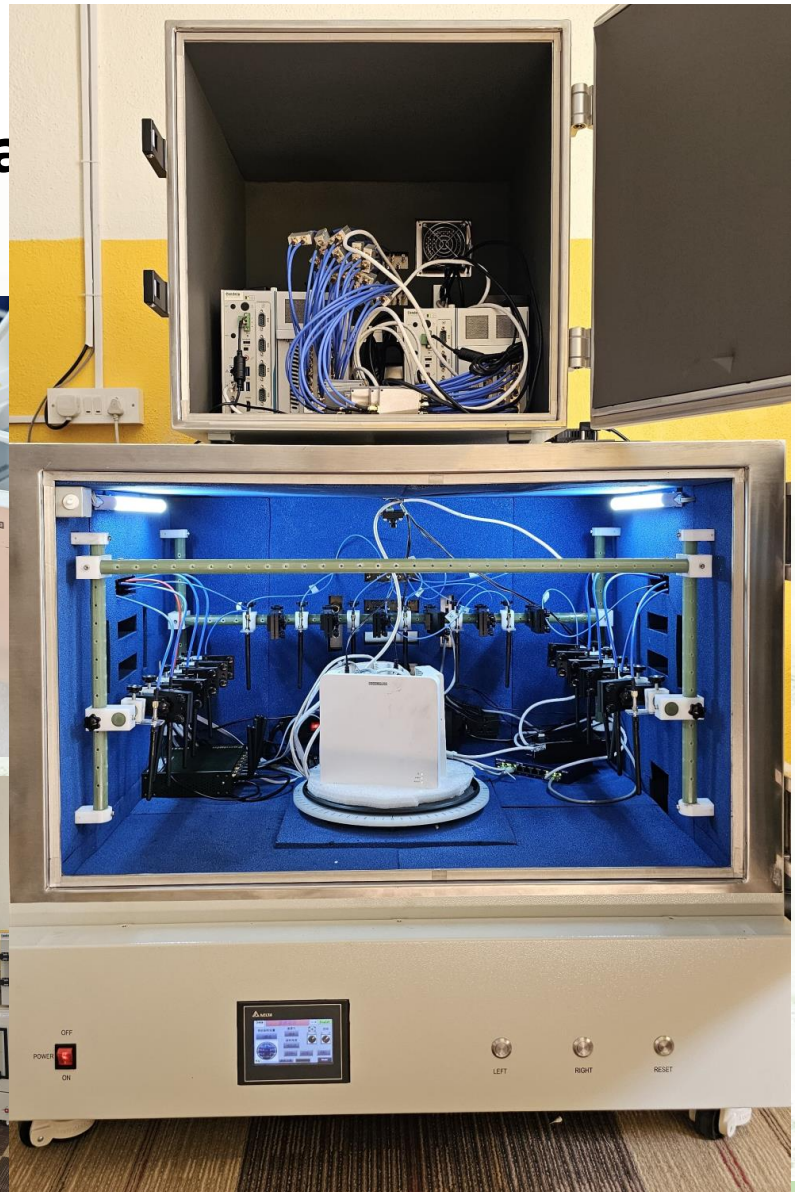
- Single AP SOHO
- SOHO Mesh
- Med-Enterprise Network
- Multi Dweller Unit (MDU)
- Campus Network/ LPV

ACCESS POINT TEST CASES

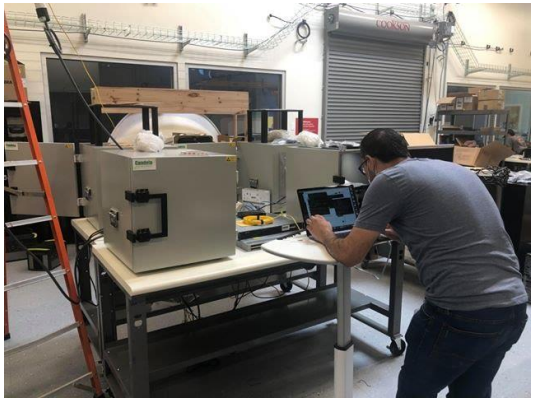
CICD Lab Candela India’s Banga

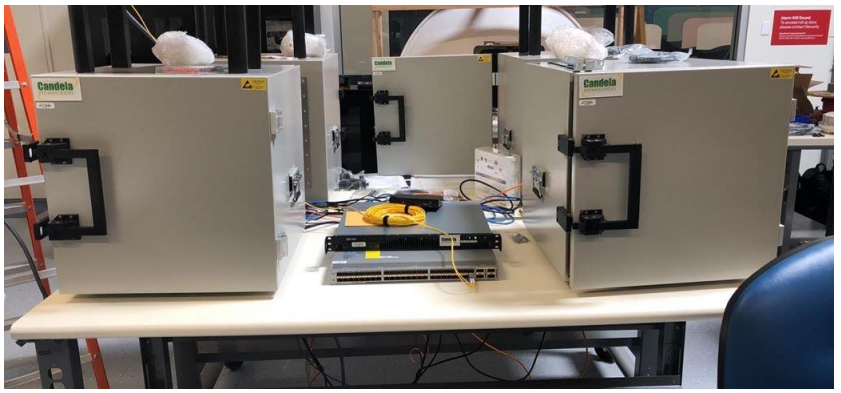






Community Lab setup in California





Menu (8:41, 78%) 10:34 AM

CT:Resources — Mozilla Firefox

CT:Resources

192.168.200.74:5463/view_all/

100%

Telecominfraproject/… DeepRacer Student L… WebGui Installation G…

Candela Technologies

Dashboard Statistics

Active User : Saurabh

- Resources
- Add New Testplans
- Test Scheduler
- Results

Access Points

edgecore_4653

903cb36c4653

edecore_eap_46da

903cb36c46da

eap101_265b

903cb3bb265b

Traffic Generator

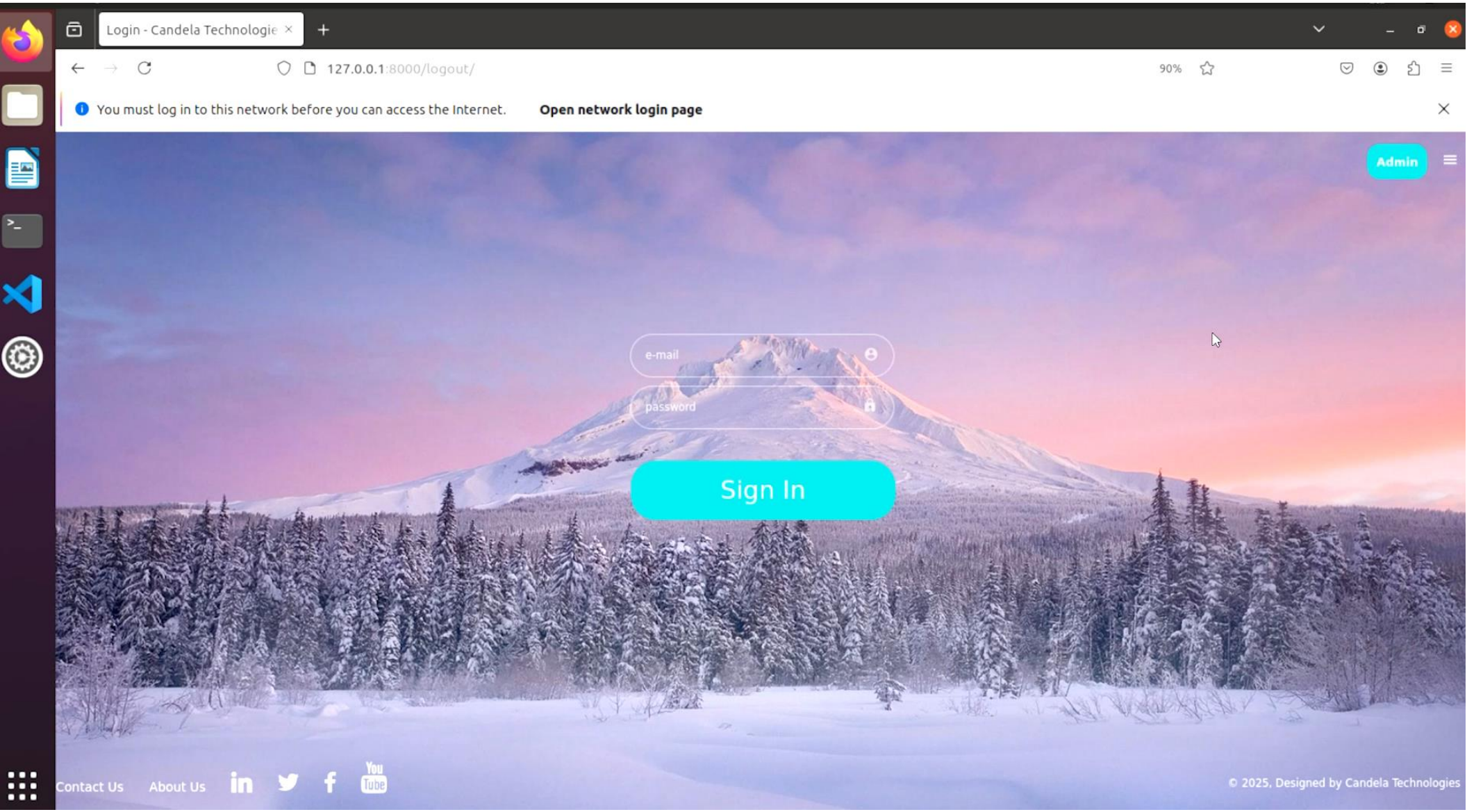
lanforge_pm_224

lanforge_qa_54

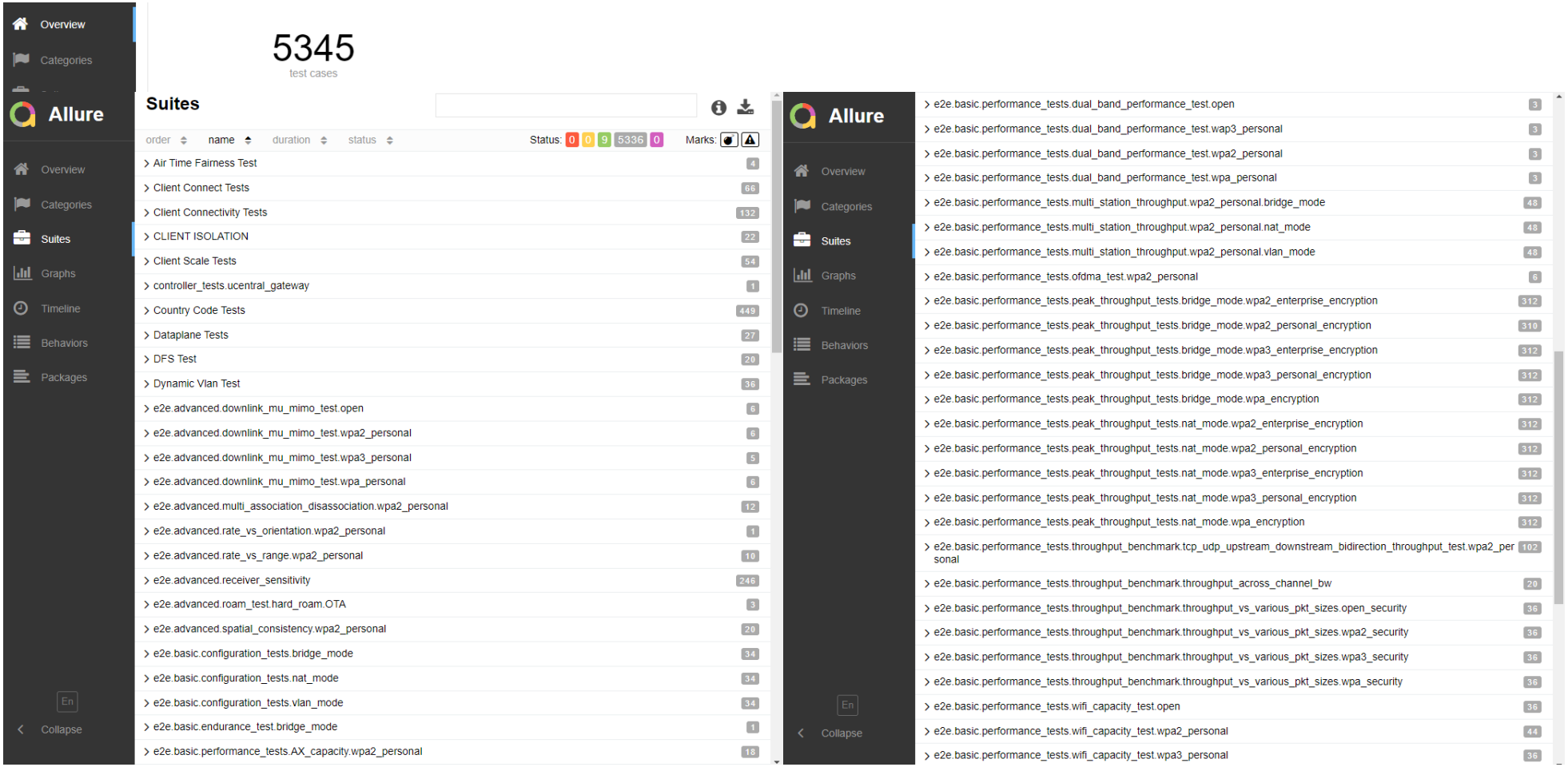
lanforge_dev_265b

Test Bed

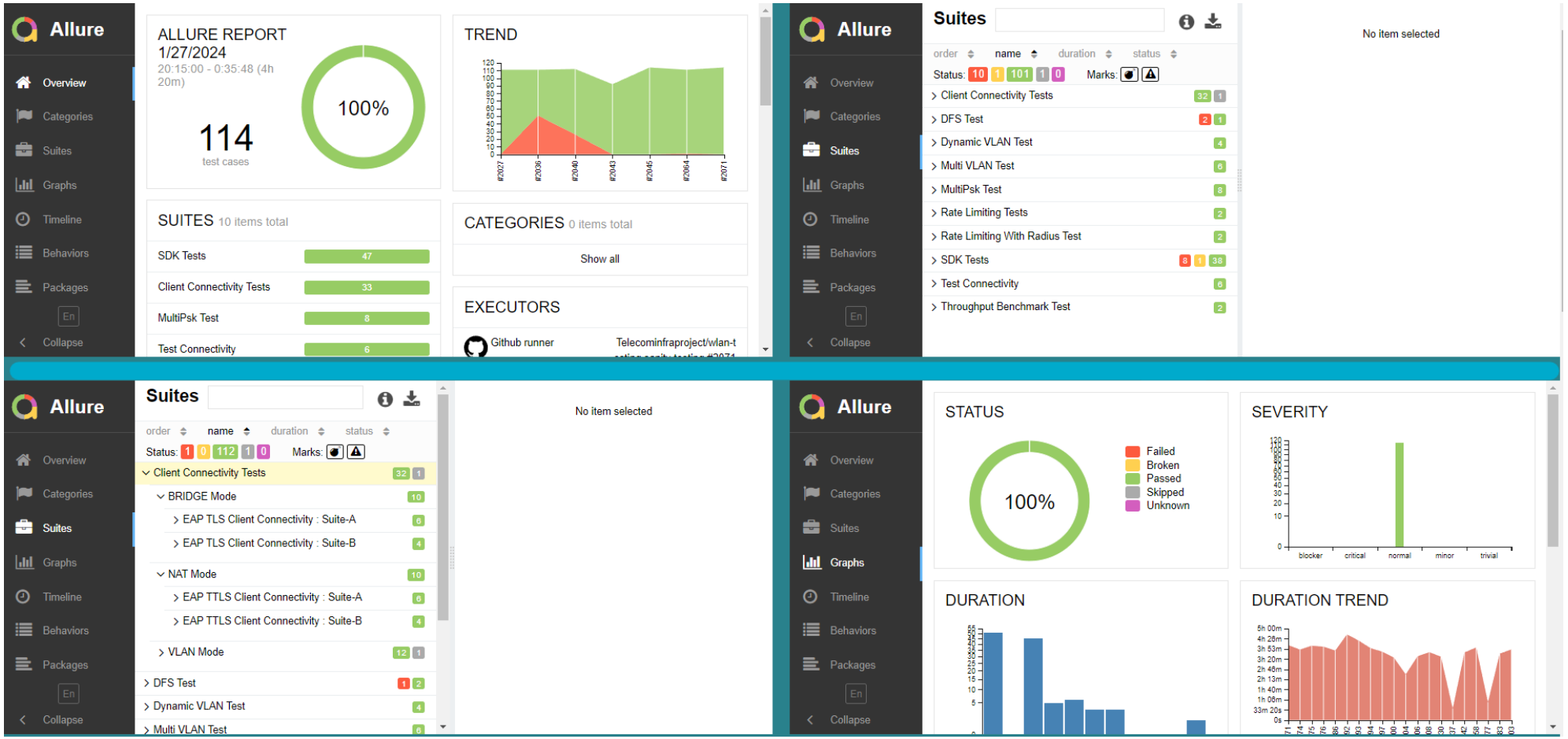
CT:Resources — Mozill…


Login - Candela Technologie
127.0.0.1:8000/logout/
90%
You must log in to this network before you can access the Internet.
Open network login page
Admin
e-mail
password
Sign In
Contact Us
About Us
© 2025, Designed by Candela Technologies

5000+ Automated Testcases



Results and Report Visualization



The 3-approaches for AP/Router Testing

Lab Testing with Virtual Devices

Repeatability:
Scalability :
Automation :
Realism :

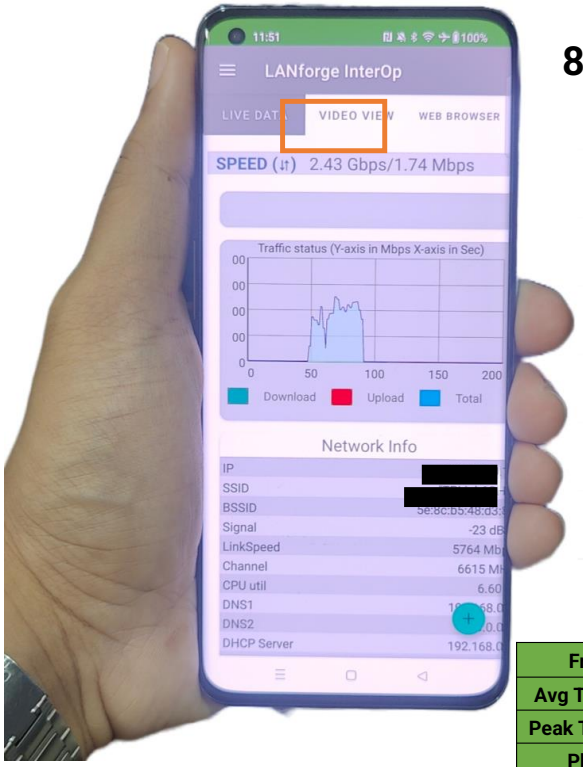
Lab Testing with Real Devices

Repeatability:
Scalability :
Automation :
Realism :

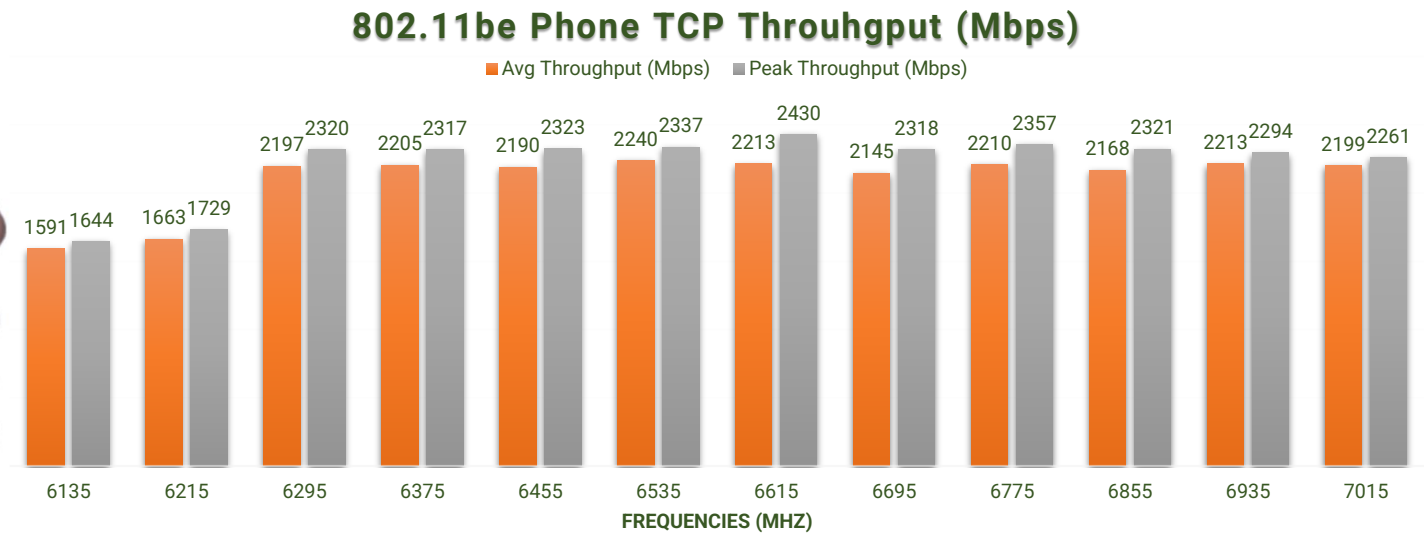
Real world Testing in Test House

Repeatability:
Scalability :
Automation :
Realism :

Throughput across 6GHz Channels

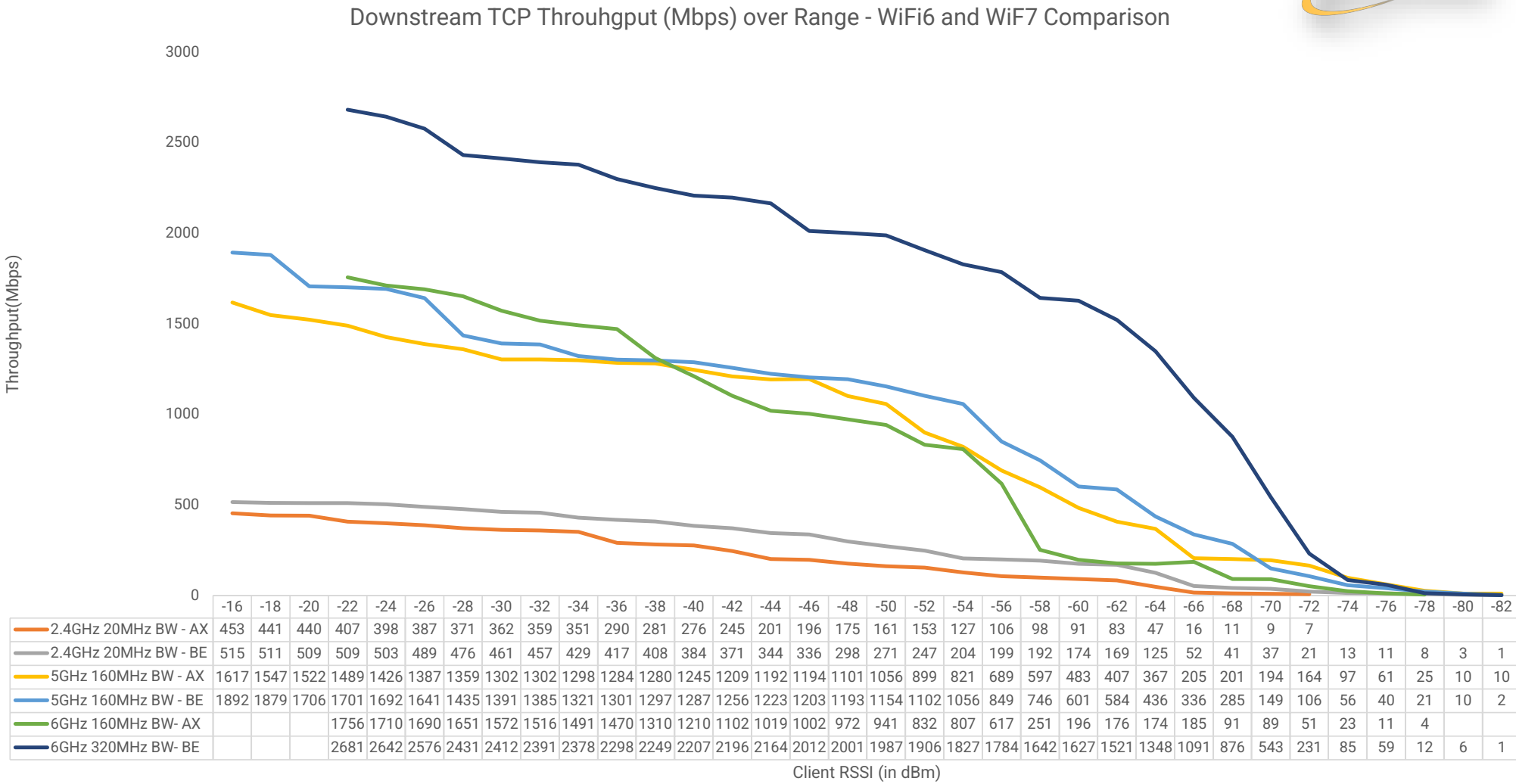


802.11be



Frequncy (MHz)	6135	6215	6295	6375	6455	6535	6615	6695	6775	6855	6935	7015
Avg Throughput (Mbps)	**1591**	**1663**	**2197**	**2205**	**2190**	**2240**	**2213**	**2145**	**2210**	**2168**	**2213**	**2199**
Peak Throughput (Mbps)	**1644**	**1729**	**2320**	**2317**	**2323**	**2337**	**2430**	**2318**	**2357**	**2321**	**2294**	**2261**
Phy-rate (Mbps)	2882	2882	5764	4803	5764	5764	5187	5187	5764	5187	4322	4322
Modulation Type	4096 QAM	4096 QAM	4096 QAM	1024 QAM	4096 QAM	4096 QAM	4096 QAM	4096 QAM	4096 QAM	4096 QAM	1024 QAM	1024 QAM
Coding Rate	5/6	5/6	5/6	5/6	5/6	5/6	3/4	3/4	5/6	5/6	3/4	3/4
Bandwidth (MHz)	320 or 160	320 or160	320	320	320	320	320	320	320	320	320	320
Num Spatial Streams	1 or 2	1 or 2	2	2	2	2	2	2	2	2	2	2

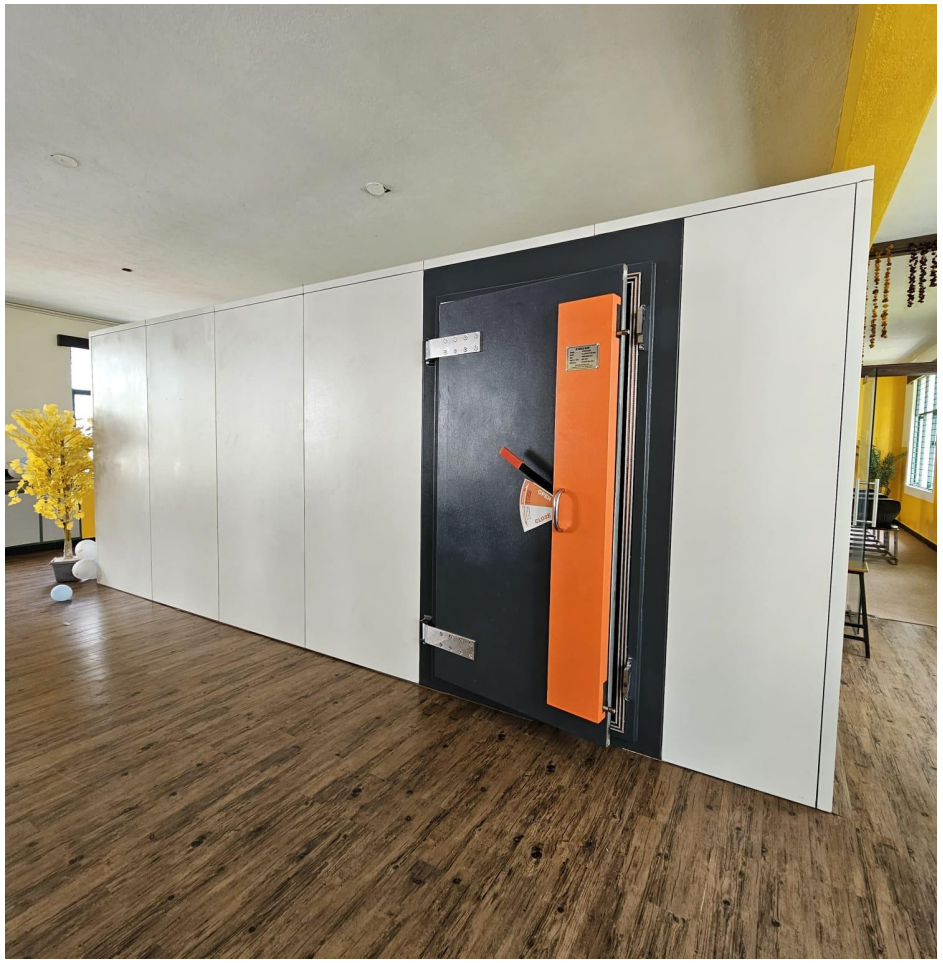
Rate vs Range Test

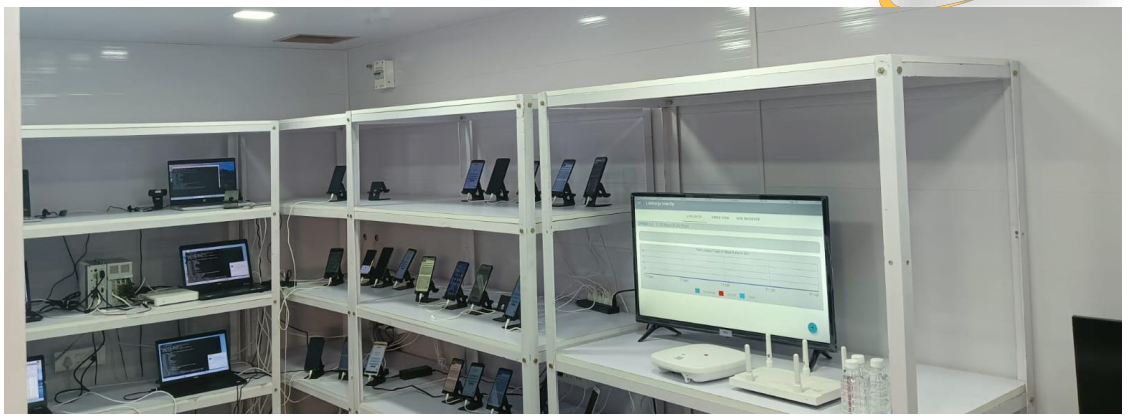


	-16	-18	-20	-22	-24	-26	-28	-30	-32	-34	-36	-38	-40	-42	-44	-46	-48	-50	-52	-54	-56	-58	-60	-62	-64	-66	-68	-70	-72	-74	-76	-78	-80	-82
2.4GHz 20MHz BW - AX	453	441	440	407	398	387	371	362	359	351	290	281	276	245	201	196	175	161	153	127	106	98	91	83	47	16	11	9	7					
2.4GHz 20MHz BW - BE	515	511	509	509	503	489	476	461	457	429	417	408	384	371	344	336	298	271	247	204	199	192	174	169	125	52	41	37	21	13	11	8	3	1
5GHz 160MHz BW - AX	1617	1547	1522	1489	1426	1387	1359	1302	1302	1298	1284	1280	1245	1209	1192	1194	1101	1056	899	821	689	597	483	407	367	205	201	194	164	97	61	25	10	10
5GHz 160MHz BW - BE	1892	1879	1706	1701	1692	1641	1435	1391	1385	1321	1301	1297	1287	1256	1223	1203	1193	1154	1102	1056	849	746	601	584	436	336	285	149	106	56	40	21	10	2
6GHz 160MHz BW- AX				1756	1710	1690	1651	1572	1516	1491	1470	1310	1210	1102	1019	1002	972	941	832	807	617	251	196	176	174	185	91	89	51	23	11	4			
6GHz 320MHz BW- BE				2681	2642	2576	2431	2412	2391	2378	2298	2249	2207	2196	2164	2012	2001	1987	1906	1827	1784	1642	1627	1521	1348	1091	876	543	231	85	59	12	6	1

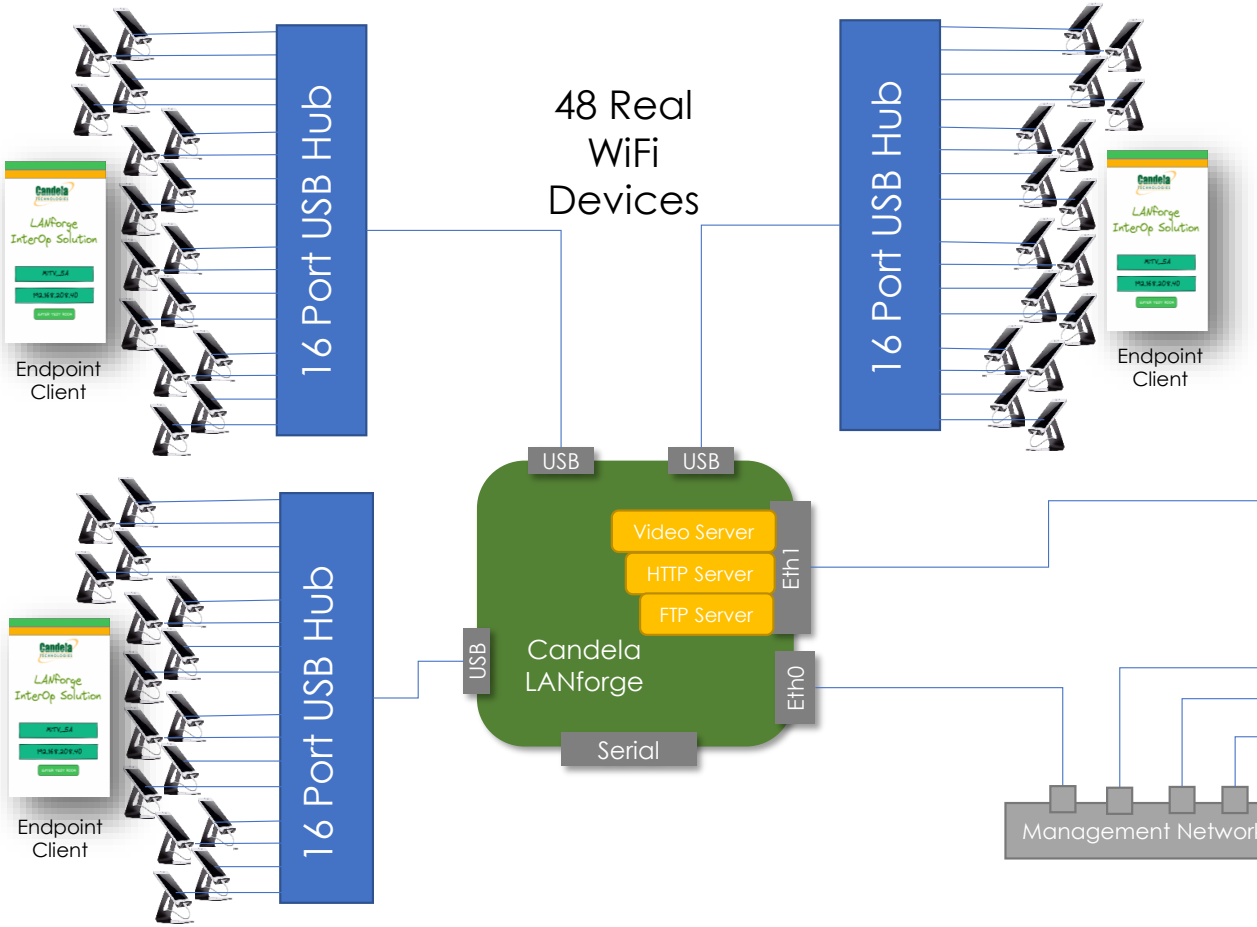
100+ Real Device Testbed

Large Walk-in Chamber with 100+ Real Devices





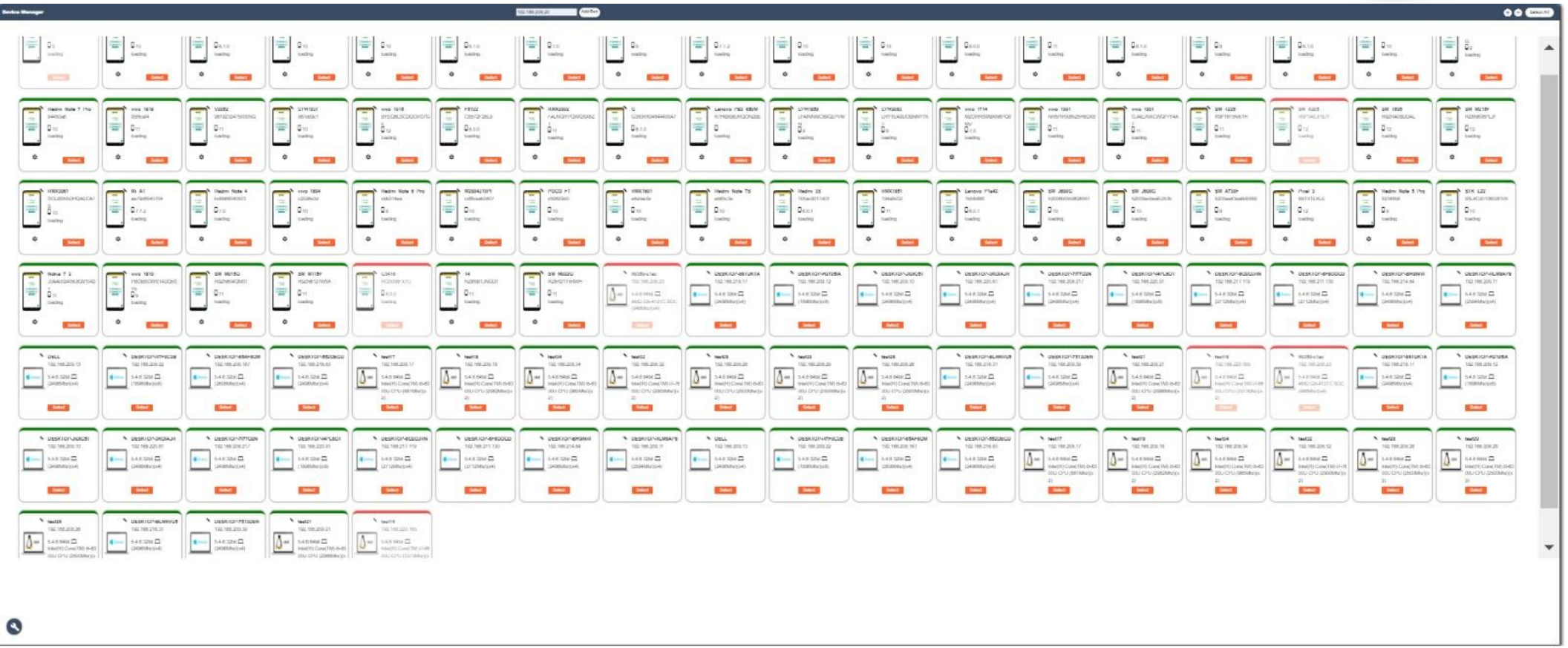
Interop Scale Testbed Topology



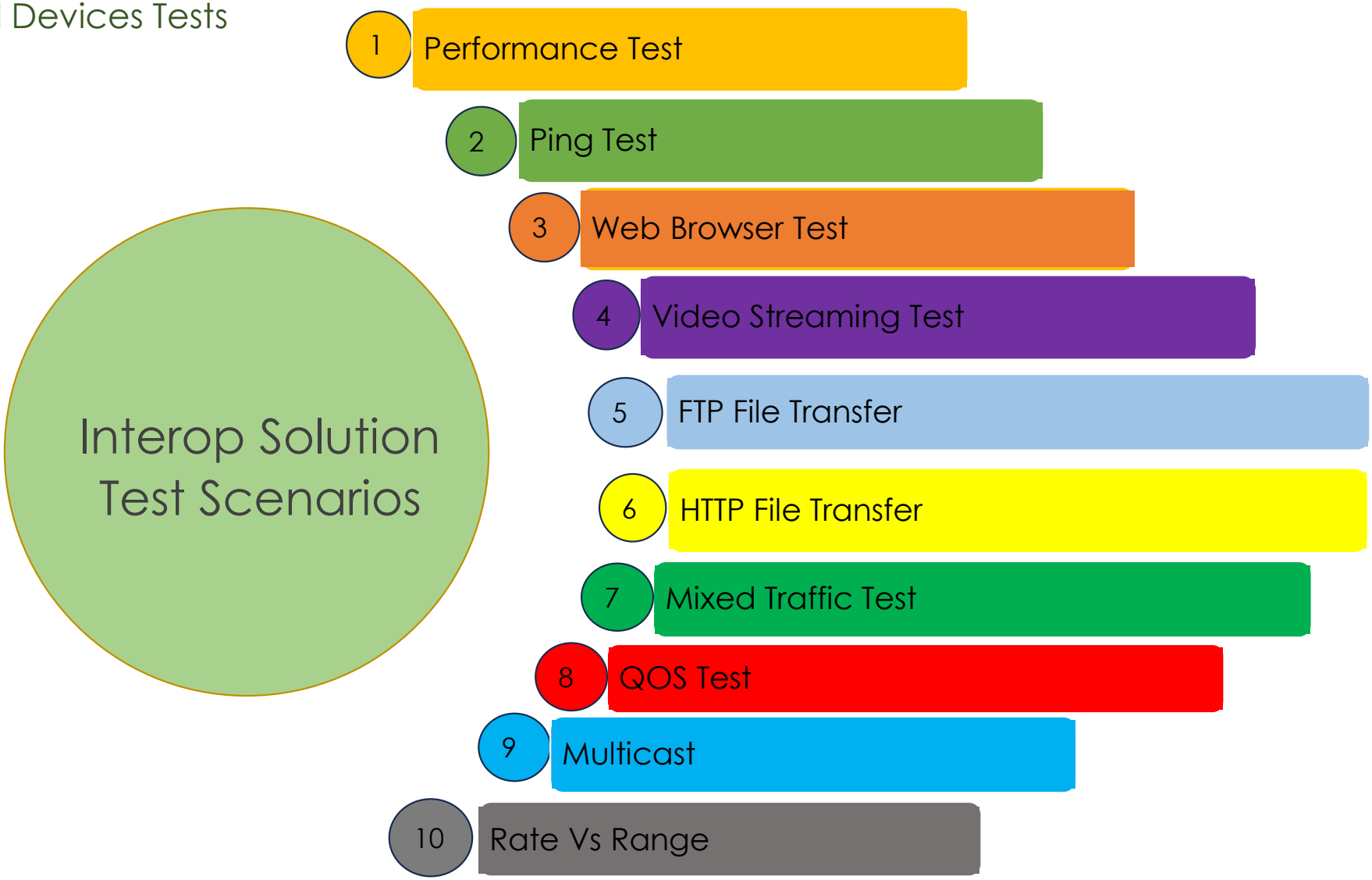
Fully Automated Tests

- Throughput/Client Capacity
- Mixed Traffic Performance/ QoS
- ACI/CCI Performance
- Load Balancing / Band Steering
- Video Streaming/Conferencing Performance
- Long Duration Stress/Stability

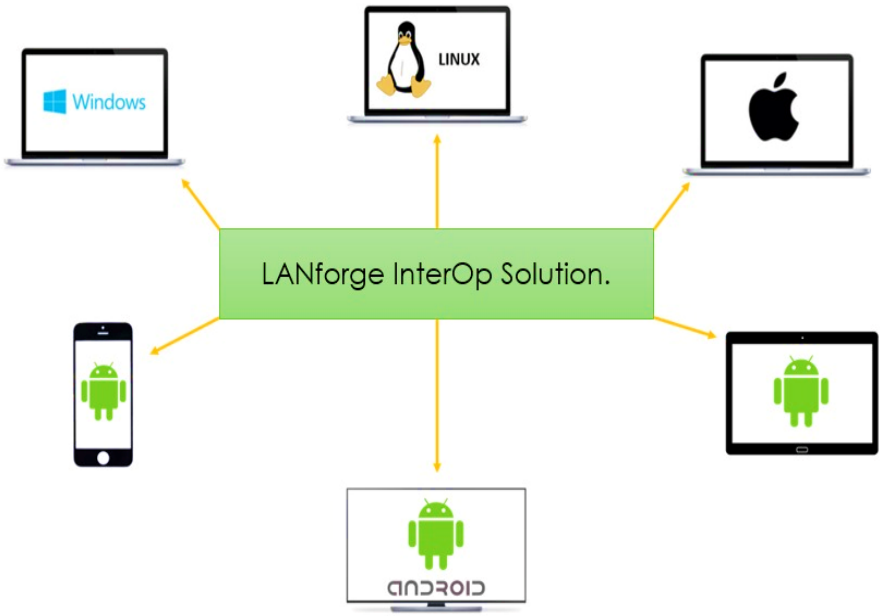
Devices Dashboard

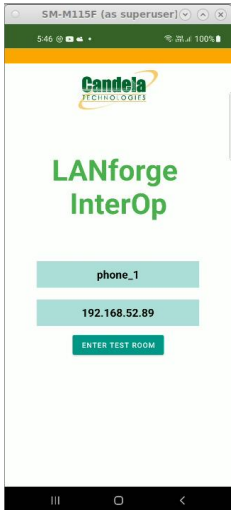


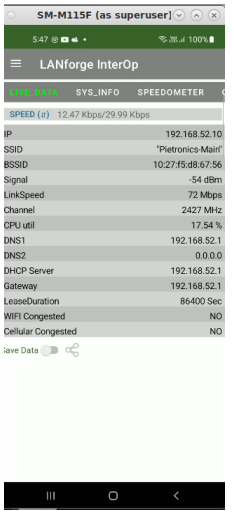
Real Devices Tests

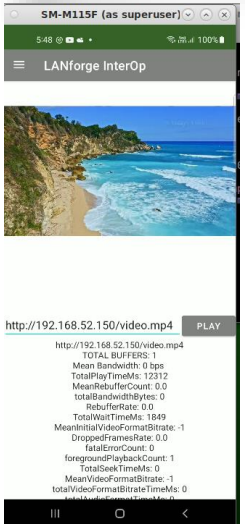


Lanforge Interop Solution to test Real devices







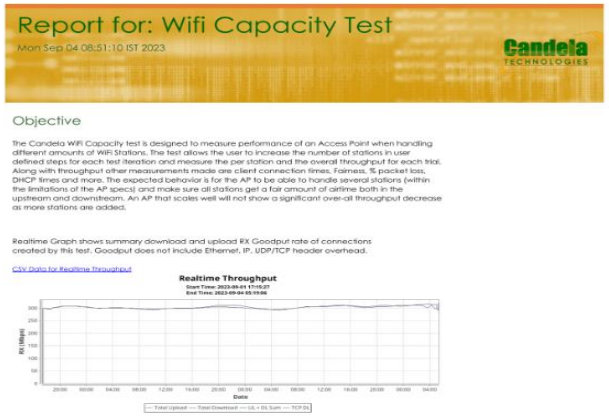


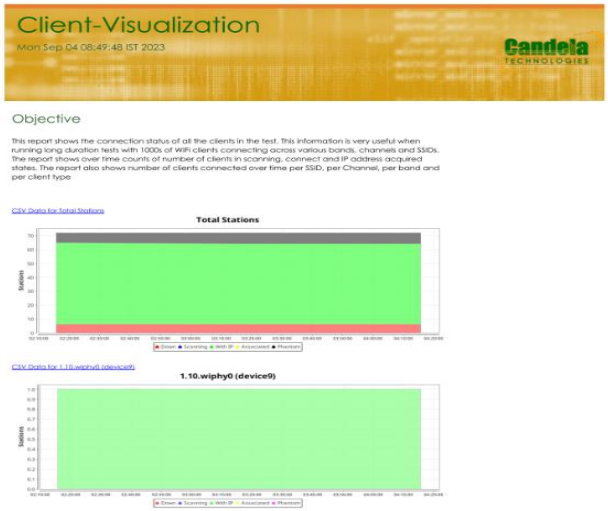
Control connecting/ disconnecting of real devices

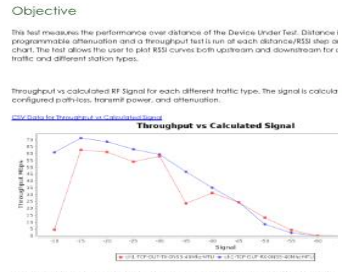
Run many different types of data, voice, video traffic and collect metrics

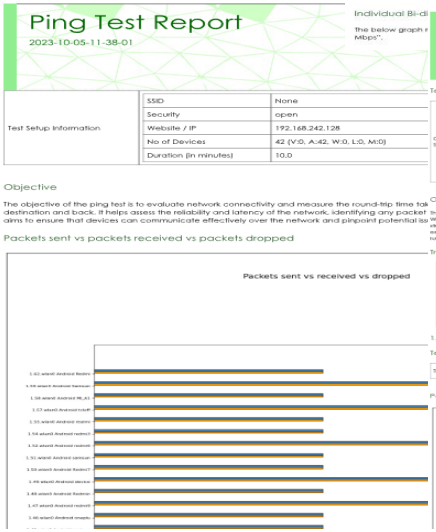
Run several automated tests, collect logs and create test reports

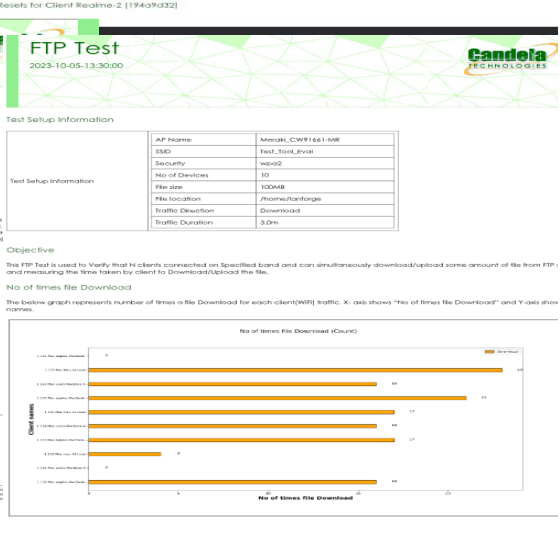
Manual and Automated Test Reports



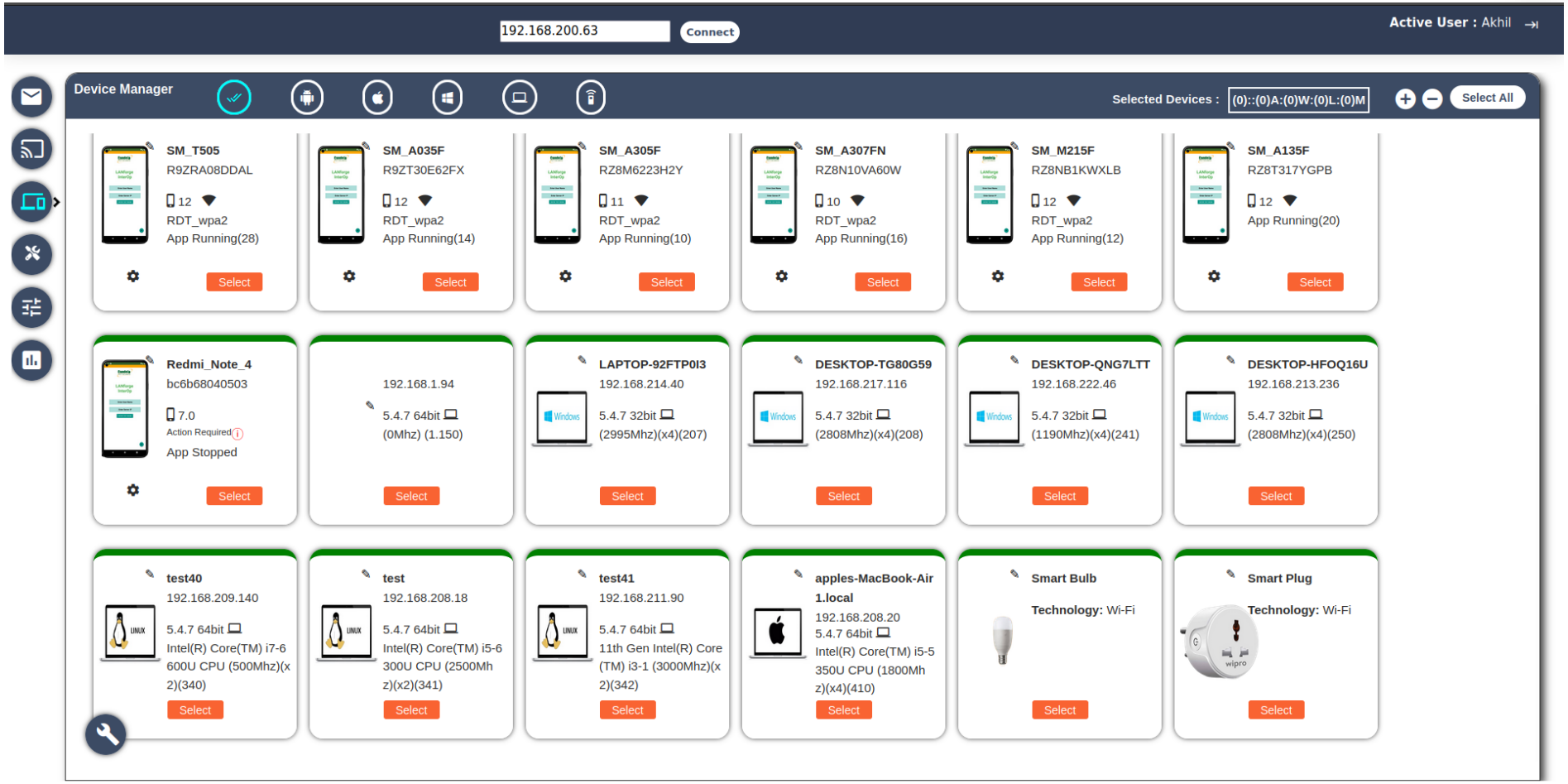






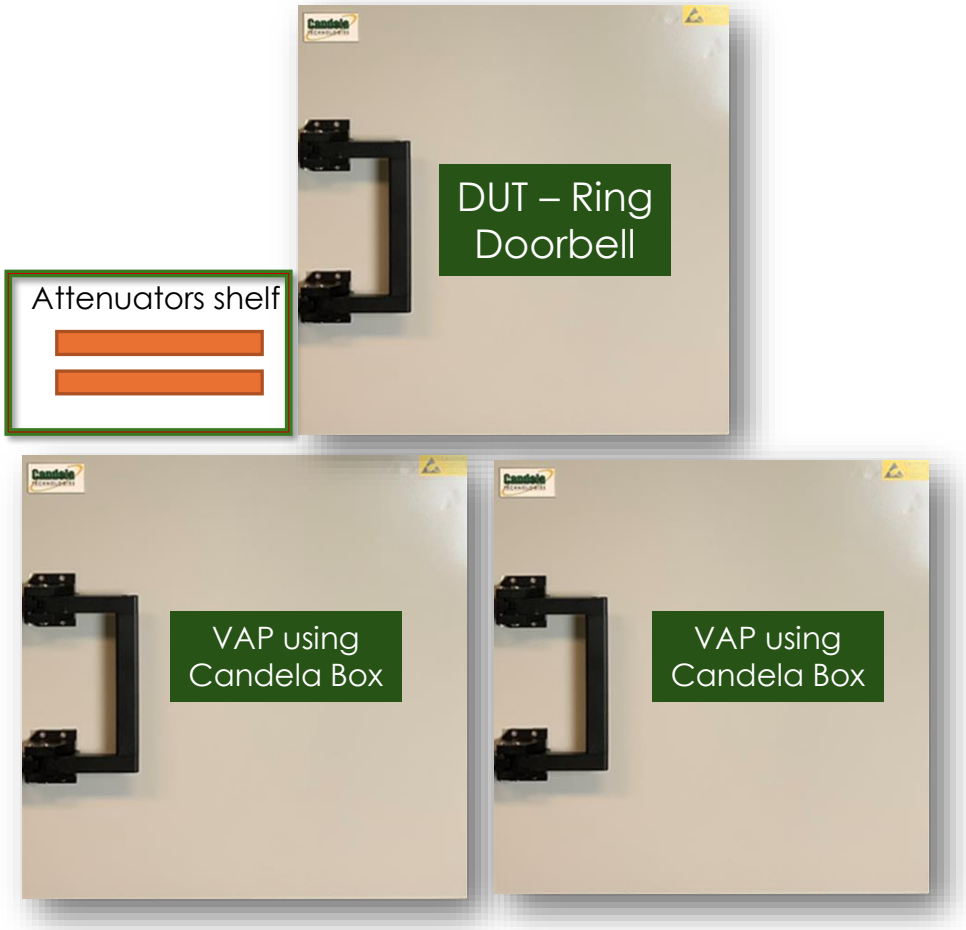


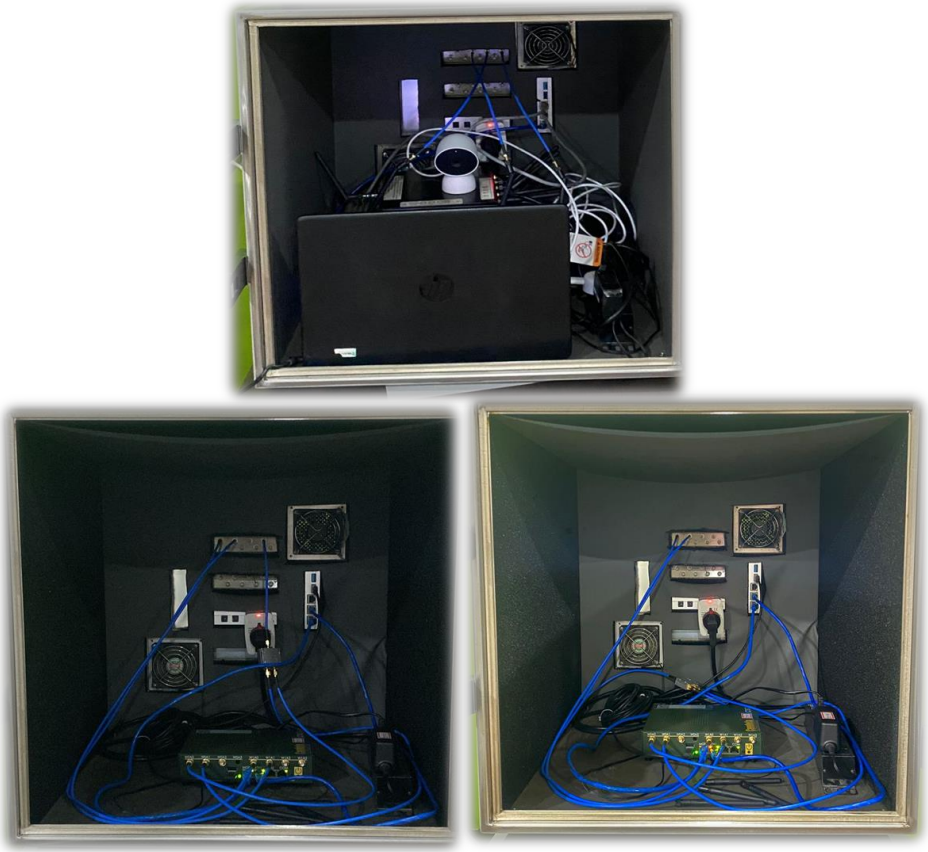
Candela's IOT automation Dashboard:



Large IOT Chamber

Testbed Images





List of Tests Executed

RvR

Wanlink

Interference

Roaming

DUT Specifications

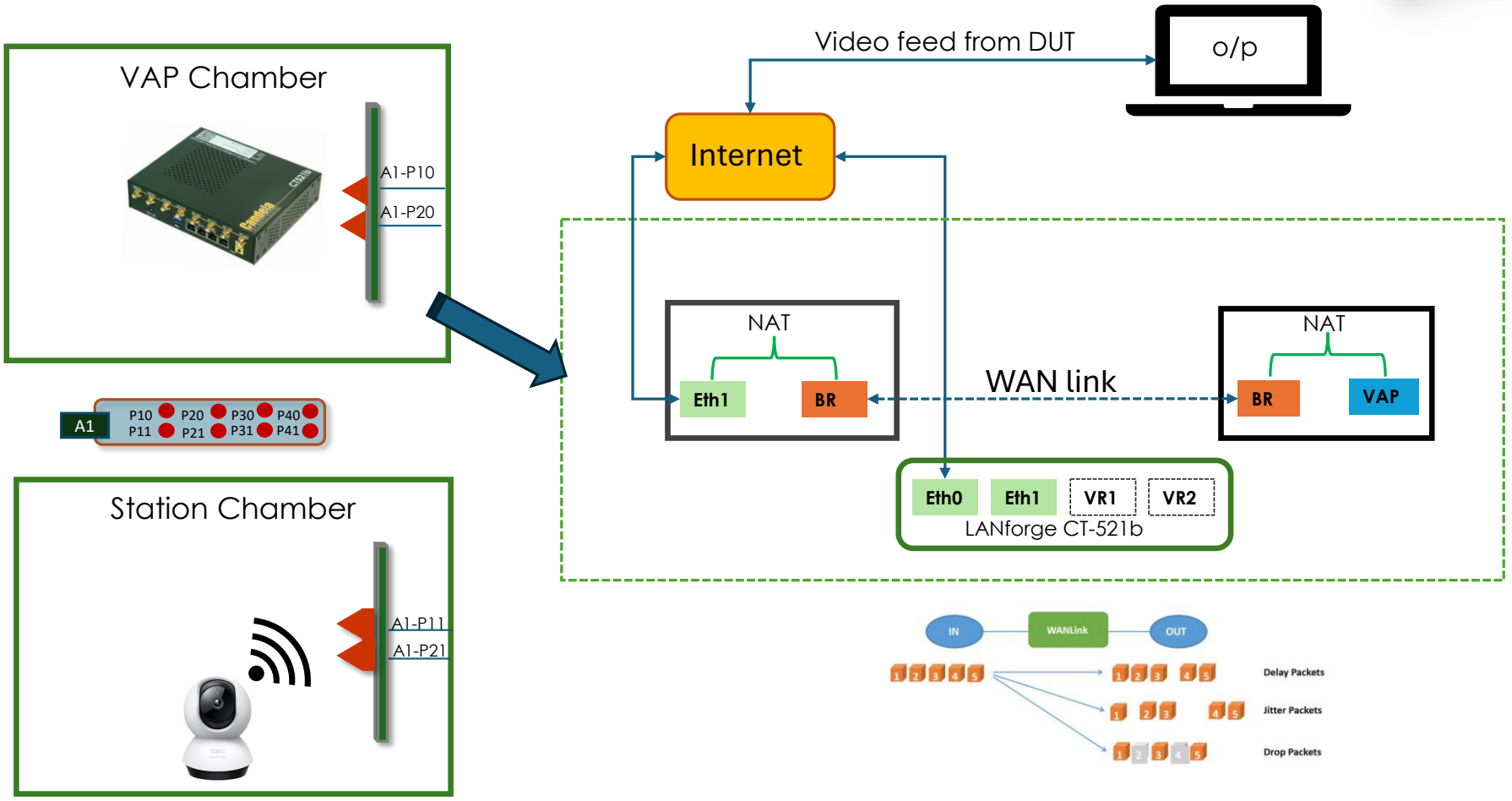
Google Nest 1080p Cam (Wired) - 2nd Generation - Snow

Spec	Description
Wireless	802.11a/b/g/n/ac (2.4GHz/5GHz) Wi-Fi WEP, WPA, WPA2, WPA3 encryption supported Bluetooth Low Energy (BLE) NSS-1X1
Camera sensor	2- mega pixel color sensor
Zoom	6x digital zoom
Video	Up to 1080p (1920 x 1080) at 30 frames/sec 24/7 live view High Dynamic Range (HDR) Night vision H.264 encoding
Security	Automatic security updates 128-bit AES encryption with TLS/SSL 2-step verification available

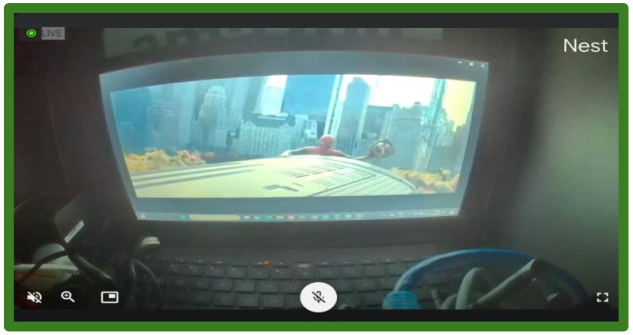
Tests:

- ✓ Long duration stress/stability, MTBF
- ✓ Connection times/failures.
- ✓ Motion Detection testing and testing other triggers.
- ✓ Medium Streaming Performance and overall system performance in:
  - ✓ Baseline ideal conditions
  - ✓ Over distance
  - ✓ With WiFi interference
  - ✓ With non- WiFi Interference

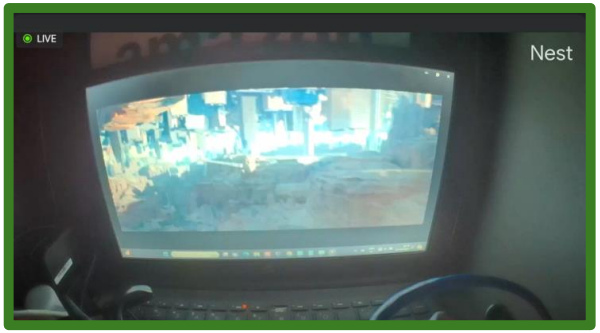
1. Testcase (WANlink Toplogy)



Video Observations



WAN link -10Mbps(Excellent)

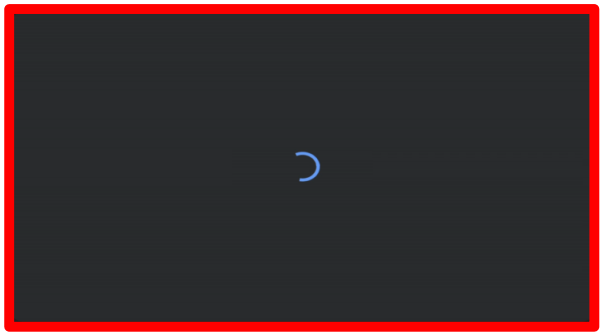


WAN link -5Mbps(Excellent)

WAN link -2Mbps(Excellent)

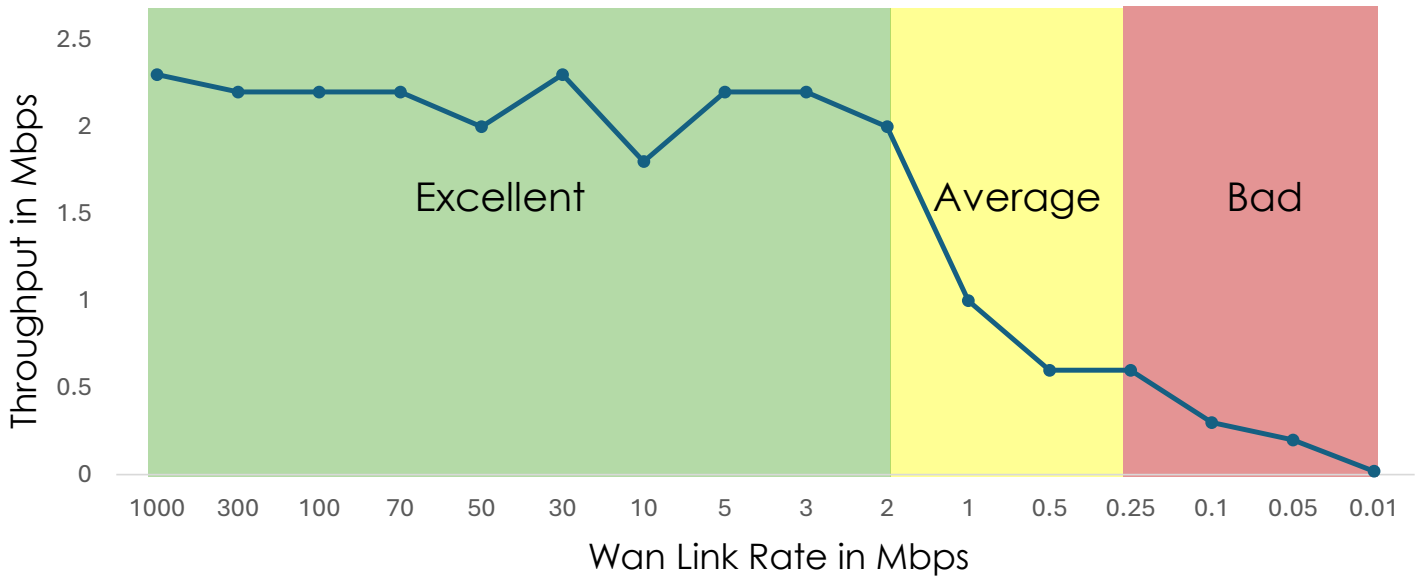
WAN link – 500Kbps(Average)

WAN link – 250Kbps(Bad)



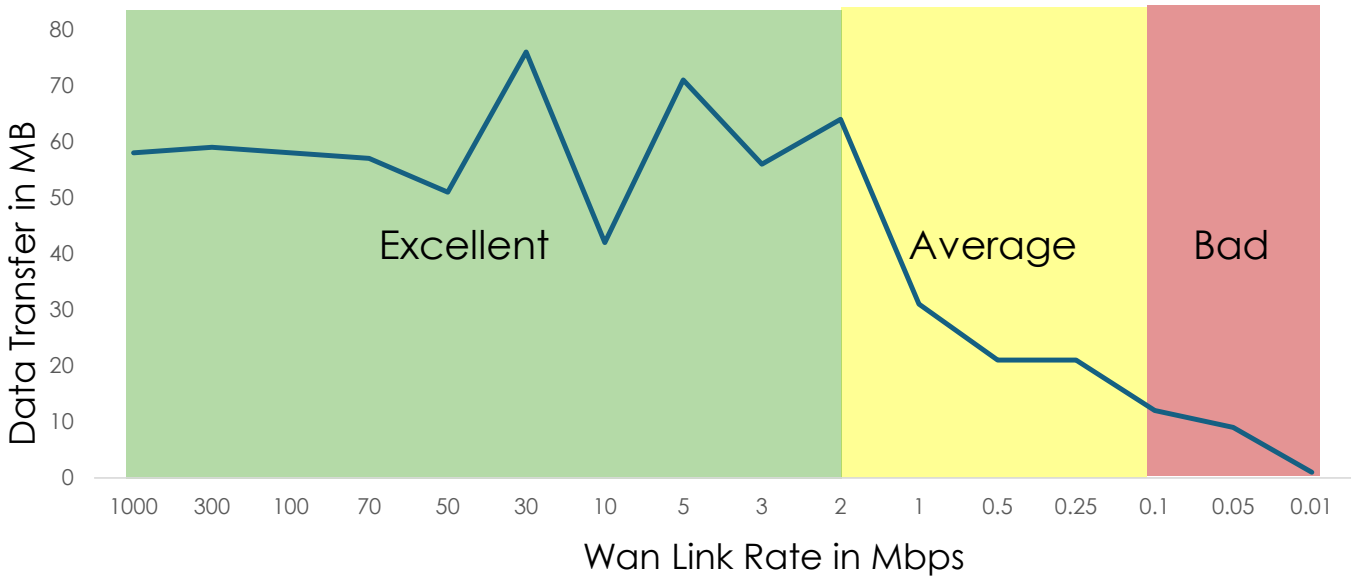
WAN link – 10Kbps(Bad)

Wan Link Rate vs Achieved Throughput (STA to VAP)

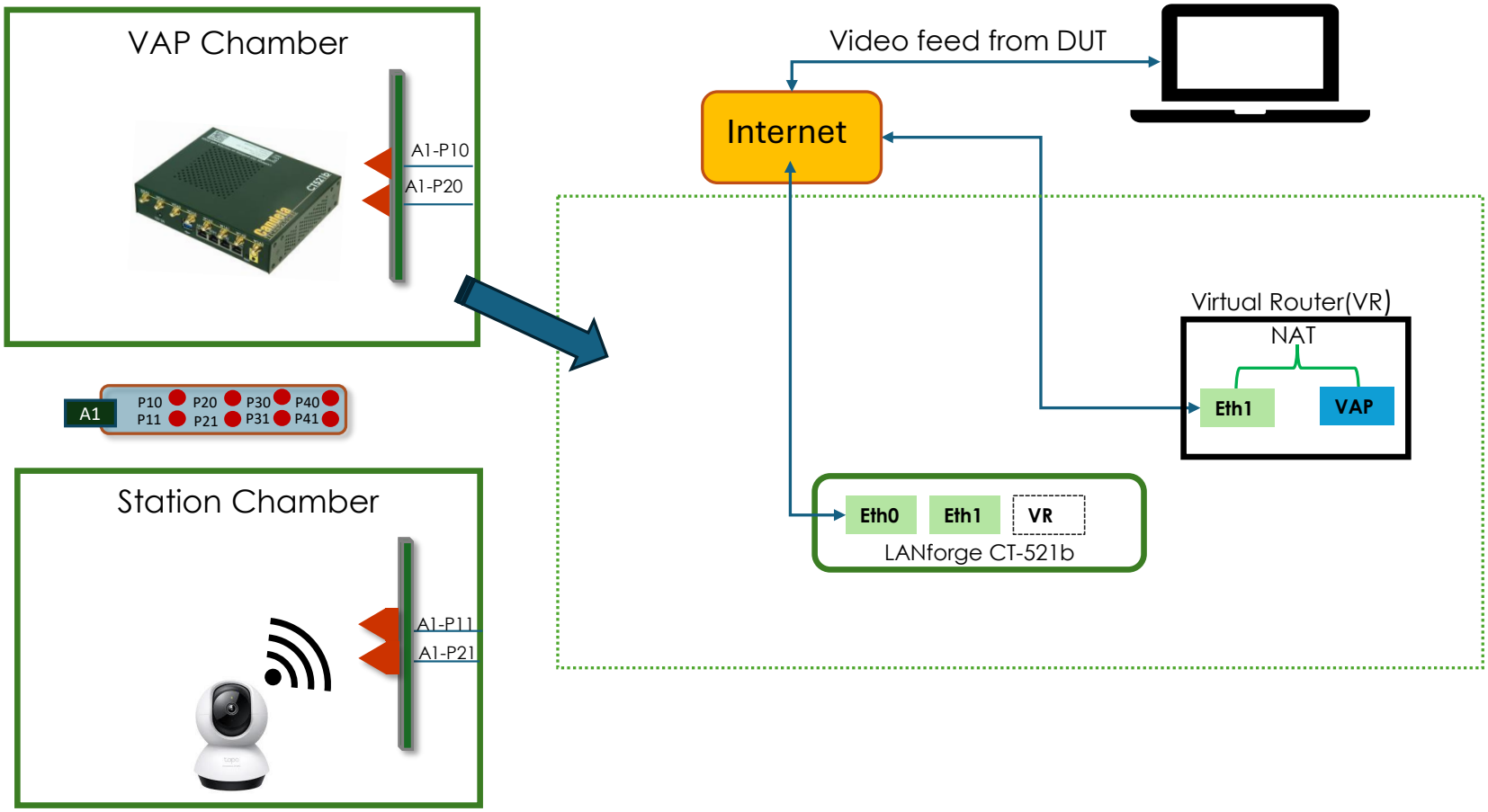


The DUT transmitted the data without packet drops till 2Mbps and the video log at monitoring device is excellent without any buffers. As the link rate at WAN is restricted between 2Mbps and 250Kbps, there is noticeable buffers. As the link rate is further restricted beyond 250Kbps, the video is unusable with complete buffering

Wan Link Rate vs Data transferred(STA to VAP)



2. Tesstcase (Rate vs Range)



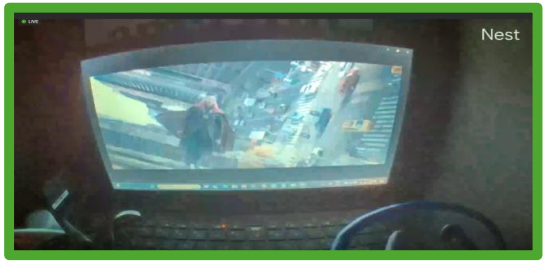
Video Observations

Attenuation 0dB (Excellent)

Attenuation 10dB (Excellent)

Attenuation 20dB (Excellent)

Attenuation 30dB (Excellent)

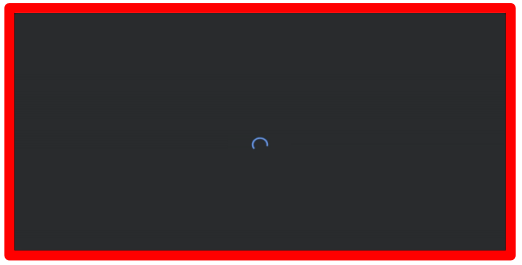


Attenuation 40dB (Excellent)

Attenuation 50dB (Average)

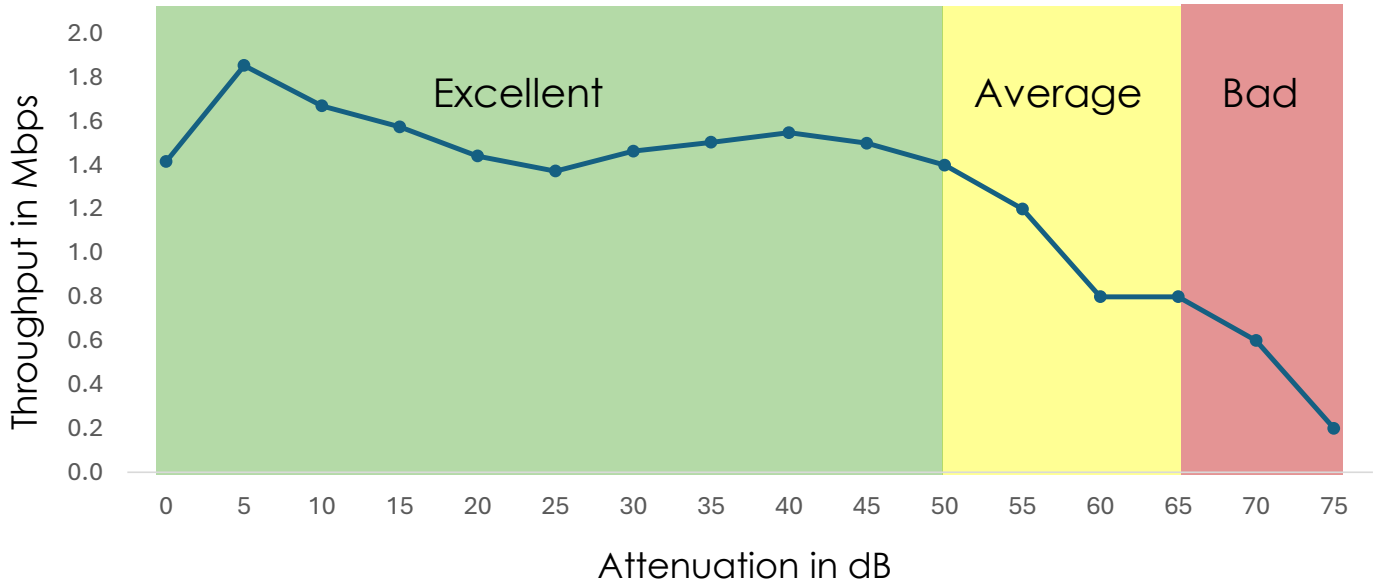
Attenuation 60dB (Average)

Attenuation 70dB (Bad)



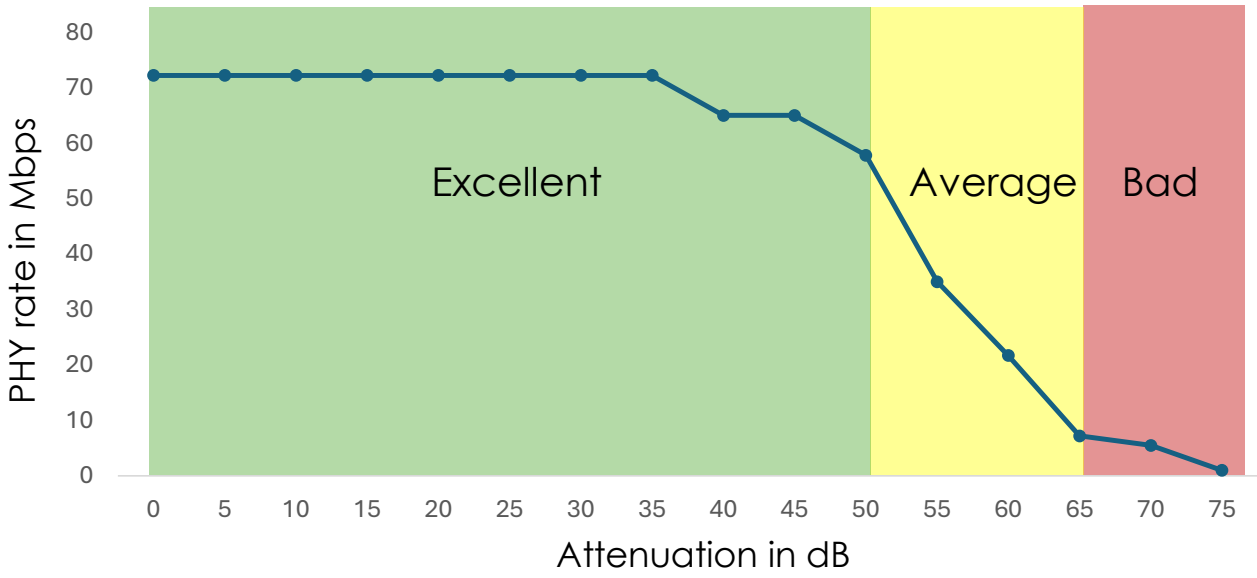
Attenuation 80dB (Bad)

Attenuation vs Achieved Throughput(STA to VAP)

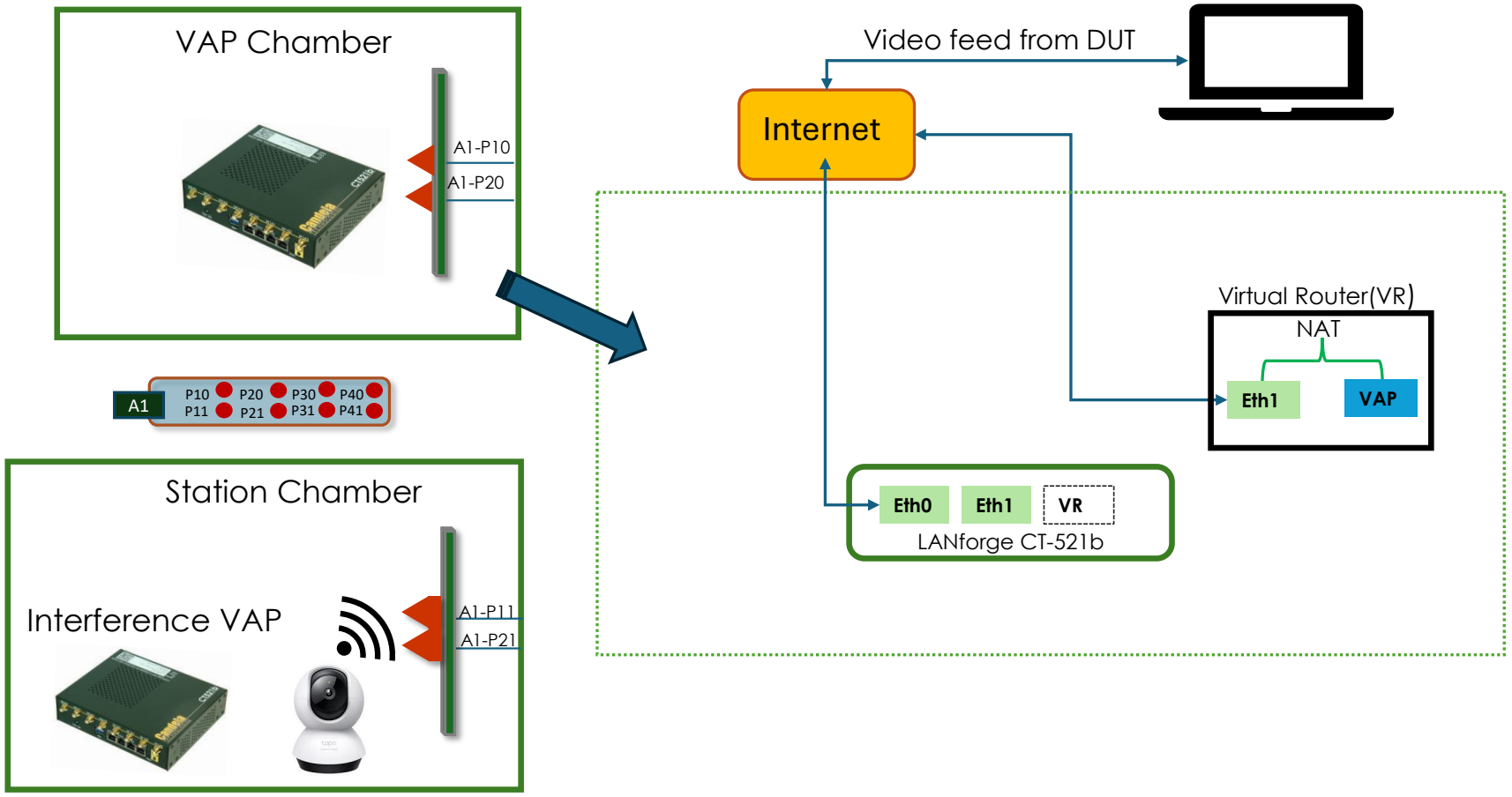


User can have good experience till 50dB attenuation, post that there is a decline in throughput

Attenuation vs Data rate(STA to VAP)



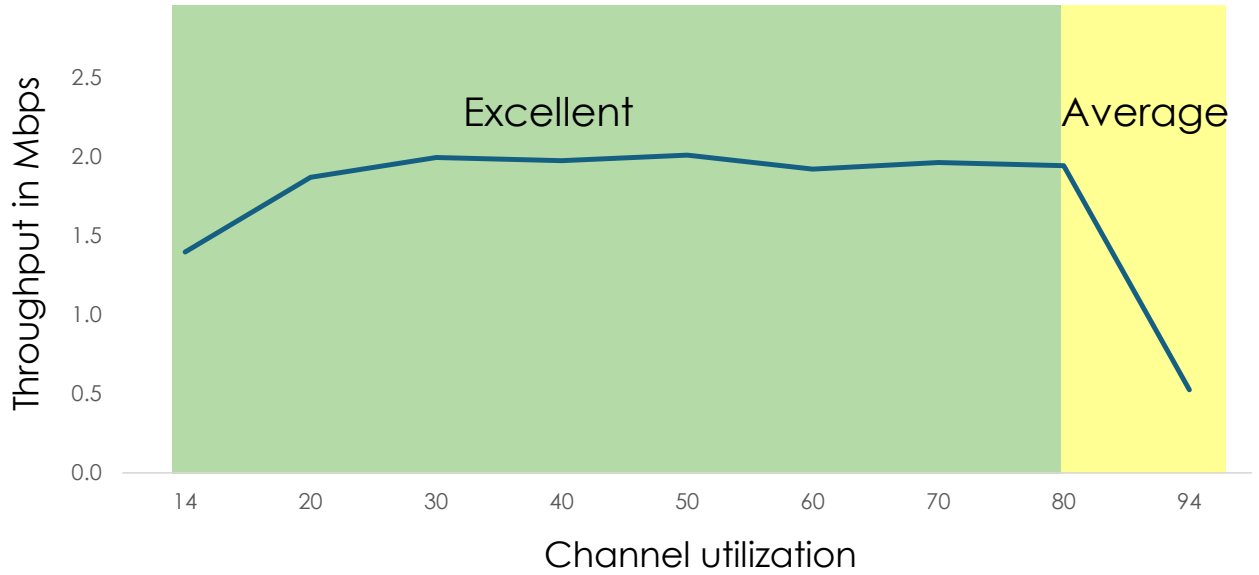
3. Testcase (Interference)



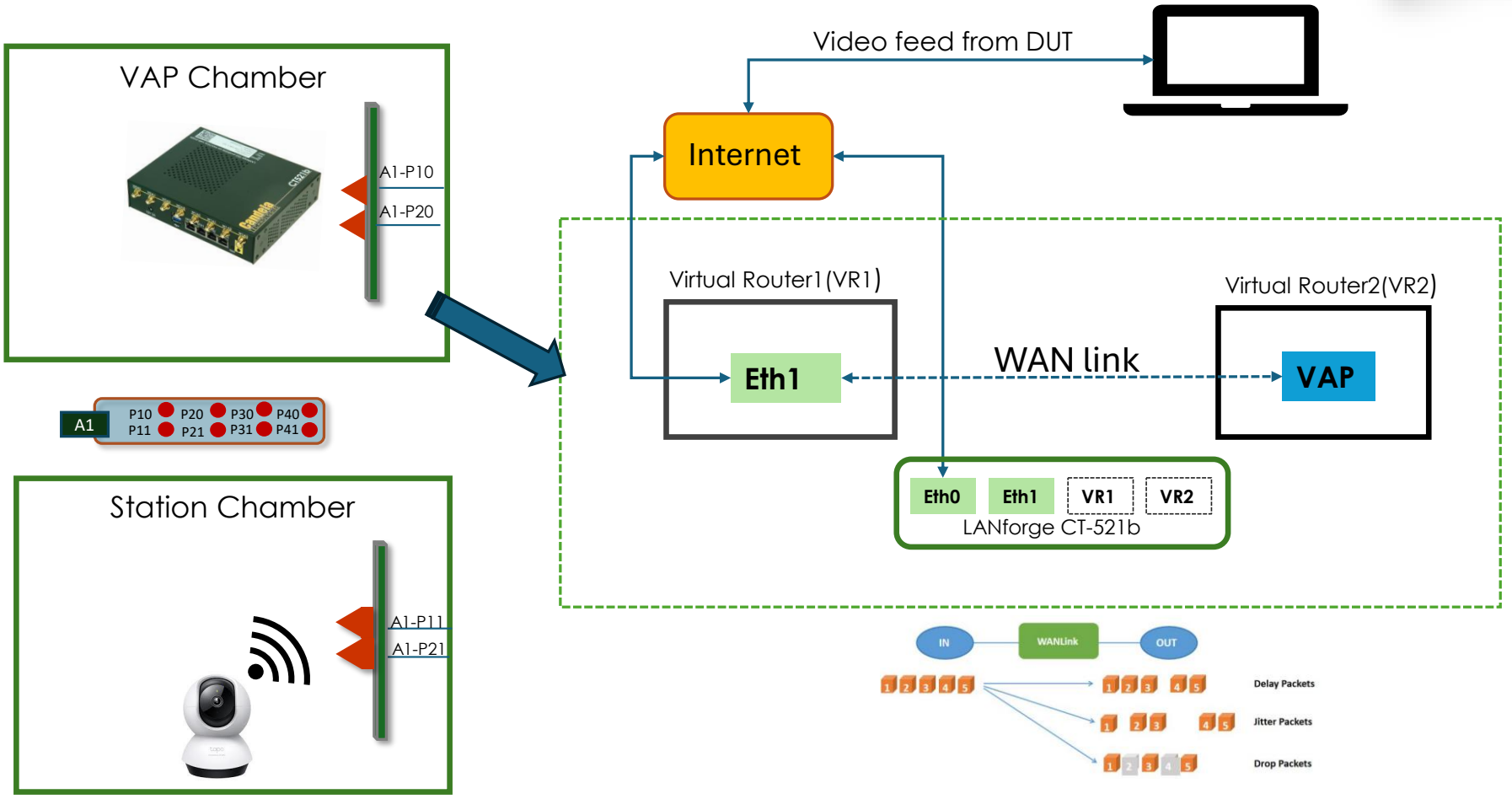
Video Observations

Noticeable video buffering is observed when channel utilization is over 90%. Video play is good till 80% channel utilization.

Wan Link Rate vs Achieved Throughput (STA to VAP)



Topology of Wan link



The 3-approaches for AP/Router Testing

Lab Testing with Virtual Devices

Repeatability:
Scalability :
Automation :
Realism :

Lab Testing with Real Devices

Repeatability:
Scalability :
Automation :
Realism :

Real world Testing in Test House

Repeatability:
Scalability :
Automation :
Realism :

Candela India Test House

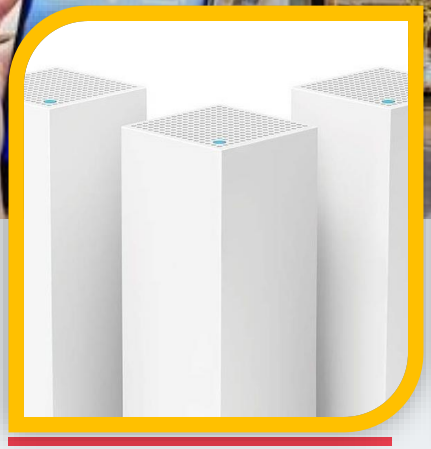
Test House – 3500 Sqft Apartment

- Brick and Mortar construction
- Tile flooring.
- 10 feet ceilings.
- Standard wooden doors, wooden cupboards and cabinets.
- 4- Bed, 4-Bath, Living, Dining, Kitchen and Media Rooms.
- Independent building with very little or no external WiFi or RF interference
- Fully equipped home with all furniture and furnishings
- Lots of WiFi Devices of various types (Laptops, Smartphones, Tablets, TVs, Cameras, IoT Devices etc…)

Devices Under Test

Single AP/Router

Full Performance Analysis of a Single WiFi Access Point in the Test House



Full Mesh Systems

Test Full in home WiFi Mesh System for Coverage, Capacity and Mobility

Computing Devices

Test the latest WiFi Laptops, Smartphone and Tablets

Smart Home Devices

All Smart Home devices including Consumer Electronics and Home Automation/Security Devices

Test Categories

Coverage

- ✓ RSSI Heat Map
- ✓ Throughput Heat Map
- ✓ Channel Heat Map
- ✓ BSSID Heat Map

Capacity

- ✓ Client Count
- ✓ Connection Times
- ✓ Total Throughput
- ✓ Throughput per Node
- ✓ Throughput per Band
- ✓ Load Balancing
- ✓ Band Steering

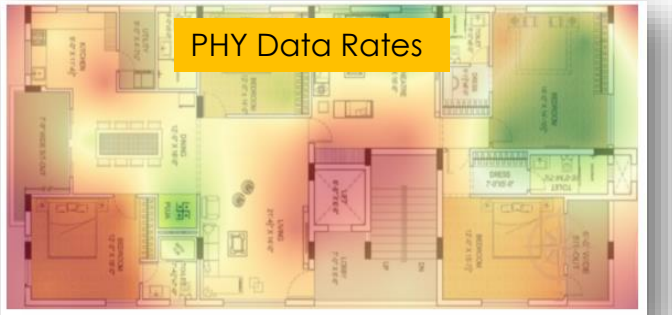
Mobility

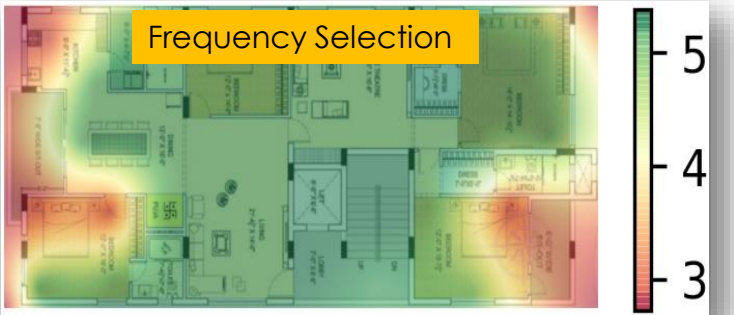
- ✓ Roam Times
- ✓ Roam Patterns
- ✓ Service Interruptions
- ✓ User Experience

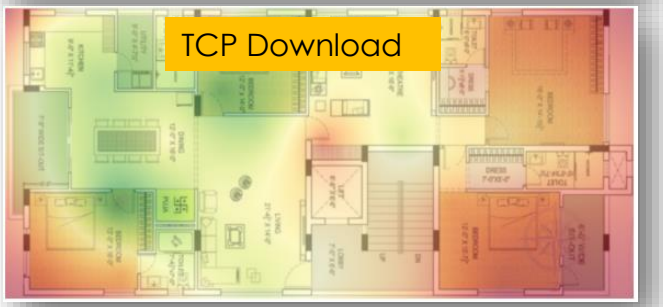
Interoperability

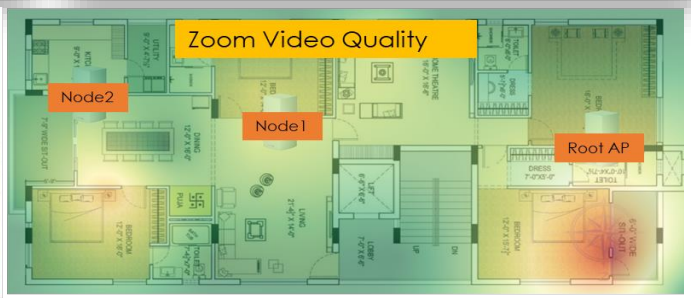
- ✓ Throughput with different types of Phones/Tablets/Laptops
- ✓ Connection Times/Performance over Distance

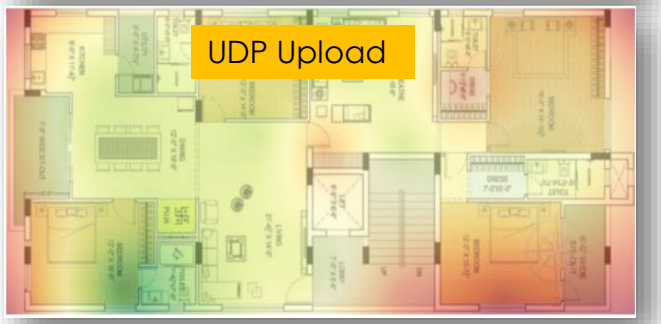
Coverage/User Experience Heatmaps

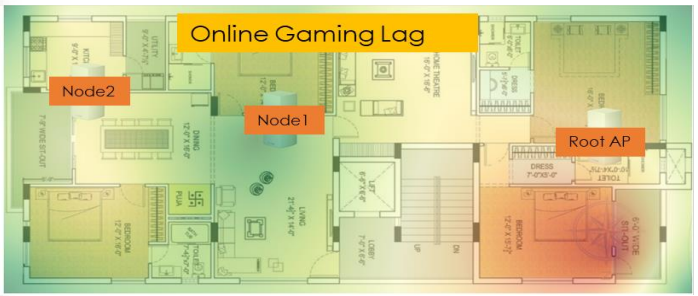












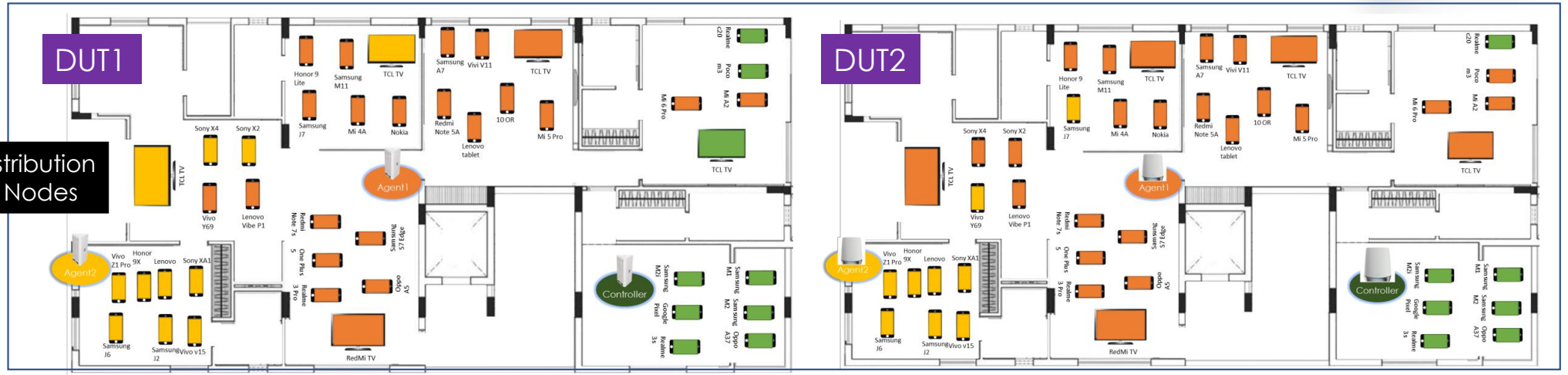
Wi-Fi Mesh System Testing in Candela Testhouse

Testing with Robotic Self Driving Vehicle

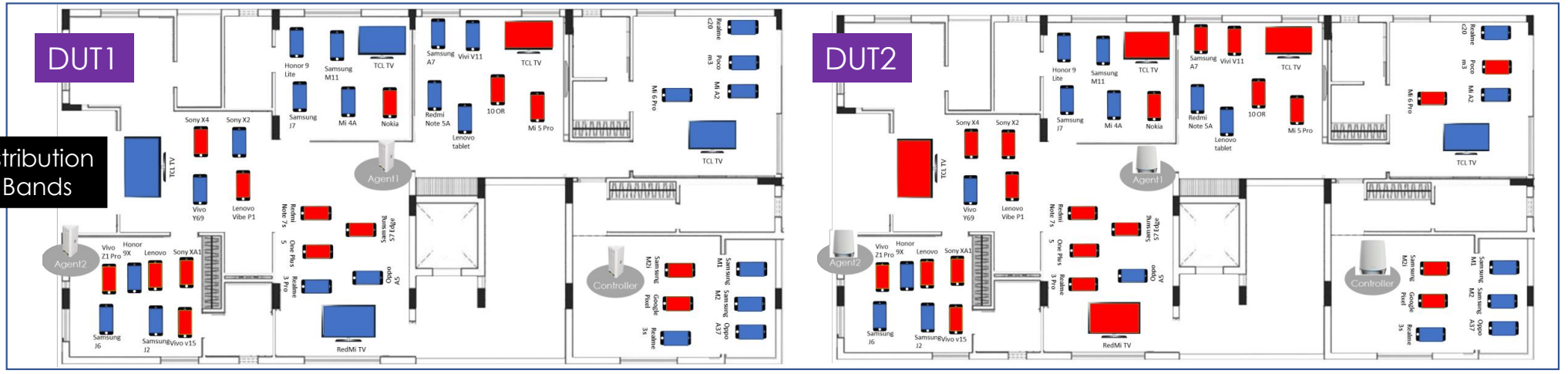
Two Story Villa Test House

Mesh Testing - Device Distribution by Nodes and Bands

Distribution By Nodes



Distribution By Bands



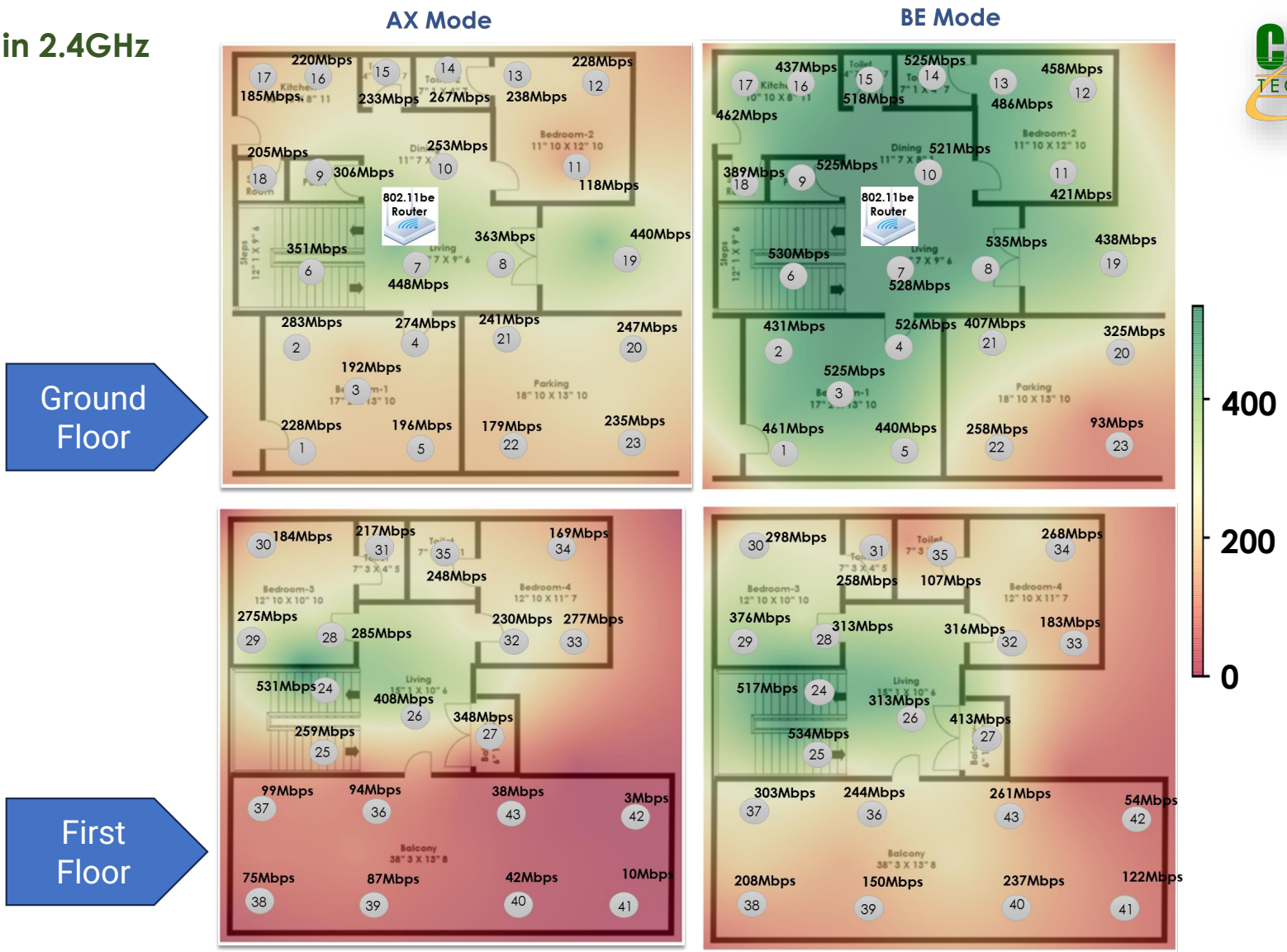
2.4GHz 5GHz

802.11be (Wi-Fi7) Router Test House Results

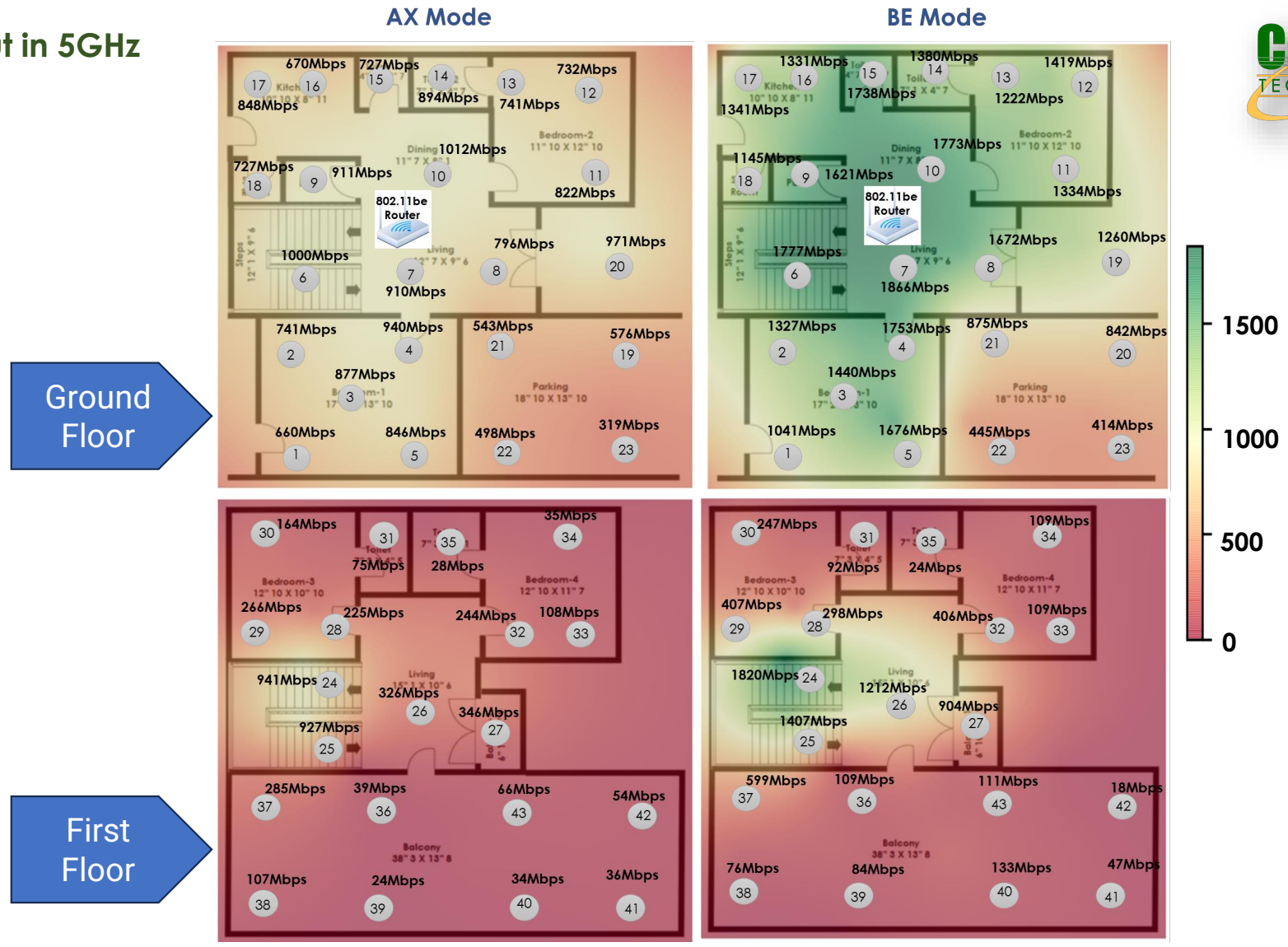
- 3000 sqft 2-level home with brick and mortar construction.
- WiFi7 Router placed in a central location in the lower level of the home.

- Observations:
  - Substantial improvement in the throughput in 2.4GHz with 11be in all locations.
  - 6GHz was not able to get proper coverage across all measurement points with client losing connectivity at many of the far points.
  - Overall 11be provided much better throughput at near distances and no real improvement in range.

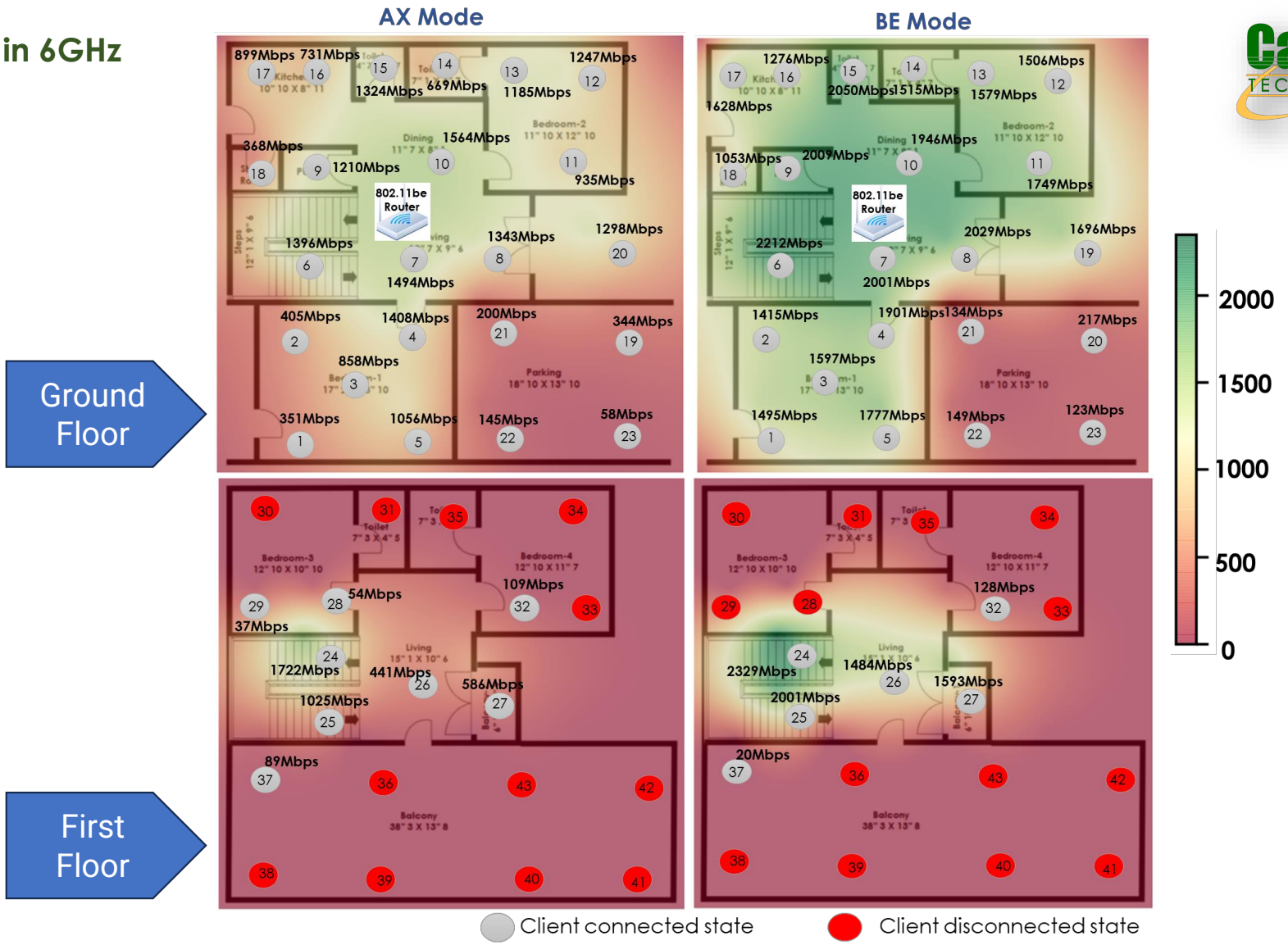
Throughput in 2.4GHz band



Throughput in 5GHz band

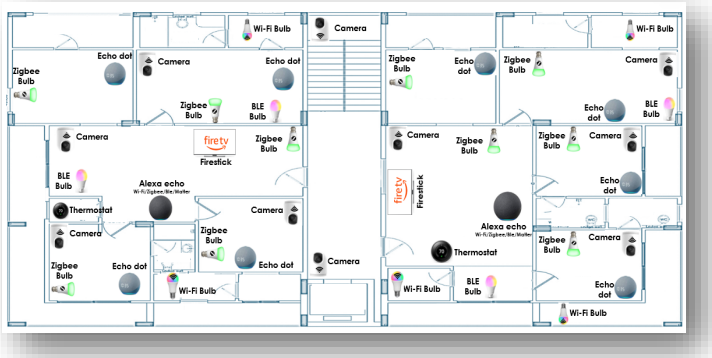


Throughput in 6GHz band



	Co-ordinates	2.4GHz		5GHz		6GHz		Improvement due to 11be		
		11ax	11be	11ax	11be	11ax	11be	2.4GHz	5GHz	6GHz
Ground Floor Throughput in Mbps	1	228	461	660	1041	351	1495	102%	58%	326%
	2	283	431	741	1327	405	1415	52%	79%	249%
	3	192	525	877	1440	858	1597	173%	64%	86%
	4	274	526	940	1753	1408	1901	92%	86%	35%
	5	196	440	846	1676	1056	1777	124%	98%	68%
	6	351	530	1000	1777	1396	2212	51%	78%	58%
	7	448	528	910	1866	1494	2002	18%	105%	34%
	8	363	535	796	1672	1343	2029	47%	110%	51%
	9	306	525	911	1621	1210	2009	72%	78%	66%
	10	253	521	1012	1773	1564	1946	106%	75%	24%
	11	118	421	822	1334	935	1749	257%	62%	87%
	12	228	458	732	1419	1247	1506	101%	94%	21%
	13	238	486	741	1222	1185	1579	104%	65%	33%
	14	267	525	894	1380	669	1515	97%	54%	126%
	15	233	518	727	1738	1324	2050	122%	139%	55%
	16	220	437	670	1331	731	1276	99%	99%	75%
	17	185	462	848	1341	899	1628	150%	58%	81%
	18	205	389	727	1145	368	1053	90%	57%	186%
	19	440	438	971	1260	1298	1696	0%	30%	31%
	20	247	325	576	842	344	217	32%	46%	-37%
	21	241	407	543	875	200	134	69%	61%	-33%
	22	179	258	498	445	145	149	44%	-11%	3%
	23	235	93	319	414	58	123	-60%	30%	112%
First Floor Throughput in Mbps	24	531	517	941	1820	1722	2329	-3%	93%	35%
	25	259	534	927	1407	1025	2001	106%	52%	95%
	26	408	487	326	1212	441	1484	19%	272%	237%
	27	348	413	346	904	586	1593	19%	161%	172%
	28	285	313	225	298	54	0	10%	32%	-100%
	29	275	376	266	407	37	0	37%	53%	-100%
	30	184	298	164	247	0	0	62%	51%	0%
	31	217	258	75	92	0	0	19%	23%	0%
	32	230	316	244	406	109	128	37%	66%	17%
	33	277	183	108	109	0	0	-34%	1%	0%
	34	169	268	35	109	0	0	59%	211%	0%
	35	248	107	28	24	0	0	-57%	-14%	0%
	36	94	244	39	109	0	0	160%	179%	0%
	37	99	303	285	599	89	20	206%	110%	-78%
	38	75	208	107	76	0	0	177%	-29%	0%
	39	87	150	24	84	0	0	72%	250%	0%
	40	42	237	34	133	0	0	464%	291%	0%
	41	10	122	36	47	0	0	1120%	31%	0%
	42	3	54	54	18	0	0	1700%	-67%	0%
	43	38	261	66	111	0	0	587%	68%	0%

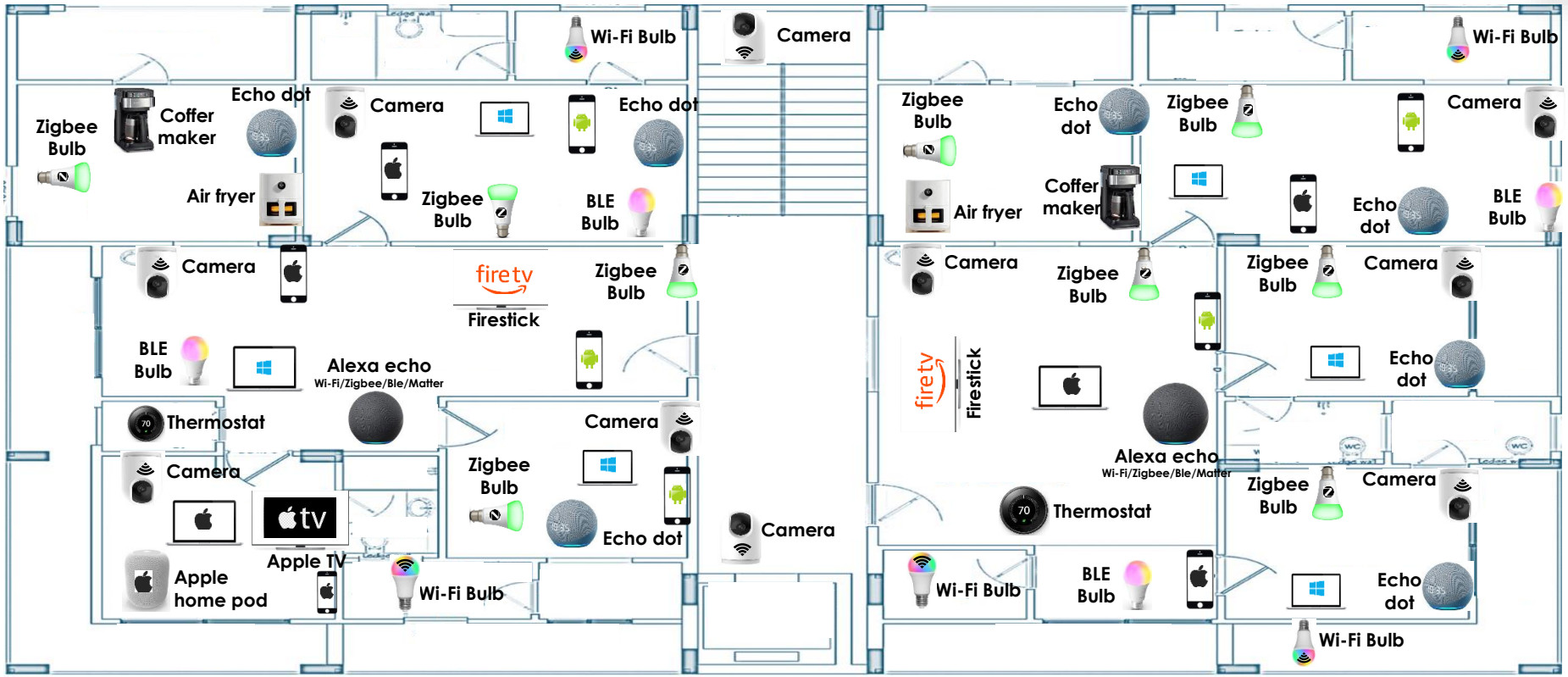
Candela's Home automation lab:



Detailed test report

- Candela's Home automation lab has a complete deployment of IOT devices that involve in home automation and security.
- Using this home automation lab, we can try to validate the performance of your access point in a real time environment which is completely controllable and can give repetitive results.
- We also have various laptops, mobiles and MacBook's deployed across the house doing various streaming activities to mimic the real-world scenarios.
- We can easily identify the co-existence and congestion problems because of IOT devices and see how your access point is handling different conditions.
- We provide a detailed test report that involves the real-time statistics, latency reporting, streaming quality and user experience scores of all the devices present in the home.

Home automation Lab with IOT and real devices:



- We have placed real devices and mobiles across the home and every device will do various activities like gaming, video streaming, sending mails etc.. to, mimic the real-world home.
- Also, we have a dedicated space for Apple home automation devices and SMP's and home pod's.

THE RESULT

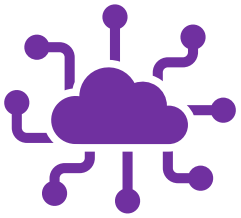
Devices available for test in Home automation lab:

Alexa controllers and extenders

Device Type	Quantity
Echo Gen 4	2
Echo show Gen 2	2
Echo dot Gen 2	5
Echo pop	2
Echo dot gen 3	2

Real devices

Device Type	Quantity
MacBooks	2
iPads	2
Tablets	2
Android phones	5
Windows/Linux	5



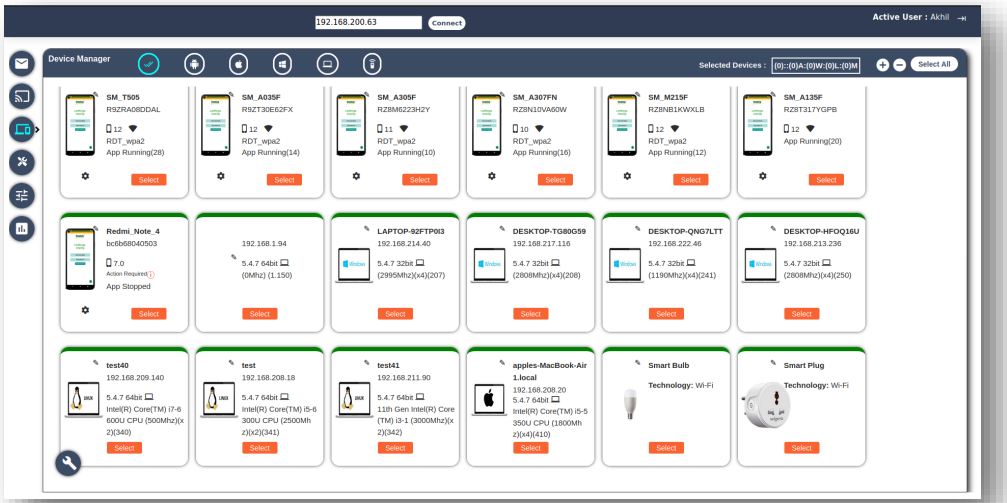
IOT devices

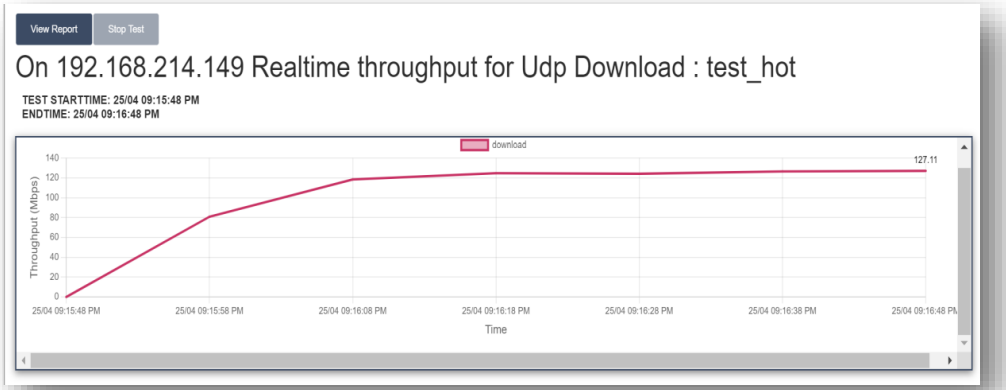
Device Type	Quantity
Wi-Fi bulbs [Philips Wiz]	5
Zigbee bulbs [Philips Hue]	5
BLE bulbs [Philips]	2
Smart plug [Zebronics]	1
Smart cameras [Nest]	5

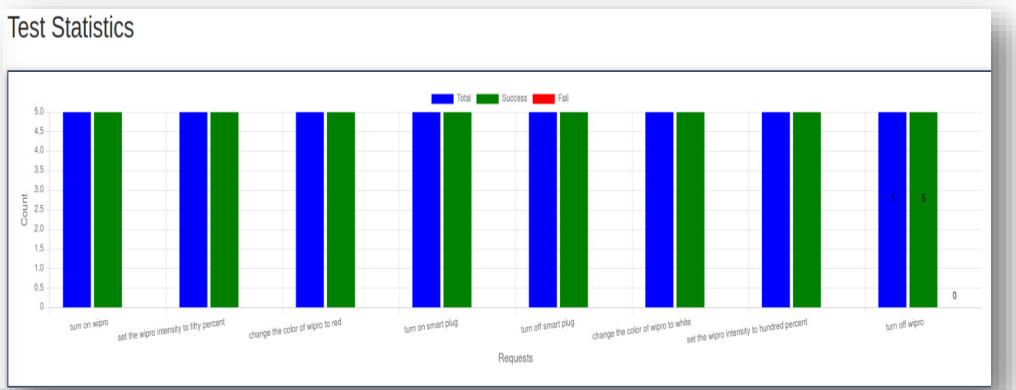
Traffic Generators and jammers

Device Type	Quantity
LANforge	5
Sniffers	5
Jammer	2
Virtual Access Points	5
Mesh extenders	2

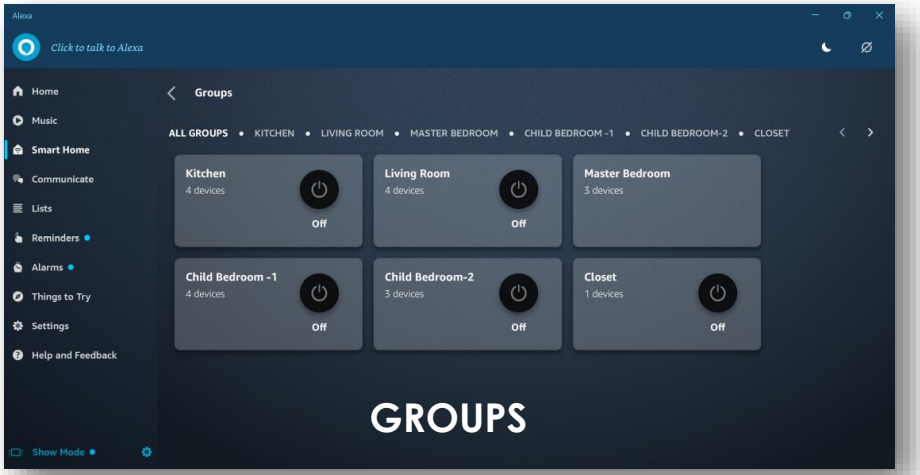
Candela Real device controller UI: LANforge Interop

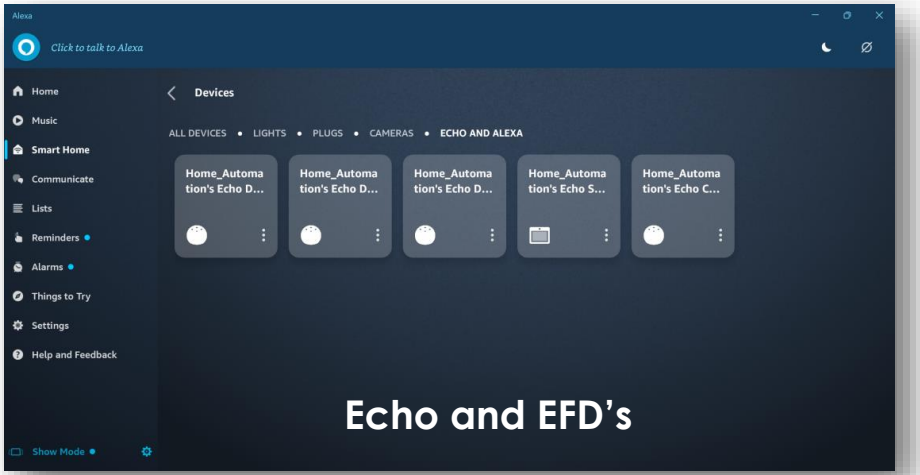


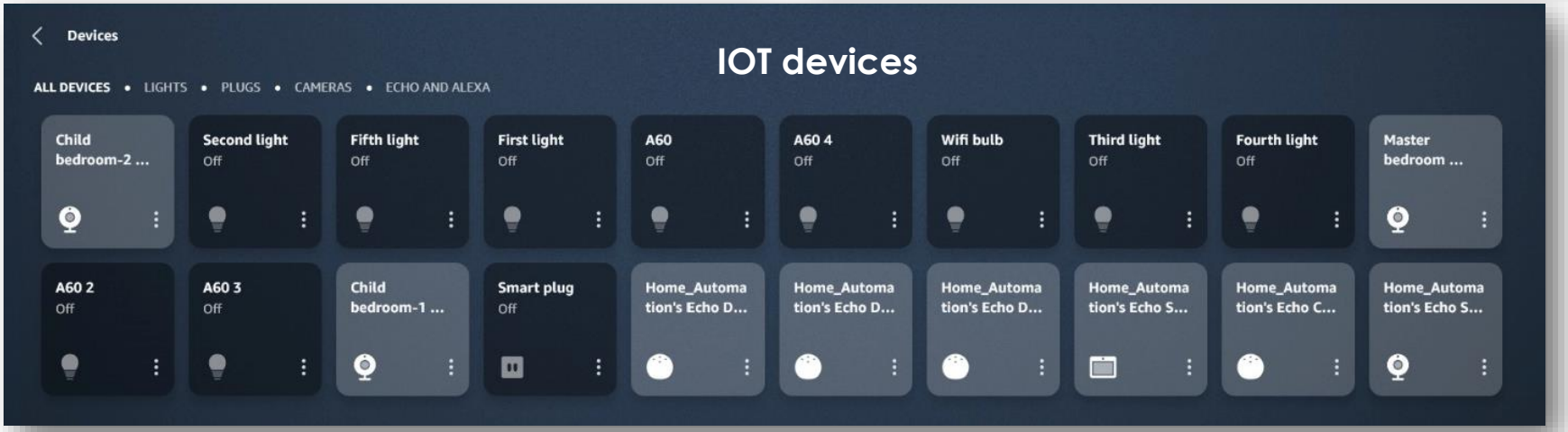




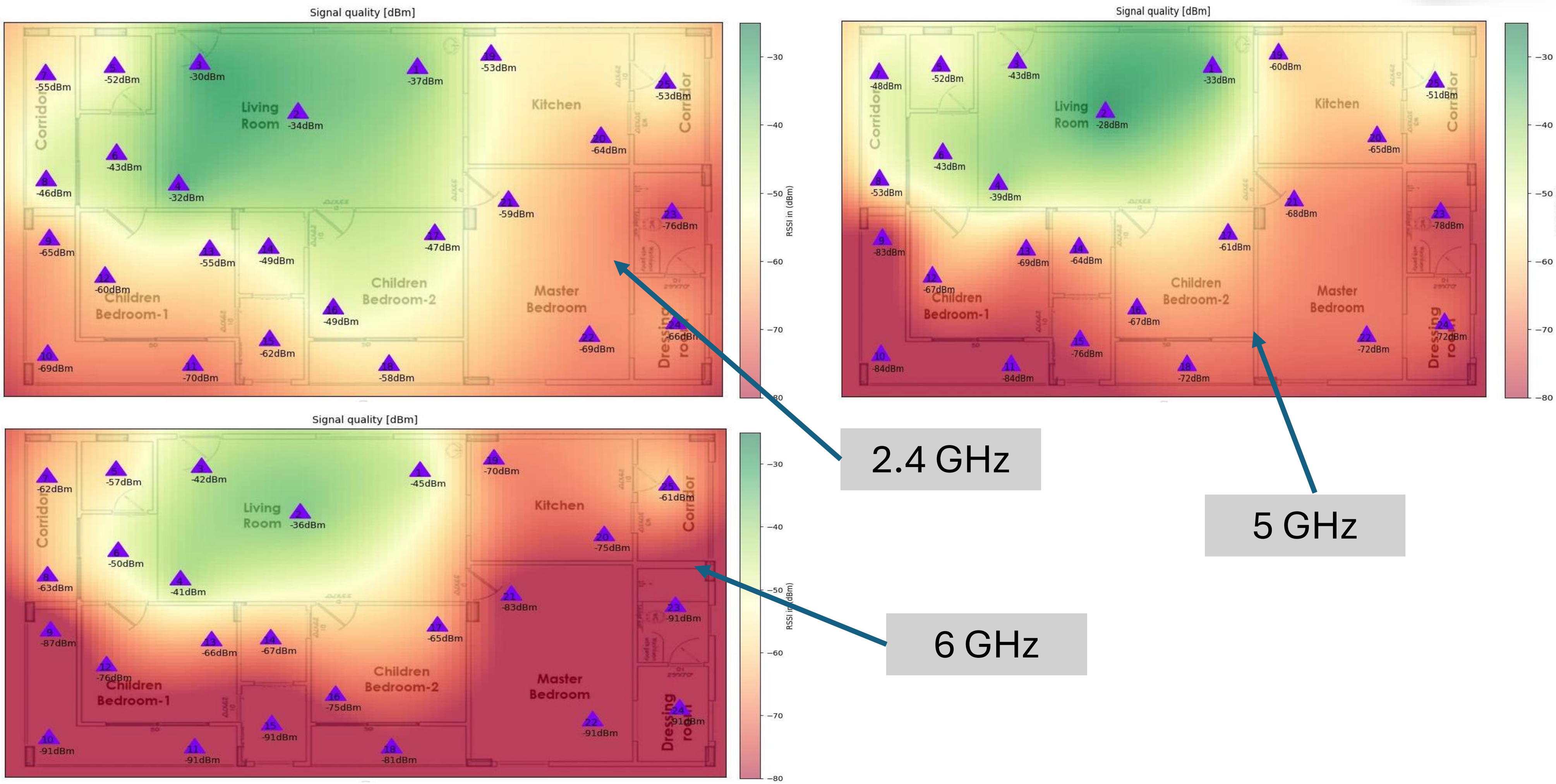
Alexa device controller UI: IOT devices invocator



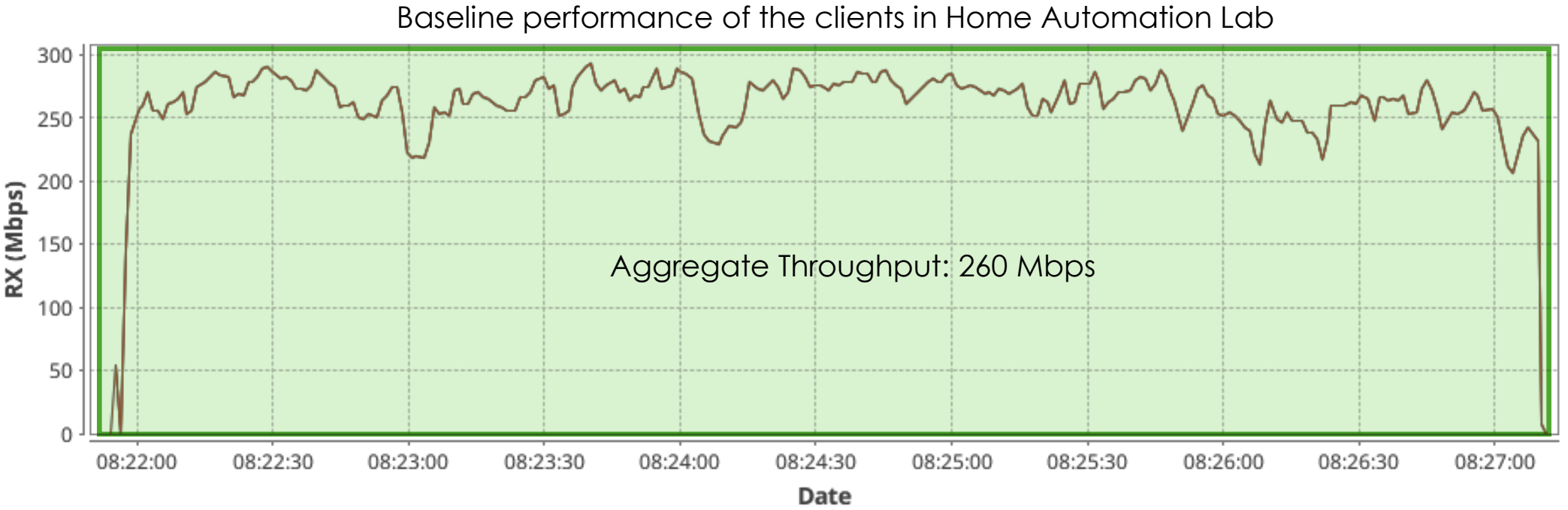




Coverage of the DUT :

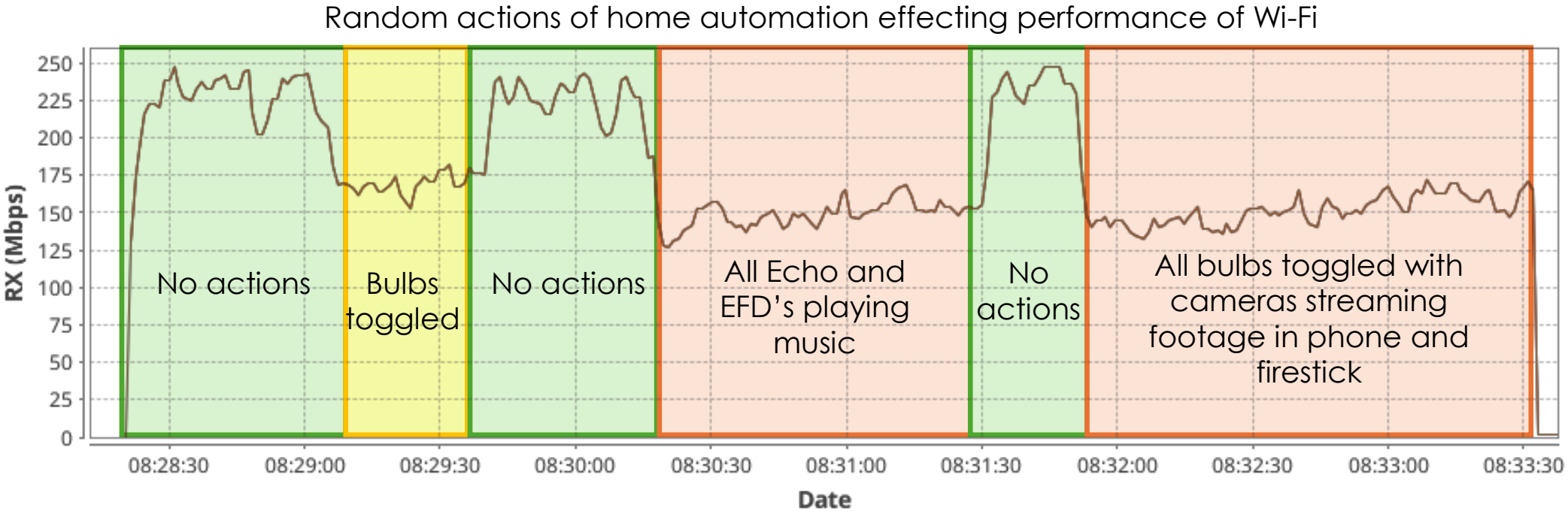


Multi-client throughput test: Base-line performance



- 12 real clients of various operating systems like Windows, Linux, MacOS and Android place at various locations in the house running UDP download emulated traffic.
- The duration of the Baseline performance test is 5min and we have run intended load of 1Gbps.

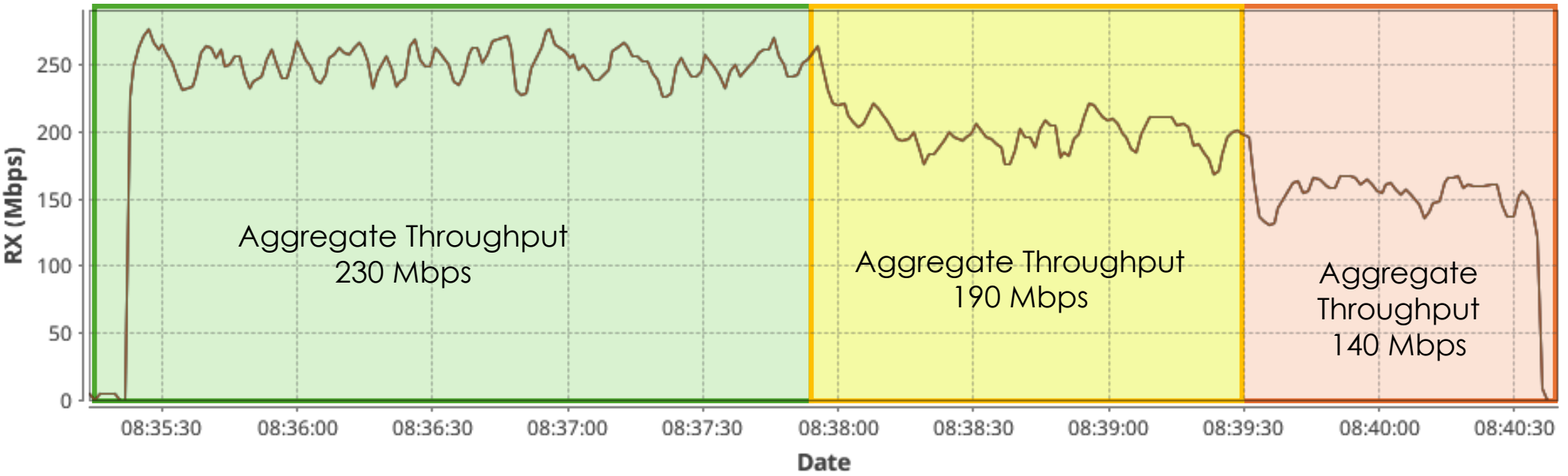
Multi-client throughput test: Random invocations



- Significant drop in performance of the 12 client's performance when randomly IOT devices are performing actions.
- The devices are placed at various locations of the Home automation lab.
- We have run the test for 5 min and provided intended load of 1Gbps to all the real-clients.

Multi-client throughput test: Incremental actions

Incremental fashion-based actions of home automation effecting performance of Wi-Fi



All the clients running traffic when all IOT bulbs and switches are being toggled randomly across the home

When security cameras have started playing footage in mobiles and firestick
Note: Bulbs are turned on

When all the echo and echo dots have started playing music.
Note: Bulbs and cameras are also active

Home automation lab test plan:

1.1 Congestion and co-existence test.

1.2 High traffic and 4k streaming test.

1.3 Performance over distance test.

1.4 Non-line of sight detection test.

1.5 Client roaming and stability test.

1.6 Intrusion detection test.

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