



Network  
Testing &  
Emulation  
Solutions

# Candela Testing as a Service

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 1-360-380-1618

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



Lab Testing with Virtual Devices



Lab Testing with Real Devices



Real world Testing in Test House/Enterprises



# Test Suite Details

| S No. | Test Category    | Testcase  | No of Testcases |
|-------|------------------|---|-----------------|
| 1     | Basic Testing    | Client Connectivity - 2.4GHz, 5GHz & 6GHz             | 25              |
| 2     |                  | Throughput with client capacity - 2.4GHz, 5GHz & 6GHz |                 |
| 3     |                  | Multi Band Throughput                                 |                 |
| 4     |                  | Data plane - 2.4GHz & 5GHz                            |                 |
| 5     |                  | Port Reset  |                 |
| 6     | Advanced Testing | Quality of Service                                    | 47              |
| 7     |                  | Dynamic Frequency Selection                           |                 |
| 8     |                  | Performance over Distance (RvR)                       |                 |
| 9     |                  | Performance over Orientation (RvO)                    |                 |
| 10    |                  | File Transfer Protocol                                |                 |
| 11    |                  | Interference (ACI/CCI)                                |                 |
| 12    |                  | MU-MIMO   |                 |
| 13    |                  | OFDMA   |                 |
| 14    |                  | Airtime Fairness                                      |                 |
| 15    |                  | Roaming   |                 |
| 16    |                  | Long Term Stability                                   |                 |
| 17    | TR-398 Testing   | TR-398 Issue-2  | 15              |
| 18    |                  | TR-398 Issue-3  | 21              |
| 19    |                  | TR-398 Issue-4  | 29              |

| S No. | Test Category                    | Testcase                                     | No of Testcases |
|-------|----------------------------------|--|-----------------|
| 20    | Real Device Testing              | Throughput Test                              | 13              |
| 21    |                                  | Interoperability Test                        |                 |
| 22    |                                  | QoS Test                                     |                 |
| 23    |                                  | Multicast Test                               |                 |
| 24    |                                  | Ping Plotter Test                            |                 |
| 25    |                                  | Port Reset Test                              |                 |
| 26    |                                  | FTP Test                                     |                 |
| 27    |                                  | HTTP Test                                    |                 |
| 28    |                                  | Video Streaming Test                         |                 |
| 29    |                                  | Reak Browser Test                            |                 |
| 30    |                                  | YouTube Streaming Test                       |                 |
| 31    |                                  | Zoom call Test                               |                 |
| 32    |                                  | Mixed Traffic Test                           |                 |
| 33    | Coverage and Capacity Test House | Coverage, Roam and capacity with 40+ devices | 5               |

# Results Summary



| Num | Tests                                 | Vendor A  | Vendor B  |
|-----|---------------------------------------|-----------|-----------|
| 1   | Basic Client connectivity – 2.4 GHz   | Good      | Excellent |
| 2   | Basic Client connectivity – 5 GHz     | Good      | Excellent |
| 3   | Client Capacity – 5 GHz TCP UL        | Good      | Excellent |
| 4   | Client Capacity – 5 GHz TCP DL        | Good      | Excellent |
| 5   | Client Capacity – 5 GHz UDP UL        | Good      | Excellent |
| 6   | Client Capacity – 5 GHz UDP DL        | Poor      | Excellent |
| 7   | Client Capacity – 2.4 GHz TCP UL      | Good      | Excellent |
| 8   | Client Capacity – 2.4 GHz TCP DL      | Poor      | Excellent |
| 9   | Client Capacity – 2.4 GHz UDP UL      | Excellent | Good      |
| 10  | Client Capacity – 2.4 GHz TCP DL      | Poor      | Excellent |
| 11  | Data Plane – 2.4 GHz                  | Excellent | N/A       |
| 12  | Data Plane – 5 GHz                    | Excellent | N/A       |
| 13  | Port Reset                            | Excellent | N/A       |
| 14  | Quality of Service – 5 GHz            | Good      | N/A       |
| 15  | Dual Band Testing – 5GHz TCP Upload   | Good      | Excellent |
| 16  | Dual Band Testing – 5GHz TCP Download | Poor      | Excellent |
| 17  | Dual Band Testing – 5GHz UDP Upload   | Poor      | Excellent |
| 18  | Dual Band Testing – 5GHz UDP Download | Poor      | Excellent |
| 19  | FTP – 2.4 GHz                         | Excellent | Excellent |
| 20  | FTP – 5 GHz                           | Poor      | Excellent |
| 21  | DFS                                   | Excellent | N/A       |
| 22  | Rate vs Range                         | Good      | Good      |
| 23  | Rate vs Orientation                   | Poor      | Good      |

# TR-398 Results Summary



| TR-398 Issue-4 - Comparison between two vendor APs |  |          |      |      |          |      |      |
|--|--|----------|------|------|----------|------|------|
| S No.  | Testcase                               | Vendor-A |      |      | Vendor-B |      |      |
|  |  | 2.4GHz   | 5GHz | 6GHz | 2.4GHz   | 5GHz | 6GHz |
| 1  | 6.1.1 Receiver Sensitivity Test        | PASS     | PASS | PASS | FAIL     | PASS | PASS |
| 2  | 6.2.1 Maximum Connection Test          | PASS     | PASS | PASS | FAIL     | PASS | FAIL |
| 3  | 6.2.2 Maximum Throughput Test          | PASS     | PASS | PASS | PASS     | PASS | PASS |
| 4  | 6.2.3 Airtime Fairness Test            | PASS     | PASS | PASS | PASS     | PASS | PASS |
| 5  | 6.2.4 Dual-Band Throughput Test        | PASS     | FAIL | FAIL | FAIL     | FAIL | PASS |
| 6  | 6.2.5 Bi-Directional Throughput Test   | PASS     | PASS | PASS | PASS     | PASS | FAIL |
| 7  | 6.2.6 Latency Test                     | PASS     | PASS | PASS | FAIL     | PASS | FAIL |
| 8  | 6.2.7 Quality of Service Test          | PASS     | PASS | PASS | FAIL     | FAIL | FAIL |
| 9  | 6.2.8 Multi-Band Throughput Test       | PASS     | PASS | PASS | FAIL     | FAIL | FAIL |
| 10   | 6.2.9 OFDMA Throughput Test            | NA       | PASS | FAIL | PASS     | PASS | FAIL |
| 11   | 6.3.1 Rate Vs Range Test               | PASS     | PASS | PASS | FAIL     | FAIL | PASS |
| 12   | 6.3.2 Spatial Consistency Test         | PASS     | PASS | PASS | FAIL     | FAIL | PASS |
| 13   | 6.3.3 Peak Performance Test            | PASS     | PASS | NA   | PASS     | PASS | NA   |
| 14   | 6.4.1 Multiple STAs Performance Test   | PASS     | PASS | PASS | FAIL     | FAIL | PASS |
| 15   | 6.4.2 Multiple Assoc Stability Test    | PASS     | PASS | PASS | PASS     | PASS | FAIL |
| 16   | 6.4.3 Downlink MU-MIMO Test            | PASS     | PASS | PASS | NA       | NA   | NA   |
| 17   | 6.4.4 Multicast Test                   | PASS     | PASS | PASS | FAIL     | FAIL | FAIL |
| 18   | 6.4.5 Uplink MU-MIMO Test              | PASS     | PASS | FAIL | NA       | NA   | NA   |
| 19   | 6.5.1 Long Term Stability Test         | PASS     | PASS | PASS | PASS     | PASS | PASS |
| 20   | 6.5.2 AP Coexistence Test              | PASS     | PASS | PASS | PASS     | PASS | FAIL |
| 21   | 6.5.3 Automatic Channel Selection Test | PASS     | PASS | PASS | FAIL     | PASS | PASS |
| 22   | 6.5.5 Puncturing Test                  | NA       | NA   | NA   | NA       | NA   | NA   |
| 23   | 6.5.6 MLO 2-Channel Test               | NA       | PASS | PASS | NA       | PASS | PASS |

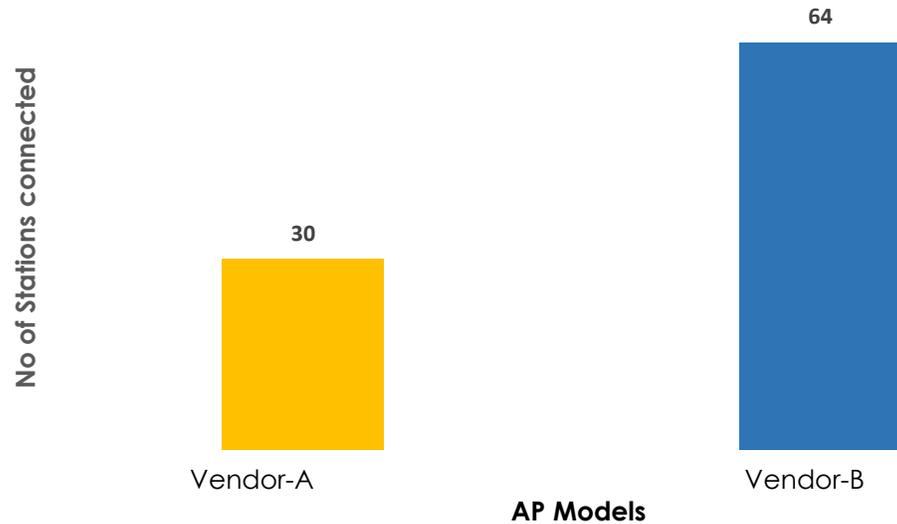
# Real Device Testing Summary



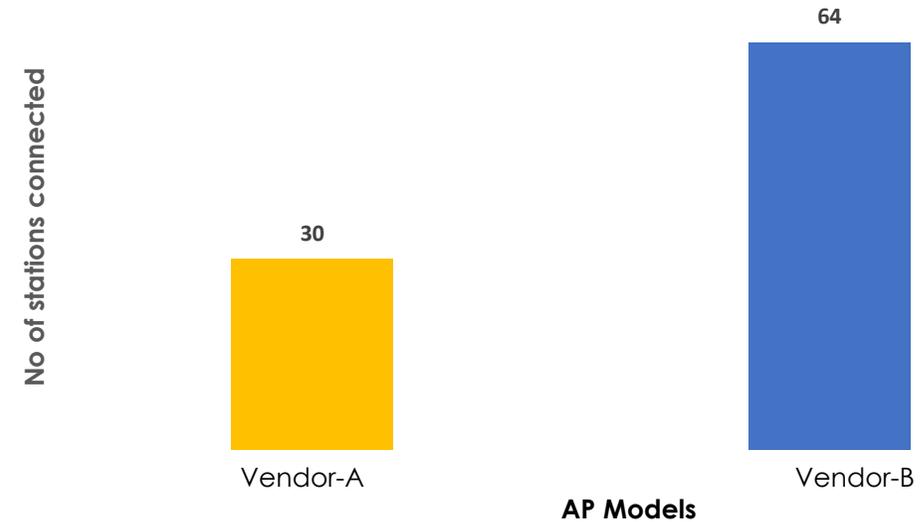
| Test Name              | VENDOR-A  | VENDOR-B  |
|------------------------|-----------|-----------|
| Throughput Test        | Excellent | Good      |
| Interoperability Test  | Excellent | Good      |
| QoS Test               | Excellent | Good      |
| Multicast Test         | Excellent | Good      |
| Ping Plotter Test      | Excellent | Good      |
| Port Reset Test        | Good      | Good      |
| FTP Test               | Good      | Excellent |
| HTTP Test              | Good      | Excellent |
| Video Streaming        | Excellent | Good      |
| Real Browser Test      | Excellent | Good      |
| YouTube Streaming Test | Good      | Good      |
| Zoom Call Test         | Excellent | Good      |
| Mixed Traffic Test     | Good      | Good      |

# Basic Client Connectivity

### Client Connectivity on 2.4 GHz band



### Client Connectivity on 5 GHz Band



## Test Description:

- DUT in ideal test conditions. No interfering APs and a good signal to the stations.
- All 2.4 GHz clients are connected in 3\*3 with ax mode.
- All the 5 GHz clients are connected in 4\*4 with ax mode.

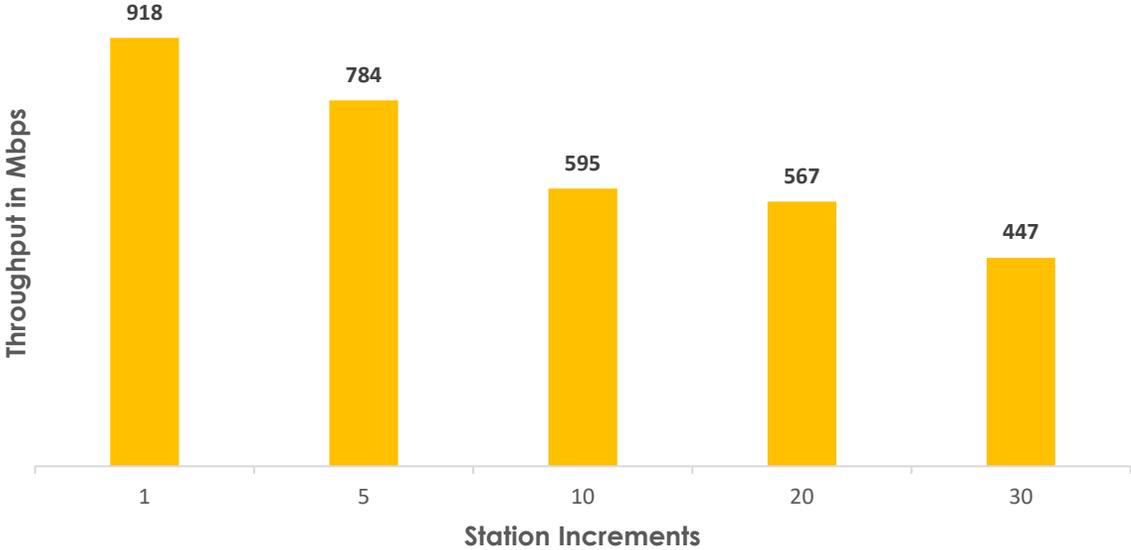
## Results Observations:

- In both bands, more clients are connecting to Vendor-B.

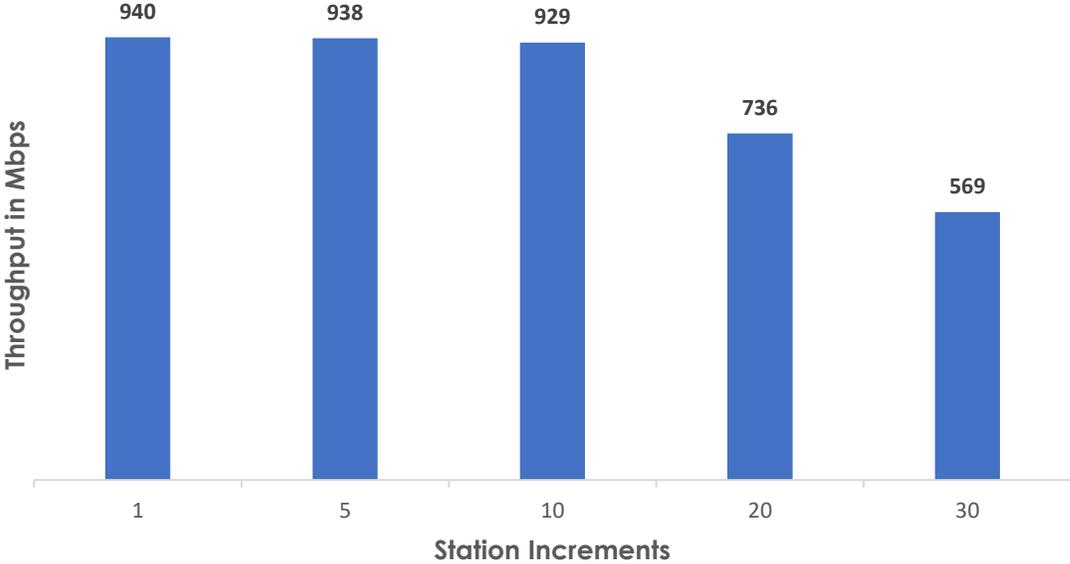
# Client Capacity – 5 GHz TCP UL



Vendor-A



Vendor-B



### Test Description:

- DUT in ideal test conditions. No interfering APs and a good signal to the stations
- Intended load set to 1 Gbps rate for 4NSS, 80MHz BW
- Test run for 60 sec trials for different station increments with upstream, TCP traffic.
- DUT-TX is from AP to Client and DUT-Rx is from Client to AP.
- Throughput test run in 5GHz on channel 36

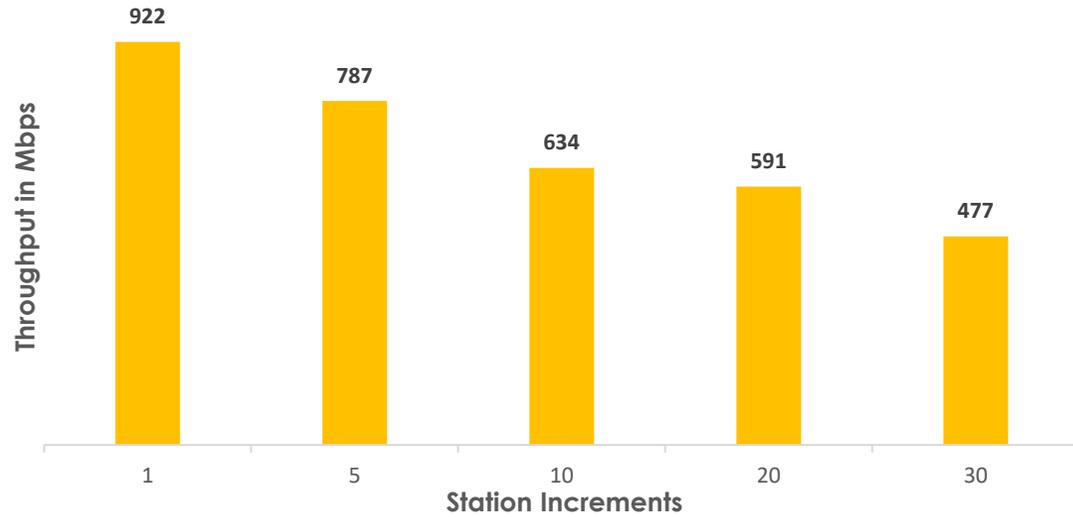
### Results Observations:

- Vendor B AP, good achieved throughput for single station and increments as well

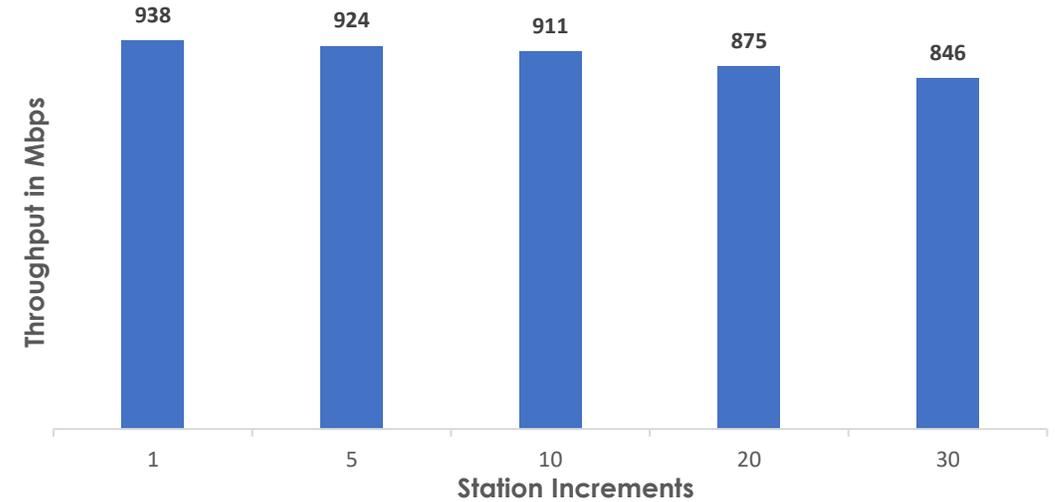
# Client Capacity – 5 GHz TCP DL



Vendor-A



Vendor-B



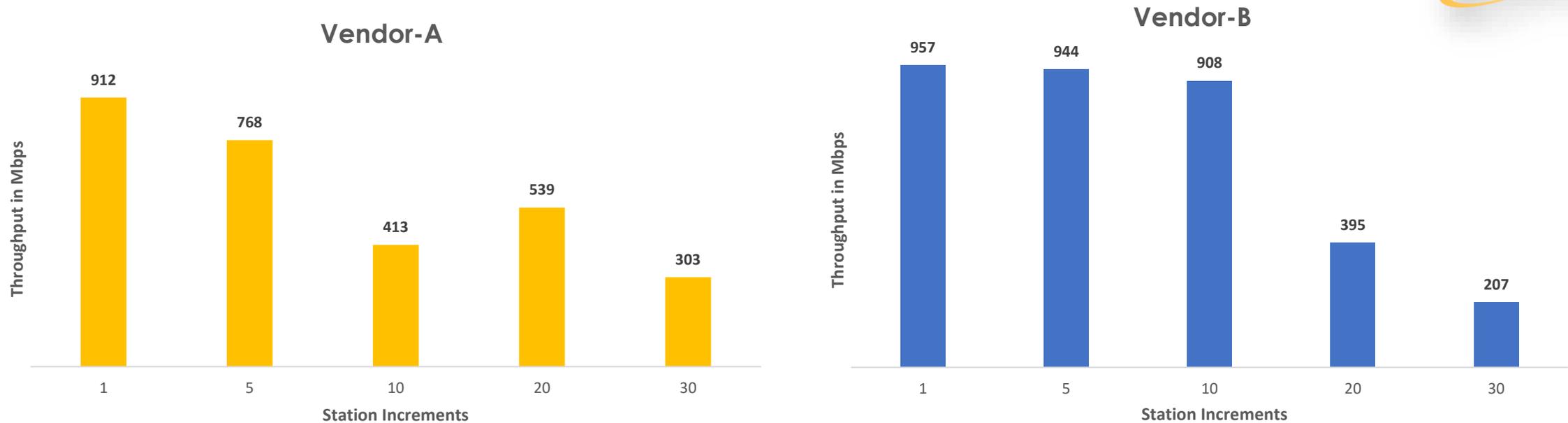
## Test Description:

- DUT in ideal test conditions. No interfering APs and a good signal to the stations
- Intended load set to 1 Gbps rate for 4NSS, 80MHz BW
- Test run for 60 sec trials for different station increments with downstream, TCP traffic.
- DUT-TX is from AP to Client and DUT-Rx is from Client to AP.
- Throughput test run in 5GHz on channel 36

## Results Observations:

- Vendor B AP, good achieved throughput for single station and increments as well

# Client Capacity – 5 GHz UDP UL



## Test Description:

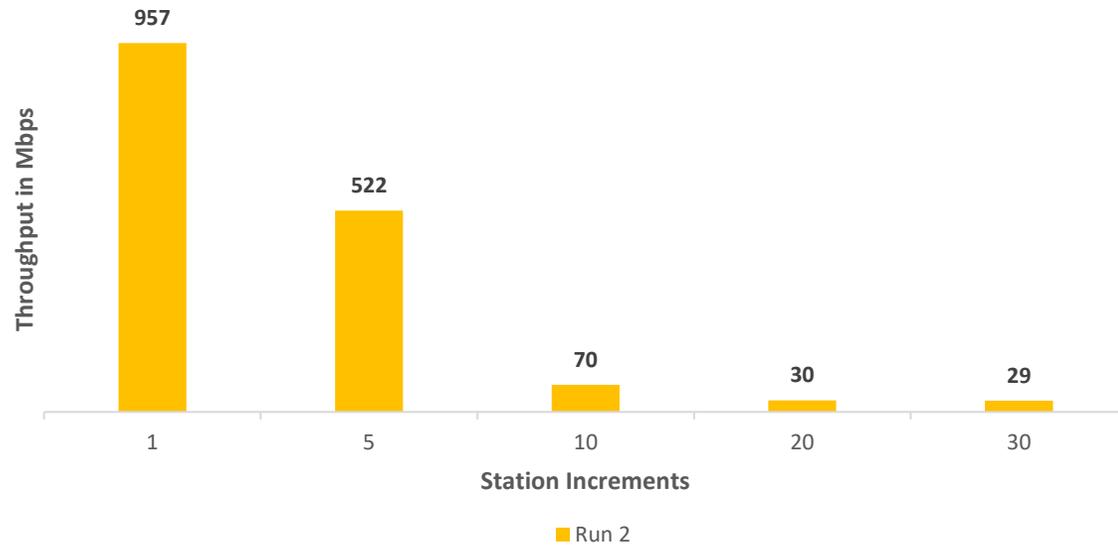
- DUT in ideal test conditions. No interfering APs and a good signal to the stations
- Intended load set to 1 Gbps rate for 4NSS, 80Mhz BW
- Test run for 60 sec trials for different station increments with upstream, UDP traffic.
- DUT-TX is from AP to Client and DUT-Rx is from Client to AP.
- Throughput test run in 5GHz on channel 36

## Results Observations:

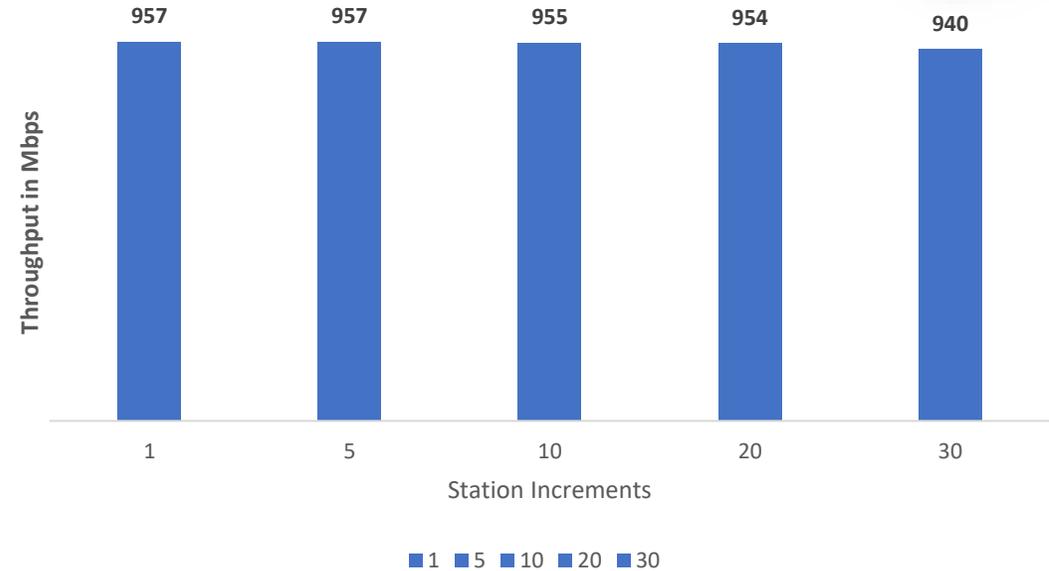
- Vendor B AP, good achieved throughput for single station and increments as well.
- Conflict at the point of 30 clients.

# Client Capacity – 5 GHz UDP DL

## Vendor-A



## Vendor-B



### Test Description:

- DUT in ideal test conditions. No interfering APs and a good signal to the stations
- Intended load set to 1 Gbps rate for 4NSS, 80Mhz BW
- Test run for 60 sec trials for different station increments with downstream, UDP traffic.
- DUT-TX is from AP to Client and DUT-Rx is from Client to AP.
- Throughput test run in 5GHz on channel 36

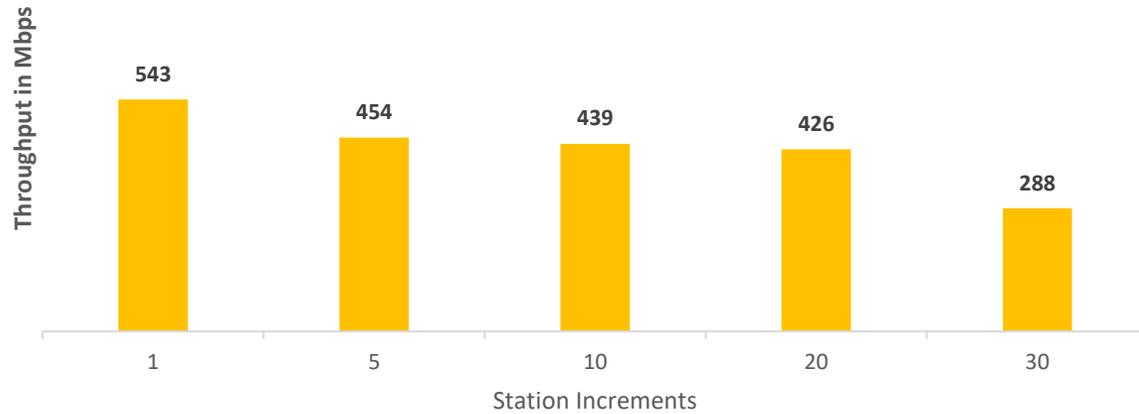
### Results Observations:

- Vendor B AP, good achieved throughput for single station and increments as well

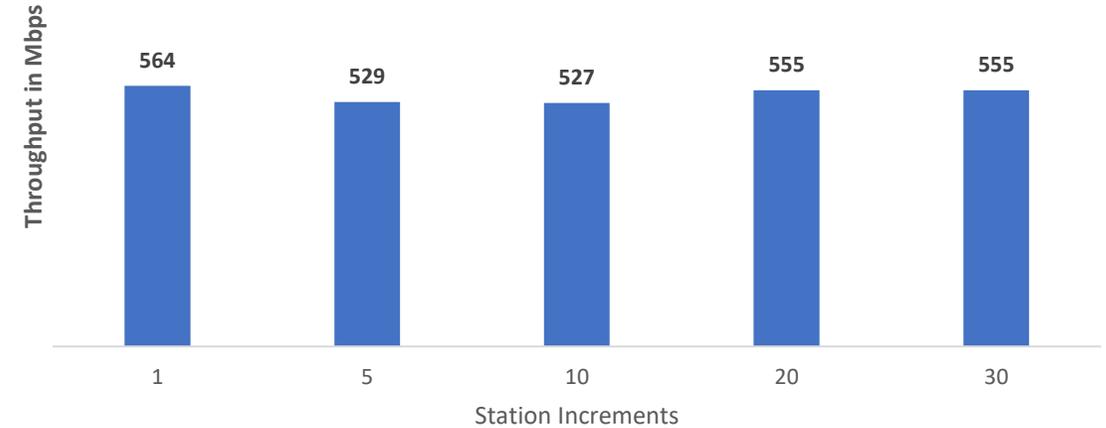
# Client capacity- 2.4GHz TCP-UL



## Vendor-A



## Vendor B



### Test Description:

- DUT in ideal test conditions. No interfering APs and a good signal to the stations
- Intended load set to 1 Gbps rate for 3NSS, 40Mhz BW
- Test run for 60 sec trials for different station increments with upstream, TCP traffic.
- DUT-TX is from AP to Client and DUT-Rx is from Client to AP.
- Throughput test run in 2.4GHz on channel 1

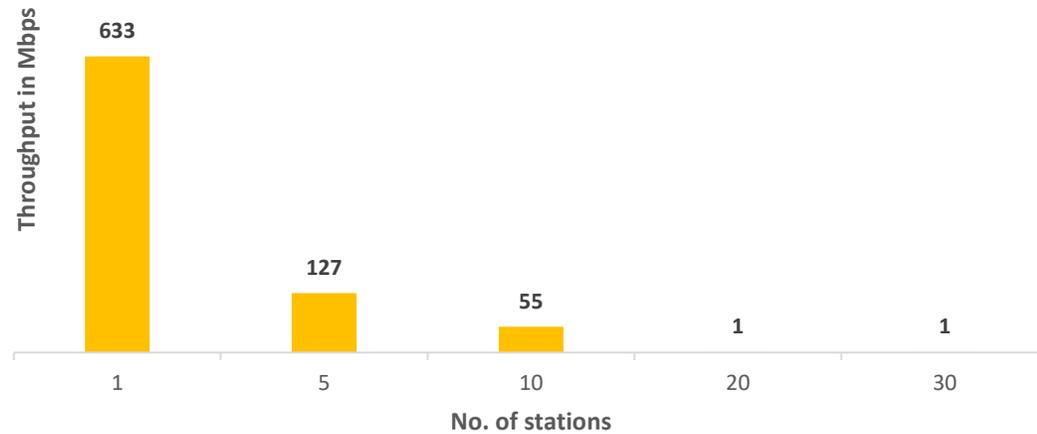
### Results Observations:

- Vendor B AP, good achieved throughput for single station and increments as well

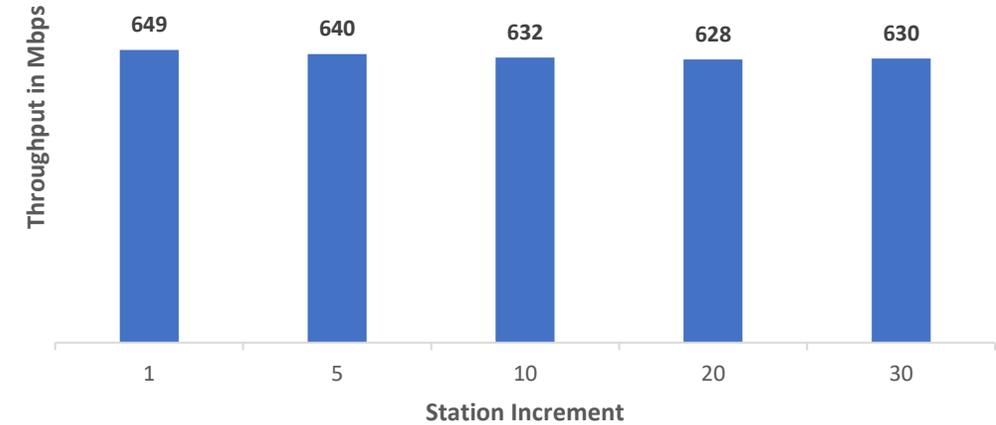
# Client capacity- 2.4GHz TCP-DL



## Vendor-A



## Vendor B



### Test Description:

- DUT in ideal test conditions. No interfering APs and a good signal to the stations
- Intended load set to 1 Gbps rate for 3NSS, 40Mhz BW
- Test run for 60 sec trials for different station increments with downstream, TCP traffic.
- DUT-TX is from AP to Client and DUT-Rx is from Client to AP.
- Throughput test run in 2.4GHz on channel 1

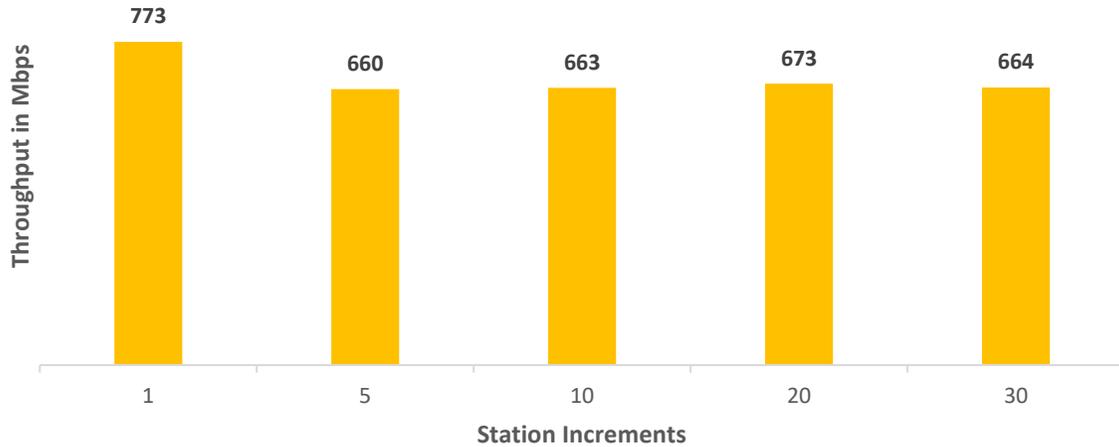
### Results Observations:

- Vendor B AP, good achieved throughput for single station and increments as well

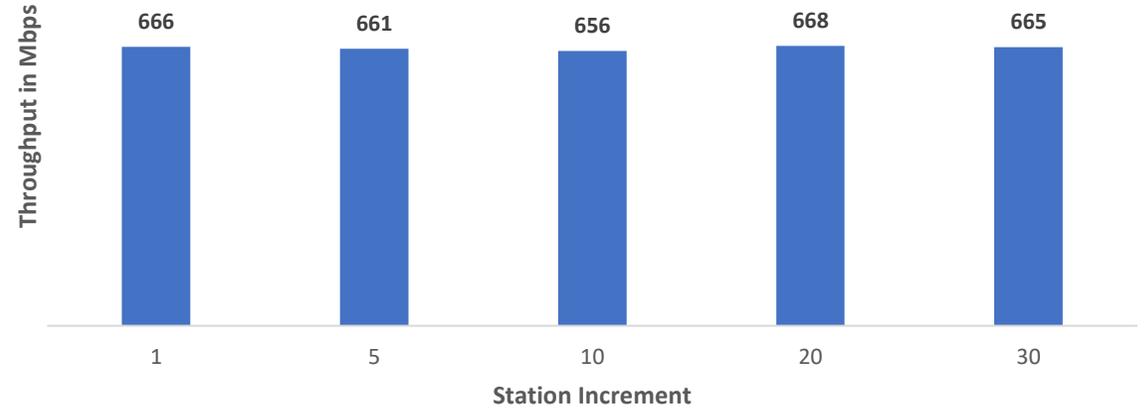
# Client capacity- 2.4GHz UDP-UL



## Vendor-A



## Vendor B



### Test Description:

- DUT in ideal test conditions. No interfering APs and a good signal to the stations
- Intended load set to 1 Gbps rate for 3NSS, 40MHz BW
- Test run for 60 sec trials for different station increments with upstream, UDP traffic.
- DUT-TX is from AP to Client and DUT-Rx is from Client to AP.
- Throughput test run in 2.4GHz on channel 1

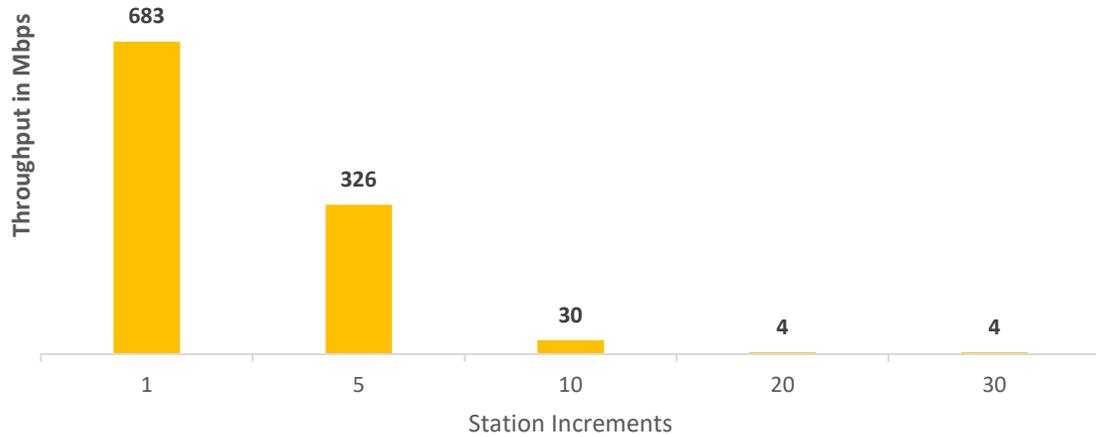
### Results Observations:

- Vendor-A, good achieved throughput for single station and increments as well
- Conflict by means of increase in throughput as the stations increase.

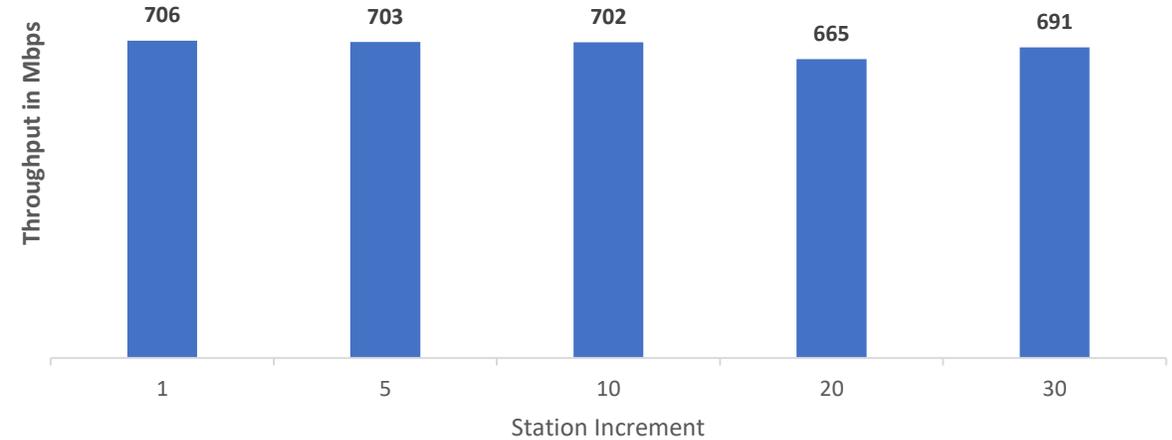
# Client capacity- 2.4GHz UDP-DL



### Vendor-A



### Vendor B



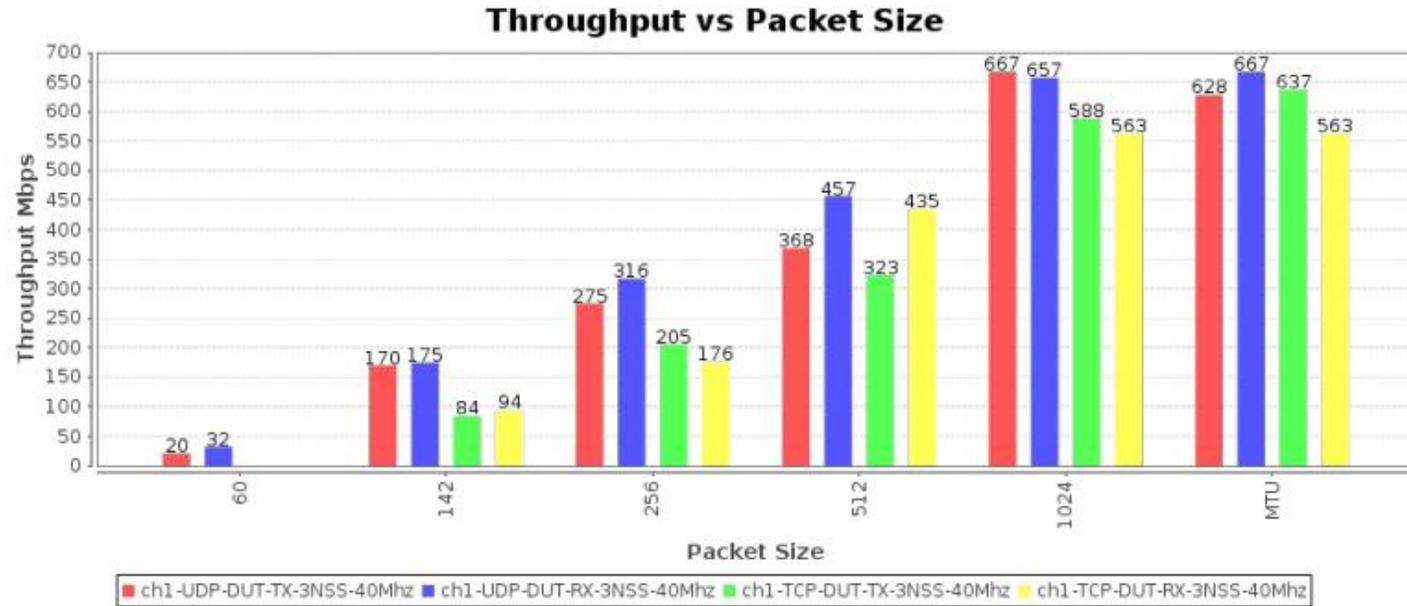
## Test Description:

- DUT in ideal test conditions. No interfering APs and a good signal to the stations
- Intended load set to 1 Gbps rate for 3NSS, 40Mhz BW
- Test run for 60 sec trials for different station increments with downstream, TCP traffic.
- DUT-TX is from AP to Client and DUT-Rx is from Client to AP.
- Throughput test run in 2.4GHz on channel 1

## Results Observations:

- Vendor B AP, good achieved throughput for single station and increments as well

# Data-Plane test 2.4GHz



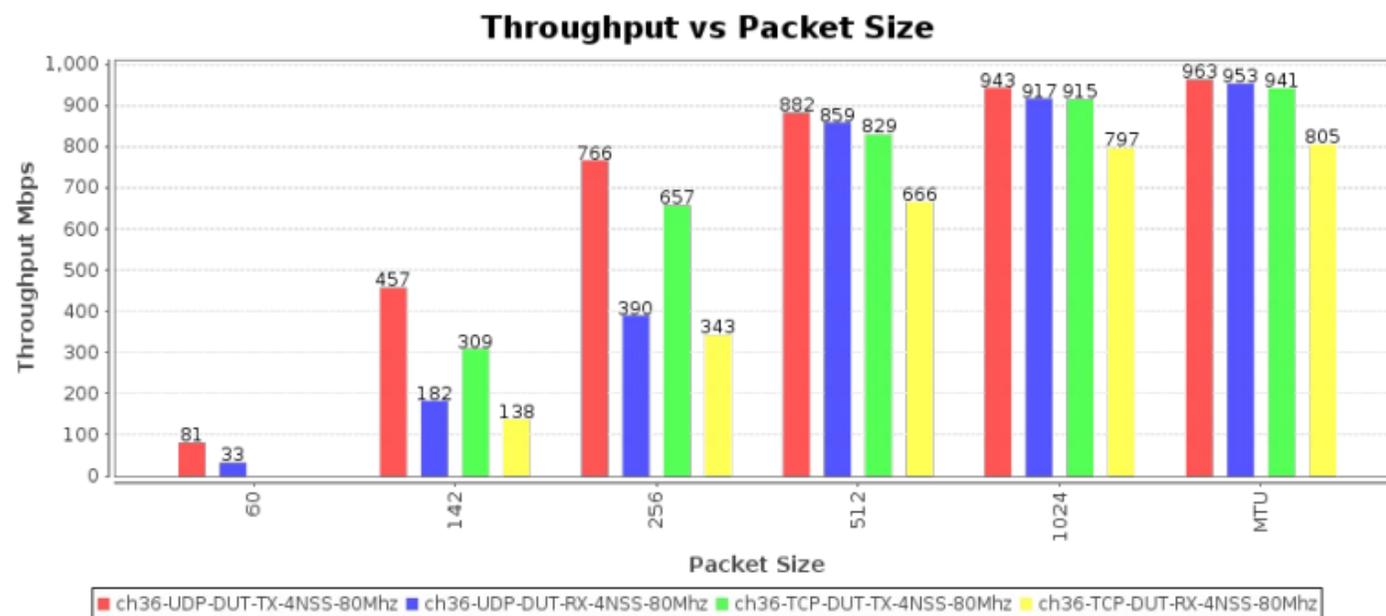
## Test Description:

- In this scenario, the throughput is calculated by means of various kinds of packet sizes.
- Here we create a single client and check what is the maximum throughput at each point.
- Test run for 60 sec trials for different station increments with downstream and upstream traffic.
- DUT-TX is from AP to Client and DUT-Rx is from Client to AP.
- Throughput test run in 2.4GHz on channel 1, 3NSS.

## Results Observations:

- Vendor-A, is performing good at the data-plane test but is relatively not as per MCS index.

# Data-Plane test 5GHz



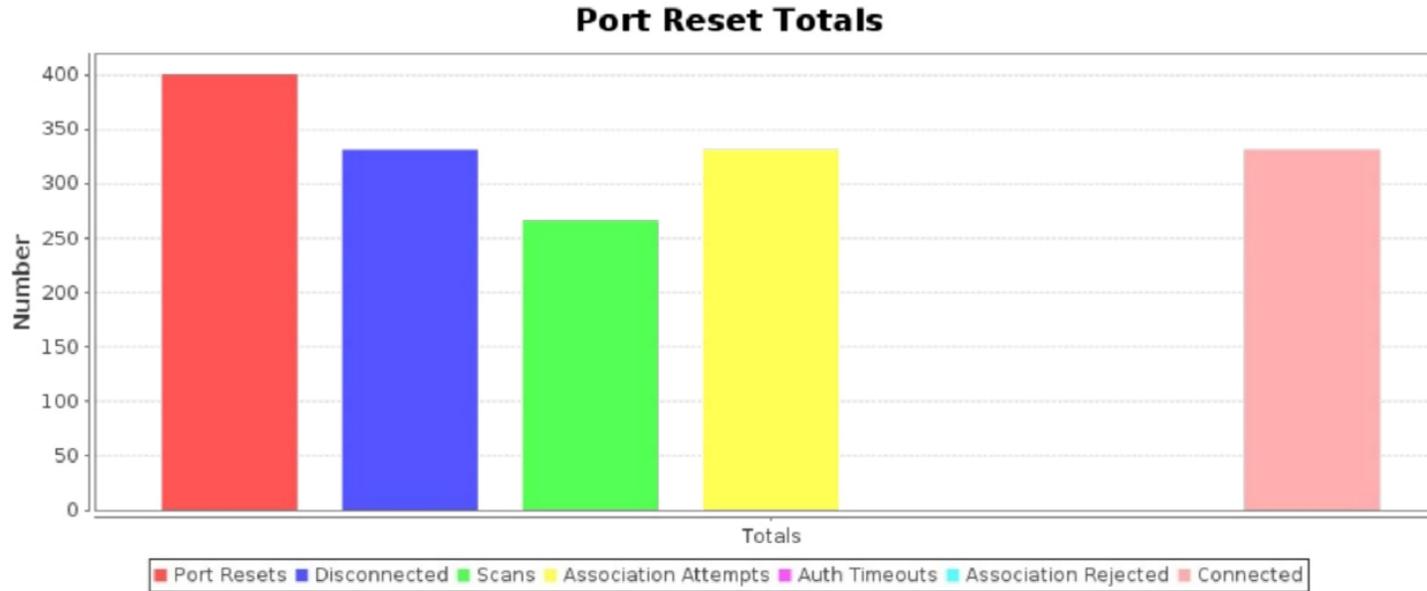
## Test Description:

- In this scenario, the throughput is calculated by means of various kinds of packet sizes.
- Here we create a single client and check what is the maximum throughput at each point.
- Test run for 60 sec trials for different station increments with downstream and upstream traffic.
- DUT-TX is from AP to Client and DUT-Rx is from Client to AP.
- Throughput test run in 5GHz on channel 36, 4NSS.

## Results Observations:

- Vendor-A, is performing good at the data-plane test but is relatively not as per MCS index.

# Port Reset-2.4GHz



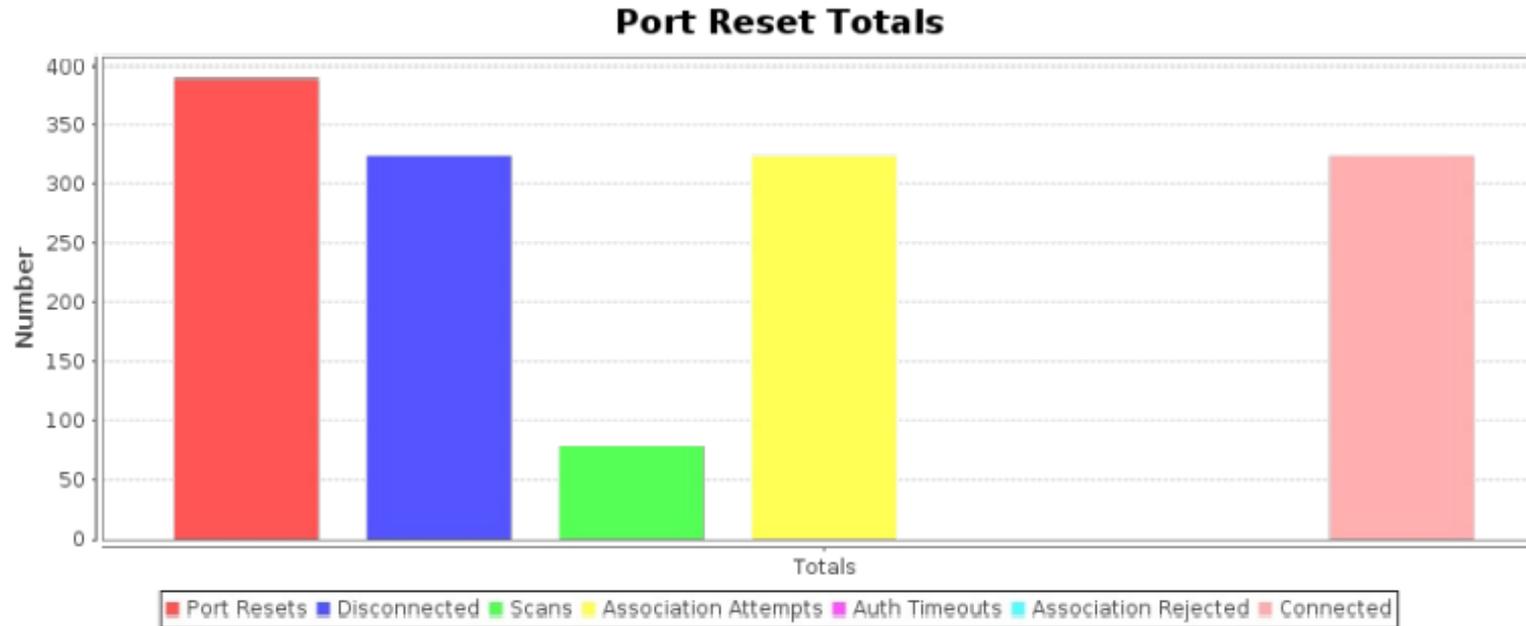
## Test Description:

- In this scenario, the port reset time and association time is calculated
- Here we create 30-clients and check what is the maximum rate of port reset at each point.
- Test run for 60 sec(min) and 120(max) trials for different port intervals.
- DUT-TX is from AP to Client and DUT-Rx is from Client to AP.
- Port reset test run in 2.4GHz on channel 1, 3NSS.

## Results Observations:

- Vendor-A, is following good port reset count for 30-clients in the span of 1 hour.

# Port Reset 5GHz



## Test Description:

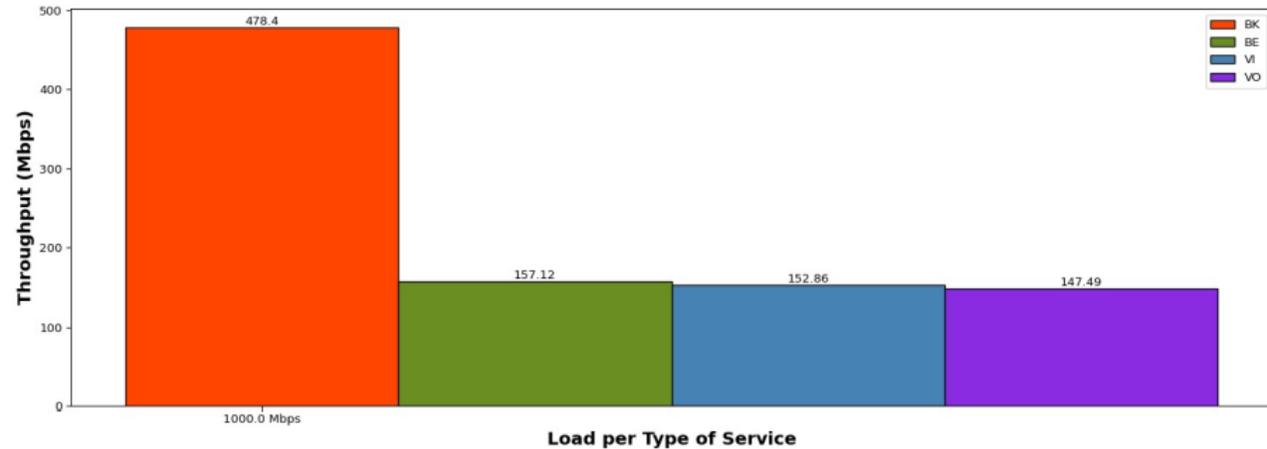
- In this scenario, the port reset time and association time is calculated
- Here we create 30-clients and check what is the maximum rate of port reset at each point.
- Test run for 60 sec(min) and 120(max) trials for different port intervals.
- DUT-TX is from AP to Client and DUT-Rx is from Client to AP.
- Port reset test run in 5GHz on channel 36, 4NSS.

## Results Observations:

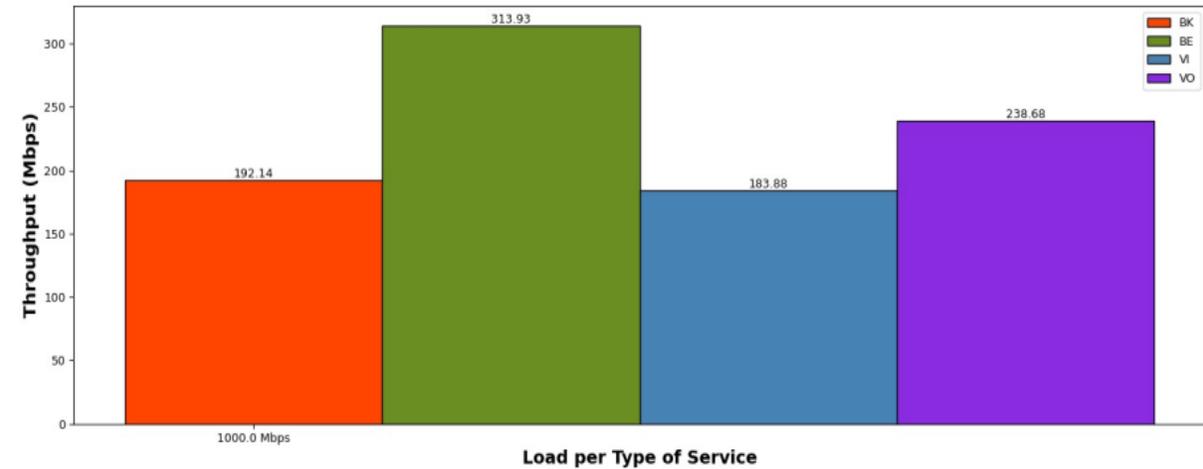
- Vendor-A, is following good port reset count for 30-clients in the span of 1 hour.

# Quality of Service for 5GHz 1-Client and 2-clients

Overall download throughput - BK, BE, VO, VI traffic streams



Overall download throughput - BK, BE, VO, VI traffic streams



## Test Description:

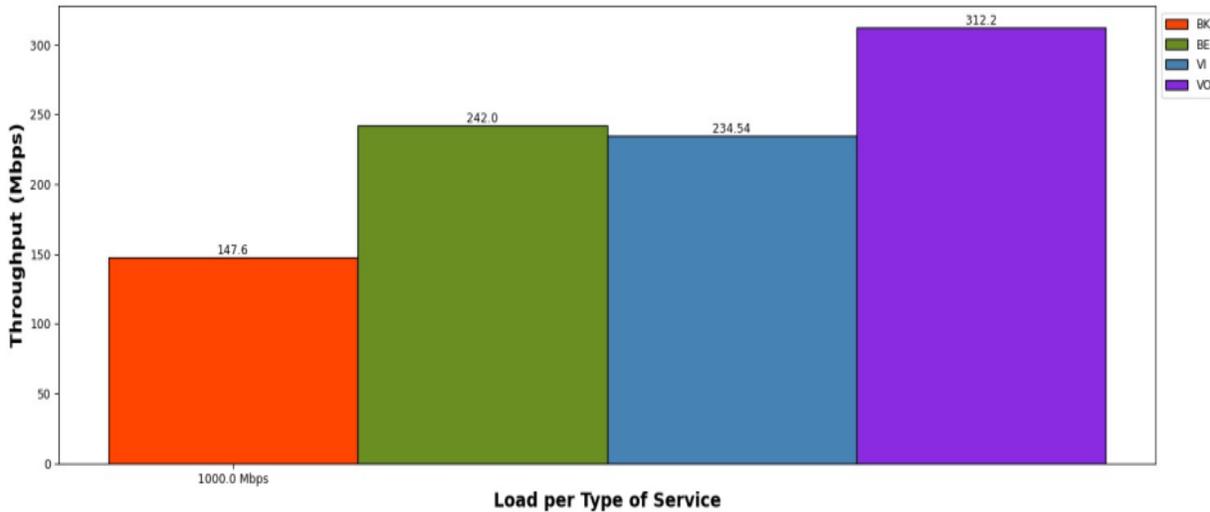
- In this scenario, the Quality of Service is observed by means of running various kinds of traffic:- VOICE, VIDEO, BACKEND, BEST EFFORT.
- Intended load set to 1 Gbps rate for 4NSS, 80MHz BW
- Test run for 60 sec trials for different station increments with downstream, QoS traffic.
- DUT-TX is from AP to Client and DUT-Rx is from Client to AP.
- Throughput test run in 5GHz on channel 36

## Results Observations:

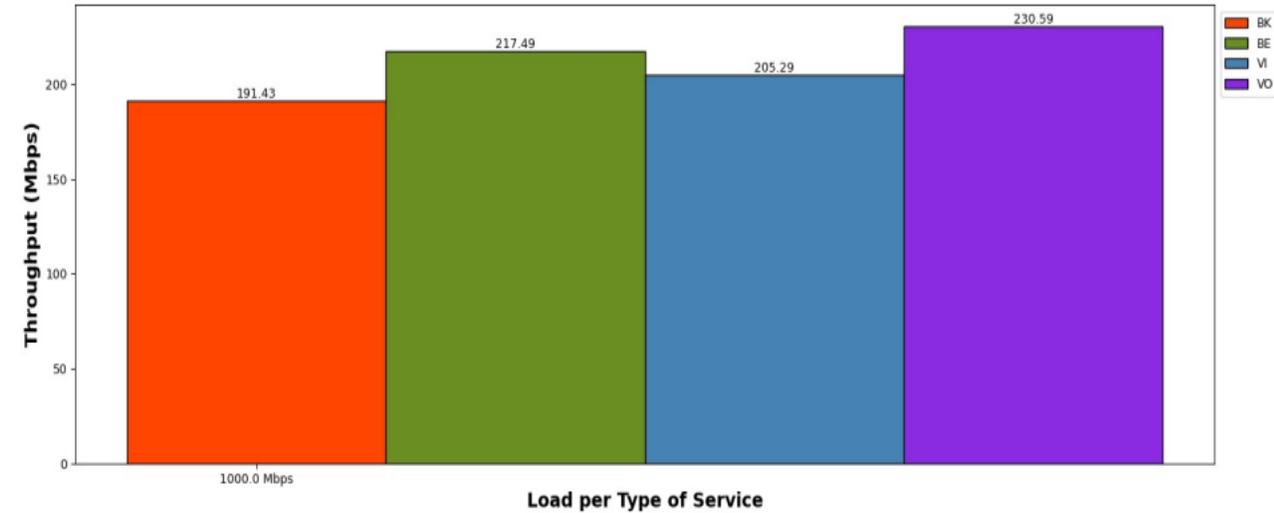
- Vendor-A, is not following the precedence of QoS for both 1-client and 2-clients.

# Quality of Service for 5GHz 5-Clients and 7-clients

Overall download throughput - BK, BE, VO, VI traffic streams



Overall download throughput - BK, BE, VO, VI traffic streams



## Test Description:

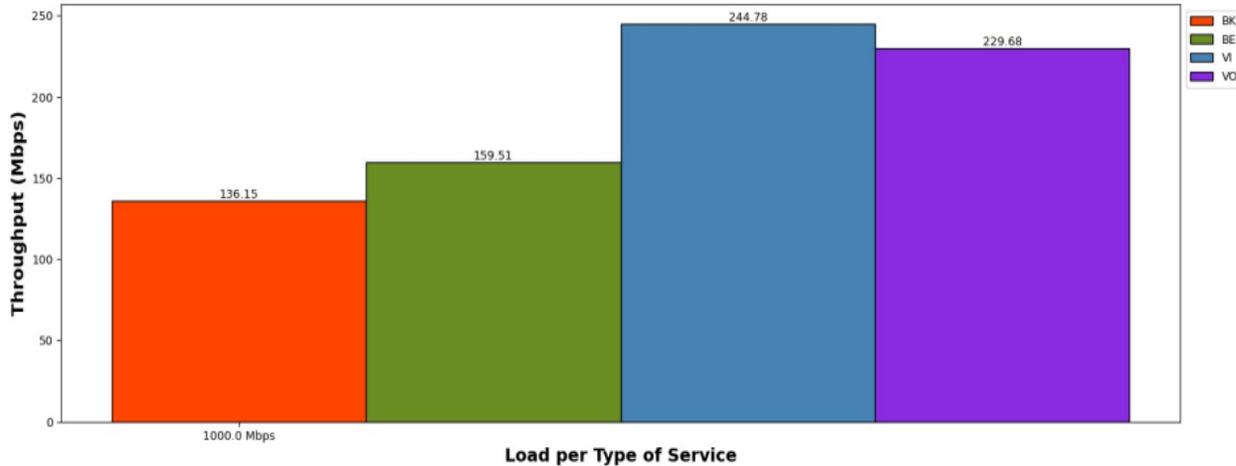
- In this scenario, the Quality of Service is observed by means of running various kinds of traffic:- VOICE, VIDEO, BACKEND, BEST EFFORT.
- Intended load set to 1 Gbps rate for 4NSS, 80MHz BW
- Test run for 60 sec trials for different station increments with downstream, QoS traffic.
- DUT-TX is from AP to Client and DUT-Rx is from Client to AP.
- Throughput test run in 5GHz on channel 36

## Results Observations:

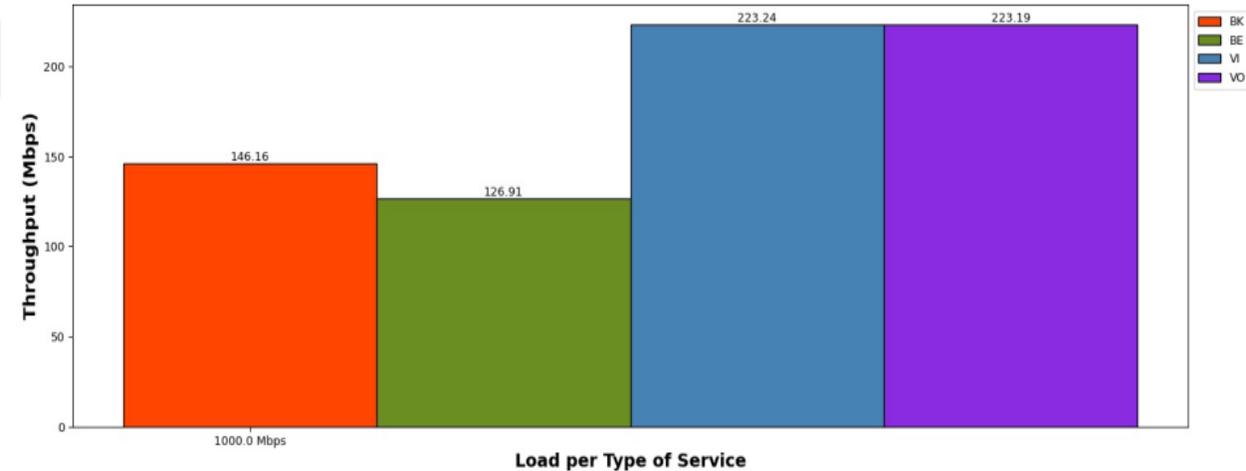
- Vendor-A, is not following the precedence of QoS for both 5-client and 7-clients.

# Quality of Service for 5GHz 10-Clients and 15-clients

Overall download throughput - BK,BE,VO,VI traffic streams



Overall download throughput - BK,BE,VO,VI traffic streams



## Test Description:

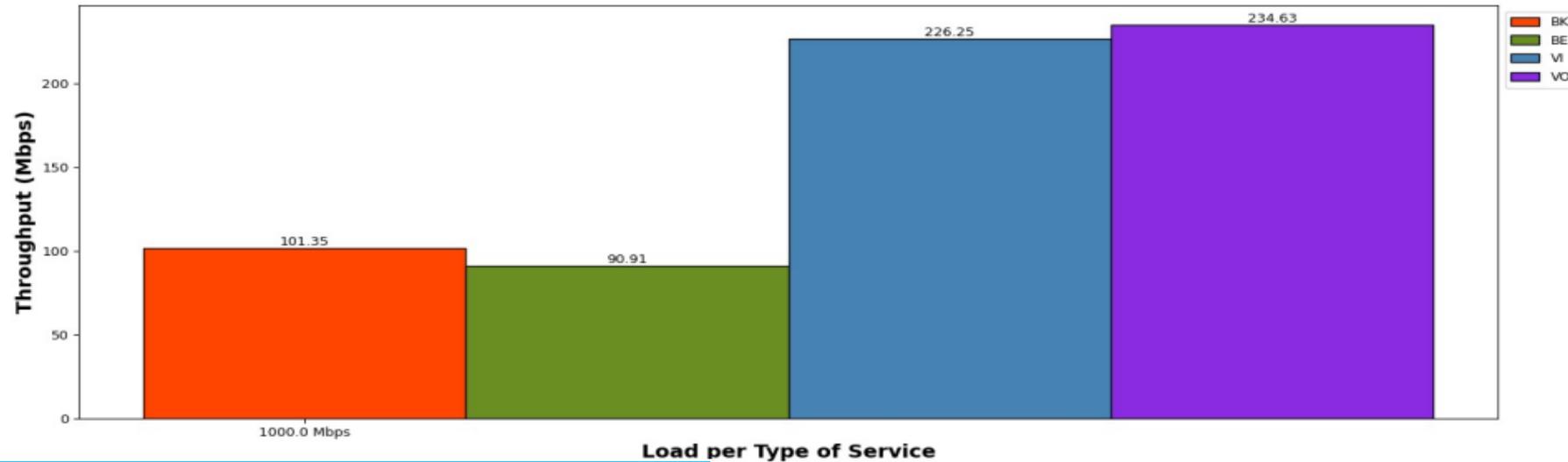
- In this scenario, the Quality of Service is observed by means of running various kinds of traffic:- VOICE,VIDEO,BACKEND,BEST EFFORT.
- Intended load set to 1 Gbps rate for 4NSS, 80MHz BW
- Test run for 60 sec trials for different station increments with downstream, QoS traffic.
- DUT-TX is from AP to Client and DUT-Rx is from Client to AP.
- Throughput test run in 5GHz on channel 36

## Results Observations:

- Vendor-A, is not following the precedence of QoS for 10-clients and is following for 15-clients.

# Quality of Service for 5GHz 19-clients

Overall download throughput - BK, BE, VO, VI traffic streams



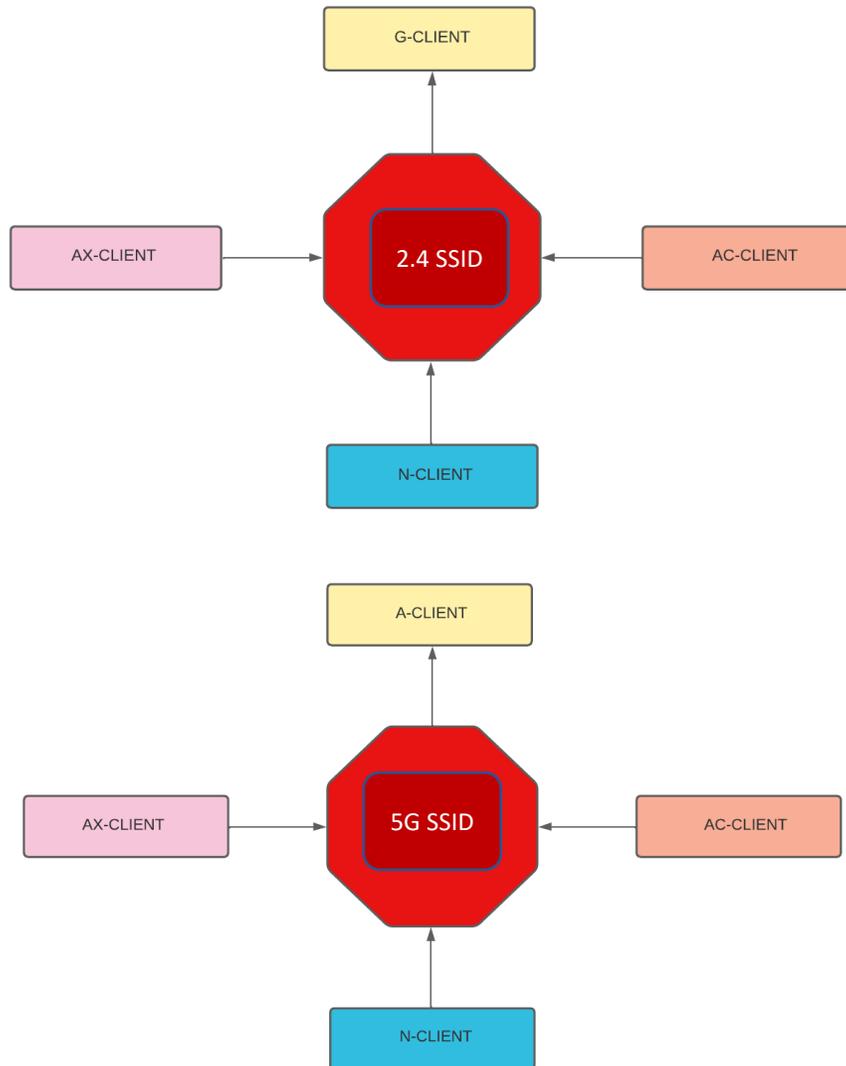
## Test Description:

- In this scenario, the Quality of Service is observed by means of running various kinds of traffic:- VOICE, VIDEO, BACKEND, BEST EFFORT.
- Intended load set to 1 Gbps rate for 4NSS, 80MHz BW
- Test run for 60 sec trials for different station increments with downstream, QoS traffic.
- DUT-TX is from AP to Client and DUT-Rx is from Client to AP.
- Throughput test run in 5GHz on channel 36

## Results Observations:

- Vendor-A, is following the precedence of QoS for 19-clients.

# Airtime Fairness testing:



## Test procedure for Airtime fairness test:

- In this testcase we create 4 different kind of clients, and connect them to the Vendor-A at the same time.
- We set the maximum traffic as 1Gbps, and run the traffic together for all the 4 clients.
- We also consider the network time as a constraint and monitor the throughput difference when Airtime Fairness is enabled.
- Airtime fairness can be observed only in the downlink traffic.

# Airtime Fairness : TCP-DL[2.4GHz]

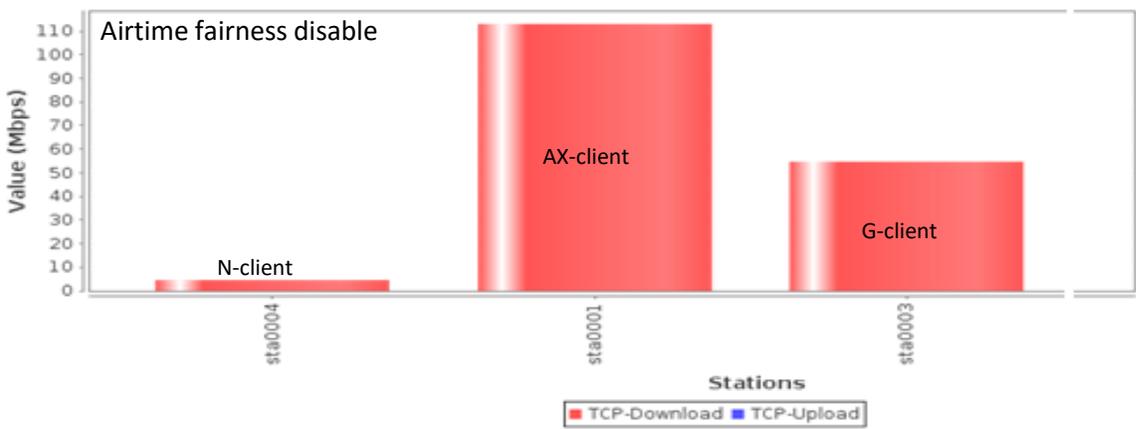
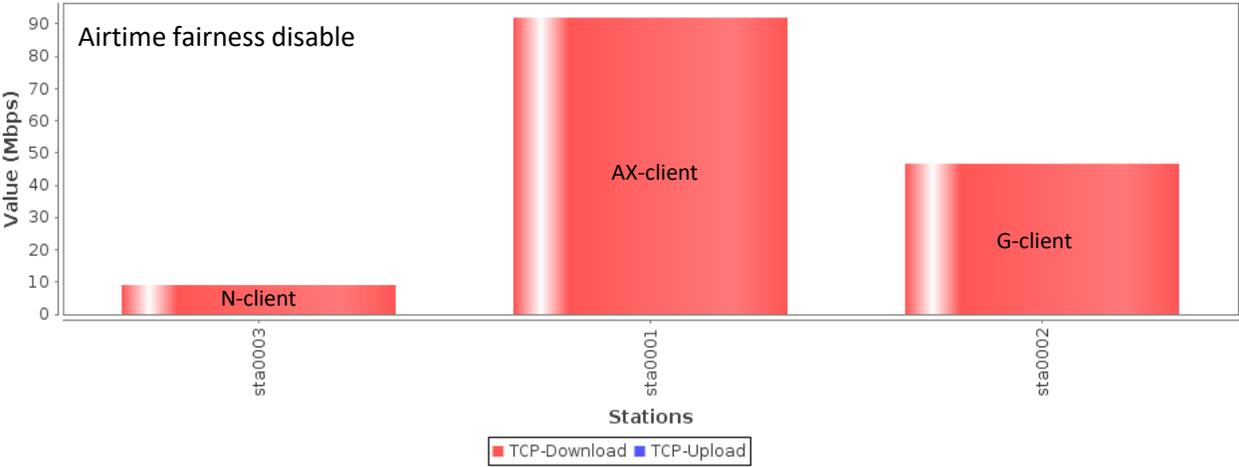


## Vendor-A

## Vendor-B

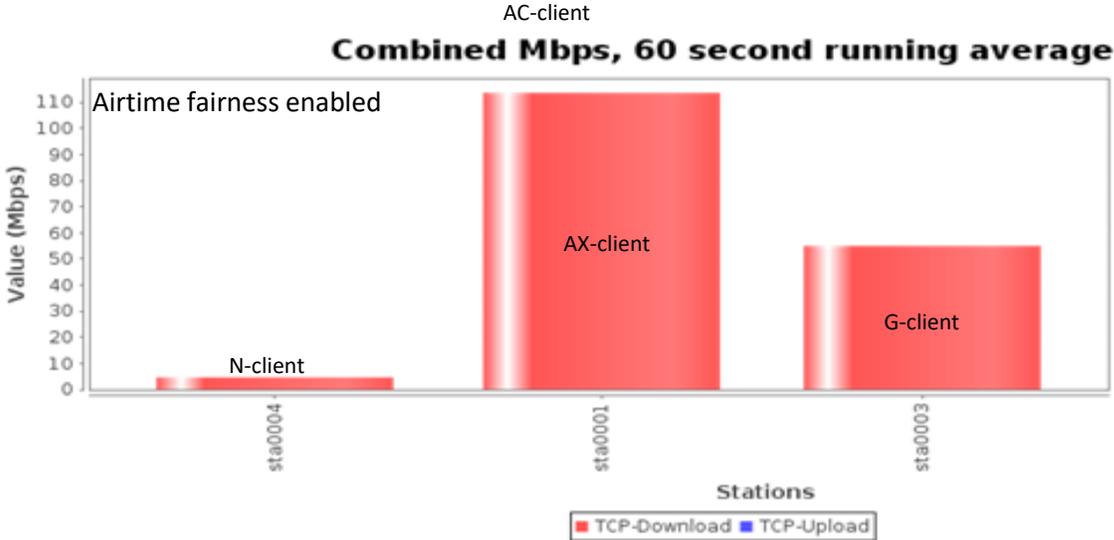
Combined Mbps, 60 second running average

Combined Mbps, 60 second running average



Combined Mbps, 60 second running average

Combined Mbps, 60 second running average

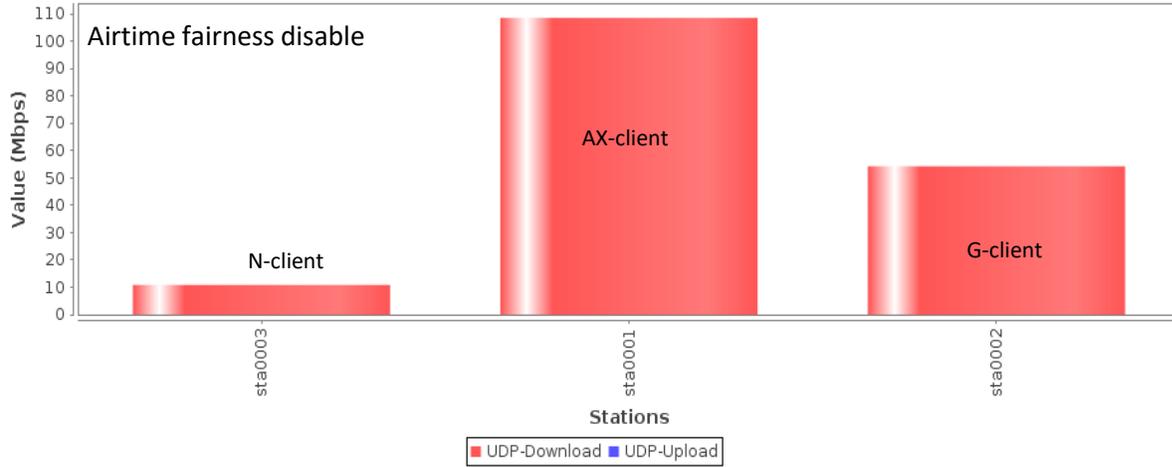


# Airtime Fairness : UDP-DL[2.4GHz]



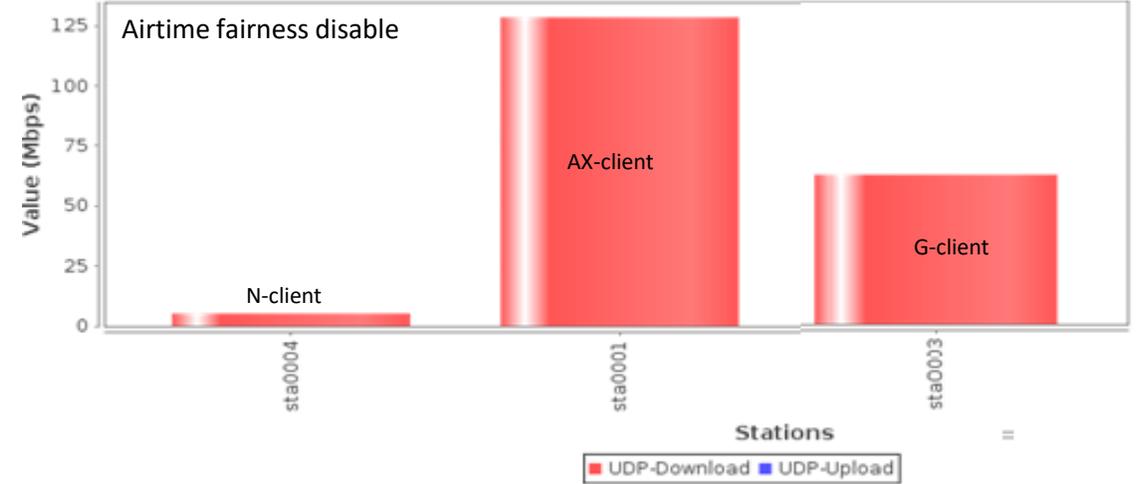
## Vendor-A

Combined Mbps, 60 second running average

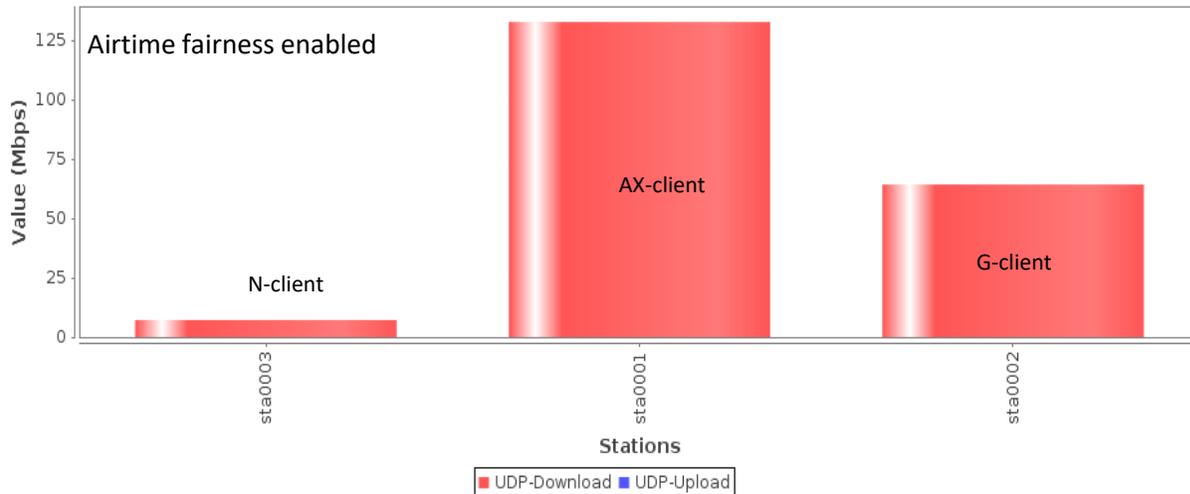


## Vendor-B

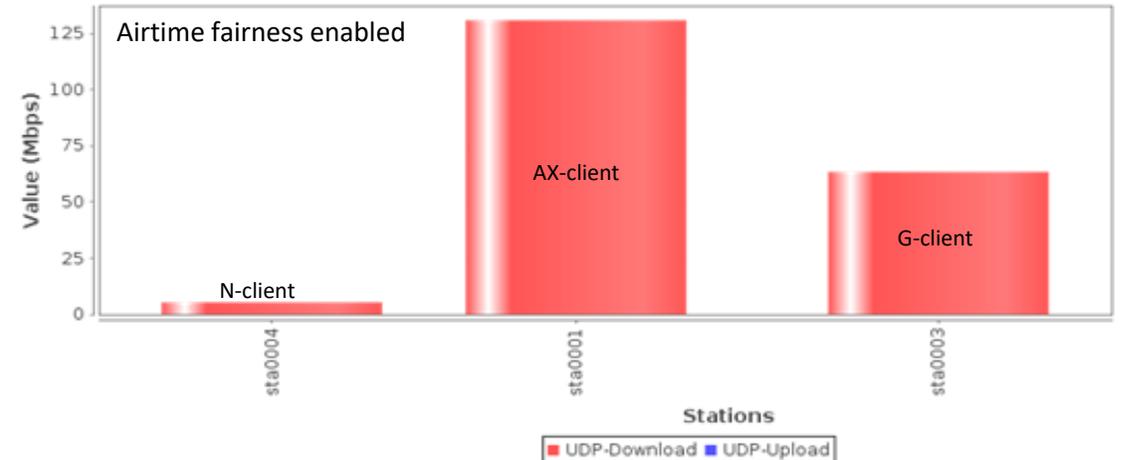
Combined Mbps, 60 second running average



Combined Mbps, 60 second running average



Combined Mbps, 60 second running average



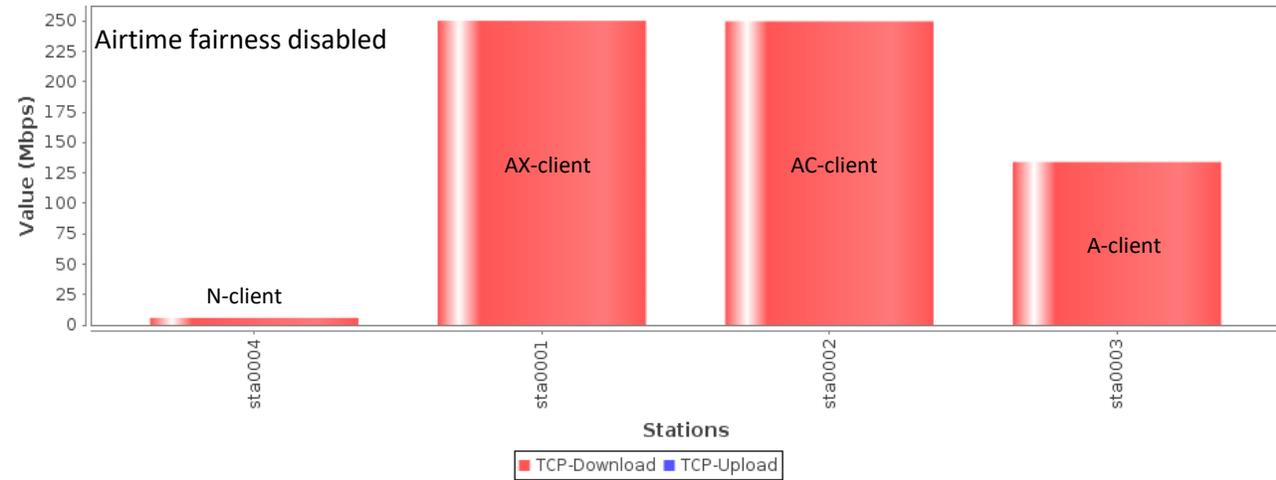
# Airtime Fairness : TCP-DL[5GHz]



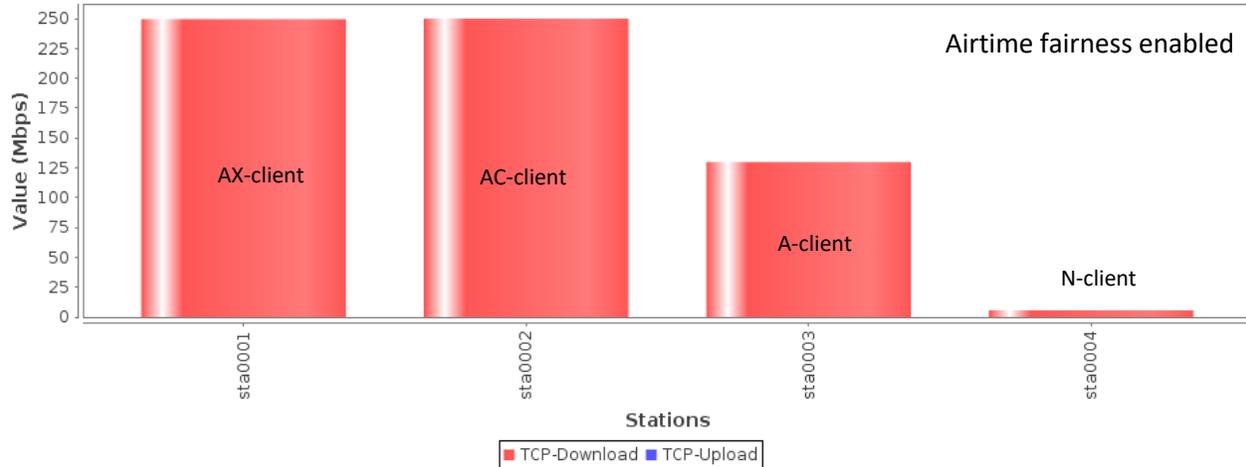
Combined Mbps, 60 second running average



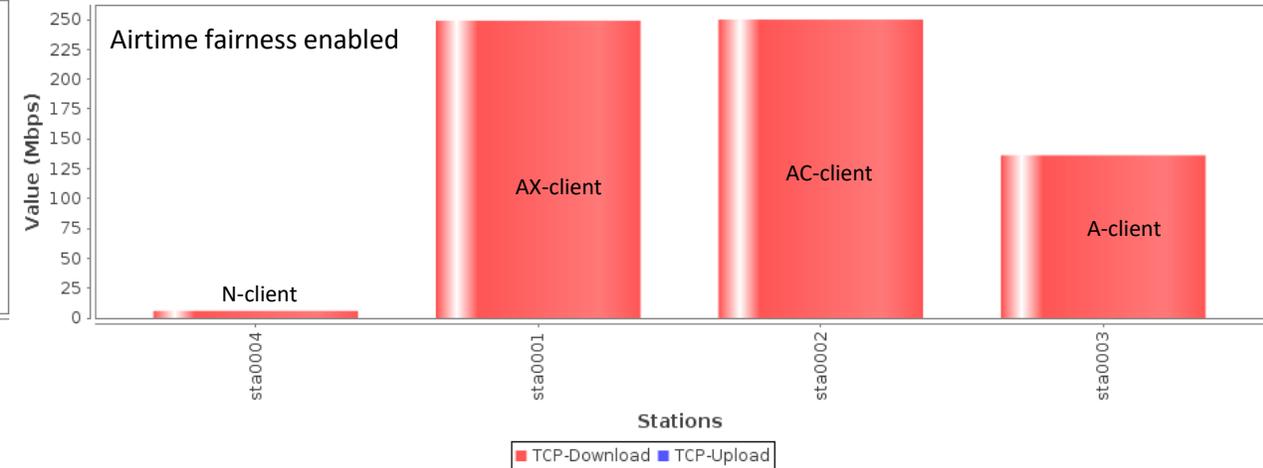
Combined Mbps, 60 second running average



Combined Mbps, 60 second running average



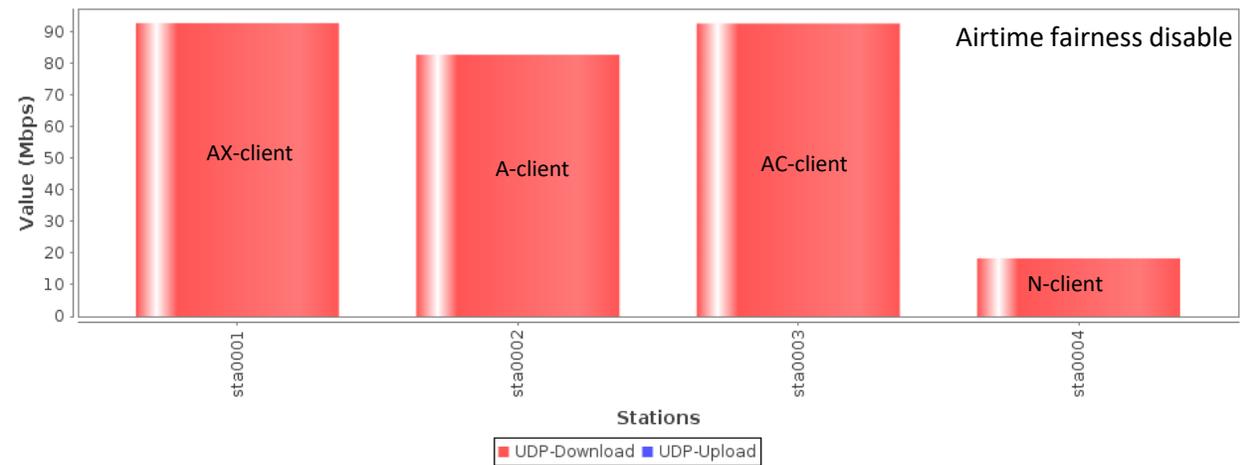
Combined Mbps, 60 second running average



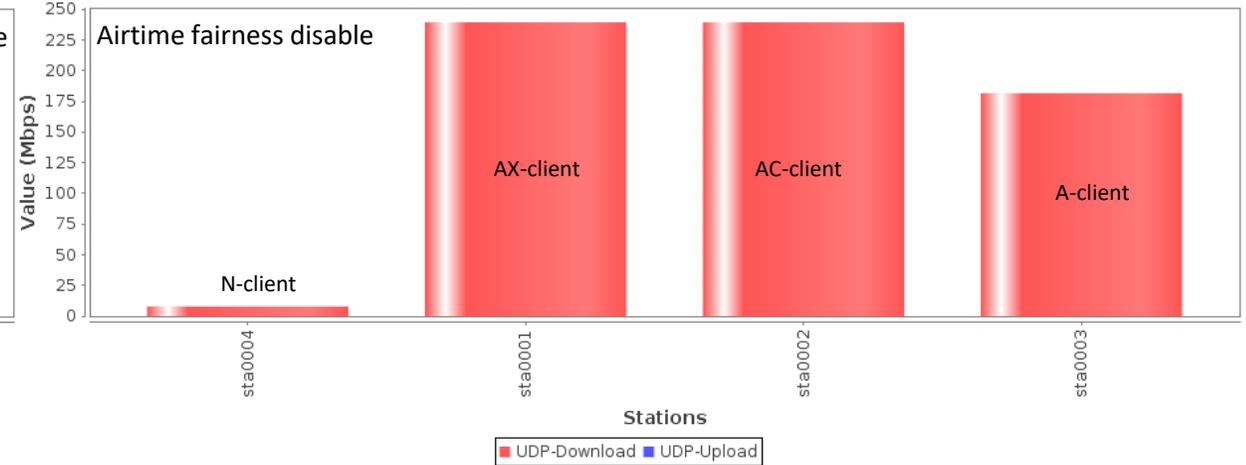
# Airtime Fairness : UDP-DL[5GHz]



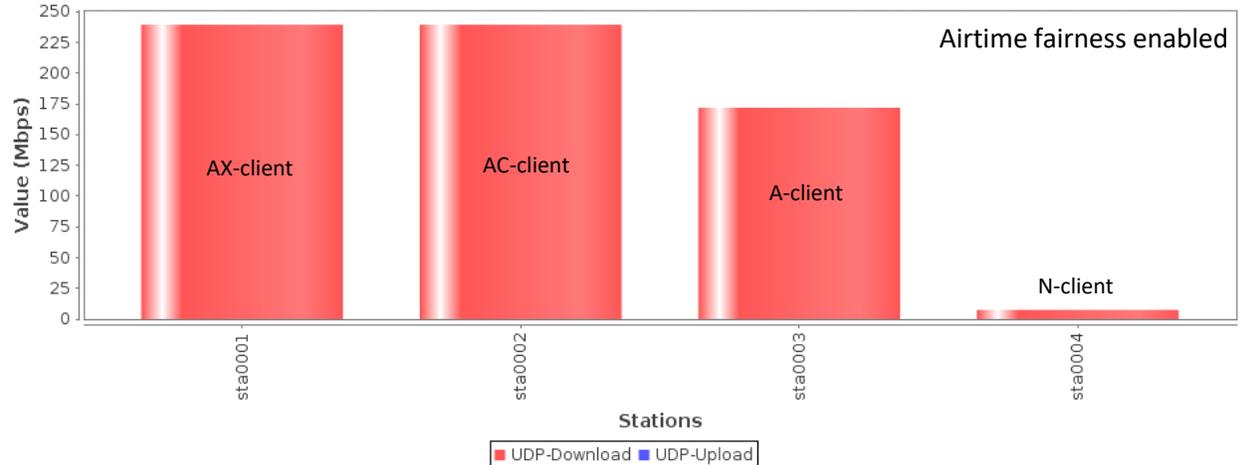
Combined Mbps, 60 second running average



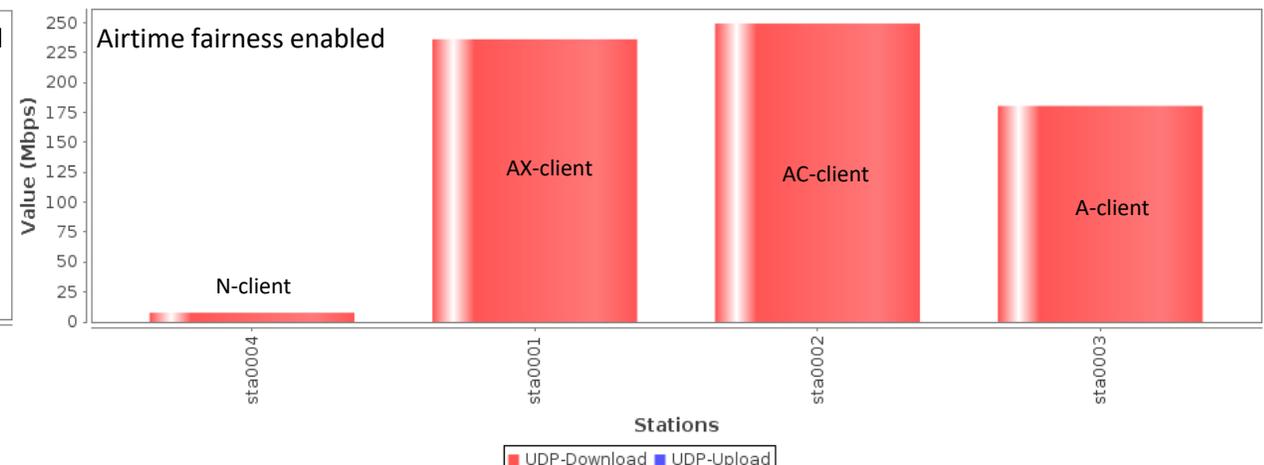
Combined Mbps, 60 second running average



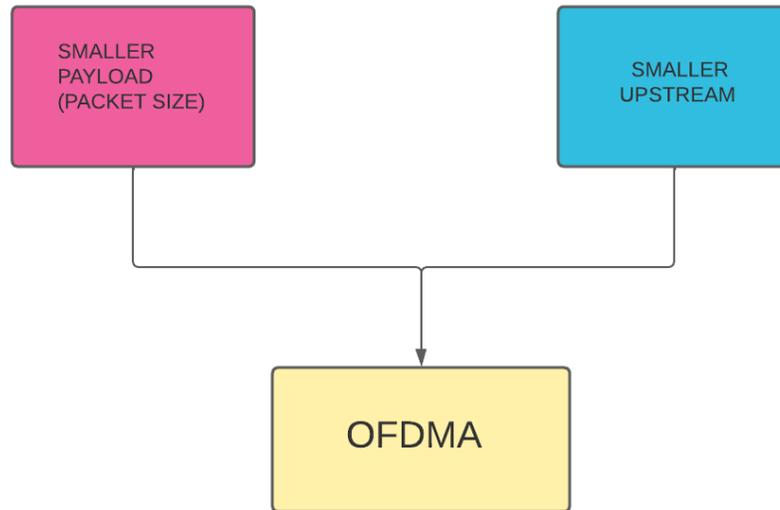
Combined Mbps, 60 second running average



Combined Mbps, 60 second running average



# OFDMA testing:



## TEST PROCEDURE for OFDMA(Orthogonal Frequency Division Multiple Access):

- It works only for 802.11ax clients.
- We have fixed the packet size to 64 bytes, and the upstream traffic to 100mbps, such that we can create the perfect scenario and observe the wire-shark captures.
- The objective of the testcase is to check the captures and ensure we are getting HE\_MU packets in data frames while we enable OFDMA, and HE\_SU packets in data frames while we disable OFDMA, and observe the throughput variations.

# Wire-shark captures-OFDMA[Enabled].

192.168.200.31:1 (ct523c-ccaa:1 [lanforge]) - VNC Viewer

2g dl tcp.pcapng

File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

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

| No. | Time         | Source | Destination | Protocol | Length | PPDU Format |
|-----|--------------|--------|-------------|----------|--------|-------------|
| 1   | 0.000000000  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 2   | -0.000000027 | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 3   | -0.000000045 | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 4   | 0.000005029  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 5   | 0.000006645  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 6   | 0.000006850  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 7   | 0.000006827  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 8   | 0.000006472  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 9   | 0.000009048  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 10  | 0.000009453  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 11  | 0.000009984  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 12  | 0.000011420  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 13  | 0.000011599  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 14  | 0.000013592  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 15  | 0.000014098  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 16  | 0.000015622  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 17  | 0.000016179  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 18  | 0.000017792  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 19  | 0.000018065  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 20  | 0.000020090  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 21  | 0.000020070  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 22  | 0.000021981  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 23  | 0.000022154  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 24  | 0.000023934  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 25  | 0.000025861  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 26  | 0.000027811  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 27  | 0.000029831  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 28  | 0.000031501  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 29  | 0.000031702  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 30  | 0.000033566  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 31  | 0.000035468  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 32  | 0.000037324  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 33  | 0.000040460  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 34  | 0.000042501  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 35  | 0.000044737  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 36  | 0.000046812  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 37  | 0.000047209  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 38  | 0.000048807  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 39  | 0.000049362  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 40  | 0.000050929  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 41  | 0.000051441  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 42  | 0.000053004  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 43  | 0.000053392  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 44  | 0.000055122  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |
| 45  | 0.000056810  | 802.11 | 238 HE_MU   | 802.11   | 238    | HE_MU       |

Frame 1: 238 bytes on wire (1904 bits), 238 bytes captured (1904 bits) on interface mon18a, id 0

- Radiotap Header v0, Length 68
  - Header revision: 0
  - Header pad: 0
  - Header length: 68
  - Present flags
    - MAC timestamp: 566536361
    - Flags: 0x00
    - Channel frequency: 2412 [BG 1]
    - Channel flags: 0x0480, 2 GHz spectrum, Dynamic CCK-OFDM
    - Antenna signal: -20dBm
    - RX Flags: 0x0000
  - timestamp information
  - HE information
    - HE Data 1: 0x02e2, PPDU Format: HE\_MU, data MCS known, data DCM known, Coding known, STBC known
      - ...10 = PPDU Format: HE\_MU (0x2)
      - ...0 = BSS Color known: Unknown
      - ...0 = Beam Change known: Unknown
      - ...0 = UL/DL known: Unknown
      - ...1 = data MCS known: Known
      - ...1 = data DCM known: Known
      - ...1 = Coding known: Known
      - ...0 = LDPC extra symbol segment known: Unknown
      - ...1 = STBC known: Known
      - ...0 = Spatial Reuse 1 known: Unknown
      - ...0 = Spatial Reuse 2 known: Unknown
      - ...0 = Spatial Reuse 3 known: Unknown
      - ...0 = Spatial Reuse 4 known: Unknown
      - ...0 = dat BW/RU allocation known: Unknown
      - ...0 = Dopler known: Unknown
    - HE Data 2: 0x0012, GI known, TxBF known
    - HE Data 3: 0x2b00, Coding: LDPC
    - HE Data 4: 0x0000
    - HE Data 5: 0x0000, GI: 0.8us, LTF symbol size: 2x
    - HE Data 6: 0x0001, NSTS: 1 space-time stream
  - Antenna signal: -22dBm
  - Antenna: 0
  - Antenna signal: -24dBm

```
0000 00 00 44 00 2b 40 c0 a8 20 08 00 a0 20 08 00 00  ..D..1.....
0010 a9 a8 c4 21 00 00 00 00 00 00 6c 09 00 04 ec 00  ..1.....
0020 00 00 00 00 00 00 00 00 e5 3d 13 82 00 00 00 00  .....+.....
0030 16 00 11 03 e2 02 12 00 00 2b 00 00 80 00 01 00  .....B..dn...
0040 ea 00 e8 01 88 42 82 00 64 6e e0 cf c3 8f c8 99  .....$...@..I
0050 b2 17 ce 24 00 60 e0 84 cc ab d0 0d 40 00 e1 49  .....E.....
0060 00 20 02 00 00 00 aa aa 03 00 00 00 08 00 45 00  .....@.....
0070 00 80 e9 a2 40 00 40 06 cd cc c0 a8 00 e6 c0 a8  .....@.....
```

Packets: 4244271 · Displayed: 4244271 (100.0%) Profile: Default

ASUS Wireless Router GT-AX6000 - Professional - Mozilla Firefox (as superuser)

2g dl tcp.pcapng

LANforge Manag... sta0001 (ct523c... Mate Terminal ASUS Wireless R... [WiFi Capacity T... ofdma (as superuser) (as superuser) (as superuser) 2g dl tcp.pcapng

# Wire-shark captures-OFDMA[Disabled].

The screenshot displays the Wireshark interface with a packet capture of HE SU data. The main window shows a list of packets, with packet 2 selected. The details pane on the right shows the structure of the HE SU data, including channel flags, antenna signal, and HE information. The packet bytes pane at the bottom shows the raw data in hexadecimal and ASCII.

| No. | Time        | Source | Destination | Protocol | Length | PPDU Format |
|-----|-------------|--------|-------------|----------|--------|-------------|
| 1   | 0.000000000 |        |             | 802.11   | 438    | HE_SU       |
| 2   | 0.00001492  |        |             | 802.11   | 438    | HE_SU       |
| 3   | 0.00004220  |        |             | 802.11   | 438    | HE_SU       |
| 4   | 0.00005711  |        |             | 802.11   | 438    | HE_SU       |
| 5   | 0.00018942  |        |             | 802.11   | 438    | HE_SU       |
| 6   | 0.00021150  |        |             | 802.11   | 438    | HE_SU       |
| 7   | 0.00023250  |        |             | 802.11   | 438    | HE_SU       |

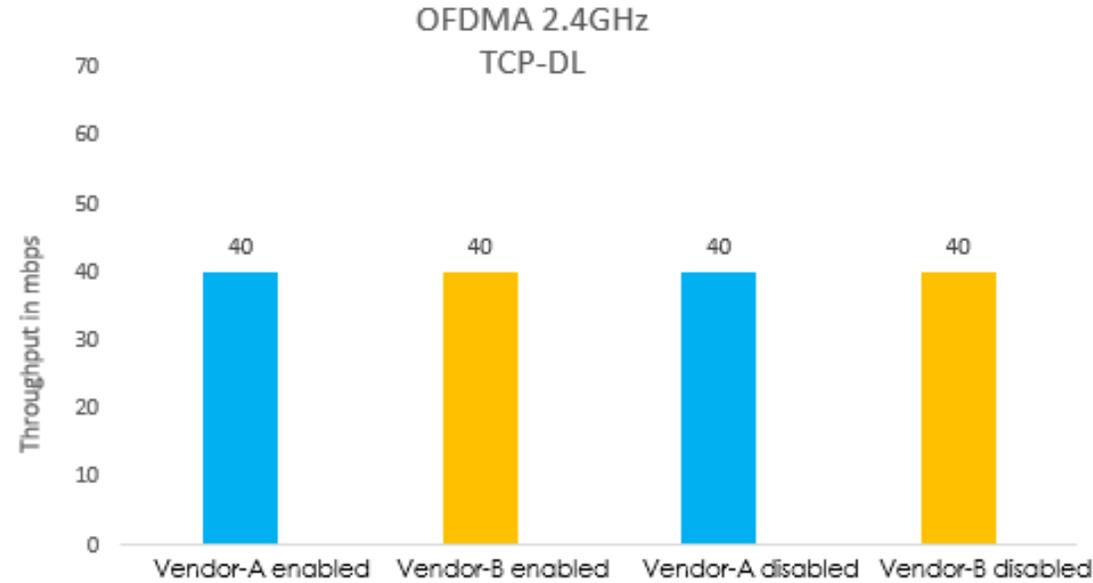
**Wireshark - Packet 2 - 1.pcapng**

- Channel flags: 0x0140, Orthogonal Frequency-Division Multiplexing (OFDM), 5 GHz spectrum
- Antenna signal: -22dBm
- RX flags: 0x0000
- timestamp information
- HE information
  - HE Data 1: 0x42e0, PPDU Format: HE\_SU, data MCS known, data DCM known, Coding known, STBC known
    - 0... = PPDU Format: HE\_SU (0x0)
    - 0... = BSS Color known: Unknown
    - 0... = Beam Change known: Unknown
    - 0... = UL/DL known: Unknown
    - 1... = data MCS known: Known
    - 1... = data DCM known: Known
    - 1... = Coding known: Known
    - 0... = LDPC extra symbol segment known: Unknown
    - 1... = STBC known: Known
    - 0... = Spatial Reuse 1 known: Unknown
    - 0... = Spatial Reuse 2 known: Unknown
    - 0... = Spatial Reuse 3 known: Unknown
    - 0... = Spatial Reuse 4 known: Unknown
    - 1... = data BW/RU allocation known: Known
    - 0... = Doppler known: Unknown
  - HE Data 2: 0x0012, GI known, TxBF known
  - HE Data 3: 0x2b00, Coding: LDPC
  - HE Data 4: 0x0000
  - HE Data 5: 0x0002, GI: 0.8us, LTF symbol size: 2x
  - HE Data 6: 0x0002, NSTS: 2 space-time streams

Antenna signal: -22dBm  
Antenna: 0

0000 00 00 44 00 2b 40 c8 a0 20 88 00 a0 20 88 00 00 ... D +@  
0010 b1 81 5f 05 00 00 00 00 00 00 3c 14 40 01 ea 00 ... < @  
0020 00 00 00 00 00 00 00 00 cc 9c 3e 01 00 00 00 00 ... +  
0030 16 00 11 03 e0 42 12 00 00 2b 00 00 82 00 02 00 ... B +  
0040 ea 00 e3 01 88 42 30 00 64 6e e0 50 44 8f c8 99 ... B0 dn PD  
0050 b2 17 ce 26 00 60 e0 84 cc ab 00 7e 00 00 e4 17 ... &  
0060 00 20 00 00 00 00 aa aa 03 00 00 00 08 00 45 00 ... E  
0070 01 48 db ec 40 00 40 11 db 67 c0 a8 00 e0 c0 a8 ... H - @ @ - g  
0080 00 1a 81 f0 01 75 01 34 ba 18 00 00 00 00 1a 20 ...  
0090 1c 40 00 92 00 93 01 00 00 00 00 52 11 02 00 ...  
00a0 0f 80 2d b0 f6 00 00 00 00 00 00 00 00 00 00 01 ...  
00b0 02 03 04 05 06 07 08 09 0a 0b 0c 0d 0e 0f 10 11 ...  
00c0 12 13 14 15 16 17 18 19 1a 1b 1c 1d 1e 1f 20 21 ...  
00d0 22 23 24 25 26 27 28 29 2a 2b 2c 2d 2e 2f 30 31 ... \*\$NA' {} \*+ , /01  
00e0 32 33 34 35 36 37 38 39 3a 3b 3c 3d 3e 3f 40 41 ... 23456789 ; <= >?@  
00f0 42 43 44 45 46 47 48 49 4a 4b 4c 4d 4e 4f 50 51 ... BCDEF GHI JKLMNOP  
0100 52 53 54 55 56 57 58 59 5a 5b 5c 5d 5e 5f ... Z[\] ^ \_  
0110 62 63 64 65 66 67 68 69 6a 6b 6c 6d 6e 6f ... 78901234567890  
0120 72 73 74 75 76 77 78 79 7a 7b 7c 7d 7e 7f ...  
0130 82 83 84 85 86 87 88 89 8a 8b 8c 8d 8e 8f ...

# OFDMA: TCP-UL [2.4GHz]



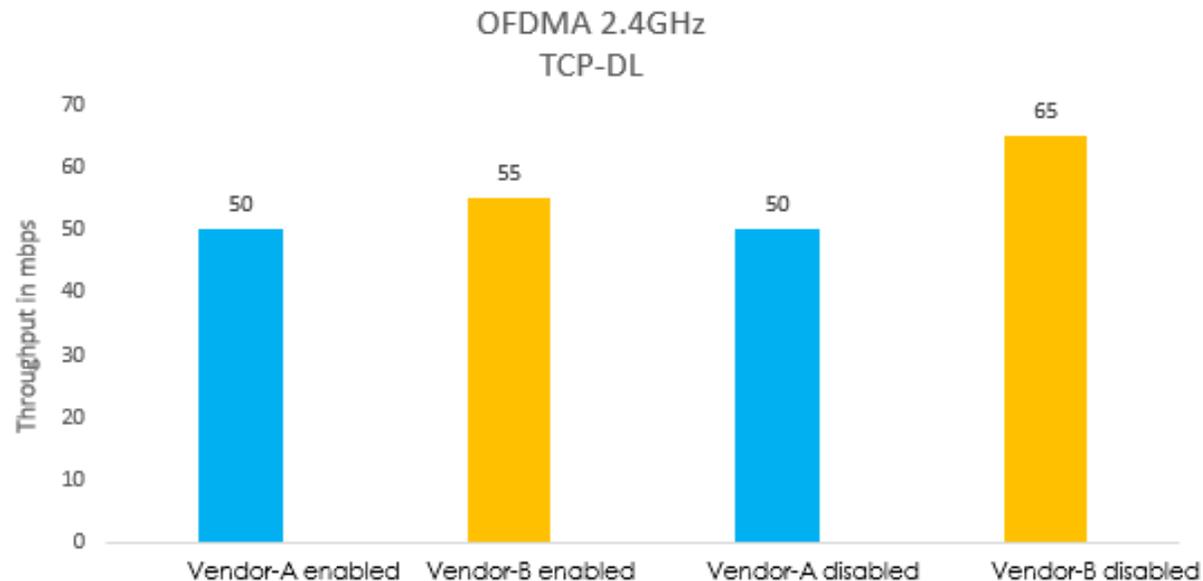
## Test description:

- The OFDMA is by default enabled for SKY-CPE , and we use the CLI commands to disable the OFDMA.
- The throughput has no variation in both the cases.
- The Asus is also having no variation in the throughput at both the scenarios.

## Result observations:

- Both the CPE's are showing HE\_MU packets when OFDMA is enabled .
- Both are showing similar outputs.

# OFDMA: TCP-DL[2.4GHz]



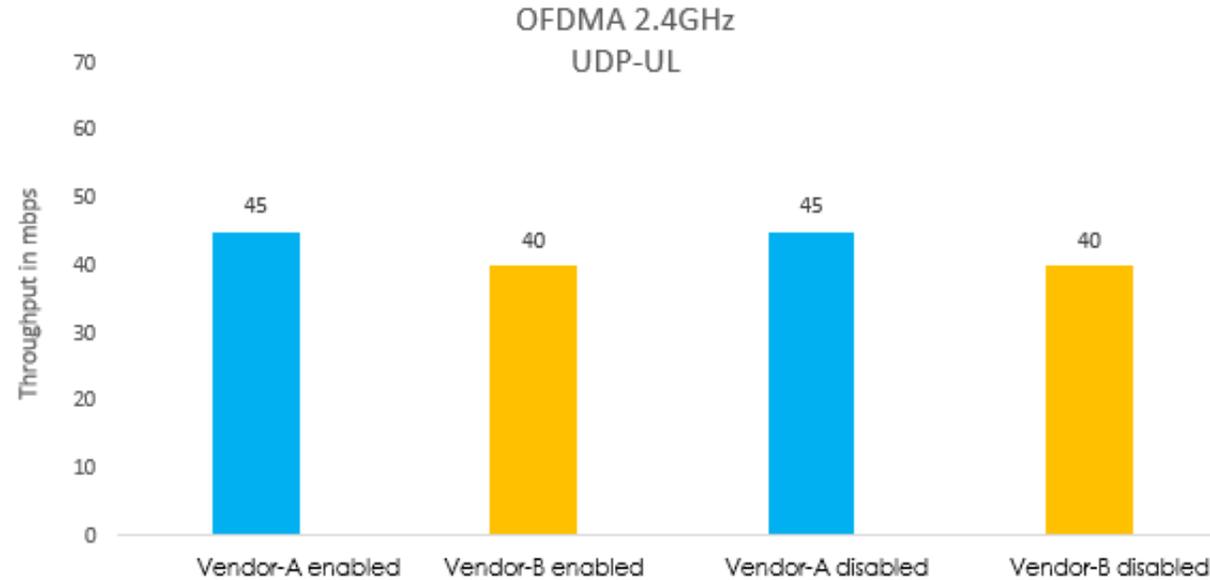
## Test description:

- The OFDMA is by default enabled for Vendor-A , and we use the CLI commands to disable the OFDMA.
- The throughput has no variation in both the cases.
- The Vendor-B AP has OFDMA option and the throughput varies by enabling and disabling OFDMA

## Result observations:

- Both the CPE's are showing HE\_MU packets when OFDMA is enabled .
- But Vendor-B is showing higher throughput.

# OFDMA: UDP-UL[2.4GHz]



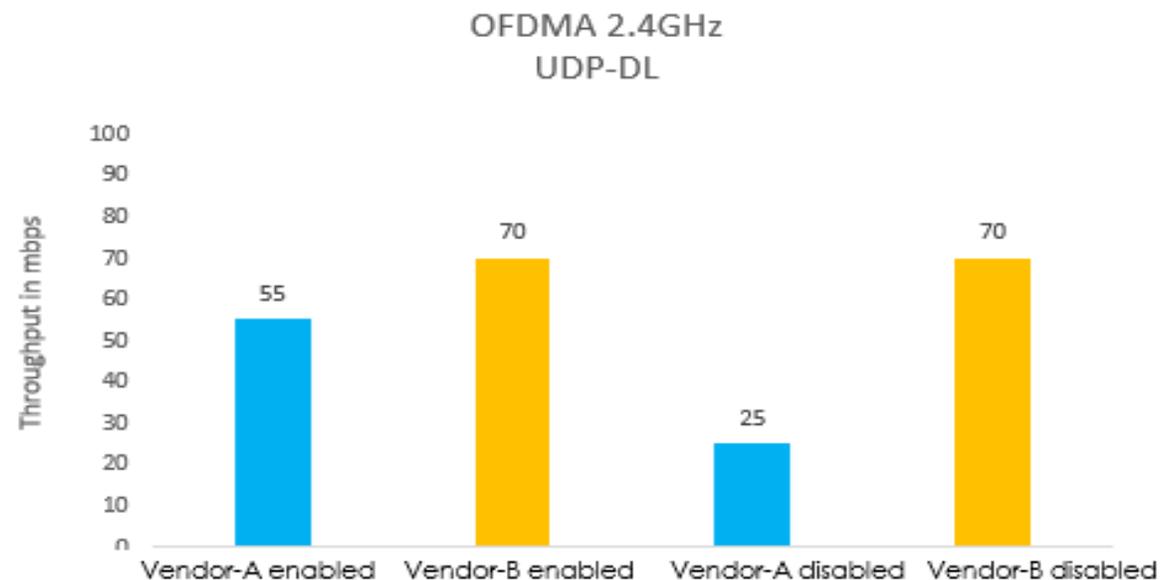
## Test description:

- The OFDMA is by default enabled for Vendor-A, and we use the CLI commands to disable the OFDMA.
- The throughput has no variation in both the cases.
- The Vendor-B has OFDMA option and the throughput varies by enabling and disabling OFDMA.

## Result observations:

- Both the CPE's are showing HE\_MU packets when OFDMA is enabled .
- Vendor-A is working better in this scenario.

# OFDMA: UDP-DL [2.4GHz]



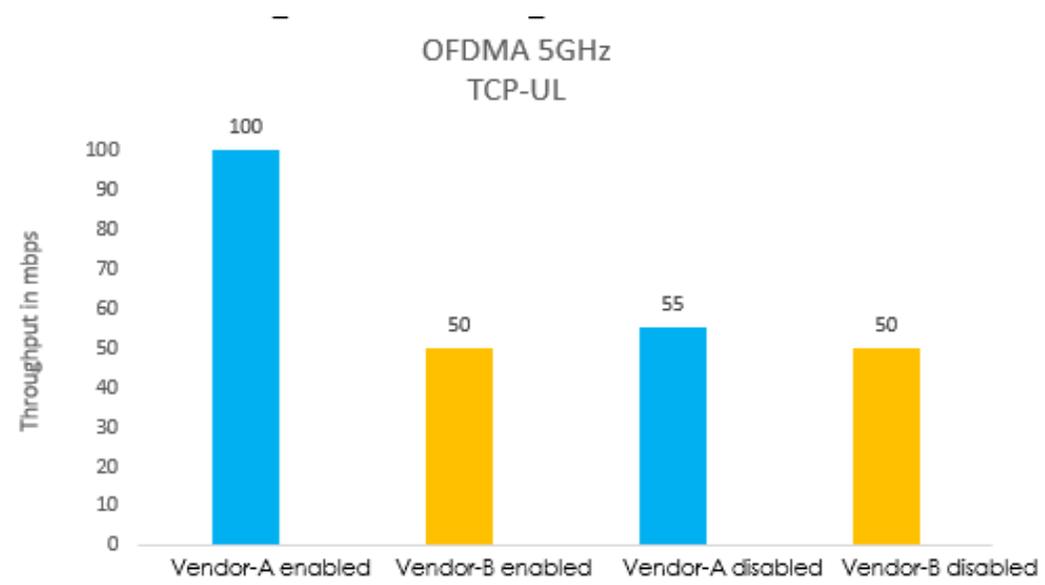
## Test description:

- The OFDMA is by default enabled for Vendor-A , and we use the CLI commands to disable the OFDMA.
- The throughput has no variation in both the cases.
- The Vendor-B has OFDMA option and the throughput varies by enabling and disabling OFDMA.

## Result observations:

- Both the CPE's are showing HE\_MU packets when OFDMA is enabled .
- But Vendor-B is showing higher throughput.

# OFDMA: TCP-UL [5GHz]



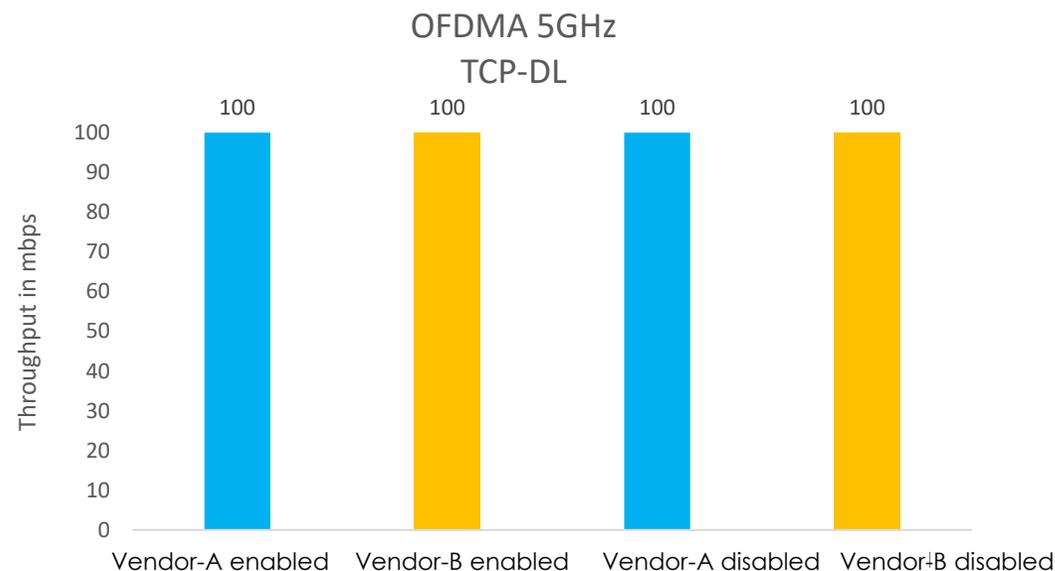
Test description:

- The OFDMA is by default enabled for Vendor-A , and we use the CLI commands to disable the OFDMA.
- The throughput has no variation in both the cases.
- The maximum throughput is around 70mbps as we have set the upstream traffic is 100mbps.

Result observations:

- Both the CPE's are showing HE\_MU packets when OFDMA is enabled .
- Vendor-A is showing higher throughput.

# OFDMA: TCP-DL[5GHz]



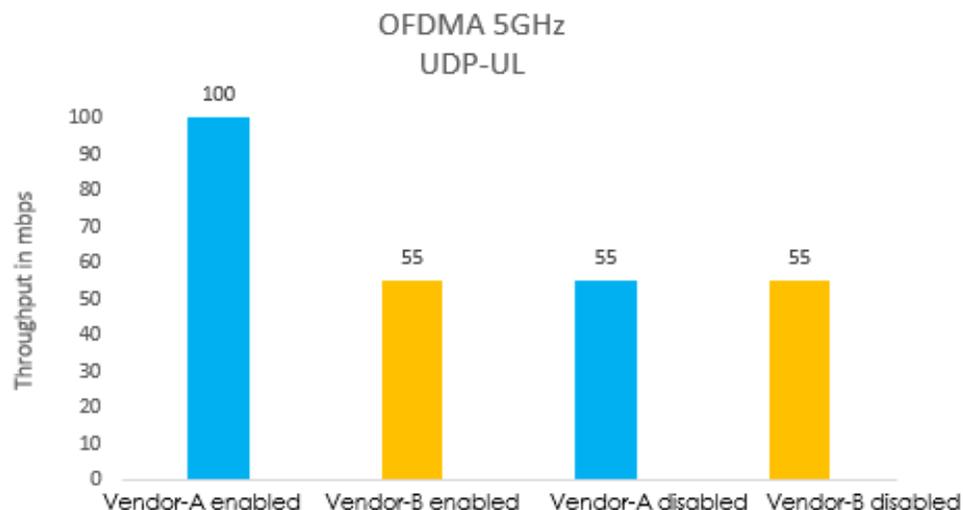
## Test description:

- The OFDMA is by default enabled for Vendor-A , and we use the CLI commands to disable the OFDMA.
- The throughput has no variation in both the cases.
- The maximum throughput is around 70mbps as we have set the upstream traffic is 100mbps.

## Result observations:

- Both the CPE's are showing HE\_MU packets when OFDMA is enabled .
- Both are showing similar higher throughput.

# OFDMA: UDP-UL[5GHz]



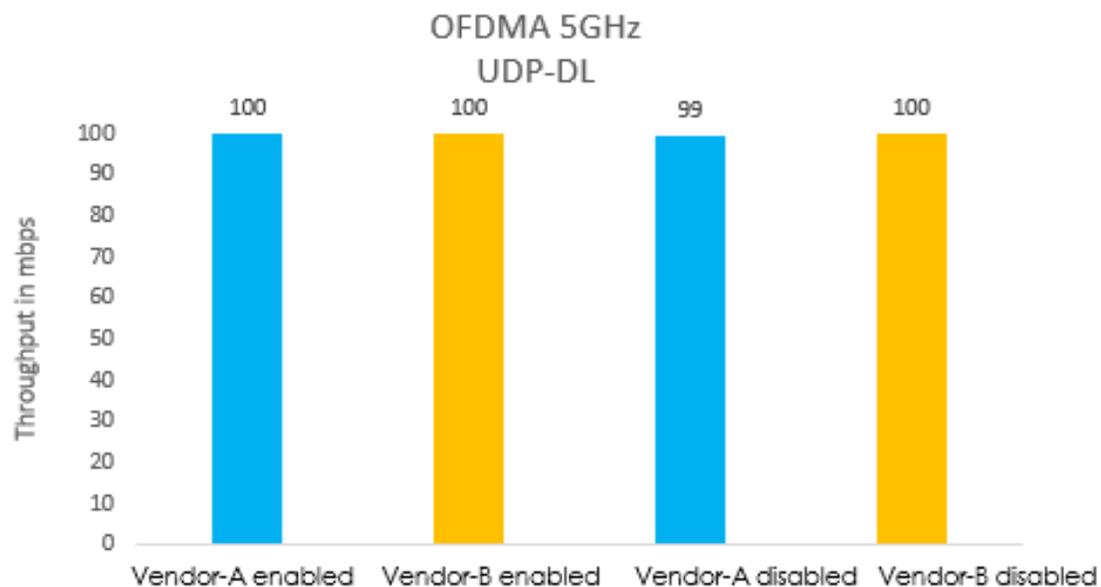
## Test description:

- The OFDMA is by default enabled for Vendor-A , and we use the CLI commands to disable the OFDMA.
- The throughput has no variation in both the cases.
- The maximum throughput is around 70mbps as we have set the upstream traffic is 100mbps.

## Result observations:

- Both the CPE's are showing HE\_MU packets when OFDMA is enabled .
- Vendor-A is showing higher throughput.

# OFDMA: UDP-DL[5GHz]



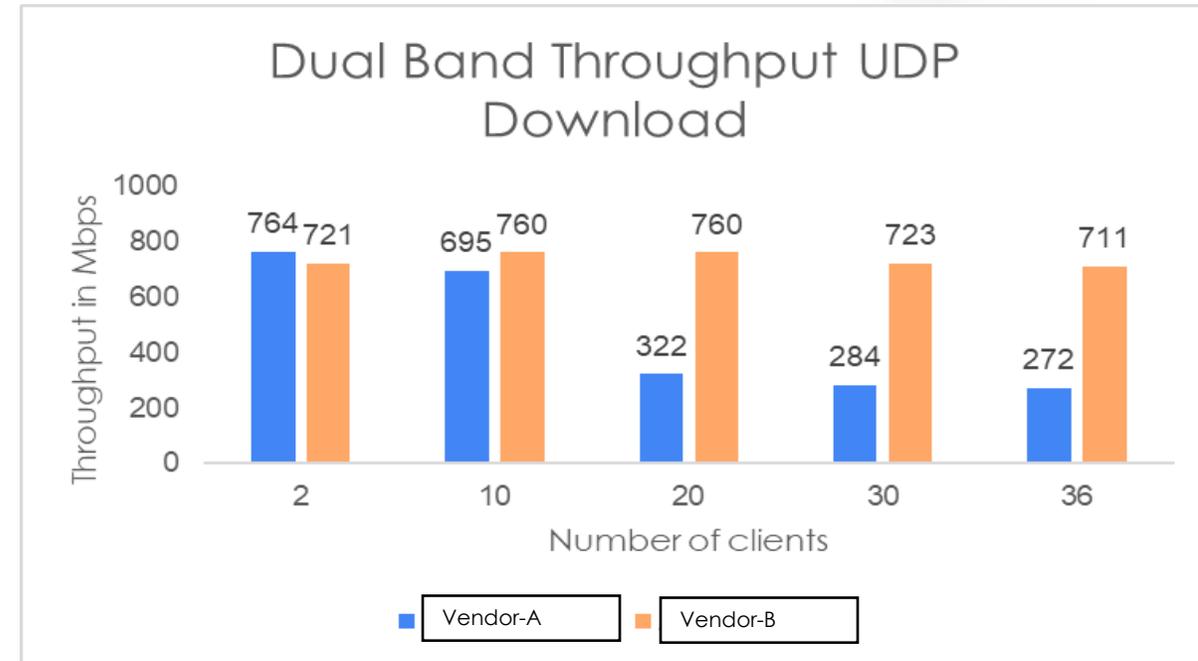
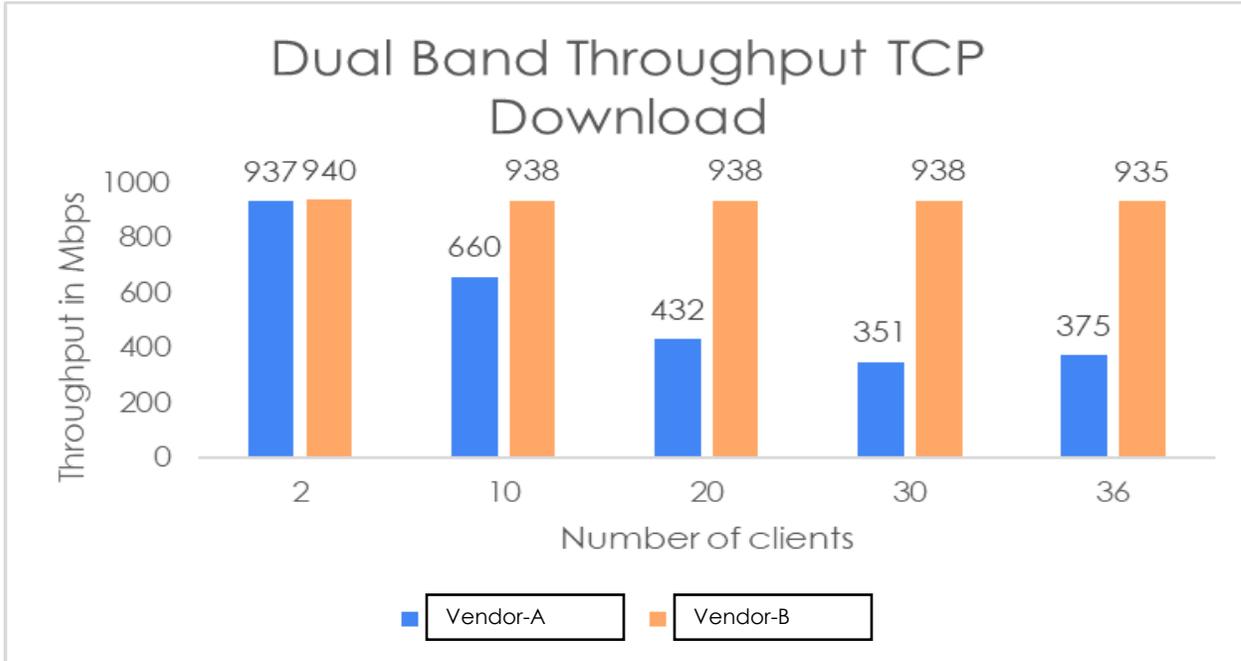
## Test description:

- The OFDMA is by default enabled for Vendor-A , and we use the CLI commands to disable the OFDMA.
- The throughput has no variation in both the cases.
- The maximum throughput is around 70mbps as we have set the upstream traffic is 100mbps.

## Result observations:

- Both the CPE's are showing HE\_MU packets when OFDMA is enabled .
- Both are showing similar throughput.

# Dual Band Performance Test



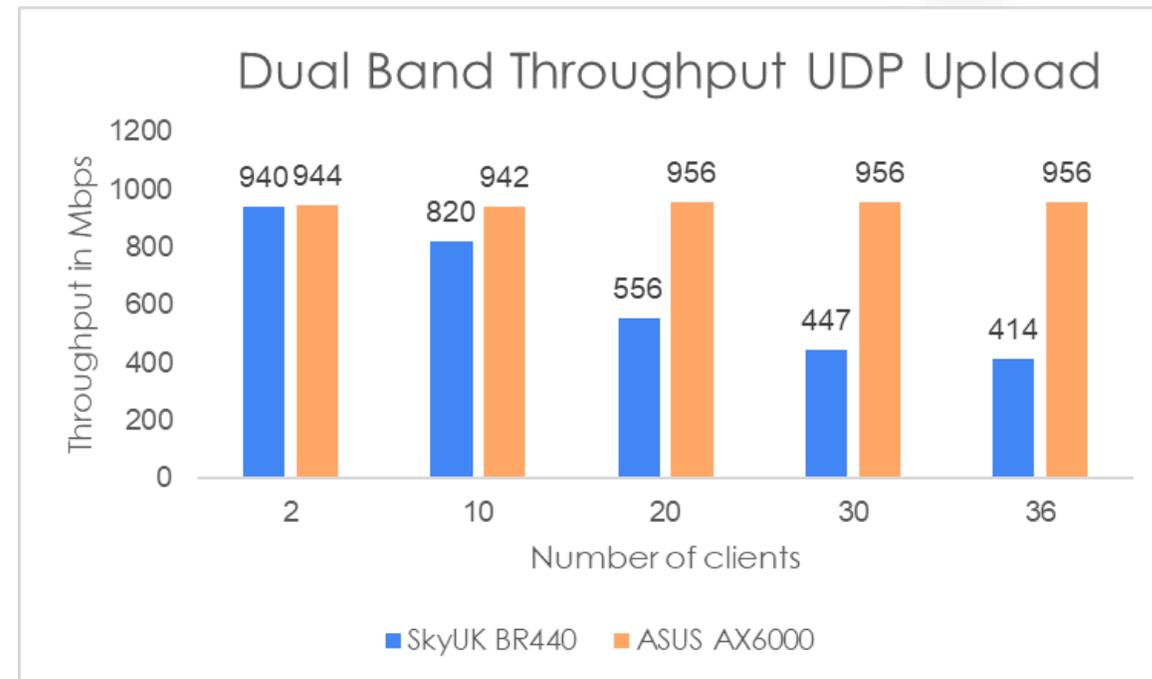
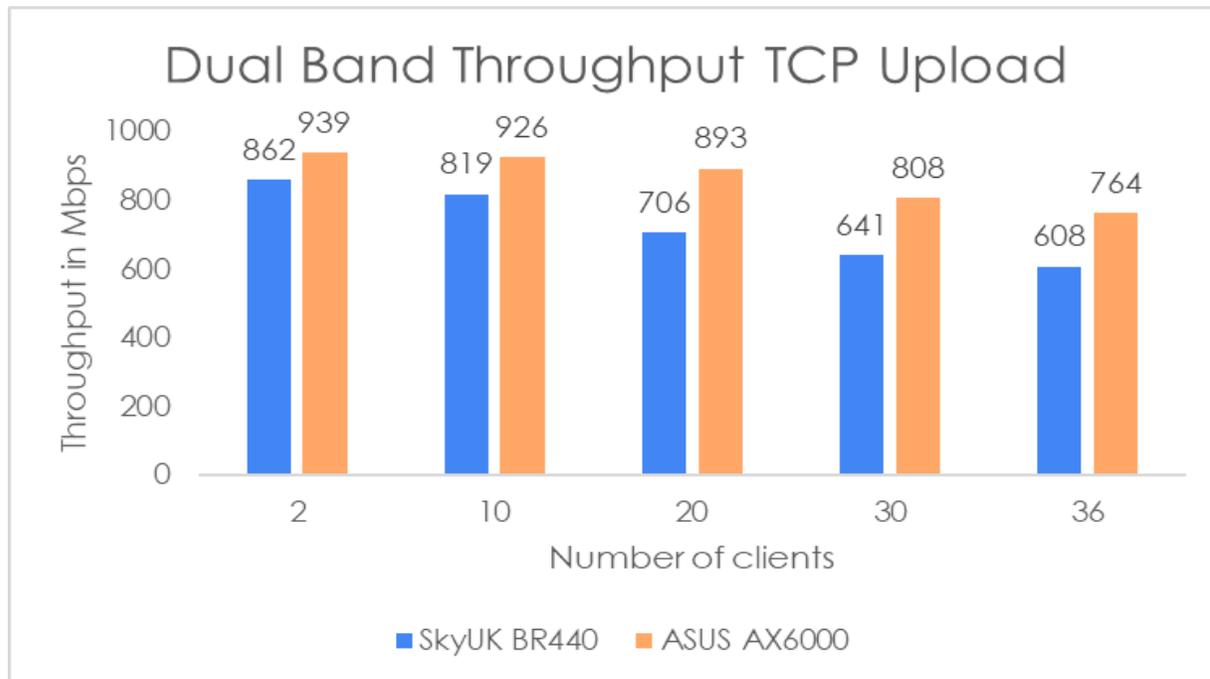
**Test Description:**

- All 2.4 GHz clients are connected in 3\*3 with ax mode. All the 5 GHz clients are connected in 4\*4 with ax mode.
- Traffic is running parallelly on both bands.

**Results Observations:**

- With Vendor-B is giving better throughput.

# Dual Band Performance Test



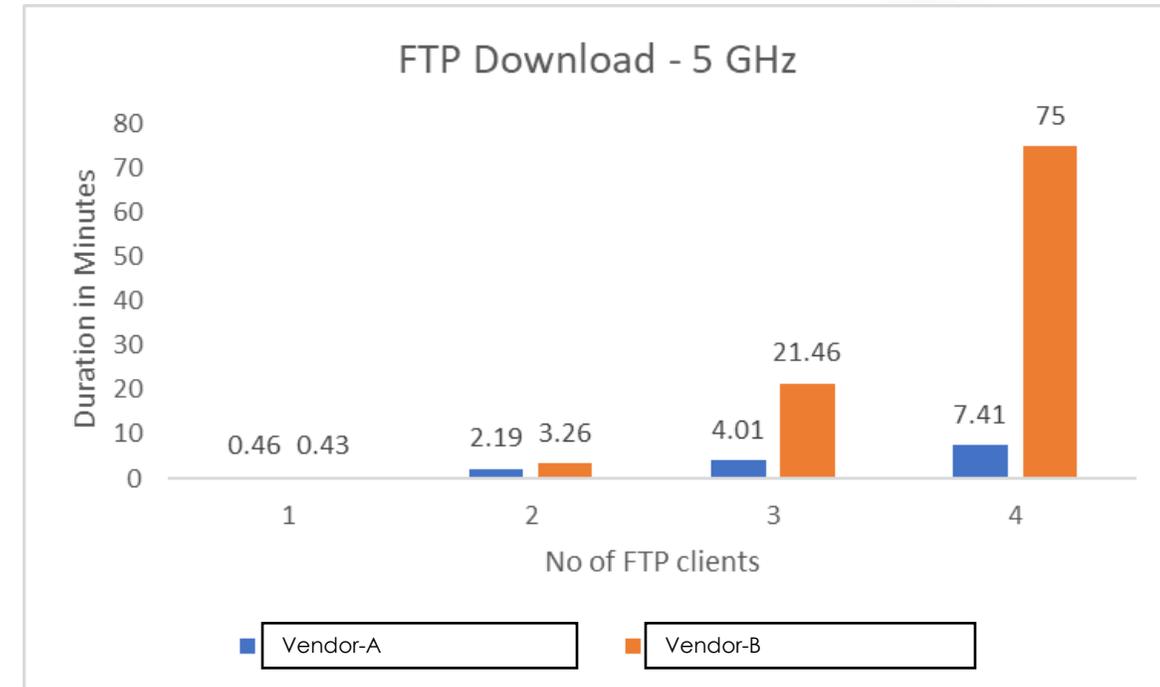
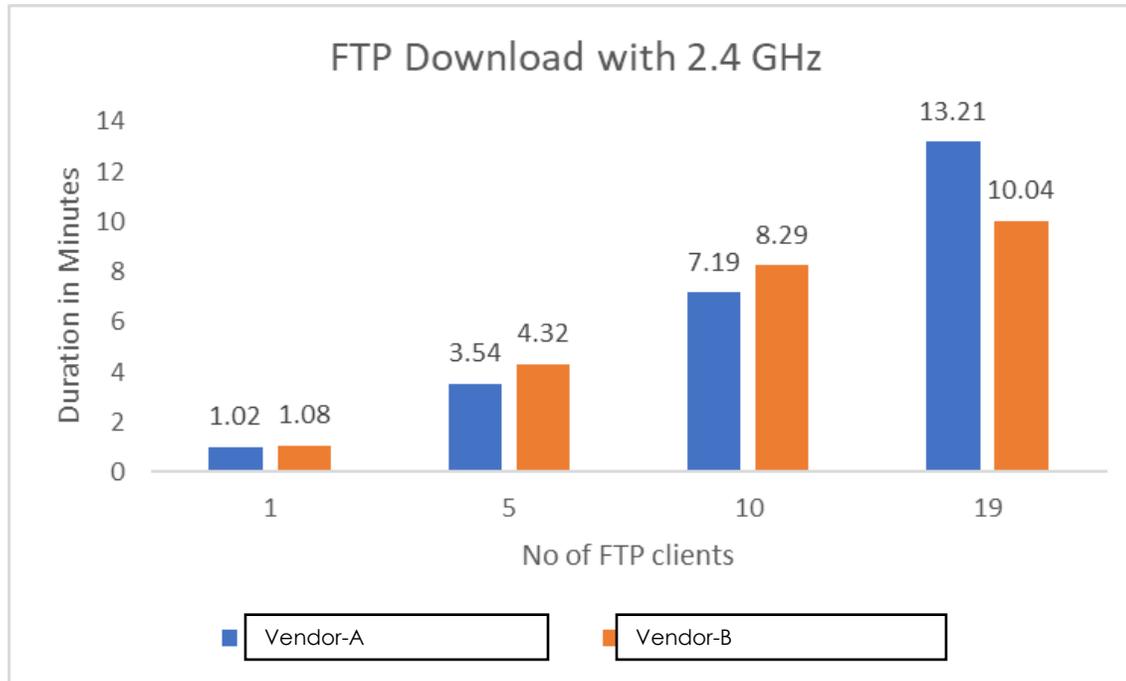
## Test Description:

- All 2.4 GHz clients are connected in 3\*3 with ax mode. All the 5 GHz clients are connected in 4\*4 with ax mode.
- Traffic is running parallelly on both bands.

## Results Observations:

- With Vendor-B is giving better throughput.

# File Transfer Protocol Testing



## Test Description:

- All 2.4 GHz clients are connected in 3\*3 with ax mode. All the 5 GHz clients are connected in 4\*4 with ax mode.
- FTP file (1GB) is transferred from server to wireless client

## Results Observations:

- With Vendor-B is performing better with respect of transferring files in 5 GHz mode

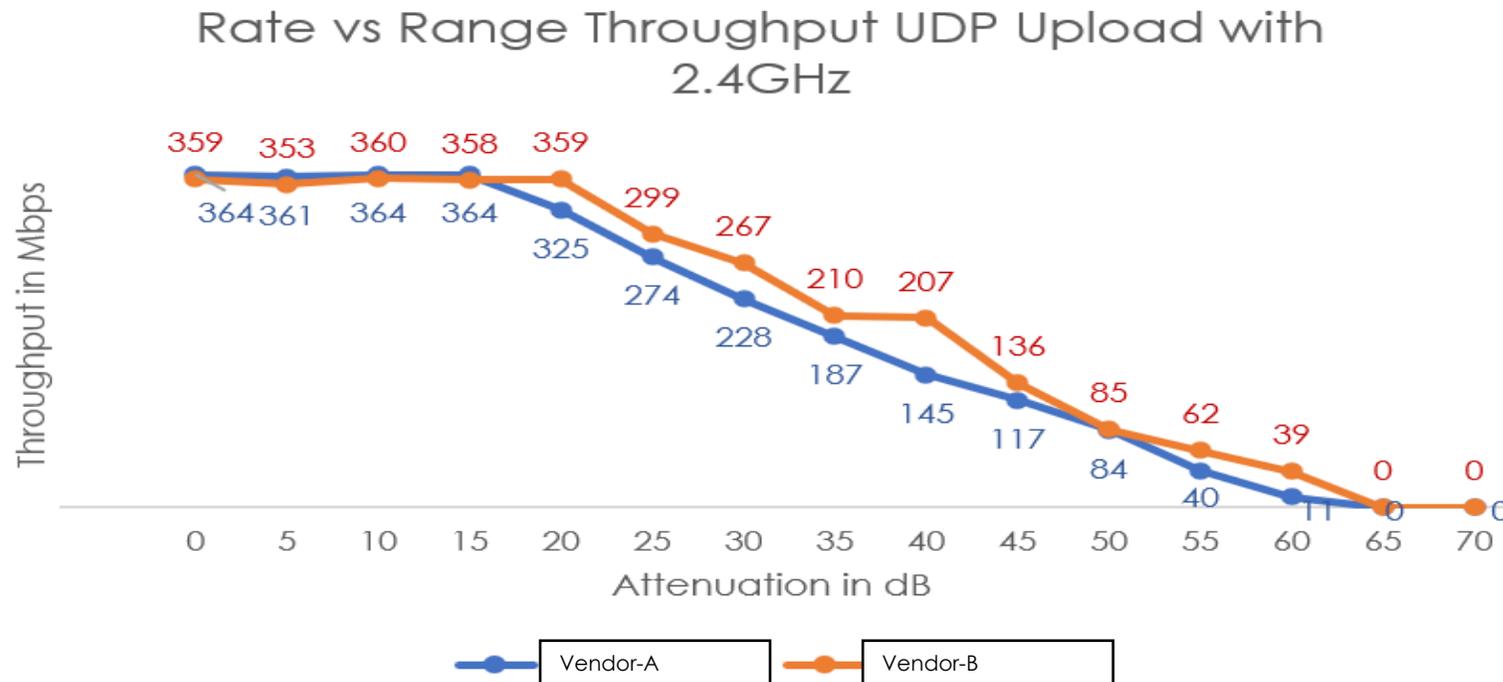
# Dynamic Frequency Selection

|                        |            |            |            |            |            |            |            |            |            |            |            |            |            |            |            |
|------------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
| <b>DFS Channels</b>    | <b>52</b>  | <b>56</b>  | <b>60</b>  | <b>64</b>  | <b>100</b> | <b>104</b> | <b>108</b> | <b>112</b> | <b>116</b> | <b>120</b> | <b>124</b> | <b>128</b> | <b>132</b> | <b>136</b> | <b>140</b> |
| <b>Radar Detected</b>  | <b>Yes</b> |
| <b>Channel Shifted</b> | <b>48</b>  | <b>40</b>  | <b>157</b> | <b>157</b> | <b>157</b> | <b>140</b> | <b>140</b> | <b>144</b> | <b>56</b>  | <b>48</b>  | <b>36</b>  | <b>36</b>  | <b>144</b> | <b>144</b> | <b>44</b>  |

## Test Description:

- Clients connected in 5 GHz with 20 MHz band with radar type used here is FCC0

# Rate Vs Range – 2.4GHz UDP Upload



## Test Description:

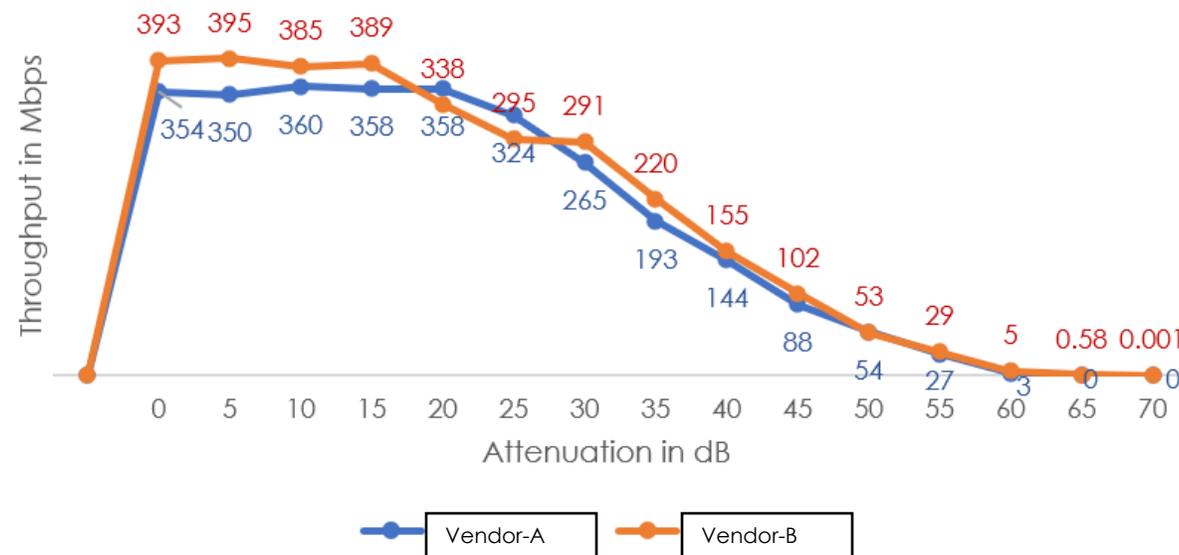
- In this scenario, Station associated and start running traffic when attenuation is 0 dB and gradually increase attenuation 5 dB steps.
- Intended load is set to 1 Gbps with UDP upload traffic with client3NSS, 20Mhz BW in AX mode.
- Traffic from Client to AP and throughput test run in 2.4GHz on channel 1.

## Results Observations:

- Vendor-B has more RSSI at zero attenuation compared to Vendor-A.
- Vendor-B is getting more throughput with the increase in attenuation than Vendor-A.
- Vendor-A, Vendor-B have disconnected after 60dB.

# Rate Vs Range – 2.4GHz UDP Download

Rate vs Range Throughput UDP Download with 2.4GHz



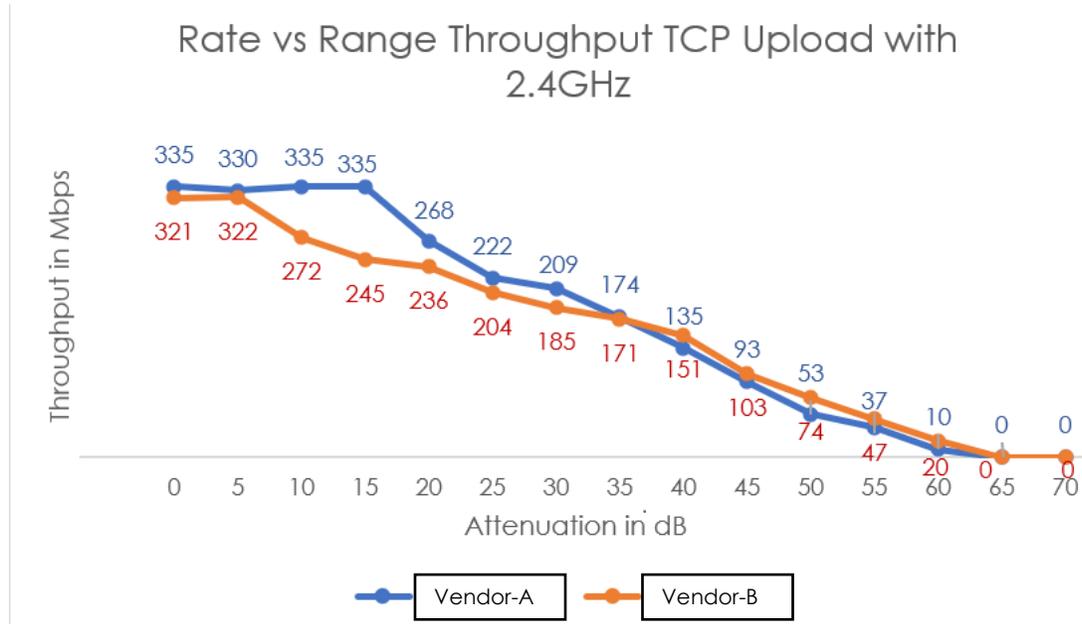
## Test Description:

- In this scenario, Station associated and start running traffic when attenuation is 0 dB and gradually increase attenuation 5 dB steps.
- Intended load is set to 1 Gbps with UDP download traffic with client3NSS, 20Mhz BW in AX mode.
- Traffic from AP to client and throughput test run in 2.4GHz on channel 1.

## Results Observations:

- Vendor-B has good RSSI at zero attenuation compared to Vendor-A. Vendor-B is getting more throughput with zero attenuation than Vendor-A.
- Vendor-A, Vendor-B have disconnected after 60dB.

# Rate Vs Range – 2.4GHz TCP Upload



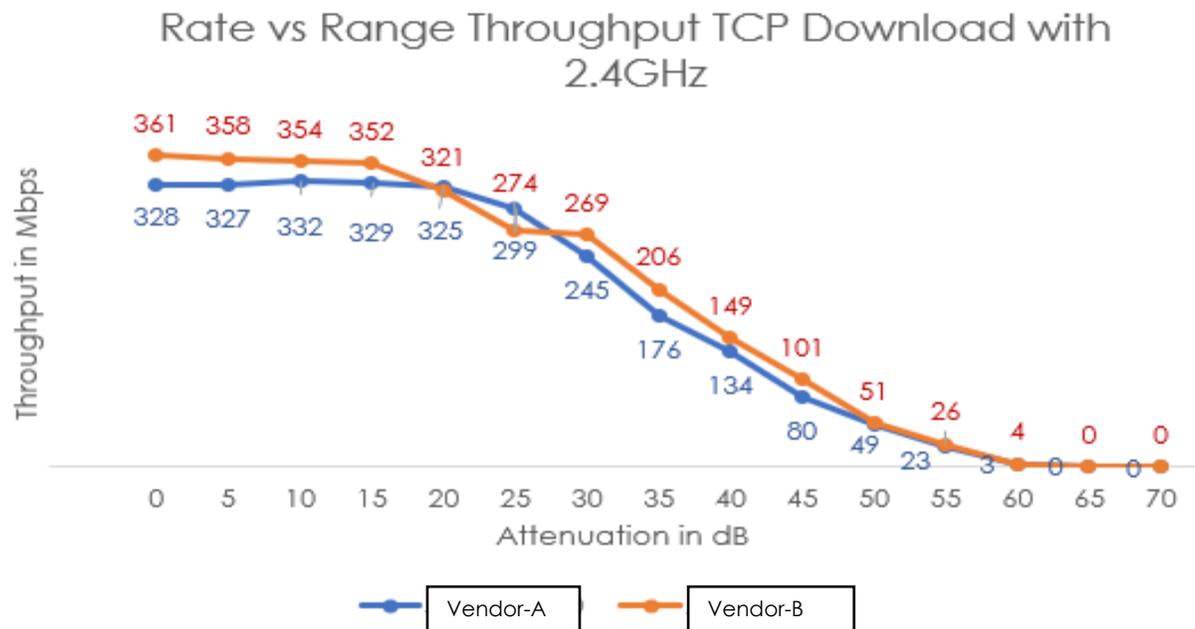
**Test Description:**

- In this scenario, Station associated and start running traffic when attenuation is 0 dB and gradually increase attenuation 5 dB steps.
- Intended load is set to 1 Gbps with TCP upload traffic with client3NSS, 20Mhz BW in AX mode.
- Traffic from client to AP and throughput test run in 2.4GHz on channel 1.

**Results Observations:**

- Vendor-B has more RSSI at zero attenuation compared to Vendor-A.
- Vendor-A is getting more throughput with zero attenuation than Vendor-B.
- Vendor-A, Vendor-B have disconnected after 60dB.

# Rate Vs Range – 2.4GHz TCP Download



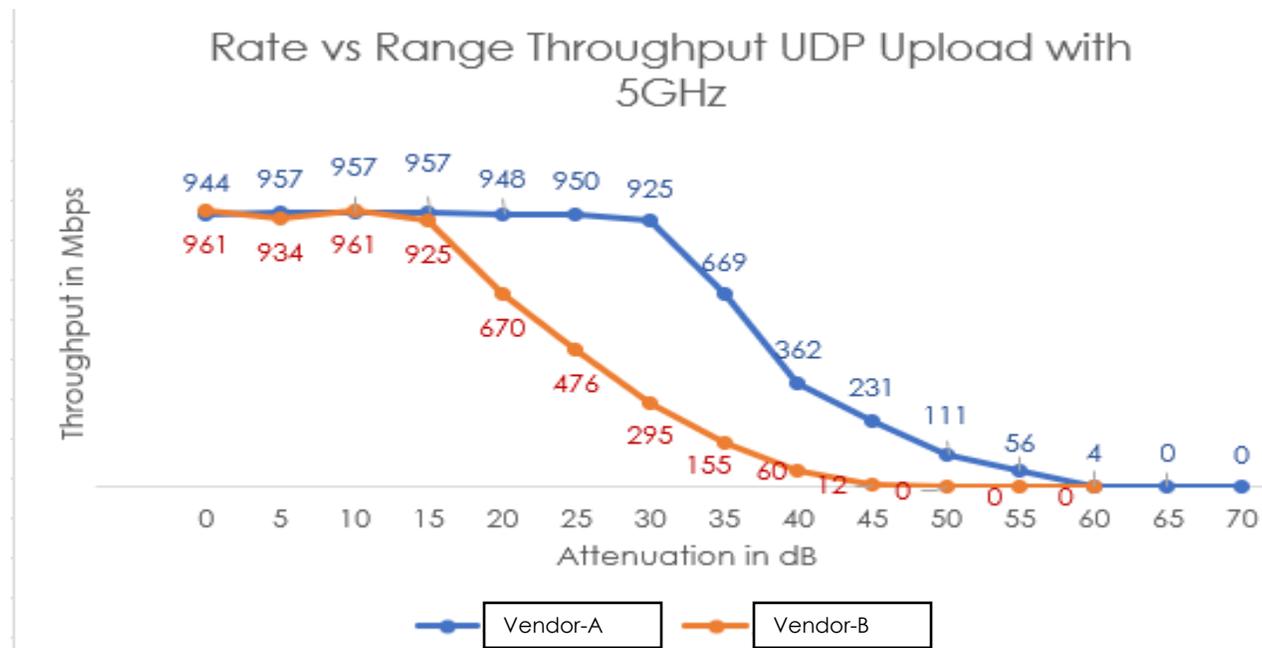
## Test Description:

- In this scenario, Station associated and start running traffic when attenuation is 0 dB and gradually increase attenuation 5 dB steps.
- Intended load is set to 1 Gbps with TCP download traffic with client3NSS, 20Mhz BW in AX mode.
- Traffic from AP to client and throughput test run in 2.4GHz on channel 1.

## Results Observations:

- Vendor-B is getting more throughput with increase in attenuation than Vendor-A.
- Vendor-A, Vendor-B have disconnected after 60dB.

# Rate Vs Range – 5GHz UDP Upload



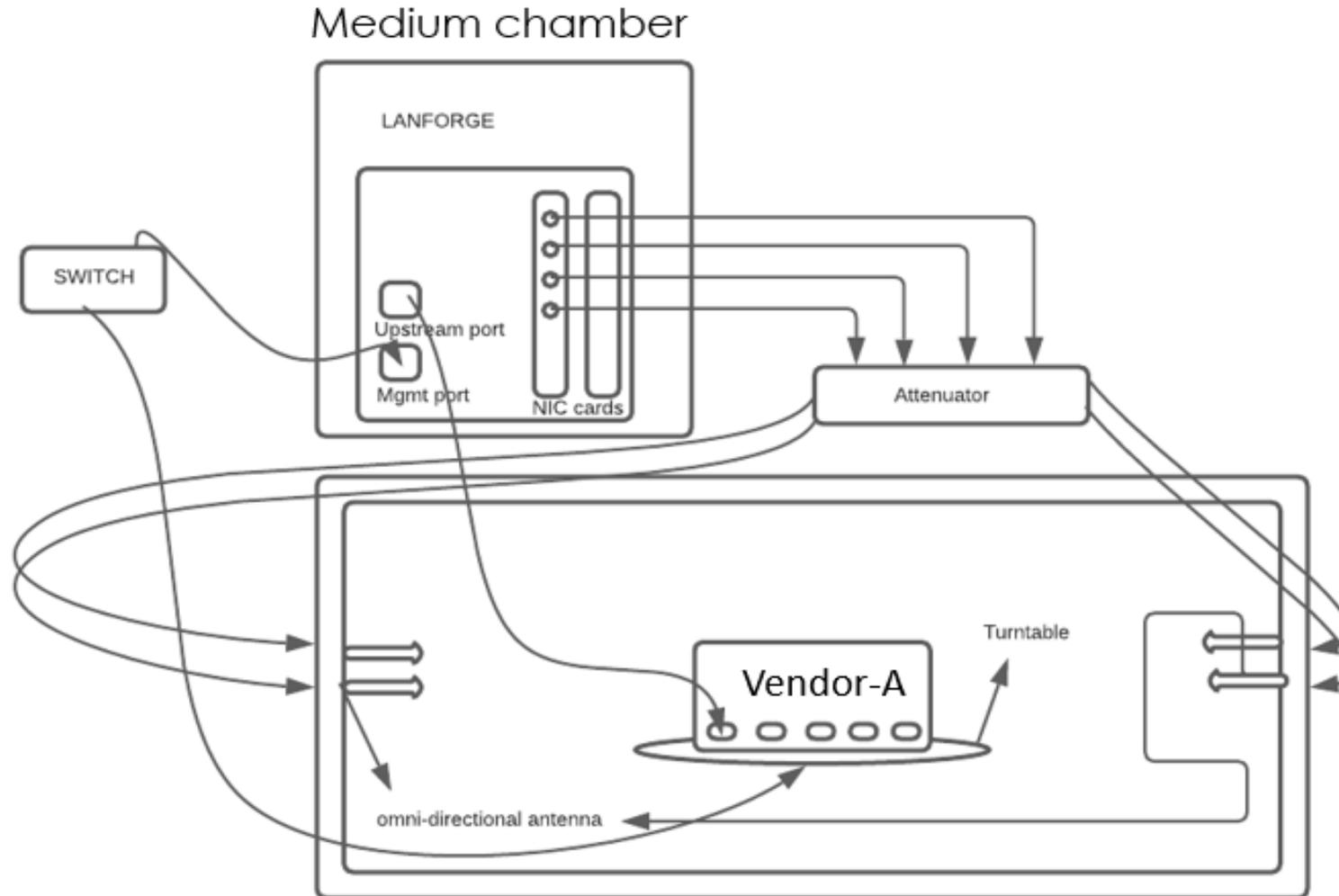
## Test Description:

- In this scenario, Station associated and start running traffic when attenuation is 0 dB and gradually increase attenuation 5 dB steps.
- Intended load is set to 1 Gbps with UDP Upload traffic with client 4NSS, 80Mhz BW in AX mode.
- Traffic from client to AP and throughput test run in 5GHz on channel .

## Results Observations:

- Vendor-B is getting more throughput with increase in attenuation than Vendor-A.
- Vendor-A, Vendor-B have disconnected after 60dB.

# Testbed Setup for Rate vs Orientation:



- We used MTK 4\*4 Radios for this test.
- The attenuator which is used can provide maximum 95dbm.
- The turntable provides 0-359 degrees rotation.

# Testing images:

V2 192.168.200.201:1 (ct523c-3b63:1 (lanforge)) - VNC Viewer

Applications Places System EN Mon Jul 18, 01:56

### LANforge Manager Version(5.4.5)

Control Reporting Windows Info Tests

Chamber View Stop All Restart Manager Refresh

Resource Mgr DUT Profiles Traffic-Profiles Alerts Warnings + Wifi-Messages

VoIP/RTP VoIP/RTP Endpts Attenuators RF-Generator File-I/O Gener

Status Port Mgr Extended Port Mgr Layer-3 L3 Endpts Layer 4-7 Armageddon WanLi

Crgate Discover Start + Stop - Modify Delete

| Attenuators |       |        |          |          |          |          |
|-------------|-------|--------|----------|----------|----------|----------|
| Name        | State | Script | Module 1 | Module 2 | Module 3 | Module 4 |
| 1.1.1001    | Idle  | None   | 20.0     | 20.0     | 20.0     | 20.0     |

Logged in to: localhost:4002 as: Admin



Show Adjustments Take Picture

Contrast: 192  
Brightness: 159  
Color: 208  
Hue: 158  
White Balance: 0

15.00 fps - current 9.42 fps - average

### Rate vs Range Test (cv-inst-1)

Settings Advanced Configuration Pass/Fail Report Configuration Report-2 Report-3

Selected DUT: Duration: 30 sec (30 s)

Downstream/WiFi Port: Upstream Port: 1.1.1 eth1

Rate: 1 Gbps Opposite Rate: 0Kbps

Path Loss: 10 AP Tx Power: 0

| Channels (STA DUT) | Mode          | Packet Size |
|--------------------|---------------|-------------|
| AUTO               | Auto          | Custom      |
| No-Change          | 802.11a       | 60          |
| 1                  | 802.11b       | 142         |
| 2                  | 802.11g       | 256         |
| 3                  | 802.11abg     | 512         |
| 4                  | 802.11abgn    | 1024        |
| 5                  | 802.11bgn     | MTU         |
| 6                  | 802.11bg      | 4000        |
| 7                  | 802.11abgn-AC | 9000        |

| Spatial Streams | Security (STA DUT) | Bandwidth (STA DUT) |
|-----------------|--------------------|---------------------|
| AUTO            | AUTO               | No-Change           |
| 1               | Open               | AUTO                |
| 2               | WEP                | 20                  |
| 3               | WPA                | 40                  |
| 4               | WPA2               | 80                  |
|                 | WPA3               | 160                 |

Traffic Type: UDP, TCP, Arm-UDP

Attenuator 1: 1.1.1001

Attenuator 2: NONE (0)

Turntable: SKY

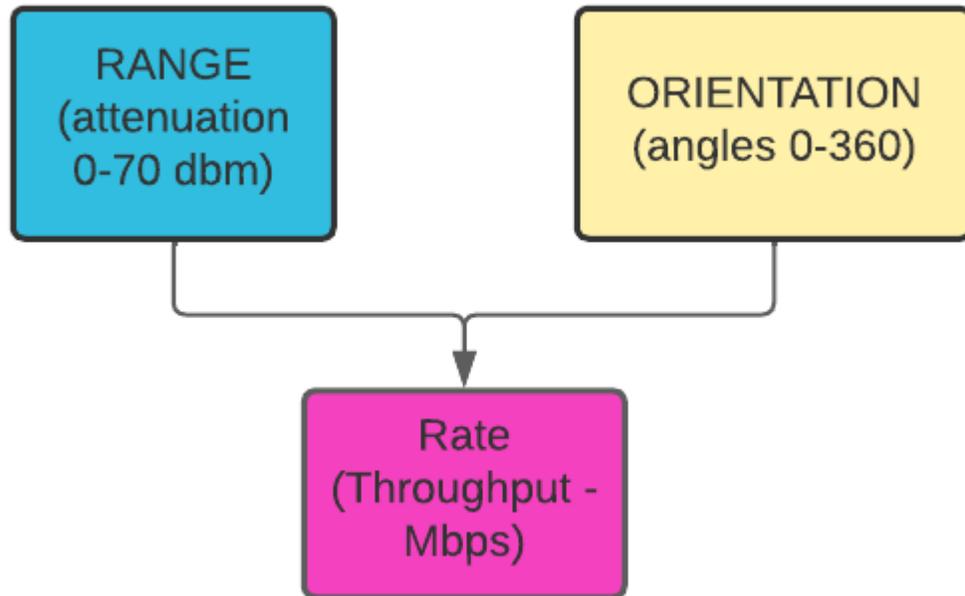
Direction: DUT Transmit, DUT Receive

per 4/32 Stop Skip Another Iteration Pause Cancel

Camorama - LRCP 1080P Camera: LRCP 1080P C - 640x480

LANforge Manager Ve... [Mate Terminal] Rate vs Range Test (cv... Camorama - LRCP 1080... [tcp AND udp] [tcp AND udp]

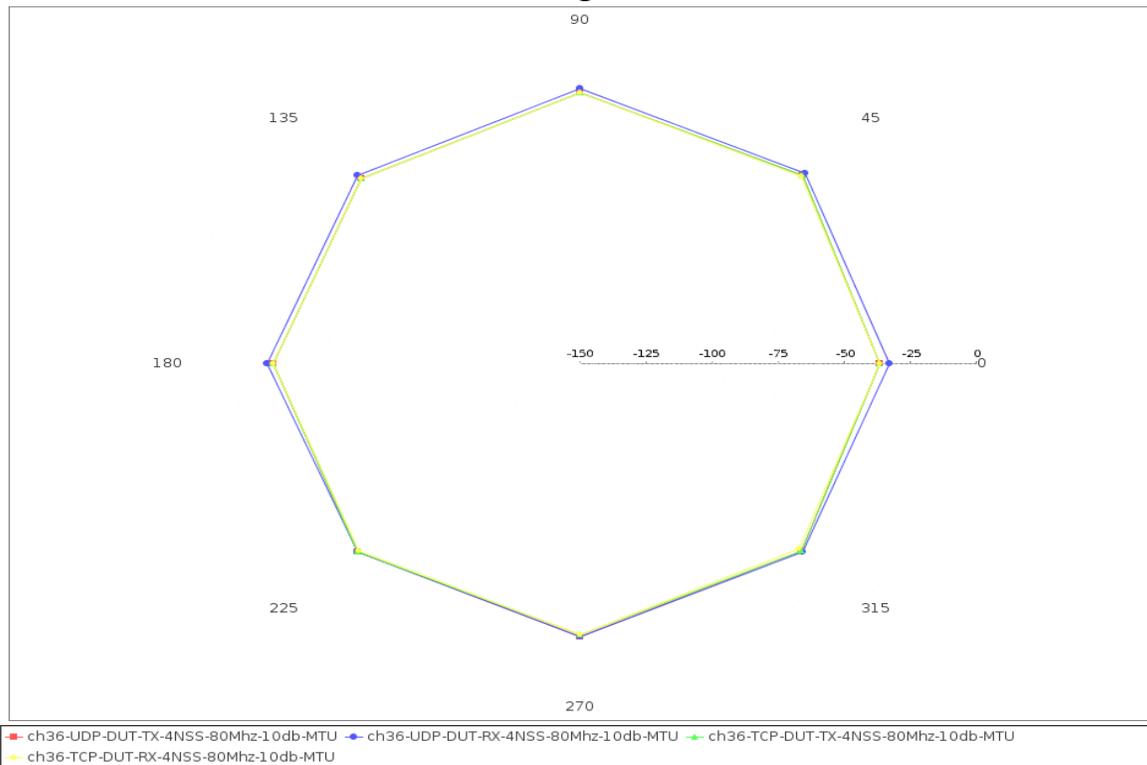
# Rate vs Orientation test:



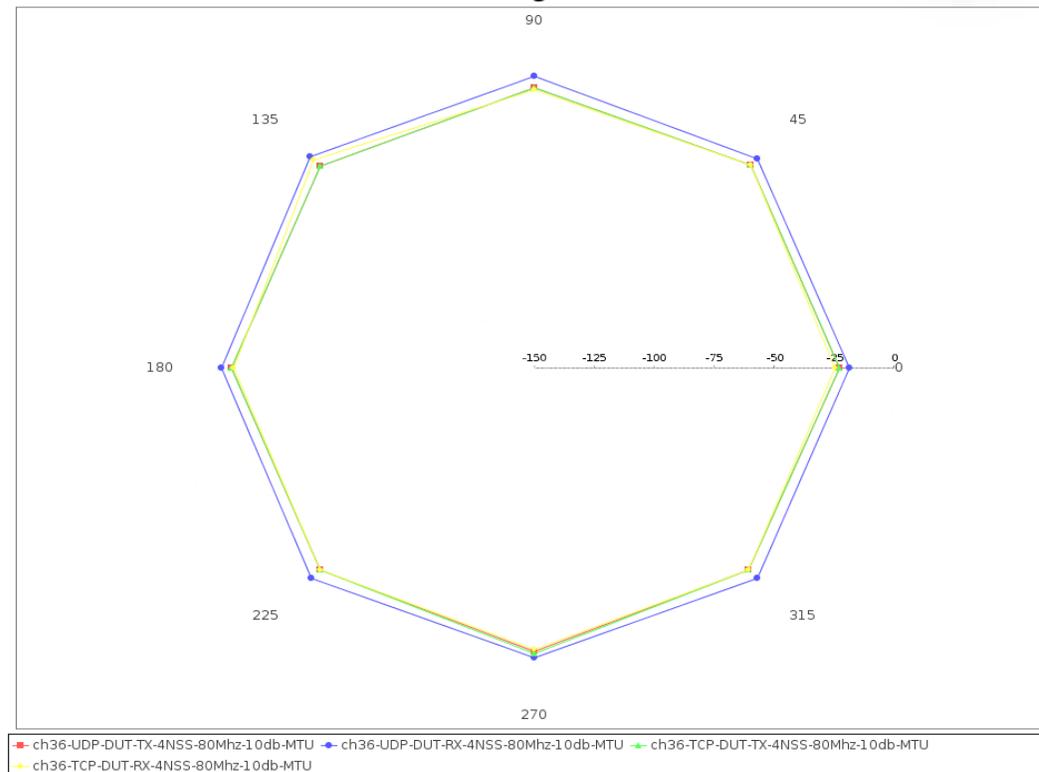
- Here we change both the distance and the angular position of the CPE and calculate the throughput.
- Changing the distance means in terms of increasing the attenuation.
- The maximum attenuation at which the client can connect to the CPE IS 60dbm.
- Changing the orientation means in terms of changing the angle of the turntable.
- The turntable can rotate from 0 to 360 degrees.
- We can run both the TCP and UDP traffics.

# Rate vs Orientation test at 0db (5GHz):

**Vendor-A**  
RSSI related to Signal and Rotation



**Vendor-B**  
RSSI related to Signal and Rotation



## Test Analysis:

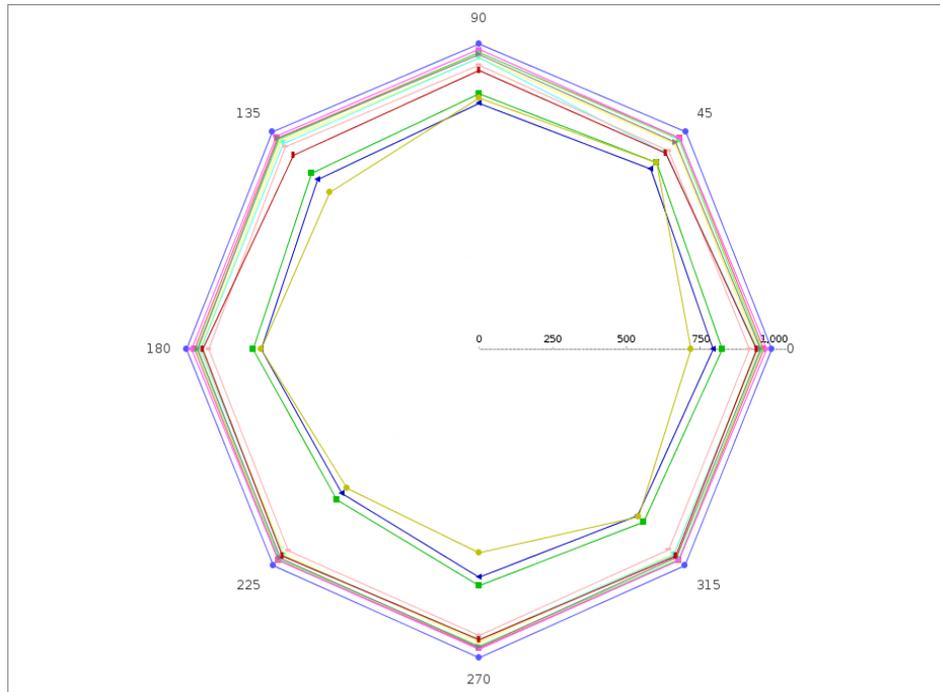
- Attenuation=0db, orientation= 0-360 degrees with an increment of 45degrees.
- Here the RSSI values are between 25dbm to 50dbm for SKY-CPE.
- The RSSI values are at 25dbm constantly for Vendor-B.

Result:  
Vendor-B is showing good RSSI values.

# Throughput at 0db (5GHz):

## Vendor-A

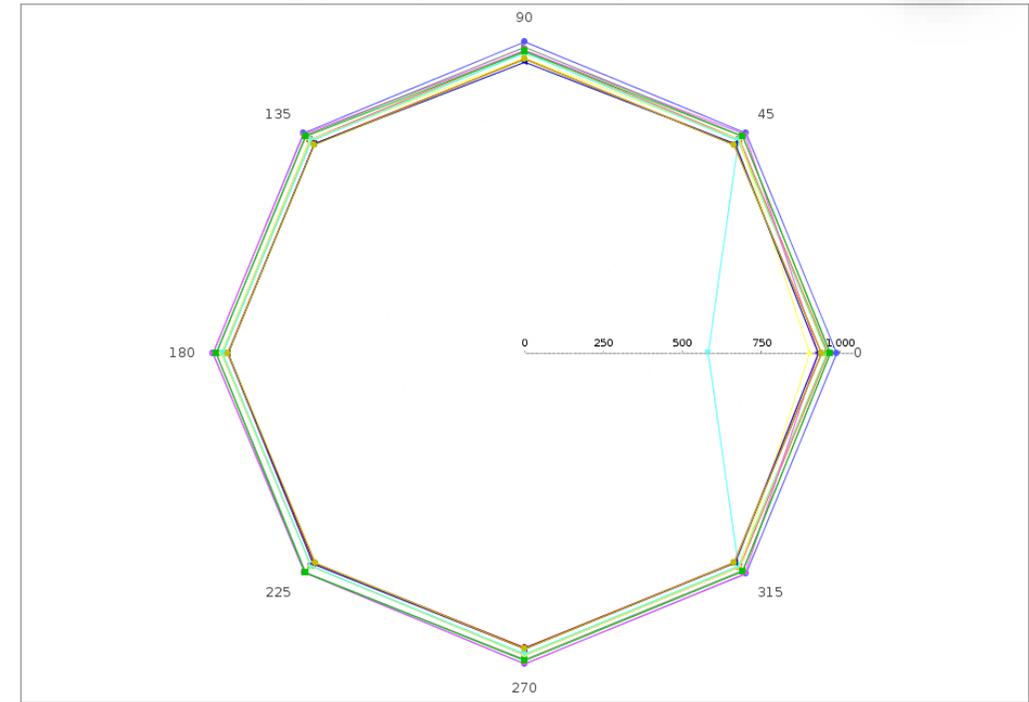
Throughput (Mbps) related to Signal and Rotation



● ch36-UDP-DUT-TX-4NSS-80Mhz-1.0db-MTU ● ch36-UDP-DUT-TX-4NSS-80Mhz-1.0db-MTU-LL ● ch36-UDP-DUT-TX-4NSS-80Mhz-1.0db-MTU-3s  
 ● ch36-UDP-DUT-RX-4NSS-80Mhz-1.0db-MTU ● ch36-UDP-DUT-RX-4NSS-80Mhz-1.0db-MTU-LL ● ch36-UDP-DUT-RX-4NSS-80Mhz-1.0db-MTU-3s  
 ● ch36-TCP-DUT-TX-4NSS-80Mhz-1.0db-MTU ● ch36-TCP-DUT-TX-4NSS-80Mhz-1.0db-MTU-LL ● ch36-TCP-DUT-TX-4NSS-80Mhz-1.0db-MTU-3s  
 ● ch36-TCP-DUT-RX-4NSS-80Mhz-1.0db-MTU ● ch36-TCP-DUT-RX-4NSS-80Mhz-1.0db-MTU-LL ● ch36-TCP-DUT-RX-4NSS-80Mhz-1.0db-MTU-3s

## VENDOR-B

Throughput (Mbps) related to Signal and Rotation



● ch36-UDP-DUT-TX-4NSS-80Mhz-1.0db-MTU ● ch36-UDP-DUT-TX-4NSS-80Mhz-1.0db-MTU-LL ● ch36-UDP-DUT-TX-4NSS-80Mhz-1.0db-MTU-3s  
 ● ch36-UDP-DUT-RX-4NSS-80Mhz-1.0db-MTU ● ch36-UDP-DUT-RX-4NSS-80Mhz-1.0db-MTU-LL ● ch36-UDP-DUT-RX-4NSS-80Mhz-1.0db-MTU-3s  
 ● ch36-TCP-DUT-TX-4NSS-80Mhz-1.0db-MTU ● ch36-TCP-DUT-TX-4NSS-80Mhz-1.0db-MTU-LL ● ch36-TCP-DUT-TX-4NSS-80Mhz-1.0db-MTU-3s  
 ● ch36-TCP-DUT-RX-4NSS-80Mhz-1.0db-MTU ● ch36-TCP-DUT-RX-4NSS-80Mhz-1.0db-MTU-LL ● ch36-TCP-DUT-RX-4NSS-80Mhz-1.0db-MTU-3s

### Test analysis:

- Attenuation=0db, orientation= 0-360 degrees with an increment of 45degrees.
- Here the Throughput values are between 730mbps to 950mbps for SKY-CPE from 0-360 degrees.
- Here the Throughput 900mbps to 950mbps above for Vendor-B from 0-360 degrees.

**Result:**  
Vendor-B is showing a consistent performance in throughput compared to Vendor-A.

Report link: <https://www.dropbox.com/s/p925d4qdz8ma996/o-att.pdf?dl=0>

# Lots of Tests Run.....

## Dataplane Test



Sat Jun 01 06:42:53 PDT 2019

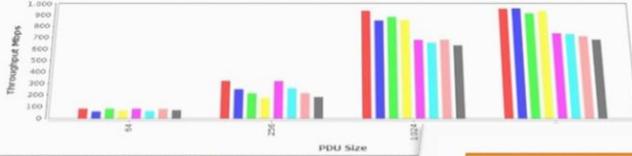
| Test Setup Information |                          |               |              |
|------------------------|--------------------------|---------------|--------------|
| Name                   | APUT                     |               |              |
| Software Version       | v5.62.3                  |               |              |
| Model Number           | AP640                    | Serial Number | 234-23-6d-35 |
| SSIDs                  | labap                    |               |              |
| BSSIDs                 | 76:ec:84:0f:18:43        |               |              |
| Operator               | John Smith@awesomeAP.com |               |              |

### Objective

The Candela WiFi 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 test 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.

Throughput by MTU, for each different traffic type:

Throughput vs PDU Size



Pps throughput by MTU, for each different traffic type. The values are estimated packet sizes such as TCP make this difficult to know for certain, so the value is extrapolated.

## RX-Sensitivity Test



Sat Jun 01 09:22:52 PDT 2019

| Test Setup Information |                          |               |              |
|------------------------|--------------------------|---------------|--------------|
| Name                   | APUT                     |               |              |
| Software Version       | v5.62.3                  |               |              |
| Model Number           | AP640                    | Serial Number | 234-23-6d-35 |
| SSIDs                  | labap                    |               |              |
| BSSIDs                 | 76:ec:84:0f:18:43        |               |              |
| Operator               | John Smith@awesomeAP.com |               |              |

### Objective

In the real-world the Device Under Test WiFi receiver is expected to handle stations at many different receive signal strengths and many different station transmit modulation and coding schemes (MCS rates). The Candela Receiver Sensitivity test provides an excellent way to test the DUT receiver for all combinations of station transmit power and MCS rates. It can report packet loss and throughput for all combinations. The test plots the receiver sensitivity curves and can provide a clear indication of problem patterns for certain combinations of Tx power and MCS rates. The expected behavior is for the DUT to achieve equal or better receiver sensitivity as defined by the spec for all RSSI and MCS settings. This test requires a special feature that is currently only supported by LANforge Wave-2 radios.

Throughput vs calculated RF Signal for each different traffic type. The signal is calculated based on the configured path-loss, transmit power, and attenuation.

Throughput vs Calculated Signal



Note that the LANforge RSSI may be 3-4 dB higher than the actual signal strength due to the power and RF splitter/combiners can.

## WiFi Mobility Report



Sat Jun 01 08:13:35 PDT 2019

### Objective

The Candela Roam test uses the forced roam method to create and roam hundreds of WiFi stations between two or more APs with the same SSID on the same channel or different channels. The user can run thousands of roams over long durations and the test measures roaming delay for each roam, station connection times, network down time, packet loss etc. The user can run this test using different security methods and compare the roaming performance. The expected behavior is the roaming delay should be 50msecs or less for all various kinds of fast roaming methods to avoid any form of service interruption to real-time delay sensitive applications.

Roam Percentage per Duration



Station Roam Times



## Rate vs Range Test



Sat Jun 01 10:01:31 PDT 2019

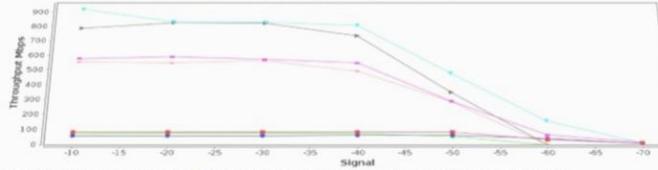
| Test Setup Information |                   |               |              |
|------------------------|-------------------|---------------|--------------|
| Name                   | APUT              |               |              |
| Software Version       | v5.62.3           |               |              |
| Model Number           | AP640             | Serial Number | 234-23-6d-35 |
| SSIDs                  | labap             |               |              |
| BSSIDs                 | 76:ec:84:0f:18:43 |               |              |
| Operator               | (BLANK)           |               |              |

### Objective

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.

Throughput vs calculated RF Signal for each different traffic type. The signal is calculated based on the configured path-loss, transmit power, and attenuation.

Throughput vs Calculated Signal



Realtime Graph shows summary download and upload RX bps of connections created by this test.

## WiFi Capacity Test



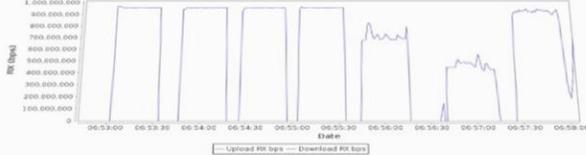
Sat Jun 01 07:00:24 PDT 2019

### Objective

The Candela WiFi Capacity test is designed to measure performance of an Access Point when handling different amounts of WiFi 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 test. Along with throughput other measurements include per station connection times, fairness, packet loss, latency times and roam. The expected behavior is for the AP to 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. An AP that scales well will not show a significant overall throughput decrease as more stations are added.

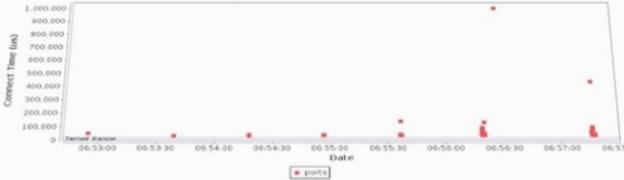
Realtime Graph shows summary download and upload RX bps of connections created by this test.

Realtime BPS



Station connect time is calculated from the initial Authenticate message through the completion of Open or RSN association/authentication.

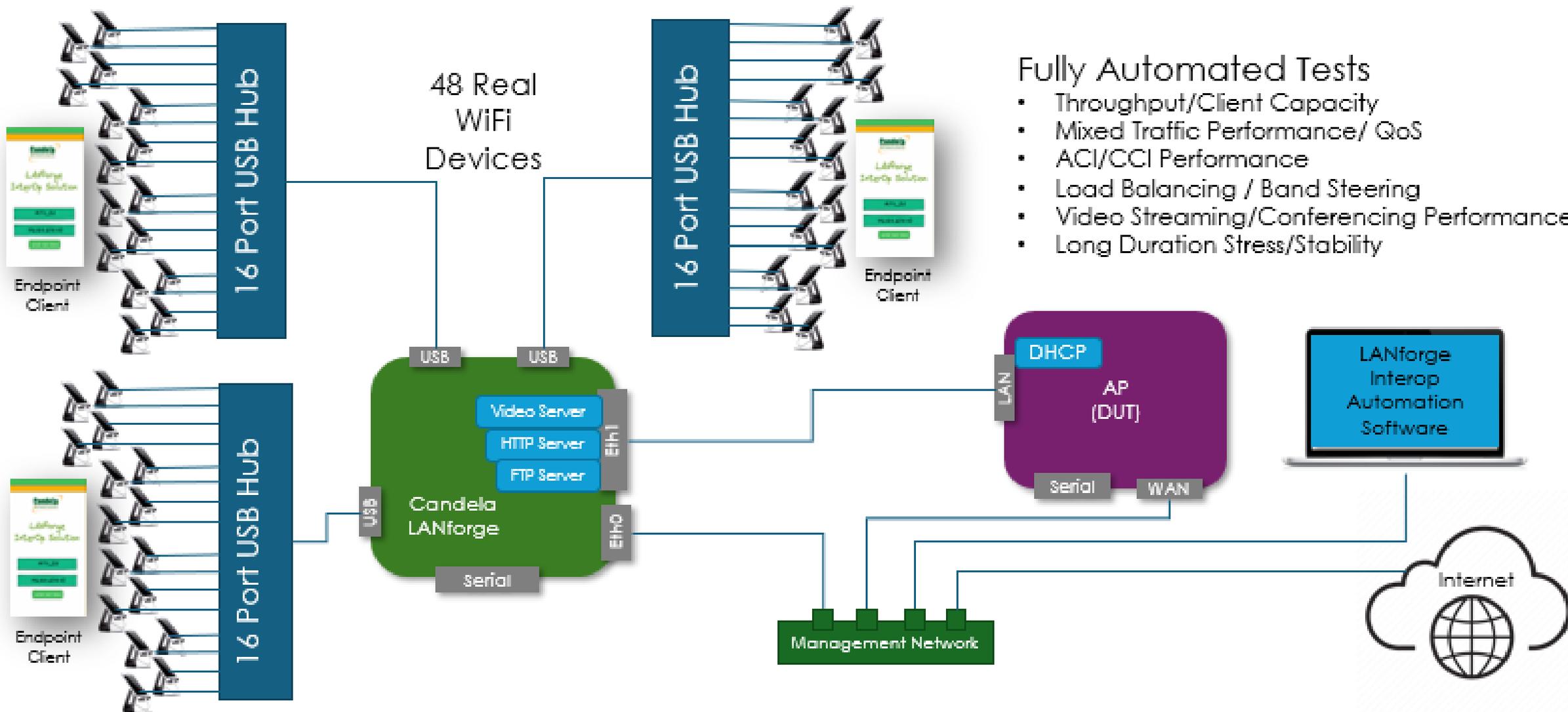
Station Connect Times



# Real Device Testing - LANforge Interop Testbed



# 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

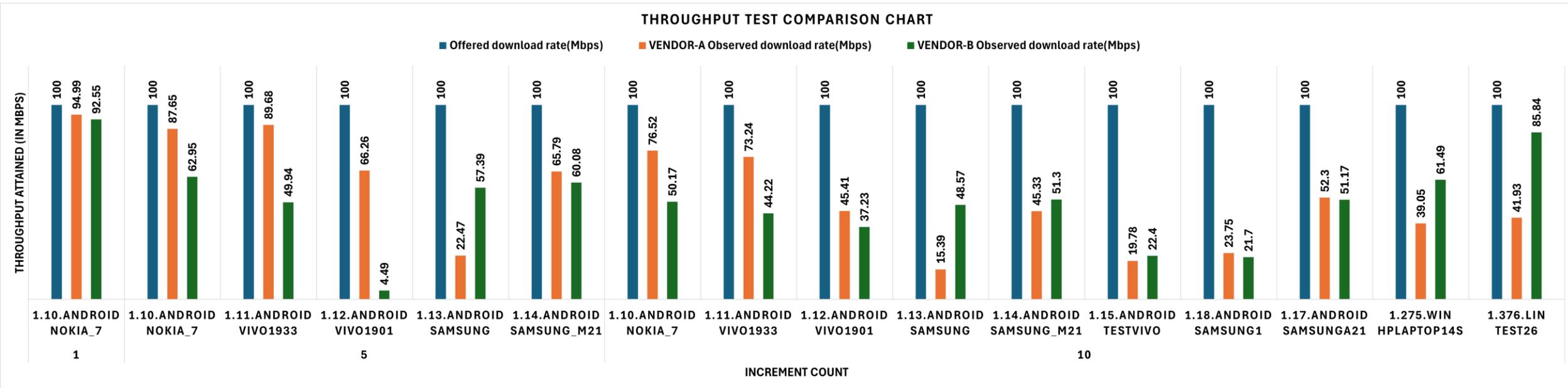
# Test Coverage

- ✓ Throughput test
- ✓ Interoperability Test
- ✓ QOS Test
- ✓ Multicast Test
- ✓ Ping Plotter Test
- ✓ Port Reset Test
- ✓ FTP Test
- ✓ HTTP Test
- ✓ Video Streaming
- ✓ Real Browser Test
- ✓ YouTube Streaming Test
- ✓ Zoom Call Test
- ✓ Mixed Traffic Test

# Throughput Test



- The **Candela Throughput test** assesses Access Point performance with real clients, including Android, Linux, and Windows, measuring per-client and overall throughput as client count increases. The test evaluates scalability, airtime fairness, and performance consistency under load.
- Vendor-A demonstrated stable and consistent throughput across multiple client increments. It performed well with Android devices like Nokia and Vivo, maintaining higher throughput as the number of clients increased. Even under load, Vendor-A sustained relatively stable performance without significant drops.

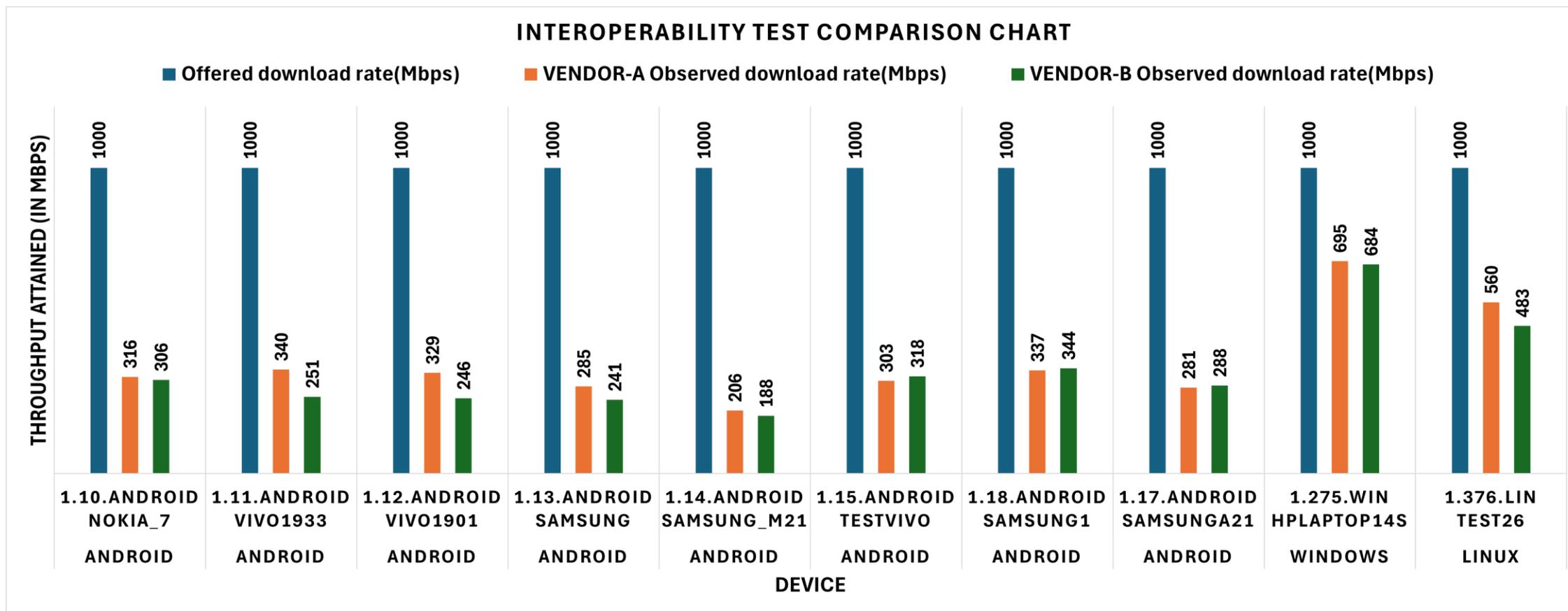


# Throughput Test

- Vendor-B showed noticeable throughput fluctuations, particularly with increasing client numbers. While it struggled with consistency, it outperformed Vendor-A on select devices, such as Samsung and Windows laptops. However, certain devices, like Vivo1901, experienced a drastic performance drop with Vendor-B.
- As client load increased, Vendor-A maintained better overall performance, while Vendor-B struggled with throughput stability. Windows and Linux devices performed better on Vendor-B, whereas Android devices showed stronger performance on Vendor-A.
- In summary, Vendor-A provided more reliable and scalable performance, handling load increases effectively. Vendor-B showed higher peak throughput in some cases but lacked overall consistency, making it less reliable under varying conditions.

# Interoperability Test

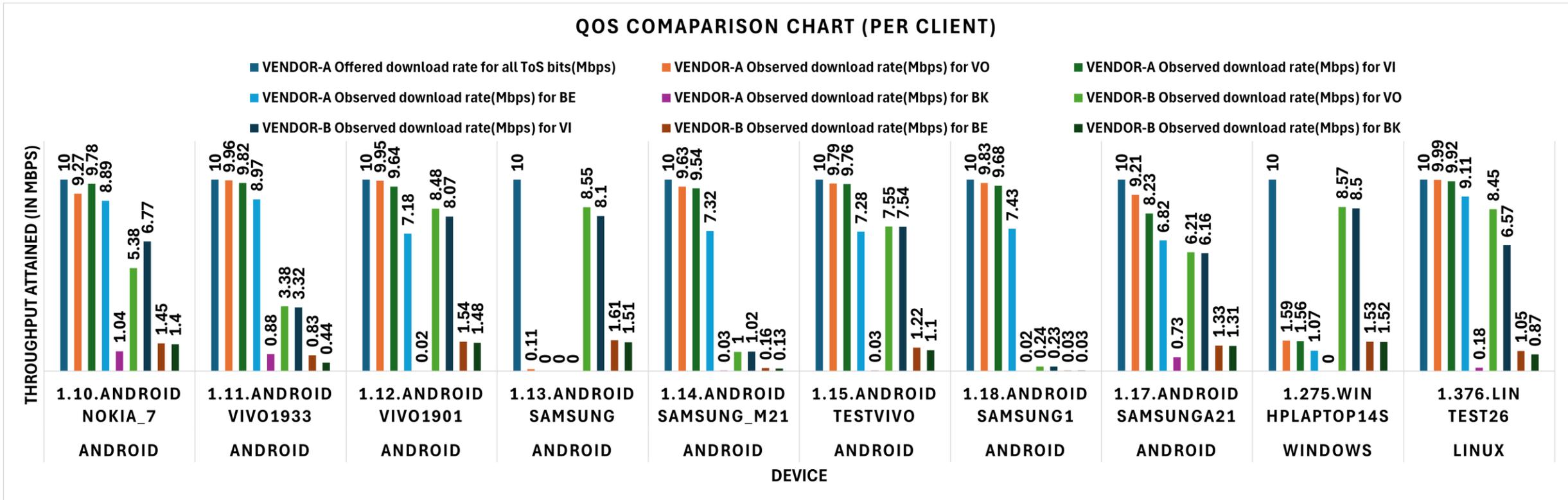
- The **Candela Interoperability test** is designed to measure an Access Point's performance when handling single real clients using different OS, such as Android, Linux, Windows, and iOS. The test evaluates the per-client performance over a given duration, measuring the throughput for each client. Additionally, it ensures that all clients receive a fair share of airtime for both upstream and downstream traffic based on the client specifications.



# Interoperability Test

- Vendor-A demonstrated strong and stable throughput across most Android devices, consistently outperforming Vendor-B on key models, including Nokia\_7, vivo1933, Vivo1901, and Samsung.
- Vendor-B exhibited more variability in performance. While it generally lagged behind Vendor-A, it outperformed in select cases, such as testvivo and Samsung1.
- For Windows and Linux, both vendors showed high performance, with Win HPLaptop14s and Lin test26 performing better on Vendor-A.
- In summary, Vendor-A provided more consistent and stable throughput, particularly excelling with Nokia\_7, vivo1933, and Vivo1901. Vendor-B demonstrated competitive performance on select devices like testvivo and Samsung1 but showed more variability overall, making it less predictable under high-load conditions.

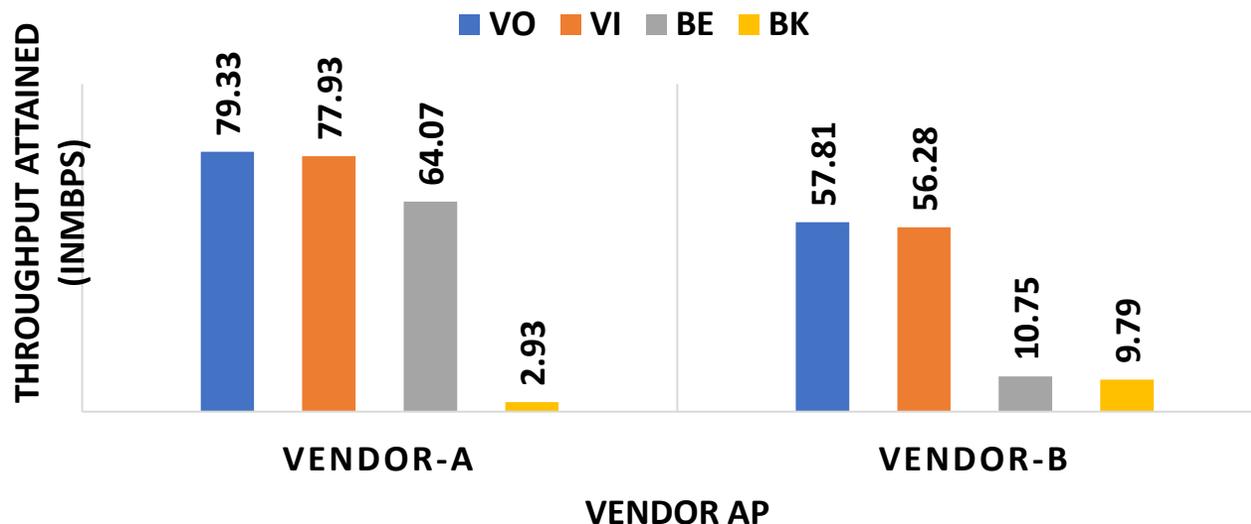
- The **Candela QoS (Quality of Service) traffic test** measures the network's ability to handle high traffic volumes while maintaining performance across different ToS (Type of Service) categories—**Voice (VO)**, **Video (VI)**, **Best Effort (BE)**, and **Background (BK)**. This ensures that the network meets QoS standards and can support real-world usage demands.



# QoS Test

- Vendor-A demonstrated strong prioritization of high-priority traffic (VO, VI), achieving near-max throughput across multiple Android devices, including Nokia\_7, vivo1933, and Vivo1901.
- Vendor-B struggled with maintaining consistent QoS, particularly in the Best Effort (BE) and Background (BK) categories, where throughput dropped significantly on several devices.
- Windows (HPLaptop14s) and Linux (Lin test26) performed better on Vendor-B in high-priority categories, while Vendor-A showed inconsistencies.
- In Summary Vendor-A delivered more reliable QoS handling, prioritizing real-time traffic efficiently, while Vendor-B displayed significant variations, particularly in lower-priority traffic categories.

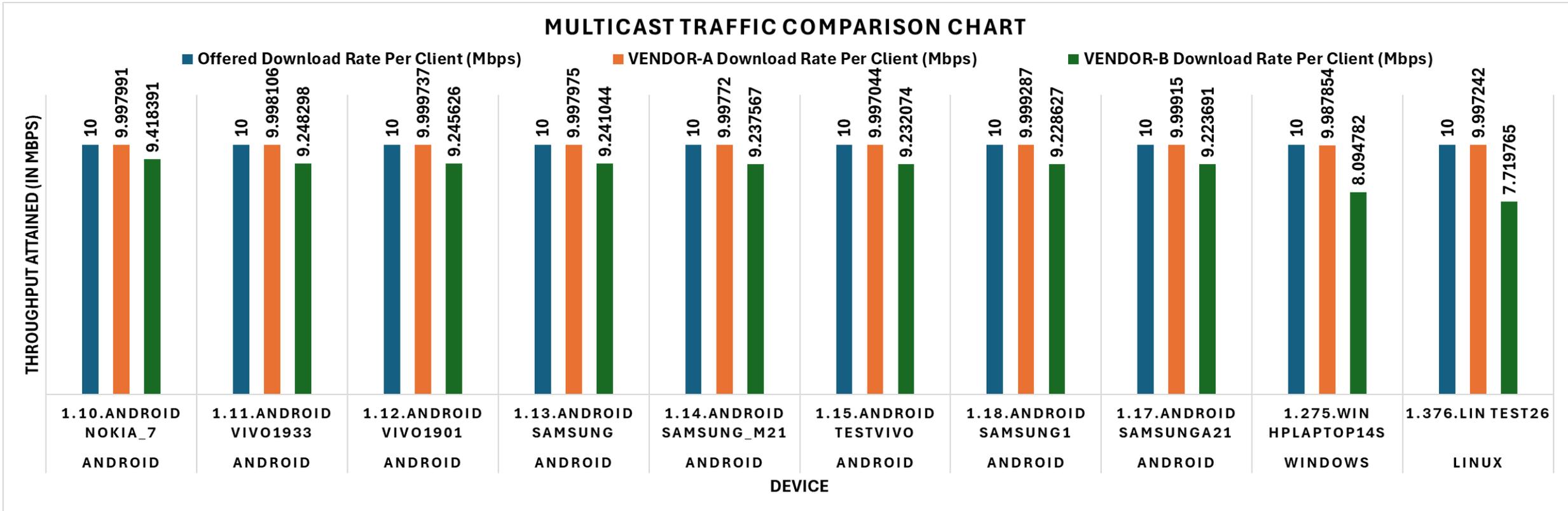
**TOTAL QOS THROUGHPUT COMPARISON CHART**



# Multicast Test



- The **Candela Multicast Traffic Test** is designed to evaluate the efficiency, reliability, and scalability of multicast communication across various real-world client devices, including Android, Linux, and Windows. By simulating multicast traffic, this test provides insights into how well the network handles multicast distribution under different conditions, identifying potential performance issues related to latency, throughput consistency, and packet delivery.

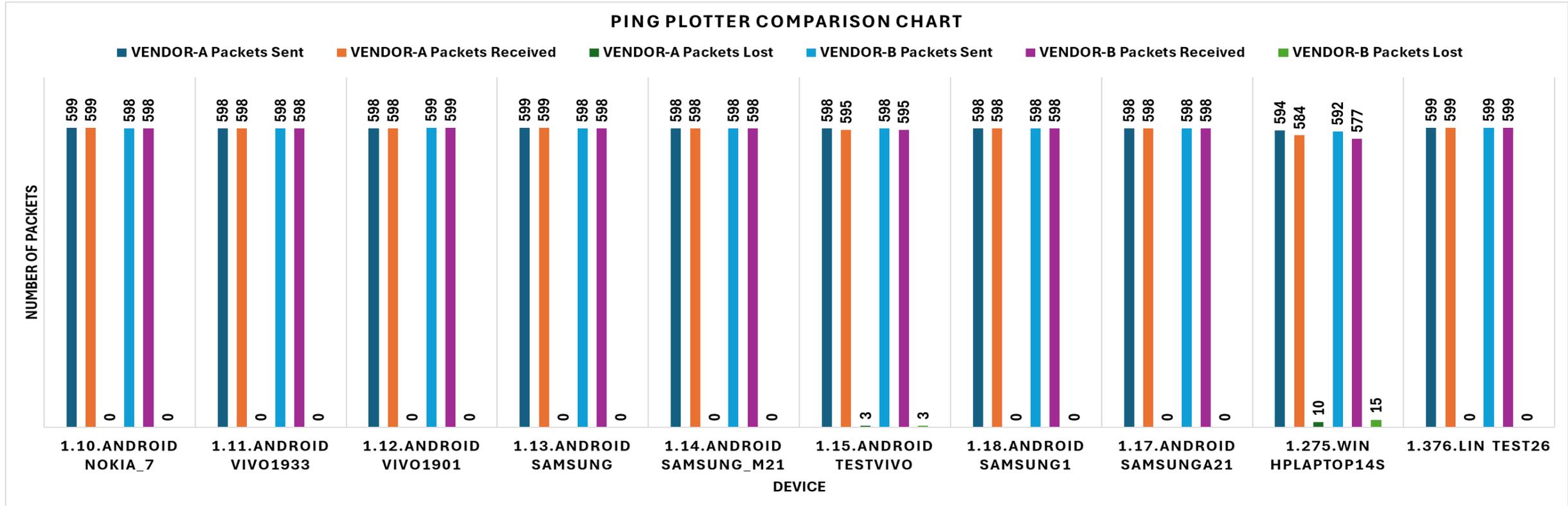


# Multicast Test

- Vendor-A maintained near-perfect multicast throughput across all devices, consistently achieving ~9.99 Mbps per client with zero packet drops, demonstrating excellent multicast efficiency.
- Vendor-B showed variations in multicast throughput, with most Android devices performing similarly to Vendor-A, but Windows and Linux devices experienced noticeable performance drops.
- The Windows (HPLaptop14s) client exhibited a 13.88% drop in throughput under Vendor-B, indicating potential inefficiencies in handling multicast traffic for Windows devices.
- The Linux (test26) client suffered the highest drop at 15.67% under Vendor-B, suggesting multicast packet loss or suboptimal handling on Linux platforms.
- Android devices maintained stable throughput under both vendors, but Vendor-A's multicast handling was more consistent across all operating systems.
- In Summary Vendor-A demonstrated superior multicast efficiency with stable throughput and zero packet loss across all tested devices. Vendor-B performed well for Android clients but struggled with multicast distribution on Windows and Linux, leading to noticeable throughput drops. Further optimizations may be needed in Vendor-B's multicast handling, particularly for non-Android platforms.

# Ping Plotter Test

- The **Candela Ping Plotter test** is to evaluate network connectivity and measure the round-trip time taken for data packets to travel from the source to the destination and back. It helps assess the reliability and latency of the network, identifying any packet loss, delays, or variations in response times. The test aims to ensure that devices can communicate effectively over the network and pinpoint potential issues affecting connectivity.

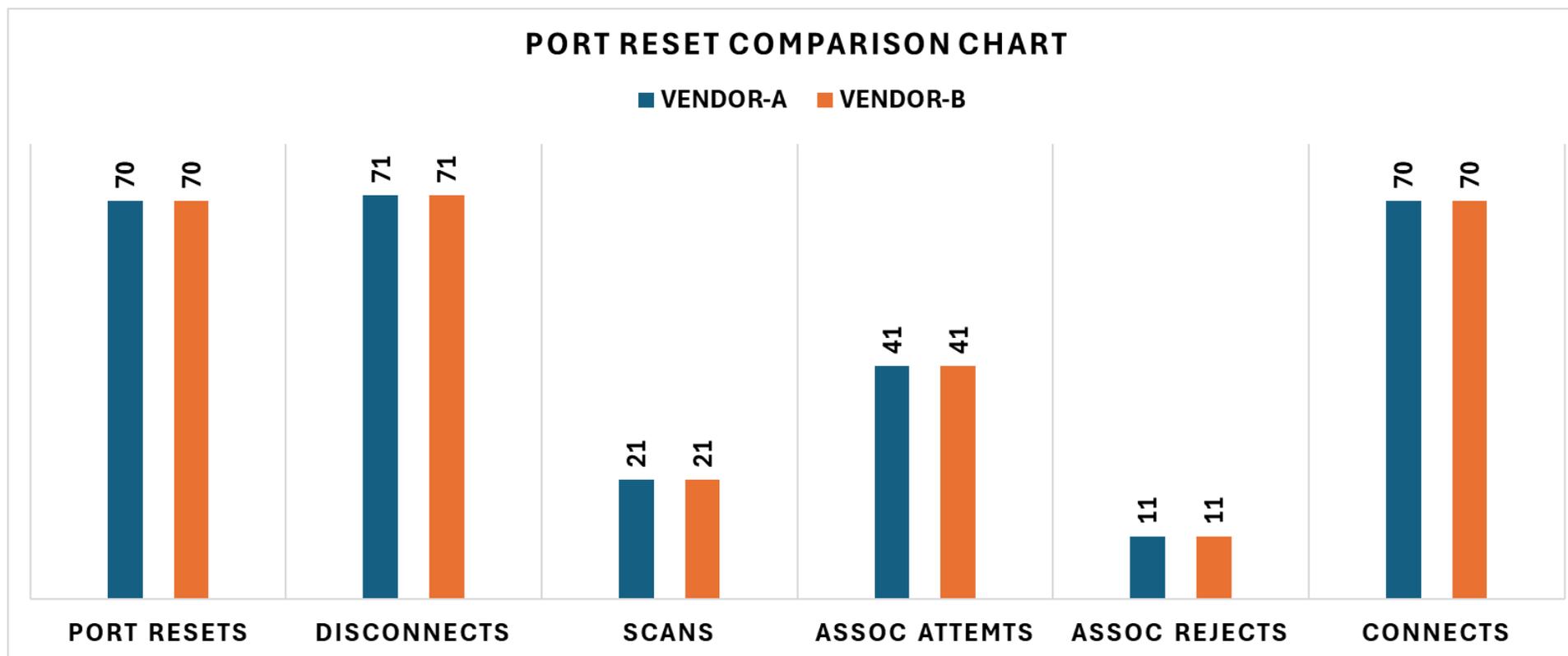


# Ping Plotter Test

- Packet Loss: Minimal across devices, except for Windows (HPLaptop14s), which recorded higher loss (1.68%-2.53%).
- RTT Performance: VENDOR-A consistently showed lower RTT (19.88 ms – 40.25 ms), whereas VENDOR-B had significantly higher RTT (64.10 ms – 102.84 ms).
- Device Trends:
  - Android devices performed better on VENDOR-A, showing lower and more stable RTT.
  - Windows device had higher packet loss and RTT, impacting performance.
  - Linux device had moderate RTT, but still performed better on VENDOR-A.
- In Summary, VENDOR-A demonstrated superior network performance, ensuring better connectivity and lower delays, while VENDOR-B exhibited higher RTT and potential network inefficiencies.

# Port Reset Test

- The **Candela Port Reset Test** is designed to evaluate the stability and performance of the Access Point (AP) under stress by simulating frequent disconnections and reconnections of multiple Wi-Fi stations. This test mimics the dynamic environment of a busy enterprise or public venue, where stations continuously arrive and depart. The primary objective is to assess the AP's control and management functions, ensuring reliable connectivity and effective handling of frequent connection disruptions.

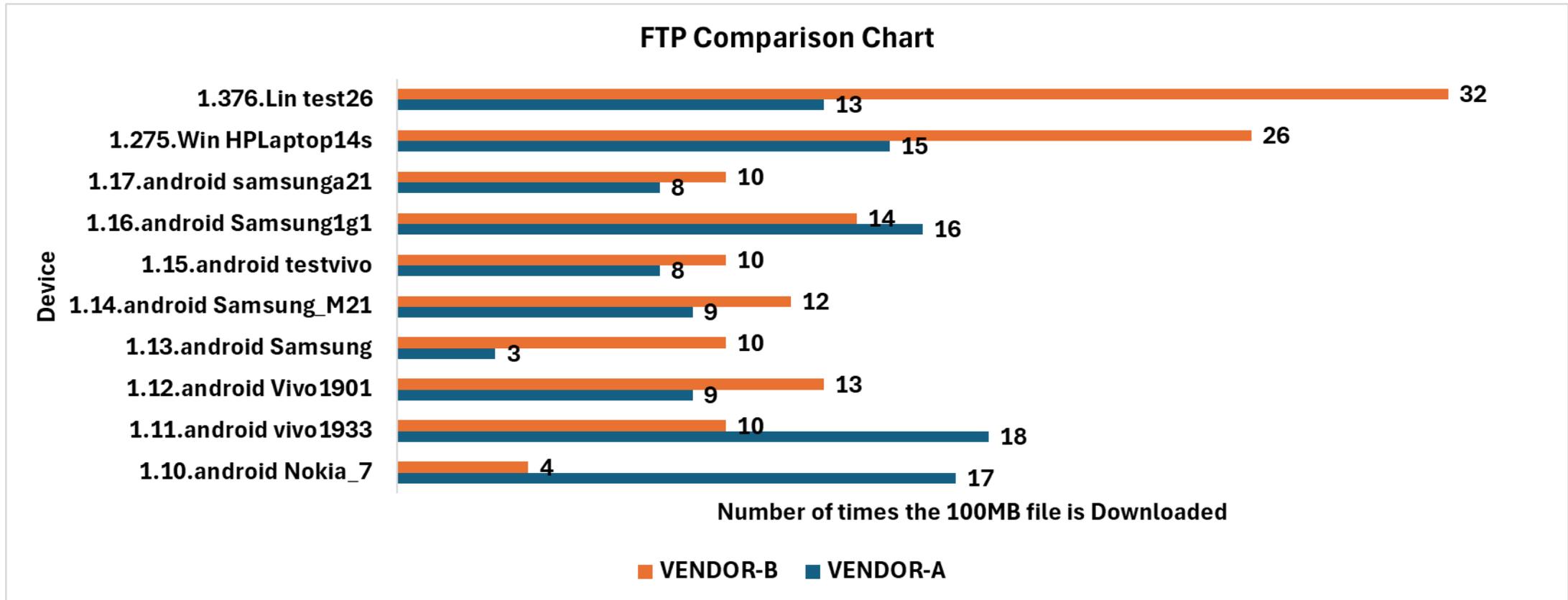


# Port Reset Test

- **Port Resets:** Both Vendor-A and Vendor-B stations experienced 10 resets each, indicating consistent behavior during disconnections and reconnections.
- **Disconnects:** Minor variation in disconnects, with Vendor-A's Win HPLaptop14s showing 11 disconnects. All other devices in both vendors had 10 disconnects.
- **Association Attempts/Rejects:** Vendor-A's Nokia\_7 had 20 attempts and 10 rejects, indicating potential compatibility issues. Vendor-B showed stable association attempts with fewer rejects.
- **Connects:** Both vendors achieved 10 successful connections, demonstrating stable reconnection performance.
- In Summary, Vendor-A and Vendor-B performed similarly, but Vendor-A's Nokia\_7 device showed higher reject rates.

# FTP Test

- The **Candela FTP Test** is designed to verify that multiple clients, connected on a specified band, can simultaneously download a specified file size from an FTP server. The test measures the time taken by each client to download the file, providing insights into the network performance and efficiency under load conditions.



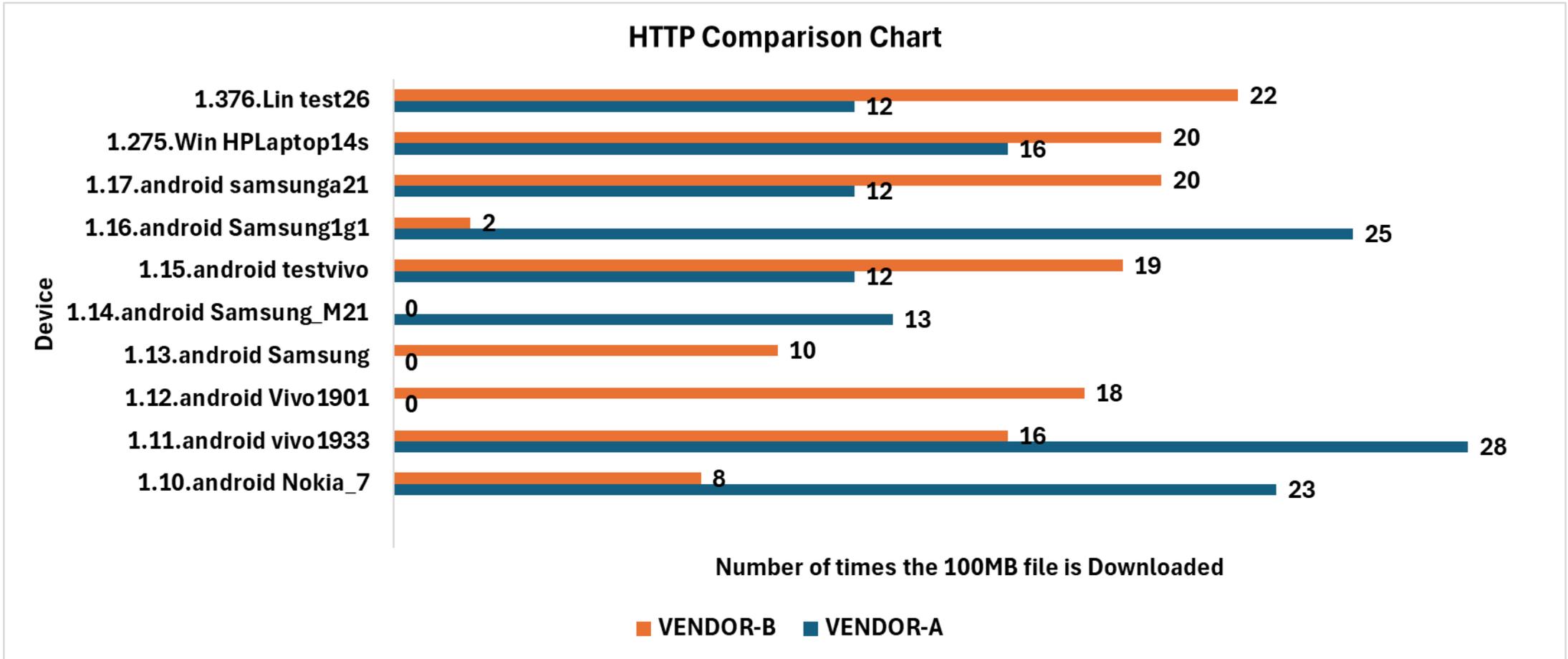
# FTP Test

- Vendor-A devices (e.g., Nokia\_7, vivo1933, Samsung) generally show varied download rates, with values ranging from 8 Mbps to 18 Mbps.
- Vendor-B devices (e.g., vivo1933, Samsung, testvivo) show better throughput with values ranging from 10 Mbps to 32 Mbps, especially in higher-end devices like HPLaptop14s (26 Mbps).
- Rx-Rate (download rate) measurements highlight that Vendor-B outperforms Vendor-A in most cases, especially in devices like vivo1933 and HPLaptop14s, showing better handling of FTP file transfers.
- Bytes-RD values represent the total number of bytes received, showing that Vendor-B devices consistently download larger files, further proving better throughput.
- In summary, Vendor-B consistently outperforms Vendor-A in terms of FTP download rates across various devices.

# HTTP Test



- The **Candela HTTP Test** is designed to verify that multiple clients, connected on a specified band, can simultaneously download a specified file size from an HTTP server. The test measures the time taken by each client to download the file, providing insights into the network performance and efficiency under load conditions.

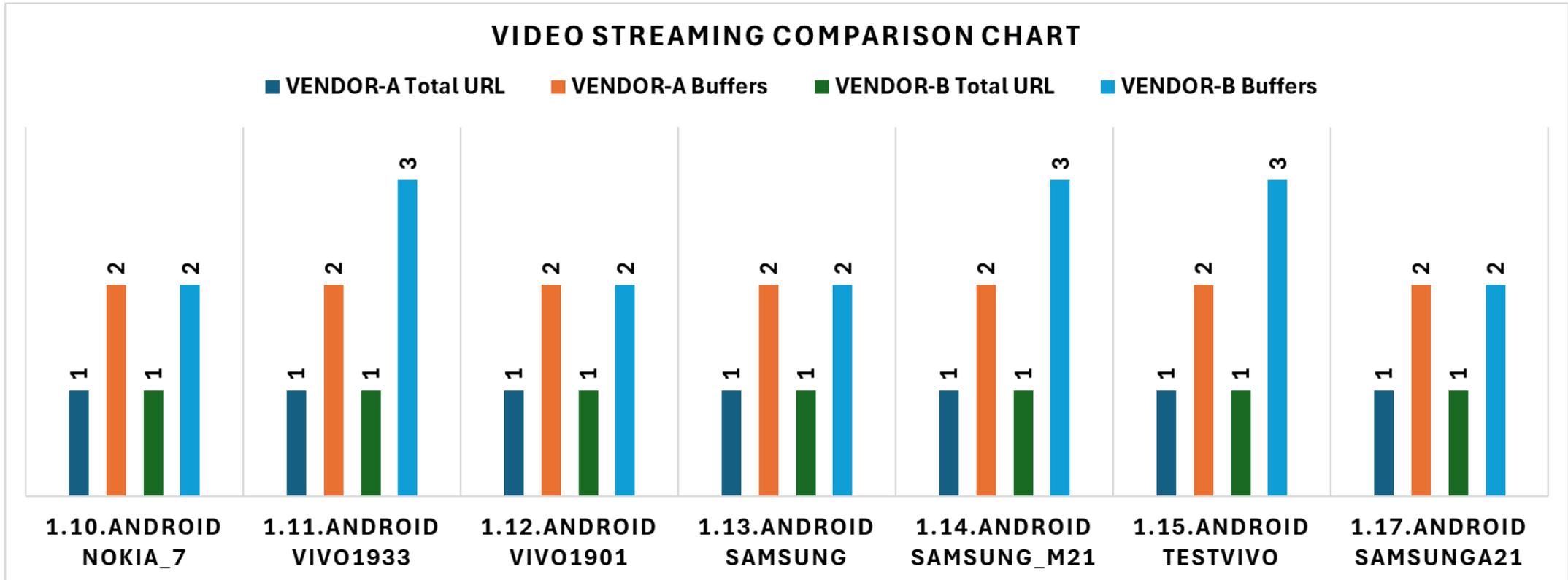


# HTTP Test

- Vendor-A devices (e.g., Nokia\_7, vivo1933, Samsung) show a wide range of performance, with download rates ranging from 8 Mbps to 28 Mbps.
- Vendor-B devices (e.g., vivo1933, Samsung, testvivo) consistently demonstrate better download speeds, ranging from 2 Mbps to 20 Mbps, with peak performance seen in testvivo and HPLaptop14s.
- The Bytes-RD values indicate that Vendor-B devices download significantly larger file sizes in comparison to Vendor-A devices, suggesting that Vendor-B devices have better throughput.
- The RX-Rate (download rate) measurements show that Vendor-B devices, particularly testvivo, vivo1933, and HPLaptop14s, outperform Vendor-A devices like Nokia\_7 and Samsung in terms of download speeds.
- In summary, Vendor-B outperforms Vendor-A in the HTTP download test across multiple devices, particularly for devices like HPLaptop14s and testvivo.

# Video Streaming Test

- The **Candela Video Streaming Test** is designed to measure the access point performance and stability by streaming the videos from the local browser or from over the Internet in real clients like android which are connected to the access point, this test allows the user to choose the options like video link, type of media source, media quality, number of playbacks. Along with the performance other measurements like No of Buffers, Wait-Time, per client Video Bitrate, Video Quality, and more.



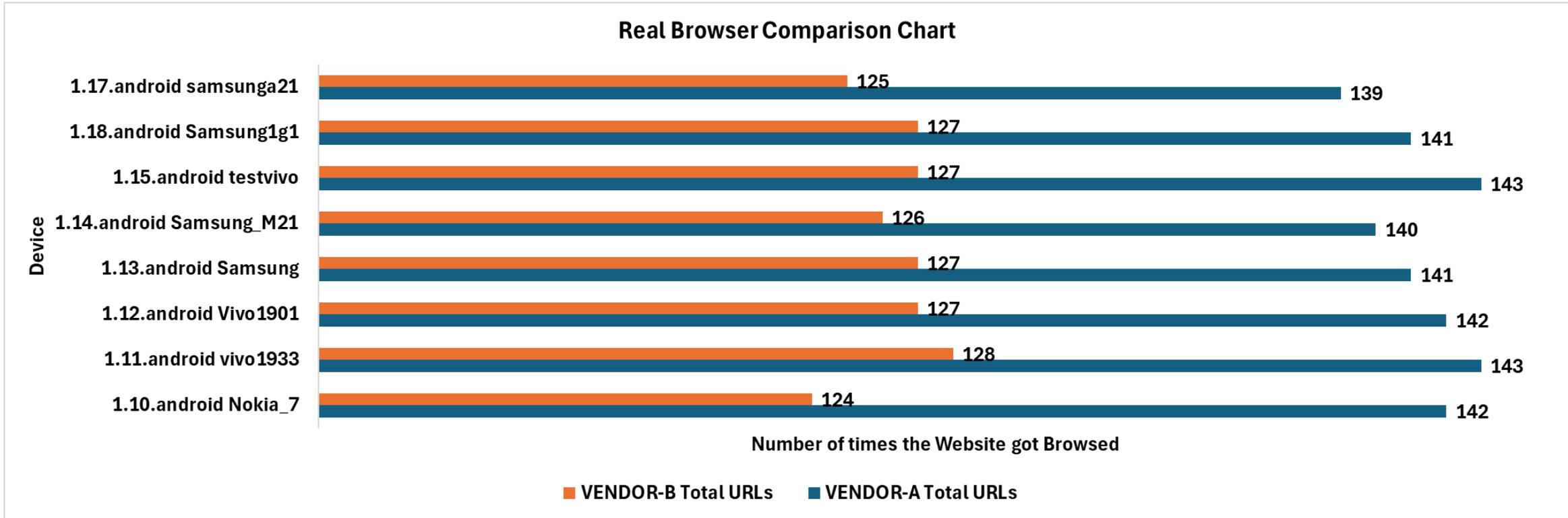
# Video Streaming Test

- Vendor-A devices (e.g., Nokia\_7, vivo1933, Samsung) show higher Bytes-RD values, indicating better throughput compared to Vendor-B.
- Vendor-B devices (e.g., vivo1933, Samsung\_M21, testvivo) experience more buffering events (2-3 times), leading to possible playback interruptions.
- RX-Rate (download speed) is consistently higher on Vendor-A across most devices, with Nokia\_7 and vivo1933 achieving peak performance.
- Vendor-B devices show lower RX-Rates, especially Samsung\_A21 (709 kbps), which could lead to video lag and buffering issues.
- In summary, Vendor-A demonstrates superior video streaming performance, offering higher throughput and fewer interruptions compared to Vendor-B.

# Real Browser Test



- The **Candela Real Browser Test** is designed to measure the performance and stability of an access point by simulating real-world browsing activities across devices such as Android, Linux, Windows, and iOS. This test allows users to configure parameters like website links, the number of times a page should be browsed, and the time taken to complete the browsing task. In addition to performance metrics, it also collects data on failed URL attempts and other relevant measurements.

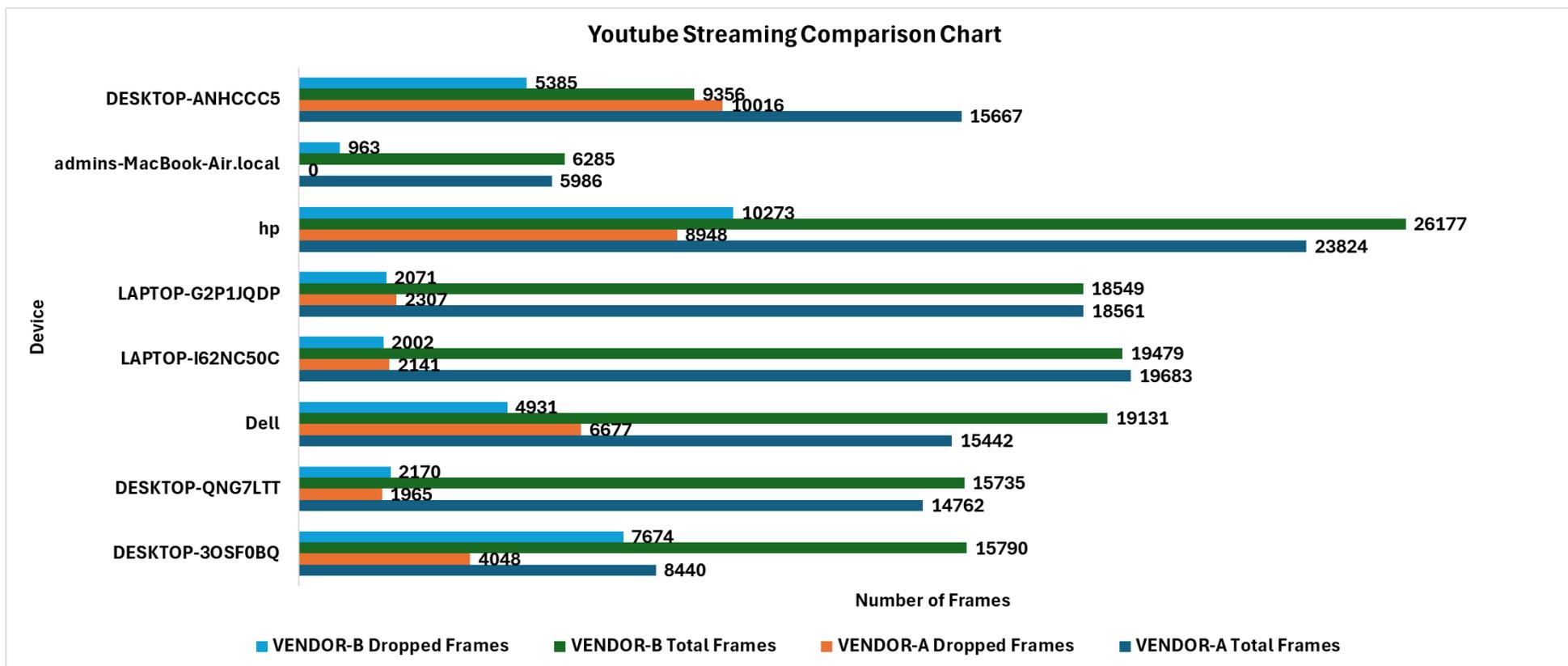


# Real Browser Test

- Vendor-A devices consistently completed more URLs (140-143) compared to Vendor-B (124-128), indicating better handling of web requests.
- Vendor-A showed faster page load times, completing 50 URLs in 311-320 seconds, whereas Vendor-B took longer (346-360 seconds).
- Nokia\_7 and vivo1933 in Vendor-A were the top performers, with the fastest completion times.
- Samsung\_A21 in Vendor-B had the slowest performance, taking 360 seconds to complete 50 URLs.
- Overall, Vendor-A demonstrates superior web browsing efficiency, achieving higher URL completion rates and faster browsing speeds than Vendor-B.

# YouTube Streaming Test

- The **Candela YouTube Streaming Test** is designed to evaluate the performance of video streaming across multiple laptops by collecting key statistics such as video resolution, buffer health, total frames, and dropped frames. This test simulates real-world streaming scenarios to assess the stability and efficiency of video playback across different devices and operating systems.



# YouTube Streaming Test

- **Buffer Health:** Vendor-A showed a generally stable maximum buffer health across all devices, with a few minor variations. Vendor-B performed well, with buffer health metrics staying close to Vendor-A. However, Vendor-B devices like hp (Linux) had slightly higher buffer health, indicating a more stable stream.
- **Total Frames vs Dropped Frames:**
  - Vendor-A: Dropped frames were minimal, with large frame counts. Devices like DESKTOP-3OSF0BQ recorded 8440 total frames with 4048 dropped frames.
  - Vendor-B: Dropped frames were also low, but certain devices like DESKTOP-QNG7LTT showed slightly higher drops (2170) compared to Vendor-A.
- **Device Performance:**
  - Windows devices from both vendors showed similar performance across the board with slight variations in dropped frames and buffer health.
  - MacOS devices (Admins-MacBook-Air. Local) showed significantly higher maximum buffer health (51.34 seconds), but this could be due to the lower streaming resolution of 1280x720, which might have resulted in more stable playback.
- In Summary, Both Vendor-A and Vendor-B demonstrated solid performance during the YouTube Streaming test. Vendor-A generally had a higher number of frames dropped on certain devices, but Vendor-B devices showed small performance fluctuations.

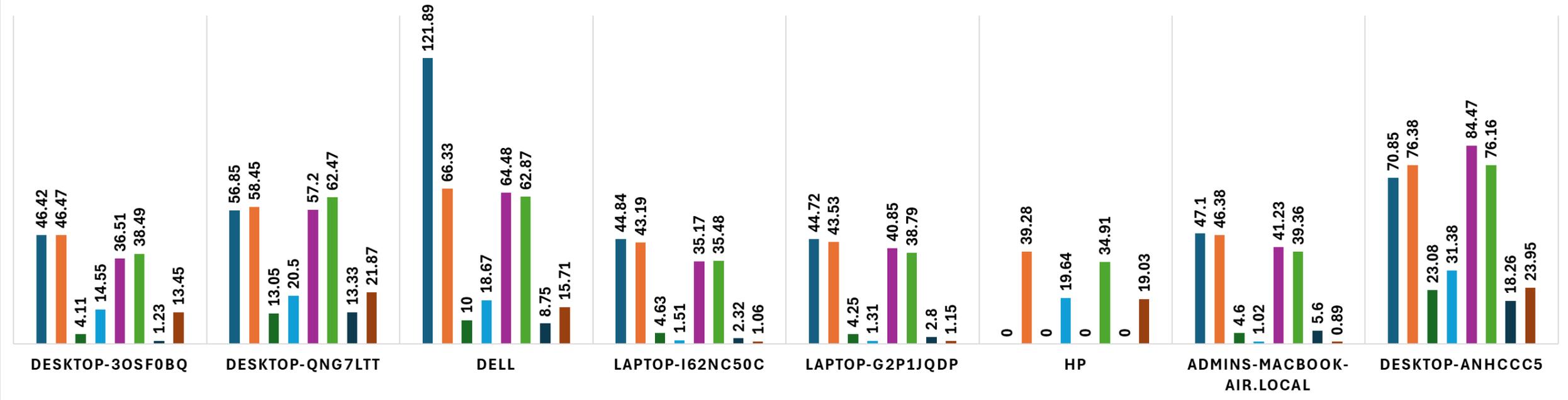
# Zoom Call Test

- The **Candela Zoom Call Test** is designed to conduct automated tests across multiple laptops to gather detailed statistics on the performance of audio and video during Zoom calls. These statistics include average latency, jitter, packet loss, and overall audio and video performance.

**ZOOM CALL AUDIO STATS COMPARISON CHART**

■ Audio stats VENDOR-A Avg Latency Sent (ms) 
 ■ Audio stats VENDOR-A Avg Latency Recv (ms) 
 ■ Audio stats VENDOR-A Avg Jitter Sent (ms) 
 ■ Audio stats VENDOR-A Avg Jitter Recv (ms)

■ Audio stats VENDOR-B Avg Latency Sent (ms) 
 ■ Audio stats VENDOR-B Avg Latency Recv (ms) 
 ■ Audio stats VENDOR-B Avg Jitter Sent (ms) 
 ■ Audio stats VENDOR-B Avg Jitter Recv (ms)



- **Audio Stats:**

1. Vendor-A showed lower average latency and jitter across most devices compared to Vendor-B. Devices like LAPTOP-I62NC50C and LAPTOP-G2P1JQDP demonstrated low latency and jitter, ensuring stable audio performance.
2. Vendor-B devices like DESKTOP-ANHCCC5 experienced higher latency and jitter (e.g., 70.85 ms avg. latency rcv), potentially indicating less stable connections compared to Vendor-A.
3. Packet loss remained minimal across both vendors, with Vendor-A devices generally showing slightly better performance with respect to packet loss (close to 0%).

- **Video Stats:**

1. Vendor-A devices like DESKTOP-3OSF0BQ demonstrated low video latency (47.37 ms avg. latency sent), ensuring smooth video transmission with minimal jitter.
2. Vendor-B devices like DESKTOP-QNG7LTT experienced higher video latency and jitter (e.g., 140.2 ms avg. latency rcv, 18.45 ms avg. jitter sent), suggesting potential delays in video rendering and transmission.
3. Packet loss in video performance was minimal for both vendors but slightly higher for Vendor-B on devices like DESKTOP-ANHCCC5, with 0.03% packet loss received.

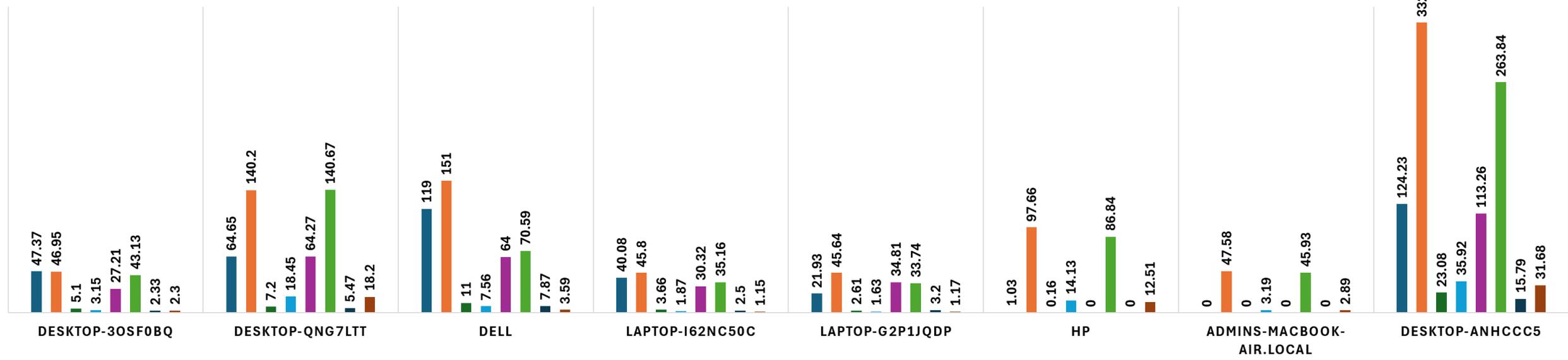
# Zoom Call Test

- In Summary, Vendor-A generally provided better audio and video performance across all devices, with lower latencies, jitter, and packet loss compared to Vendor-B.
- Vendor-B showed occasional spikes in latency and jitter, especially in video performance, which could impact overall call quality.
- Both vendors performed well with minimal packet loss, which is crucial for maintaining call stability.

ZOOM CALL VIDEO STATS COMPARISON CHART

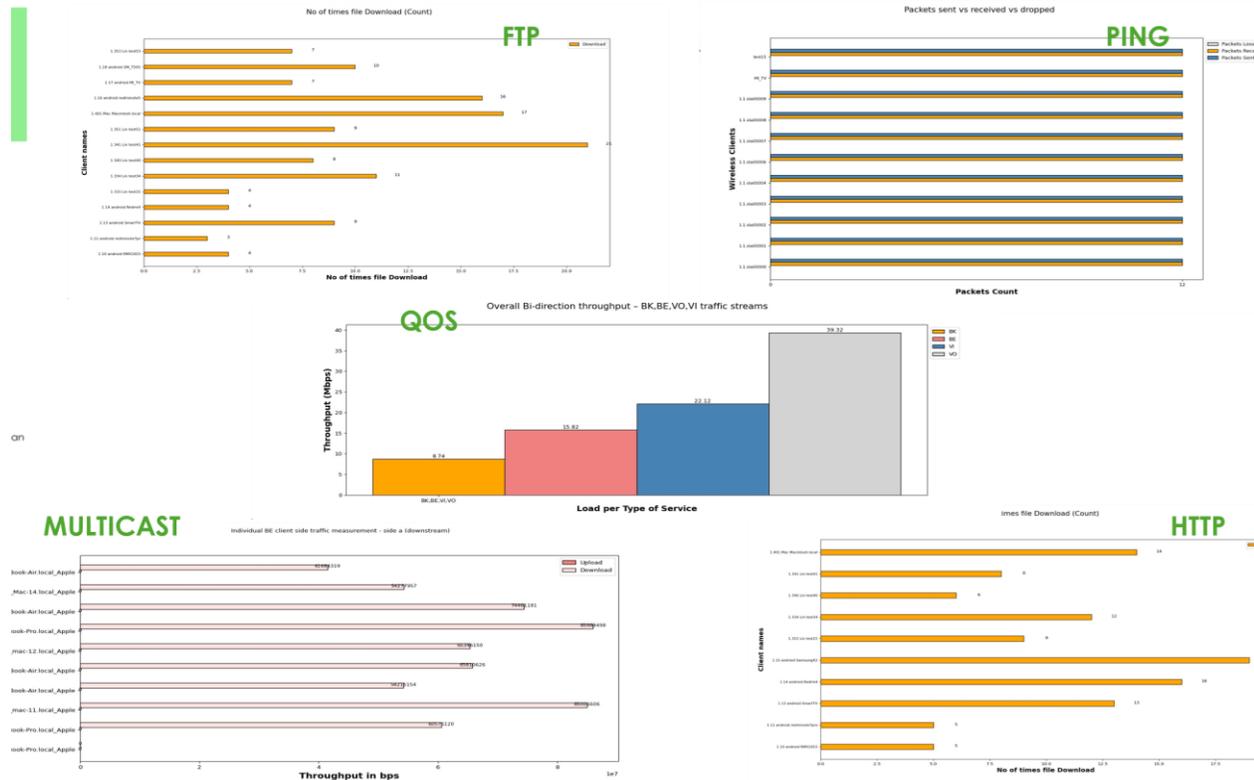
■ Video stats VENDOR-A Avg Latency Sent (ms) 
 ■ Video stats VENDOR-A Avg Latency Recv (ms) 
 ■ Video stats VENDOR-A Avg Jitter Sent (ms) 
 ■ Video stats VENDOR-A Avg Jitter Recv (ms)

■ Video stats VENDOR-B Avg Latency Sent (ms) 
 ■ Video stats VENDOR-B Avg Latency Recv (ms) 
 ■ Video stats VENDOR-B Avg Jitter Sent (ms) 
 ■ Video stats VENDOR-B Avg Jitter Recv (ms)



# Mixed Traffic Test

- The **Candela Mixed Traffic Test** is designed to assess the performance and stability of an access point by generating various types of traffic on real client devices, such as Android, Linux, Windows, and iOS, all connected to the AP. The test allows users to configure multiple traffic types, including QoS, FTP, HTTP, Multicast, and Ping, running either in series or parallel. The expected behavior is for the access point to handle all traffic types efficiently across several stations (within the limitations of the AP specifications), ensuring that all connected clients can support and run the selected traffic types seamlessly.



# Mixed Traffic Test

- Channel Utilization: VENDOR-A has 72% channel utilization on the 5G band and 46% on the 2G band, showing a more balanced distribution. In contrast, VENDOR-B utilizes the 5G band more heavily at 83%, while the 2G band is much lower at 26%.
- Ping Test: Both vendors reported that Android devices on the 2.4GHz band experienced ping loss and higher latency during the ping test, showing a similar behavior for devices on the 2.4GHz band across both vendors.
- Multicast Test: With Both vendors we observed deauthentication of some devices during the multicast traffic test.
- FTP & HTTP Tests (10MB):
  - VENDOR-A: 43 out of 46 Android devices, as well as other OS devices (Windows, Linux, MacBook), were able to download the 10MB file successfully within 5 minutes on both 5GHz and 2.4GHz bands.
  - VENDOR-B: All 46 Android devices and other OS devices successfully downloaded the 10MB file within 5 minutes on both bands. VENDOR-B performed slightly better in handling the 10MB file download test, with all devices successfully completing the test, compared to a few devices in VENDOR-A.
- In Summary, Both vendors demonstrated similar behaviors in terms of connection stability, multicast issues, and FTP/HTTP download tests. However, VENDOR-B showed better overall performance in FTP file downloads and a 100% success rate in the small file download test (10MB), whereas VENDOR-A had a few devices that struggled with the 10MB download.

# Capacity Test House



# Test Environment Details - VILLA AND FLOOR PLAN



**Two  
Story  
Villa**

**VILLA HAS 2 FLOORS WITH TOTAL AREA = 1985 SQ.FT  
GROUND FLOOR AREA = 905 SQ.FT  
FIRST FLOOR AREA = 1080 SQ.FT**

# DUT and client details

Model A  
Build A

**DUT**

Model A- GW

**Specs**

Tri-band System

Radio1: 2.4 GHz 2x2

Radio2: 5 GHz 4X4

Radio3: 6GHz 4x4

Build Info: **Build A**

Chipset: Qualcomm

Channel for 6G: 37, BW: 320MHz, TX power: 18 dBm

Channel for 5G: 36, BW: 160MHz, TX power: 23 dBm

Channel for 2.4G: 6, BW: 40MHz, TX power: 27 dBm

Model A  
Build B

**DUT**

Model A- GW

**Specs**

Tri-band System

Radio1: 2.4 GHz 2x2

Radio2: 5 GHz 4X4

Radio3: 6GHz 4x4

Build Info: **Build B**

Chipset: Qualcomm

Channel for 6G: 37, BW: 320MHz, TX power: 21 dBm

Channel for 5G: 36, BW: 160MHz, TX power: 23 dBm

Channel for 2.4G: 6, BW: 40MHz, TX power: 27 dBm



**Test Client**

One Plus 11

**Specs**

Android Version: 13

Chipset: Qualcomm

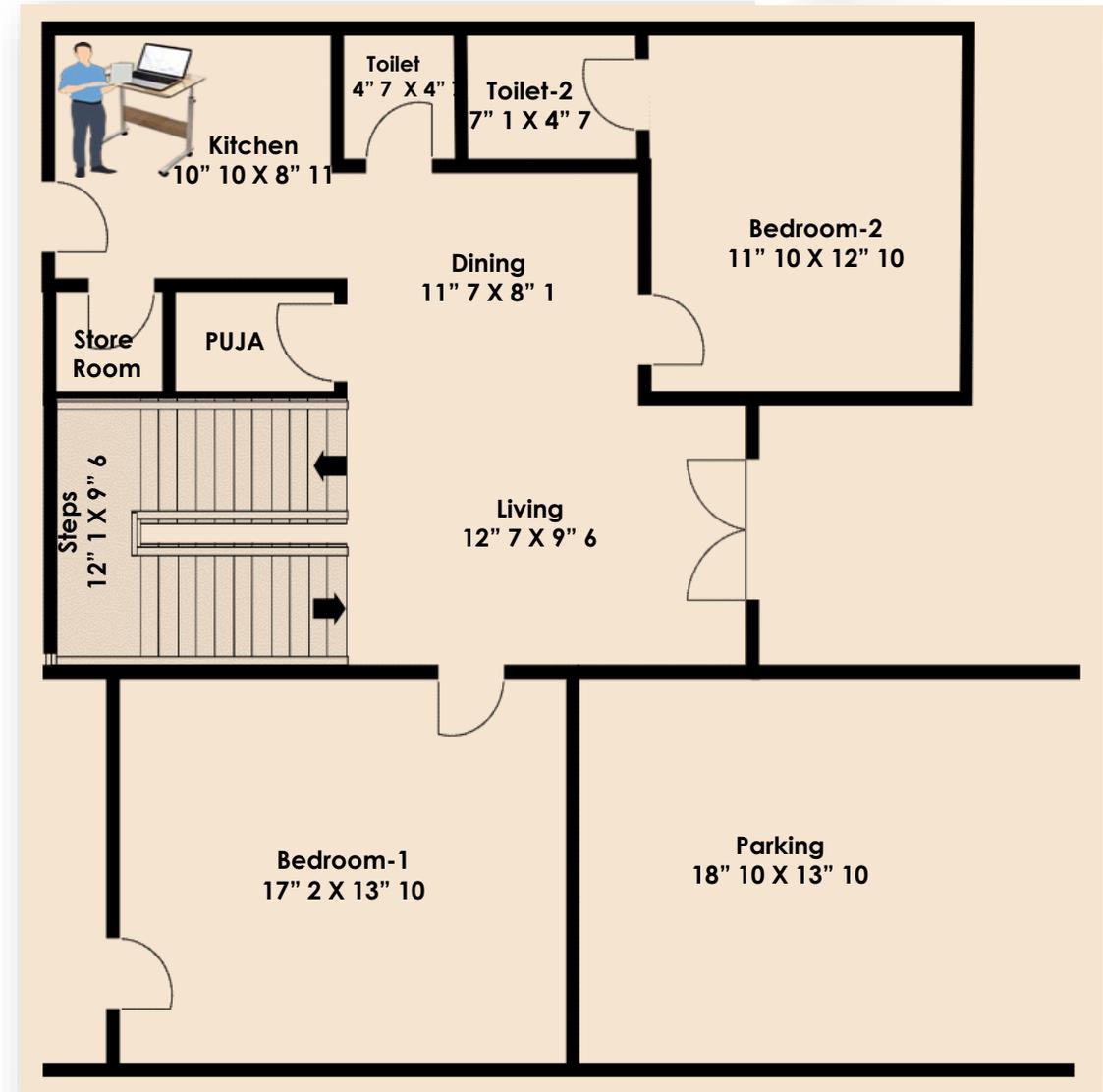
Dual band System

NSS: 2x2

WLAN: 802.11 a/b/g/n/ac/ax/be

# Test Procedure

- The floor plan is loaded into the heatmap test software.
- The test engineer will physically take the client device to each test point without disconnecting the Wi-Fi.
- At each point, the tester will measure RSSI and run the TCP Upstream/Downstream throughput and other measurements at measurement point and push results to a database.
- The software then generates the heatmaps for coverage testing.



# **Ground Floor and First Floor Residential AP Coverage Comparison for Build A vs Build B**

# Analysis on 6GHz Band Coverage:

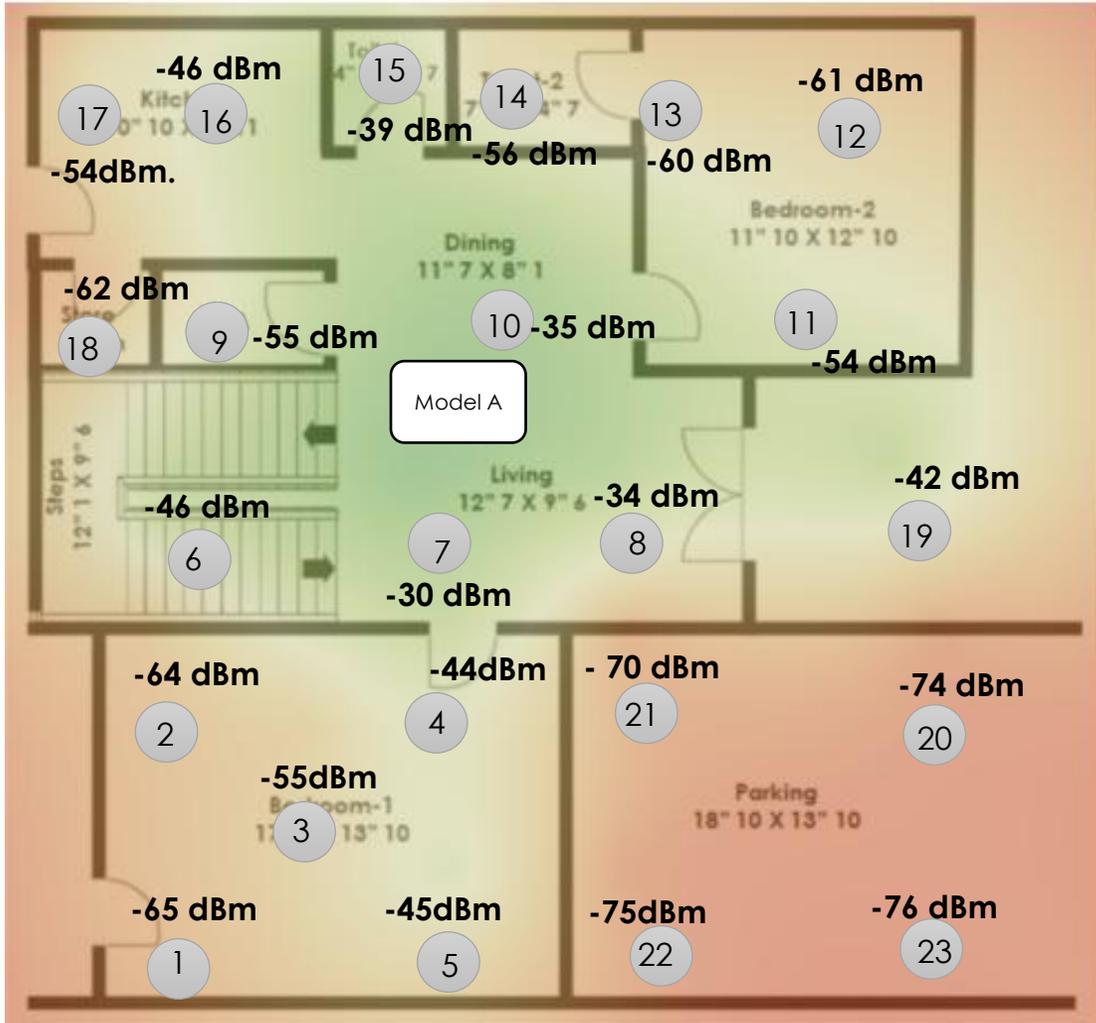
| Parameters                    | Build B  | Build A | Observations/Comments   |
|-------------------------------|----------|---------|---|
| Ground Floor - 6 GHz Coverage | Improved | Reduced | Highlights: With Build B, AP is able to provide coverage for the entire ground floor with a transmit power of 21 dB.<br>Lowlights: With Build A, the AP is unable to provide complete coverage. There is no coverage in the parking area with a transmit power of 18 dB.  |
| GF - 6GHz Max Throughput      | Improved | Reduced | Highlights:<br><ul style="list-style-type: none"> <li>With Build B max DL throughput achieved is 3706 Mbps (Coordinate:- 8) whereas with Build A max throughput is 2873 Mbps (Coordinate:- 15).</li> <li>With Build B max UL throughput achieved is 2954 Mbps (Coordinate:- 7) whereas with Build A max throughput is 2586Mbps (Coordinate:- 15).</li> </ul>    |
| GF - Overall experience       | Improved | Reduced | Highlights: Build B provides complete coverage for the entire floor. The TCP download throughput values of the Build B are higher than those of the Build A.<br>Lowlights: The Build B exhibits higher upload throughput values than the Build A, except at coordinates 10, 5, and 19.  |
| First Floor - 6 GHz Coverage  | Improved | Reduced | Highlights: With Build B, the AP is unable to provide complete coverage on First floor. There is no coverage for 13 coordinates with a transmit power of 21 dB.<br>Lowlights: With Build A, the AP is unable to provide complete coverage. There is no coverage for 14 coordinates with a transmit power of 18 dB.  |
| FF - 6GHz Max Throughput      | Improved | Reduced | Highlights:<br><ul style="list-style-type: none"> <li>With Build B max DL throughput achieved is 3604 Mbps (Coordinate:- 24) whereas with Build A max throughput is 2933 Mbps (Coordinate:- 24).</li> <li>With Build B max UL throughput achieved is 2845 Mbps (Coordinate:- 24) whereas with Build A max throughput is 3016 Mbps (Coordinate:- 24).</li> </ul> |
| FF - Overall experience       | Improved | Reduced | Highlights: The TCP download throughput values of the Build B are higher than those of the Build A.<br>Lowlights: The Build B exhibits higher upload throughput values than the Build A, except at coordinates 9, 10, 11, 15, 19, 24 and 28.  |

# AP RSSI in 6GHz

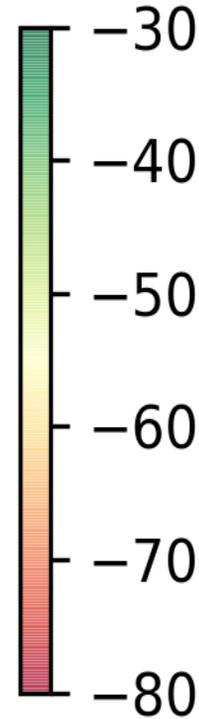
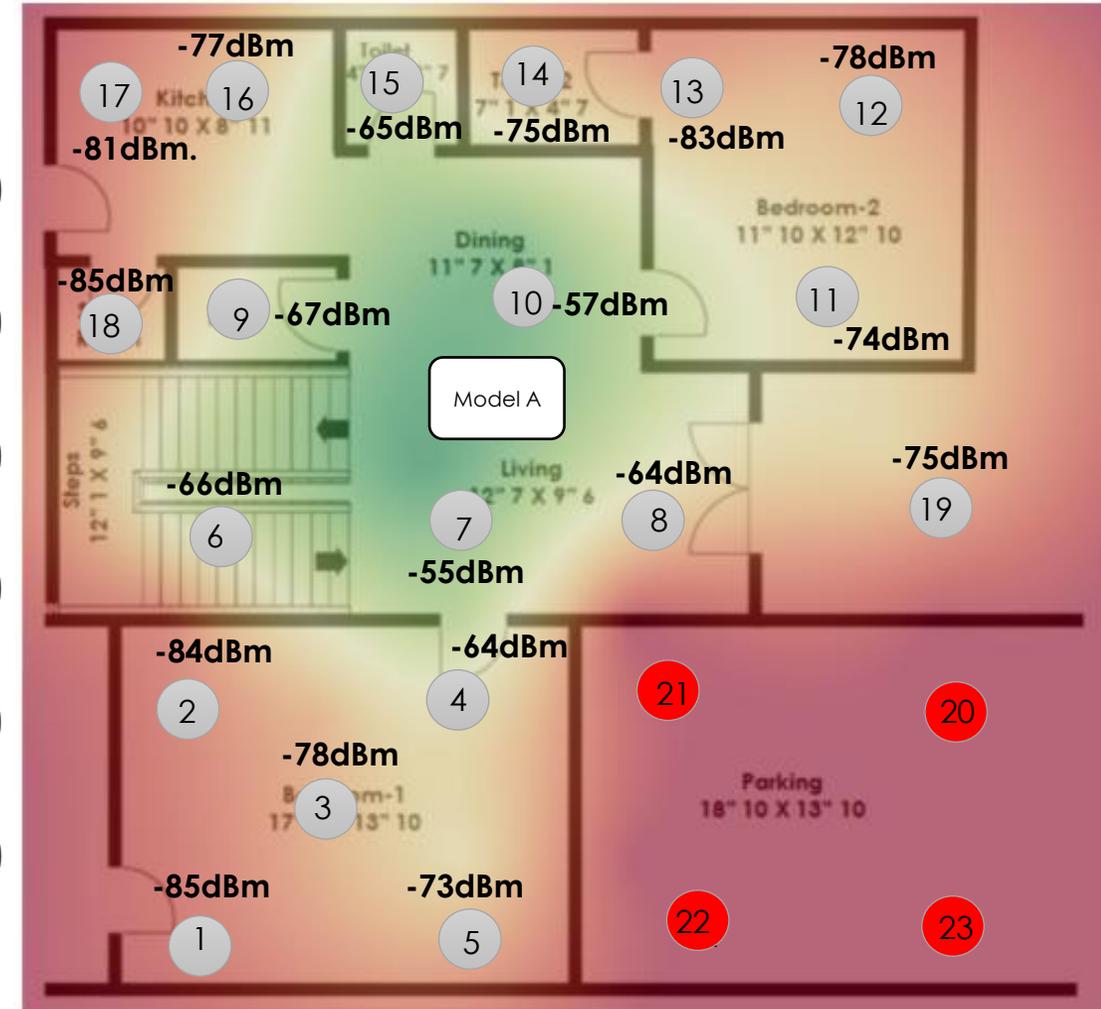
## Ground Floor signal strength (dBm)



### Build B



### Build A



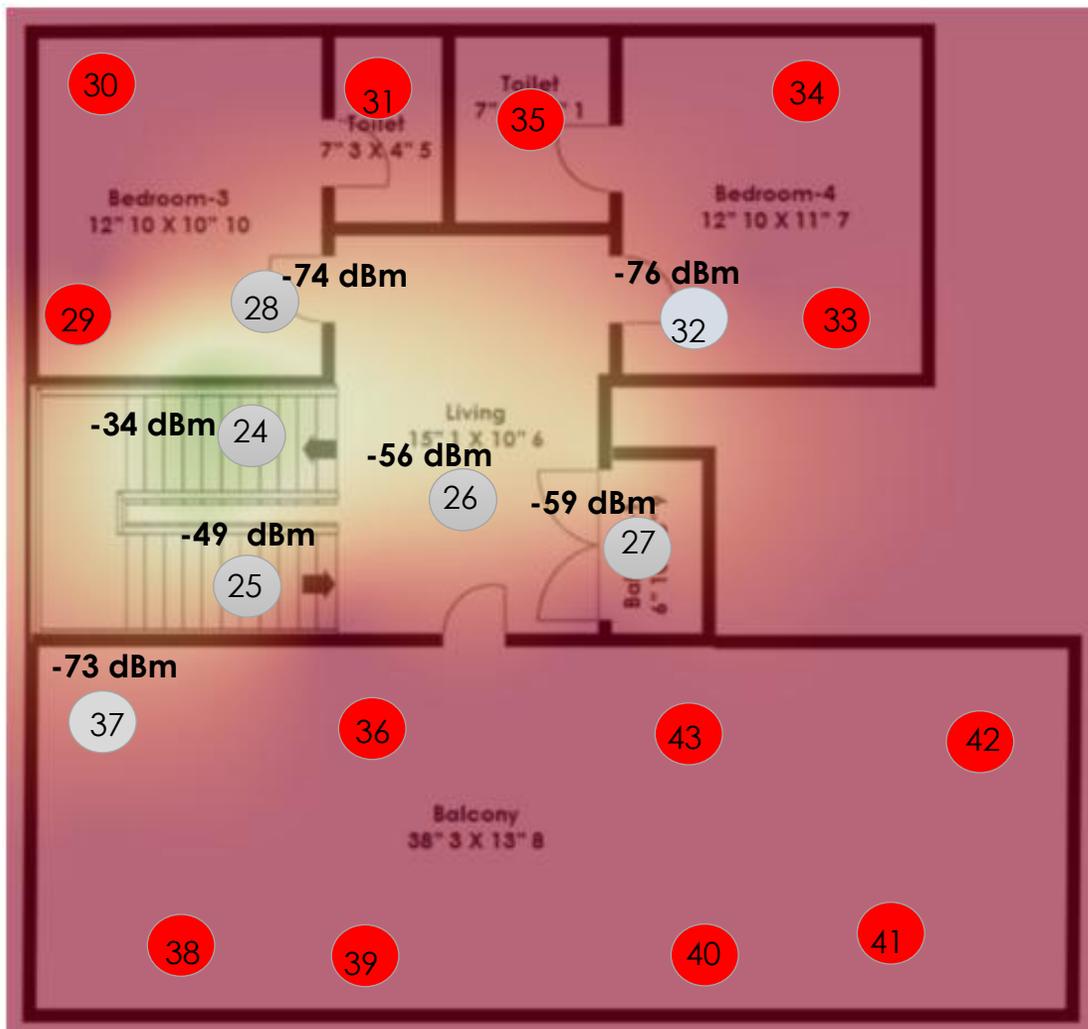
● Client connected state

● Client disconnected state

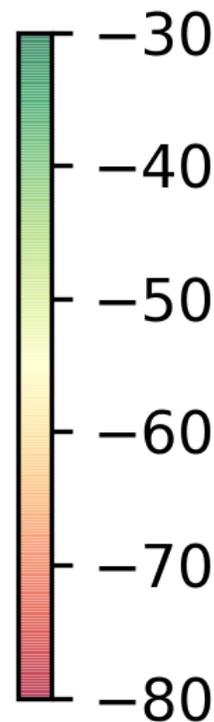
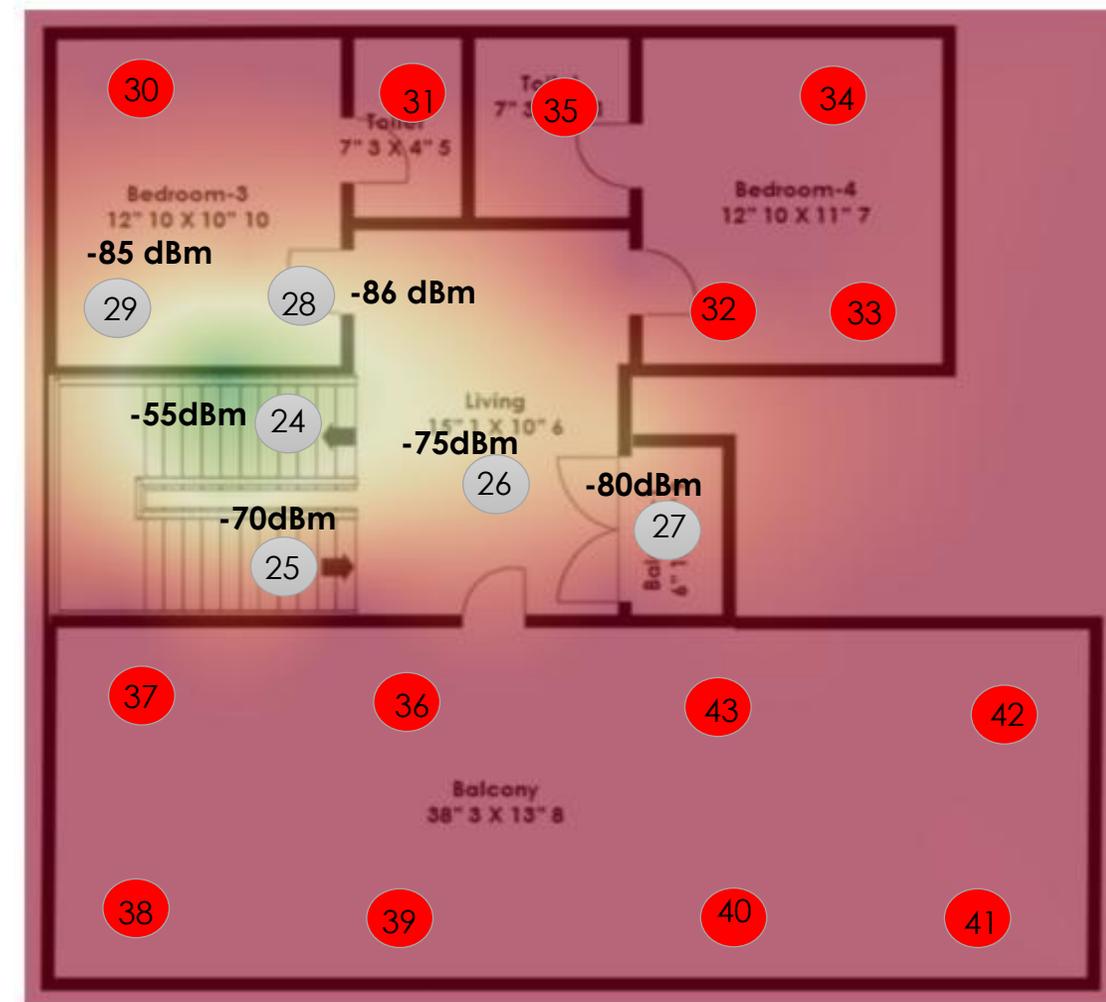
# AP RSSI in 6GHz

## First Floor signal strength (dBm)

### Build B



### Build A



● Client connected state

● Client disconnected state

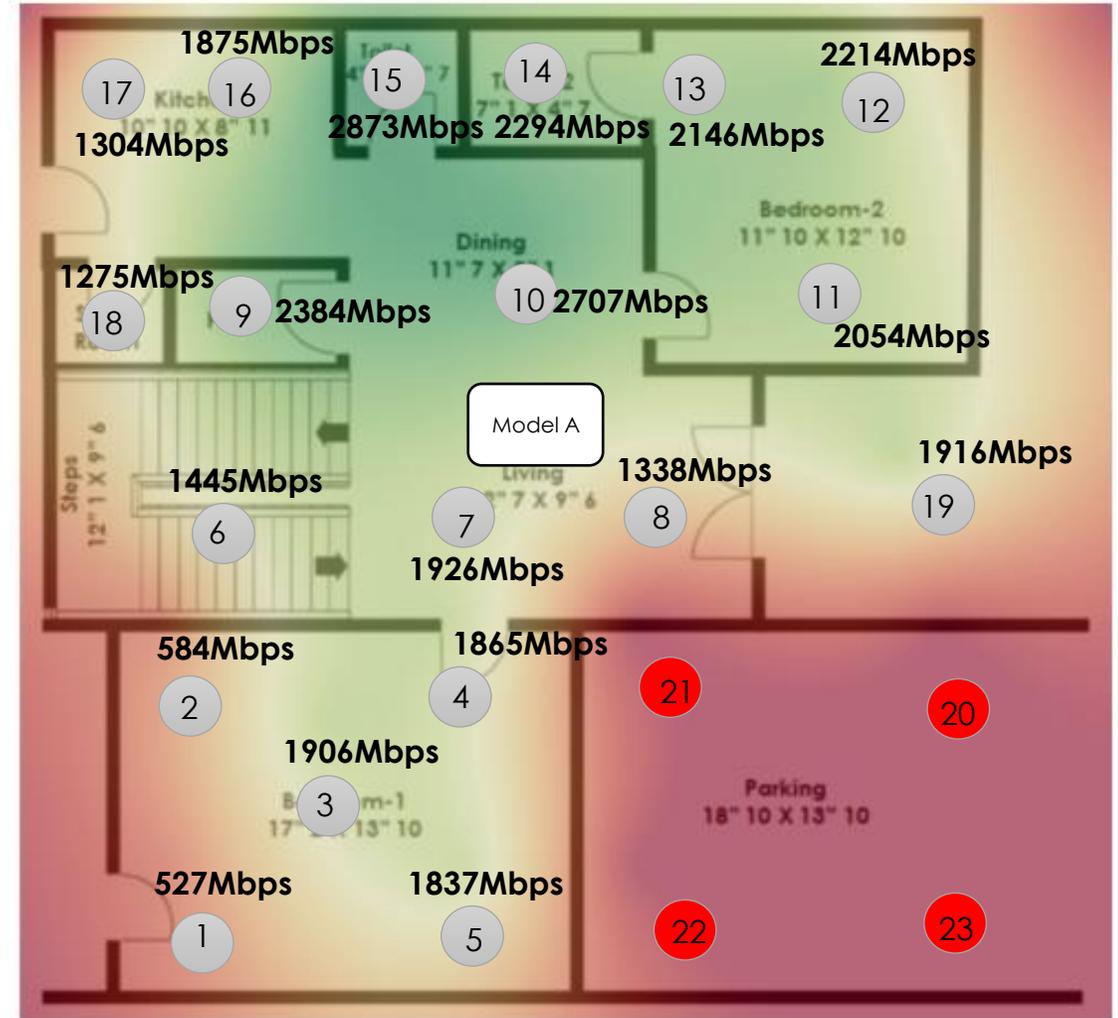
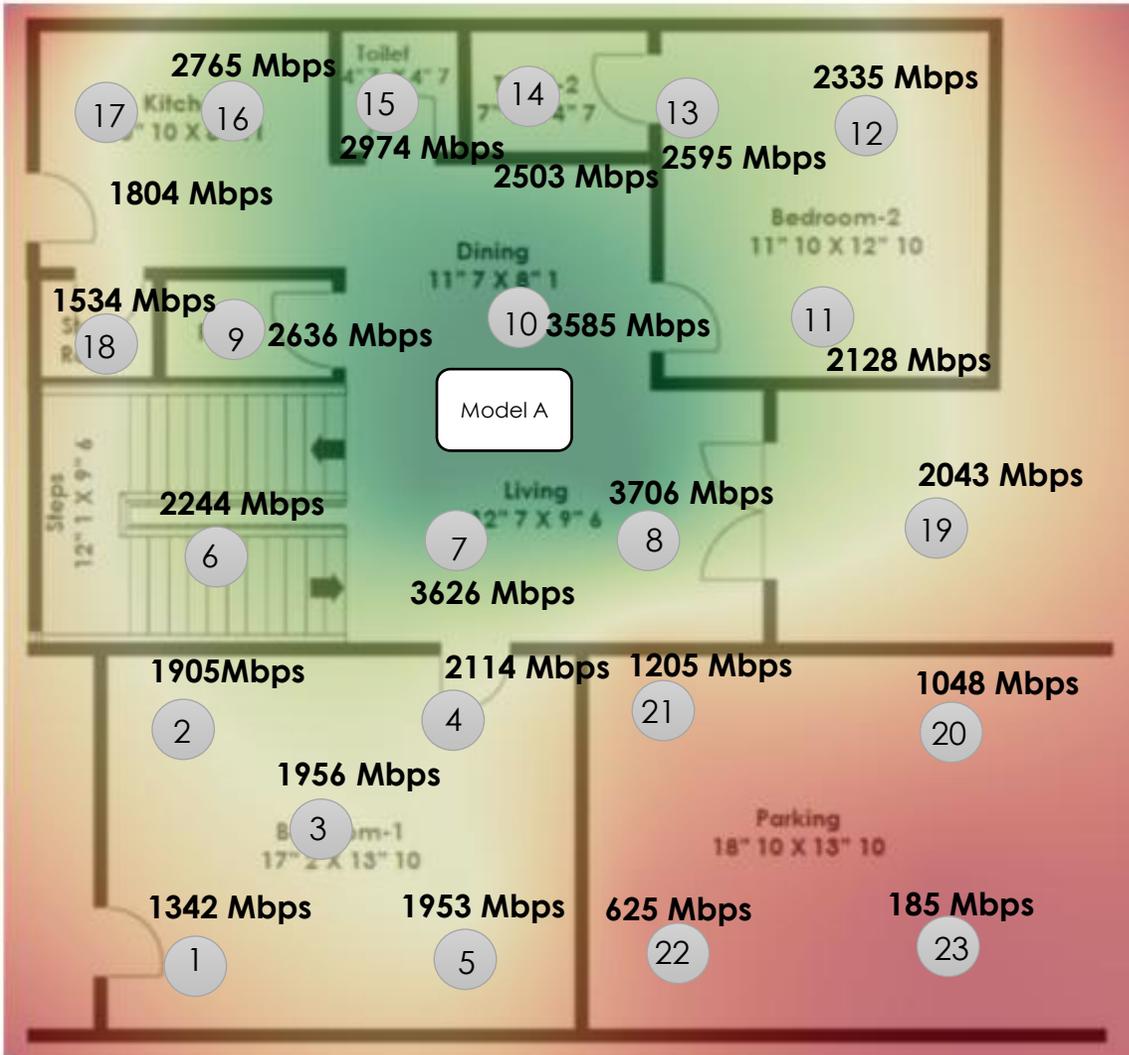
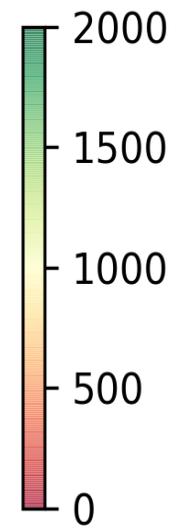
# TCP\_DL in 6GHz

## Ground Floor Download TCP (Mbit/s)



### Build B

### Build A



● Client connected state

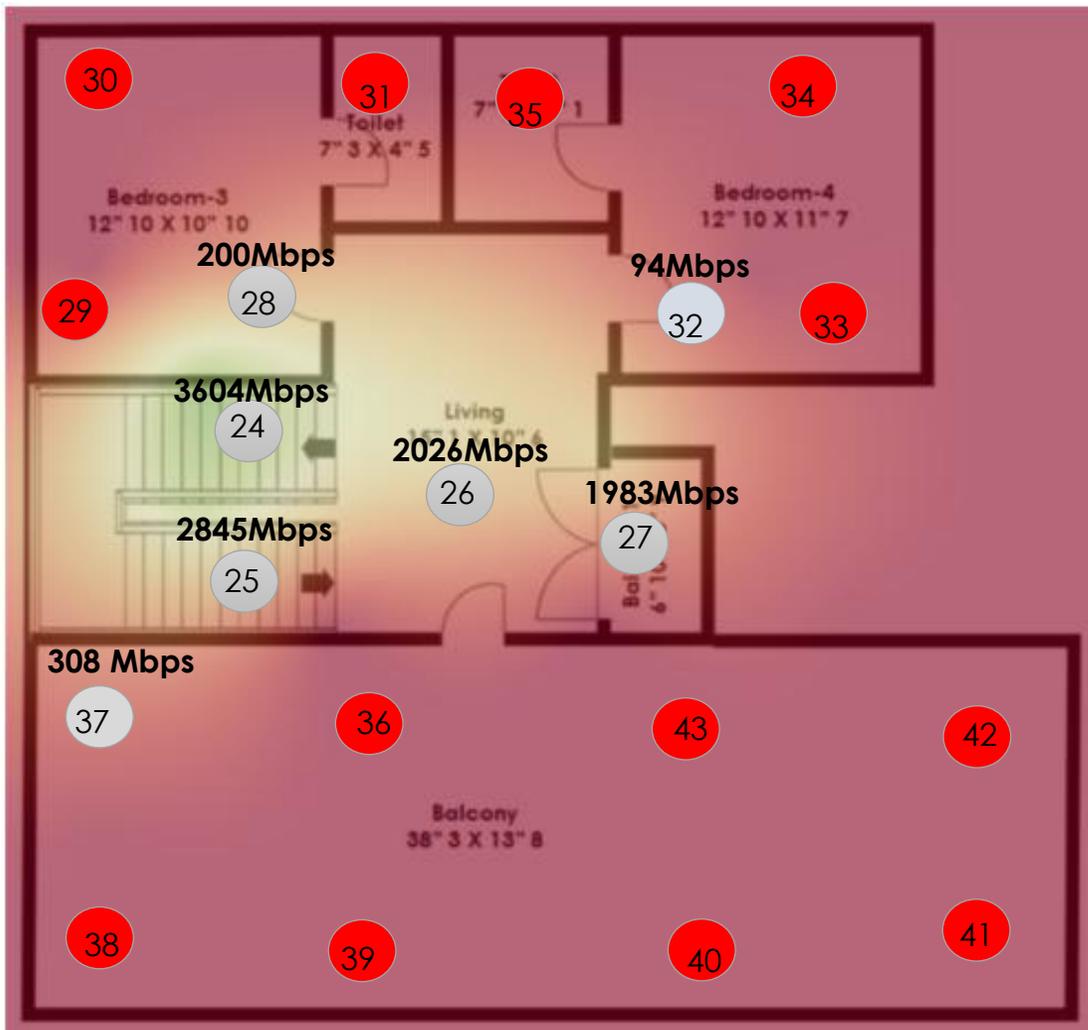
● Client disconnected state

# TCP\_DL in 6GHz

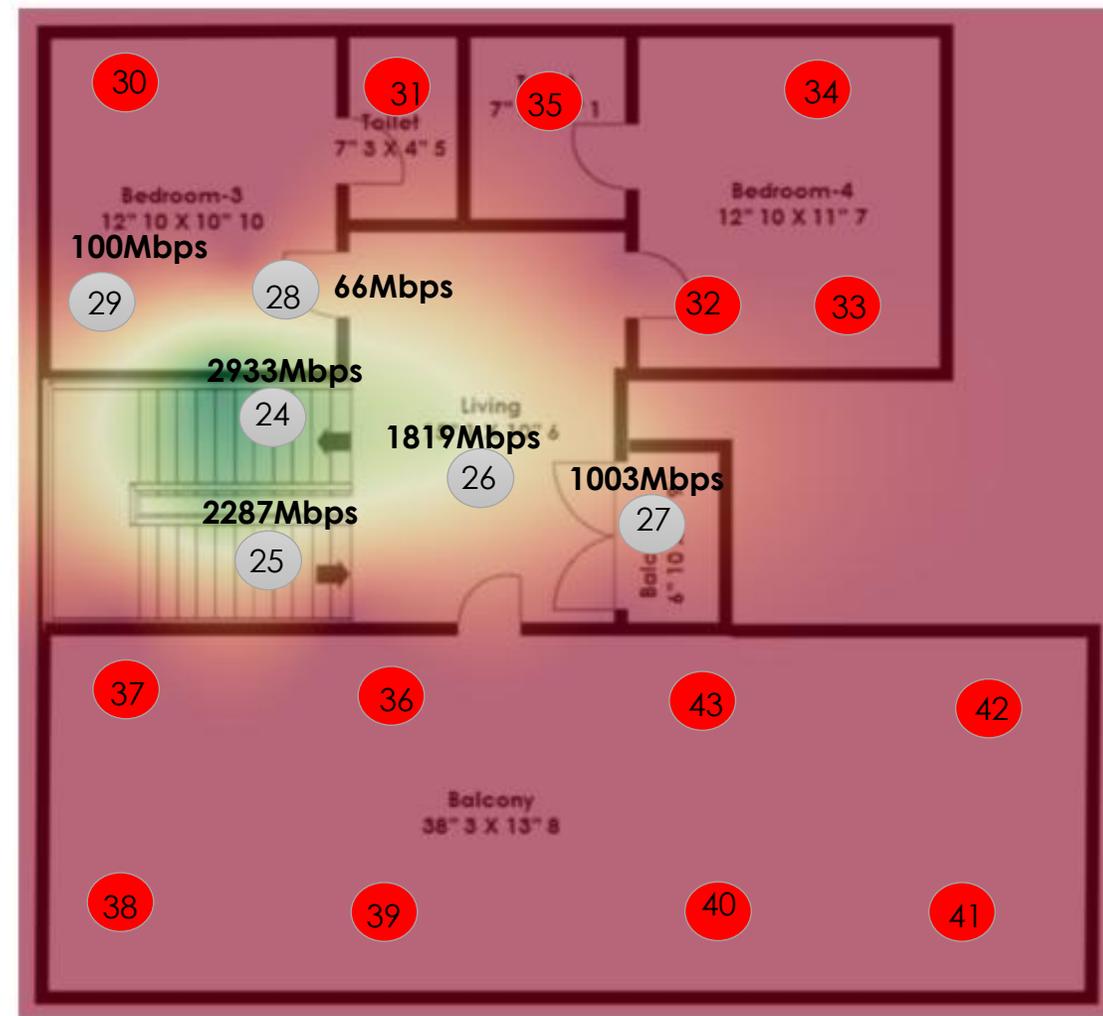


## First Floor TCP Download (Mbps)

### Build B



### Build A

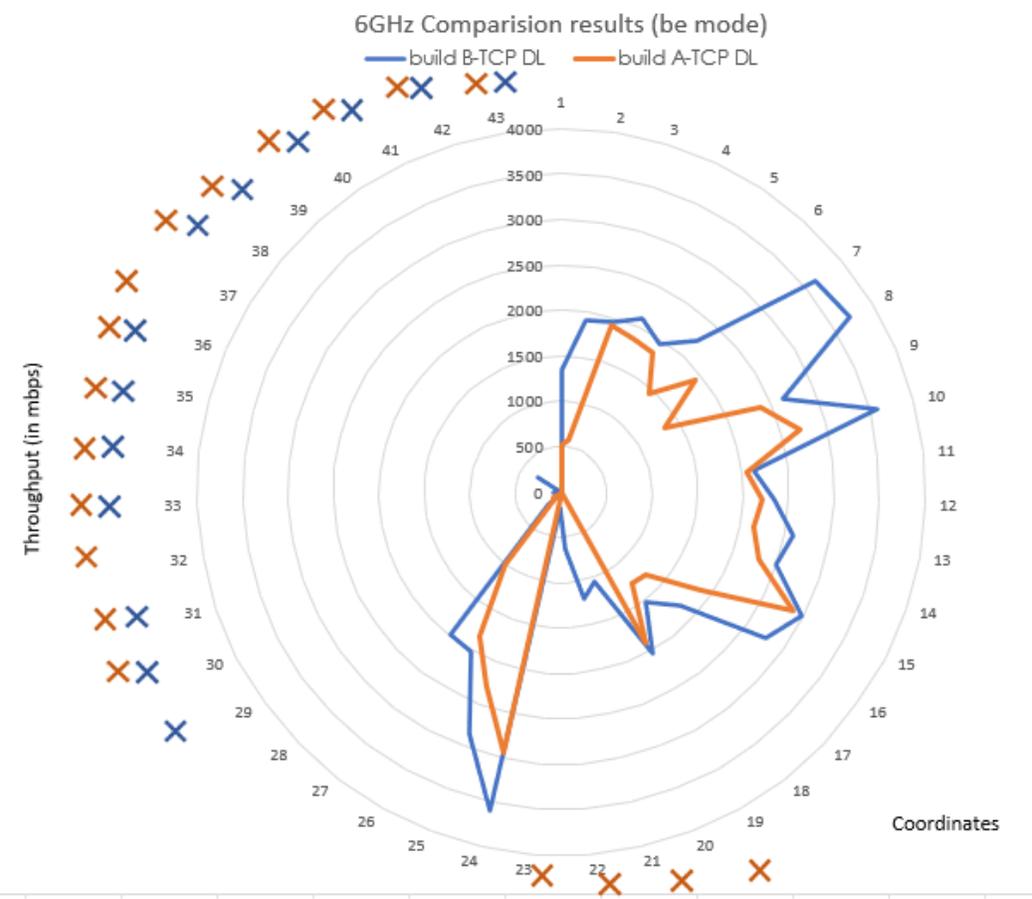


● Client connected state

● Client disconnected state

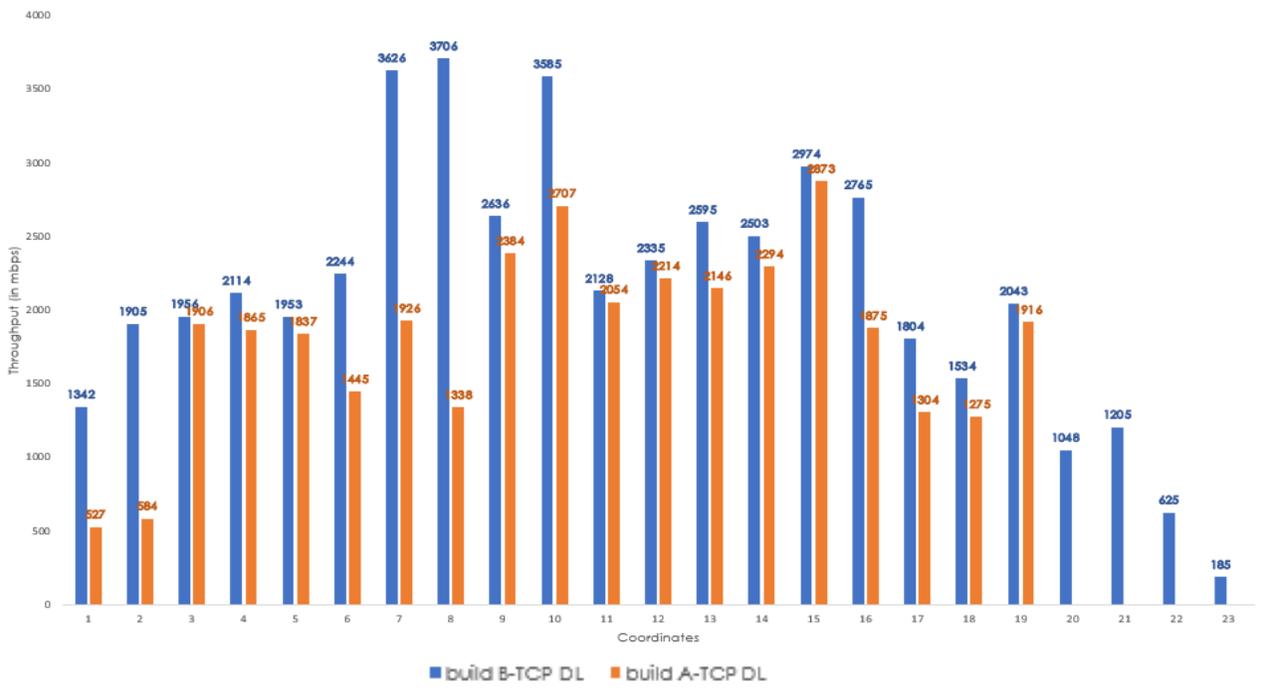


# TCP Download on 6GHz Band

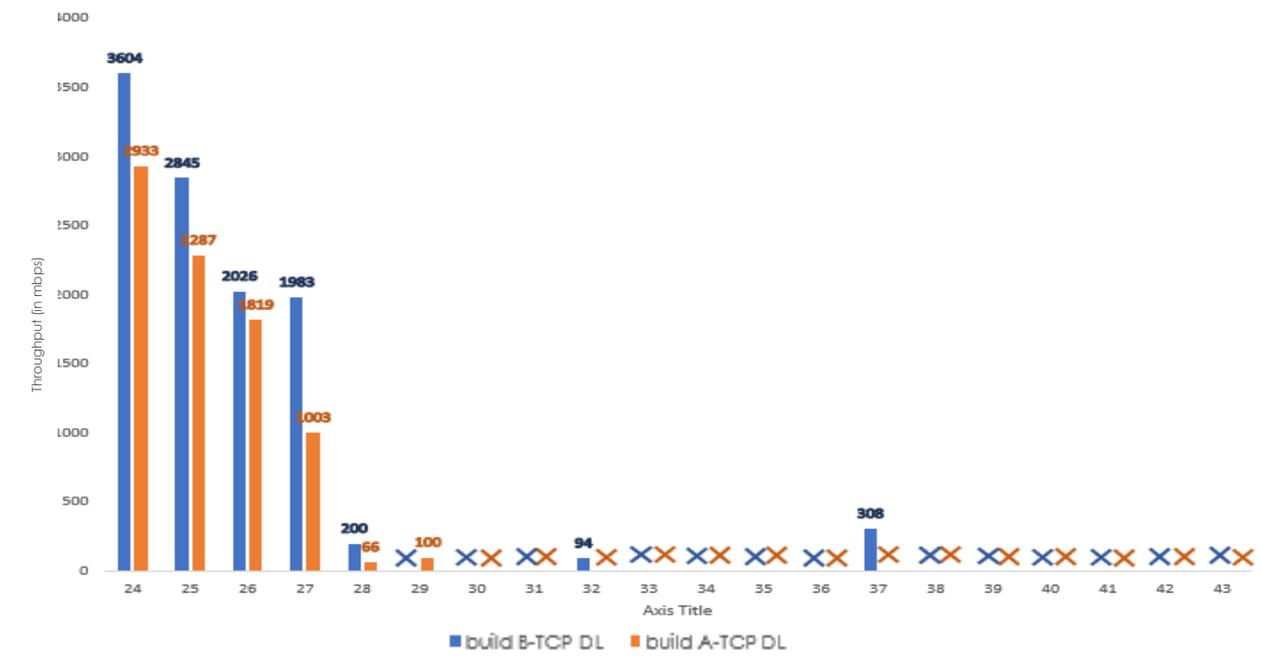


- ✗ Build A Wi-Fi Dead Zone
- ✗ Build B Wi-Fi Dead Zone

TCP Download on 6GHz -Ground Floor



TCP Download on 6GHz -First Floor



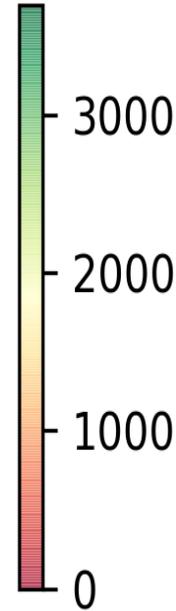
# TCP\_UL in 6GHz

## Ground Floor Upload TCP (Mbit/s)



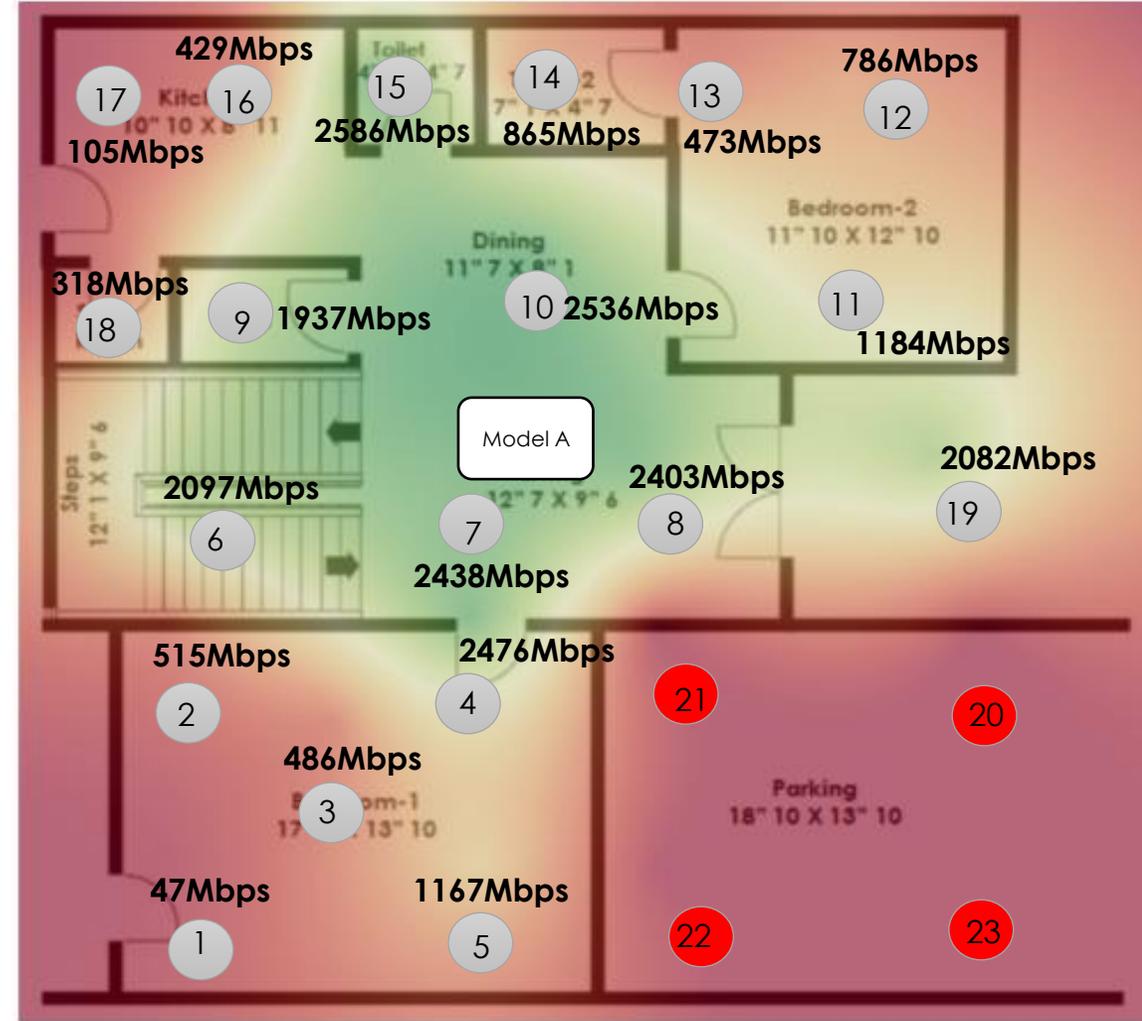
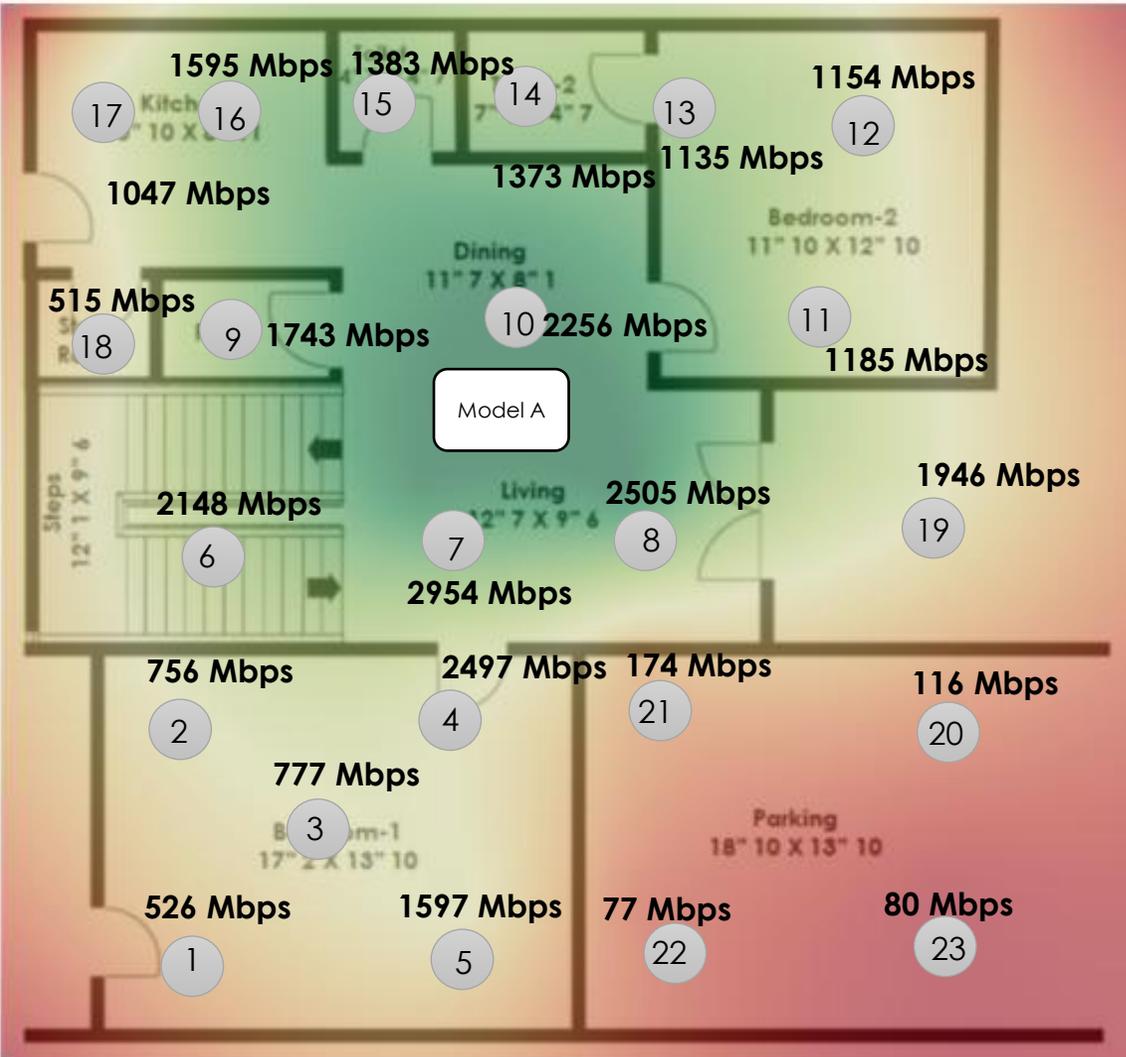
### Build B

### Build A



● Client connected state

● Client disconnected state

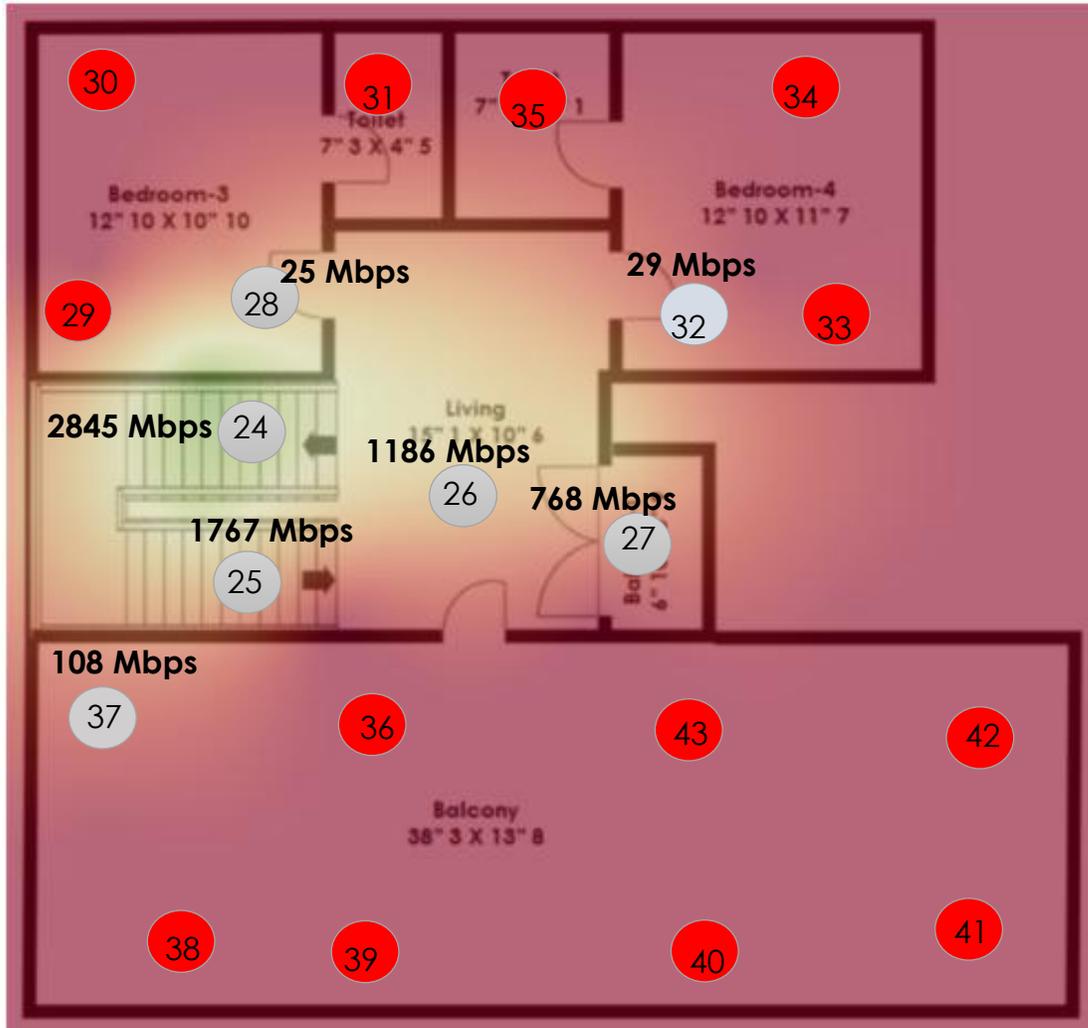


# TCP\_UL in 6GHz

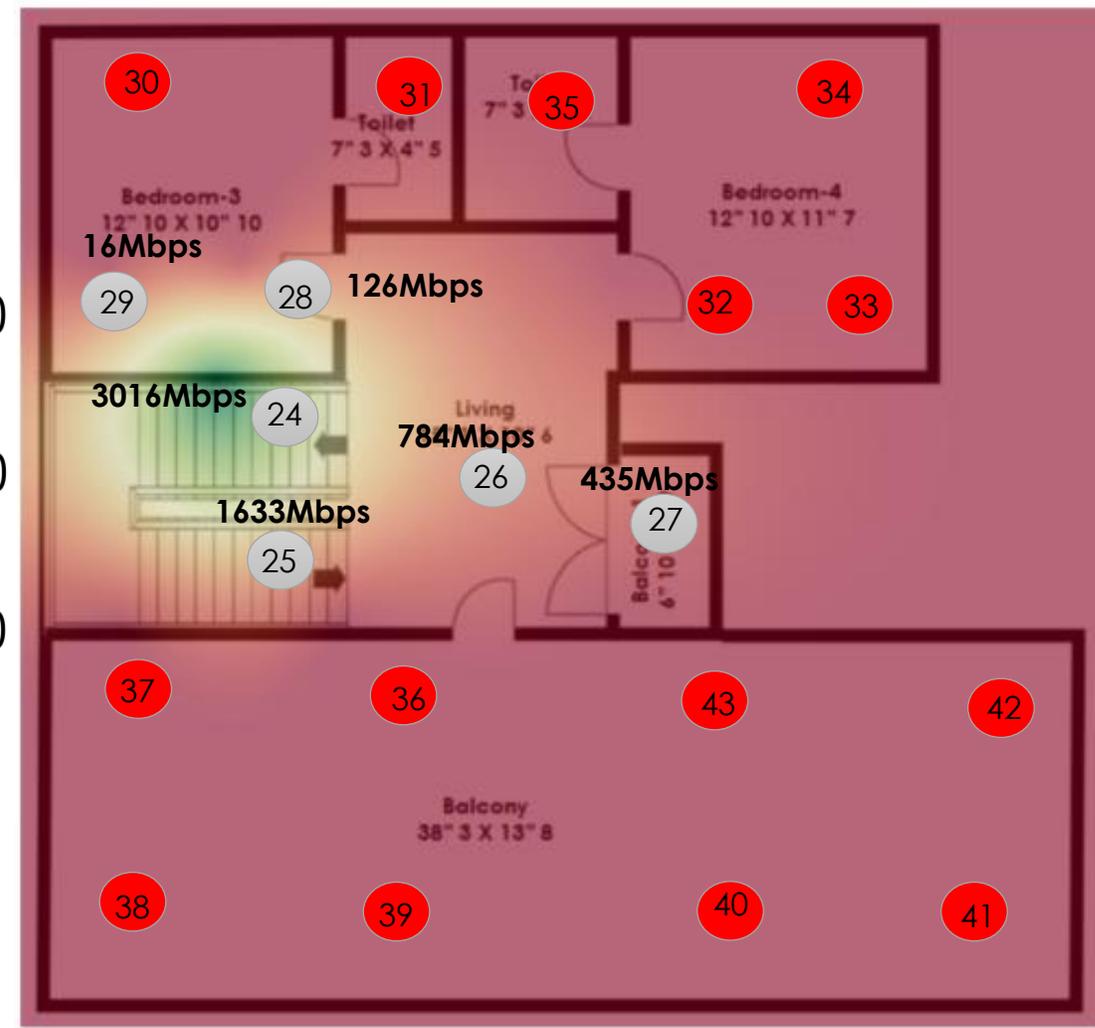
## First Floor TCP Upload (Mbps)



Build B



Build A

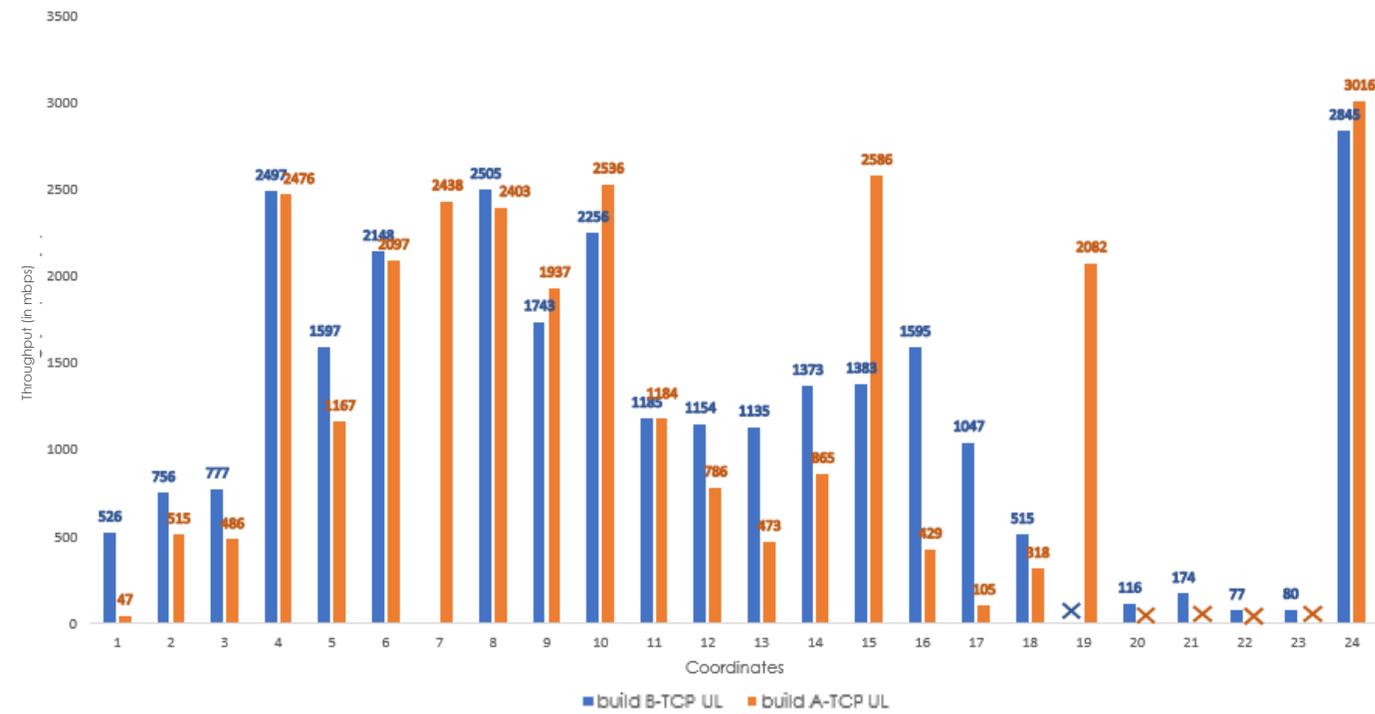


● Client connected state

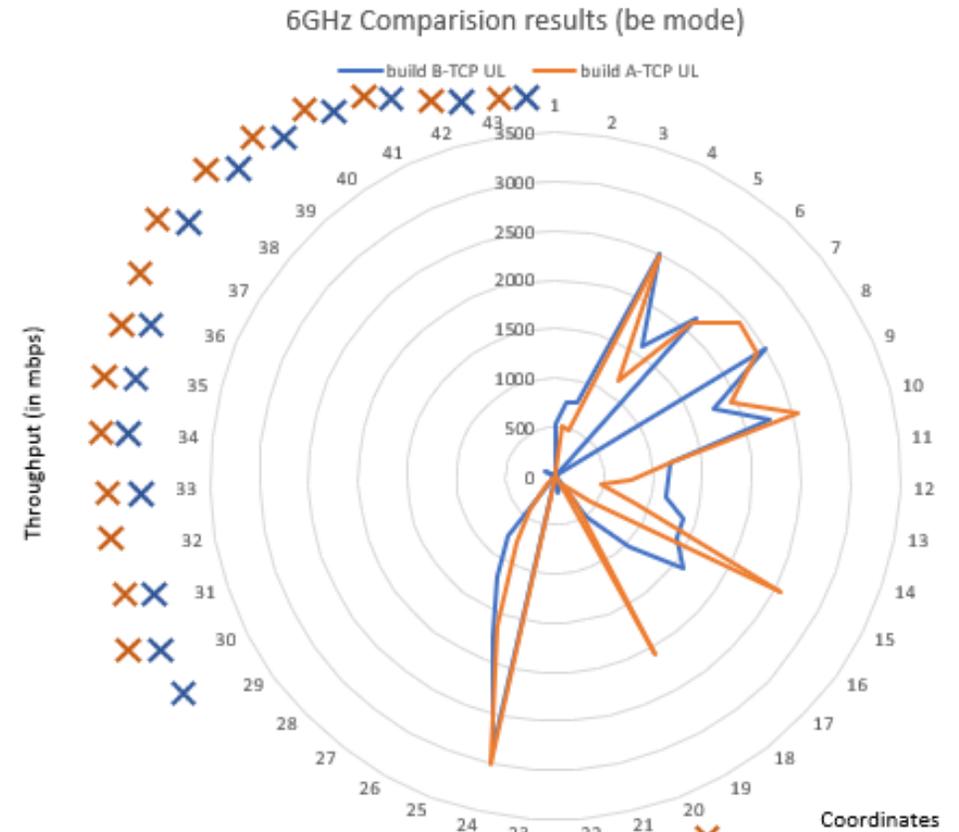
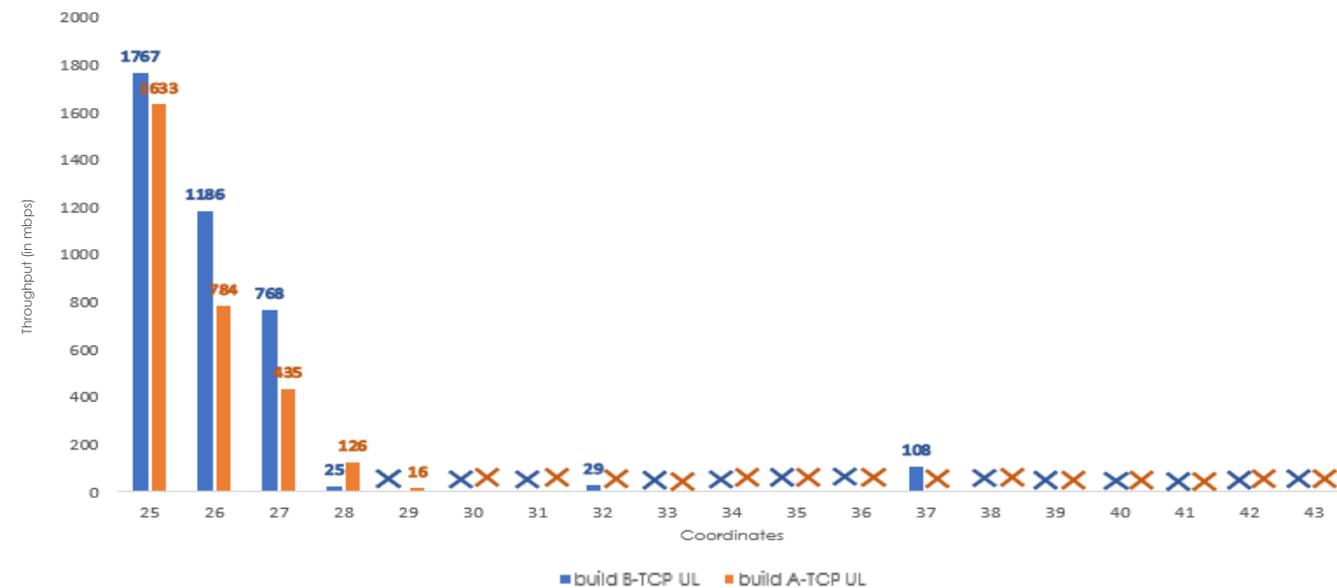
● Client disconnected state

TCP Upload on 6GHz -Ground Floor

# TCP Upload on 6GHz Band



TCP Upload on 6GHz -First Floor



✗ Build A Wi-Fi Dead Zone

✗ Build B Wi-Fi Dead Zone

# Analysis on 5GHz Band coverage:

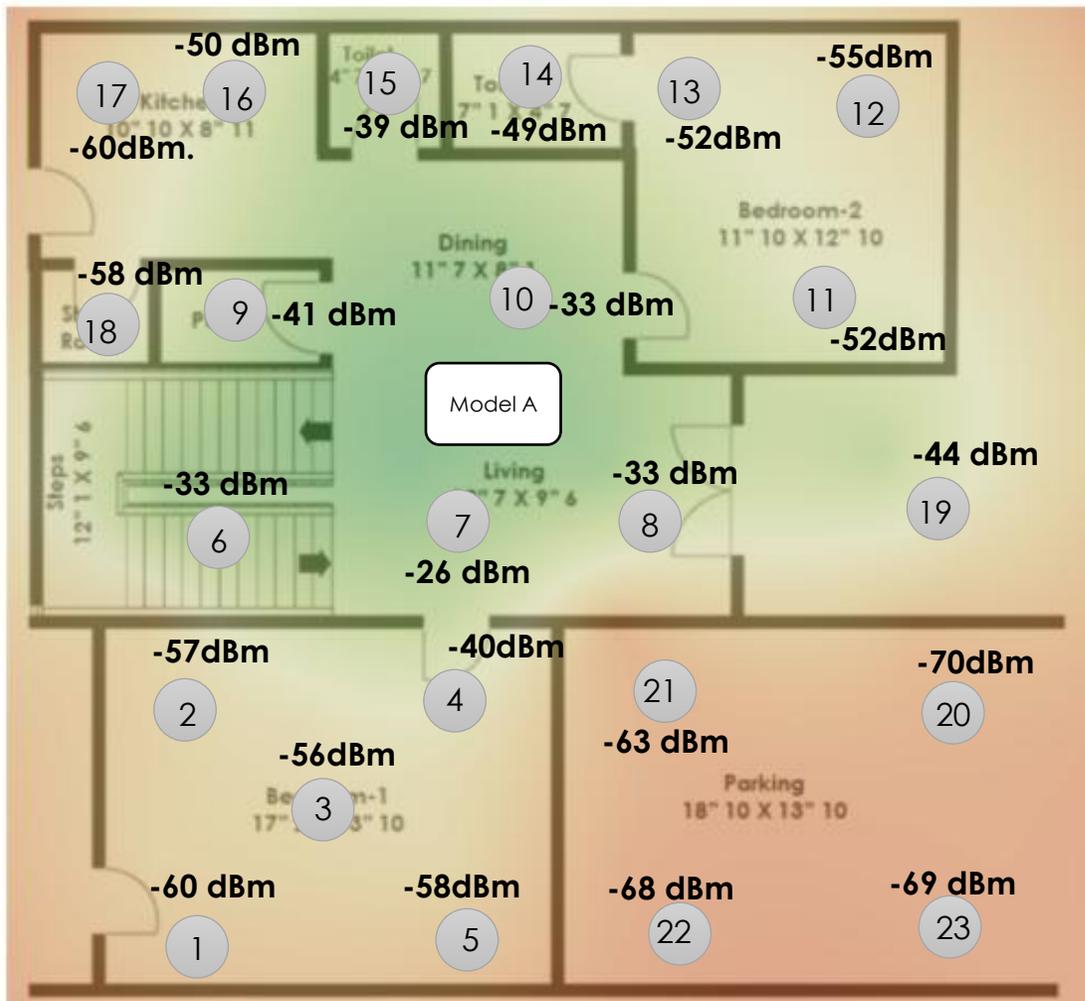
| Parameters                    | Build B  | Build A | Observations/Comments  |
|-------------------------------|----------|---------|--|
| Ground Floor - 5 GHz Coverage | Improved | Reduced | Highlights: With both Build A & Build B, AP is able to provide coverage for the entire ground floor with a transmit power of 23 dB.  |
| GF - 5 GHz Max Throughput     | Improved | Reduced | Highlights: <ul style="list-style-type: none"> <li>With Build B max DL throughput achieved is 2012 Mbps (Coordinate:- 7) whereas with Build A max throughput is 1882 Mbps (Coordinate:- 7).</li> <li>With Build B max UL throughput achieved is 1876 Mbps (Coordinate:- 6) whereas with Build A max throughput is 1924Mbps (Coordinate:- 7).</li> </ul>  |
| GF - Overall experience       | Improved | Reduced | Highlights: <ul style="list-style-type: none"> <li>Build B provides complete coverage for the entire floor.</li> <li>In both TCP DL and UL, throughput values of the Build B are higher than those of the Build A.</li> </ul> Lowlights: <ul style="list-style-type: none"> <li>The Build B exhibits higher download throughput values than the Build A, except at coordinates 1, 3, 4, 5, 9, 11, 12, 14, 16, 19 and 23.</li> <li>The Build B exhibits higher upload throughput values than the Build A, except at coordinates 4, 7, 9, 13, 14, 16, 17 and 21.</li> </ul>        |
| First Floor - 5 GHz Coverage  | Improved | Reduced | Highlights: With both Build A & Build B, AP is able to provide coverage for the entire First floor with a transmit power of 23 dB.   |
| FF - 5 GHz Max Throughput     | Improved | Reduced | Highlights: <ul style="list-style-type: none"> <li>With Build B max DL throughput achieved is 2077 Mbps (Coordinate:- 24) whereas with Build A max throughput is 1679 Mbps (Coordinate:- 24).</li> <li>With Build B max UL throughput achieved is 2103 Mbps (Coordinate:- 24) whereas with Build A max throughput is 1774 Mbps (Coordinate:- 24).</li> </ul>   |
| FF - Overall experience       | Improved | Reduced | Highlights: <ul style="list-style-type: none"> <li>Both Build A &amp; Build B provides complete coverage for the entire floor.</li> <li>In both TCP DL and UL, throughput values of the Build B are higher than those of the Build A.</li> </ul> Lowlights: <ul style="list-style-type: none"> <li>The Build B exhibits higher download throughput values than the Build A, except at coordinates 25, 26, 27, 29, 42 and 43.</li> <li>The Build B exhibits higher upload throughput values than the Build A, except at coordinates 26, 27, 32, 35, 38, 41, 42 and 43.</li> </ul> |

# AP RSSI in 5GHz

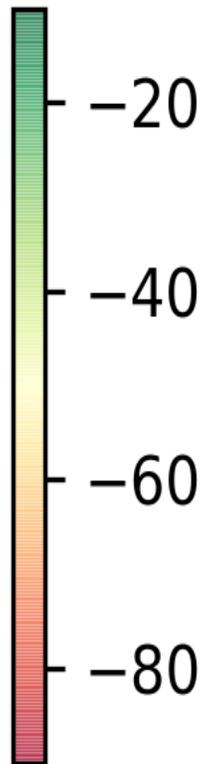
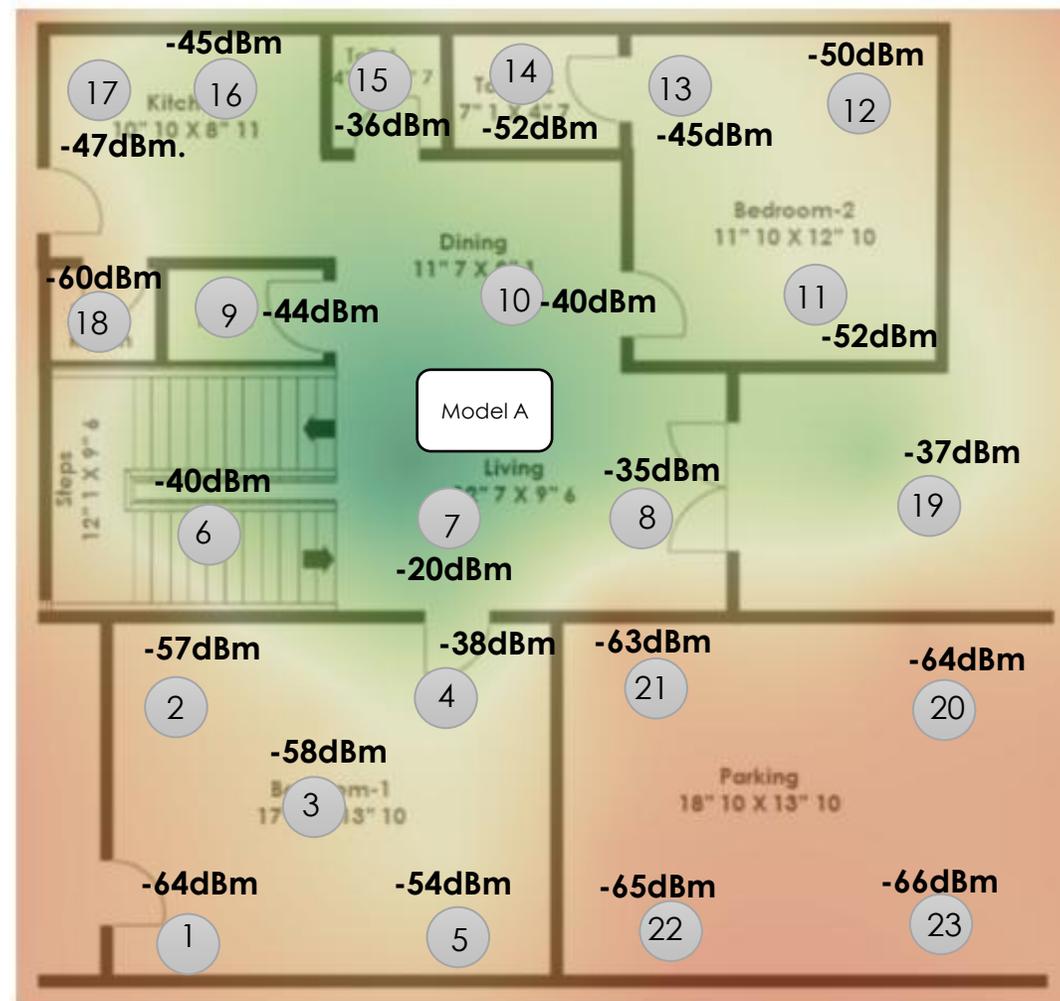
## Ground Floor signal strength (dBm)



### Build B



### Build A



● Client connected state

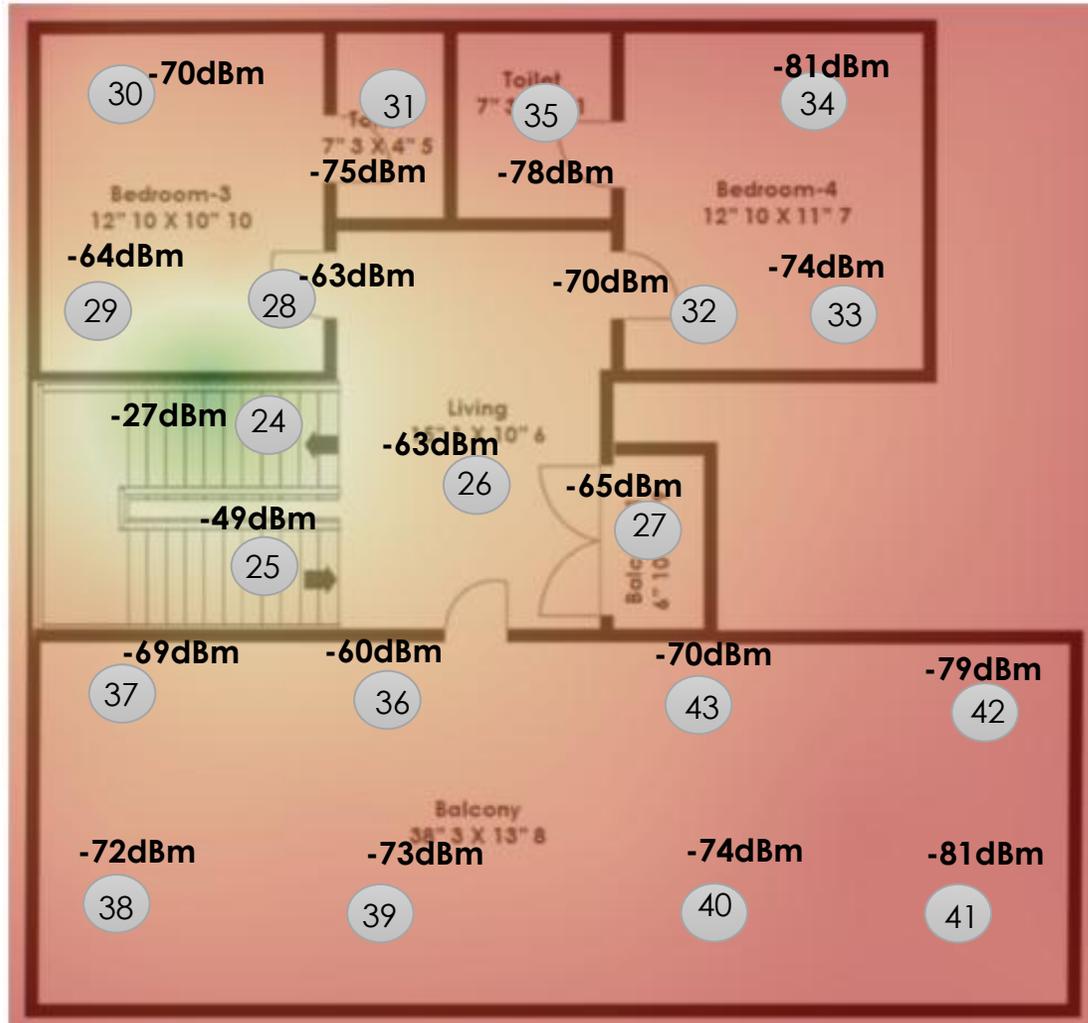
● Client disconnected state

# AP RSSI in 5GHz

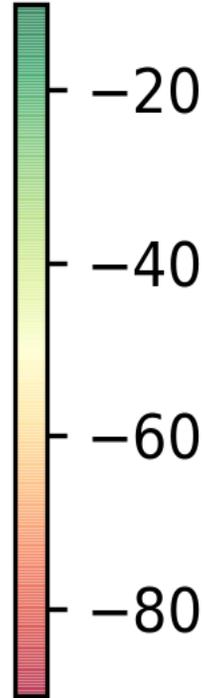
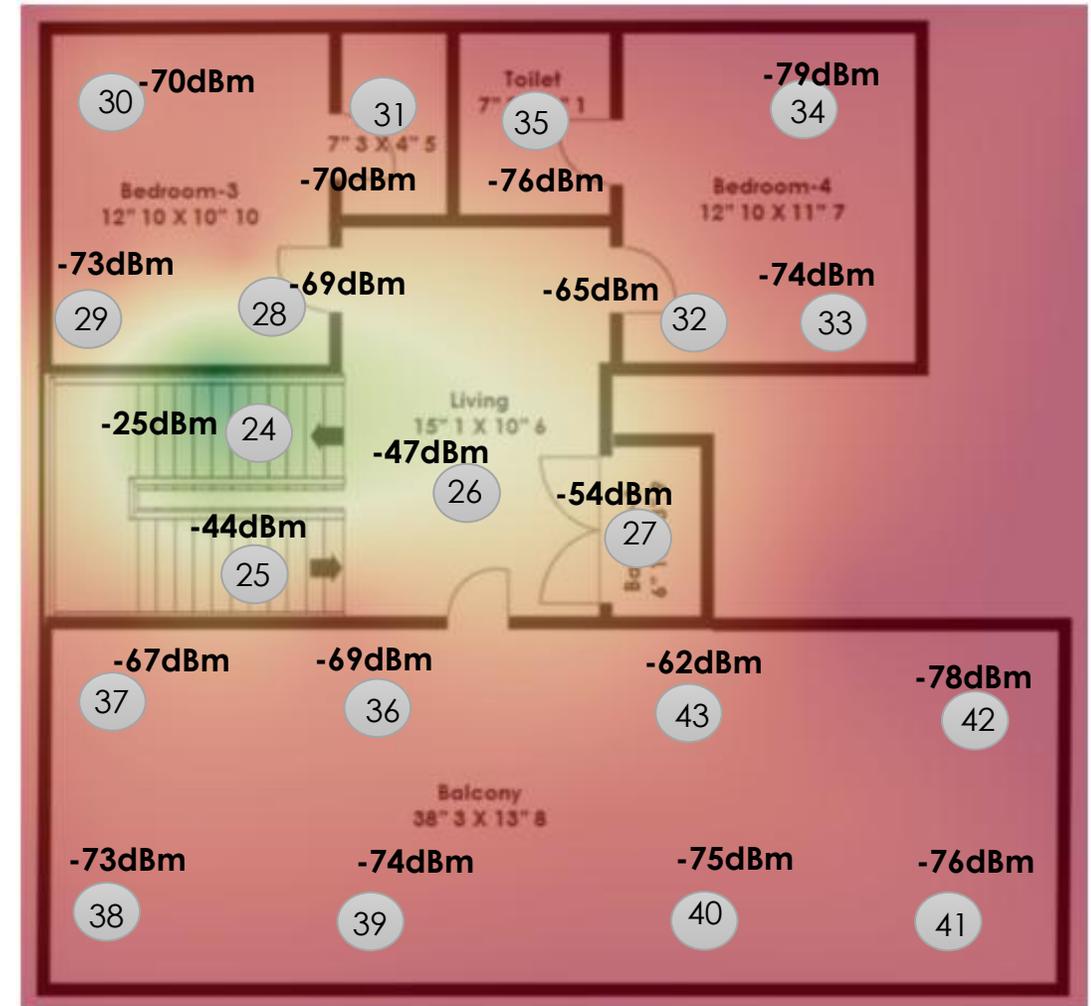
First Floor signal strength (dBm)



## Build B



## Build A



● Client connected state

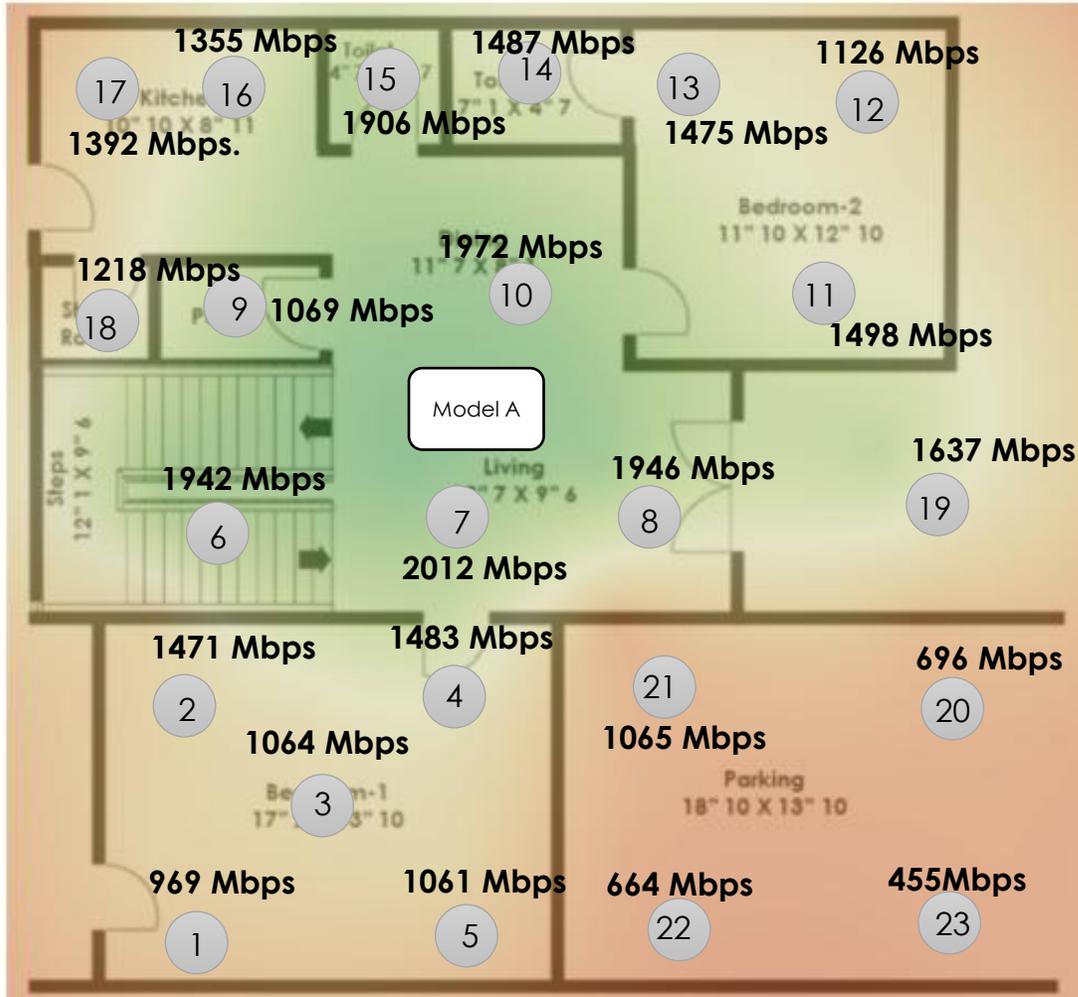
● Client disconnected state

# TCP\_DL in 5GHz

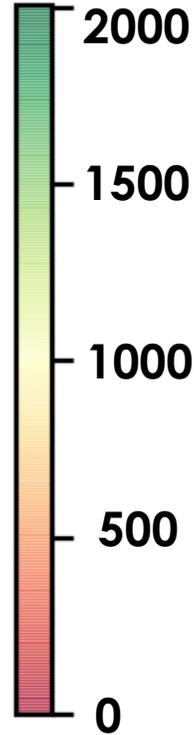
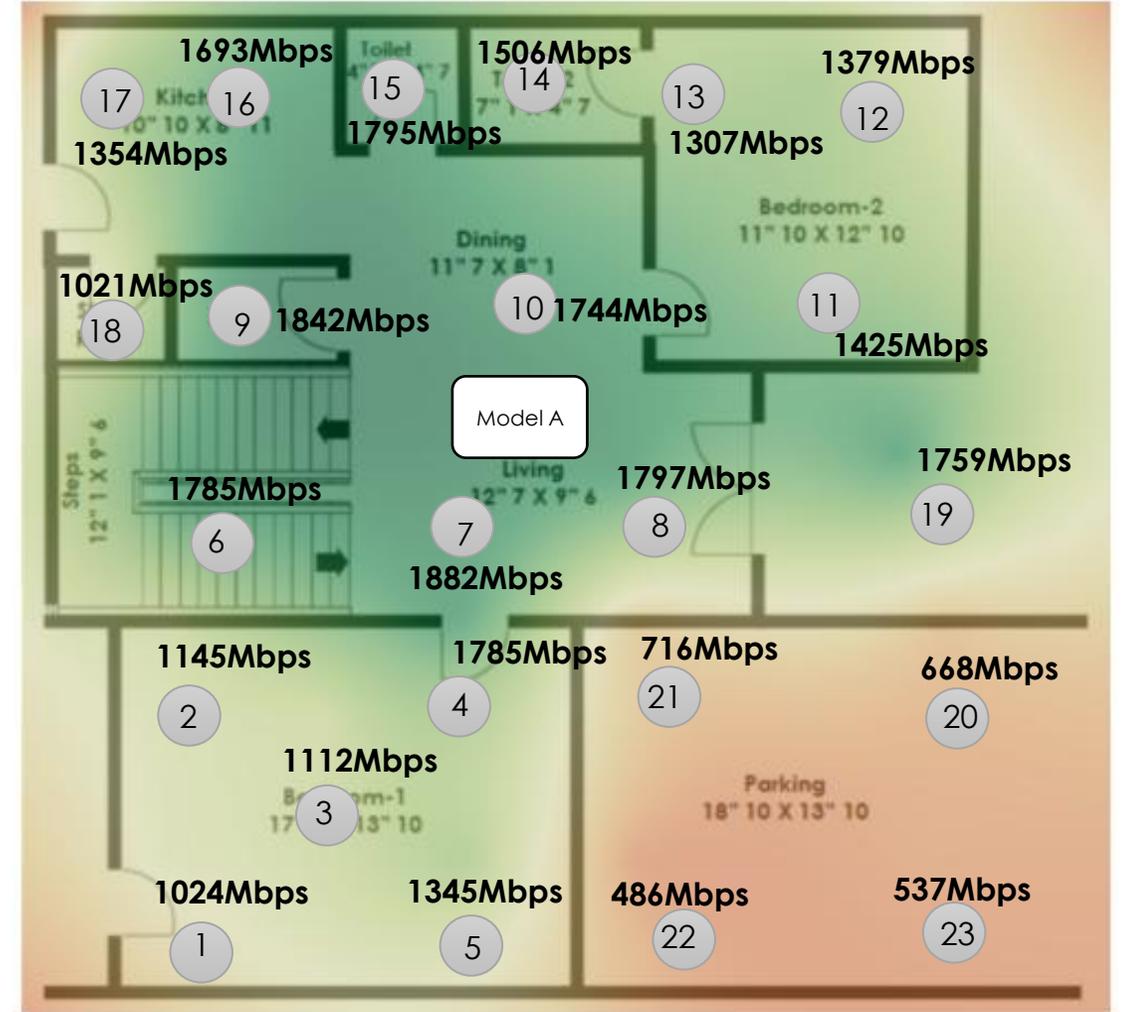
## Ground Floor Download TCP (Mbit/s)



### Build B



### Build A



● Client connected state

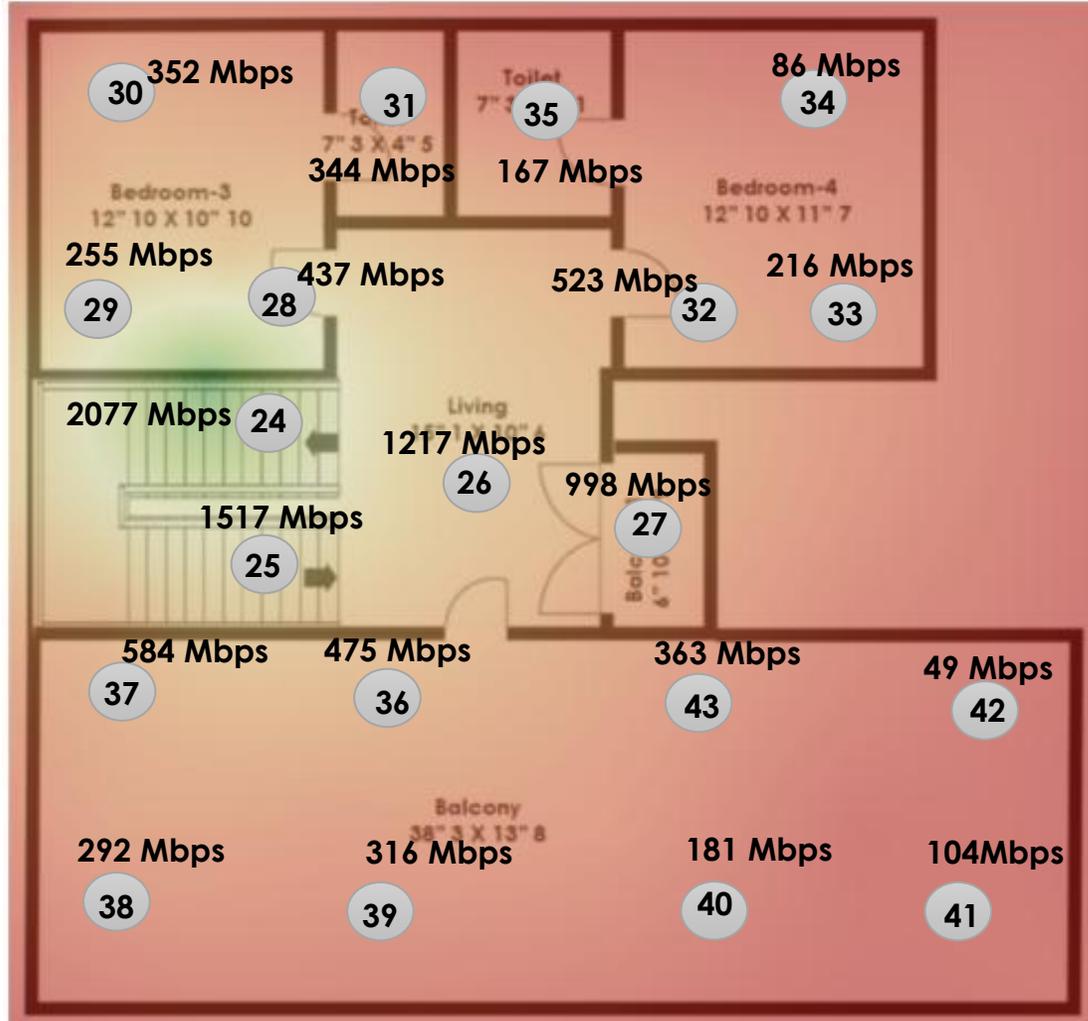
● Client disconnected state

# TCP\_DL in 5GHz

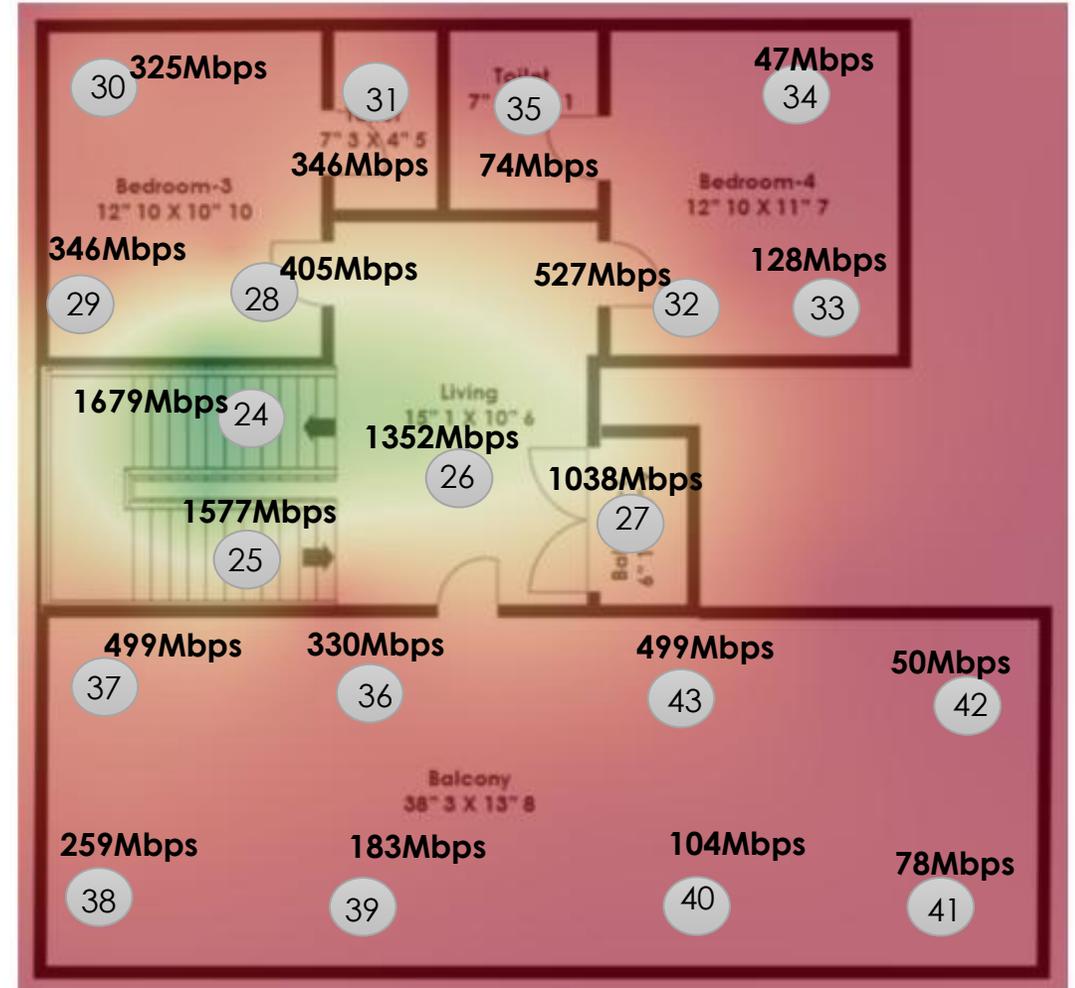
## First Floor TCP Download (Mbps)



### Build B



### Build A

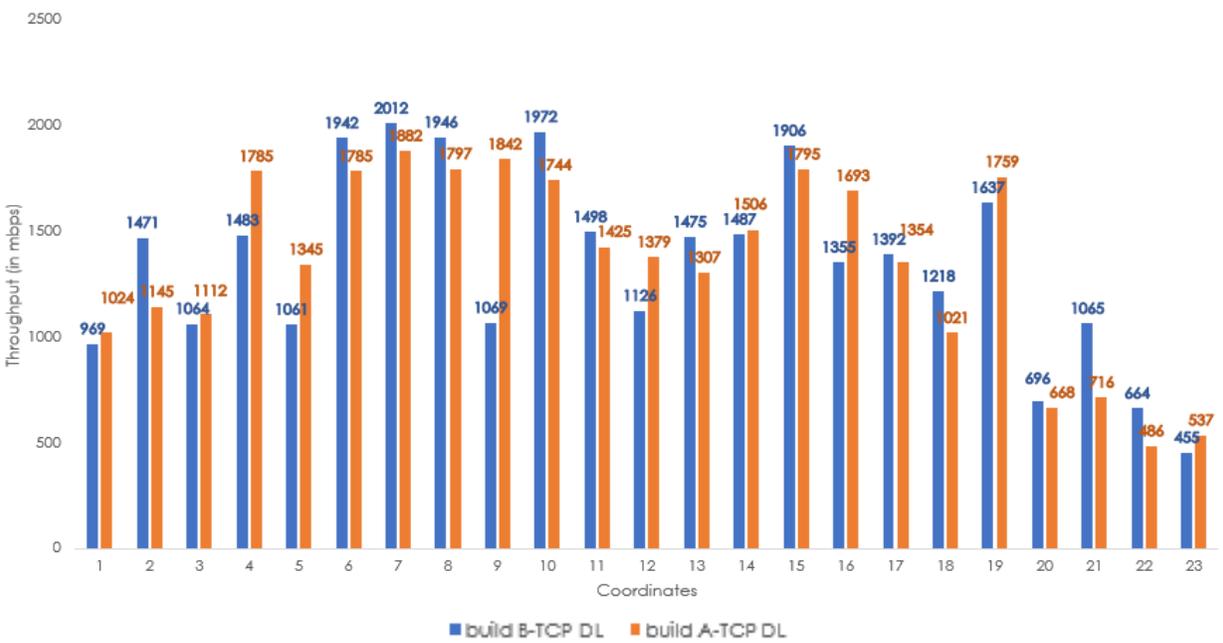


● Client connected state

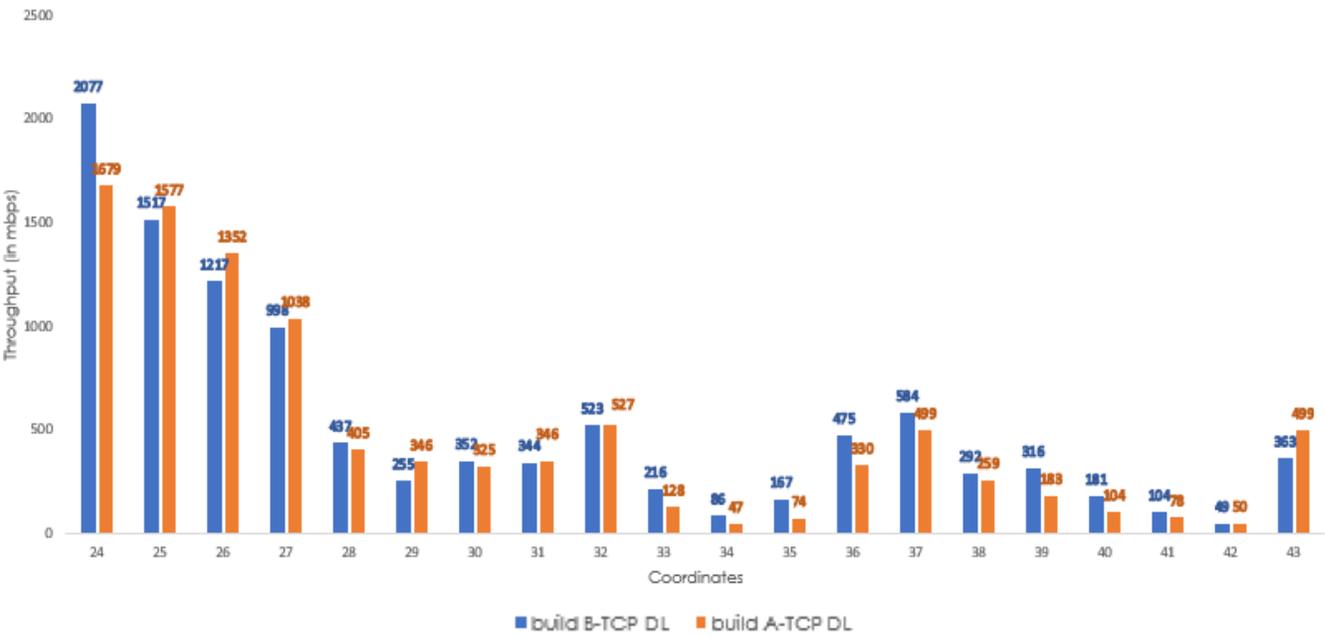
● Client disconnected state



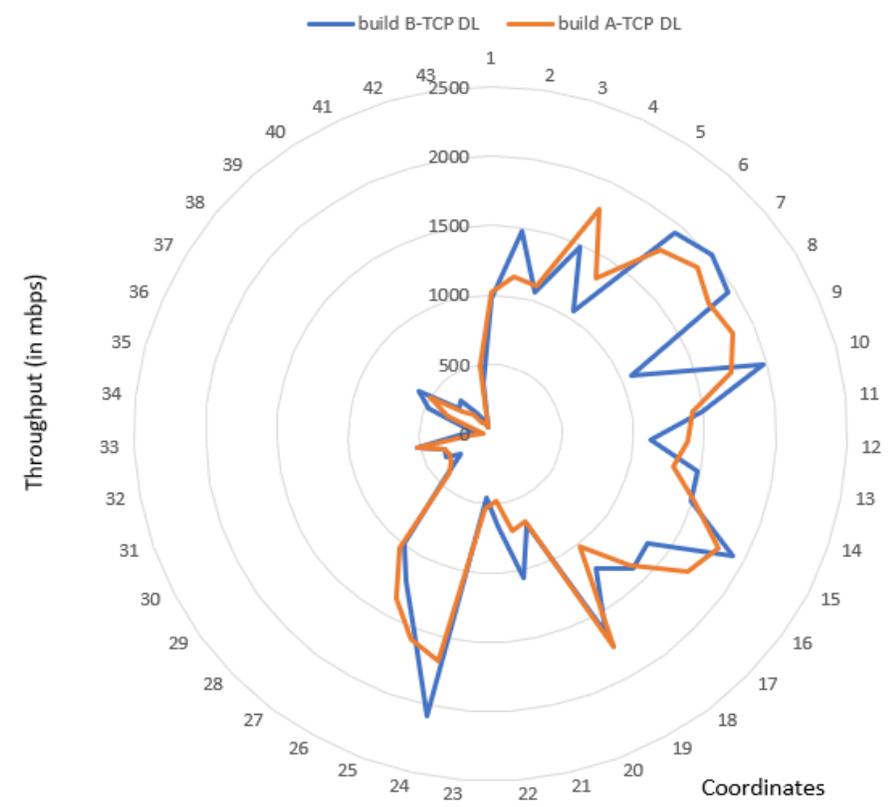
# TCP Download on 5GHz Band



TCP Download on 5GHz -First Floor



5GHz Comparison results (be mode)

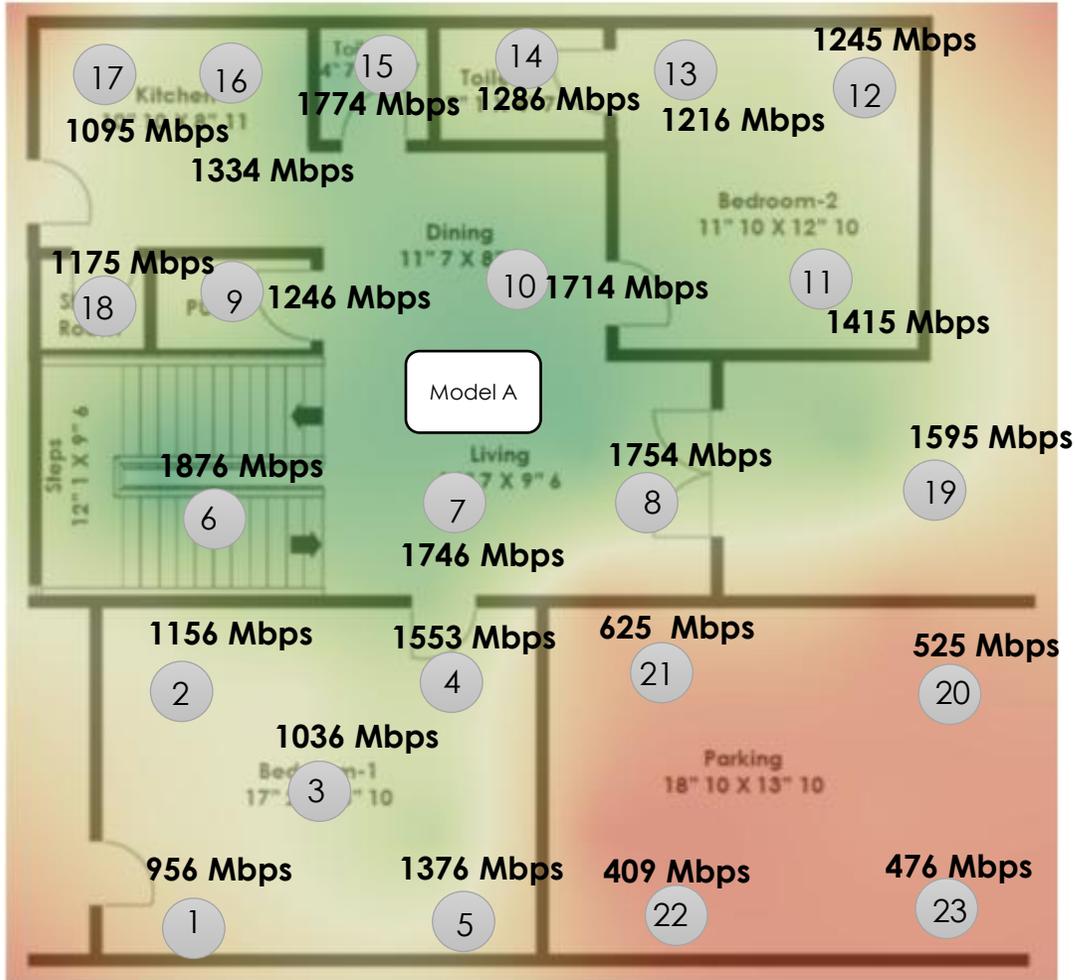


# TCP\_UL in 5GHz

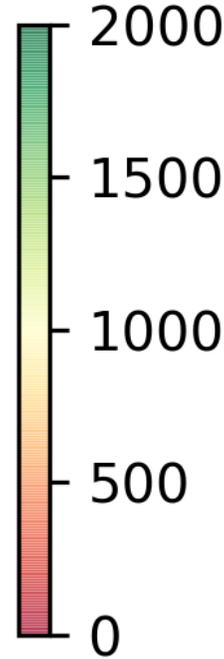
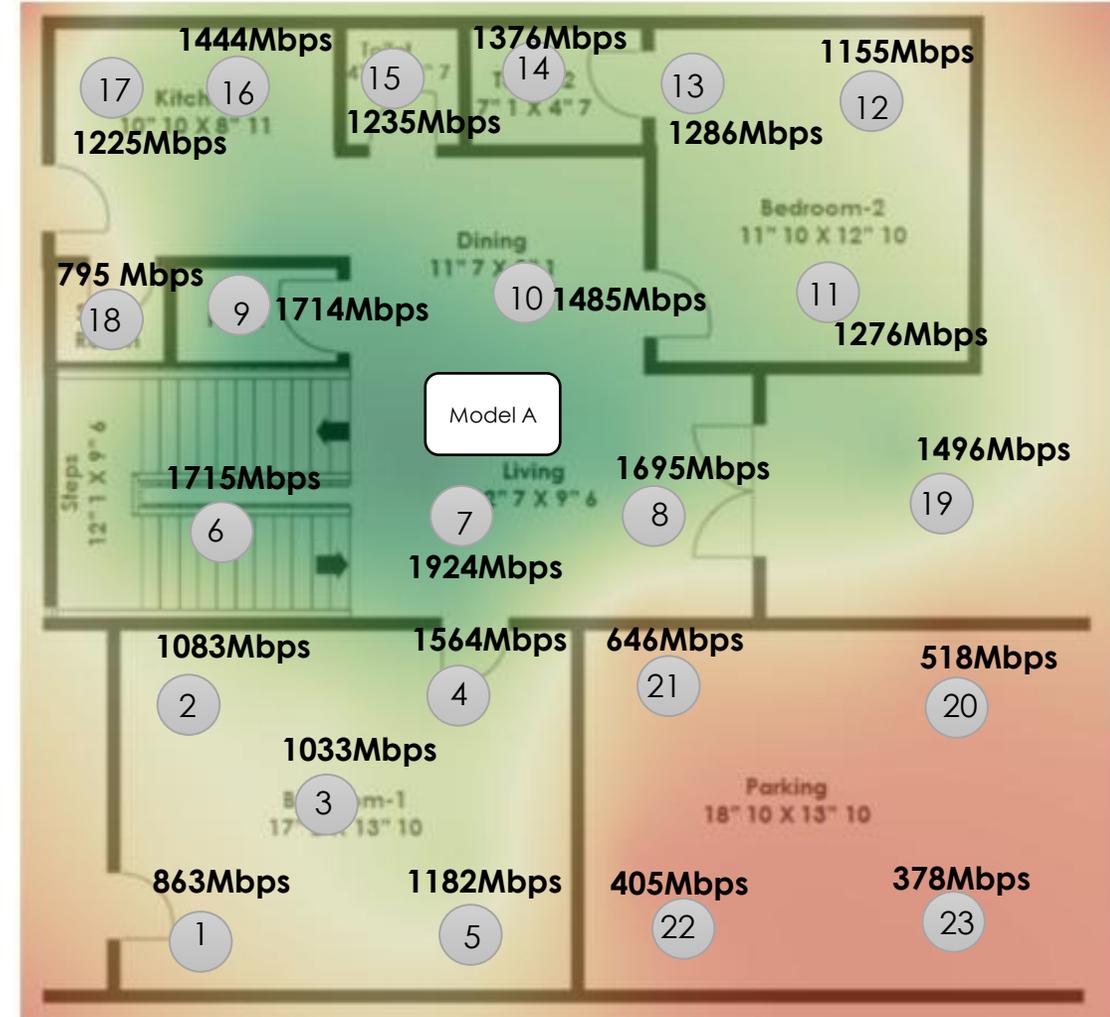
## Ground Floor Upload TCP (Mbit/s)



### Build B



### Build A



● Client connected state

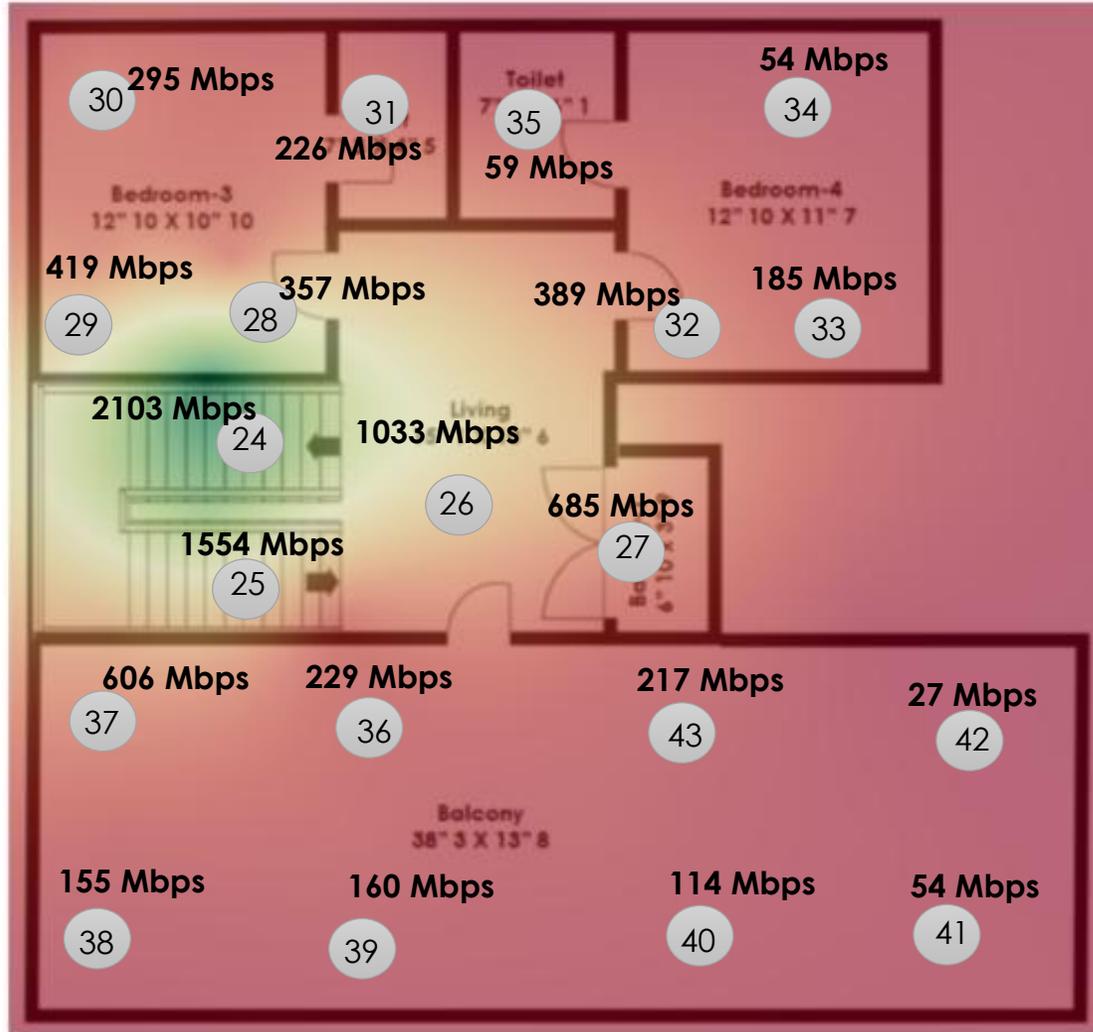
● Client disconnected state

# TCP\_UL in 5GHz

## First Floor TCP Upload (Mbps)

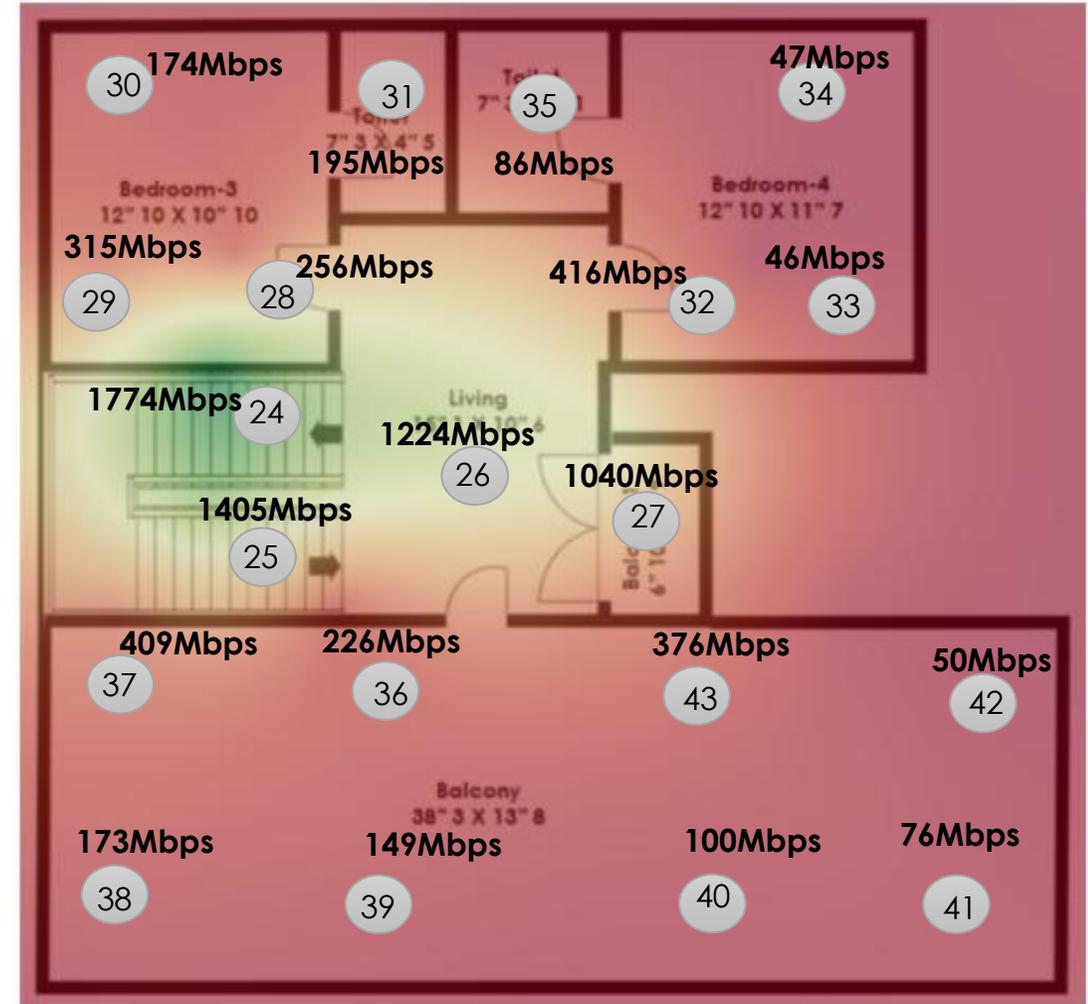


### Build B



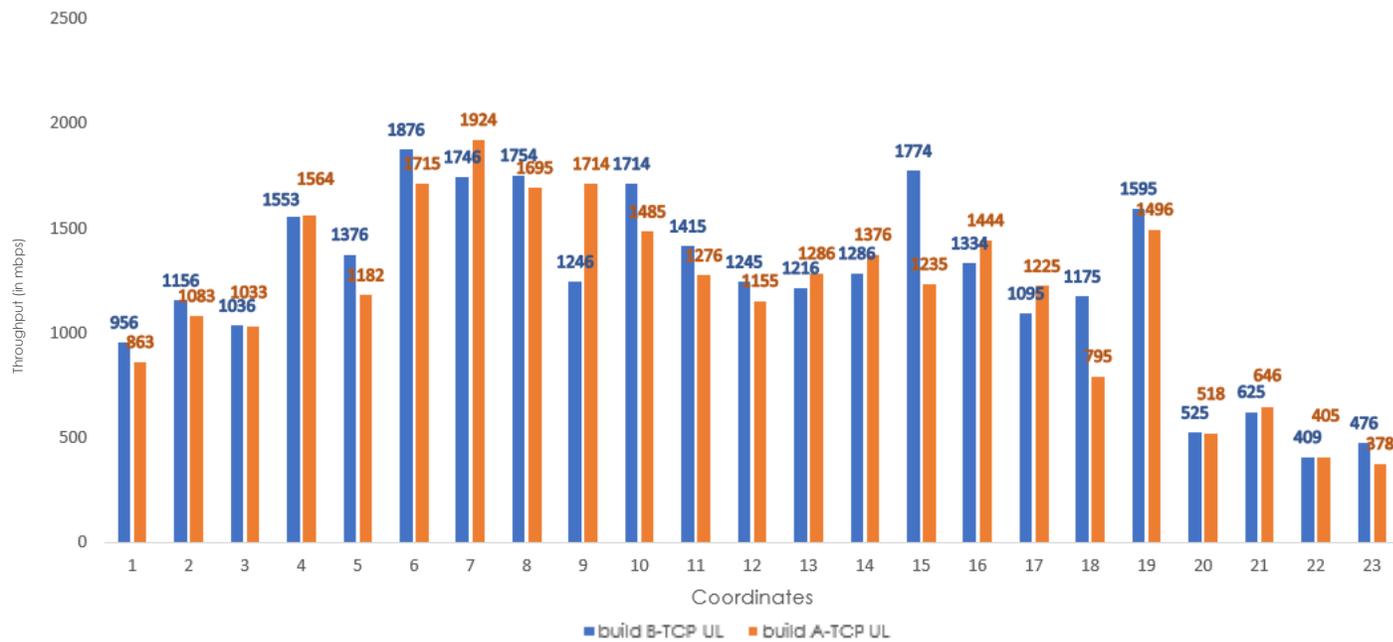
Client connected state

### Build A

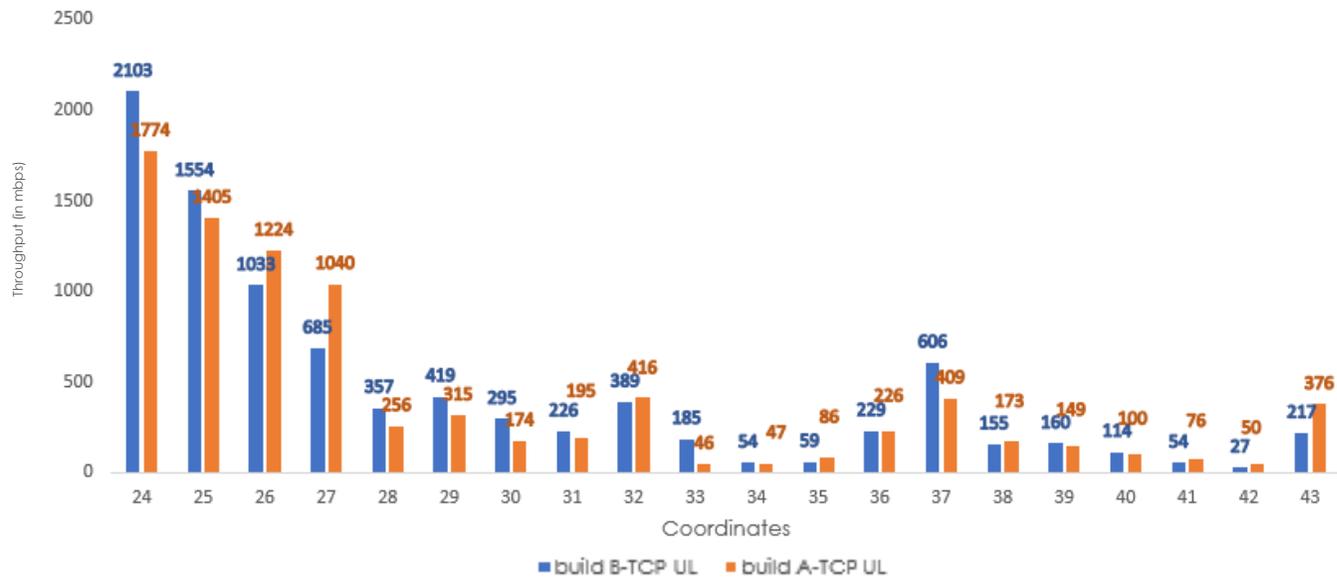


Client disconnected state

TCP Upload on 5GHz -Ground Floor



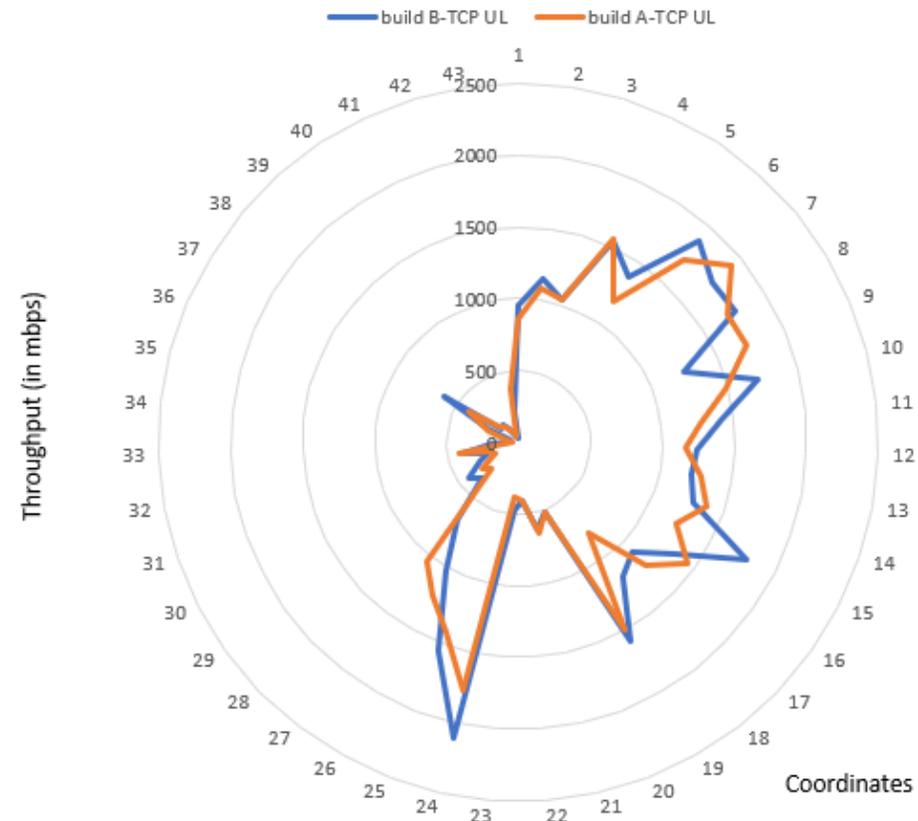
TCP Upload on 5GHz -First Floor



# TCP Upload on 5GHz Band



5GHz Comparison results (be mode)



# Analysis on 2.4GHz Band coverage:

| Parameters                      | Build B  | Build A | Observations/Comments   |
|---------------------------------|----------|---------|---|
| Ground Floor - 2.4 GHz Coverage | Improved | Reduced | Highlights: With both Build A & Build B, AP is able to provide coverage for the entire ground floor with a transmit power of 27 dB.   |
| GF - 2.4 GHz Max Throughput     | Improved | Reduced | Highlights: <ul style="list-style-type: none"> <li>With Build B max DL throughput achieved is 466 Mbps (Coordinate:- 7) whereas with Build A max throughput is 437 Mbps (Coordinate:- 9).</li> <li>With Build B max UL throughput achieved is 466 Mbps (Coordinate:- 4) whereas with Build A max throughput is 370Mbps (Coordinate:- 4).</li> </ul>   |
| GF - Overall experience         | Improved | Reduced | Highlights: <ul style="list-style-type: none"> <li>Build B provides complete coverage for the entire floor.</li> <li>In TCP DL and UL, throughput values of the Build B are higher than those of the Build A.</li> </ul> Lowlights: <ul style="list-style-type: none"> <li>The Build B exhibits higher download throughput values than the Build A, except at coordinates 9, 20, 21 and 22.</li> <li>The Build B exhibits higher upload throughput values than the Build A, except at coordinate 12.</li> </ul> |
| First Floor - 2.4 GHz Coverage  | Improved | Reduced | Highlights: With both Build A & Build B, AP is able to provide coverage for the entire First floor with a transmit power of 27 dB.  |
| FF - 2.4 GHz Max Throughput     | Improved | Reduced | Highlights: <ul style="list-style-type: none"> <li>With Build B max DL throughput achieved is 476 Mbps (Coordinate:- 24) whereas with Build A max throughput is 345 Mbps (Coordinate:- 24).</li> <li>With Build B max UL throughput achieved is 445 Mbps (Coordinate:- 24) whereas with Build A max throughput is 425 Mbps (Coordinate:- 24).</li> </ul>  |
| FF - Overall experience         | Improved | Reduced | Highlights: <ul style="list-style-type: none"> <li>Both Build A &amp; Build B provides complete coverage for the entire floor.</li> <li>In TCP DL and UL, throughput values of the Build B are higher than those of the Build A.</li> </ul>   |

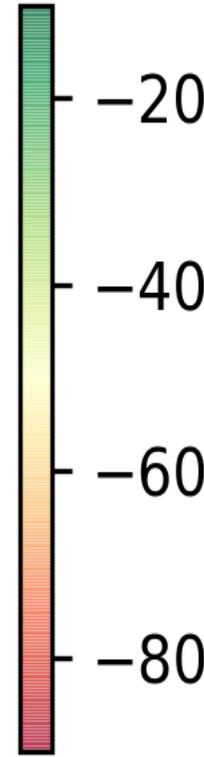
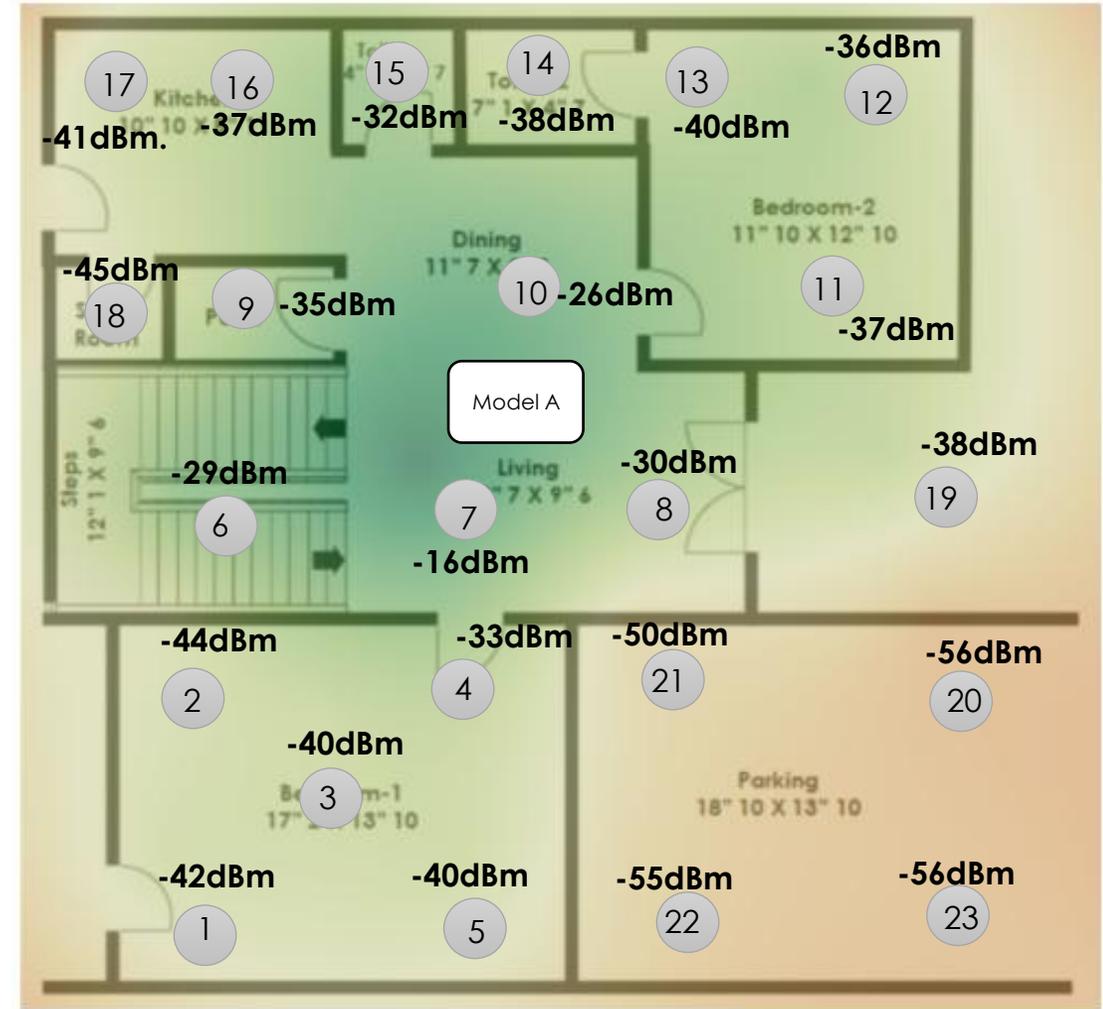
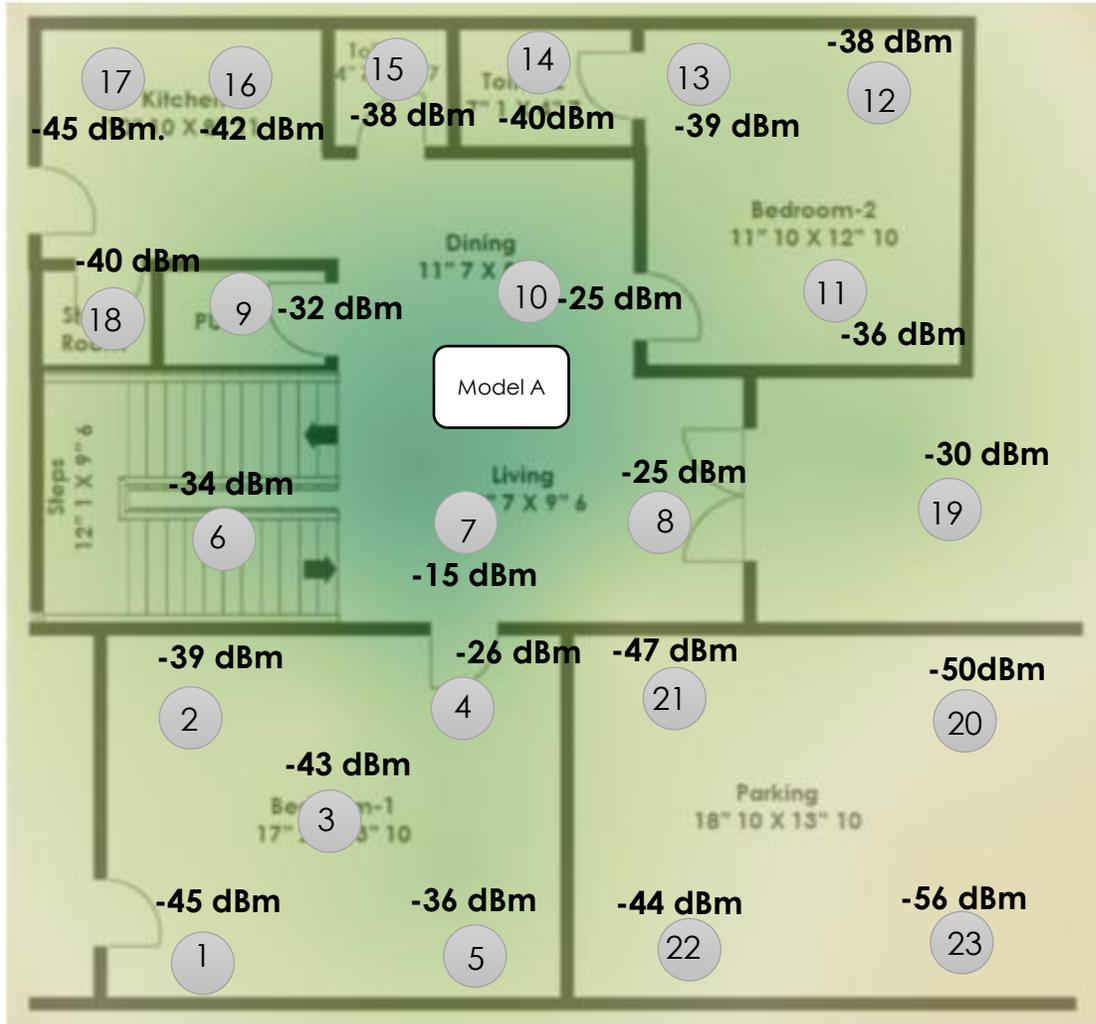
# AP RSSI in 2.4GHz

## Ground Floor signal strength (dBm)



### Build B

### Build A



● Client connected state

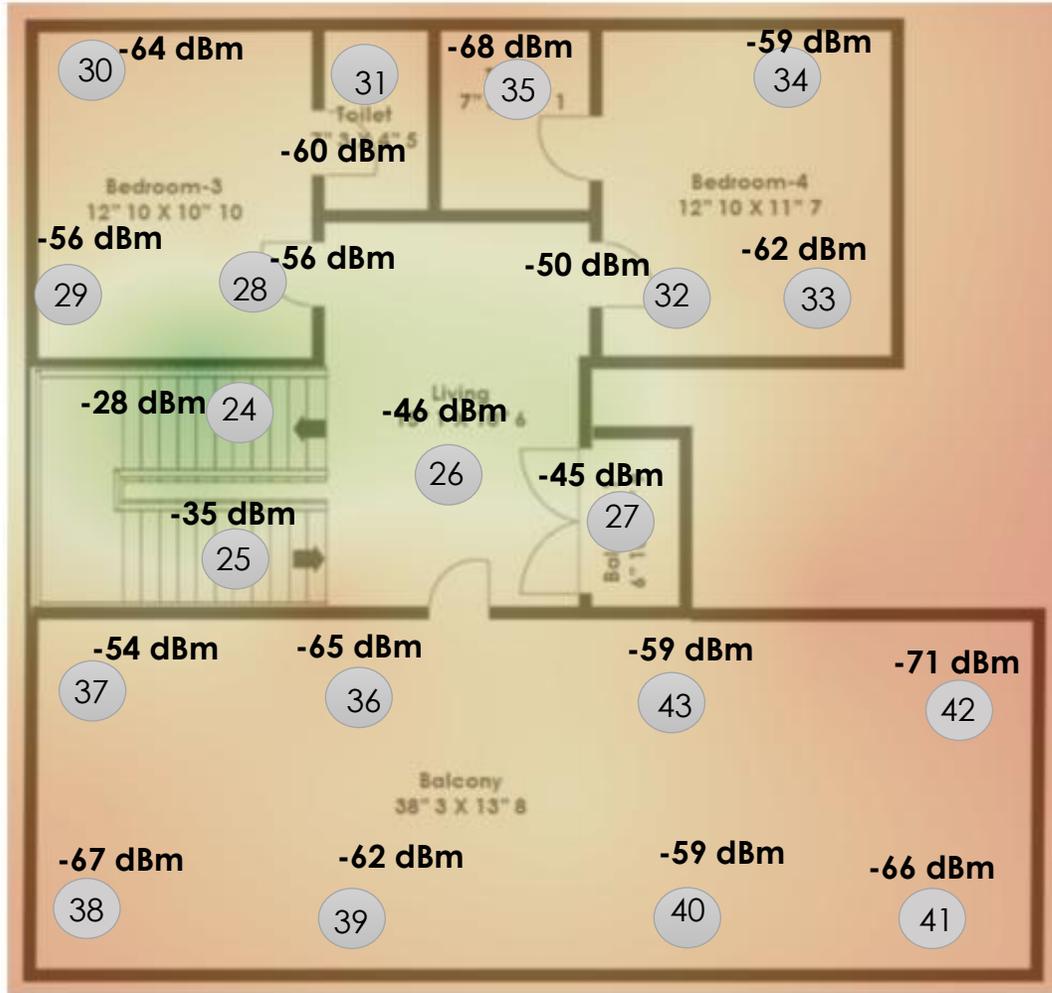
● Client disconnected state

# AP RSSI in 2.4GHz

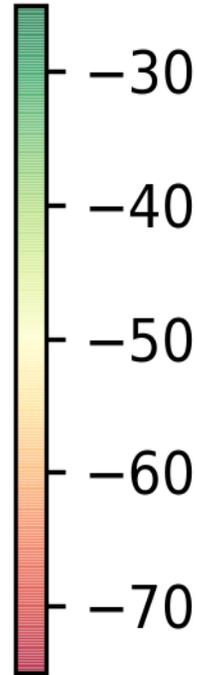
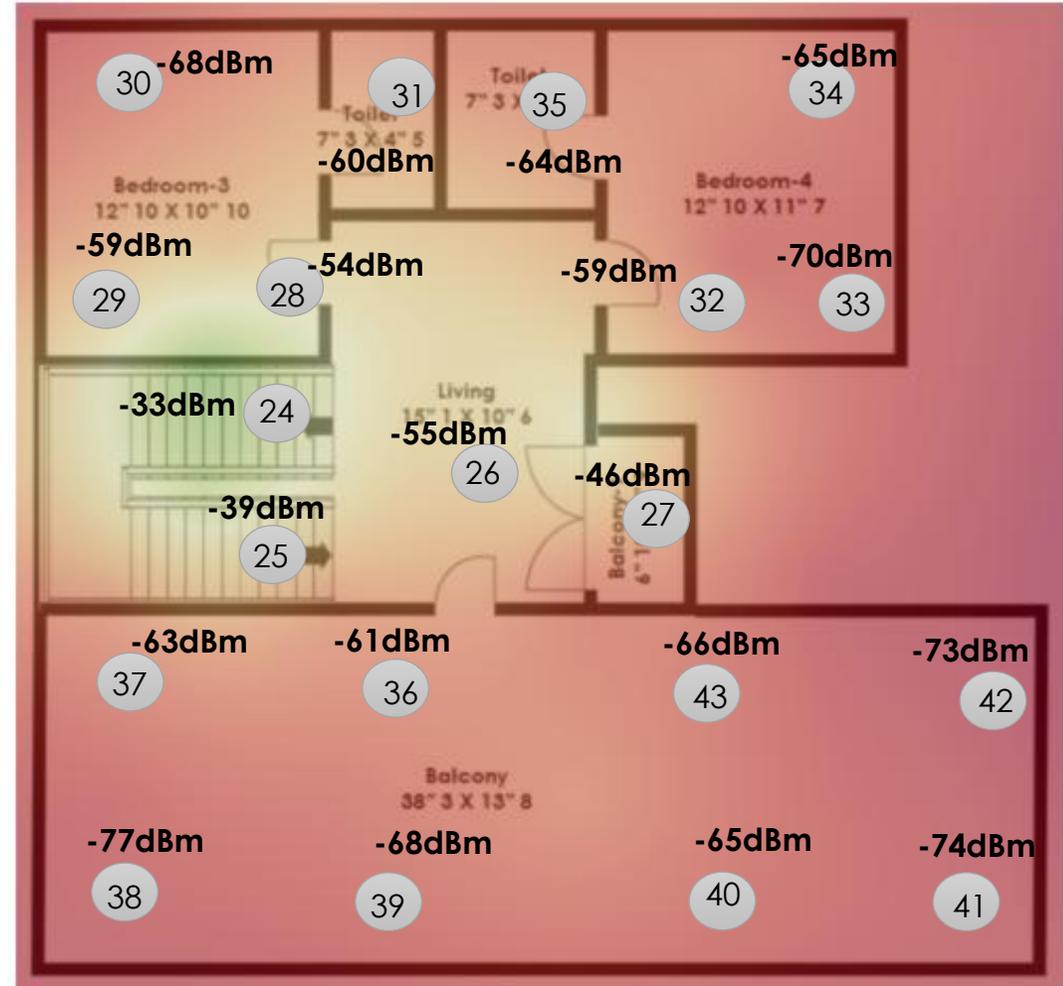
## First Floor signal strength (dBm)



### Build B



### Build A



● Client connected state

● Client disconnected state

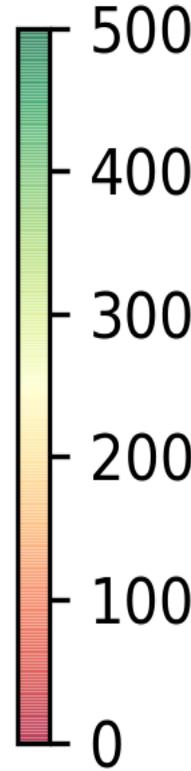
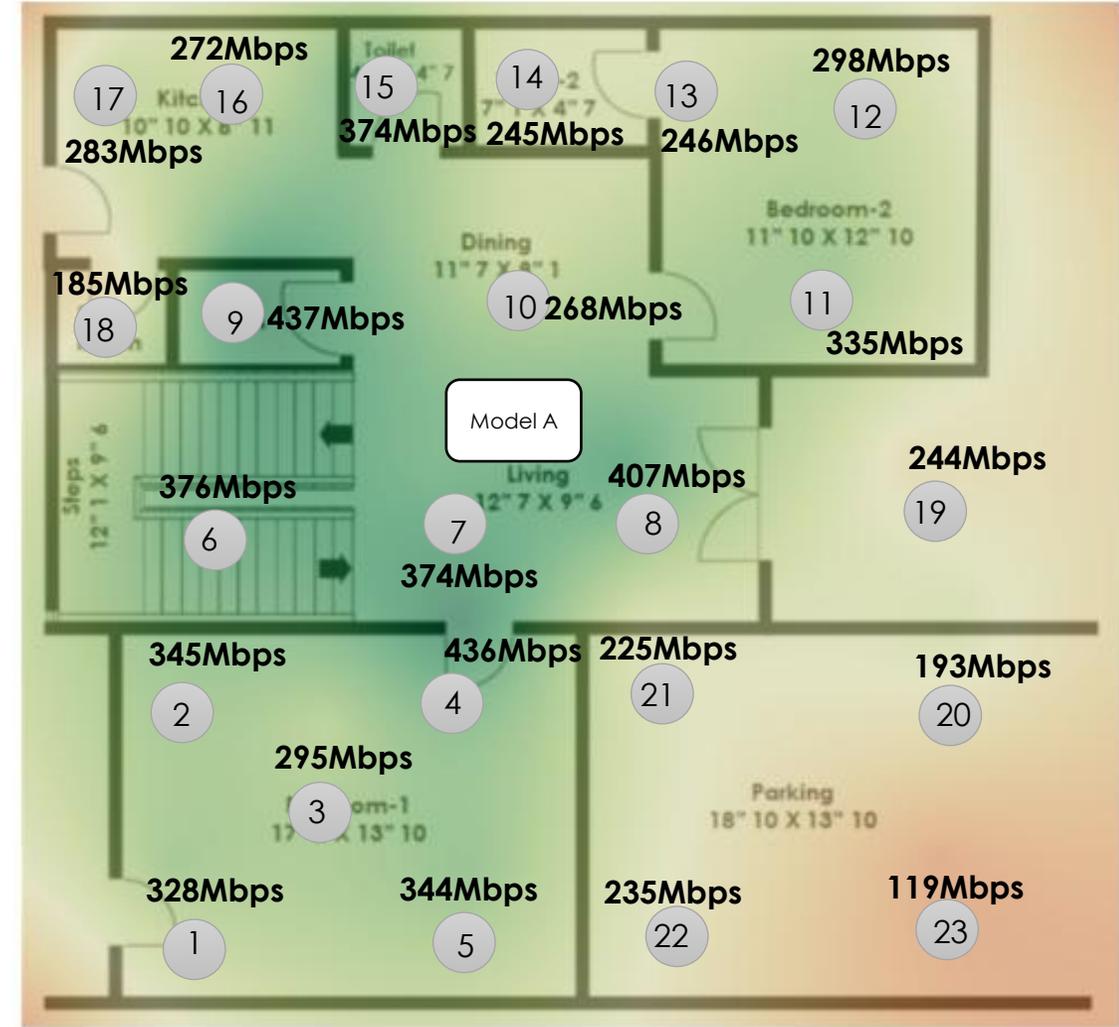
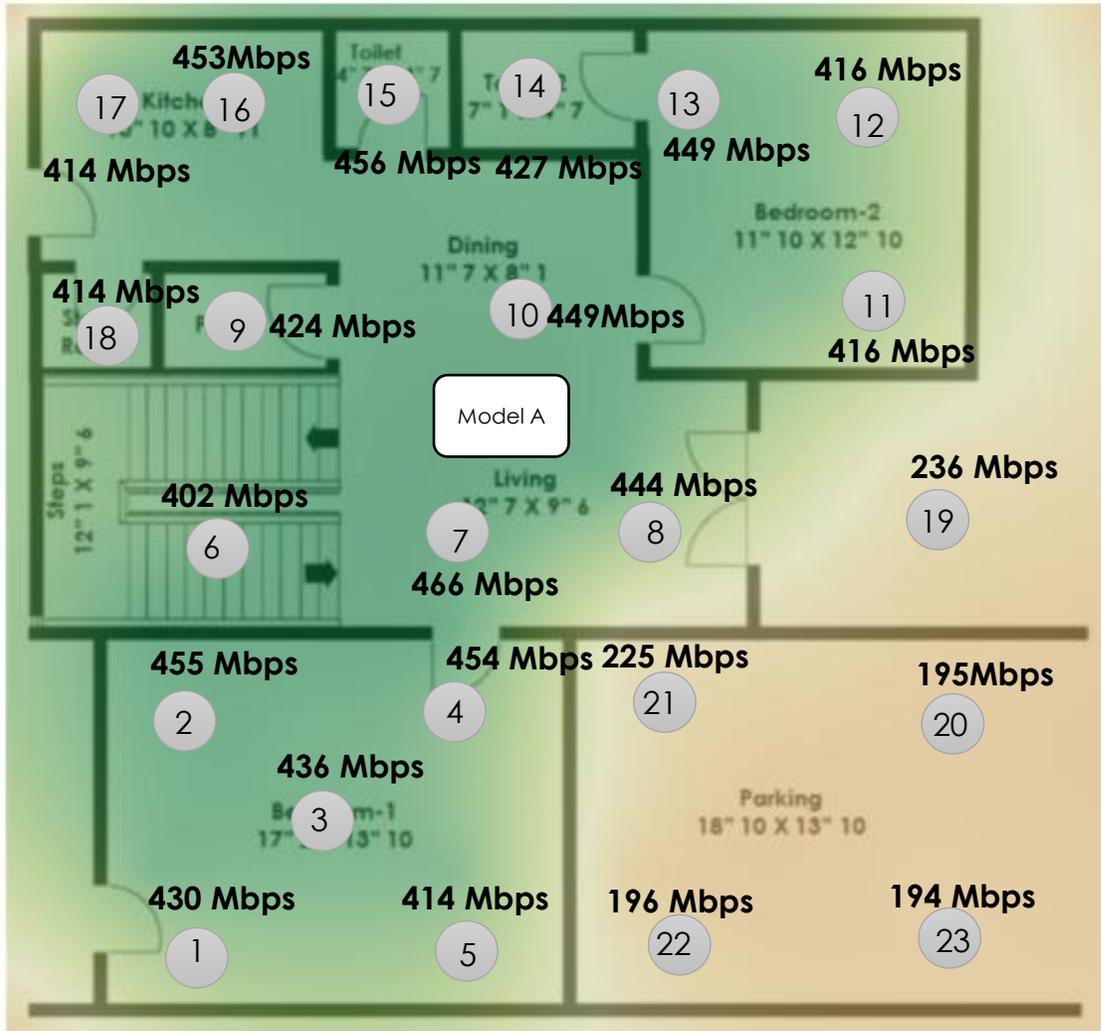
# TCP\_DL in 2.4GHz

## Ground Floor Download TCP (Mbit/s)



### Build B

### Build A



● Client connected state

● Client disconnected state

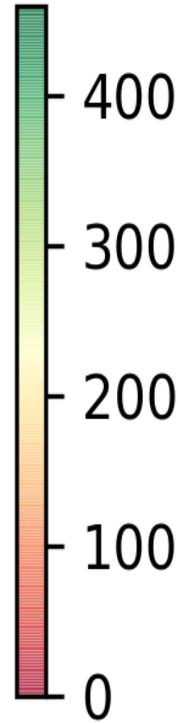
# TCP\_DL in 2.4GHz

## First Floor TCP Download (Mbps)



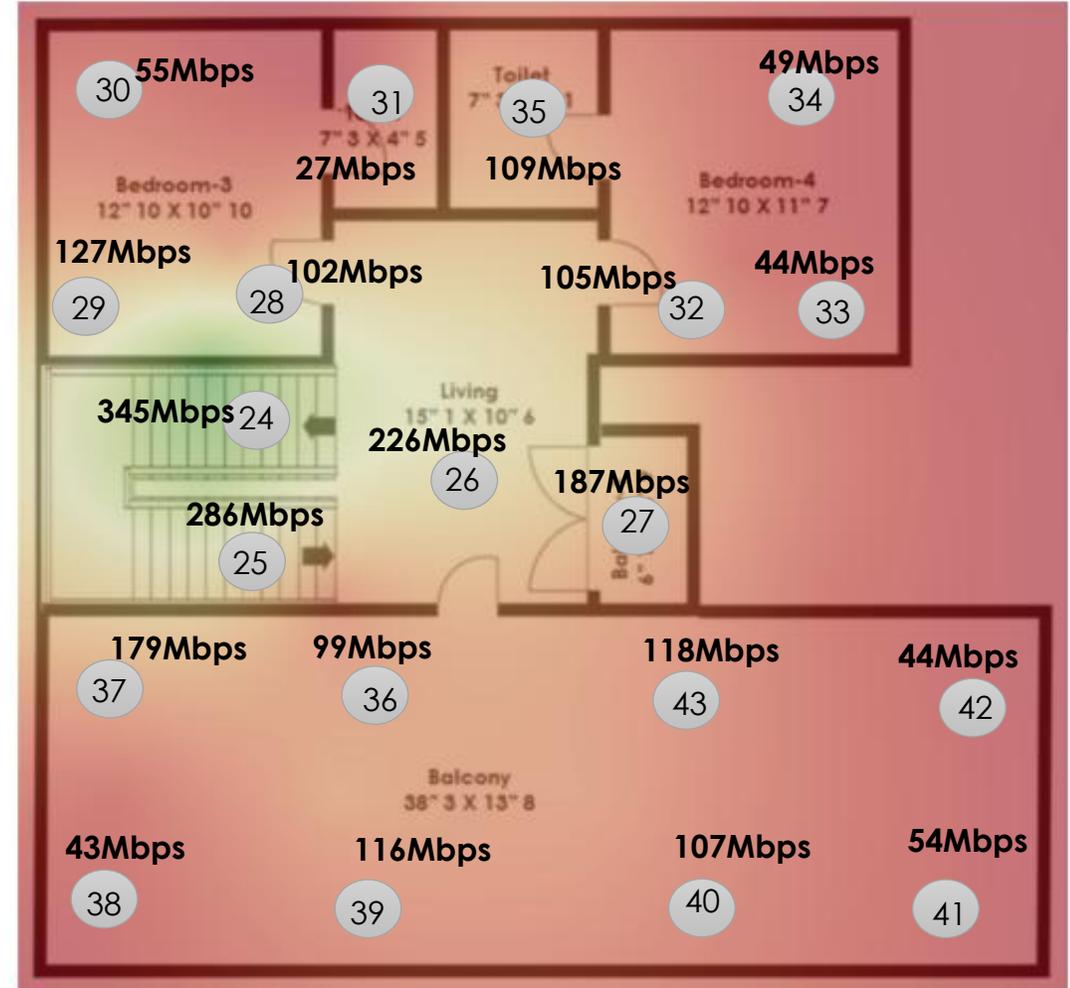
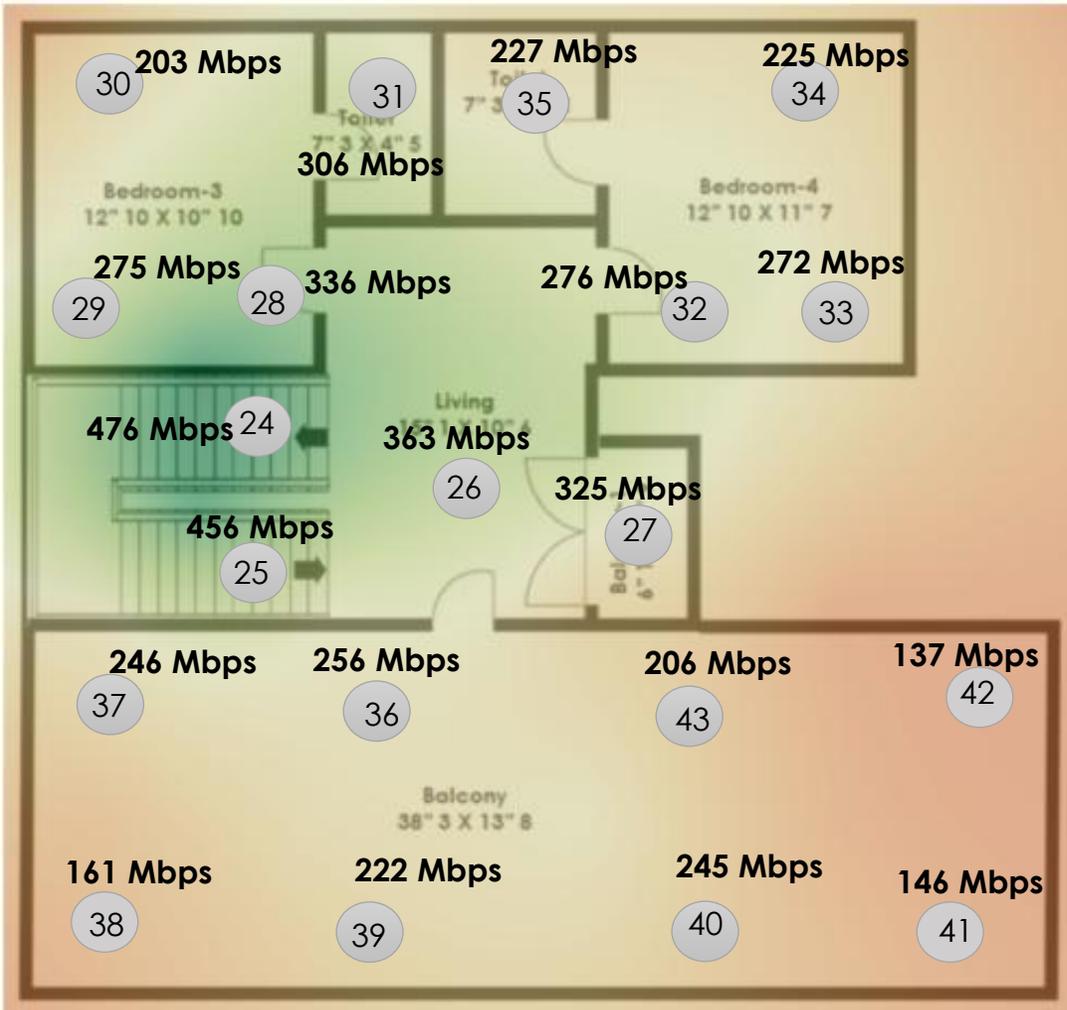
### Build B

### Build A

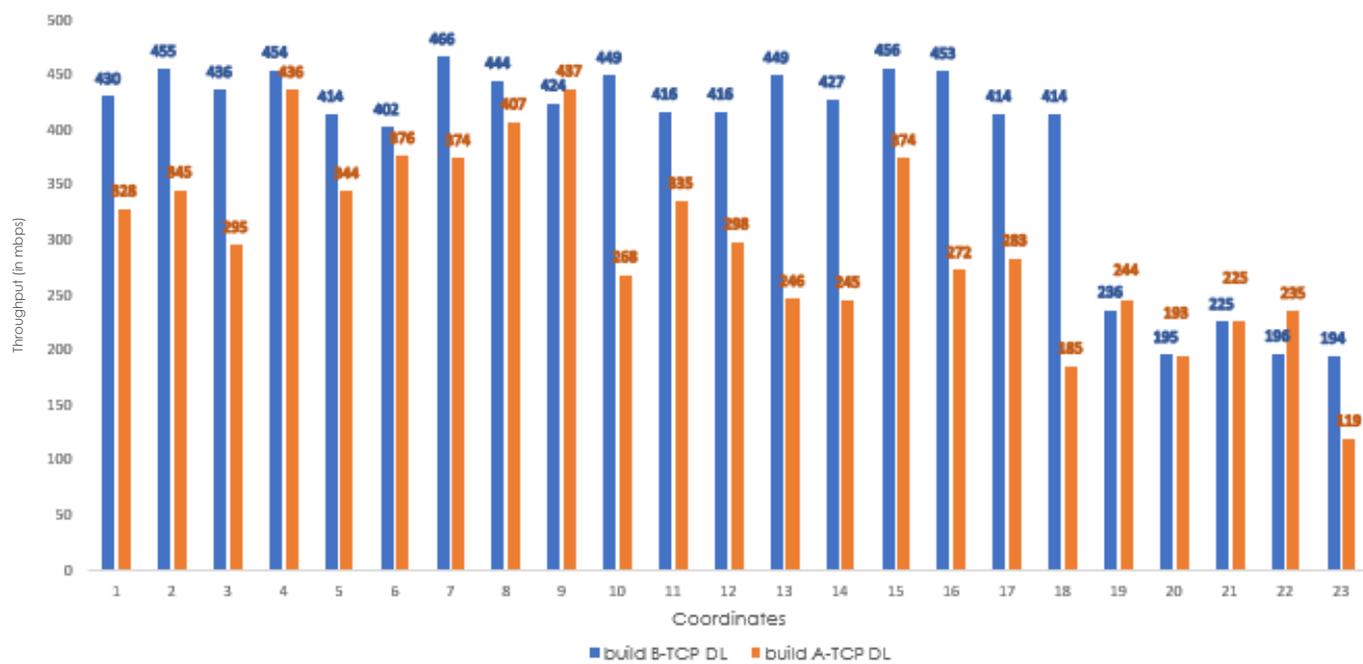


● Client connected state

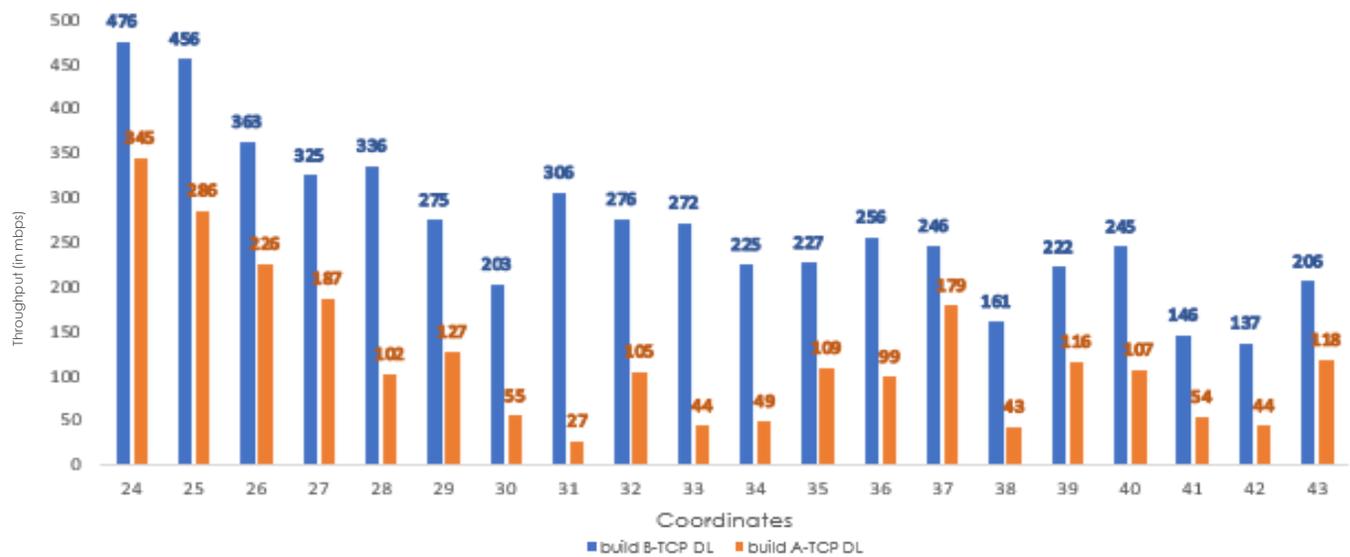
● Client disconnected state



TCP Download on 2.4GHz -Ground Floor



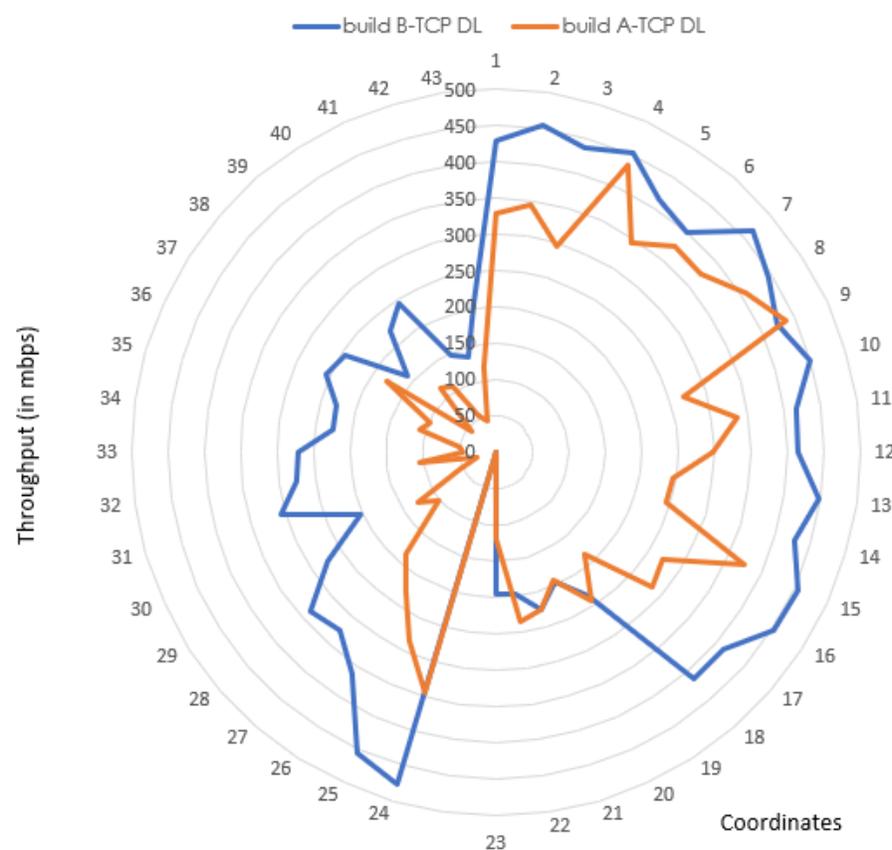
TCP Download on 2.4GHz -First Floor



# TCP Download on 2.4GHz Band



2.4GHz Comparison results (be mode)

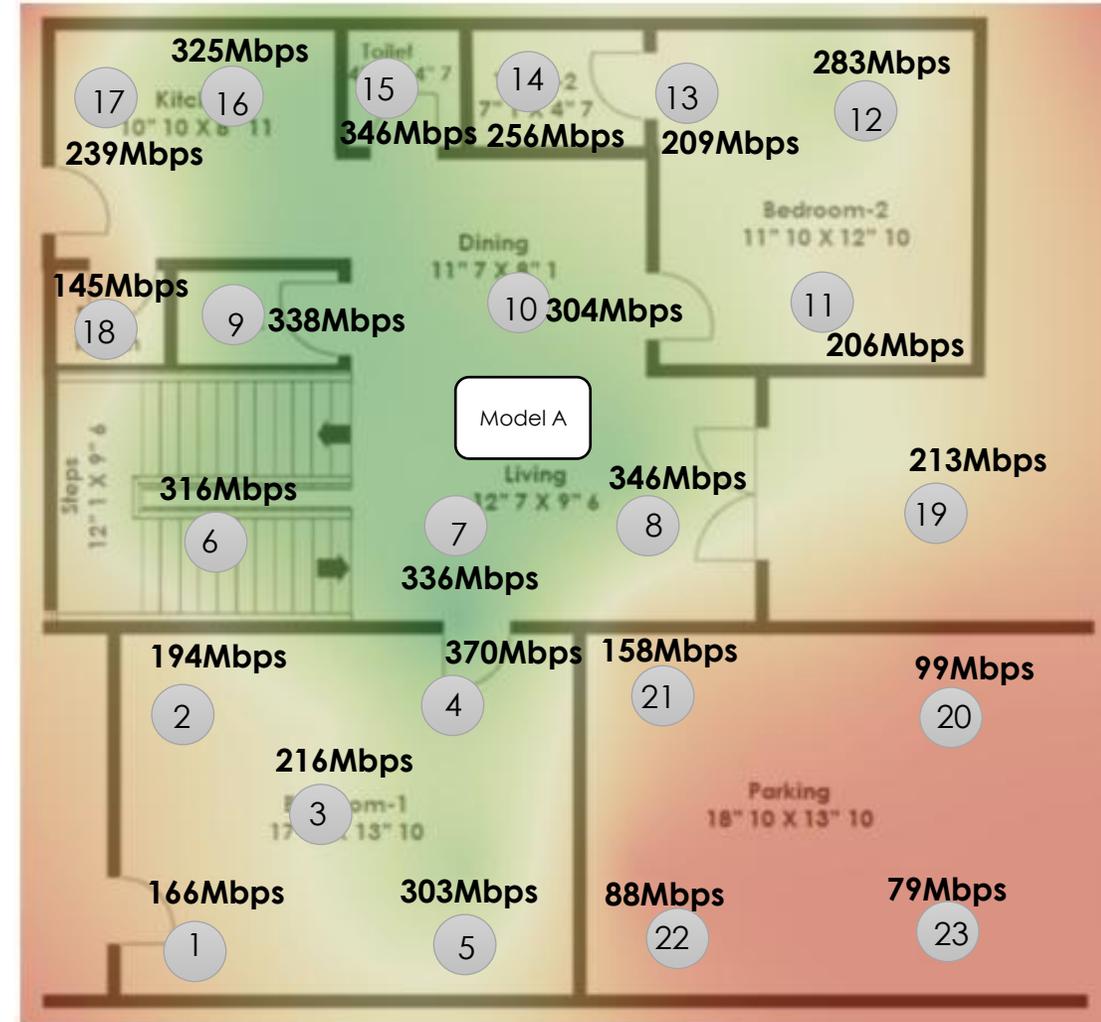
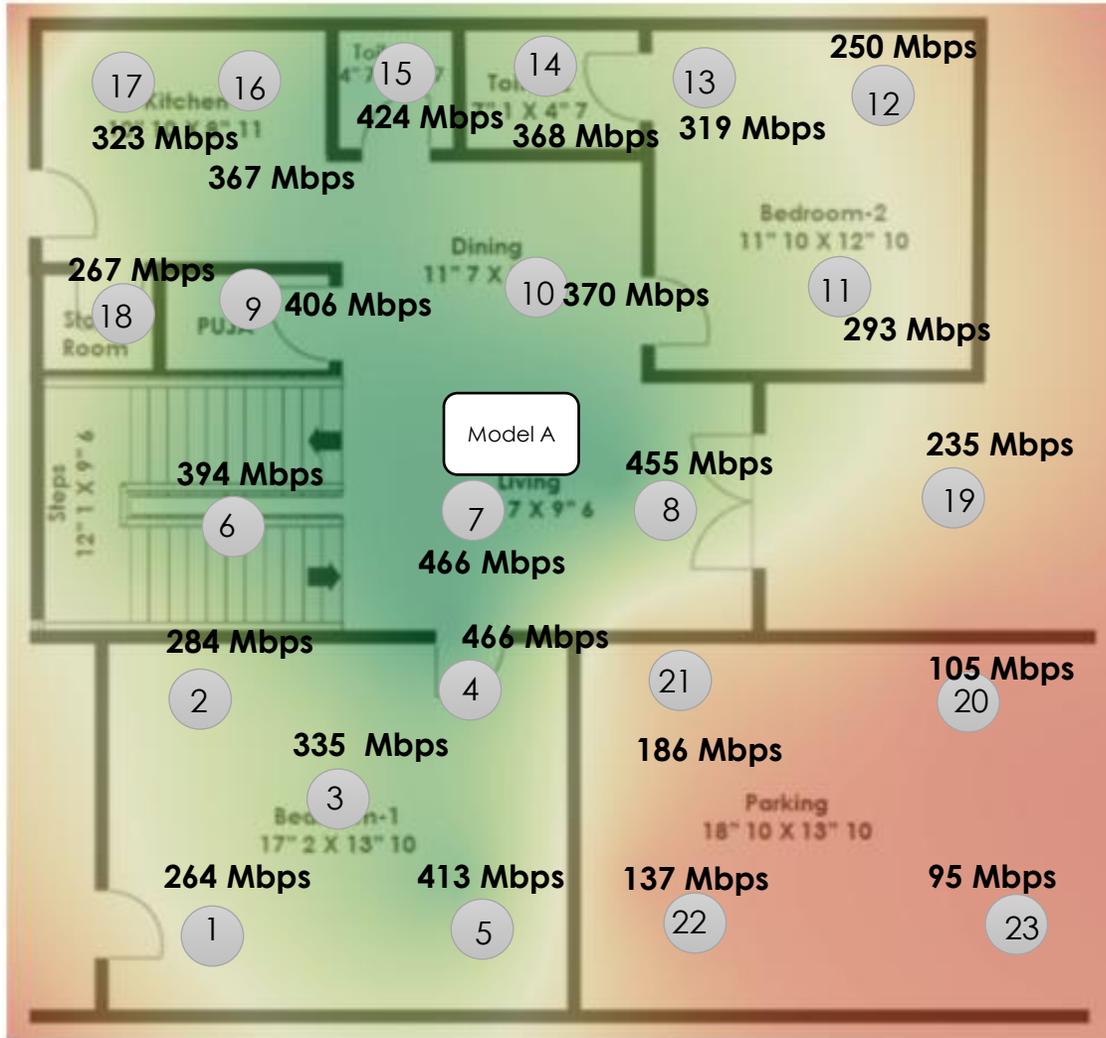
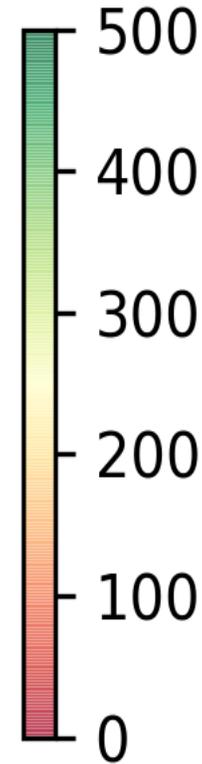


# TCP\_UL in 2.4GHz

## Ground Floor Upload TCP (Mbit/s)

### Build B

### Build A



● Client connected state

● Client disconnected state

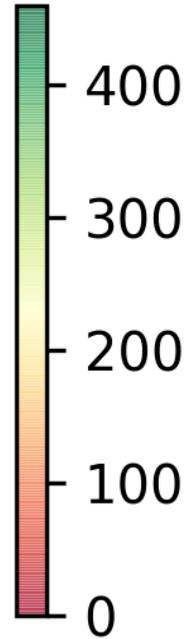
# TCP\_UL in 2.4GHz

## First Floor TCP Upload (Mbps)



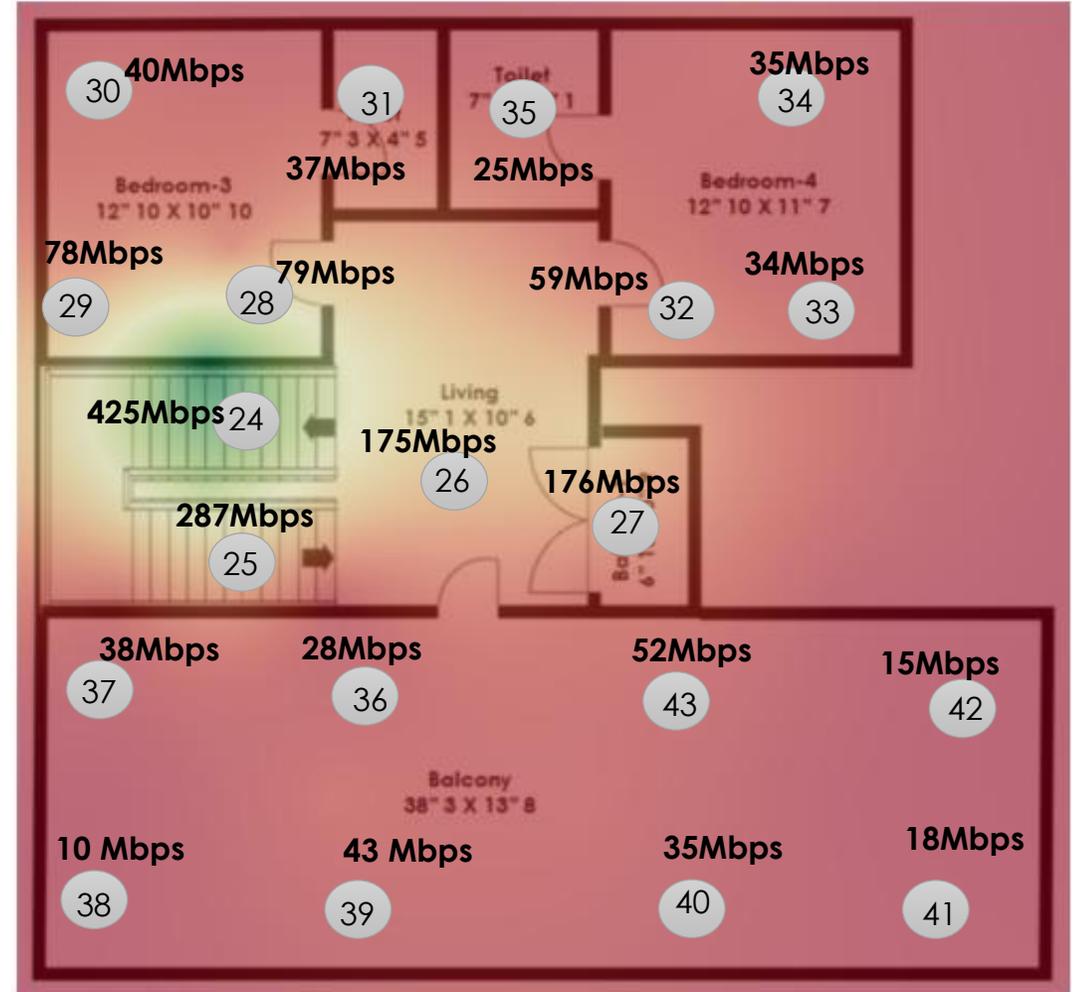
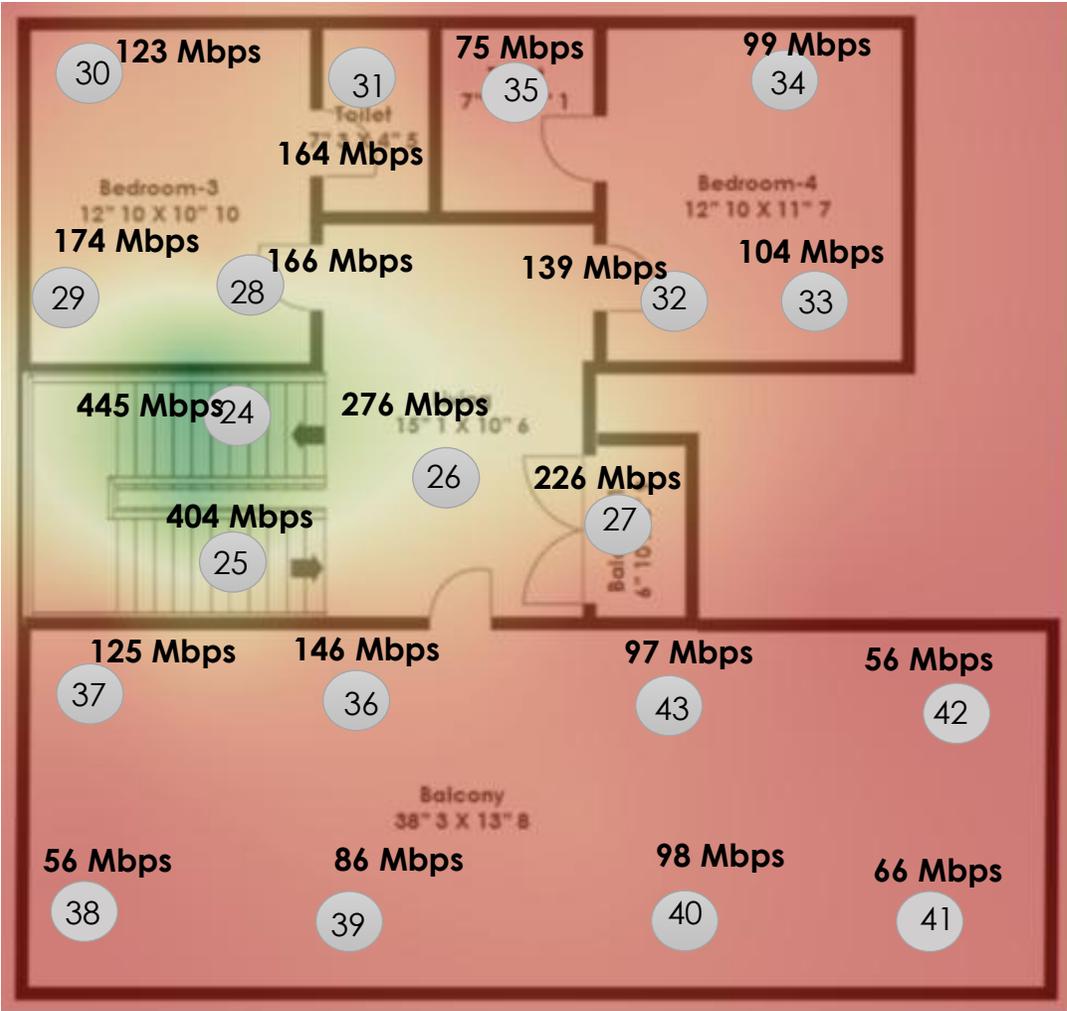
### Build B

### Build A

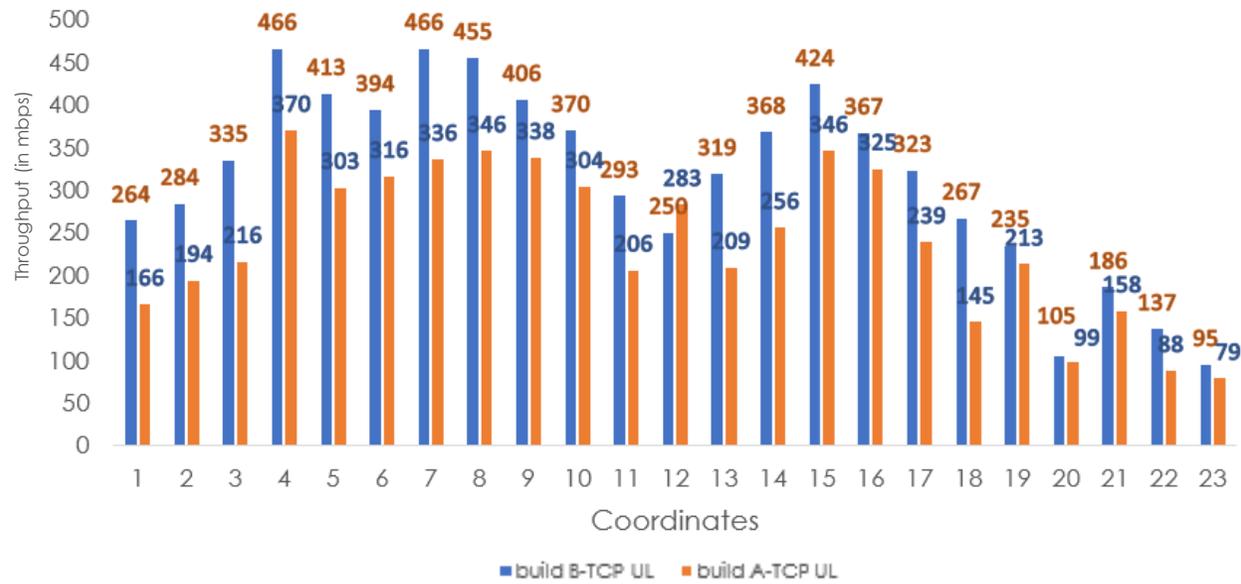


● Client connected state

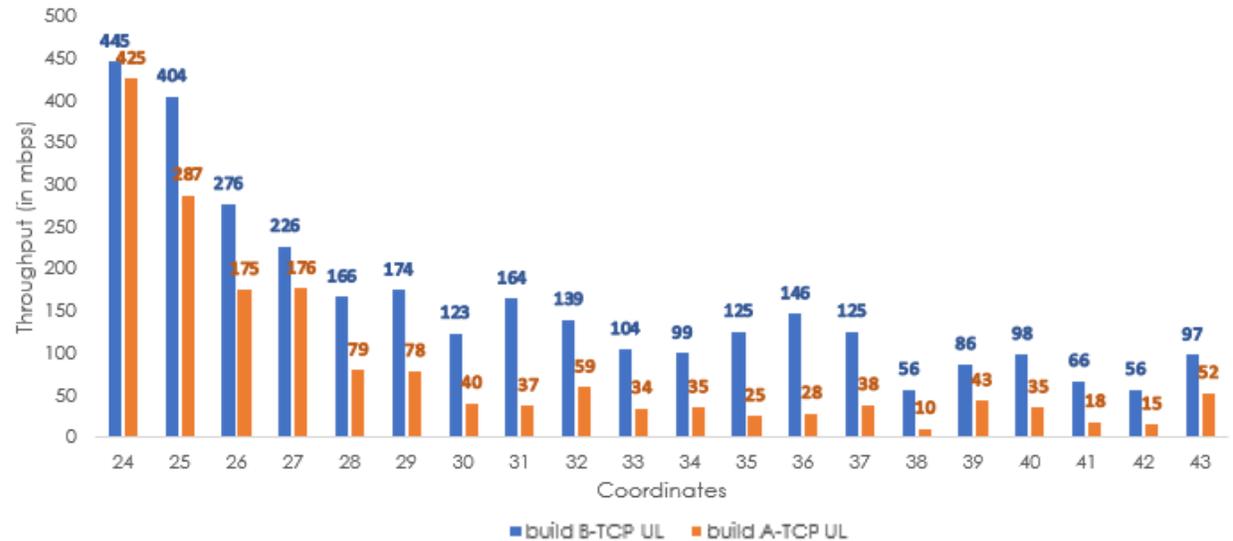
● Client disconnected state



## TCP Upload on 2.4GHz -Ground Floor



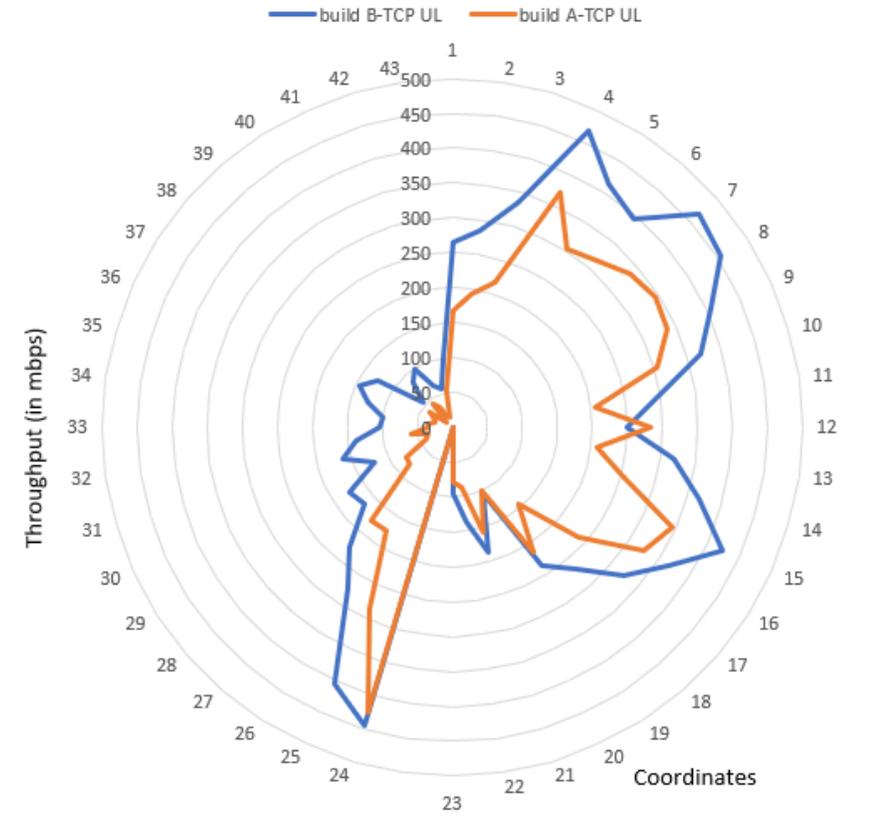
## TCP Upload on 2.4GHz -First Floor



## TCP Upload on 2.4GHz Band

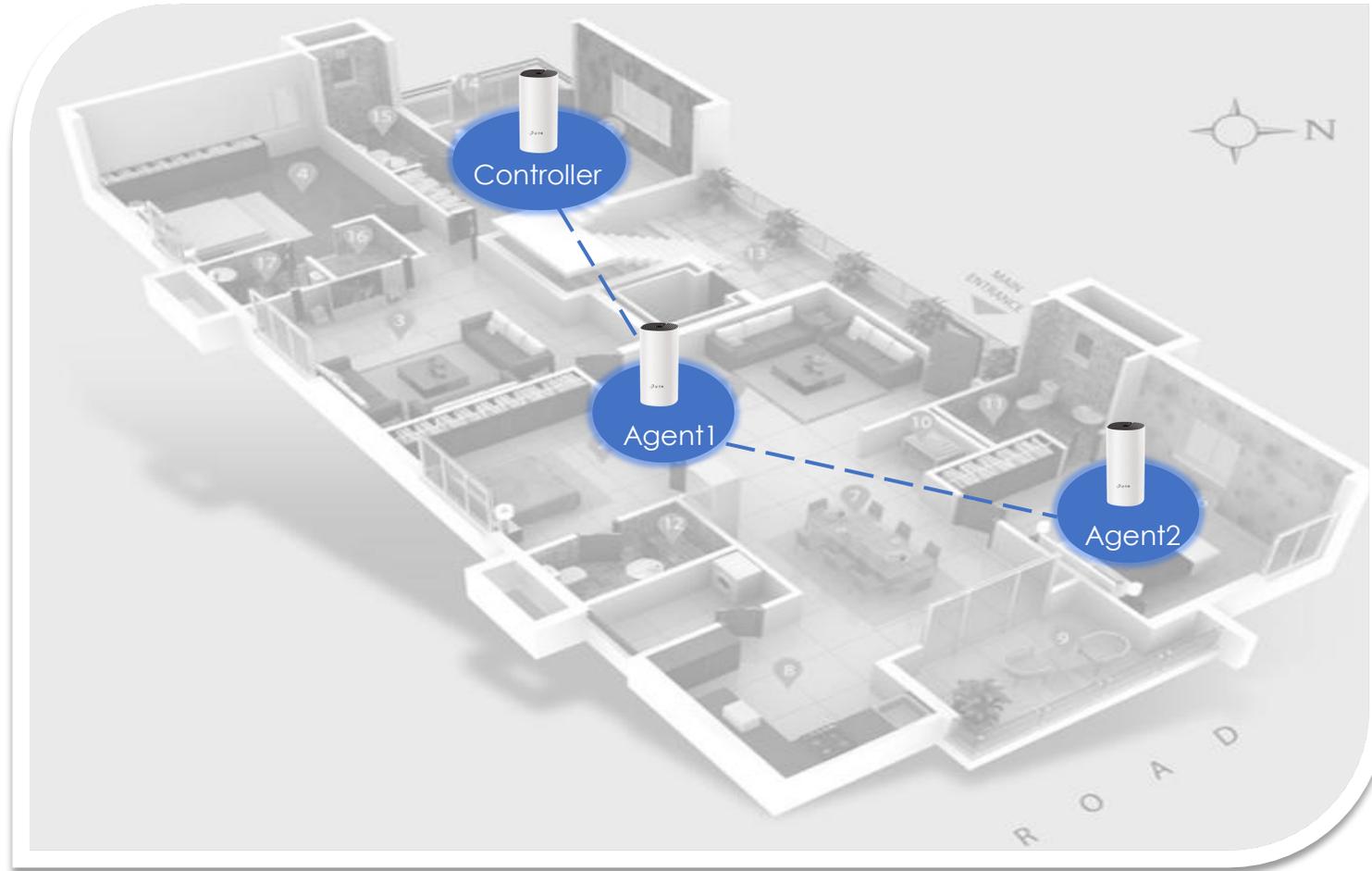


### 2.4GHz Comparison results (be mode)



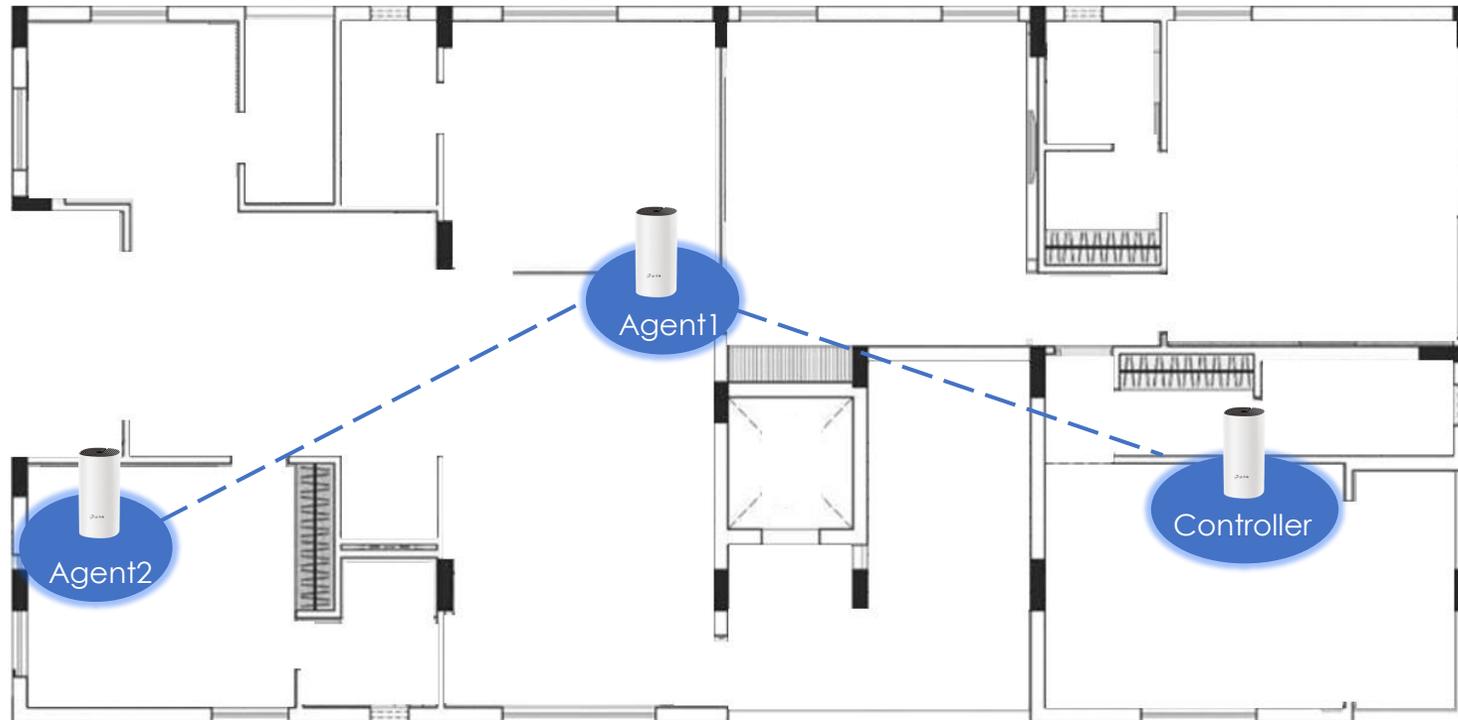
# Vendor A and Vendor B

Capacity Test house (Single Floor) comparison results



# Test House Details

- 3,500 Sqft Single Level 4 Bedroom Apartment.
- 40+ Real WiFi devices comprising of Phones, Tablets and TVs
- Devices spread across 7 sections at fixed positions
- TCP-DL, TCP-UL tests are performed on all the clients.
- Same type of clients and test environment are used for both Vendor-A and Vendor-B APs.



# DUT Details



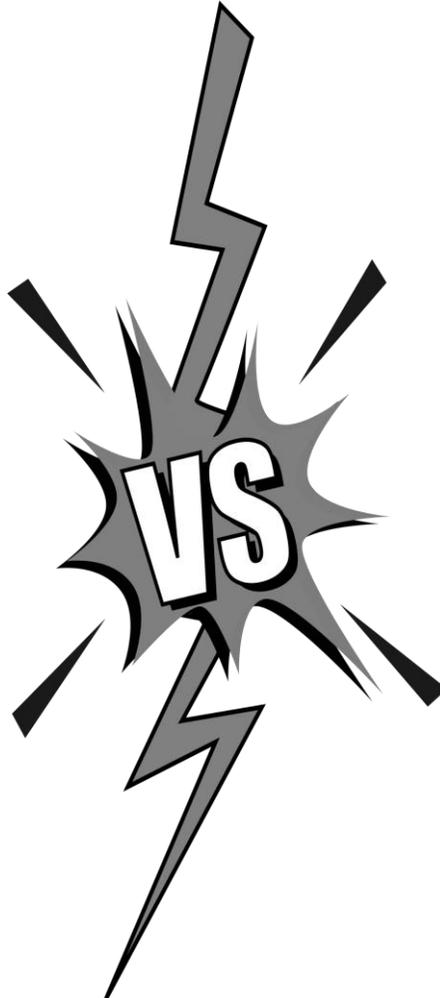
## DUT1

Vendor A Mesh System

### Specs

Chipset : Broadcom  
Triband System

Radio1: 2.4GHz b/g/n/ax 2x2 MIMO  
Radio2: 5GHz a/n/ac/ax 2x2 MIMO  
Radio3 : 5GHz a/n/ac/ax 4x4 MIMO  
1GE WAN/LAN  
AP Mode Only



## DUT2

Vendor B Mesh System

### Specs

Chipset : RealTek  
Triband System

Radio1: 2.4GHz b/g/n/ax 2x2 MIMO  
Radio2: 5GHz a/n/ac/ax 2x2 MIMO  
Radio3 : 5GHz a/n/ac/ax 4x4 MIMO  
1GE WAN/LAN  
Router and AP Modes

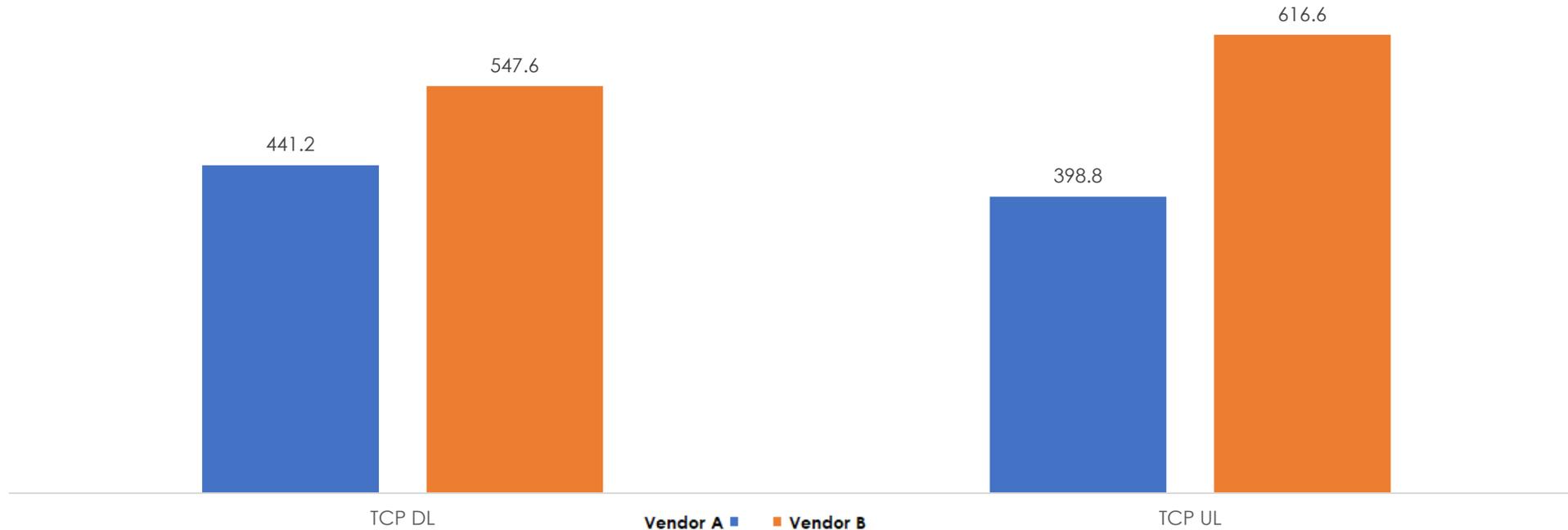
# Device Placement in the Test House – 40+ Devices



# Total Mesh System Throughput Comparison



Total Throughput (Mbps) Comparison

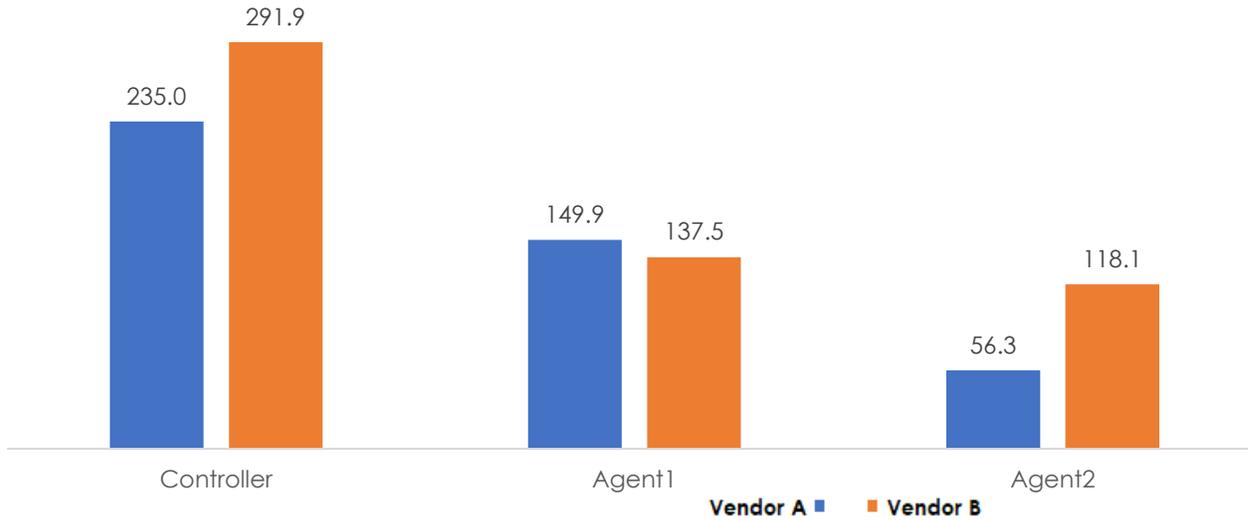


- Test run with total of 42 devices spread across 3500 sqft with devices automatically distributed across Controller and Agents and both 2.4 and 5GHz bands
- The Intended traffic load for each device was set to a Maximum of 200Mbps for both TCP Upstream and Downstream

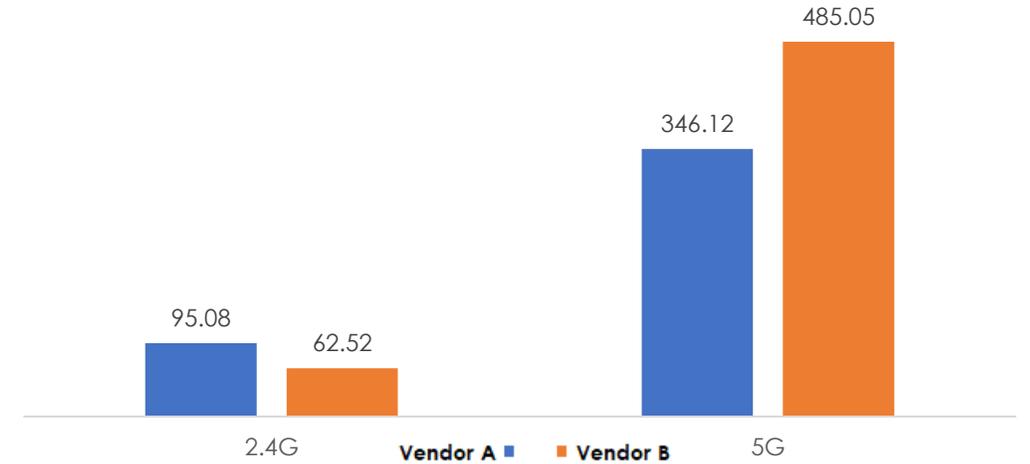
# Throughput Distribution across Nodes and Bands



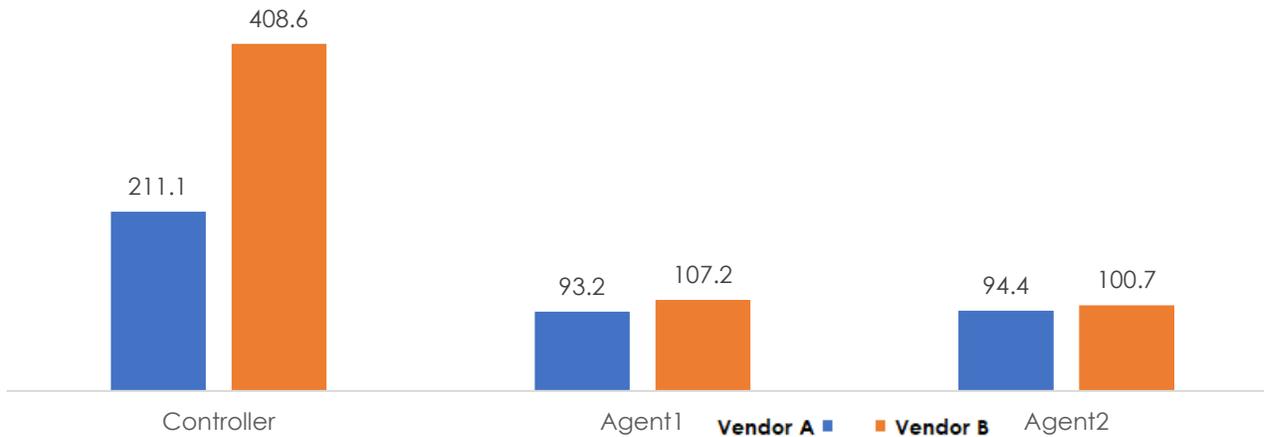
Throughput (Mbps) by Node for TCP-DL



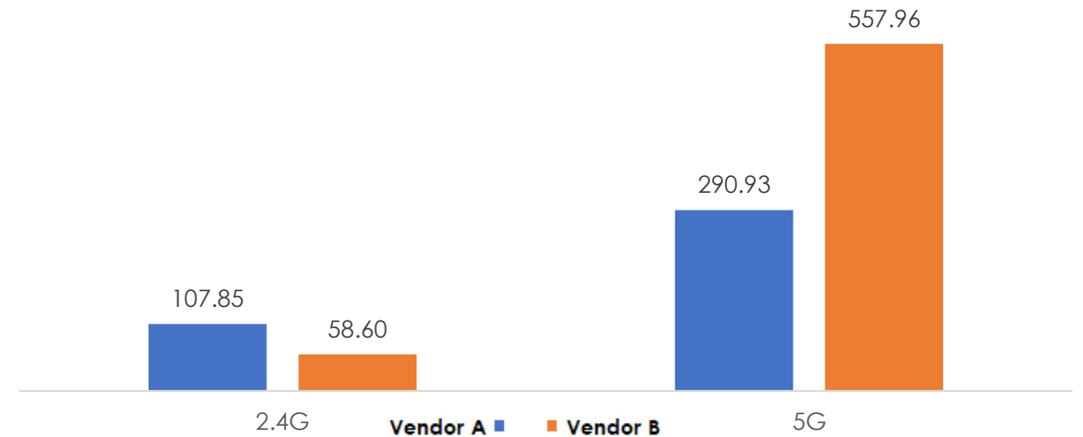
Throughput(Mbps) by Band - TCP DL



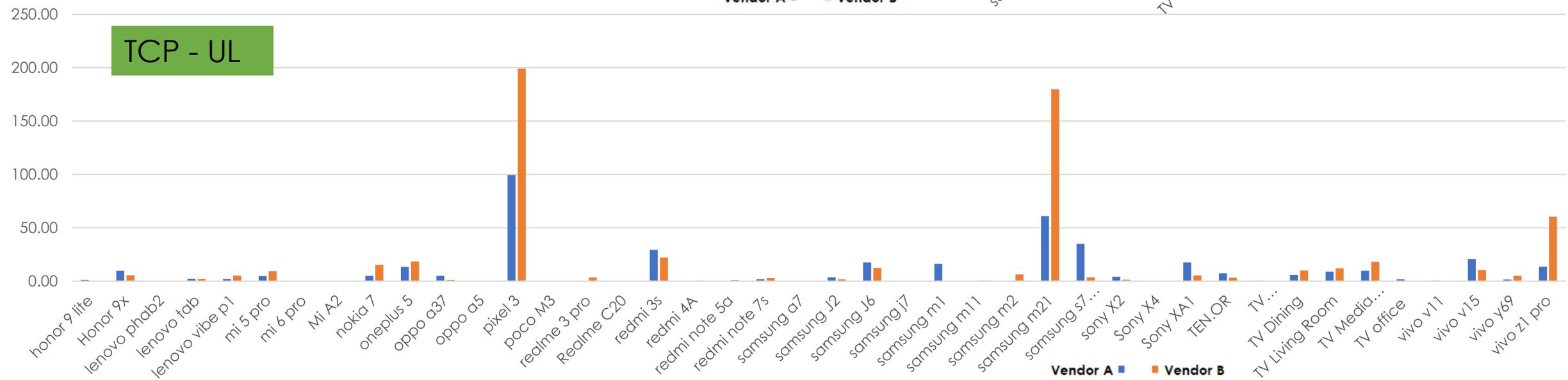
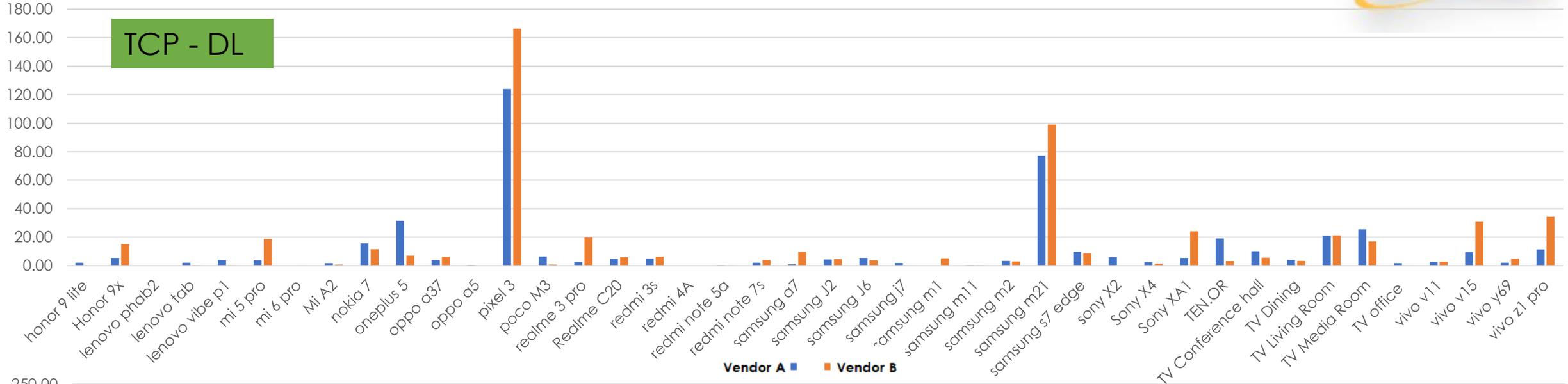
Throughput (Mbps) by Node for TCP-UL



Throughput(Mbps) by Band - TCP UL



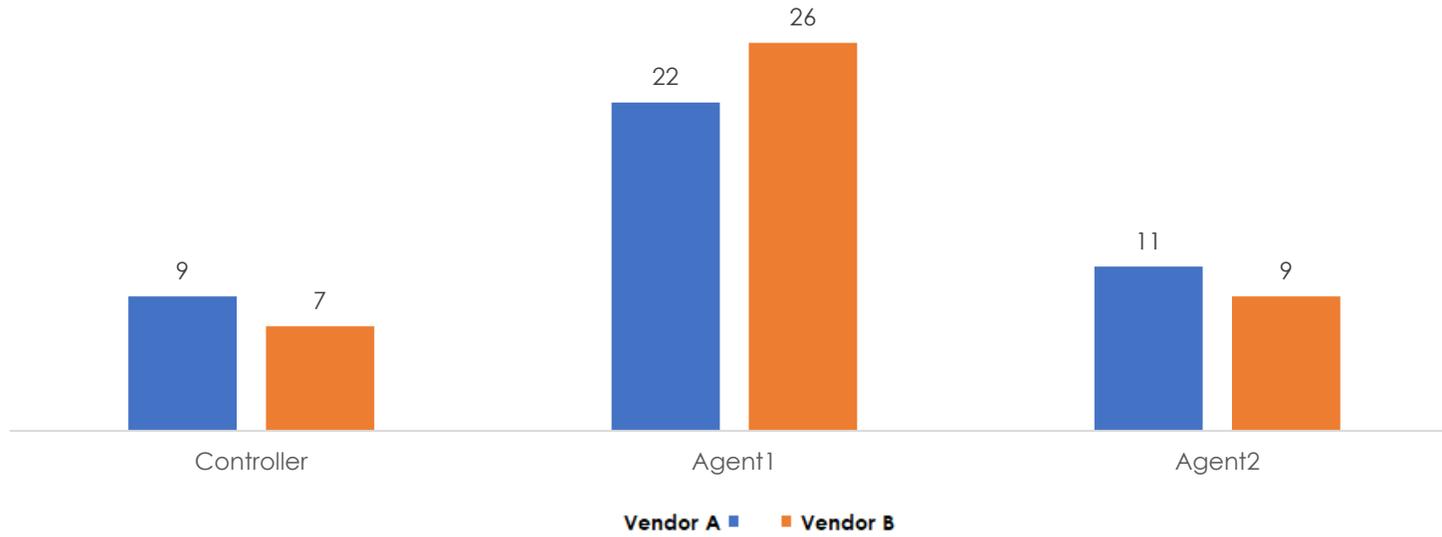
# Per Device Throughput (Mbps)



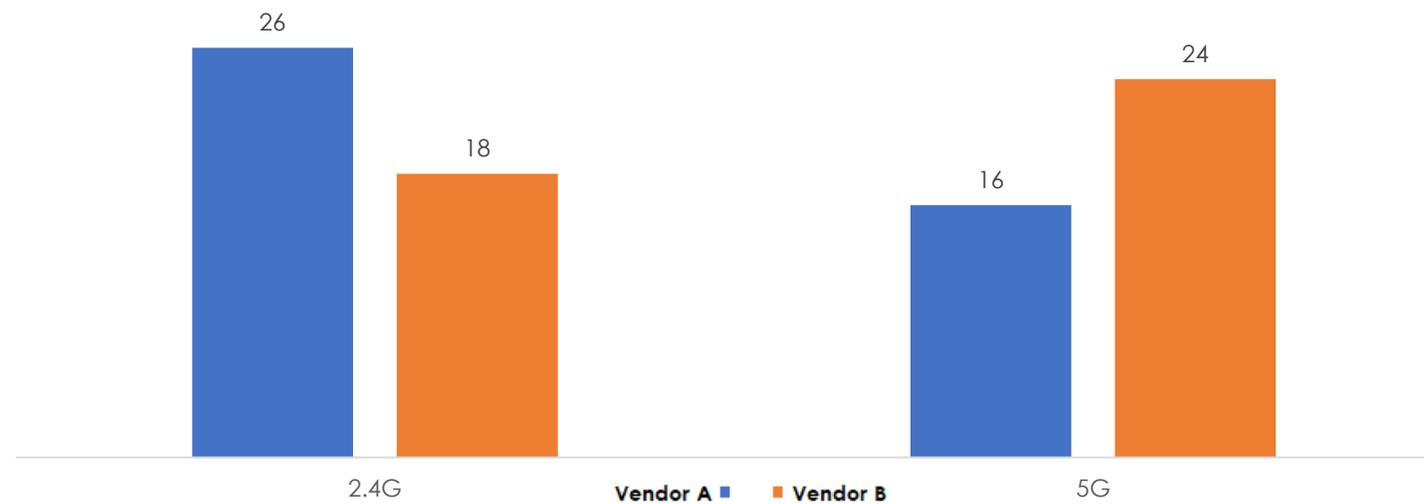
# Device Connection Distribution



Device Count per Mesh Node



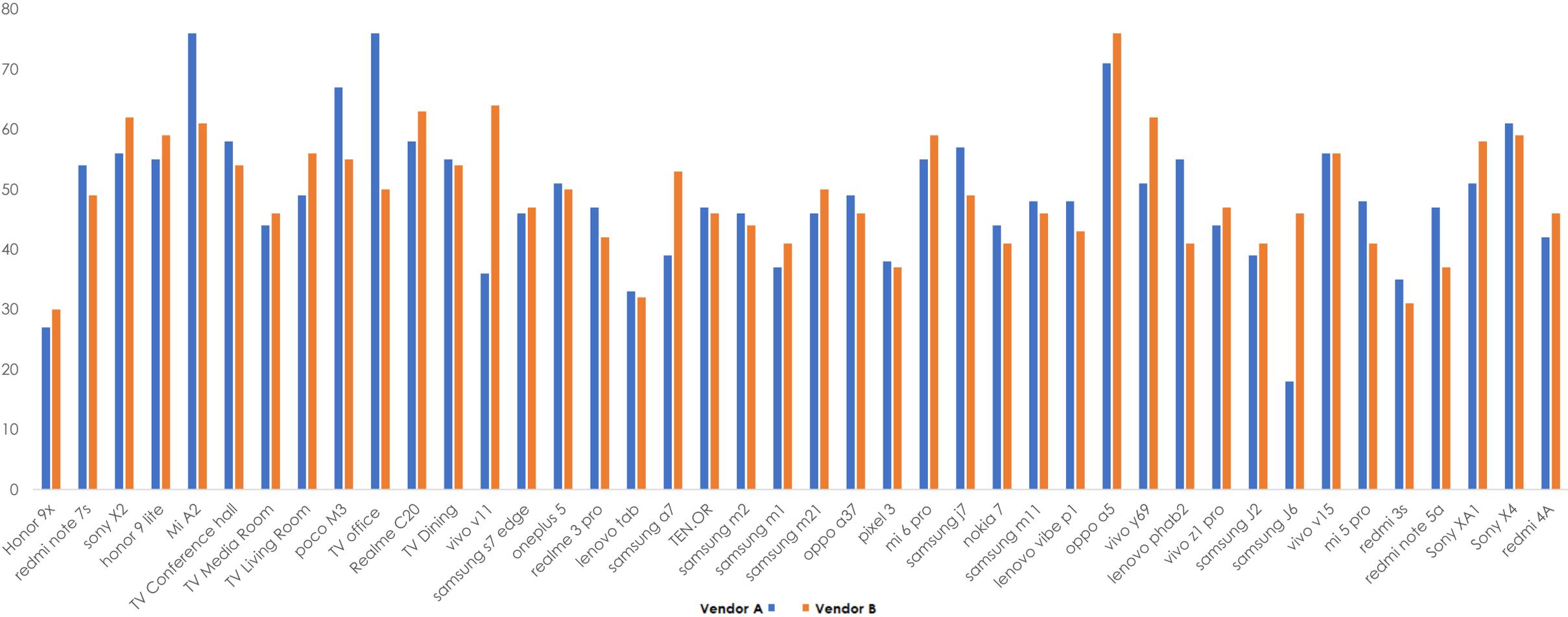
Device count per band



# RSSI of Devices in -dBm



RSSI in -dBm







[sales@candelatech.com](mailto:sales@candelatech.com)



1-360-380-1618