# WIRELESS BROADBAND ALLIANCE

## WI-FI 6 TRIAL REPORT
# EDUCATION IN RURAL AREAS

## Wi-Fi 6 Story

C-DOT and Intel ran this trial which focuses on the capability of Wi-Fi 6 in comparison to Wi-Fi 5 access technology in downlink scenario.

Downlink UDP throughput is most suitable KPI to evaluate the performance of streaming educational video contents to students having mixed client devices in rural schools.

This trial has enabled C-DOT to evaluate Wi-Fi 6 Network for Smart village applications in real time mixed client scenarios. It gave better insights to understand design requirements for C-DOT Wi-Fi 6 AP for Smart village/ Rural areas.

---

**Trial Participants**   |   • C-DOT   • Intel   • School/NGO/State agencies

## TEST OVERVIEW

- Indoor use case similar to classroom in a school, located in the rural area.
- A classroom with capacity of up to 30 students.
- Streaming educational content to the group of students in a classroom through Wi-Fi 6 Access Point.
- Mixed Client scenario with few Wi-Fi 6 STAs and more Wi-Fi 5 & 4 STAs.
- The Trial is conducted at C-DOT Campus Bengaluru, India to emulate the scenario of Rural school.
- The building has two floors and all the walls and ceiling are made up of concrete similar to schools in rural areas.
- Rooms are separated by 10 inches concrete wall. The tests are conducted in classrooms at the ground floor.
- Building location is free of Wi-Fi interference from surrounding areas.
- Devices

- Access point Configuration:
    - 4x4 Wi-Fi 6 Intel AP : Dual band, 4x4 MIMO, SU-PPDU, supports till 160 MHz, WPA2 Personal
    - 4x4 Wi-Fi 5 C-DOT AP  : Dual band, 4x4 MIMO, supports till 80 MHz , WPA2 Personal

- Clients:
    - Wi-Fi 6 capable Laptop Dell Latitude 7490 with AX200 chipset : IEEE 802.11ax, MIMO 2x2, upto 2402 Mbps, Supports till 160MHz
    - Wi-Fi 5 capable Laptop HP 348G3 with Intel 7265 chipset : IEEE 802.11ac, MIMO 2x2, upto 867Mbps, Supports till 80 MHz

- DL UDP Throughput is measured using iperf application in 160 MHz as well as in 80 MHz case.
- "Iperf" application is installed at the Wi-Fi client laptops as well as backhaul laptops connected to the AP over 1G Ethernet.
- Measurement duration is 180 seconds.

# FLOOR PLAN AND CLASS ROOM SET-UP



## Class room setup for Wi-Fi 6 Trial

Class Room 2

Class Room 1

Content Server
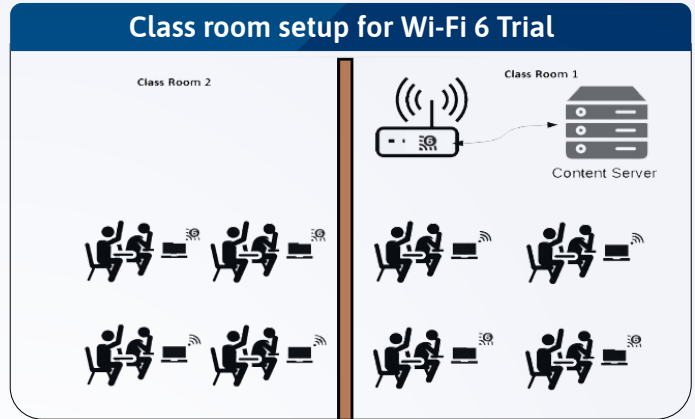
## INFORMATION

✓ The building has two floors and all the walls and ceiling are made up of concrete.

✓ Rooms are separated by 10 inches concrete wall. The tests are conducted in classrooms at the ground floor.

✓ It is observed that good signal strength present in the next room.

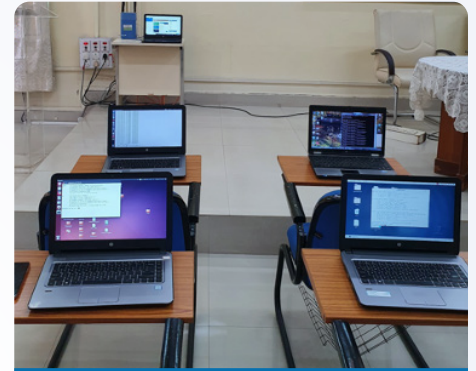✓ 10-12 dBm attenuation due to concrete wall.
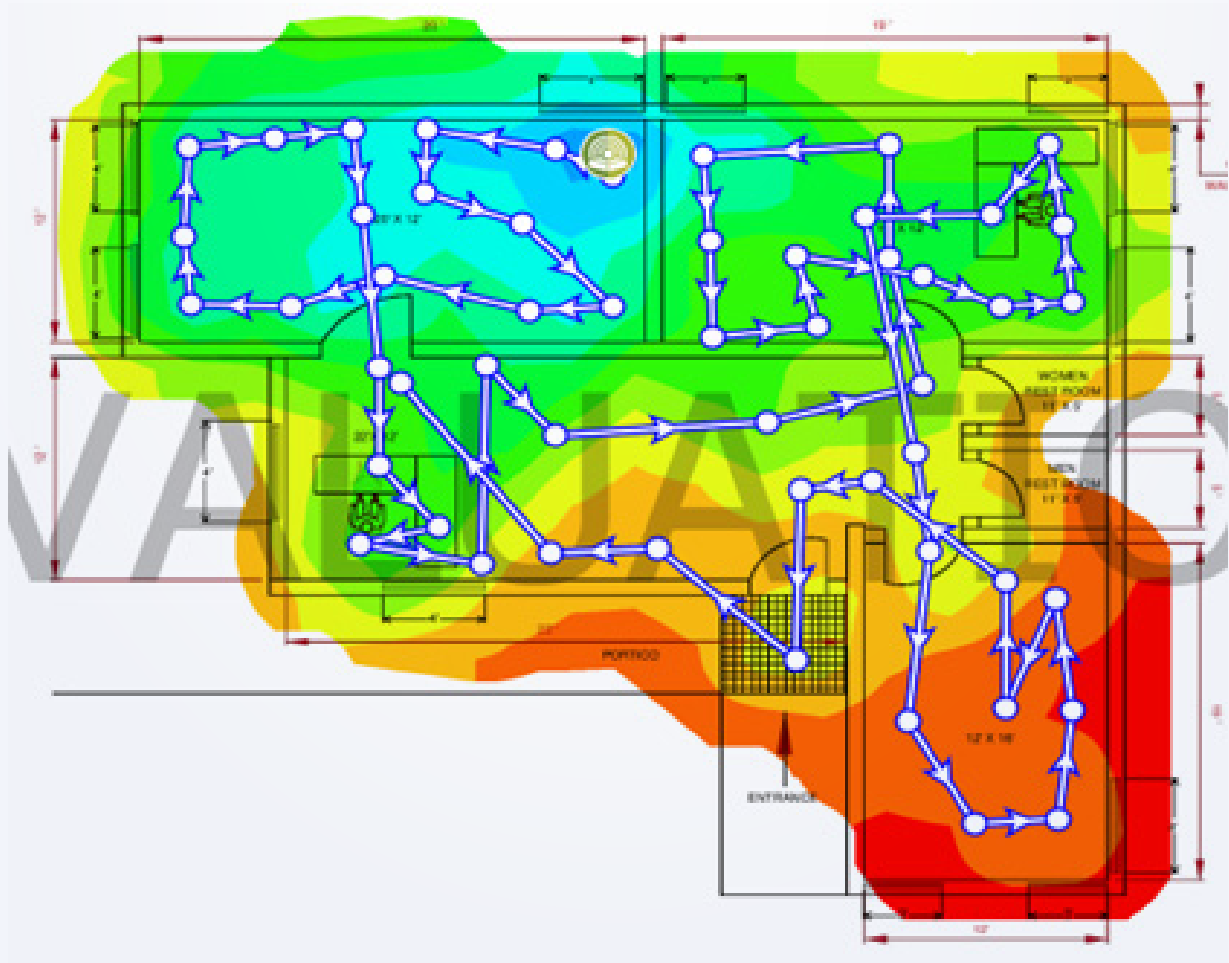
# FLOOR PLAN AND CLASS ROOM SET-UP

✅ WiFi-6 AP is placed at different location and heat map is generated for each location. The optimum AP location is mentioned in the Layout picture.

✅ It is concluded that a single AP can provide coverage in both adjacent rooms.

✅ AP is installed at the Table top. The height of the table is 2.5 feet. WiFi clients are placed 10 feet far from AP.
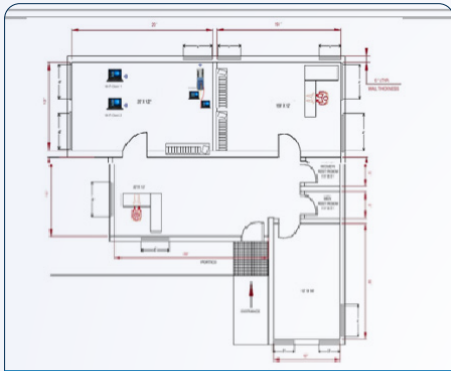

**Floor Plan with AP-Clients locations**


**Wi-Fi6 AP Placement in class**


**Wi-Fi Clients Placement in class**



1G Ethernet connection 1

1G Ethernet connection 2

Wi-Fi Client 1

Wi-Fi Client 2
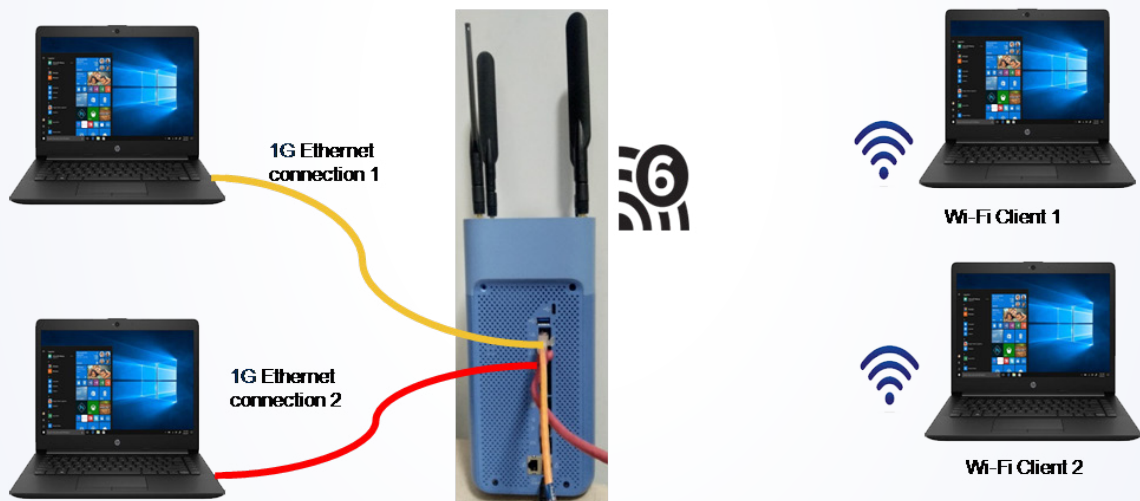
Wi-Fi 6 Intel AP, 4x4 MIMO, Dual Band, supports till 160 MHz



1G Ethernet connection 1

1G Ethernet connection 2

Wi-Fi Client 1
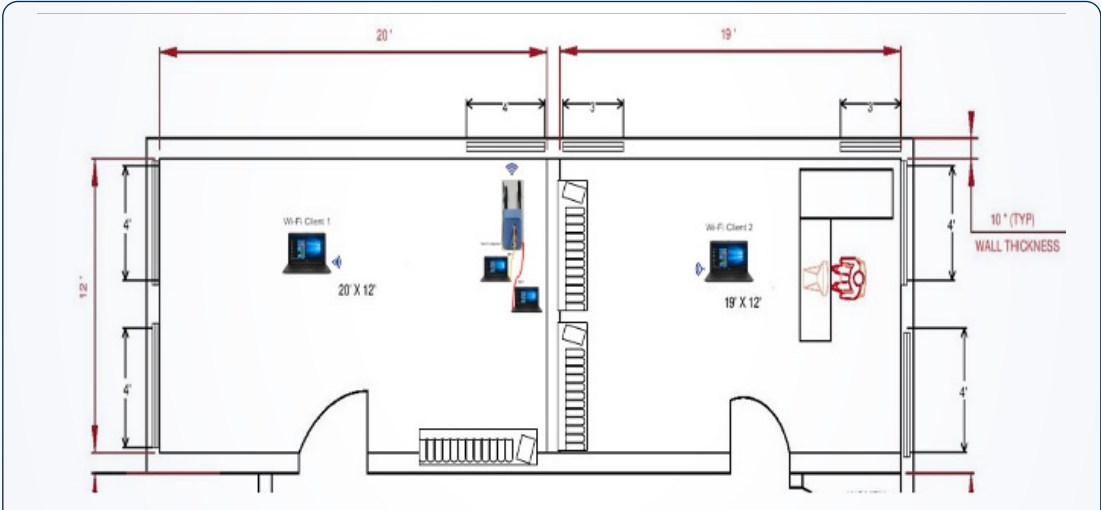
Wi-Fi Client 2
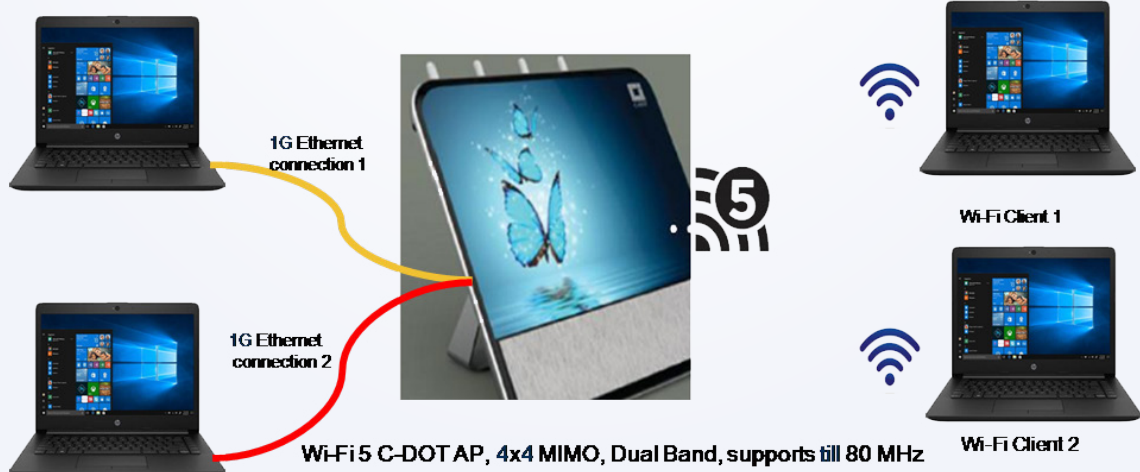
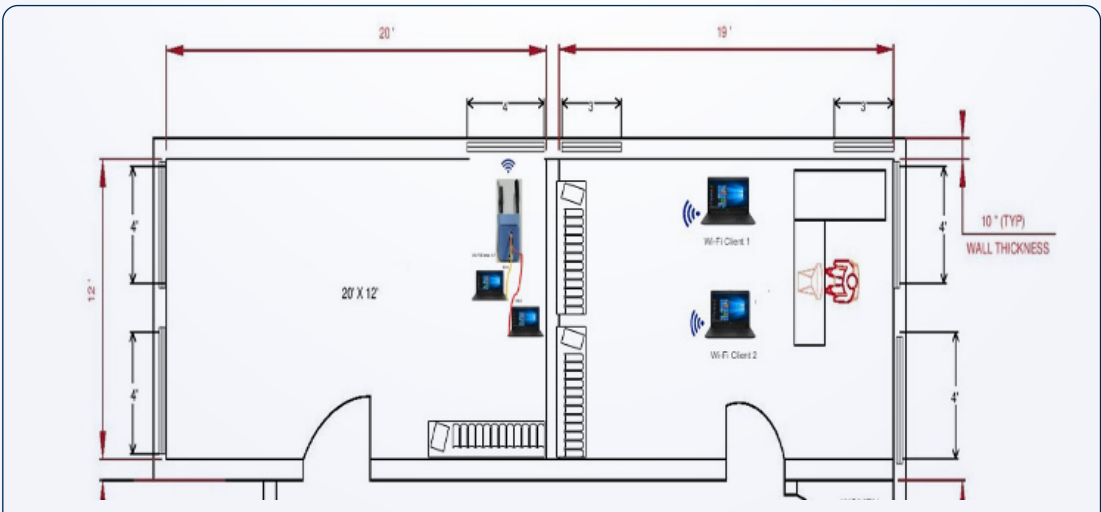Wi-Fi 5 C-DOT AP, 4x4 MIMO, Dual Band, supports till 80 MHz

# TEST SCENARIOS
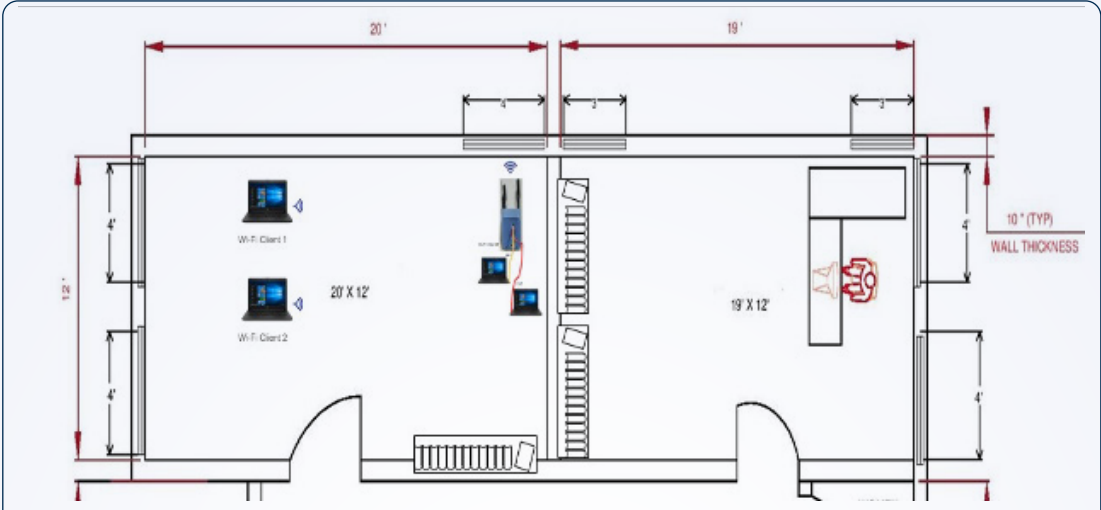


**1 - TS1 : WiFi 6 AP and all associated clients are present in class room 1.**



**2 - TS2 : WiFi 6 AP is placed in Classroom 1 and associated clients are present in both class rooms 1 and 2.**
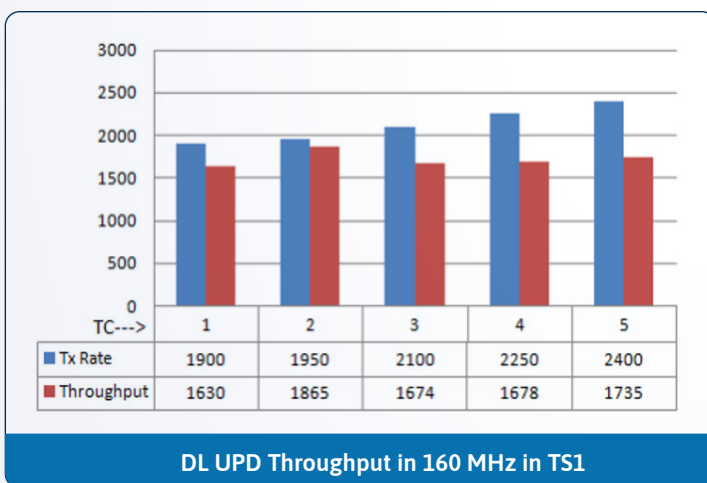


**3 - TS3 : WiFi 6 AP is placed in Classroom 1 and associated clients are present in class room 2.**

# TEST CASES IN 160MHZ

✅ Wi-Fi 6 AP is configured in 11ax mode,160 MHz channel 50, WPA2 Personal and Wi-Fi clients are connected as per following test cases in Wi-Fi 6 test Setup:

✅ DL UDP Throughput Measurement in TS1

1. With Single WiFi 6 Client
2. With Single Wi-Fi 5 Client
3. With Two WiFi 6 Clients
4. With Two WiFi 5 Clients

✅ DL UDP throughput comparison of WiFi 6 clients in three different test scenarios (TS1,TS2 and TS3)

1. Two WiFi 6  Clients
2. Four WiFi 6 Clients

## TEST RESULTS IN 160MHZ : SINGLE WIFI-6 CLIENT



| TC---> | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Tx Rate | 1900 | 1950 | 2100 | 2250 | 2400 |
| Throughput | 1630 | 1865 | 1674 | 1678 | 1735 |

**DL UPD Throughput in 160 MHz in TS1**

| Client | Measured Link Rate (in Mbps) | Measured RSSI (in dBm) |
|---|---|---|
| Wi-Fi 6 | 2402 | -47 |

**UDP Throughput is measured for single Wi-Fi 6 client for different transmit rates(load).**
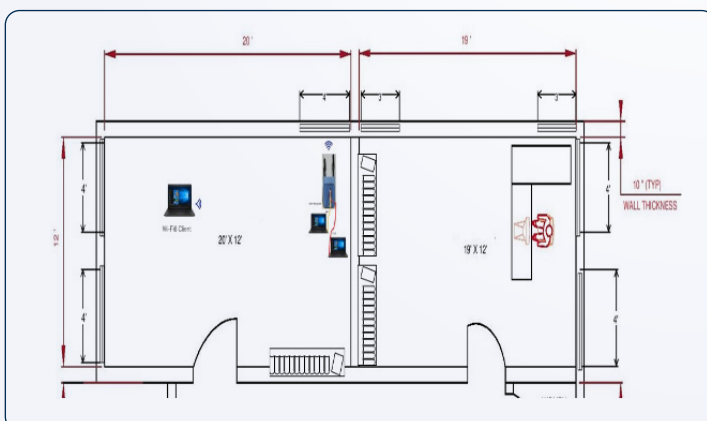


### NOTE:

Throughput and Tx rate are aggregate numbers of three separate iperf streams. Three backhauls laptops are connected to the AP over Ethernet to achieve mentioned Tx rate and three iperf server sessions are executed at the WiFi-6 client with different port numbers.

# TEST RESULTS IN 160MHZ : THROUGHPUT COMPARISON OF TWO WIFI 6 CLIENTS IN DIFFERENT TEST SCENARIOS

### Tx Rate vs Throughput for 2 WiFi6 Clients for different test scenarios in 160MHz Configuration
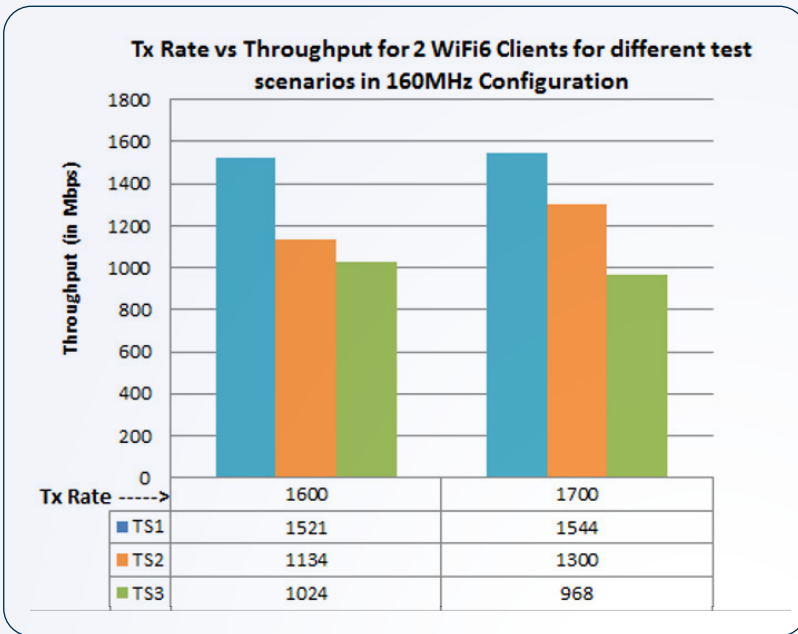
| Tx Rate -----> | 1600 | 1700 |
|---|---|---|
| TS1 | 1521 | 1544 |
| TS2 | 1134 | 1300 |
| TS3 | 1024 | 968 |

| Test Scenario | Client | Measured Link Rate (in Mbps) | Measured RSSI (in dBm) |
|---|---|---|---|
| TS1 | Wi-Fi 6 Client 1 | 2402 | -47 |
| | Wi-Fi 6 Client 2 | 2402 | -47 |
| TS2 | Wi-Fi 6 Client 1 | 2402 | -47 |
| | Wi-Fi 6 Client 2 | 1729.4 | -67 |
| TS3 | Wi-Fi 6 Client 1 | 1080.9 | -70 |
| | Wi-Fi 6 Client 2 | 1729.4 | -67 |

✔ Aggregate throughput of two clients is shown w.r.t. transmit rate.

✔ Each client is transmitted same load i.e.equal load distribution. For eg. 850Mbps is given for each client in case of 1700 Tx rate

# TEST RESULTS IN 160MHZ : THROUGHPUT COMPARISON OF 4 WIFI 6 CLIENTS IN DIFFERENT TEST SCENARIOS

### TX RATE VS THROUGHPUT FOR 4 WIFI6 CLIENTS FOR DIFFERENT TEST SCENARIOS IN 160MHZ

| TX rate--> | 1600 |
|---|---|
| TS1 | 1525 |
| TS2 | 887 |
| TS3 | 671 |

### Tx Rate & Per client Throughput for 4 Clients for different test scenarios in 160MHz Configuration

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Tx rate | 400 | 400 | 400 | 400 |
| TS1 | 375 | 377 | 372 | 381 |
| TS2 | 219 | 221 | 226 | 221 |
| TS3 | 162 | 175 | 163 | 171 |

1. Aggregate throughput (left) along with the per client throughput (right) is shown.

2. All the clients have almost equal throughput distribution in a particular scenario.

3. From the observed throughput values, it is clear that a single WiFi-6 AP can serve clients present in both the classrooms
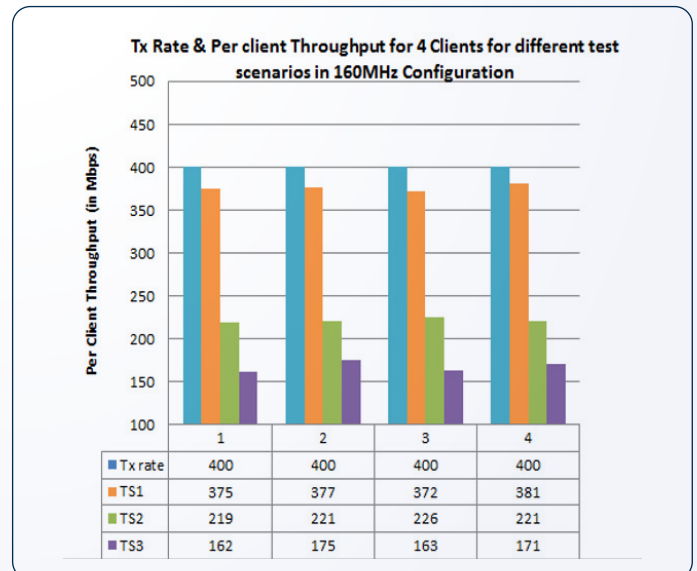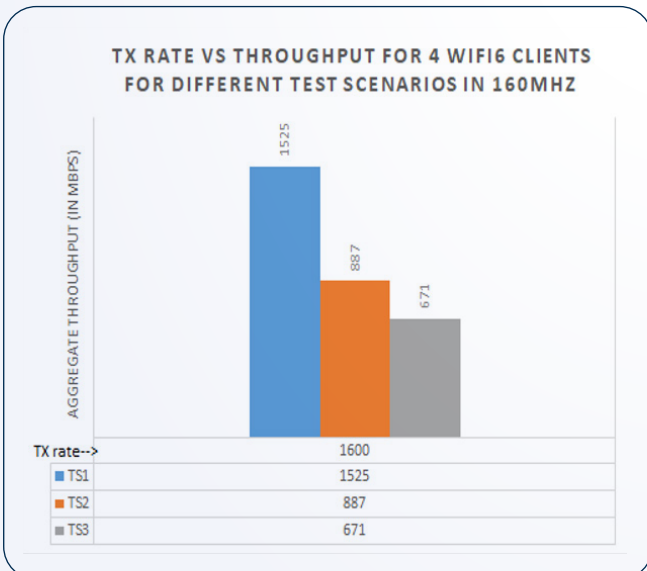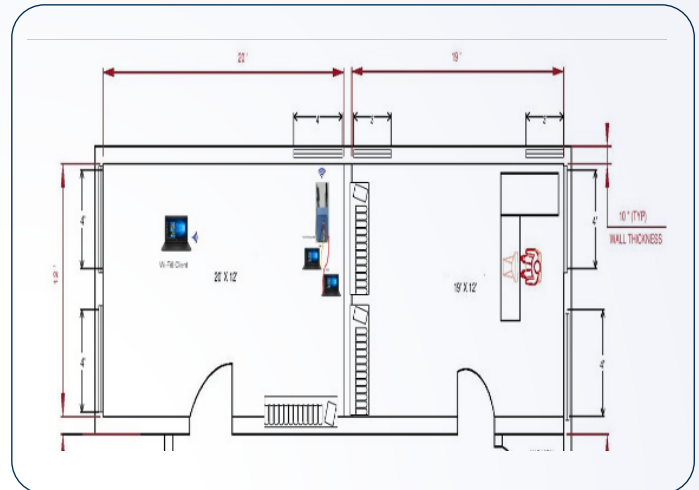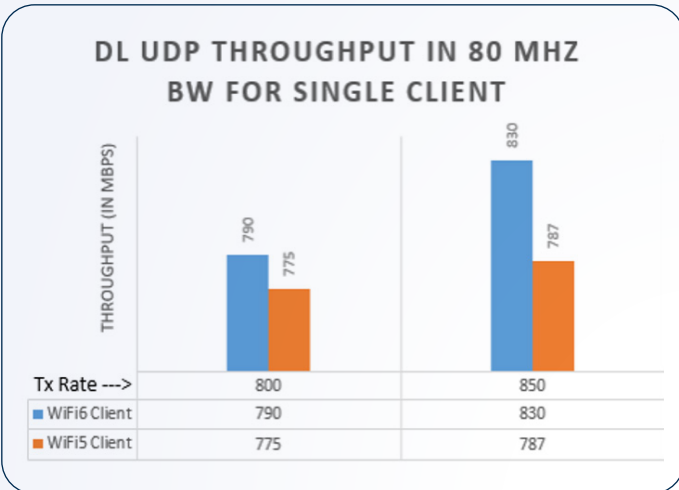
# TEST CASES IN 80MHZ

✅ Wi-Fi 6 AP is configured in 11ax mode,80 MHz channel 42, WPA2
Personal and Wi-Fi clients are connected as per following test cases
in Wi-Fi 6 test Setup:

✅ DL UDP Throughput Measurement in 5GHz band,80 MHz Channel BW done
for following test cases:

1. Single WiFi 6  Client
2. Single Wi-Fi 5 Client
3. Two WiFi 6 Clients
4. Two WiFi 5 Clients

✅ DL UDP throughput comparison of WiFi 6 clients in three different test scenarios
(TS1,TS2 and TS3)

1. Two WiFi 6 Clients
2. Four WiFi 6 Clients

## TEST RESULTS IN 80MHZ : SINGLE WIFI-6 CLIENT IN TS1

- **DL UDP Throughput is measured for single WiFi-6 client.**

| Client | Measured Link Rate (in Mbps) | Measured RSSI  (in dBm) |
|--------|------------------------------|-------------------------|
| **Wi-Fi 6** | 1201 | -47 |



DL UDP Throughput in 80MHz for Single WiFi-6 Client

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Tx Rate | 800 | 850 | 1000 | 1200 |
| Throughput | 790 | 830 | 973 | 1063 |

# TEST RESULTS IN 80MHZ : COMPARISON BETWEEN SINGLE WIFI 6 & WIFI 5 CLIENT IN TS1

- DL UDP Throughput is compared for single WiFi-6 client and single WiFi-5 client.

| Client | Measured Link Rate (in Mbps) | Measured RSSI (in dBm) |
|---|---|---|
| Wi-Fi 6 | 1201 | -47 |
| Wi-Fi 5 | 866.7 | -49 |



DL UDP THROUGHPUT IN 80 MHZ BW FOR SINGLE CLIENT

| Tx Rate ---> | 800 | 850 |
|---|---|---|
| WiFi6 Client | 790 | 830 |
| WiFi5 Client | 775 | 787 |



# 80 MHZ TEST RESULTS : DL UDP THROUGHPUT FOR TWO CLIENTS IN TS1

- Aggregate throughput of two clients is shown for the given transmit rate.
  - Two backhauls are connected with AP over Ethernet.

| TC# | Client | Measured Link Rate (in Mbps) | Measured RSSI (in dBm) |
|---|---|---|---|
| 1 | Wi-Fi 6 Client 1 | 1201 | -47 |
| | Wi-Fi 6 Client 2 | 1201 | -47 |
| 2 | Wi-Fi 5 Client 1 | 866.7 | -47 |
| | Wi-Fi 5 Client 2 | 866.7 | -47 |



DL UDP Throughput in 80 MHz for Two clients in TS1
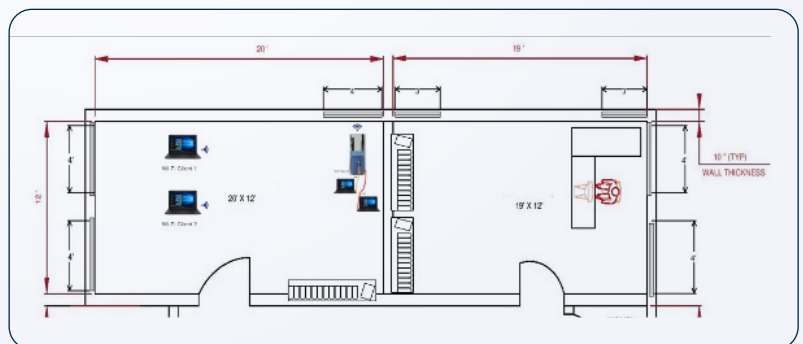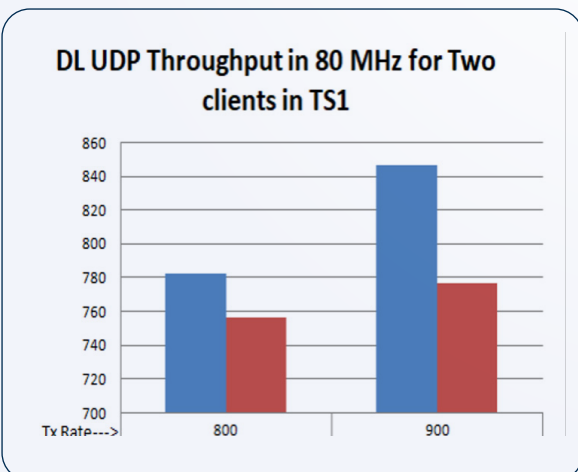
# **80MHZ** TEST RESULTS: DL UDP THROUGHPUT COMPARISON OF 4 CLIENTS IN DIFFERENT TEST SCENARIOS

- 31.5% throughput drop awhen all four clients are moved from Class room 1 to 2. (from TS1 to TS3 scenario)
- 21.6% throughput drop when two clients are moved from Class room 1 to 2 and other two clients remain in Class room 1 (from TS1 to TS2)

| Test Scenario | Client | Measured Link Rate (in Mbps) | Measured RSSI (in dBm) |
|---|---|---|---|
| TS1 | Wi-Fi 6 Client 1,2 | 1201 | -44 |
| | Wi-Fi 6 Client 3,4 | 1201 | -46 |
| TS2 | Wi-Fi 6 Client 1,2 | 1201,960.7 | -46,-48 |
| | Wi-Fi 6 Client 3,4 | 1201,960.7 | -60,-55 |
| TS3 | Wi-Fi 6 Client 1,2 | 864.7,720.6 | -72,-74 |
| | Wi-Fi 6 Client 3,4 | 648.5,432.4 | -73,-79 |



DL UDP THROUGHPUT IN 80 MHZ BW FOR FOUR WIFI-6 CLIENTS

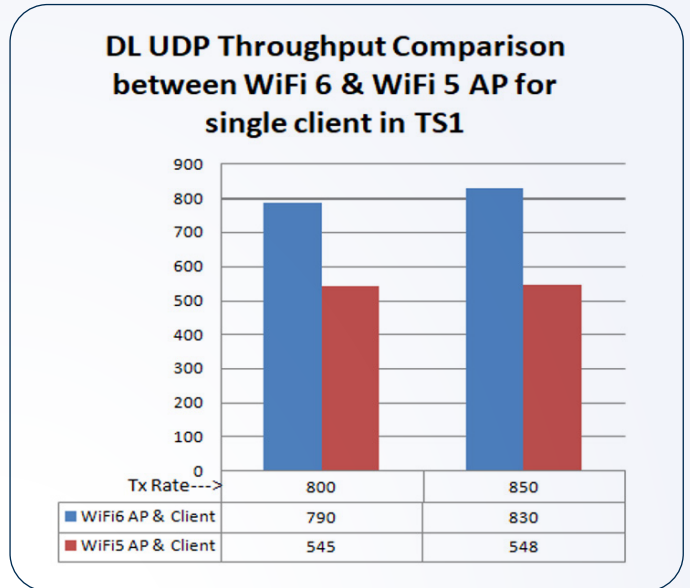| | Tx Rate 1000 Mbps |
|---|---|
| TS1 | 801 |
| TS2 | 699 |
| TS3 | 548 |
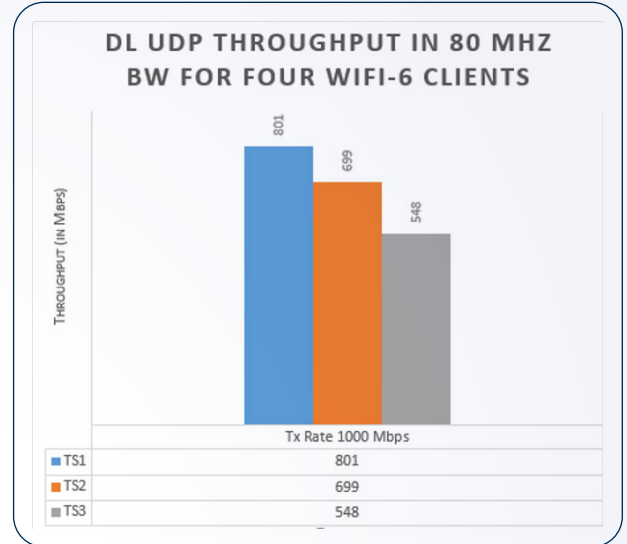
## WI-FI 6 AP VS WI-FI 5 AP IN **TS1** SCENARIO

✅ In the TS1 scenario, following tests are conducted to compare performance of Wi-Fi 6 AP and Wi-Fi 5 AP:

✅ DL UDP Throughput Measurement in 5GHz band,80 MHz Channel BW done for following test cases:

    a. **First instance** , Wi-Fi 6 AP is powered on , configured in 80 MHz BW
        i. Wi-Fi 6 client is connected and DL UDP throughput is measured.
        ii. Wi-Fi 5 client is connected. DL UDP throughput is measured.

    a. **Second instance** , Wi-Fi 5 AP is powered on, configured in 80 MHz
        i. Wi-Fi 5 client is connected and DL UDP throughput is measured.
        ii. Wi-Fi 6 client is connected. DL UDP throughput is measured.

    a. Then, comparison of DL UDP throughput is done

✅ Above test is also conducted when two clients are connected.

# 80MHZ TEST RESULTS: COMPARISON OF WI-FI 6 AP AND WI-FI 5 AP FOR SINGLE CLIENT

- It is observed that there is more than 45% throughput improvement in Wi-Fi 6 network as compared with Wi-Fi 5 network.
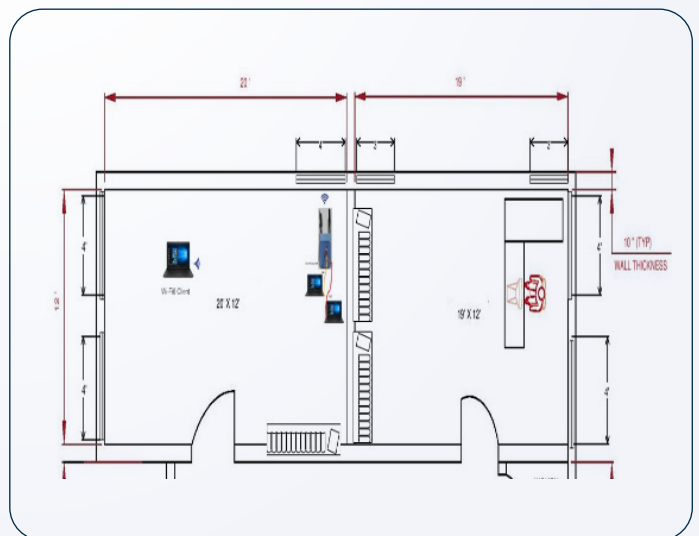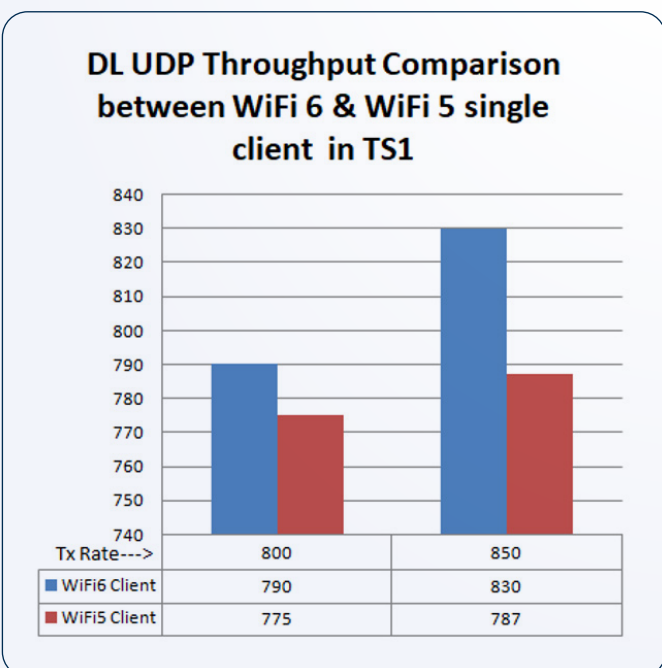
| AP-Client Scenario | Measured Link Rate (in Mbps) | Measured RSSI (in dBm) |
|---|---|---|
| Wi-Fi 6 AP and Wi-Fi 6 Client | 1201 | -47 |
| Wi-Fi 5 AP and Wi-Fi 5 Client | 866.7 | -41 |



DL UDP Throughput Comparison between WiFi 6 & WiFi 5 AP for single client in TS1

| Tx Rate---> | 800 | 850 |
|---|---|---|
| WiFi6 AP & Client | 790 | 830 |
| WiFi5 AP & Client | 545 | 548 |

## WI-FI 6 TEST SETUP : TEST RESULTS IN 80 MHZ WITH SINGLE CLIENT IN TS1

- WiFi 6 AP is configured in 80MHz channel and single client is connected.
- DL UDP Throughput is compared for single WiFi-6 client and single WiFi-5 client.

| Client | Measured Link Rate (in Mbps) | Measured RSSI (in dBm) |
|---|---|---|
| Wi-Fi 6 | 1201 | -47 |
| Wi-Fi 5 | 866.7 | -49 |



DL UDP Throughput Comparison between WiFi 6 & WiFi 5 single client in TS1

| Tx Rate---> | 800 | 850 |
|---|---|---|
| WiFi6 Client | 790 | 830 |
| WiFi5 Client | 775 | 787 |

# WI-FI 5 TEST SETUP: TEST RESULTS IN 80 MHZ WITH SINGLE CLIENT IN TS1

- WiFi 5 AP is configured in 80MHz channel and single client is connected.
- DL UDP Throughput is compared for single WiFi-6 client and single WiFi-5 client.

| Client | Measured Link Rate (in Mbps) | Measured RSSI (in dBm) |
|--------|------------------------------|------------------------|
| Wi-Fi 6 | 866.7 | -57 |
| Wi-Fi 5 | 866.7 | -44 |



DL UDP Throughput Comparison between WiFi 6 & WiFi 5 single client in TS1

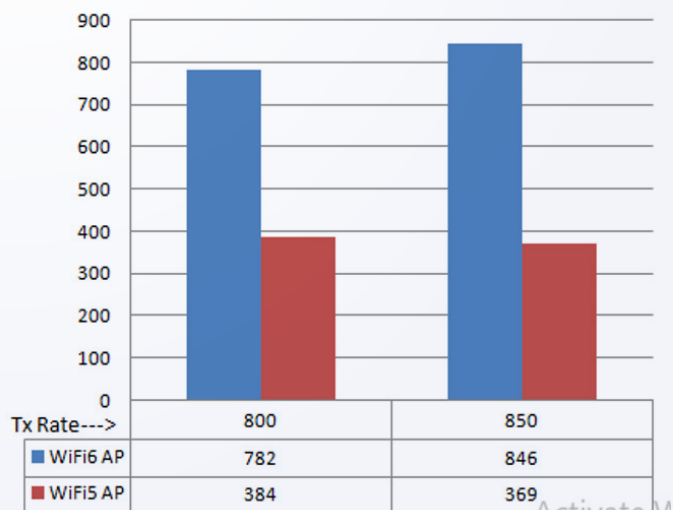| Tx Rate---> | 800 | 850 |
|-------------|-----|-----|
| WiFi6 Client | 667 | 689 |
| WiFi5 client | 545 | 548 |
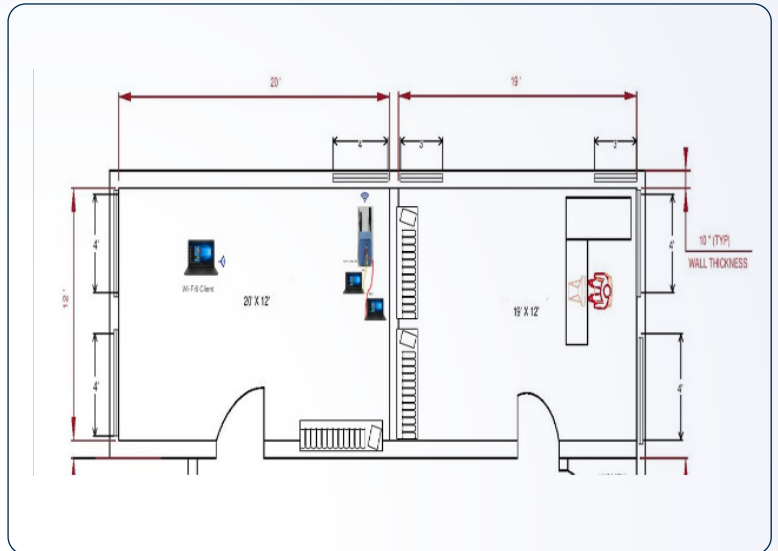


# TEST RESULTS IN 80MHZ : COMPARISON OF WI-FI 6 AP AND WI-FI 5 AP FOR TWO CLIENTS

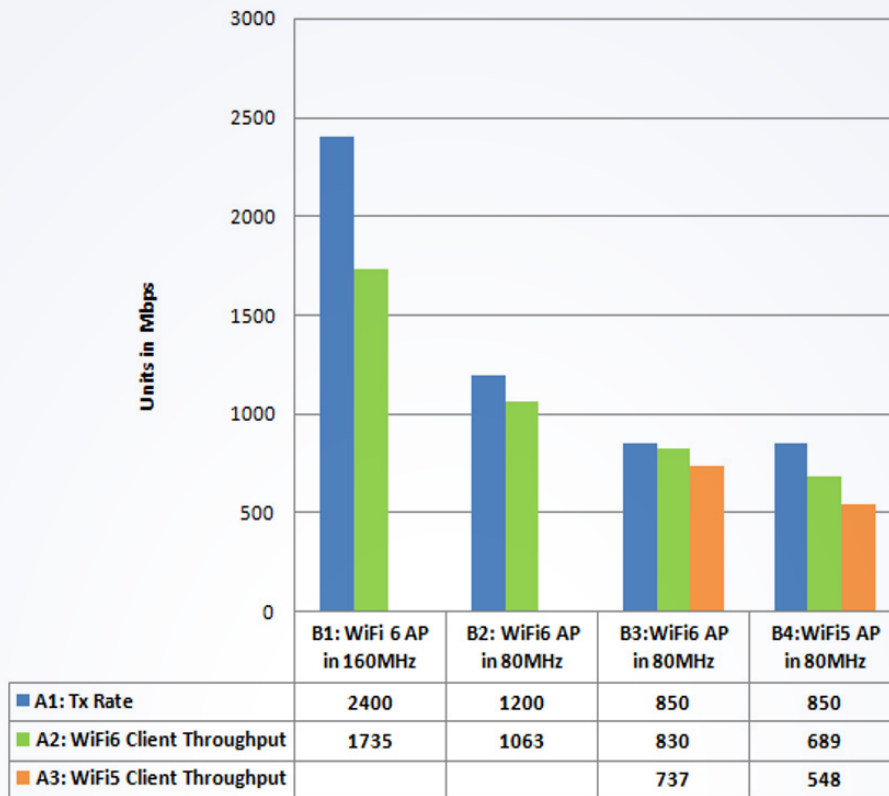In the same environment, following tests are conducted to compare performance of Wi-Fi 6 AP and Wi-Fi 5 AP:

a. First instance , Wi-Fi 6 AP is powered on , configured in 80 MHz BW and two Wi-Fi 6 clients are connected. DL UDP throughput is measured.

b. Second instance , Wi-Fi 5 AP is powered on, configured in 80 MHz and two Wi-Fi 5 clients are connected. DL UDP throughput is measured.

c. Then, comparison of DL UDP throughput is done.

d. It is observed that there is more than 50% throughput improvement in Wi-Fi 6 network as compared with Wi-Fi 5 network.

e. Full association with good RSSI level is observed in both cases.



DL UDP Throughput Comparison between WiFi 6 & WiFi 5 AP for two clients in TS1

| Tx Rate---> | 800 | 850 |
|-------------|-----|-----|
| WiFi6 AP | 782 | 846 |
| WiFi5 AP | 384 | 369 |

# TEST RESULTS SUMMARY

## WiFi 6 AP vs WiFi 5 AP



| | B1: WiFi 6 AP in 160MHz | B2: WiFi6 AP in 80MHz | B3:WiFi6 AP in 80MHz | B4:WiFi5 AP in 80MHz |
|---|---|---|---|---|
| ■ A1: Tx Rate | 2400 | 1200 | 850 | 850 |
| ■ A2: WiFi6 Client Throughput | 1735 | 1063 | 830 | 689 |
| ■ A3: WiFi5 Client Throughput | | | 737 | 548 |

✔ DL UDP throughput of 1.7 Gbps is achieved in 160 MHz configuration when single Wi-Fi 6 client connects to Wi-Fi 6 AP.

- Refer [A2,B1]

✔ Approximately 50% DL UDP throughput improvement in 80 MHz configuration when Wi-Fi 6 client connects to Wi-Fi 6 AP Vs Wi-Fi 5 client connects to Wi-Fi 5 AP.

- Refer [A2,B2] for Wi-Fi 6 AP & Client
- Refer [A3,B4] for Wi-Fi 5 AP & client

✔ Wi-Fi 6 as well as Wi-Fi 5 client have performed better with Wi-Fi 6 AP as compared to Wi-Fi 5 AP with respect to DL UDP throughput.

- Refer [A2,B3] & [A2,B4] for Wi-Fi 6 client
- Refer [A3,B3] & [A3,B4] for Wi-Fi 5 client

✔ Wi-Fi 6 client has performed better as compared to Wi-FI 5 client when connected to Wi-Fi 5 AP with respect to DL UDP throughput.

- Refer [A2,B4] for Wi-Fi 6 client
- Refer [A3,B4] for Wi-Fi 5 client

✔ Approximately 33% DL UDP throughput improvement in 80 MHz configuration when Wi-Fi 5 client connects to Wi-Fi 6 AP Vs Wi-Fi 5 client connects to Wi-Fi 5 AP.

- Refer [A3,B3] for Wi-Fi 6 AP & WI-Fi 5 Client
- Refer [A3,B4] for Wi-Fi 5 AP & Wi-Fi 5 Client

## CONNECTIVITY CHALLENGES

✔ It was challenging to find the optimum location for installation of Wi-Fi 6 AP, so that better signal coverage will be available in both the adjacent classrooms.

✔ The locations of multiple clients are fixed by multiple test runs by measuring DL UDP throughput. It ensures good quality of video streaming.

✔ As there was 10-12 dB signal attenuation due to concrete wall and due to furniture present in the classrooms, it was challenging to fix the locations of multiple clients in the second classroom where AP was not installed but Wi-Fi 6 signal propagates from adjacent classroom.

> "Wi-Fi is a social empowerment tool for countries like India with 600 thousand Villages. Wi-Fi 6 based network will provide improved performance to legacy client devices as wellas new devices with 11ax support as seen in the trial conducted by C-DOT."
>
> **Sandeep Agrawal, Team Leader, C-DOT**

> "At Intel, we are committed to driving adoption of Wi-Fi 6 across industries, localities and public spaces. The WBA trials demonstrate how Wi-Fi 6 addresses connectivity challenges in real-world deployments. We look forward to ongoing collaboration with the industry to enable the best connectivity solutions for today and in the future."
>
> **Eric McLaughlin, Vice President, Client Computing Group,**
> **General Manager Wireless Solutions Group - Intel Corporation**

## RECOMMENDATION

Since legacy (Wi-Fi 5) client performs better with Wi-Fi 6 Access point as compared to Wi-Fi 5 Access Point, **it is recommended to upgrade the legacy network to Wi-Fi 6 network.**

**Since Wi-Fi 6 client performs better as compared to Wi-Fi 5 client with Wi-Fi 5 Access Point, it is recommended to upgrade the client devices to Wi-Fi 6 in case of legacy (Wi-Fi 5) network.**

**Upgrading both Client as well as Network to Wi-Fi 6 technology is most suitable.**

## Next Steps

**Based on the experience of this trial, C-DOT continue to work on the following:**

✔ Wi-Fi 6 phase 2 Trial with OFDMA and TWT feature to test dense environment and IoT use cases

✔ Wi-Fi 6E (6GHz) Trial in India

✔ Trial of Wi-Fi 6 Access Points in dense environment such as Indian Railway Stations

✔ Trial of Wi-Fi 6 Access Point in Smart City program

**CLICK HERE**
**TO FIND**
**OUT MORE**

# Education in Rural Areas
## PARTICIPANT LIST

| Name | Company | Role |
|------|---------|------|
| Necati Canpolat | Intel | Project Leader |
| Gabriel Desjardins | Broadcom | Project Co-Leader |
| Sandeep Agrawal | C-DOT | Trial Participant |
| Suja S | C-DOT | Trial Participant |
| Kavita Mathur | C-DOT | Trial Participant |
| A R Balalakshmi | C-DOT | Trial Participant |

**PARTICIPATE IN OUR PROJECTS**