1 Multi-AP Wi-Fi Networks: Channel Allocation (Level 2)

1.1 Introduction

A single Wi-Fi Access Point (AP) can connect laptops and other devices that are a few meters distance from the AP, the actual coverage depending on the propagation characteristics of the building in which the Wi-Fi network is deployed. Thus, for large office buildings, apartment complexes, etc., a single AP does not suffice, and multiple APs need to be installed, each covering a part of the building. We will focus on 2.4GHz and 5GHz systems. In each of these systems the available bandwidth is organized into channels, with each AP being assigned to one of the channels. For example, 2.4GHz Wi-Fi systems operate in the band 2401MHz to 2495MHz, which has 14 overlapping channels each of 22MHz. There are 3 nonoverlapping channels, namely, Channels 1, 6, and 11, which are centered at 2412MHz, 2437MHz, and 2462MHz. Evidently, if neighboring APs are assigned to the same channel or overlapping channels they will interfere, thereby leading to poor performance. On the other hand, since there are only three nonoverlapping channels, some care must be taken in assigning channels to APs so that nearby APs have nonoverlapping channels, whereas APs that are far apart can use the same or overlapping channels.

In this experiment we will understand some basic issues that arise in multi-AP networks, particularly with attention to channel allocation to the APs.

1.2 Network Setup

Open NetSim and click on **Experiments>Internetworks> Wi-Fi> Multi AP Wi-Fi Networks Channel Allocation> APs on the Same channel** then click on the tile in the middle panel to load the example as shown in below
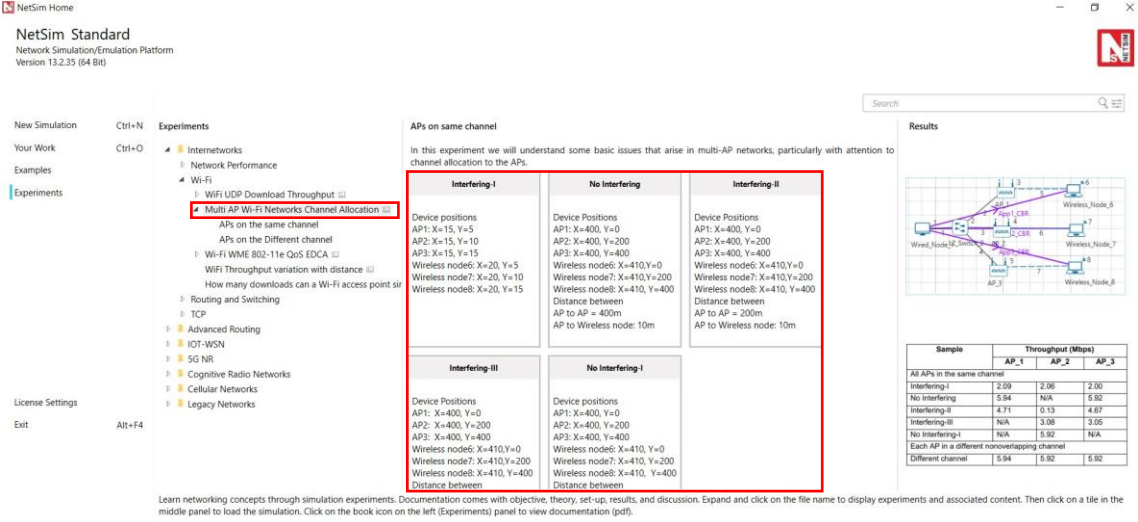
Figure 1-1: List of scenarios for the example of Multi AP Wi-Fi Networks Channel Allocation

NetSim UI displays the configuration file corresponding to this experiment as shown below Figure 1-2.
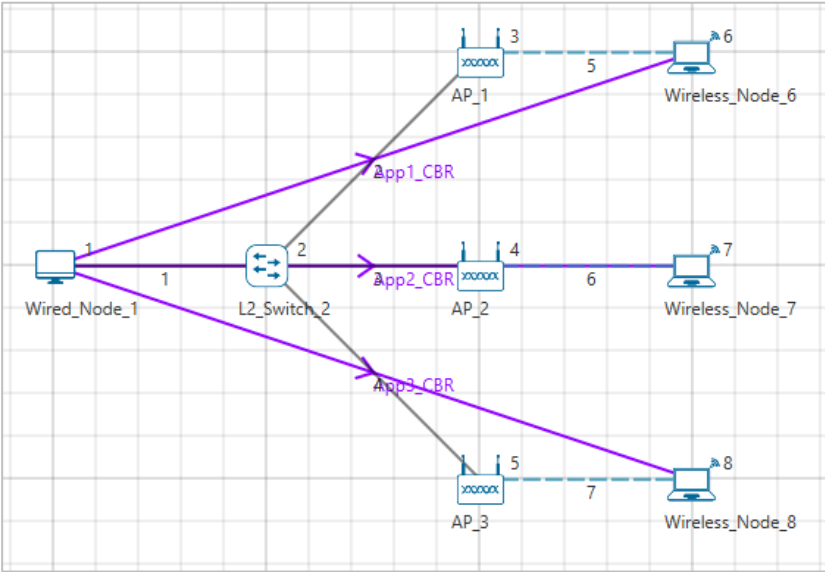
APs in the same channel

Figure 1-2: Network set up for studying the Multiple APs-WiFi Networks with APs in same Channel -Interfering-I

Interfering-I: The following set of procedures were done to generate this sample:

Step 1: Environment Grid length: 50m x 50m.

Step 2: A network scenario is designed in NetSim GUI comprising of 1 Wired Node, 1 L2 Switch, 3 Wireless Nodes and 3 Access Points in the **"Internetworks"** Network Library.

Step 3: The device positions are set as per the table given below Table 1-1.

General Properties		
Device Name	**X / Lon**	**Y / Lat**
AP_1	15	5
AP_2	15	10
AP_3	15	15
Wireless_Node_6	20	5
Wireless_Node_7	20	10
Wireless_Node_8	20	15

Table 1-1: Device positions for APs-STA - Interfering-I

Step 4: In the INTERFACE (WIRELESS) > PHYSICAL LAYER Properties of all the Wireless Nodes and Access Points, the Protocol Standard is set to IEEE 802.11 b. In the INTERFACE (WIRELESS) > DATALINK LAYER Properties of all the Wireless Nodes and Access Points, Medium Access Protocol is set to DCF.

Step 5: Right-click the link ID (of a wired link) and select Properties to access the link's properties. For all the Wired Links, Bit Error Rate and Propagation Delay is set to 0.

Step 6: The Wireless Link Properties are set according to the values given in the below Table 1-2.

Channel Characteristics	PATH LOSS ONLY
Path Loss Model	LOG DISTANCE
Path Loss Exponent	3.5

Table 1-2: Wireless Link Properties

Step 7: Right click on the Application Flow App1 CBR and select Properties or click on the Application icon present in the top ribbon/toolbar.

A CBR Application is generated from Wired Node 1 i.e., Source to Wireless Node 6 i.e., Destination with Packet Size set to 1460 Bytes and Inter Arrival Time set to 1168µs.

Transport Protocol is set to **UDP** instead of TCP.

The Packet Size and Inter Arrival Time parameters are set such that the Generation Rate equals 10 Mbps. Generation Rate can be calculated using the formula:

$$Generation\ Rate\ (Mbps) = Packet\ Size\ (Bytes) * 8/Interarrival\ time\ (µs)$$

Similarly, two more CBR applications are generated from Wired Node 1 to Wireless Node 7 and Wired Node 1 to Wireless Node 8.

Step 8: Plots is enabled in NetSim GUI. Run the Simulation for 10 Seconds and note down the throughput.

No Interfering: The following changes in settings are done from the previous sample:

Step 1: Before we start designing the network scenario, the Grid Length is set to 1000 meters. This can be set by choosing the Menu **Options>Change Grid/Map settings>Grid/Map settings** from the GUI.

Step 2: From the previous sample, we have removed App2 CBR (i.e., from Wired Node1 to Wireless Node7), set distance between the other 2 Access Points (AP 1 and AP 3) as 400m and distance between APs and Wireless nodes as 10m as shown below Figure 1-3.
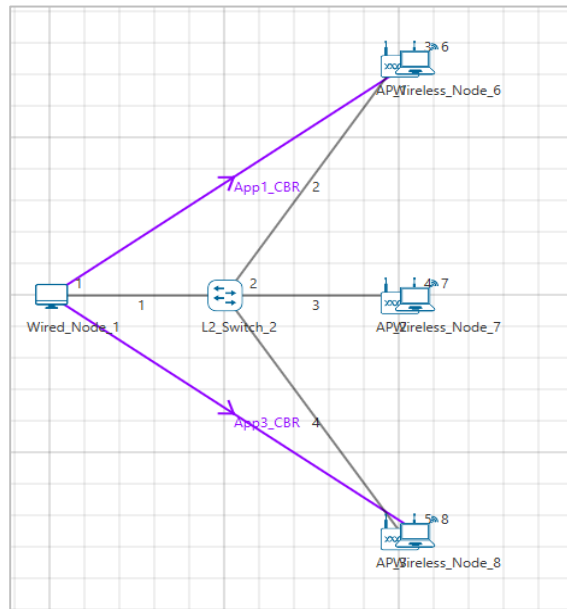

Figure 1-3: Network set up for studying the Multiple APs-WiFi Networks with APs in same Channel No-Interfering

Step 3: The device positions are set according to the table given below   Table **1-3**.

General Properties		
Device Name	**X /**	**Y /**
AP_1	400	0
AP_2	400	200
AP_3	400	400
Wireless_Node_6	410	0
Wireless_Node_7	410	200

Wireless_Node_8	410	400

Table 1-3: Device positions for APs-STA – No Interfering

Step 4: Plots is enabled in NetSim GUI. Run the Simulation for 10 Seconds and note down the throughput.

Interfering-II: The following changes in settings are done from the previous sample:

Step 1: From the previous sample, Add App2 CBR (i.e., from Wired Node1 to Wireless Node7), The distance between the Access Points (AP 1 and AP 3) is set to 400m and distance between APs and Wireless nodes as 10m as shown below Figure 1-4.
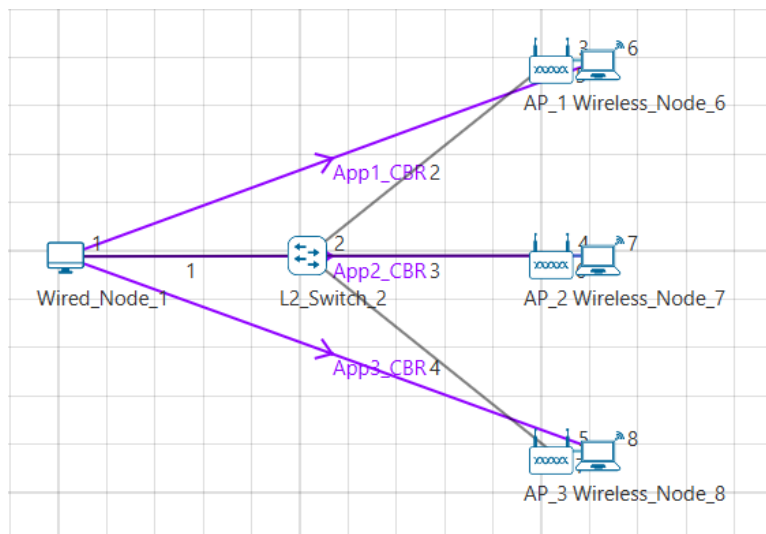

Figure 1-4: Network set up for studying the Multiple APs-WiFi Networks with APs in same Channel Interfering-II

Step 2: The device positions are set according to the table given below   Table **1-4**.

General Properties		
Device Name	**X /**	**Y /**
AP_1	400	120
AP_2	400	200
AP_3	400	280
Wireless_Node_6	420	120
Wireless_Node_7	420	200
Wireless_Node_8	420	280

Table 1-4: Device positions for APs-STA - Interfering-II

Step 3: Plots is enabled in NetSim GUI. Run the Simulation for 10 Seconds and note down the throughput.

Interfering-III: The following changes in settings are done from the previous sample:

Step 1: From the previous sample, we have removed App1 CBR (i.e., from Wired Node 1 to Wireless Node 6), set distance between the other 2 Access Points (AP 2 and AP 3) as 200m and distance between APs and Wireless nodes as 10m as shown below Figure 1-5.
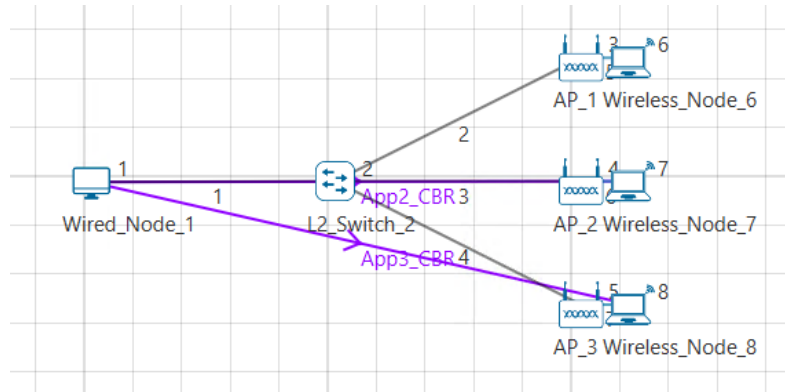

Figure 1-5: Network set up for studying the Multiple APs-WiFi Networks with APs in same Channel Interfering - III

Step 2: The device positions are set according to the table given below Table 1-5.

General Properties		
Device Name	**X /**	**Y /**
AP_1	400	150
AP_2	400	200
AP_3	400	250
Wireless_Node_6	420	150
Wireless_Node_7	420	200
Wireless_Node_8	420	250

Table 1-5: Device positions for APs-STA – Interfering III

Step 3: Plots is enabled in NetSim GUI. Run the Simulation for 10 Seconds and note down the throughput.

No Interfering-I: The following changes in settings are done from the previous sample:

Step 1: From **Interfering-II**, we have removed first, and third applications as shown below Figure 1-6.
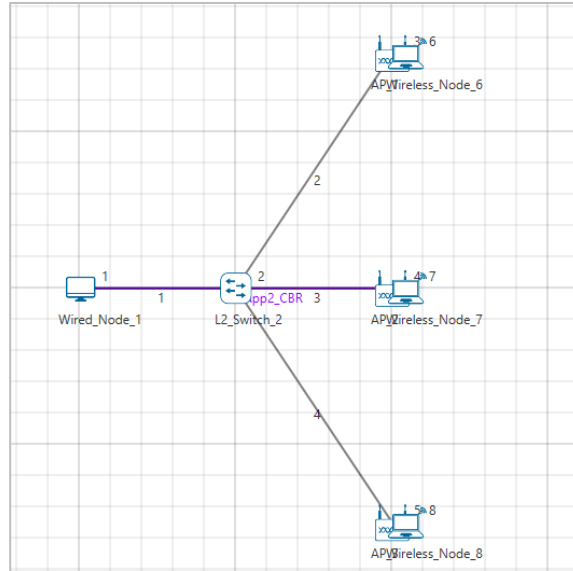
Figure 1-6: Network set up for studying the Multiple APs-WiFi Networks with APs in same Channel No Interfering-I

Step 2: The device positions are set according to the table given below   Table 1-6.

General Properties		
Device Name	**X / Lon**	**Y / Lat**
AP_1	400	0
AP_2	400	200
AP_3	400	400
Wireless_Node_6	410	0
Wireless_Node_7	410	200
Wireless_Node_8	410	400

Table 1-6: Device positions for APs-STA - No Interfering-I

Step 3: Plots is enabled in NetSim GUI. Run the Simulation for 10 Seconds and note down the throughput.

APs on the different channel: The following changes in settings are done from the previous sample:

Step 1: From previous sample, we have changed standard channel to **11_2462** under INTERFACE (WIRELESS) > DATALINK LAYER Properties of AP 2.

Step 2: Plots is enabled in NetSim GUI. Run the Simulation for 10 Seconds and note down the throughput.

1.3 Output

After running simulation, check throughput in Application metrics as shown in the below screenshot Figure 1-7.

Application ID	Throughput Plot	Application Name	Packets Generated	Packets Received	Throughput (Mbps)	Delay (microsec)	Jitter (microsec)
				Application_Metrics_Table			
				Application_Metrics			
1	Application_Throughput_plot	App1_CBR	8562	1797	2.098896	3932013.621686	4397.871297
2	Application_Throughput_plot	App2_CBR	8562	1772	2.069696	4005000.786608	4467.587679
3	Application_Throughput_plot	App3_CBR	8562	1714	2.001952	3991927.103512	4664.399586

Figure 1-7: Application Metrics Table in Result window

Sample	Throughput (Mbps)		
	AP_1	AP_2	AP_3
All APs in the same channel			
Interfering-I	2.09	2.06	2.00
No	5.94	N/A	5.92
Interfering-II	4.71	0.13	4.67
Interfering-III	N/A	3.08	3.05
No	N/A	5.92	N/A
Each AP in a different nonoverlapping channel			
Different	5.94	5.92	5.92

Table 1-7: Throughput for APs on the Same and different Channels

NOTE: Please refer "Wi-Fi UDP Download Throughput" experiment for theoretical WLAN throughput calculations in NetSim Experiment Manual.

1.4 Discussion

We recall that each AP is associated with one station (STA; e.g., a laptop). All the APs are connected to the same server which is sending separate UDP packet streams to each of the STAs via the corresponding AP. The packet transmission rate from the server is large enough so that the AP queue in permanently backlogged, i.e., the rate at which the server transmits packets is larger than the rate at which the AP can empty the packet queue.

1.4.1 All APs in the same channel

Interfering-I: All the APs and their associated STAs are close together, so that all devices (APs and STAs) can sense every other device.

- The table shows that all the AP-STA links achieve the same UDP throughput. This is because all the AP-STA links are equivalent (since all interfere with each other), and only one can be active at one time. The throughput for this scenario can be predicted from the

analysis in Section 7.4 of the book Wireless Networking by Anurag Kumar, D. Manjunath and Joy Kuri.

No Interfering: AP1 and AP3 are close to their associated STAs but are 400m apart. The link from AP2 to its STA is half-way between the other two APs and is not carrying any traffic.

- The table shows that both the links from AP1 and AP3 to their respective STAs carry the same throughput, of 5.94Mbps and 5.92Mbps. These are also the throughputs that each link would have if the other was not present, indicating that the two links are far enough apart that they do not interfere.

Interfering-II: This is the same scenario as **No Interfering**, but the AP2-STA link is now carrying traffic.

- We find that, in comparison with **No Interfering**, the AP1-STA and AP3-STA carry slightly lower throughputs of about 5.21Mbps, whereas the AP2-STA link carries a small throughput of 0.92Mbps. Comparing **Interfering-I** and **II** we conclude that in these networks there can be severe unfairness depending on the relative placement of the AP-STA links. In **Interfering-I**, all the links could sense each other, and each got a fair chance. In **Interfering-II**, we have what is called the "link-in-the-middle problem." The AP2-STA link is close enough to interfere with the AP1-STA link and the AP3-STA link, whereas the AP1-STA link and the AP3-STA link do not "see" each other. The AP2-STA link competes with the links on either side, whereas the other links compete only with the link in the center, which thereby gets suppressed in favour of the outer links.

Interfering-III: Here we stop the traffic to AP1 but send the traffic to the AP2-STA link and the AP3-STA link.

- The two active links interfere with each other, but the situation is symmetric between them (unlike in **Interfering-II**), and they obtain equal throughput. Again, the throughput obtained by these two links can be predicted by the analysis mentioned earlier in this section.

No Interfering-I: Now we send traffic only to AP2.

- The throughput is now 5.92Mbps, since the AP2-STA link can transmit without interference; there are no collisions. The reason that this throughput is less than the sum of the two throughputs in **Interfering-III** is that the single link acting by itself, with all the attendant overheads, is unable to occupy the channel fully.

1.4.2 Each AP in a different nonoverlapping channel

There is only one case here. Having observed the various situations that arose in the previous subsection when all the APs are in the same channel, now we consider the case where all the AP-STA pairs are each on a different nonoverlapping channel. As expected, every AP-STA pair gets the same throughput as when they are alone on the network.