

## 27 To analyze how the allocation of frequency spectrum to the Incumbent (Primary) and CR CPE (Secondary User) affects throughput

### 27.1 Introduction

An important component of the cognitive radio concept is the ability to measure, sense, learn, and be aware of the parameters related to the radio channel characteristics, availability of spectrum and power, radio's operating environment, user requirements and applications, available networks (infrastructures) and nodes, local policies and other operating restrictions.

NetSim simulator models IEEE 802.22 Cognitive Radio per the theory explained below.

A spectrum hole has been defined as a band of frequencies assigned to a primary user, but at a particular time and specific geographic location, the band is not being utilized by that user. Cognitive Radio was proposed as the means to promote the efficient use of spectrum by exploiting the existence of spectrum holes.

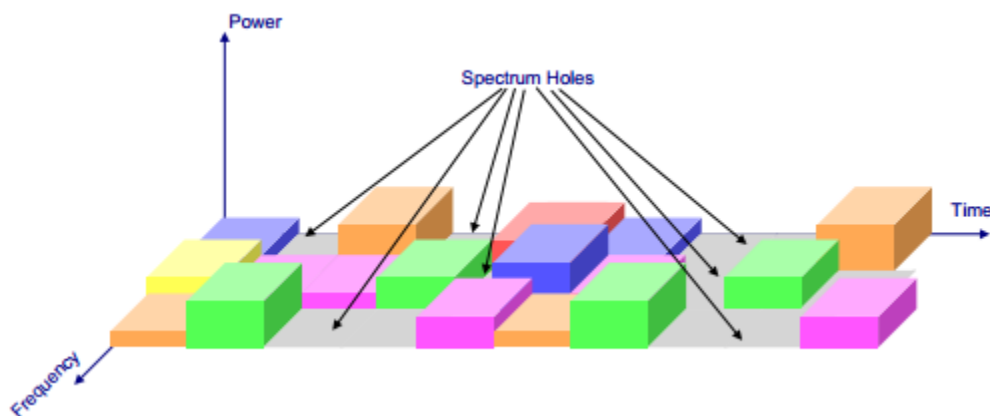


Figure 27-1: Spectrum holes are used by SU for its transmission scheme is often referred to as opportunistic spectrum access (OSA)

These spectrum holes are used by the SU for its transmission. This scheme is often referred to as opportunistic spectrum access (OSA). No concurrent transmission of the PU and the SU is allowed. The SU must vacate the channel as soon as the PU reappears, which leads to the forced termination of the SU connection (if there is no other available channel for the SU). Since the SU has no control over the resource availability, the transmission of the SU is blocked when the channel is occupied by the PU. The forced termination and blocking of a SU connection is

shown in the below figure. The forced termination probability and blocking probability are the key parameters which determine the throughput of the SU, and thus its viable existence. The forced termination depends on the traffic behavior of the PUs and the SUs (e.g. arrival rates, service time etc.). In the case of multiple SU groups with different traffic statistics, the forced termination and blocking probabilities lead to unfairness among the SU groups.

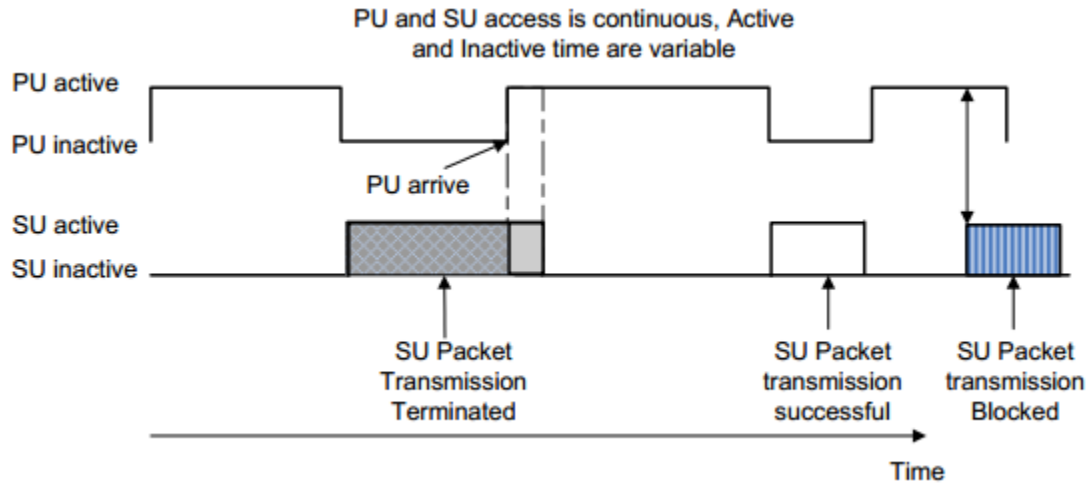


Figure 27-2: Illustration of forced termination and blocking of a SU connection

## Performance metrics

The different parameters used to analyze the performance are explained as follows:

- **Throughput:** It is the rate of successfully transmitted data packets in unit time in the network during the simulation.
- **Spectral Efficiency:** It refers to the information rate that can be transmitted over a given bandwidth in a specific communication system. It is a measure of how efficiently a limited frequency spectrum is utilized by the physical layer protocol, and sometimes by the media access control protocol.

## 27.2 Network Setup

Open NetSim and click on **Examples > Experiments > Cognitive-Radio-Impact-of-frequency-allocation-to-PU-and-SU-on-throughput > Sample-1** as shown below Figure 27-3.

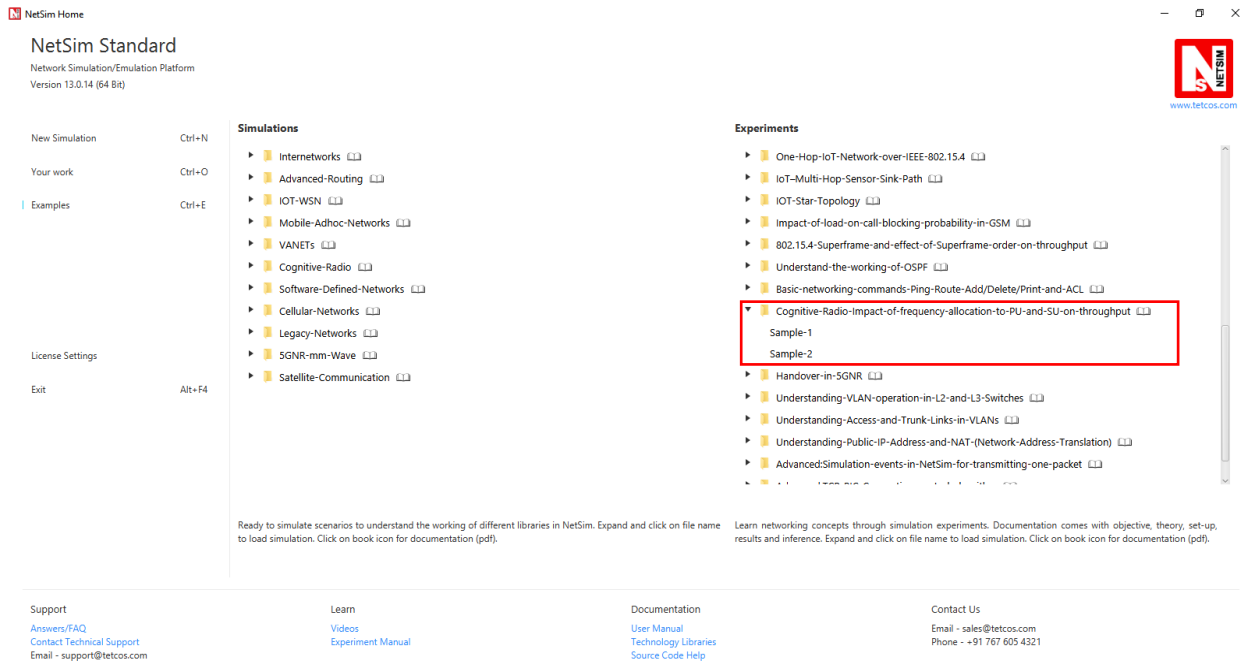


Figure 27-3: Experiments List

NetSim UI displays the configuration file corresponding to this experiment as shown below **Figure 27-4**.

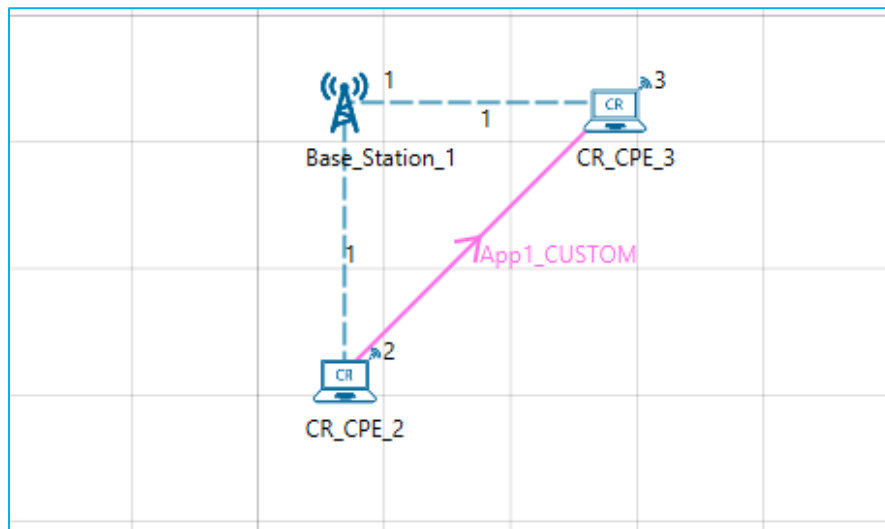


Figure 27-4: Frequency allocation to PU and SU network topology

## 27.3 Procedure

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

**Step 1:** A network scenario is designed in NetSim GUI comprising of 1 Base Station and 2 CR CPE's in the “**Cognitive Radio**” Network Library.

**Step 2:** The device positions are set as follows **Table 27-1**.

	Base Station 1	CR CPE 2	CR CPE 3
<b>X/Lat</b>	100	100	120
<b>Y/Lon</b>	100	120	100

Table 27-1: Device positions

**Step 3:** In the **Interface Cognitive Radio > Datalink Layer > Incumbent1**, the following are set as shown below **Figure 27-5**.

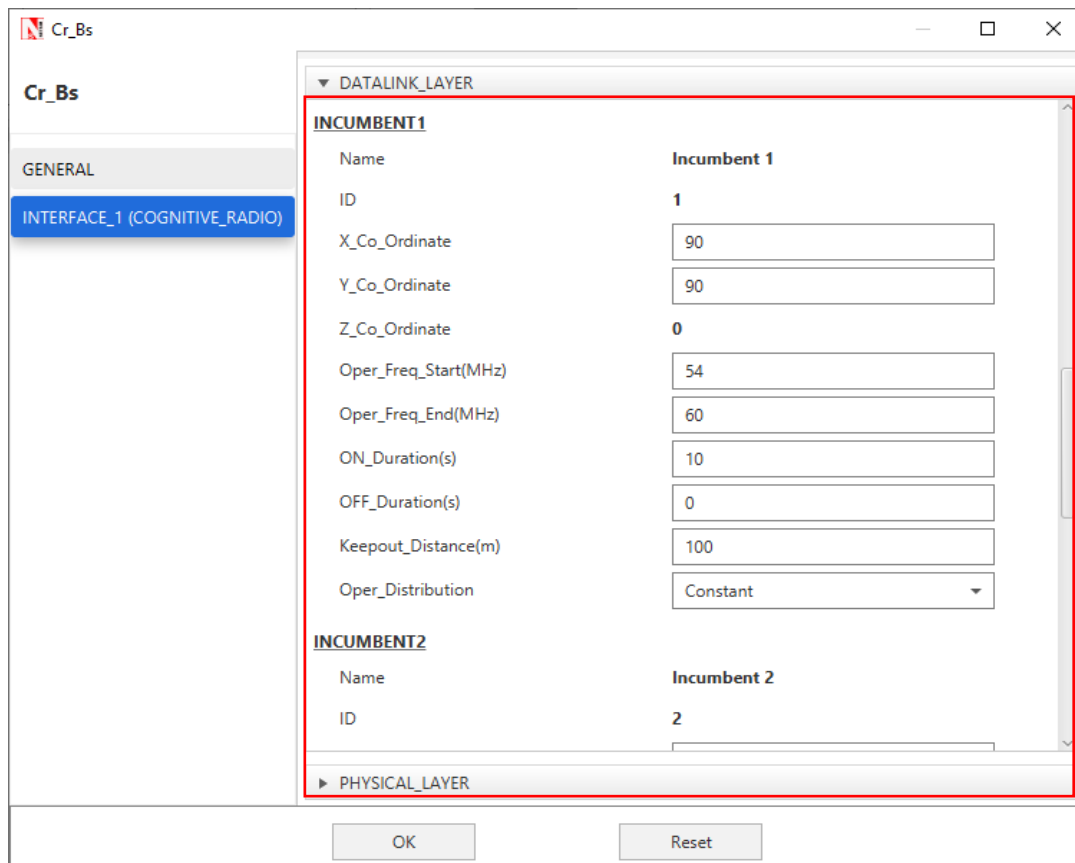


Figure 27-5: Datalink Layer properties window

**Step 4:** In the **Interface Cognitive Radio > Physical Layer**, the Min Frequency and Max Frequency parameters are set to 54 and 60 MHz respectively.

**Step 5:** Right click on the Application Flow **App1 CUSTOM** and select Properties or click on the Application icon present in the top ribbon/toolbar.

A CUSTOM Application is generated from CR CPE 2 i.e., Source to CR CPE 3 i.e., Destination with Packet Size remaining 1460Bytes and Inter Arrival Time remaining 20000 $\mu$ s.

**Step 6:** Enable the plots and run the Simulation for 100 Seconds.

## Sample 2

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

**Step 1:** In the **Interface Cognitive Radio > Physical Layer**, the Min Frequency and Max Frequency parameters are set to 54 and 90 MHz respectively.

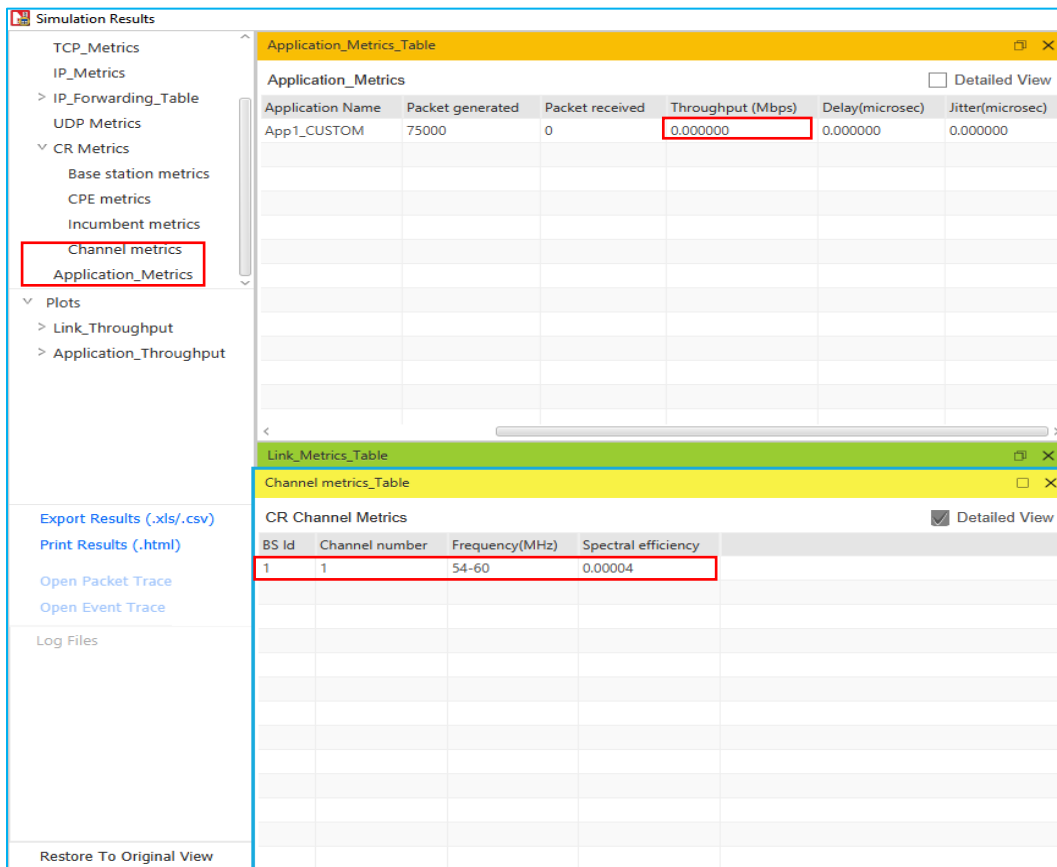
**Step 2:** Enable the plots and run the Simulation for 100 Seconds.

## 27.4 Output

Once after the simulation is complete, go to the Results Dashboard and check the **“Application Metrics”** Table. Throughput of the application will be 0.

In the Left-Hand-Side of the Results Dashboard **Figure 27-6/Figure 27-7**, click on the arrow pointer indicating **“CR Metrics”**, from the drop down select the **“Channel Metrics”** which gives you the Spectral Efficiency.

## Sample 1



The screenshot shows the Simulation Results dashboard. On the left, a navigation tree is visible with 'Channel metrics' and 'Application\_Metrics' highlighted. The main area displays two tables:

Application_Metrics_Table						
Application_Metrics						
Application Name	Packet generated	Packet received	Throughput (Mbps)	Delay(microsec)	Jitter(microsec)	
App1_CUSTOM	75000	0	0.000000	0.000000	0.000000	

CR Channel Metrics			
BS Id	Channel number	Frequency(MHz)	Spectral efficiency
1	1	54-60	0.00004

Figure 27-6: Results of Sample 1

## Sample 2

The screenshot displays the 'Simulation Results' window. On the left, a tree view shows the navigation structure, with 'Channel metrics' and 'Application\_Metrics' highlighted. The main area contains two tables:

**Application\_Metrics\_Table**

Application Name	Packet generated	Packet received	Throughput (Mbps)	Delay(microsec)	Jitter(microsec)
App1_CUSTOM	75000	74998	0.583987	19958.371348	1491.681237

**CR Channel Metrics\_Table**

BS Id	Channel number	Frequency(MHz)	Spectral efficiency
1	1	54-60	0.00004
1	2	60-66	0.00000
1	3	66-72	0.00010
1	4	72-78	0.19720
1	5	78-84	0.00510
1	6	84-90	0.15571

Figure 27-7: Result of Sample 2

## 27.5 Inference

In both the samples, the Secondary User (CR-CPE) lies within the operational region of Primary User (Incumbent), hence the frequency spectrum used by operational Primary User (Incumbent) will not be used by Secondary User (CR-CPE). Also, the Operational Interval under Incumbent is set to zero, i.e., the Incumbent will continuously use the channel allocated to it.

In the first sample, both the Primary User (Incumbent) and the Secondary User (CR-CPE) has been allocated the same channel (frequency band of 54 - 60 MHz). As Incumbent will continuously use the channel allocated to it, so there will be no Spectrum Hole, hence the secondary user will not be able to transmit any data in an opportunistic manner. Therefore, the throughput of the application in the CR-CPE and the spectral efficiency is almost equal to zero.

In the second sample, the Primary User (Incumbent) has been allocated frequency band of 54 - 60 MHz and the Secondary User (CR-CPE) has been allocated the frequency band of 54 - 90 MHz. Incumbent will continuously use the channel allocated to it, but the rest channels will remain free i.e., there will be Spectrum Hole, which the CR-CPE will utilize to transmit data.

**NOTE:** *The results are highly dependent on position/velocity/ traffic etc. Any modifications with the above-mentioned input parameters will change the final output result.*