1 To analyze how the allocation of frequency spectrum to the Incumbent (Primary), CR CPE (Secondary User) affects throughput (Level 1)

1.1 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.

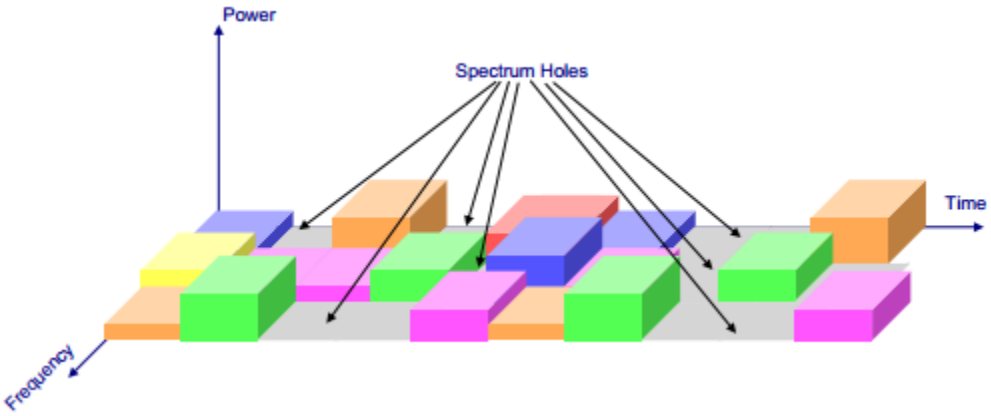

Figure 1-1: Spectrum holes are used by SU for its transmission scheme is often referred to as opportunistic spectrum access (OSA)

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.

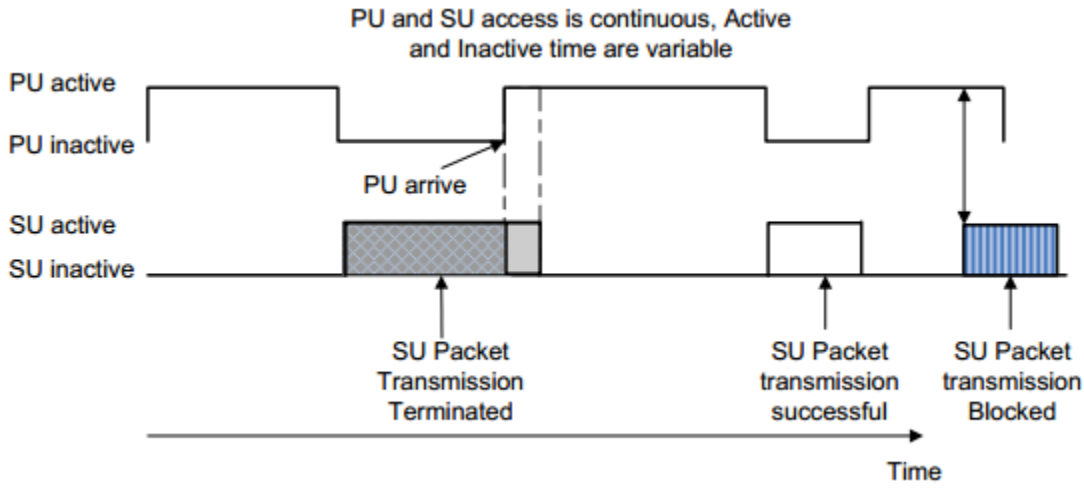

Figure 1-2: Illustration of forced termination and blocking of a SU connection

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.

1.2 Network Setup

Open NetSim and click on **Experiments> Cognitive Radio Networks> Cognitive Radio Impact of frequency allocation to PU and SU on throughput** then click on the tile in the middle panel to load the example as shown in below Figure 1-3.

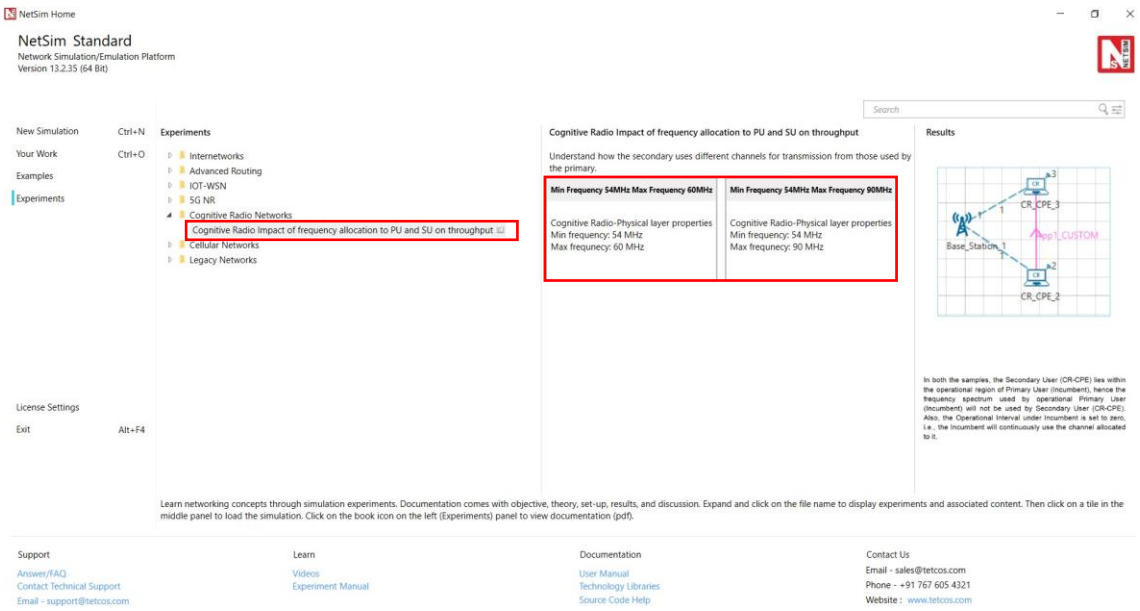

Figure 1-3: List of scenarios for the example of frequency allocation to PU and SU on throughput

NetSim UI displays the configuration file corresponding to this experiment as shown below Figure 1-4.

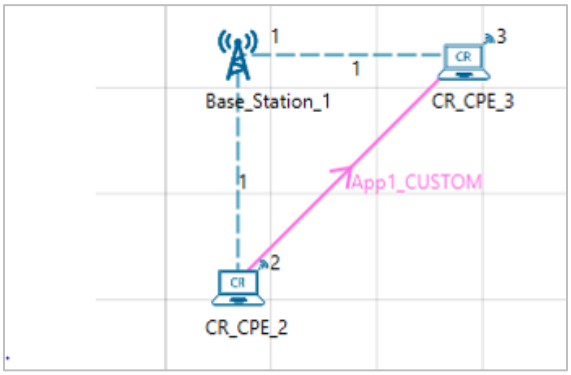

Figure 1-4: Network set up for studying the Frequency allocation to PU and SU

1.3 Procedure

Min Frequency 54MHz Max Frequency 60MHz Sample

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 1-1.

	Base Station 1	CR CPE 2	CR CPE 3
X/Lat	100	100	120

Y/Lon	100	120	100

Table 1-1: Device positions

Step 3: Go to Base Station Properties **Interface_1(Cognitive Radio)> Datalink Layer > Incumbent 1,** the following are set as shown below Figure 1-5.

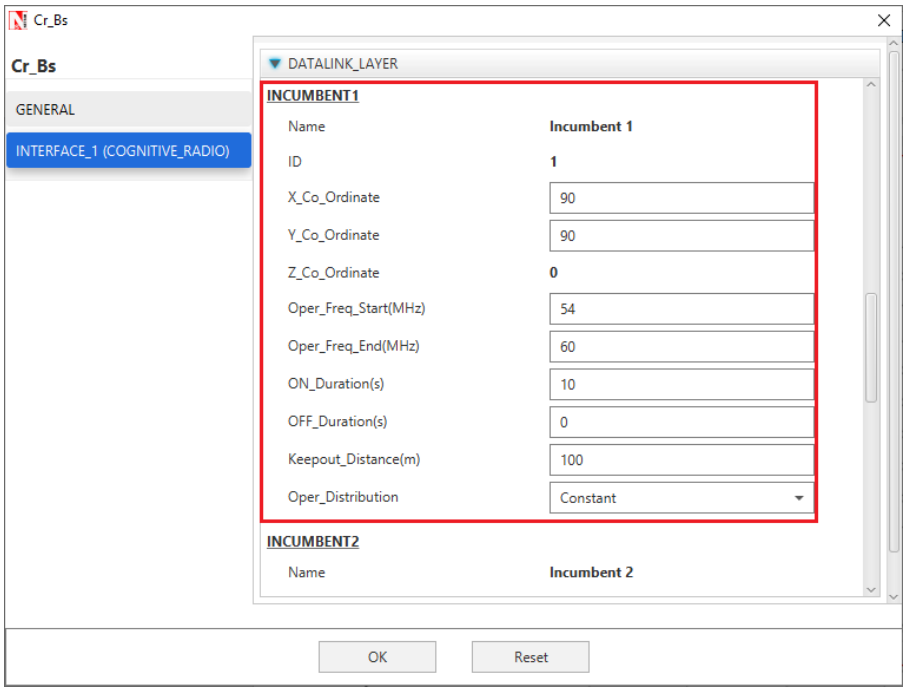

Figure 1-5: Datalink Layer properties window

Step 4: In the **Interface_1(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 20000µs.

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

Min Frequency 54MHz Max Frequency 90MHz Sample

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

Step 1: In the **Interface_1(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.

1.4 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 1-6/Figure 1-7, click on the arrow pointer indicating **"CR Metrics"**, from the drop down select the **"Channel Metrics"** which gives you the Spectral Efficiency.

Min Frequency 54MHz Max Frequency 60MHz Sample

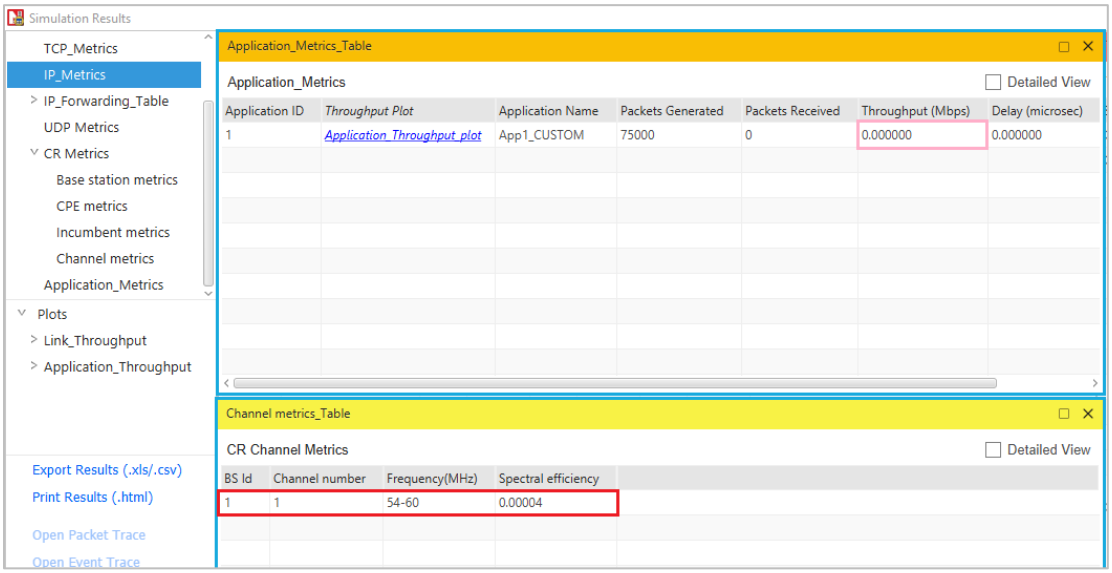

Figure 1-6: Results of Min Frequency 54MHz Max Frequency 60MHz Sample

Min Frequency 54MHz Max Frequency 90MHz Sample

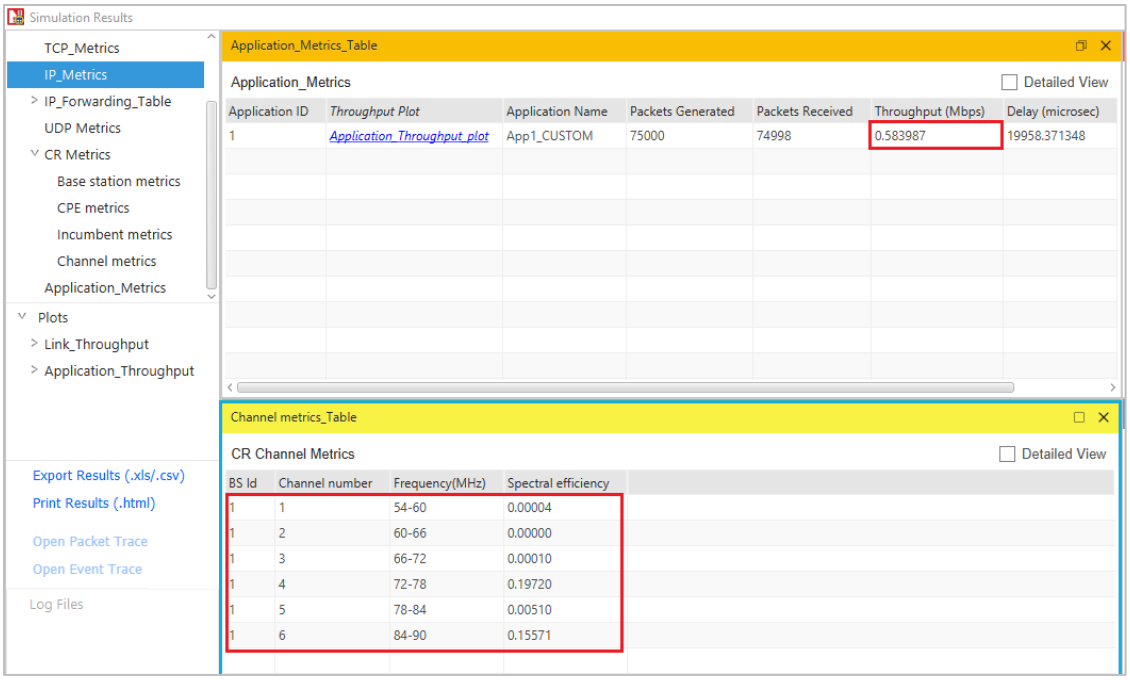

Figure 1-7: Results of Min Frequency 54MHz Max Frequency 90MHz Sample

1.5 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 **Min Frequency 54MHz Max Frequency 60MHz** 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 **Min Frequency 54MHz Max Frequency 90MHz** 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.***