Cognitive Radio - 802.22

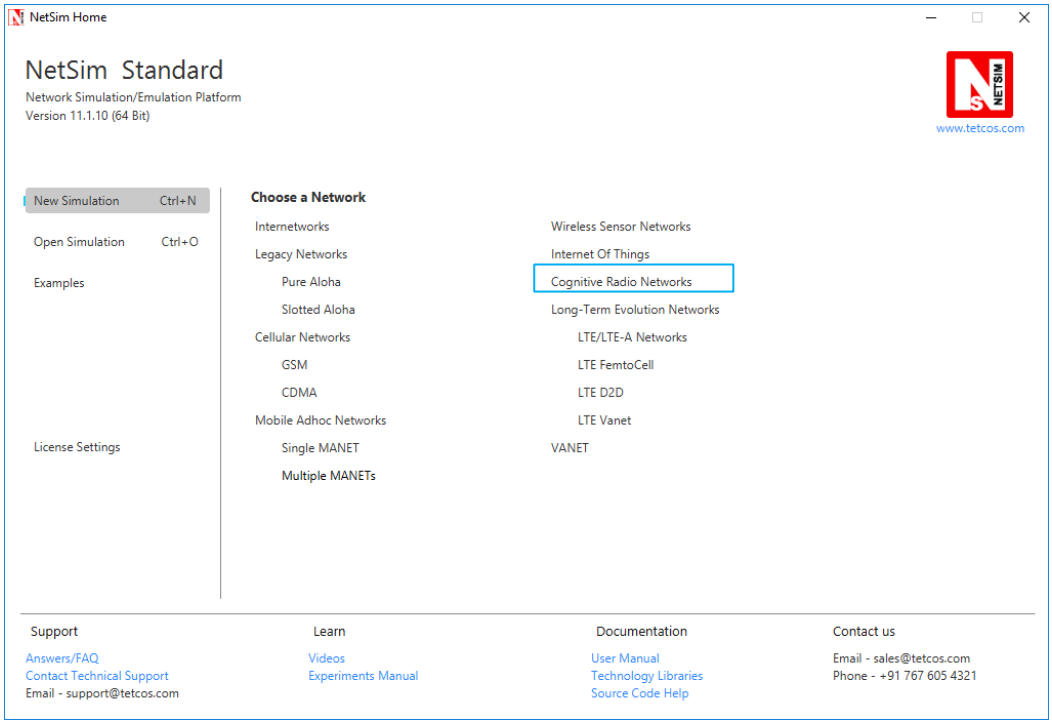
Contents

1 Introduction

Cognitive Radio Network simulation is available from v7 of NetSim. Cognitive Radio Networks allows you to connect, if required, with Ethernet, Wireless LAN, IP Routing, TCP / UDP and allows users to log packet and event traces.

2 Simulation GUI

In the Main menu select **New Simulation→Cognitive Radio Networks.**



2.1 Create Scenario

Adding Devices

- Cognitive Radio Networks comes with the palette of various devices like Cognitive Radio CPE, Cognitive Radio Base Station, Switch, Router, Wired Node, Wireless Node, Access point etc.
- Select the desired devices in the toolbar and click and drop on the environment.
- To remove devices, right click on the particular device and then click Remove.

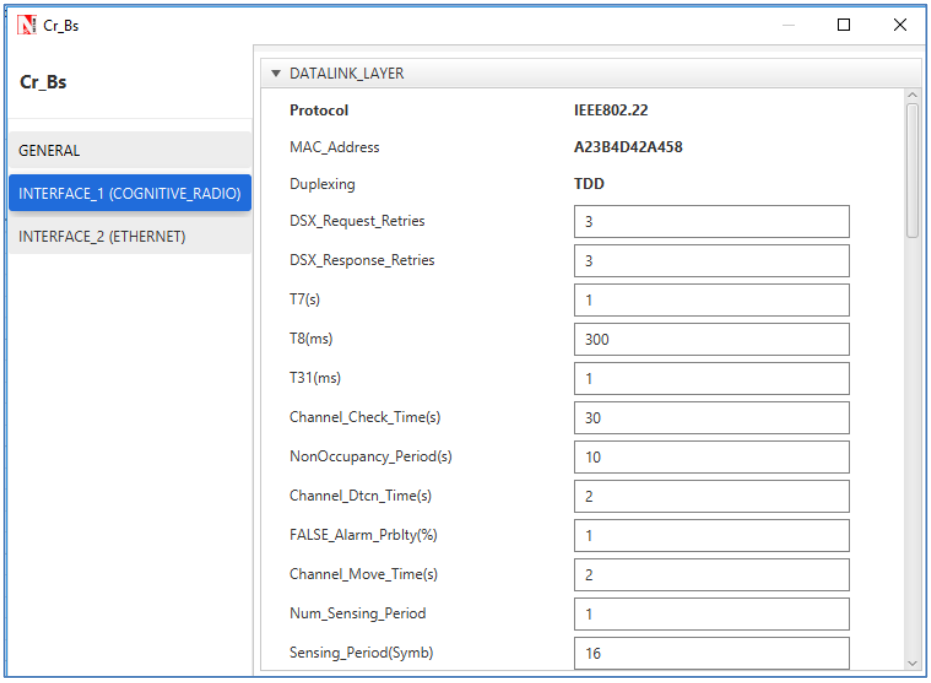
Connect the devices

Select the appropriate link in the toolbar and connect the devices by clicking on the device 1 and device 2.

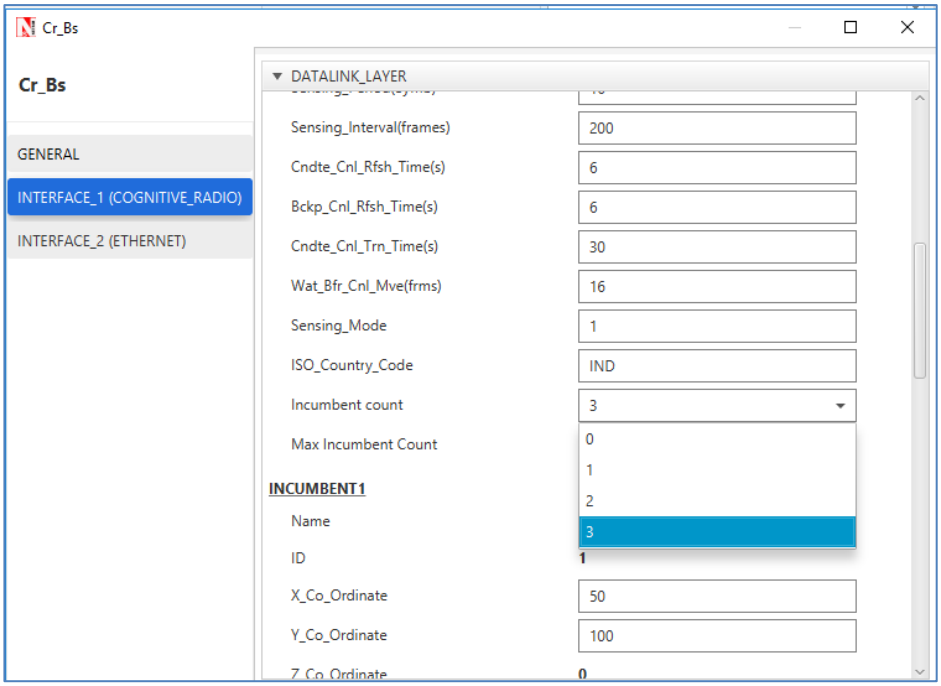
2.2 Set Node, Link and Application Properties

Right click on the appropriate node or link and select Properties. Then modify the parameters according to the requirements. Routing Protocol in Application Layer of router and all user editable properties in DataLink Layer and Physical Layer of Access Point and Wireless devices are Global i.e. changing properties in one node will automatically reflect in the others in that network.

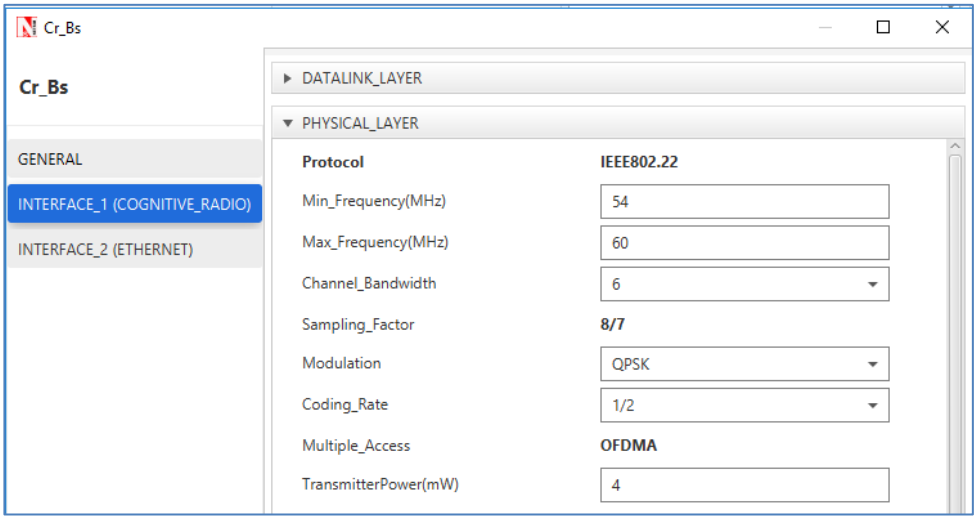
The following are the important Datalink layer properties of CR basestation:

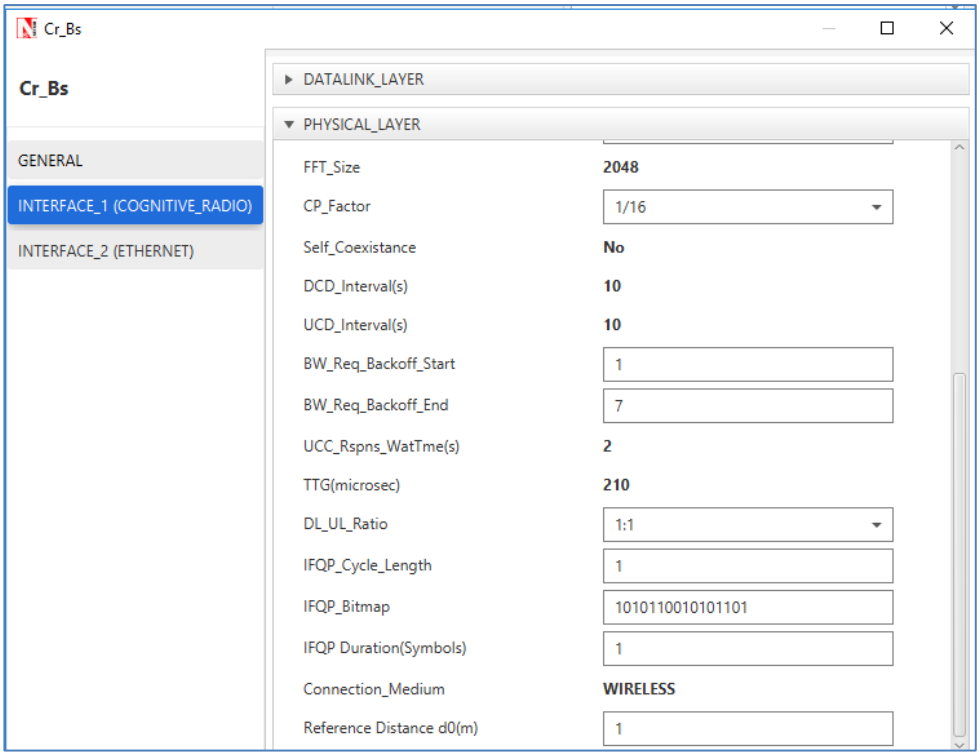


The incumbent count can be set as shown below and the maximum number of incumbents possible are 3

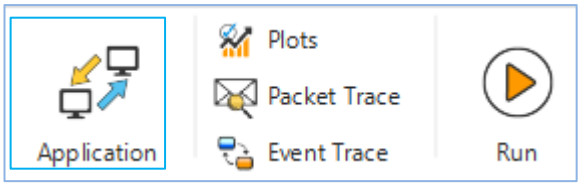


The following are the CR base station PHY layer properties

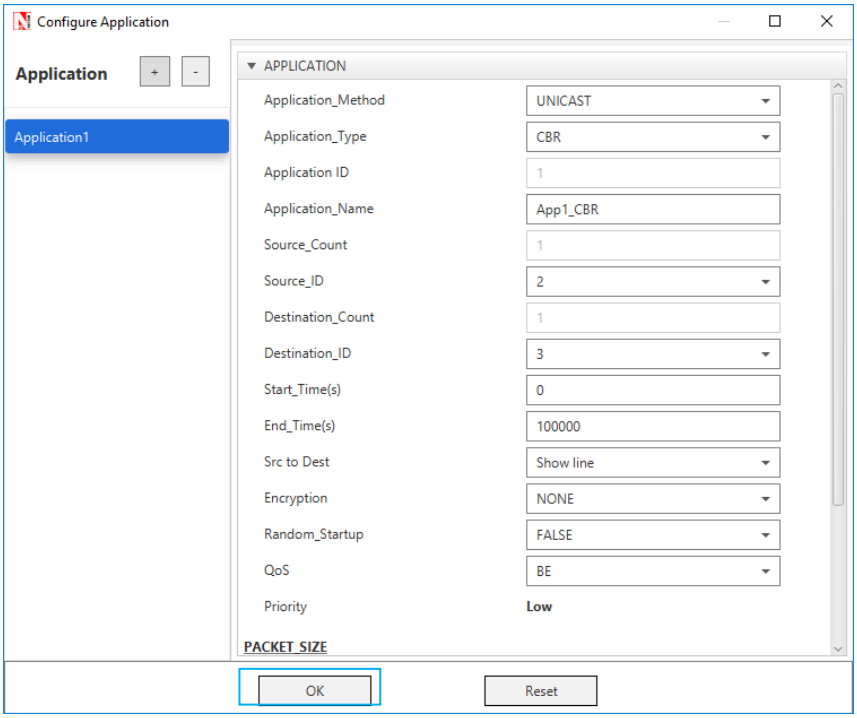




- Click on the Application icon present on the ribbon and set properties.Multiple applications can be generated by using add button in Application properties.

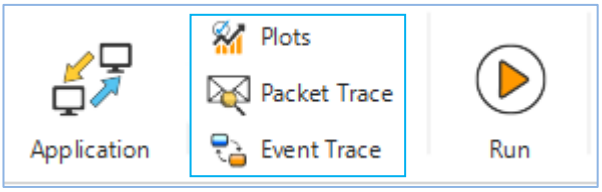


- Set the values according to requirement and click OK.



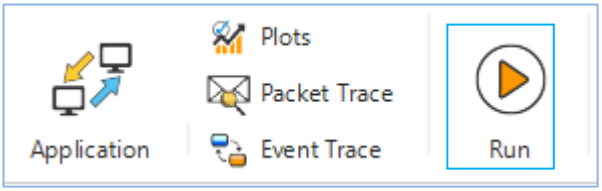
2.3 Enable Packet Trace, Event Trace & Plots (Optional)

Click Packet Trace / Event Trace icon in the tool bar and check Enable Packet Trace / Event Trace check box and click OK. To get detailed help, please refer sections 7.5 and 7.6 in User Manual. Select Plots icon for enabling Plots and click OK.



2.4 Run Simulation

Click on **Run Simulation** icon on the top toolbar. Set the Simulation Time and click on OK.



3 Model Features

3.1 Spectrum Sensing

NetSim Cognitive Radio library detects spectrum usage based on whether the primary user (incumbent) is inside / outside the keep out distance from the secondary user. This means that the SU will detect the PU if the PU is inside the keep-out distance from either the SU. Now, the secondary user (CR CPE) actively senses for the presence of the incumbent. If the CR_CPE detects the primary user then UCS Notifications will be sent by the secondary user to the base station. UCS notifications are generated at the end of the quiet period.

The Keep-out distance used in NetSim is an abstract model for simulation purposes. A user can modify keep-out distance as per their sensing technique/algorithm. Since the keep-out distance is a user input, and hence the assumption is that the user has arrived at this value based on their sensing technique.

The below link provides an understanding to how spectrum sensing is done. http://www.ieee802.org/22/Meeting_documents/2006_Mar/22-06-0028-05-0000-Spectrum-Sensing-Simulation-Model.doc

The definition of the Spectrum Sensing Function can be found in the SpectrumManager.c file. If user wants to modify this at run time, then they can write a new sensing algorithm function and change keep-out distance used in below function.

struct stru_802_22_SSFOutput* fn_NetSim_CR_CPE_SSF(struct stru_802_22_SSFInput* input,NETSIM_ID nDevId,NETSIM_ID nInterfaceId)

This function is present in spectrummanager.c and it checks if the Incumbent signal is present or not.

3.2 Channel Switching

The switching to another channel by the secondary user (CR CPE) occurs when an incumbent comes on. However, the switching will not be done to an adjacent channel.

For example, if the frequency is set from 54 to 72 MHz with 6 MHz bandwith per channel then

Channel 1 -> 54 to 60 MHz

Channel 2 -> 60 to 66 MHz

Channel 3 -> 66 to 72 MHz

If the incumbent comes on in channel 1, then the secondary user will switch to channel 3. It will not switch to channel 2 since channel 2 is an adjacent channel

3.3 ON Duration and OFF Duration

ON_Duration(s): This represents how much time incumbment operates. It ranges from 0-100000.

OFF_Duration(s): This represents the time gap between two successive incumbment operations. i.e., If ON_Duration is set to 10s, then incumbent operates with an interval of every 10s. If OFF_Duration is set to 0s, then the incumbent remains active.

Example: For ON_Duration(s) = 10, OFF_Duration(s) = 10, the timing would be: Incumbent --- 0s to 10s (OFF), 10s to 20s (ON), 20s to 30s (OFF), 30s to 40s (ON) ... and so on.

3.4 PHY Rate

Data rate in 802.22 depends on the following parameters

- Number of bits per symbol
- Coding rate
- Cyclic prefix
- Symbol duration

PHY rate in CR is calculated as

Data Rate = Bit count in one symbol/Symbol duration

Bit count in one symbol = subcarrier count * no. of bits * coding rate

= 1440*2*(1/2) where Subcarrier count = 1440 // Ref Table 201 page 310 IEEE802.22

= 1440

No. of bits is based on modulation technique (QPSK default)

Modulation	**No. of bits per symbol**
BPSK	1
QPSK	2
16-QAM	4
64-QAM	6

Coding rate = ½ (default)

Coding Rate	Data bits	Redundant bits (n-k)
1/2	1	1
2/3	2	1
3/4	3	1
4/5	4	1

Cyclic prefix = 1/16 (default)

Cyclic prefix
1/4
1/8K
1/16
1/64

Symbol duration = sub carrier spacing/cyclic prefix = 317.38

Data rate = bit count in one symbol/symbol duration

= 1440/317.38

= 4.53 Mbps

3.5 Modifying Spectrum sensing time

Please see https://tetcos.freshdesk.com/support/solutions/articles/14000084231-how-to-add-spectrum-sensing-time-in-cognitive-radio-network-

3.6 Modifying Device Parameters in Run time

Please see https://tetcos.freshdesk.com/support/solutions/articles/14000084233-how-do-i-modify-the-cognitive-radio-device-parameters-during-run-time-

3.7 Additional Notes

NetSim outputs App layer throughput which is lesser than that of MAC layer throughput because of

- TCP connection establishment
- ARP set-up
- Service flow creation CPE-BS and BS-CPE
- BW request

To avoid the above effects

- Set application traffic model as Custom
- Set DL/UL Ratio as 1:1 so that the BS transmits whatever it receives
- Run UDP in transport layer
- Use static ARP
- Run Simulation for more than 100 sec

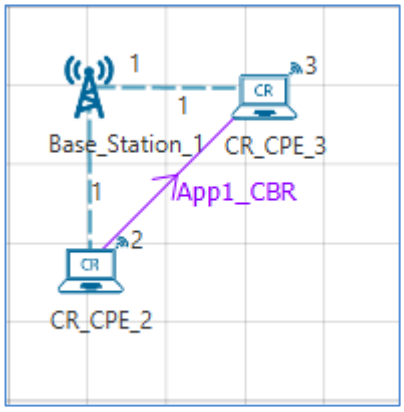
4 Featured Examples

Sample configuration files for all networks are available in Examples Menu in NetSim Home Screen. These files provide examples on how NetSim can be used – the parameters that can be changed and the typical effect it has on performance.

Cognitive Radio – Example Simulations

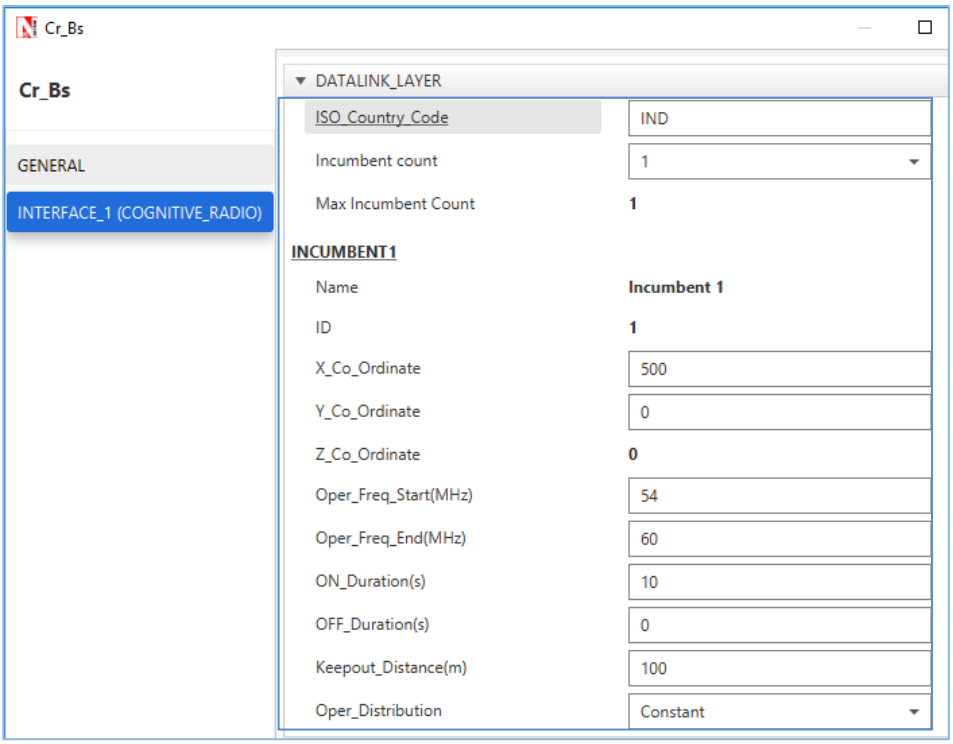
4.1 CR Keepout Distance

Open NetSim, Select Examples->Cognitive-Radio ->CR-Keepout-Distance



Settings done in example config file:

1. Grid length→500m*500m
2. Set the Incumbent Count as 1
3. Base station Properties (DataLink Layer) INCUMBENT_1 : X Co_ordinate: 500, Y Co_ordinate: 0 Operational Freq Start -> 54 MHz, Operational Freq End -> 60 MHz in both Incumbent and physical layer properties
4. ON duration →10 sec
5. OFF Duration → 0 sec



6. Simulation time → 100s

Results:

- In results windows open CR Incumbent metrics and check the operational time(100s) and idle time(0s)
- Then open Application Metrics, you should get non-zero throughput value, because there will be no Interference if distance between incumbent and CR CPEs is more than the keepout distance.

4.2 PU SU Spectrum Usage

Open NetSim, Select Examples->Cognitive-Radio ->PU-SU-Spectrum-Usage

Settings done in sample network:

1. Grid length→500m*500m
2. Set the Incumbent Count as 1
3. Base station Properties (DataLink Layer) INCUMBENT_1 : X Co_ordinate: 500, Y Co_ordinate: 0 Operational Freq Start → 54 MHz, Operational Freq End → 60 MHz in both Incumbent and physical layer properties
4. ON duration → 10 sec
5. OFF Duration → 10 sec
6. Ensure that the distance between incumbent and CR CPEs should be less than 100m (keepout distance)
7. Enable packet Trace and Simulate for 100s

Results:

- Open packet trace, filter Packet_Type to CBR, Transmitter_ID to Node-2 and check at what time data packets are transmitting (Check PHY_Layer_START time)

	PACKET_ID	SEGMENT_ID	PACKET_TYPE	TRANSMITTER_ID	RECEIVER_ID	PHY_LAYER_START_TIME(US)	PHY_LAYER_END_TIME(US)	APP_
24412	503	6	CBR	NODE-2	BASE_STATION-	10046769.21	10047001.95	
24413	503	7	CBR	NODE-2	BASE_STATION-	10047001.95	10047234.7	
24414	503	8	CBR	NODE-2	BASE_STATION-	10047234.7	10047467.45	
24415	503	9	CBR	NODE-2	BASE_STATION-	10047467.45	10047700.2	
24416	503	10	CBR	NODE-2	BASE_STATION-	10047700.2	10047932.95	
24417	503	11	CBR	NODE-2	BASE_STATION-	10047932.95	10048165.7	
24418	503	12	CBR	NODE-2	BASE_STATION-	10048165.7	10048398.45	
24419	503	13	CBR	NODE-2	BASE_STATION-	10048398.45	10048631.2	
24420	503	14	CBR	NODE-2	BASE_STATION-	10048631.2	10048863.95	
24421	503	15	CBR	NODE-2	BASE_STATION-	10048863.95	10049027.94	
24470	504	1	CBR	NODE-2	BASE_STATION-	20085288.07	20085520.82	
24471	504	2	CBR	NODE-2	BASE_STATION-	20085520.82	20085753.57	
24472	504	3	CBR	NODE-2	BASE_STATION-	20085753.57	20085986.32	
24473	504	4	CBR	NODE-2	BASE_STATION-	20085986.32	20086219.07	
24474	504	5	CBR	NODE-2	BASE_STATION-	20086219.07	20086451.82	
24475	504	6	CBR	NODE-2	BASE_STATION-	20086451.82	20086684.57	
24476	504	7	CBR	NODE-2	BASE_STATION-	20086684.57	20086917.32	
24477	504	8	CBR	NODE-2	BASE_STATION-	20086917.32	20087150.07	
24478	504	9	CBR	NODE-2	BASE_STATION-	20087150.07	20087382.82	
24479	504	10	CBR	NODE-2	BASE_STATION-	20087382.82	20087615.57	

- In the above screenshot, there is no data transmission between 10-20s for Node-2 (i.e. CR-CPE) since incumbent is using the channel.
- First 10s CPE should use the channel and next 10s Incumbent should use the channel alternatively.

OI: Operation Interval,

OT: Operation Time

CPE: CR CPE (Secondary User),

Inc.: Incumbent (Primary User)

Time	0-10s (OI)	10-20 (OT)	20-30s (OI)	30-40s (OT)	40-50s (OI)	50-60s (OT)	60-70s (OI)	70-80s (OT)	80-90s (OI)	90-100 (OT)
User	CPE	Inc.	CPE	Inc.	CPE	Inc.	CPE	Inc.	CPE	Inc.

Notes on Cognitive Radio implementation in NetSim:

- CR BS allocates max one symbol per CPE. If the generation rate is more than the data filled in one symbol then allocation fails and it results in zero throughput.
- The first symbol is reserved for CR control frames or any broadcast PDU
- **Operational frequency**: It is the frequency band at which the incumbent operates. It ranges from 54 MHz to 862 MHz.
- **ON_Duration(s)**: This represents how much time incumbment operates. It ranges from 0-100000.
- **OFF_Duration(s)**: This represents the time gap between two successive incumbment operations. i.e., If ON_Duration is set to 10s, then incumbent operates with an interval of every 10s. If the OFF_Duration is set to 0s, then the incumbent remains active.

For ON_Duration(s) = 10, OFF_Duration(s) = 10

The timing is Incumbent --- 0s to 10s (OFF), 10s to 20s (ON), 20s to 30s (OFF), 30s to 40s (ON) ... and so on.

NetSim provides App layer throughput which is lesser than that of MAC layer throughput because of

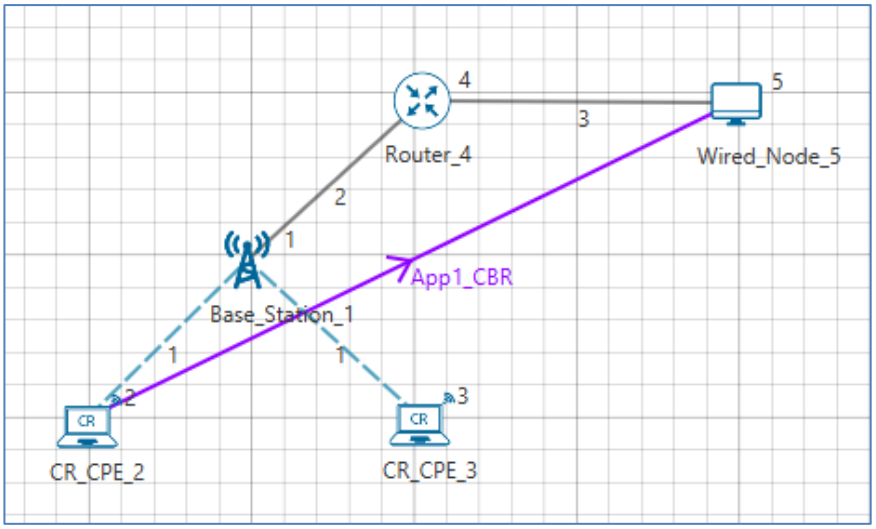
- TCP connection establishment
- ARP set-up
- Service flow creation CPE-BS and BS-CPE
- BW request

To avoid the above effects

- Generate custom traffic
- Set DL/UL Ratio as 1:1 so that the BS transmits whatever it receives
- Run UDP in transport layer
- Use static ARP
- Run Simulation for more than 100 sec

4.3 Effect of Downlink-Uplink Ratio

Open NetSim, Select Examples->Cognitive-Radio ->Effect-of-DL-UL-Ratio



Settings done in example config file:

1. Grid length→500m*500m
2. Base station Interface properties: DL:UL Ratio – 1:1

    a. DL:UL ratio is the ratio of Downstream subframes to Upstream subframes.

3. Set CBR application from 2 to 5
4. Wireless link properties – No pathloss
5. Simulation time → 30s

Output:

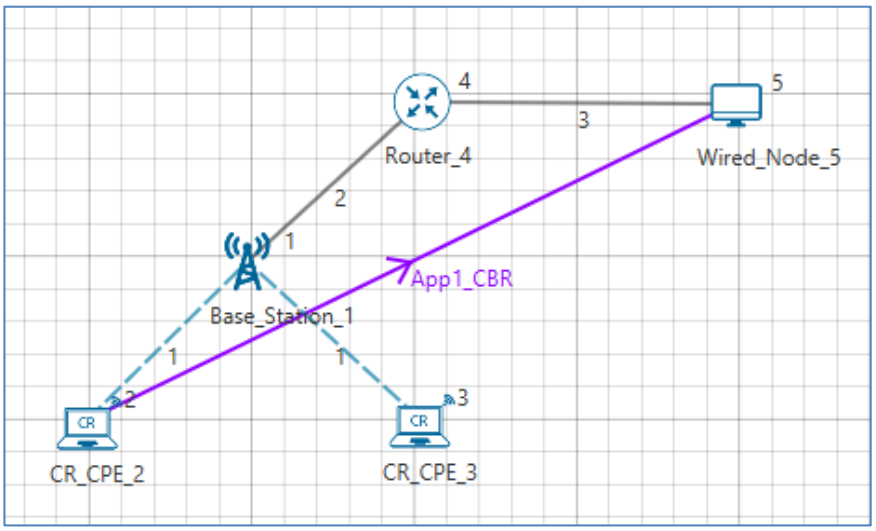
Sample	DL:UL Ratio	Throughput (Mbps)
1	1:1	0.8218
2	1:2	0.9571
3	1:3	0.9575
4	1:4	1.001

In the above table, the throughput for sample1 is less compared to sample2 since 2 subframes (i.e. more data can be transmitted in uplink) are allocated for upstream and 1 subframe for downstream.

4.4 Effect of Coding Rate

Coding rate (or information rate) is used for error correction and it is a fractional number that expresses what part of the redundant message is actually meaningful. If the code rate is k/n for every k bits of useful information, the coder generates a total of n bits of data, of which n-k are redundant.

Open NetSim, Select Examples->Cognitive-Radio ->Effect-of-Coding-Rate



Settings done in example config file:

1. Grid length→500m*500m
2. Base station Interface properties: Coding Rate – 1/2
3. Set CBR application from 2 to 5
4. Wireless link properties – No pathloss
5. Simulation time → 30s

Output:

Sample	Coding Rate	Throughput (Mbps)
1	1/2	0.8218
2	2/3	0.9573
3	3/4	0.9576
4	5/6	1.1197

The throughput for sample2 is more compared to sample1 since the number of data bits are increasing but the number of redundant bits are same. In Sample1, the coding rate is 1/2 for every 1 bit of useful information, the coder generates a total of 2 bits of data, of which 2-1 = 1 bit is redundant. Similarly, if coding rate is 2/3 for every 2 bits of data, the coder generates 1 redundant bit and vice versa.

5 Reference Documents

IEEE 802.22 - 2011 Standard for Wireless Regional Area Network (WRAN)

6 Latest FAQs

Up to date FAQs on NetSim's Cognitive Radio library is available at https://tetcos.freshdesk.com/support/solutions/folders/14000105116