# QualNet Network Simulator 5G Experiments

5G Model provides high fidelity simulation of 5G cellular networks.

- The following entities are supported in the 5G Core model: -
  - 5G Node B (gNB)
  - UE (Mobile Station)
  - Authentication Server Function (AUSF)
  - Core Access and Mobility Management Function (AMF)
  - Session Management Function (SMF)
  - Unified Data Management (UDM)
  - User Plane Function (UPF)
  - Data Network (DN)

## 1. Experiment to simulate 5G Core Network with gNB and UE.

To design and analysis of 5G network from gNB and UE using Qualnet Simulator.

## Procedures to Create Scenario: -

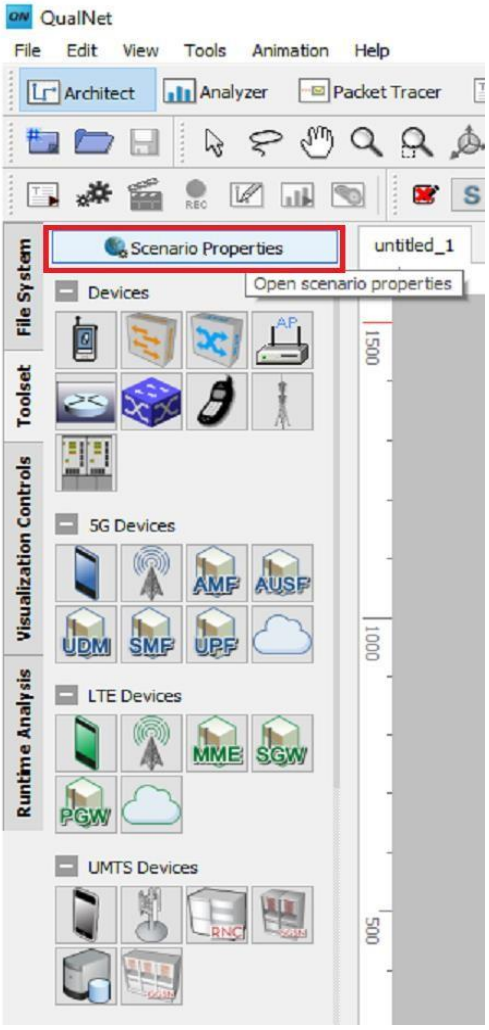
### Step1: -

- Start the QualNet GUI.
- To start, Double-click on the QualNet GUI icon on the Desktop.

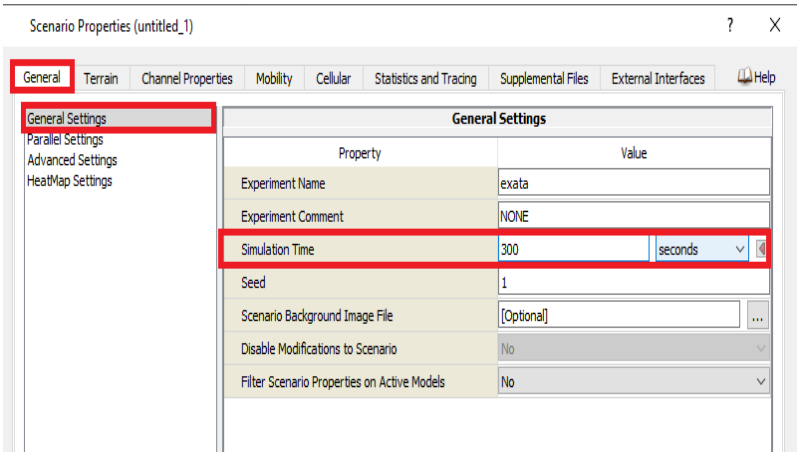
## Step 2: -

- Check the terrain size before placing the components on the canvas area.

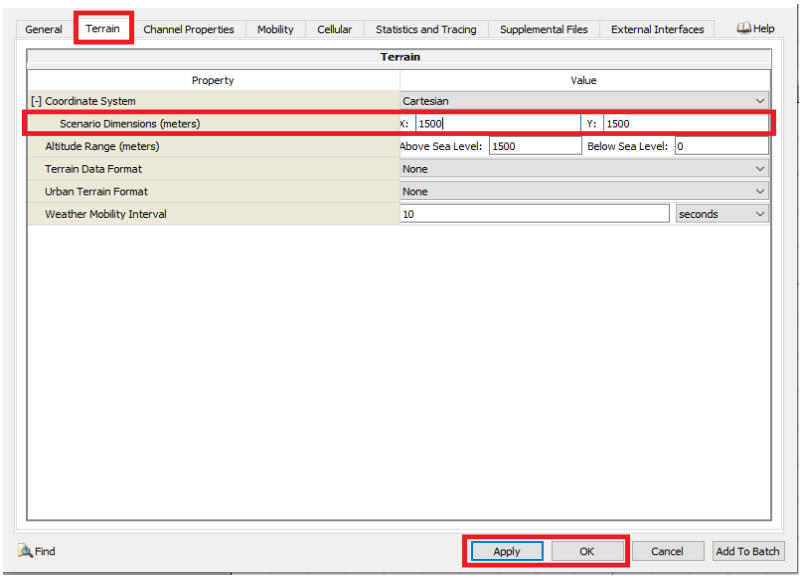
- Click on the '**Scenario Properties**' button in the toolset panel.




- Click on '**General**' button on the top of the newly opened editor. Click on > General Settings > Simulation Time to **300 sec.**

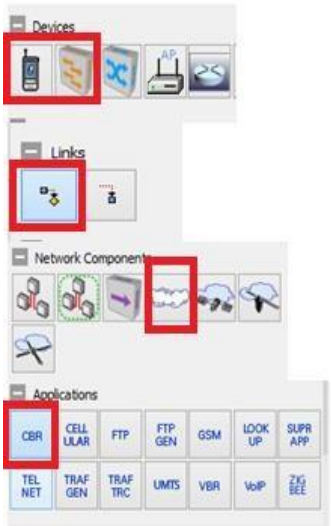


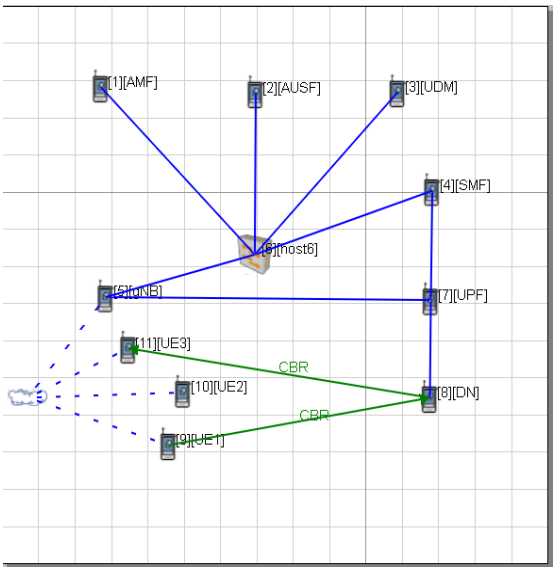
- Click on **'Terrain'** set scenario dimensions as (x:1500 and y:1500) > Apply > OK.




**Step 3:** -To create a scenario, choose the components required from toolset and place it on the canvas using drag-drop as shown in figure.

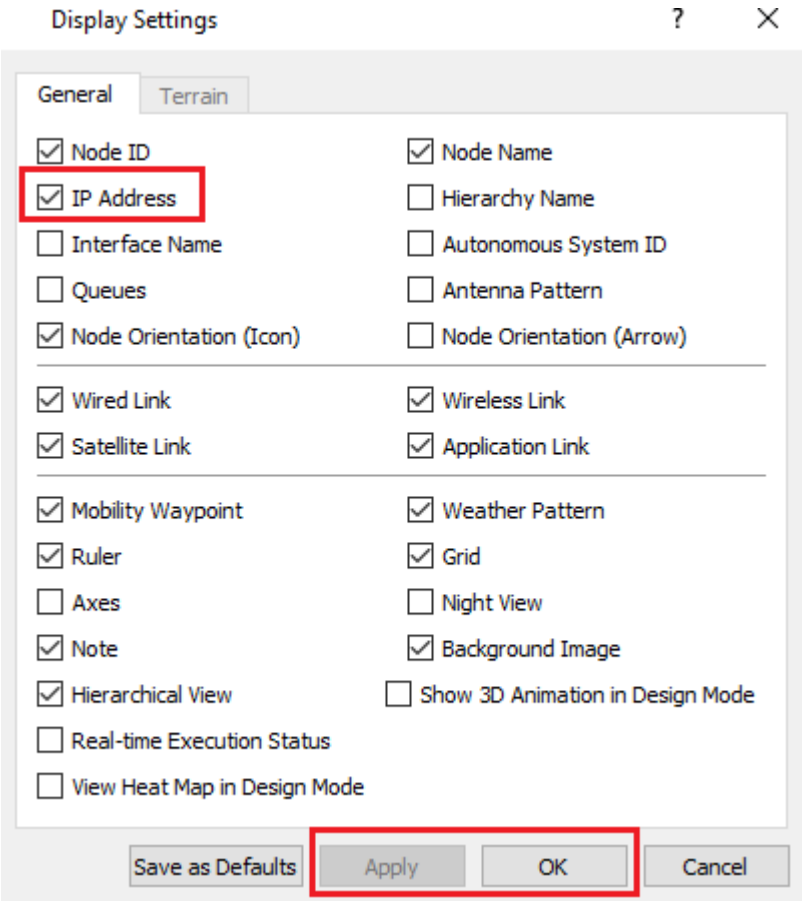
- components
- Links
- Wireless subnet
- CBR application



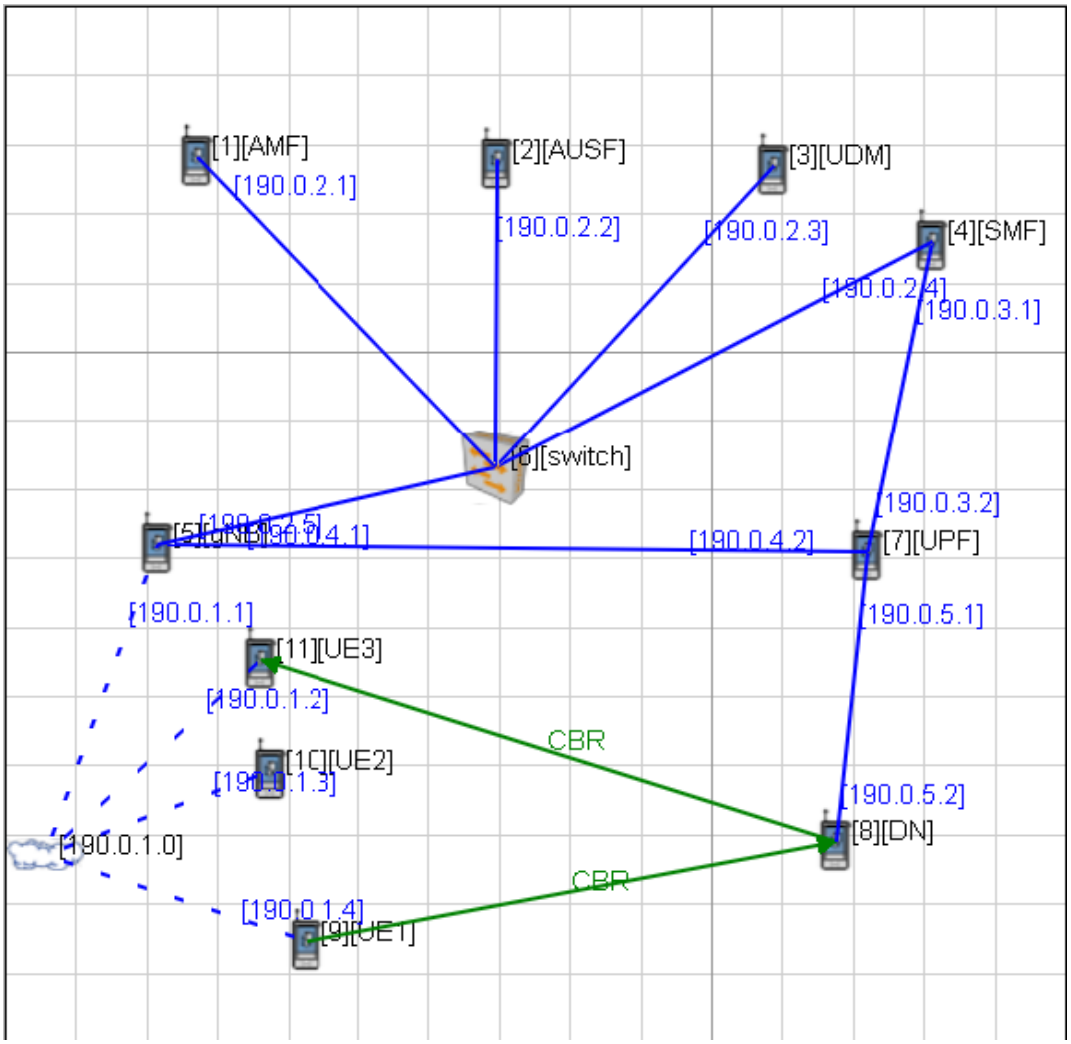
- To View Node interface IP Address > Click on Open Display settings.

- On opened Display Settings window > Enable IP Address > Click on Apply > Ok.



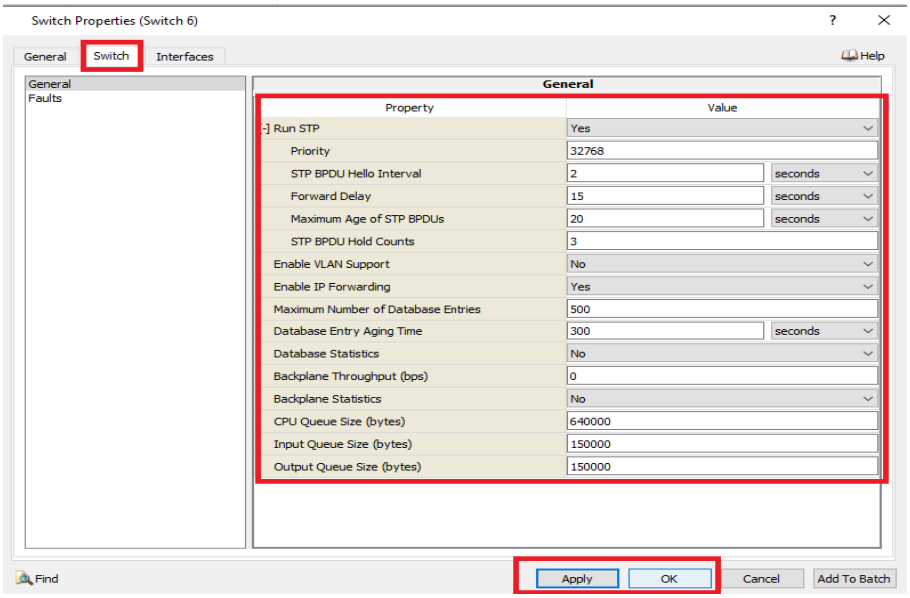
- **Create the scenario topology as shown in below figure.**

  Below Figure shows the IP addresses of the interfaces in the scenario. The IP addresses depend on the order in which nodes, subnets, and connections are created and may be different in your scenario from the ones shown in the figure. We will use these addresses in the configuration steps below.



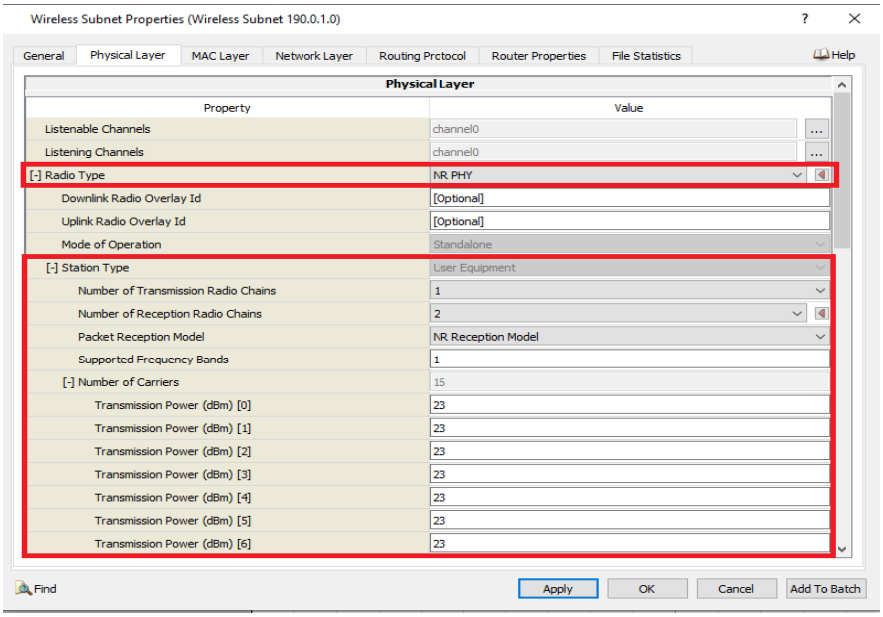
**Step 4:-** To configure the scenario in QualNet GUI, perform the following steps:

**(1).** To Configure the **Switch**, Double Click on Switch > go to Switch and set Run STP to **Yes** and use default values for all other parameter > Apply > OK.

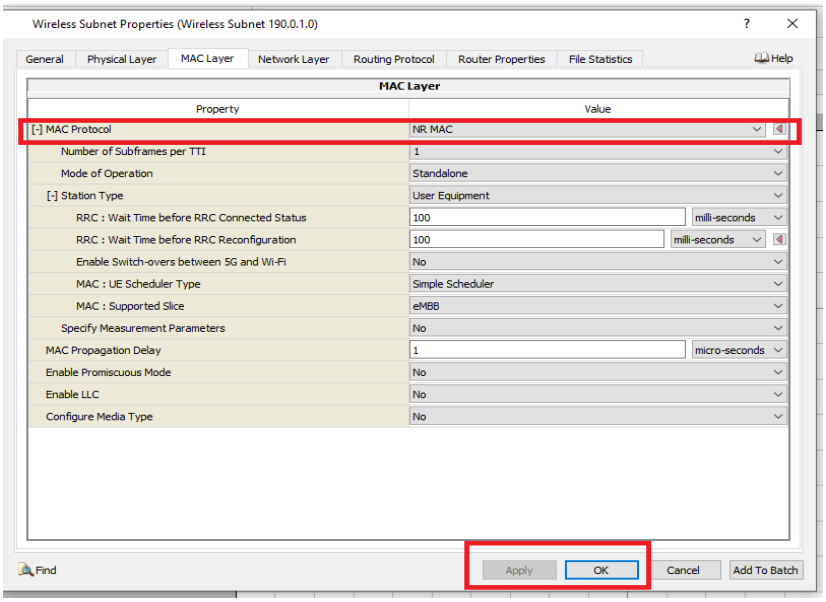



**(2).** To Configure the **wireless subnet** :-

- Double Click On wireless subnet > Go to Physical Layer
  - **i.** Set Radio Type to NR PHY.
  - **ii.** Use default values for all other PHY parameters.

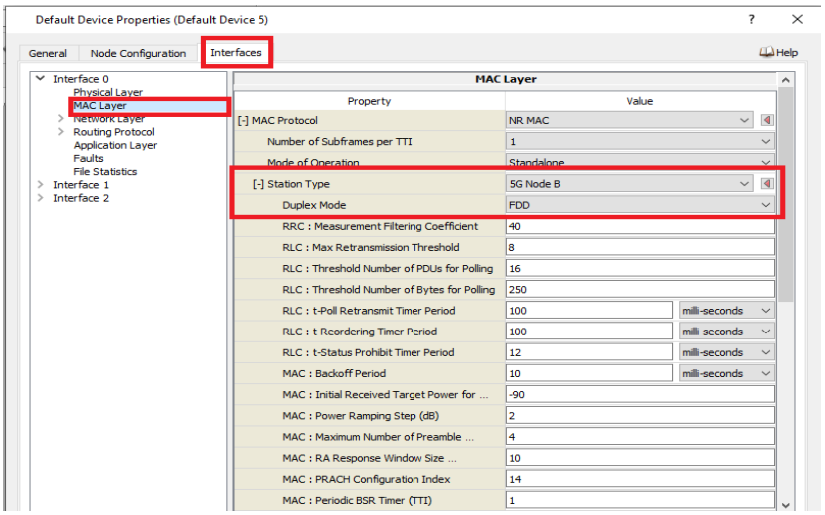


- Go to MAC Layer
  - **i.** Set MAC Protocol to NR MAC.
  - **ii.** Use default values for all MAC parameters
  - **iii.** Click on Apply > OK.

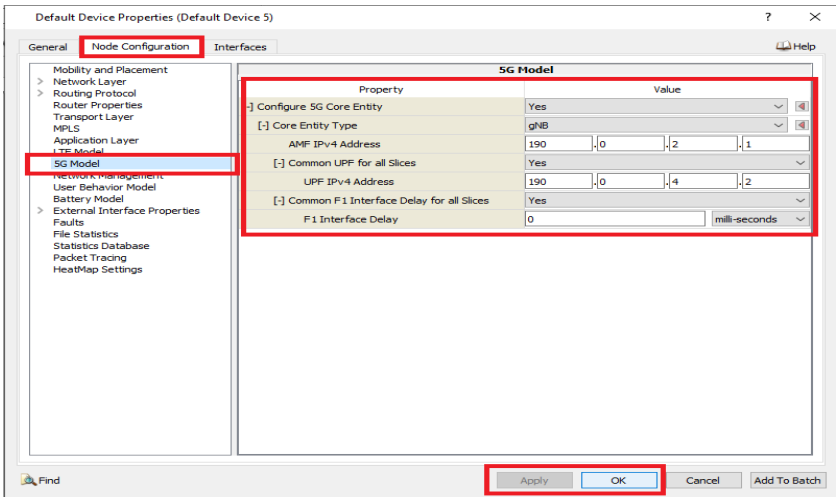



**(3).** To Configure Node 5 (**gNB**):-

- Double Click On Node 5 > Interfaces > Interface 0 > MAC Layer (Make sure that Interface 0 corresponds to the wireless interface of the node).
  - **i.** Set **Station Type** to 5g Node B.
  - **ii.** Set Duplex Mode to FDD.
  - **iii.** Use default values for all other interface parameters.

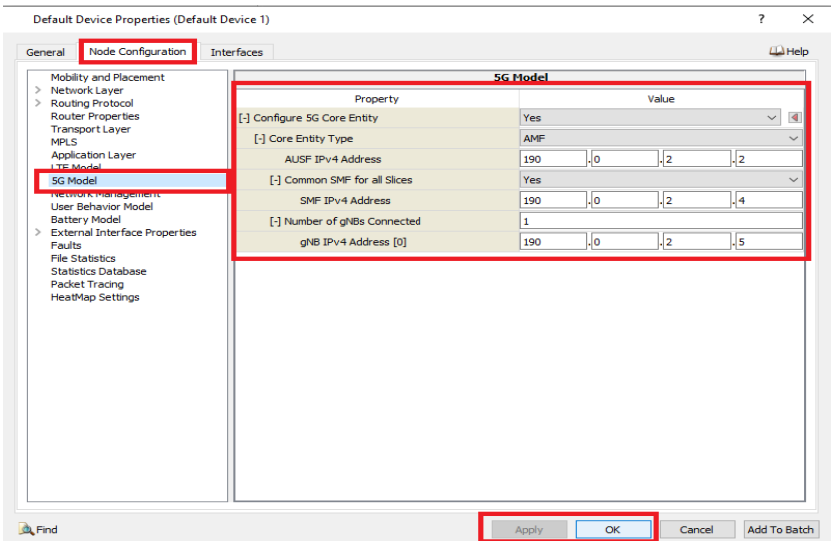


- Click On > Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to gNB.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UPF IPv4 Address to 190.0.4.2
  - **iv.** Click On Apply > OK



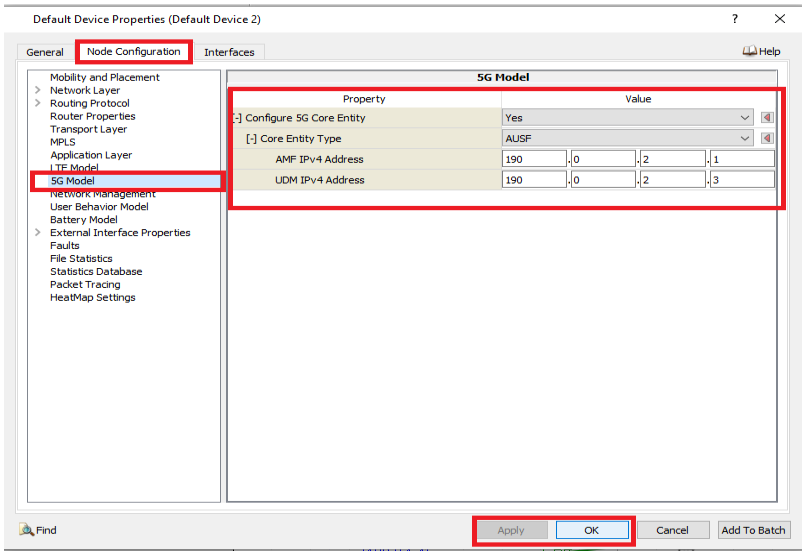

**(4).** To Configure Node 1 **(AMF)**:-

- Double Click On Node 1 > Go to Node Configuration > 5G Model .
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to AMF.
  - **ii.** Set AUSF IPv4 Address to 190.0.2.2
  - **iii.** Set SMF IPv4 Address to 190.0.2.4
  - **iv.** Set Number of gNBs Connected to 1
  - **v.** Set gNB IPv4 Address [0] to 190.0.2.5
  - **vi.** Click On Apply > Ok



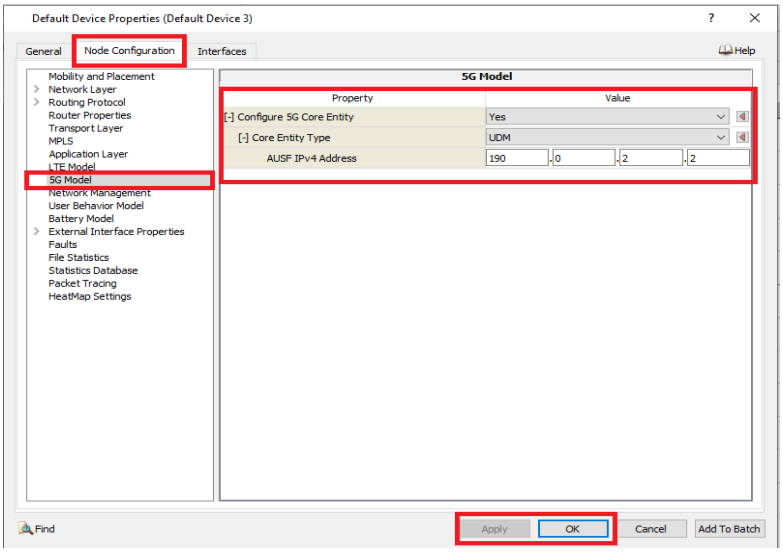
**(5).** To Configure Node 2 **(AUSF):-**

- Double Click On Node 2 > Go to Node Configuration > 5G Model .
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to AUSF.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UDM IPv4 Address to 190.0.2.3
  - **iv.** Click On Apply > OK



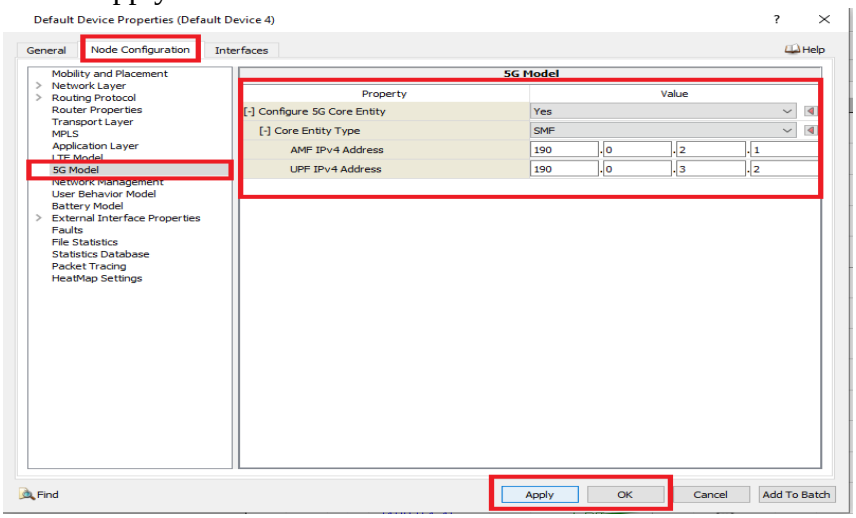

**(6).** To Configure Node 3 **(UDM)**:-

- Double Click On Node 3 > Go to Node Configuration > 5G Model.
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to UDM.
  - **ii.** Set AUSF IPv4 Address to 190.0.2.2
  - **iii.** Click On Apply > OK



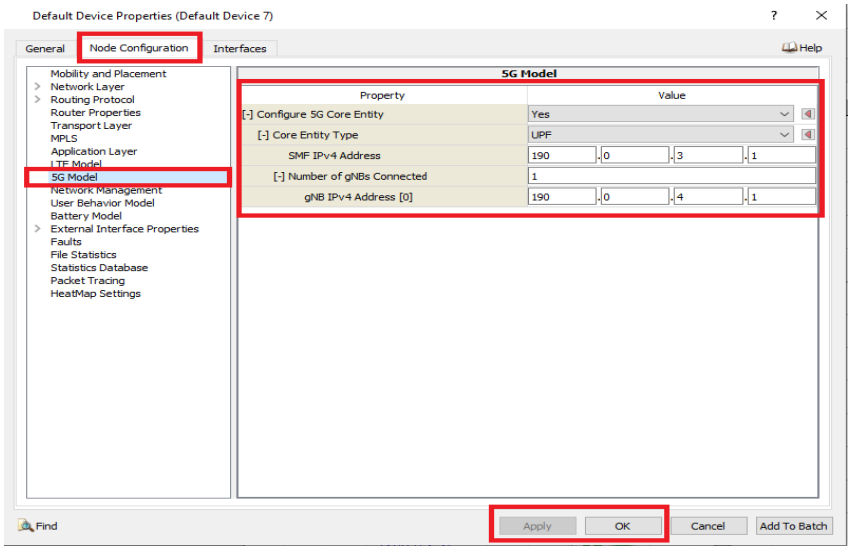
**(7).** To Configure Node 4 **(SMF)**:-

- Double Click On Node 4 > Go to Node Configuration > 5G Model .
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to SMF.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UPF IPv4 Address to 190.0.3.2
  - **iv.** Click On Apply > OK



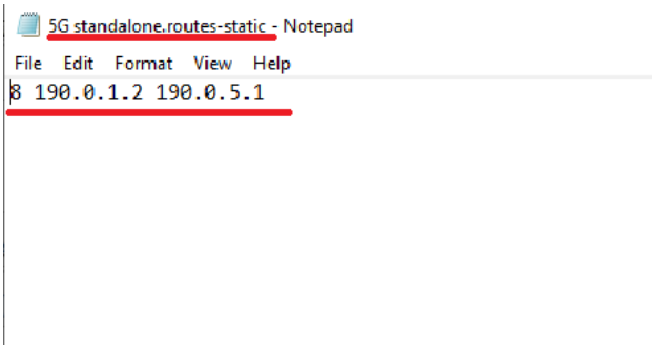

**(8).** To Configure Node 7 **(UPF)**:-

- Double Click On Node 7 > Go to Node Configuration > 5G Model.
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to UPF.
  - **ii.** Set SMF IPv4 Address to 190.0.3.1
  - **iii.** Set Number of gNBs Connected to 1
  - **iv.** Set gNB IPv4 Address [0] to 190.0.4.1
  - **v.** Click On Appy > OK

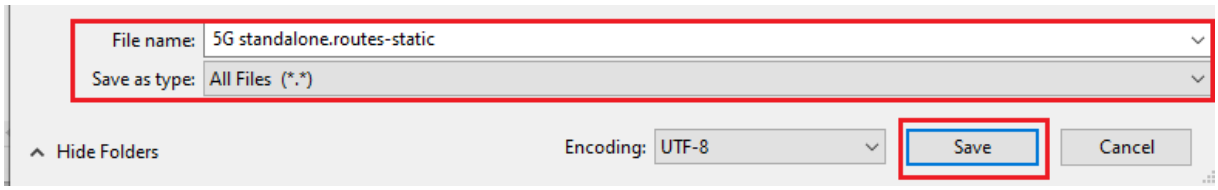


**(9).** To Configure Node 8 **(DN)**: -

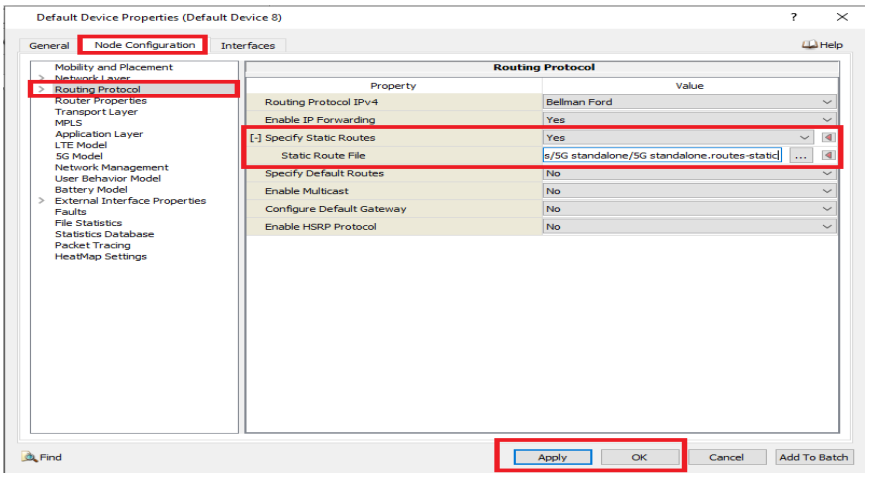
- Double Click On Node 8 > Go to Node Configuration > Routing Protocol.
  - **i.** Set Specify Static Routes to Yes.
  - **ii.** Create a file in Notepad called **Filename.routes-static** in the scenario directory which contains the static route from the DN to the UE.
  - **iii.** In the Static Routes file, **Filename.routes-static**, specify the routes as follows:-
    <Node Id of DN> <IP-ADDRESS of UE> < Next Hop IP Address/IP of UPF >
    8 190.0.1.2 190.0.5.1




**Note:-**Make sure while saving the file ,The extension is **.routes-static** and the save as type should be **All Files**

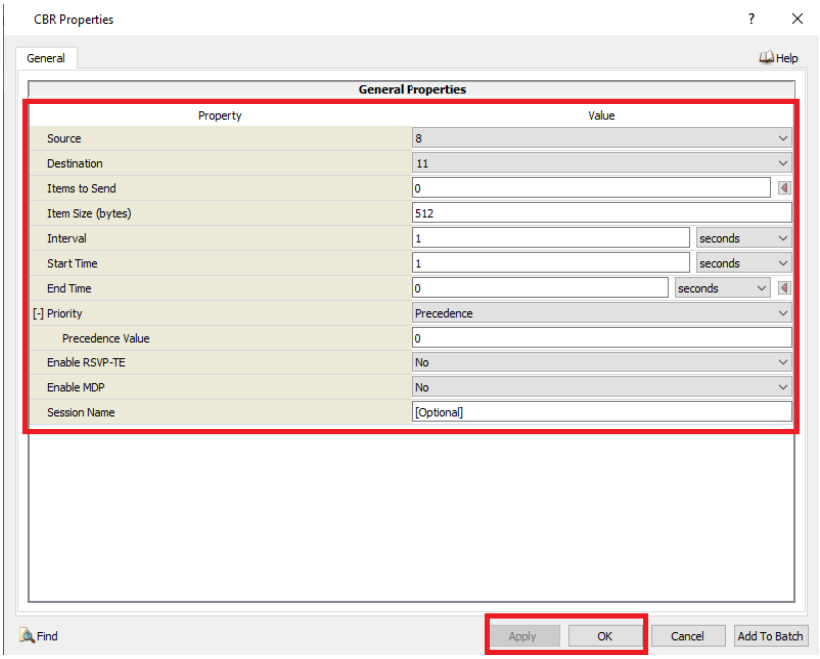



- **iv.** To Set Static Route File > Click on Select files and select **Filename.routes-static**
- **v.** Click On Apply > OK



**(10).** To set the properties of the CBR Application, do the following:-

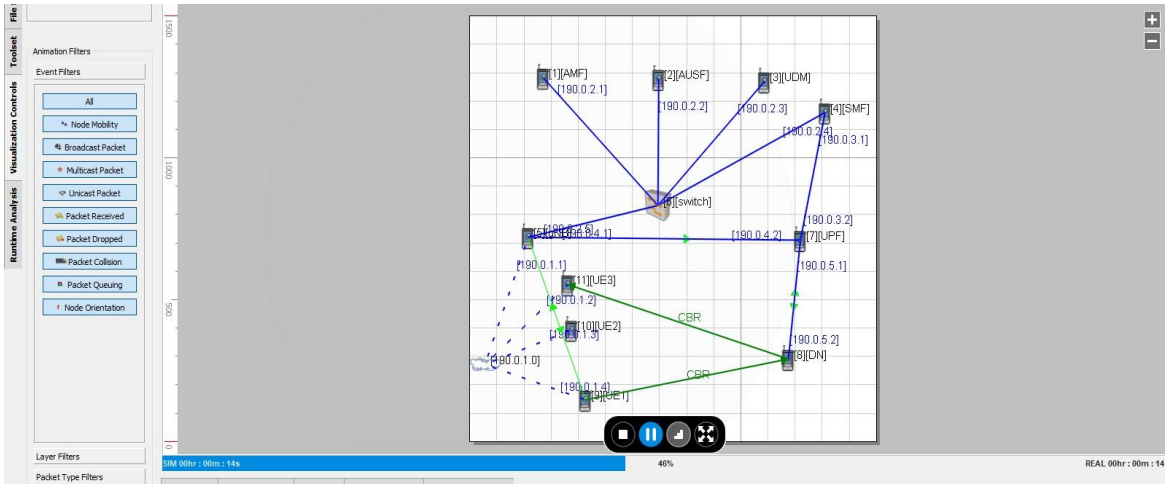
- Double-click the CBR link on the canvas.
- In the CBR Properties Editor, set the parameters as shown below
- Click On Apply > OK.
- Repeat the above Steps for other CBR application



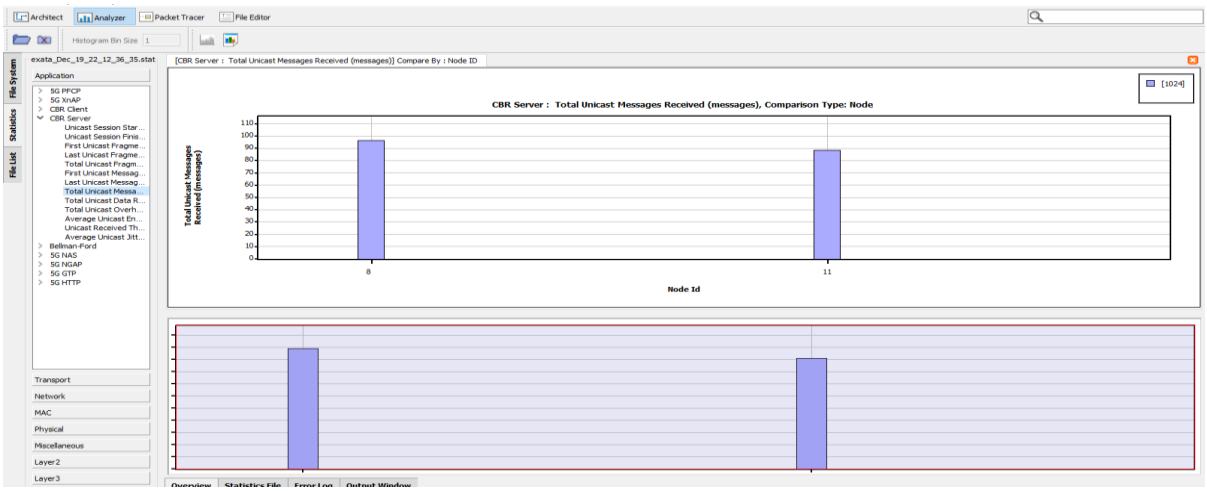

**Step5:** Save the scenario by clicking the Save button in the toolbar.

**Step6:** Click the Run Simulation button.

**Step7**: To start the simulation, click the **Play** button at the bottom of the canvas.



**Step8**: After the simulation has completed, switch to Analyzer by clicking the Analyze Results button. In the analyzer the performance parameter of the current scenario and the layer wise communication can be seen. Number of packets received, throughput, jitter, end to end delay, client and the server performance etc. can be analyzed.



## 2. Experiment for comparing the pathloss models.

To design and analysis of Path loss propagation models in 5G network using Qualnet Simulator.

**Please refer "chapter 2 propagation models" in wireless model library For more details on pathloss model.**

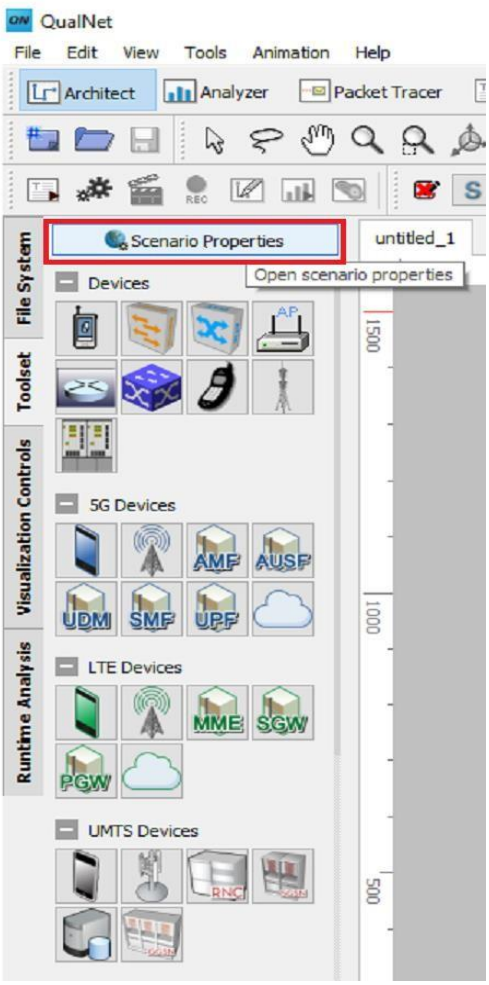
## Procedures to Create Scenario :-

### Step1: -

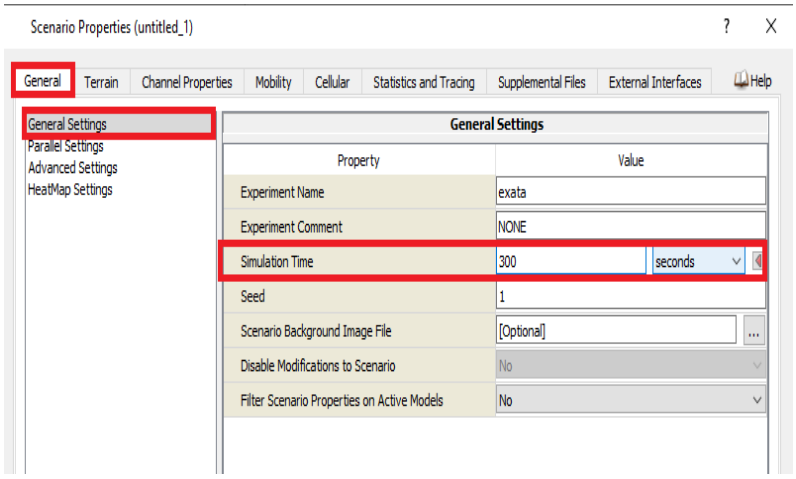
- Start the QualNet GUI.
- To start, Double-click on the QualNet GUI icon on the Desktop.

### Step 2: -

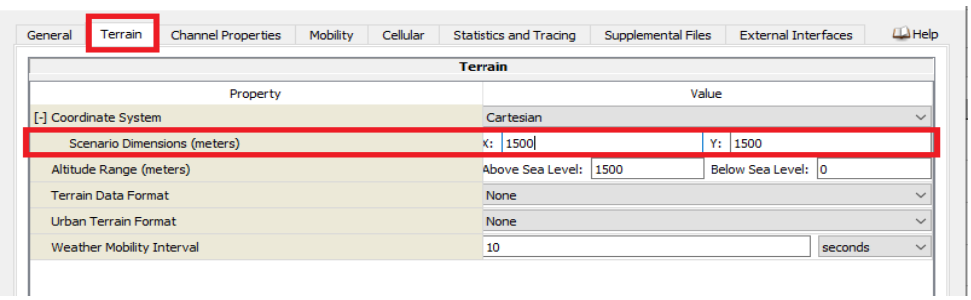
- Check the terrain size before placing the components on the Canvas area.
- Click on the '**Scenario Properties**' button in the toolset panel.



- Click on '**General**' button on the top of the newly opened editor. Click on > General Settings > Simulation Time to **300 sec.**

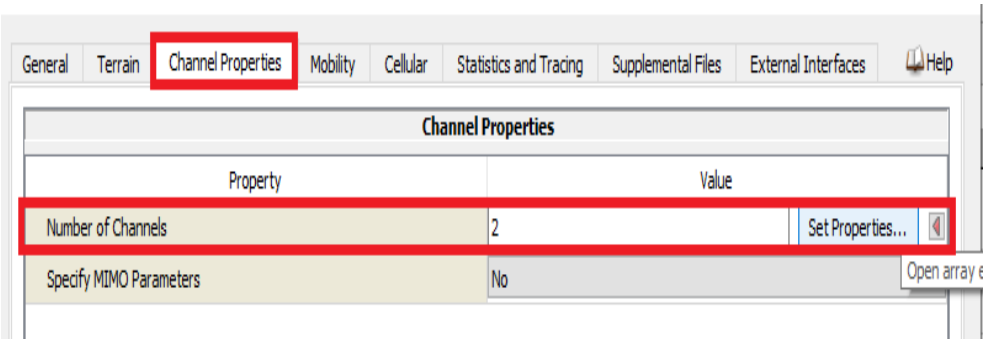



- Click on **'Terrain'** set scenario dimensions as (x:1500 and y:1500).

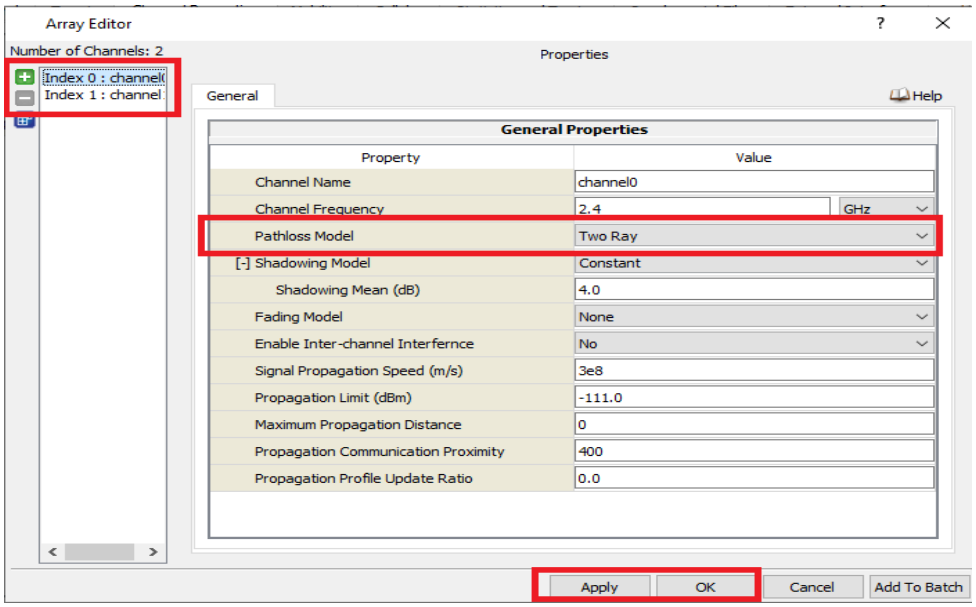



## Step 3:-

- Click on '**Channel properties**' button on the top > Set Number of channels to 2 > click on set properties.

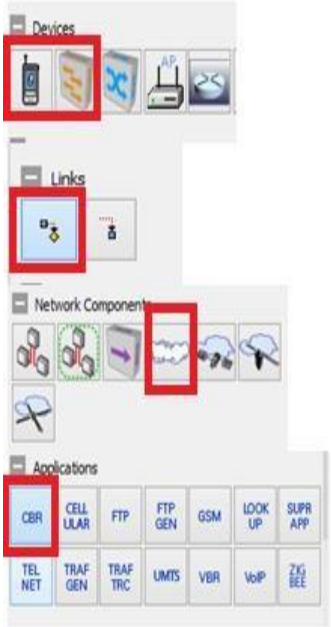


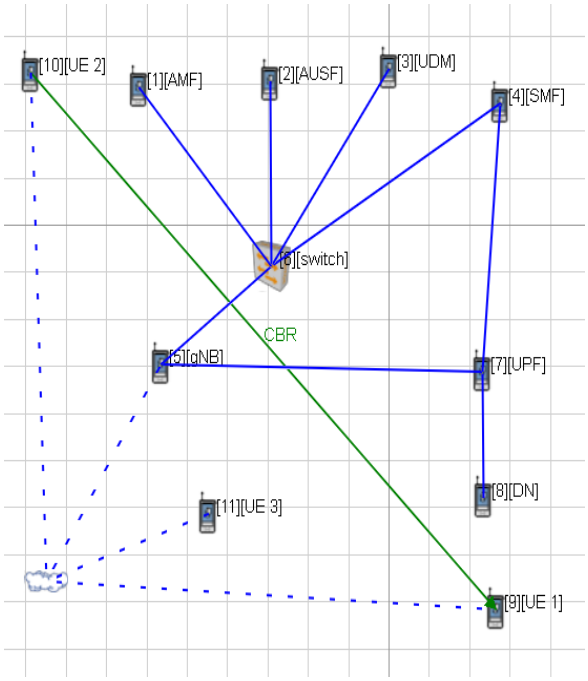
- Click on '**Index 0:channel 0**' button on the top of the newly opened Array editor > set Pathloss Model to **Two Ray** .
- Repeat the above step for **'Index 1 : channel 1'** , Apply > Ok.




**Step 4:** -To create a scenario, choose the components required from toolset and place it on the canvas using drag-drop as shown in figure.

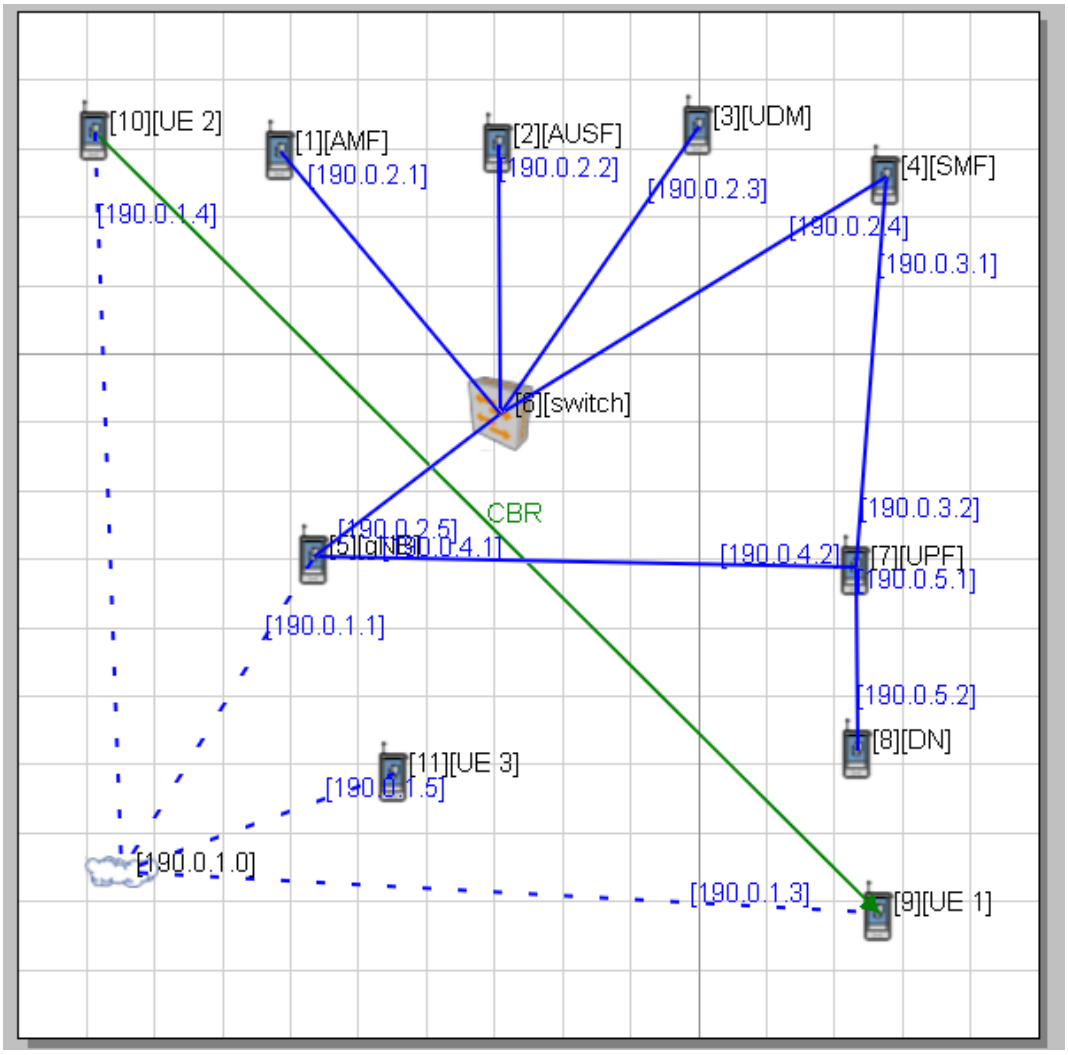
- components
- Links
- Wireless subnet
- CBR application



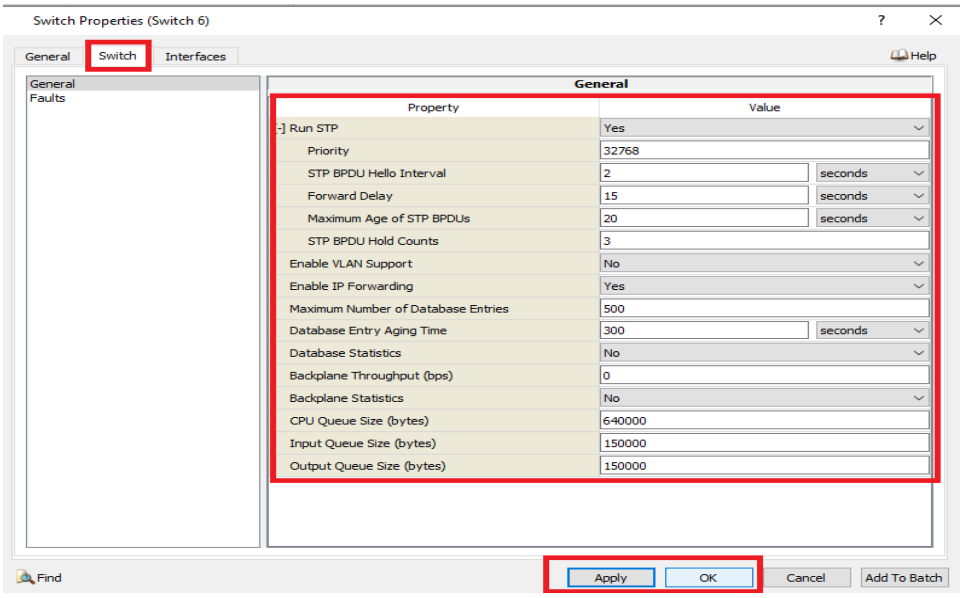
- **Create the scenario topology as shown in below figure.**

  Below Figure shows the IP addresses of the interfaces in the scenario. The IP addresses depend on the order in which nodes, subnets, and connections are created and may be different in your scenario from the ones shown in the figure. We will use these addresses in the configuration steps below.



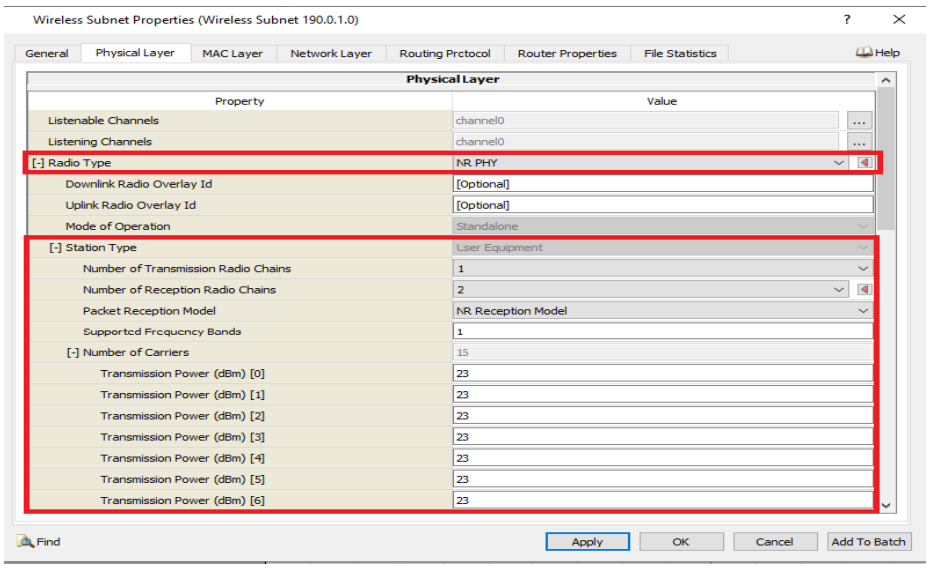
**Step 5:-** To configure the scenario in QualNet GUI, perform the following steps:

**(1).** To Configure the **Switch**, Double Click on Switch > go to Switch and set Run STP to **Yes** and use default values for all other parameter > Apply > OK.

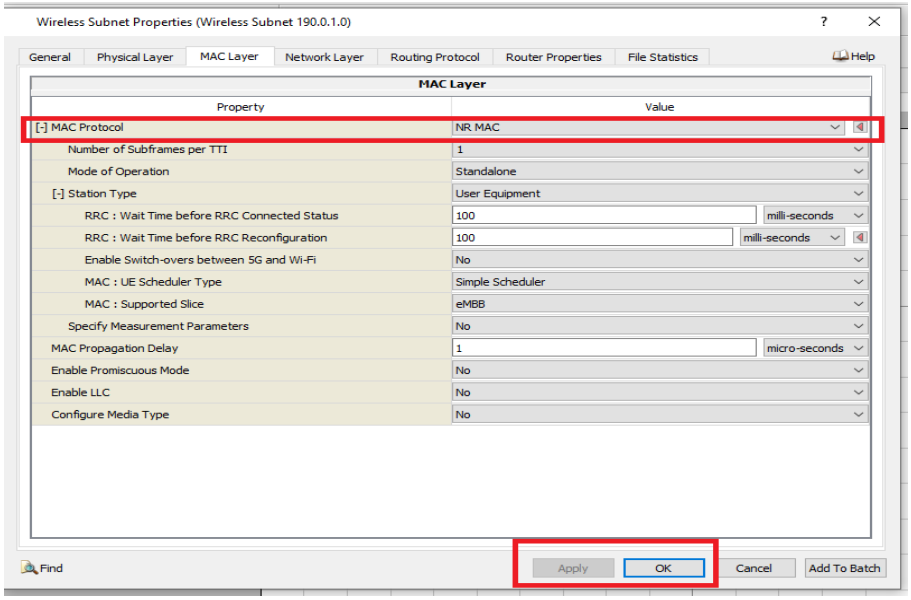



**(2).** To Configure the **wireless subnet**:-

- Double Click on Wireless Subnet > Go to Physical Layer
  - **i.** Set Radio Type to NR PHY.
  - **ii.** Use default values for all other PHY parameters.

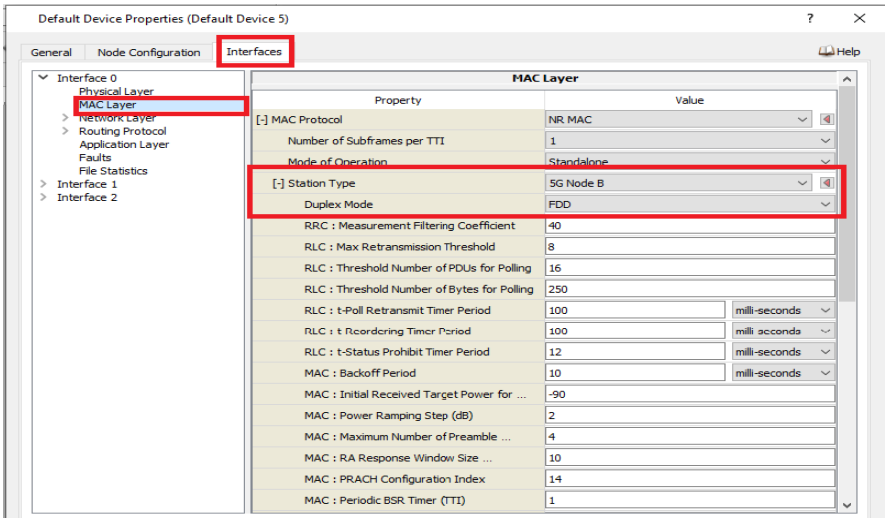


- Go to MAC Layer
  - **i.** Set MAC Protocol to NR MAC.
  - **ii.** Use default values for all MAC parameters.
  - **iii.** Click on Apply > OK

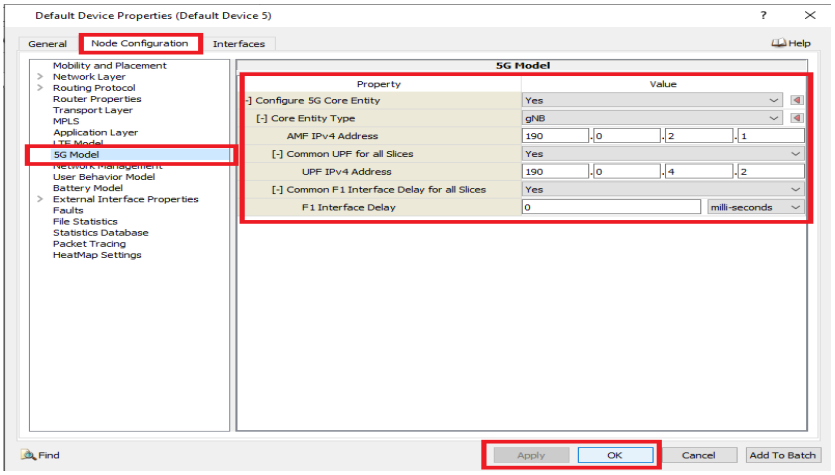



**(3).** To Configure Node 5 (**gNB**):-

- Double Click on Node 5 > Interfaces > Interface 0 > MAC Layer (Make sure that Interface 0 corresponds to the wireless interface of the node).
  - **i.** Set **Station Type** to 5g Node B.
  - **ii.** Set Duplex Mode to FDD.
  - **iii.** Use default values for all other interface parameters.

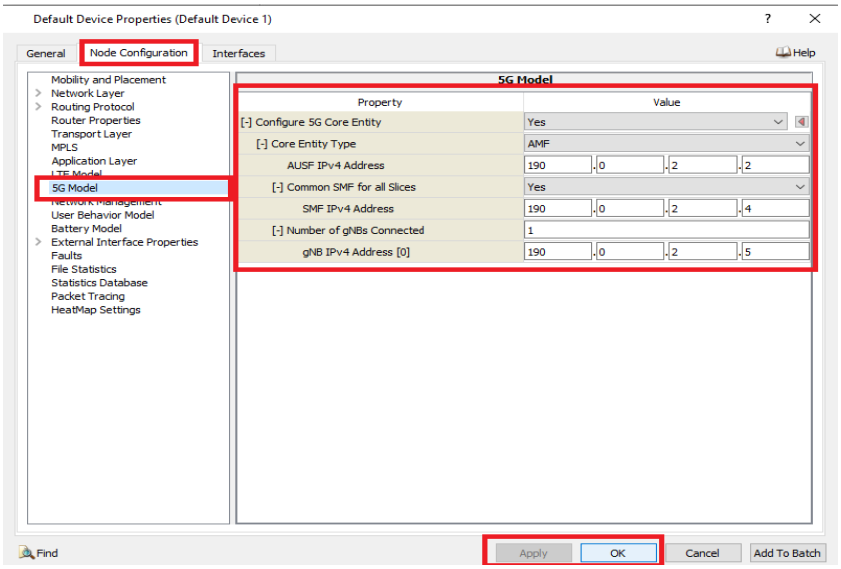


- Click on > Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to gNB.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UPF IPv4 Address to 190.0.4.2
  - **iv.** Click on Apply > OK



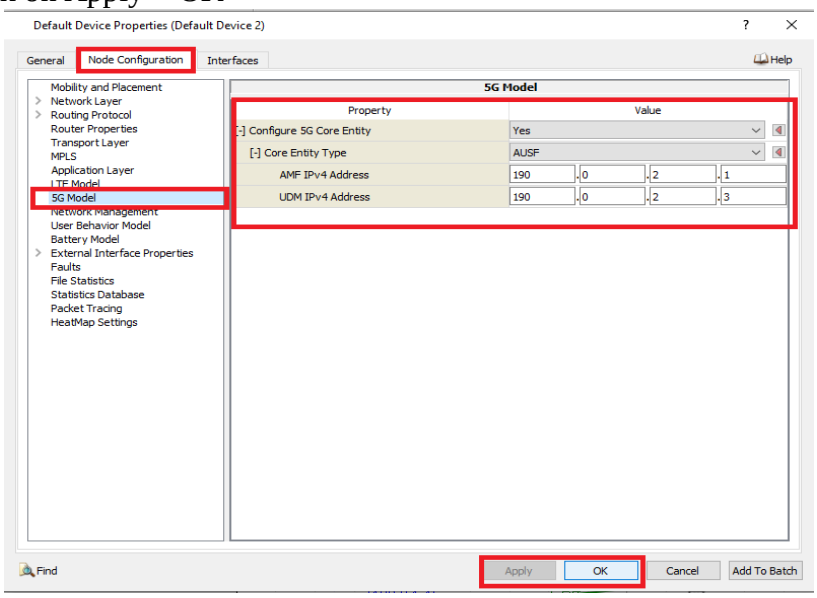

**(4).** To Configure Node 1 **(AMF)**:-

- Double Click on Node 1 > Go to Node Configuration > 5G Model .
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to AMF.
  - **ii.** Set AUSF IPv4 Address to 190.0.2.2
  - **iii.** Set SMF IPv4 Address to 190.0.2.4
  - **iv.** Set Number of gNBs Connected to 1
  - **v.** Set gNB IPv4 Address [0] to 190.0.2.5
  - **vi.** Click on Apply > OK



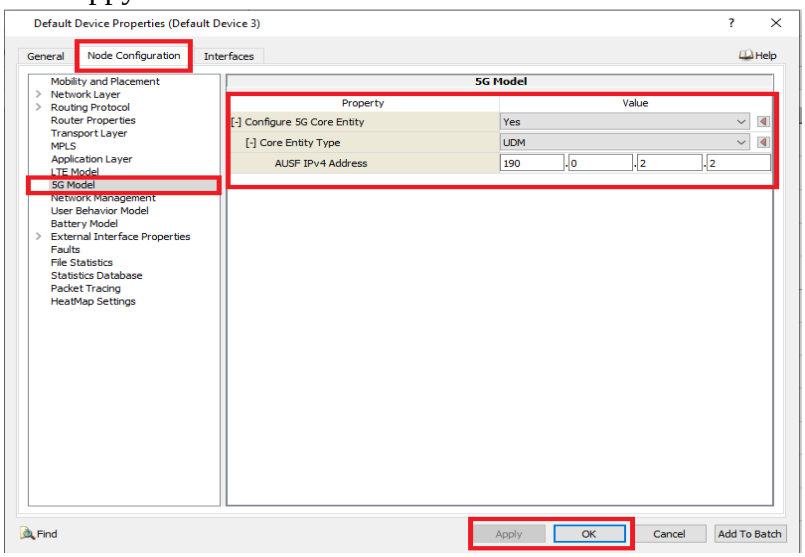
**(5).** To Configure Node 2 **(AUSF):-**

- Double Click on Node 2 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to AUSF.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UDM IPv4 Address to 190.0.2.3
  - **iv.** Click on Apply > OK



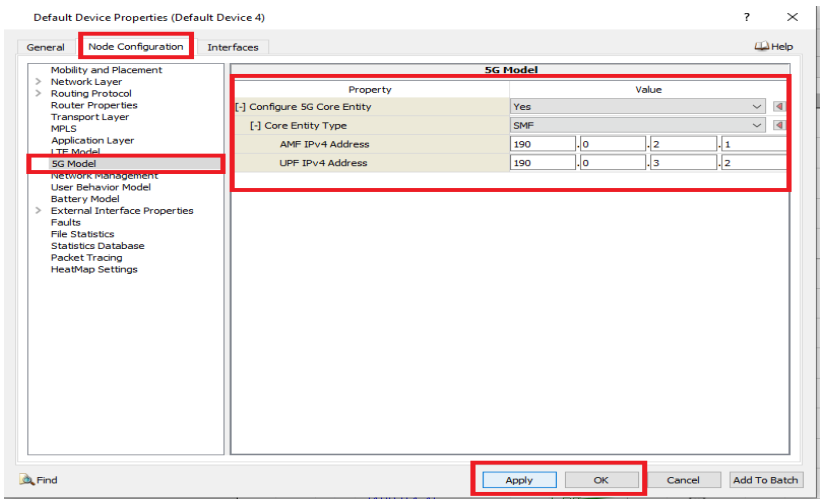

**(6).** To Configure Node 3 **(UDM)**:-

- Double Click on Node 3 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to UDM.
  - **ii.** Set AUSF IPv4 Address to 190.0.2.2
  - **iii.** Click on Appy > OK



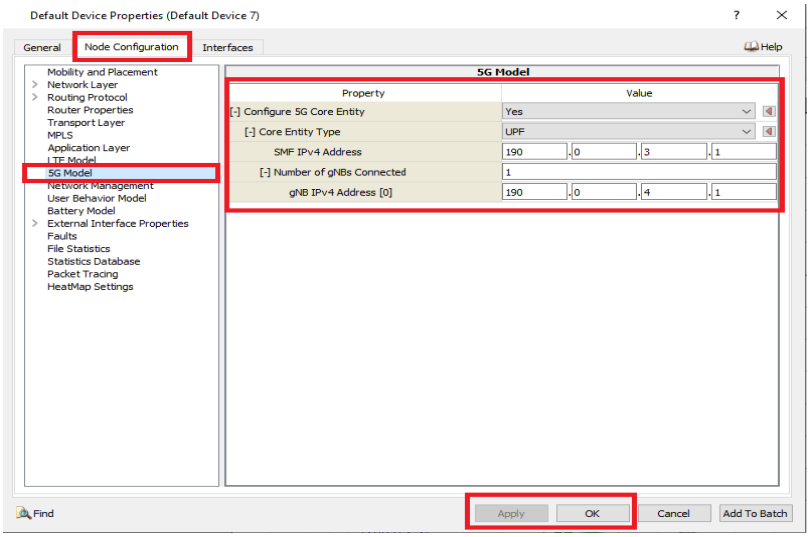
**(7).** To Configure Node 4 **(SMF)**:-

- Double Click on Node 4 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to SMF.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UPF IPv4 Address to 190.0.3.2
  - **iv.** Click on > Apply > OK



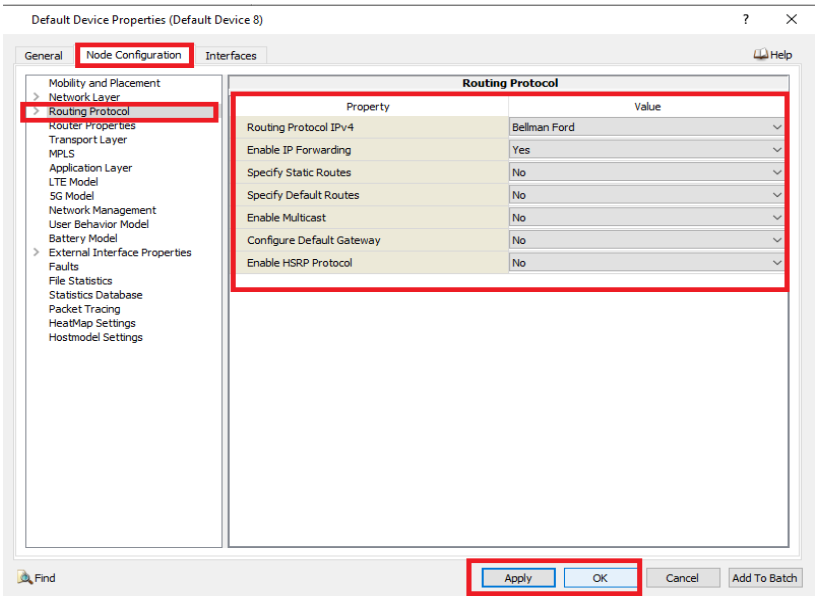

**(8).** To Configure Node 7 **(UPF)**:-

- Double Click on Node 7 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to UPF.
  - **ii.** Set SMF IPv4 Address to 190.0.3.1
  - **iii.** Set Number of gNBs Connected to 1
  - **iv.** Set gNB IPv4 Address [0] to 190.0.4.1
  - **v.** Click on > Apply > OK



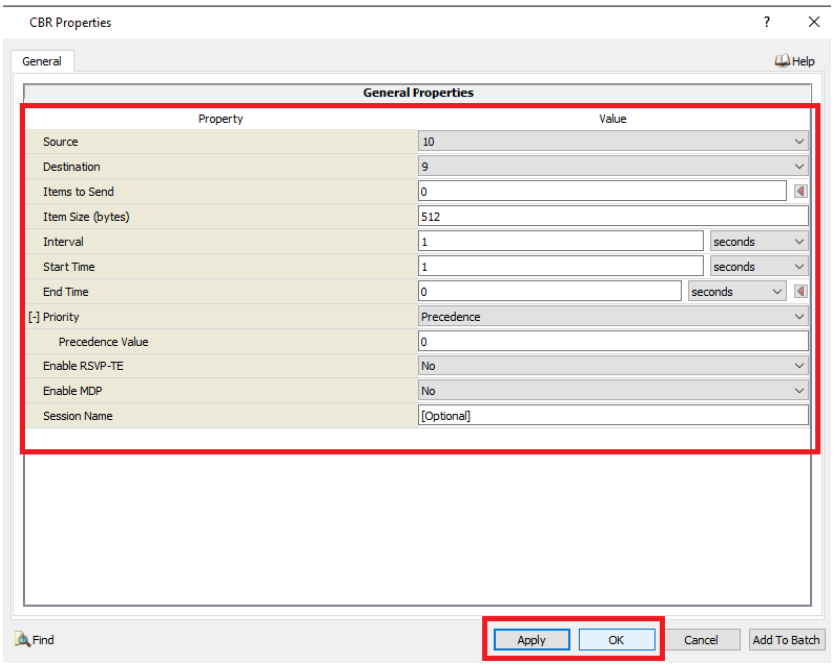
**(9).** To Configure Node 8 **(DN)**: -

- Double Click on Node 8 > Go to Node Configuration > Routing Protocol > use default values as shown in the figure > Apply > OK




**(10).** To set the properties of the CBR Application, do the following:-

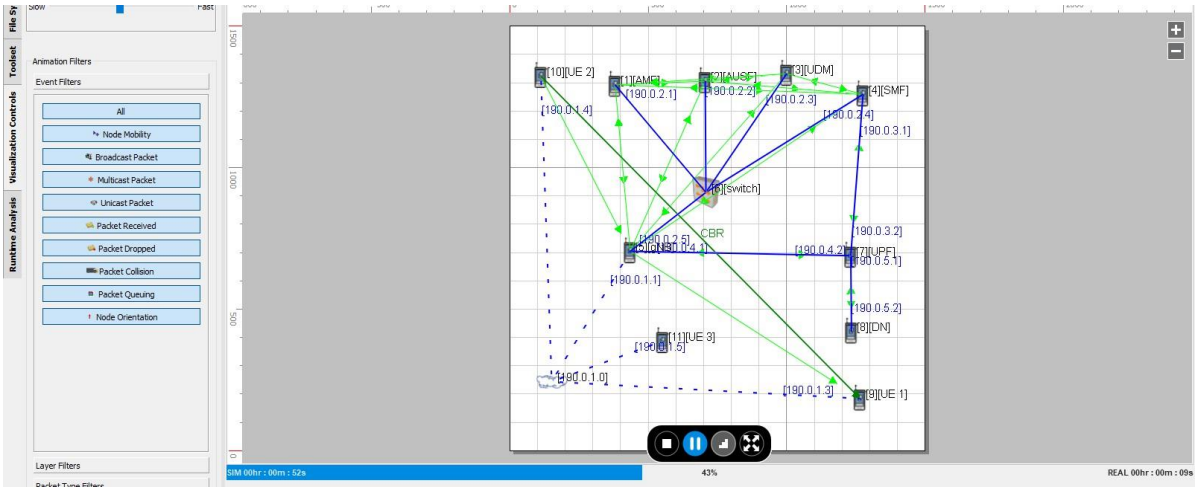
- Double-click the CBR link on the canvas.
- In the CBR Properties Editor, set the parameters as shown below
- Click On Apply > OK.



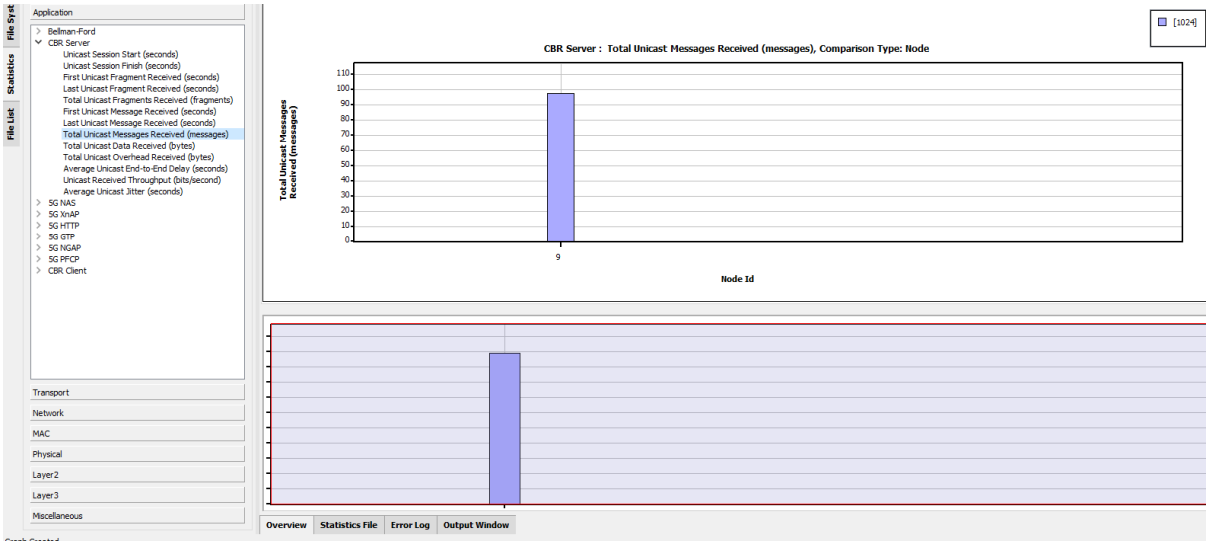
**Step 6:** Save the scenario by clicking the Save button in the toolbar.

**Step 7:** Initialize the scenario by clicking the Run Simulation button. This changes to the mode of Architect from Design mode to Visualize mode.

**Step 8**: To start the simulation, click the **Play** button at the bottom of the canvas.




**Step 9**: After the simulation has completed, switch to Analyzer by clicking the Analyze Results button. In the analyzer the performance parameter of the current scenario and the layer wise communication can be seen. Number of packets received, throughput, jitter, end to end delay, client and the server performance etc. can be analyzed.



# 3. Simulate millimeter wave in 5G.

To design and analysis of Millimeter Wave pathloss model is a propagation model for communication in 5G network.

**Please refer "chapter 2 propagation models" - 2.8 Millimeter Wave Pathloss Model in wireless model library For more details**

## Procedures to Create Scenario :-

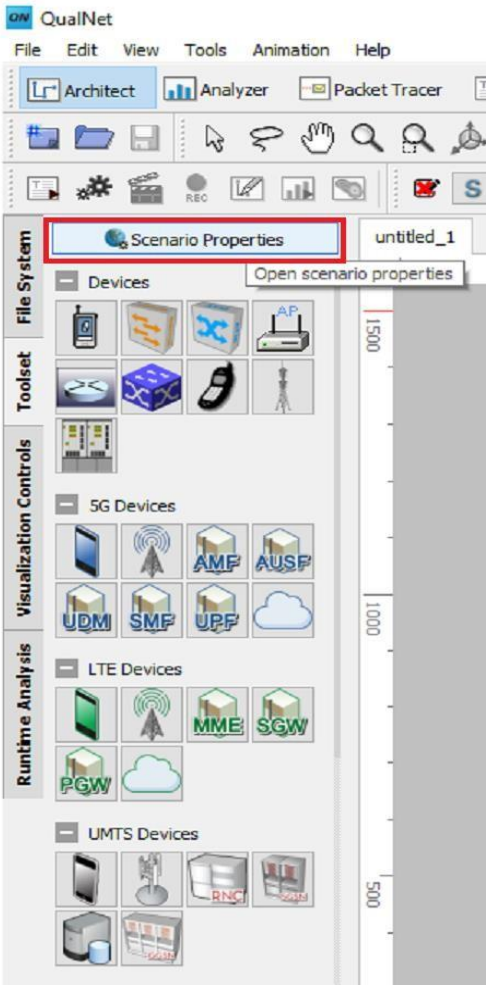
## Step1: -

- Start the QualNet GUI.
- To start, Double-click on the QualNet GUI icon on the Desktop.

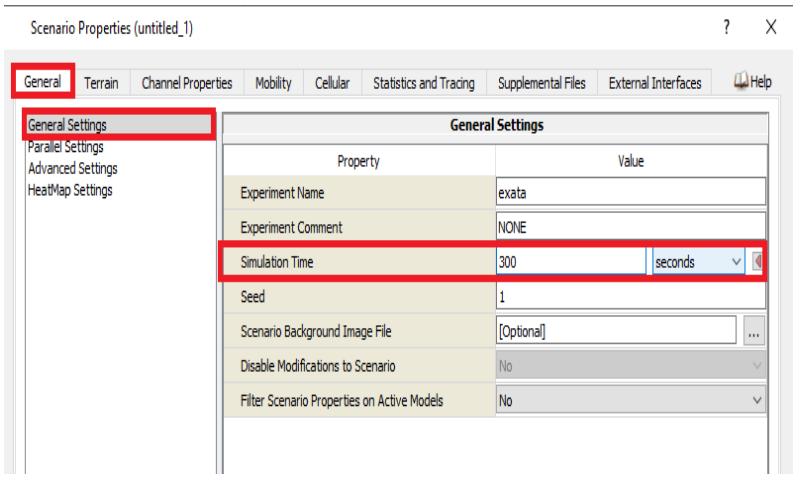
## Step 2: -

- Check the terrain size before placing the components on the canvas area.

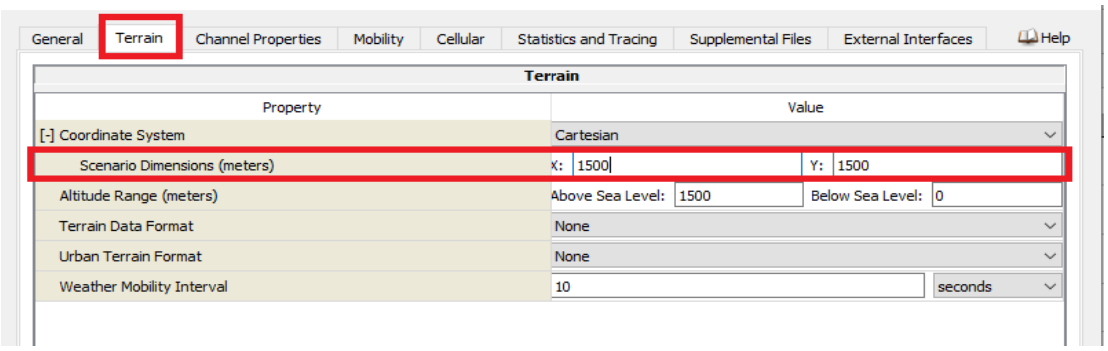
- Click on the '**Scenario Properties**' button in the toolset panel.



- Click on '**General**' button on the top of the newly opened editor. Click on > General Settings > Simulation Time to **300 sec.**

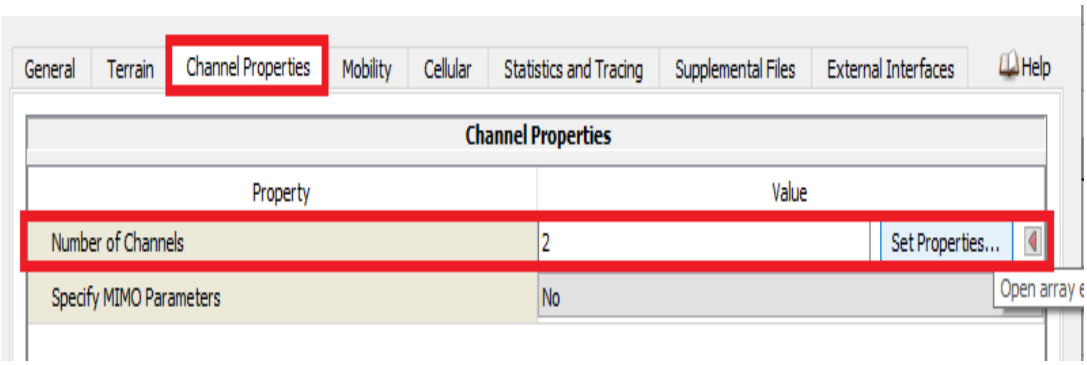



- Click on **'Terrain'** set scenario dimensions as (x:1500 and y:1500) > Apply > OK.

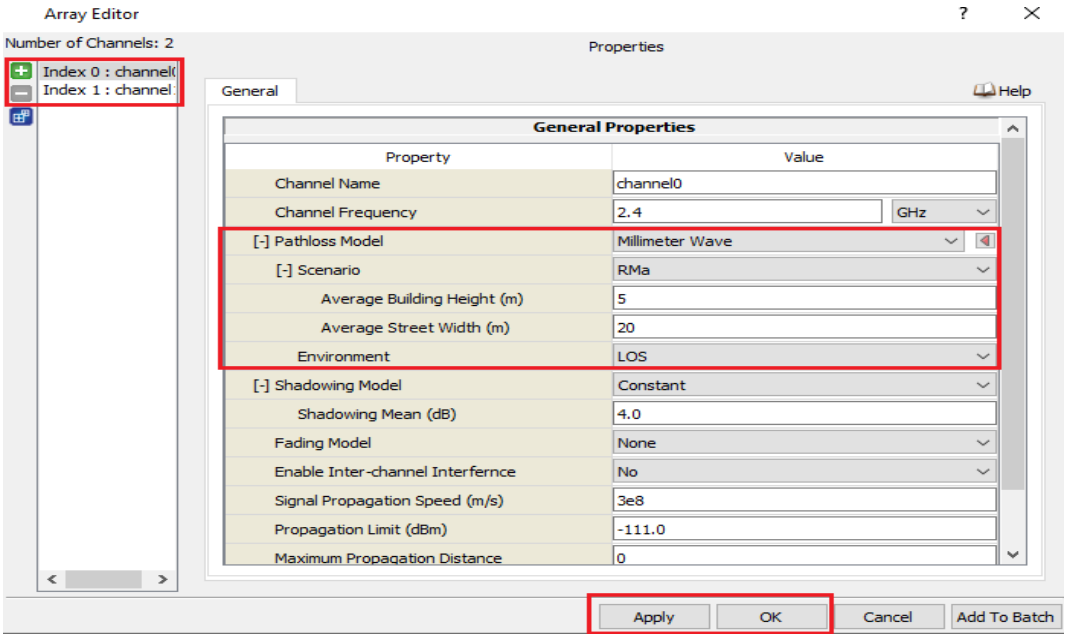



## Step 3:-

- Click on '**Channel properties**' button on the top > Set Number of channels to 2 > click on set properties.

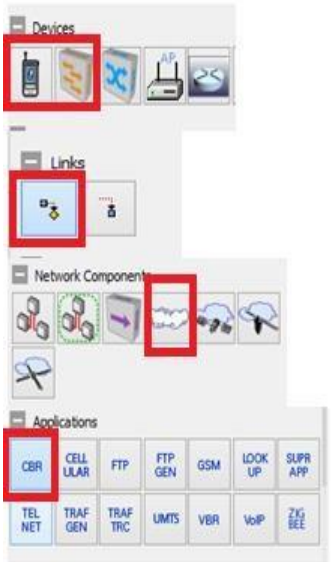


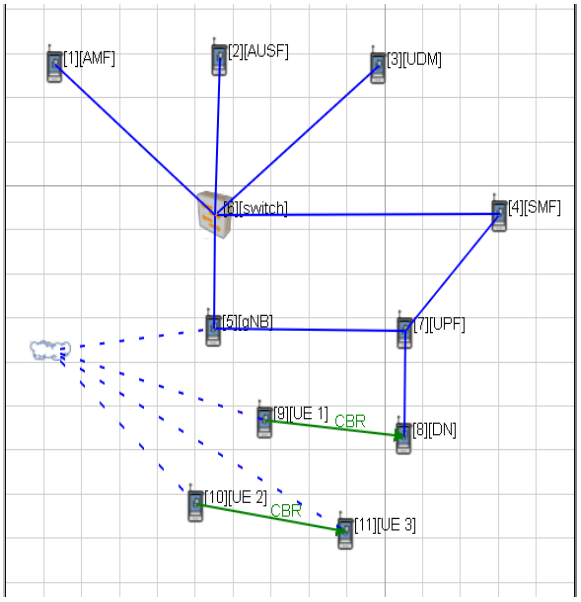
- Click on '**Index 0:channel 0**' button on the top of the newly opened Array editor > set Pathloss Model to **Millimeter Wave**
- Repeat the above step for **'Index 1 : channel 1', Apply > Ok.**




**Step 4:** -To create a scenario, choose the components required from toolset and place it on the canvas using drag-drop as shown in figure.

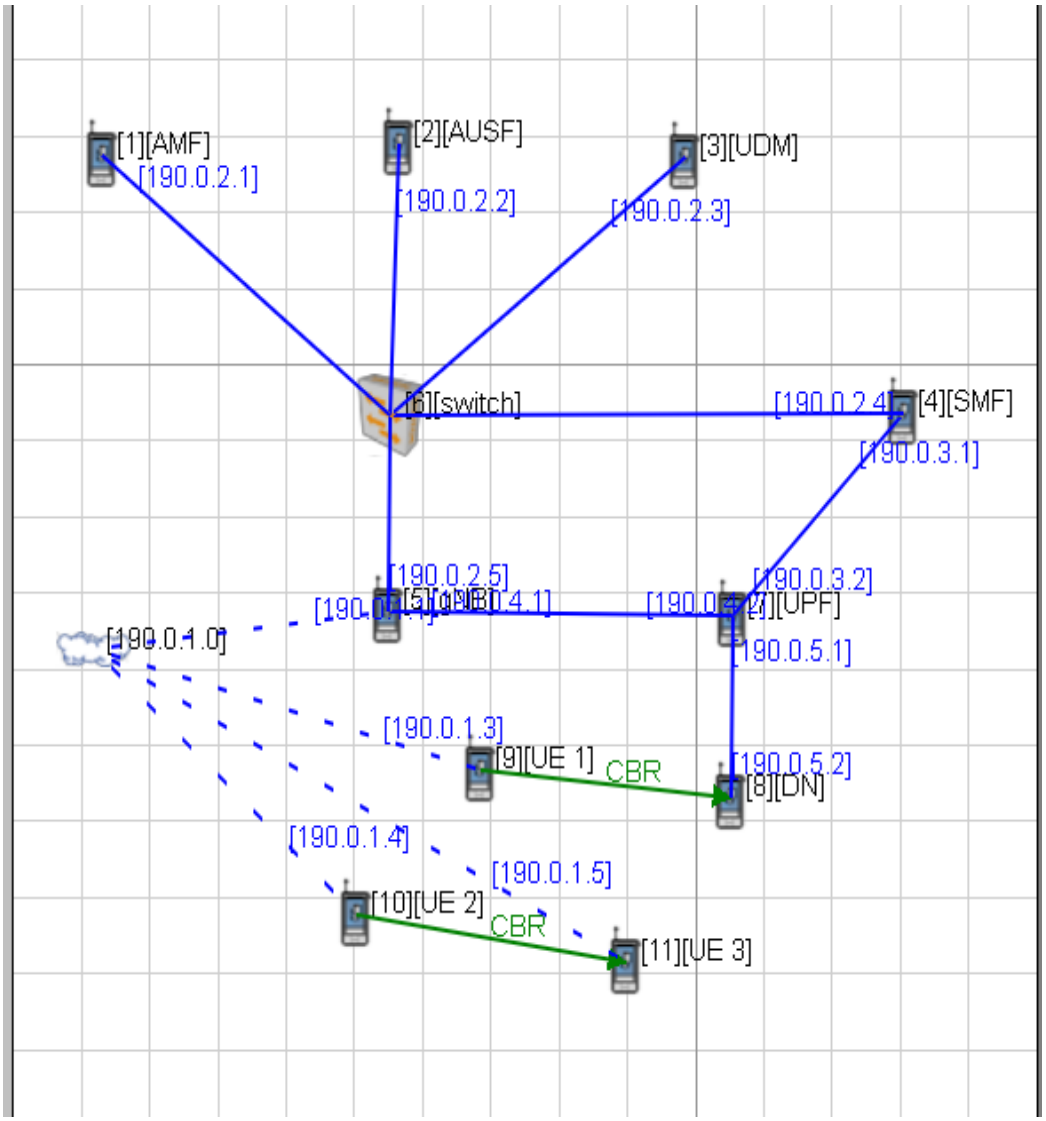
- components
- Links
- Wireless subnet
- CBR application



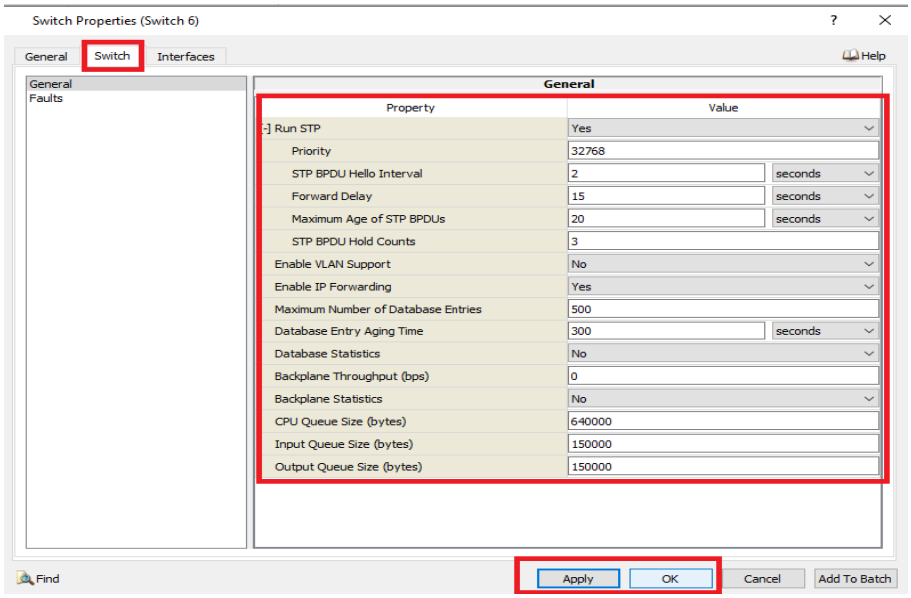
- **Create the scenario topology as shown in below figure.**

  Below Figure shows the IP addresses of the interfaces in the scenario. The IP addresses depend on the order in which nodes, subnets, and connections are created and may be different in your scenario from the ones shown in the figure. We will use these addresses in the configuration steps below.



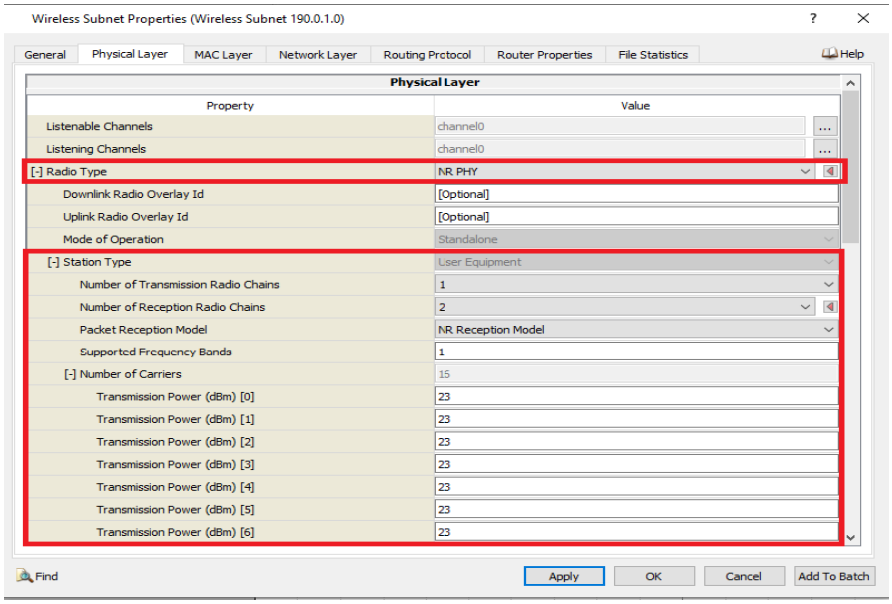
**Step 5:-** To configure the scenario in QualNet GUI, perform the following steps:

**(1).** To Configure the **Switch**, Double Click on Switch > go to Switch and set Run STP to **Yes** and use default values for all other parameter > Apply > OK.

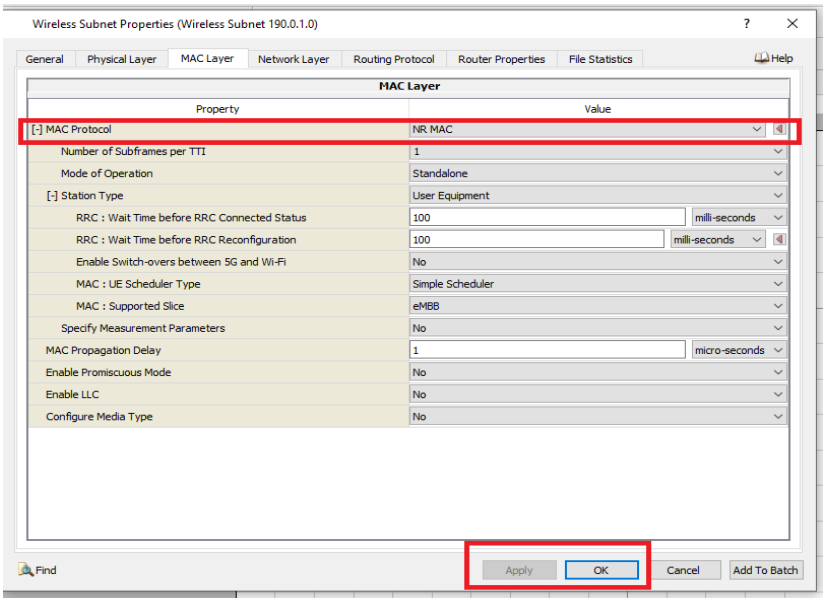



**(2).** To Configure the **wireless subnet**:-

- Double Click On wireless subnet > Go to Physical Layer
  - **i.** Set Radio Type to NR PHY.
  - **ii.** Use default values for all other PHY parameters.

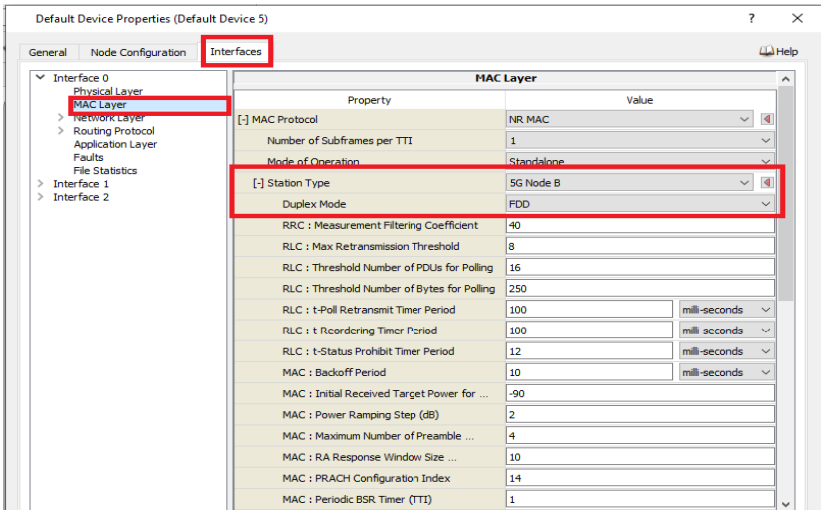


- Go to MAC Layer
  - **i.** Set MAC Protocol to NR MAC.
  - **ii.** Use default values for all MAC parameters
  - **iii.** Click on Apply > OK.

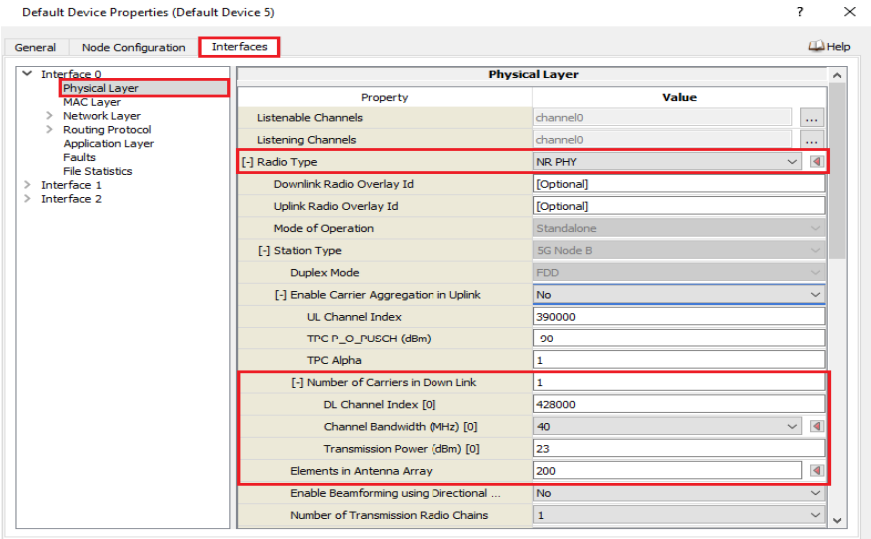



**(3).** To Configure Node 5 (**gNB**):-

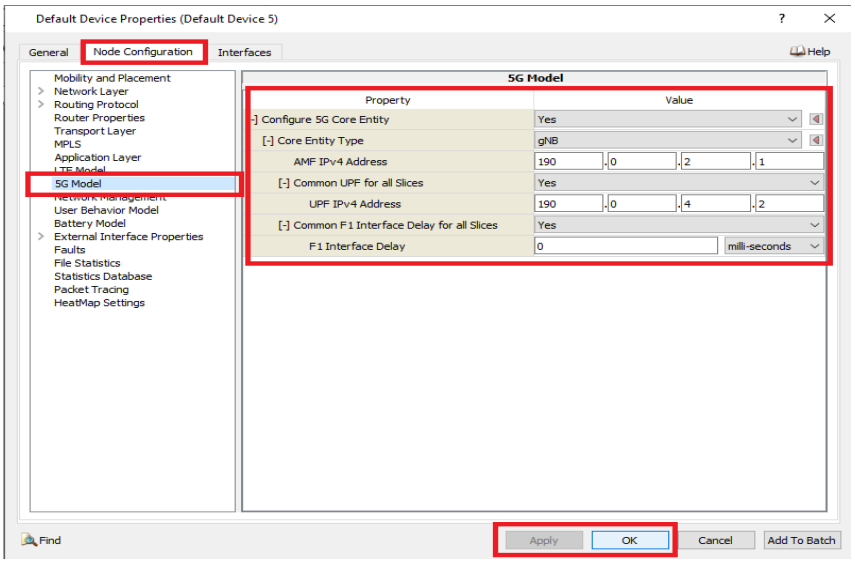
- Double Click On Node 5 > Interfaces > Interface 0 > MAC Layer (Make sure that Interface 0 corresponds to the wireless interface of the node).
  - **i.** Set **Station Type** to 5g Node B.
  - **ii.** Set Duplex Mode to FDD.
  - **iii.** Use default values for all other interface parameters.



- Go to Physical Layer
  - **i.** Set Radio Type to NR PHY
  - **ii.** Set Channel Bandwidth to 40
  - **iii.** Set Elements in Antenna Array to 200
  - **iv.** Use default values for all other interface parameters

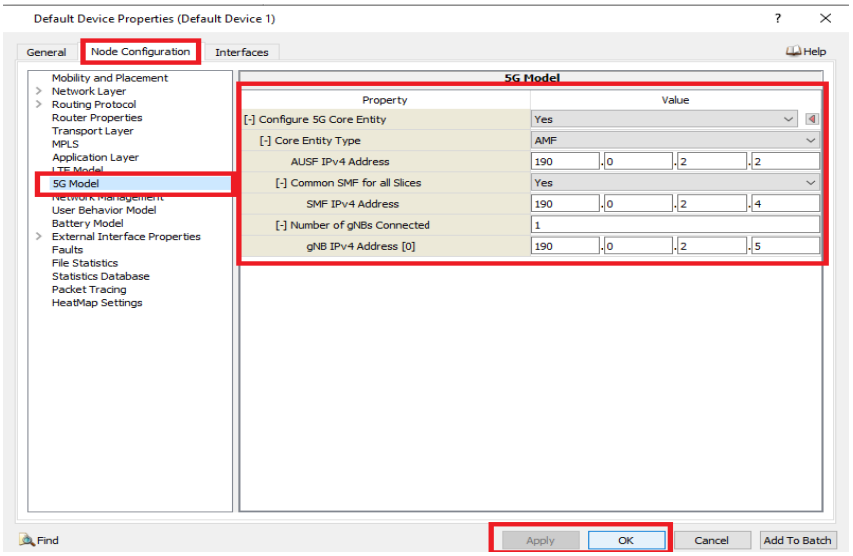



- Click on > Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to gNB.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UPF IPv4 Address to 190.0.4.2
  - **iv.** Click on Apply > OK



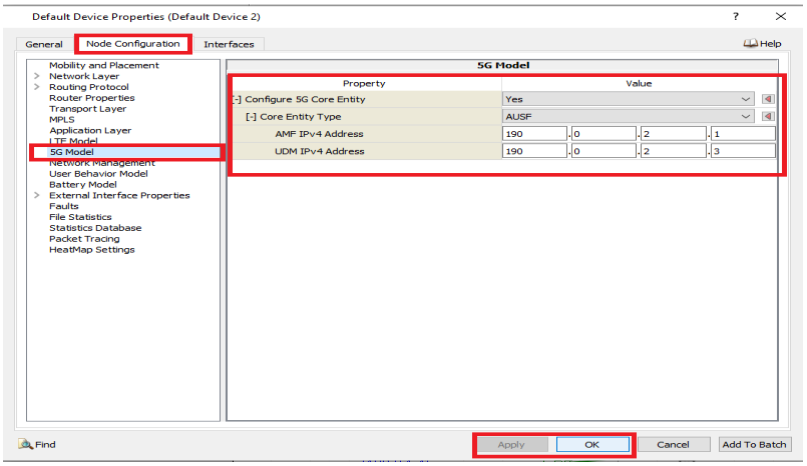
**(4).** To Configure Node 1 **(AMF)**:-

- Double Click On Node 1 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to AMF.
  - **ii.** Set AUSF IPv4 Address to 190.0.2.2
  - **iii.** Set SMF IPv4 Address to 190.0.2.4
  - **iv.** Set Number of gNBs Connected to 1
  - **v.** Set gNB IPv4 Address [0] to 190.0.2.5
  - **vi.** Click On Apply > Ok



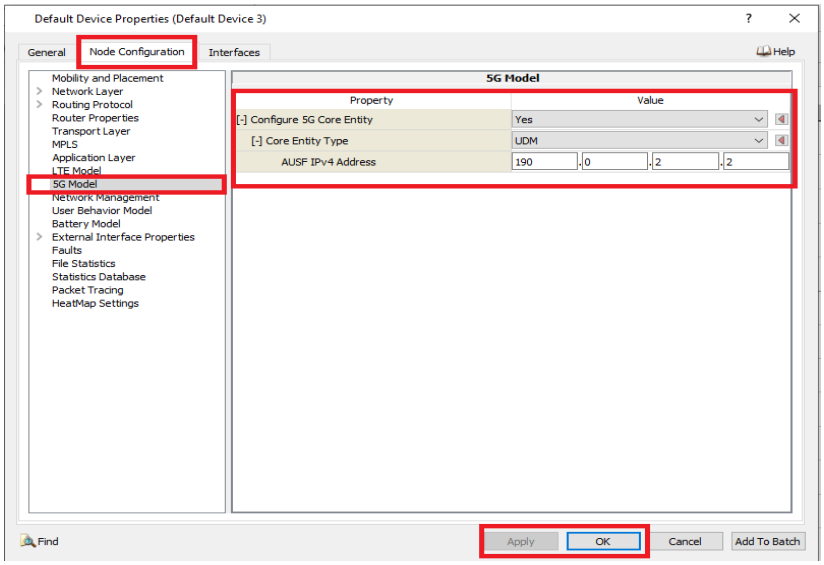

**(5).** To Configure Node 2 **(AUSF):-**

- Double Click On Node 2 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to AUSF.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UDM IPv4 Address to 190.0.2.3
  - **iv.** Click On Apply > Ok



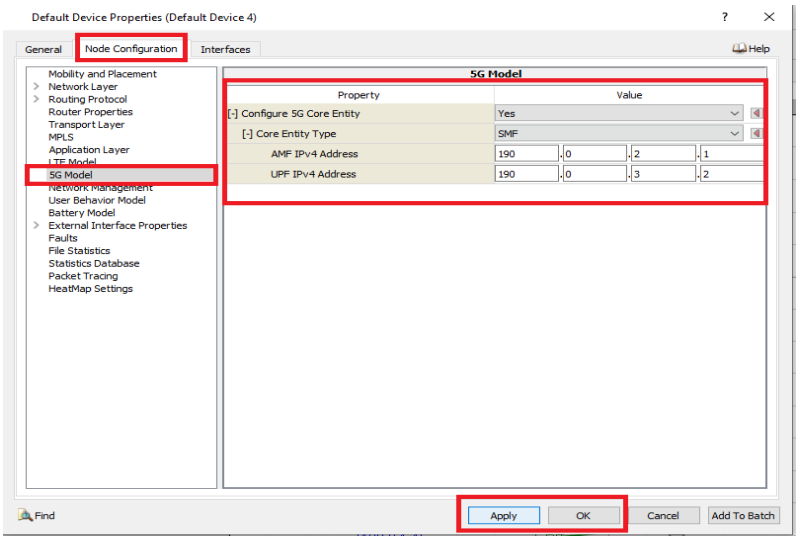
**(6).** To Configure Node 3 **(UDM)**:-

- Double Click On Node 3 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to UDM.
  - **ii.** Set AUSF IPv4 Address to 190.0.2.2
  - **iii.** Click On Apply > OK



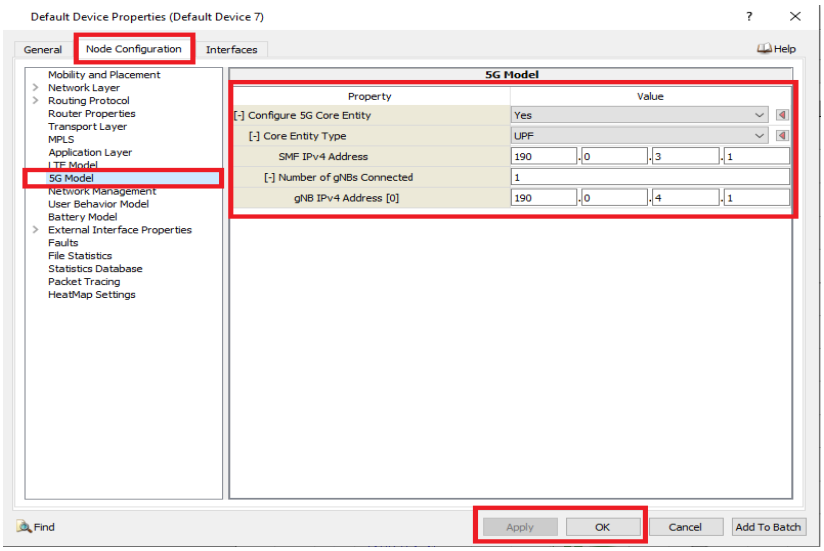

**(7).** To Configure Node 4 **(SMF)**:-

- Double Click On Node 4 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to SMF.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UPF IPv4 Address to 190.0.3.2
  - **iv.** Click On Apply > OK



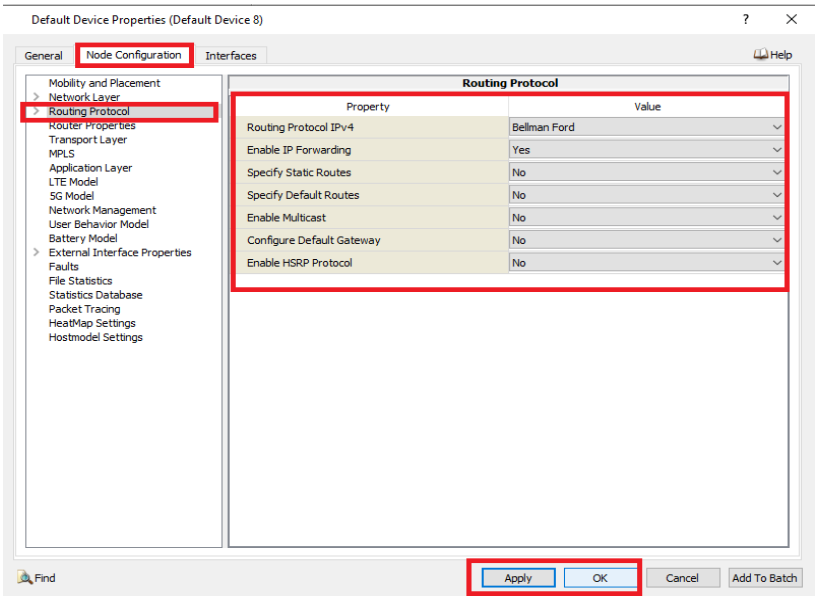
**(8).** To Configure Node 7 **(UPF)**:-

- Double Click On Node 7 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to UPF.
  - **ii.** Set SMF IPv4 Address to 190.0.3.1
  - **iii.** Set Number of gNBs Connected to 1
  - **iv.** Set gNB IPv4 Address [0] to 190.0.4.1
  - **v.** Click On Appy > OK



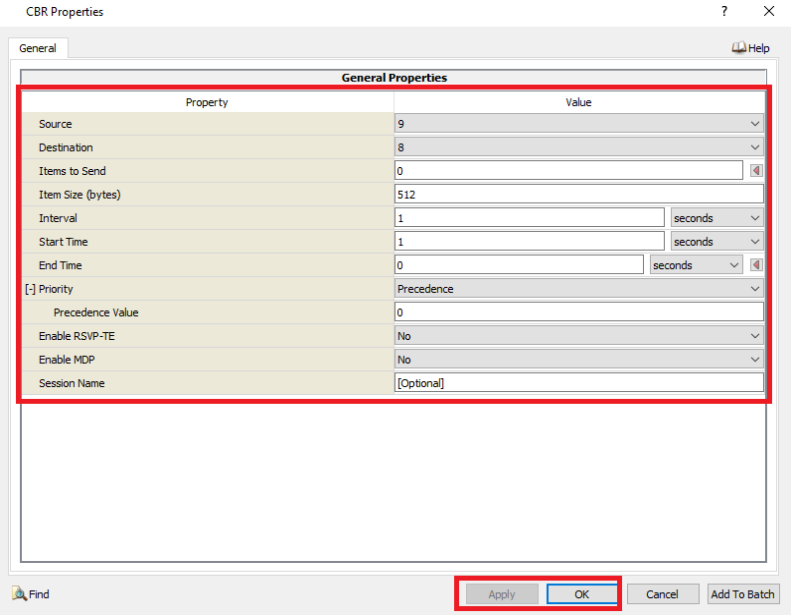

**(9).** To Configure Node 8 **(DN)**: -

- Double Click on Node 8 > Go to Node Configuration > Routing Protocol > use default values as shown in the figure > Apply > OK



**(10).** To set the properties of the CBR Application, do the following:-

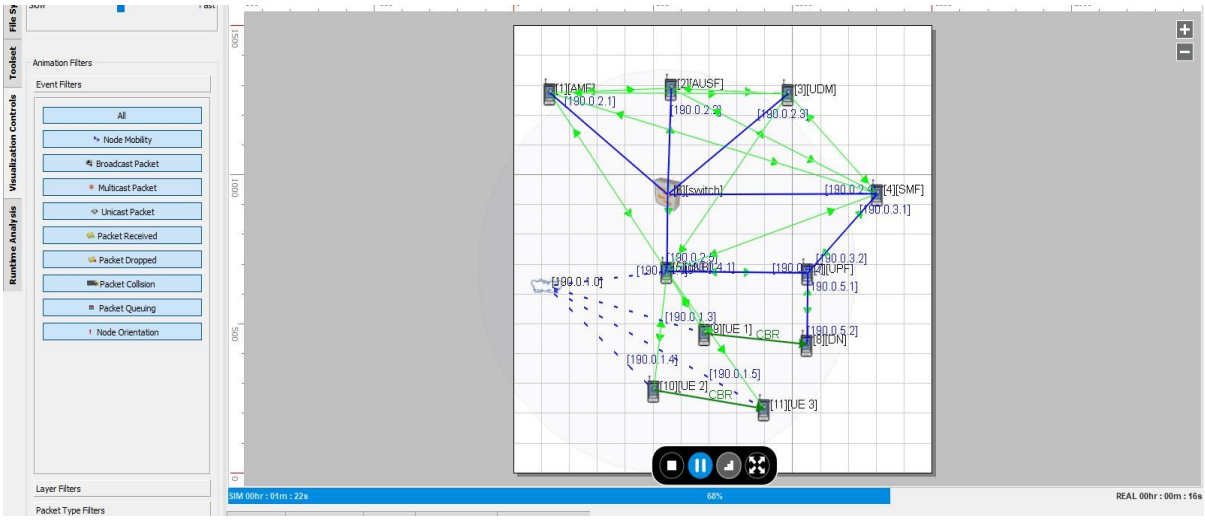
- Double-click the CBR link on the canvas.
- In the CBR Properties Editor, set the parameters as shown below
- Click On Apply > OK
- Repeat the steps for other CBR application.



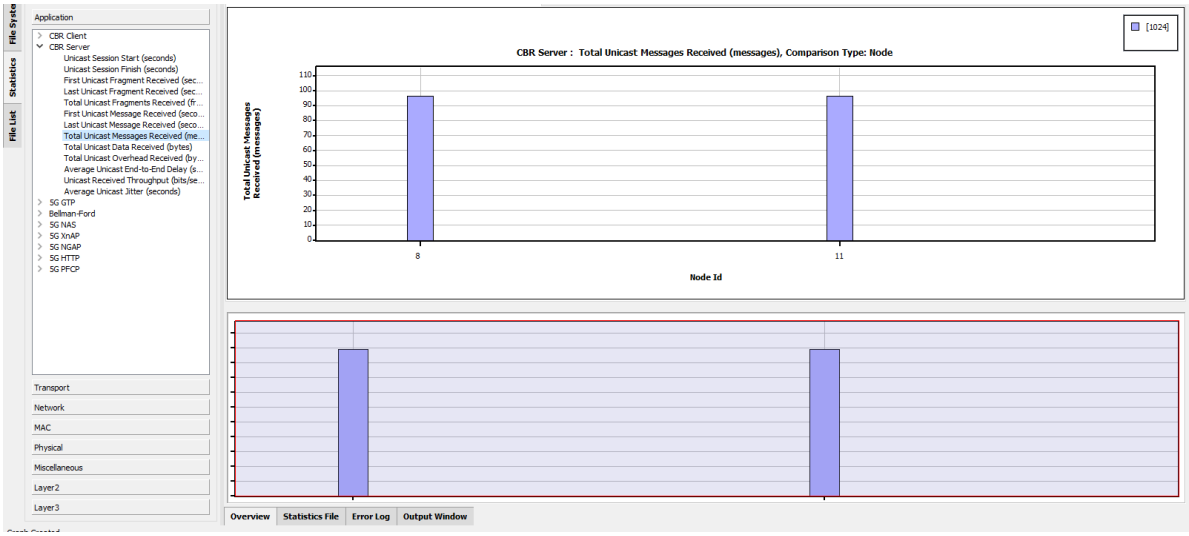

**Step 6:** Save the scenario by clicking the Save button in the toolbar.

**Step 7:** Click the Run Simulation button.

**Step 8**: To start the simulation, click the **Play** button at the bottom of the canvas.



**Step 9**: After the simulation has completed, switch to Analyzer by clicking the Analyze Results button. In the analyzer the performance parameter of the current scenario and the layer wise communication can be seen. Number of packets received, throughput, jitter, end to end delay, client and the server performance etc. can be analyzed.



## 4. Configuring different routing protocols and comparing them.

QualNet supports different Unicast routing protocols. Compare different routing protocols in 5G network.

- **Please refer "chapter 5 Unicast Routing Protocol Models" for (*AODV, DYMO, DSR, Fisheye, IARP, IERP, LANMAR, LAR, OLSR-INRIA, OLSRv2, STAR, ZRP* routing protocols) in wireless model library For more details**
- **Please refer "chapter 4 Unicast Routing Protocol Models" for (*EIGRP, IGRP, OSPFv2* routing protocols) in Multimedia and Enterprise Model Library For more details**
- **Please refer "chapter 4 Unicast Routing Protocol Models" for (*Bellman-Ford, RIP/RIPv2* routing protocols) in Developer Model Library For more details**

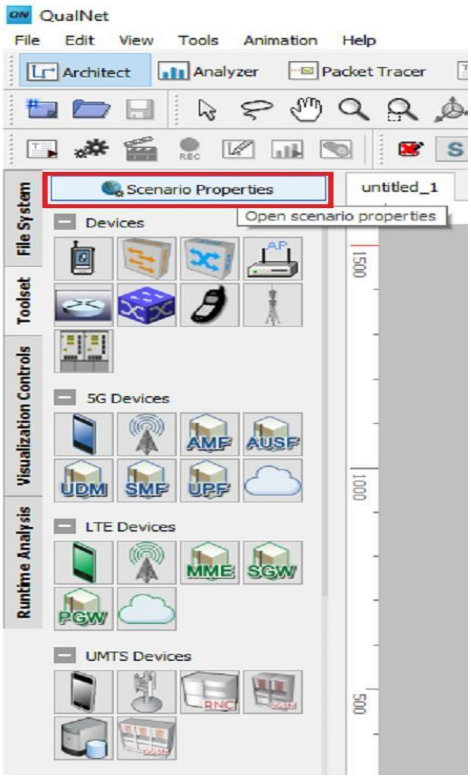
## Procedures to Create Scenario :-

### Step1: -

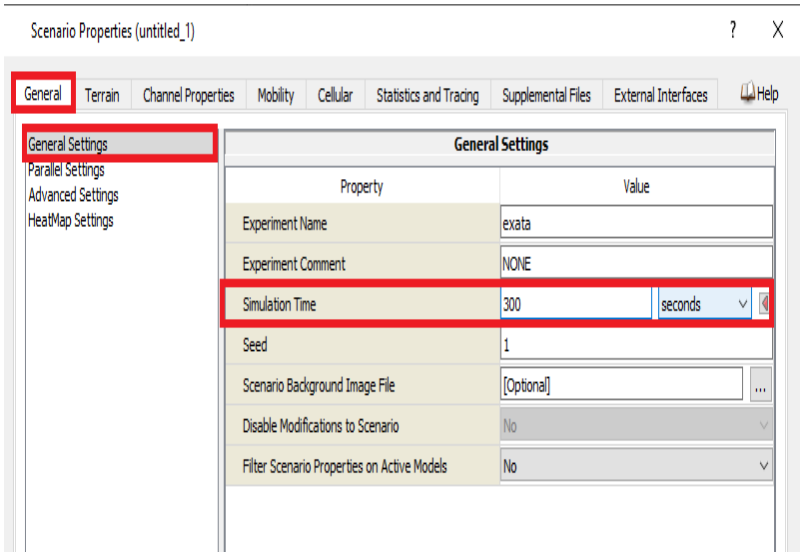
- Start the QualNet GUI.
- To start, Double-click on the QualNet GUI icon on the Desktop.

### Step 2: -

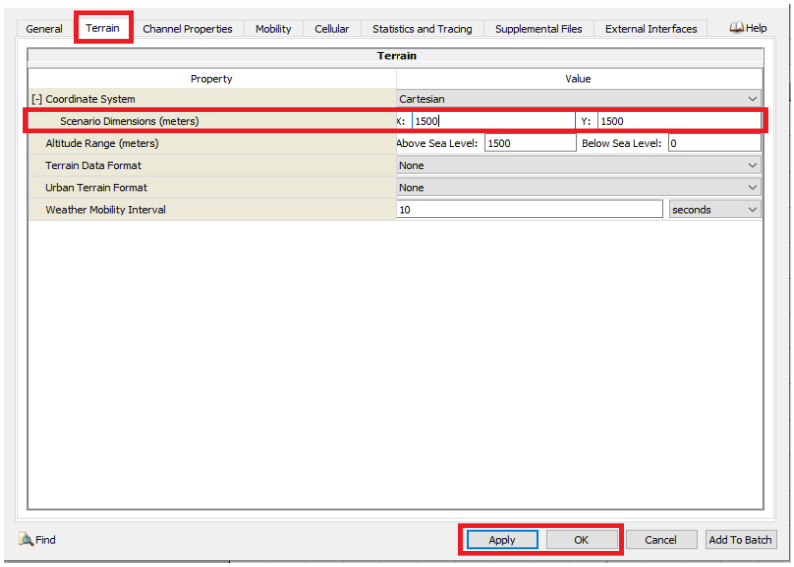
- Check the terrain size before placing the components on the canvas area.
- Click on the '**Scenario Properties**' button in the toolset panel.



- Click on '**General**' button on the top of the newly opened editor. Click on > General Settings > Simulation Time to **300 sec**.

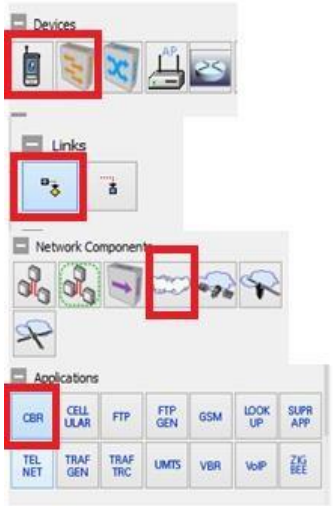


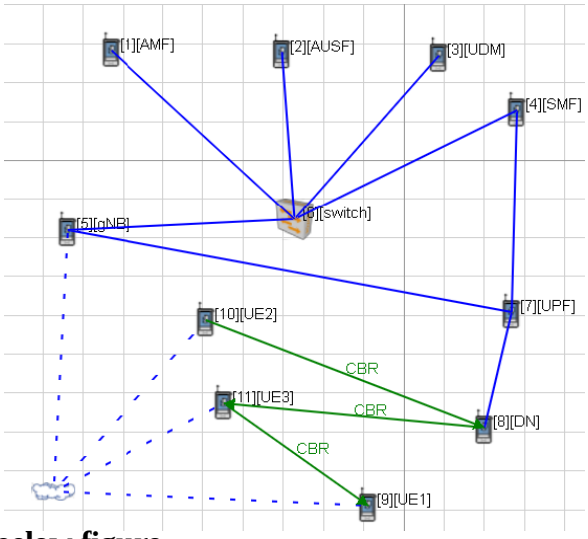

- Click on '**Terrain**' set scenario dimensions as (x:1500 and y:1500) > Apply > OK



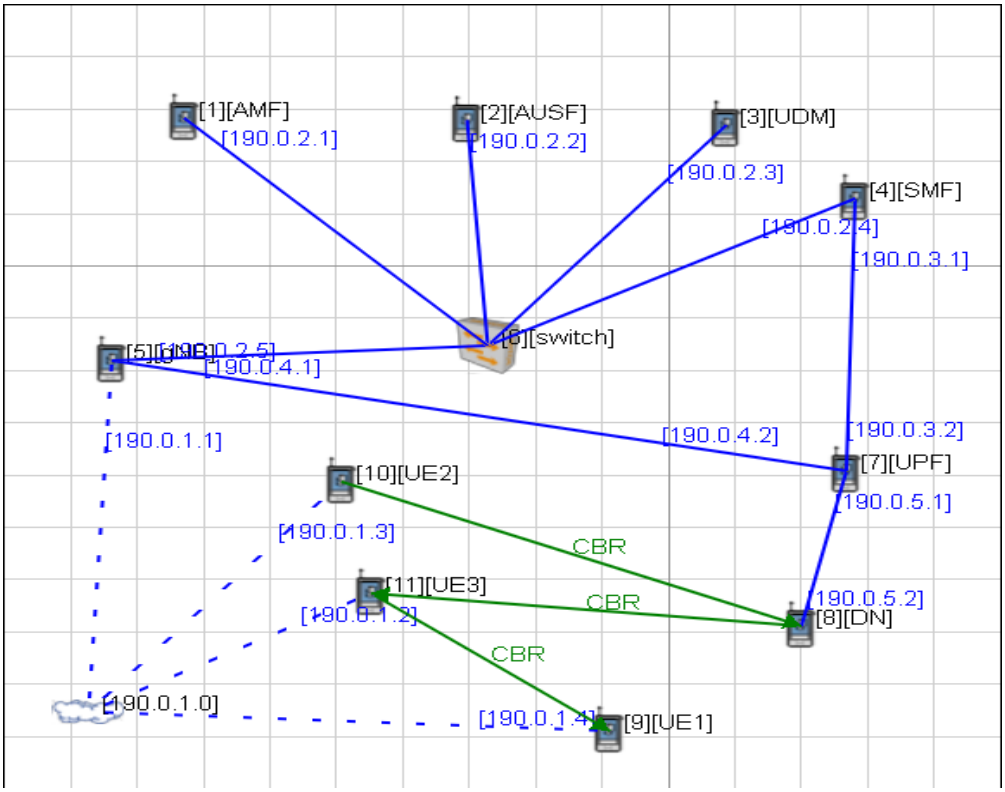
**Step 3:** -To Create a scenario, choose the components required from toolset and place it on the canvas using drag-drop as shown in figure.

- components
- Links
- Wireless subnet
- CBR application



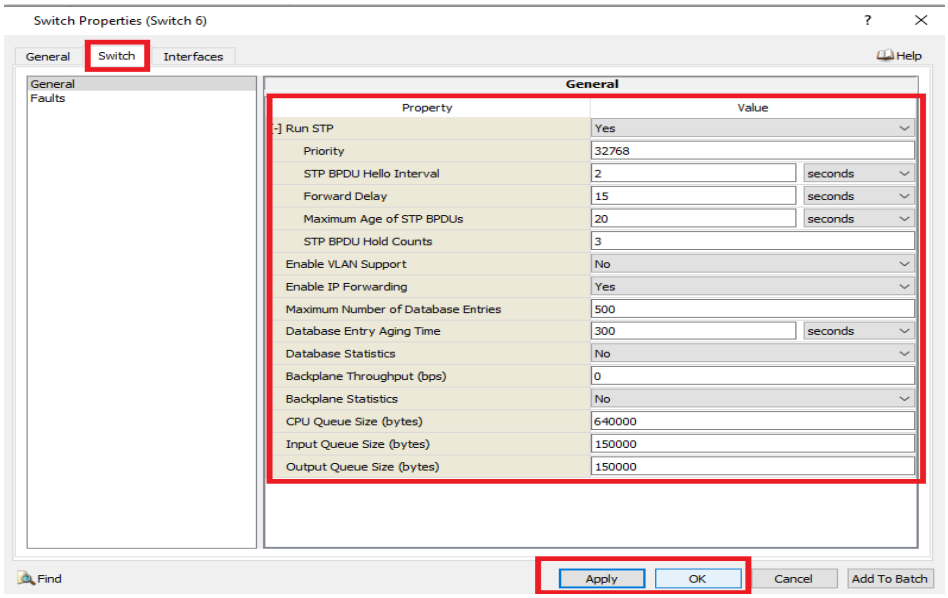




- **Create the scenario topology as shown in below figure.**
  Below Figure shows the IP addresses of the interfaces in the scenario. The IP addresses depend on the order in which nodes, subnets, and connections are created and may be different in your scenario from the ones shown in the figure. We will use these addresses in the configuration steps below.



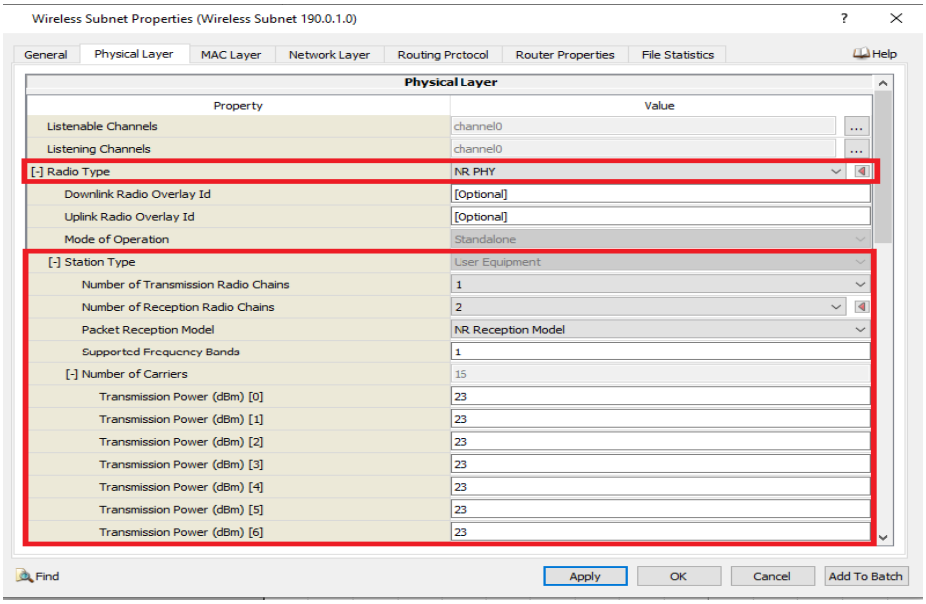
**Step 4:-** To configure the scenario in QualNet GUI, perform the following steps:-

**(1).** To Configure the **Switch**, Double Click on Switch > go to Switch and set Run STP to **Yes** and use default values for all other parameter > Apply > OK.

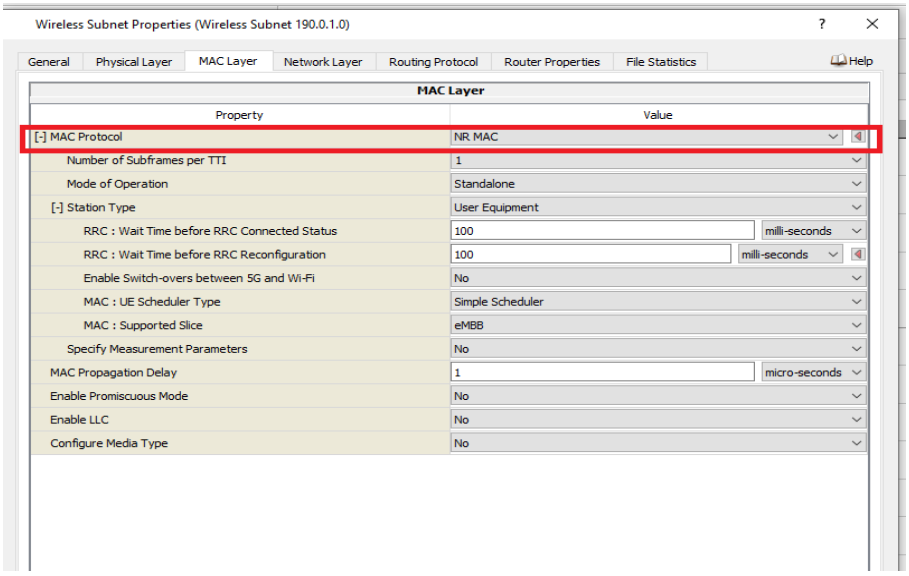



**(2).** To Configure the **wireless subnet**:-

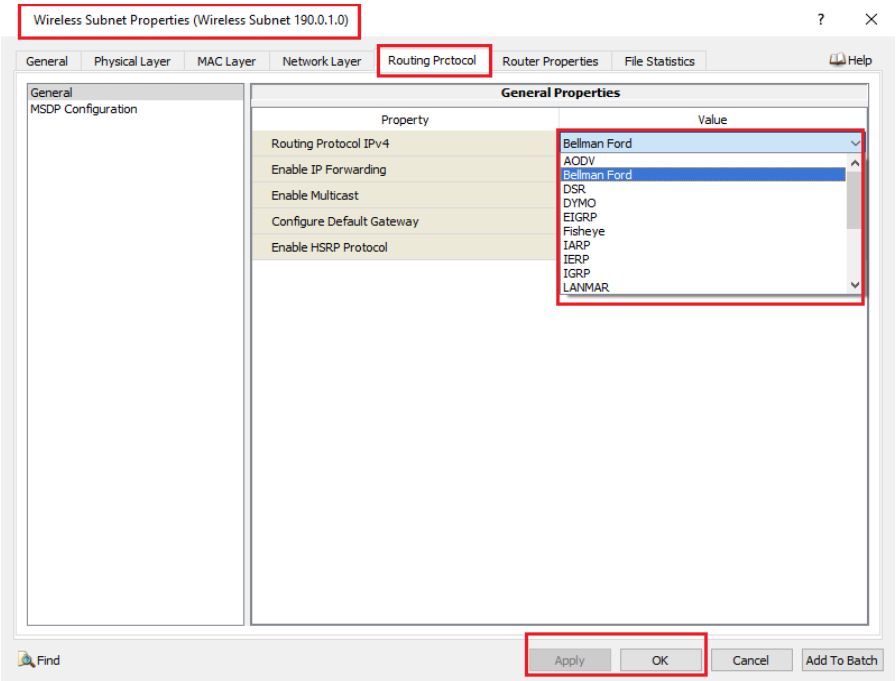
- Double Click On wireless subnet > Go to Physical Layer
  - **i.** Set Radio Type to NR PHY.
  - **ii.** Use default values for all other PHY parameters.



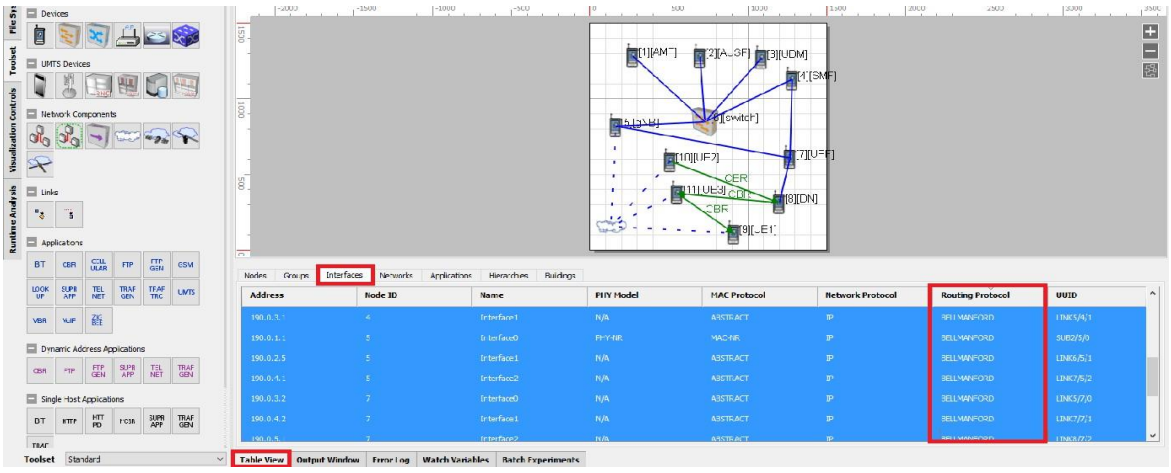
- Go to MAC Layer
  - **i.** Set MAC Protocol to NR MAC.
  - **ii.** Use default values for all MAC parameters.



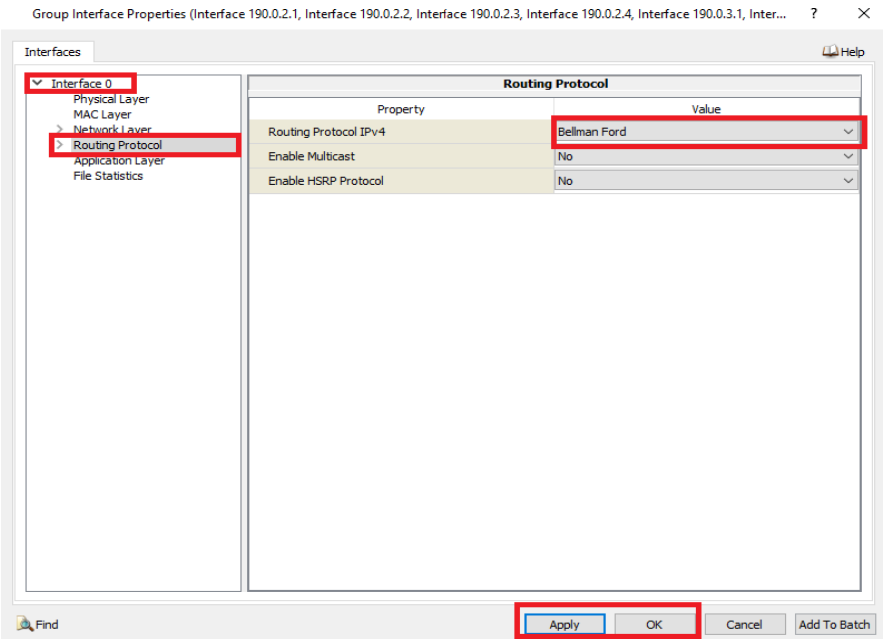

- Go to Routing Protocol
  - **i.** Set Routing Protocol IPv4 to Bellman Ford.
  - **ii.** Use default values for all other parameters.
  - **iii.** Click on Apply > OK.



- Make Sure that **wireless subnet routing protocol** and all **interfaces Routing Protocol** should be same.
  - **i.** To Set Up Interfaces Routing Protocol Click on > Table view (Below the Screen) > Interfaces > Routing Protocol.
  - **ii.** Select all interfaces Routing Protocol **Except Switch Interfaces** > Right Click > click on properties.



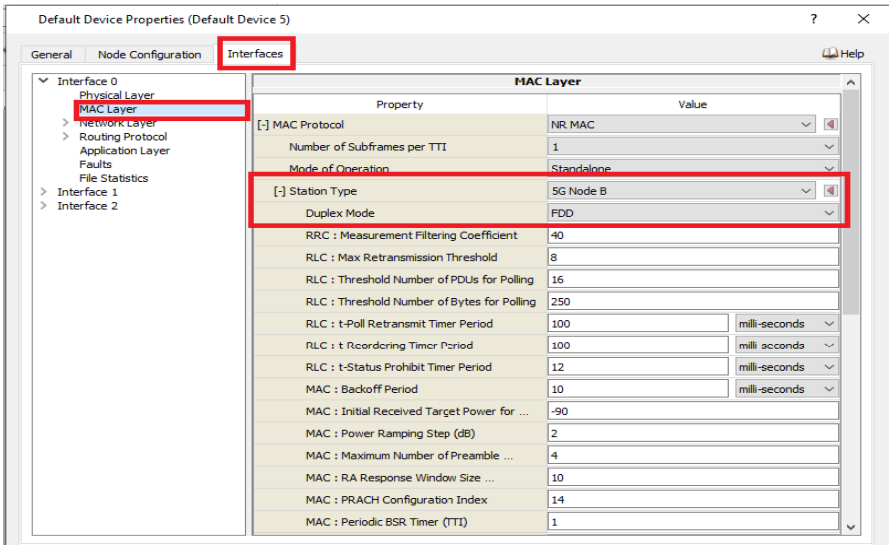

  - **iii.** On newly opened tab Click on > Interface 0 > Routing protocol > Set Routing Protocol IPv4 to Bellman Ford > Apply > OK



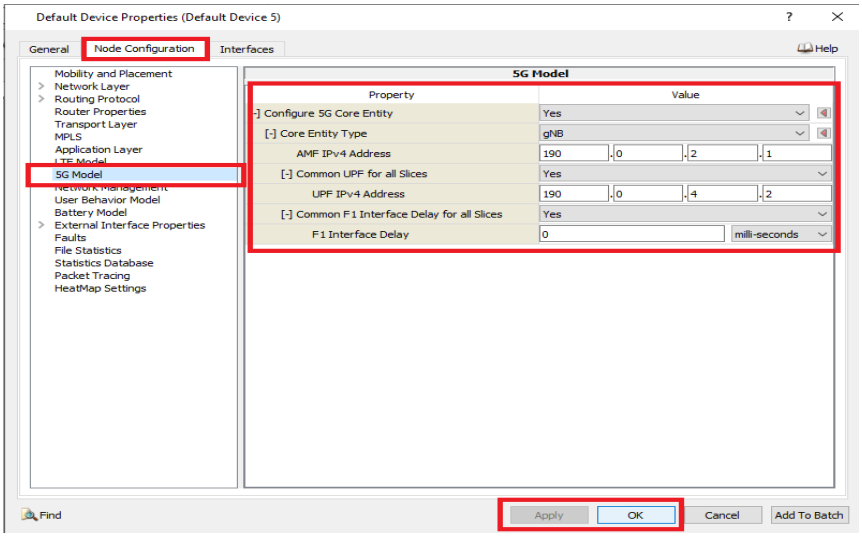

- **You can Use Different Routing Protocol which is Present in Qualnet GUI and Compare the Results.**

**(3).** To Configure Node 5 (**gNB**):-

- Double Click On Node 5 > Interfaces > Interface 0 > MAC Layer (Make sure that Interface 0 corresponds to the wireless interface of the node).
  - **i.** Set **Station Type** to 5g Node B.
  - **ii.** Set Duplex Mode to FDD.
  - **iii.** Use default values for all other interface parameters.

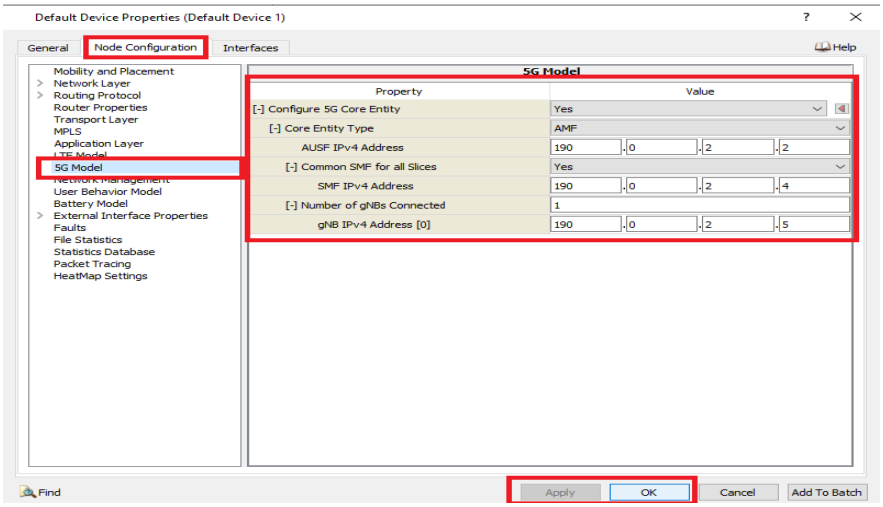



- Click On > Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to gNB.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UPF IPv4 Address to 190.0.4.2
  - **iv.** Click On Apply > OK



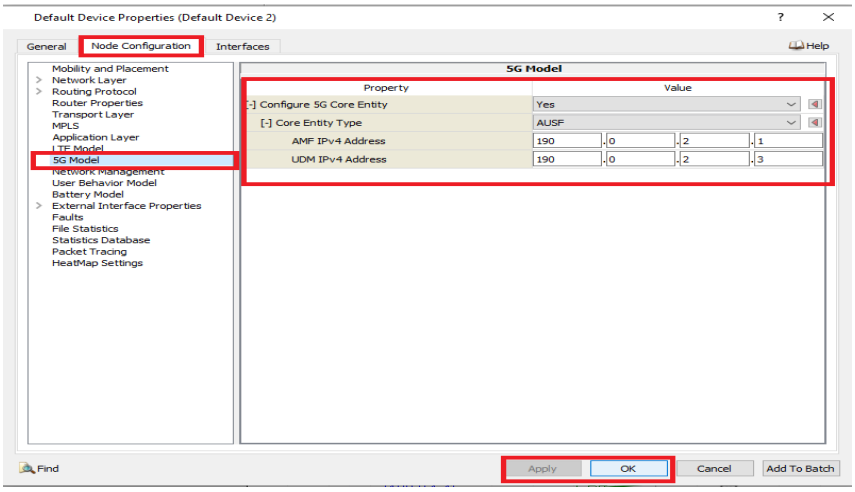
**(4).** To Configure Node 1 **(AMF)**:-

- Double Click On Node 1 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to AMF
  - **ii.** Set AUSF IPv4 Address to 190.0.2.2
  - **iii.** Set SMF IPv4 Address to 190.0.2.4
  - **iv.** Set Number of gNBs Connected to 1
  - **v.** Set gNB IPv4 Address [0] to 190.0.2.5
  - **vi.** Click On Apply > Ok



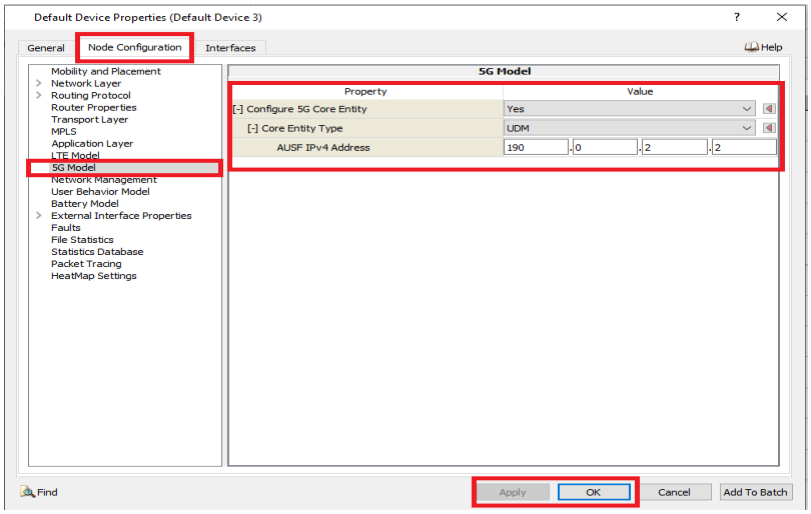

**(5).** To Configure Node 2 **(AUSF)**:-

- Double Click On Node 2 > Go Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to AUSF
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UDM IPv4 Address to 190.0.2.3
  - **iv.** Click On Apply > OK



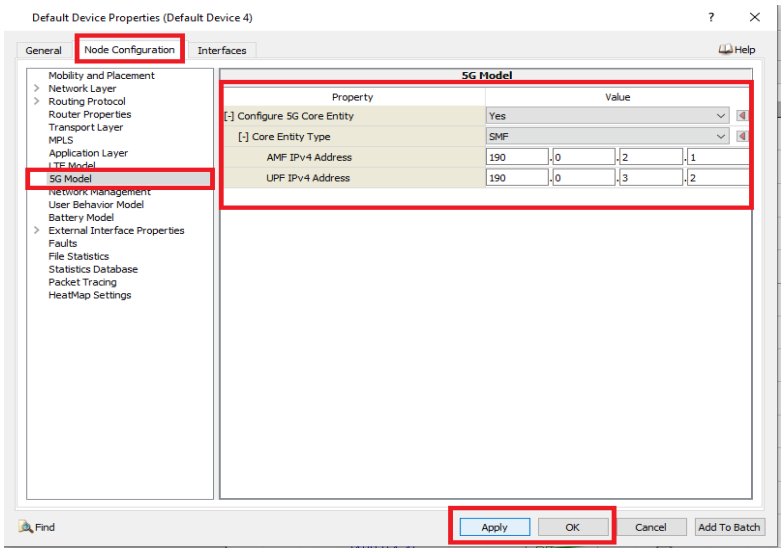
**(6).** To Configure Node 3 **(UDM)**:-

- Double Click On Node 3 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to UDM.
  - **ii.** Set AUSF IPv4 Address to 190.0.2.2
  - **iii.** Click On Apply > OK



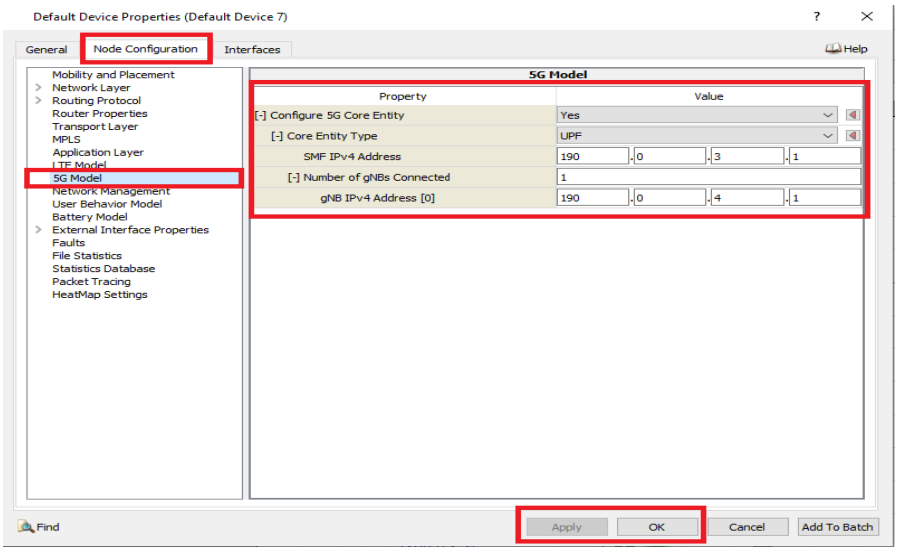

**(7).** To Configure Node 4 **(SMF)**:-

- Double Click On Node 4 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to SMF.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UPF IPv4 Address to 190.0.3.2
  - **iv.** Click On Apply > OK



**(8).** To Configure Node 7 **(UPF)**:-

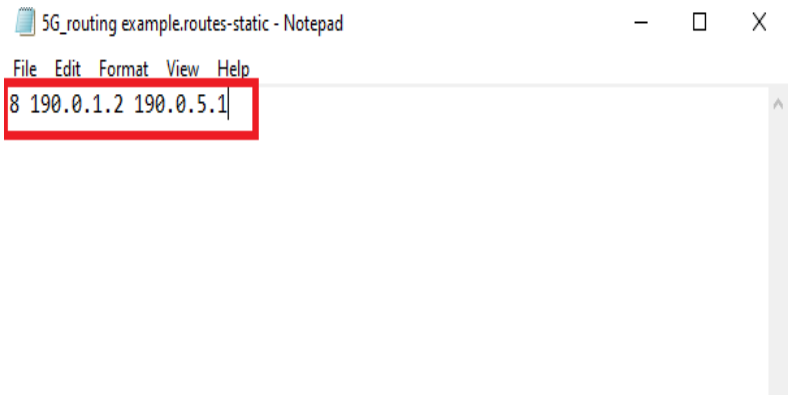
- Double Click On Node 7 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to UPF.
  - **ii.** Set SMF IPv4 Address to 190.0.3.1
  - **iii.** Set Number of gNBs Connected to 1
  - **iv.** Set gNB IPv4 Address [0] to 190.0.4.1
  - **v.** Click On Apply > OK




**(9).** To Configure Node 8 **(DN)**: -

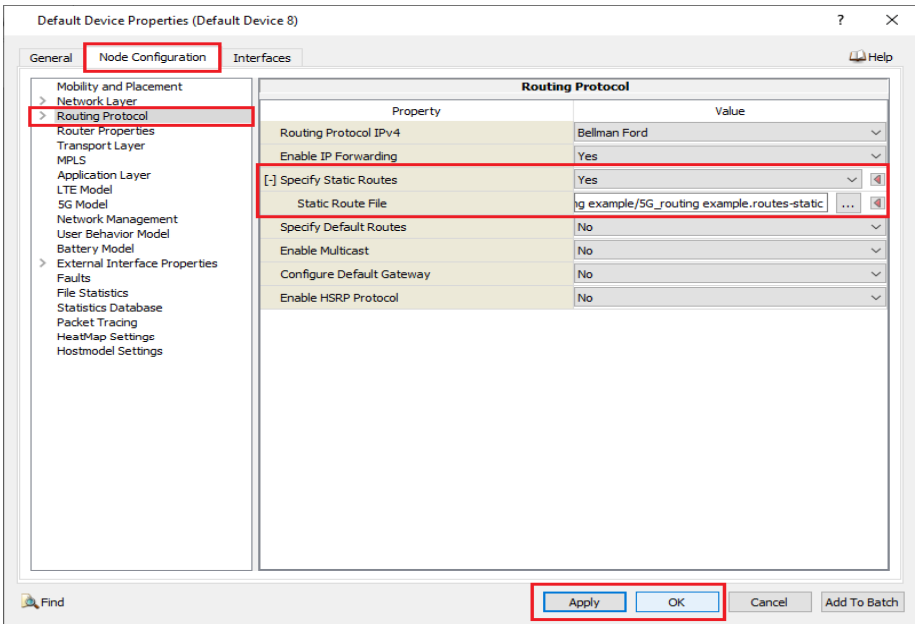
- Double Click On Node 8 > Go to Node Configuration > Routing Protocol.
  - **i.** Set Specify Static Routes to Yes.
  - **ii.** Create a file in **Notepad** called **Filename.routes-static** in the scenario directory which contains the static route from the DN to the UE.
  - **iii.** In the Static Routes file, **Filename.routes-static**, specify the routes as follows:- <Node Id of DN> <IP-ADDRESS of UE> < Next Hop IP Address/IP of UPF >

8 190.0.1.2 190.0.5.1



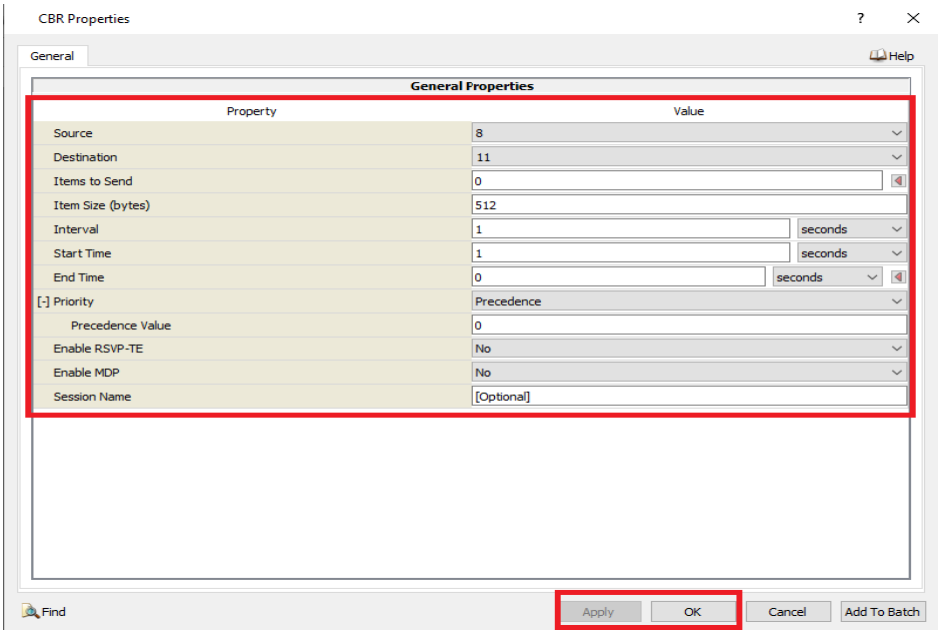
**iv.** To Set Static Route File > Click on Select files and select **Filename.routes-static**

**v.** Click On Apply > OK




**(10).** To set the properties of the CBR Application, do the following:-

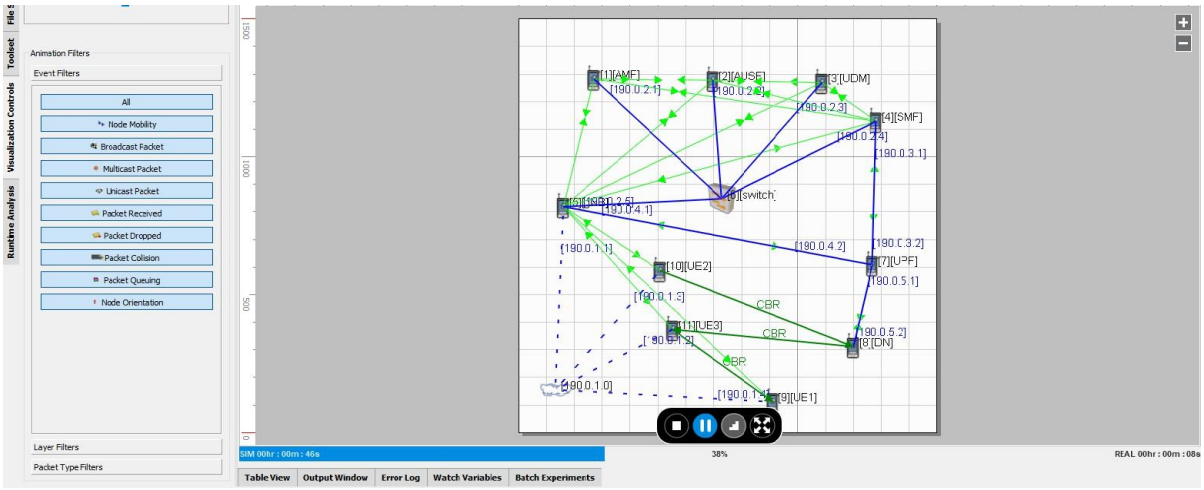
- Double-click the CBR link on the canvas.
- In the CBR Properties Editor, set the parameters as shown below
- Click On Apply > OK.
- Repeat the steps for other two CBR applications.



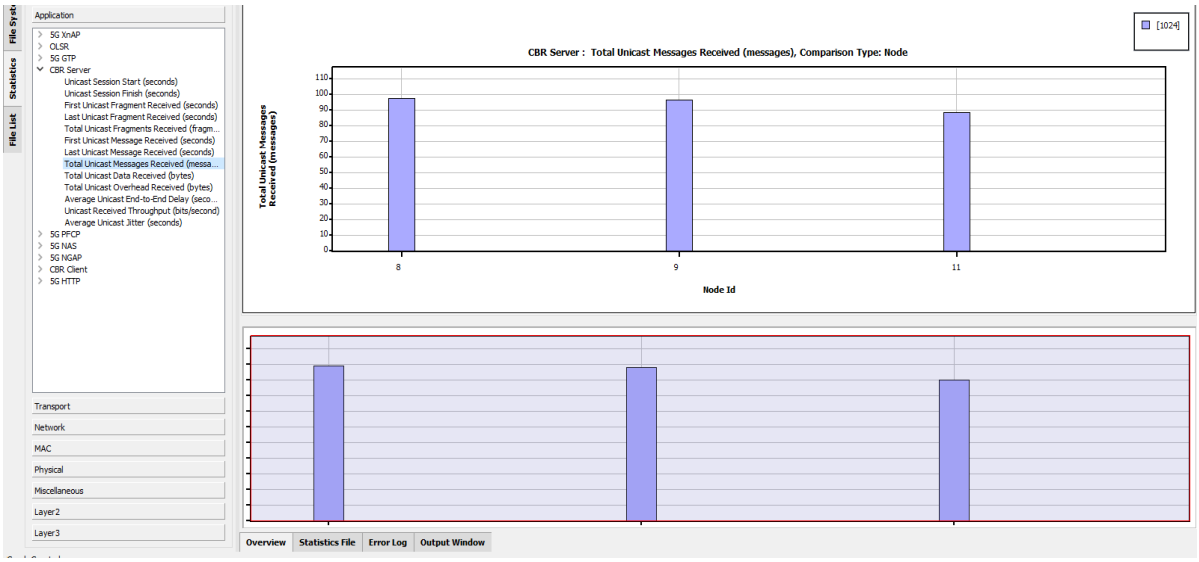
**Step5:** Save the scenario by clicking the Save button in the toolbar.

**Step6:** Click the Run Simulation button.

**Step7**: To start the simulation, click the **Play** button at the bottom of the canvas.




**Step8**: After the simulation has completed, switch to Analyzer by clicking the Analyze Results button. In the analyzer the performance parameter of the current scenario and the layer wise communication can be seen. Number of packets received, throughput, jitter, end to end delay, client and the server performance etc. can be analyzed.



# 5. Beam forming using directional antenna.

To check whether the directional antenna model compatibility in 5G Network communications i.e, steerable, switched beam and omnidirectional antennas.

**Please refer "chapter 3 Physical Layer Models" - 3.8 Antenna Models in wireless model library For more details**

## Procedures to Create Scenario :-

## Step1: -

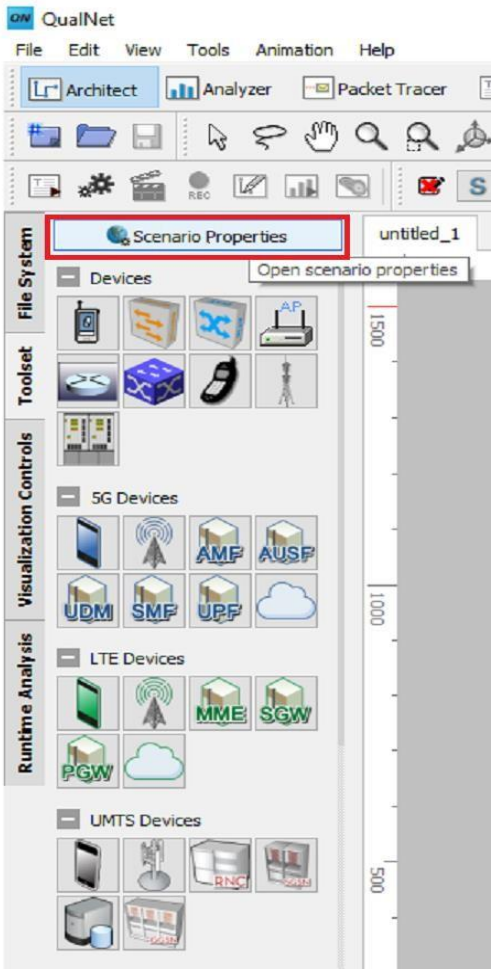
- Start the QualNet GUI.
- To start, Double-click on the QualNet GUI icon on the Desktop.

## Step 2: -

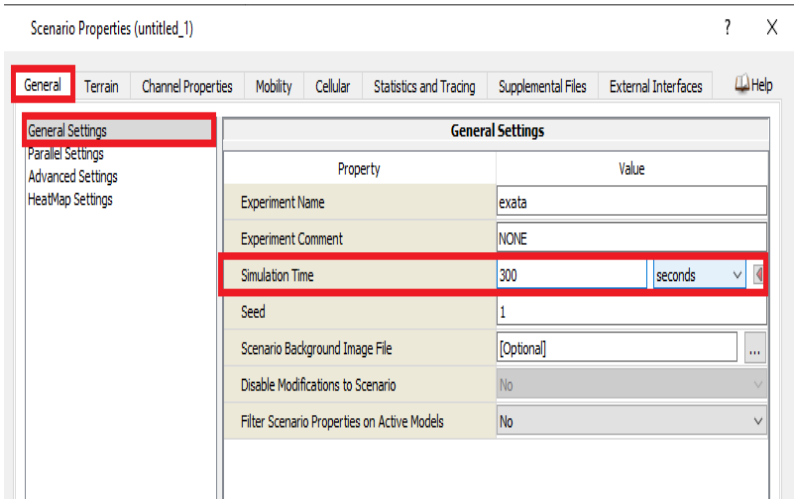
- Check the terrain size before placing the components on the canvas area

  .

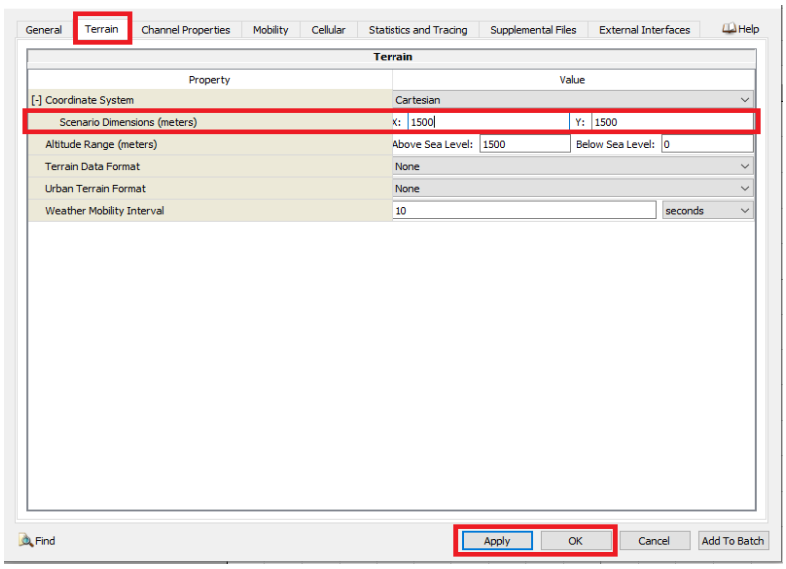
- Click on the '**Scenario Properties**' button in the toolset panel.



- Click on '**General**' button on the top of the newly opened editor. Click on > General Settings > Simulation Time to **300 sec.**

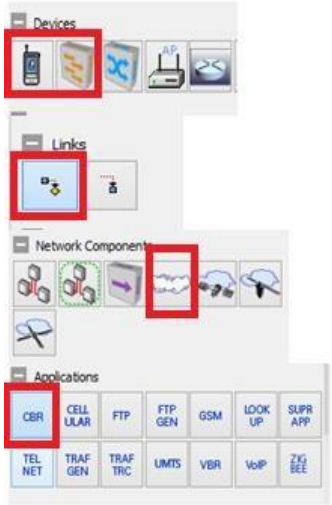


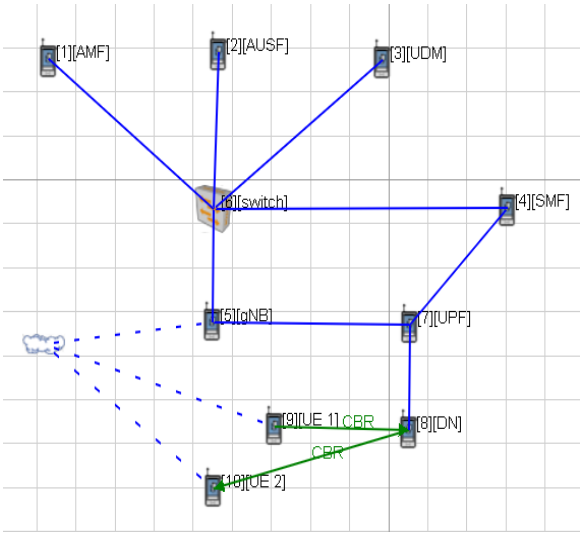

- Click on **'Terrain'** set scenario dimensions as (x:1500 and y:1500) > Apply > OK



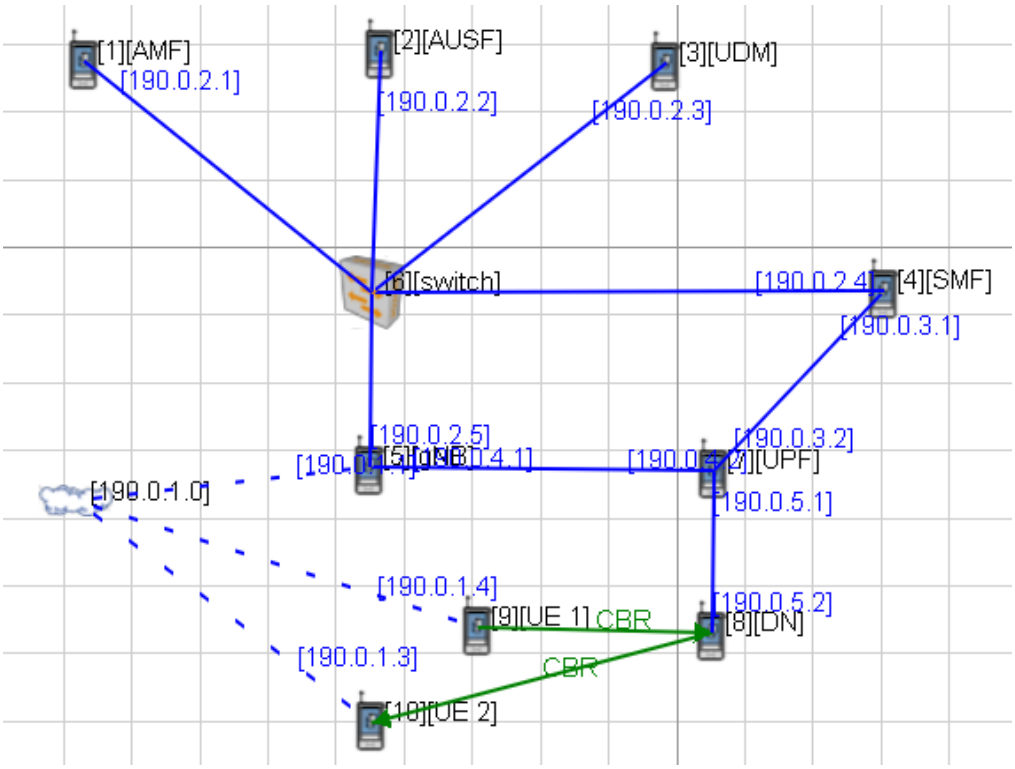
**Step 3:** -To create a scenario, choose the components required from toolset and place it on the canvas using drag-drop as shown in figure.

- Components
- Links
- Wireless subnet
- CBR application



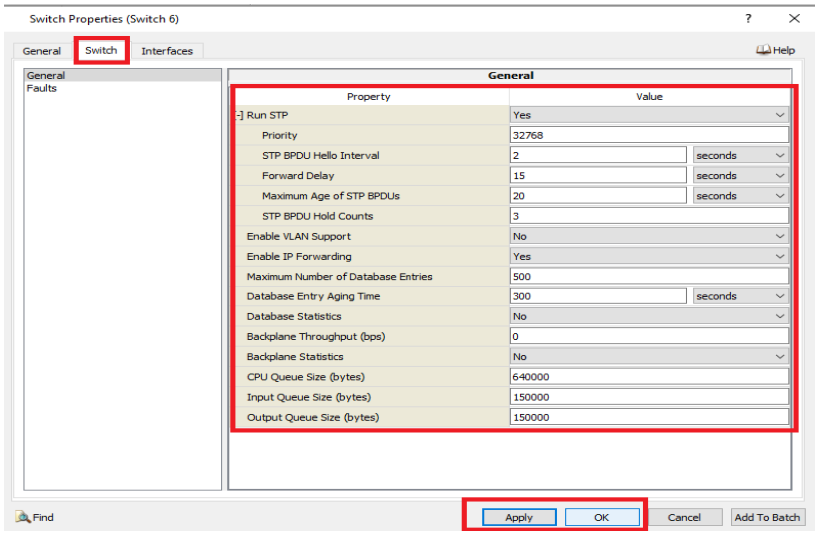




- **Create the scenario topology as shown in below figure.**
  Below Figure shows the IP addresses of the interfaces in the scenario. The IP addresses depend on the order in which nodes, subnets, and connections are created and may be different in your scenario from the ones shown in the figure. We will use these addresses in the configuration steps below.



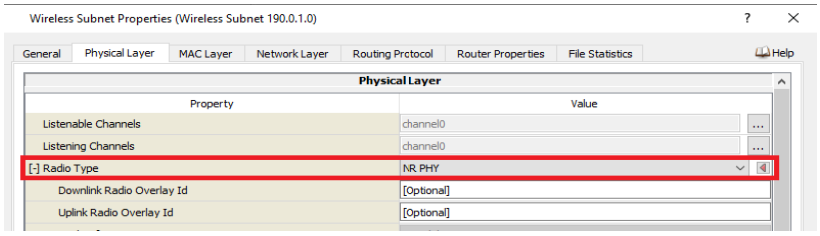
**Step 4:-** To configure the scenario in QualNet GUI, perform the following steps:

**(1).** To Configure the **Switch**, Double Click on Switch > go to Switch and set Run STP to **Yes** and use default values for all other parameter > Apply > OK.

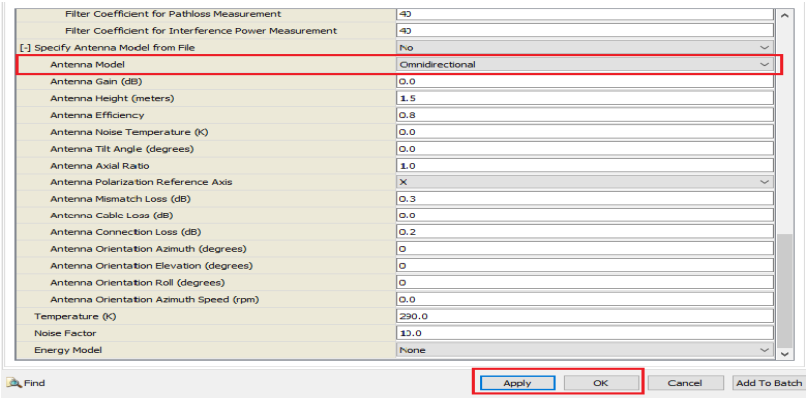



**(2).** To Configure the **wireless subnet**:-

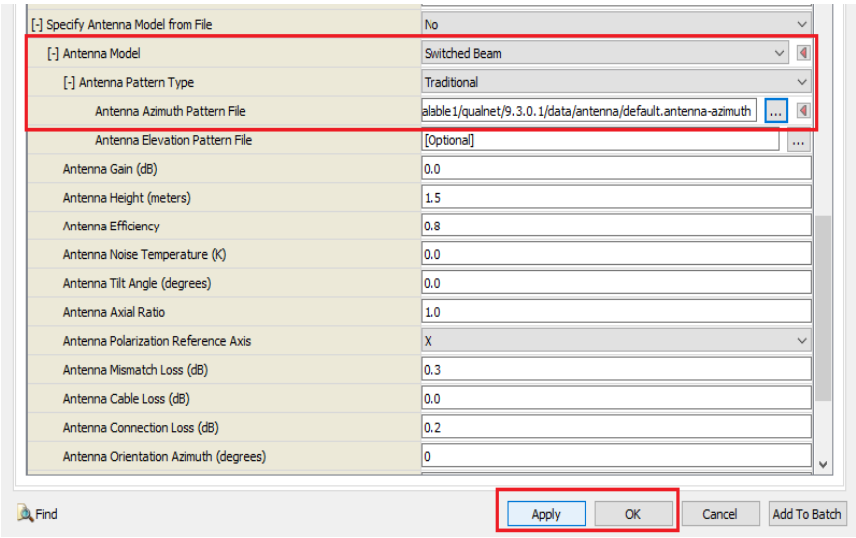
- Double Click On wireless subnet > Go to Physical Layer
  - **i.** Set Radio Type to NR PHY.



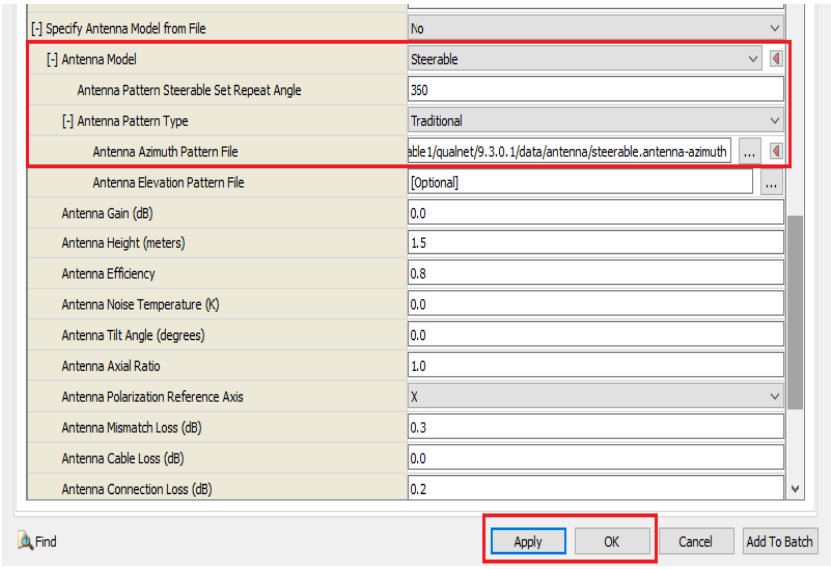

- To Set antenna model to **Omnidirectional** > Select **Omnidirectional** in Antenna Model



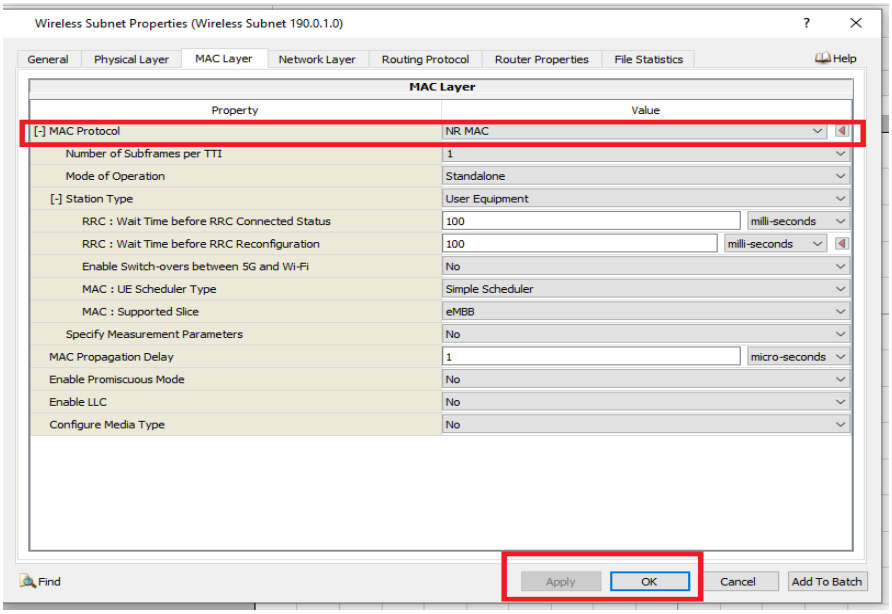
- To Set antenna model to **Switched Beam** > Select **Switched Beam** in Antenna Model and > Set Antenna Azimuth Pattern File
  - To set Antenna Azimuth Pattern File , Click on Select files >on newly opened window > go to, qualnet installed directory, you will find folder called Data >click on Data > antenna > select **default.antenna-azimuth** file >Apply>ok




- To Set antenna model to **Steerable**> Select **Steerable** in Antenna Model and > Set Antenna Azimuth Pattern File
  - To set Antenna Azimuth Pattern File , Click on Select files > on newly opened window > go to, qualnet installed directory, you will find folder called Data >click on Data > antenna > select **steerable.antenna-azimuth** file >Apply>ok

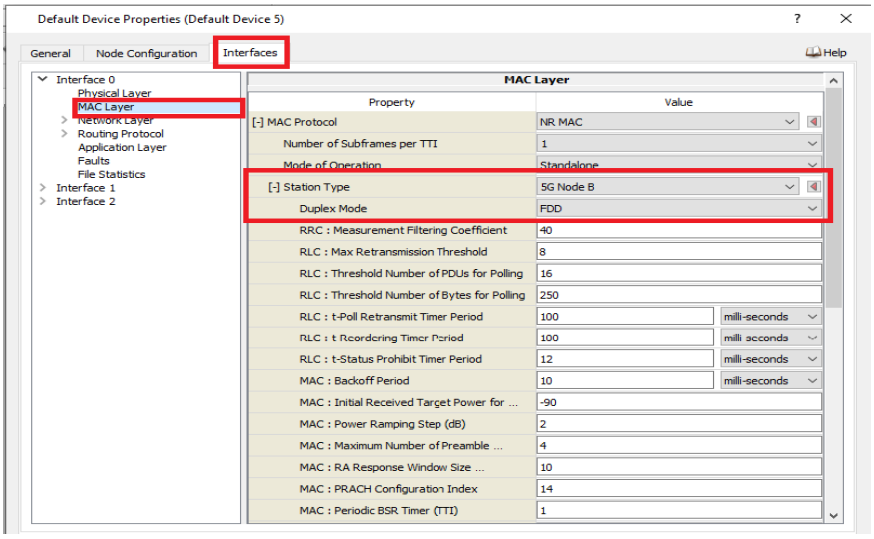


- Go to MAC Layer
  - **i.** Set MAC Protocol to NR MAC.
  - **ii.** Use default values for all MAC parameters.
  - **iii.** Click on Apply > OK

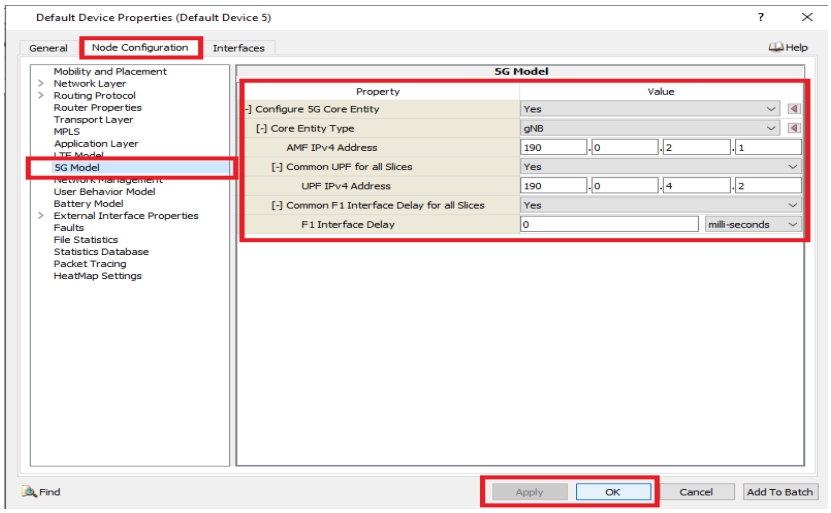



**(3).** To Configure Node 5 (**gNB**):-

- Double Click On Node 5 > Interfaces > Interface 0 > MAC Layer (Make sure that Interface 0 corresponds to the wireless interface of the node).
  - **i.** Set **Station Type** to 5g Node B.
  - **ii.** Set Duplex Mode to FDD.
  - **iii.** Use default values for all other interface parameters.

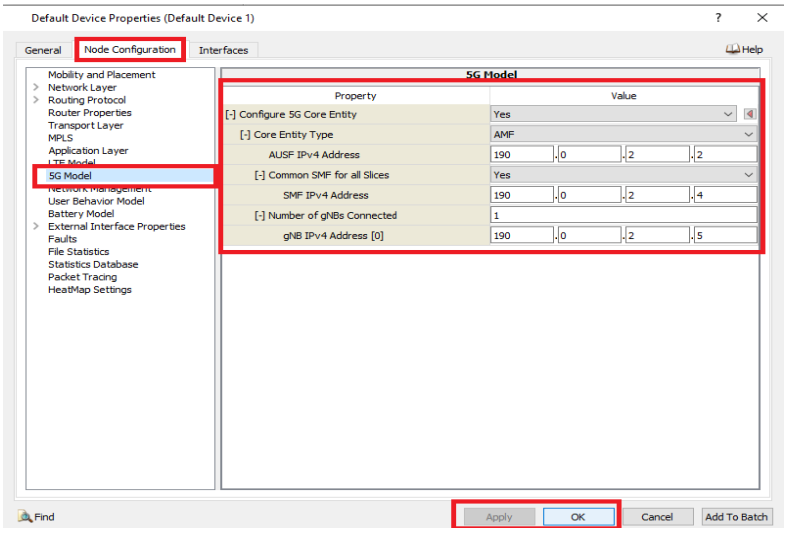


- Click On > Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to gNB.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UPF IPv4 Address to 190.0.4.2
  - **iv.** Click on Apply > OK



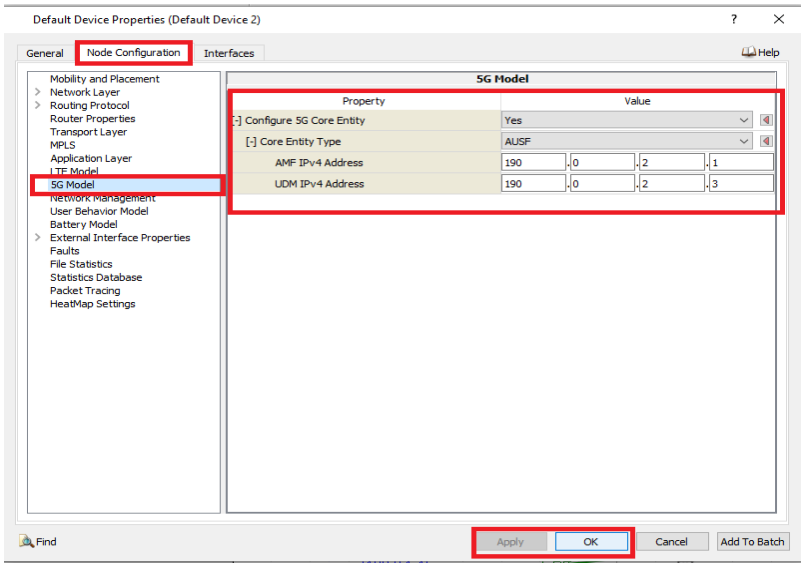

**(4).** To Configure Node 1 **(AMF)** :-

- Double Click On Node 1 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to AMF.
  - **ii.** Set AUSF IPv4 Address to 190.0.2.2
  - **iii.** Set SMF IPv4 Address to 190.0.2.4
  - **iv.** Set Number of gNBs Connected to 1
  - **v.** Set gNB IPv4 Address [0] to 190.0.2.5
  - **vi.** Click On Apply > Ok



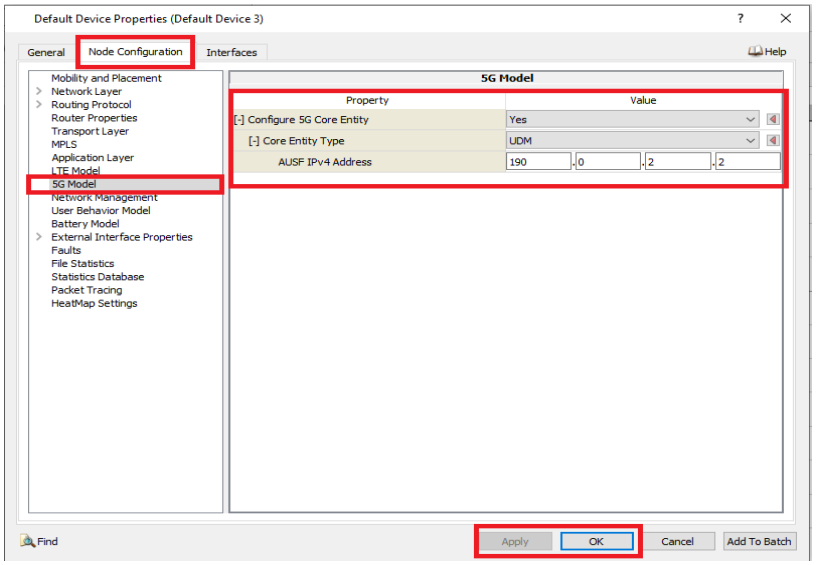
**(5).** To Configure Node 2 **(AUSF):-**

- Double Click On Node 2 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to AUSF.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UDM IPv4 Address to 190.0.2.3
  - **iv.** Click On Apply > Ok



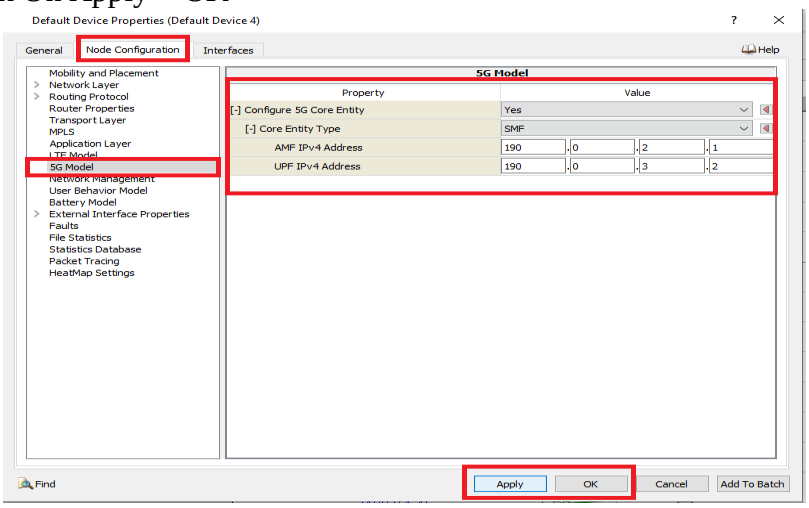

**(6).** To Configure Node 3 **(UDM)**:-

- Double Click On Node 3 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to UDM.
  - **ii.** Set AUSF IPv4 Address to 190.0.2.2
  - **iii.** Click On Apply > OK



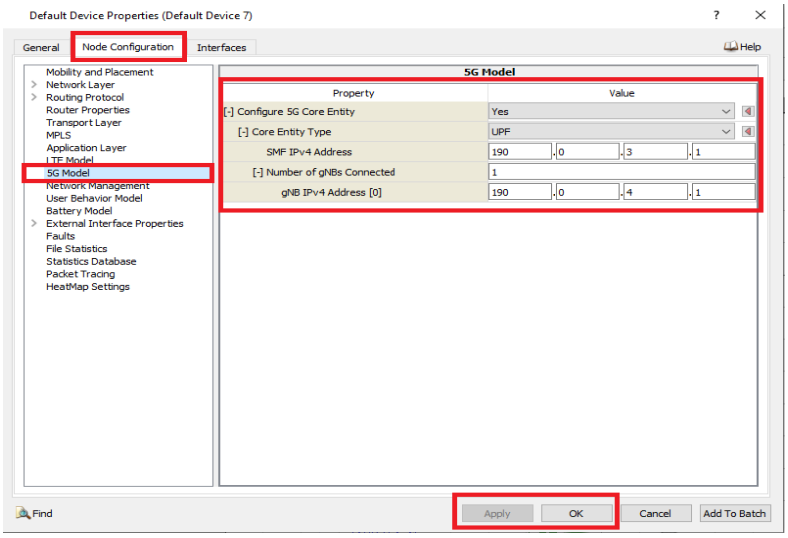
**(7).** To Configure Node 4 **(SMF)**:-

- Double Click On Node 4 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to SMF.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UPF IPv4 Address to 190.0.3.2
  - **iv.** Click On Apply > OK



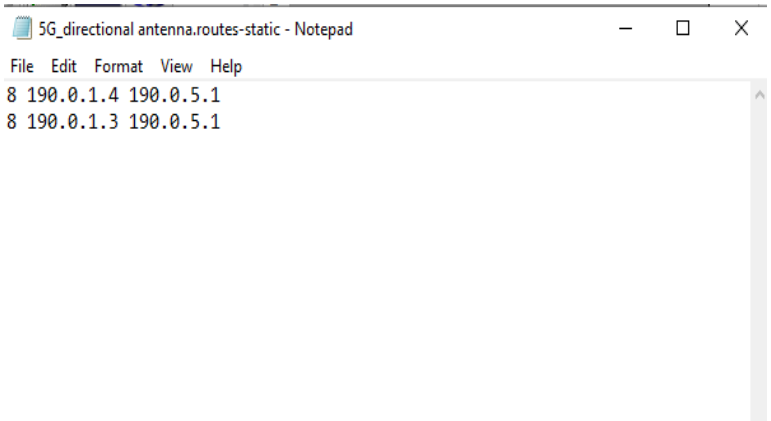

**(8).** To Configure Node 7 **(UPF)**:-

- Double Click On Node 7 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to UPF.
  - **ii.** Set SMF IPv4 Address to 190.0.3.1
  - **iii.** Set Number of gNBs Connected to 1
  - **iv.** Set gNB IPv4 Address [0] to 190.0.4.1
  - **v.** Click On Apply > OK

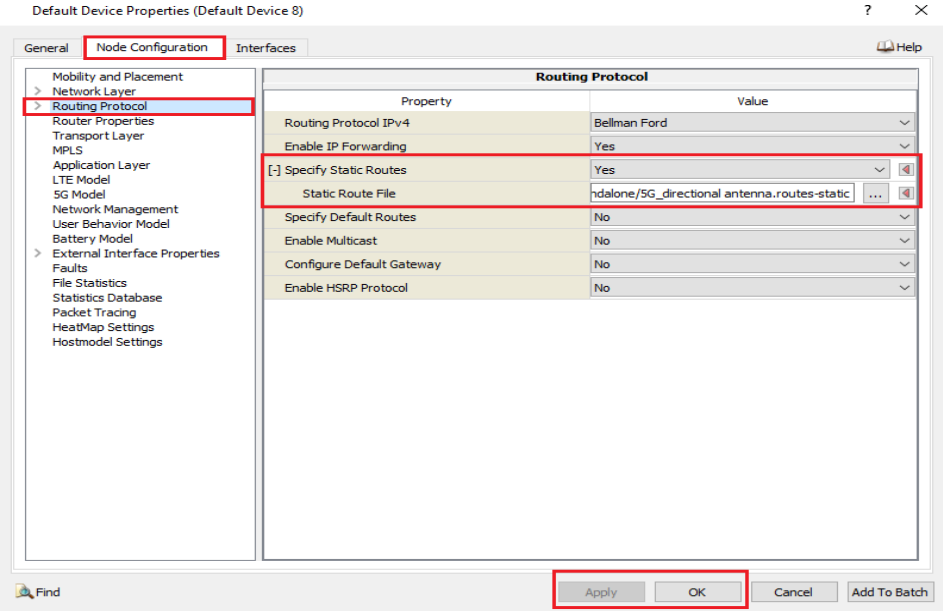


**(9).** To Configure Node 8 **(DN)**: -

- Double Click On Node 8 > Go to Node Configuration > Routing Protocol.
  - **i.** Set Specify Static Routes to Yes.
  - **ii.** Create a file in Notepad called **Filename.routes-static** in the scenario directory which contains the static route from the DN to the UE.
  - **iii.** In the Static Routes file, **Filename.routes-static**, specify the routes as follows:-
    <Node Id of DN> <IP-ADDRESS of UE> < Next Hop IP Address/IP of UPF >
    8 190.0.1.4 190.0.5.1
    8 190.0.1.3 190.0.5.1

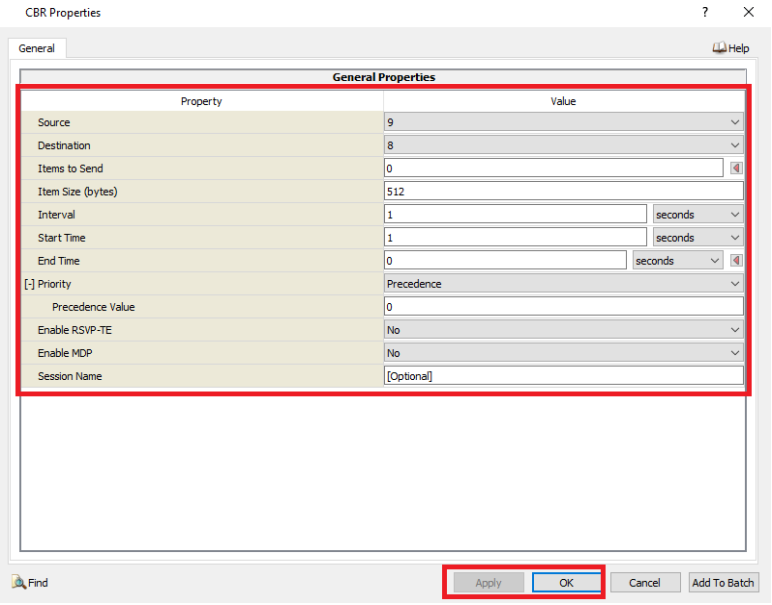



  - **iv.** To Set Static Route File > Click on Select files and select **Filename.routes-static**
  - **v.** Click On Apply > OK



**(10).** To set the properties of the CBR Application, do the following:-

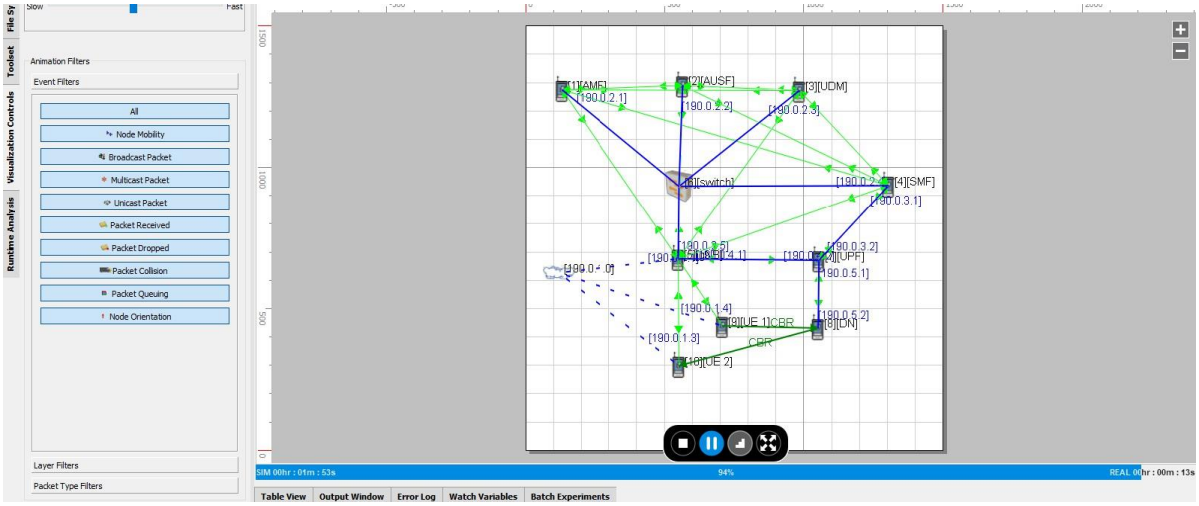
- Double-click the CBR link on the canvas.
- In the CBR Properties Editor, set the parameters as shown below
- Click On Apply > OK.
- Repeat the steps for other CBR application.



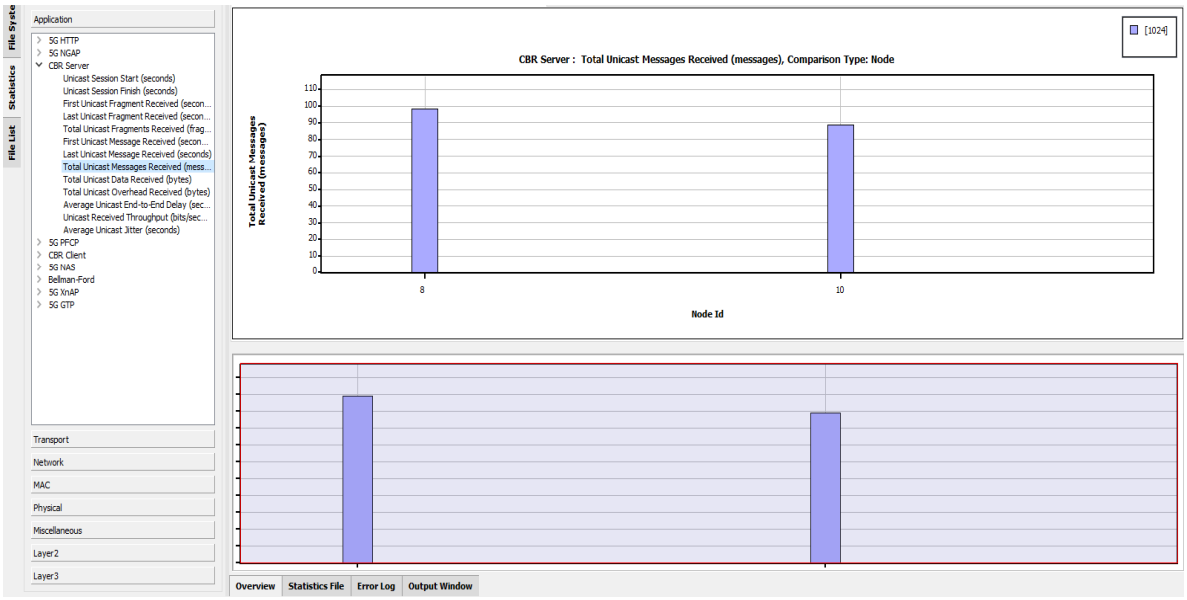

**Step5:** Save the scenario by clicking the Save button in the toolbar.

**Step6:** Click the Run Simulation button.

**Step7**: To start the simulation, click the **Play** button at the bottom of the canvas.



**Step8**: After the simulation has completed, switch to Analyzer by clicking the Analyze Results button. In the analyzer the performance parameter of the current scenario and the layer wise communication can be seen. Number of packets received, throughput, jitter, end to end delay, client and the server performance etc. can be analyzed.



## 6. Simulation for different weather conditions.

To design and analysis of different weather condition in 5G Network. User-specified weather patterns that move and affect propagation.

**Please refer "chapter 11 Miscellaneous Models" – 11.2 Weather Pattern Model in wireless model library For more details**

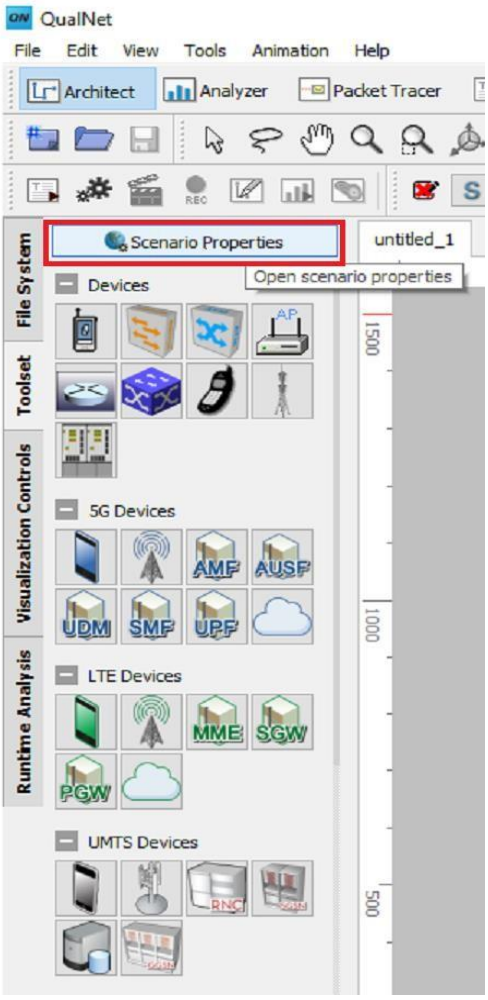
## Procedures to Create Scenario :-

### Step1: -

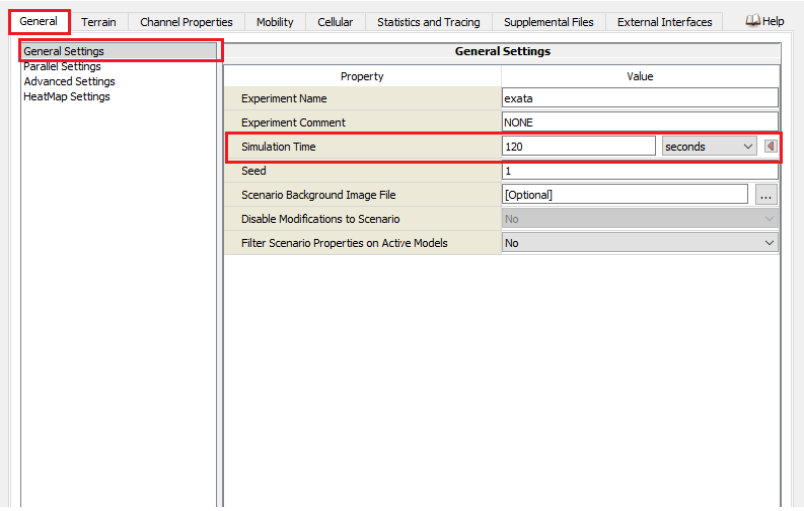
- Start the QualNet GUI.
- To start, Double-click on the QualNet GUI icon on the Desktop.

### Step 2: -

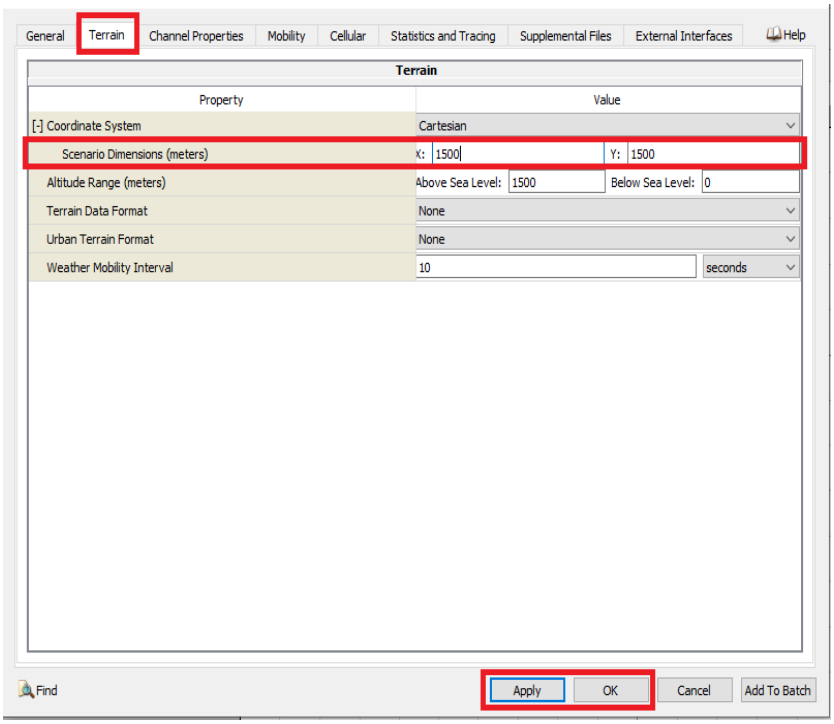
- Check the terrain size before placing the components on the canvas area.
- Click on the '**Scenario Properties**' button in the toolset panel.



- Click on '**General**' button on the top of the newly opened editor. Click on > General Settings > Simulation Time to **120** sec.

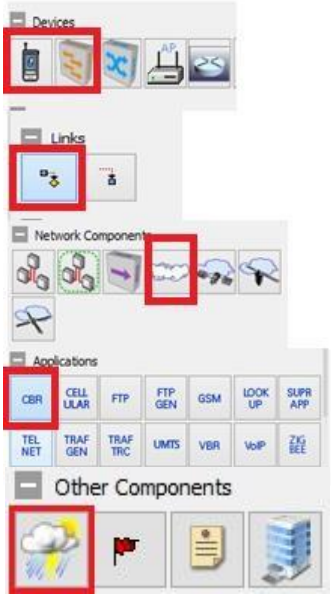


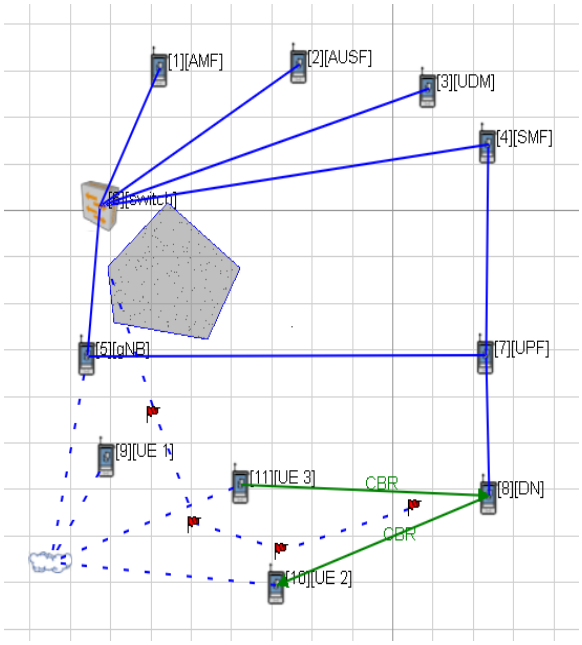

- Click on **'Terrain'** set scenario dimensions as (x:1500 and y:1500) > Apply > OK.



**Step 3:** -To create a scenario, choose the components required from toolset and place it on the canvas using drag-drop as shown in figure.

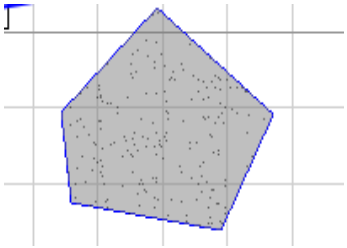
- components
- Links
- Wireless subnet
- CBR application
- Weather



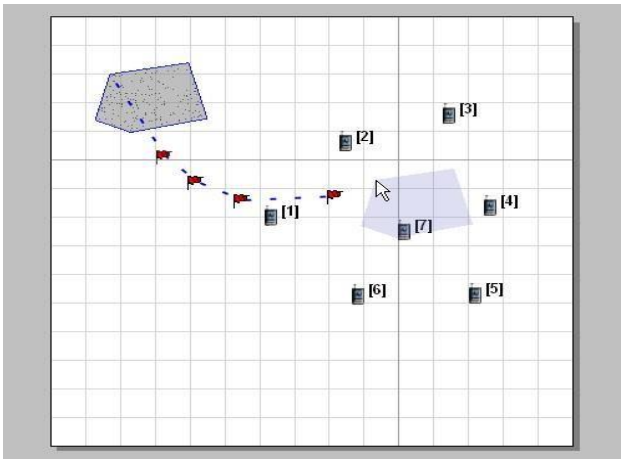




## To Create Weather Patterns

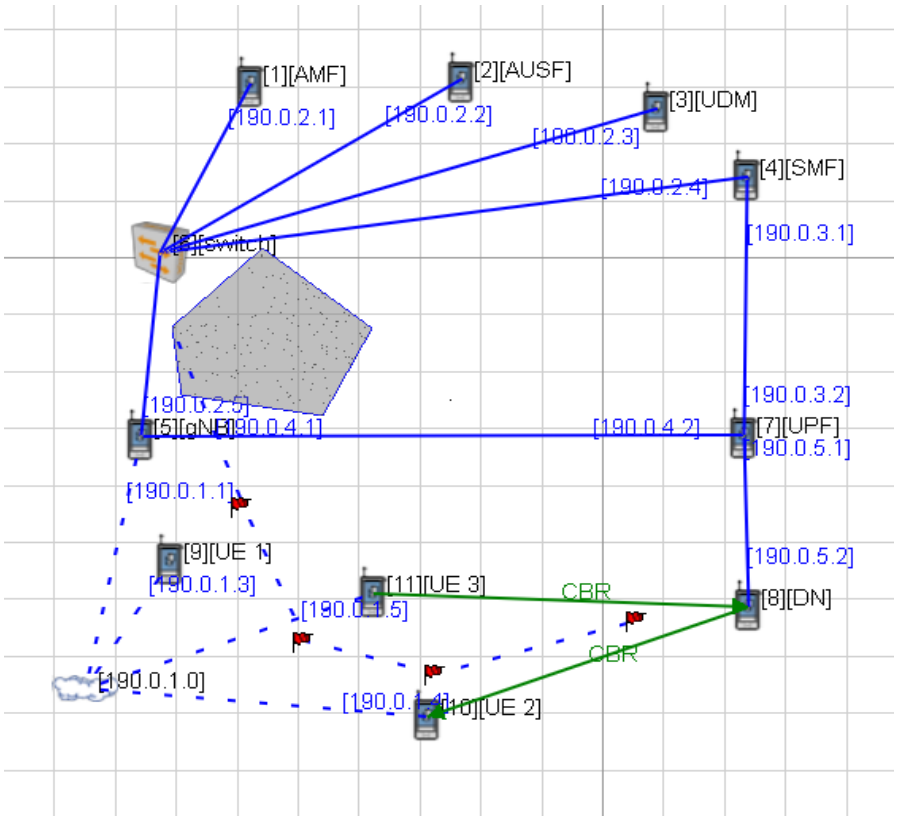
1. Select the **Weather Pattern** button from the **Other Components** toolbar of the **Standard Toolset** .
2. Draw the polygon representing the weather pattern by clicking on the canvas locations corresponding to the corners of the polygon. When you add a new point, lines is drawn from the last point to new point and the very first point to the new point.
3. After placing the last corner of the polygon, press the right mouse button.
4. To end the weather pattern insert mode, press the right mouse button again.



- Mobility can be added to a weather pattern in the same manner as a node. Note that after clicking on a weather object with the waypoint tool selected, a shadow of the weather object will follow the mouse pointer to indicate what area the weather will cover.

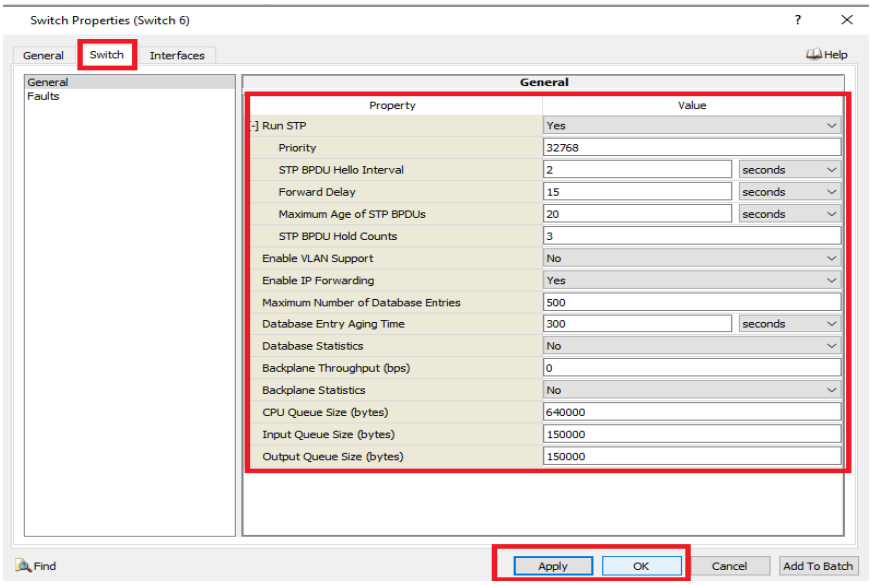



- **Create the scenario topology as shown in below figure**.
  Below Figure shows the IP addresses of the interfaces in the scenario. The IP addresses depend on the order in which nodes, subnets, and connections are created and may be different in your scenario from the ones shown in the figure. We will use these addresses in the configuration steps below.



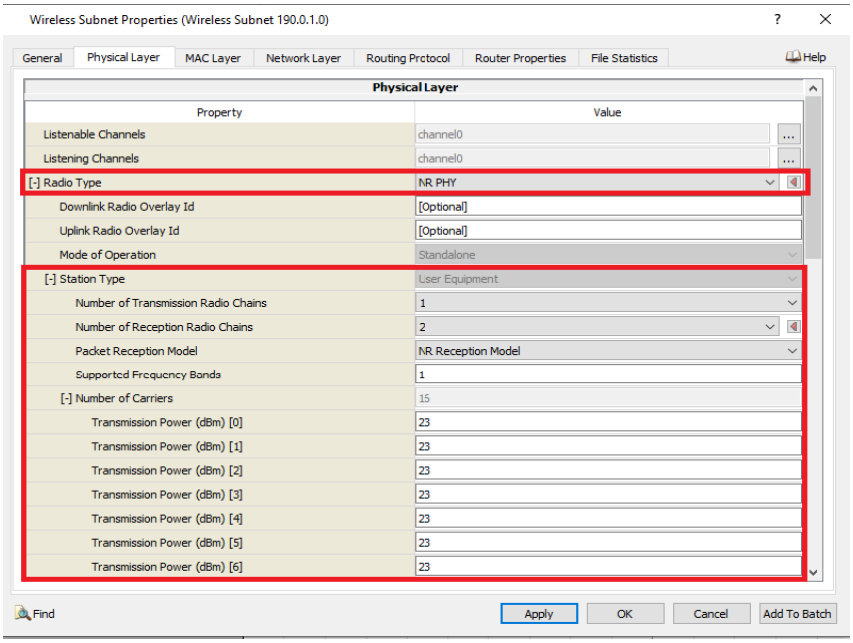
**Step 4:-** To configure the scenario in QualNet GUI, perform the following steps:-

**(1).** To Configure the **Switch**, Double Click on Switch > go to Switch and set Run STP to **Yes** and use default values for all other parameter > Apply > OK.

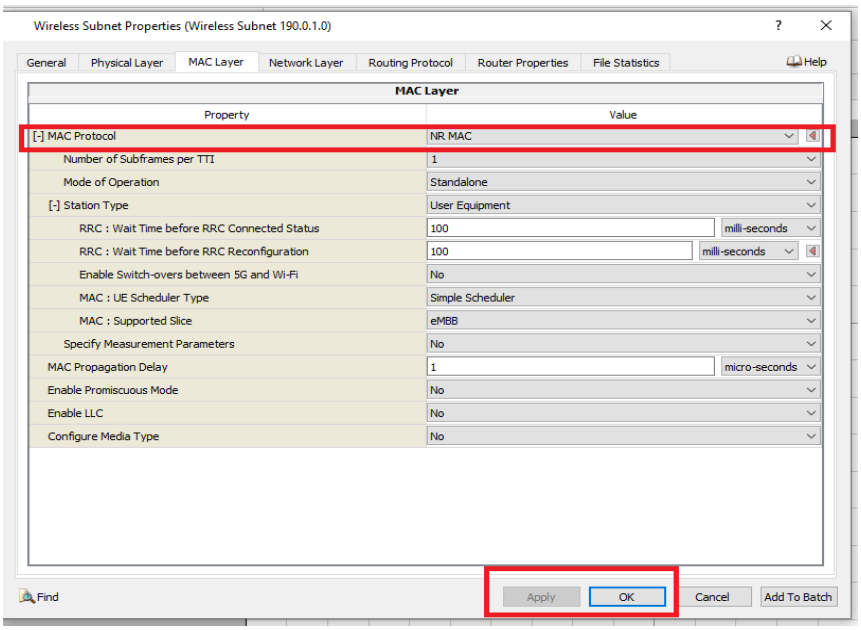



**(2).** To Configure the **wireless subnet**:-

- Double Click On wireless subnet > Go to Physical Layer
  - **i.** Set Radio Type to NR PHY
  - **ii.** Use default values for all other PHY parameters

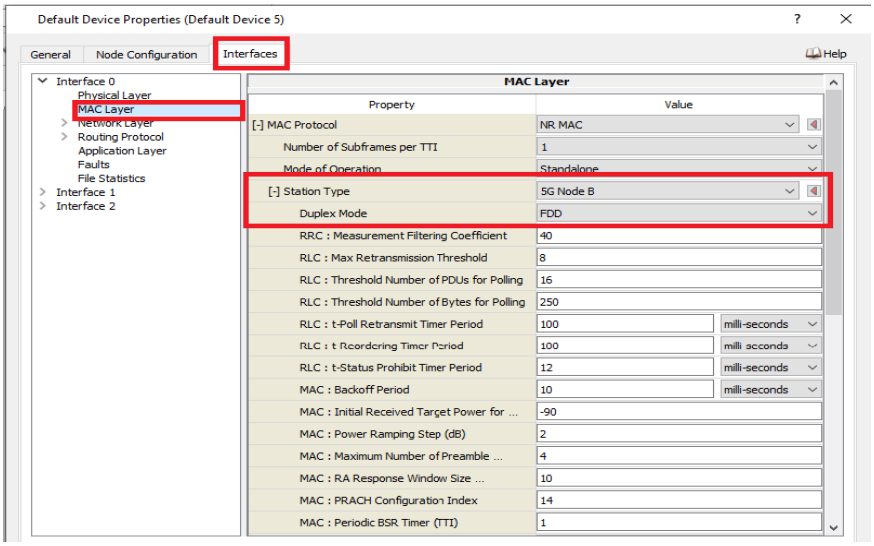


- Go to MAC Layer
  - **i.** Set MAC Protocol to NR MAC.
  - **ii.** Use default values for all MAC parameters.
  - **iii.** Click on Apply > OK

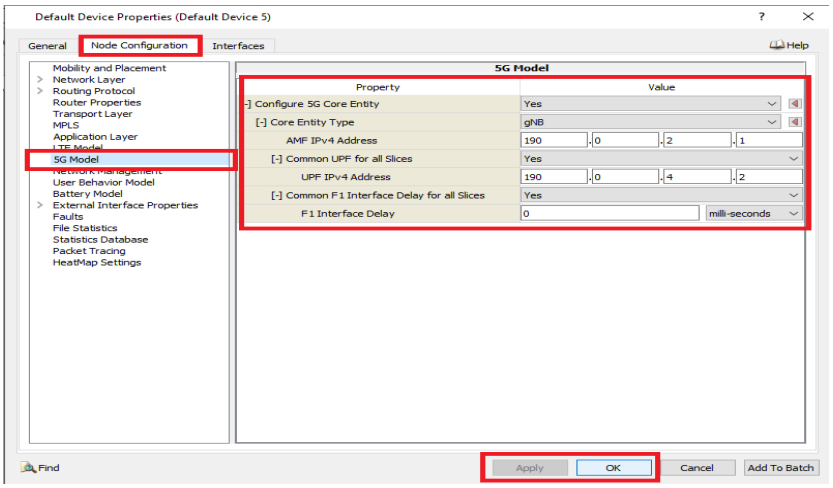



**(3).** To Configure Node 5 (**gNB**):-

- Double Click On Node 5 > Interfaces > Interface 0 > MAC Layer (Make sure that Interface 0 corresponds to the wireless interface of the node).
  - **i.** Set **Station Type** to 5g Node B.
  - **ii.** Set Duplex Mode to FDD.
  - **iii.** Use default values for all other interface parameters.

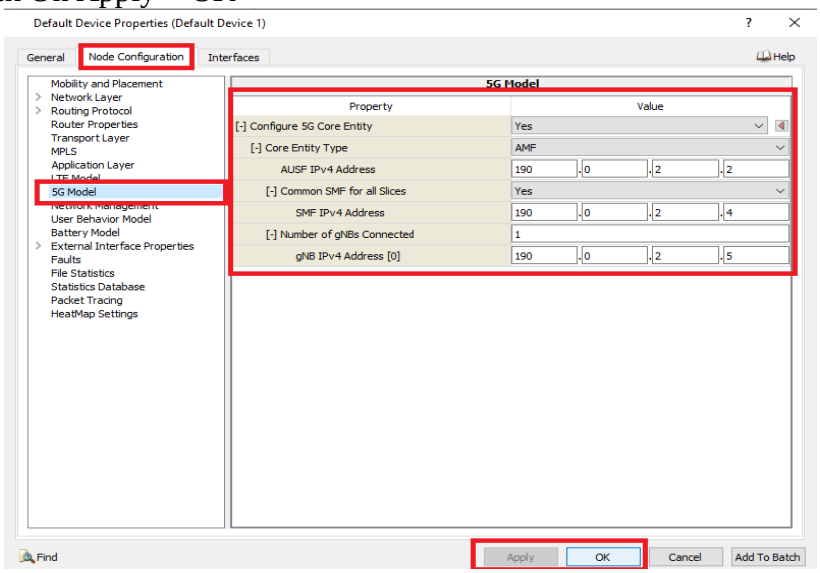


- Click On > Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to gNB.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UPF IPv4 Address to 190.0.4.2
  - **iv.** Click On Apply > OK



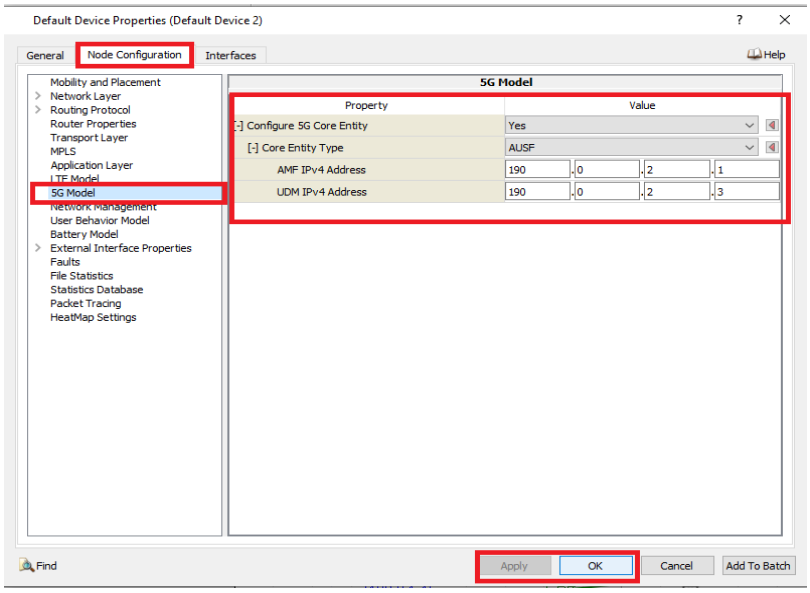

**(4).** To Configure Node 1 **(AMF)**:-

- Double Click On Node 1 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to AMF.
  - **ii.** Set AUSF IPv4 Address to 190.0.2.2
  - **iii.** Set SMF IPv4 Address to 190.0.2.4
  - **iv.** Set Number of gNBs Connected to 1
  - **v.** Set gNB IPv4 Address [0] to 190.0.2.5
  - **vi.** Click On Apply > OK



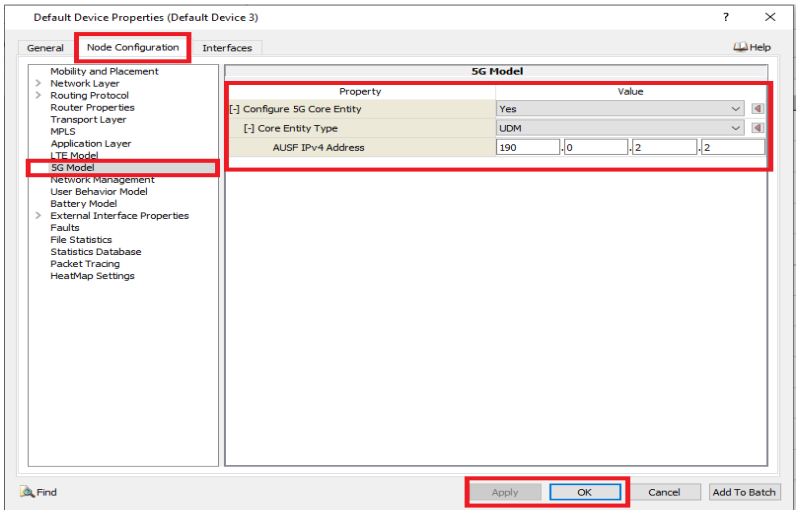
**(5).** To Configure Node 2 **(AUSF):-**

- Double Click On Node 2 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to AUSF.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UDM IPv4 Address to 190.0.2.3
  - **iv.** Click On Apply > OK



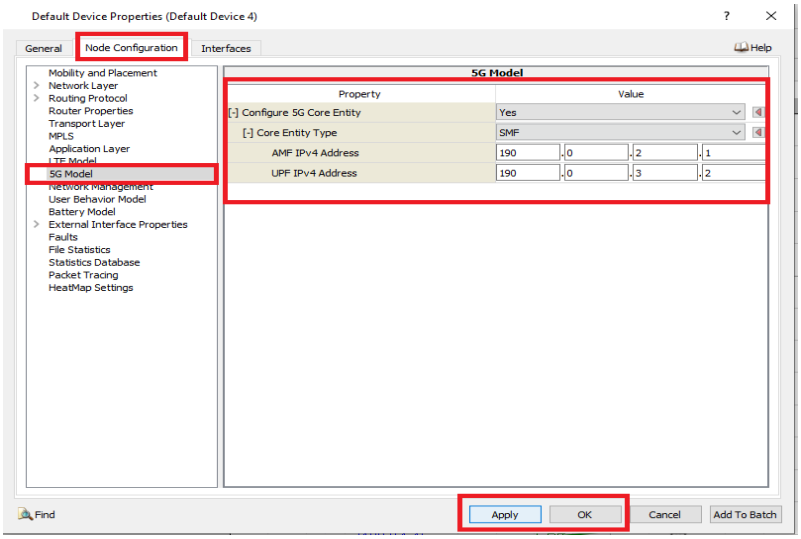

**(6).** To Configure Node 3 **(UDM)**:-

- Double Click On Node 3 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to UDM.
  - **ii.** Set AUSF IPv4 Address to 190.0.2.2
  - **iii.** Click On Apply > OK



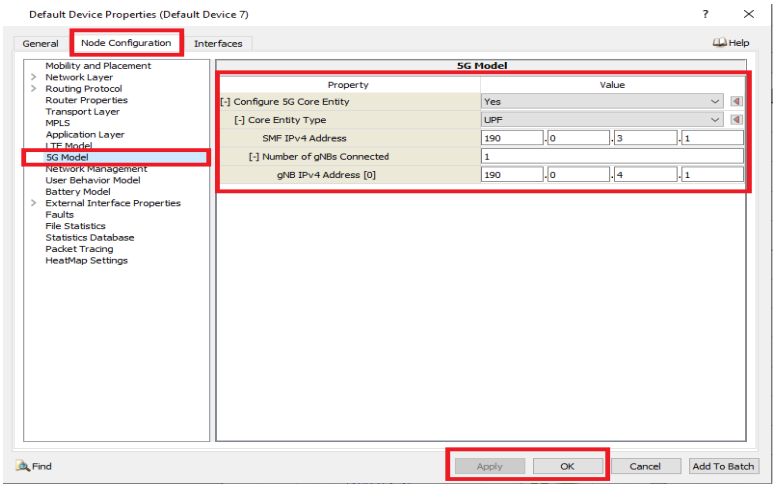
**(7).** To Configure Node 4 **(SMF)**:-

- Double Click On Node 4 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to SMF.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UPF IPv4 Address to 190.0.3.2
  - **iv.** Click On Apply > OK




**(8).** To Configure Node 7 **(UPF)**:-

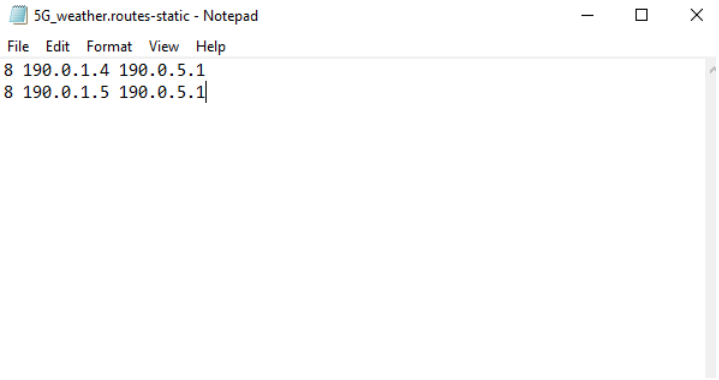
- Double Click On Node 7 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to UPF.
  - **ii.** Set SMF IPv4 Address to 190.0.3.1
  - **iii.** Set Number of gNBs Connected to 1
  - **iv.** Set gNB IPv4 Address [0] to 190.0.4.1
  - **v.** Click On Apply > OK



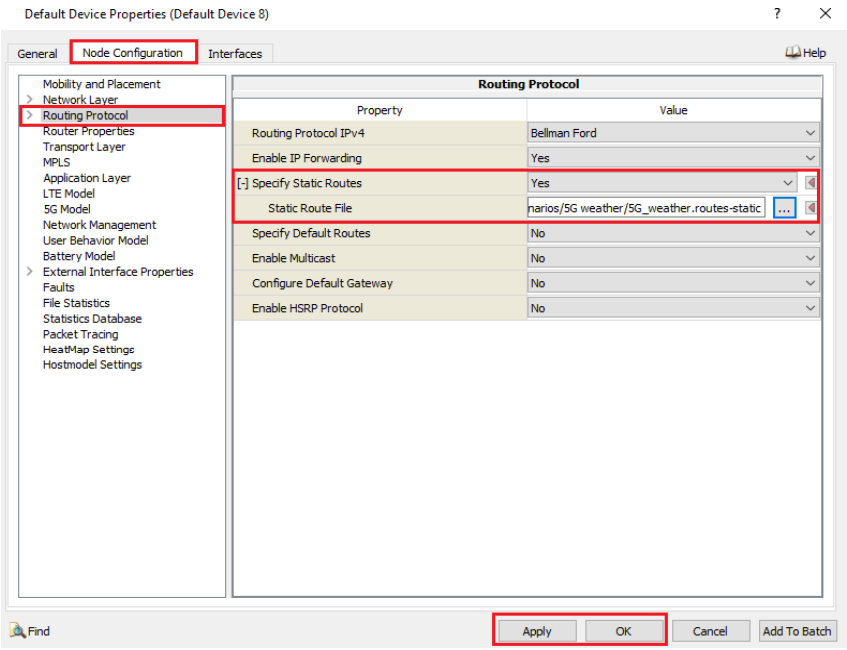
**(9).** To Configure Node 8 **(DN)**: -

- Double Click On Node 8 > Go to Node Configuration > Routing Protocol.
  - **i.** Set Specify Static Routes to Yes.
  - **ii.** Create a file in Notepad called **Filename.routes-static** in the scenario directory which contains the static route from the DN to the UE.
  - **iii.** In the Static Routes file, **Filename.routes-static**, specify the routes as follows:-
    <Node Id of DN> <IP-ADDRESS of UE> < Next Hop IP Address/IP of UPF >

    8 190.0.1.4 190.0.5.1
    8 190.0.1.5 190.0.5.1

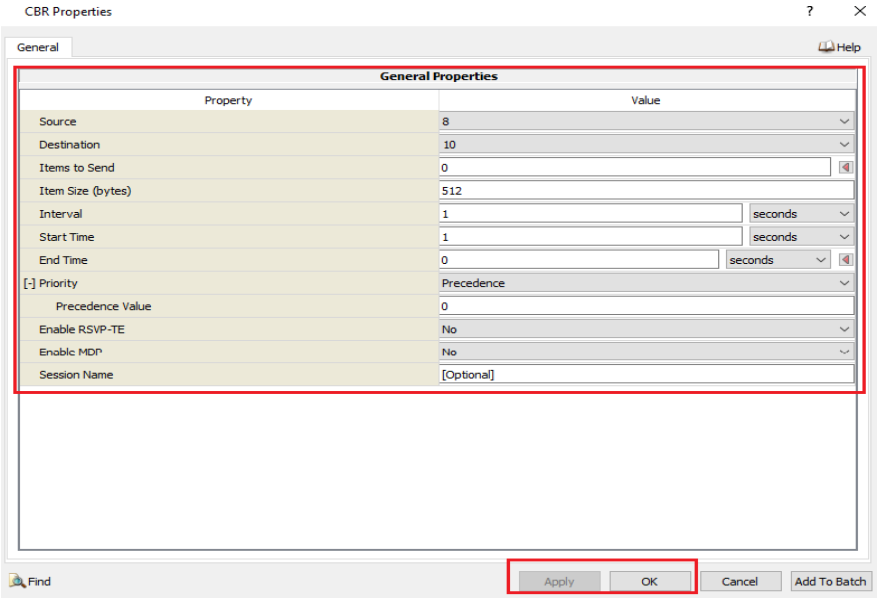



  - **iv.** To Set Static Route File > Click on Select files and select **Filename.routes-static**
  - **v.** Click On Apply > OK

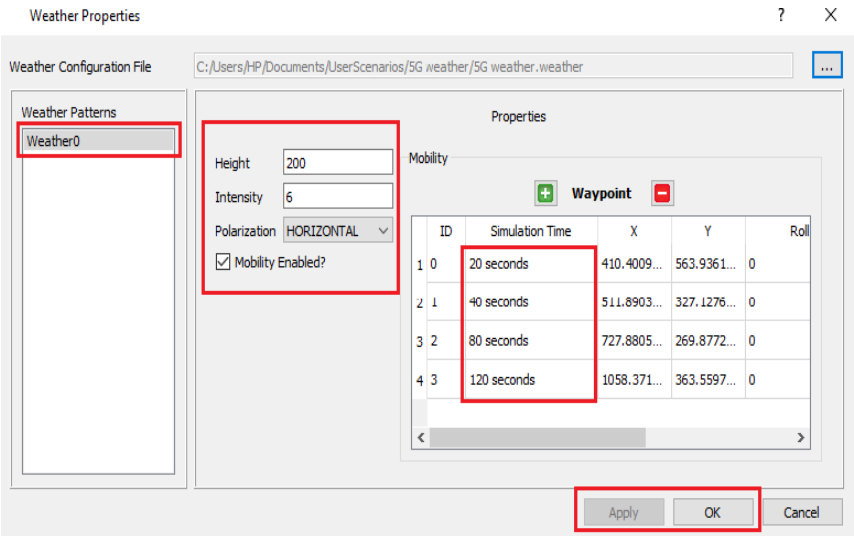


**(10).** To set the properties of the CBR Application, do the following:-

- Double-click the CBR link on the canvas.
- In the CBR Properties Editor, set the parameters as shown below
- Click On Apply > OK.
- Repeat the steps for other CBR application.



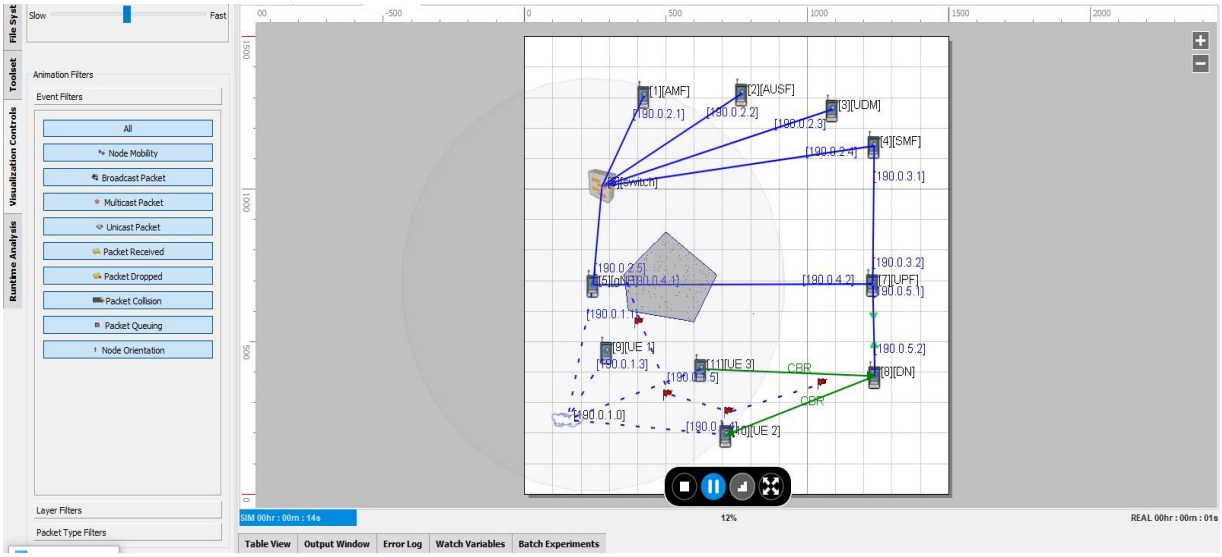

**(11).** To Set up a **Weather** > Go to the Weather Properties Editor, right-click on a weather object and select **Properties** and Configure **Height, Intensity**, **Polarization** and **Simulation Time** as shown in the below figure and Click On Apply > OK

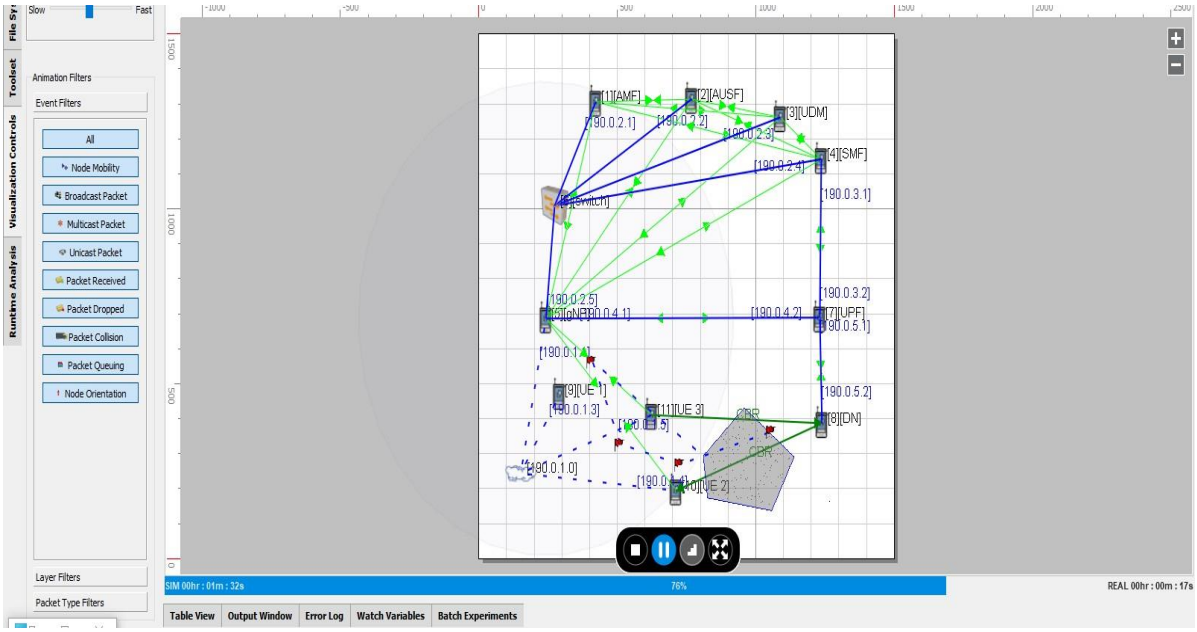


**Step5:** Save the scenario by clicking the Save button in the toolbar.

**Step6:** Click the Run Simulation button.

**Step7**: To start the simulation, click the **Play** button at the bottom of the canvas.



**Step8**: After the simulation has completed, switch to Analyzer by clicking the Analyze Results button. In the analyzer the performance parameter of the current scenario and the layer wise communication can be seen. Number of packets received, throughput, jitter, end to end delay, client and the server performance etc. can be analyzed.

# 7. X2 handover between gNBs with UPF change

X2 Handover with UPF in 5G Standalone mode, One 5G core is present in the scenario having one AMF, one AUSF, one UDM, one SMF, one UPF, two GNBs and one UE.

## Procedures to Create Scenario:-

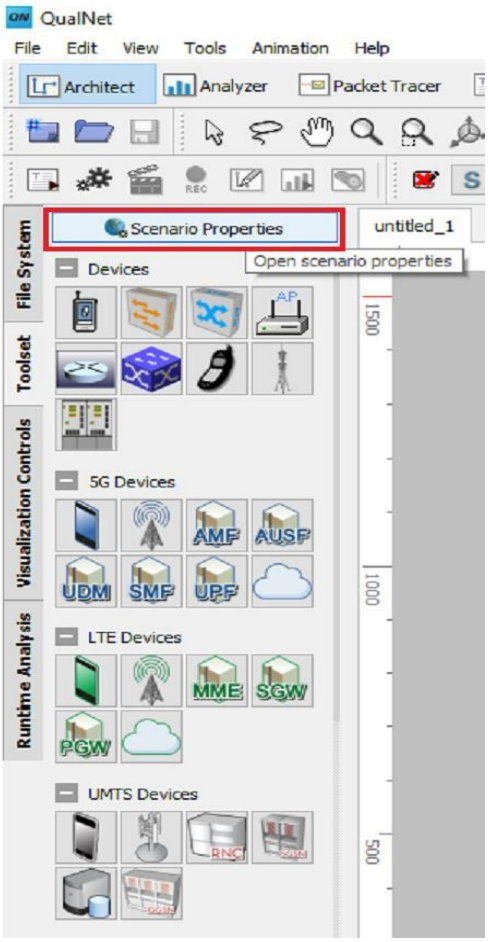
## Step1: -

- Start the QualNet GUI.
- To start, Double-click on the QualNet GUI icon on the Desktop.

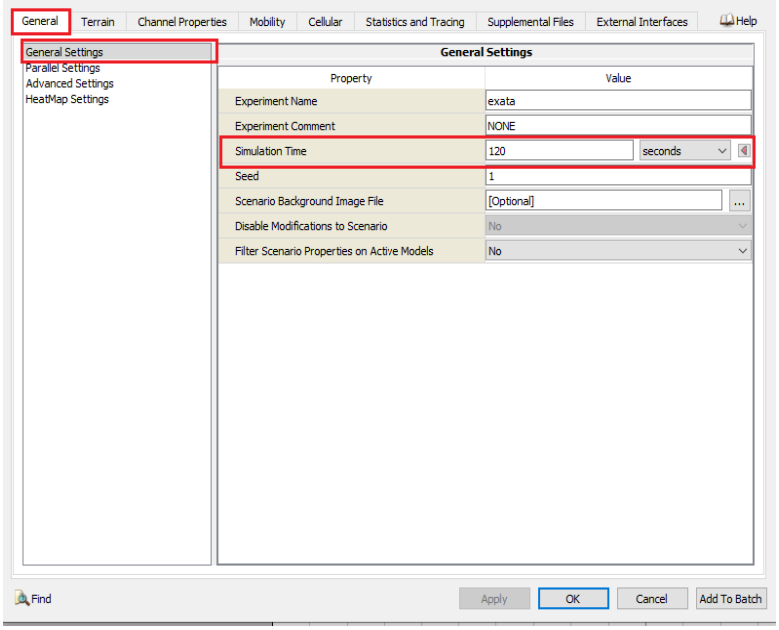
## Step 2: -

- Check the terrain size before placing the components on the canvas area.

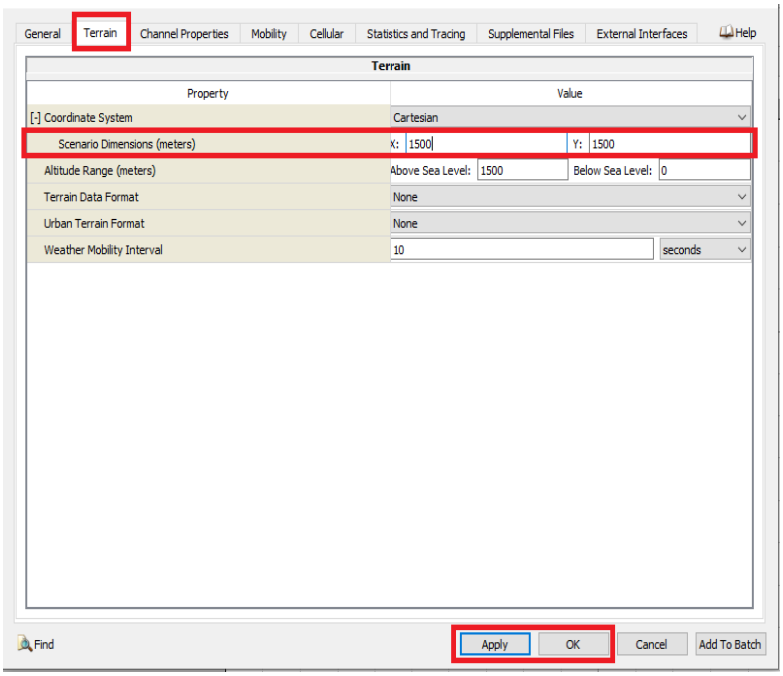
- Click on the '**Scenario Properties**' button in the toolset panel.



- Click on '**General**' button on the top of the newly opened editor. Click on > General Settings > Simulation Time > **120** sec.

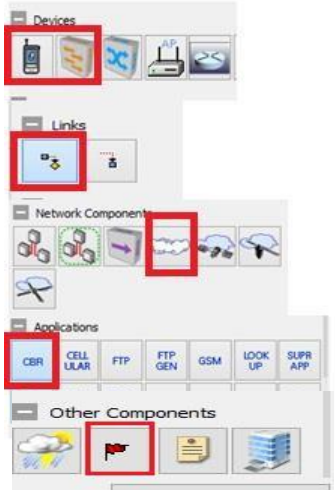


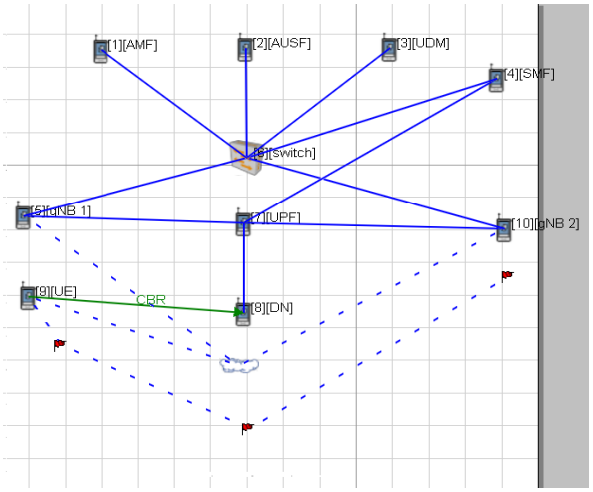

- Click on **'Terrain'** set scenario dimensions as (x:1500 and y:1500) > Apply > OK.



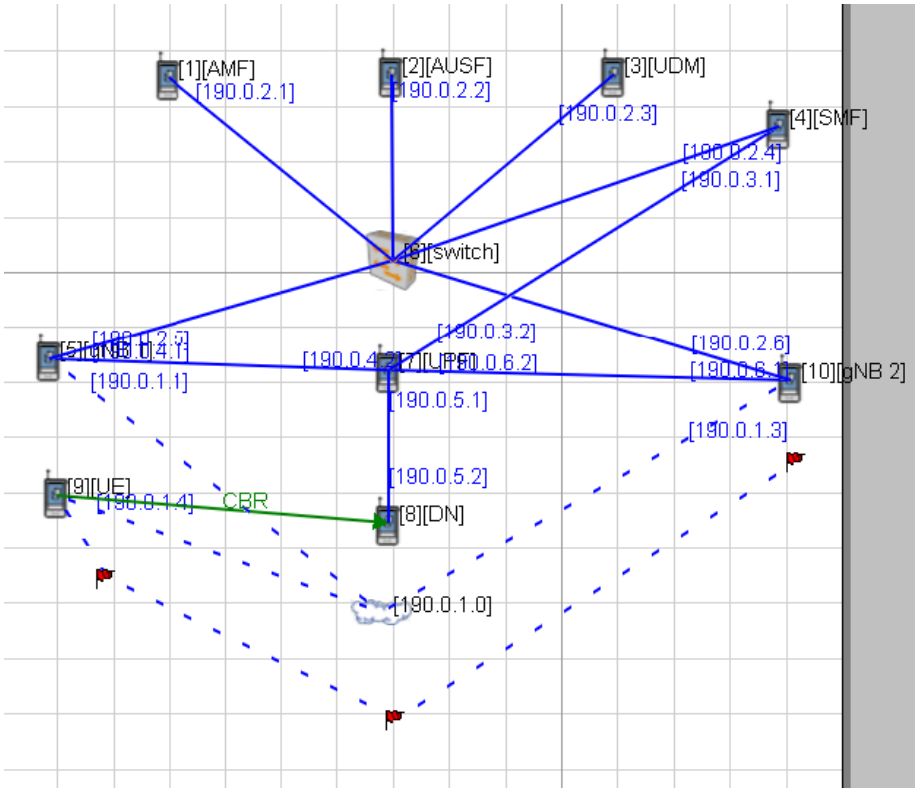
**Step 3:** -To create a scenario, choose the components required from toolset and place it on the canvas using drag-drop as shown in figure.

- components
- Links
- Wireless subnet
- CBR application
- Mobility



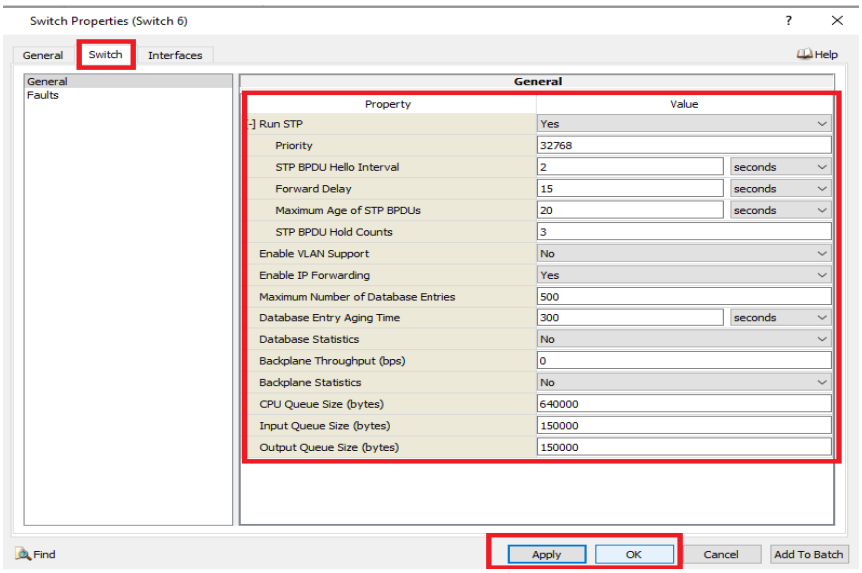




- **Create the scenario topology as shown in below figure.**
  Below Figure shows the IP addresses of the interfaces in the scenario. The IP addresses depend on the order in which nodes, subnets, and connections are created and may be different in your scenario from the ones shown in the figure. We will use these addresses in the configuration steps below.



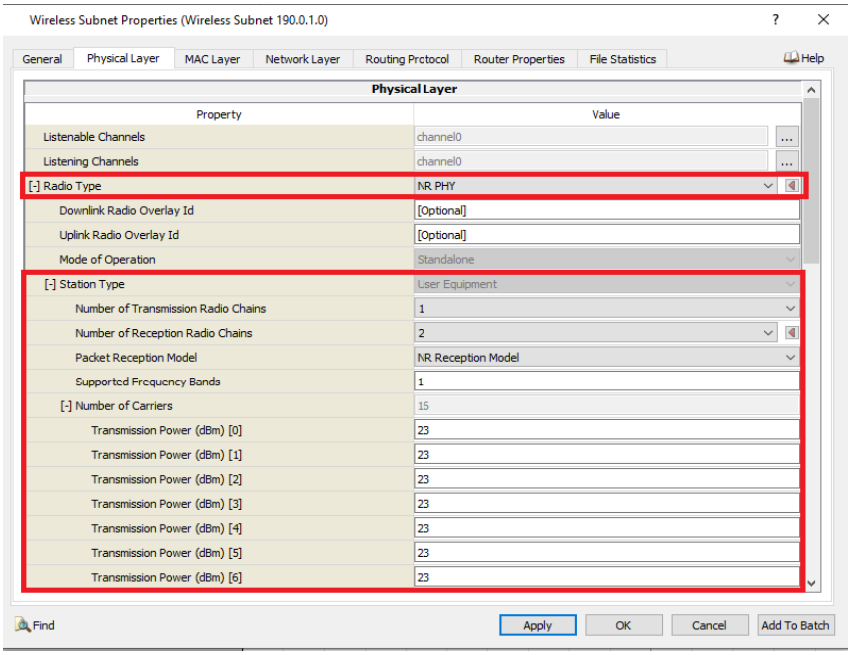
**Step 4:-** To configure the scenario in QualNet GUI, perform the following steps:

**(1).** To Configure the **Switch**, Double Click on Switch > go to Switch and set Run STP to **Yes** and use default values for all other parameter > Apply > OK.

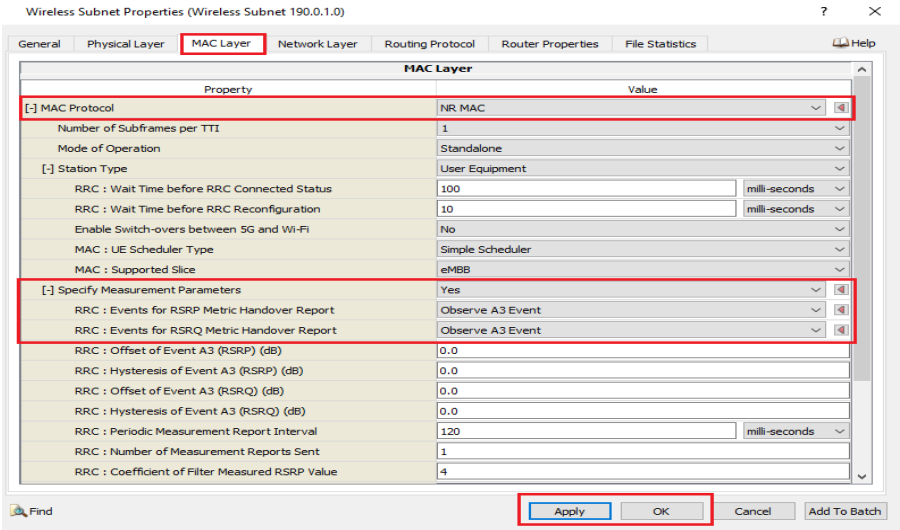



**(2).** To Configure the **wireless subnet**:-

- Double Click On wireless subnet > Go to Physical Layer
  - **i.** Set Radio Type to NR PHY.
  - **ii.** Use default values for all other PHY parameters.

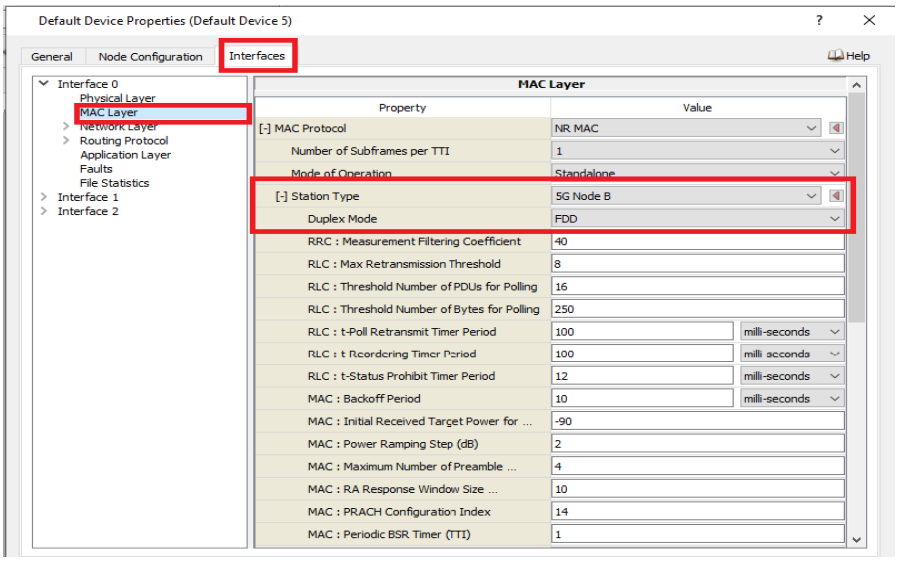


- Go to MAC Layer
  - **i.** Set MAC Protocol to NR MAC.
  - **ii.** Specify Measurement Parameters to **Yes** and use parameters as shown in below figure.
  - **iii.** Use default values for all other MAC parameters.
  - **iv.** Click on Apply > OK

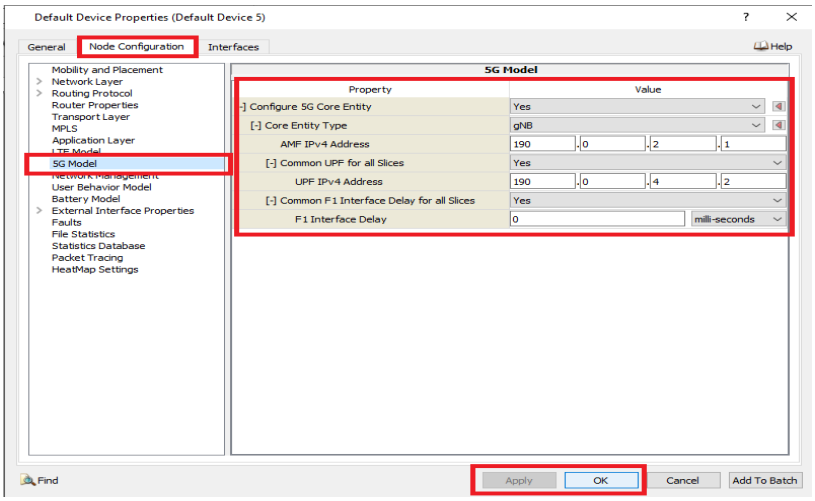



**(3).** To Configure Node 5 (**gNB 1**):-

- Double Click On Node 5 > Interfaces > Interface 0 > MAC Layer (Make sure that Interface 0 corresponds to the wireless interface of the node).
  - **i.** Set **Station Type** to 5g Node B.
  - **ii.** Set Duplex Mode to FDD.
  - **iii.** Use default values for all other interface parameters.

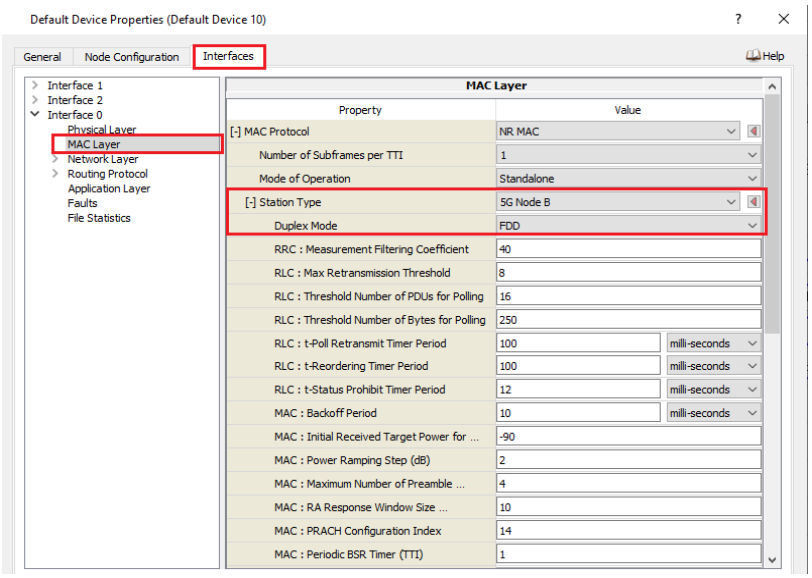


- Click On > Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to gNB.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UPF IPv4 Address to 190.0.4.2
  - **iv.** Click on Apply > OK

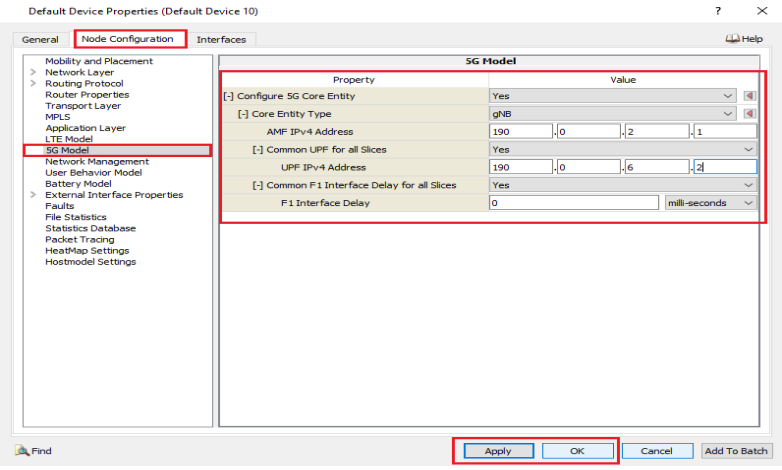



**(4).** To Configure Node 10 (**gNB 2**):-

- Double Click On Node 10 > Interfaces > Interface 0 > MAC Layer (Make sure that Interface 0 corresponds to the wireless interface of the node).
  - **i.** Set **Station Type** to 5g Node B.
  - **ii.** Set Duplex Mode to FDD.
  - **iii.** Use default values for all other interface parameters.

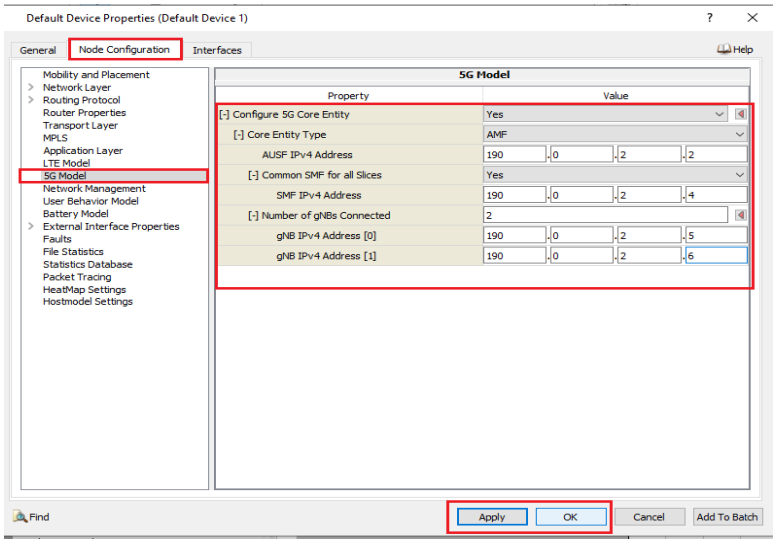


- Click On > Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to gNB.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UPF IPv4 Address to 190.0.6.2
  - **iv.** Click on Apply > OK



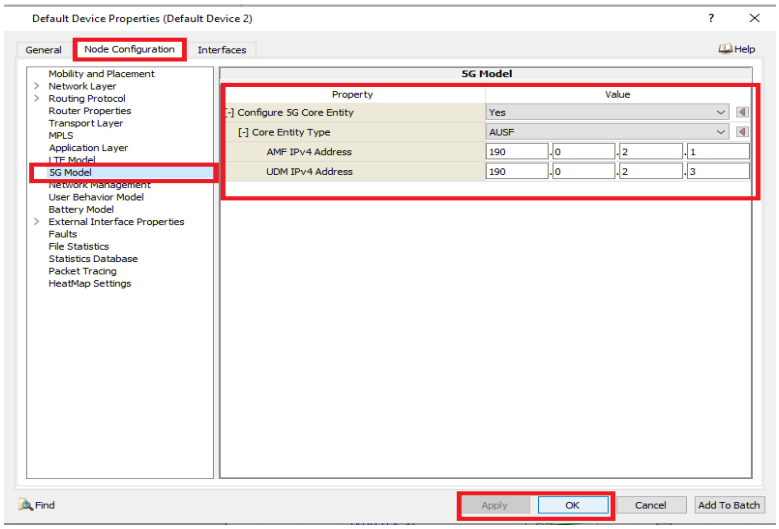

**(5).** To Configure Node 1 **(AMF)**:-

- Double Click On Node 1 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to AMF.
  - **ii.** Set AUSF IPv4 Address to 190.0.2.2
  - **iii.** Set SMF IPv4 Address to 190.0.2.4
  - **iv.** Set Number of gNBs Connected to 2
  - **v.** Set gNB IPv4 Address [0] to 190.0.2.5
  - **vi.** Set gNB IPv4 Address [1] to 190.0.2.6
  - **vii.** Click on Apply > OK



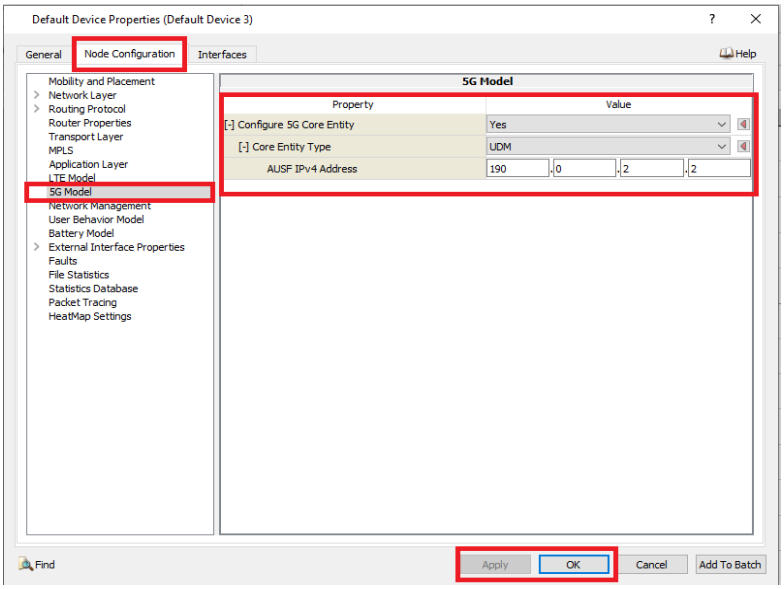
**(6).** To Configure Node 2 **(AUSF):-**

- Double Click On Node 2 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to AUSF.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UDM IPv4 Address to 190.0.2.3
  - **iv.** Click on Apply > OK



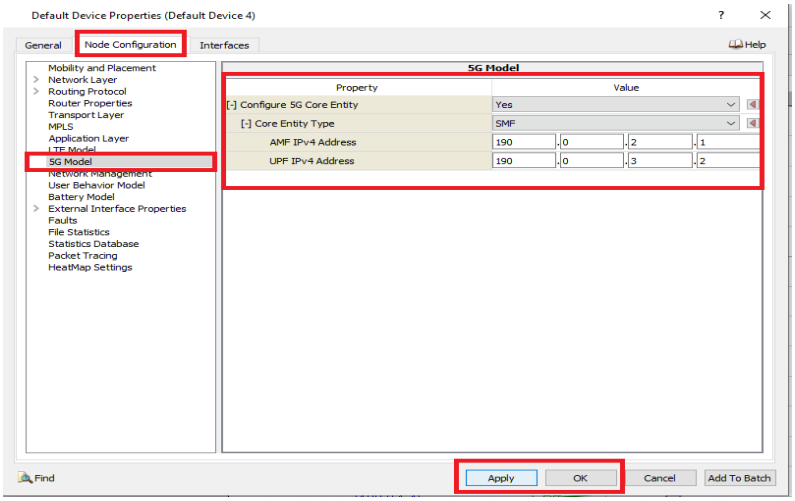

**(7).** To Configure Node 3 **(UDM)**:-

- Double Click On Node 3 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to UDM.
  - **ii.** Set AUSF IPv4 Address to 190.0.2.2
  - **iii.** Click on Apply > OK



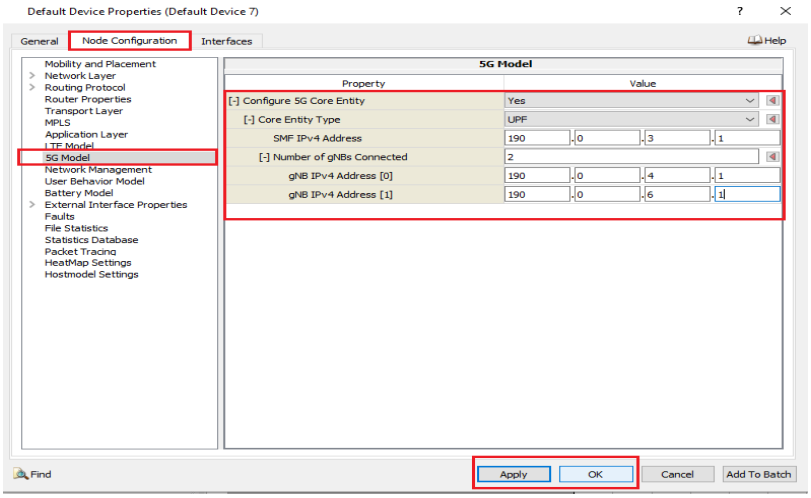
**(8).** To Configure Node 4 **(SMF)**:-

- Double Click On Node 4 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to SMF.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UPF IPv4 Address to 190.0.3.2
  - **iv.** Click on Apply > OK



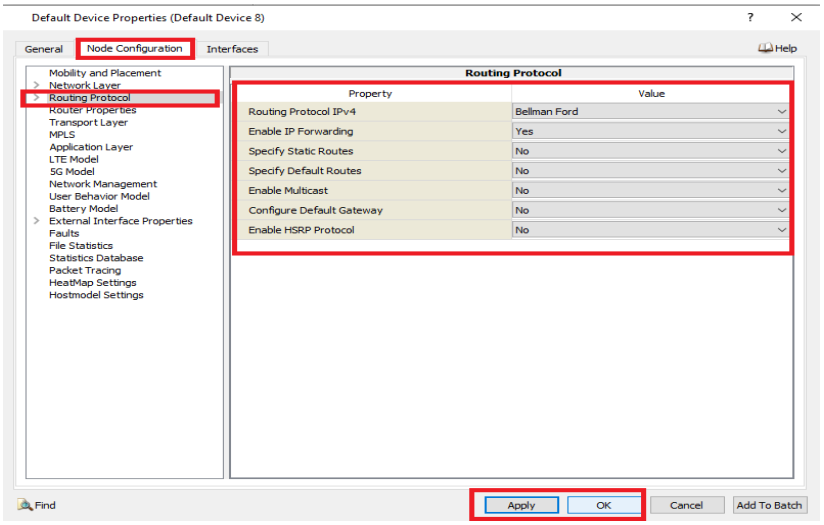

**(9).** To Configure Node 7 **(UPF)**:-

- Double Click On Node 7 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to UPF.
  - **ii.** Set SMF IPv4 Address to 190.0.3.1
  - **iii.** Set Number of gNBs Connected to 2
  - **iv.** Set gNB IPv4 Address [0] to 190.0.4.1
  - **v.** Set gNB IPv4 Address [1] to 190.0.6.1
  - **vi.** Click on Apply > OK



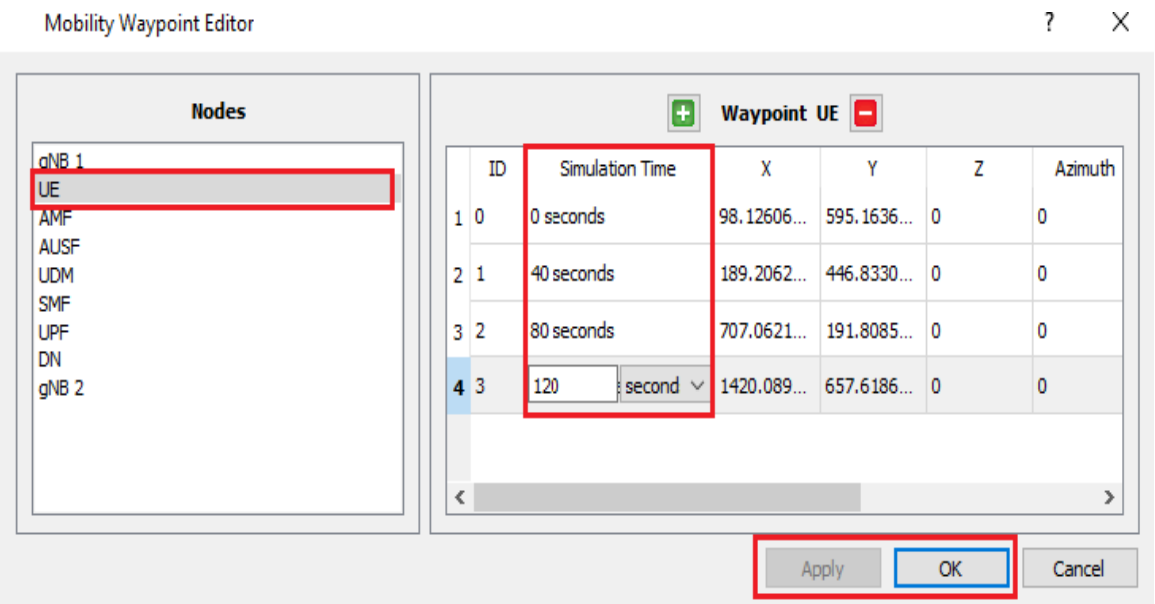
**(10).** To Configure Node 8 **(DN)**: -

- Double Click on Node 8 > Go to Node Configuration > Routing Protocol > use default values as shown in the figure > Apply > OK



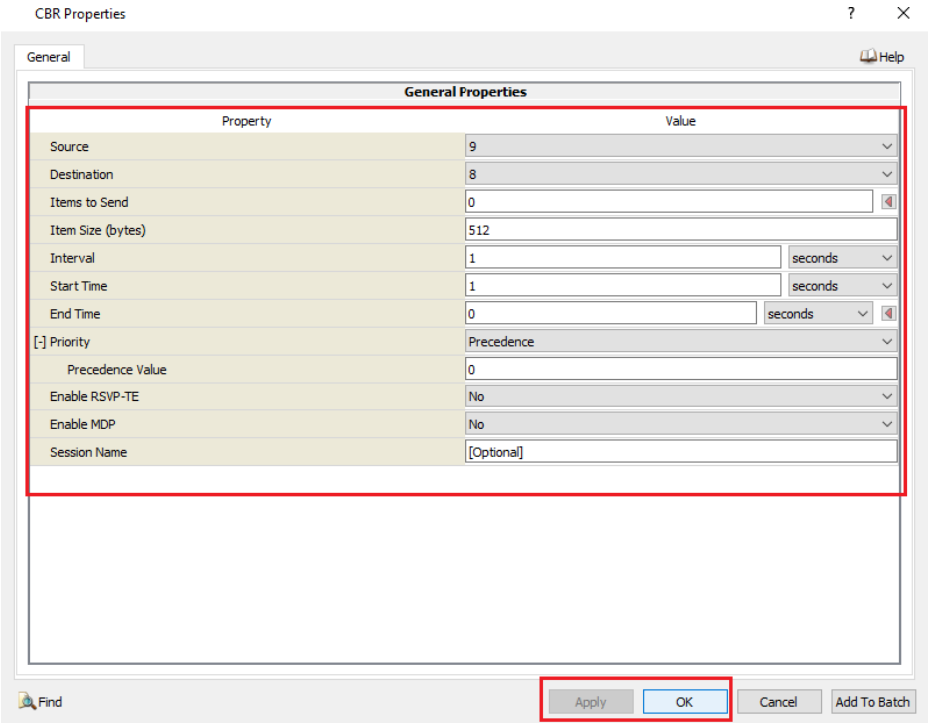

**(11).** To Configure a **Mobility** ;-

- Double Click on Mobility > go to UE > Set Simulation Time as shown in the below figure and Click on Apply > OK



**(12).** To set the properties of the CBR Application, do the following:-

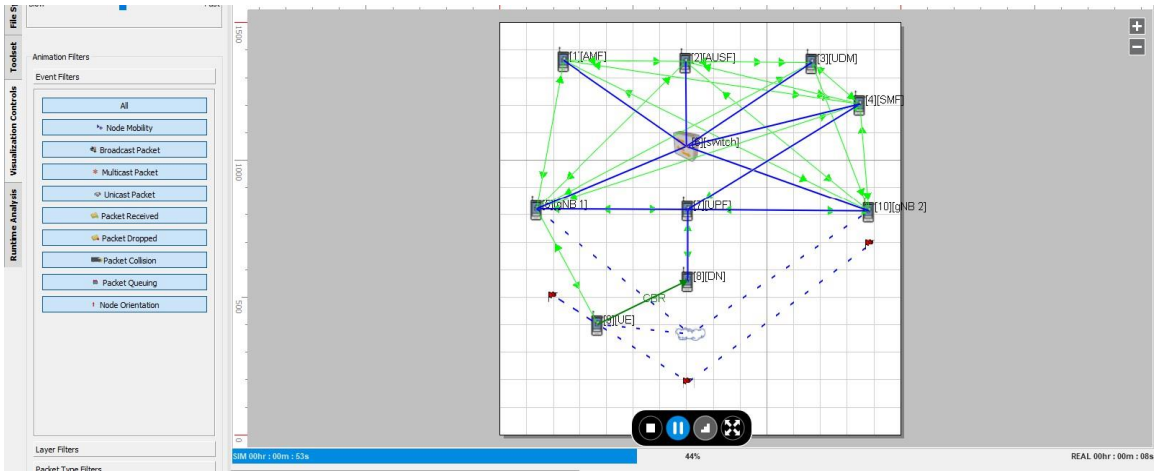
- Double-click the CBR link on the canvas.
- In the CBR Properties Editor, set the parameters as shown below
- Click On Apply > OK.

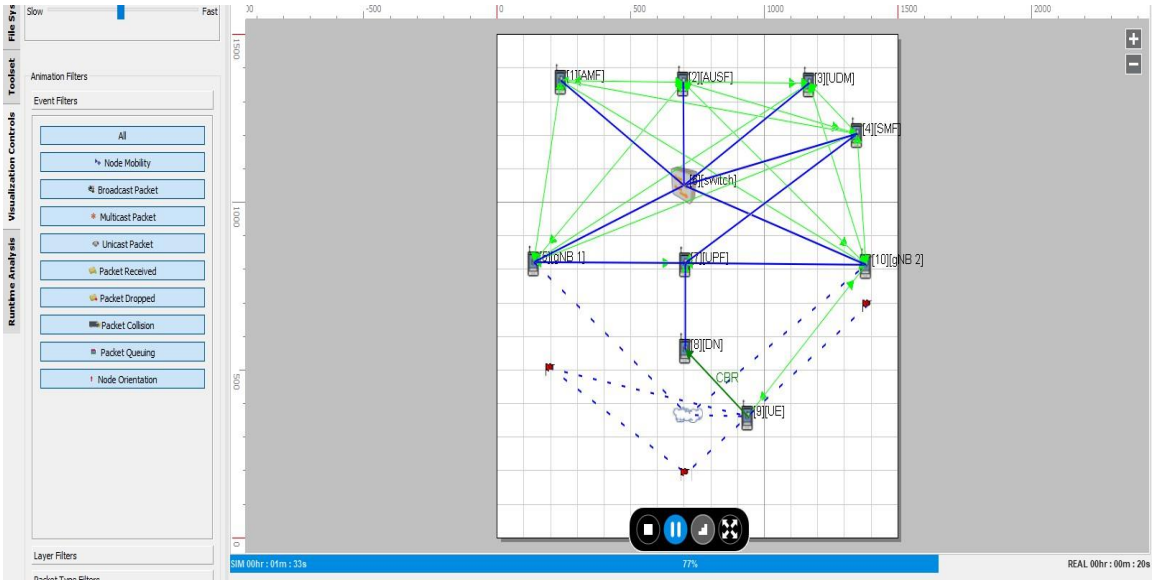



**Step5:** Save the scenario by clicking the Save button in the toolbar.

**Step6:** Click the Run Simulation button.

**Step7**: To start the simulation, click the **Play** button at the bottom of the canvas.






**Step8**: After the simulation has completed, switch to Analyzer by clicking the Analyze Results button. In the analyzer the performance parameter of the current scenario and the layer wise communication can be seen. Number of packets received, throughput, jitter, end to end delay, client and the server performance etc. can be analyzed.

# 8. Simulation on different terrain models.

To design and Observing the data efficiency in 5G by using DEM terrain files in Qualnet Simulator

**Please refer "chapter 10 Terrain Models" in wireless model library For more details on different terrain format**

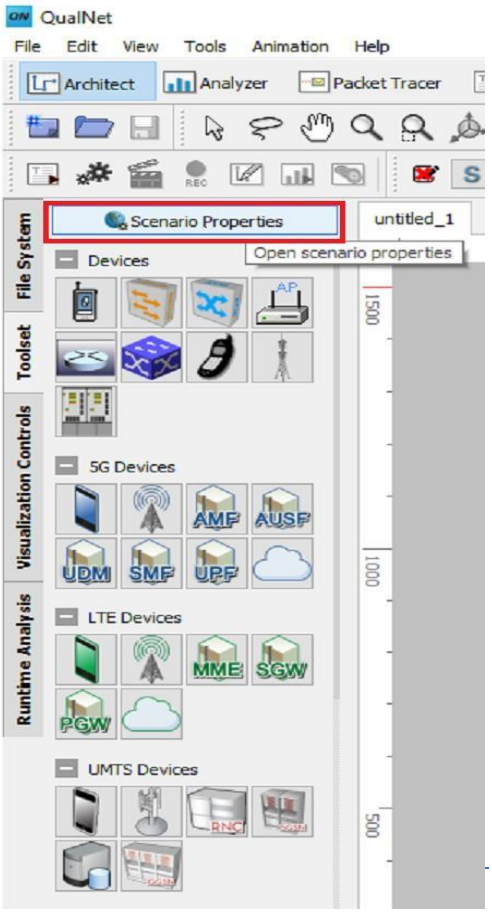
## Procedures to Create Scenario :-

### Step1: -

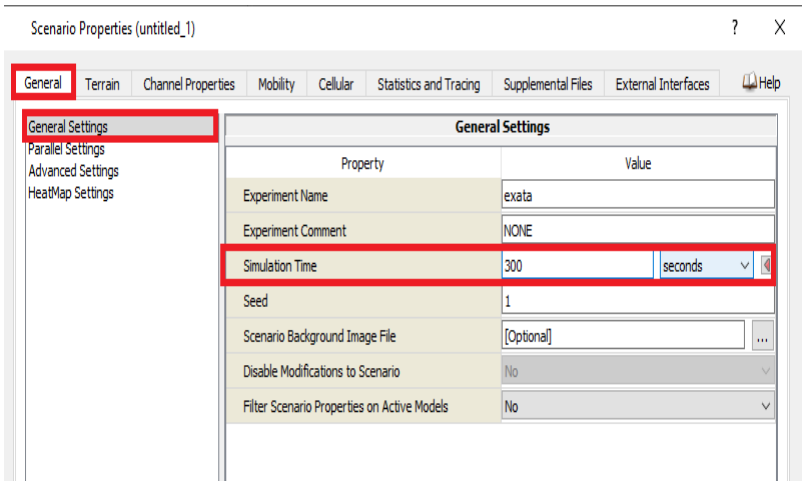
- Start the QualNet GUI.
- To start, Double-click on the QualNet GUI icon on the Desktop.

### Step 2: -

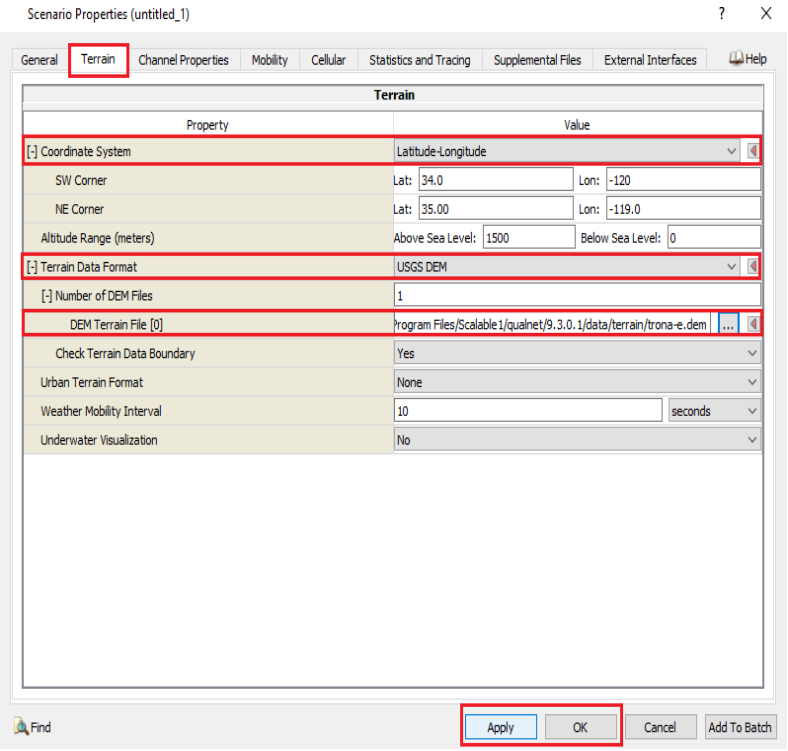
- Check the terrain size before placing the components on the canvas area.
- Click on the '**Scenario Properties**' button in the toolset panel.



- Click on '**General**' button on the top of the newly opened editor. Click on > General Settings > Simulation Time to **300 sec.**

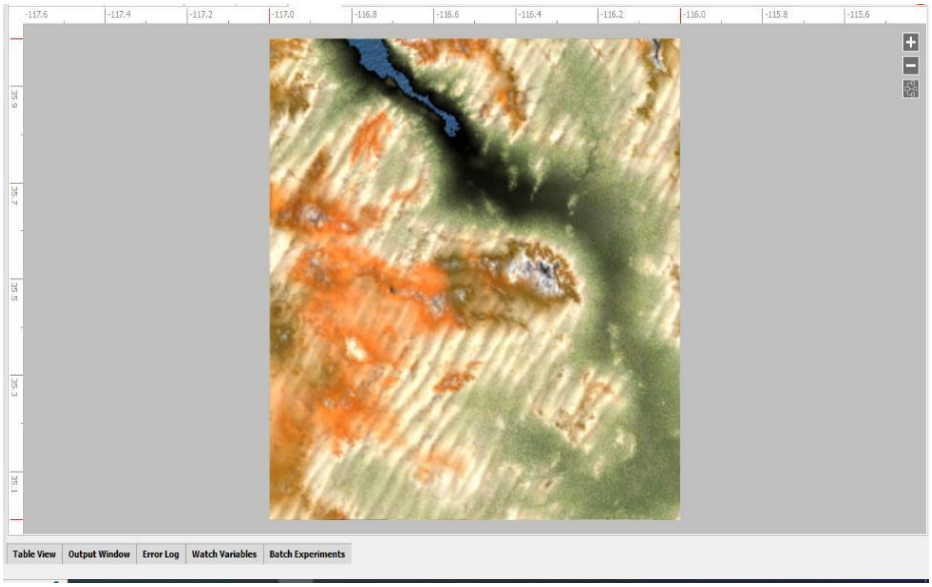



- Click on **'Terrain'** (refer below figure)
  - **i.** Set Coordinate System to **Latitude-Longitude .**
  - **ii.** Set Terrain Data Format to **USGS DEM .**
  - **iii.** Set DEM Terrain File[0]. (to set DEM Terrain file[0], Click on Select files >on newly opened window >go to, qualnet installed directory, you will find folder called Data >click on Data > terrain > select .dem extension file >Apply>ok )

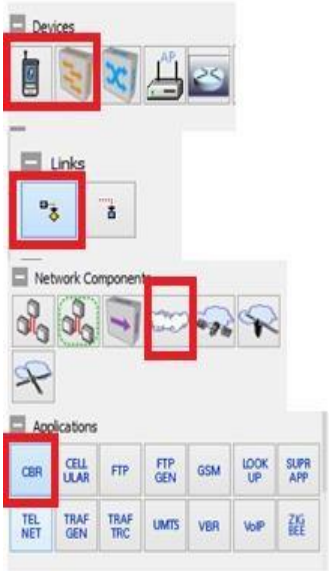


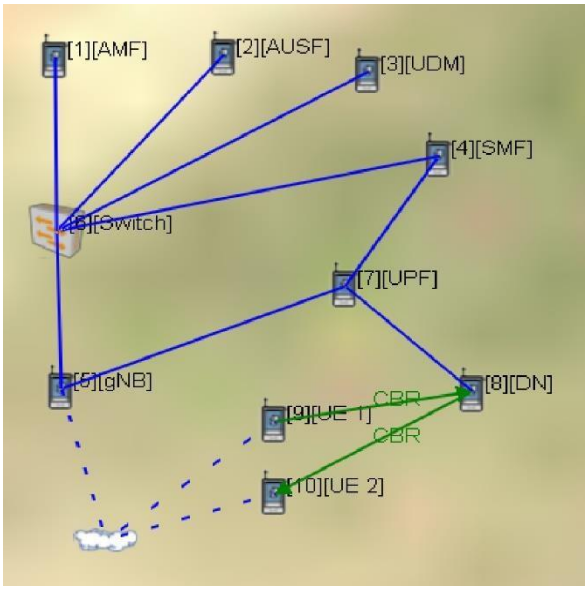
**Step 3:** -To create a scenario, choose the components required from toolset and place it on the canvas using drag-drop as shown in figure.

- The Canvas area will look like below figure > Zoom it on a particular area and place a components.



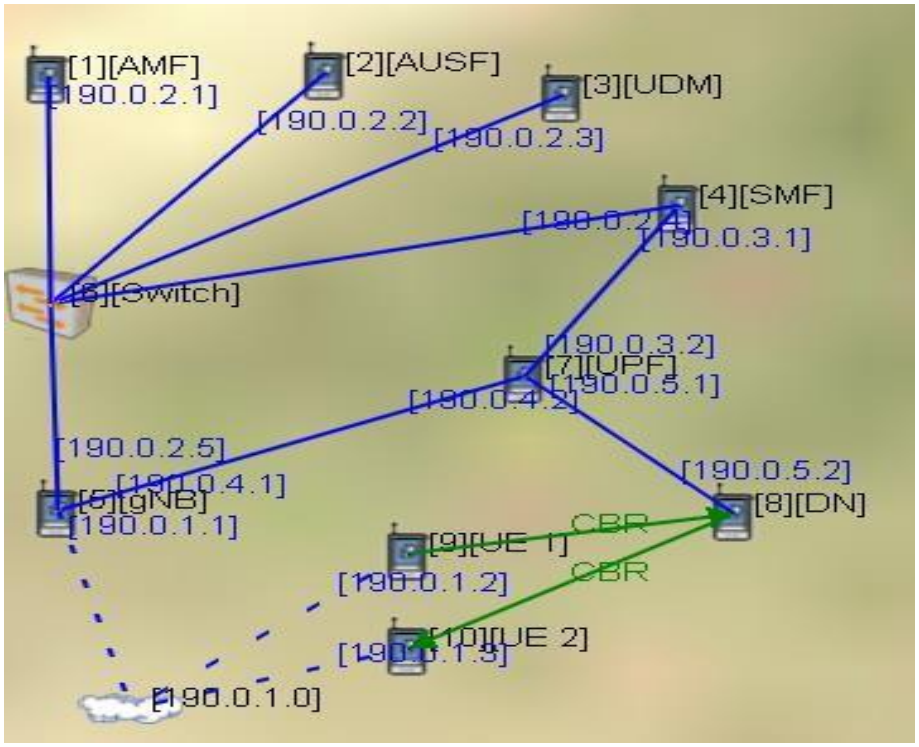

- components
- Links
- Wireless subnet
- CBR application



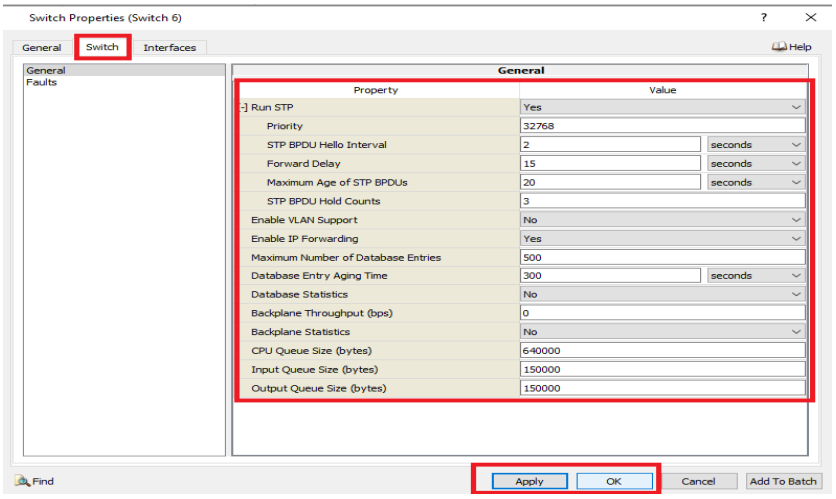
## ➢ Create the scenario topology as shown in below figure.

Below Figure shows the IP addresses of the interfaces in the scenario. The IP addresses depend on the order in which nodes, subnets, and connections are created and may be different in your scenario from the ones shown in the figure. We will use these addresses in the configuration steps below.



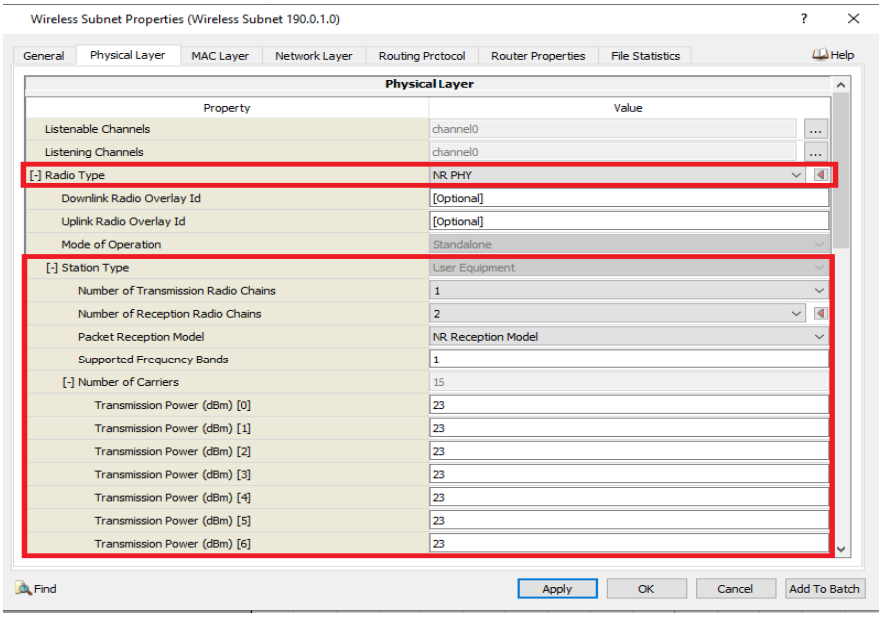

**Step 4:-** To configure the scenario in QualNet GUI, perform the following steps:

**(1).** To Configure the **Switch**, Double Click on Switch > go to Switch and set Run STP to **Yes** and use default values for all other parameter > Apply > OK

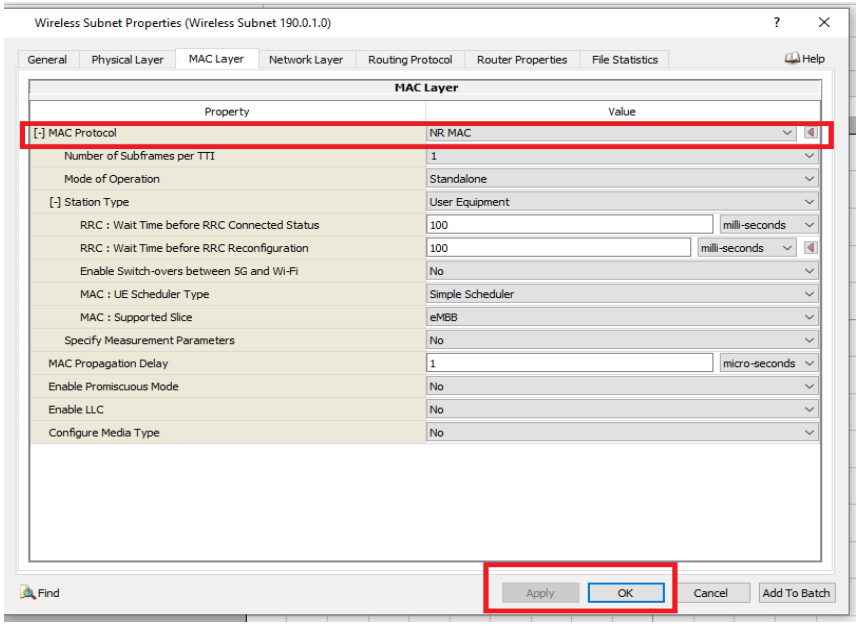


**(2).** To Configure the **wireless subnet** :-

- Double Click On wireless subnet > Go to Physical Layer
  - **i.** Set Radio Type to NR PHY.
  - **ii.** Use default values for all other PHY parameters.

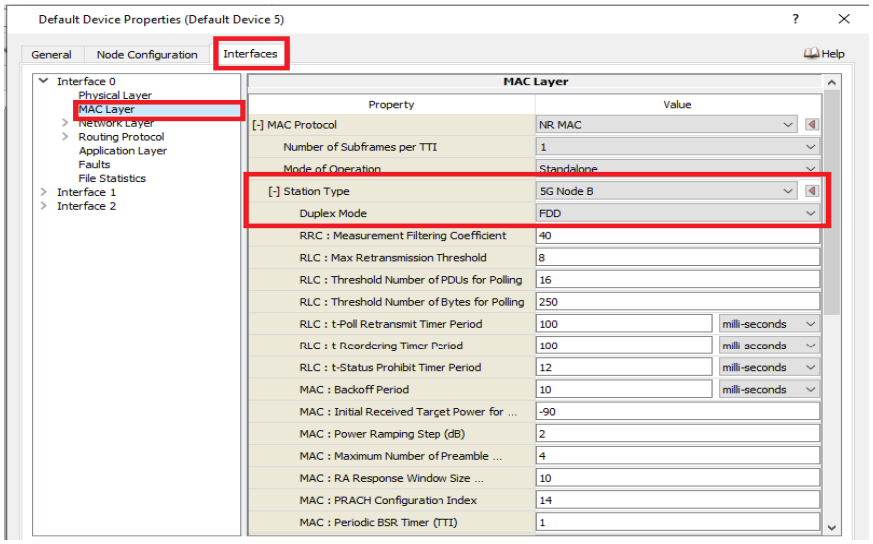



- Go to MAC Layer
  - **i.** Set MAC Protocol to NR MAC
  - **ii.** Use default values for all MAC parameters
  - **iii.** Click on Apply > OK.

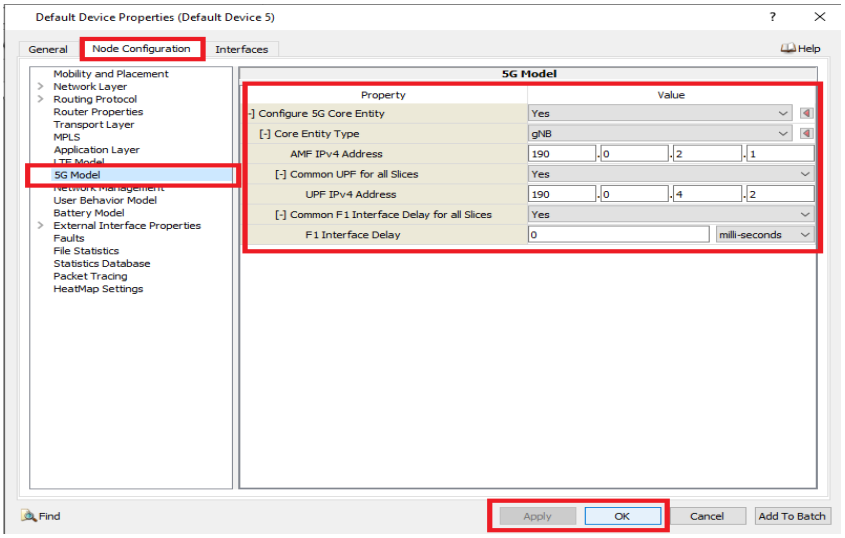


**(3).** To Configure Node 5 (**gNB**):-

- Double Click On Node 5 > Interfaces > Interface 0 > MAC Layer (Make sure that Interface 0 corresponds to the wireless interface of the node).
  - **i.** Set **Station Type** to 5g Node B.
  - **ii.** Set Duplex Mode to FDD.
  - **iii.** Use default values for all other interface parameters.

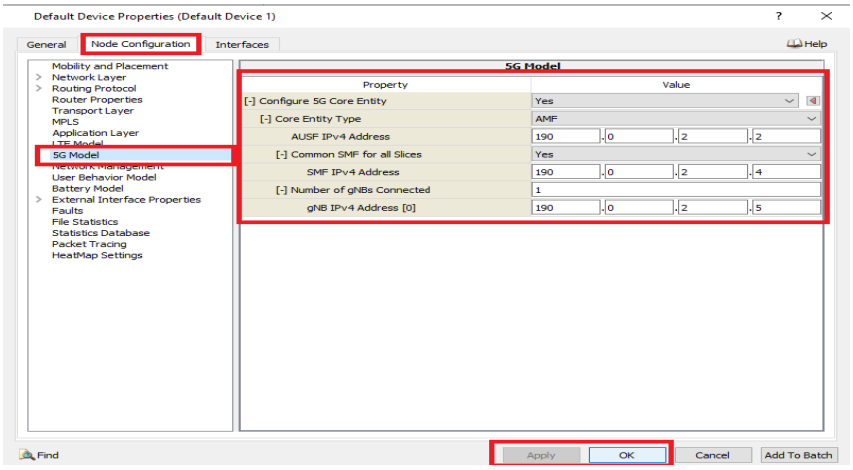



- Click On > Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to gNB.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UPF IPv4 Address to 190.0.4.2
  - **iv.** Click On Apply > OK



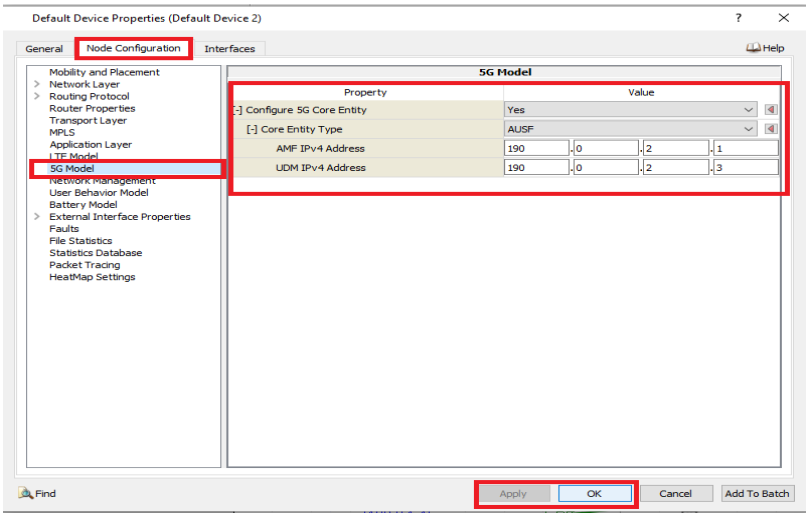
**(4).** To Configure Node 1 **(AMF)**:-

- Double Click On Node 1 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to AMF.
  - **ii.** Set AUSF IPv4 Address to 190.0.2.2
  - **iii.** Set SMF IPv4 Address to 190.0.2.4
  - **iv.** Set Number of gNBs Connected to 1
  - **v.** Set gNB IPv4 Address [0] to 190.0.2.5
  - **vi.** Click On Apply > Ok



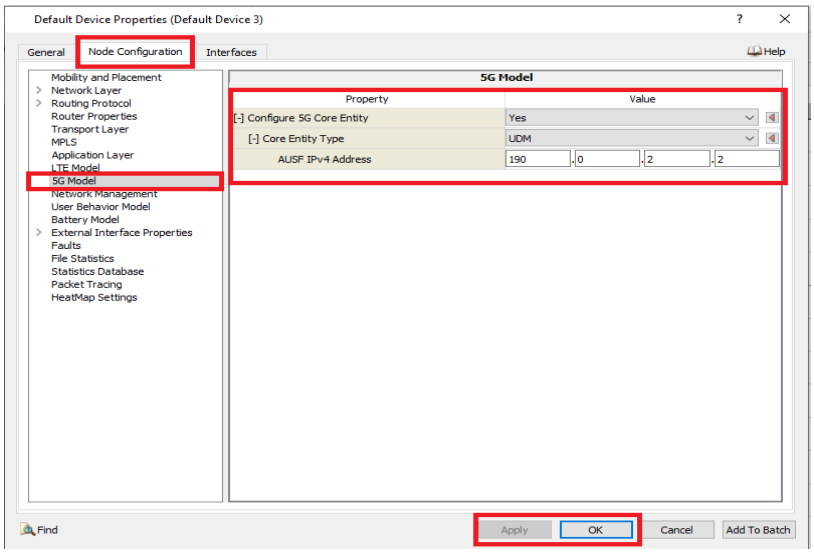

**(5).** To Configure Node 2 **(AUSF)**:-

- Double Click On Node 2 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to AUSF.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UDM IPv4 Address to 190.0.2.3
  - **iv.** Click On Apply > Ok



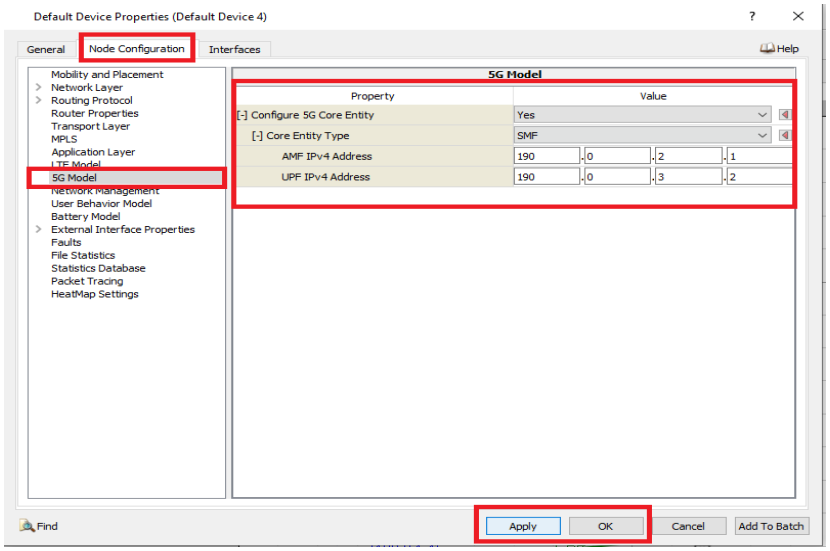
**(6).** To Configure Node 3 **(UDM)**:-

- Double Click On Node 3 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to UDM.
  - **ii.** Set AUSF IPv4 Address to 190.0.2.2
  - **iii.** Click On Apply > Ok



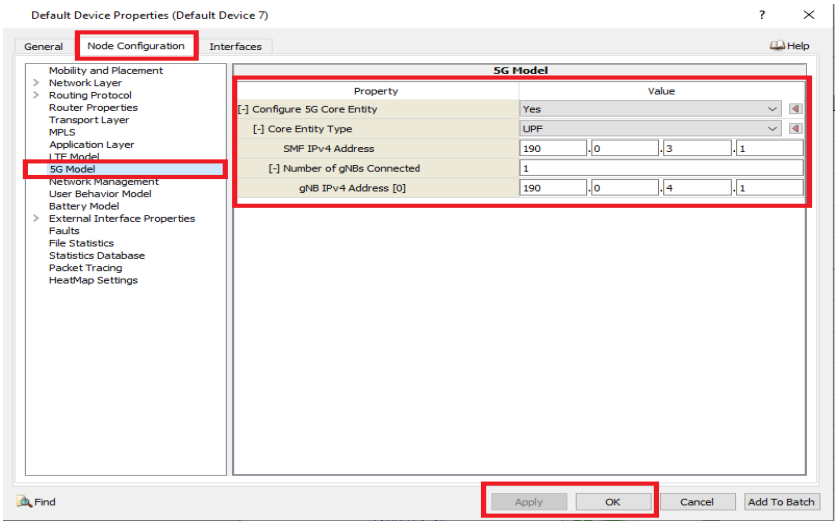

**(7).** To Configure Node 4 **(SMF)**:-

- Double Click On Node 4 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to SMF.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UPF IPv4 Address to 190.0.3.2
  - **iv.** Click On Apply > Ok



**(8).** To Configure Node 7 **(UPF)**:-

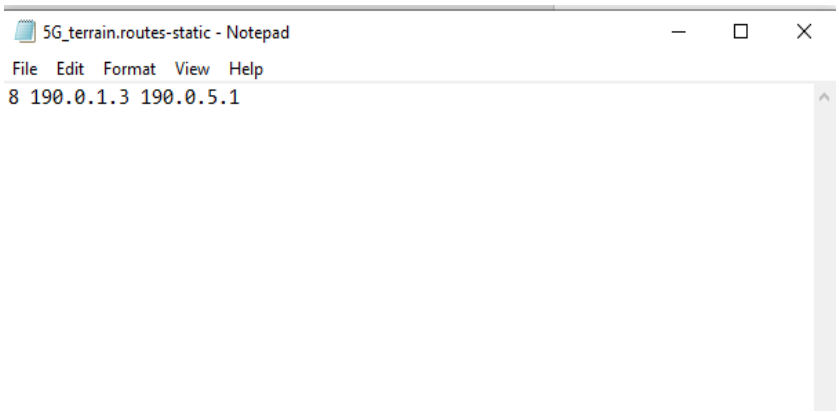
- Double Click On Node 7 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to UPF.
  - **ii.** Set SMF IPv4 Address to 190.0.3.1
  - **iii.** Set Number of gNBs Connected to 1
  - **iv.** Set gNB IPv4 Address [0] to 190.0.4.1
  - **v.** Click On Apply > Ok




**(9).** To Configure Node 8 **(DN)**: -

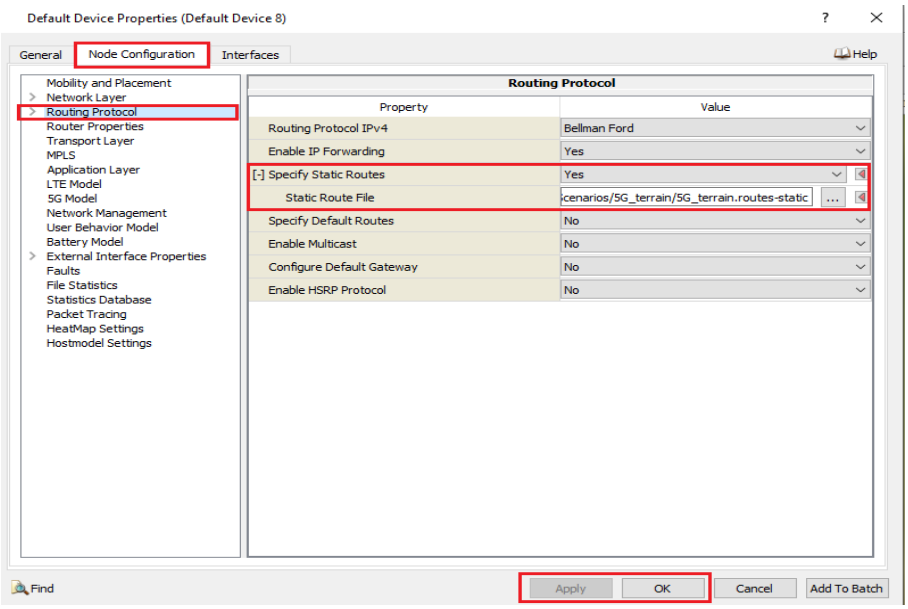
- Double Click On Node 8 > Go to Node Configuration > Routing Protocol.
  - **i.** Set Specify Static Routes to Yes.
  - **ii.** Create a file in Notepad called **Filename.routes-static** in the scenario directory which contains the static route from the DN to the UE.
  - **iii.** In the Static Routes file, **Filename.routes-static**, specify the routes as follows:- <Node Id of DN> <IP-ADDRESS of UE> < Next Hop IP Address/IP of UPF >

8 190.0.1.3 190.0.5.1



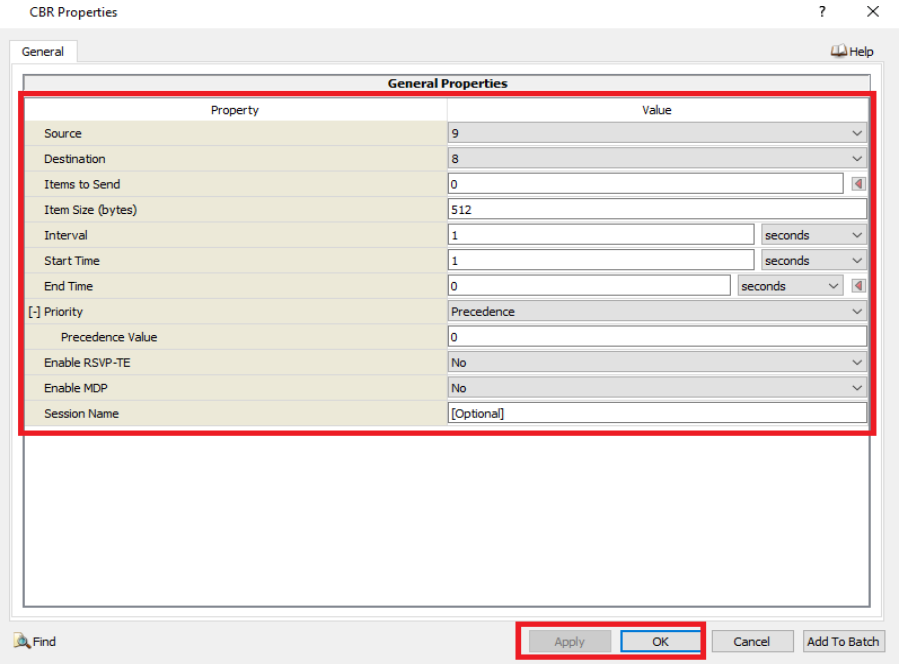
**iv.** To Set Static Route File > Click on Select files and select **Filename.routes-static**

**v.** Click On Apply > Ok




**(10).** To set the properties of the CBR Application, do the following:-

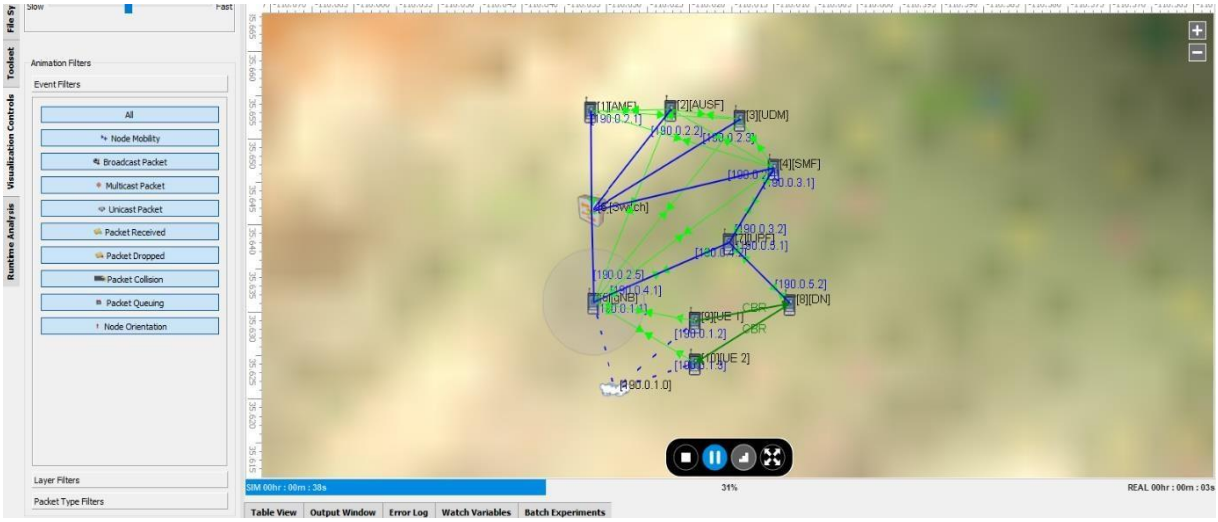
- Double-click the CBR link on the canvas.
- In the CBR Properties Editor, set the parameters as shown below
- Click On Apply > OK
- Repeat the steps for other CBR application.



**Step5:** Save the scenario by clicking the Save button in the toolbar.

**Step6:** Click the Run Simulation button.

**Step7**: To start the simulation, click the **Play** button at the bottom of the canvas.




**Step8**: After the simulation has completed, switch to Analyzer by clicking the Analyze Results button. In the analyzer the performance parameter of the current scenario and the layer wise communication can be seen. Number of packets received, throughput, jitter, end to end delay, client and the server performance etc. can be analyzed.

# 9. Simulation on Urban Terrain model.

To design and Observing data efficiency in 5G by using **Urban** model in Qualnet Simulator

## Procedures to Create Scenario :-

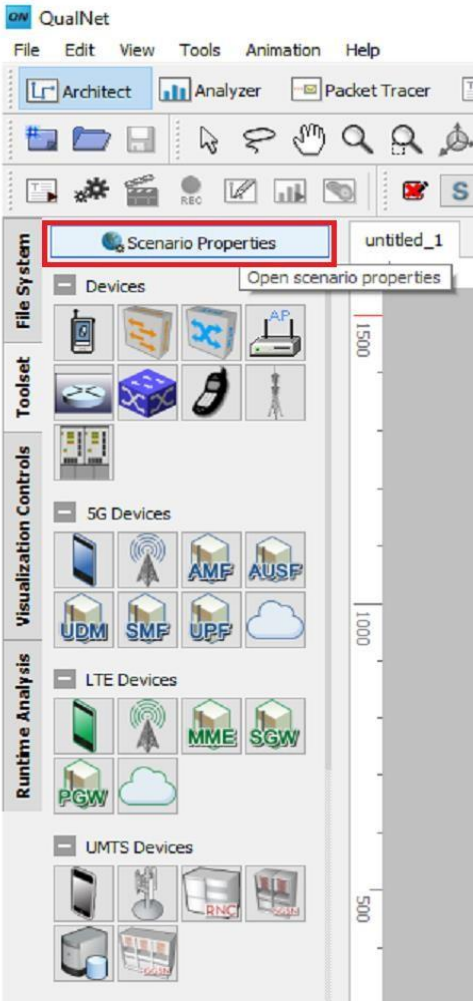
### Step1: -

- Start the QualNet GUI.
- To start, Double-click on the QualNet GUI icon on the Desktop.

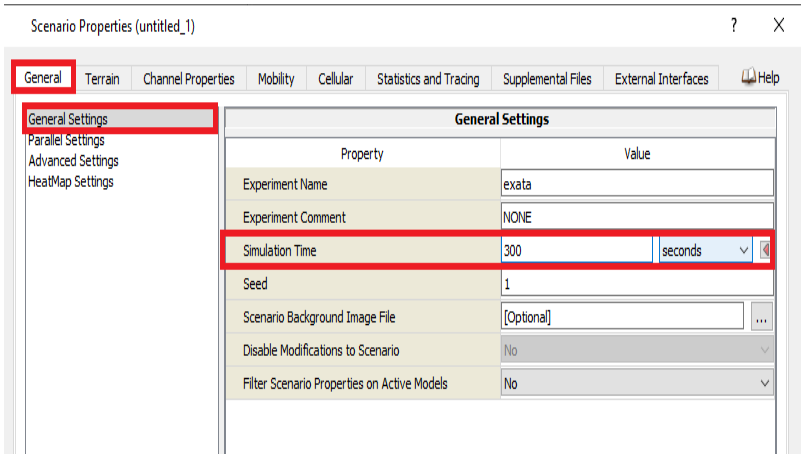
### Step 2: -

- Check the terrain size before placing the components on the canvas area.

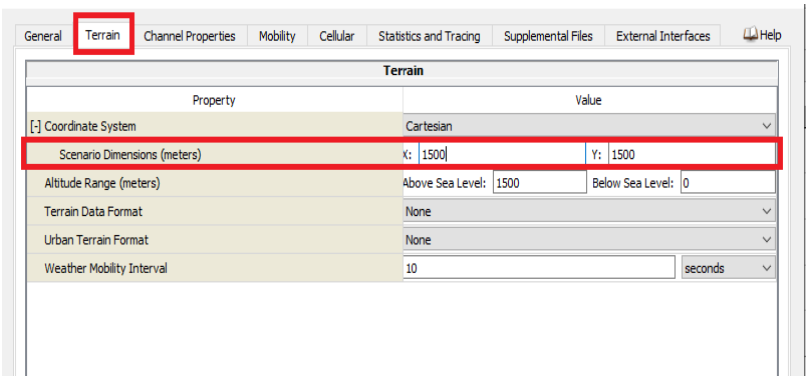
- Click on the '**Scenario Properties**' button in the toolset panel.



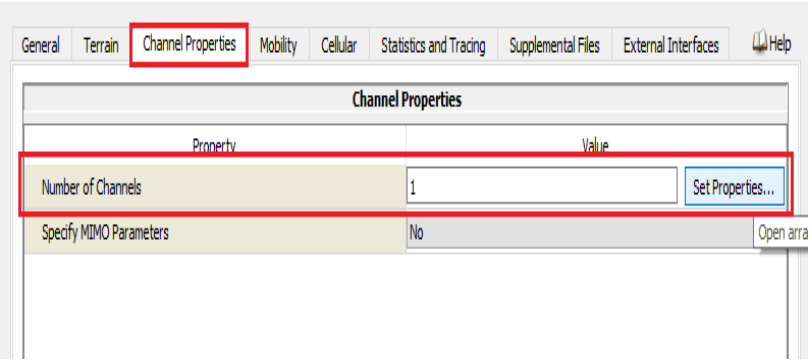
- Click on '**General**' button on the top of the newly opened editor. Click on > General Settings > Simulation Time to **300 sec.**



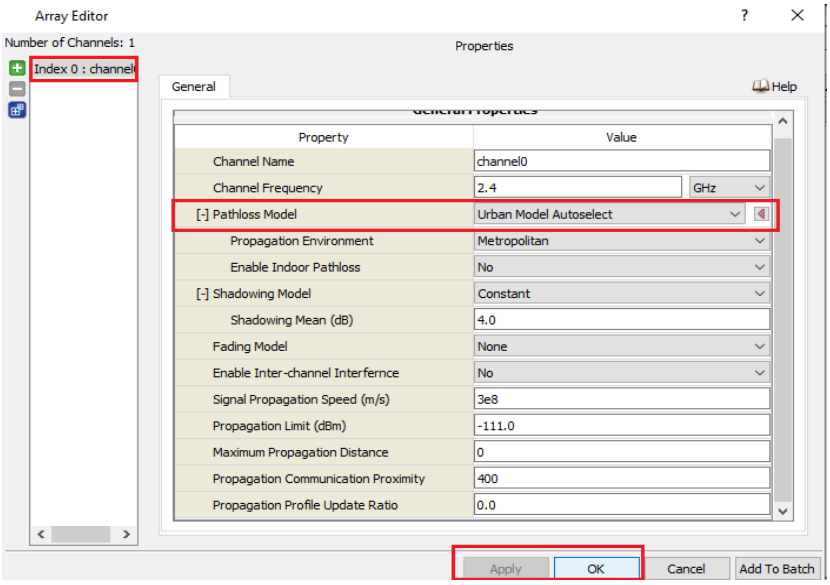

- Click on '**Terrain**' set scenario dimensions as (x:1500 and y:1500).




- Click on '**Channel properties**' button on the top > Set Number of channels to 1 > click on set properties

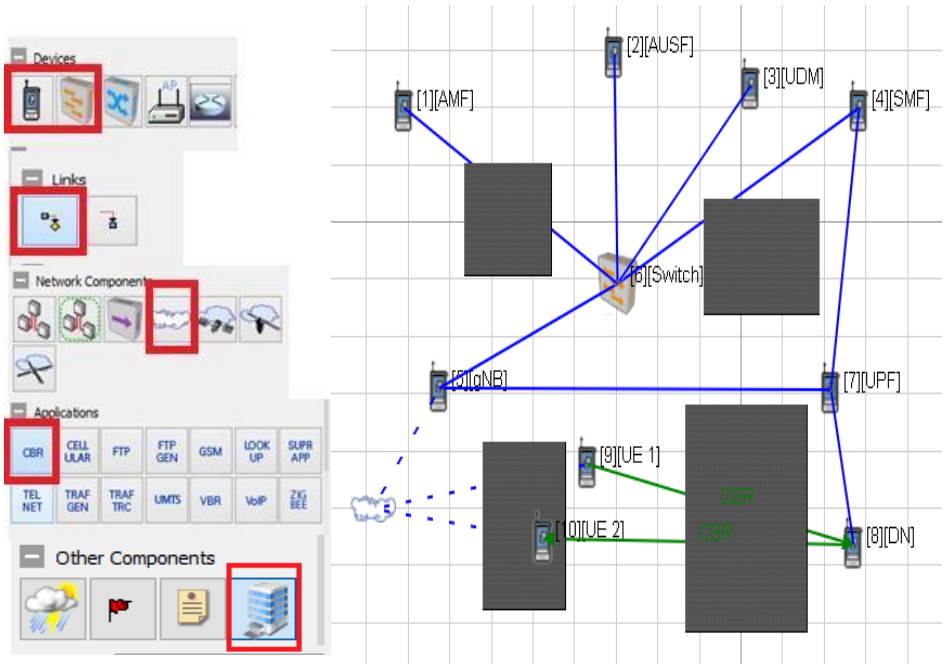


- Click on '**Index 0:channel 0**' button on the top of the newly opened Array editor > set Pathloss Model to **Urban Model Autoselect**.

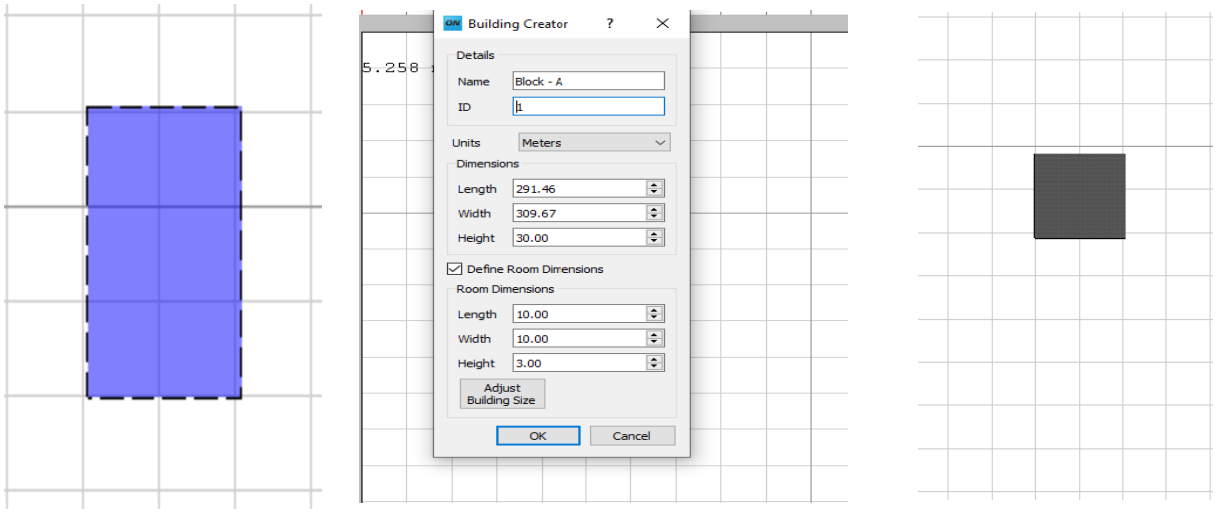



**Step 3:** -To create a scenario, choose the components required from toolset and place it on the canvas using drag-drop as shown in figure.

- Components
- Links
- Wireless subnet
- CBR application
- Building

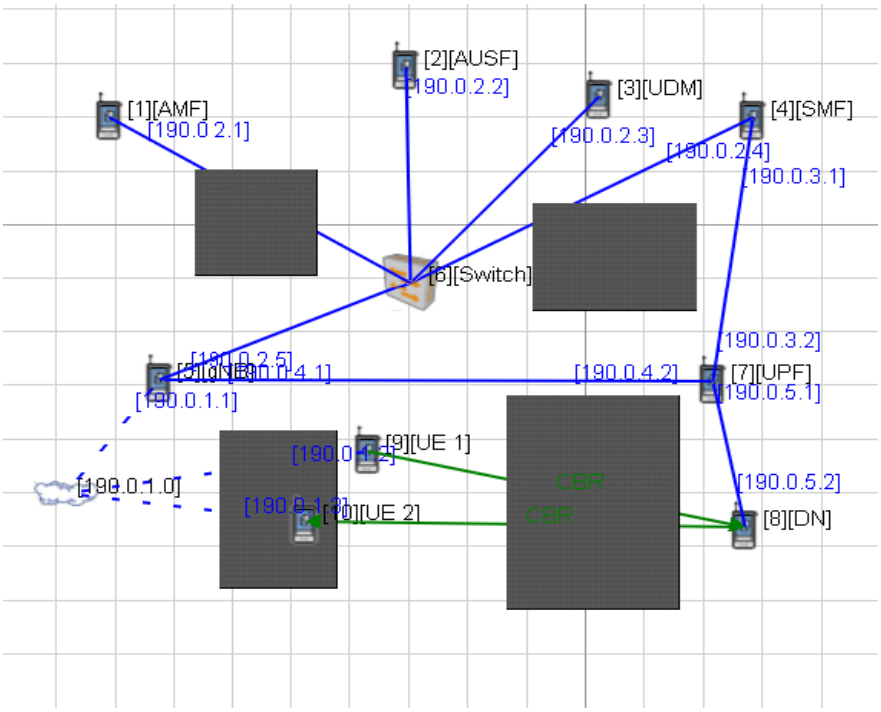


- To insert Building on Canvas > select Building from other components in Toolset and select a portion on canvas and drop a building > on newly opened tab > Set Name, ID of Building > Click Ok (refer below image).

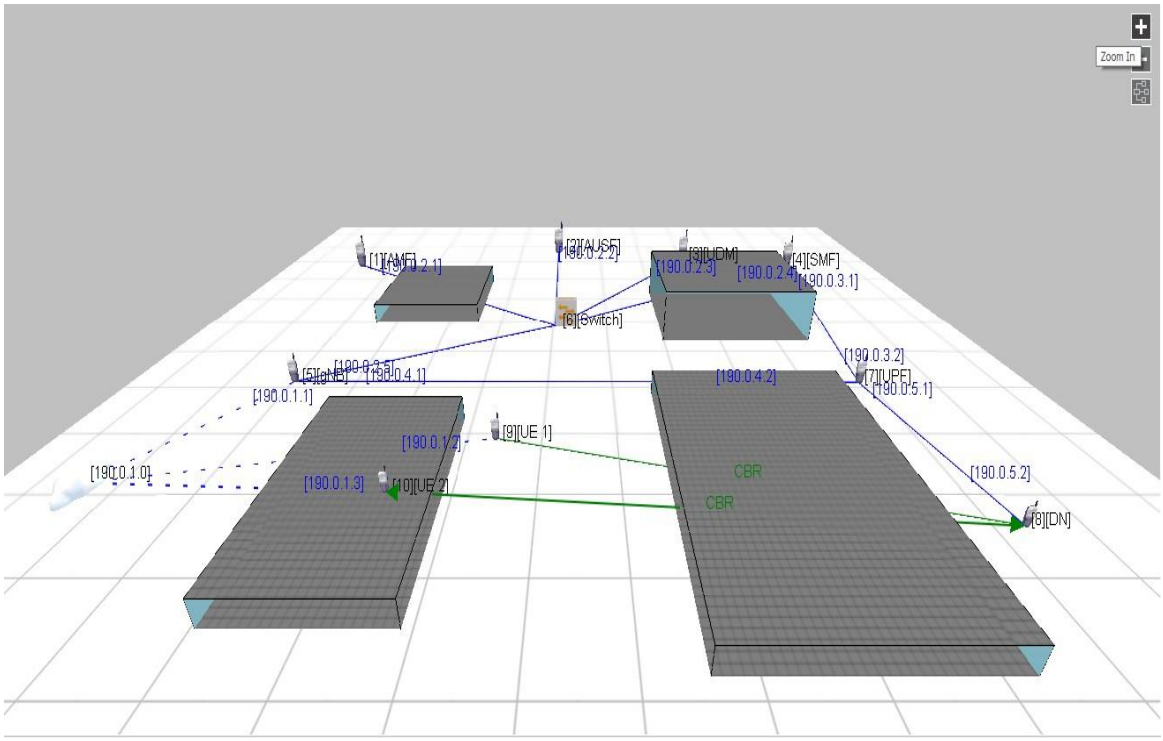



- **<u>Create the scenario topology as shown in below figure.</u>**

  Below Figure shows the IP addresses of the interfaces in the scenario. The IP addresses depend on the order in which nodes, subnets, and connections are created and may be different in your scenario from the ones shown in the figure. We will use these addresses in the configuration steps below.

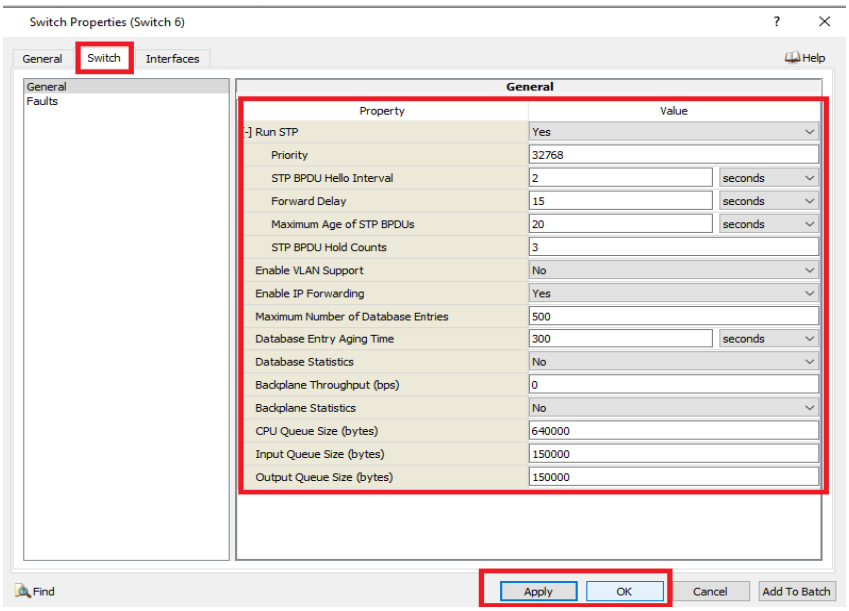


## ➢ In 3D View



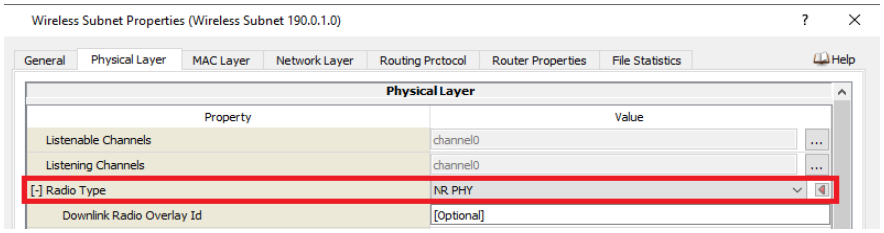

**Step 4:-** To configure the scenario in QualNet GUI, perform the following steps:-

**(1).** To Configure the **Switch**, Double Click on Switch > go to Switch and set Run STP to **Yes** and use default values for all other parameter > Apply > OK

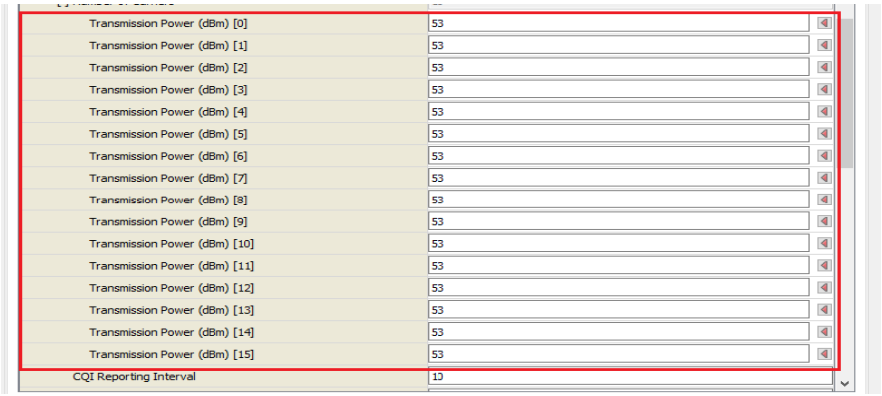


**(2).** To Configure the **wireless subnet**:-

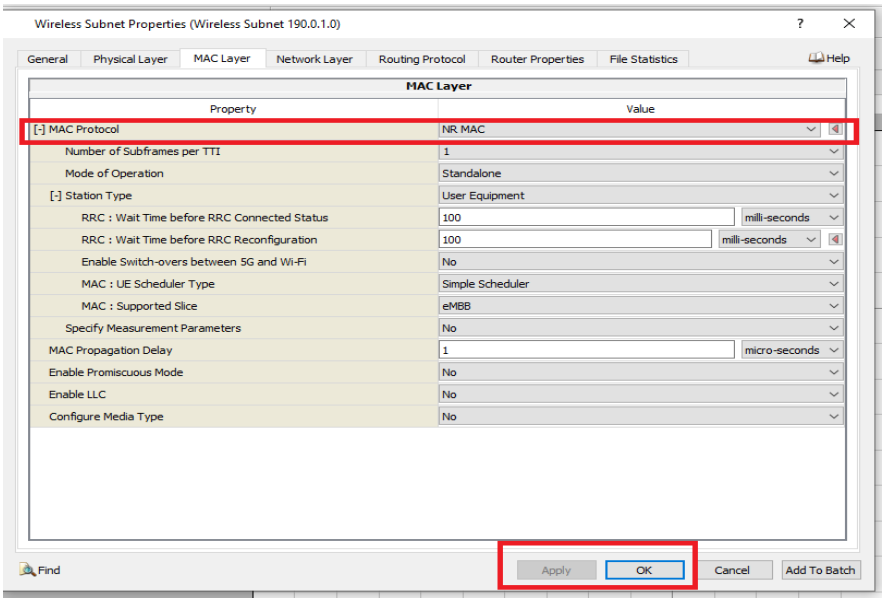
- Double Click On wireless subnet > Go to Physical Layer
  - **i.** Set Radio Type to NR PHY.




  - **ii.** Increase Transmission power(dBm)

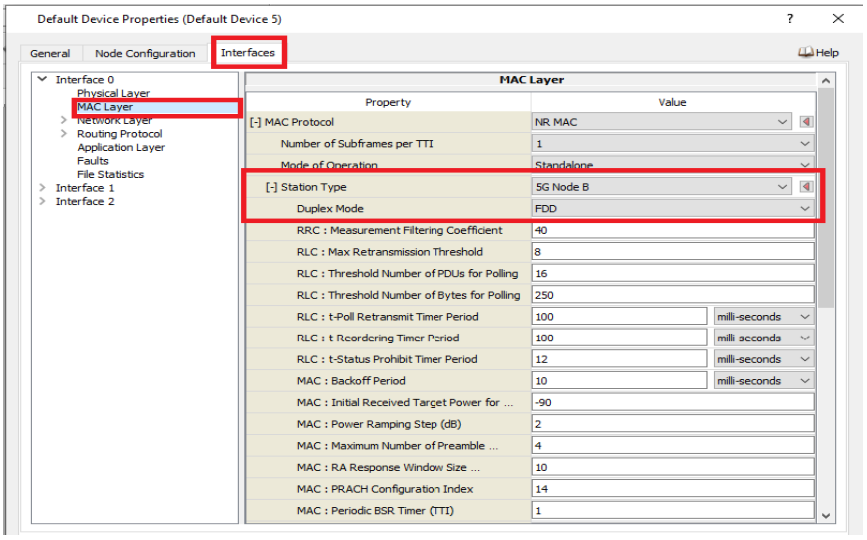



  - **iii.** Use default values for all other PHY parameters
- Go to MAC Layer
  - **i.** Set MAC Protocol to NR MAC.
  - **ii.** Use default values for all MAC parameters.
  - **iii.** Click on Apply > OK

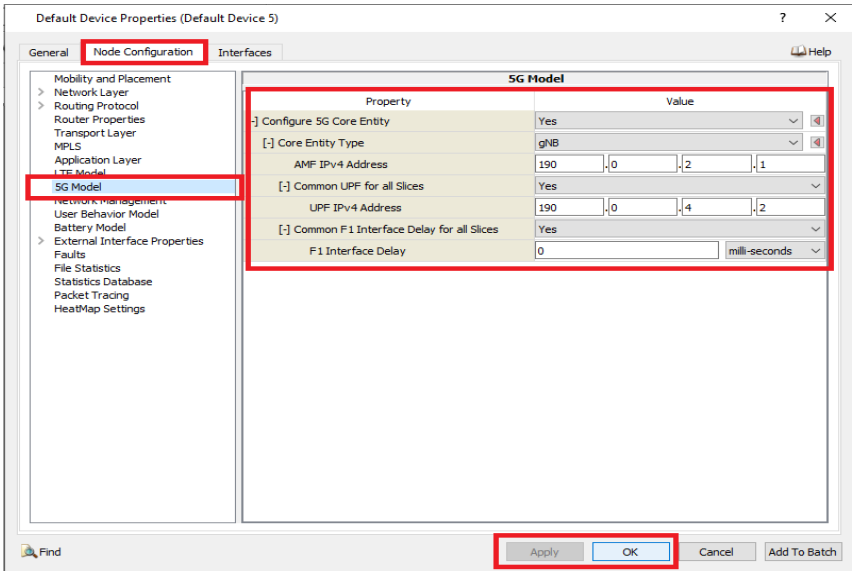


**(3).** To Configure Node 5 (**gNB**):-

- Double Click On Node 5 > Interfaces > Interface 0 > MAC Layer (Make sure that Interface 0 corresponds to the wireless interface of the node).
  - **i.** Set **Station Type** to 5g Node B.
  - **ii.** Set Duplex Mode to FDD.
  - **iii.** Use default values for all other interface parameters.

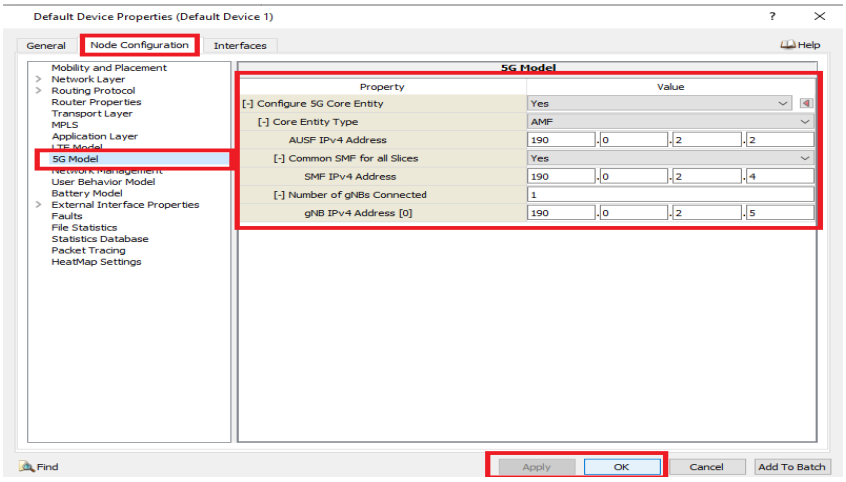



- Click On > Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to gNB.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UPF IPv4 Address to 190.0.4.2
  - **iv.** Click On Apply > OK



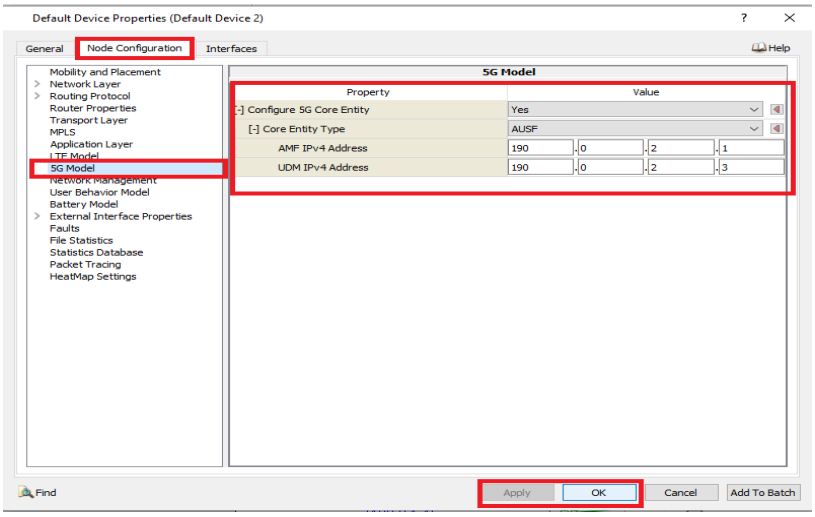
**(4).** To Configure Node 1 **(AMF)**:-

- Double Click On Node 1 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to AMF.
  - **ii.** Set AUSF IPv4 Address to 190.0.2.2
  - **iii.** Set SMF IPv4 Address to 190.0.2.4
  - **iv.** Set Number of gNBs Connected to 1
  - **v.** Set gNB IPv4 Address [0] to 190.0.2.5
  - **vi.** Click On Apply > OK



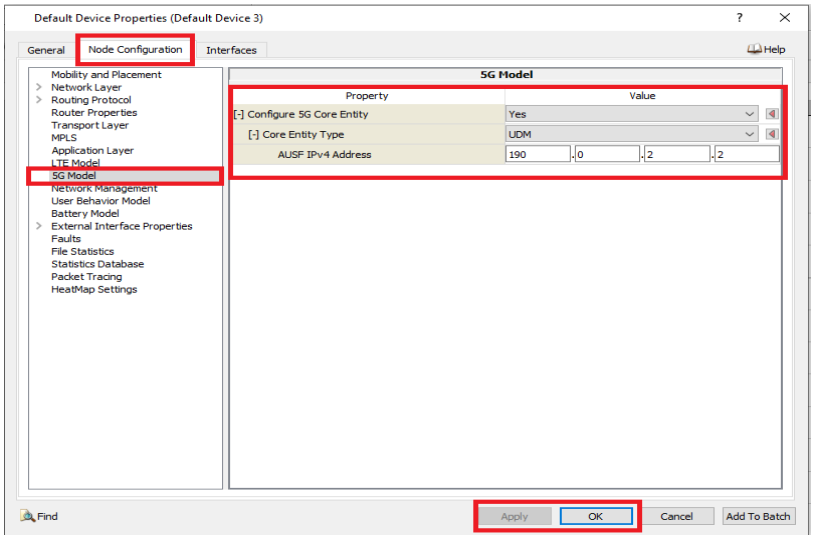

**(5).** To Configure Node 2 **(AUSF):-**

- Double Click On Node 2 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to AUSF.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UDM IPv4 Address to 190.0.2.3
  - **iv.** Click On Apply > OK



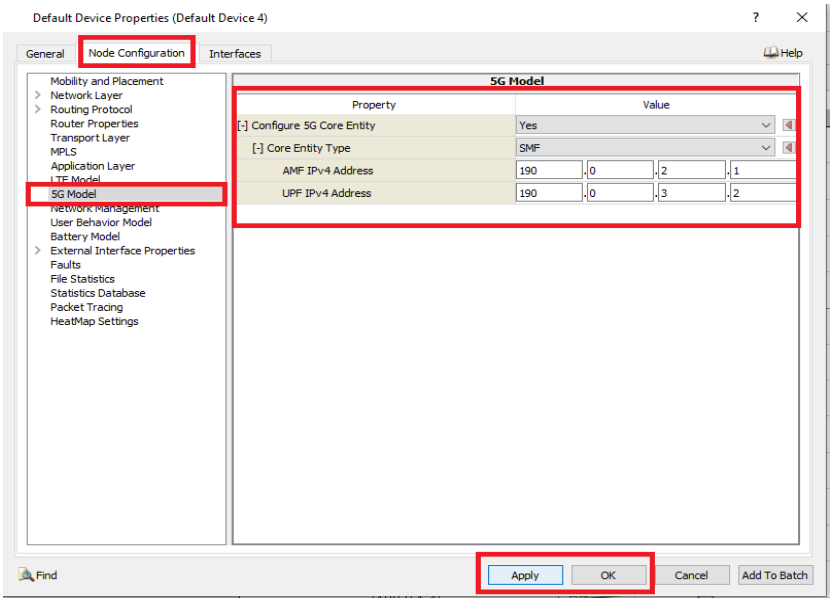
**(6).** To Configure Node 3 **(UDM)**:-

- Double Click On Node 3 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to UDM.
  - **ii.** Set AUSF IPv4 Address to 190.0.2.2
  - **iii.** Click On Apply > OK



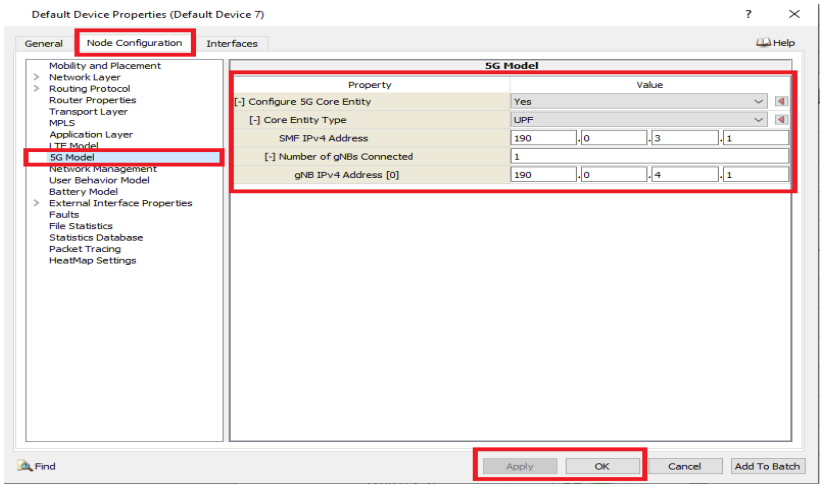

**(7).** To Configure Node 4 **(SMF)**:-

- Double Click On Node 4 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to SMF.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UPF IPv4 Address to 190.0.3.2
  - **iv.** Click On Apply > OK



**(8).** To Configure Node 7 **(UPF)**:-

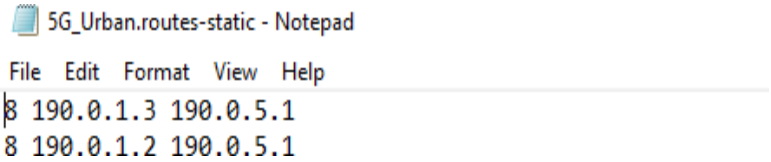
- Double Click On Node 7 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to UPF.
  - **ii.** Set SMF IPv4 Address to 190.0.3.1
  - **iii.** Set Number of gNBs Connected to 1
  - **iv.** Set gNB IPv4 Address [0] to 190.0.4.1
  - **v.** Click On Apply > OK




**(9).** To Configure Node 8 **(DN)**: -

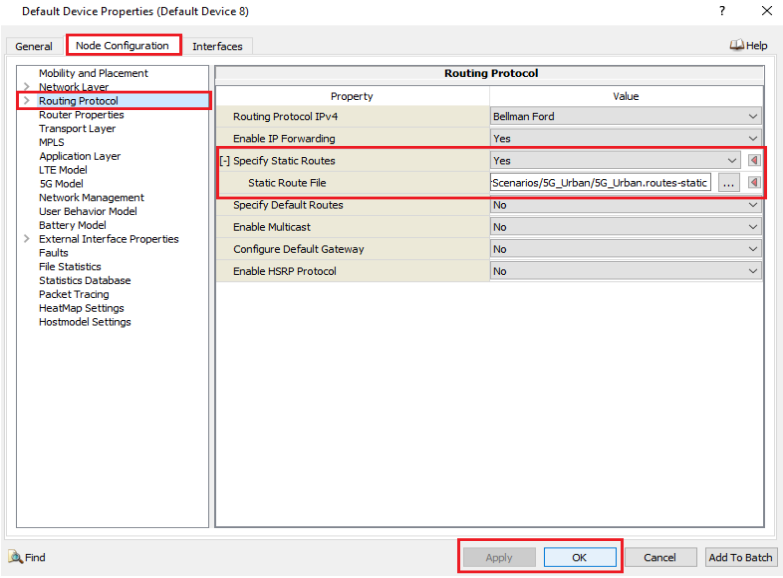
- Double Click On Node 8 > Go to Node Configuration > Routing Protocol.
  - **i.** Set Specify Static Routes to Yes.
  - **ii.** Create a file in Notepad called **Filename.routes-static** in the scenario directory which contains the static route from the DN to the UE.
  - **iii.** In the Static Routes file, **Filename.routes-static**, specify the routes as follows:-
    <Node Id of DN> <IP-ADDRESS of UE> < Next Hop IP Address/IP of UPF >

```
8 190.0.1.3 190.0.5.1
8 190.0.1.2 190.0.5.1
```



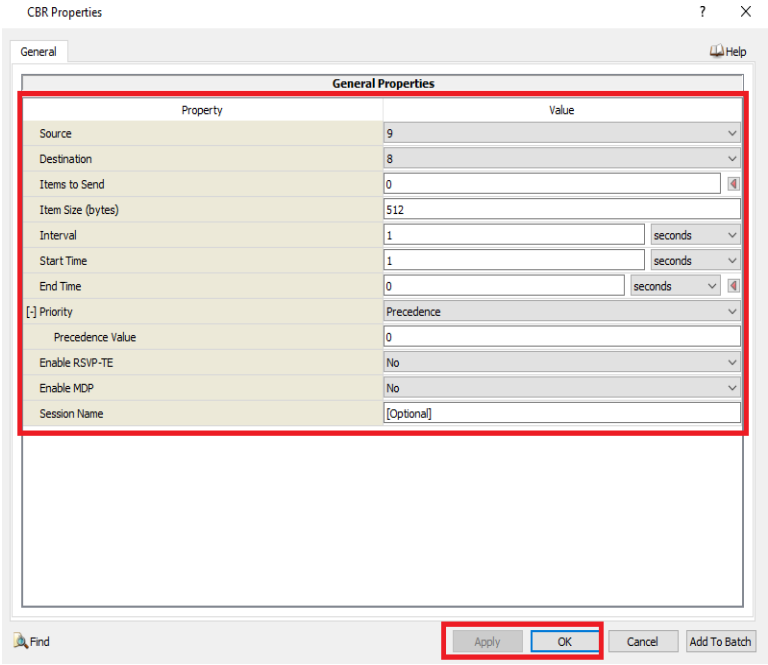
**iv.** To Set Static Route File > Click on Select files and select **Filename.routes-static**

**v.** Click On Apply > OK




**(10).** To set the properties of the CBR Application, do the following:-

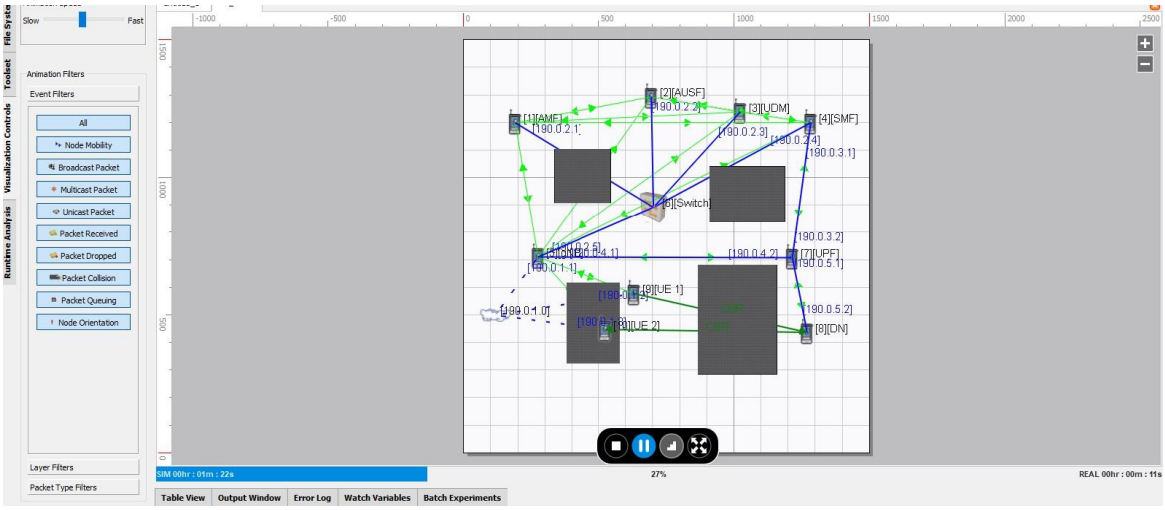
- Double-click the CBR link on the canvas.
- In the CBR Properties Editor, set the parameters as shown below
- Click On Apply > OK.
- Repeat the steps for other CBR application.



**Step5:** Save the scenario by clicking the Save button in the toolbar.

**Step6:** Click the Run Simulation button.

**Step7**: To start the simulation, click the **Play** button at the bottom of the canvas.




**Step8**: After the simulation has completed, switch to Analyzer by clicking the Analyze Results button. In the analyzer the performance parameter of the current scenario and the layer wise communication can be seen. Number of packets received, throughput, jitter, end to end delay, client and the server performance etc. can be analyzed.

# 10. Configuring one or more network slices at gNB and resource allocation per network slice.

To design and analysis of 5G network slicing is a network architecture that enables the multiplexing of virtualized and independent logical networks on the same physical network infrastructure.

**Please refer " 3.1 - 5G Layer 2 Model and 4.1 - 5G Core Model " in 5G Model Library For more details on Network slicing**

## Procedures to Create Scenario:-

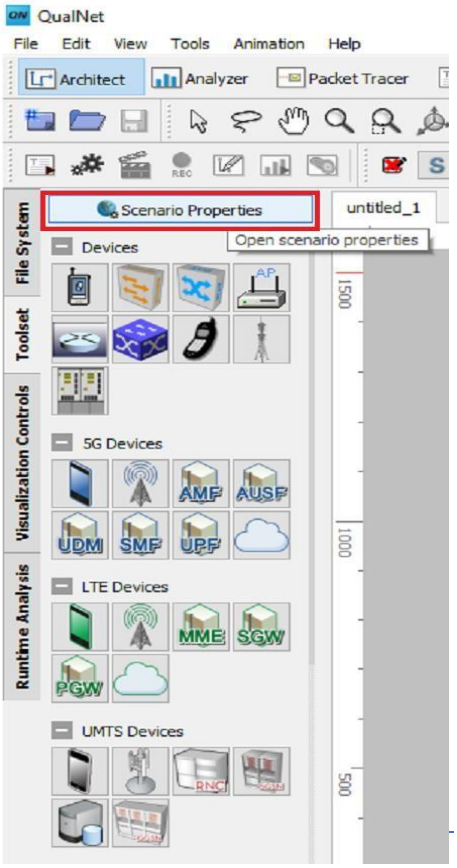
### Step1: -

- Start the QualNet GUI.
- To start, Double-click on the QualNet GUI icon on the Desktop.

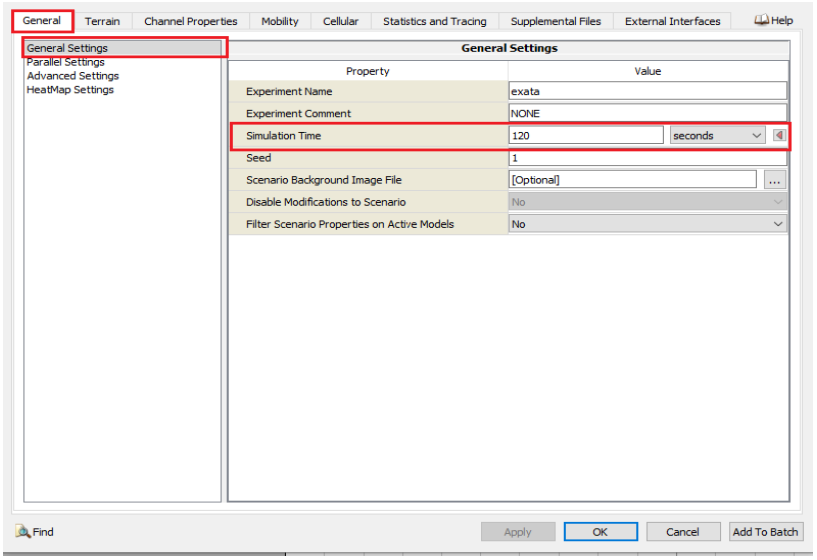
### Step 2: -

- Check the terrain size before placing the components on the canvas area.

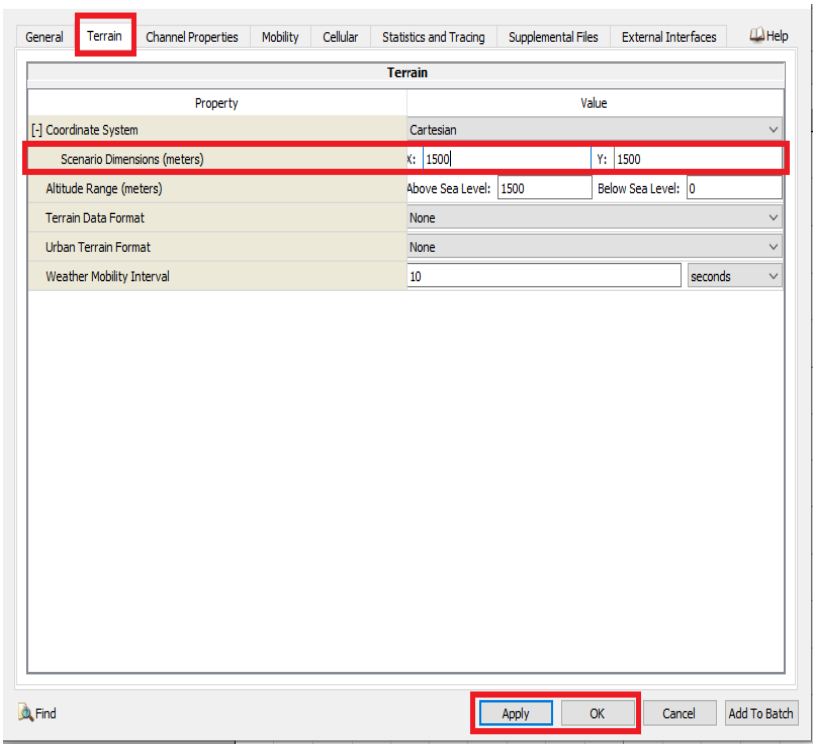
- Click on the '**Scenario Properties**' button in the toolset panel.



- Click on '**General**' button on the top of the newly opened editor. Click on > General Settings > Simulation Time to **120** sec.

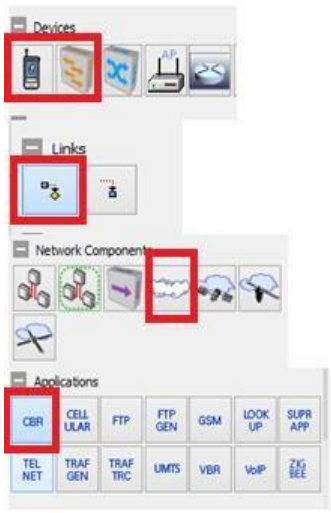


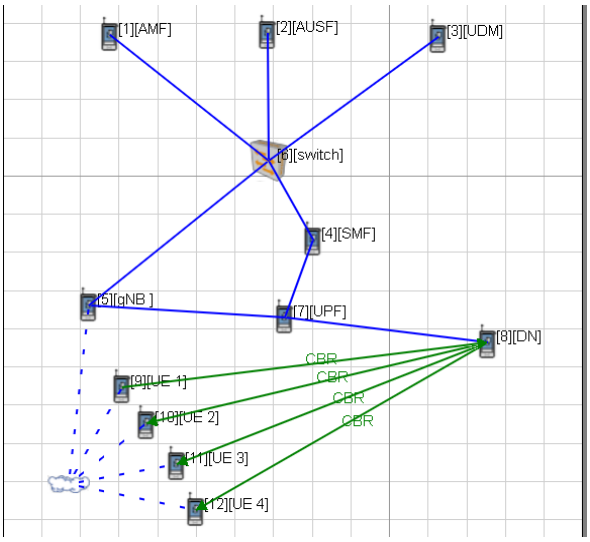

- Click on '**Terrain**' set scenario dimensions as (x:1500 and y:1500) > Apply > OK.



**Step 3:** -To create a scenario, choose the components required from toolset and place it on the canvas using drag-drop as shown in figure.

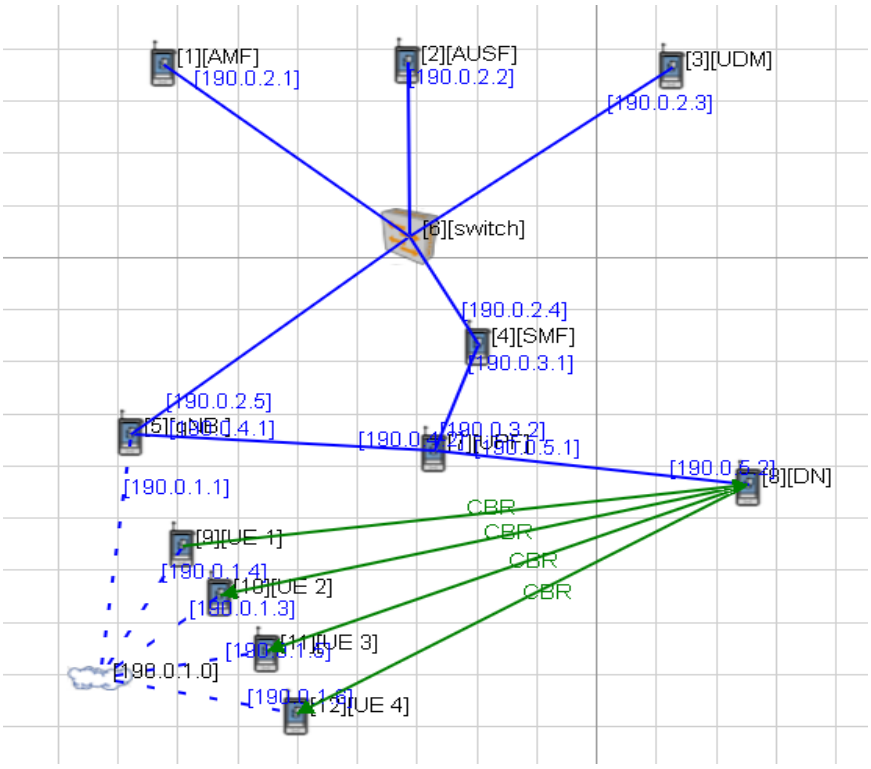
- components
- Links
- Wireless subnet
- CBR application



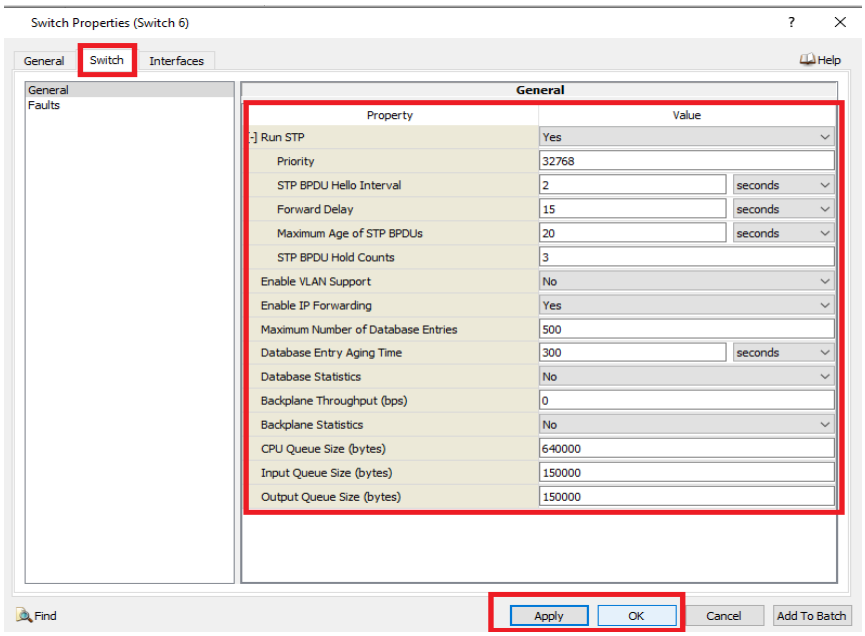

- **Create the scenario topology as shown in below figure.**

Below Figure shows the IP addresses of the interfaces in the scenario. The IP addresses depend on the order in which nodes, subnets, and connections are created and may be different in your scenario from the ones shown in the figure. We will use these addresses in the configuration steps below.



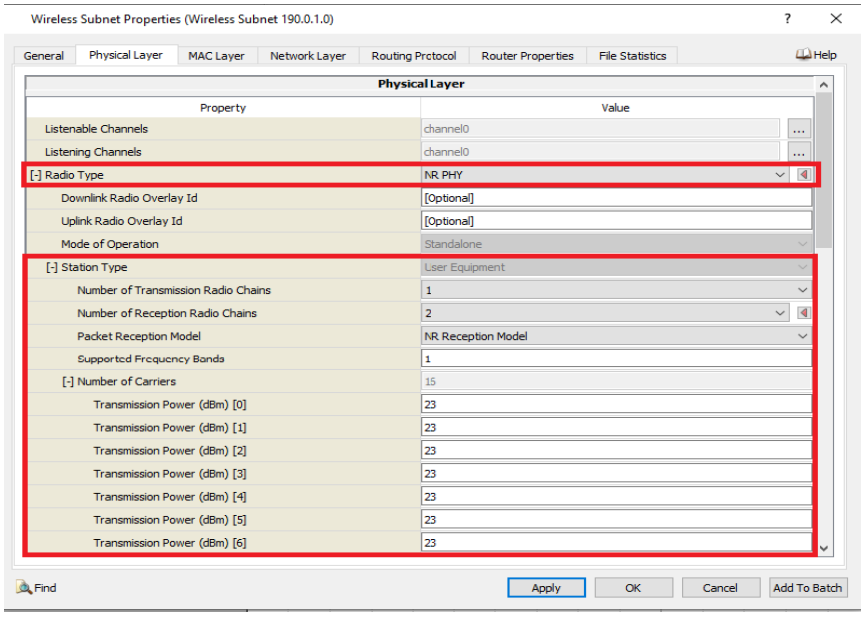
**Step 4:-** To configure the scenario in QualNet GUI, perform the following steps:-

**(1).** To Configure the **Switch**, Double Click on Switch > go to Switch and set Run STP to **Yes** and use default values for all other parameter > Apply > OK

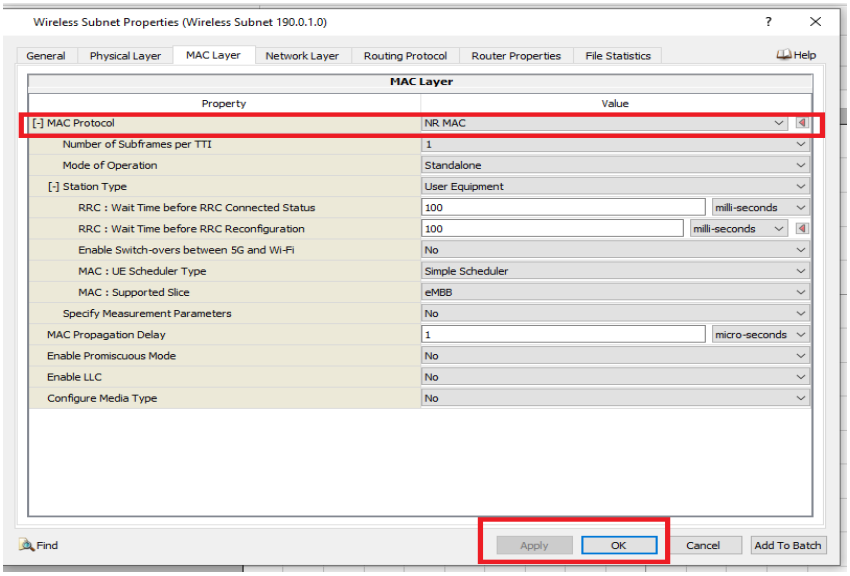



**(2).** To Configure the **wireless subnet**:-

- Double Click On wireless subnet > Go to Physical Layer
  - **i.** Set Radio Type to NR PHY.
  - **ii.** Use default values for all other PHY parameters.

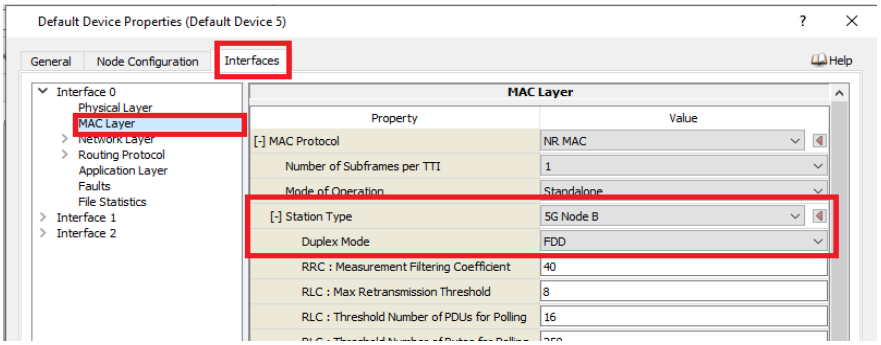


- Go to MAC Layer
  - **i.** Set MAC Protocol to NR MAC.
  - **ii.** Use default values for all MAC parameters.
  - **iii.** Click on Apply > OK.




**(3).** To Configure Node 5 (**gNB**):-

- Double Click On Node 5 > Interfaces > Interface 0 > MAC Layer (Make sure that Interface 0 corresponds to the wireless interface of the node).
  - **i.** Set **Station Type** to 5g Node B.
  - **ii.** Set Duplex Mode to FDD.




  - **iii.** Set gNB bandwidth allocation mode (see below Figure)

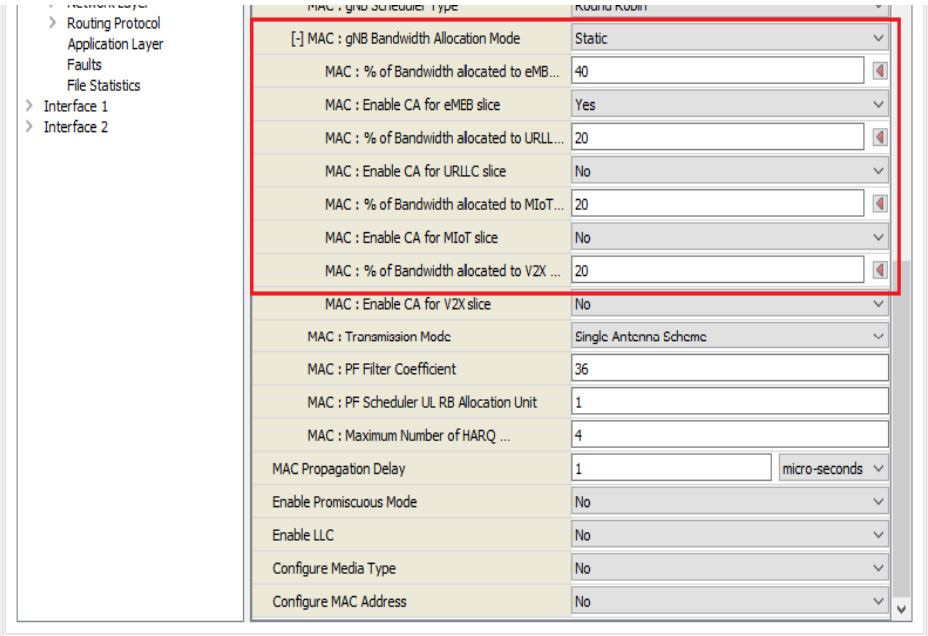
    Following is the per slice bandwidth percentage configuration at gNB:-

    eMBB slice - 40

    URLLC slice - 20

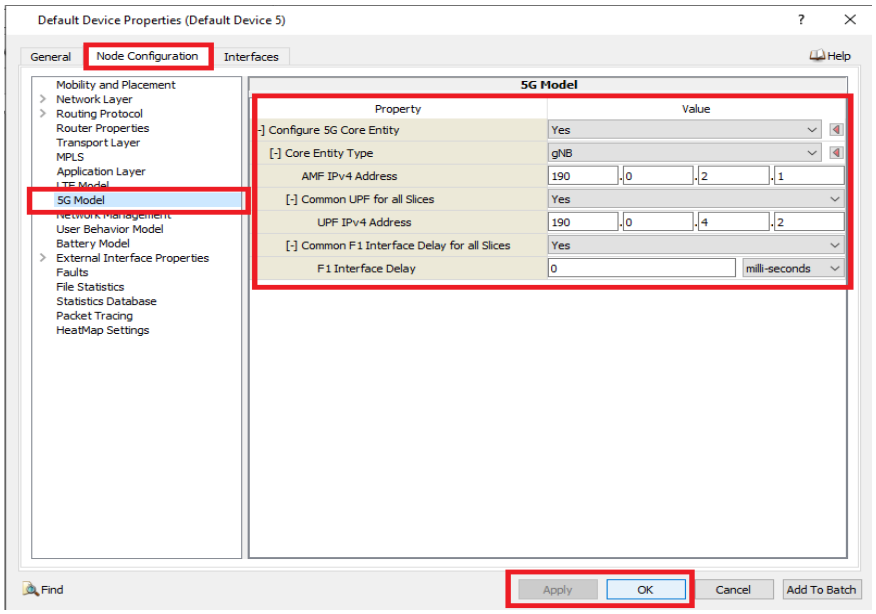
    MIoT slice - 20

    V2X slice - 20



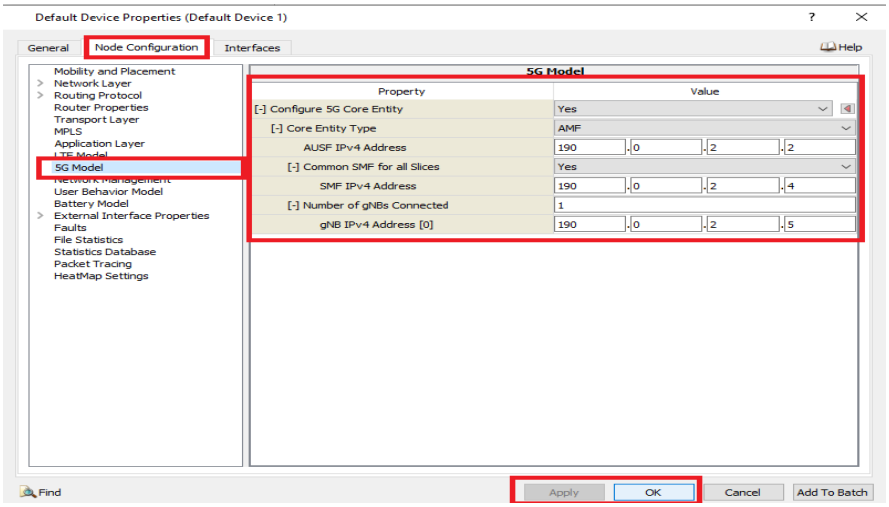

**iv.** Use default values for all other interface parameters.

- Click On > Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to gNB
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UPF IPv4 Address to 190.0.4.2
  - **iv.** Click on Apply > OK.



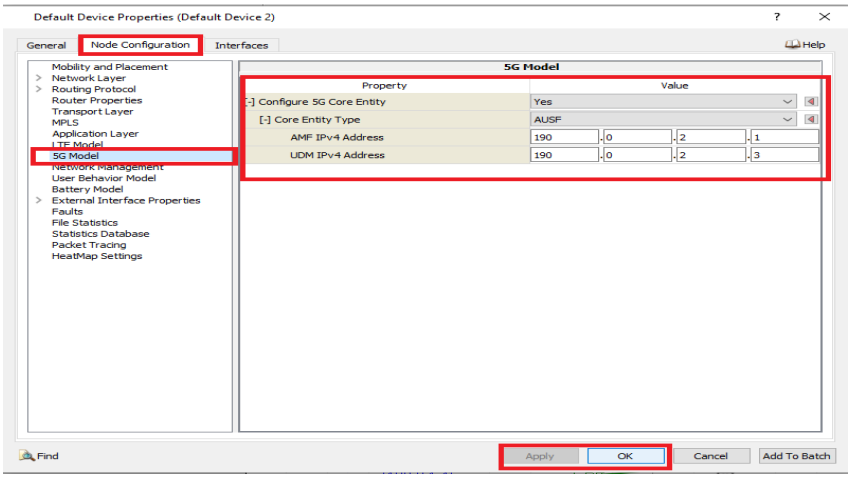
**(4).** To Configure Node 1 **(AMF)**:-

- Double Click On Node 1 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to AMF.
  - **ii.** Set AUSF IPv4 Address to 190.0.2.2
  - **iii.** Set SMF IPv4 Address to 190.0.2.4
  - **iv.** Set Number of gNBs Connected to 1
  - **v.** Set gNB IPv4 Address [0] to 190.0.2.5
  - **vi.** Click on Apply > OK.



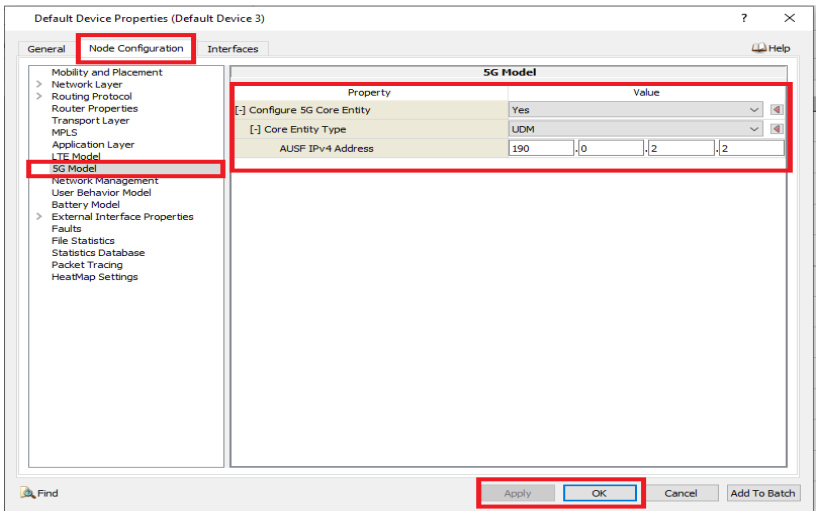

**(5).** To Configure Node 2 **(AUSF)**:-

- Double Click On Node 2 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to AUSF.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UDM IPv4 Address to 190.0.2.3
  - **iv.** Click on Apply > OK.



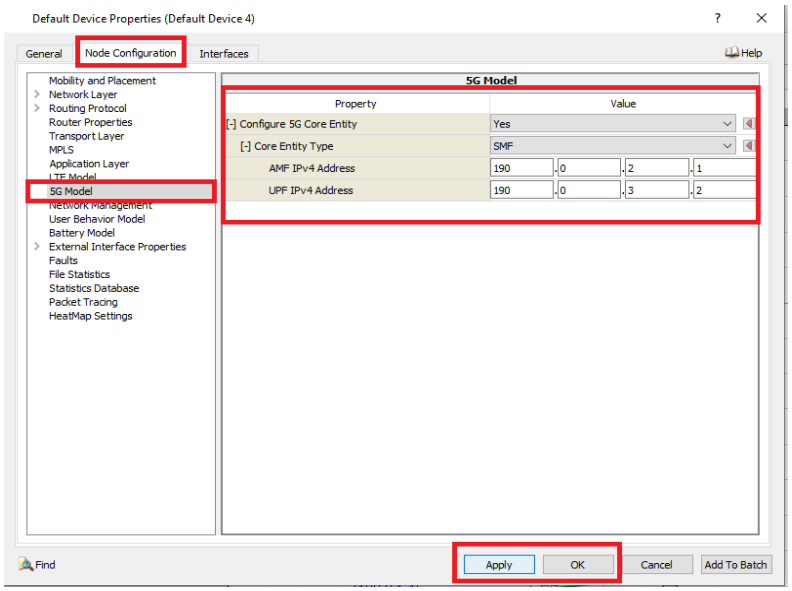
**(6).** To Configure Node 3 **(UDM)**:-

- Double Click On Node 3 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to UDM.
  - **ii.** Set AUSF IPv4 Address to 190.0.2.2
  - **iii.** Click on Apply > OK.



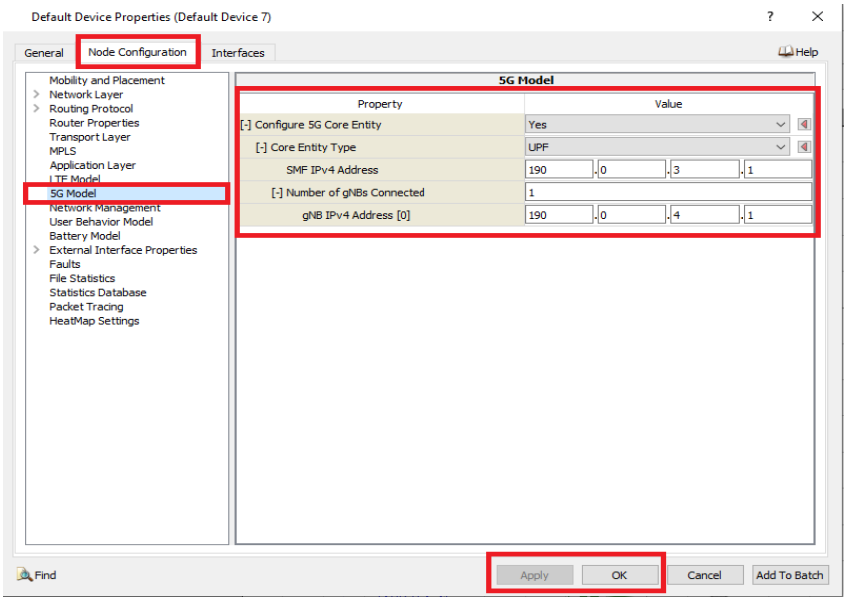

**(7).** To Configure Node 4 **(SMF)**:-

- Double Click On Node 4 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to SMF.
  - **ii.** Set AMF IPv4 Address to 190.0.2.1
  - **iii.** Set UPF IPv4 Address to 190.0.3.2
  - **iv.** Click on Apply > OK.



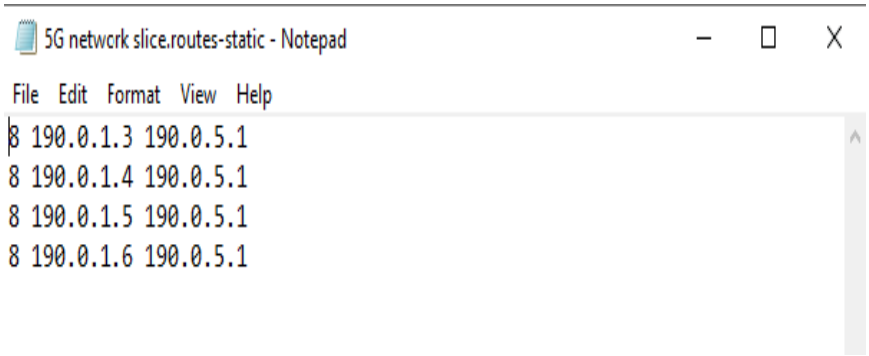
**(8).** To Configure Node 7 **(UPF)**:-

- Double Click On Node 7 > Go to Node Configuration > 5G Model
  - **i.** Set Configure 5G Core Entity to Yes and Core Entity Type to UPF.
  - **ii.** Set SMF IPv4 Address to 190.0.3.1
  - **iii.** Set Number of gNBs Connected to 1
  - **iv.** Set gNB IPv4 Address [0] to 190.0.4.1
  - **v.** Click on Apply > OK.



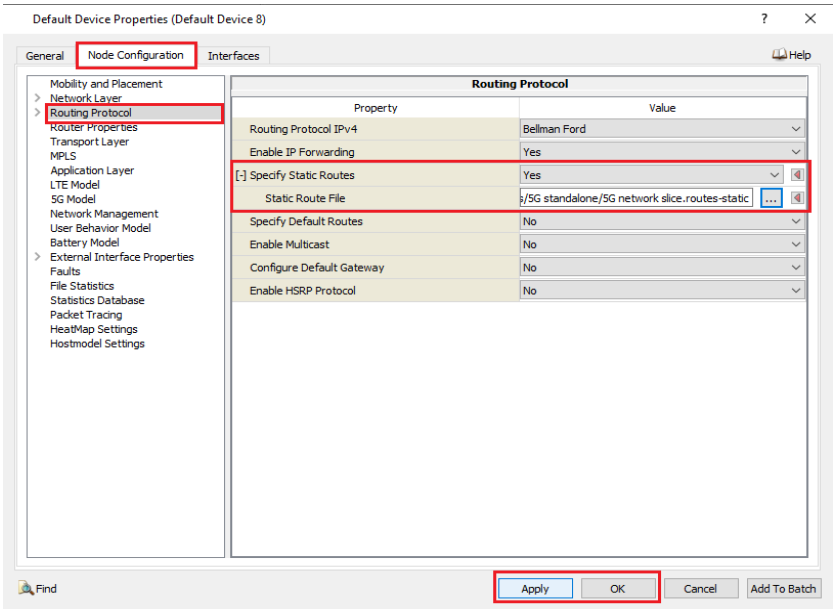

**(9).** To Configure Node 8 **(DN)**: -

- Double Click On Node 8 > Go to Node Configuration > Routing Protocol.
  - **i.** Set Specify Static Routes to Yes.
  - **ii.** Create a file in Notepad called **Filename.routes-static** in the scenario directory which contains the static route from the DN to the UE.
  - **iii.** In the Static Routes file, **Filename.routes-static**, specify the routes as follows:- <Node Id of DN> <IP-ADDRESS of UE> < Next Hop IP Address/IP of UPF >



**iv.** To Set Static Route File > Click on Select files and select **Filename.routes-static**

**v.** Click on Apply > OK.



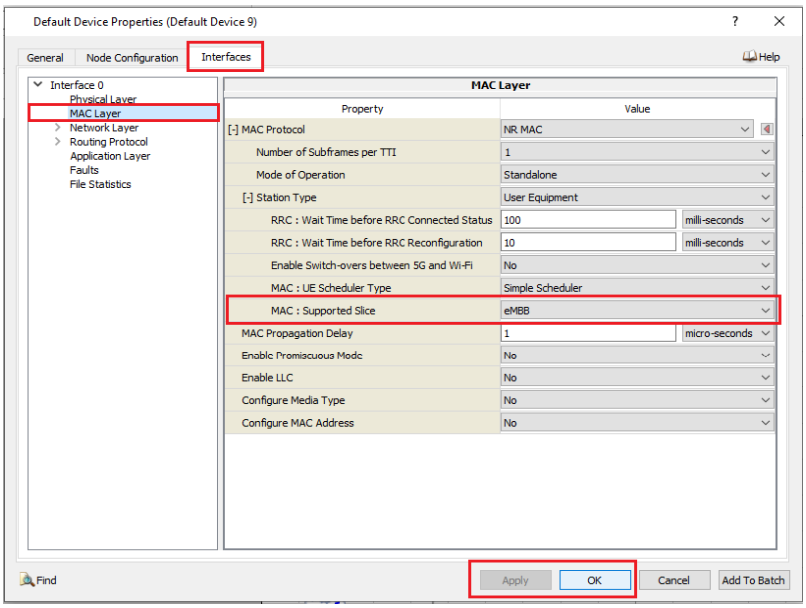

**(10).** To Configure Node 9 **(UE 1) :-**

➢ Double Click On Node 9 > Interfaces >Interface 0 > MAC layer

**i.** Set MAC Protocol to **NR MAC**

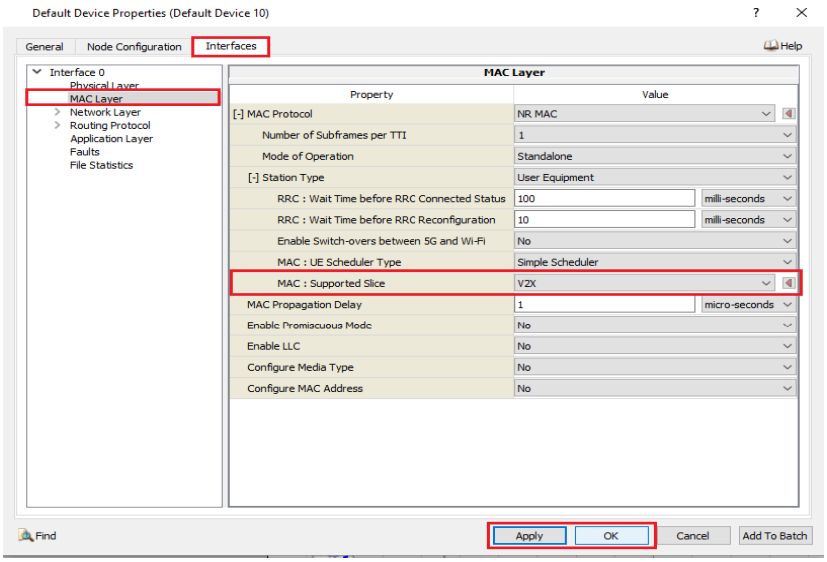
**ii.** Set MAC:Supported slice to **eMBB**

**iii.** Click on Apply > OK.



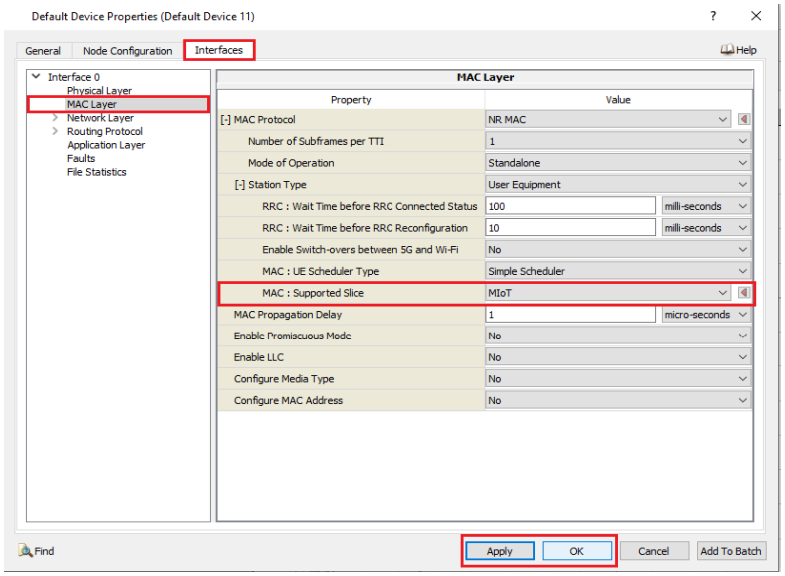
**(11).** To Configure Node 10 **(UE 2) :-**

- Double Click On Node 10 > Interfaces >Interface 0 > MAC layer
  - **i.** Set MAC Protocol to **NR MAC**
  - **ii.** Set MAC:Supported Slice to **V2X**
  - **iii.** Click on Apply > OK.



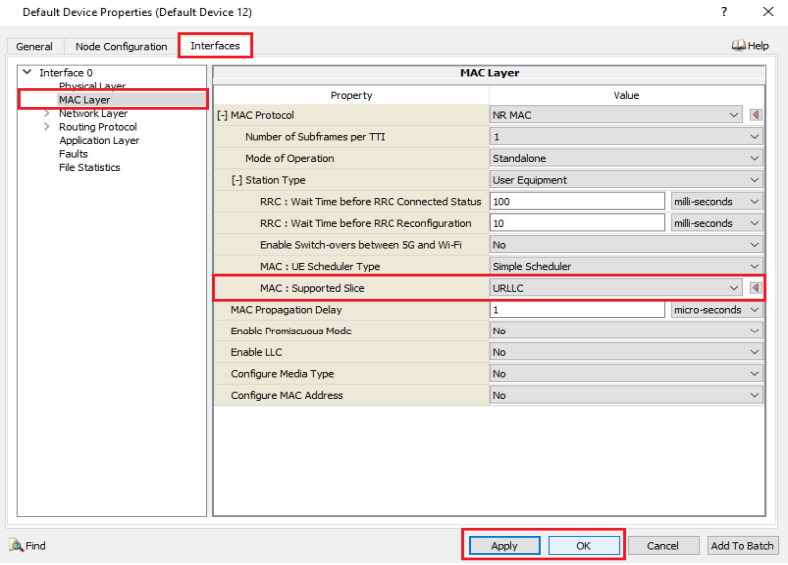

**(12).** To Configure Node 11 **(UE 3) :-**

- Double Click On Node 11 > Interfaces > Interface 0 > MAC layer
  - **i.** Set MAC Protocol to **NR MAC**
  - **ii.** Set MAC:Supported Slice to **MIoT**
  - **iii.** Click on Apply > OK.



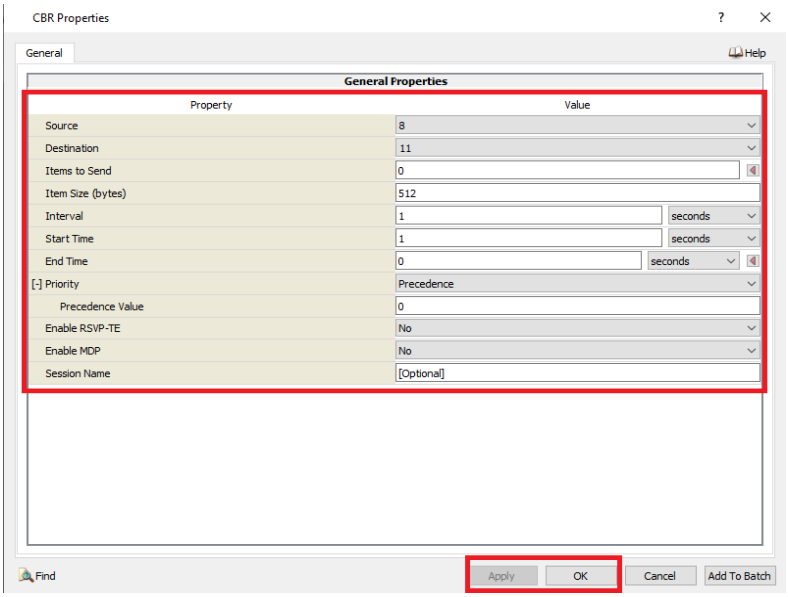
**(13).** To Configure Node 12 **(UE 4) :-**

- Double Click On Node 12 > Interfaces > Interface 0 >MAC layer
  - **i.** Set MAC Protocol to **NR MAC**
  - **ii.** Set MAC:Supported Slice to **URLLC**
  - **iii.** Click on Apply > OK.




**(14).** To set the properties of the CBR Application, do the following:-

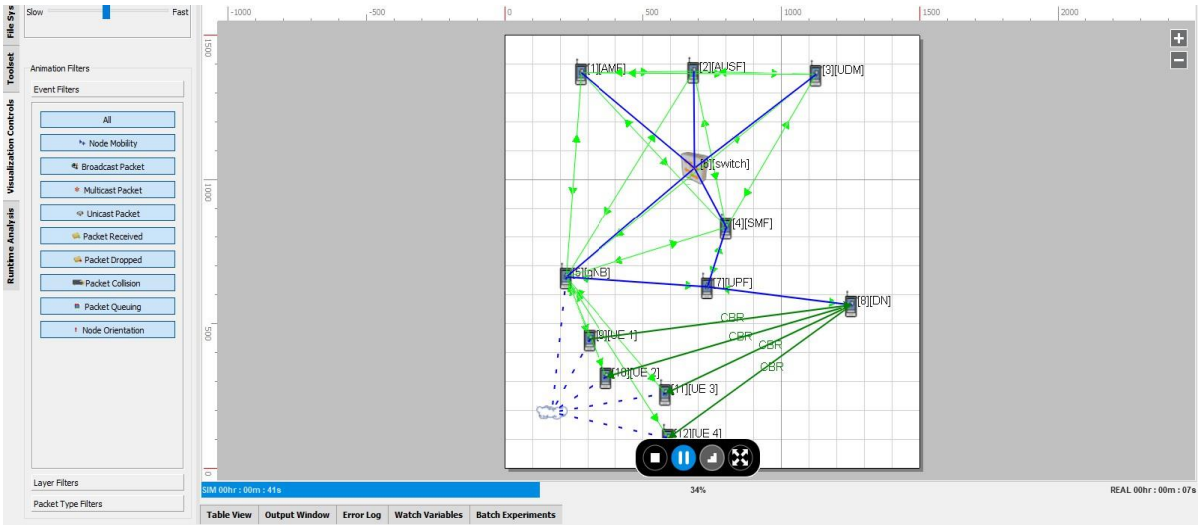
- Double-click the CBR link on the canvas.
- In the CBR Properties Editor, set the parameters as shown below
- Click On Apply > OK.
- Repeat the Steps for Other 3 CBR Applications.

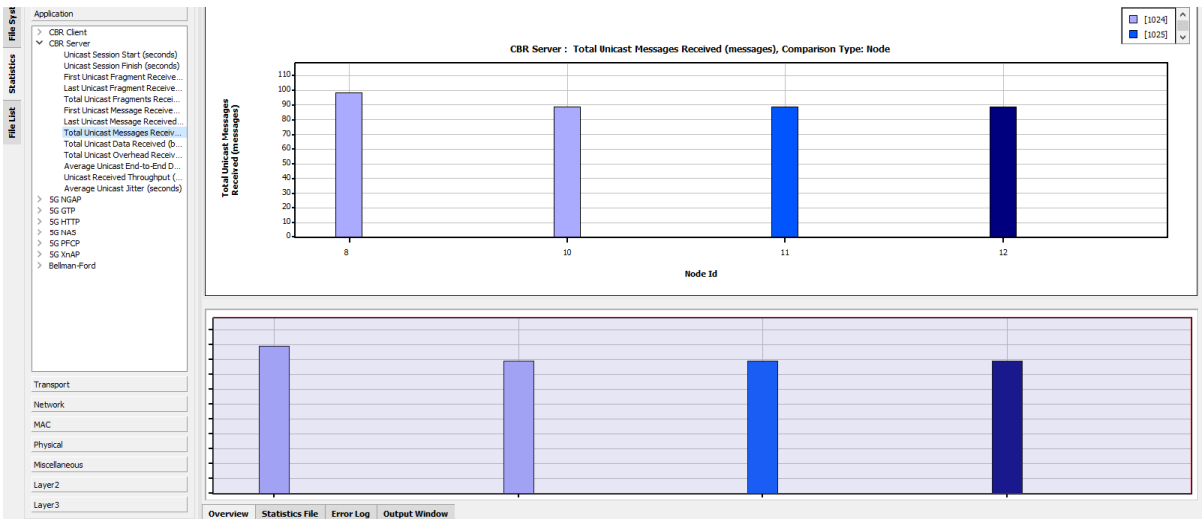


**Step5:** Save the scenario by clicking the Save button in the toolbar.

**Step6:** Click the Run Simulation button.

**Step7**: To start the simulation, click the **Play** button at the bottom of the canvas.




**Step8**: After the simulation has completed, switch to Analyzer by clicking the Analyze Results button. In the analyzer the performance parameter of the current scenario and the layer wise communication can be seen. Number of packets received, throughput, jitter, end to end delay, client and the server performance etc. can be analyzed.