Performance Analysis of Wireless Ad Hoc Networks using NetSim

Contents

Case 1: Single Link Networks: Proximity and Spatial Reuse

Procedure:

In this section we explain how users can run the simulation and obtain results that match those provided in the main document

1. Use the following download Link to download a compressed zip folder which contains the workspace:
   https://github.com/NetSim-TETCOS/Performance-Analysis-Wireless_Adhoc_Network_v13.1/archive/refs/heads/main.zip
2. Extract the zip folder.
3. The extracted project folder consists of a NetSim workspace file (WiFi_Adhoc_Performance_v13_1.netsimexp).
4. Go to NetSim Home window, go to Your Work and click on Import.

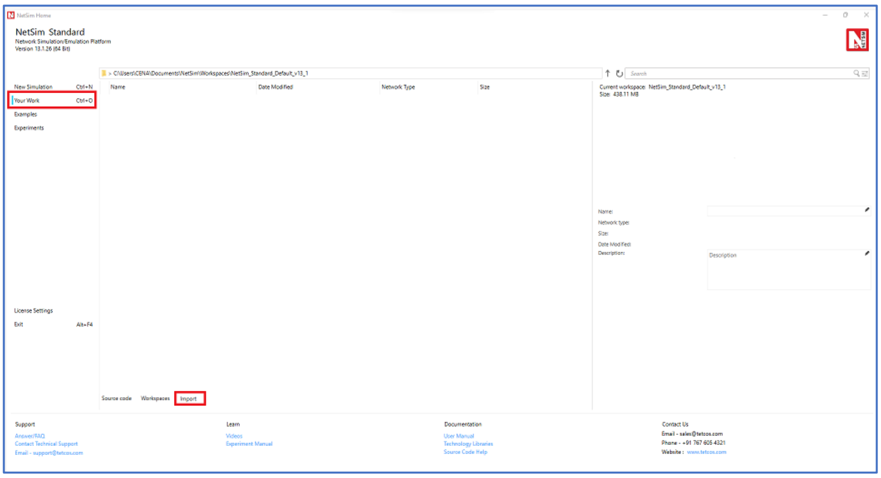


Fig 1: NetSim Home Window

5. In the Import Workspace Window, browse and select the WiFi_Adhoc_Performance_v13_1.netsimexp file from the extracted directory. Click on create a new workspace option and browse to select a path in your system where you want to set up the workspace folder.
6. Choose a suitable name for the workspace of your choice. Click Import.

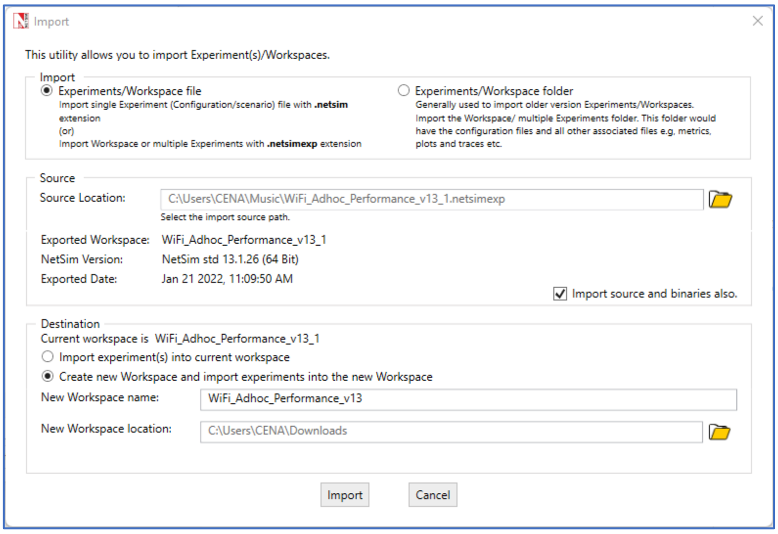


Fig 2: NetSim Import workspace window

7. The Imported Project workspace will automatically be set as the current workspace.
8. The list of experiments is now loaded onto the selected workspace.

9. The Experiments/ configuration files associated with the case mentioned above are available in the folder “Case_1_Single_Link_Networks_Proximity_and_Spatial_Reuse” inside the workspace.

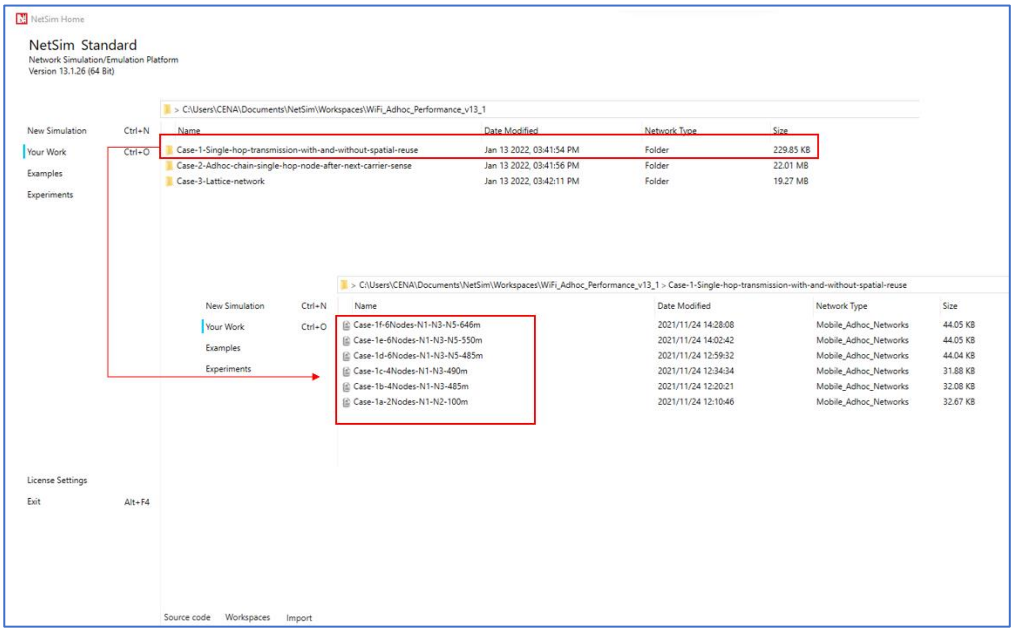


Fig 3: NetSim Your work window with experiments for Case 1- Single Link Networks Proximity and Spatial Reuse

Network Scenario

NetSim UI displays the following Network Scenarios

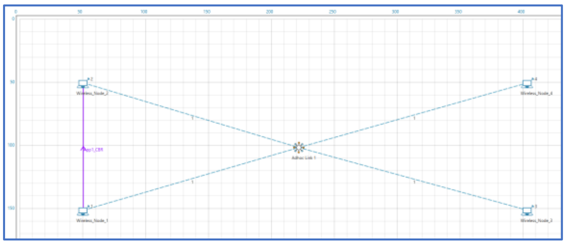


Fig 4: Network Scenario for Case 1-a

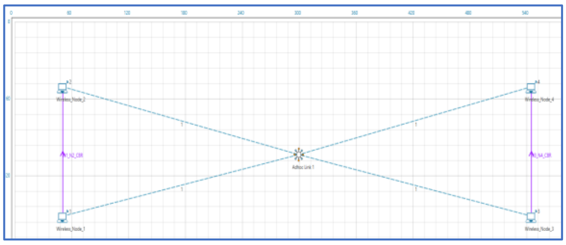


Fig 6: Network Scenario for Case 1-c

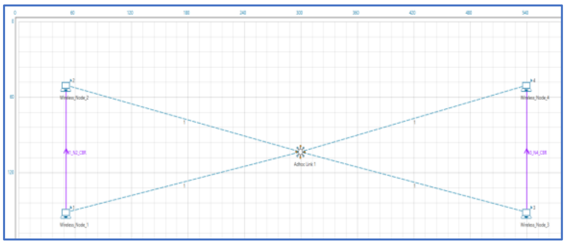


Fig 5: Network Scenario for Case 1-b

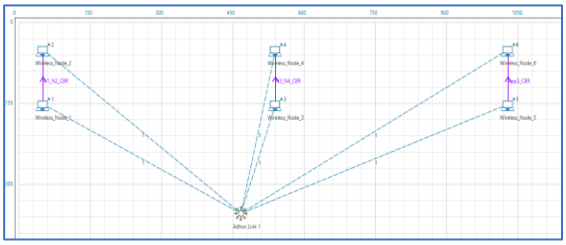


Fig 7: Network Scenario for Case 1-d

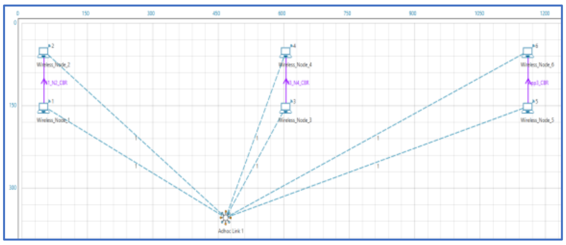


Fig 8: Network Scenario for Case 1-e

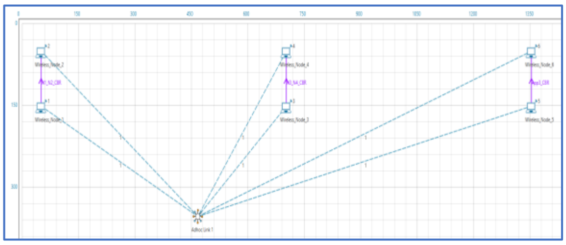


Fig 9: Network Scenario for Case 1-f

Device Coordinates

The devices were placed in the following coordinates for each of the cases shown above.

Case #	Description	Node 1	Node 2	Node 3	Node 4	Node 5	Node 6
Case 1 a	2 Nodes: N1, N2. Src-Dest separation 100m	(50,150)	(50,50)	-	-	-	-
Case 1 b	4 Nodes: N1, N2, N3, N4 Src-Dest separation 100m Src-Src separation 485m	(50,150)	(50,50)	(535,150)	(535,50)	-	-
Case 1 c	4 Nodes: N1, N2, N3, N4 Src-Dest separation 100m Src-Src separation 490m	(50,150)	(50,50)	(540,150)	(540,50)	-	-
Case 1 d	6 Nodes: N1, N2, N3, N4, N5, N6 Src-Dest separation 100m Src-Src separation 485m	(50,150)	(50,50)	(535,150)	(535,50)	(1020,150)	(1020,50)
Case 1 e	6 Nodes: N1, N2, N3, N4, N5, N6 Src-Dest separation 100m Src-Src separation 550m	(50,150)	(50,50)	(600,150)	(600,50)	(1150,150)	(1150,50)
Case 1 f	6 Nodes: N1, N2, N3, N4, N5, N6 Src-Dest separation 100m Src-Src separation 646m	(50,150)	(50,50)	(696,150)	(696,50)	(1342,150)	(1342,50)

Table 1: Description of the 5 cases under study and the device X, Y co-ordinates in each case

Simulation Parameters

1. The Grid length was set to 500×500 for Case 1-a, 600×600 for Case 1-b and Case 1-c, 1500×1500 for Case 1-d, Case 1-e and Case 1-f.
2. The simulation Parameters were configured as follows:

802.11 Parameters	
Standard	IEEE802.11g
Operating Frequency	2.4GHz
Rate Adaptation	False
Dot11_RTS Threshold	3000bytes
Frequency Band	2.4GHz
Bandwidth	20MHz
Transmitter Power	100mW
Medium Access Control	DCF

Table 2: Values set for different parameters in simulation

Wireless Link Parameters	
Channel Characteristics	Path Loss Only
Path Loss Model	Log Distance
Pathloss Exponent (η)	2.6
Simulation Duration	
Simulation Time	10 seconds

Table 3: Wireless Link parameter and Simulation time

Application Parameters	
Application Type	CBR
Source ID	Node_1, 3 and 5
Destination ID	Node_2, 4 and 6
Packet Size	1460 bytes
Packet Size Distribution	Constant
Inter-Arrival Time	467.2 microseconds (25 Mbps Application Rate. Saturated queues)
Transport Protocol	UDP

Table 4: Application properties set in this experiment

Protocol Parameters	Value
CS Threshold	-85 dBm
SIFS	10 μs
Slot Time	9 μs
DIFS (SIFS + 2 ×Slot Time)	28 μs
Preamble Time	20 μs
MPDU Size	1528 B

Table 5: 802.11 g protocol parameters. These values are set in the code

Static Route configuration

Static routes were configured in each source node such that the data gets transmitted directly from source to destination without any dynamic route formation by the routing protocols.
Static routes (whereby N_i always transmits to $N_{(i+1)}$) are set to ensure single hop transmission. Thereby each node transmits data to the next-hop node according to the topology.

To set the static routes, go to Wireless_Node properties > Network Layer > Enable Static Route IP. The Static route IP were configured in Wireless_Node_1, Wireless_Node_3 and Wireless_Node_5 as shown below:

Device	Network Destination	Gateway	Subnet Mask	Metrics	Interface ID
Wireless_Node_1	11.1.1.0	11.1.1.2	255.255.255.255	1	1
Wireless_Node_3	11.1.1.0	11.1.1.4	255.255.255.255	1	1
Wireless_Node_5	11.1.1.0	11.1.1.6	255.255.255.255	1	1

Table 6: Static route configured in devices for Cases 1- a, b, c, d, e and f

Results

The per application throughput is noted down from the NetSim Results window and tabulated in Table 8 of the main document.

Case 2: Ad Hoc Chain, Single Hop Communication: Two-Hop CS Range

Procedure:

In this section we explain how users can run the simulation and obtain results that match those provided in the main document

1. The workspace downloaded and imported earlier contains the experiment files for case 2.
2. The Experiments/ configuration files associated with the case mentioned above are available in the folder "Case_2_Adhoc_Chain_Single_Hop_Communication_Two_Hop_CS_Range" inside the workspace" inside the workspace.

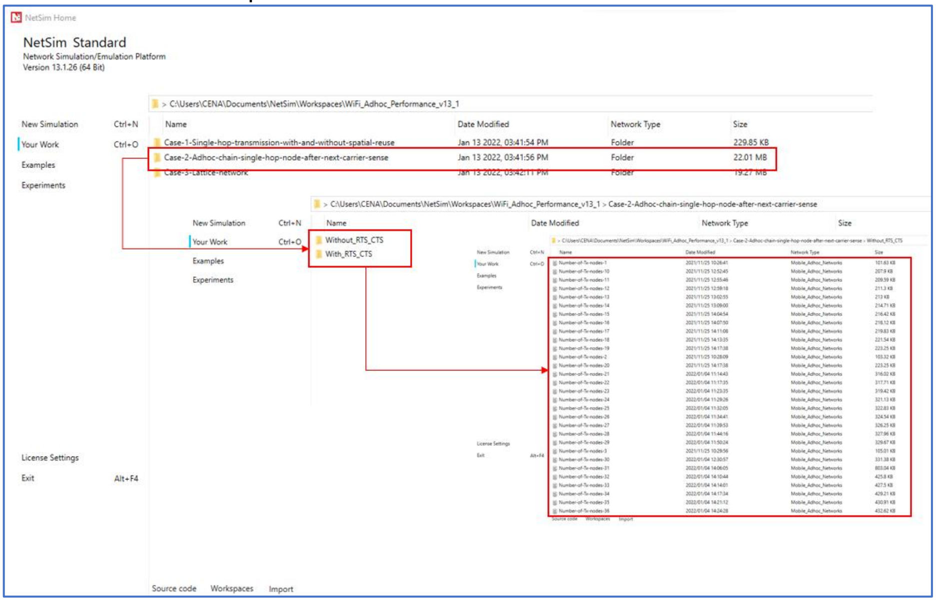


Fig 10: NetSim Your work window with experiments for Case 2- Adhoc chain, single hop communication two hop CS Range- With RTS/CTS and Without RTS/CTS

Network Scenario

NetSim UI displays the following Network Scenarios.

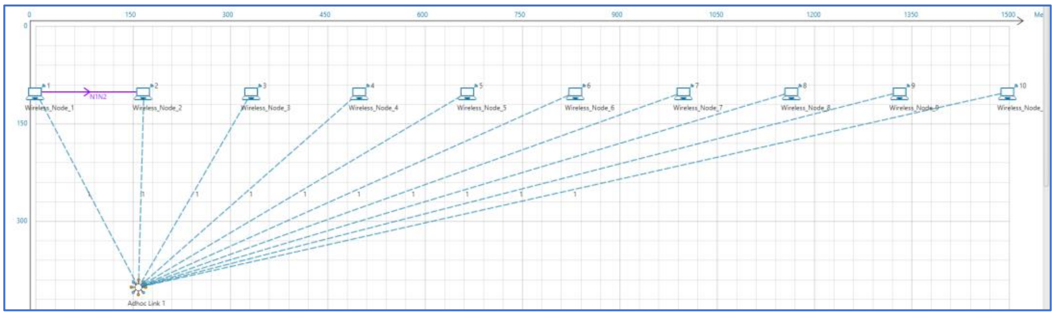


Fig 11: Network Scenario for Case with one node transmitting. The number of transmitting nodes are increased from 1 to 49.

Device Coordinates

The distance setting should be such that (i) N1-N2 are in transmission range, (ii) N1-N3 are in CS range but not in transmission range, and (iii) N1-N4 are beyond in CS range. These conditions are met when the distance to the immediate neighbour is 165m. Thus, the placement would be $N1\,(0,100)$, $N2\,(165,100)$, $N3\,(330,100)$ … and so on

The devices were placed in the following coordinates for each of the cases shown above

Case #	Description	Node 1	Node 2	Node 3	Node 4	Node 5	Node_{i+1}	Node 50
1	Number of Transmitting Nodes=1	(0,100)	(165,100)	-	-	-	-	-
2	Number of Transmitting Nodes=2	(0,100)	(165,100)	(330,100)	-	-	-	-
3	Number of Transmitting Nodes=3	(0,100)	(165,100)	(330,100)	(495,100)	-	-	-
4	Number of Transmitting Nodes=4	(0,100)	(165,100)	(330,100)	(495,100)	(660,100)	-	-
49	Number of Transmitting Nodes=49	(0,100)	(165,100)	(330,100)	(495,100)	(660,100)	(x+165, 100)	(7920,100)

Table 7: X and Y coordinates of devices in the network scenario. The devices are placed 165m away from each other.

Simulation Parameters

1. The Grid length was set to 8500×8500.
2. The simulation Parameters were configured as follows:

802.11 Parameters	
Standard	IEEE802.11g
Operating Frequency	2.4GHz
Rate Adaptation	False
Dot11_RTS Threshold	3000B and 1000B
Frequency Band	2.4GHz
Bandwidth	20MHz
Transmitter Power	100mW
Medium Access Control	DCF

Table 8: Values set for different parameters in simulation

Wireless Link Parameters	
Channel Characteristics	Path Loss Only
Path Loss Model	Log Distance
Pathloss Exponent (η)	2.6
Simulation Duration	
Simulation Time	100 seconds

Table 9: Wireless Link parameter and Simulation time

Application Parameters	
Application Type	CBR
Source ID	$Node_i$ where i= 1, 2,…etc 49
Destination ID	$Node_{i+1}$ where i= 1, 2..etc 49
Packet Size	1460 bytes
Packet Size Distribution	Constant
Inter-Arrival Time	973.33 microseconds (12 Mbps Application Rate. Saturated queues)
Transport Protocol	UDP

Table 10: Application properties set in this experiment

Protocol Parameters	Value
CS Threshold	-85 dBm
SIFS	10 μs
Slot Time	9 μs
DIFS (SIFS + $2\times$Slot Time)	28 μs
Preamble Time	20 μs
MPDU Size	1528 B

Table 11: 802.11 g protocol parameters. These values are set in the code

Static Route configuration

Static routes were configured in each source node such that the data gets transmitted directly from source to destination without any dynamic route formation by the routing protocols.
Static routes (whereby N_i always transmits to $N_{(i+1)}$) are set to ensure single hop transmission. Thereby each node transmits data to the next-hop node according to the topology.

To set the static routes, go to Wireless_Node properties > Network Layer > Enable Static Route IP.

Device	Network Destination	Gateway	Subnet Mask	Metrics	Interface ID
Wireless_Node_1	11.1.1.0	11.1.1.2	255.255.255.255	1	1
Wireless_Node_2	11.1.1.0	11.1.1.3	255.255.255.255	1	1
Wireless_Node_3	11.1.1.0	11.1.1.4	255.255.255.255	1	1
Wireless_Node_$i+1$	11.1.1.0	11.1.1.(i+1)	255.255.255.255	1	1
Wireless_Node_49	11.1.1.0	11.1.1.50	255.255.255.255	1	1

Table 12: Static route configured in Case 2. Here I vary from 3 to 4

Results

The average and aggregate application throughputs are noted down from the NetSim Results window and tabulated in Table 9 of the main document.

Steps to calculate the average and aggregate throughput:

1. Run the simulation for cases With RTS- CTS and Without RTS-CTS.
2. After the simulation note down the application throughputs (for each application), copy the values into an Excel sheet.
3. Calculate the Average and Aggregate throughputs for each case and tabulate the data.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	9.9	4.72	4.47	8.92	5.75	4.61	4.47	4.73	5.60	5.40	5.04	4.95	5.50	5.37	5.08	5.09	5.09	5.15	5.11
		5.37	2.34	0.62	3.14	2.87	2.43	2.25	2.08	2.59	2.73	2.54	2.32	2.53	2.60	2.54	2.47	2.46	2.49
			3.46	0.34	0.97	2.41	2.11	1.85	1.41	1.26	1.66	1.77	1.46	1.45	1.65	1.61	1.63	1.58	1.62
				8.98	2.85	1.65	2.28	1.90	1.29	1.01	0.78	1.12	1.00	0.89	0.92	0.98	1.00	1.02	0.96
					5.96	2.59	1.66	2.56	3.83	2.82	2.16	1.86	3.14	2.80	2.38	2.32	2.26	2.34	2.34
						5.52	2.62	1.69	2.13	3.47	2.93	2.23	1.94	2.73	2.56	2.39	2.38	2.35	2.36
							4.65	2.28	1.17	1.72	3.06	2.54	1.74	1.71	2.44	2.36	2.20	2.13	2.16
								4.46	1.83	0.87	1.24	2.45	1.83	1.37	1.38	1.88	1.86	1.75	1.75
									5.47	2.09	0.93	1.46	3.32	2.34	1.68	1.62	1.83	1.91	1.78
										5.74	2.38	1.08	1.51	3.19	2.33	1.79	1.83	2.03	2.06
											5.73	2.31	0.94	1.44	3.05	2.42	1.91	1.89	2.16
												5.57	2.11	0.95	1.47	2.94	2.33	1.82	1.81
													5.84	2.19	1.01	1.39	2.60	2.20	1.68
														5.76	2.19	0.97	1.49	2.65	2.25
															5.67	2.27	1.05	1.55	2.76
																5.66	2.32	1.07	1.50
																	5.42	2.27	1.01
																		5.42	2.28
																			5.49
Average	9.90	5.05	3.42	4.71	3.73	3.28	2.89	2.71	2.76	2.70	2.60	2.49	2.51	2.48	2.43	2.39	2.33	2.31	2.29
Aggregate	9.90	10.10	10.27	18.86	18.67	19.65	20.21	21.72	24.82	26.97	28.64	29.87	32.64	34.72	36.42	38.25	39.69	41.58	43.58

Fig 12: Average and aggregate throughput calculation for each case with number of transmitting nodes increased from 1 to 49

Plotting Average Throughput vs Number of Transmitting Nodes

The following steps were done to get the average throughput vs Number of transmitting nodes plot:

1. Go to Insert tab and click on chart option, select XY(Scatter) and select Scatter Plot from the options provided. Click on ok.

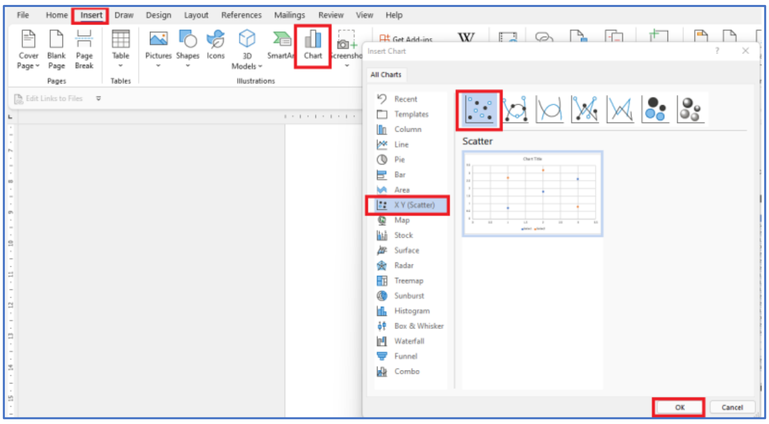


Fig 13: XY Scatter plot selection

2. In the data sheet, enter the Number of Transmitting nodes in the first column and average throughput obtained in the second column

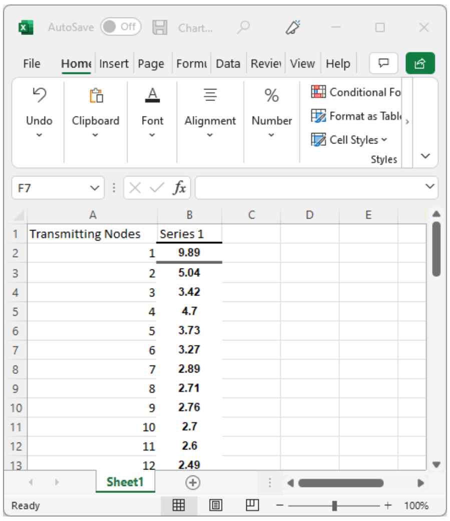


Fig 14: Plot data

3. This will provide a scatter plot. Now edit the Axis Titles to Average Throughput in the Y axis and Number of Transmitting Nodes in the X axis
4. Right click on the x axis and select format axis option. In the Bound section, set the Minimum field to 1.0 and the Maximum field to 50.0. In the Units section, set the Major field to 8.0 and Minor field to 2.0.

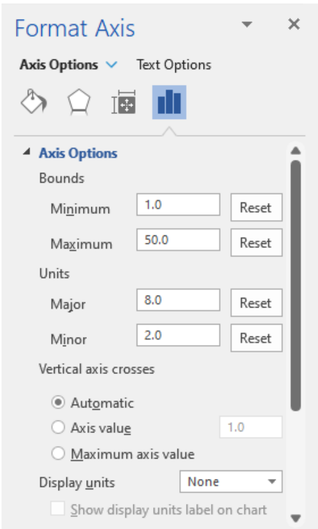


Fig 15: Format axis option

5. Enable Trendline in the chart properties. This will provide an Average throughput vs Number of transmitting nodes plot as shown below

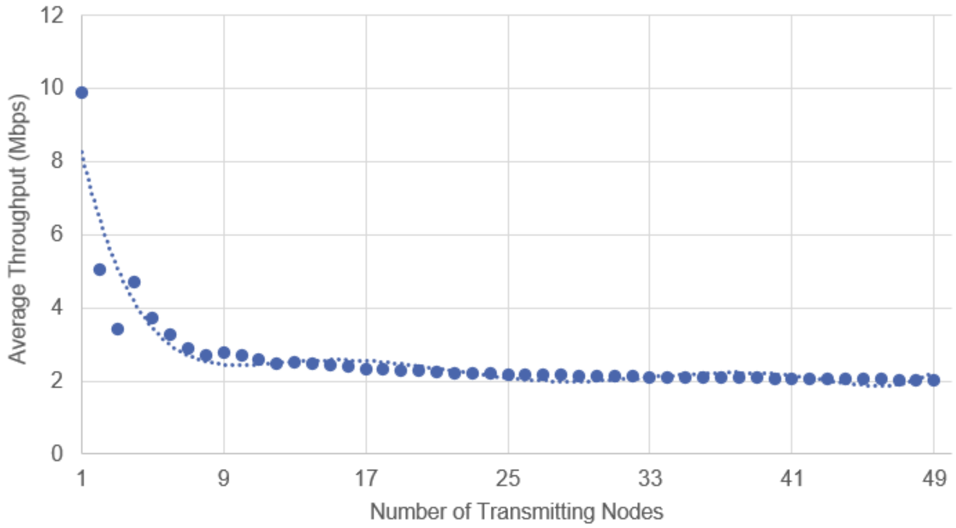


Fig 16: Average throughput vs transmitting nodes plot

Border effects in line networks: Plotting Throughput vs Transmitting Node ID

The following steps were done to get the throughput vs transmitting node ID plot:

1. Go to Insert tab and click on chart option, select XY(Scatter) and select Scatter Plot from the options provided. Click on ok.

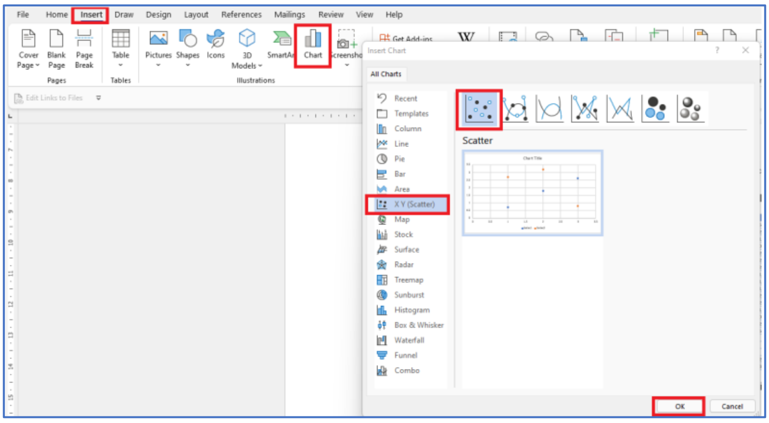


Fig 17: XY Scatter plot selection

2. In the data sheet, enter the transmitting node ID in the first column and the throughput per application obtained after simulation in the second column. Consider the 5 Transmitting Node scenario.

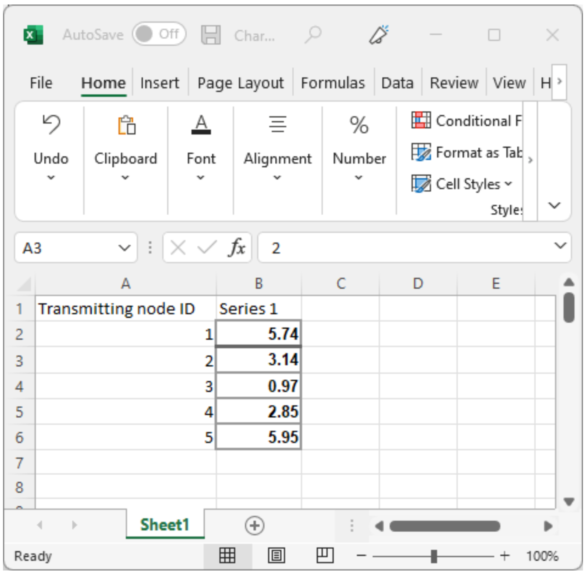


Fig 18: Plot data

3. This will provide a scatter plot. Now edit the Axis Titles to Throughput in the Y axis and Transmitting Node ID in the X axis
4. Right click on the x axis and select format axis option. In the Bound section, set the Minimum field to 1.0 and the Maximum field to 5.0. In the Units section, set the Major field to 1.0 and Minor field to 0.2.

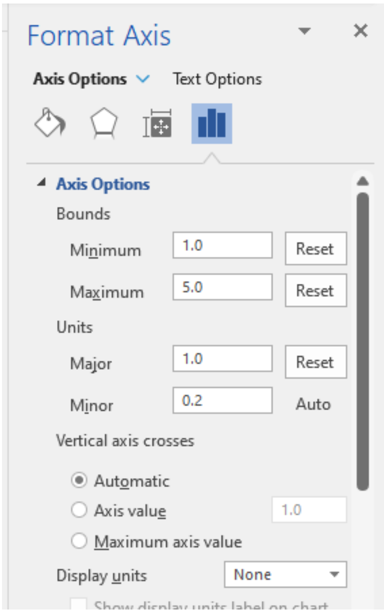


Fig 19: Format axis option

5. This will provide throughput vs Number of transmitting node ID plot as shown below.
6. Similarly plot for 24 Transmitting Nodes and 49 Transmitting Nodes scenarios.

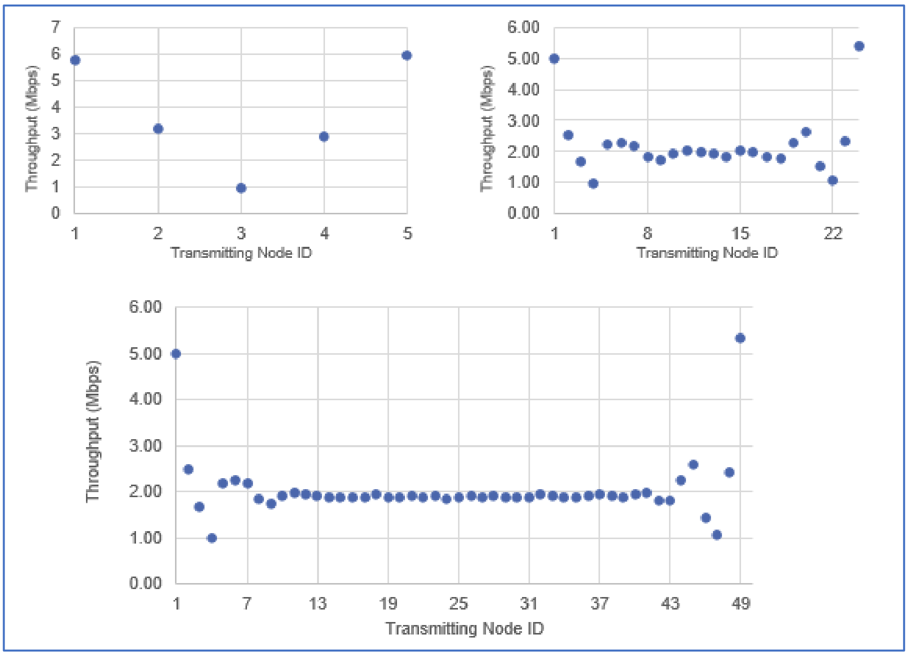


Fig 20: Throughput vs Transmitting Node ID plot for 5 transmitting nodes, 24 transmitting nodes and 49 transmitting nodes scenarios.

Case 3: Ad Hoc Lattice, Single Hop Communication, Two Hop CS Range: Horizontal Traffic

Procedure:

In this section we explain how users can run the simulation and obtain results that match those provided in the main document

1. The workspace downloaded and imported earlier contains the experiment files for case 3.
2. The Experiments/ configuration files associated with the case mentioned above are available in the folder“Case_3_Adhoc_Lattice_Single_Hop_Communication_Two_Hop_CS_Range_Horizontal_Traffic” inside the workspace” inside the workspace.

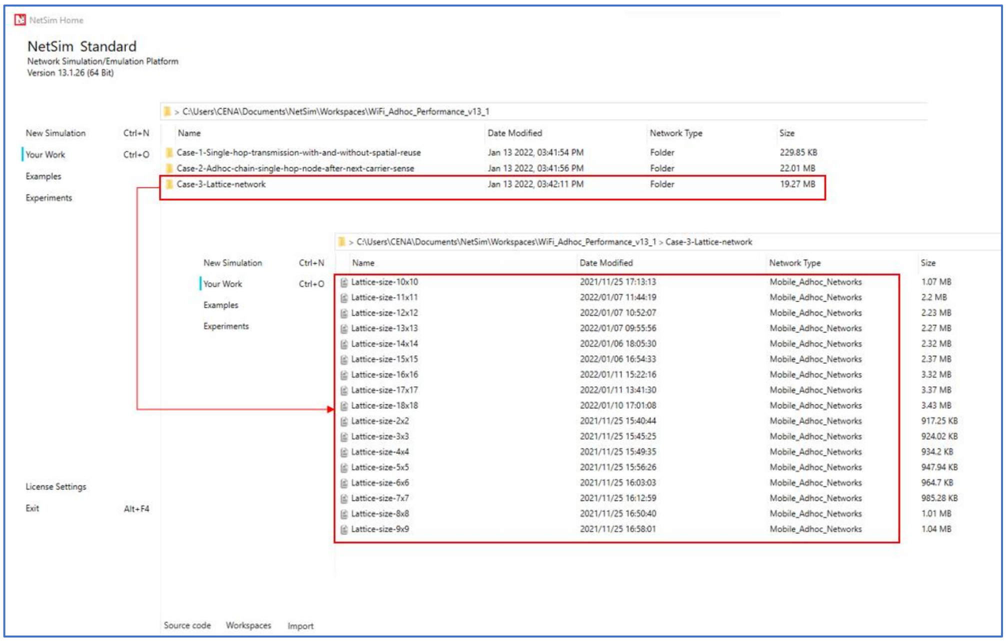


Fig 21: NetSim Your work window with experiments for Case 3- Adhoc Lattice, single hop communication two hop CS Range- Horizontal Traffic

Network Scenario

NetSim UI displays the following Network Scenarios.

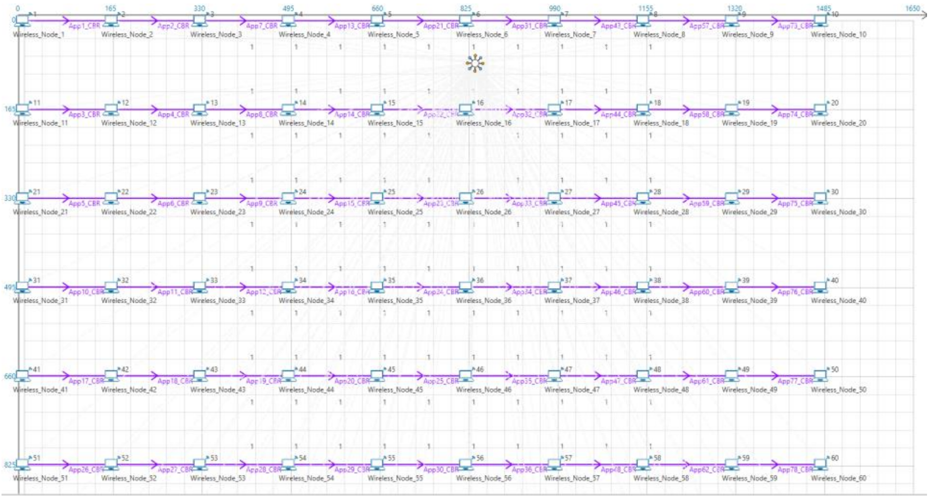


Fig 22: Network scenario with $\mathbf{10} \times \mathbf{10}$ MANET nodes. The nearest neighbour distance is 165m. The data transmissions are purely horizontal.

Device Coordinates

The distance setting should be such that the neighbour node is 165m away.
The devices were placed in the following coordinates for each of the cases shown above

Node 1	Node 2	Node 3	Node 4	Node 5	$Node_{i+1}$	Node 324
(0,0)	(165,0)	(330,0)	(495,0)	(660,0)	(x+165, y+165)	(2805,2805)

Table 13: X and Y coordinates of devices in the network scenario. The devices are placed 165m away from each other.

Simulation Parameters

1. The Grid length was set to 8500×8500.
2. The simulation Parameters were configured as follows:

802.11 Parameters	
Standard	IEEE802.11g
Operating Frequency	2.4GHz
Rate Adaptation	False
Dot11_RTS Threshold	3000B and 1000B
Frequency Band	2.4GHz
Bandwidth	20MHz
Transmitter Power	100mW
Medium Access Control	DCF

Table 14: Values set for different parameters in simulation

Wireless Link Parameters	
Channel Characteristics	Path Loss Only
Path Loss Model	Log Distance
Pathloss Exponent (η)	2.6
Simulation Duration	
Simulation Time	100 seconds

Table 15: Wireless Link parameter and Simulation time

Application Parameters	
Application Type	CBR
Source ID	$Node_i$ where i= 1, 2,…etc 49
Destination ID	$Node_{i+1}$ where i= 1, 2..etc 49
Packet Size	1460 bytes
Packet Size Distribution	Constant
Inter-Arrival Time	973.33 microseconds (12 Mbps Application Rate. Saturated queues) and 1460 microseconds (for larger lattices)
Transport Protocol	UDP

Table 16: Application properties set in this experiment

Protocol Parameters	Value
CS Threshold	-85 dBm
SIFS	10 μs
Slot Time	9 μs
DIFS (SIFS + 2 ×Slot Time)	28 μs
Preamble Time	20 μs
MPDU Size	1528 B

Table 17: 802.11 g protocol parameters. These values are set in the code

Static Route configuration

Static routes were configured in each device so that the flow of data packets will be transmitted from Node i to Node i+1
To set the static routes, go to Wireless_Node properties > Network Layer > Enable Static Route IP.

Device	Network Destination	Gateway	Subnet Mask	Metrics	Interface ID
Wireless_Node_1	11.1.1.2	11.1.1.2	255.255.255.255	1	1
Wireless_Node_2	11.1.1.3	11.1.1.3	255.255.255.255	1	1
Wireless_Node_3	11.1.1.4	11.1.1.4	255.255.255.255	1	1

Wireless_Node_$i+1$	11.1.1.(i+1)	11.1.1.(i+1)	255.255.255.255	1	1

Table 18: Static route configured for Case 3.

Results

The average and aggregate application throughput is noted down from the NetSim Results window and tabulated in Table 10 of the main document.
Steps to calculate the average and aggregate throughput are as follows:

1. Run the simulation for cases with different lattice sizes.
2. After the simulation note down the application throughputs (for each application), copy the values into an Excel sheet.
3. Calculate the Average and Aggregate throughputs for each case and tabulate the data.

	2X2	3X3	4X4	5X5
	4.70	1.72	2.35	2.72
	4.69	2.32	2.12	0.82
		0.79	0.57	0.89
		1.60	0.15	0.38
		1.72	0.56	0.88
		2.25	0.17	0.19
			3.10	1.00
			0.37	0.40
			0.38	0.10
			2.39	0.92
			2.10	0.37
			3.08	0.43
				2.22
				1.15
				0.69
				1.13
				2.73
				0.81
				0.98
				2.20
Average	4.70	1.73	1.44	1.05
Aggregare	9.40	10.40	17.33	20.99

Fig 23: Average and aggregate throughput calculation for each case with lattice size varying from $\mathbf{2} \times \mathbf{2}$ to $\mathbf{18} \times \mathbf{18}$

Plotting Average Throughput vs Number of Transmitting Nodes

The following steps were done to get the average throughput vs Number of transmitting nodes plot:

6. Go to Insert tab and click on chart option, select XY(Scatter) and select Scatter Plot from the options provided. Click on ok

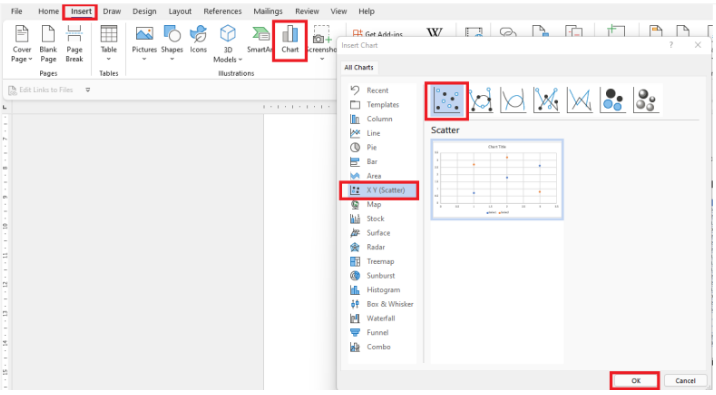


Fig 24: XY Scatter plot selection

7. In the data sheet, enter the Number of Transmitting nodes in the first column (x values) and average throughput obtained in the second column (Y values).

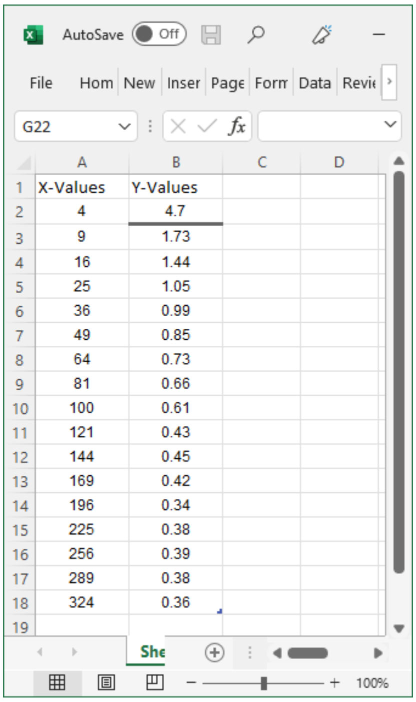


Fig 25: Plot data

8. This will provide a scatter plot. Now edit the Axis Titles to Average Throughput in the Y axis and Number of Transmitting Nodes in the X axis
9. Right click on the x axis and select format axis option. In the Bound section, set the Minimum field to 0 and the Maximum field to 350.0. In the Units section, set the Major field to 50.0 and Minor field to 10.0.

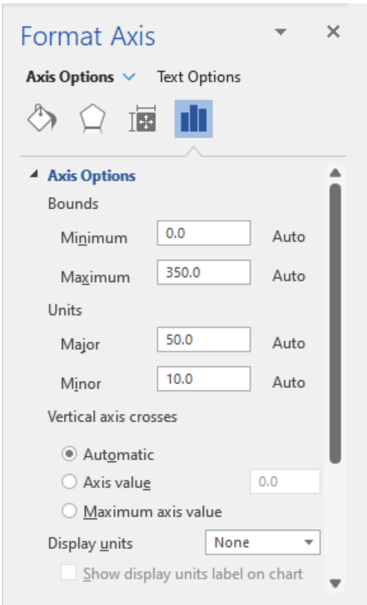


Fig 26: Format axis option

10. Enable Trendline in the chart properties. This will provide an Average throughput vs Number of transmitting nodes plot as shown below

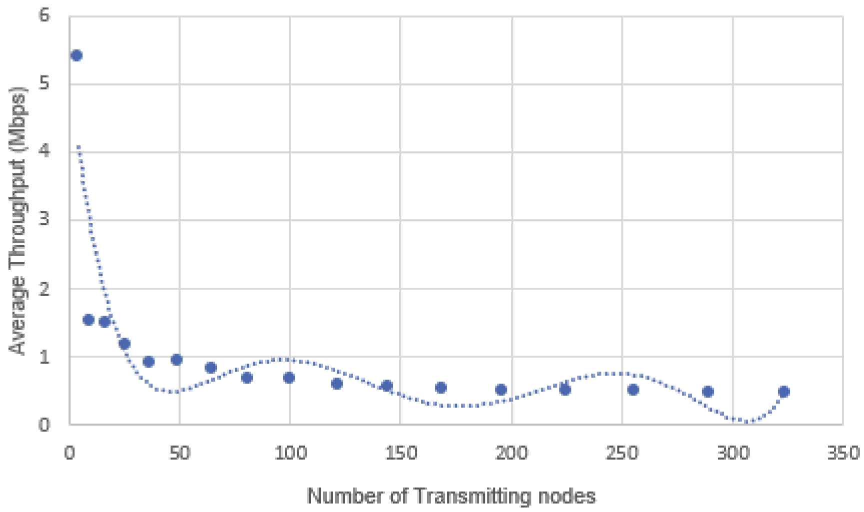


Fig 27: Average throughput vs transmitting nodes plot

Case 4: 4 Hop Network

In this section we explain how users can run the simulation and obtain results that match those provided in the main document.

Users have two options for running these simulations.

- Using the NetSim GUI. In this case the simulation will need to open one-by-one in NetSim and then run. The process is time consuming but is useful initially to get an understanding of the network the parameters configured and the results
- Using the Multi-parameter sweeper utility. With this user can sweep one or more parameters, change their values between simulation runs, and compare and analyse the performance metrics from each run. The entire process changing the values, running simulations, and collating results is done automatically by this utility.

The first sub section below explains how users can run simulations via the GUI while the next explains how to use the multi-parameter sweeper.

Using NetSim's GUI. Importing the project into NetSim.

1. Download a compressed zip folder which contains the NetSim workspace from https://github.com/NetSim-TETCOS/Performance-Analysis-Wireless_Adhoc_Network_v13.1/archive/refs/heads/main.zip
2. The extracted project folder would have a NetSim workspace file Performance-Analysis-Wireless-Adhoc-network.netsimexp.
3. Go to NetSim Home window, go to Your Work and click on Import.

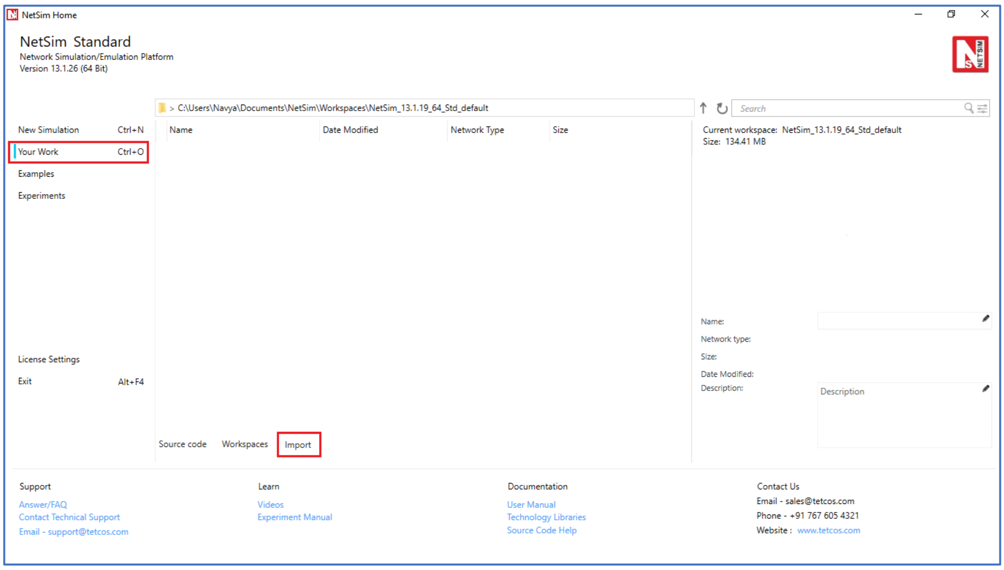


Fig 28:NetSim Home page window

4. In the Import Workspace Window, browse and select the Performance-Analysis-Wireless-Adhoc-network.netsimexp file from the extracted directory. Click on create a new workspace option. Browse to select a path where you want to have the workspace folder.
5. Choose a suitable name for the workspace. Click Import

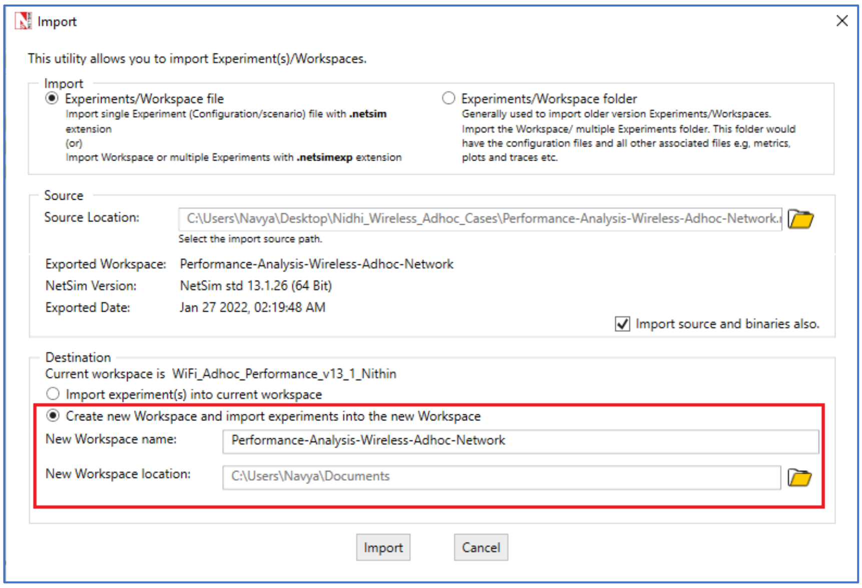


Fig 29: Importing workspace into new workspace

6. The Imported Project workspace will automatically be set as the current workspace. The list of experiments is now loaded onto the selected workspace.
7. The screen shot below shows the folder/file organization for 4-hop, 5-hop, 6-hop and 7-hop network scenarios.

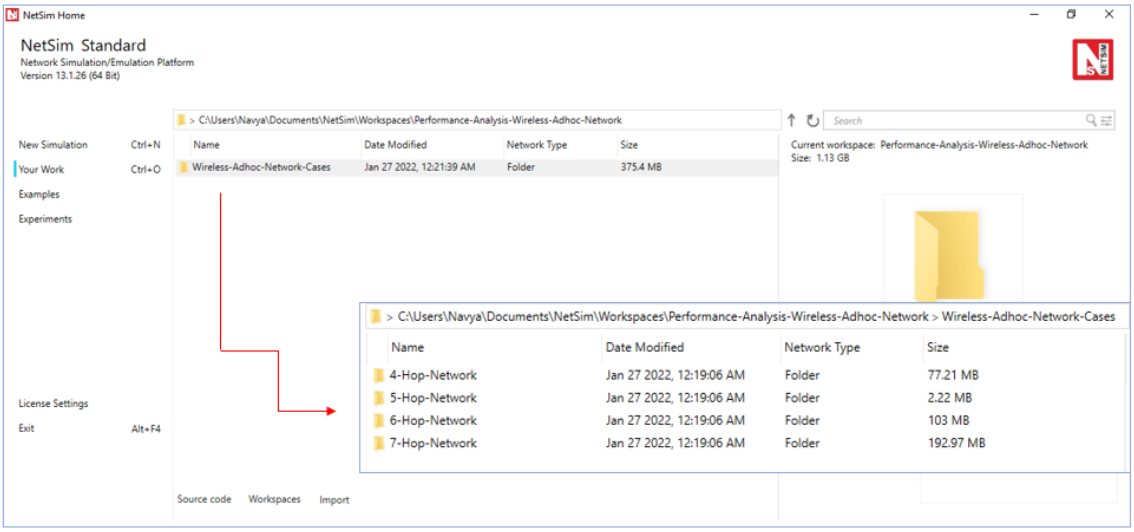


Fig 30:Folder with 4-Hop, 5- Hop, 6-Hop and 7-Hop (With RTS-CTS) examples

Simulation Parameters

1. Grid length of 1500m × 1500m

Devices	X	Y
Wireless_Node_1	0	300
Wireless_Node_2	300	300
Wireless_Node_3	600	300
Wireless_Node_4	900	300
Wireless_Node_5	1200	300

Table 19: X and Y coordinates of devices in the network scenario

2. The designed in NetSim’s MANET library. It comprises of Wireless nodes connected via an Adhoc link.

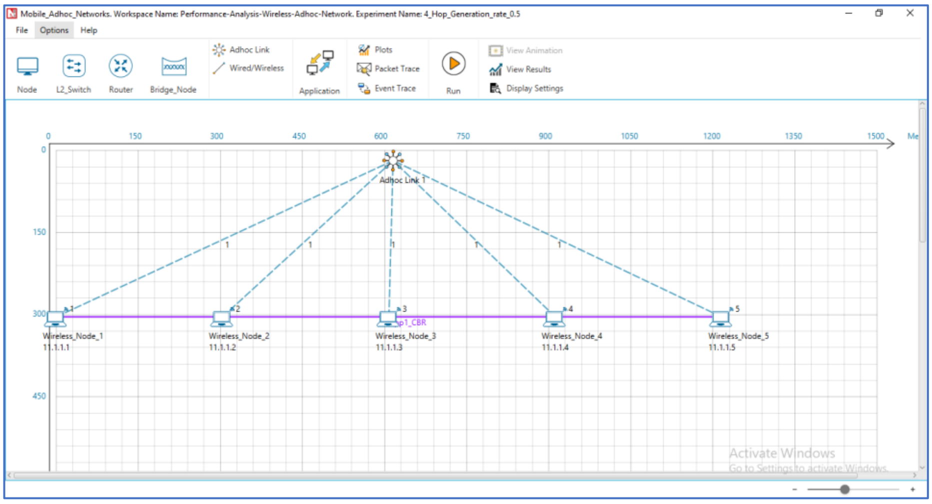


Fig 31: Network Scenario for 4-Hop Network designed with 5 wireless nodes

3. Device properties are set as shown below

802.11 properties	
Physical layer	
Standard	802.11b
Operating frequency	2.4GHz
Transmitter Power	100mW
Transmission type	DSSS
Power Source	Main
Datalink layer	
Rate Adaptation	False
Media Access protocol	DCF
Dot11_RTS Threshold	3000bytes

Table 20: Wireless Node 802.11 parameters

General Properties	
Mobility Model	No Mobility

Table 21: Wireless general properties

Wireless link Properties	
Channel Characteristics	Path Loss Only
Path Loss Model	Log Distance
Pathloss Exponent (η)	2.6

Table 22: Wireless Link Parameters

Application properties	
Application type	CBR
Source ID	Wireless_Node_1
Destination ID	Wireless_Node_5
Transport layer protocol	UDP
Packet Size	1000 bytes
Generation Rate/ Inter arrival time	Varied as shown in Table **24**

Table 23: Application properties

The interpacket arrival time is computed as shown below

$$Inter(packet)ArrivalTime\ (\mu s) = \frac{PacketSize \times 8}{GenerationRate\ (Mbps)}$$

Static Route Configuration

Static routes (whereby N_i always transmits to N_(i+1)) are set to ensure single hop transmission. Thereby each node transmits data to the next-hop node according to the topology

To set Static routes for wireless nodes in order to transmit the data from Wireless_Node_1> Wireless_Node_2>Wireless_Node_3>Wireless_Node_4>Wireless_Node_5

Go to Wireless Nodes > Network layer >Enable Static IP Route and configure as below

Wireless_Node_1:

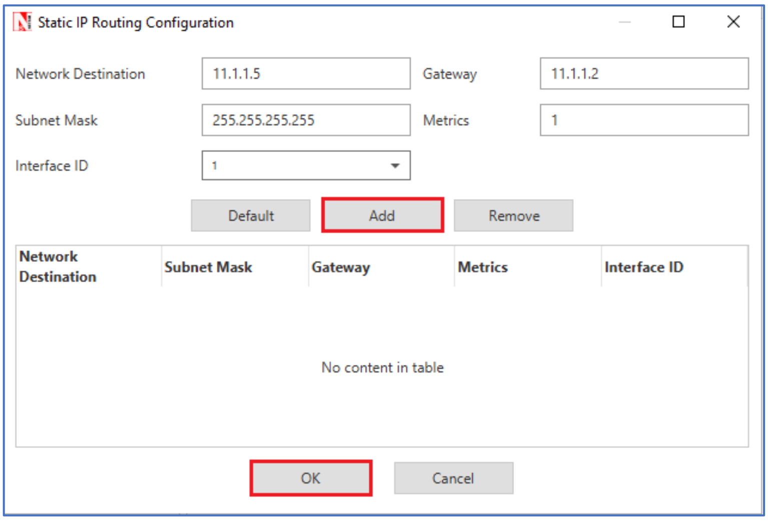


Fig 32: Static Route Configuration for Source node

Click on Add and then OK to set static routes in wireless node
Similarly configure for static routes for the remaining wireless nodes

Device	Network Destination	Gateway	Subnet Mask	Metrics	Interface ID
Wireless_node_2	11.1.1.5	11.1.1.3	255.255.255.255	1	1
Wireless_node_3	11.1.1.5	11.1.1.4	255.255.255.255	1	1
Wireless_node_4	11.1.1.5	11.1.1.5	255.255.255.255	1	1

Run the simulation for 100 sec and tabulate the throughput

Numerical Results

The following data is used to generate the plot.

Generation Rate (Mbps)	IAT (μs)	Throughput (Mbps)
0.05	160000	0.050021
0.1	80000	0.100042
0.15	53333	0.149979
0.2	40000	0.2
0.25	32000	0.250021
0.3	26666	0.299958
0.35	22857	0.349979
0.4	20000	0.399916
0.45	17777	0.449937
0.5	16000	0.499958
0.51	15686	0.509979
0.52	15384	0.519916
0.53	15094	0.492968
0.54	14814	0.471832
0.55	14545	0.460042
0.56	14285	0.447326
0.57	14035	0.434863
0.58	13793	0.420126
0.59	13559	0.420968

0.6	13333	0.416337
0.65	12307	0.410189
0.7	11428	0.404379
0.75	10666	0.3952
0.8	10000	0.3872
0.85	9411	0.379453
0.9	8888	0.376168
0.95	8421	0.372968
1	8000	0.378442

Table 24:Numerical results for 4-Hop Network

Automated simulation using multi-parameter sweeper

1. Here we run the samples for the same example mentioned above using the multi parameter sweeper
2. We use a base (first) network configuration file with packet size as 1000 bytes and Inter arrival time as 160000 µs. This gives a traffic generation rate of 0.05 Mbps.
3. The Multi parameter has been configured to run the multiple scenarios (one after the other sequentially) with Inter-arrival times varying in the steps of 0.05 Mbps.

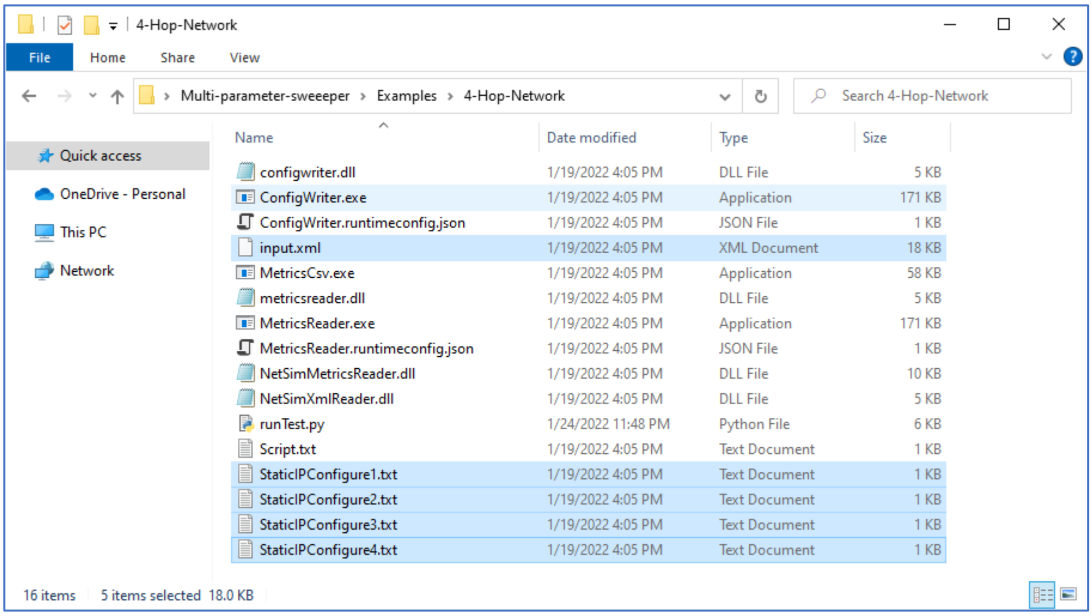


Fig 33:Multi Parameter sweeper folder consists of input.xml and several binaries

Changes done to the config file to run the Multi-Parameter sweeper

1. Users can skip this sub section if they only wish to run simulations. In this sub section we explain the changes done to run the sweeper. It would be beneficial to users who wish to run the sweeper for other scenarios.
2. The Configuration.netsim and Static Route Configuration text files are copied from the saved experiment folder to Multi-parameter sweeper folder. Configuration.netsim is renamed as input.xml
3. The value of Inter_Arrival_time has been modified during each simulation is updated to {0} in the Configuration.netsim as shown below

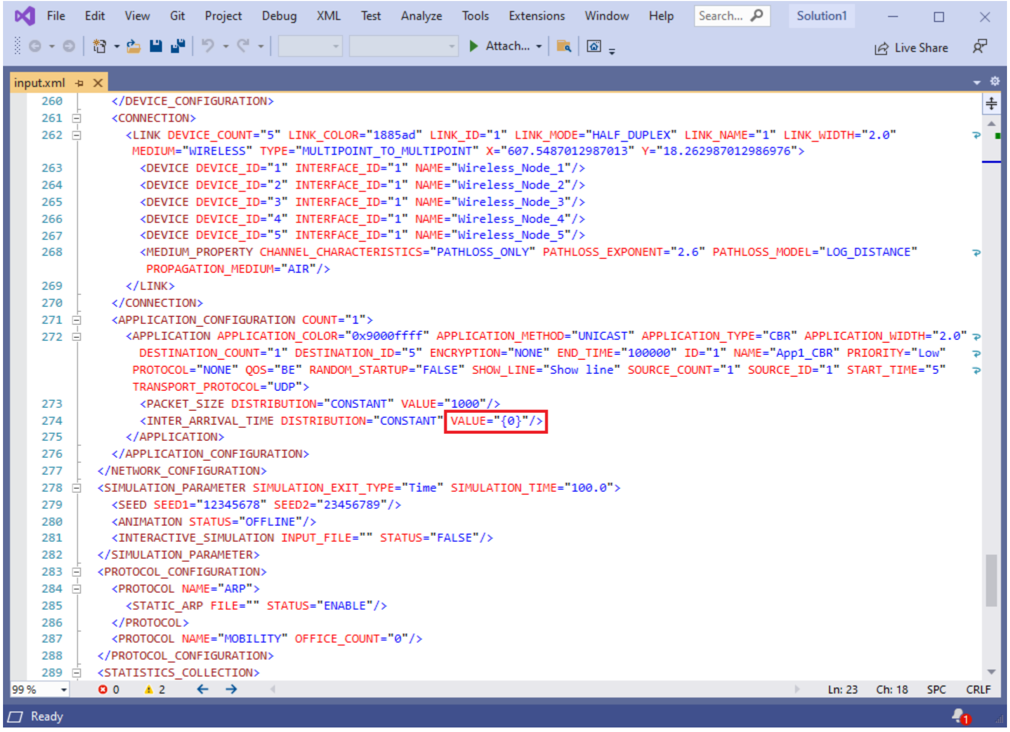


Fig 34: Modified Inter arrival time value in input.xml

4. The MP sweeper collates the results of the different simulation runs into a single XL file. How is this done? The Script.txt file (available in MP sweeper folder) is updated with the details of the output parameter to be read from the Metrics.xml file. After each run it is this output parameter's value that is added to the result csv log file.
5. In this example it the Application Throughput that we wish to log for each simulation run.
6. runTest.py is updated to (i) pass different inter-arrival values during each iteration (ii) generate configuration files (iii) run simulation and (iv) update the result csv log.

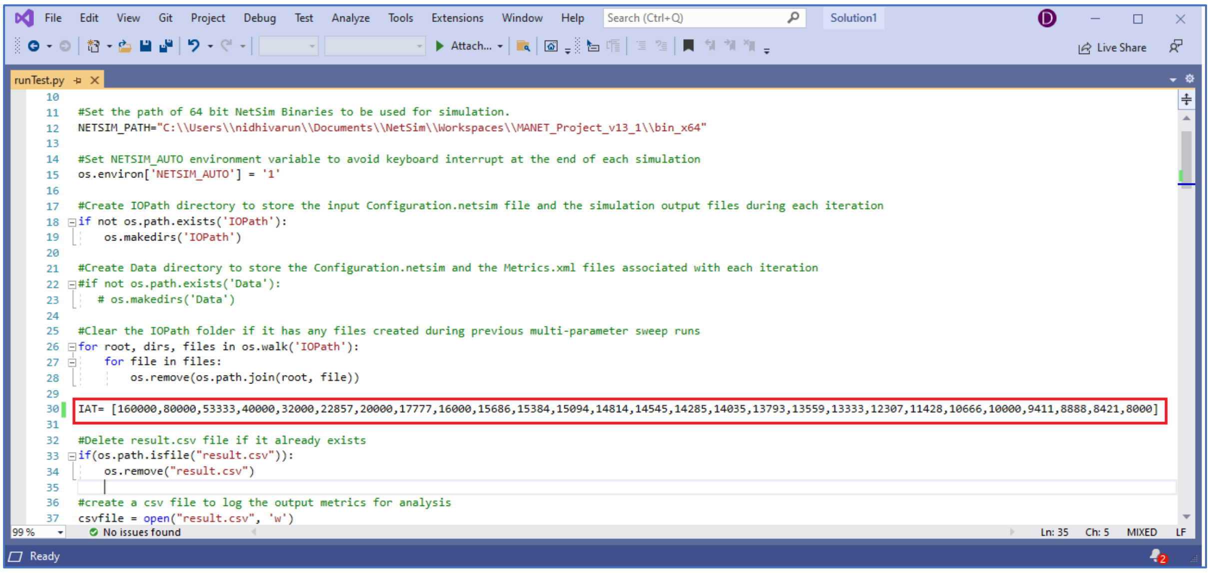


Fig 35: Varied Inter arrival time in runTest.py

7. NetSim_Path variable is set to the workspace directory and to this bin_x64 is appended. An example is shown in the screen shot below.

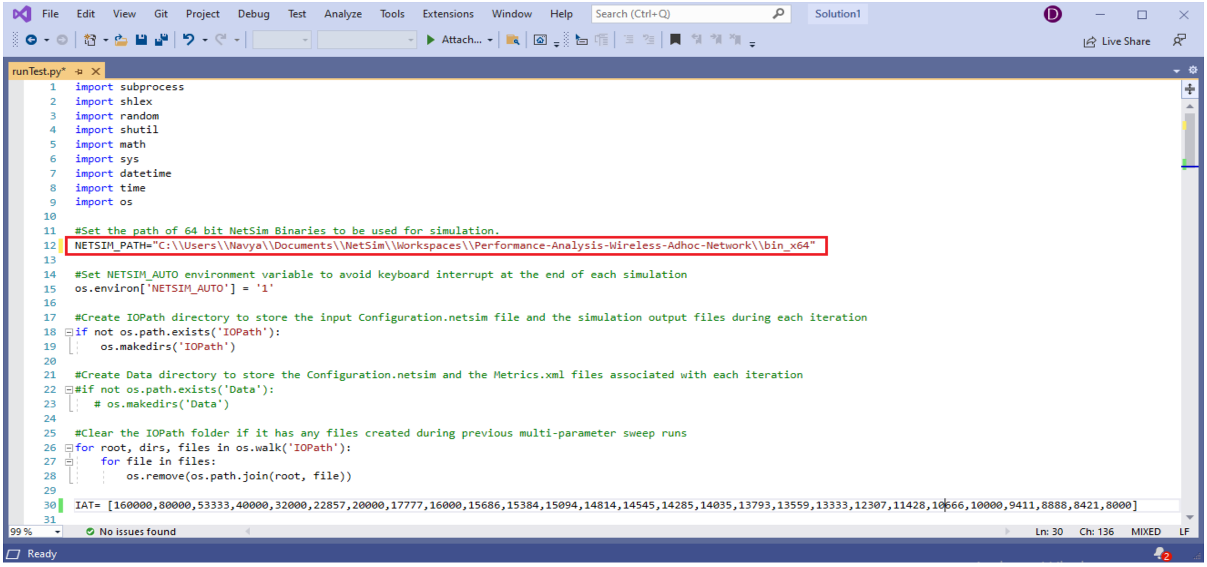


Fig 36: NetSim Path is set with x64 bit code modified workspace

8. Number of nodes used in Network scenario is given to copy the Static Route Configuration text files to IO path same as Configuration.netsim

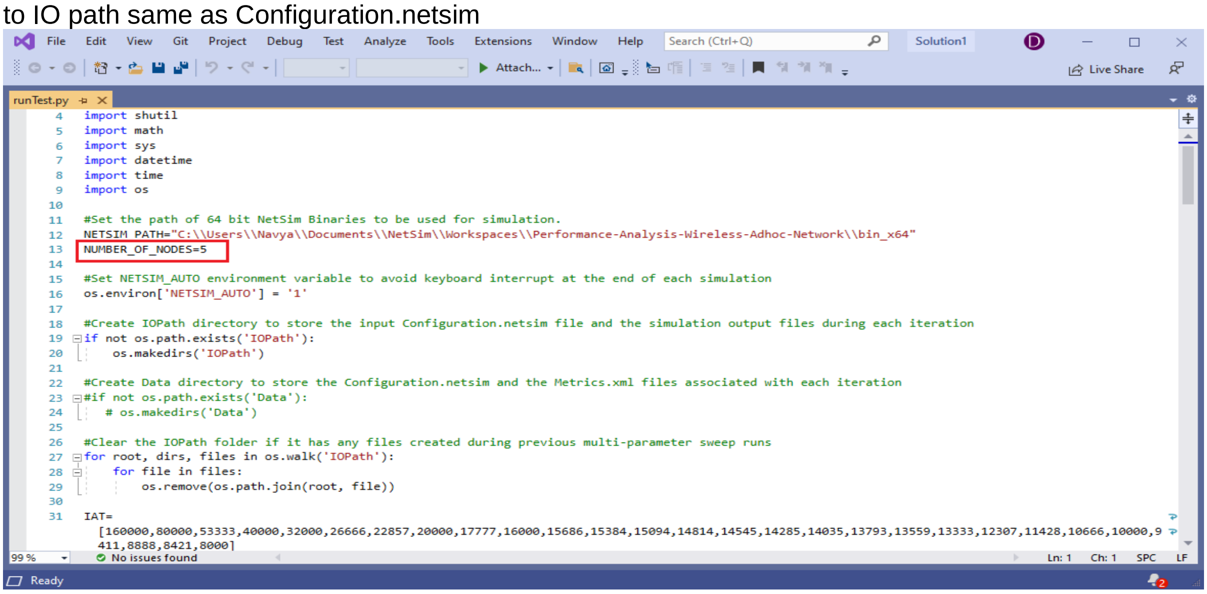


Fig 37:Number of nodes in scenario is given as input to copy the Static route configuration files to IO path

9. Modify the license Path in runTest.py file
   - If you are using server node locked or dongle based floating license cmd="start \"NetSim_Multi_Parameter_Sweeper\" /wait /min /d "+ "\""+NETSIM_PATH+ "\" "\ +"NetSimcore.exe -apppath \""+NETSIM_PATH+"\" -iopath \""+strIOPATH+\ "\" -license <Your Server IP Address>"
   - If you are using client node locked evaluation license or cloud license cmd="start \"NetSim_Multi_Parameter_Sweeper\" /wait /min /d "+ "\""+NETSIM_PATH+ "\" "\ +"NetSimcore.exe -apppath \""+NETSIM_PATH+"\" -iopath \""+strIOPATH+\"\ -license "+"\"<Your install directory>""

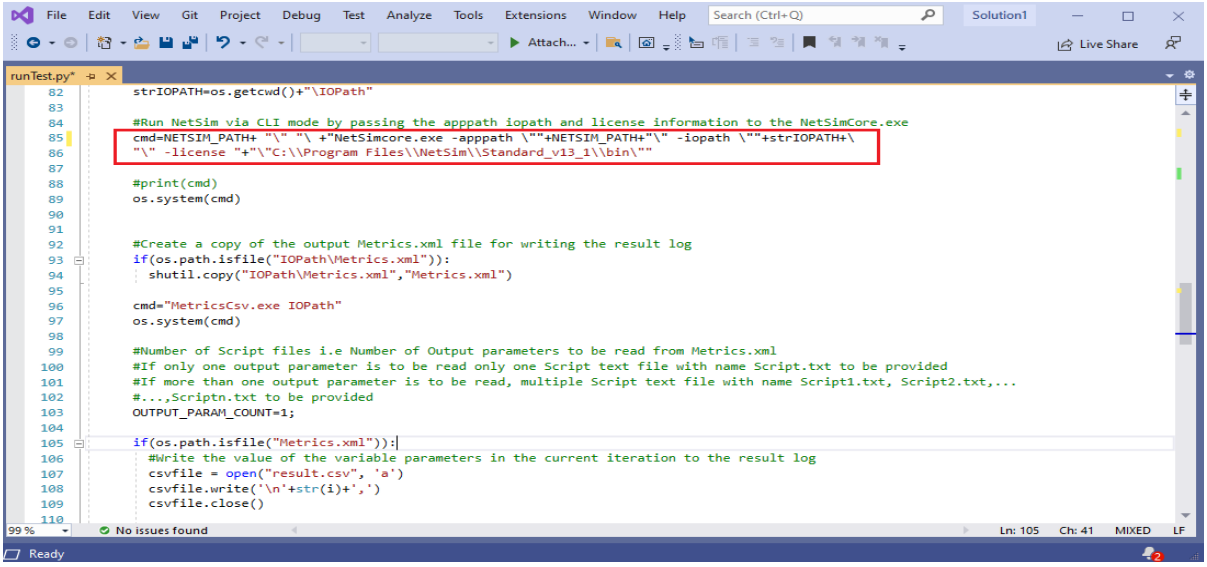


Fig 38: License path is set based on node locked evaluation license / cloud license/ server node locked/dongle based floating license

10. The sweeper process is started by opening command prompt in the directory of the Multi-Parameter-Sweeper project and starting the python script as shown below

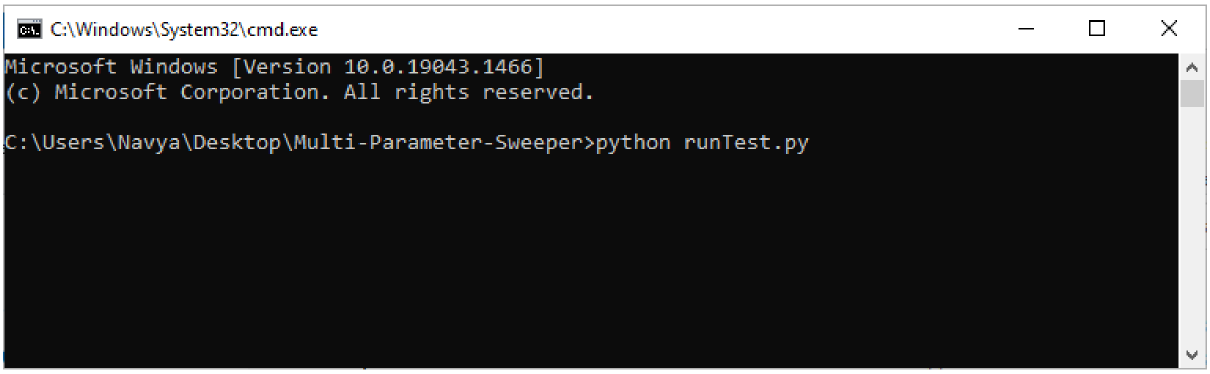


Fig 39: Running python script using cmd prompt

11. Then the Multi-Parameter-Sweeping process which runs NetSim simulations iteratively for different values of Inter Arrival time.

Results

Upon completing all the simulations, the Multi-Parameter-Sweeping folder will have the following file and folders created as shown below

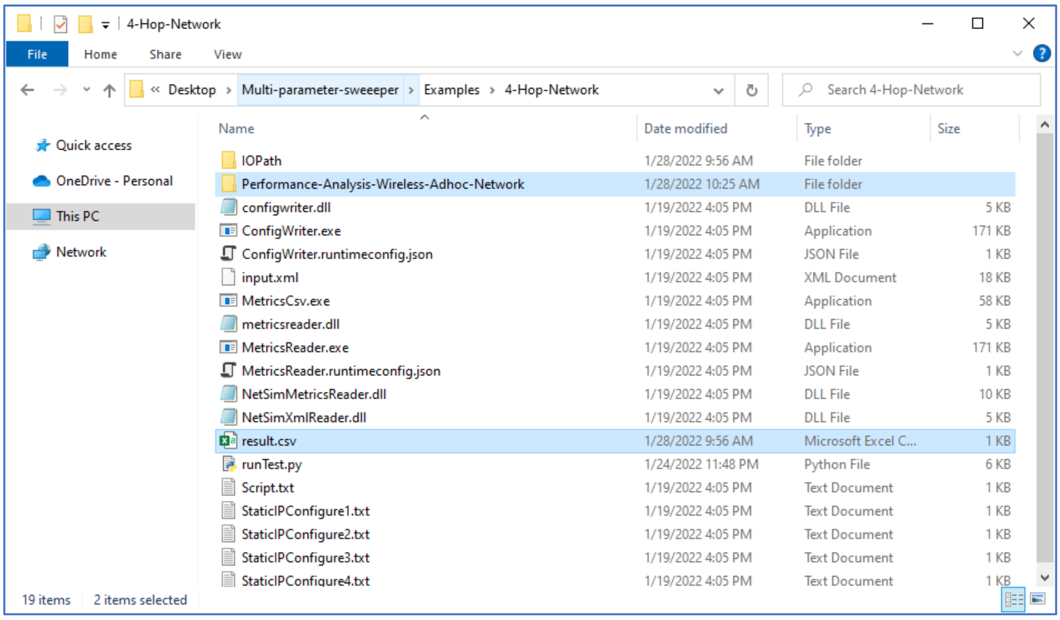


Fig 40: After Simulation Multi-Parameter-Sweeping folder contains output files like result.scv, Folders consists of related network cases

Performance-Analysis-Wireless-Adhoc-Network: Contains multiple folders corresponding to each simulation run. The file name has the value of the parameter used in that iteration

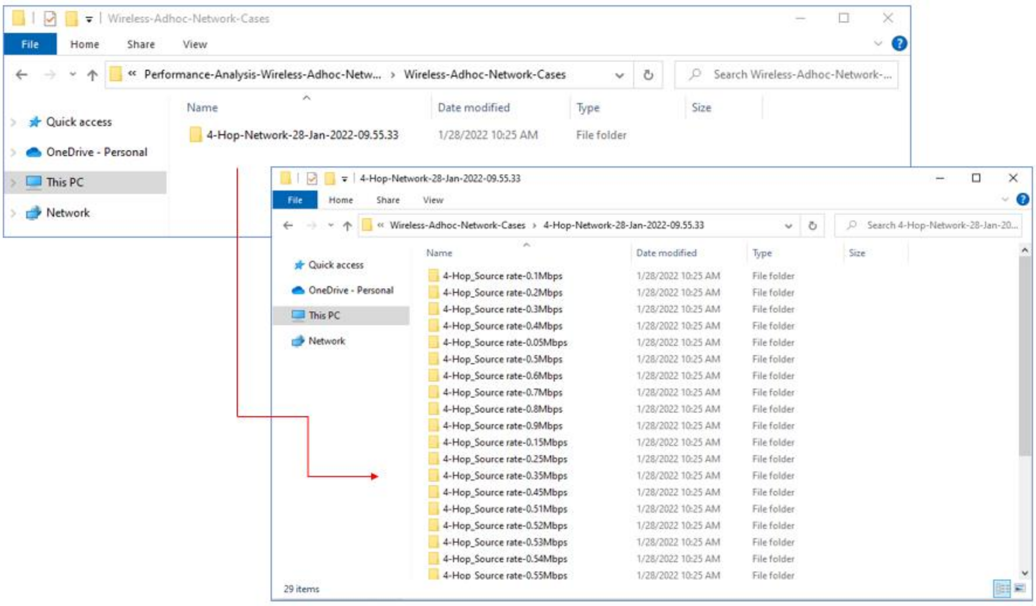
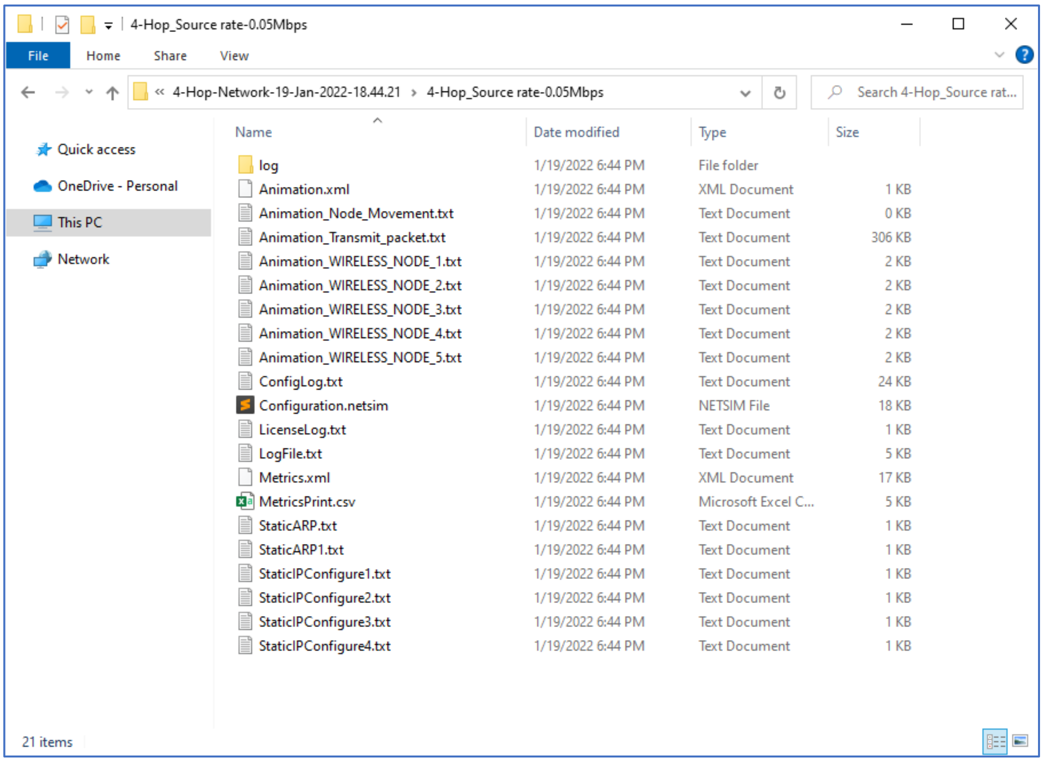


Fig 41:Based on Source rate/Different Inter arrival time Configuration files are created

Each folder contains the all the output files associated with each simulation run



4-Hop_Source rate-0.05Mbps

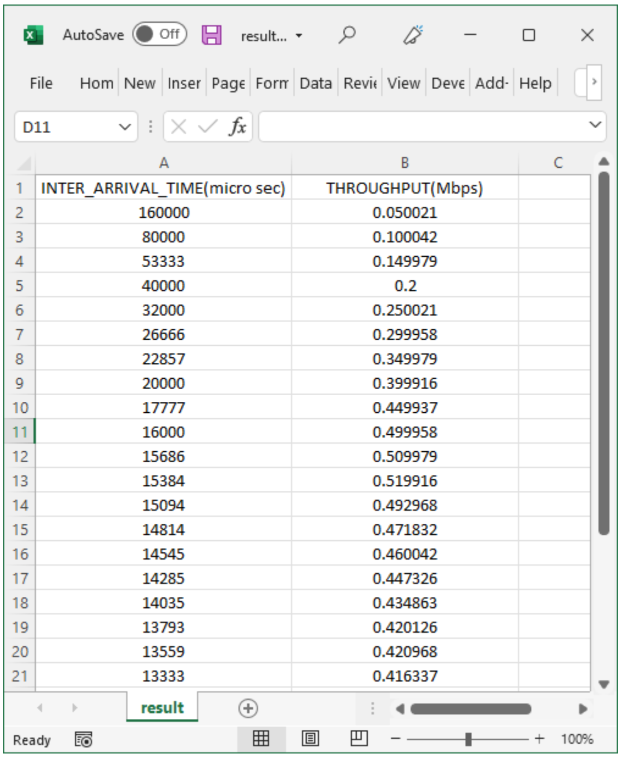
4-Hop-Network-19-Jan-2022-18.44.21 > 4-Hop_Source rate-0.05Mbps

Name	Date modified	Type	Size
log	1/19/2022 6:44 PM	File folder	
Animation.xml	1/19/2022 6:44 PM	XML Document	1 KB
Animation_Node_Movement.txt	1/19/2022 6:44 PM	Text Document	0 KB
Animation_Transmit_packet.txt	1/19/2022 6:44 PM	Text Document	306 KB
Animation_WIRELESS_NODE_1.txt	1/19/2022 6:44 PM	Text Document	2 KB
Animation_WIRELESS_NODE_2.txt	1/19/2022 6:44 PM	Text Document	2 KB
Animation_WIRELESS_NODE_3.txt	1/19/2022 6:44 PM	Text Document	2 KB
Animation_WIRELESS_NODE_4.txt	1/19/2022 6:44 PM	Text Document	2 KB
Animation_WIRELESS_NODE_5.txt	1/19/2022 6:44 PM	Text Document	2 KB
ConfigLog.txt	1/19/2022 6:44 PM	Text Document	24 KB
Configuration.netsim	1/19/2022 6:44 PM	NETSIM File	18 KB
LicenseLog.txt	1/19/2022 6:44 PM	Text Document	1 KB
LogFile.txt	1/19/2022 6:44 PM	Text Document	5 KB
Metrics.xml	1/19/2022 6:44 PM	XML Document	17 KB
MetricsPrint.csv	1/19/2022 6:44 PM	Microsoft Excel C...	5 KB
StaticARP.txt	1/19/2022 6:44 PM	Text Document	1 KB
StaticARP1.txt	1/19/2022 6:44 PM	Text Document	1 KB
StaticIPConfigure1.txt	1/19/2022 6:44 PM	Text Document	1 KB
StaticIPConfigure2.txt	1/19/2022 6:44 PM	Text Document	1 KB
StaticIPConfigure3.txt	1/19/2022 6:44 PM	Text Document	1 KB
StaticIPConfigure4.txt	1/19/2022 6:44 PM	Text Document	1 KB

21 items

Fig 42: Each folder contains the all the output files

Result.csv: This is the output log which contains the Inter Arrival time varied during each simulation run and the corresponding throughput after each run.



	A	B
1	INTER_ARRIVAL_TIME(micro sec)	THROUGHPUT(Mbps)
2	160000	0.050021
3	80000	0.100042
4	53333	0.149979
5	40000	0.2
6	32000	0.250021
7	26666	0.299958
8	22857	0.349979
9	20000	0.399916
10	17777	0.449937
11	16000	0.499958
12	15686	0.509979
13	15384	0.519916
14	15094	0.492968
15	14814	0.471832
16	14545	0.460042
17	14285	0.447326
18	14035	0.434863
19	13793	0.420126
20	13559	0.420968
21	13333	0.416337

Fig 43:Throughput (Mbps) obtained for different value of IAT in result.csv

Case 5: 5 Hop Network

1. In the imported workspace, go to 5-Hop Network folder to display the related 5-Hop cases.
2. This designed in NetSim's MANET library. It comprises of 6 Wireless nodes connected via an Adhoc link and the Application is created between Source ID Wireless_Node_1 and destination ID Wireless_Node_6.

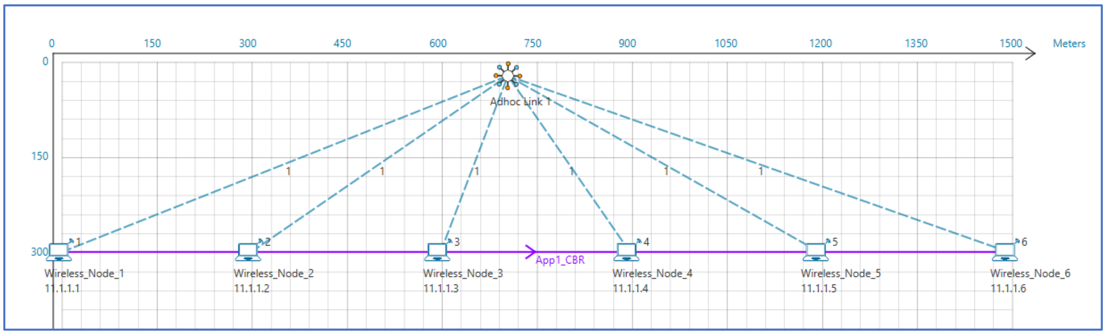


Fig 44: Network Scenario for 5-Hop Network designed with 6 wireless nodes

3. The Simulation parameters setting remains the same as previous case

Additional Setting

4. Grid length of 1500m × 1500m

Devices	X	Y
Wireless_Node_1	0	300
Wireless_Node_2	300	300
Wireless_Node_3	600	300
Wireless_Node_4	900	300
Wireless_Node_5	1200	300
Wireless_Node_6	1500	300

Table 25: X and Y Co- ordinates of devices for 5-Hop Network

5. Static route should be carefully configured to ensure the data flow from Wireless_Node_1>Wireless_Node_2> Wireless_Node_3> Wireless_Node_4> Wireless_Node_5> Wireless_Node_6

Numerical Results

The following data is used to generate the plot.

Generation Rate (Mbps)	IAT (µs)	Throughput (Mbps)
0.05	160000	0.050021
0.1	80000	0.100042
0.15	53333	0.149979
0.2	40000	0.2
0.25	32000	0.249937
0.3	26666	0.299958
0.35	22857	0.349979
0.4	20000	0.399916
0.45	17777	0.449937
0.5	16000	0.499874

0.51	15686	0.509895
0.52	15384	0.519916
0.53	15094	0.483705
0.54	14814	0.463411
0.55	14545	0.450442
0.56	14285	0.433179
0.57	14035	0.421305
0.58	13793	0.406063
0.59	13559	0.392084
0.6	13333	0.376168
0.65	12307	0.357811
0.7	11428	0.346779
0.75	10666	0.345684
0.8	10000	0.332379
0.85	9411	0.334905
0.9	8888	0.327663
0.95	8421	0.329937
1	8000	0.331705

Table 26: Numerical results for 5-Hop Network

Changes done to the config file to run the multi-Parameter sweeper

1. The Configuration file saved with above setting is replaced in the Multi parameter folder and Inter arrival time value mentioned as {0}
2. Number of nodes used in Network scenario is given to copy the Static Route Configuration text files to IO path same as Configuration.netsim

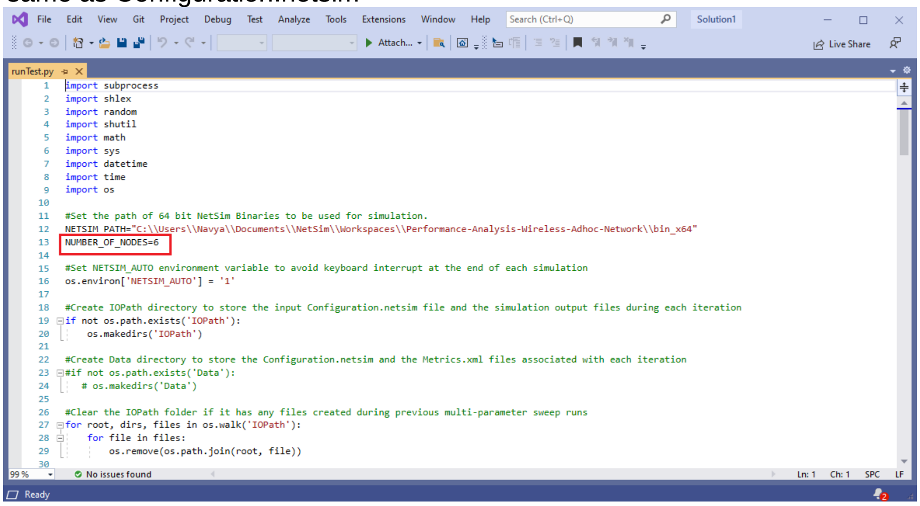


Fig 45: Number of nodes in scenario is given as input to copy the Static route configuration files to IO path

3. If the user wishes to change the output folder name, it can be renamed as 5-Hop as in shown in

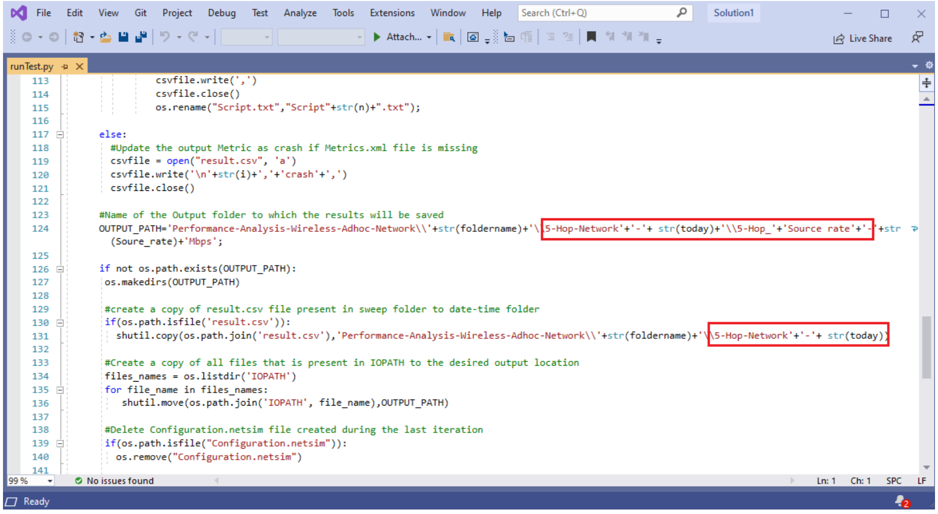
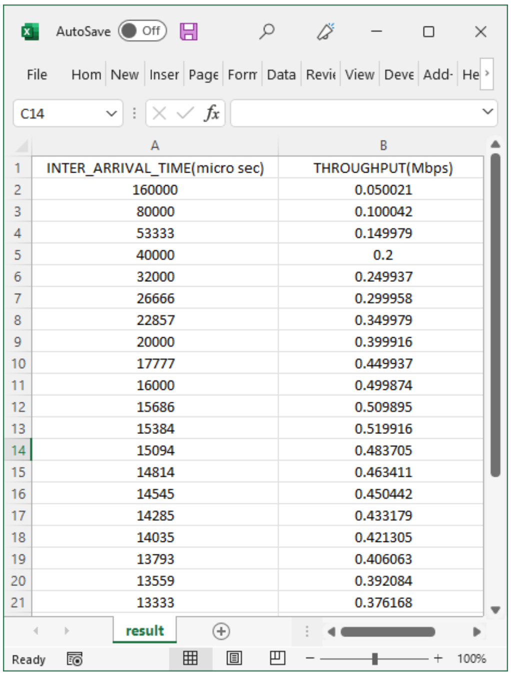


Fig 46:Renaming the output folder by Number of Hops

4. The sweeper process is started by opening command prompt in the directory of the Multi-Parameter-Sweeper project.
5. Then the Multi-Parameter-Sweeping process which runs NetSim simulations iteratively for different values of Inter Arrival time and provides the results in results.csv file as shown in below



	A	B
1	INTER_ARRIVAL_TIME(micro sec)	THROUGHPUT(Mbps)
2	160000	0.050021
3	80000	0.100042
4	53333	0.149979
5	40000	0.2
6	32000	0.249937
7	26666	0.299958
8	22857	0.349979
9	20000	0.399916
10	17777	0.449937
11	16000	0.499874
12	15686	0.509895
13	15384	0.519916
14	15094	0.483705
15	14814	0.463411
16	14545	0.450442
17	14285	0.433179
18	14035	0.421305
19	13793	0.406063
20	13559	0.392084
21	13333	0.376168

Fig 47: 5-Hop Network results

Case 06: 6- Hop Network

1. In the imported workspace, go to 6-Hop Network folder to display the related 6-Hop cases.
2. This designed in NetSim's MANET library. It comprises of 7 Wireless nodes connected via an Adhoc link and the Application is created between Source ID Wireless_Node_1 and destination ID Wireless_Node_7.

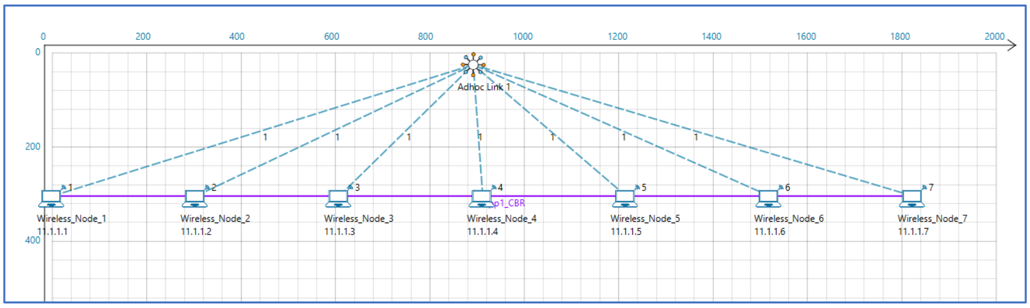


Fig 48: Network Scenario for 6-Hop Network designed with 7 wireless nodes

3. The Simulation parameters setting remains the same as previous case

Additional Setting

4. Grid length is 2000m × 2000m, Place the devices 300m apart from one another.

Devices	X	Y
Wireless_Node_1	0	300
Wireless_Node_2	300	300
Wireless_Node_3	600	300
Wireless_Node_4	900	300
Wireless_Node_5	1200	300
Wireless_Node_6	1500	300
Wireless_Node_7	1800	300

Table 27: X and Y Co- ordinates of devices for 6-Hop Network

5. Static route should be carefully configured to ensure the data flow from Wireless_Node_1>Wireless_Node_2>Wireless_Node_3> Wireless_Node_4> Wireless_Node_5> Wireless_Node_6>Wireless_Node_7.
6. Run the simulation for 100 sec and tabulate the throughput.

Numerical Results

The following data is used to generate the plot.

Generation Rate (Mbps)	IAT (μs)	Throughput (Mbps)
0.05	160000	0.050021
0.1	80000	0.100042
0.15	53333	0.149979
0.2	40000	0.2
0.25	32000	0.249937
0.3	26666	0.299958
0.35	22857	0.349895
0.4	20000	0.399916
0.45	17777	0.449937
0.5	16000	0.499874
0.51	15686	0.453642
0.52	15384	0.438232
0.53	15094	0.426442
0.54	14814	0.415579

0.55	14545	0.407411
0.56	14285	0.393347
0.57	14035	0.383242
0.58	13793	0.366905
0.59	13559	0.354442
0.6	13333	0.340884
0.65	12307	0.336926
0.7	11428	0.332884
0.75	10666	0.320084
0.8	10000	0.310063
0.85	9411	0.312084
0.9	8888	0.309389
0.95	8421	0.308716
1	8000	0.310484

Table 28: Numerical results for 6-Hop Network

Changes done to the config file to run the multi-Parameter sweeper

1. The Configuration file saved with above setting is replaced in the Multi parameter folder and Inter arrival time value mentioned as {0}
2. Number of nodes used in Network scenario is given to copy the Static Route Configuration text files to IO path same as Configuration.netsim

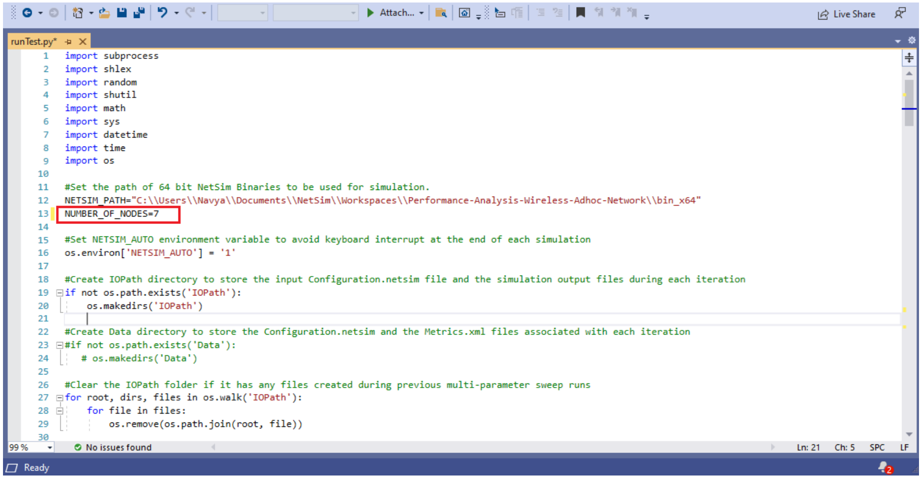


Fig 49: Number of nodes in scenario is given as input to copy the Static route configuration files to IO path

3. If the user wishes to change the output folder name, it can be renamed as 6-Hop.

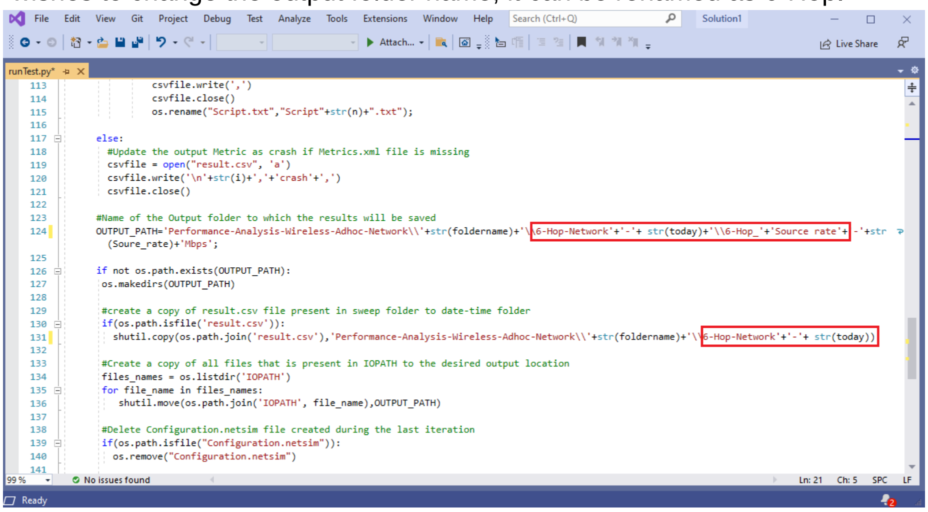
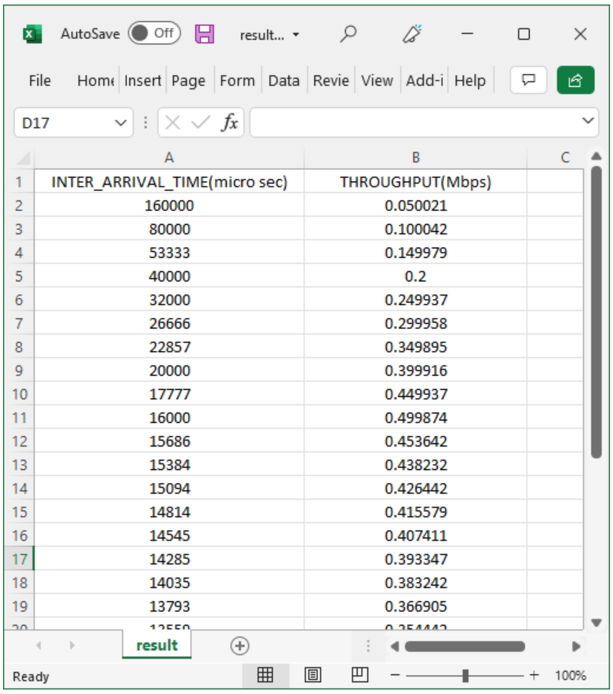


Fig 50:Renaming the Output folder by Number of Hop count

4. The sweeper process is started by opening command prompt in the directory of the Multi-Parameter-Sweeper project.
5. Then the Multi-Parameter-Sweeping process which runs NetSim simulations iteratively for different values of Inter Arrival time and provides the results in results.csv file as shown in below



	INTER_ARRIVAL_TIME(micro sec)	THROUGHPUT(Mbps)
1	INTER_ARRIVAL_TIME(micro sec)	THROUGHPUT(Mbps)
2	160000	0.050021
3	80000	0.100042
4	53333	0.149979
5	40000	0.2
6	32000	0.249937
7	26666	0.299958
8	22857	0.349895
9	20000	0.399916
10	17777	0.449937
11	16000	0.499874
12	15686	0.453642
13	15384	0.438232
14	15094	0.426442
15	14814	0.415579
16	14545	0.407411
17	14285	0.393347
18	14035	0.383242
19	13793	0.366905

Fig 51: 6-Hop Network results

Case 07: 7-Hop Network

1. In the imported workspace, go to 7-Hop Network folder to display the related 7-Hop cases.
2. This designed in NetSim's MANET library. It comprises of 8 Wireless nodes connected via an Adhoc link and the Application is created between Source ID Wireless_Node_1 and destination ID Wireless_Node_8.

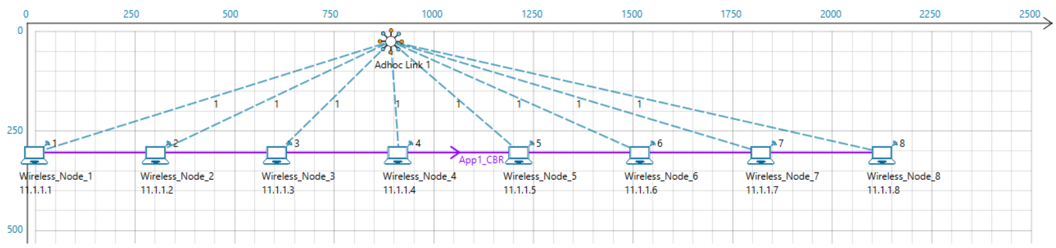


Fig 52: Network Scenario for 7-Hop Network designed with 8 wireless nodes

3. The Simulation parameters setting remains the same as previous case

Additional Setting

4. Grid length 2500m ×2500m

Devices	X	Y
Wireless_Node_1	0	300
Wireless_Node_2	300	300
Wireless_Node_3	600	300

Wireless_Node_4	900	300
Wireless_Node_5	1200	300
Wireless_Node_6	1500	300
Wireless_Node_7	1800	300
Wireless_Node_8	2100	300

Table 29: X and Y Co- ordinates of devices for 7-Hop Network

5. Static route should be carefully configured to ensure the data flow from Wireless_Node_1>Wireless_Node_2>Wireless_Node_3> Wireless_Node_4> Wireless_Node_5> Wireless_Node_6>Wireless_Node_7>Wireless_Node_8
6. Dot11_RTS Threshold value is changed to 750 bytes in all wireless nodes.
7. Run the simulation for 100 sec and tabulate the throughput.

Numerical Results

The following data is used to generate the plot.

Generation Rate (Mbps)	IAT (µs)	Throughput (Mbps)
0.05	160000	0.050021
0.1	80000	0.100042
0.15	53333	0.149979
0.2	40000	0.2
0.25	32000	0.250189
0.3	26666	0.300042
0.35	22857	0.327074
0.4	20000	0.313432
0.45	17777	0.310989
0.5	16000	0.274611
0.51	15686	0.265768
0.52	15384	0.255411
0.53	15094	0.244632
0.54	14814	0.244042
0.55	14545	0.244126
0.56	14285	0.235368
0.57	14035	0.235621
0.58	13793	0.235705
0.59	13559	0.236716
0.6	13333	0.226947
0.65	12307	0.217768
0.7	11428	0.221558
0.75	10666	0.227958
0.8	10000	0.215832
0.85	9411	0.2224
0.9	8888	0.223495
0.95	8421	0.234442
1	8000	0.220042

Table 30: Numerical results for 7-Hop Network

Changes done to the config file to run the multi-Parameter sweeper

1. The Configuration file saved with above setting is replaced in the Multi parameter folder and Inter arrival time value mentioned as {0}
2. Number of nodes used in Network scenario is given to copy the Static Route Configuration text files to IO path same as Configuration.netsim

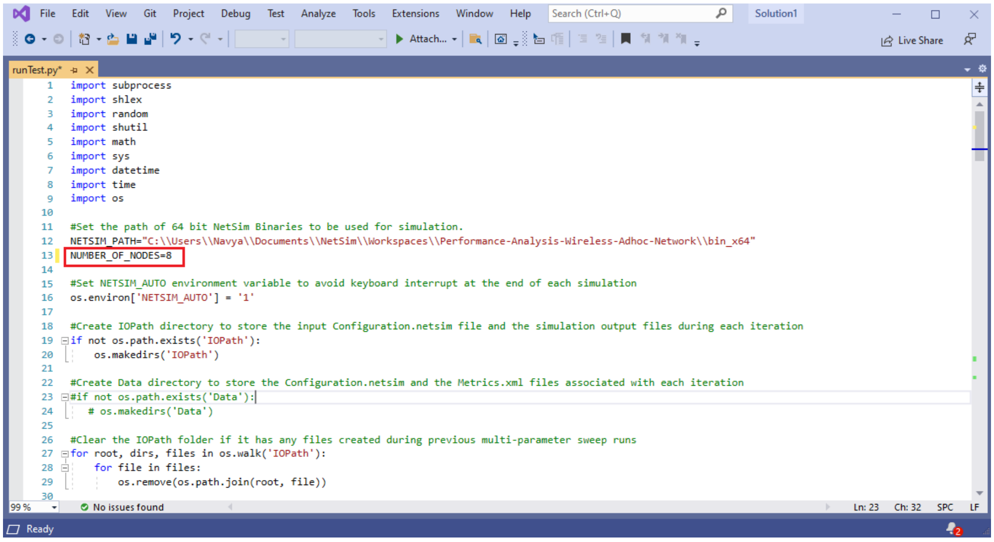


Fig 53: Number of nodes in scenario is given as input to copy the Static route configuration files to IO path

3. If the user wishes to change the output folder name, it can be renamed as 7-Hop.

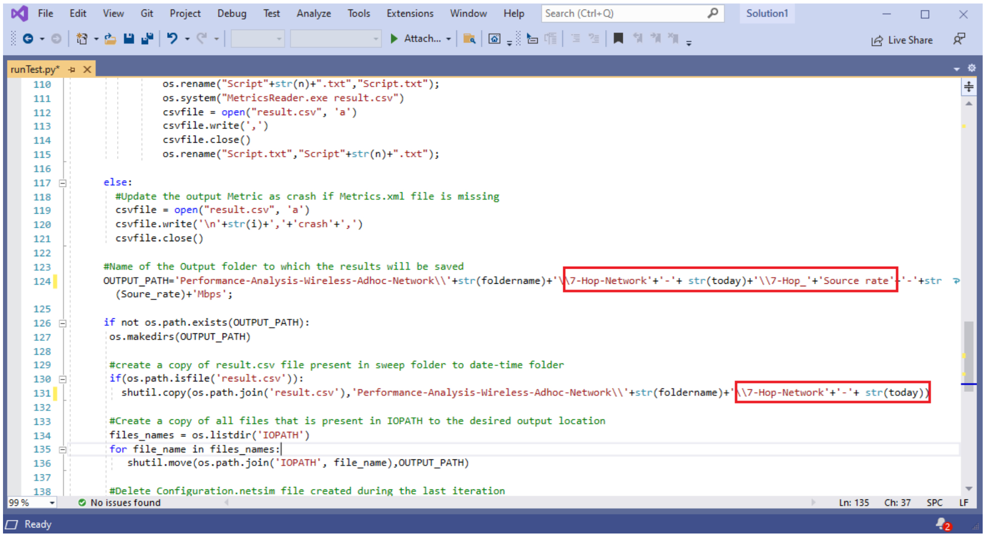
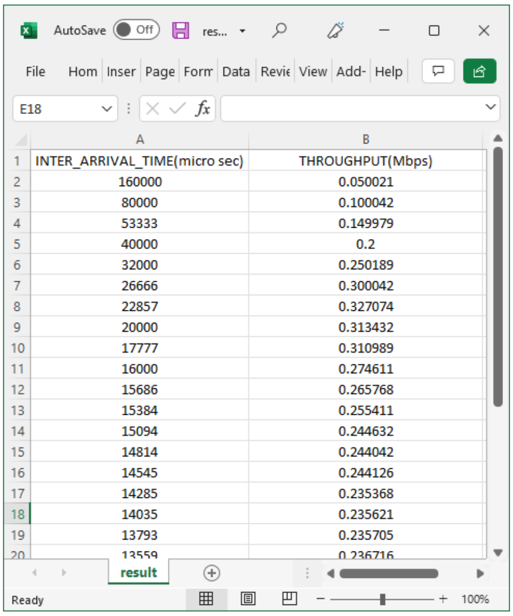


Fig 54: Renaming the output folder by Number of Hop count

4. The sweeper process is started by opening command prompt in the directory of the Multi-Parameter-Sweeper project.
5. Then the Multi-Parameter-Sweeping process which runs NetSim simulations iteratively for different values of Inter Arrival time and provides the results in results.csv file as shown in below



	A	B
1	INTER_ARRIVAL_TIME(micro sec)	THROUGHPUT(Mbps)
2	160000	0.050021
3	80000	0.100042
4	53333	0.149979
5	40000	0.2
6	32000	0.250189
7	26666	0.300042
8	22857	0.327074
9	20000	0.313432
10	17777	0.310989
11	16000	0.274611
12	15686	0.265768
13	15384	0.255411
14	15094	0.244632
15	14814	0.244042
16	14545	0.244126
17	14285	0.235368
18	14035	0.235621
19	13793	0.235705
20	13559	0.236716

Fig 55: 7-Hop network results

Appendix

Source code modifications involving in Case 1, Case 2, Case 3.

The workspace was modified with the following code changes:

1. The **CSRANGEDIFF** variable was set to -8 dB in the IEEE802_11_Phy.h file present in the IEEE802_11 project.
2. The following lines of code were commented in the IEEE802_11.h file present in the IEEE802_11 project.
   #define _RECALCULATE_RX_SENSITIVITY_BASED_ON_PEP_

To modify the source code, the steps given below are to be followed:

1. Open NetSim source codes via Your Work > Source Code > Open Code option

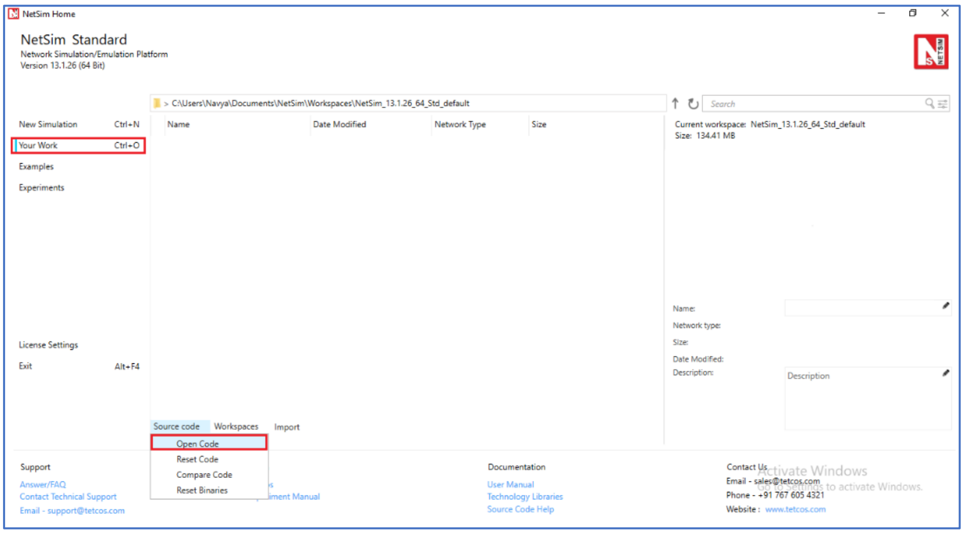


Fig 56: NetSim Open Code option

2. This will open the NetSim Source codes in Visual Studio as shown below:

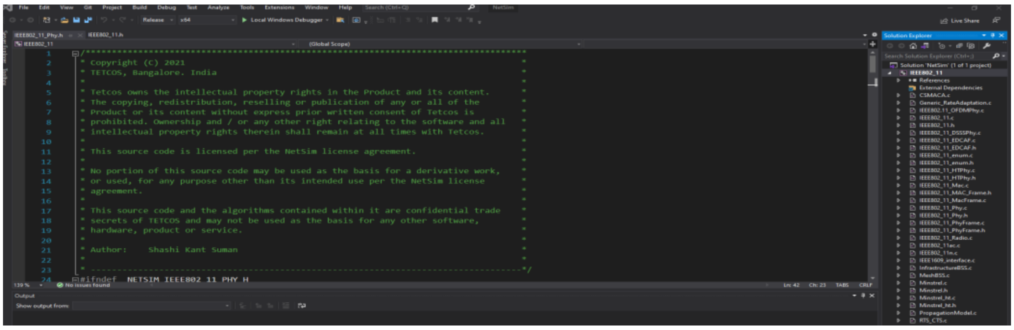


Fig 57: NetSim source codes in Visual Studio

3. Go to IEEE802_11_Phy.h file in the IEEE802_11 project. In the line #42, the CSRANGEDIFF was set to -8 dB.

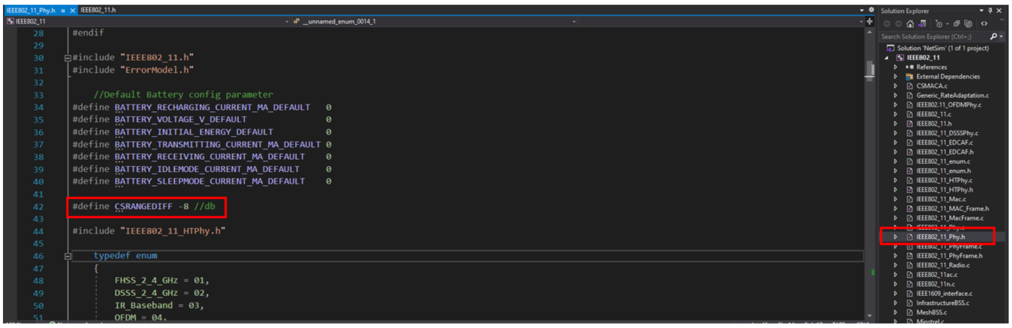


Fig 58: Code modification done in IEEE802_11_Phy.h file

4. Go to IEEE802_11.h file in the IEEE802_11 project and comment the line #38 as shown below

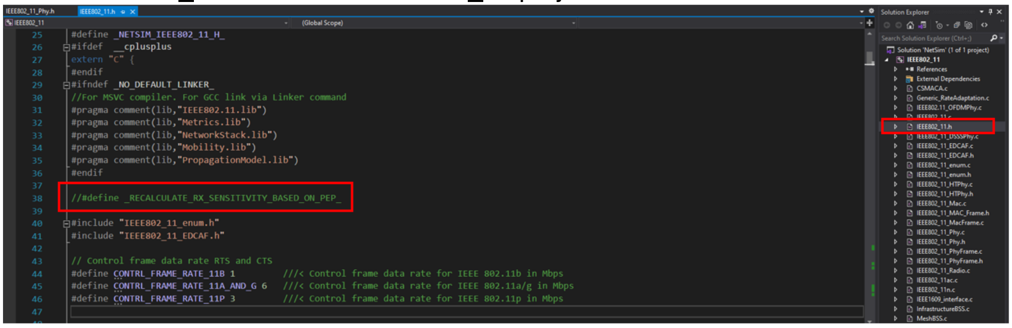


Fig 59: Code modification done in IEEE802_11.h file

5. Right click on the IEEE802_11 project in the solution Explorer and click on Rebuild.

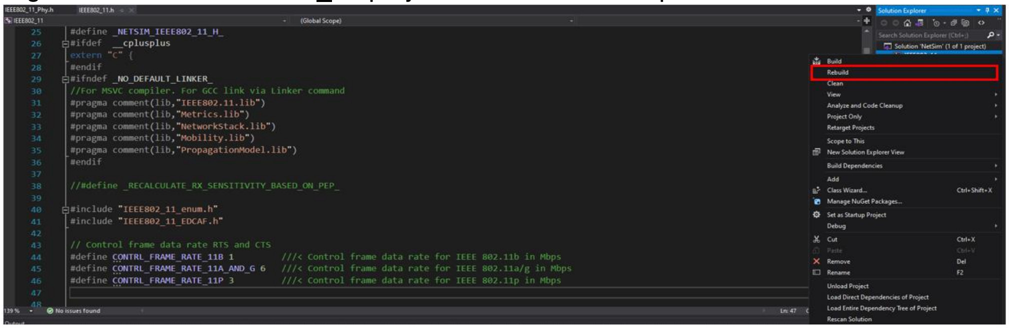


Fig 60: Rebuild code option

6. Upon a successful build, the dll in the binaries folder of the current workspace will automatically get updated.

Source code modifications involving in Case 4, Case 5, Case 6, Case 7

The workspace was modified with the following code changes:

1. The **CSRANGEDIFF** variable was set to -3 dB in the IEEE802_11_Phy.h file present in the IEEE802_11 project.
2. The following lines of code were commented in the IEEE802_11.h file present in the IEEE802_11 project.
#Define_RECALCULATE_RX_SENSITIVITY_BASED_ON_PEP_

To modify the source code, the steps given below are to be followed:

1. Open NetSim source codes via Your Work > Source Code > Open Code option

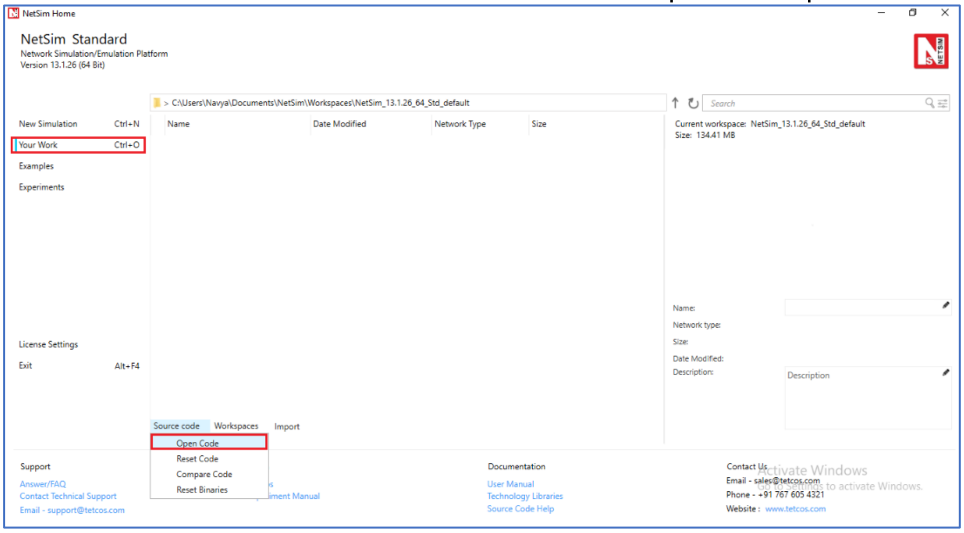


Fig 61: NetSim Open Code option

2. This will open the NetSim Source codes in Visual Studio as shown below:

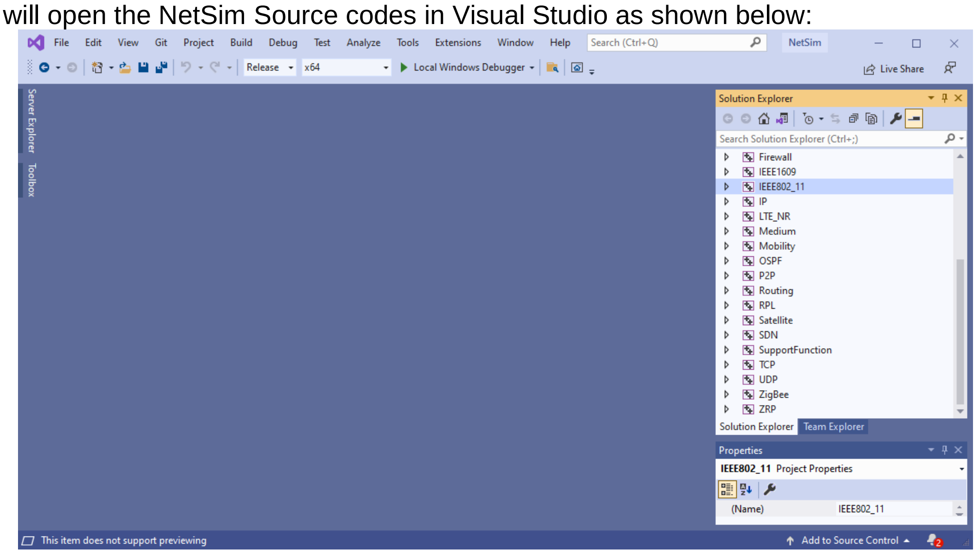


Fig 62: NetSim Source code in Visual Studios

3. Go to IEEE802_11_Phy.h file inside the IEEE802_11 project. Modifythe CSRANGEDIFF to -3 dB in line #42.

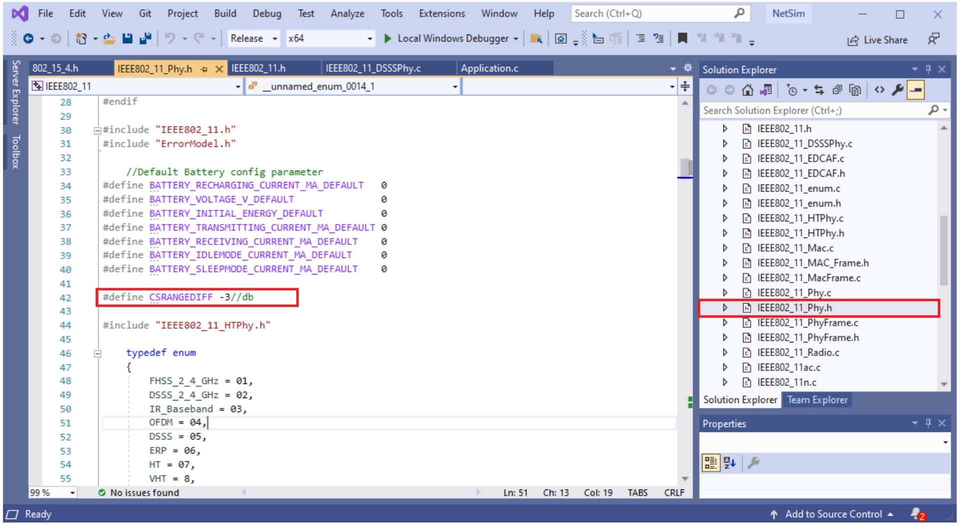


Fig 63: Code modification done in IEEE802_11_Phy.h file

4. Go to IEEE802_11.h file in the IEEE802_11 project and comment the line #38 as shown below

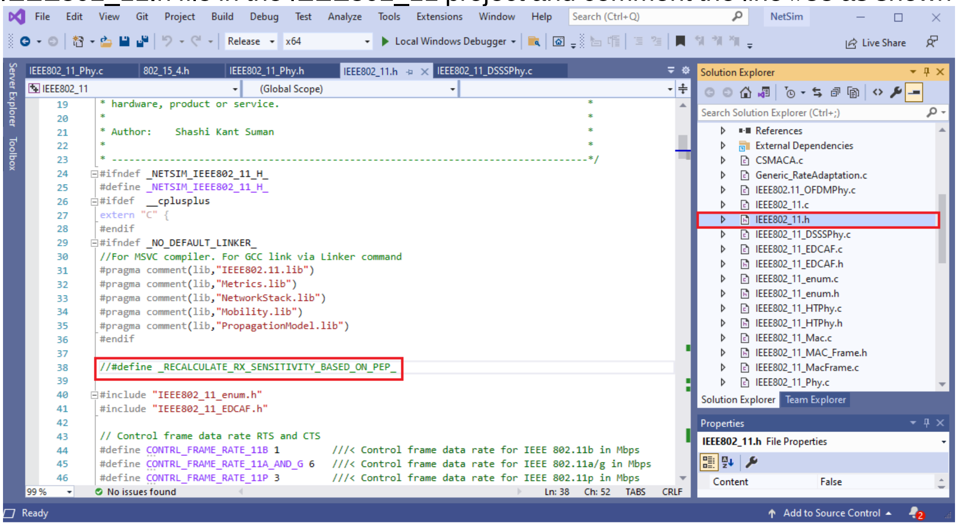


Fig 64: Code modification done in IEEE802_11.h file

5. In IEEE802_11_DSSSPhy.c, Receiver sensitivity is set to -87 dBm for 2Mbps in line#44

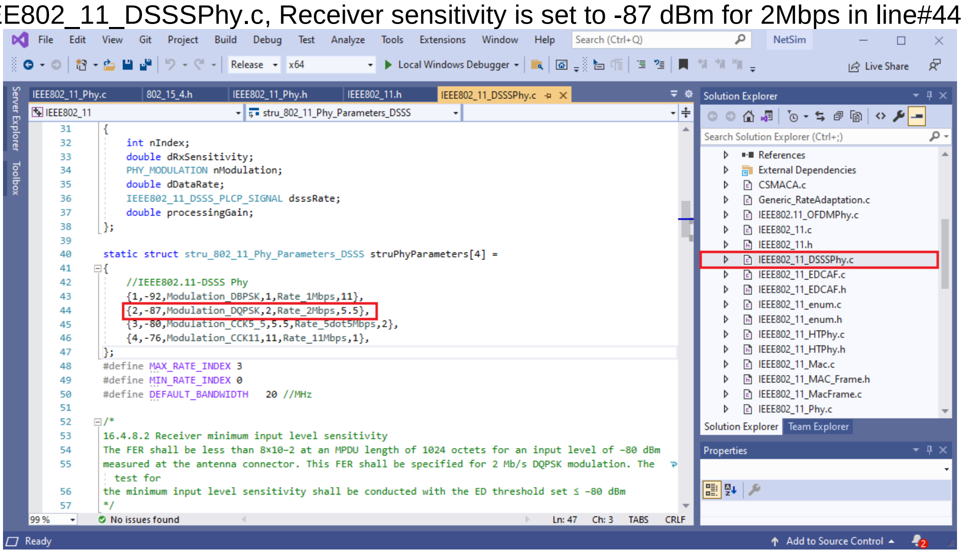


Fig 65: Code modification done in IEEE802_11_DSSSPhy.c file

6. Right click on the IEEE802_11 project in the solution Explorer and click on Rebuild

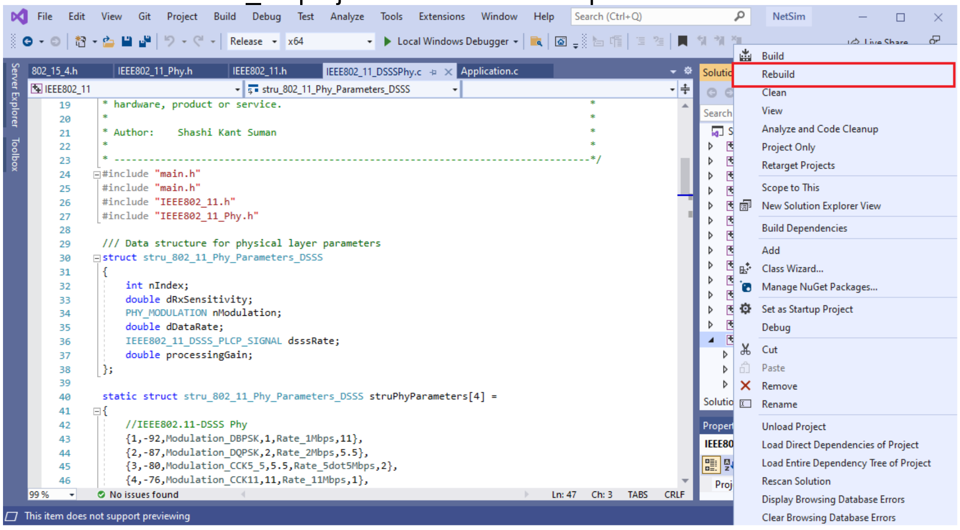


Fig 66: Rebuild 802.11project

7. Upon a successful build, the dll in the binaries folder of the current workspace will automatically get updated.