

NetSim[®]

Accelerate Network R & D

Software Defined Networks

A Network Simulation & Emulation Software

By



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1 About SDN

The salient features of SDN are:

- Directly programmable: SDN decouples the network control and forwarding functions. SDN allows programming the network control plane by abstracting the physical infrastructure.
- Agile: Decoupling and abstracting network control from forwarding helps administrators dynamically adjust network-wide traffic flow to meet the changing needs in the networks.
- Centrally managed: Network intelligence is centralized (logically) in software based SDN controllers that maintain a global view of the network, which appear to applications and policy engines as a single, logical switch.
- Programmatically configured: SDN lets network managers configure, manage, secure, and optimize network resources very quickly via dynamic, automated SDN programs, which they can write easily and quickly, because the programs do not depend on proprietary software.
- Open standards-based and vendor-neutral: Because SDN is implemented through open standards, SDN simplifies network design and operation because instructions are provided by SDN controllers instead of multiple, vendor-specific devices and protocols.

2 SDN in NetSim

SDN is available in NetSim from version 11 onwards. NetSim ‘simulates’ OpenFlow protocol. OpenFlow is an open interface to remotely control the forwarding tables in network switches, routers, etc.

2.1 SDN Controller in NetSim

An SDN controller is an application in SDN that manages flow control to enable intelligent networking. SDN controller can be used to control the packet forwarding of all Layer 3 devices in the network.

SDN controller lies between the network devices and the applications. Any communication between applications and devices must go through the controller.

NetSim has inbuilt controllers that ‘simulate’ SDN. An SDN controller in NetSim contains a Command Line Interface (CLI) to allow you to configure properties, such as, the IP forwarding table for different devices in the network.

NetSim also provides a platform whereby users can develop various kind of commands/interface compatible to any SDN enabled device.

In NetSim, any Layer 3 device can be configured as an SDN Controller. Multiple controllers can be configured in a network scenario. The following is a list of Layer 3 devices you can configure as an SDN controller:

- Internetworks – Nodes (Wired, Wireless Node), Routers
- MANETs – Nodes (Wired, Wireless Node), Bridge Node (Wired, Wireless Node), Routers
- WSN - Sensors and Sink Node
- IOT - Sensors and Gateway (LowPAN Gateway), Nodes (Wired, Wireless Node), Routers
- Cognitive Radio – CR CPE, Nodes (Wired, Wireless Node), Routers
- LTE – UE, EPC, Nodes (Wired, Wireless Node), Routers
- VANETs – Vehicle and RSU
- 5G mmWave – UE, Nodes (Wired, Wireless Node), Routers

NOTE: NetSim ‘simulates’ SDN protocol and cannot connect to real controllers such as Open Daylight.

2.2 CLI Commands for SDN in NetSim

You can use the following commands when you simulate SDN in NetSim:

- Simulation-specific – Pause, PauseAt, Continue, Stop, Exit, and Reconnect.
- Route – route add, route print, and route delete.
- Ping Command – ping (not supported on some network types, for example, Wireless Sensor Network)
- ACL configuration – ACL Enable, ACL Disable, ACL Print, and aclconfig.

Notes: CLI commands in NetSim are NOT case-sensitive. To get detailed help about how to use CLI commands in NetSim, see Section 3.14 NetSim Interactive Simulation in User Manual.

2.3 Configuring SDN in NetSim

SDN protocol parameters can be accessed and configured from the Application layer properties of the devices.

- Open-flow protocol must be enabled in the devices which are configured as SDN Controller or SDN clients.
- SDN Controller device must have the SDN Controller option set to True.
- SDN Client devices must have the SDN Controller option set to False along with the Controller Device Name set as the SDN Controller Device Name.
- Interactive Simulation option needs to be set to True in the Run time interaction tab.

When SDN commands are executed during runtime either via console or via file input, commands and response are exchanged between the controller and clients using TCP.

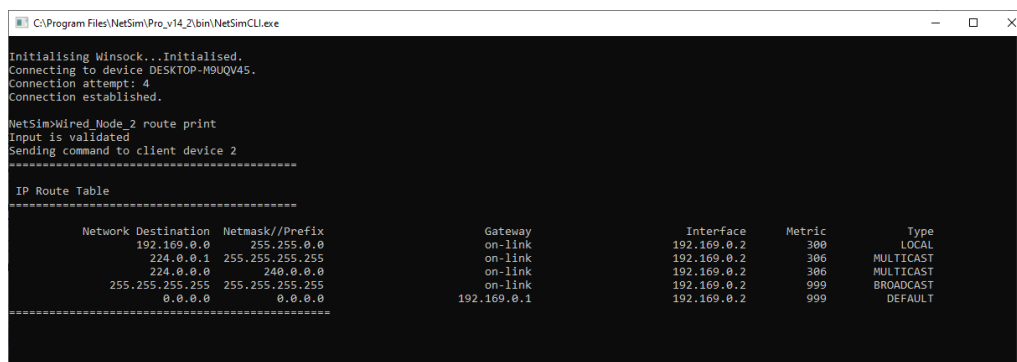
2.4 How to use CLI Commands for SDN

Each device in NetSim has a console which can be accessed by right clicking on the device. Users can execute supported SDN commands on the console of the SDN controller node to configure other nodes in the network. Let us look at a few examples.

Example 1: To view the IP routing table of a node that is controlled by the SDN controller, use the following command syntax: <DeviceName with Device ID> route print.

- For example, type `Wired_Node_2 route print` and press Enter.

The following image illustrates the output for the command.



```

C:\Program Files\NetSim\Pro_v14_2\bin\NetSimCLI.exe
Initialising Winsock...Initialised.
Connecting to device DESKTOP-H9UQV45.
Connection attempt: 4
Connection established.

NetSim>Wired_Node_2 route print
Input is validated
Sending command to client device 2
-----
IP Route Table
-----
Network Destination  Netmask/Prefix      Gateway      Interface      Metric      Type
-----
192.169.0.0          255.255.0.0        on-link     192.169.0.2    300        LOCAL
224.0.0.1           255.255.255.255   on-link     192.169.0.2    306        MULTICAST
224.0.0.0            240.0.0.0         on-link     192.169.0.2    306        MULTICAST
255.255.255.255     255.255.255.255   on-link     192.169.0.2    999        BROADCAST
0.0.0.0              0.0.0.0            192.169.0.1 192.169.0.2    999        DEFAULT
-----

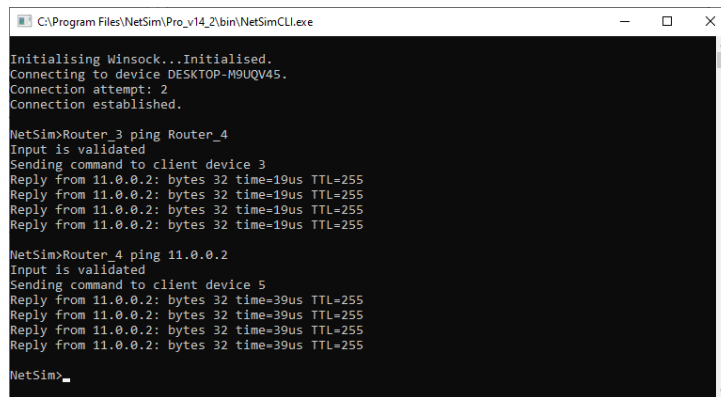
```

Figure 2-1: Printing IP routing table in Console

Example 2: To initiate ping from one node to another node where both nodes are controlled by the SDN controller, following command can be executed in the SDN controller:

```
<DeviceName with Device ID> Ping <DeviceName with Device ID> or <DeviceName with Device ID> Ping <IP Address>.
```

- For example, type Router 3 ping Router 4 or Router 4 ping 11.0.0.2 and press Enter.



```

C:\Program Files\NetSim\Pro_v14_2\bin\NetSimCLI.exe
Initialising Winsock...Initialised.
Connecting to device DESKTOP-M9UQV45.
Connection attempt: 2
Connection established.

NetSim>Router_3 ping Router_4
Input is validated
Sending command to client device 3
Reply from 11.0.0.2: bytes 32 time=19us TTL=255
Reply from 11.0.0.2: bytes 32 time=19us TTL=255
Reply from 11.0.0.2: bytes 32 time=19us TTL=255
Reply from 11.0.0.2: bytes 32 time=19us TTL=255

NetSim>Router_4 ping 11.0.0.2
Input is validated
Sending command to client device 5
Reply from 11.0.0.2: bytes 32 time=39us TTL=255
Reply from 11.0.0.2: bytes 32 time=39us TTL=255
Reply from 11.0.0.2: bytes 32 time=39us TTL=255
Reply from 11.0.0.2: bytes 32 time=39us TTL=255

NetSim>_

```

Figure 2-2: *Pinging Router 4*

NOTE: In order to initiate ping between the devices, ICMP protocol which is present in the Network Layer properties of the devices must be set to TRUE.

2.5 Excluded Features

Multiple controllers can be configured in NetSim. However, intercontroller communication requires the user to write their own code in NetSim.

2.6 Troubleshooting issues in executing SDN commands

When executing SDN commands in the SDN controller, there can be cases where there is no response coming back. Some of the reasons for this are listed below:

SDN Controller and SDN client are unable to communicate (not reachable).

- Part of two different networks
- Due to the distance between the devices in the case of wireless nodes

Failed TCP connection attempts due to high error or collision

- Commands for Controller to the client and response from the client to the controller are passed as TCP packets.
- The TCP connection attempt fails if the maximum connection attempt is reached.

High network traffic due to application packets exchanged during the simulation

Some suggestions to resolve issues with SDN command execution are listed below:

- Connectivity between the SDN controller and clients should be ensured.
- Application start time can be increased to allow necessary SDN commands to be executed prior to application traffic flow which will also avoid contention especially in the case of Wireless devices.

- SDN commands can be passed as input via file-based interactive simulation for higher accuracy in terms of the time at which the commands are to be executed.

3 Featured Examples

NetSim provides inbuilt examples to get started with the SDN module. To access these examples, you can go to Examples > Software-Defined-Networks in the NetSim Home Screen. You can change the default values of the parameters in these examples and see how they affect the performance of the SDN network.

3.1 Configuring SDN

3.1.1 Configuring One SDN Controller in a Simple Internetwork

The Internetwork model in this example consists of the following configuration:

1. A subnet with 2 wired nodes, 3 routers, and a unicast application running on one of the wired nodes.
2. Only one router is configured as the SDN controller.
3. Open Flow protocol is enabled on all wired nodes and routers.
4. A unicast application is set between Wired Node 1 to Wired Node 2.
5. Set Transport Protocol to TCP in Application Properties.
6. Simulation time is set to 500 seconds.
7. Packet trace is enabled.

To simulate the example for One SDN controller in an Internetwork:

Open NetSim and Select Examples > Software Defined Networks > Configuring SDN > SDN Internetworks then click on the tile in the middle panel to load the example as shown in below

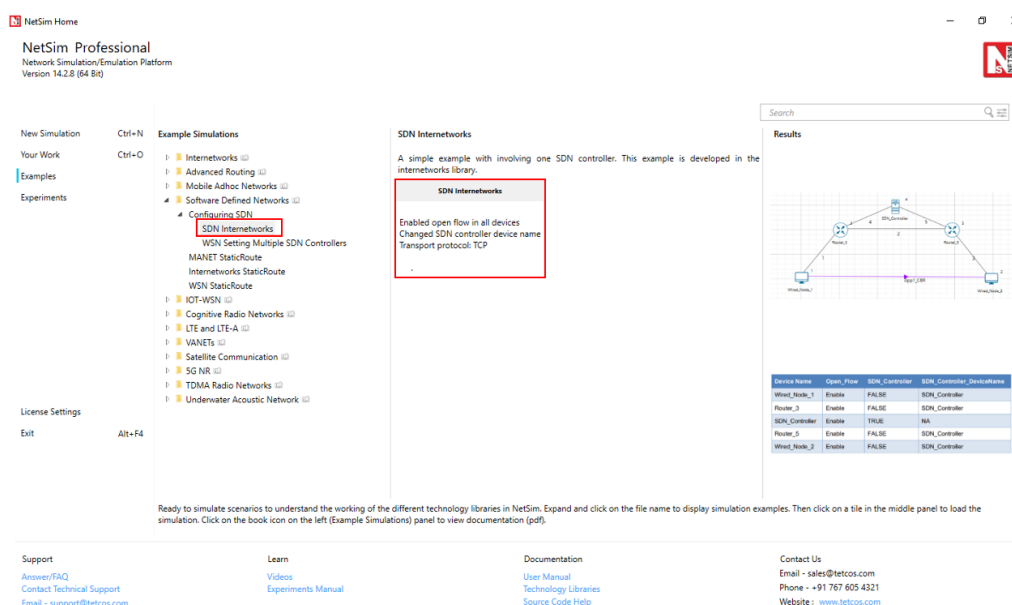


Figure 3-1: List of scenarios for the example of SDN Internetworks

1. The following network diagram illustrates what the NetSim UI displays when you open the example configuration file for SDN as shown Figure 3-2.

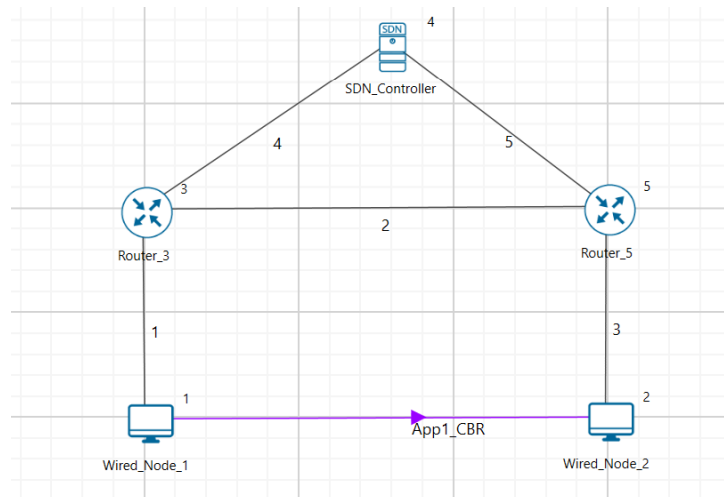


Figure 3-2: Network set up for studying the SDN Internetworks

2. In the application layer of the SDN Controller node:
 - a. SDN Controller option set to TRUE.
 - b. Open Flow protocol is enabled.

The following image illustrates the settings done in the SDN controller device:

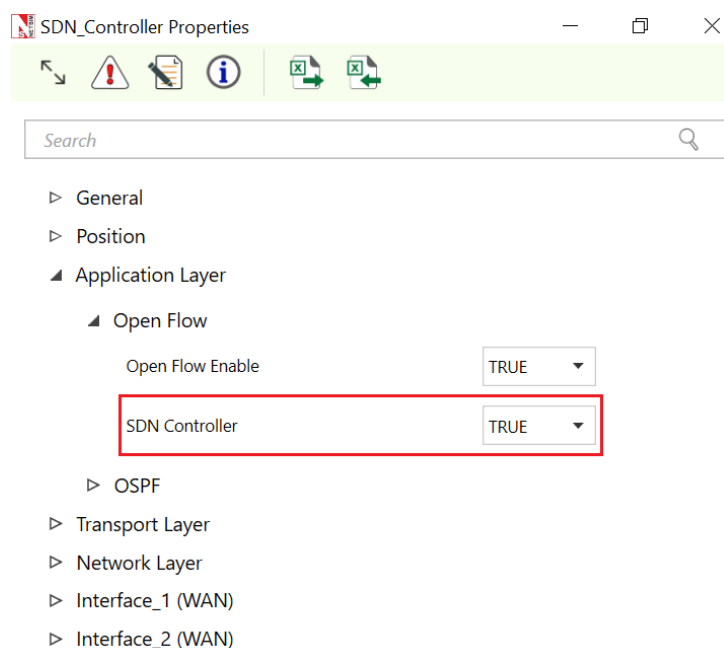


Figure 3-3: Application Layer properties Window of SDN_Controller device

3. In the other devices (Routers and wired node) that are part of the network,
 - a. SDN Controller option is set to FALSE.
 - b. SDN Controller DeviceName is set as “SDN Controller” which is the name of the controller node.
 - c. Open Flow protocol is enabled.

The following image illustrates settings done in the other devices:

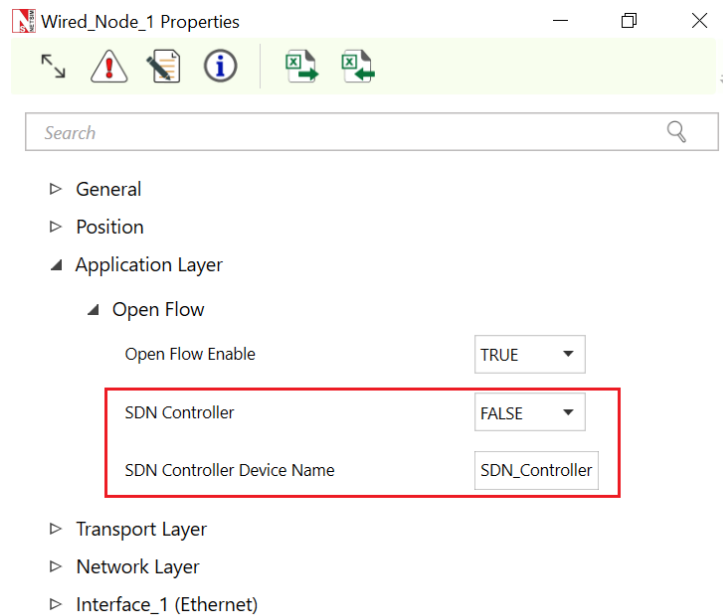


Figure 3-4: SDN Controller DeviceName is set as SDN Controller in Application layer

The following table lists the settings done in all the devices that are part of the network:

Table 3-1: Set the properties for all the devices

Device Name	Open Flow	SDN Controller	SDN Controller DeviceName
Wired Node 1	Enable	FALSE	SDN Controller
Router 3	Enable	FALSE	SDN Controller
SDN Controller	Enable	TRUE	NA
Router 5	Enable	FALSE	SDN Controller
Wired Node 2	Enable	FALSE	SDN Controller

4. Configure an application between any two nodes in the scenario by selecting an application from the Set Traffic tab.
 - a. CBR Application from Wired Node 1 to Wired Node 2 with 50 Mbps Generation Rate (Packet Size: 1460Bytes, Inter Arrival Time: 233.6µs).
 - b. Set Transport Protocol to TCP.
5. Before simulating the example, Right-click SDN Controller and select NetSim Console. Now, the client (NetSimCLI.exe) waits to establish a connection with NetSimCore.exe as shown below.

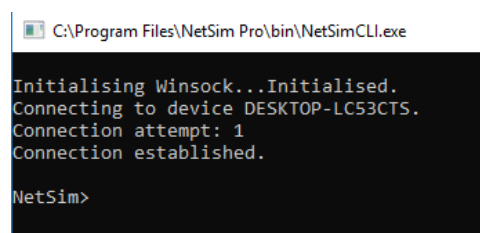


Figure 3-5: Connection Establishment

6. Follow the below steps to simulate an example.

- a. Click on the Options tab. Select Run time interaction.

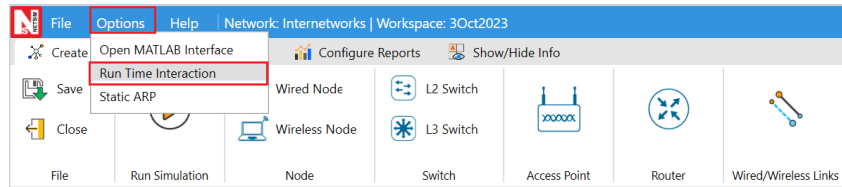


Figure 3-6: Run Time Interaction option in NetSim GUI

- b. In the Run Time Interaction tab, set Interactive Simulation to True and click on OK.

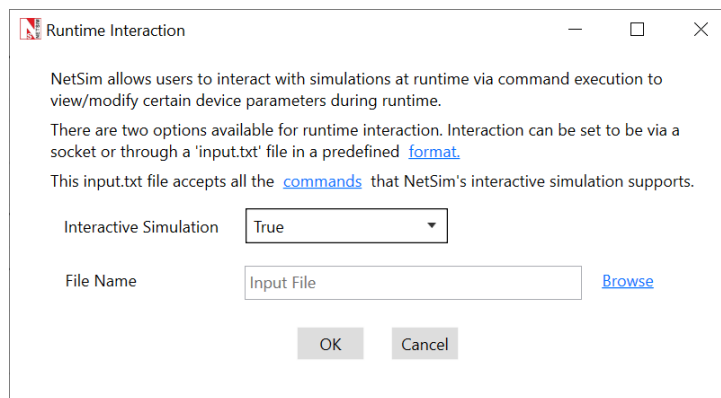


Figure 3-7: Enable Interactive Simulation

- c. Click on Run Simulation window and simulate it to 500 secs.

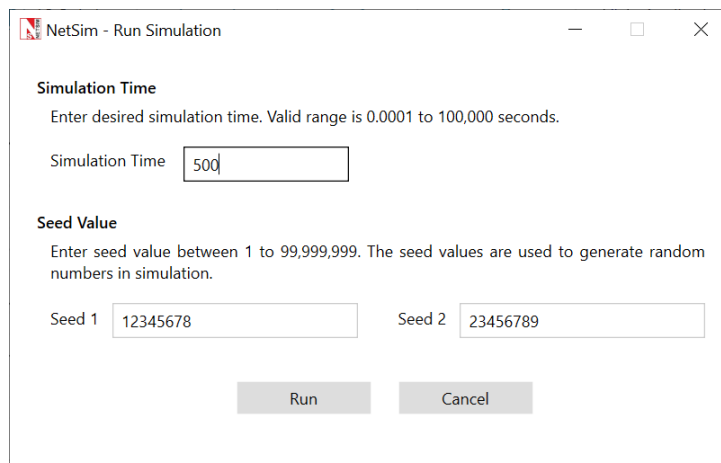


Figure 3-8: Run Simulation Window

Simulation (NetSimCore.exe) starts to run. NetSimCore.exe displays the following message: waiting for the first client to connect.

```

C:\Users\JAYDEN\Documents\NetSim\Workspaces\gr\bin_x64\NetSimCore.exe
App path - C:\Users\JAYDEN\Documents\NetSim\Workspaces\gr\bin_x64
NetSim License Manager will first check for node lock licenses.
If not available, it will then check for floating/cloud licenses
NetSim License Manager Start. Checking for licenses available (this may take upto 2 min) -
No license for product (-1)

NetSim License Manager Start. Checking for licenses available (this may take upto 2 min) -

License Manager Output. Product>Edition>Maj_ver>Min_ver>Lic_type>Components>
netsim>pro>14>3>rlm_hu>111111111111111100>
NetworkStack loaded from path- c:\Users\JAYDEN\Documents\NetSim\Workspaces\gr\bin_x64\NetworkStack.dll

***
NetSim start
Network Stack loaded
Error in creating C:\Users\JAYDEN\AppData\Local\Temp\NetSim\pro_14.3\log directory. Error number 17
Initializing simulation
Config file reading complete
License re-validation complete
Protocol binaries loaded
Executing command --- DEL "C:\Users\JAYDEN\AppData\Local\Temp\NetSim\pro_14.3\*.pcap"
Could Not Find C:\Users\JAYDEN\AppData\Local\Temp\NetSim\pro_14.3\*.pcap
Emulation is disabled
Stack variables initialized
Could Not Find C:\Users\JAYDEN\AppData\Local\Temp\NetSim\pro_14.3\PLOT_*
Metrics variables initialized
Protocol variables initialized
NetSim console Mode is enabled.
Waiting for first client to connect. Press ctrl+c to stop connection.

```

Figure 3-9: *Waiting for first client to connect.*

- d. Use this console to execute SDN commands as explained in section 2.2.

3.1.2 Configuring Multiple SDN Controllers in a Wireless Sensor Network

In this example, multiple SDN controllers are configured in a Wireless Sensor Network.

The Wireless Sensor Network model in this example consists of the following configuration:

- A subnet with 4 wireless sensors, 1 ad-hoc link, 1 WSN sink node, and a unicast sensor application running on one of the wireless sensors.
- Set Transport Protocol to TCP in Application Properties.
- Two wireless sensors are configured as SDN controllers.
- Open Flow protocol is enabled on all wireless sensors and sink node.

NetSim uses the following defaults for this SDN example:

- a. The unicast application transmits data from Wireless Sensor 3 to Wireless Sensor 5.
- b. Simulation runs for 500 seconds.
- c. Packet trace is enabled.

NOTE: For a WSN network, ping command is not supported on ZigBee device since these nodes do not support ICMP protocol.

To simulate the example for multiple SDN controllers in WSN for SDN:

Open NetSim and Select Examples \downarrow Software Defined Networks \downarrow Configuring SDN \downarrow WSN Setting Multiple SDN Controllers then click on the tile in the middle panel to load the example as shown in below screenshot

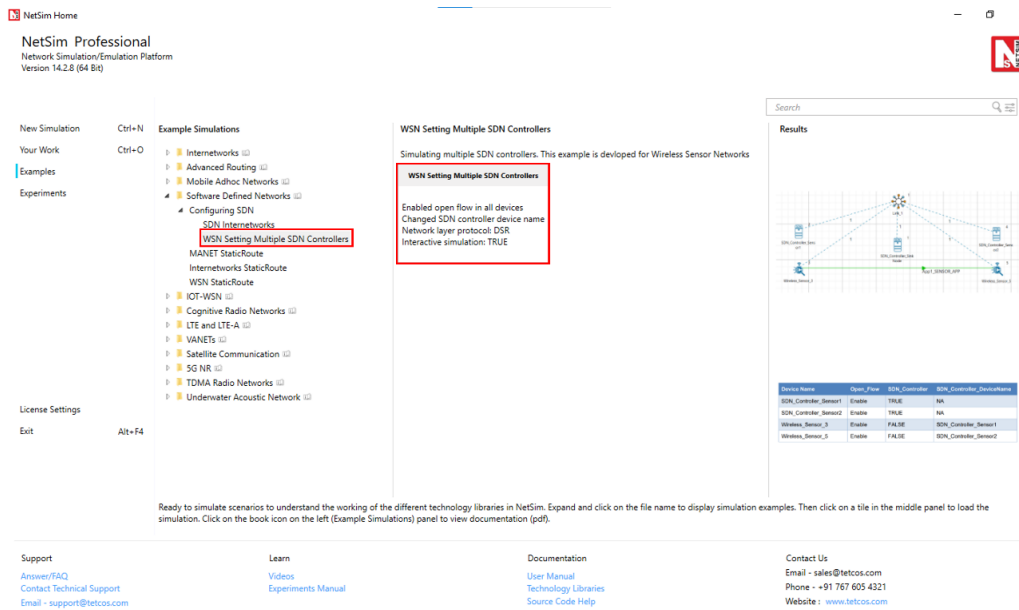


Figure 3-10: List of scenarios for the example of WSN Setting Multiple SDN Controllers

1. The following network diagram illustrates the network setup related to this example as shown below.

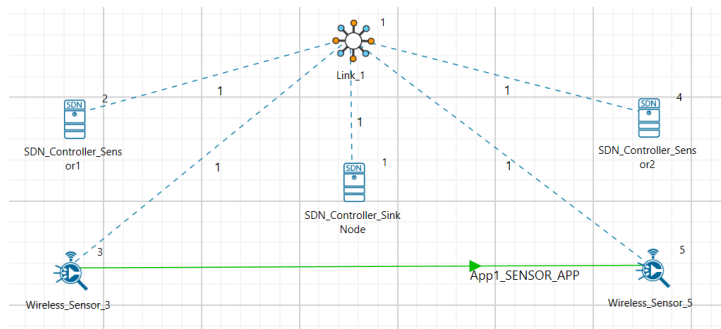


Figure 3-11: Network set up for studying the WSN Setting Multiple SDN Controllers

2. The SDN Controller Sensors, Wireless Sensors and the sinknode are configured as SDN controllers with Open Flow protocol enabled in all the nodes.

The following image illustrates the settings done in the sensors configured as SDN controller as shown below.

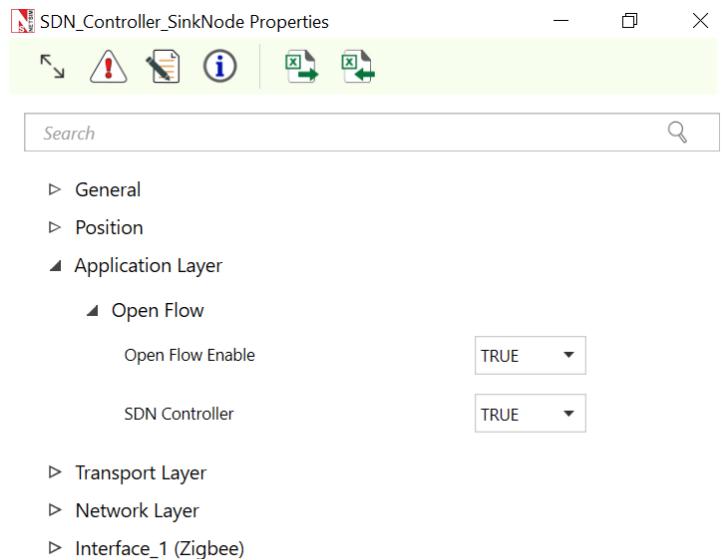


Figure 3-12: Application Layer properties Window

- The sensor SDN Controller Sensor 1 is set as the SDN controller for Wireless Sensor 3 and SDN Controller Sensor 2 is set as the SDN controller for Wireless Sensor 5.

The following image illustrates the settings done in sensor 3.

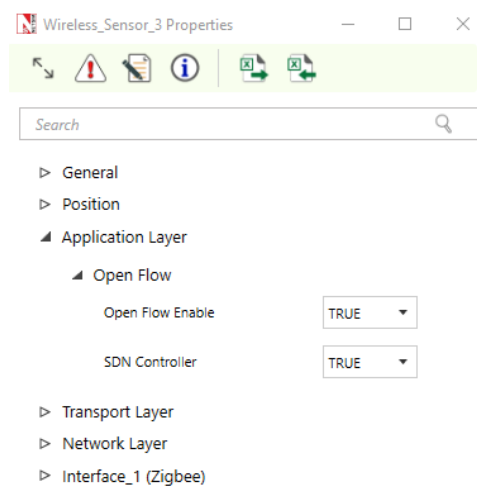


Figure 3-13: SDN Controller DeviceName is set as SDN Controller in Application layer

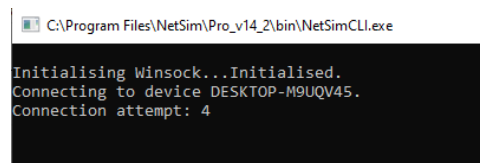
The following table lists the default setting for the wireless sensors.

Table 3-2: Set the properties for all the devices

Device Name	Open Flow	SDN Controller	SDN Controller DeviceName
SDN Controller Sink Node	Enable	TRUE	NA
SDN Controller Sensor1	Enable	TRUE	NA
SDN Controller Sensor2	Enable	TRUE	NA
Wireless Sensor3	Enable	FALSE	SDN Controller Sensor1
Wireless Sensor5	Enable	FALSE	SDN Controller Sensor2

4. Configure an application between any two nodes in the scenario by selecting an application from the Set Traffic tab.
 - a. Sensor Application from Wireless Sensor 3 to Wireless Sensor 5 with Packet Size: 50Bytes, Inter Arrival Time: 1000000 μ s).
 - b. Set Transport Protocol to TCP.
5. Packet trace is enabled under configure reports tab.
6. To use the SDN CLI Console:
 - a. Right-click SDN Controller Sensor1 or SDN Controller Sensor2 and click NetSim Console. Now, the client (NetSimCLI.exe) starts and tries to establish a connection with NetSimCore.exe.

The following image illustrates the NetSim CLI console.



```

C:\Program Files\NetSim\Pro_v14_2\bin\NetSimCLI.exe
Initialising Winsock...Initialised.
Connecting to device DESKTOP-M9UQV45.
Connection attempt: 4
  
```

Figure 3-14: Connection established.

7. Simulate the example. To do so:
 - a. Click on the Options tab. Select Run time interaction.

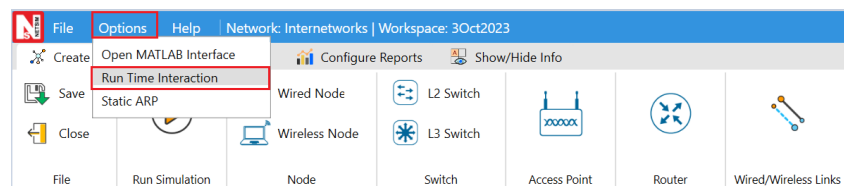


Figure 3-15: Run Time Interaction in NetSim GUI

- b. In the Run time Interaction tab, Interactive Simulation option is set to True and click on OK.

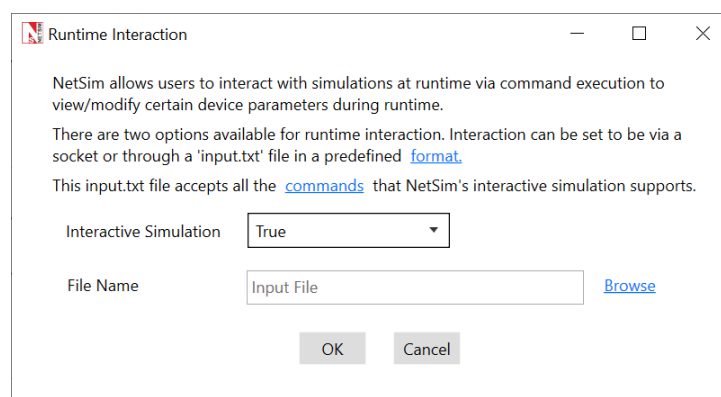


Figure 3-16: Runtime Interaction window

- c. Click on the Run Simulation window and simulate it to 500 sec.

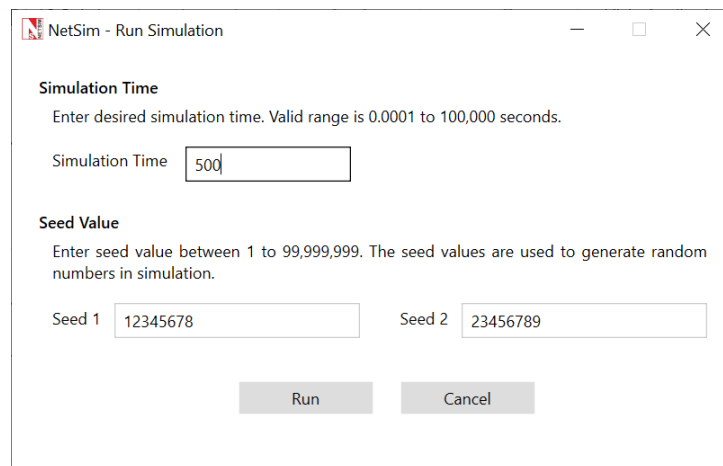


Figure 3-17: *Run Simulation Window*

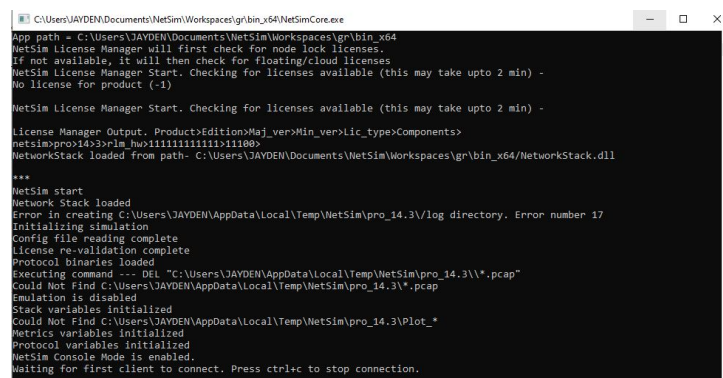


Figure 3-18: *Waiting for first Client to Connect*

You can execute various SDN commands that are supported in any of the SDN controller Sensor CLI.

3.2 Configuring Static Routes for a MANET Network by using SDN

In this example static routes are configured using the SDN controllers, in a MANET network.

The MANET network model in this example consists of the following configuration:

- A subnet with 5 wireless nodes and 1 ad-hoc link, and a unicast CBR application running on one of the wireless nodes.
- DSR is the routing protocol that is enabled on all wireless nodes.
- One wireless node is configured as the SDN controller.
- Wireless nodes do not have mobility.
- A unicast application is configured from Wireless Node 1 to Wireless Node 5.
- Simulation time is set to 500 seconds.
- Packet trace is enabled.

To simulate the example for MANET using SDN:

Open NetSim and Select Examples \downarrow Software Defined Networks \downarrow MANET StaticRoute then click on the tile in the middle panel to load the example as shown in below screenshot

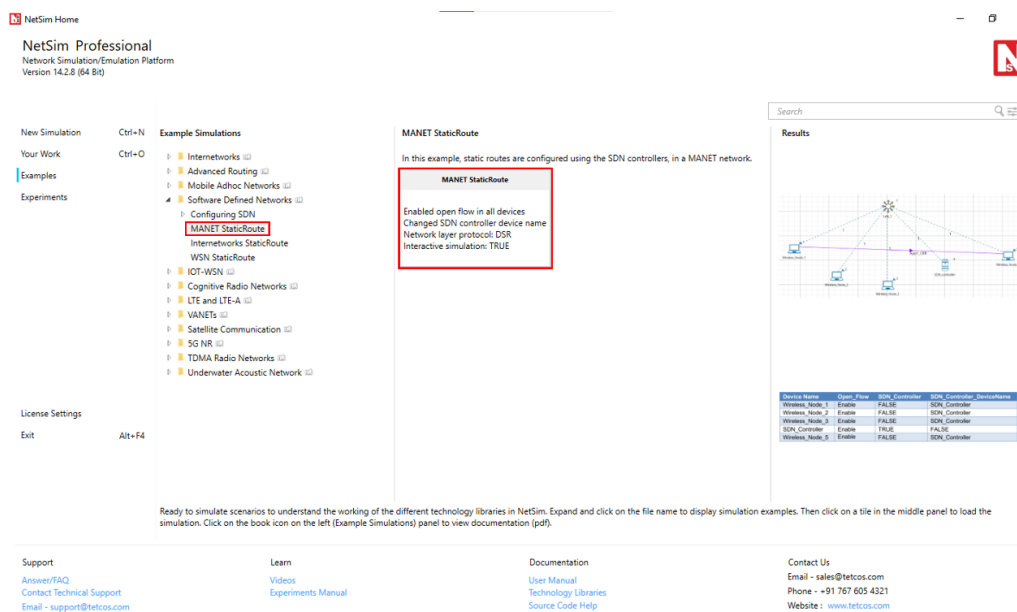


Figure 3-19: List of scenarios for the example of MANET StaticRoute

The following network diagram illustrates the network setup.

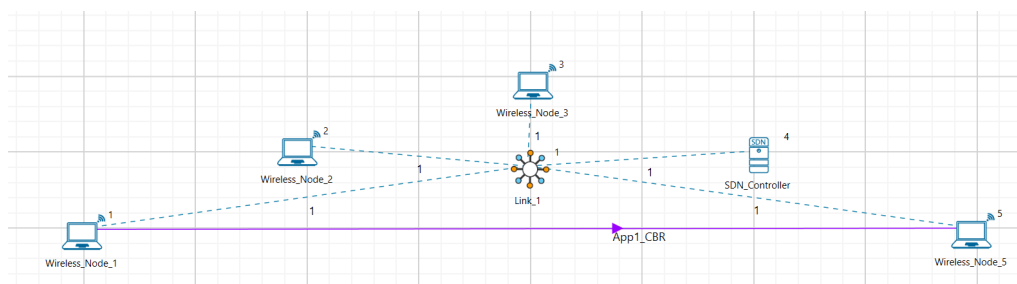


Figure 3-20: Network set up for studying the MANET Static Route

1. DSR routing protocol is configured in Network layer for all the nodes and set the nodes to be stationary.
2. Mobility model is set to NO MOBILITY in all the nodes.
3. ICMP protocol is enabled in the network layer properties of all the wireless nodes.
4. Open flow protocol is enabled in all the wireless nodes.

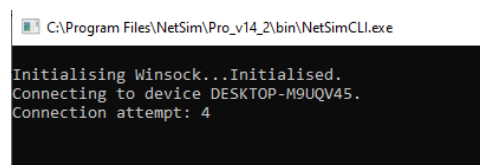
The following settings were done in the wireless nodes to configure Wireless Node 4 as SDN controller and other nodes as its clients.

Table 3-3: Set the properties for all the devices

Device Name	Open Flow	SDN_Controller	SDN_Controller DeviceName
Wireless Node 1	Enable	FALSE	SDN Controller
Wireless Node 2	Enable	FALSE	SDN Controller
Wireless Node 3	Enable	FALSE	SDN Controller
SDN Controller	Enable	TRUE	N/A
Wireless Node 5	Enable	FALSE	SDN Controller

5. Configure an application between any two nodes in the scenario by selecting an application from the Set Traffic tab.

- a. CBR Application from Wireless Node 1 to Wireless Node 5 with 0.584 Mbps Generation Rate (Packet Size: 1460Bytes, Inter Arrival Time: 20000 μ s).
 - b. Set Transport Protocol to UDP.
6. Click on link, expand the right-side property panel and set Channel Characteristics: Path Loss Only, Path Loss Model: Log Distance, Path Loss Exponent: 2.5.
 7. In NetSim Packet Trace is enabled under configure reports tab.
 8. To use the SDN CLI Console:
 - a. Right-click SDN Controller and select NetSim Console. Now, the client (NetSimCLI.exe) starts and attempts to establish a connection with NetSimCore.exe.



```

C:\Program Files\NetSim\Pro_v14_2\bin\NetSimCLI.exe
Initialising Winsock...Initialised.
Connecting to device DESKTOP-M9UQV45.
Connection attempt: 4
  
```

Figure 3-21: Connection established.

9. Simulate the example. To do so:
 - a. Click on the Options tab. Select Run time interaction.

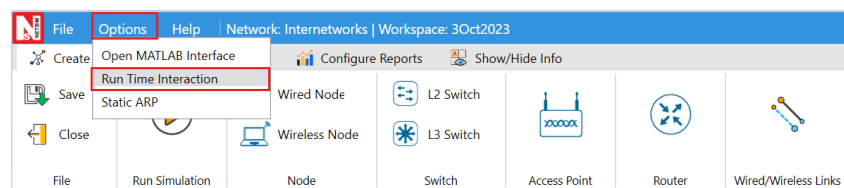


Figure 3-22: Runtime Interaction in GUI

- b. In the Run time Interaction tab, Interactive Simulation option is set to True and click on OK.

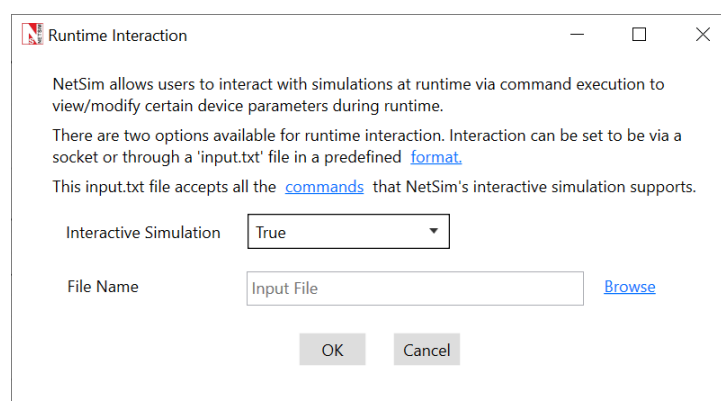


Figure 3-23: Enabling Run Time Interaction option.

- c. Click on Run simulation window and simulate it to 500 sec.

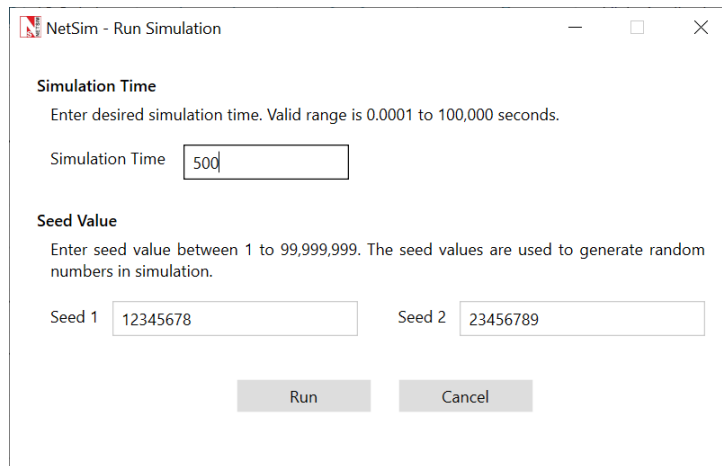


Figure 3-24: Run Simulation window

Simulation (NetSimCore.exe) starts to run. NetSimCore.exe displays the following message: waiting for the first client to connect.

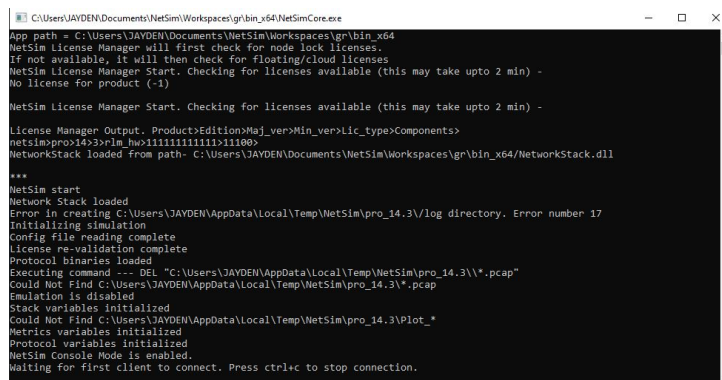


Figure 3-25: Waiting for the first Client to connect.

10. Interpret the Results

In the simulation results window select the Traces option in the left area and open the packet trace file. Once the packet trace opens apply filter in the CONTROL PACKET TYPE/APP NAME for APP1 CBR.

- a. The packets reach Wireless Node 5 from Wireless Node 1-j, Wireless Node 3-j, Wireless Node 5.

PACKET_ID	SEGMENT_ID	PACKET_TYPE	CONTROL_PACKET_TYPE/APP_NAME	SOURCE_ID	DESTINATION_ID	TRANSMITTER_ID	RECEIVER_ID
1	0	CBR	App1_CBR	NODE-1	NODE-5	NODE-1	NODE-3
	1	0	CBR	NODE-1	NODE-5	NODE-3	NODE-5

Figure 3-26: Packet trace screenshot

11. For the same example, configure static routes such that the packets will go through Wireless Node 1 j Wireless Node 2, Wireless Node 3, SDN Controller to Wireless Node 5. To configure the static routes on SDN Controller for all the nodes.

- a. Right-click SDN Controller and select NetSim Console.
- b. Re-run the simulation.
- c. Type the following commands on the NetSim CLI console, in the <DeviceName with Device ID> route add <destination IP address> MASK <subnet mask> <gateway IP address> <metric> if <interface #> format.

- d. Wireless_Node_1 route ADD 192.168.0.6 MASK 255.255.255.0 192.168.0.3 METRIC 1 IF 1
- e. Wireless_Node_2 route ADD 192.168.0.6 MASK 255.255.255.0 192.168.0.4 METRIC 1 IF 1
- f. Wireless_Node_3 route ADD 192.168.0.6 MASK 255.255.255.0 192.168.0.5 METRIC 1 IF 1
- g. SDN_Controller route ADD 192.168.0.6 MASK 255.255.255.0 192.168.0.6 METRIC 1 IF 1

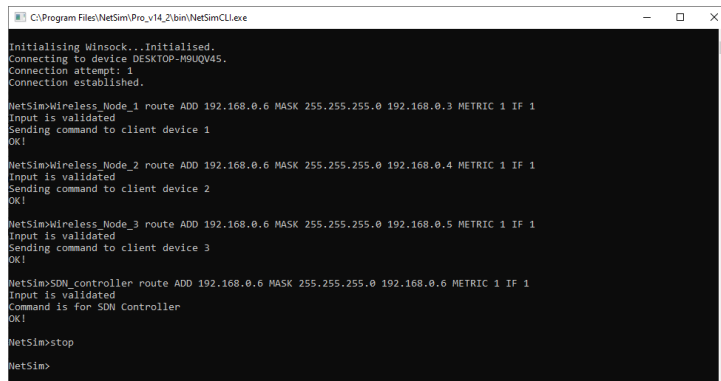


Figure 3-27: NetSim Console Window

12. Interpret the Results.

- a. Open Packet trace and filter CONTROL PACKET TYPE/APP NAME to APP1 CBR, you will see that data packets transmitted from Wireless Node 1 ; Wireless Node 2 ; Wireless Node 3 ; SDN Controller to Wireless Node 5 as part of the commands executed for static route configuration.

PACKET_ID	SEGMENT_ID	PACKET_TYPE	CONTROL_PACKET_TYPE/APP_NAME	SOURCE_ID	DESTINATION_ID	TRANSMITTER_ID	RECEIVER_ID
2185	0	CBR	App1_CBR	NODE-1	NODE-5	NODE-1	NODE-2
2185	0	CBR	App1_CBR	NODE-1	NODE-5	NODE-2	NODE-3
2185	0	CBR	App1_CBR	NODE-1	NODE-5	NODE-3	NODE-4
2185	0	CBR	App1_CBR	NODE-1	NODE-5	NODE-4	NODE-5
2186	0	CBR	App1_CBR	NODE-1	NODE-5	NODE-1	NODE-2
2186	0	CBR	App1_CBR	NODE-1	NODE-5	NODE-2	NODE-3
2186	0	CBR	App1_CBR	NODE-1	NODE-5	NODE-3	NODE-4
2186	0	CBR	App1_CBR	NODE-1	NODE-5	NODE-4	NODE-5
2187	0	CBR	App1_CBR	NODE-1	NODE-5	NODE-1	NODE-2
2187	0	CBR	App1_CBR	NODE-1	NODE-5	NODE-2	NODE-3
2187	0	CBR	App1_CBR	NODE-1	NODE-5	NODE-3	NODE-4
2187	0	CBR	App1_CBR	NODE-1	NODE-5	NODE-4	NODE-5
2188	0	CBR	App1_CBR	NODE-1	NODE-5	NODE-1	NODE-2
2188	0	CBR	App1_CBR	NODE-1	NODE-5	NODE-2	NODE-3
2188	0	CBR	App1_CBR	NODE-1	NODE-5	NODE-3	NODE-4
2188	0	CBR	App1_CBR	NODE-1	NODE-5	NODE-4	NODE-5
2189	0	CBR	App1_CBR	NODE-1	NODE-5	NODE-1	NODE-2
2189	0	CBR	App1_CBR	NODE-1	NODE-5	NODE-2	NODE-3
2189	0	CBR	App1_CBR	NODE-1	NODE-5	NODE-3	NODE-4
2189	0	CBR	App1_CBR	NODE-1	NODE-5	NODE-4	NODE-5
2190	0	CBR	App1_CBR	NODE-1	NODE-5	NODE-1	NODE-2
2190	0	CBR	App1_CBR	NODE-1	NODE-5	NODE-2	NODE-3
2190	0	CBR	App1_CBR	NODE-1	NODE-5	NODE-3	NODE-4
2190	0	CBR	App1_CBR	NODE-1	NODE-5	NODE-4	NODE-5

Figure 3-28: Packet Trace Window

3.3 Configuring Static Routes for Internetworks using SDN

In the example the IP tables in the nodes and routers on an SDN network are modified using SDN CLI commands.

The network model in this example consists of the following configuration:

- A subnet with 2 wired nodes, 5 routers, and a unicast application running on one of the wired nodes.
- SDN controller running on one of the router.
- Set Transport Protocol to TCP in Application. Open Flow protocol is enabled on all wired nodes and routers.
- A unicast application set from Wired Node 1 to Wired Node 2.
- OSPF is the routing protocol in the routers.
- The node SDN Controller is configured to be the SDN controller.
- Simulation time is set to 500 seconds.
- Packet trace, and Event trace are enabled.

To simulate SDN and change the IP tables:

Open NetSim and Select Examples > Software Defined Networks > Internetworks StaticRoute then click on the tile in the middle panel to load the example as shown in below screenshot.

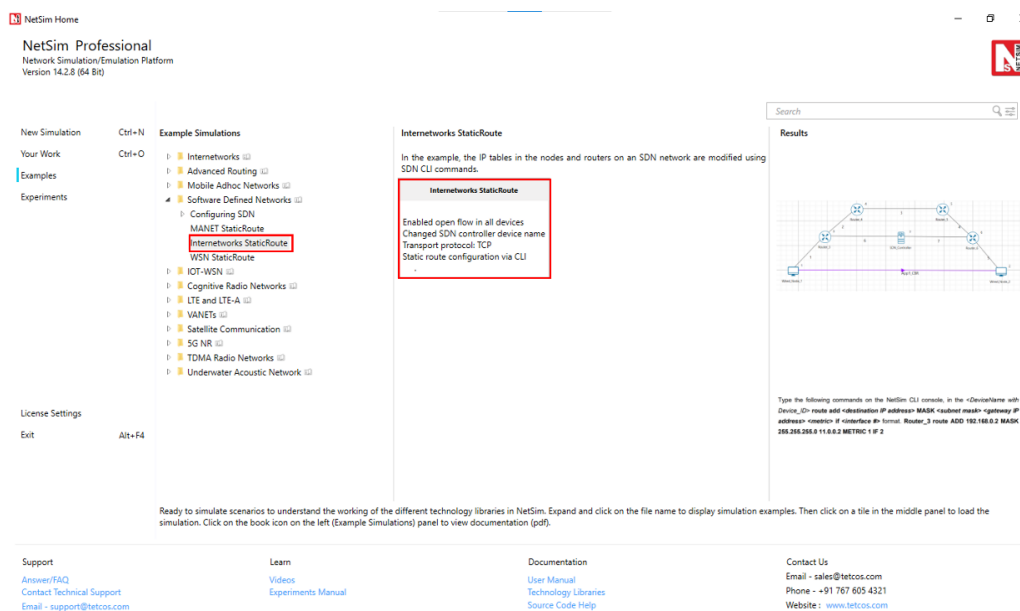


Figure 3-29: List of scenarios for the example of Internetworks StaticRoute

The following network diagram illustrates the network setup related to this example.

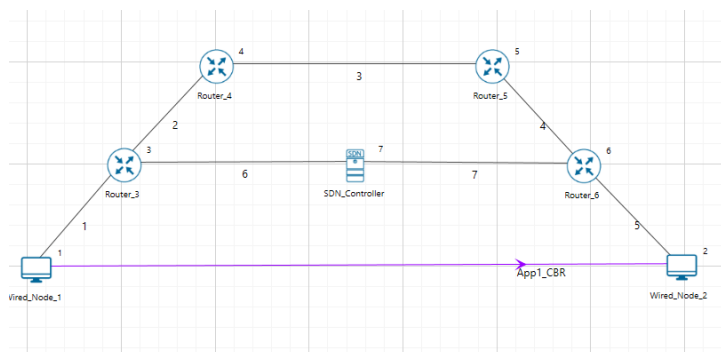


Figure 3-30: Network set up for studying the Internetworks Static Route

1. Configure an application between any two nodes in the scenario by selecting an application from the Set Traffic tab.

- a. CBR Application from Wired Node 1 to Wired Node 2 with 50 Mbps Generation Rate (Packet Size: 1460Bytes, Inter Arrival Time: 233.6µs).
 - b. Application Start time is 30 sec.
 - c. Set Transport Protocol to TCP.
2. Packet Trace and Event Trace features are enabled from Configure Reports.
 3. To use the SDN CLI: Right-click SDN Controller and select NetSim Console. Now, the client (NetSimCLI.exe) starts and attempts to establish a connection with NetSimCore.exe.

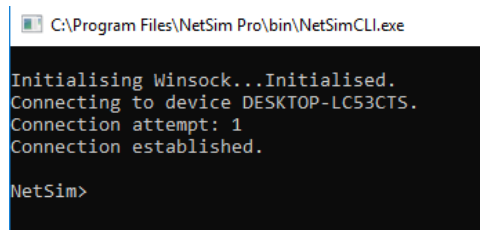


Figure 3-31: Connection Establishment.

4. Simulate SDN. To do so,
 - a. In the Run time Interaction under options tab, Interactive Simulation option is set to True.
 - b. Click the Run button. The Run Simulation pop-up window appears.
 - c. Simulation time is set to 500 Seconds.
5. Interpret the results.
 - a. Open packet trace and filter the CONTROL PACKET TYPE/APP NAME to APP1 CBR, and PACKET ID to 1. Packets reach Wired Node 2 via Wired Node 1 ; Router 3 ; SDN Controller ; Router 6.

PACKET_ID	SEGMENT_ID	PACKET_TYPE	CONTROL_PACKET_TYPE/APP_NAME	SOURCE_ID	DESTINATION_ID	TRANSMITTER_ID	RECEIVER_ID
1	0	CBR	App1_CBR	NODE-1	NODE-2	NODE-1	ROUTER-3
1	0	CBR	App1_CBR	NODE-1	NODE-2	ROUTER-3	ROUTER-7
1	0	CBR	App1_CBR	NODE-1	NODE-2	ROUTER-7	ROUTER-6
1	0	CBR	App1_CBR	NODE-1	NODE-2	ROUTER-6	NODE-2

Figure 3-32: Packet Animation window

6. Click View Results on the tool bar, Link metrics in the left area and check the Detailed View check box in the Link Metrics Table pop-up window. You will not see data packet transmissions in links 2, 3, and 4 as shown in below Figure.

Link Metrics
Performance of both wired and wireless network connections.

Link ID	Packets Transmitted		Packets Errored			Packets Collided		Bytes Transmitted	Payload Transmitt	Overhead Transmi
	Data	Control	Data	Control	Data	Control				
All	28779	28841	40	2	0	0	45077438	41958940	3118498	
1	7211	7171	10	0	0	0	11477280	10513460	963820	
2	0	29	0	0	0	0	2652	0	2652	
3	0	29	0	0	0	0	2576	0	2576	
4	0	34	0	1	0	0	3208	0	3208	
5	7179	7172	10	0	0	0	11428514	10466740	961774	
6	7200	7203	10	0	0	0	11089916	10497400	592516	
7	7189	7203	10	1	0	0	11073292	10481340	591952	

Figure 3-33: Link Metrics table in Result Window

7. For the same example, configure static routes on Router 3 such that all traffic bound for the 11.0.0.18 subnet will go to a gateway 11.0.0.2, that is, from Router 3 ; Router 4 ; Router 5 ; Router 6.

To configure the static routes for Router 3:

- a. Simulate the network again by following below steps
- b. Now, right-click SDN Controller and click NetSim Console.
- c. Now, the client (NetSimCLI.exe) starts and attempts to establish a connection with NetSim-Core.exe. NetSim CLI console opens.
- d. Type the following commands on the NetSim CLI console, in the <DeviceName with Device ID> route add <destination IP address> MASK <subnet mask> <gateway IP address> <metric> if <interface #> format.
- e. Router_3 route ADD 192.169.0.2 MASK 255.255.255.0 11.0.0.2 METRIC 1 IF 2
- f. (Optional) To check the static routes on ROUTER 3, type ROUTER.3 route print. The following image illustrates step (c) and (d).

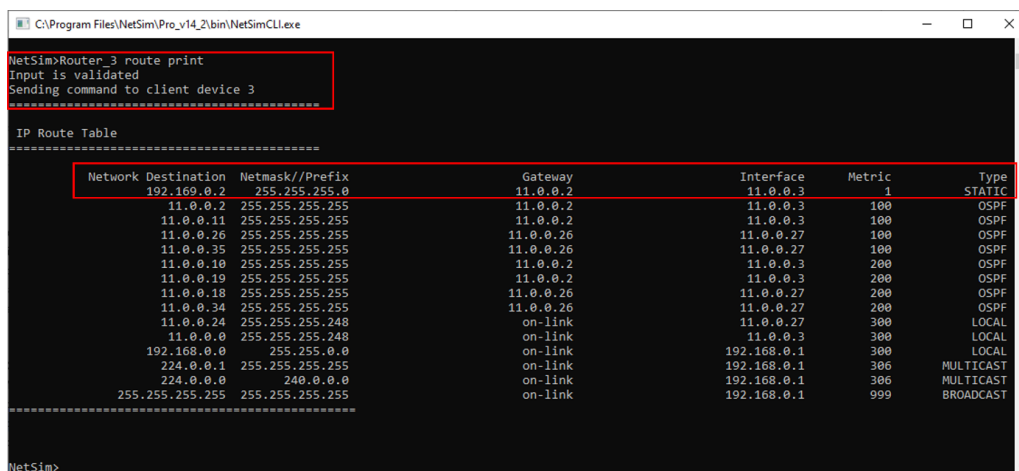


Figure 3-34: Route added to network and route printed in command.

8. Interpret the results.
 - a. Click packet trace from the results dashboard.
 - b. The packets reach Wired Node 2 via Router 3 ; Router 4 ; Router 5 ; Router 6.
 - c. Click Link metrics in the left area and check the Detailed View check box in the Link Metrics Table pop-up window.

You will see data packet transmissions in Links 2, 3, and 4.

The following figure illustrates step (7c) as shown in below.

Link ID	Packets Transmitted		Packets Error			Packets Collided		Bytes Transmitted	Payload Transmitt	Overhead Transmi
	Data	Control	Data	Control	Data	Control				
All	200902	161477	264	8	0	0	31202546	292933866	19091680	
1	40590	40321	53	2	0	0	64601534	59184020	5417514	
2	39000	31	47	0	0	0	58502788	56871380	1631408	
3	38953	33	47	0	0	0	58432396	56802760	1629636	
4	38906	38	54	1	0	0	58363528	56723920	1638608	
5	40384	40326	61	2	0	0	64287508	58871580	5415928	
6	1535	40370	1	1	0	0	3921720	2242026	1679694	
7	1534	40358	1	2	0	0	3911702	2238180	1678892	

Figure 3-35: Link Metrics Table

- d. In the simulation results window click on the Open Packet trace option in the left area. Once the packet trace opens, apply display filters to the CONTROL PACKET TYPE/APP NAME column to show only OPENFLOW COMMAND and OPENFLOW RESPONSE packets.

You will see that OpenFlow packets flow between Router 3 to SDN Controller.

9. In Router 3 under application layer use routing protocol as RIP
10. Configure static routes for Router 3 as follows:
 - a. Simulate SDN (Refer step 4).
 - b. Right-click SDN Controller and click NetSim Console.

Now, the client (NetSimCLI.exe) starts and tries to establish a connection with NetSimCore.exe. NetSim CLI console opens.

- c. Type the following commands on the NetSim CLI console, in the <DeviceName with Device ID> route add <destination IP address> MASK <subnet mask> <gateway IP address> <metric> if <interface #> format.

```
Router_3 route ADD 192.169.0.2 MASK 255.255.255.0 11.0.0.26 METRIC 1 IF 2
```

11. Interpret the results.
 - a. Click View Packets and see the Packet Trace. The packets reach Wired Node 2 via Router 3 ; SDN Controller ; Router 6.

PACKET_ID	SEGMENT_ID	PACKET_TYPE	CONTROL_PACKET_TYPE/APP_NAME	SOURCE_ID	DESTINATION_ID	TRANSMITTER_ID	RECEIVER_ID
1	0	CBR	App1_CBR	NODE-1	NODE-2	NODE-1	ROUTER-3
1	0	CBR	App1_CBR	NODE-1	NODE-2	ROUTER-3	ROUTER-7
1	0	CBR	App1_CBR	NODE-1	NODE-2	ROUTER-7	ROUTER-6
1	0	CBR	App1_CBR	NODE-1	NODE-2	ROUTER-6	NODE-2
2	0	CBR	App1_CBR	NODE-1	NODE-2	NODE-1	ROUTER-3
3	0	CBR	App1_CBR	NODE-1	NODE-2	NODE-1	ROUTER-3
2	0	CBR	App1_CBR	NODE-1	NODE-2	ROUTER-3	ROUTER-7
3	0	CBR	App1_CBR	NODE-1	NODE-2	ROUTER-3	ROUTER-7
2	0	CBR	App1_CBR	NODE-1	NODE-2	ROUTER-7	ROUTER-6
3	0	CBR	App1_CBR	NODE-1	NODE-2	ROUTER-7	ROUTER-6
2	0	CBR	App1_CBR	NODE-1	NODE-2	ROUTER-6	NODE-2
3	0	CBR	App1_CBR	NODE-1	NODE-2	ROUTER-6	NODE-2
4	0	CBR	App1_CBR	NODE-1	NODE-2	NODE-1	ROUTER-3
5	0	CBR	App1_CBR	NODE-1	NODE-2	NODE-1	ROUTER-3

Figure 3-36: Packet flow in trace file after executing the static routes for Router 3

3.4 Configuring Static Routes for a WSN Network by using SDN

In this example static routes are configured in sensors using SDN commands executed in a SDN controller. The WSN network model in this example consists of the following configuration:

- A subnet with 5 wireless sensor, 1 ad-hoc link, 1 wireless sink node, and a unicast sensor application running on one of the wireless sensors.
- One wireless Sensor is configured as the SDN controller.
- A unicast application from Wireless Sensor 1 to Wireless Sensor 5.
- Simulation time of 500 seconds.
- Packet trace is enabled.

To simulate the example for WSN using SDN:

Open NetSim and Select Examples ; Software Defined Networks ; WSN StaticRoute then click on the tile in the middle panel to load the example as shown in below screenshot

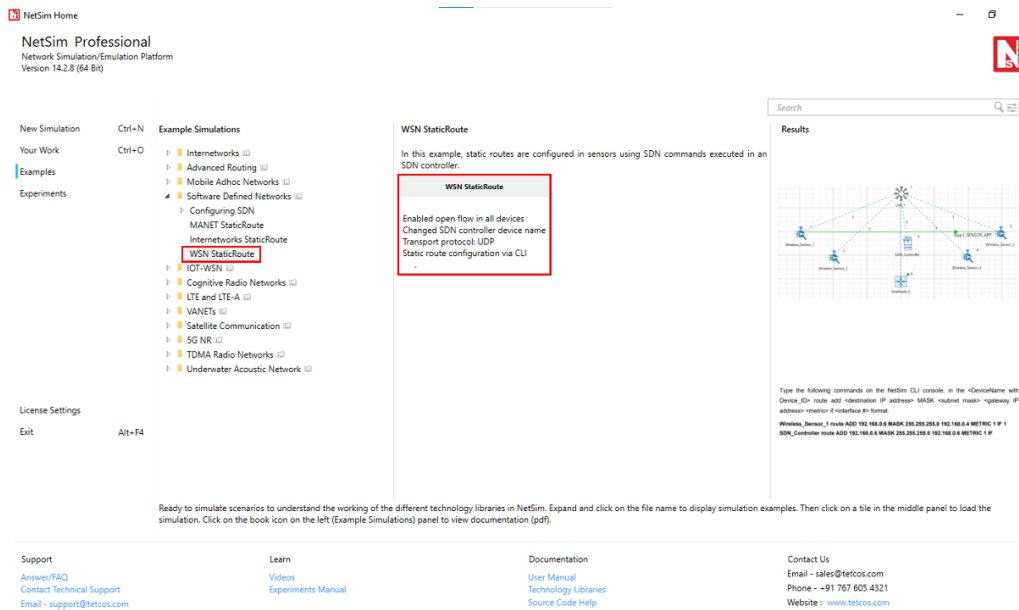


Figure 3-37: List of scenarios for the example of WSN StaticRoute

The following network diagram illustrates the network setup considered in this example:

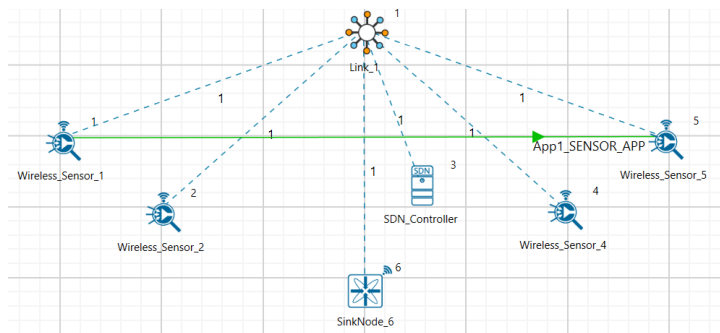


Figure 3-38: Network set up for studying the WSN Static Route

1. The following settings are done in the application layer properties of the devices for configuring SDN:

Table 3-4: Set the properties for all the devices

Device Name	Open Flow	SDN Controllor	SDN Controllor DeviceName
Wireless Sensor 1	Enable	FALSE	SDN Controllor
Wireless Sensor 2	Enable	FALSE	SDN Controllor
SDN Controllor	Enable	TRUE	NA
Wireless Sensor 4	Enable	FALSE	SDN Controllor
Wireless Sensor 5	Enable	FALSE	SDN Controllor
WSN Sink 6	Enable	FALSE	SDN Controllor

2. Configure an application between any two nodes in the scenario by selecting an application from the Set Traffic tab.

- a. Sensor Application from Wireless Sensor 1 to Wireless Sensor 5 with default Generation Rate (Packet Size: 50Bytes, Inter Arrival Time: 1000000μs).

- b. Set Transport Protocol to UDP.
- 3. Before Simulating the scenario, Right-click SDN Controller and click NetSim Console. Now, the client (NetSimCLI.exe) waits to establish a connection with NetSimCore.exe.

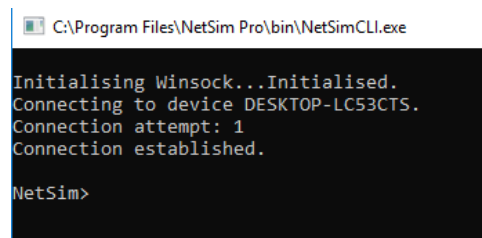


Figure 3-39: Connection Establishment.

- a. Enable the packet trace from the Configure Reports tab and click on the Options tab and select Run time interaction.

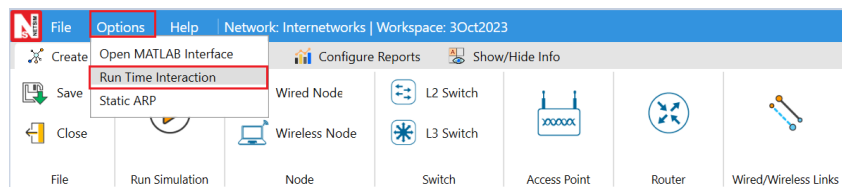


Figure 3-40: Runtime Interaction in GUI

- b. In the Run time Interaction tab, Set the Interactive Simulation option as True and click on OK.

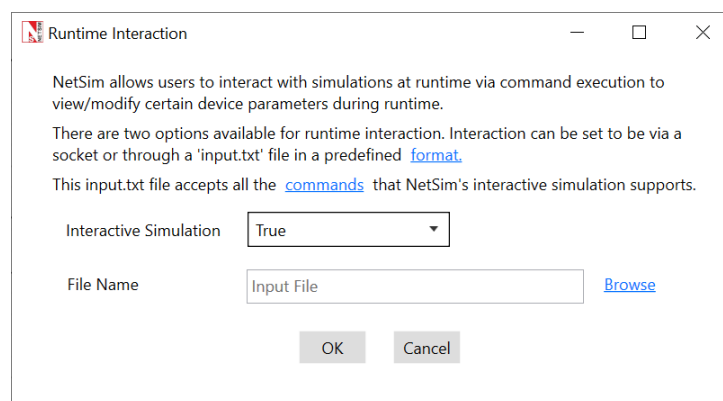


Figure 3-41: Runtime Interaction Window

- c. Click on Run simulation window and simulate it to 500 sec.

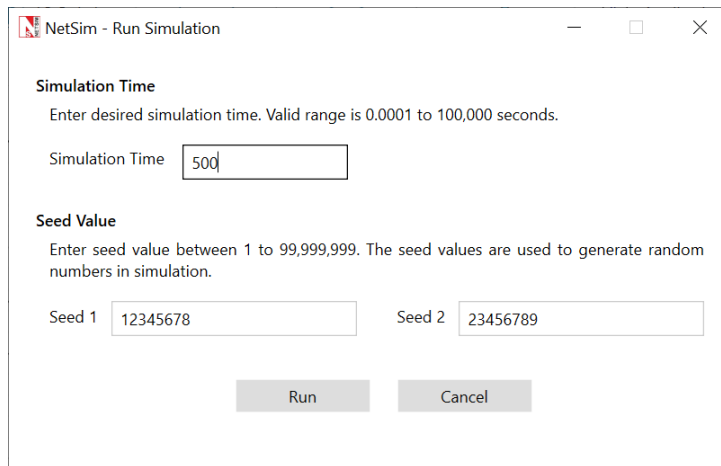


Figure 3-42: Run Simulation Window

- d. Simulation (NetSimCore.exe) starts to run. NetSimCore.exe displays the following message: waiting for the first client to connect.

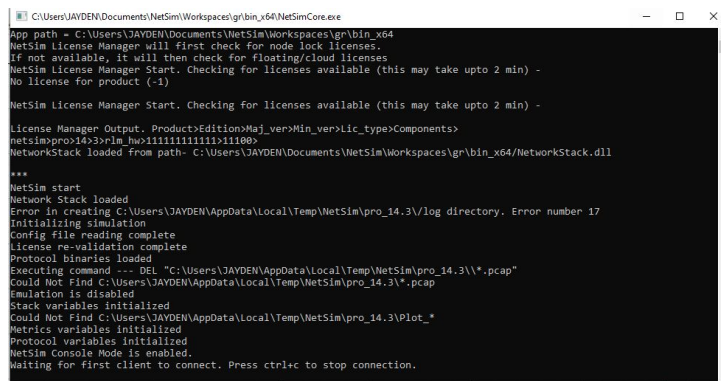


Figure 3-43: Waiting for Client to connect.

- 4. Observe the packet trace after simulation, you will see the direct communication between wireless sensor 1 and 5.

PACKET_ID	SEGMENT_ID	PACKET_TYPE	CONTROL_PACKET_TYPE/APP_NAME	SOURCE_ID	DESTINATION_ID	TRANSMITTER_ID	RECEIVER_ID
1	0	Sensing	App1_SENSOR_APP	SENSOR-1	SENSOR-5	SENSOR-1	SENSOR-5
2	0	Sensing	App1_SENSOR_APP	SENSOR-1	SENSOR-5	SENSOR-1	SENSOR-5
3	0	Sensing	App1_SENSOR_APP	SENSOR-1	SENSOR-5	SENSOR-1	SENSOR-5
4	0	Sensing	App1_SENSOR_APP	SENSOR-1	SENSOR-5	SENSOR-1	SENSOR-5
5	0	Sensing	App1_SENSOR_APP	SENSOR-1	SENSOR-5	SENSOR-1	SENSOR-5
6	0	Sensing	App1_SENSOR_APP	SENSOR-1	SENSOR-5	SENSOR-1	SENSOR-5
7	0	Sensing	App1_SENSOR_APP	SENSOR-1	SENSOR-5	SENSOR-1	SENSOR-5
8	0	Sensing	App1_SENSOR_APP	SENSOR-1	SENSOR-5	SENSOR-1	SENSOR-5

Figure 3-44: Direct communication between node 1 and node 5 in packet Animation window

- 5. For the same example, configure static routes such that the packets will go through Wireless Sensor 1 to Wireless Sensor 5 via SDN Controller. To configure the static routes in SDN Controller for Wireless Sensor 1 follow the above step 3 as explained above
- 6. Type the following commands on the NetSim CLI console, in the <DeviceName with Device ID> route add <destination IP address> MASK <subnet mask> <gateway IP address> <metric> if <interface #> format.
 - a. Wireless_Sensor_1 route ADD 192.168.0.6 MASK 255.255.255.0 192.168.0.4 METRIC 1 IF 1
 - b. SDN_Controller route ADD 192.168.0.6 MASK 255.255.255.0 192.168.0.6 METRIC 1 IF 1

7. Interpret the results.
8. Open Packet trace and filter the CONTROL PACKET TYPE/APP NAME to show only APP1 SENSOR APP, you will see that data packet flow from wireless sensor 1 to wireless sensor 5 through SDN Controller.

PACKET_ID	SEGMENT_ID	PACKET_TYPE	CONTROL_PACKET_TYPE/APP_NAME	SOURCE_ID	DESTINATION_ID	TRANSMITTER_ID	RECEIVER_ID
9	0	Sensing	App1_SENSOR_APP	SENSOR-1	SENSOR-5	SENSOR-1	SENSOR-5
10	0	Sensing	App1_SENSOR_APP	SENSOR-1	SENSOR-5	SENSOR-1	SENSOR-5
11	0	Sensing	App1_SENSOR_APP	SENSOR-1	SENSOR-5	SENSOR-1	SENSOR-5
12	0	Sensing	App1_SENSOR_APP	SENSOR-1	SENSOR-5	SENSOR-1	SENSOR-3
12	0	Sensing	App1_SENSOR_APP	SENSOR-1	SENSOR-5	SENSOR-3	SENSOR-5
13	0	Sensing	App1_SENSOR_APP	SENSOR-1	SENSOR-5	SENSOR-1	SENSOR-3
13	0	Sensing	App1_SENSOR_APP	SENSOR-1	SENSOR-5	SENSOR-3	SENSOR-5
14	0	Sensing	App1_SENSOR_APP	SENSOR-1	SENSOR-5	SENSOR-1	SENSOR-3
14	0	Sensing	App1_SENSOR_APP	SENSOR-1	SENSOR-5	SENSOR-3	SENSOR-5
15	0	Sensing	App1_SENSOR_APP	SENSOR-1	SENSOR-5	SENSOR-1	SENSOR-3
15	0	Sensing	App1_SENSOR_APP	SENSOR-1	SENSOR-5	SENSOR-3	SENSOR-5
16	0	Sensing	App1_SENSOR_APP	SENSOR-1	SENSOR-5	SENSOR-1	SENSOR-3
16	0	Sensing	App1_SENSOR_APP	SENSOR-1	SENSOR-5	SENSOR-3	SENSOR-5
17	0	Sensing	App1_SENSOR_APP	SENSOR-1	SENSOR-5	SENSOR-1	SENSOR-3
17	0	Sensing	App1_SENSOR_APP	SENSOR-1	SENSOR-5	SENSOR-3	SENSOR-5
18	0	Sensing	App1_SENSOR_APP	SENSOR-1	SENSOR-5	SENSOR-1	SENSOR-3
18	0	Sensing	App1_SENSOR_APP	SENSOR-1	SENSOR-5	SENSOR-3	SENSOR-5
19	0	Sensing	App1_SENSOR_APP	SENSOR-1	SENSOR-5	SENSOR-1	SENSOR-3
19	0	Sensing	App1_SENSOR_APP	SENSOR-1	SENSOR-5	SENSOR-3	SENSOR-5

Figure 3-45: Communication between Sensor 1 & SDN Controller & Sensor 5 in packet trace window

4 Latest FAQs

1. You can refer to the up-to-date FAQs about NetSim’s SDN library at <https://tetcos.freshdesk.com/support/solutions/folders/14000122307>.