NetSim®

Accelerate Network R & D

Vehicular Adhoc Networks (VANETs)

A Network Simulation & Emulation Software

By

TETCOS LLP

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Table of Contents

1 Introduction

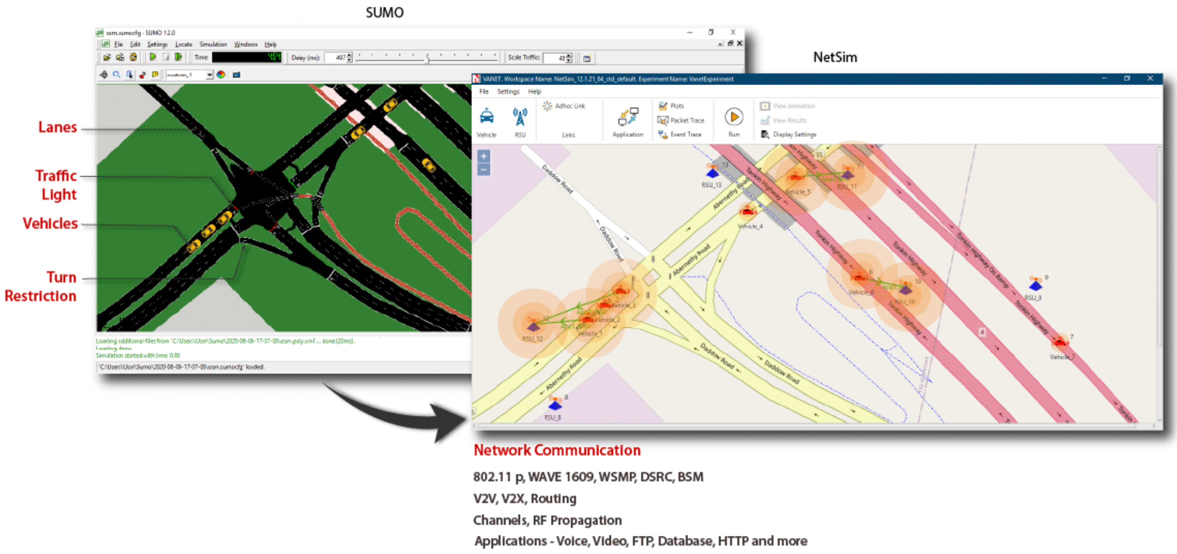
Note: NetSim VANET component is available only in standard and pro versions

The vehicular communication architecture in NetSim is based on a combination of the IEEE 1609 standard and IEEE 802.11p standard. 802.11p standard defines PHY and MAC layers while upper layers are defined by IEEE1609.

The following are the important features of the NetSim VANET library that are integrated to operate together in a harmonious fashion:

- IEEE 802.11p PHY operating in the 5.9 GHz band with a channel bandwidth of 10 MHz.
- Radio propagation modeling in the PHY layer covering pathloss, shadowing and fading.
- IEEE 802.11p MAC layer. Stations communicate directly outside the context of a BSS.
- IEEE 1609-2, which defines security services for application messages and management messages in WAVE.
- IEEE 1609-3, which defines connection set up and management of WAVE compliant devices.
- IEEE 1609-4, which sits on top of 802.11p layers. It enables upper layer operational aspects across multiple channels without knowledge of Physical layer parameters.
- DSRC SAE J2735
- BSM packets are transmitted using WSMP.
- L3 IP routing via DSR, AODV, OLSR or ZRP for non-BSM packets
- Vehicular mobility through in-built mobility models or through interfacing with SUMO software
- Interfacing between SUMO & NetSim via Traffic control interface (TraCI). Automatic import of road network and vehicle mobility from SUMO
- Wide range of output metrics including Delay, Throughput, Error, Retransmission, etc.
- Protocol source C code is provided along with NetSim software.

In VANETs, Vehicles and roadside units (RSUs) are the communicating nodes, providing each other with information, such as safety warnings and traffic information. Both types of nodes are dedicated short-range communications (DSRC) devices. The RSU is a WAVE device usually fixed along the roadside or in dedicated locations such as at junctions or near parking spaces. In NetSim, users can model network traffic between vehicles V2V and between vehicle to infrastructure V2I.



NetSim SUMO interfacing for VANET simulation

2 Simulation GUI

2.1 Create Scenario

- Open NetSim and click **New Simulation → Vehicular Adhoc Network (Vanet)** as shown Figure 2-1.

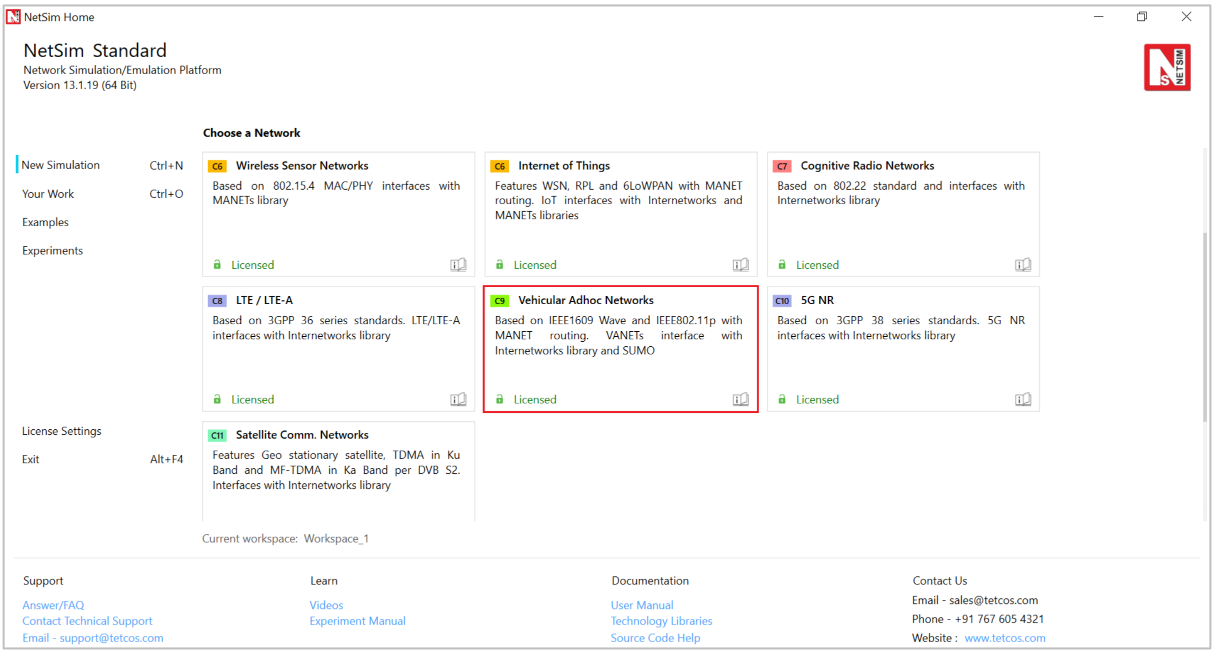


Figure 2-1: NetSim Home Screen

- A dialogue box appears as shown below, in that browse the Sumo Configuration File path. The general format of such file is **"*.Sumo.cfg".**

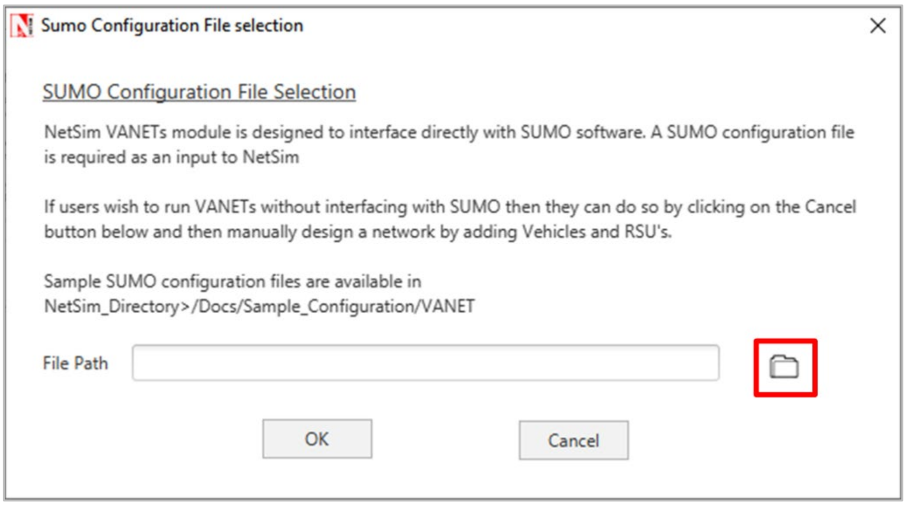


Figure 2-2: Sumo Configuration File path

- NetSim VANET module is designed to interface directly with SUMO.
- A SUMO configuration file is required as an input to NetSim.
- Sample SUMO configuration files are available inside <NetSim-Installation-Directory>**\Docs\Sample_Configuration\VANET** folder.

- Users can either use a Sumo configuration file which is provided inside NetSim's installation directory or use a different user specified SUMO configuration file. This .cfg file contains the path of NETWORK file and VEHICLES file.
- Further help on how to create SUMO configuration files is available at **http://sumo.dlr.de/wiki/Networks/Building_Networks_from_own_XML-descriptions**.

After selecting the Sumo configuration file name, the scenario is opened, with nodes placed at their respective starting positions (tracked from Sumo). Roads and Traffic Lights are also placed exactly as present in SUMO Configuration file.

2.2 Devices specific to NetSim VANETs Library

- **Vehicle:** A Vehicle is a 5-layer device that can be connected to an RSU through an Adhoc link. It supports only 1 Wireless interface and has its own IP and MAC Addresses.
- **Roadside Unit (RSU):** A devices which is used for V2I Communication. It is a 5-layer device that can be connected to a Vehicle or to a Router. It supports 1 wireless interface and 1 Serial interface and has its own IP and MAC Addresses.
- **Wired node:** A Wired node can be an end-node or for a server. It is a 5-layer device that can be connected to a switch and router. It supports only 1 Ethernet interface and has its own IP and MAC Addresses.
- **Wireless Nodes:** A Wireless node can be an end-node or a server. It is a 5-layer wireless device that can be connected to an Access point. It supports only 1 Wireless interface and has its own IP and MAC Addresses.
- **L2 Switch:** Switch is a layer-2 device that uses the devices' MAC address to make forwarding decisions. It does not have an IP address.
- **Router:** Router is a layer-3 device and supports a maximum of 24 interfaces each of which has its own IP address.
- **Access point:** Access point (AP) is a layer-2 wireless device working per 802.11 WiFi protocol. It can be connected to wireless nodes via wireless links and to a router or a switch via a wired link.

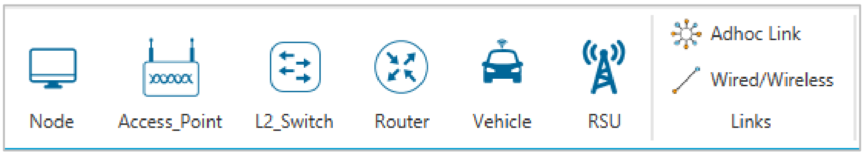


Figure 2-3: VANET Library Device Palette in GUI

2.3 Set Node, Link and Application Properties

- Right click on the appropriate node or link and select Properties. Then modify the parameters according to the requirements.

- Routing Protocol in Network Layer and all user editable properties in Data Link Layer few properties are Global or Local, Physical Layer and Power are Local.
- In Physical layer standards are acting as Link global.
- In the General properties, Mobility Model is set to SUMO, and it is Editable. This signifies that the Node movements will be traced from SUMO.
- File name gives the path to Sumo Configuration file that was given by the user.
- Step Size is taken from the Sumo Configuration file specified which tells the amount of time paused in sumo corresponding to single step of SUMO Simulation.
- In interface_wireless properties, under Physical layer, by default Standard is set to IEEE 802.11p in case of VANET.
- The following are the important properties of VANET Wireless Node (RSU/Vehicle) in Data link and Physical layers.

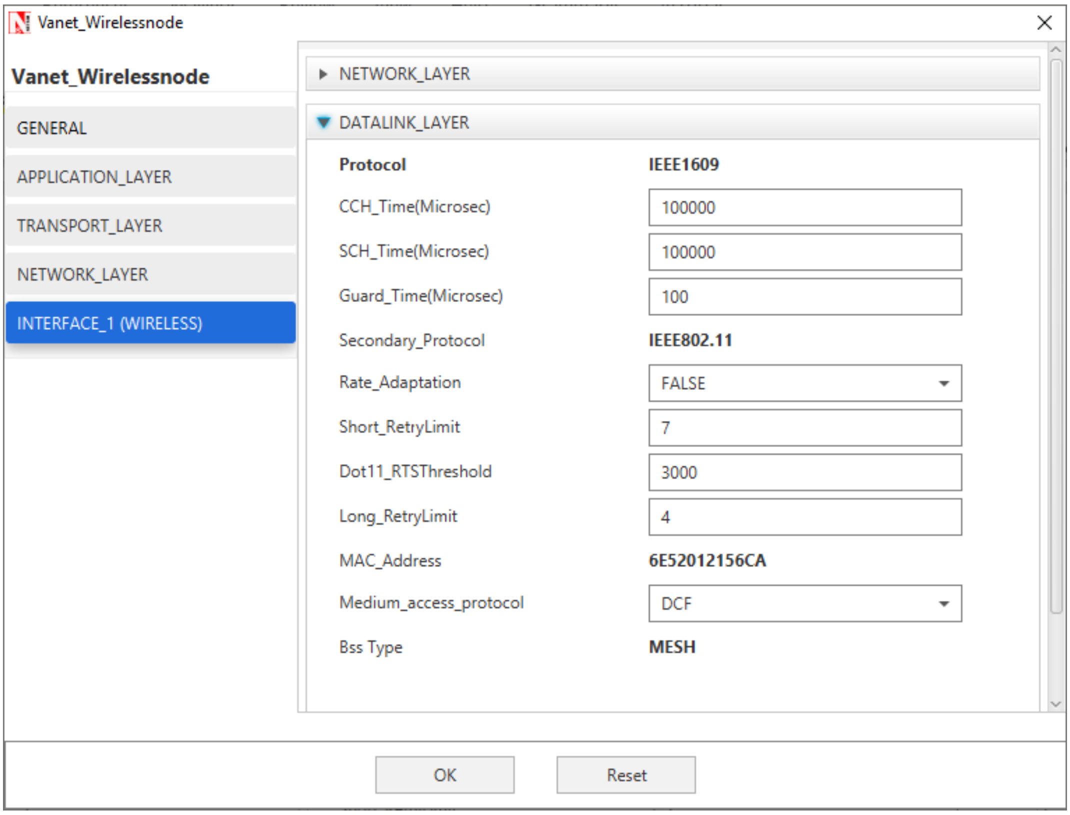


Figure 2-4: Vanet > Datalink layer Properties Window

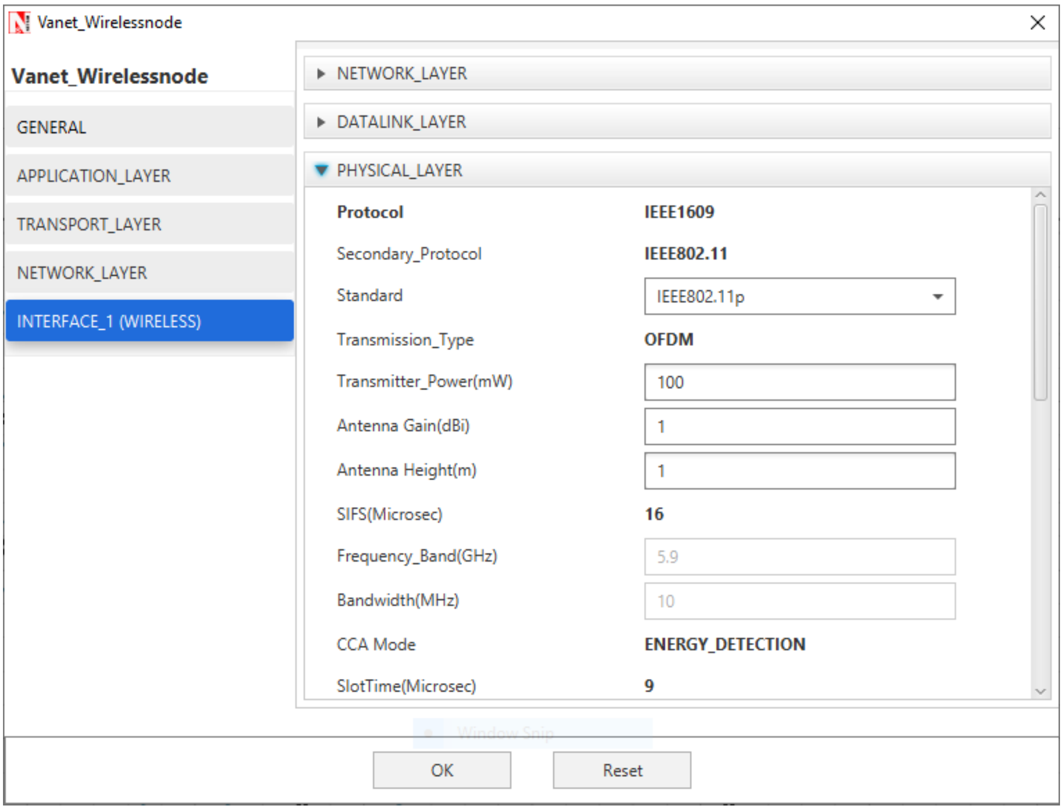


Figure 2-5: Vanet > Physical layer Properties Window

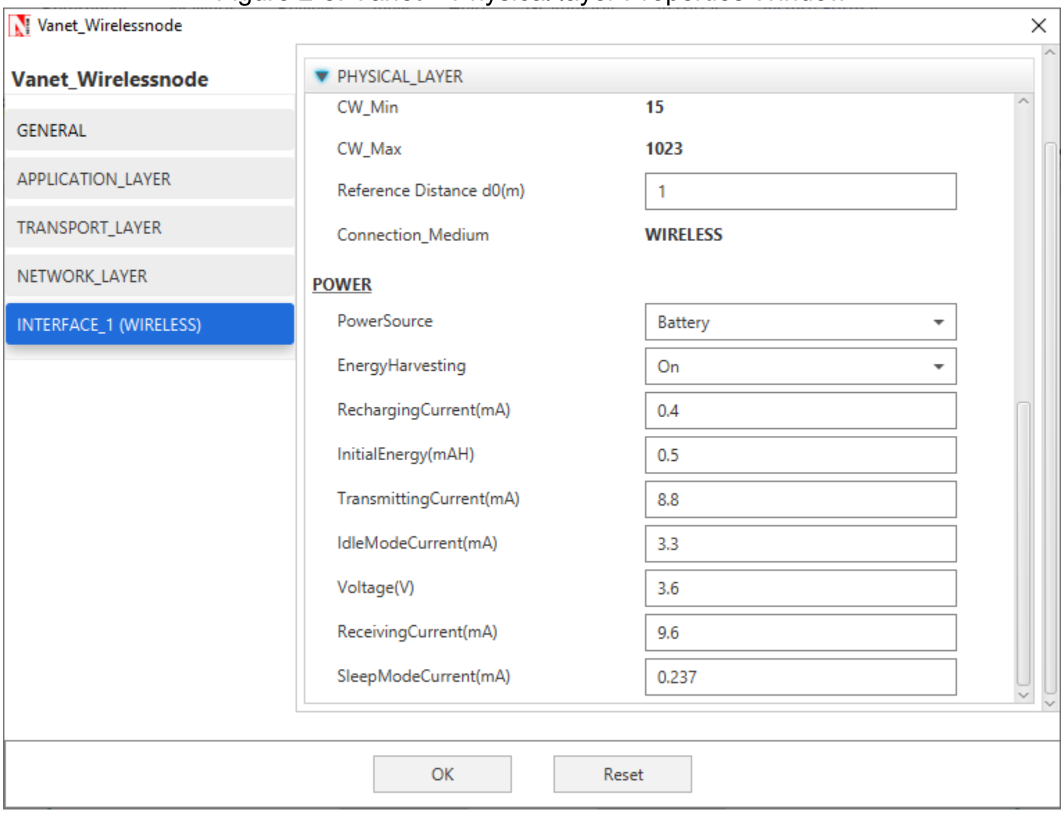


Figure 2-6: Vanet > Physical layer Properties Window > Battery Model

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

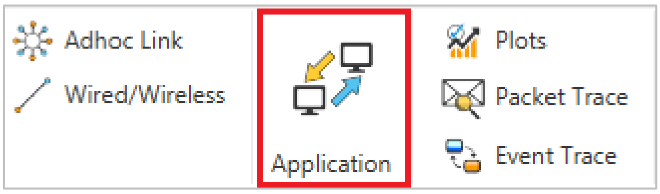


Figure 2-7: Application icon present on top ribbon

- Set the values according to requirement and click OK.

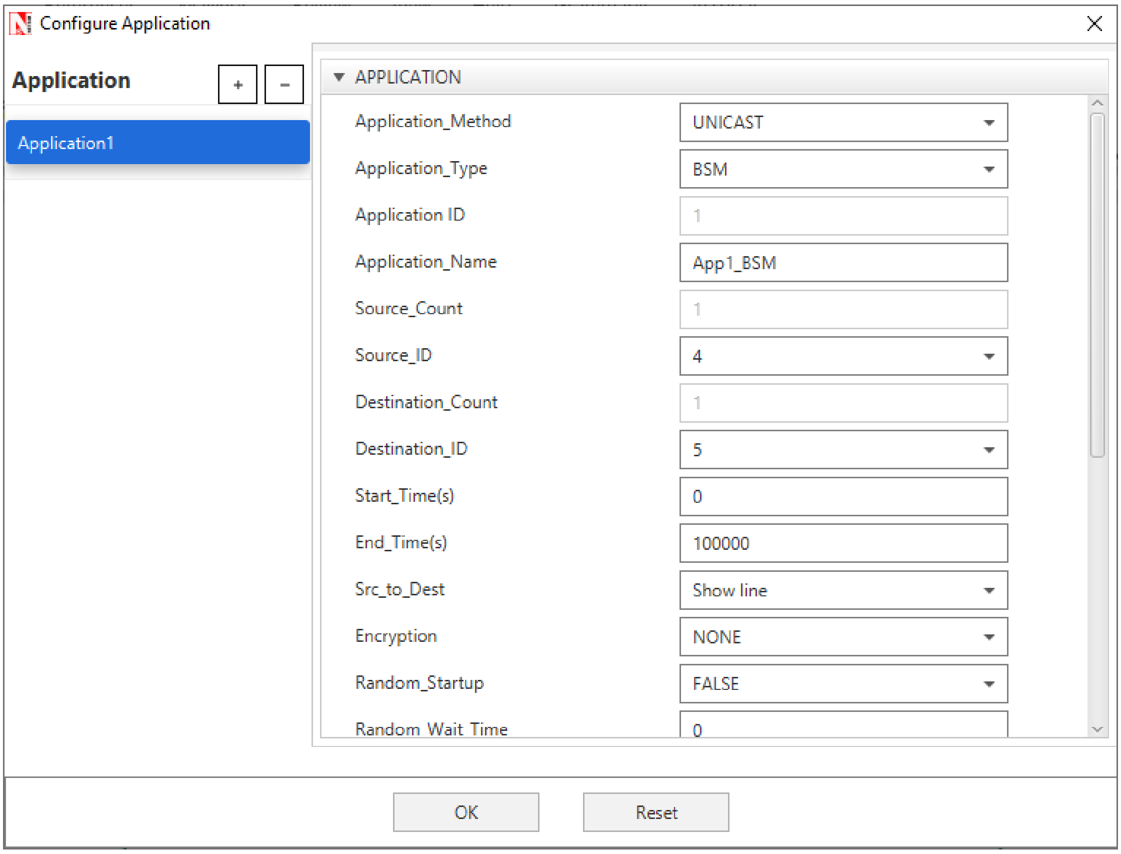


Figure 2-8: Application Configuration window

Detailed information on Application properties is available in **section 6** of NetSim User Manual.

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

Click Packet Trace / Event Trace icon in the tool bar and click OK. To get detailed help, please refer **sections 8.4 and 8.5** in User Manual. Select Plots icon for enabling Plots and click OK.

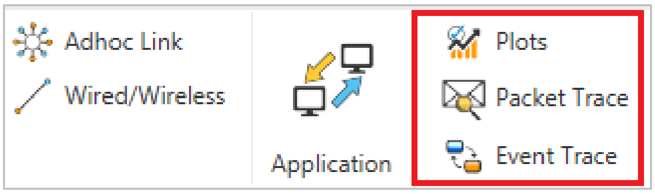


Figure 2-9: Enable Packet Trace, Event Trace & Plots options on top ribbon

2.5 Run Simulation

Click on **Run Simulation** icon on the top toolbar. Simulation Time is set from the Configuration File of Sumo. The simulation has three options.

- **Record animation** - which runs Sumo in background. Users can view animation after completion of Simulation.

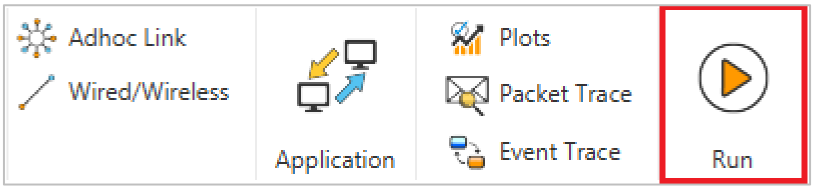


Figure 2-10: Run Simulation option on top ribbon

- **Play & Record animation** – Opens NetSim GUI and Sumo GUI in parallel with parameters being continuously passed between the two Simulators.
- **Don't play/record animation** – runs Sumo in Backend. Animation is not recorded.

On running the Simulation by selecting **Play & Record** option, users can view NetSim Packet animation and SUMO simulation simultaneously.

SUMO determines the positions of vehicles with respect to time as per the road conditions. NetSim reads the coordinates of vehicles from SUMO (through pipe) during runtime and uses it as input for vehicles mobility.

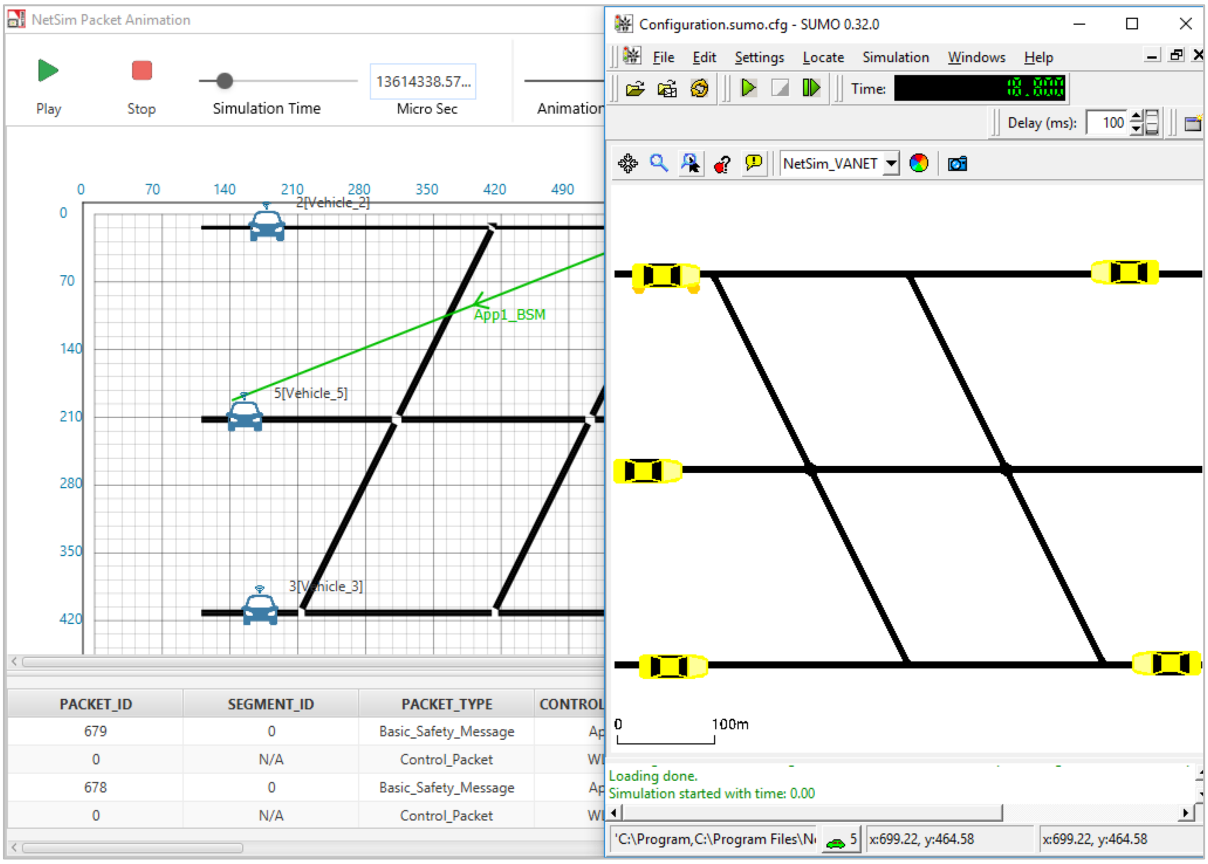


Figure 2-11: Vehicle moments on NetSim Packet animation and SUMO simulation window simultaneously

Users can see the movement of vehicles in SUMO and observe equivalent movement in NetSim. Here users can notice an inversion of view in the GUI, since origin (0, 0) in SUMO is at the left bottom, while origin is at the left top in NetSim.

When users select **Play and Record animation** option, NetSim and SUMO run separately, and users will find that the animation in SUMO is much faster than that of NetSim. This is because, NetSim has to animate the flow of packets between the vehicles in addition to the vehicle movement.

3 Model Features

3.1 Implementation of the 802.11p in NetSim

- Adhoc Wi-fi MAC allowing for STA transmission of data frames outside the context of a BSS.
- Immediate communication with no establishment of a BSS. No authentication or association
- Supports a channel bandwidth of 10 MHz in the 5.9 GHz band
- Supported PHY rates are 3, 4.5, 6, 9, 12, 18, 24 and 27 Mbps. The rate is auto determined at the sender based on the target packet error probability at the receiver (target PEP 0.1, 1000 B packets)
- Transmission type - OFDM
- Slot time - 9μs, SIFS - 16μs
- Uses a Medium Access Control (MAC) protocol based on the Carrier Sense Multiple Access Collision Avoidance (CSMA/CA) protocol
  - This means that when a node wants to send a message, the channel must be idle for a duration of SIFS. If the channel is idle, it starts transmission.
  - When a node finds the channel busy, it chooses a random backoff time from the interval [0, CW] and transmits only when the backoff timer has elapsed. The variable CW represents the size of the Contention Window.
  - When the SCH is used and a node does not receive an acknowledgement for a message, it concludes that the message has collided and is lost, so the value of CW is doubled, and it will retry transmission.
  - In the CCH however, beacons are broadcast in the channel and no acknowledgments are sent. Therefore, the value of CW is never doubled in the CCH.

3.2 DSRC Channels: CCH and SCH

- **Control channel (CCH):** A single radio channel, not a service channel, intended for the exchange of management information, including Wireless Access in Vehicular Environments (WAVE), Service Advertisements, and WAVE Short Messages.
- **Service channel (SCH):** Any channel that is not the control channel, intended for management frames and higher layer information exchanges (Wireless Access in Vehicular Environments [WAVE] Short Message [WSMs].
- **Guard interval:** A time interval at the start of each control channel (CCH) interval and service channel (SCH) interval during which devices that are switching channels do not transmit.

3.3 BSM Application

- DSRC protocol runs with BSM (Basic Safety Message) applications
- BSM is a broadcast packet transmitted at a regular interval, and it can be classified as a beacon style transmission.
- The BSM Application class sends and receives the IEEE 1609 WAVE (Wireless Access in Vehicular Environments) Basic Safety Messages (BSMs). The BSM is a 20-byte packet that is generally broadcast from every vehicle at a nominal rate of 10 Hz. In Netsim this can be configured as a broadcast or as a unicast application.
- This application does not follow the IP stack. It runs WSMP protocol over IEEE 1609. There is no routing, static routes cannot be set, and packets are sent directly to the destination.

3.4 NetSim – SUMO interfacing

NetSim's VANET module allows users to interface with SUMO which is an open-source road traffic simulation package designed to handle vehicular & road networks. The road traffic simulation is done by SUMO while NetSim does the network simulation along with RF propagation modelling in the physical layer. While SUMO Simulates the road traffic conditions and movements, NetSim Simulates the communication occurring between the Vehicles.

NetSim and SUMO are interfaced using 'pipes'. A pipe is a section of shared memory that processes use for communication. SUMO process writes information to pipe, then NetSim process reads the information from pipe. On running the Simulation, SUMO determines the positions of vehicles with respect to time as per the road conditions. NetSim reads the coordinates of vehicles from SUMO (through pipes) in runtime and uses it as input for vehicles mobility.

Users will notice an inversion along X axis in the NetSim GUI, since origin (0, 0) in SUMO is at the left bottom, while origin is at the left top in NetSim.

VANET operates in wireless environment and hence RF channel loss occurs. The amount of loss can be configured by users. To modify the Wireless channel characteristics users can right click on the adhoc/wireless link and modify the channel characteristics as per the requirement.

Source code related to interfacing of SUMO and NetSim is available in Sumo_interface.c file inside the mobility folder/project.

3.5 How to create a VANET using SUMO and simulate with NetSim

A SUMO network can be created either **manually** or using **SUMO NetEdit.**

3.5.1 Using SUMO NetEdit utility and randomtrips.py to configure road traffic models

Netedit is a Road network editor for the road traffic simulation in SUMO. Using this utility, users can quickly design road networks and obtain Network xml file which is part of SUMO configuration.

Steps to create a simple SUMO network using netedit utility

Step 1: Open **netedit** from **<SUMO_INSTALL_DIRECTORY>/bin** (C:\Program Files (x86)\Eclipse\Sumo\bin) and select **File-->New Network**

Refer SUMO Documentation: ***"http://sumo.dlr.de/wiki/NETEDIT" for more details on modes of operation.***

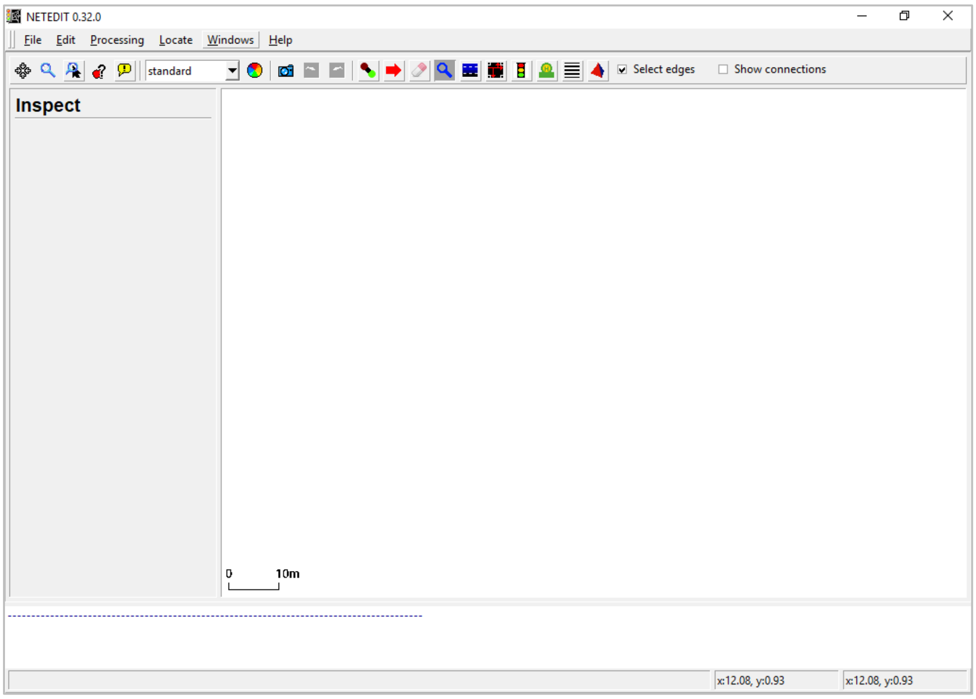


Figure 3-1: SUMO NetEdit Screen

Step 2: Select Creating junction and edges option as shown below or click on character "**e**" in the keyboard.

Step 3: Enable the check boxes "**chain**", "**two-way**" **and "Grid"** which are present in the right-side corner.

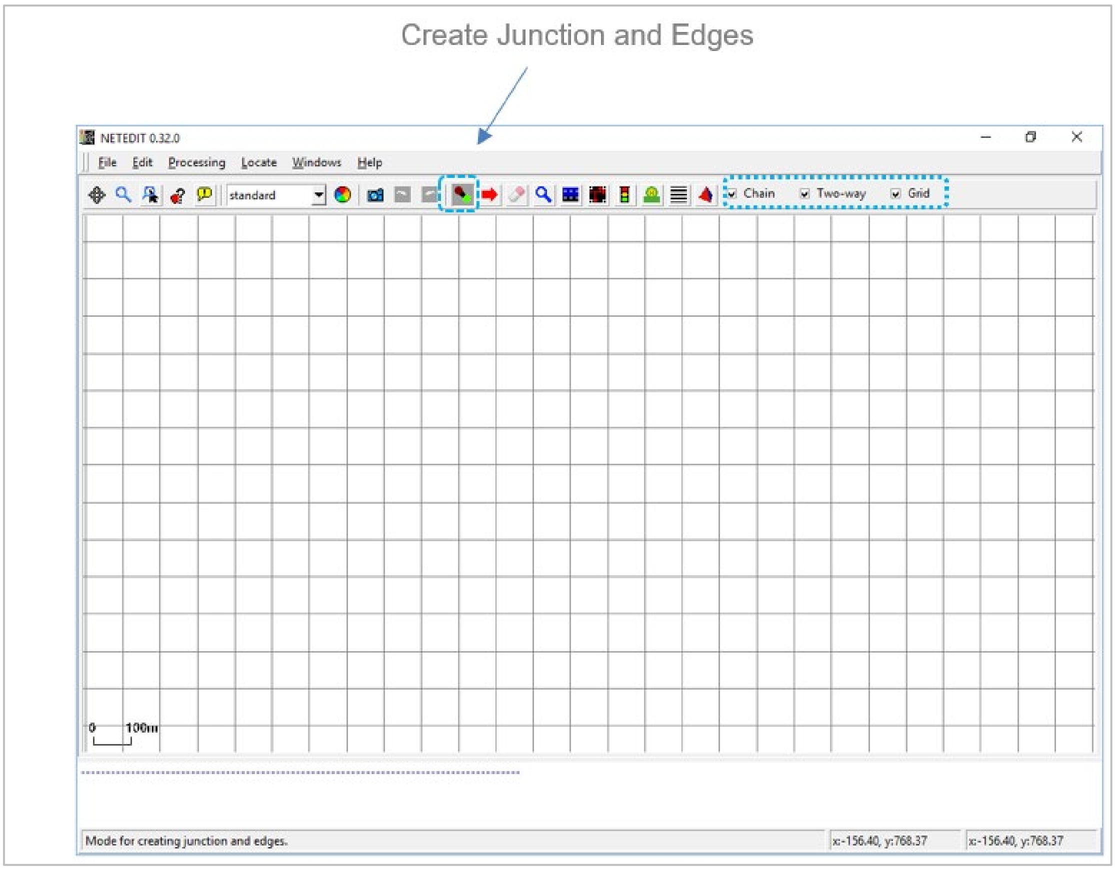


Figure 3-2: SUMO NetEdit design window

Step 4: Adjust the design area to ensure that the road network lies in the **Positive XY** quadrant. This will help in avoiding complexities when opening the network scenario in NetSim.

Step 5: Click on grid area to create edges, clicking again will create a new edge which will automatically get connected to the previous edge as shown below.

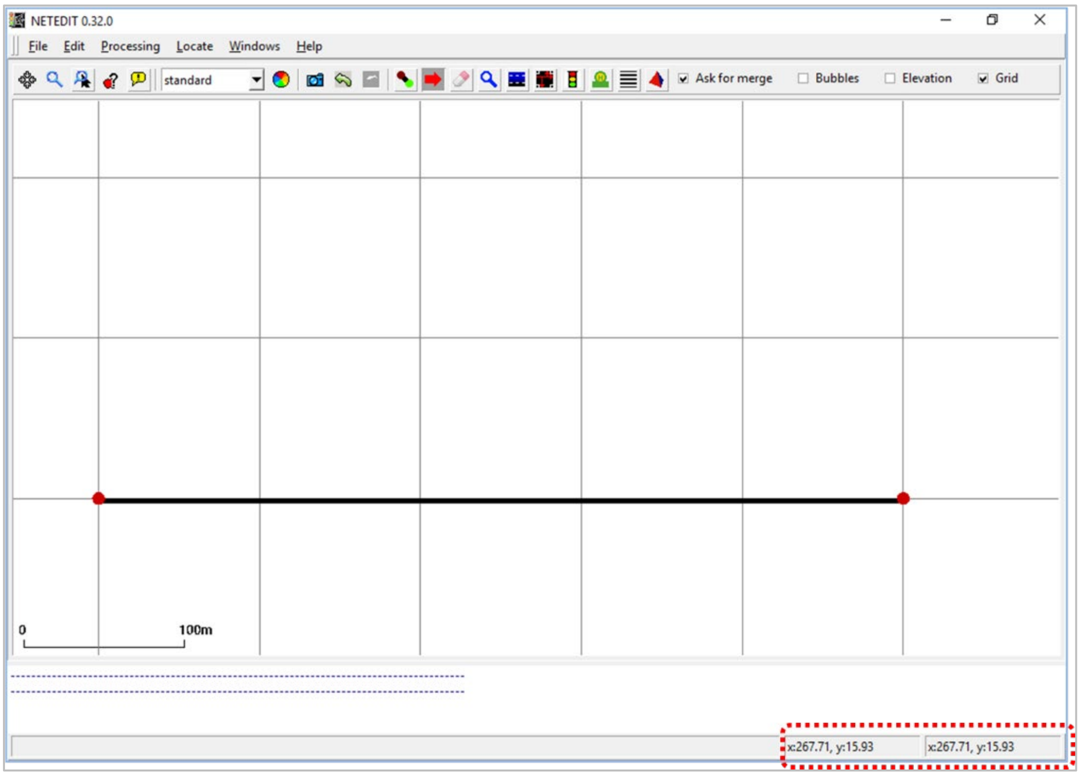


Figure 3-3: Creating edges SUMO NetEdit design window

Step 6: Select "**(t) Traffic Lights**". Select the junctions and click on **Create TLS** button on the left to add Traffic Signal to it.

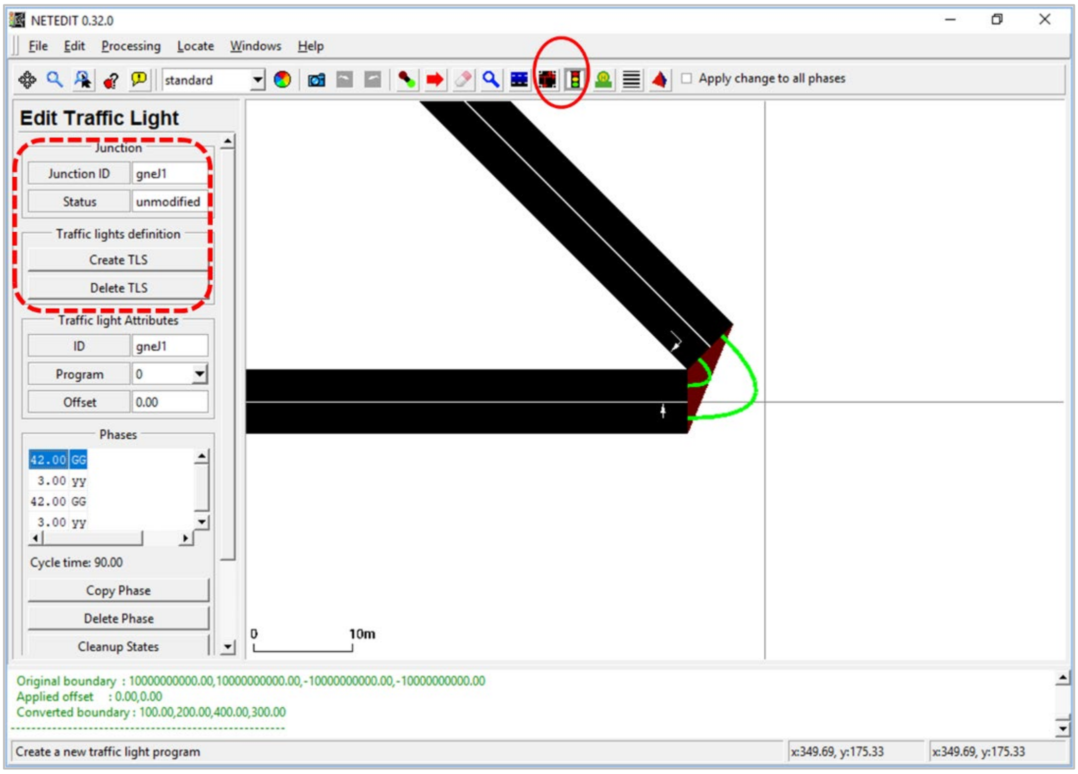


Figure 3-4: Adding Traffic Signal to Network

Step 7: Select "**(c) Connect**" icon Select the lanes and ensure connectivity between them.

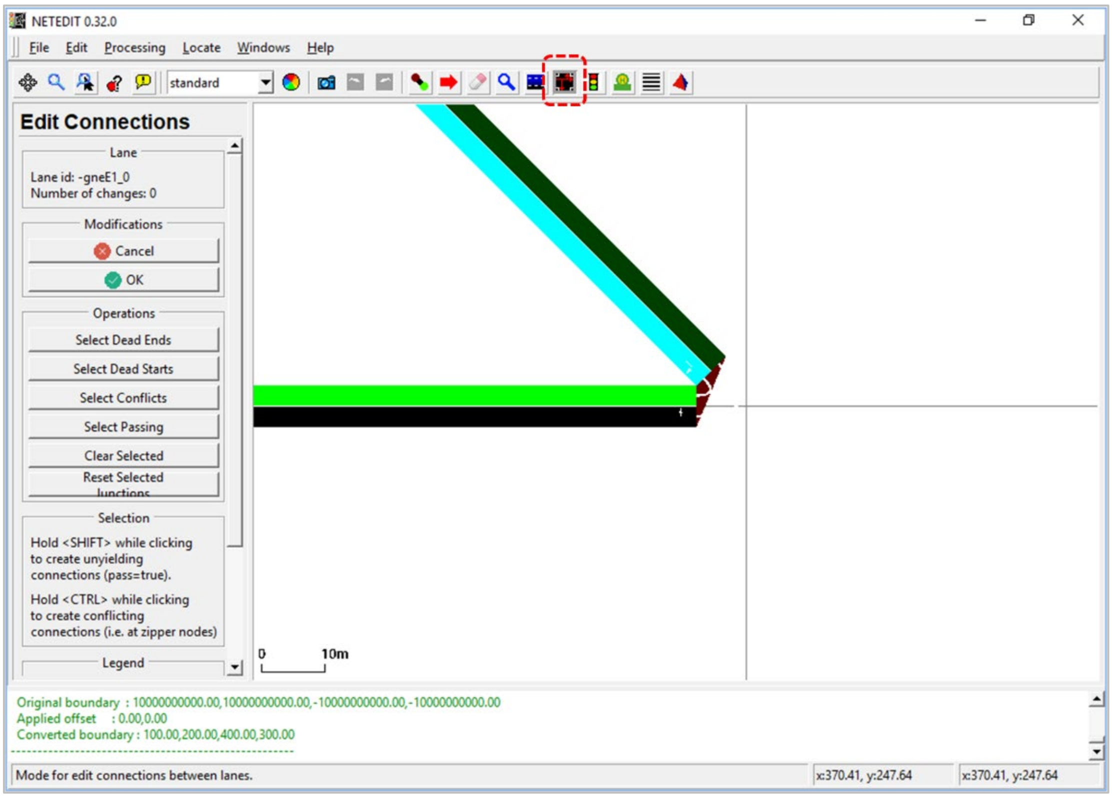


Figure 3-5: Select the lanes and connectivity between them

Step 8: Create a new folder and save the network file (***.net.xml**) over there, say with a name **network.net.xml**

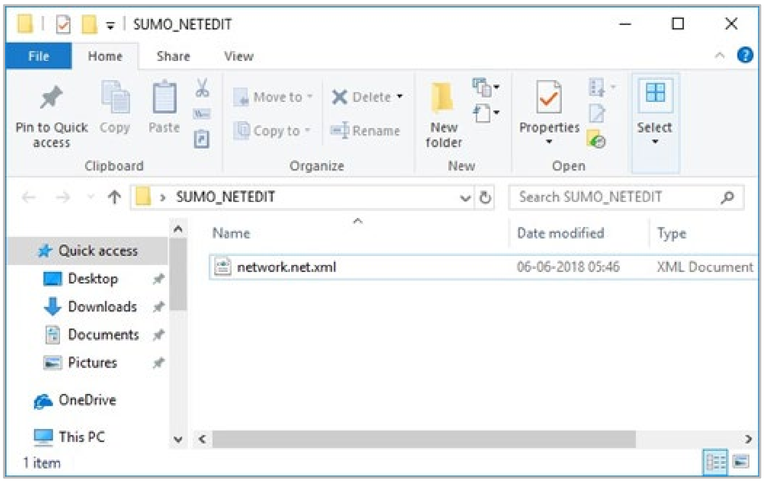


Figure 3-6: network.net.xml inside the folder

Step 9: Open command prompt with the current working directory as the folder where you have saved the network file in the previous step.

Step 10: Using **randomtrips.py** utility present in **<SUMO_INSTALL_DIRECTORY>/tools** directory create trips file with the command.

COMMAND SYNTAX >" C:\Program Files (x86)\Eclipse\Sumo\tools\randomTrips.py" -n " ***.net.xml**" -e <**NO_OF_TRIPS**> --route-file "**trips.xml**"

Example Command >" C:\Program Files (x86)\Eclipse\Sumo\tools\randomTrips.py" -n "network.net.xml" -e 2 --route-file "trips.xml"

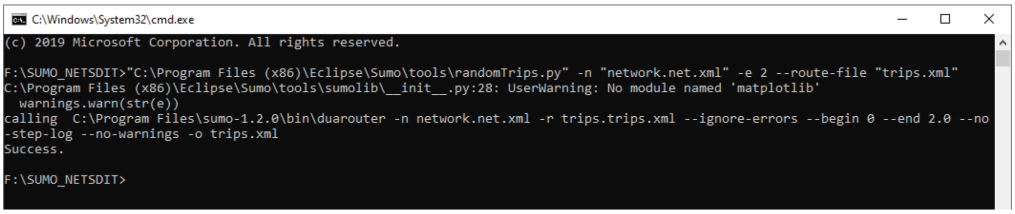


Figure 3-7: Generating route file (trips.xml)

This will create a trips file in your folder along with associated files.

Step 11: Create a SUMO configuration file (***sumo.cfg**) which points to the network and trips file, in your folder which contains the network and route file.

Refer: http://sumo.dlr.de/wiki/Tutorials/Hello_Sumo

Include parameter (To Run in NetSim)

"<step-length value="0.4"/>"

Following is a sample SUMO Configuration:

<configuration>

<input>

<net-file value="network.net.xml"/>

<route-files value="trips.trips.xml"/>

</input>

<time>

<begin value="0"/>

<end value="100"/>

<step-length value="0.4"/>

</time>

</configuration>

Note: *Save above content as* ***Configuration.sumo.cfg***

You can copy the above contents to create a SUMO configuration file in your folder.

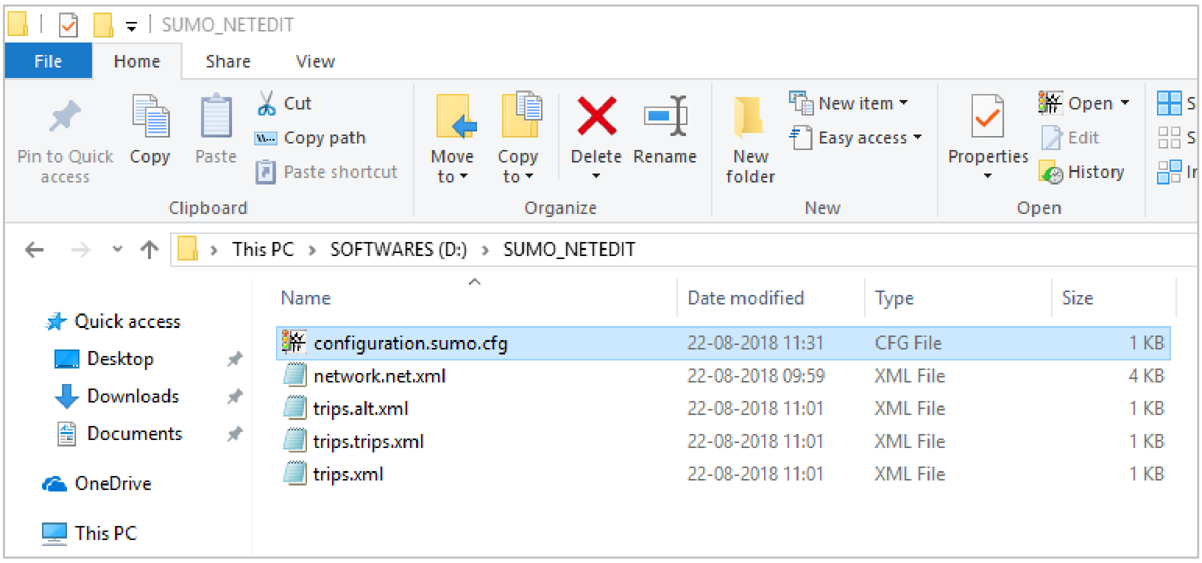


Figure 3-8: Double click on Configuration.sumo.cfg

Step 12: Open Configuration.sumo.cfg by double clicking or open SUMO using **sumo-gui.exe** present in **<SUMO_INSTALL_DIRECTORY>/bin**. Open scenario in SUMO using **Open->Simulation** and verify whether the network loads and simulation happens as per the configuration done.

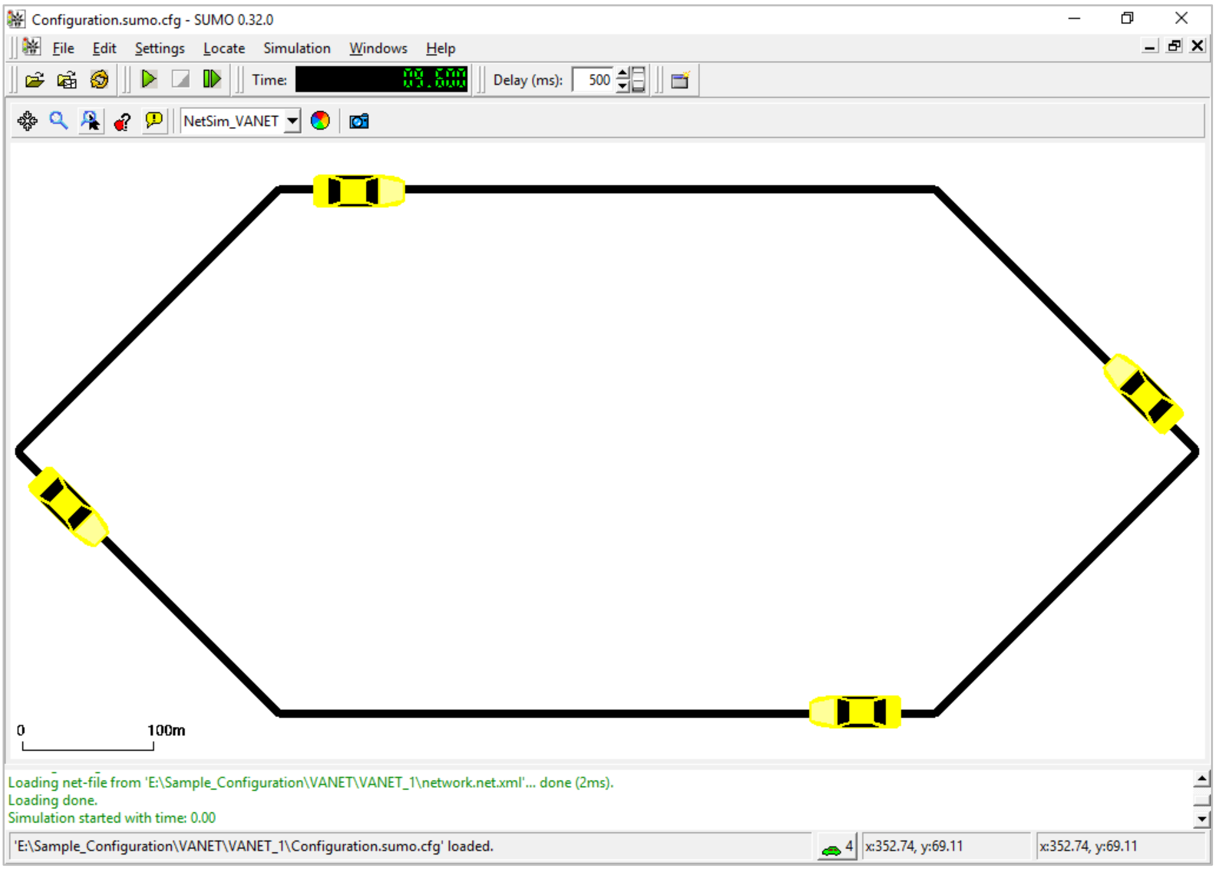


Figure 3-9: SUMO simulation window

Step 13: Open the SUMO scenario via NetSim VANET by selecting VANET under the New Simulation in the NetSim Home Screen. Browse and locate the SUMO Configuration file present in your directory to load the road traffic network in NetSim GUI. The road network created in SUMO will be automatically replicated in NetSim GUI environment.

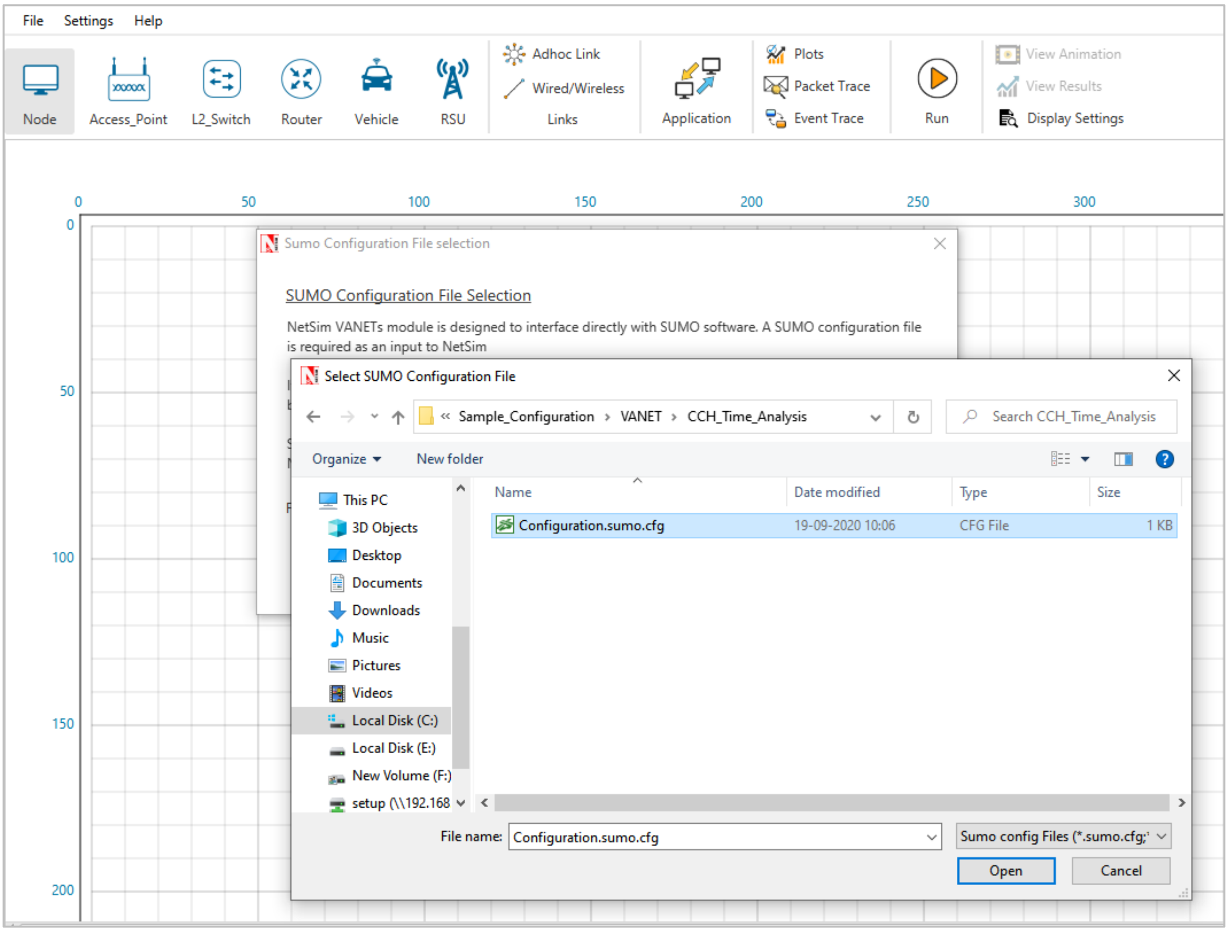


Figure 3-10: Importing a sumo network configuration into NetSim

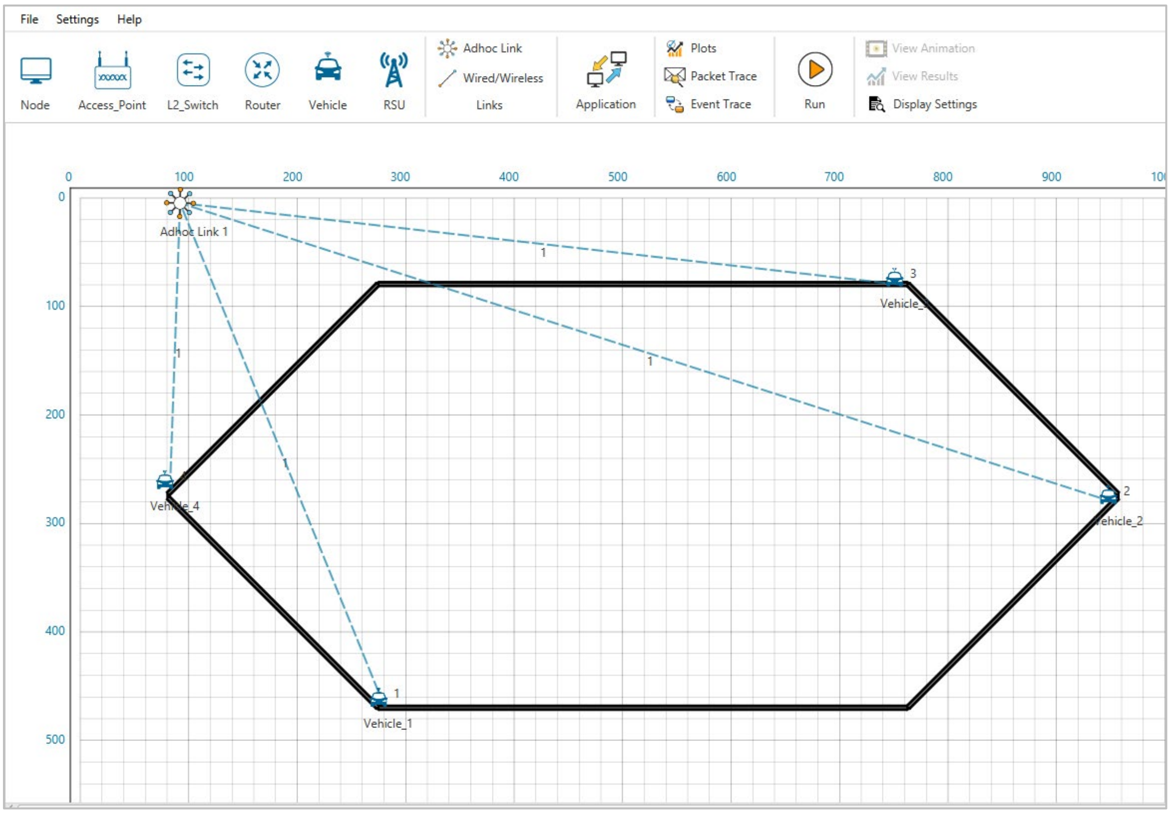


Figure 3-11: Network Topology in this experiment

Step 14: Configure traffic between vehicles using the Application icon, enable trace files

And plots

Step 15: Click on Run Simulation button. The **Simulation Time** is equal to the end time specified in sumo configuration (**sumo.cfg**) file and Simulation Time option is Non editable.

3.5.2 Creating your own network in SUMO manually

Step 1: Create a node file using any code editor (like notepad, notepad++ etc.) and the file extension will be.nod.xml. It represents the junctions in the road. Each of these attributes has a certain meaning and value range: node_id means unique name of each junction, x-y is the positions of node and type can be "priority", "traffic_light", "rail_crossing", “rail_ signal”etc.(Refer: https://sumo.dlr.de/wiki/Networks/PlainXML#Node_Descriptions).

NODES.nod.xml

```
<nodes>
<node id="n0" x="100" y="300" type="priority"/>
<node id="n1" x="300" y="300" type="traffic_light"/>
<node id="n2" x="500" y="300" type="rail_crossing"/>
<node id="n3" x="700" y="300" type="priority"/>
<node id="n4" x="300" y="100" type="traffic_light"/>
<node id="n5" x="500" y="100" type="traffic_light"/>
</nodes>
```

Figure 3-12: Device Positions in nodes file

Step 2: Create an edge file that describes how the junctions or nodes are connected to each other. The extension of this file is .edg.xml. Each edge is unidirectional and starts at the "from"-node and ends at the "to"-node. For each edge, some further attributes should be supplied, being the number of lanes, the edge has (numLanes), the maximum speed allowed on the edge speed. Furthermore, the priority may be defined optionally. (Refer: https://sumo.dlr.de/wiki/Networks/PlainXML#Edge_Descriptions).

EDGE.edg.xml

```
<edges>
<edge id="L01" from="n1" to="n0" priority="75" nolanes="2" speed="40"/>
<edge id="R01" from="n0" to="n1" priority="75" nolanes="2" speed="40"/>
<edge id="L12" from="n2" to="n1" priority="75" nolanes="2" speed="30"/>
<edge id="R12" from="n1" to="n2" priority="75" nolanes="2" speed="30"/>
<edge id="L23" from="n3" to="n2" priority="75" nolanes="2" speed="30"/>
<edge id="R23" from="n2" to="n3" priority="75" nolanes="2" speed="30"/>
<edge id="D04" from="n0" to="n4" priority="75" nolanes="2" speed="60"/>
<edge id="U04" from="n4" to="n0" priority="75" nolanes="2" speed="60"/>
<edge id="D14" from="n1" to="n4" priority="75" nolanes="2" speed="40"/>
<edge id="U14" from="n4" to="n1" priority="75" nolanes="2" speed="40"/>
<edge id="D35" from="n3" to="n5" priority="75" nolanes="2" speed="60"/>
<edge id="U35" from="n5" to="n3" priority="75" nolanes="2" speed="60"/>
<edge id="D25" from="n2" to="n5" priority="75" nolanes="2" speed="40"/>
<edge id="U25" from="n5" to="n2" priority="75" nolanes="2" speed="40"/>
<edge id="L45" from="n5" to="n4" priority="75" nolanes="2" speed="40"/>
<edge id="R45" from="n4" to="n5" priority="75" nolanes="2" speed="40"/>
</edges>
```

Figure 3-13: Edge file

Step 3: Open Command Prompt and change the directory to the binary folder of sumo using cd command. **“cd C:\Program Files (x86)\Eclipse\Sumo\bin”**

C:\Windows\System32\cmd.exe

```
Microsoft Windows [Version 10.0.18362.657]
(c) 2019 Microsoft Corporation. All rights reserved.

C:\Program Files (x86)\Eclipse\Sumo\bin>
```

Figure 3-14: Open command prompt in installation directory

Step 4: Generate Network file by using NETCONVERT command. Make a folder named like VANET_Example and place the. nod.xml and .edg.xml files i.e. NODES.nod.xml and EDGE.edg.xml respectively.

netconvert --n “<path where the.nod.xml file is present>\<filename>.nod.xml” --e “<path where the .edg.xml file is present>\<filename>.edg.xml” --o “<path where both input files are present>\<filename>.net.xml”

```
C:\Windows\System32\cmd.exe
Microsoft Windows [Version 10.0.18362.657]
(c) 2019 Microsoft Corporation. All rights reserved.

C:\Program Files (x86)\Eclipse\Sumo\bin>netconvert --n "C:\Users\Leepika\Desktop\Vanet\nodeID.nod.xml" --e "C:\Users\Leepika\Des
ktop\Vanet\EDGE.edg.xml" --o "C:\Users\Leepika\Desktop\Vanet\NETWORK.net.xml"
Warning: Minor green from edge '1o' to edge '3o' exceeds 19.44m/s. Maybe a left-turn lane is missing.
Warning: The traffic light 'n5' does not control any links; it will not be build.
Warning: Could not build program '0' for traffic light 'n5'
Warning: Speed of turning connection '1fi_0->3fi_0' reduced by 41.27 due to turning radius of 13.85 (length=27.33 angle=135.00)
Warning: Speed of turning connection '1fi_1->3fi_1' reduced by 41.80 due to turning radius of 12.22 (length=23.92 angle=135.00)
Warning: Speed of turning connection '3si_0->1si_0' reduced by 45.88 due to turning radius of 3.08 (length=4.78 angle=135.00)
Warning: Speed of turning connection '3si_1->1si_1' reduced by 43.51 due to turning radius of 7.65 (length=14.35 angle=135.00)
Warning: Speed of turning connection '1o_1->3o_1' reduced by 25.74 due to turning radius of 15.58 (length=19.35 angle=90.00)
Warning: Speed of turning connection '4fi_0->2fi_0' reduced by 28.49 due to turning radius of 7.70 (length=9.03 angle=90.00)
Warning: Speed of turning connection '4fi_1->2fi_1' reduced by 27.00 due to turning radius of 11.64 (length=14.19 angle=90.00)
Warning: Speed of turning connection '4fi_1->1fi_1' reduced by 30.74 due to turning radius of 15.58 (length=19.35 angle=90.00)
Warning: Speed of turning connection '1si_0->3o_0' reduced by 33.49 due to turning radius of 7.70 (length=9.03 angle=90.00)
Warning: Speed of turning connection '2o_0->4si_0' reduced by 39.53 due to turning radius of 5.45 (length=9.74 angle=135.00)
Warning: Speed of turning connection '2o_1->4si_1' reduced by 37.58 due to turning radius of 10.02 (length=19.31 angle=135.00)
Warning: Speed of turning connection '3o_0->3si_0' reduced by 44.53 due to turning radius of 5.45 (length=9.74 angle=135.00)
Warning: Speed of turning connection '3o_0->3si_1' reduced by 43.47 due to turning radius of 7.75 (length=14.55 angle=135.00)
Warning: Speed of turning connection '3o_1->4o_1' reduced by 29.13 due to turning radius of 21.46 (length=27.05 angle=90.00)
Warning: Speed of turning connection '3fi_0->4o_0' reduced by 31.50 due to turning radius of 62.25 (length=32.17 angle=45.00)
Warning: Speed of turning connection '3fi_1->4o_1' reduced by 32.22 due to turning radius of 57.46 (length=29.67 angle=45.00)
Warning: Speed of turning connection '3fi_1->4fi_0' reduced by 41.24 due to turning radius of 13.94 (length=27.52 angle=135.00)
Warning: Speed of turning connection '3fi_1->4fi_1' reduced by 41.86 due to turning radius of 12.05 (length=23.57 angle=135.00)
Success.
```

Figure 3-15: Generating Network file by using NETCONVERT command

Step 5: Create a .rou.xml file that describes the direction of the vehicle’s movement.

```
VEHICLES.rou.xml
<routes>
  <!-- e -->
  <vehicle id="v0" depart="0.00">
    <route edges="D04 R45 U35 L23 L12 L01"/>
  </vehicle>

  <vehicle id="v1" depart="0.00">
    <route edges="R12 R23 D35 L45 U14 L01"/>
  </vehicle>

  <vehicle id="v2" depart="0.00">
    <route edges="R01 R12 R23 D35 L45 U04"/>
  </vehicle>

  <vehicle id="v3" depart="0.00">
    <route edges="R01 D14 R45 U35 L23 L12"/>
  </vehicle>

  <vehicle id="v4" depart="0.00">
    <route edges="D35 L45 U14 R12 D25 U35 L23"/>
  </vehicle>

  <vehicle id="v5" depart="0.00">
    <route edges="R45 U25 L12 L01 D04 R45"/>
  </vehicle>

 </routes>
```

Figure 3-16: Direction of the vehicle’s movement

Step 6: Create a sumo configuration file file using any code editor (like notepad, notepad++ etc.) and the extension is. sumo.cfg. Place the file inside the same folder where the network file (i.e. NETWORK.net.xml) and route file (i.e. VEHICLES.rou.xml) are present.

Configuration.sumo.cfg

```
<configuration>
    <input>
        <net-file value="NETWORK.net.xml"/>
        <route-files value="VEHICLES.rou.xml"/>
    </input>
    <time>
        <begin value="0"/>
        <end value="200"/>
        <step-length value="1"/>
    </time>
</configuration>
```

Figure 3-17: Sumo configuration file

Step 7: Now open “New Simulation → VANET”. Choose the Configuration.sumo.cfg from the specified folder and run simulation using NetSim.

3.6 How to include Roadside Units (RSU’s) in a VANET network?

Upon importing a sumo network configuration into NetSim, roads and vehicles are automatically added in NetSim as per the configuration done in SUMO.

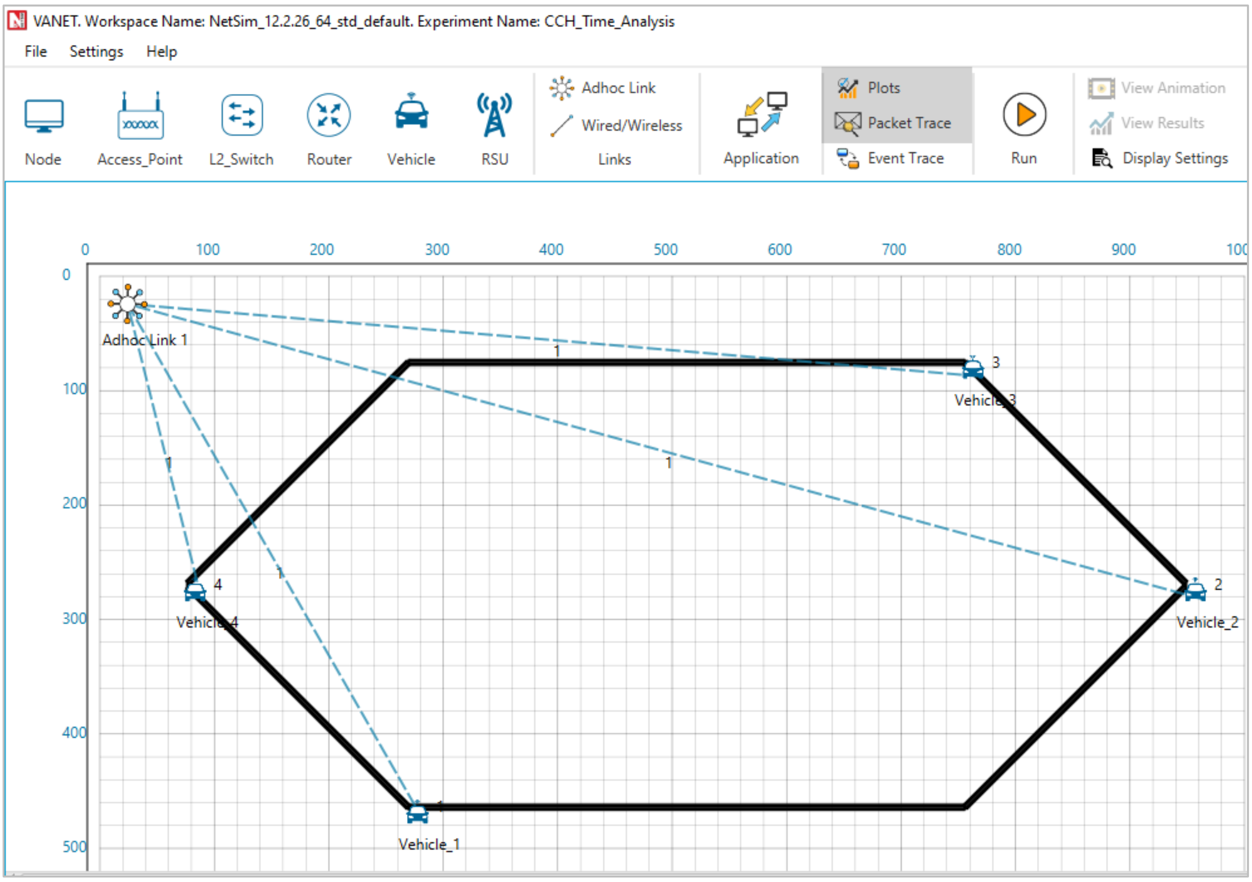


Figure 3-18: Importing a sumo network configuration into NetSim

Road Side Units can be optionally included in the network by manually clicking and dropping the RSU icon from the ribbon.

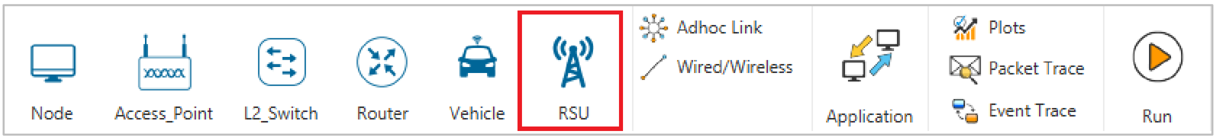


Figure 3-19: RSU icon from the ribbon.

RSU's should be connected using Adhoc links manually.

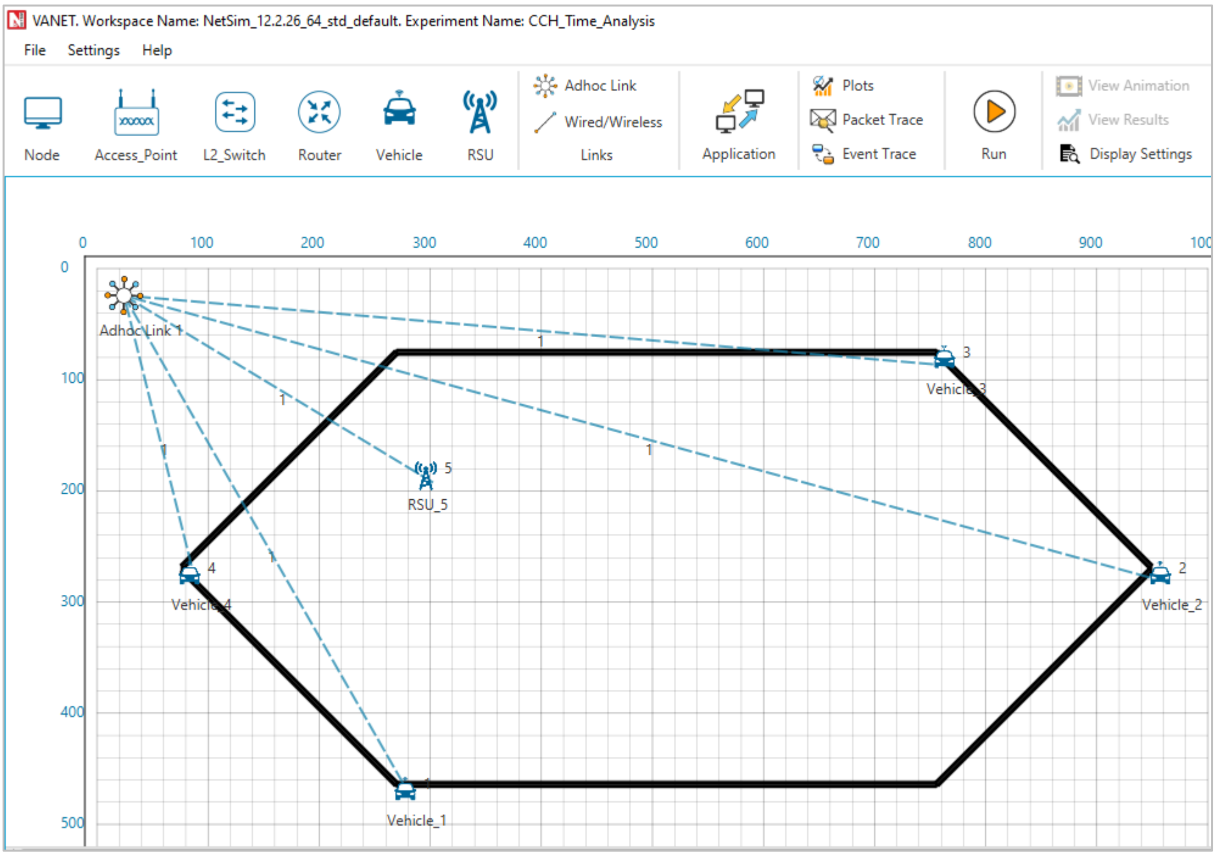


Figure 3-20: NetSim Design Window

Traffic can be configured between RSU’s and vehicles via Application configuration.

4 Featured Examples

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

4.1 Simple Scenario

Open NetSim and Select **Examples->VANETs->Simple Scenario** then click on the tile in the middle panel to load the example as shown in below screenshot

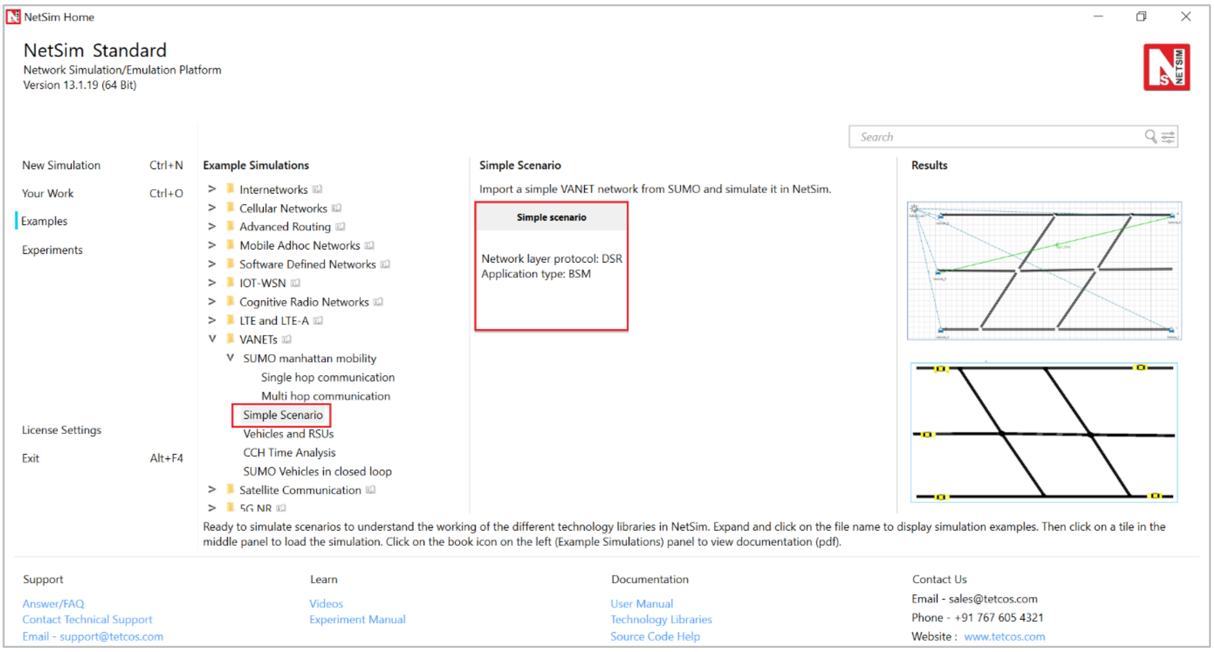


Figure 4-1: List of scenarios for the example of Simple Scenario

This scenario involves a simple road traffic network scenario as shown below:

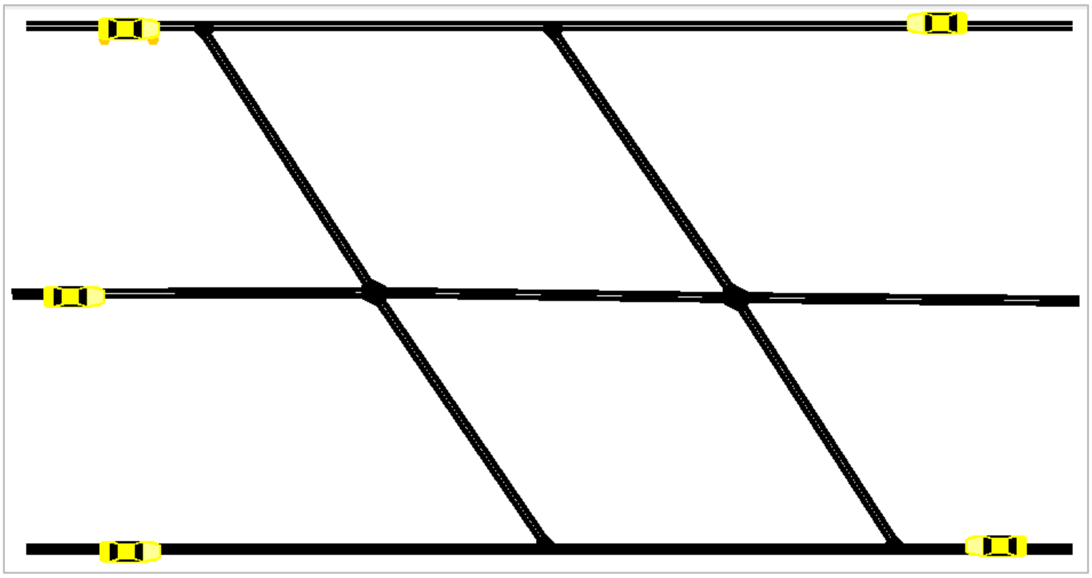


Figure 4-2: Network topology in Sumo

An equivalent network is created in NetSim by importing the SUMO configuration file as shown below:

In NetSim the TCP/IP stack parameters of the devices are configured along with network traffic between vehicles.

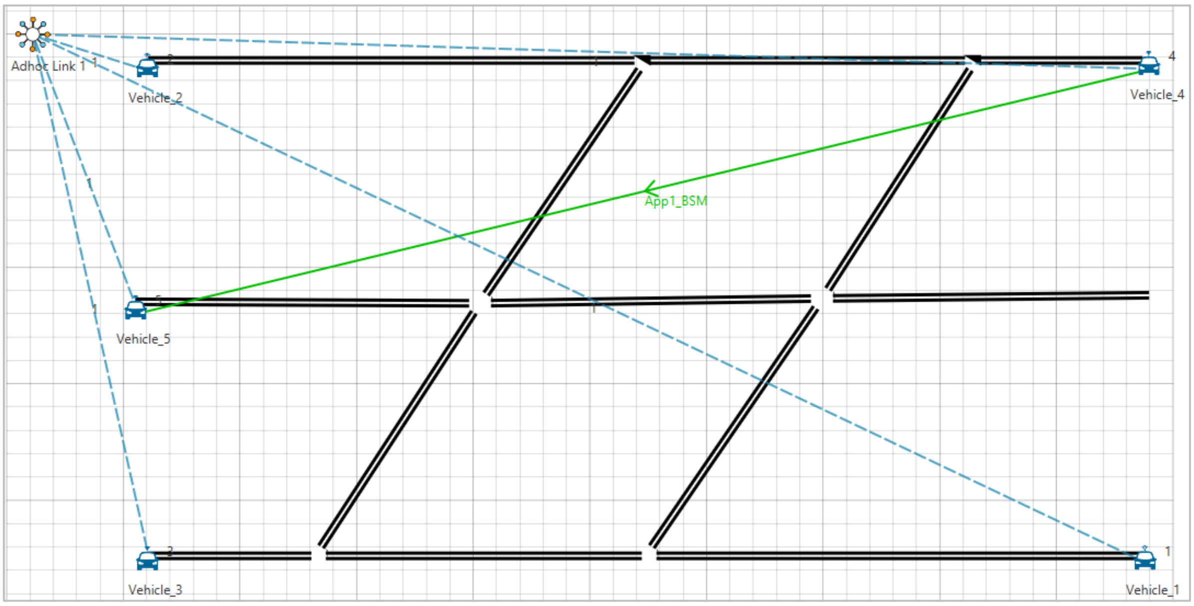


Figure 4-3: Network set up for studying the Simple Scenario

After running the simulation, NetSim Animation can be used to visualize packet flow and vehicle mobility along with packet information and throughput plots.

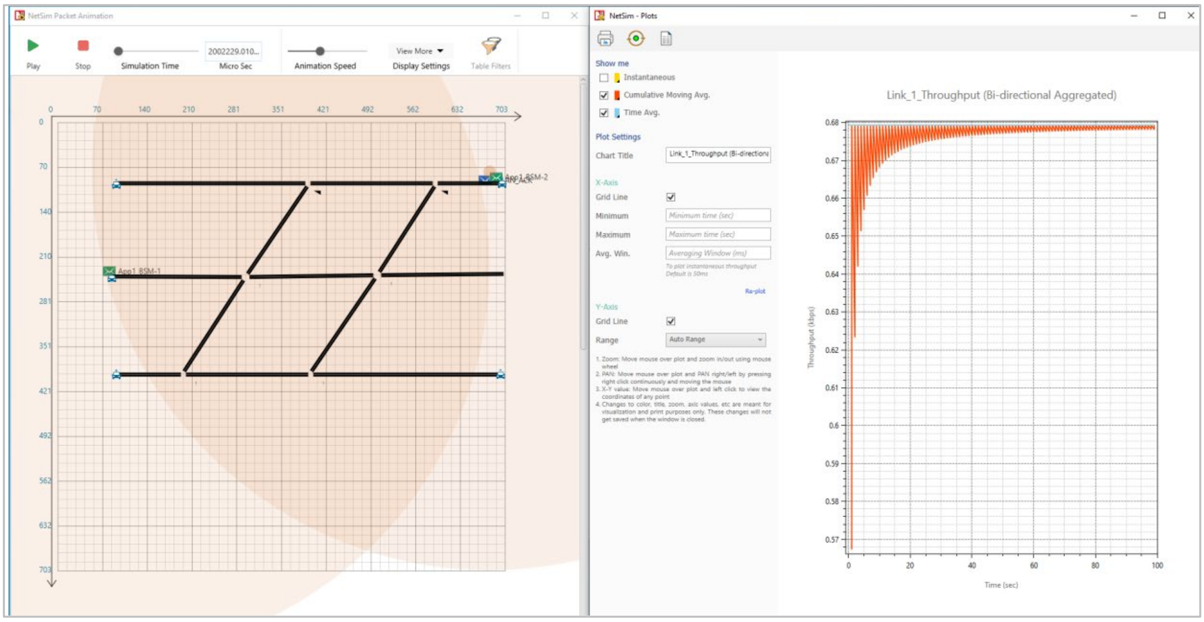


Figure 4-4: Packet animation window and link throughput plot

Simulation results dashboard provides the performance metrics of protocols running in different layers of the network stack of the devices.

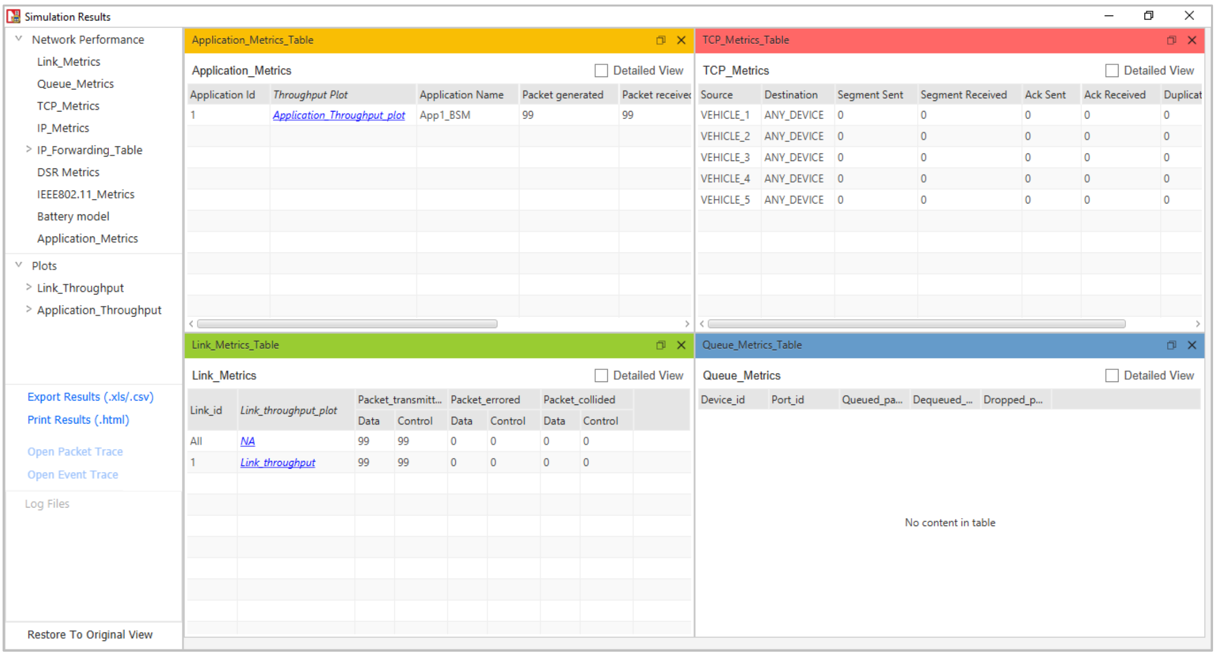


Figure 4-5: Result Dashboard

4.2 Vehicles and RSUs

Open NetSim and Select **Examples->VANETs->Vehicles and RSUs** then click on the tile in the middle panel to load the example as shown in below screenshot

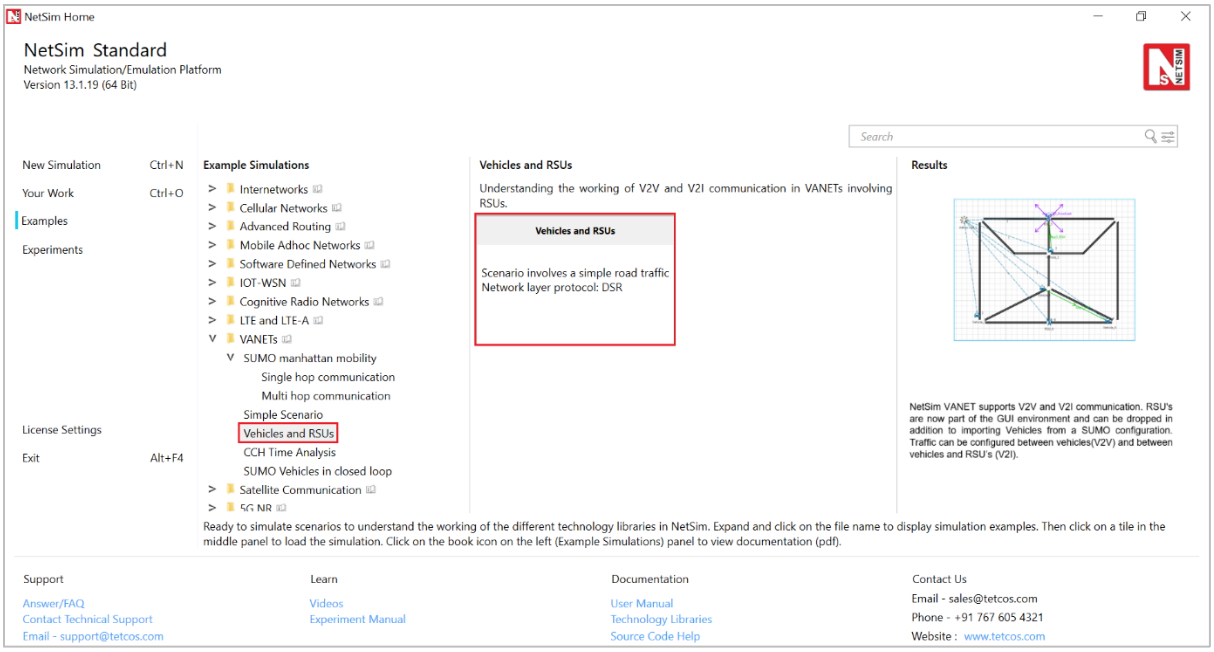


Figure 4-6: List of scenarios for the example of Vehicles and RSUs

NetSim VANETs module supports V2V and V2I communication. RSU's are now part of the GUI environment and can be dropped in addition to importing Vehicles from a SUMO configuration. Traffic can be configured between vehicles(V2V) and between vehicles and RSU’s (V2I).

This scenario involves a simple road traffic network scenario as shown below:

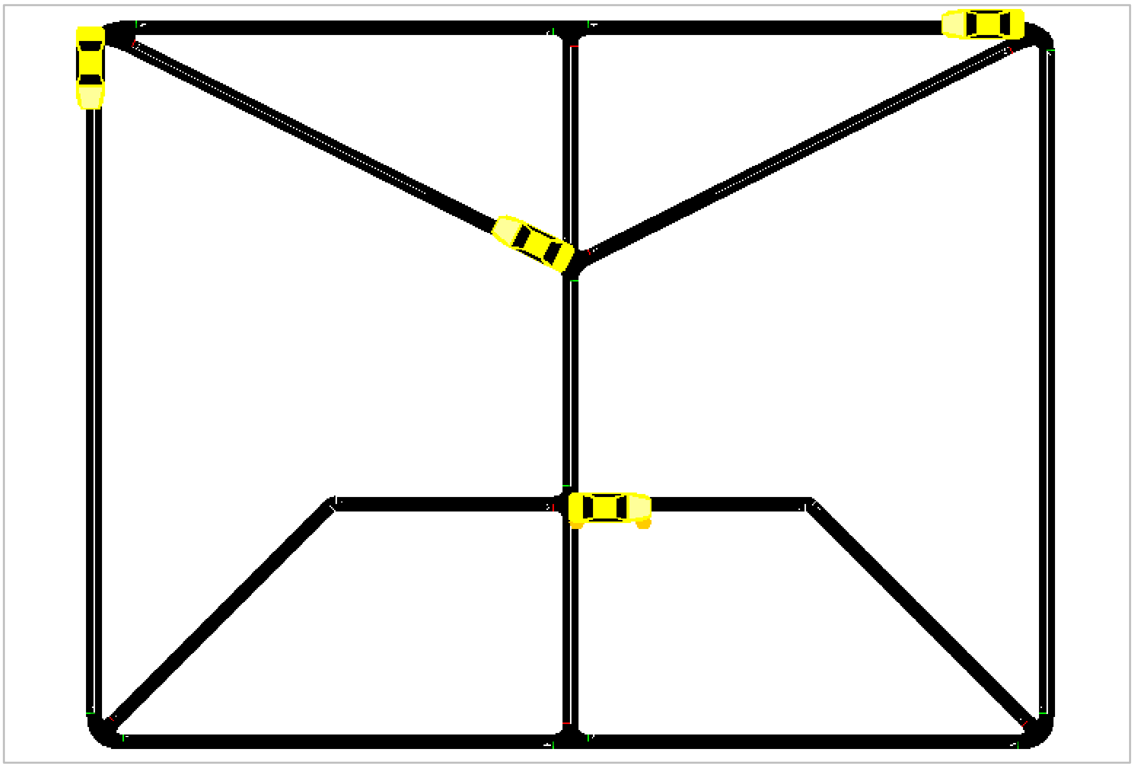


Figure 4-7: Network topology in Sumo

An equivalent network is created in NetSim by importing the SUMO configuration file as shown below:

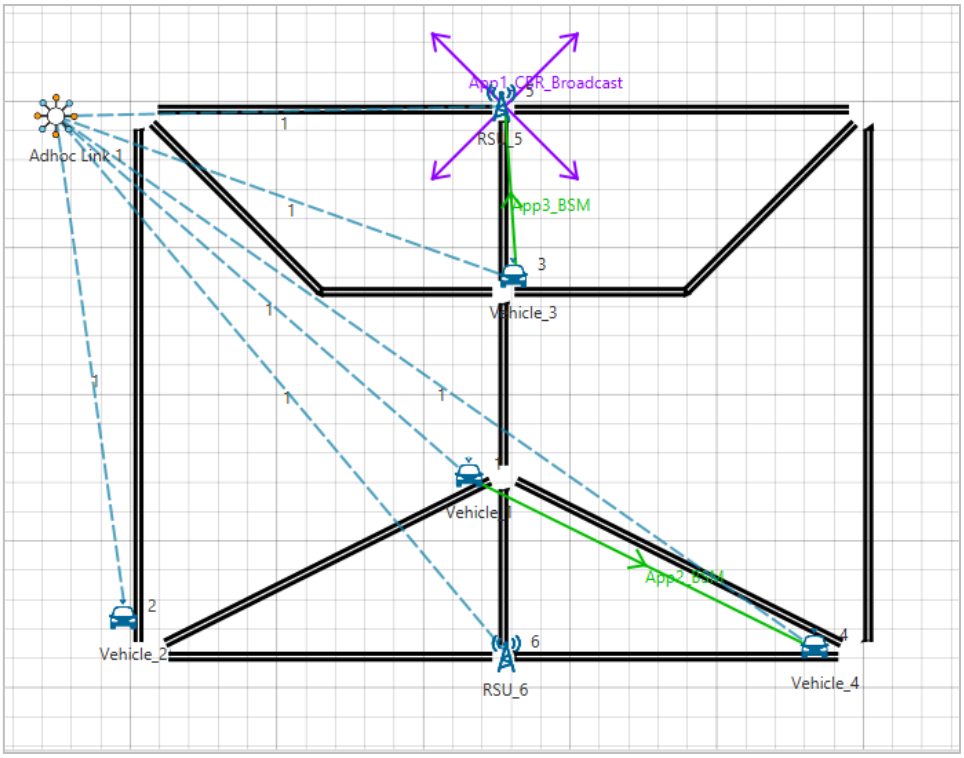


Figure 4-8: Network set up for studying the Vehicles and RSUs

After importing the SUMO configuration file in NetSim, RSU's were added at junctions. In NetSim the TCP/IP stack parameters of the devices are configured along with network traffic between vehicles and between vehicles and RSU's.

After running the simulation, NetSim Animation can be used to visualize packet flow and vehicle mobility along with packet information and throughput plots.

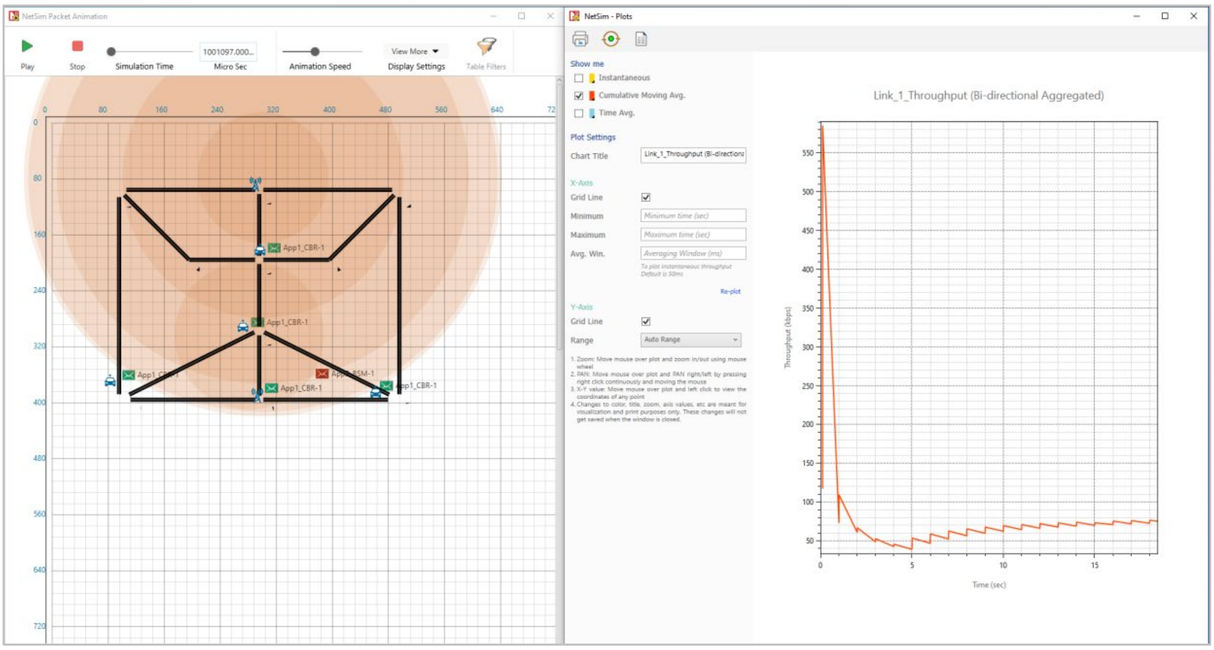


Figure 4-9: Packet animation window and link throughput plot

Simulation results dashboard provides the performance metrics of protocols running in different layers of the network stack of the devices.

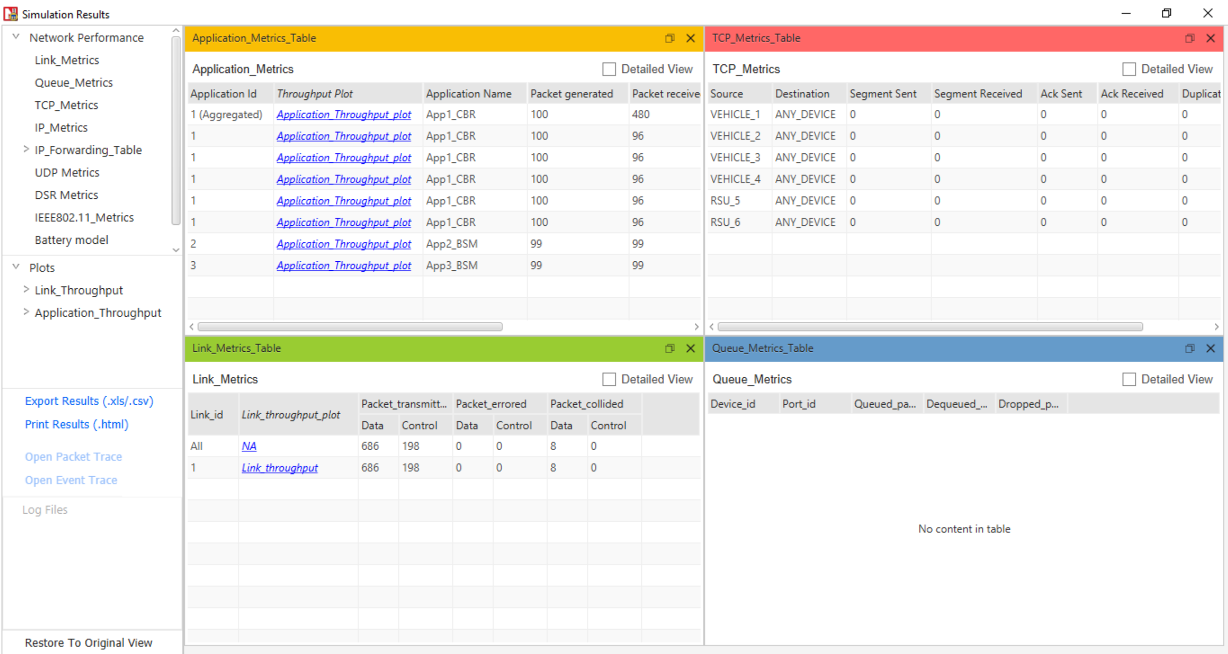


Figure 4-10: Result Dashboard

4.3 CCH Time Analysis

Open NetSim and Select **Examples->VANETs->CCH Time Analysis** then click on the tile in the middle panel to load the example as shown in below screenshot

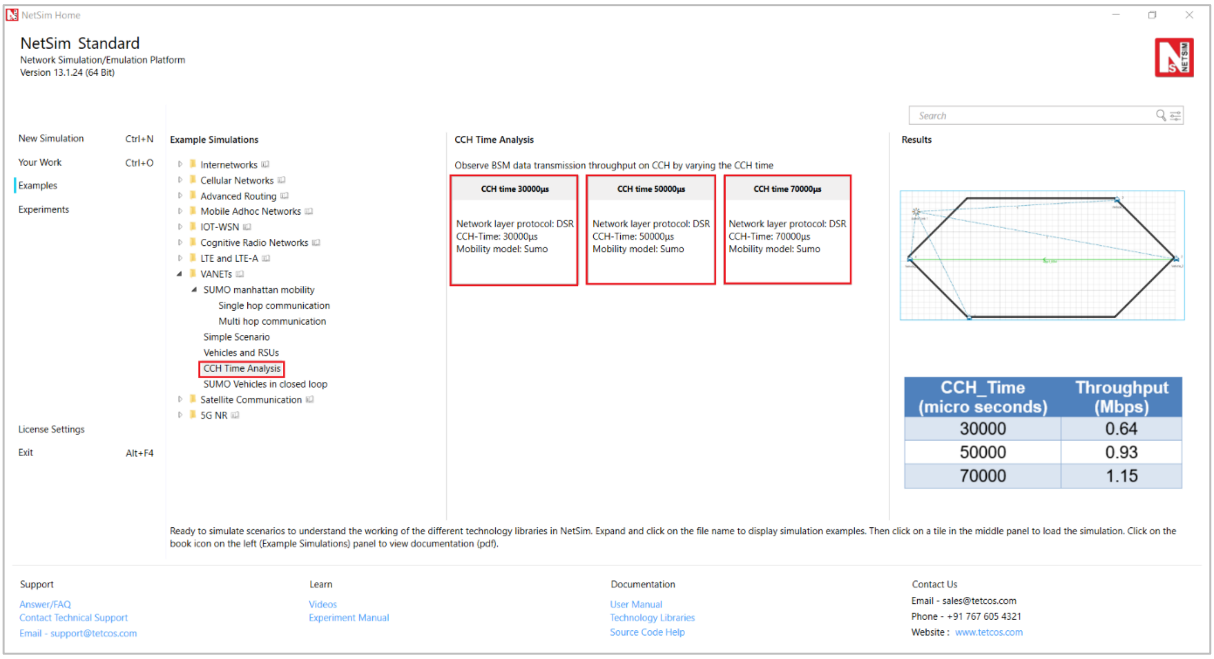


Figure 4-11: List of scenarios for the example of CCH Time Analysis

This scenario involves a simple road traffic network scenario as shown below:

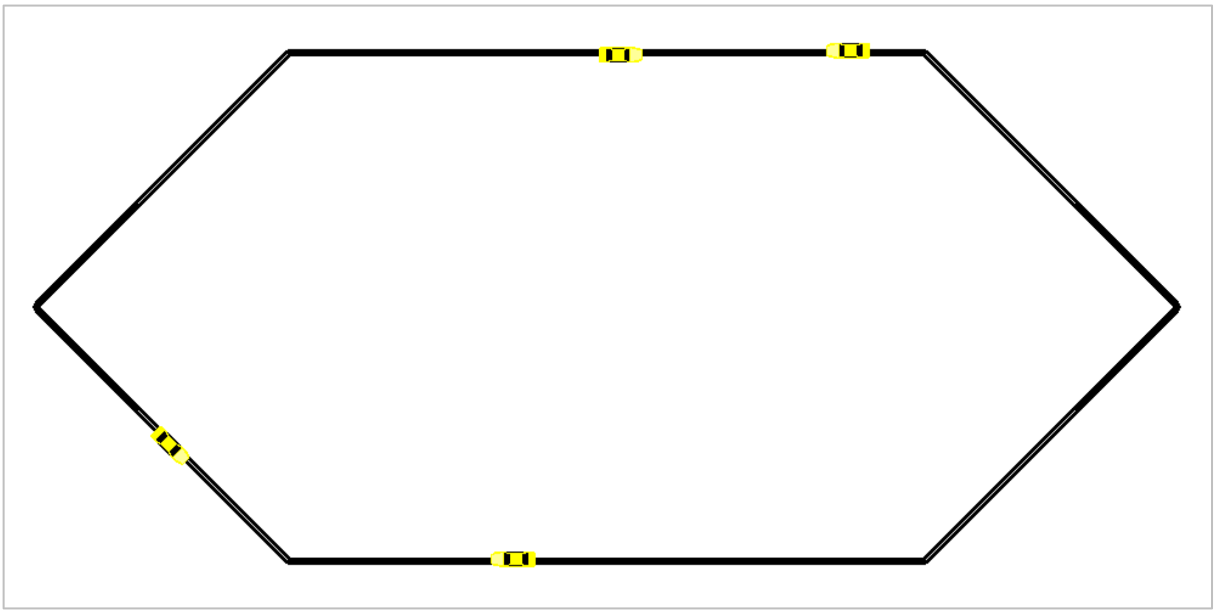


Figure 4-12: Network topology in Sumo

An equivalent network is created in NetSim by importing the SUMO configuration file as shown below:

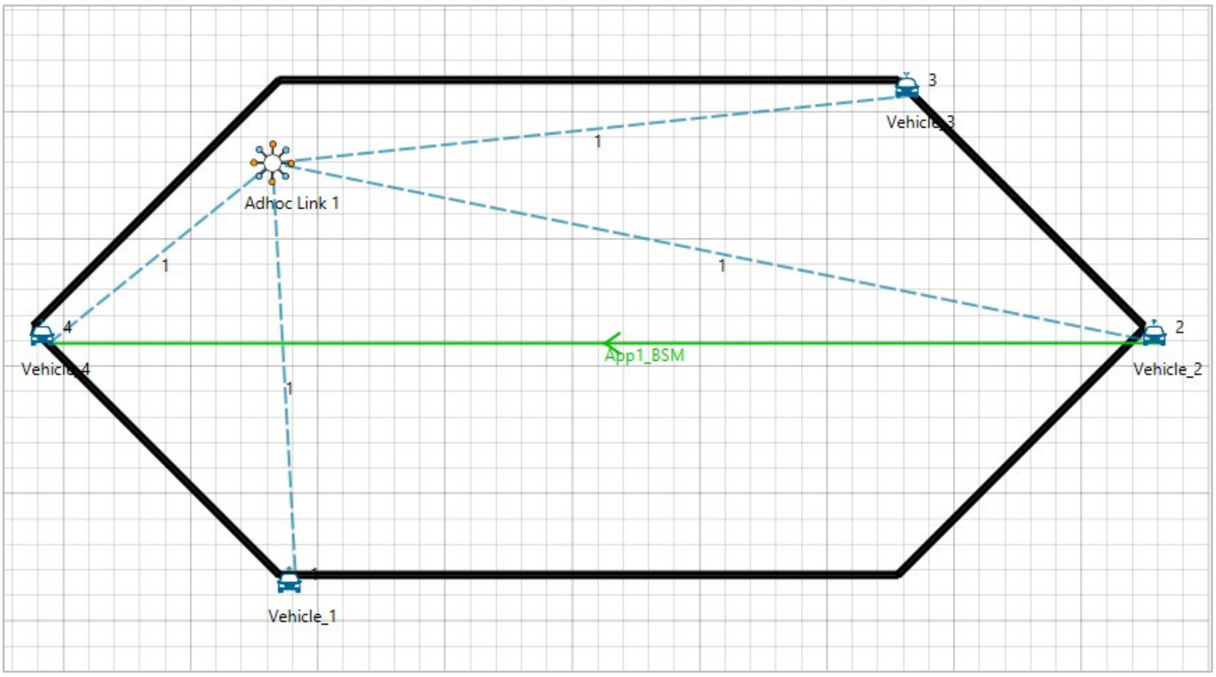


Figure 4-13: Network set up for studying the CCH Time Analysis

Settings done for this sample experiment:

- In INTERFACE_1(WIRELESS) → Data Link Layer, CCH_TIME = 30000(Microsec)

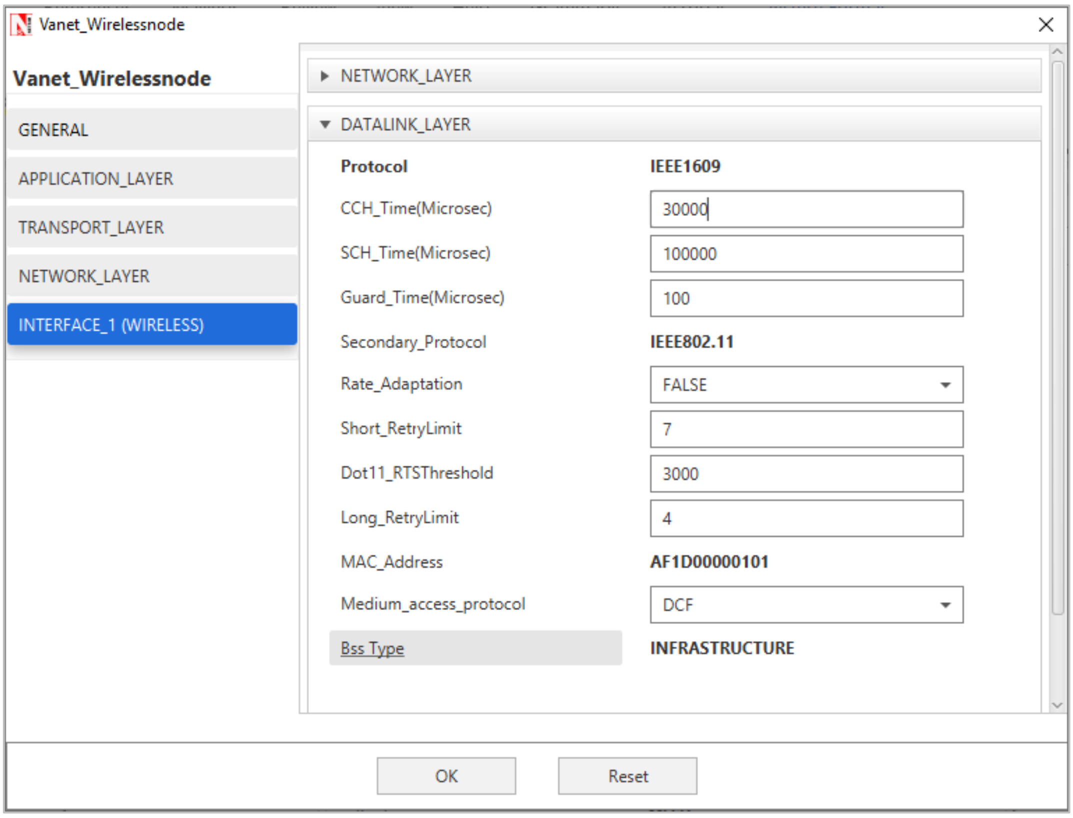


Figure 4-14: Datalink Layer for Vehicle

- Set Application BSM (Basic_Safety_Message) with 3Mbps generation rate.
  - Packet size: 100 Bytes
  - IAT: 266 (Microsec)

- In Vehicle General Properties, under SUMO file Configuration.sumo.cfg file was selected from the Docs folder of NetSim Install Directory C:\Program Files\NetSim\Standard_v13_1\Docs\Sample_Configuration\VANET\CCH

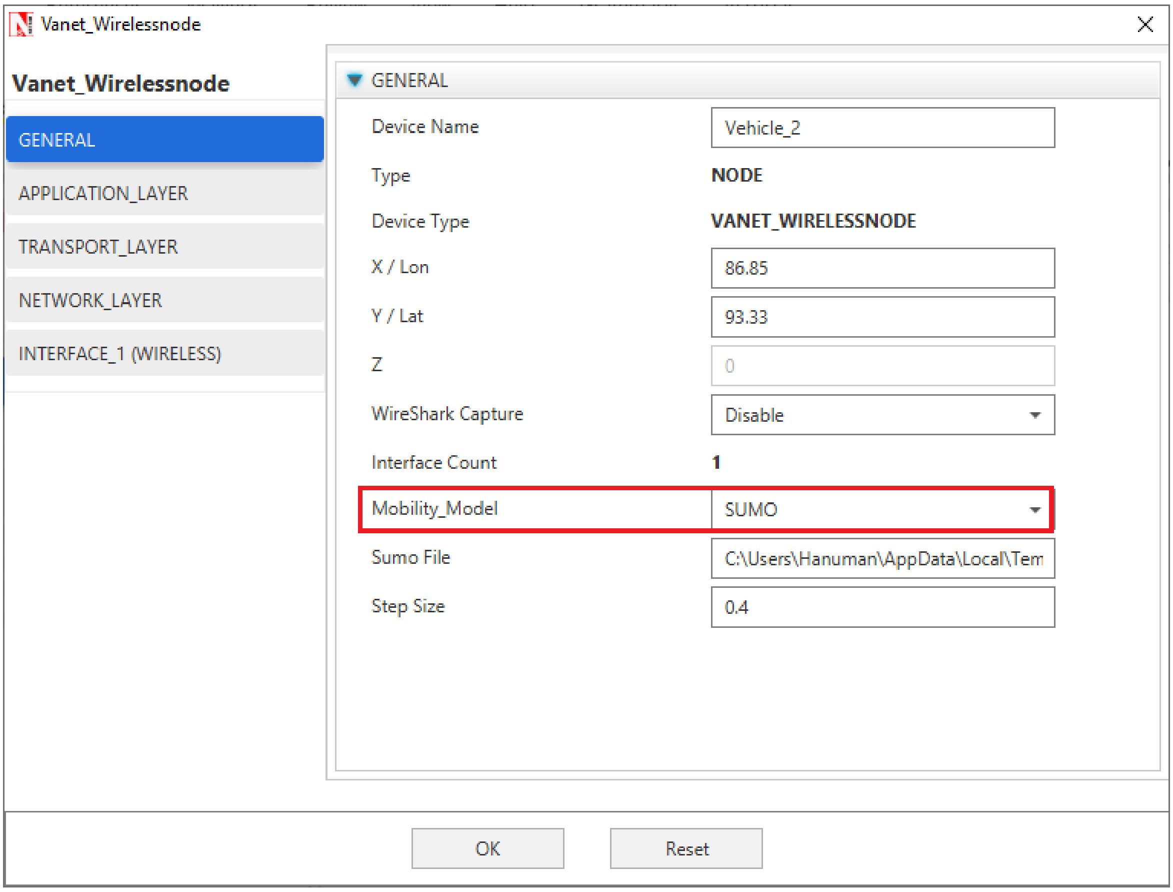


Figure 4-15: General Properties window for vehicle

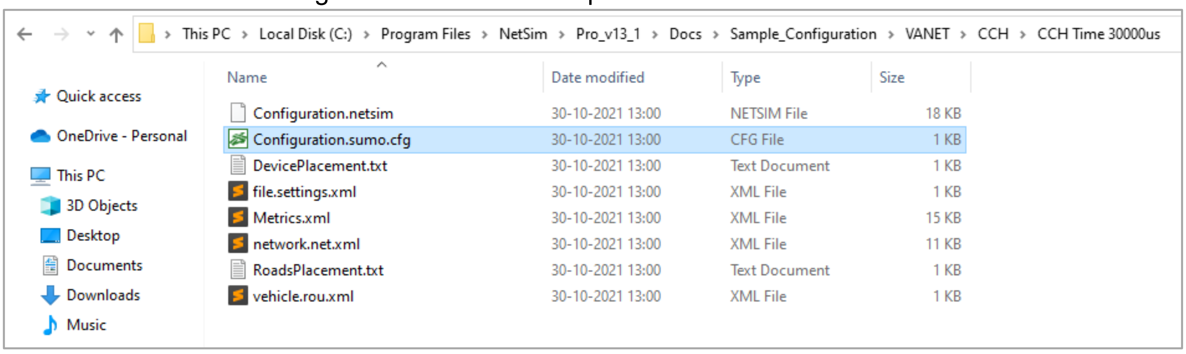


Figure 4-16: CCH Time Analysis Example folder

- Enable Packet trace and plot option.
- Run simulation and note down the number of data packets transmitted (BSM Packets) from Packet Trace by filter PACKET_TYPE to Basic_Safety_Message and throughput.
- For Same Scenario User need to Modify the CCH_TIME to 50000, 70000 microseconds respectively.
- Run the Simulation and Note down the Throughput.

CCH_Time (micro seconds)	Throughput (Mbps)
30000	0.64
50000	0.93
70000	1.15

Table 4-1: Different CCH time vs. Throughputs

Remarks: The BSM application is transmitted on CCH. Hence as we increase the CCH time, the throughput of the BSM application increases.

4.4 SUMO Manhattan Mobility with Single and Multi-hop Communication

Introduction

The Manhattan mobility in SUMO features a grid topology as shown below. It is composed of a number of horizontal and vertical streets. Each street has two lanes for each direction (North and South direction for vertical streets, East and West for horizontal streets). The mobile node is allowed to move along the grid of horizontal and vertical streets. At an intersection of a horizontal and a vertical street, the mobile node can turn left, right or go straight with certain probability.

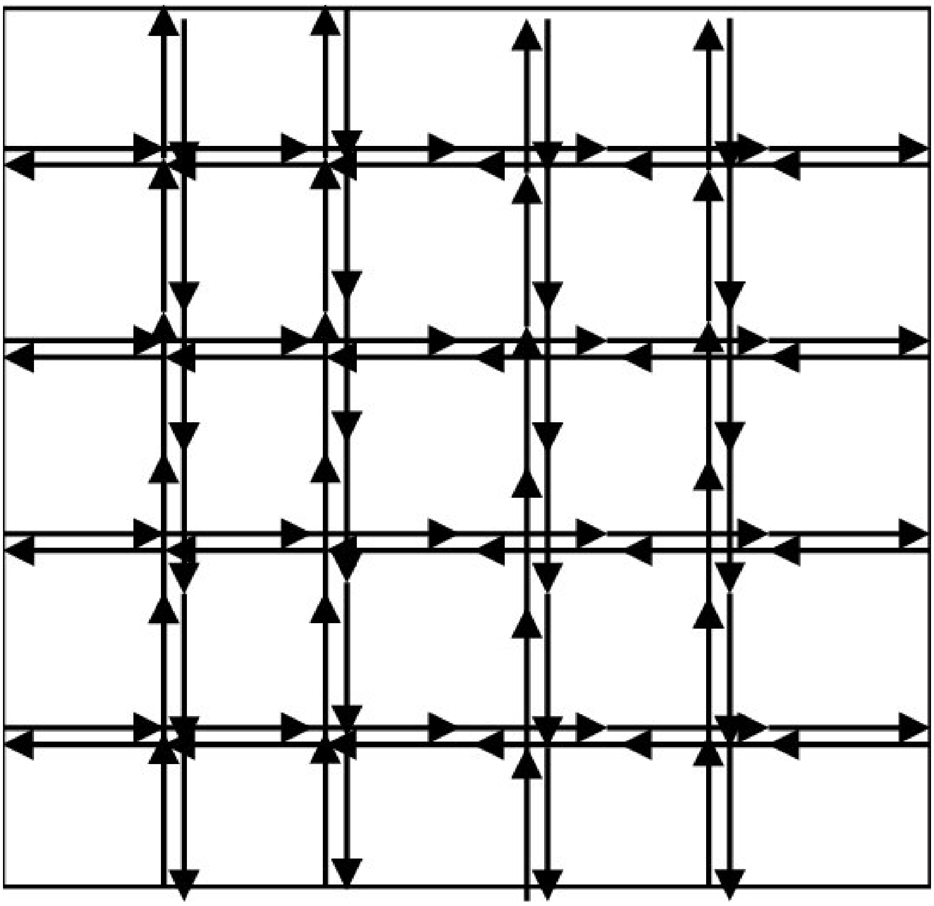


Figure 4-17: Manhattan mobility in SUMO features a grid topology

Case 1: Manhattan mobility Single-hop RSU to vehicles

Objective

To create, using SUMO, a Manhattan Road network in which vehicles drive randomly, and to have a Roadside unit (RSU) which sends safety messages continuously to vehicles continuously. The network performance is analyzed for different environments each having different RF channel characteristics.

Procedure

Open NetSim and Select **Examples-> VANETs-> SUMO Manhattan mobility-> Single hop communication** then click on the tile in the middle panel to load the example as shown in below screenshot

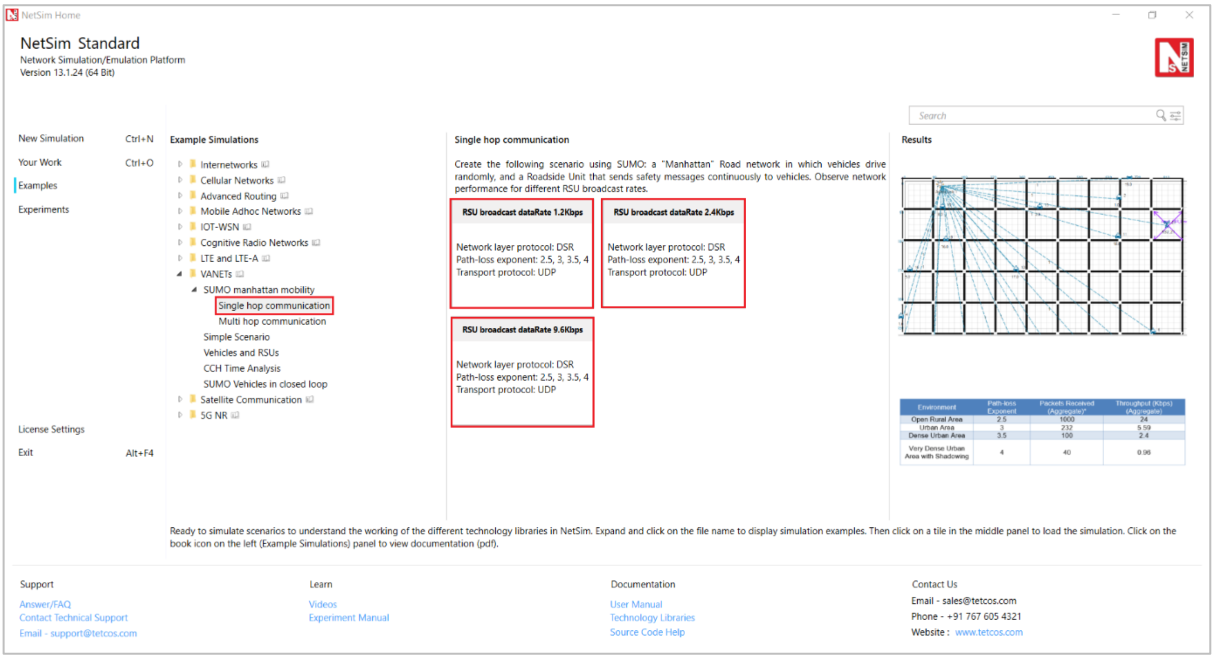


Figure 4-18: List of scenarios for the example of Single hop communication

The NetSim UI would display as shown below.

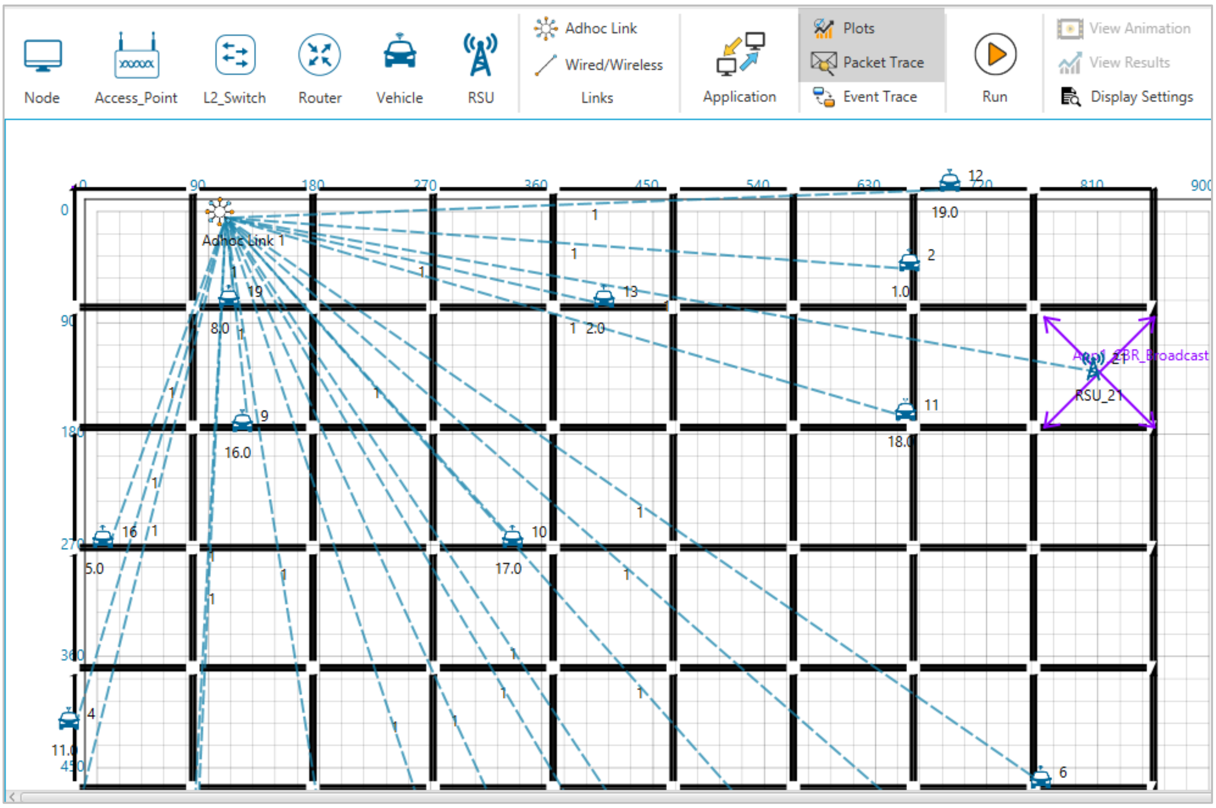


Figure 4-19: Network set up for studying the Single hop communication

Settings done for this sample experiment.

1. Applications set as CBR (Broadcast application)

Application Method	Application Type	APP_Name	Source_ID	Destination_ID	Packet_ Size (Bytes)	Inter-Arrival Time (µs)
Broadcast	CBR	APP_1_CBR_ Broadcast	21	Broadcast to all 20 vehicles	300	2,000,000

Table 4-2: CBR Applications Settings

2. Transport protocol set as UDP in application Configuring window.
3. Adhoc link/Wireless link properties were set as follows:

Channel characteristics	Pathloss Model	Pathloss Exponent
Pathloss Only	Log Distance	2.5

Table 4-3: Wireless link properties

4. Plots and packet trace are enabled and run simulation and observe the movement of the vehicles in the packet animation window.
5. In Netsim packet animation window, you can see that vehicles choose random directions when they reach a junction in the Manhattan grid network.
6. Increase the pathloss exponent (in the order 2.5, 3, 3.5, 4) and note down the aggregate throughput and packets received for different application generation rates.

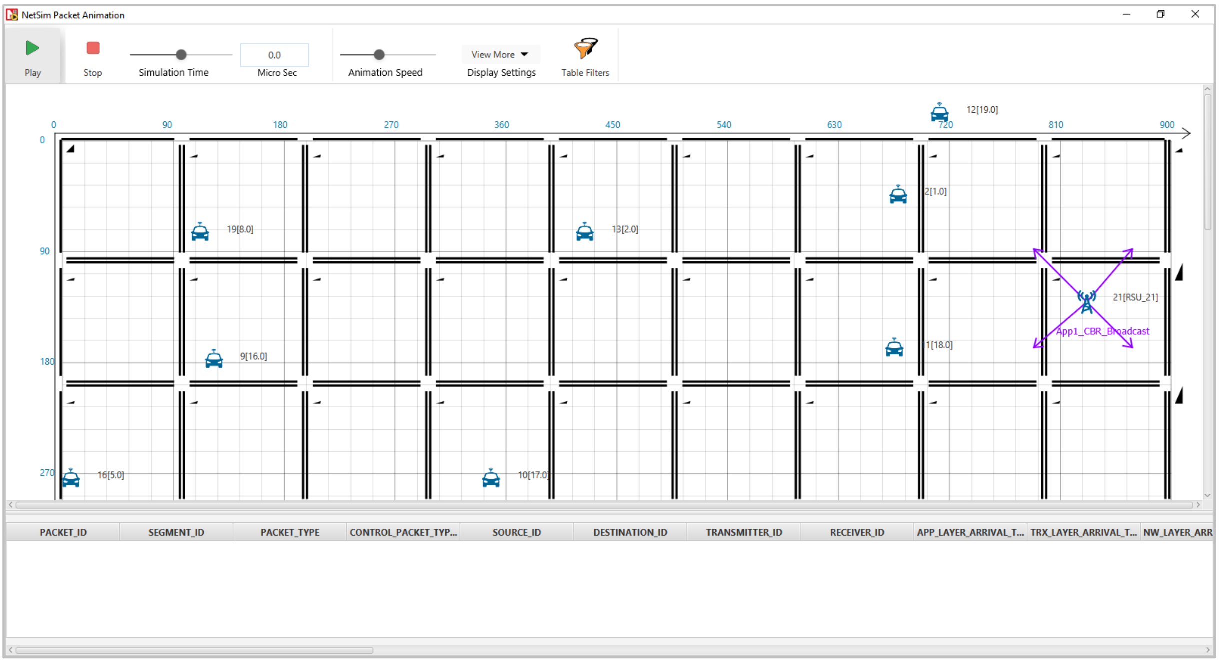


Figure 4-20: Animation Window for NetSim

With play and record animation enabled, same can be observed in SUMO as follows:

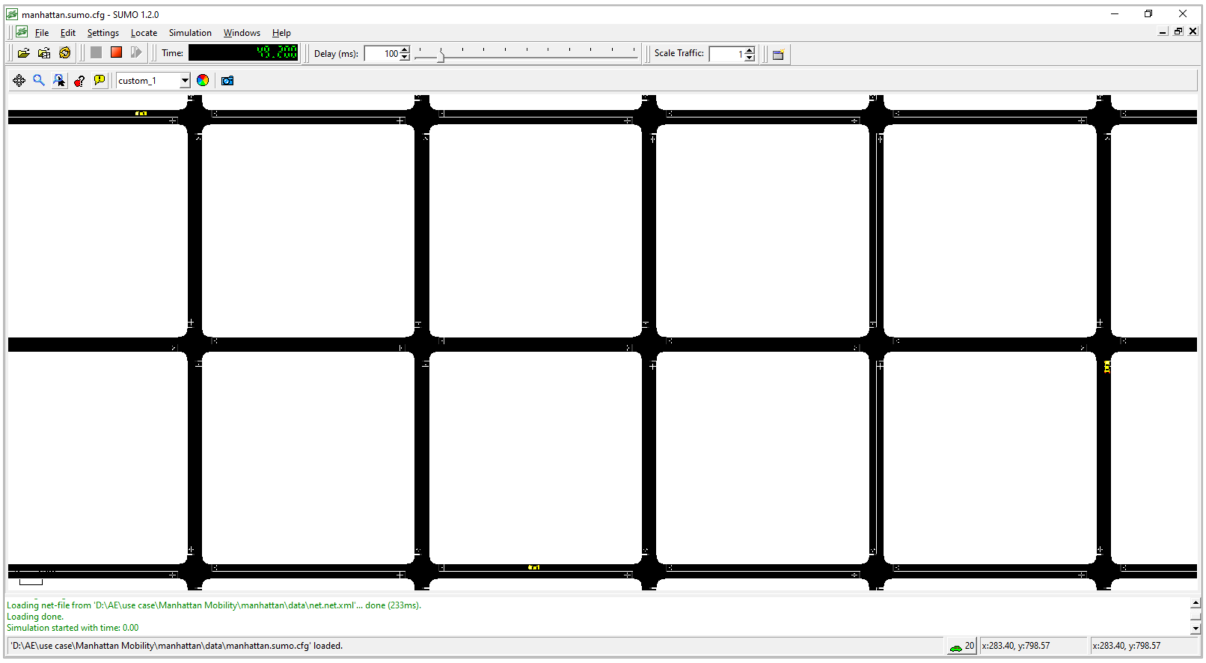


Figure 4-21: Animation Window for Sumo

Results and Observations

For sample **RSU Broadcast Data Rate = 1.2 Kbps** (Packet size = 300 bytes, IAT = 2,000,000µs. This means packets of size 300 Bytes are sent every 2 seconds)

Environment	Path-loss Exponent	Packets Received (Aggregate)*	Throughput (Kbps) (Aggregate)
Open Rural Area	2.5	1000	24
Urban Area	3	232	5.59
Dense Urban Area	3.5	100	2.4

Very Dense Urban Area with Shadowing	4	40	0.96

Table 4-4: Results Comparison for RSU Broadcast Data Rate = 1.2 Kbps

* Aggregate is the sum of the packet/throughputs obtained by all applications.

For sample **RSU Broadcast Data Rate = 2.4 Kbps** (Packet size =300 Bytes, IAT = 1,000,000µs or 1 seconds. This means packets of size 300 Bytes are sent every second)

Environment	Path-loss Exponent	Packets Received (Aggregate)	Throughput (Kbps) (Aggregate)
Open Rural Area	2.5	1980	47.52
Urban Area	3	463	11.11
Dense Urban Area	3.5	197	4.72
Very Dense Urban Area with Shadowing	4	79	1.89

Table 4-5: Results Comparison for RSU Broadcast Data Rate = 2.4 Kbps

For sample RSU Broadcast Data Rate = 9.6 Kbps (Packet size =300Bytes, IAT =250,000µs or 0.25 seconds. This means four Packets of size 300 Bytes are sent every second)

Environment	Path-loss Exponent	Packets Received (Aggregate)	Throughput (Kbps) (Aggregate)
Open Rural Area	2.5	7980	191.52
Urban Area	3	1857	44.56
Dense Urban Area	3.5	791	18.98
Very Dense Urban Area with Shadowing	4	316	7.58

Table 4-6: Results Comparison for RSU Broadcast Data Rate = 9.6 Kbps

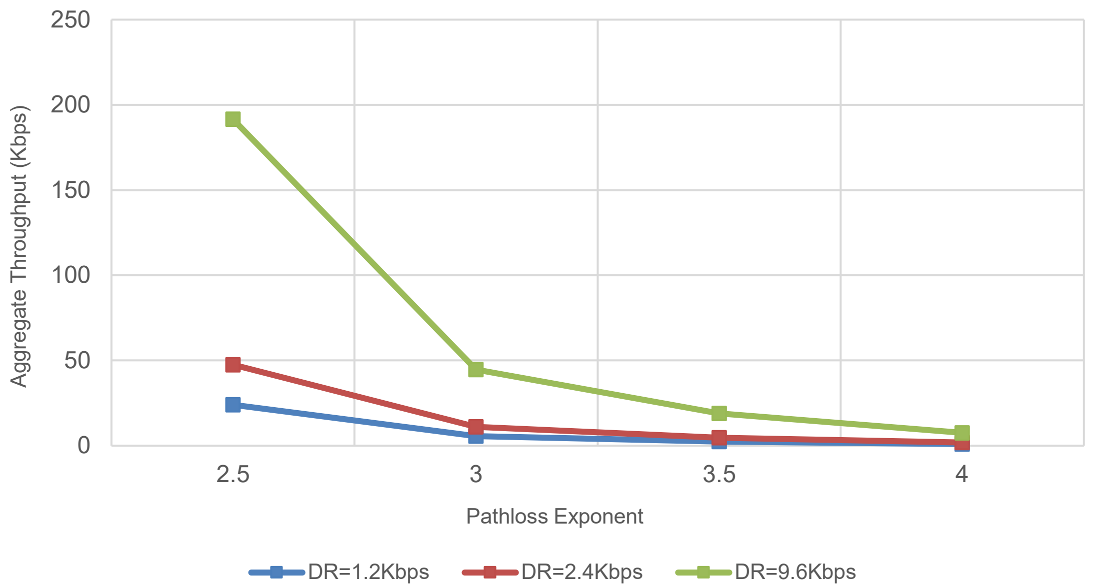


Figure 4-22: Plot of Throughput vs. Pathloss Exponent for different RSU broadcast for different DR (Data Rates)

Case 2: Manhattan mobility Multi-hop Vehicles to RSU

Objective

To create, using SUMO, a Manhattan Road network in which vehicles drive randomly, and to have a Roadside unit (RSU) to which vehicles continuously send unicast traffic via multi-hop (hopping via other vehicles if the RSU is beyond communication range). The network performance is analyzed for different vehicle counts.

Procedure

Open NetSim and Select **Examples-> VANETs-> SUMO Manhattan mobility-> Multi hop communication** then click on the tile in the middle panel to load the example

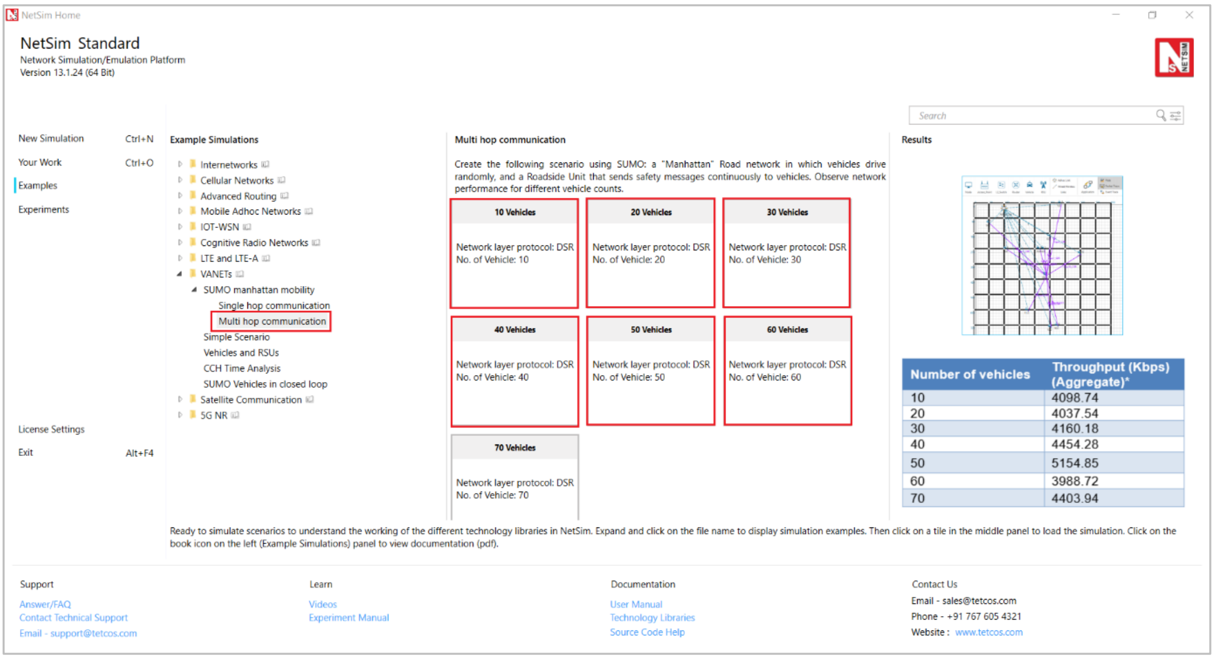


Figure 4-23: List of scenarios for the example of Multi hop communication

The NetSim UI would display as shown below.

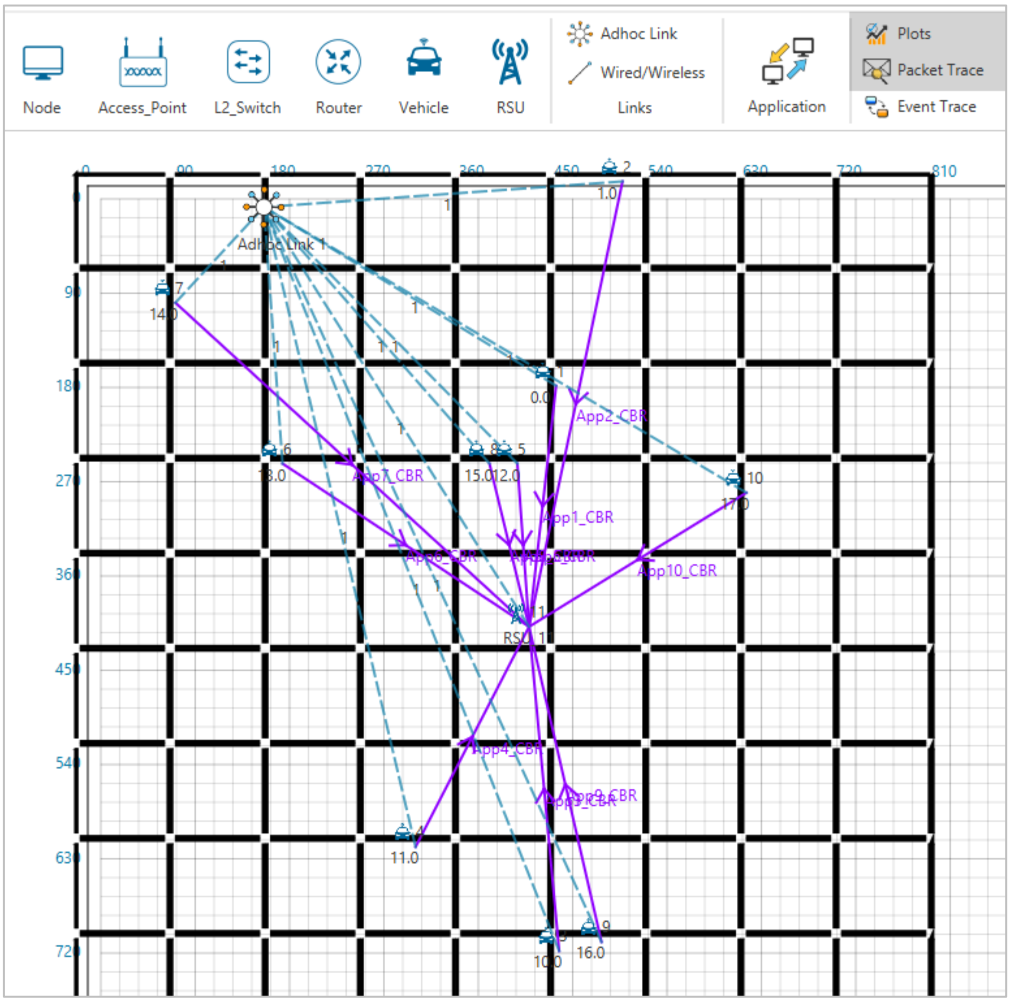


Figure 4-24: Network set up for studying the Multi hop communication

Settings done for this sample experiment.

1. Applications set as CBR.

Application Method	Application Type	Source_Id	Destination_Id	Packet size (Bytes)	Inter-Arrival Time (µs)
Unicast	CBR	(All vehicles)	RSU	1460	20,000

Table 4-7: CBR Applications settings

2. In Vehicle General Properties, under SUMO file manhattan.sumo.cfg file was selected from the Docs folder of NetSim Install Directory < C:\Program Files\NetSim Standard\Docs\Sample_Configuration\VANET\SUMO-Manhattan-mobility-Single-hop-and-Multi-hop\Multi-hop-communication>

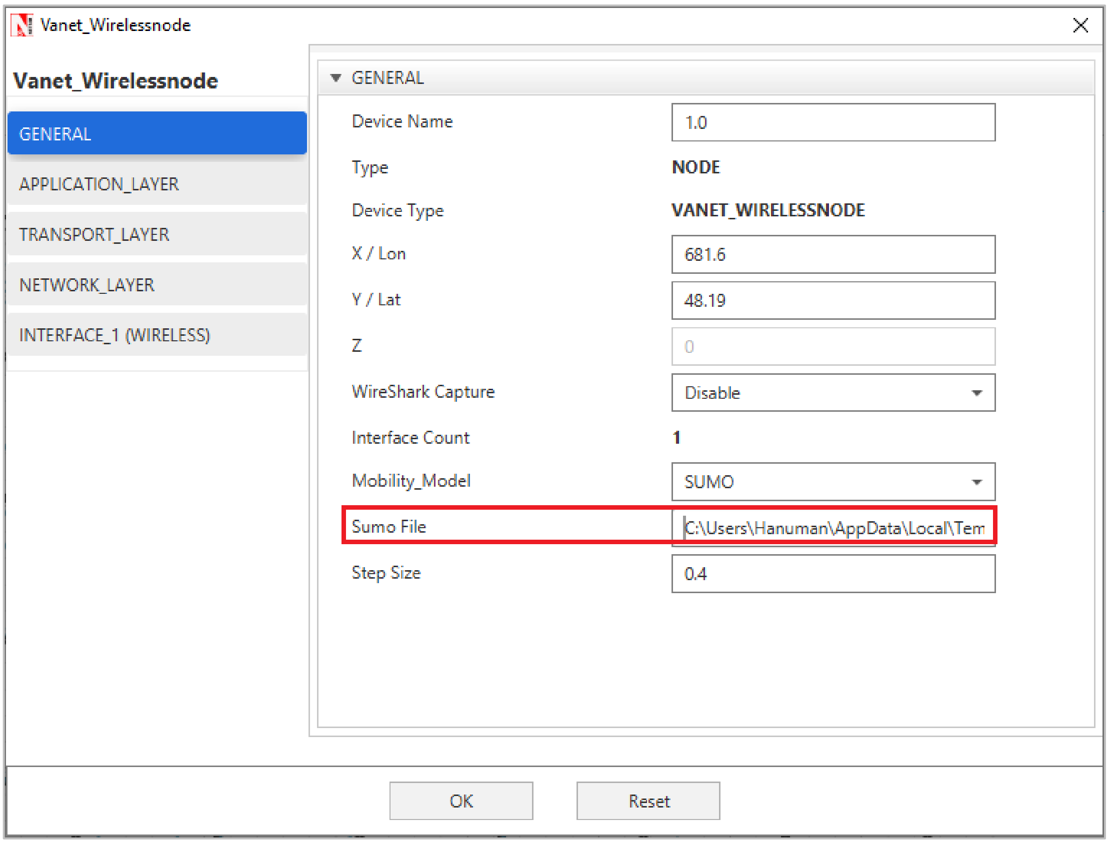


Figure 4-25: General Properties window

3. Transport protocol set as UDP in application Configuration window.
4. Adhoc link/ Wireless link properties set as follows:

Channel Characteristics	Pathloss Model	Pathloss Exponent
Pathloss_Only	Log_Distance	2.5

Figure 4-26: Wireless link properties

5. Co-ordinates of RSU are set as X = 450, and Y = 450
6. Network layer routing protocol is set as DSR.
7. Plots are enabled and run the simulation.
8. Increase the number of vehicles in the order 10, 20, 30 etc. and note down the aggregate throughput.

Result:

Number of vehicles	Throughput (Kbps) (Aggregate)*
10	4098.74
20	4037.54
30	4160.18
40	4454.28
50	5154.85
60	3988.72
70	4403.94

Table 4-8: Results Comparison

*Aggregate is the sum of the packet/throughputs obtained by all applications.

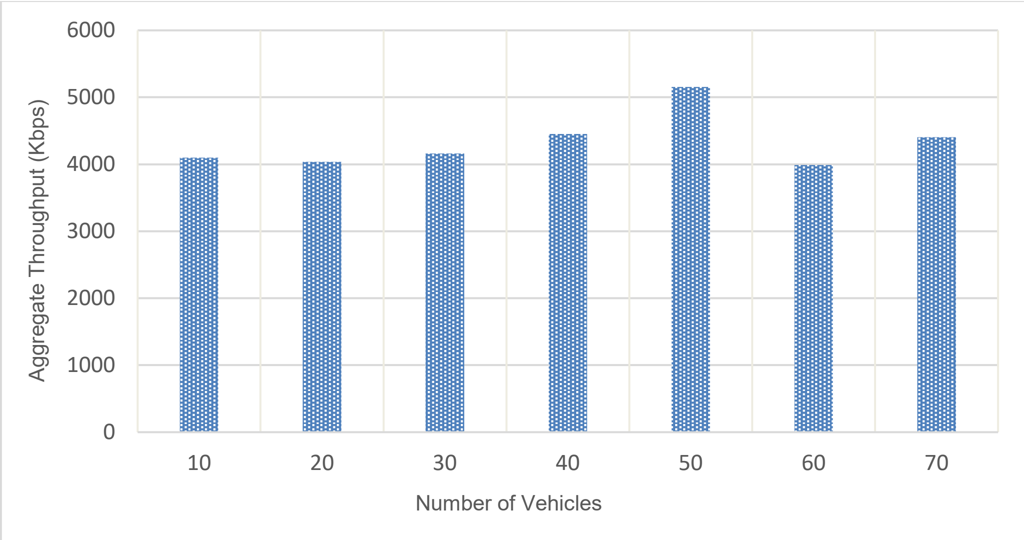


Figure 4-27: Aggregate Throughput vs. Number of Vehicles

4.5 SUMO Interfacing with vehicles moving in a closed loop

Open NetSim and Select **Examples->VANETs-> SUMO Vehicles in closed loop** then click on the tile in the middle panel to load the example as shown in below screenshot

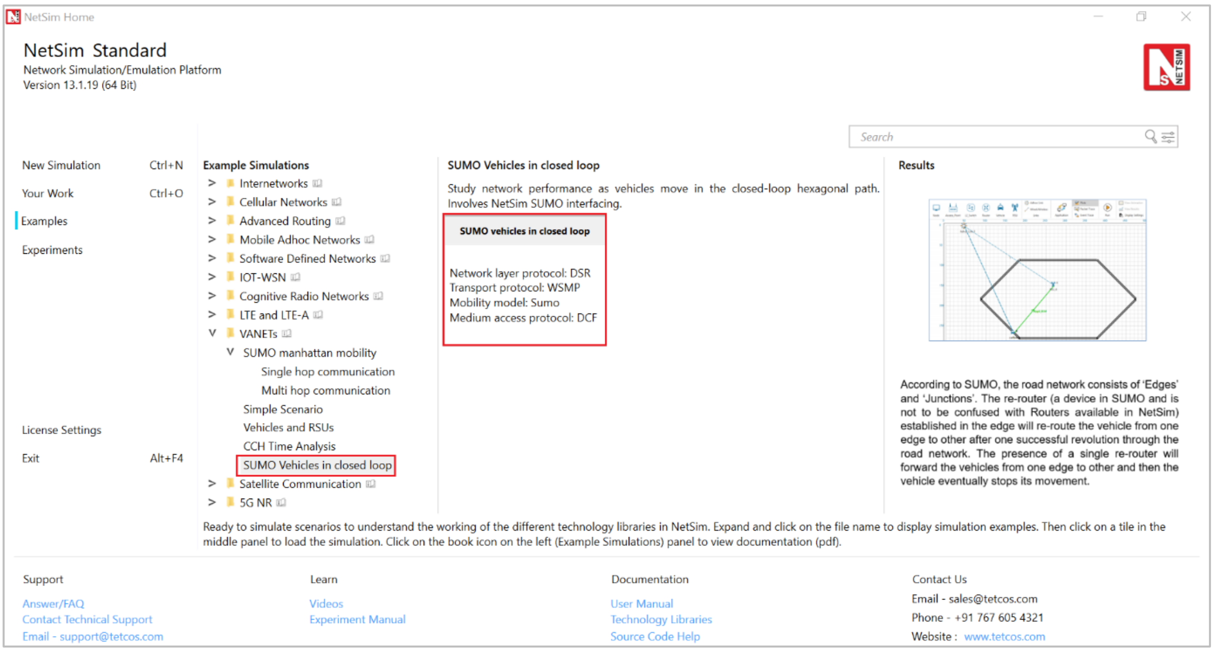


Figure 4-28: List of scenarios for the example of SUMO Vehicles in closed loop

The NetSim UI would display as shown below.

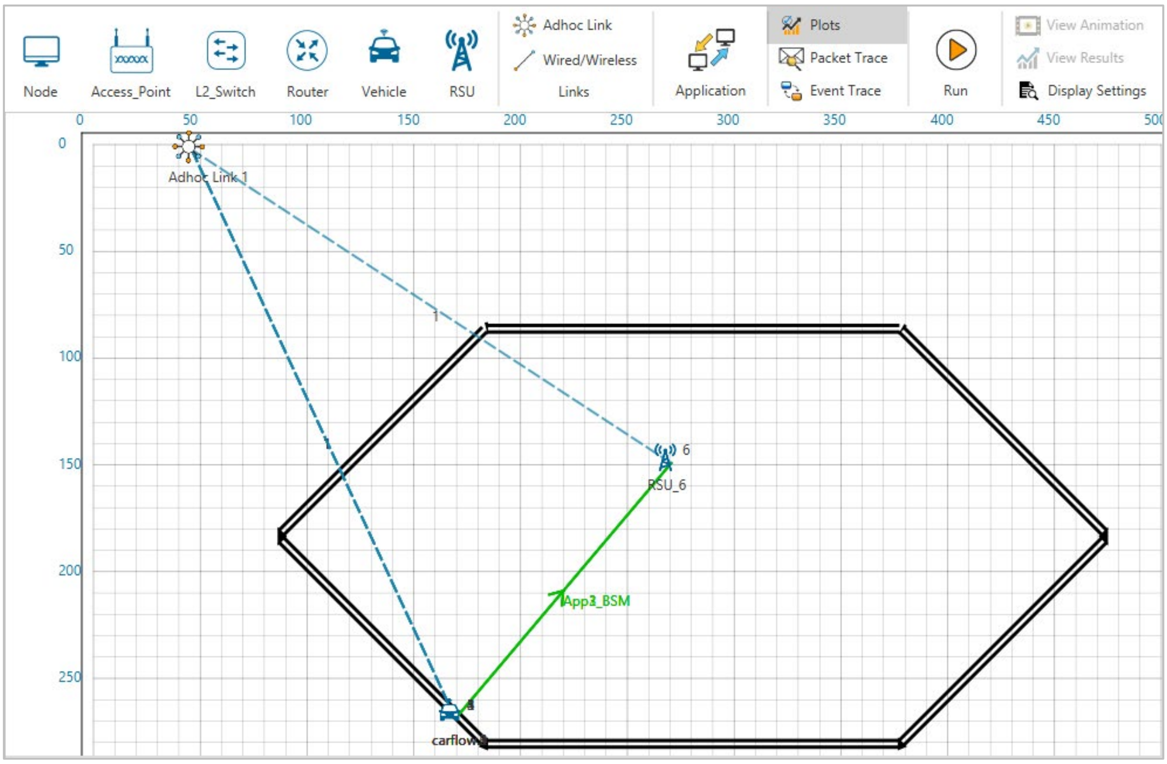


Figure 4-29: Network set up for studying the SUMO Vehicles in closed loop

Settings done for this sample experiment:

1. Applications set as BSM (Basic_Safety_Message)

APP_ID	Source_ID	Destination_ID	Packet_Size (Bytes)	Inter-Arrival Time (μs)
APP_1_BSM	1	6 (RSU)	100	2,000,000
APP_2_BSM	2	6 (RSU)	100	2,000,000
APP_3_BSM	3	6 (RSU)	100	2,000,000

Table 4-9: CBR Applications settings

2. Transport protocol set as WSMP for all applications in Application window.
3. In Vehicle General Properties, under SUMO file Configuration.sumo.cfg file was selected from the Docs folder of NetSim Install Directory < C:\Program Files\NetSim Standard\Docs\Sample_Configuration\VANET\SUMO-Vehicles-moving-in-closed-loop >

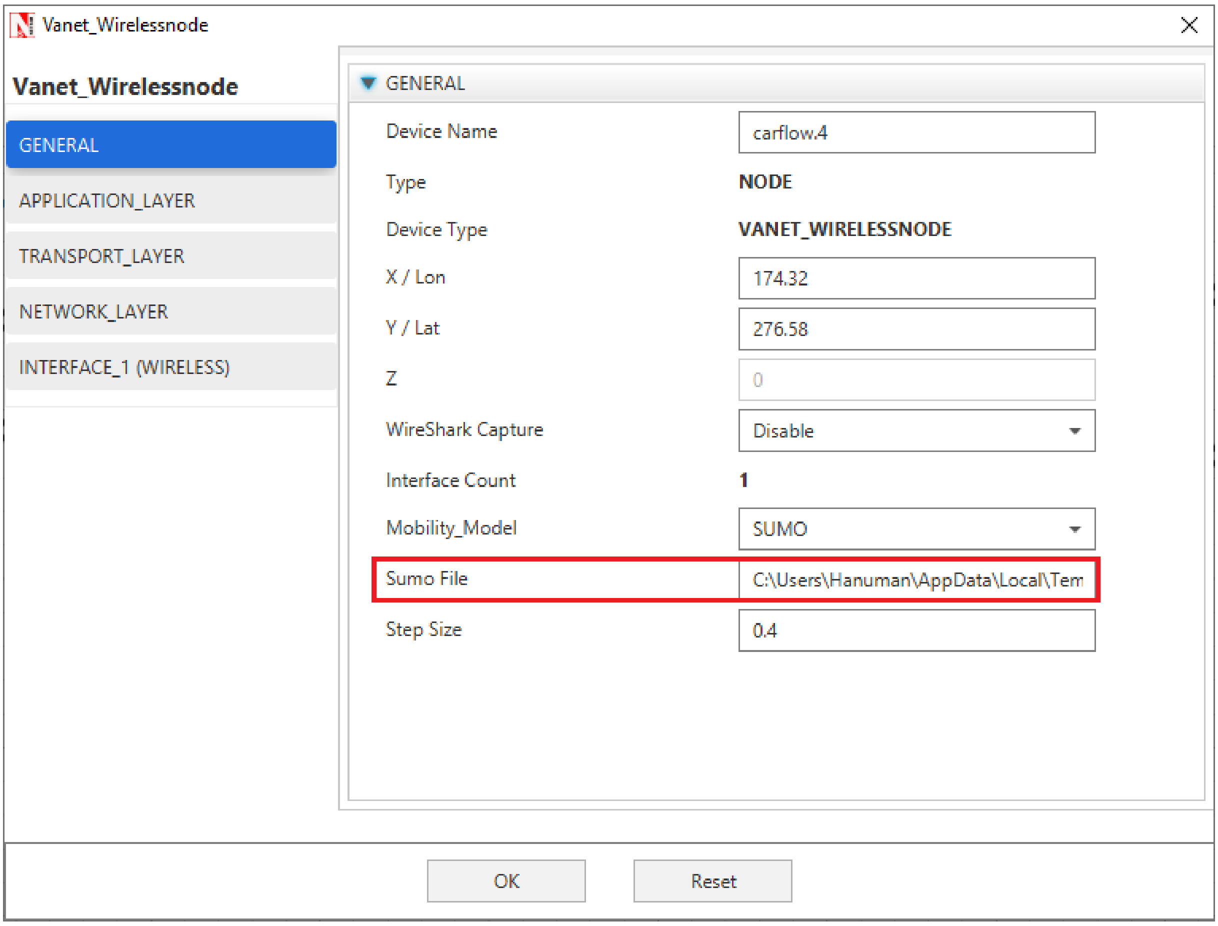


Figure 4-30: General Properties window

4. Adhock link/Wireless link properties were set as follows:

Channel Characteristics	Pathloss Model	Pathloss Exponent
Pathloss_Only	Log_Distance	2

Table 4-10: Wireless link properties

5. Medium access protocol set as DCF in all vehicles and RSU.
6. Enable Plot and Run simulation and observe the movement of the vehicles in the packet animation window.
7. After the simulation, in NetSim Packet Animation window, we can see that vehicles are moving continuously through the closed-loop hexagonal path till the given end time.

Result:

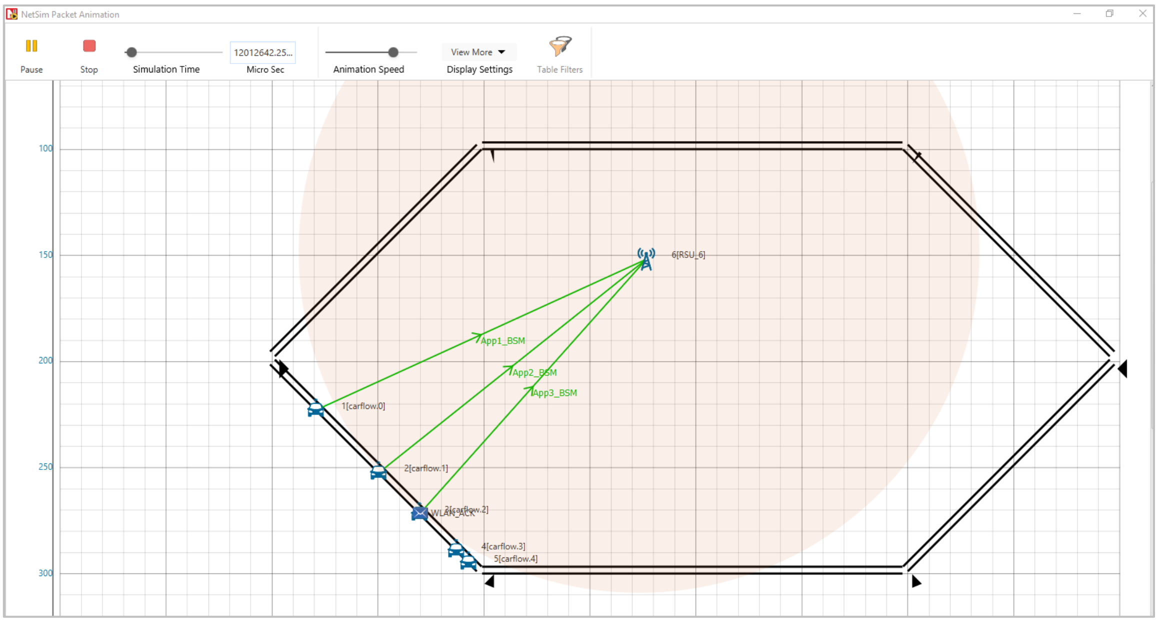


Figure 4-31: Packet animation window for NetSim

With play and record animation enabled, same can be observed in SUMO as well

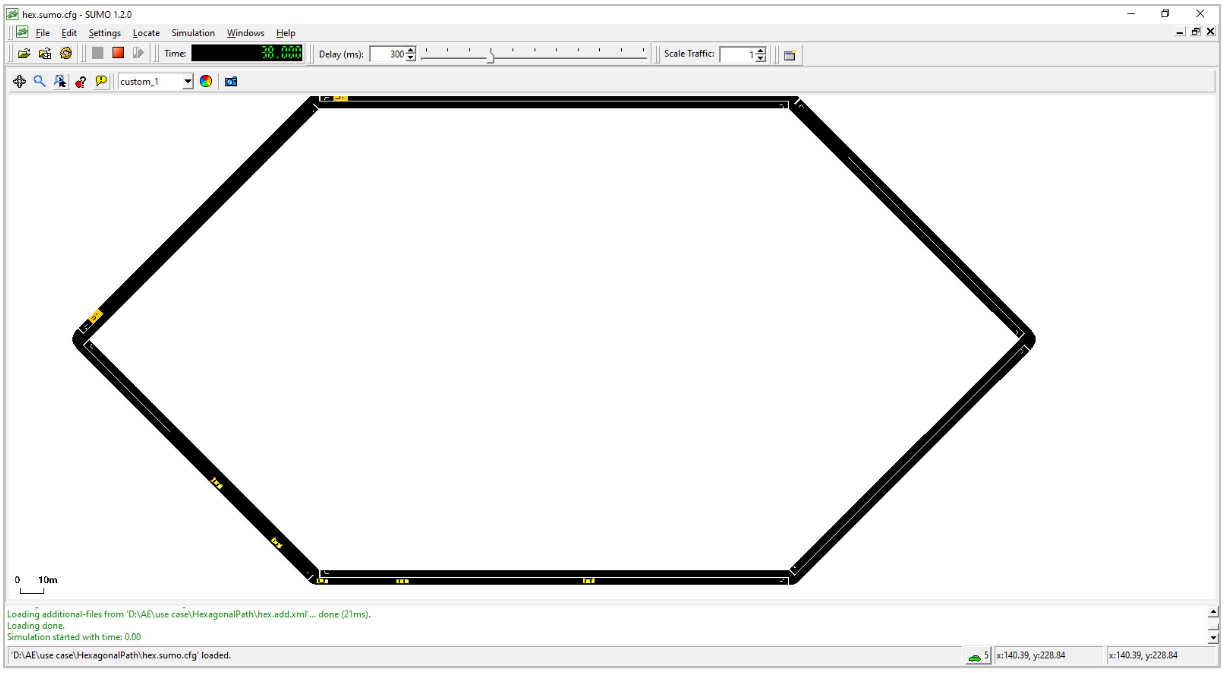


Figure 4-32: Animation window for Sumo

According to SUMO, the road network consist of 'Edges' and 'Junctions'. The re-router (a device in SUMO and is not to be confused with Routers available in NetSim) established in the edge will re-route the vehicle from one edge to other after one successful revolution through the road network. The presence of a single re-router will forward the vehicles from one edge to other and then the vehicle eventually stops its movement. Hence, two re-routers have been established in two edges which re-routes the vehicle from one edge to other. The above road network consists of six edges in which re-routers are established in the starting and ending edges, which re-routes the vehicles present in the network from starting edge to the finishing edge after one complete revolution through the road or path. As a result, the vehicles will move through the closed loop continuously, until the end time configured in the configuration file.

In the animation window, we can observe that the vehicles will start from a point in one of the edges, moves through other five edges and finally reach back the point where it started. At this point, the re-router will direct the vehicles to the next edge. This cycle will continue till the end time configured.

The RSU configured in the network will allow V2I communication. Per the application configuration a 100 bytes packet is transmitted from vehicle to RSU every 2 seconds. This can also be observed in the packet trace.

5 Reference Documents

- IEEE 802.11p 2010. Wireless Access for Vehicular Environments
- IEEE1609: Standards for Wireless Access in Vehicular Environment (WAVE)

6 Latest FAQs

Up to date FAQs on NetSim's VANETs library is available at
https://tetcos.freshdesk.com/support/solutions/folders/14000118424