NetSim®

Accelerate Network R & D

Satellite Communication Networks

A Network Simulation & Emulation Software

By

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1 Introduction

NetSim satellite library models end-to-end, full stack, packet level communication between terrestrial nodes and Geostationary satellites. Geo satellites have the unique property of remaining permanently fixed in exactly the same position in the sky as viewed from any fixed location on Earth. This means ground-based antennas do not need to track them but can remain fixed in one direction. These satellites have orbital period that is the same as Earth's rotation period and are the most common type of communications satellites.

The Satellite MAC layer protocol supported in NetSim is TDMA for forward link and MF-TDMA for return link (based on the DVB S2 standards). The forward link is in the Ku band (12 – 18 GHz) while the return link is in the Ka band (24 – 40 GHz)

The satellite can be thought of as a relay station. It operates on the bent-pipe (transparent star) principle, sending back to Earth what comes in, with only amplification and a shift from uplink to downlink frequency.

In NetSim, the satellite communication network library interfaces with Internetworks library. This means users can connect Satellite gateway and User Terminals to devices such as Routers, Switches Wired nodes, Access point and Wireless nodes etc.

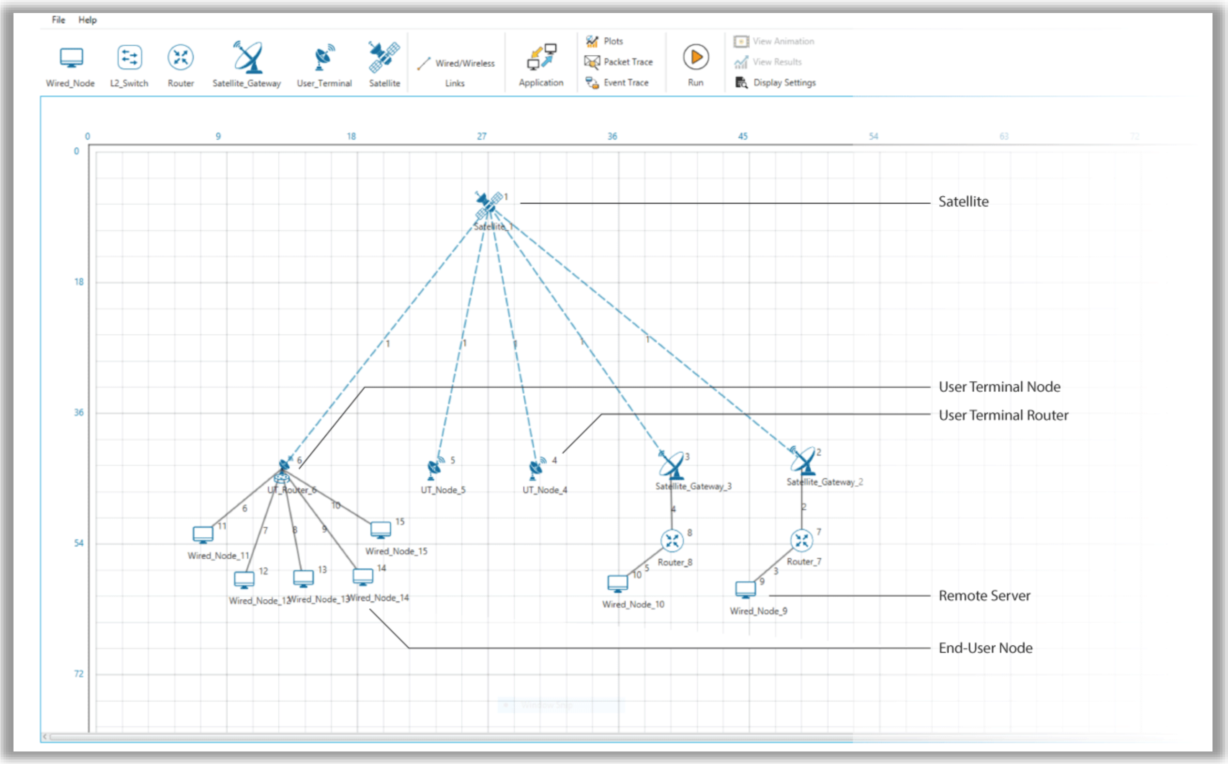


Figure 1-1: NetSim GUI showing Satellite User Terminals connected to a server via satellite links

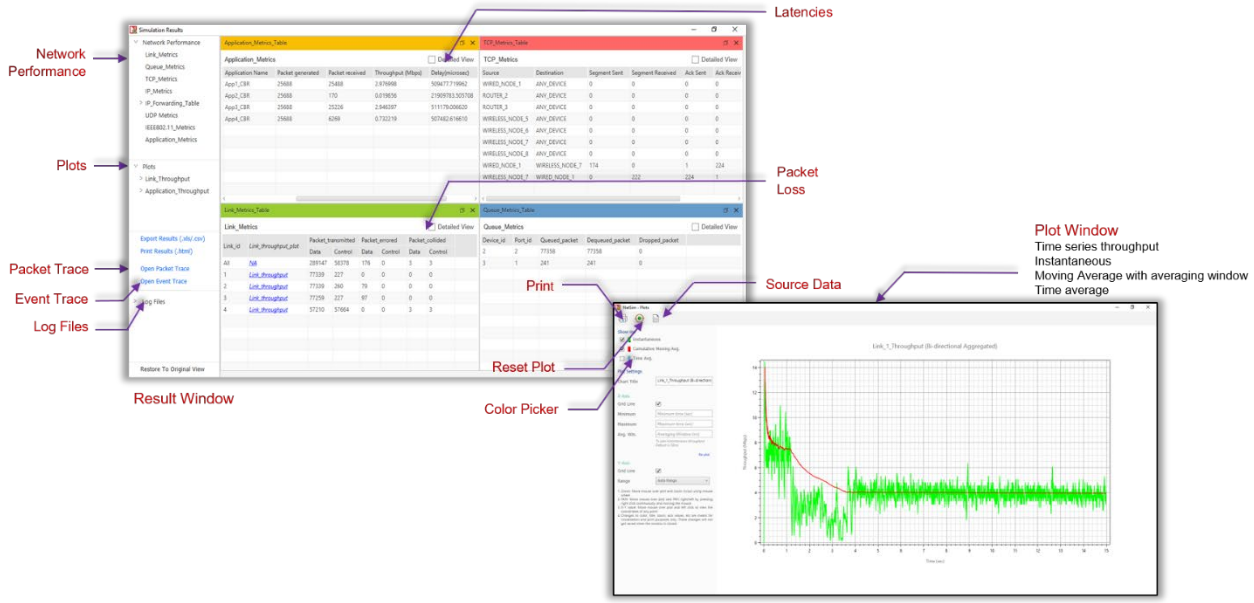


Figure 1-2: The Result dashboard and Plot window shown in NetSim after completion of simulation

The PHY layer models include:

a. Channel model: Friis free space path loss with Loo Markov fading model.
b. Modulation: QPSK, 8PSK, 16APSK, 16QAM, 32APSK with appropriate coding rates.
c. Tx, Rx Antenna gains.
d. Antenna gain to noise temperature.

All the choices of transport protocols, and all types of applications in unicast mode can be run.

NetSim's protocol source C code shipped along with (standard / pro versions) is modular and customizable to help researchers to design and test their own sat-com protocols.

2 Simulation GUI

Open NetSim, Go to **New Simulation → Satellite Comm. Networks**

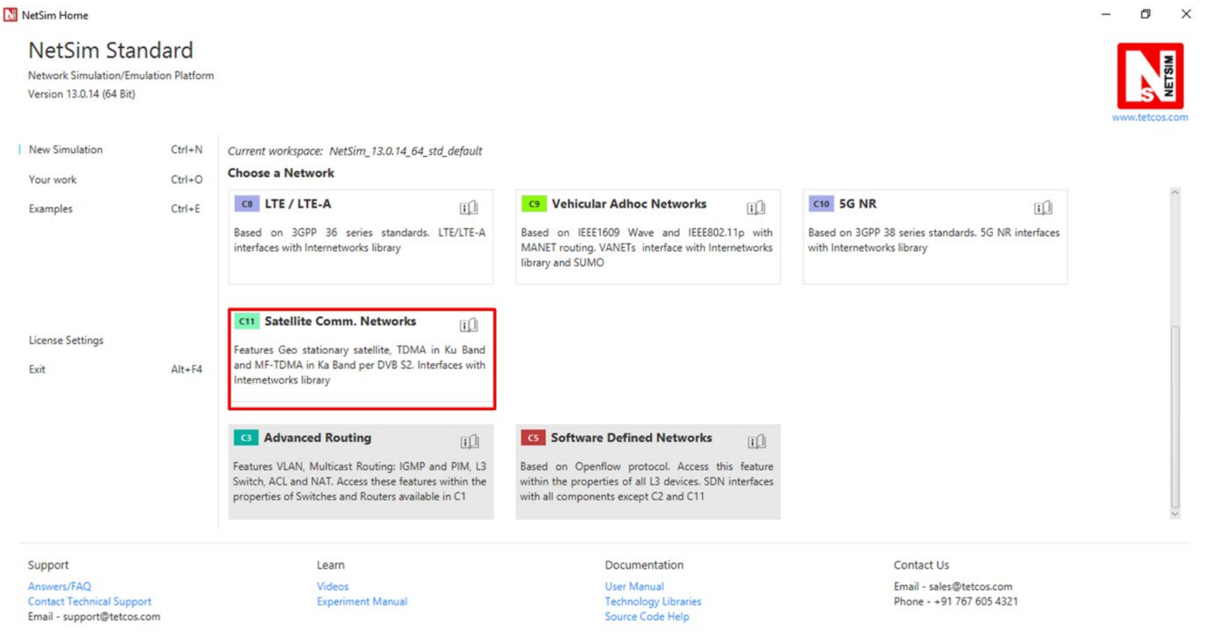


Figure 2-1: NetSim Home Screen

2.1 Create Scenario

Satellite Communication Networks palette features various devices like Wired Nodes, L2 Switch, Access Point, Wireless node, UT Router (User Terminal Router), Router, UT Node (User Terminal Node), Satellite Gateway, and Satellite.

2.2 Devices specific to NetSim Satellite Comm. Library

a. **UT -** User Terminal. The user terminals are part of the same communication network as the Satellite Gateway. The User Terminals in NetSim are UT_Node and UT_Router

b. **UT Router** - User Terminal Router. A UT_Router is used when a separate communication network is required. The typical use case is where there are multiple devices downstream who seek to utilize the sat-com link. The UT Router cannot be a source of any traffic.

c. **Satellite Gateway:** Each gateway has two interfaces, a satellite interface and multiple wired interfaces. The satellite interface connects via the forward link to the satellite. The wired interface allows for connection to routers via the wired interface. When connected to a satellite, the user terminals mapped to the gateway are part of the same network. Multiple gateways can be configured per satellite, and round-robin scheduling is run (at the Network control center (NCC) which is not displayed in NetSim GUI)

d. **Satellite:** Since the satellite model is a bent pipe the satellite does not have an IP. Each satellite can be connected to multiple gateways and to multiple User_Terminals. The satellite node cannot be the source of any traffic. The default altitude of the Satellite is 35,768,000 meters, which represents the circular geosynchronous orbit. Multiple satellites can be configured per scenario. However, no interference is modeled when multiple satellite communication occurs simultaneously.

e. **Coordinate System:** NetSim uses a Geodetic co-ordinate system. The altitude is from Mean Seal level. The geocentric co-ordinate system uses distance from the centre of the earth.

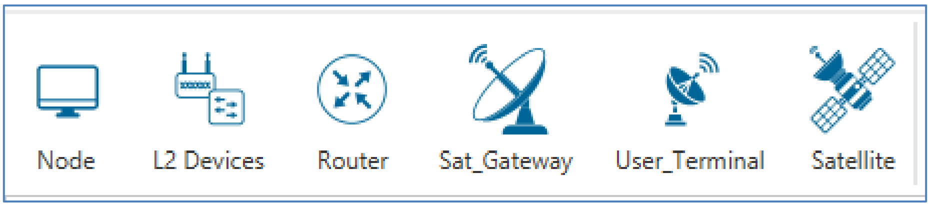


Figure 2-2: The devices present in the ribbon in NetSim's GUI

2.3 Placement of devices on the grid environment

f. Add a User Terminal (UT) – Click the **User_Terminal > UT_Node** icon on the toolbar and place the device in the grid. UT_Node must be connected to Satellite.

g. Add a UT Router – Click the **User_Terminal > UT_Router** icon on the toolbar and place the device in the grid. UT_Router must be connected to a Node or to a L2_Switch or to a Router or to an Access_Point or Satellite.

h. Add a Satellite – Click the **Satellite** icon on the toolbar and place the Satellite in the grid. Satellite must be connected to a Satellite_Gateway or to a UT_Node or to a UT_Router.

i. Add a Satellite_Gateway – Click the **Satellite_Gateway** icon on the toolbar and place the Satellite_Gateway in the grid. Satellite_Gateway must be connected to a Satellite or to a Router.

j. Add a Router – Click the **Router** icon on the toolbar and place the Router in the grid.

k. Add a Wired Node – Click the **Wired_Node** icon on the toolbar and place the device in the grid.

l. Add a L2_Switch – Click the **L2_Switch** icon on the toolbar and place the device in the grid.

m. Add an Access_Point – Click the **Access_Point** icon on the toolbar and place the Access_Point in the grid.

n. Add a Wireless Node – Click the **Wireless Node** icon on the toolbar and place the device in the grid.

Note: It is recommended not to connect multiple satellite gateways to a single satellite since this can leads to IP address and static route complications

2.4 GUI Configuration Parameters

The SATELLITE parameters can be accessed by right clicking on a Satellite, Satellite Gateway, UT Router or UT and selecting Interface (SATELLITE) Properties → Datalink and Physical Layers.

Satellite Properties			
Interface (Satellite) – Physical Layer			
Parameter	**Type**	**Range**	**Description**
G/T (dBk)	Local	0-100000dBk	Antenna gain-to-noise-temperature is (G/T) where G is the antenna gain in decibels at the receive frequency, and T is the equivalent noise temperature of the receiving system in kelvins.
Tx Power	Local	0-10000dBW	It is the signal intensity of the transmitter. The higher the power radiated by the transmitter's antenna the greater the reliability of the communications system.
Access Protocol	Fixed	TDMA	TDMA allows a number of clients to access a single radio-frequency channel without interference by allocating unique time slots to each user within each channel, reducing the loss of packets and improving the data rate thereby

			delivering QoS to the clients.
	Fixed	MF-TDMA	Multi-frequency time-division multiple access is a technology for dynamically sharing bandwidth resources in an over-the-air two-way communications network.
Base Frequency (GHz)	Local	Ku-band: 12-18GHz Ka-band: 26-40GHz	The “band” in use refers to the radio frequencies used to and from the satellite: Ku-band services uses the 12 - 18 GHz, and Ka-band services uses the 26- 40 GHz segment of the electromagnetic spectrum
Band	Fixed	KU	Microwave frequency band used for satellite communication and broadcasting, using frequencies in the range of 12 -18 GHz
	Fixed	KA	Microwave frequency band used for satellite communication and broadcasting, using frequencies in the range of 26 - 40 GHz
Rolloff Factor	Local	0-1	In NetSim, Symbol Rate = BW / (1+Roll of factor) and Bit Rate = Symbol rate * Modulation order * CodeRate

Spacing Factor	Local	0-1	In NetSim EffectiveBandwidth (Hz) = AllocatedBandwidth (Hz) / ((RollOffFactor + 1.0) * (SpacingFactor + 1.0)); Spacing factor should be in the range of [0,1]
Carrier Bandwidth (Hz)	Local	0-1000000 Hz	Bandwidth of the carrier in Hz
Framecount in Superframe	Local	0-1000000	Number of frames present in a superframe.
Frame Bandwidth (Hz)	Local	0-1000000 Hz	Bandwidth of the frame in Hz.
Frame Usage Mode	Local	NORMAL SHORT	Baseband frame usage modes.
Modulation	Local	QPSK 8PSK 16APSK 16QAM 32APSK	Modulation is the process of varying one waveform in relation to another waveform. It is used to transfer data over an analog channel.
Coding Rate	Local	1/3,1/2, 3/5, 2/3, 3/4, 4/5, 5/6, 8/9, 9/10	It states what portion of the total amount of information that is useful(non-redundant). This code rate typically a fractional number.
Slot Count in Frame	Local	Short Frame: QPSK-90, 8PSK-60, 16APSK/16QAM-45, 32APSK-36 Normal Frame: QPSK-360, 8PSK-240, 16APSK/16QAM-180, 32APSK-144	The number of slots per frame. The number of slots per frame is based on modulation and frame type chosen.
Symbol Rate	Local	0-1000000	It is ratio of total bandwidth and (1+ Roll of Factor)

Symbol per Slot	Local	0-1000000	The number of TDMA symbols within a slot, the default value of symbol per slot is 90.
Pilot Block Size (Symbols)	Local	0-1000000 symbols	Size of pilot block in symbols
Pilot Block Interval (Slots)	Local	0-1000000 slots	Interval (in symbols) between Pilot blocks
Pilot Header (Slots)	Local	0-1000000 slots	The pilot block header size in slots.
Frame Header Length (Bytes)	Local	0-1000000 bytes	Baseband frame header length in bytes
BER Model	Local	Fixed	BER value is based on the user input.
		FILE BASED	File Based is a feature in NetSim with which users can define the BER. Users will have to provide a BER_FILE.txt file as input to NetSim by clicking on the Open file link the Physical Layer-Properties of the device.
		MODEL_BASED	The BER model, calculates the BER via the pathloss model for the particular scenario.
BER	Local	0.00000001-1	This is the rate at which errors occur in the transmission of digital data.
UT Properties			
Interface (Satellite) – Physical Layer			
Parameter	Parameter	Parameter	Parameter
Tx Antenna Gain (dB)	Local	0-1000000dB	A relative measure of an antenna's ability to direct or

			concentrate radio frequency energy in a particular direction or pattern at the transmitter side.
Rx Antenna Gain (dB)	Local	0-1000000dB	A relative measure of an antenna's ability to receive radio frequency energy in a particular direction or pattern at the receiver side.

Table 2-1: Satellite, Satellite Gateway, UT Router or UT and selecting Interface (SATELLITE) Properties → Datalink and Physical Layers Description

Propagation Model			
Link Properties			
Parameter	**Type**	**Range**	**Description**
Propagation Medium	Link	Air	Medium of propagation in NetSim would be Air for RF waves.
Channel Characteristics	Fixed	Pathloss and Fading and Shadowing	Path loss and fading and shadowing: In pathloss models, for a fixed distance between source and destination, path loss is same. We get varied path loss for some distance between source and destination in shadowing and fading is variation of the attenuation of a signal with various variables. These variables include time, geographical position, and radio frequency.
Shadowing Model	Fixed	NONE	
Pathloss Model	Link	Friis Free Space	It Used to model the LOS path loss incurred in the channel. the Friis

			Free space model is restricted to unobstructed clear path between the transmitter and the receiver.
Pathloss Exponent (η)	Fixed	2	Path loss exponent indicates the rate at which the path loss increases with distance. The value depends on the specific propagation environment.
Fading Model	Fixed	Markov Loo	Each state of the three-state Markov channel models obeys the Loo distribution with different parameters; while the state transition is modeled as a first-order Markov random process.
Direct Signal Mean (dB)	Link	-∞ to ∞	Mean value of the direct signal, value can be differentiated according to the state.
Direct Signal Standard Dev (dB)	Link	0 to ∞	Standard Deviation of the direct signal value can be differentiated according to the state.
RMS Multipath Power (dB)	Link	-∞ to ∞	RMS squared multipath power in dB
Number of Direct Signal Oscillators	Link	0 to ∞	Number of direct signal oscillator is used for frequency conversion process in superheterodyne receiver.

Number of Multipath Oscillators	Link	0 to ∞	Number of multipath oscillators is used to generate higher oscillation frequencies.
Direct Signal Doppler (Hz)	Link	0 to ∞	
Multipath Doppler (Hz)	Link	0 to ∞	The normalized PSD (its integral in the whole frequency range equals to one) constitutes the PDF for the Doppler frequencies, arising from the different angles of arrival the multipath components have with respect to the receiver's motion.
Initial Probability	Link	0 to 1	An initial probability distribution, defined on S, specifies the starting state. Usually this is done by specifying a particular state as the starting state.

Table 2-2: Propagation Model/Wireless Link Properties Description

2.4.1 Mapping of User_Terminal (UT_Note / UT_Router) to Satellite_Gateway

Each satellite can be connected to multiple Satellite_Gateways and to Multiple User_Terminals. The following screen shot shows how to map the User_Terminal to Satellite_Gateway as shown **Figure 2-3.**

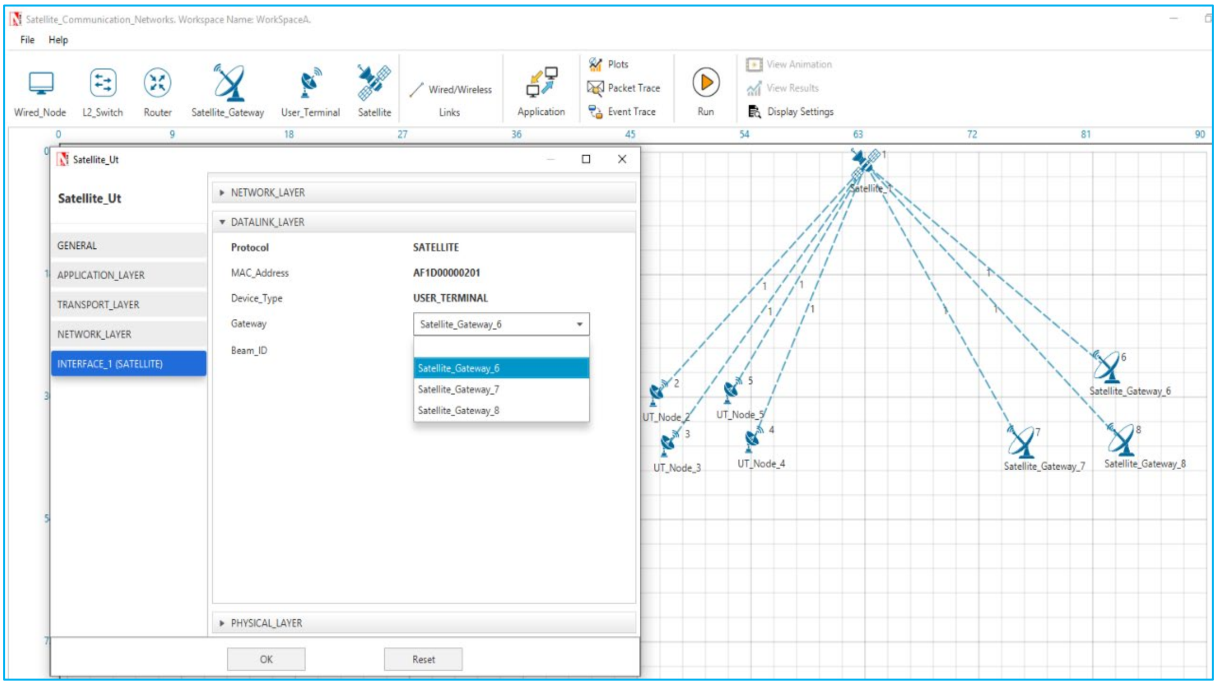


Figure 2-3: Mapping of User_Terminal (UT_Note / UT_Router) to Satellite_Gateway

In order to Map User_Terminal (UT_Node / UT_Router) to Satellite_Gateway right click go to the properties of **UT_Node/UT_Router → INTERFACE1_(SATELLITE) → DATALINK_LAYER → Gateway** user can map the Satellite_Gateway with UT_Node / UT_Router accordingly.

Additionally, in the UT_Router/UT_Node -> Interface_Satellite the default gateway IP should be set as the IP of the connected Satellite_Gateway.

Incorrect mapping of the Satellite_Gateway and/or the default_Gateway IP address, in the properties of the UT_Node / UT_Router could lead application crash or NIL application throughputs.

2.4.2 Configuring Static Routes

After mapping the UT_Router/UT_Node to a Satellite_Gateway, static routes need to be configured in the devices to forward traffic. Let us consider the following network scenario as shown **Figure 2-4.**

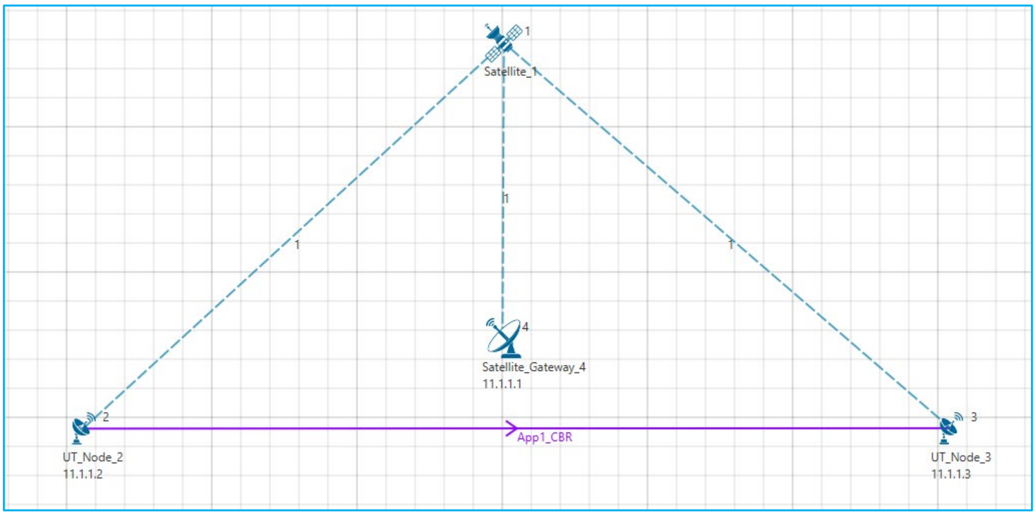


Figure 2-4: Network Topology in this experiment

In this network scenario, for UDP traffic to be sent from UT_Node_2 to UT_Node_3, static routes need to be set in UT_Node_2 and in the Satellite_Gateway_4.

If TCP traffic needs to be sent from UT_Node_2 to UT_Node_3, then static routes need to be set in UT_Node_3 as well. This is essential for connection establishment and sending acknowledgements.

Refer the featured example on Configuring applications from UT Node to UT Node for detailed information on static route configuration.

2.4.3 Multiple gateways connected to a single satellite

An example where Multiple gateways are connect to the single Satellite is shown in below screenshot **Figure 2-5.**

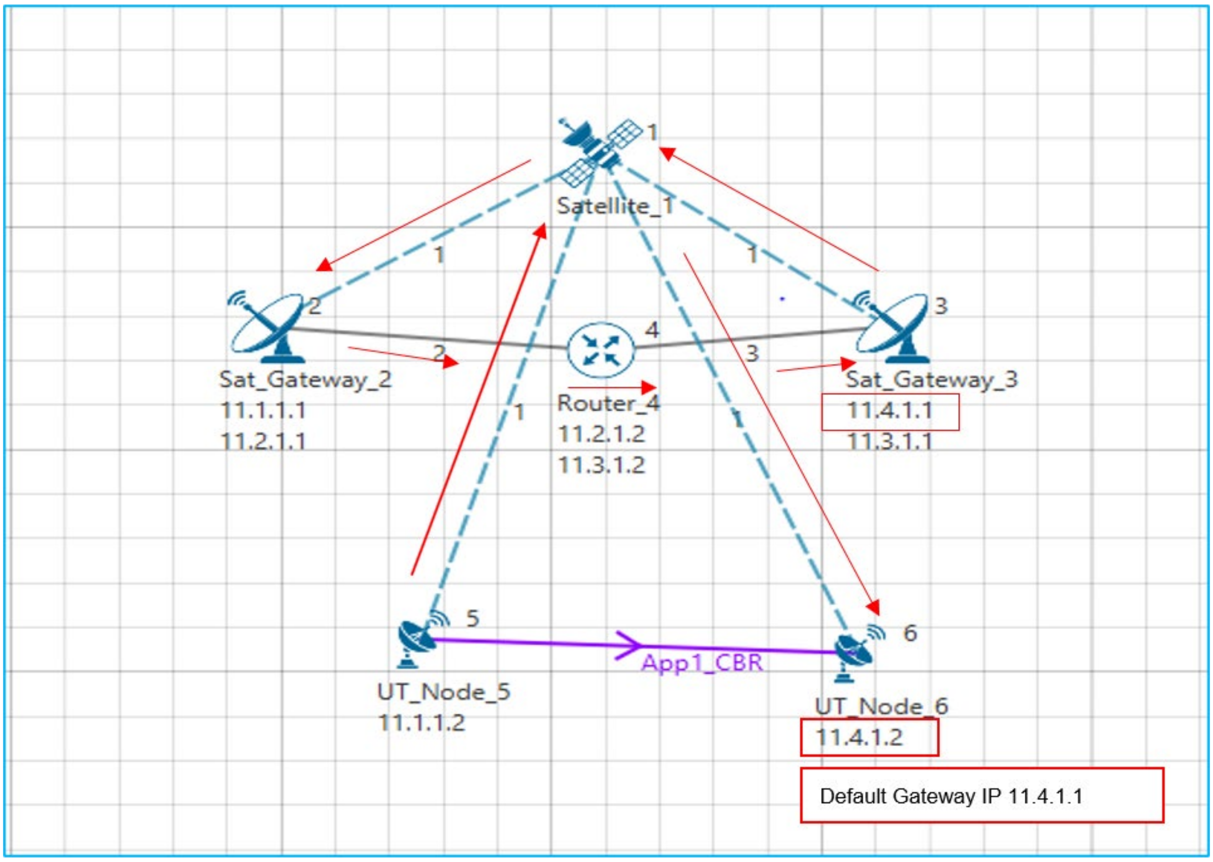


Figure 2-5: Network Topology for this experiment. The red arrows indicate packet flow. The satellite is at an atlitude ≈ 35,000 kms and hence should be imagined as being at this height.

In order to Map User_Terminal (UT_Node / UT_Router) to Satellite_Gateway, right click /properties of **UT_Node/UT_Router → INTERFACE1_(SATELLITE) → DATALINK_LAYER → Gateway.** Here the user must map the Satellite_Gateway[1] for the UT_Node / UT_Router. For UT_Node_6, the satellite gateway is 3, and for UT_Node_5 the Satellite gateway is 2.

In this network scenario, for UDP traffic is sent from UT_Node_5 to UT_Node_6. The traffic flow is UT_Node_5 > Satellite_1 > Sat_Gateway_2 > Router_4 > Sat_Gateway_3 > Satellite_1 > UT_Node_6. Appropriate static routes need to be configured in UT_Node_5, Sat_Gateway_2, Router_4, and Sat_Gateway_3.

Refer the featured example on Configuring applications from UT Node to UT Node for detailed information on static route configuration.

[1] Default Gateway IP address is an IP layer address configuration, and is different from Satellite Gateway which is a device

3 Model Features

3.1 TDMA Forward Link and MF TDMA Return Link

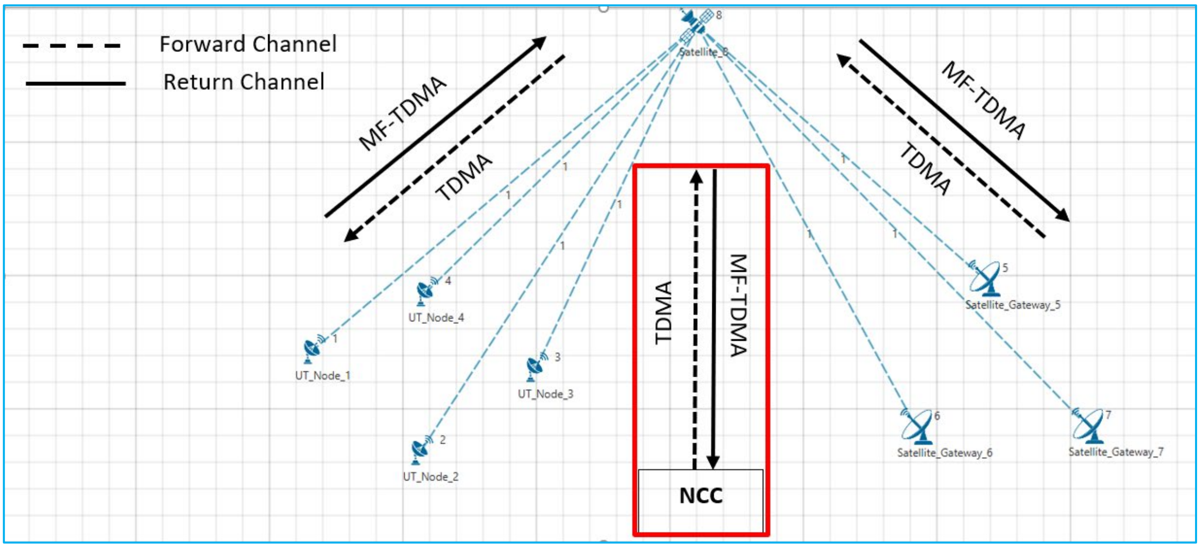


Figure 3-1: Forward and Return links. The Network Control Centre (NCC) is not displayed in NetSim and is assumed to be part of every satellite

In NetSim, a Forward link is defined as the direction from Satellite Gateway to Satellite to UT_Node / UT_Router). A Return link is defined as the direction from the UT_Node / UT_Router to Satellite to the Satellite Gateway.

The protocol operating in the Forward link is Time Division Multiple Access (TDMA). The protocol operating in the Return link is Multi Frequency Time Devision Multiple Access (MF-TDMA).

Both the Forward link and Return link transmissions in NetSim are modeled as Layer-2 transmissions. The framing is as explained in the subsequent paragraph.

Each Super Frame is composed of a number of Frames. This is taken as a user input, given by the attribute Framecount_in_SuperFrame available in Satellite -> Interface_Satellite -> Physical_Layer properties. The frames in turn are composed of carriers (in frequency) and slots (in symbols). The number of carriers would be

$$Numebr\ of\ Carriers = \frac{Frame\ Bandwidth\ (Hz)}{Carrier\ Bandwidth\ (Hz)}$$

The number of slots per frame is determined by the modulation scheme chosen by the user.

3.2 Modulation and coding schemes supported

1. QPSK with coding rates 1/3, 1/2, 3/5, 2/3, 3/4, 4/5, 5/6, 8/9, 9/10
2. 8PSK with coding rates 3/5, 2/3, 3/4, 5/6, 8/9, 9/10
3. 16APSK with coding rates 2/3, 3/4, 4/5, 5/6, 8/9, 9/10
4. 16QAM with coding rates 3/4, 5/6
5. 32APSK with coding rates 3/4, 4/5, 5/6, 8/9

3.3 Physical layer framing for forward and return links

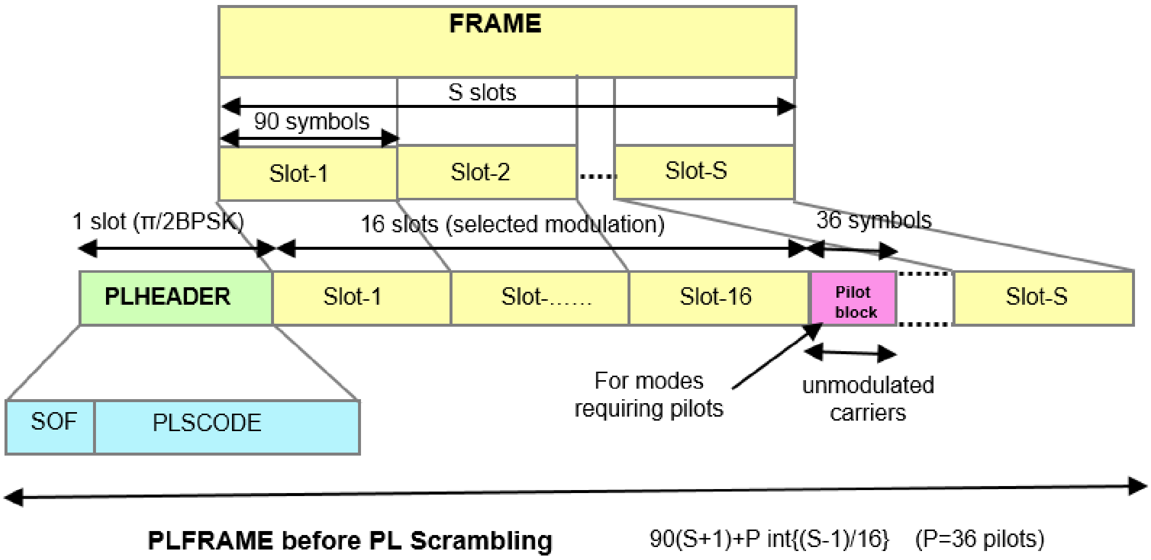


Figure 3-2: Format of a "Physical Layer Frame" PLFRAME

	$\eta_{ldpc} = 64800$ (normal frame)		$l = 16200$ (short frame)	
η_{MOD} (bits/Hz)	S	η % no − pilot	S	η % no − pilot
2	360	99.72	90	98.90
3	240	99.59	60	98.36
4	180	99.45	45	97.83
5	144	99.31	36	97.30

Table 3-1: S = number of SLOTs per FRAME (number of symbols per slot is 90)

The normal frame and short frame setting can be done using the Frame_Usage_Mode parameter in the GUI as shown **Figure 3-3.**

Changing the Modulation scheme in UI would change the value of S (Slot_count_in_frame)

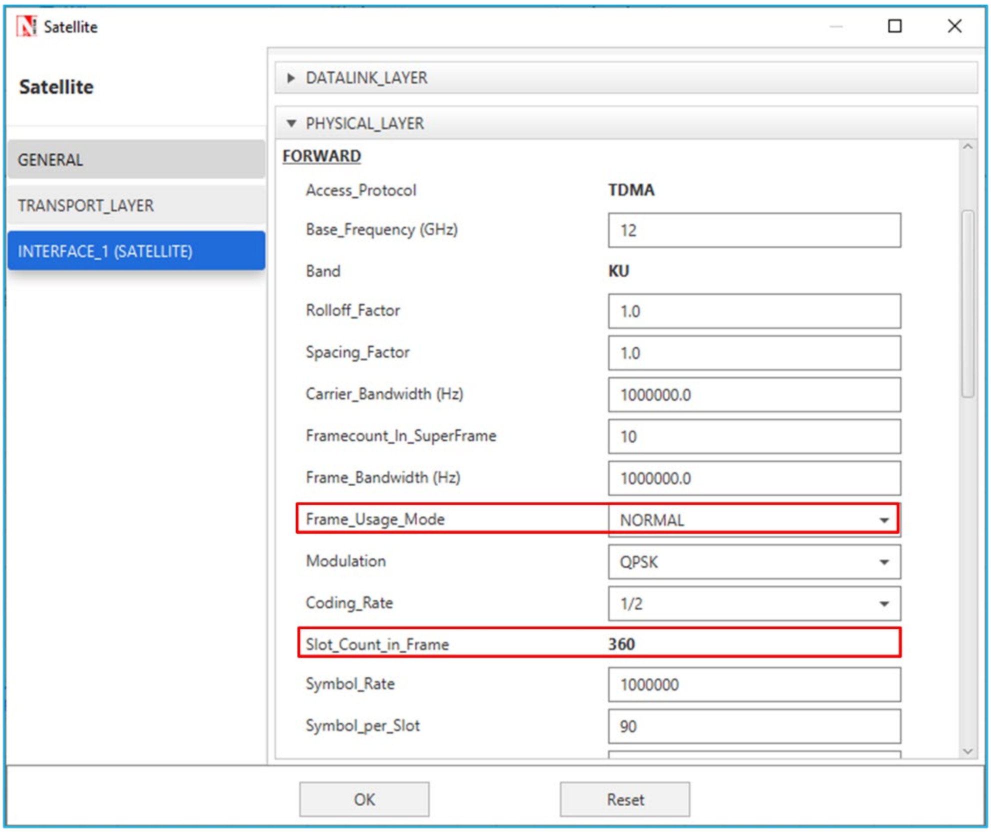


Figure 3-3: Satelittle > Physical layer properties window

Default NetSim GUI settings

- Symbols per slot: 90
- Pilot Block size (symbols): 36
- Pilot block interval (slots): 16
- PL header size (slots): 1
- Frame header size (In bytes): 10 (per ETSI EN 302 307 V1.3.1)
- Frame Type: Normal (Options are normal or short)

3.4 Satellite PHY: Date Rate

Given below is the data rate calculation methodology for both forward and return links. The parameter values used are the default values in NetSim GUI.

$$Symbol\ Rate = \frac{BW}{(1 + (Roll\ of\ factor))}$$

$$Bit\ Rate = Symbol\ rate \times Modulation\ order \times CodeRate$$

$$Bandwidth\ (Hz) = Frame\_Bandwidth\ (Hz) = 10^6\ Hz$$

$$Central\ Frequency\ (Hz) = Base\ Frequency\ (Hz) + \frac{Bandwidth\ (Hz)}{2.0}$$

$$Central\ Frequency\ (Hz) = 26 \times 10^9 + \frac{10^6}{2} = 26000500000\ Hz$$

$$Effective\ Bandwidth\ (Hz) = \frac{Carrier\ Bandwidth\ (Hz)}{(RollOfFactor + 1.0) \times (SpacingFactor + 1.0)}$$

$$Effective\ Bandwidth\ (Hz) = \frac{10^6}{(1.0 + 1.0) \times (1.0 + 1.0)} = 25 \times 10^4\ Hz$$

$$Symbol\ Rate = Effective\ Bandwidth\ (Hz) = 25 \times 10^4 Hz$$

$$Modulation\ Bits = 2$$

The number of Modulation Bits depends on the modulation scheme.

Modulation Bits (QPSK) = 2, Modulation Bits (8PSK) = 3

Modulation Bits (16APSK / 16QAM) = 4, Modulation Bits (32APSK) = 5

$$Slots = Slot\ Count\ in\ Frame + Pilot\ Header\ (slots) = 360 + 1 = 361$$

$$Data\ Symbols = Slots \times Symbol\ per\ Slot = 361 \times 90 = 32490$$

$$Pilot\ Slot = \frac{Slots}{Pilot\ Block\ Interval} = \frac{361}{16} = 22$$

$$Pilot\ Symbol = Pilot\ Slot \times Pilot\ block\ Size\ (symbols) = 22 \times 36 = 792\ Symbols$$

$$Total\ Symbol = Pilot\ Symbol + Data\ Symbols = 792 + 32490 = 33282$$

$$Frame\ length = \frac{Total\ Symbol}{Symbol\ Rate} \times 1000000 = \frac{33282}{250000} \times 1000000 = 133128\ \mu s$$

$$Pilot\ Block\ Length = \frac{Pilot\ block\ Size}{Symbol\ Rate} \times 1000000 = \frac{36}{250000} \times 1000000 = 144\ \mu s$$

$$Slot\ Length = \frac{Symbol\ per\ Slot}{Symbol\ Rate} \times 1000000 = \frac{90}{250000} \times 1000000 = 360\ \mu s$$

$$SuperFrame\ Duration = Frame\ length \times Frames\ per\ SuperFrame = 133128 \times 10 = 1331280\ \mu s$$

$$Bits\ per\ Slot = Symbol\ per\ slot\ \times Modulation\ Bits \times Coding\ Rate = 90 \times 2 \times \frac{1}{2} = 90$$

$$Bits\ per\ Frame = Bits\ per\ Slot \times\ Slot\ Count\ in\ Frame = 90 \times 360 = 32400$$

$$Data\ Rate = \frac{Bits\ per\ Slot}{Slot\ Length} = \frac{90\ bits}{360\ \mu s} = 0.25 \times 10^6\ bits/sec = 0.25\ Mbps$$

3.5 Analytical throughput estimation

Let us an example in which the Packet Size (App layer) is 1460B which translates to 1488B at the PHY layer after addition of overheads, with QPSK modulation and $\frac{1}{3}$ coding rate. For this modulation and coding rate the raw PhyRate of the channel is 162249 bps using the formulas given in 3.4. The analytical throughput estimate for such a scenario would be:

$$PacketTransmissionTime = \frac{PacketSize(at\ PHY) \times 8}{PhyRate(bps)} = \frac{1488 \times 8}{162249} = 0.0733687s = 73368.7\mu s$$

$$PacketsPerFrame = \lfloor\frac{FrameTime}{PacketTransmissionTime}\rfloor = \lfloor\frac{133128}{73368.7}\rfloor = \lfloor 1.81 \rfloor = 1$$

$PacketsPerFrame$ is the number of packets that can be packed in a frame, and hence the greatest integer or floor function is used.

$$BytesPerFrame = PacketsPerFrame \times PacketSize(B) = 1488 \times 1 = 1488$$

$$NumberOfFramesPerSecond = \frac{1}{Frame\ Duration(s)} = \frac{1}{0.133128} = 7.51$$

$$PhyThroughput = NumberOfFramesPerSecond \times (BytesPerFrame \times 8)$$
$$= 7.51 \times (1488 \times 8) = 89399.04\ bps = 0.089\ Mbps$$

$$\text{ApplicationThroughput} = \frac{1460}{1488} \times \text{PhyThroughput} = 0.087\ \text{Mbps}$$

3.6 PHY rate for various modulations and coding rates

Modulation	Modulation bits	Slot Count in a frame	Coding Rate	PHY Rate(Mbps)
QPSK	2	360	1/3	0.167
			1/2	0.250
			3/5	0.300
			2/3	0.333
			3/4	0.375

			4/5	0.400
			5/6	0.417
			8/9	0.444
			9/10	0.450
8PSK	3	240	3/5	0.450
			2/3	0.500
			3/4	0.561
			5/6	0.625
			8/9	0.667
			9/10	0.675
16APSK	4	180	2/3	0.667
			3/4	0.750
			4/5	0.800
			5/6	0.833
			8/9	0.889
			9/10	0.900
16QAM	4	180	3/4	0.750
			5/6	0.833
32APSK	5	144	3/4	0.936
			4/5	1.000
			5/6	1.042
			8/9	1.111

Table 3-2: List of support modulation schemes and coding rates, and their respective link PHY Rates

3.7 Satellite PHY: Land Satellite Channel Model

3.7.1 Propagation

The distance between the ground nodes and the satellite determines the propagation delay and path loss of the radio signal. The distance is computed based on the cartesian distance between the ground nodes and the satellite. NetSim computes the propagation delay of the radio signal traveling from the source node to the destination node at the speed of light. The propagation model calculates the weakening of the radio signal as it propagates from the source node per the pathloss and fading model.

3.7.2 Pathloss Model – Friis Free Space Propagation

The free space propagation model is used to predict received signal strength when the transmitter and receiver have a clear, unobstructed line-of-sight path between them. Satellite communication systems and microwave line-of-sight radio links typically undergo free space propagation. The free space power received by a receiver antenna which is separated from a radiating transmitter antenna by distance d, is given by the Friis free space equation.

$$P_r = P_t + G_t + G_r + 20\log_{10}[\frac{\lambda}{(4*\pi*do)}] + (10*2*\log_{10}(\frac{do}{d}))$$

where P_t is the transmitted power.

P_r is the received power.

G_t is the transmitter antenna gain.

G_r is the receiver antenna gain.

d is the T-R separation distance in meters.

λ is the wavelength in meters.

3.7.3 Fading model

NetSim uses a 3 state (state 1, state 2 and state 3) Markov model to simulate fading.

The conditional probabilities of state s_{n+1} given the state s_n are described by state transition probabilities p_{ij}

Where S_1, S_2, S_3 denotes respective channel state, P_{ij} is the probability the Markov process goes from state *i* to state *j*.

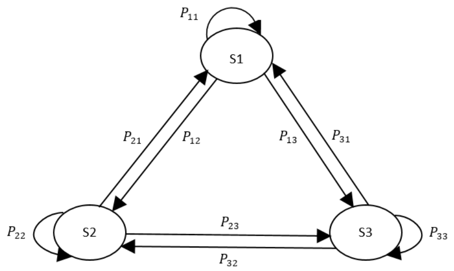


Figure 3-4: Switching of three-state Markov process

The switching among each state is described by a transition metrix P, which is

$$P = \begin{pmatrix} p_{11} & p_{12} & p_{13} \\ p_{21} & p_{22} & p_{23} \\ p_{31} & p_{32} & p_{33} \end{pmatrix}$$

Each state of the three-states of the Markov model obeys the Loo distribution with different parameters, while the state transition is modeled as a first-order Markov random process.

The Loo distribution considers the received signal as a sum of two signal components. A log-normally distributed direct signal expresses the slow fading component corresponding to varying shadowing conditions of the direct signal. A Rice distribution characterizes the fast-fading component due to multipath effects.

The Loo parameter triplet consists of the mean, the standard deviation for the log-normally distributed direct signal, and the average multipath power.

$$N(\mu, \sigma^2) + R$$

Depending on the current state interval and on the environment of the terminal, a new random Loo parameter triplet is generated. The output of the channel model is a time-series of the received signal in form of a complex envelope.

And finally, the model computes the Loo distributed time-series including Doppler shaping for every new state interval, which is the output of the proposed LMS channel model.

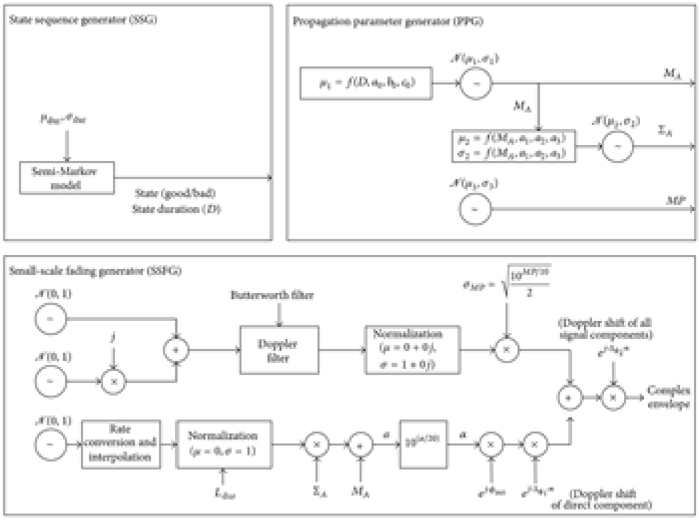


Figure 3-5: The Satellite LMS channel Model

3.7.4 SNR - BER Calculation

$$SNR\ (dBm) = \ log_{10}\left(\frac{Received\ power\ (in\ mW)}{Thermal\ Noise\ (in\ mW)}\right)$$

The SNR is calculated separately for each 'hop' of each link. This means the calculation is done from Gateway to Satellite and then separately again from Satellite to UT, and vice versa.

$Noise = k_B\ T\ B$ where $k_B$is the Boltzman's constant, B is the carrier bandwidth and T is the temperature calculated per user input of $\frac{G}{T}(dBK)$ in NetSim UI.

NetSim provides three options for BER.

- Model Based: The BER is then calculated for each link based on the SNR. Please see *Propagation-Models.pdf* document for detailed information on BER calculation.
- Fixed: the BER value can be input in the GUI. If this option is chosen, the SNR (derived from propagation model) is not used.
- File Based: SNR – BER table should be provided in a file per the format given below. This table should be in increasing order of SNR. The SNR is calculated by NetSim from the RF propagation model. For this SNR, the appropriate BER is selected from this table. BER is 1.0 for any SNR value below SNR1, and BER is 0.0 for any SNR greater than SNRn.

  SNR1, BER1

  SNR2, BER2

  …

  …

  SNRn, BERn

3.8 Results

Please see NetSim User manual, Results and Analysis section.

3.8.1 Satellite Log File

A log file specific to satellite communication, is generated post simulation as shown in screen shot below,

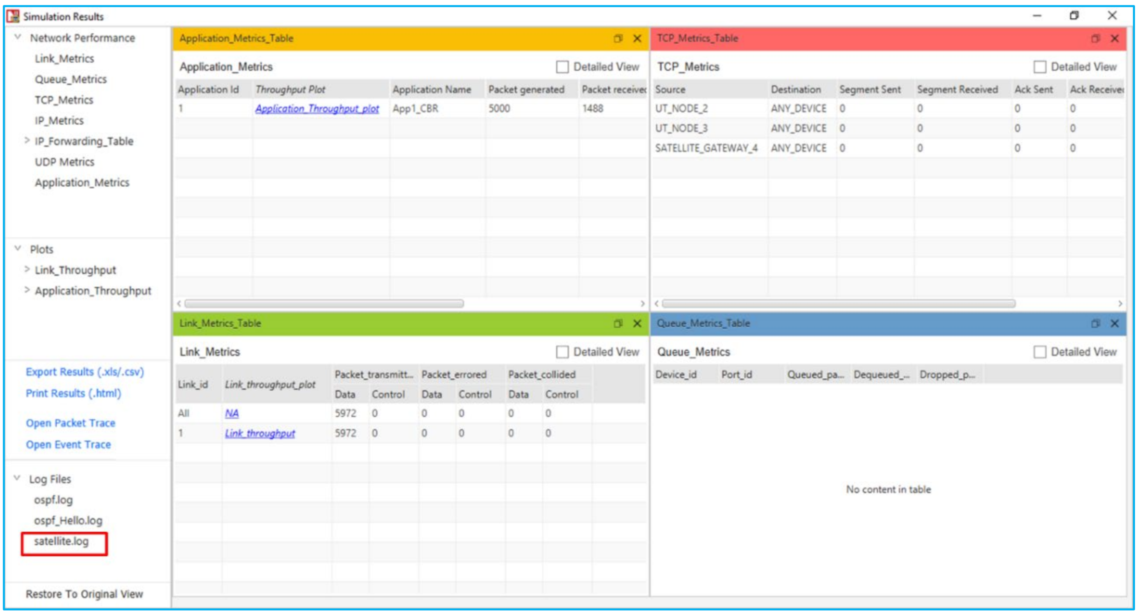
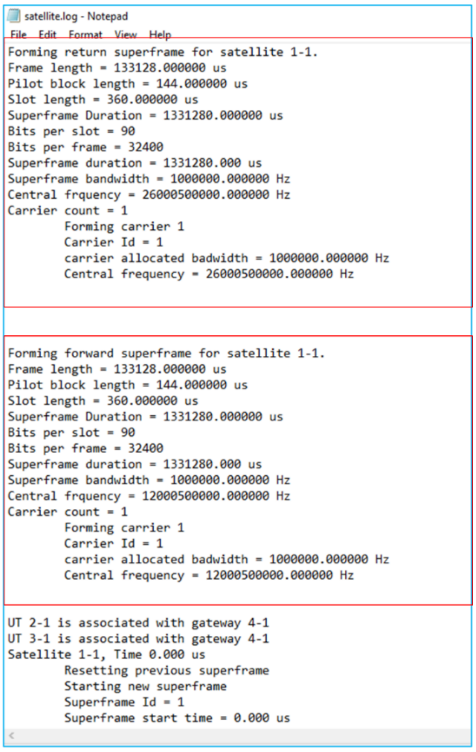


Figure 3-6: Result Window

On opening it would look like the image below



```
satellite.log - Notepad
File  Edit  Format  View  Help
Forming return superframe for satellite 1-1.
Frame length = 133128.000000 us
Pilot block length = 144.000000 us
Slot length = 360.000000 us
Superframe Duration = 1331280.000000 us
Bits per slot = 90
Bits per frame = 32400
Superframe duration = 1331280.000 us
Superframe bandwidth = 1000000.000000 Hz
Central frquency = 26000500000.000000 Hz
Carrier count = 1
        Forming carrier 1
        Carrier Id = 1
        carrier allocated badwidth = 1000000.000000 Hz
        Central frequency = 26000500000.000000 Hz

Forming forward superframe for satellite 1-1.
Frame length = 133128.000000 us
Pilot block length = 144.000000 us
Slot length = 360.000000 us
Superframe Duration = 1331280.000000 us
Bits per slot = 90
Bits per frame = 32400
Superframe duration = 1331280.000 us
Superframe bandwidth = 1000000.000000 Hz
Central frquency = 12000500000.000000 Hz
Carrier count = 1
        Forming carrier 1
        Carrier Id = 1
        carrier allocated badwidth = 1000000.000000 Hz
        Central frequency = 12000500000.000000 Hz

UT 2-1 is associated with gateway 4-1
UT 3-1 is associated with gateway 4-1
Satellite 1-1, Time 0.000 us
        Resetting previous superframe
        Starting new superframe
        Superframe Id = 1
        Superframe start time = 0.000 us
```

Figure 3-7: NetSim Satellite communication log file

This file logs details such as

- UE – Satellite Gateway association
- Calculated Super frame, frame, slot, bandwidth, carrier count etc. for each satellite.
- Frame by frame transmissions with time stamps

3.9 Omitted Features

- Regenerative transponder where the signal is demodulated, decoded, re-encoded and modulated aboard the satellite.
- Impact of Rain/Weather on signal propagation
- Forward Error Coding in Layer 2
- IPv6 Addressing
- No support for LEO, MEO

4 Featured Examples

4.1 Bandwidth variation through MCS configuration

Open NetSim, Select **Examples ->Satellite-Communication -> Bandwidth-variation-through-MCS-configuration** as shown **Figure 4-1.**

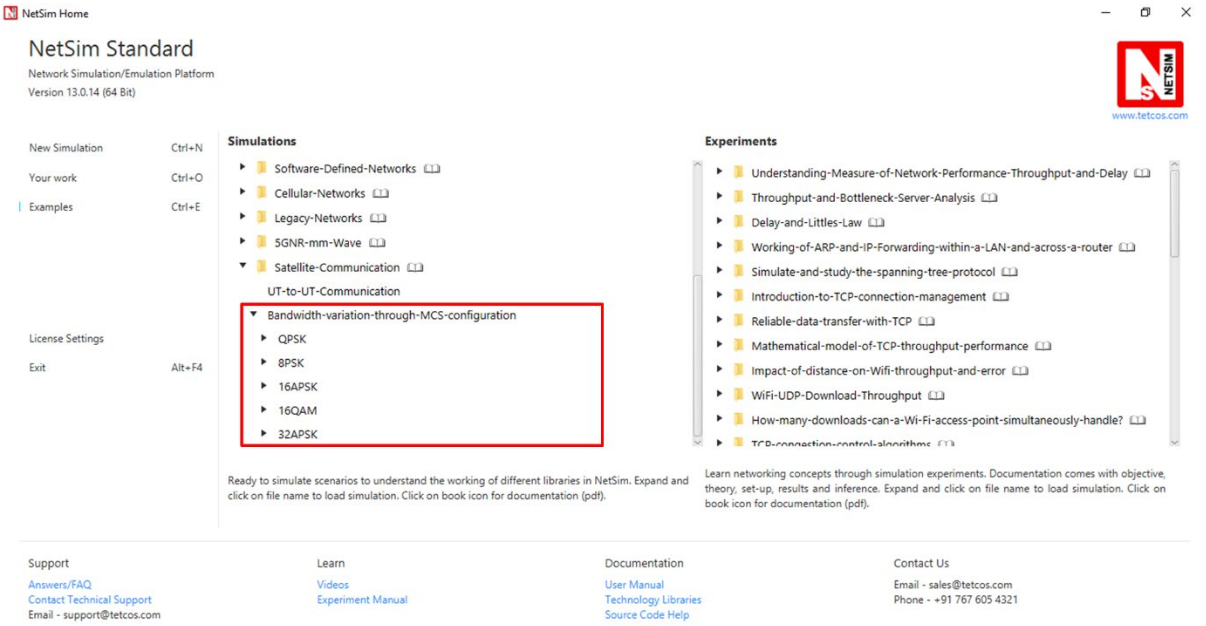


Figure 4-1: Featured Example list

The following network diagram illustrates, what the NetSim UI displays when you open the example configuration file as shown **Figure 4-2.**

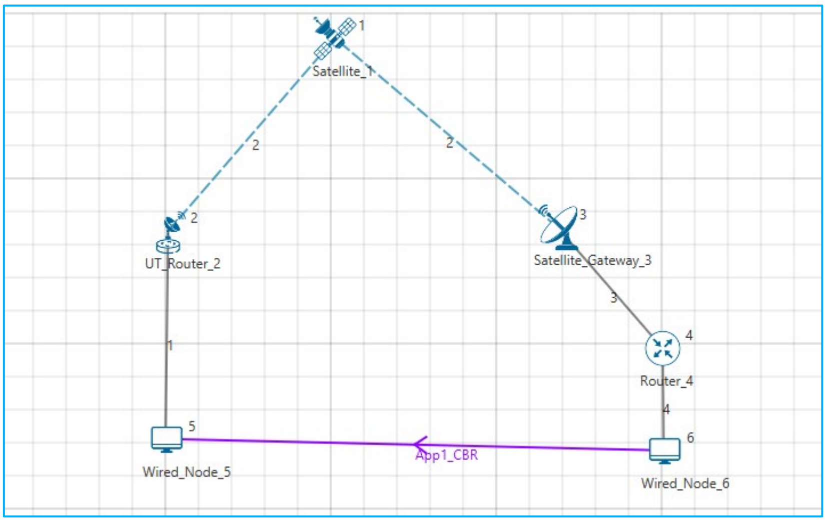


Figure 4-2: Network topology

Settings done in example config file:

1. Set the following property as shown in below given table:

Satellite Properties -> Interface (Satellite) -> Physical Layer-> Forward	
BER_Model	Fixed
BER	0.00000001

Table 4-1: Satellite Properties > Interface (Satellite) > Physical Layer > Forward

2. Set the following property as shown in below given table:

UT_Router Properties -> Interface (Satellite) -> DataLink Layer	
Gateway	Satellite_Gateway_3

Table 4-2: UT_Router Properties > Interface (Satellite) > DataLink Layer

3. Go to Router_4 properties -> Network_Layer -> Configure Static Route IP

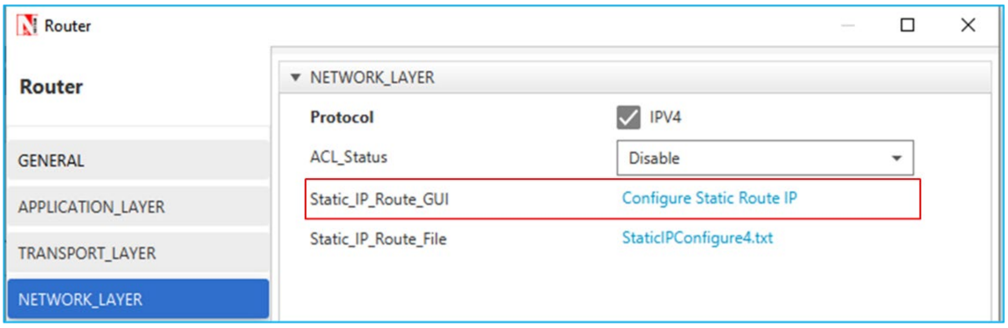


Figure 4-3: Router Network layer properties window

4. Set the properties in Static Route IP window as per the screenshot below and click on **Add**. Click on **Accept.**

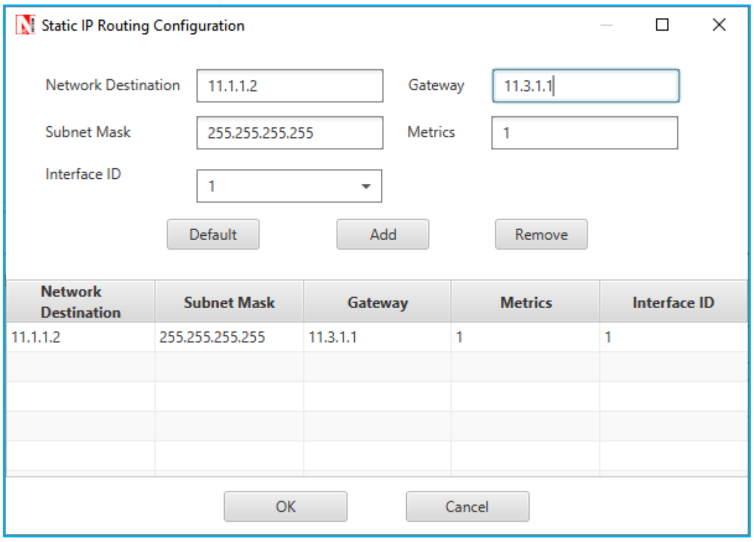


Figure 4-4: Configuring Static route window for router

5. Go to Satellite_Gateway_3 properties -> Network_Layer -> Configure Static Route IP Set the properties in Static Route IP window as per the screenshot below and click on **Add**. Click on **Accept.**

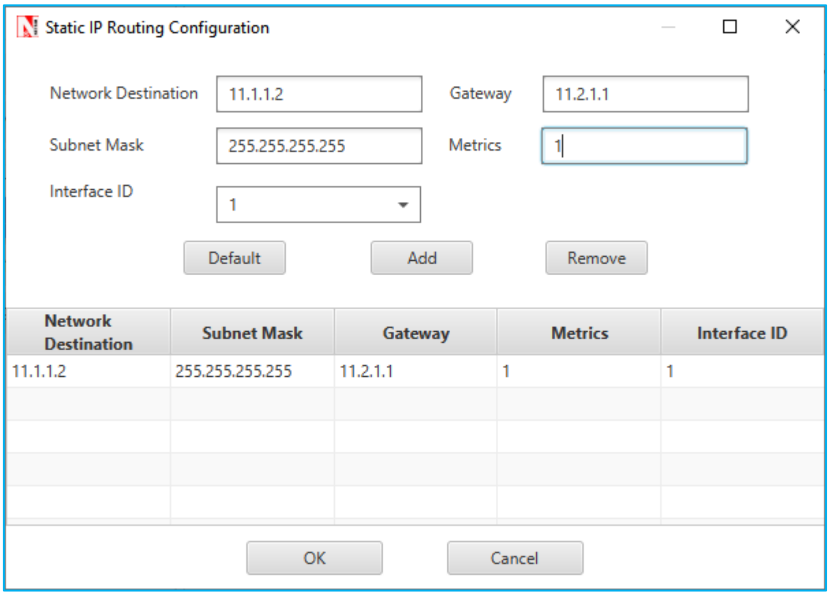


Figure 4-5: Configuring Static route window for Satellite_Gateway_3

6. Go to UT_Router_2 properties -> Network_Layer -> Configure Static Route IP Set the properties in Static Route IP window as per the screenshot below and click on **Add**. Click on **Accept.**

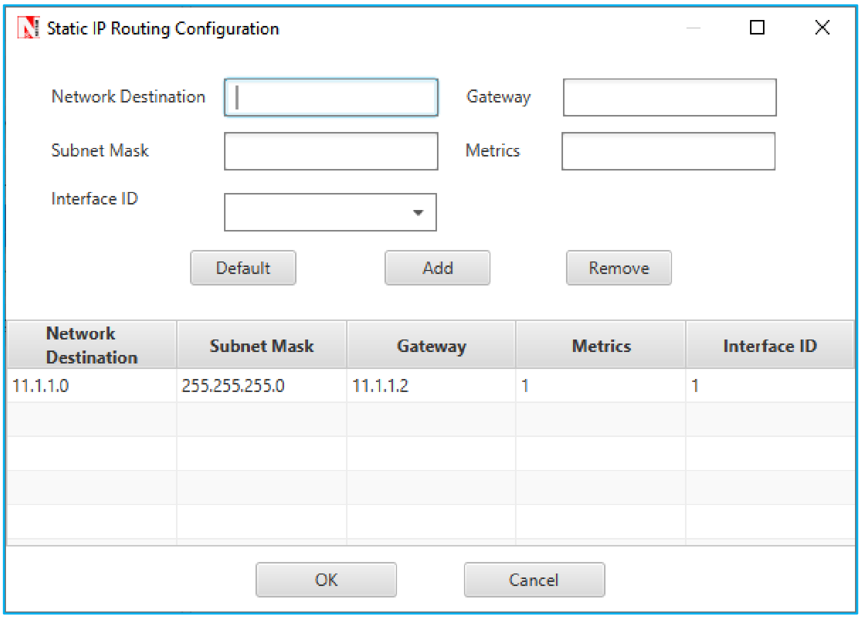


Figure 4-6: Configuring Static route window for UT_Router_2

7. CBR application source id as 6 and destination id as 5 with packet size as 1460Bytes and Inter_Arrival_time as 467µs (Generation Rate=25). Transport Protocol is set to **UDP**.

8. In NetSim GUI Plots are Enabled. Run simulation for 10 seconds and observe the result.

Note: *Satellite properties in the physical layer changes done only for the forward and Return layer properties.*

Result: Observe the application throughput as we change the modulation scheme (Satellite Properties → Inteface (Satellite) → Physical_Layer → Forward → Modulation) and respective coding rates (Satellite Properties → Inteface (Satellite) → Physical_Layer → Forward → Coding_Rate).

Modulation	Coding_Rate	Throughput (Mbps)
QPSK	1/3	0.084
	9/10	0.340
8PSK	3/5	0.380
	9/10	0.507
16APSK	2/3	0.507
	9/10	0.677
16QAM	3/4	0.676
	5/6	0.675
32APSK	3/4	0.846
	8/9	0.843

Table 4-3: Comapre the different Modulation Scheme and Coding Rate vs. Througput

4.2 Configuring applications from UT Node to UT Node

Open NetSim, Select **Examples ->Satellite-Communication -> UT-to-UT-Communication**

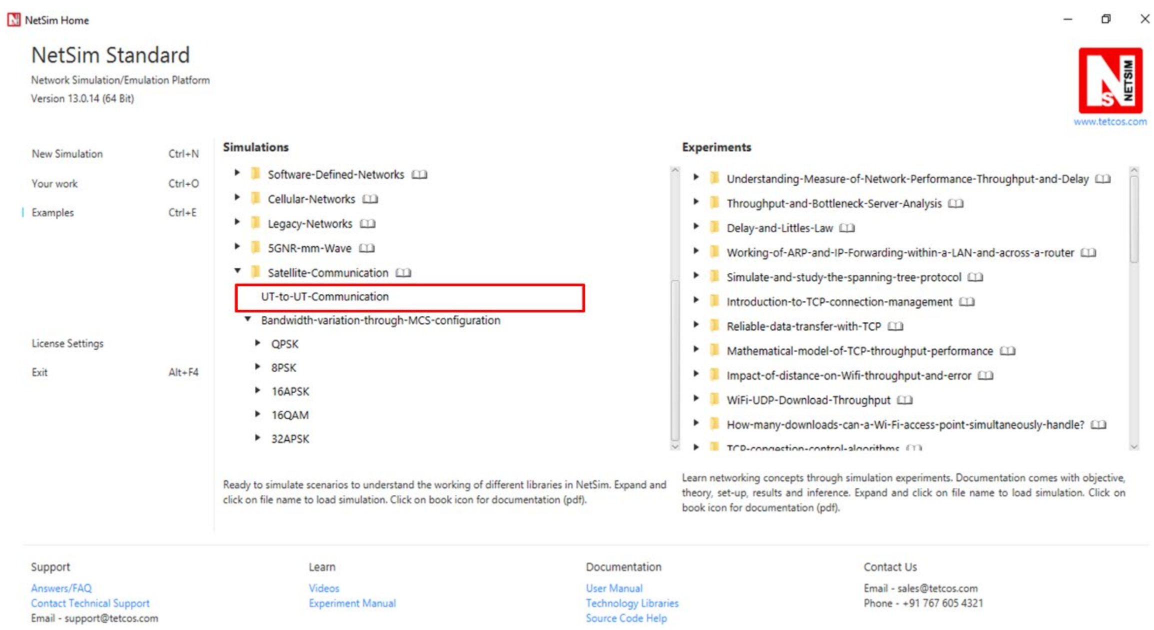


Figure 4-7: Featured Example list

The following network diagram illustrates, what the NetSim UI displays when you open the example configuration file as shown **Figure 4-8.**

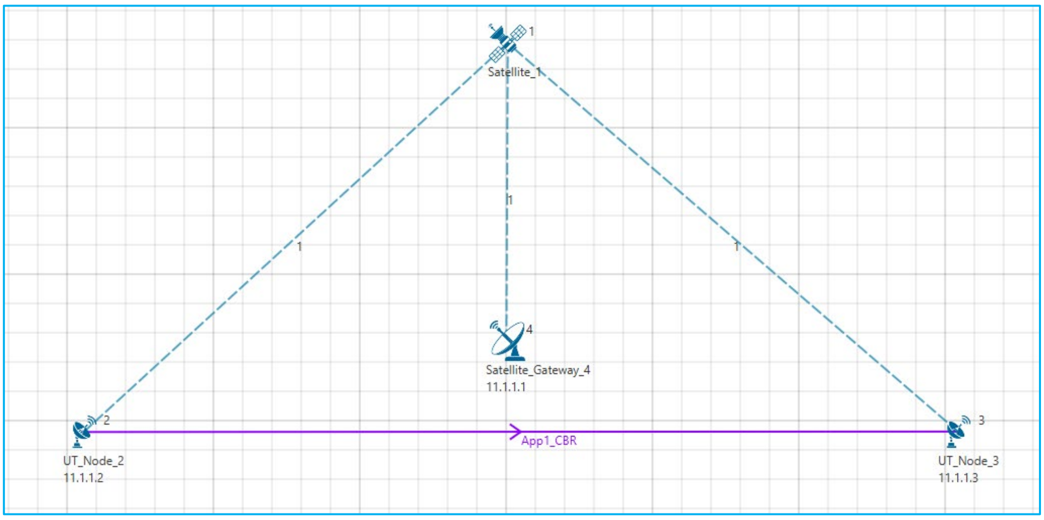


Figure 4-8: Network topology

Settings done in example config file

1. Set the following property as shown in below given table:

UT_Node Properties -> Interface (Satellite) -> DataLink Layer	
Gateway	Satellite_Gateway_4

Table 4-4: UT_Node Properties > Interface (Satellite) > DataLink Layer

2. Go to UT_Node_2 properties -> Network_Layer -> Configure Static Route IP

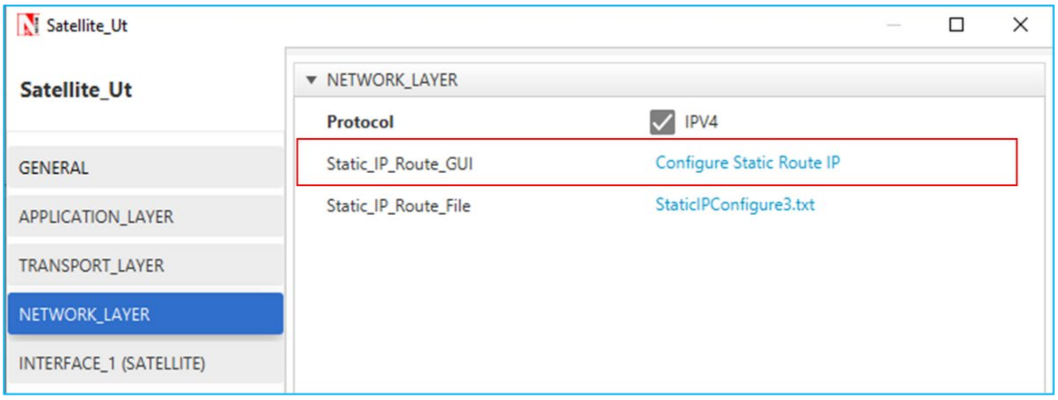


Figure 4-9: Network layer properties window for UT_Node_2

3. Set the properties in Static Route IP window as per the screenshot below and click on **Add**. Click on **Accept.**

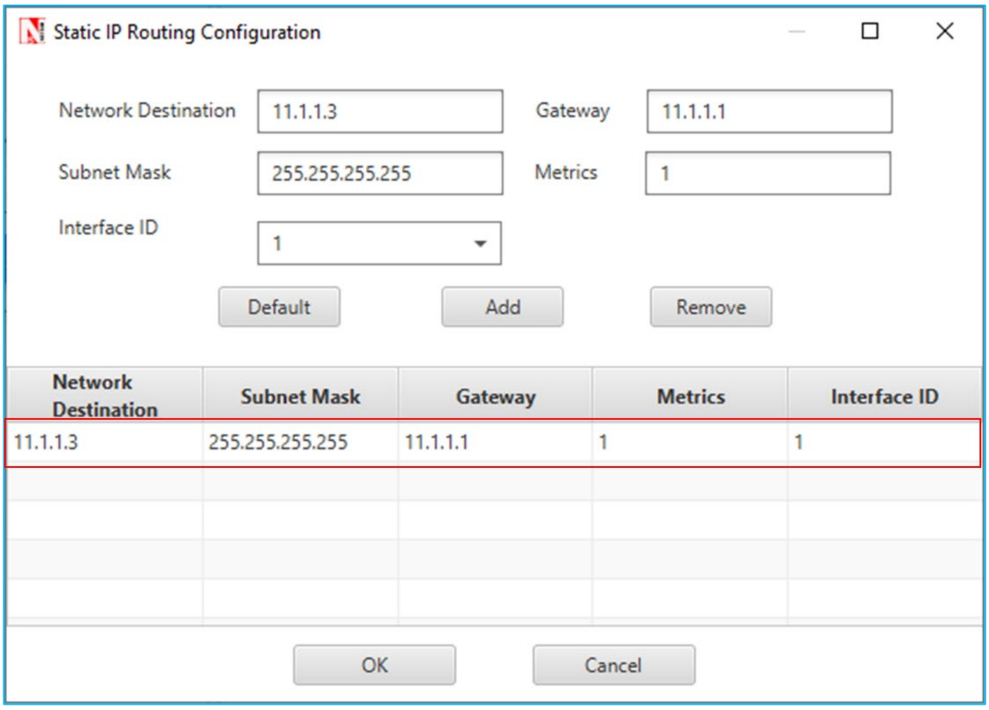


Figure 4-10: Configure static route for UT_Node_2

4. Go to Satellite_Gateway_4 properties -> Network_Layer -> Configure Static Route IP

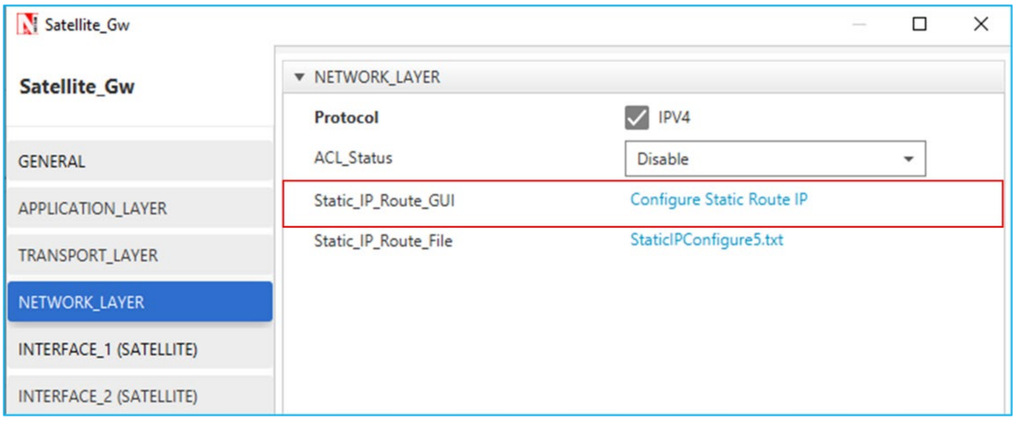


Figure 4-11: Network layer properties window for Satellite_Gateway_4

5. Set the properties in Static Route IP window as per the screenshot below and click on **Add**. Click on **Accept.**

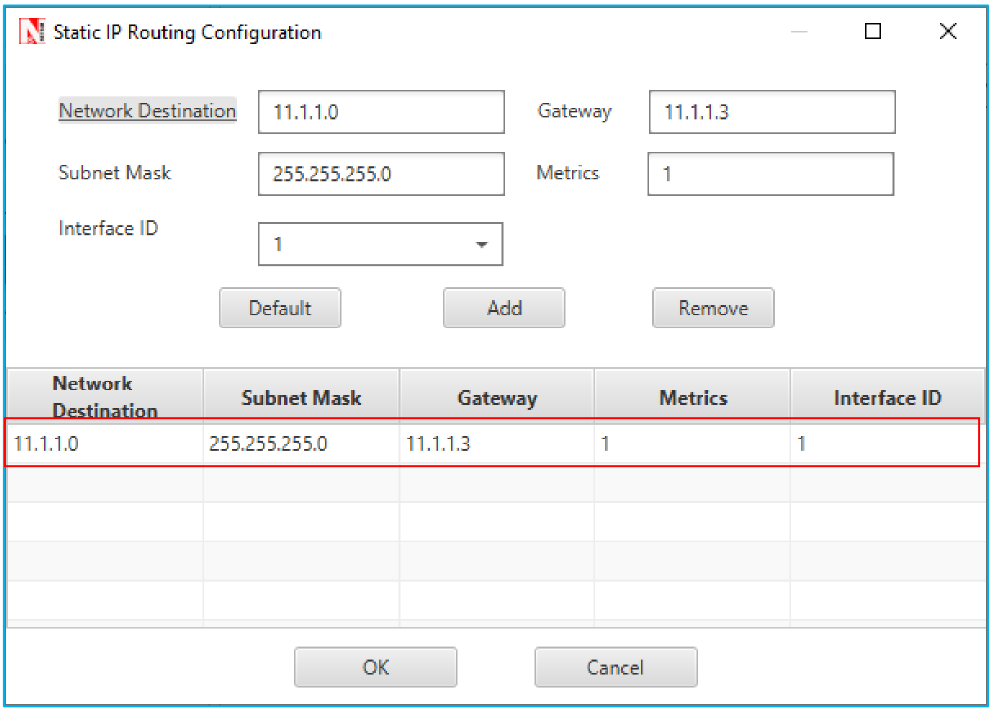


Figure 4-12: Configure static route for Satellite_Gateway_4

6. Enable Packet Trace, Event Trace and Plots.
7. Run simulation for 100 seconds and observe the result.

Result: Go to the result window and open packet trace/ Animation window user can observe the packet flow from UT node (source) → Satellite → Satellite gateway → Satellite → UT node (destination)

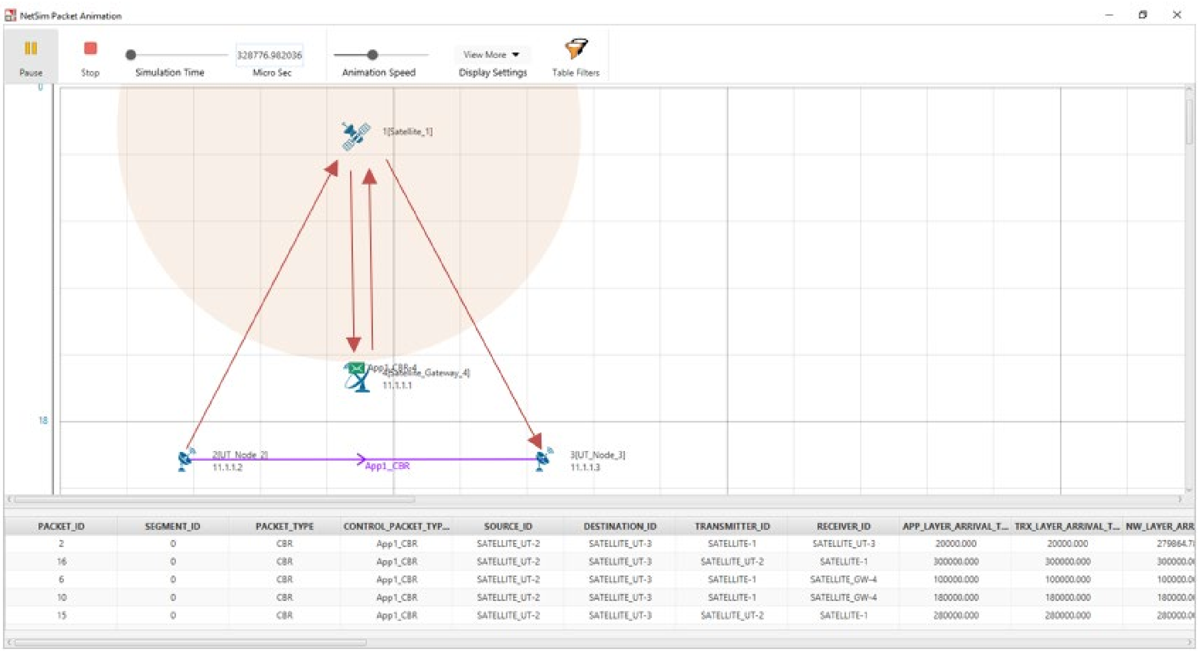


Figure 4-13: Animation Window

PACKET_ID	SEGMENT_ID	PACKET_TYPE	CONTROL_PACKET_TYPE/APP_NAME	SOURCE_ID	DESTINATION_ID	TRANSMITTER_ID	RECEIVER_ID
1	0	CBR	App1_CBR	SATELLITE_UT-	SATELLITE_UT-3	SATELLITE_UT-2	SATELLITE-1
1	0	CBR	App1_CBR	SATELLITE_UT-	SATELLITE_UT-3	SATELLITE-1	SATELLITE_GW-4
1	0	CBR	App1_CBR	SATELLITE_UT-	SATELLITE_UT-3	SATELLITE_GW-4	SATELLITE-1
1	0	CBR	App1_CBR	SATELLITE_UT-	SATELLITE_UT-3	SATELLITE-1	SATELLITE_UT-3

Figure 4-14: Packet Trace

5 Reference Documents

1. ETSI EN 301 545-2 V1.2.1 (2014-04). Digital Video Broadcasting (DVB); Second Generation DVB. Interactive Satellite System (DVB-RCS2); Part 2: Lower Layers for Satellite standard
2. ETSI EN 302 307 V1.2.1 (2009-08). Digital Video Broadcasting (DVB); Second generation framing structure, channel coding and modulation systems for Broadcasting, Interactive Services, News Gathering and other broadband satellite applications (DVB-S2)
3. Lu Lu, Daoxing Guo, Aijun Liu and Maoqiang Yang (2012). Analysis of Channel Model for GEO Satellite Mobile Communication System. *In National Conference on Information Technology and Computer Science (CITCS 2012)*
4. Chun Loo (1985). A Statistical Model for a Land Mobile Satellite Link. *IEEE Transactions on Vehicular Technology, 1985, 34(8): 122-127.*