Simulator Experiment

Physical Layer

List of Experiment

- Calculation of Signal Delivery Time
- Observation of End-to-end Delay
- Error Rate of Wired Signal
- Transmission Range of Wireless Signal

Simulator Experiment
Calculation of Signal Delivery Time

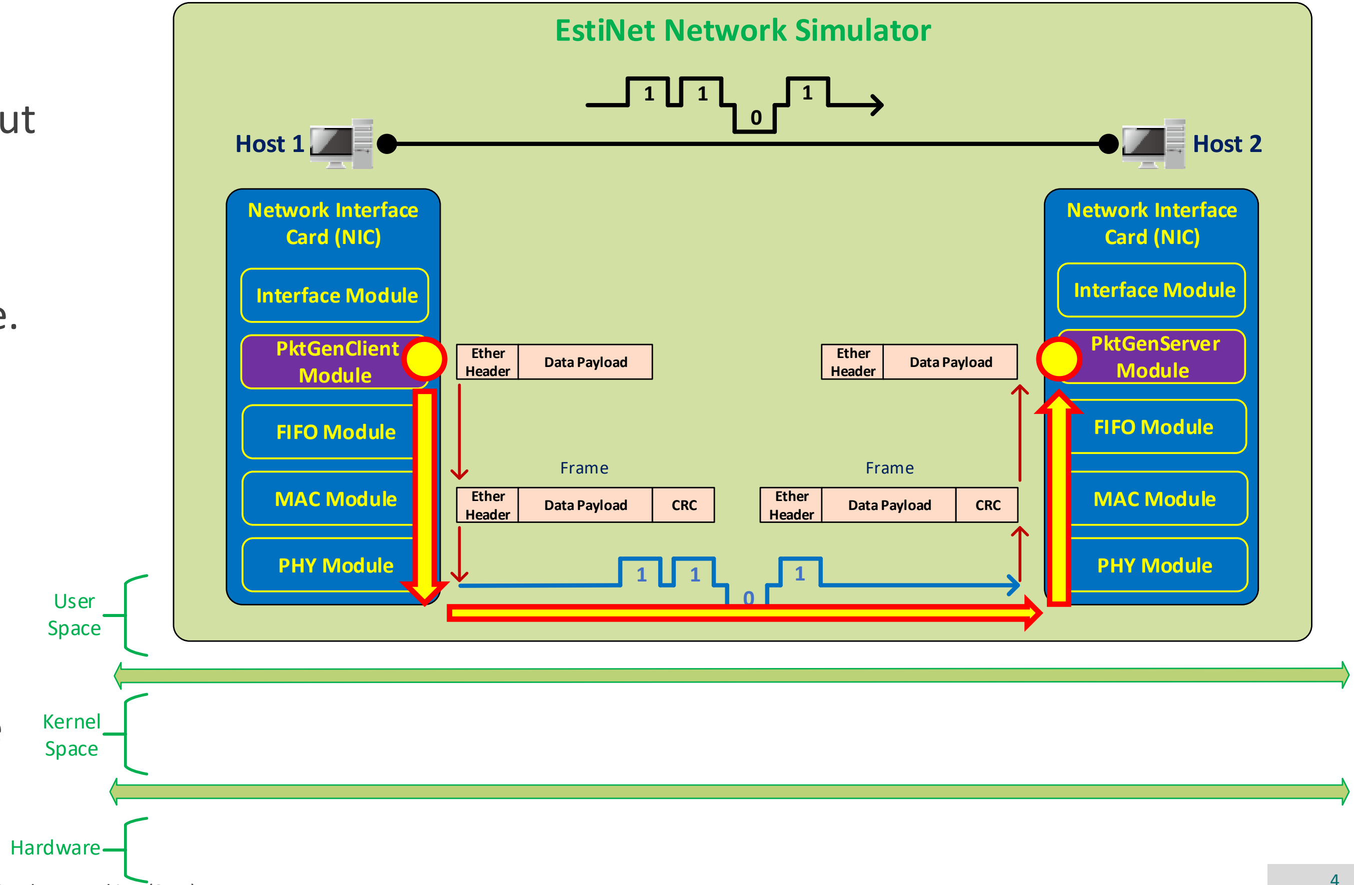
< Simulation Case >

trans_time_and_prop_delay.xtpl

trans_time_and_prop_delay_comparison.xtpl

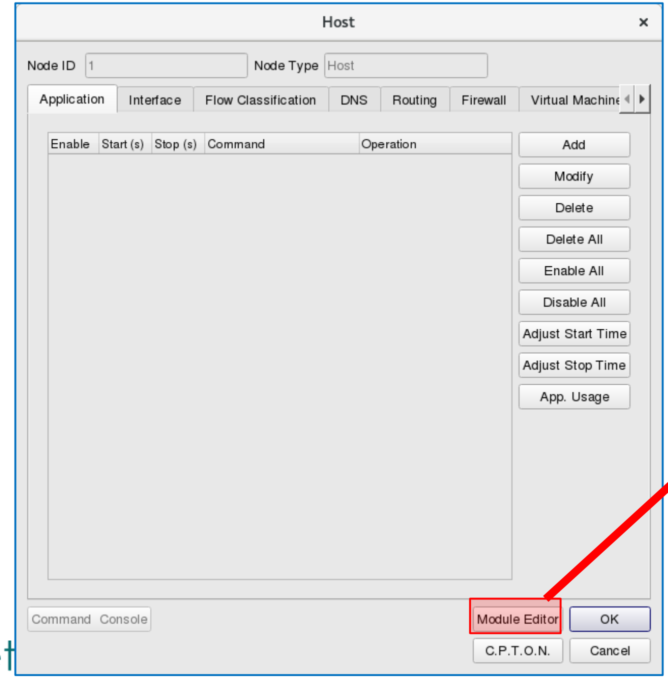
The Architecture of Simulation Environment

- On the signal transmitter Host 1, the PktGenClient Module is used to send out a frame. On the signal receiver Host 2, the PktGenServer Module is used to receive the frame.
- The behavior of transmission time and propagation delay are simulated by the PHY Module at both sites.
- Note that a FIFO Module has to be inserted below the PktGenClient Module and the PktGenServer Module.

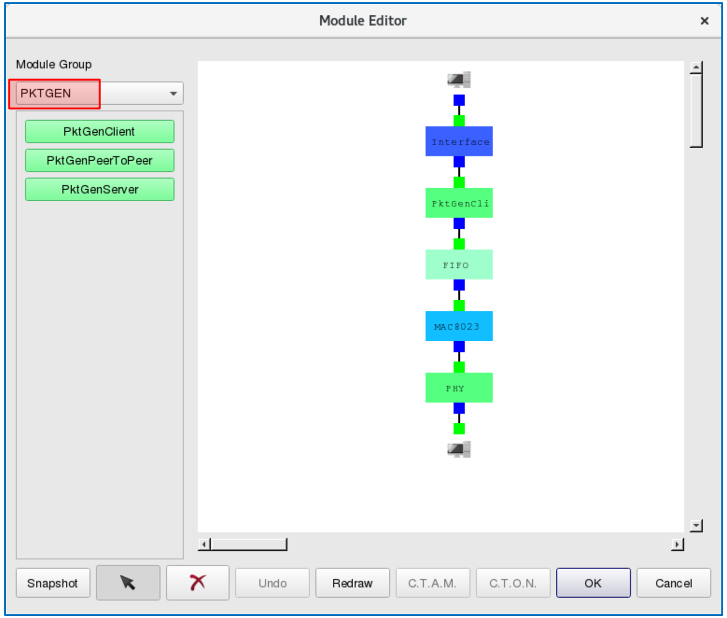


At Stage E, open the node-editor utility first and then open the module-editor utility to edit protocol stack.

- At Stage E, double click on any node to open node editor. On the node-editor window, click the Module Editor button to open module editor.



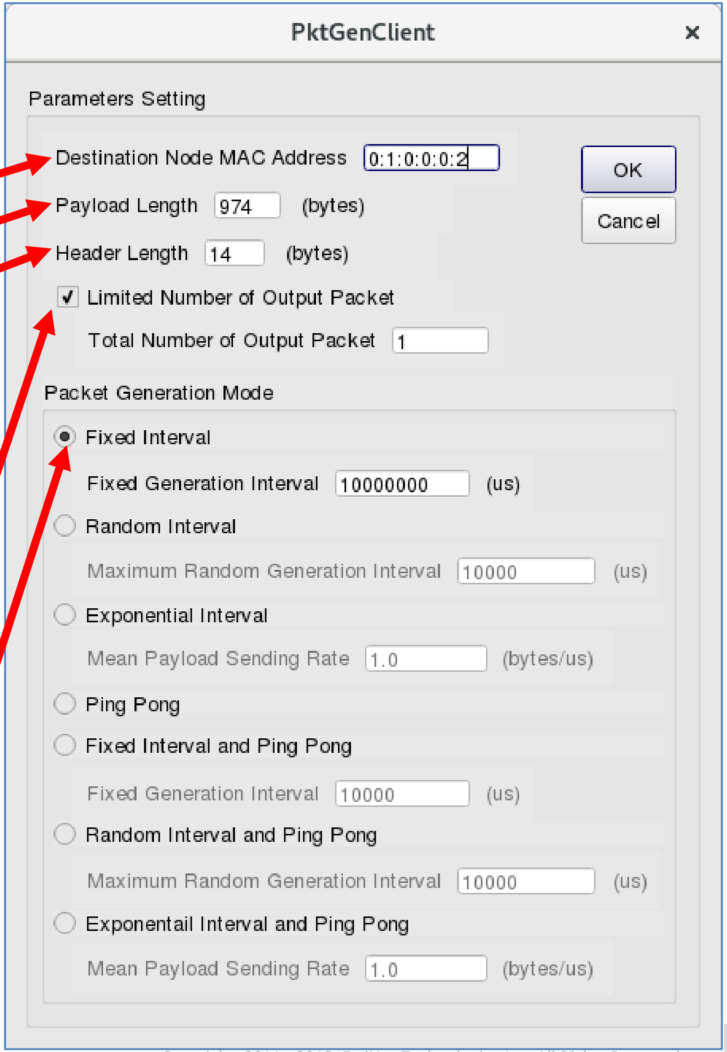
- On the left side of module-editor window, all available modules are classified by different groups. For example, PktGenServer and PktGenClient modules can be found in the PKTGEN group. Insert required modules into the protocol stack on the right side.



EstiNet

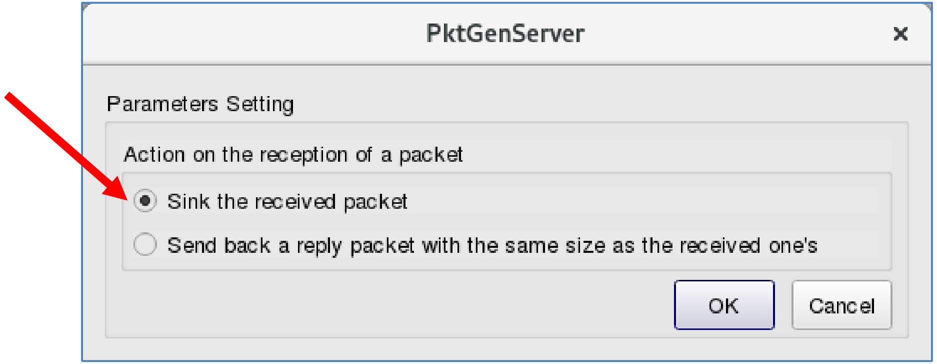
Configuration of PktGenClient Module

- Key in the MAC address of receiver Host 2.
- Key in the length of payload 974 bytes.
- Key in the length of header 14 bytes.
- Payload Length + Header Length = 988 bytes
- Within the MAC8023 module, additional 7-byte Preamble, 1-byte Start Frame Delimiter, and 4-byte CRC Checksum fields will be added into the outgoing frame. Thus, the final length of outgoing frame is 1000 bytes.
- Limit the total number of outgoing frame to be 1.
- Set the sending time of the outgoing frame to be 10,000,000 us.

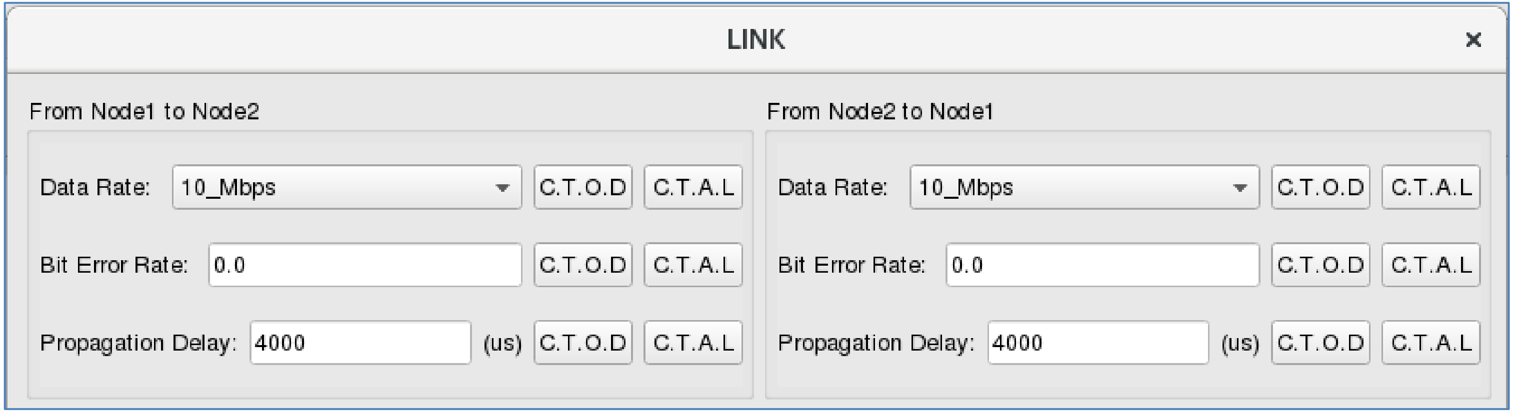


Configuration of PktGenServer Module

- Once the receiver Host 2 receives a frame, it drops the frame.



Configuration of the Link between Host 1 and Host 2



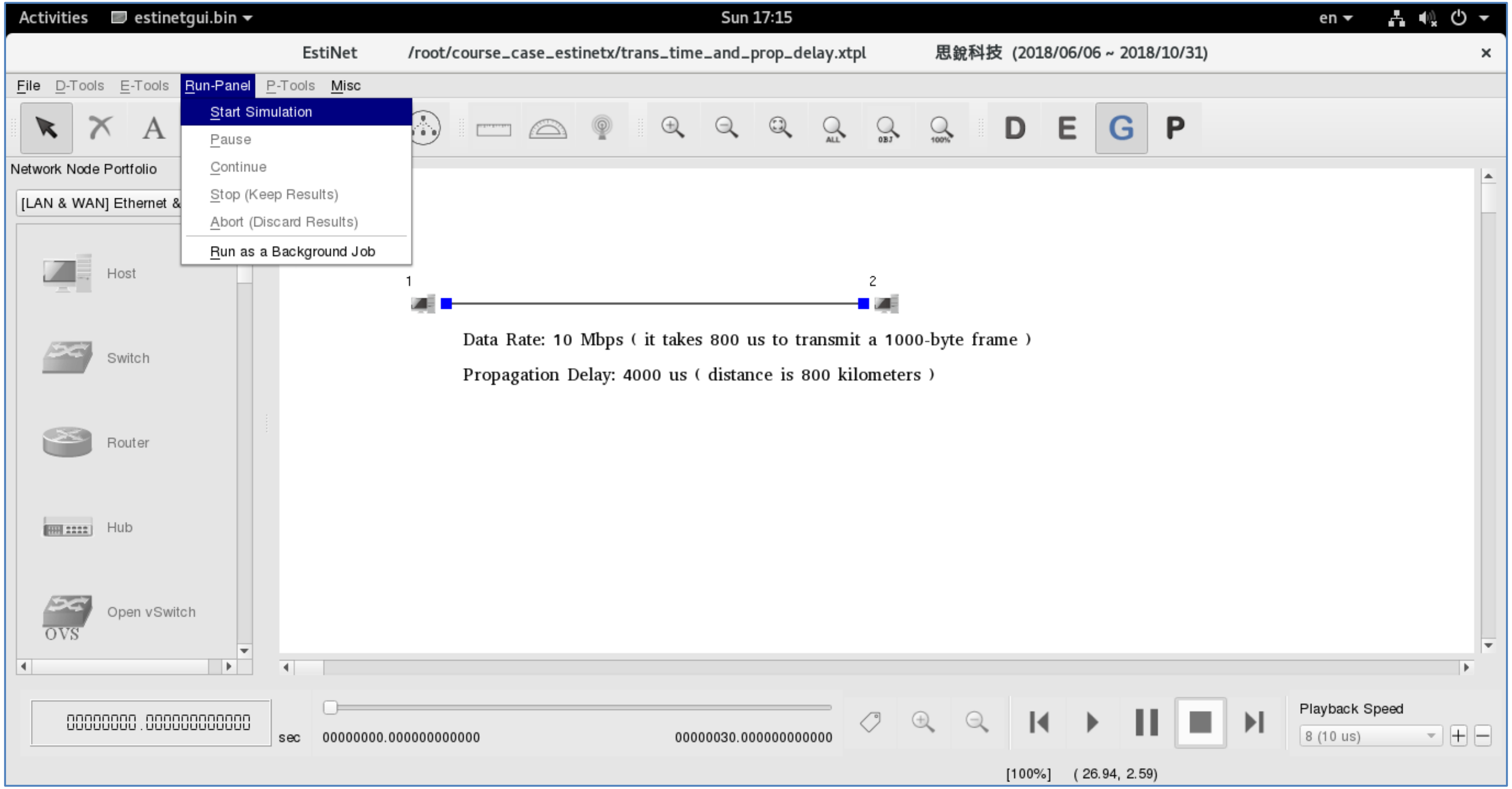
- Data Rate = 10 Mbps

  Transmission time of a 1000-byte frame = (8*1000)/(10 * 10^6) = 0.0008 sec

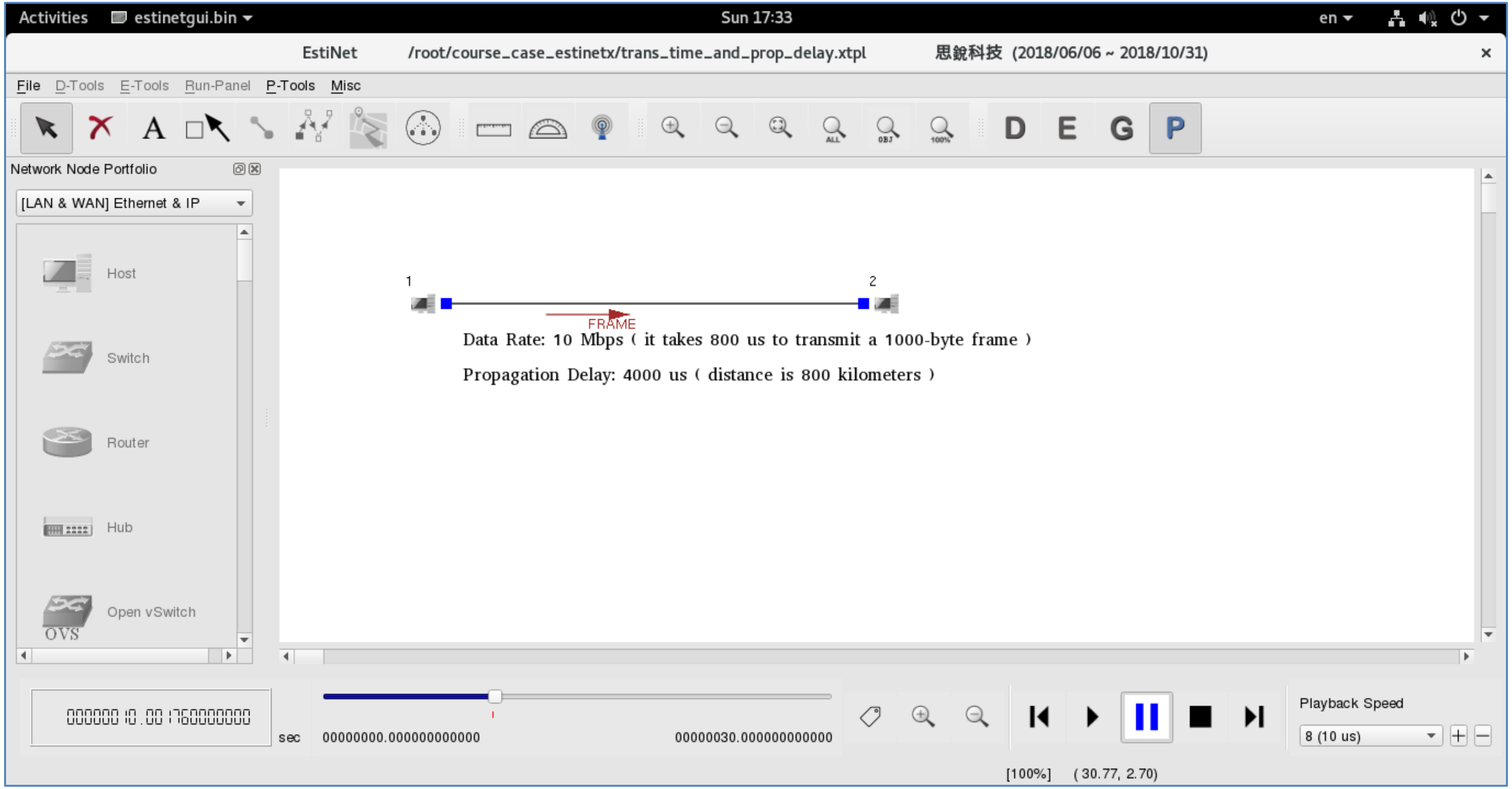
- Propagation Delay = 4000 us = 0.004 sec

  Distance = 0.004 * (2 * 10^8) = 800000 meters = 800 kilometers

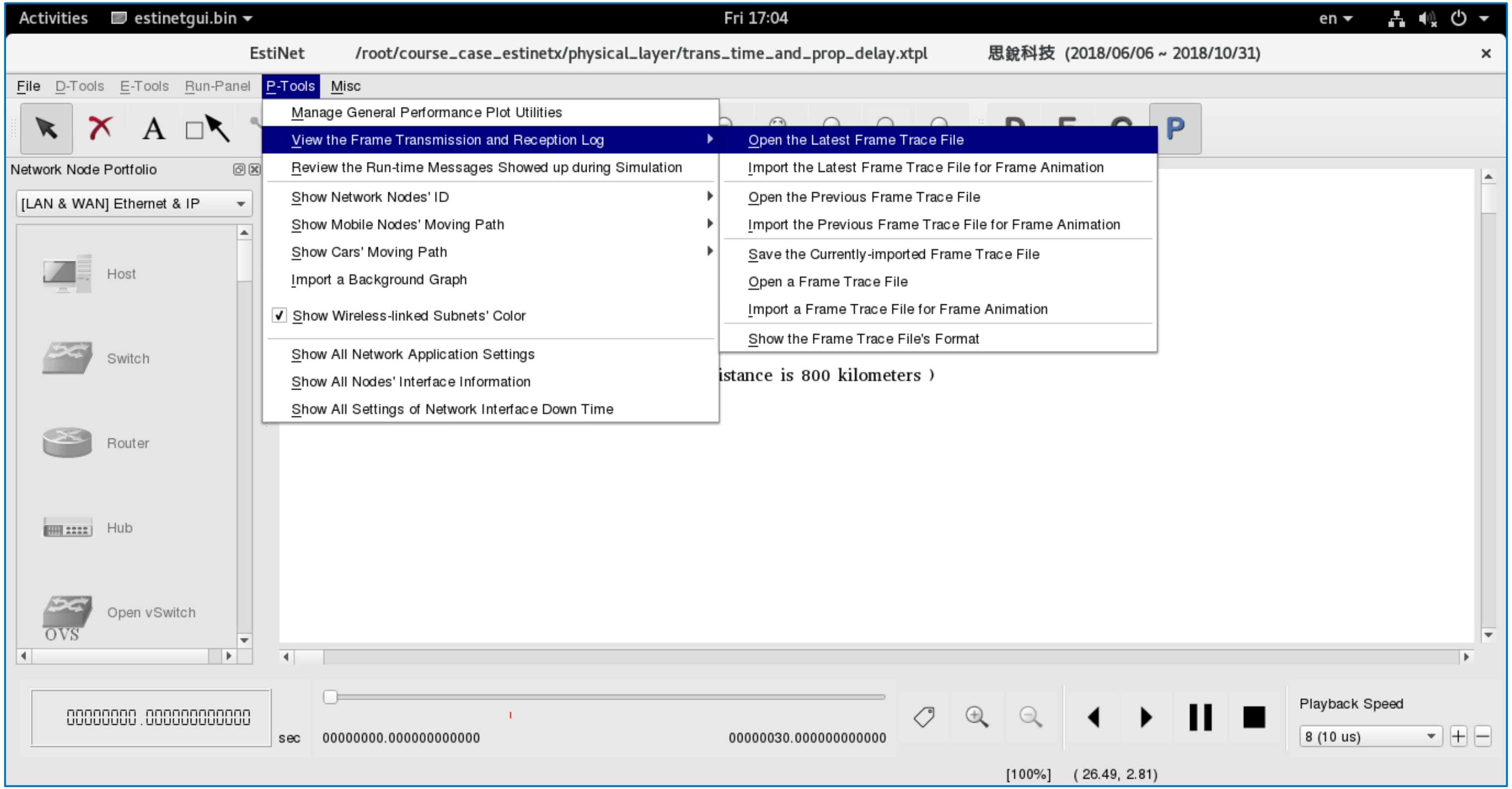
Change the operating stage to Stage G to generate all simulation configuration files. Then start simulation.



When simulation is done, check simulation results at Stage P.



At Stage P, open the frame trace file to check the logs of frame transmission and reception.



A frame’s transmission time and propagation delay can be observed in the frame trace file. The signal/frame delivery time is the sum of both.

event last period

event start time

time unit is picosecond, that is 10^(-12) second

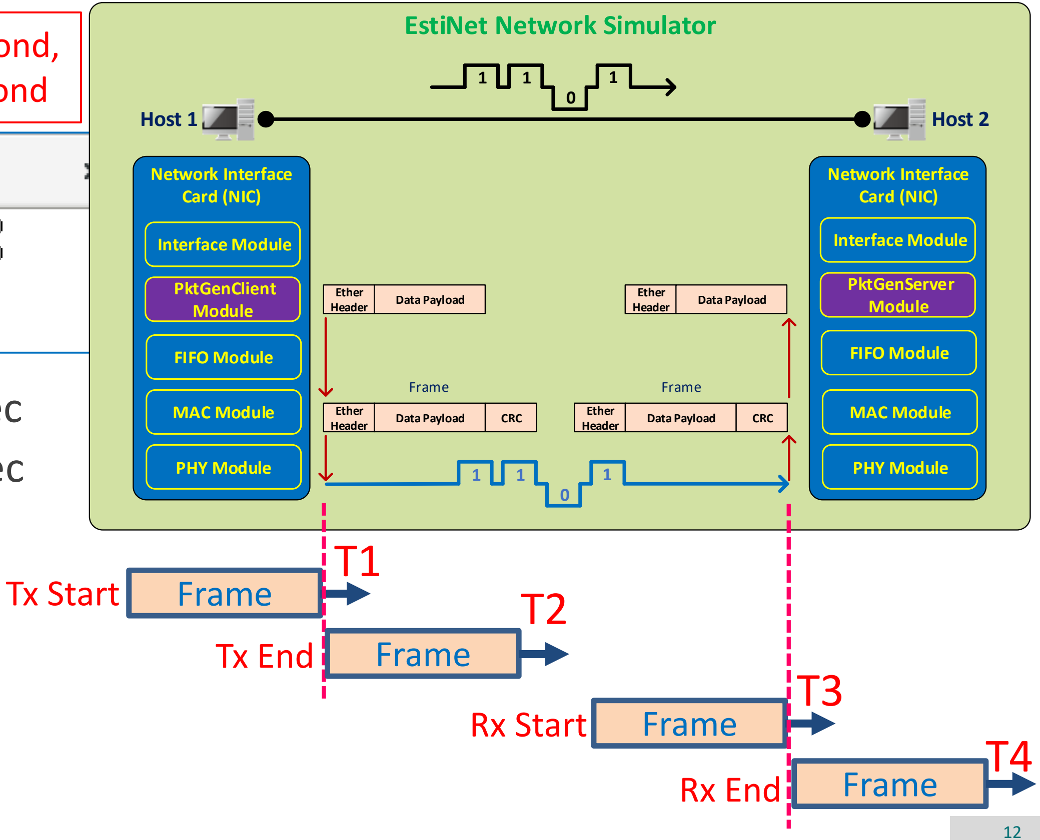
less

```
802.3 TX  10000000000000 800000000 DATA  <0 0> <1 2> 18 1000 0 NONE  0
802.3 RX  10004000000000 800000000 DATA  <0 0> <1 2> 18 1000 0 NONE  0
/tmp/frame_trace_file.log (END)
```

- T1 = 10,000,000,000,000 * 10^(-12) = 10 sec
- T2-T1 = 800,000,000 * 10^(-12) = 0.0008 sec

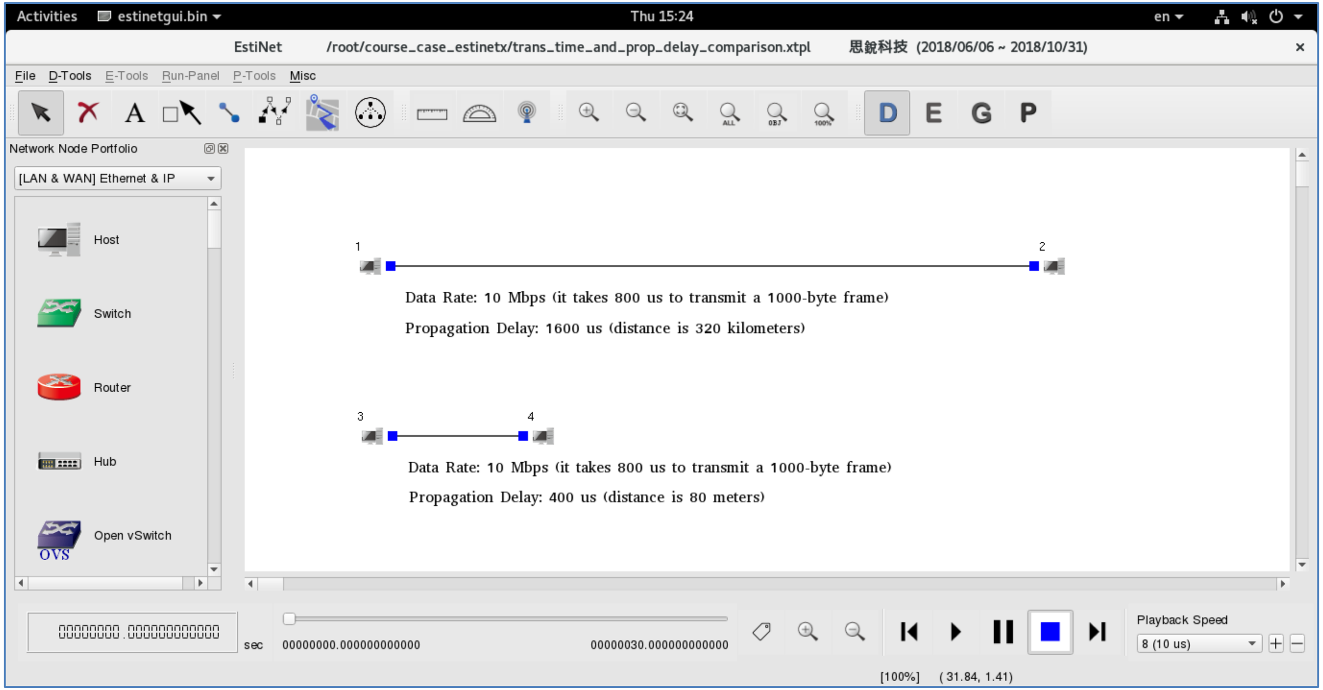
  Transmission Time = 0.0008 sec
- T3 = 10,004,000,000,000 * 10^(-12)

  = 10.004 sec
- T3-T1 = 0.004 sec
- Propagation Delay = 0.004 sec



Quiz

- Use simulator to change a frame's transmission time or propagation delay. See what is the difference between the following two conditions.
  - Transmission Time > Propagation Delay
  - Transmission Time < Propagation Delay



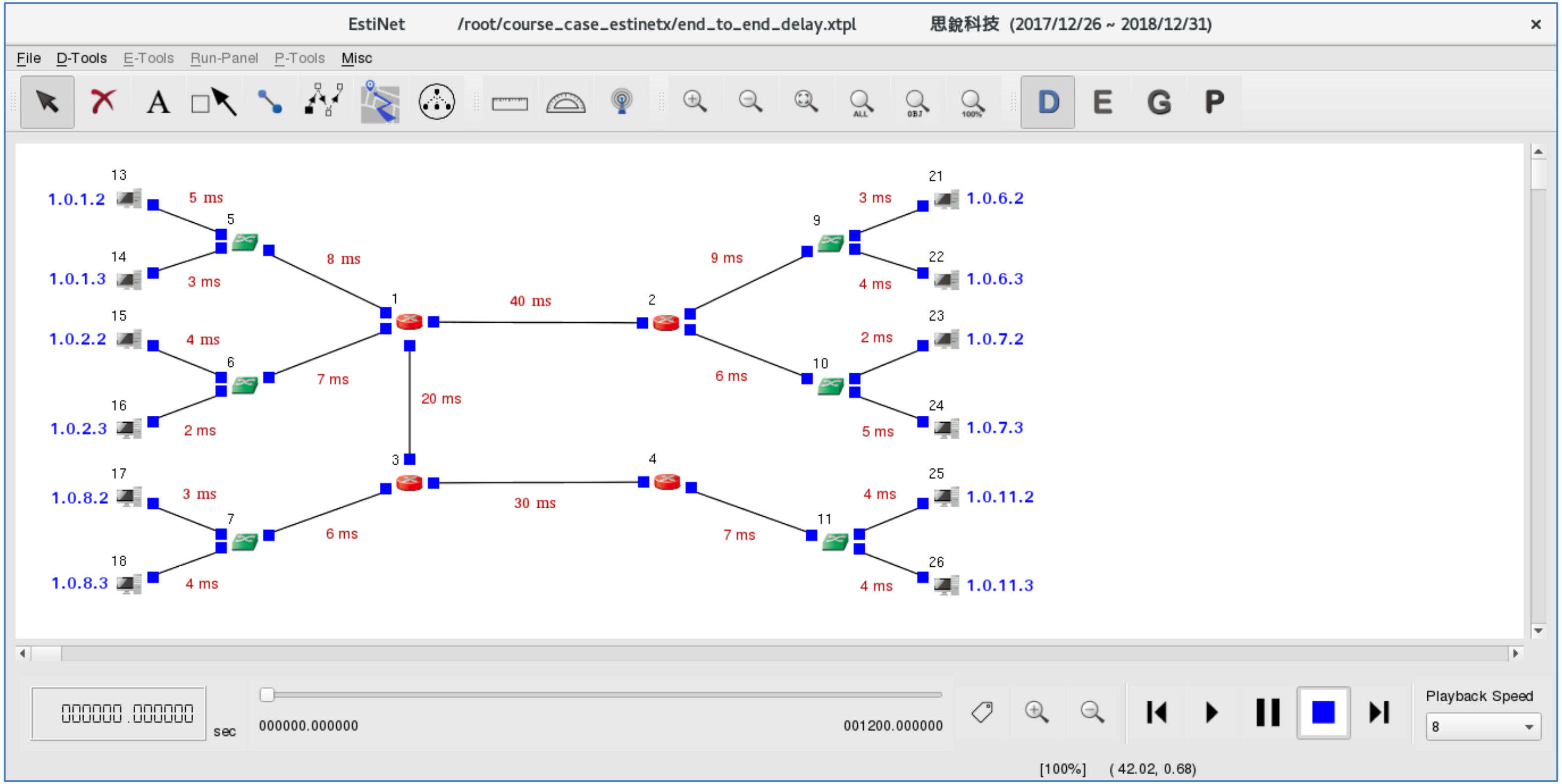
Simulator Experiment
Observation of End-to-end Delay

< Simulation Case >

end_to_end_delay.xtpl

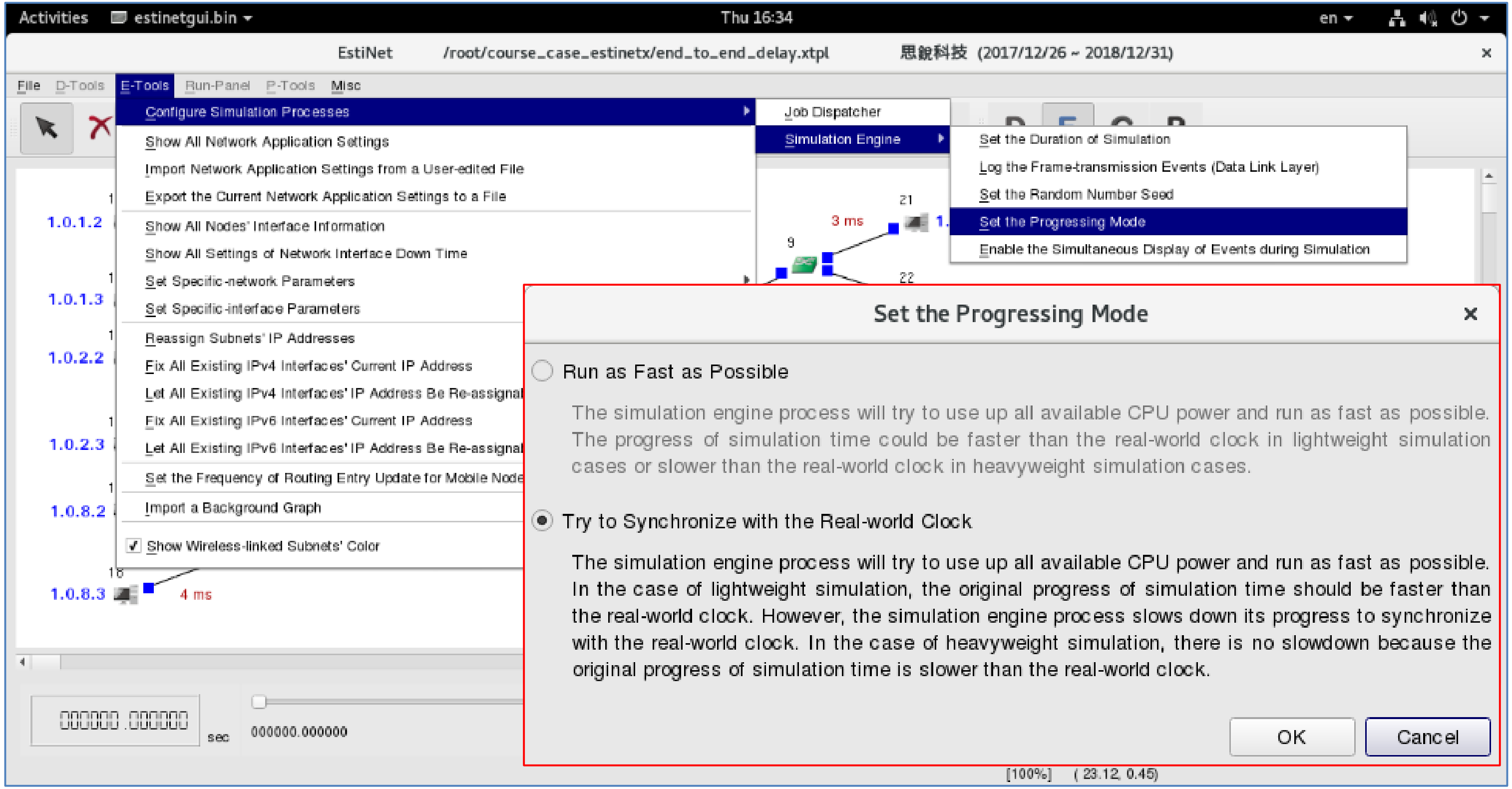
end_to_end_delay_trans_time_dominates.xtpl

Build a network at Stage D. Set each link's propagation delay at Stage E. When running simulation at Stage G, execute the ping command to observe end-to-end delays.

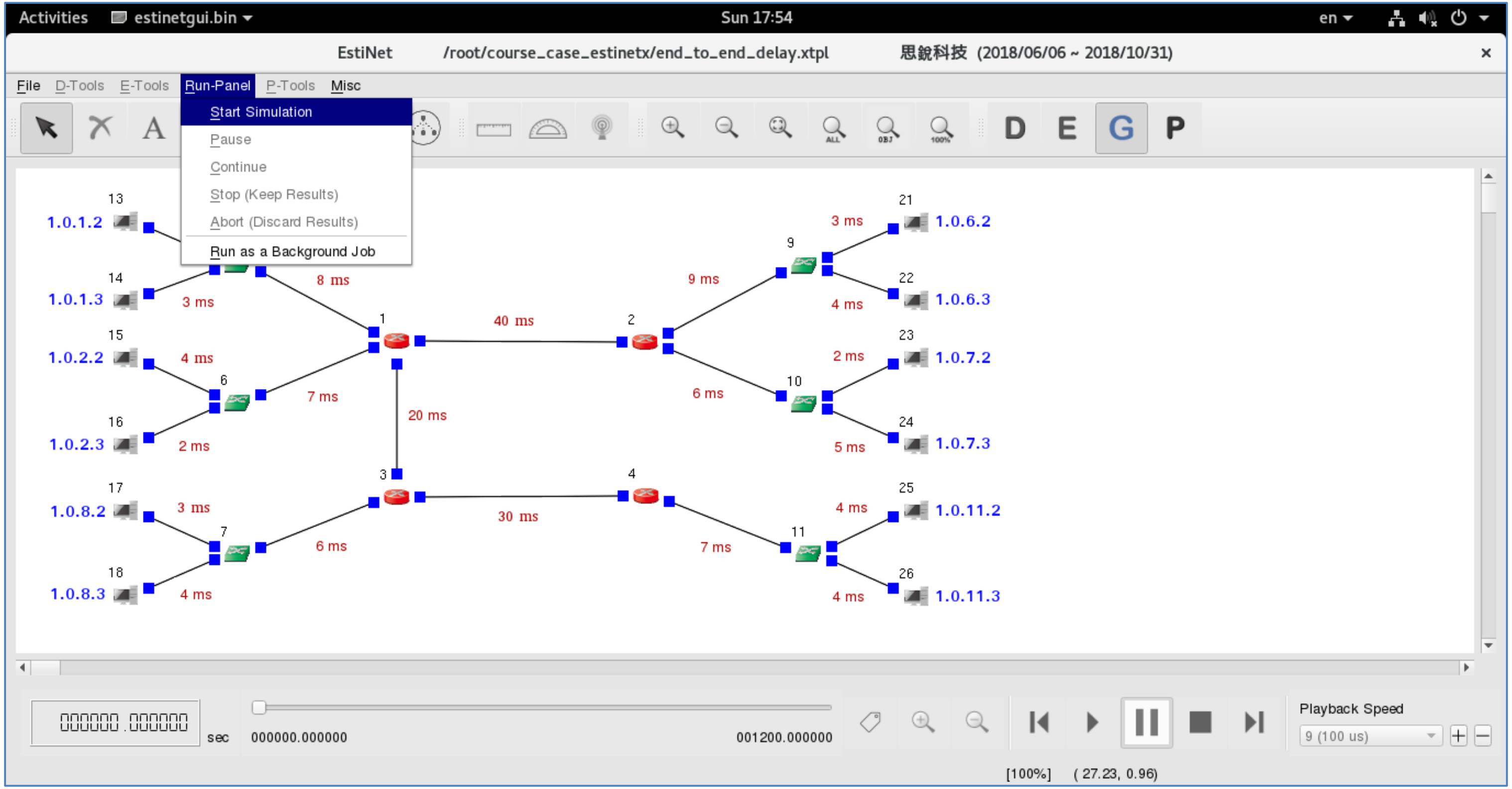


At Stage E, set the Progressing Mode to "Try to Synchronize with the Real-world Clock".

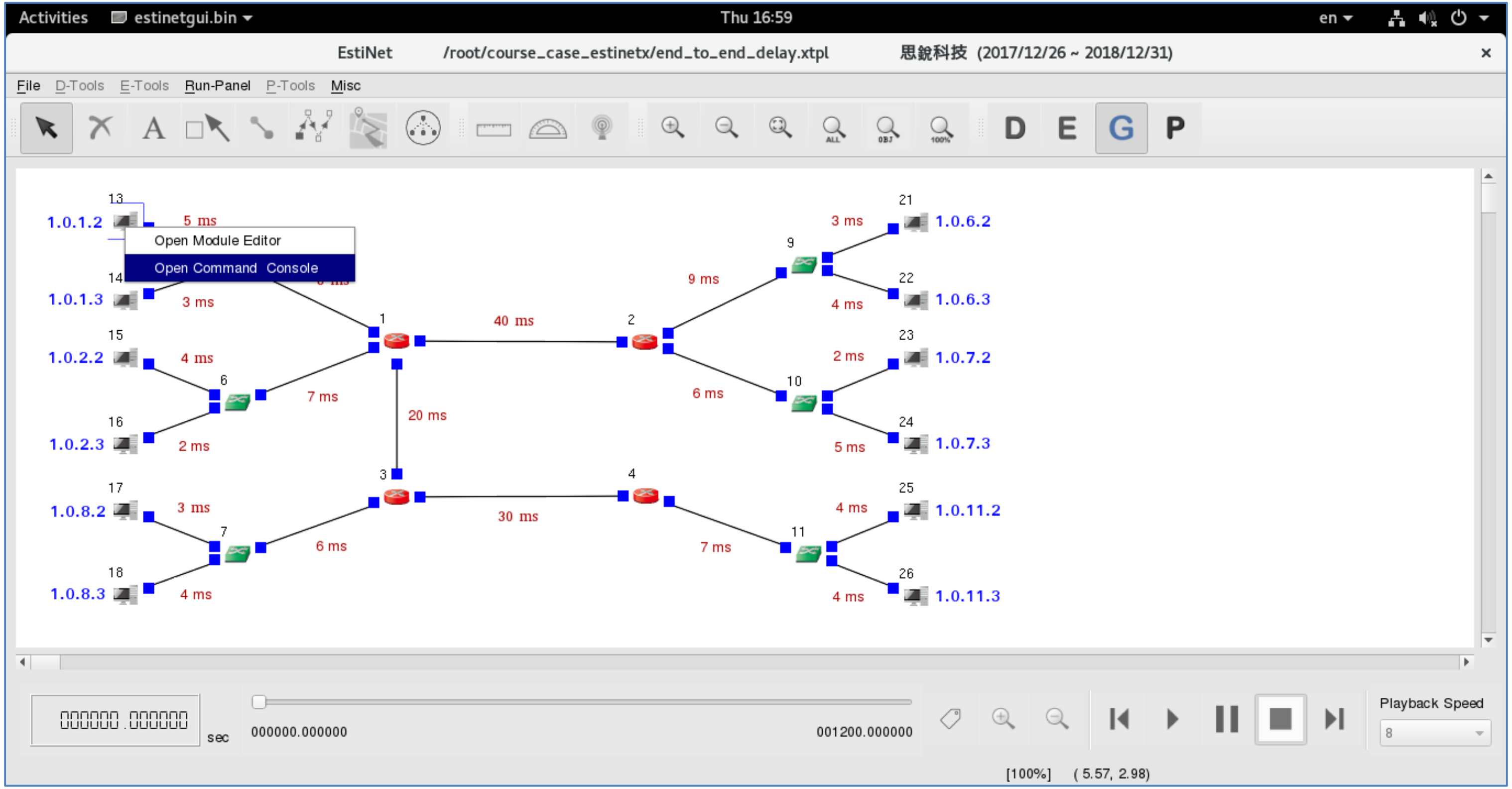
- Doing this setting is for slowing down the progress speed of virtual time during simulation so that a user is able to interact with the simulated network.



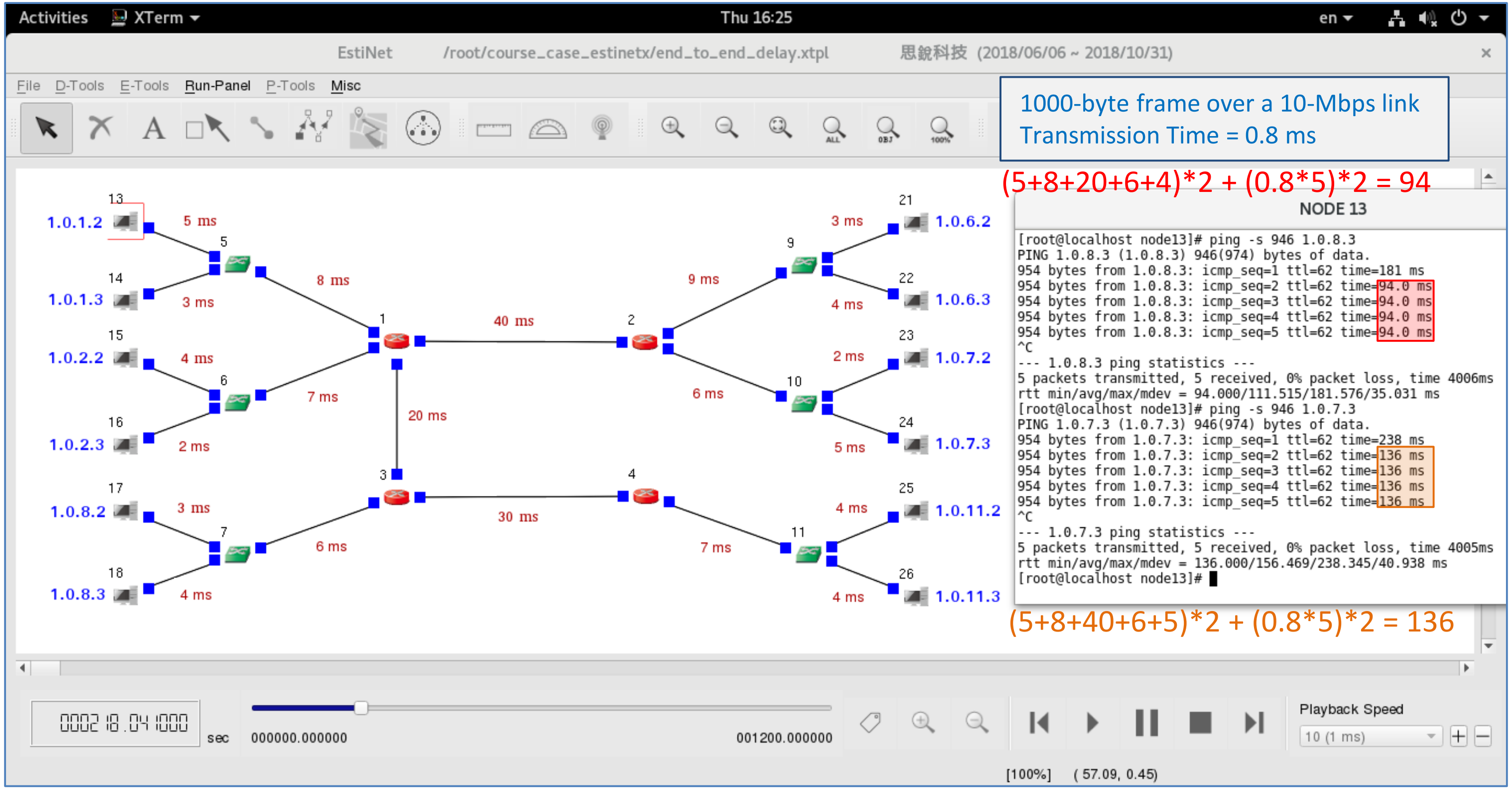
Change the operating stage to Stage G to generate all simulation configuration files. Then start simulation.



During simulation, right click on any Host Node to open a command console.

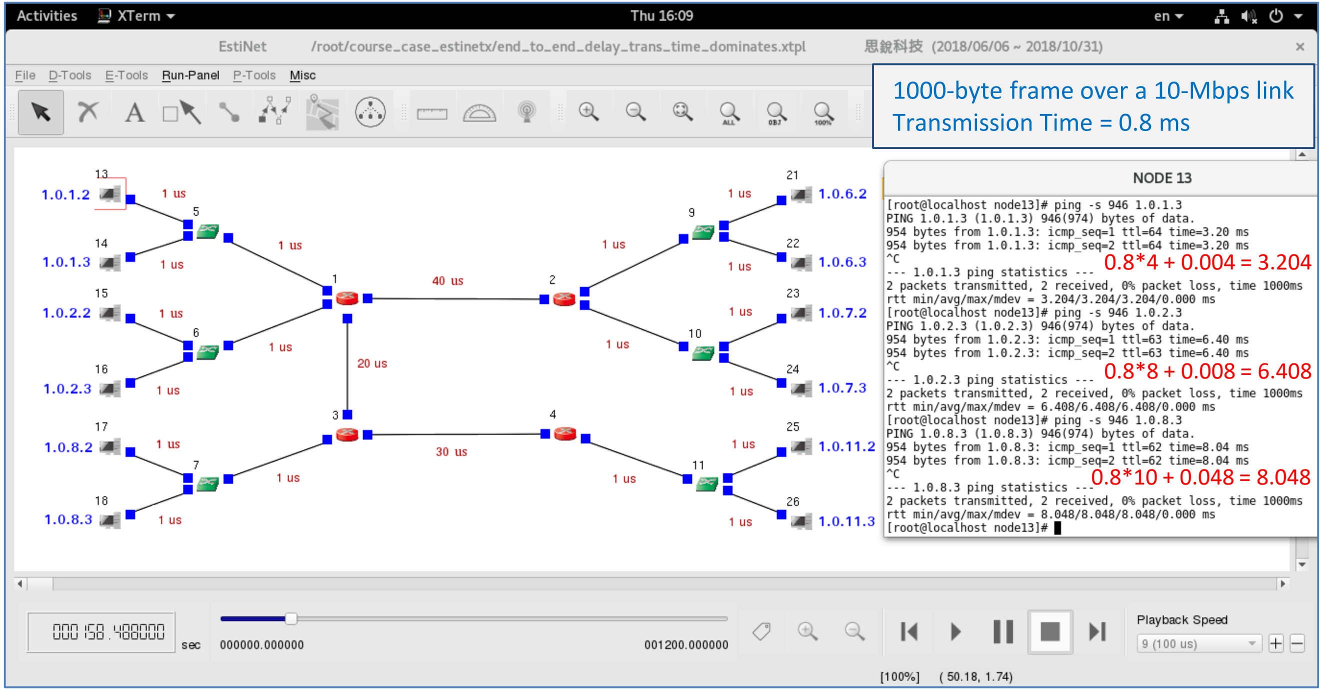


On the command console window, use ping command to observe the Round Trip Time (RTT) between any pair of Host Nodes.



Quiz

- In terms of end-to-end delay, if the processing delay on network devices are ignored, observe and discuss the following two conditions.
  - Transmission Time >> Propagation Delay
  - Transmission Time << Propagation Delay

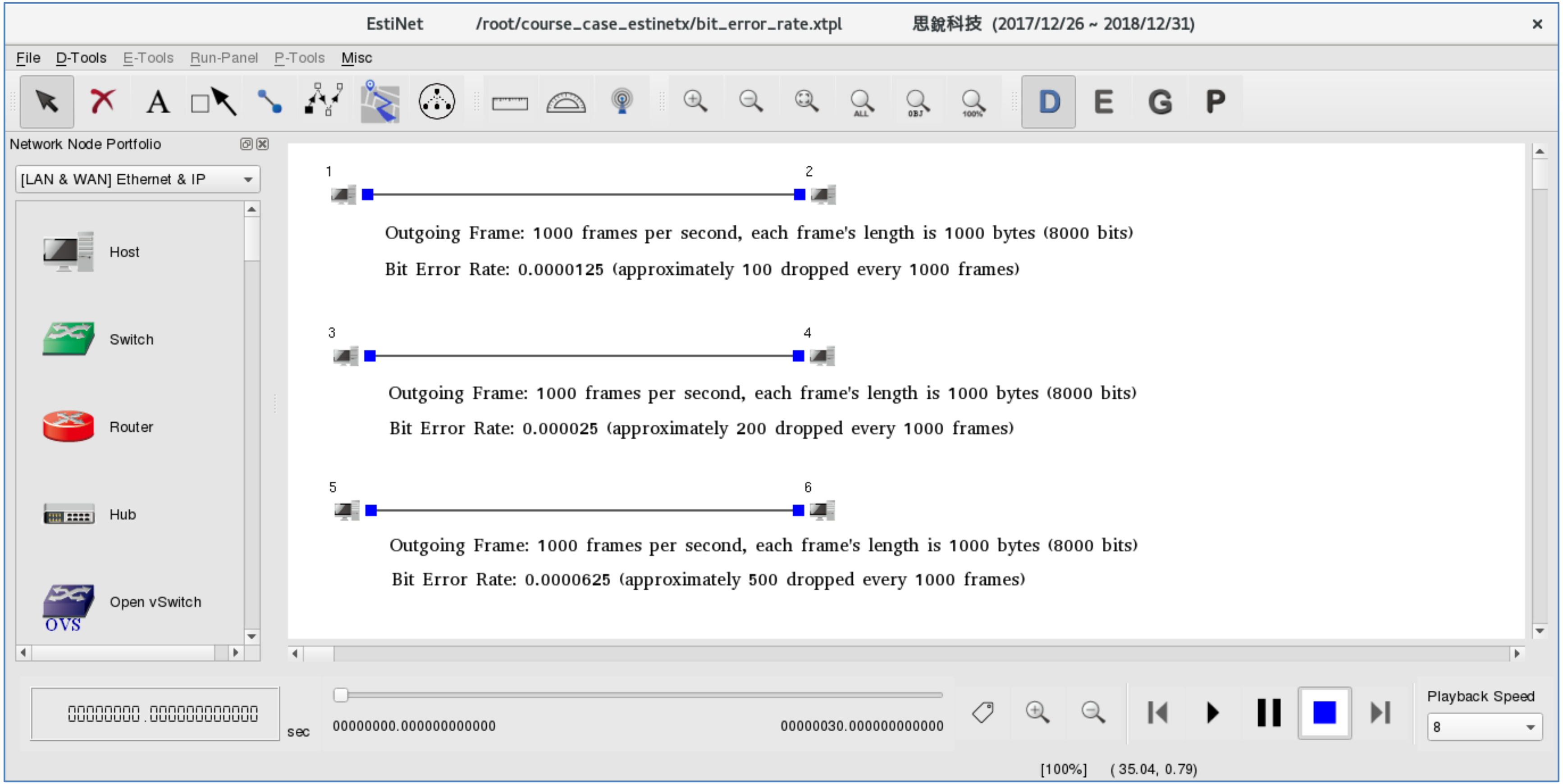


Simulator Experiment
Error Rate of Wired Signal

< Simulation Case >

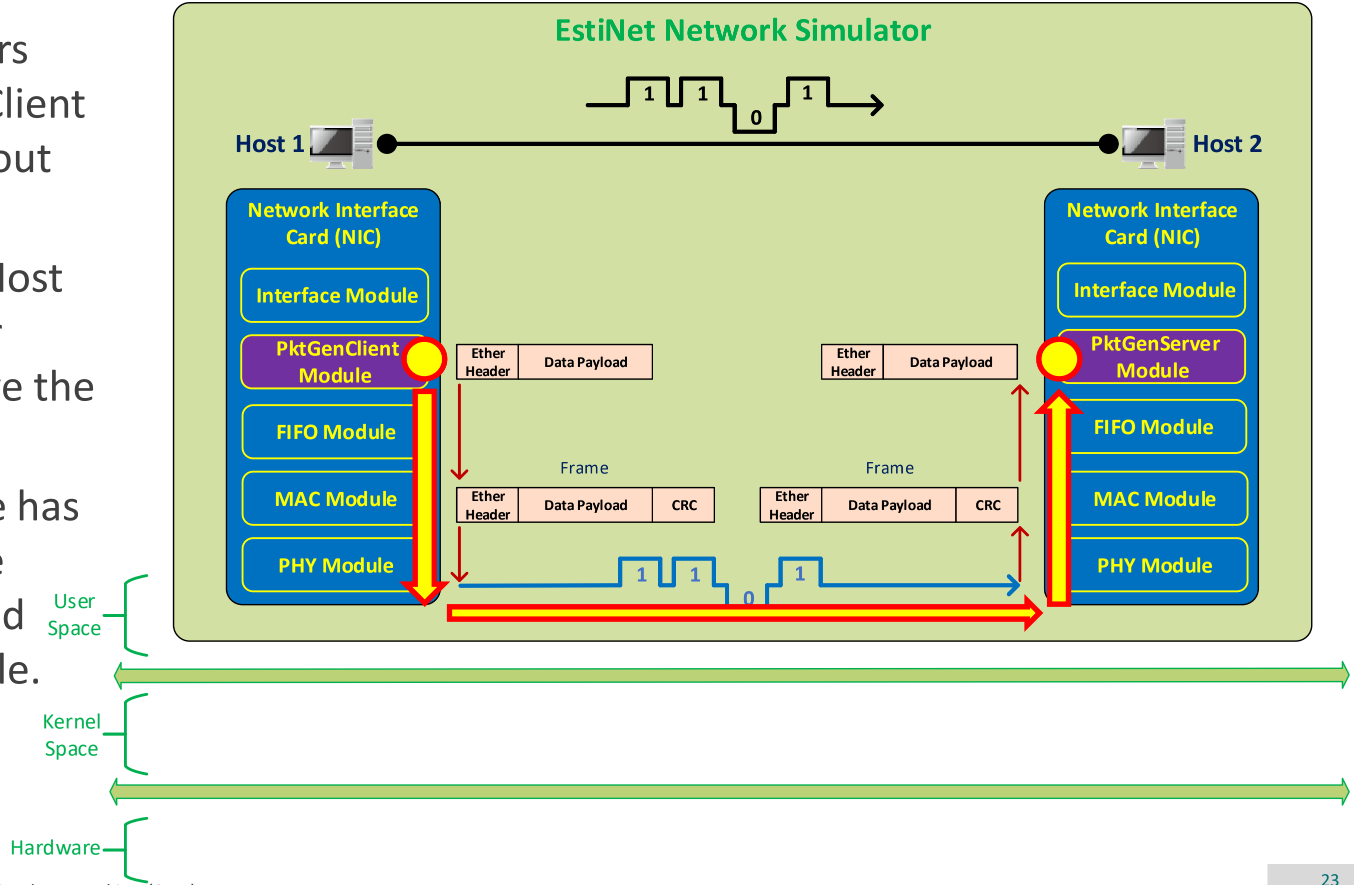
bit_error_rate.xtpl

At Stage D, build three independent networks for comparison.



At Stage E, arrange PktGen Module to send out frames during simulation.

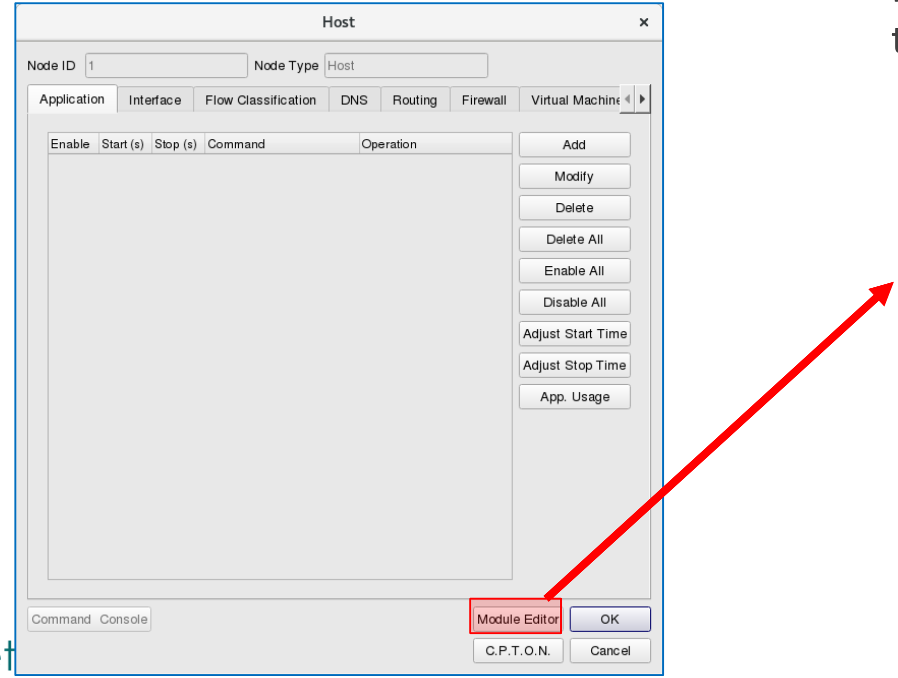
- On the signal transmitters Host 1/3/5, the PktGenClient Module is used to send out frames.
- On the signal receivers Host 2/4/6, the PktGenServer Module is used to receive the frames.
- Note that a FIFO Module has to be inserted below the PktGenClient Module and the PktGenServer Module.

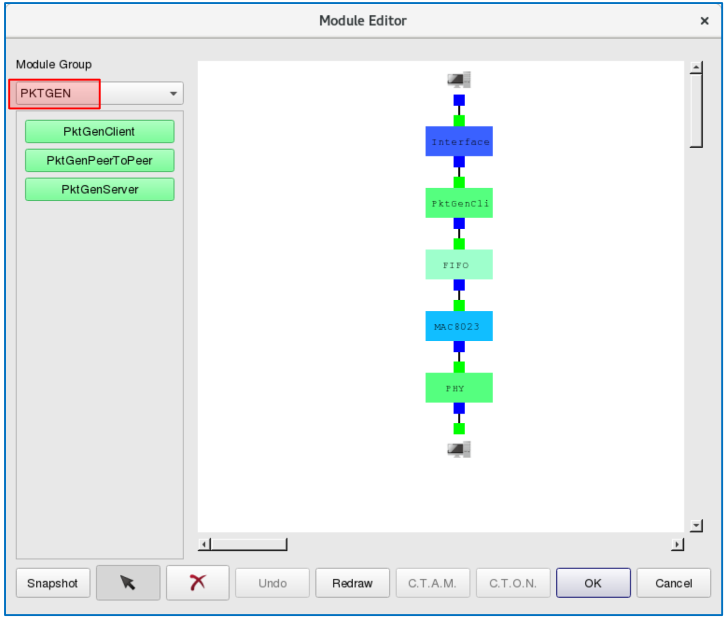


At Stage E, open the node-editor utility first and then open the module-editor utility to edit protocol stack.

- At Stage E, double click on any node to open node editor. On the node-editor window, click the Module Editor button to open module editor.

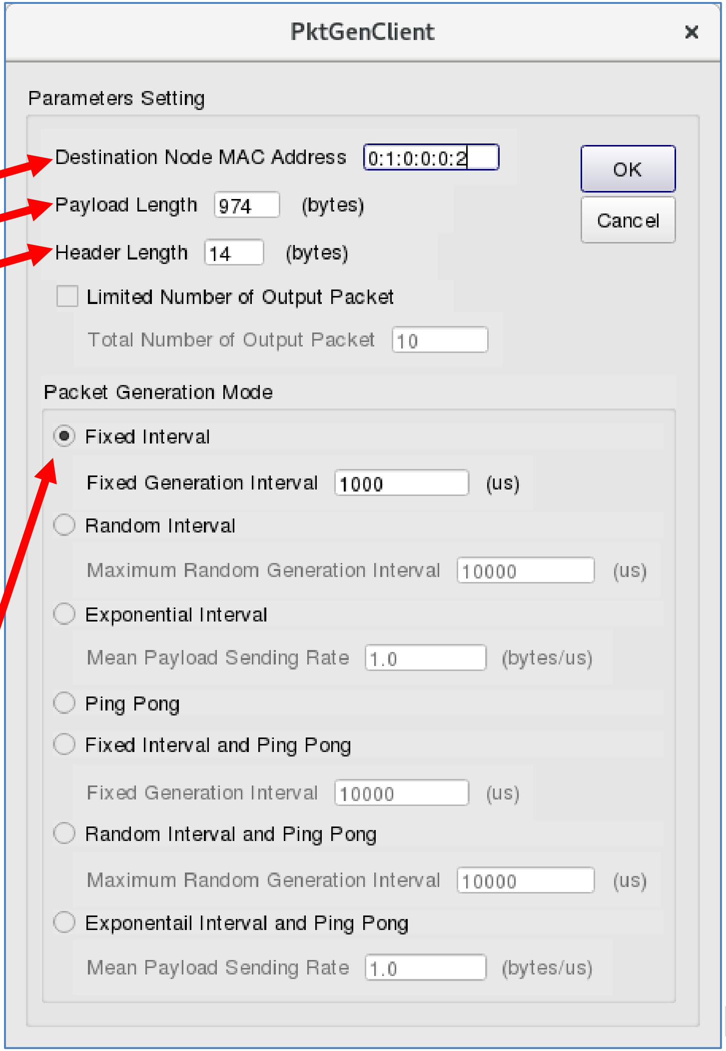
- On the left side of module-editor window, all available modules are classified by different groups. For example, PktGenServer and PktGenClient modules can be found in the PKTGEN group. Insert required modules into the protocol stack on the right side.





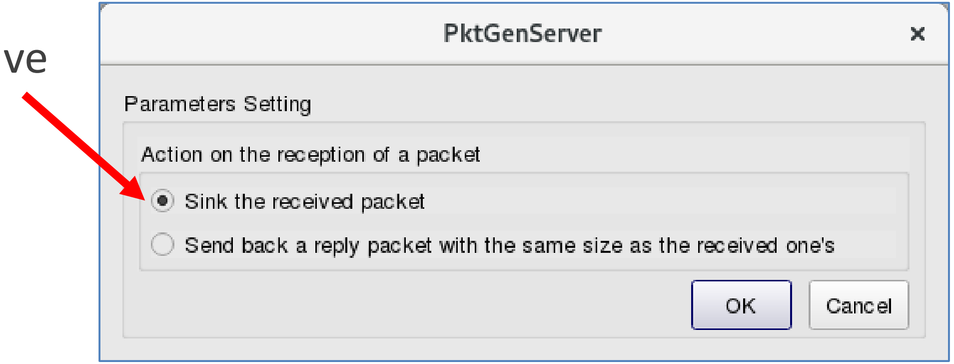
Configuration of PktGenClient Module

- Key in the MAC address of receivers Host 2/4/6.
- Key in the length of payload 974 bytes.
- Key in the length of header 14 bytes.
- Payload Length + Header Length = 988 bytes
- Within the MAC8023 module, additional 7-byte Preamble, 1-byte Start Frame Delimiter, and 4-byte CRC Checksum fields will be added into the outgoing frame. Thus, the final length of outgoing frame is 1000 bytes.
- When a simulation is started, one frame is sent out every 1000 us. In other words, 1000 frames are sent out every 1 sec.



Configuration of PktGenServer Module

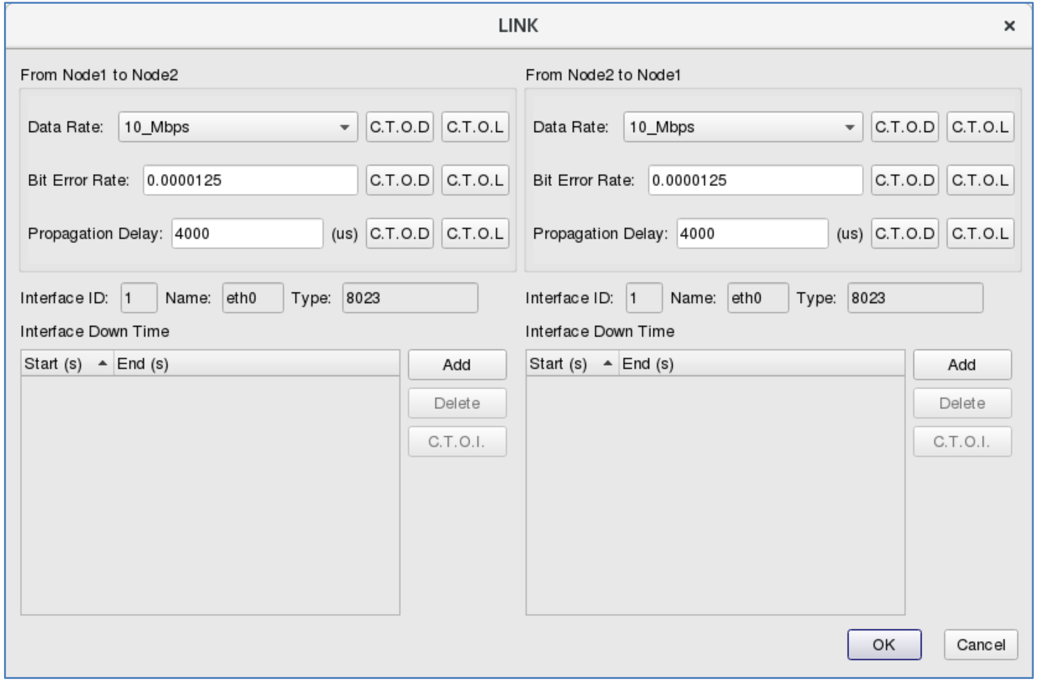
- Once the receivers Host 2/4/6 receive a frame, they drops the frame.



At Stage E, set different Bit Error Rate for the three links.

- Set Bit Error Rate to 0.0000125 for the link between Host 1 and Host 2
- Set Bit Error Rate to 0.000025 for the link between Host 3 and Host 4
- Set Bit Error Rate to 0.0000625 for the link between Host 5 and Host 6

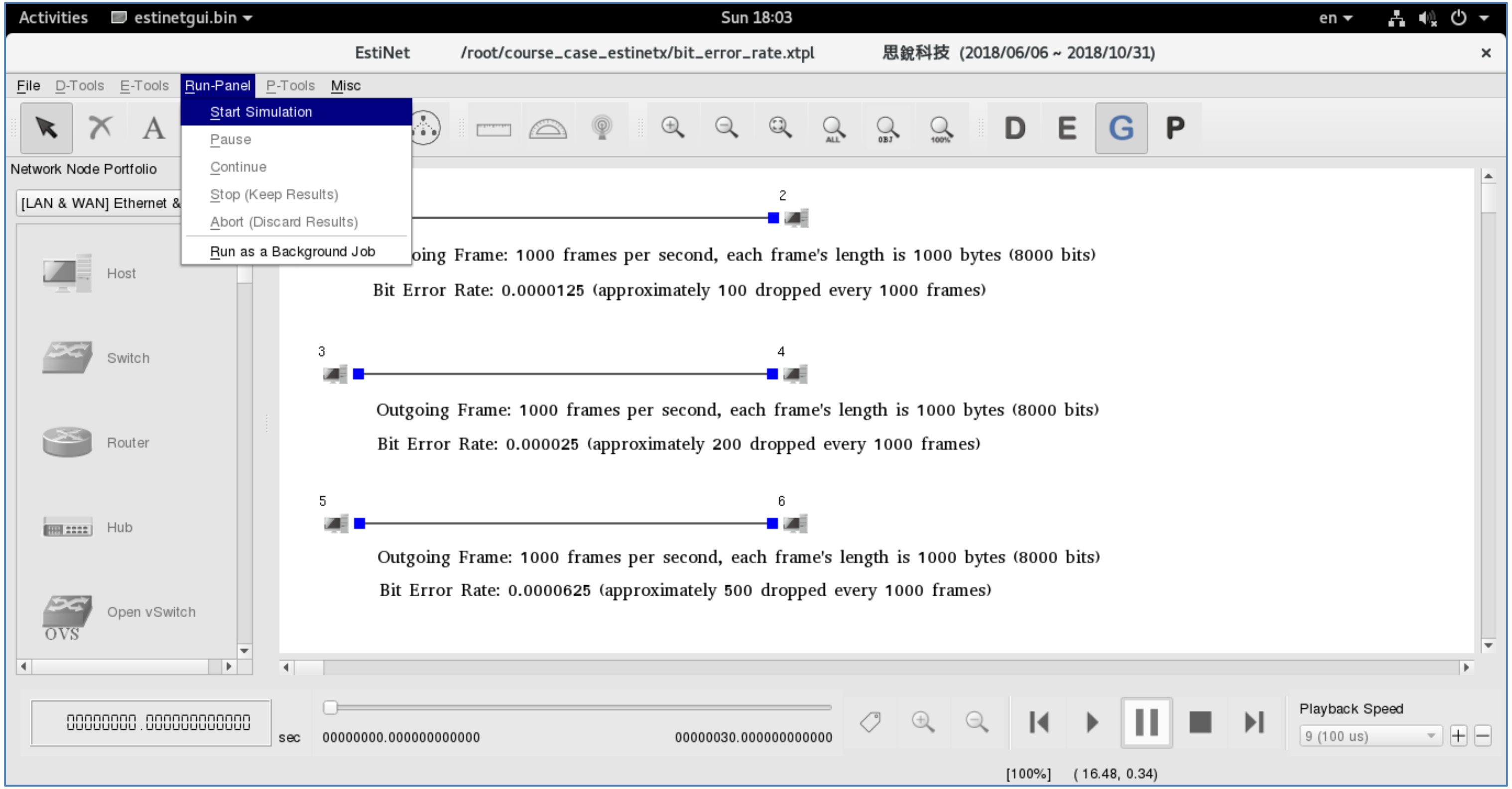
- Set Propagation Delay to 4000 us for all three links



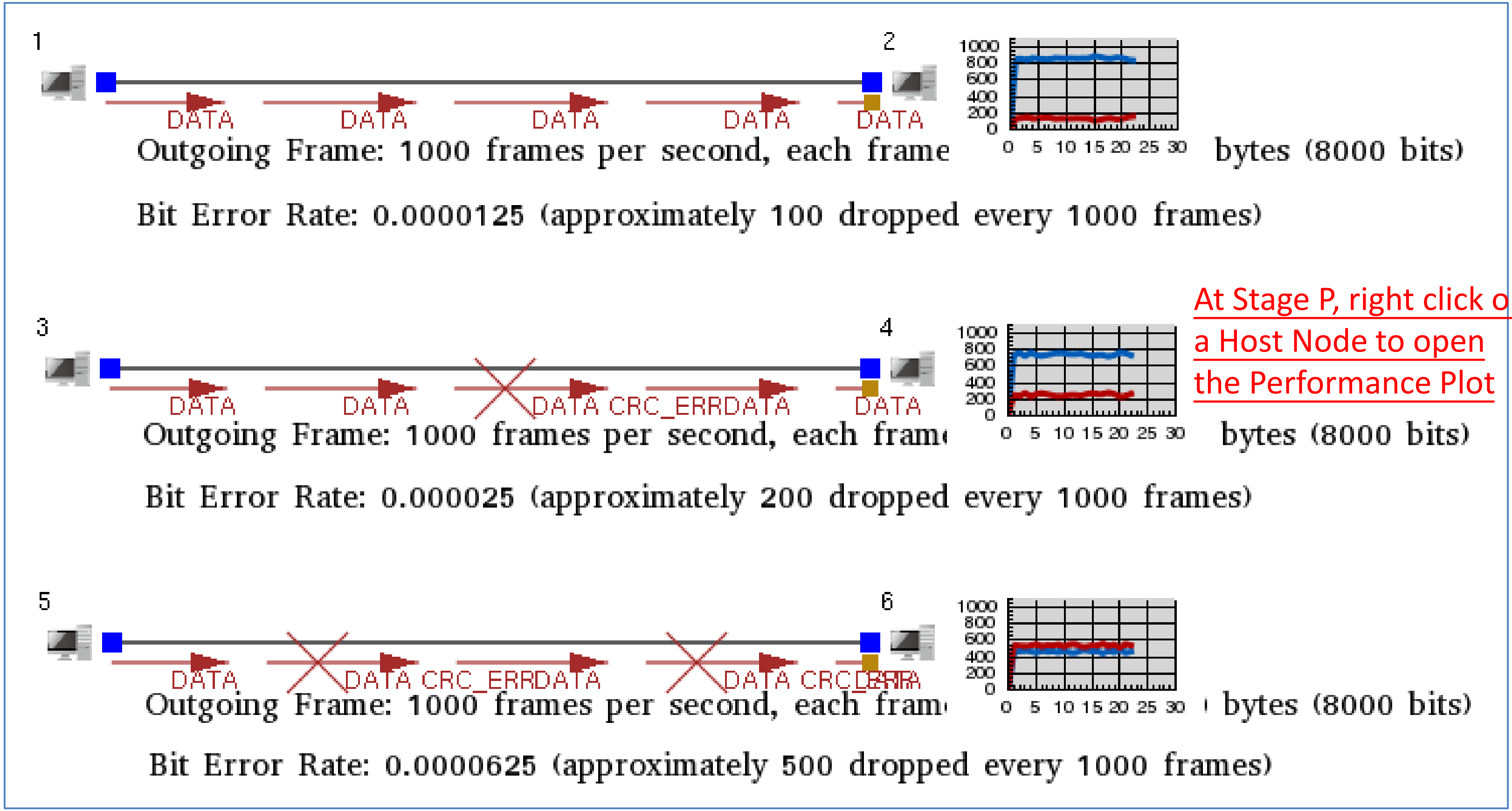
Before simulation, evaluate the frame error rate according to the bit error rate.

- If the length of a frame is 1000 bytes (8000 bits), and the bit error rate is 1/80000 (0.0000125), that means, there is one bit error every 80000 bits. In other words, there is one frame with a bit error every 10 frames. Thus, the frame error rate is 1/10 (0.1).
  - Bit Error Rate = 0.0000125 (1/80000) → Frame Error Rate = 0.1 (10%)
  - Bit Error Rate = 0.000025 (1/40000) → Frame Error Rate = 0.2 (20%)
  - Bit Error Rate = 0.0000625 (1/16000) → Frame Error Rate = 0.5 (50%)
- Consider that each sender sends out 1000 frames every second:
  - Frame Error Rate = 10% → On the receiver, about 100 frames with error and 900 frames received successfully
  - Frame Error Rate = 20% → On the receiver, about 200 frames with error and 800 frames received successfully
  - Frame Error Rate = 50% → On the receiver, about 500 frames with error and 500 frames received successfully

Change the operating stage to Stage G to generate all simulation configuration files. Then start simulation.



After simulation, at Stage P, observe the frame error rate on three different links.



Simulator Experiment
Transmission Range of Wireless Signal

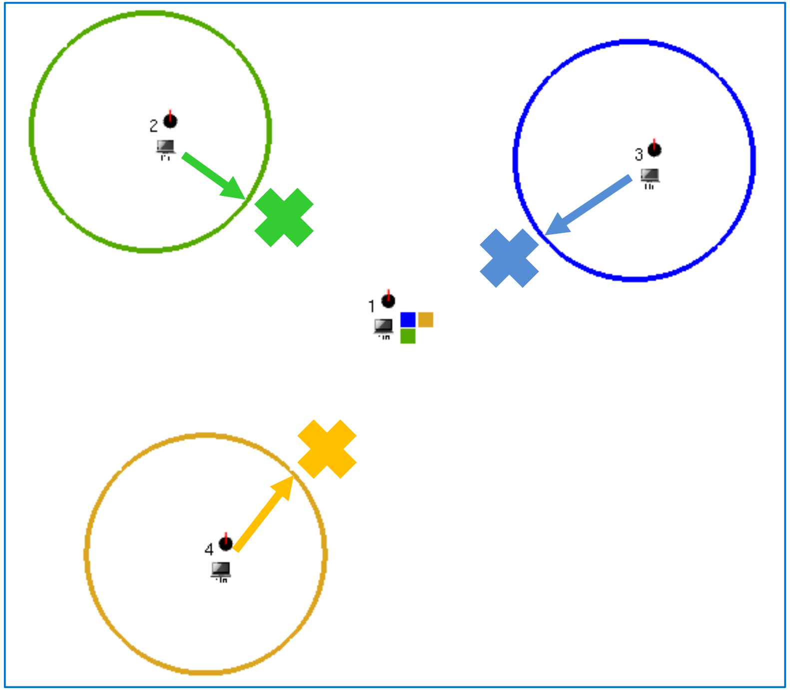
< Simulation Case >

antenna_gain_pattern_adjustment.xtpl

Factors to determine the transmission range of wireless signals:

- Antenna gain patterns of both sender site and receiver site
- Signal transmission power on sender site
- Signal receiving sensitivity on receiver site
- Signal frequency and environmental parameters (e.g., terrain, surface object, weather, interference, etc.)

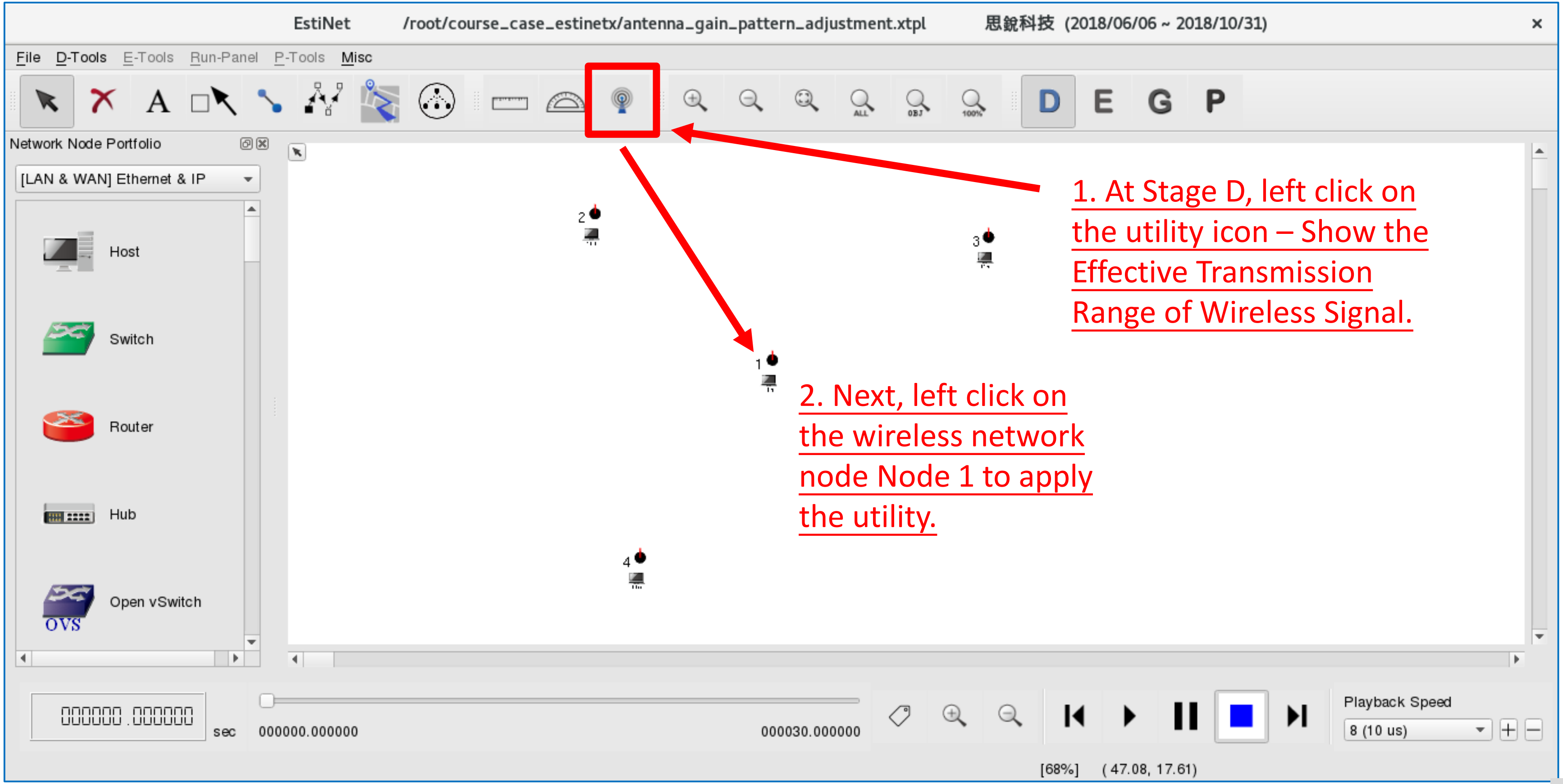
See the graph on the right-hand side. Node 1 located on the center is the signal receiver. Node 2, 3, and 4 located around Node 1 are signal senders. The situation is - the signal transmission ranges of Node 2, 3, and 4 are not far enough so that Node 1 receives no signal.



Goal:
According to the above-mentioned factors related to signal transmission range, change the corresponding simulation parameters to let Node 1 receive signals.

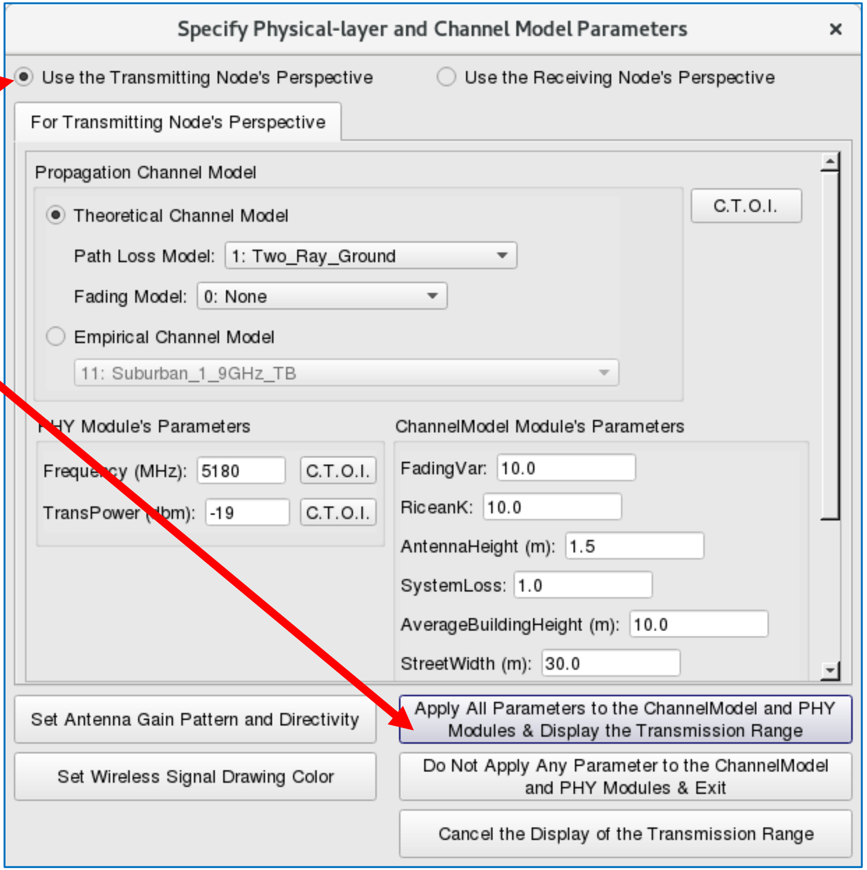
HOW TO SEE THE TRANSMISSION RANGE OF WIRELESS SIGNAL?

[Step 1] Activate the utility – Show the Effective Transmission Range of Wireless Signal.

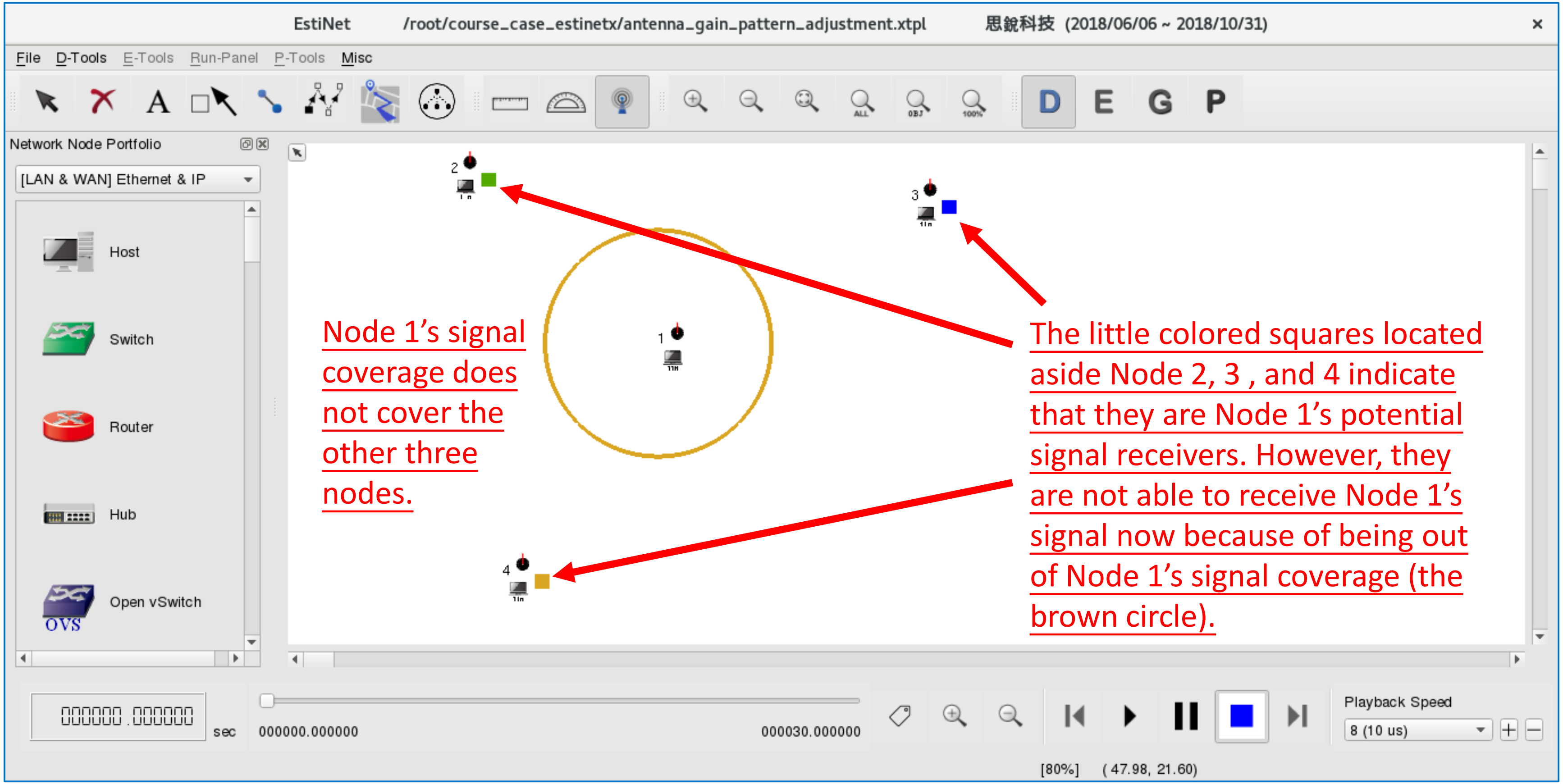


[Step 2] On the configuration window, choose to observe the transmission range of wireless signal in the perspective of a signal transmitter.

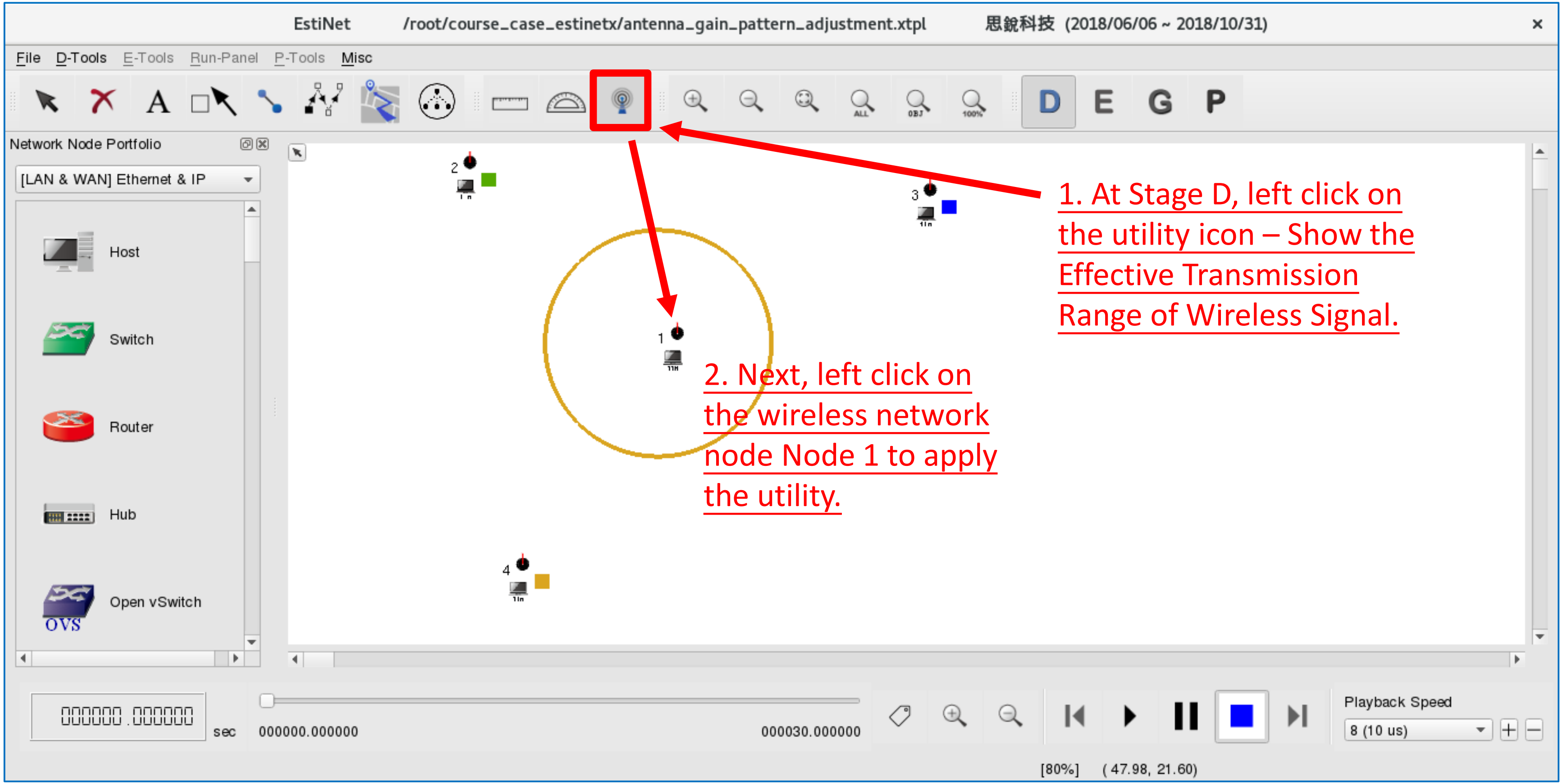
- Choose to use a signal transmitter's perspective.
- Click the button to apply the configured parameters to show the transmission range of wireless signal.



[Step 3] Observe Node 1's signal transmission range.

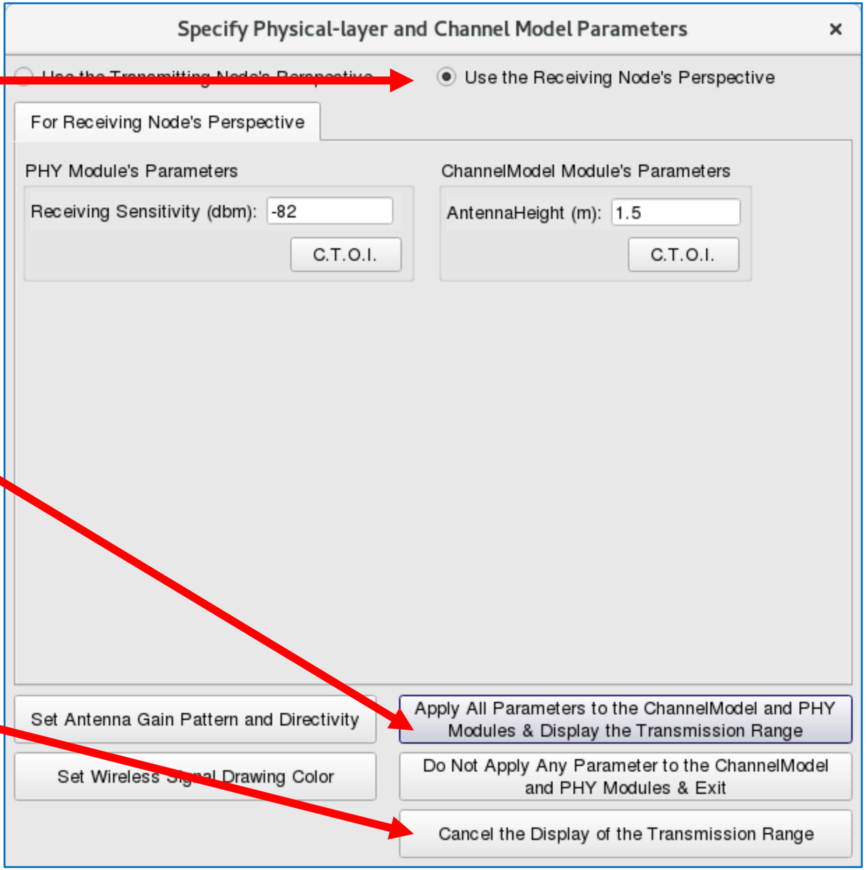


[Step 4] Again, activate the utility – Show the Effective Transmission Range of Wireless Signal.



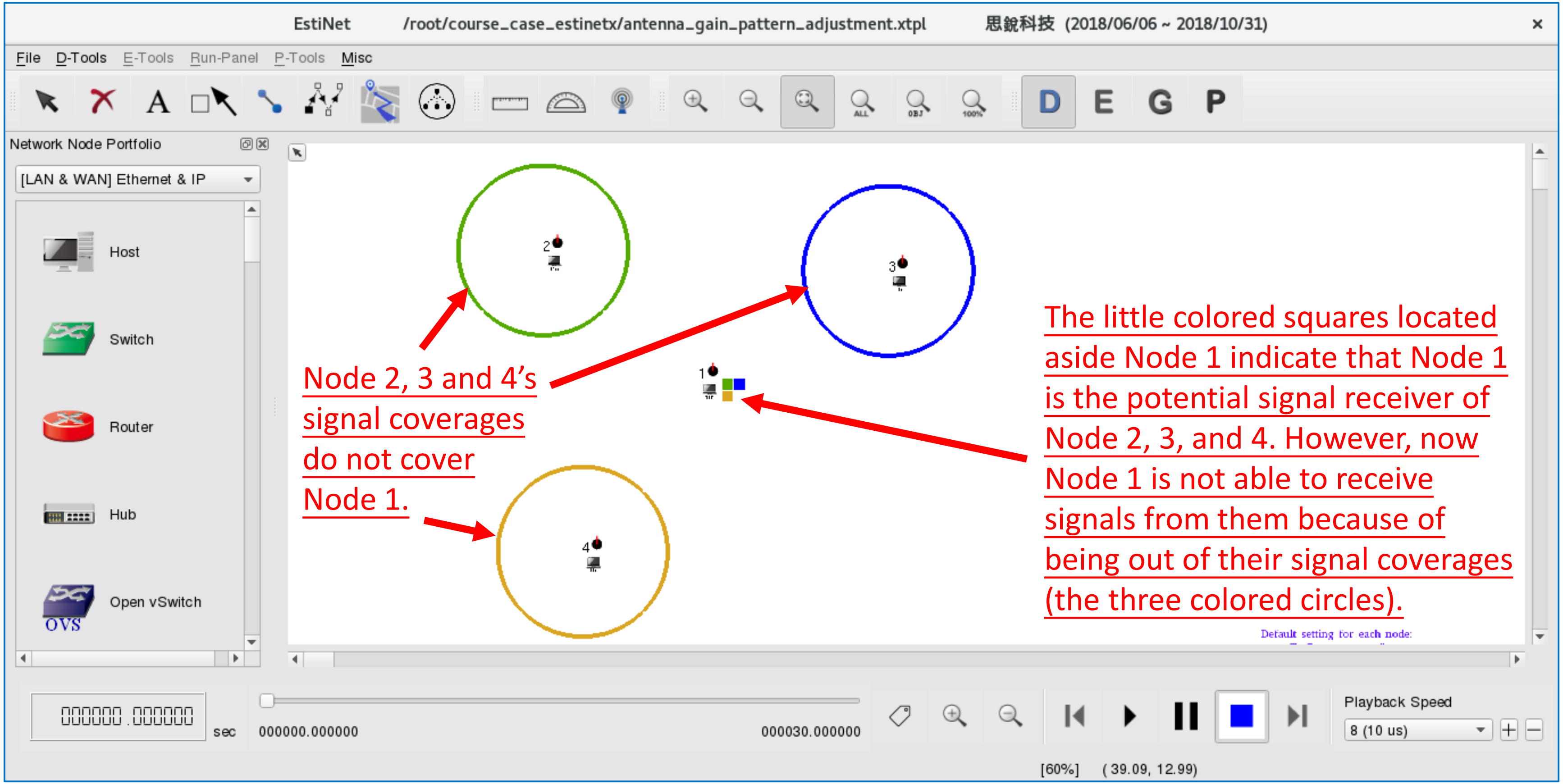
[Step 5] This time, on the configuration window, choose to observe the transmission range of wireless signal in the perspective of a signal receiver.

- Choose to use a signal receiver's perspective.
- Click the button to apply the configured parameters to show the transmission range of wireless signal.



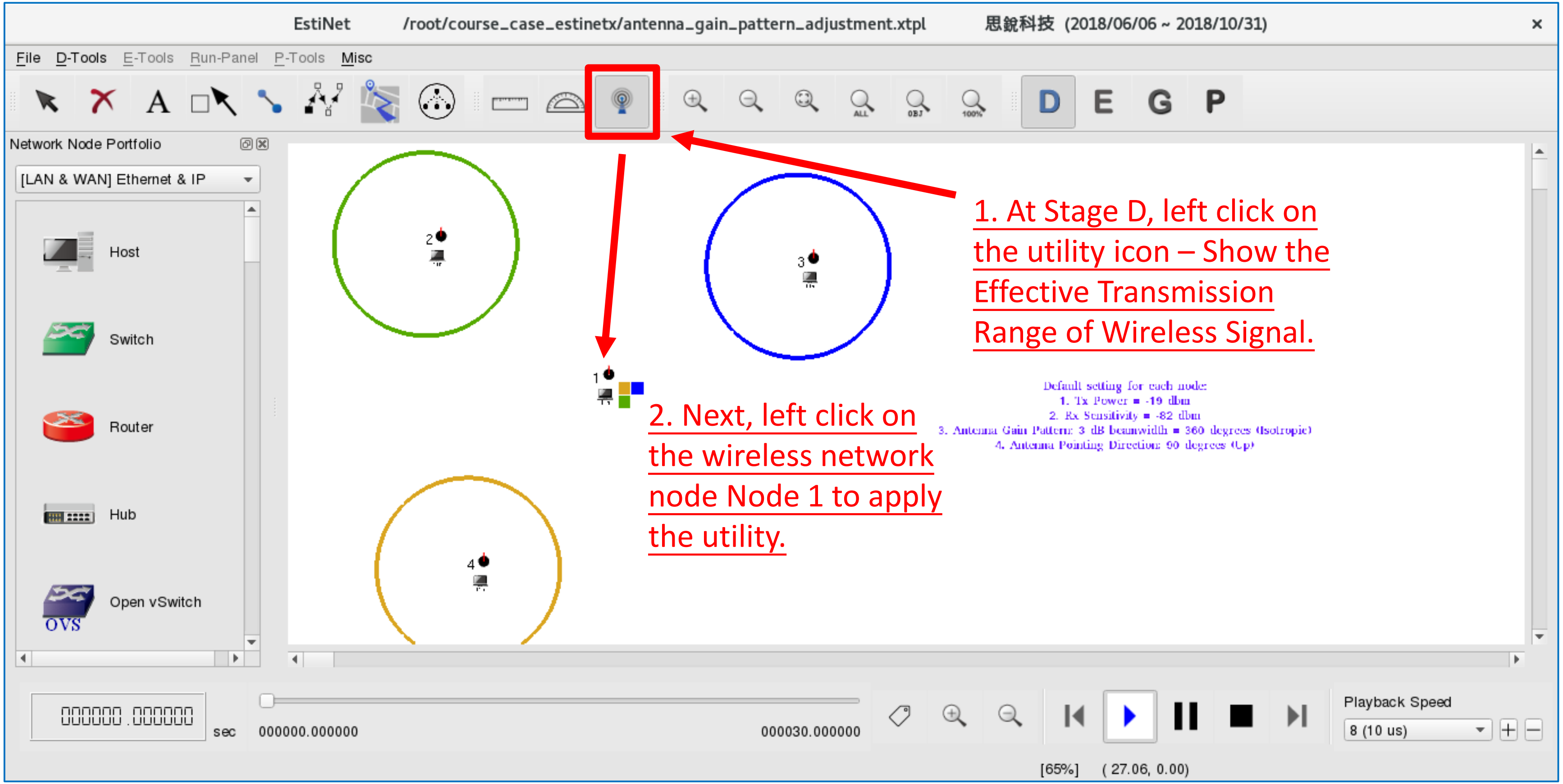
- Press this to cancel the display of wireless signal transmission range.

[Step 6] Observe the transmission ranges of all the signals that (potentially) are able to be received by Node 1.



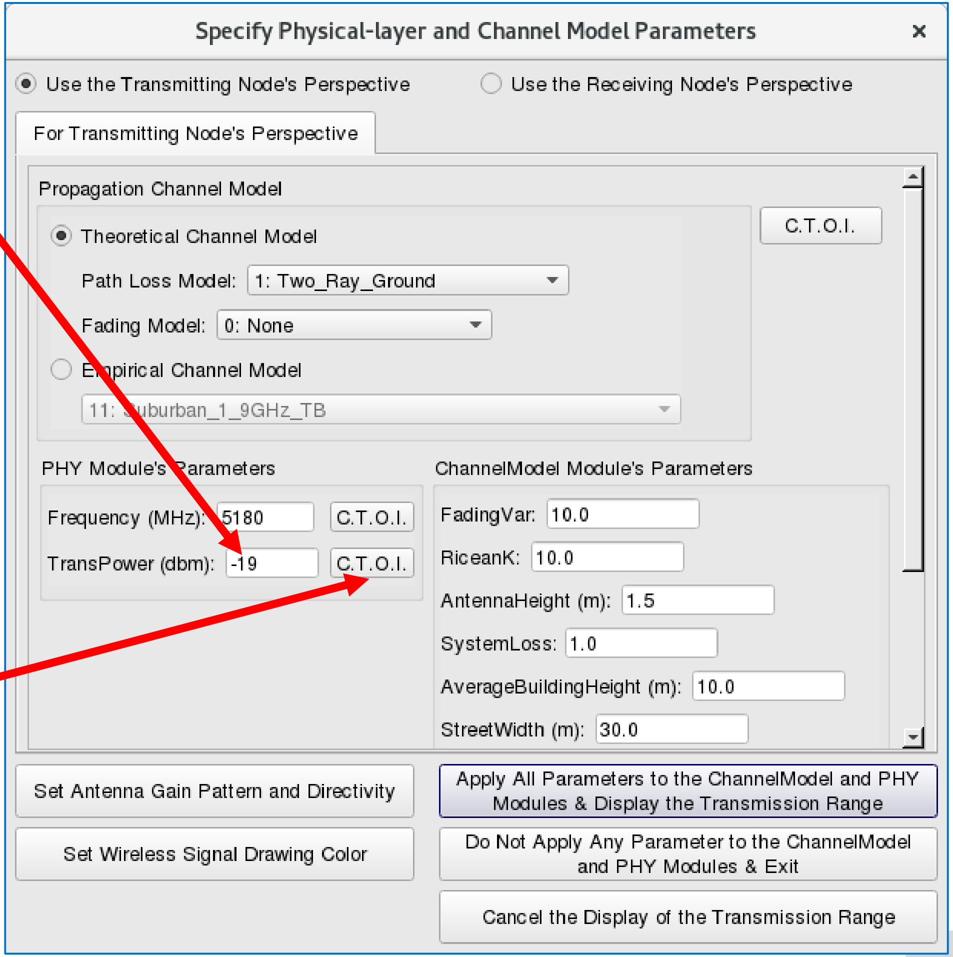
INCREASE THE TRANSMISSION POWER OF SIGNAL ON THE SIGNAL TRANSMITTER TO INCREASE THE SIGNAL TRANSMISSION RANGE

[Step 1] Activate the utility – Show the Effective Transmission Range of Wireless Signal.



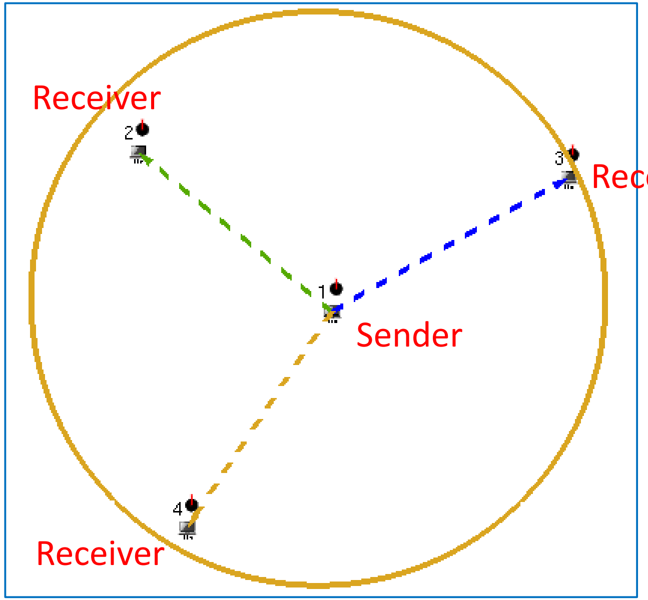
[Step 2] Adjust the transmission power of signal.

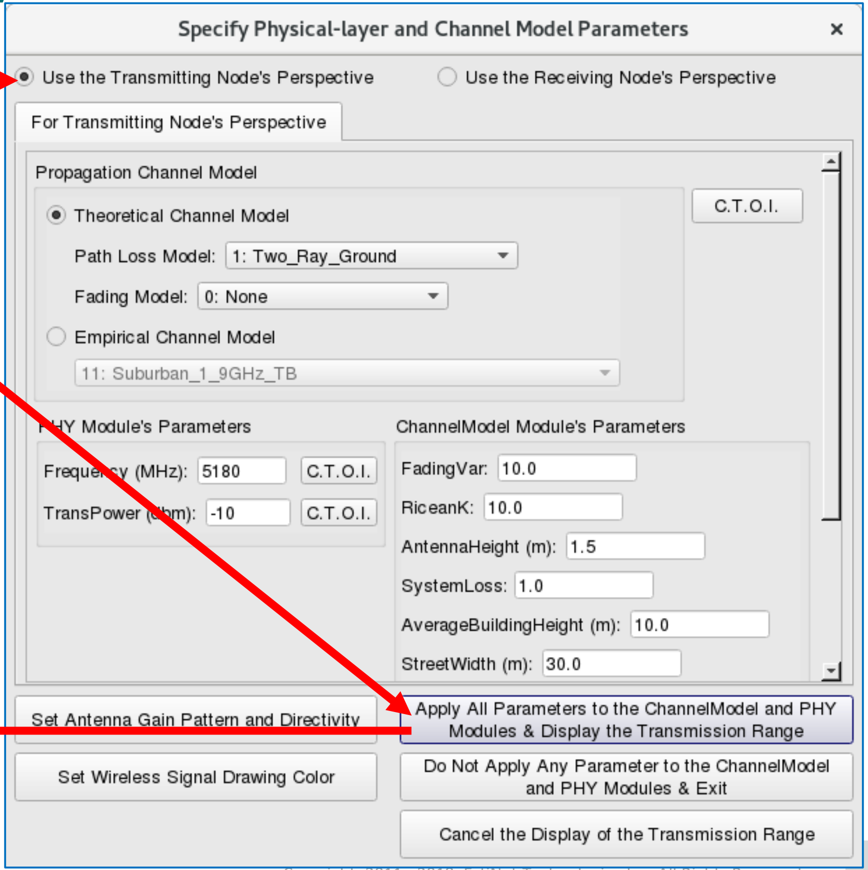
- On the configuration window of Node 1, change the value of TransPower (dbm) from -19 to -10 to increase the transmission power of signal.
  - The unit "dbm" is calculated from a logarithm formula.
  - Assume Power_mW (milliwatt) is the signal power. Power_dbm = 10 * $\log_{10}\left({}^{Power\_mW}/_{1\ milliwatt}\right)$
  - In other words, "dbm" is the logarithm operation on the ratio of the signal power to 1 milliwatt.
  - Thus, -19 dbm represents the original signal power is 0.01259 milliwatt while -10 dbm represents the original signal power is 0.1 milliwatt. The latter is nearly 7.94 times the former.
- Press the button C.T.O.I (Copy to Other Interfaces) to copy the modified value to the other three nodes (Node 2, 3, and 4).
  - Increase the transmission power of signal on both signal senders and receivers to achieve bi-directional communication.



[Step 3] Observe if the signals sent by Node 1 are able to be received by the other three nodes.

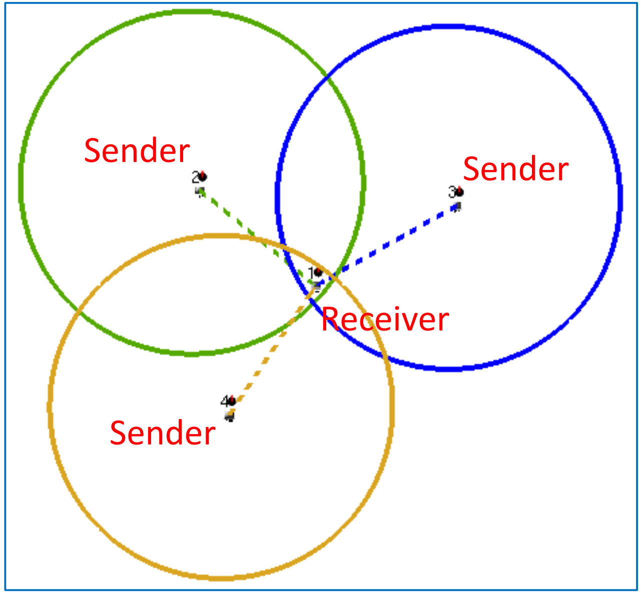
- Choose to use a signal sender's perspective to observe if the transmitted signal can be received by any potential receiver.
- Click the button to apply the configured parameters to show the transmission range of wireless signal.

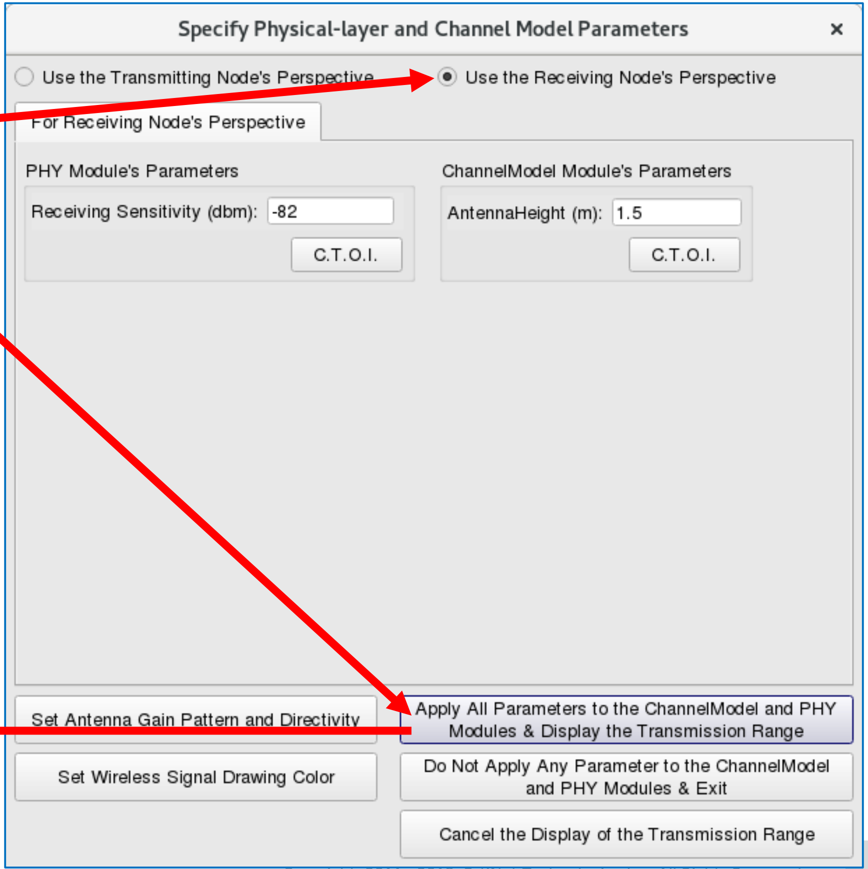




[Step 4] Observe if the signals sent by other three nodes are able to be received by Node 1.

- Again, apply the utility "Show the Effective Transmission Range of Wireless Signal" on Node 1.
- Choose to use a signal receiver's perspective to observe which sender's signals can be received by the receiver.
- Click the button to apply the configured parameters to show the transmission range of wireless signal.

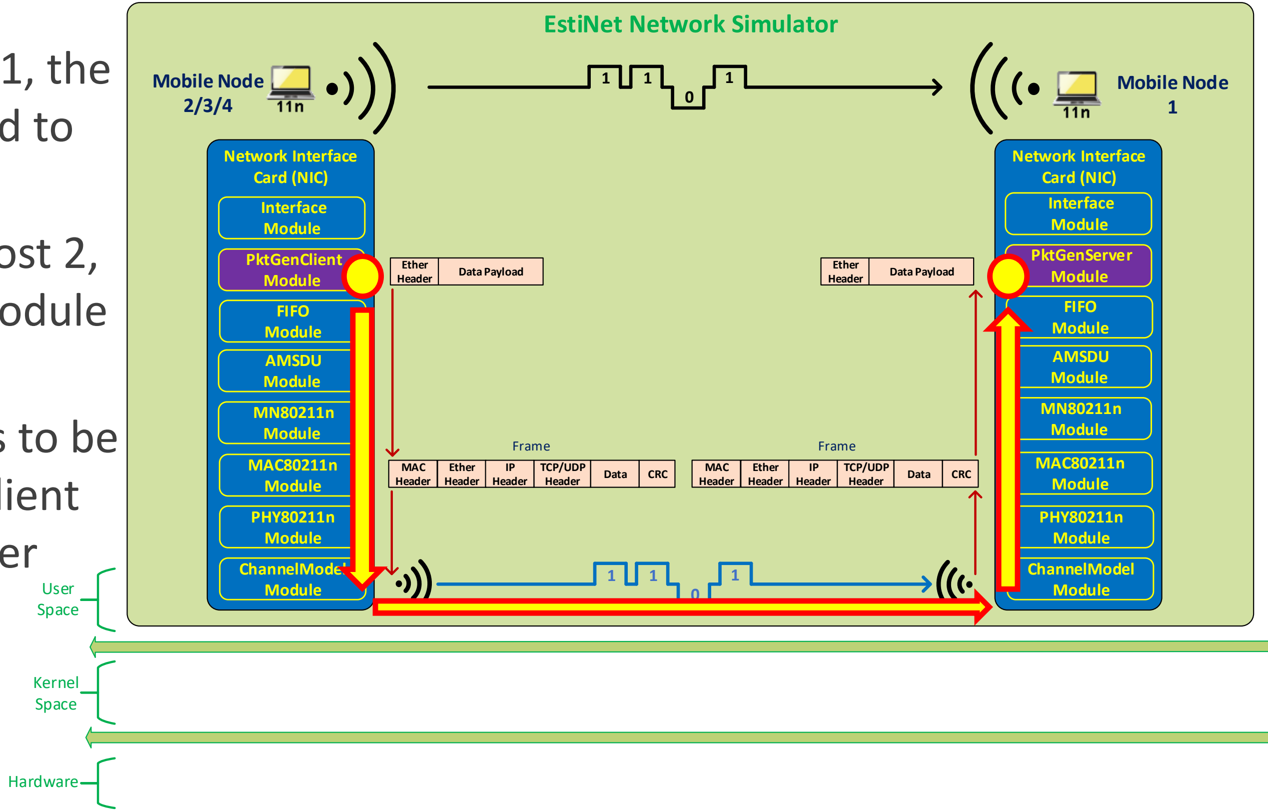




EstiNet

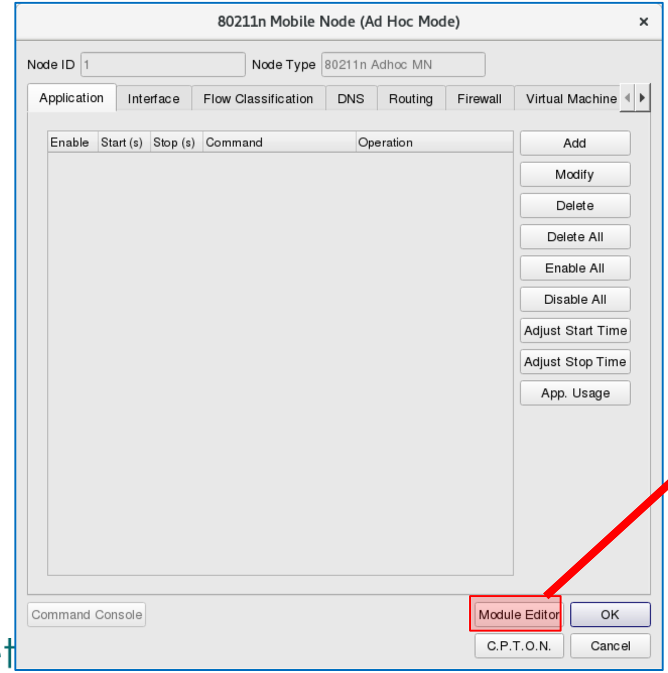
[Step 5] At Stage E, arrange the PktGen Modules to send/receive frames during simulation.

- On the signal receiver Node 1, the PktGenServer Module is used to receive frames.
- On the signal transmitters Host 2, 3 and 4, the PktGenClient Module is used to send frames.
- Note that a FIFO Module has to be inserted below the PktGenClient Module and the PktGenServer Module.

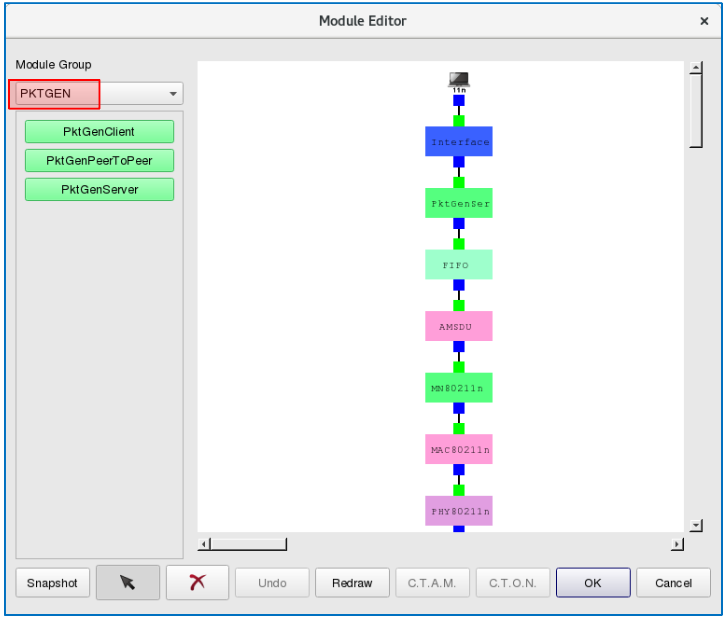


At Stage E, open the node-editor utility first and then open the module-editor utility to edit protocol stack.

- At Stage E, double click on any node to open node editor. On the node-editor window, click the Module Editor button to open module editor.

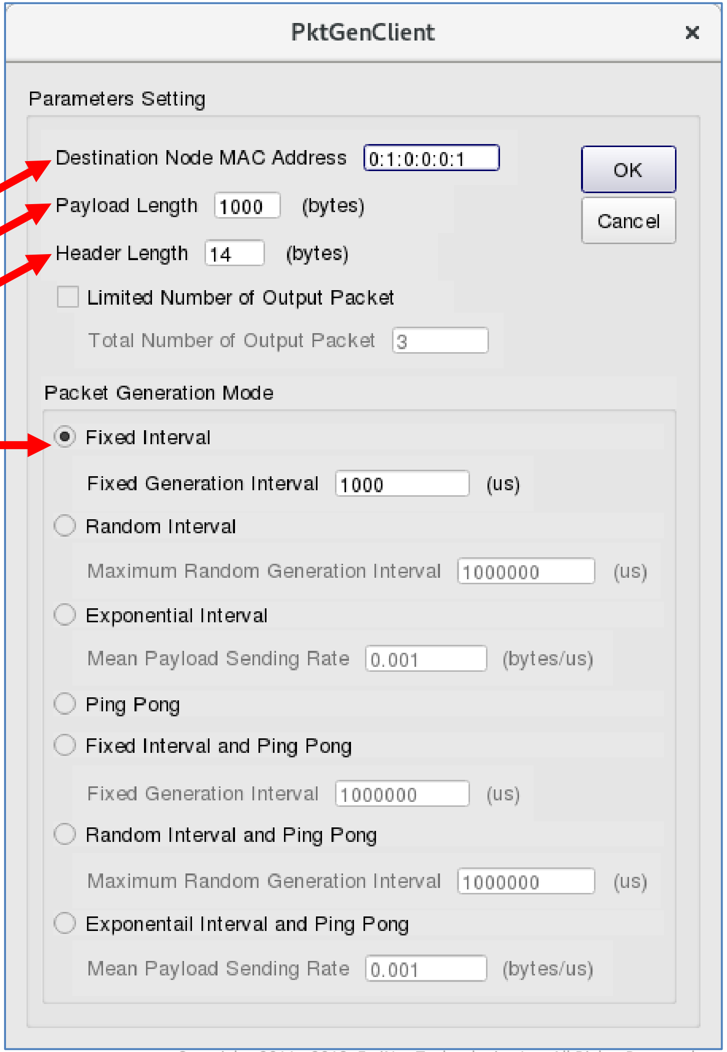


- On the left side of module-editor window, all available modules are classified by different groups. For example, PktGenServer and PktGenClient modules can be found in the PKTGEN group. Insert required modules into the protocol stack on the right side.



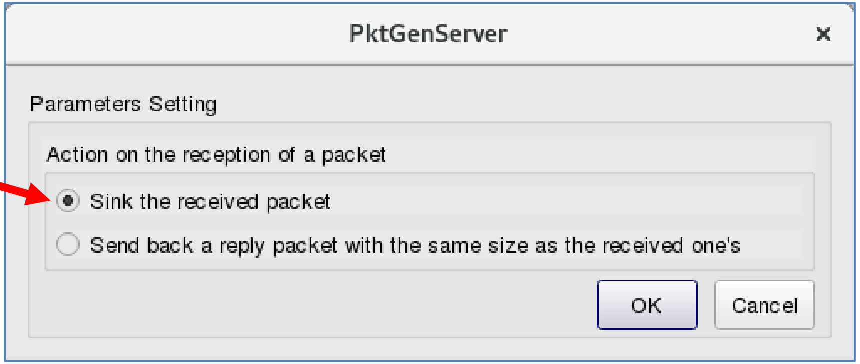
Configuration of PktGenClient Module

- Key in the MAC address of receiver Node 1.
- Key in the length of payload 1000 bytes.
- Key in the length of header 14 bytes.
- When a simulation is started, one frame is sent out every 1000 us. In other words, 1000 frames are sent out every 1 sec.

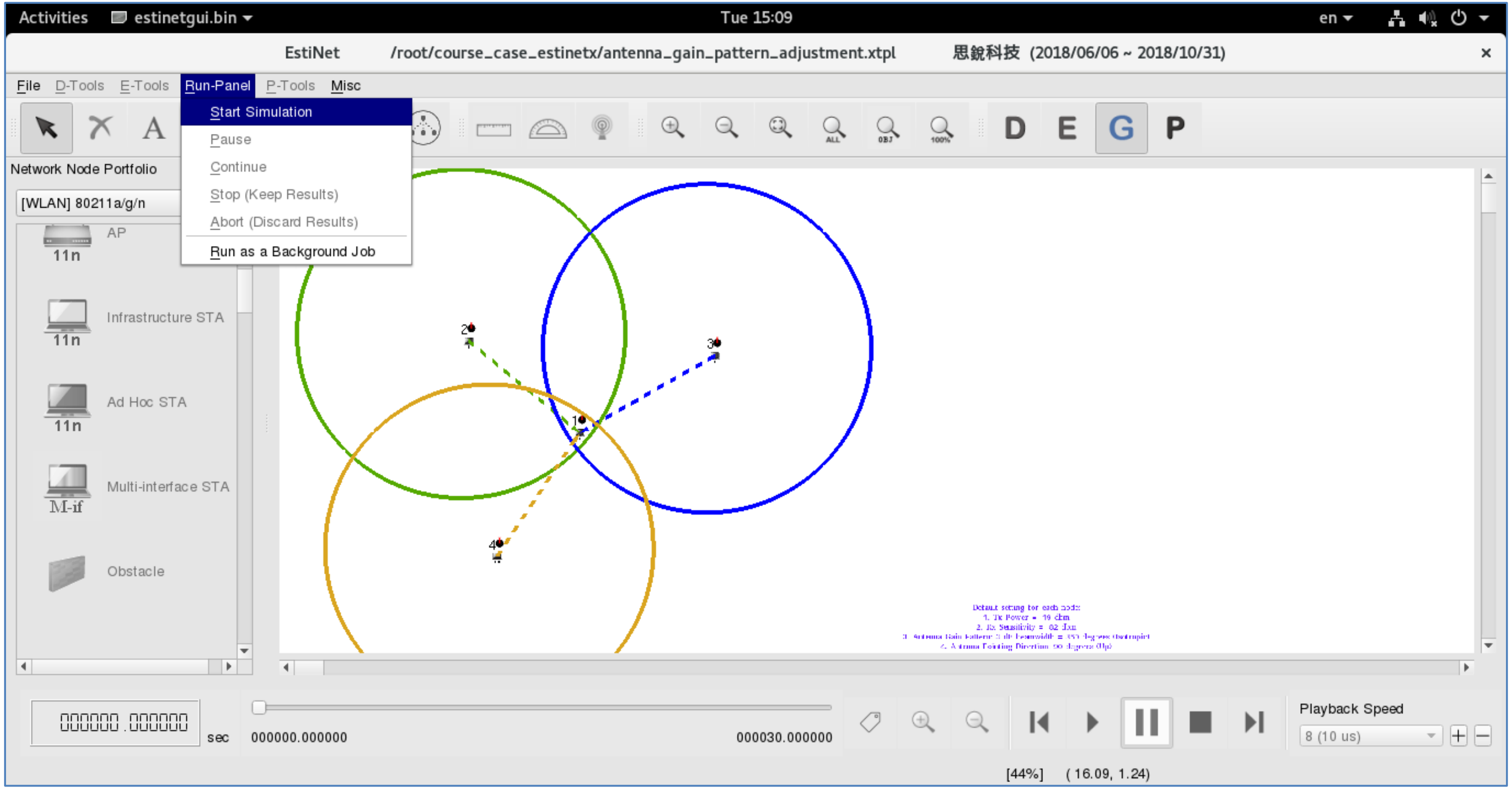


Configuration of PktGenServer Module

- Once the receiver Node 1 receives a frame, it drops the frame.

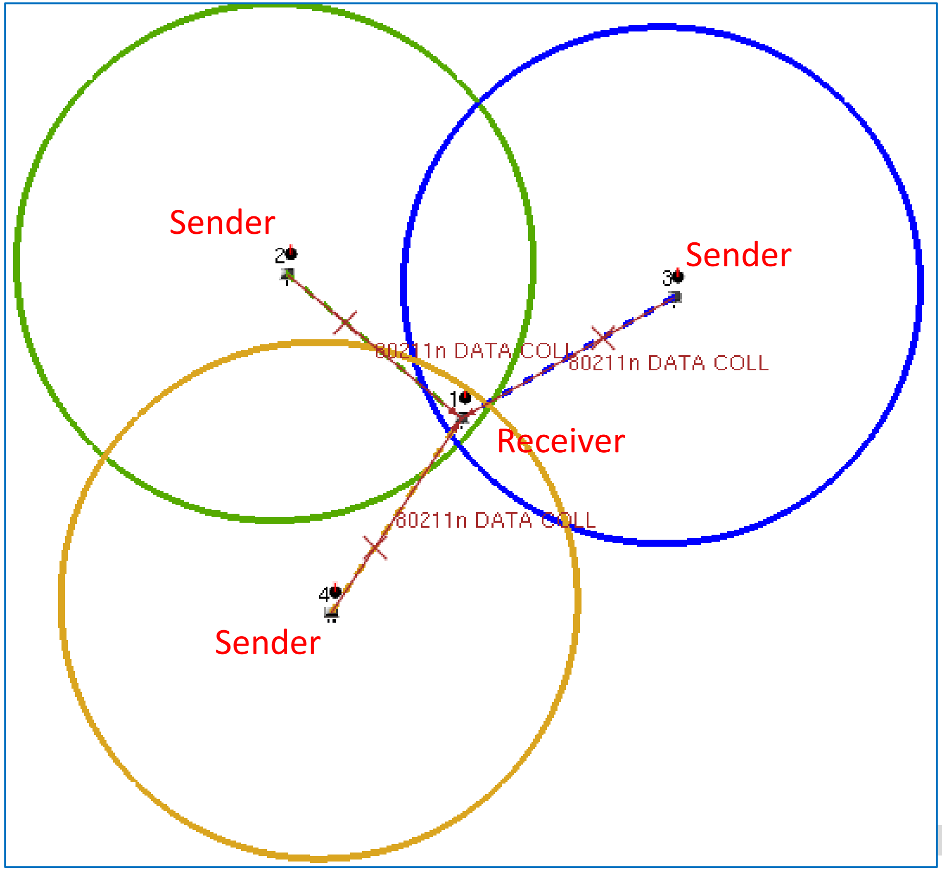


[Step 6] Change the operating stage to Stage G to generate all simulation configuration files. Then start simulation.



[Step 7] After simulation, at Stage P, observe the simulation results.

- At Stage P, the frame animation is displayed according to the simulation results. Check the graph on the right-hand side. The signals sent from Node 2, 3, and 4 are able to reach Node 1. However, those signals collide with each other because they reach Node 1 nearly simultaneously. In this case, Node 1 receives no signal eventually.
- The problems of signal collision are tackled by data link layer (layer 2). Thus, when watching the frame animation, sometimes a successful frame reception can be seen in both directions.

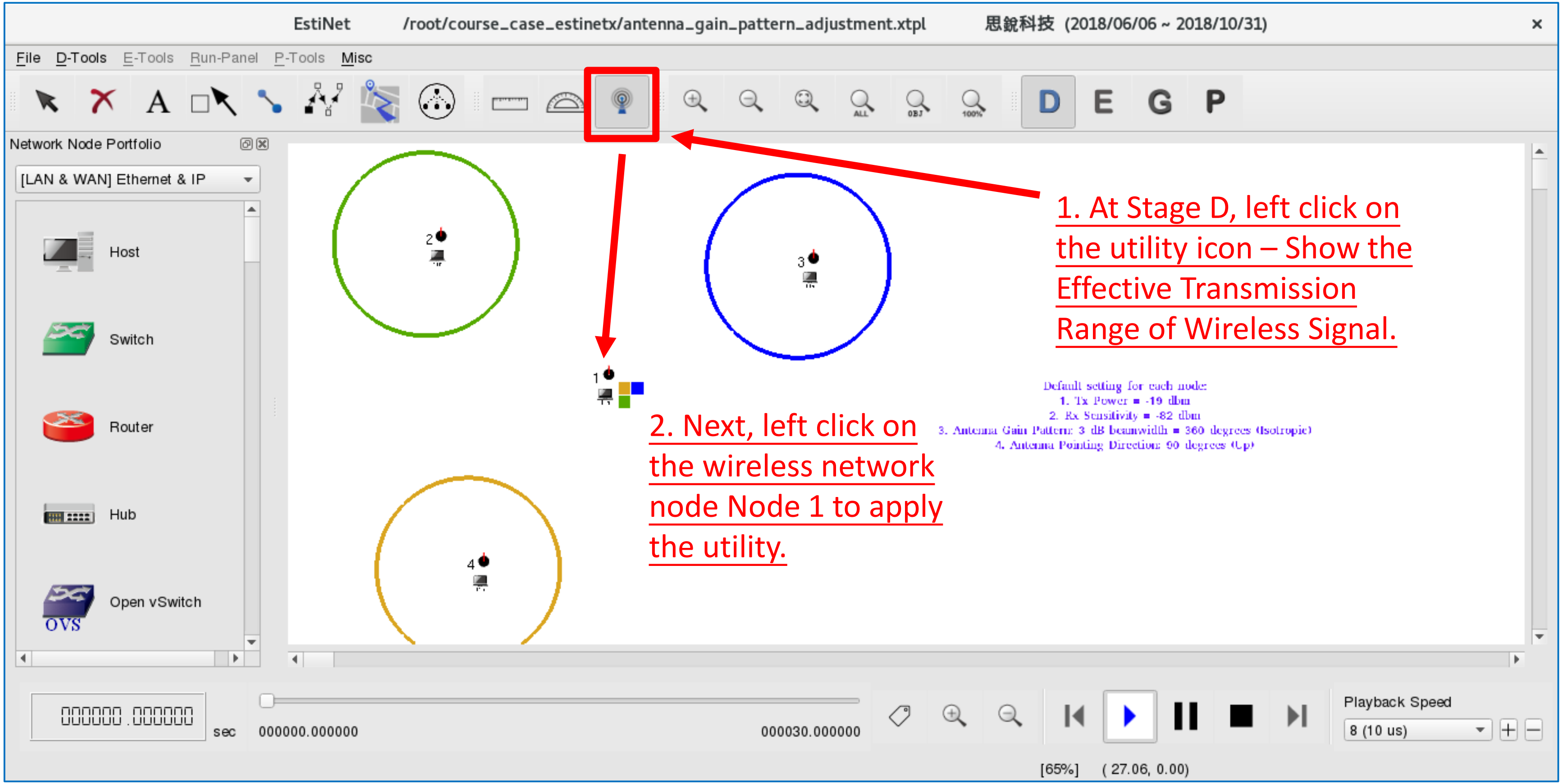


INCREASE THE RECEIVING SENSITIVITY OF SIGNAL ON THE SIGNAL RECEIVER TO INCREASE THE SIGNAL TRANSMISSION RANGE

[Step 1] Set those modified simulation parameters back to the default values

- In the previous experiment, the values of TransPower (dbm) of all nodes (Node 1, 2, 3, and 4) are changed from -19 to -10. Change those values back to -19 first before starting this experiment.

[Step 2] Activate the utility – Show the Effective Transmission Range of Wireless Signal.

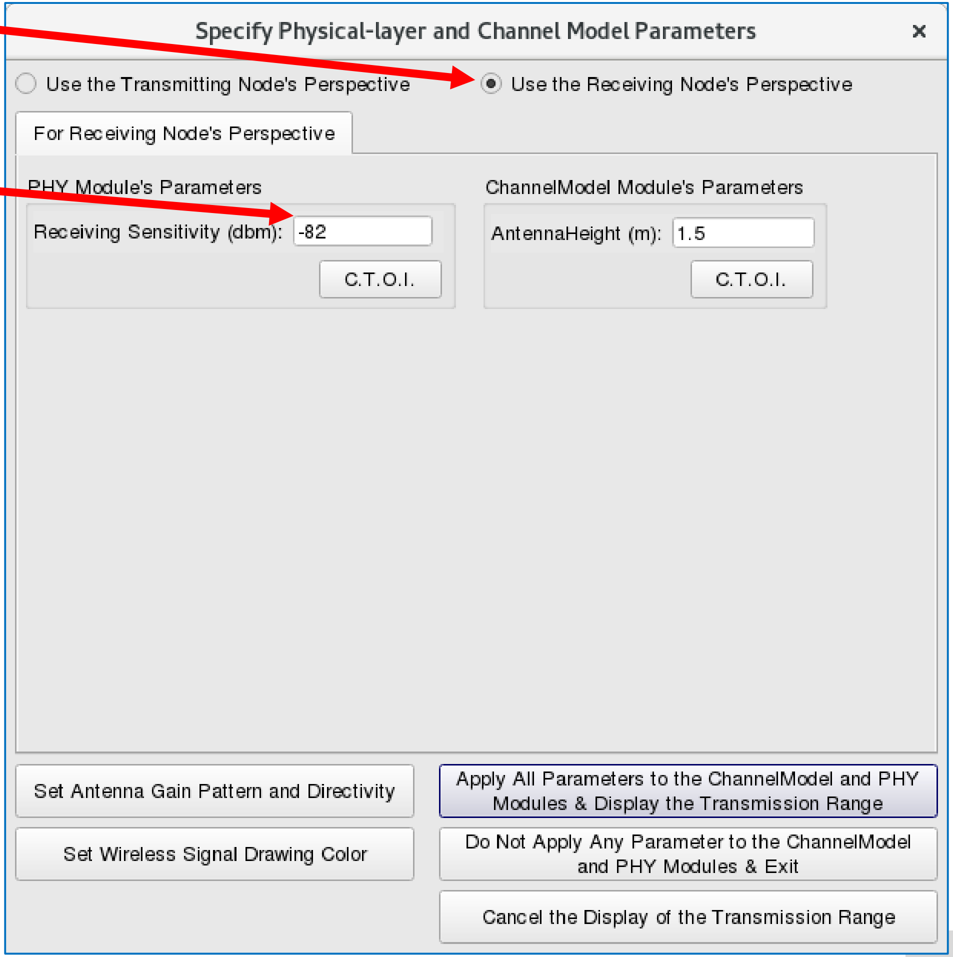


1. At Stage D, left click on the utility icon – Show the Effective Transmission Range of Wireless Signal.

2. Next, left click on the wireless network node Node 1 to apply the utility.

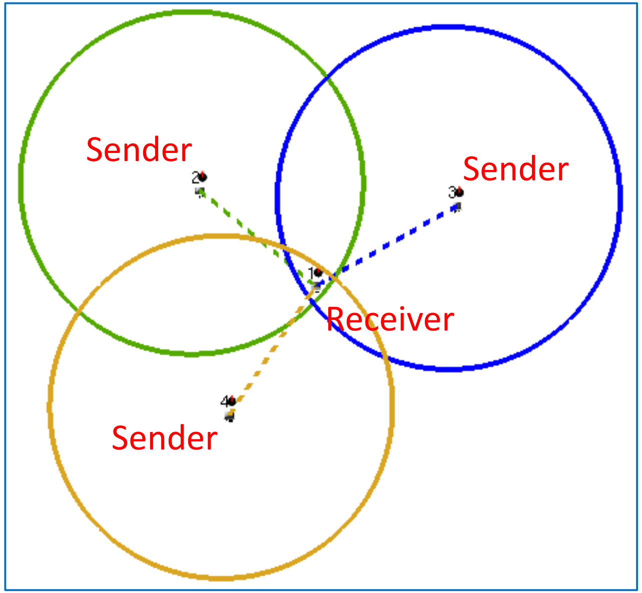
[Step 3] Adjust the receiving sensitivity of signal

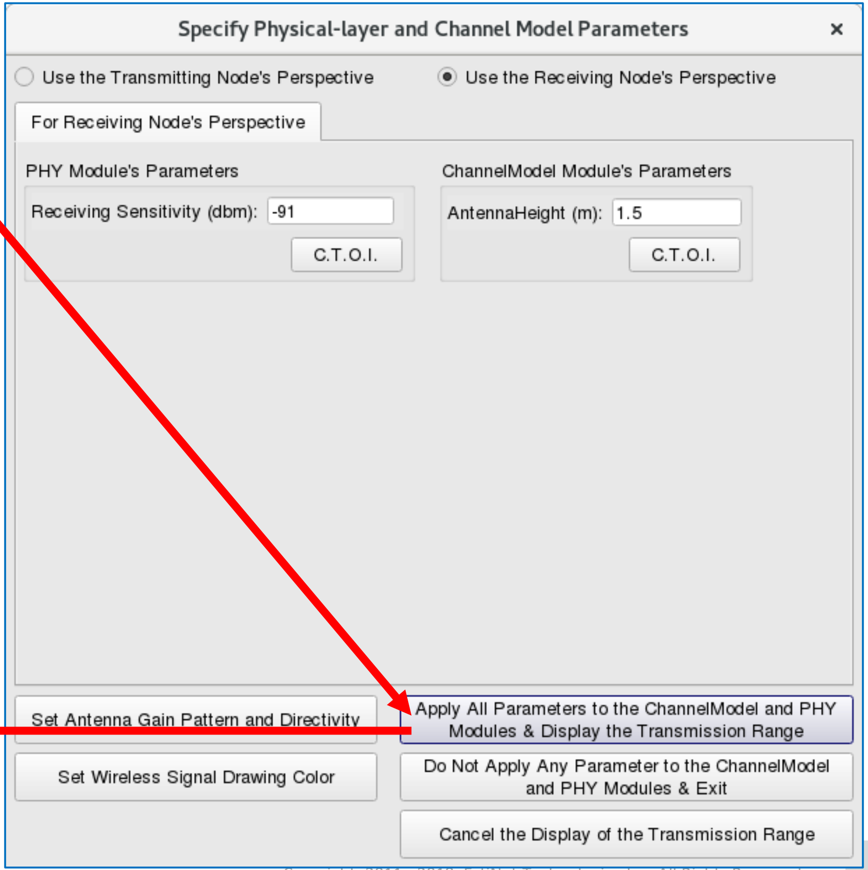
- Choose to use a signal receiver's perspective. The following parameter configuration tab will be switched to the specific tab for receiver purpose.
- Change the value of Receiving Sensitivity (dbm) from -82 to -91. This parameter represents the minimum signal power that is able to be sensed/received by a receiver. When a signal is propagated through the air, its power attenuates gradually along with the path. When the signal reaches a receiver, its power must be larger than the receiving sensitivity of the receiver so that it can be received successfully.
  - The unit "dbm" is calculated from a logarithm formula.
  - Assume RxPower_mW (milliwatt) is the minimum receiving signal power. RxPower_dbm = 10 * $\log_{10}\left({}^{RxPower\_mW}/_{1\ milliwatt}\right)$
  - In other words, "dbm" is the logarithm operation on the ratio of the minimum receiving signal power to 1 milliwatt.
  - Thus, -82 dbm represents the minimum power is 63.1*10^(-10) milliwatt while -91 dbm represents the minimum power is 7.94*10^(-10) milliwatt. The latter is nearly 7.94 times lower than the former. That means, a signal can be transmitted farther and still be received.



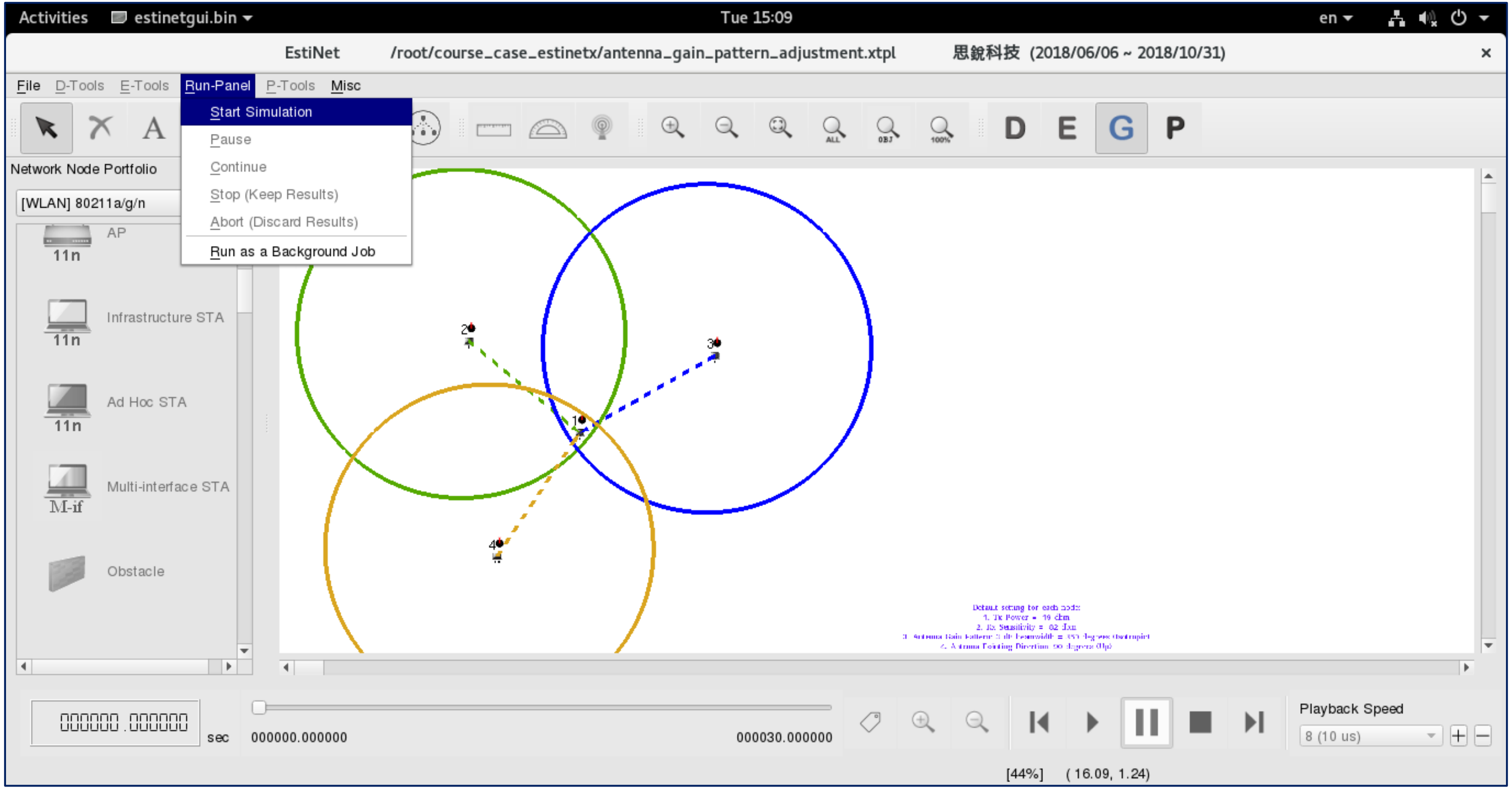
[Step 4] Observe if the signals sent by other three nodes are able to be received by Node 1.

- Click the button to apply the configured parameters to show the transmission range of wireless signal.



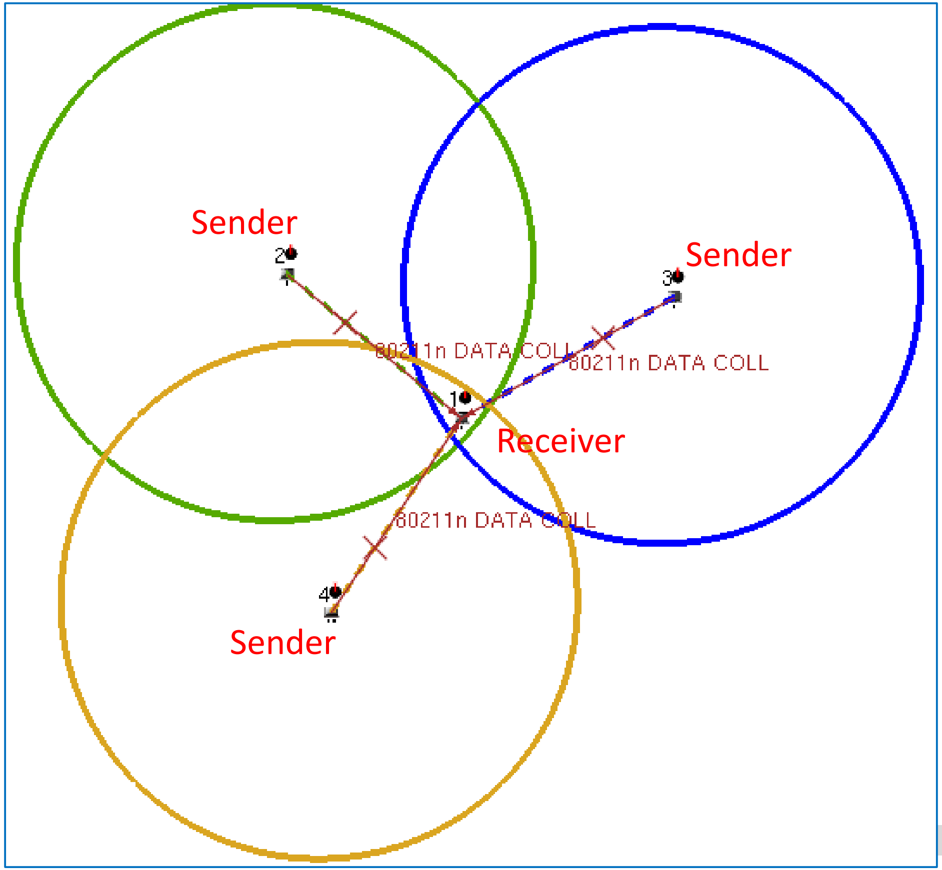


[Step 5] Change the operating stage to Stage G to generate all simulation configuration files. Then start simulation.



[Step 6] After simulation, at Stage P, observe the simulation results.

- At Stage P, the frame animation is displayed according to the simulation results. Check the graph on the right-hand side. The signals sent from Node 2, 3, and 4 are able to reach Node 1. However, those signals collide with each other because they reach Node 1 nearly simultaneously. In this case, Node 1 receives no signal eventually.
- The problems of signal collision are tackled by data link layer (layer 2). Thus, when watching the frame animation, sometimes a successful frame reception can be seen in only one direction (Node 2/3/4 to Node 1).



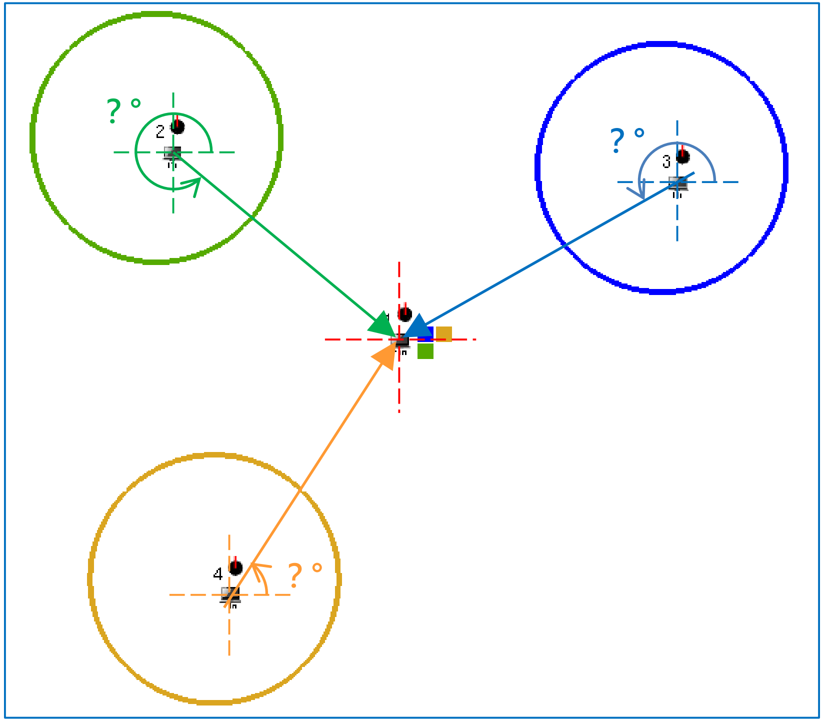
ADJUST THE ANTENNA GAIN PATTERN ON THE SIGNAL TRANSMITTER TO INCREASE THE SIGNAL TRANSMISSION RANGE

[Step 1] Set the modified simulation parameter back to the default value

- In the previous experiment, the value of Receiving Sensitivity (dbm) of Node 1 is changed from -82 to -91. Change the value back to -82 first before starting this experiment.

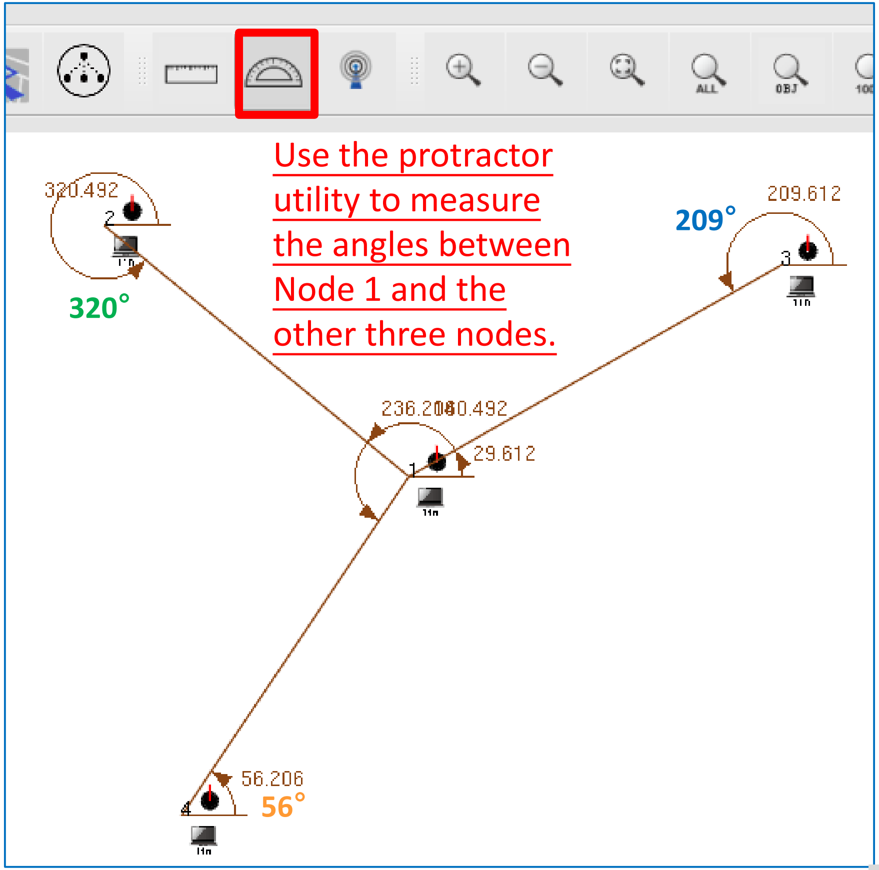
[Step 2] The principle of adjusting antenna gain pattern to increase the transmission range of signal

- The default antenna gain pattern is isotropic (360°). If an isotropic antenna is used, the available power is used to emit signals in all directions.
- If a directional antenna is used, the available power is used to emit signals in a specific direction.
- If the available power is the same, a directional antenna emits signals farther than an isotropic antenna in a specific direction.
- Thus, we are going to change the antenna gain pattern of Node 2, 3, and 4's antennas from isotropic to directional. In this way, their signal transmission range will be increased to cover Node 1.

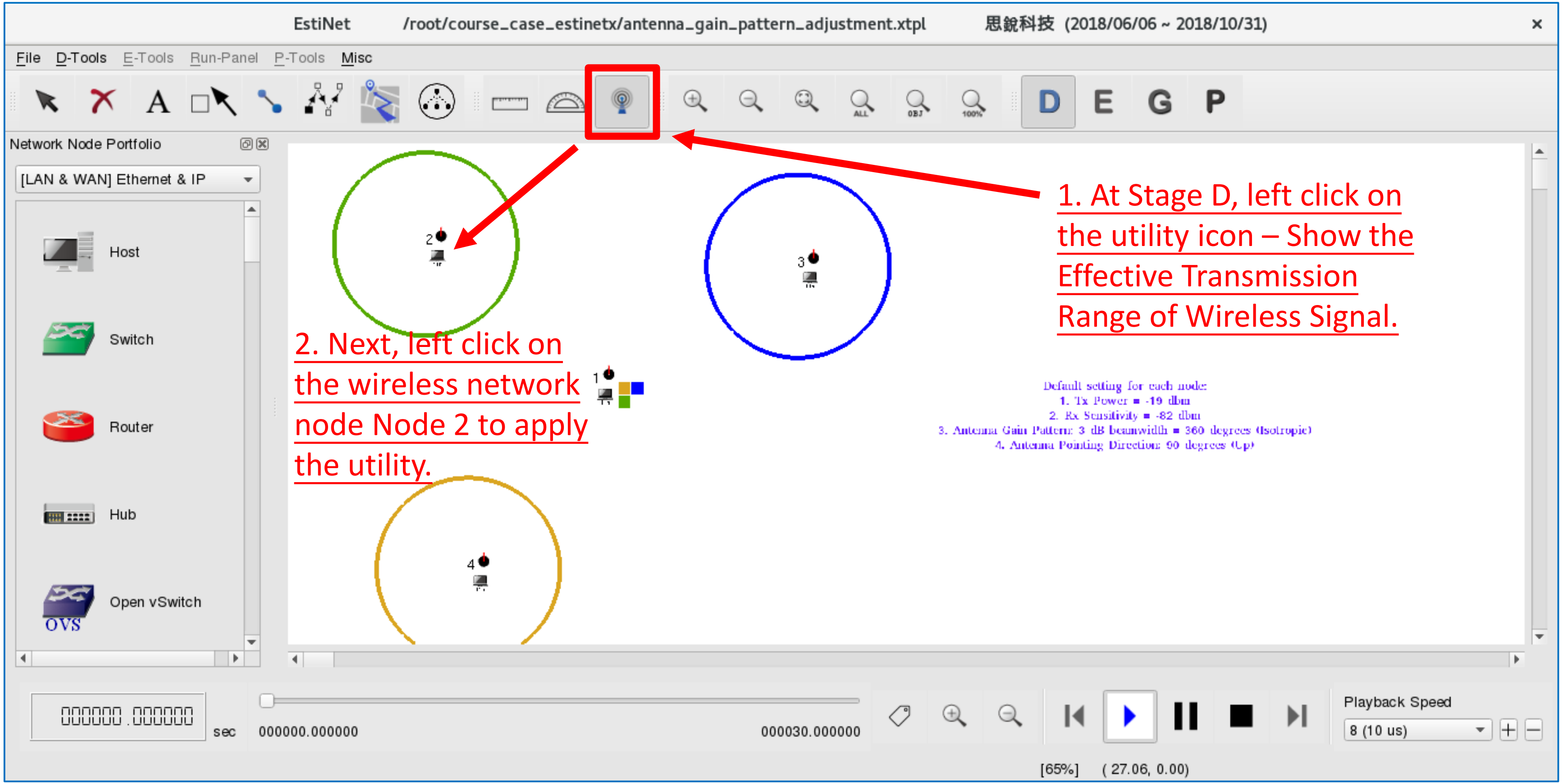


[Step 3] Measure the relative angles between Node 2/3/4 and Node 1

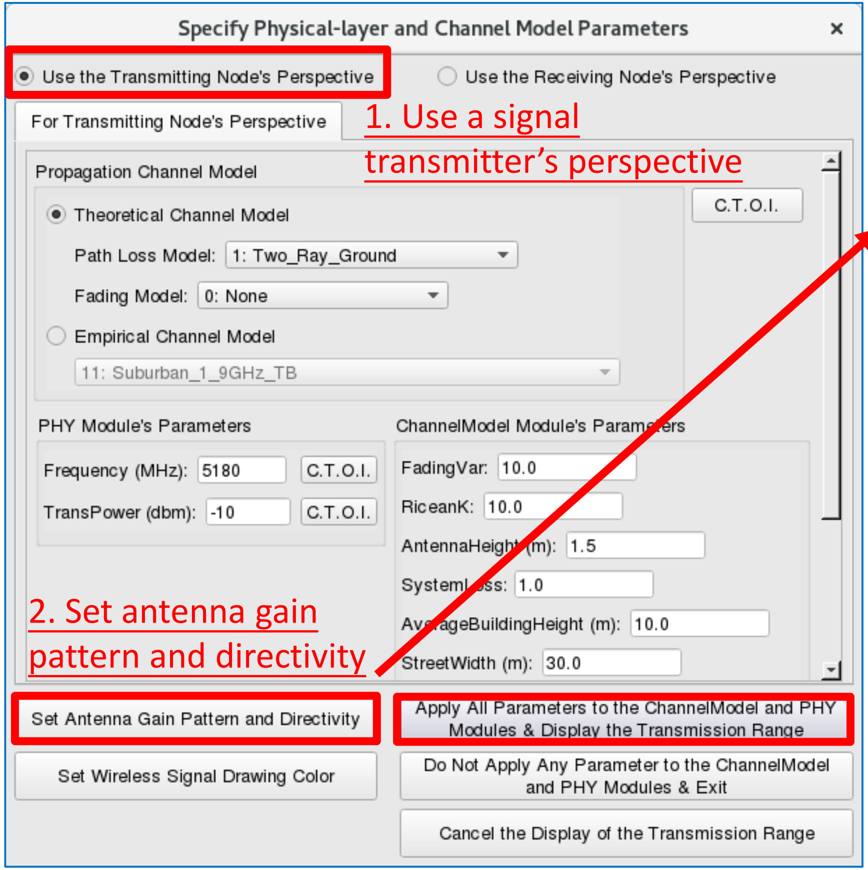
- Use the protractor utility to measure the relative angles between Node 2/3/4 and Node 1.
  - Node 2 to Node 1 → 320°
  - Node 3 to Node 1 → 209 °
  - Node 4 to Node 1 → 56 °

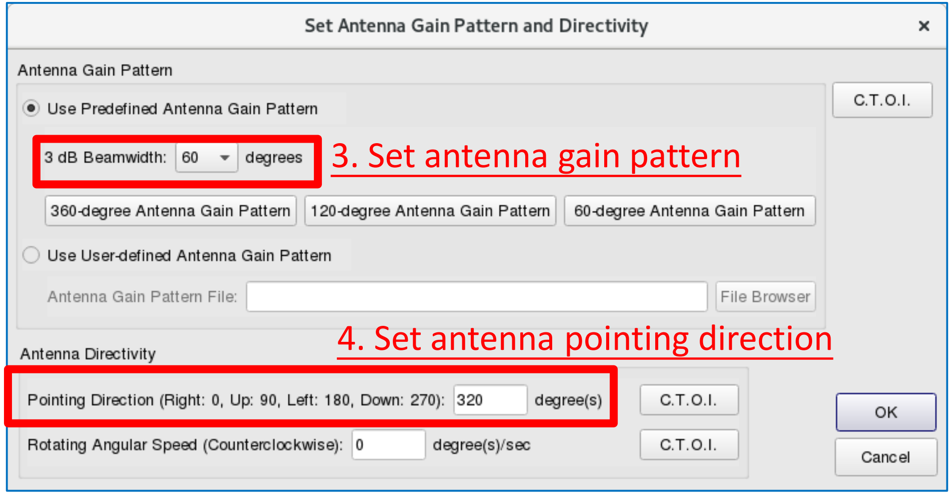


[Step 4] Activate the utility – Show the Effective Transmission Range of Wireless Signal.

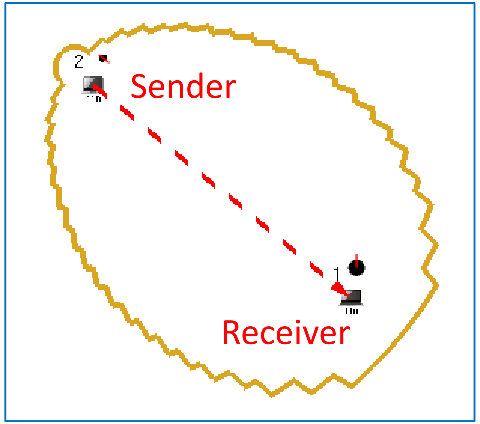


[Step 5] Adjust Node 2's antenna gain pattern and antenna's pointing direction

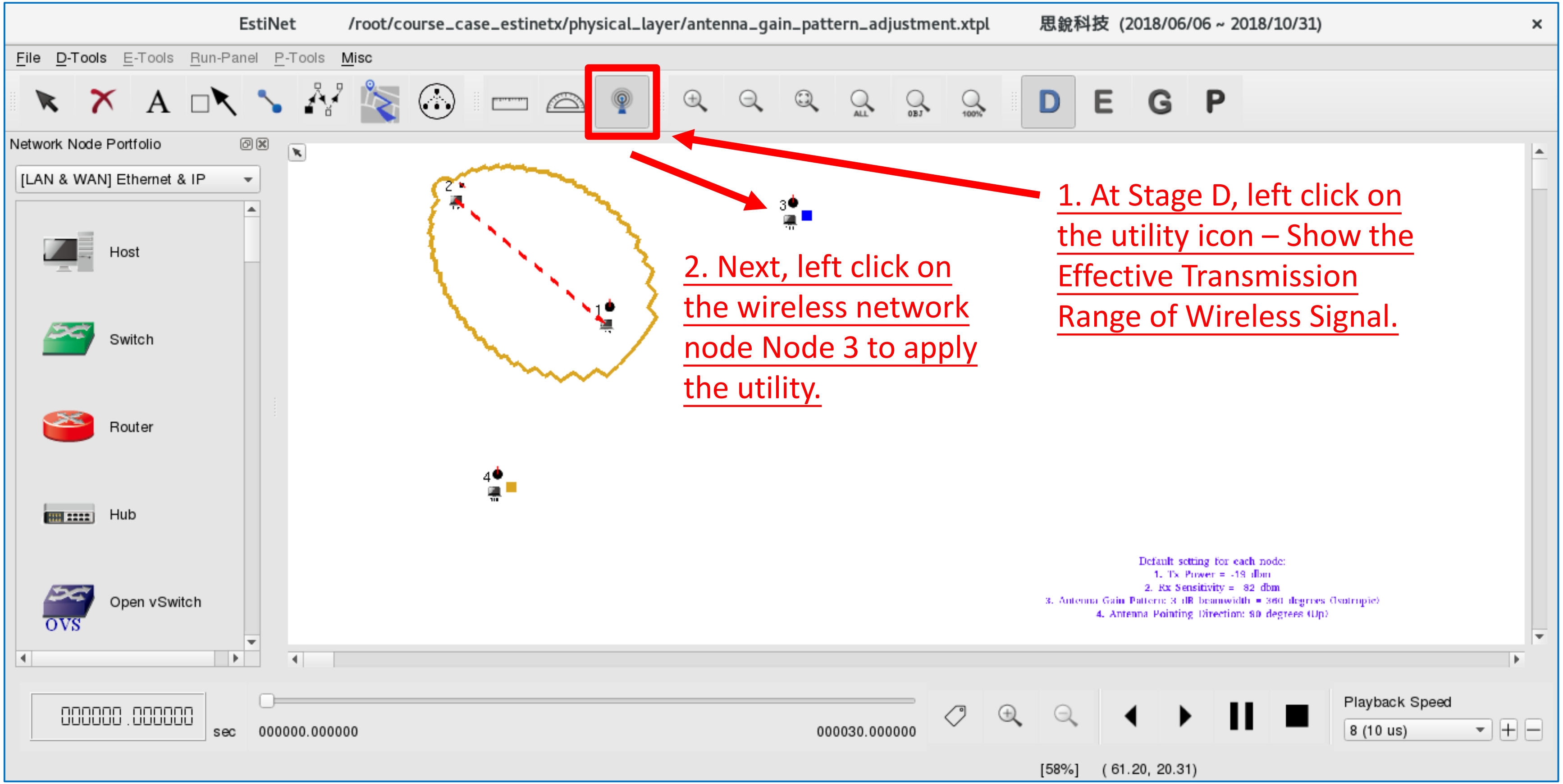




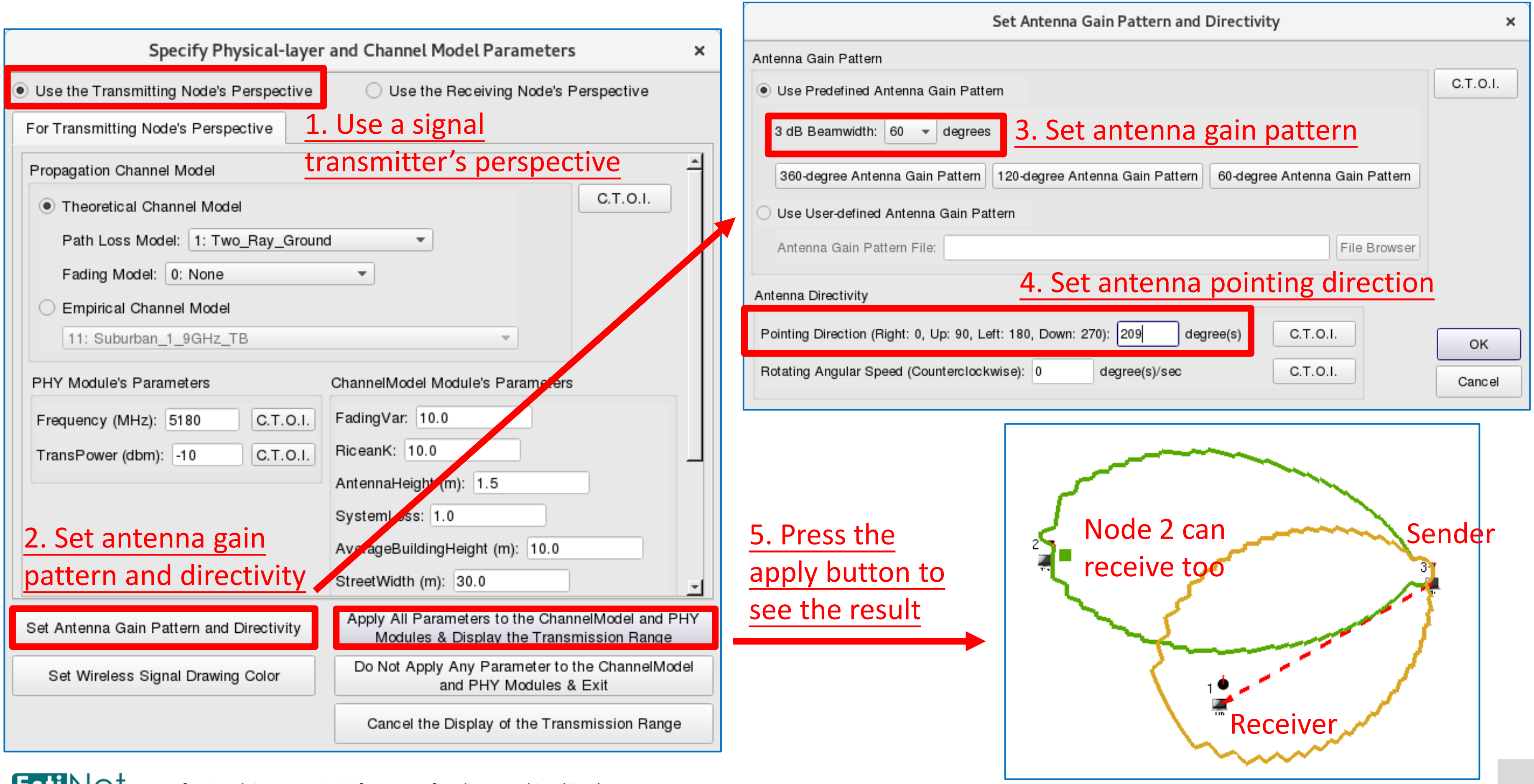
5. Press the apply button to see the result



[Step 6] Activate the utility – Show the Effective Transmission Range of Wireless Signal.



[Step 7] Adjust Node 3's antenna gain pattern and antenna's pointing direction



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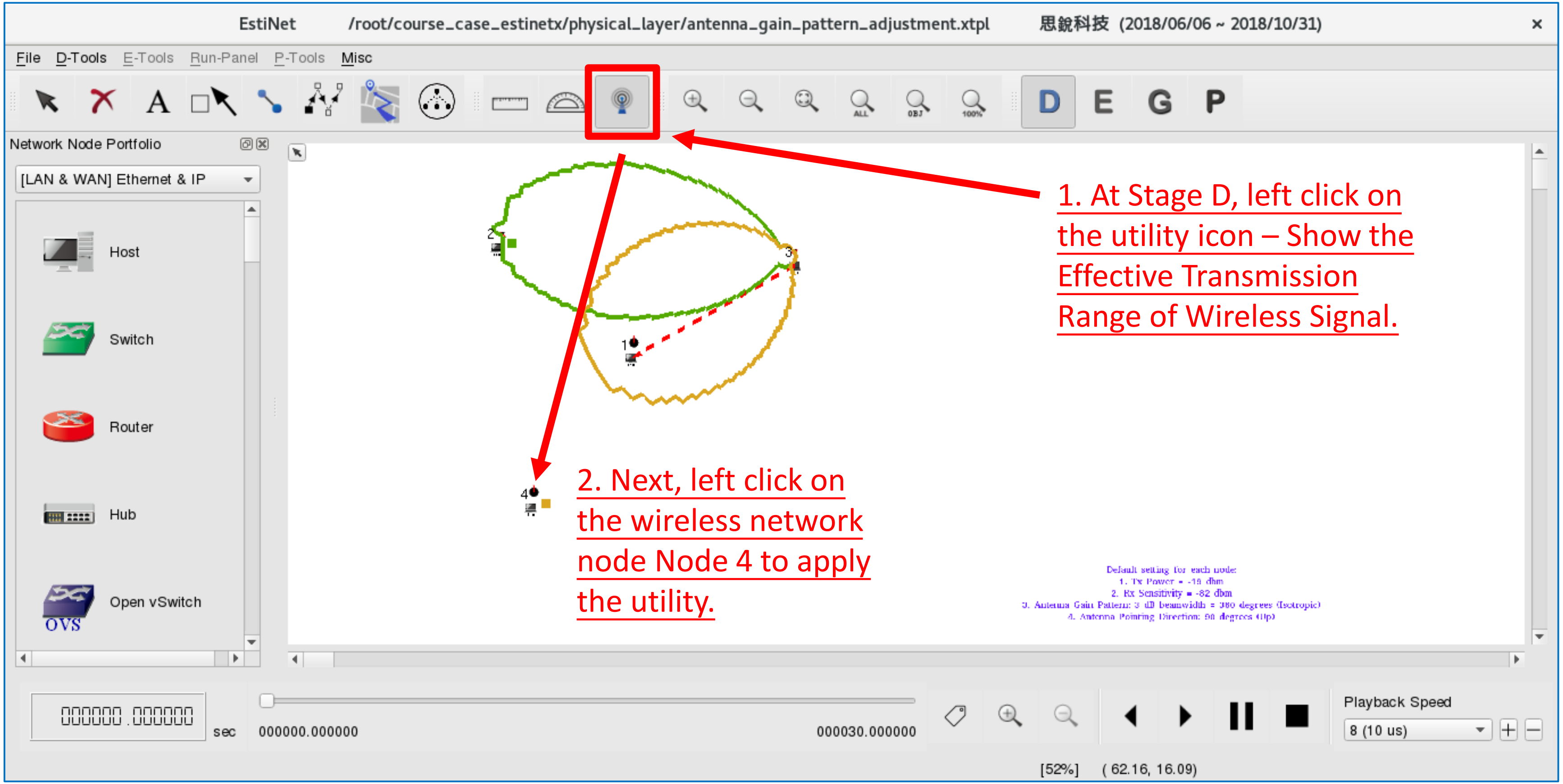
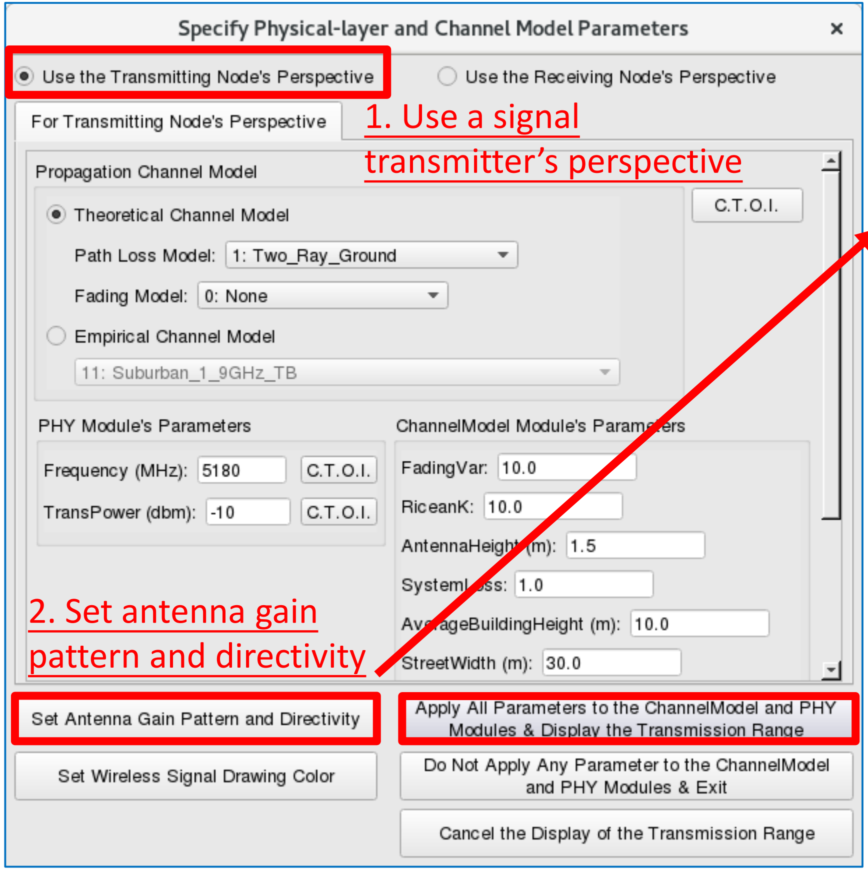
[Step 8] Activate the utility – Show the Effective Transmission Range of Wireless Signal.

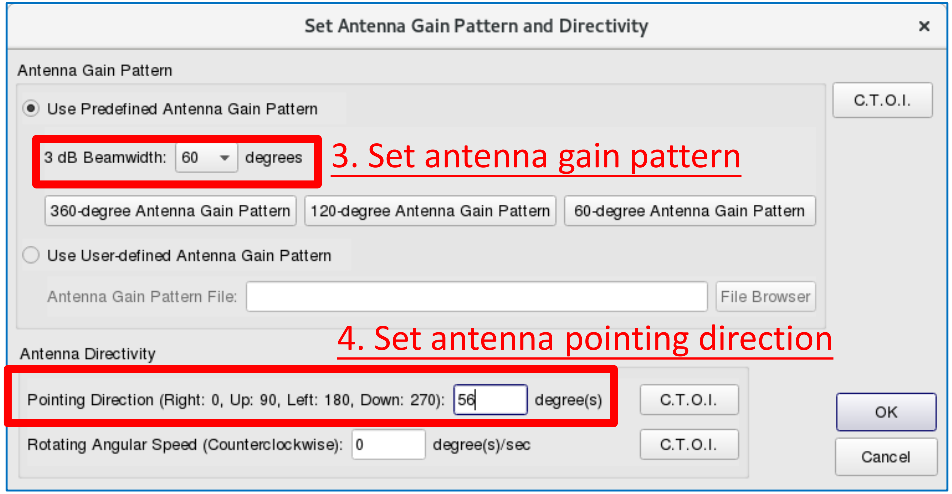


[Step 9] Adjust Node 4's antenna gain pattern and antenna's pointing direction



1. Use a signal transmitter's perspective

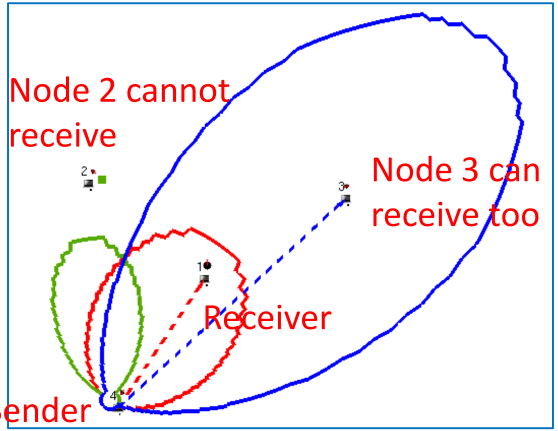
2. Set antenna gain pattern and directivity



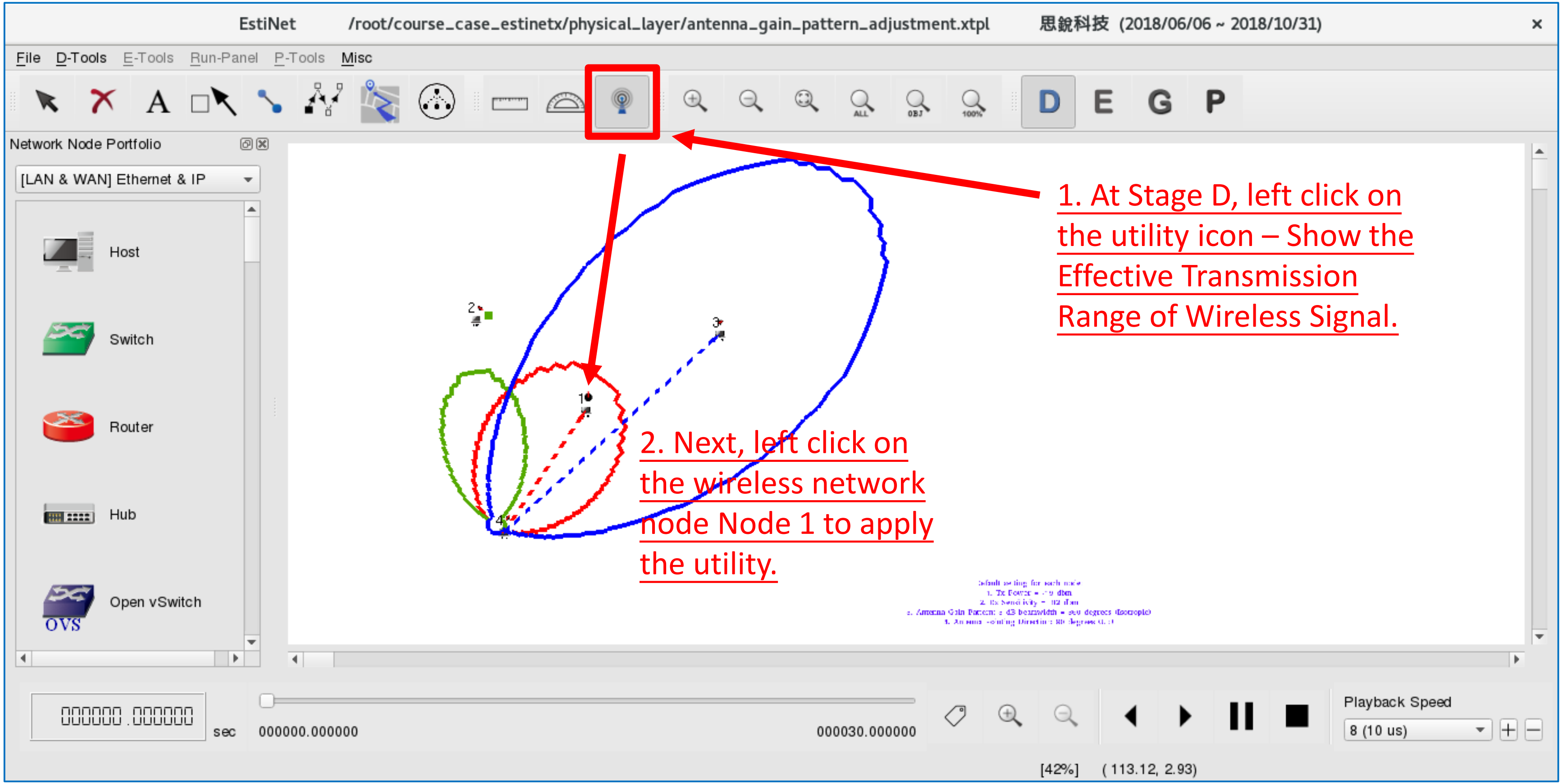
3. Set antenna gain pattern

4. Set antenna pointing direction

5. Press the apply button to see the result



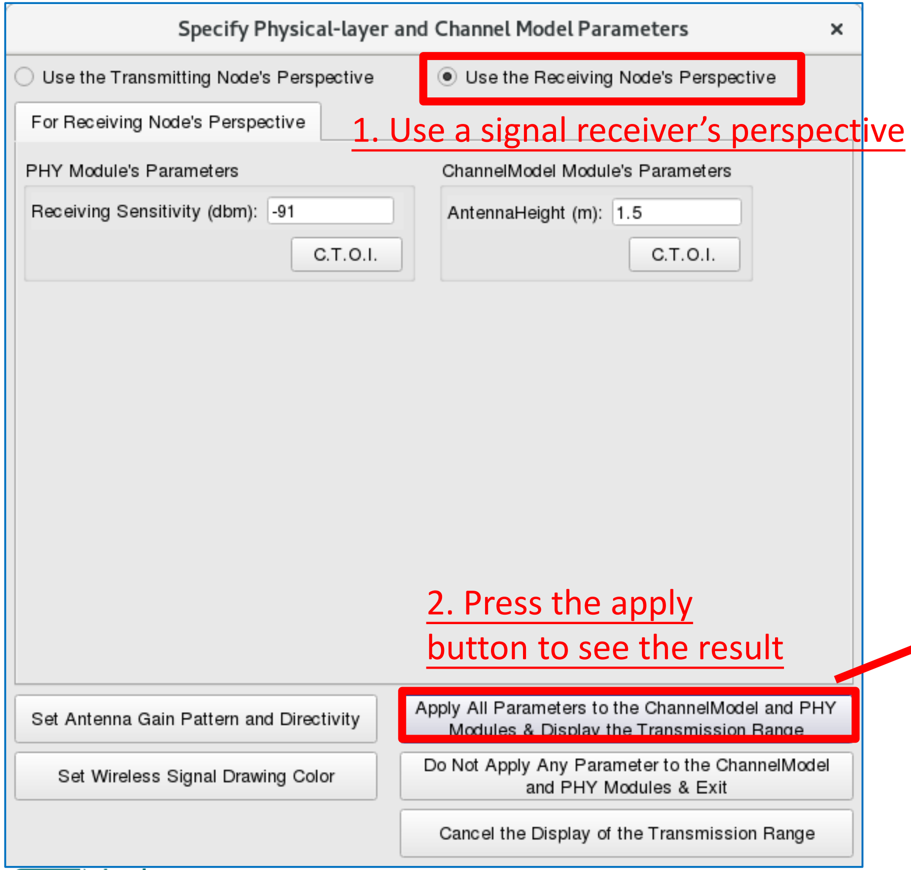
[Step 10] Activate the utility – Show the Effective Transmission Range of Wireless Signal.

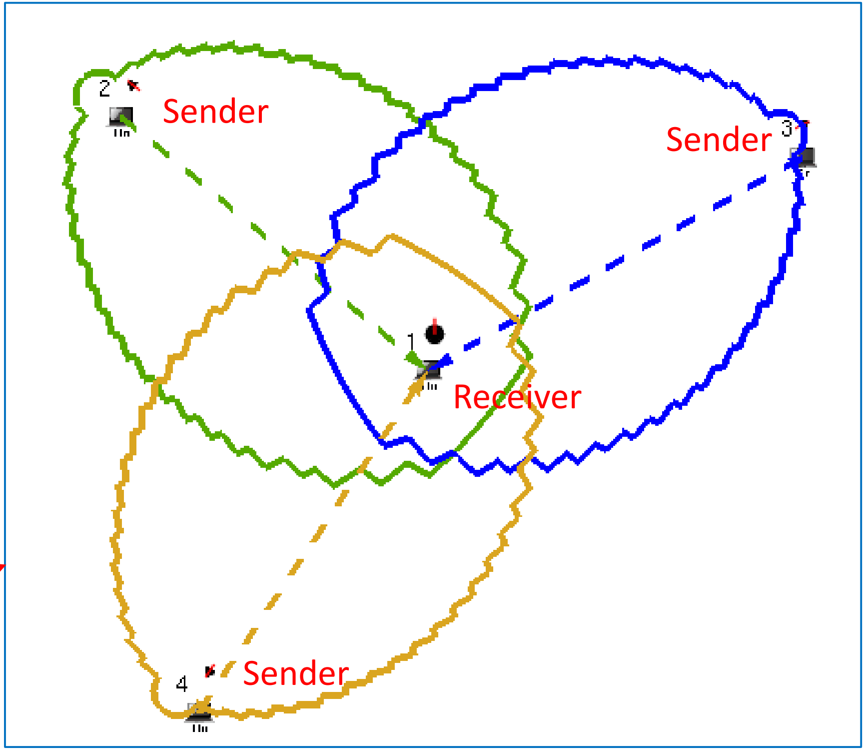


1. At Stage D, left click on the utility icon – Show the Effective Transmission Range of Wireless Signal.

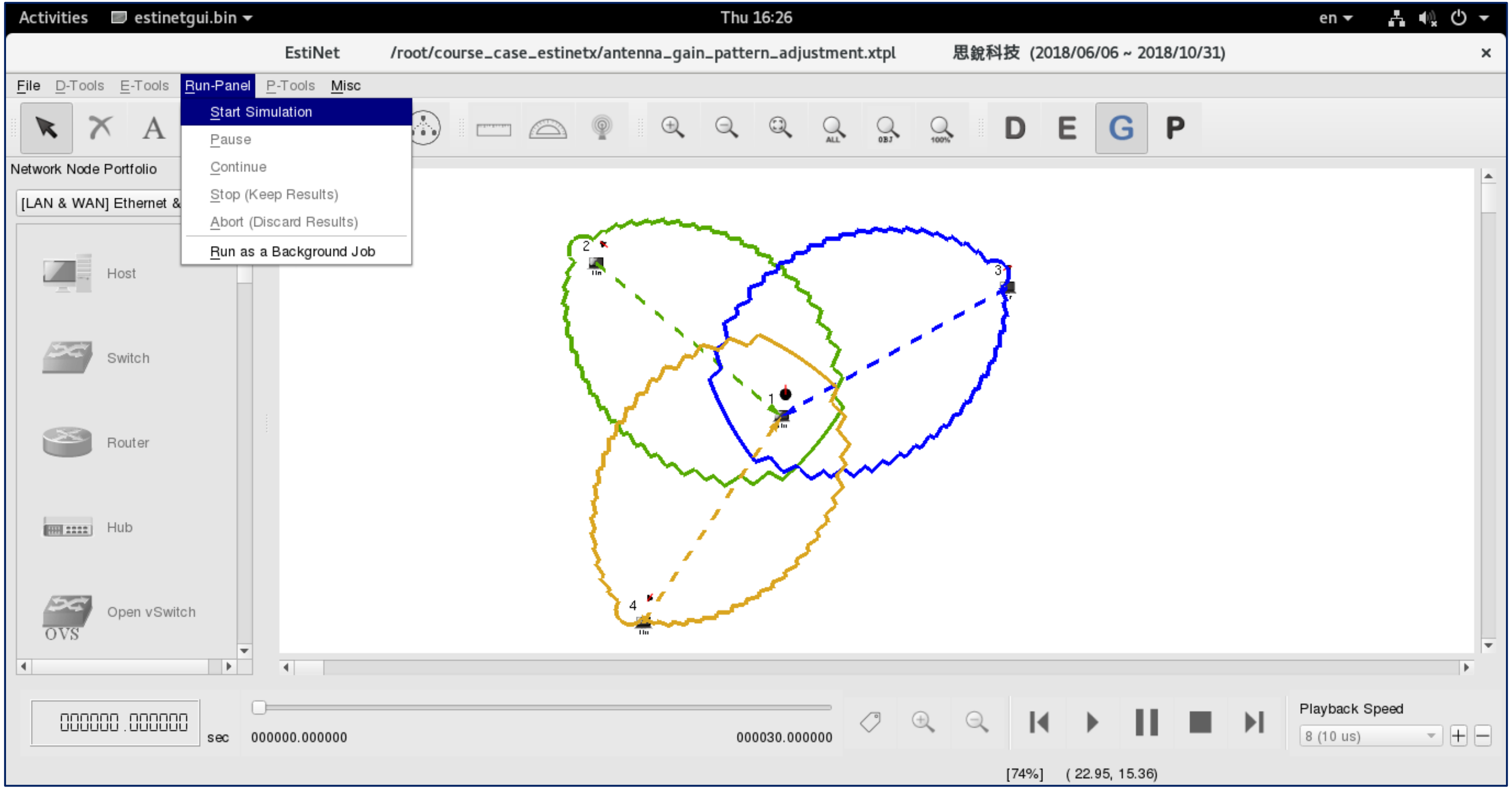
2. Next, left click on the wireless network node Node 1 to apply the utility.

[Step 11] On Node 1, as a signal receiver, observe the signal transmission ranges of other three nodes after the adjustment



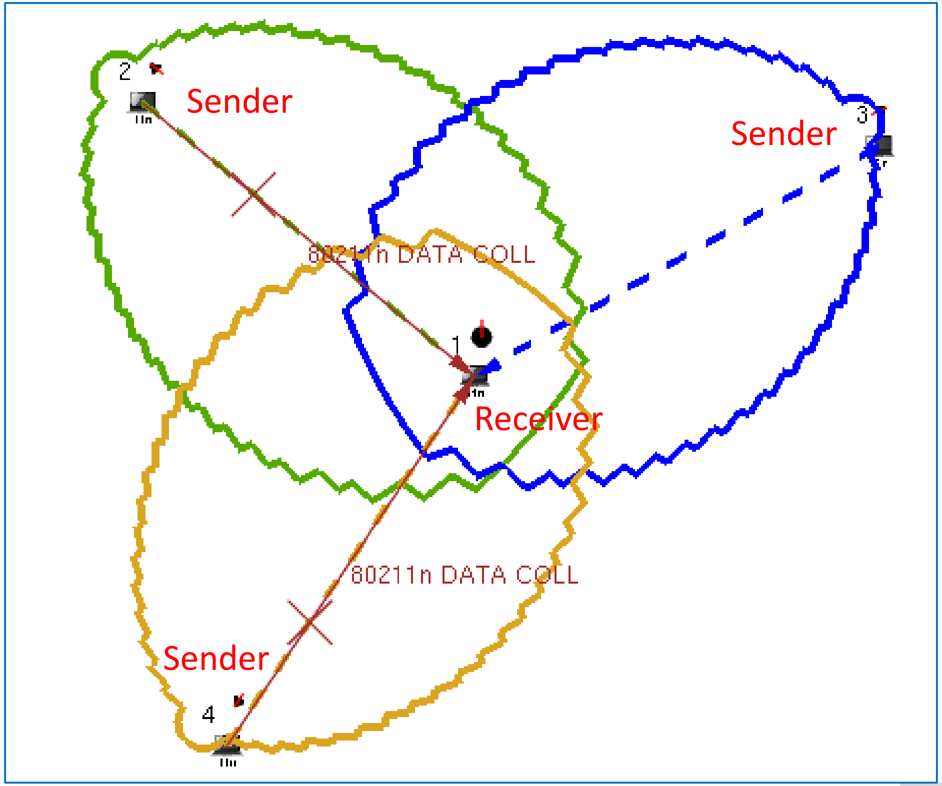


[Step 12] Change the operating stage to Stage G to generate all simulation configuration files. Then start simulation.



[Step 13] After simulation, at Stage P, observe the simulation results.

- At Stage P, the frame animation is displayed according to the simulation results. Check the graph on the right-hand side. The signals sent from Node 2, 3, and 4 are able to reach Node 1. If more than one signal reach Node 1 nearly simultaneously, these signals collide with each other.
- The problems of signal collision are tackled by data link layer (layer 2). Thus, when watching the frame animation, sometimes a successful frame reception can be seen in both directions.



ADJUST SIGNAL FREQUENCY AND ENVIRONMENTAL PARAMETERS TO OBSERVE SIGNAL TRANSMISSION RANGE

Configure signal frequency and environmental parameters (e.g., terrain, surface object, weather, interference, etc.)

- While developing a communication standard (including physical layer and data link layer), experts determine the used signal frequency and required bandwidth according to the target data rates and environmental parameters where a communication channel is applied to.
- On EstiNet X simulator, the used signal frequencies are based on the IEEE 802.11a/g/p/n standards. If the frequency is changed arbitrarily to one that does not conform the standard, the simulation results could become inaccurate. Thus, no experiment for arbitrarily changing the signal frequency now.
- EstiNet X supports the configuration of several environmental parameters. Different part of these parameters are used by different channel models. Operating on channel models requires advanced professional knowledge. Now we do not step into such advanced field. The default channel model used on EstiNet X is a theoretical model, called two ray ground. There are two other theoretical models for choice - free space and free space shadowing. Now no experiment is designed for channel models.