

Ethernet

A Direct Link Network with Media Access Control

Objective

This lab is designed to demonstrate the operation of the Ethernet network. The simulation in this lab will help you examine the performance of the Ethernet network under different scenarios.

Overview

The Ethernet is a working example of the more general Carrier Sense, Multiple Access with Collision Detect (CSMA/CD) local area network technology. The Ethernet is a multiple-access network, meaning that a set of nodes sends and receives frames over a shared link. The "carrier sense" in CSMA/CD means that all the nodes can distinguish between an idle and a busy link. The "collision detect" means that a node listens as it transmits and can therefore detect when a frame it is transmitting has interfered (collided) with a frame transmitted by another node. The Ethernet is said to be a 1-persistent protocol because an adaptor with a frame to send transmits with probability 1 whenever a busy line goes idle.

In this lab you will set up an Ethernet with 14 nodes connected via a coaxial link in a bus topology. The coaxial link is operating at a data rate of 10 Mbps. You will study how the throughput of the network is affected by the network load as well as the size of the packets.

Create a New Project

To create a new project for the Ethernet network:

- 1. Start **OPNET IT Guru Academic Edition** \Rightarrow Choose **New** from the **File** menu.
- 2. Select **Project** ⇒ Click **OK** ⇒ Name the project <**your initials>_Ethernet**, and the scenario **Coax** ⇒ Click **OK**.
- In the Startup Wizard: Initial Topology dialog box, make sure that Create Empty Scenario is selected ⇒ Click Next ⇒ Choose Office from the Network Scale list ⇒ Click Next ⇒ Assign 200 to X Span and keep Y Span as 100 ⇒ Click Next twice ⇒ Click OK.
- 4. Close the Object Palette dialog box.

Create the Network

To create our coaxial Ethernet network:

- 1. To create the network configuration, select **Topology** \Rightarrow **Rapid Configuration**. From the drop-down menu choose **Bus** and click **OK**.
- 2. Click the **Select Models** button in the *Rapid Configuration* dialog box. From the *Model List* drop-down menu choose **ethcoax** and click **OK**.
- 3. In the Rapid Configuration dialog box, set the following eight values and click OK.

Rapid Configuration: Bus	
MODELS Node Model ethcoax_station	Number 30
PLACEMENT	
● <u>H</u> orizontal	C <u>V</u> ertical
✓ Top of bus	Left of bus
Bottom of bus	Right of bus
Head of bus	Size
X 20 Y 50	Bus 170 Tap 20
Select Models.	<u>C</u> ancel <u>O</u> K

The **eth_tap** is an Ethernet bus tap that connects a node with the bus.

The eth_coax is an Ethernet bus that can connect nodes with bus receivers and transmitters via taps.

Local area networks (LANs) are designed to span distances of up to a few thousand meters.

- 4. To configure the coaxial bus, right-click on the horizontal link ⇒ Select Advanced Edit Attributes from the menu:
 - a. Click on the value of the **model** attribute \Rightarrow Select **Edit** from the dropdown menu \Rightarrow Choose the **eth_coax_adv** model.
 - b. Assign the value 0.05 to the delay attribute (propagation delay in sec/m).
 - c. Assign 5 to the thickness attribute.
 - d. Click OK.



- 5. Now you have created the network. It should look like the illustration below.
- 6. Make sure to save your project.



A higher delay is used here as an alternative to generating higher traffic which would require much longer simulation time.

Thickness specifies the thickness of the line used to "draw" the bus link.

Configure the Network Nodes

To configure the traffic generated by the nodes:

- 1. Right-click on any of the 30 nodes ⇒ **Select Similar Nodes**. Now all nodes in the network are selected.
- 2. Right-click on any of the 30 nodes \Rightarrow Edit Attributes.
- Check the Apply Changes to Selected Objects check box. This is important to avoid reconfiguring each node individually.
- 4. Expand the Traffic Generation Parameters hierarchy:
 - a. Change the value of the **ON State Time** to **exponential(100)** ⇒ Change the value of the **OFF State Time** to **exponential(0)**. (*Note:* Packets are generated only in the "ON" state.)
- 5. Expand the Packet Generation Arguments hierarchy:
 - a. Change the value of the Packet Size attribute to constant(1024).
 - b. Right-click on the Interarrival Time attribute and choose Promote Attribute to Higher Level. This allows us to assign multiple values to the Interarrival Time attribute and hence to test the network performance under different loads.

₭ (node_0) Attributes			
Type: station			
Attribute	Value		
⑦ ⊢ name	node_0		
⑦ ⊢model	ethcoax_station		
⑦ ⊡ Traffic Generation Parameters	()		
⑦ ⊢Start Time (seconds)	constant (5.0)		
⑦ ⊢ON State Time (seconds)	exponential (100.0)		
⑦ ⊢OFF State Time (seconds)	exponential (0.0)		
Packet Generation Argume ()			
Interarrival Time (seconds)	promoted		
⑦ ⊢Packet Size (bytes)	constant (1024)		
③ LSegmentation Size (bytes)	No Segmentation		
⑦ └Stop Time (seconds)	Never		
⑦ └Traffic Generation Parameter	promoted		
•			
Apply Changes to Selected Object	ts		
<u><u> </u></u>	<u>Cancel</u> <u>O</u> K		

- 6. Click OK to return back to the Project Editor.
- 7. Make sure to save your project.

The argument of the exponential distribution is the mean of the interval between successive events. In the exponential distribution the probability of occurrence of the next event by a given time is not at all dependent upon the time of occurrence of the last event or the elapsed time since that event.

The **interarrival time** is the time between successive packet generations in the "ON" state.

Configure the Simulation

To examine the network performance under different loads, you need to run the simulation several times by changing the load into the network. There is an easy way to do that. Recall that we promoted the **Interarrival Time** attribute for package generation. Here we will assign different values to that attribute:

- 1. Click on the **Configure/Run Simulation** button:
- 2. Make sure that the Common tab is chosen \Rightarrow Assign 15 seconds to the Duration.

🗄 Configure Simulation: eha_Ethernet-Coax					
Common Global A	Attributes Object	Attributes Repo	rts SLAs Animation	Profiling Advan	
Durati	on: 15	second(s)	_		
Se	ed: 128	\searrow			
Values per statis	tic: 100				
Update inter	val: 100000	Events			
✓Enable simulation	on log				
Run		<u>H</u> elp		<u>C</u> ancel	<u>о</u> к

- 3. Click on the **Object Attributes** tab.
- 4. Click on the Add button. The Add Attribute dialog box should appear filled with the promoted attributes of all nodes in the network (if you do not see the attributes in the list, close the whole project and reopen it). You need to add the Interarrival Time attribute for all nodes. To do that:
 - a. Click on the first attribute in the list (Office Network.node_0.Traffic Generation) ⇒ Click the Wildcard button ⇒ Click on node_0 and choose the asterisk (*) from the drop-down menu ⇒ Click OK.
 - b. A new attribute is now generated containing the asterisk (the second one in the list), and you need to add it by clicking on the corresponding cell under the **Add?** column.
 - c. The Add Attribute dialog box should look like the following. Click OK.

🟽 Add Attribute: scenario			X
Add	? Unresolved	d Attributes	<u> </u>
	Office Netv	work.node_0.Traffi	c Generatio
add	Office Netv	work.*.Traffic Gen	eration Para
	Office Netv	work.node_1.Traffi	c Generatio
Office Network.node_10.Traffic Generati			
Office Network.node_11.Traffic Generati			
Office Network.node_12.Traffic Generati			
Office Network.node_13.Traffic Generati			
Office Network.node_14.Traffic Generati			
Office Notwork pade 15 Traffic Concreti			
E	xpand	<u>C</u> ancel	<u>0</u> K

- Now you should see the Office Network.*.Traffic Generation Parameter ... in the list of simulation object attributes. Click on that attribute to select it ⇒ Click the Values button of the dialog box.
- 6. Add the following nine values. (*Note:* To add the first value, double-click on the first cell in the **Value** column ⇒ Type "exponential (2)" into the textbox and hit enter. Repeat this for all nine values.)

Attribute: Office	Net	work.*.Traffic Generation Paramete	K
	Ente	er one or more values:	
Value	Limit	Step	
exponential (2) exponential (1) exponential (0.5) exponential (0.25) exponential (0.1) exponential (0.05) exponential (0.03) exponential (0.02)			
<u>V</u> iew Props	De	elete <u>C</u> ancel <u>O</u> K	

7. Click **OK**. Now look at the upper-right corner of the *Simulation Configuration* dialog box and make sure that the *Number of runs in set* is **9**.

Configure Simulation: eha_Ethernet-Coax					
Common Global Attributes Object Attributes Reports SLAs Animation Profiling Advanced Envirc Image: Start			nced Envirc		
Attribute	Value				<u> </u>
Office Network.*.Tr exponential (2), exponential (1), exponential (0.5), exponential (0.25), exponen					
Add	E <u>x</u> pand	De <u>l</u> ete	<u>U</u> pdate	<u>V</u> iew Props	Values
Run		<u>H</u> elp		Cancel	<u></u> K

- 8. For each simulation of the nine runs, we need the simulator to save a "scalar" value that represents the "average" load in the network and to save another scalar value that represents the average throughput of the network. To save these scalars we need to configure the simulator to save them in a file. Click on the **Advanced** tab in the *Configure Simulation* dialog box.
- 9. Assign <your initials>_Ethernet_Coax to the Scalar file text field.

🛣 Configure	e Simulation: eha_Ethernet-Coax	
Common	Global Attributes Object Attributes Reports SLAs Animation Profilin Advanced Enviro	
Network:	eha_Ethernet-Coax	~
Probe file:	eha_Ethernet-Coax	~
Vector file:	eha_Ethernet-Coax	
Scalar file:	eha_Ethernet_Coax <	
Simulation	program: op_runsim 🗾	
Command-I	line options	
Record a da	ate/time in results: none 🔽 Date: Time:	
<u>R</u> un	<u>H</u> elp <u>Cancel</u> <u>Q</u> K	

10. Click **OK** and then save your project.

Choose the Statistics

To choose the statistics to be collected during the simulation:

- 1. Right-click anywhere in the project workspace (but not on one of the nodes or links) and select **Choose Individual Statistics** from the pop-up menu ⇒ Expand the **Global Statistics** hierarchy.
 - Expand the Traffic Sink hierarchy ⇒ Click the check box next to Traffic Received (packets/sec) (make sure you select the statistic with units of packets/sec),
 - b. Expand the Traffic Source hierarchy \Rightarrow Click the check box next to Traffic Sent (packets/sec).
 - c. Click OK.
- 2. Now to collect the average of the above statistics as a scalar value by the end of each simulation run:
 - a. Select Choose Statistics (Advanced) from the Simulation menu.
 - b. The **Traffic Sent** and **Traffic Received** probes should appear under the **Global Statistic Probes**.
 - c. Right-click on Traffic Received probe \Rightarrow Edit Attributes. Set the scalar data attribute to enabled \Rightarrow Set the scalar type attribute to time average \Rightarrow Compare to the following figure and click OK.
 - d. Repeat the previous step with the Traffic Sent probe.
 - e. Select save from the **File** menu in the *Probe Model* window and then close that window.
 - f. Now you are back to the *Project Editor*. Make sure to save your project.

🔣 (pb0) Attributes	
Attribute	Value
⑦ ⊢name	pb0
⑦ ⊢draw style	linear
⑦ ⊢group	Traffic Sink
⑦ ⊢statistic	Traffic Received (packets/sec)
⑦ ⊢ordinate label	
⑦ ⊢vector data	enabled
⑦ ⊢vector start	0.0
⑦ ⊢vector stop	infinity
⑦ ⊢scalar data	enabled 🔶
⑦ ⊢scalar type	time average 🛛 🗲 🗕
⑦ ⊢scalar start	0.0
Apply Changes to Selected O	bjects
Eind Next	<u>C</u> ancel <u>O</u> K

A **probe** represents a request by the user to collect a particular piece of data about a simulation.

Run the Simulation

To run the simulation:

- 1. Click on the **Configure/Run Simulation** button: **Second(s)** (not hours) is assigned to the **Duration** ⇒ Click **Run**. Depending on the speed of your processor, this may take several minutes to complete.
- 2. Now the simulator is completing nine runs, one for each traffic generation interarrival time (representing the load into the network). Notice that each successive run takes longer to complete because the traffic intensity is increasing.
- 3. After the nine simulation runs complete, click **Close**.
- 4. Save your project.

When you rerun the simulation, OPNET IT Guru will "append" the new results to the results already in the scalar file. To avoid that, delete the scalar file *before* you start a new run. (*Note:* Deleting the scalar file *after* a run will result in losing the collected results from that run.)

Go to the File menu ⇒ Select Model Files ⇒ Delete Model Files ⇒ Select (.os): Output Scalars ⇒ Select the scalar file to be deleted; in this lab it is <your initials>_Ethernet_Coax_Scalar ⇒ Confirm the deletion by clicking OK ⇒ Click Close.

View the Results

To view and analyze the results:

- 1. Select **View Results (Advanced)** from the **Results** menu. Now the **Analysis Configuration** tool is open.
- 2. Recall that we saved the average results in a scalar file. To load this file, select Load Output Scalar File from the File menu ⇒ Select <your initials>_Ethernet-Coax from the pop-up menu.
- 3. Select Create Scalar Panel from the Panels menu ⇒ Assign Traffic Source.Traffic Sent (packets/sec).average to Horizontal ⇒ Assign Traffic Sink.Traffic Received (packets/sec).average to Vertical ⇒ Click OK.

🐨 Select Scalar Panel Data 🛛 🔀		
Horizontal:	Traffic Source. Traffic Se	
Vertical:	Traffic Sink. Traffic Rece 💌	
	<u>Cancel</u>	

4. The resulting graph should resemble the one below:



Further Reading

To familiarize yourself with the significance, physical interpretation and the actual use of various parameters mentioned in this laboratory, use the built-in ITGuru help feature. For example, to learn more about (node) **Attributes** \rightarrow **Traffic Generation Parameters** \rightarrow **Start Time** parameter, click on the respective question mark icon, as shown in the figure below:

Project: Simica_Ethernet-Coax Scenario: Coax [Subnet: top.Office Network]	_ 🗆 🗙	
File Edit. View Scenarios Topology Traffic Protocols Simulation Results Windows Help		
0 25 Leo 172 1700 172 1700 175 (node_7) Attributes		
Attribute Value		
Orde_0 m		
50 OR State Time (seconds) constant (0.0) @ - OF State Time (seconds) exponential (100) @ - OFF State Time (seconds) exponential (0)	•	
Concentration Arguments Concentration Concentration Concentration Concentration		
75 File Edit Options node_ Image: Second se	 29	
Specifies the distribution name and arguments to be used for set to "Never", the surrounding node does not generate any traffic.		
parenthesis (e.g., mean, variance, location, etc.) with the desired numerical values.		
Line: 1	-	
Eind Next		

After you have successfully executed the steps outlined on pages 1 to 10, you are expected to do the following three exercises: E.1 to E.3. Your deliverable for this laboratory should be a 4-5 page typed report in which you will provide concise answers to all questions from E.1 to E.3 and include all required screenshots of obtained simulation results/graphs.

Exercise E.1 Load-Throughput Graph

Explain the graph shown in page 10, which shows the relationship between the sent packets (load) and received packets (throughput). Why does the throughput drop when the load is either very low or very high?

Exercise E.2 Performance (Collision Count and Throughput) Under Different Loads

Exercise E.2.a)

Modify the profile of your project <your initials>_Ethernet, by performing the following steps:

1. Click on the **Configure/Run Simulation** button *K*. From the *Object Attribute* menu/tab delete the multiple value attribute (the only shown in the list).

2. Right-click on any of the 30 nodes. Choose **Select Similar Nodes**. Now all nodes in the network are selected.

- 3. Right-click on any of the 30 nodes. Choose Edit Attributes.
 - Check the Apply Changes to Selected Objects check box. This is important to avoid reconfiguring each node individually.
 - > Expand the **Traffic Generation Parameters** hierarchy.
 - > Expand the **Packet Generation Arguments** hierarchy.
 - a. Set the Interarrival Time attribute to exponential(0.1).
 - b. Click OK twice.
- 4. Right-click on node_0. Choose Choose Individual Statistics.
 - > Expand the **Ethcoax** hierarchy.
 - a. Click the check box next to Collision Count.
 - > Expand the **Traffic Source** hierarchy.
 - a. Click the check box next to Traffic Sent (packets/sec).
 - b. Click OK.

5. Right-click anywhere in the project workspace, but not on one of the nodes or links. Choose **Choose Individual Statistics**.

- > Expand the **Global Statistics** / **Traffic Sink** hierarchy.
 - a. Click the check box next to *Traffic Received (packets/sec)*.
- > Expand the Global Statistics / Traffic Source hierarchy.
 - a. Click the check box next to Traffic Sent (packets/sec).
 - b. Click OK.

6. Save your project!

Run the simulation by clicking on **Configure/Run Simulation** button 💐, and then clicking **Run**.

View the collected results by doing the following:

1. Select View Results from Results Menu.

- > Expand the **Global Statistics / Traffic Source** hierarchy.
 - a. Click the check box next to Traffic Sent (packets/sec).
- > Expand the **Global Statistics / Traffic Sink** hierarchy.
- a. Click the check box next to Traffic Received (packets/sec).
- Expand the Object Statistics / Office Network / node_0 / Traffic Source hierarchy.
 a. Click the check box next to *Traffic Sent (packets/sec)*.
- Expand the Object Statistics / Office Network / node_0 / Ethcoax hierarchy.
 a. Click the check box next to Collision Count.

The resultant window and graphs should resemble the one(s) below.

K View Results	
Discrete Event Graphs Displayed Panel Graphs	
Global Statistics Traffic Sink Traffic Seceved (packets/sec) Traffic Sect (packets/sec) Office Network Inde_0 Ethooax Traffic Source Traffic Source Traffic Sect (packets/sec)	Show Preview
Results Generated: 20:51:10 Nov 04 2009	Unselect Add Show
	Close

Make a screenshot of your own respective)results, and include them in the final report!

Exercise E.2.b)

Repeat the steps from Exercise E.2.a), but in Step 3 set the *Interarrival Time* attribute to **exponential(0.05)**. **Make a screenshot of obtained results, and include them in the final report!**

Exercise E.2.c)

Repeat the steps from Exercise E.2.a), but in Step 3 set the *Interarrival Time* attribute to **exponential(0.025)**. **Make a screenshot of obtained results, and include them in the final report!**

Exercise E.2.d)

Compare **node_0**'s *Collision Counts* from the previous three exercises (E.2.a), E.2.b), E.2.c)). What do you observe, and how do you explain the difference in the obtained graphs?

Exercise E.3 Performance under Smaller Packet Size

Exercise E.3.a)

Modify the profile of your project **<your initials>_Ethernet**, by performing the following steps:

1. Right-click on any of the 30 nodes. Choose **Select Similar Nodes**. Now all nodes in the network are selected.

2. Right-click on any of the 30 nodes. Choose Edit Attributes.

- Check the Apply Changes to Selected Objects check box. <u>This is important to avoid reconfiguring</u> each node individually.
- > Expand the **Traffic Generation Parameters** hierarchy.
- > Expand the **Packet Generation Arguments** hierarchy.
 - a. Set the *Packet Size* attribute to constant(512).
 - b. Set the Interarrival Time attribute to exponential(0.05).
 - c. Click OK twice.

3. Right-click on node_0. Choose Choose Individual Statistics.

- > Expand the Ethcoax hierarchy.
 - a. Click the check box next to Collision Count.
- > Expand the **Traffic Source** hierarchy.
 - c. Click the check box next to Traffic Sent (packets/sec).
 - d. Click OK.

4. Right-click anywhere in the project workspace, but not on one of the nodes or links. Choose **Choose Individual Statistics**.

- > Expand the **Global Statistics / Traffic Sink** hierarchy.
 - a. Click the check box next to *Traffic Received (packets/sec)*.
- > Expand the Global Statistics / Traffic Source hierarchy.
 - c. Click the check box next to Traffic Sent (packets/sec).
 - d. Click OK.

5. Save your project!

Run the simulation by clicking on **Configure/Run Simulation** button *(intersection)*, and then clicking **Run**. Access the collected results by following the procedure from exercise E.2. **Make a screenshot of obtained results**, and include them in the final report!

Exercise E.3.b)

Compare the graphs obtained in exercise E.3.a) with those from exercise E.2.b). (In the two exercises, the packet interarrival times are the same, the packet sizes are different.) What do you observe, and how do you explain the difference in the obtained graphs?