

# **Token Ring**

A Shared-Media Network with Media Access Control

# Objective

This lab is designed to demonstrate the implementation of a token ring network. The simulation in this lab will help you examine the performance of the token ring network under different scenarios.

#### Overview

A token ring network consists of a set of nodes connected in a ring. The ring is a single shared medium. The token ring technology involves a distributed algorithm that controls when each node is allowed to transmit. All nodes see all frames, and the node identified as the destination in the frame header saves a copy of the frame as it flows past. With a ring topology, any link or node failure would render the whole network useless. This problem can be solved by using a star topology where nodes are connected to a token ring hub. The hub acts as a relay, known as a multistation access unit (MSAU). MSAUs are almost always used because of the need for robustness and ease of node addition and removal.

The "token," which is just a special sequence of bits, circulates around the ring; each node receives and then forwards the token. When a node that has a frame to transmit sees the token, it takes the token off the ring and instead inserts its frame into the ring. When the frame makes its way back around to the sender, this node strips its frame off the ring and reinserts the token. The *token holding time* (THT) is the time a given node is allowed to hold the token. From its definition, the THT has an effect on the utilization and fairness of the network, where utilization is the measure of the bandwidth used versus that available on the given ring.

In this lab, you will set up a token ring network with 14 nodes connected in a star topology. The links you will use operate at a data rate of 4 Mbps. You will study how the utilization and delay of the network are affected by the network load as well as the THT.

#### **Create a New Project**

To create a new project for the token ring network:

- 1. Start **OPNET IT Guru Academic Edition**  $\Rightarrow$  Choose **New** from the **File** menu.
- 2. Select **Project** and click **OK** ⇒ Name the project **<your initials>\_Token**, and the scenario **Balanced** ⇒ Click **OK**.
- 3. In the *Startup Wizard: Initial Topology* dialog box, make sure that **Create Empty Scenario** is selected ⇒ Click **Next** ⇒ Choose **Office** for the Network scale ⇒ Click **Next** three times ⇒ Click **OK**.
- 4. Close the Object Palette and then save your project.

#### **Create the Network**

To create our token ring network:

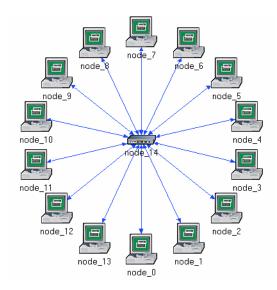
- 1. Select **Topology**  $\Rightarrow$  **Rapid Configuration**. From the drop-down menu choose **Star** and click **OK**.
- 2. Click the **Select Models** button in the *Rapid Configuration* dialog box. From the *Model List* drop-down menu choose **token\_ring** and click **OK**.
- 3. In the Rapid Configuration dialog box, set the following six values and click OK.

The **tr32\_hub** node model is a token ring hub supporting up to 32 connections at 4 or 16 Mbps. The hub forwards an arriving packet to the next output port. There is no queuing of packets in the hub itself as the processing time is considered to be zero.

The **TR4 link** connects two token ring devices to form a ring at 4 Mbps.

Rapid Configuration: Star	×
MODELS Center Node Model tr32_hub	Number 14
PLACEMENT Center X 50 Y 50	Radius 35
Select Models	<u>C</u> ancel <u>O</u> K

4. You have now created the network, and it should look like the following:



5. Make sure to save your project.

#### **Configure the Network Nodes**

Here you will configure the THT of the nodes as well as the traffic generated by them. To configure the THT of the nodes, you need to use the **tr\_station\_adv** model for the nodes instead of the current one, **tr\_station**.

- 1. Right-click on any of the 14 nodes ⇒ **Select Similar Nodes**. Now all nodes in the network are selected.
- 2. Right-click on any of the 14 nodes  $\Rightarrow$  **Edit Attributes.** 
  - a. Check the **Apply Changes to Selected Objects** check box. This is important to avoid reconfiguring each node individually.

The following figure shows the attributes we will change in steps 3 to 6:

Attribute	Value
rname	node_0
⊉ ⊢model	tr_station_adv 🛛 🔶
▶ ⊢Highest Destination Addr	e Maximum Dest Address
Lowest Destination Addr	ess Minimum Dest Address
Distance in the termination of terminatio o	()
Address	Auto Assigned
Hop Propagation Delay	/ ( 3.3E-006
Operational Mode	Switched
Promiscuous Mode	Disabled
D ⊢Ring ID	Auto Assigned
Spawn Station Offset	0
Stack Modification Tim	e 5E-006
Station Latency (bits)	4
LTHT Duration (seconds)	s) promoted 🖌 🗲
CTraffic Generation Param	ne ()
Start Time (seconds)	constant (5.0)
ON State Time (second)	ds) exponential (100.0) 🛛 🗲
OFF State Time (secord)	nd exponential (0.0) 🛛 🖌 🔶
Packet Generation Arg	u ()
Interarrival Time (sec	co exponential (0.025) 🛛 🔶
Packet Size (bytes)	exponential (1024)
(	<b>•</b>
Apply Changes to Selected	Objects 🔶 🛛 🗖 A <u>d</u> vanc

- 3. Click on the model value: **tr\_station** and select **Edit** from the drop-down menu. Now select **tr\_station\_adv** from the extended drop-down menu.
- 4. To test the network under different THT values, you need to "promote" the THT parameter. This allows us to assign multiple values to the THT attribute.
  - a. Expand the Token Ring Parameters hierarchy.
  - b. Right-click on the THT Duration attribute  $\Rightarrow$  Choose Promote Attribute to Higher Level.
- 5. Expand the **Traffic Generation Parameters** hierarchy ⇒ Assign **exponential(100)** to the **ON State Time** attribute ⇒ Assign **exponential(0)** to the **OFF State Time** attribute. (*Note:* Packets are generated only in the "ON" state.)
- 6. Expand the **Packet Generation Arguments** hierarchy  $\Rightarrow$  Assign **exponential(0.025)** to the **Interarrival Time** attribute.
- 7. Click **OK** to return back to the *Project Editor*.
- 8. Make sure to save your project.

The **THT** (token holding time) specifies the maximum amount of time a token ring MAC (media access control) may use the token before releasing it.

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

state.

#### **Configure the Simulation**

To examine the network performance under different THTs, you need to run the simulation several times by changing THT with every run of the simulation. There is an easy way to do that. Recall that we promoted the **THT Duration** attribute. 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 **5** minutes to the **Duration**.

🗄 Configure Simulation: eha_Token-Balanced				
Common Global Attrib	outes Object	Attributes Reports SLAs Animation Profiling Advanced Envi	irc 💶 🕨	
Duration:	5	minute(s)		
Seed:	128			
Values per statistic:	100	-		
Update interval:	100000	Events		
✓Enable simulation lo	g			
Run		Help <u>C</u> ancel <u>O</u>	ĸ	

- 3. Click on the **Object Attributes** tab  $\Rightarrow$  Click the **Add** button.
- 4. As shown in the following *Add Attribute* dialog box, you need to add the **THT Duration** attribute for all nodes. To do that:
  - a. Add the unresolved attribute: Office Network.\*.Token Ring Parameters[0].THT Duration by clicking on the corresponding cell under the Add? column ⇒ Click OK

🗙 Add Attribute: scenario	×
Add? Unresolved Attributes	<b>A</b>
add Office Network.*.Token Ring Parameters	
<b>N</b>	
N .	
	-
Expand Cancel OK	

5. Now you should see the **Office Network.\*.Token Ring Parameters[0].THT Duration** in the list of simulation object attributes (widen the "Attribute" column to see the full name of the attribute). Click on that attribute ⇒ Click the **Values** button, as shown below.

Configure Simulatior	n: eha_Toke	en-Balanced				
Common Global Attribu	Common Global Attributes Object Attributes Reports SLAs Animation Profiling Advanced Envirc					
Use de <u>f</u> ault values fo				Numbe	er of runs in set: 1	
Save vector file for ea	ach run in se	et		Simula	ation set info	
Attribute			Val	le		4
Office Network.*.Token	Ring Paran	neters [0].THT Du	uration			
					$\sim$	
Add E	xpand	De <u>l</u> ete	<u>U</u> pda	e	<u>V</u> iew Props	Values
Run		<u>H</u> elp			<u>C</u> ancel	<u>O</u> K

6. Add the following six values. (*Note:* To add the first value, double-click on the first cell in the **Value** column ⇒ Type "0.01" into the textbox and hit enter. Repeat this for all six values.)

🔣 Attribute: Office	e Network.*.T	oken Ring Para	meters [0]	.T 🔀
	Enter one or	more values:		
Value Limit Step				<b>A</b>
0.01				
0.02				
0.04				
0.08				
0.16				
0.32				
				-
<u>V</u> iew Props	<u>D</u> elete	Cancel	<u>O</u> ł	<

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 **6**.

Configure Sim	ulation: eha_Tok	en-Balanced			
✓Use default va Save vector fi Attribute	I Attributes Object alues for unresolved le for each run in s *.Token Ring Paran	d attributes et	Numbe S <u>i</u> mula	on Profiling Advan er of runs in set: 6 ation set info	<b>←</b>
Add	E <u>x</u> pand	Delete	<u>U</u> pdate	<u>V</u> iew Props	Values
<u>R</u> un		<u>H</u> elp		<u>C</u> ancel	<u>O</u> K

- 8. For each of the six simulation runs we need the simulator to save "scalar" values that represent the "average" values of the statistics to be collected from the simulation. 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>\_Token\_Balanced to the Scalar file text field.

🛣 Configure Sir	nulation: eha_Toke	n-Balanced			
Common Glob	al Attributes Object A	ttributes Repo	orts SLAs Animation	Profiling Advan	
Network: eha	a_Token-Balanced				<u> </u>
Probe file: eha	a_Token-Balanced				-
Vector file: eha	a_Token-Balanced				
Scalar file: eha	a_Token_Balanced ┥	<del>(</del>			
Simulation prog	gram: op_runsim	•			
Command-line	options				
Record a date/	time in results: none	▼ Dat	te:	Time:	
			,	,	
	1		1		
<u>R</u> un		<u>H</u> elp		<u>C</u> ancel	<u>O</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 a node or link) and select **Choose Individual Statistics** from the pop-up menu.
  - a. Expand the Global Statistics hierarchy:
    - Expand the **Traffic Sink** hierarchy  $\Rightarrow$  Click the check box next to **Traffic Received (packets/sec).**
    - Expand the Traffic Source hierarchy  $\Rightarrow$  Click the check box next to Traffic Sent (packets/sec).
  - b. Expand the Node Statistics hierarchy:
    - Expand the Token Ring hierarchy  $\Rightarrow$  Click the check box next to **Utilization.**
  - c. Click OK.
- 2. Now we want 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**. The **Utilization** probe should appear under the **Node Statistics 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.

🛣 (pb0) Attribu	ıtes		×
Attribute		Value	
⑦ ⊢name		pb0	
⑦ ⊢draw style	)	linear	
⑦ ⊢group		Traffic Sink	
⑦ ⊢statistic		Traffic Received (packets/sec)	
⑦ ⊢ordinate la	abel		
⑦ ⊢vector dat	а	enabled	
⑦ ⊢vector sta	rt	0.0	
⑦ ⊢vector sto	р	infinity	
⑦ ⊢scalar dat	а	enabled	
⑦ ⊢scalar typ	e	time average 🛛 🗲 🗕	
⑦ ⊢scalar sta	rt	0.0	
⑦ ⊢scalar sto	р	infinity	-
	es to Selected O	bjects	
	Eind Next	<u>Cancel</u> <u>O</u> K	

d. Repeat the previous step with the **Traffic Sent** and **Utilization** probes.

The **utilization** is a measure of the bandwidth used versus that available on the given ring.

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

- 3. Since we need to analyze the effect of THT on the network performance, THT must be added as an "input" statistic to be recorded by the simulation. To do that:
  - a. Select **Create Attribute Probe** from the **Objects** menu. Now a new attribute is created under the **Attribute Probes** hierarchy as shown.
  - b. Right-click on the new attribute probe and select **Choose Attributed Object** from the pop-up menu  $\Rightarrow$  Expand the **Office Network** hierarchy  $\Rightarrow$  Click on **node\_0** (actually you can pick any other node)  $\Rightarrow$  Click **OK**.

🖼 Probe Model: eha_Token-Balanced [Subnet: top.Office Network] 📃 🗖 🔀
File Edit Objects Windows Help
Global Statistic Probes
- collect Name Group.Statistic
http://www.com/com/com/com/com/com/com/com/com/com/
└ <u>ば๗/1</u> pb1 Traffic Source.Traffic Sent (packets/sec)
P Node Statistic Probes
- collect Name Group.Statistic Object
u use use use use use use use use use us
由환 Link Statistic Probes
🕂 🔀 Demand Statistic Probes
由쇻 Coupled Node Statistic Probes
다후 Attribute Probes
Name Attribute Object
pb3 Office Network.node_0
🕂 🗭 Automatic Animation Probes

c. Right-click again on the new attribute probe and select **Edit Attributes** from the pop-up menu  $\Rightarrow$  Assign the **Token Ring Parameter[0].THT Duration** value to the "attribute" Attribute, as shown in the figure  $\Rightarrow$  Click **OK**.

🗮 (pb3) Attributes	
Attribute	Value
⑦ ⊢ name	pb3
⑦ ⊢object	Office Network.node_0
⑦ ⊢attribute	Token Ring Parameters [0].THT Duration 📃
▲ 1 ===0:==== 1=== 1	
Apply Changes to Selected Ol	bjects
Eind Next	<u>C</u> ancel <u>O</u> K

- 4. Select save from the **File** menu in the *Probe Model* window and then **Close** the window.
- 5. Now you are back to the Project Editor. Make sure to save your project.

#### **Duplicate the Scenario**

The token ring network scenario we just implemented is *balanced:* the distribution of the generated traffic in all nodes is the same. To compare performance, you will create an "unbalanced" scenario as follows:

- 1. Select **Duplicate Scenario** from the **Scenarios** menu and give it the name **Unbalanced**  $\Rightarrow$  Click **OK**.
- Select node\_0 and node\_7 by shift-clicking on both nodes ⇒ Right-click on one of these two selected nodes and select Edit Attributes ⇒ Expand the Traffic Generation Parameters hierarchy ⇒ Expand the Packet Generation Arguments hierarchy ⇒ Change the value of the Interarrival Time attribute to exponential(0.005) as shown. Make sure to check the Apply Changes to Selected Objects box before you click OK.

🛣 (node_0) Attributes			
Type: station			
Attribute	Value 🔺		
⑦ ⊢name	node_0		
⑦ ⊢model	tr_station_adv		
⑦ ⊢Highest Destination Address	Maximum Dest Address		
⑦ ⊢Lowest Destination Address	Minimum Dest Address		
⑦	()		
⑦ ⊡ Traffic Generation Parameters	()		
③ +Start Time (seconds)	constant (5.0)		
ON State Time (seconds)	exponential (100.0)		
OFF State Time (seconds)	exponential (0.0)		
Packet Generation Arguments	()		
Interarrival Time (seconds)	exponential (0.005) <		
⑦ ⊢Packet Size (bytes)	exponential (1024)		
✓ <u>Apply Changes to Selected Objects</u>	← A <u>d</u> vanced		
<u>Find Next</u>	<u>C</u> ancel <u>O</u> K		

- 3. Select all nodes except node\_0 and node\_7 ⇒ Right-click on one of the selected nodes and select Edit Attributes ⇒ Change the value of the Interarrival Time attribute to exponential(0.075) as in the previous step. Make sure to check the Apply Changes to Selected Objects box before you click OK.
- 4. Click anywhere in the workspace to unselect objects.
- Click on the Configure/Run Simulation button: Simulation button: Simulation the Advanced tab in the Configure Simulation dialog box ⇒
   Assign <your initials>\_Token\_Unbalanced to the Scalar file text field.
- 6. Click **OK** and then save your project.

#### **Run the Simulation**

To run the simulation for both scenarios simultaneously:

- 1. Go to the Scenarios menu  $\Rightarrow$  Select Manage Scenarios.
- 2. Change the values under the **Results** column to <collect> (or <recollect>) for both scenarios. Compare to the following figure.

🗄 Manage Scenarios							
Project Name: eha Token							
#	Scenario Name	Saved	Results	Sim Duration	Time Units 🔺		
1	Balanced	saved	<collect></collect>	5.0	minute(s)		
2	Unbalanced	saved	<collect></collect>	5.0	minute(s)		
					<b>~</b>		
Ē	Delete Discard Re	sults <u>C</u> ol	lect Results		C <u>a</u> ncel <u>O</u> K		

- 3. Click **OK** to run the simulations. Depending on the speed of your processor, this may take several minutes to complete.
- 4. After the simulation completes the 12 runs, 6 for each scenario, click **Close**.
- 5. 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.

 Go to the File menu ⇒ Select Model Files ⇒ Delete Model Files ⇒ From the list, choose other model types ⇒ Select ( .os): Output Scalars ⇒ Select the scalar file to be deleted; in this lab they are
 <your initials>\_Token\_Balanced\_Scalar and
 <your initials>\_Token\_Unbalanced\_Scalar ⇒ 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 two scalar files, one for each scenario. To load the scalar file for the **Balanced** scenario, select **Load Output**

Scalar File from the File menu  $\Rightarrow$  Select <your initials>\_Token\_Balanced from the pop-up menu.

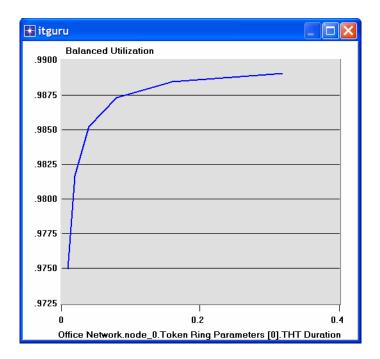
3. Select **Create Scalar Panel** from the **Panels** menu ⇒ Select the scalar panel data as shown in the following dialog box: **THT** for **Horizontal** and **Utilization** for **Vertical**. (*Note:* If any of the data is missing, make sure that you carried out steps 2.c and 2.d in the *Choose the Statistics* section.)

🞛 Select Scalar Panel Data 🛛 🔀				
Horizontal:	Office Network.node			
Vertical:	top.Office Network.n			
	<u>C</u> ancel <u>O</u> K			

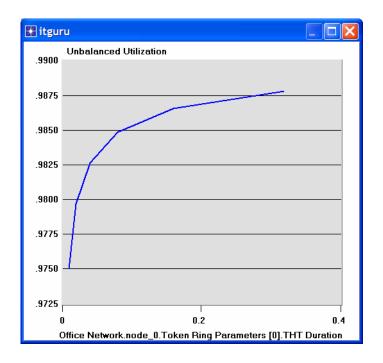
- 4. Click OK.
- 5. To change the title of the graph, right-click on the graph area and choose **Edit Graph Properties**  $\Rightarrow$  Change the **Custom Title** to **Balanced Utilization** as shown.

🚼 Graph #1 of Panel #1						
top.Office Network.node_14.Token Ring.Utilizatic						
Custom Title:	Balanced Utilization					
File:		S <u>h</u> ow				
Report:		Sho <u>w</u>				
Object:		Show				
Statistic:		Show				
Annotation:		Show				
Parameter:		Show				
Draw Style:	linear 💌	Set Color				
Vertical Min:	0.974916	Eull Scale				
Vertical Max:	0.989051	Legend				
Height (pixels):	308	Set <u>C</u> olor				
Show Confidence Interval						
Apply Cancel OK						

6. Click **OK**. The resulting graph should resemble the one shown below. Do not close the graph and continue with the following step.



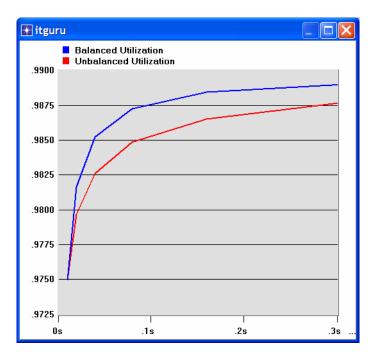
- To compare with the Unbalanced scenario, load its scalar file, select Load Output Scalar File from the File menu ⇒ Select <your initials>\_Token\_Unbalanced from the pop-up menu.
- 8. Select Create Scalar Panel from the Panels menu  $\Rightarrow$  Select the scalar panel data as in step 3.
- Click OK ⇒ Change the graph title to Unbalanced as in step 5 ⇒ Click OK. The resulting graph should resemble the one shown below. Do not close this graph or the previous one and continue with the following step.



10. To combine the above two graphs on a single graph, select **Create Vector Panel** from the **Panels** menu ⇒ Click on the **Display Panel Graphs** tab ⇒ Select both **Balanced** and **Unbalanced** statistics ⇒ Choose **Overlaid Statistics** from the drop-down menu in the right-bottom area of the dialog box as shown.

<b>₩</b> View Results	
Graph Output Files Displayed Panel Graphs	Show Preview Balanced Utilization Unbalanced Utilization .99 .98
×	
	Unselect Add Show
	<u>C</u> lose

11. Click **Show** and the resulting graph should resemble the one shown below.



- 12. Repeat the same process to check the effect of the THT on Traffic Received for both scenarios. Assign the appropriate titles to the graphs.
- 13. The resulting graph, which combines the Traffic Received statistic for both the Balanced and Unbalanced scenarios, should resemble the following one:



#### **Further Readings**

 OPNET Token Ring Model Description: From the Protocols menu, select Token Ring ⇒ Model Usage Guide.

### Questions

- 1) Why does the utilization increase with higher THT values?
- 2) Create a duplicate scenario of the Balanced scenario. Name the new scenario Q2\_HalfLoad. In the Q2\_HalfLoad scenario, decrease the load into the network (i.e., load from all nodes in the network) by half and repeat the simulation. Compare the utilization and traffic received in the Q2\_HalfLoad scenario with those of the Balanced scenario.

#### Hints:

- Decreasing the load from a node by half can be done by doubling the "Interarrival Time" of the node's **Packet Generation Arguments**.
- Do not forget to assign a separate "scalar file" for the new scenario.
- 3) Create a duplicate scenario of the Balanced scenario. Name the new scenario Q3\_OneNode. In the Q3\_OneNode scenario, reconfigure the network so that node\_0 generates a traffic load that is equivalent to the traffic load generated by all nodes in the Balanced scenario combined. The rest of the nodes, node\_1 to node\_13, generate no traffic. Compare the utilization and traffic received in Q3\_OneNode scenario with those of the Balanced scenario.

#### Hints:

- One way to configure a node so that it does not generate traffic is to set its **Start Time** (it is one of the **Traffic Generation Parameters**) to the special value **Never**.
- Do not forget to assign a separate "scalar file" for the new scenario.

## Lab Report

Prepare a report that follows the guidelines explained in Lab 0. The report should include the answers to the above questions as well as the graphs you generated from the simulation scenarios. Discuss the results you obtained and compare these results with your expectations. Mention any anomalies or unexplained behaviors.