

## Laboratory **2**

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# **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.

## Procedure

### Create a New Project

To create a new project for the token ring network:

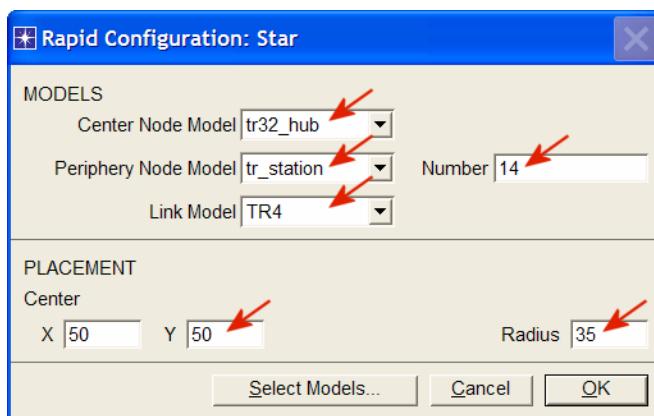
1. Start **OPNET IT Guru Academic Edition** ⇒ Choose **New** from the **File** menu.
2. Select **Project** and click **OK** ⇒ Name the project <your initials>\_Token, and the scenario **Balanced** ⇒ Click **OK**.
3. In the *Startup Wizard: Initial Topology* dialog box, make sure that **Create Empty Scenario** 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:

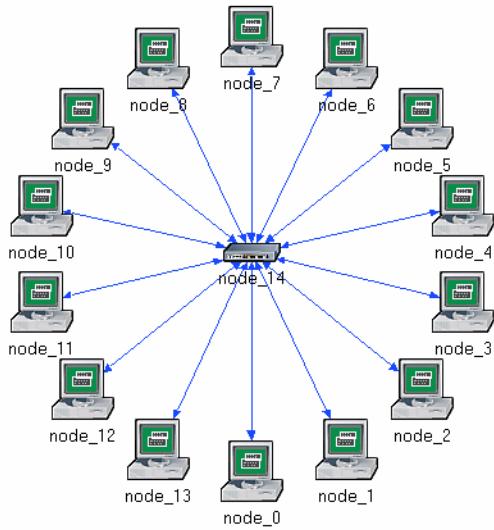
1. Select **Topology** ⇒ **Rapid Configuration**. From the drop-down menu choose **Star** and click **OK**.
2. Click the **Select Models** button in the *Rapid Configuration* dialog box. From the *Model List* drop-down menu choose **token\_ring** and click **OK**.
3. In the *Rapid Configuration* dialog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

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

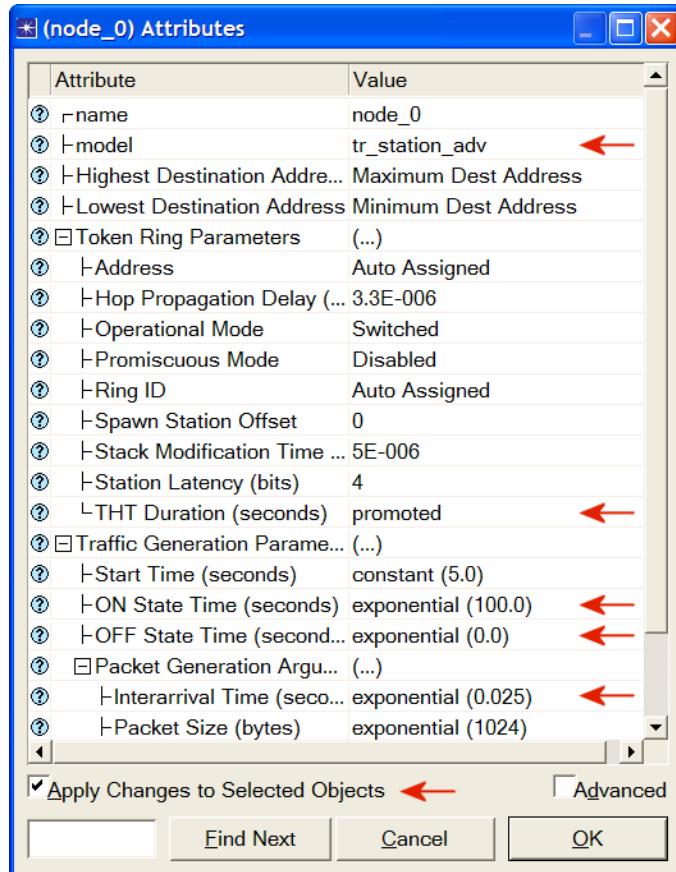
Here you will configure the THT of the nodes as well as the traffic generated by them. To configure the THT of the nodes, you need to use the **tr\_station\_adv** model for the nodes instead of the current one, **tr\_station**.

1. Right-click on any of the 14 nodes  $\Rightarrow$  **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:

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.

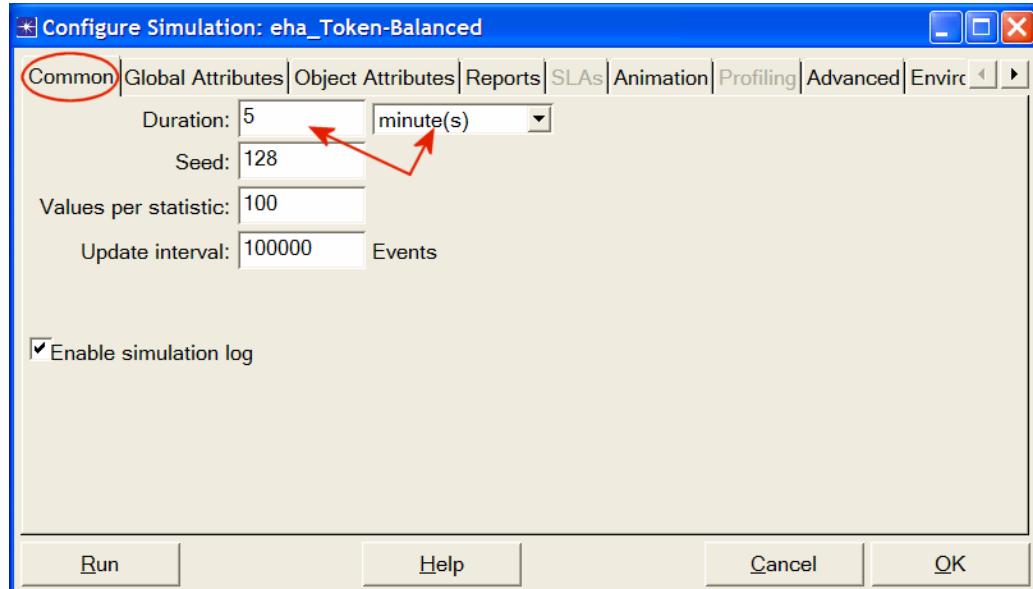


3. Click on the model value: **tr\_station** and select **Edit** from the drop-down menu. Now select **tr\_station\_adv** from the extended drop-down menu.
4. To test the network under different THT values, you need to "promote" the THT parameter. This allows us to assign multiple values to the THT attribute.
  - 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  $\Rightarrow$  Assign **exponential(100)** to the **ON State Time** attribute  $\Rightarrow$  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.

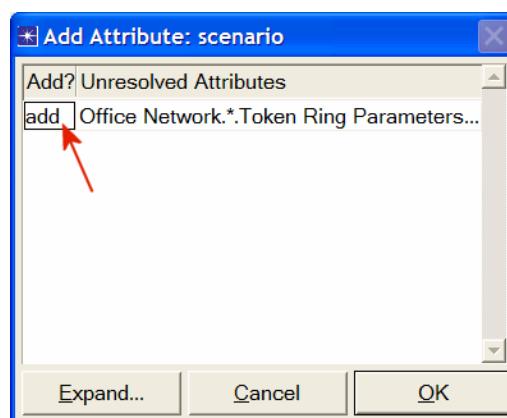
## Configure the Simulation

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:

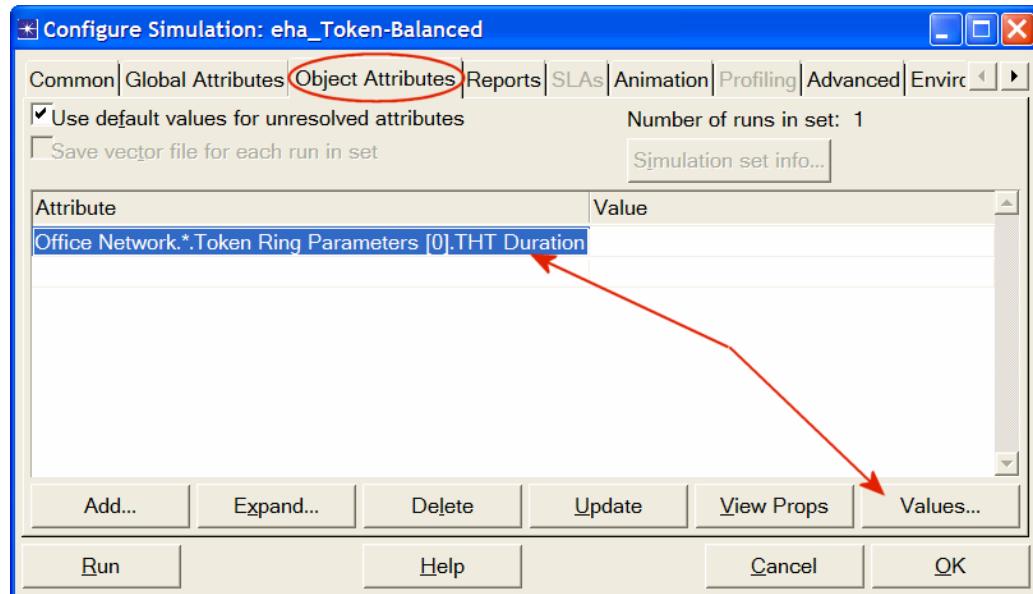
1. Click on the **Configure/Run Simulation** button:
2. Make sure that the **Common** tab is chosen  $\Rightarrow$  Assign **5** minutes to the **Duration**.



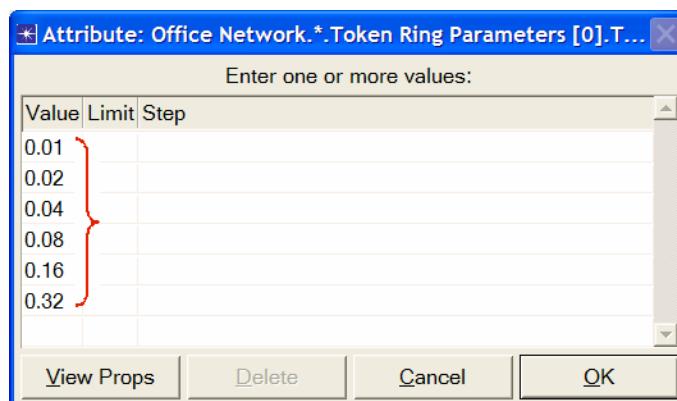
3. Click on the **Object Attributes** tab  $\Rightarrow$  Click the **Add** button.
4. As shown in the following *Add Attribute* dialog box, you need to add the **THT Duration** attribute for all nodes. To do that:
  - a. Add the unresolved attribute: **Office Network.\*.Token Ring Parameters[0].THT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



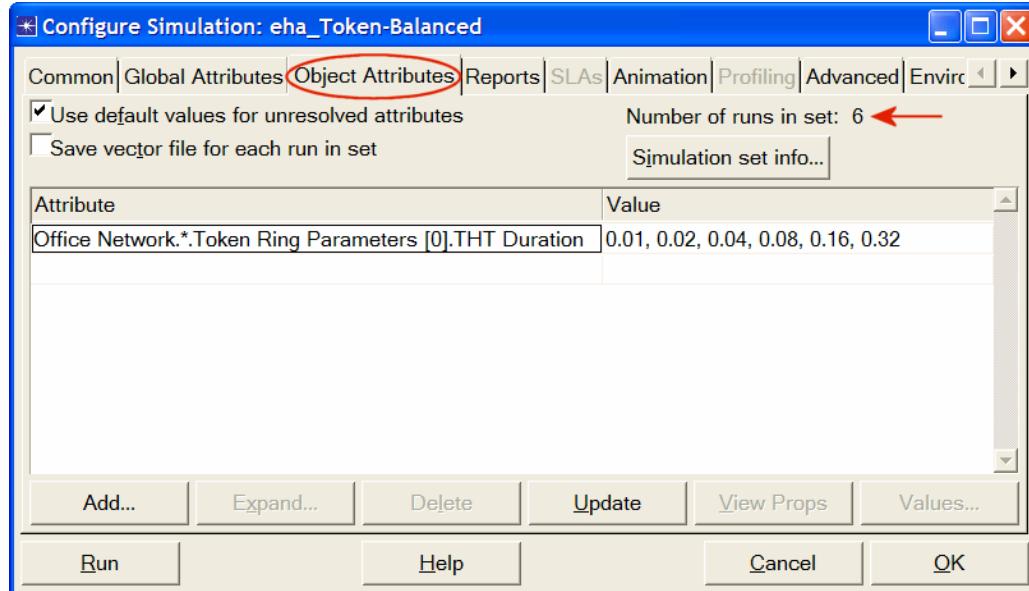
5. Now you should see the **Office Network.\*.Token Ring Parameters[0].THT Duration** in the list of simulation object attributes (widen the “Attribute” column to see the full name of the attribute). Click on that attribute ⇒ Click the **Values** button, as shown below.



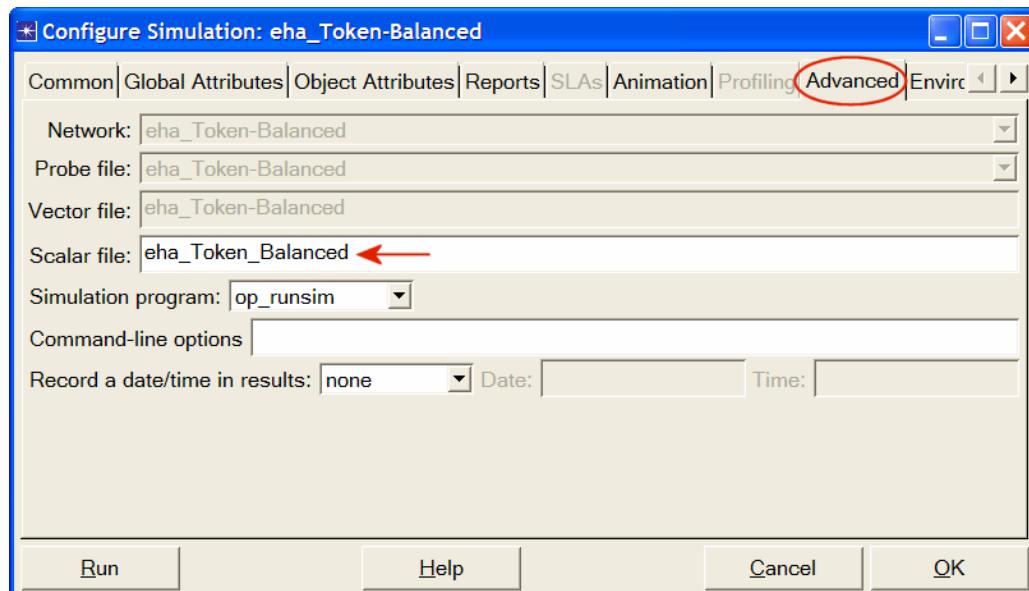
6. Add the following six values. (Note: To add the first value, double-click on the first cell in the **Value** column ⇒ Type “0.01” into the textbox and hit enter. Repeat this for all six values.)



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**.



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.

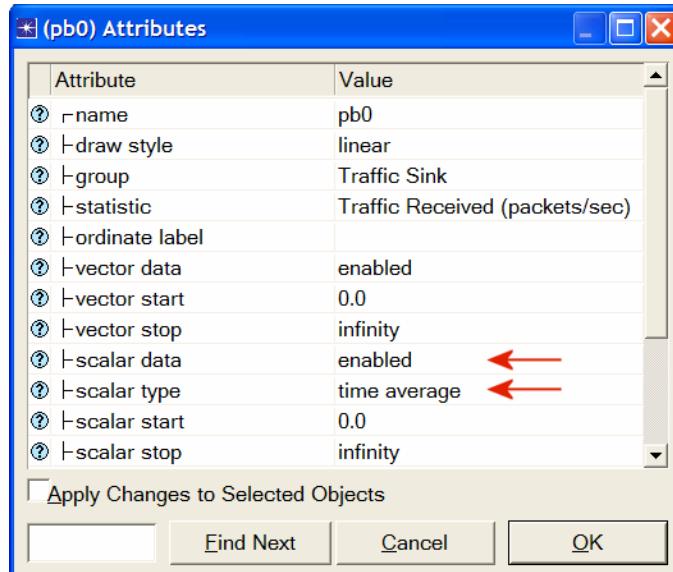


10. Click **OK** and then save your project.

## Choose the Statistics

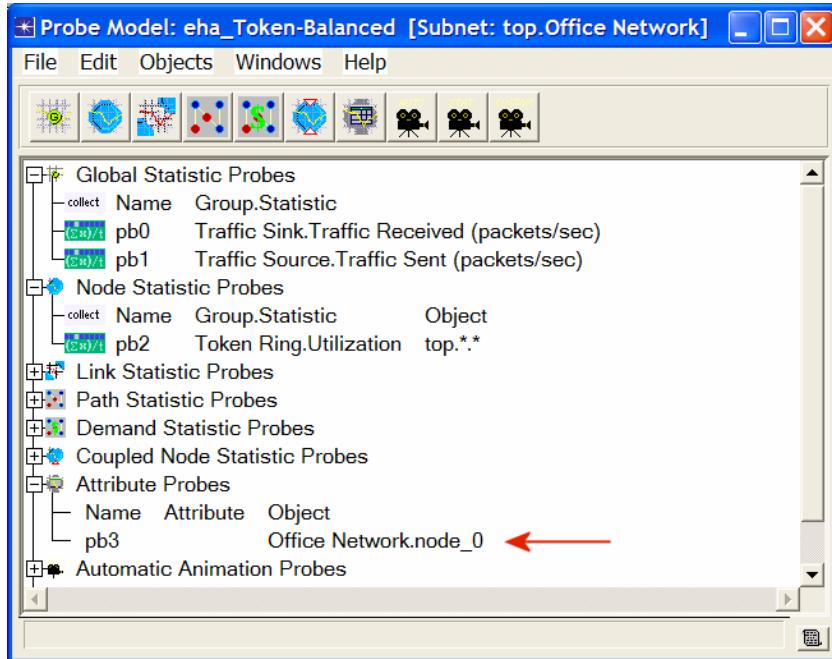
To choose the statistics to be collected during the simulation:

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 ⇒ Click the check box next to **Traffic Received (packets/sec)**.
    - Expand the **Traffic Source** hierarchy ⇒ Click the check box next to **Traffic Sent (packets/sec)**.
  - b. Expand the **Node Statistics** hierarchy:
    - Expand the **Token Ring** hierarchy ⇒ 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 ⇒ **Edit Attributes**. Set the **scalar data** attribute to **enabled** ⇒ Set the **scalar type** attribute to **time average** ⇒ Compare to the following figure and click **OK**.

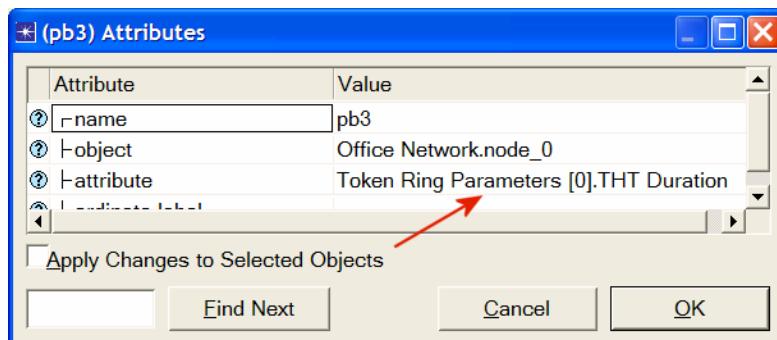


- d. Repeat the previous step with the **Traffic Sent** and **Utilization** probes.

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**.



- 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**.

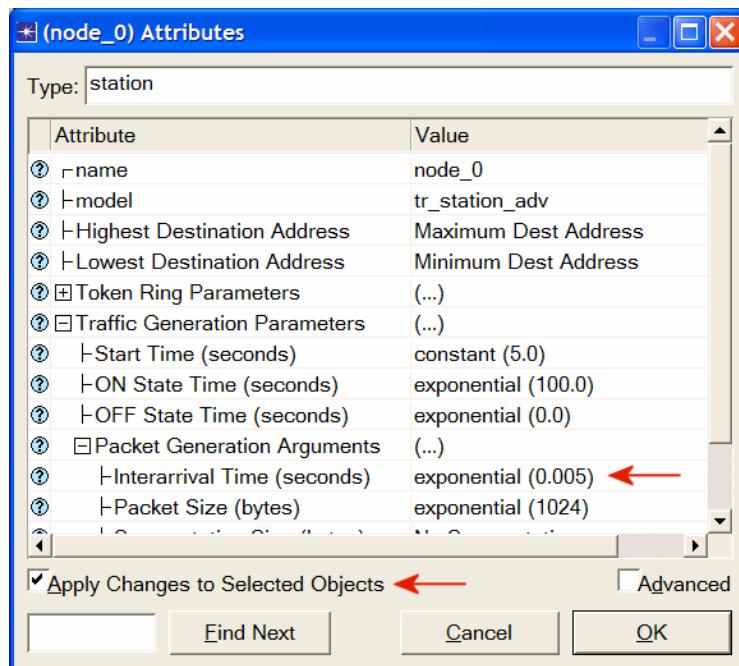


4. Select save from the **File** menu in the *Probe Model* window and then **Close** the window.
5. Now you are back to the *Project Editor*. Make sure to save your project.

## 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** ⇒ Click **OK**.
2. 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**.

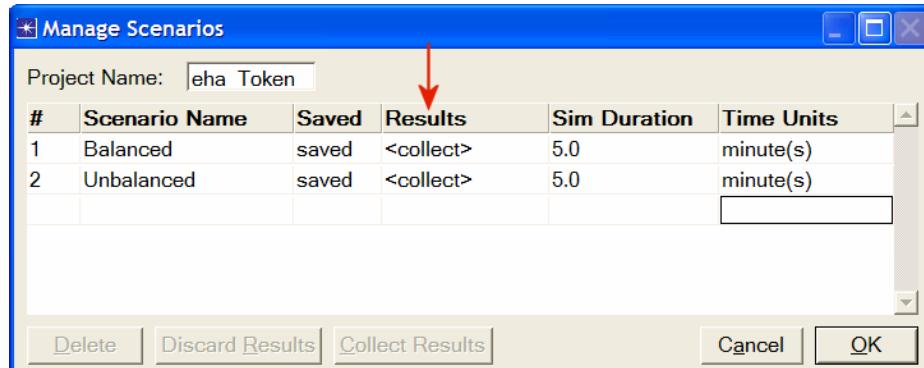


3. Select all nodes except **node\_0** and **node\_7** ⇒ Right-click on one of the selected nodes and select **Edit Attributes** ⇒ Change the value of the **Interarrival Time** attribute to **exponential(0.075)** as in the previous step. Make sure to check the **Apply Changes to Selected Objects** box before you click **OK**.
4. Click anywhere in the workspace to unselect objects.
5. Click on the **Configure/Run Simulation** button: ⇒ Click on 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 ⇒ Select **Manage Scenarios**.
2. Change the values under the **Results** column to **<collect>** (or **<recollect>**) for both scenarios. Compare to the following figure.



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**.

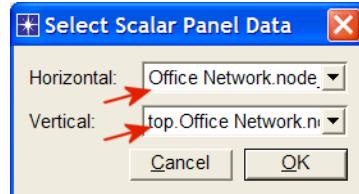
## View the Results

To view and analyze the results:

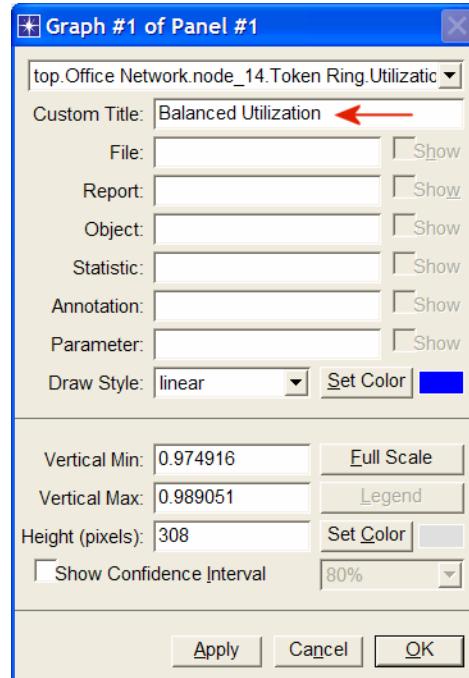
1. Select **View Results (Advanced)** from the **Results** menu. Now the **Analysis Configuration** tool is open.
2. Recall that we saved the average results in two scalar files, one for each scenario. To load the scalar file for the **Balanced** scenario, select **Load Output**

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

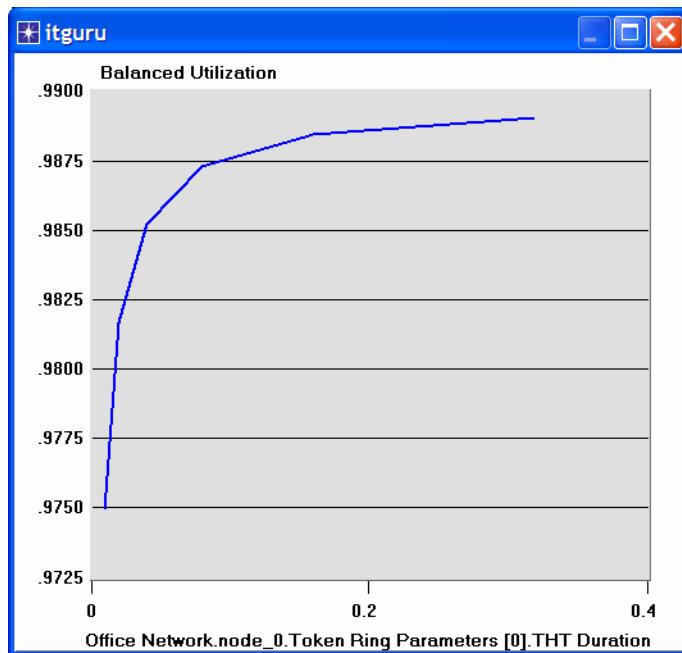
3. Select **Create Scalar Panel** from the **Panels** menu  $\Rightarrow$  Select the scalar panel data as shown in the following dialog box: **THT** for **Horizontal** and **Utilization** for **Vertical**. (Note: If any of the data is missing, make sure that you carried out steps 2.c and 2.d in the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



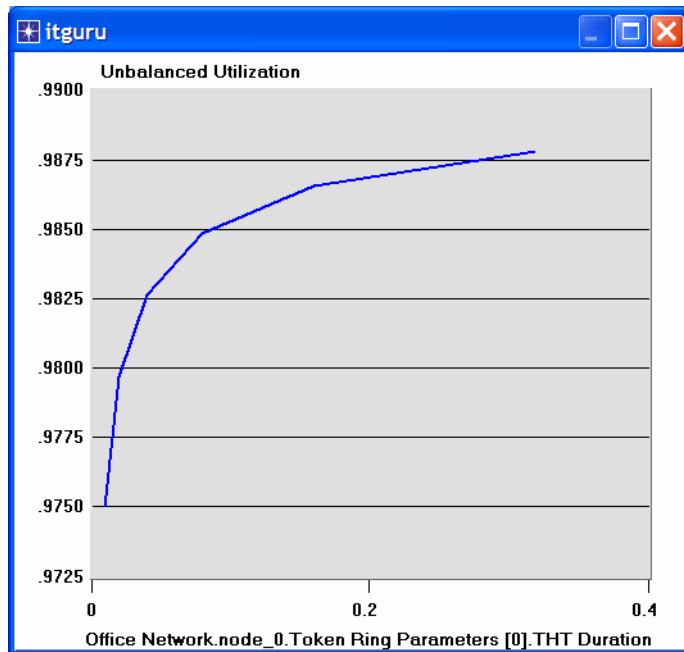
4. Click **OK**.
5. To change the title of the graph, right-click on the graph area and choose **Edit Graph Properties**  $\Rightarrow$  Change the **Custom Title** to **Balanced Utilization** as shown.



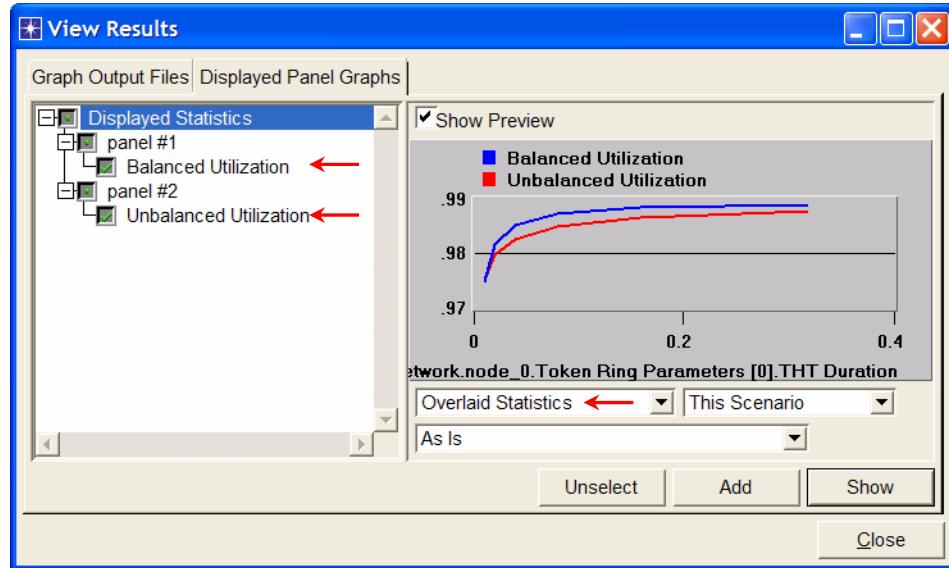
6. Click **OK**. The resulting graph should resemble the one shown below. Do not close the graph and continue with the following step.



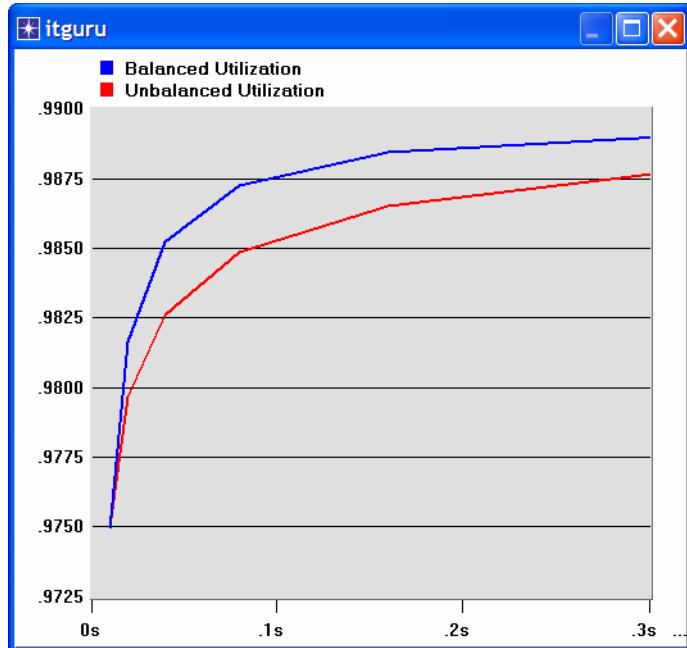
7. To compare with the **Unbalanced** scenario, load its scalar file, select **Load Output Scalar File** from the **File** menu  $\Rightarrow$  Select <your initials>**\_Token\_Unbalanced** from the pop-up menu.
8. Select **Create Scalar Panel** from the **Panels** menu  $\Rightarrow$  Select the scalar panel data as in step 3.
9. Click **OK**  $\Rightarrow$  Change the graph title to **Unbalanced** as in step 5  $\Rightarrow$  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.



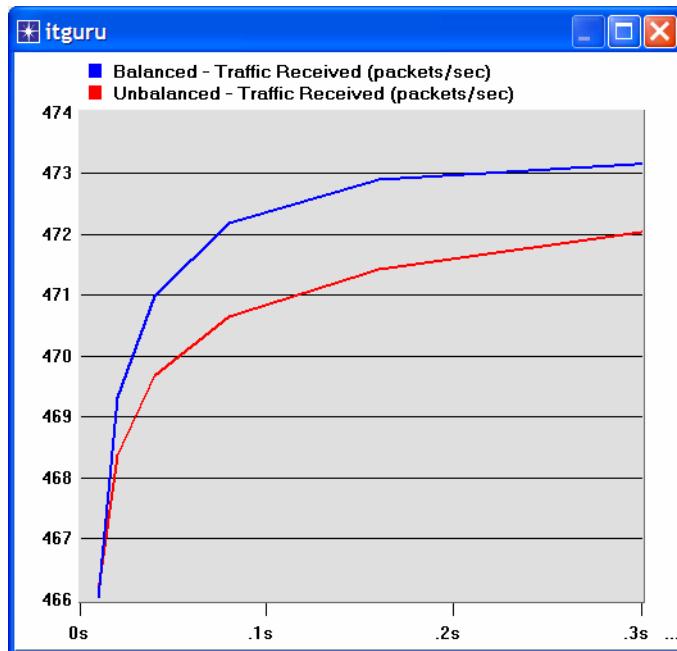
10. To combine the above two graphs on a single graph, select **Create Vector Panel** from the **Panels** menu ⇒ Click on the **Display Panel Graphs** tab ⇒ Select both **Balanced** and **Unbalanced** statistics ⇒ Choose **Overlaid Statistics** from the drop-down menu in the right-bottom area of the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



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**  $\Rightarrow$  **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.