# Planning Wireless LAN Network Deployments

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## LAB 1: Mixed 11g/11n WLAN Performance

## **Overview**

The network administrator at a campus plans to upgrade all access points in the buildings from 802.11g access points (APs) to 802.11n access points (APs) to improve network performance. Clearly, the users of the network are not forced to buy new 802.11n cards as the technology is legacy compatible i.e. 802.11n APs can service 802.11g devices.

The network administrator wants to investigate the impact of 11g legacy devices in 11n BSS. He wants to find out if 11n users will see any degradation in the network performance and the extent of degradation if any.

## Objective

Determine impact of legacy 11g nodes on an 11n WLAN network.

## Methodology

- 1. Create an 802.11n-based wireless LAN network using the Wireless Deployment Wizard.
- 2. Configure traffic on the stations.
- 3. Introduce legacy nodes in the network and determine if there is degradation in throughput.

## Instructions

## **Open Project**

- 1. Start Riverbed Modeler Academic Edition 17.5, if it is not already open.
- 2. Select File/Open.
- 3. Select **1504\_Lab1** and click Open.
  - a. The project will open with the scenario named **all\_11n**.
- 4. Maximize the project by clicking on the **Maximize** button on the top right corner of the project editor.

*Important Note:* Because Riverbed Modeler Academic Edition has a limited set of tools compared to the full version of Modeler, some sections of this tutorial have been configured for you. An example of a feature that is missing in the Modeler Academic Edition is the Wireless Deployment Wizard which can be used to interactively deploy a wireless network. You can still accomplish the same functionality by selecting nodes from the object palette and configuring all the attributes manually; however this can be laborious for a large wireless deployment. For purposes of this tutorial, we have already configured the topology

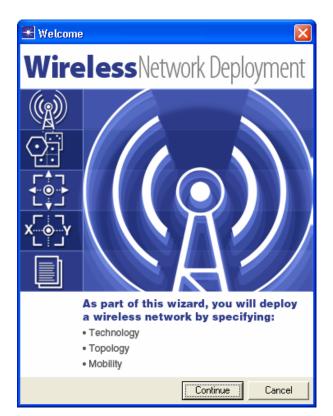
## for <u>steps 5-27</u> below. Please read through the steps so as to understand the attribute configurations that are in place.

Use the Wireless Deployment Wizard to create a WLAN network

5. Select Topology/Deploy Wireless Network...



6. Click on **Continue** on the Welcome screen.



7. The **Network Creation** stage opens up. In this stage, the user chooses if they will use the wizard to specify the network deployment parameters, or use a previously saved network specification file. Make sure that the "**Use wizard to provide network specifications**" option is selected.

迷 Wireless De	eployment Wiz	ard - Network (	Creation		
	ху ⊳	(g) •			
Network Creation	Location	Technology	Topology	Node Mobility	Configuration Summary
and mobility. After defining have a previo Choose from © Use wizard © Load spec	Use this wizard iter	ns: k specifications wed file	Itiple network segr	nents into the sam	e project.
	Quit	Back	Next	Finish	Help

• Click **Next** to go to the next stage of the wizard.

- 8. The **Location** stage can be used to specify the location of the network.
  - Select the option Create network in current subnet
  - Set **X** and **Y** to **0** and **0** respectively
  - Make sure that the settings look as shown below:

<del>米</del> Wireless Depl	oyment Wizar	d - Location			×		
Network Creation	X O Y	Technology	Topology	Node Mobility	Configuration Summary		
specify location a new subnet choice.	You can deploy the wireless network into the current subnet or into a new subnet for which you specify location coordinates. If your current subnet is not defined in units of meters, you must create a new subnet for the deployment. If your current subnet is defined in meters, you may use either choice.						
- Location	C Lreate network in new subnet						
	Quit	Back	Next	Finish	Help		

• Click **Next** to continue

- The Technology stage is used to select a particular deployment technology and to specify technology specific parameters. Make sure that the Choose Technology option is set to WLAN (Infrastructure).
- 10. Since the desired operational mode for the network is 802.11n, set the **Operational Mode** to **802.11n** (**2.4GHz**). Note that this implies that all nodes will be operating in 802.11n mode.
- 11. Set the Data Rate to **26 Mbps (base) / 240 Mbps (max)**. Note that this implies that the data rate on all nodes will be set to **26 Mbps (base) / 240 Mbps (max)**.

🛣 Wireless Deployment Wizard - Technology 🛛 🔀						
Network Creation	K	Technology	Topology	Node Mobility	Configuration Summary	
all applicable	e nodes during the y Specifications —	nt to deploy and spa network creation. AN (Infrastructure)	ecify its parameters.	These values w	vill be applied to	
Node Tra Operation Data Rate		w)		Based (2.4GHz) : (base) / 240 Mł		
	0	)uit Back	K Next	Finish	Help	

Make sure that the **Technology** stage looks as below:

- 12. Click **Next** to open the **Topology** stage of the wizard. In this stage a **Geographical Overlay** and **Node Placement Algorithm** is specified for the deployment.
- 13. Make sure that **Cell (Hexagon)** is selected as the geographical overlay.
- 14. Set the **Number of Cells** is set to **1**.
- 15. Set the Cell Radius (km) to 0.25.
- 16. Make sure that the Mobile Node Placement Specifications, is set to Random
- 17. Make sure that the stage looks as below:

🛣 Wireless Depl	loyment Wizar	d - Topology			
Network Creation	Location	Technology	Topology	Node Mobility	Configuration Summary
Specify the no is not a true re Geographic Choose Geo Number of Cell Radiu	ode placement for epresentation of yo cal Overlay Specifi graphical Overlay f Cells 1	Cell (Hexagon) 25	n your network. No	te that the examp	le displayed
	Quit	Back	Next	Finish	Help

- 18. Click **Next** to provide node specifications as part of the **Topology** stage.
- 19. Users are given the option of choosing a particular node model for the Access Points and the Mobile Nodes. For the purposes of our lab, we will leave the "**Mobile Node**" node model to the default value.
- 20. Select wlan\_eth\_bridge\_adv node model for the access point
  - Click on drop down menu beside Node Model under Access Point and click on Edit.
  - The object palette of wireless\_lan\_adv opens up.
  - Select wlan\_eth\_bridge\_adv from the object palette and click OK.
- 21. Users are given the option of choosing the number of the mobile nodes per cell. Set the Mobile Node **Count (per-cell)** to **8.**
- 22. The wireless wizard provides the ability to connect the access points using a backbone network. For this lab, we do not require this functionality, so **uncheck** the **Connect all Access Points (via serial interfaces) using a backbone network** checkbox
- 23. Make sure that the stage looks as below:

🕷 Wireless Deployment W	🗄 Wireless Deployment Wizard - Topology 🛛 🛛 🔀					
Network Creation	n Technology	Topology	Node Mobility	onfiguration Summary		
Select the number of nodes node model for your Access			) network. You can als Mobile Node	o specify the		
Node Model	wlan_eth_bridge_adv	Ī	wlan_station_adv			
Count (per-cell)	Access Point		Mobile			
Connect all Access Points (via serial interfaces) using a backbone network						
	Quit	Back	Next Finish	Help		

- 24. Click **Next** to open the Mobility Specification dialog. For simplicity, we will not have any mobility in the network.
- 25. In the Node Mobility screen, click on the first row and hit **Delete Row** button.

Make sure that the stage looks as below:

🛣 Wireless De	ployment Wi	zard - Noo	le Mobility				×
Network Creation	X O Y	Technol		pology	Nod Mobil	e lity	Configuration Summary
a trajectory or 0 out of 12	You have chosen to deploy 12 Mobile Nodes in every cell of the network. You can optionally attach a trajectory or a random mobility profile to the Mobile Nodes using the table below. <b>0</b> out of <b>12</b> nodes have been configured with mobility parameters						
Trajectory Ir	formation Numb	per of Nodes	Speed (m/s)	Area of M	ovement	Altitude	(m)
					Add Row		elete Row
	Qui	t	Back	Next	Fin	ish	Help

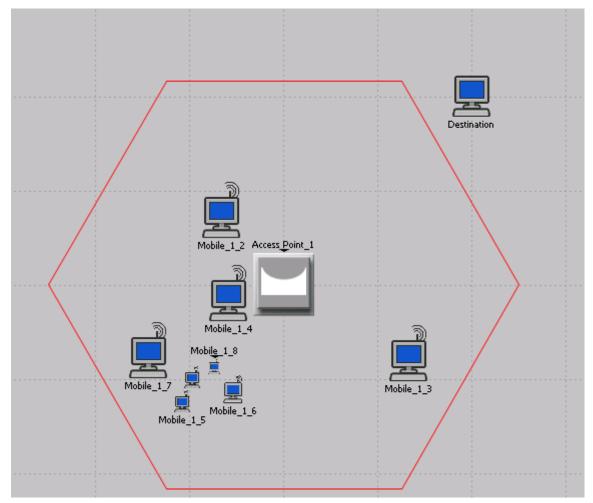
26. Click **Next** to open the **Configuration Summary** stage.

Review the Configuration Summary.

Wireless Deployment Wizard	- Configuration Summary		
Network Creation	Technology Topology	Node Mobility	Configuration Summary
Configuration Summary			
Technology	WLAN (Infrastructure)		
Overlay	Cell (Hexagon)		
Node Placement	Random		
Number of Access Points	1		
Number of Mobile Nodes	8		
Nodes with Mobility Configured	0		
Save technology, topology and mo parameters to a file for later use.	bility Save to File		Å
Quit	Back Next	Finish	Help

27. Click **Finish** to deploy the network.

A WLAN Infrastructure network with 1 hexagonal cell will be created. Note that the WLAN stations are placed in a random fashion and the access point is at the center of the cell.



- 28. The wireless wizard has automatically configured certain attributes on the Access point and Mobiles as per the specification in the wizard. Right click on Access Point\_1 and click on Edit Attributes. Right click on any mobile station between Mobile\_1\_1 to Mobile 1\_8 (say Mobile\_1\_3 for example) and click on Edit Attributes and place the two attribute dialog boxes side by side.
- Expand the **Wireless LAN/Wireless LAN Parameters** attribute. We will look at the highlighted attributes below in the next few bullet points

📧 (Ac	cess Point_1) Attributes		
Type:	bridge		
At	iribute	Value	<b>_</b>
?	Wireless LAN Parameters	()	
	- BSS Identifier	0	
?	- Access Point Functionality	Enabled	
?	- Physical Characteristics	HT PHY 2.4GHz (802.11n)	
0	- Data Rate (bps)	26 Mbps (base) / 240 Mbps (max)	
	Channel Settings	Auto Assigned	
?	- Transmit Power (W)	0.0016	

迷 (М	obile_1_3) Attributes	
Туре:	station	
A	ttribute	Value
6	9 Wireless LAN	
2	- Wireless LAN MAC Address	Auto Assigned
2	Wireless LAN Parameters	()
	- BSS Identifier	0
2	- Access Point Functionality	Disabled
2	- Physical Characteristics	HT PHY 2.4GHz (802.11n)
	- Data Rate (bps)	26 Mbps (base) / 240 Mbps (max)
2	Channel Settings	Auto Assigned
2	- Transmit Power (W)	0.0016
-		

- On Access Point\_1: Note that the BSS Identifier has been configured to 0. Note that the Mobile\_1\_3 has the BSS Identifier configured to 0 as well.
- On Access Point \_1: Note that the attribute Access Point Functionality it set to Enabled.
- On Access Point\_1 and Mobile\_1\_3: Note that the attribute Physical Characteristics is set to HT PHY 2.4GHz (802.11n) as per our specification in the wireless wizard. This attribute has been set to the same value on all nodes in the network
- On Access Point\_1 and Mobile\_1\_3: Note that the attribute Data Rate is set to 26 Mbps (base) / 240 Mbps (max) as per our specification in the wireless wizard. This attribute has been set to the same value on all nodes in the network
- 29. Click **Cancel** to close the two attribute dialog boxes.

## Configuring High Throughput Parameters (802.11n configuration):

The actual physical data rate used for data frame transmissions of the STAs using 802.11n physical layer depends on the configurations of **Wireless LAN/Wireless LAN Parameters/ High Throughput Parameters** attribute.

30. Set the number of spatial streams to 2 and enable greenfield operation on the mobile nodes

- Right click on any of the Mobile nodes and select Select Similar Nodes
- Right click on any one of the selected nodes and select **Edit Attributes** making sure that all the 8 nodes are still selected.
- Select the check box "Apply to selected objects".
- Expand the Wireless LAN/Wireless LAN Parameters/ High Throughput Parameters attribute.
- Set the attribute Number of Spatial Streams to 2
  - i. Configuring spatial streams greater than 1 results in a higher physical data rate
- Observe that the attribute Guard Interval is set to Short (400ns)
  - i. Configuring short guard interval results in a higher physical data rate
- The above two configurations sets the actual physical data rate at **57.8 Mbps** as per Table 20-30 in IEEE 802.11n-2009
- Also set the attribute **Greenfield Operation** to **Enabled**, thereby the wireless nodes will be able to use a shorter physical layer header HT –Greenfield format which will increase the wireless LAN throughput.

2	🗉 High Throughput Parameters	[]		
2	- Number of Spatial Streams	2		
0	- Guard Interval	Short (400ns)		
	- Greenfield Operation	Enabled		Important
2	40MHz Operation Parameters	Disabled		r .
	AP Specific Parameters	Default		
2	Frame Aggregation Parameters	Default	-	
			Advanced	
2		<u>Filter</u>	Apply to selected objects	
E E:	kact match			
			<u>0</u> K <u>C</u> ancel	

• Click on **OK**.

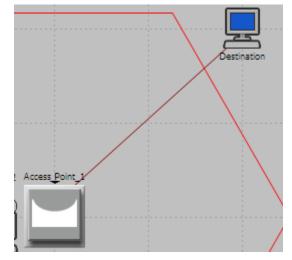
- 31. Configure High Throughput Parameters on the **Access\_Point\_1** such that the number of spatial streams is 2 and Greenfield operation is enabled.
  - Right click on Access\_Point\_1 and click on Edit Attributes.
  - Expand the Wireless LAN/Wireless LAN Parameters/ High Throughput Parameters attribute.
  - Set the attribute Number of Spatial Streams to 2
  - Observe that the attribute Guard Interval is set to Short (400ns)
  - Set the attribute Greenfield Operation to **Enabled**.
  - Click on **OK** and accept the changes

#### Connect Access Point\_1 to the Destination by a 1000BaseX link

- 32. Open the object palette by clicking on  $\square$ .
- 33. Search for **1000BaseX** link model.
- 34. Click on the **1000BaseX** as marked in the figure given below:

🛣 Object Palette Tree: 1504_	Lab1-all_11	n	
Earch by name: 1000BaseX			<u>Find Next</u>
Drag model or subnet icon into workspa	ice		
i ask conrig 			1000 Base X
1000BaseX	Duplex Link	Ethernet 1000BaseX	TOODBASEA
100BaseT 100Gbps_Ethernet	Duplex Link Duplex Link	Ethernet 100BaseT Ethernet 100Gbps Link	1000BaseX

35. Then draw a link between **Access Point\_1** and **Destination**.



- 36. Right click on empty space in project editor to bring cursor back to normal.
- 37. Close the object palette.

#### Configure Traffic in the network

The station nodes (**Mobile\_1\_1** to **Mobile\_1\_8**) shall send traffic to the **Destination**. In order to direct the traffic to the Destination, you have to set the destination address on the nodes generating traffic to the MAC address of the Destination. The MAC address of the destination is configured as 1 under **Ethernet\Ethernet Parameters\Address** attribute.

🗶 (D	estination) Attributes		
Type:	station		
A	ttribute	Value	<u> </u>
2	- name	Destination	
6	8 Ethernet		
0	Ethernet Parameters	()	
0	- Address	1	
? ?	- Frame Bursting	Enabled	
Ô	- Operational Mode	Full Duplex	

We shall configure the traffic generation attributes on the nodes using by editing the **Traffic Generation Parameters** attribute.

38. Right click on any of the mobile nodes and select Edit Attributes.

- Observe that the **Destination Address** attribute is set to **1**.
- Set the **Traffic Generation Parameters** > **Traffic Type of Service** to **Interactive Voice** (6) as shown below:

★ (Mobile_1_7) Attributes		
Type: station		
Attribute	Value	A
🕐 📺 name	Mobile_1_7	
⑦ trajectory	NONE	
⑦ Destination Address	1	
⑦	()	
⑦ - Start Time (seconds)	constant (1)	
⑦ - ON State Time (seconds)	constant (5)	
OFF State Time (seconds)	constant (0)	
Packet Generation Arguments	()	
③ Stop Time (seconds)	Never	
Traffic Type of Service	Interactive Voice (6)	
Wireless LAN		N

39. Double click on the **Value** of attribute **Traffic Generation Parameters** and set the attributes as shown in the figure below.

🛣 (Traffic Generation Parameters) Table		
Attribute	Value	<u>_</u>
Start Time (seconds)	constant (1)	
ON State Time (seconds)	constant (5)	
OFF State Time (seconds)	constant (0)	
Packet Generation Arguments	()	
Stop Time (seconds)	Never	
		•
<u>D</u> etails <u>P</u> romote	<u> </u>	

- The traffic generator is basically an ON-OFF traffic generator. The **Traffic Generation Parameters** were set using the Model Assistant file. The time at which the node will start sending traffic (**Start Time**) is set at 1 second. The **ON State Time** is configured to be 5 seconds and the **OFF State Time** is set to 0 seconds.
- 40. Click on the Value of Packet Generation Arguments.

🛣 (Packet Generation	n Arguments) Table	×
Attribute	Value	
Interarrival Time (seconds)	exponential (0.0005)	
Packet Size (bytes)	constant (500)	
Segmentation Size (bytes)	No Segmentation	
		Ţ
<u>D</u> etails <u>P</u> romot	te <u>O</u> K <u>C</u> ance	

- Set the **Interarrival Time** during the ON state is set to exponential with a mean of 0.0005 and the packet size is set at **500 bytes.**
- Note that the total expected Load on the Wireless LAN network can be computed as follows:

Load = ((Mean ON Time) / (Mean ON Time + Mean OFF Time)) \* (Packet size in bits) \* (Number of nodes Generating traffic) / (Mean Inter-arrival Time)

This implies that the Load = (5/5) \* (500 \* 8) \* 8 / (0.0005) = 64.0 Mbps

The load is configured in such a way that the WLAN queues are never empty.

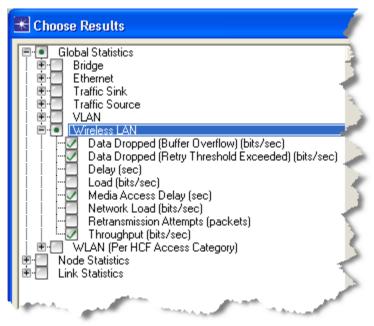
• Make these traffic changes to nodes **Mobile\_1\_1** to **Mobile\_1\_8**. A simple way to configure this may be right-clicking on one of the mobile nodes then choosing **Select Similar Nodes**. Once the attribute changes are done as described in steps 38-40 above, make sure that the **Apply to** 

**Selected Objects** option is checked, then click on OK so that the changes are applied to all mobile nodes at once.

#### **Collect Statistics**

41. Select DES/Choose Individual Statistics.

• Expand Global Statistics, and subsequently expand Wireless LAN and observe that Throughput (bits/sec), Data Dropped (Buffer Overflow) (bits/sec), Data Dropped (Retry Threshold Exceeded) (bits/sec) and Media Access Delay (sec) are selected.



42. Click **Cancel** to close the statistics selection window.

#### Run Simulation

- 43. Click on the Configure/Run Discrete Event Simulation (DES) button
- 44. Verify that the Simulation Duration is set to 30 seconds and then click the Run button
- 45. When the simulation completes click on the **Close** button.

## Measuring the impact of the legacy nodes

46. Switch to scenario **mixed\_11g\_no\_traffic** by selecting the menu option **Scenario** \ **Switch to Scenario**.

- 47. This is the exactly the same scenario as before but a **legacy\_11g** is introduced into the BSS. The legacy node is configured with **Extended Rate PHY (802.11g)** physical characteristics and data rate set to **18 Mbps.** 
  - Note that the **11g\_legacy** node does not send any traffic

迷 (leg	gacy_11g) Attributes		
Type:	station		
At	tribute	Value	•
🕐 r	name	legacy_11g	
?	trajectory	NONE	
	Destination Address	Random	
? ▪	Traffic Generation Parameters	None	
?	Traffic Type of Service	Best Effort (0)	
	Wireless LAN		
0_	- Wireless LAN MAC Address	Auto Assigned	
0	Wireless LAN Parameters	()	
0	- BSS Identifier	0	
0	<ul> <li>Access Point Functionality</li> </ul>	Disabled	
0 0 0 0	- Physical Characteristics	Extended Rate PHY (802.11g)	
	- Data Rate (bps)	18 Mbps	
0	E Channel Settings	Auto Assigned	-
	T	0.0010	

#### Run simulation

48. Click on the Configure/Run Discrete Event Simulation (DES) button



- 49. Verify that the **Simulation Duration** is set to **30 seconds** and then click the **Run** button.
- 50. When the simulation completes click on the **Close** button.

#### **View Results**

51. Click on the Hide/Show Graph Panels icon to open up Saved Template.

Subnet_0]						
NetMapper	DES	3DNV	Design	Windows	Help	
· [ 🎌 🖽	*	<b>1</b>	L L		V4 V6	
	-500		Hide	/Show Gr	aph Panels	

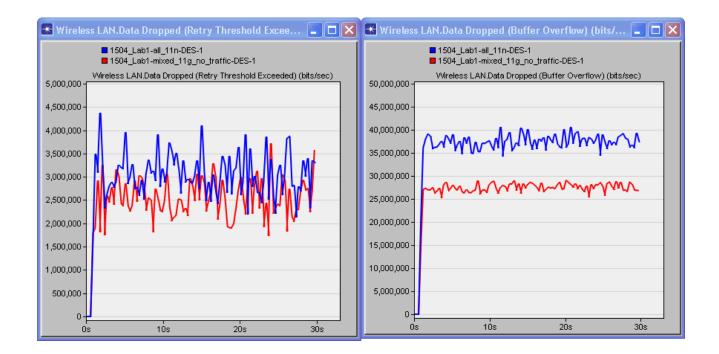
#### 52. Click on DES / Panel Operations / Panel Templates / Load With Latest Results.

)er	DES 3DNV Design Windows Help	_		
맯	Choose Individual Statistics Choose Statistics (Advanced)			
	Record Packet Flow 2D Animation For Subnet	500	600	700 80
	Record Node Movement 2D Animation For Subnet			
	Expert Service Prediction			
	Configure/Run Discrete Event Simulation Ctrl+R			
	Configure/Run Discrete Event Simulation (Advanced)			
$\checkmark$	Run Discrete Event Simulation Ctrl+Shift+R Restart Discrete Event Simulation			
		p-DES-1		
	Open DES Log Results	s/sec)		
	Play 2D Animation			
	Reports			
	Panels •			
	Panel Operations	Arrange P		
			otations	Create From All Panels
		Panel Tem Reload Da	piaces ta Into All Panels Ctrl+F5	Load With Lates Results
	·····	Keillau Da	ta Into Air Panels CUTEFS	Load With Lates Results

The graph compares the throughput achieved in the scenario where all nodes were 802.11n and the scenario where we had a 802.11g legacy nodes.

📧 Wireless LAN. Throughput (bits/sec)	🔣 Wireless LAN.Media Access Delay (sec) 📃 🗖 🔀
<ul> <li>1504_Lab1-all_11n-DES-1</li> <li>1504_Lab1-mixed_11g_no_traffic-DES-1</li> <li>Wireless LAN.Throughput (bits/sec)</li> </ul>	■ 1504_Lab1-all_11n-DES-1 ■ 1504_Lab1-mixed_11g_no_traffic-DES-1 Wireless LAN Media Access Delay (sec)
40,000,000	0.090
30,000,000	0.070- 0.060-
<sup>25,000,000</sup> 20,000,000	
15,000,000 -	0.040 - MM WW VV V WV V WV V WN
5,000,000 -	0.020 -
0 0 0s 10s 20s 30s	0.010- 0.000

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## **Results Analysis**

- The network administrator expected to see performance degradation in the presence of legacy 802.11g but to his astonishment he finds the opposite in WLAN Throughput statistics.
- Since the **Data Dropped (Retry Threshold Exceeded) (bits/sec)** is almost the same in both scenarios the loss of packets due contention conditions is the same across both scenarios.
- With eight contenders and non-empty buffers, WLAN transmissions experience a large number of collisions.
- However in mixed\_11g\_no\_traffic scenario, the higher layer packets are sent at a much faster rate which is inferred from lesser **Data Dropped (Buffer Overflow) (bits/sec)** and lesser **Media Access Delay (sec)**.
- The network administrator used default frame aggregation settings which has Aggregated MSDU enabled for Interactive Voice (6) traffic category. Aggregated MSDU (A-MSDU) is a huge frame packed with multiple MSDUs. The default maximum A-MSDU size of 3935 bytes is used by the 11n STAs in this study.
- Note that CTS-to-self is enabled by default. In the presence of legacy 802.11g STAs and with CTS-to-self is enabled, a 11n STAs transmits a CTS at 11g data rate ahead of A-MSDU frames transmitted at 11n data rates to protect them from 11g devices.
- Recovery from small CTS frame collisions is much faster compared to recovery from huge A-MSDU frame collisions. Hence having legacy devices indirectly improves network throughput.

#### EXTRA CREDIT:

Can you suggest the network administrator another way to improve throughput without having legacy 11g nodes in the BSS and using CTS-to-self protection?

**Answer:** Set RTS Threshold such that huge frames are protected by RTS/CTS frame exchange. When transmitting large packets it is always recommended to precede it with an RTS/CTS frame exchange to improve the overall network throughput.

## Conclusion

It is general notion that legacy STAs in the BSS will be detrimental to network performance. Here we see a situation where it actually improves the 11n throughput when CTS-to-self protection is enabled. You can take a look at the **WLAN** example network scenarios **11b\_11g\_coexistenece** and **11n\_11g\_11b\_roaming**, which study the impact of legacy nodes in other situations. Simulations of WLANs using Modeler reveal such interesting situations and help us plan our network better.

# LAB 2: Improving Performance with QoS Aware Wireless LAN Layer

## Overview

The network administrator of an enterprise has been asked to dimension the company's wireless network to support voice users. Currently, the wireless network is an 802.11n network and the most used applications are HTTP and Email. The administrator decides to study the feasibility of using the current network to support voice users. If the network does not perform suitably he plans to tune QoS features in the network to prioritize voice users.

## Objective

Assess the performance of high-quality voice application together with HTTP application in an 11n infrastructure Wireless LAN BSS operating at 7.2 Mbps

Improve the performance of the network further by adjusting 802.11e parameters based on application load and topology conditions in the network.

## Methodology

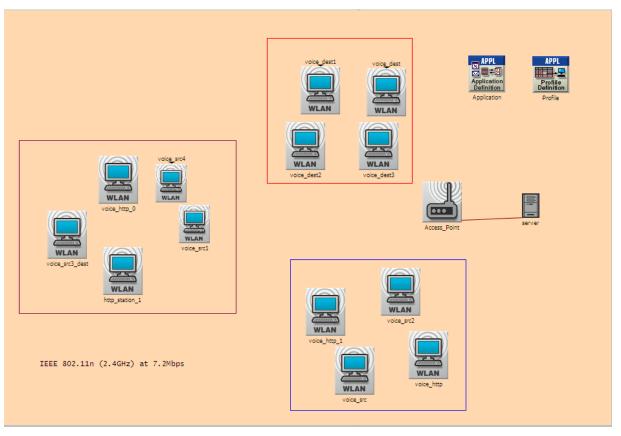
Create the baseline infrastructure BSS operating at 7.2 Mbps with WLAN workstations running voice and HTTP application, and measure the performance observed at application layer with default 11e settings.

In the second scenario, adjust the related EDCA parameters based on network and traffic conditions and change the acknowledgement policies for the traffic categories corresponding to application traffic, and then compare the performance observed at the application layer against the performance measured with default parameters.

## **Observe baseline network running 802.11n**

## Open the scenario

- 1. Start Riverbed Modeler Academic Edition 17.5, if it is not already started.
- 2. Select File/Open and select 1504\_Lab2 and click Open to open the project for lab 2.
- 3. Maximize the project by clicking on the **maximize** button on the top right corner of the project editor.
- 4. Make sure that you are in "voice\_baseline" scenario.



- 5. Application configuration in the network is as follows:
  - a. There are total of 8 workstations running voice application as voice data source and calling 5 workstations configured as voice destinations ("**voice\_src3\_dest**" is configured both as voice source and voice destination).
  - b. All voice source and destination nodes belong to the same BSS and hence all voice traffic has to flow through AP.
  - c. The voice application is configured to generate G.711 encoded voice traffic at 64kbps.
  - d. There are 4 workstations running HTTP web browsing application (the stations whose names start with prefix "**voice\_http**" are running both voice and HTTP browsing applications).
  - e. HTTP clients connect their server node "server" through the access point.

#### Wireless LAN workstation settings

- 1. All the nodes are configured with HT PHY 2.4GHz (802.11n) with data rate "6.5 Mbps (base) / 60 Mbps (max)".
  - a. Number of Spatial Streams is set to 1, 40MHz Operation Parameters is set to Disabled and Guard interval is set to Short (400ns). Therefore the physical data rate that will be used is 7.2Mbps.

2. The attribute **Wireless LAN Parameters** \ **HCF Parameters** is set to **Default** on all wireless LAN workstation nodes.

$\odot$	; man nooono Eroano (ooooj	0.0
2	- Buffer Size (bits)	256000
2	- Roaming Capability	Disabled
0 0	- Large Packet Processing	Drop
2	PCF Parameters	Disabled
0 0	HCF Parameters	Default
0	High Throughput Parameters	

3. The attribute **Wireless LAN Parameters** \ **HCF Parameters** is set to **Default** (**QAP**) on the **Access\_Point**.

	; moanning capability	Disabica	
1	<ul> <li>Large Packet Processing</li> </ul>	Drop	
1	PCF Parameters	Disabled	
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	HCF Parameters	Default (QAP)	
?	High Throughput Parameters	Default 802.11n Settings	-
		1	Advanced

4. Click **Cancel** to close dialog box if opened.

All WLAN nodes in the network are 11e-capable such that they will contend for the medium according to EDCA rules, and the values of EDCA parameters are set to 802.11e recommended values.

As per the QoS prioritization at the WLAN layer, Voice and HTTP traffic will be mapped to WLAN Voice and Best Effort access categories, respectively.

In the figure below, we can see that HTTP is configured to use Type of Service "0".

	★ (Http) Table		×
	Attribute	Value	<b>A</b>
	HTTP Specification	HTTP 1.1	
APPL	Page Interarrival Time (seconds)	exponential (15)	
	Page Properties	()	
Application	Server Selection	()	
Definition	RSVP Parameters	None	
	Type of Service	Best Effort (0)	
			Ŧ
	<u>D</u> etails <u>P</u> romote	<u> </u>	

The table below, excerpted from IEEE 802.11e standard, shows the mapping of User Priority (Type of Service) values to the access categories.

Priority	UP (Same as 802.1D user priority)	802.1D designation	AC	Designation (informative)
Lowest	1	вк	AC_BK	Background
		—	AC_BK	Background
	Ő	BE	AC_BE	Best Effort
	3	EE	AC_BE	Best Effort
•	4	CL	AC_VI	Video
Highest	5	VI	AC_VI	Video
	6	VO	AC_VO	Voice
	7	NC	AC_VO	Voice

Table 20i-UP-to-AC mappings

\* Source: IEEE Std 802.11e-2005

Similarly voice application is configured to use Type of Service "6", which is mapped to voice AC as seen in the table above.

1	K (Voice) Table	×
	Attribute	Value 🔄
	Silence Length (seconds)	default
	Talk Spurt Length (seconds)	default
/	Symbolic Destination Name	Voice Destination
APPL	Encoder Scheme	G.711
Na=≠0	Voice Frames per Packet	1
Application	Type of Service	Interactive Voice (6)
Definition	RSVP Parameters	None
	Traffic Mix (%)	All Discrete
	Signaling	None
$\langle \rangle$	Compression Delay (seconds)	0.02
	Decompression Delay (seconds)	0.02
	<u>D</u> etails <u>P</u> romote	<u> </u>

5. Click **Cancel** all the way to close the dialog boxes.

#### Run simulation and load results

- 1. Click on the **Configure/Run Discrete Event Simulation (DES)** button
- 2. Note that the simulation Duration is "120 seconds".
- 3. Click **Run**.

The simulation will take about 1 to 2 minute to execute.

4. When the simulation completes click on the **Close** button.

5. Click on the **Hide/Show Graph Panels** button



6. Select DES/Panel Operations/Panel Templates/Load with Latest Results.

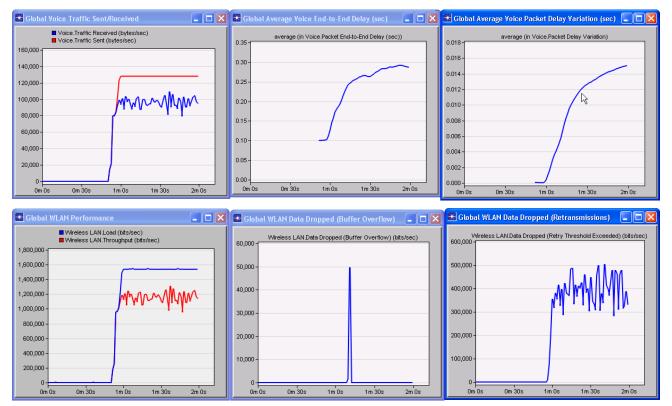
The panels will be updated with the latest results.

## Results analysis

STOP

HTTP.Page Response Time (seconds)	AN (Per HCF Access Category).Data Dropped (Retry Threshold Exceeded) ( 1,200
16-	
	1,000 -
14-	800 -
10-	600 -
8-	400-
4-	200-
2-	
	10- 8- 8- 4-

The performance of HTTP application is poor. Only one page is downloaded before 60 • seconds and no object or page information is downloaded after 60 seconds, due to increasing voice traffic in the network.



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- The Data Dropped due to buffer overflow is fairly low.
- Considerable amount of data drops due to excessive retransmissions indicating tough contention conditions and possibly a "too-small" contention window used by contending stations.
- In conclusion, with default 11e parameters it is observed that voice application has a better throughput than the HTTP but still has some losses and longer delays while secondary application, HTTP, is still not networkable.
- High number of WLAN layer retransmissions implies the main bottleneck at layer-2 needs to be tackled for further improvement.
- The network administrator decides that using QoS would be beneficial and has potential to address the requirements but realizes that he would have to fine tune parameters to satisfy performance constraints before deployment.



## Performance tuning for 11e network

• Please refer to presentation for a discussion on WLAN protocol behavior related to the attribute configurations we will perform in this part of the lab.

## Adjust contention window for Voice access category

- 1. Select Scenarios/Switch To Scenario.
- 2. Select "voice\_11e\_better" scenario.

This is the same network as in "voice\_baseline" scenario.

- 3. Configure AP to use a larger CWmax for Voice access category.
  - a. Right click on "Access\_Point" and choose Edit Attributes.
  - b. Expand the attribute Wireless LAN/Wireless LAN Parameters.
  - c. Set the attribute HCF Parameters/EDCA Parameters/Access Category Parameters/Voice/CWmax to "15"
  - d. Do not close the window. Continue reading.
- 4. Make all other WLAN workstations use a larger CWmax for Voice access category too by setting the following attribute on the node "Access Point".
  - a. Set the attribute HCF Parameters/AP Specific Parameters/Parameters Advertised in BSS/EDCA Parameter Set/Voice/CWmax to "15".

- b. Since EDCA parameters used by the WLAN nodes in the BSS are advertised by the access point (because **EDCA Parameter Set Distribution** is "**Enabled**") this change is sufficient to make all the WLAN workstations use the new CWmax value for their Voice access categories.
- c. Do not close the window. Continue reading.

∗	(Access_Point) Attributes				
Тур	Type: router				
	Attribute	Value	<b></b>		
2	EDCA Parameters	()			
2	Access Category Parameters	()			
	E Voice	()			
2	- CWmin		min + 1) / 4 - 1		
0	- CW/max	15			
2	AIFSN	1			
2	TXOP Limits	Default			
0	🗉 Video	Default (Q	AP)		
0	🖲 Best Effort	Default (Q	AP)		
0	🖲 Background	Default (Q	AP)		
0	Traffic Category Parameters (8 R	()			
0	Block ACK Capability	Supported	1		
0	AP Specific Parameters	()			
0	Parameters Advertised in BSS	()			
0	EDCA Parameter Set Distri	Enabled			
0	🖻 EDCA Parameter Set	()			
0	🗏 Voice	()			
0	- CW/min		min + 1) / 4 - 1		
0	- CWmax	15			
0	AIFSN	2			
1	TXOP Limits	Default			
0		Filter	Advanced		
		Tuco	Apply to selected objects		
	Exact match		<u> </u>		

#### Switch to "No Acknowledgement" policy for voice traffic

To help with the reduction of end-to-end delays for voice traffic and to improve the WLAN layer performance for both applications by lowering its overhead, we will turn off layer-2 acknowledgements for Voice Access Category traffic.

After this configuration change, WLAN protocol will start performing RTS/CTS frame exchange before the first frame of Voice AC TXOPs (transmission opportunities) in order to provide protection for the unacknowledged voice traffic at layer-2 by reserving the medium in a confirmed manner.

Hence retransmissions (of RTS frames instead of data frames) and packets due to reaching retry limit are still probable.

- 5. Set Service Class of Voice Traffic Category to "No Acknowledgement" on AP
  - a. Edit the attribute **Traffic Category Parameters** by left clicking on its value and selecting **Edit...**.
  - b. Set Service Class for TID (Traffic Identifier) "6 (Interactive Voice)" to "No Acknowledgement".

\star (Traffic	Category Parameters)	Table		×
	TID	Service Class	Block ACK Usage	
0	1 (Background)	QoS ACK (Normal or Bloc	Disabled	
1	2 (Standard)	QoS ACK (Normal or Bloc	Disabled	
2	0 (Best Effort)	QoS ACK (Normal or Bloc	Disabled	
3	3 (Excellent Effort)	QoS ACK (Normal or Bloc	Disabled	
4	4 (Streaming Multimedia)	QoS ACK (Normal or Bloc	Disabled	
5	5 (Interactive Multimedia)	QoS ACK (Normal or Bloc	Disabled	
6	6 (Interactive Voice)	No Acknowledgement	Disabled	
7	7 (Reserved)	QoS ACK (Normal or Bloc	Disabled	
				-
8	Rows Delete	Insert Dyplicate	Move Up Move Down	
D <u>e</u> tails	Promote S	how row labels	<u> </u>	

- c. Since priority (ToS) of voice application traffic is set to "6" in application configuration, the voice traffic is mapped to TID "6 (Interactive Voice)" at WLAN layer.
- d. Click on the **OK** buttons twice to complete AP's configuration.
- 6. Make the same configuration for all WLAN workstations.
  - a. Right click on one of the workstations and choose Select Similar Nodes.
  - b. Right click on one of the selected nodes and choose Edit Attributes.
  - c. Check the Apply changes to selected objects box.
  - d. Expand the attribute Wireless LAN/Wireless LAN Parameters/HCF Parameters.
  - e. Edit the attribute **Traffic Category Parameters** by left clicking on its value and selecting **Edit...**

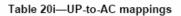
f.Set Service Class for TID (Traffic Identifier) "6 (Interactive Voice)" to "No Acknowledgement"

g. Click on the **OK** buttons twice to complete the attribute configuration.

## Promote HTTP traffic from Best Effort to a higher WLAN access category

- 7. Configure HTTP traffic to use a better ToS, namely "Streaming Multimedia (4)".
  - a. This will make HTTP traffic be mapped to "Video" access category at the WLAN layer.

Priority	UP (Same as 802.1D user priority)	802.1D designation	AC	Designation (informative)	
Lowest	1	BK	AC_BK	Background	
	2		АС_ВК	Background	
	9	BE	AC_BE	Best Effort	
	3	EE	AC_BE	Best Effort	
	4	CL	AC_VI	Video	
Highest	5	VI	AC_VI	Video	
	6	vo	AC_VO	Voice	
	7	NC	AC_VO	Voice	



\* Source: IEEE Std 802.11e-2005

- b. Right click on "Application" node and select Edit Attributes.
- c. Set the attribute **Application Definitions/http (Description)/Http/Type of Service** to "**Streaming Multimedia (4)**".
- d. Close all windows by clicking **OK** on all of them.

K (Applicat	ion) Attributes		PL ∓⊡ ation
Attribute		Value	ation
🕐 🐺 name		Application	
🕐 🗏 Applica	tion Definitions	()	
- Num	ber of Rows	2	
😑 http			
? No	ame	http	
() ED	escription	[]	
0	Custom	Off	
0	Database	Off	
0	Email	Off	
0	Ftp	Off	
	Http	[]	
	Print	Off	
0	🛣 (Http) Table		
	Attribute	Value	
E voice			
€ MOS	HITP Specification	HTTP 1.1	
🕐 🗉 Voice E	Page Interarrival Time (second		
	Page Properties Server Selection	[]	
	Server Selection RSVP Parameters	() None	
	Type of Service	Streaming Multimedia (4)	
	Type of Service	oreaning Multimedia (4)	
1		-	
Exact mate	Details Promote	   OK Cancel	

As HTTP is mapped to a higher priority access category, although it is still a lower priority than the one used by voice traffic, now we expect HTTP traffic to perform better at the WLAN layer.

#### Run simulation and load results

- 1. Click on the Configure/Run Discrete Event Simulation (DES) button
- 2. Note that the simulation **Duration** is "120 seconds".
- 3. Click Run.

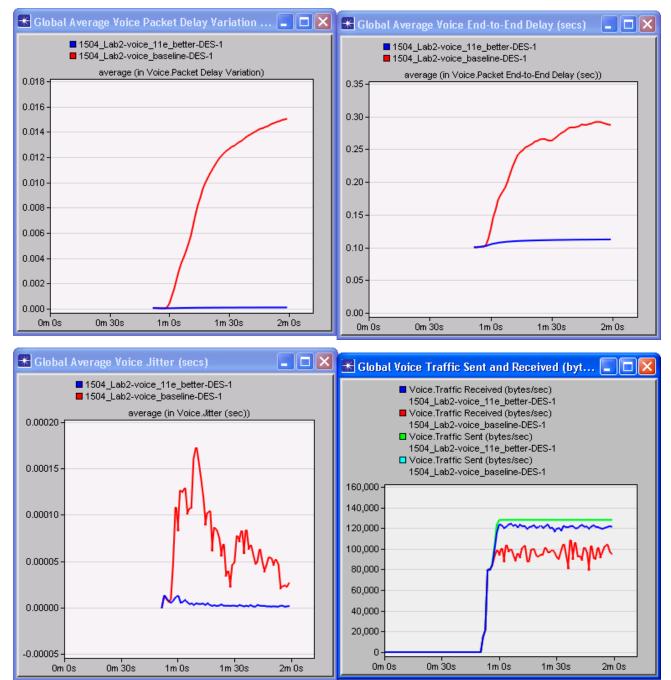
The simulation will take about 1 minute to execute.

- 4. When the simulation completes click on the **Close** button.
- 5. Click on the **Hide/Show Graph Panels** button
- 6. Select DES/Panel Operations/Panel Templates/Load with Latest Results.

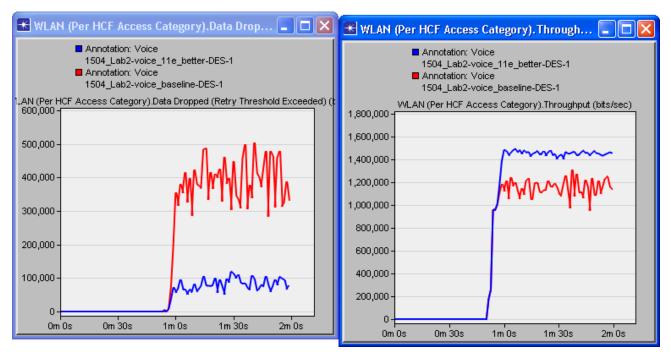
The panels will be updated with the latest results.



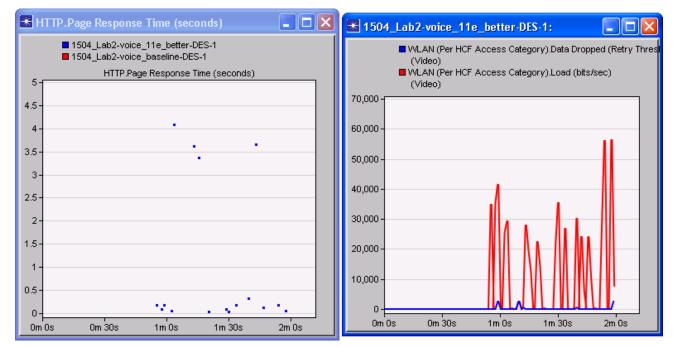
#### Results analysis



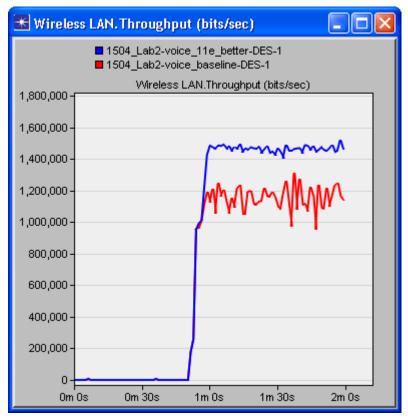
• Great news for voice users: with the adjustment of related WLAN 802.11e parameters, we increased the quality of voice calls across our network by reducing end-to-end, delay variation and jitter values as well as increasing the percentage of voice traffic that could be successfully delivered from source to destination.



- In addition to the increase in Voice AC throughput, we also achieved a decrease in amount of dropped Voice AC data due to reaching retry limit.
- The dropped data due to retry threshold exceeded has significantly reduced for Voice access category compared to previous scenario.
- Apparently our adjustment of maximum contention window size worked out and made Voice ACs of the WLAN nodes contend for the medium more efficiently.



- Now we have also good news for HTTP clients: their HTTP application traffic is not blocked by voice traffic anymore. Page downloads complete even when all the voice users are active.
- The percentage of HTTP packet drops at WLAN layer (i.e., drops reported by Video access category) is low.
- Any lost HTTP data is retransmitted by the TCP layer.
- To conclude, by adjusting Traffic Category parameters and EDCA parameters used in prioritized medium access based on the conditions in our network, we configured the WLAN layer, such that now it performs at a level that provides acceptable quality for all applications running in our network.



- The considerable increase in global WLAN layer throughput with the same physical layer also confirms the positive outcome of our parameter adjustments.
- 1. Click on the **Hide/Show Graph Panels** button is to hide the graphs.
- 2. Type **Ctrl+S** to save the project

## List of ACRONYMS

## **Riverbed Acronyms**

- DES: Discrete Event Simulation
- TMM: Terrain Modeling Module

## General IEEE 802.11 related

- IEEE: Institute of Electrical & Electronics Engineers
- LAN: Local Area Network
- WLAN: Wireless LAN (a name used for IEEE 802.11 Technology)
- BSS: Basic Service Set
- MAC: Medium Access Control
- PHY: Physical (layer)
- AP: Access Point
- STA: A station that contains a WLAN MAC/PHY interface
- MANET: Mobile Ad Hoc Network

## IEEE 802.11 Acronyms (PHY Related)

- FHSS: Frequency Hopping Spread Spectrum
- DSSS: Direct Sequence Spread Spectrum
- IR: Infrared Light
- OFDM: Orthogonal Frequency Division Multiplexing
- ERP-OFDM: Extended Rate PHY-OFDM
- CCK: Complimentary Code Keying

## IEEE 802.11 Acronyms (Medium Access)

- CSMA/CA: Carrier-Sense Multiple Access with Collision Avoidance
- DCF: Distributed Coordination Function
- CP: Contention Period
- PCF: Point Coordination Function
- CFP: Contention Free Period
- NAV: Network Allocation Vector
- CW: Contention Window
- RTS: Request To Send frame
- CTS: Clear To Send frame
- ACK: Acknowledgement frame
- IFS: Inter-frame Space
- SIFS: Short IFS
- PIFS: PCF IFS
- DIFS: DCF IFS
- EIFS: Extended IFS
- AIFS: Arbitration Inter-frame Space

## IEEE 802.11 Acronyms (802.11e Related)

- HCF: Hybrid Coordination Function
- EDCA: Enhanced Distributed Channel Access
- AC: Access Category
- TXOP: Transmission Opportunity
- AIFS: Arbitration Inter-frame Space
- AIFSN: Arbitration Inter-frame Space Number
- ToS: Type of Service
- QoS: Quality of Service
- TC: Traffic Category
- BAR: Block Acknowledgement Request
- BA: Block Acknowledgement
- ADDBA: Add Block-ACK
- DELBA: Delete Block-ACK