

IEEE 802.11 WLAN: QoS for Data and Voice Services

Objective

The purpose of this lab is to study the capability of IEEE 802.11 WLAN networks to deliver adequate QoS to voice and data applications.

Case Study

A company wants to deploy a VoIP application in its IEEE 802.11 WLAN. Currently, the main applications used in the WLAN are Web browsing and email.

The IT Department decides to study the feasibility of deploying the VoIP application in the WLAN and plans to use for this purpose (if necessary) the enhanced QoS mechanisms introduced in the IEEE 802.11e amendment. The study is made on an infrastructure BSS, shown in Figure 1, which is typical for the company's network. The BSS operates at 6 Mbps. Overall, the test network consists of 13 stations, an access point, and an HTTP server. The applications are configured as follows:

- Voice application: The voice application is configured to generate G.711 encoded voice traffic at 64 Kbps. All voice data sources and destinations belong to the BSS, hence all voice traffic flows through the AP. There are 8 workstations configured as voice data sources.
- HTTP application: There are 4 workstations running HTTP Web browsing application. The HTTP clients connect to their HTTP server through the AP.

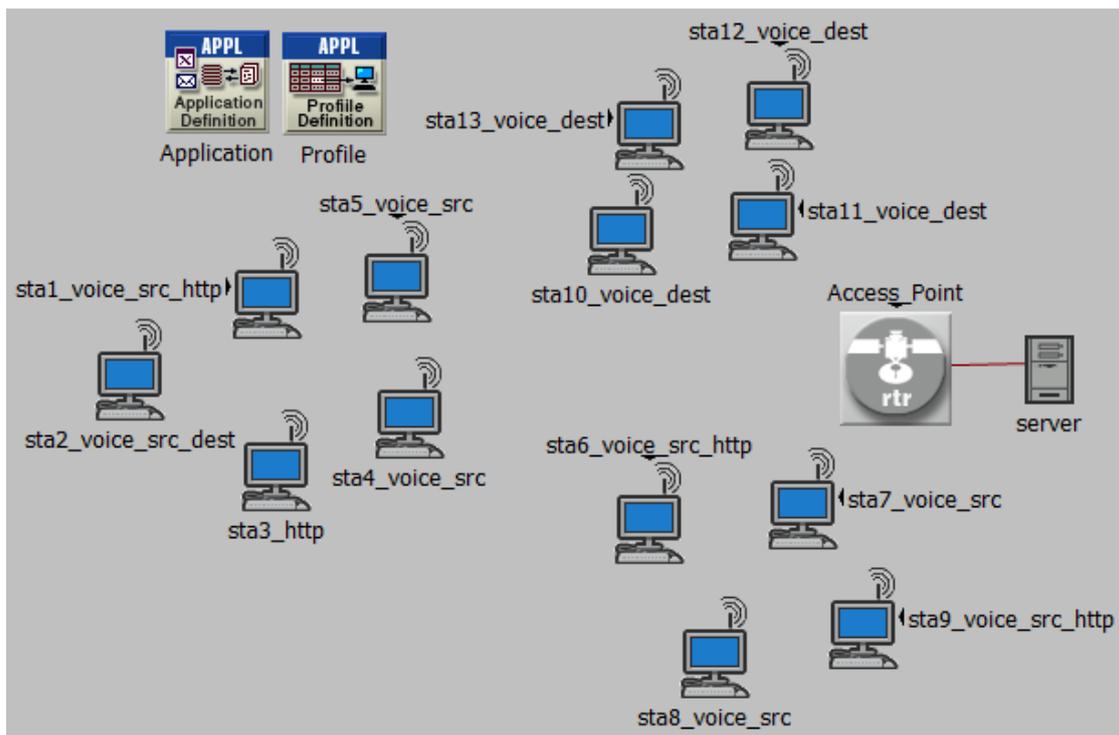


Figure 1. Network configuration: a BSS with 13 stations running voice and data applications.

Main phases

1. Create the baseline BSS shown in Figure 1, without 802.11e QoS mechanisms. Measure the performance of the baseline BSS.
2. Enable on all WLAN stations and the AP the 802.11e EDCA (Enhanced Distributed Channel Access) protocol with default EDCA parameters. Map the VoIP and HTTP traffic to AC_VO (Voice) and AC_BE (Best Effort) EDCA access categories, respectively. Measure the performance of the WLAN for EDCA with default parameters (Table 1). Compare it with the performance of the baseline configuration.

- Based on these results, adjust the EDCA parameters such that to improve the QoS for the target applications.

Measure the performance of the WLAN for EDCA with adjusted parameters. Compare it with the performance of the default EDCA configuration.

- Modify the acknowledgement policy in order to further improve the QoS for the VoIP application (mainly the end-to-end packet delay).

Measure the performance of this configuration and then make the final assessment of the feasibility of deploying the VoIP application in the WLAN.

Overview of IEEE 802.11e QoS mechanisms

The amendment 802.11e extends the 802.11 MAC sub-layer by introducing the Hybrid Coordination Function (HCF) in order to provide enhanced QoS support (Figure 2).

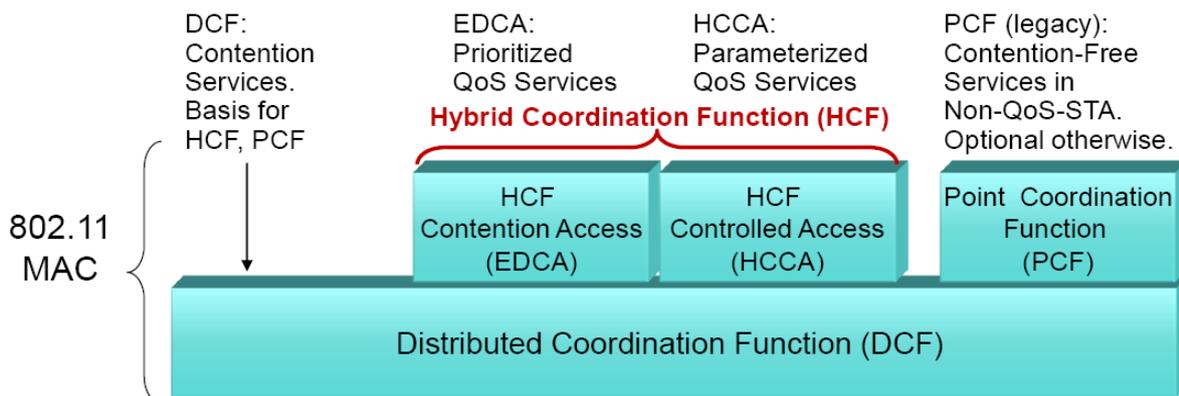


Figure 2. MAC sub-layer architecture with 802.11e QoS enhancements.

The HCF provides two medium access mechanisms:

- Contention-based channel access, called Enhanced Distributed Channel Access (EDCA). EDCA enhances the DCF medium access (CSMA/CA) in order to provide differentiated, distributed access based on user priorities. It defines 4 access categories aimed at supporting 4 service types: background (lowest priority), best effort, video, and voice (highest priority). EDCA uses for this purpose a different set of backoff parameters for each access category, such that traffic priority matches the probability of winning medium access during CSMA/CA contention (Table 1).
- HCF controlled channel access (HCCA): HCCA uses a centralized hybrid coordinator (HC), collocated with the AP of the BSS, and provides polling-based contention-free access according to QoS parameters. The HC grants medium access as needed to meet the QoS requirements of (registered) traffic streams, by polling the stations during periodic contention-free periods (similar to PCF), as well as during contention periods.

Table 1. EDCA Access Categories (AC) and default values of the backoff parameters.

AC	CWmin	CWmax	AIFSN	Designation
AC_BK	15	1023	7	Background
AC_BE	15	1023	3	Best Effort
AC_VI	7	15	2	Video
AC_VO	3	7	2	Voice

1. The baseline WLAN configuration

1.1. Start the OPNET Modeler and open the project RMR_Lab_3 (File > Open, navigate to the project folder, and double-click on RMR_Lab_3). The project opens with the Baseline scenario and displays the network configuration shown in Figure 1. The baseline WLAN is already configured, including the voice and data applications.

1.2. Examine the initial configuration of the WLAN stations and the access point (Figure 3).

Right-click on the icon of a device (workstation, access point), select Edit Attributes, and examine the WLAN parameters and the applications. The name of a station describes the applications it runs (Voice or/and HTTP) and its role (Voice Source or/and Destination).

Notice that all the devices are configured to use 802.11g PHY Layer and to operate at 6 Mbps. Moreover, in the initial configuration the advanced QoS support provided by the HCF is not supported, hence EDCA is not available.

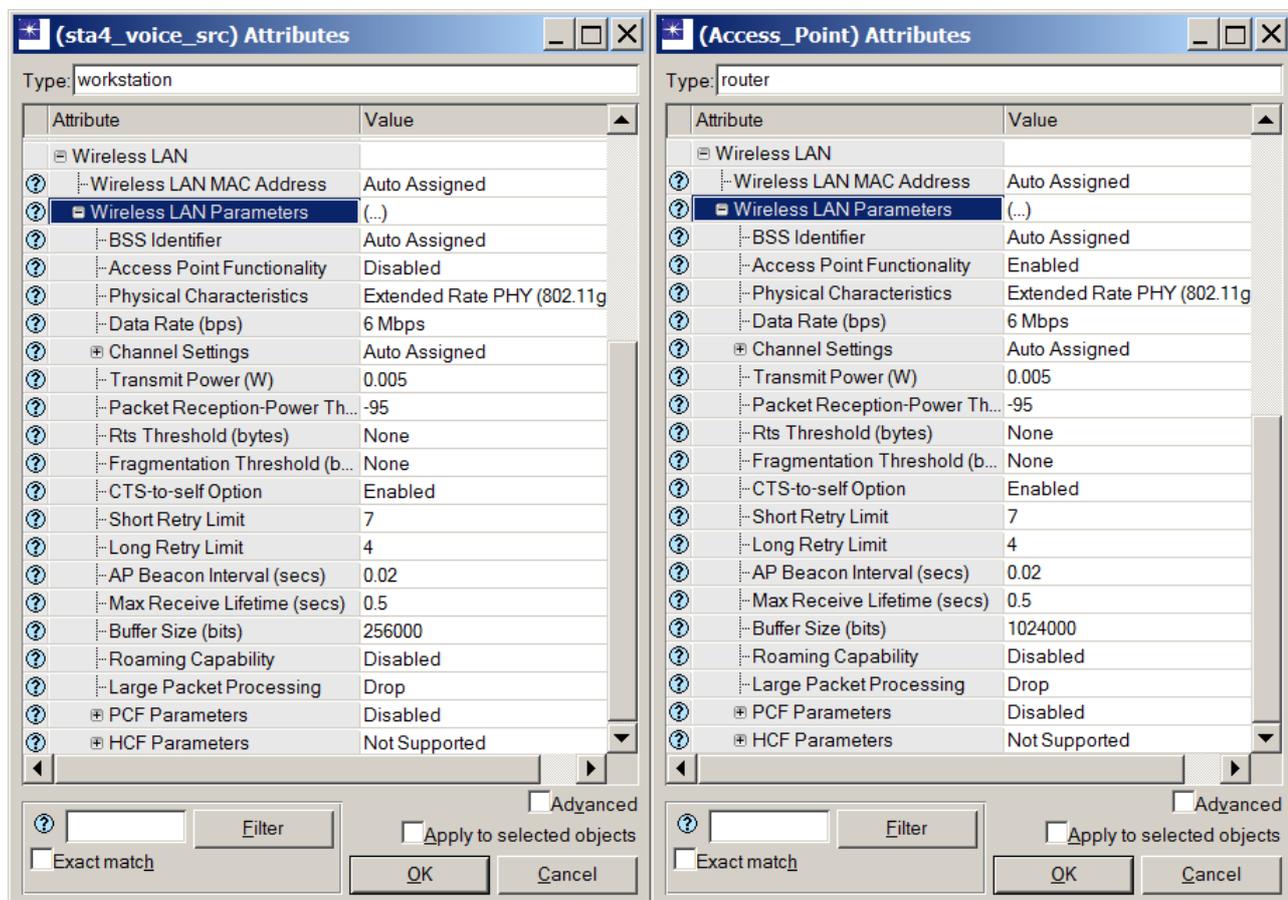


Figure 3. Initial configuration of the WLAN stations and the AP.

1.3. Examine the initial configuration of the voice and data applications (Figure 4).

Right-click on the Application icon, select Edit Attributes, and examine the description of the HTTP and Voice applications. Notice the ToS configured for these applications. However, in the initial configuration, the MAC sublayer handles all the traffic as Best Effort traffic (no mechanisms for service differentiation).

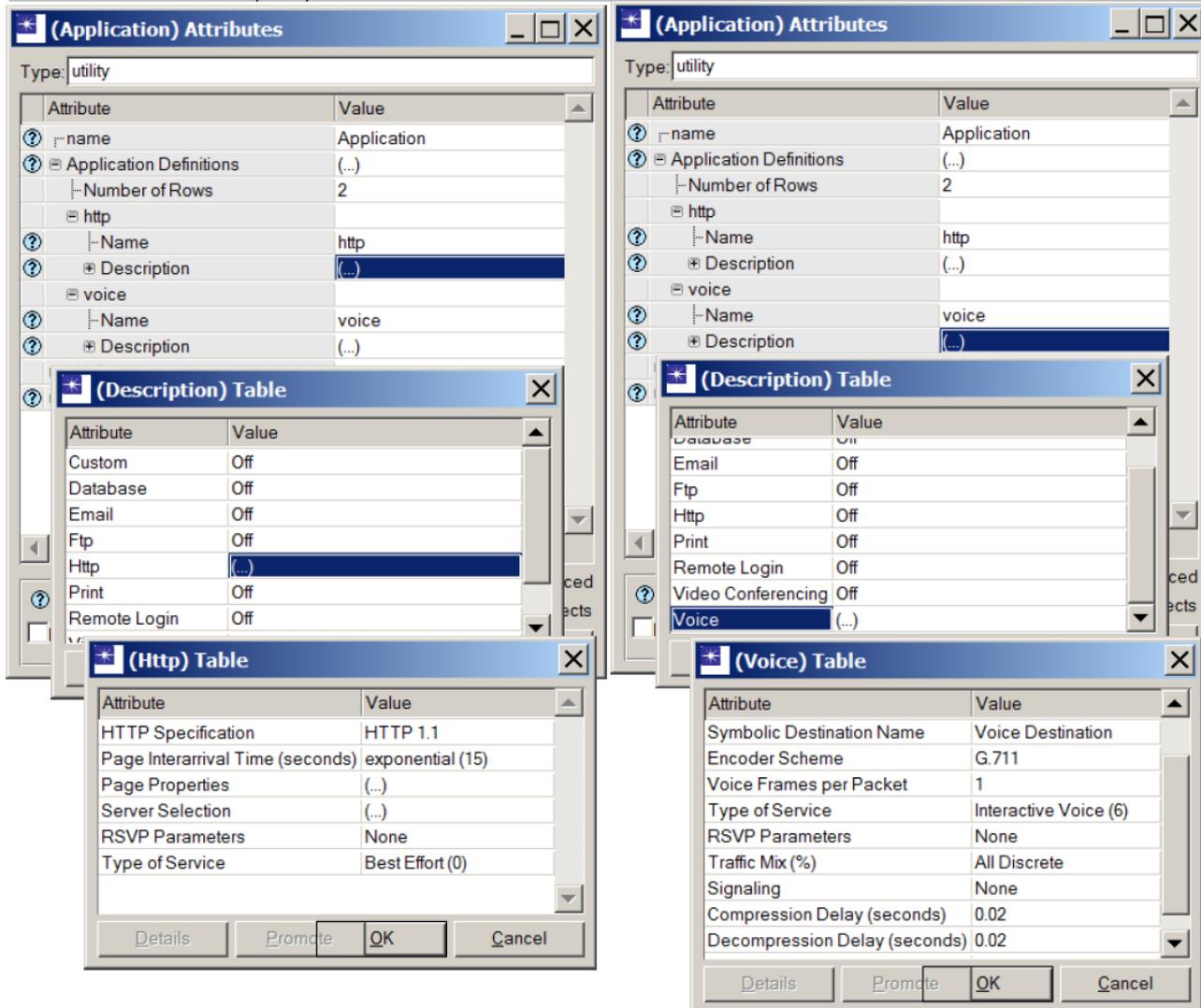


Figure 4. Initial configuration of the voice and data applications.

1.4. Run the simulation in order to determine the performance of the baseline WLAN configuration.

Click the button Configure/Run Discrete Event Simulation (DES) in the Project Editor (or select in the menu DES > Configure/Run Discrete Event Simulation). The dialog box Configure/Run DES appears. Set Simulation Kernel to Optimized and Duration to 120 seconds.

Click Run to launch the simulation. Click Close when finished.

1.5. Examine the results. Click the button View Results in the Project Editor and examine the statistics shown in Figure 5. Examples:

- For Voice application performance, select Global Statistics > Voice and then Packet End-to-End Delay and Packet Delay Variation, then set Presentation > Overlaid Statistics.
- For WLAN performance, select Global Statistics > Wireless LAN and then Network Load and Throughput, then set Presentation > Overlaid Statistics.

Analyze the results and explain what happens. To view the definitions of the statistics, right-click on the project window, select Choose Individual DES statistics, then select Wireless LAN in either Global Statistics or Node Statistics, and the particular statistics you are interested in.

1.6. Use Object Statistics to figure out which is the bottleneck, i.e., in which device are the packets delayed (queuing and medium access delays) and dropped.

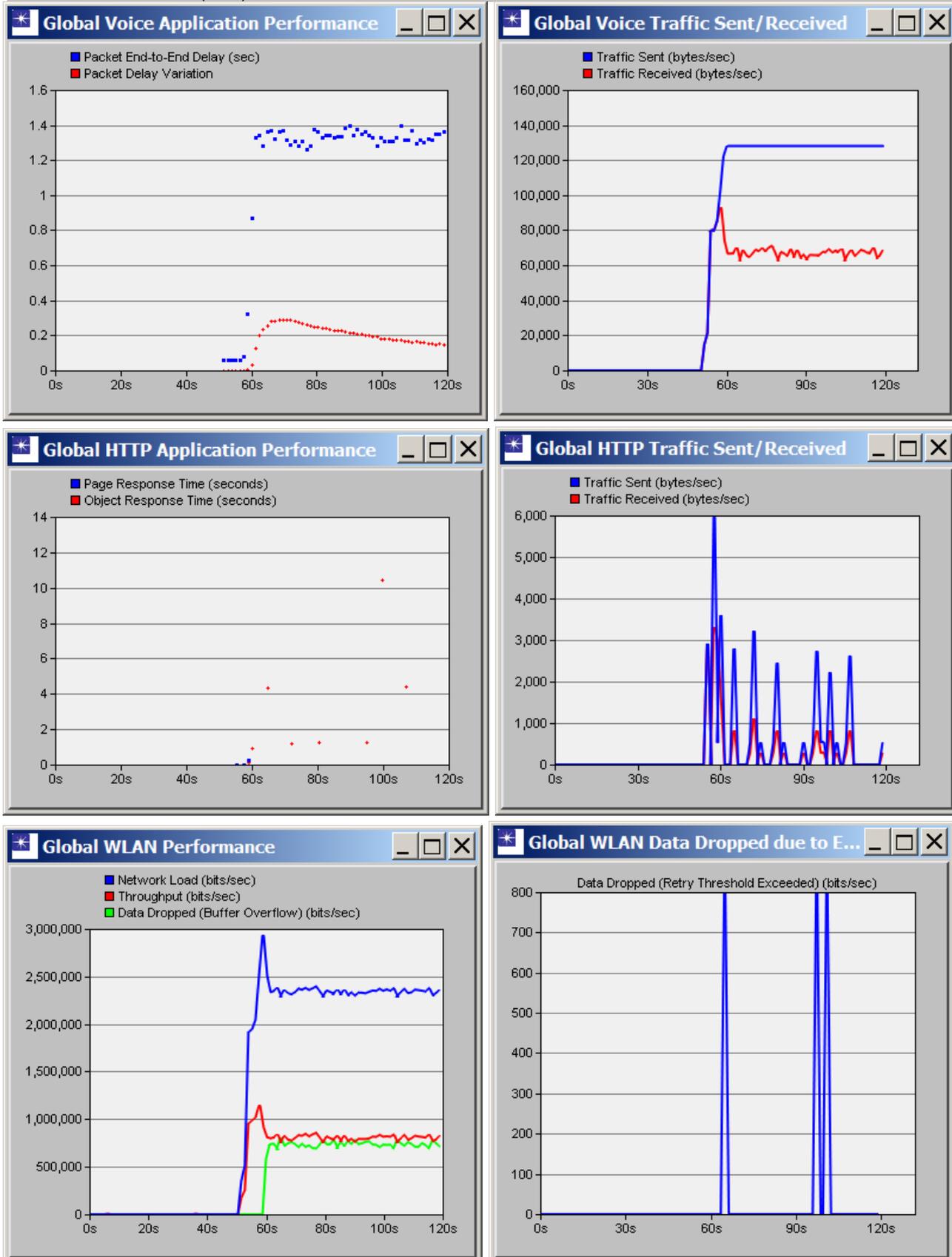


Figure 5. Performance of the baseline WLAN configuration.

1.7. Summary of baseline WLAN performance.

The results of the simulation show that the current configuration is not suitable for adding the voice application to the existing data application:

- Application performance: For both applications, most of the packets are dropped. The end-to-end delay is excessive, especially for the voice application. The voice application is not usable in the baseline configuration and, furthermore, it also hinders the data application.
- WLAN performance: The network is strongly congested. Throughput is roughly 1/3 of the network load and 1/2 of WLAN load. Packets are dropped due to buffer overflow (mainly) and retry threshold exceeded (occasionally).
- Note, however, that the load of the WLAN (about 1.6 Mbps) is much less than the channel capacity (6 Mbps), so congestion seems to be caused by inefficient use of the available bandwidth.

2. Enable EDCA with default parameters

We enable now EDCA, trying to solve the performance issues of the baseline configuration by providing differentiated services for the voice application and the data applications. As you have seen in step 1.3, the applications are already configured to request a suitable type of service.

We use the EDCA access category AC_VO for the voice application (highest priority) and AC_BE for the data application. We first try to use EDCA with the default parameters specified in the standard.

2.1. Create a new scenario starting from the initial one.

Select Scenarios > Duplicate Scenario and name the new scenario "voice_802_11e_default".

2.2. Enable EDCA on the wireless stations.

Right-click on one of the workstations and choose Select Similar Nodes. Right-click on one of the selected nodes and choose Edit Attributes. Check the box Apply to selected objects.

Expand Wireless LAN > Wireless LAN Parameters and set HCF Parameters to "Default".

Click OK to commit the changes to all the wireless workstations.

2.3. Enable EDCA on the access point.

Right click on the access point and choose Edit Attributes.

Expand Wireless LAN > Wireless LAN Parameters and set HCF Parameters to "Default (QAP)".

Click OK to commit the changes.

2.4. Run the simulation in order to determine the performance of the baseline WLAN configuration.

Click the button Configure/Run Discrete Event Simulation (DES) in the Project Editor (or select in the menu DES > Configure/Run Discrete Event Simulation). The dialog box Configure/Run DES appears. Set Simulation Kernel to Optimized and Duration to 120 seconds.

Click Run to launch the simulation. Click Close when finished.

2.5. Examine the results.

Click the button View Results in the Project Editor and examine the statistics shown in Figure 6.

Analyze the results and determine what has changed after enabling EDCA. In particular:

- How did the throughput change for the WLAN and for the voice application?
- How did the end-to-end delay change for the voice application?
- What happened to the dropped voice packets?
- What happened to the HTTP application?

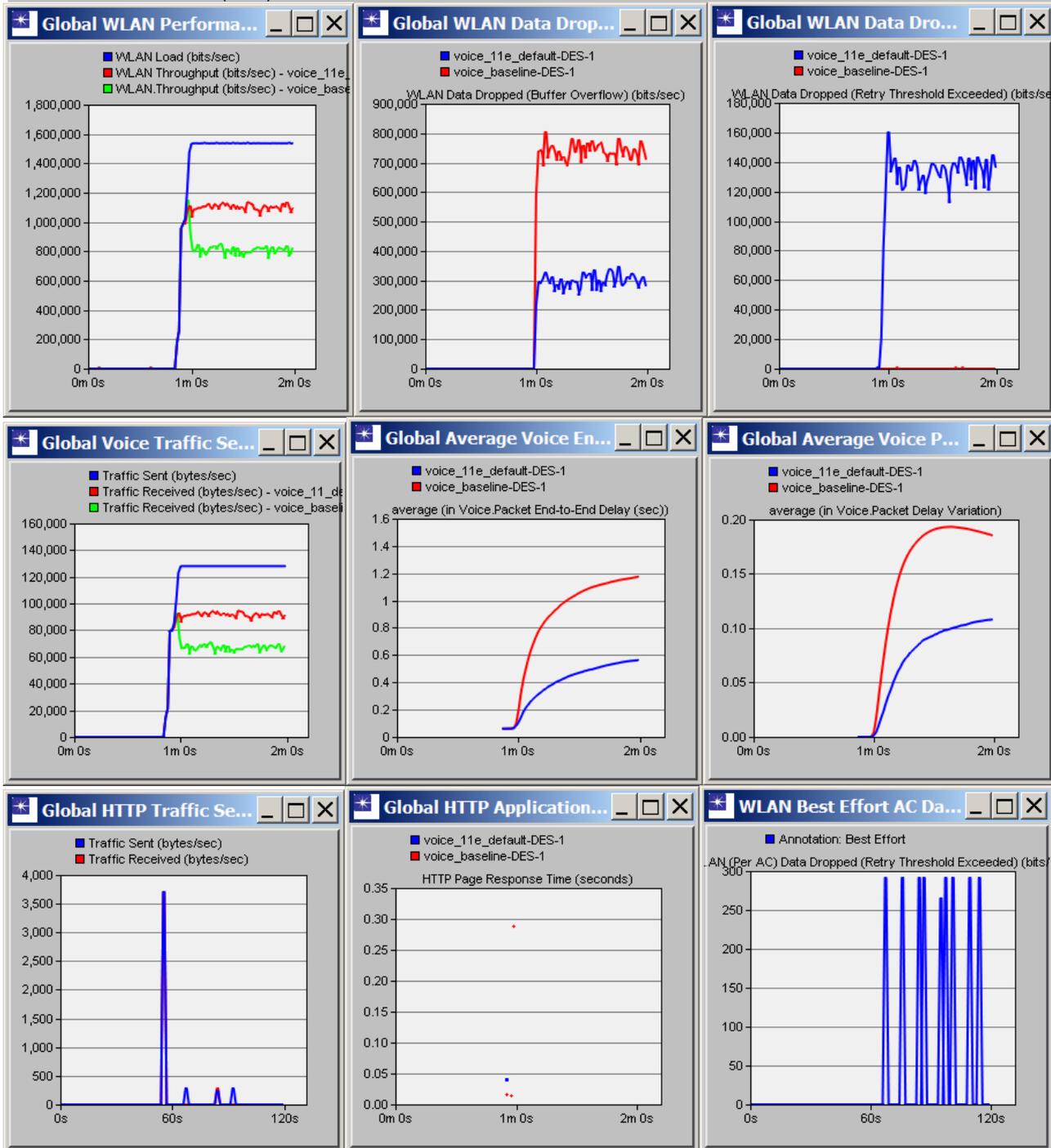


Figure 6. WLAN and application performance for EDCA with default parameters.

Explain these changes, in particular:

- How does EDCA improve the throughput and the delay of the voice application?
- Why does the HTTP application traffic vanish after 60 seconds?
- After enabling EDCA, less voice packets are dropped due to buffer overflow, but many packets are dropped due to "retry threshold exceeded". How do you explain this?

2.6. Summary of WLAN performance for EDCA with default parameters:

- The throughput of the WLAN has increased substantially (from 0.8 Mbps to 1.1 Mbps), but it is still much less than the load (1.55 Mbps). The WLAN is still strongly congested and the bandwidth is not used efficiently.

- Enabling EDCA with default parameters worsened the performance of the HTTP application (which is actually locked out) without bringing sufficient performance improvement to the voice application.

3. Modify the EDCA parameters to improve WLAN and application performance

We modify now the EDCA parameters in order to address the performance issues identified in the previous section. We use the access category AC_VO for the voice application (highest priority) and AC_BE for the data application. The first experiment uses EDCA with the default parameters specified in the standard.

3.1. Create a new scenario starting from the previous one.

Select Scenarios > Duplicate Scenario and name the new scenario "voice_802_11e_better".

3.2. Modify the EDCA parameters for the access point.

Configure the access point to use a larger CWmax for the access category AC_VO (used by the voice application). We increase CWmax from the default value 7 to 15. The larger maximum value of the contention window will better spread in time the attempts to access the medium for voice packets (after a failed attempt) and reduce the number of collisions. The price we expect to pay for this is a slight increase of the average medium access delay.

Right click on the access point and choose Edit Attributes.

Expand Wireless LAN > Wireless LAN Parameters > HCF Parameters > EDCA Parameters > Access Category Parameters > Voice and set CWmax to 15. Click OK to commit the changes.

3.3. Modify the EDCA parameters for the wireless workstations.

The EDCA parameters used by the workstations are advertised by the access point in the Beacon frames. Therefore, we have to modify the configuration of the access point such that to advertise the larger CWmax value.

Right click on the access point and choose Edit Attributes.

Expand Wireless LAN > Wireless LAN Parameters > HCF Parameters > AP Specific Parameters > Parameters Advertised > EDCA Parameter Set > Voice and set CWmax to 15. Click OK to commit the changes.

3.4. Run the simulation in order to determine the performance of the modified WLAN configuration.

Click the button Configure/Run Discrete Event Simulation (DES) in the Project. Set Simulation Kernel to Optimized and Duration to 120 seconds.

Click Run to launch the simulation. Click Close when finished.

3.5. Examine the results.

Click the button View Results in the Project Editor and examine the statistics shown in Figure 7. Examine also the statistics for individual access categories. Analyze the results and determine what has changed after modifying the EDCA parameters. In particular:

- How did the throughput change for the WLAN and for the voice application?
- How did the end-to-end delay change for the voice application?
- What happened to the dropped voice packets?
- What happened to the HTTP application?

Explain these changes, in particular:

- The improvement of the WLAN and voice traffic throughput.

- The degradation of end-to-end voice traffic delay.
- Why less voice packets are dropped due to buffer overflow and (especially) due to "retry threshold exceeded"?

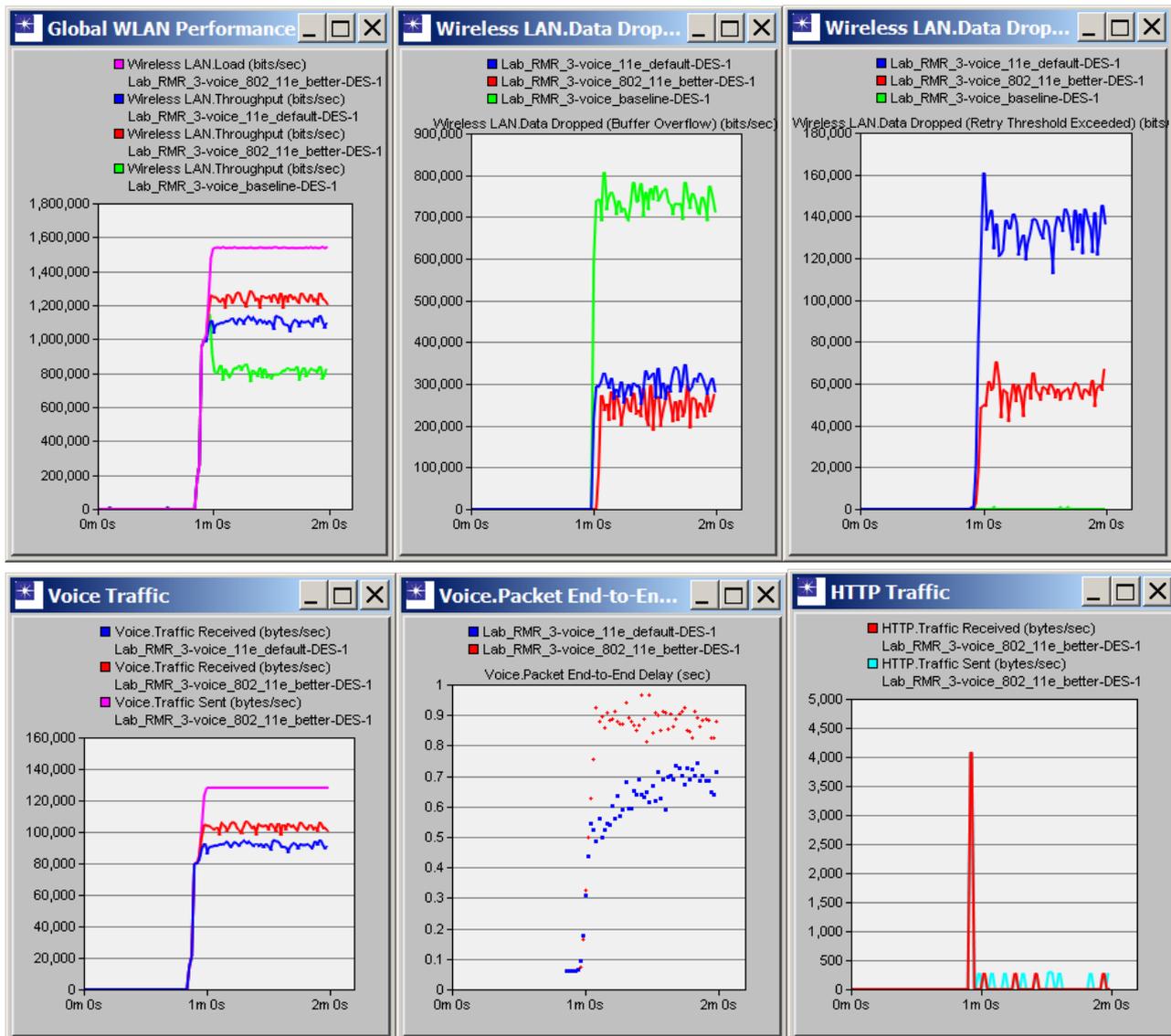


Figure 7. WLAN and application performance for EDCA with modified parameters.

3.6. Summary of WLAN performance for EDCA with modified parameters:

- The throughput of the WLAN further increased significantly (from 1.1 Mbps to 1.25 Mbps), but it is still much less than the load (1.55 Mbps). The WLAN is strongly congested.
- Increasing CWmax for AC_VO improved the WLAN performance, but the current WLAN configuration is not able to handle the mixed voice and HTTP traffic load.

4. Turn off acknowledgements for voice traffic

In order to reduce the end-to-end delay for voice traffic and to improve the overall WLAN performance for both applications, we turn off MAC acknowledgements for the access category AC_VO. The MAC protocol will start using the RTS/CTS frame exchange for AC_VO TXOPs (transmission opportunities) to protect the unacknowledged voice traffic by reserving the medium. Collisions may still occur for RTS frames (instead of voice data frames). However, the number of dropped voice packets due to reaching the retry limit should be reduced.

4.1. Create a new scenario starting from the previous one.

Select Scenarios > Duplicate Scenario and name the new scenario "voice_802_11e_noack".

4.2. Configure the access point to turn off acknowledgements for voice traffic.

Right click on the access point and choose Edit Attributes.

Expand Wireless LAN > Wireless LAN Parameters > HCF Parameters > Traffic Category Parameters > Row 6 (TID 6, Interactive Voice) and set Service Class to No Acknowledgement. Click OK to commit the changes.

4.3. Configure the wireless workstations to turn off acknowledgements for voice traffic.

Right-click on one of the workstations and choose Select Similar Nodes. Right-click on one of the selected nodes and choose Edit Attributes. Check the box Apply to selected objects.

Expand Wireless LAN > Wireless LAN Parameters > HCF Parameters > Traffic Category Parameters > Row 6 (TID 6, Interactive Voice) and set Service Class to No Acknowledgement.

Click OK to commit the changes to all the wireless workstations.

4.4. Run the simulation in order to determine the performance of the modified WLAN configuration.

Click the button Configure/Run Discrete Event Simulation (DES) in the Project. Set Simulation Kernel to Optimized and Duration to 120 seconds.

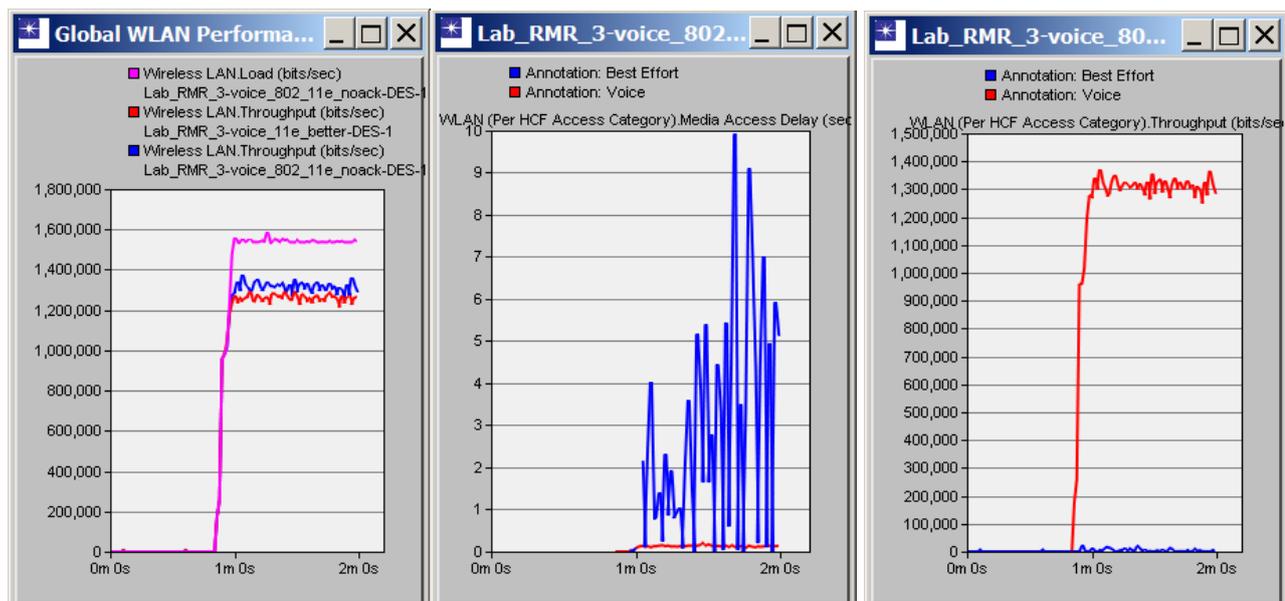
Click Run to launch the simulation. Click Close when finished.

4.5. Examine the results.

Click the button View Results in the Project Editor and examine the statistics shown in Figure 8.

Analyze the results and determine what has changed after turning off the acknowledgements for AC_VO traffic. In particular:

- How did the throughput change for the WLAN and for the voice application?
- How did the end-to-end delay change for the voice application?
- What happened to the HTTP application?



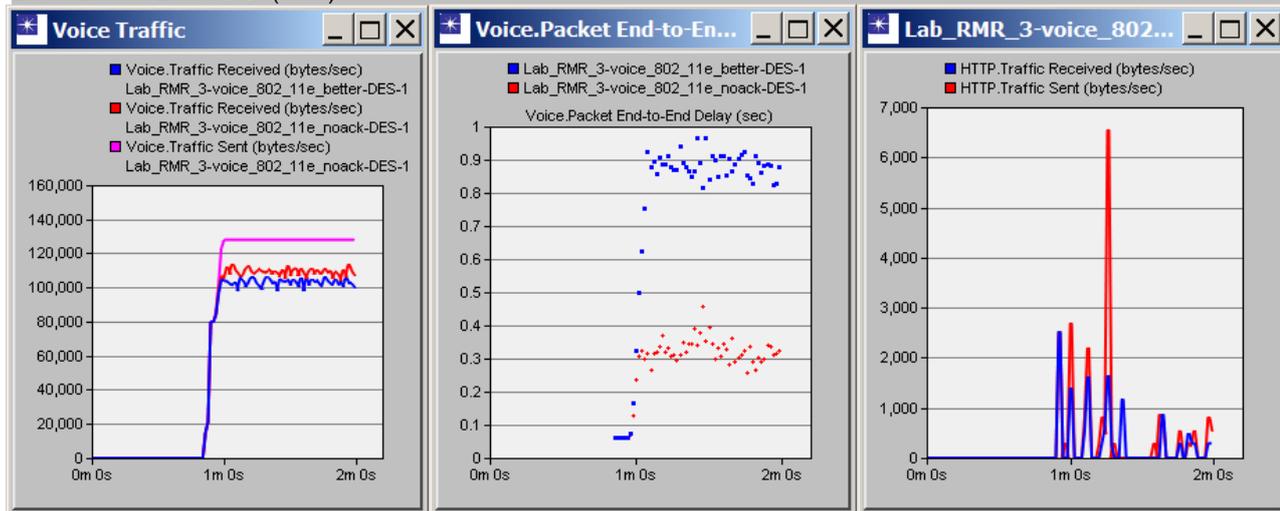


Figure 8. WLAN and application performance for AC_VO without acknowledgements.

4.6. Summary of WLAN performance for the current configuration:

- We have substantially improved the WLAN performance for the given application scenario (voice and data traffic, available channel bandwidth), by using several mechanisms offered by the 802.11 MAC protocols. For example, the WLAN throughput increased from 0.8 to 1.3 Mbps, while the end-to-end delay of the voice packets decreased from 1.3 to 0.3 seconds).
- Nevertheless, the current channel bandwidth is not sufficient even for proper operation of the voice application.

5. Increase the WLAN bandwidth

In this final experiment we increase the WLAN bandwidth from 6 Mbps to 9 Mbps.

5.1. Create a new scenario starting from the previous one.

Select Scenarios > Duplicate Scenario and name the new scenario "voice_802_11e_9mbps".

5.2. Increase the channel bandwidth for the access point.

Right click on the access point and choose Edit Attributes. Expand Wireless LAN > Wireless LAN Parameters and set the Data rate to 9 Mbps. Click OK to commit the changes.

5.3. Increase the channel bandwidth for the wireless workstations.

Right-click on one of the workstations and choose Select Similar Nodes. Right-click on one of the selected nodes and choose Edit Attributes. Check the box Apply to selected objects.

Expand Wireless LAN > Wireless LAN Parameters and set the Data rate to 9 Mbps. Click OK to commit the changes to all the wireless workstations.

5.4. Run the simulation in order to determine the performance of the modified WLAN configuration.

Click the button Configure/Run Discrete Event Simulation (DES) in the Project Editor. Set Simulation Kernel to Optimized and Duration to 120 seconds.

Click Run to launch the simulation. Click Close when finished.

5.5. Examine the results.

Click the button View Results in the Project Editor and examine the statistics shown in Figure 9.

Analyze the results and determine what has changed after increasing the channel bandwidth.

Is the WLAN (finally) providing adequate QoS to the two applications?

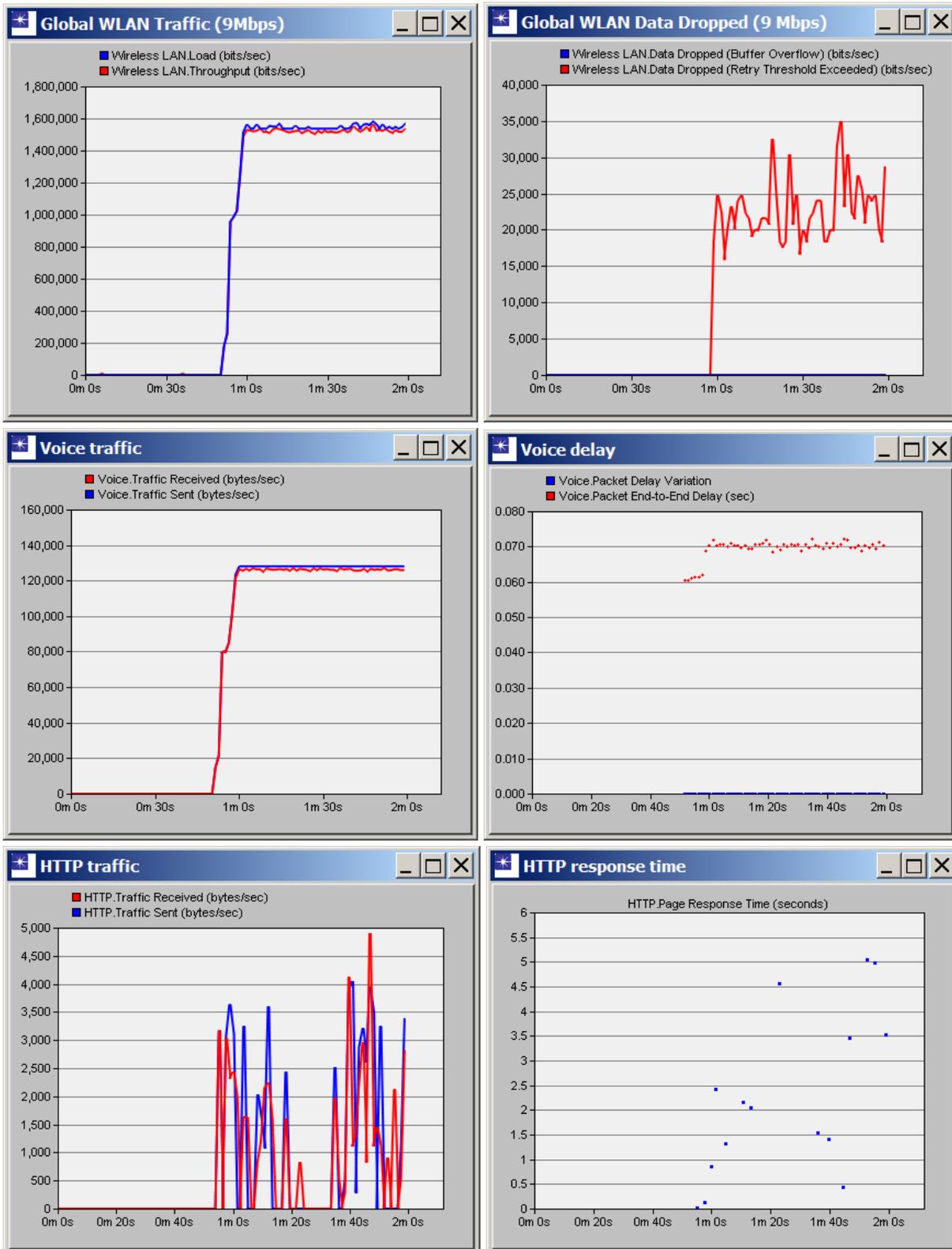


Figure 9. WLAN and application performance for EDCA and 9 Mbps.