Lab 2
WiMAX: QoS for Data and Voice Services

Objective

Examine the capability of WiMAX networks to deliver adequate QoS to voice and data applications.

Case Study

This lab examines a case of QoS deployment over a cellular WiMAX network (Figure 1).

A wireless network service provider needs to assess whether it can accommodate the traffic requirements of a new customer.

The customer's employees are mobile throughout a certain area and use two applications: a data application consisting of Oracle transactions that requires remote access to the corporate servers and a voice application consisting of calls made to the company headquarters using VoIP.

The customer has captured the traffic of the Oracle application and has given it to the provider as an ACE trace. The voice traffic is PCM Quality voice. All the customer's employees will run the data applications, but only one in five will run the voice application in any cell.

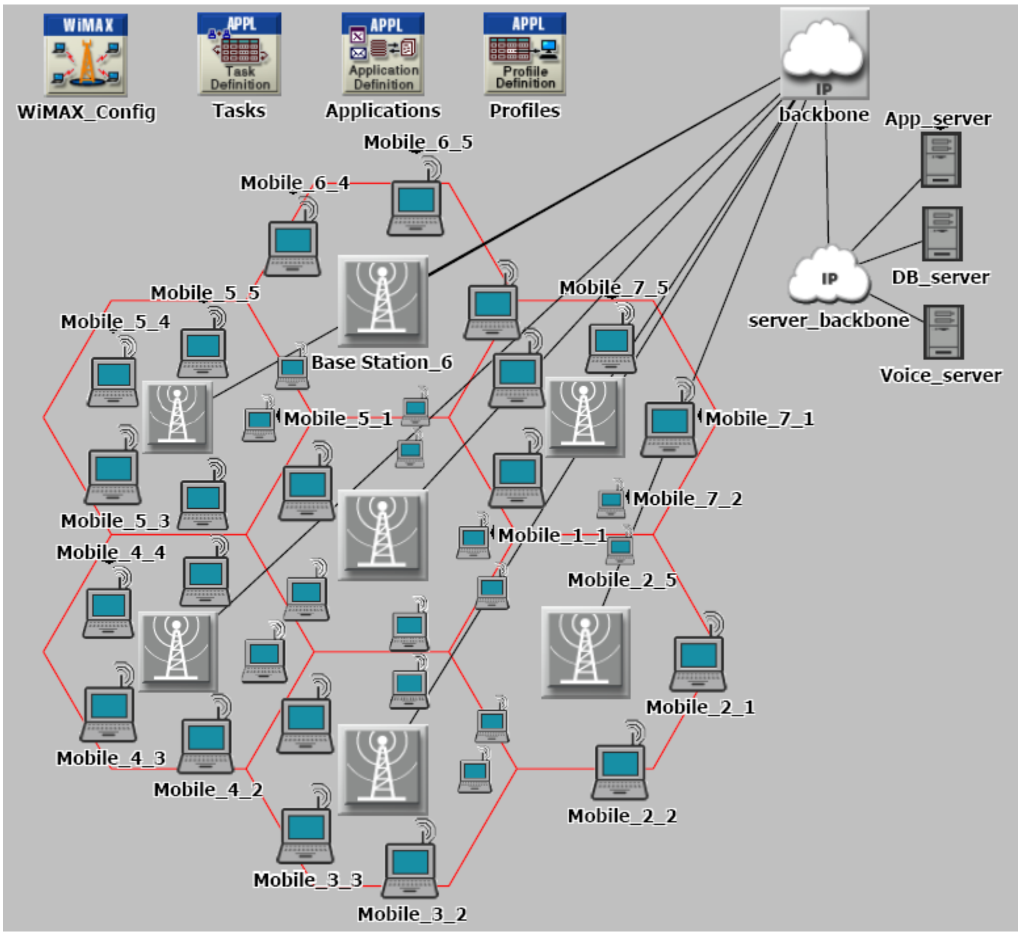

Figure 1. WiMAX network topology.

Main phases

1. Create the WiMAX network, consisting of 7 cells and an IP backbone, and deploy the applications required by the client.

2. Configure QoS in the WiMAX mobile and base stations according to the application requirements. Run the simulation and examine the results.

3. Adjust the QoS configuration within the WiMAX cells to meet the requirements of the voice application. Run the simulation and examine the results.

4. Further adjust the QoS configuration to improve data application performance, without degrading the performance of voice. Run the simulation and examine the results.

1. Examine the initial configuration

1.1. Start OPNET Modeler and open the project RMR_WiMAX_2 (File > Open, navigate to the project folder, and double-click on RMR_WiMAX_2). The project opens with the Start scenario and displays the network configuration shown in Figure 1:

- The provider's network, consisting of 7 WiMAX cells connected to an IP backbone>
- The customer's application servers, connected to a server backbone and then to the provider's backbone.
- The customer's mobile stations, distributed among the WiMAX cells (5 stations per cell).

The customer applications have already been deployed.

1.2. Examine the initial configuration of the WiMAX mobile stations and base stations.

Right-click on an icon (base station, mobile station, WiMAX_Config, Applications), select Edit Attributes, and examine the WiMAX parameters (including SS Parameters and BS Parameters) and the customer's applications (Figure 3 and Figure 2).

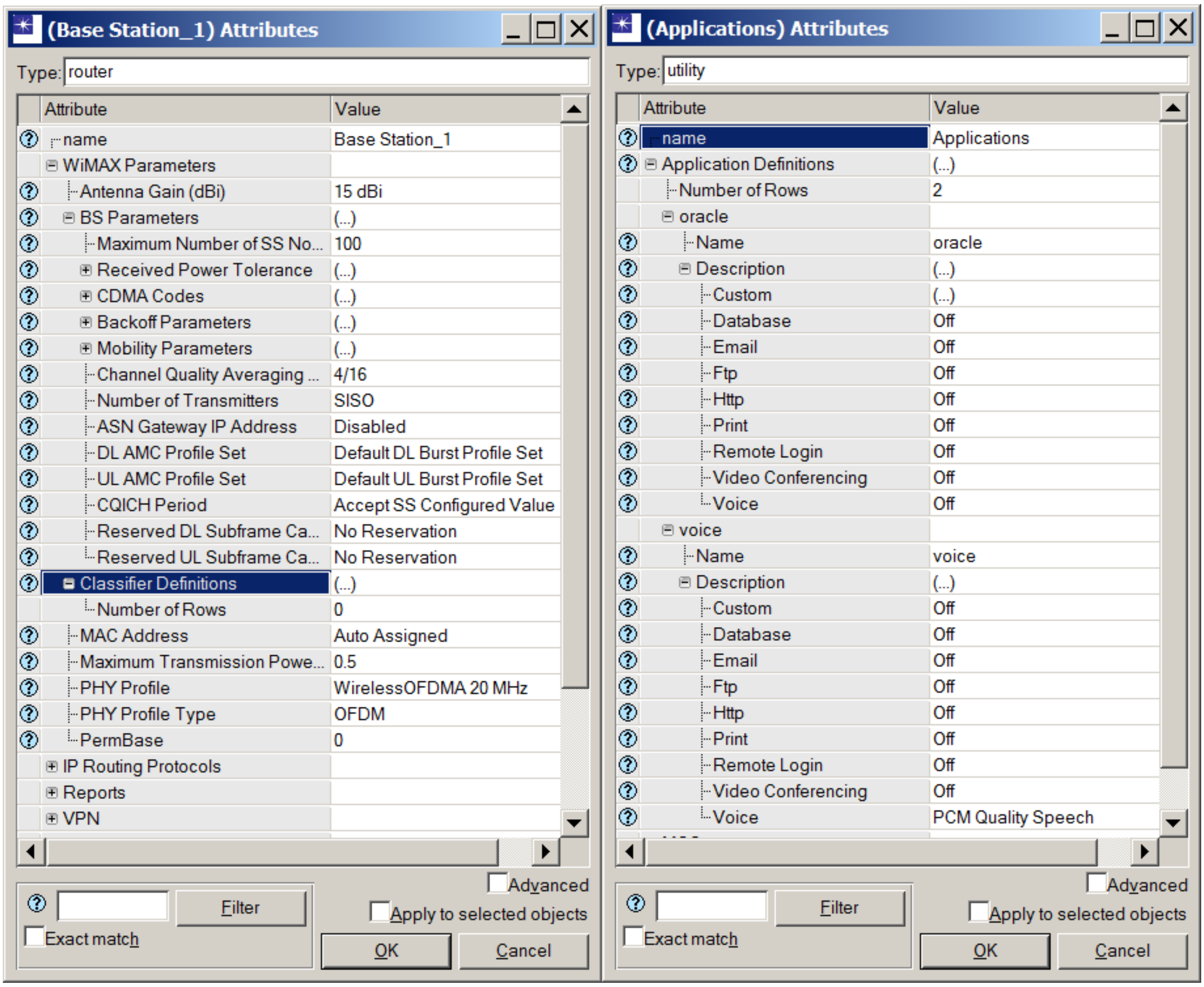

Figure 2. (a) Base station. (b) Applications.

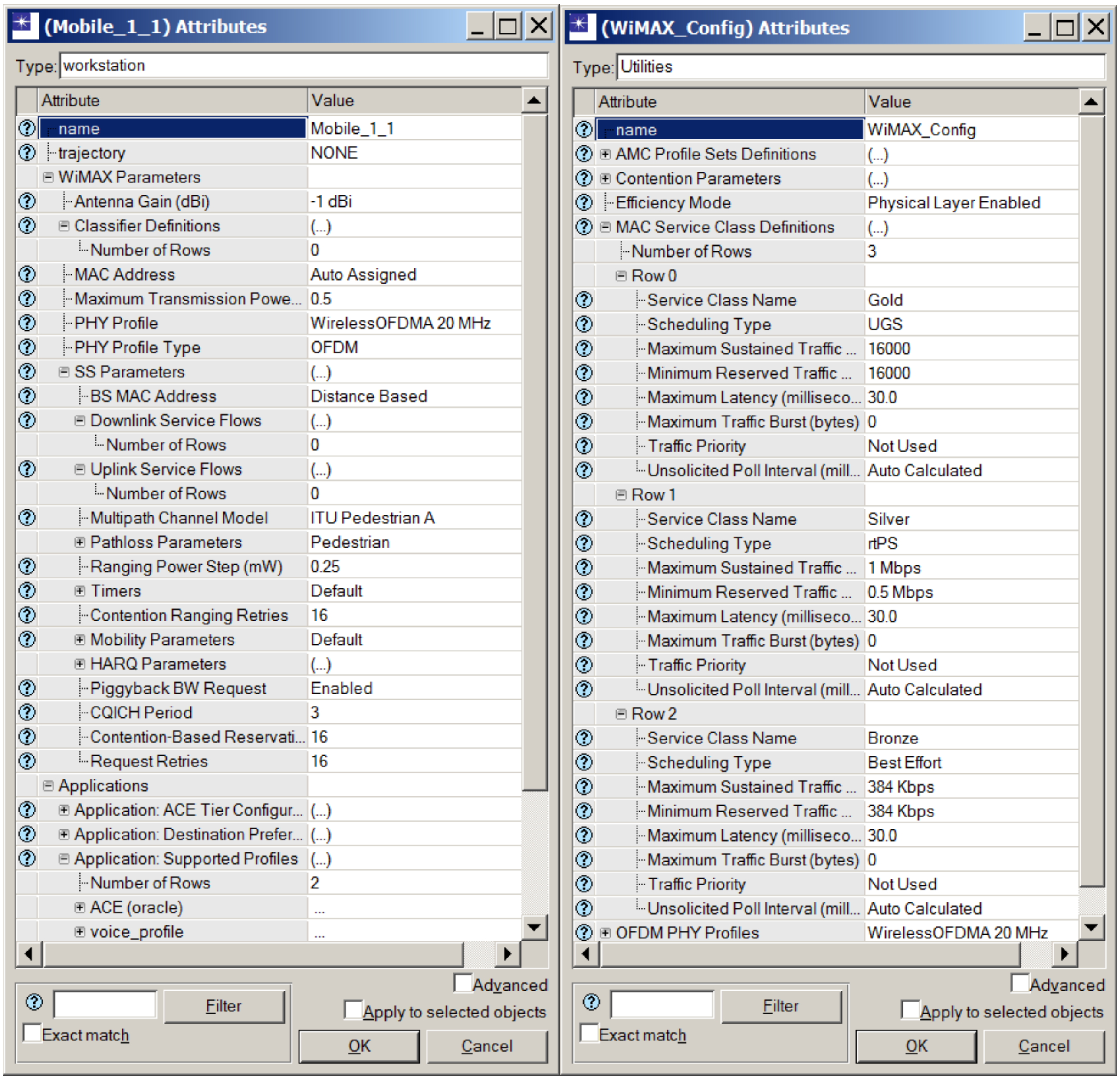

Figure 3. (a) Mobile station. (b) WiMAX_Config.

Remarks:

Note that the data application runs on all the mobile stations, while the voice application runs on one station per cell, namely the stations Mobile_1_1, Mobile_2_1, an so on, to Mobile_7_1.

Observe that the Classifier Definitions, Downlink Service Flows and Uplink Service FLows are empty in the initial configuration of the mobile and base stations, so currently no QoS-based service flows are configured in the mobile stations and base stations.

On the other hand, observe that WiMAX_Config contains 3 pre-defined service classes: Gold, SIlver, and Bronze. Are they suitable for the customer's applications?

2. Configure Layer-2 QoS in the WiMAX network

The next step is to configure QoS-based service classes in the WiMAX mobile and base stations, according to the customer's requirements.

The customer intends to use UGS (Unsolicited Grant Service) connections for its voice application (strong QoS guarantees) and Best Effort connections for the data application (no QoS guarantees).

We model the bandwidth already assigned by the network provider to the other customers as a constant UGS bandwidth allocation. The new customer will be accommodated within the remaining bandwidth.

2.1. Create the second scenario starting from the initial one. Select Scenarios > Duplicate Scenario and name the new scenario "deployment_qos". Open the network browser pane by selecting View > Show Network Browser.

2.2. Configure the MAC Service Class Definitions in WiMAX_Config.

In the network browser pane, right-click on WiMAX_Config and select Edit Attributes. Click on the value field of the MAC Service Class Definitions attribute to open the MAC Service Class Definitions Table window.

a). The default *Gold* service class uses UGS and would meet the requirements of the customer's voice application, but we have to modify the data rate to match the 64 Kbps rate of the voice codec. Modify the *Gold* service class by setting:

- Maximum Sustained Traffic Rate (bps) to 64000.
- Minimum Reserved Traffic Rate (bps) to 64000.

b). Create a service class *Platinum* with UGS allocation to reserve the bandwidth granted by the network service provider to existing clients. Add a row to the MAC Service Class Definitions Table (click Rows value) and set:

- Service Class Name: Platinum.
- Scheduling Type: UGS.
- Maximum Sustained Traffic Rate (bps): 2500000.
- Minimum Reserved Traffic Rate (bps): 2500000.

Click OK twice to accept all changes.

2.3. Configure the *service flows and classifiers* on the WiMAX mobile stations on which the voice application has been deployed, i.e., Mobile_1_1, Mobile_2_1, Mobile_3_1, Mobile_4_1, Mobile_5_1, Mobile_6_1 and Mobile_7_1.

In the network browser pane, select the 7 stations listed above (by holding down the Ctrl key while selecting), right-click on one of them, and choose Edit Attributes.

In the Attributes window check Apply to selected objects.

Then carry out the following configuration steps:

a). Choose WiMAX Parameters > Classifier Definitions. Open the Classifier Definitions table, add one row, and set:

- Type of SAP: IP.
- Traffic Characterstics: IP ToS, Equals, Interactive Voice (6).
- Service Class Name: Gold.

Click OK to accept table changes.

b). Choose WiMAX Parameters > SS Parameters > Downlink Service Flows. Open the Downlink Service Flows table, add one row, and set:

- Service Class Name: Gold.

- Modulation: QPSK 1/2.

Click OK to accept table changes.

c). Choose WiMAX Parameters > SS Parameters > Uplink Service Flows. Open the Uplink Service Flows table, add two rows, and set:

- Service Class Name: Gold.
- Initial Modulation: QPSK 1/2.
- Service Class Name: Platinum.
- Initial Modulation: QPSK 1/2.

Click OK to accept table changes.

Click OK again to apply all these changes to the 7 selected objects (click yes for the warning).

2.4. Configure the classifiers on the WiMAX base stations.

In the network browser pane, select the 7 base stations, right-click on one of them, and choose Edit Attributes.

In the Attributes window check Apply to selected objects.

Choose WiMAX Parameters > Classifier Definitions. Open the Classifier Definitions table, add one row, and set:

- Type of SAP: IP.
- Traffic Characterstics: IP ToS, Equals, Interactive Voice (6).
- Service Class Name: Gold.

Click OK to accept table changes.

Click OK again to apply these changes to the 7 selected objects (click yes for the warning).

2.5. Configure the statistics to be collected during the simulation.

a. Right-click in the scenario space and select Choose Individual DES Statistics.

b. Expand Global Statistics group and select Voice statistics.

c. Expand Node Statistics group and select WiMAX, WiMAX Connection and Voice Application statistics.

Click OK to accept selections. Save the scenario.

2.6. Run the simulation.

Click the button Configure/Run Discrete Event Simulation (DES) in the Project Editor (or select in the meniu DES > Configure/Run Discrete Event Simulation). The Configure/Run DES dialog box appears. Set Simulation Kernel to Optimized and Duration to 420 seconds.

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

2.8. Examine the results.

Select from the main menu Scenarios > Scenario Components > Import. Choose Analysis Configuration and then choose Lab_RMR_WiMAX_2_deplyment_qos. You should see graphs similar to those in Figure 4. To reload the results in the panels press Ctrl+F5.

You can also view these statistics for any station by clicking the button View Results and then selecting Object Statistics > Logical Network > Mobile_x_x and choosing the statistics indicated in Figure 4.

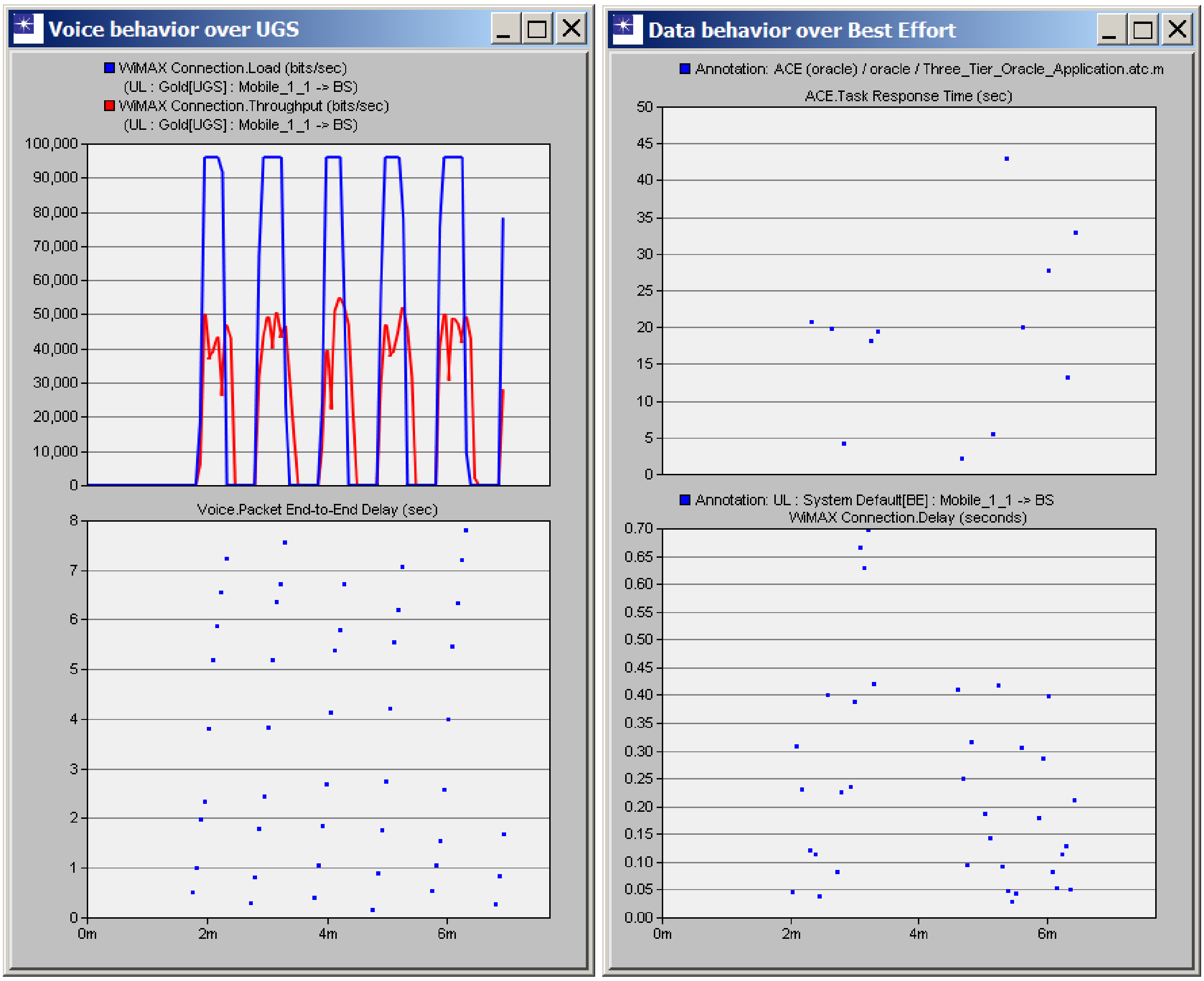

Figure 4. Simulation results for the "deployment_qos" scenario.

a). Examine the graphs Voice behavior over UGS and Voice Packet End-to-End Delay.

- Observe that the WiMAX load is about 96 Kbps while WiMAX throughput is only about 45 Kbps. Notice also that the throughput curve is shifted in time with respect to the load, indicating substantial queuing delay. Indeed, the delay of voice packets is up to 8 sec.

- These graphs are for Mobile_1_1. Check the other mobile stations as explained above. What is the situation?

- Something seems to be quite wrong with the current settings. Recall the configuration and compare with the graphs. What do you think is the cause of this behavior? How do you explain the voice packet delay, despite the use of UGS? How do you explain the discrepancy between load, throughput, and the codec data rate? How would you solve the problem?

b). Examine the graphs Data behavior over Best Effort and WiMAX Connection Delay.

- Notice the excessive delay of the application data packets, which reaches more than 20 sec, out of which the WiMAX uplink delay is only a fraction of a second.

3. Adjust WiMAX QoS for voice performance

Since the voice application offers a peak load of 96 Kbps on the WiMAX connection, we need to redimension the service class Gold UGS accordingly.

3.1. Create a third scenario starting from the second. Select Scenarios > Duplicate Scenario and name the new scenario "Deployment_Improve_Voice".

3.2. Change the definition of the Gold MAC Service Class in WiMAX_Config.

Right-click on WiMAX_Config and select Edit Attributes. Open the MAC Service Class Definitions Table window and modify the *Gold* service class by setting:

- Maximum Sustained Traffic Rate (bps) to 96000.
- Minimum Reserved Traffic Rate (bps) to 96000.

Click OK twice to accept the changes.

3.3. Run the simulation.

Click the button Configure/Run Discrete Event Simulation (DES) in the Project Editor (or select in the meniu DES > Configure/Run Discrete Event Simulation). The Configure/Run DES dialog box appears. Set Simulation Kernel to Optimized and Duration to 420 seconds.

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

3.4. Examine the results.

Select from the main menu Scenarios > Scenario Components > Import. Choose Analysis Configuration and then Lab_RMR_WiMAX_2_deplyment_improve_voice. You should see graphs similar to those in Figure 5. To reload the results in the panels press Ctrl+F5.

You can also view these statistics for any station by pressing the button View Results and then selecting Object Statistics > Logical Network > Mobile_x_x and choosing the statistics indicated in Figure 5.

a). Examine the graphs Voice application.

- Observe that the end-to-end delay of the voice packets has dropped to 75-80 ms and most of the voice traffic is delivered, altheough there is still some data loss.
- These graphs are for Mobile_1_1. Check the other mobile stations as explained above. What is the situation?
- Something is still wrong in the updated settings. What do you think is the cause of this behavior? How do you explain the discrepancy between load, throughput, and the codec data rate? How would you solve the problem?

b). Examine the graphs Data application.

- Notice that the throughput of the Best Effort traffic on the WiMAX uplink has dropped to almost nothing and the queue keeps growing. How do you interpret this behavior? Recall the configuration changes that you have made so far and try understand what could have happened. How would you solve this problem?

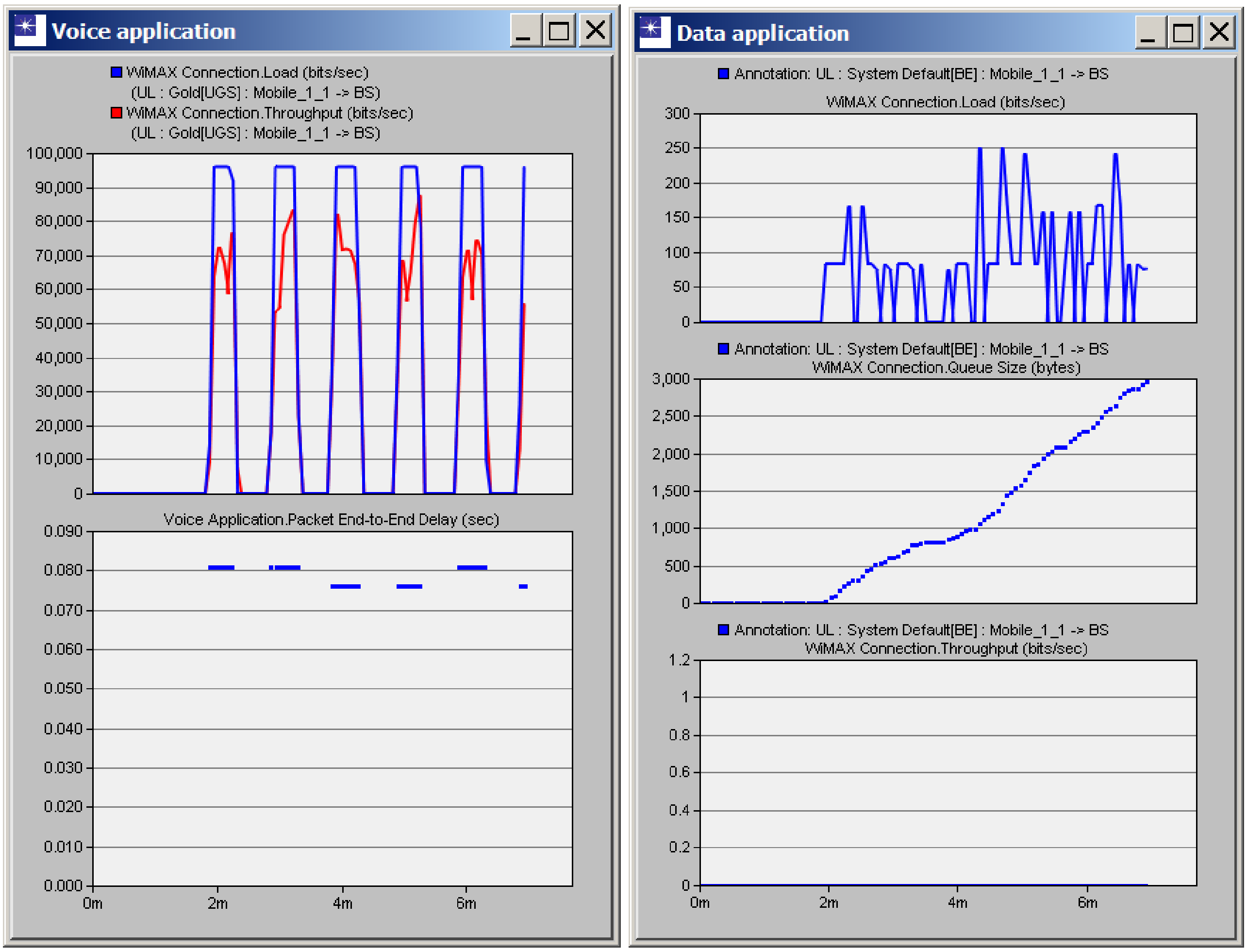

Figure 5. Simulation results for the scenario "deployment_improve_voice".

4. Adjust WiMAX QoS for data performance

The results of the simulations have shown that with the current configuration UGS consumes all the available bandwidth, leaving the data application (Best Effort taffic) to "starve". We'll assume that the network service provider cannot increase the total bandwidth, hence the only possibility is to use the available bandwidth more efficiently, by changing the scheduling (statistical multiplexing). More precisely, we'll replace the UGS scheduling for the voice application by ertPS (Extended Real-Time Polling Service).

4.1. Create a forth scenario starting from the third. Select Scenarios > Duplicate Scenario and name the new scenario "Deployment_Improve_Data".

4.2. Change the definition of the Gold MAC Service Class in WiMAX_Config.

Right-click on WiMAX_Config and select Edit Attributes. Open the MAC Service Class Definitions Table window and modify the *Gold* service class by setting:

- Scheduling type: ertPS.

Click OK twice to accept the changes.

4.3. Run the simulation.

Click the button Configure/Run Discrete Event Simulation (DES) in the Project Editor (or select in the meniu DES > Configure/Run Discrete Event Simulation). The Configure/Run DES dialog box appears. Set Simulation Kernel to Optimized and Duration to 420 seconds.

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

4.4. Examine the results.

Select from the main menu Scenarios > Scenario Components > Import. Choose Analysis Configuration and then Lab_RMR_WiMAX_2_deplyment_improve_data. You should see graphs similar to those in Figure 6. To reload the results in the panels press Ctrl+F5.

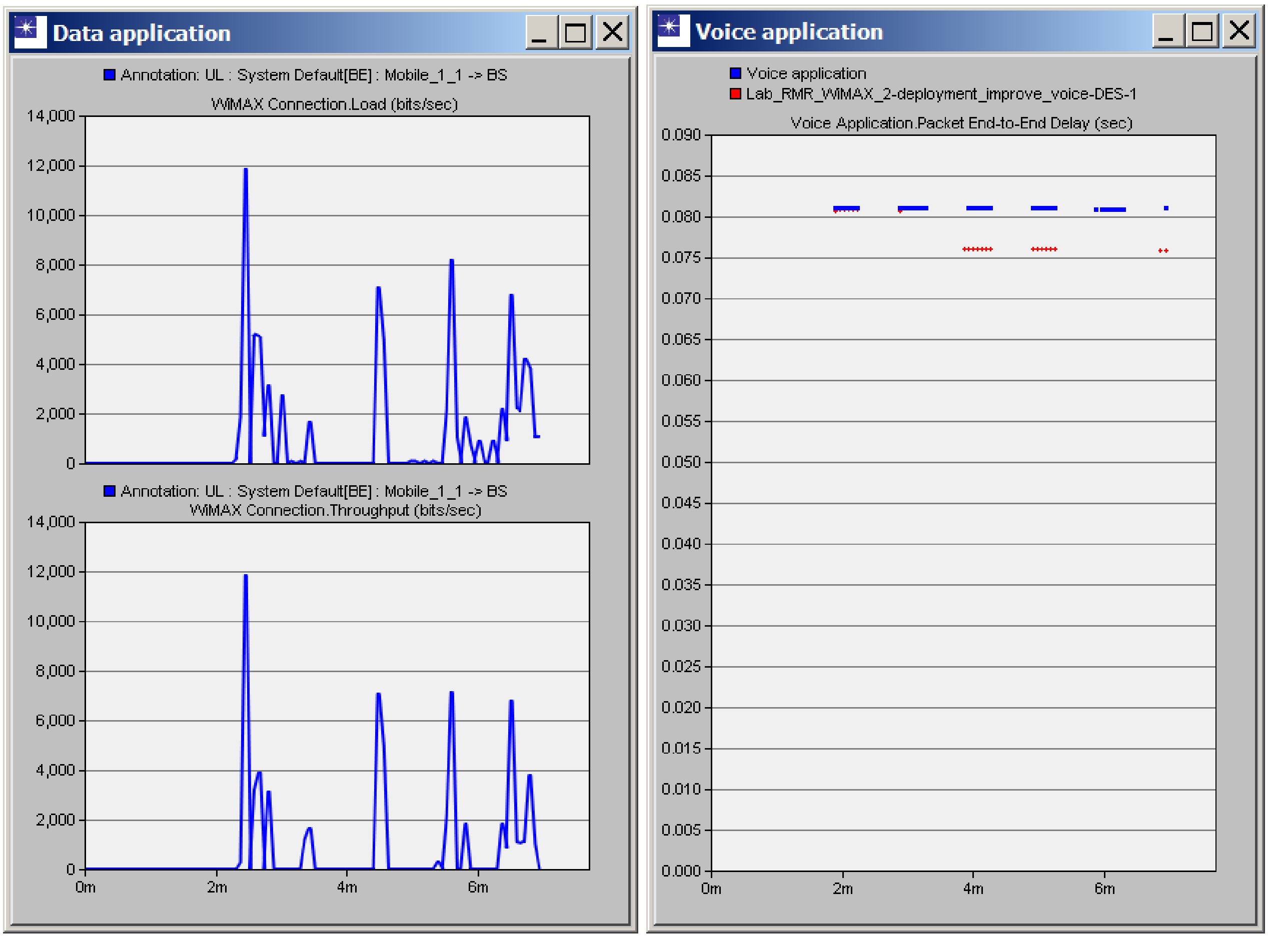

Figure 6. Simulation results for the scenario "deployment_improve_data".

a). Examine the graphs for the Data application.

- Notice that the throughput of the data application matches now the load, so this strategy worked fine for the Best Effort traffic.

b). Examine the graph for the end-to-end delay of the voice application.

- Observe that the delay has increased with only about 5 ms with respect to the previous one, so the effects of the modification on the voice application is acceptable.

c). These graphs are for Mobile_1_1. Check the other mobile stations as explained earlier. What is the situation?

Conclusions

Use the WiMAX Connection statistics (e.g. load, throughput, queue sizes) to infer the behavior of traffic mapped to service flows. Check if the load offered to a connection is matched by the throughput of the connection. For instance, in the scenario “deployment”, we inferred that the UGS connection for voice needs to be enlarged. Check if the connection is starved and traffic from the higher layer builds up in the connection’s queue. For instance, in the scenario “deployment_improve_voice”, we inferred that the enlarged UGS connection for voice is starving the Best Effort connection of bandwidth.

For delay-sensitive traffic that fluctuates beyond its nominal rate, use ertPS scheduling class. This scheduling class has the advantage of giving back some of its reserved bandwidth, if there is no traffic to be served by this bandwidth. For instance, by switching UGS to ertPS we eased the capacity bottleneck for Best Effort traffic in the scenario “deployment_improve_data”.

The maximum Oracle application response time in the last scenario is still quite large. The question is whether this delay can be further reduced, for instance, by using ARQ on the Best Effort connection to make the traffic more resilient to the high level of interference present in this wireless deployment.

Annex

Review: WiMAX Scheduling Services

Service	**Applications**	**Service flow parameters**
Unsolicited grant service (UGS)	Constant bit-rate and strong delay guarantees, e.g., T1/E1 emulation or VoIP without silence suppression.	Maximum sustained rate. Maximum latency. Tolerated jitter.
Real-time polling service (rtPS)	Real-time applications that have variable data rate and are delay-tolerant but require a minimum data rate, e.g., video or audio streaming.	Minimum reserved rate. Maximum sustained rate. Maximum latency. Traffic priority.
Extended real-time polling service (ertPS)	Real-time applications that have variable data rate and require guaranteed minimum data rate and maximum delay, e.g., VoIP with silence suppression.	Minimum reserved rate. Maximum sustained rate. Maximum latency. Tolerated jitter. Traffic priority.
Non-real-time polling service (nrtPS)	Delay-tolerant data streams that require minimum guaranteed rate, e.g., FTP.	Minimum reserved rate. Maximum sustained rate. Traffic priority.
Best-effort service (BE)	Applications that do not require a minimum service-level guarantee, e.g., Web browsing.	Maximum sustained rate. Traffic priority.