WiMAX: Combining AMC and HARQ to Improve Performance and Capacity

Objective

In this lab, you will learn how to use advanced WiMAX features such as adaptive modulation and coding (AMC) and hybrid automatic repeat request (HARQ) to tune the WiMAX network such that to improve application throughput and delay as well as network capacity. Moreover, this lab will demonstrate how to use OPNET to conduct interesting planning studies in WiMAX (this lab is adapted from Lab 1571, OPNETWORK 2010).

Main phases

1. Baseline setting: Examine the performance of the WiMAX network with respect to capacity usage and application delay for static QPSK ½ modulation.

2. Aggressive AMC: Study the impact of an aggressive AMC configuration on system performance (capacity usage and application delay) with respect to the baseline.

3. Conservative AMC: Study the effects of a conservative AMC configuration on system performance.

4. AMC with HARQ: Study the effects of the combination of aggresive AMC and HARQ on system performance.

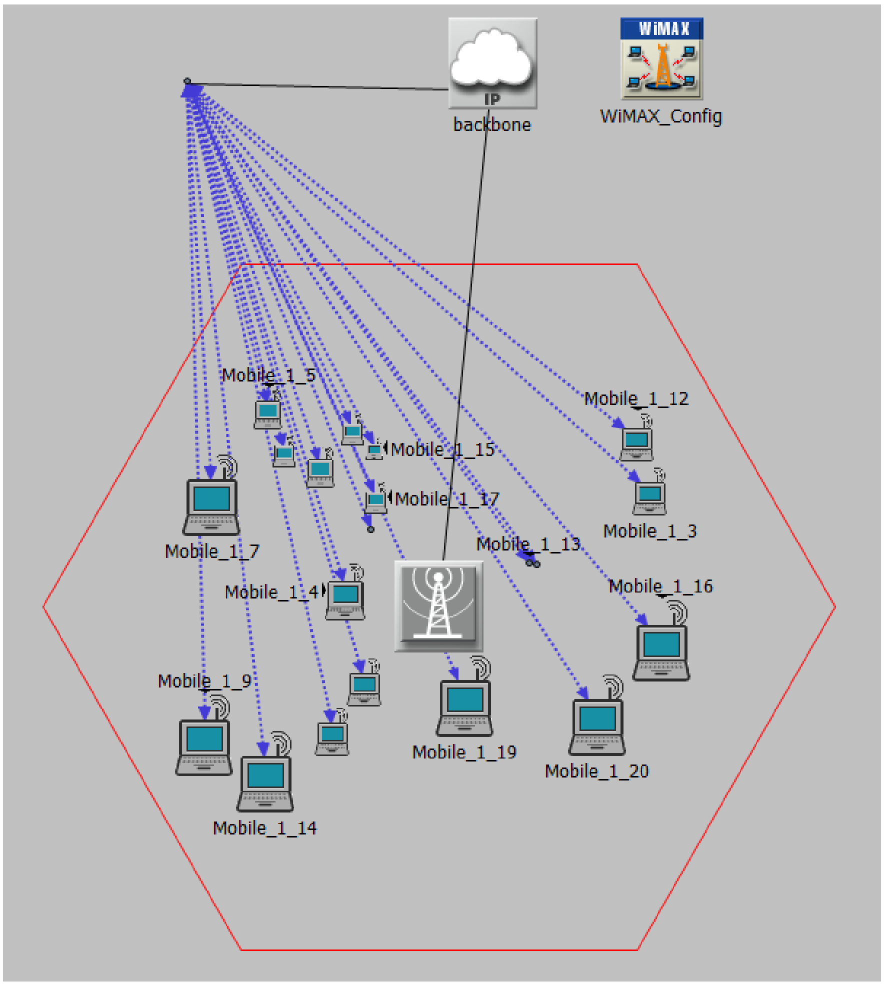


Figure 1. WiMAX network topology.

1. Scenario: QPSK ½ as Static MCS for WiMAX Service Flows

In the first scenario we configure the WiMAX network to operate without AMC, using static QPSK ½ modulation. QPSK ½ is a conservative MCS with 1 bit per symbol. Using QPSK ½ reduces the block error rate, hence there will be less TCP retransmissions, which will improve application performance. On the other hand, it will use more symbols to transmit the same data, increasing the consumption of system capacity. We will now examine this tradeoff.

1.1. Start OPNET Modeler and open the project Lab2_RMR_WiMAX-1 (File > Open, navigate to the project folder, and double-click on Lab2_RMR_WiMAX-1). The scenario QPSK should appear.

The network is one WiMAX cell, with 1 BS node and 20 SS nodes, as shown in Figure 1. The channel is configured to vary according to ITU Pedestrian A multipath fading model. The traffic is configured as follows:

- All SS nodes have an uplink application load of 20 Kbps (Bronze/BE service class) for a total of 0.4 Mbps.
- All SS nodes are configured to use QPSK ½ for the uplink application.
- The cell uses an S-OFDMA frame with 512 subcarriers and 5 milliseconds duration.
- For QPSK ½, the expected uplink capacity is about 0.59 Mbps.

1.2. Examine the WiMAX configuration parameters: subscriber (mobile) station, base station, WiMAX_Config (see Figure 3 and Figure 2). Right-click on the icon and select Edit Attributes. Check the relevant attributes for this scenario (especially the BS and SS parameter sets).

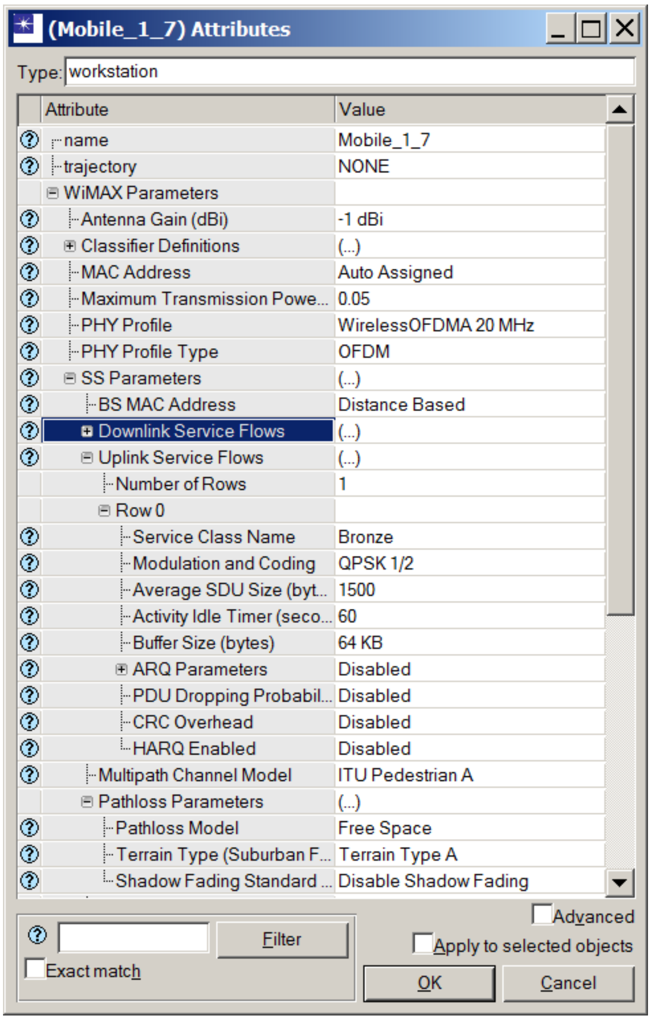


Figure 2. Configuration parameters for QPSK scenario: subscriber (mobile) stations.

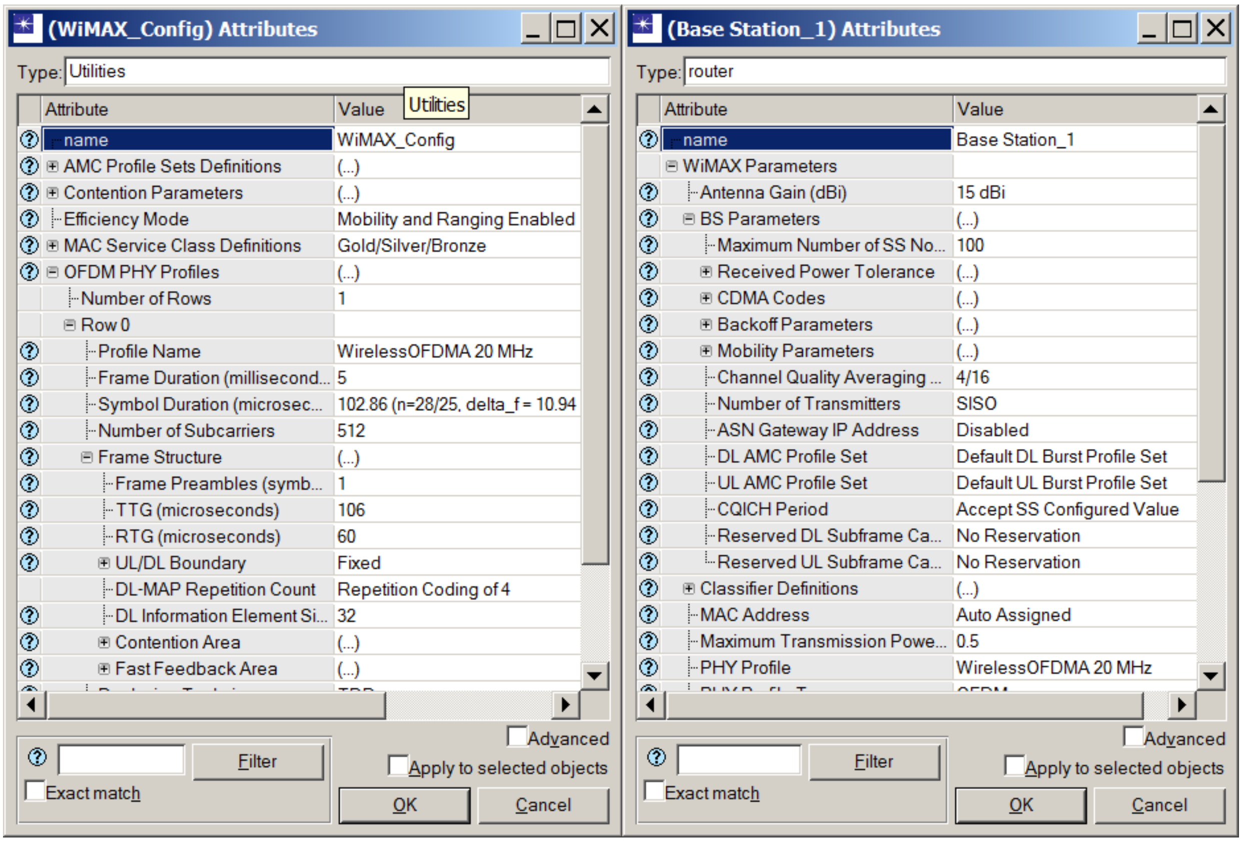


Figure 3. Configuration parameters for QPSK scenario: WiMAX_Config and base station.

1.3. Run the simulation. Select DES > Configure/Run Discrete Event Simulation in the Project Editor. The Configure/Run DES dialog box appears. Configure the simulation as in Figure 4. In particular, set the simulation duration to 200 sec. Click Run to launch the simulation. When the execution completes, click Close.

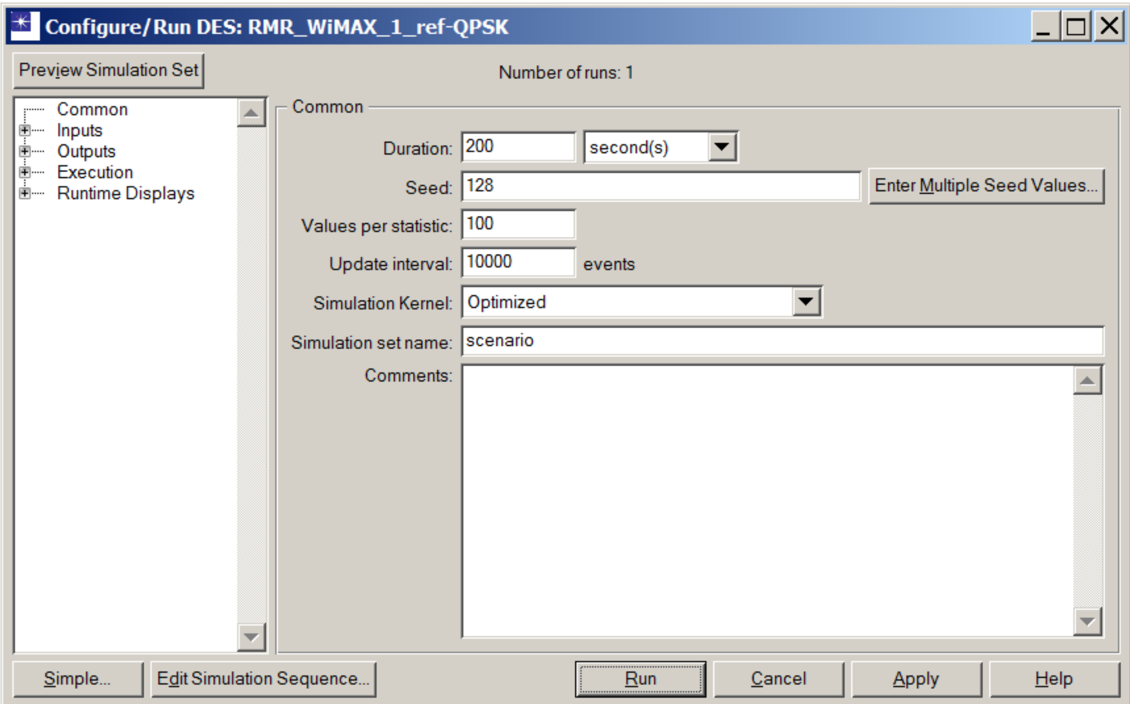


Figure 4. Configure and run DES.

1.4. Examine the results (Figure 5). Select DES > Panel Operations > Arrange Panels > Show All and DES > Panel Operations > Reload Data Into All Panels. Alternatively, you can right-click on the Project Editor window, select View Results to open the Results Browser, and then examine the relevant parameters shown in Figure 5.

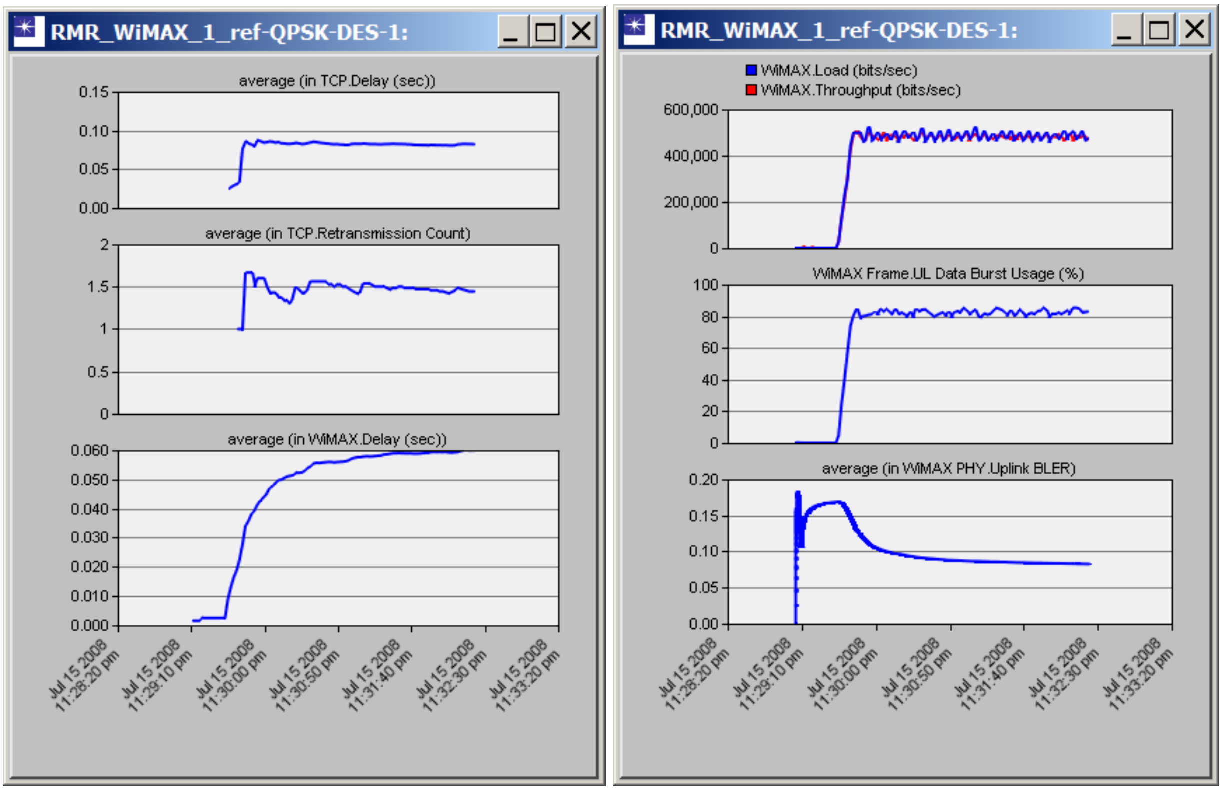


Figure 5. Simulation results for the scenario QPSK.

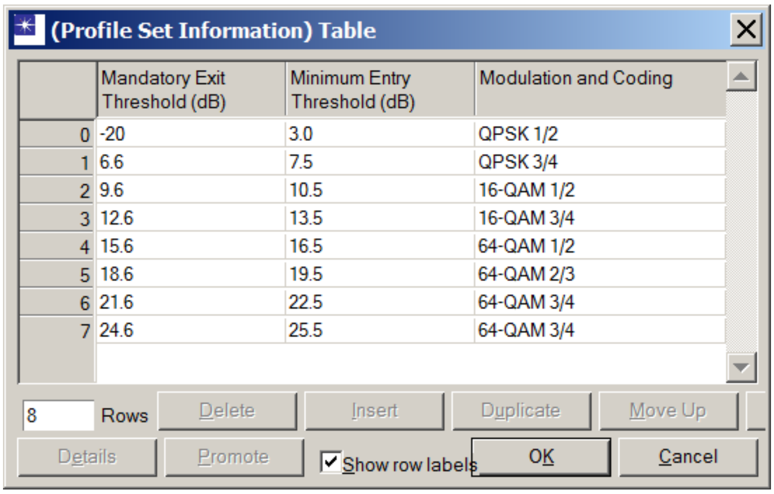
For the simulation results shown in Figure 5, the TCP delay is about 80 ms. A large part of the TCP delay is due to the WiMAX delay, which is about 60 ms. The effect of the data loss and TCP retransmissions is negligible. The WiMAX load and throughput are roughly equal, about 480 Kbps (essentially, the application traffic and the encapsulation overhead). Finally, notice that the UL frame usage is more than 80%, hence the use of static QPSK ½ is consuming large system resources. Therefore, in this initial setting we trade off application delay for system capacity.

2. Scenario: Aggresive AMC

We will now turn on the AMC functionality on the service flows of the SS nodes and choose an AMC table for the BS to use on the uplink. The advantage of AMC is that it automatically adjusts to an appropriate MCS (Modulation and Coding Scheme) given an SNR (Signal to Noise Ratio) value. If the SNR is good, a node does not have to use QPSK ½. We will determine if using AMC has any disadvantages against static QPSK ½.

2.1. We create the second scenario starting from the initial one. Select Scenarios > Duplicate Scenario and name the new scenario AMC_A. In the second scenario we will activate AMC using an AMC table configured on the WiMAX_Config node.

2.2. Configure the AMC table. Right-click on WiMAX_Config, select Edit Attributes, expand AMC Profile Sets Definitions, and then click the Value field of UL Profile Sets. The UL Profile Sets table pops up. To add the new profile, type 3 in the number of rows and then edit the new profile: edit the Name and write AMC Table A, then edit the Profile Set Information field and fill out the table that pops up as shown in Figure 6.


(Profile Set Information) Table

	Mandatory Exit Threshold (dB)	Minimum Entry Threshold (dB)	Modulation and Coding
0	-20	3.0	QPSK 1/2
1	6.6	7.5	QPSK 3/4
2	9.6	10.5	16-QAM 1/2
3	12.6	13.5	16-QAM 3/4
4	15.6	16.5	64-QAM 1/2
5	18.6	19.5	64-QAM 2/3
6	21.6	22.5	64-QAM 3/4
7	24.6	25.5	64-QAM 3/4

Figure 6. AMC Table A.

2.3. Configure AMC on SS nodes as follows:

a. Right-click on any of the mobile nodes, and then choose Select Similar Nodes.

b. Right-click on one of the selected nodes, choose Edit Attributes, and check Apply to selected objects.

c. Expand WiMAX Parameters > SS Parameters > Uplink Service Flows > Row 0 and set the attribute Modulation and Coding to Adaptive.

d. Click OK to accept the changes.

e. Click Yes to dismiss the compound attribute warning. You should see the message "20 objects changed" in the status bar.

2.4. Configure the Uplink AMC profile on the BS as follows:

a. Right-click on the BS node and click on Edit Attributes.

b. Expand WiMAX Parameters > BS Parameters. Set UL AMC Profile Set as AMC Table A (the table in Figure 6, created earlier).

c. Click OK to apply the change.

2.5. Run the simulation. Select DES > Configure/Run Discrete Event Simulation in the Project Editor. The simulation is configured as in the previous scenario (Figure 4). Click Run to start the simulation. When the execution completes, click Close.

2.6. Examine the results (Figure 7). Select DES > Panel Operations > Arrange Panels > Show All and DES > Panel Operations > Reload Data Into All Panels. Alternatively, you can right-click on the Project Editor window, select View Results to open the Results Browser, and then examine the relevant parameters shown in Figure 7.

2.7. Questions: Compare the simulation results of this scenario and the previous scenario.

How does the TCP delay change and why?

How does the data loss change and why?

How does the UL frame usage change and why?

Make an overall assessment of the strategies used in these two scenarios, QPSK and AMC_A.

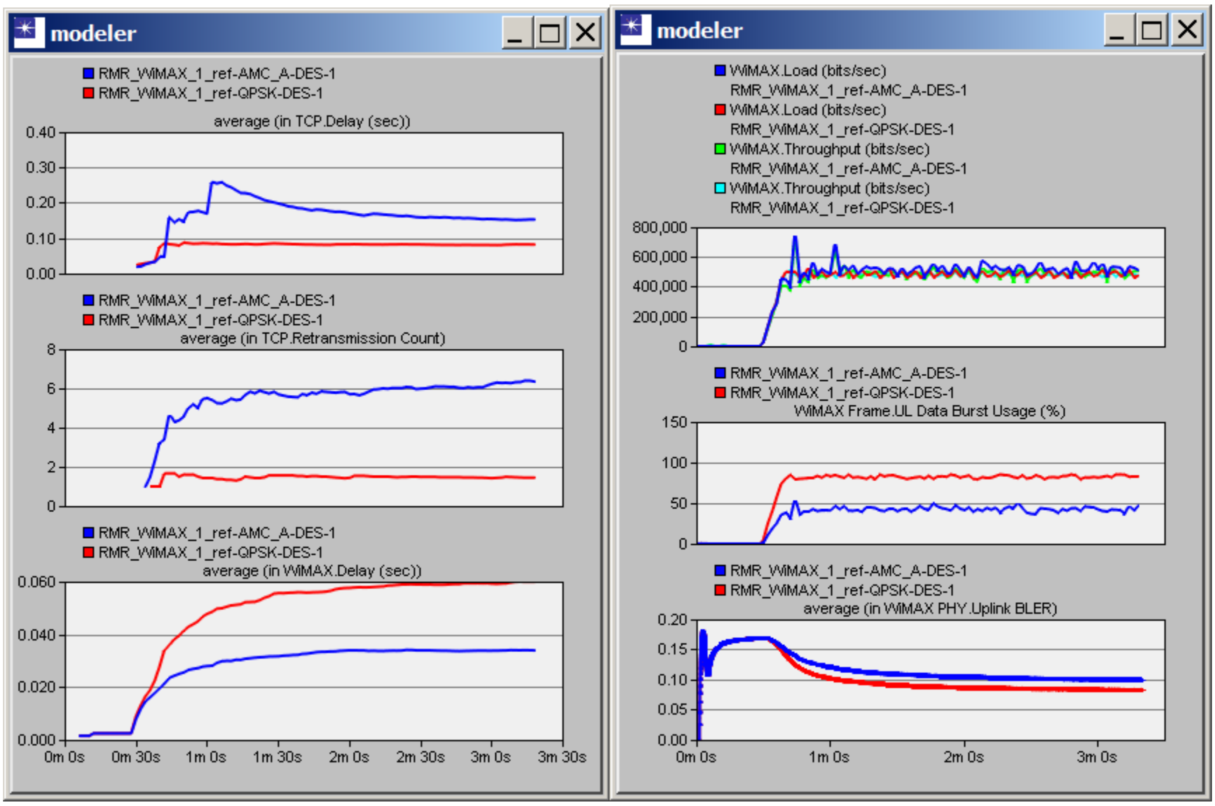


Figure 7. Simulation results for the scenario AMC_A versus the scenario QPSK.

3. Scenario: Conservative AMC

Based upon the previous results, we found that the AMC table A was too aggressive. Our first strategy is to use a more conservative AMC table. In this case, we will switch to conservative MCS at higher SNR values. This will reduce BLER, but may use more system capacity.

3.1. We create the third scenario based on the second scenario. Starting from scenario AMC_A select Scenarios > Duplicate Scenario and name the new scenario AMC_B. In the third scenario we will change the AMC configuration by using a more conserbative AMC table configured on the WiMAX_Config node.

3.2. Configure the AMC table. Right-click on WiMAX_Config, select Edit Attributes, expand AMC Profile Sets Definitions, and then click the Value field of UL Profile Sets. The UL Profile Sets table pops up. Modify the profile AMC Table A: edit the Name and write AMC Table B, then edit the Profile Set Information field and fill out the table that pops up as shown in Figure 8.

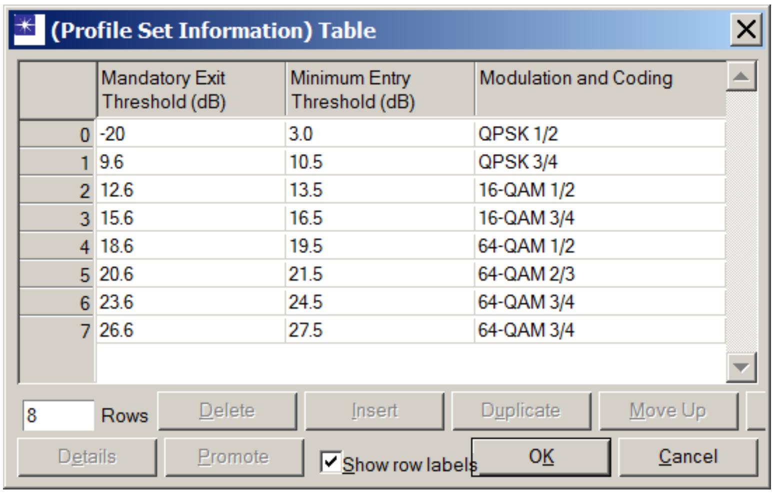
3.3. Configure the new Uplink AMC profile on the BS as follows:

a. Right-click on the BS node and click on Edit Attributes.

b. Expand WiMAX Parameters > BS Parameters.

c. Set UL AMC Profile Set as AMC Table B.

d. Click OK to apply the change.



(Profile Set Information) Table

	Mandatory Exit Threshold (dB)	Minimum Entry Threshold (dB)	Modulation and Coding
0	-20	3.0	QPSK 1/2
1	9.6	10.5	QPSK 3/4
2	12.6	13.5	16-QAM 1/2
3	15.6	16.5	16-QAM 3/4
4	18.6	19.5	64-QAM 1/2
5	20.6	21.5	64-QAM 2/3
6	23.6	24.5	64-QAM 3/4
7	26.6	27.5	64-QAM 3/4

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Figure 8. AMC Table B.

3.5. Run the simulation. Select DES > Configure/Run Discrete Event Simulation in the Project Editor. The simulation is configured as in the previous scenario (Figure 4). Click Run to start the simulation. When the execution completes, click Close.

3.6. Examine the results (Figure 9). Select DES > Panel Operations > Arrange Panels > Show All and DES > Panel Operations > Reload Data Into All Panels. Alternatively, you can right-click on the Project Editor window, select View Results to open the Results Browser, and then examine the relevant parameters shown in Figure 9.

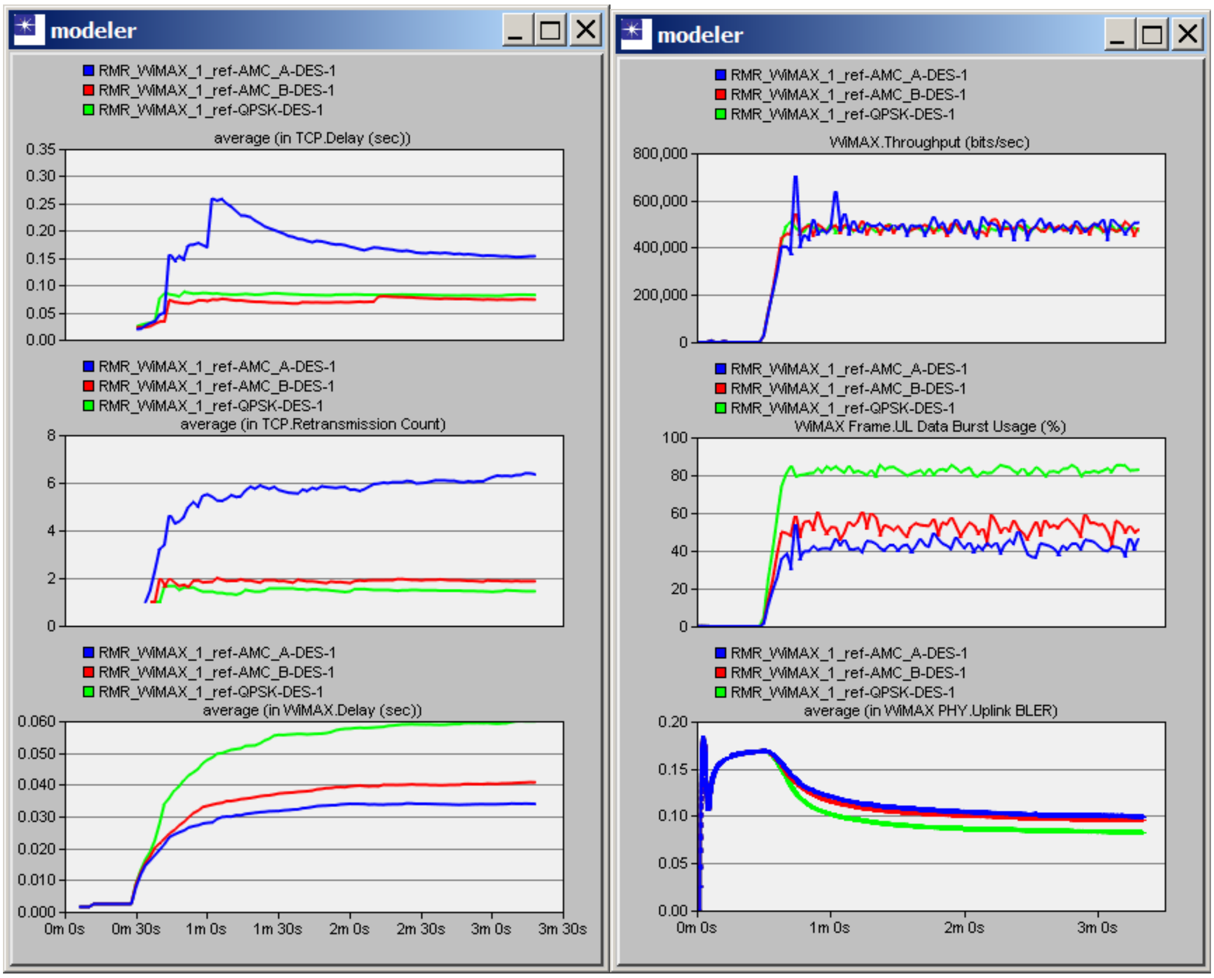

Figure 9. Simulation results for scenario AMC_B versus AMC_A and QPSK.

3.7. Questions: Compare the simulation results of this scenario and the previous scenarios.

How does the TCP delay change and why?

How does the data loss change and why?

How does the UL frame usage change and why?

Make an overall assessment of the strategy used in the scenario AMC_B with respect to the scenarios AMC_A and QPSK.

4. Scenario: Aggresive AMC with HARQ

Using a conservative AMC table improved application performance significantly at the expense of system capacity. We do not want to lose the advantages of AMC A (less system capacity usage) and at the same time, we do not want to cause TCP retransmissions that significantly degrade application performance. Thus we decide to keep the AMC table A, but use HARQ on service flows. HARQ gives us dual advantages of SNR gain and fast retransmissions. We will now configure HARQ on the SS nodes.

4.1. We create the forth scenario starting again from the second scenario, AMC_A. Select Scenarios > Switch to Scenario and click on AMC_A. Now select Scenarios > Duplicate Scenario and name the new scenario AMC_A_with_HARQ. In the forth scenario we will use the more aggressive AMC in Table A and add HARQ to reduce the TCP retransmissions.

4.2. Configure HARQ on SS nodes as follows:

a. Right-click on any of the mobile nodes, and then choose Select Similar Nodes.

b. Right-click on one of the selected nodes, choose Edit Attributes, and check Apply to selected objects.

c. Expand WiMAX Parameters > SS Parameters > Uplink Service Flows > Row 0 and set HARQ Enabled attribute to Enabled.

d. Click OK to accept the changes.

e. Click Yes to dismiss the compound attribute warning. You should see the message “20 objects changed” in the status bar.

4.3. Run the simulation. Select DES > Configure/Run Discrete Event Simulation in the Project Editor. The simulation is configured as in the previous scenario (Figure 4). Click Run to start the simulation. When the execution completes, click Close.

4.4. Examine the results (Figure 10). Select DES > Panel Operations > Arrange Panels > Show All and DES > Panel Operations > Reload Data Into All Panels. Alternatively, you can right-click on the Project Editor window, select View Results to open the Results Browser, and then examine the relevant parameters shown in Figure 10.

4.5. Questions: Compare the simulation results of this scenario and the previous ones.

How does the TCP delay change and why?

How does the data loss change and why?

How does the UL frame usage change and why?

Switching back to AMC A and using HARQ is the optimal strategy. Explain why, by comparing the simulation results.

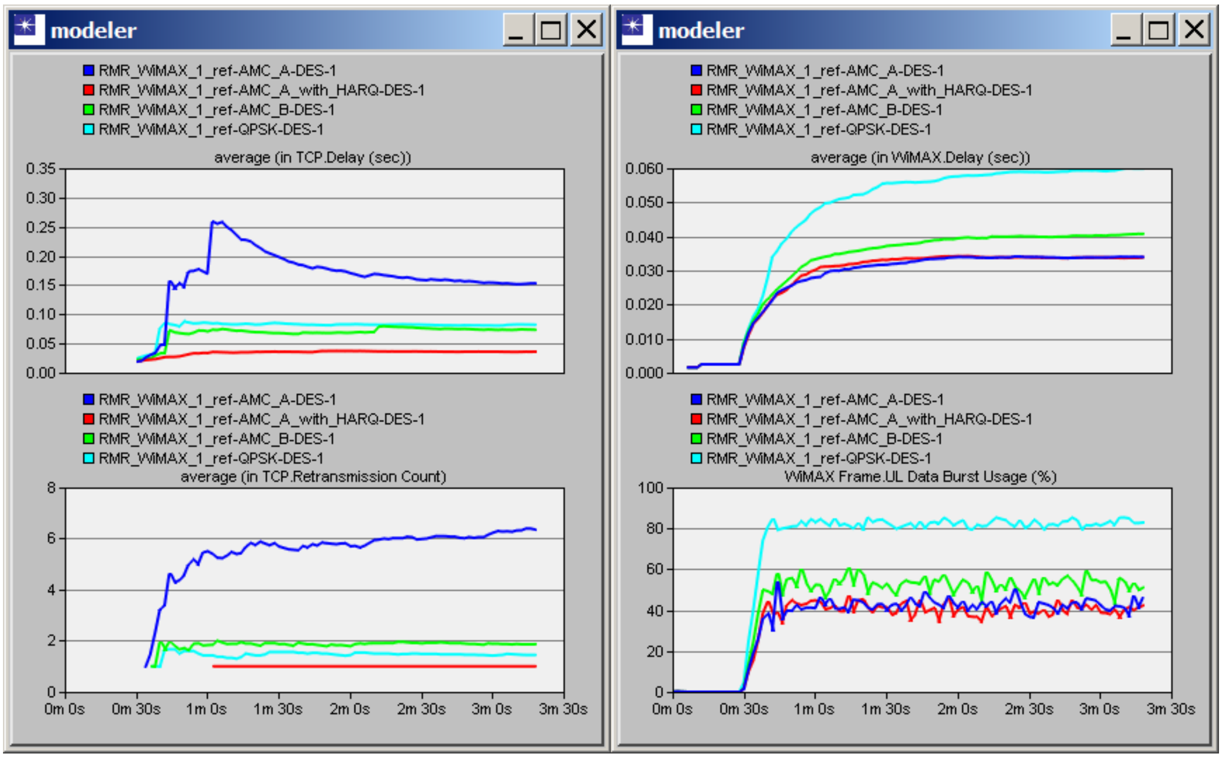

Figure 10. Simulation results for scenario AMC_A_with_HARQ versus AMC_A, AMC_B, and QPSK.