ECE 6610: Wireless Networks

Programming Assignment 2
Due on: September 29, 2025 at 11:59 PM ET

About the assignment:
This assignment has two questions and it focuses on understanding contention in 802.11 MAC and Mobile IP using ns3. The deliverables are summarized at the end.

Create an MS Word document "PA2.docx" and enter answers for the questions in the document. This file ("PA2.docx") is common for all the questions in this assignment. At the top of this document, include your names and group name.

Q1 - 802.11 contention and backoff - [50 points]

Q1-1 Briefly explain how medium access control is handled in IEEE 802.11 with DCF. When and how is the contention window updated? How is the back-off duration/counter chosen?

The goal of this question is to analyze the effect of traffic and number of STAs on contention and backoff in a WiFi network using the ns3 simulator. Question 2 can be expected to be completed in around 60 minutes. We will start with "pa2_q1.cc" from "Files⟶PAs⟶ECE6610_PA2_uploadItems.zip" in Canvas. Copy this to your "scratch" folder. This is based on an example from ns-3 and it is fairly involved. **We will not be making any changes to this source file (except logging format).** Ensure the source file compiles and runs properly as it is.

This simulation will take about 5 minutes to run completely. If you need to stop the simulation before it completes, you can interrupt the command line with *Ctrl + c*.

The scenario of this wireless network is a collection of Wi-Fi nodes that will operate in infrastructure mode. The simulation repeats itself with increasing number of nodes - starting with 5 to 40 in steps of 5. Note that the required trace sources, config paths and sinks have already been configured in this source file. We will be making use of the trace that tracks the contention window of each node. The simulation will save this trace with the file name 'wifi-cw-trace.out'. Whenever the number of nodes is increased, a new line is inserted specifying the number of nodes for that specific iteration.

The STAs are set up to send dummy frames to the AP and the contention window (among other traces) for each node is traced whenever there is a change (or update).

We will make use of the trace 'wifi-cw-trace.out'. The goal is to visualize the average contention window values as the number of nodes changes. Go to line 610 in the code. The function *CwTrace()* specifies how the values will be written in the trace file. It follows the format below:

```
time=<Time of contention window update>;node=<Node ID>;newCw=<New Contention window value>;
```

If you wish to change the format of this trace file, you can do so here. The trace file will contain only the CW updates for Node 0 after t = 3 seconds. We will focus only on Node 0 in this question. Note that we have conducted only a single trial for a short duration for each network scenario. This may result in variations from expected trends due to randomness.

Now, run the simulation. You will see that for each iteration the number of nodes increases by 5. Wait till the program completes. We are going to parse and process the trace file 'wifi-cw-trace.out' (found in the ns3 parent directory). You can use any program of your choice (Python, R, C++, or even Microsoft Excel) to process this file. Each line in the trace file represents to an update to the CW size for Node 0 in a given iteration at a given time. The goal is to find the time-average of CW size for Node 0 starting from t = 3 seconds for each iteration (There is one iteration for a given number of nodes).

For every iteration (with a given number of nodes), follow these steps:

1. First, filter only the lines of trace with selected number of nodes in the network. For example, when calculating for the iteration with 20 nodes, ensure no traces from other iterations are included for the corresponding calculation
2. Calculate the total duration of simulation traces for this iteration (timestamp of last trace - timestamp of first trace). Let this be $totalDuration[i]$ where i is the current iteration
3. For each j^{th} CW ($CW[j]$) update, calculate the duration for which the CW size lasted. That is, calculate $sampleDuration[j] = timestamp[j+1] - timestamp[j]$
4. Calculate the time weighted CW value for each $CW[j]$: $weightedCW[j] = CW[j] \times sampleDuration[j]$ (except for the last line of trace for which the duration is unknown)
5. Calculate the time-weighted average CW for iteration i as: $\left(\sum_j weightedCW[j]\right) / totalDuration[i]$

This should result in one value for each iteration.

Q1-2 Plot the time-weighted average CW value against the number of nodes in any program of your choice. Tabulate the average contention window size and the number of nodes for each iteration. Include the plot and the table in your submission document.

Q1-3 What do you observe as a general trend? Why do you think this trend arises? What is the implication of a higher average contention window value?

Q2 - Mobile IP - [50 points]

To understand mobile IP, we first suppose that two stations (**STA A** and **B**) are connected to the same Wi-Fi router (**ATL_router**) in Atlanta. STA A and B are connected to the same remote TCP server (**DC_server**) in Washington DC. STA A and STA B are sending TCP data packets to DC_server. The TCP ACKs are sent back to Node A and Node B from DC_server. In this setup, ATL_router is the home network for both A and B. We will not simulate this scenario but will use it as a reference for the next scenario.

We then suppose that Node B has moved to a different location (Chicago) which is served by the Wi-Fi router **CHI_router**. However, ATL is still the home network for Node B. **Hence, all the packets addressed to Node B are sent to ATL_router, which then forwards the packets to Node B through CHI_router.**

Download "pa2_q2.cc" from "Files⟶PAs⟶ECE6610_PA2_uploadItems.zip" in Canvas. Make sure that this program runs as is. In order to emulate the scenario above, the following topology is already setup in ns3:

- DC_server and ATL_router are connected by a P2P link (10 Mbps, delay *p2pDelay1*= 30 ms).
- ATL_router and CHI_router are connected by a P2P link (100 Mbps, delay *p2pDelay2*= 30 ms).
- CHI_router and DC_server are connected by a P2P link (10 Mbps, delay *p2pDelay3*=40 ms).

- **Node A is connected to ATL_router. Node B is connected to CHI_router**.

Note that in this setup, triangular routing is implemented by *injecting* a manual entry into the routing table of DC_server (see section *RoutingTableModification* in code). Packets from Node B are directly routed to DC_server (TCP data packets) but packets from DC_server to Node B (TCP ACK packets) are routed through ATL_router. Note that the routing tables for DC_server (Node 4 in logs) and CHI_router (Node 1 in logs) are printed to *ns-3-dev/pa3.routes* for your reference. Static routes (with the flag **S**) have higher precedence over the global routes.

Ignore the delays associated with the wireless links for all RTT calculations and consider only the P2P links.

Q2-1 Draw both the network topologies: (1) before STA B moved out of Atlanta, and (2) after STA B is connected to CHI_router. For the second network, show the following: all nodes, wired (P2P) and wireless (Wi-Fi) communication links between all nodes, bandwidth and delay of all P2P links, and IP addresses of all interfaces for all nodes. Note that a node can have multiple interfaces where each interface connects a node to one communication link. Feel free to use any software to draw the topologies (PowerPoint, draw.io, etc.).

Q2-2 For the network scenario given (with triangular routing), what is the RTT for a packet from Node A to DC_server and back? Express this RTT in terms of P2P link delays also.

Q2-3 For the network scenario given (with triangular routing), what is the RTT for a packet from Node B to DC_server and back? Express this RTT in terms of P2P link delays also.

Q2-4 What is the observed collective average throughput as reported by the packet sink at DC_server? How would the TCP data throughput for the two scenarios: (1) before STA B moved out of Atlanta, and (2) after STA B is connected to the CHI_router compare?

Q2-5 Increase *p2pDelay3* from 40ms to the following values: 50, 60, 80, 100, 125, 150, 175, 200 ms. Run the simulation for each of these values and plot the data throughput for both the TCP connections. What do you observe? What is the relation between RTT and TCP throughput?

Deliverables:

Please upload PA2.docx directly.