Project 3: Why am I always connected?

Important Note

Please begin this project as soon as possible. It requires you to understand the terms mentioned here and to design your own system. Do not wait until the last few days to start; starting late is unlikely to yield good grades.

Background

When I was 5 years old, I got my first laptop. It didn't have wireless connectivity; I had to use an ethernet cable and dial-up to access the internet. When I got my first phone, I was amazed by its ability to connect to wireless internet at home, avoiding the need for expensive cellular data. Back then, to avoid dead spots in your home, you had to set up multiple wireless routers, and moving around often required reconnecting. Today, as we walk around campus, you can connect to the campus Wi-Fi seamlessly without needing to reconnect constantly. This is made possible by a technique called Wi-Fi roaming. In this project, you are required to implement a simulator that mimics the Wi-Fi roaming process.
To understand the process of roaming, we need to first understand the several network terms: AP, AC, Client. All above are something called network entities. APs, refer to access point, is often offer wireless connection. AC, on the other side, are devices in wireless networks that manage and control access points (APs). They provide centralized management for configuring APs, including handling network settings, security concerns, and other parameters. By using an AC, administrators can manage these aspects from a single location, ensuring consistent control and streamlined network management.

Network Terms

WiFi roaming refers to the process by which a wireless client device (such as a smartphone, tablet, or laptop) transitions from one Access Point (AP) to another within the same wireless network without losing connectivity. Roaming is crucial in environments with extensive WiFi coverage, such as large buildings, campuses, and public spaces, where a single AP cannot provide adequate coverage for the entire area.

As a client device moves through an environment, it may encounter areas where the signal strength from its current AP diminishes while the signal strength from a nearby AP becomes stronger. To maintain a reliable and high-quality connection, the client must disconnect from the current AP and reconnect to the stronger one. This transition needs to happen seamlessly to avoid interruptions in network service.

WiFi roaming involves several key processes and technologies that ensure smooth transitions between APs:

1. 802.11k - Radio Resource Management: 802.11k helps devices understand the wireless environment by providing information about nearby APs. This includes details like the signal strength, channels, and load of surrounding APs. With this information, the client can make more informed decisions about when and where to roam.

2. 802.11v - Network-Assisted Roaming: 802.11v enhances client mobility by enabling the network to assist with roaming decisions. It allows the network to inform the client about the best AP to connect to based on factors like network load and client location. This standard also includes power-saving features that help clients manage battery life more effectively during roaming.

3. 802.11r - Fast BSS Transition: 802.11r, also known as Fast Transition (FT), significantly reduces the time required for a client to switch from one AP to another by streamlining the authentication process. Normally, when a client roams to a new AP, it must undergo a complete reauthentication process, which can cause delays. With 802.11r, the client can pre-authenticate with the new AP while still connected to the current one, allowing for faster handoffs.

Input Requirement

For the simulation, your program's input file consists of lines of text. Each file will fit the certain format, described below.

```
AP AP1 0 0 6 20 2.4/5 WiFi6 true true true 50 10 75
AP AP2 100 100 6 20 5 WiFi7 false true false 40 60
CLIENT Client1 10 10 WiFi6 2.4/5 true true true 73
MOVE Client1 10 9
```

So basically you are give a file contains the following:

```
AP <APNAME> <x> <y> <channel> <power_level> <frequency> <standard> <supports_11k>
<supports_11v> <supports_11r> <coverage_radius> <device_limit>
<minimal_rssi(optional)>
CLIENT <CLIENTNAME> <x> <y> <standard> <speed> <supports_11k> <supports_11v>
<supports_11r> <minimal_rssi(required)>
MOVE <CLIENTNAME> <x> <y>
```

x and y here were always represent the coordinates. All number should be positive. Assume that each move will only be one change. Each field is seperated by a space.

Notice that:

1. A line could start with AP, followed by its parameters.

2. A line could start with CLIENT, followed by its parameters.

3. A line could start with MOVE followed by how clients moved in the map.

4. A line could be completely blank, which you can safely ignore.

5. There is no restriction about the order in which you'll find the lines of the file. Any of those kinds of lines can appear anywhere in the file.

Once all move are simulated and all network entities logged required output, your program should end.

Output Requirement

Each device, AP, and AC should keep a list of actions it takes which a step number, which I represent here as n. For clients:

1. When roaming happened, log where to roam based on the signal strength, AP capacity, and supported WIFI standards. For example, "Step n: CLIENT ROAM FROM AP1 TO AP2" If got denied, message will be "Step n: CLIENT ROAM DENIED"

2. When disconnect happened, log the signal strength before disconnect, the last AP connects to. For example, "Step n: CLIENT DISCONNECT FROM AP2 WITH SIGNAL STRENGTH 89"

3. When connection happened, log AP name with current signal strength. For example, "Step n: CLIENT CONNECT TO AP 1 WITH SIGNAL STRENGTH 62"

For APs:

1. When a device roaming happened, log which device roamed and which new AP it roam to. For example "Step n: Client1 ROAM TO AP3" If the new AP support 802.11r, the message will be "Step n: Client1 FAST ROAM TO AP3". In case, the roaming got declined by the AP if it reach the maximum client, message will be "Step n: Client1 TRIED _APNAME BUT WAS DENIED"

2. When a device disconnect happened, log the device name and also its last location. For example, "Step n: Client1 DISCONNECTS AT LOCATION 10 9"

3. When a device connect, log the device information and all its supported protocols. For example, "Step n: Client1 CONNECT LOCATION 10 9 WiFi6 2.4/5 true true true"

For AC: The Access Controller (AC) is designed to comprehensively manage and order information from all Access Points (APs). It ensures optimal channel allocation by instructing APs to switch channels when an overlap occurs. The channel selection adheres to the following criteria:

1. Channels should range from 1 to 11.

2. Preferred channels are 1, 6, and 11, with a preference for the highest available among these.

3. If none of 1, 6, or 11 are available, the AP should switch to one channel lower than its current setting. If the current channel is 1, then it should switch to channel 2.

At the start of the simulation, the AC logs all channel assignments and changes. For instance, it might log "Step n: AC REQUIRES AP1 TO CHANGE CHANNEL TO 11" to indicate a mandated switch due to an overlap. This system ensures that all APs operate on the most efficient and least conflicting channels.

Each device should be supported to be called and generated a **binary file** contain this list.

When to Roam

While AP and AC are there, the client has the ultimate power to decide if it wants to roam. The client will consider the following process order:

1. Trigger the roaming process if signal strength drops below the threshold. It can be AP tell client to be roamed because the client is below the minimal signal strength(RSSI) or client decided to roam. If this happened at the same time, the AP will always tell the client to roam.

2. Discover and evaluate nearby APs.

3. Prefer APs with higher or more compatible WiFi standards. For this one, they prefer in such order, device with WIFI 6 always prefer AP with WIFI 6 or higher. In tie, device prefer APs with more supported roaming standard. For example if two AP both support WIFI6, but the one AP support close number of roaming standard with the device, the device would choose that one. More detailed example is that client one support 802.11r and 802.11v, one AP support all three standards and the other AP support only 802.11r and 802.11v, the client will prefer the one support only 802.11r and 802.11v.

4. If there is a tie, prefer AP with more power.

5. Ensure the AP has not reached its device limit and consider load.

6. Evaluate the frequency band and prefer higher bands(prefer 6GHz then 5GHz then 2.4GHz, prefer channel 11 then 6 then 1)

7. If 802.11r is supported, prefer 802.11r AP because fast transition capabilities for minimal handoff disruption.

8. Now select the best AP and execute the roaming process.

Calculate RSSI

Use the formula to calculate RSSI:
$\text{power} - 20 \cdot \log_{10}(\text{distance to AP}) - 20 \cdot \log_{10}(\text{AP frequency}) - 32.44$
Also assume that the AP only cover a standard circle rather than an ellipse by given coverage_radius

Design

Is this no specific design requirement. Instead, it will be your job to design this system as well as test the system. So you need to submit a design document not exceed 1 page to explain the design process. Also, write unittest to test your functionality of the simulator.

Submissions

Design Document

- Submit a concise design document that does not exceed one page. This document should detail your design process and be uploaded to your Canvas Assignment section.

Python Files and Test Cases

- Submit all Python files necessary to run the simulation and your test cases through Gradescope.

Testing and Assumptions

- Write unit tests to ensure the functionality of your simulator.
- Document any assumptions made in cases where there is no clear answer regarding which AP a device connects to or the order of device logging.

Evaluation Criteria

Manual Review

- This project will be manually reviewed; there is no autograder. Ensure your test cases strictly follow the specified output and order. Document any assumptions made if outputs or order are not specified here in your design file.

Implementation Techniques

- Use any techniques discussed in the course to implement the simulation. However, your design must incorporate at least two specific topics from this course, such as inheritance and class magic methods. Document these topics clearly in your design file.

Important Note

Please ensure all components are submitted to the correct platform to avoid any issues.