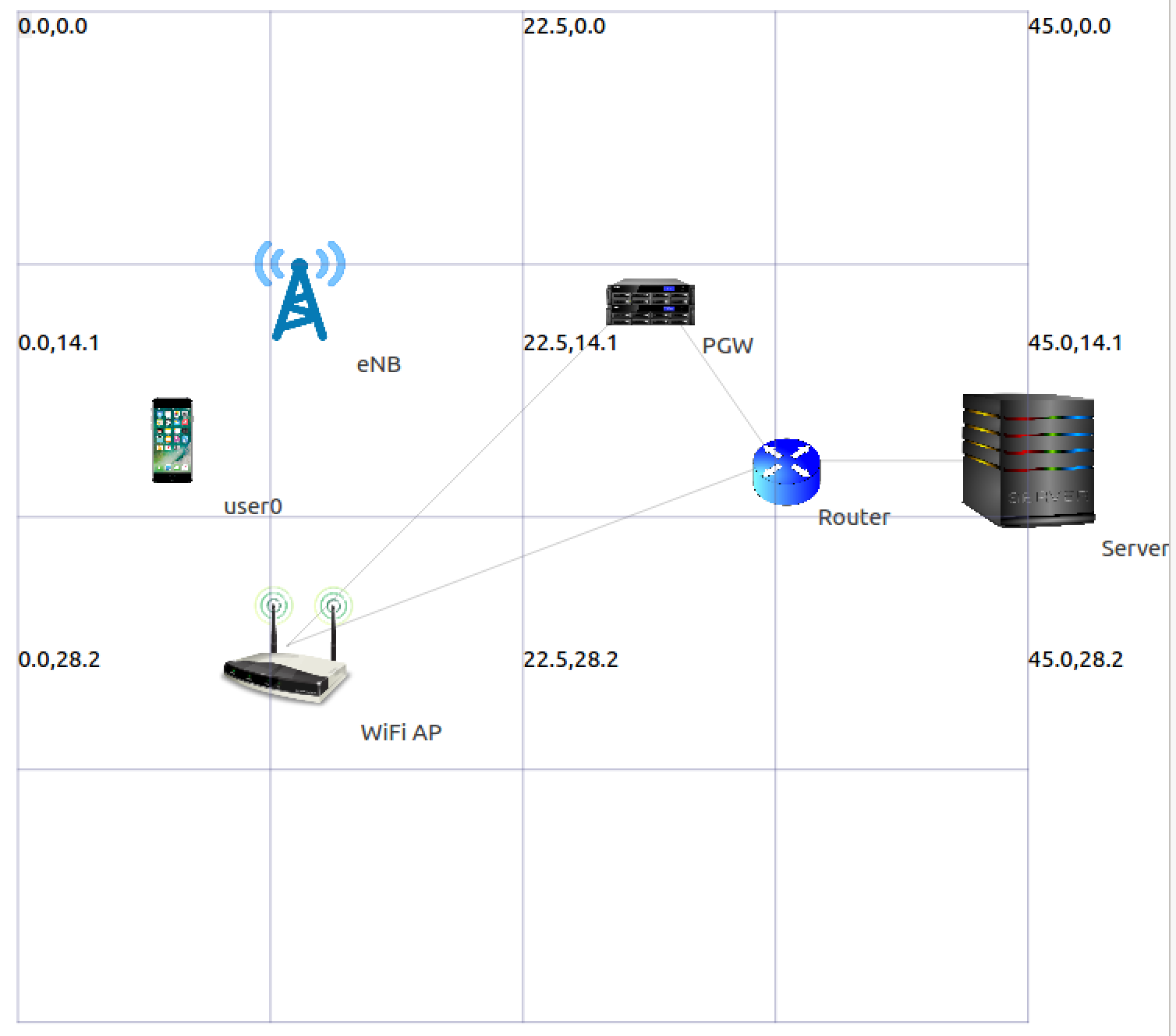
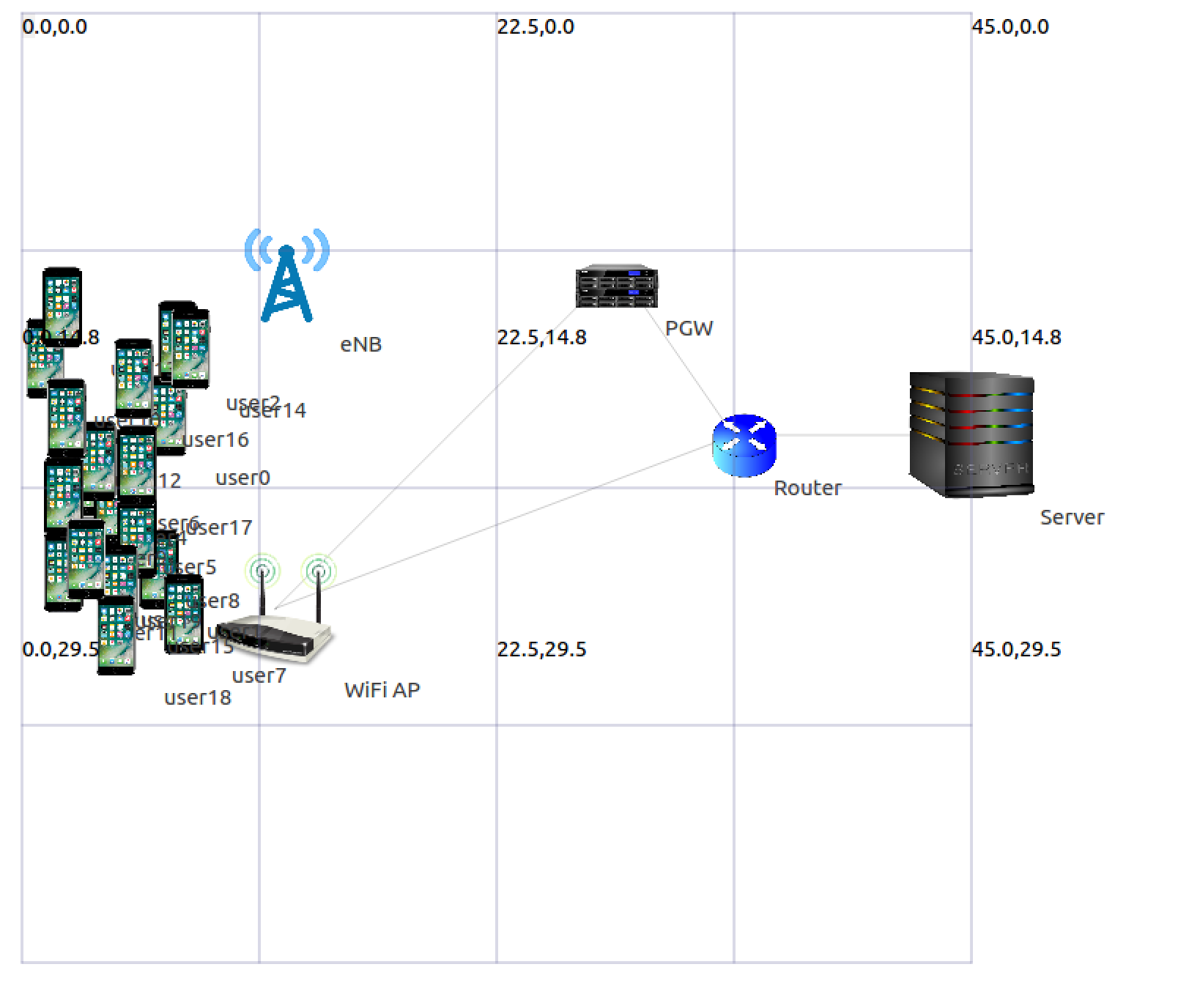
**CIS 549 Project 3 Report**

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**Question #1**

Network Topology for 1UE

Network Topology for 20 UE



**Question #3**

Throughput chart

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| RTT(ms) | RWND (Bytes) | MCS | 1 UE | | 3 UE | | | |
| Per UE | | Per UE | | System level | |
| Wi-Fi TCP | | Wi-Fi TCP | | Wi-Fi TCP | |
| Peak (Mbps) | Avg (Mbps) | Peak (Mbps) | Avg (Mbps) | Peak (Mbps) | Avg (Mbps) |
| 30 ms | 64000 | HtMcs1 | 14.67 | 11.11 | 12.64 | 7.12 | 24.08 | 21.23 |
| 200 ms | 64000 | HtMcs1 | 5.04 | 2.48 | 5.04 | 2.63 | 13.66 | 6.94 |
| 30 ms | 1024000 | HtMcs1 | 23.97 | 21.04 | 23.86 | 13.70 | 23.86 | 20.68 |
| 200 ms | 1024000 | HtMcs1 | 23.86 | 16.32 | 23.97 | 11.34 | 23.97 | 16.78 |
| 30 ms | 64000 | HtMcs7 | 16.80 | 15.38 | 16.58 | 13.79 | 46.59 | 41.36 |
| 200 ms | 64000 | HtMcs7 | 5.04 | 4.59 | 5.04 | 3.00 | 15.12 | 7.73 |
| 30 ms | 1024000 | HtMcs7 | 70.34 | 25.80 | 114.46 | 61.76 | 114.46 | 92.27 |
| 200 ms | 1024000 | HtMcs7 | 113.57 | 72.70 | 81.76 | 27.32 | 114.13 | 66.66 |

TCP Analysis with 1UE

A screenshot of a cell phone

Description automatically generated

Note how the highest throughput is achieved with a combination of the lowest RTT of 30ms, the best MCS setting of 7 (64-QAM modulation), and highest receive buffer size of 1MB. This is what we would expect since we have the best of all 3 control variables.

Also note how the second highest throughput is achieved with a 200ms RTT delay (more than 3 times that of 30ms). This indicates that delay time is not as impactful to throughput as the other 2 control variables (MCS and TCP receive buffer).

In contrast, the worst throughput is achieved with a combination of 200ms RTT and a small receive window of 64K, regardless of which MCS modulation (1=QPSK, 7=64-QAM) method is used. The bottleneck here is the 64K window size and long (200ms) delay time, meaning that many more packets must be sent with longer delay times, resulting in poor throughput.

If we compare 30ms vs 200ms delay times with a 1MB window and MCS1, we can see similar throughput results with the different being the start time of the transmission is delayed more with the 200 RTT, which makes sense since there is a longer delay in setting up the 10MB file download.

Finally, we get just OK throughput if we combine small window size of 64K with low RTT of 30ms, regardless of which modulation method we use. As expected, we get slightly higher throughput with 64-QAM vs. QPSK.

TCP Analysis with 3UEs

A picture containing screenshot, map

Description automatically generated

As we observed with 1UE, the best 2 sets of results with 3UEs are achieved with the higher receive window size of 1MB and MCS7 modulation (64-QAM). Again, the difference between the 30ms vs. 200ms RTT delay was not as impactful as that of the other 2 control variables. However, we also see almost the same higher throughput using 30 and 200 RTT. Notably, there was no observed penalty in throughput for increasing the delay time to 200ms with 3UEs running. This indicates more efficient utilization of the line with multiple UEs because while one UE is writing its TCP receive buffer, another UE can be receiving data.

In the worst performing category, we have the simulations with small window sizes of 64K and longer RTT times of 200ms. In these 2 cases, we can see the difference between MCS 1 (QPSK) and MCS 7 (64-QAM). With MCS1 (QPSK) modulation, we see the throughput continually oscillating between 0-10Mbps in the form of a sine wave while 64-QAM appears to maintain a more constant throughput. This is because QAM uses both phase shifting and amplitude shifting.

TCP Analysis for single UE with 3UEs

UE1

A screenshot of a social media post

Description automatically generated

UE2

A screenshot of a social media post

Description automatically generated

UE3

A screenshot of a cell phone

Description automatically generated

The above results with 1UE out of 3UEs running look a lot like the results of 1UE running by itself. However, if we look at UE2 and UE3, we can see a delay in start time for MCS1 and 1024 RWIN regardless of RTT, indicating that UE1 is starting to download the file first.

NetAnim analysis

For 1UE, we can observe in NetAnim that the download throughput is slower than the upload. This is to be expected because we are downloading a 10MB file. There is a conversation between the UE and the AP, then part of the file is downloaded, then this process repeats until the file is downloaded.

For 3UEs, we can see multiple conversations between the 3 UEs and the WiFi Access Point before the download starts, then we see part of the file being downloaded from the server to the AP via the Router, then we see the 3 UEs again communicating with the AP. This process also repeats until the file is downloaded. As with 1UE, the download is slower that the upload.

**Question #4**

|  |  |  |  |
| --- | --- | --- | --- |
| RTT | MCS | 1 UE | |
| System Level | |
| Wi-Fi UDP | |
| Peak (Mbps) | Avg (Mbps) |
| 30 ms | HtMcs1 | 25.20 | 25.09 |
| 200 ms | HtMcs1 | 25.09 | 25.09 |
| 30 ms | HtMcs7 | 121.97 | 121.73 |
| 200 ms | HtMcs7 | 121.97 | 121.73 |

30ms vs. 200ms

MCS1 vs. MCS 7

Peak vs. Average

b. Why use UDP traffic instead of using the result obtained using TCP in Problem 3?

c. Compare the TCP and UDP peak throughput observed in Problems 3 and 4 for every combination of the configurations listed in Problem 4. What is your most significant observation?