**CIS 549 Project 4 Report**

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**Question #2**

Each subframe is downloading to 3 UEs per TTI, indicating the PRBs are shared evenly amongst the 3 UEs. There are 32 PRBs available, so this a 5.76MHz network (32x180K). The transmit blocks are consistently 2961 Bytes, so a 2 MB file downloading to 3 UEs would take (2048000/2961\*3=2075 TTI, i.e., roughly 2.1 seconds) and we do observe 2160 TTIs in the DLMacStat.dat file.

First 30 rows of DlMacStat.dat file:

% time cellId IMSI frame sframe RNTI mcsTb1 sizeTb1 mcsTb2 sizeTb2 Nprb

1.042 1 3 105 3 1 28 2961 0 0 32

1.042 1 1 105 3 2 28 2961 0 0 32

1.042 1 2 105 3 3 28 2961 0 0 32

1.139 1 1 114 10 2 28 2961 0 0 32

1.139 1 2 114 10 3 28 2961 0 0 32

1.139 1 3 114 10 1 28 2961 0 0 32

1.236 1 2 124 7 3 28 2961 0 0 32

1.236 1 3 124 7 1 28 2961 0 0 32

1.236 1 1 124 7 2 28 2961 0 0 32

1.333 1 3 134 4 1 28 2961 0 0 32

1.333 1 1 134 4 2 28 2961 0 0 32

1.333 1 2 134 4 3 28 2961 0 0 32

1.334 1 1 134 5 2 28 2961 0 0 32

1.334 1 2 134 5 3 28 2961 0 0 32

1.334 1 3 134 5 1 28 2961 0 0 32

1.43 1 2 144 1 3 28 2961 0 0 32

1.43 1 3 144 1 1 28 2961 0 0 32

1.43 1 1 144 1 2 28 2961 0 0 32

1.431 1 3 144 2 1 28 2961 0 0 32

1.431 1 1 144 2 2 28 2961 0 0 32

1.431 1 2 144 2 3 28 2961 0 0 32

1.527 1 1 153 8 2 28 2961 0 0 32

1.527 1 2 153 8 3 28 2961 0 0 32

1.527 1 3 153 8 1 28 2961 0 0 32

1.528 1 2 153 9 3 28 2961 0 0 32

1.528 1 3 153 9 1 28 2961 0 0 32

1.528 1 1 153 9 2 28 2961 0 0 32

1.529 1 3 153 10 1 28 2961 0 0 32

1.529 1 1 153 10 2 28 2961 0 0 32

1.529 1 2 153 10 3 28 2961 0 0 32

**Question #3**

Throughput charts (LTE and Wi-Fi)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| RTT(ms) | RWND (Bytes) | MCS | 1 UE | | 3 UE | | | |
| Per UE | | Per UE | | System level | |
| LTE-TCP | | LTE-TCP | | LTE-TCP | |
| Peak (Mbps) | Avg (Mbps) | Peak (Mbps) | Avg (Mbps) | Peak (Mbps) | Avg (Mbps) |
| 30 ms | 64000 | Default | 14.11 | 10.00 | 11.20 | 10.00 | 33.60 | 30.00 |
| 200 ms | 64000 | Default | 4.93 | 1.95 | 4.93 | 1.92 | 14.78 | 5.75 |
| 30 ms | 1024000 | Default | 72.58 | 47.05 | 22.85 | 20.00 | 68.54 | 59.99 |
| 200 ms | 1024000 | Default | 72.46 | 22.85 | 22.85 | 16.00 | 68.54 | 47.99 |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 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 (LTE and Wi-Fi):

**A screenshot of a cell phone

Description automatically generated**

A screenshot of a cell phone

Description automatically generated

We observe best throughput with Wi-Fi (~125Mbps) vs LTE (~75Mbps). With LTE, we observe similar throughput with 30ms and 200ms RTT with the same 1Mb window size. The smaller 64K window size had much lower throughput with LTE and Wi-Fi.

TCP Analysis with 3UEs (LTE and Wi-Fi)

A screenshot of a cell phone

Description automatically generated

A picture containing screenshot, map

Description automatically generated

Again, with 3 UEs, Wif-Fi outperforms LTE throughput (~125 vs ~75 Mbps). With LTE, throughput was identical with the 1Mb window size and we see the delayed start with 200ms RTT vs. 30ms RTT for both FTE and Wi-Fi.

TCP Analysis for single UE with 3UEs (LTE and Wi-Fi)

UE1

A screenshot of a social media post

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A screenshot of a social media post

Description automatically generated

UE2

A screenshot of a social media post

Description automatically generated

A screenshot of a social media post

Description automatically generated

UE3

**A screenshot of a social media post

Description automatically generated**

A screenshot of a cell phone

Description automatically generated

The 3UEs have similar throughputs with LTE (~23Mbs) as do the 3 UEs with Wi-Fi. With LTE, the individual UEs look almost identical, indicating they are getting roughly the same amount of throughput per UE.

NetAnim analysis:

We can see the file download coming from the server via the PGW and the eNodeB serially. Then, the data moves from the eNodeB to the 3UEs simultaneously, as we would expect since the PRBs are evenly split between the UEs, so each micro-second, all 3 UEs receive data.

**Question #4**

|  |  |  |  |
| --- | --- | --- | --- |
| RTT | MCS | 1 UE | |
| System Level | |
| LTE-UDP | |
| Peak (Mbps) | Avg (Mbps) |
| 30 ms | Default | 73.70 | 73.70 |
| 200 ms | Default | 73.70 | 73.70 |

|  |  |  |  |
| --- | --- | --- | --- |
| 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 |

UDP Analysis LTE and WiFi

A screenshot of a social media post

Description automatically generated

LTE throughput (~75Mbps) is roughly in between Wi-Fi MCS1 (~25Mps) and MCS7 (~121Mbps) for UDP.