



Amalie Arena

Opening Day User Experience Testing (AT&T and Verizon)

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Overview and Testing Methodology

- MobileNet Services was tasked with testing mobile data user experience inside Amalie Arena during opening night (October 3rd, 2019) for the Tampa Bay Lightning for the 2019 season.
- Stationary comparative testing was opted over walk testing as most users are stationary as well as due to the difficulty of performing repeatable walks of the entire venue throughout the game.
- Since we wanted to compare how the performance varied throughout the game, eight locations were chosen that were tested before, during and after the game.

Testing Methodology

- The eight locations were tested (see slide 4 for details) across Levels 100, 200 and 300.
- Testing was performed with AT&T and Verizon phones (Ue's)
- Testing comprised of consecutive FTP DL and UL tasks on FTP servers dedicated to each operator
- Two Test Engineers performed the testing, collecting data during various timeframes throughout the game (see slide 4 for details)

Test Equipment

- Testing was performed using Rohde and Schwarz QualiPoc Freerider
- Samsung Galaxy S9's were used for testing on Verizon and AT&T's network
- Engineering SIM's were used for both operators
- Testing was performed simultaneously by each tester and there was a 65%+ overlap in tasks during the testing

Test Locations



Testing Times

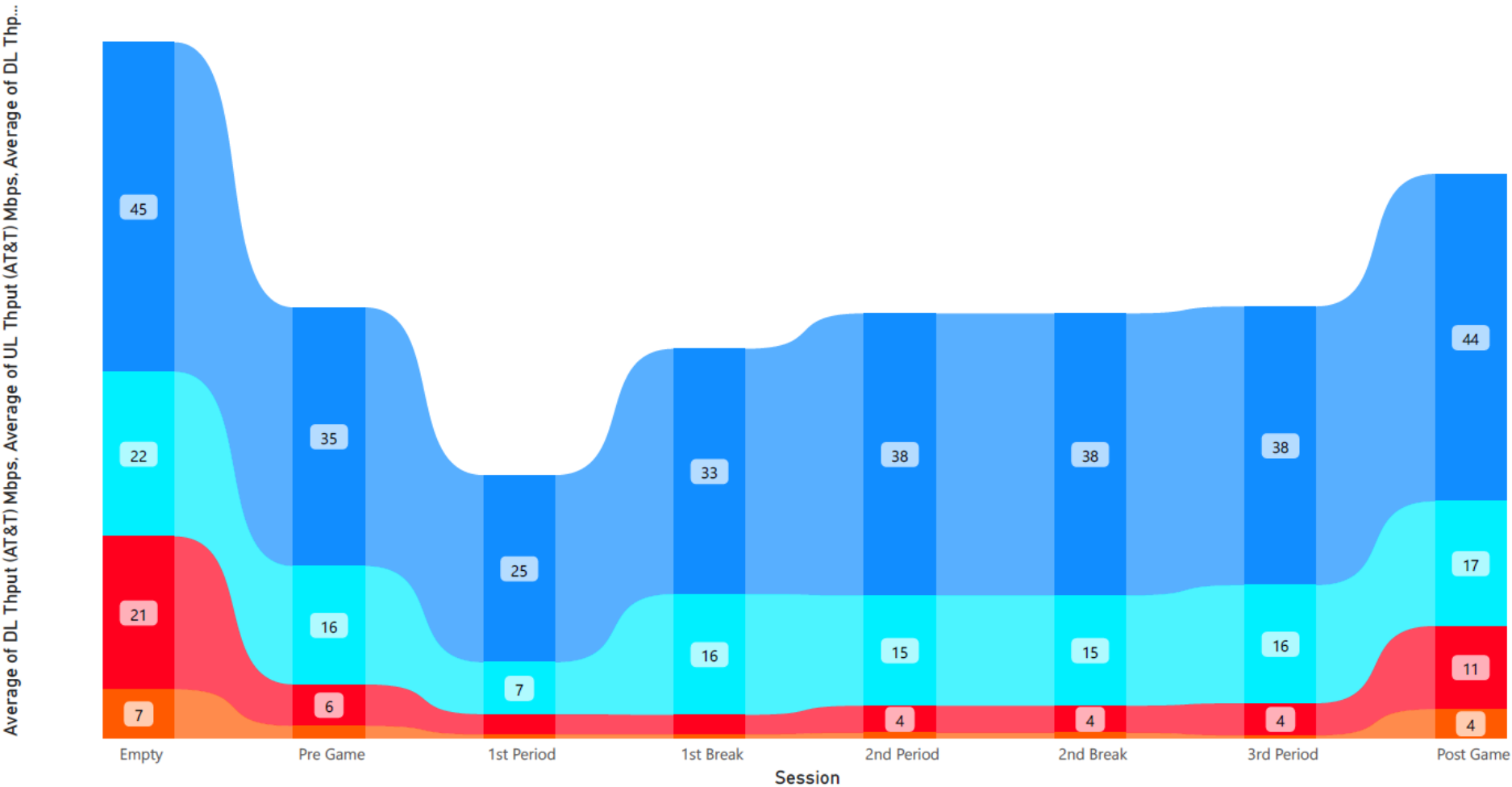
Testing was performed for each of the eight locations outlined during the following times:

1. Empty (Morning)
2. Pre-game
3. 1st Period
4. 1st Break
5. 2nd Period
6. 2nd Break
7. 3rd Period
8. Post-game

Throughput Performance Throughout Event

Breakdown of Throughput (Mbps) by Session

● Average of DL Thput (AT&T) Mbps ● Average of UL Thput (AT&T) Mbps ● Average of DL Thput (VzW) - Mbps ● Average of UL Thput (VzW) - Mbps



Observations

- AT&T's performance (both DL and UL) was significantly better throughout the event
- The peak data rates were observed when the arena was empty
- Lowest data rates were experienced during the start of the game (1st Period)

Signal Strength and Quality

AT&T Signal Levels by Session

Session	Average of RSRP	Average of SINR	Average of RSRQ	Average of RI	Average of UE Power	Average of DL Thput (AT&T) Mbps	Average of UL Thput (AT&T) Mbps
Empty	-69.54	8.96	-10.35	1.54	-26.70	44.77	22.38
Pre Game	-73.14	6.63	-12.39	1.41	-25.22	35.13	16.10
1st Period	-74.79	7.07	-12.58	1.48	-24.14	25.42	7.08
1st Break	-74.68	6.79	-12.94	1.54	-21.88	33.32	16.42
2nd Period	-73.87	8.56	-11.61	1.37	-24.65	38.31	15.00
2nd Break	-73.87	8.56	-11.61	1.37	-24.65	38.31	15.00
3rd Period	-75.09	7.69	-12.52	1.49	-22.85	37.86	16.07
Post Game	-75.20	8.25	-11.71	1.49	-21.20	44.47	16.96
Total	-73.93	7.67	-12.08	1.46	-23.89	36.00	14.23

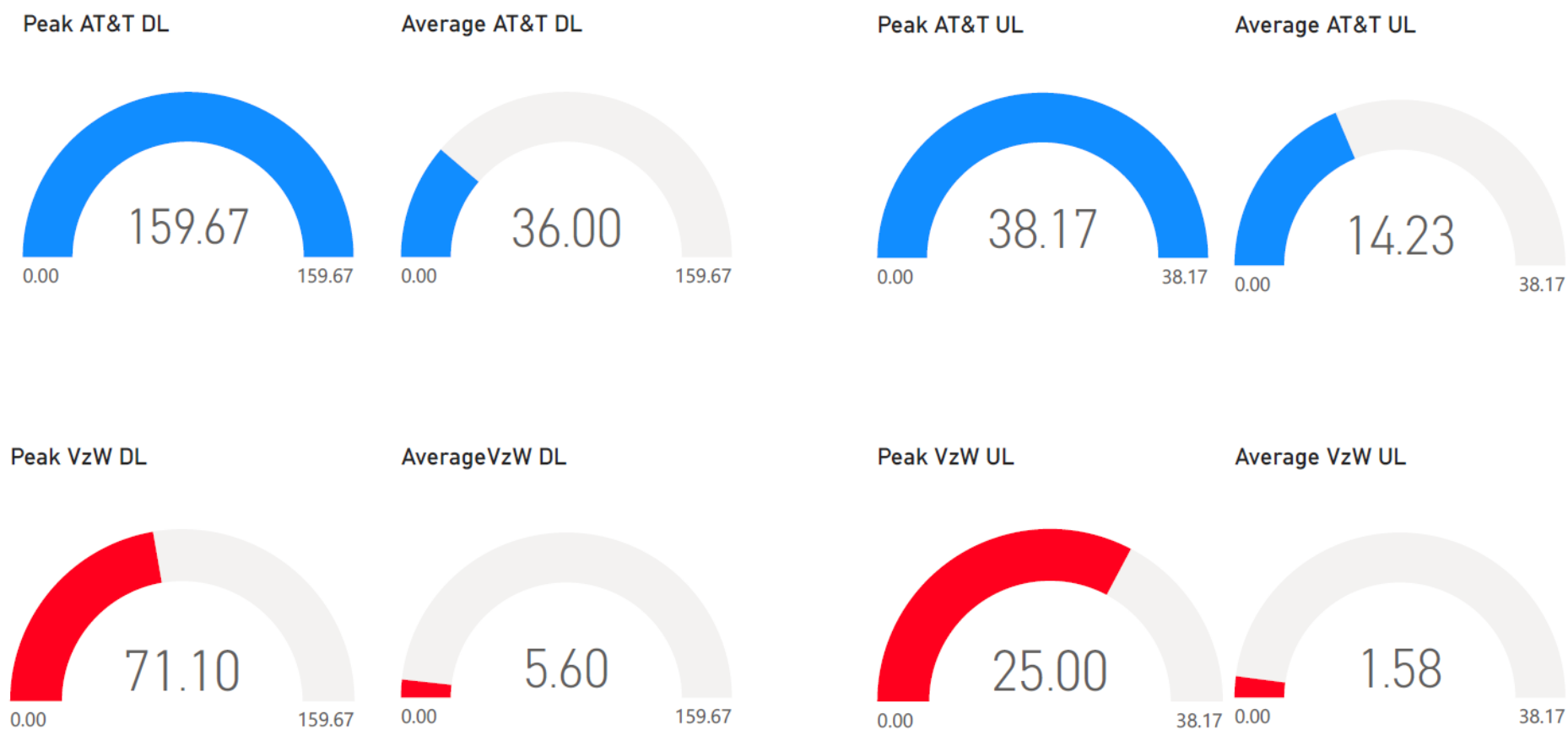
Verizon Signal Levels by Session

Session	Average of RSRP	Average of SINR	Average of RSRQ	Average of RI	Average of UE Power	Average of DL Thput (VzW) - Mbps	Average of UL Thput (VzW) - Mbps
Empty	-96.43	3.72	-12.22	1.32	9.14	20.77	6.67
Pre Game	-93.99	4.43	-12.89	1.20	7.27	5.62	1.71
1st Period	-90.38	6.02	-12.27	1.26	4.95	2.72	0.56
1st Break	-88.67	3.95	-12.44	1.23	4.74	2.63	0.57
2nd Period	-94.06	3.62	-12.73	1.21	8.37	3.67	0.77
2nd Break	-94.06	3.62	-12.73	1.21	8.37	3.67	0.77
3rd Period	-88.51	5.81	-11.62	1.26	3.66	4.35	0.42
Post Game	-92.80	2.31	-13.20	1.08	5.53	11.29	3.98
Total	-92.14	4.35	-12.51	1.22	6.39	5.60	1.58

Observations

- AT&T's throughput performance can be attributed to better signal levels and signal quality (SINR)
- Average AT&T signal strength (RSRP) was stronger (by approx. 20dB) than VzW
- Average AT&T signal quality (SINR) levels were around 3dB better
- The impact on quality and strength can also be seen in the Phone (Ue) Power values, with the Verizon phones operating at much higher transmit power. This also will lead to lower battery life for Verizon phones.

Peak versus Average Throughputs



Observations

- Both AT&T and Verizon Ue's were able to achieve good peak throughput.
- The average throughput outlines the overall data experience during the event, with the uplink throughput for Verizon less than 2Mbps

Summary

- AT&T Ue's performed better for both data DL and UL
 - With average values above 30Mbps and 10Mbps for DL and UL
 - With peak values reaching over 155Mbps and 35Mbps for DL and UL
- The best performance for both networks were observed when the venue had the least number of users (pre and post game)
- AT&T's superior performance over Verizon Wireless can be attributed to better signal strength and quality

Thank You

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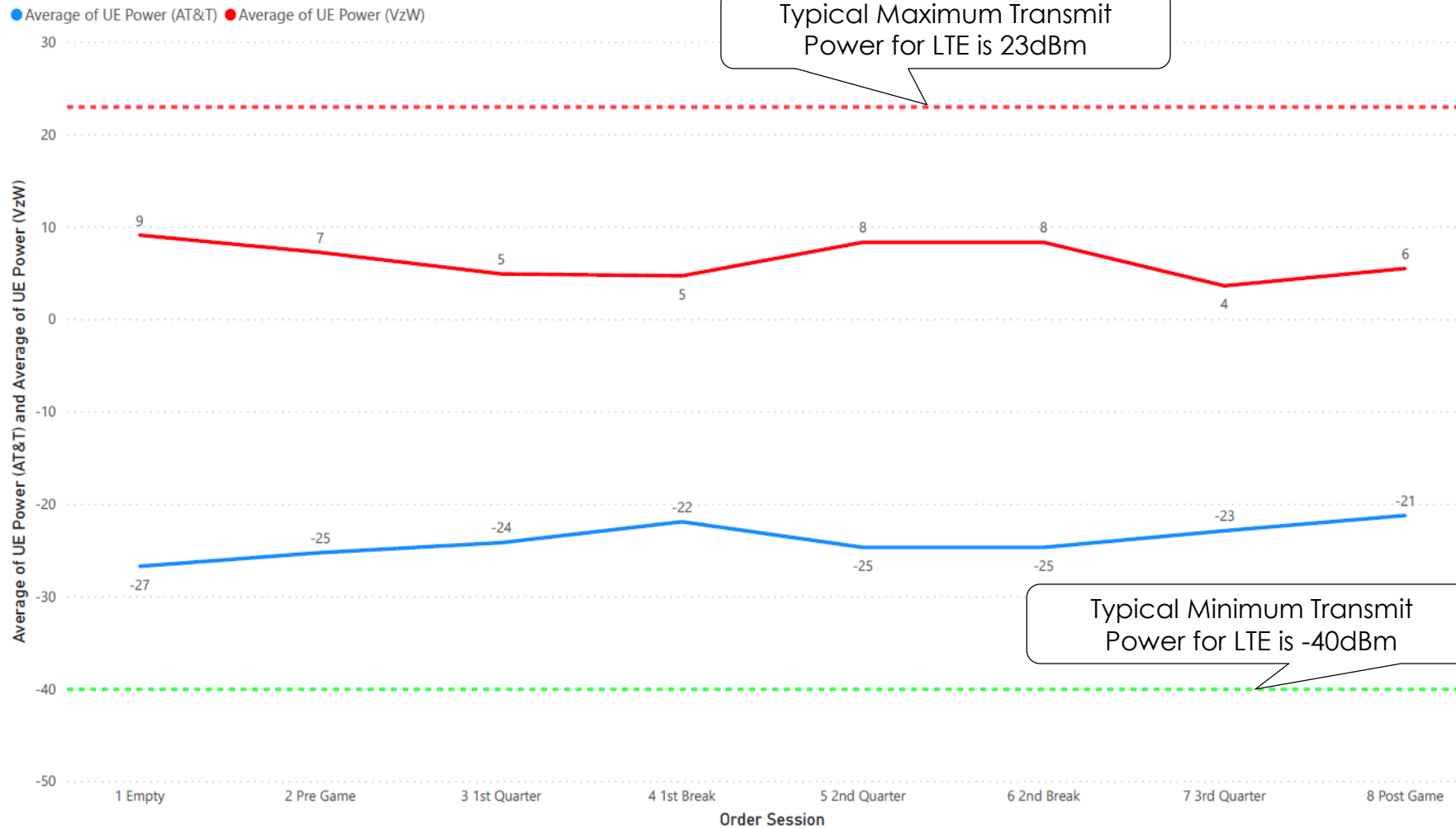
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Supporting Slides

UE Transmit Power

AT&T Ue Tx Power



Observations

- The UE transmit powers for the two operators were quite different
- The Verizon phone was transmitting at significantly higher power
- AT&T phone transmit power was always seen to be below -20dBm
- Verizon phone transmit power was always above 4dBm
- The higher transmit power will give rise to higher noise floor and will also impact performance and capacity
- The higher transmit power on the Verizon phones could also lead to lower battery life



RRC and Task Breakdown

AT&T RRC and Task Breakdown

Session	RRConnection Attempts	RRConnection Complete	Task Start	Task End	Task Fail
Empty	32	32	78	73	5
Pre Game	61	61	142	137	5
1st Period	36	36	94	83	11
1st Break	41	41	94	88	6
2nd Period	33	33	87	81	6
2nd Break	33	33	87	81	6
3rd Period	46	46	111	105	6
Post Game	38	38	92	86	6
Total	320	320	785	734	51

VzW RRC and Task Breakdown

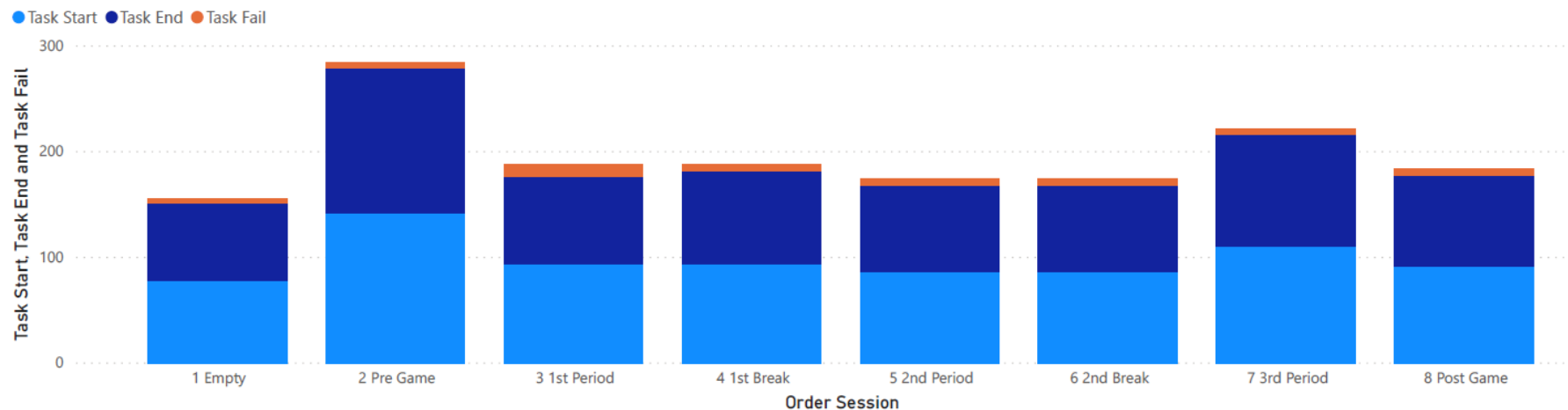
Session	RRConnection Attempts	RRConnection Complete	Task Start	Task End	Task Fail
Empty	15	15	43	35	8
Pre Game	11	8	39	18	21
1st Period	4	3	31	3	28
1st Break	3	1	25	4	21
2nd Period	4	7	24	4	20
2nd Break	4	7	24	4	20
3rd Period	2	1	27	5	22
Post Game	15	4	37	25	12
Total	58	46	250	98	152

Observations

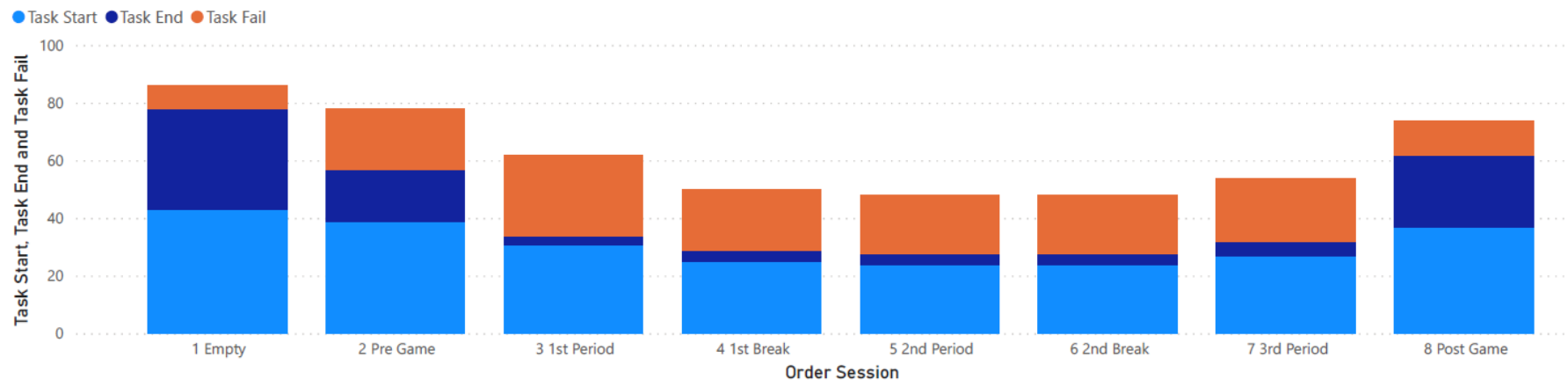
- AT&T's had a 100% RRC success rate compared to 79% for Verizon
- However, for task completion, Verizon's performance was significantly poorer at 39% compared to AT&T's 94%
- The lower numbers and poorer performance of the Verizon FTP tasks was due to the low throughput at times, resulting in timeouts.

RRC and Task Breakdown (contd.)

AT&T RRC and Task Breakdown



VzW RRC and Task Breakdown



Observations

- Following up from the prior slides, FTP Task completion for Verizon is significantly poorer at 39% compared to AT&T's 94%
- The lower numbers and poorer performance of the Verizon FTP Tasks was due to the low throughput at times, resulting in timeouts.

SINR and MCS

AT&T RRC and Task Breakdown

Session	Average of SINR	Average of DL Thput (AT&T) Mbps	Median of DL MCS Index	Average of UL Thput (AT&T) Mbps	Median of UL MCS Index
Empty	8.96	44.77	11	22.38	23
Pre Game	6.63	35.13	9	16.10	19
1st Period	7.07	25.42	9	7.08	15
1st Break	6.79	33.32	11	16.42	19
2nd Period	8.56	38.31	8	15.00	19
2nd Break	8.56	38.31	8	15.00	19
3rd Period	7.69	37.86	10	16.07	19
Post Game	8.25	44.47	10	16.96	21
Total	7.67	36.00	10	14.23	19

VzW RRC and Task Breakdown

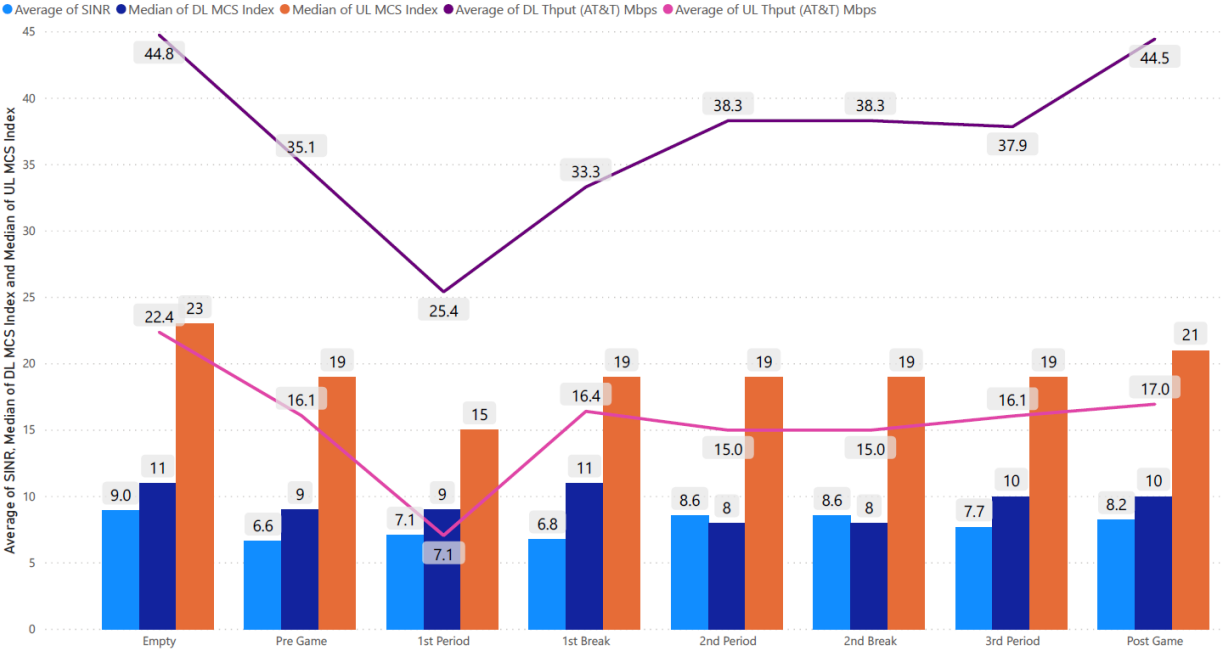
Session	Average of SINR	Average of DL Thput (VzW) - Mbps	Median of DL MCS Index	Average of UL Thput (VzW) - Mbps	Median of UL MCS Index
Empty	3.72	20.77	9	6.67	12
Pre Game	4.43	5.62	9	1.71	10
1st Period	6.02	2.72	6	0.56	10
1st Break	3.95	2.63	7	0.57	12
2nd Period	3.62	3.67	7	0.77	10
2nd Break	3.62	3.67	7	0.77	10
3rd Period	5.81	4.35	8	0.42	10
Post Game	2.31	11.29	8	3.98	12
Total	4.35	5.60	7	1.58	10

Observations

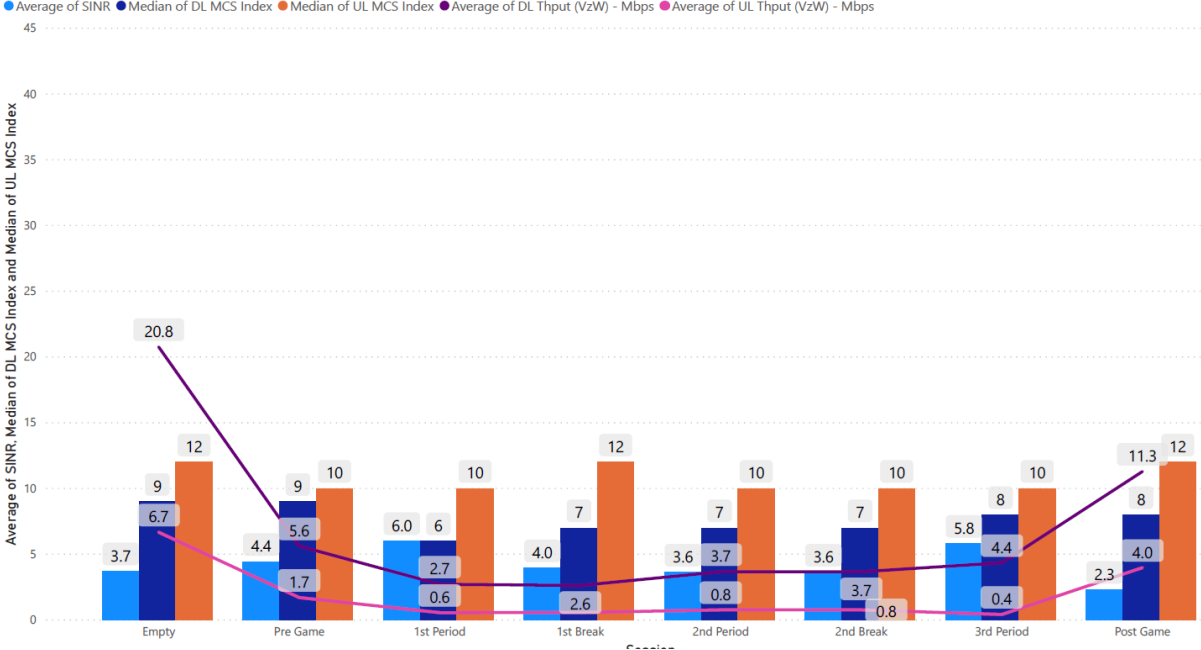
- Comparing SINR, Thput and MCS (Modulation and Coding Scheme) Index, we can see that for AT&T, DL MCS Index Mean is 10 throughout the game compared to 7 for VzW.
- The higher order modulation impact can be seen in the Throughput values throughout the game.

SINR and MCS (contd.)

AT&T SINR, MCS Index and Thput Breakdown



VzW SINR, MCS Index and Thput Breakdown



The plots above outline the interaction of the various KPI's that impact throughput (SINR, MCS Index, and throughput)