Consumer Survey, Test and Analysis Conducted at Kansas Speedway May 10, 2014

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1.0 Executive Summary

An RF engineering data collection test was performed at the Speedway in order to measure the RF parameters and wireless performance of the four major Operators AT&T, Sprint, T-Mobile and Verizon at the Kansas Speedway during the NASCAR race on May 10, 2014.

A consumer survey was also conducted by a team of 9 people asking specific questions to race fans about their perception of wireless performance at the Speedway on race day.

The data from both the RF data collection and the consumer survey are presented in this report.

1.1 Scope

Voice calls and 3G/4G data tests were conducted for all for 4 major wireless operators AT&T, Sprint, T-Mobile and Verizon. The ZK-MPX product was used to collect the data. Data was collected in areas during the day when the most people would be in that area. The parking and camping areas were collected first followed by the Infield then the Grandstands, Suites & Broadcast Booths then finally the Concourse. Testing was done in this sequence to maximize the number of people in these areas so that a true worst case scenario of the performance would be measured.

Five major areas of the Speedway were measured.

- Parking and Camping Areas

- Infield

- Grandstands

- Suites & Broadcast Booths

- Concourse

The parking, camping and part of the infield areas were driven and data is combined in the plots and charts. The private section of the Infield including the Pits and Garages were measured separately (walked) as no vehicles were allowed in there. The Suites, Broadcast booths, Grandstands and Concourse (below the grandstands) were all walked using floor plans of the area.

The consumer survey was conducted from noon to 6pm (race started at 6pm) mainly in front of the entrance to the Grandstand/Concourse area. During the afternoon this area was filled with vendors and fans. Secondary collection of the consumer surveys were also conducted in the parking areas where people were tailgating as well as the infield area where people were viewing the cars in the pits. Appendix A shows the actual questionnaire that was used.

1.2 Consumer Survey Results

An estimated 85.000 fans attended the race. Our team collected 519 survey responses. The confidence intervals for the questions are provided in the raw data and can be provided upon request.

The following charts show the consumer's response to the questions of their perception of voice call quality at the Speedway. This was shown by Operator. Note that the "Other" category were typically resellers of service such as Walmart, Best Buy, etc. A score of 10 would be Excellent and a score of 0 would be poor.
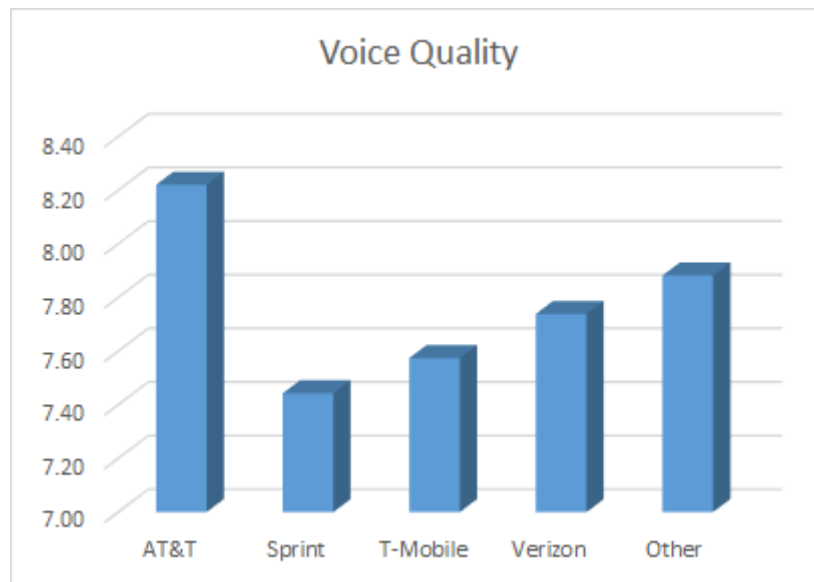
FIGURE 1. Consumer Survey - Voice Quality by Operator

FIGURE 2. Consumer Survey - Data Quality by Operator

On both charts the range between all of the Operators was within one score point and the lowest score was 7.4. This indicates that on average most users have a better than average perception of their quality of service at the Speedway.

The following chart shows how users feel about the features and functions of the phone itself by phone type. The lowest score is a 7.9 so again most users have a better than average view of the features of their phone.
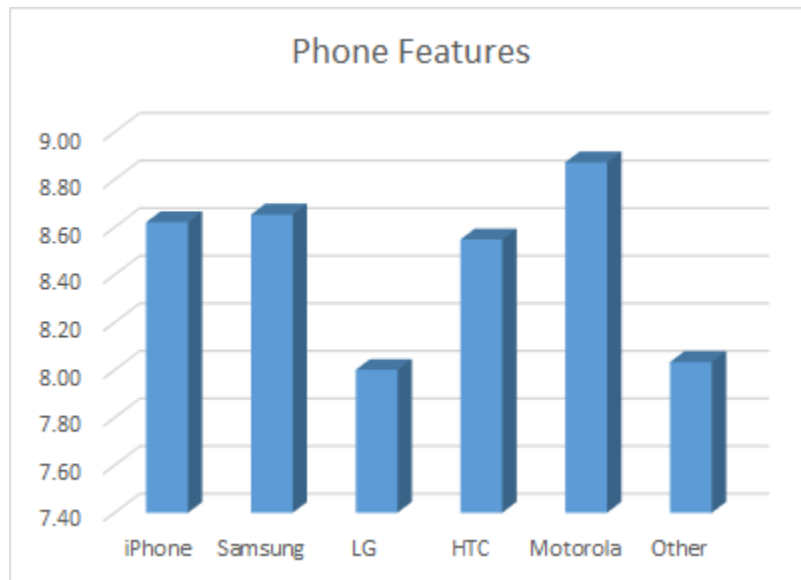

FIGURE 3. Consumer Survey - Phone Features by Manufacturer

1.3 Throughput Test Results

The following charts show the average throughputs measured for the major areas. The wide area includes the parking, camping, surrounding roads and the drivable (East side) of the Infield. The Infield area consisted of the pits and garages. This area was not accessible by vehicle or the public.

The throughput values for Sprint's 2.5GHz Spark service was a magnitude higher than everyone else. It seems like they supplemented the Concourse area with their 1900 LTE. Verizon's AWS LTE service was faster than its 700 MHz band. AT&T 700 LTE was fairly even across all areas. T-Mobile scored adequate in the wide area drive most likely because of being served by their macros.

Other than Sprint the Infield pit/garage area scored lower across all the Operators.

AT&T and Verizon were on the DAS. Sprint had about 12 COW's and T-mobile served the area from its macros.
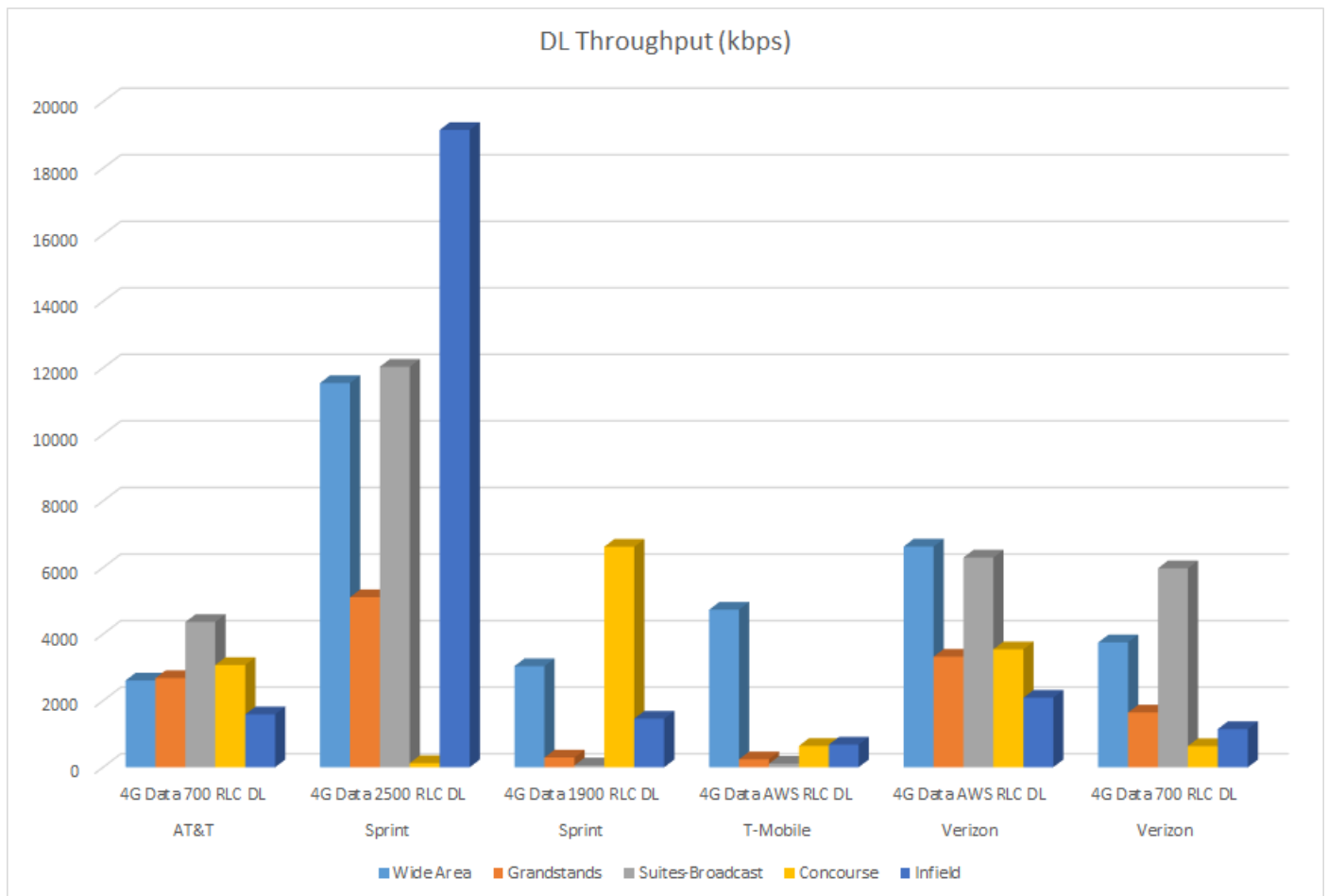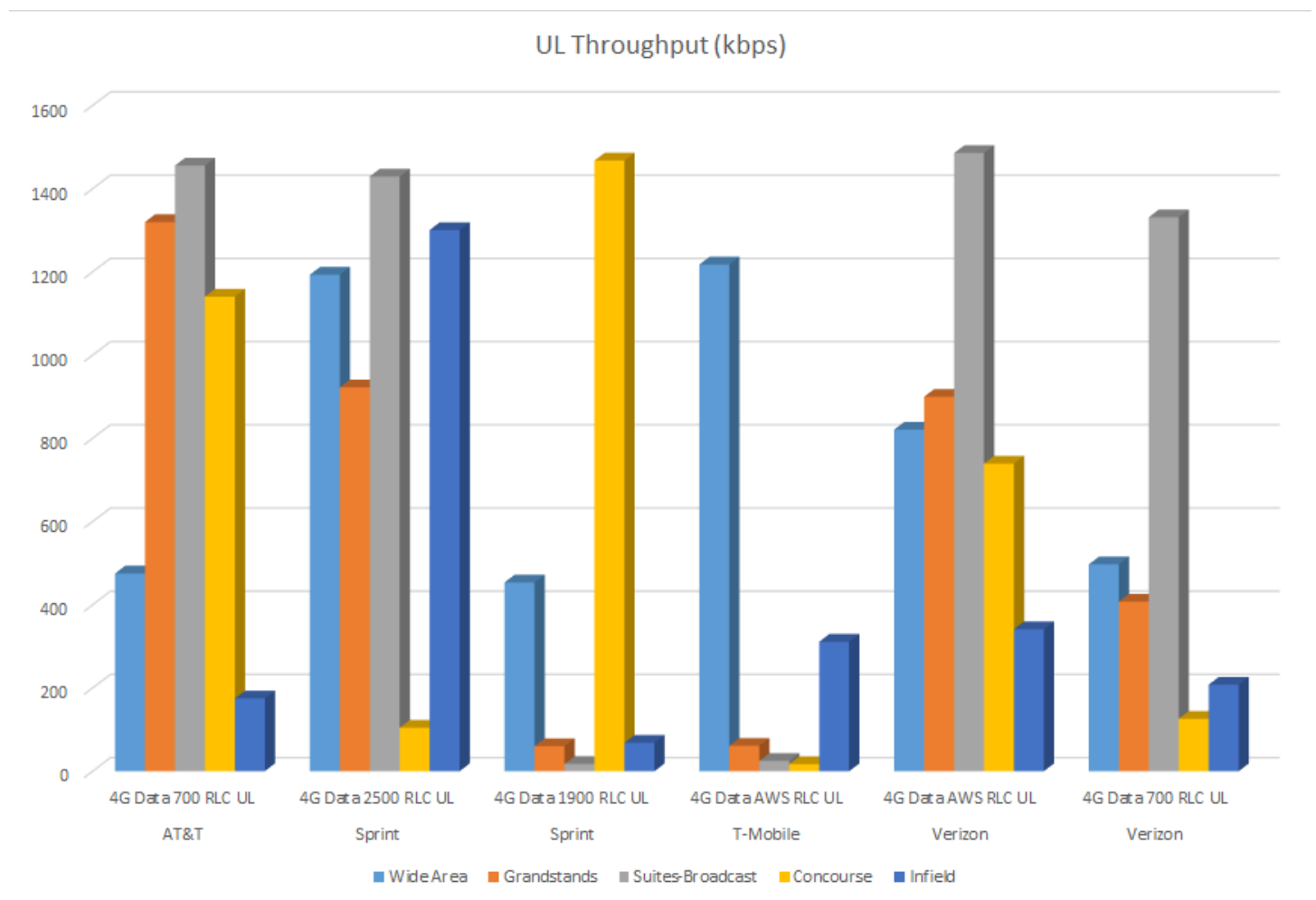

FIGURE 4. 4G Download Throughput

FIGURE 5. 4G Upload Throughputs

1.4 RF 4G Coverage and Quality

The following chart shows the RSRP for LTE coverage. Average coverage values seem acceptable. The low RSRP for Sprint 2.5GHz in the Concourse could partially explain the lower throughput values.
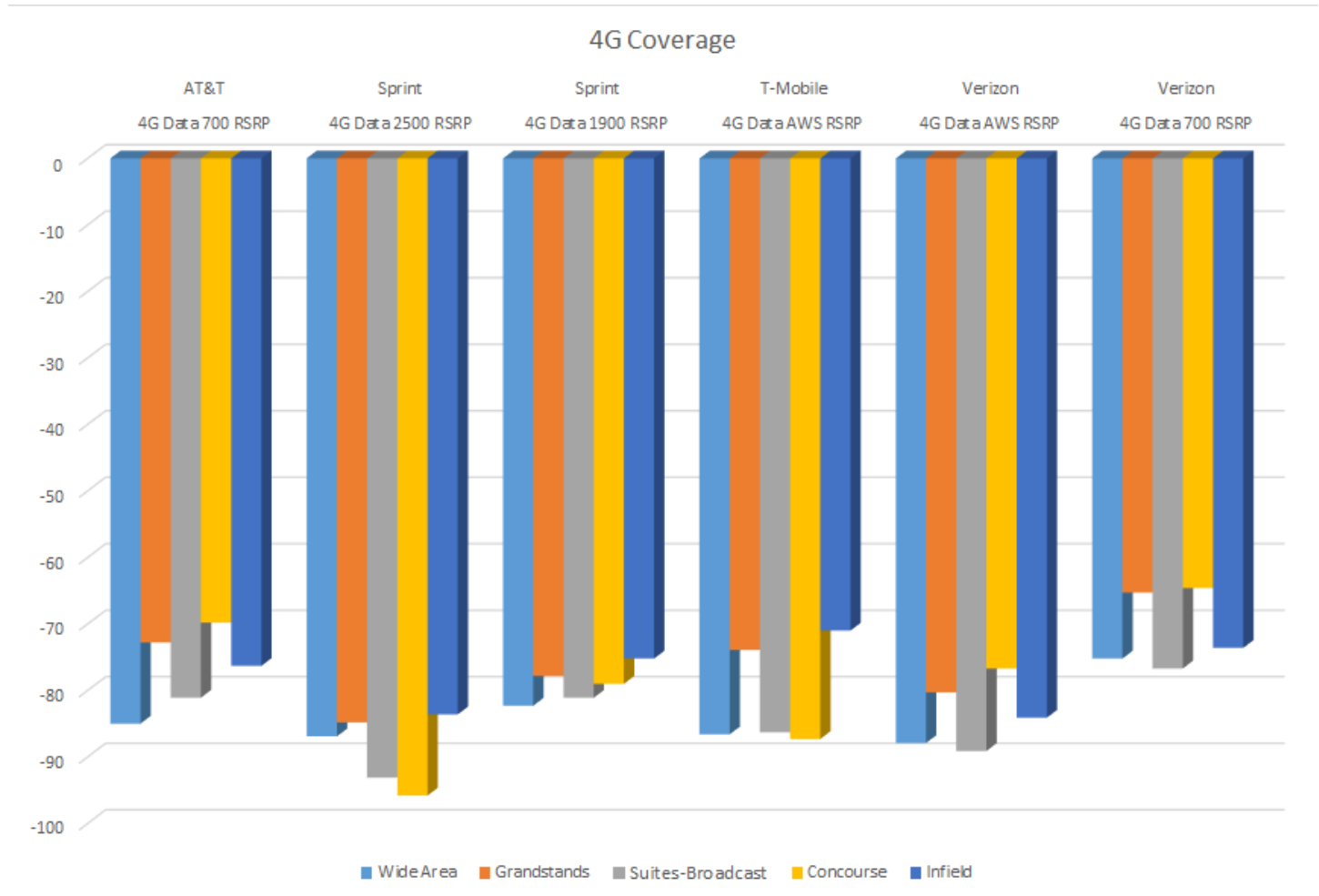

FIGURE 6. 4G RSRP Coverage

The following chart shows the average SINR values. SINR is a signal to noise ratio where the higher the number the better the signal to noise and typically the better the quality of the channel. Higher SINR usually relates to higher throughput. As you see the Sprint 2.5GHz service had very high SINR which did translate into higher throughputs. T-Mobile however, had good SINR levels yet throughput was lower than expected. This most likely is due to capacity issues as T-Mobile was serving the speedway from macro cells.
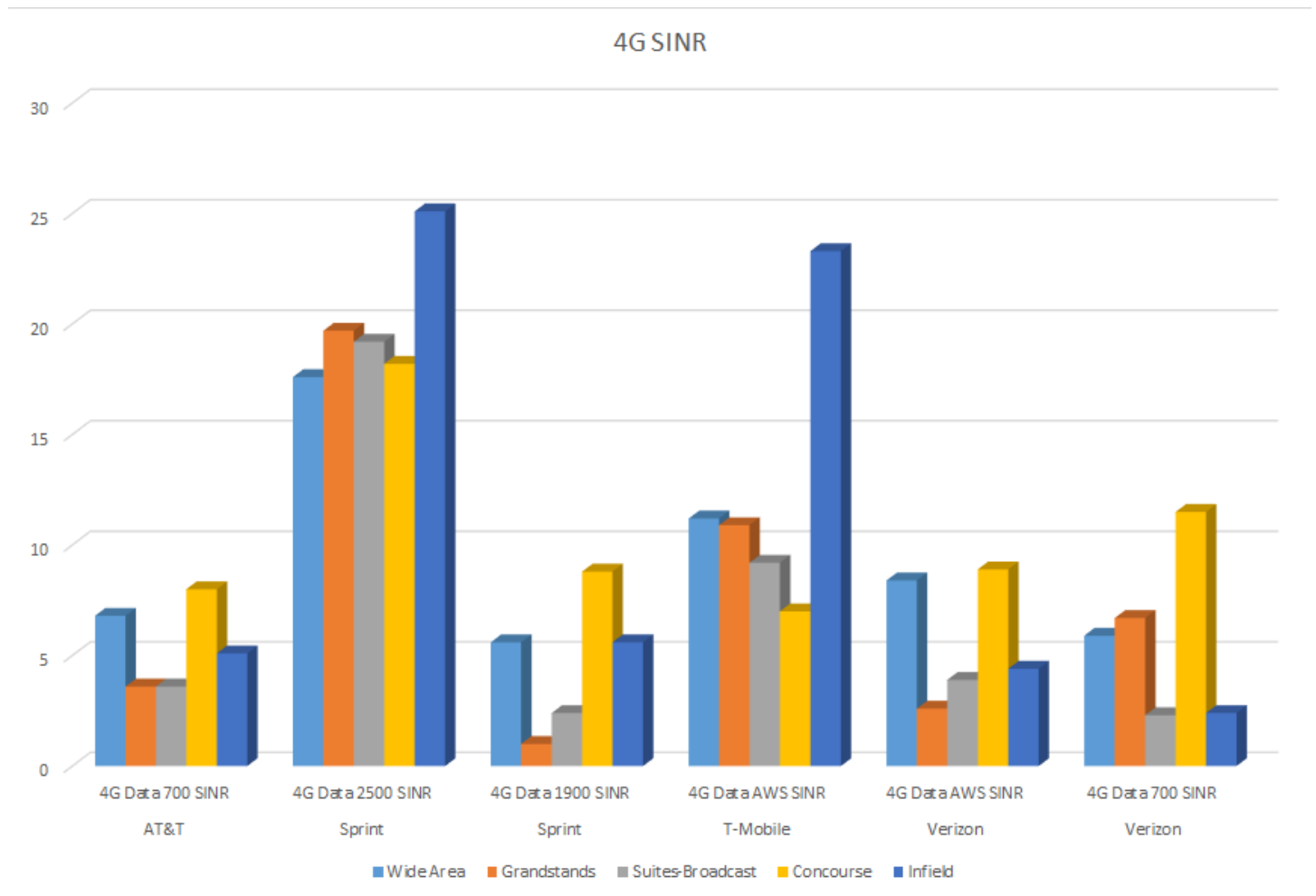

FIGURE 7. 4G SINR

1.5 RF Voice Coverage

The following charts show the coverage and signal to noise for the voice calls. All the Operators were within the same range with the exception of T-Mobile. T-Mobile used GSM to serve voice for all areas except the infield and most of the grandstands. The Ec/Io values below are for UMTS voice and don't represent the GSM coverage which ecxplains the low values for T-Mobile. GSM voice plots for T-Mobile are in the body of this report and in Appendix B.
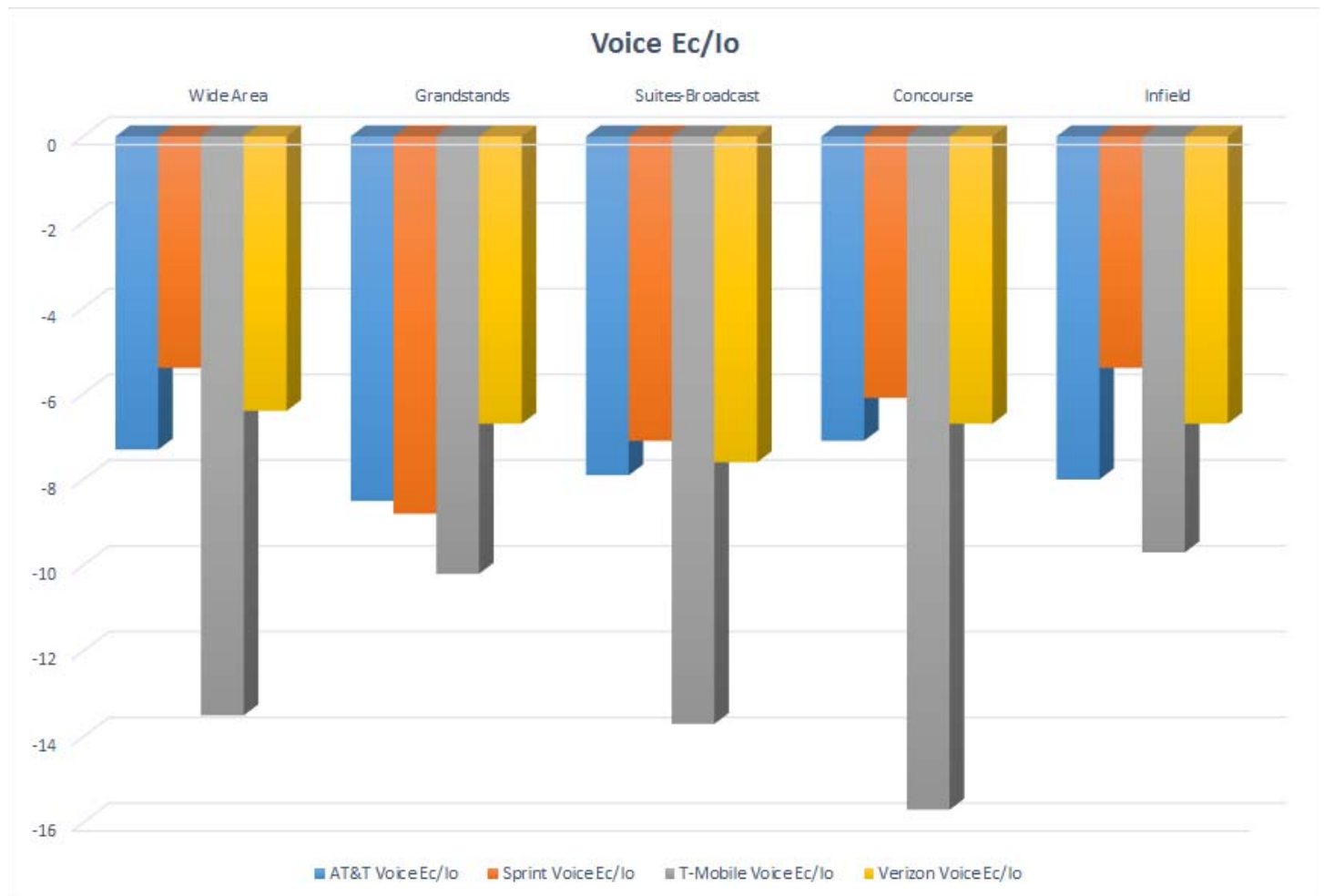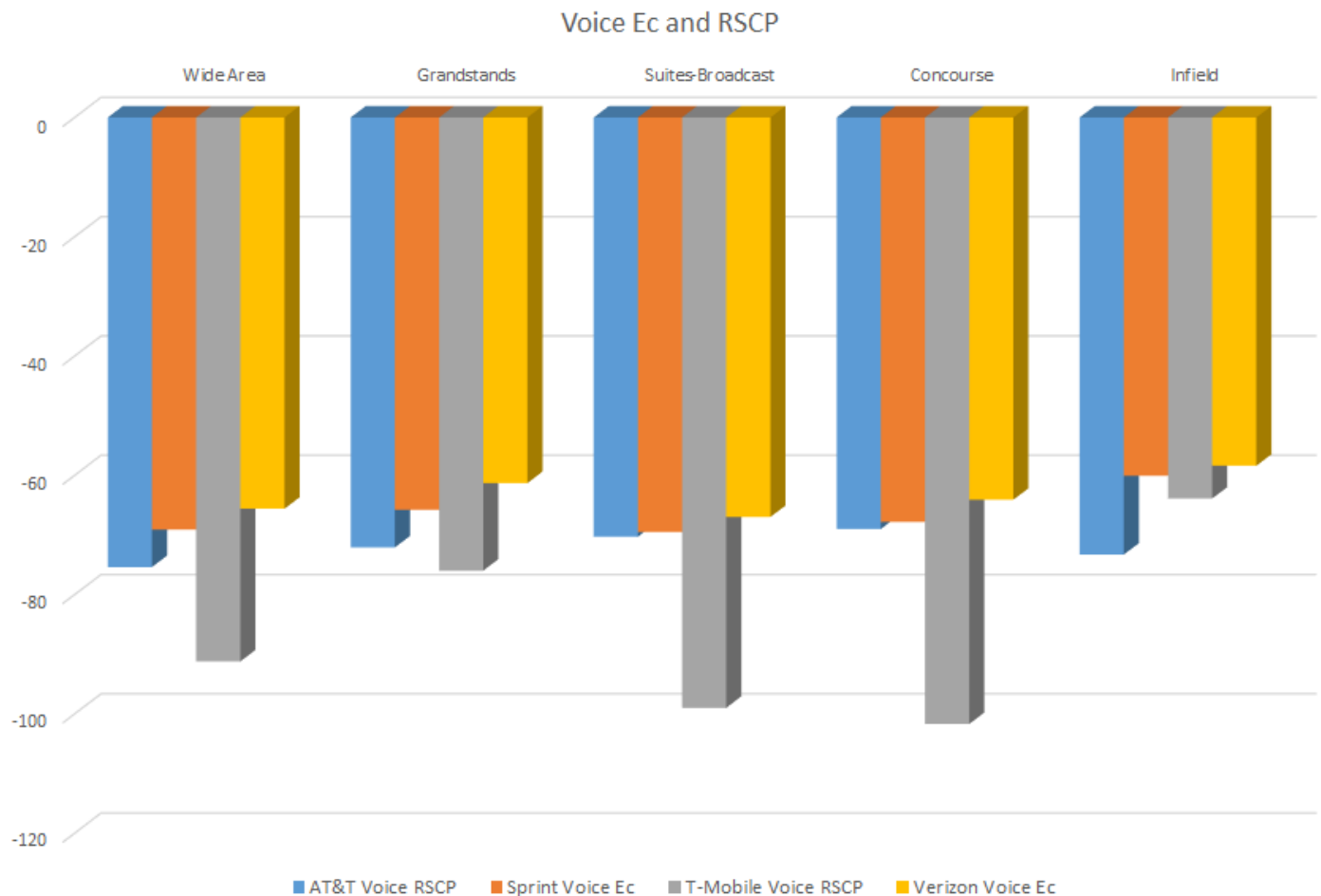

FIGURE 8. Voice Ec/Io

Note that the T-Mobile data below applies to their 3G service and doe not incorporate their GSM service which they used to serve voice through most of the Speedway.

1.6 Executive Summary Conclusion

Consumer perception of the wireless performance for voice and data as well as the features of their phones was very good. On a scale of 1 to 10 the voice performance ranged from 7.4 to 8.2, data performance ranged from 7.7 to 8.2 and phone features ranged from 8.0 to 8.8.

AT&T came in first in voice performance, Verizon (AT&T close second) came in first in data quality and Motorola came in first on phone features.

For data throughput testing the Sprint 2.5GHz service had the highest throughputs by a large margin except in the concourse area but their 1900 service provided good throughput in this area providing a solid throughput if both are combined. AT&T and Verizon had consistent levels of throughput throughout the speedway averaging in the 1 Mbps to 6 Mbps range. Upload throughput levels were well below download levels achieving less than 2 Mbps at their best. T-Mobile had the lowest throughput levels most likely due to serving the Speedway from the surrounding macro cells.

Voice channel coverage was good for all Operators. T-Mobile served most of their voice with GSM channels which is not indicated in the charts above.

2.0 Introduction

Millions of dollars are being spent on indoor DAS networks for raceways and other large venues. A DAS is the only way to properly serve a high density of users in order to serve fans with quality wireless service during games.

The goal of this study is to measure the wireless performance from the users' perspective on race day and *during the race* in order to understand the reality of what users are experiencing. In addition, it is also the goal of this study to ask fans questions about their wireless experience at the speedway and present those results here.

Voice, 3G and 4G data testing were performed for AT&T, Sprint, T-Mobile and Verizon in addition to collecting scanning data on all transmitting bands and technologies. 4G data throughput and quality and voice coverage and quality are presented in the main body with analysis. All plots including 3G are provided in Appendix B.

2.1 Glossary of Terms

- 3G - Third generation cellular mobile technology. Verizon and Sprint implement EVDO Rev. A technology and AT&T implements UMTS/HSPA technology. EVDO is data only. UMTS is voice and data. HSPA is a higher speed 3G data service overlaid onto the UMTS frequency channel.

- 4G - Fourth generation cellular mobile technology. LTE or Long Term Evolution technology is implemented by all Operators. This is currently a high speed data only service although some Operators are beginning to roll out Voice over LTE (VoLTE)

- Throughput - Data speed in kbps (kilobits per second) or Mbps (Megabits per second)

- DL TPut - Downlink Throughput. Speed of data transfer from the Internet down to the mobile.

- RSRQ - RSRQ provides a measure of channel quality and is defined as the ratio of RSRP to the carrier received signal strength indicator (RSSI). Measuring RSRQ becomes particularly important near the cell edge when decisions need to be made, regardless of absolute RSRP, to perform a handover to the next cell. RSRQ ranges from -40dB to 0 dB. Above -10 dB is considered good quality. -20 to -10 dB is considered fair quality and below that is poor quality.

- RSRP - RSRP measures the signal coverage on a per call basis and is the most basic of the UE physical layer coverage measurements. RSRP ranges from -140 dBm to 0 dBm and values above -80 dBm are considered good for indoor DAS. Values between -90 to -80 dBm are considered fair and below -90 dBm is considered poor. These vary from outdoor conditions and more rural areas where there is less external noise. In these areas -100 dBm to -90 dBm would be considered fair and above -90 dBm would be considered good.

- SINR/SNR - Signal to Noise ratio. SINR is a measure of signal quality as well. Unlike RSRQ, it is not defined in the 3GPP specs but defined by the UE vendor. It is not reported to the network. SINR is used a lot by operators, and the LTE industry in general, as it better quantifies the relationship between RF conditions and throughput. Values above +10 are good, between 0 and +10 are fair and negative values are poor. SINR ranges between -20 to +30 in units of dB

- RF - Radio Frequency. Generic term for the radio link between the cell tower and the mobile.

- RSSI - The RSSI parameter represents the entire received power including the wanted power from the serving cell as well as all co-channel power and other sources of noise. It is not generally used to optimize LTE, UMTS or CDMA networks as it provides too general of a measurement. However it is an indicator of total energy which when compared with other parameters provides useful information. It is also used in the RSRQ

calculation. It also ranges from -140 dBm to 0 dBm with good being anything above -80 dBm, between -90 and -100 dBm being fair and below that poor.

- DAS - Distributed Antenna System. A combination of equipment, cabling and antennas installed in a venue to increase the capacity of wireless voice and data services.
- AWS - Licensed frequency band offered by some Operators.
- Band - Frequency bands licensed for cellular service.
- PCI - Physical Cell Indicator. Number that identifies a particular sector of a cell site for LTE technology.
- PN - Pseudorandom Noise code. Number that identifies a particular sector of a cell site for EVDO technology.
- PSC - Physical Scrambling Code. Number that identifies a particular sector of a cell site for UMTS technology.
- Macro Cell - Cellsite outside the stadium.

3.0 Testing Plan and Consumer Survey

Two ZK Celltest ZK-MPX data collection products were used to drive and walk the Kansas Speedway during the 5-Hour Energy 400 NASCAR race on May 10, 2014. Wireless performance parameters were collected for Voice and 3G/4G data for Operators AT&T, Sprint, T-Mobile and Verizon. Thirteen handsets/devices were used to collect the information along with scanning data for all bands being transmitted. The phone data is primarily presented in this report as the focus herein is to provide a customer perception study of wireless performance during the race.

In addition to performance measurements a team of 9 people asked fans survey questions about their wireless usage and perception of wireless quality at the Speedway. The questions were designed to mainly determine the perception of users' voice quality and data quality and phone functionality at the Speedway.

4.0 Kansas Speedway

In 1996, International Speedway Corporation (ISC) began exploring options to build a speedway facility in the Midwest region. In 1997, Wyandotte County and Kansas City, KS., were selected as the site for the new speedway. Located at the intersection of interstates 70 and 435, construction began in May of 1999 on the 1.5 mile trioval, 75,000 seat Kansas Speedway.

FIGURE 9. Kansas Speedway Grandstands

In May 2000, NASCAR and Indy Racing League announced they will bring events to Kansas Speedway for its inaugural racing season in 2001.

The Kansas Speedway is a 1.5 mile tri-oval suitable for all types of racing. A road course was added in the summer of 2012 that winds through the infield. The speedway is strategically located at the intersection of I-435 and I-70 in Kansas City, KS., about 15 miles west of downtown Kansas City. The track seats over 72,000. The facility has fan friendly access to 65 rows of seating, with a unique ground level concourse that allows spectators to walk down 30 rows (on grade) or up 35 rows (on structure). Parking for the facility accommodates more than 35,000 vehicles. Parking is always free at Kansas Speedway.

5.0 Consumer Survey

A team of 9 people conducted a survey that asked race fans a series of questions about their wireless performance at the Speedway. The survey questions are in Appendix A.

In general, the scores for voice quality, data quality and phone features were very good. Over 45% of responses for these categories scored the highest rating of 10. These are broken down by Operator and phone type as well.

The survey was mainly conducted outside of the grandstands during the day prior to the race. This may have had an affect on the results as this area was covered well and there was not a large density of people. If surveys were conducted during the race in the grandstands or in the infield then perhaps we would have seen differing results.

The category "Other" included responses from customer that purchased their phones at Walmart, Best Buy, etc. They did not know who their Operator was that provided the service.
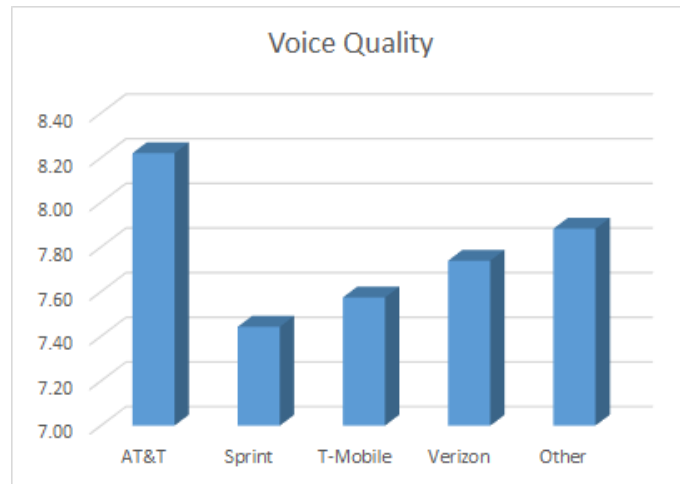
FIGURE 10. Voice Quality by Operator

FIGURE 11. Data Quality by Operator
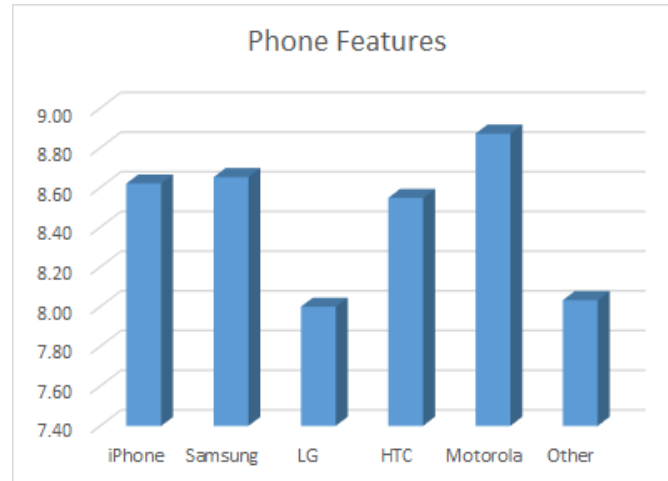
FIGURE 12. Phone Features and Functions

Less than 10% of the respondents had Motorola phones but they scored the highest in terms of how users liked their features and functions.
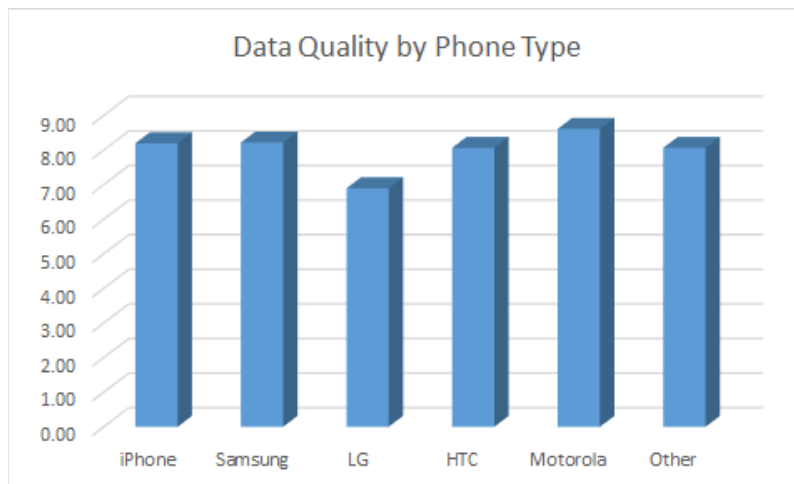
FIGURE 13. Data Quality by Phone Type

All phones scored well in customers' perception of data quality.
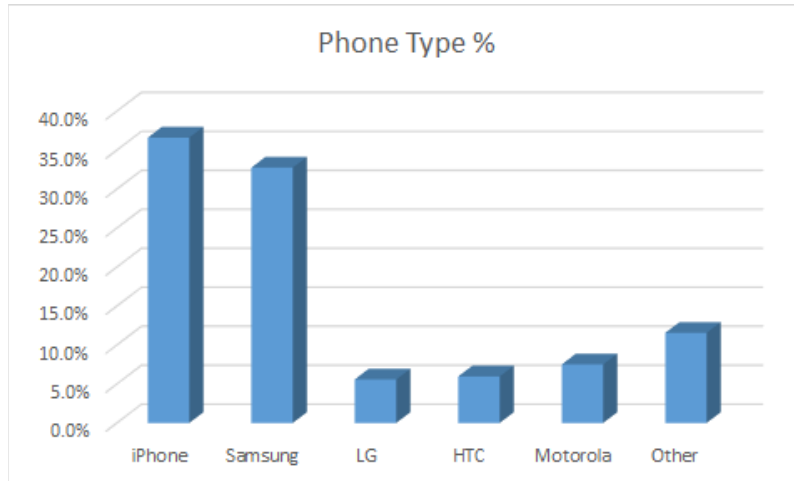
FIGURE 14. Respondents phone types

These numbers track the overall market share numbers for the US. Most market share estimates have Apple and Samsung dominating the mobile phone market.
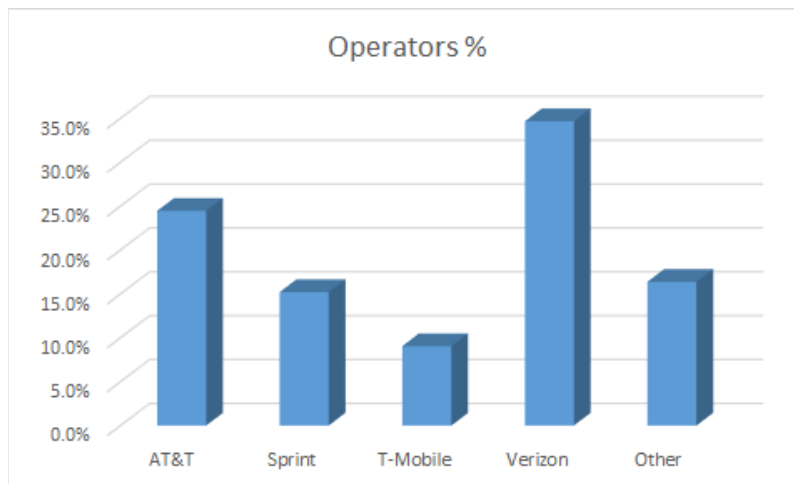
FIGURE 15. Respondents Service Providers

Most respondents had Verizon service with AT&T in second. The category "Other" included responses from customer that purchased their phones at Walmart, Best Buy, etc. They did not know who their Operator was that provided the service.
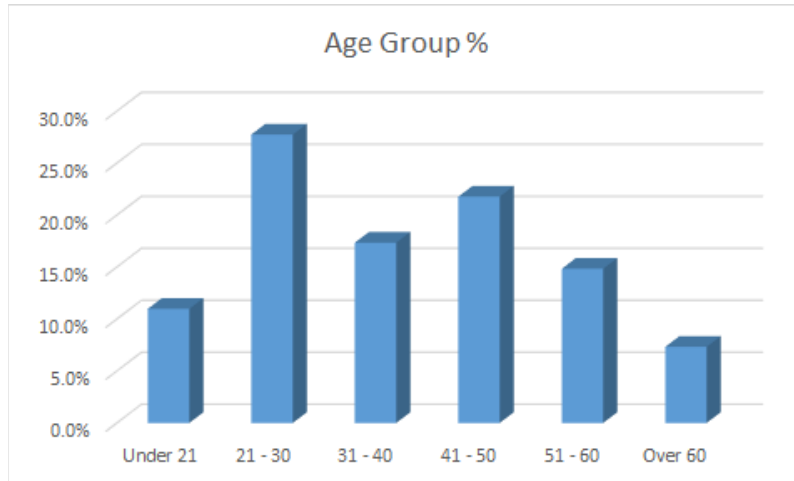
FIGURE 16. Respondents Age Groups

The ages of respondents was slightly lower than typical NASCAR fans with the 21-30 age group having the most respondents.
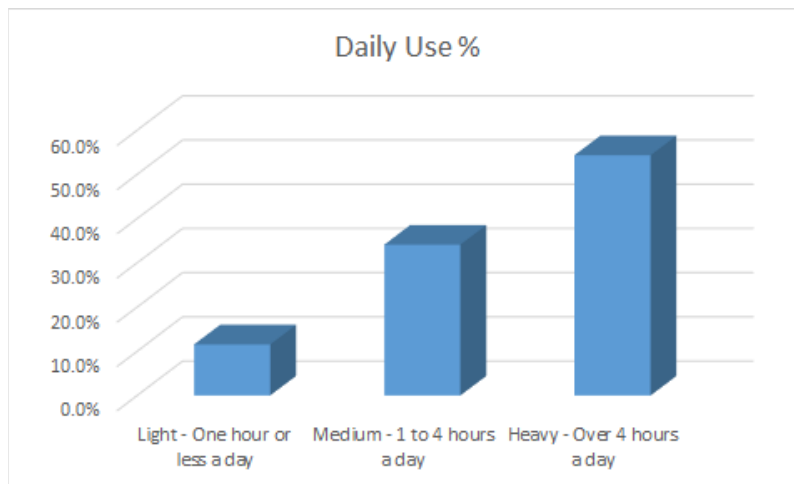
FIGURE 17. Respondents Daily Usage

Half of the respondents indicated they were heavy users. This is quite heavy usage.
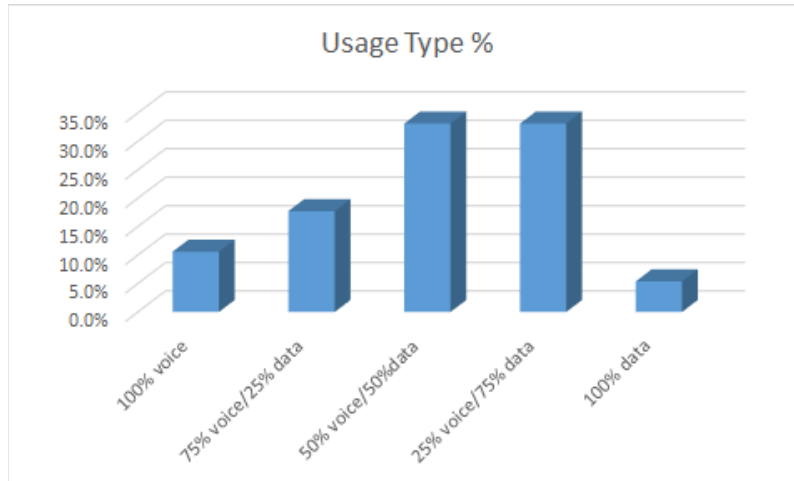
FIGURE 18. Respondents Usage Type

Respondents use data more than voice.

FIGURE 19. Overall Voice Quality

Users were happy with their voice quality overall. This included all phones and all Operators combined.
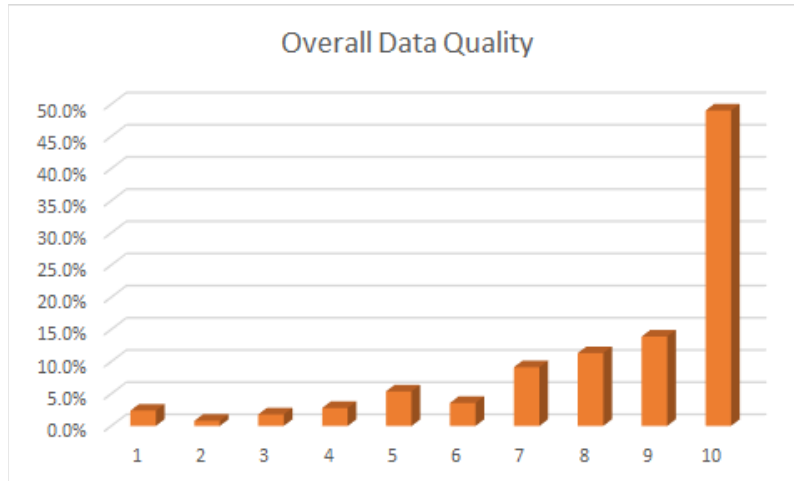
FIGURE 20. Overall Data Quality

Users were happy with their data quality overall. This included all phones and all Operators combined.
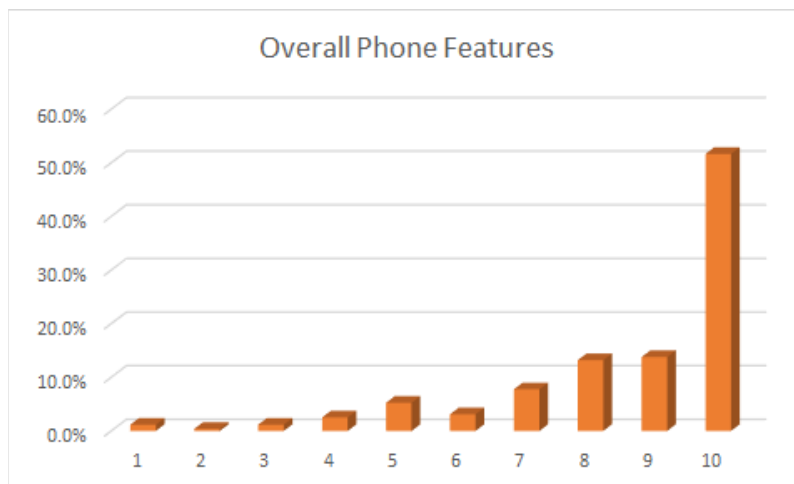
FIGURE 21. Overall Phone Features and Functions

Users were happy with their phones' features and functions overall. This included all phones and all Operators combined.

6.0 Walk-Test RF Survey

Two ZK-MPX's were used as the walk-around testing devices. The product contains a high speed digital scanner that can scan multiple technologies on the 700/850/1900/AWS frequency bands. Although not used for this test it also has a built-in spectrum analyzer that can scan frequencies between 3MHz and 3GHz. In addition, it allows the user to connect up to eleven (12) cellular handsets and/or modems (Devices) in order to capture voice and data calling performance information.

FIGURE 22. ZK-MPX

The ZK-MPX unit integrates scanning hardware and computer processing and Android Tablet display into a single integrated unit. An internal dual battery system provides 6 - 8 hours of power for the entire system including powering the scanners, Tablet and handsets. The unit weighs 10 lbs including batteries and comes with a side/backpack carrying case that can swing to the side to make connections then swing to the back for walking. It has many compartments for devices and cables.

The user does not have to worry about charging multiple batteries since a single dual battery system powers everything. Additional batteries are included along with an external charger so they can be easily swapped when required.

Log files were stored to the Android Tablet.

6.1 ZK-MPX Setup

Two ZK-MPX's were used. Six devices were connected to one and 7 devices to the other. Each MPX also scanned multiple channels and frequency bands. The following device types were connected. Note that Port 1 is reserved for the scanners.

6.1.1 ZK-MPX 1 Setup

AT&T and T-Mobile Devices

- Port 2: AT&T Voice Phone
- Port 3: AT&T 3G Data Phone
- Port 4: AT&T 4G Data Phone
- Port 5: T-Mobile 4G Data Phone
- Port 6: T-Mobile 3G Data Phone
- Port 7: T-Mobile Voice Phone

AT&T and T-Mobile UMTS channels

- ATT 850 ch4413 UMTS Scanner
- ATT 1900 ch612 UMTS Scanner
- T-Mobile 1900 ch512 UMTS Scanner
- T-Mobile 1900 ch9784 UMTS Scanner

6.1.2 ZK-MPX 2 Setup

Sprint and Verizon Devices

- Port 2: Verizon Voice Phone
- Port 3: Verizon 3G Data Phone
- Port 4: Verizon S4 4G Data Phone
- Port 5: Verizon HTC 4G Data Phone
- Port 6: Sprint Voice Phone
- Port 7: Sprint Data Phone
- Port 8: Sprint Data Phone

Sprint and Verizon CDMA/EVDO channels and all LTE channels

- ATT 700 ch5780 LTE Scanner
- Sprint 1900 ch50 CDMA Scanner
- Sprint 1900 ch200 CDMA Scanner
- T-Mobile 2100 ch2200 LTE Scanner

- Verizon850 ch119 CDMA Scanner
- Verizon850 ch160 CDMA Scanner
- Verizon850 ch242 CDMA Scanner
- Verizon1900 ch325 EVDO Scanner
- Verizon 700 ch5230 LTE Scanner
- Verizon2100 ch2350 LTE Scanner

6.2 Floor Plan Setup

Most of the measured area was outdoors so we were able to log the location of the data using GPS. However, in the Grandstands, Suites, Broadcast and Concourse areas we logged the data using a floor plan image.

Floor plan images were imported into the ZK-MPX. The user displays the floor plan image on the screen while walking the area and drops bread crumbs by tapping the screen of the Tablet computer.

A sample of the floor plan image is shown below:
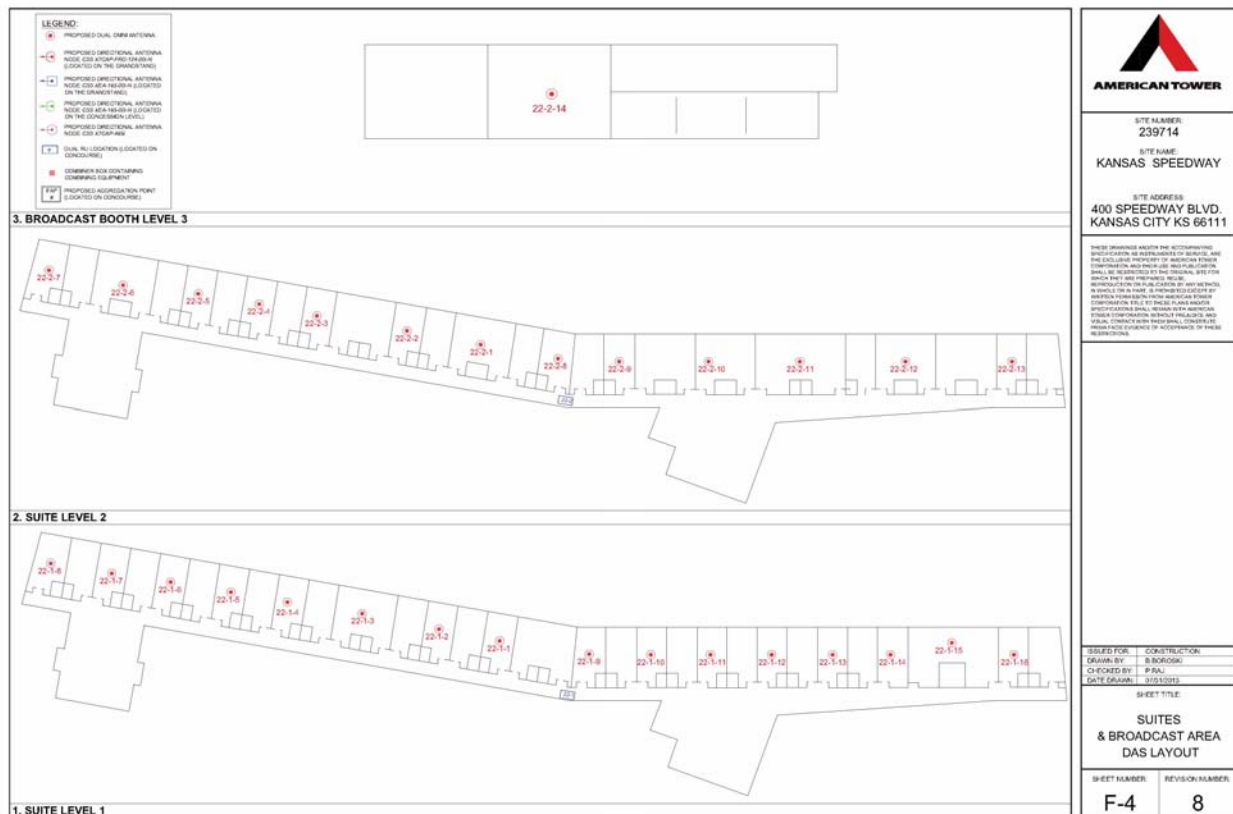
FIGURE 23. Floor plan image of Suites and Broadcast Booth used for data collection

6.3 Post-Processing

Although ZK log files have an open, ASCII format and can be imported with many other third party software packages including Actix, Windcatcher and IBWave, this data analysis was performed using Windcatcher and Excel software. Windcatcher creates the plots and csv files for import into Excel to create the charts. Excel was also used to create the consumer data charts.

7.0 Data Analysis

The goal of the project was to measure the wireless performance of the four major Operators from the users' perspective using engineering measurement and consumer survey methods then mine both data sets and provide an analytical output of the results.

Voice and data performance were measured and surveyed and the results are presented herein. The engineering measurements are presented by area of the speedway primarily focusing on 4G data and voice. 3G data was also measured and plots are in the Appendix along with the entire set of plots for all Operators.

7.1 Infield

The Infield consisted of a public section (right side) and a private section (left side). The pits and the garages were in the private section. We had access to all areas and thus measured the private area as well.

7.1.1 Data Throughput

The following plots show the 4G download throughput speeds for the 4 major Operators in the Infield section.

- AT&T 700MHz LTE
- Sprint 2.5GHz LTE
- Sprint 1900MHz LTE
- T-Mobile AWS LTE
- Verizon 700MHz LTE
- Verizon AWS LTE

The left portion of the Infield is where the pits and garages were. It is fairly clear that the best throughputs were provided by the Sprint 2.5GHz service. This is a fairly new offering so it is most likely lightly loaded which could be one reason why the throughput levels are better. Sprint had several COWs set up in the Infield.

Sprint 1900 and T-Mobile did fairly well on the right side of the Infield which is the public area and AT&T and Verizon throughput were fairly low throughput the Infield. This was surprising since AT&T ad Verizon were on the DAS.
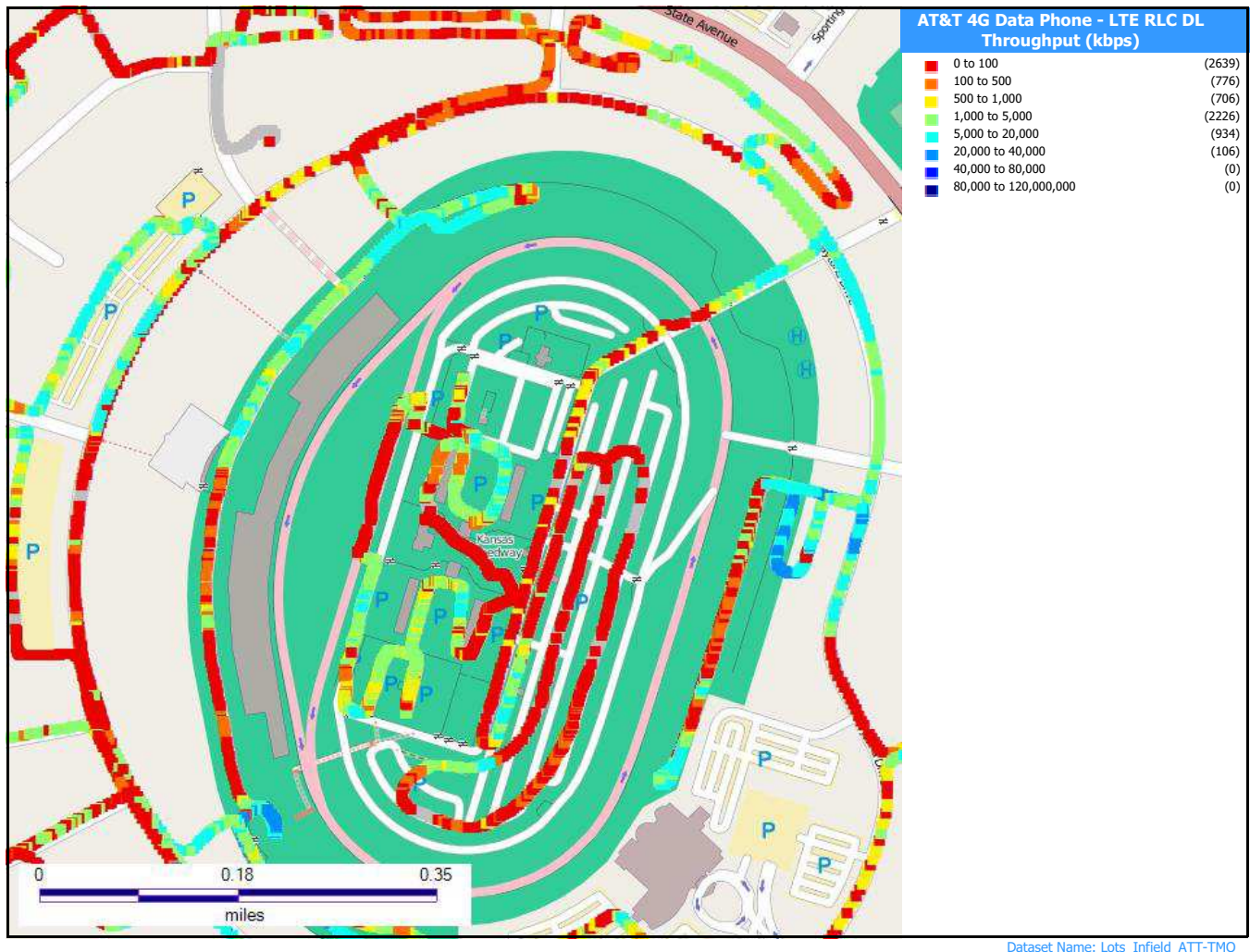
FIGURE 24. AT&T 700 LTE DL Throughput - Infield
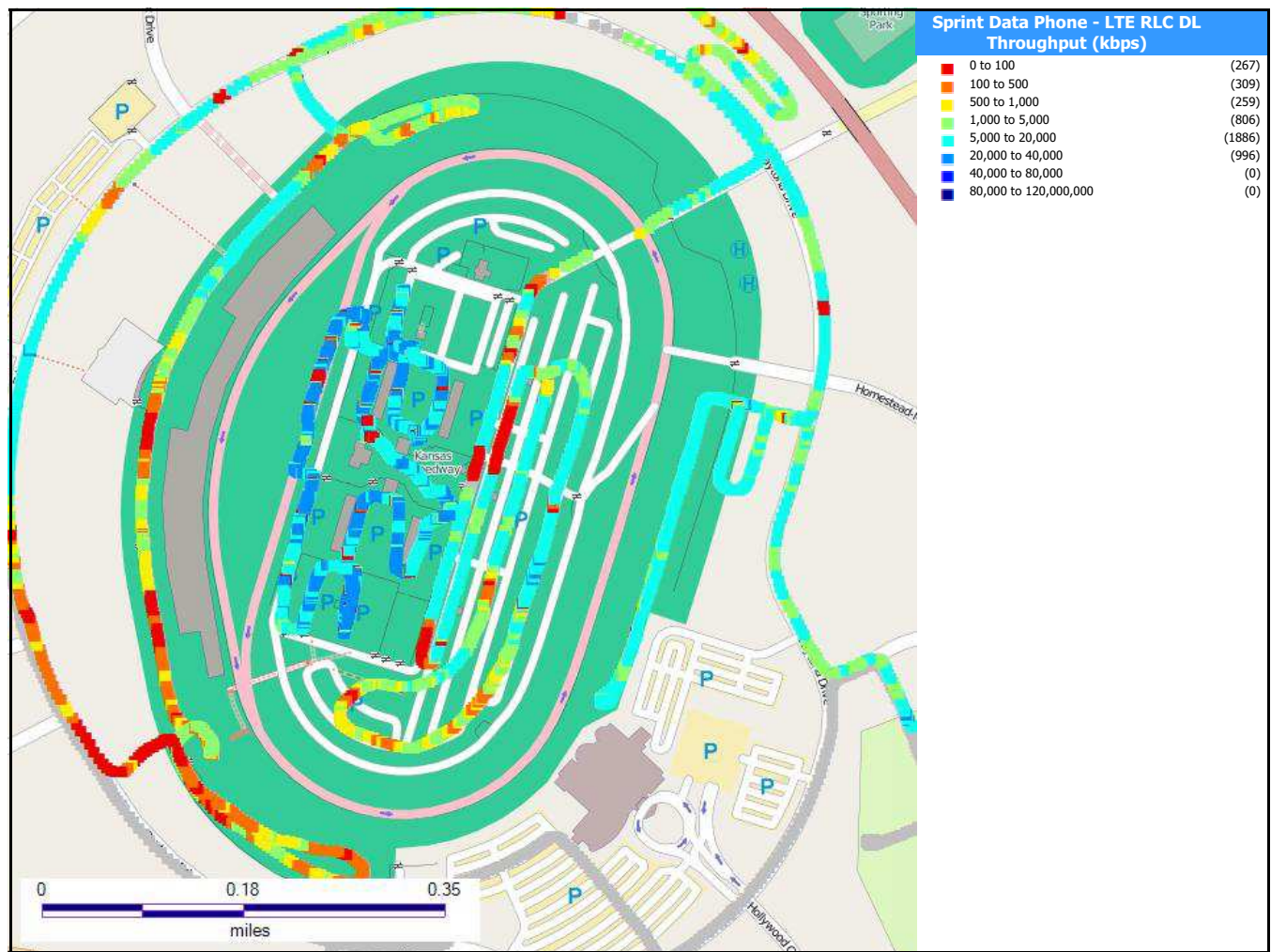
FIGURE 25. Sprint 2.5GHz LTE DL Throughput - Infield
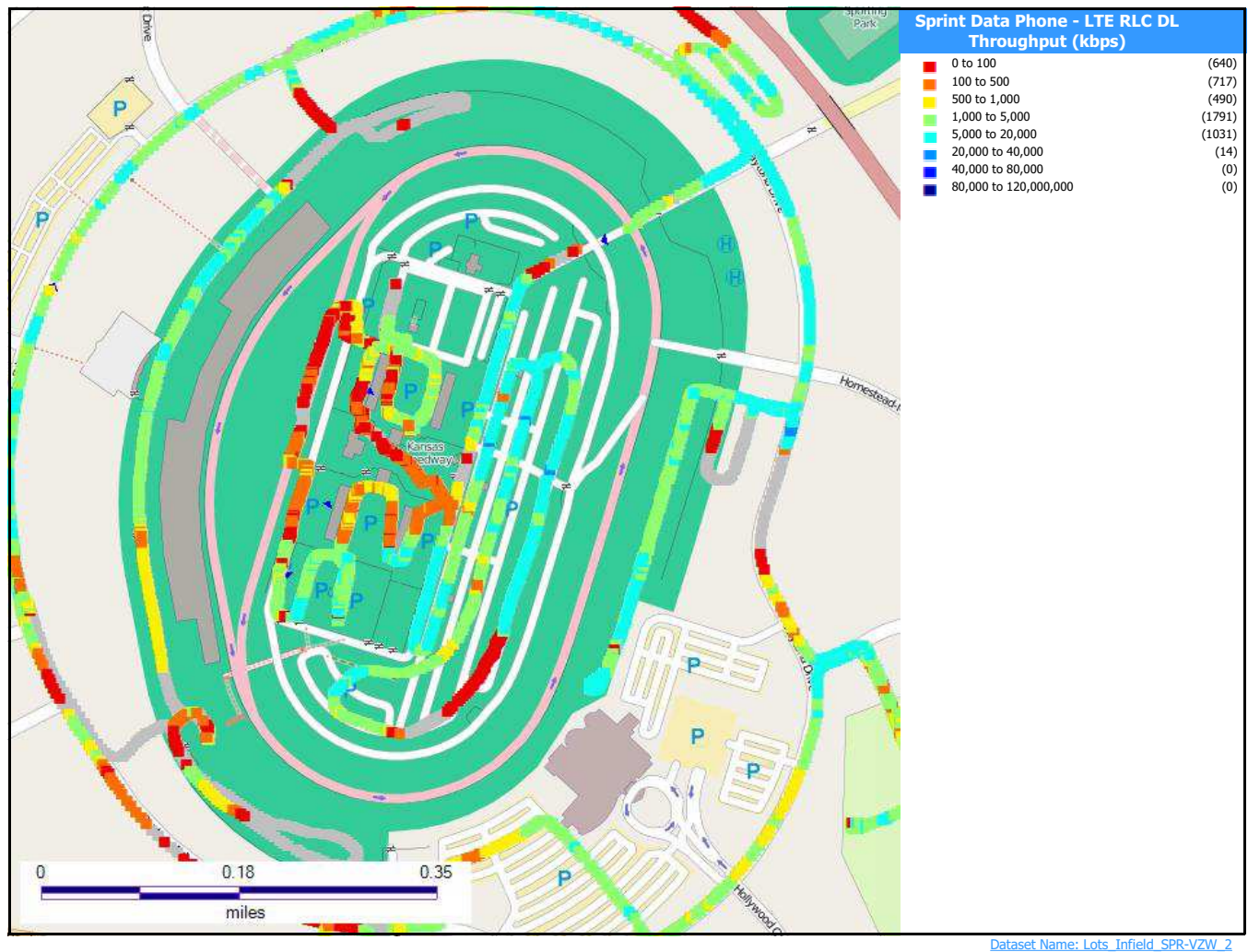
FIGURE 26. Sprint 1900MHz LTE DL Throughput - Infield
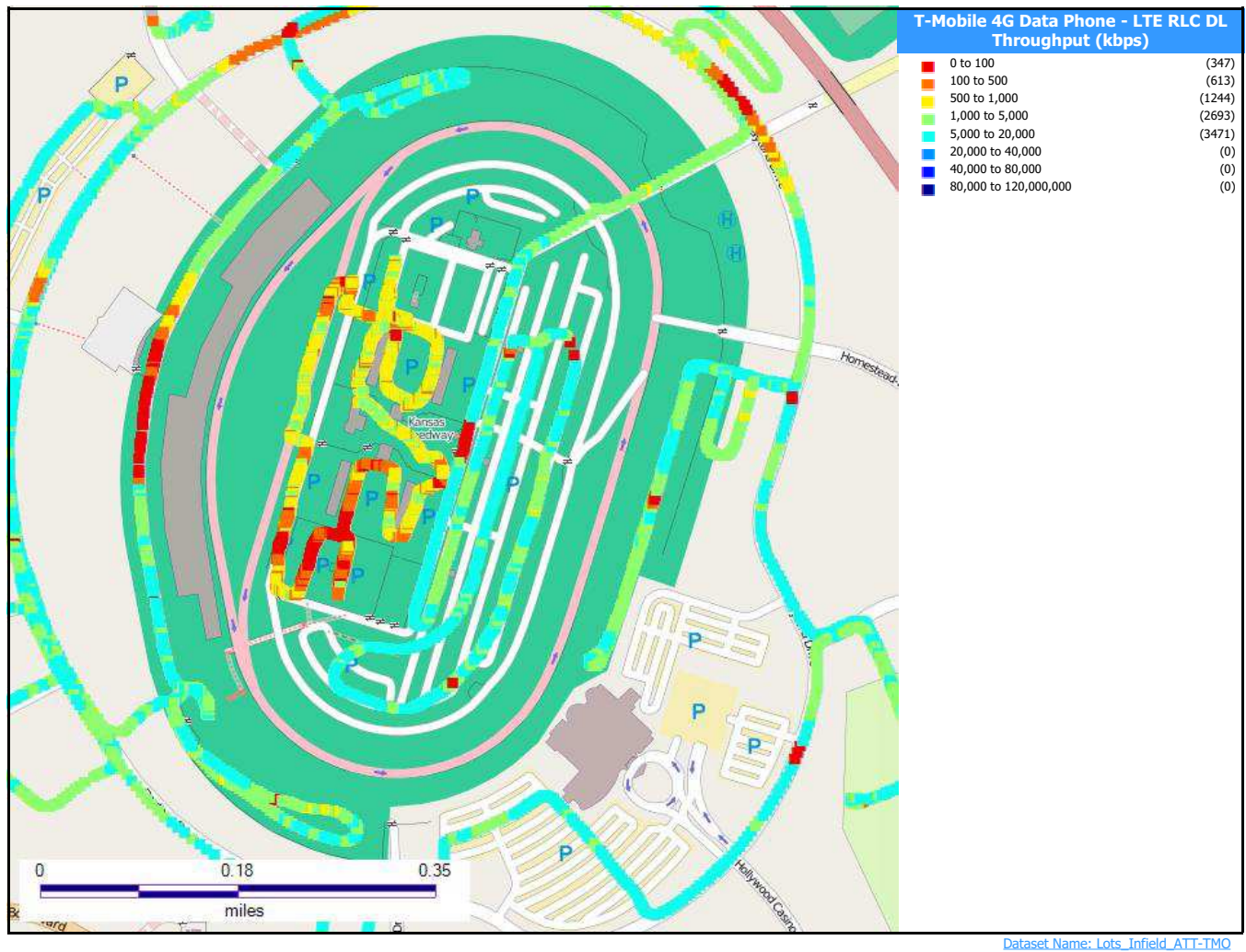
FIGURE 27. T-Mobile AWS LTE DL Throughput - Infield
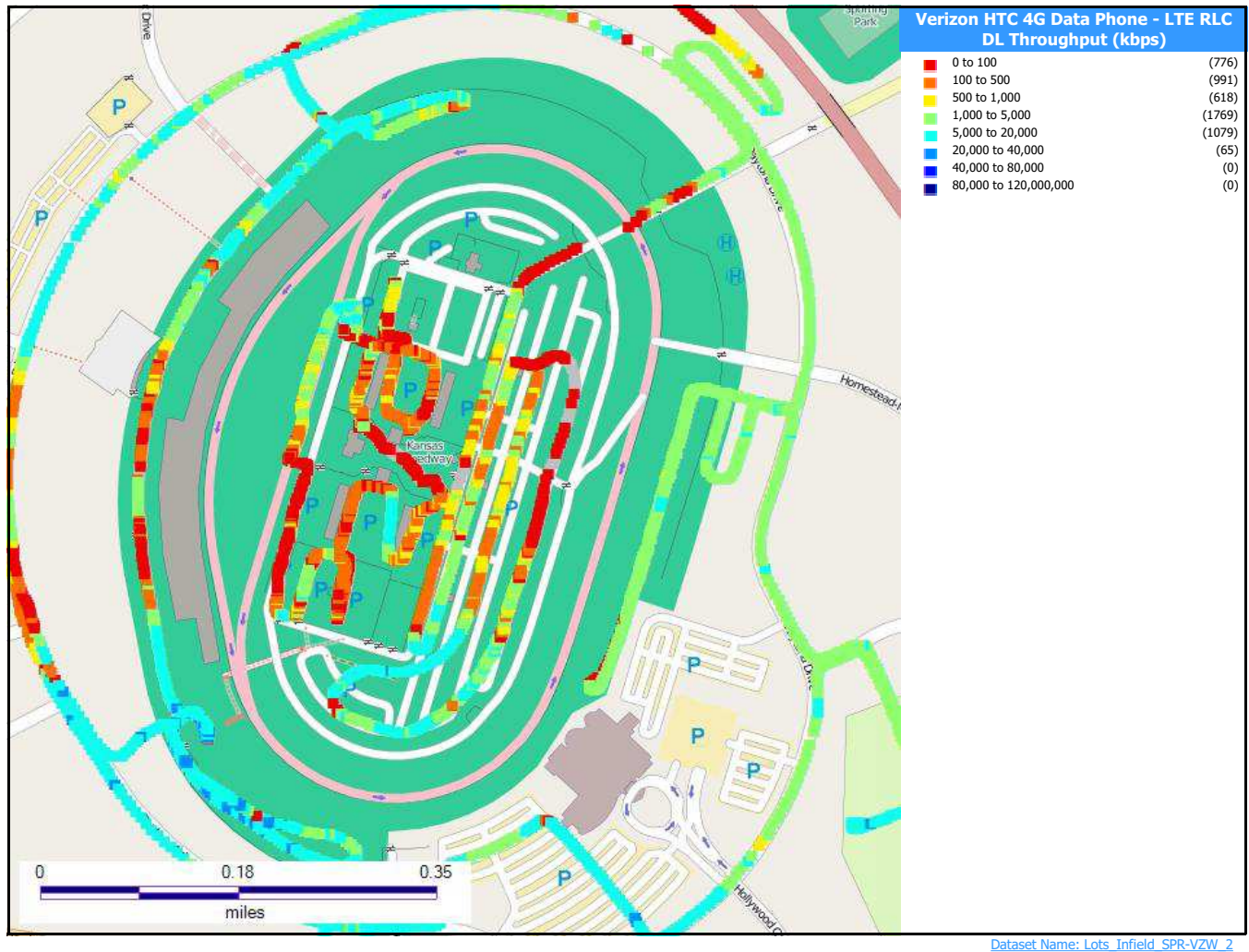
FIGURE 28. Verizon 700 LTE DL Throughput - Infield

Dataset Name: Lots_Infield_SPR-VZW_2
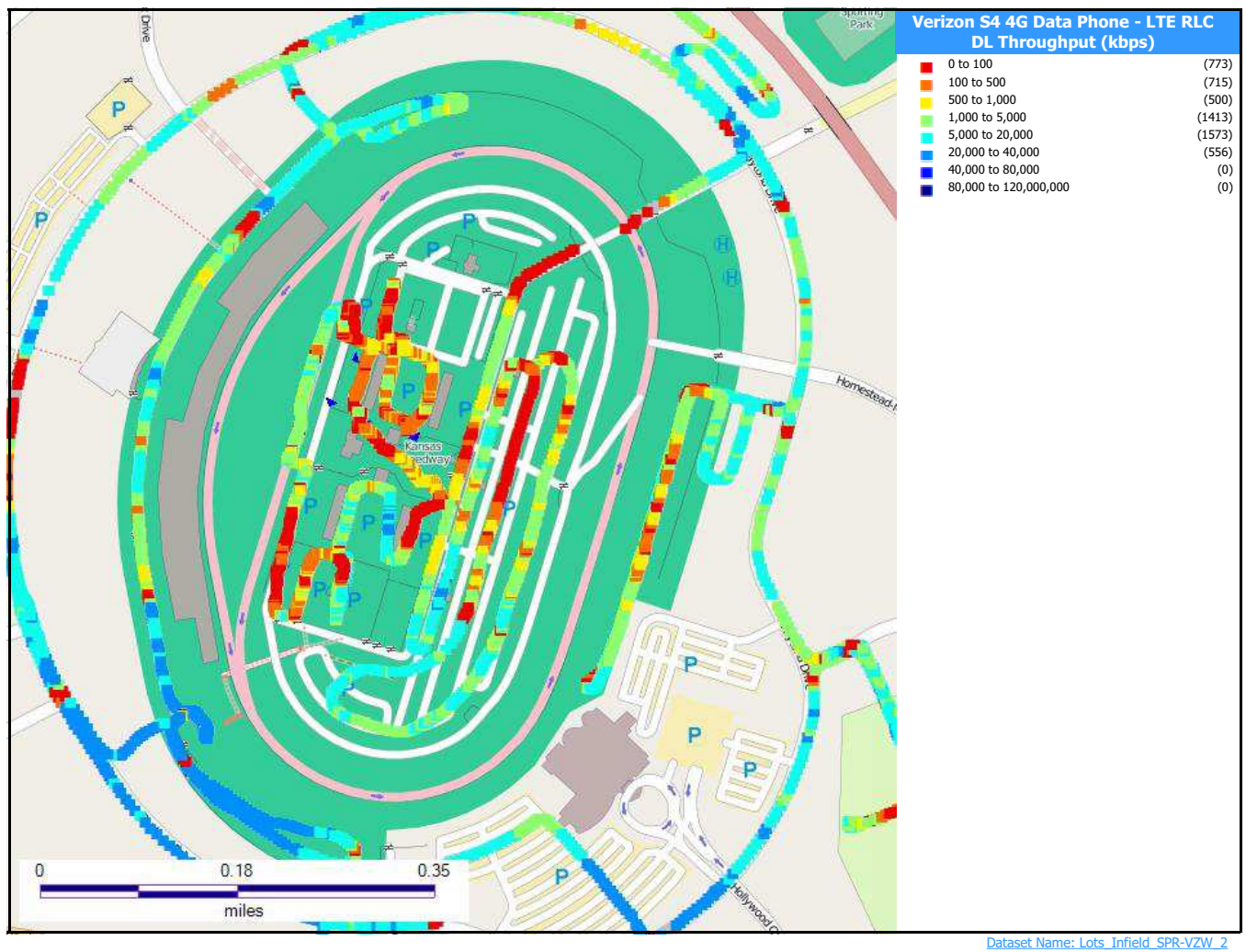
FIGURE 29. Verizon AWS LTE DL Throughput - Infield

7.1.2 4G Coverage and Quality

RSRP was used to display the coverage of the LTE channels for the Operators. Colors toward the red and orange are low and colors toward the green and blue are strong.

RSRP coverage is spotty for all Operators in the Infield. AT&T has stronger coverage on the left side of the Infield than the right. Sprint has better coverage on the right side with 2.5GHz but better coverage on the left side with 1900MHz. Verizon 700 coverage is a magnitude better than their AWS.

FIGURE 30. AT&T 700 LTE RSRP - Infield
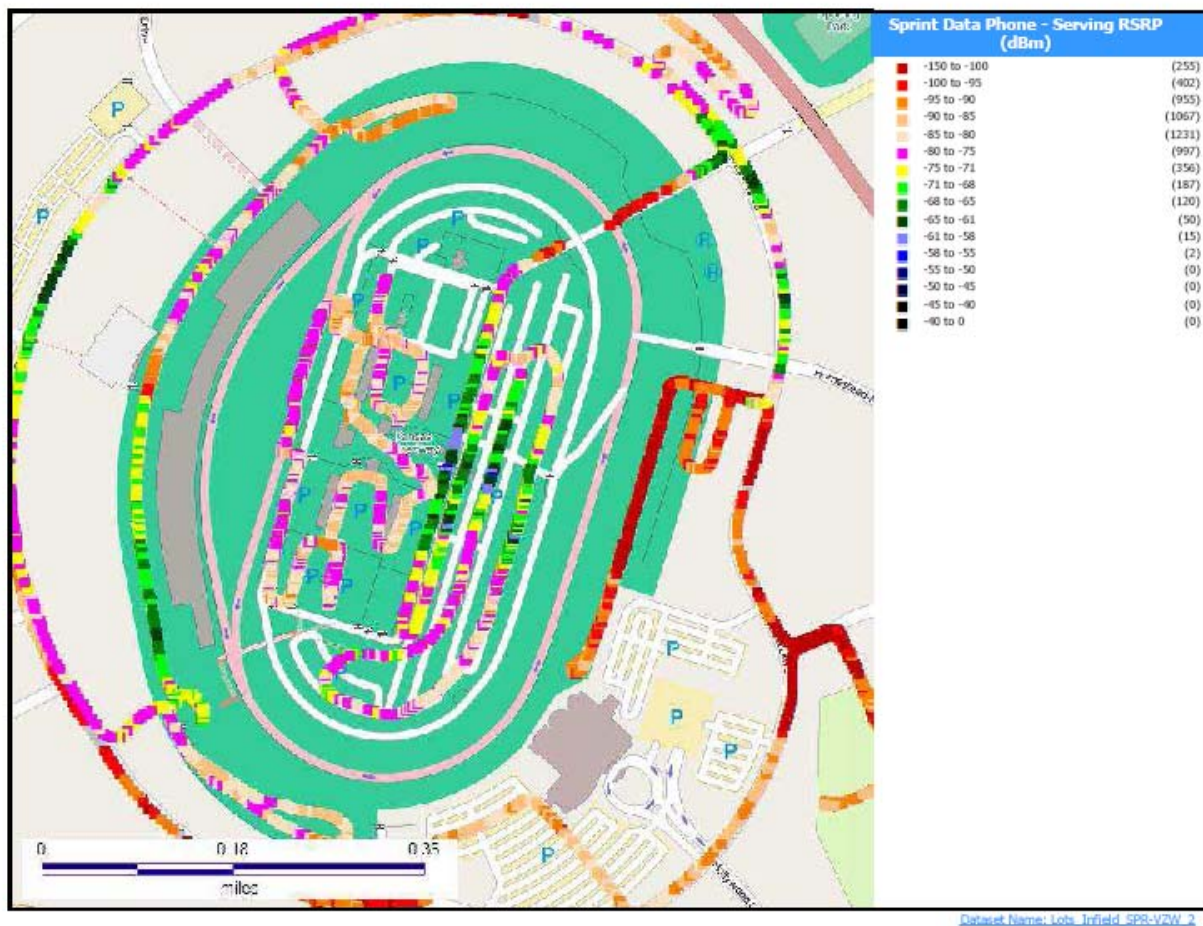
FIGURE 31. Sprint 2.5GHz LTE RSRP - Infield
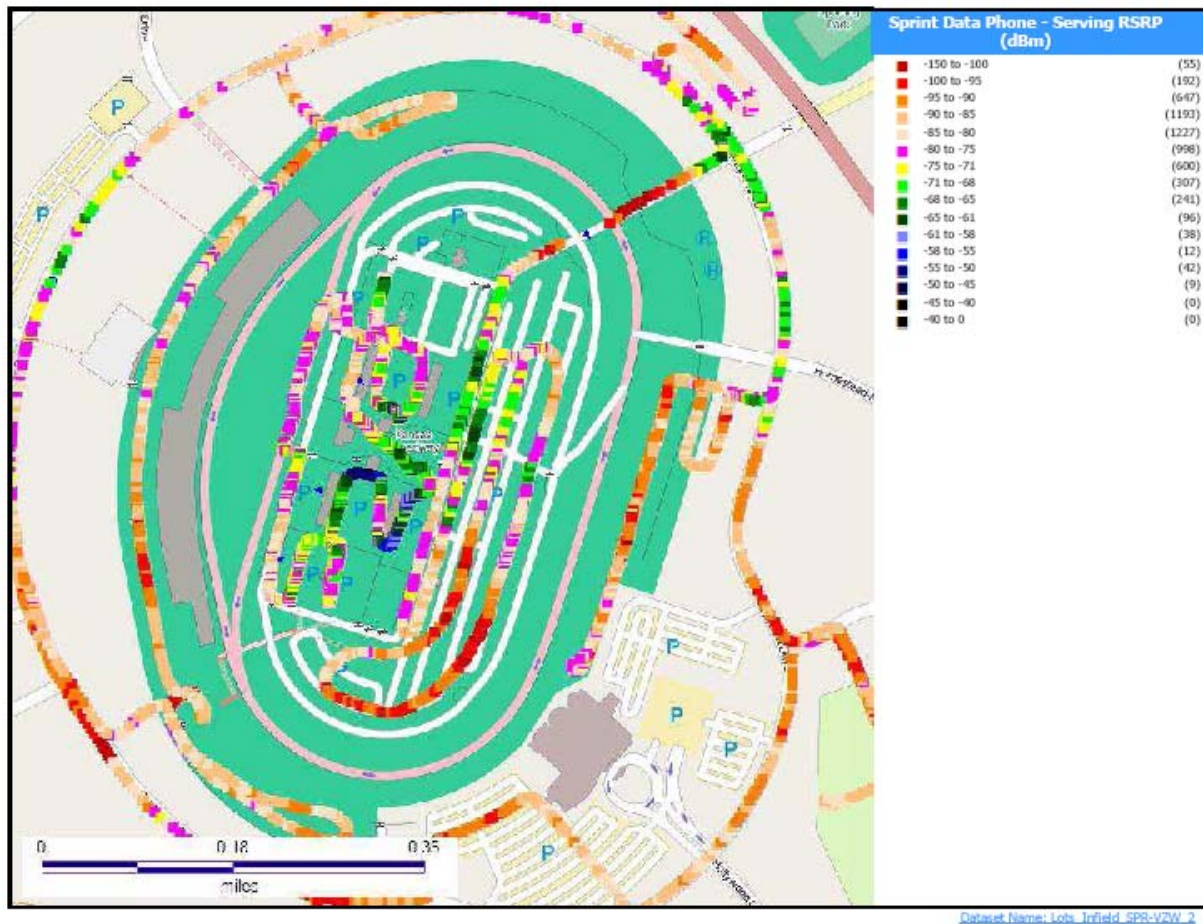
FIGURE 32. Sprint 1900 LTE RSRP - Infield
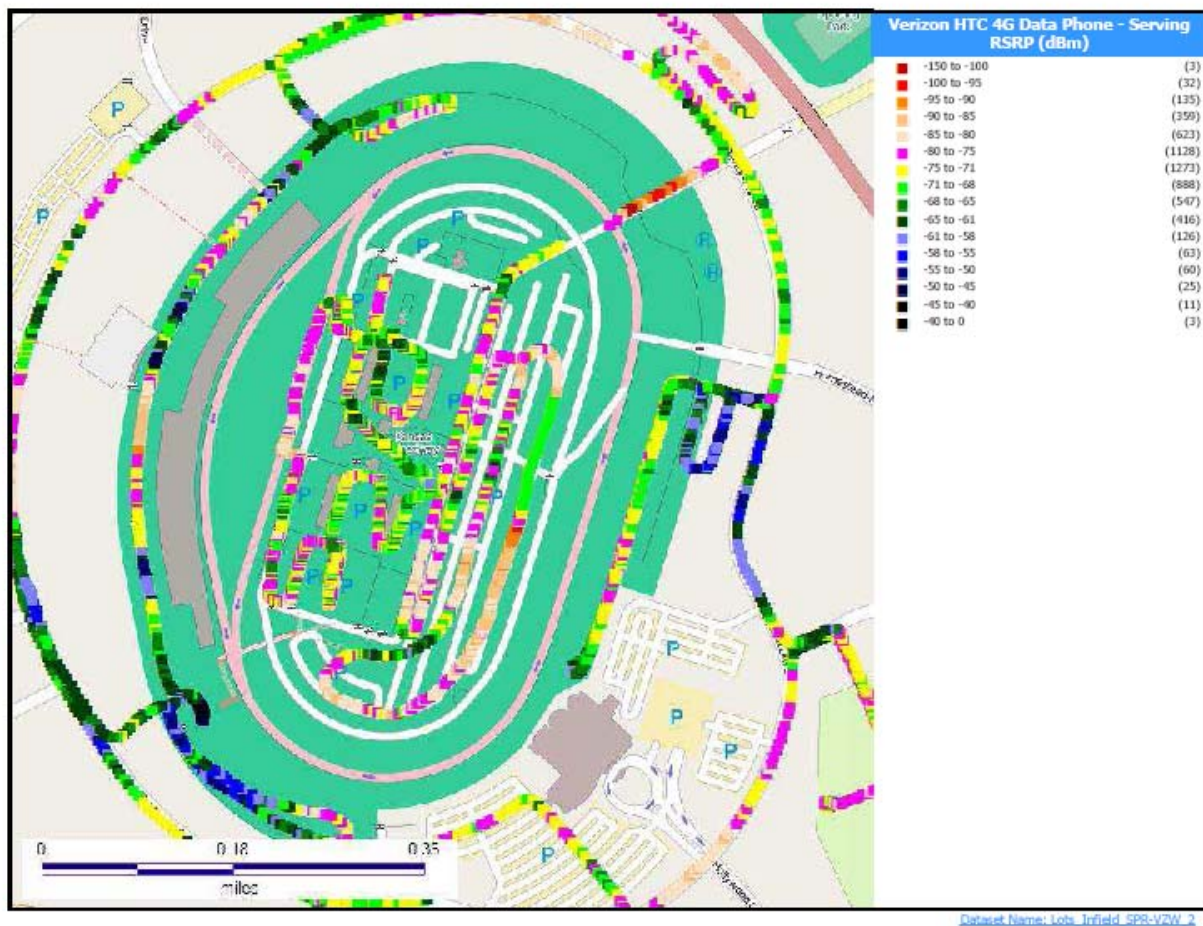
FIGURE 33. Verizon 700 LTE RSRP - Infield
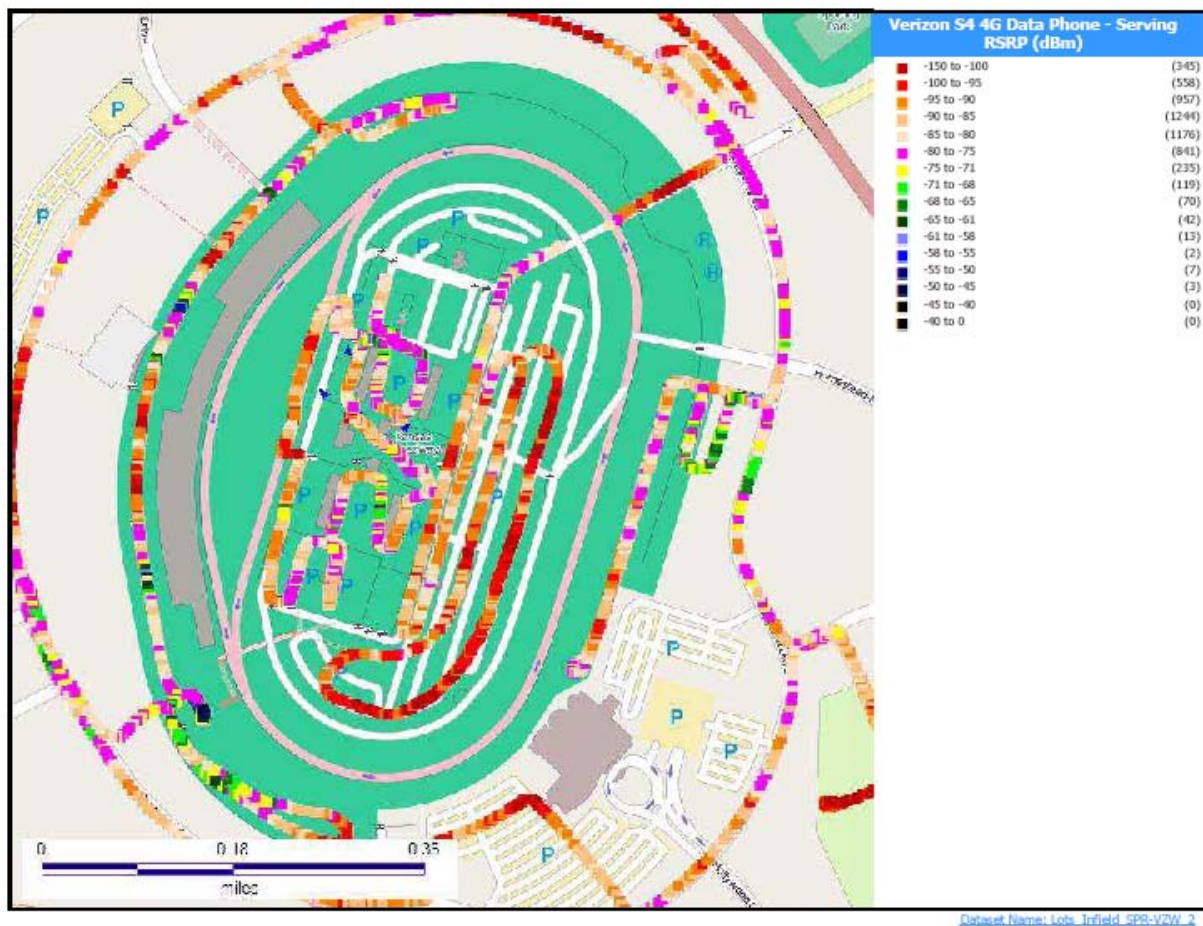
FIGURE 34. Verizon AWS LTE RSRP - Infield

The following plots display the SINR or signal to noise ratio of the logical LTE channel. SINR is typically used by engineers to determine the quality of the channel the higher the SINR value the better the quality.

Sprint 2.5GHz and T-Mobile have the best SINR plots. For Sprint the good SINR translated into solid high throughput numbers. For T-Mobile this is not the case. The plot following the T-Mobile SINR plot is the Serving Cell PCI. As you can see the Infield and surrounding area are served by a single PCI or cell sector which most likely can not handle the capacity so we can deduce that the low throughput is due to lack of capacity.

AT&T and Verizon have a significant amount of negative SINR values in the Infield which indicates poor quality of the channel due to low RSRP and high noise.
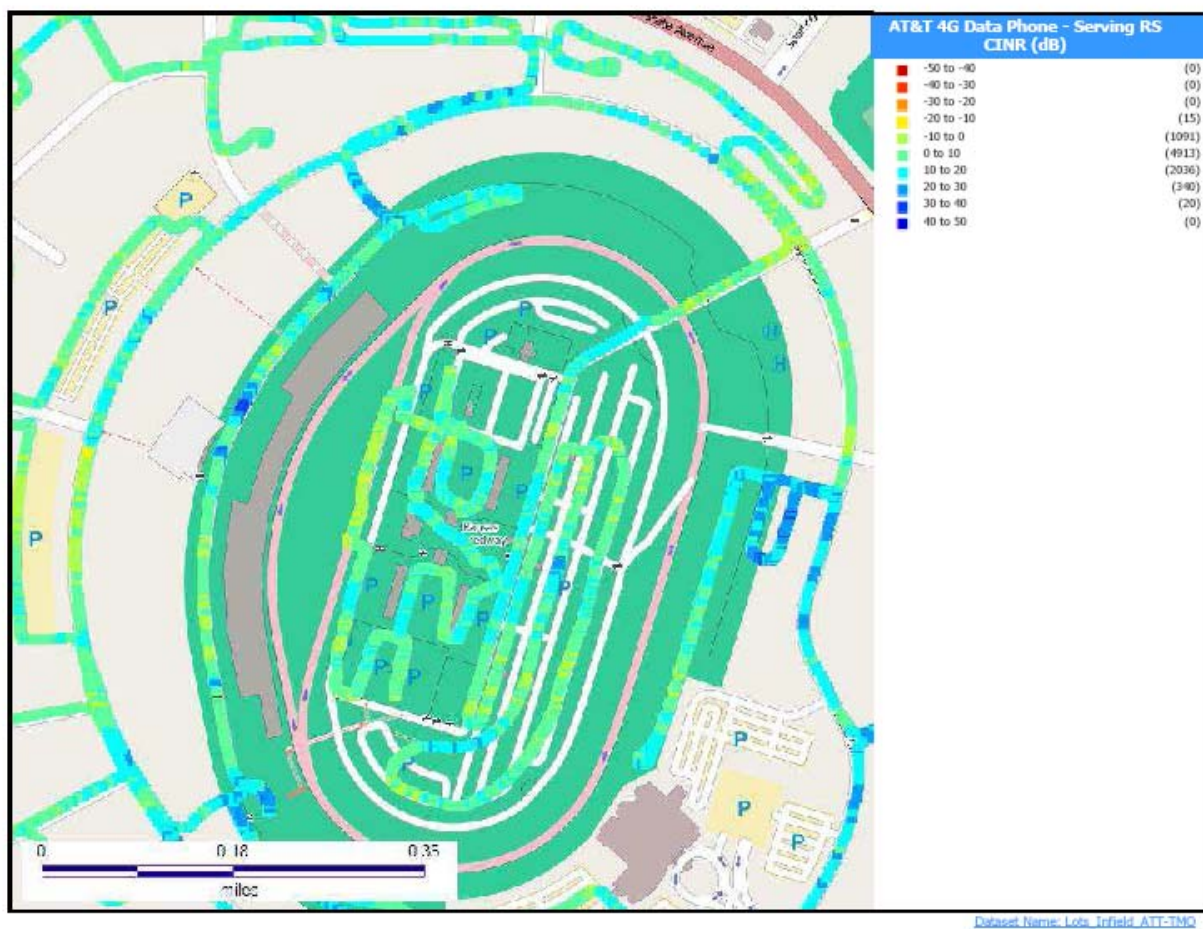
FIGURE 35. AT&T 700 LTE SINR - Infield
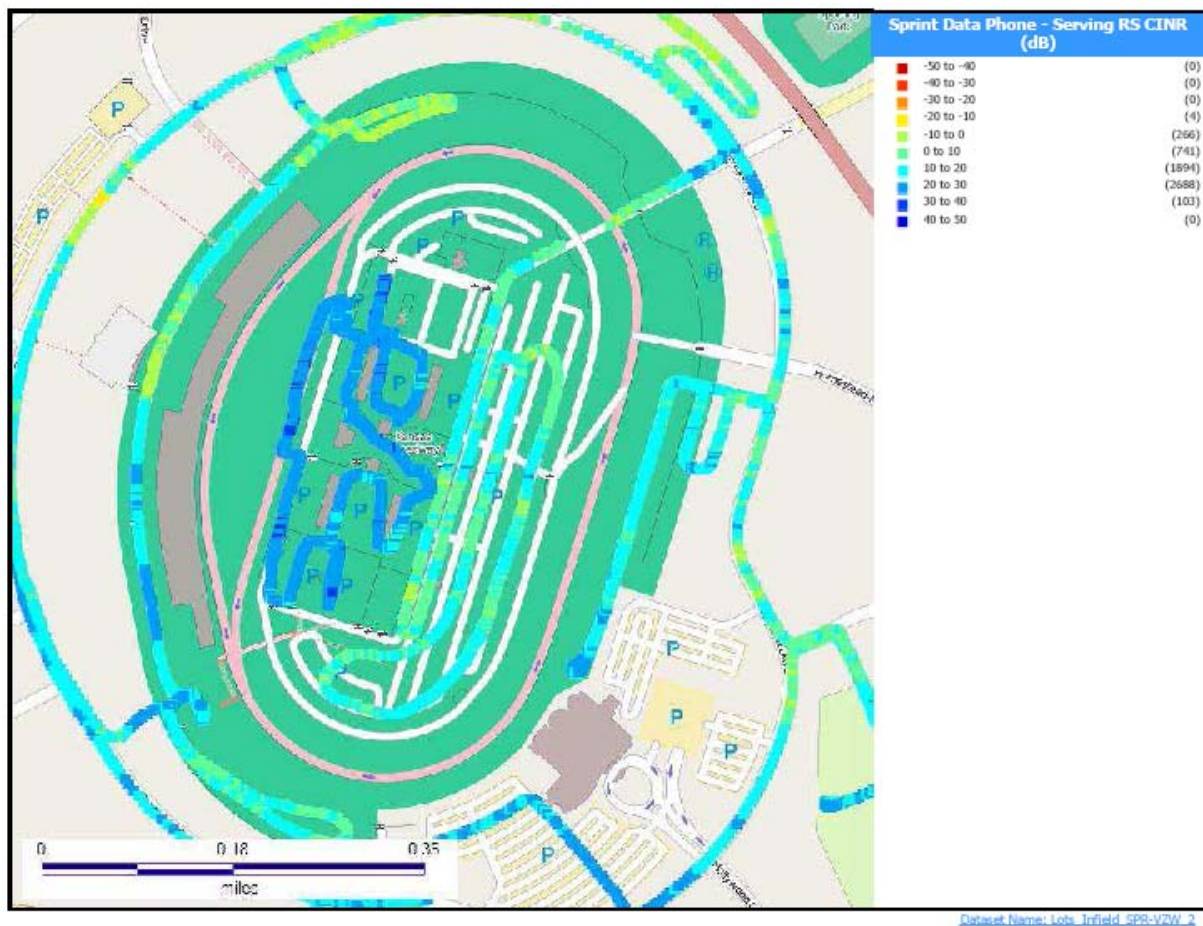
FIGURE 36. Sprint 2.5GHz LTE SINR - Infield
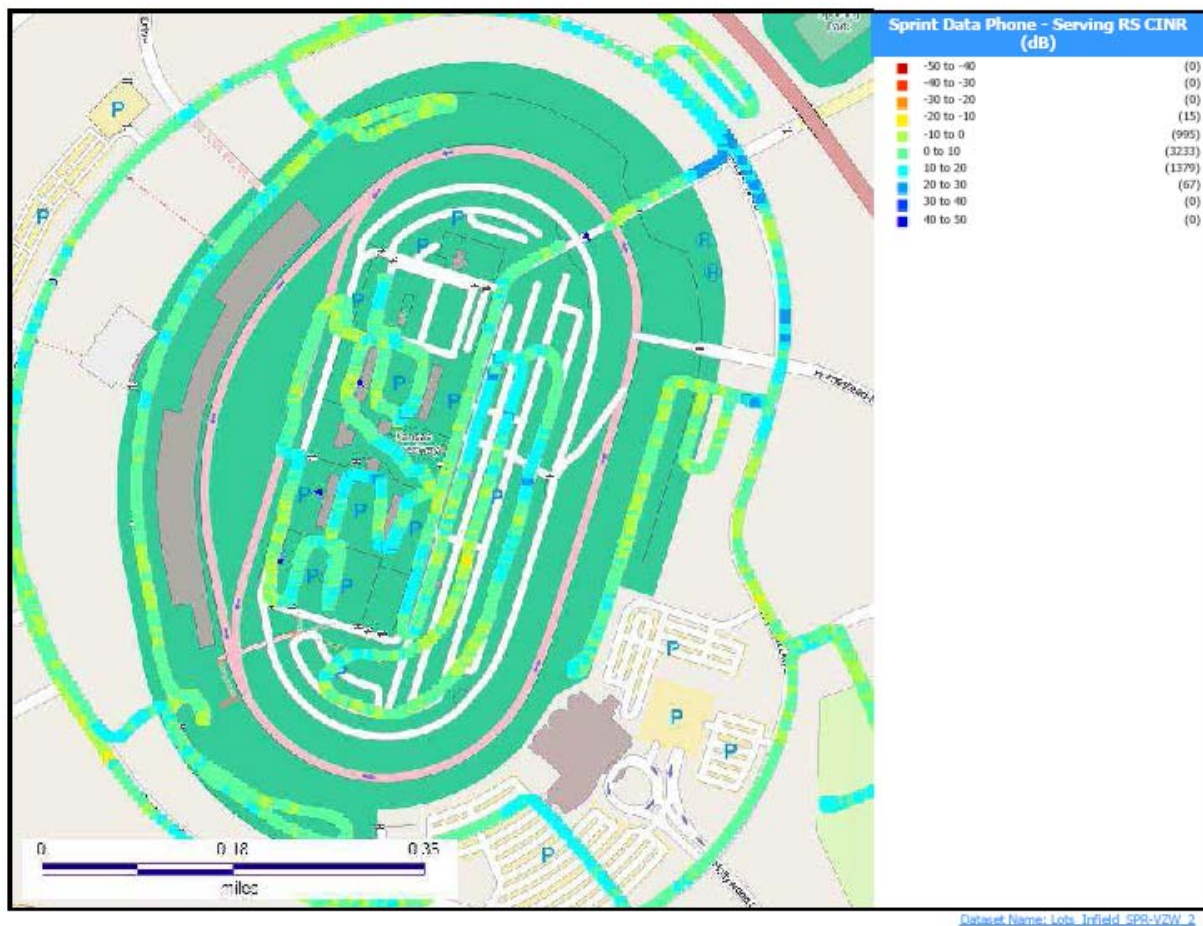
FIGURE 37. Sprint 1900 LTE SINR - Infield
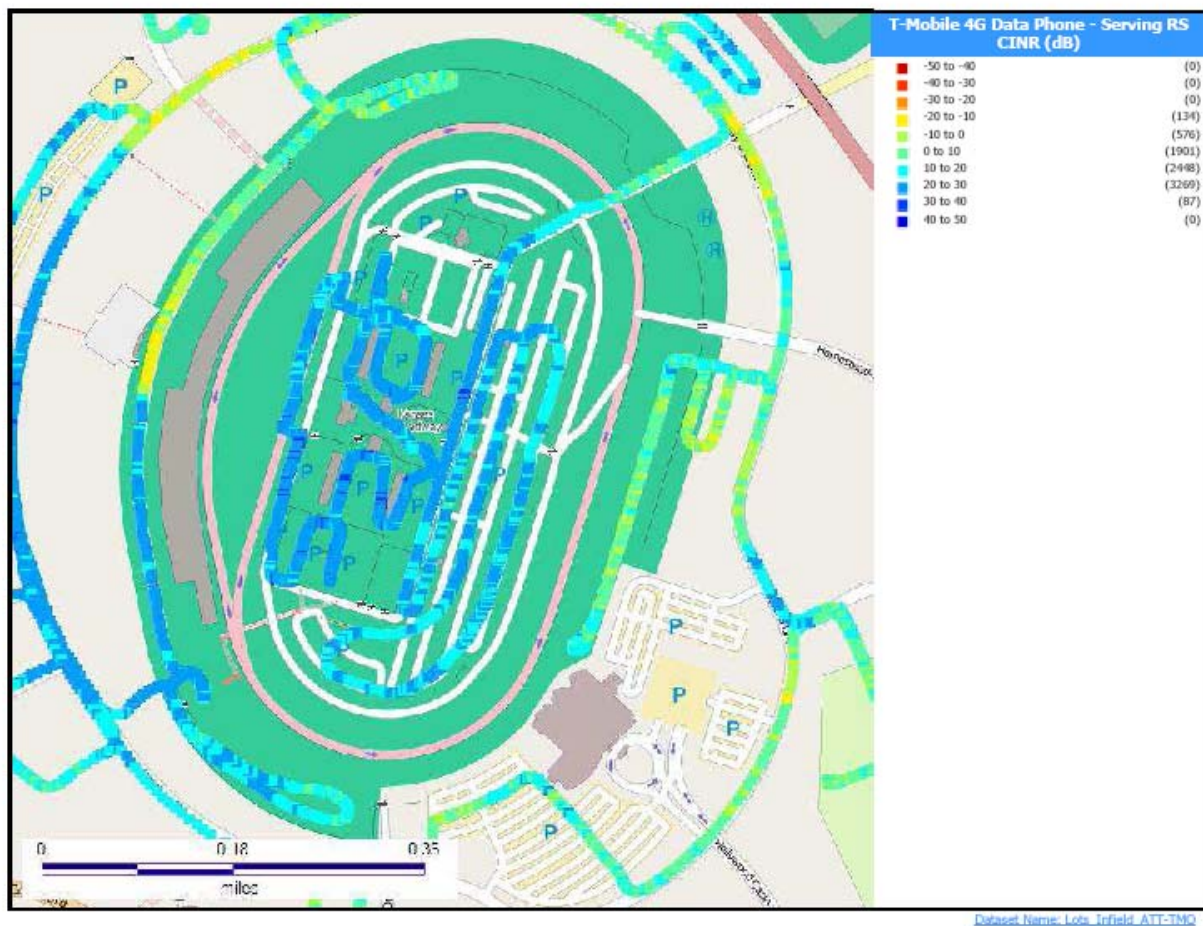
FIGURE 38. T-Mobile AWS LTE SINR - Infield
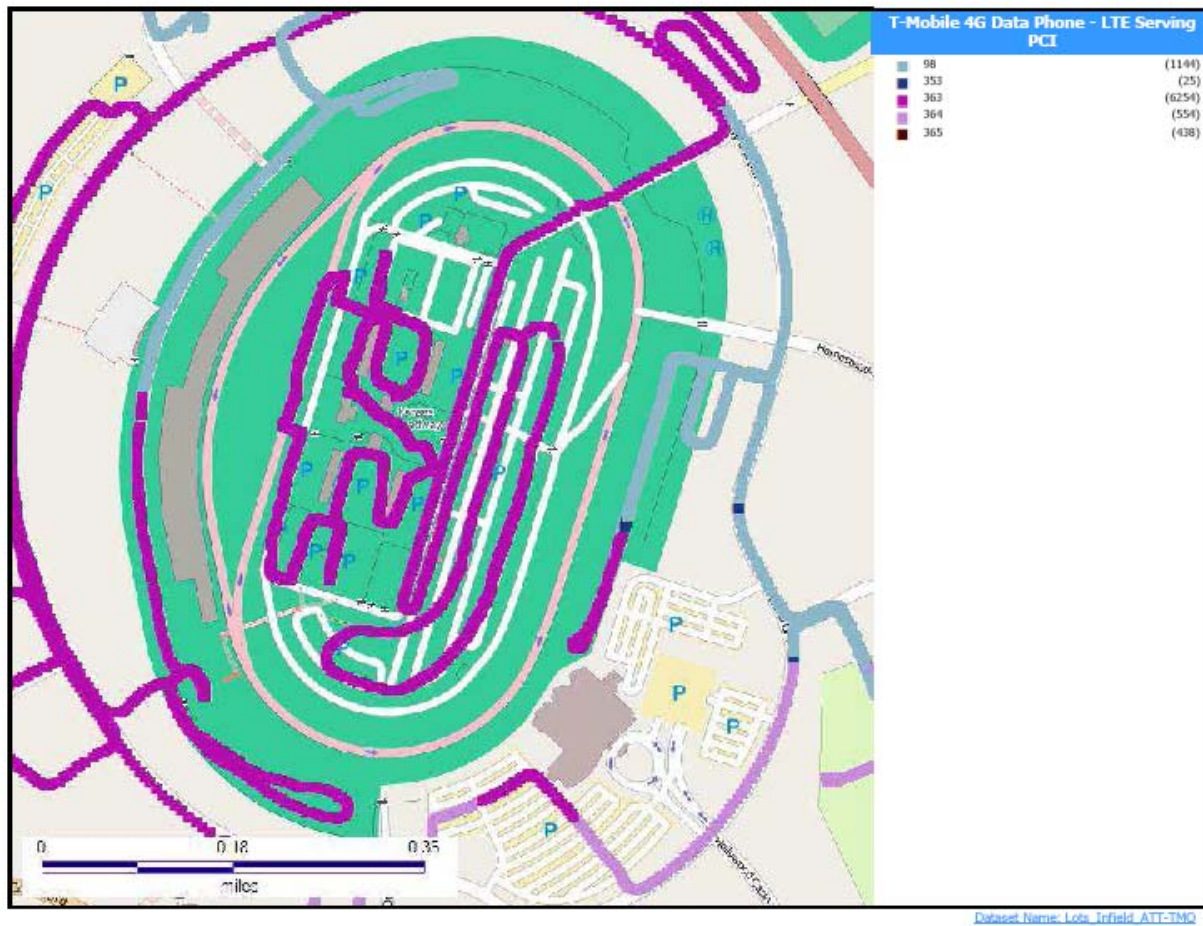
FIGURE 39. T-Mobile AWS LTE Serving PCI - Infield
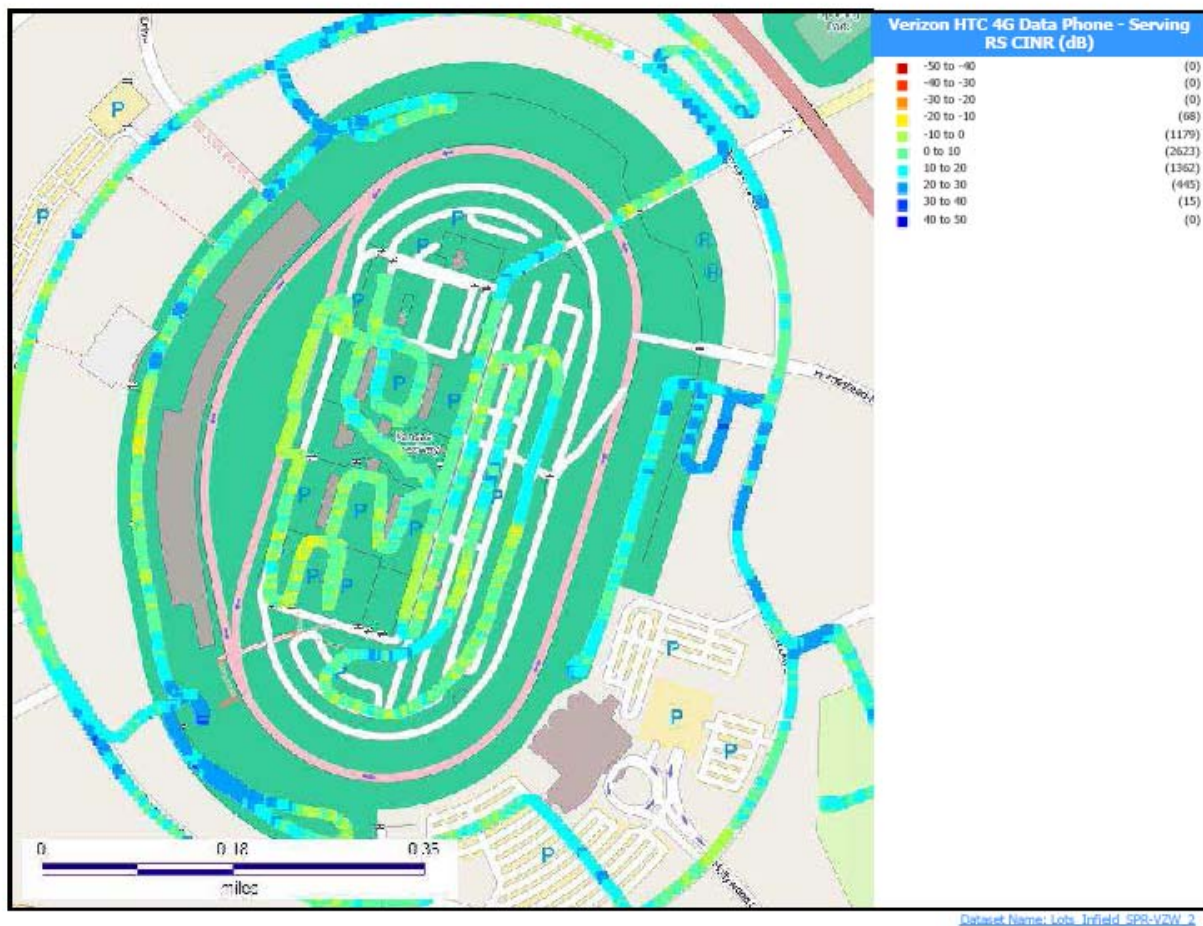
FIGURE 40. Verizon LTE SINR - Infield
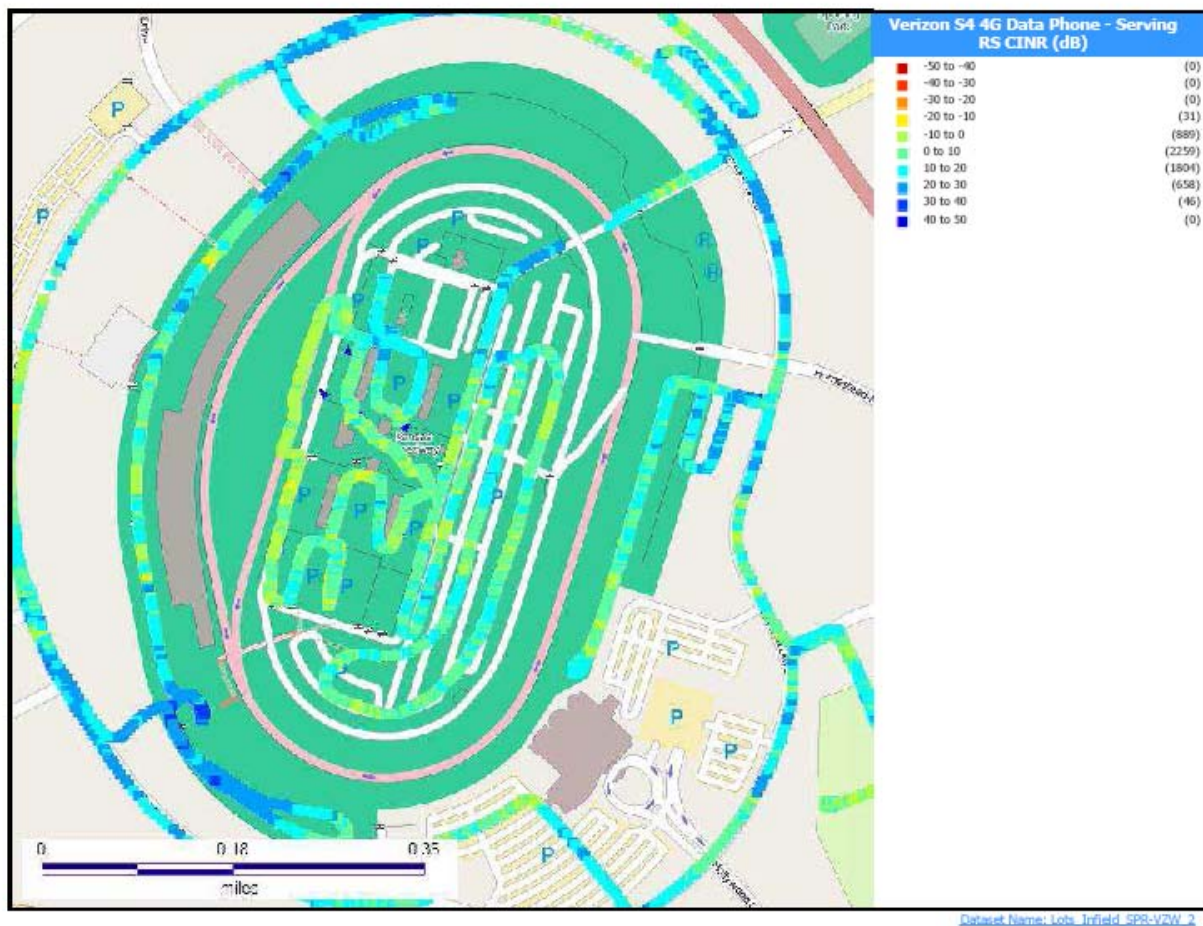
FIGURE 41. Verizon AWS LTE SINR - Infield

7.1.3 Voice

AT&T signal levels were lower than the rest of the operators. Sprint and Verizon had strong levels in the Infield. T-Mobile had UMTS voice coverage in the Infield. For some reason data was not collected on the right side of the Infield. This may have been due to a lost connection between the ZK-MPX and the phone.

FIGURE 42. AT&T Voice Coverage - Infield
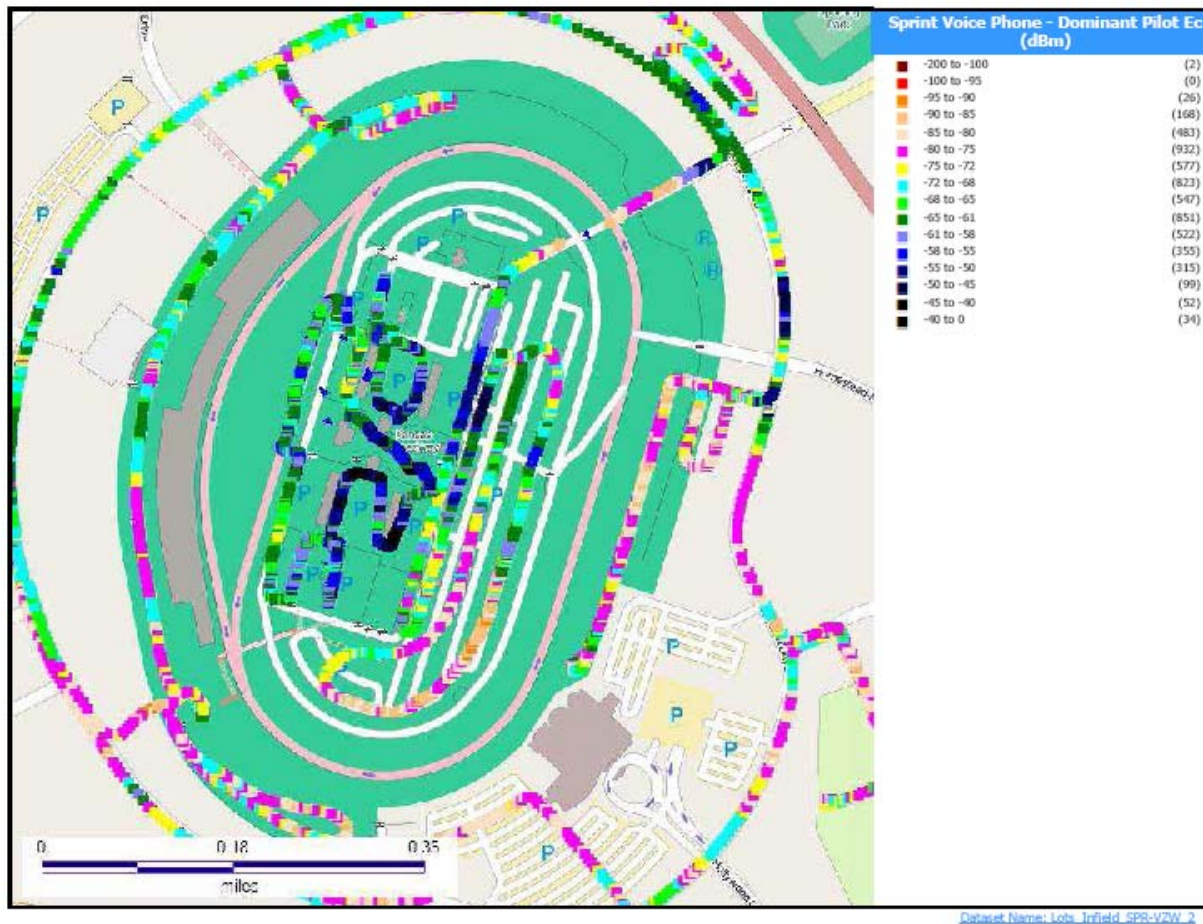
FIGURE 43. Sprint Voice Coverage - Infield
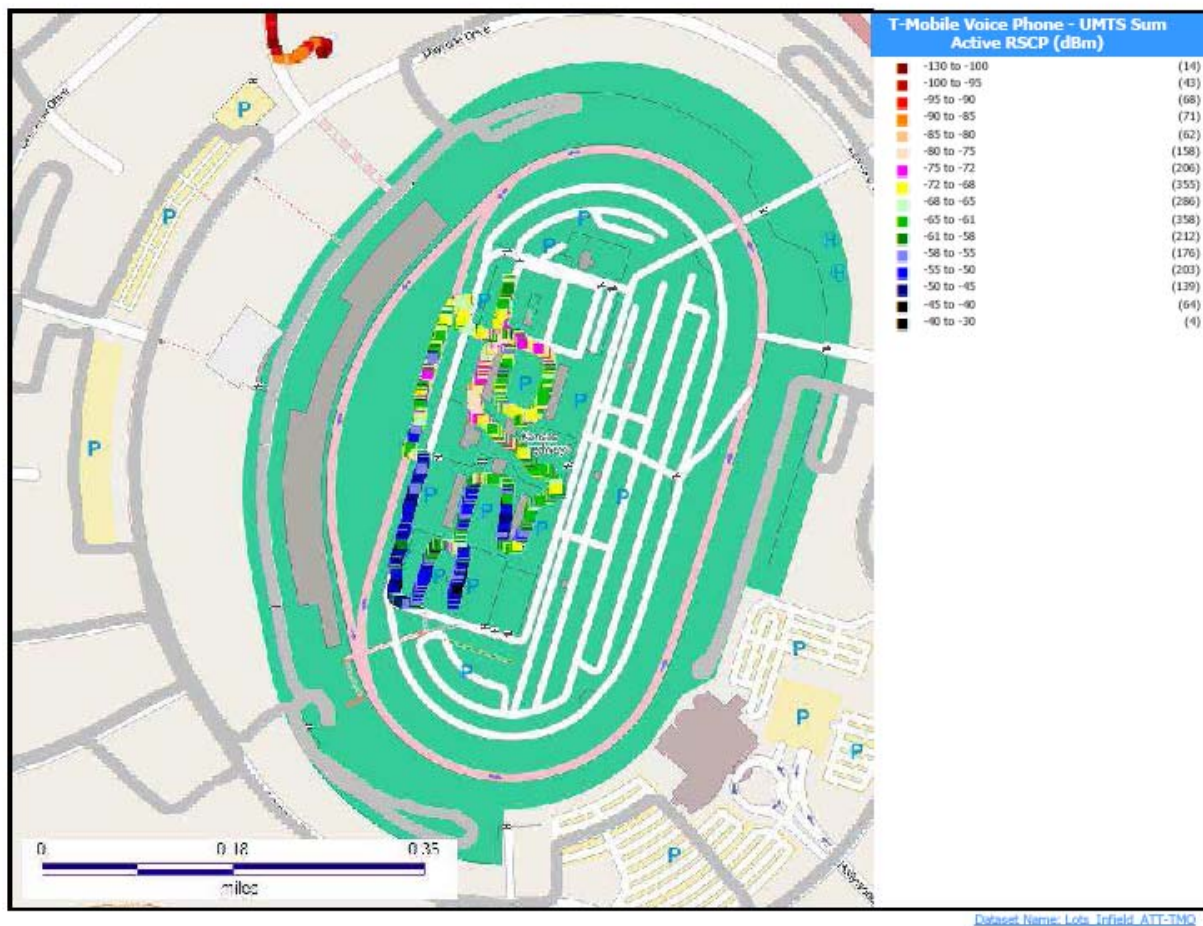
FIGURE 44. T-Mobile Voice Coverage - Infield
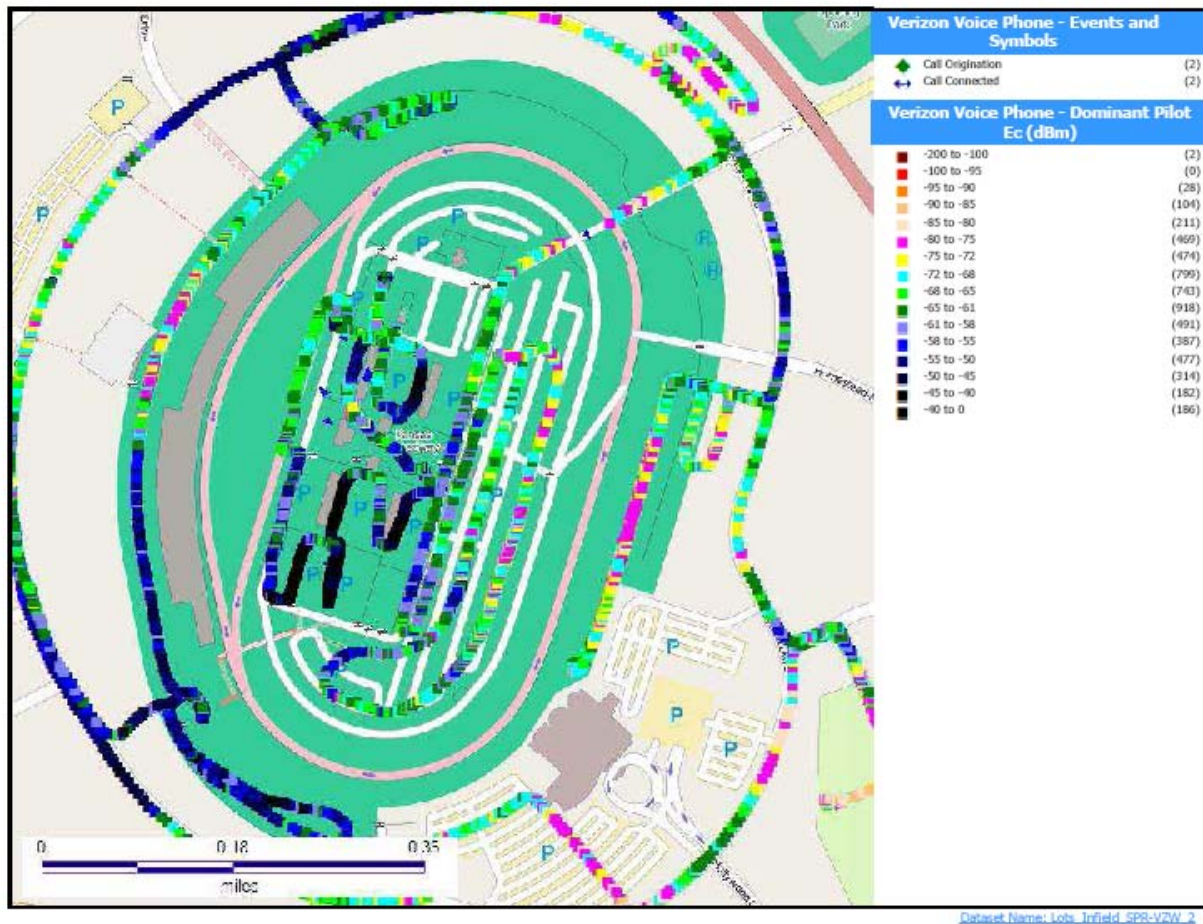
FIGURE 45. Verizon Voice Coverage - Infield

7.2 Grandstands

The grandstands were measured just prior to the beginning of the race. They were completely filled with fans. Three swipes through the grandstands were made. The lowest swipe next to the race track was actually in the corridor in front of the grandstands in front of a 6 foot wall which the seats were directly behind. We walked close to the track so the wall would not block much of the signal coming from the antennas mounted at the top of the grandstands pointing down.

7.2.1 Data Throughput

The following plots show the 4G download throughput speeds for the 4 major Operators in the Grandstands section.

Sprint's 2.5GHz service looks the best in terms of data rates. The front row section of the plots were actually in front of the stands with a 6 foot wall in between. AT&T and Verizon were next best but had large sections of low throughput levels as indicated by areas of orange and red.
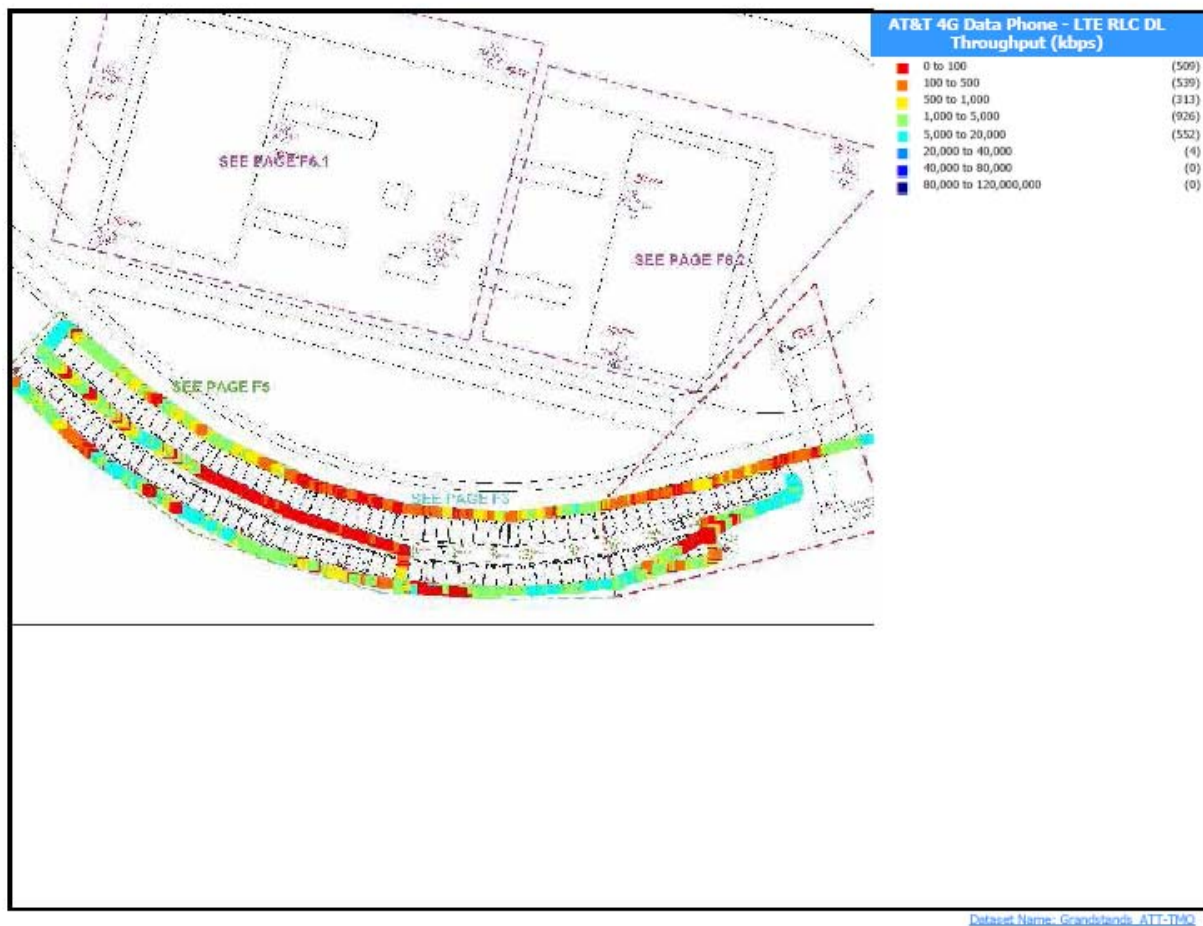
FIGURE 46. AT&T 700 LTE DL Throughput - Grandstands
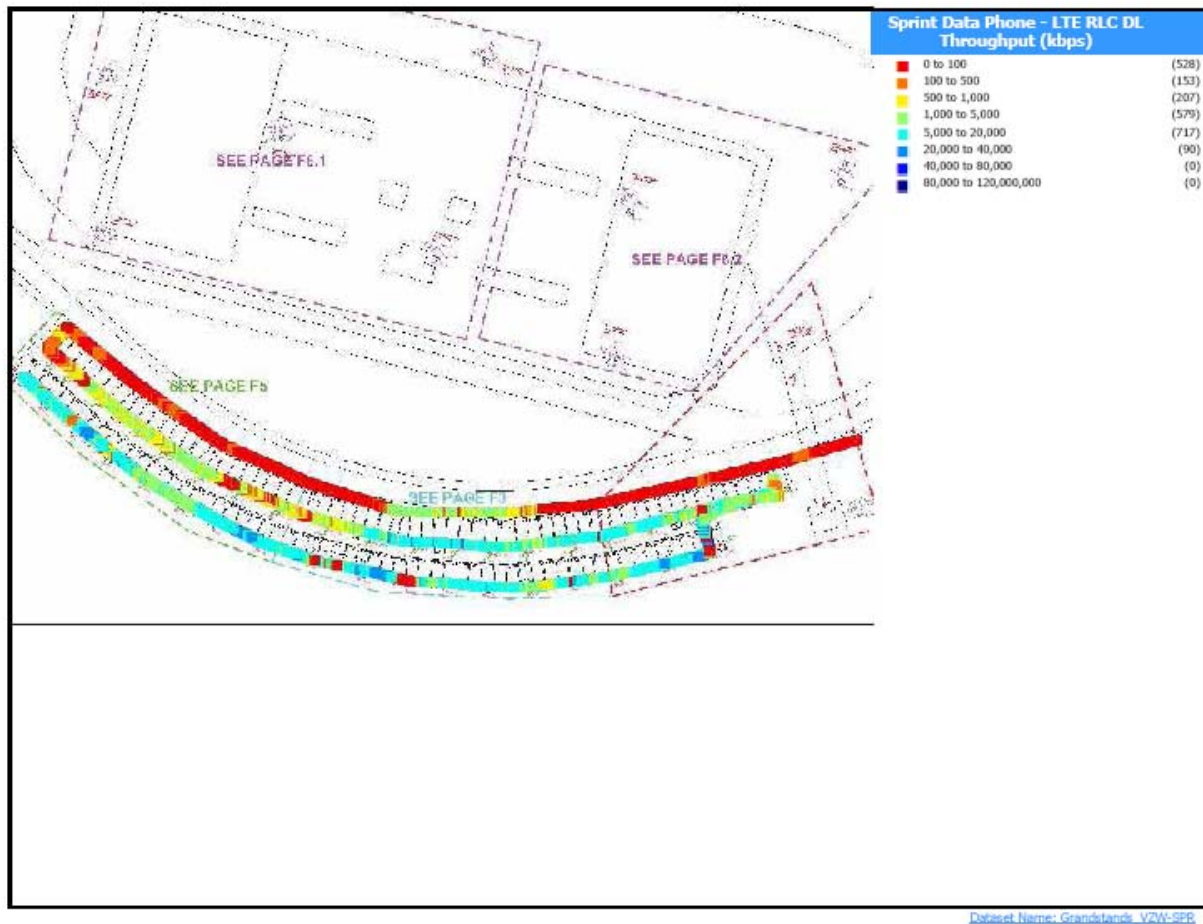
FIGURE 47. Sprint 2.5GHz LTE DL Throughput - Grandstands
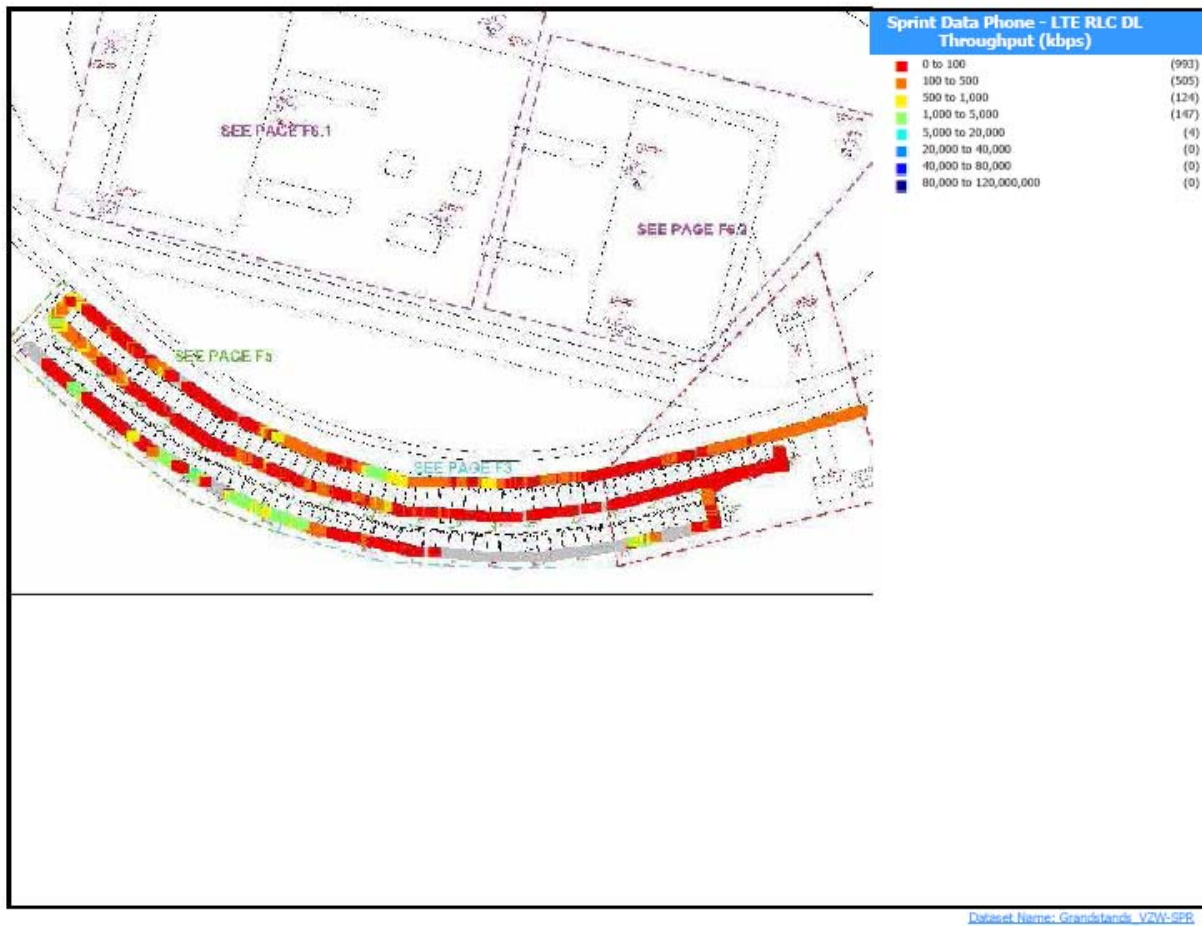
FIGURE 48. Sprint 1900 LTE DL Throughput - Grandstands
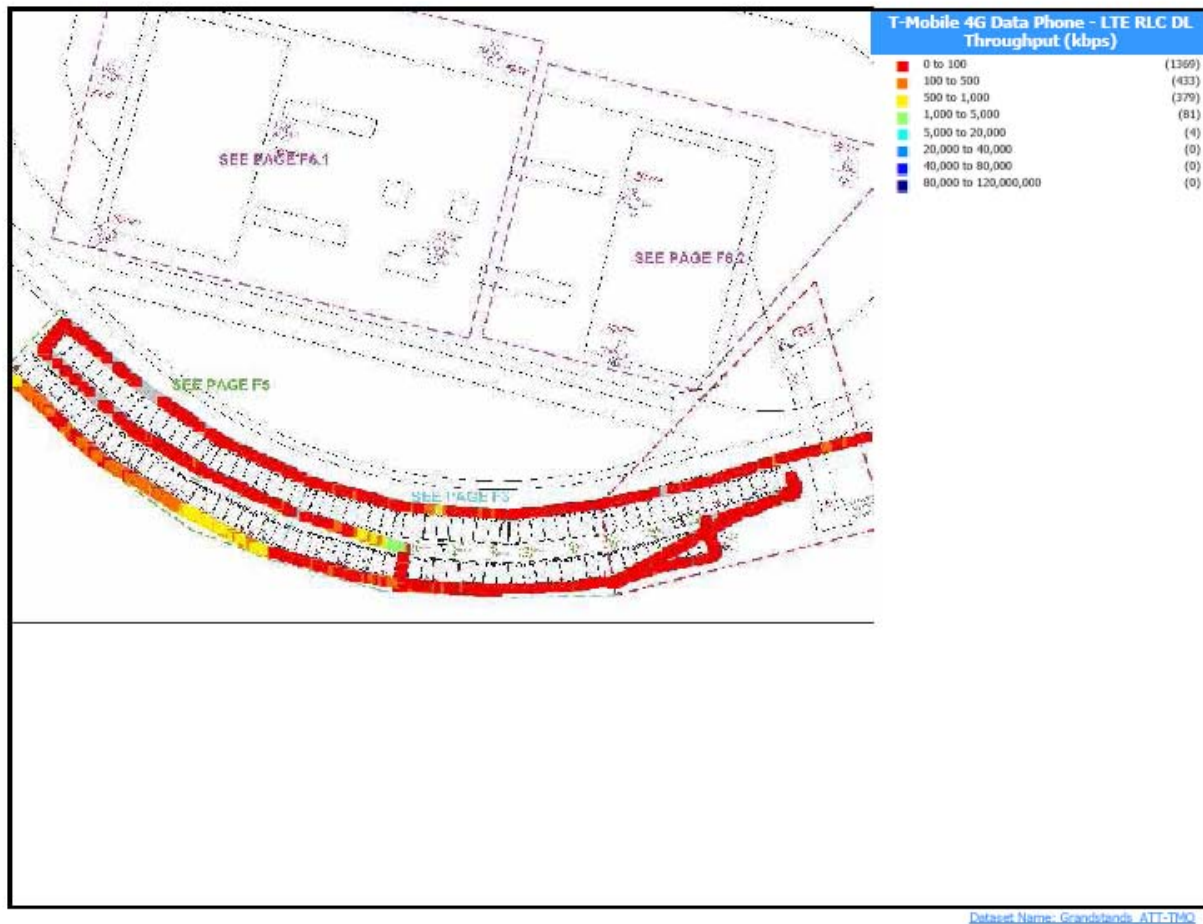
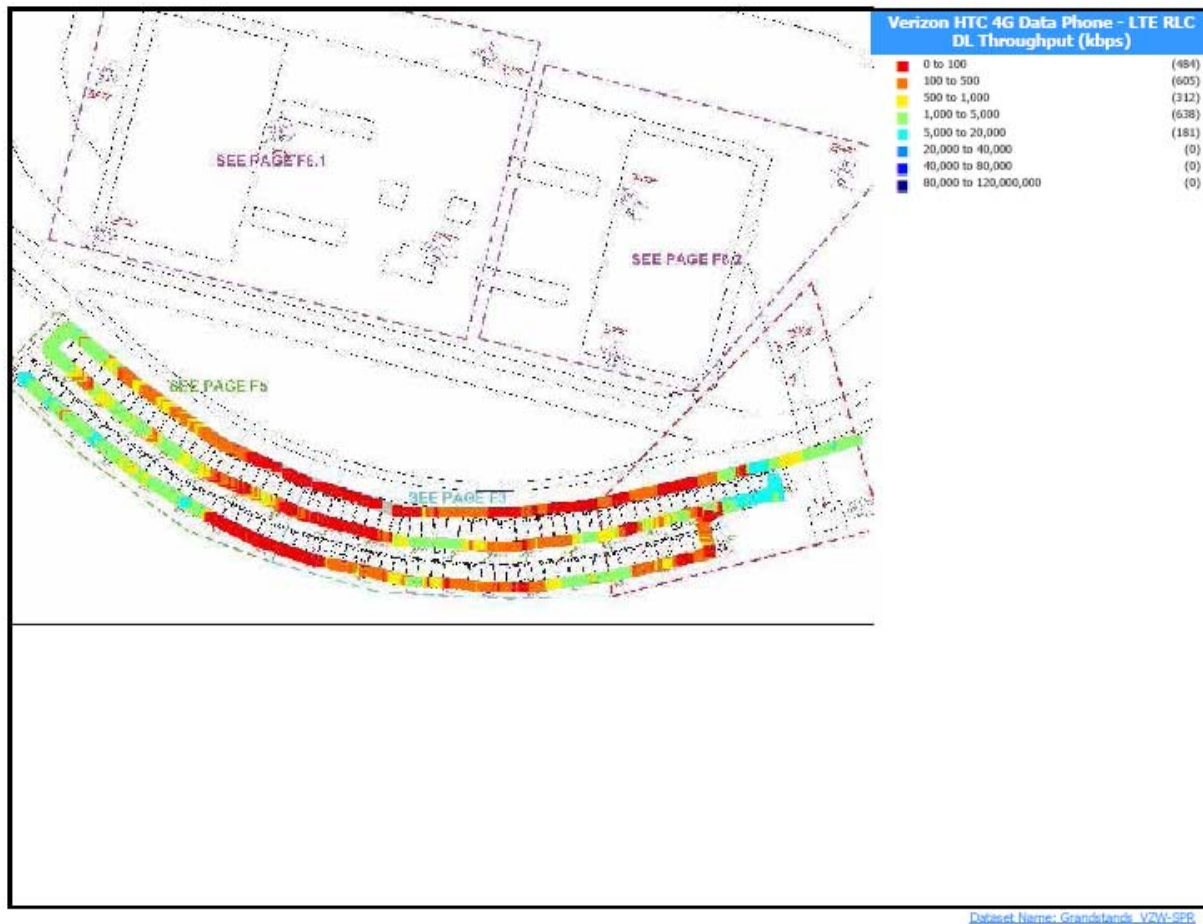*FIGURE 49. T-Mobile AWS LTE DL Throughput - Grandstands*

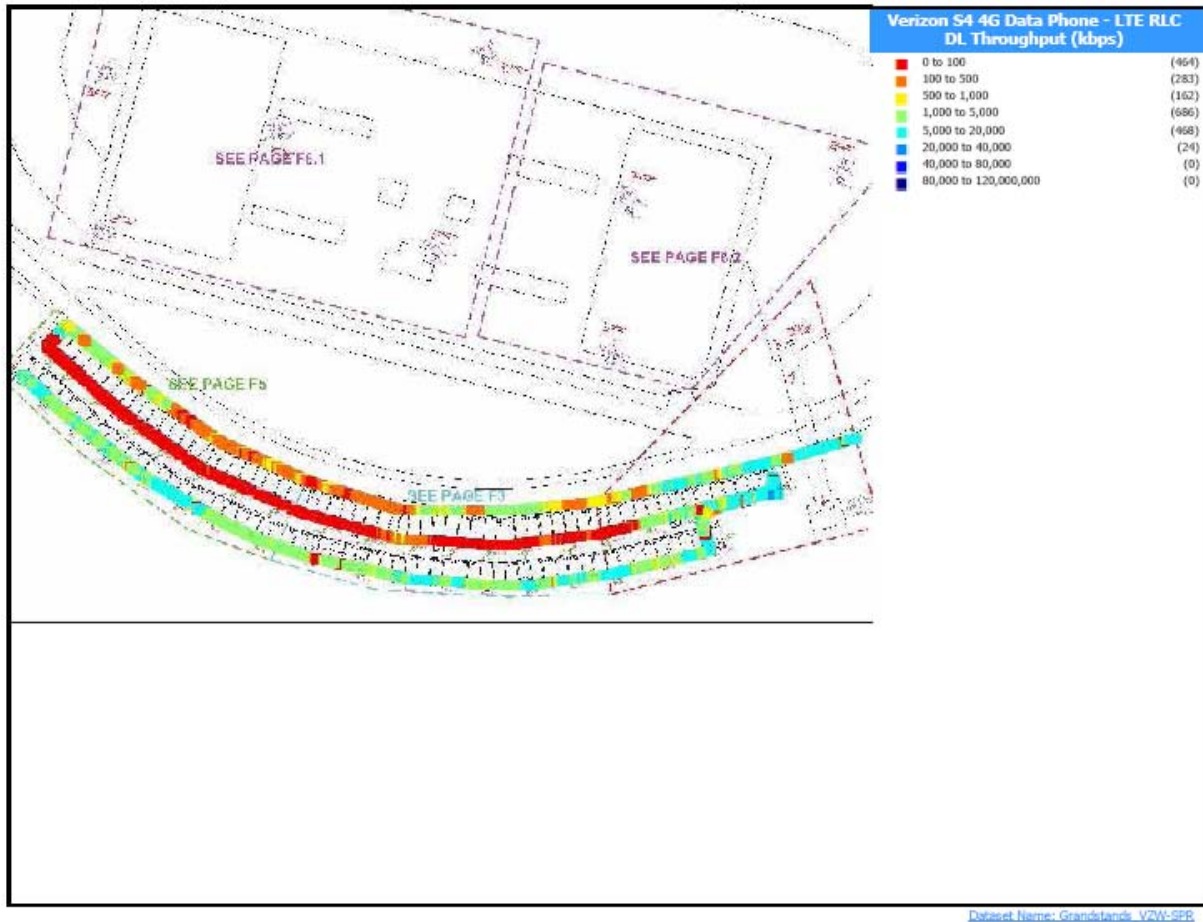*FIGURE 50. Verizon 700 LTE DL Throughput - Grandstands*

FIGURE 51. Verizon AWS LTE DL Throughput - Grandstands

7.2.2 Voice

AT&T had lower levels of voice coverage but still adequate. Sprint and Verizon had strong signals. T-Mobile was on their UMTS channel in the grandstands adequate but lower signal levels.
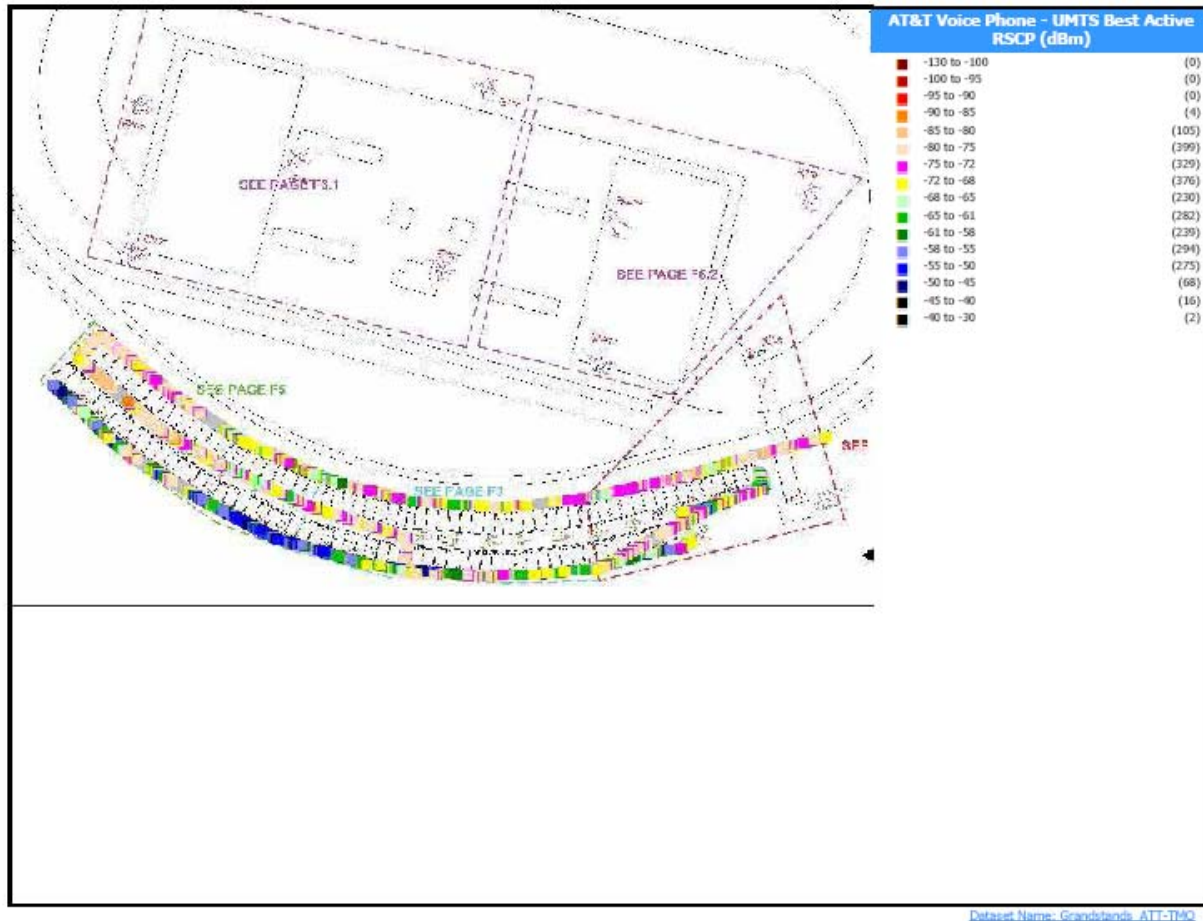

FIGURE 52. AT&T Voice Coverage - Grandstands
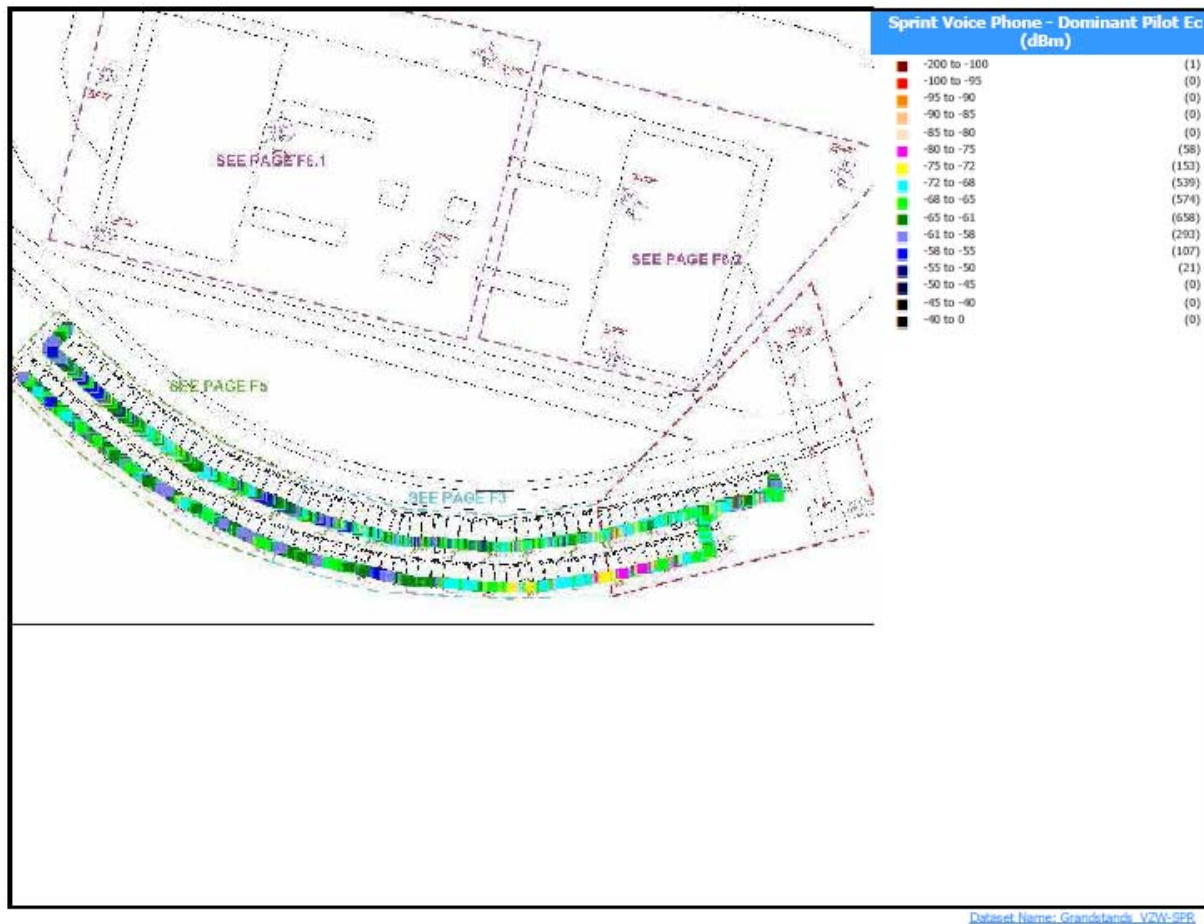
FIGURE 53. Sprint Voice Coverage - Grandstands
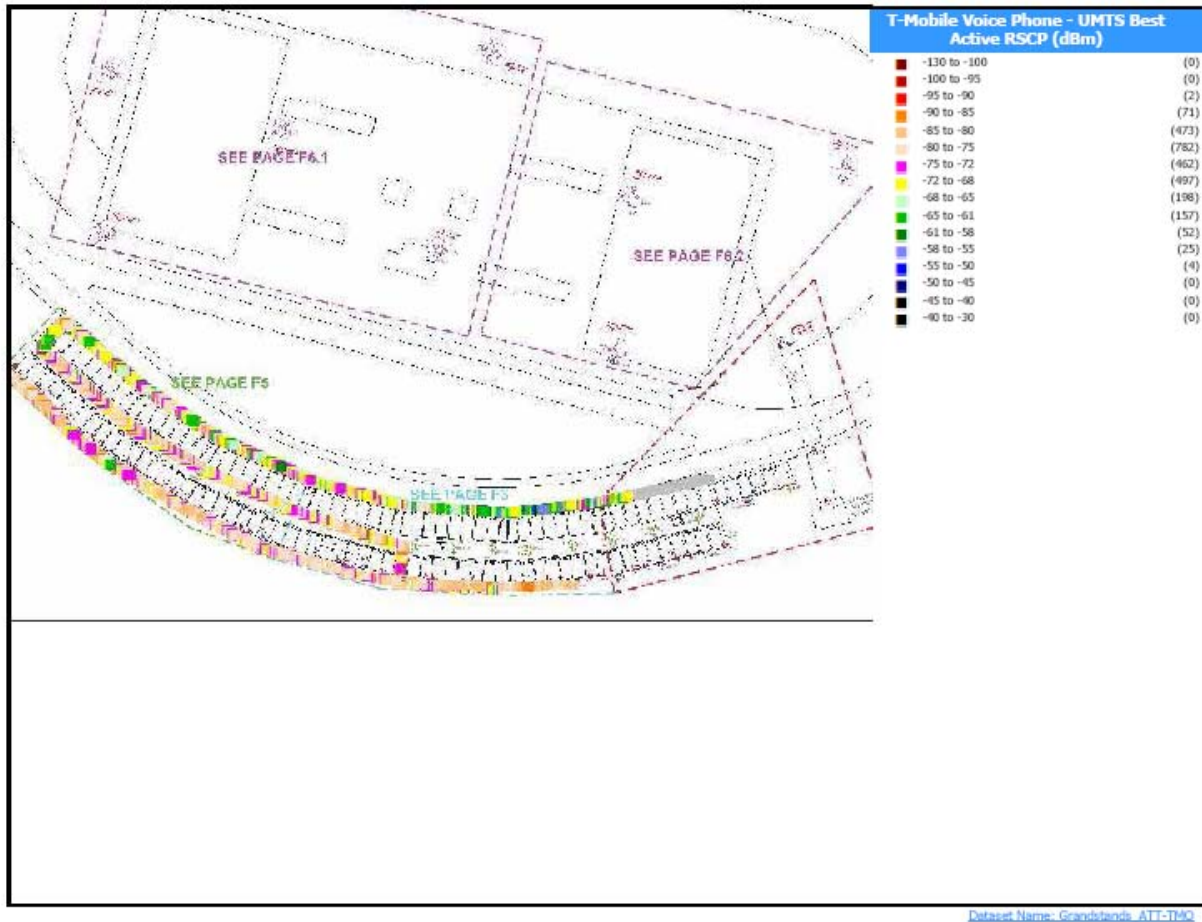
FIGURE 54. T-Mobile Voice Coverage - Grandstands
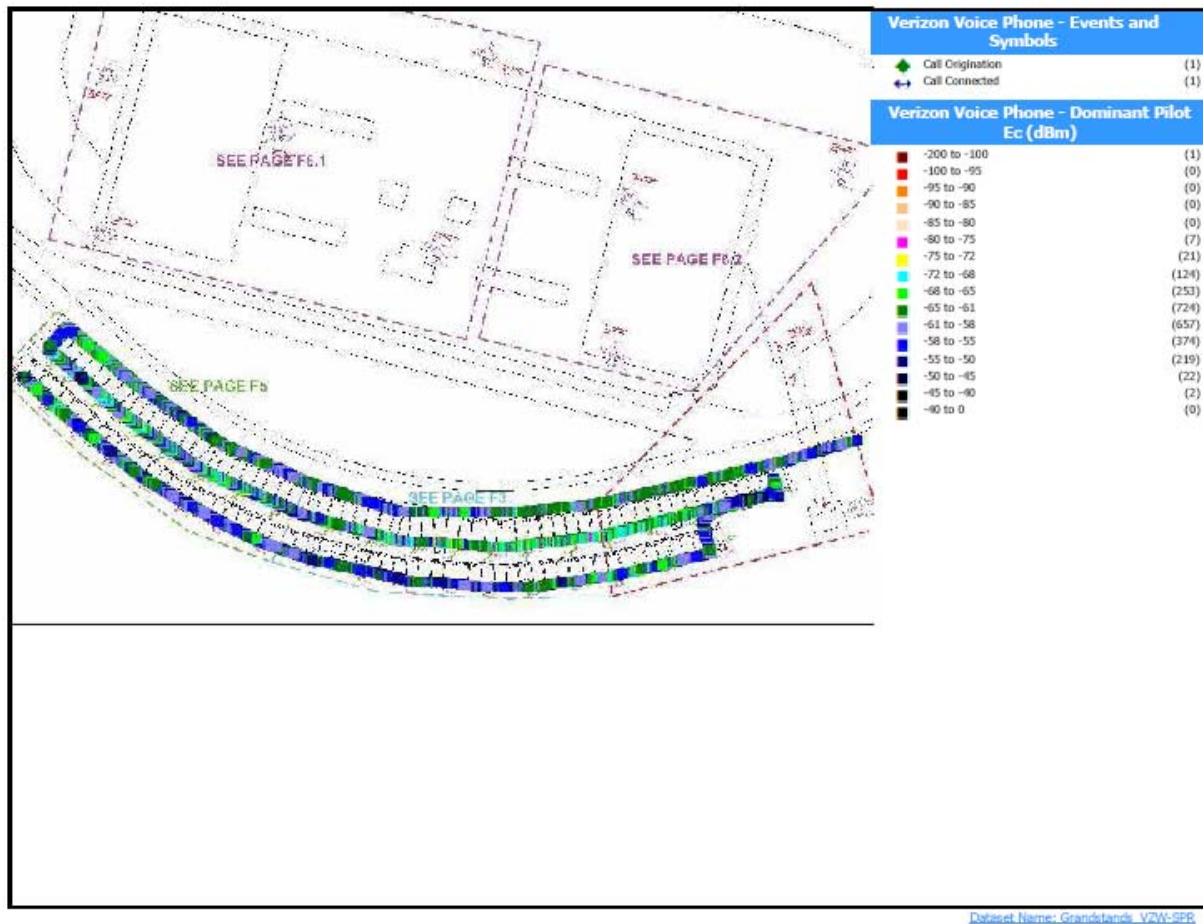
FIGURE 55. Verizon Voice Coverage - Grandstands

7.3 Suites and Broadcast Booths

7.3.1 4G Throughput

The Suites and Broadcast booths were situated above the Grandstands. There were two levels of suites with the Broadcast booths being above the second suite level.

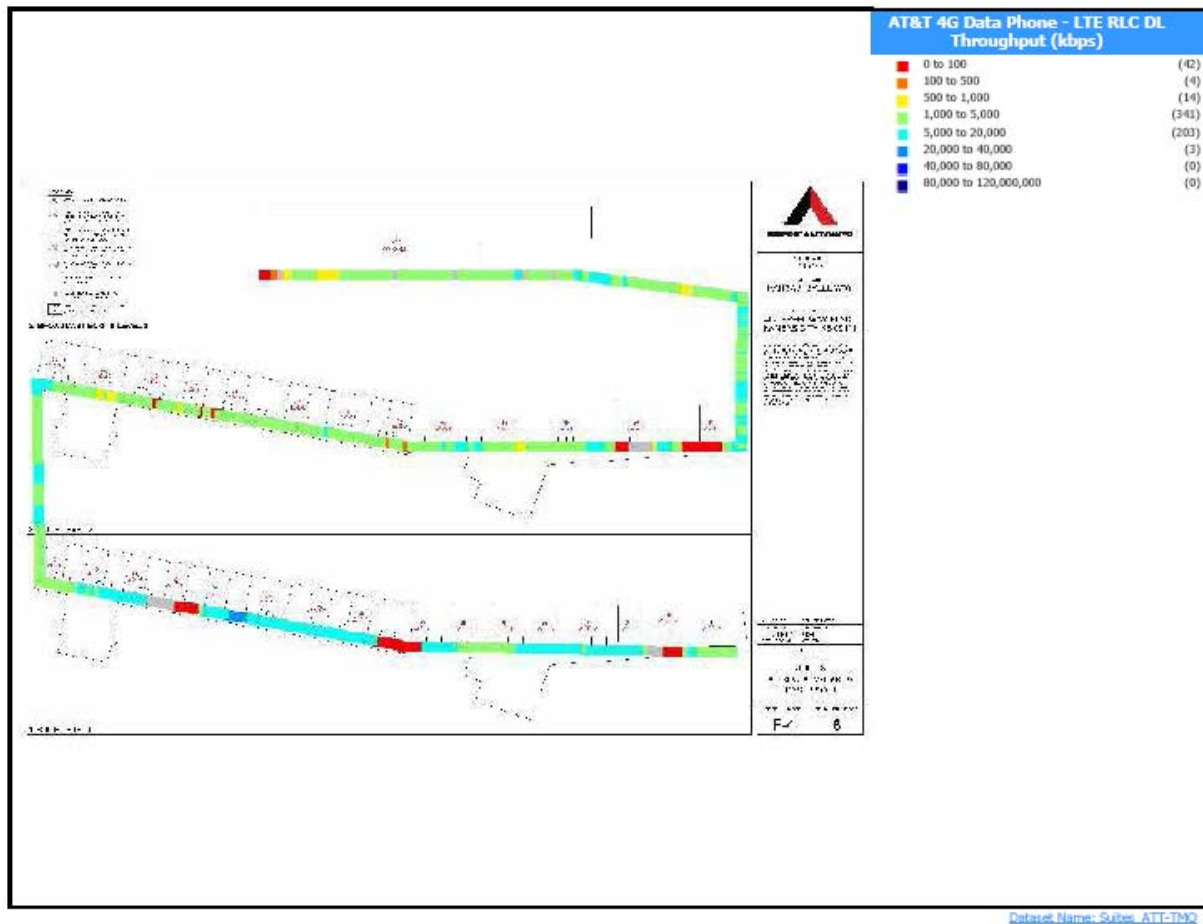Throughput levels were generally good relative to the other areas of the speedway with the exception of Sprint's 1900 LTE and T-Mobile LTE.
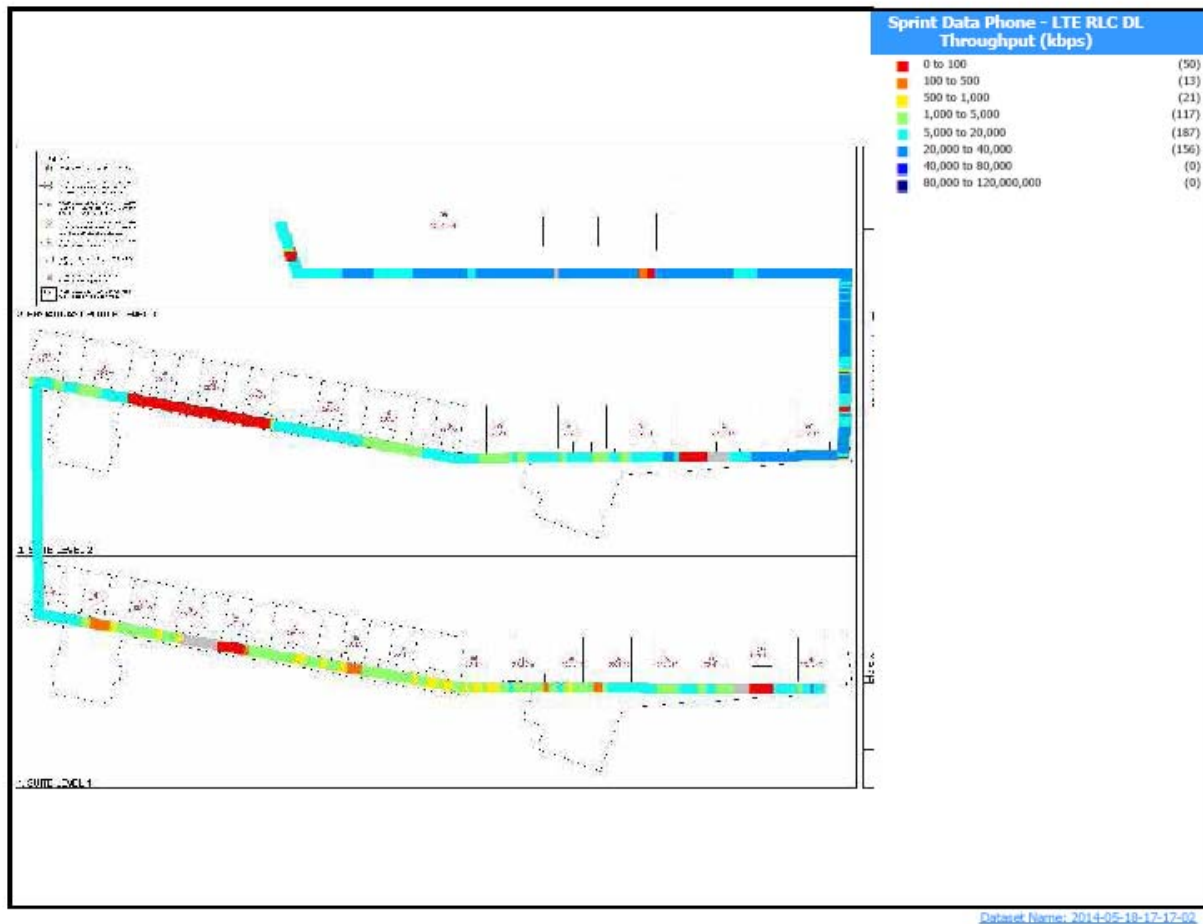

FIGURE 56. AT&T 700 LTE DL Throughput - Suites & Broadcast

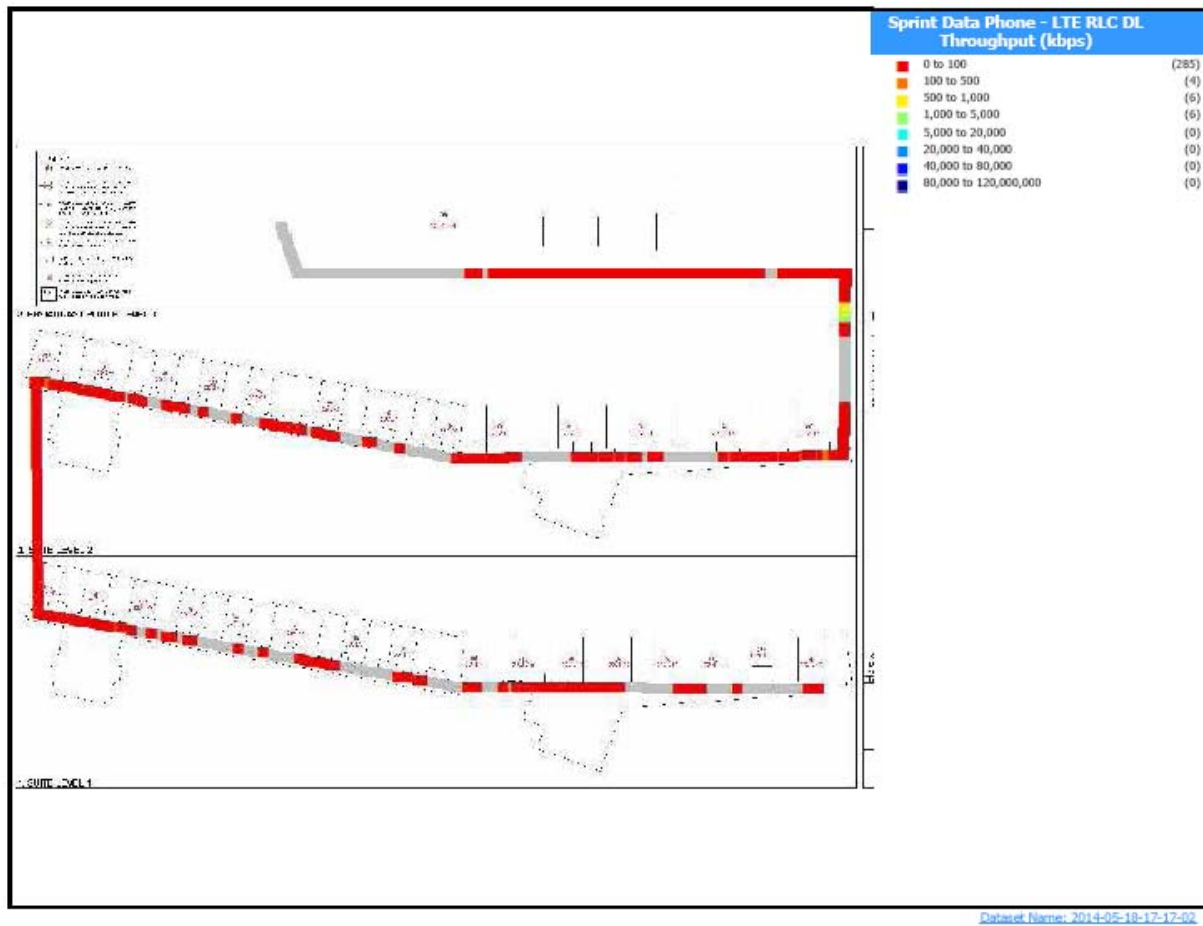*FIGURE 57. Sprint 2.5GHz LTE DL Throughput - Suites & Broadcast*

FIGURE 58. Sprint 1900 LTE DL Throughput - Suites & Broadcast
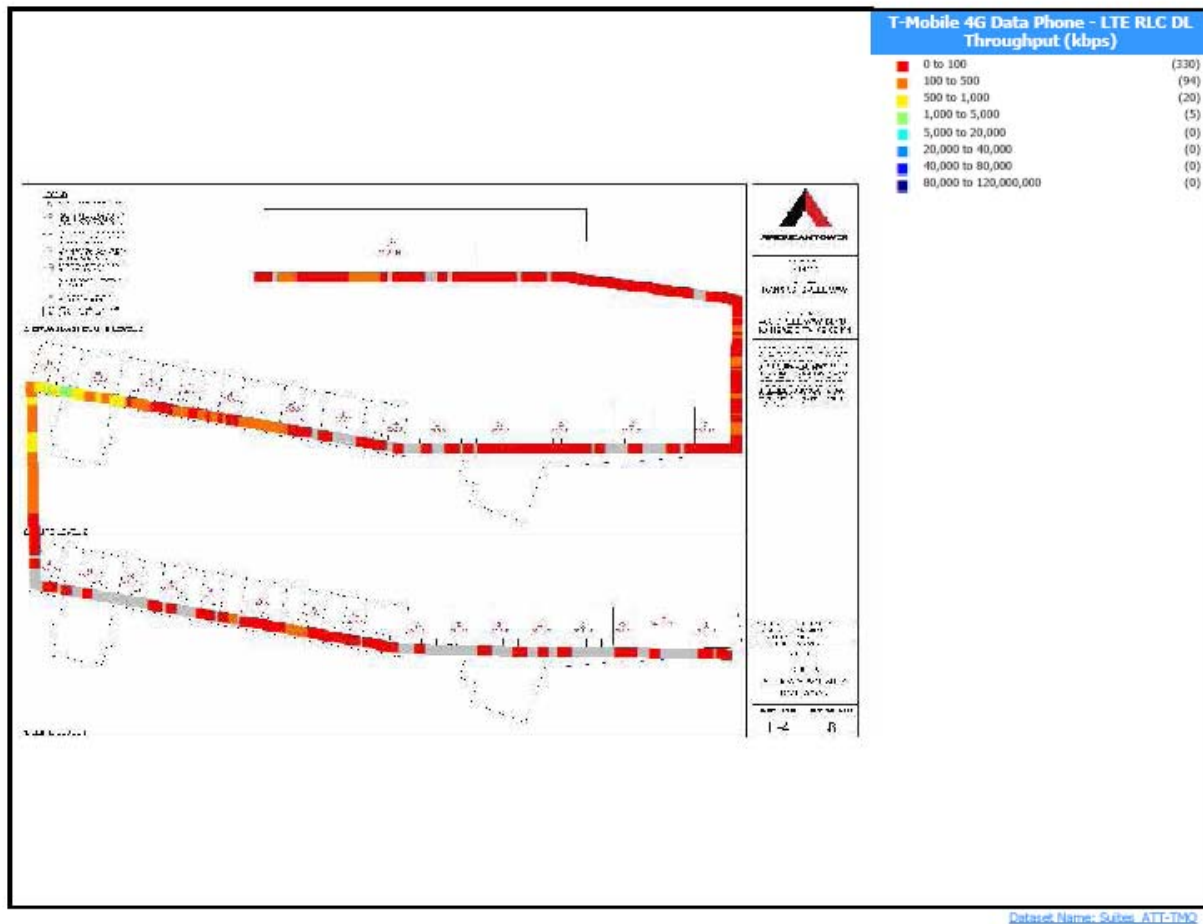
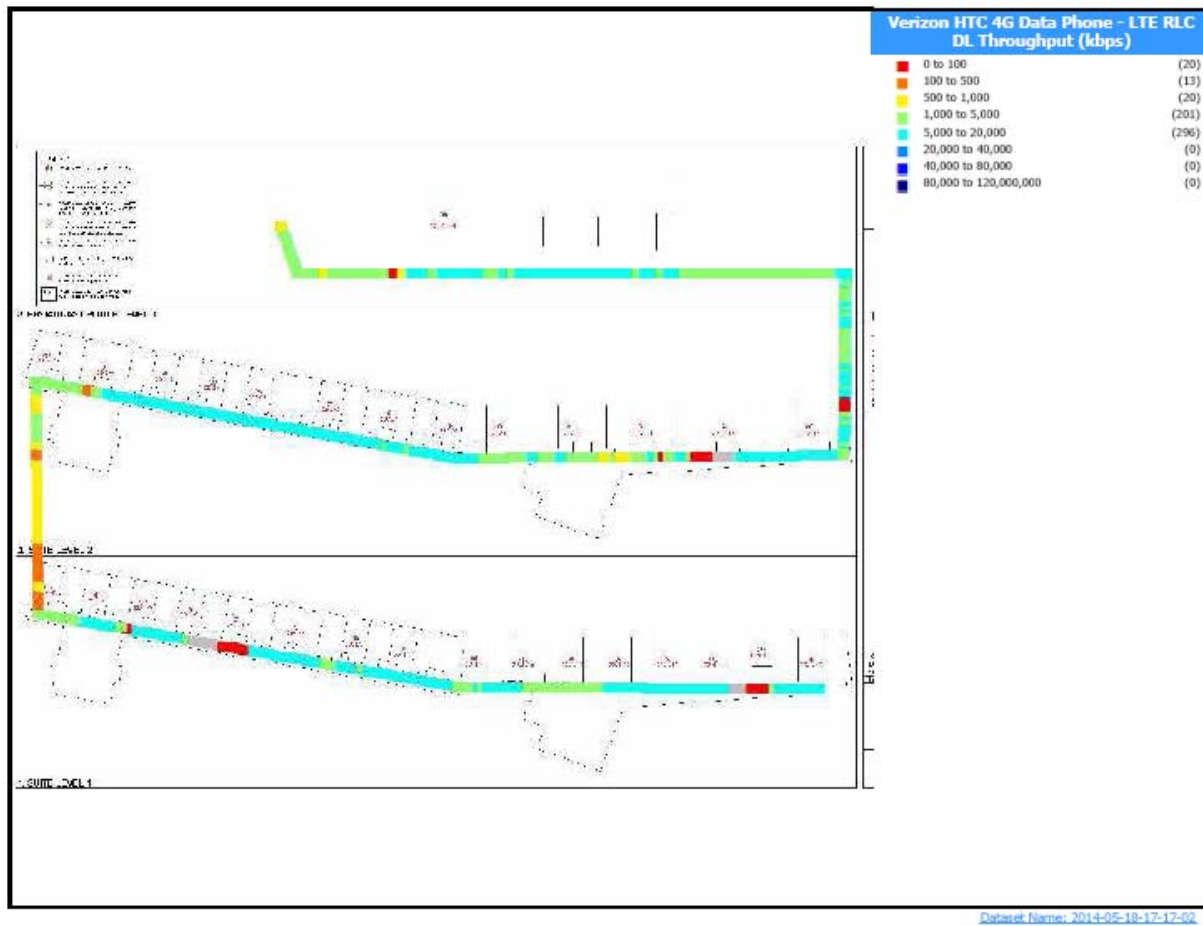*FIGURE 59. T-Mobile AWS LTE DL Throughput - Suites & Broadcast*

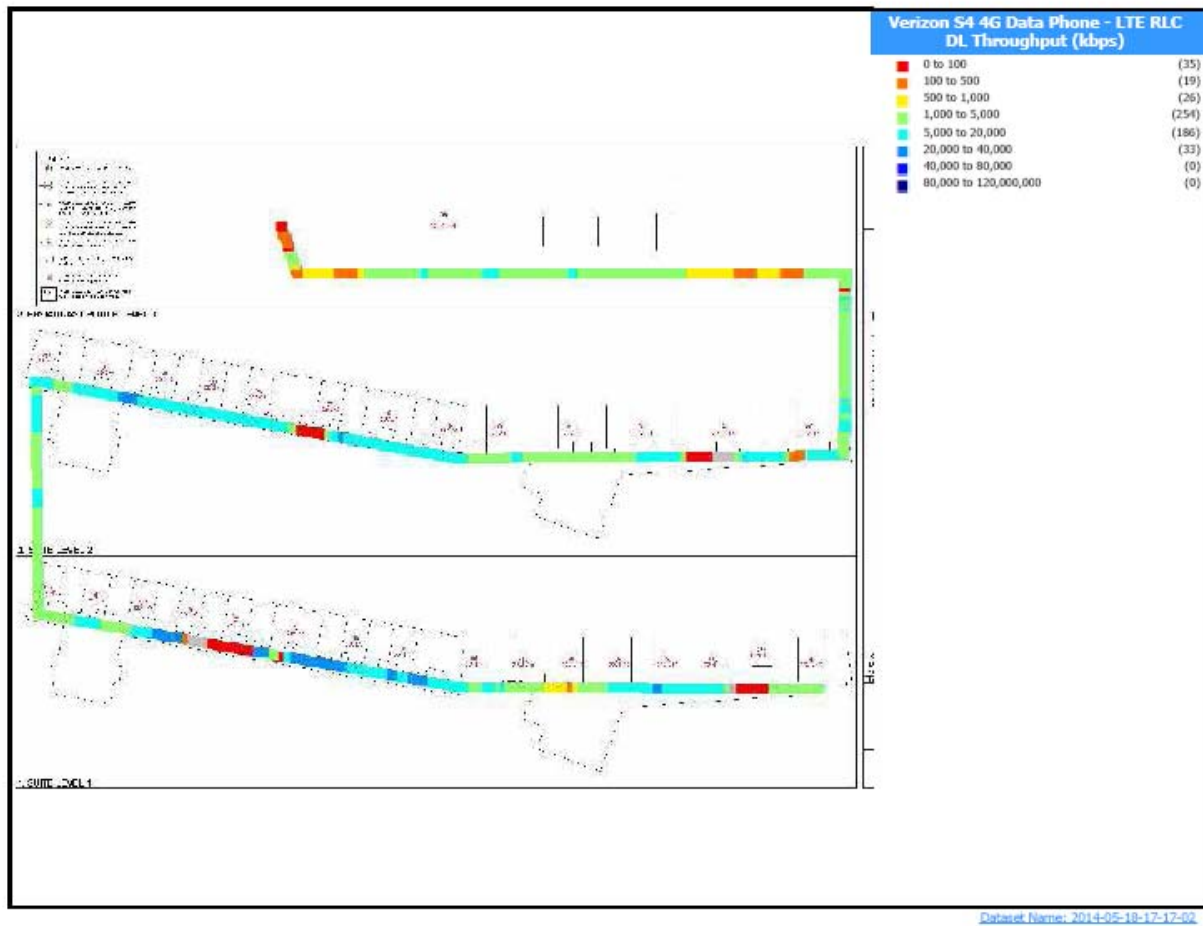*FIGURE 60. Verizon 700 LTE DL Throughput - Suites & Broadcast*

FIGURE 61. Verizon AWS LTE DL Throughput - Suites & Broadcast

7.3.2 Voice

AT&T had low levels of voice coverage in the broadcast area. T-Mobile had sections of low coverage.
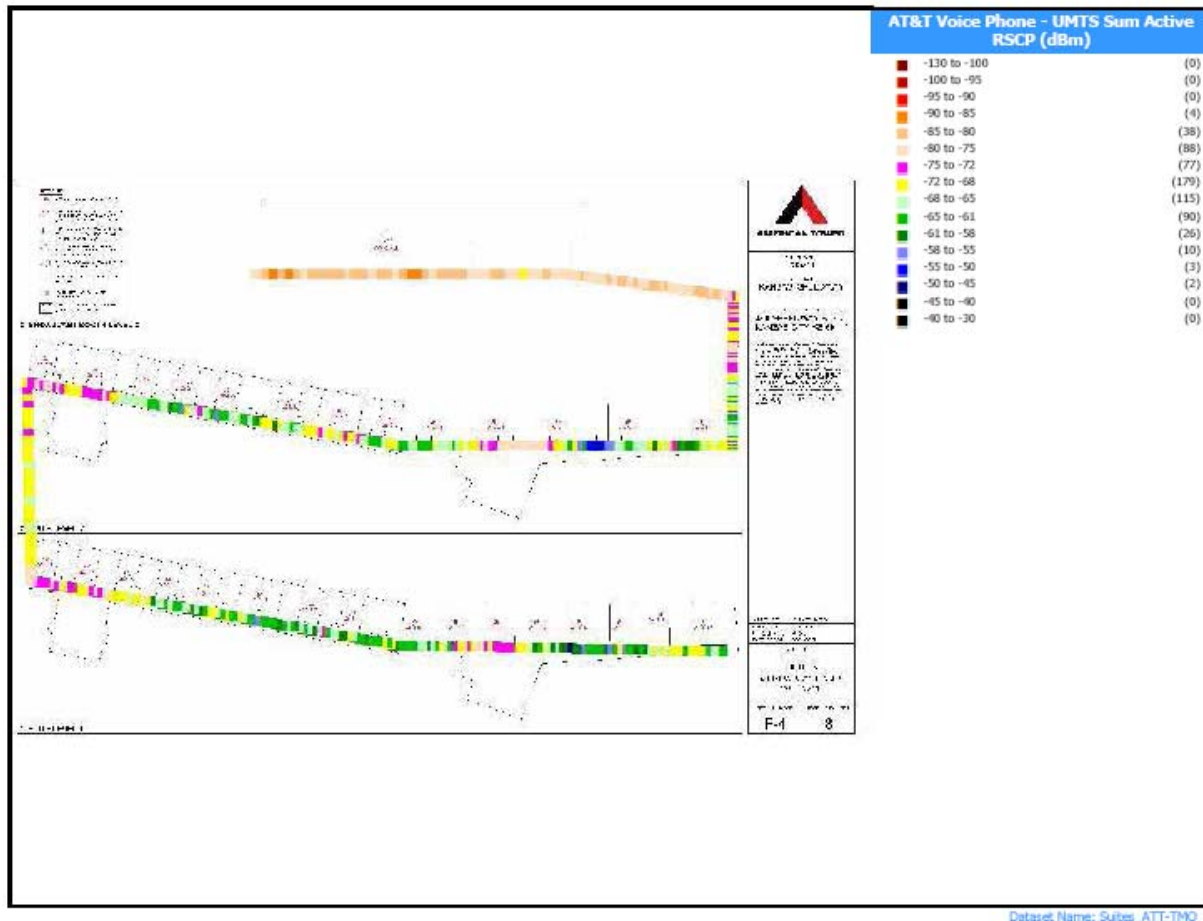

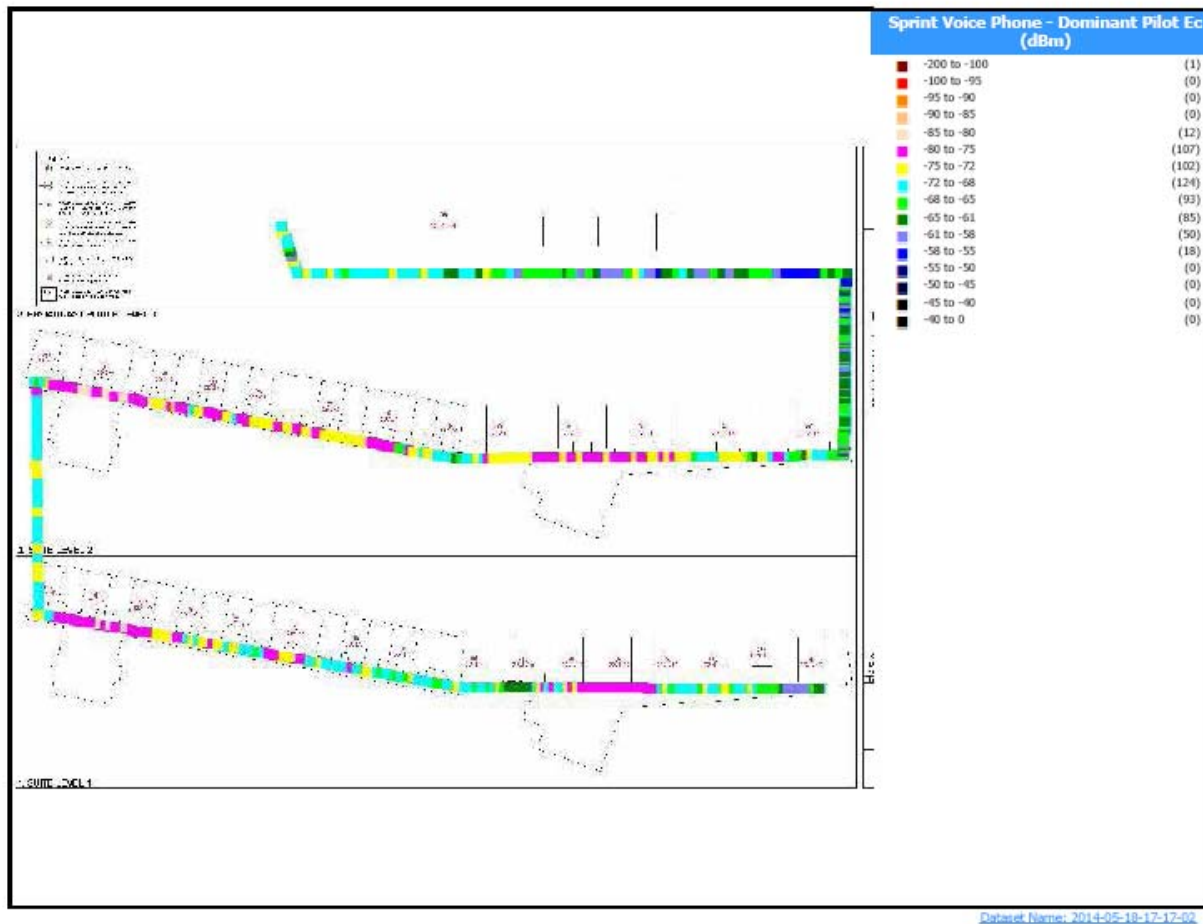*FIGURE 62. AT&T Voice Coverage - Suites & Broadcast*

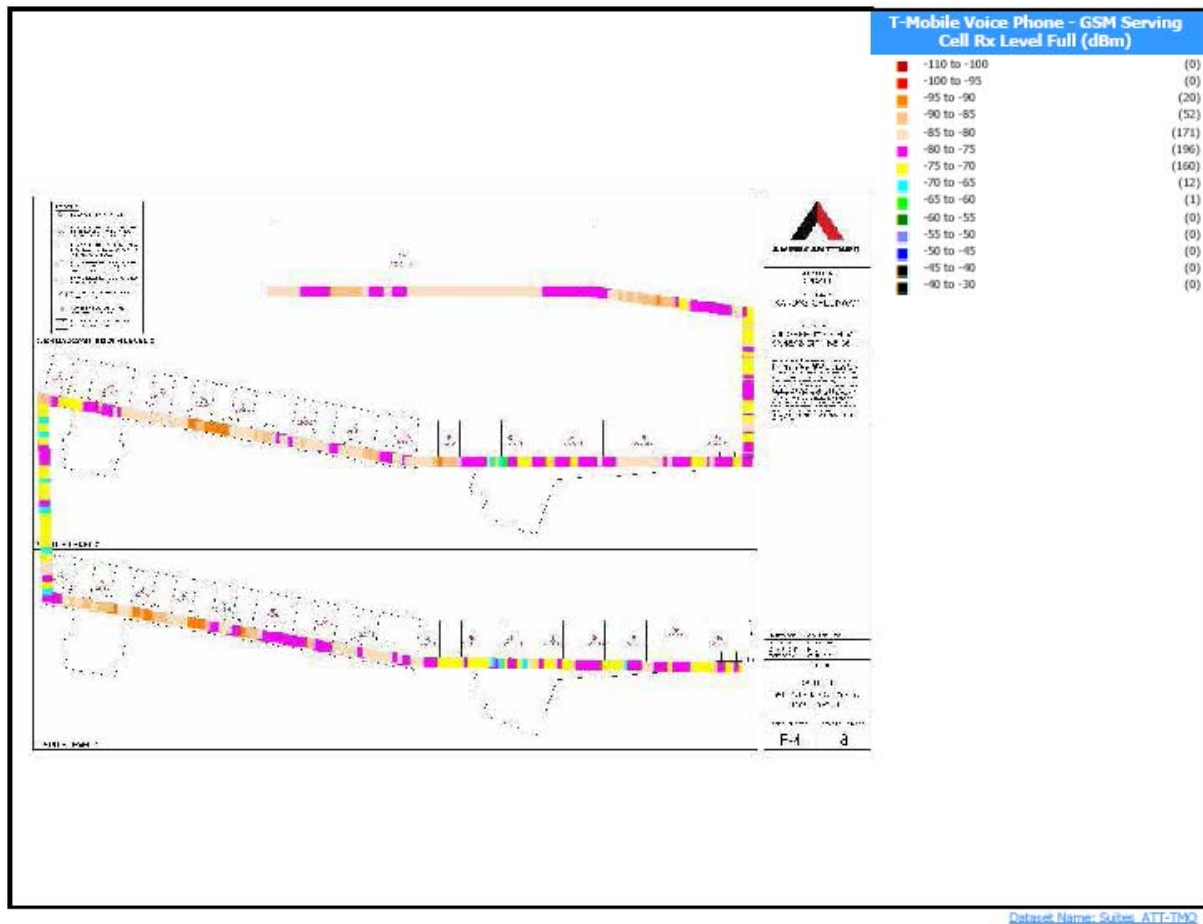*FIGURE 63. Sprint Voice Coverage - Suites & Broadcast*

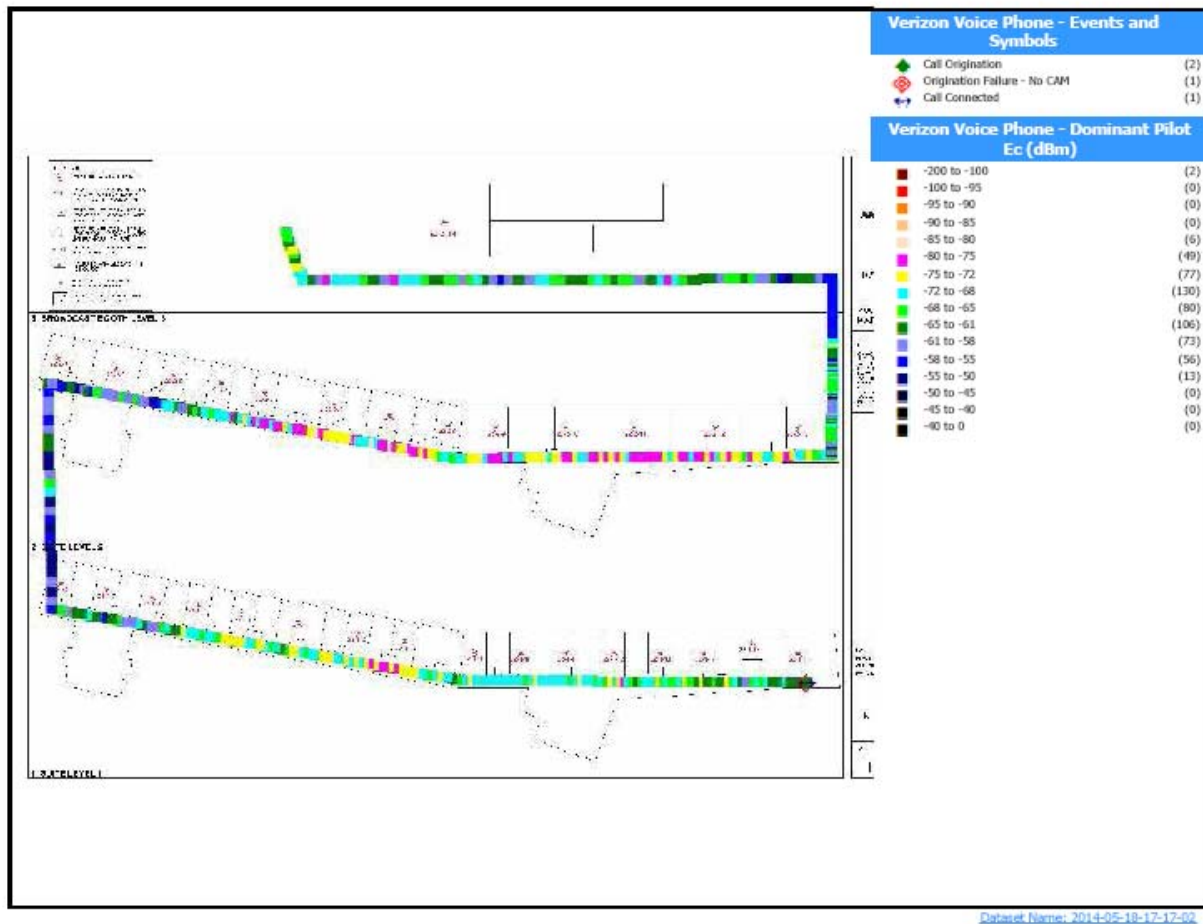*FIGURE 64. T-Mobile Voice Coverage - Suites & Broadcast*

FIGURE 65. Verizon Voice Coverage - Suites & Broadcast

7.4 Concourse

7.4.1 4G Throughput

The concourse is the section below the grandstands. We walk-tested this area during the race and did one swipe through.

AT&T throughput was spotty. Sprint's 1900 faired well while its 2.5GHz service did not. T-Mobile had adequate service through two thirds of the concourse. Verizon's AWS did much better than its 700 service.
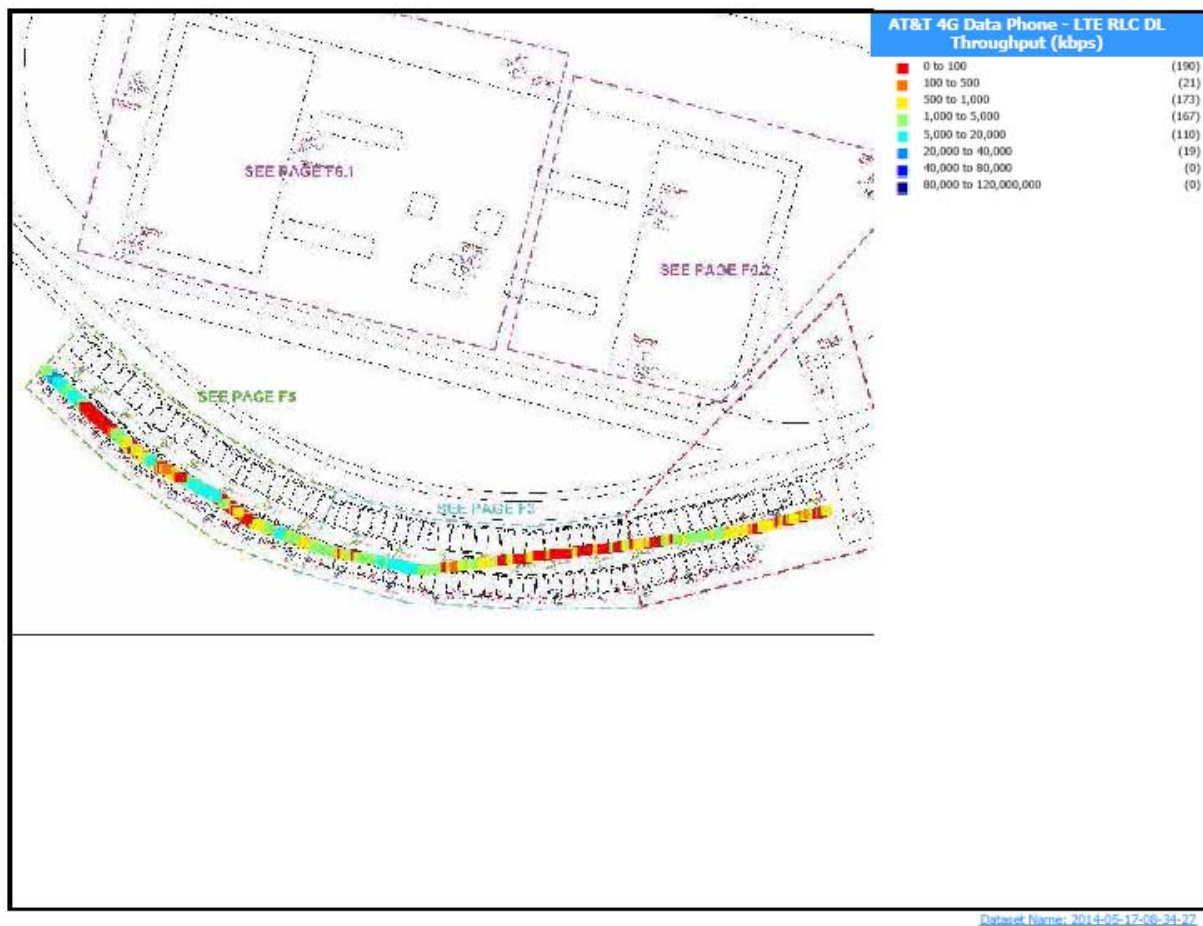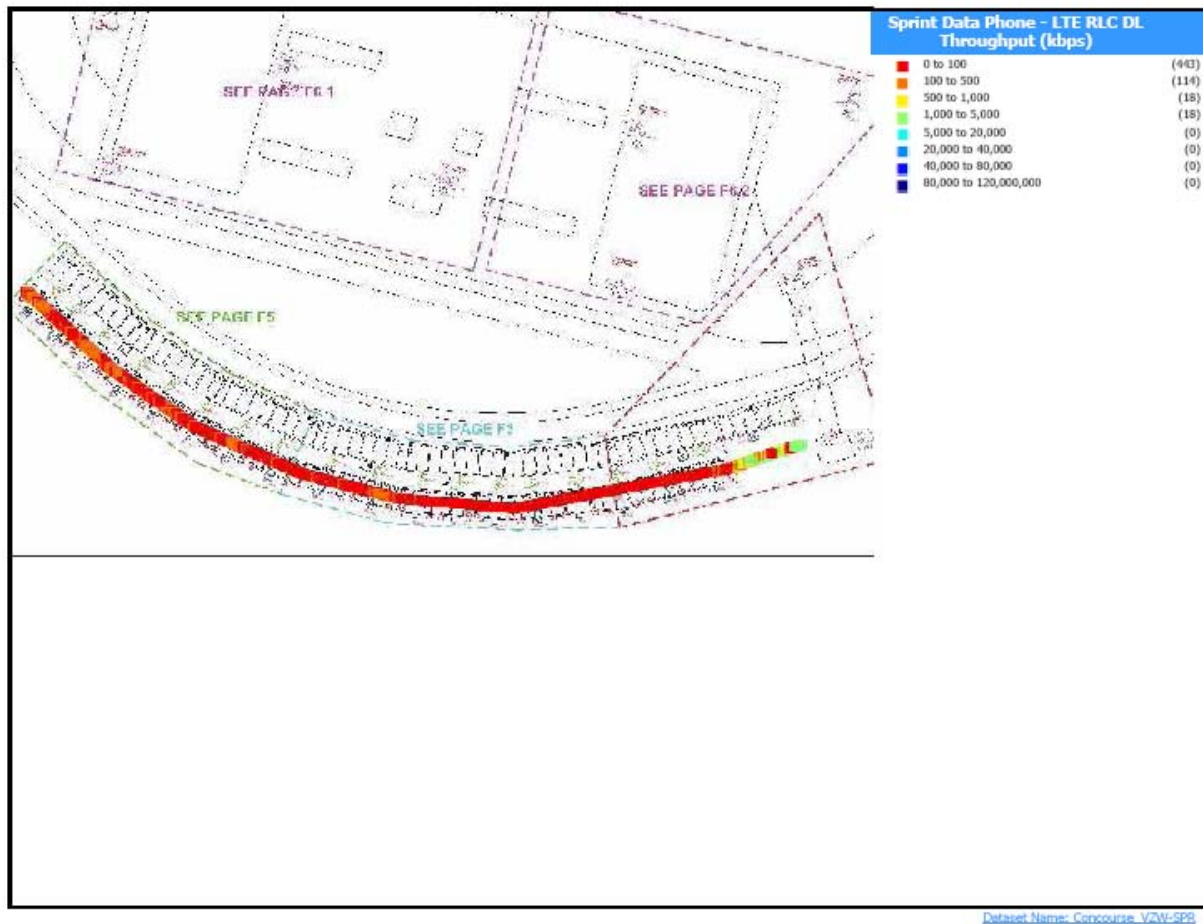

FIGURE 66. AT&T 700 LTE DL Throughput - Concourse

FIGURE 67. Sprint 2.5GHz LTE DL Throughput - Concourse
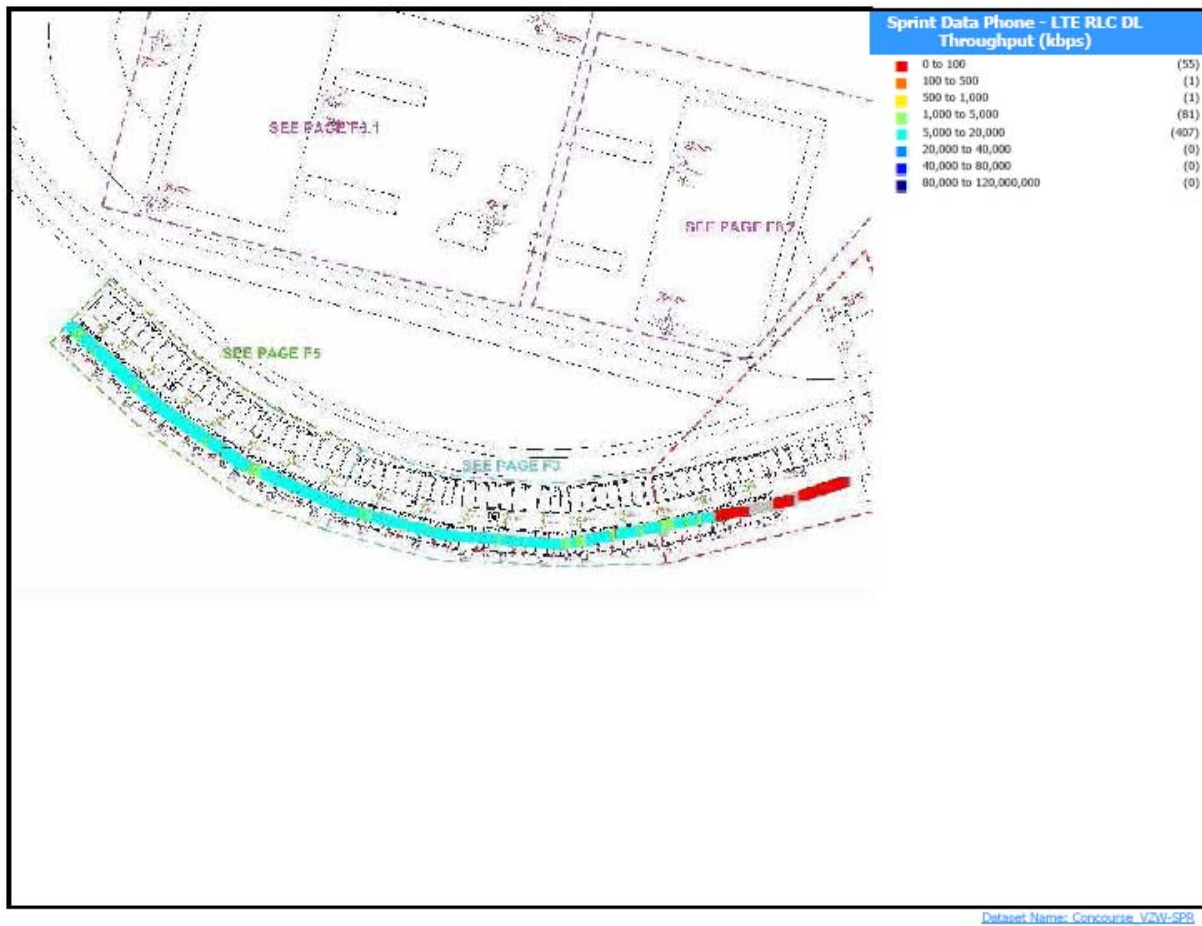
FIGURE 68. Sprint 1900 LTE DL Throughput - Concourse
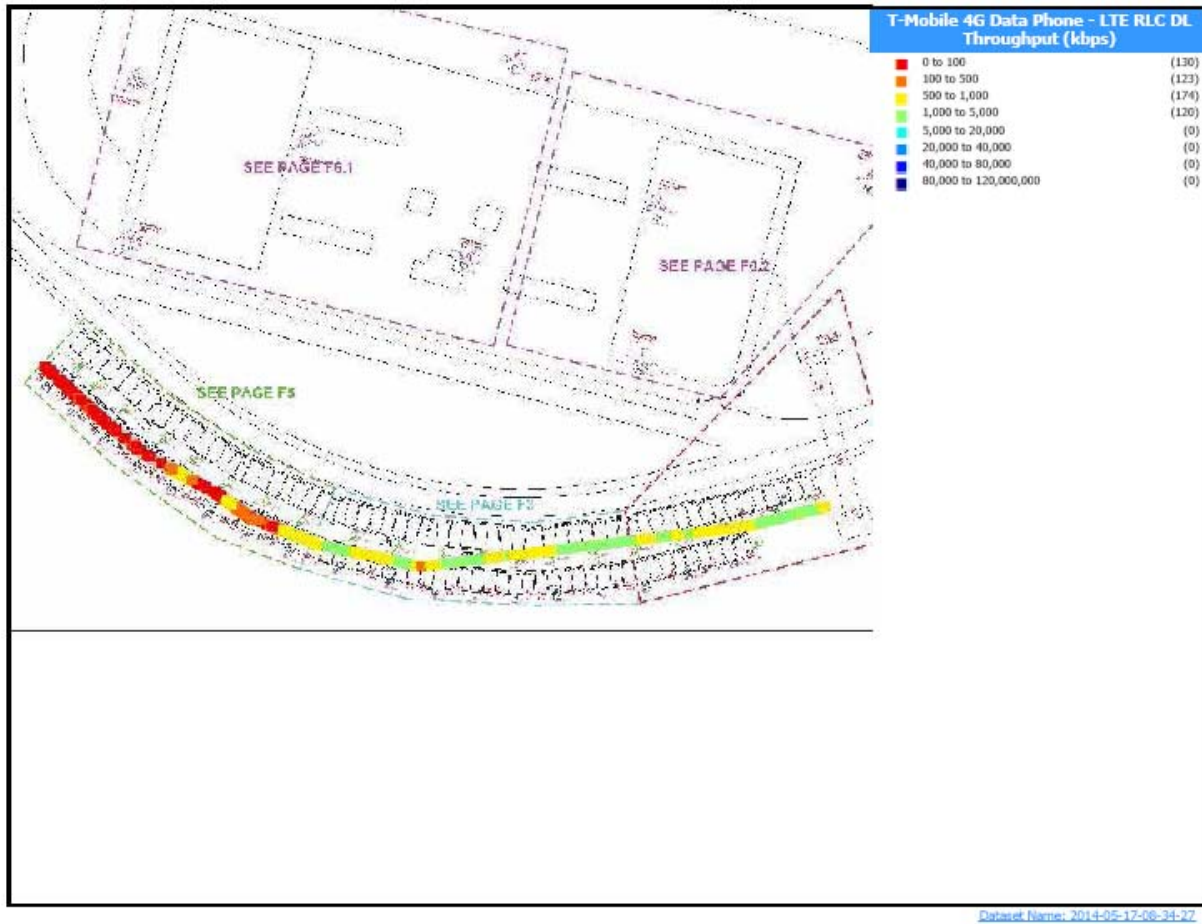
FIGURE 69. T-Mobile AWS LTE DL Throughput - Concourse
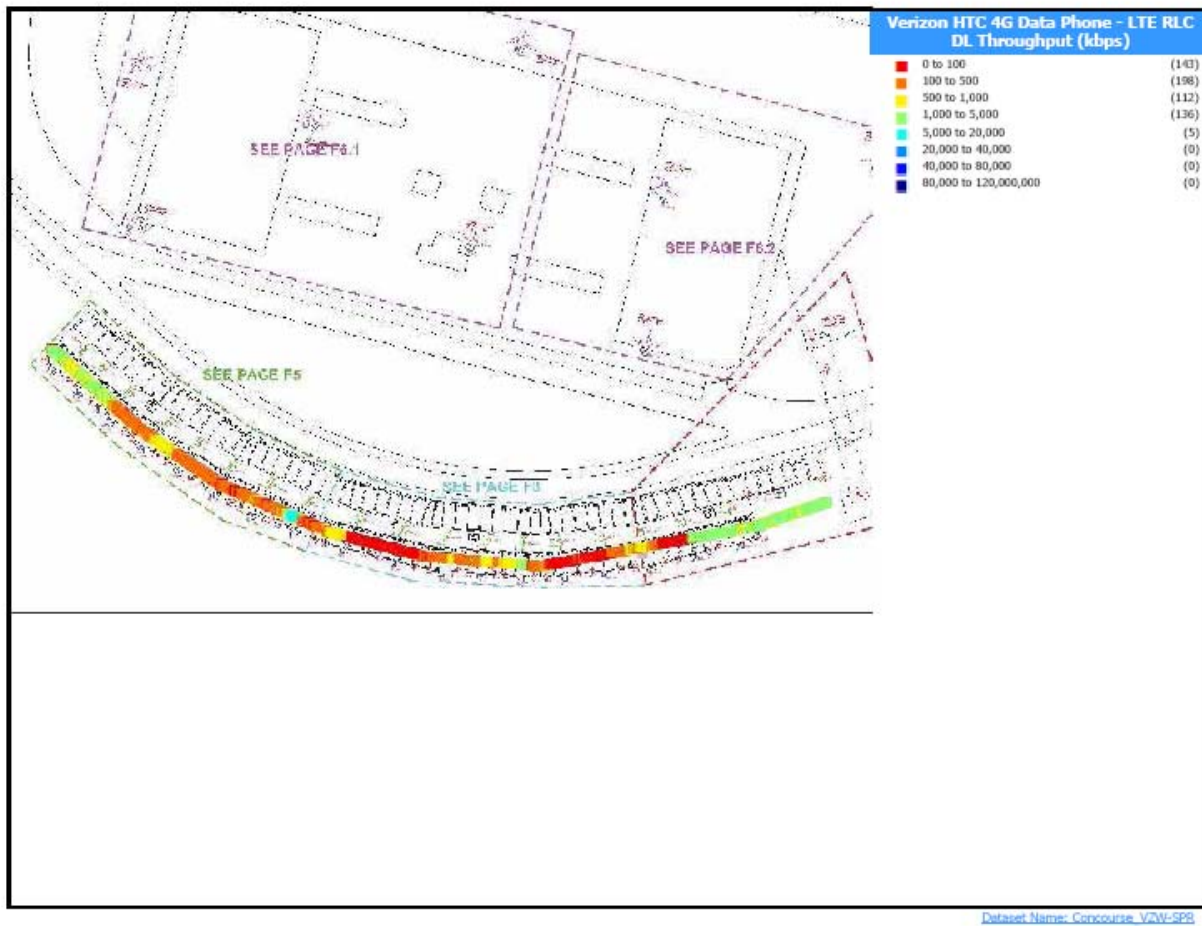
FIGURE 70. Verizon 700 LTE DL Throughput - Concourse
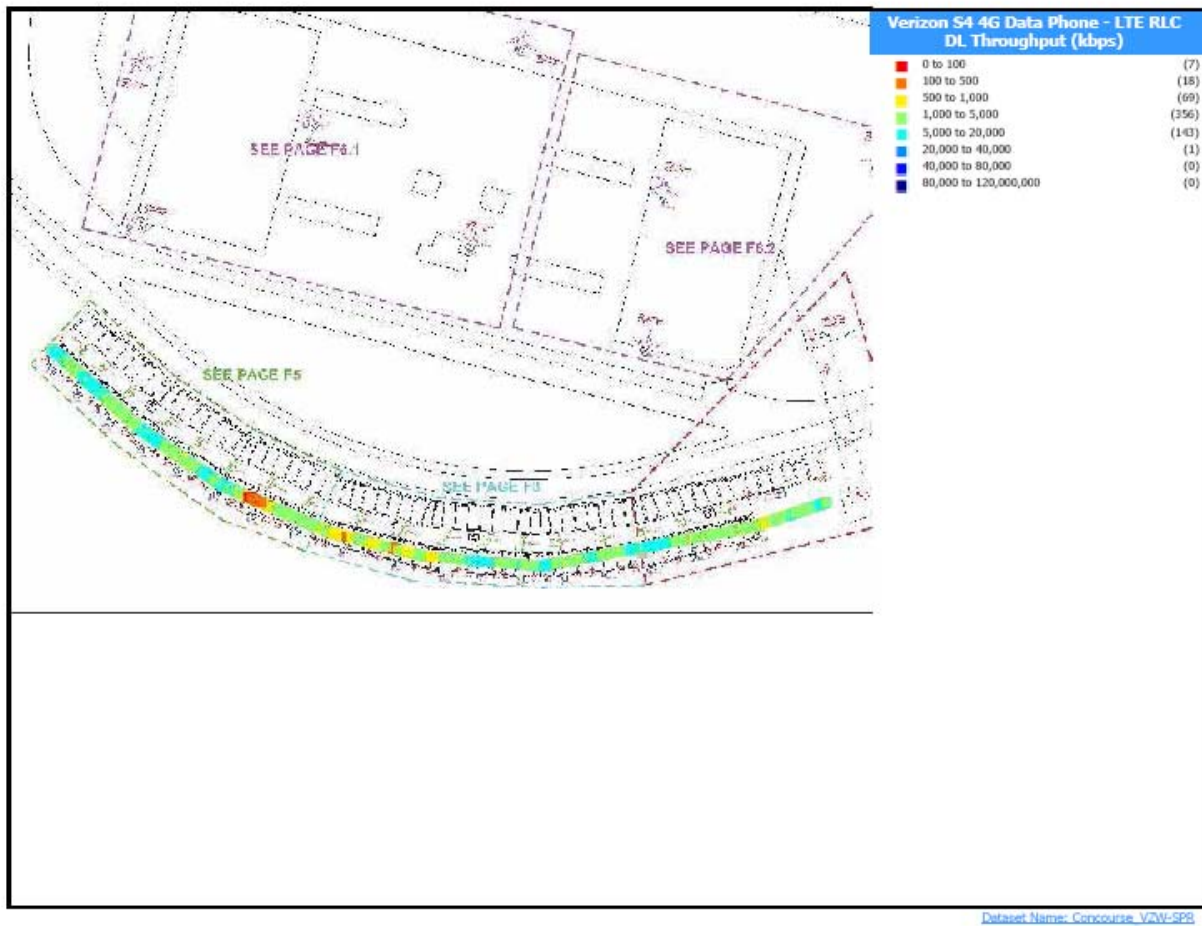
FIGURE 71. Verizon AWS LTE DL Throughput - Concourse

7.4.2 Voice

All Operators had adequate voice coverage in the concourse with T-Mobile serving voice with GSM.
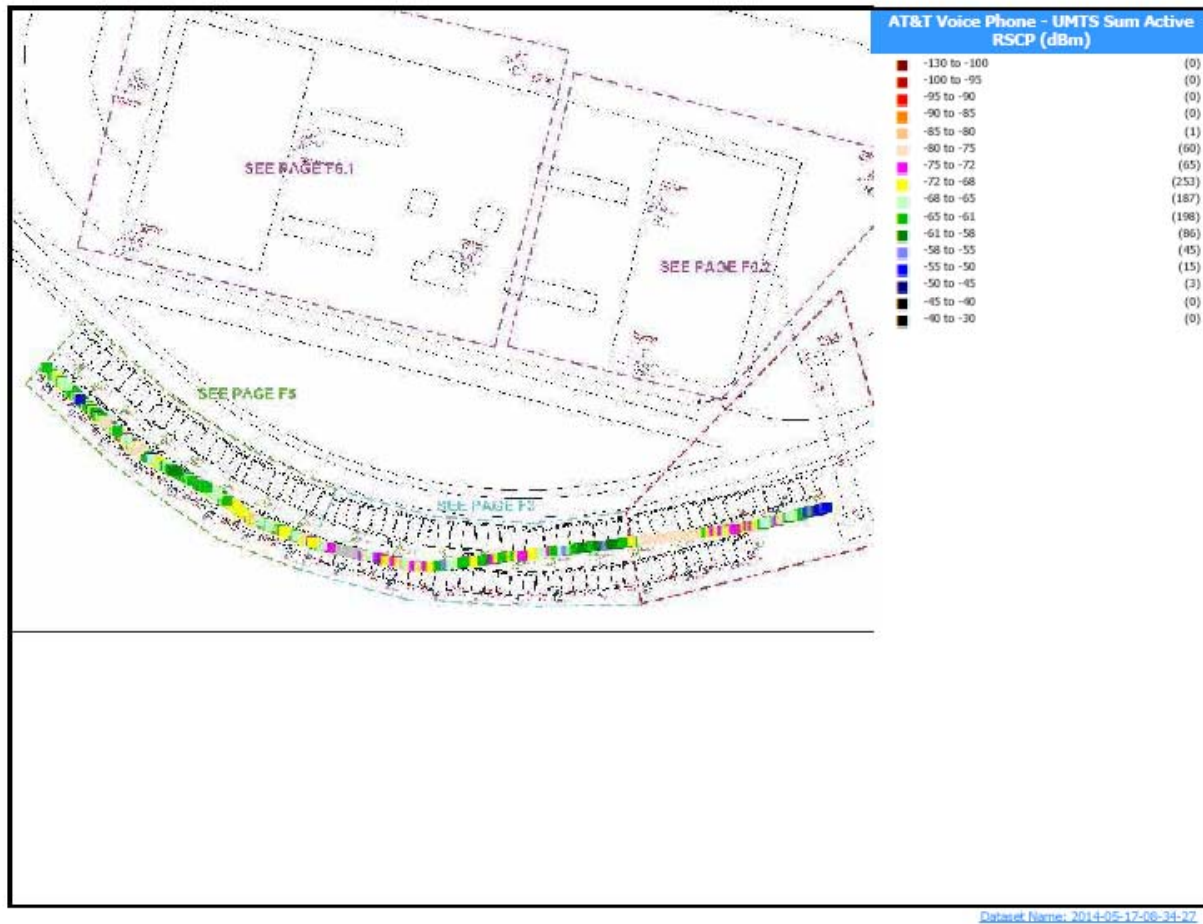
FIGURE 72. AT&T Voice Coverage - Concourse
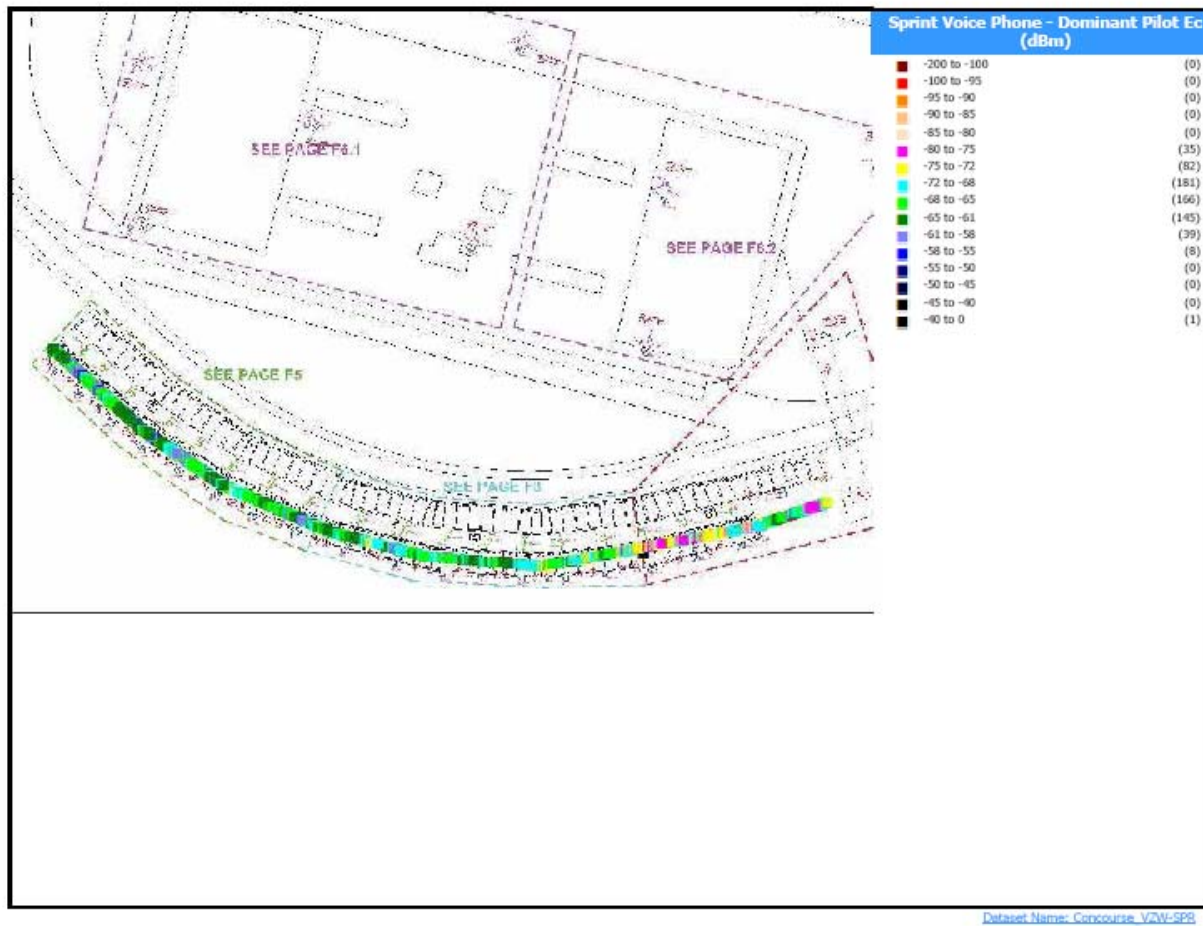
FIGURE 73. Sprint Voice Coverage - Concourse
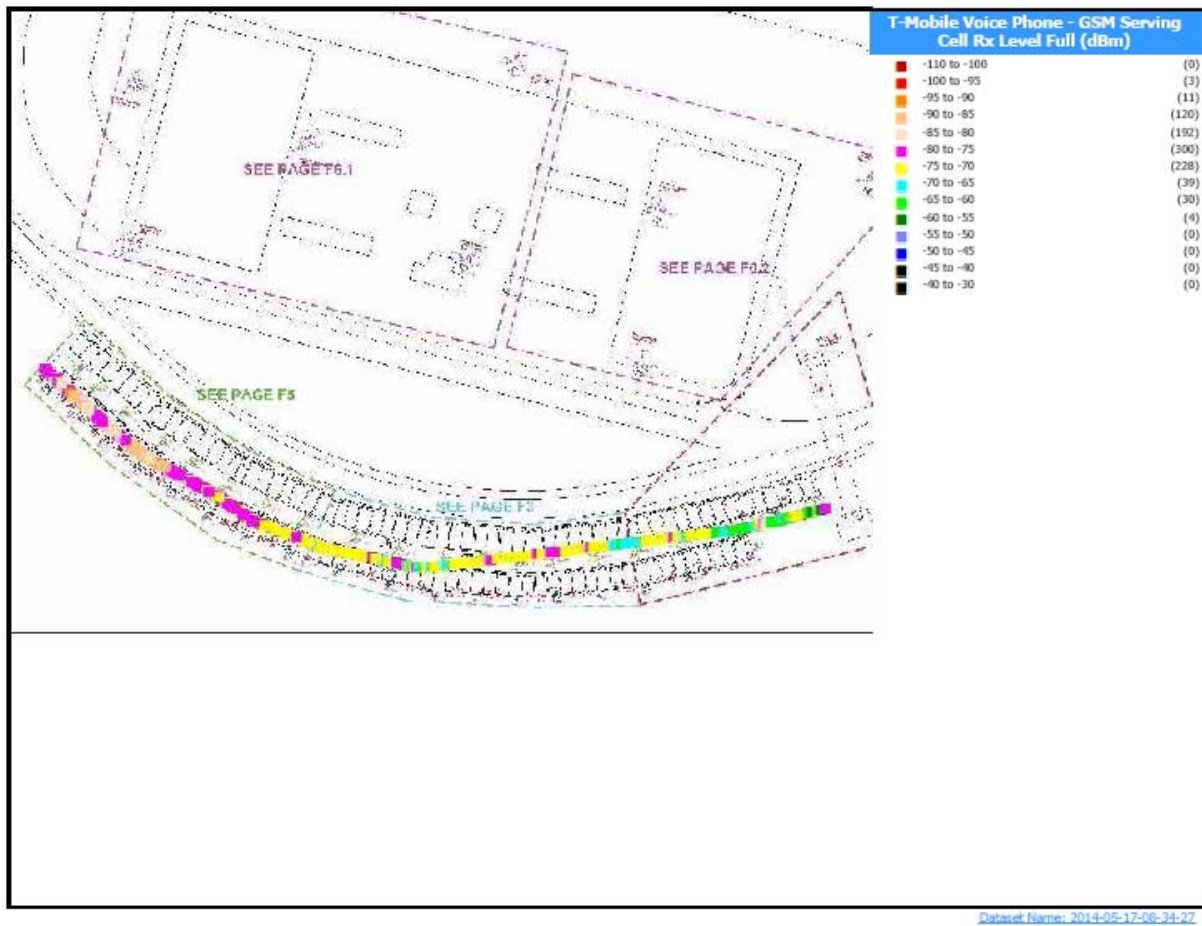
FIGURE 74. T-Mobile Voice Coverage - Concourse
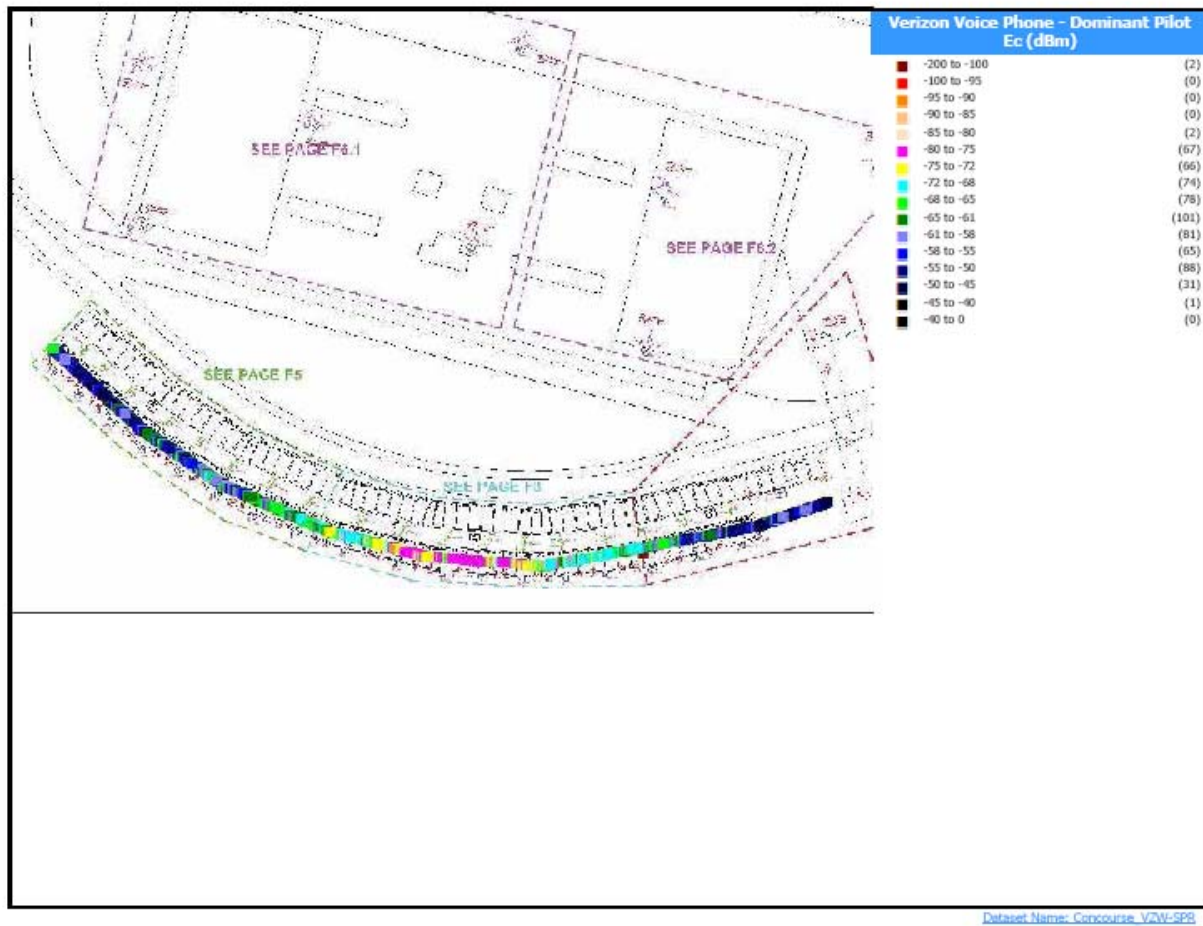
FIGURE 75. Verizon Voice Coverage - Concourse

7.5 Parking

The main parking and tailgating area was to the west of the speedway. This area was driven prior to the race when most of the lot was full and people were hanging out tailgating.

7.5.1 4G Throughput

AT&T throughput was poor in the parking areas. Sprint's 2.5GHz service was good and its 1900 service was bad. T-Mobile and Verizon provided adequate 4G service in the parking areas.
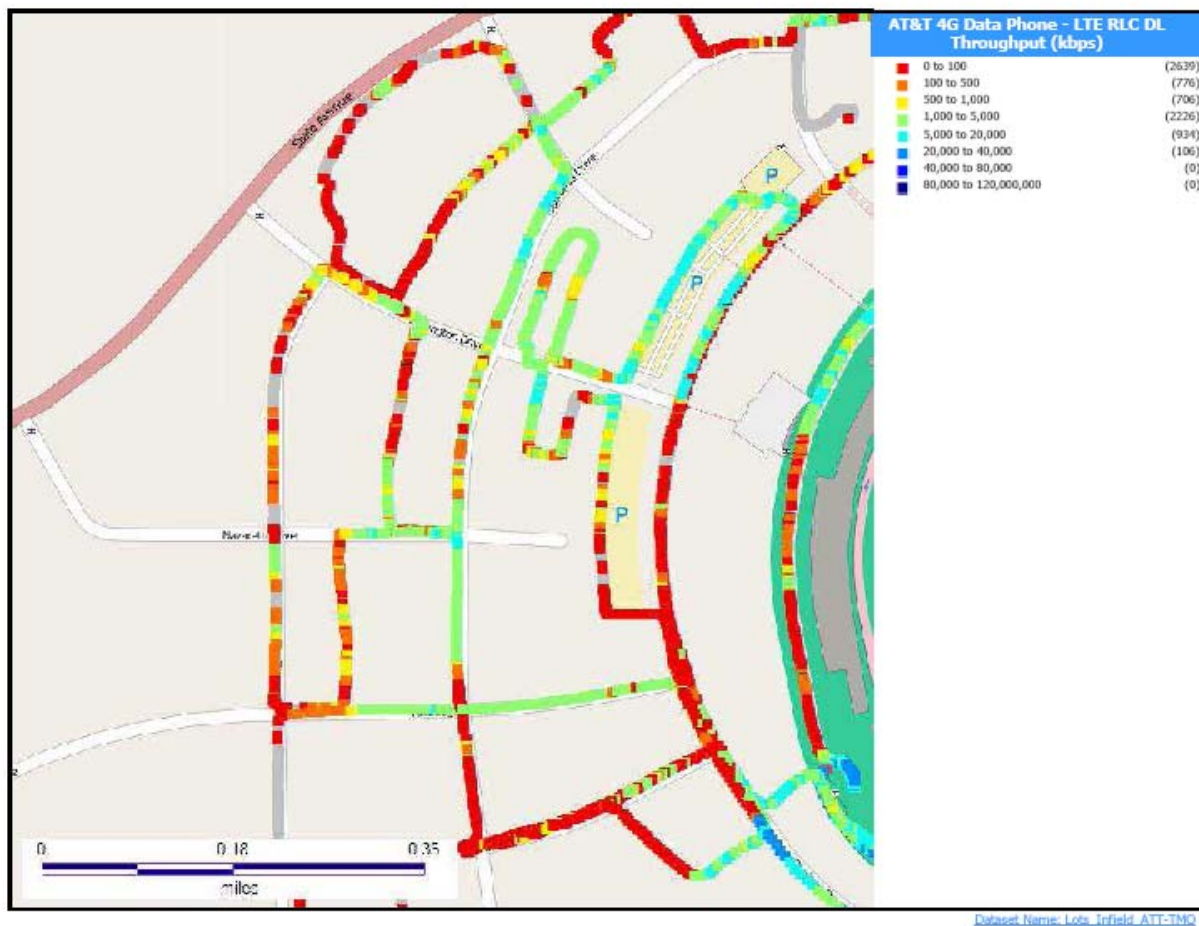
FIGURE 76. AT&T 700 LTE DL Throughput - Parking

FIGURE 77. Sprint 2.5GHz LTE DL Throughput - Parking
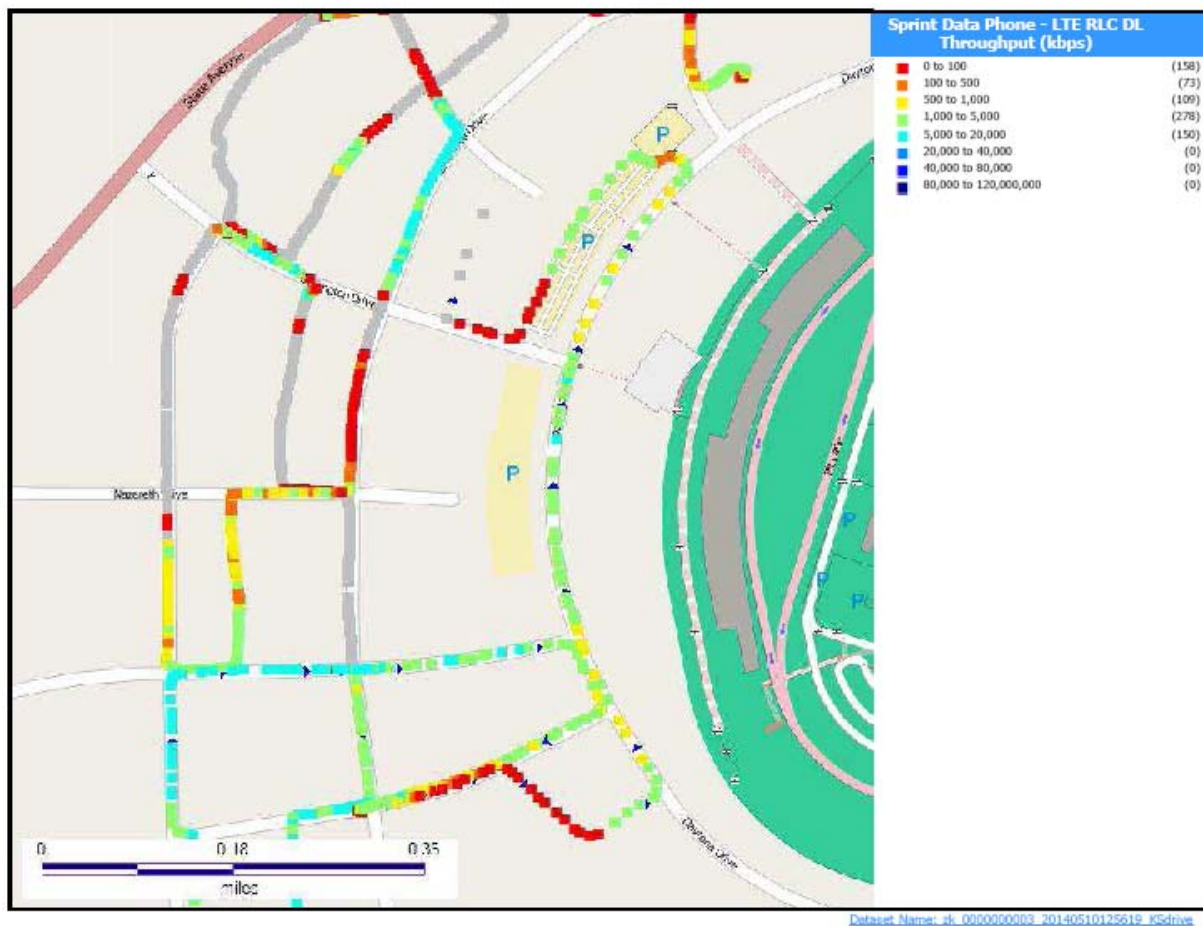
*FIGURE 78. Sprint 1900 LTE DL Throughput - Parking*
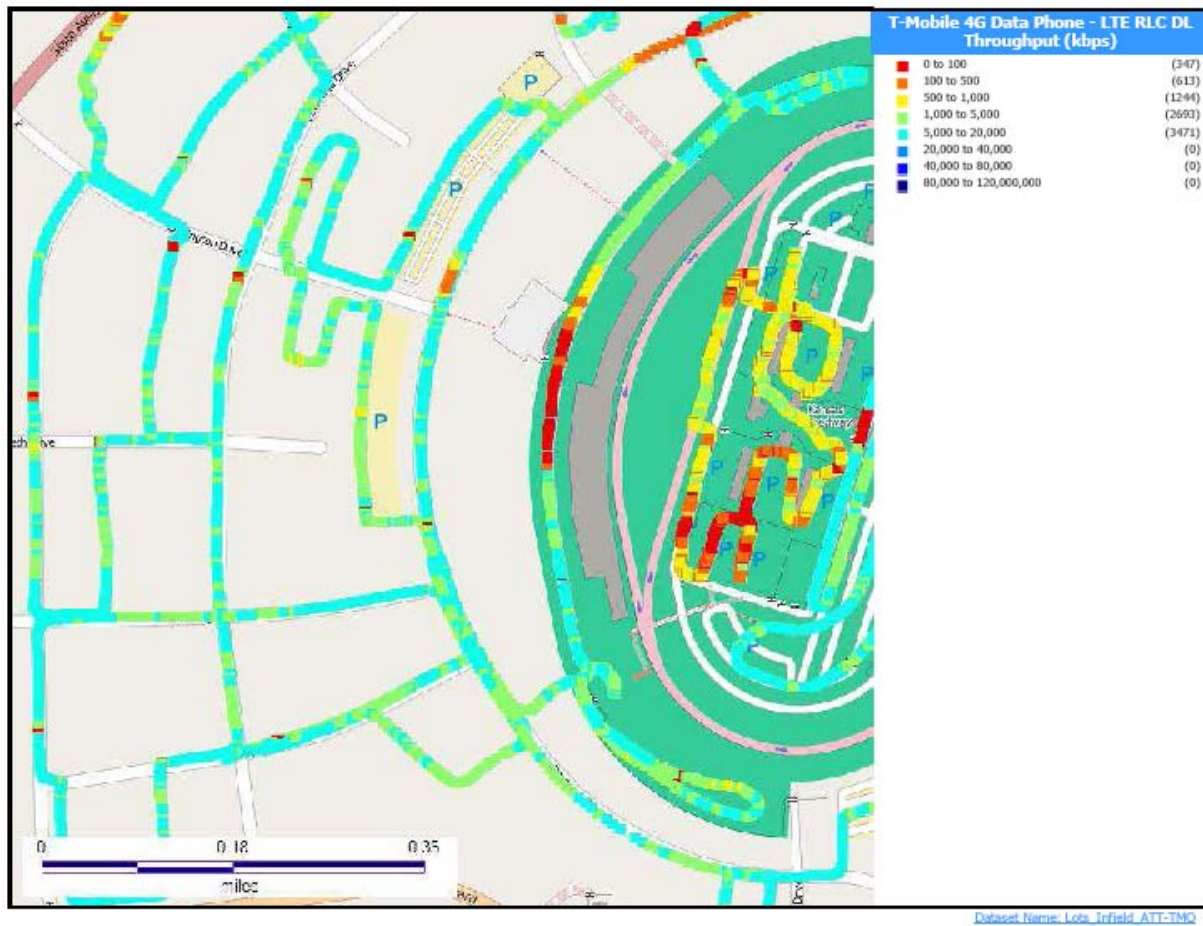
FIGURE 79. T-Mobile AWS LTE DL Throughput - Parking
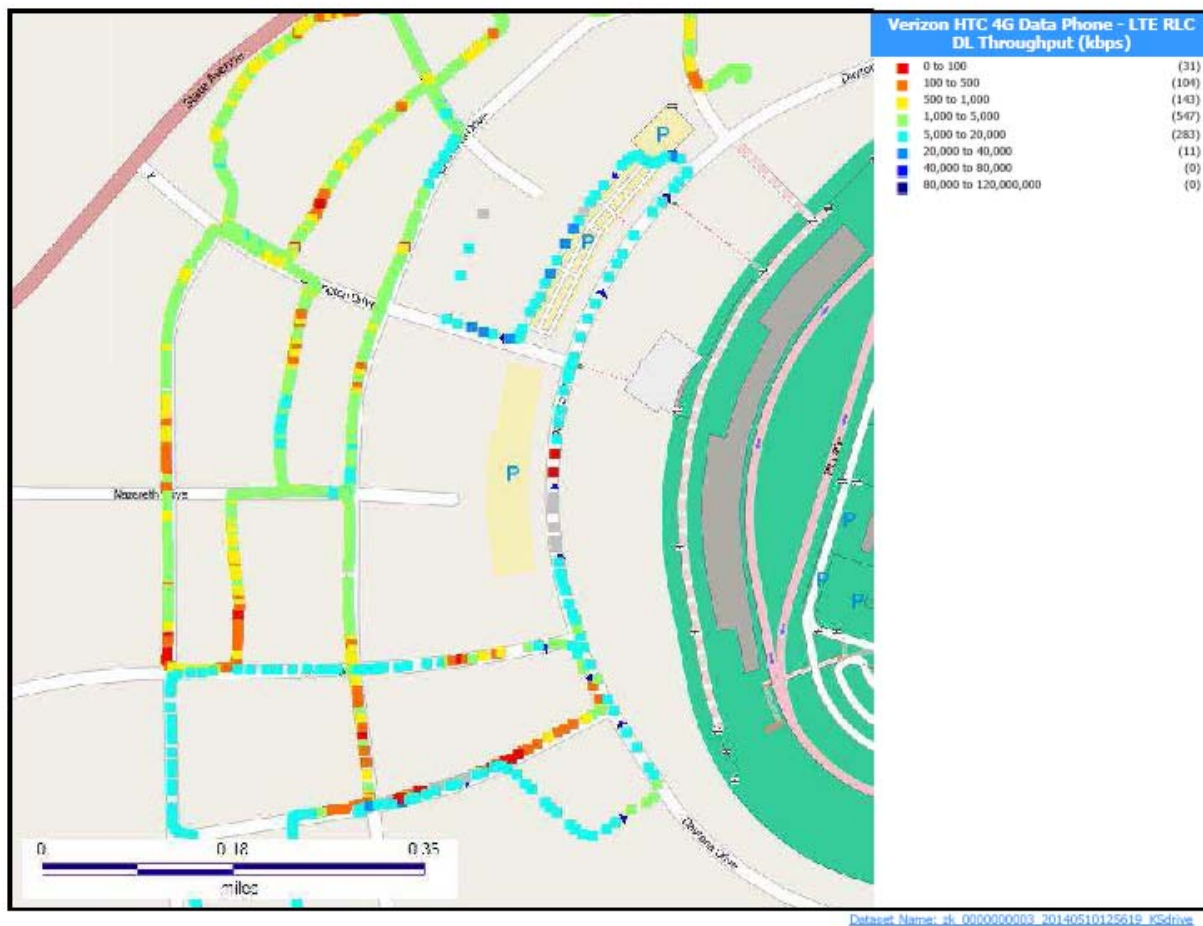
FIGURE 80. Verizon 700 LTE DL Throughput - Parking

FIGURE 81. Verizon AWS LTE DL Throughput - Parking

7.5.2 Voice

AT&T had the lowest coverage levels in the parking area which may be the main contributor to their low throughput levels. The other Operators mainly had adequate voice coverage with some spotty low areas. T-Mobile voice was on GSM.
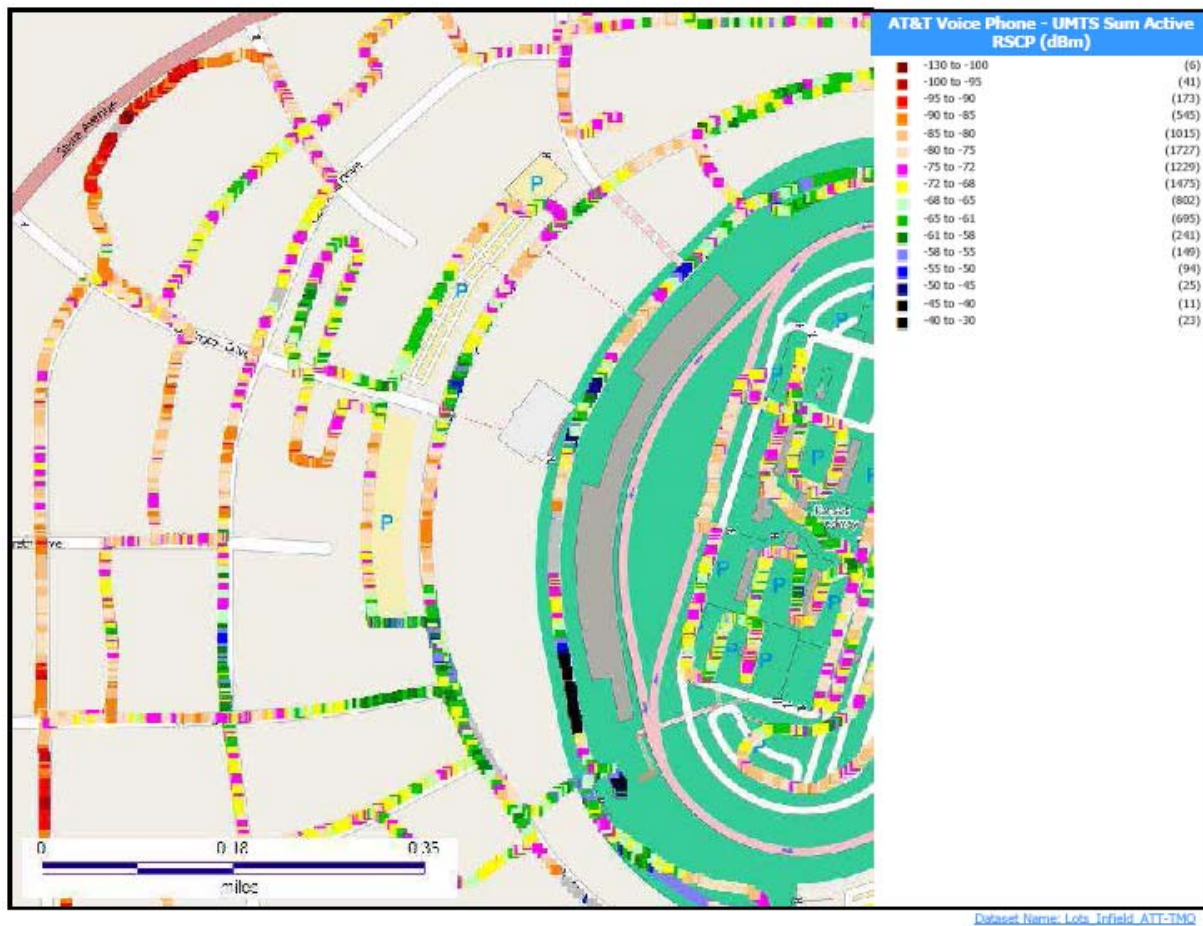
FIGURE 82. AT&T Voice Coverage - Parking
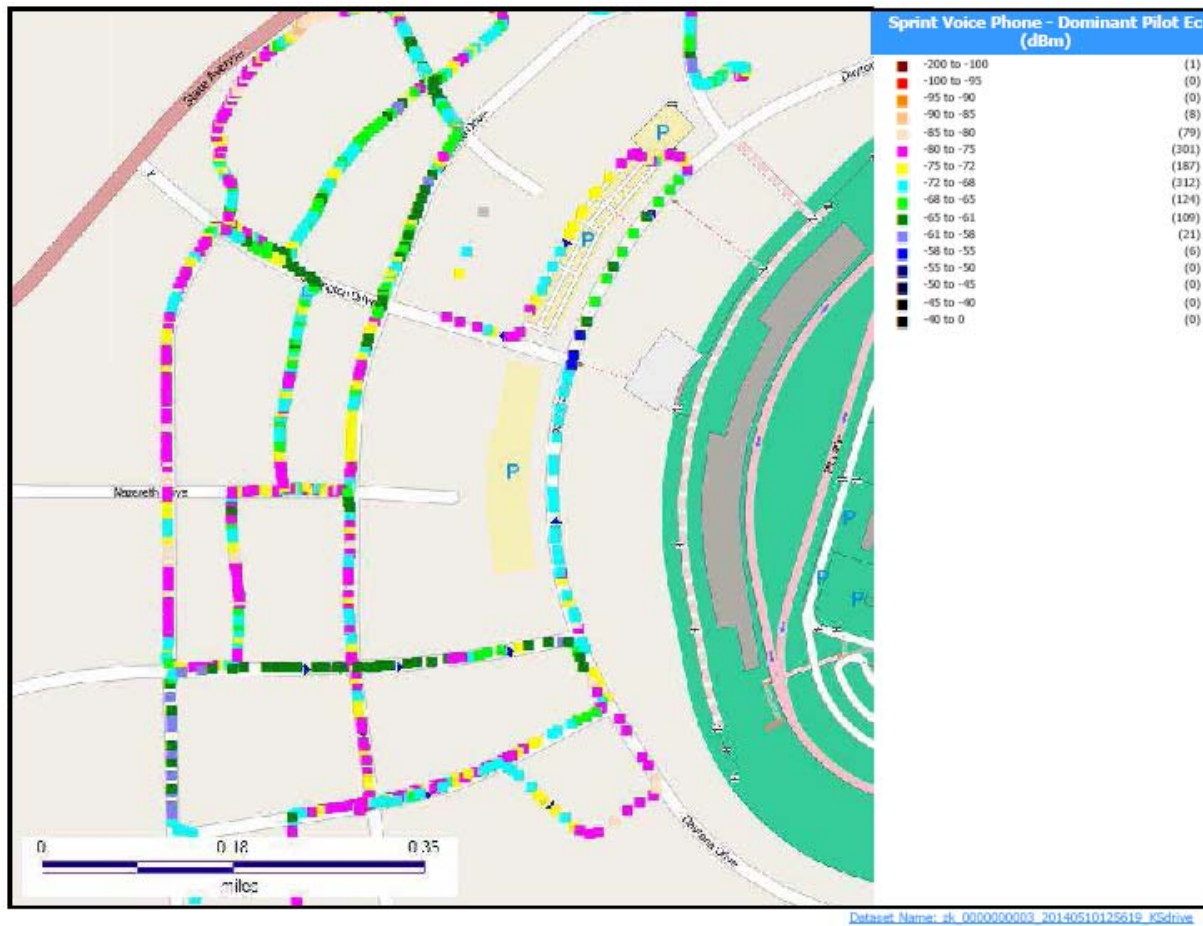
FIGURE 83. Sprint Voice Coverage- Parking

FIGURE 84. T-Mobile Voice Coverage- Parking

FIGURE 85. Verizon Voice Coverage - Parking

8.0 Conclusion

The consumer survey results for voice and data quality and phone features and functions were very good. The surveys were taken mainly outside the grandstand area prior to the race where vendors had set up and many people were walking around prior to the race. Results may have differed if surveys were taken in the grandstands during the race or in the infield just prior to the race. These areas were higher density and showed some issues during the RF walk-testing.

The RF walk-testing indicated that the highest throughput in most of the key areas was delivered by Sprint's 2.5GHz band which is what they are calling their Spark service. Sprint had several Cell On Wheels (COWs) covering the speedway. The high throughput in the 2.5GHz band could be a symptom of being lightly loaded as there may not be that many users that have Spark capable phones. Their 1900 LTE service did not fair as well.

Verizon and AT&T were both on the DAS and delivered consistent data results on average in all areas, however they had issues in the high density locations such as the Infield, Grandstands and Concourse. Overall download throughputs were in the 2 Mbps to 6 Mbps range but several areas had much lower values. AT&T had unexpectedly low data rates in the parking area as well. AT&T's voice coverage was consistently lower than Verizon. This may be due to a design difference and doesn't necessarily indicate an issue. We did notice however that in certain areas where coverage was low there was lower throughput levels on the data channel.

T-Mobile was not on the DAS and did not have COWs, thus they were serving the speedway with their macro cells. Their data performance was adequate in the parking areas but in the high density areas it was poor. Voice was mostly served by their 2G GSM channels with the exception of the Infield and most of the Grandstands.

Finally, if you were to go to the Speedway and you were mainly concerned with a fast data connection then the Sprint Spark phone would be your choice. If you were interested in consistent voice and data without the need for very fast data rates then Verizon or AT&T would be the choice.

A1.0 Race Survey Questionnaire

What model of phone are you using today? (check one)

iPhone	[ ]
Samsung	[ ]
LG	[ ]
HTC	[ ]
Motorola	[ ]
Other	[ ]

Who is your Service Provider? (check one)

AT&T	[ ]
Sprint	[ ]
T-Mobile	[ ]
Verizon	[ ]
Other	[ ]

What is your age group? (check one)

Under 21	[ ]
21 - 30	[ ]
31 - 40	[ ]
41 - 50	[ ]
51 - 60	[ ]
Over 60	[ ]

What is your home zip code?   _____

Describe your cell phone usage (check one)

Light - One hour or less a day	[ ]
Medium - 1 to 4 hours a day	[ ]
Heavy - Over 4 hours a day	[ ]

Choose the percentage of time you spend on voice vs. data (includes texting and browsing) (check one)

100% voice	[ ]
75% voice/25% data	[ ]
50% voice/50%data	[ ]
25% voice/75% data	[ ]
100% data	[ ]

Circle the number that best describes the quality of your voice calls you have used TODAY (1 = poor, 10 = excellent)

    1   2   3   4   5   6   7   8   9   10

Circle the number that best describes the quality of your text and data sessions you have used TODAY (1 = poor, 10 = excellent)

    1   2   3   4   5   6   7   8   9   10

Circle the number that best describes your phone's features and function (1 = poor, 10 = excellent)

    1   2   3   4   5   6   7   8   9   10

Enter to win an Android Tablet (OPTIONAL)

Name _____

Phone _____

Email _____

B1.0 Plots

See file "Appendix_B_Kansas_Speedway_Plots.zip"

Note: Plots of 3G AT&T and T-Mobile Data Throughput are in KiloBytes per second. Multiply times 8 to get Kilobits per second. This was a flaw in the processing software we identified. Values for 4G throughput and 3G throughput for Sprint and Verizon are correctly shown in Kilobits per second.