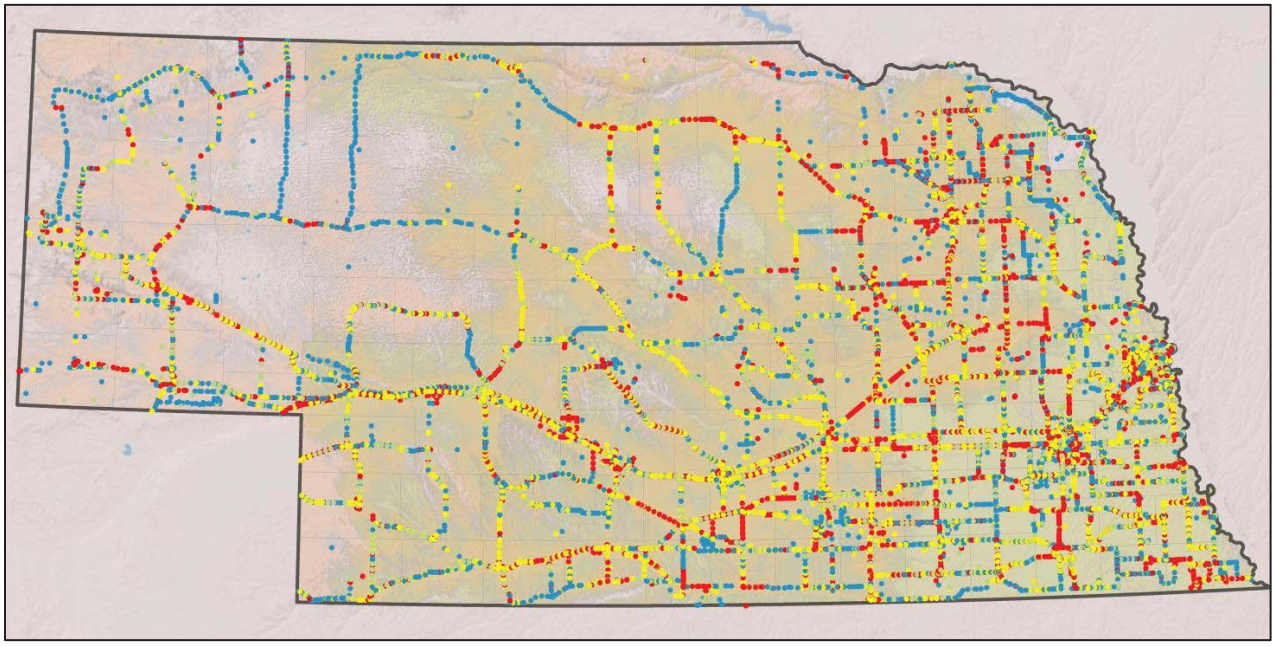
# *MOBILE BROADBAND IN NEBRASKA*

**Data Collected Using the Mobile Pulse Application**




**Cullen Robbins – IT/Telecom/GIS Analyst**

**Telecommunications Department**

**Nebraska Public Service Commission**


**August 2015**

## Application and Testing Overview

Since October, 2013, the Nebraska Public Service Commission (PSC) has contracted with Mobile Pulse for the use of its mobile wireless network testing app. The app, free to users, ran periodic tests in the background of any cellular-network enabled device onto which it is installed. Once installed on a device, it was designed to be as unobtrusive as possible, and require the least amount of device resources as possible to collect information. The app did not collect any personal information. It also had safeguards in place to ensure that the app didn't run out the battery of the device, or go over a predetermined amount of data usage during any given month. Collection of meaningful data relied on running as many tests as possible within a geographically diverse area in Nebraska on as many carriers' networks as possible.

The app was designed to perform two types of tests: speed and connectivity. The speed tests required some of the users' monthly data to test upload and download speeds, connectivity, collect provider information, and the general location of the user. Information regarding the type of wireless access technology being used is also collected. For this report, the types of technology were grouped into broader categories for analysis: 2G, 3G, and LTE. 2G technologies are typically capable of speeds below 385 Kbps, 3G technologies range typically between 385 Kbps to 2-3 Mbps. 4G LTE technologies average between 3 and 10 Mbps, though higher speeds are possible. The connectivity tests were much less data intensive because they only checked whether the device could connect to the network. The provider and location information were also recorded, but no speed information was collected. For these reasons, these tests were run much more frequently than the speed tests.

Users of the app fit into two categories for data collection: the "public," or "standard" users, and the "advanced" users. Both versions of the app collected speed and connectivity tests as described above. The "advanced" version, however, collected much more information during each test. The thresholds in place regarding data usage, battery level, and test frequency, as well as other parameters, could be adjusted by the app Administrator. For this reason, users could only be added to the "advanced" user group by invitation.

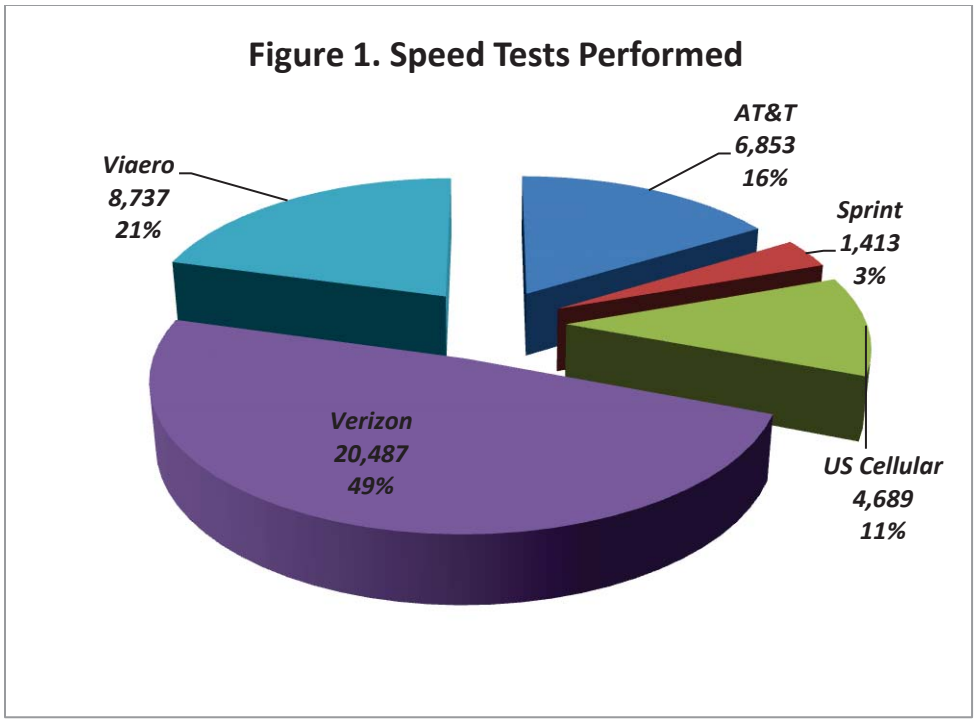
The data collected was displayed on a password-protected "dashboard" on a website hosted by Mobile Pulse. This dashboard allowed authorized users to view data collected using the app, and some basic analysis could be performed. Mobile Pulse also provided raw data monthly to the PSC, allowing for the data to be loaded into a Geographic Information System (GIS) for further analysis. The GIS facilitated analyzing the data and displaying results spatially. The data analyzed in this report reflects what was collected between August 2013 and May, 2015. The bulk of the data collection ended in May, 2015, and the agreement with Mobile Pulse was completed in June 2015. While data was collected continuously between October 2013 and May, 2015, it was essentially collected in two phases: Pre drive-testing and post-drive testing. The pre drive-testing phase focused on efforts to encourage the general public to download, install, and use the app; i.e. – a crowdsourcing model, where the amount and quality of the data collected was dependent on how many people downloaded and used the app,

and how those people were distributed throughout the state. Towards the end of 2014, it became apparent that for all carriers except Verizon, there were too few tests with poor spatial distribution across the state to complete a reasonable assessment of those carriers. A plan for manual drive testing was developed to improve both of these conditions. Carriers AT&T, U.S. Cellular, Verizon, and Viaero provided demonstration devices that were utilized for testing. Sprint elected not to participate in the drive testing portion of the study. The devices were set to conduct speed tests continuously every 2 minutes in a vehicle travelling around the state. The drive testing period commenced in April, 2015, and was completed by the end of May, 2015. A list of the devices used for drive testing is shown in Table 1.

**Table 1. Drive testing Carriers and Devices used**

| Carrier | Device Model | OS |
|---|---|---|
| US Cellular | Samsung Galaxy S5 | Android |
| US Cellular | Apple iPhone 5c | iOS |
| Viaero | HTC One (M8) | Android |
| Viaero | HTC One (M8) | Android |
| Verizon | Apple iPhone 5 | iOS |
| Verizon | Verizon Droid Mini | Android |
| AT&T | Apple iPhone 6 | iOS |
| AT&T | Samsung Galaxy S5 | Android |

Initially, data was analyzed without regard to the carrier footprints. In other words, tests were used regardless of whether the point was within what the carrier defined as their coverage area. For speed test data, tests that resulted in an error were not used. Tests were analyzed based on the carrier network that was being used, i.e. if one device from Carrier X was roaming on the network of Carrier Y, the test would be analyzed based on the network being used (Carrier Y, in this case). Figure 1 shows the number of speed tests performed on the network of each carrier. Verizon is generally considered the dominant provider in Nebraska, and the number of speed tests on Verizon's network supports that (See Figure 1), when compared to other carriers. There were more than twice as many speed tests run on the Verizon network compared to next closest provider (Viaero), and nearly 10 times as many as AT&T. Note again that Sprint elected not to participate in the drive testing phase, so there are very few tests on the Sprint network relative to other carriers.




The impact of the PSC drive testing on the number of tests conducted can be observed in Table 2. For example, approximately 732 tests per month were being performed on the Verizon network prior to drive testing. During the two months of drive testing, an average of 3,590 tests were being conducted, an increase of 390% (Table 1). Of the drive test participants (AT&T, U.S. Cellular, Verizon, and Viaero), that represented the *smallest* increase of the 4 carriers. The increase in tests/month on the Viaero and U.S. Cellular networks increased exponentially.

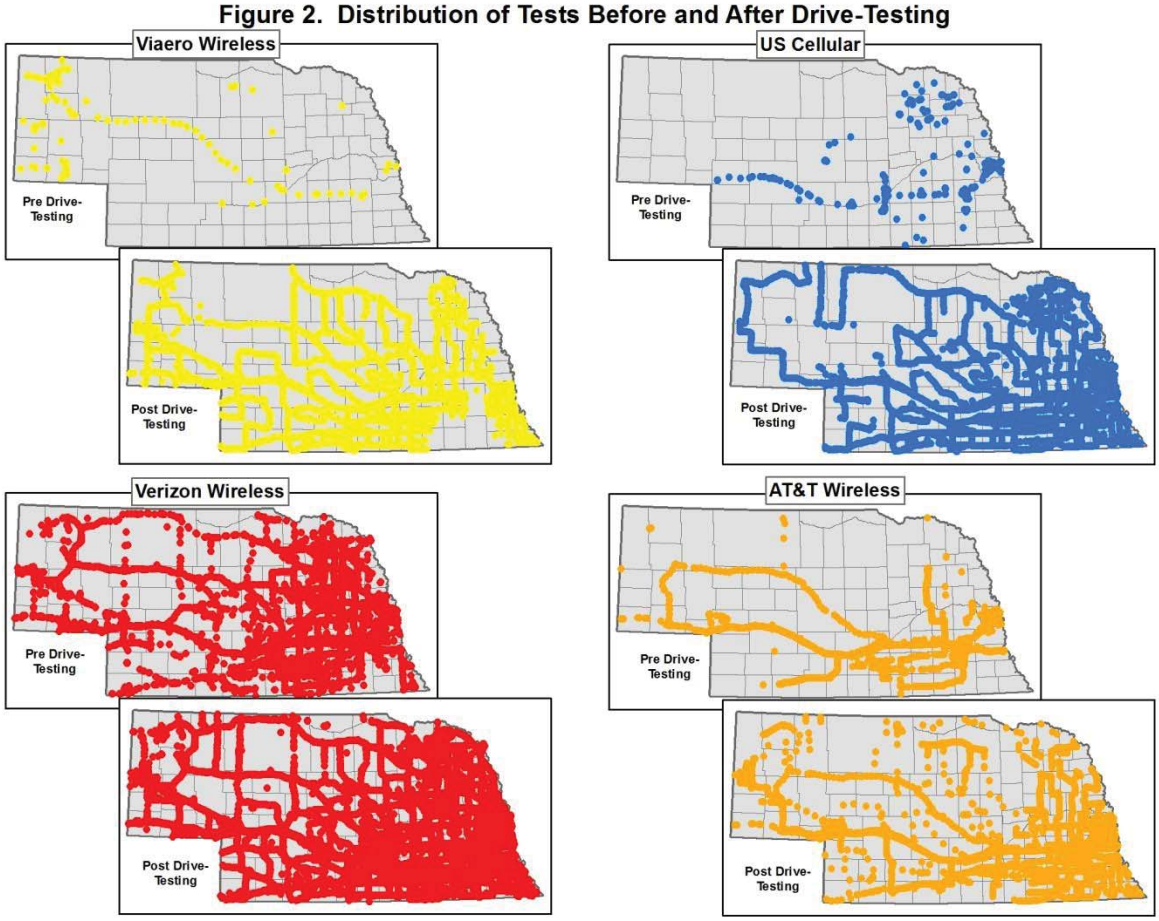
**Table 2. Pre vs Post Drive Testing**

| | Tests/Month (Pre) | Tests/Month (Post) | % Increase |
|---|---|---|---|
| AT&T | 206 | 1,564 | 658% |
| Sprint | 69 | 51 | -26% |
| US Cellular | 33 | 2,051 | 6,189% |
| Verizon | 732 | 3,590 | 390% |
| Viaero | 41 | 3,998 | 9,597% |

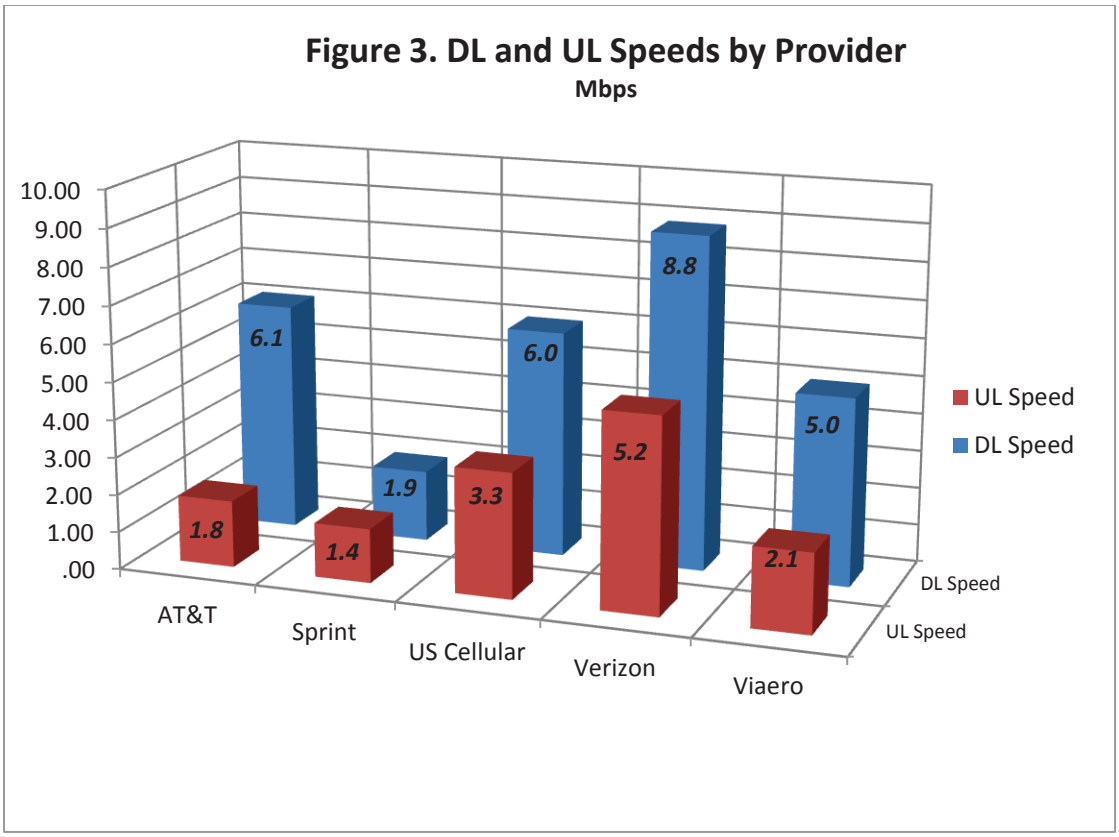
The effects of drive testing can also be shown spatially. Figure 2 shows the distributions of tests collected for the 4 drive-test participants both before and after drive testing was completed. The distribution of Verizon tests included some of the western portion of the state before drive-testing commenced, but the other three participating carriers had poor statewide distribution of test results prior to PSC drive testing. Even after drive-testing, there still appears to be holes in some areas of the

Sandhills region. Some of these areas were actually part of the PSC drive-testing, but technical difficulties with the app resulted in some tests not being recorded by the Mobile Pulse servers. This issue surfaced only on Android devices during that period.

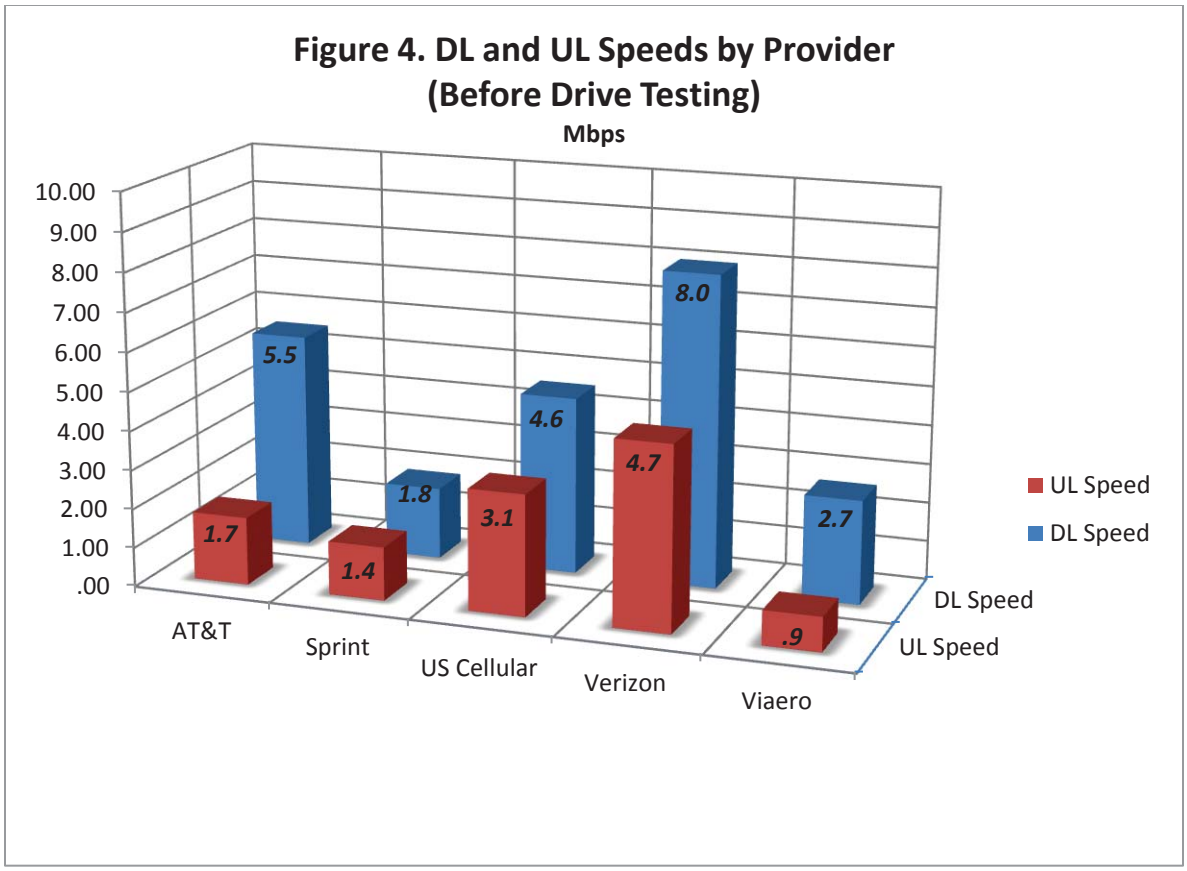
**Figure 2. Distribution of Tests Before and After Drive-Testing**




Upload and download speeds are one metric that can be used to measure carrier network performance. This metric, in megabits per second (Mbps), is commonly used when discussing broadband speeds provided by both wireline and wireless carriers. In fact, the FCC has defined broadband by the upload and download speeds of a connection. Recently, the FCC modified their definition of broadband for purposes of compliance with Section 706 of the 1996 Telecommunications Act, from 4 Mbps download and 1 Mbps upload, to 25 Mbps download and 3 Mbps upload. For wireless carriers in Nebraska, upload and download speeds were the highest for Verizon (See Figure 3), followed by AT&T, U.S. Cellular, and Viaero. Sprint was the slowest of the 5 providers. When compared to the previous FCC definition of broadband (4 Mbps download, 1 Mbps upload), 4 of the 5 providers (Verizon, US Cellular, and AT&T) met the threshold (Figure 3). Only one carrier (Sprint) did not meet the threshold (Figure 3).




Prior to the drive-testing phase of data collection, Viaero also did not meet the previous FCC threshold (Figure 4). Download and upload speeds were lower for all 4 of the drive-test-participating carriers; however, Sprint remained essentially the same. Table 3 shows the effects that the drive testing phase had on observed upload and download speeds. Viaero showed the largest increase subsequent to the PSC drive testing, with download speeds increasing 87% and upload speeds increasing nearly 140%. U.S. Cellular's download speeds increased nearly 32%, and the other two drive-test participants (AT&T and Verizon) showed increases in download speeds that were over 10% (10.2% and 10.7%, respectively). Increases in upload speeds were not as large for the other three drive-test participants as they were for Viaero, but all three did increase (Table 3). Sprint saw an increase in upload speeds of over 5% during that time as well (Table 3).




| Table 3. Pre Drive Testing Speeds vs. Overall Speeds (Mbps) | | | | | | |
|---|---|---|---|---|---|---|
| | DL Speeds Pre-DT | DL Speeds Overall | % Change | UL Speeds Pre-DT | UL Speeds Overall | % Change |
| AT&T | 5.5 | 6.1 | 10.2% | 1.74 | 1.77 | 2.1% |
| Sprint | 1.8 | 1.9 | 2.8% | 1.37 | 1.44 | 5.3% |
| US Cellular | 4.6 | 6.0 | 31.9% | 3.10 | 3.32 | 7.2% |
| Verizon | 8.0 | 8.8 | 10.7% | 4.70 | 5.16 | 9.7% |
| Viaero | 2.7 | 5.0 | 87.4% | .88 | 2.10 | 139.5% |

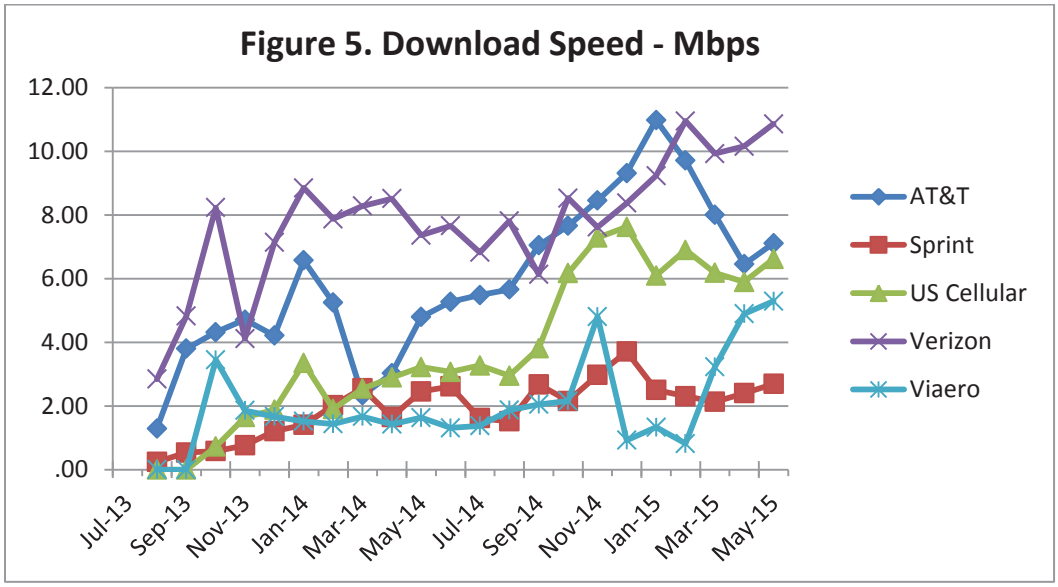
Looking at individual measurements for each company provides some additional detail regarding the 4/1 FCC broadband definition. Table 4 shows the number and percentage of tests for each provider that met the broadband threshold. Verizon, at 64% of all tests meeting the broadband threshold, is the highest percentage of the five providers, followed by U.S. Cellular (60%), Viaero (58%), AT&T (47%), and Sprint (14%), respectively.

| Table 4. Number of Broadband Tests meeting FCC 4/1 threshold | | | | | |
|---|---|---|---|---|---|
| **Provider** | AT&T | Sprint | US Cellular | Verizon | Viaero |
| Meets 4/1 Broadband | 3,212 | 198 | 2,624 | 12,639 | 4,639 |
| Total Measurements | 6,847 | 1,429 | 4,369 | 19,658 | 8,010 |
| % Meeting BB Definition | 47% | 14% | 60% | 64% | 58% |

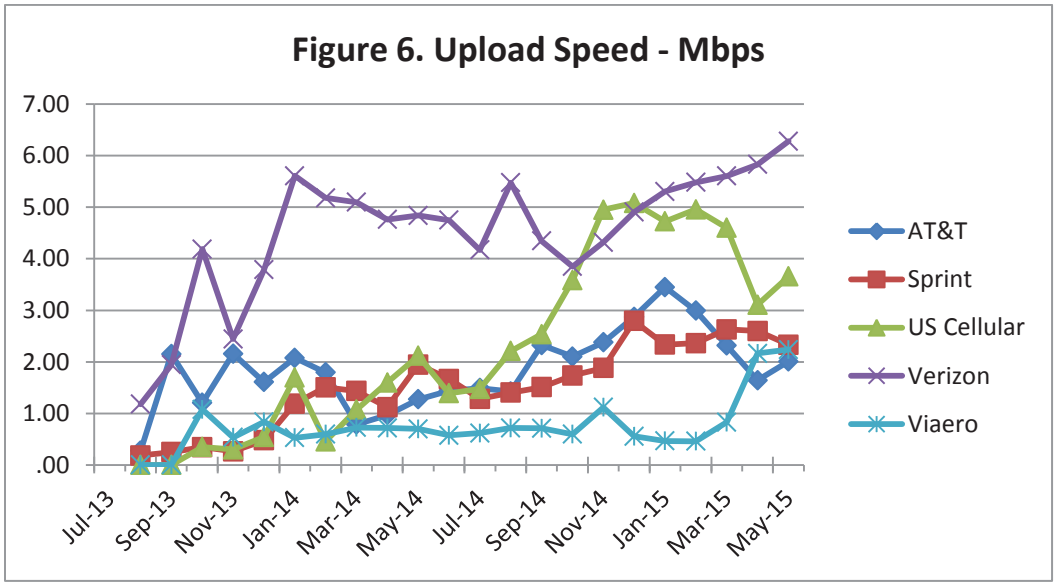
Table 5 shows the test results when all speed tests are compared to the FCC's new broadband definition (25 Mbps download and 3 Mbps upload). In this scenario, only 675 of 40,313 total tests (1.7%) met that threshold, and of those 675, 635 were on the Verizon network (the other 40 were on the AT&T network). It would be difficult to define wireless carriers as broadband providers under the Section 706 FCC definition.

| Table 5. Number of Broadband Tests meeting NEW FCC 25/3 threshold | | | | | |
|---|---|---|---|---|---|
| **Provider** | AT&T | Sprint | US Cellular | Verizon | Viaero |
| Meets 25/3 Broadband | 40 | 0 | 0 | 635 | 0 |
| Total Measurements | 6,847 | 1,429 | 4,369 | 19,658 | 8,010 |
| % Meeting BB Definition | 1% | 0% | 0% | 3% | 0% |

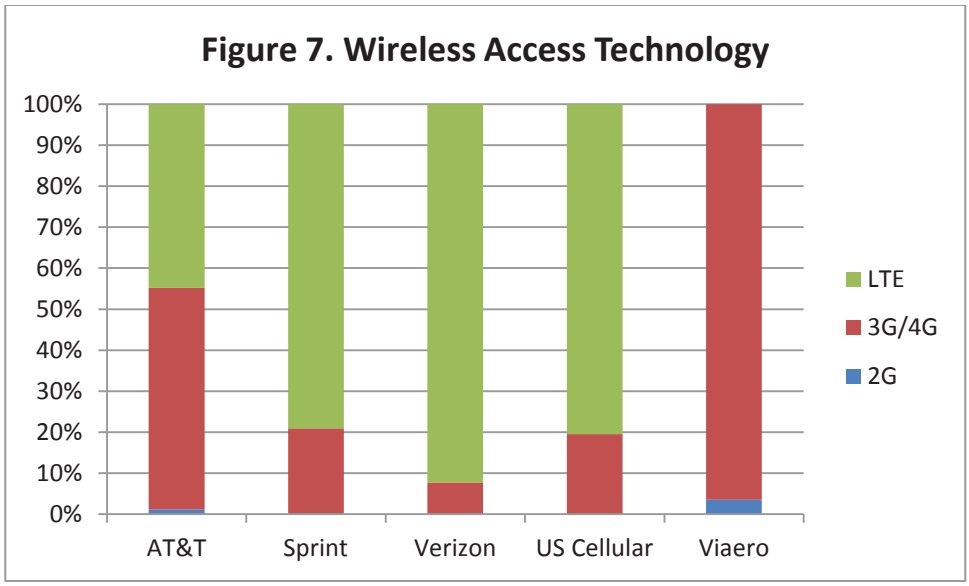
The data collected can also be broken down into monthly download speed averages by provider. As Figure 5 shows, Verizon's monthly download speeds were the highest for most months, followed by AT&T. U.S. Cellular has consistently shown up as the third fastest over the last year. Viaero showed an increase in speeds over recent months (during the drive-testing period) that are close to U.S. Cellular and AT&T, though prior to that they were consistently one of the lower performers with Sprint. Download speeds have generally increased for all carriers over the course of testing. AT&T speeds have shown some drop-off in recent months, likely due to more tests from more devices over a wider area.



Some similar trends are observed when viewing upload speeds by month (Figure 6). Verizon tests consistently show the highest upload speeds across nearly the entire period of data collection. Unlike download speeds, AT&T upload speeds do not consistently show up as the second-best provider in this category. U.S. Cellular has consistently seen the second fastest upload speeds over the past 12 months, while AT&T and Sprint have shown similar speeds over the past year. Upload speeds for Viaero have increased markedly over the drive-testing period after showing the lowest upload speeds prior to that time.

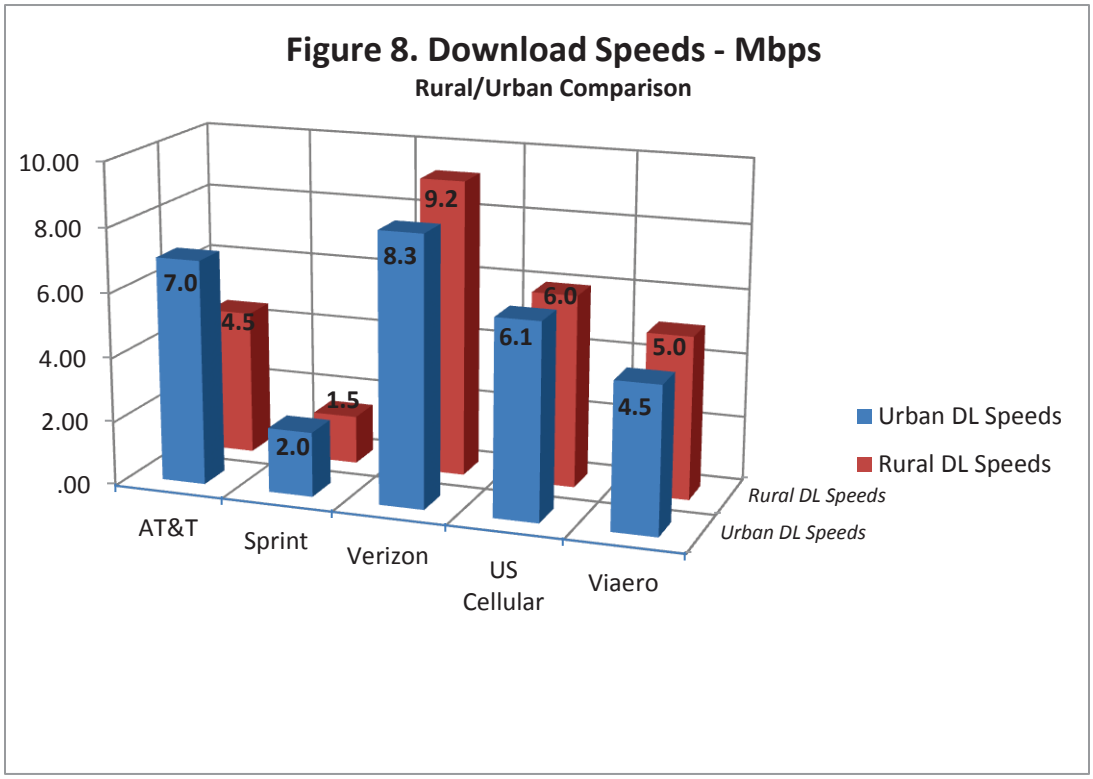


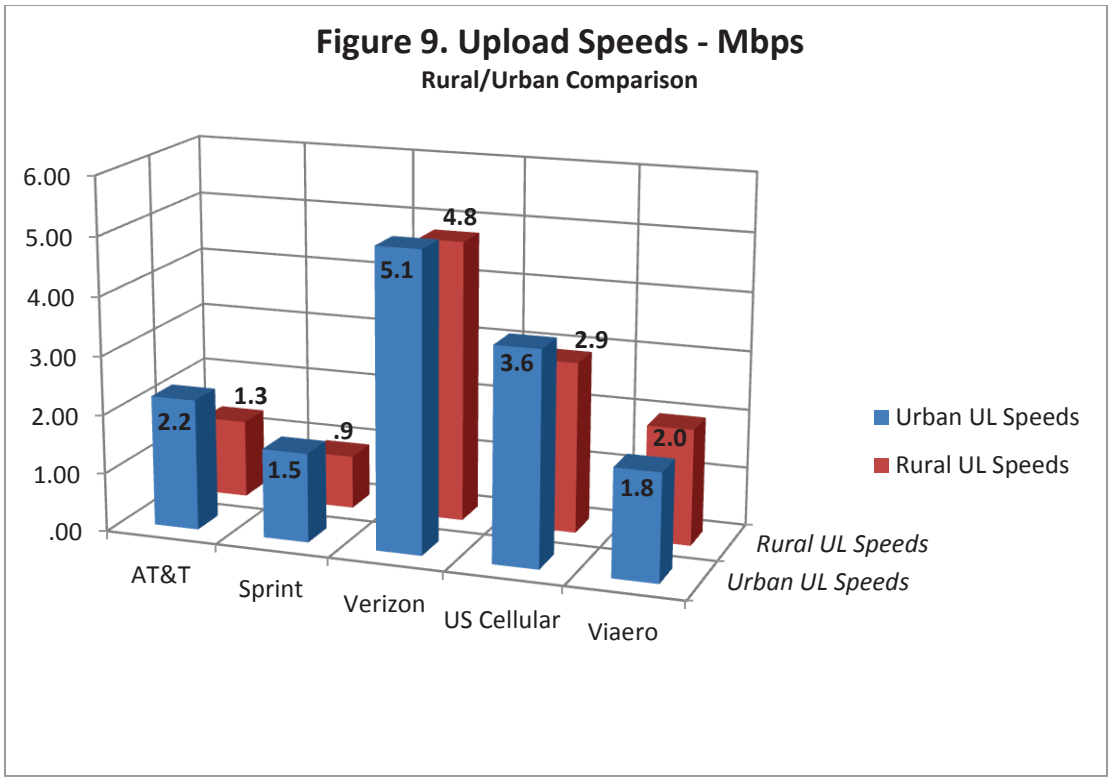

Technology Type information collected by the app shows that 3G and 4G/LTE technologies are the dominant types in use today (Figure 7). Very few tests showed evidence of 2G technology still in use. Verizon, Sprint, and U.S. Cellular all showed a large percentage of LTE tests performed on their network, while tests on the AT&T network showed evidence that approximately 45% were conducted using 4G/LTE network (Figure 6). Viaero tests were collected predominantly on 3G/4G networks, and no tests were taken using an LTE network according to the data received (Figure 7).




In Nebraska, there is often a perception among users that a wide divide exists between rural and urban areas when discussing any number of different topics. With respect to mobile wireless speeds, the spatial nature of the data collected using the app allows that perception to be tested. For the purpose of this analysis, urban tests were considered to be those collected within the city limits of any community in Nebraska. Those tests collected outside of city limits were considered rural tests. Table 6 shows the numbers of tests and percentages for urban and rural tests for each of the 5 carriers. Sprint test were performed in urban areas nearly 80% of the time. AT&T and Verizon tests were performed in rural areas around 40% of the time, and US Cellular and Viaero tests were conducted in urban areas 29% and 14% of the time, respectively. Of the five carriers tested, AT&T and Sprint had download speeds that were significantly faster in urban areas (Figure 8). U.S. Cellular download speeds were nearly identical between rural and urban areas, while Verizon and Viaero download speeds were faster in rural areas than in urban areas (Figure 8). Upload speeds were faster in urban areas for 4 of the 5 carriers (Viaero was the exception) (Figure 9). The differences between rural and urban tests for all 4 of those carriers was less than 1 Mbps, and the rural/urban upload speed difference for Viaero was only 0.2 Mbps (Figure 9). Some states, such as Colorado, have observed faster speeds in rural environments, possibly due to reduced demand on rural networks.

| Table 6. Urban and Rural Test Numbers | | | |
|---|---|---|---|
| **Provider** | **Urban Tests** | **Rural Tests** | **% Urban** |
| AT&T | 3,175 | 3,937 | 44.6% |
| Sprint | 1,175 | 333 | 77.9% |
| Verizon | 8,615 | 12,207 | 41.4% |
| US Cellular | 1,347 | 3,342 | 28.7% |
| Viaero | 1,216 | 7,522 | 13.9% |






## Advertised vs. Actual Speeds

Viewing results statewide is a useful tool for looking at carrier performance, but that method fails to consider that each of the carriers has a footprint within the state that they advertise as their coverage area. While devices from many of the carriers may work outside of their advertised area, it makes sense to analyze how the carriers perform only within their advertised area. For this analysis, the advertised footprints used were part of the final data submission to the National Telecommunications & Information Administration (NTIA) as part of their biannual broadband data submissions. The most current submission was based on December, 2014 data, and reflects footprints as of June, 2014. While the PSC assisted in the collection of this data, the dataset used in the analysis was the publicly available version, which can be found at http://www2.ntia.doc.gov/June_2014_datasets. The dataset for mobile wireless carriers includes the spatial footprints for each speed tier reported. The speed tiers for the NTIA data collection effort are shown in Table 7. To compare actual vs. advertised speeds for each carrier, download speeds recorded by the Mobile Pulse app. were converted to the speed tiers into which they fit. Data reported by providers to the NTIA occasionally reported multiple speed tiers that were available for some areas within Nebraska. Each speed tier for these carriers was analyzed independently.

| Speed Tier | Description |
|---|---|
| 1 | Less than 200 kbps |
| 2 | Greater than 200 kbps and less than 768 kbps |
| 3 | Greater than or equal to 768 kbps and less than 1.5 mbps |
| 4 | Greater than or equal to 1.5 mbps and less than 3 mbps |
| 5 | Greater than or equal to 3 mbps and less than 6 mbps |
| 6 | Greater than or equal to 6 mbps and less than 10 mbps |
| 7 | Greater than or equal to 10 mbps and less than 25 mbps |
| 8 | Greater than or equal to 25 mbps and less than 50 mbps |
| 9 | Greater than or equal to 50 mbps and less than 100 mbps |

**Table 7. Speed Tier information.**

| Carrier | Speed Tier | # Tests | Errors | % Errors | Avg. Speed (DL) (Mbps) | Avg. Speed (UL) (Mbps) | >= 1 Speed Tier Lower | Meets Adv. Speed Tier | >= 1 Speed Tier Higher | % Meeting or Exceeding |
|---|---|---|---|---|---|---|---|---|---|---|
| AT&T | 4 | 5,792 | 560 | 9.7% | 6.7 | 2.0 | 1,168 | 653 | 3,411 | 77.7% |
| | 5 | 5,695 | 554 | 9.7% | 6.8 | 2.0 | 1,751 | 1,074 | 2,316 | 65.9% |
| | 7 | 3,846 | 182 | 4.7% | 7.5 | 2.4 | 2,514 | 1,114 | 36 | 31.4% |
| Sprint | 3 | 1,717 | 305 | 17.8% | 2.0 | 1.5 | 691 | 269 | 452 | 51.1% |
| | 6 | 1,674 | 288 | 17.2% | 2.0 | 1.5 | 1,265 | 69 | 52 | 8.7% |
| US Cellular | 3 | 4,580 | 215 | 4.7% | 6.3 | 3.3 | 434 | 287 | 3,644 | 90.1% |
| Viaero | 6 | 7,740 | 376 | 4.9% | 5.0 | 2.0 | 4,321 | 2,784 | 259 | 41.3% |
| Verizon | 3 | 22,339 | 1,604 | 7.2% | 8.9 | 4.9 | 2,891 | 1,503 | 16,341 | 86.1% |
| | 7 (6) | 22,408 | 1,647 | 7.4% | 8.9 | 4.9 | 8,391 | 4,528 | 7,842 | 59.6% |

**Table 8. Breakdown of test results by provider, with advertised speed tier(s) also displayed.**

Regardless of the speed tier reported, US Cellular showed the highest percentage of tests meeting or exceeding the advertised speed tier (90.1%, Table 8). Verizon's lowest reported speed tier (3) showed the second highest percentage of tests meeting or exceeding that tier (86.1%), followed by AT&T at 77.7% at speed tier 4 (Table 8). Sprint and Viaero had the lowest percentages of tests meeting or exceeding their advertised speed tiers (51.1%/speed tier 3, and 41.3%/speed tier 6, respectively). In Viaero's case, however, note that the advertised speed tier was 6, a relatively high speed tier. When comparing across companies and looking at the lowest advertised speed tier as a baseline for comparison, Viaero had the highest speed tier to attain, so it might be expected that the percentage of tests that met or exceeded that advertised tier is lower. The speed tier information, however, is self-reported, so they essentially set the bar for themselves.

Table 8 also displays data regarding the number and percentages of tests that were errors within the advertised footprints. US Cellular, Viaero, and AT&T (at speed tier 7) all showed low error percentages that were very close to each other. The percent of tests on the Verizon network that were errors was slightly higher at 7.2% for speed tier 3, and 7.4% at speed tier 7/6. The highest percentages of errors were on the Sprint network (both tiers between 17% and 18%, Table 8).

## Latency/Connectivity

The Mobile Pulse app takes connectivity tests in addition to speed tests. These latency tests require less data transfer between the device and the provider's network, and can be performed more often than the speed tests. While these tests do not collect speed information, they determine whether the device can connect to a network. For this reason, connectivity, defined as the percentage of tests that successfully connect to the network, can be analyzed wherever a latency test is collected. And because more latency tests are performed, additional locations can be analyzed for connectivity versus speed. Results were initially analyzed on a statewide basis for each carrier; i.e. all tests for each carrier were analyzed regardless of location. Connectivity ranged from 80% (Sprint) to 97% (Viaero) among the five carriers tested (Table 9). All 4 of the carriers that participated in drive testing (AT&T, US Cellular, Verizon, and Viaero) were above 90%.

| Provider | Latency Tests | # Successful Tests | Connectivity (%) |
|---|---|---|---|
| **AT&T** | 2,477 | 2,331 | 94% |
| **Sprint** | 17,513 | 14,036 | 80% |
| **Verizon** | 102,232 | 93,326 | 91% |
| **US Cellular** | 15,640 | 14,001 | 90% |
| **Viaero** | 8,764 | 8,544 | 97% |

**Table 9. Connectivity Test Results by Provider**

Results were also analyzed for connectivity tests performed only within the advertised footprint of the carriers. Results were largely the same, however, with only AT&T and Viaero showing changes in the % of successful tests, and in both of those cases, only by an increase of 1% (Table 10).

| Provider | Latency Tests | # Successful Tests | Connectivity (%) |
|---|---|---|---|
| **AT&T** | 2,343 | 2,217 | 95% |
| **Sprint** | 17,382 | 13,960 | 80% |
| **Verizon** | 102,150 | 93,292 | 91% |
| **US Cellular** | 15,625 | 13,990 | 90% |
| **Viaero** | 8,600 | 8,398 | 98% |

**Table 10. Connectivity Test Results by Provider for tests within the Provider Footprint**

Figure 10 shows the spatial distribution of successful and failed tests for all carriers statewide. It is difficult to determine any pattern based on the locations of the failed tests. The geographic distribution of successful and failed tests is similar. When looking at failed tests in this context, they appear to be randomly distributed, and not confined to any particular geography, which one might expect if a particular area were experiencing issues.

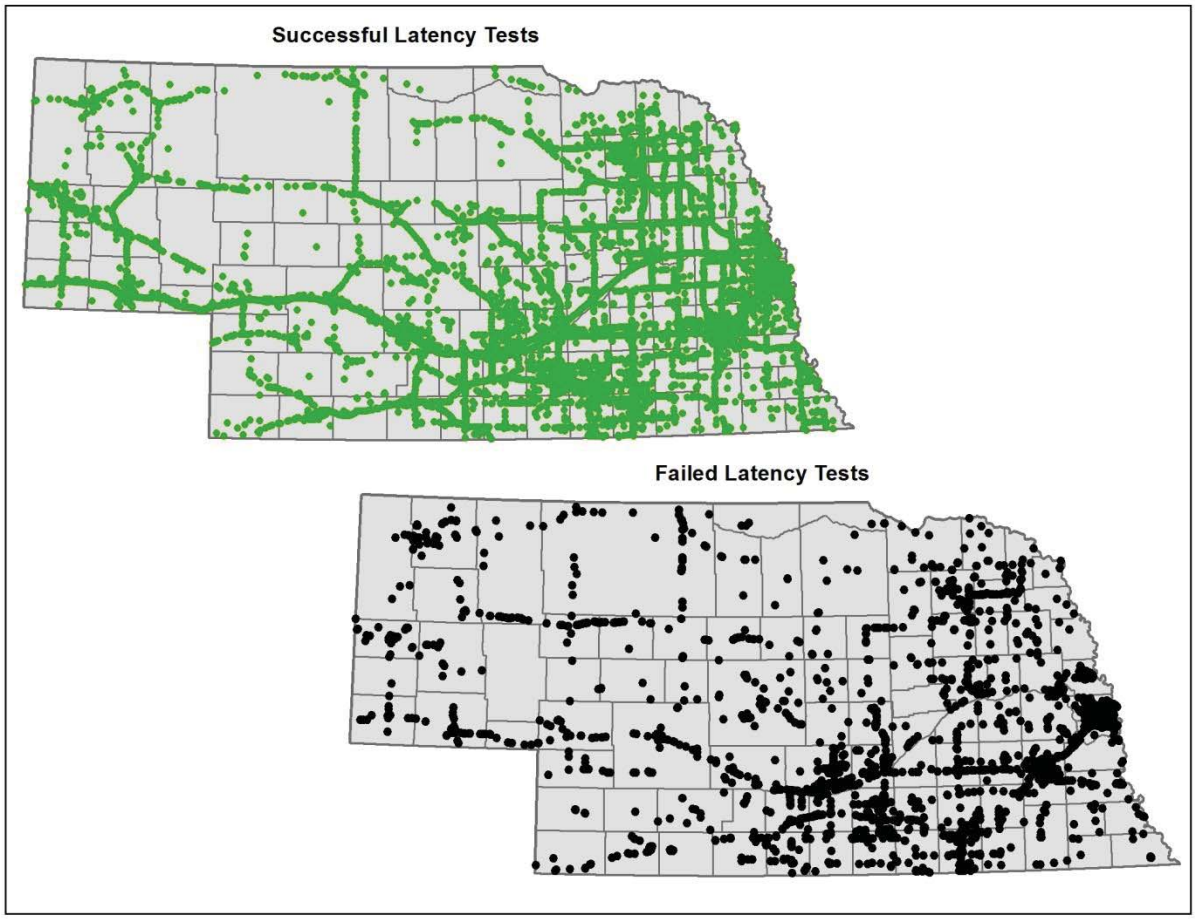



Figure 10. Spatial Distribution of Successful and Failed Latency Tests for all Carriers.

Breaking the latency tests down by provider reveals similar patterns to those observed from the map of all successful and failed latency tests, but there are some additional patterns of interest that emerge. When the latency tests are overlaid on the footprint of advertised coverage, the data for AT&T shows that devices on their network are often successful at connecting to an AT&T network even when outside of its advertised area (Figure 11). Tests outside the I-80 corridor also tended to be successful, rather than failed, contrary to what one might predict. Test results indicate good connectivity (86%,

Table 10), even outside of the provider's footprint, indicating a possible under-reporting of the company's footprint.

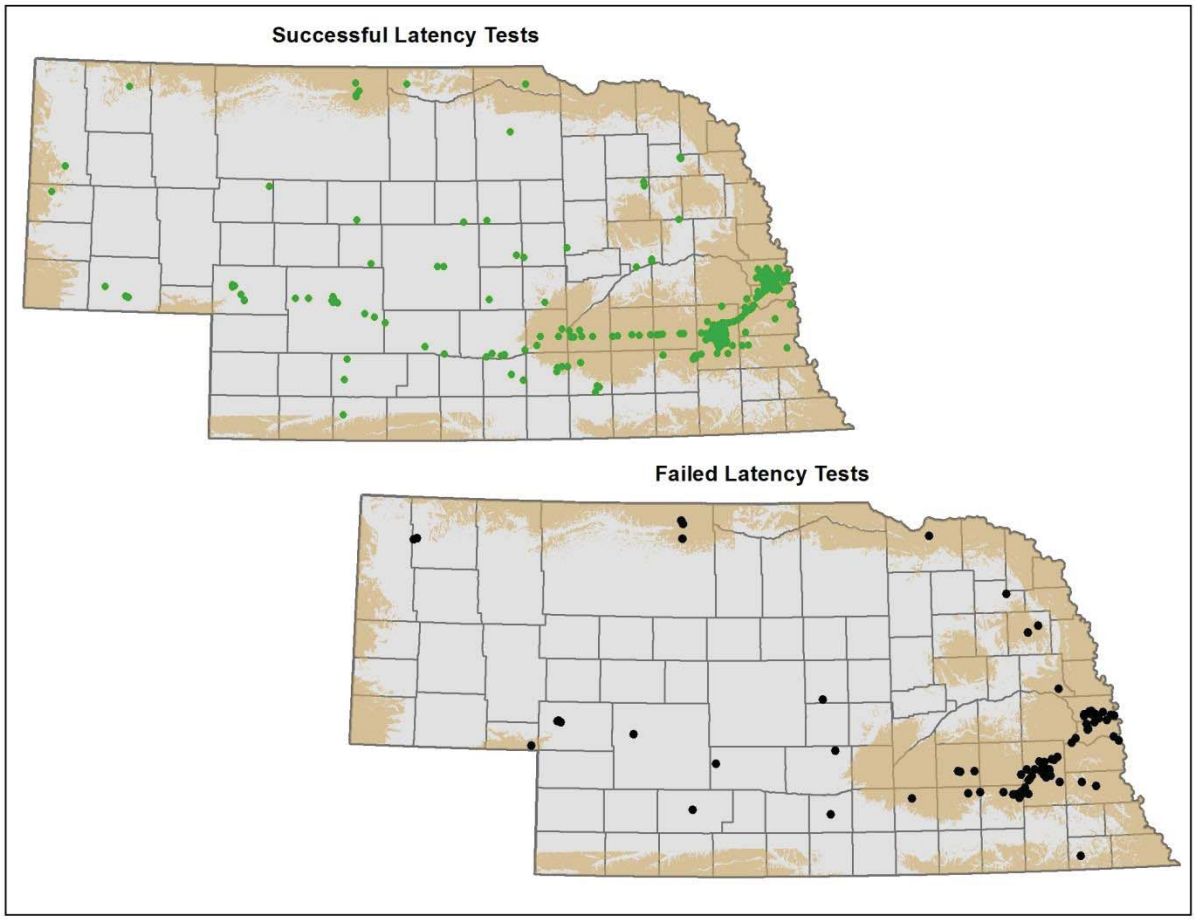



Figure 11. Successful (green) and Failed (black) latency tests for AT&T. The tan area is the advertised AT&T coverage area.

The Sprint connectivity results are predominantly confined to within its advertised footprint, which is concentrated on the larger population centers in eastern Nebraska, like Lincoln, Omaha, Grand Island, Kearney, Fremont, Columbus, and Norfolk (Figure 12). The patterns of successful and failed latency tests are similar. Their connectivity is the lowest among the five carriers tested (80%, Tables 9 and 10), even though tests occur mostly along the I-80 corridor. These results indicate a network that is smaller than most of the other providers, with lower connectivity as well.

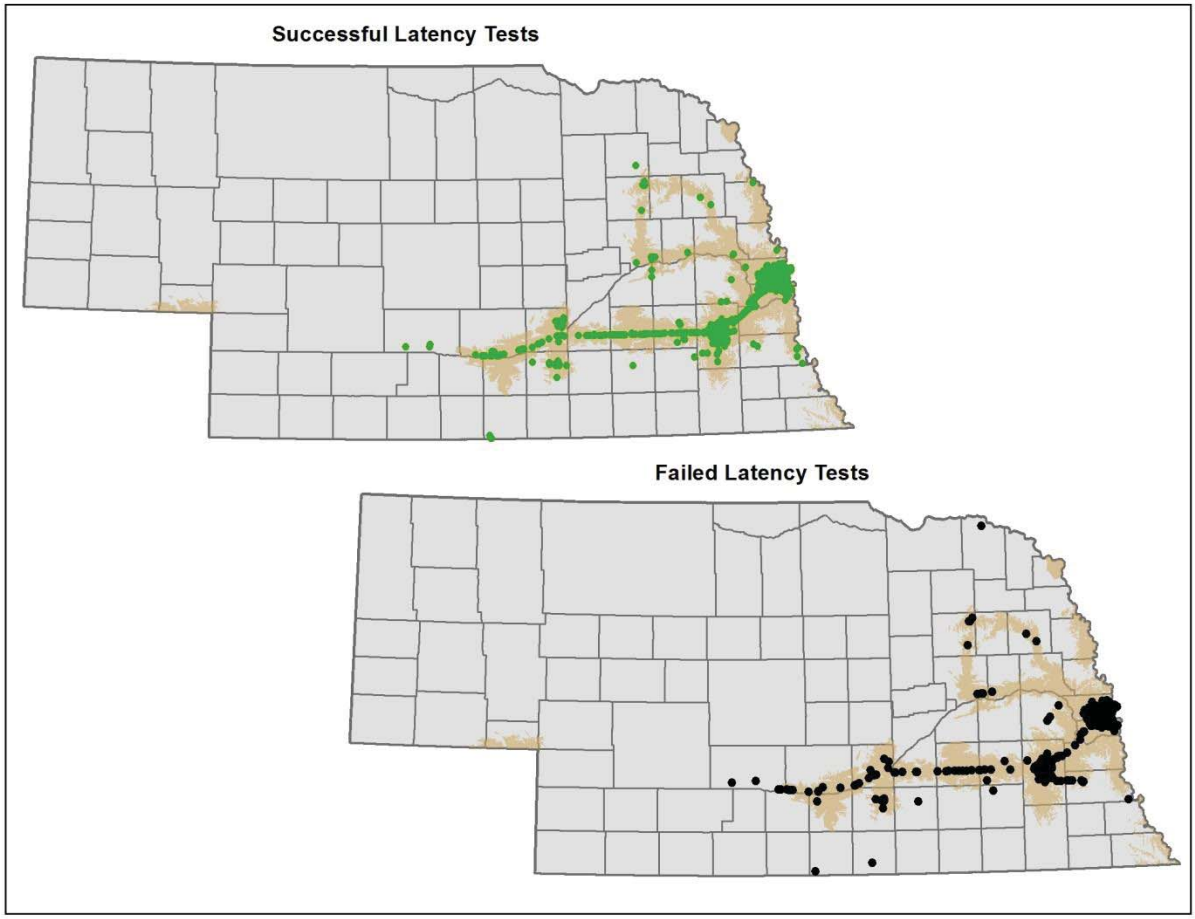



Figure 12. Successful (green) and failed (black) latency tests on the Sprint network. The tan area is the advertised network footprint for Sprint.

Figure 12 shows the latency results for U.S. Cellular. Latency results show high levels of connectivity (90%, Tables 9 and 10)) within their advertised footprint, with few tests completed outside of that footprint (Figure 13). Failed latency tests appear to follow the same distribution as the successful tests, except that there are very few failed tests along the I-80 corridor, even though there are a large number of successful tests.

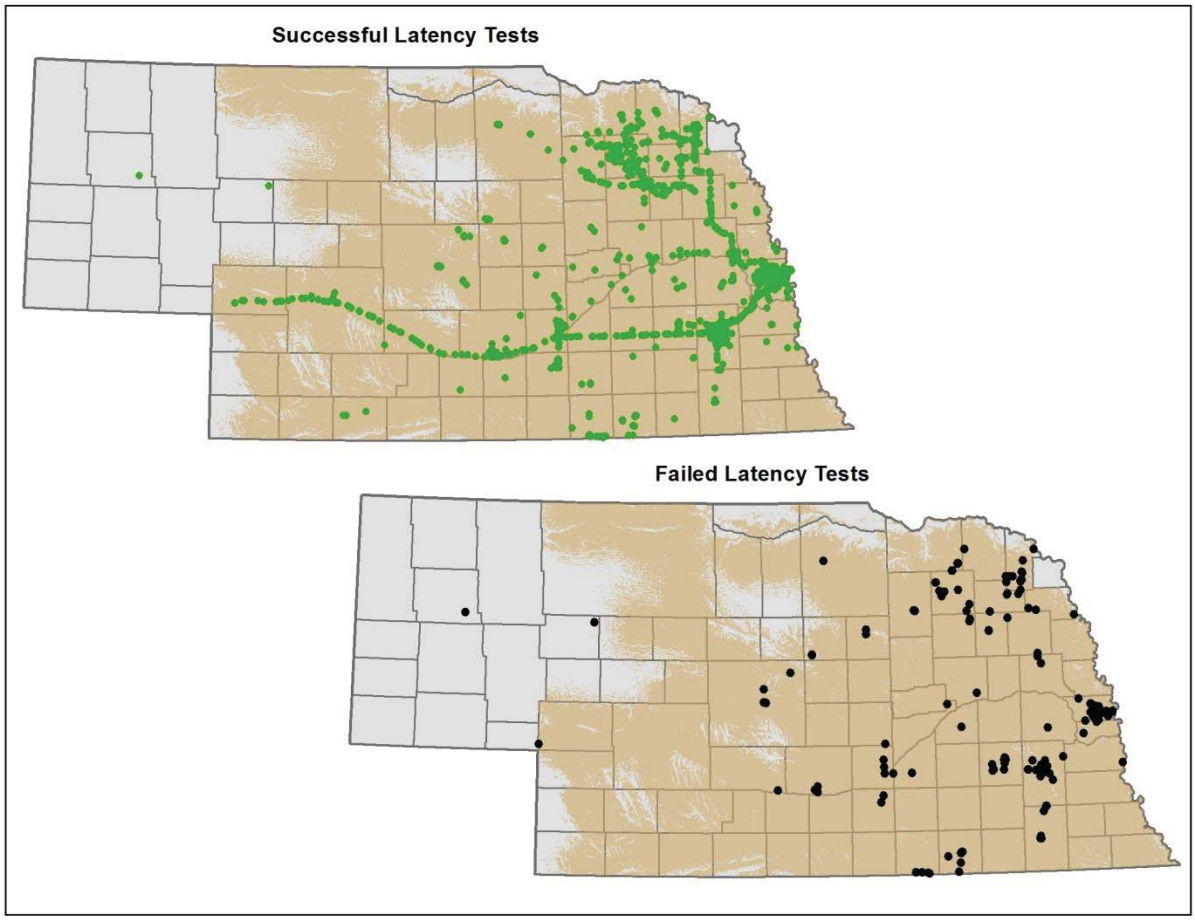



Figure 13. Successful (green) and failed (black) latency tests on the U.S. Cellular network. The tan area represents the advertised footprint for U.S. Cellular.

Verizon shows a generally random pattern of failed tests (Figure 14). The Verizon footprint covers nearly the entire state, and tests that happened to be performed outside of that footprint usually failed, though there were few of them. When taken into account with the high connectivity figure (91%, Tables 9 and 10), the results indicate a robust network that was accurately reported.

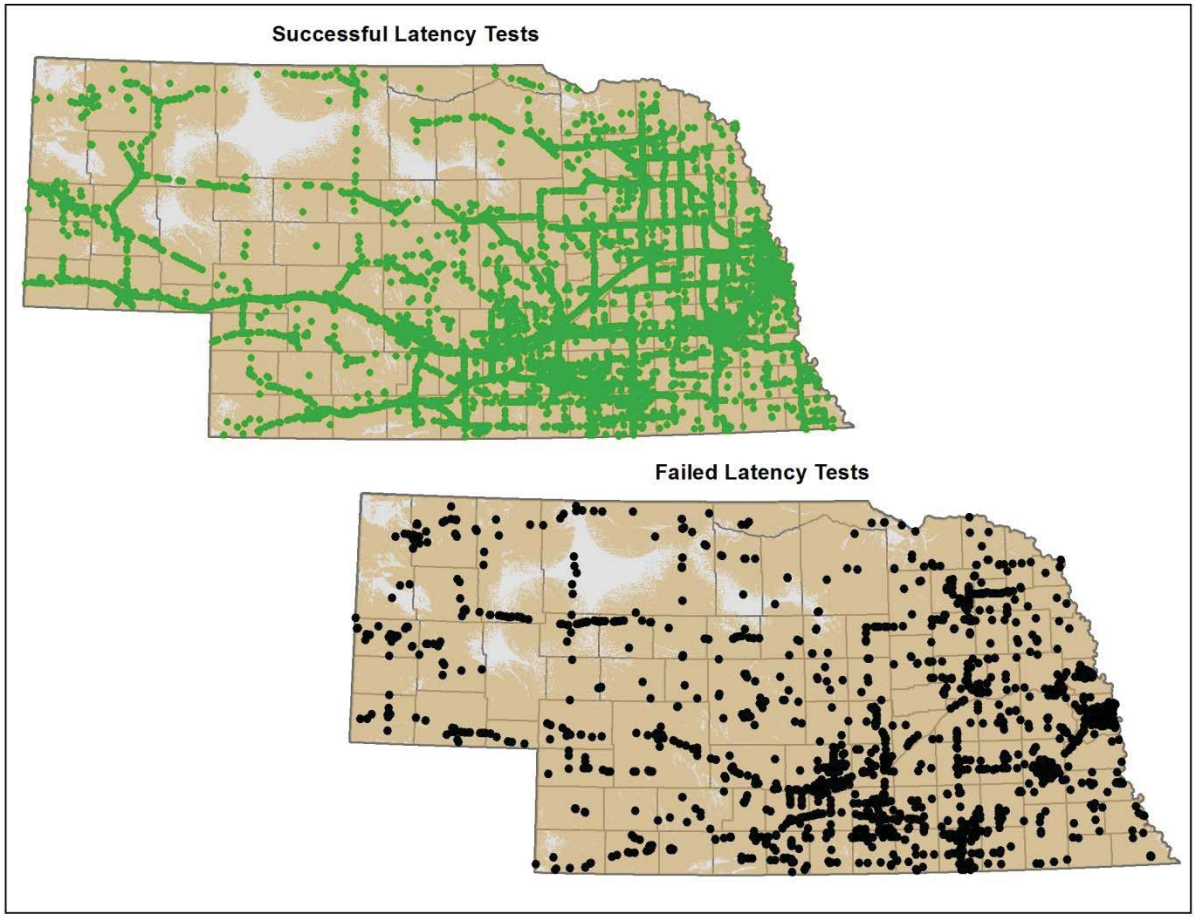



Figure 14. Successful (green) and failed (black) latency tests on the Verizon network. The tan areas represent the advertised footprint for Verizon.

The Viaero latency test results show the highest levels of connectivity among the five providers tested (97/98%, Tables 9 and 10). Unlike the other four providers, the majority of the tests are in the western portion of the state, which is consistent with their advertised footprint (Figure 15).

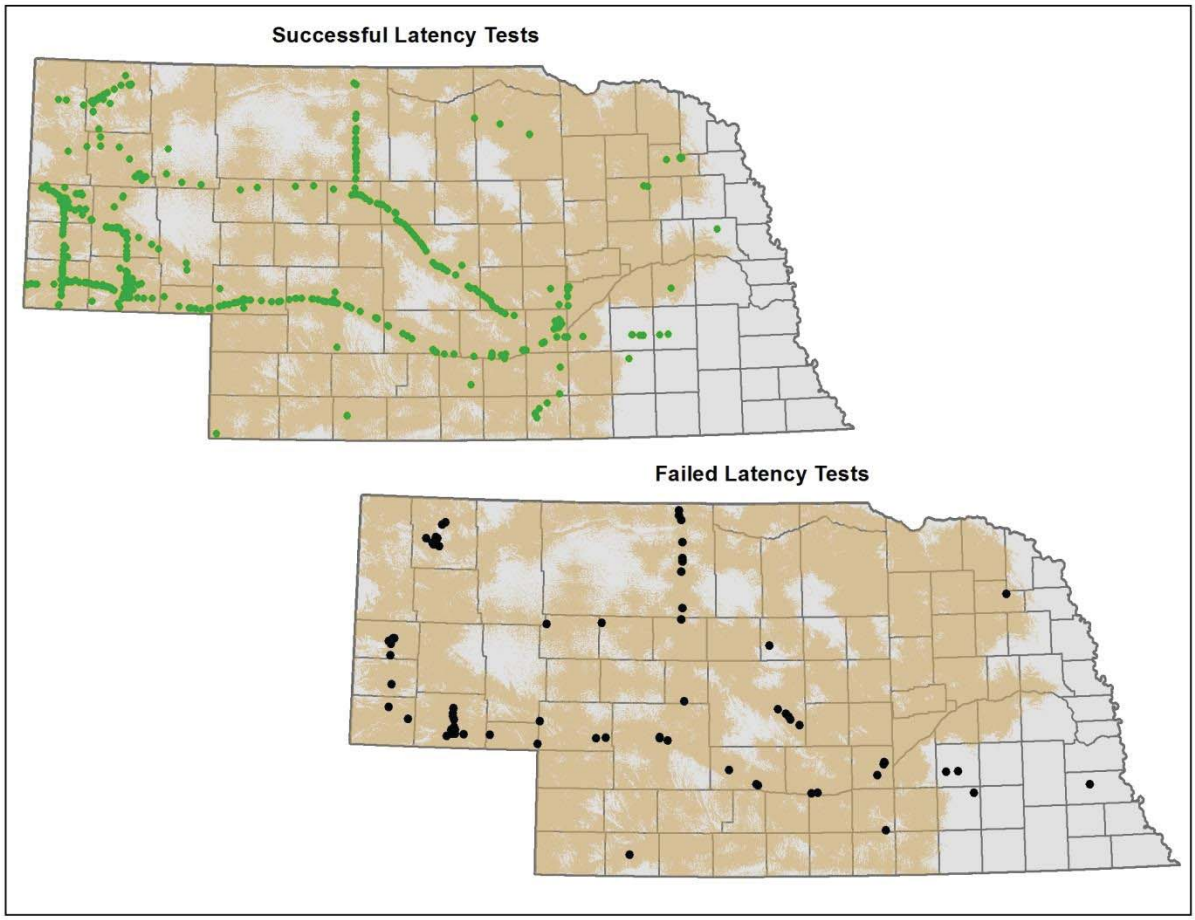



Figure 15. Successful (green) and Failed (black) latency tests on the Viaero network. Areas in tan indicate the advertised footprint for Viaero.

**Device Comparison**

The "advanced" version of the app collected information regarding the types of devices used to take tests, which allows for some comparisons of different devices on the same network. For instance, three of the four carriers that loaned devices to the PSC provided both an Apple iPhone running iOS (Apple's iPhone operating system) and a device running an Android operating system. While the iPhones were all different models, and the Android devices included two devices from the same manufacturer and one from a different manufacturer, test information could be compared within networks to assess whether there was a difference between devices running different operating

systems. Table 11 shows a breakdown of the devices using the "advanced" version of the app and that conducted significant numbers of tests during the drive-testing period.

| Device | OS | Network | # Tests | DL_Speed (Mbps) | UL_Speed (Mbps) |
|---|---|---|---|---|---|
| Samsung Galaxy S5 | Android | AT&T Wireless | 1,220 | 7.5 | 2.1 |
| iPhone 6 | iPhone | AT&T Wireless | 1,416 | 6.5 | 1.7 |
| iPhone 5 | iPhone | AT&T Wireless | 387 | 6.4 | 1.6 |
| Samsung Galaxy S5 | Android | US Cellular | 1,599 | 8.2 | 4.8 |
| iPhone 5c | iPhone | US Cellular | 2,435 | 4.9 | 2.4 |
| Verizon Droid Mini | Android | Verizon Wireless | 1,688 | 9.6 | 6.5 |
| Droid Razr | Android | Verizon Wireless | 702 | 9.5 | 6.5 |
| Droid Razr | Android | Verizon Wireless | 1,237 | 14.5 | 7.2 |
| iPhone 5 | iPhone | Verizon Wireless | 2,668 | 10.5 | 5.6 |
| iPhone 5s | iPhone | Verizon Wireless | 408 | 7.9 | 5.1 |
| HTC One | Android | Viaero Wireless | 1,808 | 5.2 | 2.2 |
| HTC One | Android | Viaero Wireless | 4,920 | 5.5 | 2.3 |

Table 11. Summary of devices used on the "advanced" version of the app during drive-testing.

It should be noted that during the drive-testing period, the testing was completed by driving two vehicles on separate routes around the state, with each vehicle carrying a demonstration device from each of the four participating carriers (US Cellular, AT&T, Verizon, and Viaero). With this data collection method, the effort was made to maximize the geography statewide over which data was collected. To accomplish this, the two individuals collecting data rarely covered the same routes, so the devices collecting information weren't typically testing the exact same area. Yet, for the carrier that provided two identical devices (Viaero), the download and upload speeds observed between the two devices were remarkably similar (Table 11). On the AT&T network, the two iPhones collecting data also showed very similar upload and download speeds (Table 11). On the Verizon network, two of the three Android devices showed very similar results, while the two iPhones did not (Table 11).

When comparing Android vs. iOS devices as a whole, the Android download and upload speeds were higher than iOS for all 3 carriers (Table 12). While upload speeds were similar between iOS and Android for Verizon and AT&T, for US Cellular the difference was much larger (Table 12). For US Cellular, this is a comparison between only 2 devices, so it would be interesting to see if this trend is replicated if more devices were used. Regardless, the difference between the two operating systems bears noting.

| Provider | OS | # Tests | DL Speed (Mbps) | UL Speed (Mbps) |
|---|---|---|---|---|
| AT&T | Android | 1,285 | 7.2 | 2.0 |
| AT&T | iOS | 1,803 | 6.5 | 1.7 |
| US Cellular | Android | 1,599 | 8.2 | 4.8 |
| US Cellular | iOS | 2,435 | 4.9 | 2.4 |
| Verizon | Android | 3,632 | 11.3 | 6.8 |
| Verizon | iOS | 3,076 | 10.1 | 5.5 |

Table 12. Comparison of iOS and Android operating systems by carrier.

**Reference Maps**

It can be difficult to make sense of data points when they are simply plotted on a map. For this reason, maps were developed that show the number of tests recorded on a county level, and the average download speed of all of those tests are indicated by the color of the county. These maps also contain some general information displaying each carrier's advertised footprint, speed tests performed, and a summary of the ranks compared to the other carriers. See Appendix A for maps for each provider.

**Conclusions**

The drive testing phase proved to be the most efficient method of collecting data, and any future endeavors should consider the efficacy of the "crowd-sourcing" method before utilizing a similar method of data collection. Relying on the public to download, install, and collect data with the app resulted in few tests with poor spatial distribution on all carriers except Verizon. While our intentions were to include other government agencies in assisting with the data collection, that proved to be difficult to achieve. The application itself held some limitations that were difficult to overcome as well. Any update of the application required the user to re-initiate the app, and if they were part of the "advanced" group, would have to log in once again. It was often difficult to determine when looking at the app whether the user was logged in to the "advanced" group or still collecting data as part of the "standard" group. Also, the app was designed to run in the background of the device it was installed on, but on iOS devices, in particular, it didn't always seem to reliably collect data in the background if the user didn't have the app running on the screen.

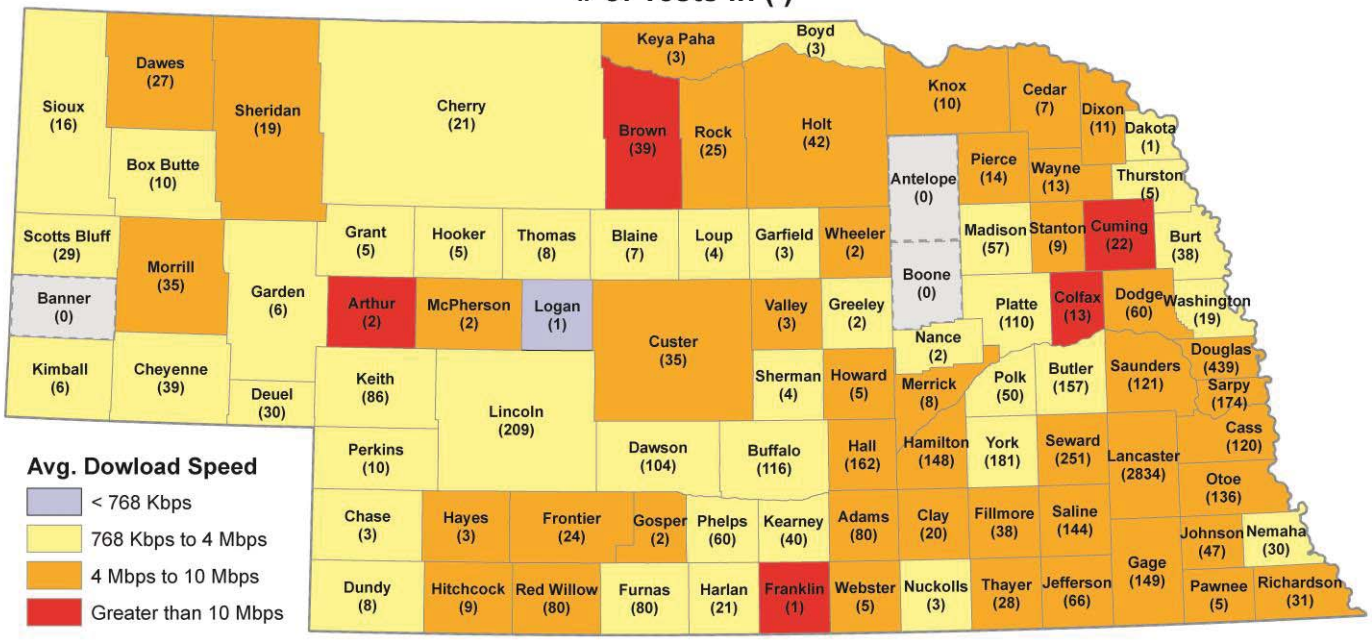
Verizon tested well in nearly all of the metrics tested, from upload and download speeds to connectivity, and when measured against advertised speeds. It also showed the best spatial distribution of any of the carriers, which is a reflection of the Verizon footprint in Nebraska. Prior to drive testing, US Cellular had showed promising results in the few months prior, but still had too few tests to draw any conclusions about the overall performance. The drive testing phase reinforced that those performance tests were not a fluke, and the US Cellular network proved to be robust, as the devices on their network performed well in most of the metrics. Their advertised footprint is the second largest, next to Verizon, and their network showed the highest percentage of tests that met or exceeded the advertised speed tier. Viaero Wireless also benefitted greatly from the drive testing results. After being consistently

ranked as one of the lower performers prior to drive testing, their results improved greatly as more tests were collected. Like US Cellular and Sprint, there were so few tests prior to drive-testing that it was difficult to make any determination about the quality of their network. They ranked 4th in download speeds and 3rd in upload speeds, but in both cases were within range of the other three drive-test participating carriers, and well above the lowest ranking carrier (Sprint). They did rank last in meeting or exceeding their advertised speeds, but they also reported the highest speed tier of the five carriers, meaning that they set a higher bar for themselves than the other carriers. They also report a coverage area that includes a large portion of the western part of the state, with Verizon as the only other carrier that reports a comprehensive coverage area in the panhandle of the state. AT&T was consistently one of the top performers in this group, with the exception of upload speeds. They showed the second highest download speeds, with speeds meeting or exceeding what was advertised at levels slightly below the leaders (Verizon and US Cellular). Their connectivity tests scored the second highest among the carriers tested. Sprint was consistently one of the lowest rated providers in all of the metrics tested, from speed to connectivity. The distribution of Sprint tests showed that most of the tests were taken in the Lincoln and Omaha metro areas, and along Interstate 80. With this distribution, one might expect better test results than what was observed. More tests and a better distribution would assist in determining whether their network performance does actually rank consistently below the others.

While this report contains information that could be very helpful for consumers who are looking at provider information, there is an additional factor that was not addressed at all in this report – cost. The number and variety of mobile wireless plans adds an additional layer of complexity and choice that consumers must factor when deciding on a mobile wireless carrier. This report also does not directly address the fact that the mobile wireless market is ever-changing, especially regarding coverage areas and device capabilities. It is recognized that tests from over a year ago may not accurately reflect the current situation as it relates to coverage and connectivity. Also, the footprints of carriers are in constant flux, with new towers being built and older technology being replaced. Using footprint data that is essentially a year old is not ideal, but it was the best publicly available dataset at the time, in our estimation. It is recommended that carriers continue to report as accurately as possible their footprint and speed tier offerings when submitting data to the FCC or other collecting entities.

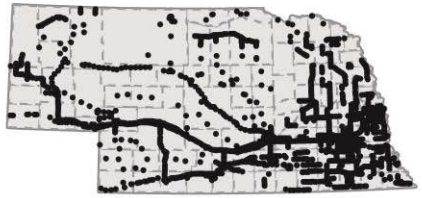
## Appendix A – Statewide Test results by County

## AT&T Testing Summary
## # of Tests in ( )

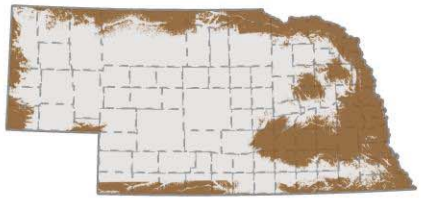



| Rank | Avg. DL Speeds | Avg. Upload Speeds | Meets or Exceeds Adv. Speeds | Connectivity |
|---|---|---|---|---|
| 1 | Verizon Wireless | Verizon Wireless | US Cellular | Viaero Wireless |
| 2 | AT&T | US Cellular | Verizon Wireless | AT&T |
| 3 | US Cellular | Viaero Wireless | AT&T | Verizon Wireless |
| 4 | Viaero | AT&T | Sprint | US Cellular |
| 5 | Sprint | Sprint | Viaero Wireless | Sprint |

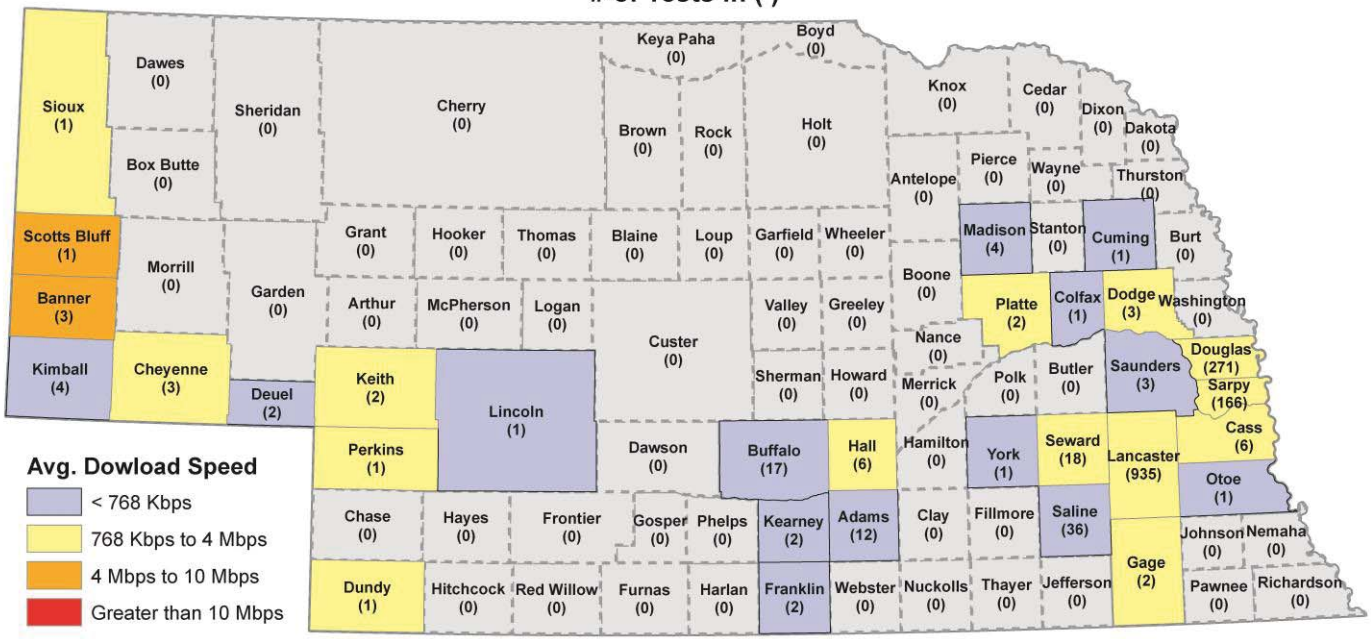
**Distribution of Tests**



**Carrier Advertised Footprint (In Brown)**

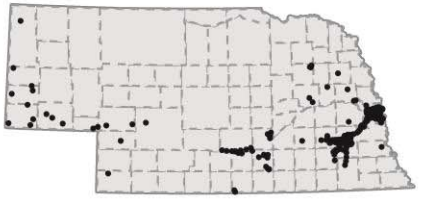


## Sprint Testing Summary
### # of Tests in ( )

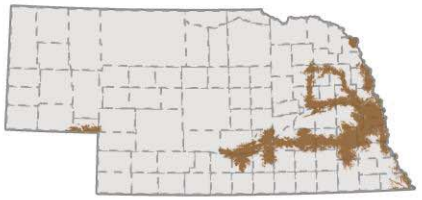



| Rank | Avg. DL Speeds | Avg. Upload Speeds | Meets or Exceeds Adv. Speeds | Connectivity |
|---|---|---|---|---|
| 1 | Verizon Wireless | Verizon Wireless | US Cellular | Viaero Wireless |
| 2 | AT&T | US Cellular | Verizon Wireless | AT&T |
| 3 | US Cellular | Viaero Wireless | AT&T | Verizon Wireless |
| 4 | Viaero | AT&T | Sprint | US Cellular |
| 5 | Sprint | Sprint | Viaero Wireless | Sprint |

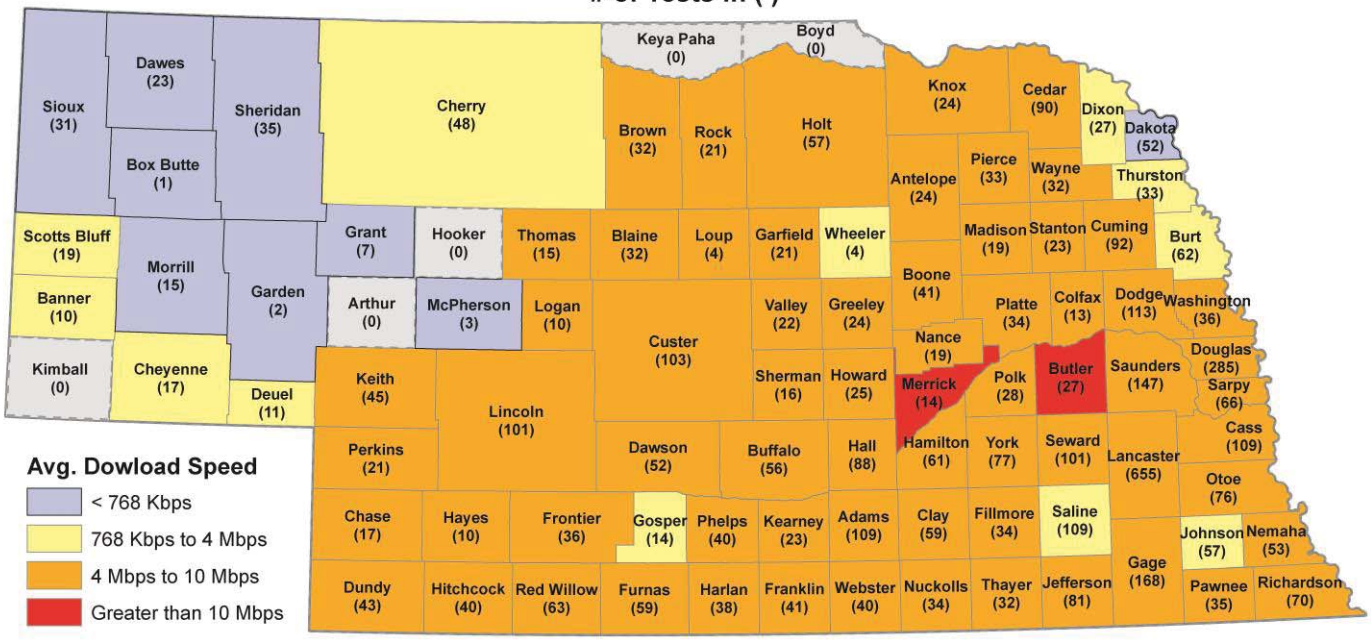
**Distribution of Tests**



**Carrier Advertised Footprint (In Brown)**

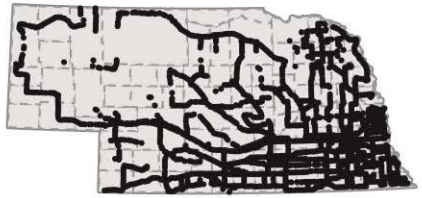


## US Cellular Testing Summary
### # of Tests in ( )

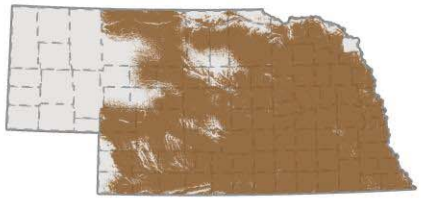



| Rank | Avg. DL Speeds | Avg. Upload Speeds | Meets or Exceeds Adv. Speeds | Connectivity |
|---|---|---|---|---|
| 1 | Verizon Wireless | Verizon Wireless | US Cellular | Viaero Wireless |
| 2 | AT&T | US Cellular | Verizon Wireless | AT&T |
| 3 | US Cellular | Viaero Wireless | AT&T | Verizon Wireless |
| 4 | Viaero | AT&T | Sprint | US Cellular |
| 5 | Sprint | Sprint | Viaero Wireless | Sprint |

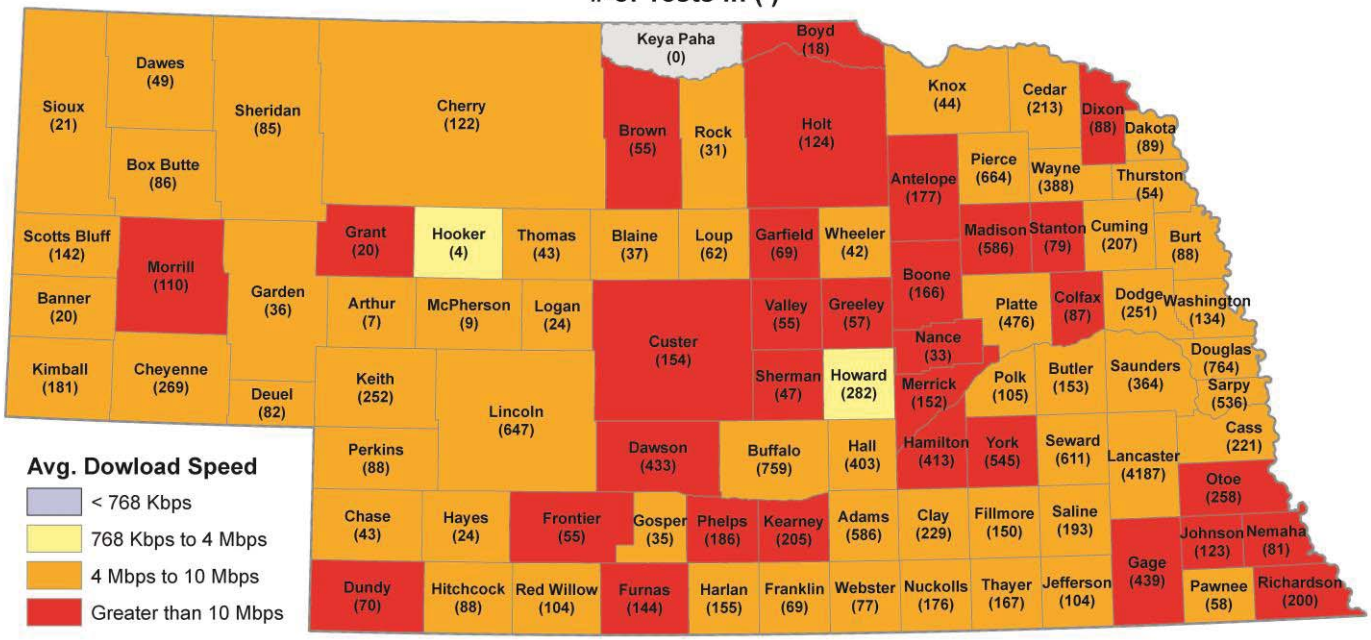
**Distribution of Tests**



**Carrier Advertised Footprint (In Brown)**

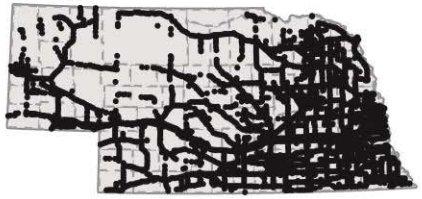


## Verizon Wireless Testing Summary
### # of Tests in ( )

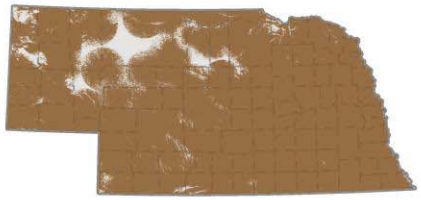



| Rank | Avg. DL Speeds | Avg. Upload Speeds | Meets or Exceeds Adv. Speeds | Connectivity |
|---|---|---|---|---|
| 1 | Verizon Wireless | Verizon Wireless | US Cellular | Viaero Wireless |
| 2 | AT&T | US Cellular | Verizon Wireless | AT&T |
| 3 | US Cellular | Viaero Wireless | AT&T | Verizon Wireless |
| 4 | Viaero | AT&T | Sprint | US Cellular |
| 5 | Sprint | Sprint | Viaero Wireless | Sprint |

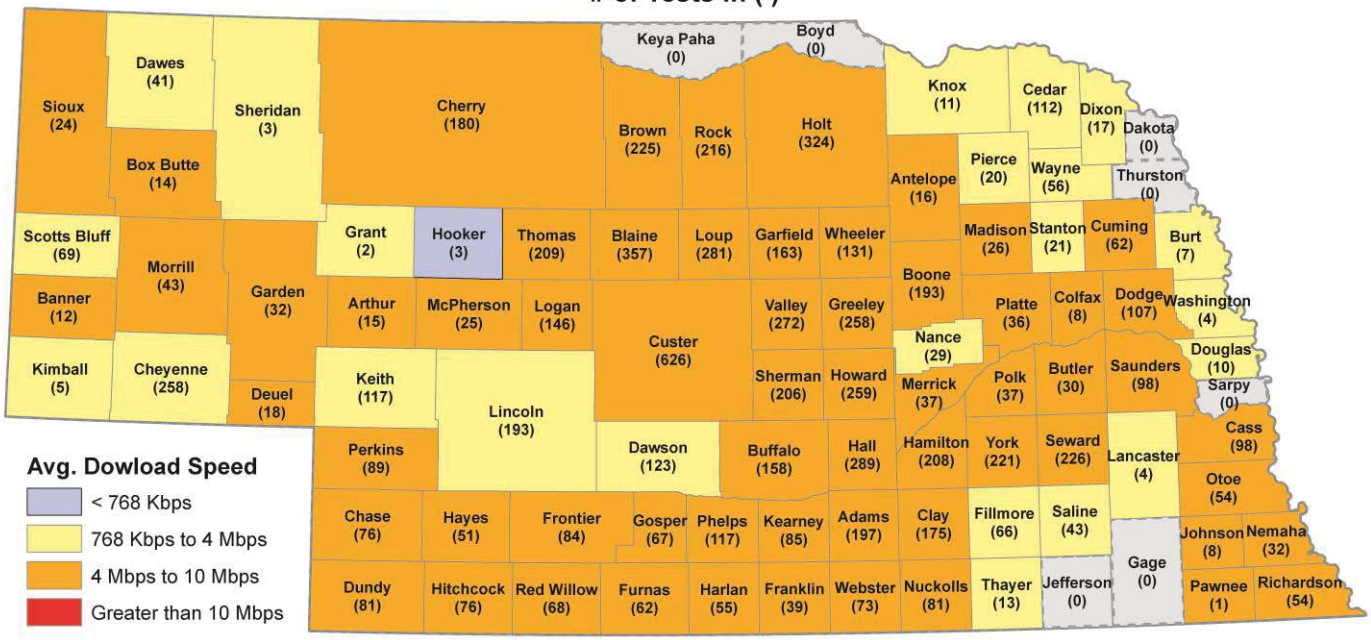
**Distribution of Tests**



**Carrier Advertised Footprint (In Brown)**

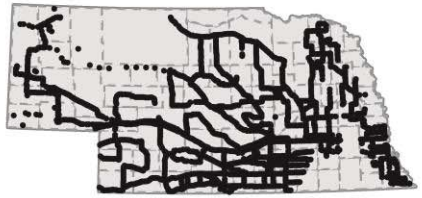
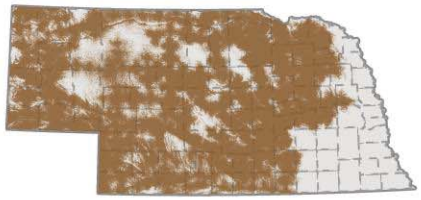


## Viaero Wireless Testing Summary
### # of Tests in ( )




| Rank | Avg. DL Speeds | Avg. Upload Speeds | Meets or Exceeds Adv. Speeds | Connectivity |
|---|---|---|---|---|
| 1 | Verizon Wireless | Verizon Wireless | US Cellular | Viaero Wireless |
| 2 | AT&T | US Cellular | Verizon Wireless | AT&T |
| 3 | US Cellular | Viaero Wireless | AT&T | Verizon Wireless |
| 4 | Viaero | AT&T | Sprint | US Cellular |
| 5 | Sprint | Sprint | Viaero Wireless | Sprint |

**Distribution of Tests**



**Carrier Advertised Footprint (In Brown)**