GN Docket No. 19-367

MOBILITY FUND PHASE II
COVERAGE MAPS INVESTIGATION
STAFF REPORT

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I. INTRODUCTION

1. Bridging the digital divide is the Federal Communications Commission's top priority, and accurate broadband deployment data are critical to this mission. As part of the Commission's ongoing effort to reform universal service funding of mobile wireless services and focus subsidies on unserved areas rather than on areas that already have service, the Commission unanimously adopted a new data collection of 4G Long-Term Evolution (LTE) mobile broadband coverage maps and a challenge process to determine areas eligible for support in the Mobility Fund Phase II (MF-II) auction. The largest mobile providers supported both this data collection and the challenge process. After mobile providers submitted coverage maps to the Commission and during the challenge process, some parties raised concerns regarding the accuracy of the maps submitted by providers. Based on these parties' complaints and its own review of the record, staff became concerned that maps submitted by Verizon, U.S. Cellular, and T-Mobile overstated their coverage and thus were not accurate reflections of actual coverage.

2. Mobile providers are responsible for submitting accurate coverage maps in accordance with the Commission's rules and orders. In response to these concerns and based upon a preliminary staff review of the challenger data, on December 7, 2018, the Commission launched an investigation into whether one or more major mobile providers violated the requirements of the one-time collection of coverage data. The investigation was led by the Rural Broadband Auctions Task Force in coordination with the Office of Economics and Analytics, Enforcement Bureau, Wireless Telecommunications Bureau, Wireline Competition Bureau, and the Office of Engineering and Technology. Commission staff initially requested information directly from several providers in order to understand providers' mapping processes, and later issued subpoenas to Verizon and U.S. Cellular.

3. The Commission dispatched Enforcement Bureau field agents to conduct speed tests of the Verizon, U.S. Cellular, and T-Mobile networks. Commission field agents measured on-the-ground network performance in 12 states across six drive test routes,[1] conducting a total of 24,649 tests and driving nearly 10,000 miles in the course of this testing. Field agents also conducted 5,916 stationary speed tests at 42 distinct locations in nine states. Commission staff analyzed the speed test data from both the staff tests and MF-II challengers' speed tests and compared these test data with the maps submitted for the MF-II data collection as well as with maps providers had previously submitted to the Commission in other proceedings. This report documents the steps and processes undertaken by staff to investigate the coverage maps, analyzes speed tests taken by staff and submitted by challengers, and explains why discrepancies may exist between the submitted maps and actual coverage.

4. Through the investigation, staff discovered that the MF-II coverage maps submitted by Verizon, U.S. Cellular, and T-Mobile likely overstated each provider's actual coverage and did not reflect on-the-ground performance in many instances. Only 62.3% of staff drive tests achieved at least the minimum download speed predicted by the coverage maps—with U.S. Cellular achieving that speed in only 45.0% of such tests, T-Mobile in 63.2% of tests, and Verizon in 64.3% of tests. Similarly, staff stationary tests showed that each provider achieved sufficient download speeds meeting the minimum cell edge probability in fewer than half of all test locations (20 of 42 locations). In addition, staff was unable to obtain any 4G LTE signal for 38% of drive tests on U.S. Cellular's network, 21.3% of drive tests on T-Mobile's network, and 16.2% of drive tests on Verizon's network, despite each provider reporting coverage in the relevant area.

5. The Commission and the public must be able to rely on the deployment data that providers submit to the Commission. Inaccurate data jeopardize the ability of the Commission to focus our limited universal service funds on the unserved areas that need the most support. Accordingly, and considering the findings in this report, the Rural Broadband Auctions Task Force makes the following recommendations:

6. *First*, the Commission should terminate the MF-II Challenge Process. The MF-II coverage maps submitted by several providers are not a sufficiently reliable or accurate basis upon which to complete the challenge process as it was designed. The MF-II Challenge Process was designed to resolve coverage disputes regarding generally reliable maps; it was not designed to correct generally overstated coverage maps.

7. *Second*, the Commission should release an Enforcement Advisory on broadband deployment data submissions, including a detailing of the penalties associated with filings that violate federal law, both for the continuing FCC Form 477 filings and the new Digital Opportunity Data Collection. Overstating mobile broadband coverage misleads the public and can misallocate our limited universal service funds, and thus it must be met with meaningful consequences.

8. *Third,* the Commission should analyze and verify the technical mapping data submitted in the most recent Form 477 filings of Verizon, U.S. Cellular, and T-Mobile to determine whether they meet the Form 477 requirements. Staff recommends that the Commission assemble a team with the requisite expertise and resources to audit the accuracy of mobile broadband coverage maps submitted to the Commission. The Commission should further consider seeking appropriations from Congress to carry out drive testing, as appropriate. While Form 477 currently affords providers significant discretion in

[1] Although staff focused its testing on these six drive test routes in particular states, some tests were taken in neighboring states along several test routes. Specifically, a portion of tests were taken in Arizona on the New Mexico test route; in Kansas, New Mexico, and Texas on the Oklahoma test route; in Wyoming and North Dakota on the Montana test route; and in Massachusetts and New Hampshire on the Vermont test route. Tests on the Alabama and Arizona drive test routes were taken entirely within those states.

determining the extent of their mobile broadband coverage, this discretion does not encompass reporting inaccurate mobile coverage across extended areas in which consumers cannot receive any wireless signal whatsoever.

9. *Fourth*, the Commission should adopt policies, procedures, and standards in the Digital Opportunity Data Collection rulemaking and elsewhere that allow for submission, verification, and timely publication of mobile broadband coverage data. Mobile broadband coverage data specifications should include, among other parameters, minimum reference signal received power (RSRP) and/or minimum downlink and uplink speeds, standard cell loading factors and cell edge coverage probabilities, maximum terrain and clutter bin sizes, and standard fading statistics. Providers should be required to submit actual on-the-ground evidence of network performance (e.g., speed test measurement samplings, including targeted drive test and stationary test data) that validate the propagation model used to generate the coverage maps. The Commission should consider requiring that providers assume the minimum values for any additional parameters that would be necessary to accurately determine the area where a handset should achieve download and upload speeds no less than the minimum throughput requirement for any modeling that includes such a requirement.

10. Because detailed information on propagation model parameters and deployed infrastructure is necessary to fully verify the engineering assumptions inherent in mobile coverage data, the Commission should collect specific information used in the models, including the locations and specific characteristics of certain cell sites used for mobile wireless service, the modeling software used, the entire link budget, the sources of terrain and clutter data, and clutter values. The Commission should require engineering certifications of mobile broadband deployment data submissions. And the Commission should convene a workshop of stakeholders on best practices for the generation and submission of accurate mobile broadband deployment data including speed testing methodologies.

II. BACKGROUND

11. The Commission relies upon coverage maps submitted by providers in accordance with data collection rules and specifications adopted through notice and comment rulemakings. For almost two decades, the Commission has relied on FCC Form 477 to collect data on mobile services. In 2000, when the Commission first established the form, the Commission focused on subscription data at a broad level, envisioning that the data collected would help it better assess the availability of broadband services, such as high-speed Internet access service, and the development of competition for telephone service.[2] A decade later, the Commission recognized that such a high-level data collection, focused on subscriptions, was insufficient. Accordingly, in conjunction with reforms to reorient the Universal Service Fund toward supporting broadband deployment,[3] the Commission revised Form 477 to collect data on deployments at a granular level: census blocks for fixed services and the boundaries of coverage areas for mobile services.[4]

12. The Commission adopted a framework for an MF-II auction to focus our limited universal service funds to the areas most in need of support.[5] The Commission defined the eligible areas

[2] *Local Competition and Broadband Reporting*, Report and Order, 15 FCC Rcd 7717, 7718, 7719, 7752-53, paras. 1, 3, 69-72 (2000).

[3] *Connect America Fund et al.*, Report and Order and Further Notice of Proposed Rulemaking, 26 FCC Rcd 17663, 17682 (2011) (*USF/ICC Transformation Order*).

[4] *Modernizing the FCC Form 477 Data Program*, Report and Order, 28 FCC Rcd 9887 (2013).

[5] *Connect America Fund; Universal Service Reform – Mobility Fund*, Report and Order and Further Notice of Proposed Rulemaking, 32 FCC Rcd 2152, 2157-88, paras. 16-83 (2017) (*MF-II Report & Order*).

for MF-II as those areas that lacked unsubsidized 4G LTE service.[6] The Commission initially decided to use providers' Form 477 mobile broadband coverage data to determine which areas lack service in advance of the MF-II auction.[7] In light of concerns raised in the record about the accuracy and suitability of providers' Form 477 submissions for use in MF-II—in particular, the absence of standardization among coverage maps, as well as the extent of areas reported on Form 477 as having 4G LTE deployed, despite numerous on-the-ground reports of a lack of mobile broadband—the Commission also established a challenge process by which certain entities could contest the coverage data.[8] Responding to lingering concerns about whether the Commission could rely on providers' Form 477 submissions even as a starting point for a challenge process, the Commission decided to conduct a one-time, standardized collection of coverage data specifically for purposes of MF-II that would address the reliability issues with the Form 477 data.[9]

13. The process adopted by the Commission was largely based upon an industry consensus proposal to hold a one-time, standardized collection of 4G LTE coverage data, with certain modifications to the proposed standardized propagation parameters.[10] Draft specifications were included in the public version of the order establishing the challenge process, and this order was released to the public in advance of the August 2017 Commission meeting. The Commission ultimately adopted a cell edge probability in the middle of the range supported in the record in order to avoid parameters for the one-time collection that would be lower than the performance requirement for winners in the MF-II auction.[11] The adopted specifications thus sought to avoid the possibility that bidders could win funding in the auction without having to commit to additional deployment.[12] In reaching this conclusion, the

[6] *Id.* at 2173, para. 51.

[7] *Id.* at 2175, para. 56 (concluding that "Form 477 data is the most reliable data currently available for the purpose of determining the coverage levels of existing mobile services"). While the Commission acknowledged the concerns raised by parties that opposed use of these data, it explained that "none of the commenters criticizing the Form 477 data has identified a better data source for moving forward expeditiously to implement MF-II." *Id.* at 2177, para. 58.

[8] *Id.* at 2177, para. 58 ("Recognizing that no data source – including Form 477 – will be perfectly accurate, we will utilize a challenge process to improve the accuracy of the coverage analysis underlying eligibility determinations reached in reliance on Form 477 data.").

[9] *Connect America Fund; Universal Service Reform – Mobility Fund*, Order on Reconsideration and Second Report and Order, 32 FCC Rcd 6282, 6299-6302, paras. 35-39 (2017) (*MF-II Challenge Process Order*).

[10] *Id*. Based upon record evidence, the adopted parameters were tailored for rural areas to include an 80% cell edge probability and a 30% cell loading factor. *Id.* at 6298, 6300-01, paras. 34 n.89, 36-37 (citing support for a 70% cell edge probability and 30% cell loading factor and explaining that the adopted parameters "exceed the parameters that wireless operators typically use when deploying networks into previously-unserved areas"). Also differing from CTIA's proposal, the specifications adopted by the Commission did not specify support for VoLTE or particular Multiple-Input Multiple-Output (MIMO) antenna configuration assumptions but did require disclosure of the modeled signal strength and range of signal loss values associated with terrain clutter. *Id*. at 6302-03, paras. 39-40 & n.111. The adopted parameters did not otherwise deviate significantly from the industry consensus proposal. *Id.* at 6302, para. 39.

[11] *Id.* at 6300, para. 36 ("[W]e estimate that the cell area median download speed in the cell areas associated with CTIA's proposed parameters would be significantly in excess of 10 Mbps and therefore higher than the MF-II performance requirement.").

[12] *Id.* ("Adopting the higher cell edge probability and cell loading factor parameters in CTIA's proposal, however, would increase the likelihood that MF-II funds would be directed to areas that already meet the MF-II performance requirement of a 10 Mbps median download speed.").

Commission sought to "appropriately balance the concern of misrepresenting coverage with our priority of directing our limited universal service funds to areas most in need of support."[13]

14. Under the adopted framework, providers would first submit qualified, 4G LTE coverage data as part of the one-time collection, and from these data, combined with current subsidy data from the Universal Service Administrative Company (USAC), the Commission would release a map of areas presumptively eligible for MF-II support.[14] Parties that believed the coverage data were inaccurate would next be able to conduct on-the-ground speed testing and submit results to the Commission during the challenge process.[15] Providers whose coverage data were challenged would then have an opportunity to respond,[16] and ultimately challenges would be adjudicated by Commission staff.[17] Lastly, the Commission would release a final map of eligible areas that reflected the results of successful challenges.[18] This final map of eligible areas would ultimately serve as the basis for where support would be offered in the MF-II auction.[19]

15. The data specifications adopted for the one-time data collection were the most granular and standardized that the Commission had ever adopted for assessing mobile wireless coverage. The industry consensus proposal, which the adopted specifications largely mirrored, was supported by most parties in the proceeding, and no parties sought reconsideration of the Commission's decision to use the adopted specifications to establish eligibility for MF-II funding.

16. Under the one-time data collection framework, each mobile service provider that had previously reported 4G LTE coverage as part of its Form 477 filings was required to submit and certify 4G LTE coverage maps showing where its propagation models predicted that devices would receive a download speed of at least 5 Mbps with an 80% cell edge probability and a 30% cell loading factor,[20] or alternatively certify that it provides no such service.[21] In addition to these specifications, the data collection required that filers report an outdoor level of coverage, that coverage boundaries have a resolution of 100 meters or better, and that filers use an appropriate clutter factor and terrain model with a resolution of 100 meters or better.[22] Providers were also required to report the propagation modeling software, spectrum band or bands, bandwidth, clutter factor categories (and associated loss value), and

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[13] *Id.* at 6301, para. 36.

[14] *Id.* at 6296, para. 28; *Procedures for the Mobility Fund Phase II Challenge Process*, Public Notice, 33 FCC Rcd 1985, 1987-89, paras. 4-8 (WCB/WTB 2018) (*MF-II Challenge Process Procedures PN*).

[15] *MF-II Challenge Process Order*, 32 FCC Rcd at 6296-97, para. 29; *MF-II Challenge Process Procedures PN*, 33 FCC Rcd at 1989-90, para. 9.

[16] *See generally MF-II Challenge Process Order*, 32 FCC Rcd at 6311-12, paras. 58-60; *MF-II Challenge Process Procedures PN*, 33 FCC Rcd at 2005-13, paras. 43-65.

[17] *MF-II Challenge Process Order*, 32 FCC Rcd at 6313-14, paras. 63-64.

[18] *MF-II Challenge Process Procedures PN*, 33 FCC Rcd at 2014, para. 67.

[19] *MF-II Report & Order*, 32 FCC Rcd at 2181-82, paras. 66-67.

[20] *MF-II Challenge Process Order*, 32 FCC Rcd at 6287-88, 6298, paras. 11, 34. We use the term "coverage map" throughout this report to refer specifically to these predictive maps based upon standardized propagation models.

[21] *See Instructions for Filing 4G LTE Coverage Data to Determine Areas Presumptively Eligible for Mobility Fund II Support,* Public Notice, 32 FCC Rcd 7023 (WCB/WTB 2017).

[22] *MF-II Challenge Process Order*, 32 FCC Rcd at 6302, para. 39.

signal strength used to generate the coverage maps.[23] Filers were otherwise required to use the optimized RF propagation models and parameters used in their normal course of business.[24]

17. Providers submitting coverage maps were also required to submit a list of at least three handsets that interested parties could use in conducting speed tests on the provider's network for the MF-II challenge process, at least one of which must run the Android operating system and one of which must support industry-standard drive test software.[25] Along with these data, filers were required to submit a certification by a qualified engineer that the propagation maps and model details reflected the filer's coverage in accord with all required parameters at the time the map was generated.[26] Submissions for the one-time collection of 4G LTE coverage data were due on January 4, 2018.[27] In total, 48 mobile service providers filed the required data, with an additional five providers filing certifications that they did not provide 4G LTE service meeting the specifications of the data collection.[28]

18. In February 2018, Commission staff released the map of areas presumptively eligible for MF-II support.[29] Using the one-time collection of qualified 4G LTE coverage data—i.e., coverage based upon mobile service providers' propagation models that predicted a download speed of at least 5 Mbps—the Commission considered any areas that did not have qualified 4G LTE coverage to be presumptively eligible for MF-II support.[30] In determining whether an area lacked qualified 4G LTE coverage, the Commission excluded from each provider's submitted coverage data those areas where the provider receives legacy frozen high-cost support, factoring in subsidy data from USAC.[31]

19. *MF-II Challenger Speed Tests*. After release of the map of presumptively eligible areas, mobile service providers, state, local, and Tribal government entities, and other interested parties granted a waiver were eligible to submit challenges in the challenge process via an online system operated by USAC.[32] Challengers that requested access to the USAC MF-II Challenge Portal were able to access the provider-specific coverage maps, after agreeing to keep the coverage data confidential, and to file challenges to providers' coverage claims by submitting speed test data.[33] Challengers were required to conduct speed tests pursuant to a number of standard parameters using specific testing methods on the

[23] *Instructions for Filing 4G LTE Coverage Data to Determine Areas Presumptively Eligible for Mobility Fund II Support*, Public Notice, 32 FCC Rcd 7023, 7024-25 (WCB/WTB 2017) (*MF-II 4G LTE Data Collection PN*).

[24] *MF-II Challenge Process Order*, 32 FCC Rcd at 6302, para. 39.

[25] *MF-II 4G LTE Data Collection PN*, 32 FCC Rcd at 7024-28; *Mobility Fund Phase II Challenge Process Handsets and Access Procedures for the Challenge Process Portal*, Public Notice, 32 FCC Rcd 10372, 10373-74, para. 5 (WCB/WTB 2017) (*MF-II Challenge Process Handsets and Portal Access PN*).

[26] *MF-II Challenge Process Order*, 32 FCC Rcd at 6302, para. 39.

[27] *Responses to the Mobility Fund Phase II 4G LTE Data Collection Are Due by January 4, 2018*, Public Notice, 32 FCC Rcd 7431 (WCB/WTB 2017).

[28] Appendix C contains a complete list of the 48 providers that submitted MF-II 4G LTE coverage data.

[29] *Mobility Fund Phase II Initial Eligible Areas Map Available; Challenge Window Will Open March 29, 2018*, Public Notice, 33 FCC Rcd 2041 (WCB/WTB 2018) (*MF-II Initial Eligible Areas Map PN*).

[30] *MF-II Challenge Process Procedures PN*, 33 FCC Rcd at 1987, para. 4 (adopting a "methodology for generating the initial map of areas presumptively eligible for MF-II support, i.e., those areas lacking unsubsidized qualifying coverage by any provider").

[31] *See id.* at 1987-88, paras. 4-5.

[32] *MF-II Challenge Process Order*, 32 FCC Rcd at 6303-04, paras. 42-43.

[33] *Id.* at 6296-97, para. 29; *MF-II Challenge Process Handsets and Portal Access PN*, 32 FCC Rcd at 10375-76, paras. 7-10.

providers' pre-approved handset models.[34] The Commission adopted the requirement that challengers use one of the handsets specified by the provider primarily to avoid inaccurate measurements resulting from the use of an unsupported or outdated device—e.g., a device that does not support all of the spectrum bands for which the provider has deployed 4G LTE.[35] The window to file challenges was open from March 29, 2018, through November 26, 2018.[36]

20. During the eight-month challenge window, 106 entities were granted access to the MF-II Challenge Portal.[37] Of the 106 entities granted access to the MF-II Challenge Portal, 38 were mobile service providers required to file Form 477 data, 19 were state government entities, 27 were local government entities, 16 were Tribal government entities, and six were other entities that filed petitions requesting, and were each granted, a waiver to participate.[38]

21. During the window to file challenges in the MF-II challenge process, 21 challengers submitted 20.8 million speed tests across 37 states.[39] Of these submitted tests, the Challenge Portal validated approximately 20.5 million speed tests and these tests were thus considered to be valid challenges.[40] Challengers then certified almost 19.8 million valid tests by the close of the challenge window. Approximately 4 million speed tests fell outside of the reported 4G LTE coverage area for the provider tested—leaving approximately 15.9 million tests within areas reported as covered.[41]

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[34] *MF-II Challenge Process Order*, 32 FCC Rcd at 6307-10, paras. 49-52.

[35] *See id.* at 6308, para. 50; *MF-II Challenge Process Handsets and Portal Access PN*, 32 FCC Rcd at 10372-73, 10375, paras. 3, 6 (declining to adopt a proposal to limit the cost of handsets because doing so would "reduce the accuracy of data collected . . . by limiting the number of handsets compatible with the latest versions of drive test software and mobile network technologies.").

[36] *MF-II Initial Eligible Areas Map PN*, 33 FCC Rcd at 2041 (announcing that the challenge window would open on March 29, 2018 and conclude on August 27, 2018); *Connect America Fund; Universal Service Reform – Mobility Fund*, Order, Notice of Proposed Rulemaking, and Memorandum Opinion and Order, 33 FCC Rcd 8463, 8465, para. 6 (2018) (*MF-II Challenge Process Extension Order*) (extending the challenge window by 90 days to run through November 26, 2018).

[37] *Mobility Fund Phase II Challenge Process Portal Update: November 2018*, Public Notice, 33 FCC Rcd 11706 (WCB/WTB 2018) (*November MF-II Challenge Portal Update PN*).

[38] *See, e.g.*, *Petition of the Mississippi Farm Bureau Federation for Waiver to Participate in Mobility Fund II Challenge Process*, Order, 33 FCC Rcd 8093 (WTB 2018); *see also MF-II Challenge Process Handsets and Portal Access PN*, 32 FCC Rcd at 10376, para. 10; *MF-II Challenge Process Order*, 32 FCC Rcd at 6304, para. 43 n.119. No petitions to participate in the challenge process were denied.

[39] *November MF-II Challenge Portal Update PN*, 33 FCC Rcd at 11706. While challenger speed tests reported a variety of measurement methods and measurement applications, the vast majority of speed tests submitted by challengers appeared to be drive tests where speed readings were recorded at frequent intervals (i.e., every 1-2 seconds) along the route driven. Three Tribal government entities submitted 4,869 speed tests across four states (Idaho, Washington, Kansas, and Nebraska).

[40] The USAC MF-II Challenge Portal system performed automated validation on speed test data submitted by challengers, rejecting as invalid any speed tests that failed specific validation checks. For example, among other checks, the system validated that each record: recorded the latitude and longitude of the test in decimal degrees with a precision of at least five decimal places; recorded a timestamp value between 6:00 AM and 12:00 AM (midnight) from Feb. 27, 2018 through the date of submission; and identified a valid combination of provider and device, per the list of providers' pre-approved handsets. *See Mobility Fund Phase II Data Specifications and Error Codes* (Mar. 20, 2018), https://www.usac.org/_res/documents/hc/pdf/MF-II-Challenge-Process_Data-Specifications.pdf.

[41] In order to facilitate analysis of challenger speed test data as compared to the coverage maps, we excluded tests that fell outside the reported coverage of the tested provider. We also excluded from our calculations, tables, and

22. As shown in Table 1, challengers submitted speed tests of all nationwide providers' networks, as well as some regional providers' networks. These data therefore included providers other than the three (Verizon, U.S. Cellular, and T-Mobile) for which staff were most concerned with overstated coverage. When aggregated across all challengers and states, 66.4% of challenger-submitted speed tests recorded no download speed whatsoever and 87.2% of the submitted challenger speed tests recorded download speeds below the minimum speed required (5 Mbps). A detailed analysis of the challenger speed testing is provided in Appendix B, and the full dataset of those speed tests is available for download on the Commission's website.[42]

Table 1. Within-Coverage, Certified Challenger Speed Test Results by Provider Challenged

Provider Name	Test Count Zero Mbps	Test Count > 0 & < 5 Mbps	Test Count ≥ 5 Mbps	Test Count Total	Percentage ≥ 5 Mbps
Verizon	5,724,909	1,453,000	1,016,652	8,194,561	12.41%
T-Mobile	2,615,362	1,158,577	170,025	3,943,964	4.31%
AT&T	1,970,651	629,014	778,859	3,378,524	23.05%
Sprint	167,767	55,419	63,197	286,383	22.07%
US Cellular	468	2,216	387	3,071	12.60%
All Other Providers	99,756	18,449	2,795	121,000	2.31%
Total	**10,578,913**	**3,316,675**	**2,031,915**	**15,927,503**	**12.76%**

23. Under the framework adopted by the Commission, the USAC MF-II Challenge Portal system validated challenger-submitted speed tests by overlaying a uniform grid of one square kilometer cells and determining whether challengers submitted evidence of insufficient coverage in at least 75% of the challengeable portion of each grid cell.[43] Across the 126,164 grid cells for which challengers submitted and certified challenges, speed tests with download speeds of less than 5 Mbps meeting the 75% coverage threshold were certified in 45,309 grid cells (36% of the challenged grid cells), and were thus presumptively successful challenges.[44]

charts an additional 170 speed tests for T-Mobile and one speed test for Verizon that recorded a negative download speed or a positive signal strength RSRP, which are clearly erroneous data that were not rejected during automated system validations. An analysis quantifying anomalous and erroneous data within the challenger speed test results is included in Appendix B.

[42] The complete challenger speed test data associated with valid, certified challenges can be downloaded at https://www.fcc.gov/mobility-fund-phase-2#data, alongside the file specifications for these data files. Please note that certain data fields have been masked to maintain the confidentiality of entities that submitted challenges.

[43] *MF-II Challenge Process Order*, 32 FCC Rcd at 6310-11, paras. 53-57.

[44] While challengers were required to submit data for all speed tests, including those showing speeds greater than or equal to 5 Mbps, the system calculated whether a challenger had submitted evidence covering 75% of the challengeable portion of each grid cell only considering tests with download speeds below 5 Mbps. *MF-II Challenge Process Procedures PN*, 33 FCC Rcd at 2013-14, para. 66. The Commission, however, emphasized that staff would adjudicate each challenge on a preponderance-of-the-evidence standard based on all the evidence submitted by challengers and challenged parties, irrespective of the presumptive status calculated by the system. *MF-II Challenge Process Order*, 32 FCC Rcd at 6313, para. 63 & n.180 (adopting "a preponderance of the evidence standard to evaluate the merits of any challenges" but retaining "discretion to discount the weight of a challenger's evidence if a challenge appears designed to undermine the goals of MF-II").

24. *Allegations of Inaccurate MF-II Coverage Data*. While the challenge process was underway, certain parties raised concerns in the record about the accuracy of the coverage maps submitted by certain nationwide providers.[45] Smith Bagley (d/b/a Cellular One) submitted maps of its service area in Arizona overlaid with Verizon's publicly-stated 4G LTE coverage and the preliminary results of drive tests that Smith Bagley had conducted.[46] Smith Bagley asserted that, for large stretches of road in areas where Verizon reported coverage, its drive testers recorded no 4G LTE signal on Verizon's network.[47] Smith Bagley argued that the "apparent scope of Verizon's inaccurate data and overstated coverage claims is so extensive that, as a practical matter, the challenge process will not and cannot produce the necessary corrections."[48]

25. The Vermont Department of Public Service also participated in the challenge process "primarily to demonstrate that good cause exists to expand the territory that is deemed eligible" for MF-II support.[49] As part of a public report detailing its experience, Vermont published a map showing its speed test results which contradicted the coverage maps in Vermont of U.S. Cellular, T-Mobile, and Verizon, among others. This map included information on the approximately 187,000 speed tests submitted by Vermont, including download speed, latency, and signal strength.[50] In the report, Vermont detailed that 96% of speed tests for U.S. Cellular, 77% for T-Mobile, and 55% for Verizon failed to receive download speeds of at least 5 Mbps.[51]

26. The Rural Wireless Association (RWA) similarly criticized the coverage data submitted by Verizon and later by T-Mobile. RWA initially submitted a map created by engineers working for RWA member Panhandle Telecommunication Systems, Inc. (Panhandle) that estimated Verizon's coverage in the Oklahoma panhandle to cover less than half of the area Verizon publicly claims to be

[45] *See Universal Service Reform – Mobility Fund*, WC Docket No. 10-90, WT Docket No. 10-208, Informal Request of the Rural Wireless Association, Inc. for Commission Action (Aug. 6, 2018) (First RWA MF-II Informal Request); *Universal Service Reform – Mobility Fund*, WC Docket No. 10-90, WT Docket No. 10-208, Informal Request of the Rural Wireless Association, Inc. for Commission Action (Dec. 26, 2018) (Second RWA MF-II Informal Request); *Universal Service Reform – Mobility Fund*, WC Docket No. 10-90, WT Docket No. 10-208, Informal Request of Smith Bagley, Inc. for Commission Action (Oct. 18, 2018) (SBI MF-II Informal Request); Letter from Caressa D. Bennet, General Counsel, RWA, and Erin P. Fitzgerald, Regulatory Counsel, RWA, to Marlene H. Dortch, Secretary, FCC, WC Docket No. 10-90, WT Docket No. 10-208 (Apr. 20, 2018) (April 20, 2018 RWA *Ex Parte* Letter); Letter from Mark Seagren, CTO/Senior RF Engineer, 4G Unwired, Inc., Lynn R. Merrill, P.E., President and CEO, Monte R. Lee and Company, Howard Gorter, P.E., Executive Vice President, Engineering Operations, Palmetto Engineering & Consulting, and Jeff Little, President – Central Division, CT&T, to Marlene H. Dortch, Secretary, FCC, WC Docket No. 10-90, WT Docket No. 10-208 (July 5, 2018) (July 5, 2018 RF Engineering Coalition *Ex Parte* Letter).

[46] SBI MF-II Informal Request at Ex. B.

[47] *Id.* at 8-9; *id.* at Ex. B.

[48] *Id.* at 5.

[49] Letter from Caressa D. Bennet, General Counsel, RWA, to Marlene H. Dortch, Secretary, FCC, WC Docket No. 10-90, WT Docket No. 10-208 at Ex. 1 (Feb. 13, 2019) (Feb. 13, 2019 RWA *Ex Parte* Letter); Vermont Department of Public Service, Mobile Wireless in Vermont at 2 (2019), *available at* https://publicservice.vermont.gov/content/mobile-wireless-drive-test-report-january-2019 (Vermont Mobile Wireless Report).

[50] Vermont Mobile Wireless Report at 6; Vermont Wireless Drive Test Results, Vermont Department of Public Service, http://vtpsd.maps.arcgis.com/apps/webappviewer/index.html?id=444a3d49c2374d509958f1c0e1d0d21b (last visited Sept. 30, 2019).

[51] *See* Vermont Mobile Wireless Report at 4.

covered.[52] RWA subsequently asserted in an informal request for Commission action that the results of testing by Panhandle similarly "indicates that Verizon has overstated its coverage by more than 50 percent in the Oklahoma Panhandle."[53] RWA members, in coordination with a coalition of radiofrequency (RF) engineers, also raised specific concerns about technical assumptions made by Verizon in its propagation modeling.[54] In addition, RWA argued that T-Mobile's coverage was overstated in Alabama, Oklahoma, and Montana, where speed testing by three of its members showed that 95.8% of all tests failed to achieve download speeds of at least 5 Mbps.[55] RWA alleged that T-Mobile relied upon facilities with insufficient backhaul in Montana and additionally that in Oklahoma "the installation of the [backhaul] circuits occurred after the January 4, 2018 deadline [to submit 4G LTE data], meaning that the coverage claimed by T-Mobile could not have been in place prior to the January 4, 2018 deadline."[56]

27. Verizon and T-Mobile directly responded to several of the claims made by RWA and its members. Verizon argued that the map submitted by Panhandle "underestimates Verizon's Mobility Fund coverage because it fails to take into account all of the Verizon cell sites that provide coverage to customers in the Oklahoma Panhandle."[57] Verizon also rejected the comparison to the Panhandle map because it did not reflect the standardized parameters adopted for MF-II, and because it "reflects an uplink constraint, which the Commission specifically declined to include in the Mobility Fund mapping specifications."[58] Additionally, Verizon specifically responded to a number of technical claims made by RWA's engineers, explaining that it used more than 2,500 separately-calibrated propagation models for different markets to generate the MF-II coverage map.[59]

28. T-Mobile similarly rejected RWA's contention that its coverage maps were incorrect because they did not reflect service as of January 2018. Citing its required construction notifications on file with the Commission, T-Mobile explained that it "was required to provide signal coverage and offer service to at least 40 percent of the geographic area covering each of the three licenses [for which it received a waiver of the Commission's rules] and file the necessary construction notifications with the Commission by January 21, 2018."[60]

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[52] April 20, 2018 RWA *Ex Parte* Letter, App. C at 6.

[53] First RWA MF-II Informal Request at 6.

[54] Letter from Caressa D. Bennet, General Counsel, RWA, and Erin P. Fitzgerald, Regulatory Counsel, RWA, to Marlene H. Dortch, Secretary, FCC, WC Docket No. 10-90, WT Docket No. 10-208 at Attachment A, Attachment B (Apr. 30, 2018); July 5, 2018 RF Engineer Coalition *Ex Parte* Letter at 4-5; Letter from Mark Seagren, CTO/Senior RF Engineer, 4G Unwired, Inc., Lynn R. Merrill, P.E., President and CEO, Monte R. Lee and Company, Howard Gorter, P.E., Executive Vice President, Engineering Operations, Palmetto Engineering & Consulting, and Jeff Little, President – Central Division, CT&T, to Marlene H. Dortch, Secretary, FCC, WC Docket No. 10-90, WT Docket No. 10-208 at 1-3 (Aug. 3, 2018) (Aug. 3, 2018 RF Engineering Coalition *Ex Parte* Letter). These parties generally assert that Verizon's propagation models did not adequately account for local terrain and clutter conditions.

[55] Second RWA MF-II Informal Request at 5-7, 8-9.

[56] *Id.* at 8-10, 14-15 (emphasis removed).

[57] Letter from Alan Buzacott, Executive Director, Federal Regulatory Affairs, Verizon, to Marlene H. Dortch, Secretary, FCC, WT Docket No. 10-208, WC Docket No. 10-90 at 3 (July 27, 2018) (July 27, 2018 Verizon *Ex Parte* Letter).

[58] *Id.* at 3 (citing *MF-II Challenge Process Order*, 32 FCC Rcd at 6293, para. 19).

[59] *Id.* at 2-3.

[60] Letter from Cathleen A. Massey, Vice President, Federal Regulatory, T-Mobile, to Marlene H. Dortch, Secretary, FCC, WC Docket No. 10-90, WT Docket No. 10-208 at 6 & n.21 (Jan. 30, 2019).

29. No other provider that filed coverage data submitted anything in the record seeking to defend its maps.

30. *Initiation of the Coverage Map Investigation*. Considering the claims filed in the record, initially regarding Verizon's coverage, Commission staff requested information from Verizon about the parameters and other data used to generate its coverage maps. The information submitted by Verizon led the staff to become concerned about whether Verizon, as well as other providers, may have modeled their propagation in a way that did not account for any uplink channel capacity, and if that was the case, whether this could be responsible for inaccurate projections. In a mobile wireless network, the uplink channel refers to the uplink connection required for a user of a mobile device to transmit to a cell phone tower or building mounted antenna, and for that antenna to successfully receive the user's transmission. For a device to be able to upload data to a network, there must be an uplink connection and sufficient uplink channel capacity. Mobile Internet traffic requires both downlink transmission of data packets from the sender to the receiver (i.e., base station to handset) as well as uplink transmissions from the receiver to the sender (i.e., handset to base station) acknowledging receipt of packets as well as initiating transmission from the handset to the network.

31. In October and November 2018, staff made inquiries directly to each of the five largest providers—AT&T, Sprint, T-Mobile, Verizon, and U.S. Cellular—to better understand the assumptions underlying each provider's propagation models. In particular, staff inquired whether each provider's model used to generate its MF-II 4G LTE coverage data took into consideration an uplink channel constraint—that is, the limitation imposed by uplink channel capacity—and if so, what was the minimum uplink channel throughput (i.e., upload speed) assumed in the model.[61] Staff also asked whether the provider uses an uplink channel constraint when generating maps in its normal course of business. Three of the providers responded that their MF-II propagation models provided for sufficient uplink channel throughput.[62] U.S. Cellular and Verizon, however, responded that their MF-II propagation models did not take into account any uplink channel.[63] Staff requested additional propagation model details from Verizon, including link budget and infrastructure information in several of the areas identified by parties in the record as having insufficient coverage. Verizon responded with the technical parameters and infrastructure details requested by staff along with a request for confidential treatment of its response.[64]

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[61] This report uses different terms to discuss different aspects of how uplink works in a mobile network. In order to provide users with an uplink speed, a network must first provide uplink coverage and then the network must have some uplink capacity. Uplink capacity only describes the uplink bandwidth, but a network needs to provide both uplink coverage and uplink capacity to provide users with uplink speed. The uplink constraint on a network — effectively, how far the network can project uplink coverage — could be either uplink coverage, uplink capacity, or both.

[62] From their responses to staff inquiries, AT&T confirmed that the uplink channel throughput associated with its maps was more than sufficient to sustain download speeds of 5 Mbps; Sprint stated that it used an uplink channel constraint of between {[ ]} and {[ ]}; and T-Mobile stated that it used an uplink constraint of {[ ]}. Material highlighted and set off by double brackets {[ ]} is redacted from the public version of this document.

[63] {[ ]}

[64] Staff thereafter requested that Verizon generate and submit new 4G LTE coverage data that took into account an uplink channel constraint. After the staff request, Verizon initially indicated that it would be willing to file new coverage data that would take into account an uplink channel constraint, and that such data would be {[ ]}. However, prior to the date by which staff requested Verizon file new data, the Commission announced the launch of an investigation into whether one or more major providers violated the MF-II requirements. Verizon did not file the requested new coverage data.

32. Shortly after the close of the challenge window and considering the record evidence that called into question the accuracy of the submitted coverage map of at least one nationwide provider, staff conducted a preliminary review of the speed test data submitted during the MF-II challenge process. The staff review of challenger data, in combination with the record evidence focusing on specific areas in which coverage appeared to be overstated, suggested, among other things, that some providers had reported inaccurate coverage data to the Commission. Based upon this review and the providers' responses to staff inquiries, the Commission decided to launch a formal investigation of the MF-II 4G LTE coverage data submitted by certain providers. In announcing the start of the investigation into potential violations of the data collection rules, the Commission suspended the response phase of the challenge process pending conclusion of the investigation.[65] The staff investigation comprised collecting additional information from certain providers regarding their generation of coverage data, gathering independent speed test data to verify the challenger data, and analyzing specific allegations made in the record to evaluate the accuracy of the submitted coverage maps.

33. As part of the investigation, and based upon the responses to staff inquiries, subpoenas were served on Verizon and U.S. Cellular in December 2018 requesting detailed answers to questions pertaining to each provider's assumptions regarding its propagation models, as well as copies of internal communications related to the generation of the MF-II 4G LTE coverage data. Specifically, Commission staff asked each provider for details about the uplink and downlink channel capacity accounted for in its propagation models for both the MF-II 4G LTE coverage data (including any revisions submitted to the Commission) and as used in its normal course of business. Staff requested the basis for each provider's assertion that their MF-II 4G LTE coverage data submission met the Commission's requirements if it did not account for any uplink channel capacity.[66] The subpoena also asked each provider about its methodology for considering terrain variation and for specific parameters used in its link budget, including the target signal-to-interference-plus-noise ratio used to develop the maximum operational path loss for the downlink channel link budget. The providers were asked about differences between the propagation models used for the MF-II 4G LTE coverage data and other coverage data submitted to the Commission (including Form 477 and Form 601 construction notification filings) and whether the MF-II 4G LTE coverage maps reflect the data, spectrum, and network infrastructure each provider had in place at the time the coverage data were generated. Finally, the subpoena asked each provider to provide details on any drive testing or other measurements they had conducted to confirm the MF-II 4G LTE coverage data.

34. U.S. Cellular submitted all requested information in its subpoena response on February 22, 2019, and filed amended responses and updated declarations on March 19, 2019. In its subpoena response, U.S. Cellular clarified that it did initially account for an uplink channel link budget in preparing its maps for the MF-II 4G LTE coverage data collection.[67] U.S. Cellular explained that because the uplink channel link budget it used resulted in a higher maximum allowable path loss than the downlink channel it calculated, its coverage area for uplink applications was greater than (and entirely contained within) the coverage area for downlink applications.[68] As a result, according to U.S. Cellular, constraining the coverage area by the calculated uplink channel capacity was unnecessary and it therefore

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[65] *See* News Release, FCC, FCC Launches Investigation into Potential Violations of Mobility Fund Phase II Mapping Rules (Dec. 7, 2018) (MF-II Coverage Map Investigation News Release).

[66] *See MF-II Challenge Process Order*, 32 FCC Rcd at 6302, para. 39 (requiring providers to model unspecified parameters as they would in the normal course of business).

[67] Responses of U.S. Cellular to Subpoena dated December 27, 2018 at 1 (File No. EB-IHD-18-00028278) (U.S. Cellular Subpoena Response).

[68] *Id*.

did not rely upon an uplink channel link budget to calculate coverage in its MF-II 4G LTE coverage data submission.[69] U.S. Cellular explained that the uplink channel link budget it initially considered would have resulted in a minimum upload speed of 64 kbps with an 80% cell edge probability and 30% cell loading factor.[70] Addressing the subpoena questions about the differences between its propagation models used for the MF-II 4G LTE coverage data and other coverage maps in its normal course of business, U.S. Cellular stated that the uplink channel link budget used to generate its maps {[

]}.[71] U.S. Cellular additionally provided the requested detailed technical parameters for both its uplink and downlink link budgets used by its propagation models.[72]

35. Verizon submitted narrative responses to subpoena questions in its subpoena response on February 19, 2019. Verizon submitted a supplemental production on March 8, 2019, privilege logs on March 18, 2019, and additional files on March 27, 2019. In its subpoena response, Verizon reiterated that it did not account for an uplink channel link budget in generating its MF-II 4G LTE coverage data,[73] but that it had subsequently estimated that the minimum upload speed for the area throughout its MF-II 4G LTE coverage would be 115 kbps.[74] Verizon asserted that this uplink channel capacity would have been sufficient to establish a downlink channel that met the specifications for MF-II.[75] Verizon further explained that, in its normal course of business and for other coverage maps that it generates (including those submitted to the Commission as part of its Form 477 filings and Form 601 notifications), Verizon's propagation model {[

]}.[76] Verizon also indicated that its MF-II propagation model assumed that the device was outdoors and stationary (as opposed to within a vehicle and in-motion), which it asserted could have resulted in drive test measurements recording lower performance than predicted by its model.[77] Additionally, Verizon provided the requested detailed technical parameters for the downlink channel link budget it used for its propagation model when generating the MF-II 4G LTE coverage data.[78]

36. Shortly after staff made inquiries to the providers, and concurrent with the initial staff review of challenger data, field agents from the Commission's Enforcement Bureau commenced a five-month effort to examine coverage data in certain MF-II 4G LTE areas by conducting their own speed tests, via a mix of drive and stationary testing. Staff conducted speed tests along six separate test routes

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[69] *Id*.

[70] *Id*.

[71] *Id.* at 2.

[72] *Id.* at 2, 4.

[73] Responses of Verizon to Subpoena dated December 27, 2018 at 1 (File No. EB-IHD-18-00028219) (Verizon Subpoena Response).

[74] *Id.* at 8.

[75] *Id.*

[76] *Id.* at 4, 13-14.

[77] *Id.* at 10.

[78] *Id*. at Attachment A.

in 12 states, recording 24,649 drive tests and 5,916 stationary tests on the mobile networks of T-Mobile, U.S. Cellular, and Verizon.[79]

III. COMPARATIVE ANALYSIS OF THE MF-II 4G LTE COVERAGE DATA

37. In an initial analysis of the MF-II 4G LTE coverage data, staff compared the MF-II 4G LTE coverage data submitted by each provider with its then-most-recent Form 477 4G LTE coverage data. Given that the rationale for adopting the one-time collection of 4G LTE coverage data specifically for MF-II was to improve upon the accuracy of the Form 477 data, such comparison is useful to determine the extent to which standardizing the technical parameters affected each provider's coverage maps. Specifically, staff sought to determine whether allegations in the record that many providers' Form 477 4G LTE coverage data overstated their service area were correct, and to what extent standardizing propagation model parameters reduced any such overstatement.[80]

38. The difference in the area predicted to be within coverage between the MF-II data and the December 2017 Form 477 data varied significantly among the five largest providers (see Table 2).[81] AT&T, Sprint, and T-Mobile saw similar reductions of approximately 18-19% in the total area of 4G LTE coverage with the MF-II data as compared to their coverage reported on Form 477. Verizon and U.S. Cellular, however, reported modest *increases* in their MF-II 4G LTE coverage compared to their Form 477 submissions from similar timeframes.

Table 2. Comparison of 4G LTE Coverage Area Dec. 2017 Form 477 vs. MF-II Collection

Provider Name	4G LTE Coverage (Form 477 Only)	4G LTE Coverage (MF-II Only)	Percent Difference Form 477 vs. MF-II
AT&T	5,287,563 sq. km	4,276,681 sq. km	-19.12%
Sprint	2,546,499 sq. km	2,086,801 sq. km	-18.05%
T-Mobile	5,376,006 sq. km	4,329,075 sq. km	-19.47%
U.S. Cellular	1,024,633 sq. km	1,029,916 sq. km	0.52%
Verizon	6,489,764 sq. km	6,583,288 sq. km	1.44%

39. Staff additionally compared coverage data among providers. This comparison suggests that some providers refined their projections for the MF-II data collection, while others submitted coverage data that were substantially similar to the unstandardized Form 477 maps. For example, AT&T's coverage data show substantial differences between its Form 477 coverage and the significantly smaller coverage in its MF-II data (see Figure 1), with clear delineations apparent for individual cell sites. While we are unable to confirm that AT&T's MF-II coverage map based on MF-II parameters is necessarily more accurate than its Form 477 filing, the modeled MF-II propagation map has less uniformity and more precise definition. Staff engineers found that these characteristics could be indicative of realistic coverage experienced on the ground, where gaps in coverage would be expected due to the statistical nature of the link channel. On the other hand, for both Verizon and U.S. Cellular, the providers' MF-II coverage and their Form 477 coverage cover broadly the same area without much

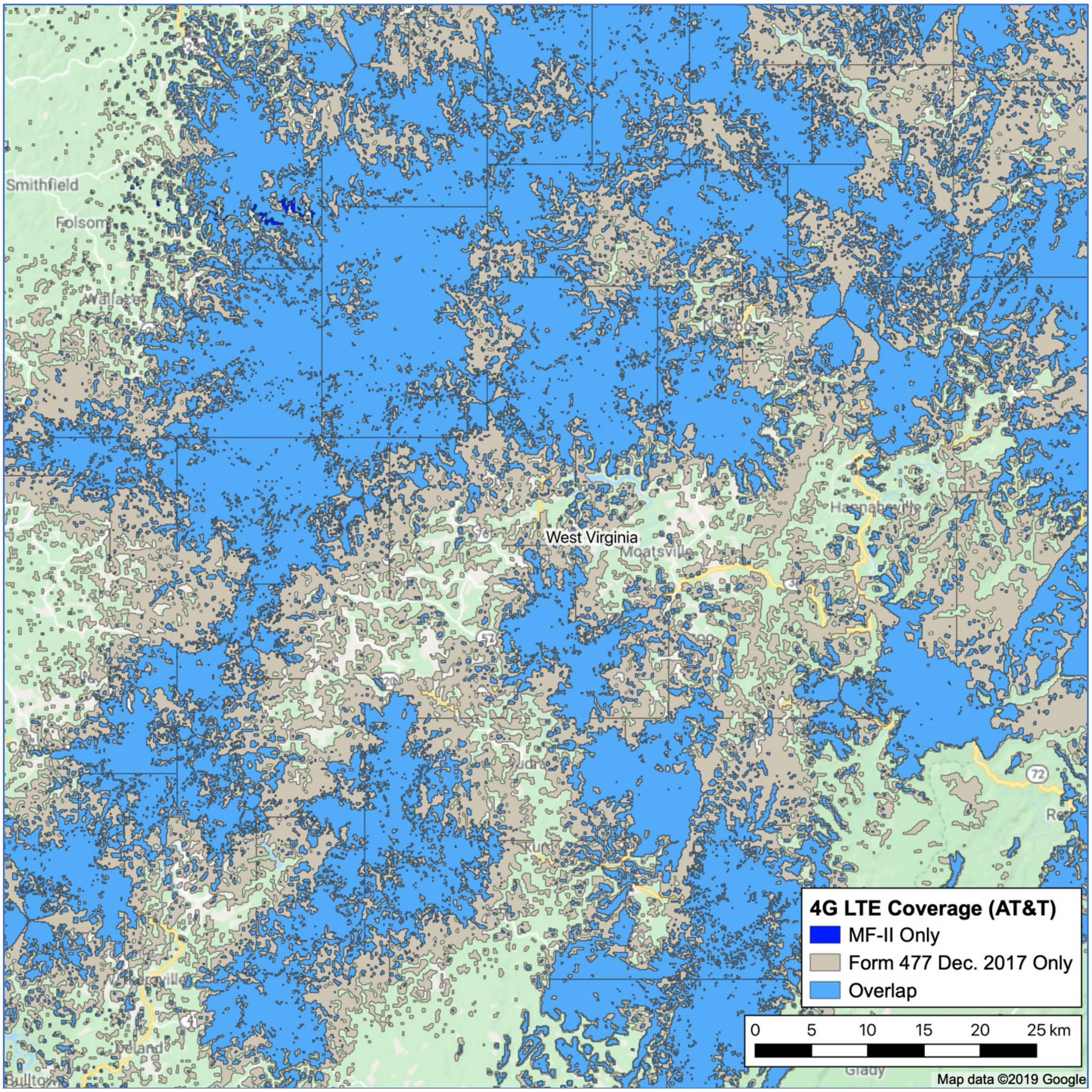
[79] We exclude staff speed tests that were conducted outside of each provider's submitted 4G LTE coverage area.

[80] This comparative analysis led to the staff's recommendation for the Commission to explore further the accuracy of mobile wireless providers' Form 477 data.

[81] We have calculated the 4G LTE coverage area for each of the providers excluding any coverage in Alaska, Puerto Rico, or the U.S. Virgin Islands, as those states or territories were not included as part of MF-II.

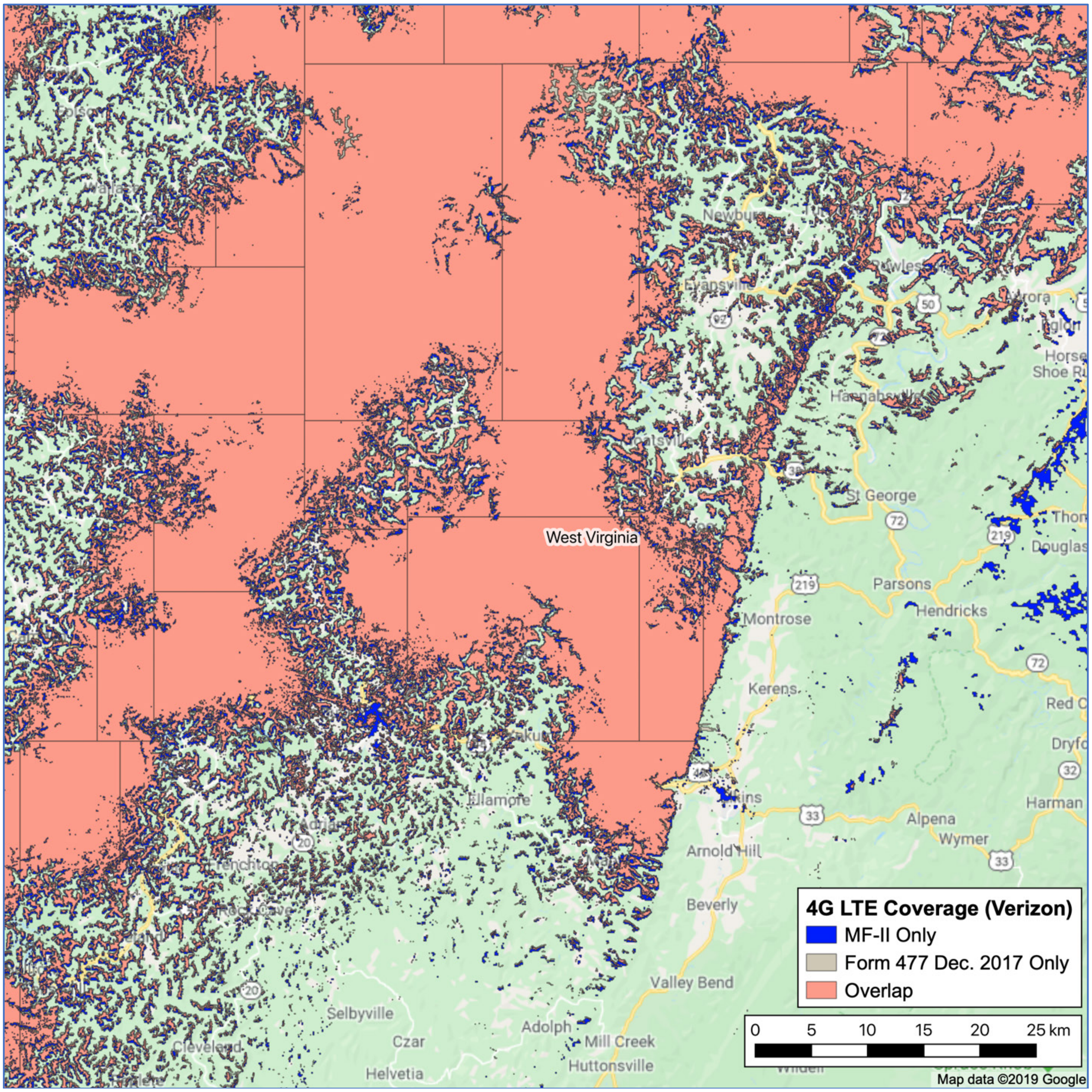
noticeable difference in the pattern of their modeled propagation, and with the two datasets often overlapping in their entirety (see Figure 2 and Figure 3).

Figure 1. AT&T 4G LTE Coverage in West Virginia (MF-II vs. Form 477)[82]



[82] Because the maps in Figure 1, Figure 2, and Figure 3 contain provider-specific coverage data that the Commission has now released, these three figures have not been redacted. *See Rural Broadband Auctions Task Force Releases Mobility Fund Phase II 4G LTE Coverage Maps*, Public Notice, DA 20-525 (WCB/WTB/OEA May 18, 2020).

Figure 2. Verizon 4G LTE Coverage in West Virginia (MF-II vs. Form 477)[83]



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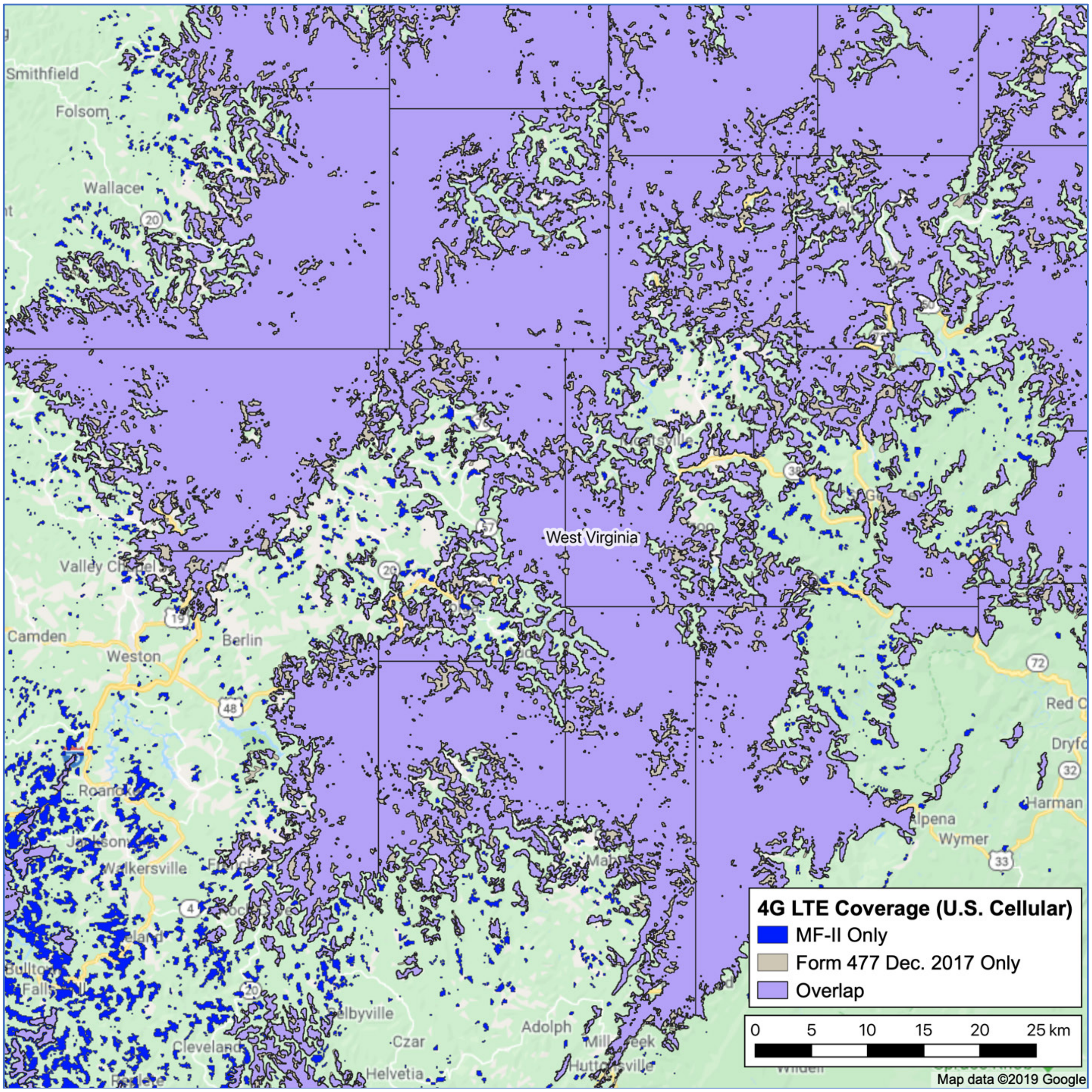
[83] *See supra* note 82.

Figure 3. U.S. Cellular 4G LTE Coverage in West Virginia (MF-II vs. Form 477)[84]



40. The areas predicted by Verizon and U.S. Cellular's propagation models to have coverage are effectively identical for most areas when comparing between the provider's MF-II 4G LTE coverage and its December 2017 Form 477 coverage. Conversely, AT&T's propagation models predicted a smaller area to have coverage when using the MF-II parameters, and the shapes generated by that model appear to better reflect the real-world characteristics of RF propagation, especially at the apparent edge of cells.

41. We acknowledge that these datasets may not be directly comparable due to differences in the provider's use of standardized versus non-standardized link budget parameters (e.g., cell edge probability, cell loading factor, etc.). In addition, the Form 477 coverage data depict the boundaries

[84] *See supra* note 82.

where users should expect to receive a set of minimum advertised speeds (both upload and download) submitted by the provider, which may differ from the 5 Mbps download speed standard for MF-II. Some providers may, for example, have modeled their Form 477 4G LTE coverage using a stricter specification—e.g., a higher minimum download speed—than was required for MF-II, which could result in an increased coverage depicted in their MF-II maps as compared to Form 477 coverage. Others may have used a less strict specification in their Form 477 coverage models, which could result in decreased coverage depicted in their MF-II maps as compared to Form 477 coverage.

42. The two sets of coverage data are also not necessarily contemporaneous snapshots of 4G LTE coverage. For its MF-II 4G LTE coverage data, a provider was permitted to model its network as of any time between August 4, 2017, and the deadline to submit its data, January 4, 2018, whereas for its Form 477 filing, the data was required to be current as of December 31, 2017. As such, some difference between Form 477 and MF-II coverage could be the result of deployment subsequent to the date a provider generated its MF-II 4G LTE coverage data if it did so prior to the end of December.[85] Consequently, by themselves, changes in the total area covered do not necessarily indicate a problem.

43. Staff engineers, however, found that AT&T's adjustments to its model to meet the MF-II requirements may have resulted in a more realistic projection of where consumers could receive mobile broadband. This suggests that standardization of certain specifications across the largest providers could result in coverage maps with improved accuracy. Similarly, the fact that AT&T was able to submit coverage data that appear to more accurately reflect MF-II coverage requirements raises questions about why other providers did not do so. And while it is true that MF-II challengers submitted speed tests contesting AT&T's coverage data, unlike for other major providers, no parties alleged in the record that AT&T's MF-II coverage data were significantly overstated.

IV. UPLINK CHANNEL INQUIRIES

44. Mobile broadband requires uplink channel capacity in order to generate a two-way mobile data transmission at any speed. Specifically, network protocols operating on the transport layer (such as TCP/IP, which is used for Internet traffic) require both downlink transmission of data packets from the sender to the receiver (i.e., base station to handset) as well as uplink transmissions from the receiver to the sender (i.e., handset to base station) acknowledging receipt of packets and/or initiating transmission. As such, in order to achieve download speeds of at least 5 Mbps, per the *MF-II Challenge Process Order*, some minimal speed in the uplink direction to provide this return link (i.e., handset to base station) is required. As the Commission recognized, there exists an "interplay between download and upload speeds when designing and optimizing an LTE network."[86] According to an analysis submitted into the record, uplink speeds may vary widely, with most of the measured uplink data rates being from around 64 kbps to well in excess of 1 Mbps.[87] But in all cases, a mobile network requires an uplink speed to function.

45. When not otherwise specified, the *MF-II Challenge Process Order* directed providers to "use the optimized RF propagation models and parameters used in their normal course of business" in

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[85] This appears to be the case in particular for T-Mobile, which was at the time deploying new 600 MHz band spectrum in certain markets. *See* Letter from Michael A. Lewis, Senior Engineering Advisor, DLA Piper LLP, to Marlene H. Dortch, Secretary, FCC, MB Docket No. 16-306, GN Docket No. 12-268 (filed on June 1, 2017) (detailing 4G LTE expansion planned in 2017 using 600 MHz spectrum). When comparing the MF-II 4G LTE coverage to its June 2017 Form 477 4G LTE coverage, there is a much smaller 5.39% reduction in area.

[86] *MF-II Challenge Process Order*, 32 FCC Rcd at 6293, para. 19.

[87] *See* Petition of T-Mobile USA, Inc. for Reconsideration, WC Docket No. 10-90, WT Docket No. 10-208 (filed Apr. 27, 2017).

preparing their 4G LTE coverage data for submission.[88] Although the Commission specified some of the parameters that providers were to use in the data collection, providers were afforded flexibility to use the parameters that they used in their normal course of business when parameters were not specified by the Commission. For example, the Commission did not specify fading statistics or clutter loss values, and providers were required to model these factors as they would in the normal course of business. Because the Commission did not specify the uplink channel constraint that each provider was to use in its model, providers were expected to account for uplink channel capacity as they would in the normal course of business. Not surprisingly, in the pre-subpoena inquiries, staff learned from multiple providers that they had accounted for an uplink channel in their models.

46. In general, if a provider failed to properly account for an uplink channel corresponding to the downlink requirements when generating its coverage data, it could result in overstated coverage. This is because the downlink speeds projection could indicate coverage in some areas in which the propagation model would not predict to have an uplink connection with sufficient capacity for the specified downlink speeds. If such an uplink channel constraint had been considered in the model, the projected downlink coverage could be smaller when the uplink is the limiting link. During the challenge process, staff received complaints in the record about Verizon's coverage maps.[89] Verizon and U.S. Cellular told staff that the propagation models used to generate their submitted MF-II coverage data did not include an uplink channel constraint. Accordingly, staff served subpoenas on Verizon and U.S. Cellular to obtain more detailed information on each provider's uplink channel assumptions in its propagation models to determine whether the MF-II data collection requirements had been followed.

47. Based upon the explanations and link budget details given by U.S. Cellular in its subpoena response, staff concluded that U.S. Cellular had, in fact, taken into account uplink channel capacity in its propagation models when it generated its MF-II 4G LTE coverage data. Notwithstanding its response to the pre-subpoena inquiries that the uplink channel was not considered, U.S. Cellular's subpoena response clarified that the "uplink channel budget was considered and accounted for, but not used in preparing the map because it would have created greater coverage than the downlink channel budget, which contained the parameters the FCC required to be included for determining coverage at the required download speeds."[90] Moreover, U.S. Cellular's explanation is consistent with its description of how it accounts for the uplink channel link budget when generating coverage maps in its normal course of business. Specifically, U.S. Cellular stated that it models propagation using both uplink and downlink channel link budgets and then uses the limiting link (i.e., the link with smaller path loss) to determine coverage.[91] Because it modeled both the uplink and downlink channel in accordance with the technical specifications required for MF-II, and used the limiting link—in this case, the downlink channel—to create its 4G LTE coverage, U.S. Cellular's approach was consistent with the MF-II data collection requirements.

48. Verizon, on the other hand, did not take into account uplink channel capacity in its propagation models when it generated and submitted its 4G LTE coverage data. In its subpoena response, Verizon stated that it "did not account for an Uplink Channel Link Budget in its MF-II Data," and that, "Verizon did not use an Uplink Channel Link Budget to develop its MF-II Data."[92] Verizon argued that it nonetheless complied with the requirements of the *MF-II Challenge Process Order* based upon its

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[88] *MF-II Challenge Process Order*, 32 FCC Rcd at 6302, para. 39.

[89] *See supra* nn. 45, 54 (complaints filed in the record about Verizon's coverage).

[90] U.S. Cellular Subpoena Response at 1.

[91] *Id.* at 1-2, 6.

[92] Verizon Subpoena Response at 1, 7.

interpretation of those regulations, which, it argued, did not "allow for an uplink constraint" and, moreover, was the only reasonable interpretation of the requirements.[93] Verizon simultaneously explained that in the normal course of business it models propagation {[ ]} when generating coverage and that an uplink is necessary to establish a downlink for mobile service.[94]

49. Verizon asserted that not accounting for an uplink channel link budget was inconsequential for its MF-II coverage maps.[95] In its response, Verizon estimated that the upload speed within its MF-II coverage area would be at least 115 kbps, with an 80% cell edge probability and 30% cell loading factor, and that an uplink speed of 115 kbps would be "sufficient to establish a Downlink that meets the . . . 5 Mbps download speed requirement."[96] Thus, Verizon asserted that the absence of an uplink channel link budget in its model had not led it to submit coverage maps where the upload speed would be insufficient to achieve the required download speeds.[97]

50. Verizon misconstrues the Commission declining to adopt an *upload speed benchmark* as an affirmative requirement to ignore entirely any consideration of an *uplink channel link budget*, irrespective of how a provider would account for the uplink channel in its normal course of business.[98] Moreover, in making this argument, Verizon disregards the fact that some uplink channel capacity is required to facilitate the two-way communication necessary for a mobile device to achieve download speeds of at least 5 Mbps.[99] Nonetheless, staff engineers reviewed the coverage maps and link budgets

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[93] *Id.* at 1-5 ("The Commission rejected the use of an upload speed requirement and instead adopted standards for the submission of MF-II Data that do not contemplate or *allow* for an uplink constraint."), ("[T]he *only* interpretation of the *MF-II Second R&O* that is consistent with the Commission's objective of standardizing mapping parameters is that all carriers were required to develop their MF-II Data using *solely* the Downlink Channel Link Budget.") (emphasis added). Verizon further claimed that because, according to Verizon, the Commission had directed providers not to use an uplink constraint, the uplink constraint was wholly exempt from the "normal course of business" requirement that applied to parameters not otherwise specified by the rules, *id.* at 5, in effect arguing that any provider that had accounted for uplink capacity had deviated from the requirements. *Id.* at 2-3, 5-6 ("[T]he *MF-II Second R&O* could not reasonably be interpreted as permitting carriers to decide on their own to include some uplink constraint.").

[94] *Id.* at 4, 7.

[95] *Id.* at 8.

[96] *Id.* at 1, 8.

[97] *Id.* at 8.

[98] An upload speed benchmark (i.e., the target throughput) is merely one component of an uplink channel link budget, and in the absence of an expressly defined parameter, the Commission's requirement was to use the "RF propagation models and parameters used in [the provider's] normal course of business." *MF-II Challenge Process Order*, 32 FCC Rcd at 6302, para. 39. While it is true that a provider may have had to modify its uplink budget in light of the specified parameters to project coverage accurately, it was unreasonable for a provider to ignore the uplink channel in its entirety when generating its MF-II coverage data. To the extent that Verizon believed that the uplink channel assumptions it uses in its normal course of business were otherwise inconsistent with the objectives of the MF-II collection, it could have sought reconsideration of the data collection rules or it could have sought a waiver to allow it to model propagation based upon the particular characteristics of its network. Alternatively, Verizon could have modified how it treats the uplink channel, consistent with its standard engineering practices used in the normal course of business, in order to more accurately model those areas that should achieve the target download speed (such as {[ ]}).

[99] It would have been inconsistent with the objectives of MF-II for the Commission to adopt a mobile download speed benchmark and then require a provider to claim coverage where the provider's model would predict

that Verizon submitted in other proceedings and found little variation between those filings and the MF-II coverage maps. Staff did not find evidence indicating that Verizon's model or its coverage projections were clearly unreasonable.

51. Verizon's coverage maps for MF-II were also not significantly different from its Form 477 filings, and Verizon stated that it {[ ]}[100] And after review of the data, subpoena responses, and document production, staff was unable to determine that Verizon's failure to account for an uplink channel link budget in its MF-II coverage data was a significant factor affecting the accuracy of the area it determined had 4G LTE coverage meeting the Commission's specifications. Based on the totality of the circumstances, staff concluded that an enforcement action was not warranted.

V. MOBILE SPEED TESTING AND ANALYSIS OF SPEED TEST DATA

52. To provide the Commission with its own speed test data that could be used to evaluate the accuracy of the submitted coverage maps and verify the challenger data, staff field agents conducted on-the-ground mobile network speed testing of three providers' networks in six areas of the country over a period of five months. The purpose of this testing was to provide the Commission with independent speed tests that staff could rely upon because the tests were taken using standardized methods and equipment. The decisions as to which geographic areas and provider networks to test were informed by submissions in the record questioning Verizon's and T-Mobile's coverage and by the challenger speed test data. Staff primarily attempted to confirm the assertions made by RWA and SBI in their respective informal requests for Commission action about the sufficiency of the coverage maps submitted by Verizon and T-Mobile in several states.[101] Staff additionally attempted to confirm results published by the Vermont Department of Public Service for Verizon and U.S. Cellular.[102] The on-the-ground testing consisted of both app-based drive testing and stationary testing along select routes, primarily in Arizona, New Mexico, Oklahoma, Vermont, Alabama, and Montana.[103]

insufficient uplink channel necessary to achieve the target download speed for mobile devices. And this argument is even more at odds with the objectives of MF-II when considering Verizon's even bolder claims that the Commission *prohibited* providers from including an uplink constraint in their models and that Verizon's coverage map met the requirements even if it could be shown that the projected coverage had insufficient uplink for the required downlink. Verizon Subpoena Response at 8 ("Verizon's MF-II Data would comply with the *MF-II Second R&O* even if *it were possible to show that the uplink speed may not be sufficient* to establish a Downlink in an area shown as covered.") (emphasis added).

[100] *Id.* at 11.

[101] *See* SBI MF-II Informal Request at Ex. B, Ex. C (identifying areas in Arizona for which SBI's contractor tested Verizon's network); First RWA MF-II Informal Request at 4-6 (claiming that Verizon's coverage is incorrect throughout the Oklahoma Panhandle); Second RWA MF-II Informal Request at 5-7, 8-9 (claiming that T-Mobile's coverage is incorrect in Alabama, Oklahoma, and Montana, in addition to identifying particular areas in Montana where RWA claims T-Mobile had insufficient backhaul capacity).

[102] Vermont PSD Mobile Wireless Report; Vermont Wireless Drive Test Results, Vermont Department of Public Service, http://vtpsd.maps.arcgis.com/apps/webappviewer/index.html?id=444a3d49c2374d509958f1c0e1d0d21b (last visited Sept. 30, 2019).

[103] While the drive test routes and stationary test locations primarily fell in these six states, and are identified as such in the tables below, some tests for particular test routes were also taken in neighboring states (e.g., some tests associated with the Montana test route were taken just across the state border in Wyoming and North Dakota). *See supra* note 1.

53. A detailed summary of the speed testing conducted by staff is provided below, and the full dataset of those speed tests is available for download on the Commission's website.[104] Staff performed geospatial processing on speed test data using geographic information system software. We have excluded from this dataset and our analyses any staff speed tests that were conducted outside of the areas identified in the respective provider's coverage maps. While staff took care to minimize discrepancies, we acknowledge that differences between geographic information system software platforms, computational precision, and processing steps may lead to slightly different results even when using the same source data.

54. The staff speed testing revealed significant discrepancies between the coverage maps generated by the providers whose networks were tested and the actual, on-the-ground mobile experience, as measured by the speed tests. For the consumer experience to reflect the service predicted in the coverage maps, a mobile device should receive 4G LTE service with a download speed of at least 5 Mbps with an 80% probability at the cell edge, which corresponds to a 92% probability within the area reported to have coverage.[105] That is, a set of speed tests taken uniformly throughout the cell area should achieve the required download speeds 92% of the time, whereas tests taken exclusively around the cell edge should achieve such speeds 80% of the time. The staff speed tests were not necessarily taken uniformly throughout the cell area, but nevertheless we would expect that tests recorded within the predicted coverage area would achieve download speeds of at least 5 Mbps 80% of the time or more. The staff speed test data did not approach the 92% threshold for any route-provider combination and in fact achieved the required download speed for less than 80% of tests across every route tested.

A. Test Methodology

55. For each speed test route, staff conducted in-motion drive tests as well as a number of stationary tests, both using an app-based testing platform customized for the Commission.[106] Based upon the speed test configuration parameters using a one-second "inter-test delay"[107] and two-second "inter-cycle delay,"[108] the app recorded one test approximately every 20 seconds along the drive test route or at each stationary test location.

[104] The staff speed test data can be downloaded at https://www.fcc.gov/mobility-fund-phase-2#data.

[105] *MF-II Challenge Process Order*, 32 FCC Rcd at 6300, para. 36; *see also* Christophe Chevallier et al., WCDMA (UMTS) Deployment Handbook: Planning and Optimization Aspects 33 Figure 2.6 (1st ed. 2006); D. O. Reudink, Microwave Mobile Communications 126-28 Figure 2.5-1 (William C. Jakes ed. 2d ed. 1974). We recognize that there may be discrepancies between coverage maps and on-the-ground performance because the assumptions made in the propagation model may not necessarily reflect actual conditions at the time of measurement.

[106] The Commission used a version of the FCC Speed Test app developed by SamKnows Ltd. modified to run continuous tests throughout the coverage area and that is thus better suited for the drive testing conducted by staff. This functionality differs from the publicly-available FCC Speed Test app, which is designed to run on-demand, user-initiated speed tests. *See, e.g.*, FCC Speed Test, Apple App Store, https://apps.apple.com/us/app/fcc-speed-test/id794322383 (last visited Nov. 26, 2019); FCC Speed Test, Apps on Google Play, https://play.google.com/store/apps/details?id=com.samknows.fcc (last visited Nov. 26, 2019).

[107] Inter-test delay controls how long the app pauses between completing and initiating a new test metric (i.e., measuring download speed and measuring latency, which are measured separately).

[108] Inter-cycle delay controls how long the app pauses between completing and initiating a new test (comprised of a set of test metrics including both latency and download speed measurements).

56. EB field agents conducted in-motion drive testing using the following standardized test procedures:

- The agent turned off all other phones in the vehicle (including any modem built into the test vehicle) and configured the test handsets in the vehicle.
- The agent recorded the date and time that testing commenced.
- The agent then initialized the measurement application on the test handsets and drove along a pre-planned route with a "not-to-exceed" vehicle speed of between 35 and 60 miles per hour (depending on the route), while monitoring the measurement app for any errors.
- After completing the drive test route, the agent stopped the app and noted the date and time that testing concluded.
- The agent then evaluated and verified recorded data using a laptop.
- For most routes, the agent repeated the same testing steps while driving along the route in the opposite direction.[109]

57. EB field agents also conducted stationary testing using the following standardized test procedures:

- At selected locations along the drive test routes,[110] the agent stopped the vehicle, turned off all other phones (including any modem built-in to the test vehicle), and configured the test handset to perform tests outside of the vehicle.
- The agent recorded the date and time that testing commenced, as well as the geographic coordinates of the location.
- The agent then initialized the measurement application on the test handsets.
- After continuous testing for between one and two hours,[111] the agent stopped the app and noted the date and time that testing concluded.
- The field agent then evaluated and verified recorded data using a laptop.

58. All tests were conducted using a Samsung Galaxy S9 handset (model SM-G960U1), which was mounted in a vehicle for the drive tests. We note that the staff speed tests were conducted approximately one year after providers submitted their list of pre-approved handsets, and the newer Samsung Galaxy S9 had been released in the intervening period. Although the Samsung Galaxy S9 was therefore not one of the pre-approved devices for any of the three carriers tested, all three providers sold

[109] Staff made multiple passes, conducting drive testing along the same roads at different times, for most drive test routes in order to mitigate false positives arising from the inherent variability of mobile networks. As we found when analyzing the staff drive test data below, there are clear patterns that emerge from analyzing the drive test data indicating insufficient coverage across large areas. Because we would expect that speed tests would fail in a coverage area that meets the cell edge probability only a small percentage of time, lengthy stretches of roadways where speed tests record download speeds below 5 Mbps (especially taken at different times) are unlikely due to any inherent variability.

[110] Locations for the first set of stationary tests, conducted on the Arizona and New Mexico routes, were selected and conducted after conducting drive tests, based upon the signal strength recorded while drive testing. All later stationary test locations were pre-selected based upon areas location near the edge of each providers' coverage and were conducted at various points while drive testing.

[111] We note that the stationary test results for locations in Arizona, which was the first route tested by staff, did not follow the same methodology as for stationary tests conducted on other, later test routes. Specifically, the Arizona tests were conducted for a much shorter duration (for approximately one-to-two minutes) and thus recorded far fewer tests than were conducted at each location for later testing where stationary tests were conducted continuously for between one-to-two hours. Notwithstanding the duration of testing at each location, the Arizona stationary test results are otherwise comparable, and thus have not been excluded from the analysis.

and supported this handset by the time of the staff testing and all three providers approved similar, prior-year Samsung Galaxy models for conducting speed tests during the challenge process.[112] Because the Samsung Galaxy S9 uses a newer chipset with improved peak 4G LTE download speeds (LTE category 18) and supports all of the 4G LTE spectrum bands that were supported by the prior-year models, staff engineers concluded that use of the newer model handset would not meaningfully impact the results.

B. Drive Test Results

59. An analysis of the staff drive test data reveals wide variation across areas in the percentage of tests that were successful, with a "successful" test defined as one that achieved a download speed of at least 5 Mbps (see Table 3 and Table 4) in an area where the provider claimed to offer 4G LTE satisfying the Commission's requirements.

60. Across all three providers tested, no combination of route driven and provider tested (i.e., a route-provider combination, such as Verizon-Alabama) by staff achieved a success rate of 92% across the provider's coverage area, which would be consistent with a download speed of at least 5 Mbps at the cell edge 80% of the time, nor did any route-provider combination even meet the lower 80% success rate associated with the cell edge.[113] The lowest observed success rate recorded by staff drive tests was 45.0% for U.S. Cellular in Vermont, while the highest success rate was 74.6% for Verizon in Montana. The overall success rate of all providers and routes drive tested was 62.3%.[114]

61. This success rate includes tests taken on non-4G LTE (i.e., 2G or 3G) networks. While a non-4G LTE test may indicate that there was no 4G LTE signal in that location, it may also indicate there is a 4G LTE network, but that the handset switched to a 2G or 3G network due to congestion or some other reason. However, tests on 2G or 3G networks account for only about 8% of all tests and excluding them would not materially change the analysis (see Table 5 and Table 6).

62. Finally, we note that the handsets could not obtain any 4G LTE signal for a portion of the staff drive tests conducted in areas where the tested provider claimed to have 4G LTE coverage. For example, handsets could not obtain a 4G LTE signal for 16.2% of tests on Verizon's network, for 21.3% of the tests on T-Mobile's network, and for 38.0% of the tests on U.S. Cellular's network for the routes drive tested.

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[112] Specifically, the Samsung Galaxy S8 was pre-approved by both Verizon Wireless and U.S. Cellular, and the similar Samsung Galaxy S8 Active, which includes support for LTE spectrum band 71 (600 MHz band), was approved by T-Mobile. *See Rural Broadband Auctions Task Force Releases List of Handsets to be Used in Mobility Fund Phase II Challenge Process Speed Tests*, Public Notice, 33 FCC Rcd 5324 (WCB/WTB 2018); MF-II Challenge Process Provider Handsets, https://www.fcc.gov/files/mf-ii-challenge-process-provider-handsets (last updated Jun. 11, 2018); Built for the Way We Communicate Today: Samsung Galaxy S9 and S9+ (Feb. 25, 2018), https://news.samsung.com/us/samsung-galaxy-s9-s9plus/ ("AT&T, Sprint, T-Mobile, U.S. Cellular, Verizon Wireless and Xfinity mobile will carry Galaxy S9 and Galaxy S9+ in stores beginning March 16, 2018").

[113] *See MF-II Challenge Process Order*, 32 FCC Rcd at 6300, para. 36 ("Our analysis shows that the 80 percent cell edge probability we adopt corresponds with a 92 percent cell area probability, which means users would have a greater than 90 percent chance of achieving a download speed of at least 5 Mbps across the entire coverage area of a cell.").

[114] We recognize there may be differences in the results between stationary tests and drive tests due to a number of factors, including additional signal loss associated with measurements conducted inside a vehicle and in-motion.

Table 3. Staff Drive Test Results by Provider

Provider Name	Test Count Zero Mbps	Test Count > 0 & < 5 Mbps	Test Count ≥ 5 Mbps	Test Count Total	Percentage ≥ 5 Mbps
Verizon	2,717	3,094	10,487	16,298	64.3%
U.S. Cellular	654	587	1,015	2,256	45.0%
T-Mobile	1,258	986	3,851	6,095	63.2%
Total	**4,629**	**4,667**	**15,353**	**24,649**	**62.3%**

Table 4. Staff Drive Test Results by Route and Provider

Provider Name	Test Route	Date Range	Test Count ≥ 5 Mbps	Test Count Total	Percentage ≥ 5 Mbps
Verizon	Alabama	Mar. 04-07, 2019	2,674	4,671	57.2%
Verizon	Arizona	Nov. 27-29, 2018	322	658	48.9%
Verizon	Montana	Apr. 01-04, 2019	2,009	2,694	74.6%
Verizon	New Mexico	Dec. 03-05, 2018	563	890	63.3%
Verizon	Oklahoma	Jan. 28-31, 2019	3,219	4,389	73.3%
Verizon	Vermont	Mar. 05-08, 2019	1,700	2,996	56.7%
U.S. Cellular	Vermont	Mar. 05-08, 2019	1,015	2,256	45.0%
T-Mobile	Alabama	Mar. 04-07, 2019	3,024	4,500	67.2%
T-Mobile	Montana	Apr. 01-04, 2019	827	1,595	51.8%
		Total	**15,353**	**24,649**	**62.3%**

Table 5. Staff Drive Test Results by Provider (Excluding 2G / 3G Tests)

Provider Name	Test Count Zero Mbps	Test Count > 0 & < 5 Mbps	Test Count ≥ 5 Mbps	Test Count Total	Percentage ≥ 5 Mbps
Verizon	2,120	2,727	10,487	15,334	68.4%
U.S. Cellular	290	315	1,015	1,620	62.7%
T-Mobile	969	870	3,848	5,687	67.7%
Total	**3,379**	**3,912**	**15,350**	**22,641**	**67.8%**

Table 6. Staff Drive Test Results by Route and Provider (Excluding 2G / 3G Tests)

Provider Name	Test Route	Date Range	Test Count ≥ 5 Mbps	Test Count Total	Percentage ≥ 5 Mbps
Verizon	Alabama	Mar. 04-07, 2019	2,674	4,330	61.8%
Verizon	Arizona	Nov. 27-29, 2018	322	618	52.1%
Verizon	Montana	Apr. 01-04, 2019	2,009	2,489	80.7%
Verizon	New Mexico	Dec. 03-05, 2018	563	860	65.5%

Provider Name	Test Route	Date Range	Test Count ≥ 5 Mbps	Test Count Total	Percentage ≥ 5 Mbps
Verizon	Oklahoma	Jan. 28-31, 2019	3,219	4,237	76.0%
Verizon	Vermont	Mar. 05-08, 2019	1,700	2,800	60.7%
U.S. Cellular	Vermont	Mar. 05-08, 2019	1,015	1,620	62.7%
T-Mobile	Alabama	Mar. 04-07, 2019	3,021	4,464	67.7%
T-Mobile	Montana	Apr. 01-04, 2019	827	1,223	67.6%
		Total	**15,350**	**22,641**	**67.8%**

63. The results of staff drive tests reveal significant variance across time and location along the test routes driven, with performance achieving the minimum download speed across some portions of the test route but with substantial sections where download speeds drop below 5 Mbps or where no 4G LTE signal was received. In the following maps, we have visualized the routes driven by Commission staff by calculating for each route-provider combination the average download speed across tests that fell within each one square kilometer grid cell. We have not included the boundaries of each provider's 4G LTE coverage maps submitted as part of the MF-II one-time collection because the Commission previously indicated that it would treat such data as confidential.[115] Instead, we have plotted the staff drive test results on the publicly released 4G LTE coverage maps from Form 477 submitted by each provider from a similar time period (December 2017) in order to aid the visualization.[116] As discussed in Section III, we acknowledge that the Form 477 4G LTE coverage data may not be directly comparable to that provider's MF-II 4G LTE coverage data. Nevertheless, the Form 477 4G LTE coverage maps are still useful to help understand in which areas the provider's propagation model predicts users should expect to receive some baseline 4G LTE service.

[115] *MF-II 4G LTE Data Collection PN*, 32 FCC Rcd at 7028.

[116] *See Mobile Deployment Form 477 Data*, https://www.fcc.gov/mobile-deployment-form-477-data (last updated Sep. 10, 2019, 4:13 PM). The coverage maps in the following figures are based upon the public mobile broadband data from the December 2017 Shapefiles for technology 83 (4G LTE) for the relevant providers.

Figure 4. Staff Drive Test Route for Arizona (Verizon)

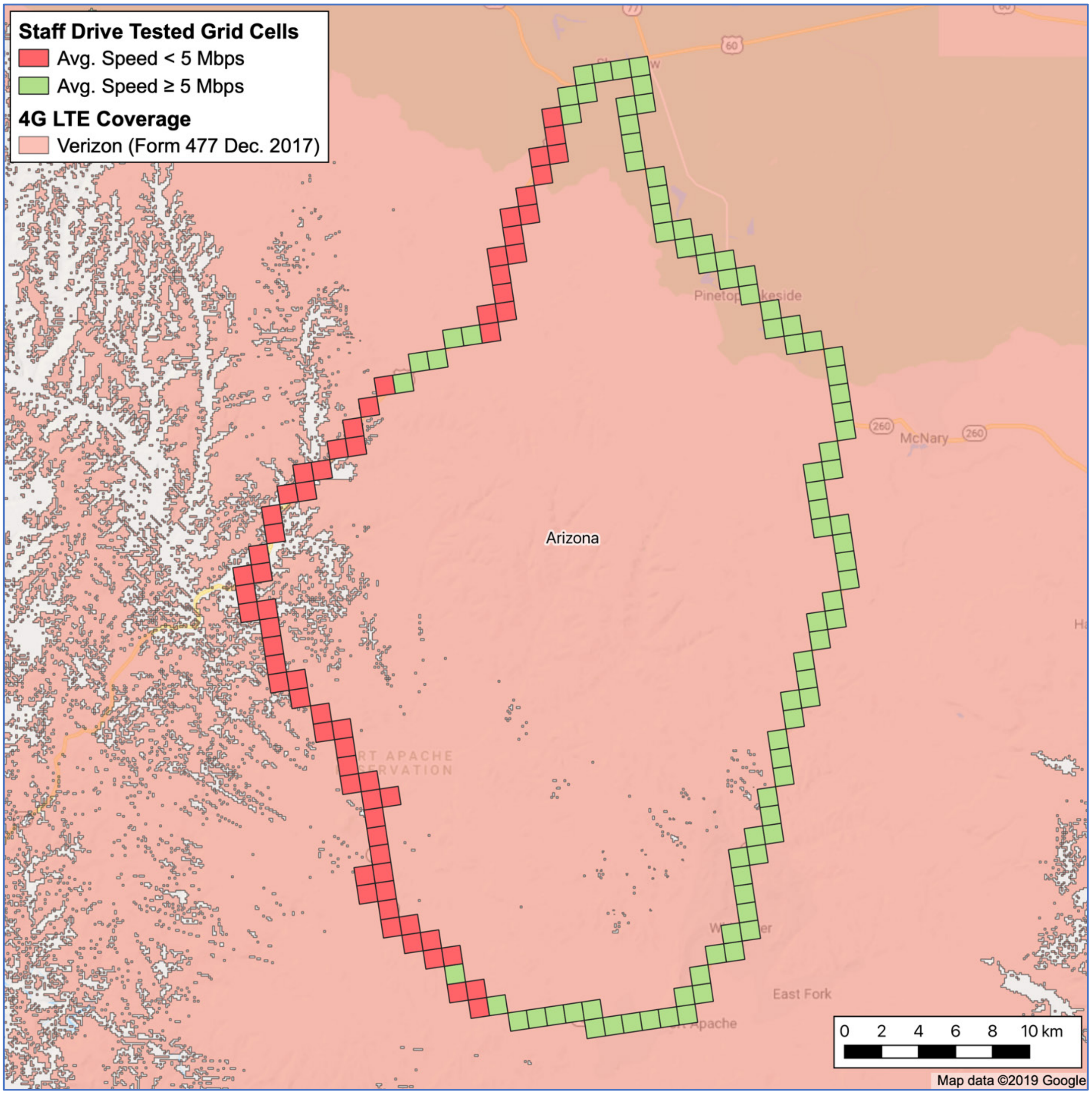


Figure 5. Interstate 40 Portion of Staff Drive Test Route for New Mexico (Verizon)

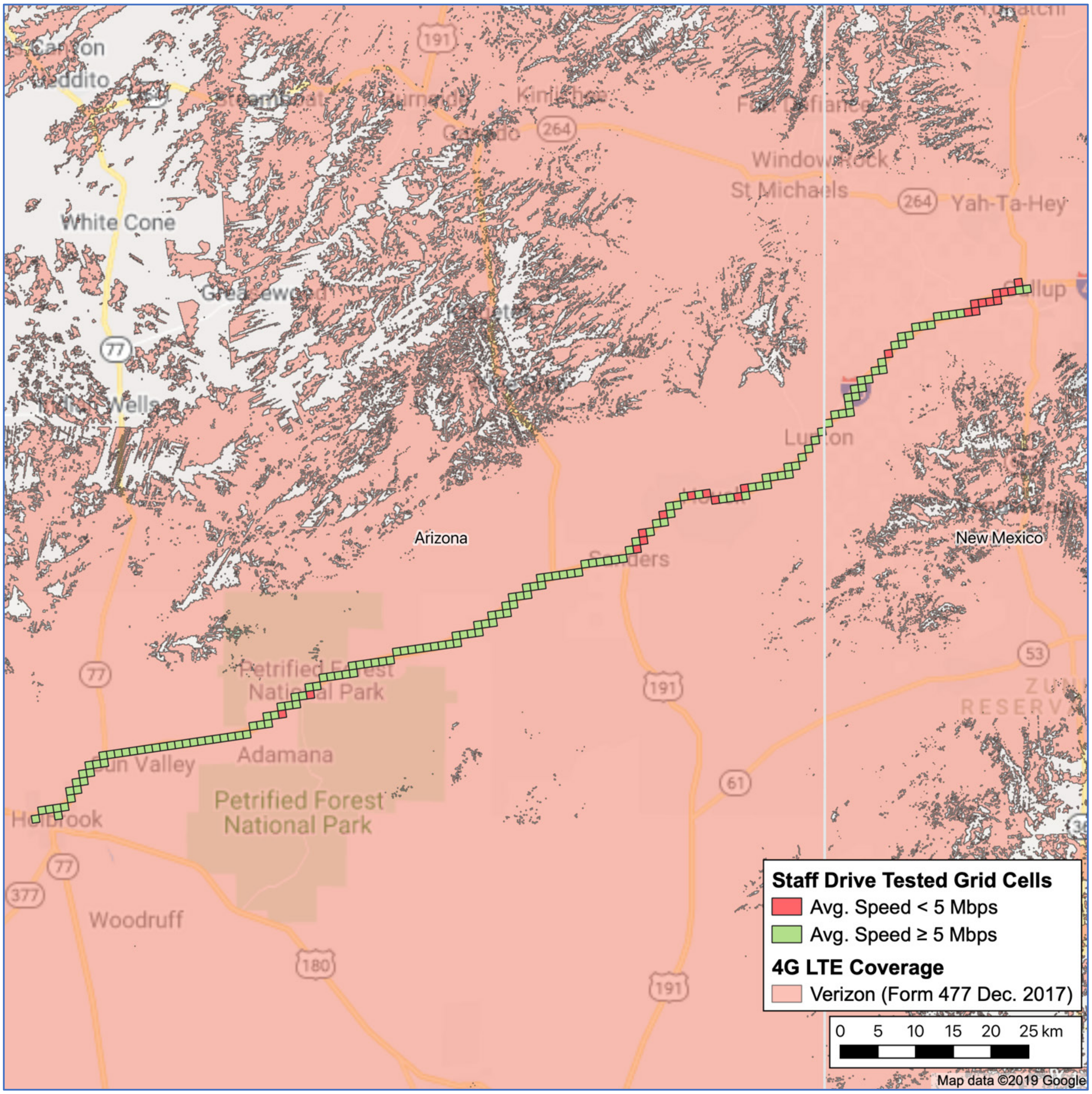


Figure 6. Eastern Portion of Staff Drive Test Route for New Mexico (Verizon)

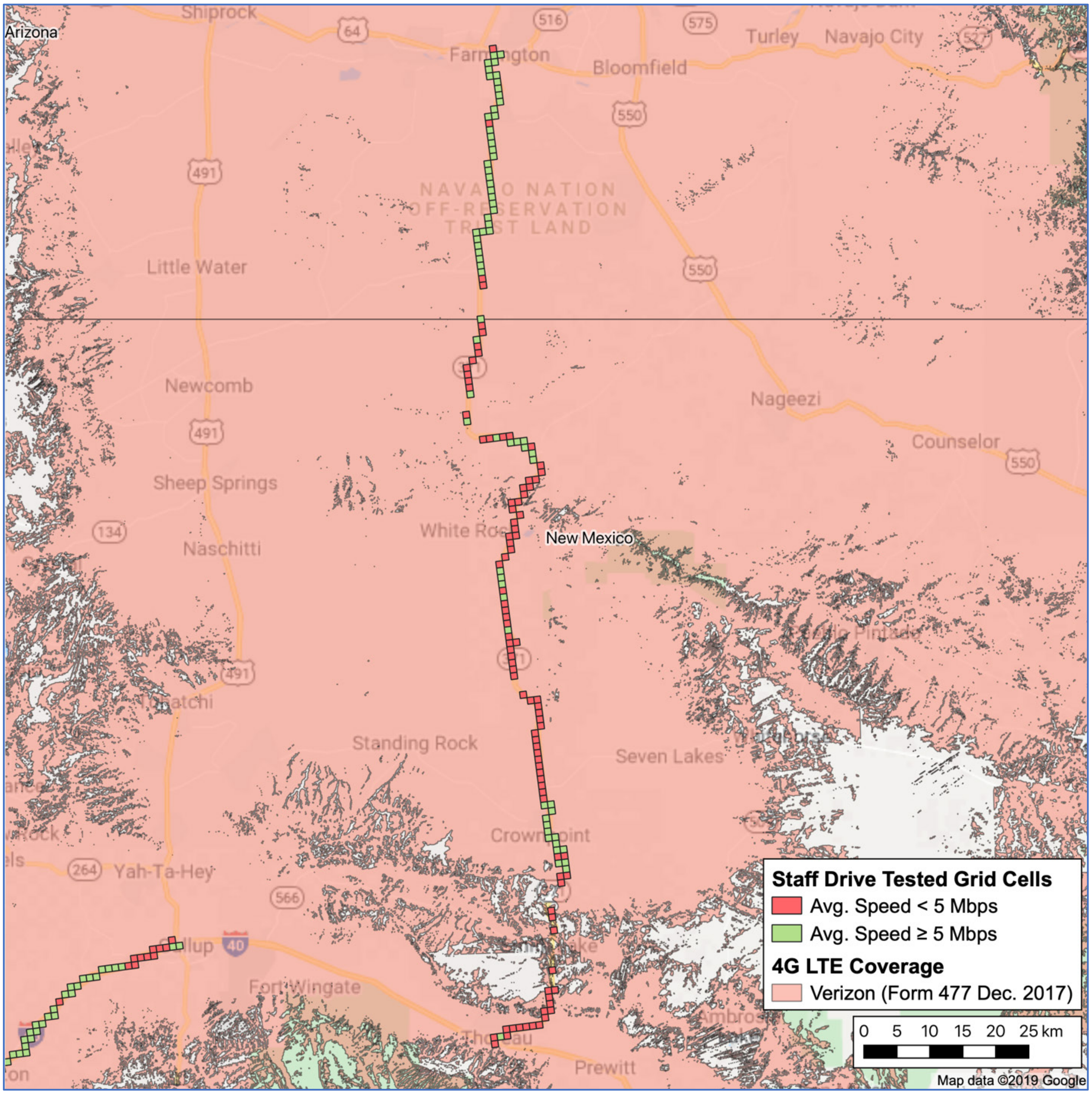


Figure 7. Western Portion of Staff Drive Test Route for Oklahoma (Verizon)

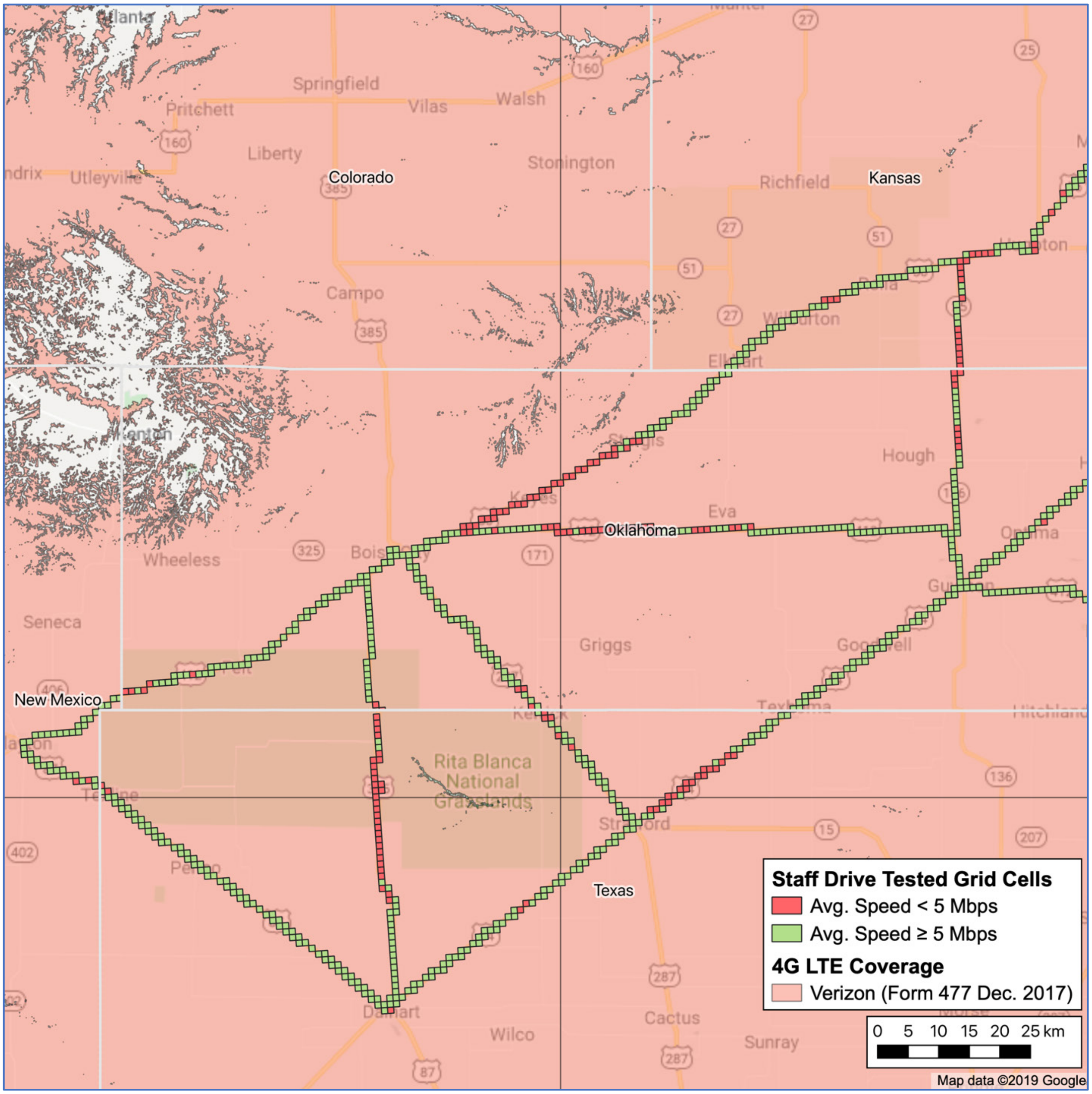


Figure 8. Eastern Portion of Staff Drive Test Route for Oklahoma (Verizon)

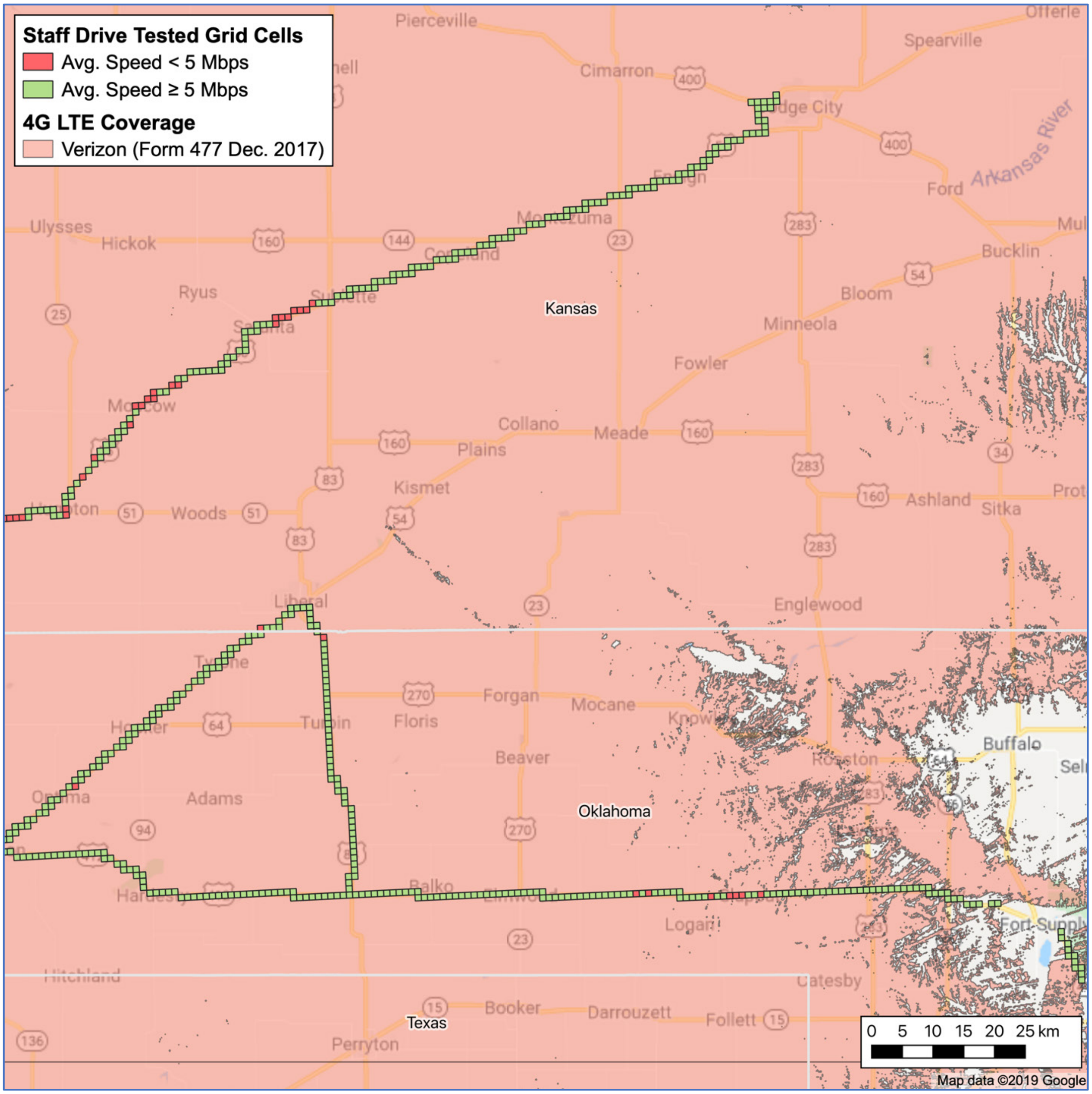


Figure 9. Northern Portion of Staff Drive Test Route for Alabama (Verizon)

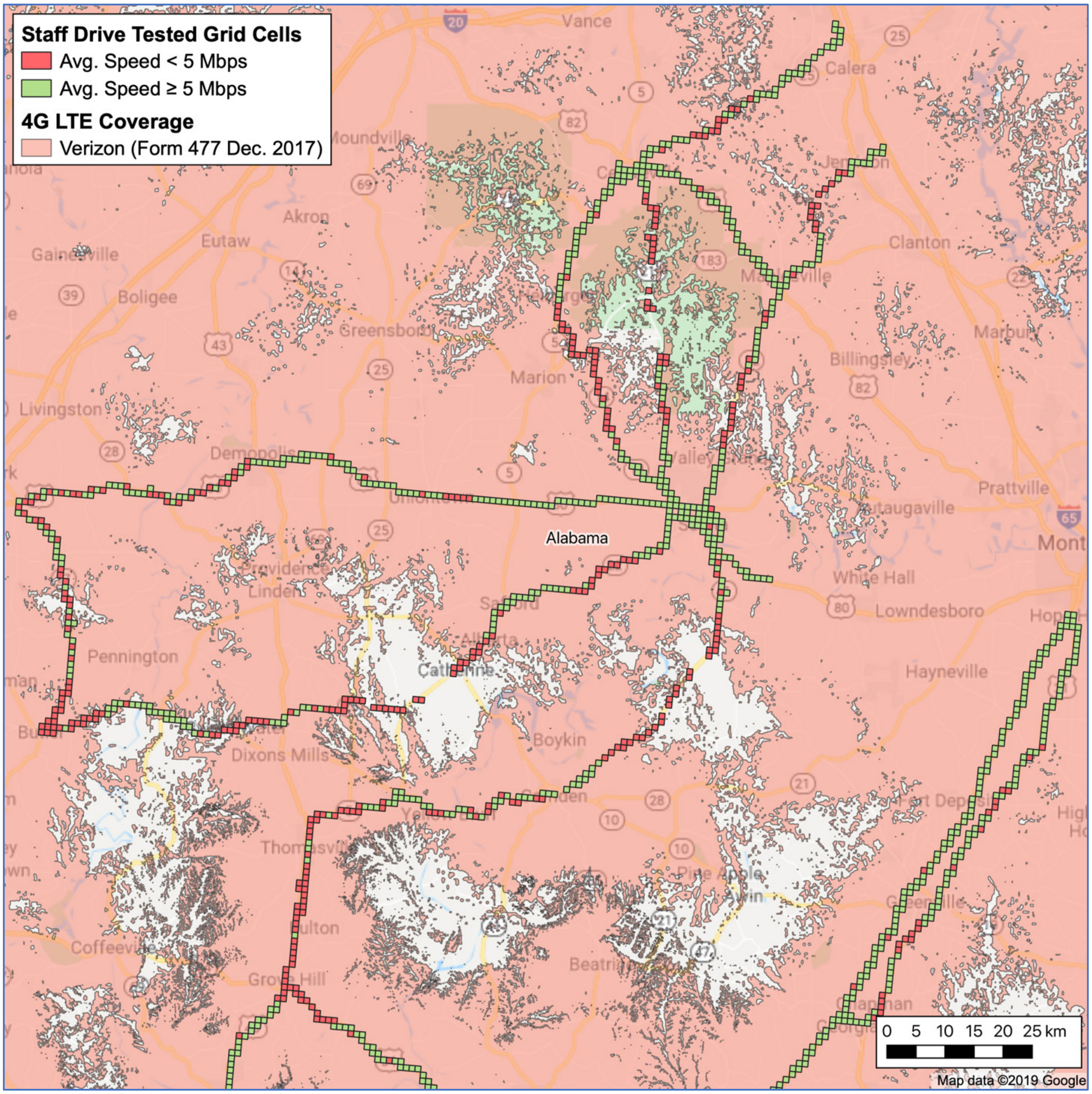


Figure 10. Southern Portion of Staff Drive Test Route for Alabama (Verizon)

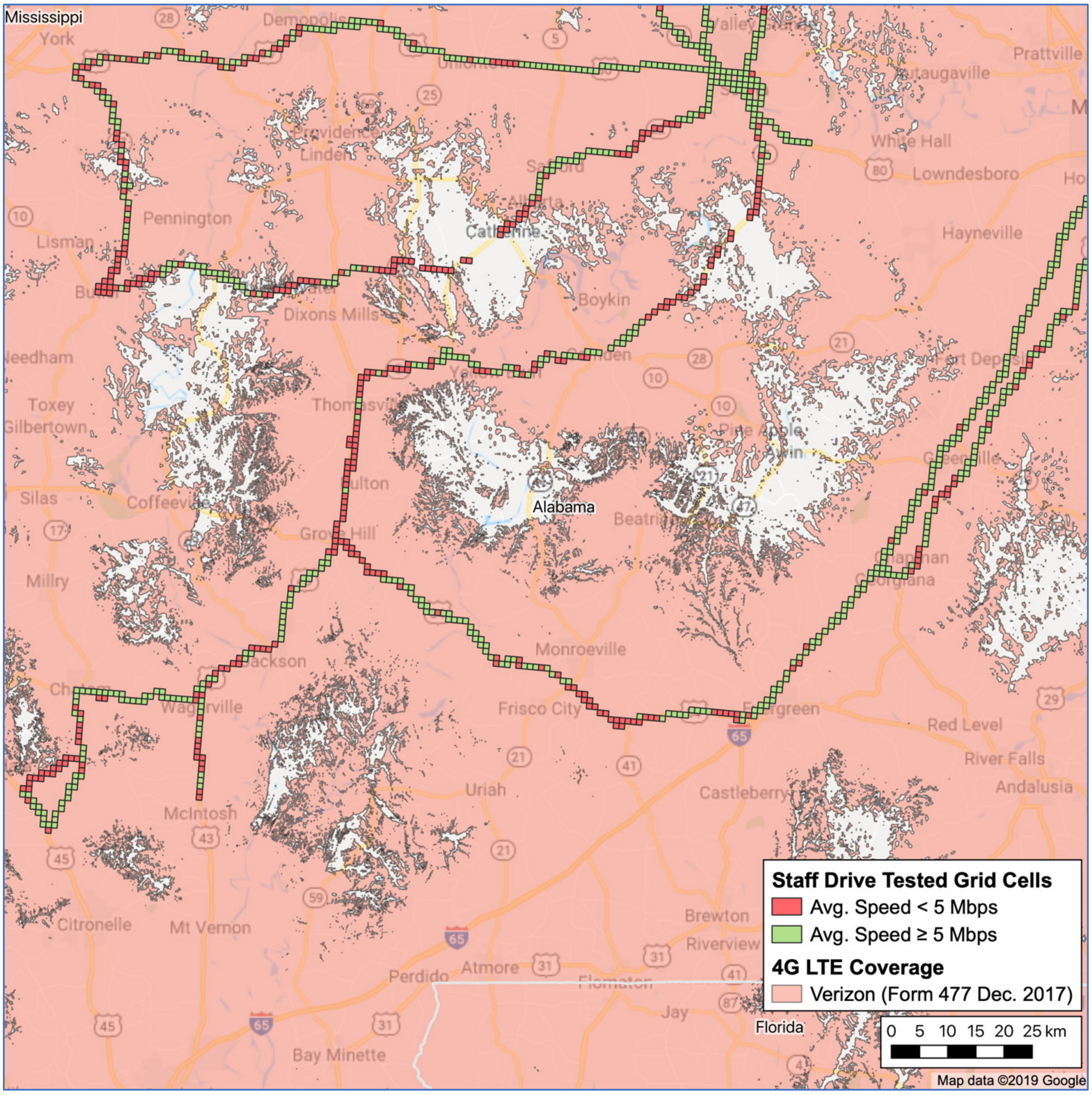


Figure 11. Staff Drive Test Route for Vermont (Verizon)

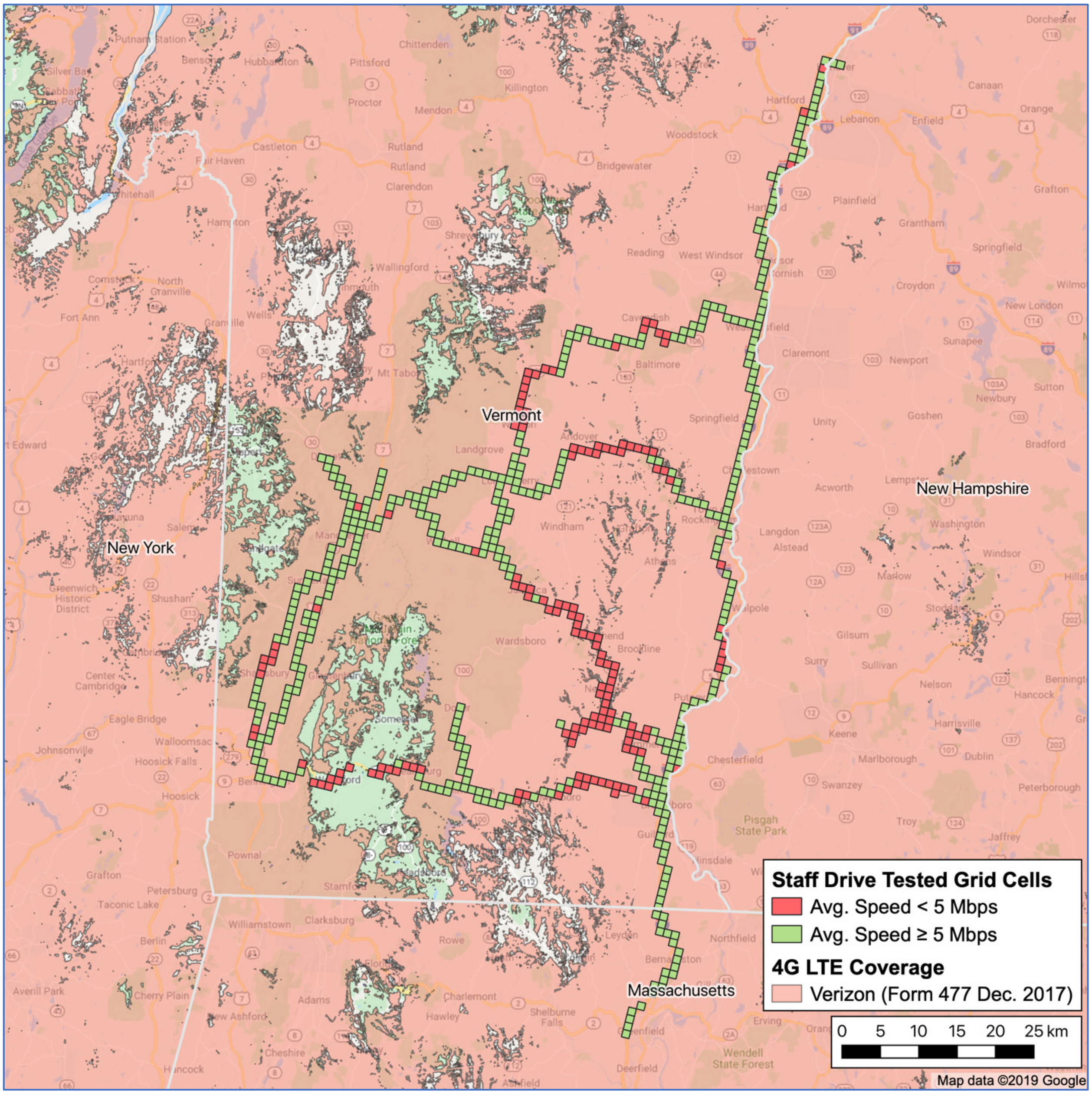


Figure 12. Southwestern Portion of Staff Drive Test Route for Montana (Verizon)

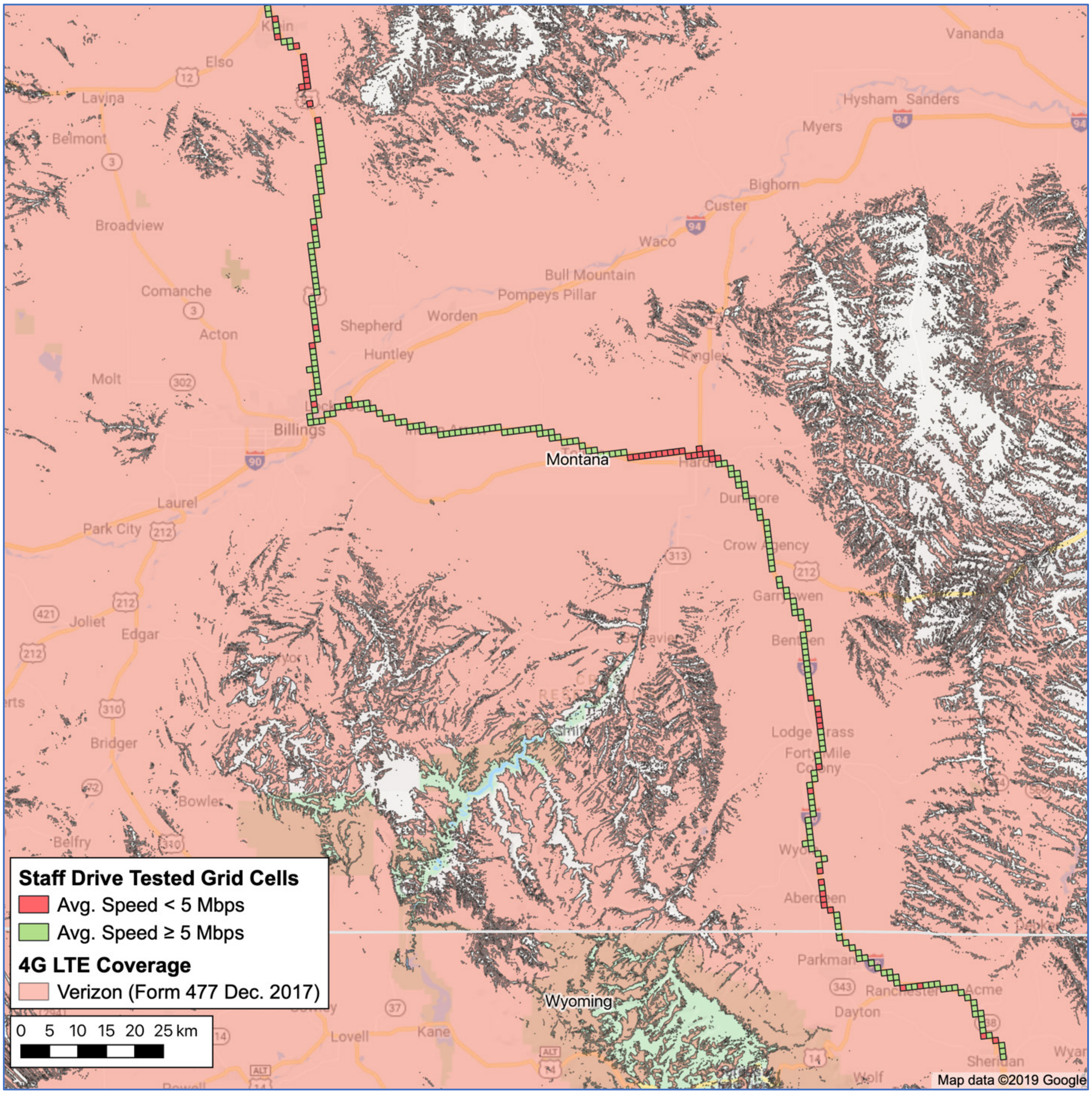


Figure 13. Western Portion of Staff Drive Test Route for Montana (Verizon)

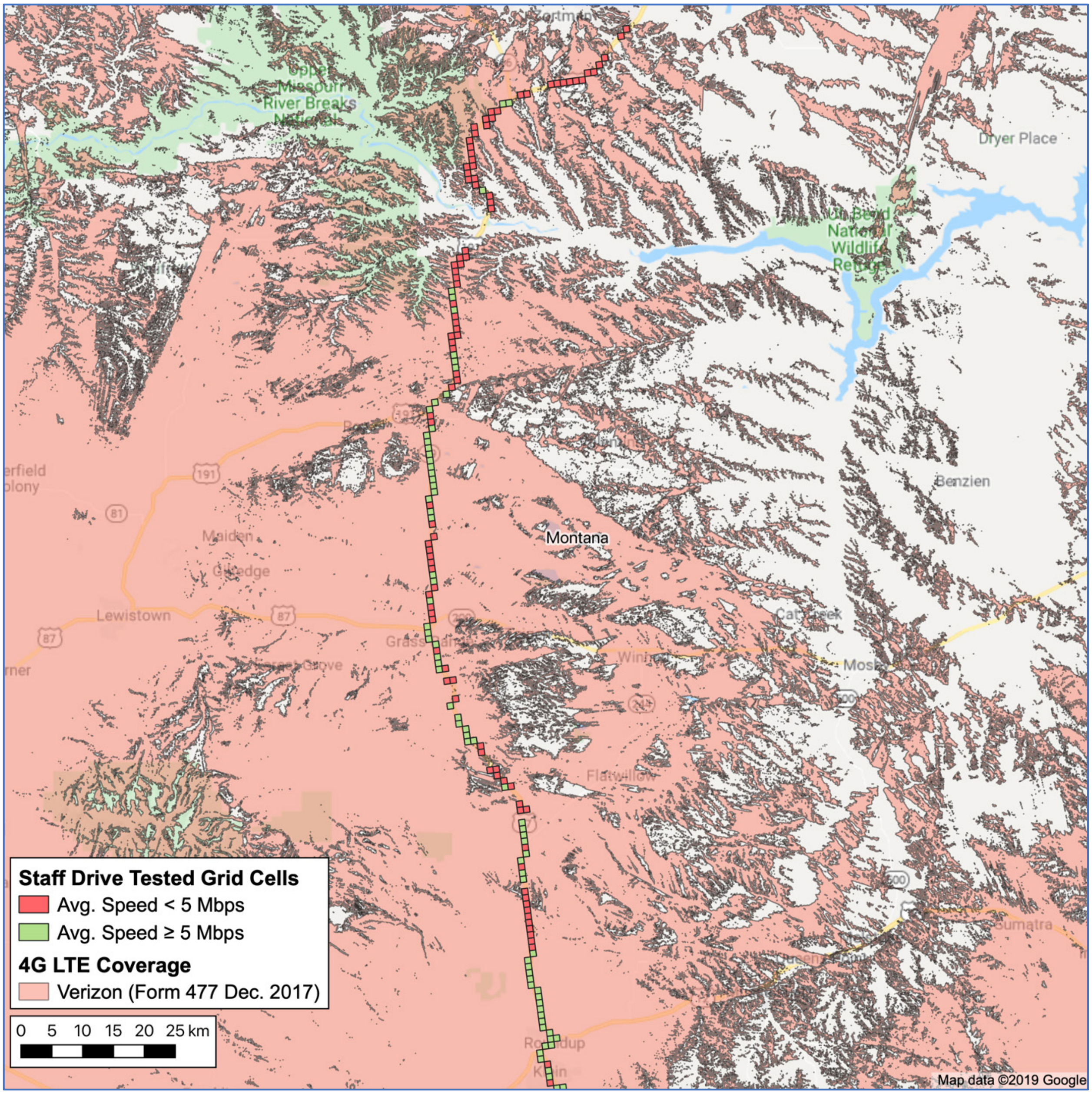


Figure 14. Northwestern Portion of Staff Drive Test Route for Montana (Verizon)

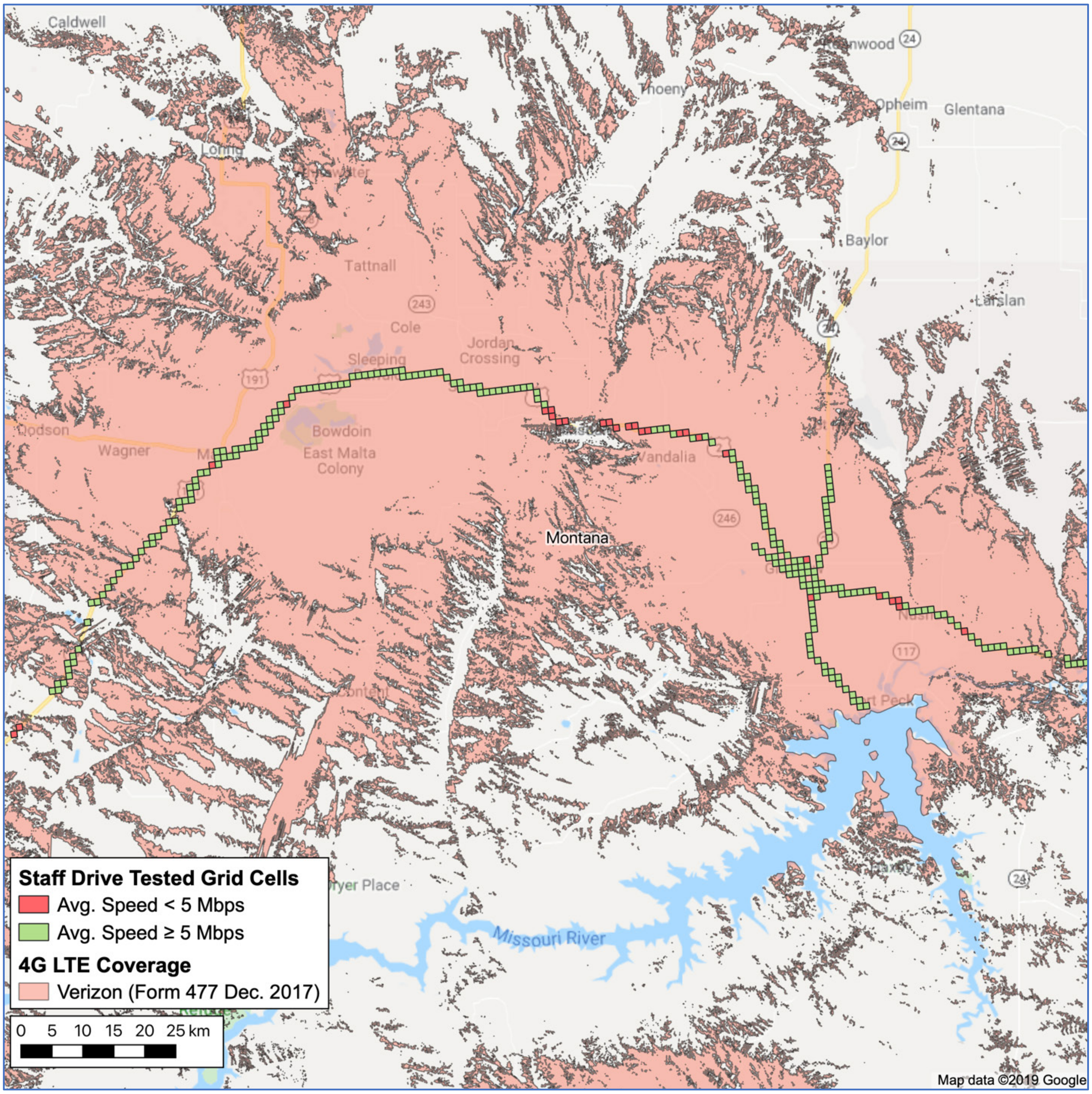


Figure 15. Northeastern Portion of Staff Drive Test Route for Montana (Verizon)

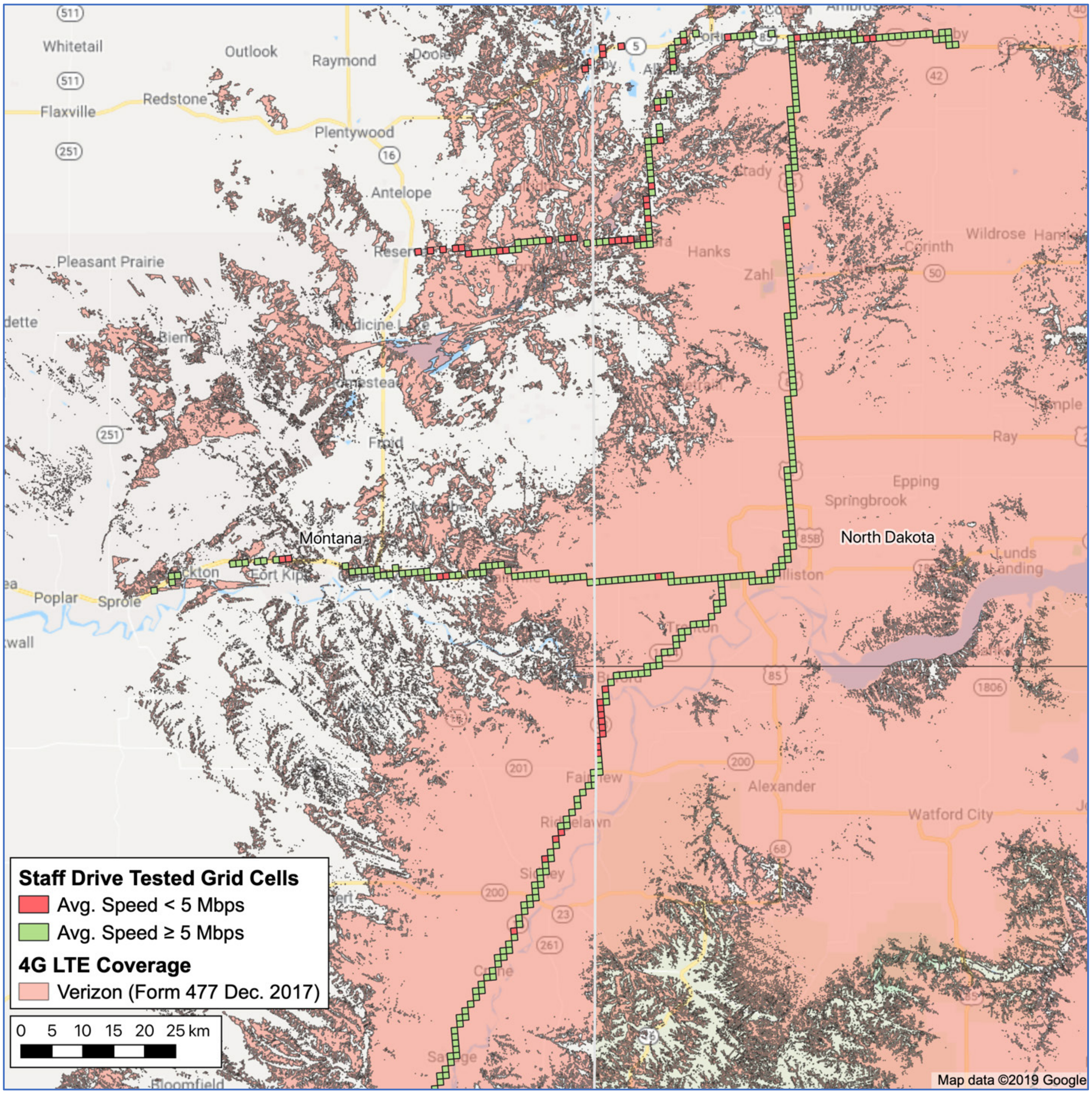


Figure 16. Southeastern Portion of Staff Drive Test Route for Montana (Verizon)

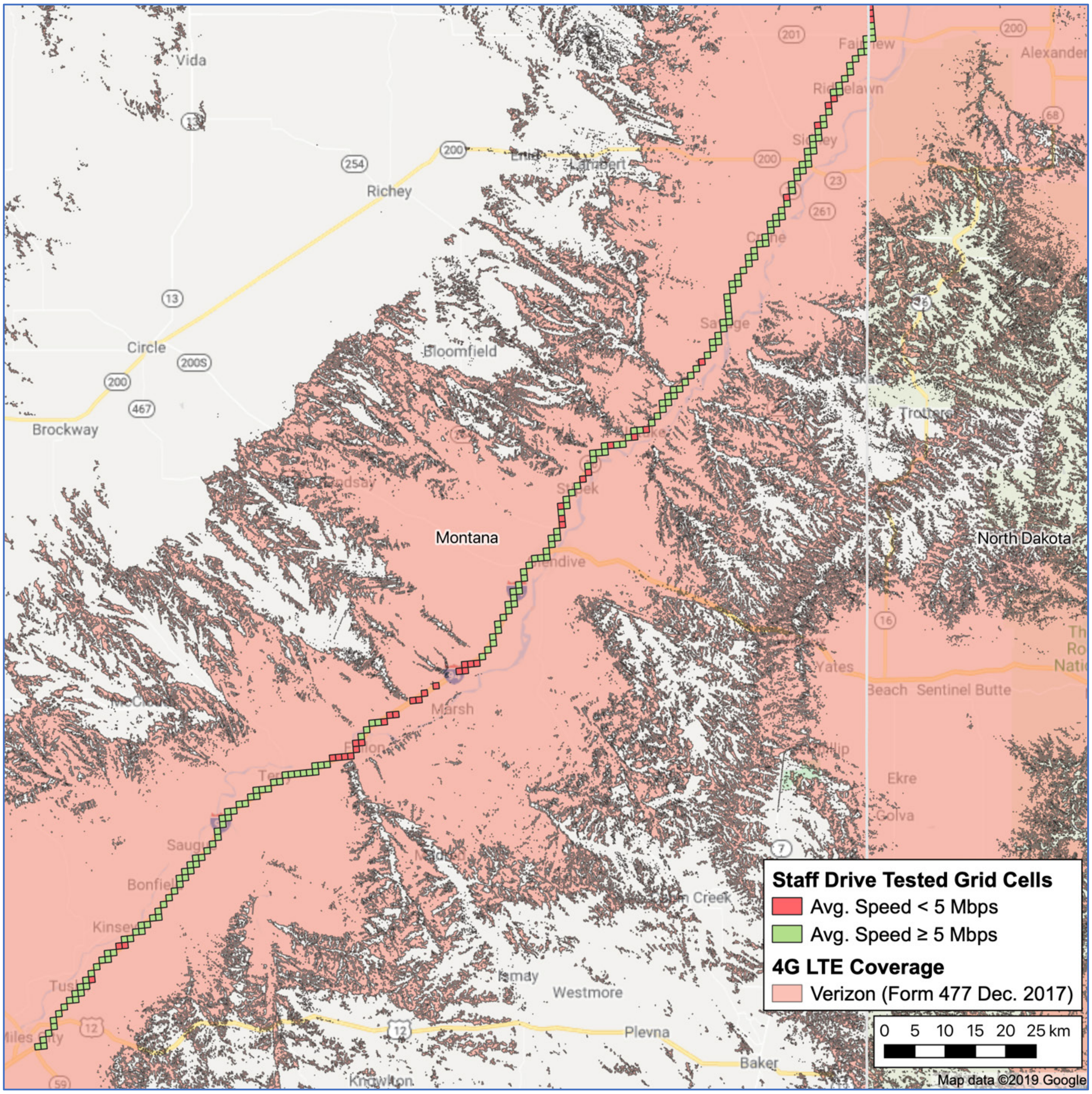


Figure 17. Staff Drive Test Route for Vermont (U.S. Cellular)

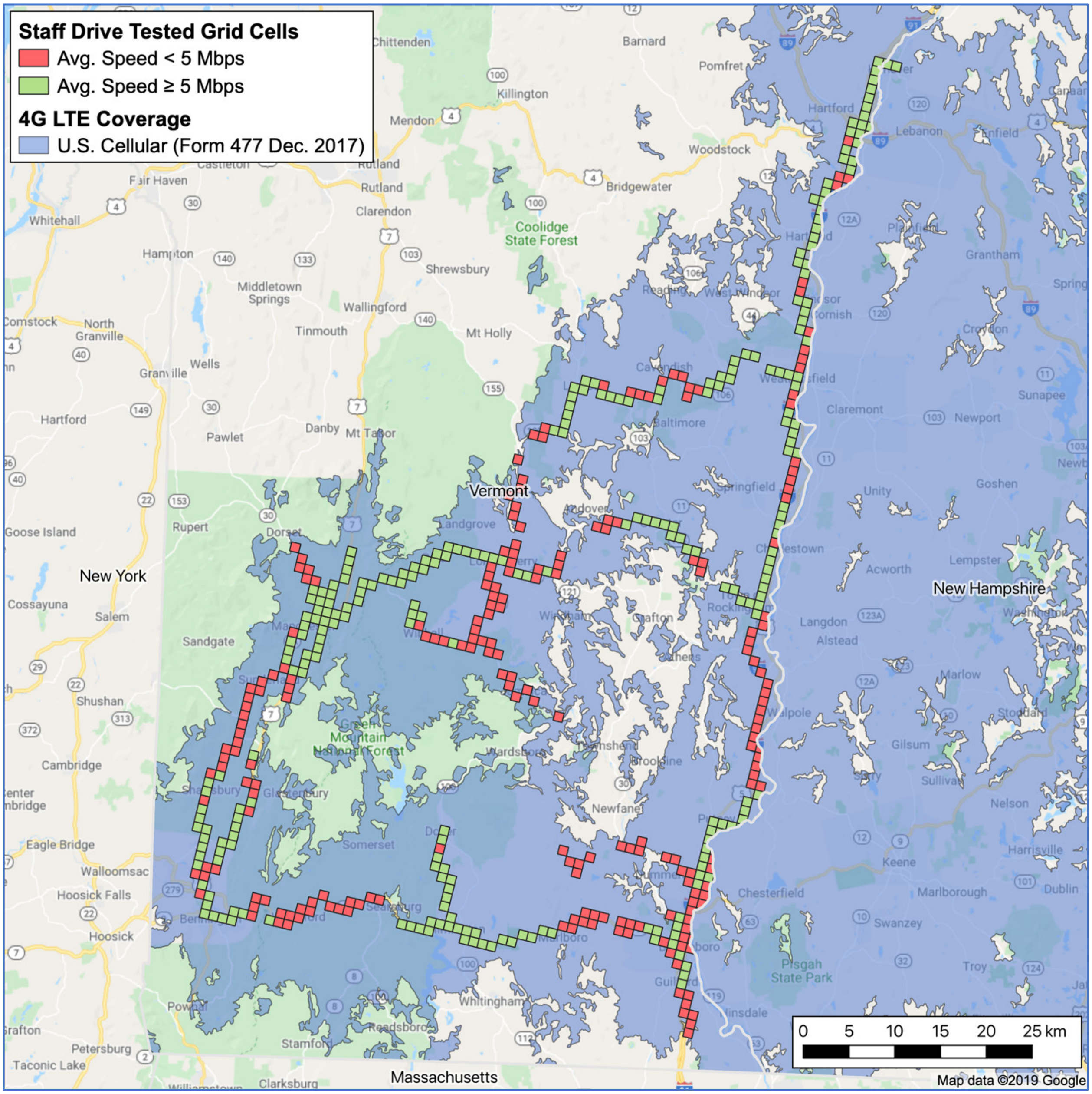


Figure 18. Northern Portion of Staff Drive Test Route for Alabama (T-Mobile)

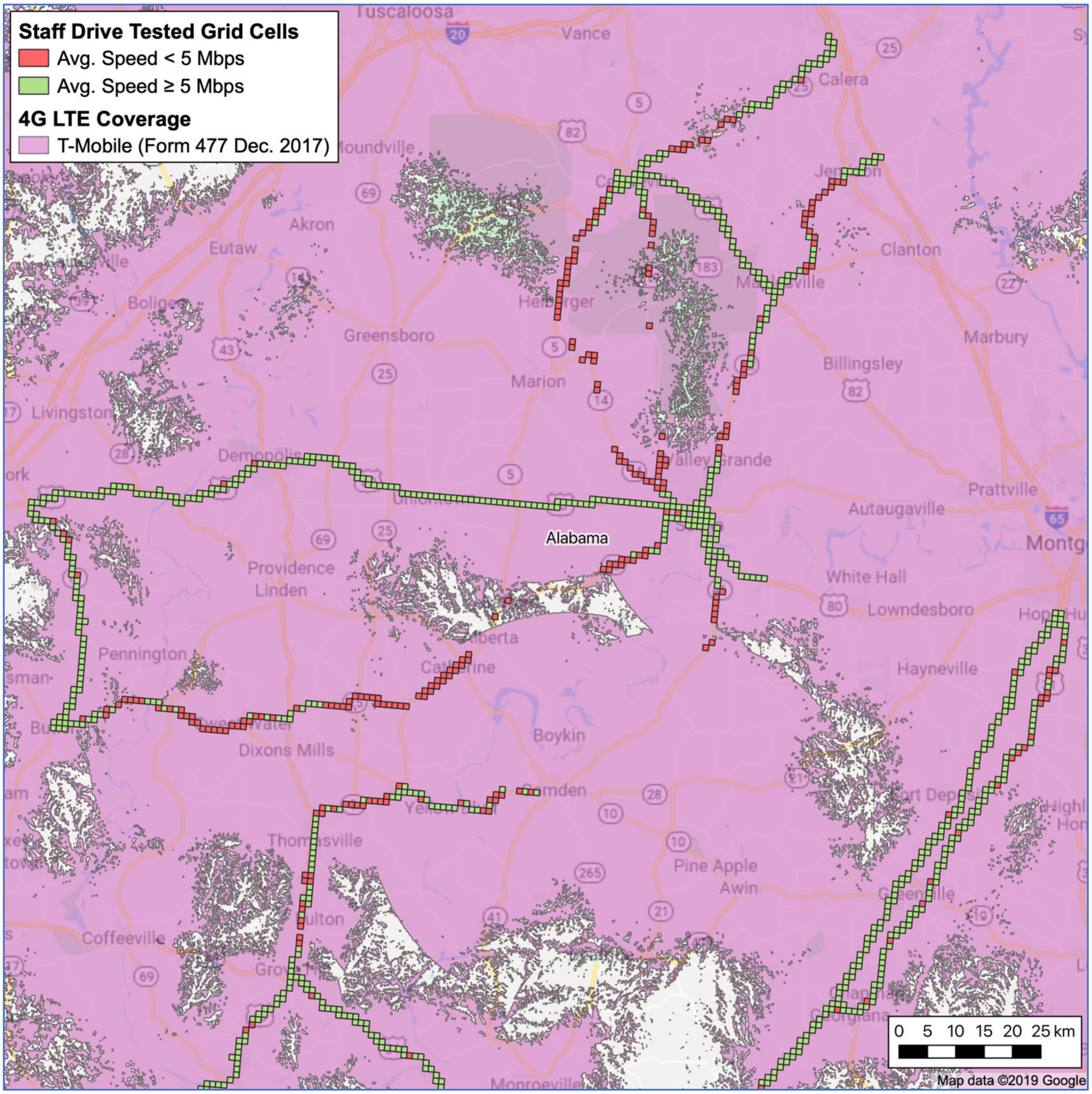


Figure 19. Southern Portion of Staff Drive Test Route for Alabama (T-Mobile)

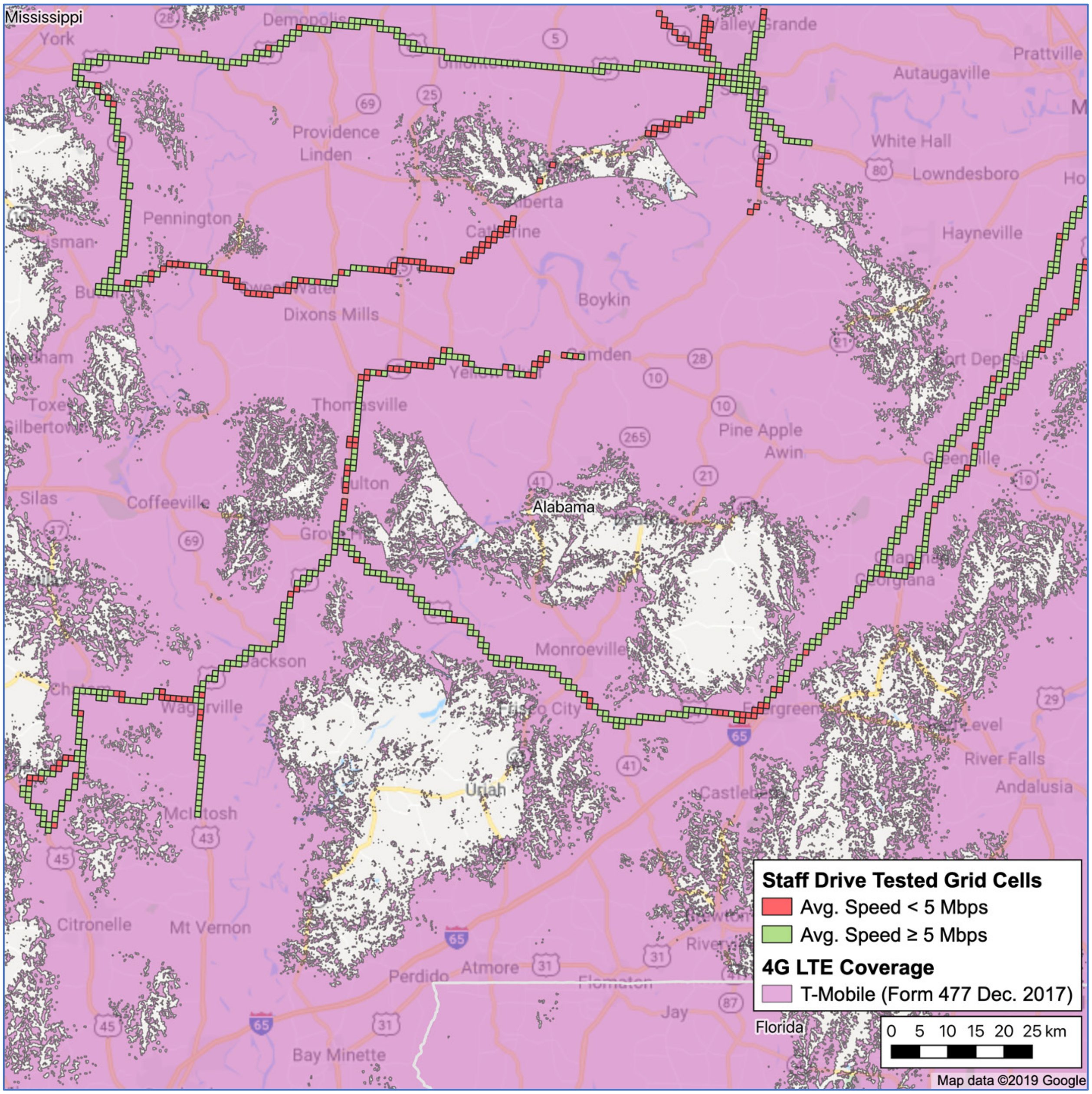


Figure 20. Big Horn and Yellowstone County Portion of Staff Drive Test Route for Montana (T-Mobile)

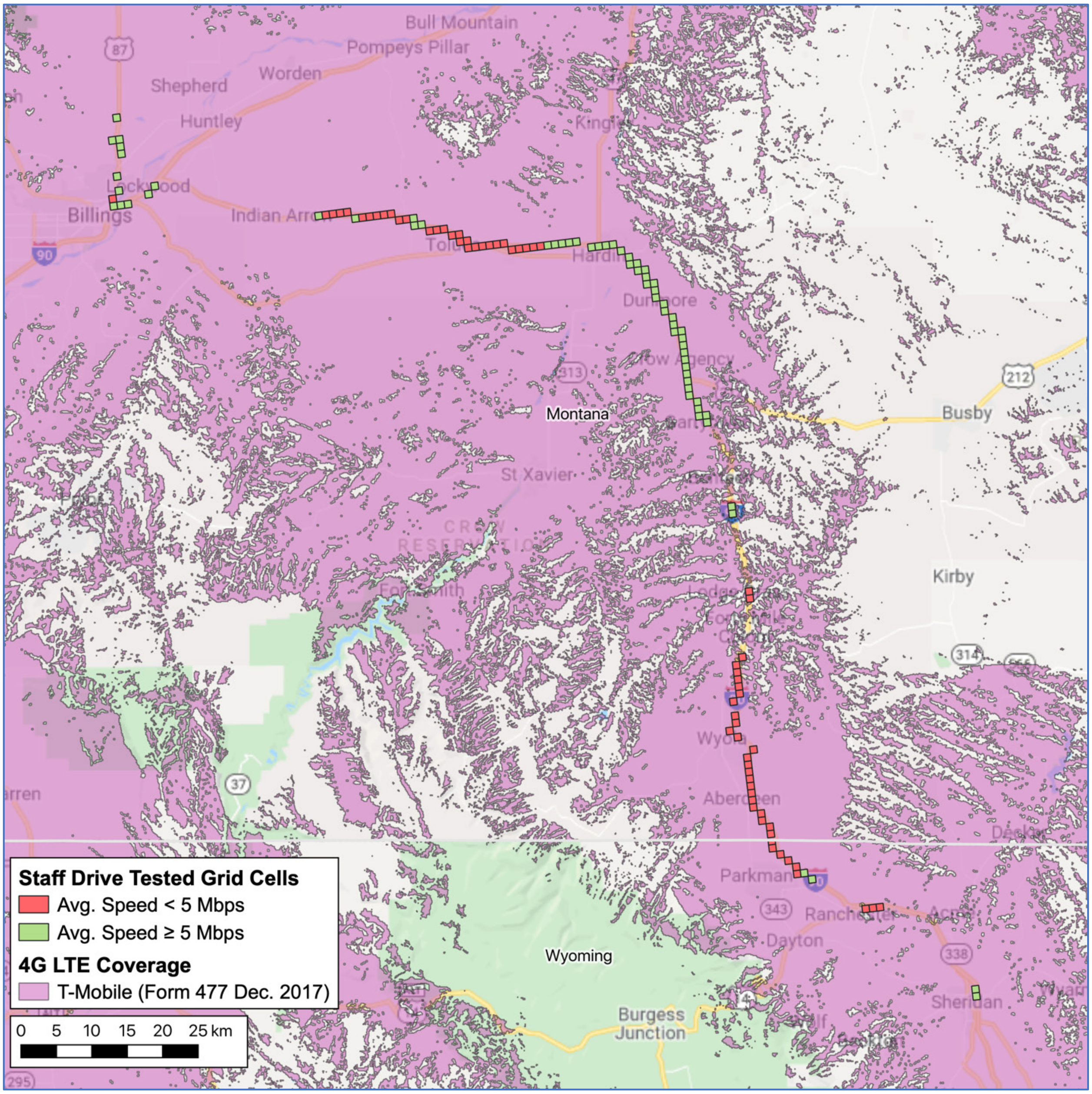


Figure 21. Phillips and Valley County Portion of Staff Drive Test Route for Montana (T-Mobile)

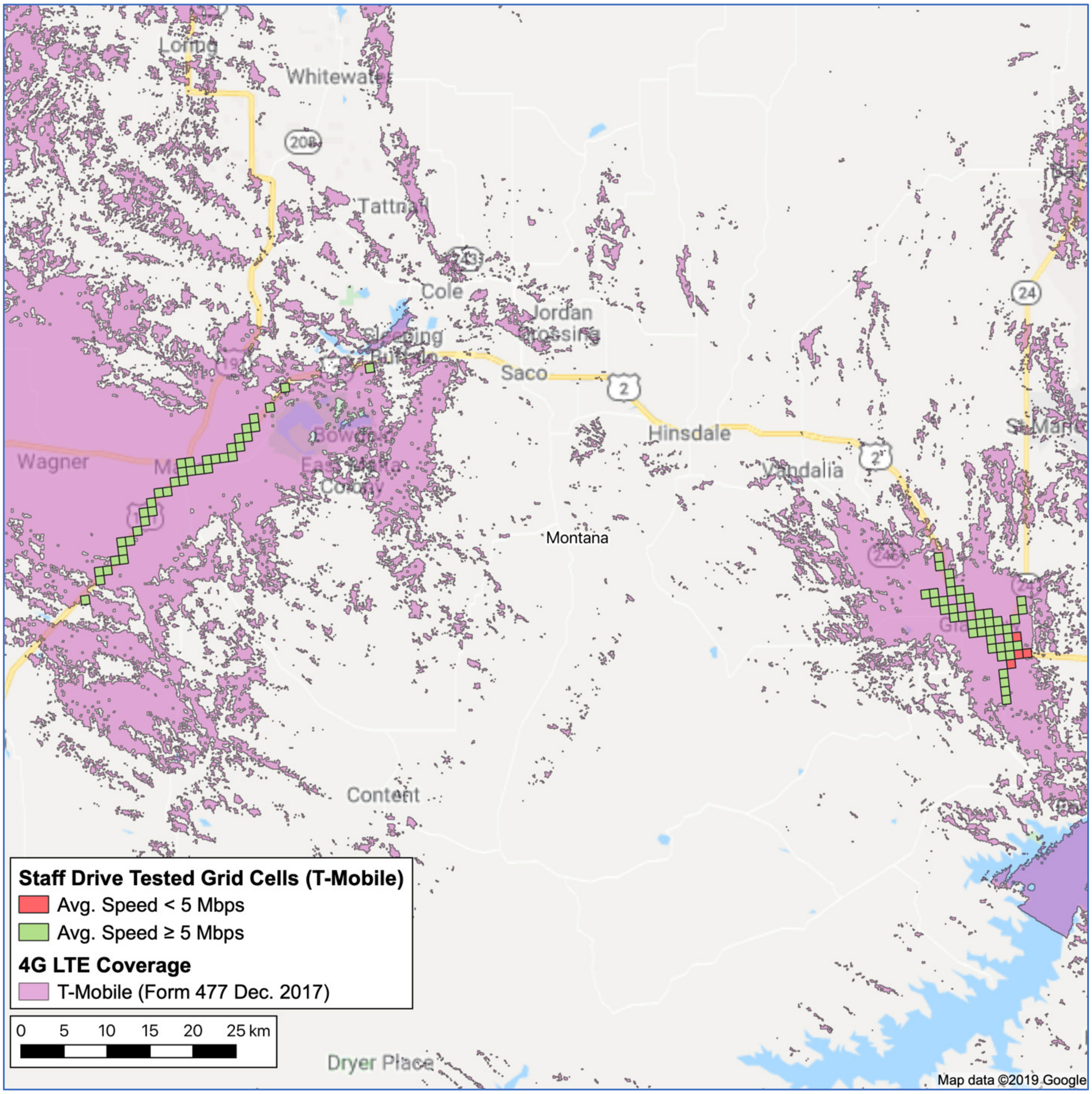


Figure 22. Northeastern Portion of Staff Drive Test Route for Montana (T-Mobile)

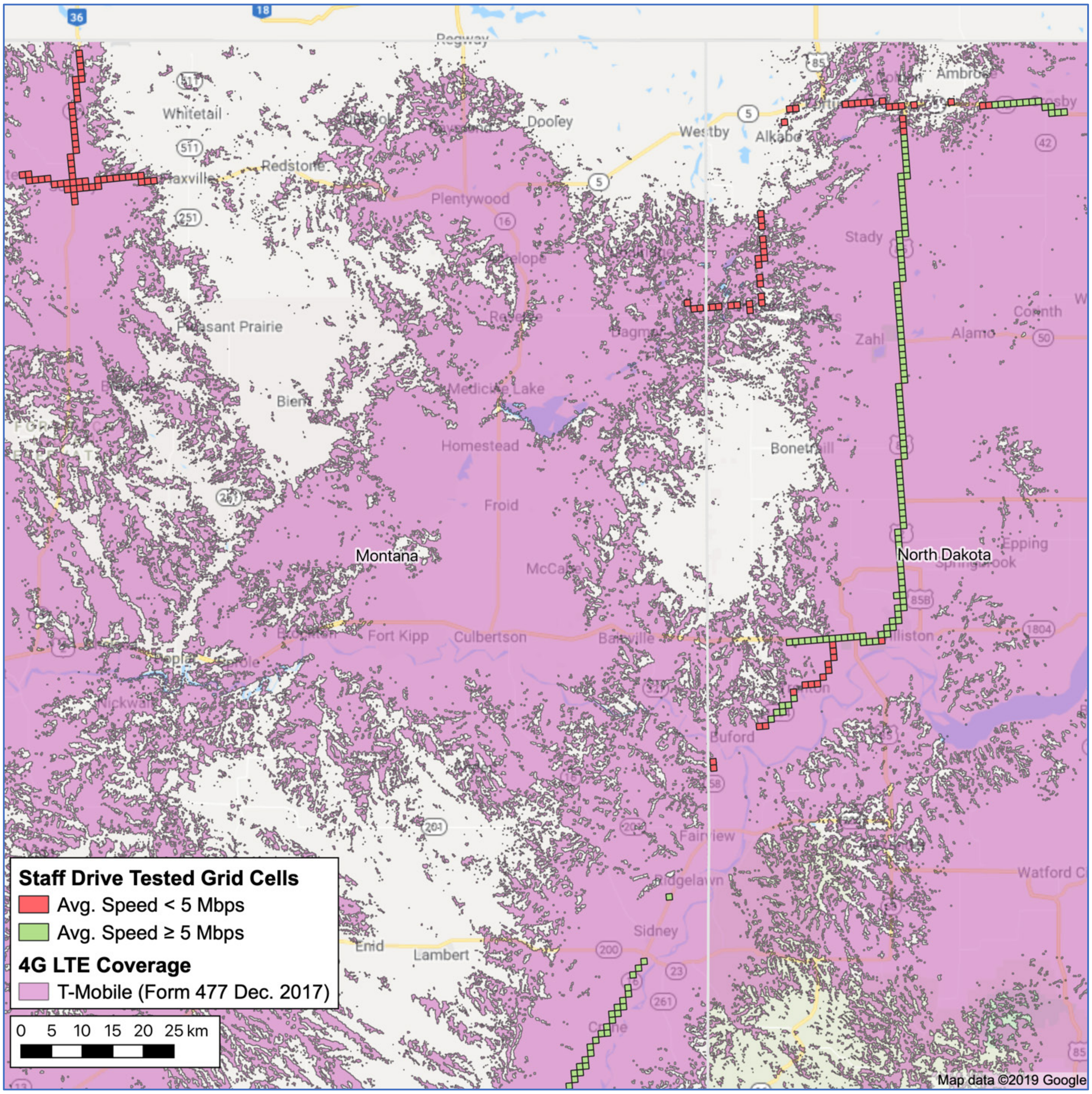
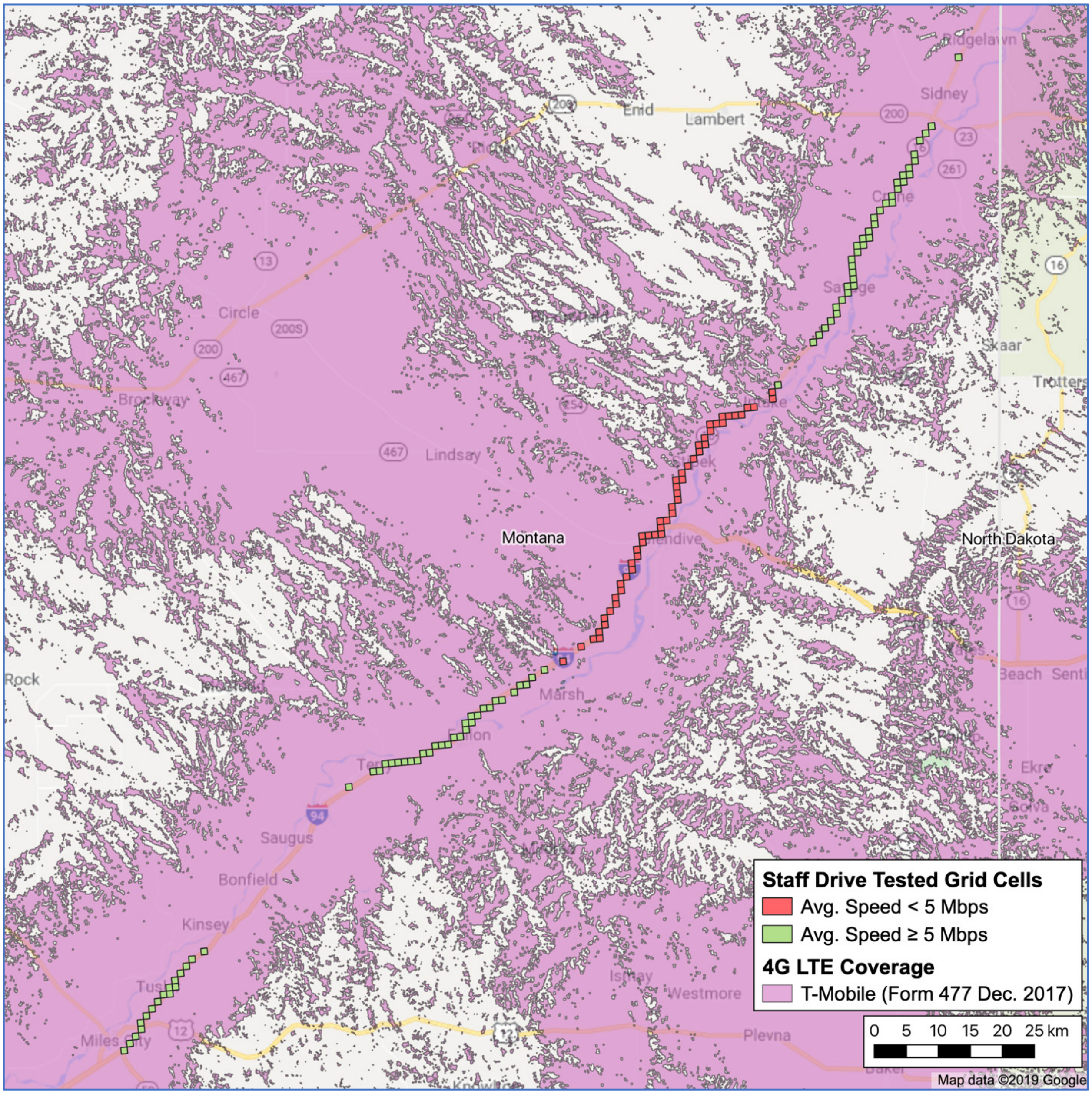


Figure 23. Interstate 94 Portion of Staff Drive Test Route for Montana (T-Mobile)



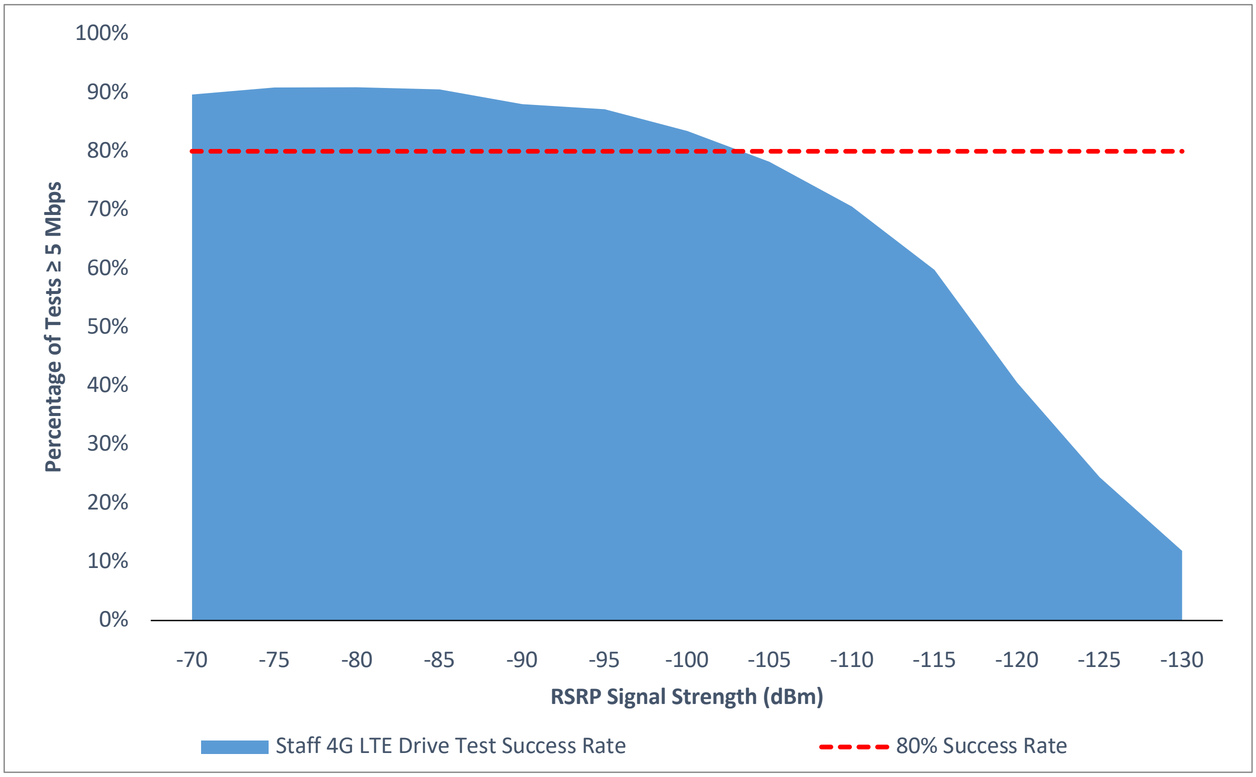
64. *Relationship Between RSRP Signal Strength and Success Rate*.—In addition to download speed, the staff speed tests recorded the RSRP signal strength value in decibel-milliwatts (dBm) received by the handset with each speed test on a 4G LTE network.[117] Among other analyses, we analyzed

[117] The RSRP value recorded by handsets is a standard measurement of signal strength indicative of cell coverage of 4G LTE networks. *See* Stefania Sesia et al., LTE–The UMTS Long Term Evolution: From Theory to Practice § 22.3.1.1, at 513 (Wiley 2nd ed. 2011). RSRP as a metric for signal strength only pertains to 4G LTE networks. Accordingly, for these purposes we excluded tests that did not include a recorded RSRP value, either because the test was conducted on a non-4G LTE network (e.g. 3G) or because the handset was unable to detect a 4G LTE signal.

whether the measurements helped explain the discrepancies found between model-predicted download speeds and on-the-ground tests.

65. We found a strong positive relationship between the RSRP signal strength recorded and the percentage of 4G LTE speed tests that achieved a download speed of at least 5 Mbps (see Figure 24). Across all 4G LTE staff drive tests, when RSRP values were -80 dBm or higher, the observed success rate was at least 90%. An 80% or better success rate was found with RSRP values of -105 dBm or higher. We saw a sharp drop off in success rates at RSRP values below -105 dBm.

Figure 24. Percentage of Successful 4G LTE Staff Drive Tests by RSRP



66. To compare these signal strength observations to the Commission's coverage map standards, we refer to the RSRP signal strength at which an 80% success rate is achieved as the "observed cell edge." While the observed cell edge RSRP was -105 dBm across all staff drive tests that obtained a 4G LTE signal within the coverage area, it varied considerably among the three providers tested. T-Mobile's observed cell edge RSRP was approximately -115 dBm, while Verizon's was approximately -105 dBm and U.S. Cellular's was approximately -100 dBm.

67. The Commission also required each provider to report the minimum cell edge RSRP signal strength values that its propagation model predicts a device would receive for its coverage maps (the "reported cell edge").[118] The reported cell edge RSRP values reported by the three providers were {[ ]} dBm for T-Mobile, {[ ]} dBm for U.S. Cellular, and {[ ]} dBm for Verizon. As a benchmark, we compared the recorded signal strength of staff speed tests to the lowest of these

[118] The MF-II LTE coverage data include an RSRP value that represents the minimum signal strength that each provider used to determine the cell edge in its propagation model. *See How Should I Format My LTE Coverage Data?* (Nov. 28, 2017, 10:04 AM), https://www.fcc.gov/MF2-LTE-Collection (follow "Description & Formatting" hyperlink under "Mobile LTE Coverage Maps").

reported cell edge RSRP values in performing our analysis.[119] We found that the recorded signal strengths were sometimes inconsistent with the provider's filings, recording values below the lowest reported cell edge RSRP of the tested provider. More specifically, we found that {[ ]}, {[ ]}, and {[ ]} of 4G LTE drive tests conducted within the reported coverage areas of T-Mobile, U.S. Cellular, and Verizon, respectively, had an RSRP value below the provider's reported cell edge RSRP value (see Table 7). In cases where the handset recorded signal strength values below the minimum predicted by the provider's propagation model, that suggests that its model may not be properly considering on-the-ground factors such as clutter or terrain.

Table 7. Reported versus Observed Cell Edge by Provider

Provider Name	Percentage Non-4G LTE Tests	Percentage 4G LTE Tests with RSRP Below Reported Cell Edge RSRP	Reported Cell Edge RSRP	Observed Cell Edge RSRP
T-Mobile	21.3%	{[ ]}	{[ ]} dBm	-115 dBm
U.S. Cellular	38.0%	{[ ]}	{[ ]} dBm	-100 dBm
Verizon	16.2%	{[ ]}	{[ ]} dBm	-105 dBm

68. We further compared the observed cell edge RSRP value for each provider with its reported cell edge RSRP and found the reported cell edge values to be lower than the observed cell edge values in some cases. For example, the staff drive test data indicate an observed cell edge RSRP—that is, the RSRP signal strength at which an 80% success rate is achieved—on Verizon's 4G LTE network of approximately -105 dBm, which is higher than Verizon's reported cell edge RSRP value of {[ ]} dBm.

69. In cases where the reported cell edge RSRP is lower than the observed cell edge RSRP for a particular provider, it suggests that the RSRP value used by the provider to determine the cell edge in its propagation model may have been too low to allow for handsets to achieve the required download speed with sufficient probability to meet the MF-II specification. In these cases, prescribing a higher minimum RSRP value may provide a more accurate depiction of actual coverage meeting the Commission's standard for the 4G LTE data collection. We also note that even if the reported cell edge RSRP for one of the three providers were equal to the observed cell edge RSRP, the submitted coverage maps would still not accurately reflect actual network performance due to the large number of tests that did not record a 4G LTE signal and had no RSRP values.

[119] Providers that submitted coverage data for multiple spectrum bands generally reported different RSRP values for different spectrum bands. Because the staff speed test data did not record which spectrum band the handset used for each test or in each location, we compared the test data to the lowest value in the range of RSRP values in cases where the provider reported different RSRP values for different spectrum bands. We also acknowledge that the providers for which staff conducted speed tests may have networks that used carrier aggregation—a technology by which the handset is able to receive and transmit over multiple spectrum bands simultaneously. The staff speed tests recorded only a single RSRP signal strength value associated with each test and did not record which spectrum band or bands were in use at the time of the test. As a result, it is possible that the test handset measured multiple RSRP signal strengths on different bands despite only recording the RSRP signal strength associated with the primary band.

C. Stationary Test Results

70. The results of the stationary tests conducted by Commission staff vary widely based upon the specific location at which the tests were run (see Table 8 and Table 9).[120] Locations were selected based upon the planned drive test route and staff analysis of each provider's 4G LTE coverage maps identifying areas close to the edge of coverage. As a result, we would likewise expect that the percentage of stationary tests at each location that were successful—i.e., recorded a download speed of at least 5 Mbps—would be at least 80%. Additionally, because staff stationary testing recorded numerous tests at the same location over an extended time, the success rate should be more representative of performance at a particular location than a single drive test point.

71. Out of the 42 stationary test locations, nearly half (20) measured a success rate of 80% or better—and, for slightly more than a third (15) of the locations, the 92% benchmark was met—indicating that in at least those areas the provider's coverage map appeared to be accurate. However, the success rates for the remaining locations were generally considerably lower than the 80% benchmark, including eight locations for which no stationary test achieved download speeds of at least 5 Mbps. Such results indicate that the provider's coverage data may not be an accurate representation of the on-the-ground consumer experience in these 22 locations.

Table 8. Staff Stationary Test Results by Route, Location, and Provider

Provider Name	Test Route	Location	Test Count ≥ 5 Mbps	Test Count Total	Percentage ≥ 5 Mbps
T-Mobile	Alabama	Federal Rd., Hope Hull, AL	149	170	87.6%
T-Mobile	Alabama	Four Points Rd., Fruitdale, AL	75	175	42.9%
T-Mobile	Alabama	Rt. 10, Camden, AL	147	170	86.5%
T-Mobile	Alabama	Rt. 16, Sweet Water, AL	164	165	99.4%
T-Mobile	Alabama	Marvel Rd., Brierfield, AL	93	156	59.6%
T-Mobile	Montana	Hwy. 248, Scobey, MT	0	143	0%
T-Mobile	Montana	Scotty Pride Dr., Glasgow, MT	171	172	99.4%
U.S. Cellular	Vermont	Rt. 9, Bennington, VT	80	165	48.5%
U.S. Cellular	Vermont	N. Hartland Rd., White River Junction, VT	142	169	84.0%
U.S. Cellular	Vermont	S. Main St., Chester, VT	169	169	100%
U.S. Cellular	Vermont	Bonnet St., Manchester Center, VT	175	175	100%
U.S. Cellular	Vermont	Putney Rd., Brattleboro, VT	0	164	0%
Verizon	Alabama	Federal Rd., Hope Hull, AL	165	165	100%
Verizon	Alabama	Four Points Rd., Fruitdale, AL	10	146	6.8%
Verizon	Alabama	Rt. 10, Camden, AL	88	154	57.1%
Verizon	Alabama	Rt. 16, Sweet Water, AL	41	155	26.5%

[120] We have again excluded from our analysis any stationary test points that fell outside of the tested provider's coverage maps.

Provider Name	Test Route	Location	Test Count ≥ 5 Mbps	Test Count Total	Percentage ≥ 5 Mbps
Verizon	Alabama	Marvel Rd., Brierfield, AL	167	170	98.2%
Verizon	Arizona[121]	E. Woolford Rd., Show Low, AZ	2	4	50.0%
Verizon	Arizona	S. Penrod Ln., Pinetop-Lakeside, AZ	30	30	100%
Verizon	Arizona	Winners Cir., McNary, AZ	0	5	0%
Verizon	Arizona	Farm Rd., Canyon Day, AZ	9	13	69.2%
Verizon	Arizona	Faught Ridge Rd., Show Low, AZ	0	5	0%
Verizon	Arizona	Rim Rd., Show Low, AZ	0	3	0%
Verizon	Arizona	W. Whipple St., Show Low, AZ	0	4	0%
Verizon	Montana	4th Ave. SE, Crosby, ND	169	169	100%
Verizon	Montana	Scotty Pride Dr., Glasgow, MT	154	162	95.1%
Verizon	New Mexico	Rt. 371, Thoreau, NM	0	221	0%
Verizon	New Mexico	Rt. 371, Crownpoint, NM	147	220	66.8%
Verizon	New Mexico	Rt. 371, Bloomfield, NM	56	221	25.3%
Verizon	New Mexico	W. Main St., Farmington, NM	193	216	89.4%
Verizon	Oklahoma	Rt. 287, Stratford, TX	163	165	98.8%
Verizon	Oklahoma	N0350 Rd., Boise City, OK	162	172	94.2%
Verizon	Oklahoma	Rt. 412, Guymon, OK	167	168	99.4%
Verizon	Oklahoma	Rt. 56, Dodge City, KS	171	171	100%
Verizon	Oklahoma	Rt. 412, Felt, OK	124	167	74.3%
Verizon	Oklahoma	Rt. 54, Tyrone, OK	125	168	74.4%
Verizon	Oklahoma	Rt. 385, Dalhart, TX	106	170	62.4%
Verizon	Vermont	Rt. 9, Bennington, VT	169	169	100%
Verizon	Vermont	N. Hartland Rd., White River Junction, VT	102	168	60.7%
Verizon	Vermont	S. Main St., Chester, VT	0	155	0%
Verizon	Vermont	Bonnet St., Manchester Center, VT	25	26	96.2%
Verizon	Vermont	Putney Rd., Brattleboro, VT	143	161	88.8%
		Total	**4,053**	**5,916**	**68.5%**

[121] We note that stationary tests for locations in Arizona did not follow the same methodology as for stationary tests along subsequent test routes. Specifically, see *supra* note 111, stationary tests in Arizona were conducted for a duration of one-to-two minutes compared to one-to-two hours for later stationary tests. Staff thus recorded far fewer tests for stationary test locations in Arizona.

Table 9. Staff Stationary Test Results by Route and Provider

Provider Name	Test Route	Test Count Zero Mbps	Test Count > 0 & < 5 Mbps	Test Count ≥ 5 Mbps	Test Count Total	Percentage ≥ 5 Mbps
T-Mobile	Alabama	5	203	628	836	75.1%
T-Mobile	Montana	4	140	171	315	54.3%
US Cellular	Vermont	96	180	566	842	67.2%
Verizon	Arizona	12	11	41	64	64.1%
Verizon	New Mexico	1	481	396	878	45.1%
Verizon	Oklahoma	1	162	1,018	1,181	86.2%
Verizon	Alabama	4	315	471	790	59.6%
Verizon	Vermont	41	199	439	679	64.7%
Verizon	Montana	0	8	323	331	97.6%
Total		**164**	**1,699**	**4,053**	**5,916**	**68.5%**

72. The staff stationary testing results additionally underscore some of the temporal variability of mobile networks that complicates attempts to accurately measure performance. Even at locations where stationary tests met or exceeded the threshold success rate of 80%, a small percentage of tests nevertheless failed. For example, despite an overall success rate of 89.4% on Verizon's network at the Farmington, NM stationary test location, 21 speed tests recorded download speeds below 5 Mbps. As such, due to the inherent variability of mobile networks, we would expect that drive tests would similarly fail periodically to achieve download speeds of at least 5 Mbps even for areas that meet the 80% cell edge probability. While this implies that the results of any particular speed test are not dispositive for a specific location, the likelihood of false positives decreases with additional measurements, and a more accurate measurement of performance emerges.[122] The numerous stationary test locations that fall within the provider's 4G LTE coverage maps where staff recorded success rates well below 80%, which appear consistent with the results from nearby staff drive tests, bolsters our conclusion that the coverage maps do not accurately represent the areas where consumers can expect to receive 4G LTE download speeds of at least 5 Mbps.

[122] For the same reason, staff therefore made multiple passes, conducting drive testing along the same roads at different times, for most drive test routes. Moreover, there are clear patterns that emerge from analyzing the drive test data indicating insufficient coverage across large areas. Because we would expect that speed tests would fail in a coverage area that meets the cell edge probability only a small percentage of time, lengthy stretches of roadways where speed tests record download speeds below 5 Mbps (especially taken at different times) are unlikely due to any inherent variability.

VI. CONCLUSIONS

73. Accurate broadband data is essential to bridging the digital divide, and bridging the digital divide is the Commission's top priority. Mobile providers are legally responsible for submitting accurate and reliable coverage maps to the Commission. It is incumbent upon mobile providers to accurately model their networks, to test and retest these models, and to improve continually the accuracy of their projections so that their submissions can be confidently relied upon by the Commission, USAC, and the public.[123]

74. Our analysis and speed tests suggest that the submitted MF-II coverage maps did not match actual coverage in many instances. Accordingly, the Commission has sought comment in another proceeding on how it can improve the reliability of the data submitted by mobile service providers.[124] This staff report documents the extensive efforts of staff to investigate the coverage maps submitted by providers for the MF-II data collection and, in doing so, to provide insights into potential ways the Commission can improve the accuracy of mobile coverage going forward.

75. Specifically, staff recommends that the Commission terminate the MF-II challenge process. Despite the extensive efforts of staff and challengers that contributed to the challenge process, the submitted coverage maps are not a sufficiently accurate basis upon which to continue a process meant to address coverage disputes at the margins. The challenge process was not designed to correct generally overstated coverage maps.

76. Staff recommends that the Commission issue an Enforcement Advisory on broadband data accuracy in the Form 477 filing, and, separately, for future Digital Opportunity Data Collection filings. Broadband data accuracy should be made a top priority going forward and providers should be put on notice of the penalties that could arise from coverage filings that violate federal law.

77. Staff recommends that the Commission assemble a team with the requisite expertise, resources, and capacity to audit, verify, and investigate the accuracy of mobile broadband coverage maps submitted to the Commission. The Commission should further consider seeking appropriations from Congress to carry out any necessary drive testing. This team should specifically analyze the most recent Form 477 filings of Verizon, U.S. Cellular, and T-Mobile to determine if they complied with the Form 477 requirements. The Form 477 rules prohibit providers from reporting coverage where they provide none.

78. Additionally, staff recommends that the Commission adopt several changes in its mobile data collections. For MF-II, the Commission adopted the most granular and standardized mobile coverage collection it had ever undertaken. The staff analysis in this report, and the staff and challenger speed tests upon which the analysis relies, are an unprecedented examination into how accurately the coverage maps submitted by mobile providers to the Commission reflect on-the-ground, consumer experiences. This analysis indicates that the coverage data submitted by several providers did not accurately reflect actual on-the-ground coverage in many cases, and thus indicates that our mobile data coverage collections should become more standardized, more detailed, and include actual speed test data. Providers should submit more than just projections of coverage; providers should be required to submit actual speed test data sampling that verifies the accuracy of their propagation models. The Commission should adopt policies, procedures, and standards that allow for submission, verification, and disclosure of

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[123] The Commission requires truthful and accurate statements in its proceedings. *See, e.g.*, 47 CFR § 1.17(a)(1).

[124] *See, e.g.*, *Establishing the Digital Opportunity Data Collection; Modernizing the FCC Form 477 Data Program*, Report and Order and Second Further Notice of Proposed Rulemaking, 34 FCC Rcd 7505, 7549-52, paras. 112-20 (2019) (proposing to require mobile service providers to submit "infrastructure information sufficient to allow for verification of the accuracy of providers' broadband data" upon request).

mobile coverage data and also convene a workshop of stakeholders on best practices for the generation and submission of accurate mobile broadband data.

79. Staff is unable to determine the specific reasons for every difference between providers' model-predicted and on-the-ground coverage. Our speed testing, data analyses, and inquiries, however, suggest that some of these differences may be the result of some providers' models: (1) using a cell edge RSRP value that was too low, (2) not adequately accounting for network infrastructure constraints, including backhaul type and capacity, or (3) not adequately modeling certain on-the-ground factors—such as the local clutter, terrain, and propagation characteristics by spectrum band for the areas claimed to be covered.

80. For proceedings in which the Commission collects mobile broadband deployment data, staff recommends that the Commission standardize the propagation map parameters and assumptions that providers use to generate their coverage data. The propagation map parameters adopted in the *MF-II Challenge Process Order*, as well as the coverage and other data required by that Order, should serve as the starting point, but key elements could be further standardized to determine more accurately where consumers can expect to obtain a mobile broadband connection.[125] Based on what we have learned from this process, in the future the Commission should be able to obtain more accurate mobile coverage data by specifying additional technical parameters. Specifically, the Commission should adopt mobile broadband coverage data specifications that include, among other things, minimum throughput and/or signal strength (as appropriate), standard cell loading factors and cell edge probabilities, maximum terrain and clutter bin sizes, and standard fading statistics. For any modeling with minimum throughput parameters, the Commission should require that providers assume the minimum values for whatever additional propagation model parameters would be necessary in order to accurately determine the area where a handset is demonstrated to achieve performance with download and upload speeds no less than the requirement meeting the cell edge probability. The Commission should allow for refinements of propagation models based on experience in any given area but should not allow elimination of elements such as clutter and fading that play a major role in the likelihood of connectivity. Additionally, all data submissions should require an engineering certification.[126]

81. The Commission should collect additional, more detailed data from mobile providers on the inputs and assumptions that underlie their propagation models, including the locations and specific characteristics of certain cell sites used for mobile wireless service, the modeling software that is being used, the entire link budget and values, and terrain data source.[127] To ensure the integrity and reliability of submitted maps, the Commission should also require that all filers submit sufficient actual speed test data sampling that verifies the accuracy of the propagation model used to generate the coverage maps. Actual speed test data is critical to validating the models used to generate the maps.

82. Although a challenge process may seem capable of correcting inaccurate coverage maps, we caution that, as with coverage projections based on propagation models, there are inherent limits to

[125] Standardization should be implemented as appropriate for the purposes of the coverage data collection, taking into account relevant variations, for example in terrain.

[126] We understand that mobile providers closely monitor the performance of their networks including data that can provide insight as to whether service is actually available in an area. We note that the tests conducted for this project found there was no connectivity at all in many areas. We expect that providers should be aware of this from monitoring their networks or their own field tests.

[127] The Commission should adopt procedures for providers that use modeling programs that rely upon proprietary information, e.g., clutter loss values, that would allow for such providers to disclose information necessary to validate their model assumptions. The Commission should consider requiring submission of traffic models to validate the relevant assumptions.

how accurately individual speed tests reflect network performance because performance on mobile broadband networks is inherently variable. Managing a granular challenge process is highly time- and resource intensive and may not significantly improve the accuracy of the underlying maps. Accordingly, staff does not recommend adoption of granular mobile challenge processes as a means of improving the accuracy of mobile coverage maps. This recommendation is separate and aside from creating processes for stakeholders to provide the Commission with evidence that challenges the mapping and modeling assumptions of mobile providers, thus enabling the Commission to respond to evidence of generalized problems with submitted coverage maps, and thus increasing the legitimacy of a final assessment of coverage. While adoption of these staff recommendations should lead to improvements in the Commission's data collection processes, enforcement of data collection rules, and the accuracy of submitted data, mobile providers are ultimately responsible for the accuracy of the coverage data they file.

APPENDIX A:

Form 477 Filers that Submitted MF-II 4G LTE Coverage Data

MF-II Provider Name
Appalachian Wireless
ATN
AT&T
Bluegrass Cellular
Bluesky
C Spire
Carolina West Wireless
Cellcom
Central Texas Telephone Coop (CTTC)
Chariton Valley
Chat Mobility
Choice Phone
ClearTalk
Custer Telephone Cooperative
DoCoMo Pacific
FTC Wireless
GTA Wireless
Horizon Communications
Illinois Valley Cellular
Indigo Wireless
Inland Cellular
Iowa Wireless
James Valley Cooperative Telephone
MBO Wireless

MF-II Provider Name
MCG PCS
Mid-Rivers Cellular
Nex-Tech Wireless
Northwest Missouri Cellular
Panhandle Telephone
Pine Cellular
Pioneer Enid Cellular
PTI Pacifica
Sagebrush Cellular
Smith Bagley (d/b/a Cellular One)
Sprint
SRT Communications
Standing Rock Telecom
Strata Networks
Thumb Cellular
T-Mobile
Triangle
Union Telephone
United Telcom
US Cellular
Verizon Wireless
Viaero Wireless
VTel Wireless
Worldcall

APPENDIX B:

Additional Findings from the MF-II Challenger Data

1 Analysis of the MF-II Challenger Speed Test Data

1. The staff conducted an in-depth analysis of the MF-II challenger speed test data that passed the automated system validations, were certified by the close of the challenge window, and were recorded within the tested provider's coverage area.

2. This in-depth analysis reveals significant variance in the data among challengers and even among handsets used by the same challenger, as well as anomalous and problematic data that nevertheless passed automated system validations and were certified.[1] Examples of such anomalous and problematic data, all of which were certified and within-coverage, include: tests that recorded negative download speeds or positive signal strength values (171 tests); tests for a single challenger that were identified as being on different device models but which used the same device International Mobile Equipment Identity (IMEI) value (497,124 tests); and tests identified as conducted on the same device within a one-minute period but which included hundreds or thousands of points along multiple-mile stretches of road (approximately 228,107 tests). While such tests represent only 4.6% of certified challenger speed tests that were within the coverage map of the provider tested, they indicate that certain challengers may have submitted data without fully verifying their results.[2]

3. Anomalies within the challenger speed test dataset also call into question the reliability of challenger data in establishing actual on-the-ground consumer experience in specific areas. For example, unlike other challengers who reported connecting to servers within the U.S. and often within the same state, one challenger submitted 72,877 tests conducted in Kansas that reported connecting to a server in Roubaix, France, and every speed test that ran on this server failed—meaning that it recorded a download speed below 5 Mbps. Another challenger submitted and certified almost 1.7 million tests that were within the coverage of the providers tested, all of which failed. There are also several instances where challengers obtained only zero download speeds in the same geographic area where Commission staff obtained speed tests with much higher speeds.

4. In addition, data submitted by challengers were sometimes internally inconsistent. For example, one challenger submitted speed tests taken in and around two cities in Alabama on one day that had download speeds of zero but a strong signal, but also submitted data for speed tests taken the following week along a similar route that recorded download speeds far exceeding 5 Mbps, also with a strong signal. This same challenger also submitted speed test data that were inconsistent between devices of the same model. The challenger recorded speed tests taken by two distinct devices of the same model that show largely divergent results in the same general areas. For example, of the 187,182 speed tests

[1] We note that variance among challenger data could result from different testing methodologies, from the different networks tested and the varying quality of those networks across states, as well as from terrain, weather, or other factors. Similarly, significant variation in results from a single challenger between two different handset models could be due to the specific characteristics of a particular model (i.e., different cellular modems or device design) or could reflect differences in the quality of the network for different areas tested. Some variance, however, could reflect anomalies, such as a faulty device, especially when starkly divergent results were recorded on the same device model (but two separate devices as identified by IMEI codes) within the same state or even the same general area.

[2] Conducting the same analysis across all certified challenger speed tests, including those that were not within the coverage map of the provider tested, does not meaningfully change the results, with erroneous data representing 4.4% of all certified challenger speed tests.

taken with the device with IMEI ending 0755 (Device 0755), 95.3% recorded a download speed of zero, and only 35 tests achieved a download speed of at least 5 Mbps. In grid cells where Device 0755 recorded an average signal strength of -110 dBm or higher, the device consistently averaged download speeds of between 0 to 0.1 Mbps (see Figure B-1 and Figure B-2).[3] The device with IMEI ending in 9244 (Device 9244) took 49,939 speed tests across a similar area and recorded similar average signal strength values but a wider range of download speed values (see Figure B-3 and Figure B-4).[4] Nearly 19% of Device 9244's speed tests achieved a download speed of at least 5 Mbps.

5. Taken together, these errors, anomalies, and inconsistencies implicate at least 15.4% of the certified within-coverage speed test data submitted by challengers.[5] Such issues raise concerns about using challenger speed test data as evidence that 4G LTE coverage is lacking in a specific area, particularly within the framework adopted in the *MF-II Challenge Process Order*. Without further information concerning the challenger's testing procedure and methodology or the state of the provider's network during that time period of the test, it is difficult to determine from inconsistent data which set of varying speed test results is more indicative of expected consumer performance in a particular area.[6] Further, anomalies and inconsistencies suggest that a number of factors that were not addressed or specified by the Commission in the *MF-II Challenge Process Order* can affect speed test results in ways that may not reflect a consumer's typical on-the-ground performance.[7]

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[3] For Device 0755, the mean recorded signal strength per grid cell ranged from -168 dBm to -60 dBm.

[4] For Device 9244, the mean recorded signal strength per grid cell ranges from -186 dBm to -60 dBm.

[5] Further analysis of the data may reveal additional anomalies or inconsistencies. This calculation also does not include those speed tests recorded in areas where Commission staff speed tests were conducted that show significantly faster download speeds. Analyzing across all certified challenger speed tests, these erroneous, anomalous, and inconsistent speed tests represent 15.6% of such data.

[6] However, as discussed in Section 2 of this appendix, results from the staff speed tests in the same area recorded download speeds meeting or exceeding 5 Mbps, indicating that the challenger speed tests with download speeds of zero were likely anomalous.

[7] For example, if a challenger happened to purchase a device with faulty hardware, or if other conditions on the handset negatively impacted network performance, such results could accurately have recorded throughput on the particular handset while also being unrepresentative of typical performance.

Figure B-1. Device 0755 – Average RSRP Signal Strength by Grid Cell

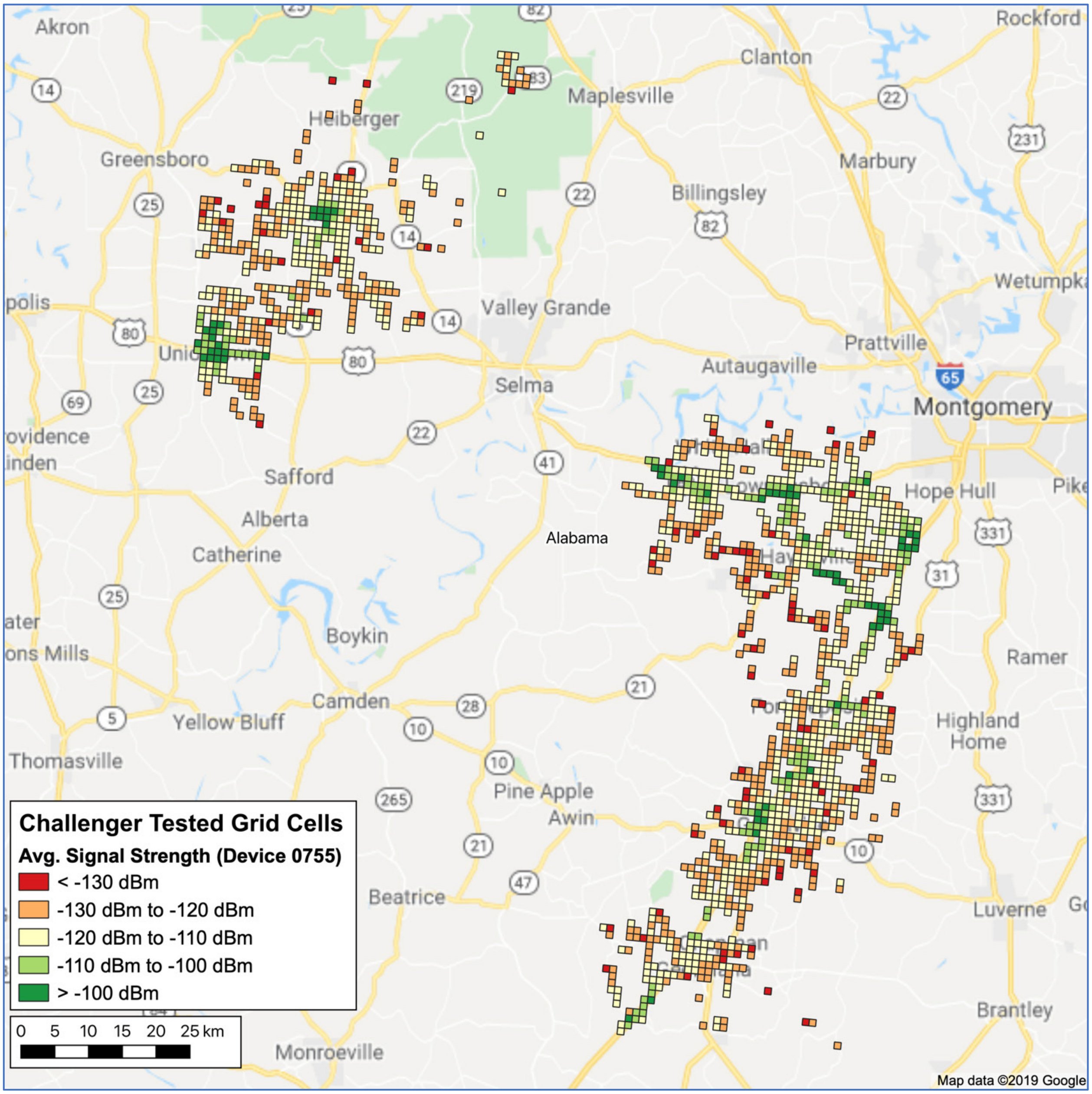


Figure B-2. Device 0755 – Average Download Speed by Grid Cell

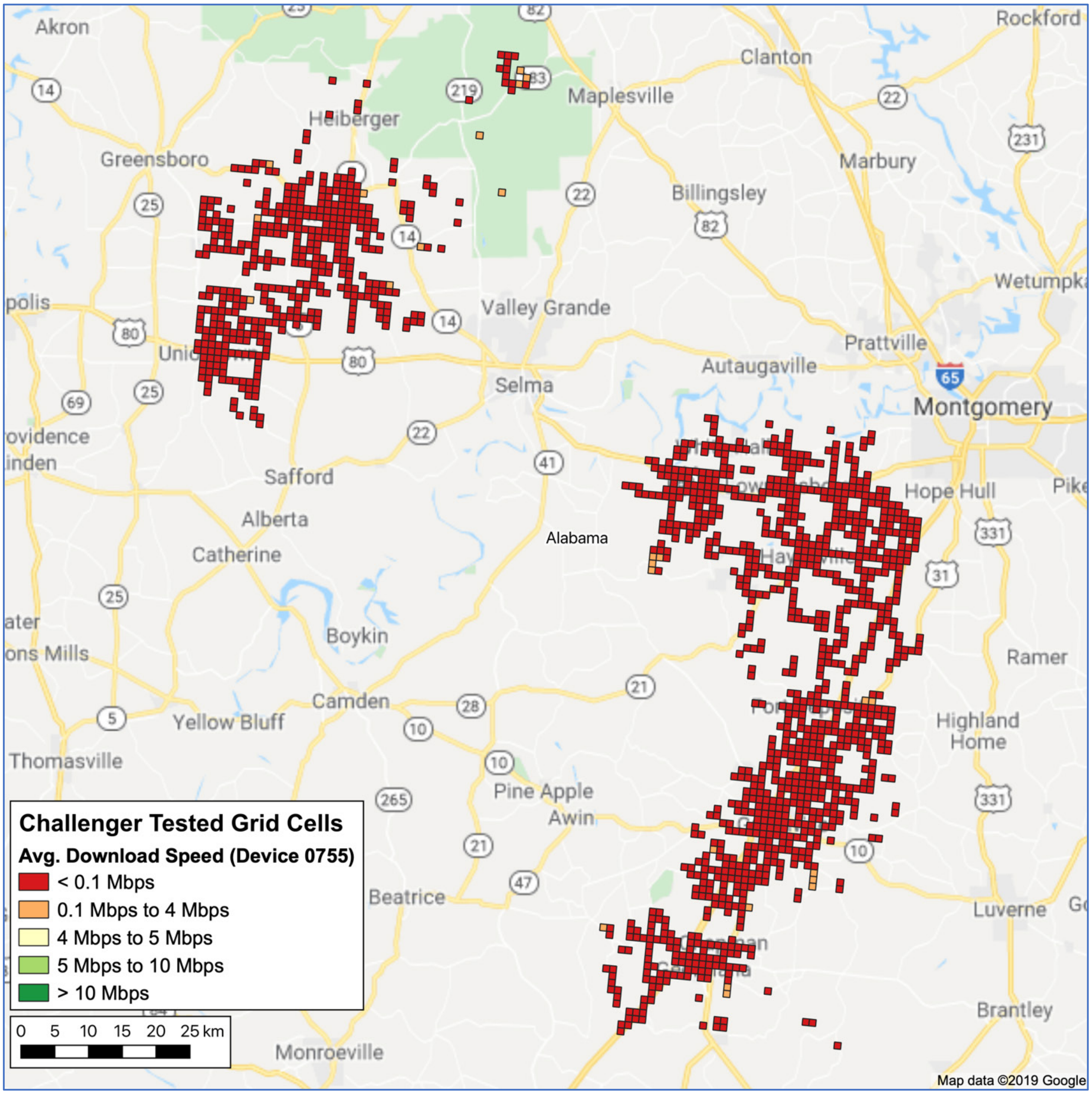


Figure B-3. Device 9244 – Average RSRP Signal Strength by Grid Cell

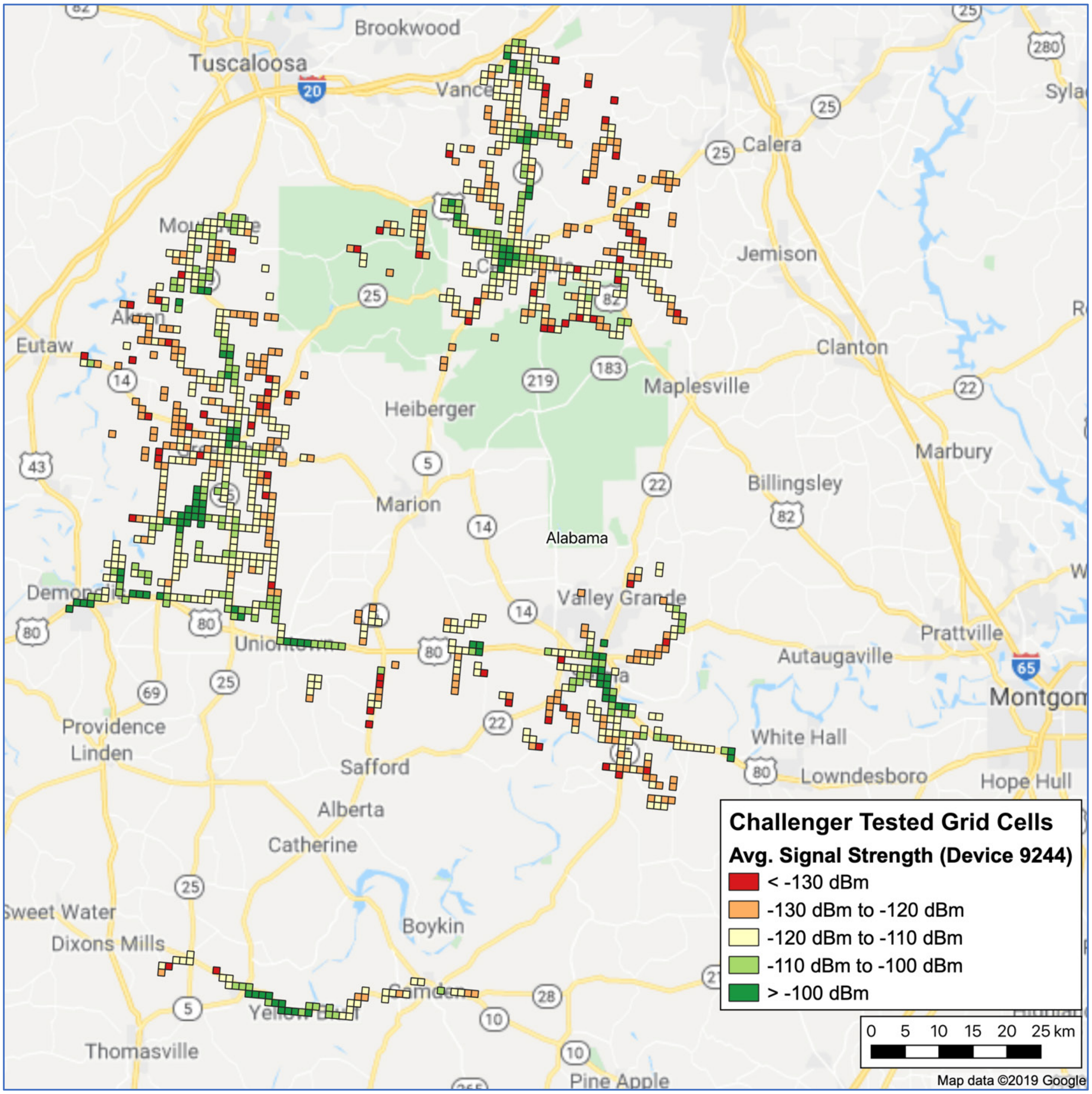
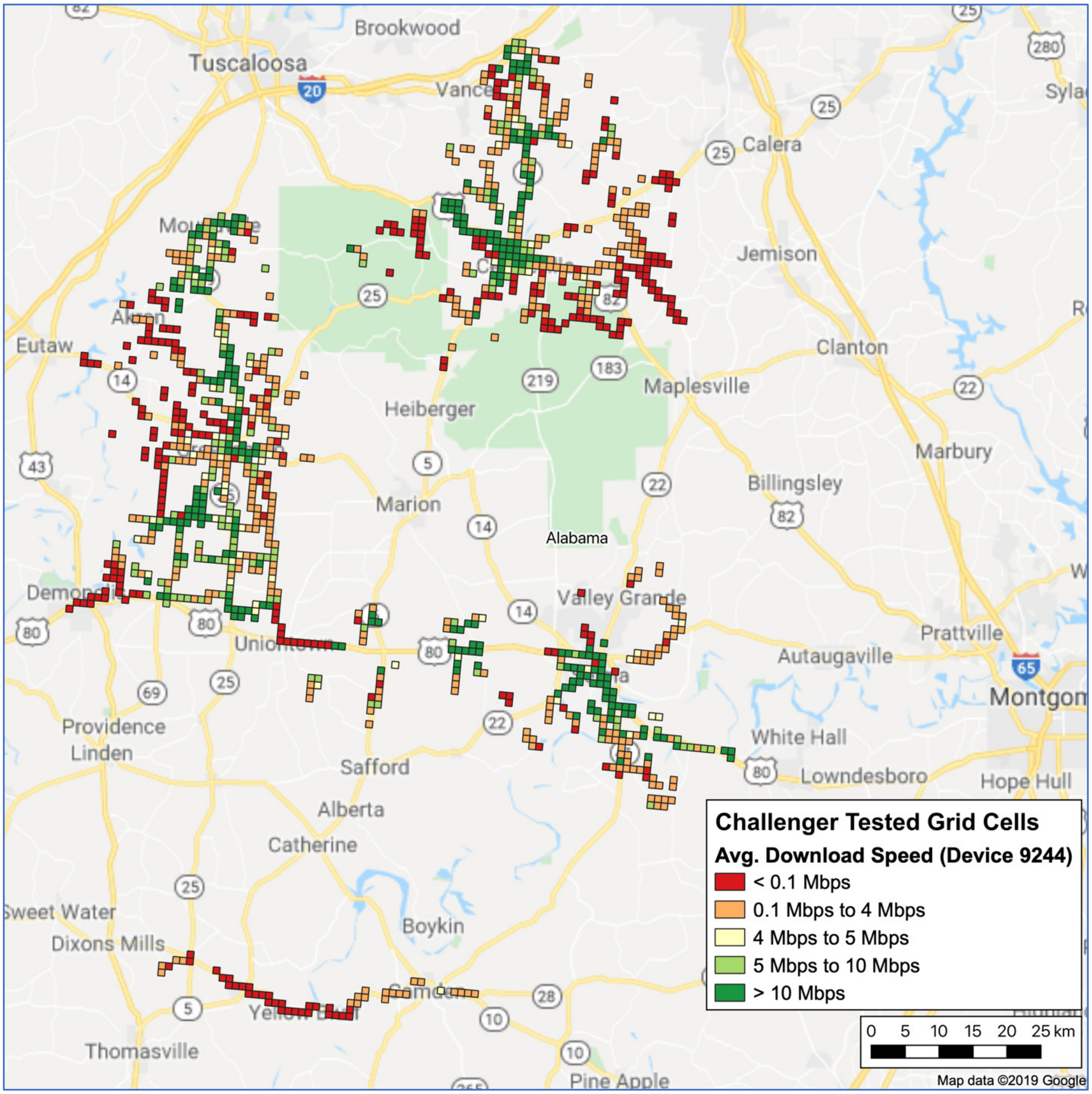


Figure B-4. Device 9244 – Average Download Speed by Grid Cell



6. Lastly, analyzing the challenger speed test data using the automated system processing framework adopted by the Commission highlighted some of the inconsistencies in the challenger speed test data even within the same one square kilometer area. After speed tests were submitted, the MF-II Challenge Portal system created a "buffer" (i.e., drew a circle) with a radius of 400 meters around each geographic point where a valid speed test recorded a download speed below 5 Mbps, and then, for each grid cell, calculated whether the area for all buffered points covered at least 75% of the ineligible area in the cell to determine its presumptive status—that is, whether the challenge was presumptively successful

or unsuccessful.[8] While this approach may lead to a reliable determination of whether a challenger has established a lack of 4G LTE coverage in a grid cell when a challenger submits a small number of stationary speed tests conducted at different points within the grid cell, it is less reliable for data where a challenger conducted dozens of continuously recorded drive tests along roads within a grid cell.[9] In particular, staff analysis revealed that, while the system calculated that 35.9% of challenged grid cells were presumptively successful, when conflicting evidence within those same grid cells was considered—that is, speed tests showing download speeds of 5 Mbps or greater—the percentage of presumptively successful grid cells dropped to 16.2%.[10] This indicates that a large portion of challenger data include speed tests both above and below 5 Mbps within the same general area. We note that challengers were required to submit data for all speed tests, including those showing speeds greater than or equal to 5 Mbps, and Commission staff would adjudicate each challenge on a preponderance-of-the-evidence standard based on all the evidence submitted by challengers and challenged parties.[11] Nevertheless, the presumptive status as calculated may not provide an accurate assessment of where mobile 4G LTE coverage exists.

2 Comparison of Staff Drive Tests to MF-II Challenger Speed Tests

7. Commission staff conducted drive tests in certain areas that were also the subject of significant numbers of challenges. For more than half of the grid cells in which staff conducted drive tests, challengers had submitted speed tests as well. We were therefore able to compare the results of staff drive tests to challenger speed tests that were conducted in close proximity to one another.[12] For the analysis here, we chose to compare staff and challenger speed tests that were measured within 100 meters of one another. This comparison shows that the two sets of tests resulted in significantly different recorded download speeds in many cases.[13] When compared to 4G LTE staff drive tests conducted within 100 meters, challengers generally reported much lower speeds at the same RSRP signal strength (see

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[8] *MF-II Challenge Process Order*, 32 FCC Rcd at 6310-11, paras. 55-56; *Connect America Fund; Universal Service Reform – Mobility Fund*, Order on Reconsideration, 33 FCC Rcd 4440, 4441-42, para. 4 (WTB/WCB 2018); *MF-II Challenge Process Procedures PN*, 33 FCC Rcd at 2002-03, para. 38.

[9] For example, if a challenger submitted 100 drive tests within the same grid cell, most of which recorded download speeds greater than or equal to 5 Mbps but some of which recorded speeds below 5 Mbps, the challenge process framework as adopted considers only the tests below 5 Mbps in determining the presumptive status of the challenge. Instead, a more appropriate framework for processing a large number of speed tests recorded in a short time period over a limited area could be the use of statistical calculations (e.g., 90^{th} percentile) to mitigate noise in the data due to the variability of wireless networks.

[10] To perform this analysis, staff extracted all certified challenger speed tests that recorded download speeds of at least 5 Mbps and were otherwise valid. These extracted speed tests were then processed as if the data had been submitted by the challenged provider as respondent speed tests, and the system calculated a new presumptive status. *See MF-II Challenge Process Procedures PN*, 33 FCC Rcd at 2024-26, App. B (outlining the methodology by which the system processes response evidence).

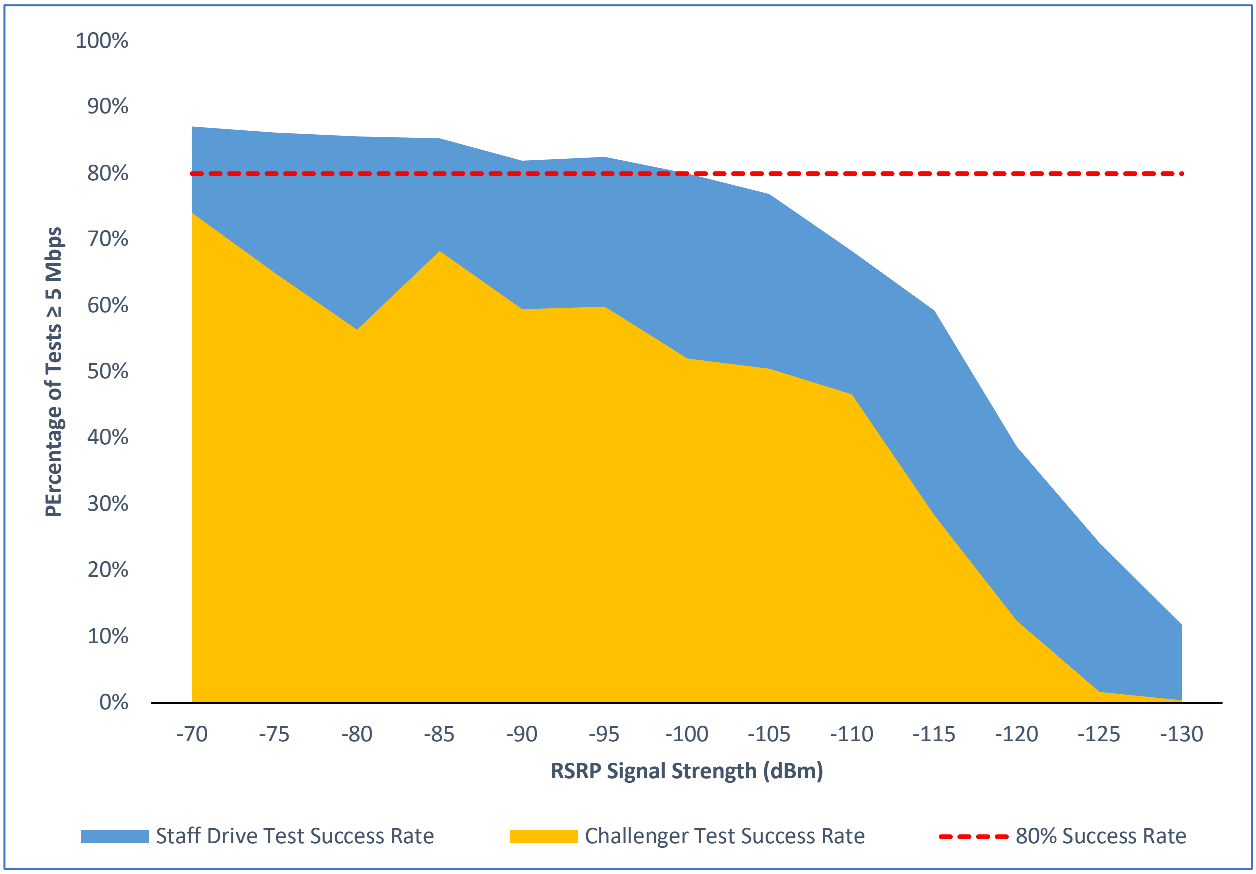
[11] *MF-II Challenge Process Order*, 32 FCC Rcd at 6313, para. 63; *MF-II Challenge Process Procedures PN*, 33 FCC Rcd at 2013-14, para. 66.

[12] Because challengers did not disclose whether tests were conducted while drive testing or while stationary, we are unable to identify which challenger speed tests were the results of drive tests. However, the patterns in the data (e.g., distance and time between tests) indicate that the vast majority of submitted tests were likely drive tests. For the analysis in this section, we have assumed that all challenger speed tests were drive tests to facilitate comparison with staff drive tests.

[13] This analysis was also performed while restricting the sample to tests conducted within 25 meters and the results did not change in any meaningful way.

Figure B-5).[14] Comparing across all staff drive tests, including tests that recorded no signal or were otherwise not on a 4G LTE network, a much higher percentage of challenger tests recorded no download speed (see Table B-1). The observed staff success rate (drive tests with a download speed of at least 5 Mbps) in the sample is 54.8%, while the observed challenger success rate is only 22.2% (see Figure B-6). This is in part due to the large number of tests in the challenger data that recorded a download speed of zero; just over 60% for challenger speed tests compared to only 23.2% of staff drive tests. Both the average (mean) and median download speeds are considerably lower in the challenger speed test data than the staff data.

Figure B-5. Success Rate of 4G LTE Staff Drive Tests and Challenger Speed Tests Conducted within 100 Meters of Each Other by RSRP Signal Strength[15]



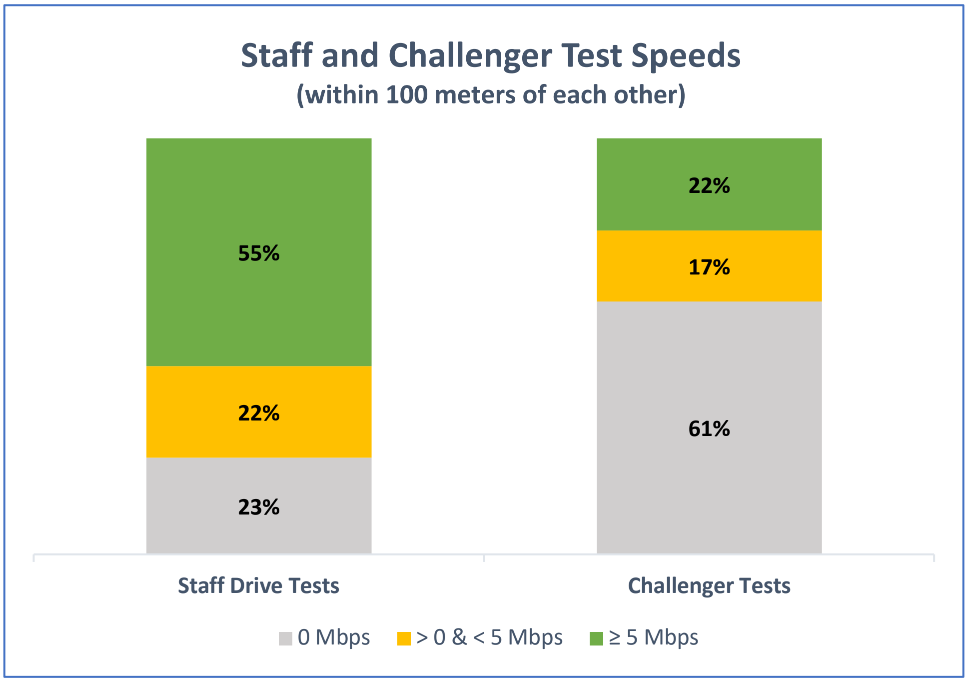
[14] For the comparison in Figure B-5, as with our analysis in Section V.B, we have included only the staff drive tests that were recorded as conducted on a 4G LTE network, as there is no RSRP value for tests that recorded no signal or that were conducted on a non-4G LTE network. *See supra* note 117.

[15] The 4G LTE staff drive test success rate portion of Figure B-5 (in blue) differs slightly from the graph in Figure 24 because the latter includes all of the 19,508 4G LTE staff drive tests within the signal strength range, while Figure B-5 includes only the 9,355 4G LTE staff drive tests within the signal strength range that were also conducted within 100 meters of challenger speed tests.

Table B-1. Staff Drive Tests and Challenger Speed Tests Conducted within 100 Meters of Each Other

Dataset	Test Count Total	Percentage Zero Mbps	Percentage ≥ 5 Mbps	Median Speed	Average Speed	Average Speed Excl. Zeros
Staff (Only 4G LTE)	9,355	4.4%	71.4%	11.1 Mbps	18.6 Mbps	19.5 Mbps
Staff	12,189	23.2%	54.8%	6.6 Mbps	14.3 Mbps	18.6 Mbps
Challenger	87,958	60.8%	22.2%	0.0 Mbps	4.1 Mbps	10.3 Mbps

Figure B-6. Staff Drive Tests and Challenger Speed Test Results by Download Speed Category



8. When tests with zero download speed are excluded from the challenger and staff data sample, challenger speed tests are still significantly slower, averaging 10.3 Mbps as compared to 18.6 Mbps in the staff data. Except for the Arizona route, the differences between the staff and challenger success rates are significant, but the differences are similar across test routes (see Table B-2). For example, the success rate of staff drive tests is at least double the success rate of challenger speed tests conducted within 100 meters of each other for five of the route-provider combinations. For no route was the success rate for staff drive tests lower than the challenger data.[16] An example of these differences is the Alabama route, which contained the most staff drive tests and challenger speeds tests that were within 100 meters of each other. Along the Alabama route, staff recorded download speeds of zero no more than 20.5% of the time, as compared to between almost 44% and slightly more than half of the time with challenger data, depending on the provider tested. The discrepancy between datasets in Montana on Verizon's network is even starker, as more than 80% of staff drive tests achieved download speeds of at least 5 Mbps versus approximately 8% of challenger speed tests.

[16] On only one route (Arizona) did the success rates match, with each staff drive test and challenger speed test recording a download speed of zero, albeit with fewer staff measurements than in other areas.

Table B-2. Staff Drive Tests and Challenger Speed Tests Conducted within 100 meters of Each Other by Route

Test Route	Provider Name	Dataset	Median Speed	Average Speed	Percentage Zero Mbps	Percentage ≥ 5 Mbps	Test Count
Alabama	T-Mobile	Staff	10.5 Mbps	21.0 Mbps	20.5%	64.8%	3,390
		Challenger	0 Mbps	5.3 Mbps	50.3%	30.0%	25,444
	Verizon	Staff	5.2 Mbps	10.6 Mbps	15.1%	51.0%	3,413
		Challenger	0.9 Mbps	6.6 Mbps	43.7%	35.0%	21,167
Arizona	Verizon	Staff	0 Mbps	0 Mbps	100%	0%	187
		Challenger	0 Mbps	0 Mbps	100%	0%	2,529
Montana	T-Mobile	Staff	0.1 Mbps	15.5 Mbps	48.1%	26.8%	646
		Challenger	0 Mbps	0.4 Mbps	95.6%	1.8%	15,702
	Verizon	Staff	15.7 Mbps	21.3 Mbps	11.0%	80.5%	626
		Challenger	0 Mbps	1.5 Mbps	70.7%	8.1%	11,576
Oklahoma	Verizon	Staff	9.6 Mbps	13.7 Mbps	10.6%	68.2%	1,490
		Challenger	0 Mbps	5.2 Mbps	53.9%	28.2%	9,281
Vermont	U.S. Cellular	Staff	2.3 Mbps	6.5 Mbps	25.9%	42.9%	983
		Challenger	1.2 Mbps	2.6 Mbps	10.8%	19.7%	775
	Verizon	Staff	2.0 Mbps	11.6 Mbps	43.7%	43.1%	1,454
		Challenger	0.6 Mbps	5.4 Mbps	40.9%	31.5%	1,484

9. The causes of the large differences in measured download speed between the staff and challenger speed tests taken within the same geographic areas, as well as of the high percentage of tests with a download speed of zero in the challenger data, are difficult to determine. Discrepancies may be attributable to differences in testing methodologies, network factors at the time of test, differences in how speed test apps or drive test software process data, or other factors.[17] We acknowledge that some aspects of conducting speed tests along with other parameters or factors that could affect the results were left unspecified by the Commission in the *MF-II Challenge Process Order* to provide flexibility to and reduce burdens on challengers.[18] Had the Commission further standardized the methodology and speed test parameters, such results may have been less divergent from the staff speed tests. Given the large differences between challenger and staff results however, we are not confident that individual challenger speed test results provide an accurate representation of the typical consumer on-the-ground experience.

[17] The factors could include, among others: (1) the characteristics of the server (or servers) that a speed test application connects to – including the server's location, load, and Internet connection speed; (2) the method by which a speed test app measures the download speed portion of a speed test (e.g., network protocol or file size of transmitted data); and/or (3) the number of simultaneous downloads occurring on the test phone during the test. However, the speed test data required for the MF-II challenge process does not provide the granularity necessary to determine which of these factors may be potentially influencing the measurement results.

[18] *MF-II Challenge Process Order*, 32 FCC Rcd at 6307-08, para. 49; *MF-II Challenge Process Procedures PN*, 33 FCC Rcd at 1999-2000, paras. 29-30.

APPENDIX C:

Resources

1. Additional information about the MF-II proceeding, one-time collection of 4G LTE coverage data, and the MF-II challenge process is available at the Mobility Fund Phase II website: https://www.fcc.gov/mobility-fund-phase-2.

2. Data referenced in this report, including the results of staff testing, as well as challenger speed tests submitted during the MF-II challenge process, can be downloaded at: https://www.fcc.gov/mobility-fund-phase-2#data.

3. Current and historical FCC Form 477 geographic information system data for mobile broadband deployment, including the December 2017 4G LTE coverage by mobile service providers discussed in Section IV and displayed as part of the maps in Section V.B, is available at: https://www.fcc.gov/mobile-deployment-form-477-data.

4. The maps shown in Section V.B are also available as part of an online, interactive map available at: https://www.fcc.gov/reports-research/maps/mobility-fund-phase-ii-investigation-staff-report-map.

5. Information on the Commission's efforts to improve broadband data mapping is available at the Digital Opportunity Data Collection website: https://www.fcc.gov/digital-opportunity-data-collection-dodc.

6. Additional information on the Commission's efforts to measure broadband performance is available at the Measuring Broadband America website: https://www.fcc.gov/general/measuring-broadband-america. The Commission also publishes the FCC Speed Test app, developed by SamKnows Ltd., which the public can use to conduct on-demand, user-intiated speed test measurements using mobile devices. The FCC Speed Test app can be downloaded on iOS devices from the Apple App Store (available at https://apps.apple.com/us/app/fcc-speed-test/id794322383) or on Android devices from the Google Play Store (available at https://play.google.com/store/apps/details?id=com.samknows.fcc).

7. Further information about the Commission's rural broadband auctions is available at: https://www.fcc.gov/auctions/ruralbroadbandauctions.

8. Questions about the MF-II Coverage Maps Investigation Staff Report may be emailed to the Commission's Rural Broadband Auctions Task Force at ruralbroadband@fcc.gov.