Economics at the FCC 2021–22: 5G Spectrum Auctions, Affordable Connectivity, Broadband Data Collection, and Merger Review

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Abstract

The Federal Communications Commission (FCC) is responsible for regulation in the communications marketplace and for management of the nation's non-federal radio spectrum. During the past year, FCC economists continued to work on auctions so as to repurpose mid-band spectrum for advanced wireless services – including 5G – as well as initiatives to close the connectivity gap and make broadband more affordable. FCC economists also evaluated the likely competitive effects of Verizon's proposed acquisition of prepaid competitor TracFone Wireless. Finally, FCC economists helped in setting up the novel Broadband Data Collection.

Keywords Affordable Connectivity · Broadband Data Collection · Connectivity Gap · FCC · Homework Gap · Rural Health · Merger · Telecommunications Policy

1 Introduction

The U.S. Federal Communications Commission (FCC) is an independent regulatory agency that is responsible for regulating interstate and international wired, wireless, and satellite communications, and domestic electronic media (TV, radio, cable, DBS), in addition to public safety communications. Further, the FCC allocates and assigns radio spectrum for non-Federal use.

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For fiscal years 2022–2026, the FCC revised its strategic goals to reflect the fact that individuals increasingly rely on broadband connectivity for work, learning, healthcare, and access to information that is necessary to make everyday life decisions (FCC, 2022a, p. 1). To further broader and better connectivity and greater broadband adoption, the FCC's goals include (among others): pursuing a "100%" broadband policy; promoting diversity, equity, inclusion, and accessibility; empowering consumers; and advancing America's global competitiveness by promoting and advancing the development and deployment of new communications technologies such as 5G (FCC, 2022a, pp. 1–2).[1] All of the actions that will be described below helped to advance these strategic goals.

In Sect. 2, we review the FCC's latest spectrum auctions that seek to repurpose additional mid-band spectrum, which is critical for 5G buildout because of its coverage and capacity characteristics. We discuss how the FCC modified its ascending clock auction to deal with certain novel incumbency issues.

In Sect. 3, we discuss the FCC's efforts to increase the availability and affordability of broadband throughout the United States, which include supporting remote learning, making broadband more affordable for low-income households, and more cost-effectively distributing broadband and telecommunications service funding that is used to support rural healthcare providers.

Section 4 describes the FCC's analysis of the proposed acquisition of TracFone Wireless, Inc. (TracFone) by Verizon. As part of its analysis, the FCC evaluated potential horizontal unilateral harms from the loss of competition as well as incentives to raise rivals' costs that could result from Verizon's vertical relationship with TracFone. The FCC approved the transaction on November 22, 2021, subject to certain conditions.

Finally, in Sect. 5, we discuss the steps that have been taken by the FCC in setting up its new Broadband Data Collection (BDC). We describe how fixed and mobile broadband providers will need to report broadband deployment going forward. We also discuss how individuals and entities can challenge and verify the accuracy of the data that service providers report.

2 Auction Designs for Spectrum Repurposing Auctions

In 2021–22, the FCC continued its efforts to enable 5G services by making more mid-band spectrum available to the commercial market. Because of the absence of "greenfield" spectrum bands, however, the FCC had to devise efficient ways to repurpose spectrum that had been previously allocated for other uses and assigned to other users – a challenging process.

The auction of spectrum licenses in the 3.45–3.55 GHz Band (Auction 110) began in October 2021 and closed in January 2022 (FCC, 2021b). The auction of licenses in the 2.5 GHz Band (Auction 108) began on July 29, 2022 and, at the time

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[1] 5G stands for the fifth generation of mobile communications, with the potential for data rates that are up to 100 times faster than 4G: the previous generation of technology (FCC, 2021a).

of writing, had not yet closed (FCC, 2022b). The FCC used an ascending clock auction for both auctions, as it has for other spectrum repurposing auctions.[2]

The clock format has proved to be a flexible and efficient mechanism for accommodating various approaches to address the rights of existing licensees.[3] The FCC's basic ascending clock auction design consists of two phases: (1) a clock phase in which substantially similar ("generic") spectrum blocks are assigned to bidders in a series of ascending price bidding rounds; and (2) an assignment phase in which contiguous specific-frequency licenses that correspond to the number of generic blocks that were won in the clock phase are assigned in a series of single rounds of bidding, with one round per geographic area.

2.1 3.45–3.55 GHz Band (Auction 110)

For the 3.45–3.55 GHz Band auction (Auction 110), the FCC again used the ascending clock auction format. The clock phase offered 10 generic 10-megahertz blocks in one or two categories in each of the 406 Partial Economic Areas in the continental United States.[4] The assignment phase assigned specific-frequency licenses to the clock phase winners of the generic blocks. Although this general format was relatively familiar for an FCC ascending clock auction, the process of defining the generic license blocks to ensure a simple and workable auction format was less straightforward.

Congress identified the 3.45–3.55 GHz Band as a candidate for potential commercial 5G use that would be shared with existing federal operations in March 2018 (U.S. Congress, 2018). Existing Department of Defense (DOD) operations included military radar systems that would require protection: some on a periodic basis, and others on a more regular basis. DOD, the National Telecommunications and Information Administration (NTIA),[5] and the FCC worked out a series of user protocols

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[2] In its simplest form, an ascending clock auction is one in which an auctioneer announces a series of successively higher prices, and bidders indicate the quantity that they demand for the item at that price. The price stops increasing, and the winner is determined, when the demand for the item becomes equal to the available supply.

[3] Indeed, each repurposing auction so far has presented unique incumbency issues that have had to be accommodated through modifications to the basic ascending clock auction design. For example, in the 2016 broadcast incentive auction (Auction 1002), the FCC employed an iterative reverse/forward auction process that included an ascending forward clock auction (FCC, 2015a). In the auction of the 37, 39, and 47 GHz Bands (Auction 103), existing licensees in effect were allowed to either "buy back" equivalent new licenses in the auction at no net cost or receive a payment that was based on auction prices in exchange for relinquishing their existing rights (FCC, 2019a). In the 3.7 GHz Band (C Block) (Auction 107), new overlay licensees were obligated to pay a pro-rated share of relocation costs for the satellite incumbents that cleared the band, in addition to their winning bid amounts. In addition, as the incumbent providers would clear the spectrum earlier in some areas, bidders were offered a choice of early and later clearing blocks in the clock phase in those areas (FCC, 2020a).

[4] Partial Economic Areas (PEAs) are geographic licensing areas that aggregate counties and are subdivisions of Economic Areas (EAs); PEAs were first used by the FCC in 2016.

[5] The NTIA is an agency of the United States Department of Commerce that allocates and assigns spectrum for federal government use, while the FCC allocates and assigns spectrum for commercial and state uses.

for sharing and coordination that did not mandate exclusion zones. A reserve price was established to cover expected sharing and relocation costs for federal users that currently operated in the band.

This irregular pattern of differing license requirements did not fit neatly into the clock auction framework that the FCC had used up to that time. Previously, licenses in a single auction had been easily categorized as one or possibly two types of generic frequency blocks, with the categorization consistent across all areas.

In the 3.45–3.55 GHz Band auction, however, there were many more permutations of license conditions than had previously been present. Of the 406 PEAs, some had no coordination requirements in any of the ten blocks; other PEAs had requirements in only the lower four blocks; still others had different coordination requirements in the lower four blocks compared with the upper six blocks. In a few areas, the lower eight blocks carried restrictions while the upper two blocks did not. If the FCC had created separate bidding categories that were based on their use requirements and their location in the upper or lower parts of the band, it would have resulted in numerous different categories, and an auction format that was confusing for bidders and technically more complicated.

Fortunately, within each geographic area, the frequency blocks could be divided into no more than two categories. Therefore, to maintain a reasonably simple format, two categories – "1" and "2" – simply defined differences across the blocks within a geographic area. For example, in an area with coordination requirements in the lower 40 megahertz and none in the upper 60 megahertz, the lower four blocks were considered category 1, and the upper six blocks were category 2. In an area with no requirements, all ten blocks were considered category 1. As a result, the FCC was able to preserve many of the advantages of a clock auction that offers generic blocks in the clock phase – even though the structure of the clock phase of Auction 110 was somewhat less streamlined than prior FCC clock auctions because of the cross-area differences in categories.

The 3.45–3.55 GHz Band auction also required an adjustment to typical assignment phase procedures. In prior clock auctions, the assignment phase combinatorial optimization software had not needed to take into account assignment interactions between two or more categories of blocks – either all blocks were assigned together, or licenses for each category in an area were assigned separately. A bidder that won multiple blocks would be assured that its assignment would consist of contiguous frequencies within a category, and there was no strong need to coordinate winnings across categories.

In this auction, however, in an area with two categories of blocks, the frequency blocks were contiguous across the two categories. A bidder with winnings in both categories would logically prefer its lower-band licenses to be adjacent in frequency to its upper-band license assignment. However, more than one bidder could win blocks in both categories; but only one of them could be assigned licenses that were both consistent with their winnings by category and consisting of contiguous frequency blocks. To address this issue, the assignment procedures incorporated an additional step that would award the contiguous licenses to the bidder with the highest total bid amounts for the category 1 and category 2 options that contained adjacent blocks.

The 3.45–3.55 GHz Band auction was the third-highest grossing FCC spectrum auction to date, with total gross proceeds that exceeded $22.5 billion; this was well above the reserve price of $14.8 billion.

2.2 2.5 GHz Band (Auction 108)

The auction of overlay licenses in the 2.5 GHz Band took yet another major step toward moving an underused spectrum band to more intensive and efficient use. The 2.5 GHz band was licensed to qualifying institutions for instructional TV beginning in the 1960s.[6] Over time, use restrictions were loosened in this Educational Broadband Service (EBS) so as to allow for some commercial broadcasting and leasing, and channels in the band were set aside for a separate Broadcast Radio Service (BRS). However, much of the band – particularly in rural areas – remained unlicensed in terms of both frequency and geography.

In the rulemaking that preceded the auction, the FCC removed the education-related eligibility requirements for EBS licensees as well as the restrictions on use. The rulemaking also established a new county-based licensing scheme to replace the previous plan, which granted circular geographic licenses with a 35-mile radius, and consolidated the channels that were used for EBS into three blocks of spectrum. It established an opportunity for Tribal Nations to obtain EBS licenses on rural Tribal Lands prior to the auction; over 300 licenses have been granted to date through this opportunity. Incumbent EBS licensees will retain their existing license boundaries, and consequently, new licensees (including the Tribal Nations) will receive overlay licenses that exclude those channels and portions of the counties that EBS licensees and their lessees occupy (FCC, 2019b).

The FCC originally sought comment on two alternative auction formats for the 2.5 GHz Band auction[7]: One potential format was the FCC's simultaneous multiple-round (SMR) auction format; this was the approach that has been taken in the past when licenses could not be categorized as generic blocks and therefore license-by-license bidding was required. However, the auction would include over 8,000 county-based licenses, so an SMR auction could require many months of bidding rounds; this would likely pose a particular hardship on the smaller entities that were expected to participate in the auction.

The second potential format was a single-round auction format with procedures to facilitate aggregation of channel blocks within an area and limited aggregation of geographic licenses; this was an approach that clearly would reduce the duration of the auction and might increase the likelihood that some smaller, regionally focused service providers could win licenses in their local areas when competing against a larger provider that was building a nationwide footprint.

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[6] The 2019 2.5 GHz Report and Order addresses in more detail the history of the band. *See, generally,* FCC (2019b).

[7] After initially seeking comment (FCC, 2021c), the FCC issued a further public notice that sought comment on the clock auction approach (FCC, 2022c).

The response to the two formats was mixed: A number of commenters – large and small alike – indicated that they preferred a multiple-round format because the bidding strategies that they are accustomed to using depend upon the pricing and demand information that is revealed through multiple rounds of bidding. Relatedly, several entities expressed concern that the novelty and perceived complexity of the single-round auction would discourage participation. Given this dissatisfaction with the single-round format, but mindful that an SMR auction could last an unreasonably long time, the FCC staff proposed – and the Commission subsequently adopted – an ascending clock auction with optional proxy bidding for future rounds, which would alleviate some of the need for bidders to monitor every bidding round (FCC, 2022b).

Bidding on generic blocks clearly would not be appropriate because – even in counties without encumbrances – no two blocks would be alike because of bandwidth differences. In this "clock-1" format, instead of including multiple generic blocks within a bidding category, each county has a single license in each of up to three categories that correspond to the channel blocks (some counties do not have available "white space" to license in all three channel blocks). The auction can move more quickly than an SMR auction because intra-round bidding[8] will allow larger bid increments while still giving bidders the opportunity to bid up to their maximum willingness-to-pay; this enhances efficiency over an SMR auction where larger bid increments to speed up the auction would risk overshooting the equilibrium price. Moreover, the FCC's ascending clock auction software was able to incorporate a proxy bid option, whereby a bidder can indicate a price at which, if reached in a future round, the bidder wants to stop bidding for a license. The bidding system will then automatically place bids accordingly on behalf of the bidder, thereby reducing the bidder's need to bid in every round of the auction.

As the FCC attempts to make new spectrum bands available for commercial use, its auction staff will need to continue developing new auction formats that accommodate the needs of existing licensees while offering potential new licensees a bidding process that is responsive to their needs.

3 Making Broadband Available and Affordable

In addition to continuing to reform, streamline, and modernize its Universal Service programs, in 2021–2022 the FCC implemented important Congressional mandates to make broadband more accessible and affordable throughout the United States.

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[8] To bid for an item in an SMR auction, a bidder chooses from a menu of bid amounts: a minimum acceptable bid amount and several higher amounts. In a clock auction, a bidder can accept the next highest clock price or indicate a price lower than the clock price at which it wishes to stop bidding for the item (an "intra-round" bid). With a large bidding increment in an SMR auction, a bidder that is willing to pay more than the starting price but less than the full increment has no way to indicate that additional willingness to pay and, consequently, stops bidding at the starting price. In contrast, in a clock auction, a bidder can indicate the highest price it is willing to pay, so the auction is able to identify bidders' demands (and hence equilibrium prices) more precisely – even when bidding increments are large.

These mandates include implementing the Emergency Connectivity Fund, which is intended to help schools and libraries support remote learning, and the Emergency Broadband Benefit and its successor, the Affordable Connectivity Program, which provides discounts off the cost of broadband service and certain devices for qualifying low-income households.

In this section, we describe the implementation of these two programs as well as FCC efforts to reform its Universal Service Rural Health Care Program to distribute more cost-effectively the Universal Service funding that is used to support rural healthcare providers.

3.1 Emergency Connectivity Fund

The $7.171 billion Emergency Connectivity Fund (ECF) that was established by the American Rescue Plan Act of 2021 is intended to help schools and libraries support remote learning during the COVID-19 pandemic (FCC, 2021d, ¶ 1; U.S. Congress, 2021a, § 7402). Unlike the FCC's E-Rate program, which generally provides funding for broadband services that are delivered to and within schools and libraries (FCC, 2022d), ECF program funding allows eligible schools and libraries with students, school staff, or library patrons who have unmet Internet connectivity needs to connect to the Internet at locations other than the school or library (FCC, 2021d, ¶ 6).[9]

In implementing the ECF, the FCC sought to use the funds that were allocated by Congress to support remote learning in light of the need to connect millions of students who lacked the necessary connected devices and broadband services. The standard forms that applicants must submit in seeking ECF funding, which generally parallel those for E-Rate, provide substantial information that can provide pricing transparency and can inform future policy and purchasing decisions (FCC, 2021d, ¶ 15).

3.1.1 Application Process

To ensure that funding focused on unmet connectivity needs,[10] the FCC initially adopted an application process that prioritized funding to eligible schools and libraries for eligible equipment and services for the school year 2021–22; and, given remaining available funding, the FCC later allowed funding requests through the end of 2023.[11] Requests that were received across all application filing windows totaled more than $9.2 billion.

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[9] At the time of writing, the FCC had committed ECF funding for over 10 million connected devices and 5 million broadband connections (FCC, 2022f).

[10] The American Rescue Plan Act defined the COVID-19 emergency period as beginning on January 27, 2020, which left open the prospect that ECF applicants could ask for reimbursement for equipment and connections that they purchased before the inception of the ECF in 2021.

[11] Specifically, the FCC opened three filing windows: two to support eligible equipment and services received or delivered between July 1, 2021, and June 30, 2022; and one to support eligible equipment and services between July 1, 2022, and December 31, 2023 (FCC, 2021d, ¶ 78; FCC, 2021e; FCC, 2022e).

3.1.2 Support for Eligible Services and Equipment

The ECF provides funding for Wi-Fi hotspots, modems, routers, devices that combine a modem and router, and Wi-Fi-enabled connected devices: laptops and tablets (FCC, 2021d, ¶¶ 29–30). The ECF excludes funding for desktops (because of a lack of portability)[12] or for mobile phones (because the FCC concluded that these devices did not have the same capabilities as laptops and tablets to meet the remote learning needs of students, school staff, or library patrons).[13]

After considering the record, the FCC concluded that $400 was a reasonable, maximum support amount for connected devices (FCC, 2021d, ¶ 69).[14] The funding cap does not prohibit ECF applicants from purchasing more expensive devices; instead, it functions like a maximum copayment for those educational institutions that are willing to pay more, while increasing the likelihood of funding unmet needs for a larger number of institutions.[15]

3.1.3 ECF Open Data

The FCC established three performance goals for the ECF Program: (1) connecting and facilitating remote learning for students, school staff, and library patrons who otherwise would lack adequate access to connected devices and broadband Internet access connectivity during the pandemic; (2) ensuring that the Universal Service Administrative Company (USAC) efficiently and effectively administers the ECF Program[16]; and (3) providing pricing transparency for eligible equipment and services to inform future policy and purchasing decisions (FCC, 2021d, ¶ 15). The FCC required USAC to collect and release data needed to achieve and measure success towards its goals (FCC, 2021d, ¶¶ 17–18, 22). The data, which USAC will continue to update as it administers the ECF, are available at USAC's ECF Open Data portal (USAC, N.D.b).

For each funding application, the schools and libraries must submit certain required information, such as: student count and estimated unmet student needs; dollars requested; service provider and invoicing information; and product/service data,

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[12] Congress defined "connected devices" as "laptop computer[s], tablet computer[s], or similar end-user device[s]," which the FCC interpreted as containing a portability component.

[13] The FCC reasoned that a mobile phone could limit a student's ability to develop a class presentation or draft a research paper. The FCC also noted that its record did not contain any comment from a school or library that claimed that it had purchased smartphones to use instead of laptops or tablets (FCC, 2021d, ¶ 32).

[14] For Wi-Fi hotspots, the FCC adopted a maximum support amount of $250. Funding requests for other eligible equipment and services are reviewed to ensure that they are reasonable (FCC, 2021d, ¶¶ 71–72).

[15] The FCC allowed applicants to request waivers of the $400 cap for students, school staff, or patrons with disabilities (FCC, 2021d, ¶ 70).

[16] The USAC is an independent not-for-profit company that administers the Universal Service Fund and related programs to promote expansion and adoption of broadband and voice services under the direction of the FCC (USAC, N.D.a).

costs, and quantities.[17] For instance, a school that requests funding must report not only its student population, but also an estimate of the number of students who lack a connected device or a broadband connection and the extent to which the school met those needs in the 2020–2021 school year (prior to the ECF). The applicant later must provide invoicing documentation that includes product type, make, and model; or connection type, bandwidth, and other connection characteristics that match the equipment/service that was approved for funding and evidence that the equipment/service was received prior to ECF funding.

3.2 Affordable Connectivity Program

On December 27, 2020, the Consolidated Appropriations Act became law, which in part established a $3.2 billion Emergency Broadband Connectivity Fund for the fiscal year 2021 (U.S. Congress, 2020a). The Act directed the FCC to use that fund to establish an Emergency Broadband Benefit (EBB) Program, under which eligible low-income households could receive up to a $50 per month discount off the cost of broadband service (up to $75 in tribal areas) and up to a $100 discount off the price of certain connected devices (after paying a copay between $10 and $50) during the emergency period of the COVID-19 pandemic.

On November 15, 2021, the Infrastructure Investment and Jobs Act (Infrastructure Act) was signed into law. Among other things, the Infrastructure Act transformed the EBB Program from a temporary emergency program to a longer-term broadband affordability program: the Affordable Connectivity Program (ACP) (U.S. Congress, 2021b). The Infrastructure Act appropriated an additional $14.2 billion for the ACP and modified program support amounts and eligibility criteria, including reducing the discount amount from $50 a month to $30 a month in non-Tribal areas and increasing the household income eligibility threshold from an annual income at or below 135% of the federal poverty level to an income threshold of 200%.[18] The EBB – which concluded on December 30, 2021 – and its more than nine million enrolled subscribers were immediately transferred into ACP.

3.2.1 Program Overview

The Affordable Connectivity Program operates much like the FCC's Lifeline program in that it is managed by the USAC and utilizes the National Verifier – the National Lifeline Accountability Database (NLAD) – and the Lifeline claims systems.[19] Every Lifeline subscriber is eligible to enroll in the ACP. A subscriber that participates in both Lifeline and ACP can stack the Lifeline and ACP benefits to be

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[17] The ECF Open Data portal contains a data glossary with 82 fields (USAC, N.d.b).

[18] Additionally, recipients of the Special Supplemental Nutrition program for Women, Infants, and Children (WIC) are eligible for ACP though they were not for the EBB Program. The ACP also removed the eligibility criteria of significant loss of income, which was a qualifying path into the EBB Program.

[19] The FCC's Lifeline program provides discounted phone and broadband support to qualifying low-income consumers (FCC, 2022g).

applied to one plan or use the benefits with two different providers for two different plans, but the subscriber must apply for Lifeline first (FCC, 2022 h, ¶ 121). Consumers can apply to the ACP through their provider, through a consumer portal, or through a paper application. Enrollment is a two-step process: A consumer must first be verified to ensure eligibility; then the consumer must pick an ACP provider so as to enroll in the NLAD.[20]

An important difference between the Lifeline program and the ACP is that Lifeline requires participating providers to be designated as "eligible telecommunications carriers" (ETC).[21] However, non-ETC providers are eligible and encouraged to participate in the ACP; and as of June 1, 2022, non-ETC providers constituted approximately 37% of providers that participated in the ACP.[22]

The FCC established three performance goals for the ACP: (1) reduce the digital divide for low-income consumers; (2) promote awareness and participation in the ACP and Lifeline program; and (3) ensure that the USAC efficiently and effectively administers the program. The FCC continues to explore sources of data and various methods of analysis to measure progress towards these goals.

3.2.2 ACP Enrollment Data

As of June 1, 2022, the ACP is providing a monthly subsidy to over 12.1 million households. Approximately 62% of enrollees are receiving a monthly benefit for mobile broadband services, while about 38% of enrollees are receiving a benefit for fixed services, for which the leading technology is cable.

An important measure of ACP program performance is the participation rate of eligible households, which requires knowledge of the currently enrolled population as well as the overall eligible population. Calculating the ACP eligible population is complicated by the difficulty in estimating the population that is eligible under certain individual criteria and estimating the population eligible under overlapping criteria. The same issues exist for the calculation of eligible population in the Lifeline program, however, and USAC attempts to address these challenges by utilizing the American Community Survey (ACS) microdata to estimate the rate at which Lifeline-eligible households participate in the Lifeline program.[23]

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[20] Service providers may use one of four verification methods: (1) based on Lifeline program participation; (2) using the National Verifier; (3) obtaining FCC approval for an Alternative Verification Process; or (4) for households with students, based on participation in the free and reduced-price school lunch or school breakfast programs (FCC, 2022h , ¶ 63).

[21] ETCs are providers that have met specific guidelines that allow them to receive universal support and participate in the Lifeline Program; providers receive the ETC designation by a state regulatory agency (and in some cases the FCC). 47 CFR § 54.201; USAC (N.D.c).

[22] As of June 1, 2022, there are currently 1,462 providers that participate in the ACP: 1,306 that offer fixed-only services; 83 that offer mobile broadband only; and 73 that offer both fixed and mobile services. A total of 136 providers have indicated that they offer a connected device to consumers for a one-time copay between $10 and $50.

[23] Lifeline eligible household counts are based on the U.S. Census Bureau's American Community Survey (U.S. Census, 2022). Households are determined to be eligible for Lifeline if the householder reported any of the following in response to ACS: (1) Medicaid, Medical Assistance, or any kind of gov-

The same methodology can be applied to the ACP. The Center for Poverty has utilized this methodology and published estimates of the total eligible ACP population for each state (Friedman & Wimer, 2022). The Center for Poverty calculated the participation rate for each state: the total enrollments in each state divided by the estimated eligible population. It found that the three areas with the highest estimated participation rates are Washington D.C. at 40%, Ohio at 32%, and Louisiana at 31%; while the three areas with the lowest participation rates are North Dakota at 6%, South Dakota at 7%, and Idaho at 8%.

3.2.3 Future ACP-related Items

The ACP Report and Order directed "OEA, with support from USAC, to determine appropriate avenues to collect service plan characteristics, such as possible future modifications to NLAD or conducting a provider survey" (FCC, 2022h , 100). Collecting this information will help the FCC gauge whether the ACP is providing value to households beyond what the Lifeline program offers, and whether that value is in-line with market rates for broadband services (FCC, 2022h , ¶ 100). The Report and Order also included a further notice that sought comment on an outreach grant program, a separate pilot program that is targeted to reach residents of public housing and other federal housing assistance participants, and an enhanced benefit for high-cost areas. On August 5, 2022, the FCC approved the creation of the Affordable Connectivity Outreach Grant Program and the Your Home, Your Internet Pilot Program (which targeted outreach to federal housing assistance recipients) (FCC, 2022i; FCC, 2022j).

Additionally, the Infrastructure Act requires the FCC to collect data on ACP plan prices and rates (U.S. Congress, 2021b). Under the Infrastructure Act, final rules for the data collection must be issued no later than November 15, 2022. On June 8, 2022, the FCC released a notice of proposed rulemaking (NPRM) that outlined different options for an annual collection of information about the price and subscription rates of Internet service offerings that are received by households that are enrolled in the ACP (FCC, 2022k).

The NPRM asked for comment on an aggregate, subscriber-level, or hybrid approach for collecting these data. The aggregate approach would be a static, stand-alone data collection of total ACP subscribers on each relevant provider plan, while the subscriber-level approach would collect the relevant data for each ACP subscriber through NLAD on an ongoing basis. A hybrid approach would take elements of each.

This data collection would begin in 2023, and the data would be instrumental in understanding the type of service and rates that subscribers receive from an

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Footnote 23 (continued)

ernment-assistance plan for those with low incomes or a disability; (2) yearly food stamp/Supplemental Nutrition Assistance Program (SNAP) recipiency; 3. public assistance income over the past 12 months (any amount); (4) Supplemental Security Income over the past 12 months (any amount); or (5) household income below the 135% poverty threshold.

ACP-subsidized plan. Further, these data would allow the FCC to understand better how ACP services differ from Lifeline services, which would help inform the future of low-income programs that are administered by the FCC.

3.3 Rural Health Care Program

The Rural Health Care Program of the Universal Service Fund subsidizes rural healthcare providers' purchase of broadband and telecommunications services (FCC, 2022 l). This support is provided through two component programs: the Telecommunications (Telecom) Program, and the Healthcare Connect Fund Program.

The Telecom Program, which was established by statute in 1997, subsidizes the difference between urban and rural rates for telecommunications service for rural health care providers. The subsidy to telecommunications providers equals the rate "for similar services provided to other customers in comparable rural areas" in the state (the rural rate) minus the rate paid for similar services in urban areas of the same state (the urban rate).[24] In funding year 2021, commitments under this program totaled $180 million.

The Healthcare Connect Fund, which was established in 2012, subsidizes the purchase of a broader set of advanced telecommunications and information services, including: Internet access; dark fiber; business data; traditional DSL; and private carriage services.This program also provides support for healthcare provider consortia, and a consortium can include providers in both rural and urban areas. The subsidy is a flat 65% discount on the service rate. In funding year 2021, commitments under this program totaled $317 million.

3.3.1 Incentives in the Telecom Program

A healthcare provider that participates in the Telecom Program pays the urban rate by selecting a rate that is no greater than "the highest tariffed or publicly-available rate charged to a commercial customer for a functionally similar service" in any city in the same state with a population of at least 50,000.[25] The Telecom Program compensates the contracted telecommunications provider by paying the difference between an appropriate rural rate and the selected urban rate. Until 2019, the healthcare provider and the telecommunications provider determined the rural rate based on one of three methods:

1. The average of rates that are charged by the telecommunications provider to commercial customers, other than healthcare providers, for the same or similar services that are provided in the rural area where the healthcare provider is located.
2. If the telecommunications provider does not have any commercial customers in this area, then the rural rate is the average of tariffed and other publicly available

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[24] 47 U.S.C. § 254(h)(1)(A).

[25] 47 CFR § 54.605. This version of the rule predates a 2019 Reform Order (FCC, 2019c). However, the Commission currently operates under this rule as a practical matter.

rates that are charged by other telecommunications providers for the same or similar services that are provided over the same distance in the same area.

3. If there are no such rates or the telecommunications provider reasonably determines that those rates would be unfair, a rate that is based on an itemization of costs must be approved by the FCC for interstate services (or the relevant state commission for intrastate services).[26]

Because the healthcare provider always paid the urban rate, it had an incentive to identify the lowest urban rate possible for the requested service in the state. Meanwhile, the Telecom Program compensated carriers for the difference between this rate and the corresponding rural rate for the service provided. Therefore, the carrier had an incentive to identify the highest rural rate that it could justify, so as to maximize program support (FCC, 2019c, ¶ 10).

In 2019, a new approach was adopted whereby the subsidy was based on the difference between the medians of rates that are collected for both rural and urban areas under the Telecom Program, Healthcare Care Connect Fund, and E-Rate, as well as rates from other approved sources.[27] Rural and urban medians were calculated for each available combination of state, level of rurality, and bandwidth – as well as the presence or absence of a service-level agreement. Use of this database has been suspended, however, due to anomalies and inconsistencies in the calculation of the median rates (FCC, 2022 m, ¶¶ 10–14).[28]

3.3.2 Competition in Bidding

Both components of the Rural Health Care program require competitive bidding, but many rural areas tend to have fewer competitors. The programs are intended to provide support in rural areas where costs are significantly higher than in more densely populated areas. For the Healthcare Connect Fund in the funding year 2020, which records the number of bids that have been received for service requests, nearly 80% of recent funding requests had only one bidder.[29]

3.3.3 Current Rulemaking

The FCC adopted a further notice of proposed rulemaking (Further Notice) on February 18, 2022, that sought comment on a range of possible reforms to the Rural Health Care Program (FCC, 2022 m). The Further Notice considered several options for reform including, for example, better differentiating rural areas so as to reflect

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[26] 47 CFR § 54.607 (2019).

[27] The Rural Health Care Available Rates database can be accessed through USAC's Open Data platform (USAC, 2020).

[28] One example of anomalous rates for otherwise similar services was a higher rate for a 20 Mbps service than for a 50 Mbps service. Another example was a higher rate in an area that is classified as "less rural" than in an area that is classified as "extremely rural", since a greater degree of rurality is meant to identify areas that cost more to serve.

[29] USAC (2022b). Some applicants reported zero bids or left the field blank due to various exemptions.

the variation in costs of providing telecommunications service due to various factors (FCC, 2022 m, ¶¶ 20–28). These factors included: population density; distance to the nearest metropolitan area; topography; and existing infrastructure.[30] The Further Notice also asked whether rates should incorporate information specific to each census tract.

The Further Notice asked how to categorize the service technologies that are purchased by healthcare providers (FCC, 2022 m, ¶¶ 31–40). Currently, the FCC recognizes bandwidth, reliability, and security as the primary attributes of service. If these categorizations are too general, the program may be treating services – which should be distinguished – as similar. The Further Notice asked if there are additional attributes that should be considered when identifying services as similar. In the Further Notice, the FCC proposed various attributes, such as: the type of network (private, managed performance, or best efforts); the arrangement of endpoints (one-to-one, one-to-many, or many-to-many); the facilities that are deployed (copper, cable, terrestrial wireless, or satellite); and additional service features (such as redundancy and various ways of guaranteeing a minimum amount of downtime).

The Further Notice also proposed alternative mechanisms for urban and rural rate determination. One method would replace the use of rate medians with rates that are predicted by a regression model. A regression model would identify the contribution of each attribute of service, as well as state-level effects, to the variation in price.[31] The Further Notice sought comment on how such a model should be specified and the data that should be used.[32]

4 Verizon/TracFone Merger

In September 2020, Verizon announced that it had entered into an agreement with América Móvil to acquire TracFone Wireless, Inc., for a combined $6.25 billion in approximately equal portions of cash and Verizon common stock (Verizon, 2020). TracFone, which offered prepaid services to more than 20 million customers at the

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[30] The FCC sought comment on using alternative measures of rurality. Currently, the FCC relies on the Census Bureau's designation of "core based statistical areas" to distinguish between levels of rurality. The FCC suggests two possible alternatives: the "index of relative rurality" (Waldorf and Kim, 2018); and "rural urban commuting area codes (USDA, 2020). The index of relative rurality is a continuous measure of rurality that assigns a value of 0 to 1 to a location based on its size, population density, remoteness, and urbanization. The rural urban commuting area codes classify census tracts with the use of measures of population density, urbanization, and daily commuting.

[31] The Further Notice sought comment on whether this approach would be more systematic than the use of median rates for separate combinations of rurality, bandwidth, and service categorization. It also would retain an advantage of using median rates, as predictions from a model fitted to the observed rates would temper the more extreme values. Model specification and data selection would require careful technical analysis. Those who are interested can view the existing data through USAC's Rural Health Care Available Rates database (USAC, 2020).

[32] Other options were also considered: applying discounts to the service rate that vary by level of rurality; using cost curves to account for the relationship between bandwidth and the cost of providing service; and covering only 95% of the difference between the urban and rural rates, so as to mitigate moral hazard.

time of the transaction, would become a direct subsidiary of Verizon following the transaction (FCC, 2021f, ¶ 2). The merger would combine the second largest facilities-based mobile wireless service provider in the United States with the largest mobile virtual network operator (MVNO), which raised the potential for both horizontal and vertical competitive harms.[33]

The merger raised concerns that, post-transaction, the combined entity would have the incentive and ability to raise prices unilaterally – particularly for lower-income customers in the FCC's Lifeline program.[34] In addition, there was a concern that the merger could incentivize Verizon to foreclose MVNO competitors or increase prices in the wholesale market.[35]

The Applicants claimed several transaction-specific benefits: efficiency from the elimination of double marginalization (EDM); an improved bargaining position in purchasing devices; improved access to devices and 5G technologies for Trac-Fone customers; and enhanced distribution channels for TracFone customers (FCC, 2020b, pp. 2–3; FCC, 2021 g, p. 4). The Applicants claimed that the transaction posed no risk of material harm (FCC, 2020b, p. 14). The Applicants also claimed that post-transaction, Verizon would retain a strong incentive to sell wholesale services to MVNOs – in part, because of the differentiation between TracFone and the other MVNOs that Verizon served (FCC, 2021g , pp. 76–77; CPUC, 2021, p. 28).

Verizon's pre-transaction relationship as a mobile network operator (MNO) wholesale supplier to TracFone as well as a mobile wireless competitor to TracFone required the FCC staff to account for both the horizontal and vertical aspects of this transaction. This required staff to modify its approach to screening for competitive harms because the screens that had been used in previous horizontal merger analyses could not account for the vertical aspects of this transaction. Additionally, because TracFone is an MVNO, staff could not rely on the Local Number Portability (LNP) data that it normally uses to measure diversion when analyzing horizontal mergers among mobile wireless service providers.

4.1 HHI Screen

In the past, in evaluating horizontal mergers the FCC has used the post-transaction Herfindahl–Hirschman Index (HHI) and the change in the HHI to help identify markets that require further competitive analysis (FCC, 2021f, 35).[36] The Applicants argued that in calculating nationwide market shares, including for market

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[33] MVNOs do not own their own network facilities, but instead purchase mobile wireless services wholesale from facilities-based service providers and resell these services to consumers.

[34] At the time of the Application, TracFone had approximately 1.7 million Lifeline customers (FCC, 2020b, p. 18).

[35] The FCC also considered other potential effects of the transaction, including: coordinated harms; implications for offers of roaming services; and the potential impact on employment. We focus only on the analysis of potential unilateral horizontal and vertical effects in this survey article.

[36] As in past mobile wireless transactions, the FCC used a combined "mobile telephony/broadband services" product market that comprises mobile voice and data services, including those provided over advanced broadband wireless networks. See FCC (2021f, ¶¶ 27–29) for additional detail.

concentration metrics, the FCC should attribute MVNO customers to their host facilities-based providers, whereas commenters argued that attribution of market shares to host MNOs is misleading because it ignores the market power that prepaid MVNOs can exercise by pricing above their wholesale cost (FCC, 2021f, ¶ 36).[37]

Not surprisingly, attributing MVNO shares to their MNO providers leads to a substantially smaller change in HHI than if pre-transaction TracFone were treated as an independent competitor because the former methodology results in a reallocation of market shares across the wholesale MNO's that supplied TracFone,[38] while the latter methodology reallocates the share of an independent TracFone to that of Verizon.

The FCC did not find either approach appropriate and declined to rely on HHIs; the FCC noted that there are other generally accepted initial screens that are available to evaluate the likelihood of potential adverse unilateral effects (FCC, 2021f, ¶ 37). Attributing MVNO customers to the underlying MNOs effectively treats the MVNO as fully under the control of its MNO suppliers and thus could underestimate the transaction's competitive impact by ignoring the downward pricing pressure that the MVNO exerts on its competitors when setting its own pre-transaction retail price. Conversely, treating the MVNO as a fully independent competitor ignores the MNOs' ability to influence MVNOs' network costs, which limits MVNOs' competitive impact.

4.2 Upward Pricing Pressure Screens

In its review of previous proposed transactions, the FCC has calculated upward pricing pressure (UPP) indices as an additional preliminary screen for potential unilateral effects (FCC, 2021f, ¶ 41).[39] The FCC calculated the net upward pricing pressure index that was proposed by Farrell and Shapiro (Farrell & Shapiro, 2010), which had the advantage of screening for upward pricing pressure while accounting for the potential pro-competitive effect of EDM that stemmed from Verizon's pre-transaction vertical relationship with TracFone.[40]

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[37] In reviewing transactions involving MNOs, the FCC typically has focused its initial analysis of market concentration on facilities-based providers of mobile-telephony/broadband services. The FCC also has recognized that MVNOs may provide additional competitive constraints and considered their role in this transaction.

[38] Pre-transaction, approximately 64% of TracFone customers relied on Verizon's network, while approximately 19% and 16% relied on, respectively, the networks of T-Mobile and AT&T (FCC 2020b, p. 4). Attributing MVNO shares to their MNO suppliers would increase Verizon's share and decrease those of T-Mobile and AT&T in the HHI calculations.

[39] Adverse unilateral price effects can arise when a merger gives the merged entity an incentive to raise the price of a product previously sold by one merging firm and thereby divert the sales to products previously sold by the other merging firm to increase profits. Holding other prices and product offers constant, the increase in profits is equal to the value of the diverted sales to the merger partner. UPP measures the value of the diverted sales as the number of units that are diverted to a product multiplied by the margin between price and incremental cost of the product (U.S. DOJ/FTC, 2010, § 6.1).

[40] This is in comparison to the Gross Upward Pricing Pressure Index (GUPPI), which seeks to quantify the loss of direct competition between merging parties without accounting for potential efficiencies (FCC, 2019d, ¶ 129). As Farrell and Shapiro observe, the net UPP "involves comparing two opposing

To calculate the net UPP, staff estimated the diversion rates between the merging firms' products, the merging firms' profit margins, and the marginal-cost efficiencies that were expected to result from the merger (FCC, 2021f, ¶ 41). The UPP index for TracFone was [41]:

$$UPP_T = D_{T \to V} \times (P_V - C_V) - E_T \times C_T$$

where: $D_{T \to V}$ is the "diversion ratio" from TracFone to Verizon; P_V is the pre-transaction price of Verizon products; C_T and C_V are, respectively, the marginal costs of the TracFone and Verizon products; and E_T is TracFone's credited marginal cost efficiencies.[42] The first part of the expression represents the upward pricing pressure on TracFone's services, while the second part of the expression represents the opposing downward pricing pressure that is due to merger efficiencies.

In calculating upward pricing pressure, staff estimated profit margins by using the Applicants' data to calculate a "customer lifetime value" (CLV) margin that accounted for the incremental costs of serving individual customers as well as one-time subscriber acquisition and upgrade costs over the customer lifetime (FCC, 2021f, ¶ 43).[43] Staff focused on efficiencies that were likely to result from EDM, while erring on the side of overestimating merger harms by ignoring other potential merger efficiencies claimed by the Applicants. Elimination of double marginalization could result from this transaction, because pre-transaction TracFone purchased wholesale network access at prices that were above Verizon's network cost and the transaction would allow it instead to realize lower costs by internalizing Verizon's incremental network costs when setting prices (CPUC, 2021, pp. 8–10).

To quantify EDM, staff subtracted Verizon's monthly on-network costs per TracFone customer from TracFone's pre-transaction per-customer weighted-average wholesale costs across all MNOs from which it purchased network access (FCC, 2021f, ¶ 45).

4.3 Diversion

Since 2004, the FCC has relied on porting data from the LNP database to calculate diversion ratios in evaluating mobile wireless transactions (FCC, 2021f, ¶ 41). Unfortunately, the FCC's LNP data do not distinguish MVNO customer ports from the ports of the underlying facilities-based service providers that those customers use, which prevented staff from using the LNP data to calculate customer switching rates for this transaction. Because the Applicants did not provide an alternative

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Footnote 40 (continued)

forces: the loss of direct competition between the merging parties, which creates upward pricing pressure, and marginal-cost savings from the merger, which create (offsetting) downward pricing pressure.".

[41] The UPP expression for Verizon was analogous.

[42] Efficiencies of E_T imply that the post-transaction marginal cost for TracFone would be $(1 - E_T) \times C_T$.

[43] Staff then assumed that the CLV margin – M_V^{CLV} – corresponded to a "simple margin" in which the marginal cost effectively incorporates incremental and one-time acquisition costs, so as to back out C_V: $C_V = P_V(1 - M_V^{CLV})$.

estimate of diversion, staff relied on nationwide market-share-based diversion that was based on the Applicants' and public subscribership data.[44] Staff viewed market-share based diversion as conservative because it likely overstated the true diversion between Verizon and TracFone, which, in turn, implied an estimate of UPP that overstated true upward pricing pressure.[45]

4.4 Net Upward Pricing Pressure Calculation

After accounting for the elimination of double marginalization, staff found a negative net UPP for TracFone (FCC, 2021f, ¶ 46). Staff did not have the data to calculate Verizon's likely efficiencies, which made the estimate of Verizon's UPP necessarily positive. However, the estimate was below the threshold that staff would consider as likely to raise significant unilateral effects (FCC, 2021f, ¶ 46, n. 144). Moreover, as was noted above, staff estimates of net UPP were likely too high because market-share-based diversion likely overstated customer switching between Verizon and TracFone and because staff did not have the data to quantify efficiencies other than EDM.

4.5 Lifeline Commitment

While on balance, the FCC – based on the net UPP calculation – found that significant unilateral effects were unlikely, staff based this calculation on the potential average impact on consumers. Staff could not conclude that certain groups of consumers – such as very low-income consumers – might not be harmed by the transaction (FCC, 2021f, ¶ 46). A specific concern that was raised in the record was the post-transaction availability of Lifeline – particularly in areas where TracFone's resale services were outside Verizon's network (FCC, 2021f, ¶ 131). Even if EDM resulted in lower average prices, if Verizon ceased participating in the program in certain areas, TracFone's Lifeline consumers could face higher prices.[46]

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[44] Market-share-based diversion rates are sometimes used in calculating diversion ratios when better data are unavailable. See, e.g., Shapiro (1996, pp. 25–26). Market-share-based diversion also underpins the logit model of differentiated product competition that is often used to study mergers. See, e.g., Miller and Sheu (2021, p. 149).

[45] The Applicants argued that Verizon and TracFone focused on serving distinctly different retail segments (CPUC, 2021, p. 26; FCC, 2021h , p. 11–12), which suggested that customers switched across Verizon and TracFone in proportions that were below their respective market shares. In particular, one reason why TracFone consumers might switch to Verizon proportionally less than Verizon's market share concerns Verizon's relatively limited prepaid presence (FCC, 2021h , p. 12) coupled with some TracFone customers' inability to pass the credit check that is necessary to qualify for Verizon's postpaid service (Verizon, 2021). To assess potential credit constraints that would prevent certain consumers from switching to postpaid service following a price increase, staff also used credit-score distribution data to modify the market-share-based diversion estimates (FCC, 2021f, ¶ 42, n. 131).

[46] The Applicants' documents indicated that the Applicants anticipated that average revenue per user per gigabyte would decline following the transaction (FCC, 2021f, ¶ 46). However, unless this translated into a decline in absolute prices, consumers who do not value additional data would be worse off.

The FCC conditioned its approval of this transaction on Verizon's commitment to continue offering Lifeline services to existing and new customers for at least seven years from the close of the transaction over the same service area where TracFone previously had offered Lifeline service (FCC, 2021f, ¶ 133).[47]

4.6 Raising Rivals' Costs

Various commenters argued that the acquisition of TracFone could increase Verizon's incentive post-transaction to increase wholesale prices or degrade wholesale service quality that was provided to independent MVNOs – particularly those that offered prepaid service in competition with TracFone (FCC, 2021f, ¶ 53). A vertical merger could increase a merged firm's incentive to raise rivals' costs either by foreclosing the supply of the input that it sells to downstream competitors or by raising the price at which it sells the input to competitors (FCC, 2021f, ¶ 56). The integrated firm would have an incentive to foreclose or raise input prices if the profits that are gained in the downstream (retail) market exceed the profits that are lost in the upstream (wholesale) market (Riordan & Salop, 1995, p. 528). The changes to Verizon's incentives to foreclose access or raise wholesale prices to particular MVNOs hinged therefore on the degree of substitutability – the diversion rate – between TracFone and the non-TracFone MVNOs that Verizon supplied (FCC, 2021f, ¶ 56).

The FCC found that there was a high degree of differentiation between TracFone and the largest MVNOs that Verizon supplied: in particular, Comcast and Charter (FCC, 2021f, ¶ 57). In contrast to TracFone, which focused on the prepaid segment, Comcast and Charter offered post-paid plans to their cable subscribers who preferred to bundle their wireless and wireline services. There were, however, a few MVNOs that Verizon supplied that offered low-cost prepaid services that directly competed with TracFone.

To mitigate the potential vertical harms to such MVNOs, the FCC conditioned the approval of this merger (on November 22, 2021) on a commitment by Verizon to provide MVNOs that had contracts with Verizon at the time of approval an option to extend their existing MVNO wholesale agreements until three years after the transaction closed (FCC, 2021f, ¶ 145).

5 Broadband Data Collection

In 2019 the FCC determined that its Form 477 broadband deployment data were insufficient to meet its Universal Service Fund policy goals, and the Commission initiated a new nationwide data collection.[48] We report on the progress of this

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[47] Verizon would have to provide service via its own network or through MVNO agreements where it did not have coverage unless it obtained a waiver where it could not extend a necessary MVNO agreement under commercially reasonable terms.

[48] See also, FCC (2019e).

broadband availability data collection: the Broadband Data Collection (BDC).[49] The Broadband Data Collection's more granular and precise maps will allow the FCC to better target Universal Service to Americans living in areas without broadband access (FCC, 2020c, ¶ 1). The BDC also establishes processes for members of the public and other entities to challenge and verify the coverage maps to improve their accuracy.

The filing window for the first round of BDC data – which depicts broadband deployment as of June 30, 2022, from fixed and mobile broadband providers (FCC, 2022o), closed on September 1, 2022. Once the FCC analyzes the data, it will publish maps – following which, individuals and certain entities may challenge the data with the use of the FCC's challenge processes. We will highlight below various data collection methodologies and statistical issues that are addressed in both the fixed broadband and mobile broadband challenge and verification processes.[50]

5.1 Broadband DATA Act Mandates

In March 2020, the Congress passed the Broadband Deployment Accuracy and Technological Availability Act (Broadband DATA Act or BDA), which required the FCC twice a year to collect and disseminate more granular and consistent data from "broadband Internet access service" (BIAS) providers on the availability and quality of broadband service. The BDA further required the FCC to establish various processes to verify the accuracy and reliability of the broadband availability data that are submitted by these providers.[51] It also directed the FCC to create a Broadband Serviceable Location Fabric (the Fabric) to serve as a common dataset of all locations in the United States where fixed BIAS is or can be installed.[52] The Fabric is to contain geocoded information for each location – to serve as the foundation for which all fixed BIAS availability data are reported and overlaid – and the FCC is required to update it at least every six months.[53]

Fixed wireless providers must submit propagation maps and propagation model details that reflect the speeds and latency of the service that they provide, or a list of addresses or locations that constitute the area where service can be made available.[54] Wired and satellite providers must report polygon shapefiles or lists of addresses or

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[49] The BDC had been previously known as the Digital Opportunity Data Collection (FCC, 2019e). Throughout this section, we will generally refer to the BDC as a reference to either.

[50] The "mobile challenge process" is initiated by on-the-ground speed testing that is submitted by consumers and other third parties (e.g., local governments), whereas the "mobile verification process" is initiated by the FCC based upon evidence that is available at the FCC's disposal: e.g., crowdsourced data, infrastructure information, etc.

[51] U.S. Congress (2020b). BIAS providers include terrestrial fixed, fixed wireless, satellite, and mobile BIAS providers of mass-market retail service. 47 U.S.C. § 642(a)(1) and 47 C.F.R. 8.1(b).

[52] 47 U.S.C. § 642(b)(1)(A)(i).

[53] 47 U.S.C. § 642(b)(1)(B).

[54] 47 U.S.C. § 642(b)(2)(A)(iv)(I). Latency refers to the time that a data packet takes to travel from one point to another in a network (FCC, 2020c, ¶ 92).

locations that constitute the service area of the provider.[55] The BDA further requires mobile BIAS providers to submit propagation maps and propagation model details that reflect a provider's 3G coverage, 4th generation Long-Term Evolution (4G LTE) coverage, and 5G New Radio (5G-NR) coverage.[56]

The BDA required the FCC to establish a user-friendly challenge process through which consumers, governmental entities, and other entities or individuals may submit coverage data to challenge the accuracy of the coverage maps, any information submitted by a provider regarding the availability of BIAS, or information included in the Fabric.[57] The BDA requires the FCC to "verify the accuracy and reliability" of the BIAS data that the providers submit in their biannual filings in accordance with measures that have been established by the FCC.[58]

5.2 Fixed Broadband

In January 2021, the FCC adopted BDC rules that require facilities-based fixed service providers to report BIAS coverage and to identify where such services are offered to residential and business locations (FCC, 2021i, ¶¶ 9–10). Fixed providers must report the maximum advertised download and upload speeds.[59] In addition, fixed providers must report latency information that is associated with each maximum speed and technology combination for a particular geographic area (FCC, 2021i, ¶ 27). Fixed providers may report broadband availability data with the use of either availability polygons or a list of addresses or locations.

Regardless of how the data are reported, the FCC will publish data based on the Fabric locations that are reported as having broadband service available to allow for location-specific challenges.

5.2.1 Location Fabric

A criticism of the FCC's Form 477 fixed broadband deployment data is that providers need to indicate only whether a given level of service is available in at least one location within a census block (Baker et al., 2021). Critics have argued that this leads to a potential overstatement of coverage – especially in rural areas where census blocks are geographically larger than in urban areas (Mack et al., 2019). The

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[55] 47 U.S.C. § 642(b)(2)(A)(iv)(II).

[56] 47 U.S.C. § 642(b)(2)(B).

[57] 47 U.S.C. § 642(b)(5).

[58] 47 U.S.C. § 642(b)(4)(B).

[59] For services that are offered that are below 25/3 Mbps, providers must report the speed that is associated with the service with the use of two speed tiers: (1) greater than 200 kbps in at least one direction and less than 10/1 Mbps; and (2) greater or equal to 10/1 Mbps and less than 25/3 Mbps. For speeds that are greater than or equal to 25/3 Mbps, the provider must report the maximum advertised download and upload speeds that are associated with the service (FCC, 2021i, ¶ 22).

Fabric will address this granularity issue by supplying a comprehensive dataset of all of the broadband serviceable locations in the United States.[60]

5.2.2 Challenging the Data

Consumers may challenge the accuracy of the coverage maps at a particular location where they own property or reside and are authorized to request service (FCC, 2021i, ¶ 72).[61] Similarly, governmental and other entities may challenge coverage data at various locations by submitting in individual or bulk form the required information about the location(s) and provider(s) whose data is being disputed and evidence supporting the challenge (FCC, 2021i, ¶ 90). Consumers and governmental and other entities may also challenge the Fabric data on the basis of: (1) a wrong placement of a location on the map; (2) a location that is not broadband serviceable; (3) a serviceable location that is not reflected in the Fabric; or (4) information about a location that is incorrect in the Fabric (FCC, 2021i, ¶¶ 89, 95). Challenges to the fixed maps and Fabric are intended to improve the accuracy of the underlying foundation of any broadband availability analysis as well as to supplement the maintenance of the Fabric over time.

5.3 Mobile Broadband

The FCC requires mobile providers twice a year to submit propagation maps and model details for 3G, 4G LTE, 5G-NR,[62] and voice technologies. These models should estimate results for both on-street/pedestrian "stationary" usage (stationary maps) and in-vehicle mobile usage (in-vehicle maps) that account for various propagation model details (FCC, 2020c, ¶¶ 32–33, 48). Each technology must be modeled to predict coverage for certain minimum download/upload speeds: 200/50 kbps for 3G; 5/1 Mbps for 4G LTE; and 7/1 and 35/3 Mbps for 5G-NR (FCC, 2020c, ¶¶ 44–45, 47).[63]

Mobile service is probabilistic, and the quality of service may vary from one minute to the next at a given location. The mobile broadband coverage maps are based

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[60] The Fabric will reflect each location as a single point defined by a set of geographic coordinates that fall within the footprint of a building, with multi-tenant environments (MTEs) identified as a single record that includes, to the extent feasible, the number of units within each MTE (FCC, 2021i, ¶¶ 126, 130). Residential locations are defined as "all residential structures, including all structures that are, or contain, 'housing units' or 'group quarters' based on the U.S. Census Bureau definition of these terms." Business locations are defined as "all non-residential (business, government, non-profit, etc.) structures that are on a property without residential locations and that would be expected to demand broadband Internet access service" (FCC, 2021i, ¶¶ 127, 128).

[61] Consumers must choose a dispute category from pre-approved options in the online BDC portal: e.g., no service at the location; the provider failed to install service within ten business days; the provider denied request for service; or the reported speed is not offered.

[62] 5G-NR refers to 5th generation New Radio: the successor mobile network technology to 4G LTE.

[63] The two-tiered approach for mapping 5G-NR service is intended to provide the best information to end users as to where they can expect to receive 5G-NR services that are capable of supporting a variety of potential use cases.

on predictive propagation modeling that attempts to account for the many variables that can affect the quality of service for a mobile user, including: terrain variation; clutter (e.g., foliage, manmade structures, vehicular traffic); and network demand (cell loading).[64] The FCC defined a set of required parameters that are to be used in the models so as to ensure that maps across providers are generally consistent in terms of what they represent.[65] For example, a provider's 4G LTE map will show its coverage footprint where it claims 5 Mbps download and 1 Mbps upload speeds at the cell edge – the farthest distance from the cell site that the provider claims the minimum speeds – with a cell edge probability of not less than 90% (and assuming the cell is not less than 50% loaded).[66]

A provider's coverage maps are generated under assumptions that may not reflect on-the-ground reality at a particular moment and location when a consumer is accessing the provider's network. Unlike the coverage maps, which represent a hypothetical state of the network, speed tests that are conducted with the use of a device on a dynamic mobile network reflect the on-the-ground reality of wireless availability at the time that the test was run.[67] The submitted coverage maps will serve as a baseline estimate by providers of their coverage, and these estimates will be refined through challenges and Commission-led verification inquiries. Geographic areas that are subject to challenges or verification inquiries that are not successfully rebutted or confirmed by the providers will be removed from coverage maps.

Because of the probabilistic nature of mobile broadband service, staff, in designing the challenge and verification processes, considered spatial and temporal sampling issues along with the need for a statistically robust sample size to draw conclusions about a provider's network. This includes taking into account the selection bias problem in crowdsourced testing, which arises from the fact that testers are more likely to conduct tests when experiencing particularly poor coverage or especially strong coverage. Staff also recognized that challengers likely would be highly diverse and not coordinate their testing, which implies that the testing and sampling process would need to make it possible for these various entities collectively to generate a representative sample to challenge the coverage data.

5.3.1 Mobile Challenge Process (MCP)

The FCC established various rules and thresholds to ensure that a set of speed tests that constitute a challenge to which a provider is required to respond to – a cognizable challenge – reasonably represents the provider's network (FCC, 2022n). To

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[64] Cell loading refers to the percentage of the available air interface resources of a base station that are used by consumers with respect to broadband Internet access service. 47 U.S.C. § 641(4).

[65] In the Form 477 mobile coverage maps, the FCC did not prescribe modeling parameters for different technologies. This flexibility for providers meant that maps were not comparable across providers.

[66] The farther that a device is from the cell site, the lower is the probability of coverage (all else equal).

[67] We note that factors that are beyond a provider's control may affect the observed quality of service that consumers receive on their devices. For example, different devices have different chipsets that support different spectrum bands in a way that could affect speeds; consequently, while one device may surpass the threshold at a particular time and location, another device may not.

create a cognizable challenge, a consumer needs to submit on-the-ground speed test data. Consumers may submit speed test results via an FCC-approved speed test app. Governmental and other entities may submit speed tests using either an FCC-approved speed test app or, alternatively, with the use of their own hardware and software so long as the data contain the same metrics that are collected by approved speed test apps and the entity submits a complete description of the methodologies that were used to collect the data.

All speed tests must be taken outdoors and must specify whether they were taken in a stationary or in-vehicle testing environment.[68] Test submissions will be aggregated to determine whether a cognizable challenge has been established.[69] A valid speed test will contain three performance metrics: download speed, upload speed, and latency. The download and upload speed components are independently considered in classifying the component as either "positive" or "negative" based on whether they are, respectively, above or below the FCC-required speeds for each technology.[70]

To group speed tests geographically, the FCC will use the H3 standardized, open-source geospatial indexing system developed by Uber Technologies, Inc (Brodsky, 2018). This system overlays the Earth with hexagonal cells of different sizes ranging from resolution 15 (approximately 0.9 square meters) to resolution 0 (approximately 4.25 million square kilometers). The mobile challenge process (MCP) will rely on resolutions 9 through 6. We refer to a hexagon with resolution *n* as "hex-*n*."

The smallest cognizable challenge is at the hex-8 level.[71] To establish a challenge at a hex-8 level, challengers must meet three thresholds: (1) a geographic threshold; (2) a temporal threshold; and (3) a testing threshold (FCC, 2022n, ¶ 32). These thresholds are intended to mitigate the risk of a biased sample of speed tests and to ensure statistical confidence in the aggregate speed test results.

5.3.1.1 Geographic Threshold The geographic threshold ensures that challengers demonstrate that a lack of coverage exists over a sufficiently large area and is not concentrated in one small area. Therefore, speed tests generally must be conducted in multiple hex-9 s ("point hexes") within the hex-8 that the challenger seeks to challenge. The system will count the number of point hexes that satisfy two conditions: (1) at least two of the same test components (either download or upload); and (2) at

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[68] A test that is taken in a vehicle is considered "outdoors" and mobile and will be considered against the in-vehicle map.

[69] The FCC assumes that stationary coverage is generally superior to in-vehicle coverage and expects performance to be better for stationary tests than in-vehicle tests (all else equal). Therefore, a stationary coverage challenge will also create an in-vehicle coverage challenge if the provider reports both sets of coverage data for a particular hex.

[70] For example, a 4G LTE speed test that reports 4 Mbps download and 2 Mbps upload would be considered as having a negative download component and positive upload component based on the 4G LTE 5/1 Mbps thresholds.

[71] The H3 nesting structure means that each "parent" hex cell has 7 "child" hex cells. Hex-9 s have an average area of 0.105 square kilometers; hex-8s have an average area of 0.737 square kilometers; and hex-6 s have an average area of 36.129 square kilometers.

least one component is negative. To satisfy the geographic threshold, a hex-8 cell must generally meet both criteria for at least four point hexes.[72] The goal of the geographic threshold is to ensure that the inadequate coverage is not a single geographic point but instead is somewhat geographically dispersed while also reducing the burden when the area is more difficult to conduct speed tests.

5.3.1.2 Temporal Threshold The temporal threshold ensures that challengers demonstrate that the lack of coverage is persistent rather than a temporary aberration in network performance. To satisfy this requirement, a hex-8 cell would need to include two negative components of the same type (download or upload) with a time-of-day difference of at least four hours with another set of two other negative components.[73]

5.3.1.3 Testing Threshold Given the variable nature of wireless signal propagation and network load, occasional negative tests are possible within areas that have adequate coverage. The testing threshold requires that challengers demonstrate statistically significant evidence that coverage is inadequate based on a one-sided confidence interval where the null hypothesis is that the probability of adequate coverage is at least 90% (FCC, 2022n, ¶ 55).[74]

5.3.1.4 Creating a Cognizable Challenge At the end of each month, any hex-8 with speed tests will be evaluated. Hex-8s in which the result exceeds the thresholds for either download components, upload components, or both, are considered challenged.

5.3.1.5 Challenges to Larger Hexagons If multiple hex-8s within the same parent hex-7 meet the three thresholds, it may point to a more systemic lack of coverage across a larger area. Rather than requiring that challengers meet these thresholds

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[72] If a hex-8 only partially intersects the provider's coverage map or if there are few roads within the hex-8, the geographic threshold may be reduced. If fewer than four point hexes are "accessible" – e.g., at least 50% of the point hex overlaps with the provider's coverage map and a road intersects the point hex – the geographic threshold reduces based on the number of accessible point hexes. The speed tests included in the challenge must be located within the provider's coverage map, but the challenger does not necessarily need to conduct the speed tests in the accessible point hex(es).

[73] In other words, if all the test components in the hex-8 were ordered by time-of-day (regardless of date), the second earliest and second latest tests would need to have a difference of at least 4 hours. For example, if the second earliest test on one day is at 9:00am and the second latest test on the following day is at 9:30am, the threshold would not be met because there is only a 30-min time-of-day difference.

[74] Staff used the Clopper-Pearson method for calculating an exact binomial confidence interval. For any set of measurements that meet the geographic and temporal thresholds, challengers must show that the upper bound of the confidence interval is less than 90% with 95% confidence. The 10% or greater negative rate corresponds loosely with the cell edge probability of 90% with 50% cell loading. In practice, many speed tests will be taken within the cell – not at the cell edge – where the expected probability of meeting the speed thresholds is higher than 90%, so that the 10% negative rate threshold is a simplification to avoid adjustments based on cell site distance.

in every hex-8 cell near a cluster of challenged hex-8 cells, staff will use the nested structure of H3 to establish challenges across larger geographic areas (FCC, 2022n, ¶ 49).[75]

5.3.1.6 Challenges Across Technologies Challenges may be submitted for multiple technologies (3G, 4G LTE, 5G-NR) as follows (FCC, 2022n, ¶ 27): First, a "no connection" test component will count as a negative – 0 Mbps – test component for all technologies where the provider claims coverage at the test location.[76] Second, lower-generation-technology speed tests may be used to challenge higher-generation-technology coverage. For example, suppose that a provider claimed it provided 4G LTE and 5G-NR coverage in the same area; but whereas the 4G LTE coverage was adequate, the 5G-NR was poor. Thus, a challenger who wants to challenge the poor 5G-NR service at that location would likely be put on the 4G LTE network by default.

To resolve this issue, the FCC allows tests on lower-reported technologies to count potentially towards higher technology coverage map challenges.[77] In the example, the challenger who wanted to show poor 5G-NR coverage would be able to submit the 4G LTE test as part of a 5G-NR coverage map challenge.[78]

5.3.1.7 Provider Notification and Response At the end of each calendar month, the FCC will notify mobile service providers of all hexagonal cells for which cognizable challenges were generated during that month.[79] Upon notification, challenged providers will have 60 days to respond to each challenge by either conceding or disputing a particular challenge; and, if they wish to dispute the challenge, they may submit either on-the-ground speed test data or, in certain circumstances, infrastructure data (FCC, 2022n, ¶¶ 60–85). If the provider chooses to submit on-the-ground speed test data, then – as with challenger data – the data are evaluated against geographic, temporal, and testing thresholds.

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[75] If four or more of the seven child hex-8 cells in a hex-7 cell are challenged, then the entire hex-7 will also be considered challenged. Similarly, if four or more of the seven child hex-7 cells in a hex-6 cell are challenged, the entire hex-6 cell will be considered challenged. Staff will not consider challenges to areas with resolution lower than hex-6 and will instead rely on the mobile verification process (MVP) to address cases where sufficient evidence suggests a more systemic issue with a provider's coverage data.

[76] Even if a device is unable to connect to a provider's network, an approved app will record a location, and the test will be saved on the device until it is reconnected to the Internet – at which point the test is uploaded to the server.

[77] If the FCC did not allow challenges across technologies, the challenger would receive adequate 4G LTE coverage that could count as a positive test for 4G LTE, but may be unable to challenge the provider's 5G-NR claim. Because many devices are not capable of using every network technology – particularly 5G-NR – the FCC allows a device's speed tests to count only towards technologies that the device is capable of using. This prevents a device that is capable of using only 4G LTE from challenging 5G-NR when the device is conducting tests in areas with claimed 5G-NR coverage.

[78] If that 4G LTE test component were below the 5G-NR speed threshold at the location, the test component would count as negative, whereas if the 4G LTE test component were equal or greater than the 5G-NR speed threshold at the location, it would count as positive. Conversely, higher technologies do not count for or against lower technology coverage maps: E.g., a 5G-NR speed test cannot demonstrate any information about whether there is adequate 3G or 4G LTE coverage.

[79] Speed tests will remain valid for the MCP for up to one year from the date that the test was taken (FCC, 2022n, ¶ 34).

The FCC determined that infrastructure information, on its own, would be of comparable value as on-the-ground speed test data in six scenarios. In these scenarios, a provider may rely solely on infrastructure data to rebut successfully specific challenger speed tests (FCC, 2022n, ¶¶ 75–80). Scenarios where infrastructure data may suffice to invalidate speed tests include, among others: extenuating circumstances (e.g., outage or maintenance); devices that are incapable of using or service plans that do not permit using the technologies that are being challenged; and uncommon special events (e.g., unusually high traffic at the time of the test).

If the FCC accepts the rebuttal evidence, the invalidated speed tests will be removed, and the BDC system will determine whether the challenge thresholds are still met (FCC, 2022n, ¶¶ 63, 81).[80] If the provider either concedes the challenge or fails to rebut the challenge successfully within the allowed time period, the provider will have 30 days to submit new maps that reflect that the challenger successfully demonstrated insufficient coverage in the hex (FCC, 2021i, ¶ 112).

5.3.2 Mobile Verification Process (MVP)

The FCC may request and collect verification data from providers on a case-by-case basis when staff have a credible basis for analyzing the provider's coverage data (FCC, 2022n, ¶ 86). In response to a verification inquiry, a provider must submit either on-the-ground test data or infrastructure information for the target area. The factors that staff will use to determine whether a credible basis exists include, but are not limited to: the geographic size of the area; an evaluation of crowdsourced data (including the number and reliability of tests); the number of tests that are taken; the reliability of the tests; the infrastructure data accuracy; and backhaul and cell loading factor requirements (FCC, 2022n, ¶ 88).

5.3.2.1 Provider Response via On-the-Ground Speed Test Data
If a provider chooses to respond to a verification inquiry via on-the-ground speed test data, the provider must follow a sampling methodology that has been established by the FCC. After establishing a target area for the verification inquiry, FCC staff will divide the area into individual hex-8 cells that together comprise a sampling frame.

5.3.2.2 Stratified Random Sampling and Sample Selection
Staff will divide the frame into non-overlapping/mutually exclusive groups, or strata, and randomly select hexes within each stratum and independently across strata. Staff will choose a set of variables that are correlated with broadband coverage – e.g., terrain variation, population, etc. – as stratification variables to divide further the drive-testable cells into

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[80] If the challenge thresholds are still met after removing invalidated speed tests, the provider has not successfully rebutted the challenge; if the challenge thresholds are no longer met to create a challenge, the challenged hex returns to an unchallenged status. Conversely, if the provider successfully rebuts a challenge with on-the-ground speed tests, the hex becomes immune from future challenges for a period of time.

strata.[81] To calculate an appropriate sample size, staff will choose a desired margin of error and assume that the cost of drive-testing is constant across drive-testable hexes in the target area.[82] Once the sample size is determined, staff will use Neyman allocation to apportion the sample of hex-8s across the various strata and randomly select the specific hex-8s in each stratum.[83] Within each selected hex-8, an accessible point hex will be randomly selected where the testing must occur.[84]

5.3.2.3 Valid On-the-Ground Test Measurements Because the MVP evaluates coverage throughout a larger target area, there is no testing threshold for sampled hexes: The sample size is based on the number of hex-8s where the provider must conduct speed tests. To ensure temporal variation, staff will generally require at least two tests within each sampled hex where the time-of-day difference is at least four hours (FCC, 2022n, Technical Appendix Sect. 4.5). Staff will use only the first two tests in each hex-8, based on the time and date, with at least a 4-h time-of-day difference when calculating the stratum level proportion.[85]

5.3.2.4 Adjudication of Outcome of Verification Inquiry Staff will calculate an overall estimate of broadband availability; and unlike in the MCP, speed tests in the MVP will be evaluated jointly based on the download and upload speeds against the technology-specific download and upload speed thresholds. For example, a 4G LTE speed test must have a download speed of at least 5 Mbps *and* an upload speed of at least 1 Mbps to be considered a positive test; otherwise, the test is classified as negative.[86] The overall proportion of positive tests is a weighted average of the stratum level proportions. Similar to the MCP, coverage is verified if there is 95% confidence that the probability of coverage is greater than or equal to 90% (FCC, 2022n, Technical Appendix Sect. 4.6).

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[81] Staff will identify hex cells in the frame that can be feasibly drive-tested and divide the frame into drive-testable and non-drive-testable hex cells and only sample from drive-testable hex cells.

[82] See FCC (2022n), Technical Appendix Sect. 4.4 for sample size formula.

[83] Neyman allocation is a special case of optimal allocation, which assigns sample units within each stratum in proportion to the product of the population stratum size and the within-stratum standard deviation (Mathew et al., 2013).

[84] A precise location, in terms of a single (hex-9) point hex, is intended to keep the provider from choosing the best coverage location within the hex-8. We note that even within a hex-8, coverage quality may vary.

[85] Generally using only two tests from each sampled hex-8 will ensure that the stratum level sample proportion is not distorted by many tests in a small number of the sampled hex-8s within the stratum and is designed to eliminate any incentive to take more tests in the sampled hex-8s with the best coverage within the stratum. While we could weight each sampled hex-8 proportion equally, we would be concerned that providers would still have the incentive to continue testing when the first test fails but stop testing if the first test passes, which would create a potential bias in the sample.

[86] In the MCP, challengers are not restricted to the hexes in which they run their speed tests, and thus the download and upload components may be reported in different hex-8s – especially in the case of a challenger in motion during the speed test. In the MVP, the provider is required to conduct speed tests in randomly selected point hexes, and thus the location of the download and upload component should be in the same point hex.

6 Conclusion

Over the past year, FCC economists have assisted in several proceedings to narrow the connectivity gap. These efforts extend beyond implementing programs such as the ECF and ACP, which are meant to tackle the connectivity gap head on, and include the FCC's auction and merger review work that is aimed at, among other things, improving the quality of broadband, and enhancing and preserving competition among broadband service providers.

Additionally, the improved broadband deployment data that the FCC will collect pursuant to its BDC – along with the data that result from the ECF and ACP – will be useful not only to policy makers who seek to reform and update Universal Service, but also to service providers, researchers and other stakeholders that recognize the importance of closing the connectivity gap.

Declarations

Competing interests The authors declare no competing interests.

Conflict of interests The authors declare no competing interests

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