Broadband Access: Assessing the Interplay Between Wireline, Fixed Wireless, and Mobile Networks in the U.S.

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ABSTRACT

Broadband connectivity underpins economic opportunity, education, and social inclusion. Given its importance, accurate assessment of broadband availability and quality is critical. In this study, we analyze terrestrial broadband availability across the United States using CostQuest's Broadband Serviceable Location Fabric and provider-reported data from the Federal Communications Commission's National Broadband Map. We then align millions of crowdsourced Ookla Speedtest measurements with the reported data to assess how patterns in the provider-reported data translate into real-world performance, with particular focus on fixed wireless networks. We observe that provider-reported data suggests near-universal coverage with about 50% of locations advertising gigabit speeds; however, real-world performance is often significantly lower. We find a positive correlation between advertised speed tiers and measured performance, yet this information, along with other reported metadata, cannot reliably predict actual performance. Fixed Wireless Access (FWA) covers 85% of locations, often co-located with wireline; the occurrences of FWA as the only connectivity option are primarily in rural regions. Finally, we observe that the presence of FWA and the availability of higher FWA-advertised speed tiers positively correlate with mobile broadband performance. These findings emphasize the importance of integrating independent measurement data with provider-reported information to better inform broadband policy decisions.

1 INTRODUCTION

Access to reliable, high-speed broadband is essential for full participation in economic, social, and civic life [8, 11, 34, 43]. Yet, millions of households in the United States (U.S) continue to lack high-quality broadband, particularly in rural areas and marginalized communities [10, 14, 23, 26]. To address these disparities and to ensure equitable broadband connectivity, the U.S. federal government has launched several large-scale initiatives, including the Connect America Fund, the Rural Digital Opportunity Fund, and the Broadband Equity, Access, and Deployment (BEAD) program [12], to support and/or incentivize providers to deploy broadband infrastructure in unserved and underserved areas.

Accurately targeting broadband investments requires detailed availability data. To improve the accuracy of broadband availability data, the Federal Communications Commission (FCC) now publishes the National Broadband Map (NBM) [20], developed under the requirements of the Broadband DATA Act [7]. The map is based on semiannual coverage submissions from internet service providers (ISPs), who are required to report the technologies they offer and the maximum advertised speeds at each location they serve, under the Broadband Data Collection program [28]. These locations are defined using the Broadband Serviceable Location Fabric (BSLF or Fabric), a standardized geospatial dataset that enumerates all structures in the U.S. where fixed broadband is or can be installed [18]. However, since this map relies on self-reported data from ISPs, it is prone to overstatements of coverage and performance, as confirmed by multiple empirical studies [36, 44, 47, 48, 52, 53]. While the FCC allows challenging ISP-reported availability [15, 40], the process is often time-consuming and resource-intensive [17, 21], and hence, researchers increasingly rely on independent measurement data from platforms like Ookla® Speedtest® [9] and Measurement Lab [19] to assess real-world performance.

The NBM reports availability for multiple types of broadband connectivity such as terrestrial fixed broadband, which includes fixed wireline and fixed wireless access (FWA) technologies, satellite broadband, and mobile broadband. Fixed wireline technologies, such as fiber, cable, and DSL, deliver internet through physical infrastructure and are typically associated with higher reliability and capacity. In contrast, FWA transmits broadband over radio links from nearby base stations, often using licensed 4G and 5G spectrum [22].

Since 2019, FWA availability has expanded rapidly [29, 30, 32, 33], coinciding with the nationwide rollout of 5G networks [3, 5, 6, 16]. However, since FWA delivers broadband over cellular infrastructure, its performance tends to be variable due to signal quality, congestion, and other environmental factors [24]. In one study [50], addresses covered by terrestrial FWA accounted for the majority of challenge claims submitted to the FCC. These trends raise key questions about how broadband technologies are distributed, and whether reported availability patterns in the NBM data align with real-world user experience.

Within this context, the objective of our work is to analyze provider-reported availability data and identify patterns such as technology overlap and speed tier distributions, and evaluate whether these patterns are reflected in real-world performance datasets. Given its unique usage niche and variable performance, we are particularly interested in the role of FWA and its interaction with other available broadband technologies. Specifically, we ask three core research questions:

(1) What do provider-reported coverage availability and advertised speed tiers reveal about the relationships between different terrestrial broadband technologies?
(2) What is the role of FWA in broadband connectivity?
(3) What is the relationship between FWA and mobile broadband performance in 2024?

To answer these questions, we begin by mapping the technological composition of provider-reported coverage at the level of individual Broadband Serviceable Locations (BSLs) obtained from the BSLF dataset. Because urban and rural areas often differ in infrastructure investment and population density [57], we analyze patterns in the datasets disaggregated by urban and rural classification. We then assess how advertised speed tiers are distributed across larger geographies, and how advertised availability relates to real-world measured speeds as reflected by publicly available Ookla crowdsourced data. By combining high-resolution location data and provider-reported coverage data with real-world measurement evidence, this study contributes an empirically grounded perspective on the current state of broadband connectivity in the U.S. Our key findings are the following:

- Provider-reported data indicates near-universal coverage, with about 99% of urban and 95% of rural BSLs covered by at least one broadband technology. However, only 73% of rural BSLs report access to more than one technology, as opposed to 97% urban BSLs, highlighting geographic disparities in reported multi-technology availability.
- Although many providers advertise gigabit or multi-gigabit speed tiers, measured speeds fall far below these thresholds. Average measured download speeds in census blocks with reported maximum speeds of >1 Gbps are ~300 Mbps and ~210 Mbps in urban and rural areas, respectively, indicating a widespread mismatch between advertised maximums and actual service.
- Advertised speed tiers show a positive linear relationship with measured performance; each higher tier corresponds to a measurable increase in actual speeds. However, predictive modeling using metadata from the NBM, such as speed tiers, number of technologies, providers, and area type, explains only a small fraction of measured performance variation, indicating that provider-reported data alone is insufficient for assessing broadband quality.
- FWA covers over 85% of BSLs in most U.S. states, and appears as the only reported technology in fewer than 5% of BSLs. While it plays an important role in extending coverage, particularly in rural regions, its observed performance varies widely by geography and deployment strategy.
- Mobile broadband performance is highly variable and shows a clear urban-rural divide, with the presence and higher speed tiers of FWA positively associated with higher mobile broadband speeds, suggesting alignment between FWA deployments and enhanced cellular infrastructure.

The remainder of this paper is organized as follows. In Section 2, we describe the datasets we utilize in this work, and in Sections 3 and 4, we characterize their basic properties. Section 5 presents our analyses and findings. We review related literature in Section 6. Finally, we conclude the paper in Section 7.

2 DATASETS

In this section, we describe each of the datasets we utilize in our study and our strategy for integration and analysis.

2.1 Ookla Public Data

Since January 2019, the Ookla Open Data Initiative has released an aggregated, quarterly dataset of its global, crowdsourced Speedtest measurements [2, 4]. Individual tests that include GPS-derived location information are aggregated into Web Mercator tiles at zoom level sixteen, which correspond to approximately 610.8 meters by 610.8 meters at the equator; each tile is identified by a unique quadkey. Underperforming servers are routinely removed from Ookla's network of tens of thousands of measurement endpoints to ensure data quality. For each tile and quarter, the public dataset provides separate averages for fixed and mobile broadband, reporting download speed, upload speed, round-trip latency, latency under load, the total number of measurements, and the number of distinct devices submitting tests.

For this study, we utilize both fixed and mobile Speedtest data across the four quarters of 2022 and 2024. When a user initiates a Speedtest via their web portal or mobile application, Ookla selects geographically proximate servers by lowest latency and employs multiple parallel TCP connections to fully saturate the link. While each individual measurement reflects the instantaneous performance at a particular location, device, and moment in time, aggregating millions of tests across diverse regions yields robust estimates of typical network behavior for both fixed and mobile services.

Limitations: Crowdsourced Speedtest measurements are inherently uncontrolled and may introduce biases related to test timing, user device capabilities, subscription plans, signal conditions, and local network congestion. Prior studies have documented that users often run tests when experiencing service issues or after equipment changes, and that higher-tier subscribers and tech-savvy individuals may be over-represented. Although these biases complicate characterizing every individual tile, our use of a two-year, aggregated dataset mitigates transient effects and captures a wide array of user scenarios, enabling meaningful analysis of spatial and temporal trends in broadband performance.

2.2 Broadband Serviceable Location Fabric

The Broadband Serviceable Location Fabric (BSLF, or Fabric) [18] is a comprehensive, twice-yearly geospatial dataset developed under the FCC's direction to meet the Broadband DATA Act's requirement for identifying all U.S. structures where fixed broadband is or could feasibly be deployed. Each potential serviceable location is represented as a single latitude/longitude point with a unique assigned location identifier linking it to a census block and corresponding H3[1] hexagon (resolution eight). The Fabric attaches critical attributes such as unit counts, land-use classifications, and an optional flag indicating eligibility for mass-market broadband installation, facilitating precise spatial alignment with FCC coverage and third-party performance datasets.

The Fabric integrates multiple authoritative data sources, including lidar-derived building footprints, parcel boundaries, USPS delivery addresses, and provider-reported service locations. Automated classification methods and human expert reviews are used to determine broadband serviceability, assign land-use categories, and validate geographic positions. Access to the Fabric is provided under a commercial license and subject to FCC data-use agreements.

Limitations. The Fabric's accuracy relies on the completeness and timeliness of input datasets. Lags in data updates, such as newly constructed buildings or recent infrastructure changes, can cause omissions or geolocation inaccuracies. Therefore, for critical planning or policy use, supplemental validation such as field surveys or crowdsourced performance data comparisons is recommended.

2.3 National Broadband Map Data

The FCC's National Broadband Map (NBM) presents provider reported information on fixed and mobile broadband service in the U.S [20]. It leverages the BSLF dataset to obtain the set of locations where broadband service could be or is deployed. The NBM dataset primarily uses broadband availability and speed data submitted by internet service providers to report where different network technologies are deployed. The dataset uses two formats: a list of individual service locations for fixed networks and a grid of hexagonal cells (resolution nine) for mobile networks.

Fixed Coverage. Fixed broadband availability is reported at the granularity of individual serviceable locations, each identified by a unique location identifier that corresponds directly to an entry in the BSLF dataset. Each of these identifiers is geocoded to a specific census block and to a H3 hexagon at resolution eight, enabling precise spatial alignment with other datasets. For each unique location, providers declare one or more terrestrial technology categories, such as copper DSL, cable modem, fiber-to-the-premises, or fixed wireless access (FWA). They also specify which of six standardized speed tiers is offered at that location: at least 0.2/0.2 (download/upload) Mbps, at least 10/1 Mbps, at least 25/3 Mbps, at least 100/20 Mbps, at least 250/25 Mbps, or at least 1000/100 Mbps.

Mobile Coverage. Mobile network availability is mapped using H3 hexagonal cells at resolution nine, with each cell covering approximately 0.1 square kilometers. For each hexagon, the NBM dataset provides geometry files in ESRI Shapefile or GeoPackage format along with attributes for each generation of service. Technology generations include 3G, 4G LTE, and two categories of 5G NR. Providers report minimum advertised download and upload speeds, respectively, for each generation, namely 0.2/0.05 Mbps (download/upload) for 3G, 5/1 Mbps for 4G LTE, 7/1 Mbps and 35/3 Mbps for 5G NR. An additional field indicates whether these speed values apply exclusively to outdoor stationary use or also to in-vehicle mobile scenarios. These mobile coverage cells are also available as aggregated to state, county, or congressional district levels for broader analyses.

Limitations. Although the NBM data is the FCC's official repository for fixed and mobile coverage, it is subject to well-documented accuracy challenges [13, 36, 44, 47, 52, 53]. Provider-submitted data tend to overstate coverage footprints and advertised speeds, particularly in rural and sparsely populated areas where network deployments may be limited. The Broadband DATA Act's challenge process [40–42] allows individuals and organizations to submit real-world speed tests to correct map errors, yet the procedural complexity and verification requirements have resulted in relatively few successful challenges [17, 21]. Independent audits and academic studies have repeatedly identified misclassified technologies, inflated speed tiers, and unreported gaps in both fixed and mobile datasets. Until more rigorous, measurement-based validation methods are routinely incorporated, the NBM should be viewed as a useful but imperfect indicator of actual broadband availability and performance.

2.4 Socioeconomic and Demographic Data

We utilize socioeconomic and demographic data sourced from the 2020 U.S. Census [25]. This dataset provides extensive U.S. data, including population density, household income, racial demographics, and broadband usage statistics. The Census Bureau also provides detailed classifications at the census block level, distinguishing between urban and rural areas, facilitating the examination and analysis of the spatial distribution of urban and rural areas across the country. By integrating this dataset with network performance metrics obtained from the NBM data and Ookla's public data, we study the effect of factors such as area type and population type on broadband availability and quality across different U.S. geographic regions, including census blocks, divisions, counties and states.

2.5 Dataset Integration and Challenges

Combining fixed-coverage records, crowdsourced performance metrics, and mobile-availability maps delivers a comprehensive view of broadband connectivity that each dataset alone cannot provide. Fixed-network entries from the NBM dataset and the BSLF dataset use unique location identifiers linked to census blocks, H3 resolution-eight hexagons, and exact latitude–longitude coordinates. Ookla's public Speedtest data are aggregated into Web Mercator tiles identified by quadkeys, with separate summaries for fixed and mobile tests each quarter. Mobile coverage is published in H3 resolution-nine cells annotated by technology generation and speed thresholds. By mapping each location identifier in the NBM to its corresponding quadkey and hexagon, we can directly compare provider-reported coverage, actual throughput observations, and demographic and socioeconomic characteristics. This integrated approach reveals how wireline, FWA, and mobile networks coexist or substitute for each other in different communities, identifies performance shortfalls in underserved areas, and guides precisely targeted infrastructure investments and policy interventions.

Merging these sources requires careful alignment across differing spatial schemes and resolutions. Aggregating serviceable locations into quadkeys or hexagons can blur fine-scale variations when multiple points fall within a single tile or straddle cell boundaries. Crowdsourced Speedtest results may reflect participation biases: active users or particular regions can be overrepresented, skewing performance estimates. Demographic and socioeconomic information is often available only at larger geographic units, such as census block groups, tracts or counties, which can obscure local disparities when merged with finer-resolution coverage data. Furthermore, each dataset carries its own reporting inaccuracies and uncertainties: providers may overstate coverage in the NBM, the BSLF dataset may omit newly constructed or accessory structures, and these datasets may report incorrectly mapped locations to census block geographies or misclassified technologies and/or speed tiers, as we briefly describe in Section 3. Recognizing these challenges is essential when interpreting our analysis and deriving conclusions for policy and planning.

3 OOKLA DATASET CHARACTERIZATION

We begin by quantifying the scale and geographic scope of Ookla Speedtest measurements for both fixed and mobile networks for

Table 1: Top and bottom five states by number of Speedtest tiles.

Type	State	Tile Count	% of National Total
Fixed	Texas	268,579	7.88%
	California	163,641	4.80%
	North Carolina	157,146	4.61%
	Hawaii	7,335	0.22%
	Rhode Island	7,334	0.22%
	District of Columbia	792	0.02%
Mobile	Texas	151,175	4.44%
	California	118,157	3.47%
	Florida	95,608	2.81%
	Vermont	4,184	0.12%
	Rhode Island	3,828	0.11%
	District of Columbia	768	0.02%

2022 and 2024. During this period, there were approximately 4.5 million mobile Speedtest measurements spanning 1.76 million unique Web Mercator quadkey tiles, and about 12.8 million fixed network measurements across 3.4 million quadkey tiles. Each quarter, between 470k and 640k tiles recorded at least one mobile Speedtest, while between 1.5 and 1.6 million tiles recorded at least one fixed connectivity Speedtest. To illustrate the geographic distribution of Speedtest activity, Table 1 presents the three states with the highest and lowest numbers of unique quadkey tiles in the fixed and mobile datasets, along with their respective shares of total national tiles. In both cases, the large-population states of Texas and California dominate, while smaller states and territories like Rhode Island and the District of Columbia have the smallest number of quadkey tiles.

To evaluate the geographic extent of the Speedtest dataset, we join the centroids of each Ookla quadkey tile to the full set of U.S. census blocks (totaling approximately 8.18 million blocks). While this method introduces minor spatial approximations, it provides a consistent and tractable approach for mapping Speedtest activity to the smallest available geographic unit used in broadband reporting and policy. Using this linkage, we find that fixed Speedtests were recorded in 1.84 million census blocks, covering 22.6% of all blocks nationally, while mobile Speedtests appeared in 1.23 million blocks, representing 15.2% coverage. Disaggregating by area type, we observe that 27.5% of rural blocks and 17.5% of urban blocks had at least one fixed Speedtest recorded. For mobile tests, 14.8% of rural and 15.3% of urban census blocks were covered. Finally, to establish a national performance baseline, we summarize download speeds, upload speeds, and latency across all fixed and mobile Speedtest measurements from 2022 and 2024. Table 2 presents the 25th percentile, median, and 75th percentile values for each of these metrics. In both mobile and fixed networks, we observe clear performance improvements between 2022 and 2024. Notably, mobile broadband exhibits a stronger relative gain, with median download speeds increasing from 63 Mbps to 130 Mbps (a 106% increase), while fixed networks show a median download speed increase from 163 Mbps to 243 Mbps (a 48% increase). Upload speed and latency metrics show similar trends, but with fixed networks improving more sharply than mobile counterparts. We observe that mobile performance is more variable than fixed: while the median mobile download speed in 2024 is nearly 47% lower than its fixed counterpart (130 Mbps vs. 243 Mbps), the 75th percentile values are much closer: 331 Mbps for mobile compared to 362 Mbps for fixed,

Table 2: Summary of national performance metrics for mobile and fixed Speedtests in 2022 and 2024.

Type	Metric	Year	25th	Median	75th
Fixed	Download (Mbps)	2022	56.09	163.87	267.41
		2024	100.12	242.80	362.17
	Upload (Mbps)	2022	10.02	19.02	55.25
		2024	15.18	34.51	141.74
	Latency (ms)	2022	12.0	16.0	26.0
		2024	10.0	15.0	23.0
Mobile	Download (Mbps)	2022	22.26	62.90	151.40
		2024	38.32	129.66	330.83
	Upload (Mbps)	2022	2.74	8.71	20.67
		2024	3.26	10.52	25.90
	Latency (ms)	2022	25.0	33.0	48.0
		2024	21.0	29.0	41.0

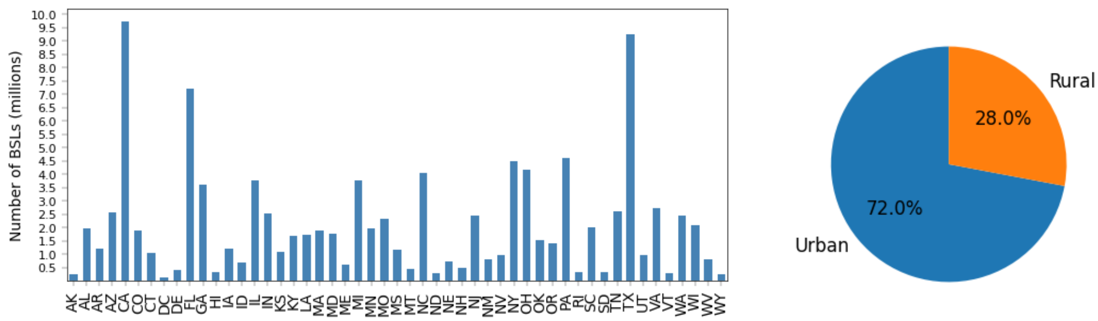
indicating that top-end mobile performance can rival fixed service in some areas, even as typical outcomes remain lower.

4 FABRIC DATASET CHARACTERIZATION

In this section, we characterize the BSLF dataset to provide foundational context for subsequent analyses of broadband coverage and infrastructure deployment. The objective of this section is to understand the nationwide distribution of Broadband Serviceable Locations (BSLs), which informs both geographic variability in broadband availability and potential policy implications for addressing disparities in connectivity.

We begin our analysis by aligning provider-reported coverage from the NBM dataset with the BSLF dataset, which we treat as the ground truth for all BSLs in the U.S. The most recent BSLF dataset consists of approximately 115.8 million BSLs across all U.S. states and territories. For our analysis, we focus only on residential and mixed-use (residential and business use) locations in the 50 U.S. states and the District of Columbia, leaving us with 106.7 million BSLs. Interestingly, applying the same filter to the NBM data leaves us with 111.8 million unique served BSLs, roughly 6 million more than the BSLF dataset. Further analysis showed that these 6 million BSLs were termed "business only" in the BSLF dataset, while the NBM data terms them as "residential" or "mixed-use" locations. For consistency, in this study, we restrict our analysis to the 106.7 million BSLs in the BSLF dataset and report coverage statistics based solely on this data. This ensures that our baseline reflects a consistent, independently verified set of physical locations and business types, rather than relying on provider-submitted identifiers.

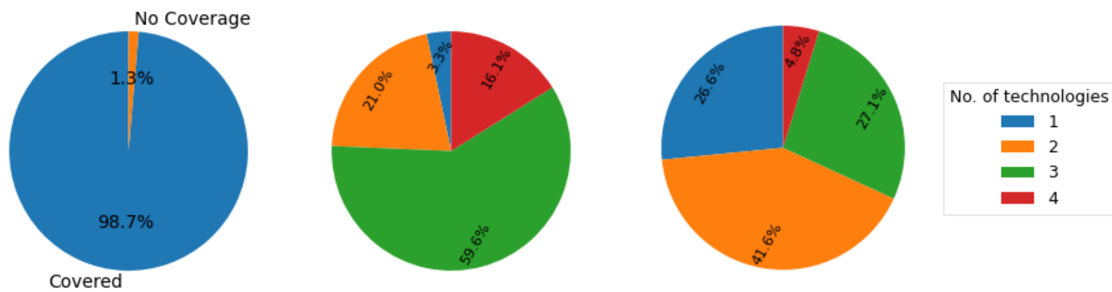
Figure 1a shows the total number of BSLs by state. States vary widely: the District of Columbia has the fewest locations (under 100 k); West Virginia, Wyoming, South Dakota, North Dakota, Vermont and Alaska each have less than 0.5 million. California has the greatest number at nearly 10 million while Texas exceeds 9 million. Most states fall in the 1–4 million range, yielding an average of roughly 2 million serviceable locations per state. Disaggregating by region type reveals that 72% of all BSLs lie in urban areas, with the remaining 28% in rural areas, as shown in Figure 1b. We begin our analysis with the full Fabric data, encompassing roughly 106 million BSLs across about 5.8 million census blocks.



(a) Number of Broadband Serviceable Locations

(b) Area Type Composition

Figure 1: Number and composition of Broadband Serviceable Locations from the Fabric data.



(a) Total

(b) Urban

(c) Rural

Figure 2: Composition of provider-reported coverage by area type and technology

Understanding the baseline distribution of BSLs across states and between rural and urban geographies is critical for interpreting broadband coverage patterns, evaluating infrastructure investments, and designing targeted policy interventions. These foundational patterns help contextualize subsequent analyses on coverage gaps, technology deployment, and performance disparities.

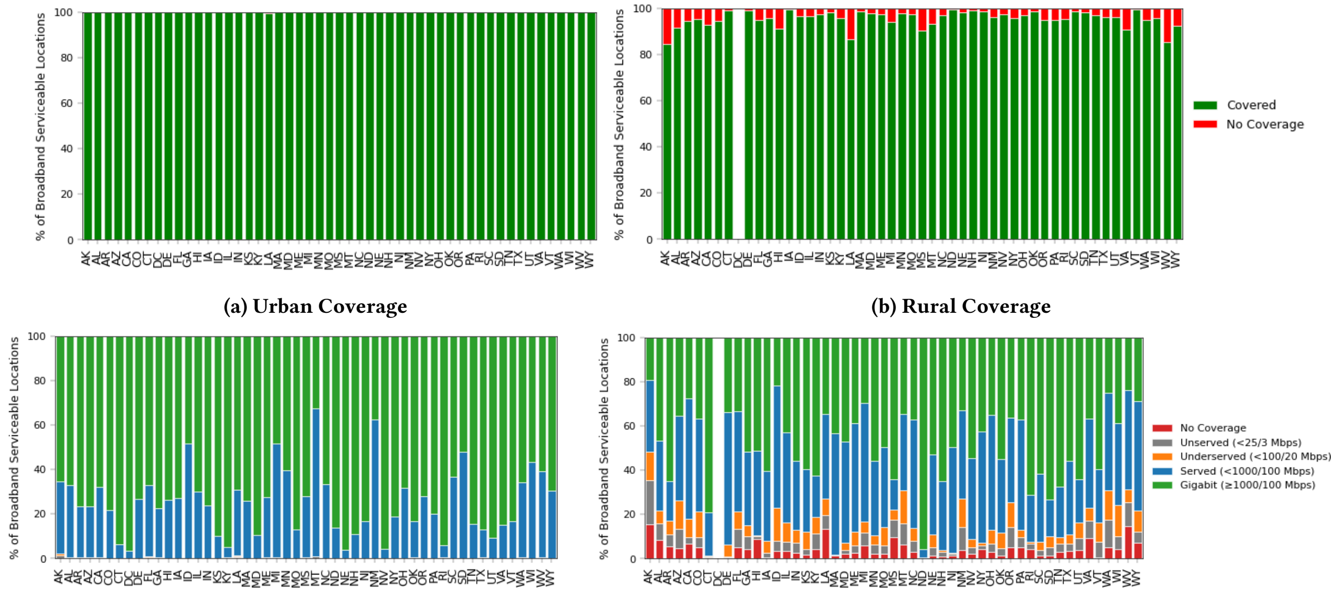
5 INTERACTIONS BETWEEN TYPES OF U.S. BROADBAND AVAILABILITY

Our analysis is guided by three core research questions: (1) What do provider-reported coverage availability and advertised speed tiers reveal about the relationships between different terrestrial broadband technologies? (2) What is the role of FWA in broadband connectivity? and (3) What is the relationship between FWA and mobile broadband performance in 2024? To answer these questions, we use serviceable location information from the BSLF dataset, reported coverage from the NBM dataset and performance from crowdsourced Ookla Speedtest datasets. We first characterize the reported availability of different terrestrial broadband access technologies and their stated maximum available speeds. Then, we examine the coverage footprint of FWA across the country. Finally, we assess whether the presence of FWA is associated with better mobile performance, exploring whether its expansion contributes to higher speeds in the areas it serves.

Question 1: What do provider-reported coverage availability and advertised speed tiers reveal about the relationship between different terrestrial broadband technologies?

In this section, we examine how provider-reported availability and advertised speed tiers reflect the state of terrestrial broadband access across different geographies. Prior work [57] has examined the availability and evolution of cellular network performance in the U.S. For this question, we focus on terrestrial fixed broadband access technologies (fixed wireline and fixed wireless access (FWA)). We begin by contrasting the coverage footprints of each technology in urban and rural settings. We then examine how these patterns relate to the distribution of advertised speed tiers as well as measured performance, shedding light on how providers balance performance and reach through the use of multiple access technologies.

Terrestial broadband availability. Using the set of residential and mixed-use locations in the BSLF dataset as ground truth for broadband serviceable locations and the NBM dataset for coverage information, we analyze coverage percentages overall, and for different broadband access technologies. We observe that provider-reported coverage varies markedly between urban and rural contexts, and that no single access technology has 100% reach. Figure 2a shows that out of all BSLs, 98.7% are reported to be covered by at least



(a) Urban Coverage

(b) Rural Coverage

(c) Urban Coverage by Speed Tiers

(d) Rural Coverage by Speed Tiers

Figure 3: Statewise provider-reported coverage by area type and technology.

Table 3: Categorization of broadband service tiers by advertised speed ranges.

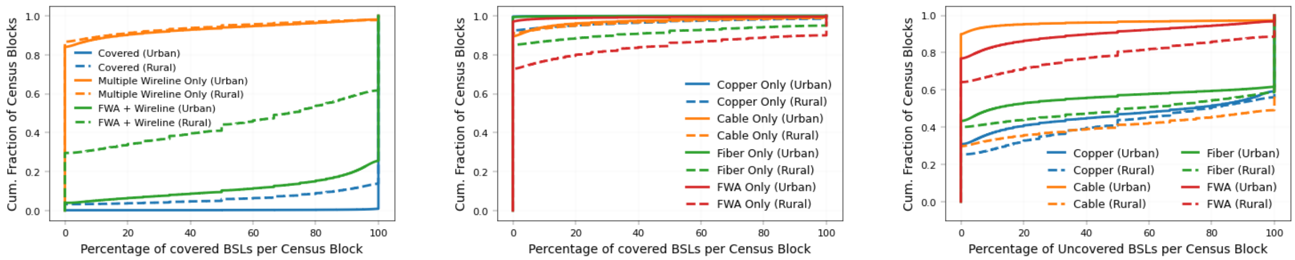
Speed Tier	Download Range (Mbps)	Upload Range (Mbps)
Unserved	< 25	< 3
Underserved	25–100	3–20
Served	100–1000	20–100
Gigabit	≥ 1000	≥ 100

one terrestrial broadband technology with download and upload speeds each at least 0.2 Mbps. More specifically, ~85% of BSLs are reported to have cable coverage, ~42% for copper, ~55% for fiber, and ~86% for FWA coverage.

To better understand the range of broadband access options available at each BSL, we examine the number of distinct access technologies reported as available per BSL, as shown in Figures 2b and 2c. The presence of multiple access technologies varies significantly between urban and rural contexts. 96.7% of urban BSLs are reported to be covered by at least two access technologies, with 16.1% covered by all four technologies (copper, cable, fiber and FWA). This reflects strong multi-technology availability in urban BSLs. However, the share of rural BSLs with two or more technologies drops to 73.5%, and only 4.8% of rural BSLs report coverage by all four technologies. Additionally, 26.5% of rural BSLs are limited to just a single access technology, as opposed to only 3.3% in urban BSLs. Next, we analyze state-level variations in broadband coverage, disaggregated by area type and advertised speed tiers, and present those results in Figure 3.[1] We begin with state-wise coverage, disaggregated by area type, in Figures 3a and 3b. Across urban BSLs, reported coverage exceeds 99% for each state. In contrast, rural areas show slightly lower coverage with an average of ~90% across states.

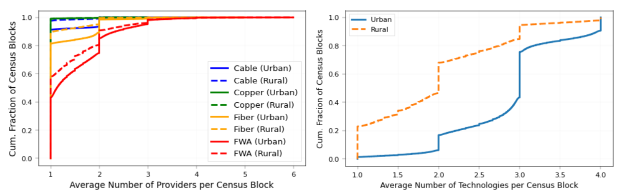
We examine service level classifications [35] based on the maximum advertised speeds, as described in Table 3, and present the state-level findings in Figures 3c and 3d. Results from this analysis mimic the spatial and technological divides between urban and rural BSLs. In almost 90% of the states, at least 60% urban BSLs report gigabit speed availability, with the "served" tier constituting the remaining 40%. Less than 1% of urban BSLs are reported to be "Underserved" and "Unserved". Rural gigabit availability, in contrast, ranges from as low as 20% in Alaska to a high of 98% in North Dakota. The share of underserved and unserved rural BSLs reaches at least 20% in 27% of the states. Together, these state-wise profiles highlight where multi-technology strategies offering higher speeds are most needed to elevate performance outside dense urban corridors. Next, we examine coverage at the census-block level, disaggregated by urban and rural area types and also by the reported broadband access technologies, in Figure 4. While earlier state-level comparisons highlighted broad regional trends, such aggregations can mask important local variations. Conversely, individual serviceable locations offer granular detail but lack the regional context needed to identify deployment patterns and policy-relevant clusters. Census blocks offer a balanced view: they are the smallest geographic unit for which comprehensive coverage and population data are available [27], and they also serve as the unit for federal funding decisions such as in the Connect America Fund (CAF) program [31]. Analyzing coverage at the block level allows us to detect localized infrastructure gaps while preserving enough aggregation to assess systemic trends across area types and technologies.

[1] We note that the District of Columbia (DC) is entirely urban and hence does not show any rural coverage.



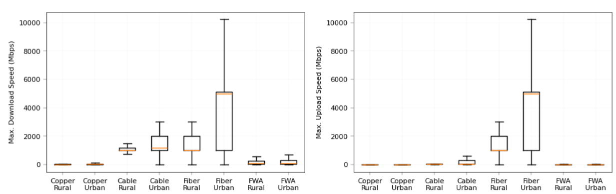
(a) Overall Coverage **(b) Single Technology Coverage** **(c) Non-Coverage**

Figure 4: Distribution of covered and uncovered BSLs by technology at the census block level.



(a) Number of Providers **(b) Number of Technologies**

Figure 5: Average number of providers and the available access technologies at a census block level.



(a) Download Speed **(b) Upload Speed**

Figure 6: Distribution of the advertised maximum speeds by available access technology.

We find that urban blocks report near-universal coverage; over 99% of urban census blocks report at least 95% of all their BSLs to be covered by at least one fixed broadband technology, whereas in rural blocks, about 90% of blocks reach that same threshold; this is shown in Figure 4a. Interestingly, the percentage of census blocks that report coverage by both one or more fixed wireline technologies and FWA is significantly higher than blocks that report coverage only by multiple wireline technologies. For instance, 80% and 40% of urban and rural blocks, respectively, report all BSLs to be covered by at least one wireline technology and FWA, as opposed to less than 5% of urban and rural blocks that report coverage by more than one wireline technology only. To isolate reliance on a single access technology, we compute the percentage of BSLs reported to be covered by exactly one access technology for each census block, as shown in Figure 4b. Urban blocks rarely have BSLs that report coverage by a single technology. Cable shows the highest single-coverage percentage: 3% of census blocks have 20% of BSLs as Cable-Only. In contrast, rural blocks report a higher percentage of BSLs with only one access technology: in about 15% and 8% of rural census blocks, all its constituent BSLs are reported to be covered only by FWA, and only by fiber, respectively.

We next examine the distribution of coverage gaps (percentage of BSLs that are reported to not be covered) for each access technology at the census block level, in Figure 4c. Cable networks in urban blocks have exceptionally low coverage gaps, with over 80% of blocks reporting less than 5% of BSLs to not have cable Internet service. On the other hand, rural cable has much larger coverage gaps: in 50% of census blocks, every BSL is reported to not have cable broadband access. FWA reports low coverage gaps, with only 5% urban and 18% rural blocks reporting complete lack of FWA availability. Surprisingly, coverage gaps for copper and fiber are comparable across both rural and urban blocks, with about 60-65% of rural and urban blocks lacking reported coverage in half of BSLs.

Provider and technology competition. We now examine the competitive landscape and technology mix per census block in urban versus rural blocks and present the findings in Figure 5. We first study the number of providers that report fixed broadband service at the census block level, sub-divided by technology, and present the results in Figure 5a. Cable and copper networks exhibit minimal variation across geographies: nearly all blocks report service by just one provider, regardless of area type. Fiber shows a modest gap: 20% of urban blocks report two providers, while rural blocks more often have only one. FWA displays the most pronounced rural–urban divide: 40% of urban blocks have only one FWA provider, as opposed to 60% for rural blocks. Across all technologies, the number of competing providers is consistently higher in urban blocks, and this disparity is most prominent for FWA. Next, we examine how many

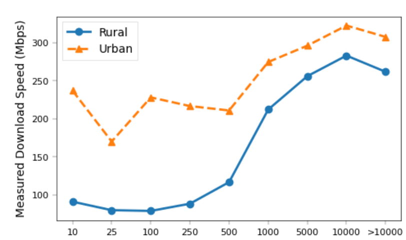
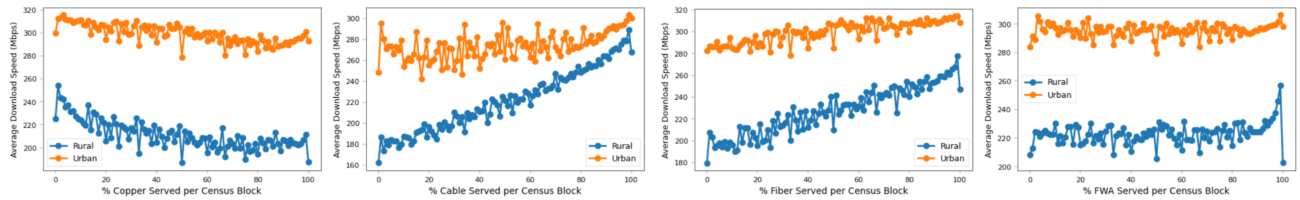
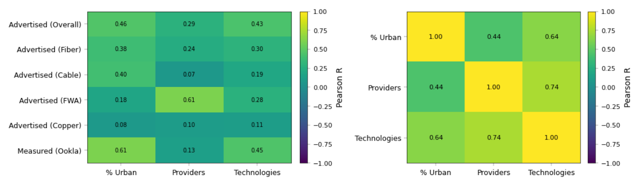


Figure 7: Relationship between reported advertised peak speeds on measured download speeds.



(a) Copper (b) Cable (c) Fiber (d) FWA

Figure 8: Relationship between reported coverage and observed download speeds, by technology.



(a) Download Speed **(b) Broadband Metadata**

Figure 9: Relationship between advertised speeds, measured speeds and broadband availability metadata.

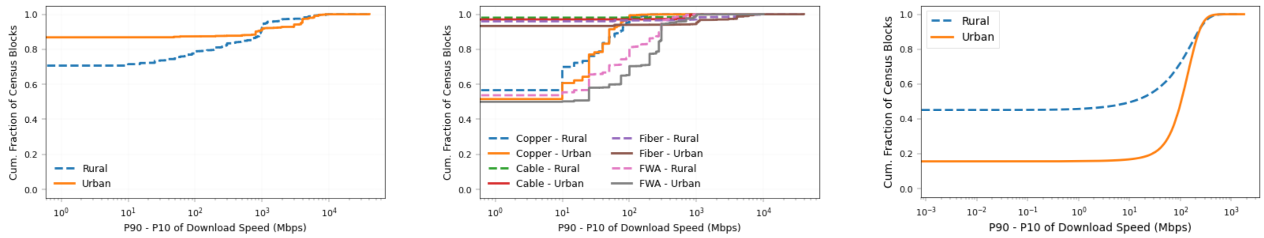
broadband technologies reach each block, as reported by providers, in Figure 5b. Urban blocks see greater technology diversity, with a median of three technologies (e.g. cable, fiber, FWA) compared to a median of two in rural blocks. About 75% of urban blocks support three or more technologies, while fewer than 20% of rural blocks do. Approximately 15% of urban blocks have all four technologies available, but less than 5% of rural blocks report availability of all four technologies.

Advertised speed tiers: We examine the distribution of maximum download and upload speeds providers advertise at each BSL, disaggregated by access technology and area type, and present the results as boxplots in Figure 6. The line in the boxes represents the median, the box shows the interquartile range (IQR), and the whiskers represent 1.5 times the IQR. Fiber networks dominate the upper tail for download speeds, as shown in Figure 6a: urban fiber network medians are near 5 Gbps with interquartile ranges spanning roughly 1–10 Gbps; rural fiber networks advertise a median of about 1 Gbps. This is followed by cable networks, with urban and rural medians ~1 Gbps; urban networks show a wider range of advertised values. FWA follows, with advertised medians clustering below 200 Mbps in both urban and rural blocks. Copper offers the slowest speeds, with urban medians about 30 Mbps and rural medians under 15 Mbps. Similar trends are observed for upload speeds, as shown in Figure 6b. Across both download and upload speed metrics, there is, unsurprisingly, a clear technological hierarchy (fiber > cable > FWA > copper) and a consistent urban–rural split in the maximum advertised values, highlighting where infrastructure upgrades would most effectively raise baseline performance.

Reported speed and measured speed. In this section, we explore the relationship between maximum speeds advertised by providers and the real-world speeds as measured by Ookla Speedtest. For this analysis, we only utilize the BSLs that lie within the quadkey tiles reported in the Ookla Public dataset, resulting in approximately 5 million BSLs spanning 1.6 million unique census blocks. We begin by plotting the advertised maximum download speeds against average measured Ookla download speeds for urban and rural BSLs in Figure 7. We see a two-phase pattern: for reported tiers up to 500 Mbps, measured speeds increase at a slower rate, but after that, the increase is rapid. We note that these trends are consistent for upload speeds (not shown) as well. This results show that advertised maximums substantially exceed typical performance, but that measured performance has a positive relationship with advertised speeds. This could be due in part to the availability of different subscription tier options; advertised speeds are the *maximum* speeds providers report, and users may elect to subscribe to lower speed tiers for financial or other reasons.

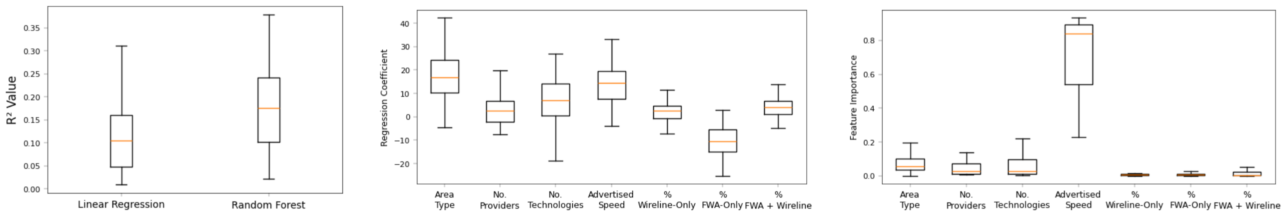
Next, we examine how measured Ookla download speeds vary with the percentage of BSLs reported to be covered in each census block. We observe that measured speeds have a moderate positive linear relationship with coverage percentage (Pearson correlation coefficient of 0.39) We observe similar trends with upload speeds (not shown) as well. Interesting patterns appear when we disaggregate performance by technology-based coverage, as shown in Figure 8. We find a strong positive correlation for fiber and cable: urban fiber speeds climb from 280 Mbps in minimally covered blocks to 320 Mbps with full fiber penetration (rural: 180 to 260 Mbps), and urban cable from 180 Mbps to 300 Mbps (rural: 160 to 280 Mbps). In contrast, copper speeds actually decline as copper share grows (urban: 310 to 280 Mbps; rural: 255 to 195 Mbps), and FWA speeds remain flat ~290 Mbps in urban and ~225 Mbps in rural blocks. These patterns highlight that deeper penetration of high-capacity networks translates into real performance gains, whereas legacy copper footprints offer limited uplift as coverage increases.

Influences on advertised and measured speeds. In the following subsection, we seek to understand the impact of factors, such as level of urbanization and metadata reported in the NBM about broadband availability, on download speeds, both advertised maximums and measured values from Ookla Speedtest. To do so, we compute the percentage of urban (and rural) census blocks at the county-level. We then aggregate block level data about broadband availability and Ookla Speedtest measurements into county-level averages. We compute the Pearson correlation coefficients (Pearson R) between these factors and download speeds (advertised and measured), and present the findings in Figure 9. We observe that the advertised maximum download speeds show moderate positive correlation with urbanization (Pearson R = 0.46) and number of



(a) Advertised speed **(b) Advertised speed by technology** **(c) Measured speed**

Figure 10: Variability in advertised and measured download speeds at the census block level.



(a) R^2 Value **(b) Linear Regression** **(c) Random Forest**

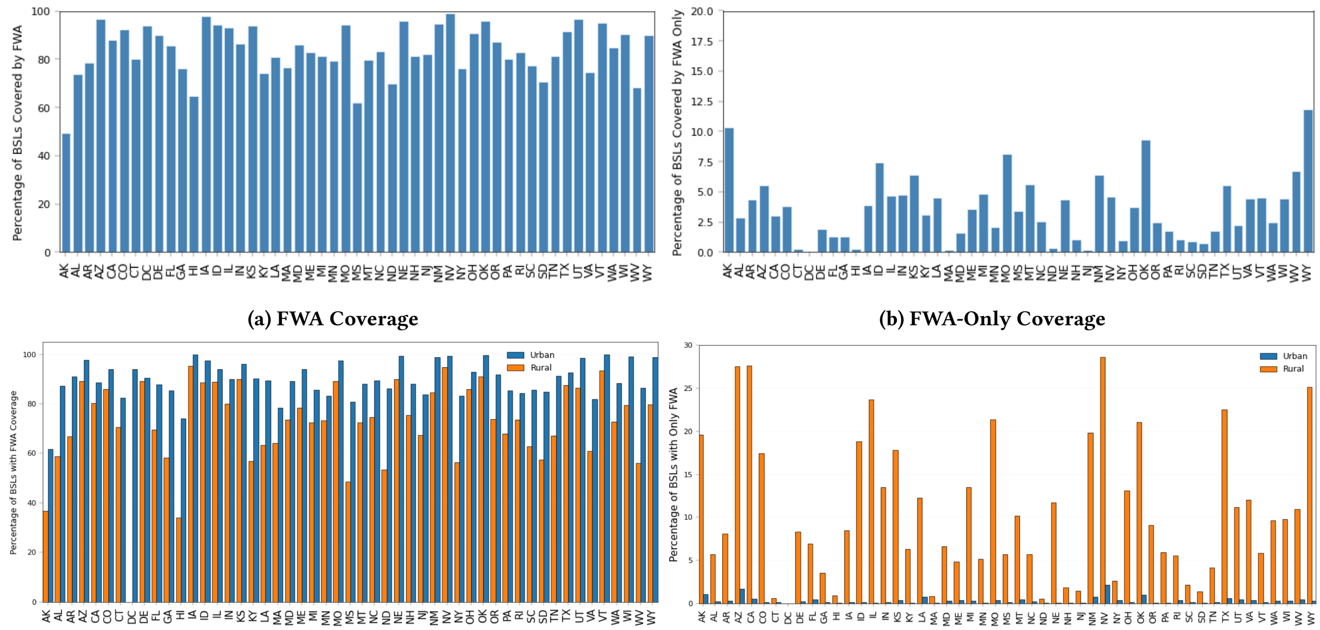
Figure 11: Relationship between advertised features and measured Ookla Speedtest download speeds.

technologies (Pearson R = 0.43), and a weak positive correlation with provider count (Pearson R = 0.29). Across technologies, fiber and cable exhibit the highest correlations with urbanization and number of technologies, while FWA and copper remain largely uncorrelated, as we show in Figure 9a. In contrast, FWA exhibits a strong positive correlation (Pearson R = 0.61) with number of FWA providers, highlighting the impact of competition. Measured download speeds show strong positive correlations with urbanization (Pearson R = 0.61) and number of technologies (Pearson R = 0.45), but only a weak relationship with provider count (Pearson R = 0.13). In Figure 9b, we show that at the county level, the percentage of urban population is positively correlated with both the average number of providers (Pearson R = 0.44) and the number of technologies reported to be available (Pearson R = 0.64). Additionally, the number of providers and the number of technologies are strongly correlated (Pearson R = 0.74), as one would expect. These results confirm that predominantly urban areas not only command higher speeds, particularly via fiber and cable, but also benefit from richer provider competition and multi-technology deployments. We note that the trends are similar for upload speeds as well.

How much do advertised and measured speeds vary? Here, we analyze how peak advertised and measured download speeds vary within a census block, to understand whether speed advertisements are consistent on small geographic scales. In Figure 10a and 10c, we present the difference between the 90^{th} and 10^{th} percentile values of the advertised maximum and measured average download speeds at the census block level, respectively. For advertised speeds, about 90% of urban blocks report an intra-block variation less than 10 Mbps, as opposed to about 77% in rural blocks, as shown in Figure 10a. When disaggregated by access technology, however, as shown in Figure 10b, we observe that urban blocks show slightly more variability than rural blocks. Cable networks, across rural and urban settings, show the smallest intra-block variation, with over 99% of blocks reporting less than 10 Mbps spread. Copper reports moderate variability at the lower tail, with about 40% of blocks reporting over 10 Mbps and 99% of blocks reporting under 100 Mbps variability. For fiber networks, about 95% of blocks report variability under 10 Mbps, but the remaining 5% of blocks report variability of 1000 Mbps or more. FWA shows the highest variability in the lower tail, with 38% of urban and 25% of rural blocks reporting a spread of at least 100 Mbps, suggesting more inconsistency in advertised speeds. Overall intra-block variation is higher in rural blocks, but when disaggregated by access technology, urban blocks tend to report more variability. This may be because rural blocks have a greater mix of technologies with higher variability, such as FWA and copper, whereas urban deployments of the same technology likely advertise multiple speed tiers.

In contrast to overall advertised speeds, Figure 10c reveals significantly higher variability in measured performance for urban blocks, with nearly half exhibiting intra-block variation of over 100 Mbps. This indicates that real-world experiences often diverge substantially from advertised rates, potentially because of higher congestion in urban settings, the possibility of the coexistence of disparate access technologies, and the existence of multiple subscription tier options.

Can availability and speed tiers predict measured performance? Finally, we assess how well provider-reported indicators explain real-world performance. To do so, we train simple linear regression and random forest models on the 2024 Speedtest data to predict quadkey-level download speeds, disaggregated statewise, using features such as advertised speed, number of providers, percentage of different fixed broadband access categories at the



(a) FWA Coverage

(b) FWA-Only Coverage

(c) FWA Coverage

(d) FWA-Only Coverage

Figure 12: Percentage of BSLs covered by FWA, and covered exclusively by FWA, disaggregated state-wise.

BSL-level (as described in Table 4) and area type. As shown in Figure 11a, random forests consistently outperform linear models across states, though overall R^2 values remain low, indicating that much of the variation in measured speeds is not captured by provider-reported data alone. We also observe that the proportion of variation explained by the models vary state by state.

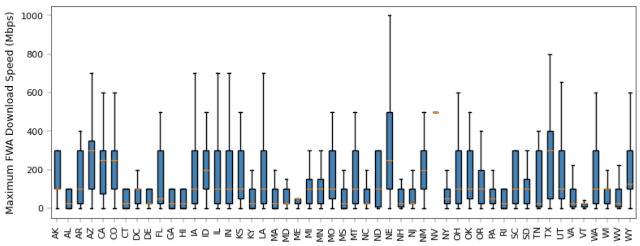
Figure 11b shows normalized linear regression coefficients. The area type has the highest positive relationship with measured performance, followed by advertised speed and number of access technologies. The percentage of FWA-Only BSLs has a negative relationship with measured performance, while percentages of FWA+Wireline and Wireline-Only BSLs have a positive relationship. In contrast, Figure 11c shows that advertised speed is the single most important feature in the random forest model, suggesting it provides useful non-linear signals even if its linear effect is not the strongest. These results highlight the limited explanatory power of provider-reported data, especially in isolation. While some features carry predictive value, actual performance remains only partially explained, reinforcing the need for direct measurement data to assess and infer broadband quality.

Key takeaways. Provider-reported data states that over 98% of urban BSLs and 95% of rural BSLs are covered by one or more terrestrial broadband access technologies. Rural BSLs are most limited in access options, where about 27% of BSLs are covered by only one access technology. Urban BSLs also report significantly higher maximum speeds compared to rural BSLs, in part due to multi-technology deployments, especially fiber and cable, and greater competition between providers. The distribution of advertised maximum speeds follows a clear hierarchy: fiber > cable > FWA > copper, and measured speed rises between 50 and 100 Mbps with each higher advertised speed tier. Both advertised and measured speeds increase with increasing urban population and increasing access technology diversity. Predictive modeling shows that provider-reported coverage metrics and region type data together explain only a minimal share of actual measured performance variance: random forests outperform linear regression across every state but still show R^2 values that rarely exceed 0.3, indicating that much of the variation in real-world performance is driven by factors not captured in the provider-reported National Broadband Map data. Together these findings highlight persistent urban–rural performance gaps, the need for finer-grained data beyond advertised tiers, and the limited utility of provider reports for forecasting actual broadband quality.

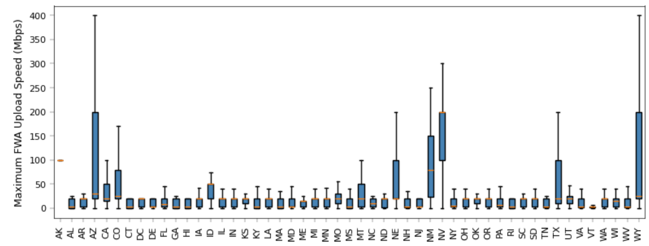
Question 2: What is the role of FWA in broadband connectivity?

Building on our finding that rural areas often rely on single-technology footprints and exhibit notable coverage and speed shortfalls, we now focus on FWA to understand how it helps bridge gaps in broadband connectivity, particularly where wireline infrastructure remains limited.

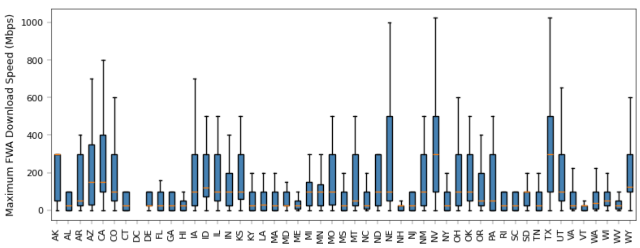
We begin with state-level percentages of BSLs covered by FWA, as shown in Figure 12a. FWA reaches the vast majority of BSLs in every state, with coverage exceeding 80% in nearly 70% of the states. The share of BSLs covered exclusively by FWA is shown in Figure 12b. Pure FWA-only deployments are minimal, under 5% of BSLs in 80% of the states only have FWA as an Internet access option. This suggests that FWA typically augments, rather than substitutes for, terrestrial broadband. We disaggregate the statewise FWA and FWA-Only shares by region type in Figures 12c



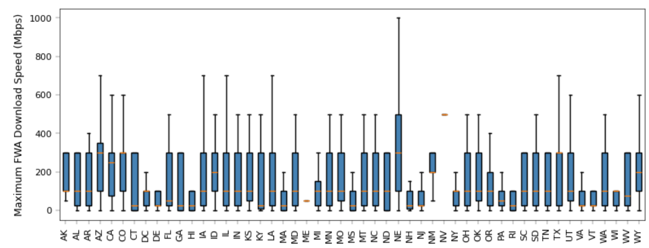
(a) Download Speed



(b) Upload Speed



(c) Download Speed - Rural



(d) Download Speed - Urban

Figure 13: Distribution of maximum advertised FWA speeds.

and 12d, respectively, to assess how the presence of FWA varies with urbanization. We observe that FWA availability varies widely across states and region types: in rural areas it ranges from 33% in Hawaii to 95% in Iowa, and in urban areas from 61% in Alaska to 99.8% in Vermont, as shown in Figure 12c. In 85% of the states, at least 90% of the urban BSLs are reported to be covered by FWA, while 62% of states have less than 80% FWA coverage in rural BSLs. Interestingly, we observe that FWA-Only coverage is primarily a rural phenomenon: in 90% of states, less than 1% urban BSLs are reported to have only FWA as the sole means of connectivity, while 43% of states have over 10% of rural BSLs reported to only have FWA-based Internet access. 15% of states report at least 20% of BSLs with FWA-Only coverage, as shown in Figure 12d.

Based on these results, we complete the analysis for Question 2 by exploring the role of FWA across multiple dimensions, such as advertised maximum speeds, measured average speeds, and interaction with wireline technologies.

FWA advertised speeds. We examine the state-level maximum advertised FWA download and upload speeds, shown as boxplots in Figures 13a and 13b. The distribution of the advertised maximum FWA download speeds vary considerably between states; Nevada reports the highest median speeds at 500 Mbps[2], followed by Arizona and Texas at 300 Mbps, while 40% of the states have a median 50 Mbps or less. On the other hand, the distribution of maximum advertised FWA upload speeds is relatively consistent, with the median value of 92% states about 20 Mbps. Similar to download speeds, Nevada shows the highest median upload speeds, at 200 Mbps. States such as Arizona, and Wyoming have median values ~20 Mbps, but their 75^{th} percentile values reach 200 Mbps, showing variability in speed values in the upper tail.

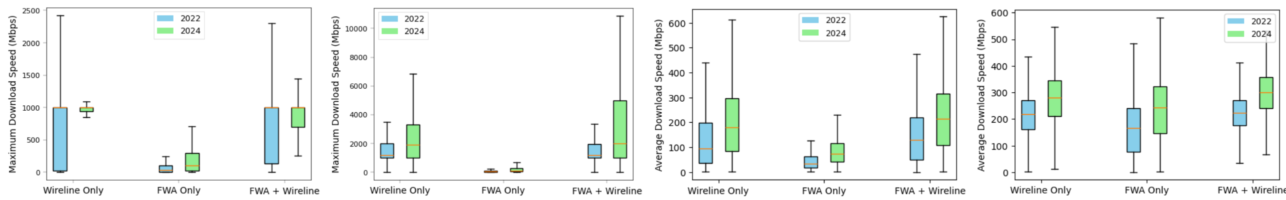
[2]We note that the median for Nevada reflects a single advertised FWA download speed. As a result, the box appears compressed. Other advertised speeds exist for Nevada, but appear only as isolated outliers.

Table 4: Census block proportion by fixed-broadband categories.

Category	Total Distribution	Urban	Rural
FWA + Wireline	93.54%	74.89%	25.11%
Wireline-Only	3.93%	54.57%	45.43%
FWA-Only	2.53%	11.41%	88.59%

Next, we contrast state-level advertised maximum FWA download speeds disaggregated by rural and urban regions in Figures 13c and 13d, respectively. We observe that the distribution of advertised download speeds is heavily right-tailed. In rural areas, the median download speed is below 150 Mbps for 92% of the states; however, the whiskers extend to over 400 Mbps in 33% of the states, with Nevada and Texas reaching 1 Gbps. Urban advertised download speed distributions follow a similar pattern with heavy right tails and higher median speeds. Nevada is again an exception, with a median of 500 Mbps and little to no variability. Between rural and urban regions, the median of advertised download speeds is identical for 50% of the states. For 20% of states, urban regions show a relative difference in median speeds of at least 100% when compared with rural regions. This demonstrates the high variability of provider-reported FWA peak downloads speeds, as well as the presence of a rural-urban gap. Although 85% of BSLs are reported to have FWA coverage, about 50% of urban BSLs and 60% of rural BSLs are nevertheless reported to be "Underserved" (advertised peak download speeds less than 100 Mbps).

Census block disaggregation. To better understand the role of FWA in relation to wireline infrastructure, we conduct a block-level classification based on the technology mix observed across all BSLs within each census block. Specifically, we assign each block to one of three mutually exclusive categories, as shown in Table 4:



(a) Advertised - Rural **(b) Advertised - Urban** **(c) Measured - Rural** **(d) Measured - Urban**

Figure 14: Advertised vs. measured download speeds in different types of census blocks.

- FWA + Wireline blocks, where every BSL within the block is covered by both a wireline technology (e.g., cable, fiber, copper) and fixed wireless access
- Wireline-Only blocks, where all BSLs are covered exclusively by one or more wireline technologies and have no FWA coverage
- FWA-Only blocks, where all BSLs lack wireline availability and are covered solely by FWA

This approach allows us to isolate blocks where deployment strategies are consistent across all locations, reducing ambiguity caused by mixed footprints. It also enables robust comparisons of coverage patterns, performance distributions, and urban-rural variation across distinct infrastructure types. By evaluating these categories separately, we can assess whether FWA acts more as a supplement to wireline service or as a primary mode of access, particularly in areas where wireline buildout is limited or absent. We note that Wireline + FWA blocks account for about 95% of the census blocks utilized for this analysis.

Relative changes in advertised and measured speeds. Using the above census block designations, we compare the distributions of maximum advertised FWA download speeds and the distributions of the measured average download speeds from Ookla Speedtest, from 2022 to 2024, for each block type, as shown in Figure 14. For statistical significance, we filter out census blocks that report fewer than five total measurements, leaving 2 million measurements with 1.2 million unique census blocks. Figures 14a and 14b present maximum advertised download speeds in Wireline-Only, FWA-Only, and FWA+Wireline blocks for rural and urban areas, respectively. In both settings, FWA-Only blocks consistently report the lowest advertised speeds, with medians less than 200 Mbps. However, they also show the highest relative improvement in median speeds, about 200% in rural areas and 100% in urban areas, from 2022 to 2024. On the other hand, the absolute speeds in Wireline-Only blocks and FWA + Wireline blocks are significantly higher, over 1 Gbps. These blocks show little to no change in median advertised speeds in rural areas, but substantial increases in urban areas: 66% in Wireline-Only blocks and 57% in FWA + Wireline blocks. Measured download speeds, shown in Figures 14c and 14d for rural and urban areas, respectively, show a similar but more balanced trend. All three block types experienced performance gains between 2022 and 2024, but the improvement was highest in FWA-Only blocks: rural blocks measure a relative percentage increase in median measured speeds of 118% and urban blocks measure a 47% increase.

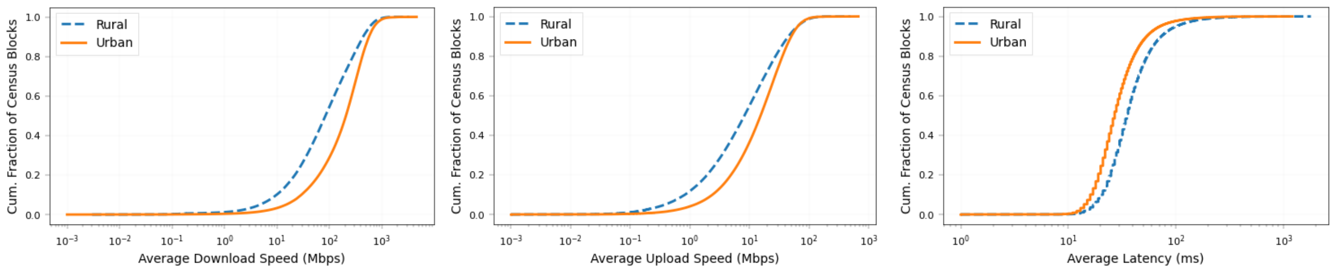
Additionally, we note that measured speeds in rural FWA-Only blocks are the lowest. However, in urban areas, FWA-Only blocks offer speeds that are comparable to those of Wireline-Only and FWA + Wireline blocks. This suggests that FWA can serve as a robust standalone option in urban areas. Further, while absolute speeds in rural FWA-Only areas remain lower, they show the highest relative improvement, indicating that performance is trending upward.

Key takeaways. According to provider-reported data, FWA now covers more than 80% of serviceable locations in roughly 75% of U.S. states. Census blocks covered only by FWA are uncommon, representing less than 5% of BSLs nationwide; this indicates that FWA is typically added alongside wireline rather than replacing it. Most FWA covered locations are urban; however, more than 90% of FWA-Only sites are rural, showing its role where wired infrastructure is limited. In urban blocks, FWA-Only blocks deliver measured download speeds that are comparable to those in Wireline-Only and FWA + Wireline blocks, indicating FWA's viability as a standalone access option in dense settings. Although rural FWA-Only blocks continue to exhibit lower absolute speeds, they show the highest relative gains between 2022 and 2024, over 100% increase in both advertised and measured speeds, suggesting meaningful performance improvements in areas with wireline gaps.

Question 3: What is the relationship between FWA and mobile broadband performance in 2024?

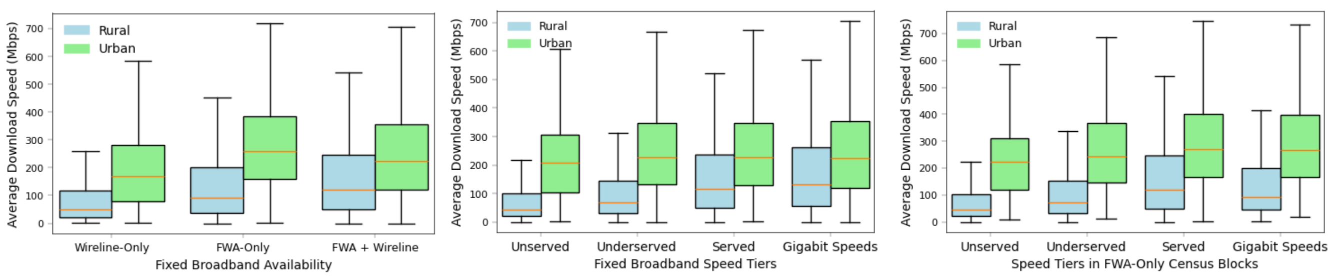
FWA and mobile broadband both deliver connectivity over cellular spectrum and infrastructure, often using the same base stations and radio access technologies. In this question, we analyze the relationship between mobile broadband performance and the availability and performance of FWA using the 2024 NBM data and Ookla Speedtest performance data.

Distribution of mobile broadband performance. We begin by analyzing 2024 cellular Ookla Speedtest data that spatially intersect with the NBM data. For statistical significance, we filter out census blocks that report fewer than five total measurements, leaving 975k measurements in 570k unique quadkey tiles and 493k unique census blocks. For each tile, we then evaluate average download speed, upload speed, and latency to characterize its mobile broadband performance. In Figure 15, we present the cumulative distributions of these metrics across rural and urban census blocks. Urban blocks show higher performance across all three metrics. In Figure 15a, 60% of rural blocks record average download speeds below 100 Mbps, compared to only 30% of urban blocks. Urban areas also see 30% of blocks with download speeds exceeding 500 Mbps. In Figure 15b,



(a) Download Speed **(b) Upload Speed** **(c) Latency**

Figure 15: Distribution of mobile broadband performance in 2024, disaggregated by geography type.



(a) Fixed broadband availability **(b) Fixed broadband speed tiers** **(c) Speed tiers in FWA-Only blocks**

Figure 16: Distribution of mobile broadband performance across census blocks, disaggregated by fixed broadband availability and speed tier categories.

60% of rural blocks have average upload speeds under 10 Mbps, as opposed to only 35% of urban blocks. Latency distributions in Figure 15c show that 75% of urban blocks maintain average latencies below 50 ms, compared to 60% of rural blocks.

Relationship between FWA and mobile broadband performance. To understand the relationship between FWA and mobile broadband performance, we examine how the availability of fixed broadband technologies influences measured mobile broadband performance. For this analysis, we use census block categorization based on their fixed broadband footprints, as detailed in Table 4. Figure 16a shows the distribution of average mobile download speeds in 2024, grouped by fixed broadband availability type across rural and urban census blocks. We observe that FWA + Wireline blocks report the highest median mobile speeds in rural settings, while in urban settings, FWA-Only blocks report the highest median speeds, at ~300 Mbps. Wireline-Only blocks show the lowest median mobile speeds, particularly in rural blocks, where the median is ~150 Mbps. Overall, urban blocks consistently outperform rural ones across all categories. We previously found that fixed broadband performance in FWA-Only blocks was lower than in Wireline-Only and FWA + Wireline blocks. However, for mobile broadband, the trend reverses. Mobile performance is higher in FWA-Only blocks than in Wireline-Only and FWA + Wireline blocks.

In Figure 16b, we present the relationship between mobile broadband performance and fixed broadband speed tiers. Mobile performance improves steadily, though minimally, with higher fixed broadband speeds. Blocks classified as "Unserved" or "Underserved" show the lowest median mobile download speeds, while those that report over 100 Mbps download speeds exhibit higher performance. This trend holds across both rural and urban areas, although the difference is more noticeable in rural areas. We observe identical trends in FWA-Only census blocks, as shown in Figure 16c, where we analyze mobile broadband download speed distributions across FWA-Only census blocks disaggregated by reported fixed broadband speed tiers. In the absence of wireline service, mobile broadband performance improves with higher advertised FWA speed tiers. In rural areas, median mobile speeds increase from about 30 Mbps in unserved blocks to nearly 120 Mbps in served and gigabit-tier blocks. Urban areas show a similar trend, with medians increasing from 200 Mbps to 250 Mbps. This suggests that higher-tier FWA deployments are often co-located with more advanced cellular infrastructure, which in turn yields better mobile broadband performance. We confirm that the findings are similar for upload speeds and latency.

Key Takeaways. Mobile broadband performance in 2024 shows a clear rural–urban divide, with urban areas exhibiting significantly higher download and upload speeds and lower latency. Blocks with FWA, especially FWA-Only, report higher mobile performance than Wireline-Only blocks, suggesting co-location of advanced cellular infrastructure in areas with FWA deployments. Mobile performance improves with higher fixed broadband speed tiers, even in FWA-Only areas, indicating that stronger FWA deployments are associated with better mobile infrastructure.

6 RELATED WORK

Prior work has utilized crowdsourced speed test data to assess broadband performance and identify digital inequities. Platforms such as Ookla and NDT7 (M-Lab) have enabled researchers to benchmark regional performance [37, 49, 54], compare cellular and WiFi networks [56], and explore sampling biases across demographic groups [45]. These efforts highlight the value of independently observed measurements in supplementing provider-reported data, while also emphasizing the need for contextualization and richer metadata [38, 39, 46, 55]. In [57], the authors analyzed the evolution of cellular networks in the U.S., and looked at the relationship between cellular network infrastructure and performance.

From a policy perspective, a growing body of empirical work has documented persistent discrepancies between reported availability and real-world performance. Studies analyzing Form 477 submissions, FCC field measurements, and independent audits have identified recurring issues of overstated coverage and speed, particularly in rural and tribal areas [13, 36, 44, 47, 52]. [53] demonstrated how provider-reported availability, quality and pricing overstate true measured performance, and in [48], the authors examined the efficacy of the federal broadband subsidy Connect America Fund program.

Recent work has explored the integration of data from the FCC's broadband collection program and challenge process[50, 51], along with crowdsourced performance data, in order to provide a comprehensive view of provider-reported availability and performance claims. These studies underscore the importance of validating availability maps against independently observed performance, particularly as newer technologies like FWA and 5G reshape the broadband access landscape.

Our work builds on these efforts by examining how provider-reported coverage and speed tiers in the NBM data reflect the relationships between wireline, FWA, and mobile broadband technologies, and by evaluating how well reported speeds align with real-world performance outcomes.

7 CONCLUSION

This study examines the structure of broadband access in the United States by analyzing the relationships between wireline, FWA, and mobile technologies as reported in the National Broadband Map. Our goal is to understand how different technologies co-exist, overlap, or substitute for one another, and how this reported availability translates into real-world performance. We find that FWA increasingly fills wireline coverage gaps in rural areas, often acting as the sole form of connectivity. In contrast, FWA tends to complement wireline in urban areas, where multiple technologies co-exist. However, the lack of provider and technology metadata in performance datasets limits our ability to fully validate these patterns. Additionally, our attempt to predict measured Ookla Speedtest performance measurements using features extracted from the NBM data, such as number of access technologies available, maximum advertised speed tiers, number of providers and area type (urban or rural), yielded very low R^2 values. This suggests that advertised availability and its associated metadata alone are not sufficient predictors of real-world performance, and that deeper insights are needed to bridge the gap between reported coverage and user experience. With access to crowdsourced broadband performance datasets that include provider and technology metadata, as well as more detailed and publicly available cellular infrastructure datasets, this gap could be bridged, enabling accurate validation of coverage and performance trends across the different broadband access technologies. We note that recently developed tools that automate the extraction of plan and pricing information from ISP websites [47, 53, 55] offer promising avenues for analyzing availability and affordability. Integrating such tools with coverage and performance data could further enhance broadband policy evaluation, as well as investment and funding decisions.

8 ACKNOWLEDGMENTS

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