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|---|---|
| Docket: | I.11-15-007 |
| Exhibit Number: | ORA- |
| Commissioner: | Commissioner Peterman |
| Admin. Law Judge: | K. Bemesderfer |
| ORA Project Mgr.: | Ana Maria Johnson |
| ORA Expert Witness: | Adam Clark |

ORA
OFFICE OF RATEPAYER ADVOCATES

**Office of Ratepayer Advocates**

**California Public Utilities Commission**

# Office of Ratepayer Advocates Testimony Regarding the Substitutability of Mobile and Wireline Broadband Services

San Francisco, California
June 1, 2016

# MEMORANDUM

This report was prepared by Adam Clark of the Communications & Water Policy Branch of the Office of Ratepayer Advocated (ORA) under the general supervision of Program & Project Supervisor, Ana Maria Johnson. A statement of qualifications from Adam Clark is presented in Attachment A to this testimony. ORA is represented in this proceeding by legal counsel, Travis Foss.

This supplemental testimony is comprised of the following chapters:

| Chapter | Description |
|---|---|
| **I** | **Introduction**: A brief introduction to the issues at hand, including the assessment of competition in the telecommunications marketplace and the importance of separately evaluating broadband services with advanced communications capabilities. This chapter also presents the questions that this testimony seeks to address, including the substitutability of mobile data service and wireline broadband services. |
| **II** | **Discussion**: Presents the Federal Communications Commission's declaration that mobile data services and wireline broadband services are commentary services, not substitutes. This chapter also analyzes the capabilities of mobile data services as compared to wireline broadband services, the manner in which providers sell the services, the manner in which users utilize the services, the cost of service, and the purchasing habits of consumers. |
| **III** | **Conclusion**: A brief conclusion recapping main points and concluding that mobile data service is not a substitute for wireline broadband service. |

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# EXECUTIVE SUMMARY

The November 12, 2015 *Order Instituting Investigation into the State of Competition Among Telecommunications Providers in California, and to Consider and Resolve Questions Raised in the Limited Rehearing of Decision 08-09-042* ("Competition OII") explains the California Public Utilities Commission's ("CPUC" or "Commission") intent to gather information about the state of competition in the telecommunications marketplace in California and assess whether competition exists and if it has produced just and reasonable prices.[1]

In the *Competition OII*, the Commission asks if wireless and wireline services are substitutes in the data markets, and – if so – to what extent?[2] The Commission also asks, "…whether there are barriers to such substitution, and what the limits of such substitution might be."[3] This testimony evaluates wireless mobile data services[4] as compared to wireline broadband services. I discuss reports and data from the FCC and CPUC, data submitted by service providers in response to the CPUC's Information Requests,[5] and other relevant data from publicly available sources. This testimony compares service availability, speeds, functional capabilities, prices and consumer choices. As demonstrated below, these service elements make mobile data service a complement to, rather than a substitute for, wireline broadband service.

**Key Findings**

- In September 2015, the CPUC submitted comments to the Federal Communications Commission (FCC) that include detailed, technical data indicating that mobile data services are not a sufficient substitute to wireline broadband services.
- The FCC recently declared that mobile data services and wireline broadband services are complementary services, and not functional

[1] *Order Instituting Investigation into the State of Competition Among Telecommunications Providers in California, and to Consider and Resolve Questions Raised in the Limited Rehearing of Decision 08-09-042*, I.11-15-007 (Issued November 12, 2016) at 13 (hereinafter, "Competition OII").

[2] *Id.* at 13.

[3] *Id.* at 13. *See* Footnote 42.

[4] The phrase "mobile data services" refers to broadband services that connect an end user to the Internet or other IP applications through a mobile network, irrespective of data transfer speeds.

[5] Competition OII at Appendix B.

substitutes. The FCC also declared advanced telecommunications capability should be deemed deployed only in areas where consumers have access to both services.

- Wireline broadband far outperforms mobile data services in terms of maximum, minimum and average data transfer speeds. Wireline broadband services frequently exceed speeds of 25 Mbps download and 3 Mbps upload.

- Mobile data service with speeds of at least 25 Mbps download and 3 Mbps upload is available in only 2% to 4% of the service areas of the four main providers.

- Mobile data services do not match the quality of wireline broadband services according to various technical measures, including: latency, packet loss rates, consistency, and TCP failure rates.

- Providers of mobile broadband services frequently impose "data caps" that limit the amount of data end-users consume each month; wireline broadband service providers usually do not impose such restrictions, or – if they do – the limits are far more lenient.

- Consumers use mobile data services and wireline broadband services for different purposes, suggesting the services are complementary.

- After accounting for differences in data allowances or download speeds, mobile data services are significantly more expensive than wireline broadband services.

- Consumers frequently purchase *both* mobile data service and wireline broadband service.

- Considering mobile data service a substitute for wireline broadband service will disproportionately harm low-income and disadvantaged communities.

**Organization of Report**

Chapter I of this report contains a brief introduction to the issues at hand, including the assessment of competition in the telecommunications marketplace and the importance of separately evaluating data services with advanced communications capabilities. This chapter also

presents the questions that this testimony seeks to address, including the substitutability of mobile data service and wireline broadband services.

Chapter II presents the FCC's declaration that mobile data services are commentary, and not substitutes to, wireline broadband services. This chapter also analyzes the capabilities of mobile data services as compared to wireline broadband services, the manner in which providers sell the services, the manner in which users utilize the services, the cost of service, and the purchasing habits of consumers.

Chapter III recaps the main points presented throughout this report, and concludes that mobile data service is not a substitute for wireline broadband service.

# I. INTRODUCTION

In order for the Commission to assess the state of competition in the telecommunications marketplace in California, it must first carefully identify the relevant services as well as the needs and preferences of consumers. As an initial step, the Commission explicitly notes the evolution of the public switched telephone network into a multi-service platform capable of providing a variety of voice, video and data services to consumers.[6] The Commission also recognizes the recent regulatory changes at the federal level, including the reclassification of broadband as a telecommunications service by the FCC.[7] As a result, the CPUC intends to evaluate the role of broadband in the telecommunications marketplace in California.[8]

Broadband services providing advanced telecommunications capabilities are the cornerstone of the telecommunications industry. These services provide a wide array of functions essential to everyday life, including applications related to emergency services, healthcare, commerce, education, and employment. Today, service providers provision broadband services to consumers through a variety of platforms, including: digital subscriber lines (DSL), cable modems, satellite, fiber and wireless technologies.[9] These various platforms provide different levels of functionality, as is discussed below. To best serve the public interest, the CPUC should assess competition in the telecommunications marketplace with regard to reliable, high quality data services that provide advanced telecommunications capabilities.

Section 706 of the 1996 Federal Telecommunications Act defines the term advanced telecommunications capability as, "high-speed, switched, broadband telecommunications capability that enables users to originate and receive high-quality voice, data, graphics, and video telecommunications using any technology."[10] The FCC set the current speed benchmark for

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[6] Competition OII at 8.

[7] *Id.* at 8.

[8] *Id.* at Appendix B.

[9] FCC *Consumer Guide: Getting Broadband*, Consumer and Governmental Affairs Bureau (November 4, 2015) at 1. Available at http://transition.fcc.gov/cgb/consumerfacts/highspeedinternet.pdf.

[10] *See* 47 U.S.C. § 1302(d)(1).

wireline (fixed) broadband services with advanced telecommunications capabilities at 25 Mbps download and 3 Mbps upload (25/3 Mbps).[11]

In the *Competition OII*, the Commission asks "[h]ow much competition is there for advanced telecommunications services at the present national standard of 25 Mbps down (and 3 Mbps up)?"[12] The Commission also asks if wireless and wireline services are substitutes in the data markets, and – if so – to what extent?[13] Further, the Commission asks, "…whether there are barriers to such substitution, and what the limits of such substitution might be."[14] ORA testimony of Dr. Lee Selwyn addresses these questions with respect to *voice* services.

This testimony evaluates wireless mobile data services as compared to wireline broadband services like cable modem, fiber, and DSL. I discuss reports and data from the FCC and CPUC, data submitted by service providers in response to the CPUC's Information Requests,[15] and other relevant data from publicly available sources. This testimony compares service availability, speeds, functional capabilities, prices and consumer choices. As demonstrated below, these service elements make mobile broadband service a complement to, rather than a substitute for, wireline broadband services.

[11] *In the Matter of Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment Pursuant to Section 706 of the Telecommunications Act of 1996, as Amended by the Broadband Data Improvement Act*, 2016 Broadband Progress Report, GN Docket No. 15-191, FCC 16-6, (rel. Jan. 29, 2016) (hereinafter, "2016 Broadband Progress Report") at 3.

[12] Competition OII at 13.

[13] *Id.* at 13.

[14] *Id.* at 13. *See* Footnote 42.

[15] Competition OII at Appendix B.

# II. DISCUSSION

In several instances, the Commission correctly recognizes that mobile data services are likely *not* a substitute to wireline broadband services. For example, the *Competition OII* states:

> "A majority of Americans subscribe to wireless phone service, although many may subscribe to another broadband or telephone service for increased reliability, accessibility in the home, and/or the increased bandwidth available through fiber and coaxial cable. It has been said that more spectrum is available on one strand of fiber than on all spectrum deployed today for wireless communication in the United States… While some wired broadband providers, particularly those using cable or fiber, may offer broadband speeds for 50, 100, 500 Mbps symmetrical or more, few wireless broadband services offer speeds of more than 25 Mbps down, and fewer offer 25 Mbps up. **These differences in speed, capability, and availability may influence telecommunications and broadband competition, particularly as high-bandwidth applications and uses (tele-education and tele-medicine, for instance) become more prevalent.** The impact of data usage caps on some services and not others will also be examined."[16]

Furthermore, in September 2015, the Commission submitted comments to the FCC that include detailed, technical data indicating that mobile data service is *not* a sufficient substitute to wireline broadband service.[17] Those comments are attached hereto as Attachment B. The Commission's analysis of mobile data services in California includes recommendations on how and what to measure to determine the quality and reliability of mobile data services.

The CPUC ultimately recommended, "…the FCC defer its decision on including mobile data services in its definition of advanced telecommunications capability until the FCC confirms that it has reliable mobile data, and has first set mobile performance benchmarks."[18] The CPUC made this recommendation based, in part, on the findings and analysis of the CalSPEED data:

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[16] Competition OII at 13 and 14. *See* Footnote 42. (Emphasis added.)

[17] Comments of the California Public Utilities Commission, *In the Matter of In Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment Pursuant to Section 706 of the Telecommunications Act of 1996, as Amended by the Broadband Data Improvement Act*, GN Docket No. 15-191, (September 15, 2015) (hereinafter, "September 2015 Comments") at 3.

[18] CPUC's September 2015 Comments to the FCC at 3.

> "CPUC Communications Division (CD) staff (Staff) have been studying broadband measurement techniques, particularly with regard to mobile broadband service, for several years. Staff has: 1) created and implemented CalSPEED, a project to measure mobile data services throughput, quality and reliability data for the four national carriers; 2) published a mobile crowd-sourcing application; and 3) performed semi-annual field testing of mobile broadband service quality in urban, rural and tribal areas throughout the state of California. Every six months since 2012, CPUC Staff have collected approximately 2,000,000 test results at the same 1,986 locations throughout California…. In addition, CPUC Staff have developed an on-line tool, CalSPEED.org, to collect fixed broadband service speed, quality and reliability information using the same testing protocol as our mobile app."[19]

CD's findings also incorporate analysis performed by CPUC consultant Ken Biba at Novarum, Inc., and CPUC consultants at California State University at Monterey Bay and the Geographic Information Center at CSU Chico. Mr. Bida's analyses of Fall 2014 CalSPEED data[20] and Spring 2015 CalSPEED data[21] are attached hereto as Attachment C and Attachment D, respectively. The Section II-B below, which discusses the technical limitations of mobile data service, incorporates CD's findings.

## A. <u>The FCC Declares Mobile Data Services are Not a Functional Substitute for Wireline Broadband Service</u>

Recently, the FCC released its 2016 Broadband Progress Report concluding that mobile data services are *not* a functional equivalent to wireline broadband services.[22] The FCC states:

> "We find that today fixed and mobile data services are often used in conjunction with one another and, as such, **<u>are not functional substitutes</u>**. We base this finding on the capabilities both services offer to consumers, the manner in which these services are marketed to and used by consumers, and evidence suggesting that consumers overwhelmingly purchase both services when they have the financial means. Taken together, fixed and mobile data services

[19] *Id*. at 2.

[20] Biba, Ken, *CalSPEED: California Mobile Broadband – An Assessment – Fall 2014* (June 2015) (hereinafter, "2014 CalSPEED Report").

[21] Biba, Ken, *CalSPEED: California Mobile Broadband – An Assessment – Spring 2015* (December 2015) (hereinafter, "2015 CalSPEED Report").

[22] 2016 Broadband Progress Report at 12.

> are currently tailored to serve different consumer needs. Finally, we find that fixed and mobile data services each provide essential components of advanced telecommunications capability, and that, as such, **advanced telecommunications capability should be deemed deployed only in areas where consumers have access to both services as defined herein**."[23]

As stated above, the FCC relied on three categories of evidence to determine that mobile and wireline broadband services are complements and not substitutable services:

1. The capabilities of wireline versus mobile data services;
2. Service constraints and day-to-day utility; and,
3. Consumer behavior.

The sections below discuss these three categories of evidence and incorporate the FCC's underlying data, CD's findings from the CalSPEED project, data submitted by the service providers in response to the Commission's Information Requests, and other relevant data from publically available sources.

## B. Mobile and Wireline Broadband are Not Substitutes Due to the Unique Capabilities of Each Service

Mobile data services and wireline broadband services each provide consumers with connectivity to the Internet and the ability to utilize other IP-enabled applications. Mobile service provides end users with the unique benefit of an untethered and mobile connection, but generally fails to match the performance level of wireline service (as is discussed below). As a result, wireline and mobile data services provide dissimilar, yet partially overlapping, capabilities. This dynamic is evidence that mobile data services and wireline broadband services are compliments, rather than functional substitutes.

### 1. Service Availability

Service availability is the most important characteristic of any broadband service. A broadband service must be available in order for consumers to utilize the various capabilities of that service. The Commission seeks to assess competition between broadband service providers

[23] 2016 Broadband Progress Report at 12. (Emphasis added.)

offering speeds of at least 25/3 Mbps.[24] Mobile data service with speeds of 25/3 Mbps is not available in the vast majority of the state. CalSPEED data demonstrates that mobile data service at speeds of 25/3 Mbps is available in 4% of Verizon Wireless' coverage area, and in less than 2% of areas served by Sprint, T-Mobile and AT&T.[25]

Even considering the modest speed of 6 Mbps download and 1.5 Mbps upload, the availability of mobile data services is far behind the availability of wireline services. In California, nearly 98% of urban households are served by wireline broadband at speeds of at least 6 Mbps download and 1.5 Mbps upload.[26] In contrast, only 16% of urban households were served by mobile data services at those speeds.[27] A similar juxtaposition is true for rural households, as well. Nearly 43% of rural households are served by wireline broadband at speeds of at least 6 Mbps download and 1.5 Mbps upload, while only 15% are served by mobile data services at similar speeds.[28] Clearly, the availability of wireline broadband far exceeds that of mobile data services even at the modest speeds of 6 Mbps download and 1.5 Mbps upload.

### 2. Data Transfer Speeds

The *Competition OII* notes the FCC's recent update to the definition of advanced telecommunications capabilities to include benchmark broadband speeds of 25/3 Mbps.[29] As mentioned above, the Commission notes, "[w]hile some wired broadband providers, particularly those using cable or fiber, may offer broadband speeds for 50, 100, 500 Mbps symmetrical or more, few wireless broadband services offer speeds of more than 25 Mbps down, and fewer offer 25 Mbps up."[30] Indeed, wireline broadband far outperforms mobile data services in terms of data transfer speeds.

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[24] Competition OII at 13.

[25] 2015 CalSPEED Report at 7.

[26] California Advanced Services Fund 2015 Annual Report, Communications Division, California Public Utilities Commission (April 1, 2016) at 3.

[27] *Id.* at 3.

[28] *Id.* at 3.

[29] Competition OII at 8. *See also,* 2016 Broadband Progress Report at 3.

[30] Competition OII at 13 and 14. *See* Footnote 42.

The four large largest providers serve over 32.4 million mobile data subscriptions in California. The Table 1 below depicts the distribution of those subscriptions according to the average speed of the mobile data service.

**Table 1**. Mobile Data Subscriptions by Speed Tier (California)[31]

| Download Speed Tier | Upload Speeds | Total Subscribers | Percent of Subscriptions |
|---|---|---|---|
| Less than 2 Mbps | Less than 0.4 Mbps | 2,305,997 | 7.1% |
| 2 to 5.9 Mbps | Less than 3.4 Mbps | 10,801,706 | 33.3% |
| 6 to 9.9 Mbps | Less than 3.4 Mbps | 6,044,062 | 18.6% |
| 10 to 12.9 Mbps | Less than 3.4 Mbps | 13,324,760 | 41.0% |

As shown above, the average speeds for mobile data services in California generally do not exceed 13 Mbps download and 3.5 Mbps upload. Conversely, wireline broadband with speeds of at least 25/3 Mbps is available to 94% to California's households.[32] And while technological advancements will eventually elevate speeds for both mobile and wireline services, recent trends demonstrate that mobile speeds have dramatically *decreased* in recent years.[33] CD's CalSPEED data demonstrates:

> Major carriers are showing decreasing mean throughput. This slowdown in performance has been apparent for the last two measurement rounds and appears to be a trend. Detailed analysis suggests this is coming from throttling high performance results… This trend of decreasing throughput appears not to be isolated to just one geographic category.[34]

Today's mobile data services do not provide speeds sufficient to accommodate all of the advanced capabilities that are possible with wireline broadband services, such as telemedicine,

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[31] Customers do not necessarily subscribe to a speed tier; rather, service providers reported the actual (average) speeds experienced per subscription of mobile data service based on the results from the FCC's Measuring Broadband America program or some other measurement of past performance. Table 1 includes mobile data subscriptions of AT&T, Sprint, T-Mobile & Verizon Wireless as of December 31, 2015. *See*, responses to the CPUC Information Request no.7 (March 15, 2016).

[32] Direct Testimony of Dr. Lee L. Selwyn on behalf of ORA (June 1, 2016) at 47 in Table 8.

*See also*, California Advanced Services Fund 2015 Annual Report, Communications Division, California Public Utilities Commission (April 1, 2016) at 38.

[33] 2015 CalSPEED Report at 3.

[34] *Id.* at 1-4.

remote education and high definition video streaming. The FCC set the benchmark for wireline broadband services providing advanced telecommunications capabilities at 25/3 Mbps in order to account for the needs of the average household.[35] As noted above, mobile data services rarely offers speeds greater than 6 Mbps download. Thus, mobile data services do not provide the same capabilities as wireline broadband services.

### 3. Quality of Service

Data transfer speeds are only one piece of the puzzle when assessing the capabilities of broadband services. A more accurate assessment of a particular broadband service should include additional metrics to more accurately gauge the capabilities and quality of the service. For example, the CPUC urges the use of *latency* and *consistency* as part of the criteria defining "advanced telecommunications capability" for both wireline and mobile data services.[36]

In addition to data transfer speeds, the capabilities of a broadband service (mobile or otherwise) also depend on the following factors:

- **Latency** – The delay from input to outcome; the amount of time it takes for a packet of data to travel across a network, from one designated point to another.
- **Packet Loss Rate** –The rate at which one or more transmitted packets fails to arrive at their destination.
- **Consistency** – Transmission Control Protocol (TCP) throughput variation; Average actual data transfer speed expressed as a percentage of maximum data transfer speed.
- **Reliability** – The rate at which a device fails to establish a connection with an Internet protocol address; when an end-user is unable to access a web site on their broadband connected device.

#### i. Latency & Packet Loss Rate

Latency measures the amount of time it takes for a packet of data to travel across a network, from one designated point to another. The Packet Loss Rate is similar, but instead measures the rate at which data packets fail to arrive at their destination.

[35] 2015 Broadband Progress Report at 3.

[36] CPUC's September 2015 Comments to the FCC at 20.

Latency and packet loss rates are two important measures of the quality of broadband connections. For both factors, a lower measurement indicates a higher quality of service. Poor latency and/or packet loss rates can hinder or preclude certain capabilities of a broadband connection, even if the connection provides fast data transfer speeds. Highly interactive or real time applications, like video and voice communications, require sufficient latency and packet loss rates to function properly.

Wireline broadband connections have low latency and low packet loss rates, even during times of peak usage.[37] As such, wireline broadband services are well suited to accommodate highly interactive applications, including IP-enabled voice communications (VoIP). Conversely, wireless data services frequently operate with much higher (lower quality) latency and packet loss rates than wireline services, as discussed below.

In its assessment of CalSPEED data, CD measured the latency and packet loss rates of mobile services to calculate a "Mean Opinion Score" (MOS) for various locations.[38] CD uses the MOS to determine if the quality of a connection is sufficient for VoIP applications. The MOS is a value between zero and five, with five representing the optimal score and four representing the lowest acceptable performance for VoIP communications.[39]

The four major mobile data service providers failed to achieve MOS scores of four or better – indicating the service is *not* suitable for VoIP communications – in five to 25% of tested locations throughout the state.[40] The CalSPEED data also demonstrates that mobile data service is not suitable for VoIP communication in a significant percentage of rural and tribal areas.[41] T-Mobile's service is *not* suitable for VoIP communications at nearly 35% of rural locations where service is available, and Sprint's service is not suitable in 20% of rural locations where service is

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[37] FCC, *2015 Measuring Broadband America Fixed Broadband Report: A Report on Consumer Fixed Broadband Performance in the United States* (hereinafter, "2015 Measuring Broadband Report") at 17-19. Available at https://www.fcc.gov/reports-research/reports/measuring-broadband-america/measuring-broadband-america-2015

[38] CPUC's September 2015 Comments to the FCC at 5 to 7.

[39] VoIP communications refers to over-the-top applications allowing for IP-enabled voice services, and does not refer to standard cellular phone voice service. Refer to CPUC's September 2015 Comments to the FCC at 5. *See* Footnote 11.

[40] 2015 CalSPEED Report at 11.

[41] *Id.* at 11.

available. Tribal lands fared worse than rural areas. T-Mobile's service is *not* suitable for VoIP communications at almost 80% of tribal lands where service is available. Even Verizon's service is *not* suitable for VoIP communications throughout nearly a quarter of tribal lands where service is available.

#### ii. Consistency

Consistency conveys a broadband connection's actual data transfer speeds expressed as a percentage of the maximum data transfer speed. In other words, consistency measures the stability of a broadband connection's speed. A lower consistency score indicates that a connection's speed fluctuated, while a higher level of consistency indicates the connection provided steady data transfer speeds.

Wireline broadband connections offer fairly high rates of consistency, especially cable and fiber services, as noted by the FCC:

> "Customers of Cablevision, Comcast, or Verizon Fiber (FiOS) experienced actual download speeds that are very consistent; over 80% of their customers experienced actual download speeds at or above advertised download speeds during at least 80% of the peak usage period."[42]

Mobile data services, on the other hand, do not offer the same high levels of consistency as wireline services. CD's CalSPEED data indicates that the maximum, minimum and average upload or download speeds are *not* representative of the consumer experience.[43] The data transfer speeds of a mobile data service can vary widely depending on a host of factors. CD's 2014 CalSPEED Report notes the performance of a mobile data service varies depending on the following factors:

- Location of the end user;
- Choice of carrier;
- Location of the used server;
- Session Variation; and,
- Time of day.[44]

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[42] 2015 Measuring Broadband Report at 16.

[43] CPUC's September 2015 Comments to the FCC at 2.

[44] 2014 CalSPEED Report at 3.

The 2014 CalSPEED Report concludes that variance between 25% and 50% can be considered "typical" for mobile data service.[45] This problem is even more pronounced in rural areas, where speeds at a particular location can vary by more than 200% within a 30 minute timeframe.[46] The 2015 CalSPEED Report reaffirmed these conclusions, and only found "modest improvement" on the very high end of the variation."[47]

The issue of poor speed consistency is compounded because mobile data services generally offer data transfer speeds that *already* fall well below the speeds of many wireline broadband connections, as previously noted.[48] In all, the capabilities of mobile data services are potentially impaired by poor consistency, especially for speed sensitive applications, as compared to wireline broadband services.

#### iii. Reliability

The reliability of a broadband connection measures the frequency of functional availability. A "TCP failure rate" is a commonly used assessment of broadband reliability.[49] A TCP failure rate measures the rate at which a TCP connection failure occurs when a user is attempting to access a website from a mobile browser.

Mobile data services are reliant on a signal from a radio access network, and signal conditions or fluctuations correlate with connection failures and loss.[50] As a result, mobile data services can experience high TCP failure rates, which indicate low levels of service reliability. Most notably, rural areas experience TCP connection failures at four times the rate of urban

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[45] *Id.* at 9.

[46] CPUC's September 2015 Comments to the FCC at 9.

[47] 2015 CalSPEED Report at 9-10.

[48] Refer to Section II-B-2 of this report.

[49] 2015 CalSPEED Report at 9. *See* Footnote 7: "The fundamental reliable connection service for the Internet is TCP - Transmission Control Protocol. It provides reliable delivery of an ordered stream of bytes and is the foundation service for web browsing, most streaming media services, email, IM and most other user Internet services. CalSPEED measures TCP quality in several ways: the failure rate of making a connection, and the consistency of the throughput during the connection - throughput variation."

[50] Baltrunas, Elmokashfi and Kvanlbein, *Measuring the Reliability of Mobile Broadband Networks,* Simula Research Laboratory (November 2014) at 46. Available at http://dx.doi.org/10.1145/2663716.2663725.

areas.[51] CalSPEED data demonstrates that all four of the leading mobile data services providers experience TCP failure rates in excess of 10% (statewide), and above 15% in rural areas.[52]

High TCP failure rates can impair the capabilities of the mobile data services to the point of sporadic inoperability. As a result, consumers cannot always rely on mobile data services to sufficiently replace wireline broadband services.

#### 4. Urban vs Rural Areas

CalSPEED data show that the quality of mobile data services in rural areas significantly and consistently trails that of urban areas, across nearly all metrics (including data transfer speeds, latency, packet loss, and TCP failure rate).[53] The lesser quality of service is due, at least in part, to the older radio access technology and slower backhaul serving rural areas.[54] These legacy networks only offer very poor quality mobile data services due to dramatically longer latencies and much slower speeds.[55] VoIP services are nearly impossible on these legacy networks and streaming video service unlikely to deliver acceptable quality. Unfortunately, older legacy networks are no longer being replaced with newer technologies at a significant rate, if at all.[56]

Long Term Evolution (LTE) is a 4G wireless communications standard associated with some of the highest quality mobile data services available today.[57] Each of the four major mobile data service providers offers LTE service in urban areas with higher population density, but do *not* provide LTE service in approximately 30% to 64% of their *rural* service territory.[58] An analysis of CalSPEED data from 2015 finds that LTE penetration has peaked in both urban and rural areas,[59] which suggests many rural areas will continue to receive a lower quality of service.

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[51] 2015 CalSPEED Report at 9.

[52] *Id.* at 9.

[53] 2014 CalSPEED Report at 12-13. *See also*, 2015 CalSPEED Report at 9 and 11-12.

[54] CPUC's September 2015 Comments to the FCC at 6.

[55] 2015 CalSPEED Report at 12.

[56] *Id.* at 11.

[57] *See* http://www.verizonwireless.com/support/4g-mobile-broadband-faqs/.

[58] 2014 CalSPEED Report at 13.

[59] 2015 CalSPEED Report at 12.

## C. The Manner in Which Mobile and Wireline Broadband Services Are Sold to and Used by Consumers Indicates the Services Are Not Substitutes

Mobile data services differ from wireline broadband services due to dissimilar pricing models and cost of service. The dissimilar pricing conventions, in conjunction with the aforementioned differences in capabilities, affect the ways in which consumers utilize the services. As a result, consumers use mobile data services and wireline broadband services for different needs and purposes. This dynamic is additional evidence that mobile data service is not an adequate substitute for wireline broadband service.

### 1. Data Caps

Mobile data services do not provide the same level of functionality as wireline broadband services, in part, due to restrictions on total data consumption per month. Service providers frequently limit the capabilities of mobile data services by placing restrictions, called "Data Caps," on total data consumption per month. These restrictions are meant to address certain limitations of mobile data services networks. Mobile data services networks function with stricter capacity and congestion limitations than wireline broadband networks.[60] Wireline broadband services frequently do not have Data Caps, and, when they do, the caps are usually significantly higher than those associated with mobile data services.[61]

Data Caps directly affect how consumers utilize broadband services, as evidenced by the stark differences in the average amount of data consumed on mobile versus wireline broadband services. Fixed (including wireline) broadband consumers use an average of 57.4 gigabyte (GB) of data per month per household,[62] while mobile data consumers use 1.9 GB of data per month.[63] This disparity is significant even after accounting for the possibility of multiple users in a single household. This disparity in data consumption is evidence that consumers use mobile and

[60] 2016 Broadband Progress Report at 15.

[61] *Id.* at 15.

[62] Sandvine Incorporated ULC, *Global Internet Phenomena Report: 2H 2014* (November 21, 2014) at 5. Available at https://www.sandvine.com/downloads/general/global-internet-phenomena/2014/2h-2014-global-internet-phenomena-report.pdf.

[63] GSM Association. *The Mobile Economy North America 2015* (2015) at 11. Available at http://gsmamobileeconomy.com/northamerica/.

wireline broadband services for different purposes. For example, T-Mobile, a leading mobile data services provider, explains:

> "[C]onsumers generally access different content and services on different devices depending on the nature of their broadband connection. For example, fixed services allow consumers to view high definition video for larger screens and download and share large files, while mobile data services powers smartphones, wearable devices, mobile health monitoring, video suitable for smaller screens and countless location-based services."[64]

Additionally, a recent survey of 2,149 Americans found that, "people have clear views about which applications are better suited to different means for going online… [and] those with both a home broadband connection and a smartphone prefer to use the former for looking for information, watching video, or shopping, while the latter is used more for straying in touch with others."[65] That study, which is attached hereto at Attachment E, also concludes that consumers view home broadband service and smartphones as complementary means to access the Internet.[66]

Figure 1 below depicts the top 15 types of mobile applications and websites accessed by smartphone users as of September 2015.

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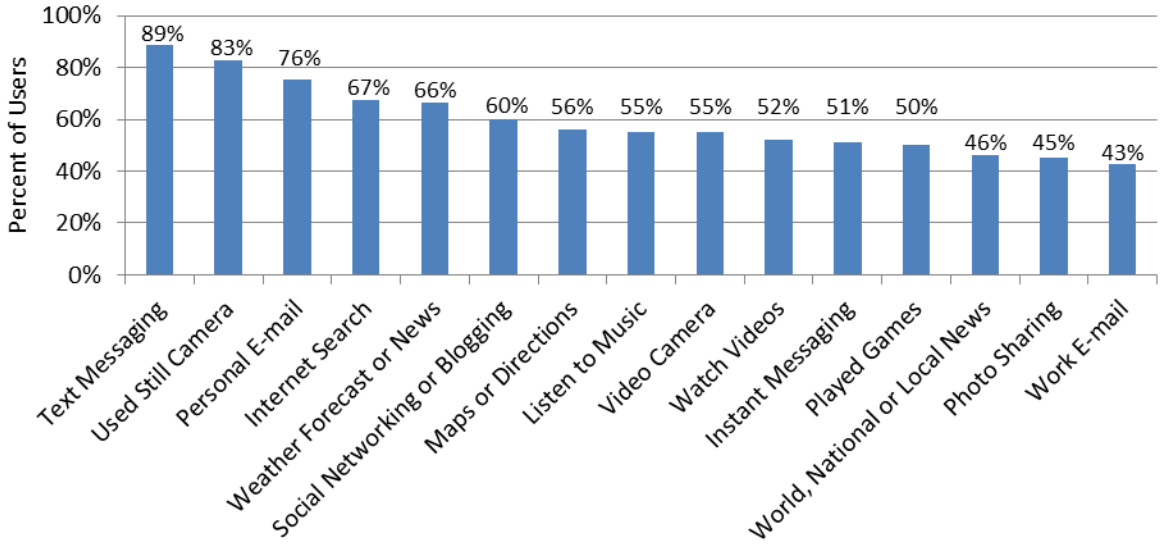
[64] *See* Reply Comments of T-Mobile USA, Inc in FCC GN Docket No. 15-191 (September 30, 2015) at 3.

[65] John Horrigan, PhD, *Smartphones and Broadband: Tech Users See Them as Complements and Very Few Would Give Up Their Home Broadband Subscription in Favor of Their Smartphone* (November 2014) at 6.

[66] *Id.* at 2.

**Figure 1**. Top 15 Uses for Mobile Data on Smartphones[67]




Consumers use mobile data services for applications that are conducive to mobile service and devices. As such, the top 15 applications of mobile data services do not include many data-intensive applications that require a high-quality broadband connection. Advanced telecommunication capabilities, which mobile data services generally do not (independently) provide, include many data-intensive applications, such as high definition video streaming, online gaming, video conferencing, VoIP, telehealth, telecommute and various educational applications. Consumers usage patterns provide further evidence that mobile data services, although extremely useful, do not sufficiently accommodate those data-intensive applications. This is additional evidence that mobile data services are not a sufficient substitute for wireline broadband services.

### 2. Cost of Service

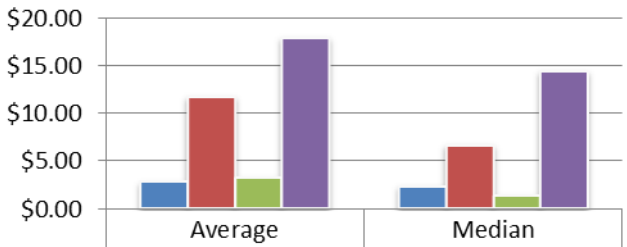
The price of mobile data service depends on many factors; service providers offer various levels of service at different price points, and frequently change prices or offer limited-time promotional pricing.[68] On average, mobile data subscribers pay $69 per month (excluding taxes

[67] FCC's 2015 Mobile Competition Report at 94.

[68] *In the Matter of Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993 and Annual Report and Analysis of Competitive Market Conditions With Respect to Mobile Wireless, Including Commercial Mobile Services.* Eighteenth Report, WT Docket No. 15-191, DA 15-1487, (rel. Dec. 23, 2015) (hereinafter, "2015 Mobile Competition Report") at 53-57.

and surcharges) per unique subscription.[69] However, in order to perform an apples-to-apples comparison of the cost of mobile data services and wireline broadband services, the Commission should first account for differences in service capabilities and pricing conventions. Figure 2 below depicts the average and median monthly recurring costs of mobile data services alongside wireline broadband services, according to the download speeds of 339 service plans available in California.

**Figure 2**. Cost of Download Speed per Month (Dollar per Mbps)[70]




| | Average | Median |
|---|---|---|
| Cable | $2.77 | $2.33 |
| DSL | $11.73 | $6.65 |
| FTTH | $3.19 | $1.33 |
| Mobile Data | $17.90 | $14.38 |

Normalizing the prices of mobile data services and wireline broadband services to account for the significant differences in download speeds provides additional evidence that a mobile data service is not a sufficient substitute for wireline broadband. Figure 2 above depicts the average cost of services according to the download speed of that service. In this comparison, mobile data services are by far the most expensive; the median price of mobile data services per 1 Mbps of download speed is over 13 times higher than FTTH, over six times higher than cable broadband services, and over double that of DSL services.

[69] GSM Association. *The Mobile Economy North America 2015* (2015) at 12. Available at http://gsmamobileeconomy.com/northamerica/.

[70] Cable, FTTH and DSL speeds and prices reflect the service plans of 11 major providers, as reported in the FCC's *2016 Urban Rate Survey for Fixed Voice and Broadband Services* (April 5, 2016), which is available at https://www.fcc.gov/general/urban-rate-survey-data-resources.

Mobile data prices reflect the monthly rates of post-paid service plans for a mobile smartphone (as of May 24, 2016) of Verizon Wireless, AT&T/Cingular, Sprint and T-Mobile. See Attachment F for more information.

Mobile data download speeds are as reported in *2015 CalSPEED Report*, see "Mean Downstream Throughput (Phone)" at 3.

Next, Table 2 below depicts the average and median monthly recurring costs of mobile data services alongside wireline broadband services, according to the data allowances of 339 service plans available in California.

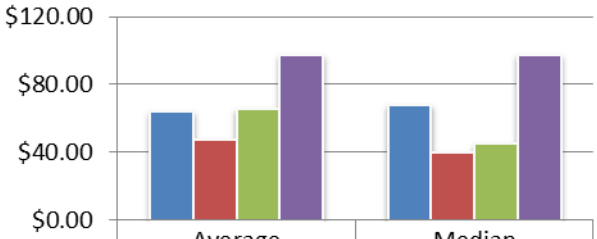
**Table 2**. Cost of Data Allowance per Month (Dollar per GB)[71]

| Service Type | Average | Median |
|---|---|---|
| Cable | $1.50 | $0.33 |
| DSL | $0.34 | $0.33 |
| FTTH * | n/a | n/a |
| Mobile Data | $21.98 | $8.75 |

*FTTH service plans offer unlimited data.

For services that offer unlimited data allowance per month, Figure 3 below depicts the average and median monthly recurring costs of 339 service plans available in California including both mobile data services and wireline broadband services.

**Figure 3**. Cost of Unlimited Data Allowance per Month[72]




| | Average | Median |
|---|---|---|
| Cable | $64.25 | $67.99 |
| DSL | $47.30 | $39.95 |
| FTTH | $65.69 | $44.95 |
| Mobile Data | $97.50 | $97.50 |

Again, normalizing the prices of mobile data services and wireline broadband services to account for the significant differences in data allowances (Data Caps) provides additional evidence that a mobile data service is not a sufficient substitute for wireline broadband. Mobile data plans that offer unlimited monthly data allowance are far more expensive than wireline broadband services. For those unlimited data plans, the median cost of mobile data services are over 26 times more expensive than DSL and Cable broadband services. Likewise, for plans with

[71] *Id.*

[72] *Id.*

data caps, the median cost of mobile data services are 1.5 to 2.5 times more expensive than FTTH, DSL and Cable broadband services.

In all, the cost of service, when normalized for capabilities and data allowance, is further evidence that a mobile data service is not a sufficient substitute for wireline broadband service.

## D. Consumers Purchase Both Mobile and Wireline Broadband Services when They Have the Financial Means

If mobile data service were a sufficient substitute for wireline service and also afforded users the additional benefit of mobility, many consumers would forgo wireline subscriptions to avoid the cost of purchasing a redundant service. Consumers' behavior and purchasing patterns demonstrate that this is not the case, as consumers generally choose to purchase both mobile *and* wireline broadband services, when possible. Approximately 83 percent of residential consumers with mobile data services connections also have broadband at home.[73]

Mobile data services subscriptions *and* wireline broadband subscriptions are increasing, year over year. The top telecommunications and cable companies added more than 3.1 million wireline broadband subscriptions nationwide in 2015.[74] Mobile data services connections also grew, with the percentage of mobile phones classified as smartphones increasing from 50 percent in 2013 to 77 percent in 2015.[75]

Consumers want *both* mobility and high performance broadband connections. As previously demonstrated, mobile data services generally fail to provide the same level of quality, reliability and performance as wireline connections. Still, the demand for and importance of mobile data services are clear. Thus, mobile and wireline are complementary goods for the majority of consumers.

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[73] John Horrigan, PhD, *Broadband Adoption and Usage: What Has Four Years Taught Us?* (2013) at 3-4. Available at http://moody.utexas.edu/sites/communication.utexas.edu/files/images/content/tipi/Horrigan.FCC_.Summit.02.06.pdf

[74] Leichtman Research Group, Inc. *Press Release: 3.1 Million Added Broadband from Top Providers in 2015* (March 11, 2016). Available at http://www.leichtmanresearch.com/press/031116release.html.

[75] Ericsson Mobility Report: On the Pulse of the Networked Society (November 2015) at 2. Available at http://www.ericsson.com/res/docs/2015/mobility-report/ericsson-mobility-report-nov-2015.pdf.

### 1. Considering Mobile Data Services a Substitute for Wireline Broadband will Disproportionately Harm Low-Income and Disadvantaged Consumers

Characterizing mobile and wireline broadband as substitutes might create a new variation of the classic digital divided dilemma. In this new divide, people that can afford both *mobile and wireline* service will enjoy benefits that are out of reach for people that must choose only one, wireline or wireless.

There are several reasons why a person might have to choose between one modality or the other, most notably financial constraints and service availability. For consumers on the wrong side of this new digital divide, the constraints typically lead to adoption of wireless, and not wireline, broadband service.

> "Many low-income, minority, and other households choose not to subscribe to fixed-line broadband but have adopted smartphones and other mobile devices to access the Internet. In part this is because mobile data services coverage helps fill in gaps left by fixed-line service in some areas, **but in larger part because of consumer preferences given the options and prices**."[76]

In 2013, households that made less than $25,000 per year were nearly five times more likely to rely on a mobile service as their only form of broadband connection than households that made more than $100,000 per year.[77] Households that made $25,000 to $49,999 per year were four times more likely to rely on a mobile service as their only form of broadband connection than households that made more than $100,000 per year.[78]

The fact that many low income households are forced to forgo wireline broadband service, and only subscribe to wireless service, is problematic due to the significant shortcomings of wireless data services as compared to wireline broadband.

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[76] Prieger, James. *The Growth of the Broadband Internet Access Market in California: Deployment, Competition, Adoption, and Challenges for Policy*, Pepperdine University, School of Public Policy (March 31, 2016) at 7. Available at http://digitalcommons.pepperdine.edu/sppworkingpapers. (Emphasis added.)

[77] US Census Bureau, Computer and Internet Use in the United States: 2013, American Community Survey Reports (November 2014) at 9.

[78] *Id.* at 9.

On average, households connected *only* by wireless service receive a lower quality of service,[79] higher price per GB consumed,[80] and slower speeds[81] than households connected by wireline services. These factors relegate wireless-only households to the wrong wide of this new digital divide.

As broadband functionality expands, access to a high quality connection becomes even more essential to everyday life. Users will increasingly rely on broadband applications that require a high-quality, fast connection without significant limitations on consumption. Many wireless-only households are already at a disadvantage, and, in looking to the future, these households are at risk of being left behind if mobile data service is considered a sufficient substitute to wireline service. Thus, the Commission should recognize that wireless data services are *not* a substitute for wireline broadband service.

[79] Refer to Section II-B-3 of this report at pages II-6 to II-9.

[80] Refer to Section II-C-2 of this report at pages II-13 to II-15.

[81] Refer to Section II-B-2 of this report at pages II-4 to II-6.

# III. CONCLUSION

Mobile data services are *not* functional equivalents for wireline broadband services, and – as such – cannot be considered a competitive choice to wireline broadband. The services provide some overlapping functionality, but mobile data services do not have the same capabilities as wireline broadband services. A mobile data service generally cannot match the quality and reliability of a wireline broadband service. As a result, mobile data services frequently fail to provide advanced communications capabilities.

Mobile data services do not provide the same quality of service and reliability as wireline broadband services. After normalizing prices to account for data allowances or download speeds, mobile data services are significantly more expensive than wireline broadband services. Nonetheless, mobile data services provide capabilities that consumers value and wireline broadband services do not provide. Consumers frequently choose to subscribe to *both* a mobile data service and a wireline broadband service. Consequently, mobile and wireline broadband services are best characterized as complementary services.

# ATTACHMENT A

**Statement of Qualifications and Experience**

My name is Adam Clark. I am currently employed by the CPUC as a Public Utility Regulatory Analyst V assigned to the Communications and Water Policy Branch of the ORA. I received a Bachelor of Arts Degree in Business Economics and Sociology from the University of California at Santa Barbara in 2006.

I joined the CPUC in June of 2007 as a Regulatory Analyst in the Communications Division, where I worked on various issues, including inter-carrier compensation, public purpose programs, and broadband deployment. I have performed extensive research on California's telecommunications and broadband markets. I have also aided the CPUC in review of previously proposed mergers and acquisitions. I joined ORA in October of 2014.

# ATTACHMENT B

**BEFORE THE**
**FEDERAL COMMUNICATIONS COMMISSION**
**WASHINGTON, D.C. 20554**

| | |
|---|---|
| In the Matter of<br><br>Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment Pursuant to Section 706 of the Telecommunications Act of 1996, as Amended by the Broadband Data Improvement Act. | GN Docket No. 15-191 |

**COMMENTS OF THE CALIFORNIA PUBLIC UTILITIES COMMISSION**

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September 15, 2015

154424089

## I. INTRODUCTION

The California Public Utilities Commission (California or CPUC) submits these comments in response to the Federal Communications Commission's (FCC or Commission) Eleventh Broadband Progress Notice of Inquiry (NOI) Concerning Deployment of Advanced Telecommunications Capability Pursuant to Section 706 of the Telecommunications Act of 1996.[1]

As required by Section 706 of the Telecommunications Act of 1996, the FCC annually reports to Congress on whether advanced telecommunications capability is being deployed to all Americans in a reasonable and timely fashion.[2] In this NOI the FCC solicits data and information that will help it make this annual determination. In particular, the FCC seeks comments on whether "advanced telecommunications capability" should include access to mobile broadband service as well as fixed broadband service, what basic criteria the FCC should use in defining advanced telecommunications capability, including speed, latency, and service consistency, and the development of specific benchmarks to judge whether the criteria have been met.[3]

California comments here on some, but not all, of the issues raised in the NOI. The CPUC herein provides the FCC with data and analysis regarding the state of mobile broadband service in California in order to inform the FCC's decision on whether to require both types of

[1] In the Matter of Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, *Eleventh Broadband Progress Notice of Inquiry*, GN Docket No. 15-191, FCC 15-101, rel. Aug. 7, 2015 (NOI).

[2] Section 706 of the Telecommunications Act of 1996, as amended (1996 Act), requires the Commission to determine and report annually on "whether advanced telecommunications capability is being deployed to all Americans in a reasonable and timely fashion." *See* 47 U.S.C. § 1302(b).

[3] NOI, at ¶¶ 3 and 4.

service, and on how and what to measure to determine quality and reliability of service, in addition to speed.

CPUC Communications Division (CD) staff (Staff) have been studying broadband measurement techniques, particularly with regard to mobile broadband service, for several years. Staff has: 1) created and implemented CalSPEED, a project to measure mobile broadband throughput, quality and reliability data for the four national carriers; 2) published a mobile crowd-sourcing application; and 3) performed semi-annual field testing of mobile broadband service quality in urban, rural and tribal areas throughout the state of California. Every six months since 2012, CPUC Staff have collected approximately 2,000,000 test results at the same 1,986 locations throughout California.[4] Enhancements were made in our testing protocol prior to the most recent field test to capture backhaul and middle mile information in order to compare its urban, rural and tribal service characteristics and impacts. Analysis of the latest data collection is currently under way.[5] In addition, CPUC Staff have developed an on-line tool, CalSPEED.org, to collect fixed broadband service speed, quality and reliability information using the same testing protocol as our mobile app.

Because of our CalSPEED program, the CPUC is in a unique position to provide California data-driven recommendations to the FCC. Our data provides empirical evidence on the FCC's questions relating to how it should measure and analyze the quality of broadband services. These comments rely on the analysis of CalSPEED data performed by CPUC Staff, CPUC consultant Ken Biba at Novarum, Inc., and CPUC consultants at California State University (CSU) at Monterey Bay and the Geographic Information Center at CSU Chico. Mr.

[4] Test locations increased from 1,200 to 1,896 as of Fall 2013.

[5] CalSPEED code and testing results are all open source. Data sets are available at http://www.cpuc.ca.gov/PUC/Telco/bb_drivetest.htm.

Biba's analysis of Fall 2014 results is attached hereto as Attachment 1.[6] Mr. Biba's preliminary analysis of the Spring 2015 field test results is also referenced in these comments.

While the CPUC does not take a position here on the question of whether both fixed and mobile services should be included in the definition of "advanced telecommunications service," we recommend the FCC defer its decision on including mobile broadband in its definition of advanced telecommunications capability until the FCC confirms that it has reliable mobile data, and has first set mobile performance benchmarks. Finally, the CPUC urges the FCC to use latency and consistency as part of the criteria defining "advanced telecommunications capability", both for fixed broadband services as well as mobile broadband services.

Silence on other questions posed by the FCC's NOI signifies neither agreement nor disagreement by the CPUC.

## II. DISCUSSION

### A. Criteria and Benchmarks for Assessing Advanced Telecommunications Capability

Section 706 provides that advanced telecommunications capability "enables users to originate and receive high-quality voice, data, graphics, and video telecommunications using any technology."[7] To date, the FCC has focused on upload and download speed benchmarks to evaluate broadband services.[8] This NOI asks whether the FCC should use additional criteria to define advanced telecommunications capability, including latency, reliability and consistency of service. The NOI asks whether and how to apply these criteria to both fixed and mobile broadband services.

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[6] CalSPEED: California Mobile Broadband – An Assessment - Fall 2014, Ken Biba, Managing Director and CTO Novarum, Inc.

[7] NOI, at ¶ 19, citing 47 U.S.C. § 1302(d)(1).

[8] *Id.*

### 1. Mobile Broadband Service

#### a) CalSPEED Analysis -- Deployment, Speed, Quality and Reliability Trends in California's Mobile Broadband Marketplace

The CPUC analysis of the Fall 2014 and Spring 2015 CalSPEED field test results[9] may provide a fuller understanding of the state of mobile broadband service in California, and inform the FCC's decision on establishing mobile speed and performance benchmarks, as well as whether to include mobile broadband in its definition of advanced telecommunications capability. The CPUC began its testing program in the Spring of 2012, and recently completed its seventh semi-annual field test in the Spring of 2015. During that time period, and from one round of testing to the next, we have seen significant changes in average speed and quality of service, particularly in urban areas. From the beginning of our program through Spring 2014, service has generally improved over all metrics we use. However, while carriers have continued deploying LTE, the technology in part responsible for the observed improvements, most rural and tribal areas have been left out of high quality LTE coverage in some significant ways. And beginning with the Spring 2014 field test, we have seen a slowdown in improvement, and sometimes a reversal, in certain metrics.

Mr. Biba's report titled *CalSPEED: California Mobile Broadband - An Assessment - Fall 2014* (Assessment), which is attached to these comments, contains the following conclusions:

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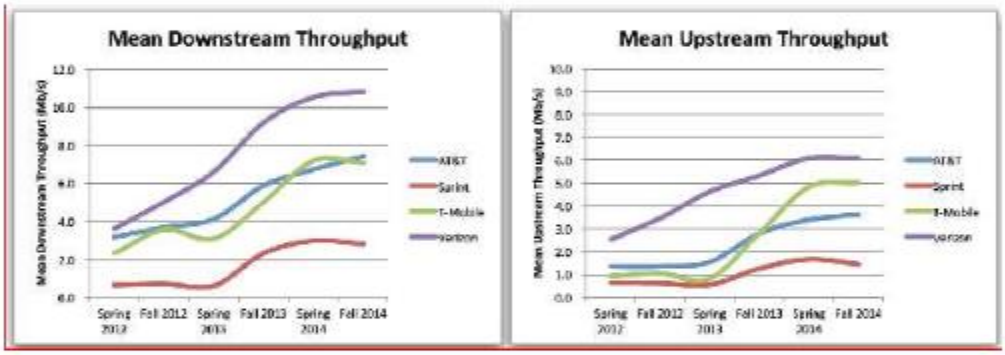
[9] For other material regarding the CPUC's CalSPEED program and analysis of results, see also Comments of California Public Utilities Commission *In the Matter of Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment Pursuant to Section 706 of the Telecommunications Act of 1996, as Amended by the Broadband Data Improvement Act*, Tenth Broadband Progress Notice of Inquiry, GN Docket No. 14-126, filed September 4, 2014. Comments of the California Public Utilities Commission, *Inquiry Concerning Proposed Methodology for Connect American High-Cost Universal Service Support Recipients to Measure Speed and Latency Performance to Fixed Locations*, WC Docket No. 10-90, (DA 14-1499), filed Dec. 22, 2014.

- Mobile broadband's overall performance and quality has stopped improving and shows signs of degradation.
- Mobile broadband continues trends of wide variation across California among carriers, and locations of services, with a growing divide between urban and rural service.
- Quality degradation is particularly noticeable in rural areas - in which dropped connections can be 2x worse than in urban.
- Deployment of rural LTE shows signs of stalling.
- There is substantial variation among devices on the performance and quality of service.

The graphs of mobile throughput below show that, for the first time, several carriers' average measured speeds have stalled or even declined.[10]

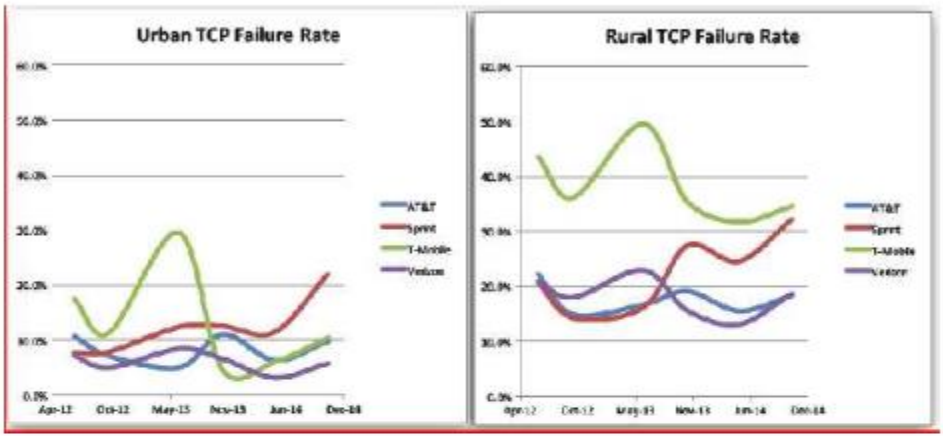



In evaluating CalSPEED service quality results, we examined three factors: TCP connection failure rate, packet loss rate, and estimated Mean Opinion Score (MOS) for over the top VoIP services.[11] The Assessment points to a recent drop in service quality in our Fall 2014 data. The first graph below illustrates the not only the increase in TCP failure rates overall, but

[10] Spring 2015 preliminary results show reductions in speed for smartphones, while for newer tablet devices, speeds increased. We are investigating why this is the case.

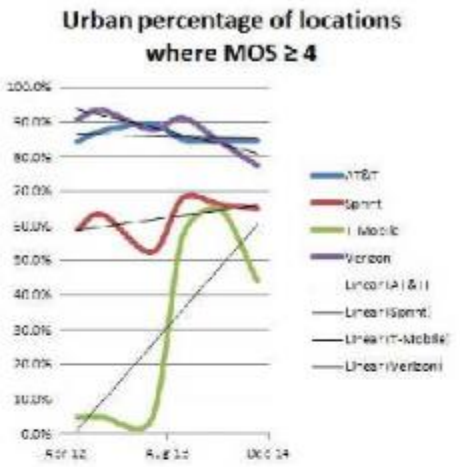
[11] We estimate over the top Mean Opinion Score (MOS) using latency and packet loss measurements to create an R value. Base on the R value, we calculate a MOS value between zero and five. We consider a MOS value greater than or equal to 4 as acceptable for voice communications. While we do not call out latency separately here, poor latency affects MOS directly.

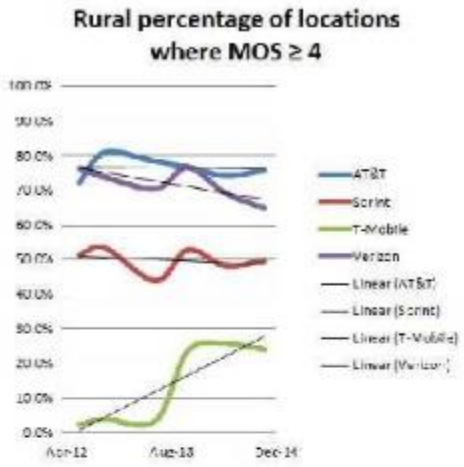
also the discrepancy between urban and rural[12] areas, which continues to be roughly double. A TCP failure happens when a user is unable to access a web site from a mobile browser. Often, the browser progress bar stops, and the user needs to retry connecting to a particular site.



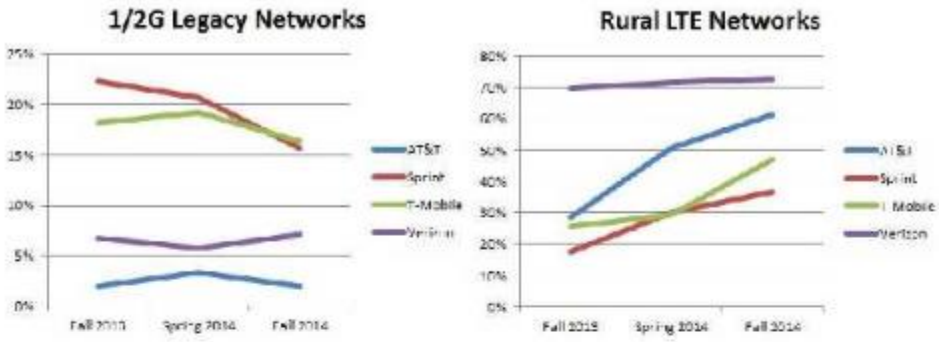

In the next graph, we show the percentage of tested locations falling within each provider's stated coverage footprint where the estimated Mean Opinion Score is 4 or greater. As with TCP failure rates, we see an overall decline in service quality by the decrease in the number of locations that can support VoIP at an acceptable level, and, like TCP failure rates, the problem is worse in rural areas than it is in urban areas. This is because of higher latency and higher packet loss rates in rural areas, which may be attributable to older radio access technology and slower backhaul connections.

[12] We use the U.S. Census Bureau's designation of urban and rural areas. "Urban" combines both urban and suburban.




While our Spring 2015 field test results seem to indicate an improvement in the number of locations where estimated MOS is greater than or equal to 4, there are indications that rural and tribal areas are being left behind in the carriers' network upgrade plans. In the six months between our last two field tests, new LTE deployment in both urban and rural areas for the first time shows no measurable improvement. We see this reflected in the number of test sites where our LTE devices default to older, obsolete, 1, 2 and 3G technologies, reflecting the persistence of legacy equipment and lack of upgrades. The following graphs show the level at which each carrier has deployed LTE at our rural test locations. Even for the carrier with the most rural service, almost 30% of our rural test locations are not serviced by LTE.




### b) Implications for Mobile Speed Benchmarks

The NOI seeks comment on various benchmarks the FCC should use to define advanced telecommunications capability, in addition to speed.[13] The NOI proposes to retain the previous 10th Broadband Progress Report's definition of wireline advanced communications capability – upstream/downstream throughputs of at least 25/3 Mbps – for fixed terrestrial broadband services.[14] The FCC seeks comment on what speed benchmark it should apply to mobile broadband services.[15]

The CPUC has used CalSPEED data and analysis to determine the impact of various speed benchmarks (i.e., 6/1.5, 10/1, 25/3) being applied to mobile broadband coverage in California. This analysis shows the impact of various benchmark speeds on the percentage of California's population and land area consistently receiving those benchmark speeds or higher.

Our analysis illustrates that mobile broadband is subject to extreme variability. Because of this variability, use of mean speed alone is of little value, especially when using mean speed to classify a particular area, such as a census block, as served by a provider. A consumer may

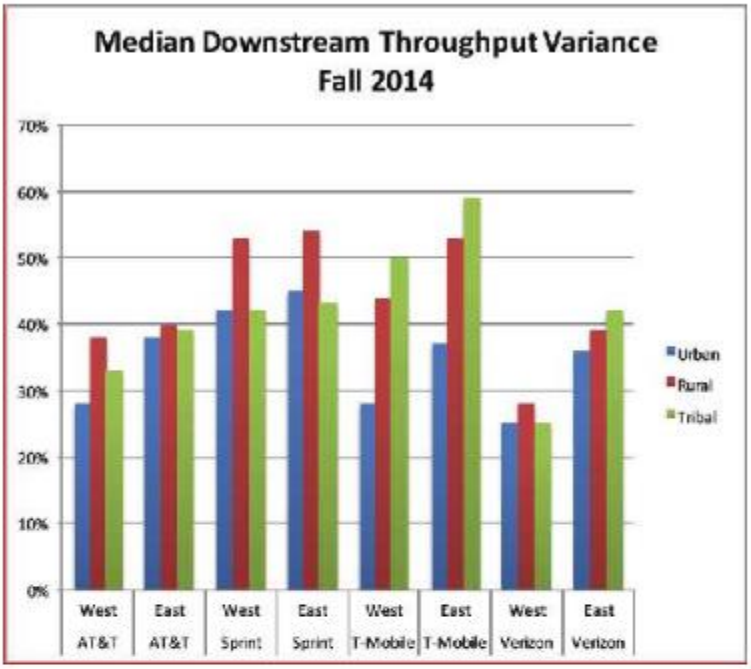
[13] NOI, at ¶¶ 22-30.

[14] NOI, at ¶ 24.

[15] NOI, at ¶¶ 27-30.

receive 10/3 throughput one moment, but 5/1 the next, and 20/10 the moment after that. Variance during a testing session of between 25% and 50% can be considered typical, as seen in the following graph, but specific rural locations can sometimes see TCP throughput variations during a single measurement session that exceed 200%. Such extremely high variances are almost always located in rural or tribal locations. Unlike other mobile speed test apps, CalSPEED tests to two servers, one located in Amazon Web Service's east coast location, and one in the AWS west coast location. We have noticed significant differences in latency between these two servers for some providers; however, there appears to be ongoing reductions in those differences over time as providers place more focus on real-time services such as VoIP.[16]

[16] For an explanation of why testing to both east and west coast servers is important, see *Novarum Analysis Comparing Ookla, FCC, and CPUC's Mobile Speed Tests*, available at ftp://ftp.cpuc.ca.gov/telco/BB%20Mapping/Field%20Testing/Biba%20Mobile%20BB%20Comparison%209%204%2014%20Filed%20(2).pdf.




Just as carrier-provided maximum advertised speeds do not represent the typical user experience, it is apparent that even the mean result of many repeated tests at a particular location cannot be said to represent the typical user experience.[17] In light of such large variability the question becomes, what is the typical consumer experience, and how should this be reflected in throughput benchmarks?

[17] Through its testing program, the CPUC has shown that carrier-reported "highest advertised speeds" certainly are not representative of the typical user experience. The FCC similarly rejects the adequacy of the carrier-reported maximum advertised speeds collected by the NTIA under its Broadband Data Initiative, and instead requires carriers to report their lowest advertised speeds on FCC Form 477. The FCC has not yet determined whether "lowest advertised speeds" now being collected will be any better at representing that experience.

The results of the FCC's data collections for the periods ending June 30, 2014, and December 31, 2014, have not yet been reported by the FCC to the public, nor made available to state utility commissions. On October 1, 2015, the FCC will collect yet another round of Form 477 data. These new data will be as of June 30, 2015. Because of the rapid pace of change in deployment, usage patterns and technologies, the FCC's analysis of its Form 477 mobile broadband data may well be badly out of date before it is published and thus not representative of the current status of mobile services.

The CPUC recommends that the FCC consider this variability phenomenon before determining whether to apply the same benchmarks for mobile broadband service that it has adopted for wireline, and before deciding whether to include mobile service in its definition of "advanced telecommunications capability."

The CPUC has found that average measured speeds are not representative of a consumers' actual mobile experience. Rather than use the mean throughput, CPUC Staff's analysis quantifies expected speeds at varying probabilities by taking into account the distribution of throughput results around the mean in a single testing session. Thus, if the mean throughput is 10/3, one standard deviation below the mean indicates that a consumer will receive service at least as fast approximately 84% of the time.[18]

Similarly, CPUC Staff has calculated the throughput level represented by two standard deviations below the tested mean, indicating that a consumer will receive service at least that fast at a 98% confidence interval.[19]

For the purposes of determining whether a location has mobile service that meets the California Advanced Services Fund 6/1.5 speed benchmarks, the CPUC has begun to use an interpolation of CalSPEED measurements that lowers mean test results at each test point by two standard deviations. Only if that adjusted number is 6/1.5 Mbps or greater, is the area deemed to be "served," and thus ineligible for a grant. To do otherwise would be to foreclose grants in areas without fixed service and without adequate mobile service at "served" levels. The CPUC's

[18] Assuming a normal distribution of data, adopting a speed standard at either one or two standard deviations below the mean provides that available speeds meet or exceed the speed standard 84 or 98% of the time. Because test data is not normally distributed, the probability of availability will vary.

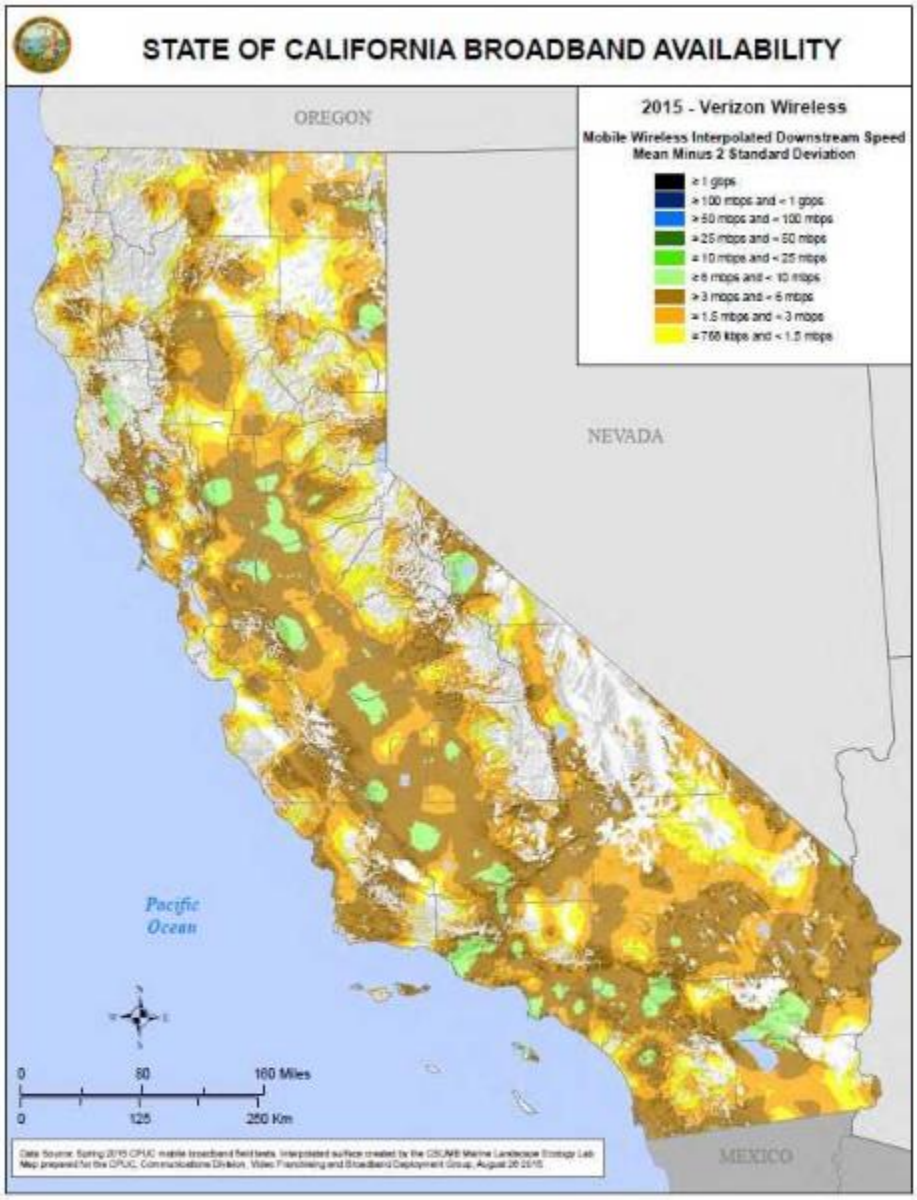
[19] *Id*. By way of comparison, initial FirstNet specifications require service to first responders to have at least 95% reliability.

approach thus requires mobile broadband not only to have acceptable speeds, but also for those speeds to be reliably and consistently available.

The following charts show the percentage of California's population and land area that is "served" by Verizon[20] at various downstream speed thresholds (6/1.5, 10/1 and 25/3) using both the -1 and -2 standard deviation adjustment method.[21] Areas shown in dark brown indicate downstream speeds between 3 and 6 megabits per second. Light green represents 6-10 megabits per second and dark green, 10-25 megabits per second. Notice the significant reduction in green area in the second map (adjusted downward by 2 standard deviations rather than 1).

[20] We illustrate Verizon results here, as Verizon has the largest LTE coverage area among the four national carriers. Maps and coverage percentages for the other three are included in Attachment 1.

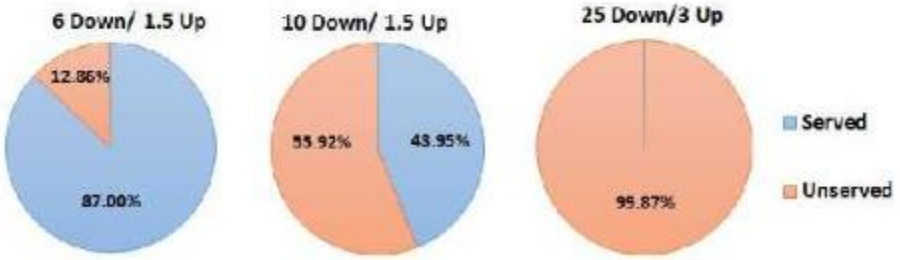
[21] Unlike the FCC, the CPUC uses the term "underserved" to represent service with "broadband" speeds (i.e., greater than dial-up speeds), but at speeds below the CPUC's "served" benchmark.


STATE OF CALIFORNIA BROADBAND AVAILABILITY
2015 - Verizon Wireless
Mobile Wireless Interpolated Downstream Speed
Mean Minus 2 Standard Deviation
≥ 1 gbps
≥ 100 mbps and < 1 gbps
≥ 50 mbps and < 100 mbps
≥ 25 mbps and < 50 mbps
≥ 10 mbps and < 25 mbps
≥ 6 mbps and < 10 mbps
≥ 3 mbps and < 6 mbps
≥ 1.5 mbps and < 3 mbps
≥ 768 kbps and < 1.5 mbps
OREGON
NEVADA
MEXICO
Pacific Ocean
0
80
160 Miles
0
125
250 Km

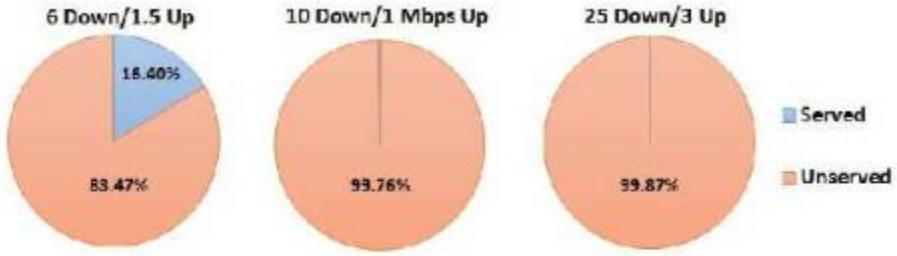
The first map shows Verizon downstream throughput when we lower the testing results by one standard deviation prior to the interpolation process. The second map shows Verizon's downstream throughput when we lower the mean test results by two standard deviations. The CPUC believes the two standard deviation adjustment approximates the consistency and reliability experienced by most consumers. If we were to assume a normal distribution, the two maps indicate that Verizon customers would receive service at, or in excess of, the indicated speeds approximately 84% and 98% of the time, respectively. Comparison of the map areas indicate that available speeds diminished as the probability of availability increased.

The pie charts below consider the fastest mobile service that is available by any of the four carriers in a given location, and show the percentage of population that have access to each of three benchmark speeds (25/3, 10/1 and 6/1.5). Practically none of the population in California is able to consistently receive mobile broadband service from any of the carriers at the 25/3 level when we adjust the mean downward by two standard deviations. Indeed, even when adjusting by only one standard deviation, speeds meeting the 25/3 benchmark are available to nearly none of the population.

**Percent Population with Mobile Access to Different Served Speed Thresholds Using Mean Minus 1 Standard Deviation**



**Percent Population with Mobile Access to Different Served Speed Thresholds Using Mean Minus 2 Standard Deviations**



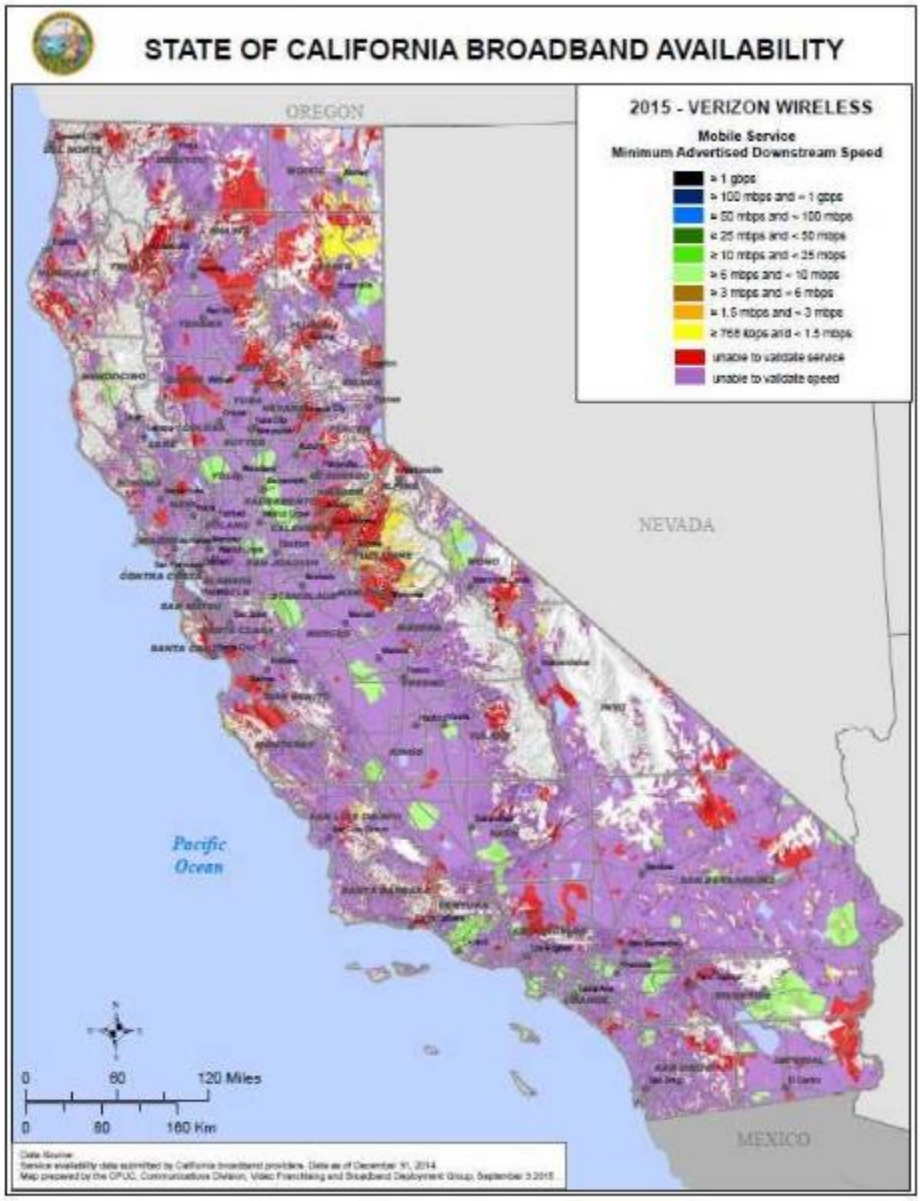

It does not seem likely that the FCC's requirement that carriers report their lowest average speeds on Form 477, as opposed to the NTIA's highest advertised speed reporting requirement, will yield sufficiently reliable results on which to base its policy decisions.

Under California's Digital Infrastructure and Video Competition Act[22], holders of state-issued video franchises (Holders) must report certain information to the CPUC annually, every April 1, for themselves and their affiliates. Holders are required to report the number of households they offer broadband and how many broadband subscribers they have. To satisfy this requirement, Holders submit to the CPUC the Form 477 broadband availability and broadband connection data for California that they file with the FCC. For Holders' April 1, 2015 annual filings, the CPUC received the most recent Form 477 data filed with the FCC. Those data are as-of December 30, 2014, and include data for AT&T Mobility and Verizon Wireless, since they are affiliates of state franchise Holders.

We have validated this lowest advertised speed data with our mobile test results with mean speeds lowered by two standard deviations. The resulting validation map for Verizon is shown below. Red areas are those where we were unable to validate the existence of service

[22] The Digital Infrastructure and Video Competition Act of 2006 (DIVCA), codified at California Public Utilities Code §§ 5800 *et seq*.

using our interpolated Fall 2014 mobile test results, and the purple areas are those where our field testing indicated there was service available, but interpolated mean minus two standard deviations values fell below reported lowest advertised speeds. We do not believe that the FCC's new approach to collecting mobile deployment data accurately portrays service speeds received on a consistent and reliable basis in California. Thus, the CPUC recommends that the FCC not yet make a determination on whether to take mobile service into account in determining whether advanced telecommunications service is being made available to all Americans on a reasonable and timely basis. The FCC should first determine a way to collect accurate and representative data on mobile broadband deployment.


STATE OF CALIFORNIA BROADBAND AVAILABILITY
2015 - VERIZON WIRELESS
Mobile Service
Minimum Advertised Downstream Speed
≥ 1 gbps
≥ 100 mbps and < 1 gbps
≥ 50 mbps and < 100 mbps
≥ 25 mbps and < 50 mbps
≥ 10 mbps and < 25 mbps
≥ 6 mbps and < 10 mbps
≥ 3 mbps and < 6 mbps
≥ 1.5 mbps and < 3 mbps
≥ 768 kbps and < 1.5 mbps
unable to validate service
unable to validate speed
OREGON
NEVADA
MEXICO
Pacific Ocean
0 60 120 Miles
0 60 160 Km

### 2. Fixed Service

The NOI proposes to retain the 25 Mbps/3 Mbps speed benchmark for fixed terrestrial broadband services. Unlike mobile service where the CPUC has determined that testing yields a more accurate picture of mobile service speed and quality than relying on carrier-submitted data, the CPUC does not yet have a data set of actual measured speeds for fixed services. The FCC, however, has done fixed testing with its SamKnows program, and has concluded that carrier-reported highest advertised speeds closely reflect their test results. The CPUC has now completed development of a testing app for fixed services, called CalSPEED.org, and expects to be able to perform its own comparison of submitted and measured data in the future. While we expect wireline service to be more consistent than mobile, we have no data yet on the amount of variation inherent in wireline service.

If poor backhaul and/or backbone arrangements may be responsible for poor rural/tribal mobile service, it is possible CalSPEED.org testing will show the same for wireline rural/tribal service.[23] If such is the case, and large variations within test sessions are present, it would be appropriate to use the same method of adjusting mean speeds downward, to make the results more representative of reality than using unadjusted mean speed test results.

## B. Quality of Service Benchmarks

The FCC seeks comment on whether it should include latency[24] and service consistency[25] in addition to speed as part of the basic criteria used in defining advanced telecommunications capability, and what those benchmarks should be. While the FCC's Tenth Broadband Progress

[23] Our testing for Spring 2015 was augmented to include recording trace route results from ping tests. Analysis of those results is expected to provide additional insight into the cause for the rural service problems identified in these comments.

[24] NOI, at ¶¶ 31-40. Latency is a measurement of the time it takes a packet of data to travel from one point in the network to another, and is typically measured by round-trip time in milliseconds (ms).

[25] NOI, at ¶¶ 41-46.

Report declined to set a benchmark for fixed broadband latency due to limited and poor quality data, it stated that collecting reliable data on latency should be a priority for the next Inquiry.[26] The following discussion addresses the CPUC's approach to quantifying service quality and reliability issues.

### 1. Applying Consistency Criteria to Mobile Broadband Service

As discussed above, the CPUC's preliminary analysis of Spring 2015 test results indicates improvements in some factors related to mobile broadband quality. The CPUC calculates an interpolated Mean Opinion Score (MOS) for each test point, which we find is a good proxy for overall quality of service to consumers.

While we have seen improvements in latency (likely due to improvements in backhaul and backbone service) for the carriers generally, rural/tribal areas still face a significant penalty in service quality and reliability. As shown earlier, TCP failure rate and estimated MOS are key quality indicators for mobile broadband deployment. An extensive gap in overall reliability (as reflected in dropped TCP connections) between urban and rural/tribal service remains. Rural/tribal consumers experience as many as 3 to 4 times the number of dropped connections than urban users do. This difference in quality and reliability between urban and rural/tribal areas raises serious concerns about whether advanced mobile capabilities are being deployed to all Americans in a timely fashion in California.

The FCC should adopt the CPUC's methods of determining quality and reliability – TCP failure rate and estimated Mean Opinion Score (MOS).[27] A method of determining the quality of

[26] NOI, at ¶ 33, citing 2015 Broadband Progress Report at ¶ 75.

[27] MOS is a mathematical calculation of users' subjective judgement of whether voice service is acceptable. MOS takes into account jitter and other metrics of whether the underlying broadband service is stable enough to provide good quality (Over the Top) VoIP service.

streaming video service should be included as well (e.g., CPUC Staff is creating a MOS equivalent for video streaming quality, which we are in the process of building into our testing and evaluation.)

### 2. Applying Consistency Criteria to Fixed Broadband Service

The NOI seeks information about whether the FCC should develop benchmarks for quality of service, including latency and consistency (reliability) for fixed broadband service, as well as mobile, as part of its definition of advanced telecommunications capability.

The same metrics as used in the mobile CalSPEED app and analysis should be applied to fixed service. The CPUC's online tool, CalSPEED.org, measures these factors for fixed service. It mirrors the testing protocol used to measure mobile performance in CalSPEED.[28] The CPUC has previously submitted comments to the FCC regarding fixed broadband testing considerations, and incorporates those comments by reference here.[29]

CalSPEED.org can be used to determine whether Connect America Fund (CAF) supported broadband grantees deliver on the technical requirements of their grant, i.e., that they actually deliver speeds of at least 10/1.

## III. CONCLUSION

The CPUC appreciates this opportunity to share our testing methodologies and other information with the Commission, and we urge the FCC to consider the metrics and testing methodologies we have cited here in developing criteria and benchmarks for assessing consumer broadband. Furthermore, while we urge the FCC to include latency and consistency as part of

[28] The CPUC, however, has not yet had the opportunity to analyze CalSPEED.org results, as the tool has just recently been released.

[29] *See* Comments of the California Public Utilities Commission, *Inquiry Concerning Proposed Methodology for Connect American High-Cost Universal Service Support Recipients to Measure Speed and Latency Performance to Fixed Locations,* (WC Docket No. 10-90, ( DA 14-1499), filed Dec. 22, 2014.

the criteria defining "advanced telecommunications capability," until the FCC adopts standards and benchmarks for mobile broadband technology it should delay including mobile service in its definition of "advanced telecommunications capability".

Respectfully submitted,

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Attorney for the
California Public Utilities Commission

September 15, 2015

# ATTACHMENT C

# CalSPEED: California Mobile Broadband - An Assessment - Fall 2014

***Ken Biba***
***Managing Director and CTO***
***Novarum, Inc.***

This paper examines the key findings of the first six measurement rounds of CalSPEED covering three years of measurement between Spring 2012 and Fall 2014. CalSPEED is the open source, mobile broadband measurement tool and methodology of the California Public Utilities Commission. This is an update thru Fall 2104 collected. The data reinforce the findings of that previous report and extend the foundation for five key incremental findings.

- Mobile broadband's overall performance and quality has stopped improving and shows signs of degradation.
- Mobile broadband continues trends of wide variation across California among carriers, locations of services, the growing digital divide between urban and rural,
- Quality degradation is particularly noticeable in rural areas - in which quality metrics can be 2x worse than in urban.
- Penetration of rural LTE shows signs of stalling.
- There is substantial variation between user devices on the performance and quality of service.

## 1. Calibrating the Mobile Internet Experience

Each of us relies on the Internet to research school papers, find a job, find and buy new products, read the news and increasingly to entertain ourselves. The Internet is not only becoming our newspaper, but also our phone, radio and television. How we do our jobs, raise our families, educate ourselves and our children, interact as responsible citizens, and entertain ourselves are all influenced by the quality of the Internet service we obtain. And ever increasingly, that service is not on our desk, but in our hand wherever we go.

Knowing the quality of this service is a vital piece of our modern ecosystem much in the same way as we research the brand of car we drive or the type of house we own. With multiple mobile Internet providers, an independent third party assessment of this quality allows consumers and policy makers to make informed choices.

CalSPEED is an open source, non-proprietary, network performance measurement tool and methodology created for the California Public Utilities Commission with the original assistance via a grant from the National Telecommunications and Information Administration. CalSPEED is now funded by California. CalSPEED uses a methodology pioneered by Novarum. The software measurement system is created and maintained by a team at California State University Monterey Bay, led by Professors Sathya Narayanan and YoungJoon Byun. CalSPEED mapping and

measurement field operations are managed by the Geographic Information Center at California State University at Chico. Statisticians at CSU Monterey Bay assist the team with detailed geographic and statistical analysis of the dataset.

CalSPEED has now been in use in California for three years with six rounds of measurement over the entire state collecting over 10,000,000 measurements across California of the four major mobile broadband carriers: AT&T Mobility, Sprint, T-Mobile and Verizon Wireless. This paper does a deep analysis of the first six rounds of measurement. A previous paper analyzed the first five rounds of measurement[1]. The methodology has been rigorously analyzed with respect to other available mobile measurement tools[2].

This paper examines the incremental changes from the previous report extending thru the Fall of 2014.

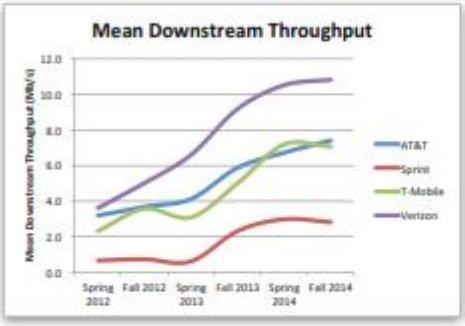
Let's examine what CalSPEED tells us about the state of mobile broadband in California.

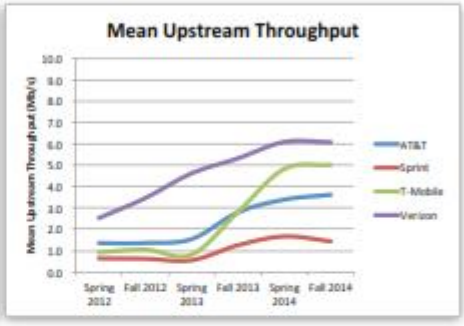
[1] Ken Biba, "Assessment of California Mobile Broadband Spring 2014", Novarum, September 2014.

[2] Ken Biba, "Comparison of CalSPEED, FCC and Ookla", Novarum, Inc., September 2014.

## 2. Wide Variation in Mobile Broadband Continues

The following graphs show a histogram of the measured TCP throughput across the sampled locations to both of the two geographic measurement servers. Much of the growth in average throughput has occurred by dramatic increases in the high performance tail of the distribution. A minority of locations get much better throughput, while the majority of locations have much more modest improvements in throughput. The wide variation in delivered throughput across the entire sample set is apparent. For example, it is possible (though uncommon) to get a downstream throughput for Verizon to a local (West) server that is 50 Mbps even though the Verizon state-wide mean is 17.5 and the median is 13.8 Mbps.



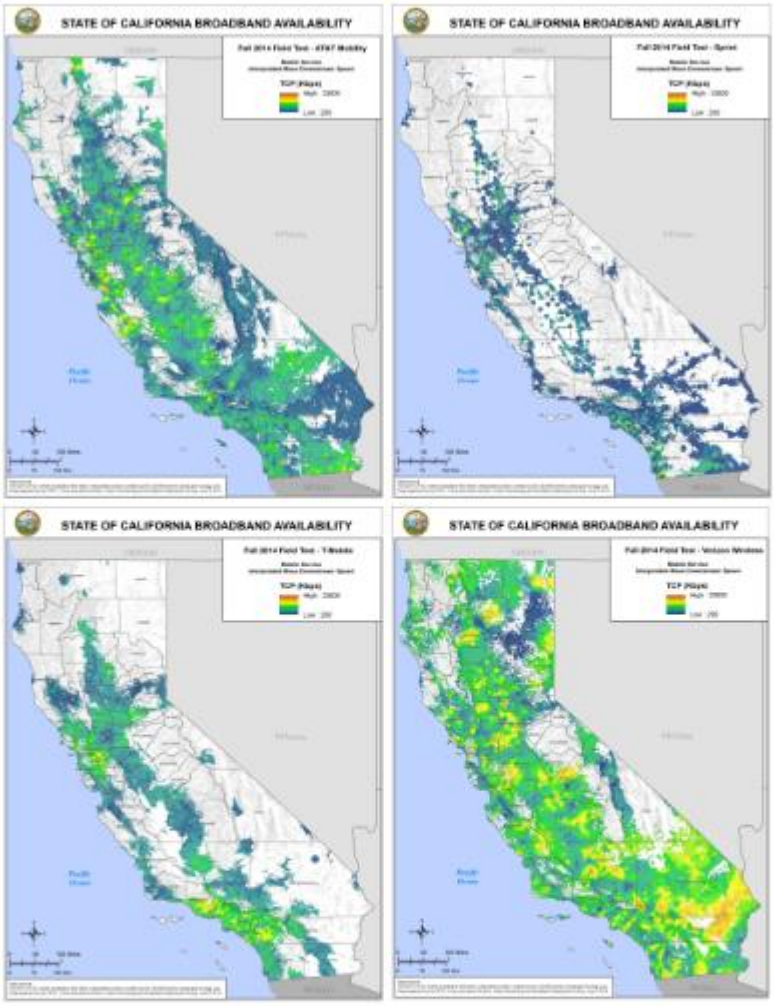




This variation in performance, echoed in other network metrics of upstream throughput, latency and jitter - is a composite of other, more fundamental variations. In order of importance these include:

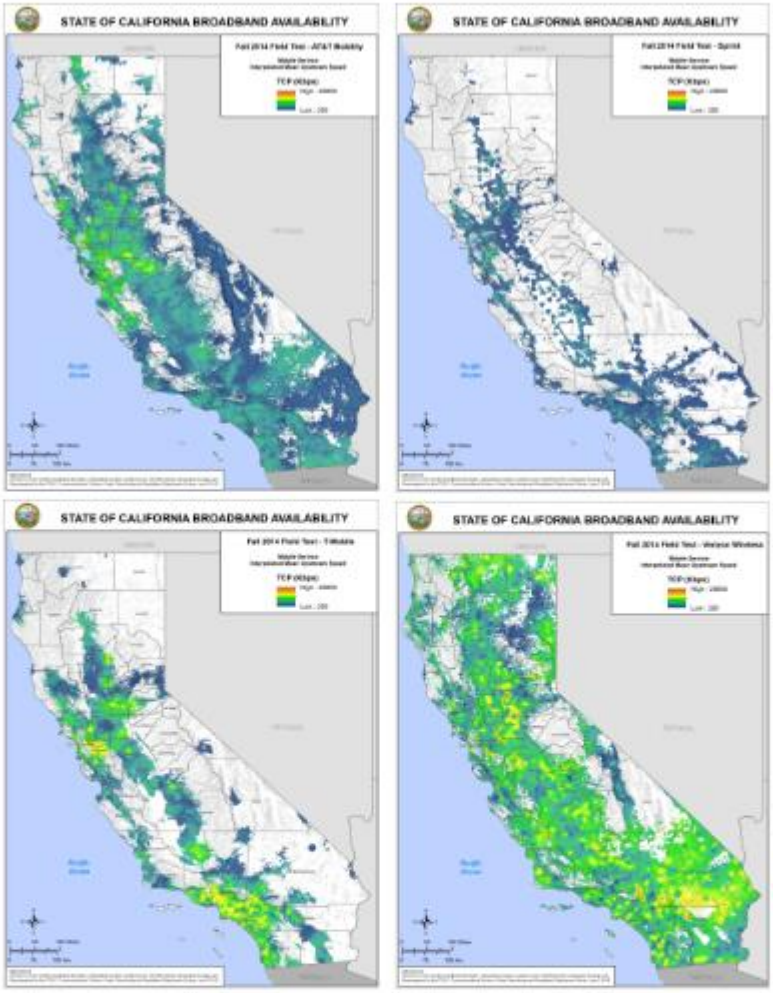
- Location of user within California
- Choice of carrier
- Location of used server on the Internet
- Session variation
- Time of day.

### 2.1 Location of the User

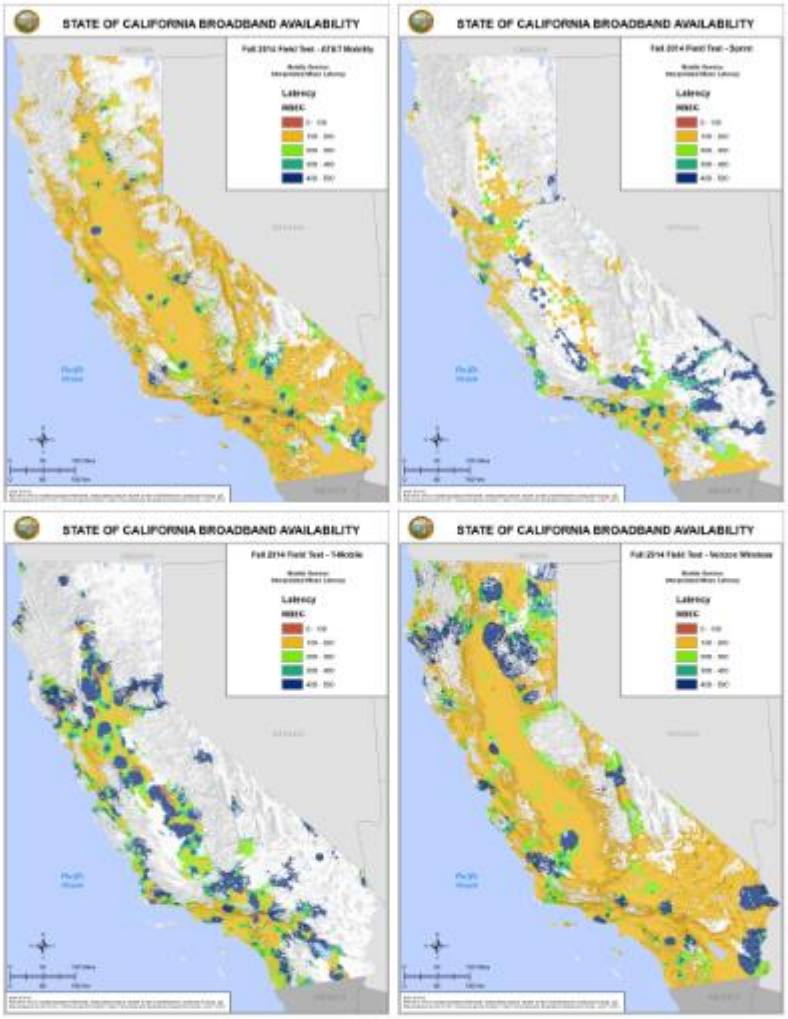
The most important variation is location within the state of the user. The following interpolated kriging maps for downstream throughput for the four carriers illustrate this variation. Depending on the carrier there is almost a 25:1 variation between mean TCP downstream performance based on where in the state the user is at the time of Internet access.



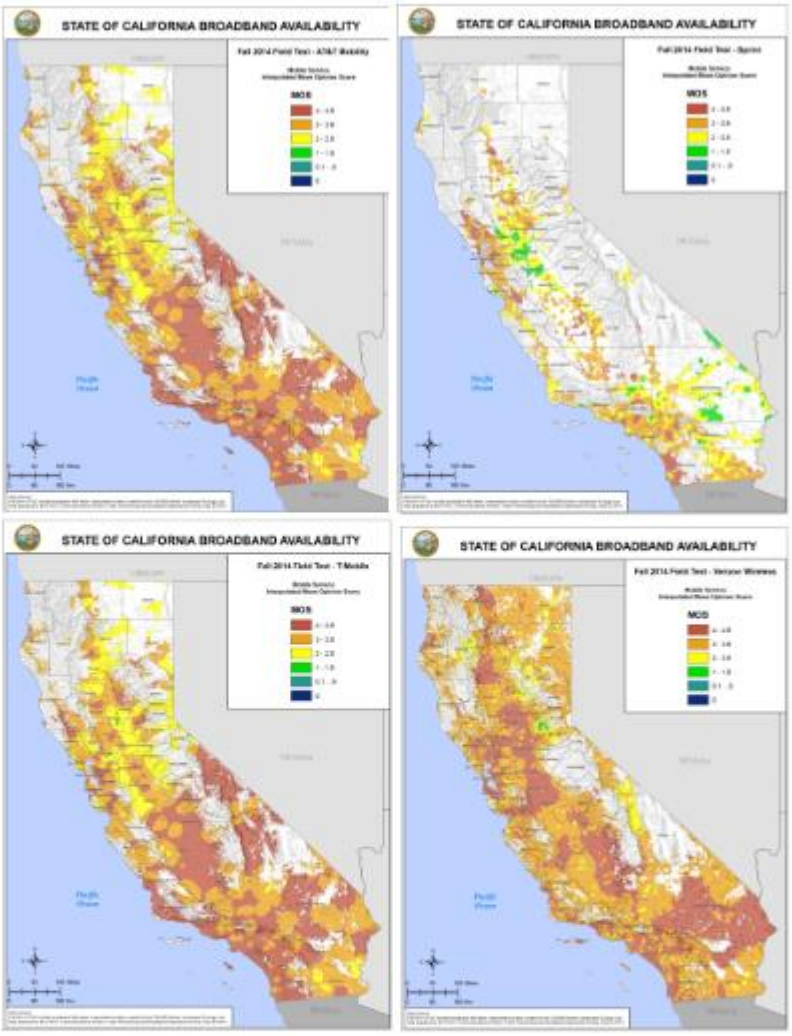

A similar variation exists for upstream TCP throughput.




And for latency.



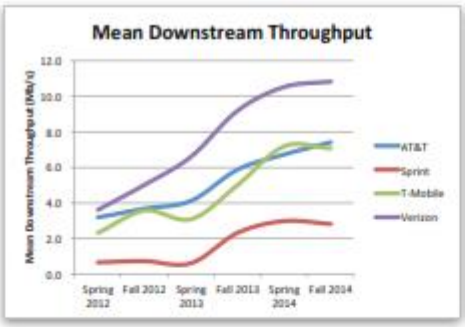

And for the integrated MOS metric, the wide variance across the state is easily seen.

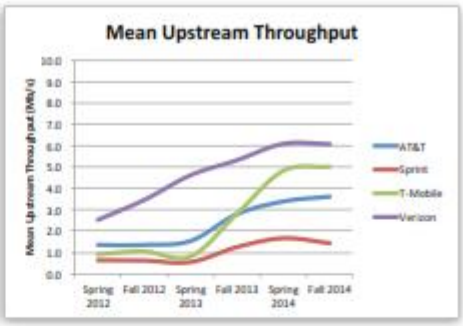



## 2.2 Choice of Carrier

There is a wide variation between the service delivered by each carrier. This variation is illustrated in the graphs below charting the overall mean downstream throughput for each carrier across the entire state. We can see a range of greater than 4:1 between the fastest and the slowest carriers

in both upstream and downstream throughput.

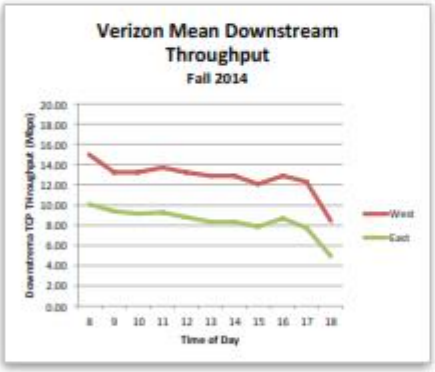



The coverage maps for throughput, latency and MOS in the previous section illustrate the wide variance between carriers in service in California.

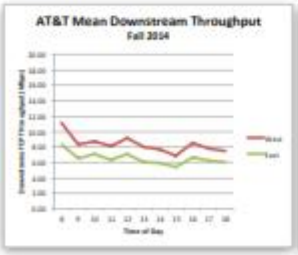
## 2.3 Location of the Service

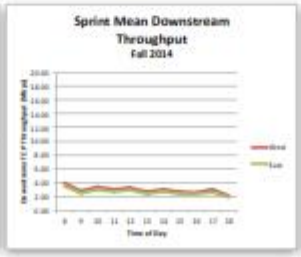
The Internet backbone, not just the local wireless access network, has significant impact on user performance. The graphs below illustrate the mean downstream TCP throughput to the West and East servers. The difference in mean throughput between the East and West servers is solely due to the impact of the Internet backbone connection strategy chosen by the carrier.

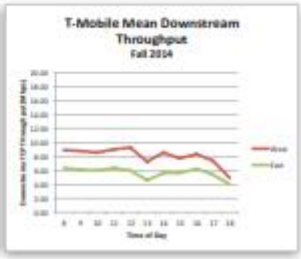



In Verizon's case in Fall 2014, this choice of backbone can result in about a 50% performance difference between a California user accessing a server on the East Coast vs a server in California.

The data suggest that the effects of server location get more pronounced as network performance increases as the data from the other three carriers suggest.



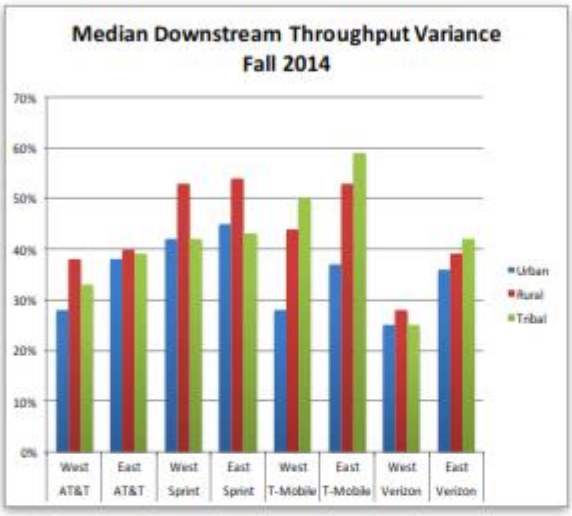




For Sprint, the lowest performing throughput carrier, there is almost no difference in performance

due to server location.

### 2.4 Intra-Session Variation

CalSPEED measures 40 separate TCP throughput measurements in both the upstream and downstream directions for each sample location, for each carrier over a period of about 30 minutes.



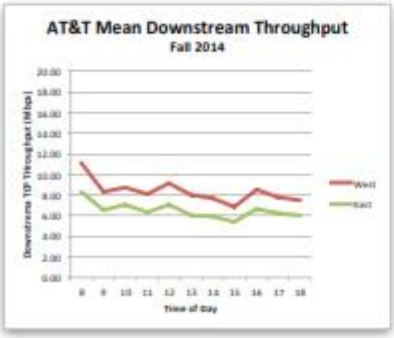

The CalSPEED analysis computes a standard deviation for the variation among these measurements for each test location - giving a metric for the variation in throughput during the duration of the measurement session. This local variation depends on carrier and location - as can be seen to the left charting median variance.

Some general trends can be noted:

- Rural and tribal see median variances higher than urban demographics; and
- backbone Internet contributes variance particularly for AT&T, T-Mobile and Verizon.

Variance during a session of between 25% and 50% can be considered typical.

### 2.5 Time of Day Variation




The least important variation is by time of day. Each CalSPEED measurement records the time of day of the measurement. As the chart below demonstrates for AT&T for Fall 2014, the mean downstream throughput shows some variation with time of day, but the variation is on the order of 10% - much smaller than the other sources of variation.

All the carriers show a similar pattern of largely constant average throughput during the day, with a modest decrease from morning towards evening.

Our measurements are limited by our choice to only collect data during daylight hours in consideration of the safety of our field teams.

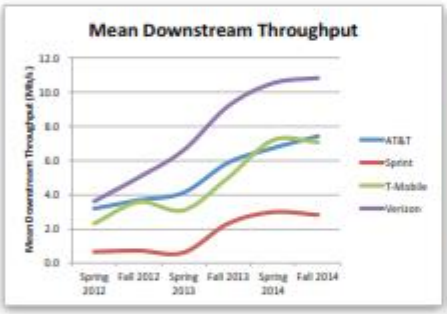
## 3. Mobile Broadband Has Stopped Improving

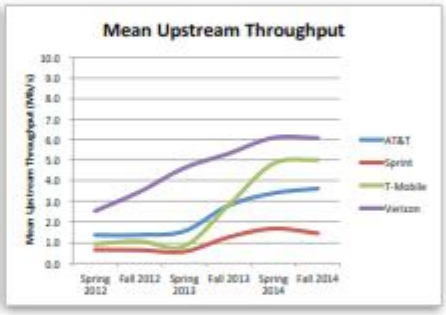
CalSPEED was designed to support comparison over time of network performance. We have tracked four major trends over time: changes in throughput, latency, jitter and service quality. The Fall 2014 data suggests that the capacity and quality of mobile broadband has (at least) stopped improving.

A speculation on this pause in mobile performance improvement might be mobile offered load catching up to network capacity. When offered load approaches or exceeds network capacity, measured performance will stop improving and might begin to degrade if additional capacity is not brought online.

### 3.1 Throughput

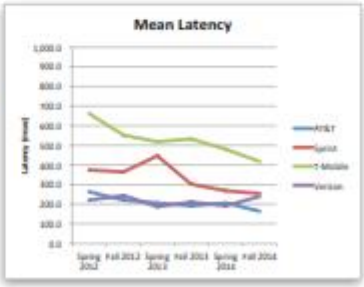
One straightforward summary measurement is the mean across all measurement locations, for both user devices[3] and geographic measurement servers of the downstream and upstream TCP throughput. The following chart documents the change in upstream and downstream TCP throughput by carrier.




Note that since the last measurement round in the Spring of 2014, performance increase has stalled in the case of Verizon downstream and T-Mobile upstream, decreased in the cases of Verizon upstream, T-Mobile downstream, Sprint downstream and upstream and continued to improve for AT&T downstream and upstream.

### 3.2 Latency




The analysis of overall average latency for each of the carriers shows a similar mixed story as noted for throughput.

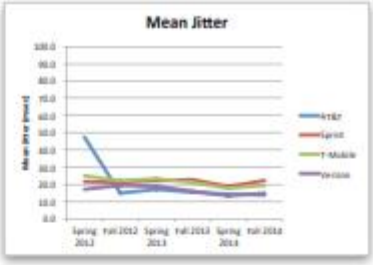
The historic trend has been for decreasing latency over time. Since the Spring of 2014 however, Verizon's latency has increased while AT&T, T-Mobile

[3] There is a difference between user devices, but it appears to be unique to each device - not structural by technology or carrier. Not all user devices perform equally well.

and Sprint continued trends of decreasing latency.

### 3.3 Jitter

Jitter, with the exception of AT&T, has degraded since Spring 2014.



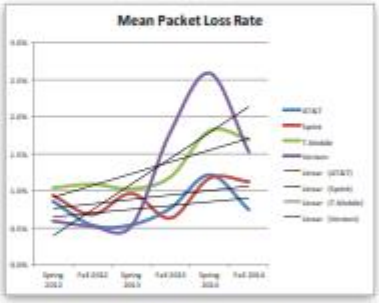

### 3.4 Service Quality

CalSPEED has several metrics of quality:

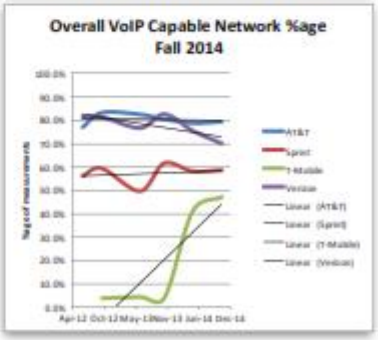
- overall rates of TCP connection failures (percentage of failed TCP connections)
- packet loss; and
- MOS (VoIP Mean Opinion Score)

With the Fall 2014 survey, an overall increase in TCP connection failures can be seen for all carriers in California.

While packet loss rates for Fall 2014 improved for all carriers, a longer term trend towards increasing packet loss continues.



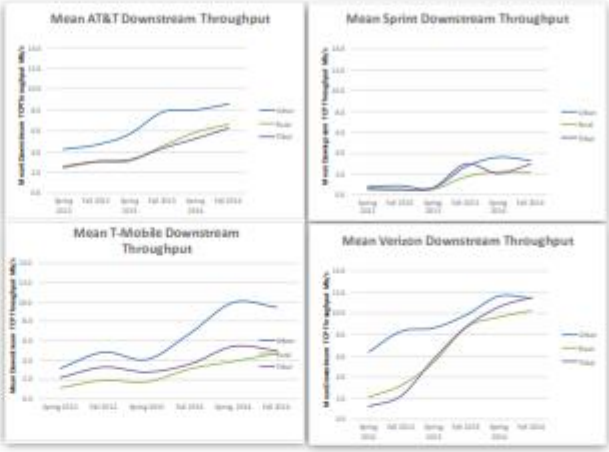

VoIP MOS is a leading indicator of network quality as it integrates packet latency, packet loss and jitter into one metric. While T-Mobile continues a dramatic trend towards increasing network quality, Sprint is stagnant and the two leading VoIP quality networks in California (AT&T and Verizon) show a continuing trend towards overall decreasing MOS quality.



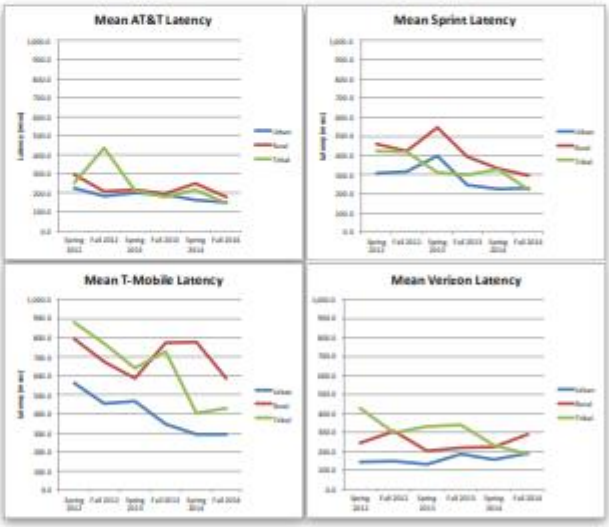
## 4. Rural Quality Continues to be Materially Lower than Urban

The digital divide between urban and rural continues as measured in Fall 2014.

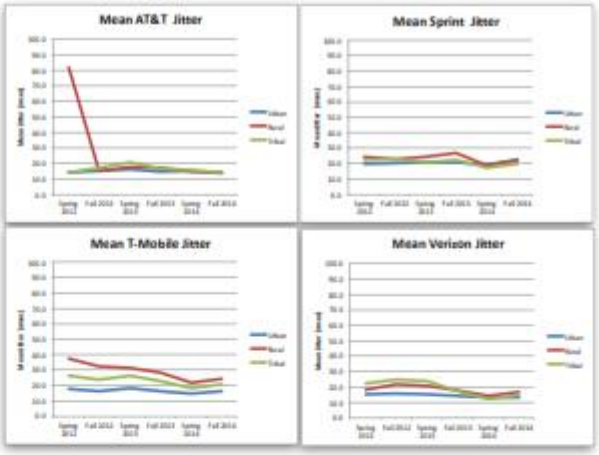
In the chart to the right we can see that the downstream throughput performance gap continues for all carriers between urban and rural demographics.



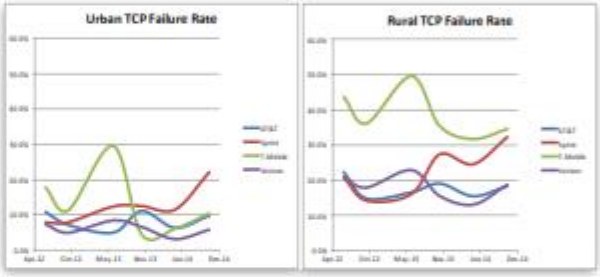

Similarly, latency for rural demographics continues to exceed urban latency for all carriers. For Verizon, the most extensive rural carrier, latency for both urban and rural users increased in Fall 2014.



For three of the four networks jitter degraded for rural users more than for urban users. For Verizon, jitter improved for urban users by about 2% but degraded for rural users by over 20%.




The overall rate of TCP connection failure has increased for all carriers in Fall 2014. However, the connection failure rate has increased more for rural users.

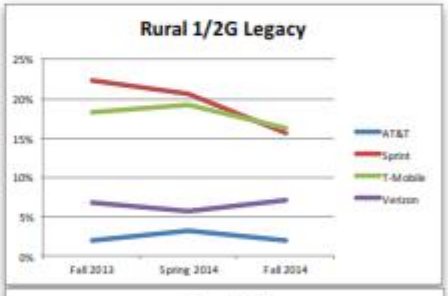


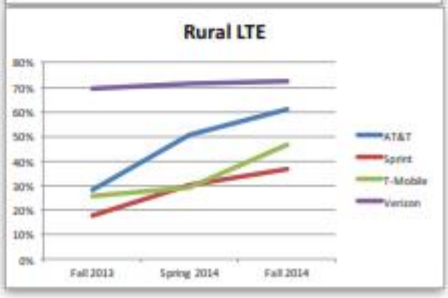

## 5. Rural Mobile Technology Deployment Slows

The pace of rural deployment of modern mobile access technology appears to be peaking in California. In the chart to the right, we can see that the percentage of sample locations with 1G or 2G service has stabilized for Verizon (~7%) and for AT&T (~2%) while still high and decreasing for the less deployed networks of Sprint (~16%) and T-Mobile (~17%).

Similarly, the percentage of rural sample locations indicating LTE service has stabilized for Verizon at ~72% while still improving for AT&T (~60%), Sprint (~36%) and T-Mobile (~47%).

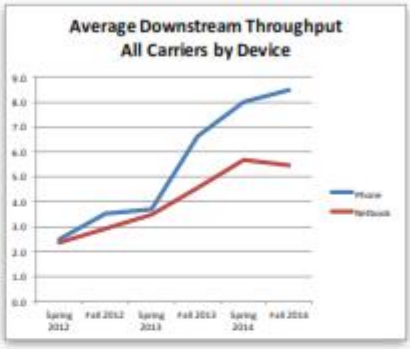
These trends suggest that legacy mobile access technology will remain in a minority of locations while LTE deployment will level out without being deployed completely throughout the state.



## 6. User Device Variation can be VERY Wide

User network experience varies with the specific device used for connection to the network. CalSPEED has used both an Android smartphone and a Windows laptop with a USB modem for each carrier to give some sense of the diversity of user experience.



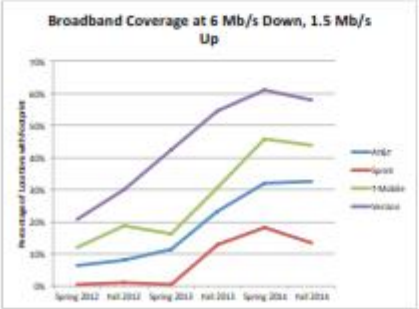

Looking at all carriers, we can see that for the first 18 months of the CalSPEED survey (thru Spring 2013) smartphones and USB modems were increasing in performance at similar rates. However, beginning in the Fall of 2013 and dramatically continuing through the Fall of 2014 smartphones have increased performance at a MUCH higher rate than USB modems - with smartphones now almost 2x the performance of USB modems - on average.

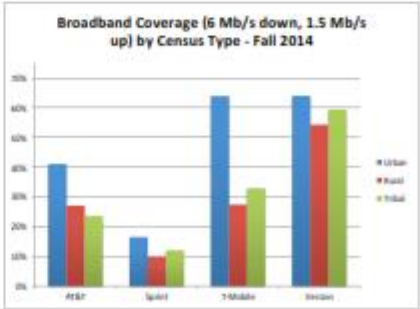
It is unclear as to the cause, other than to speculate that USB modems have fallen behind in technology upgrades - and now do not match the performance in the much more widely used smartphones.

Reflecting this divergence and decreasing market share of USB modems, CalSPEED will be changing devices beginning in Spring 2015 - replacing USB modems for laptops with tablets. We will retain phones as a constant across all survey periods.

## 7. Broadband Coverage Degrades

CalSPEED measures comparative coverage for each carrier's performance within the announced coverage area that meet current standards for broadband service. The chart to the left below documents the percentage of sample locations, within the announced footprint of each carrier, that meet or exceed the current California standard for sufficient broadband service - 6 Mbps downstream AND 1.5 Mbps upstream. Areas that do not meet this standard are eligible for

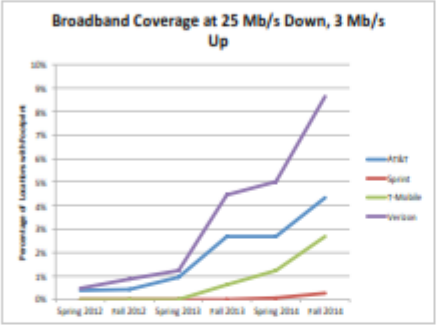


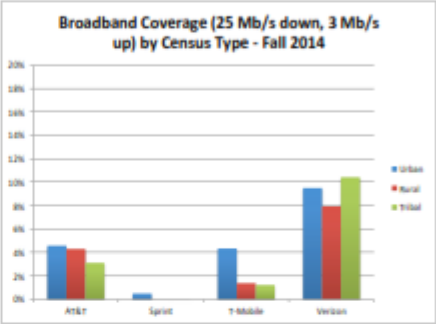




broadband infrastructure subsidies. Note the decrease in broadband coverage in Fall 2014 for

Verizon, T-Mobile and Sprint. The chart to the right breaks down the Fall 2014 survey by demographic area. We can see that for all carriers, a higher percentage of urban locations meet the 6/1.5 Mbps standard than do rural locations.

The FCC has determined the federal standard for broadband as 25 Mbps down and 3 Mbps up. The following chart documents the percentage of sample locations in Fall 2014 that meet that federal standard - under 10% for the best carrier Verizon and well under 1% for the lowest quality carrier - Sprint.




## 10. Conclusions

This paper has examined the key findings of the sixth measurement rounds of CalSPEED covering 36 months of measurement between Spring 2012 and Fall 2014. There have been rapid changes during that time and the data provide a solid foundation for five key incremental findings since the Spring of 2014 analysis.

- Mobile broadband's overall performance and quality has stopped improving and shows signs of degradation.
- Mobile broadband continues trends of wide variation across California among carriers, locations of services, the growing digital divide between urban and rural,
- Quality degradation is particularly noticeable in rural areas - in which quality metrics can be 2x worse than in urban demographics.
- Penetration of rural LTE shows signs of stalling.
- There is substantial variation between user devices on the performance and quality of service.

## Appendix A: CalSPEED: Capturing the End to End User Experience

### How CalSPEED Measures

CalSPEED performs the following sequence of measurements to gather its information:

1. ICMP ping to the West server for four seconds for connectivity checking. If the ICMP ping fails, CalSPEED presumes that there is no effective connectivity to the Internet and records that result.
2. iPerf TCP test (4 parallel flows) to the West server - both downstream and upstream. CalSPEED uses four parallel flows to ensure that the maximum capacity is measured during the test.
3. ICMP ping to the West server for 10 seconds to measure latency to the West server.
4. UDP test to the West server. CalSPEED constructs a UDP stream of 220 byte packets to emulate a VoIP connection with 88kb/s throughput. This UDP stream is used to measure packet loss, latency and jitter.
5. iPerf TCP test (4 parallel flows) to the East server to measure downstream and upstream TCP throughput.
6. ICMP ping to the east server for 10 seconds to measure latency to the East server.
7. UDP test to the East server to measure packet loss, latency and jitter with a simulated VoIP data stream.

CalSPEED uses two identical measurement servers on the opposite ends of the US Internet. One hosted in the Amazon AWS near San Jose, CA and for many California users has performance like a CDN server. The second measurement server is in the Amazon AWS in Northern Virginia.

CalSPEED uses two device measurements - a current smartphone and current USB datastick for laptops. Both are upgraded for each measurement round to match the latest wireless technology deployed by each carrier.

***Open Source.*** CalSPEED is an open source network performance measurement tool that is in turn based on an industry standard open source performance measurement tool - iPerf[4]. iPerf provides the foundation network measurement engine for both the TCP and UDP protocols. CalSPEED packages this engine in both Windows and Android client tools for measuring and recording mobile network performance.

***End-to-End User Experience***. A foundation assumption of CalSPEED, uniquely among network measurement tools, is an attempt to replicate the end to end user experience. In particular, CalSPEED recognizes that the Internet resources that a typical user accesses are scattered across the entire Internet … and despite the use of content delivery networks to speed Internet performance by caching frequently accessed content, are not always "local" to the user. Many measurement tools focus on evaluating just the local radio access network - the last few miles - and not the backhaul network to the ultimate server resource used. CalSPEED instead tests the complete network path, from the client device, through the local access network, through the Internet backbone, to several ultimate server destinations.

[4] http://en.wikipedia.org/wiki/Iperf

CalSPEED emulates this user experience with two fixed servers - one physically located in Northern California and the other in Northern Virginia - both in the Amazon AWS cloud. CalSPEED reports performance both to each individual server and the average between them. Not only does this method measure the different local access methods, but provides a network interferometry that gives insight into the different backhaul strategies chosen by carriers. We find carrier unique 2:1 differences in end to end latency and jitter and material difference in upstream and downstream throughput between the two servers.

These differences in fundamental network performance illustrate that location matters - Internet performance delivered to the user - the Internet user experience - will vary based on where on the Internet the desired server is located. And desired servers are scattered across the Internet, not just close to every user. Measurement to a local server only results in an overly optimistic expectation of service quality than a typical user will actually experience.

CalSPEED measures a complete portfolio of network metrics including end-to-end packet latency, bidirectional TCP throughput, UDP packet loss and jitter.

***Just the Facts.*** CalSPEED does not filter any of its results - throughput, coverage, latency or other network metric - rather uses the results of all tests performed and recorded. We believe that just like the user experience with sometimes failing web page loading, all results are valid representing the user experience. Other testing systems filter results in a way that biases results to give a more optimistic expectation of network performance than a user will typically experience.

***Not Just for Crowds.*** Crowdsourcing is a fashionable method for collecting data at scale - but it has an inherent selection bias of only collecting data from where it is chosen to be used by those people who choose to use it. Where there is no crowd there is no data. And even where there is is data, it is biased towards who collected it, why, when and where.

CalSPEED has two complementary methods of testing - the first is a structured sampling program of 1986[5] measurement locations scattered throughout California (tribal, rural and urban) that are each periodically (every six months) visited and methodically measured with CalSPEED on both the latest Android phones and a USB network device on a Windows based netbook for each of the four major carriers. The use of multiple contemporary user devices gives a good snapshot of the best

[5] Originally 1200, but later increased to improve predictive precision of the interpolation models.

user experience.

The second method is the independent use of CalSPEED to provide crowdsourced data. The structured sampling program avoids selection bias of when and where measurements are made, giving a full map that covers the entire state, including places not often visited by smartphone users but having mobile broadband service. The crowd sourced data adds additional detail to areas where there are people who choose to use the test and adds additional detail about the range of the installed base of phones (particularly legacy mobile devices) and the performance those user devices are seeing. The structured measurement program uses the most current user devices available at the time of each round of field measurement and thus gives a snapshot of the latest deployed network technology. Older user devices, with older wireless technology still in use by many, will likely get slower performance in many locations.

Because CalSPEED samples all areas of California - urban (37%), rural (56%) and tribal (7%), analysis of its results explicitly measures the state's mobile digital divide.

***Maps for decision-makers not just for information.*** We then take the measurement data and create geospatial kriging[6] maps interpolating CalSPEED measurements of (but not limited to) latency, downstream and upstream throughput, jitter and packet loss over the entire state.

These maps can be overlaid with other geostatistical data on population, income, ethnicity, education, and census areas to provide more informed choices for consumers, businesses and governments. The CPUC web site uses this data to suggest what mobile service is available and at what performance at locations of the consumer's choice.

CalSPEED has now had six rounds of sampling California (Spring 2012, Fall 2012, Spring 2013, Fall 2013, Spring 2014, and Fall of 2014) and is shortly to finish a seventh round (Spring 2015). In each sampling round, we have surveyed the entire state and all four of the major wireless carriers - AT&T Mobility, Sprint, T-Mobile and Verizon Wireless.

[6] http://en.wikipedia.org/wiki/Kriging

## Appendix B: Terms

CalSPEED's kriging methodology creates maps plotting a number of mobile broadband metrics. The body of the paper included the maps for mean downstream TCP throughput, this appendix includes the maps for mean latency.

| Term | Definition |
|---|---|
| **Downstream** | The Internet direction from a server to a client. |
| **East Server** | Test server located on the East Coast in Northern Virginia |
| **Jitter** | The variation in end to end packet latency between user and server. |
| **Kriging** | A geostatistical technique for interpolating data from a sample set. |
| **Latency** | The end to end round trip delay for a single packet to traverse the Internet from user to server and back. |
| **MOS** | Mean Opinion Score. A measurement of VoIP quality |
| **Packet Loss** | The rate of loss of packet delivery end to end. |
| **TCP** | Transmission Control Protocol. The essential end to end protocol for the Internet that creates a reliable, sequentially delivered byte stream from a sequence of individual IP datagrams. |
| **TCP Connection Failure** | Each TCP connection requires a bidirectional packet handshake to initialize data flow. If the handshake cannot occur within a timeout period, the connection fails. The rate of failure measures the quality of the Internet connection. |
| **Throughput** | The number of bytes per second of user data communicated end to end. |
| **Upstream** | The Internet direction from a client to a server. |
| **VoIP** | Voice over Internet Protocol. Generic name for a family of IP based protocols to replace legacy circuit switched voice with packet based voice. |
| **West Server** | Test server located on the West Coast in the San Francisco Bay Area |

# ATTACHMENT D

# CalSPEED: California Mobile Broadband - An Assessment - Spring 2015

## *Quality vs Throughput*

***Ken Biba***[1]
***Managing Director and CTO***
***Novarum, Inc.***

This is an analysis of the Round 7 Spring 2015 dataset for CalSPEED. It shows substantial changes happening in the wireless broadband networks in California for all carriers.

- Major carriers are showing decreasing mean throughput. This slowdown in performance has been apparent for the last two measurement rounds and appears to be a trend. Detailed analysis suggests this is coming from throttling high performance results.
- Broadband coverage is decreasing for all carriers. For the 25 mbps downstream/3 Mbps upstream threshold, Verizon decreased from 16% coverage in fall of 2014 to 4% coverage in the spring of 2015.
- Many measures of quality (latency, jitter, TCP failures, mean packet loss) are improving for most carriers.
- Substantial improvement in estimated OTT MOS is apparent for digital voice service.
- Penetration of LTE in both urban and rural geographic categories appears to have peaked with a floor on 1/2G legacy replacement and on a cap on LTE deployment.
- The performance difference between East and West servers is decreasing suggesting material improvements in backhaul
- In recent rounds, USB modems were ~30% slower than the phones, in Round 7 the tablets (that replaced the USB modems) were about ~20% faster than the phones - reflecting dramatic performance differences between the USB modems and the tablets.
- Program change from using USB modems to tablets complicates the analysis. This paper is based on using the phone measurements alone. Tablets strongly outperform the legacy USB modems.

These trends, considered in aggregate, suggest wireless networks that are being managed more carefully to deliver higher quality of service, particularly for VoIP, at the price of decreased throughput. The stall in LTE deployment in both urban and rural geographic categories can only be speculated on.

[1] Ken Biba is a consultant to the CPUC's CalSPEED project. He was tasked with preparing this analysis of the Spring 2015 CalSPEED field test results. The content of, and conclusions reached in, this Report are Mr. Biba's own, and do not necessarily reflect those of the State of California, the CPUC, its Commissioners or its employees.

## 1. Calibrating the Mobile Internet Experience

Each of us relies on the Internet to research school papers, find a job, find and buy new products, read the news and increasingly to entertain ourselves. The Internet is not only becoming our newspaper, but also our phone, radio and television. How we do our jobs, raise our families, educate ourselves and our children, interact as responsible citizens, and entertain ourselves are all influenced by the quality of the Internet service we obtain. And ever increasingly, that service is not on our desk, but in our hand wherever we go.

Knowing the quality of this service is a vital piece of our modern ecosystem much in the same way as we research the brand of car we drive or the type of house we own. With multiple mobile Internet providers, an independent third party assessment of this quality allows consumers and policy makers to make informed choices.

CalSPEED is an open source, non-proprietary, network performance measurement tool and methodology created for the California Public Utilities Commission, funded originally via a grant from the National Telecommunications and Information Administration. CalSPEED is now funded through the California Advanced Services Fund. CalSPEED uses a methodology pioneered by Novarum. The software measurement system is created and maintained by a team at California State University Monterey Bay, led by Professors Sathya Narayanan and YoungJoon Byun. CalSPEED mapping and measurement field operations are managed by the Geographic Information Center at California State University at Chico. Statisticians at CSU Monterey Bay assist the team with detailed geographic and statistical analysis of the dataset.

CalSPEED has now been in use in California for three and a half years with seven rounds of measurement over the entire state collecting over 15,000,000 measurements across California of the four major mobile broadband carriers: AT&T Mobility, Sprint, T-Mobile and Verizon Wireless. This paper does a deep analysis of the first seven rounds of measurement. Previous papers have analyzed the first six rounds of measurement[2] [3]. The methodology has been rigorously analyzed with respect to other available mobile measurement tools[4].

This paper examines the incremental changes from the previous report extending thru the spring of 2015.

Let's examine what CalSPEED tells us about the state of mobile broadband in California after over three years of measurements in the same locations.

[2] Ken Biba, "Assessment of California Mobile Broadband Spring 2014", Novarum, September 2014.

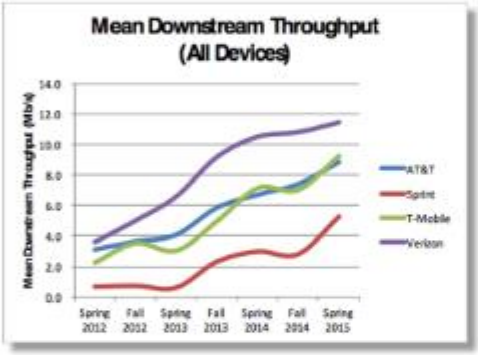
[3] Ken Biba, "Assessment of California Mobile Broadband Fall 2014", Novarum, June 2015.

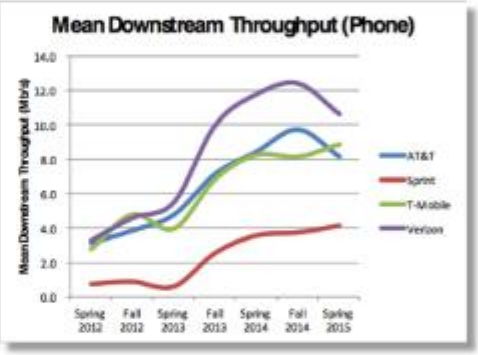
[4] Ken Biba, "Comparison of CalSPEED, FCC and Ookla", Novarum, Inc., September 2014.

## 2. Change in Devices

The CalSPEED program for spring 2015 replaced the USB modems that had been used along with Android smartphones with Android tablets. We replaced the USB modems because their performance had been decreased relative to the Android smartphones. We attributed this relative performance decrease to declining market share of USB modems and hence declining commercial support by the carriers to update their technology.

While most major overall trends are consistent, the tablets are clearly outperforming the USB modems and that changes the results for the combined device averages. It is thus imperative to do the comparative trend baseline analysis using only the smartphone data. Further, it is imperative for the integrity of the study going forward that each round use at least one device equipped with the latest cellular radio technology. The next version of LTE to be deployed in the U.S. is LTE Advanced, and we can anticipate the next measurement round to show material increases in throughput based on the improvement in the underlying wireless technology.




The graph on the left shows the mean (average) downstream throughput for both USB modems/tablet and smartphones devices. Prior to the spring of 2015 this was the average of a USB modem (and its attached Windows laptop) and an Android smartphone. From the spring of 2015, it is the average of an Android smartphone and an Android tablet. There is a clear trend towards ever increasing throughput.

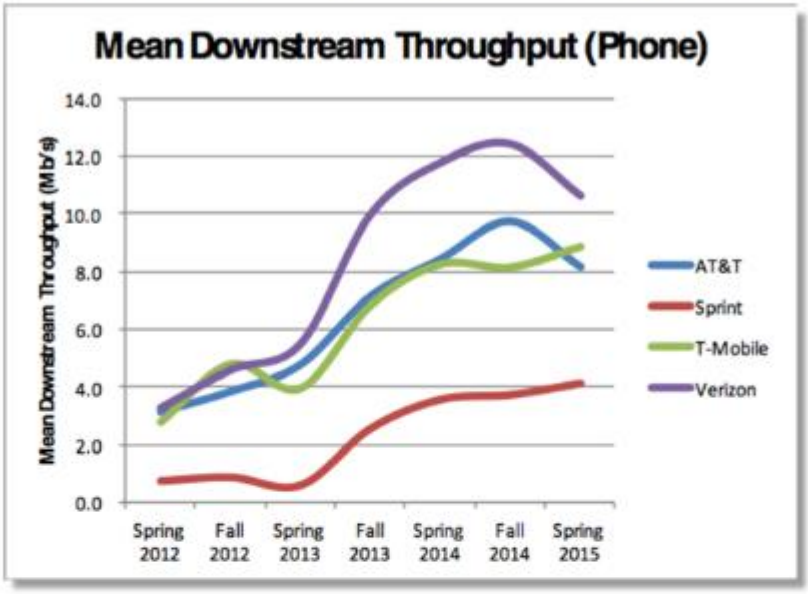
However, just looking at the Android smartphone data (the graph on the right) we see a very different story. While there is a clear trend towards increasing throughput across all carriers through spring 2014, there are clear trends that throughput performance peaked for all carriers subsequently and for the highest performing carriers – AT&T and Verizon – downstream throughput has actually decreased subsequently – and rather dramatically. Further, we can see that the lower throughput of the USB modems, brought the combined average down, particularly during the 2014 measurements.

Other analysis (see Section 8) will look more closely at the difference in performance among difference devices – smartphones, USB modems and tablets.

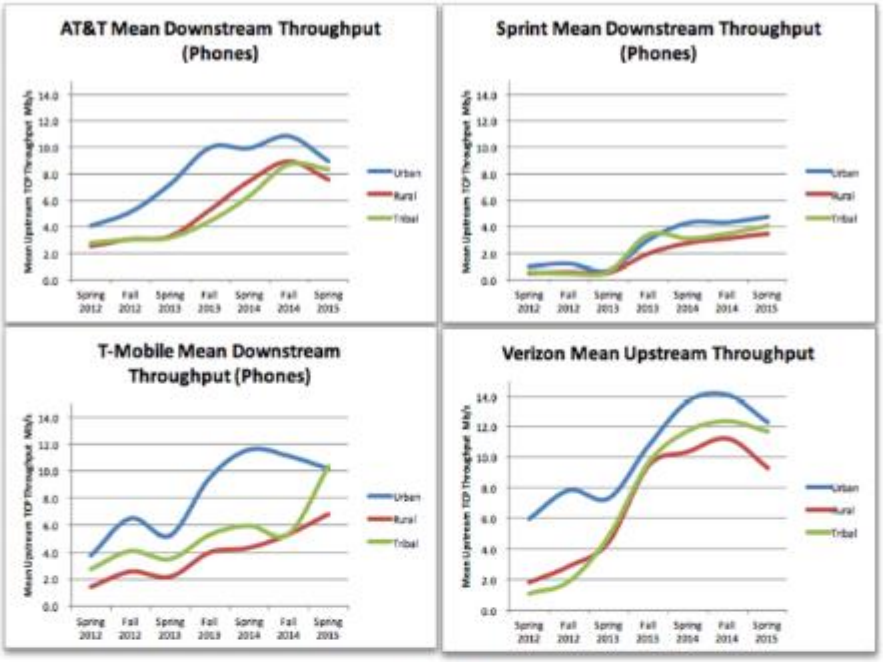
For the rest of this analysis we have chosen to look only at the smartphone data. We think it is more representative of the underlying trends.

## 3. Throughput Decreasing

AT&T and Verizon are showing clear decreases of ~15% in mean throughput for phones.



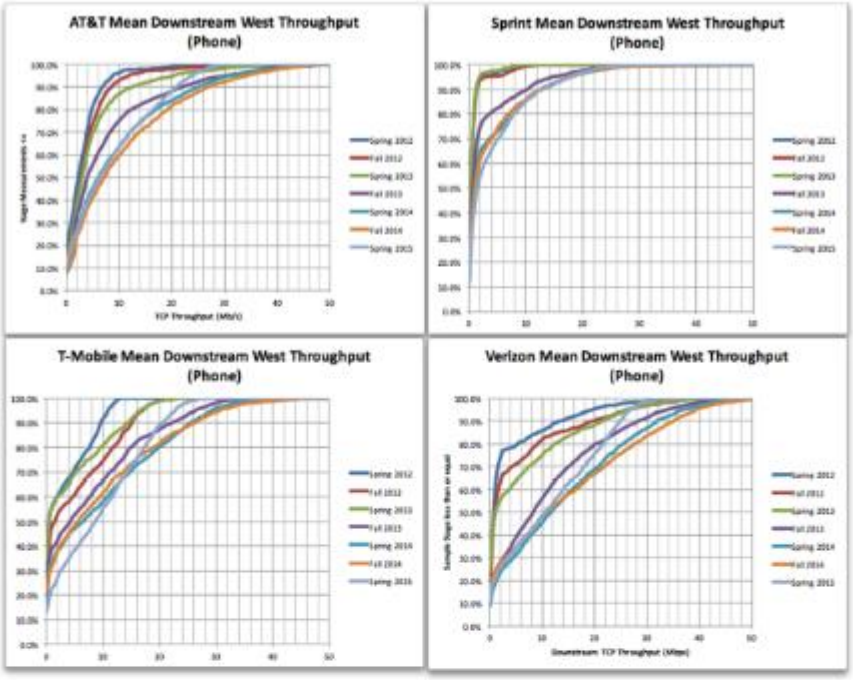

This trend of decreasing throughput appears not to be isolated to just one geographic category.. As the chart below demonstrates, for AT&T and Verizon, downstream throughput is decreasing in all geographic categories, stalled for Sprint in all geographic categories and dramatically decreasing in urban areas for T-Mobile.

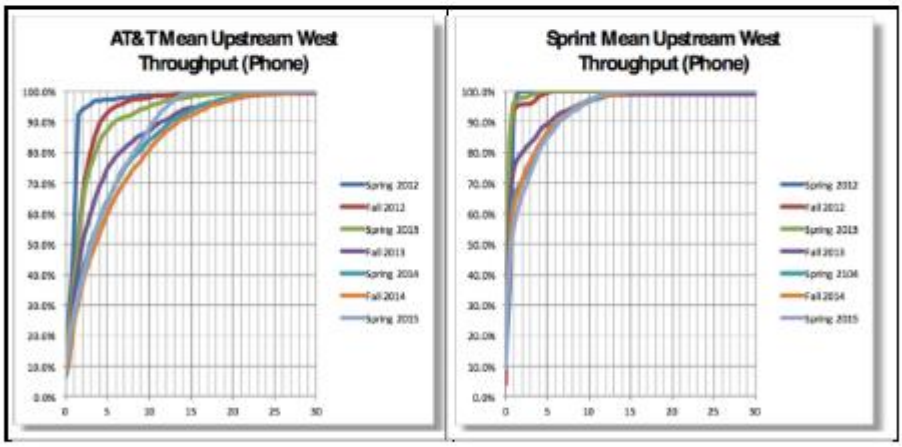


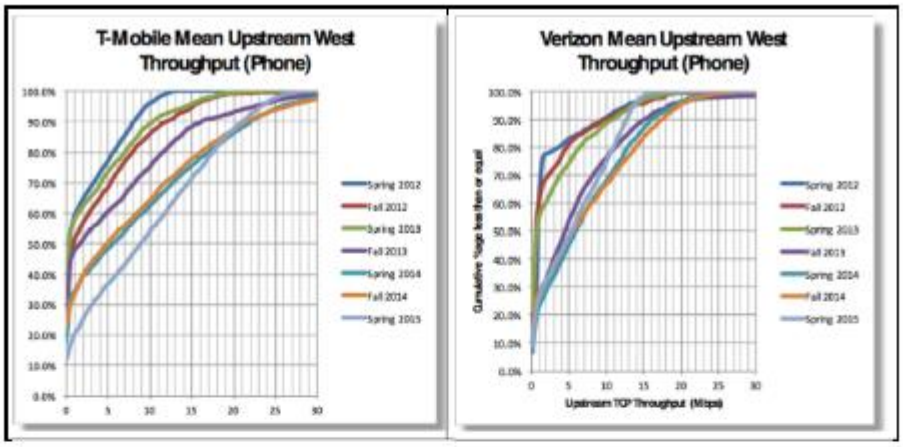

Below are the cumulative histograms of downstream throughput for phones. We can see a clear change in the distribution for spring 2015. In prior measurement rounds we can see the distribution, for every carrier, move further to the right with time – indicating more measurement locations with higher performance. For spring 2015 we can see a clear difference – across all carriers – of the distribution curve moving to the left (both downstream and upstream), documenting a change in the performance distribution towards lower speeds.

This suggests intentional filtering of high performance throughput results.

This decrease is reflected in the full histogram of samples for both downstream and upstream throughput - throttling high throughput both downstream and up.


AT&T Mean Downstream West Throughput (Phone)
Sprint Mean Downstream West Throughput (Phone)
T-Mobile Mean Downstream West Throughput (Phone)
Verizon Mean Downstream West Throughput (Phone)


AT&T Mean Upstream West Throughput (Phone)
Sprint Mean Upstream West Throughput (Phone)
Spring 2012
Fall 2012
Spring 2013
Fall 2013
Spring 2014
Fall 2014
Spring 2015

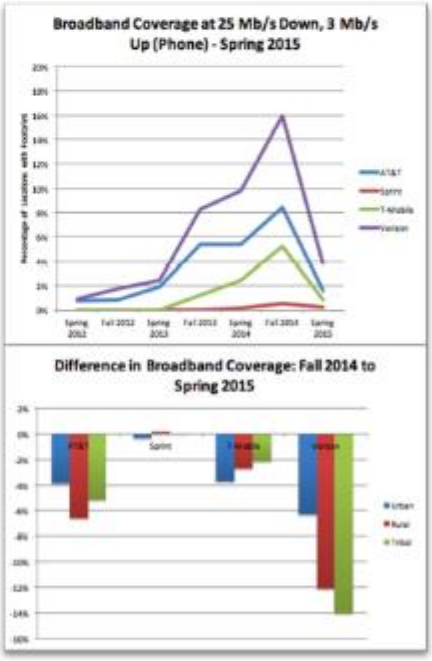



## 4. Broadband Coverage Decreasing

With decreasing mean throughput, statewide coverage at any given standard of throughput performance decreases.

Let's first look at the distribution of downstream performance, in particular the percentage of measurements that have downstream throughput greater than or equal to 25 Mb/s and upstream throughput greater than 3 Mb/s.. There is a dramatic decrease in the number of locations with high throughput – for all carriers.

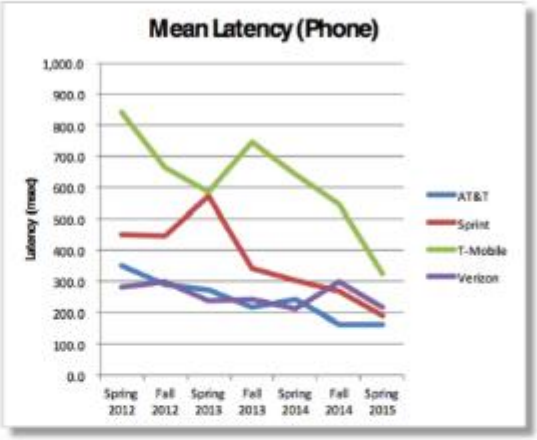
If we then look at the change in coverage - that is the change in the number of locations meeting the 25/3 threshold between fall 2014 and spring 2015 - we see dramatic decrease for all carriers and all demographics.



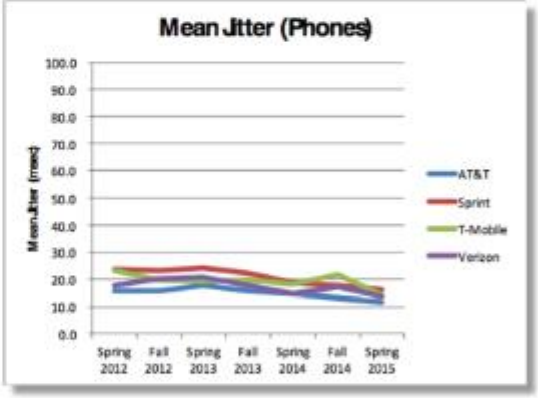
## 5. Many Measures of Service Quality Improve

Even while both mean throughput and the throughput distribution is decreasing (a suggestion of throttling of high throughput users), many measures of quality improved.

Mean latency improved for all carriers.

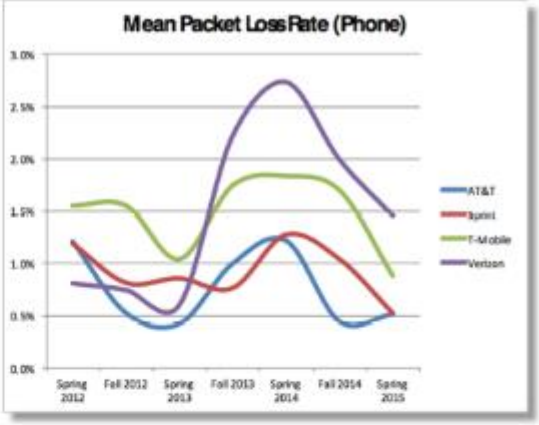



Mean jitter[5] improved for all carriers.

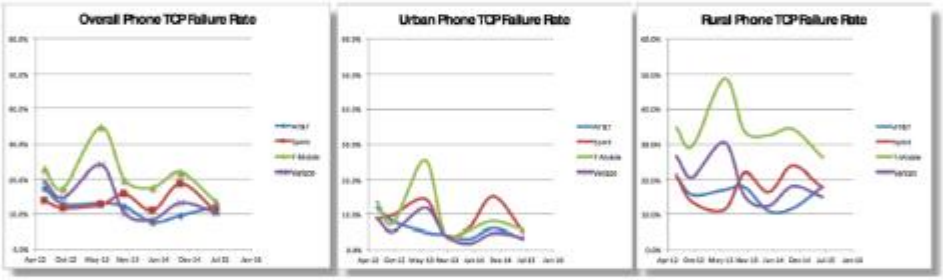



[5] Jitter is the measure of variation in latency. It is important component of performance for real time streaming of audio and video.

Mean packet loss[6] rates improved for all carriers.

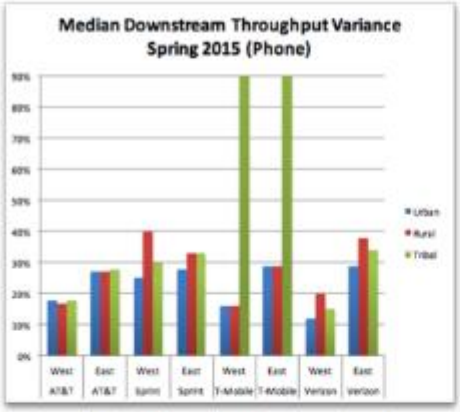


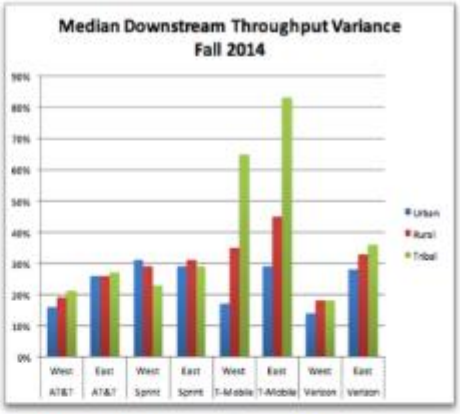

TCP quality[7], as measured by failed TCP connection attempts[8], slightly improved but there remain profound differences between urban and rural areas with rural users having an almost 400% higher TCP connection failure rate over urban users.



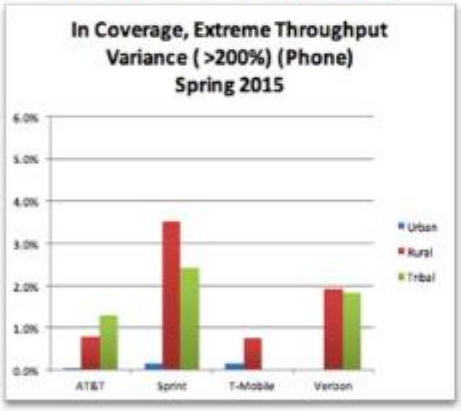

TCP quality, as measured by TCP throughput variation[9] did not show much improvement in the median variation. This is a measure of the standard deviation of throughput variation during TCP sessions.

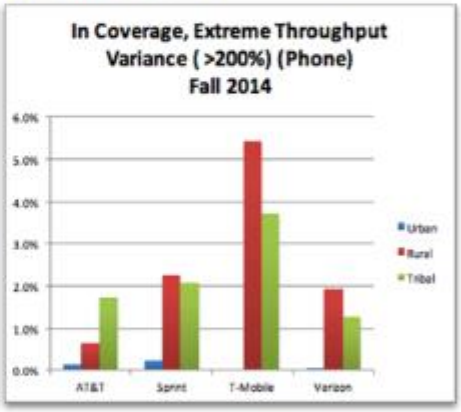
[6] Mean packet loss is the average percentage of packets that are lost during transmission. Small increases in packet loss are particularly degrading for streaming media services.
[7] The fundamental reliable connection service for the Internet is TCP - Transmission Control Protocol. It provides reliable delivery of an ordered stream of bytes and is the foundation service for web browsing, most streaming media services, email, IM and most other user Internet services. CalSPEED measures TCP quality in several ways: the failure rate of making a connection, and the consistency of the throughput during the connection - throughput variation.
[8] TCP connection failure is a measure of how often TCP attempts to make a connection between source and destination and succeeds or fails to make the connection. It is the Internet equivalent to how often, in making a phone call, the call fails to connect to the destination.
[9] TCP throughput variation measures how consistent throughput is during a connection - does it vary and by how much. A more consistent connection will deliver higher quality streaming media service.



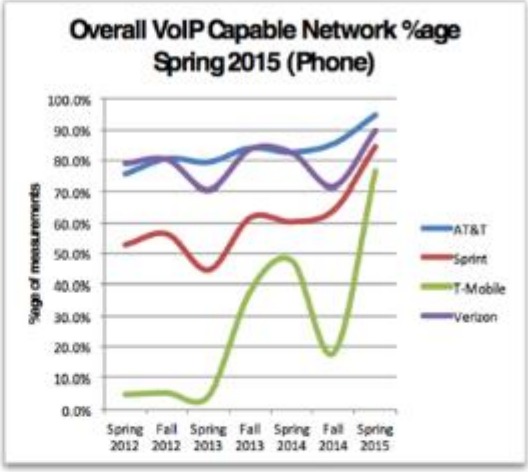

However, there is modest improvement on the very high end of variation. For connections with extreme throughput variations - where the standard deviation of throughput during a session is > 200% of the mean throughput - there are selective decreases in variability. A decrease in variability translates to a more consistent service particularly for streaming media. The biggest improvement in this metric came from T-Mobile. Modest improvements for AT&T rural and Verizon Tribal. Sprint showed modest increases in high variability connections in rural and tribal.



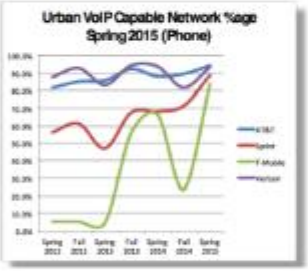



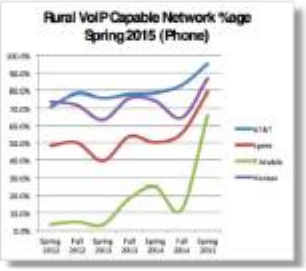
## 6. Estimated OTT MOS Improves

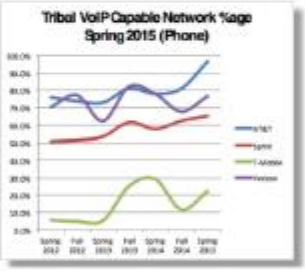
The improvement in underlying Internet quality metrics, particularly in latency, jitter and packet loss, means a substantial increase in the OTT MOS quality for all four carriers.




This improvement occurred in all geographic categories.

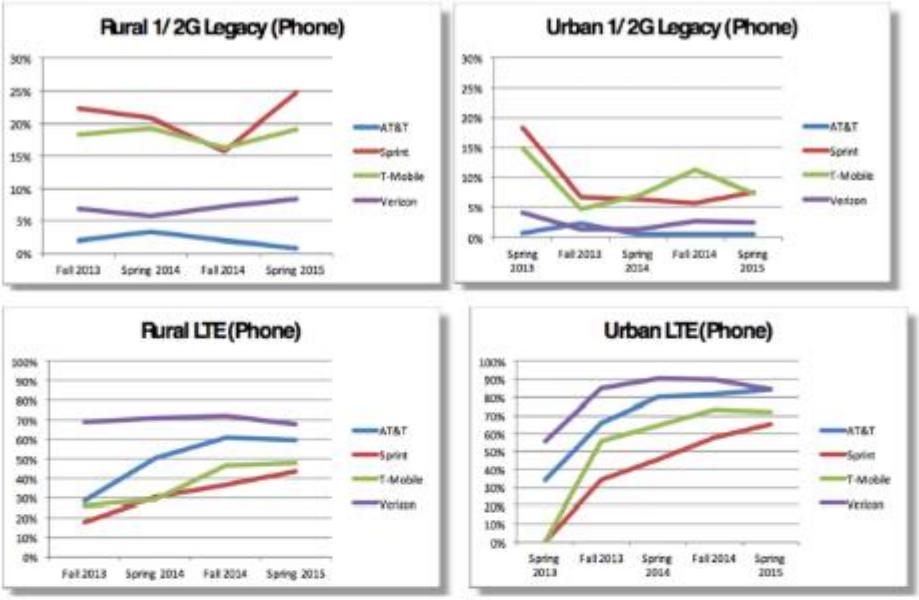



## 7. LTE Deployment Coverage Appears Capped

The deployment of LTE as well as the replacement of legacy 1G and 2G wireless access networks seems to be stabilizing - particularly for AT&T and Verizon. Sprint and T-Mobile appear to be still catching up with carriers that deployed LTE earlier and have greater rural footprints. There seems to be substantial stability with the percentage of measurements that still use 1G and 2G technologies – both in urban and rural areas.




As the charts above illustrate, legacy 1/2G technologies still represent as much as 20%+ of the measurements in rural areas for Sprint and T-Mobile and appear to have stabilized at ~7% for Verizon and ~2% for AT&T. The use of 1/2G technologies is only a third as frequent in urban areas decreasing to ~7% for spring and T-Mobile and ~2% for Verizon. These legacy technologies have substantial impact on user performance, with dramatically longer latencies and much slower throughput. VoIP services are impossible on these legacy networks and streaming video service unlikely to deliver acceptable quality.

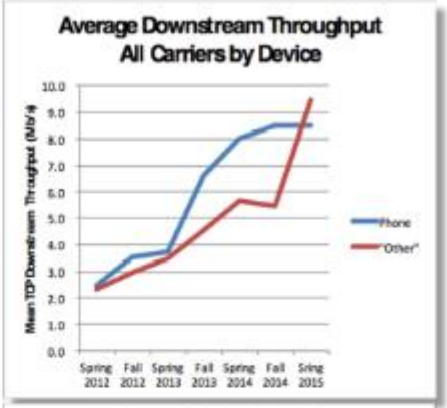
It also appears that the deployment of LTE has peaked in both rural and urban areas for AT&T, T-Mobile and Verizon. AT&T and Verizon both have peaked at about 85% in urban areas, and below 70% in rural. T-Mobile appears to have peaked at 70% in urban and below 50% in rural. Sprint continues to catch up.

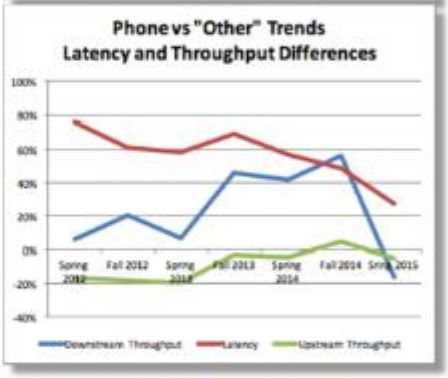
## 8. Dramatic Performance Difference Among Devices

CalSPEED has always included measurements from multiple devices, recognizing that user performance is a composite between the capabilities of the network and the capabilities of each individual user device. And while the network can enforce stringent standards on network service, there is a wide variation between different brands and models of user devices - even in the same year.

The most dramatic difference was between the USB modems (used through fall 2014) and the Android tablets that were introduced in spring 2015 (shown together as "Other" in the adjacent graphs). Thru spring 2013, USB modems and Android smartphones delivered very similar downstream speeds. Beginning in the fall 2013 survey, USB modem performance increased modestly, but were far outdistanced by the improvement in Android smartphones. But the fall 2014 survey, Android smartphones were over 50% faster than the USB modems.

With the upgrade to the Android tablet in spring 2015 - this difference in downstream throughput was erased.



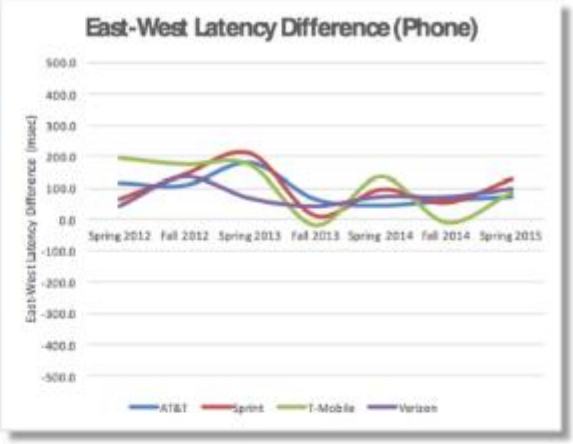

There remains a difference in latency - even with a common operating system between smartphones and tablets. In the spring 2015 survey, while the downstream throughput difference was small, tablets remained with a 30% latency deficit to smartphones.

Note that all devices for these surveys represent the latest wireless technology for each carrier. Older models of user devices, with older wireless technology, will show much more dramatic differences.

## 9. Performance Difference between East and West Servers Decreases

We measure performance not just to local servers in CalSPEED, we also measure performance to "distant" servers to get measure of how each carrier chooses to connect to the Internet. Since users will be accessing Internet resources located not just locally, but distributed around the U.S. and the world, how each carrier integrates the full Internet as well as local access is a key component of the wireless broadband experience. For these measurements - we have two test servers, one in the San Francisco Bay Area ("West") and one in northern Virginia ("East").

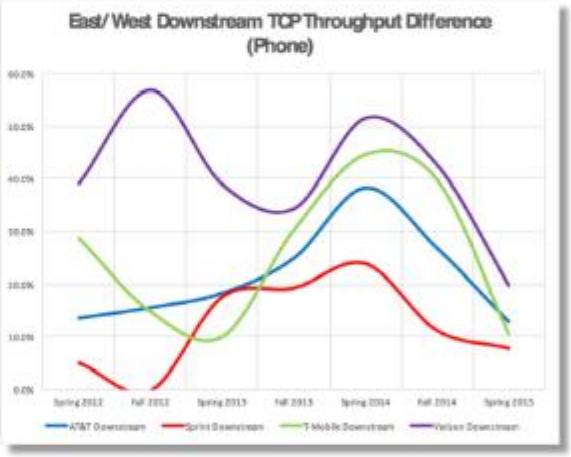
In the best possible time, the physics of data transmissions[10] adds about 80 msec of additional latency to get from one Coast to another - in addition to any local wireless access latency. Additional latency differences over 80 sec suggests carrier Internet routing choices for traffic between East and West. In the case where the latency difference between servers is zero, we speculate that traffic for both servers is peered through a geographically central location, such a Kansas, where the Internet distance to either the East coast server or the West coast server is essentially the same.




It is interesting to note that the latency difference between East and West servers has decreased over time - converging on 80 milliseconds. We speculate that each carrier is continuing to optimize its networks to deliver consistent performance throughout the Internet - regardless of the location of the content server.

TCP throughput is related to latency … the longer the latency, the smaller the throughput[11]. Historically, we have seen that downstream throughput from the East server to California clients is 10-50% less than throughput from the West server. The chart to the right illustrates this trend.

Note the recent (fall 2014 thru spring 2015) decrease in the difference and the convergence of all the carriers on just 10-20% difference between East and West Internet locations.




We speculate, consistent with the other metrics, that we are seeing a more mature, controlled Internet in which consistent performance is more valued than just pure throughput.

[10] Including the speed of light.
[11] A consequence of TCP's data reliability and congestion control mechanisms.

## 10. Conclusions

This is an analysis of the Round 7, spring 2015 dataset for CalSPEED. It shows substantial changes happening in the wireless broadband networks in California for all carriers.

- Major carriers are showing decreasing mean throughput. This slowdown in performance has been apparent for the last two measurement rounds and appears to be a trend. Detailed analysis suggests this is coming from throttling high performance results.
- Broadband coverage is decreasing for all carriers. For the 25 mbps downstream/3 Mbps upstream threshold, Verizon decreased from 16% coverage in fall of 2014 to 4% coverage in the spring of 2015.
- Many measures of quality (latency, jitter, TCP failures, mean packet loss) are improving for most carriers.
- Substantial improvement in estimated OTT MOS is apparent for digital voice service.
- Penetration of LTE in both urban and rural geographic categories appears to have peaked with a floor on 1/2G legacy replacement and on a cap on LTE deployment.
- The performance difference between East and West servers is decreasing suggesting material improvements in backhaul
- In recent rounds, USB modems were ~30% slower than the phones, in Round 7 the tablets (replacing the USB modems) were about ~20% faster than the phones - reflecting dramatic performance differences between the USB modems and the tablets.
- Program change from using USB modems to tablets complicates the analysis. This analysis is based on using the phone measurements alone. Tablets strongly outperform USB modems.

These trends, considered in aggregate, suggest wireless networks that are being managed more carefully to deliver higher quality of service, particularly for VoIP, at the price of decreased throughput. The stall in LTE deployment suggests maturing networks.

## Appendix A: CalSPEED: Capturing the End to End User Experience

### How CalSPEED Measures

CalSPEED performs the following sequence of measurements to gather its information:

1. ICMP ping to the West server for four seconds for connectivity checking. If the ICMP ping fails, CalSPEED presumes that there is no effective connectivity to the Internet and records that result.
2. iPerf TCP test (4 parallel flows) to the West server - both downstream and upstream. CalSPEED uses four parallel flows to ensure that the maximum capacity is measured during the test.
3. ICMP ping to the West server for 10 seconds to measure latency to the West server.
4. UDP test to the West server. CalSPEED constructs a UDP stream of 220 byte packets to emulate a VoIP connection with 88kb/s throughput. This UDP stream is used to measure packet loss, latency and jitter.
5. iPerf TCP test (4 parallel flows) to the East server to measure downstream and upstream TCP throughput.
6. ICMP ping to the east server for 10 seconds to measure latency to the East server.
7. UDP test to the East server to measure packet loss, latency and jitter with a simulated VoIP data stream.

CalSPEED uses two identical measurement servers on the opposite ends of the US Internet. One hosted in the Amazon AWS near San Jose, CA and for many California users has performance like a CDN server. The second measurement server is in the Amazon AWS in Northern Virginia.

CalSPEED uses two device measurements - a current Android smartphone and current Android tablet for laptops. Both are upgraded for each measurement round to match the latest wireless technology deployed by each carrier. Thru Round 6 (fall 2014), Windows laptops with USB modems were used in place of the tablets.

***Open Source.*** CalSPEED is an open source network performance measurement tool that is in turn based on an industry standard open source performance measurement tool - iPerf[12]. iPerf provides the foundation network measurement engine for both the TCP and UDP protocols. CalSPEED packages this engine in both Windows and Android client tools for measuring and recording mobile network performance.

***End-to-End User Experience***. A foundation assumption of CalSPEED, uniquely among network measurement tools, is an attempt to replicate the end to end user experience. In particular, CalSPEED recognizes that the Internet resources that a typical user accesses are scattered across the entire Internet … and despite the use of content delivery networks to speed Internet performance by caching frequently accessed content, are not always "local" to the user. Many measurement tools focus on evaluating just the local radio access network - the last few miles - and not the backhaul network to the ultimate server resource used. CalSPEED instead tests the

[12] http://en.wikipedia.org/wiki/Iperf

complete network path, from the client device, through the local access network, through the Internet backbone, to several ultimate server destinations.

CalSPEED emulates this user experience with two fixed servers - one physically located in Northern California and the other in Northern Virginia - both in the Amazon AWS cloud. CalSPEED reports performance both to each individual server and the average between them. Not only does this method measure the different local access methods, but provides a network interferometry that gives insight into the different backhaul strategies chosen by carriers. We find carrier unique 2:1 differences in end to end latency and jitter and material difference in upstream and downstream throughput between the two servers.

These differences in fundamental network performance illustrate that location matters - Internet performance delivered to the user - the Internet user experience - will vary based on where on the Internet the desired server is located. And desired servers are scattered across the Internet, not just close to every user. Measurement to a local server only results in an overly optimistic expectation of service quality than a typical user will actually experience.

CalSPEED measures a complete portfolio of network metrics including end-to-end packet latency, bidirectional TCP throughput, UDP packet loss and jitter.

***Just the Facts.*** CalSPEED does not filter any of its results - throughput, coverage, latency or other network metric - rather uses the results of all tests performed and recorded. We believe that just like the user experience with sometimes failing web page loading, all results are valid representing the user experience. Other testing systems filter results in a way that biases results to give a more optimistic expectation of network performance than a user will typically experience.

***Not Just for Crowds.*** Crowdsourcing is a fashionable method for collecting data at scale - but it has an inherent selection bias of only collecting data from where it is chosen to be used by those people who choose to use it. Where there is no crowd there is no data. And even where there is is data, it is biased towards who collected it, why, when and where.

CalSPEED has two complementary methods of testing - the first is a structured sampling program of 1986[13] measurement locations scattered throughout California (tribal, rural and urban) that are each periodically (every six months) visited and methodically measured with CalSPEED on both the latest Android phones and a USB network device on a Windows based netbook for each of the four major carriers. The use of multiple contemporary user devices gives a good snapshot of the best user experience.

[13] Originally 1200, but later increased to improve predictive precision of the interpolation models.

The second method is the independent use of CalSPEED to provide crowdsourced data. The structured sampling program avoids selection bias of when and where measurements are made, giving a full map that covers the entire state, including places not often visited by smartphone users but having mobile broadband service. The crowd sourced data adds additional detail to areas where there are people who choose to use the test and adds additional detail about the range of the installed base of phones (particularly legacy mobile devices) and the performance those user devices are seeing. The structured measurement program uses the most current user devices available at the time of each round of field measurement and thus gives a snapshot of the latest deployed network technology. Older user devices, with older wireless technology still in use by many, will likely get slower performance in many locations.

Because CalSPEED samples all areas of California - urban (37%), rural (56%) and tribal (7%), analysis of its results explicitly measures the state's mobile digital divide.

***Maps for decision-makers not just for information.*** We then take the measurement data and create geospatial kriging[14] maps interpolating CalSPEED measurements of (but not limited to) latency, downstream and upstream throughput, jitter and packet loss over the entire state.

These maps can be overlaid with other geostatistical data on population, income, ethnicity, education, and census areas to provide more informed choices for consumers, businesses and governments. The CPUC web site uses this data to suggest what mobile service is available and at what performance at locations of the consumer's choice.

CalSPEED has now had six rounds of sampling California (spring 2012, fall 2012, spring 2013, fall 2013, spring 2014, and fall of 2014) and is shortly to finish a seventh round (spring 2015). In each sampling round, we have surveyed the entire state and all four of the major wireless carriers - AT&T Mobility, Sprint, T-Mobile and Verizon Wireless.

[14] http://en.wikipedia.org/wiki/Kriging

## Appendix B: Terms

| Term | Definition |
|---|---|
| **Downstream** | The Internet direction from a server to a client. |
| **East Server** | Test server located on the East Coast in Northern Virginia |
| **Jitter** | The variation in end to end packet latency between user and server. |
| **Kriging** | A geostatistical technique for interpolating data from a sample set. |
| **Latency** | The end to end round trip delay for a single packet to traverse the Internet from user to server and back. |
| **MOS** | Mean Opinion Score. A measurement of VoIP quality |
| **Packet Loss** | The rate of loss of packet delivery end to end. |
| **TCP** | Transmission Control Protocol. The essential end to end protocol for the Internet that creates a reliable, sequentially delivered byte stream via a sequence of individual IP datagrams. |
| **TCP Connection Failure** | Each TCP connection requires a bidirectional packet handshake to initialize data flow. If the handshake cannot occur within a timeout period, the connection fails. The rate of failure is one measurement of the quality of the Internet connection. |
| **Throughput** | The number of bytes per second of user data communicated end to end. |
| **Upstream** | The Internet direction from a client to a server. |
| **VoIP** | Voice over Internet Protocol. Generic name for a family of IP based protocols to replace legacy circuit switched voice with packet based voice. |
| **West Server** | Test server located on the West Coast in the San Francisco Bay Area |

# ATTACHMENT E

# Smartphones and Broadband:

## Tech users see them as complements and very few would give up their home broadband subscription in favor of their smartphone

John B. Horrigan, PhD
November 2014

Prepared for Public Knowledge

## Summary of Findings

It was only seven years ago that the iPhone was introduced into the U.S. telecommunications market, setting off change in how and where people use the Internet. Since 2007, the smartphone has entered the lexicon of American consumers and many of us have become sophisticated navigators of today's market for information and communications technologies (ICTs). People connect with multiple devices, manage data caps through Wi-Fi (at home and in public places), and use home broadband access and mobile access to expand their digital horizons.

From the perspective of market dynamics, an issue for policymakers and marketers is whether new means of online access serve as substitutes for one another or complements. Do people give up one means of access when a new comes along, the same way pagers and pay phones faded away as cell phones became more ubiquitous and powerful? Or do more ways of communicating and accessing information mean people rely on multiple tools in different ways, the way that TV did not supplant radio?

This report examines the issue of substitutability through a survey of ICT users that asked a series of questions about how they use their smartphones and home broadband subscriptions. The survey finds that ICT users rely on their home broadband subscriptions for many key online applications, and use their smartphones for staying in touch with others. They are also acutely aware of how to manage data consumption in an environment where most are subject to data caps on their smartphone plans.

***Tech users see broadband and smartphones as complementary ways to get online.***

Very few respondents said they would give up their home broadband connection in favor of their smartphone alone, and most are very intentional in making choices about what connection type to use for different applications.

- An overwhelming majority – 92% – say it is very (63%) or somewhat (29%) unlikely that they would cancel their home broadband connection in favor using their smartphone only for online access.
- Those with smartphones and home broadband favor using their home high-speed subscriptions to look for information or shopping, while they prefer the smartphone to their home broadband subscription for getting in touch with family or friends. Few prefer watching video on their smartphones (as compared to a laptop or tablet computer). Specifically:
    - 89% agree very (63%) or somewhat (26%) strongly that their computer is their preferred means for looking for information about health care or for school work.
    - 83% agree very (56%) or somewhat (29%) strongly that they prefer to use their computer for shopping.
    - 78% agree very (43%) or somewhat (35%) strongly that the smartphone is their preferred way to get hold of a family or friend.
    - Just 29% agree very (11%) or somewhat (28%) strongly that the smartphone is the preferred device for watching online video.

***Most smartphone users are subject to data caps and they rely on Wi-Fi – at home and in public places – to manage data caps. They also find their broadband speeds more satisfactory and in line with their expectations than what they experience on their wireless devices.***

- More than half of smartphone users (55%) have data caps on their wireless plans and, of those respondents, most (52%) either avoid doing certain activities or wait until they are in range of a Wi-Fi signal to engage in them (such as watching video).
    - Some 49% wait until they can use a Wi-Fi connection to do certain activities on their smartphone.
    - 42% occasionally do not engage in data-intensive activities, such as watching video, out of concern for hitting their monthly data cap.
- Respondents are more likely to say that speeds on their home broadband connections meet their expectations when asked to compare to their wireless smartphone connection speeds.
    - By a 39% to 28% margin, those with smartphones and home high-speed service strongly agree that their home broadband connection speeds is satisfactory compared with their smartphone speeds.
    - By a 35% to 25% margin, those with smartphones and home high-speed services strongly agree that their home broadband speed meets their expectations, as compared with their smartphone speeds.

***Public Wi-Fi plays an important role for certain population segments in how they routinely go online.***

- One in five (21%) respondents say that they often use the Internet on a public Wi-Fi network, such as a library, coffee shop, community center, or school.; 7% do this often and 14% somewhat often.
- For specific sub-groups:
    - 39% of young adults – between the ages of 18 and 29 – have used public Wi-Fi
    - 30% of African Americans have done this
    - 27% of Latinos have done this
    - 27% of poor Americans – those whose household incomes are under $25,000 annually – have done this

## Introduction

The advent of portable Internet-enabled devices, in conjunction with fourth generation wireless network speeds, has given American consumers new options for Internet access. As more people have subscribed to smartphone service plans, some communications policy stakeholders wonder whether smartphones, especially those that run on 4G wireless networks, can serve as substitutes for home broadband subscriptions.

National surveys reveal very little evidence that people use smartphones as principle access devices in lieu of a home broadband service plan. Recent data released by the Census Bureau from the American Community Survey finds that 73% of households have broadband service, but only 5% use devices such as smartphones exclusively for their Internet access.[1] Other research, based on national telephone surveys, has placed the "smartphone only figure" in the 8% to 10% range and found that the home broadband subscription is the anchor for the online access experience for most people.[2]

In the survey for this report, nearly two-thirds (65%) of respondents reported that they had a smartphone and 85% have high-speed Internet connections at home. This gives a large portion of the sample – 92% – two ways of going online, which in turn presents a research opportunity to investigate whether they use these online ramps in different ways. This report goes beyond the question of who has "smartphone only" (and not home broadband) access, but explores user behaviors and attitudes. The survey asked people about whether they have data caps, how they deal with them, and the access means they use for different online applications. The results paint a picture of online users who are astute in how they manage their online use when faced the different attributes and constraints that come with home broadband and smartphone subscription plans.

This report is based on a survey of 2,149 online Americans. The survey was conducted by GfK and, with the online frame for the survey, respondents are only those adult Americans with Internet access at home. According to the Census Bureau's American Communities Survey, in 2013 some 79% of Americans were Internet users, with 73% having broadband at home. Results in this report, therefore, refer to online Americans. In the survey, 1,831 respondents had broadband at home, 2,181 had either broadband or smartphones, and 1,212 had smartphones.

[1] Lee Rainie and D'Vera Cohn, "Census: Computer ownership, internet connection varies widely across U.S." Pew Research Center, September 19, 2014. Available online at: http://www.pewresearch.org/fact-tank/2014/09/19/census-computer-ownership-internet-connection-varies-widely-across-u-s/

[2] John B. Horrigan, "Adoption of Information and Communications Technologies in the United States: Narrowing Gaps, New Challenges." Prepared for the Knight Foundation and available online at: http://knightfoundation.org/media/uploads/media_pdfs/DigitalAccessUpdateFeb2014.pdf

## I. Smartphones, Data Caps, and Wi-Fi

Smartphone users are well attuned to the limitations that many service providers impose on access. More than half (55%) of smartphone users say that their provider places a limit on the amount of data they can use per month for online access; 38% said they did not have a data cap. Among those who do have a cap on data usage, 80% say they pay an extra fee if they exceed the limit. When asked whether they had their access speed slowed if they exceeded their data limit, just 16% said this would happen, 37% said it would not, and a striking 47% of respondents with a data cap did not know.

Wi-Fi plays a large role in how smartphone users use their devices and deal with data caps. Many smartphone users with a data cap take steps to minimize their use of the data allocation they have, as 42% say that the monthly data cap means they do not do certain online activities, such as streaming music or watching video, because they worry they may exceed their data limit. And half (49%) say they wait to do some online activities (such as watching video) until they can find a Wi-Fi connection. This means that, among the 55% of smartphone users with a data cap, more than half – 52% – have altered their online behavior because of the cap – either by not doing some online activities out of concern for hitting the limit or by waiting until they were within Wi-Fi range.

Another key point about people's surfing preferences is that American Internet users like Wi-Fi – whether they have broadband, a smartphone, or both. When asked how often they use various methods for going online, 65% of home broadband users say they *very often* use Wi-Fi from a home network configured through their home high-speed subscription. This is far greater than the number of broadband users who use the wireline broadband connection at home (36% use it very often) and broadband users with smartphones – 38% of whom very often go online with their smartphone. The following table shows full results for the question.

**Table 1**

| | Very often | Somewhat often | Not too often | Never |
|---|---|---|---|---|
| A wireless WiFi network in my home whose signal comes from my home broadband Internet subscription, | 65% | 15% | 8% | 11% |
| My smartphone using its data plan. | 38 | 28 | 24 | 8 |
| My home broadband Internet subscription that connects my computer to the Internet using a wire. | 36 | 12 | 13 | 36 |
| A public wireless WiFi network, for instance, at a library, coffee shop, community center, or school. | 7 | 14 | 38 | 38 |

Note that 21% of Internet users are at least somewhat reliant on public Wi-Fi, as they go online using public Wi-Fi hotspots very often or somewhat often. However, this number is higher for several groups. For use of Wi-Fi in public areas:

- 39% of young adults – between the ages of 18 and 29 – have used public Wi-Fi

- 30% of African Americans have done this
- 27% of Latinos have done this
- 27% of poor Americans – those whose household incomes are under $25,000 annually – have done this

For rural Americans, Wi-Fi plays only a small role in how they go online; just 8% of respondents in non-Metro areas use Wi-Fi hotspots to get online.

When asked what device they use most often when using a Wi-Fi connection, 50% of Wi-Fi users said it was their laptop, 25% said it was a smartphone, and 24% said it was a tablet computer.

## II. Substitutability of smartphones and broadband

The survey data show that people have clear views about which applications are better suited to different means for going online. Questions probed into people's preferences for using different online applications, holding a comparison between their home broadband connection and smartphones in mind.

As the table below shows, those with both a home broadband connection and a smartphone prefer to use the former for looking for information, watching video, or shopping, while the latter is used more for staying in touch with others. Nonetheless, a sizable minority (29%) prefer to watch video on their smartphone rather than a device with a larger screen, with 11% strongly agreeing that online video is better viewed on a smartphone and 18% somewhat agreeing with that notion.

**Table 2**

| | Strongly agree | Somewhat agree | Somewhat disagree | Strongly disagree |
|---|---|---|---|---|
| When I need information on a specific topic, such as looking for a job, doing school work, or searching for health care information, I prefer using a computer (such as a desktop, laptop, or tablet) that uses my home broadband connection rather than my smartphone. | 63% | 26% | 7% | 3% |
| When I am shopping for a product online, I prefer using a computer (such as a desktop, laptop, or tablet) that uses my home broadband connection rather than my smartphone. | 56 | 29 | 9 | 4 |
| If I need to get in touch with a friend or family member, I prefer using my smartphone to a device that uses my home broadband connection. | 43 | 35 | 14 | 7 |
| When I want to watch video online, I prefer using my smartphone to a device that uses my home broadband connection. | 11 | 18 | 32 | 38 |

For several segments, there were significant differences in response for preferences for watching online video.

- 40% of younger respondents (between the ages of 18 and 29) are more likely to prefer watching video on smartphones
- 45% of African Americans say they prefer to watch video on a smartphone
- 38% of Latinos saying they prefer to watch video on a smartphone.

### III. Speeds on home broadband versus wireless data plans

Consumers' preference for their home broadband connection for bandwidth intensive activities carries over into their views on the relative speeds of their smartphone connection compared to their home broadband connection. The table below demonstrates this and the differences are most striking when looking at the extent to which respondents strongly agree with specific propositions.

**Table 3**

| | Strongly agree | Somewhat agree | Somewhat disagree | Strongly disagree |
|---|---|---|---|---|
| **Satisfaction with speed** | | | | |
| I am satisfied with the speed of the connection from my home high-speed Internet subscription. | 39% | 42% | 14% | 4% |
| I am satisfied with the speed of the connection I experience on my smartphone. | 28 | 50 | 17 | 5 |
| **Expectations about speed** | | | | |
| The Internet speed on my home high-speed Internet subscription consistently meets my expectations. | 35% | 43% | 16% | 5% |
| I can always get online at the speed I need using my smartphone. | 25 | 43 | 14 | 4 |
| | | | | |

By margins of roughly 10 percentage points, broadband users are more likely than smartphone users to *strongly agree* that they are satisfied with their connection speeds with home broadband versus smartphone speeds. The same is true when queried about the expectations of their home broadband connections in contrast to speeds on their smartphone. It is worth noting that, notwithstanding advances in wireless data speeds, wireless download speeds tend to lag those of home broadband subscriptions. The questions were framed in such a way not to ask respondents to compare speeds, but to compare their perspectives about the speeds of each service, given that wireless speeds will likely to be slower than home broadband speeds for most respondents. The results indicate that within the context of different speeds for smartphones and home broadband subscriptions, respondents have higher levels of satisfaction for home broadband speeds than those available on smartphone plans.

History is an important dimension to bring into discussions about people's views on access speeds. Surveys over the past decade consistently find that people are very satisfied with home broadband connection speeds, notwithstanding (for the most part) ignorance of what the speed is and increasing home broadband speeds over this timeframe. A 2002 survey by the Pew Research Center found that 90% of early broadband adopters said their home Internet service was excellent (40%)

or good (50%).[3] A 2010 FCC survey found that 91% of home Internet users were either very (50%) or somewhat (41%) satisfied with their home connection speeds, even if 80% could not specify their home connection speed.[4]

A similar pattern is evident for mobile devices. The same 2010 FCC survey asked people if they were satisfied with the Internet speed they could get on their cell phone. At a time when carriers had not widely deployed 4G wireless networks, 33% of respondents with mobile access were very satisfied with their access speeds and 38% were somewhat satisfied.

Though comparing findings across these surveys over long timeframes requires caution, the findings suggest that consumers are perhaps a bit more discerning today about home broadband speeds than a few years ago. For wireless, handheld Internet access was novel enough in 2010 that people seemed satisfied with the speeds they got, with today's faster speeds largely meeting expectations.

Finally, it is worth noting that respondents' perspectives on home broadband speed do not vary significantly depending on connection type. Among those who identified their home Internet service as a cable company, such as Comcast, Brighthouse, Charter, Cox, or Time Warner Cable, 37% strongly agreed that they were satisfied with the speed of their home Internet connection. Among those with a fiber service, such as FiOS, Google, and the one respondent fiber service in Chattanooga, Tennessee, 35% strongly agreed that they were satisfied with their home connection's speed. Even though the figures slightly lag the average, the differences (given the sample sizes) are not statistically significant.

## IV. Smartphones and broadband: Anyone ready to switch?

Given the findings noted above – higher satisfaction with broadband than smartphone speeds and reliance on home broadband service for key applications – it is little surprise that few people want to give up broadband in favor of a smartphone. Those with both a home broadband subscription and a smartphone have little interest in choosing a smartphone exclusively for access over a home broadband subscription. When asked how likely it is that they would cancel a home broadband subscription and *only* rely on their smartphone to access the Internet, here is what people with both services said:

- 63% -- Not likely at all
- 29% -- Not too likely
- 6% -- Somewhat likely
- 1% -- Very likely

[3] John B. Horrigan and Lee Rainie, "The Broadband Difference: How online behavior changes with high-speed Internet connections." Pew Research Center, June 2002. Available online at: http://www.pewinternet.org/2002/06/23/the-broadband-difference-how-online-behavior-changes-with-high-speed-internet-connections/

[4] John B. Horrigan and Ellen Satterwhite, "Americans' perspectives on online connection speeds for home and mobile devices." Federal Communications Commission, April 2010. Available online at: https://apps.fcc.gov/edocs_public/attachmatch/DOC-298516A1.doc

In other words, 93% of all American adults with a smartphone and a home broadband subscription are unlikely to do away with their broadband service in favor of their smartphone only. Budget-constrained low-income homes are twice as likely as all respondents to say they might cancel broadband and rely only on their smartphone, but it is still the case that only 14% have considered doing this.

It is also likely that those who rely solely on their smartphone, while foregoing a home broadband subscription, are doing so for economic reasons. The survey asked people without broadband at home and a smartphone why they did not have a broadband subscription. Because the survey was administered to an online panel, these respondents are mainly dial-up users and few in number; only 34 people responded to the question. That is not enough so that their answers have statistical validity and, because the sampling did not reach non-Internet users, it is not a random sample. Nonetheless, the answers are suggestive.

Those with smartphones but not a home broadband subscription were asked the following question: "You said that you have a smartphone but not a home broadband Internet subscription. Please indicate whether any of the following are reasons you do not have broadband at home." Respondents were also asked a follow-up question to identify the main reason they did not have broadband at home.

- When allowed to cite *multiple reasons*, more than half cited the monthly cost for broadband service and half said their smartphones could do all they need. Roughly one-third cited each of the other three reasons – i.e., they could use the Internet at work, library, or community center, that service in their neighborhood was not adequate, or that they could not afford an Internet access device.
- With respect to the *main reason* they did not have broadband given that they had a smartphone, the monthly cost of broadband was the most frequent response. About half said monthly cost was the main reason to do without broadband at home, about three times the frequency of those who said the main reason was inadequate service in their neighborhood or that their smartphone could do all they needed. Few said access at work or library was the reason or unaffordability of an access device for home broadband.

The small set of "smartphone only" users interviewed in this survey seem to be operating under tight household budgets – which is why they rely on the smartphone rather than a home broadband subscription that may have more utility, but is out of reach financially.

## V. Conclusions

American tech users have developed a clear sense of how to navigate across different communication devices. The home broadband connection is an important anchor – really the gateway to how a majority of tech users engage with the Internet. It offers access to the Internet that most often flows through a home wireless network. This lets consumers offload data consumption from smartphones and other devices to Wi-Fi in the home and thus alleviates constraints that most tech users experience from data caps.

Mobile devices such as the smartphone enter the picture as an important complementary path to Internet access. For communicating with family and friends and for the quick fact on-the-go, smartphones deepen people's online habits. Although the research reported here finds smartphones to be a complement to home broadband, this does not make it secondary. Given, however, the presence of data caps, smartphones usefulness grow when people have a home Wi-Fi network that can open the spigot for mobile data use. It grows even more with public Wi-Fi, an important access on-ramp for young people, communities of color, and low-income tech users.

As wonderful as tech users find smartphones, the survey shows that they do not substitute for home broadband connections. A small fraction of tech users would contemplate doing away with their home broadband subscription in favor of a smartphone alone to surf the Internet. Given respondents' lower expectations for very fast access speeds for wireless relative to home high-speed connections, broadband subscriptions in consumers' homes will likely remain at the center of people's online pathways for some time.

## Appendix I: Detailed data on access assets for respondents

As this report focuses on technology use among those with broadband at home and smartphones, it is worthwhile understanding access patterns for broadband and smartphones across population segments of likely interest. The table below summarizes the findings of the survey. Note that the figures do not represent access rates for the general population, but rather for the online panel recruited by GfK. The GfK panel is balanced to be representative of the *online* population in the United States.

**Table 4: Access by age**

| | All | 18-29 | 30-44 | 45-59 | 60+ |
|---|---|---|---|---|---|
| Smartphone | 65% | 86% | 80% | 60% | 37% |
| Broadband | 85 | 87 | 85 | 85 | 83 |
| Number of respondents | 2,287 | 333 | 518 | 646 | 790 |

**Table 5: Access by race/ethnicity and location**

| | White | African America n | Hispanic | Non-Metro | Metro |
|---|---|---|---|---|---|
| Smartphone | 62% | 63% | 74% | 52% | 68% |
| Broadband | 87 | 71 | 83 | 79 | 86 |
| Number of respondents | 1,734 | 212 | 205 | 359 | 1,928 |

**Table 6: Access by household income**

| Household income | Less than $25,000 per year | Between $25K & $50K | Between $50K &$75K | Between $75K &$100K | Greater than $100K |
|---|---|---|---|---|---|
| Smartphone | 40% | 51% | 62% | 68% | 77% |
| Broadband | 63% | 80% | 91% | 92% | 95% |
| Number of respondents | 433 | 500 | 437 | 315 | 602 |

## Appendix II: Topline results from the survey

**Question numbers are not sequential because not all questions used in the survey were used for analysis in this report**

We'd like to ask some questions about the communications services and products you use.

Q1. Do you have a cell phone?

| | |
|---|---|
| Yes | 92% |
| No | 7% |

[If Q1=1]
[sp]
Q2 Some cell phones are called "smartphones" because of certain features they have. Is your cell phone a smartphone such as an iPhone, Android, Blackberry or Windows phone, or are you not sure?

| | |
|---|---|
| Yes, smartphone | 65% |
| No, not a smartphone | 33% |
| Not sure/Don't know | 2% |

[if q2=1]
[sp]
Q3 Does the company that provides your smartphone service place a limit on the amount of data you can use per month to access the Internet?

| | |
|---|---|
| Yes | 55% |
| No | 38% |
| Don't know | 7% |

[IF Q3=1]
Q3a If you use more than the monthly allocation of data on your smartphone, does your service provider: [AMONG THOSE WITH A FEE]

a. Charge you an extra fee that is beyond your monthly service charge?

| | |
|---|---|
| YES | 80% |
| NO | 10% |
| DK/REF | 10% |

b. Slow down the speed of your Internet access?

| | |
|---|---|
| YES | 16% |
| NO | 37% |
| DK/REF | 47% |

[if Q3=1]
Q3b Does the monthly limit on data ever prevent you from doing certain online activities, such as streaming music from the Internet or watching online video, because you worry you might exceed the limit? [AMONG THOSE WITH A FEE]

| | |
|---|---|
| Yes | 42% |
| No | 53% |
| Don't know | 5% |

[if Q2=1]
[sp]
Q3c. Do you wait to do certain activities, such as streaming music from the Internet or watching online video, on your smartphone until you can find a WiFi connection? [AMONG THOSE WITH A FEE]

| | |
|---|---|
| Yes | 49% |
| No | 47% |
| Don't know | 4% |

Q12 When you go online, how often do you use the following ways to access the Internet?

a. My home broadband Internet subscription that connects my computer to the Internet using a wire. [if q7=2]

| | |
|---|---|
| 1. Very often | 36% |
| 2. Somewhat often | 12% |
| 3. Not too often | 13% |
| 4. Never | 36% |

b. My smartphone using its data plan. [if q2=1]

| | |
|---|---|
| 1. Very often | 38% |
| 2. Somewhat often | 28% |
| 3. Not too often | 24% |
| 4. Never | 8% |

c. A wireless WiFi network in my home whose signal comes from my home broadband Internet subscription. [if q7=2]

| | |
|---|---|
| 1. Very often | 65% |
| 2. Somewhat often | 15% |
| 3. Not too often | 8% |
| 4. Never | 11% |

d. A public wireless WiFi network, for instance, at a library, coffee shop, community center, or school

| | |
|---|---|
| 1. Very often | 7% |
| 2. Somewhat often | 14% |
| 3. Not too often | 38% |
| 4. Never | 38% |

[IF Q12c=1 OR Q12d=1]
Q12a What device do you use most often when you go online using a WiFi connection?

| | |
|---|---|
| a. A laptop computer | 50% |
| b. A smartphone | 25% |
| c. A tablet computer, such as an iPad, Android device, or Kindle Fire | 24% |

[IF Q2=1 AND IF Q7=2 (Have home broadband and a smartphone)]

Q13 Below are several statements about using the Internet on your smartphone and other devices, such as a computer or tablet (like an iPad, Kindle Fire, or Android device), that rely on your home broadband connection. Please indicate whether you agree or disagree.

a. When I want to watch video online, I prefer using my smartphone to a device that uses my home broadband connection.

| | |
|---|---|
| 1. Strongly agree | 11% |
| 2. Somewhat agree | 18% |
| 3. Somewhat disagree | 32% |
| 4. Strongly disagree | 38% |

b. If I need to get in touch with a friend or family member, I prefer using my smartphone to a device that uses my home broadband connection.

| | |
|---|---|
| 1. Strongly agree | 43% |
| 2. Somewhat agree | 35% |
| 3. Somewhat disagree | 14% |
| 4. Strongly disagree | 7% |

c. When I need information on a specific topic, such as looking for a job, doing school work, or searching for health care information, I prefer using a computer (such as a desktop, laptop, or tablet) that uses my home broadband connection rather than my smartphone.

| | |
|---|---|
| 1. Strongly agree | 63% |
| 2. Somewhat agree | 26% |
| 3. Somewhat disagree | 7% |
| 4. Strongly disagree | 3% |

d. When I am shopping for a product online, I prefer using a computer (such as a desktop, laptop, or tablet) that uses my home broadband connection rather than my smartphone.

1. Strongly agree 56%
2. Somewhat agree 29%
3. Somewhat disagree 9%
4. Strongly disagree 4%

Q14 Next, you will read some statements about the quality of your Internet connection when you use different ways of getting online. Please indicate whether you agree or disagree.
a. I am satisfied with the speed of the connection I experience on my smartphone. [if q2=1]

1. Strongly agree 28%
2. Somewhat agree 50%
3. Somewhat disagree 17%
4. Strongly disagree 5%

b. I am satisfied with the speed of the connection from my home high-speed Internet subscription. [if q7=2]

1. Strongly agree 39%
2. Somewhat agree 42%
3. Somewhat disagree 14%
4. Strongly disagree 4%

c. I can always get online at the speed I need using my smartphone. [if q2=1]
1. Strongly agree 25%
2. Somewhat agree 43%
3. Somewhat disagree 24%
4. Strongly disagree 7%

d. The Internet speed on my home high-speed Internet subscription consistently meets my expectations. [if q7=2]

1. Strongly agree 35%
2. Somewhat agree 43%
3. Somewhat disagree 16%
4. Strongly disagree 5%

[q2=1 and q7=2]
Q15 How likely is it that you would cancel your home broadband subscription and use ONLY your smartphone to access the Internet?

a. Very likely 1%
b. Somewhat likely 6%
c. Not too likely 29%
d. Not at all likely 63%

# ATTACHMENT F

**Mobile Data Prices of AT&T, Sprint, T-Mobile, & Verizon Wireless,**

AT&T – Mobile Data Plans

Create your Mobile Share Value plan

| Choose your data | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Includes talk, text & domestic data in Mexico<br>Includes unlimited talk & text to Mexico & Canada[1] | | | | | |
| Shared data | 300MB | 2GB | 5GB | 15GB | 20GB | 25GB | 30GB | 40GB | 50GB |
| Your monthly price | $20 | $30 | $50 | $100 | $140 | $175 | $225 | $300 | $375 |

**Overage:** $20 per 300MB on the 300MB plan, and $15 per 1GB on all other plans shown above. Must be used in the billing period it is provided and does not roll over.

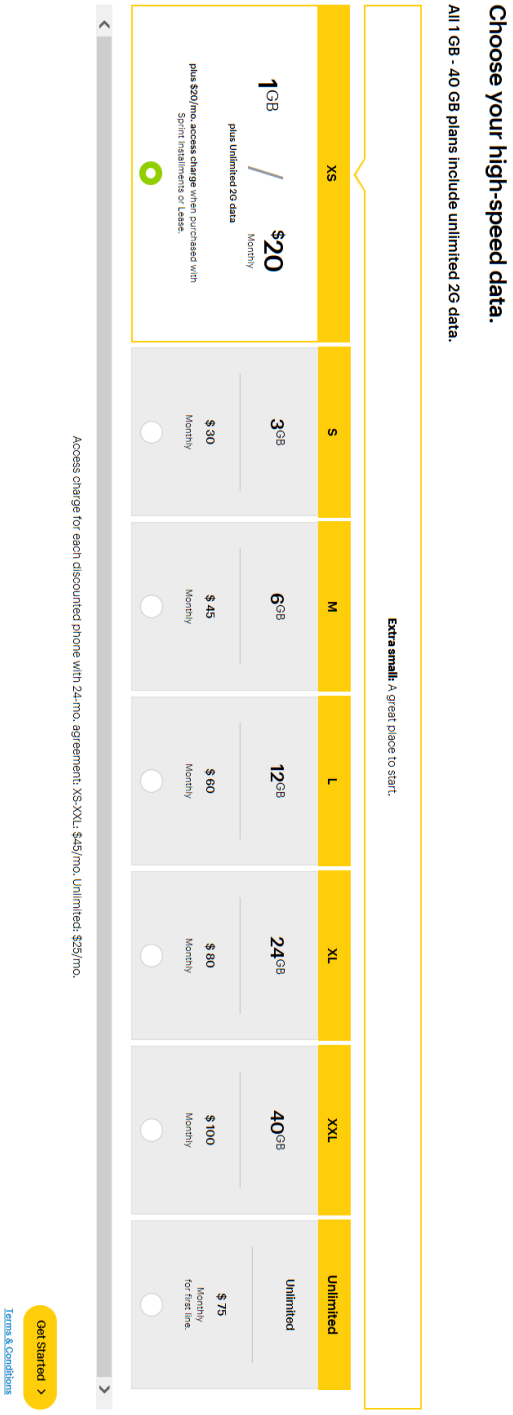
| Add phones | Monthly Access Charge | |
|---|---|---|
| | 5GB or Less | 15GB or More |
| **Smartphone access charge**[1]<br>(purchase at full price, bring your own, or on a month-to-month contract) | $25/mo. | $15/mo. |
| **All Basic & Messaging Phones**[2] | $25/mo. | $15/mo. |

[1]If you are on a 2-year Agreement your monthly access charge will be $15 to $40 based on your plan.
[2]If on a previous Mobile Share Value plan your access charge has not changed. If you change plans your access charge may increase.

Source: https://www.att.com/shop/wireless/data-plans.html

Accessed on May 24, 2016

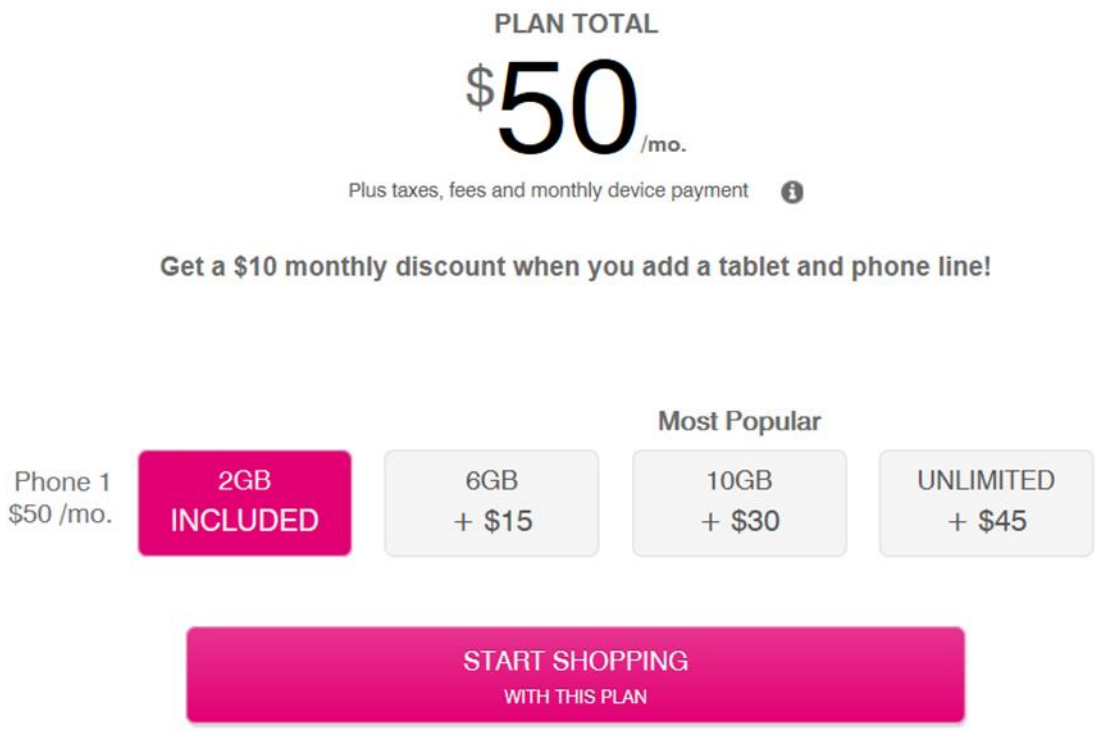
Sprint – Mobile Data Plans




Source: https://www.sprint.com/shop/plan-wall/

Accessed on May 24, 2016

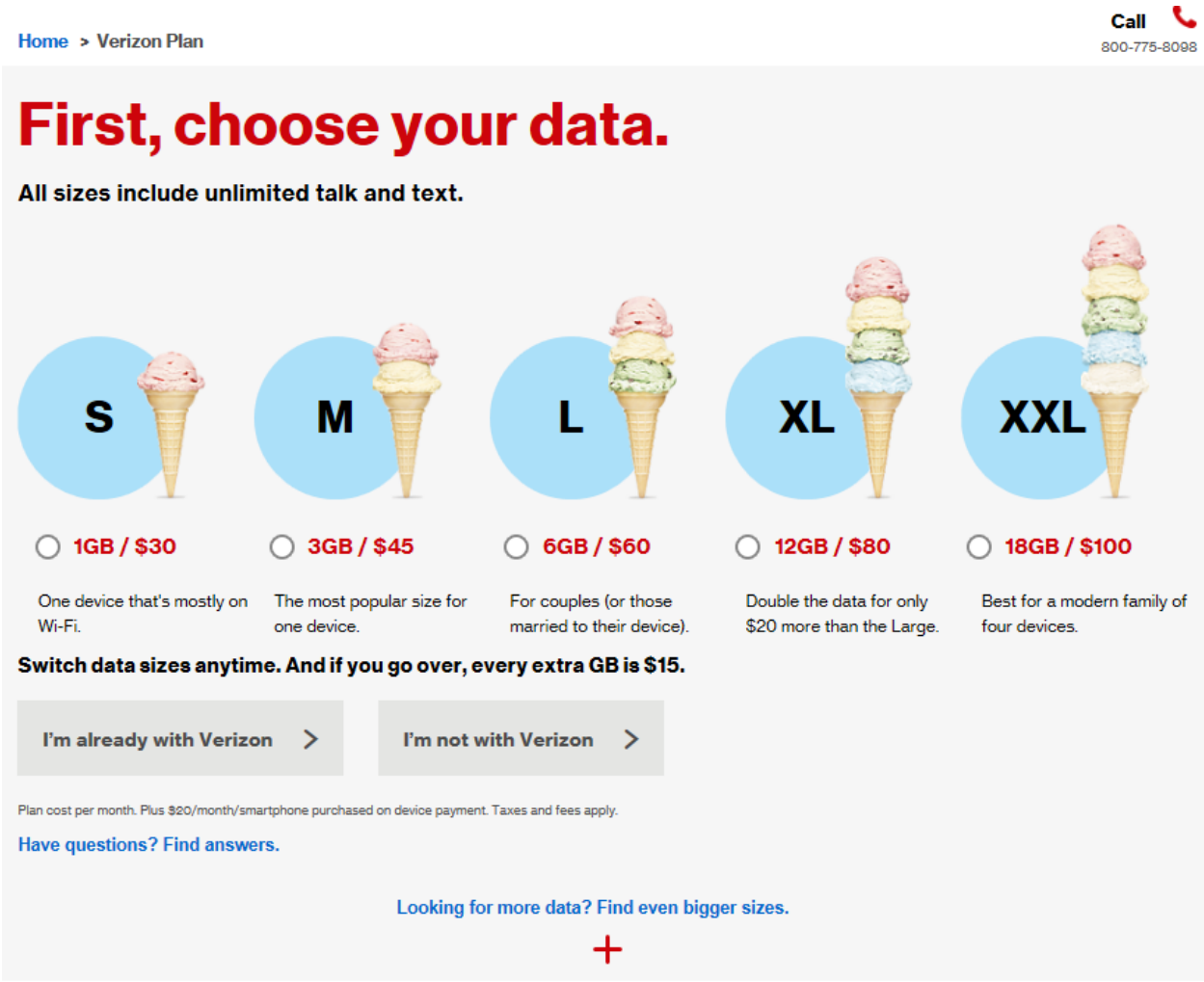
T-Mobile – Mobile Data Plans




Source: http://www.t-mobile.com/cell-phone-plans.html

Accessed on May 24, 2016

Verizon Wireless – Mobile Data Plans



Source: http://www.verizonwireless.com/landingpages/verizon-plan/

Accessed on May 24, 2016