CalSPEED Home: Measuring Wired and WiFi Residential Broadband Performance in California

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Our purpose is to measure the tangible user experience of residential broadband (DSL, cable, fixed wireless, fiber and satellite) in California using both via a wired connection (Ethernet) or via a WiFi wireless connection. Recent measurements[1] in three California cities (San Francisco, Merced and El Centro) suggest there is at least one WiFi router per household and in San Francisco approaching one per person! The matches our intuition of WiFi's importance as the vast majority of residential broadband service is via WiFi - to smartphones, tablets, laptops, smart TVs, and desktop computers.

Methodology

Our methodology is an extension of the successful California Public Utilities' Commission mobile broadband measurements of 2012 thru 2017[2]. We deploy an inexpensive Linux ARM measurement unit in the homes of volunteers over the state of California. Each unit attaches to the Internet thru the home router - both on a direct "wired" broadband connection via Ethernet to the home router and also via the WiFi connection to the same home router. Each unit periodically (nominally every hour) measures the residential broadband alternately between the two connections.

Interface	Specification	Max Raw Link Throughput (Mb/s)	Max Cooked TCP Link Throughput (Mb/s)
Ethernet	802.3-2002 10/100/1000	1000	860+
WiFi	802.11ac Dual band, 2x2 MIMO	867	~500+

[1] Ken BIba, ***Residential WiFi in California: Measurements in Three California Cities***, Novarum, January 2019

[2] Ken Biba, ***Final Report: Mobile Broadband Assessment of California - 2012-2017***, Novarum, January 2019.

These units use the same measurement software as the CPUC CalSPEED mobile measurement and use the same West and East measurement servers in the Amazon AWS cloud - one in San Jose and the other in Northern Virginia. Each unit is based on an octa-core ARM Linux processor. Each unit has two Internet measurement interfaces: a gigabit Ethernet connection and a local 802.11ac capable WiFi connection. Lab measurements of the two interfaces show that under best circumstances in the table above.

Users enter their local WiFi security credentials to enable association and use of the local WiFi connections. This information is not retained.

Almost all currently deployed Internet user devices have communications connections equal to or worse than these specifications. Our actual measurements will reveal actual residential Internet performance constraints that come from the router, residential Internet connection, local WiFi, and from the Internet itself (particularly in traversing the entire Internet to get to the East measurement server).

Key Early Findings

We have just completed a beta test of this measurement system consisting of 27 units in Fresno. We measure performance from every unit every hour, alternating between the Ethernet and WiFi connections. Internet Service Provider connections include DSL, cable, satellite, fiber and fixed wireless.

We must remember that this remains a small sample size and not yet statistically significant. Each unit performed over 1000 measurements. Five of the installations never completed the WiFi authentication to permit WiFi measurements.

Technology	#
Cable	10
DSL	12
Fiber	1
Fixed Wireless	3
Satellite	1

Technology	W Ethernet Down (Mb/s)	W Ethernet Up (Mb/s)	E Ethernet Down (Mb/s)	E Ethernet Up (Mb/s)	Ethernet Reliability	W WiFi Down (Mb/s)	W WiFi Up (Mb/s)	E WiFi Down (Mb/s)	E WiFi Up (Mb/s)	WiFi Reliability
Cable	202.8	12.1	48.0	11.7	97.8%	120.6	8.2	36.3	8.0	89.0%
DSL	17.0	3.9	10.4	3.1	98.6%	12.2	2.4	8.0	2.4	69.4%
Fiber	331.3	690.7	32.8	52.5	100.0%	199.0	220.4	31.8	30.7	97.0%
Fixed Wireless	4.6	1.3	4.4	1.3	100.0%	3.4	1.0	3.3	0.9	98.8%
Satellite	6.6	4.5	6.5	4.5	98.8%	6.3	4.1	6.2	4.1	99.8%

What can we learn from this initial dataset?

Technology Matters	Clear difference between Internet connection technologies. • Old DSL offers only very low performance (a few Mb/s of performance) and sometimes marginal reliability with failed connection attempts • New DSL is faster (with 10s of Mb/s of performance) but still not competitive with cable • Cable is the new standard of Internet performance with 100s of Mb/s of performance • Fiber is not often available and seems not to deliver on the promise of very high performance (Gb/s). • Fixed wireless delivers low performance (roughly equivalent to old DSL). • Satellite (one sample) offered relatively slow throughput with very long delays.
I***nternet Penalty***	As we found for mobile broadband, the Internet "distance" of the destination server from the user dramatically influences performance. Comparing East server measurements to West server measurements we find dramatic performance decreases for East compared to West for all technologies. This penalty seems to be minimal for slow throughput connections (under ~ 20 Mb/s) but increases the faster the service. For connections above 20 Mb/s, this penalty averages ~ 70%! And for connections above 200 Mb/s to the West server - performance degradation to the East server can be as much as a 90% decrease. While we await more data, our speculation suggests bottlenecks in the backbone.
WiFi Penalty	For slow connections, under ~10 Mb/s, the WiFi connection is generally as fast as the wired connection. For faster connections, over ~ 20 Mb/s, the WiFi connection is materially less than the wired connection - averaging ~30% decrease.
Legacy Routers Unreliable	We found that some units could not complete some measurements some of the time. Ethernet connections these failures averaged 1-3% of all measurement attempts with one example of 10% failures. But for slower DSL WiFi connections, particularly for routers with decade old WiFi - this averaged 30% of all measurement attempts and for some homes - over 60%. Our speculation is that this is both an artifact of the Internet connection (as demonstrated by the Ethernet failures) as well as an artifact of legacy WiFi compatibility.

Next Steps

Now it is time for operational deployment. We plan on waves of deployment for two week measurement periods as we recruit new volunteer households in California. We will report as we believe we get enough data to be statistically meaningful.

We expect more data to validate our initial conclusions as well as more data will allow inferences of about geographic differences in performance.