# Preliminary Findings from Spring 2012 Mobile Broadband Field Testing

Presented to the California Broadband Council

August 14, 2012


Ken Biba, Novarum

Michael Morris, CPUC

Rob Osborn, CPUC


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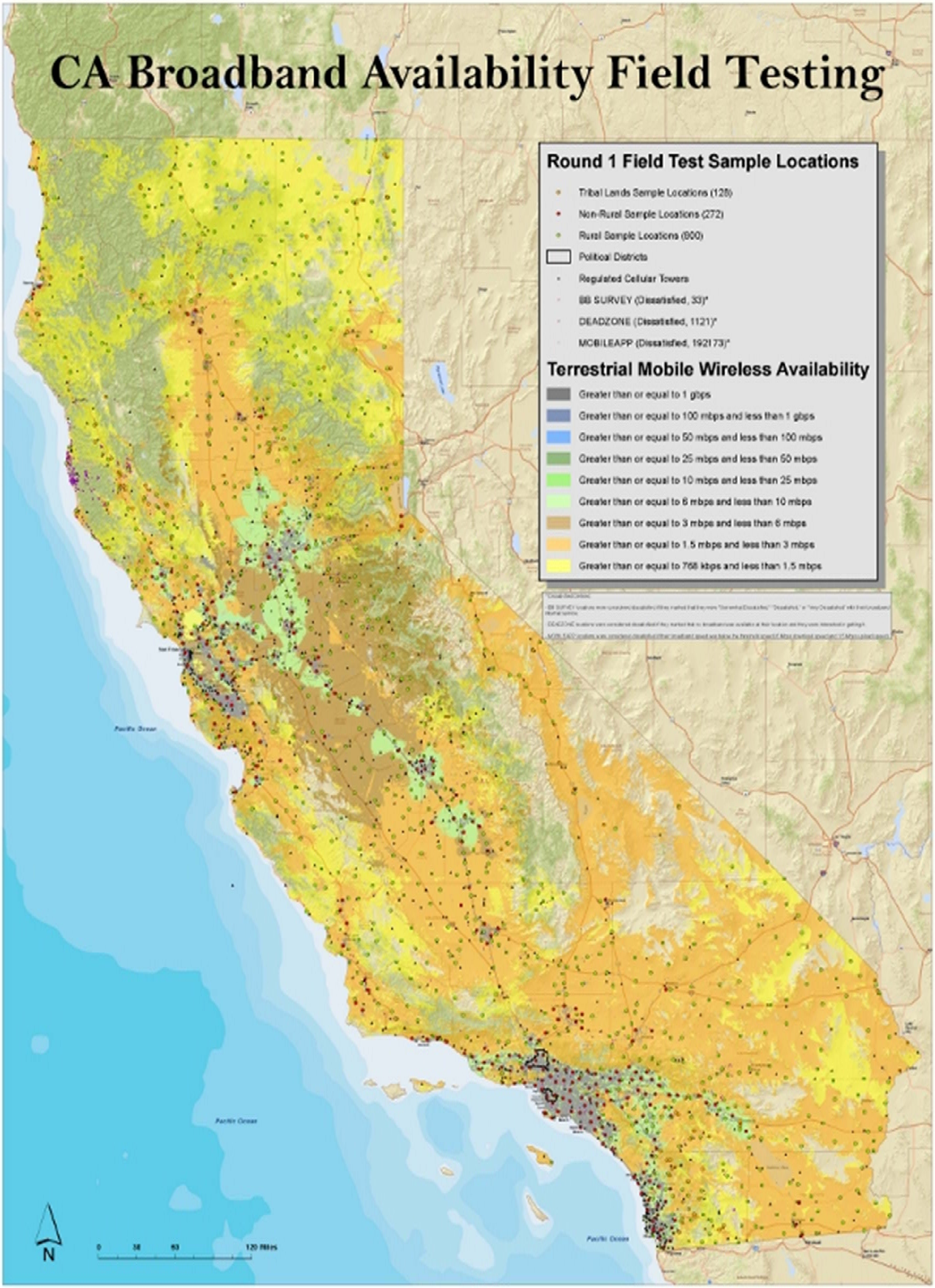
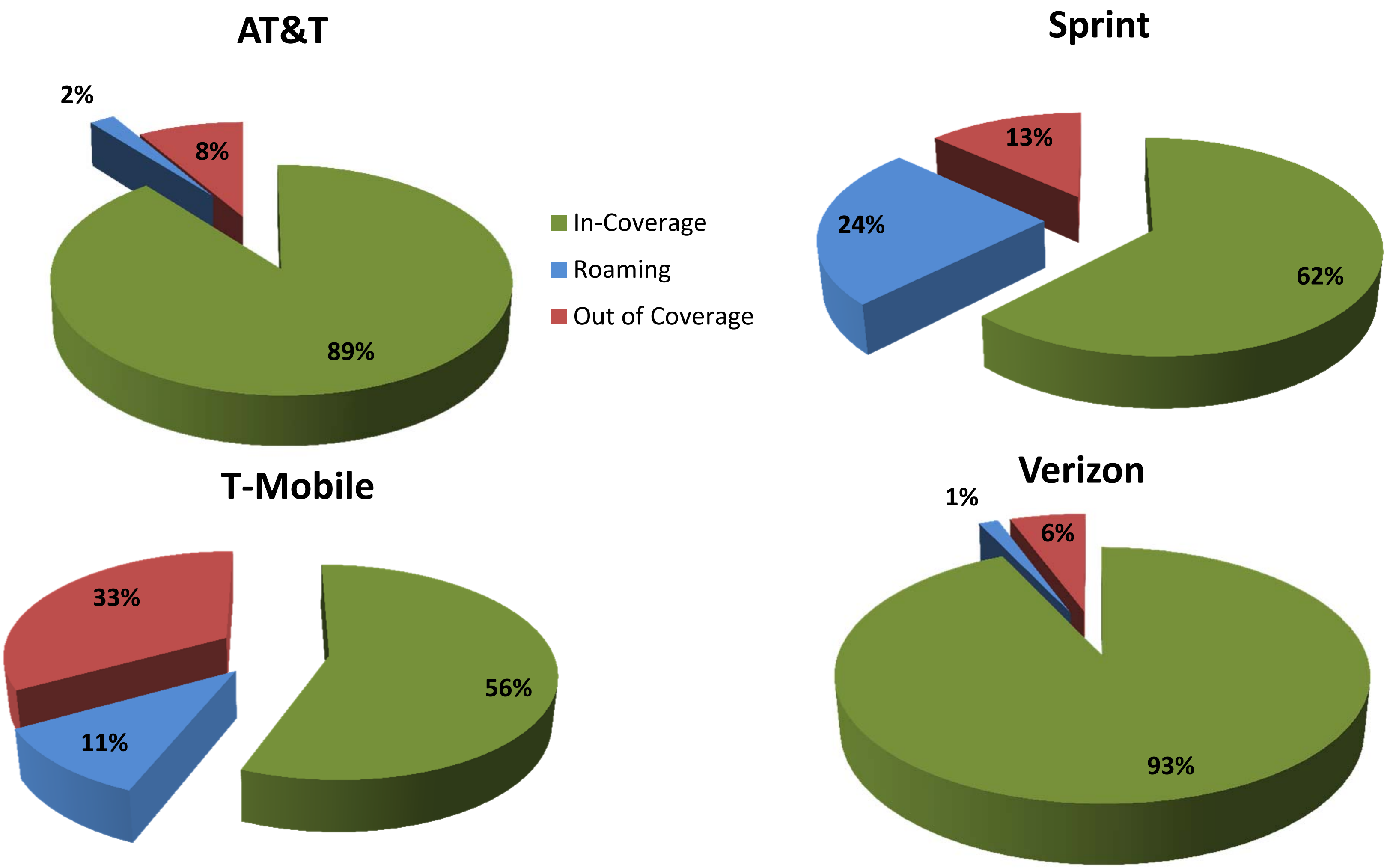
# Background on CPUC Mobile Testing

- Mobile broadband field testing is part of a larger broadband mapping project funded by a grant to the California Public Utilities Commission (CPUC) from by the National Telecommunications Information Administration's (NTIA) State Broadband Data & Development Grant Program. The CPUC does mobile testing twice a year.
- The CPUC contracted with California State University (CSU), Chico to hire and manage a team of eight testers who performed speed and availability tests on commercially available smartphones and USB modems from the 4 major carriers (Verizon, AT&T, Sprint, and T-Mobile) at 1,200 locations throughout the state.
- The testing application was developed by CSU Monterey Bay and is based on open source, industry standard network performance measurement tools. The testing application will eventually be made available for use anywhere in the U.S. See Appendix for details.
- The first round of tests ran from May 7, 2012 to June 1, 2012 this year and covered over 35,000 miles of roads and highways. The second round of tests is scheduled for September, 2012.
- Preliminary results of these tests are summarized in this report and will also be incorporated as subsequent layers in the California Interactive Broadband Map. The CPUC also plans to make the raw data from these tests, as well as the testing application itself, available to the public online.


CA Broadband Availability Field Testing
Round 1 Field Test Sample Locations
Tribal Lands Sample Locations (128)
Non-Rural Sample Locations (272)
Rural Sample Locations (800)
Political Districts
Regulated Cellular Towers
BB SURVEY (Dissatisfied, 33)*
DEADZONE (Dissatisfied, 1121)*
MOBILEAPP (Dissatisfied, 192173)*
Terrestrial Mobile Wireless Availability
Greater than or equal to 1 gbps
Greater than or equal to 100 mbps and less than 1 gbps
Greater than or equal to 50 mbps and less than 100 mbps
Greater than or equal to 25 mbps and less than 50 mbps
Greater than or equal to 10 mbps and less than 25 mbps
Greater than or equal to 6 mbps and less than 10 mbps
Greater than or equal to 3 mbps and less than 6 mbps
Greater than or equal to 1.5 mbps and less than 3 mbps
Greater than or equal to 768 kbps and less than 1.5 mbps
N
120 Miles

# Coverage Breakdown of 1,200 Test Locations by Carrier

## Downstream

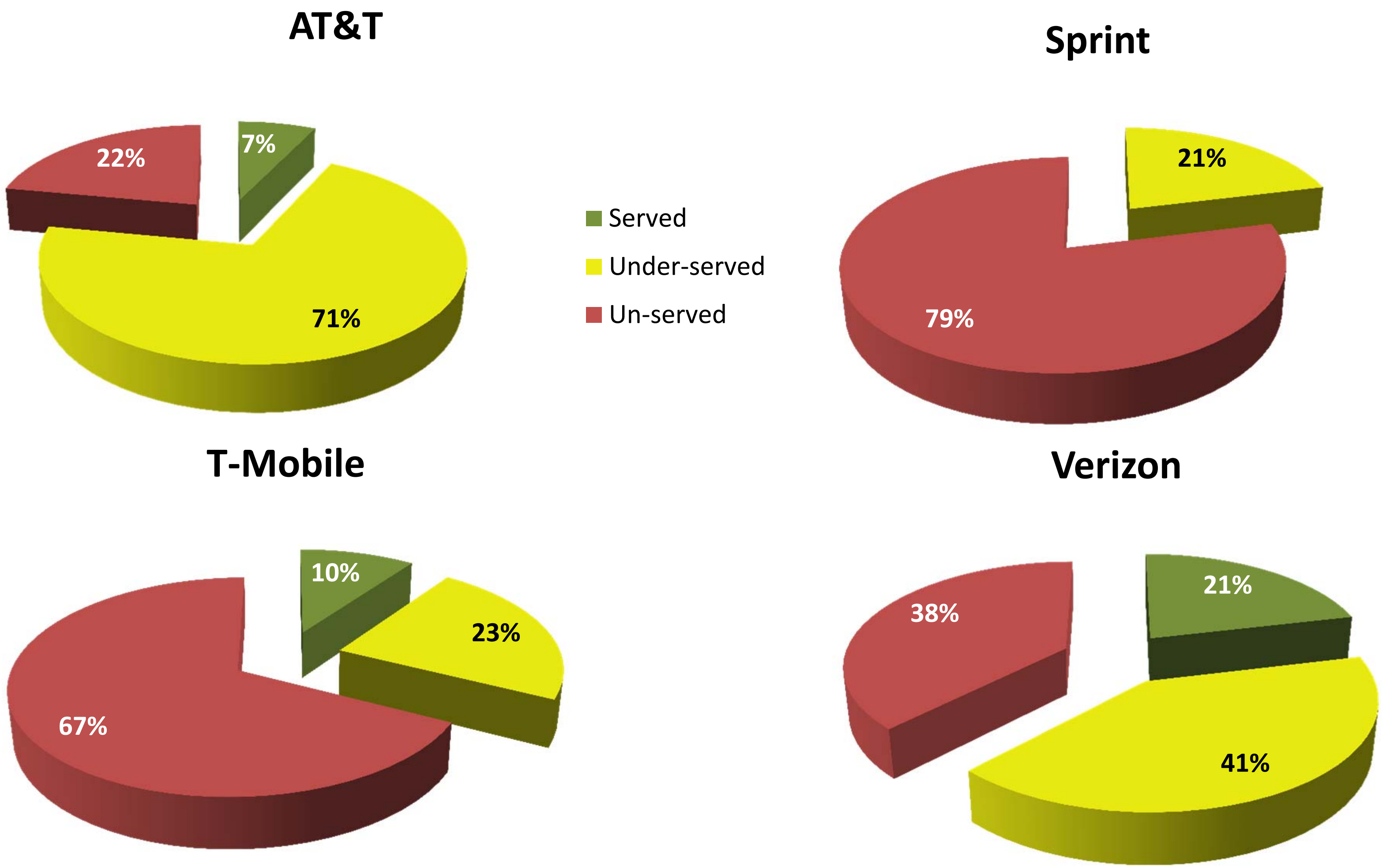



Test locations falling outside a provider’s coverage area that showed a positive TCP result are considered as roaming locations

# “Served” Breakdown of 1,200 Test Locations by Carrier

## (≥1.5 Mb/s Upstream and ≥ 6.0 Mb/s Downstream)

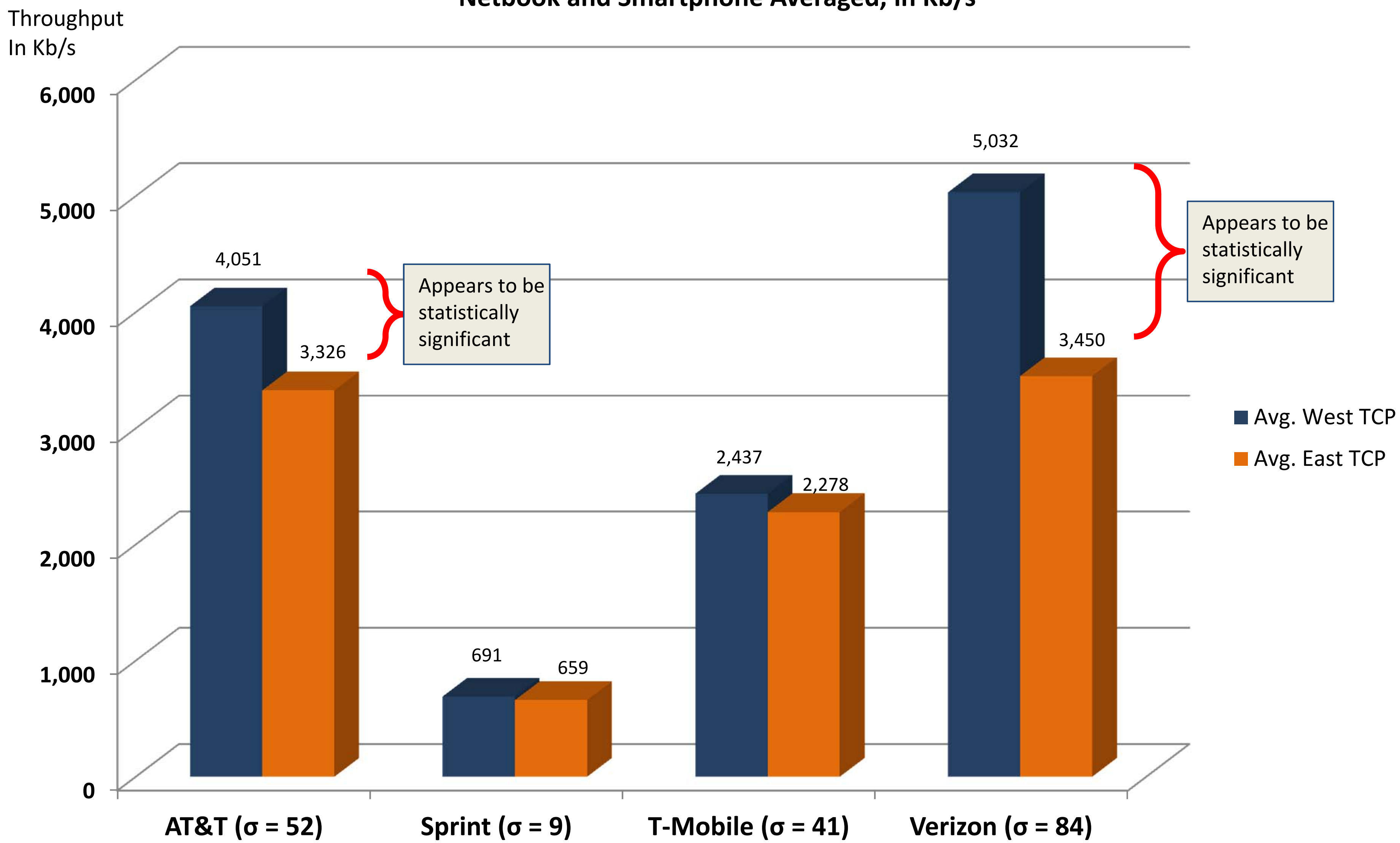
Netbook and Smartphone averaged, West & East averaged



# West vs. East Server Differences

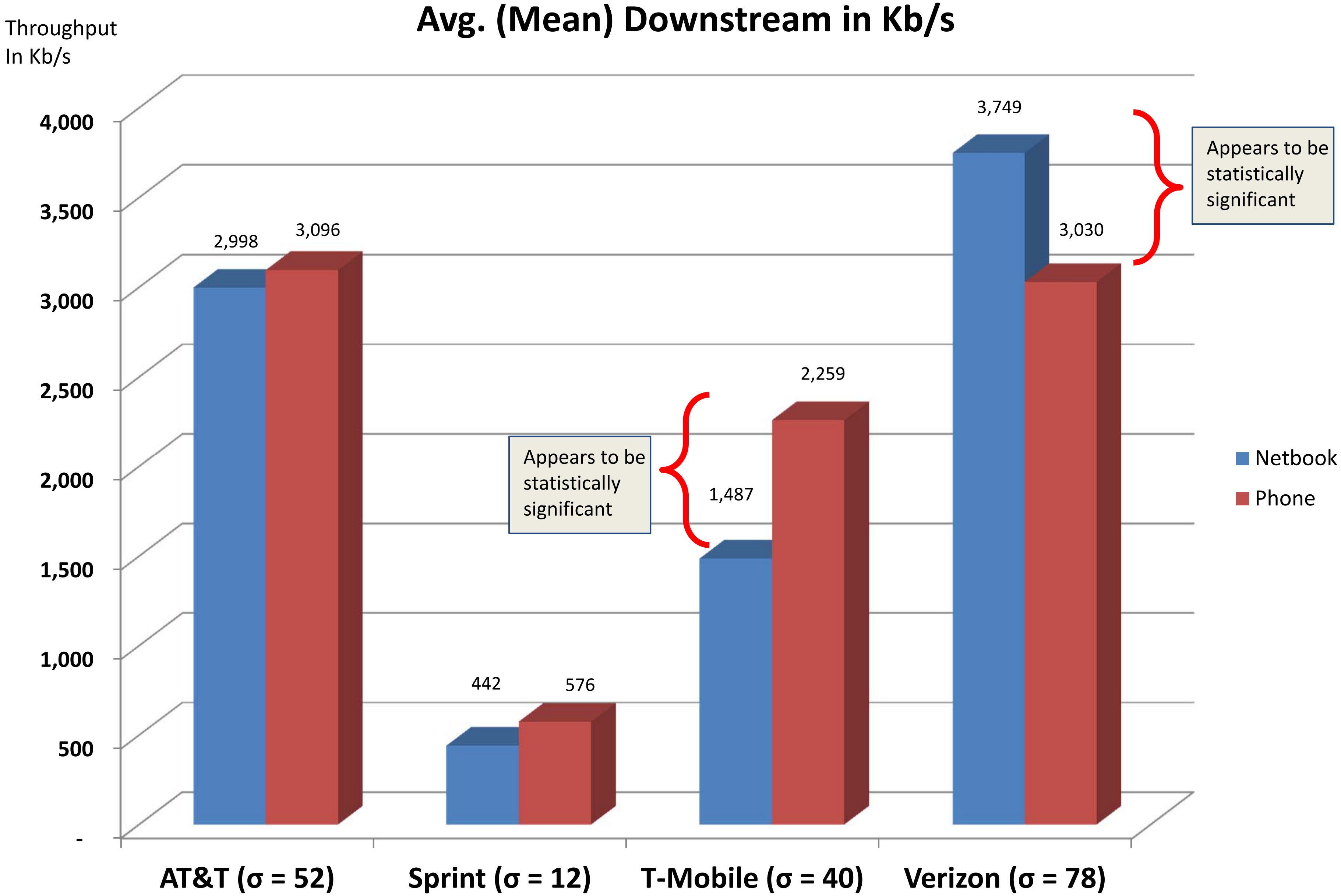
## Downstream

### Netbook and Smartphone Averaged, in Kb/s



# Netbook vs. Smartphone Differences

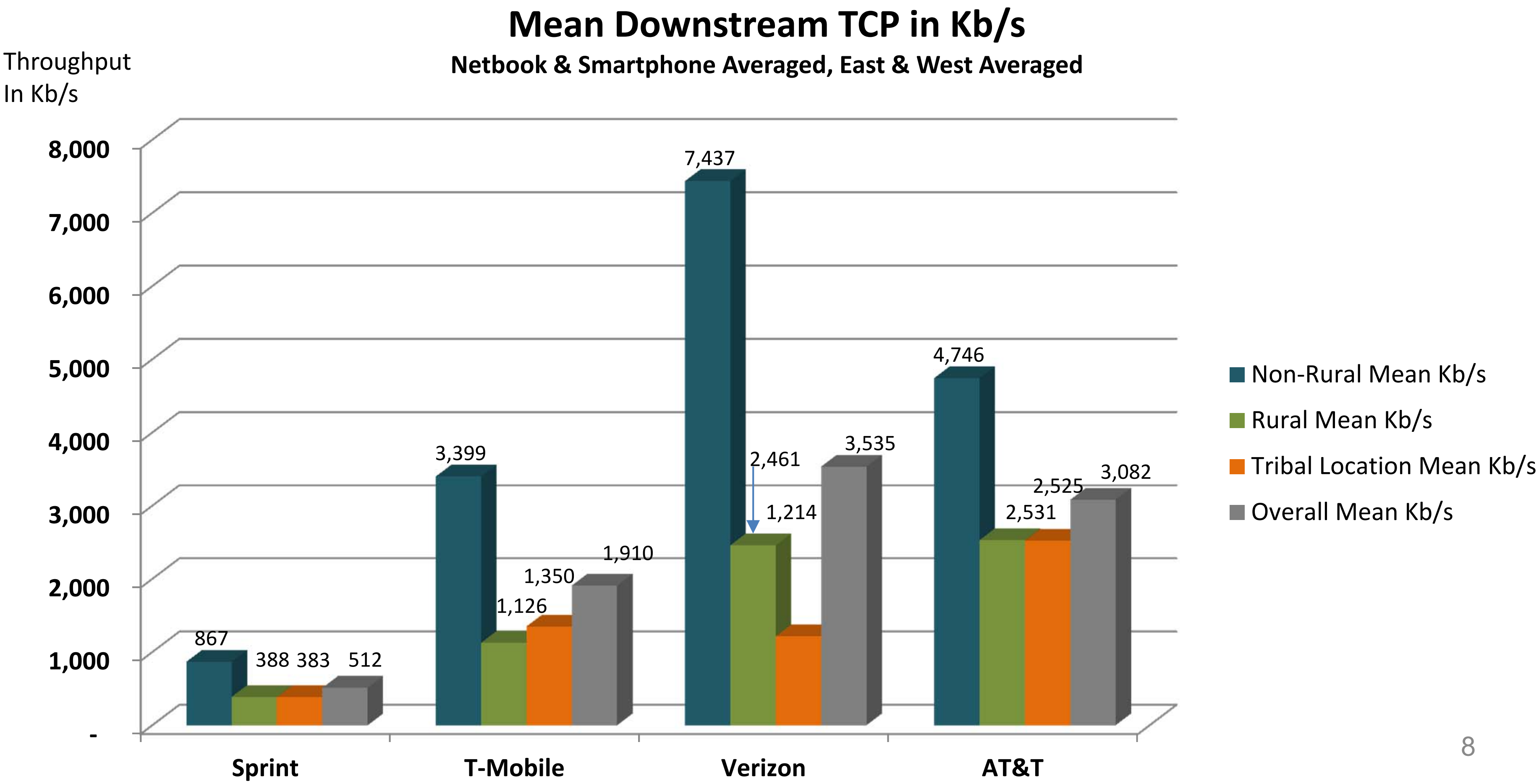
## Avg. (Mean) Downstream in Kb/s



# Mean Downstream Throughput Non-Rural / Rural / Tribal

(Netbook + Smartphone averaged, West & East averaged, out of coverage sites not included)

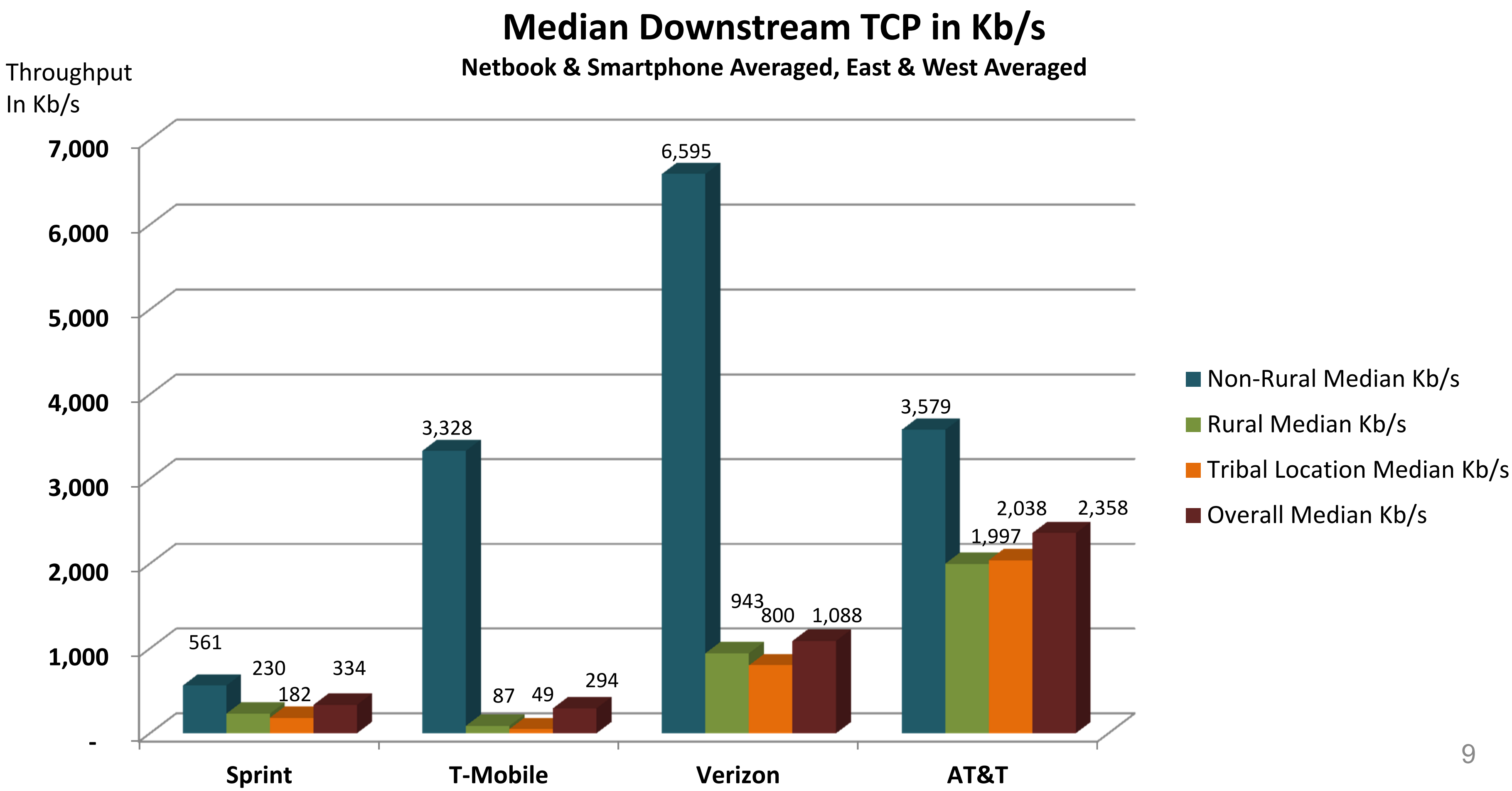
| Mean Downstream TCP in Kb/s | | | | | |
|---|---|---|---|---|---|
| | Sprint | T-Mobile | Verizon | AT&T | Overall Avg. |
| **Non-Rural** Mean Kb/s | 866.63 | 3,398.57 | 7,437.00 | 4,746.13 | 4,118.30 |
| **Rural** Mean Kb/s | 388.29 | 1,126.32 | 2,461.24 | 2,531.49 | 1,705.98 |
| **Tribal** Location Average Kb/s | 383.27 | 1,350.17 | 1,214.22 | 2,524.52 | 1,386.28 |
| **Overall** Mean Kb/s | 512.06 | 1,909.64 | 3,535.30 | 3,081.94 | 2,320.27 |
| **# Locations** (In-Coverage + Roaming) | 1,028 | 785 | 1,115 | 1,085 | |

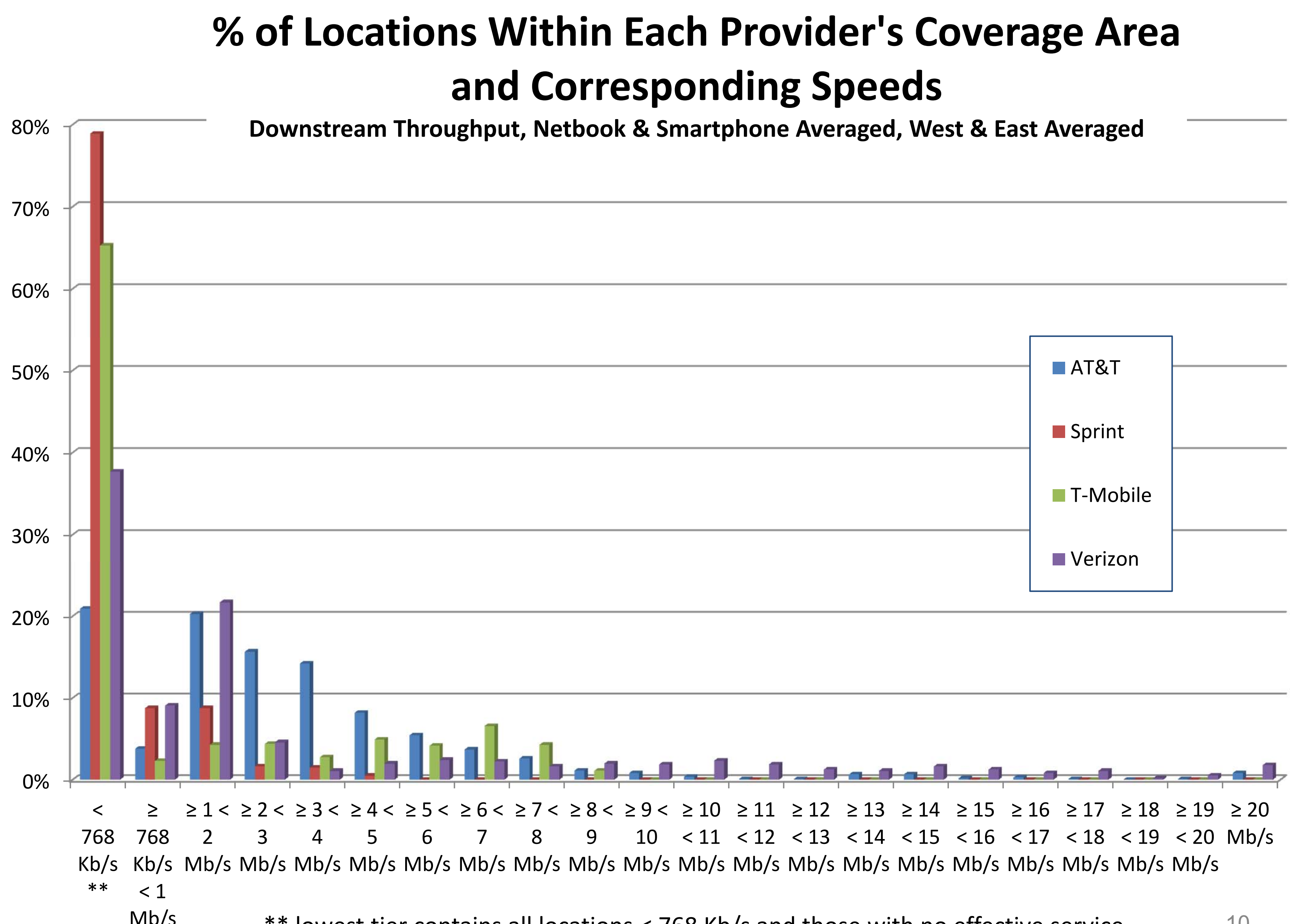


# Median Downstream Throughput Non-Rural / Rural / Tribal

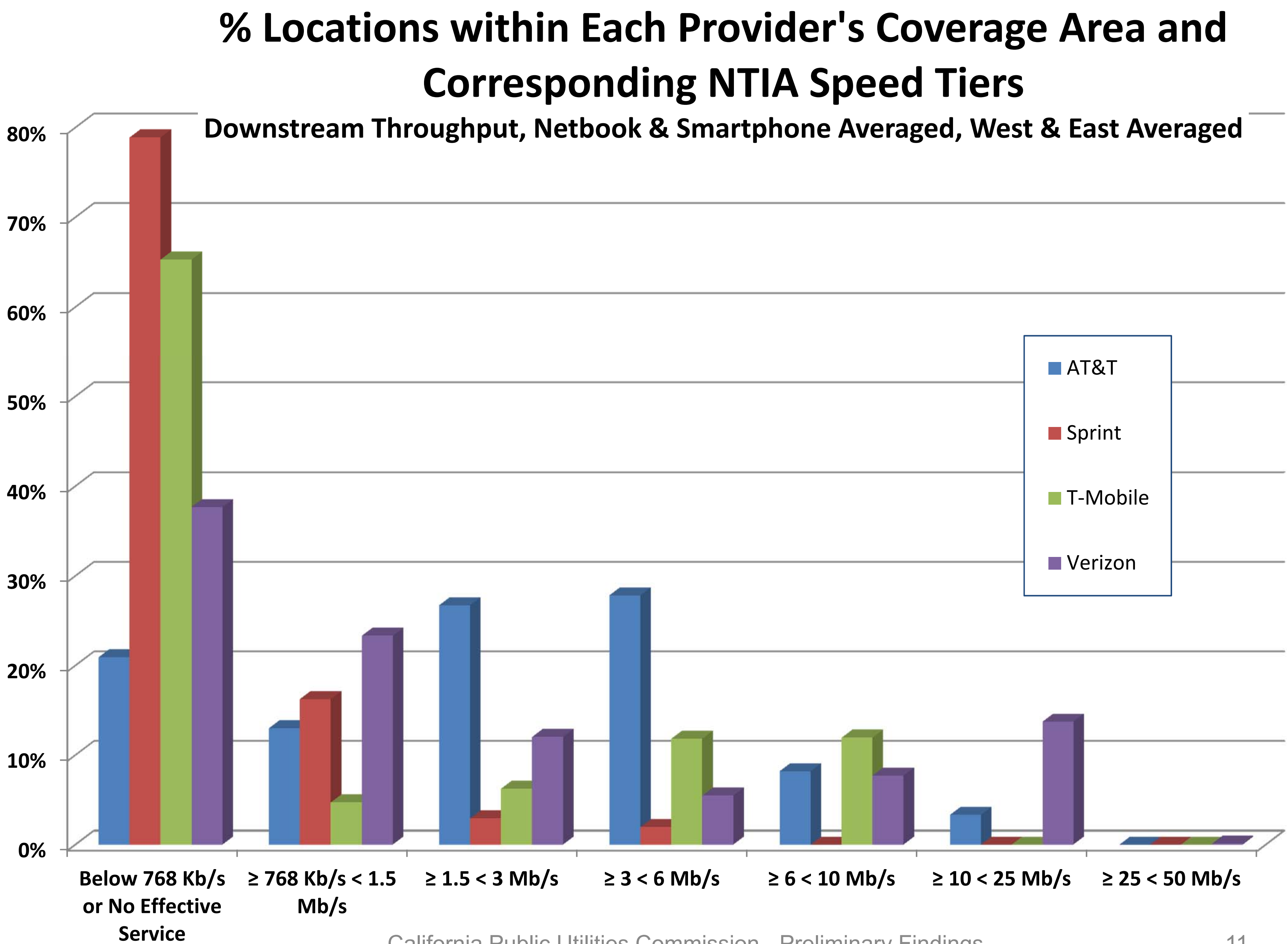
(Netbook + Smartphone averaged, West & East averaged, out of coverage sites not included)

| Median Downstream TCP in Kb/s | Sprint | T-Mobile | Verizon | AT&T |
|---|---|---|---|---|
| Non-Rural Median Kb/s | 561 | 3,328 | 6,595 | 3,579 |
| Rural Median Kb/s | 230 | 87 | 943 | 1,997 |
| Tribal Location Median Kb/s | 182 | 49 | 800 | 2,038 |
| **Overall Median Kb/s** | **334** | **294** | **1,088** | **2,358** |
| # Locations (In-Coverage + Roaming) | 1,028 | 913 | 1,115 | 1,085 |






** lowest tier contains all locations < 768 Kb/s and those with no effective service


% Locations within Each Provider's Coverage Area and Corresponding NTIA Speed Tiers
Downstream Throughput, Netbook & Smartphone Averaged, West & East Averaged
80%
70%
60%
50%
40%
30%
20%
10%
0%
AT&T
Sprint
T-Mobile
Verizon
Below 768 Kb/s or No Effective Service
≥ 768 Kb/s < 1.5 Mb/s
≥ 1.5 < 3 Mb/s
≥ 3 < 6 Mb/s
≥ 6 < 10 Mb/s
≥ 10 < 25 Mb/s
≥ 25 < 50 Mb/s

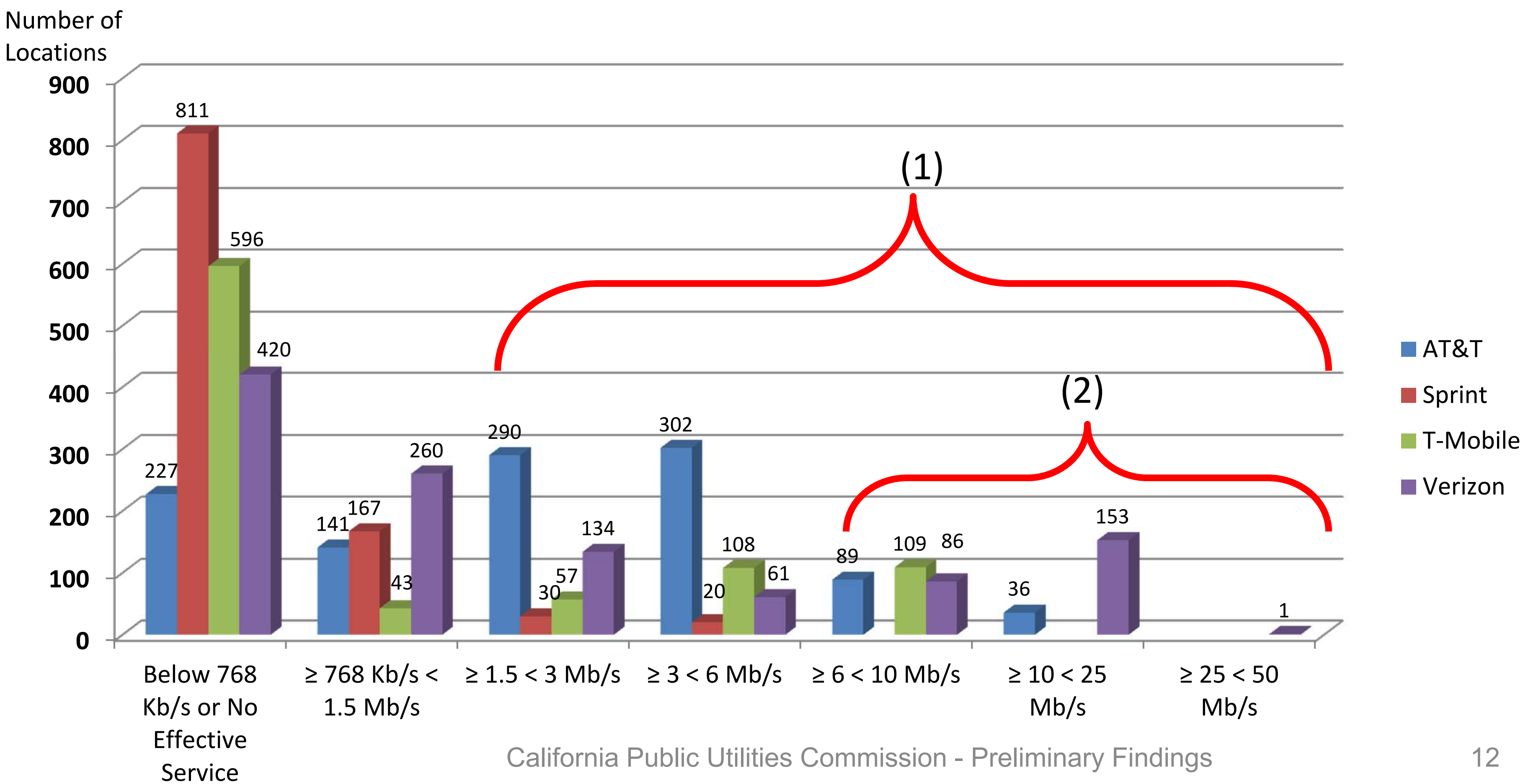
# Analysis of Downstream Distribution

(1) **AT&T appears to be stronger in the mid-range** speed tiers

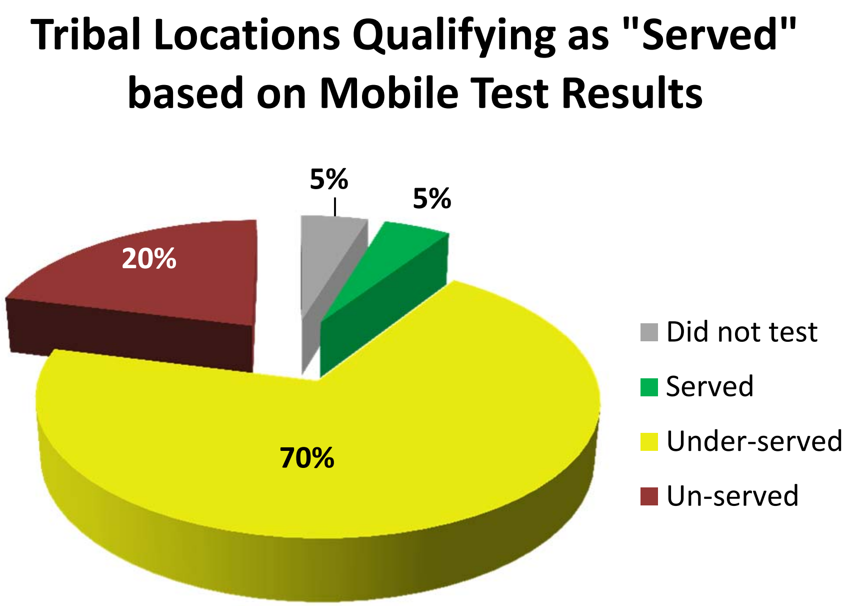
- AT&T – 717 out of 1,200 locations, or 60%, with throughput ≥ 1.5 Mb/s
- Verizon – 434 out of 1,200 locations, or 36%, with throughput ≥ 1.5 Mb/s

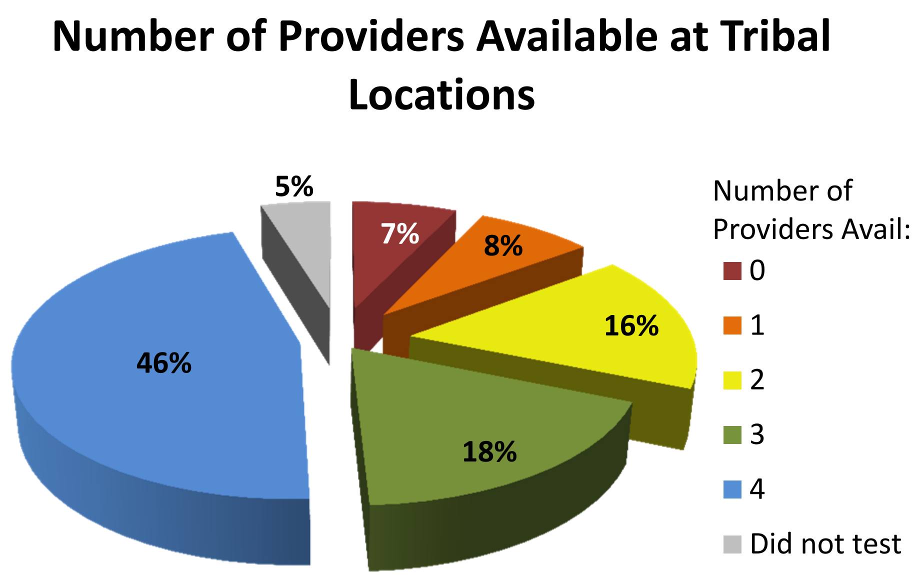
(2) **Verizon's aggressive rollout of LTE is evident** in the larger number of locations with ≥ 6.0 Mb/s throughput

- Verizon – 240 out of 1,200 locations (20%)
- AT&T – 125 out of 1,200 locations (10%)



# Mobile Broadband on Tribal Lands



# Evidence of Rate Limiting (Glasnost)

| ISP | Direction | Positive Rate | Conclusion |
|---|---|---|---|
| AT&T | Upload | 2.63% | Negative |
| | Download | 7.69% | Positive |
| Verison | Upload | 2.44% | Negative |
| | Download | 23.08% | Positive |
| Sprint | Upload | 20.00% | Positive |
| | Download | 33.33% | Positive |
| T-Mobile | Upload | 3.33% | Negative |
| | Download | 15.00% | Positive |

- Rate limiting occurs when an Internet service provider (ISP) such as Verizon, Sprint, I-Mobile or AT&T intentionally slows down a user's Internet connection speed.
- ISP s may employ rate limiting for the purpose of preserving available bandwidth. For example, if multiple users are downloading bitTorrent files and consuming a large amount of bandwidth, the overall network connection for all the users can be affected. By limiting the amount of data that individual users can download or upload ISPs conserve bandwidth and make the general network connection faster for the majority of users.
- We tested all 4 carriers at 50 locations using the open source rate limit testing software, "Glasnost."
- Glasnost tries to determine if a carrier is limiting Internet traffic based on traffic type. In this case, we compared bitTorrent download throughput with non bitTorrent download throughput.
- Each of these tests took roughly 8 minutes per location, and the testing was limited to 50 locations to get a large enough sample-set in a practical amount of time.

# Appendix: Testing Application

CSU Monterey Bay developed a testing suite based on an open source tool set called “iPerf,” which measures network throughput and performance.

The client software in a client device requests either a TCP or UDP data connection to the server side software. After the connection is established, the tool measures the throughput between the two ends. For this project, we set up the iPerf server software on two Amazon Linux machines on the East and West coasts.

Existing testing applications sometimes omit high and low results as outliers, they often default to the nearest server, and they often only perform TCP and ping tests.

During the tests, the iPerf tool measures TCP upload bandwidth, TCP download bandwidth, UDP jitter, and UDP datagram loss rate.

For the TCP upload, the client software makes a connection to the server side software and sends data streams to the server side for 10 seconds. After that, the server side software sends data streams from the server to the client to measure download bandwidth. Note that the original iPerf tool used two separate connections to measure upload and download speeds. But because many client devices and network operators do not allow the server side software to make a new connection with the client device, we kept the connection used for the upload measurement and used it for the download measurement as well. By using this technique, we avoided the firewall which would have blocked the client device. Another measurement parameter used by iPerf is a 64.0 Kbytes window size (-w 64k). This determines the amount of data that can be buffered during a connection without a validation from the receiver. This setting executes four threads concurrently (-P 4) at both sides, which can increase the data volumes to be exchanged between the client and server.

In order to measure UDP jitter and datagram loss rate, iPerf sends data to the client side for either one or five seconds. Note that there are no data streams from the server to the client in the UDP measurement. For this measurement, we set the following parameters of 220K buffer length (-l 220) and 88K bits/sec bandwidth (-b 88k) to send data. The following shows all measurements taken in a single testing:

- TCP upload (10 seconds) and download (10 seconds) measurement to the West server (twice)
- TCP upload (10 seconds) and download (10 seconds) measurement to the East server (twice)
- UDP jitter and datagram loss (1 second) to the West server (three times)
- UDP jitter and datagram loss (1 second) to the East server (three times)
- UDP jitter and datagram loss (5 seconds) to the West server (one time)
- UDP jitter and datagram loss (5 seconds) to the East server (one time)