LARGE-SCALE INTERNET MEASUREMENTS FOR DATA-DRIVEN PUBLIC POLICY

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Overview

- Why measure?
- Results of FCC MBA 2011 and 2012
- The challenge of mobile measurements
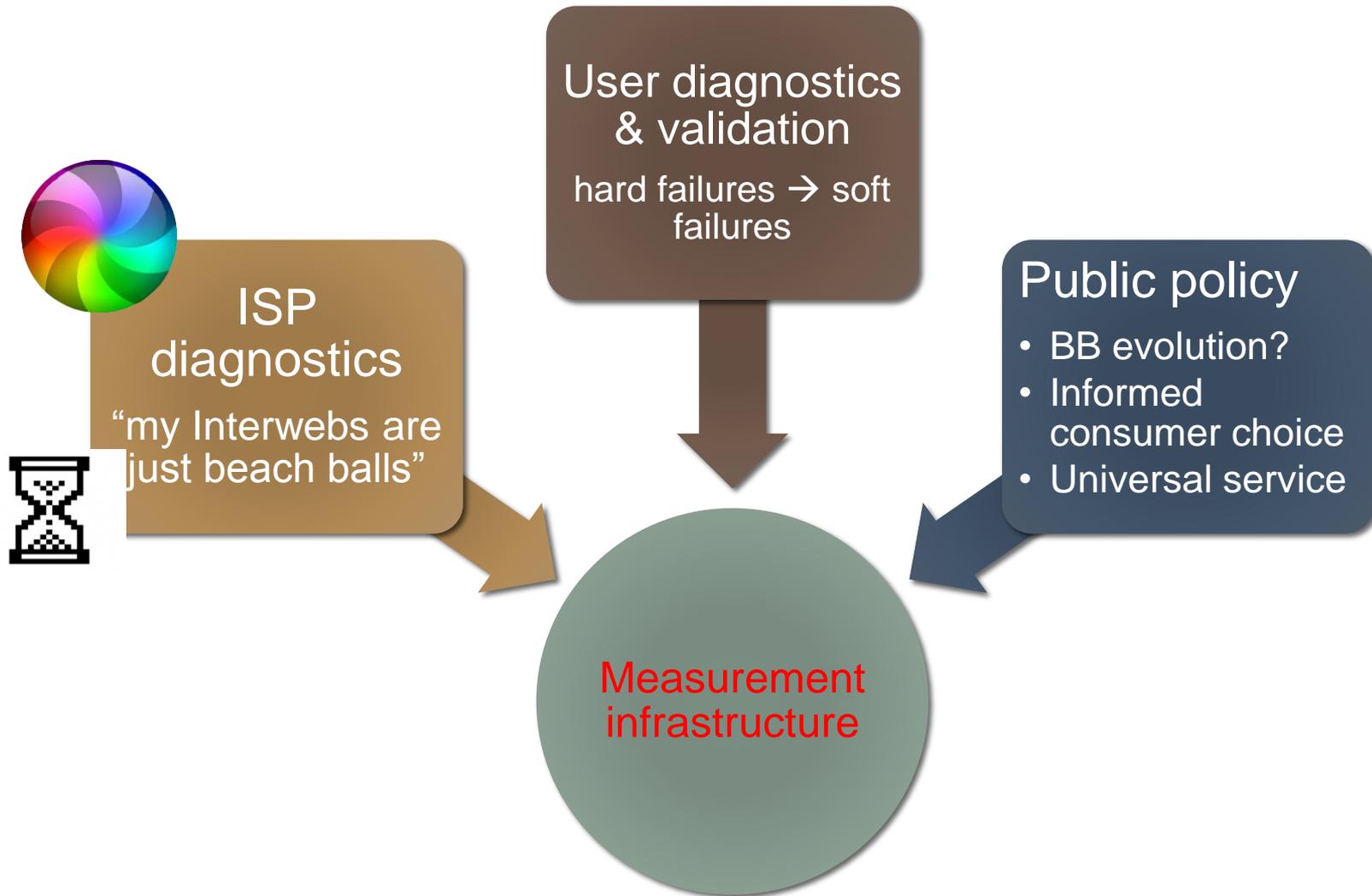- Baking measurements into the infrastructure

Why measure?

- Whole conferences on measurement
  - often driven by lost-key method
- Long history of IETF measurement work
  - RFC 2330: 1998
  - focused on specific metrics, not so much overall architecture
- Performance measurements don't work well
  - Individual consumers:
    - not statistically reliable (geek-heavy)
    - no ground truth data
    - confounding factors (e.g., home networks)
    - data generally not published → hard to compare metrics
  - Service providers:
    - limited infrastructure → hard to scale

FCC measurement history

- FCC has acquired and analyze data on legacy PSTN
- More recent and evolving broadband interest
  - Section 706 of 1996 Telecommunications Act ➔ annual report on availability of advanced telecommunications services to all Americans
    - Resulted in information on deployment of broadband technology ("Form 477")
    - but not its performance
  - FCC's National Broadband Plan – March 2010
    - Proposed performance measurements of broadband services delivered to consumer households
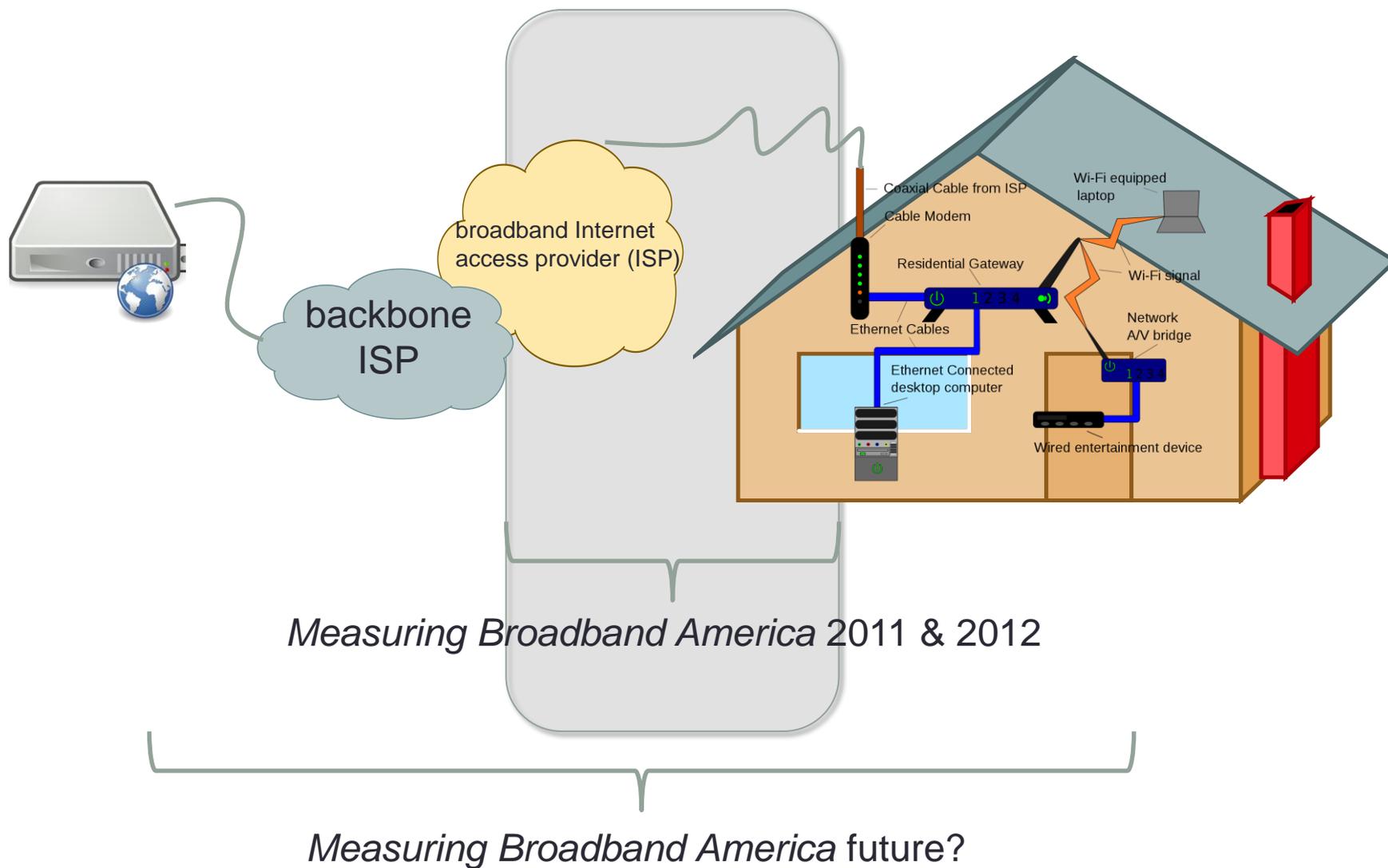   - Work plan evolved from recommendations of National Broadband Plan

The role of network measurements

User diagnostics & validation

hard failures → soft failures

ISP diagnostics

"my Interwebs are just beach balls"

Public policy

- BB evolution?
- Informed consumer choice
- Universal service

Measurement infrastructure

Principles

- The FCC Measuring Broadband America program is based on principles of openness, transparency and partnership with diverse stakeholders.

- We are committed to:
  - Ensuring that commonly accepted principles of *scientific research*, *good engineering practices*, and *transparency* guide the program;
  - Encouraging *collaboration* of industry, academia and government;
  - *Publishing the comprehensive technical methodology* used to collect the data, including the source code for the tests as open source;
  - *Releasing data* used to produce each report coincident with the report's release, and releasing all data for each collection cycle within one year of collection.

Measurement architecture

broadband Internet
access provider (ISP)

backbone
ISP

Coaxial Cable from ISP

Cable Modem

Residential Gateway

Ethernet Cables

Ethernet Connected
desktop computer

Wi-Fi equipped
laptop

Wi-Fi signal

Network
A/V bridge

Wired entertainment device

Measuring Broadband America 2011 & 2012

Measuring Broadband America future?

Lucid

The MBA project - logistics

- Enlisted cooperation:
  - 13 ISPs covering 86% of US population
  - vendors, trade groups, universities and consumer groups
- Reached agreement reached on what to measure and how to measure it
- Enrolled roughly 9,000 consumers as participants
  - 6,800 (7,782) active during March 2011 (April 2012)
  - A total of 9,000 active over the data collection period

What was measured

|	
Sustained Download	Burst Download
Sustained Upload	Burst Upload
Web Browsing Download	UDP Latency
UDP Packet Loss	Video Streaming Measure
VoIP Measure	DNS Resolution
DNS Failures	ICMP Latency
ICMP Packet Loss	Latency Under Load
Total Bytes Downloaded	Total Bytes Uploaded

What was released

- *Measuring Broadband America* reports
  - Main section describing conclusions and major results
  - Technical appendix describing tests and survey methodology
- Spreadsheet providing standard statistical measures of all tests for all ISPs and speed tiers measured
- Report period data set with 4B data elements from over 100M tests
  - Data set presented as used with anomalies removed
  - Documentation provided on how data set was processed
  - All data, as recorded
- Geocoded data on test points recently released
- Information available at http://www.fcc.gov/measuring-broadband-america

2011: Most ISPs deliver close to advertised during peak hours

Chart 1: Average peak period and 24-hour sustained download speeds as a percentage of advertised, by provider
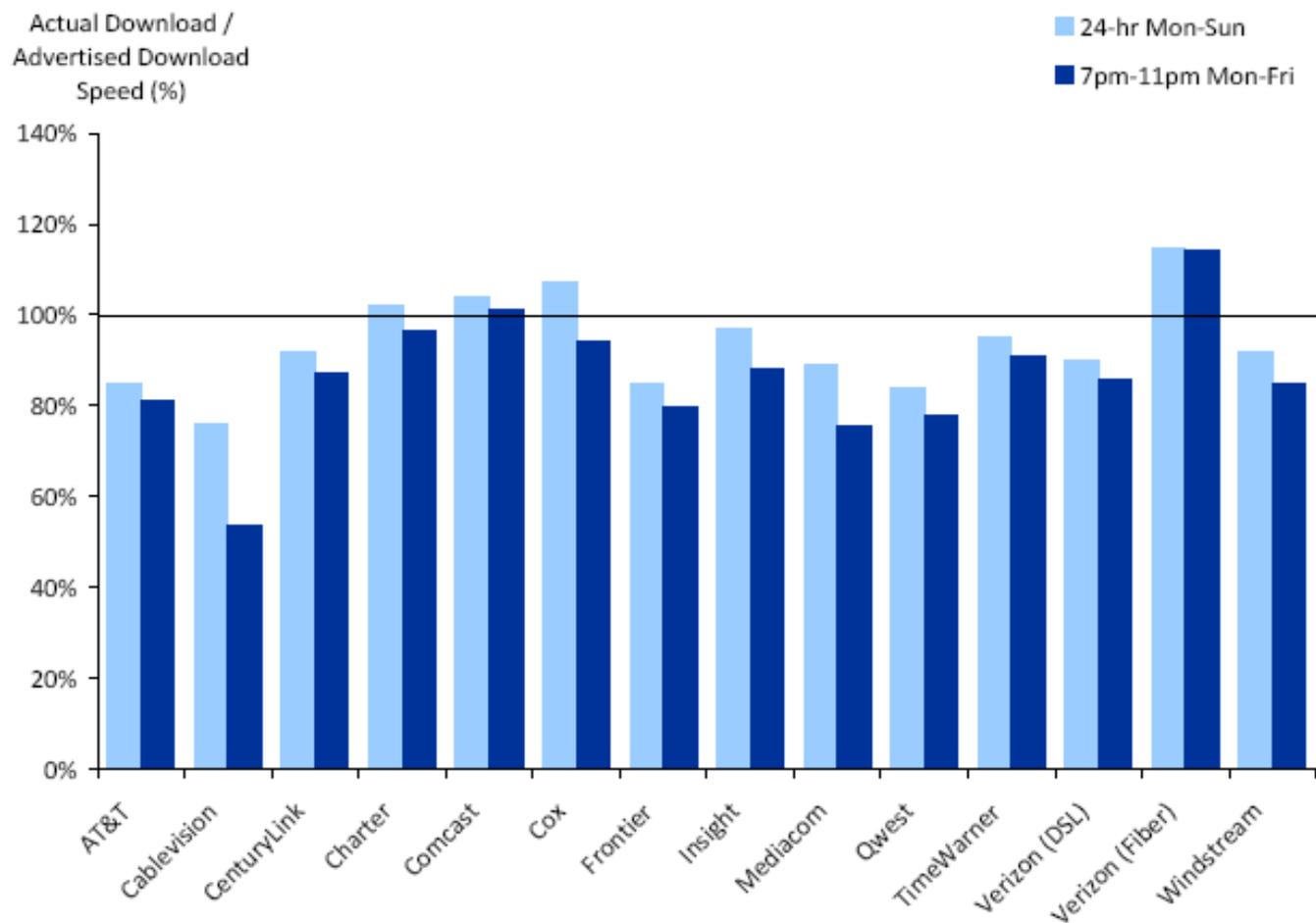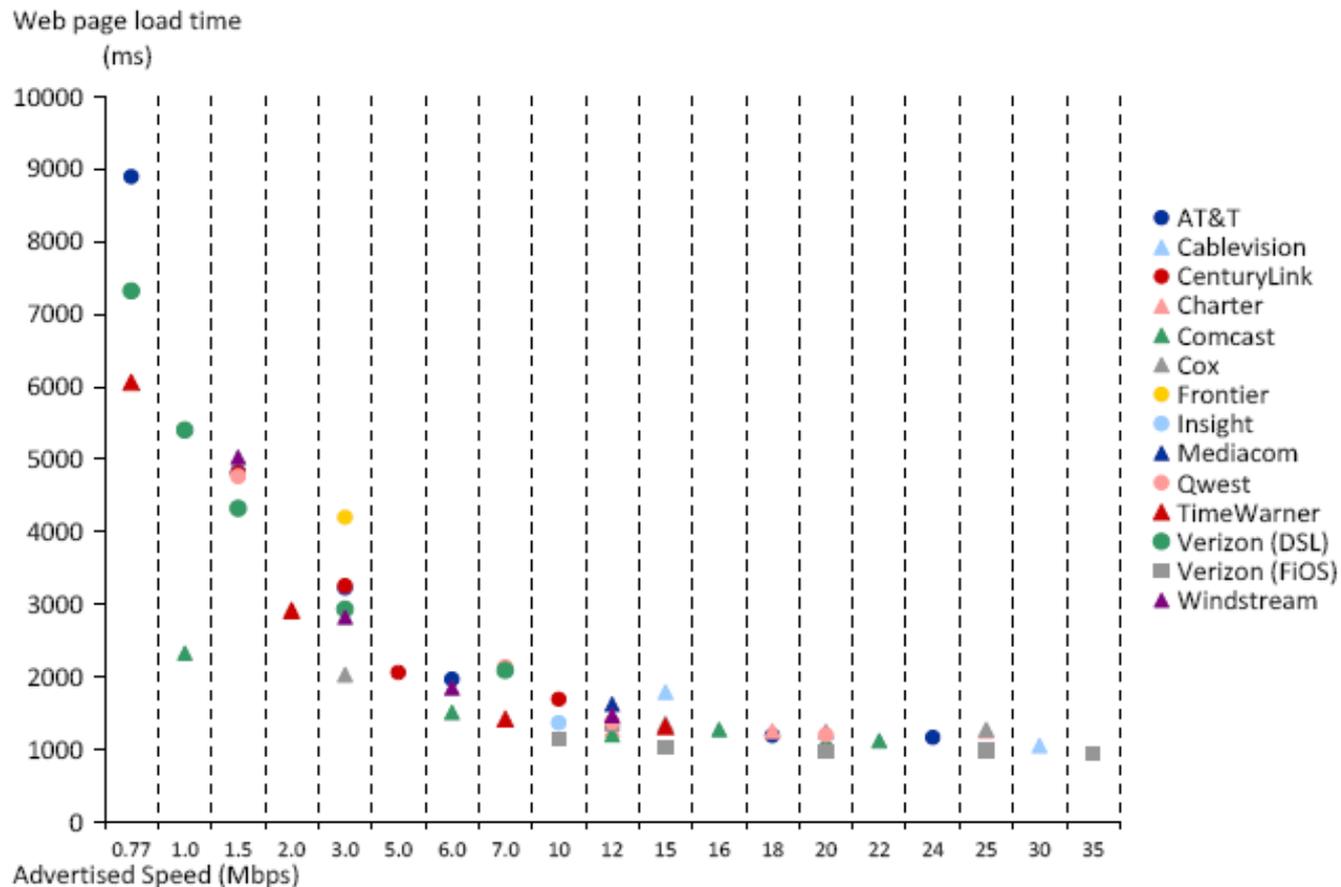
2012: You improve what you measure…
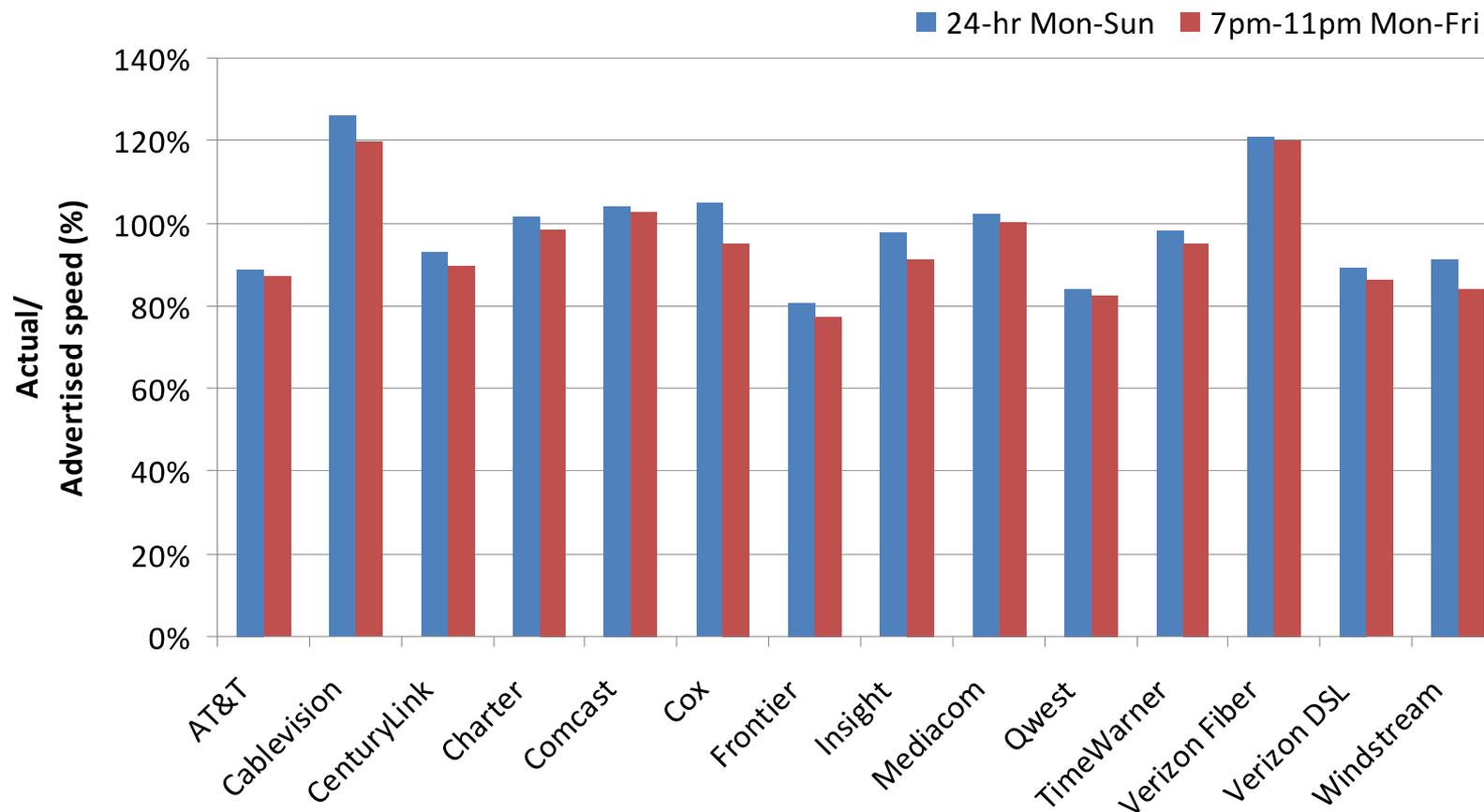
Web page downloading

Chart 10: Web loading time by advertised speed, by technology

The Internet is not a series of (fixed-width) tubes

- Some cable companies advertise burst speed
  - Quota based technique providing temporary speed increase of < 15 seconds
    - Also affected by other household activity
  - Can't be applied generally to DSL where sync rate often limiting factor
  - Marginal value to fiber where each subscriber has potentially available 37 Mb/s to 75 Mb/s provisioned bandwidth
  - → Links are no longer constant-size bit pipes
- Measured both burst and sustained speed

Broadband 2012

- Deployment
  - USF: Connect America Fund
- Performance
  - Measuring Broadband America
  - mobile project announced
- Significant progress:
  - wider availability of 100 Mb/s
  - fiber available to 46 million homes (FiOS, U-verse)
  - community/non-traditional broadband (Chattanooga, Kansas City)
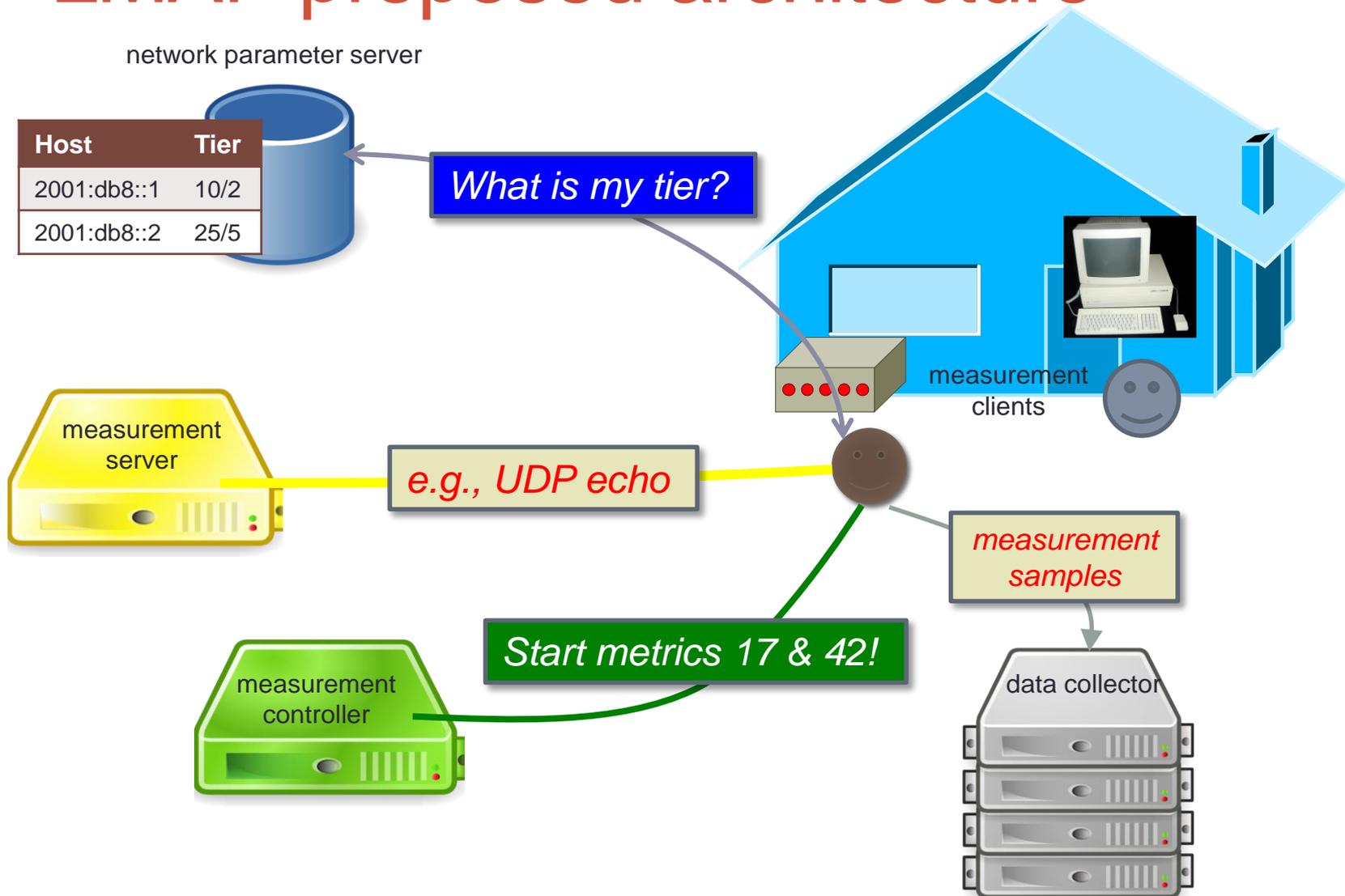 - LTE networks

Mobile performance

- Announced effort with 4 largest wireless providers
- Options available
  - structured drive testing → expensive
  - semi-formal drive testing → snapshot, limited coverage
  - passive measurements → privacy concerns, limited sampling
- ➔ Smartphone app + volunteers + existing infrastructure
- Challenges:
  - how to capture variation in time, space and device?
  - how to ensure location privacy?
  - impact of bandwidth usage for metered & capped plans?

What can't we measure?

- Small providers
  - may be more infrastructure- & engineering-challenged
- Anchor institutions
- Network reliability
  - large-scale outages gathered by "Part 4" outage reporting, but not public
  - small-scale outages?
- Network features
  - Who has access to DNSsec? IPv6? Which ports are being blocked?
- Which country has the cheapest broadband?
  - And why?
- What drives consumer adoption of higher speeds & new applications?
  - Speed → applications OR applications → speed?
- Why does 1/3 of US not use the Internet?
  - Relative importance of availability, affordability, relevance?

LMAP proposed architecture

network parameter server

Host	Tier
2001:db8::1	10/2
2001:db8::2	25/5

What is my tier?

measurement clients

measurement server

e.g., UDP echo

measurement samples

measurement controller
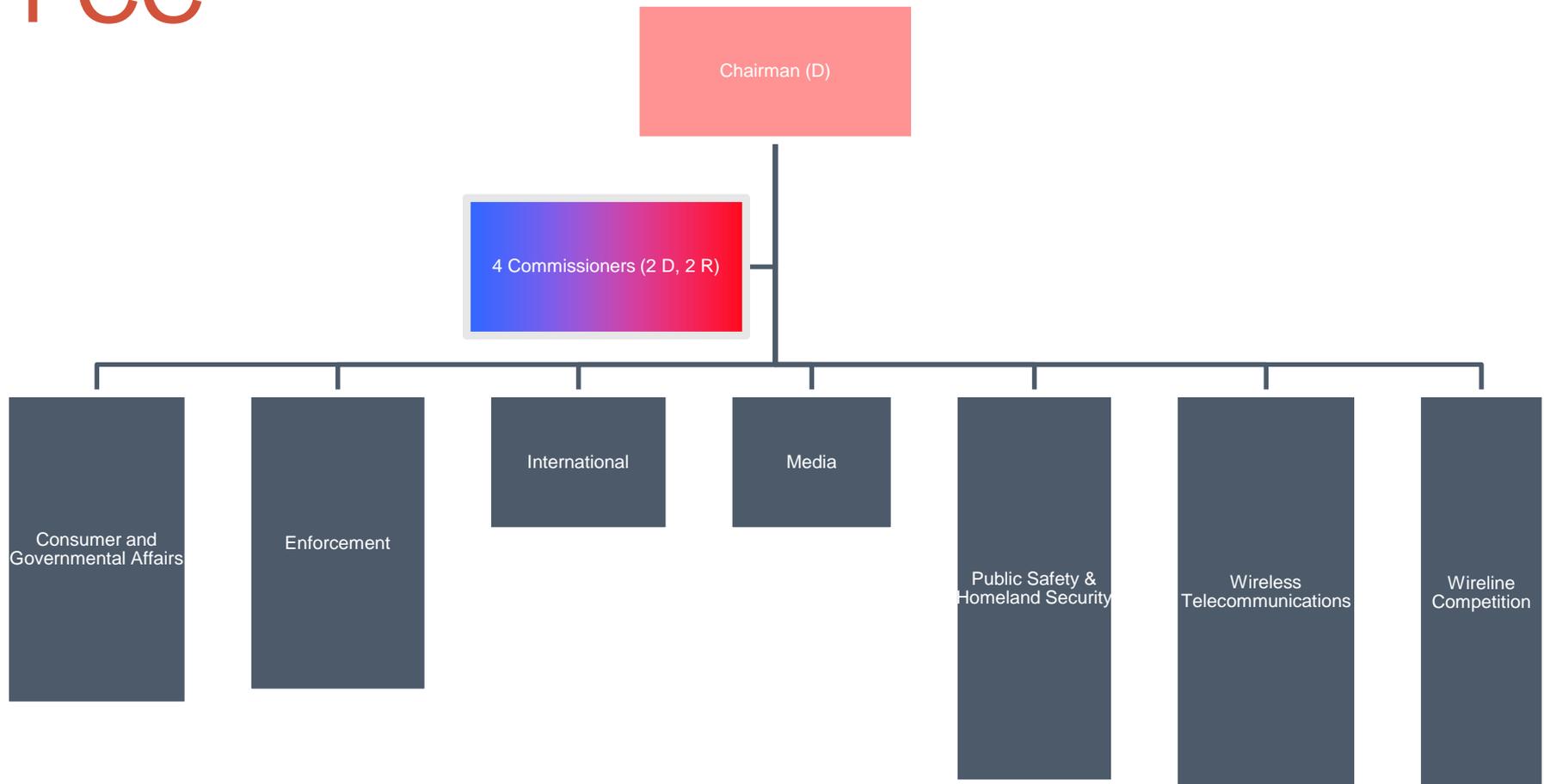
Start metrics 17 & 42!

data collector

Conclusion

- Measurements: from sometime experiment and LAN to built-in capability
- Good telecom policy needs good data
  - not just counting lines
  - PSTN transition to IP → there is no second network
- Re-use measurement for three purposes:
  - ISP diagnostics and planning
  - Consumer diagnostics
  - Public policy data gathering
- Dear IETF: We need your help!

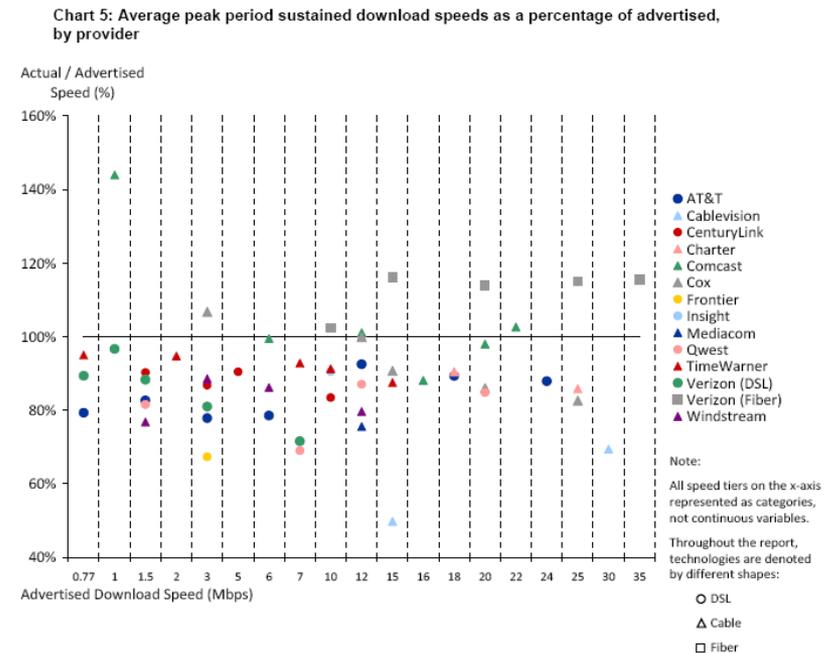# BACKUP

FCC

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                        ┌─────────────────────┐
                        │    Chairman (D)      │
                        └─────────────────────┘
              ┌─────────────────────┐
              │ 4 Commissioners (2 D, 2 R) │
              └─────────────────────┘
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| Consumer and Governmental Affairs | Enforcement | International | Media | Public Safety & Homeland Security | Wireless Telecommunications | Wireline Competition |

- Independent federal agency
- About 1,600 employees

Process

NOI
- Notice of Inquiry

NPRM
- Notice of Proposed Rule Making

R&O
- Report & Order

comments & ex parte
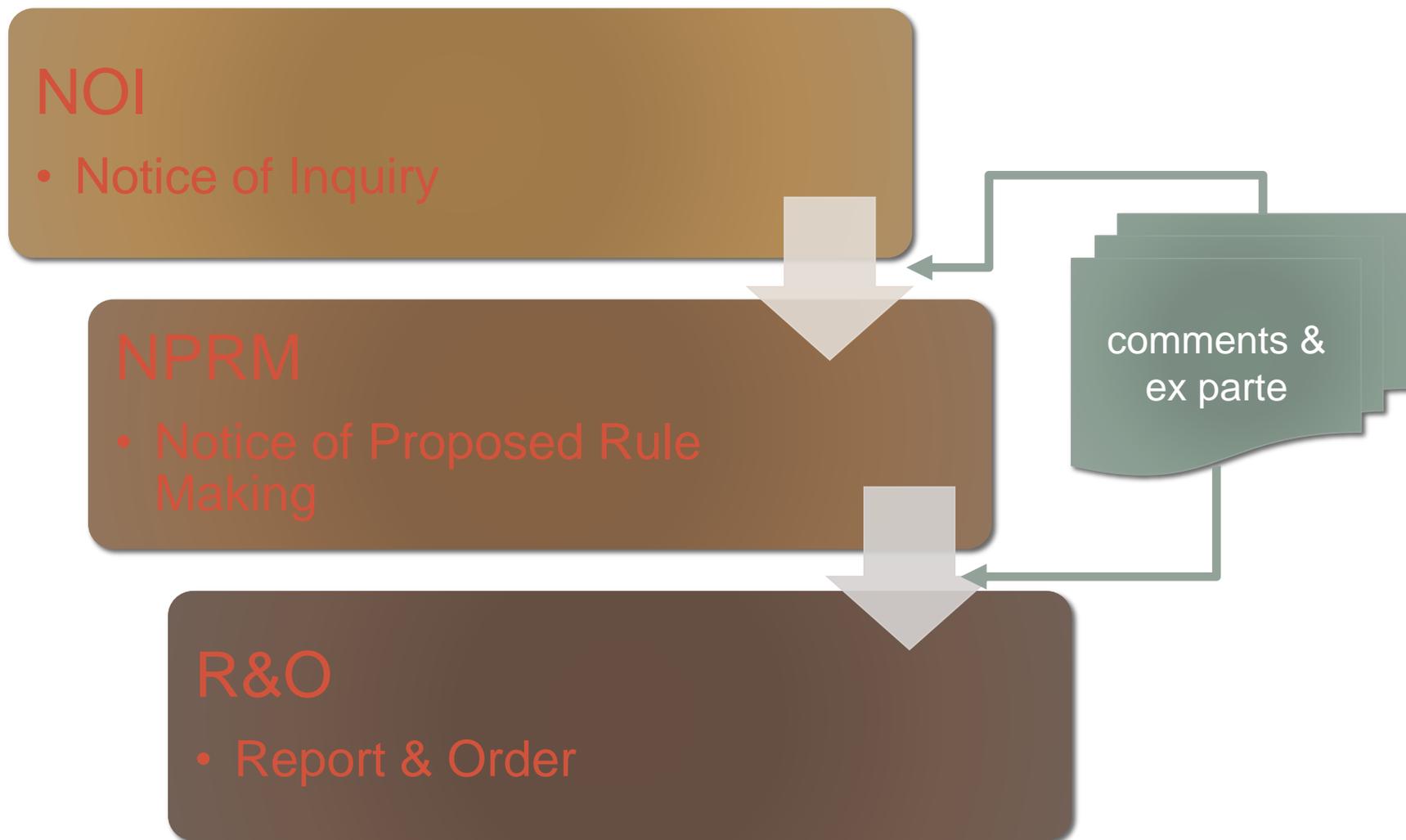
Performance varies

- ISPs seem to impose network wide performance standards
- However, there can be exceptions by speed tier

Chart 5: Average peak period sustained download speeds as a percentage of advertised, by provider

2011: some don't

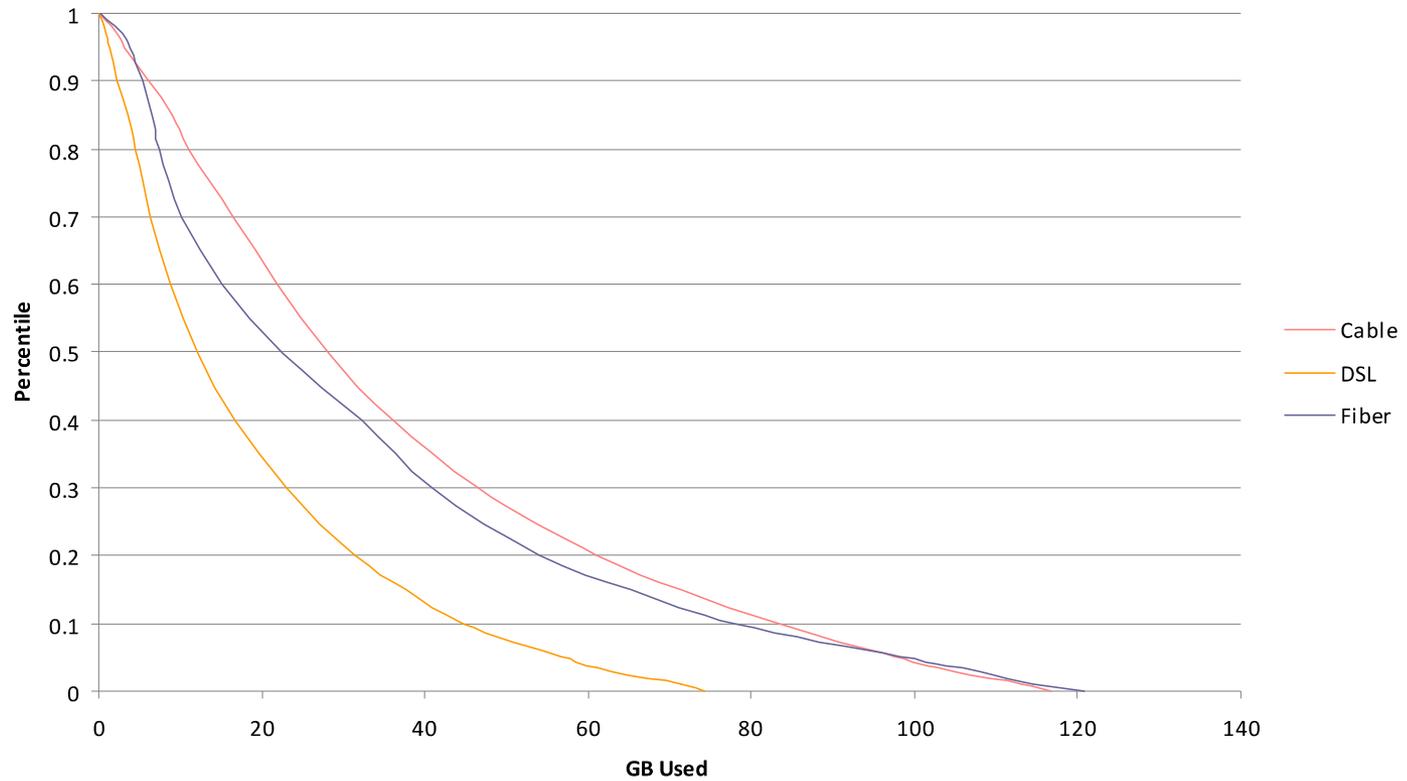Chart 11: Average sustained download speeds as a percentage of advertised over a 24-hour period, by provider
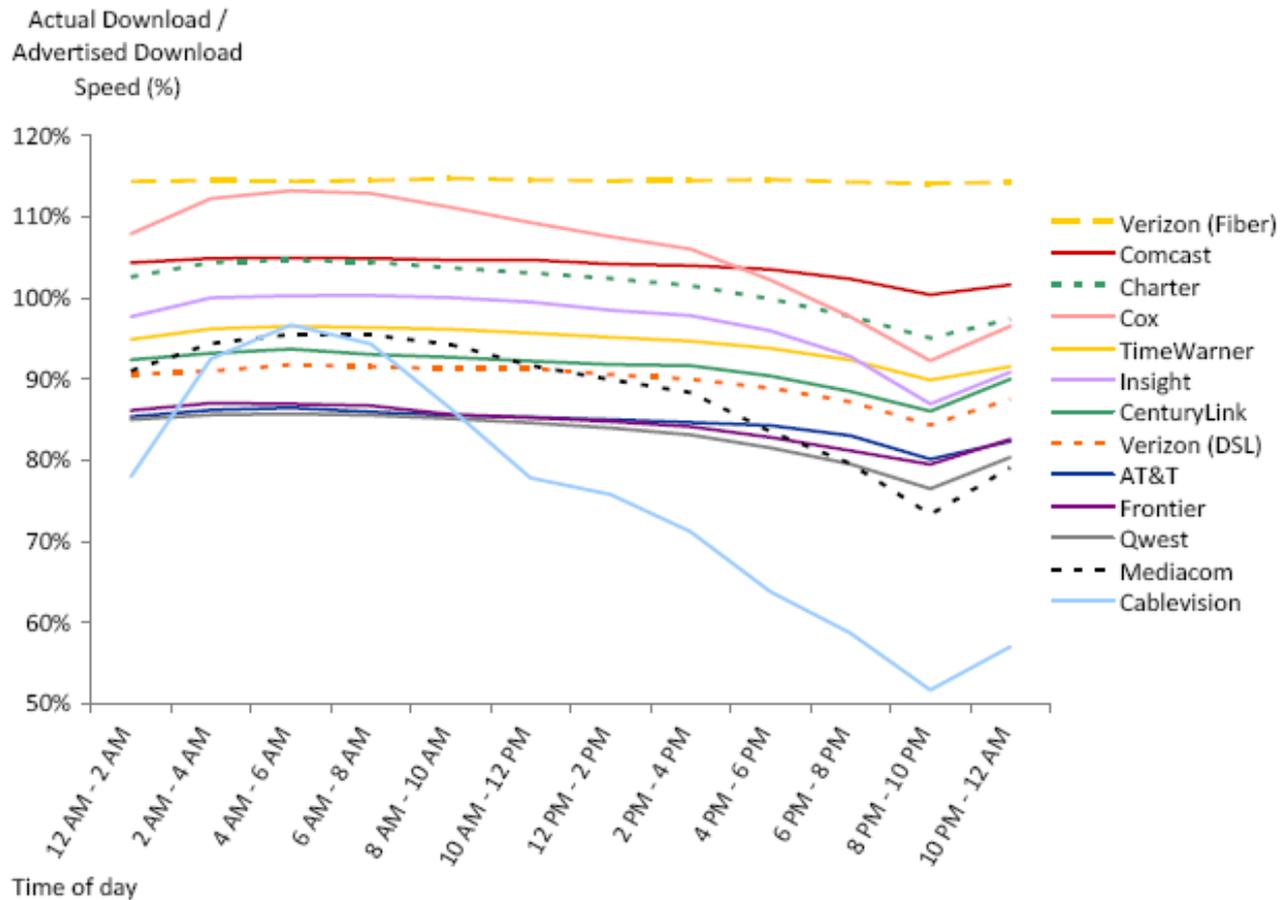
Burst speed increase
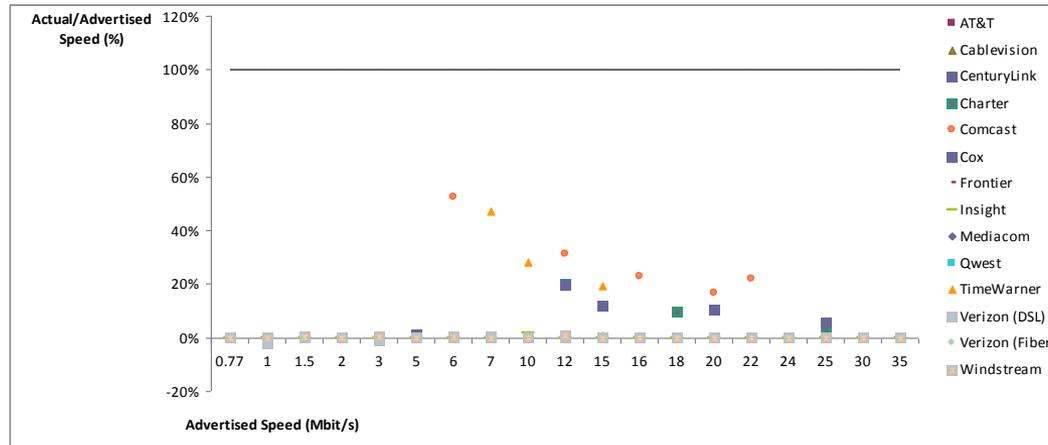
- Most impact of burst speed seen between 6 and 12 Mb/s
- Note: This chart not in report and shows calculated difference between burst and sustained performance

Latency by technology
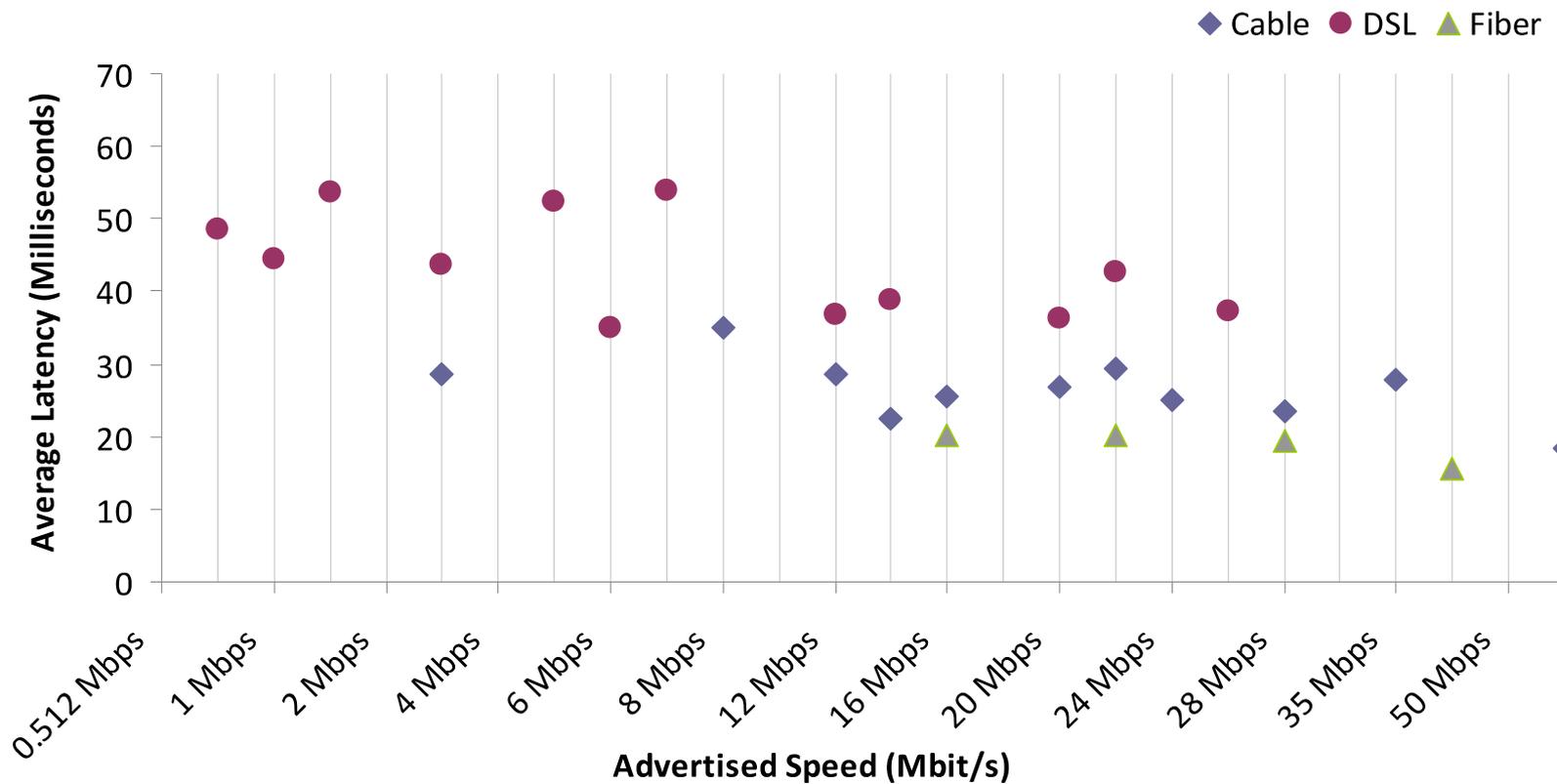
Data usage

Reliability

- Packet loss rate < 1%
- Correlation between peak periods and packet loss
  - Higher loss during peak hours
- Most companies during peak experience < .4% packet loss
- Worst case seen during March: .8%
- Data from other periods may have numbers in excess of 1% (Georgia Tech)
- 1% packet loss often cited as video threshold
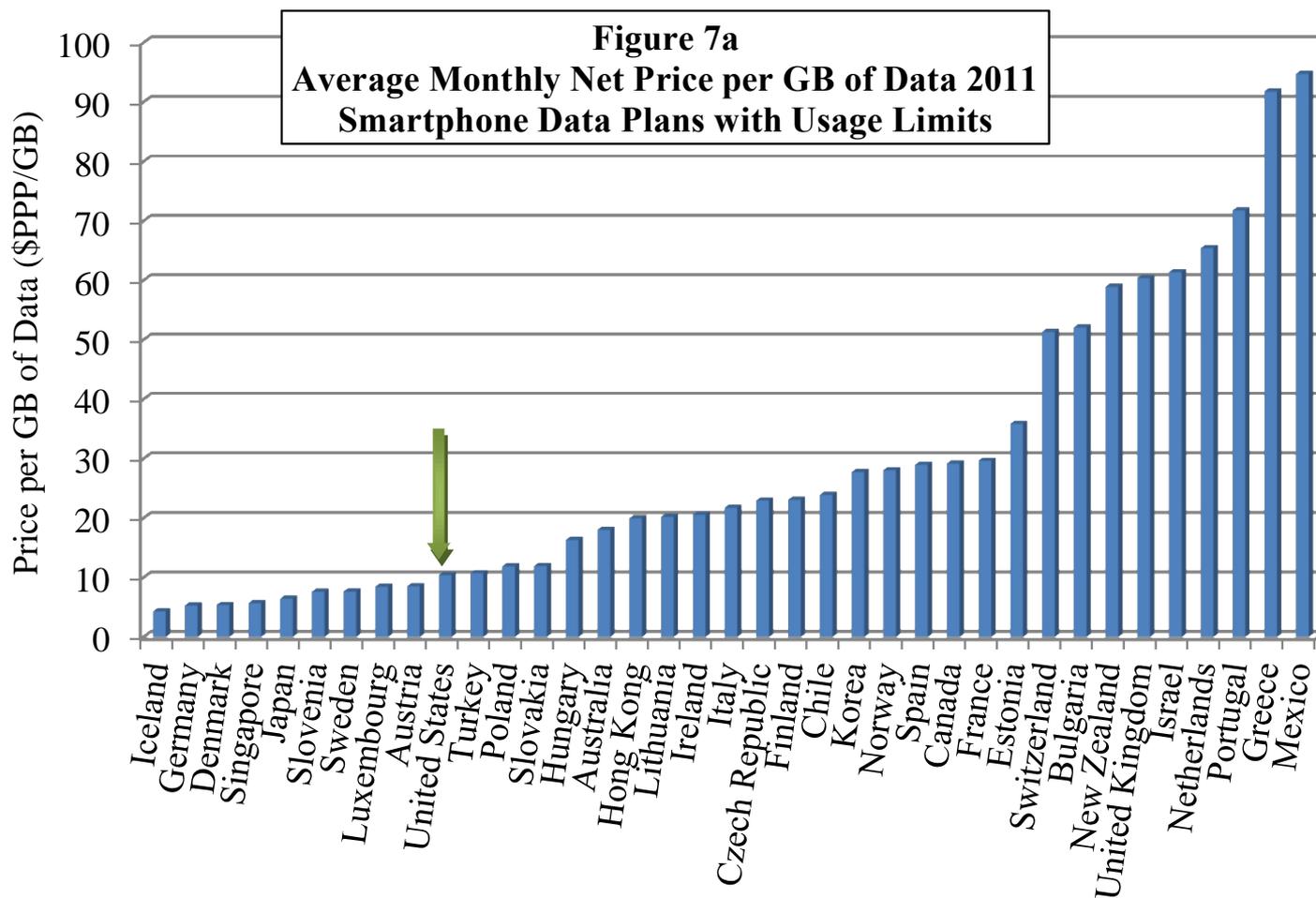
Web page downloading: Canary in the Coal Mine?

- Performance seems to top out after 10 Mb/s
- Many possible explanations
  - Latency, TCP issues, server loading, household platform limitations, …
- However, discussions with Georgia Tech indicate that they have seen similar performance issues
- Discussion with Ofcom and others suggest that globally, full benefits of higher line rates not being realized
- Higher ISP speed may challenge industry to examine performance bottlenecks
- More data needed

International comparison: fixed

Figure 2c
Average Monthly Net Price ($ PPP) of Residental (Fixed) Standalone
Broadband 2011
15-25 Mbps of Download Speed

3rd International Broadband Data Report (IBDR), August 2012
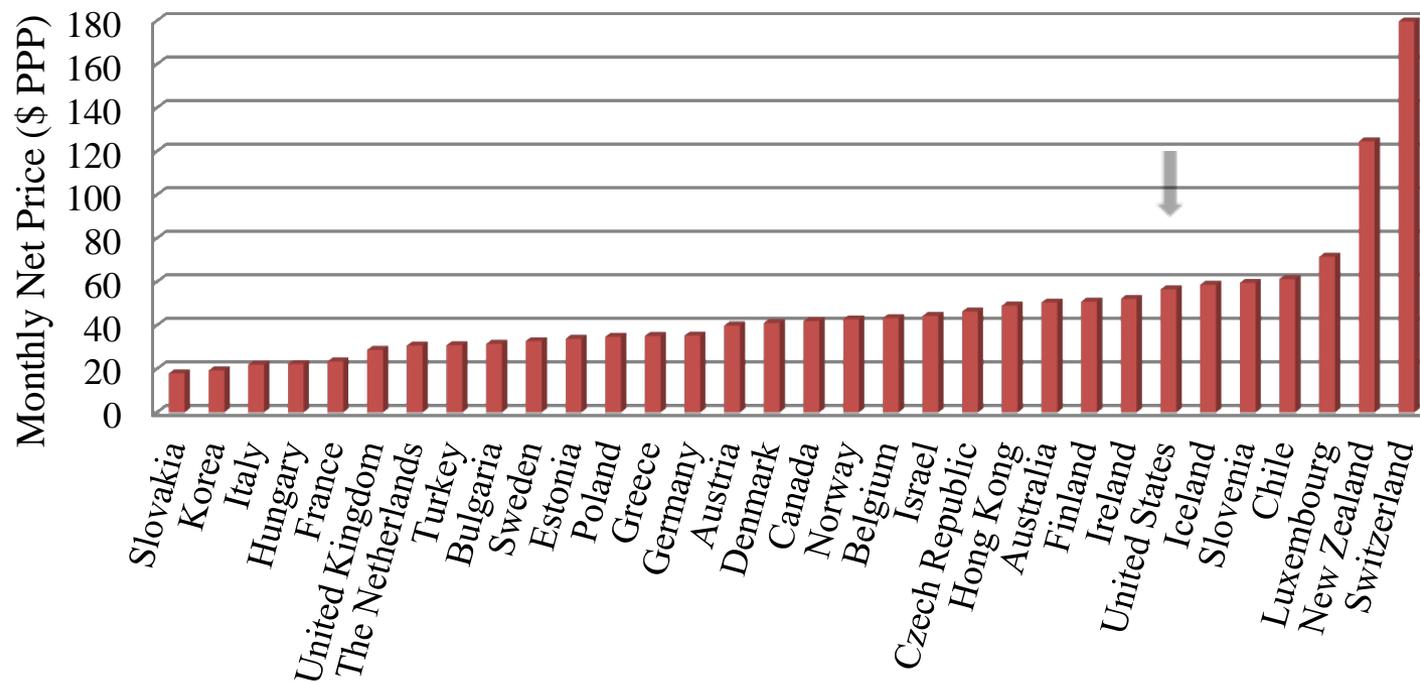
International comparison: mobile

Figure 7a
Average Monthly Net Price per GB of Data 2011
Smartphone Data Plans with Usage Limits

3rd International Broadband Data Report (IBDR), August 2012

2012 Upload speeds

Chart 2: Average Peak Period and 24-Hour Sustained Upload Speeds as a Percentage of Advertised, by Provider—April 2012 Test Data
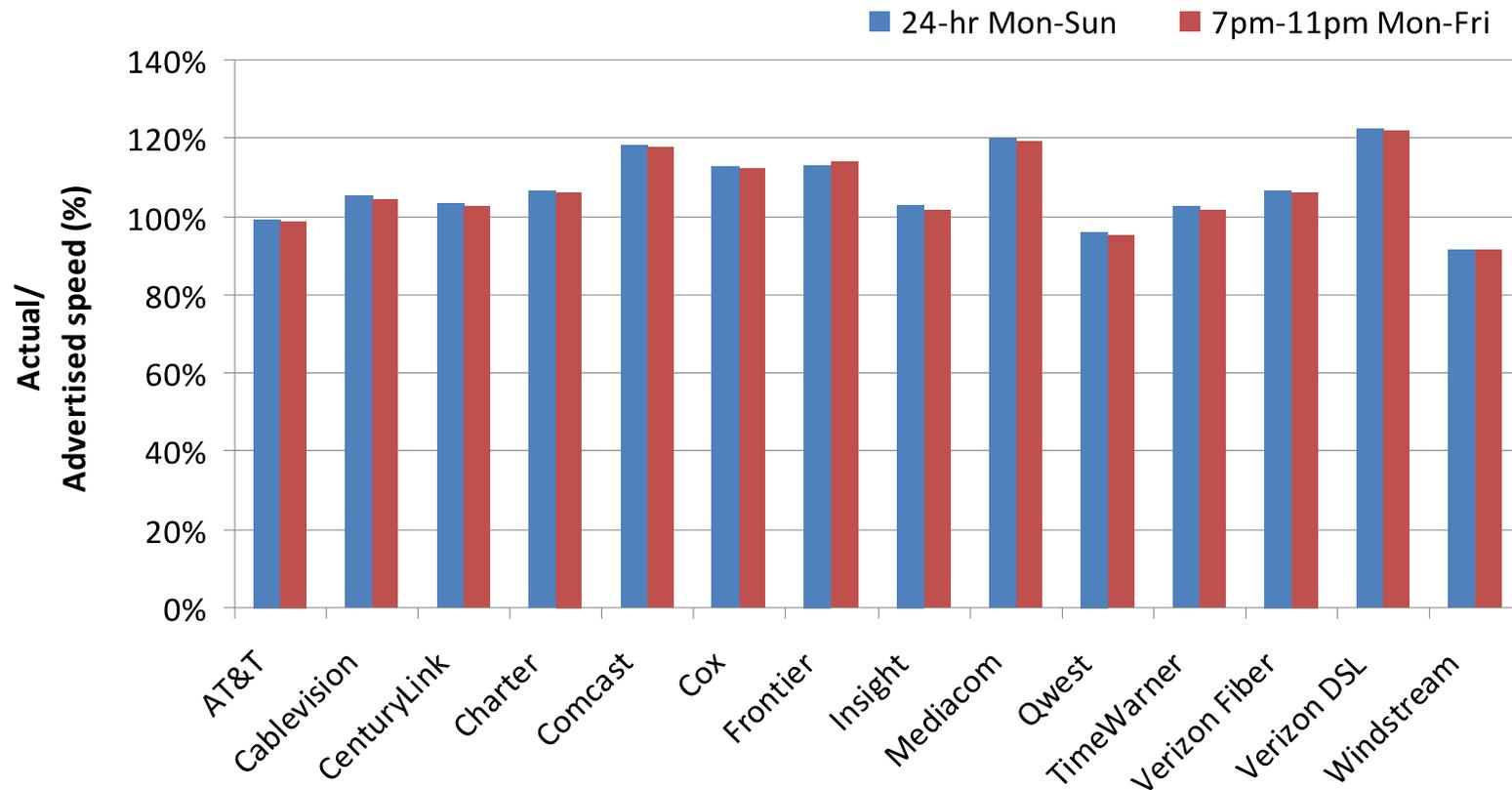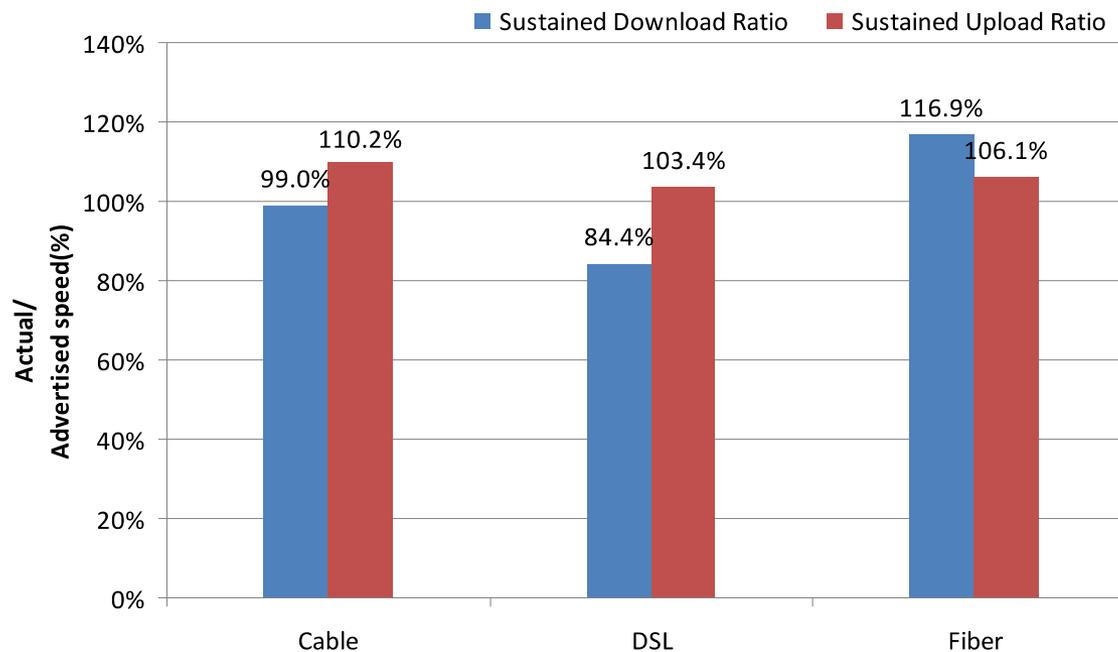
2012 peak period actual vs. advertised

Chart 3: Average Peak Period Sustained Download and Upload Speeds as a Percentage of Advertised, by Provider—April 2012 Test Data
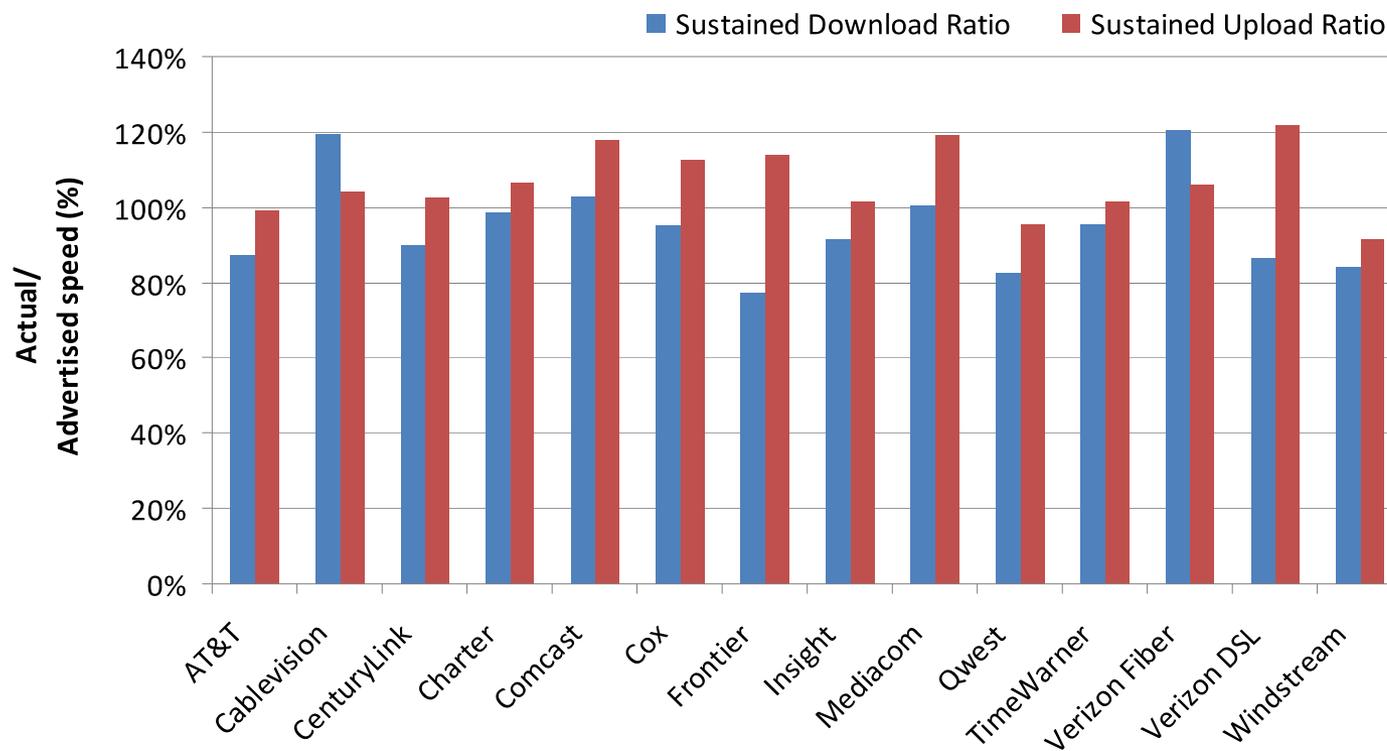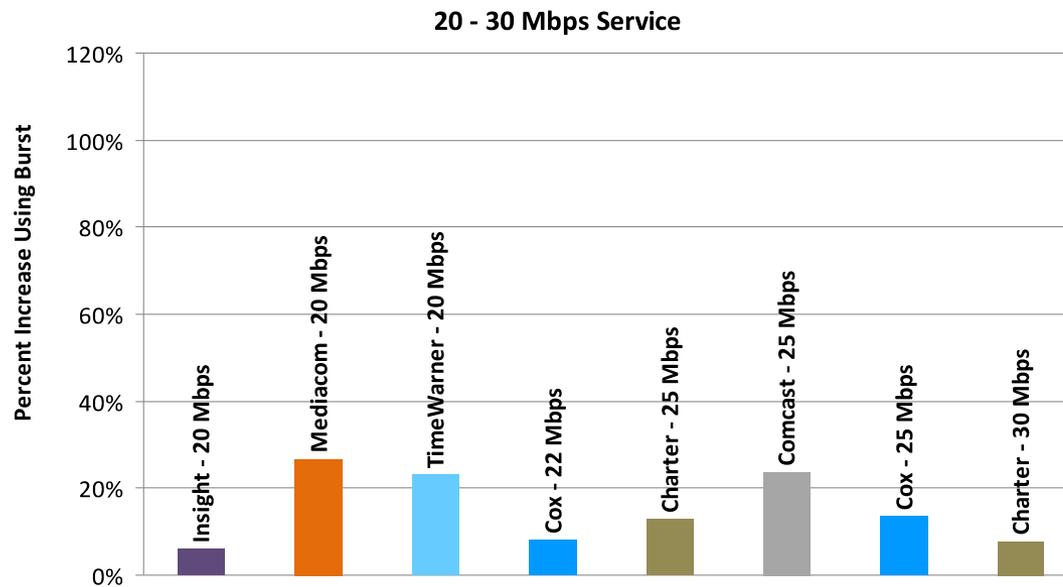
Advertised vs. actual

Chart 4: Average Peak Period Sustained Download and Upload Speeds as a Percentage of Advertised, by Technology—April 2012 Test Data
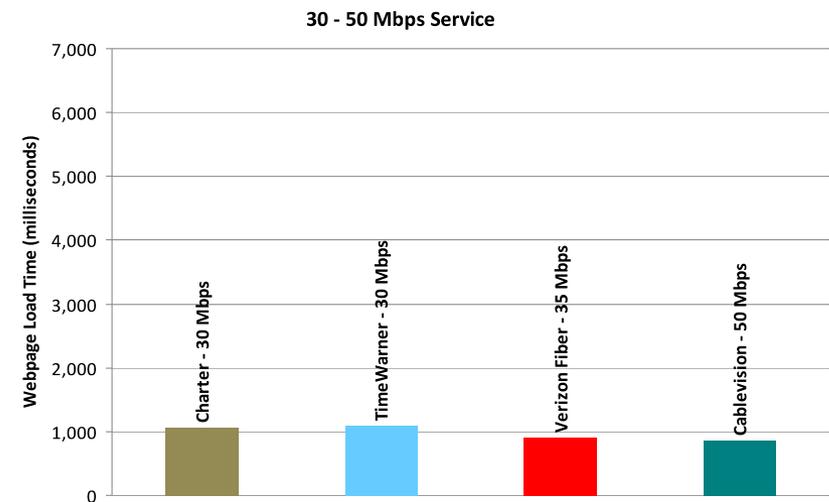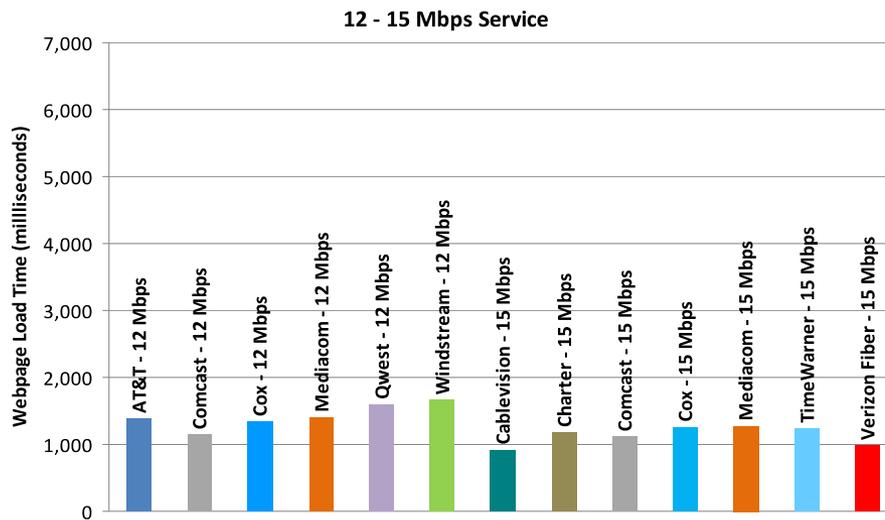
Burst download vs. sustained download

Chart 7.2: Average Peak Period Burst Download Speeds as a Percentage Increase over Sustained Download Speeds, by Provider (20-30 Mbps)—April 2012 Test Data
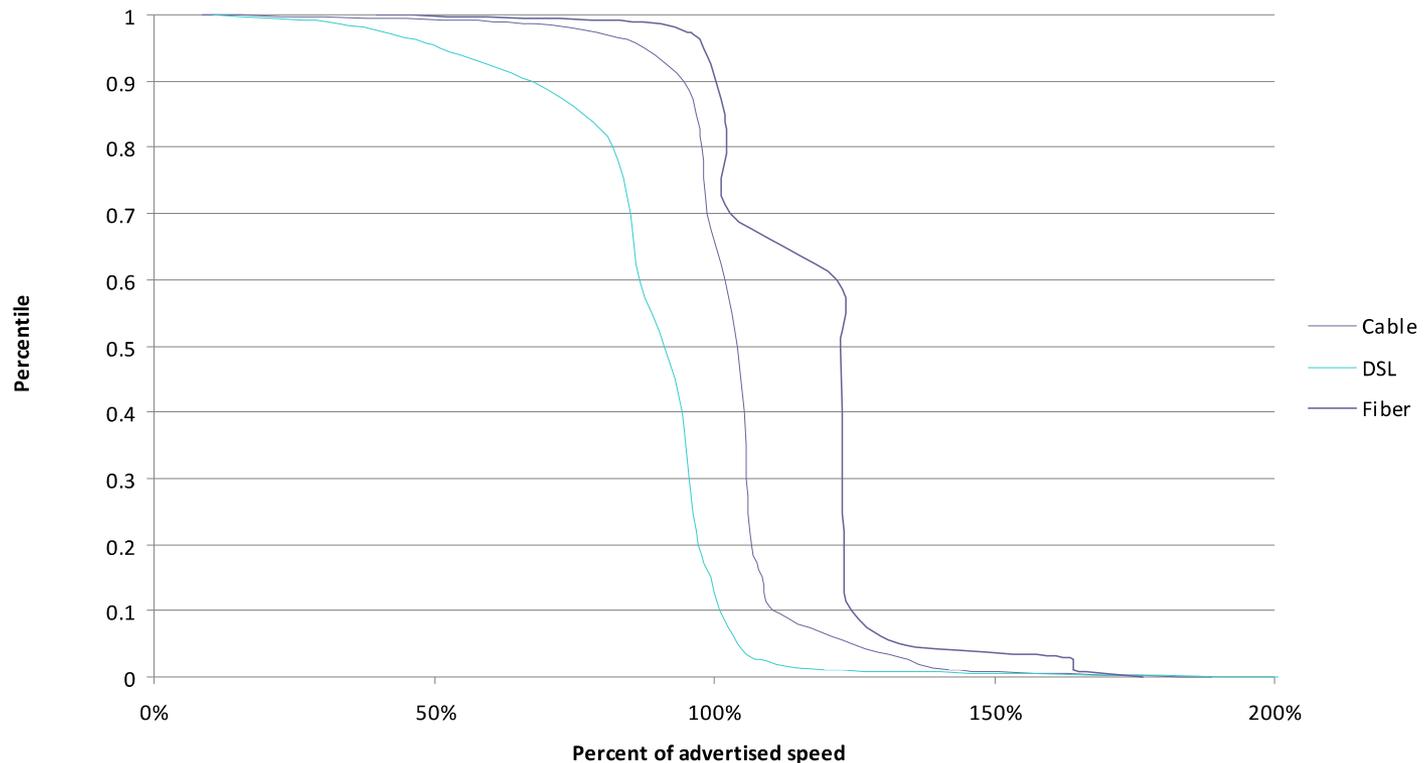

20 - 30 Mbps Service

Web page loading time

Chart 11.3: Web Loading Time by Advertised Speed, by Technology (12-15 Mbps Tier)—April 2012 Test Data
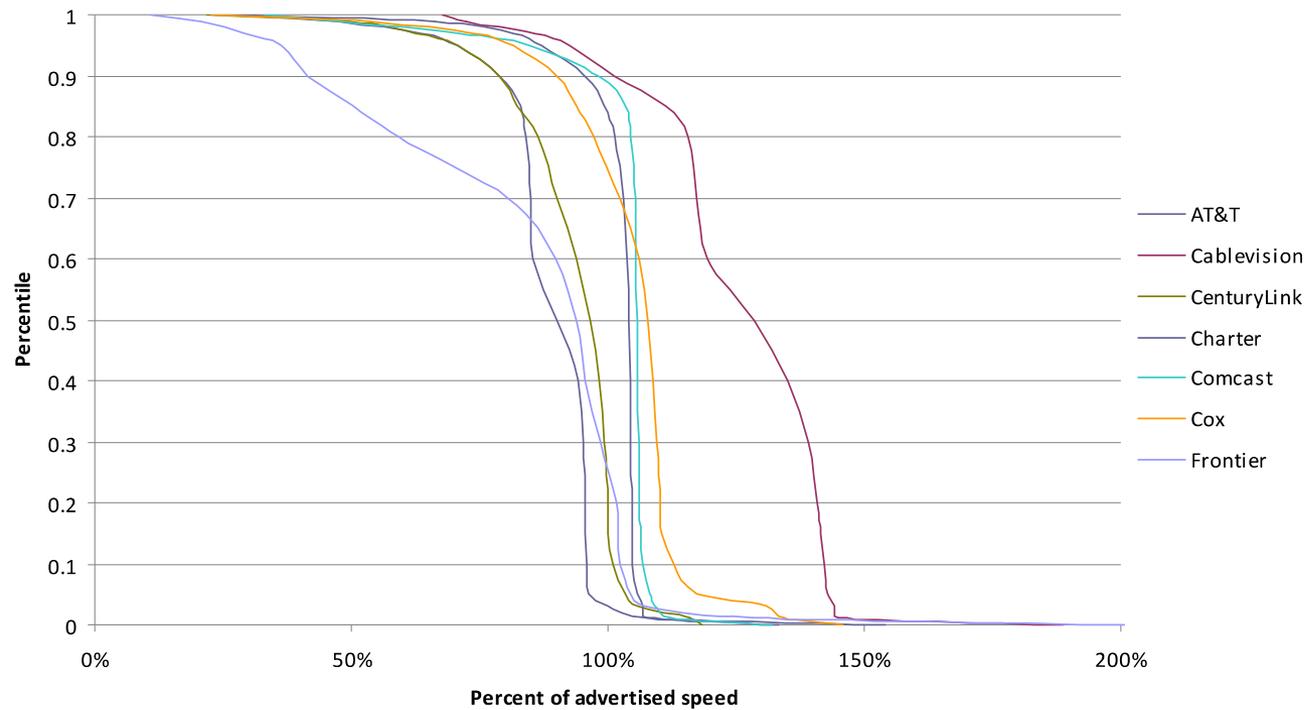
Cumulative distribution of download speeds

Chart 14: Cumulative Distribution of Sustained Download Speeds as a Percentage of Advertised Speed, by Technology—April 2012 Test Data

CDF of sustained download speed

Chart 15.1: Cumulative Distribution of Sustained Download Speeds as a Percentage of Advertised Speed, by Provider (7 Providers)—April 2012 Test Data

Throughput predictability

Figure 1: Percentage of Sustained Advertised Download Speed Delivered During Peak Period, by Provider

	70th Percentile	80th Percentile	90th Percentile	95th Percentile
AT&T	85%	84%	79%	71%
Cablevision	117%	116%	101%	93%
CenturyLink	90%	86%	79%	71%
Charter	103%	101%	96%	87%
Comcast	105%	105%	98%	85%
Cox	102%	97%	90%	82%
Frontier	81%	59%	42%	37%
Insight	98%	97%	92%	88%
Mediacom	104%	102%	97%	88%
TimeWarner	97%	97%	95%	91%
Verizon Fiber	122%	106%	102%	99%
Verizon DSL	86%	77%	60%	53%
Windstream	87%	84%	78%	67%

Actual download speeds: 2011 vs. 2012

Figure 2: Year by Year Comparison of Sustained Actual Download Speed as a Percentage of Advertised Speed (2011/2012)

	Year 2011	Year 2012
AT&T	81%	87%
Cablevision	54%	120%
CenturyLink	87%	89%
Charter	96%	98%
Comcast	101%	103%
Cox	95%	95%
Frontier	81%	79%
Insight	89%	92%
Mediacom	75%	100%
Qwest	77%	83%
TimeWarner	91%	96%
Verizon (DSL)	86%	87%
Verizon (Fiber)	114%	120%
Windstream	85%	84%

Chart 18: Normalized Average User Traffic—April 2012 Test Data

Normalized Average User Traffic Per Tier

$y = 0.0125x^{0.6364}$
$R^2 = 0.7849$