PRACTICAL ECONOMICS OF NETWORKS

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SDP (Turin, Italy) - April 2013

Overview

- What questions do policy makers ask?
- What data sources are available?
- Access network issues
  - capex & opex
  - competition
- The pitfalls of QoS
- Open Internet principles in the US

POLICY QUESTIONS

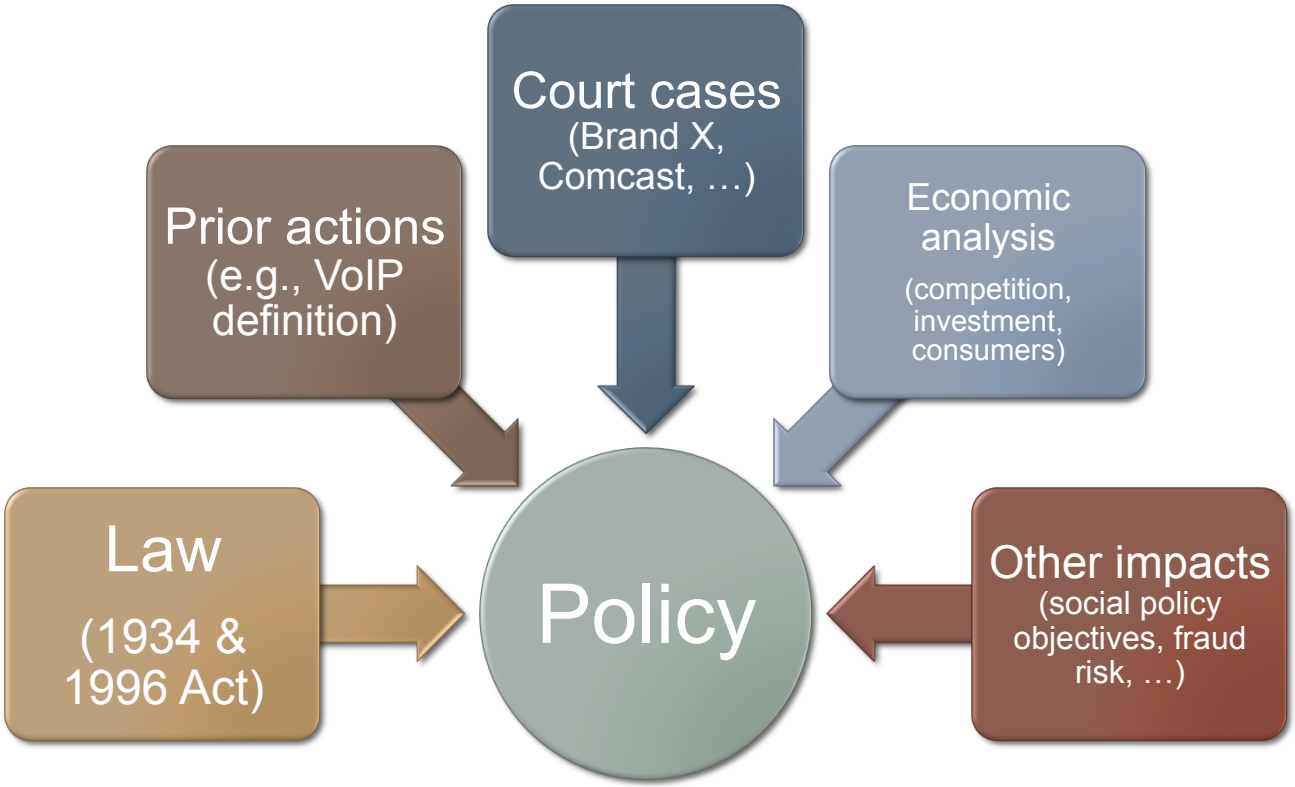
Policy questions

- Should content and service providers pay access networks for access?
- How do content and service providers relate to CDNs, transit providers and access providers?
- What are some of the pitfalls when talking about QoS in the context of network economics?
- What real-world economic data sources are available to analyze network performance and pricing and what are some of their limitations?
- How is interconnection handled in the non-IP world, e.g., for interconnecting voice (PSTN) networks?
- What are some of the economics of building access networks?

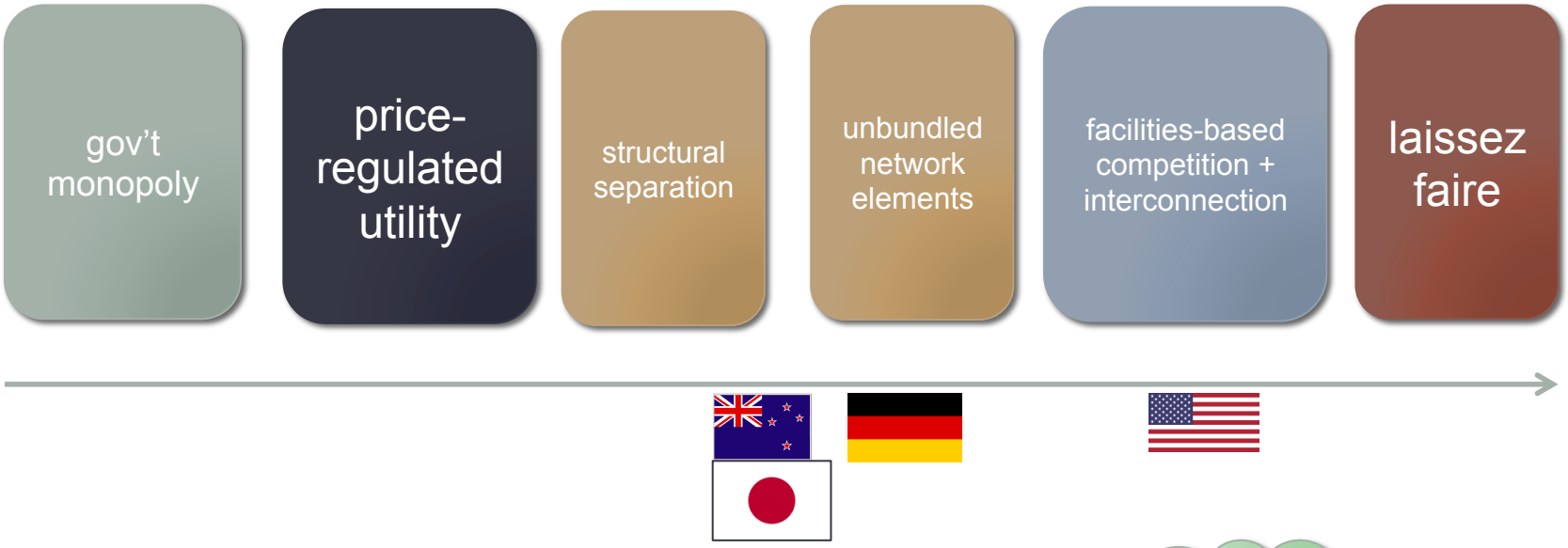
Why policy & regulators?

- Market failure
  - private monopoly
    - e.g., pre-divestiture BOCs as local phone companies
  - competitive market failures (e.g., duopoly, consumer rights)
    - → merger reviews (e.g., Comcast + NBC, AT&T + T-Mobile, T-Mobile + MetroPCS)
  - social policy objectives (e.g., disability rights, universal access)
- Law enforcement
  - illegal conduct (consumer/subsidy fraud, misrepresentation, …)
  - unsafe conduct (“no fence around antenna”)
- Consumer education
  - information asymmetry (e.g., “lemon laws”)
- Economic development
  - “public goods” (e.g., scientific research)

Policy inputs



Telecom policy tool kit



Telephone Social Policies

Universal service (Lifeline, high cost, …)	Necessary to function (call doctor, call school, …)
Basic service price regulation	Ensure widespread availability
911	Report emergencies for self and others
Power backup	Ensure emergency communications
Outage reporting	Ensure reliability
Lawful intercept (CALEA)	Phone as tool for criminals
Disability access (ringers, HAC)	Ensure participation in society
CPNI	Phone as private medium

Telecom regulation

- Local, state and federal
  - local: CATV franchise agreements
  - state: Public Utility Commission
    - responsible for all utilities – gas, water, electricity, telephone
  - federal: FCC, FTC (privacy), DOJ (monopoly)
- Elsewhere: gov't PTT → competition
  - vs. US: regulated private monopolies
- Based on 1934 Telecommunications Act
- Amended in 1996

Before the Internet, Before the Phone… Common Carrier

Content

Common Carrier Trains

Right-of-way

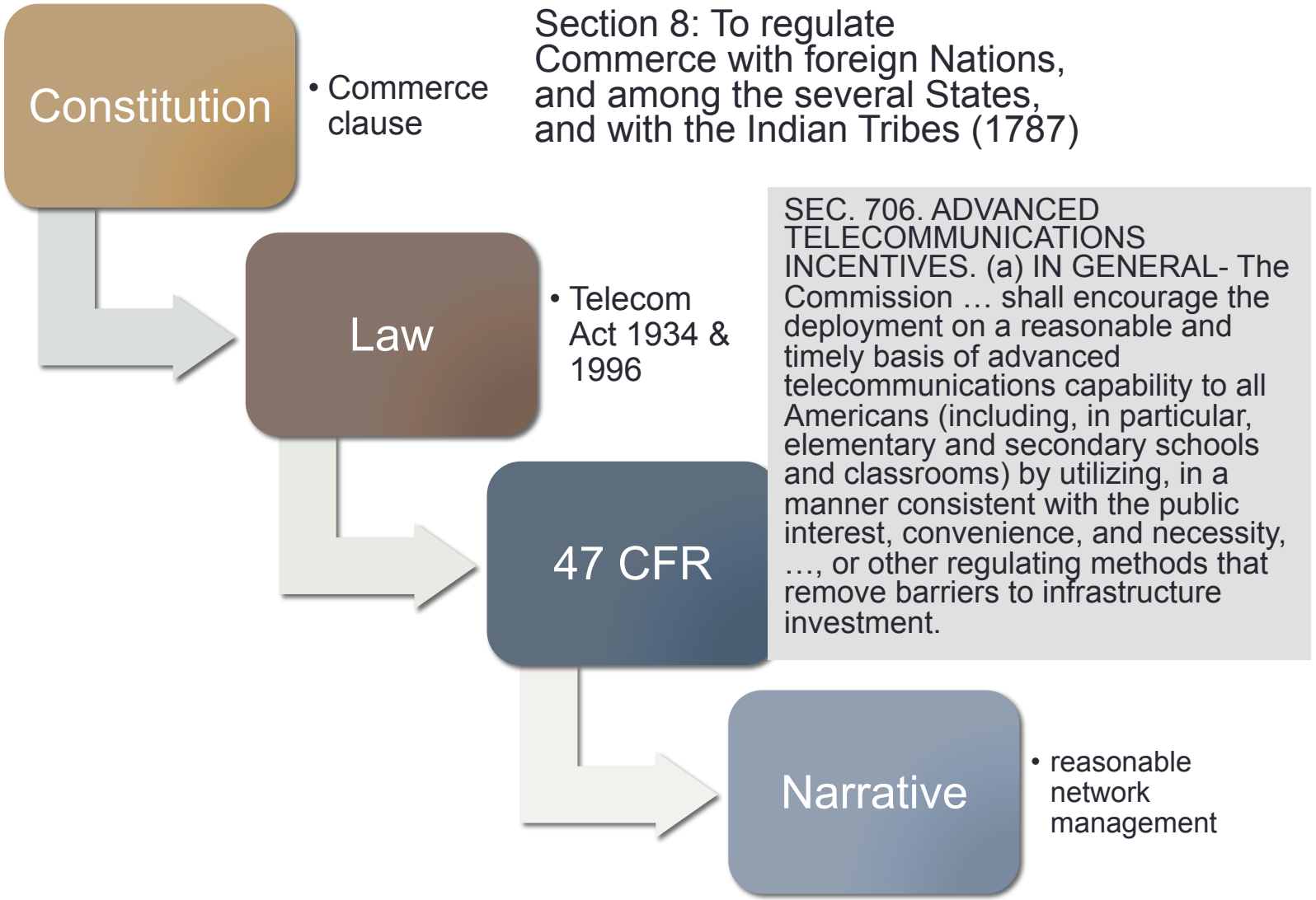
Coal

Communications Carriers

- **Characteristics:**
  - Carrier of third parties' goods / Bailment
  - Market power / infrastructure
  - Vital economic Input: goods carried are important
- **Policy**:
  - Non-discrimination
  - Just & reasonable rates
  - Liability
    - Not liable for what content is
    - Liable for damage to content
  - Benefit from sovereign
    - Access to right of way
  - Privacy / security

Importance and value of information – stocks, elections, agriculture.

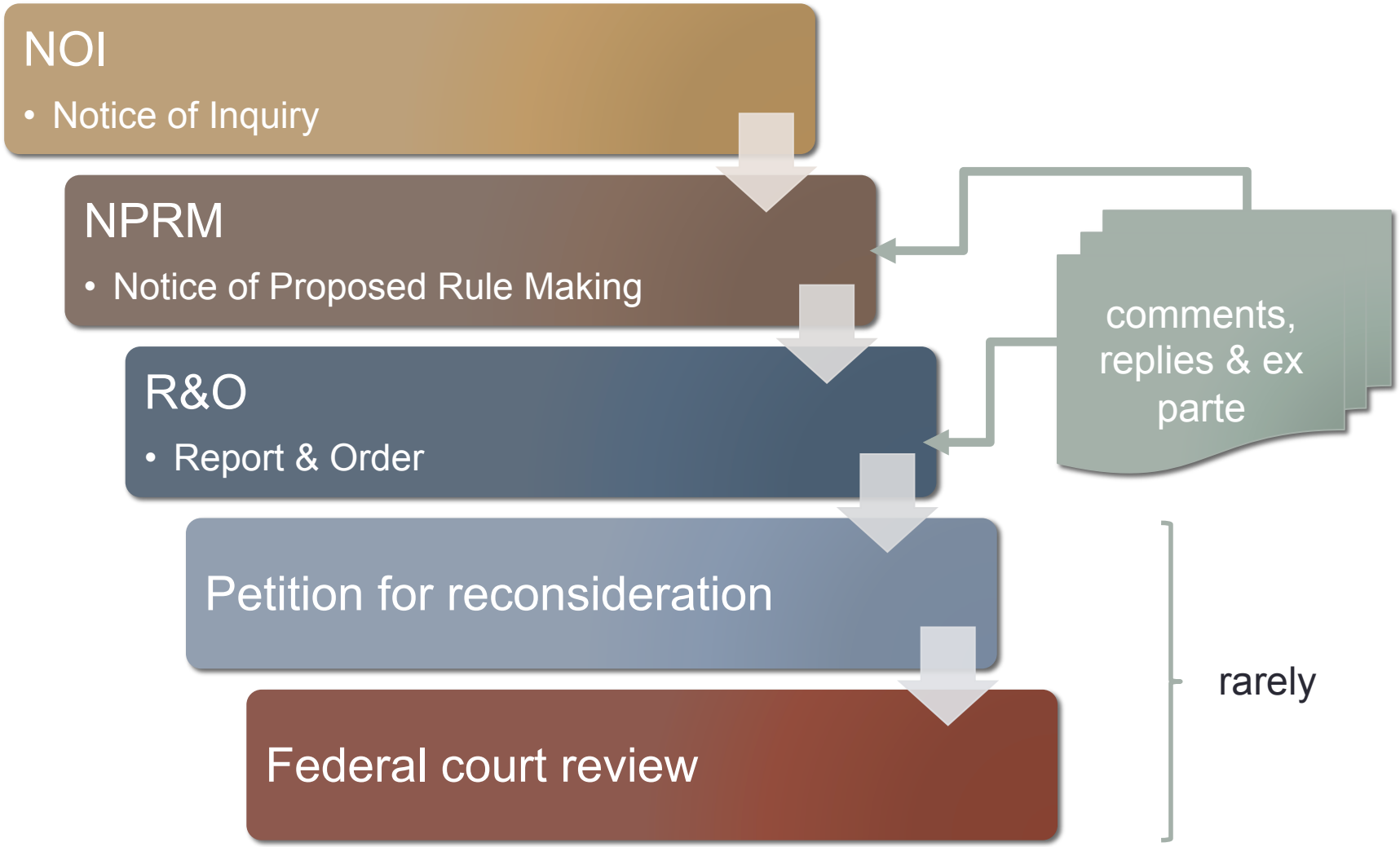
The US hierarchy of laws



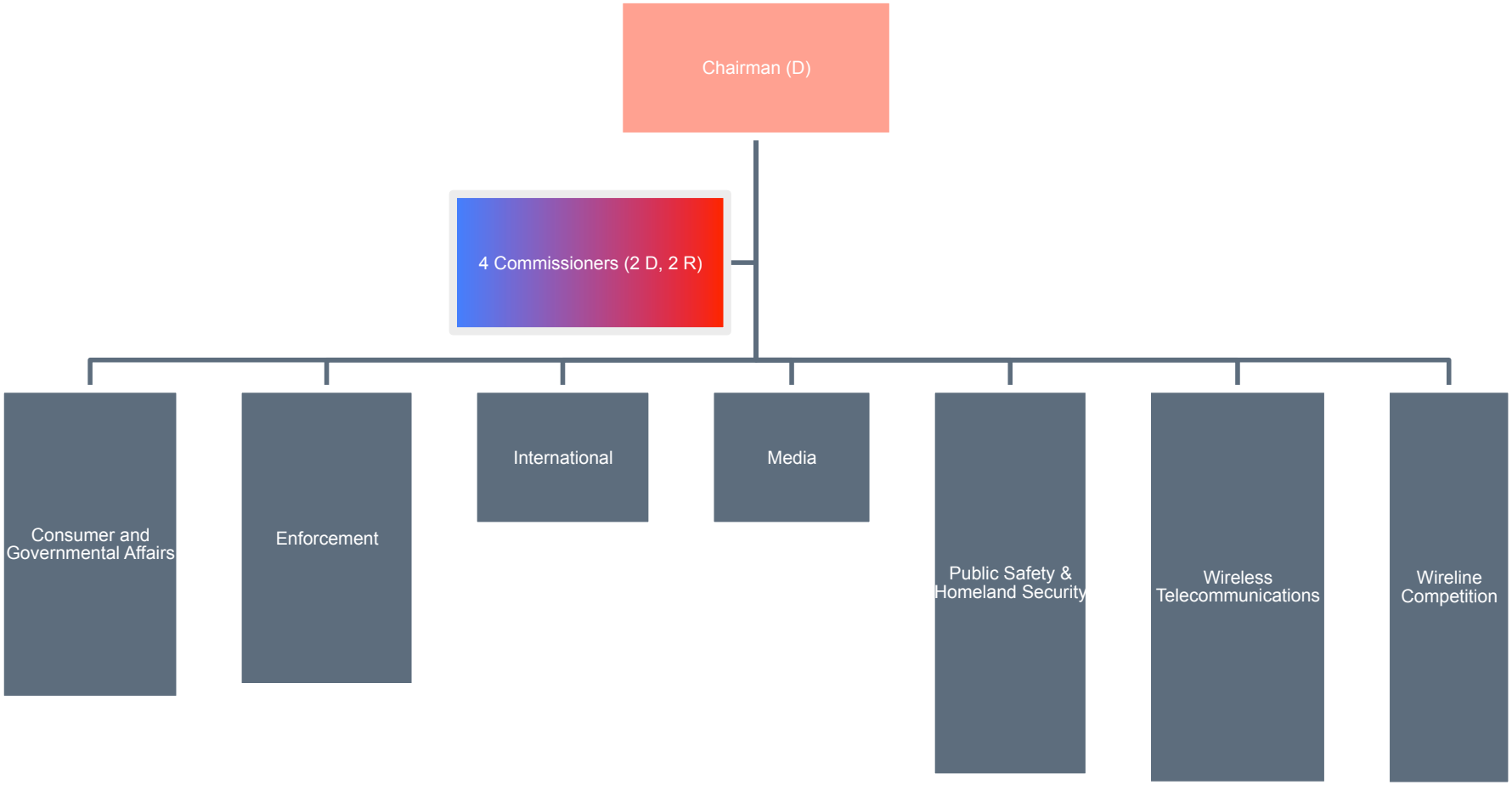
Example: CFR 47

§ 15.5 General conditions of operation.
(a) Persons operating intentional or unintentional radiators shall not be deemed to have any vested or recognizable right to continued use of any given frequency by virtue of prior registration or certification of equipment, or, for power line carrier systems, on the basis of prior notification of use pursuant to §90.35(g) of this chapter.
(b) Operation of an intentional, unintentional, or incidental radiator is subject to the conditions that no harmful interference is caused and that interference must be accepted that may be caused by the operation of an authorized radio station, by another intentional or unintentional radiator, by industrial, scientific and medical (ISM) equipment, or by an incidental radiator.

Process


NOI
• Notice of Inquiry
NPRM
• Notice of Proposed Rule Making
R&O
• Report & Order
Petition for reconsideration
Federal court review
comments, replies & ex parte
rarely

FCC



- Independent federal agency
- About 1,600 employees

Open Internet Principles

Transparency. Fixed and mobile broadband providers must disclose the network management practices, performance characteristics, and terms and conditions of their broadband services;

No blocking. Fixed broadband providers may not block lawful content, applications, services, or non-harmful devices; mobile broadband providers may not block lawful websites, or block applications that compete with their voice or video telephony services

No unreasonable discrimination. Fixed broadband providers may not unreasonably discriminate in transmitting lawful network traffic.

FCC DATA - EXAMPLES

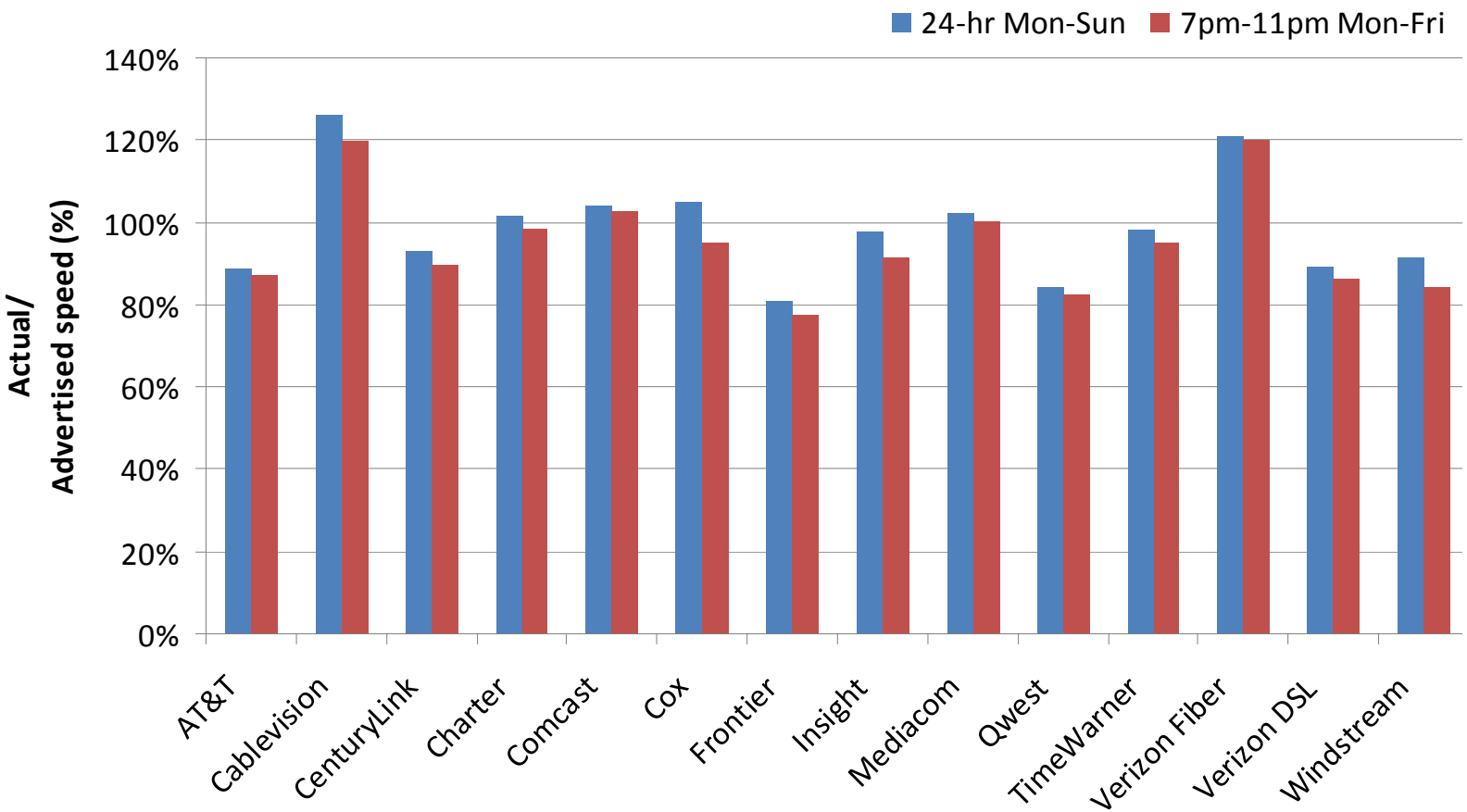
FCC data sets and reports of (Internet) interest

- *Measuring Broadband America* (Internet performance measurements)
- *Broadband Progress Report* ("706 report")
  - Broadband deployment data ("Form 477")
- *International Broadband Data Report*
- *Mobile Wireless Competition Report*
- *Universal Service Monitoring Report* (telephone service)
- *Telephone Subscribership in the United States*
- *Report on Cable Industry Prices*
- *Trends in Telephony Service*
- Not available:
  - detailed price & subscription data
  - outage and reliability information

What Was Measured

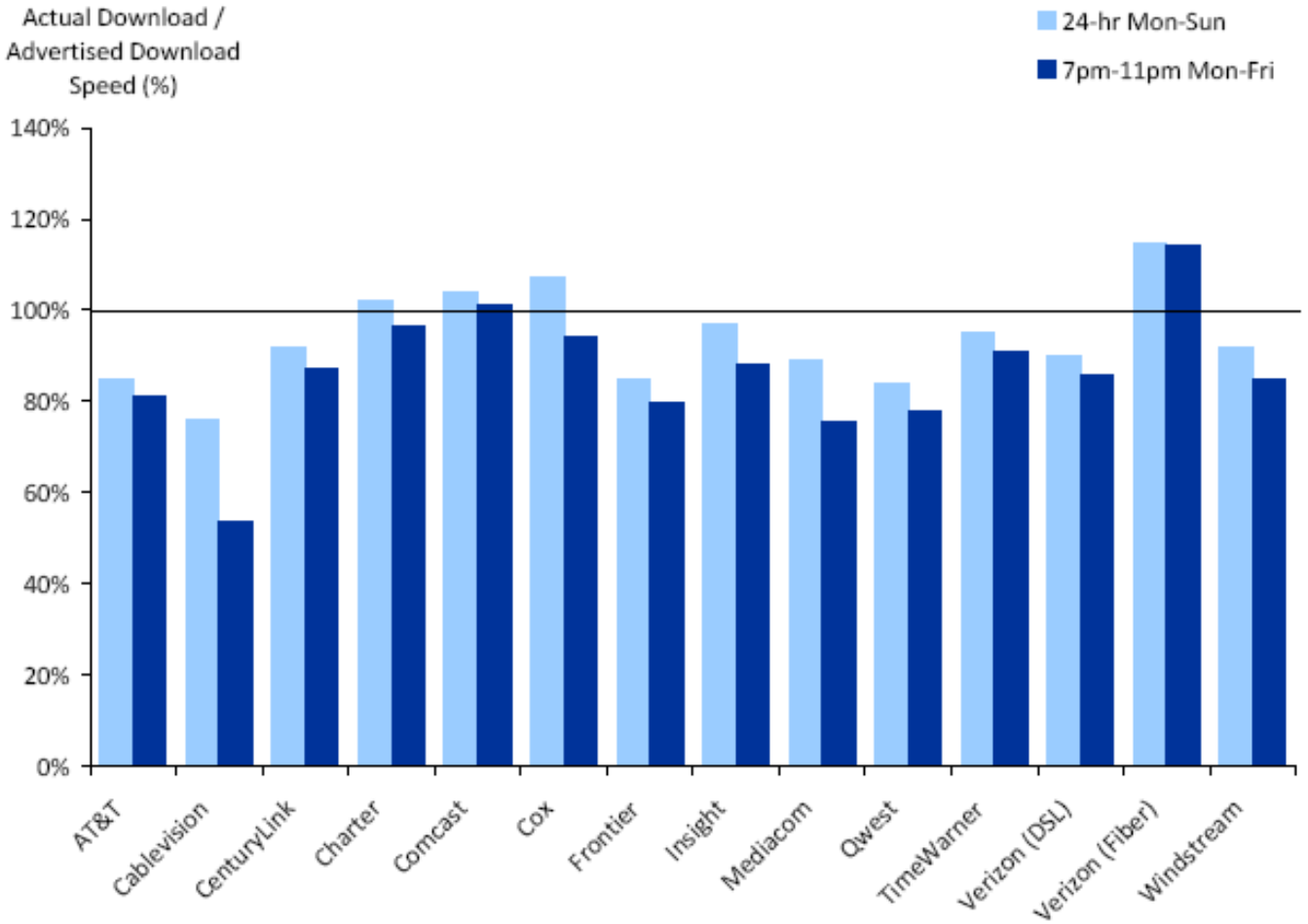
Sustained Download	Burst Download
Sustained Upload	Burst Upload
Web Browsing Download	UDP Latency
UDP Packet Loss	Video Streaming Measure
VoIP Measure	DNS Resolution
DNS Failures	ICMP Latency
ICMP Packet Loss	Latency Under Load
Total Bytes Downloaded	Total Bytes Uploaded

Advertised vs. actual 2012

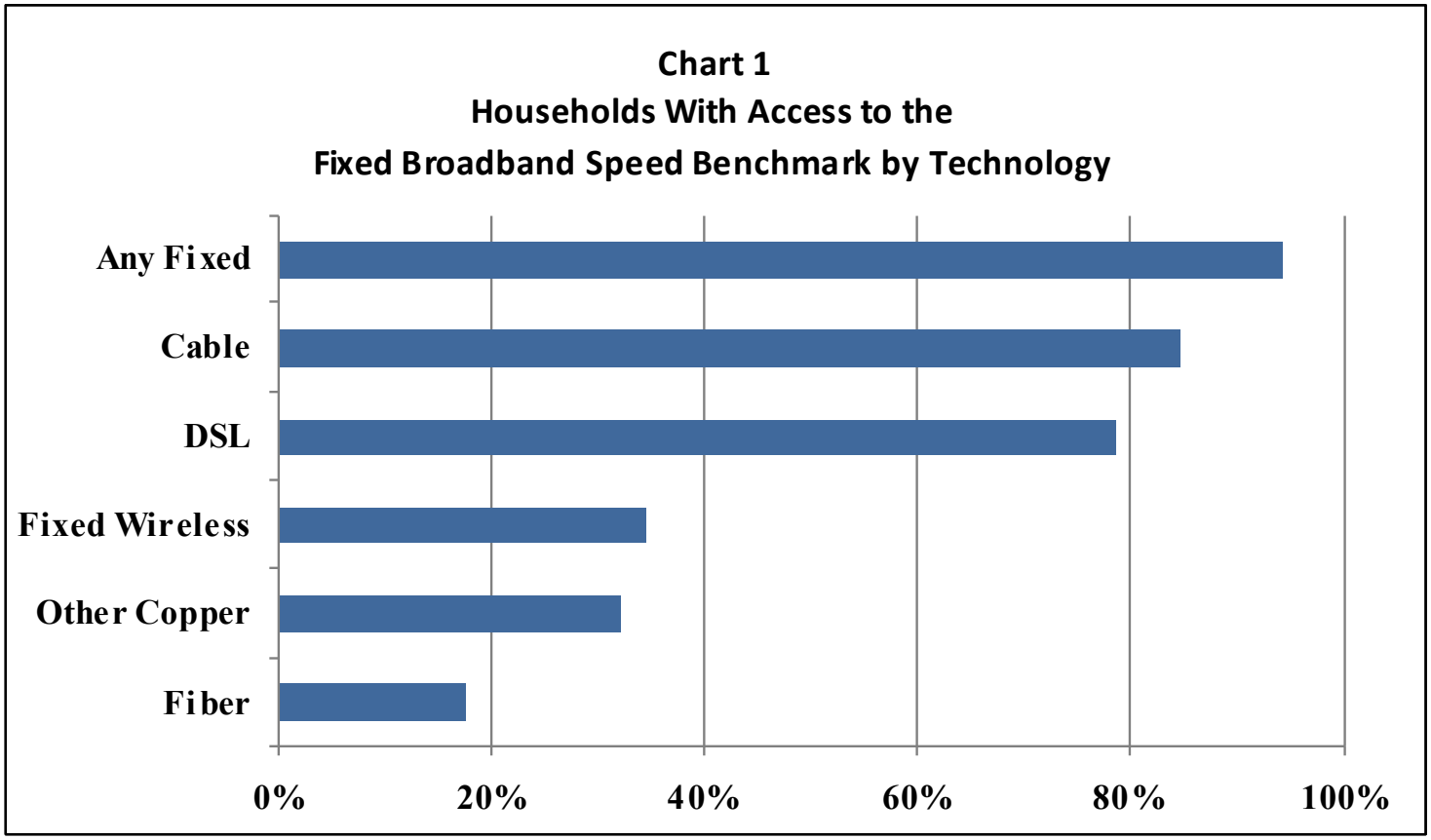


Significantly better than 2011

Chart 1: Average peak period and 24-hour sustained download speeds as a percentage of advertised, by provider



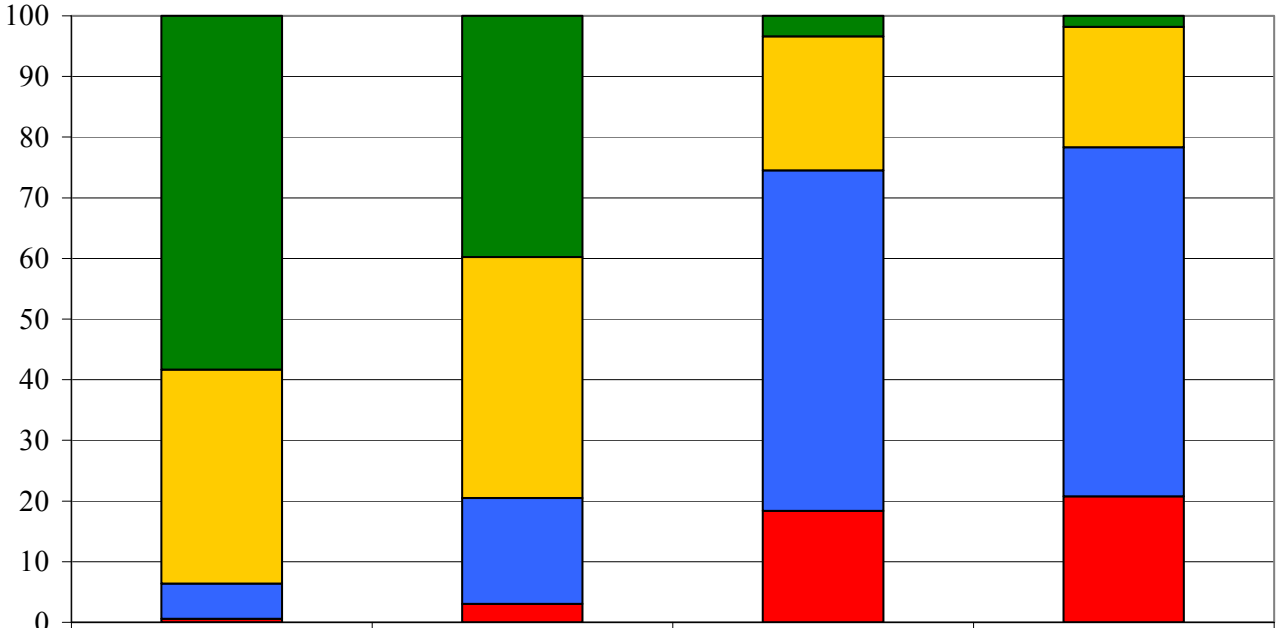
Access to broadband



Eighth Broadband Progress Report, August 2012

State of competition (US)

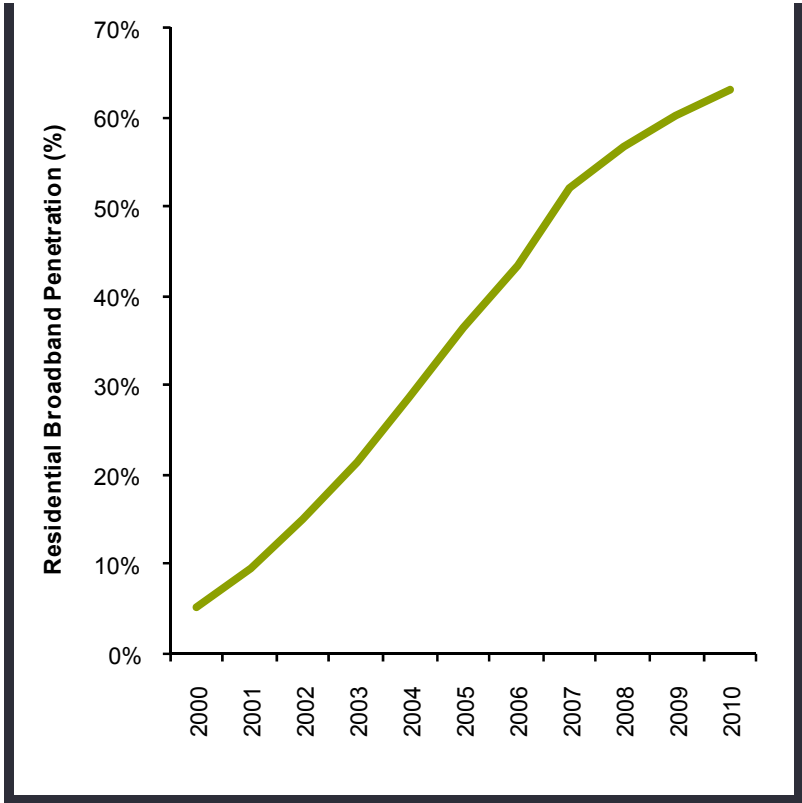
Figure 3(b)
Percentages of Households Located in Census Tracts Where Providers Report Residential Fixed-Location Connections of Various Speeds or Operate a Mobile Wireless Network Capable of Delivering Service of Various Speeds as of December 31, 2009



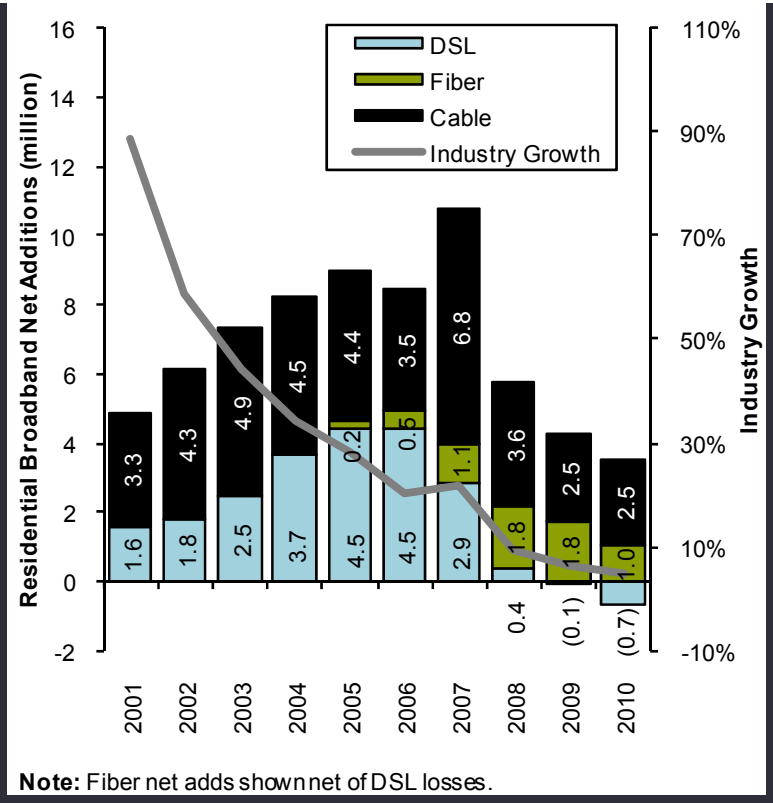
	At least 3 mbps downstream & over 200 kbps upstream	At least 3 mbps downstream & 768 kbps upstream	At least 6 mbps downstream & 1.5 mbps upstream	At least 10 mbps downstream & 1.5 mbps upstream
3+ Providers	58	40	3	2
2 Providers	35	40	22	20
1 Provider	6	17	56	58
0 Providers	1	3	18	21

FCC: Internet Access Services Status as of December 31, 2009

Residential broadband penetration (US)



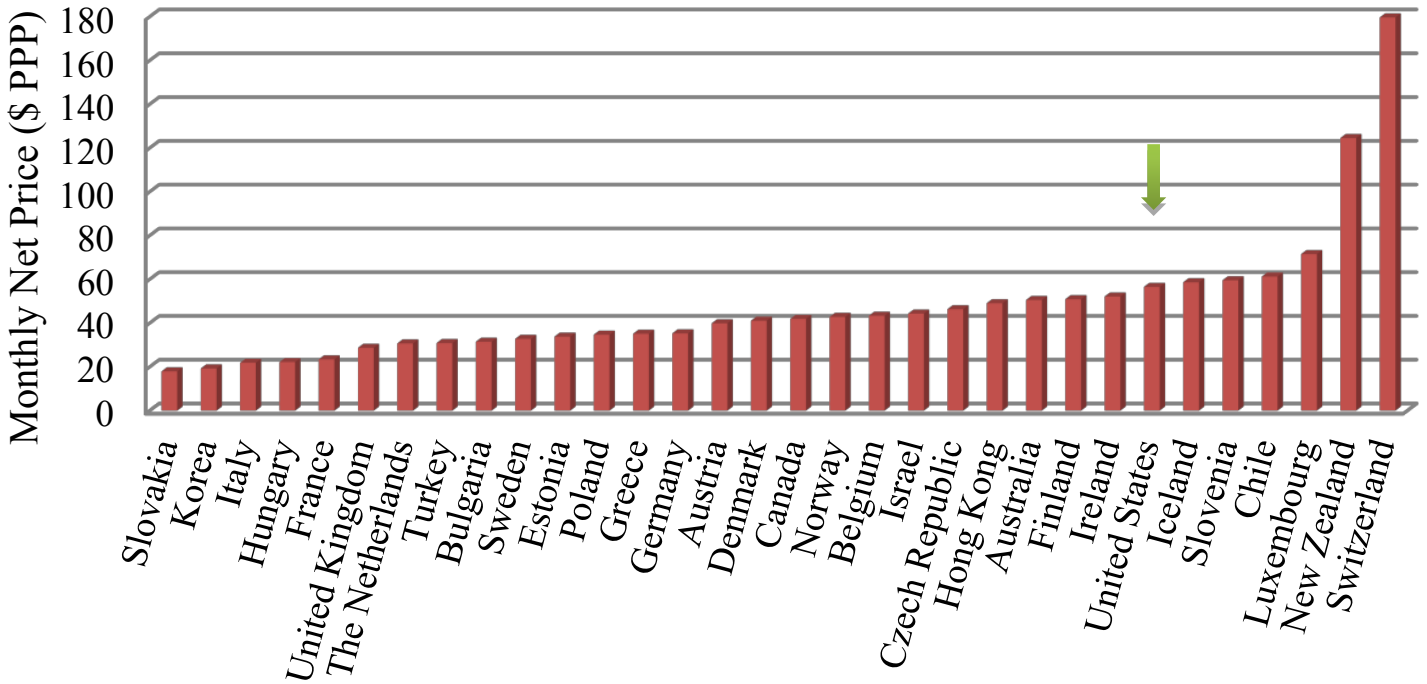
Source: Kagan, corporate reports and Bernstein estimates and analysis.



Source: Kagan, corporate reports and Bernstein estimates and analysis.

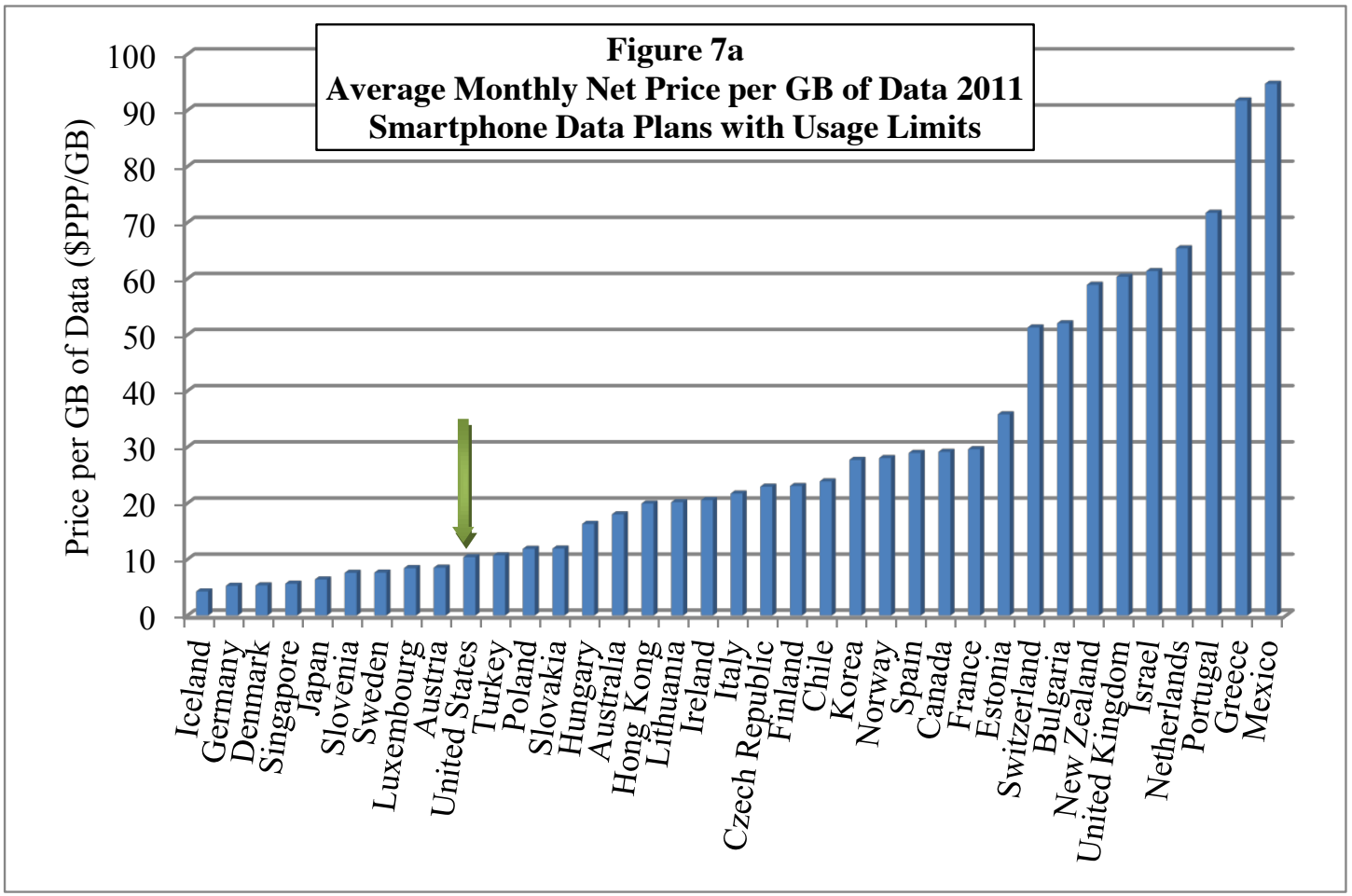
International comparison: fixed

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

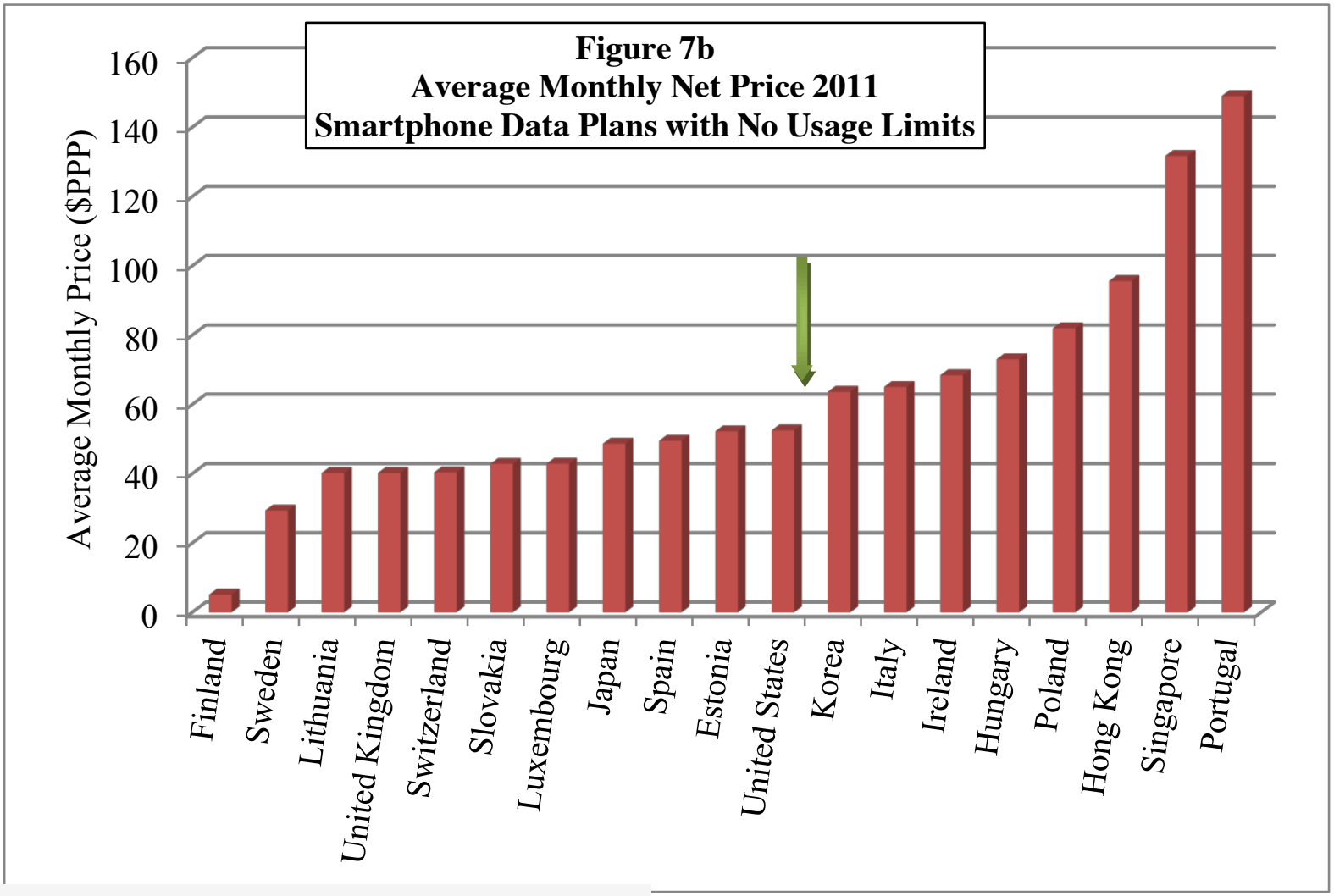
International data pricing - mobile



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

http://www.fcc.gov/document/international-broadband-data-report

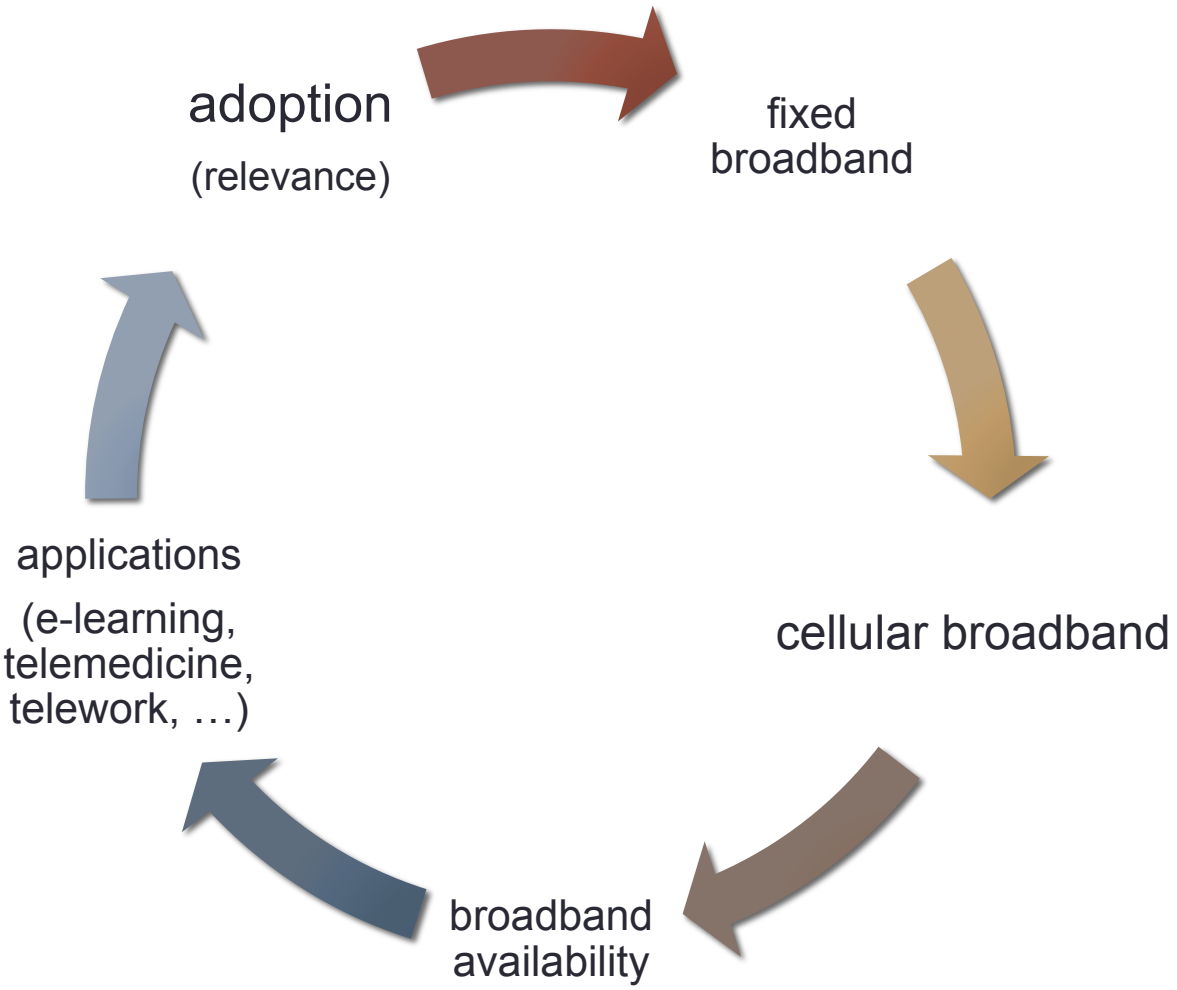
International data pricing - mobile



http://www.fcc.gov/document/international-broadband-data-report

THE COST OF NETWORKS

Broadband virtuous cycle



Cost of bandwidth (2011)

Service	Speed (Mb/s)	Average price/month	$/Mb/s
DS1 (T1)	1.54	$450	$292.20
DS3	45	$5,000	$111.11
Ethernet over Copper	10	$950	$95.00
Fast Ethernet	100	$5,000	$50.00
Metro Ethernet	1000	$25,000	$25.00

The value of bits

- Technologist: A bit is a bit is a bit
- Economist: Some bits are more valuable than other bits
  - e.g., $(email) >> $(video)

Application	Volume	Cost per unit	Cost / MB	Cost / TB
Voice (13 kb/s GSM)	97.5 kB/minute	10c	$1.02	$1M
Mobile data	5 GB	$40	$0.008	$8,000
MMS (pictures)	< 300 KB, avg. 50 kB	25c	$5.00	$5M
SMS	160 B	10c	$625	$625M

Broadband cost

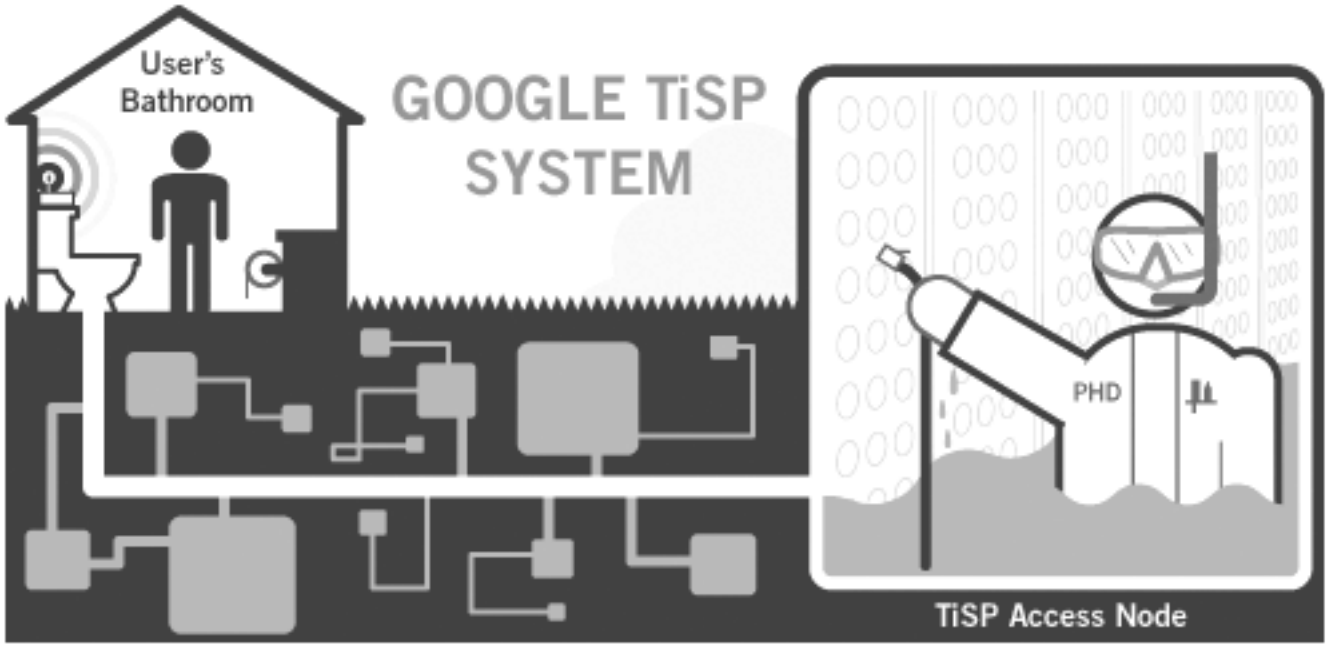
30%

e.g., CenturyLink: capital investment = 15% of revenues

Maybe revisit?

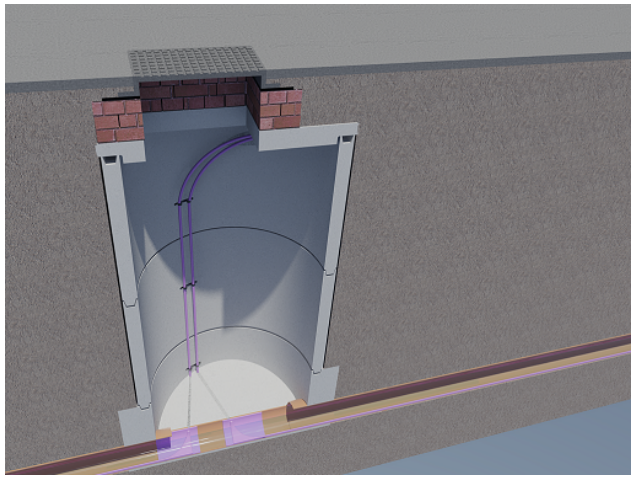
TiSP: Going with the Flow

Google TiSP (BETA) is a fully functional, end-to-end system that provides in-home wireless access by connecting your commode-based TiSP wireless router to one of thousands of TiSP Access Nodes via fiber-optic cable strung through your local municipal sewage lines.

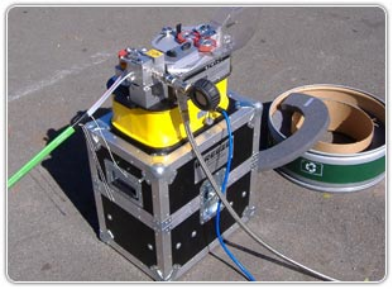


Google
April 1, 2007

Fiber deployment



wastewater pipe
(3-5 km/week)



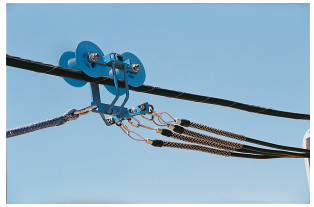
Broadband network cost - FTTP

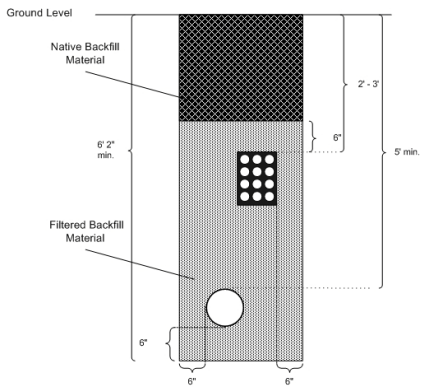
Category	Details	Outside plant
FTTP in existing right-of-way	All underground, not including drops or electronics	$1,200…$1,300 per passing
	40% aerial, 60% underground, not including drops or electronics	$1,000…$1,100 per passing
FTTP drops	Range of distances and complexity	$300…$700 per connected home

Crown Fibre Holdings (Govt. of New Zealand); provided by CTC

Broadband network cost – Fiber middle mile

Category	Details	Outside plant	Source
aerial, new attachment	Northeastern city municipal utility; 96% aerial, 4% underground; 87.6 miles	$30,000/mile	Public utility (actual cost)
aerial overlash	Major metropolitan area (U.S. east coast)	$15,000/mile	
buried	Mixed suburban/ urban locations and pot/bore construction	$89,000/mile	Washington, D.C.-area BTOP project (actual cost)





Data provided by CTC

Middle mile cost example

Independent 2" Conduit Run for Three User Co-Location

LABOR

Category	Quantity	Unit	Low Cost/Unit	High Cost/Unit	Low Cost	High Cost
Design	5,280	FT.	$0.08	$0.10	$422	$528
Engineering and Permits	0	FT.	$0.25	$0.25	$0	$0
Railroad Crossing	0	LOT	$5,000.00	$15,000.00	$0	$0
Directional Boring for 2" Conduit	0	FT.	$8.00	$20.00	$0	$0
Directional Boring for 4" Conduit	0	FT.	$11.00	$25.00	$0	$0
Trenching for 24" - 36" Depth	5,280	FT.	$5.00	$12.00	$26,400	$63,360
Place Conduit	15,840	FT.	$1.00	$1.75	$15,840	$27,720
Place Inner Duct	0	FT.	$0.50	$1.50	$0	$0
Place Vault	33	EACH	$500.00	$750.00	$16,500	$24,750
Place Fiber in Conduit	15,840	FT.	$1.25	$2.50	$19,800	$39,600
Install Splice Enclosure	3	EACH	$300.00	$500.00	$900	$1,500
Splice Fiber	648	EACH	$12.00	$30.00	$7,776	$19,440
TOTAL LABOR					**$87,638**	**$176,898**

MATERIALS

Category	Quantity	Unit	Low Cost/Unit	High Cost/Unit	Low Cost	High Cost
216 Count Fiber	18,216	FT.	$1.80	$2.50	$32,789	$45,540
Splice Kit	3	EACH	$500.00	$750.00	$1,500	$2,250
4" Conduit and Materials	0	FT.	$2.98	$3.50	$0	$0
2" Conduit and Materials	15,840	FT.	$0.88	$1.50	$13,939	$23,760
1" Inner Duct	0	FT.	$0.30	$45.00	$0	$0
Vault	33	EACH	$450.00	$600.00	$14,850	$19,800
Tax and Freight	1	LOT	$6,307.80	$9,135.00	$6,308	$9,135
TOTAL MATERIAL					**$69,386**	**$100,485**

CTC, 2009 (“Brief Engineering Assessment: Efficiencies available through simultaneous construction and co-location of communications conduit and fiber”)

Broadband network cost – TV white spaces

- Rural Appalachian community
- 3,000-passing service area
- 30% taking service
- $2.4 million capital cost for all towers and electronics
  - site, user, and backhaul
- ➔$800/passed

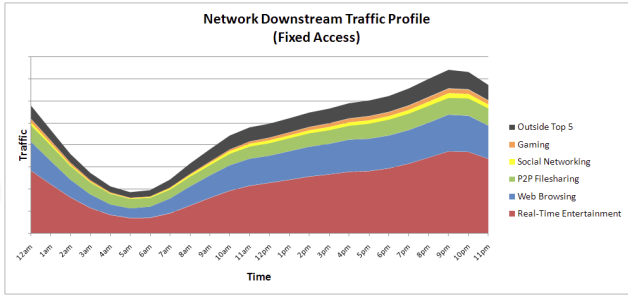
CTC design study for Garrett County, Maryland

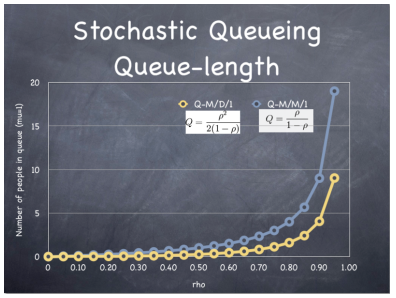
CONCLUDING REMARKS

Common fallacies in economic analysis

- Assume perfect competition
  - or ability to have multiple access providers
  - or zero switching costs
- Assume QoS = ATM or phone circuit
  - rather than per-packet choice
- Assume QoS for voice >> data
  - TCP: 5% packet loss → 500 kb/s max.
  - Marginal cost difference between 80% and 100%-loaded network
- Assume variable bandwidth demand
  - Human-driven, with a bit of video quality adaptation
- Ignore real-world profitability of entities
  - non-existing profits shuffled to other parties

differentiated goods





Things policy makers might like to know…

- Why is wireless/wireline broadband in my country more expensive or cheaper than in country X?
- How can I ensure continued investment in network infrastructure?
- What drives new network applications?
- What is the impact of metered broadband?
  - Will there be only one speed tier?
- What is keeping 20-30% from adopting broadband?
- Are there economic incentives to make networks more secure?

MOBILE DATA PRICING

Differentiation – classical models

- Speed differentiation
  - Residential broadband model
  - European LTE plans (usually combined with volume)
  - = rough division into non-video (web, email) & video customers
- Volume metering
  - Mobile model
  - = rough division into video & non-video customers
  - harder to visualize – discourages experimentation
  - room for surprise
    - mid-month cut-off
    - bill shock
- Commonly combined

Differentiation – new models

- Application restrictions
  - “business” vs. personal use
  - e.g., restrict tethering
  - Open Internet concerns
- Priority-based pricing
- Content provider pays
  - “like 800 numbers”
  - potential for confusion? Which links are “free” and which aren’t?
  - transaction costs – how to collect from millions of content providers?
  - revenue potential?

Example: vodafone.de

Plan	Speed	Volume
€ 17.99	≤ 3.6 Mb/s	1 GB
€ 26.99	≤ 21.6 Mb/s	3 GB
€ 35.99	≤ 42.2 Mb/s	6 GB
€ 44.99	≤ 50.0 Mb/s	10 GB

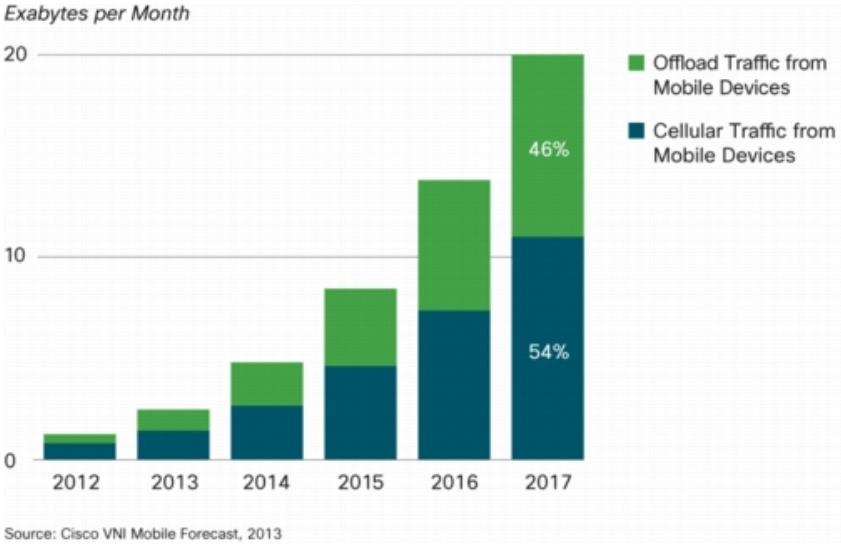
“unlimited” at 64 kb/s

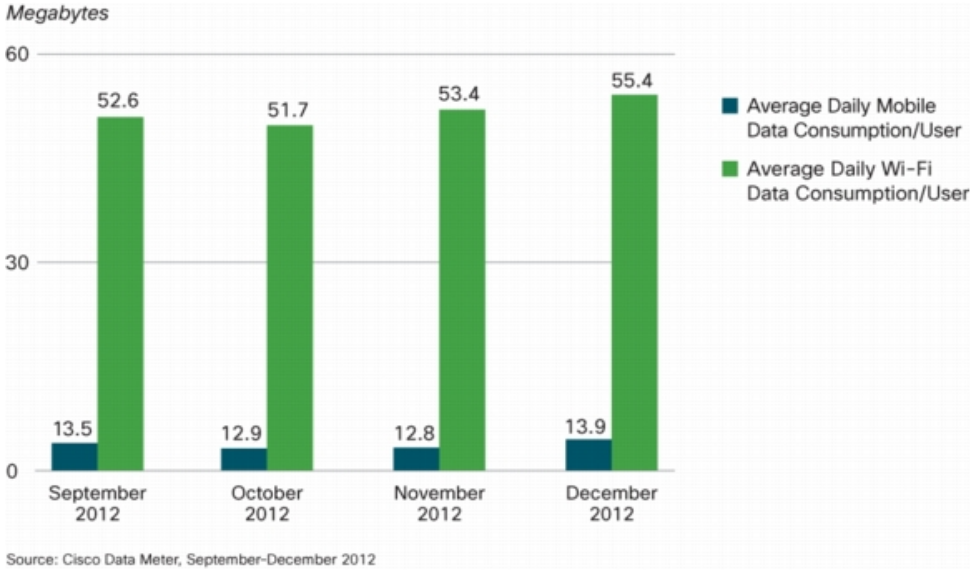
http://shop.vodafone.de/Shop/internet/mobile-internet-flat/

What about consumers?

- Predictability – no “bill shock”
  - “When did I download 1 GB and why?”
  - What about teenagers?
- Allow for a simple mental model
  - Can users predict direct usage costs for activities?
  - Do they want to know that the YouTube cat video costs $1.45?
  - How close is day/night model to optimal model?
- Minimize mental load
  - Anticipating consequences
    - It’s April 15 – am I going to run out by April 30? Or leave bytes on the table?
    - Byte budgeting?
- Perception of fairness
  - Airline pricing?
  - Why should I pay for my provider’s bugs?
- Allow comparison between plans and providers
  - Should I switch providers given my usage profile?

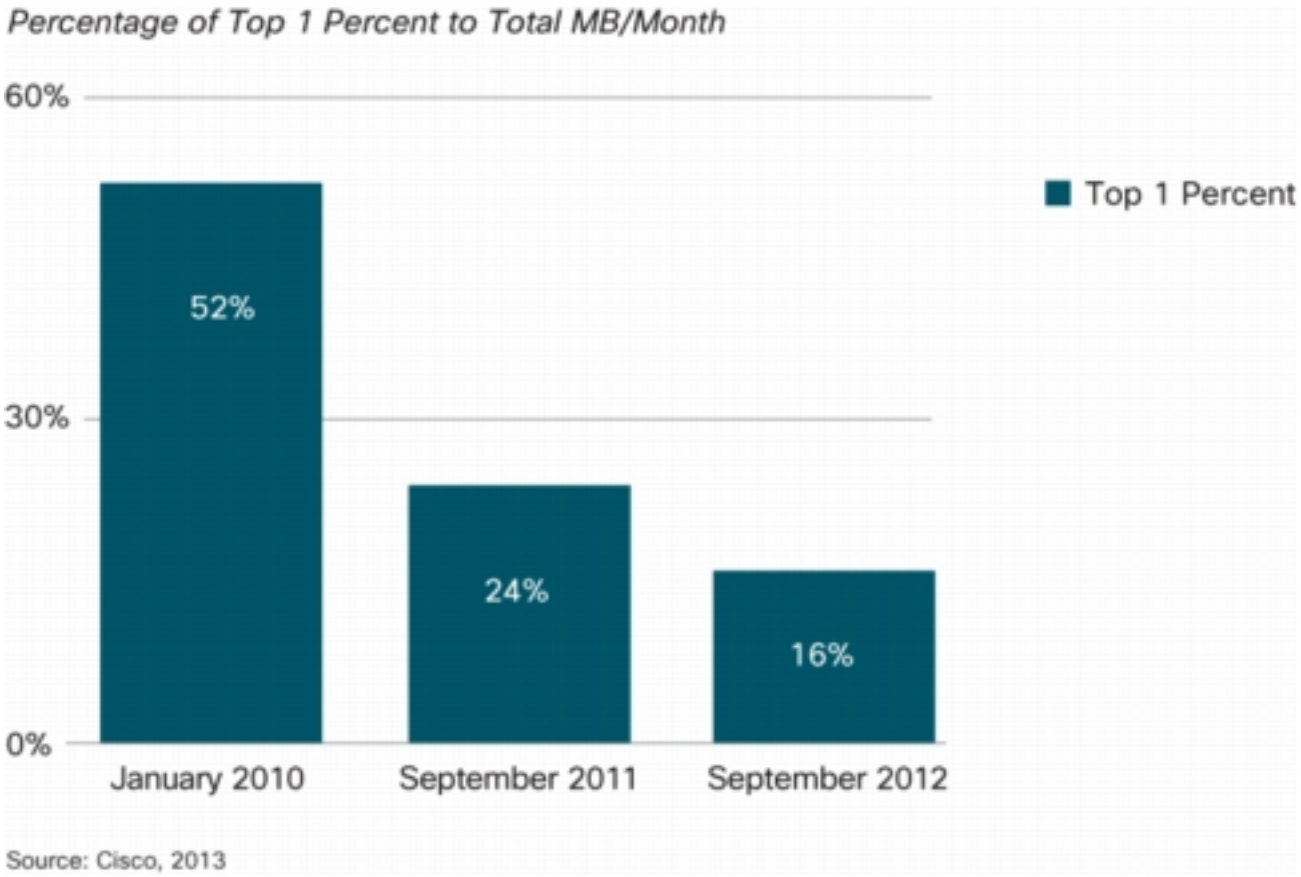
WiFi off-load





Cisco Visual Networking Index: Global Mobile Data Traffic Forecast 2012-2017

The 1% are becoming less dominant

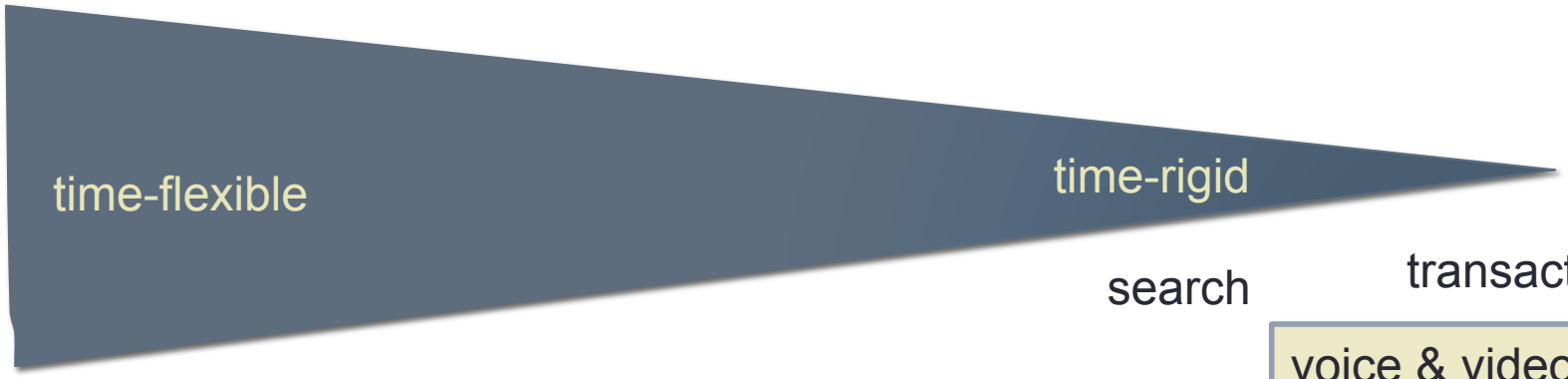


ARPU across providers

Provider	ARPU (month), US-based	Net income (1Q2013)
Verizon	$146.80*	$1.95B
AT&T	$65.20	
Google	$2.38	$3.35B
Facebook	$0.74	$64M
Netflix	$11.65	$8M
Pandora (mobile)	$3.87	$2.2M

*VZ is ARPA (per account)

Demand shifting



search

transactions

voice & video call

email

software updates

IM

navigation

video (sideloading)

web (FB, news)

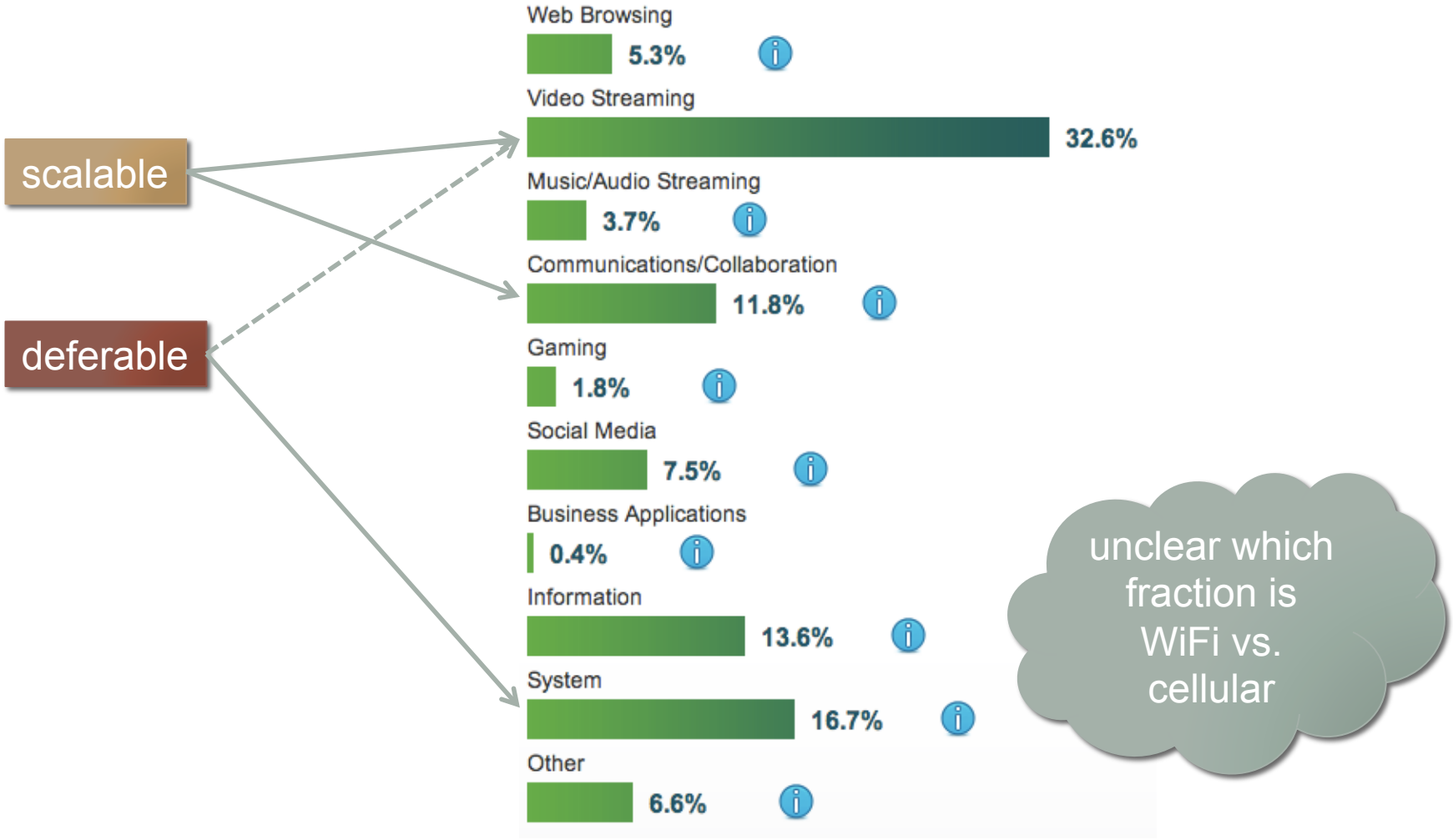
augmented reality

app store

Advertising and two-sided markets

- eCPM: $3.50 for PC, $0.75 for mobile
- one click cost $0.84 on average (PPC)
- one hour of higher-quality video: 1 GB = $10
  - mobile: 10 MB / minute
- → one minute commercial costs user $0.10
- thus, plausible two-sided market for clicking on video ads
- YouTube: *Gangnam Style* generated $0.0065 per play
  - video is 4.2 minutes long → cost is $0.43
- not so much for supporting video content

Application usage



http://ciscovni.com/data_meter/

SINE: automated policy

- Goal: make hetnets user-friendly
  - primarily, $0 WiFi vs. $10/GB cellular
  - but can accommodate variable cellular pricing
- Policy engine:
  - for each application, express value and delay tolerance
    - “best network available, keep to $N/hour”
    - “delay for N minutes” → email
    - “user confirmation if cost > $X”
  - willing to pay more as delay increases
    - eventually, may pay for software download
- Need better sideloading support for apps
  - video queue, maps
- Mapping database for predictive demand shifting
  - “reaching WiFi in one hour”

Conclusion

- Economics of networks – more than micro economics
  - = longer-term congestion control
    - demand shifting in time (and space)
    - realistic expectations for gain
    - video already largely WiFi
  - = price differentiation
- Needs to take consumer behavior into account
  - do users want to constantly watch the meter?
  - realistic expectation of take-up – is 10% improvement worth the hassle as the smartphone novelty wears off?
  - can we automate this?
- Public policy concerns
  - transparency
  - non-discrimination
  - effects on competition – carrier-carrier & vertical