

*How do we close the digital divide? It
requires more than routers and
protocols!*

Henning Schulzrinne
Columbia University

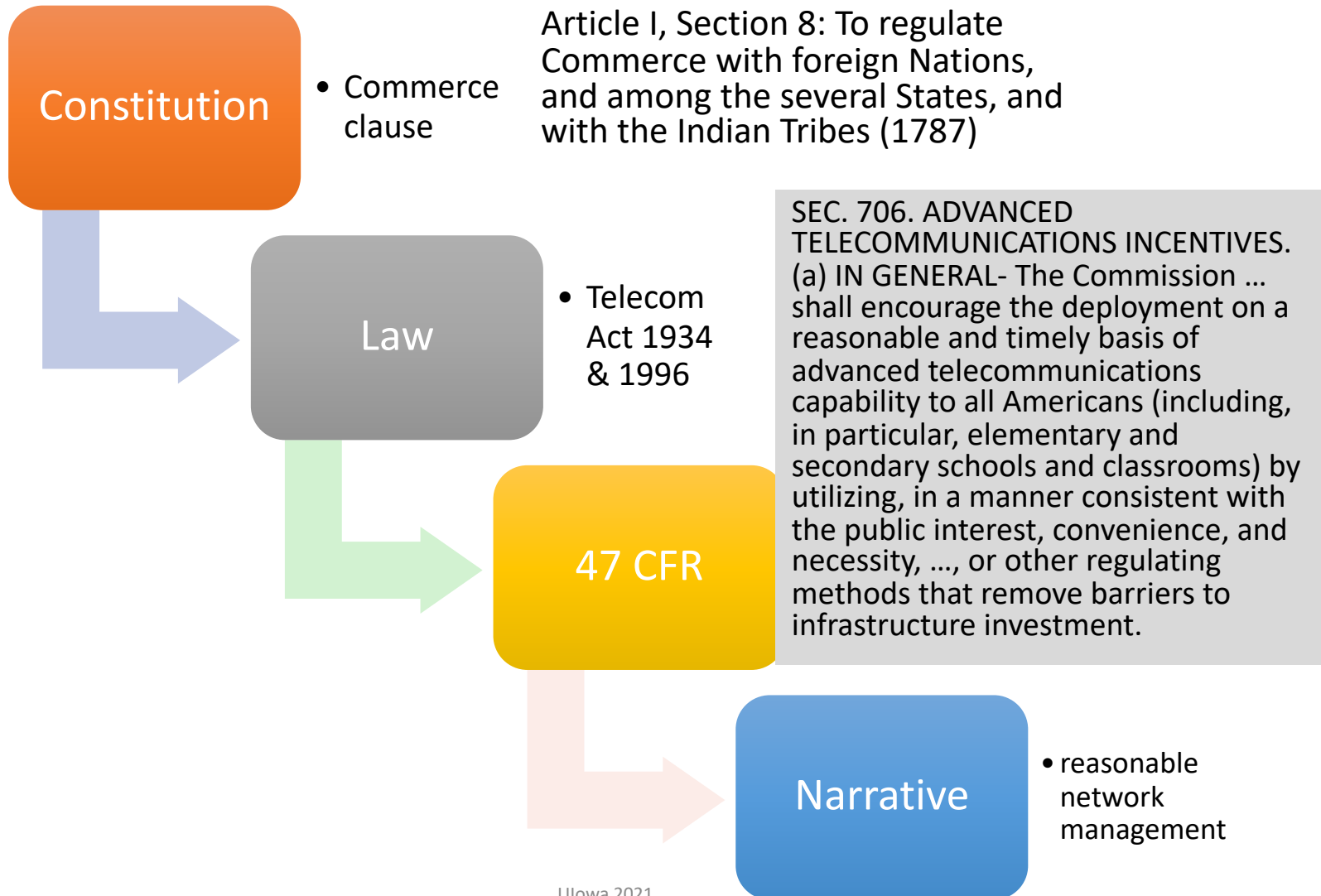
Itinerary

- Background: Making laws in practice
- Background: What do Congressional offices do all day?
- Making broadband available to useful to everyone → closing the “digital divide”

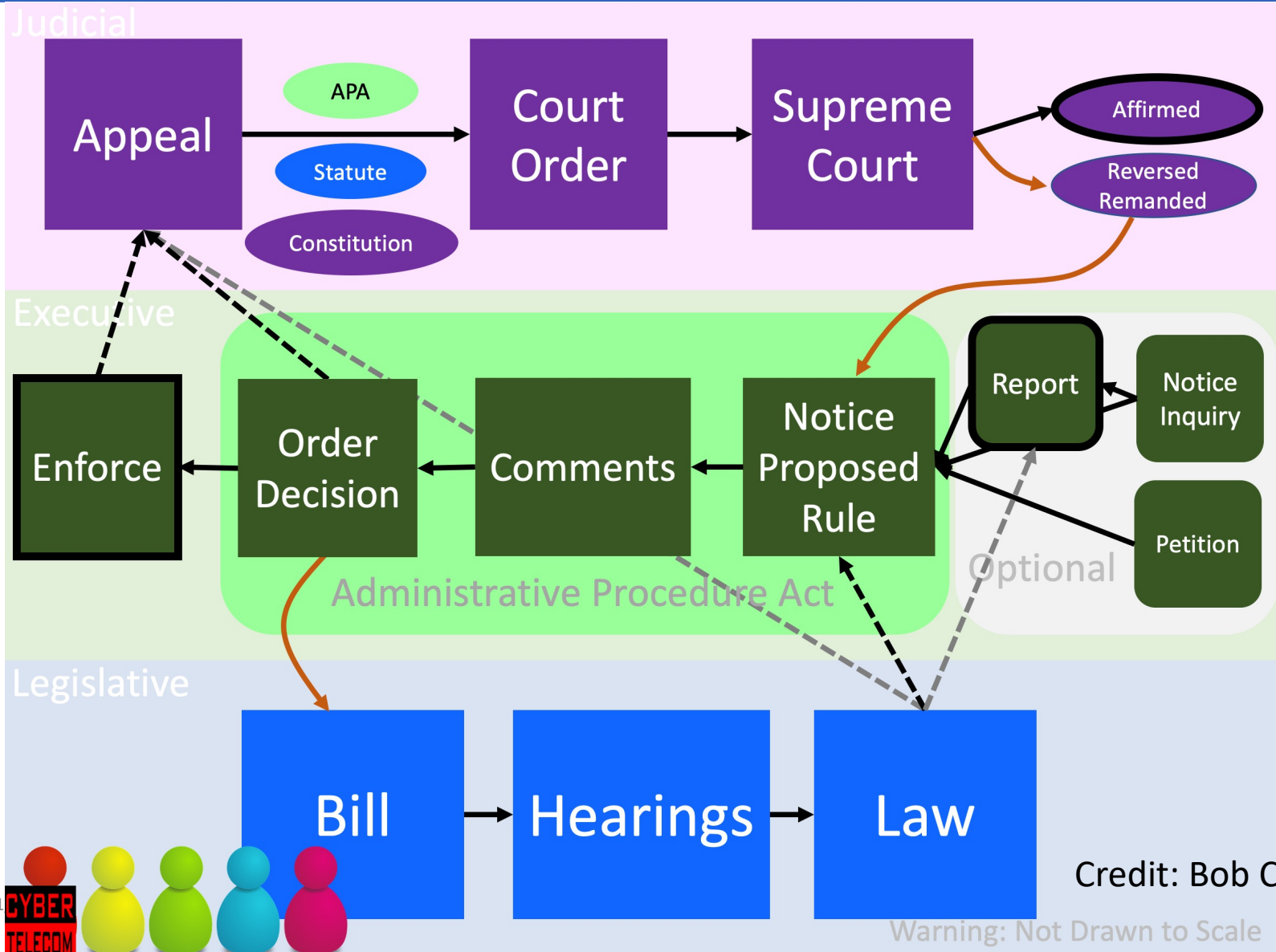
The kinds of law

- Constitutional law (1787)
 - relationship between
 - president and Congress
 - federal government and states
 - bill of rights (1791) + 17 amendments
 - short compared to other constitutions
- Criminal law
 - “Homicide means conduct which causes the death of a person or an unborn child with which a female has been pregnant for more than twenty-four weeks under circumstances constituting murder, manslaughter in the first degree, manslaughter in the second degree, criminally negligent homicide, abortion in the first degree or self-abortion in the first degree.” (NYS S125.00)
 - "Person," when referring to the victim of a homicide, means a human being who has been born and is alive.
- Civil law
 - contract, uniform commercial code, labor laws, ...
- Administrative law
 - e.g., how can regulations be made and enforced

The US hierarchy of laws



Three branches, intertwined



Credit: Bob Cannon

Warning: Not Drawn to Scale



Example: Law requiring 911

LII > U.S. Code > Title 47. TELECOMMUNICATIONS > Chapter 5. WIRE OR RADIO COMMUNICATION > Subchapter VI. MISCELLANEOUS PROVISIONS > **Section 615a-1. Duty to provide 9-1-1 and enhanced 9-1-1 service**

615a-1

U.S. Code Notes

[prev](#) | [next](#)

(a) DUTIES

It shall be the duty of each [IP-enabled voice service](#) provider to provide 9-1-1 service and [enhanced 9-1-1 service](#) to its subscribers in accordance with the requirements of the Federal Communications Commission, as in effect on the date of enactment of the [New and Emerging Technologies 911 Improvement Act of 2008](#) and as such requirements may be modified by the [Commission](#) from time to time.

(b) PARITY FOR IP-ENABLED VOICE SERVICE PROVIDERS

An [IP-enabled voice service](#) provider that seeks capabilities to provide 9-1-1 and [enhanced 9-1-1 service](#) from an entity with ownership or control over such capabilities, to comply with its obligations under subsection (a), shall, for the exclusive purpose of complying with such obligations, have a right of access to such capabilities, including interconnection, to provide 9-1-1 and [enhanced 9-1-1 service](#) on the same rates, terms, and conditions that are provided to a provider of commercial [mobile service](#) (as such term is defined in section 332(d) of the [Communications Act of 1934 \(47 U.S.C. 332\(d\)\)](#)), subject to such regulations as the [Commission](#) prescribes under subsection (c).

Example of rule – 47 CFR 20.18

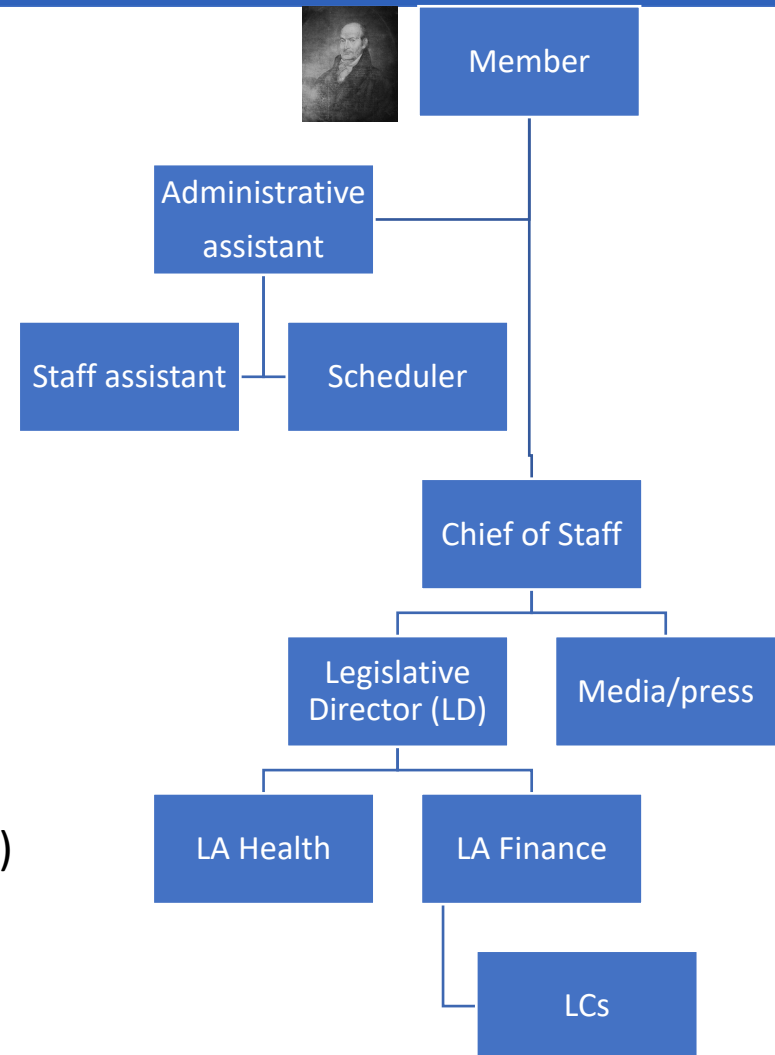
- **§ 20.18 911 Service.**
- (a) Scope of section. The following requirements are only applicable to CMRS providers, excluding mobile satellite service (MSS) operators, to the extent that they:
 - (1) Offer real-time, two way switched voice service that is interconnected with the public switched network; and
 - (2) Utilize an in-network switching facility that enables the provider to reuse frequencies and accomplish seamless hand-offs of subscriber calls. These requirements are applicable to entities that offer voice service to consumers by purchasing airtime or capacity at wholesale rates from CMRS licensees.
- (b) Basic 911 Service. CMRS providers subject to this section must transmit all wireless 911 calls without respect to their call validation process to a Public Safety Answering Point, or, where no Public Safety Answering Point has been designated, to a designated statewide default answering point or appropriate local emergency authority pursuant to § 64.3001 of this chapter, provided that “all wireless 911 calls” is defined as “any call initiated by a wireless user dialing 911 on a phone using a compliant radio frequency protocol of the serving carrier.”

What does a Congressional office do?

- Legislation
 - research, draft, submit, manage
 - mostly done by LAs, LD
- Oversight
 - letters, hearings
- Constituent correspondence
 - semi-automated via LCs
- Constituent service
 - case workers
- Media

House member: 15 staff (incl. field)
Senator: 41 staff (incl. field)

+ staff for committees (majority & minority)



Congress during a pandemic

- March 12: Wyden office switches to home mode
- March 12: Capitol closed to visitors
- But each office makes own decision
 - the political becomes personal
- Senate still votes in person; House has proxy voting
- Minimal personal staff remain on-site
- Staff geographically distributed
- Congress designed for in-person hearings, votes, negotiation, visits, ...
 - normally, anybody can walk into a Member front office
- Spring dominated completely by CV-19 packages and home state support



Closing the Digital Divide

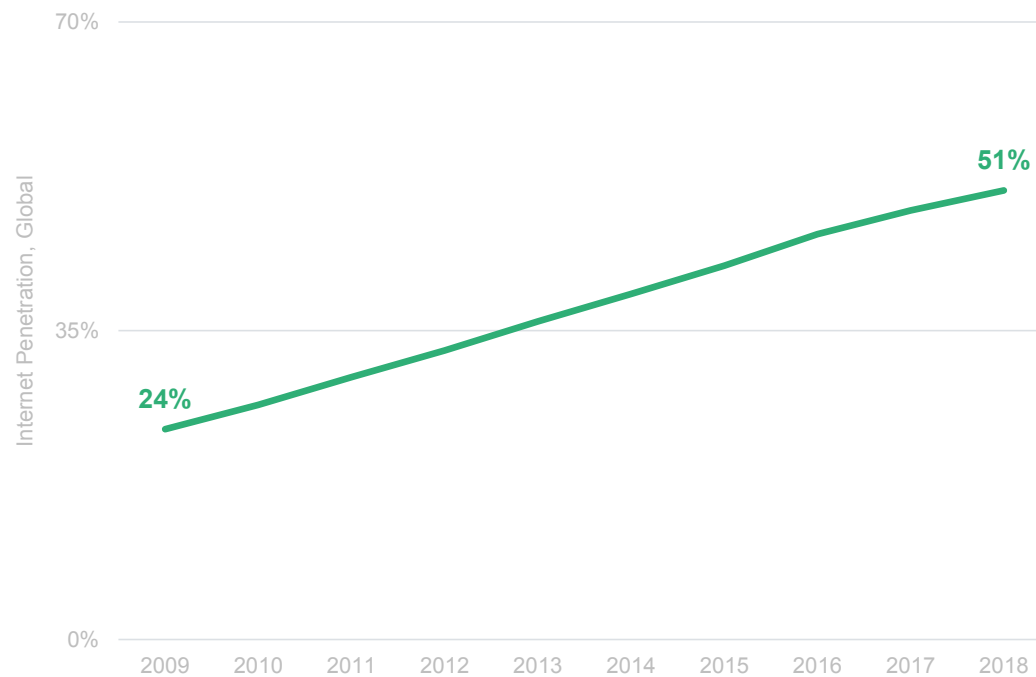
Overview

- **Availability, affordability** and relevance
- What makes deploying fixed broadband necessary & expensive?
- Technology may help – if it can dig trenches & automate operations
- Affordability may become a larger problem than availability
- Government is likely to play a major role
- Mostly focus on United States, but basic problems similar elsewhere

How bad is the problem?

Global Internet users

Internet Penetration, 2018

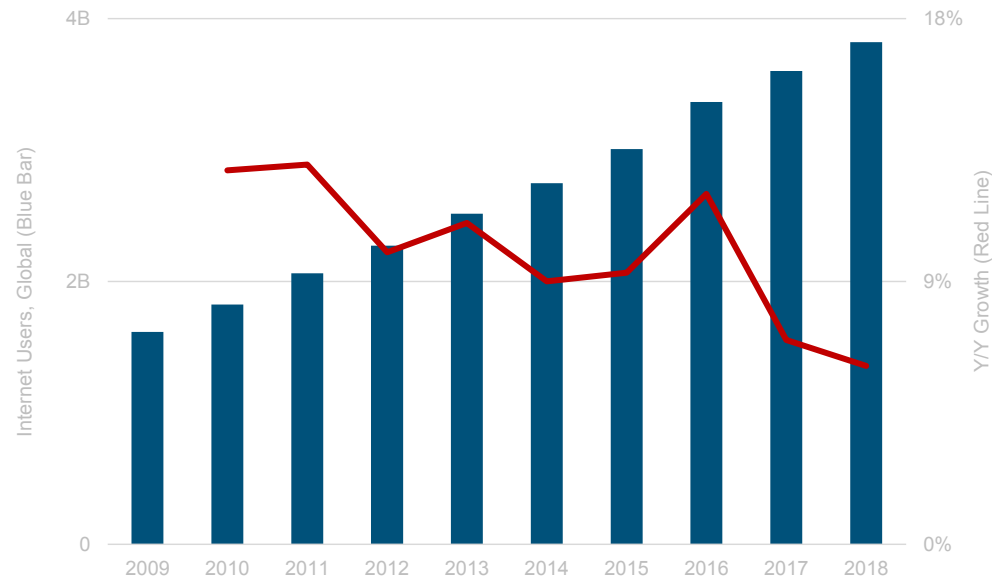


KLEINER PERKINS
2018
INTERNETTRENDS

Source: CIA World Factbook, United Nations / International Telecommunications Union, USA Census Bureau. Internet user data is as of mid-year. Internet user data: Pew Research (USA), China Internet Network Information Center (China), Islamic Republic News Agency / InternetWorldStats / KP estimates (Iran), KP estimates based on IAMA data (India), & APJII (Indonesia). Note: Historical data (particularly in Sub-Saharan Africa) revised by ITU in 2017 to better account for dual-SIM subscriptions (i.e. two Internet subscriptions per single smartphone user).

Global internet growth – 2009–2018

Internet Users vs. Y/Y Growth

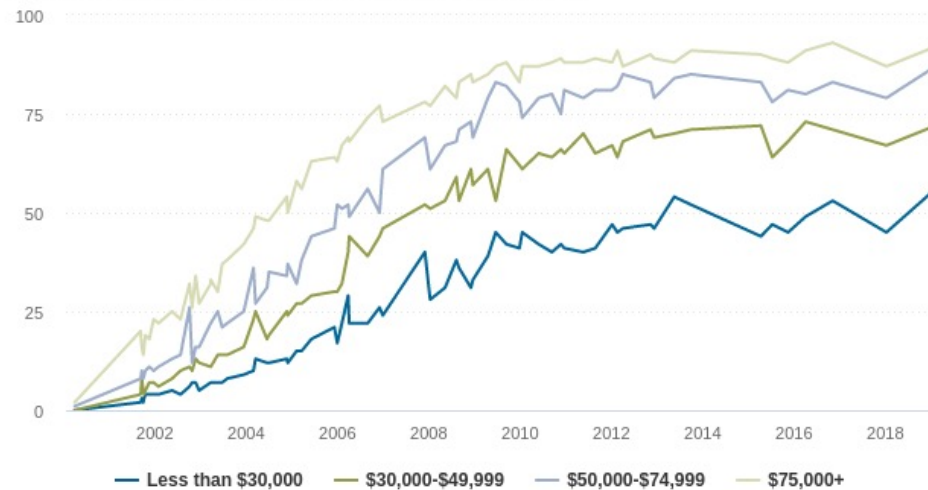


Internet user data is as of mid-year. Source: United Nations / International Telecommunications Union, USA Census Bureau, Pew Research (USA), China Internet Network Information Center (China), Islamic Republic News Agency / InternetWorldStats / Bond estimates (Iran), Bond estimates based on IAMAI data (India), & APJII (Indonesia).

US: Income plays a major role

Home broadband use by income

% of U.S. adults who are home broadband users, by income

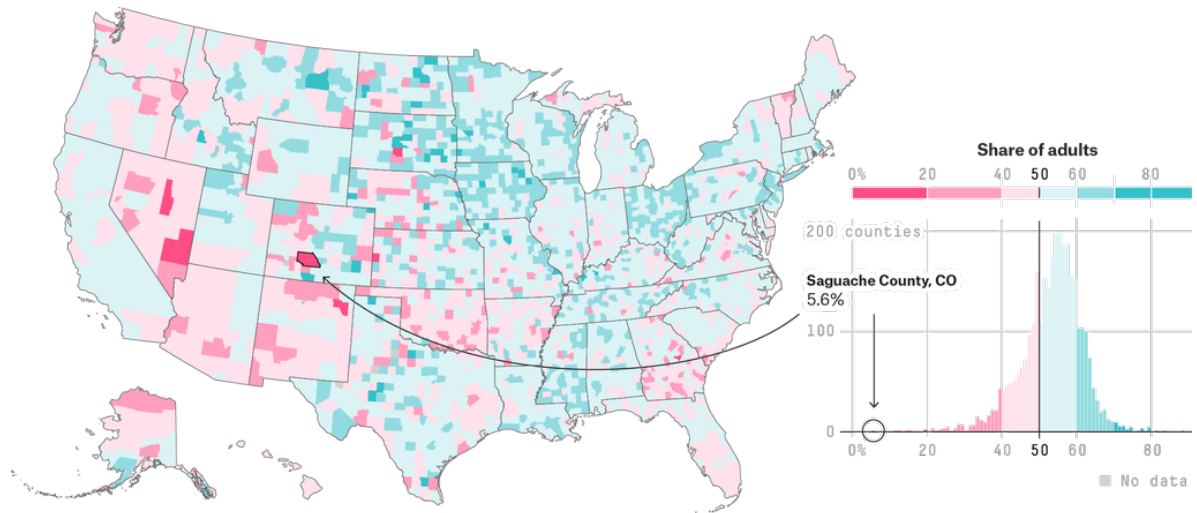


Note: The Center has used several different question wordings to identify broadband users in recent years, which may account for some variance in broadband adoption figures between 2015 and 2018. Our survey conducted in July 2015 used a directly comparable question wording to the one conducted in January 2018.

Source: Surveys conducted 2000-2019.

Pew Research

Rural broadband US



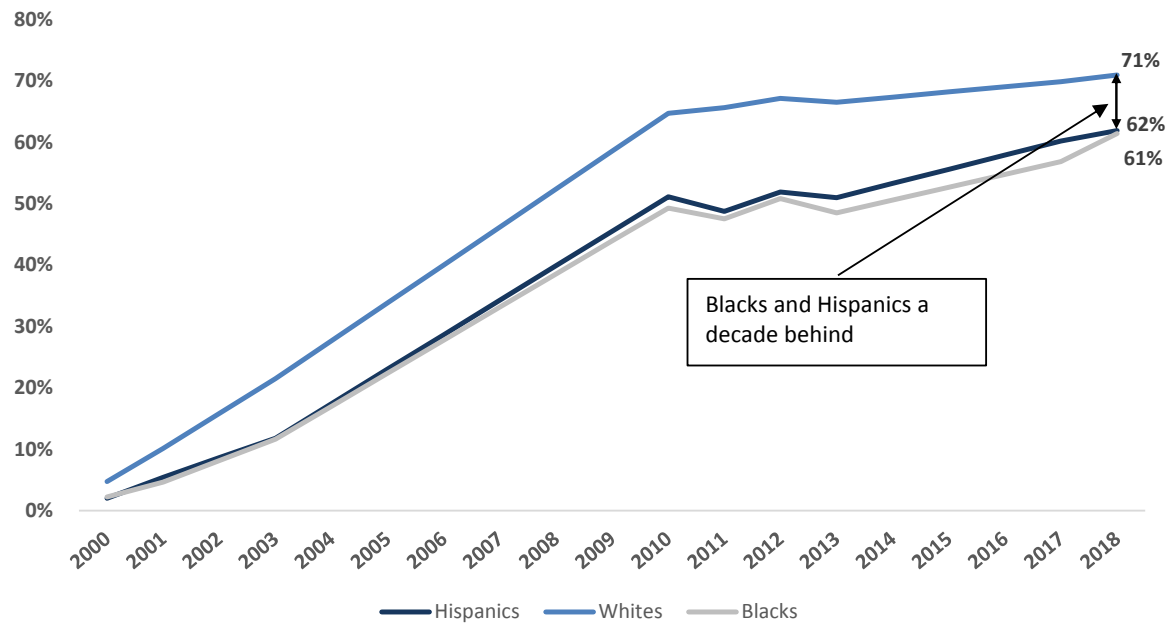
County shares are estimated using data from a 1 percent sample of 240 million voting-age Americans provided by Catalist, an election data firm. Internet connections faster than dial-up include those via DSL, cable, fiber-optic, satellite, etc.

FiveThirtyEight

SOURCE: ARIZONA STATE UNIVERSITY'S CENTER FOR POLICY INFORMATICS

By race, too

Figure 5: Broadband penetration among US households by Race

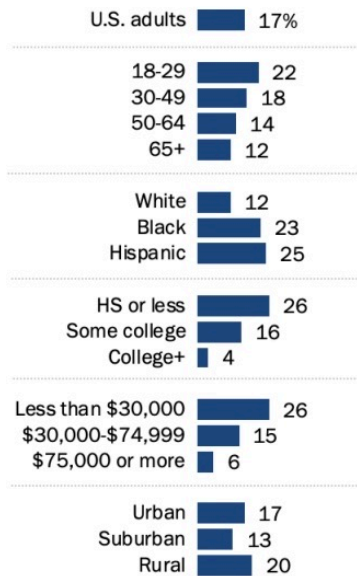


Source : NTIA

% of U.S. adults who do not use broadband at home but own smartphones

17% of Americans are “smartphone only” internet users

% of U.S. adults who say they own a smartphone, but do not have a high-speed internet connection at home



Note: Respondents who did not give an answer are not shown. Whites and blacks include only non-Hispanics. Hispanics are of any race.

Source: Survey of U.S. adults conducted Jan. 8-Feb. 7, 2019.

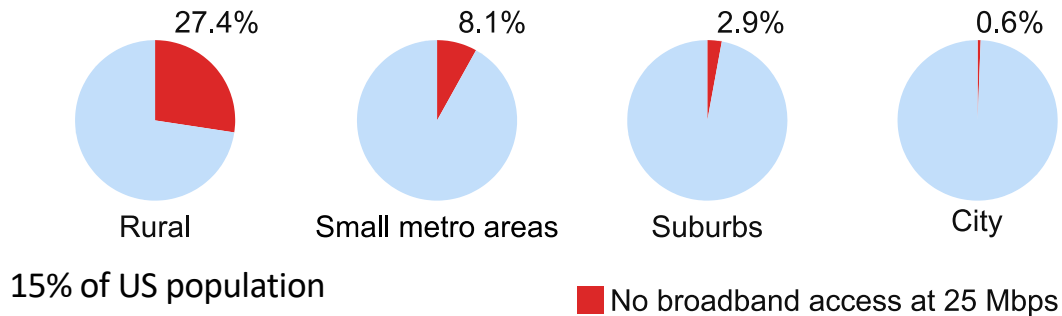
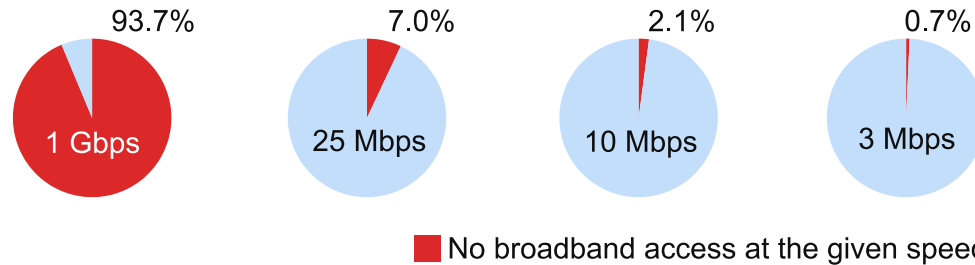
"Mobile Technology and Home Broadband 2019"

PEW RESEARCH CENTER

- Smartphones = mostly consumption devices
- + TikTok!
- Hard to do homework on a smartphone
- Hard to do telework

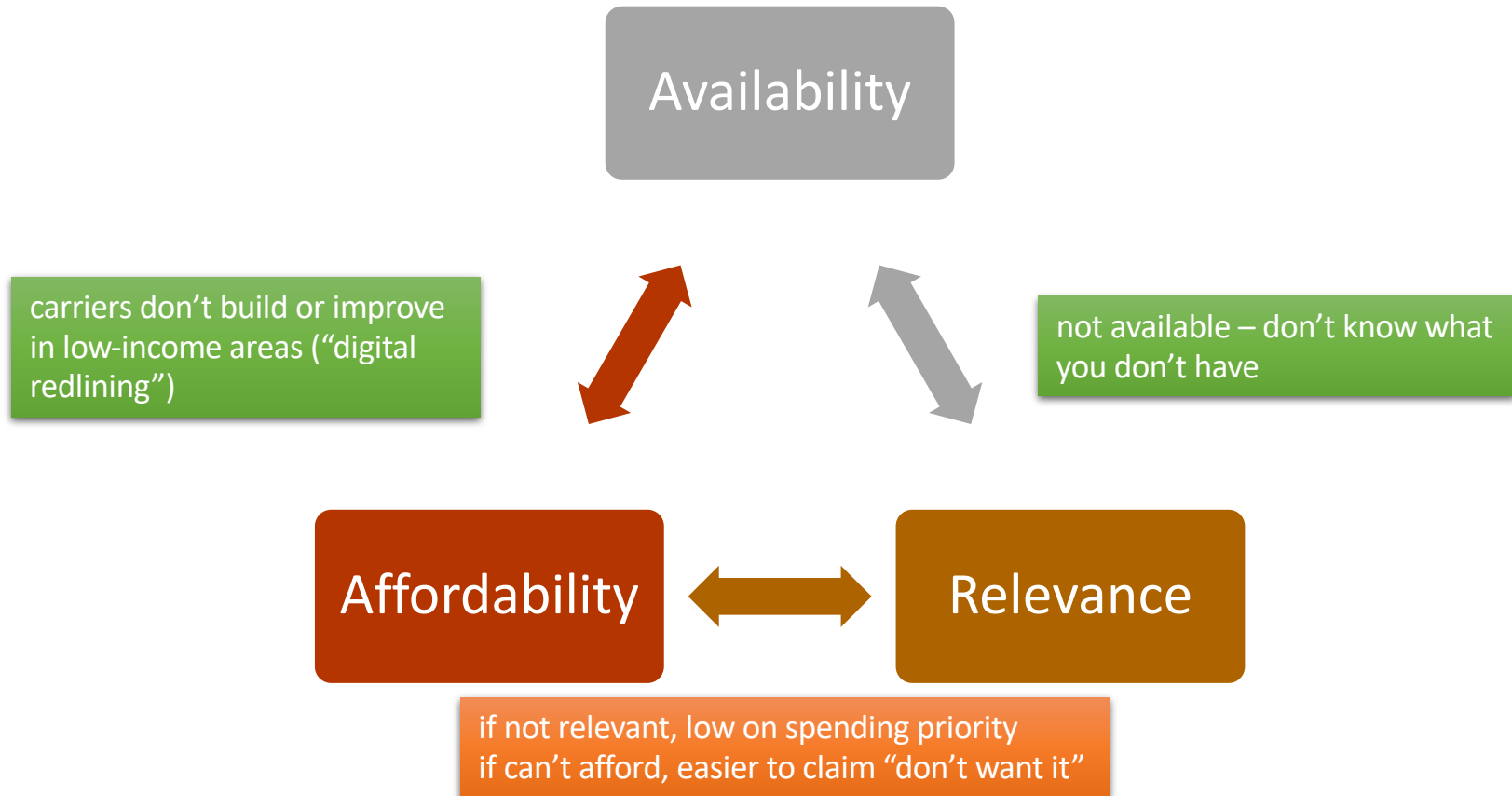
Broadband access by speed & geography

BROOKINGS



What are the causes?

Availability, affordability and relevance are coupled

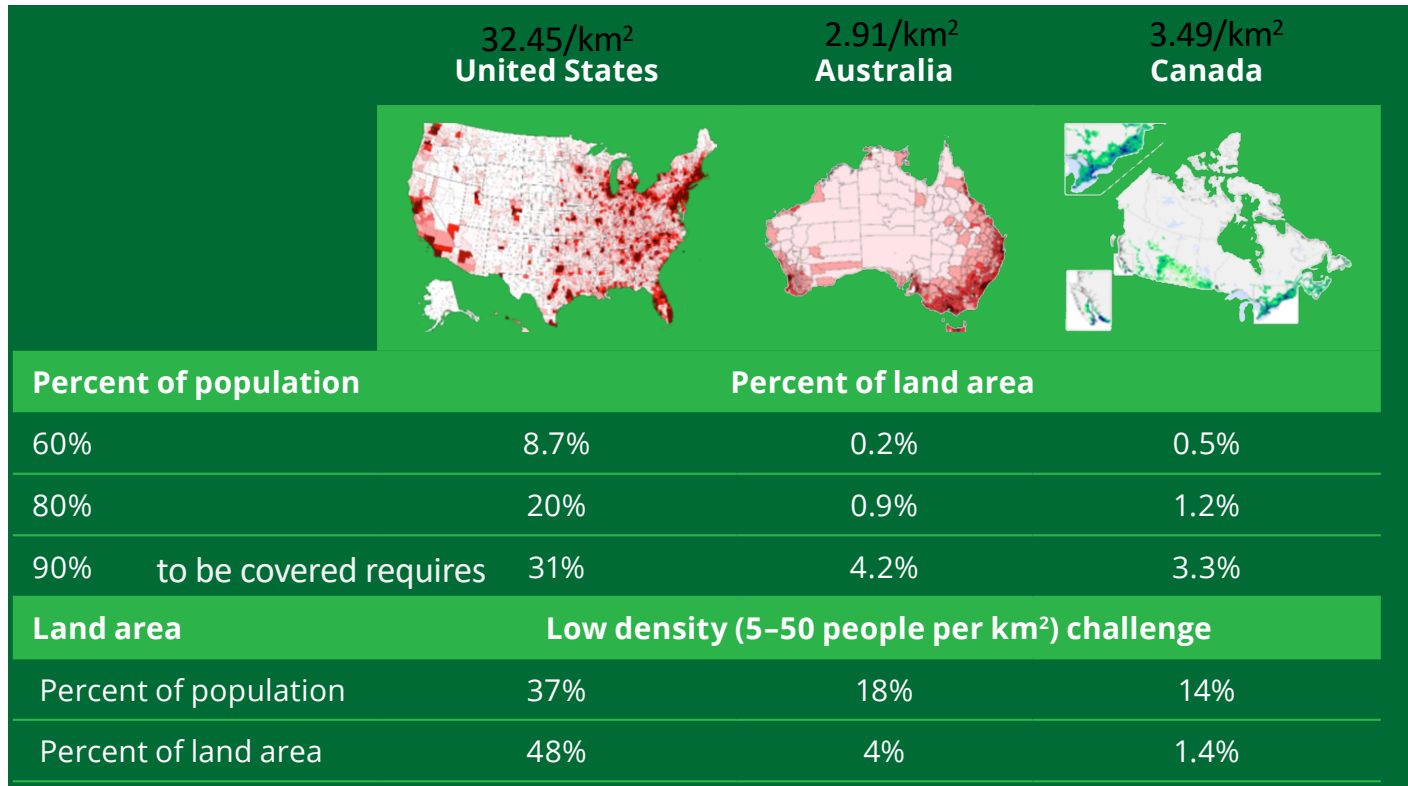


Reason for non-adoption

Survey	Primary Reason	Secondary Reason	Tertiary Reason	Fourth Reason	Type of question
Pew Research Center (2019)	Cost – either service is too expensive	Smartphone does everything they need	Other access options outside the home	Cost of computer is too expensive	Closed-ended
	Listed as a reason: (50%)	Listed as a reason: (45%)	Listed as a reason: (43%)	Listed as a reason: (45%)	
	Most important reason (21%)	Most important reason (23%)	Most important reason (11%)	Most important reason (10%)	
Pew Research Center (2015)	Cost – either service is too expensive	Smartphone does everything they need	Other access options outside the home	Cost of computer is too expensive	Closed-ended
	Listed as a reason: (59%)	Listed as a reason: (27%)	Listed as a reason: (46%)	Listed as a reason: (31%)	
	Most important reason (33%)	Most important reason (12%)	Most important reason (10%)	Most important reason (6%)	

<https://www.digitalinclusion.org/measuring-the-gap/>

Lower population density, easier broadband



Deloitte, 2017

It all depends on your (network)
roots

Who runs communication systems and networks?

incumbent local exchange carriers ("ILEC")

at&t
verizon
windstream.

competitive local exchange carriers ("CLEC")

CABLEVISION

cable companies ("MVPD")

~6

COMCAST

T-Mobile

Sprint

cellular providers (3-4)

at&t
verizon

rural local exchange carriers ("RLEC")

~1,000

DIRECTV

dish NETWORK

satellite providers

HUGHES

Connect to the future.

~2

Level(3)[®]

COMMUNICATIONS

wholesaler providers ("carriers' carrier")

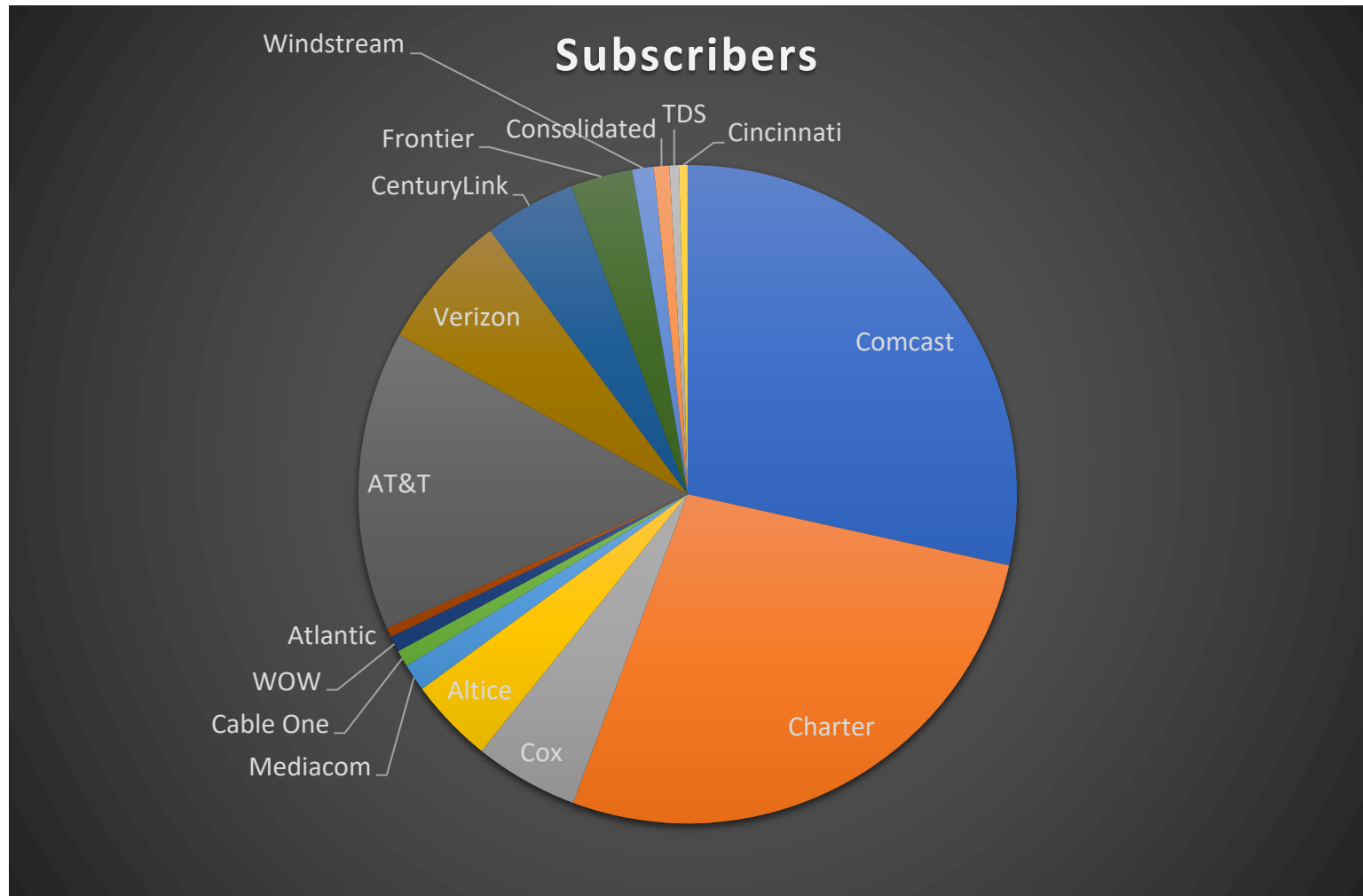
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GROUP

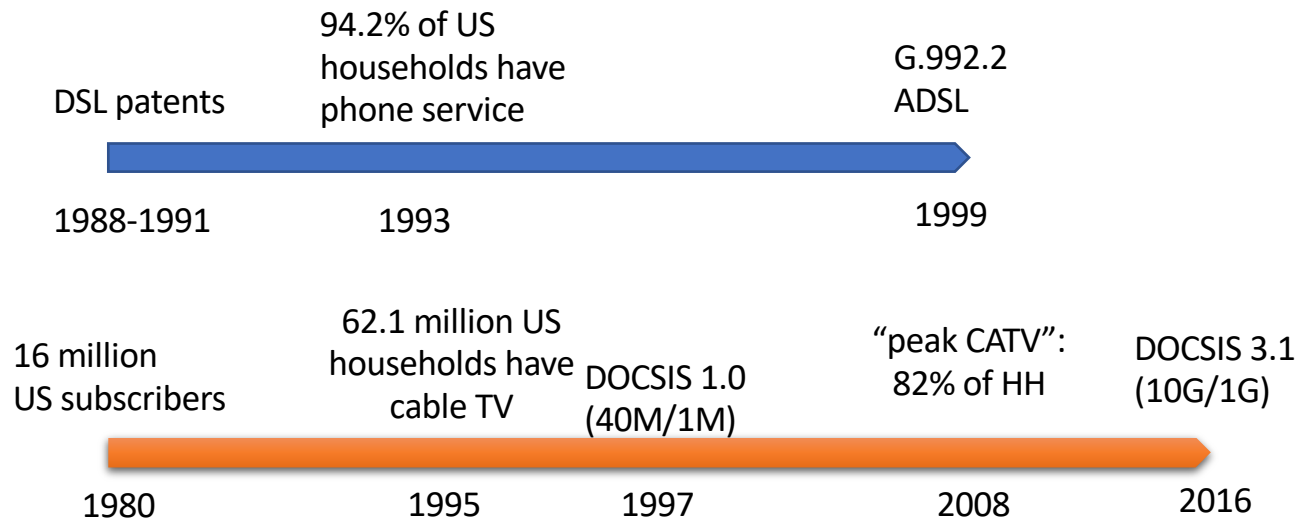
communities & cooperatives ("muni networks", REC)

with ~90% marketshare

But a few large carriers dominate

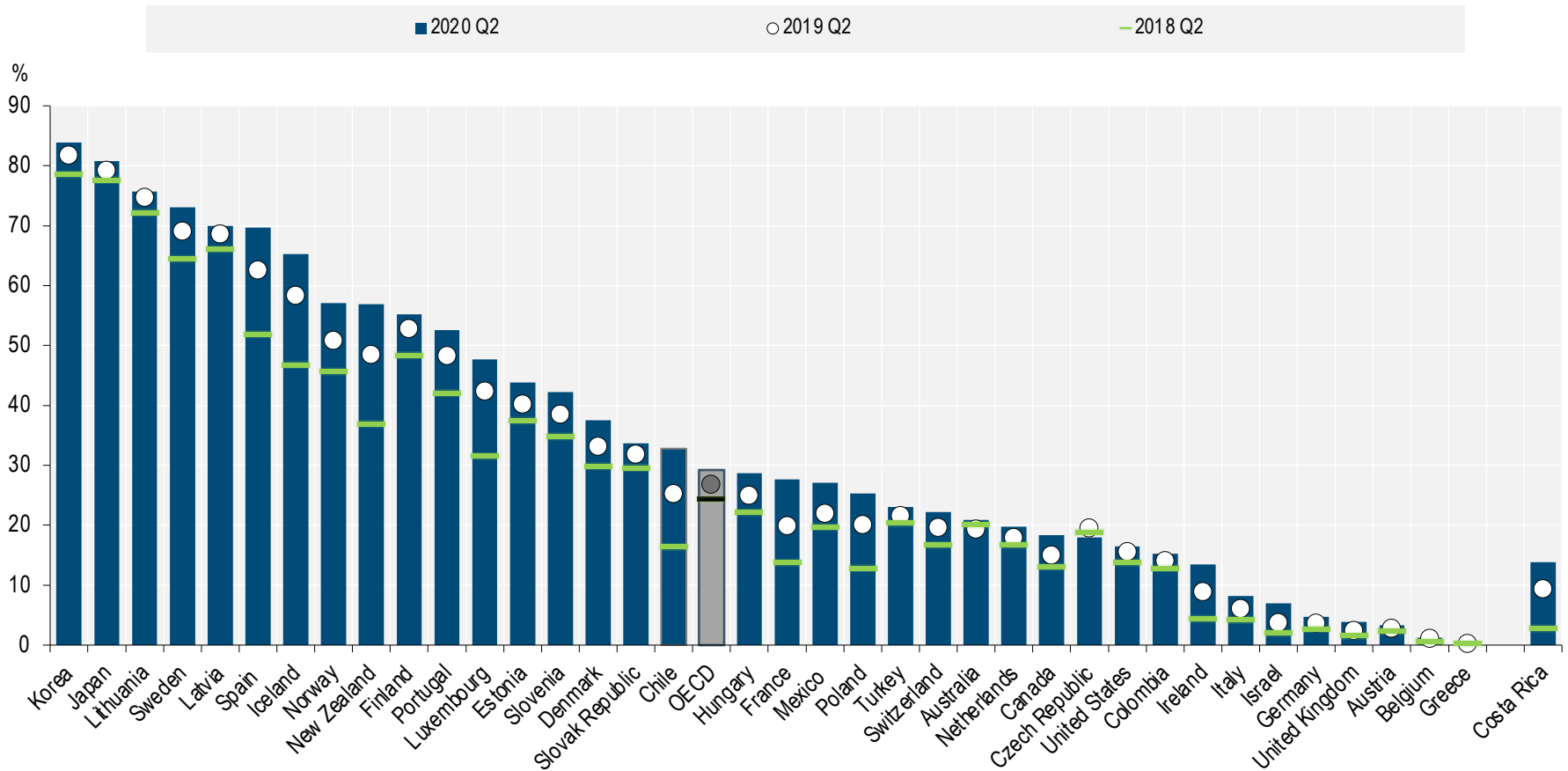


Accidental broadband



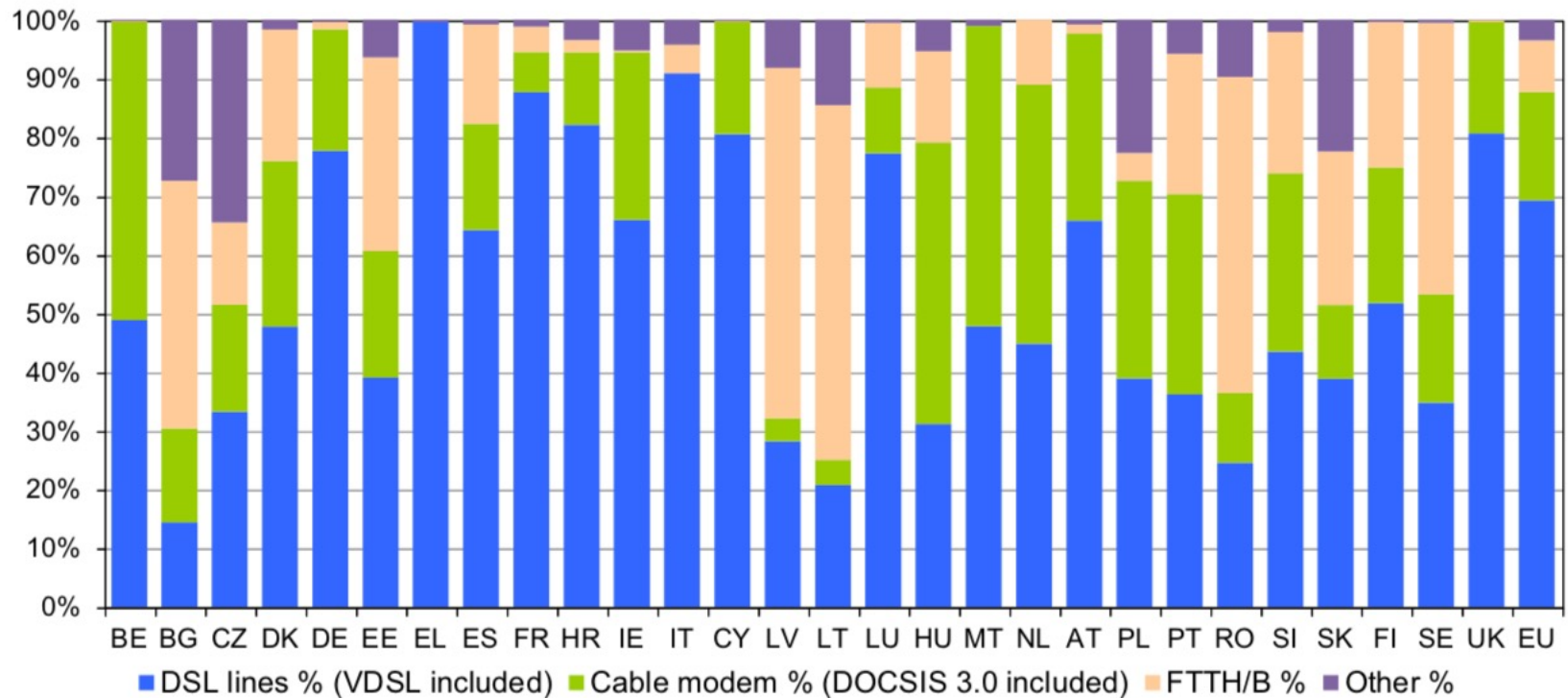
→ DSL and cable infrastructure near-universally or widely available well before use as Internet access

FTTH internationally



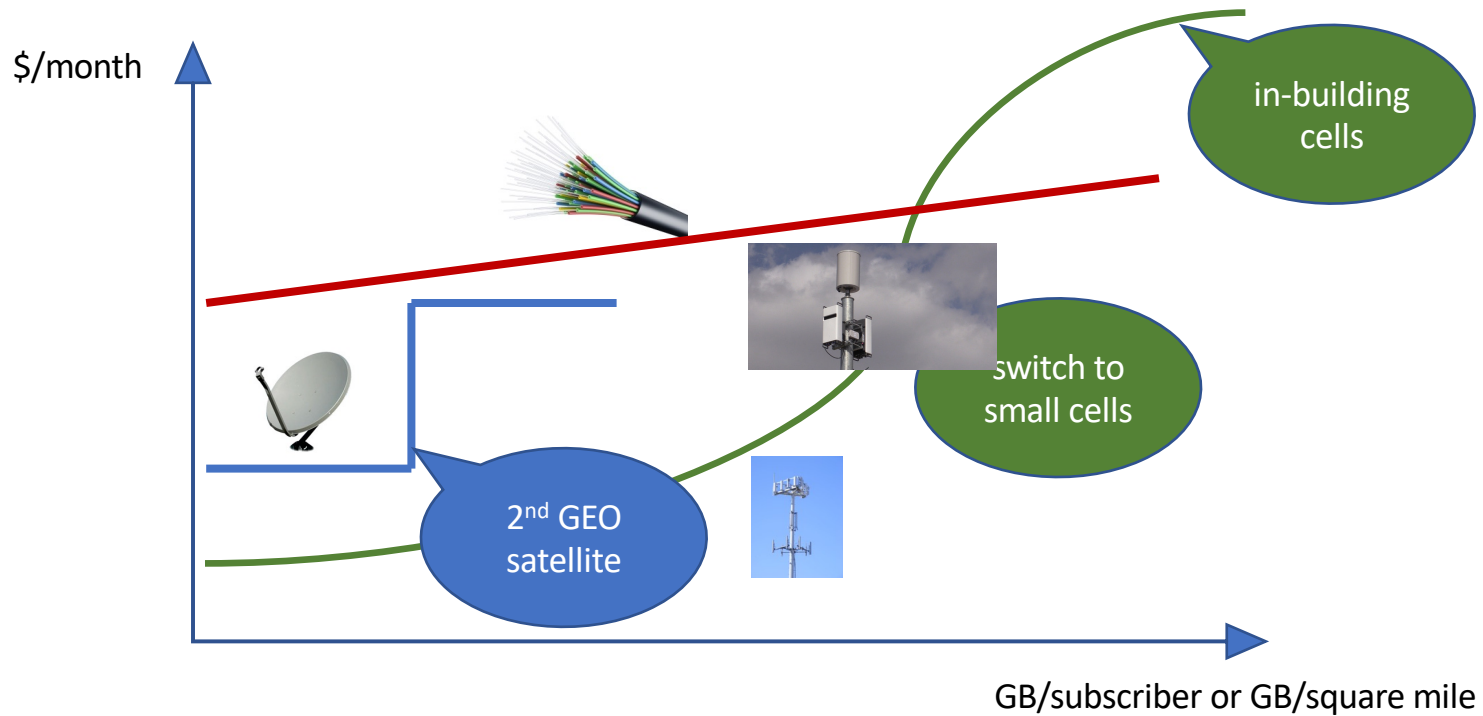
Technology path dependence

Fixed broadband subscriptions - technology market shares, July 2015

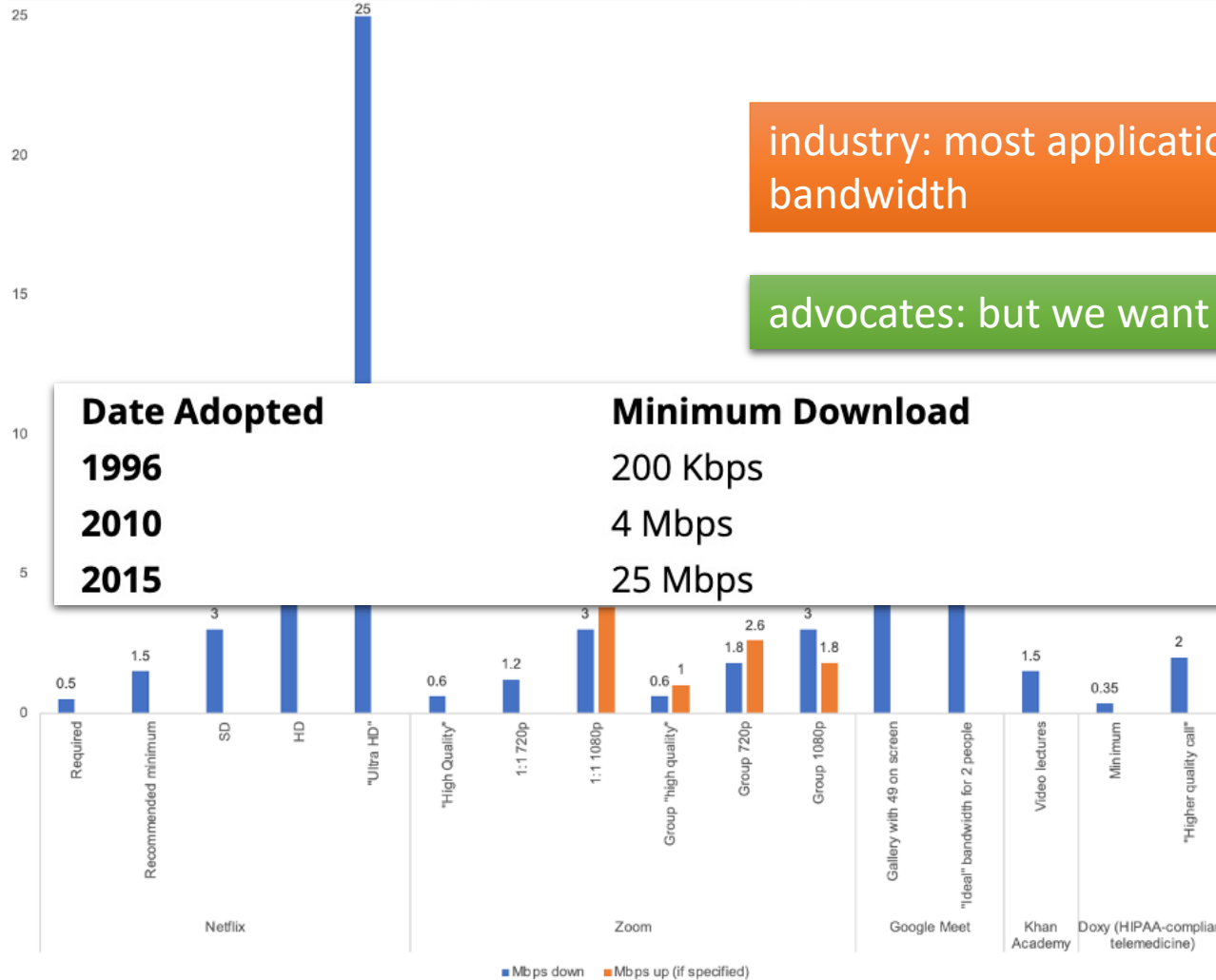


Improving availability

Metrics: not Gb/s or b/s/Hz, but \$/GB and \$/year



How much speed do we need?



industry: most applications don't need lots of bandwidth

advocates: but we want future-proof networks!

Date Adopted
1996
2010
2015

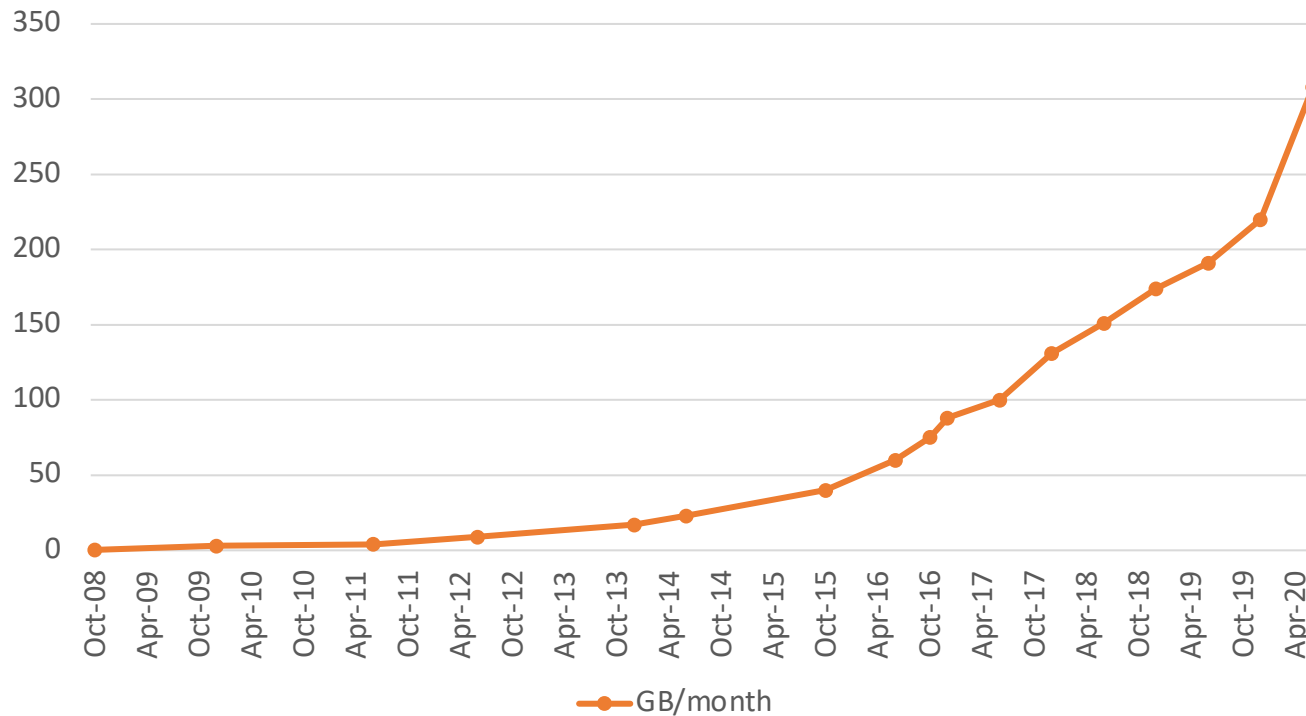
Minimum Download
 200 Kbps
 4 Mbps
 25 Mbps

Minimum Upload
 200 Kbps
 1 Mbps
 3 Mbps

Technology Policy Institute, 3/21

For non-fiber networks, problem is likely capacity, not speed

Comcast Median Household Usage in GB/month



History: rural electrification

- Early 1920s, between 2 and 3% of farms (likely less)
 - 1921: DC had 98.2%, MA 97.8%
- “In 1935, only 10.9% of American farms (744,000) enjoyed central station power, compared with Germany and Japan at 90%, France between 90 and 95%, and New Zealand at 60%.”
- “In 1940, just four and a half years after Roosevelt signed Executive Order No. 7037 (followed by 1936 “Rural Electrification Act”), 25% of American farms had been electrified.”
- 1950: 90% had been electrified nationally
- Today: 850 distribution coops serving 14 M homes

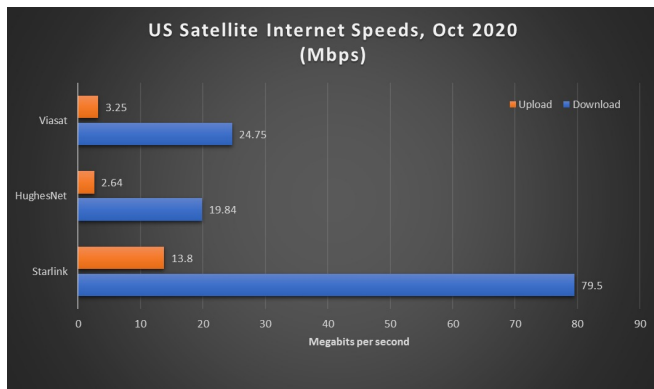
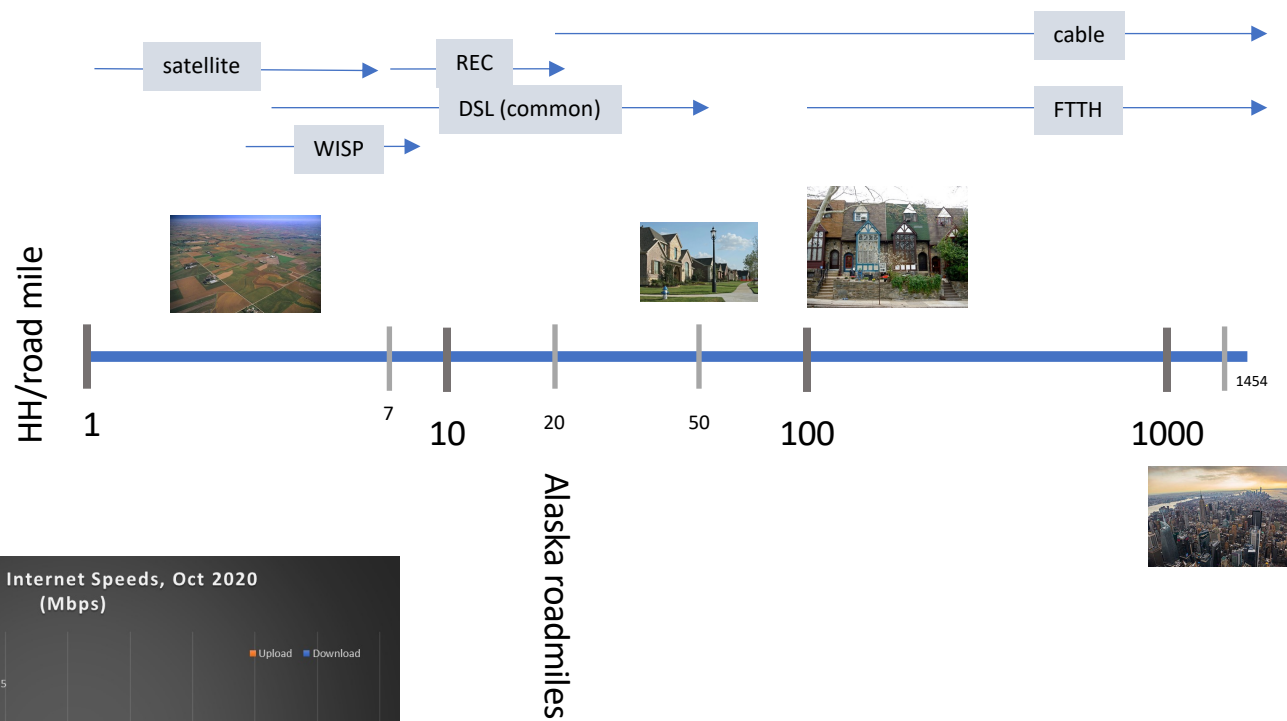
Rural electrification

- “In 1935, Morris Llewellyn Cooke, a mechanical engineer ... appointed by Roosevelt as the REA's first administrator, Cooke applied an engineer's approach to the problem, instituting what was known at the time as "scientific management" —essentially systems engineering. ... By 1939 the cost of a mile of rural line had dropped from \$2,000 to \$600. Almost half of all farms were wired by 1942 and virtually all of them by the 1950s.”
- Cost of aerial **fiber** installation: \$14k/mile material, \$39k/mile installation (Singer, 2017)
- USDA loans at 2.81% for 30 years



\$10,958
in 2017

Density determines network choices



Challenges for rural broadband

- Who is going to build out?
 - some incumbent local exchange carriers (ILECs) are not interested
 - municipalities may be prohibited by state laws
 - or hurdle is extremely high
 - rural electric cooperatives – serve 14M homes in US (out of ~110M)
 - average, 5.8 electric meters per mile
- Upgrade copper or new infrastructure?
 - fiber closer to the home (“FTTN”) OR
 - fiber to the home (FTTH) or fixed wireless or LEO
- Who is going to pay for broadband?
 - subsidize once, for N years, or forever?
- Are non-landline approaches scalable?
 - TV white spaces, HAPS
 - satellite – NGS like OneWeb (600 satellites) or StarLink
 - currently, about 500k residential satellite subscribers
 - “better than nothing”
 - lacking capacity, high delay, low reliability, expensive
 - LEOs change the picture



50-150 Mb/s, 40 ms RTT
\$99/month
\$499 antenna

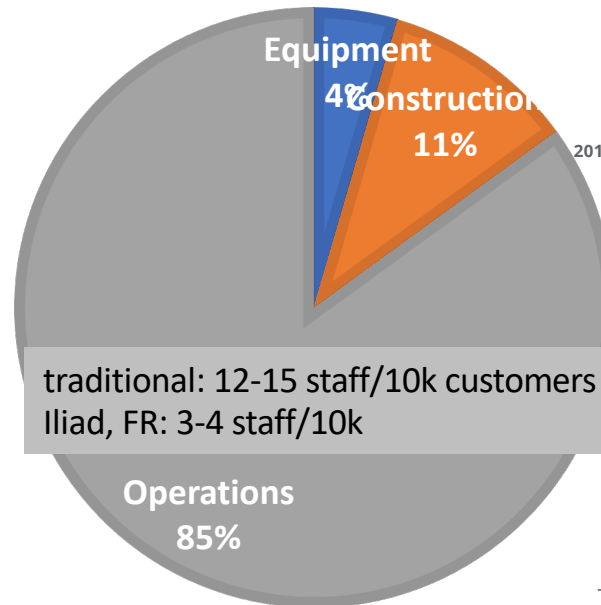
How do we pay for this?

Network economics, (over)simplified



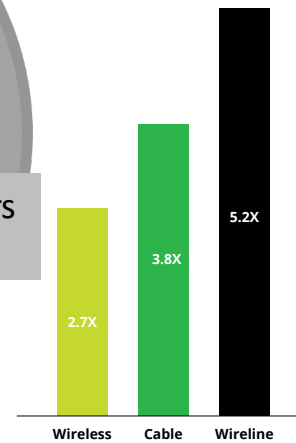
% OF REVENUE

■ Equipment ■ Construction ■ Operations ■



traditional: 12-15 staff/10k customers
Iliad, FR: 3-4 staff/10k

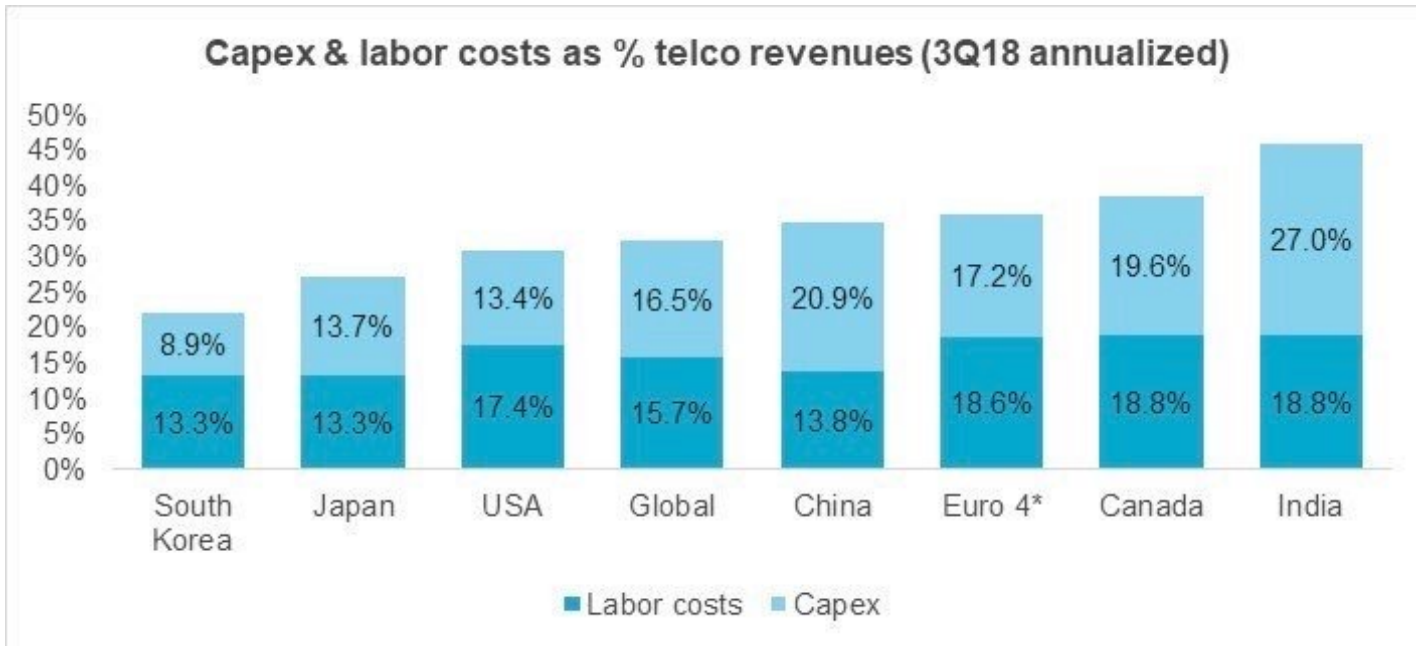
2016 Average OPEX to CAPEX ratios⁴⁴



More fiber observations

- Fiber middle-mile cost: \$50-70k/mile
- Fiber cost: 144 strands = \$10k/mile, 48 strands = \$4.7k/mile
- Common characteristics:
 - avoid active elements in network → power, maintenance → PON
 - recently: avoid anything except fiber (including splitters)
 - cf. wireless last mile approach
 - fiber home run, even if PON (Google Fiber, Stockholm)
- Fiber cost higher for buried, but cheaper if conduit or aerial
- Recent FTTH:
 - avoid indoor installation (cf. Verizon FiOS)
 - one box in home (ONT + 802.11ac), not ONT + MoCa STB

Labor and capital expenditures

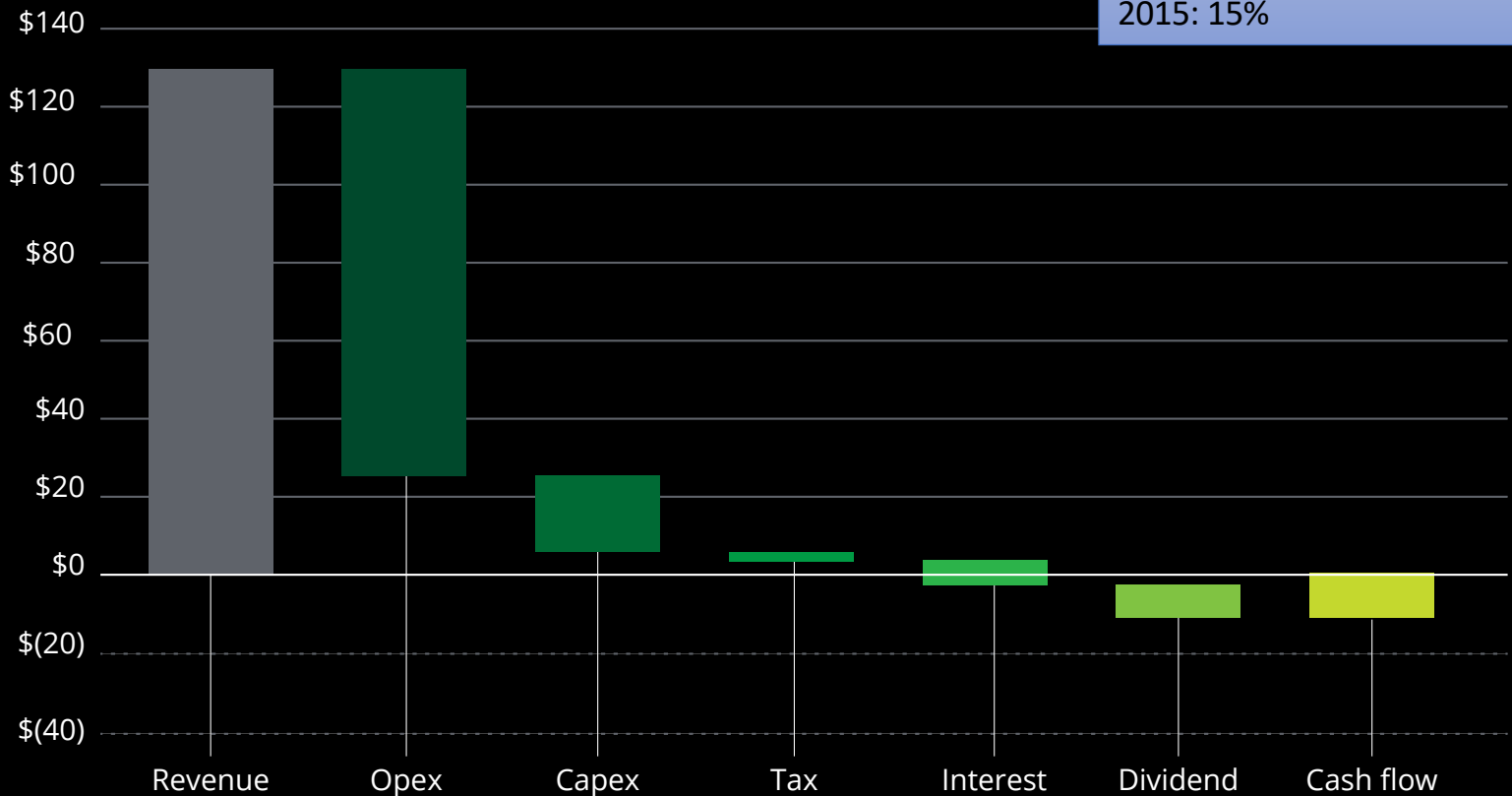


Rural wireline ILECs lack resources

Average 2016 wireline financials³⁹

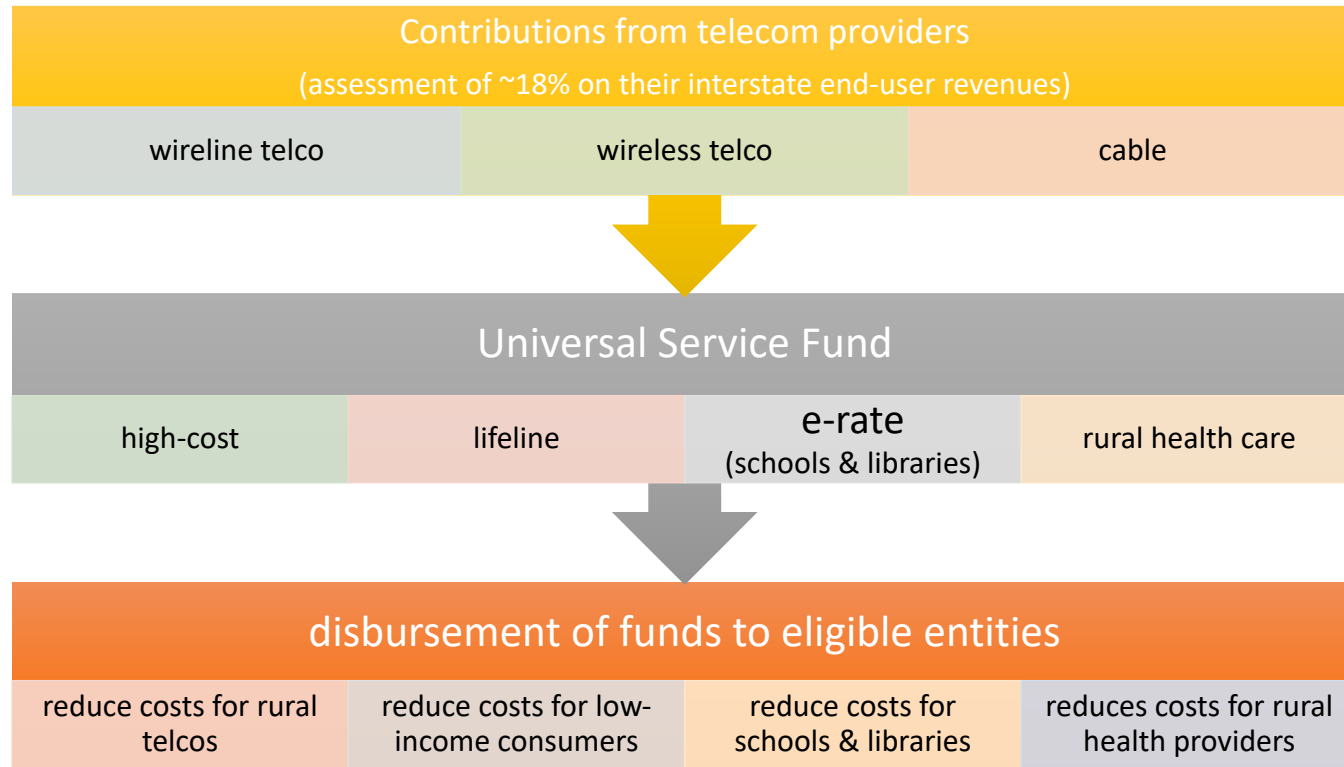
(in thousands of dollars)

Wireline share of voice revenue:
2005: 79%
2015: 15%



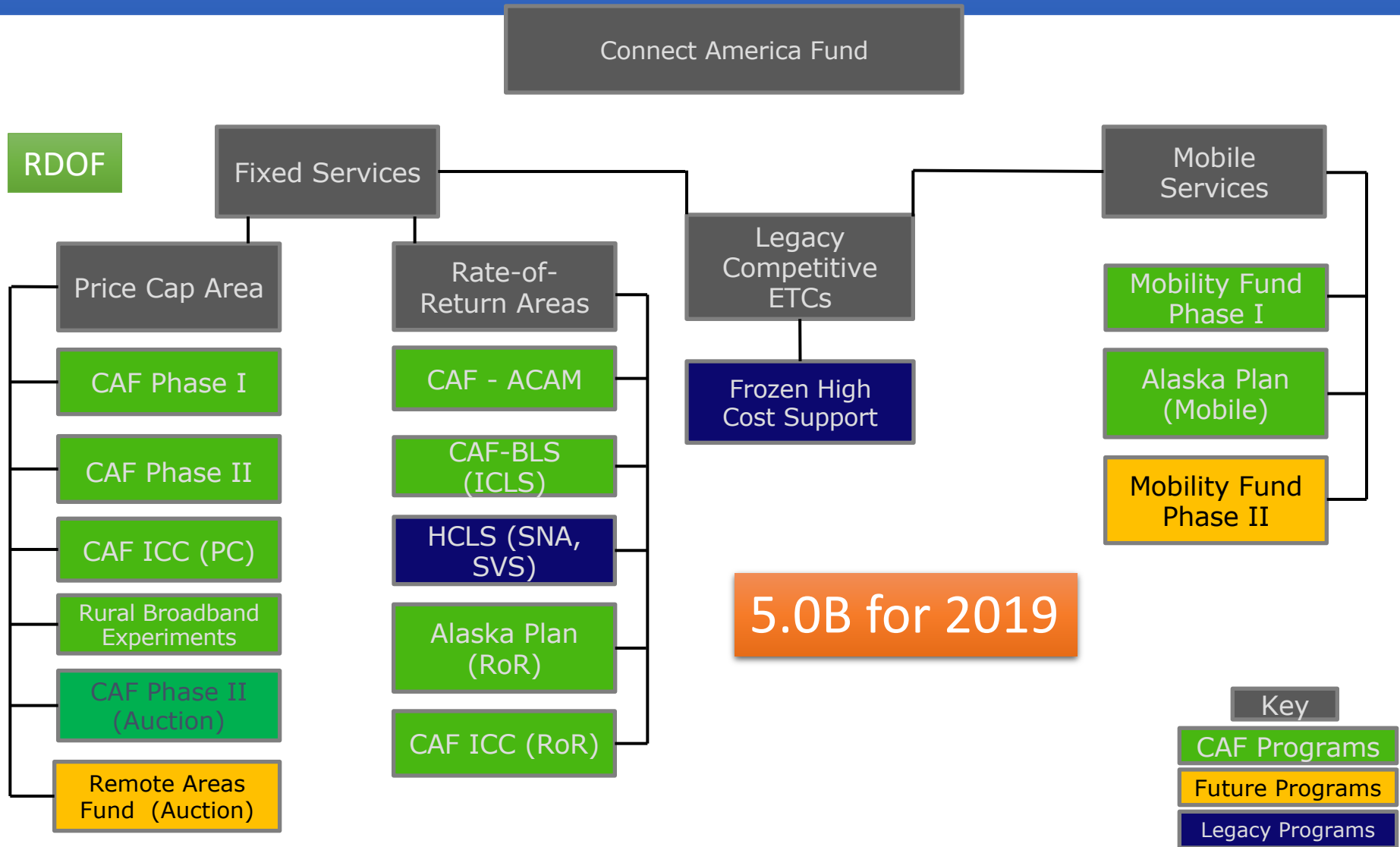
$ARPU(\text{fiber}) = ARPU(\text{DSL}) + \epsilon$
 $\text{cost}(\text{fiber}) \gg \text{cost}(\text{DSL})$

Universal Service Fund (USF)



Allison Baker, 2017

We've tried this for a while: Connect America Fund (CAF) and off-spring

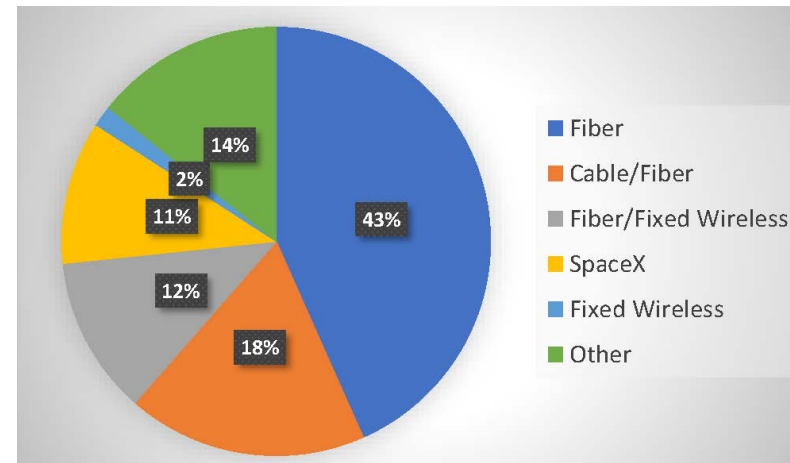


Rural Digital Opportunity Fund (RDOF) - 2020

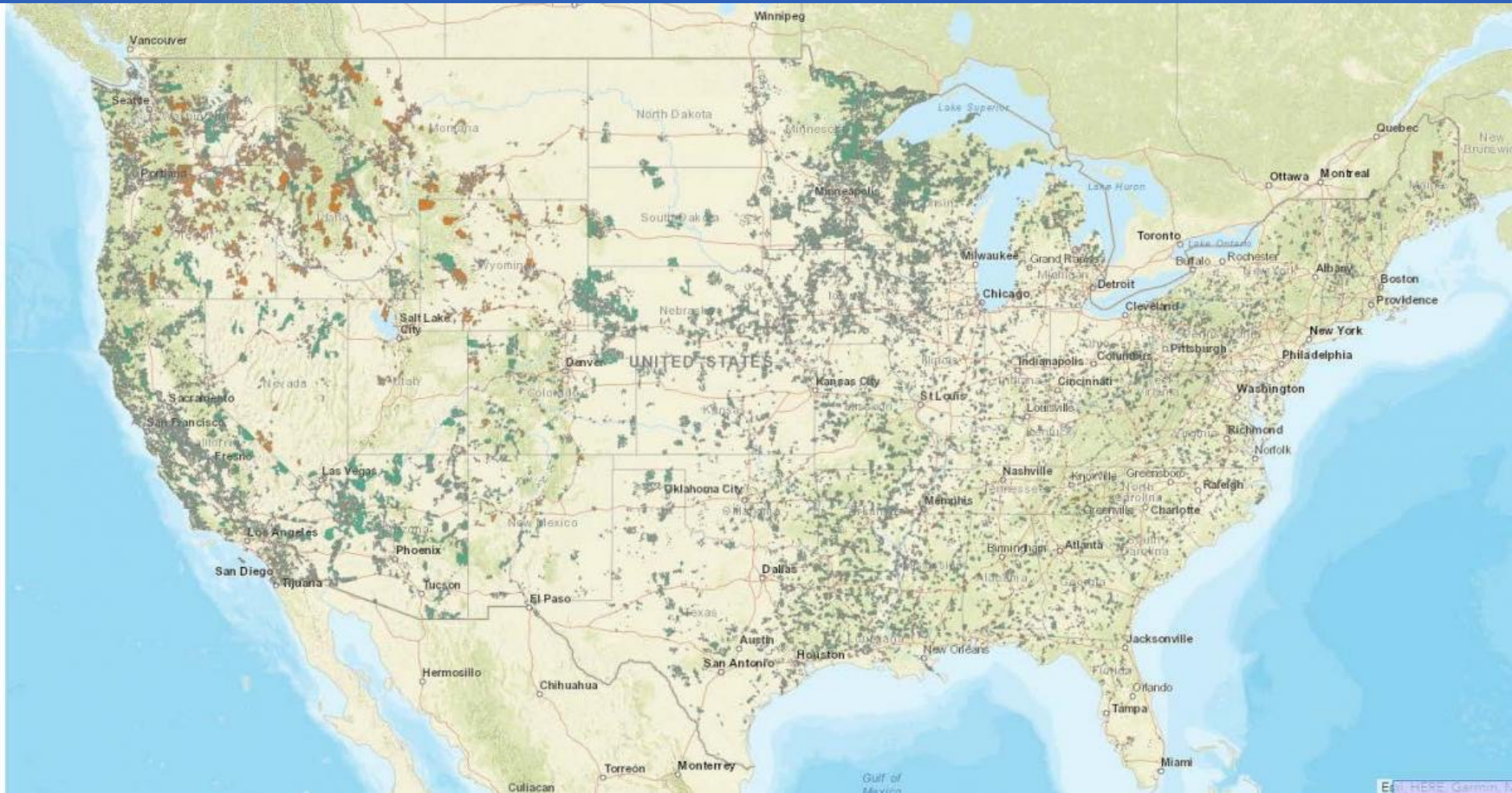
- Old (pre-1996) model: incumbent is obligated to provide “universal service”
 - even if economically inefficient
 - “carrier of last resort” (COLR)
- Transition model: large incumbent telephone companies get money
 - based on cost estimates → often upgrade DSL from really slow to slow
- New model: reverse auction → lowest subsidy wins support
 - non-traditional providers, new entrants, satellite, ...

Performance Tier	Speeds Required	Bandwidth Allowance
Minimum	≥ 25/3 Mbps	≥ 250 GB or U.S. average, whichever is higher
Baseline	≥ 50/5 Mbps	≥ 250 GB or U.S. median, whichever is higher
Above baseline	≥ 100/20 Mbps	≥ 2 TB
Gigabit	≥ 1 Gbps/500 Mbps	≥ 2 TB
Latency	Requirement	
Low Latency	≤ 100 ms	
High Latency	≤ 750 ms & MOS of ≥4	

Weight
50
35
20
0
Weight
0
40



RDOF (2020) outcome



<https://www.ctcnet.us/analytics/rdo-f-winners/>

Your phone, video & Internet bill

Taxes, Governmental Fees & Surcharges		
	NJ State Sales Tax	4.09
	Federal Excise Tax	.24
	911 System/Emerg Resp Fee	.90
	Verizon Surcharges & Fees	
	Video Franchise Fee	1.40
	CATV Universal Access Fund	.19
	Federal Universal Service Fee	2.81
	Regulatory Recovery Fee - Federal	.06
	Federal Subscriber Line and Access Recovery Charge	8.00
	VLD Carrier Cost Recovery Charge	1.25
	VLD Long Distance Administrative Charge	.74
	Fios TV Broadcast Fee	<u>4.49</u>

state video franchise (NJ)	911 fee (by county)
Verizon long distance	subsidy (high-cost, low-income, e-Rate)
	funds the FCC

Investment calculation

- \$50/month per subscriber → 15% for investment
 - assume 10% for end user investment, rest for backbone, data centers, ...
- \$5 per month → \$60/year → 16.6 years payback for \$1,000
- Expected lifetime of fiber: 20 years
- Carriers want ROIC of 10-12%
- cf. Apple iPhone financial model (2.77 years, \$300 avg. → \$9/month)

	Verizon
ROIC ex-special items and ARILIA, w wireless	16.3%
ROIC ex-special items and ARILIA, w ireline	-0.3%
ROIC ex-special items and ARILIA, consolidated	11.5%

Trade-offs across the world?

- If new deployment, predicted return on investment
 - with unbundling: what is the wholesale price going to be?
 - no magic algorithm --- margin squeeze
- Allow infrastructure owner to provide services?
- Impact on consumer surplus
- US: pole attachment problems
 - if incumbents are pole owners

Long-running arguments

- Who should fund universal service?
 - Old model: interstate communication – now, 27%
 - New model (Congressional bills): general revenue
 - Other models: connection-based, number-based, include BIAS revenue, ...
- Balance between rural (build-out, provider subsidy) and urban (consumer subsidy)?
 - cf. farm bills -- agricultural subsidies vs. SNAP
- Build for today's perceived minimum need or tomorrow?
 - subsidies paid over seven to ten years
 - AT&T 2014: 4 Mbps “Given the pace at which the industry is investing in advanced capabilities, there is no present need to redefine “advanced” capabilities”
- Minimum usable speed or closer to “urban” (cable) speeds?

Affordability

Lifeline

- Established in 1985 by the FCC and mandated by Congress in the Telecommunications Act of 1996
 - used to be mostly local phone, now mostly mobile
- Federal program that lowers the monthly cost of phone and internet for qualified low income consumers
 - Program qualification based on income or participation in a qualifying assistance program (e.g., SNAP, Medicaid, SSI, Public Housing Assistance)
 - Basic support amount is \$9.25 per month and up to \$34.25 for consumers living on Tribal lands
 - e.g., 1,000 minutes of voice, 3 GB of data
- Concerns about fraud
 - unused phones
 - multiple phones in one household
 - phones to ineligible consumers



But Lifeline has reached (mostly) the end of its line

State	July 2020 Subscriber Count	2018 Lifeline Eligible Households Based on ACS Data	Estimated 2020 Lifeline Participation Rate
Alabama	84,707	586,269	14%
Alaska	21,218	63,554	33%
Arizona	171,625	724,439	24%
Arkansas	79,667	390,538	20%
California	1,612,738	3,772,226	43%
Colorado	62,177	490,133	13%
Connecticut	73,640	357,860	21%
Delaware	14,001	99,002	14%
District of Columbia	18,876	87,184	22%
Florida	396,392	2,294,462	17%
Georgia	272,302	1,056,298	26%
Hawaii	7,579	104,985	7%

- one per household – who gets the phone?
- too little data even if tethering enabled
 - 3 hours of Zoom per month
- not all children can get access

Provider-based: Comcast Internet Essentials

internet essentials FROM COMCAST

Affordable Internet at Home for Eligible Households

How to Apply

Low-Cost Computer

Click here to read about how we are responding to the COVID-19 crisis

Bring home affordable high-speed Internet.

\$9.95
Per Month + Tax

25 Mbps
No Term Contract
No Credit Check
In-Home WiFi

Apply Now »

Some school districts give out bulk vouchers

- Fear of bills
- *It's free – must be a scam*
- Not available in 58% of households
- "have not subscribed within 90 days"
- "no overdue bill within 12 months"

see also **NDIA**
NATIONAL DIGITAL INCLUSION ALLIANCE

COVID-19 changed thinking

Pre-COVID-19

- Biggest problem: no broadband in small parts of rural America
- Low income households have Lifeline for basic connectivity
- Need to solve mapping problem first to understand scope of unavailability
- 10-year programs (USF CAF II, RDOF)
- Can always go to the local library or school
- 25/3 is plenty fast

With COVID-19

- Biggest problem: lots of people can't afford broadband
 - and quality of supposedly-covered areas is low
 - no 25/3 broadband in urban areas
 - only 1.5%, but that's 3.9 M people
 - vs. 11.1 M rural
 - "digital redlining"
 - or cannot afford devices
- Students cannot wait 10 years
- Local library (and school) is closed
- Multiple video conferences bust 3 Mb/s upstream

Emergency broadband benefit (2021)

- \$50 discount on broadband access during pandemic
- \$3.2B program → ~64 M “discount months”
- one-time discount of \$100 for a device (e.g., Chromebook)
- eligible:
 - “Qualifies for the [Lifeline](#) program (e.g., about **21 M** households get SNAP)
 - Receives benefits under the free and reduced-price school lunch program or the school breakfast program, including through the USDA Community Eligibility Provision, or did so in the 2019-2020 school year;
 - Received a Federal Pell Grant during the current award year;
 - Experienced a substantial loss of income since February 29, 2020 and the household had a total income in 2020 below \$99,000 for single filers and \$198,000 for joint filers; or
 - Meets the eligibility criteria for a participating providers' existing low-income or COVID-19 program.”

Conclusion

- Availability, affordability & relevance
- Except for large cable companies, challenging economics for ISPs
- Introducing competitive fiber speeds is difficult everywhere
- Who should subsidize high-cost and low-income areas? Taxes or fees?
- Emphasis on automation (+ staff cuts) and simplified service structure
 - not new services, protocols, speeds
- Research directions:
 - fully autonomous, self-configuring networks

And in closing

- Technology now plays a central role in key policy debates
- Hot topics: privacy, algorithmic fairness, broadband access, IT modernization, autonomous/electric vehicles
- Congress is not well engineered to get things done in a time of polarization and divided government
 - US has an unusually high number of veto points
- But computer science has significant roles to play:
 - build, design and advise on better IT infrastructure
 - advise decision makers – both in Congress and in federal agencies
 - consider internships for students
- More likely as part of an organization than as an individual