Technological Developments in Broadband Networking

Evolution of Broadband Networking: 2008 to 2018

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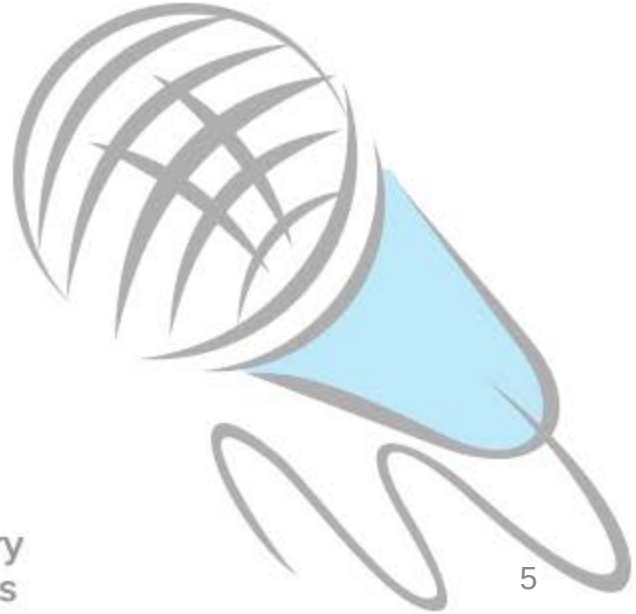
Data Analysis



Outline

- Technology primer: traffic, topology, transit
- Evolution: platforms, interconnection, complexity
- Implications: competition, potential harms
- Technology attempts to measure/mitigate potential harms
- What's different this decade?

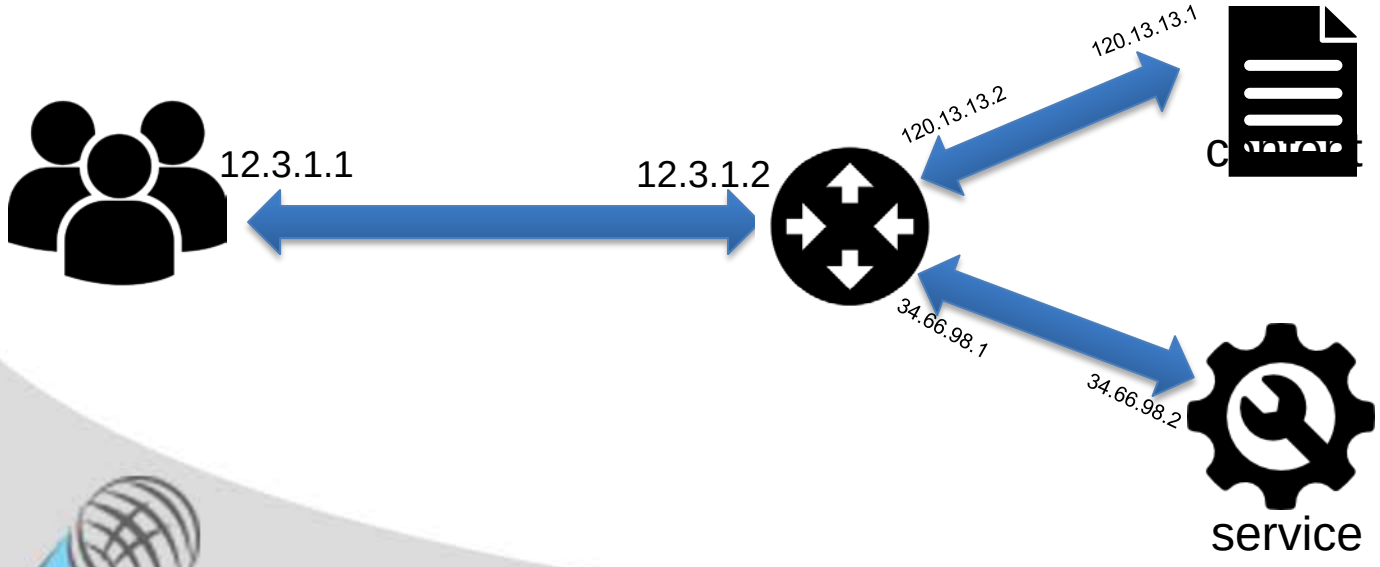
Aim to address this question

- Which (recent and expected) technological developments, or lack thereof, are important for understanding the competitiveness of the industry or impacts on the public interest?

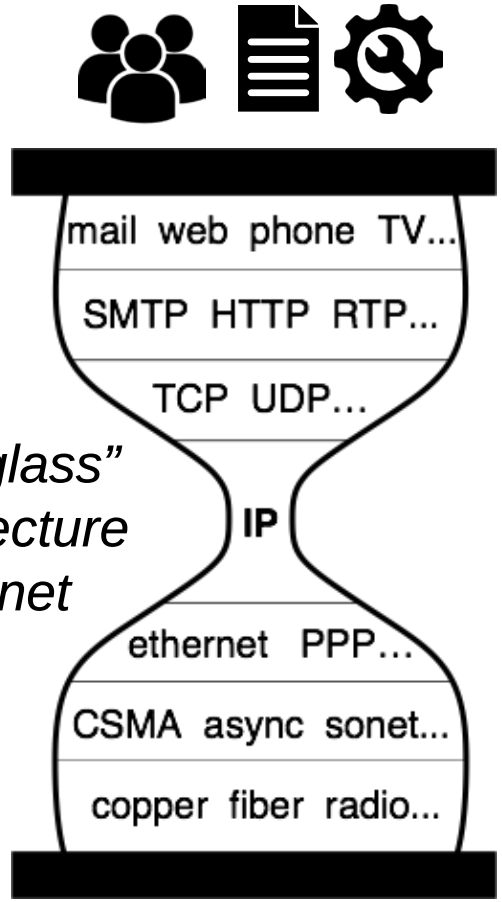
Global public IP platform

Traffic routed across global Internet platform, i.e., devices reachable via an IP address.

Anyone (two) can interconnect!

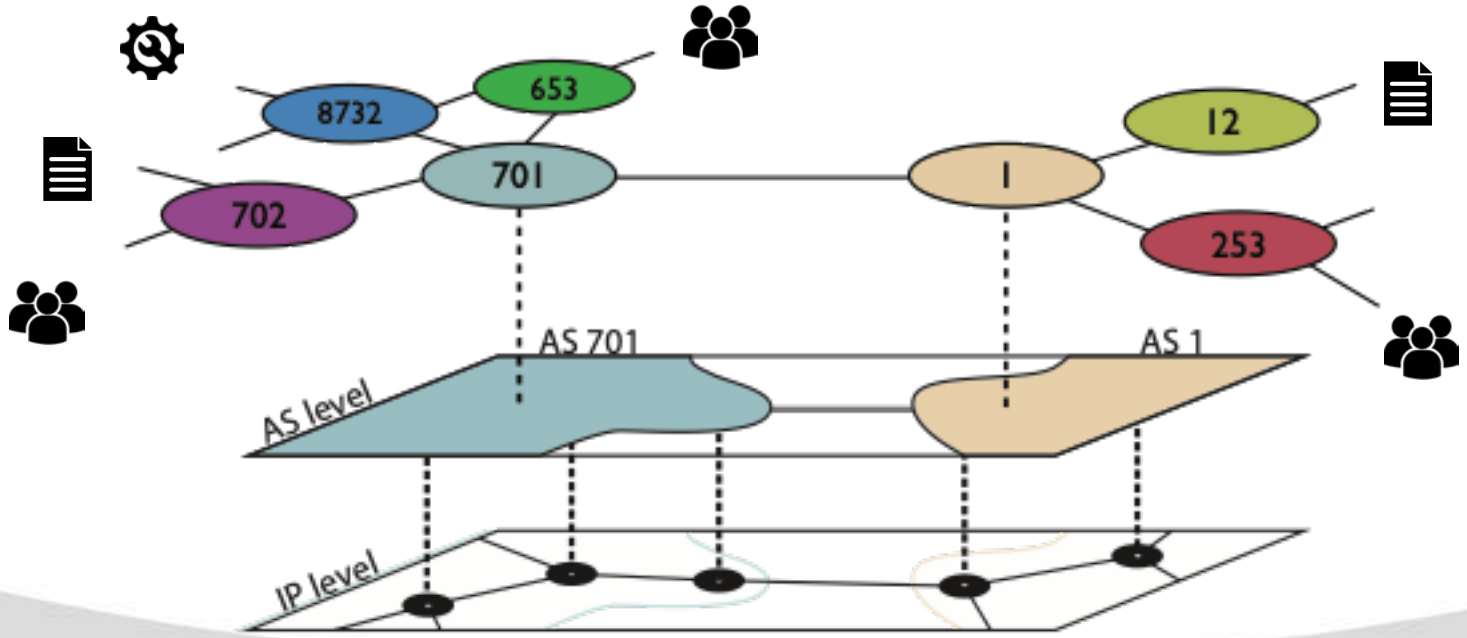


Layered "hourglass" protocol architecture of TCP/IP Internet



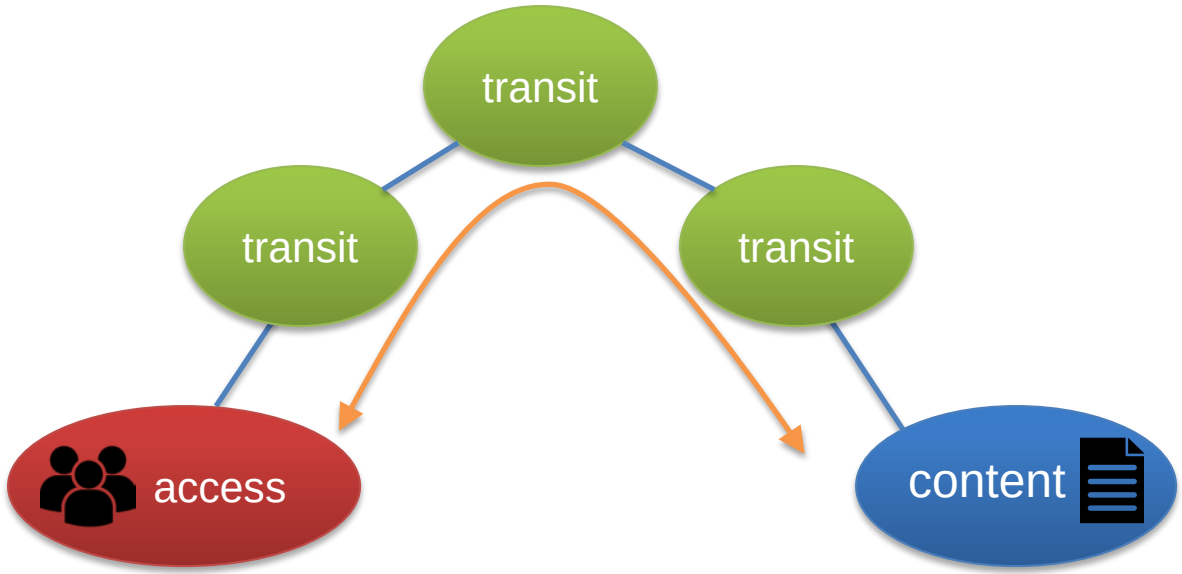
Internet interconnection

- IP addresses grouped (on routers and) into networks
- Organized by Autonomous Systems (ASes)
- 70K+ ASes independently interconnect to form global Internet



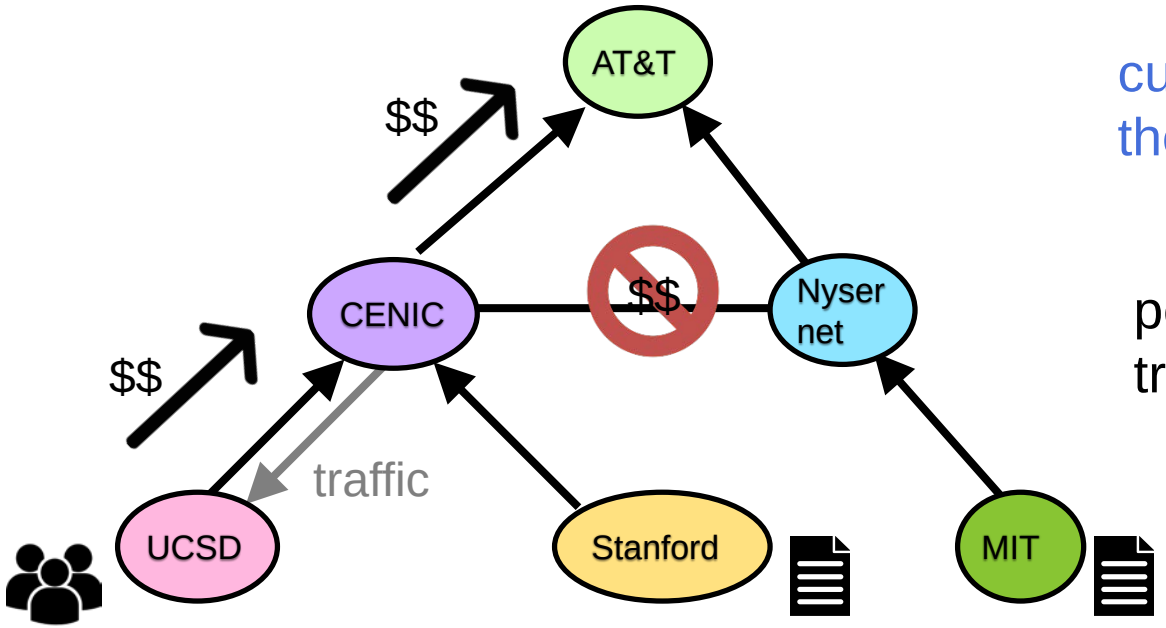
Internet transport (simplified)

Traffic flows through **transit providers** between **access** and **content** providers



Early (90s) AS interconnection hierarchy

One can conceptualize interconnection structure based on (inferred) money flows.



customer —$$ →— **provider**

customer pays provider to transit their traffic

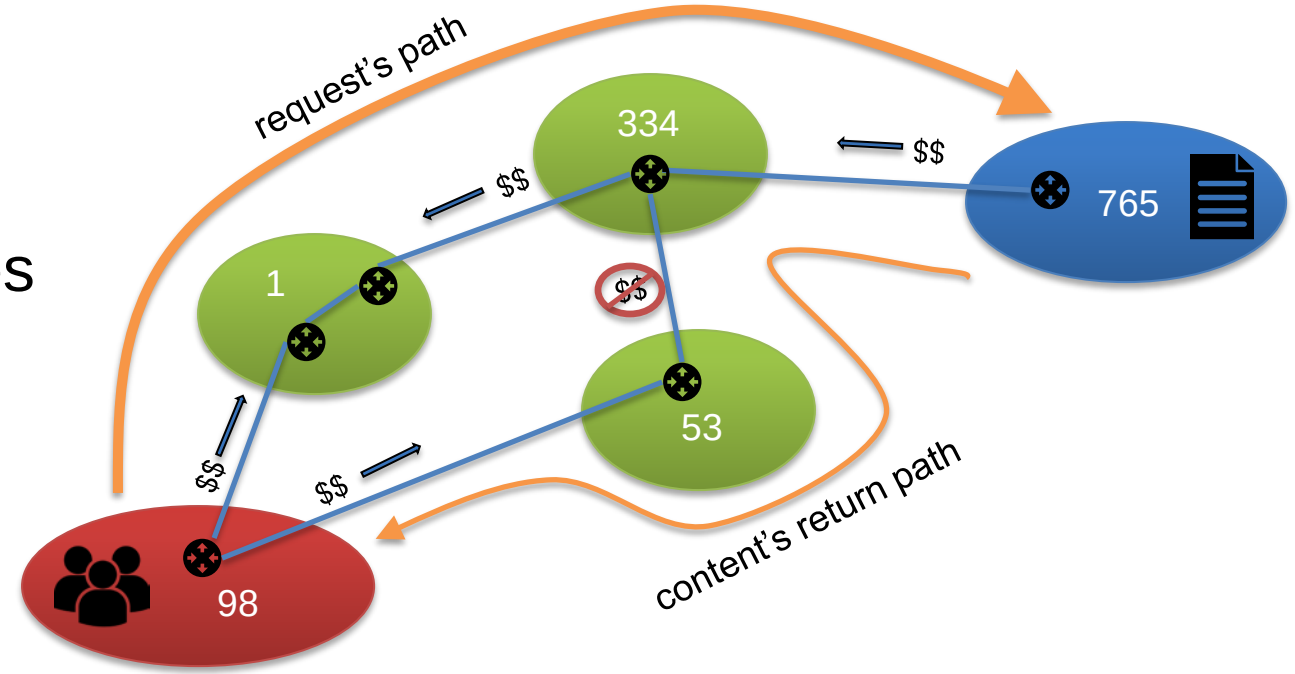
peer — $$ — **peer**

peers do not pay to accept each other's traffic (assumed symmetric traffic flow)

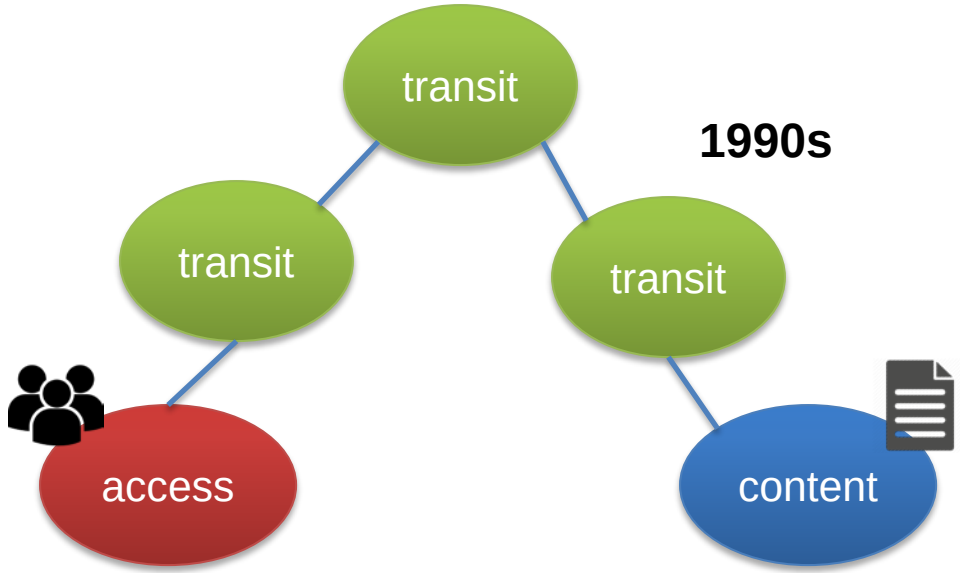
IX(P): neutral facility for traffic exchange (was "point")

Internet routing (simplified)

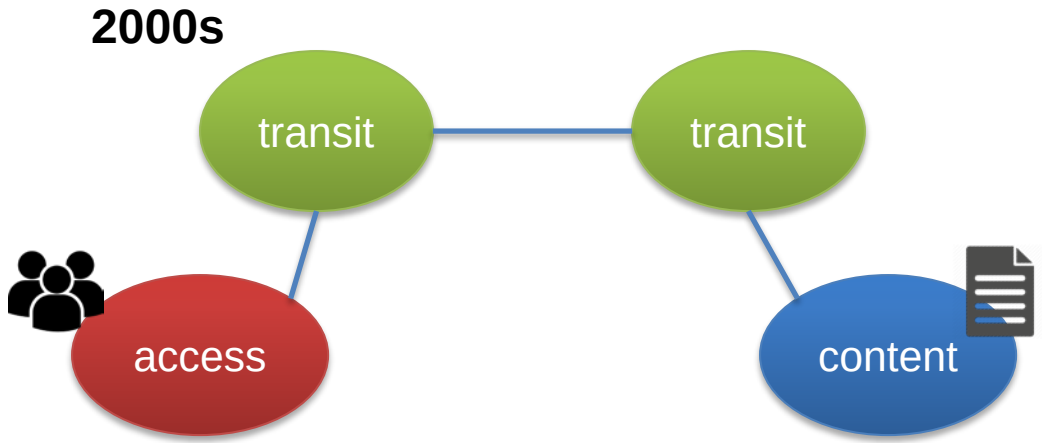
- Each router **locally optimizes** choice of next hop along path
- Applies network operator's routing policy to known topology; computes & propagates best paths
- Network operators balance: cost, performance, path length
- Often results in asymmetric routes
- Many edge networks (blue) only have *default route,* to transit provider



2010s: Content moves closer to consumer

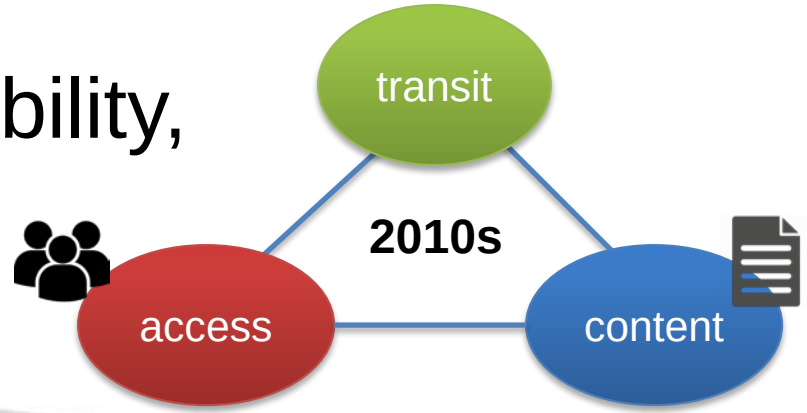


1990s



2000s

Optimizes performance, reliability, availability cost

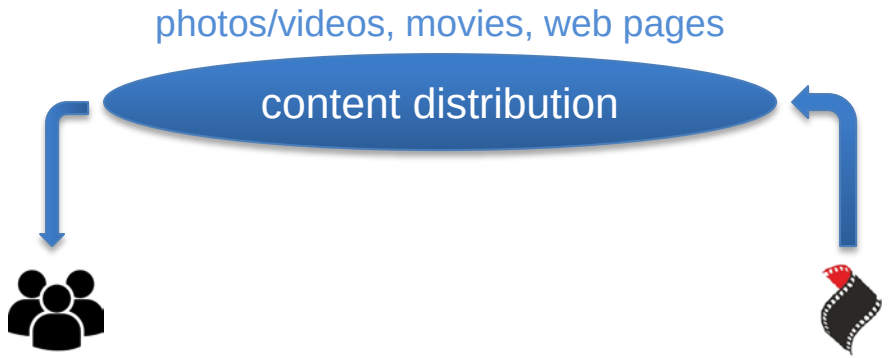


2010s

In face of relentless growth in demand (mostly video)

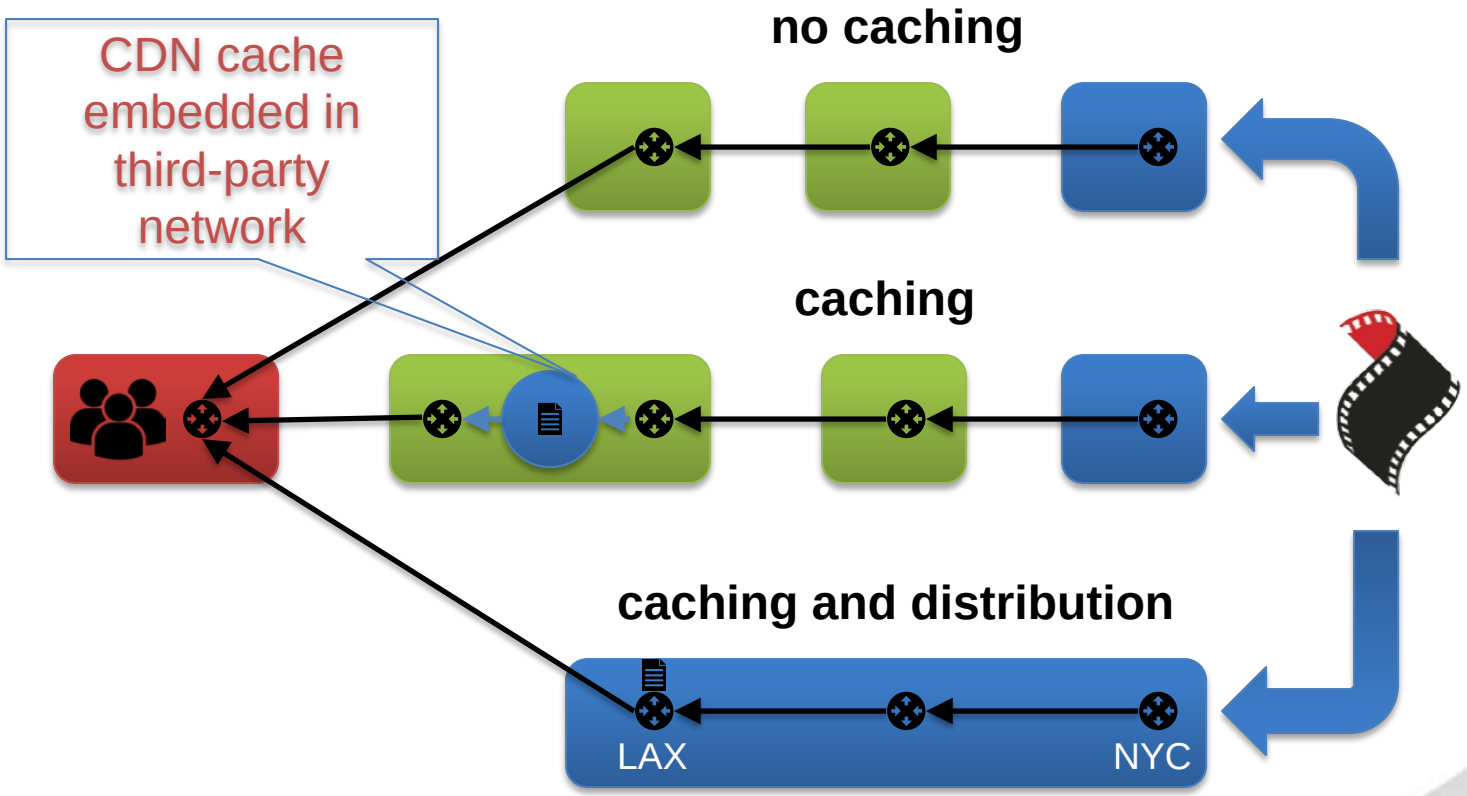
Consolidation in content distribution

- While there continue to be small local content providers (UCSD), most traffic now handled by a few giant content providers (Google) or content distribution networks (Akamai)
- CDN business: transiting traffic from point where it enters CDN platform to an exit near consumer. At low cost.
- Key driver: Internet eating TV, gaming

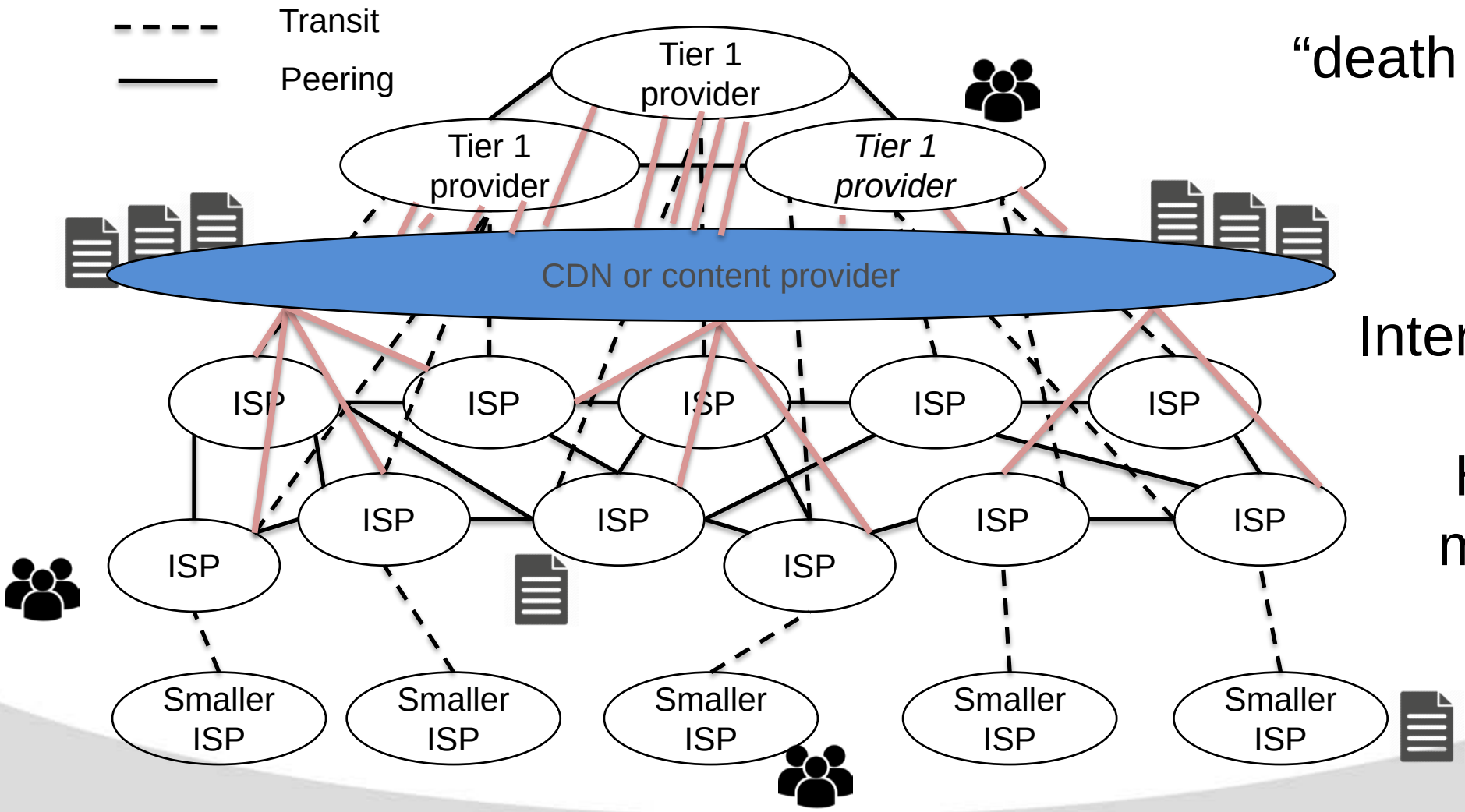


Content distribution strategies

Large companies may combine all three strategies.



Does not reduce complexity..

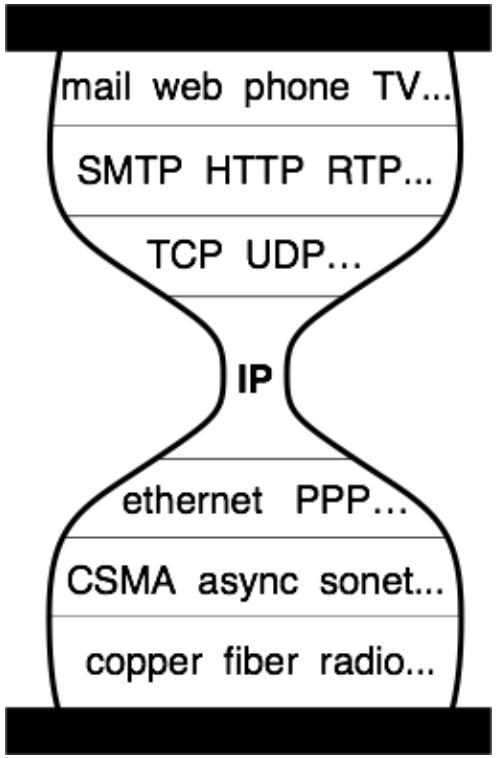


"death of transit"?

Dense Interconnection

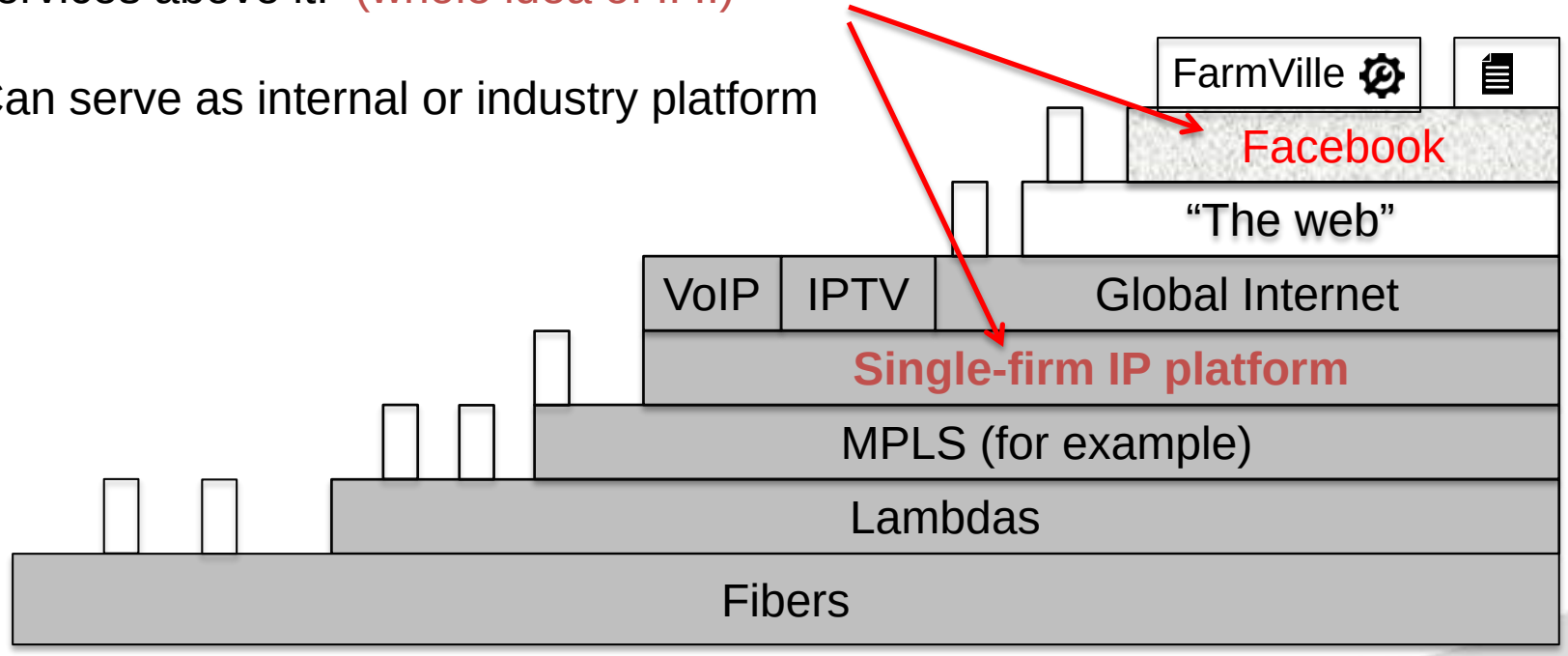
Hard to measure

Internet platform layers



Allows the integration of multiple technologies below the platform and support of multiple services above it. (whole idea of IP..)

Can serve as internal or industry platform

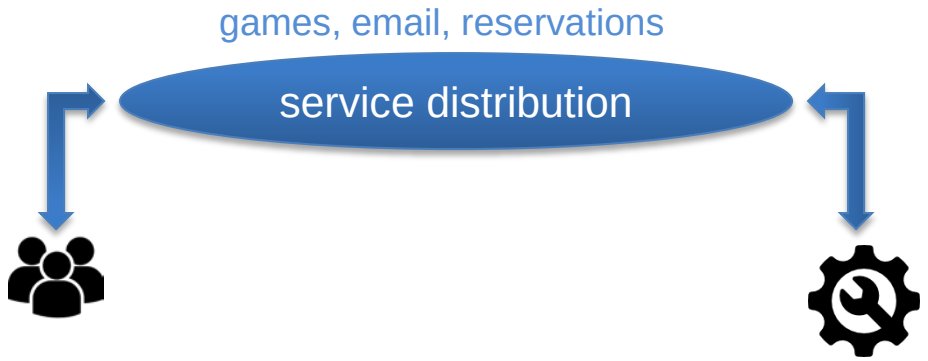


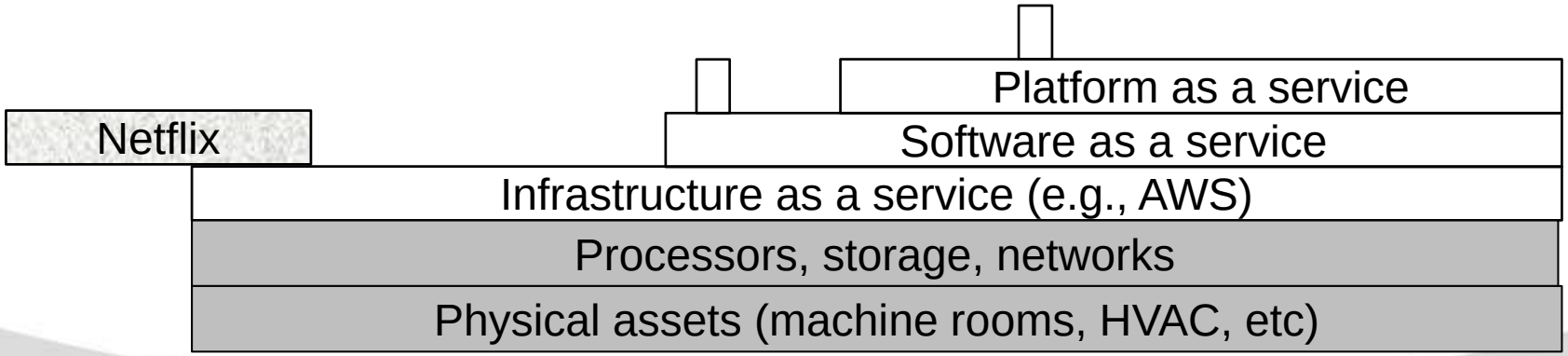
Dueling definitions

- **Online platform**: An online marketplace that places one party in touch with another, such as buyers and sellers. E.g., eBay, Craigslist, Amaz Mktplce, Airbnb, app store
  - Emphasis—multisided
- **Online platform**: a group of technologies that are used as a base upon which other apps or technologies are developed. E.g., IP, IoS, Android, AWS
  - Emphasis—programmable, service component, generality

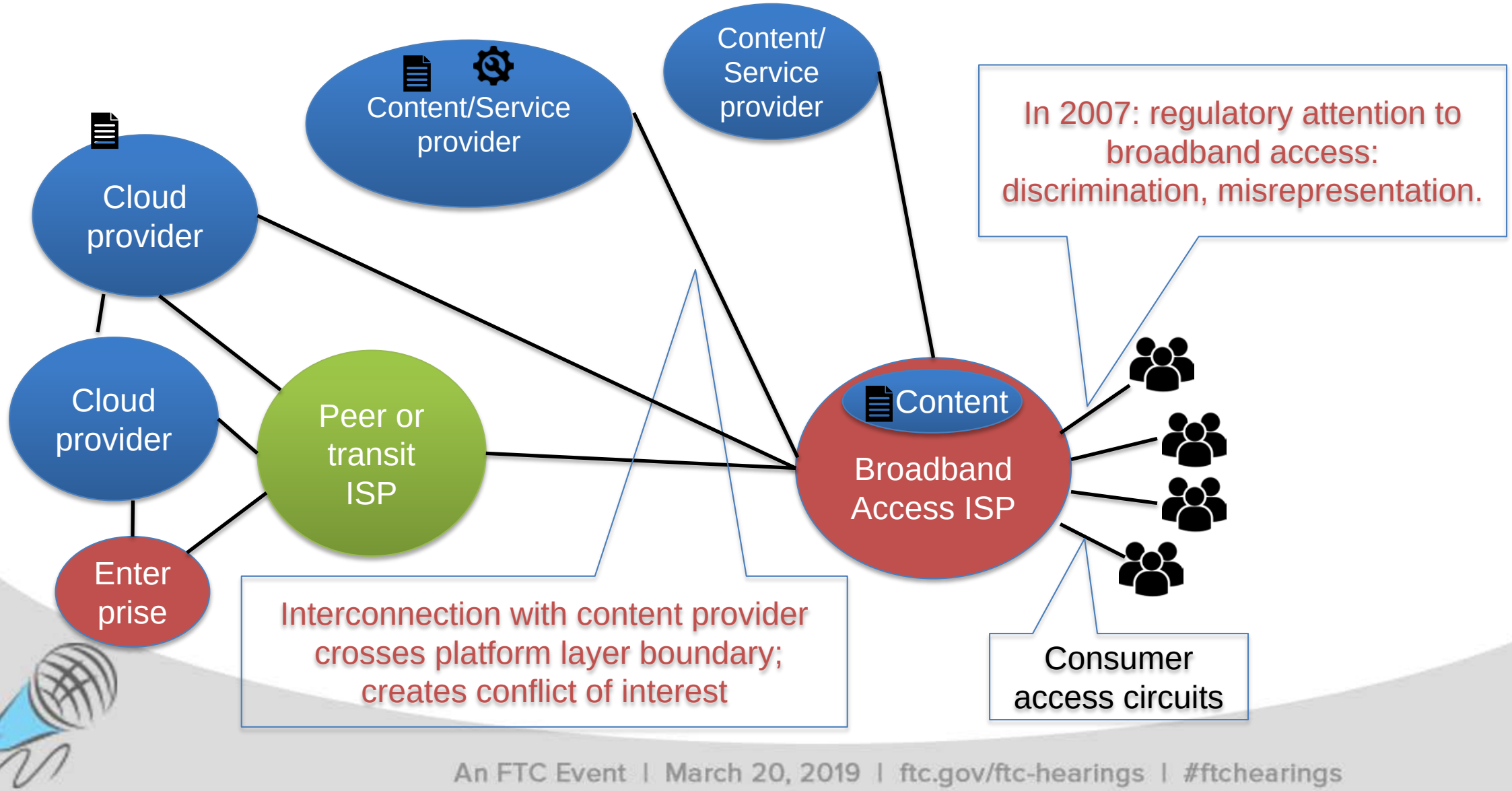
Growing: Cloud Service Platforms

- Externalizing internal industry platform
- New platform layer through which to distribute content and services
- Provide service replication and distribution
- Many web applications/services now first built upon “Internet giants’” cloud service platforms





Interconnection *across* platform layers



Implications of cross-platform-layer interconnection dynamics for competition

Smaller ISPs have less opportunity to interconnect with BigContent

→ Must access content providers via exchange points (85%)
→ Less likely to vertically integrate themselves
→ Cannot leverage transit and content cost savings
  → Particularly hard in rural areas, with 10-40X buildout cost
→ Cannot give customers a better experience in accessing content

Like with video programming…

American Cable Association (smaller ISPs) survey:
https://www.ftc.gov/system/files/documents/public_comments/2018/08/ftc-2018-0049-d-1623-155196.pdf

Potential Interconnection Harms

- Carrier and third-party services on top of single-firm IP platform can compete with third-party services running over “common” Internet.
- Interconnection points enable exercise of market power
  - Technical discrimination of traffic across the link.
    - Selective dropping or rate limiting
  - Inadequate capacity leading to impaired QoE
  - Discriminatory pricing or business terms (more likely?..)

These are not new concerns

"*Principally, … concern about the following issues:*

- ***blockage, degradation, and discrimination of content/apps***
- *vertical integration*
- *effects on innovation at edges*
- *lack of "last-mile" access competition*
- *legal and regulatory uncertainty*
- *diminution of political and other expression on the Internet"*

Broadband Connectivity Competition Policy, FTC Staff Report, 2007, p.5.
https://www.ftc.gov/sites/default/files/documents/reports/broadband-connectivity-competition-policy/v070000report.pd

See also: http://www.cybertelecom.org/notes/cc_history.htm

Technology Approach Tried in 2015

- Measure the key characteristics of interconnection links.
  - Or mandate the reporting of those parameters
  - FCC used this approach in ATT/DirecTV merger
  - Outsourced to “Independent Measurement Expert”
- That approach begs many questions:
  - Is measuring individual links actually the right approach?
  - How does one measure the key characteristics of a link?
  - How well does that map to consumer harm?
  - Note: no agreed methods to measure QoE!

These are “Complex Empirical Questions”

“The balance between competing incentives on the part of *broadband providers* to engage in, and the potential benefits and harms from, discrimination and differentiation in the *broadband* area raise complex empirical questions and may call for substantial additional study of the market generally, of local markets, or of particular transactions. Again, further evidence of particular conduct would be useful for assessing both the likelihood and severity of any potential harm from such conduct.”

FTC’s “Broadband Connectivity Compeition Policy”,2007
https://www.ftc.gov/sites/default/files/documents/reports/broadband-connectivity-competition-policy

Technology to detect harmful discrimination

- Not clear what FCC learned from AT&T reporting exercise
- Several other approaches to interconnection measurement
  - Each provides a part of a very complex picture
  - Need objective perspective to integrate and cross-validate
- No silver measurement bullet
- Limited ability for academics to sustain this kind of work
  - And yet much of it is research

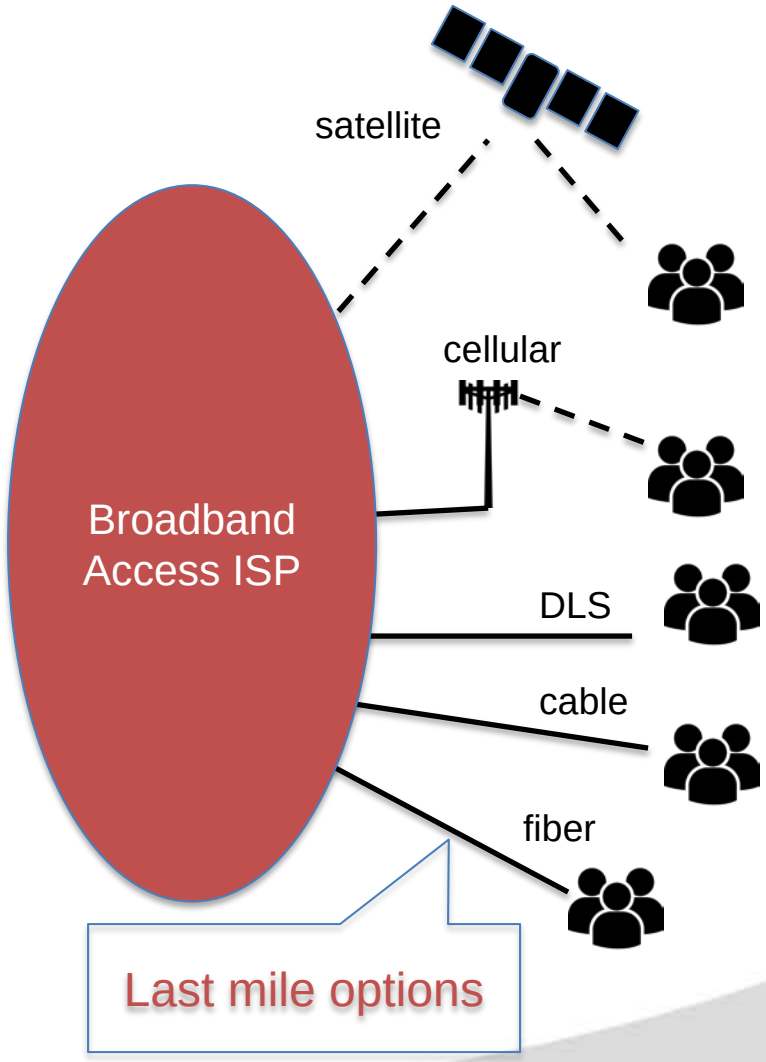
[Feb 27 11:31:03 2019] Shutting down Netalyzr

"After nearly a decade of providing this service we have decided to shut down Netalyzr in the first week of March 2019…. We simply no longer have the resources to advance Netalyzr or to provide reasonable support for your many questions about connectivity problems.

What FCC is measuring: access bandwidth

(4K video= 15-25 Mbps/sec)

	Downstream bandwidth
Satellite	12-25Mbps
DSL	3-45Mbps
Cable	100-200Mbps
Fiber	100-100Mbps (sym, stable)



Limitations:
Rural regions not well sampled (see recent Microsoft data)
Does not measure interconnection performance
Does not capture many things consumers care about
performance to top 10 sites, privacy, data caps
Does not measure mobile (mobile data released 2019, no analysis/report)

FCC MBA program, "*8th Measuring Broadband America Fixed Broadband Report*" (2017 data, 10K homes)

Since 2007, same concerns have expanded

- To multiple platform layers
  - Gathering & analyzing evidence difficult. Validating harder.
  - Complex sector. And complexity increasing.
  - More at stake ➡ more at risk

Concerns from 2007 FTC broadband report

blockage, degradation, and discrimination of content/apps
vertical integration
effects on innovation at edges
lack of "last-mile" access competition
legal and regulatory uncertainty
diminution of political and other expression on the Internet

Why so complex?

- Market, technology, legal, political, cultural, social forces interact in co-evolving adaptive systems
- Topology & traffic shifts not primarily driven by technology
- But if we do not understand the role, capabilities, and limitations of technology to *create* and *solve* problems, attempted interventions are likely to fail

Evidence-based policy needs to understand:

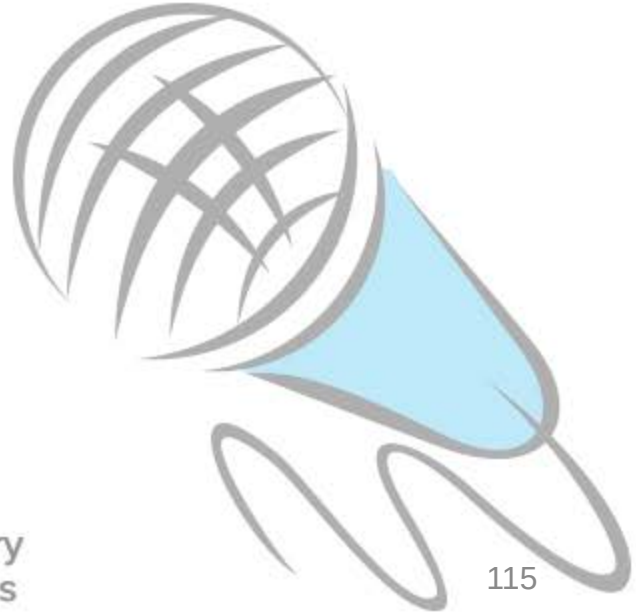
- Internet operates as set of layered, multi-sided, platforms, interconnecting **across** layers, e.g., content to transit
- Platform structure and dynamics, including market sides and incentives
- How to achieve relevant transparency and public accountability related to specific potential harms
- How to find/fund sources of objective, unbiased expertise

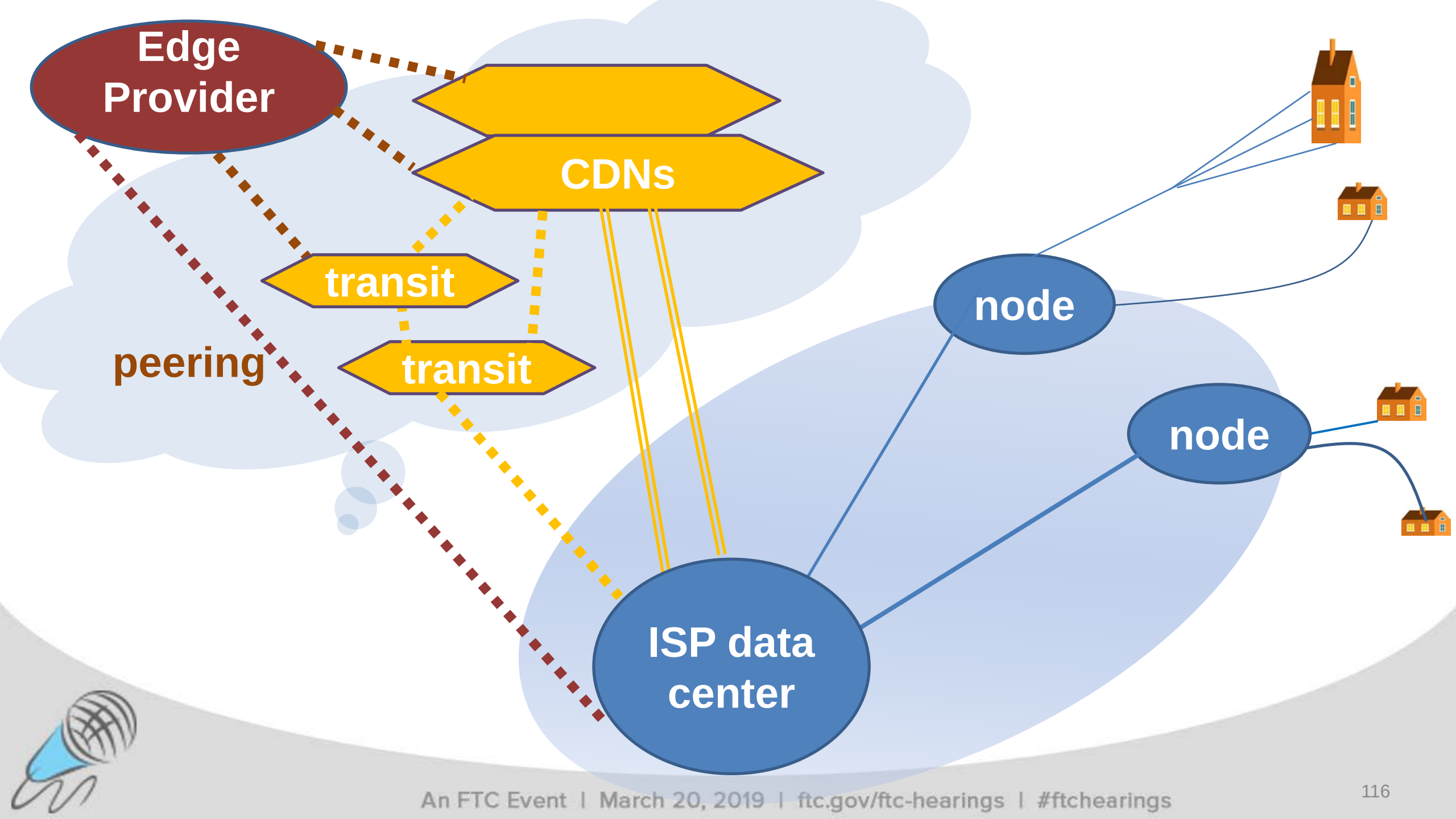
Evolving Markets and Technological Developments: Market Structure

Panel Discussion:

Matthew A. Brill, Thomas A. Whitaker,
Tithi Chattopadhyay, John Bergmayer,
kc claffy

Moderator: Ruth Yodaiken




Edge Provider
CDNs
transit
transit
peering
node
node
ISP data center

Thank You

Hearing #11: March 25-26

The FTC's Role in a Changing World

Federal Trade Commission, Headquarters

Hearing #12: March 25

Roundtable with

State Attorneys General

Federal Trade Commission, Constitution Center