Interconnection and its Discontents

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Internet is a Network of Networks

- Internet consists of over 66,000 *autonomous* networks*
  - Each network is connected to one or more "neighboring" networks
  - Information may pass through many autonomous networks en route from sender to recipient
- Challenges:
  - How does a network know which of its neighbors can move info towards the intended recipient?
    - A path to destination must exist, and all networks on that path must be willing to carry this traffic
  - Why should a network in the middle carry this traffic?

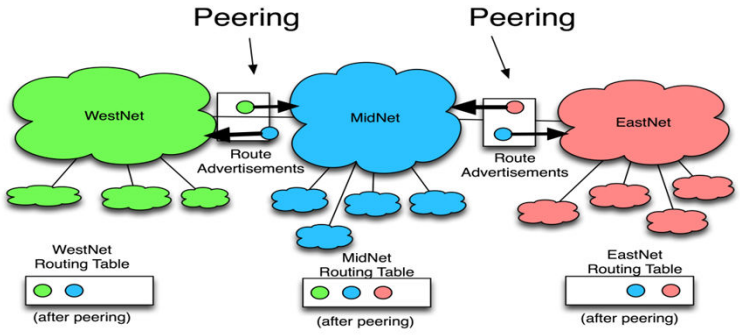
 *Based on data from Regional Internet Registries as of May 1, 2014

Interconnection Agreements

- Where two networks agree on technical and business issues of exchanging Internet traffic
  - Internet traffic, not telephone
  - Unregulated
  - Highly confidential
- Two basic types
  - *Peering*: arrangement whereby networks reciprocally provide connectivity to each others' customers
  - *Transit*: arrangement whereby one network provides (sells) access to all networks on the Internet
    - or a subset of those networks

Peering

Networks reciprocally provide connectivity to each others' customers

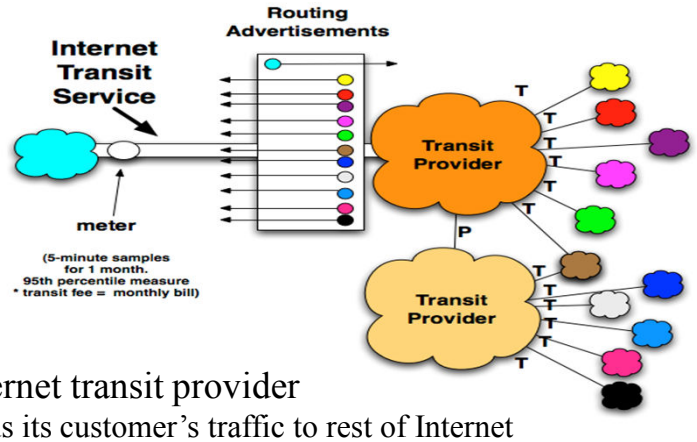


- Peering is not transitive.
- Business arrangements vary
  - Peering can be settlement free (unpaid)
  - Peering can involve settlements (paid peering)

Figure from W. B. Norton, "Internet Service Providers and Peering"

Transit

One net provides access to rest of the Internet

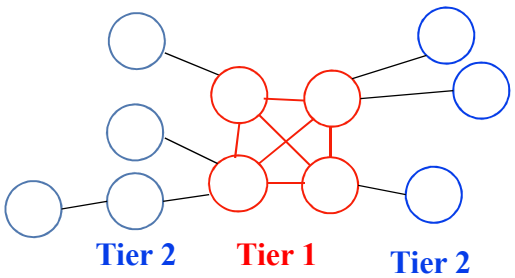


- An Internet transit provider
  - Sends its customer's traffic to rest of Internet
  - Advertises to rest of Internet that it can reach customer
- Business arrangement: Usually metered pricing
  - Based on traffic sent and traffic received.

Figure from W. B. Norton, "Internet Service Providers and Peering"

First Among Equals

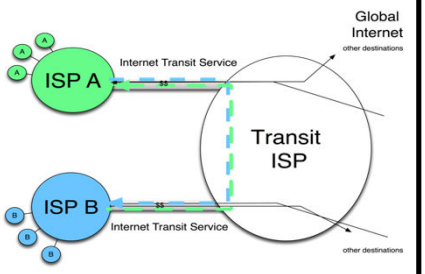
- A network is *Tier 1* if it can send traffic to the entire Internet without paying peering or transit fees
  - Tier 1 nets charge other nets for transit to rest of Internet
  - Tier 1 nets compete to provide this service to tier 2 nets
  - Tier 1 nets peer with each other, settlement-free

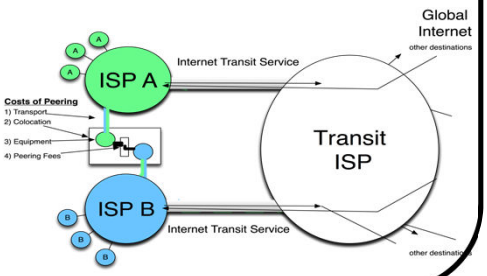


Traditional Internet hierarchy

More Peering, Bypassing Tier 1

- If Tier 2 networks peer
  - Both networks save cost of transit fee to Tier 1 network
  - Must pay cost of peering point
- Peering saves money if
  - Total cost of peering < total cost of transit





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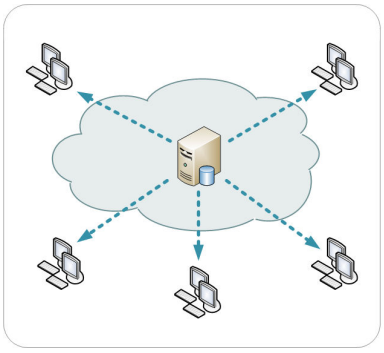
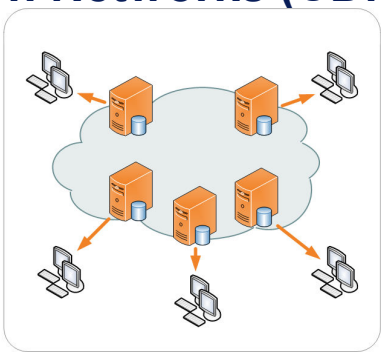
Figures from W. B. Norton, "A Business Case for Peering"

Content Distribution Networks (CDN)





- A collection of geographically-distributed servers on which copies of content can be stored
  - Content is stored closer to end user
- Commercial companies operate CDNs, host content
- A commercial CDN may operate its own network

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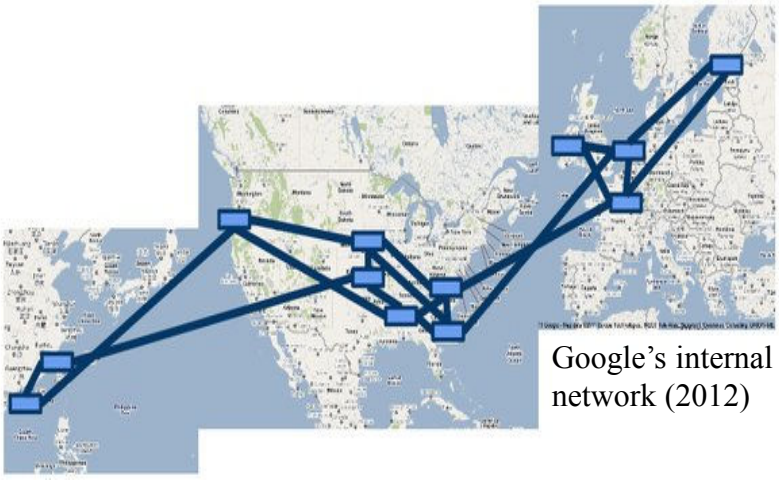
Figure from Wikipedia, "Content Distribution Networks"

Some Content Providers Build Their Own Networks



Google's internal network (2012)

If Google were an ISP, it would be one of the world's largest

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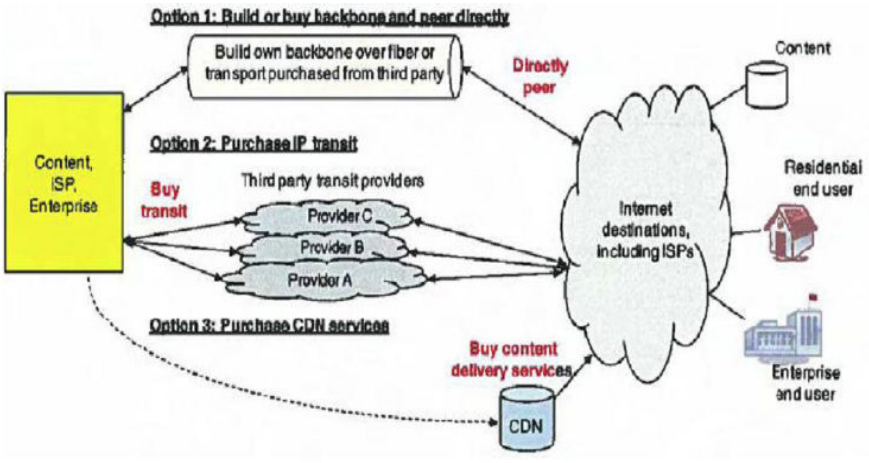
Figure from Q. Hardy, "Google Opens Up About Its Network," New York Times, 4/18/2012

Options for Content Provider



Source: Level 3 declaration in FCC docket IB 11-78

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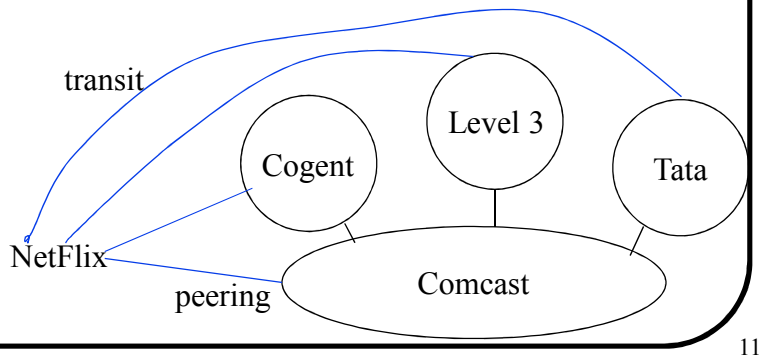
Figure from Level 3 filing to FCC

Comcast and NetFlix?

Caveat: most info is from unreliable sources

- NetFlix served Comcast customers via transit networks, such as Cogent, Level 3
- NetFlix, Cogent complain of congestion via transit
- So NetFlix peers directly with Comcast, and pays



Impact of Direct Peering

- The ***wrong*** debate:
  If a content-heavy net peers with an access provider:
  - this inevitably generates traffic that is a burden on the access provider, so the content-heavy network should pay this cost

    or
  - this inevitably generates traffic that benefits both networks, so interconnection should be settlement free
- *If* there are any differences in traffic carried with/without peering
  - Because one path is more congested, *and* some applications or users adapt to congestion
- To understand this peering agreement, we must understand the context, including congestion

Summary

- Interconnection agreements are an essential component of a large decentralized network of networks
- Interconnection takes many forms
  - Peering and transit
  - Paid and unpaid
  - Result of private unregulated negotiations among parties
- Interconnection agreements have been changing
  - New roles for CDNs, content provider networks
  - More peering relationships
  - Changing financial terms

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