How the Net Works

A Brief History of Internet Interconnection

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Virtuous Circle

- Internet is always changing. Dynamism is one of its chief virtues.

- Advances in bandwidth, digital storage, and computation drive new forms of content and alter traffic patterns.

- New content likewise places new demands on networks, data centers, and end devices.

- Adaptability has led to historically successful economic and cultural platform.

- U.S. Internet is healthy — far more Internet traffic per capita and per user than any nation except South Korea

Traffic Patterns

- CDNs now deliver more than half of Internet traffic
- Google (w YouTube) up to 25% of U.S. Internet traffic, up from 6-7% in 2010
- Netflix up to 33% of evening broadband traffic
- HBO, ESPN, MLB moving to Web in big way
- Twitch.tv video game channels now 4th largest bandwidth consumer
- Hyper Giants build own networks and data centers and connect directly to broadband service providers

Interconnection Terms

- **Tier 1 ISP** — a large continental or global network that, through its own infrastructure and its peering relationships, can reach any point on the Internet. It generally does not pay others for transit.

- **Tier 2 ISP** — a network, often regional in nature, that connects broadband service providers, content providers and websites, and enterprises to larger Tier 1 networks. These entities pay Tier 2 networks, who pay Tier 1 networks for transit to the rest of the Internet.

- **Content Delivery Network (CDN)** — a network of computers and "caches" that stores data, webpages, and videos close to end users and optimizes routes across the Internet, both logically and geographically. Content providers and websites pay CDNs to speed their content to end users. Some large providers like Google have their own CDNs. CDNs pay broadband providers for direct connectivity.

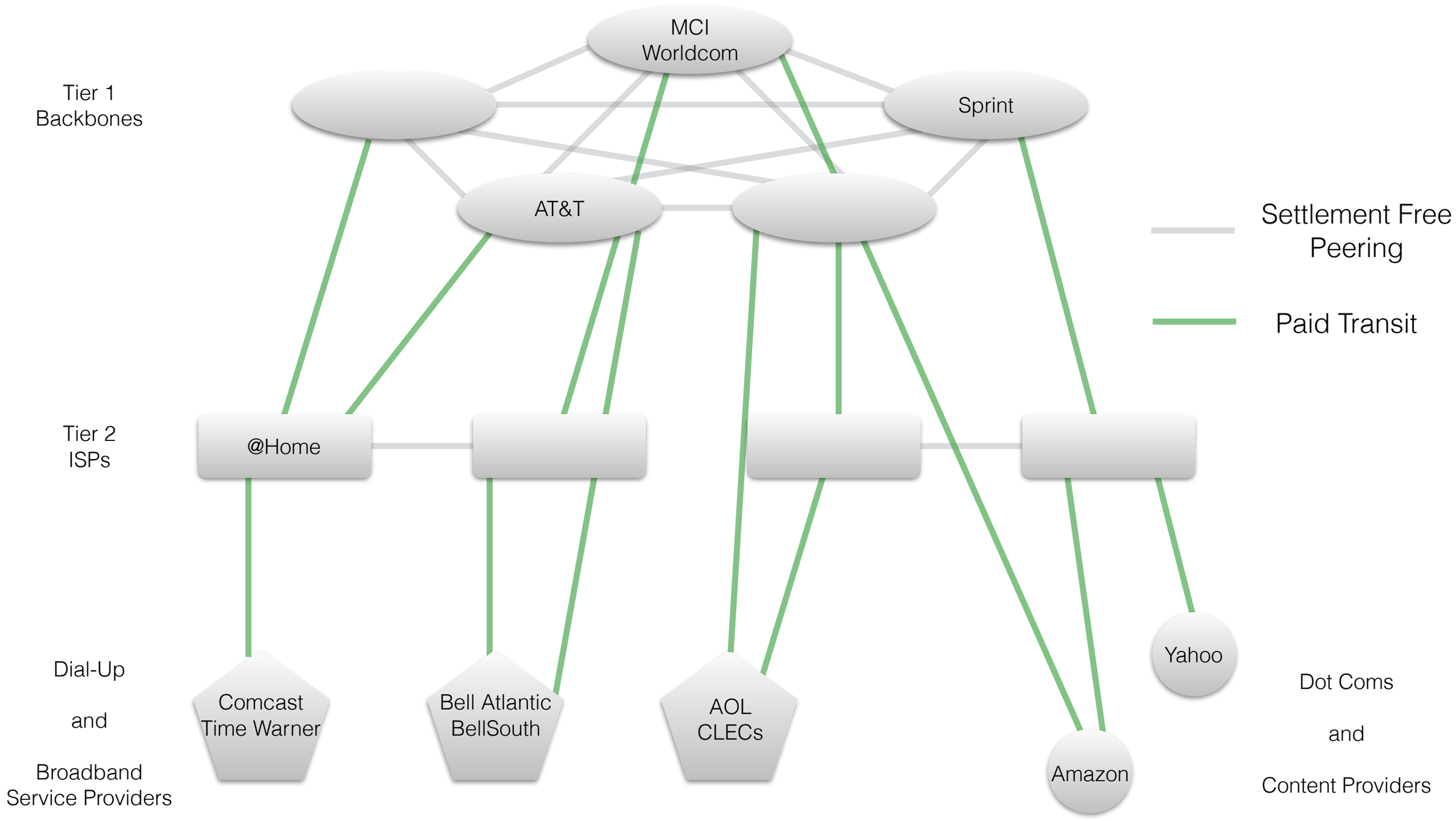
- **Transit** — a network access service in which, most often, a smaller entity or network pays a larger network for access to that network and the wider Internet. Consumers pay their broadband service provider for "transit" to the Internet. Broadband service providers, Tier 2 ISPs, content providers, and website hosts pay for "transit" to the Internet.

- **On-Net Transit** — a network access service that provides connectivity to all points within a network but not across the entire Internet.

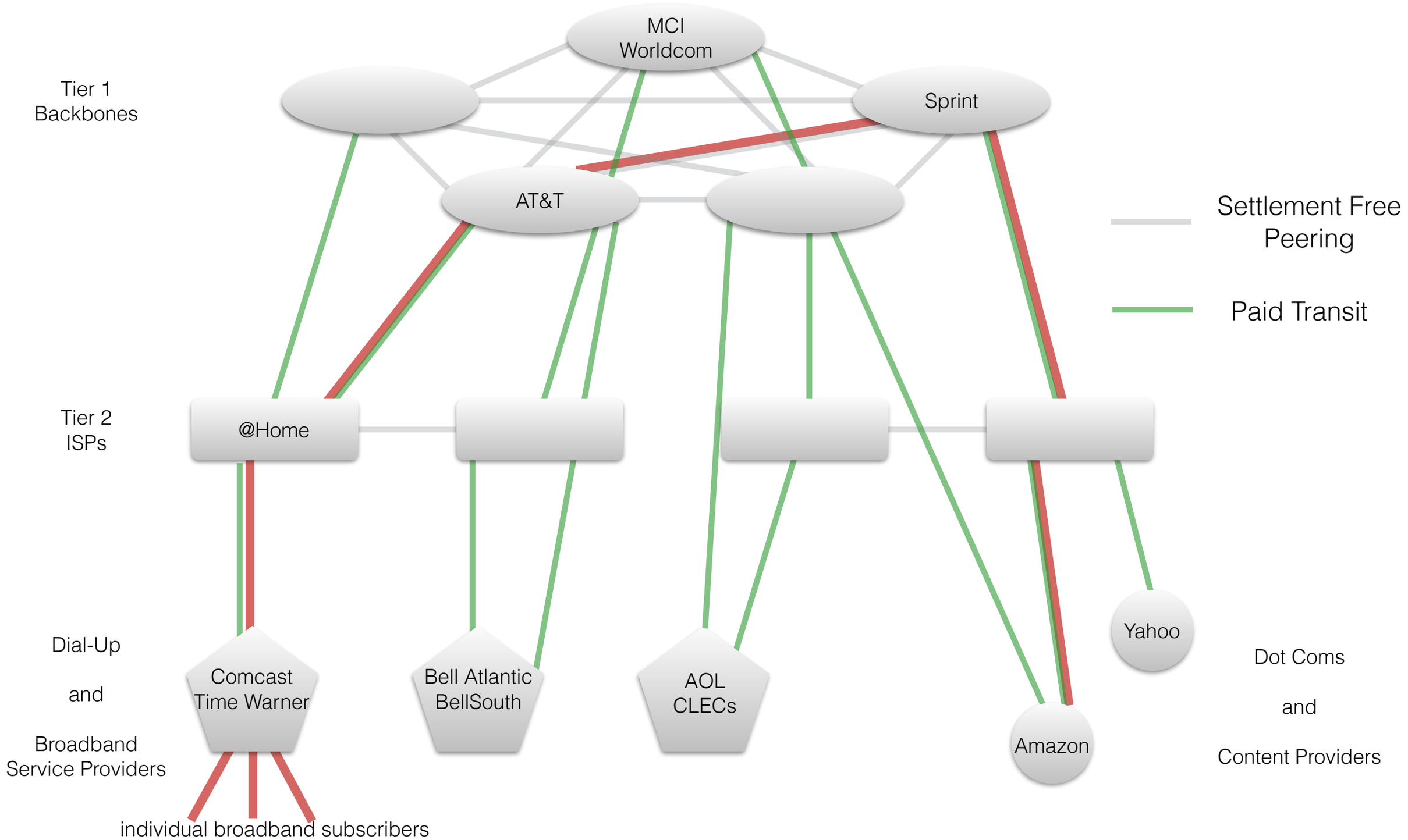
- **Settlement-free Peering** — an interconnection agreement in which two networks trade traffic with one another at no charge.

- **Paid Peering** — an interconnection agreement in which networks trade traffic with one another but, because the traffic is "asymmetric" (one network is carrying far more data than the other, incurring higher costs) or the networks do not otherwise offer the other similar value, the party offering less value pays the other a fee to make up the disparity.

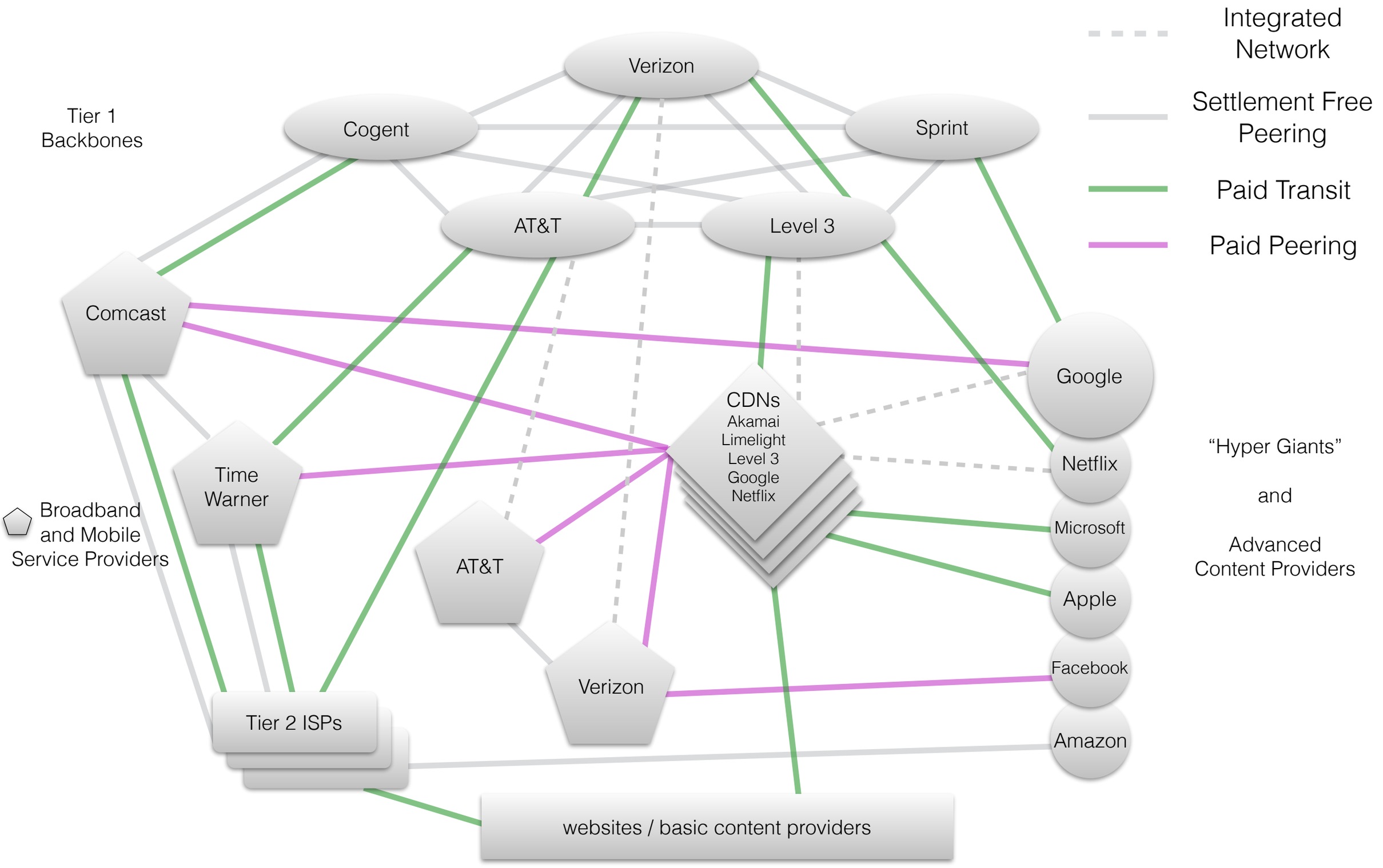
Interconnection — 1998



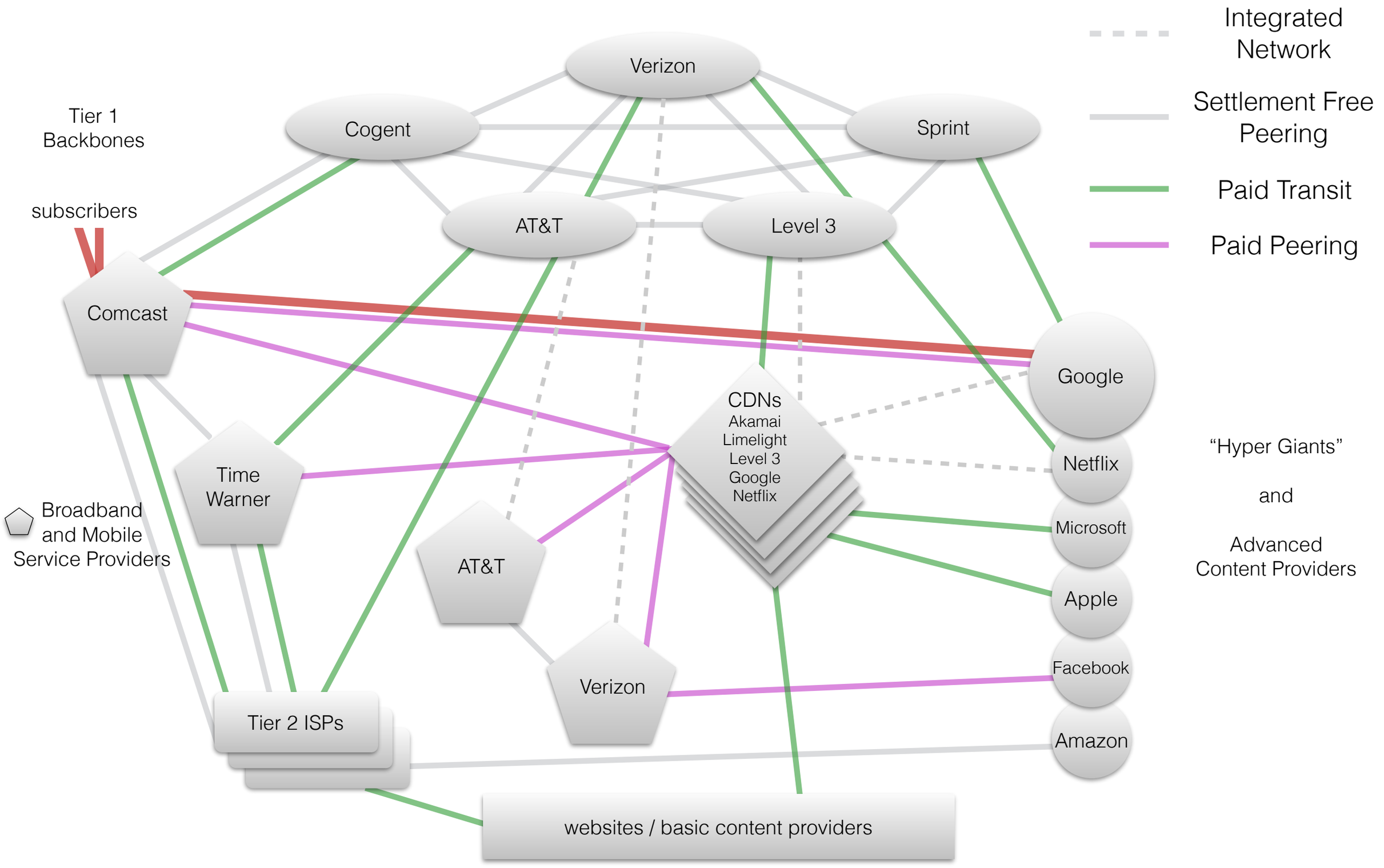
Typical Route — 1998



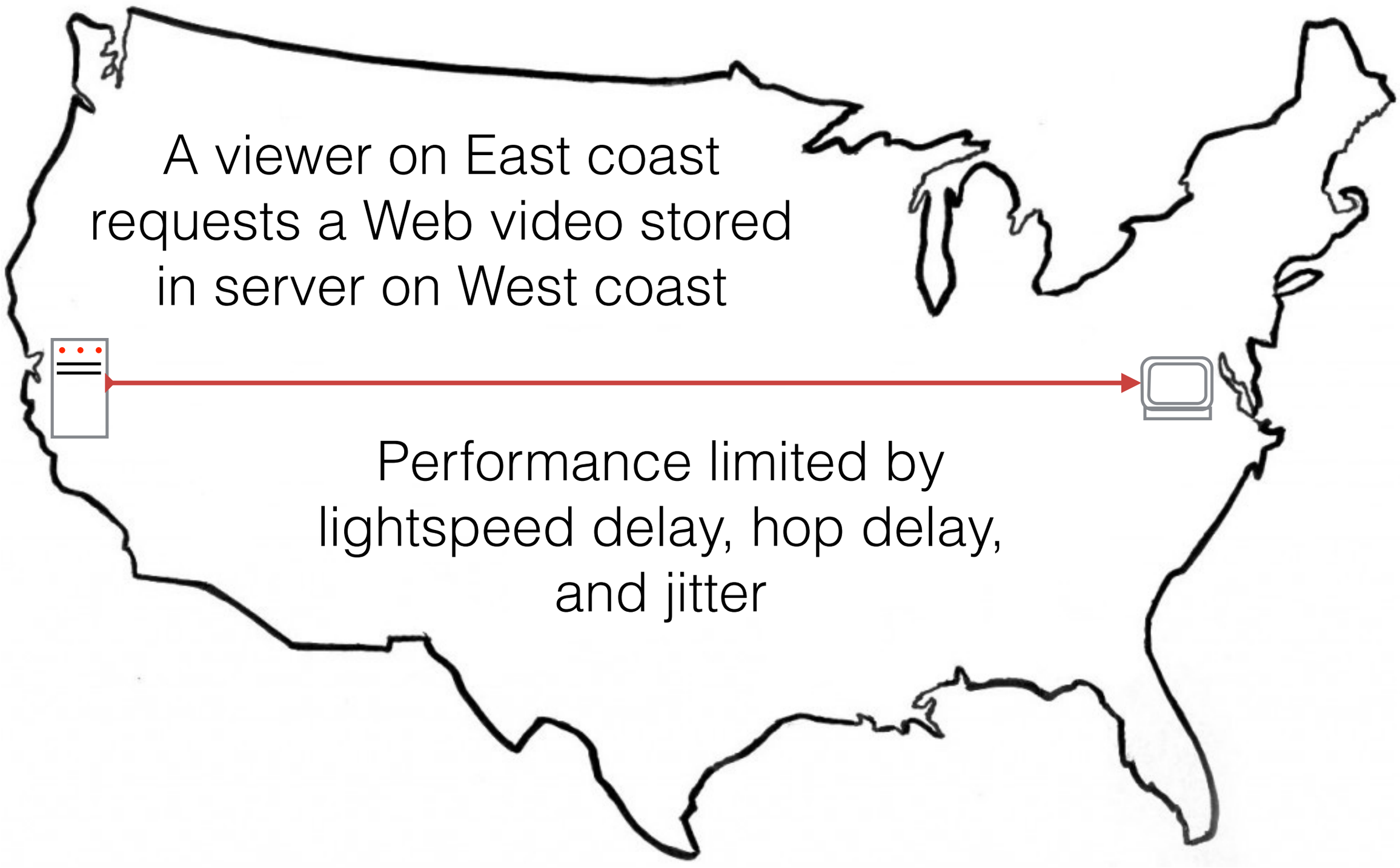
Interconnection — 2014



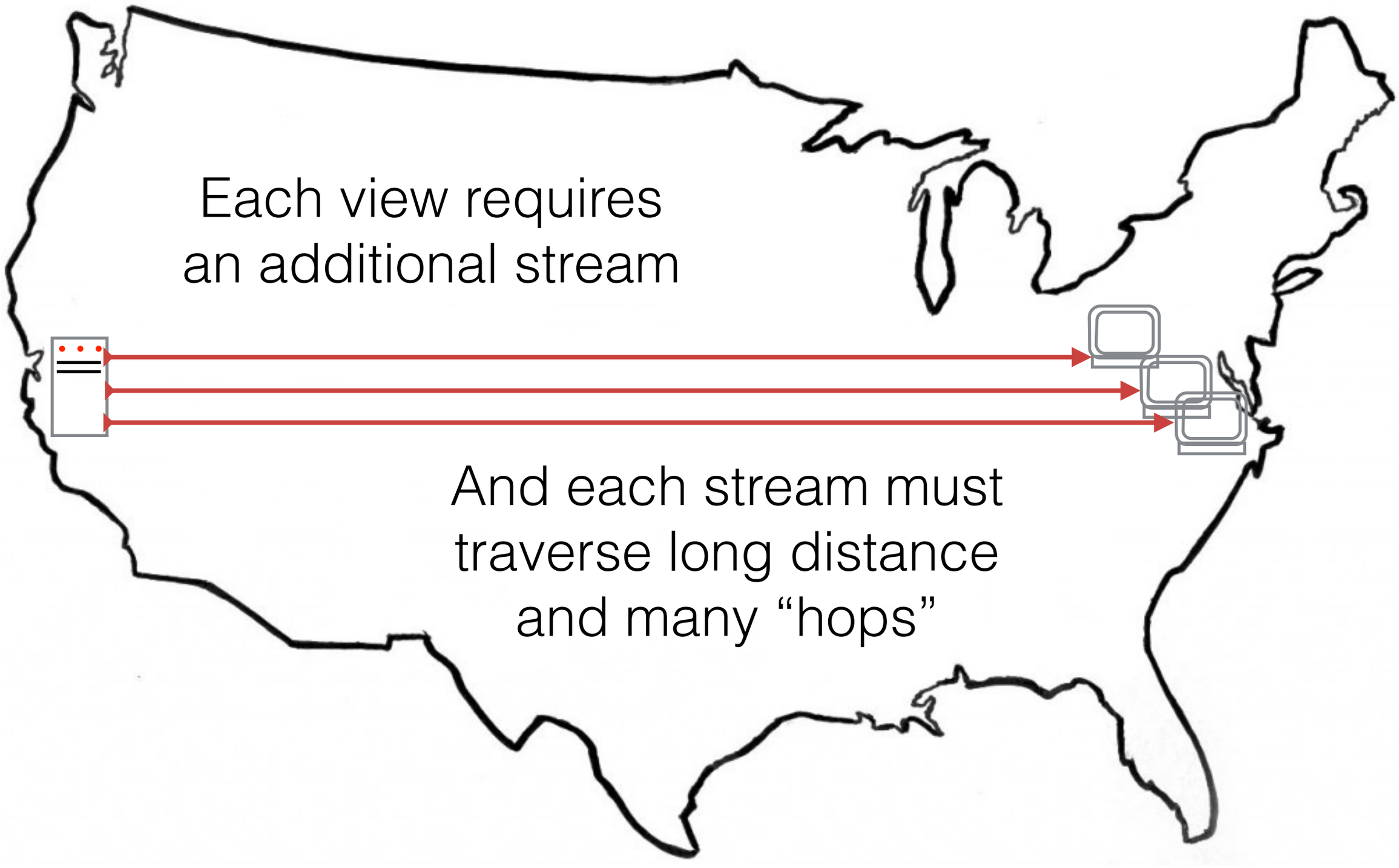
Typical Route — 2014



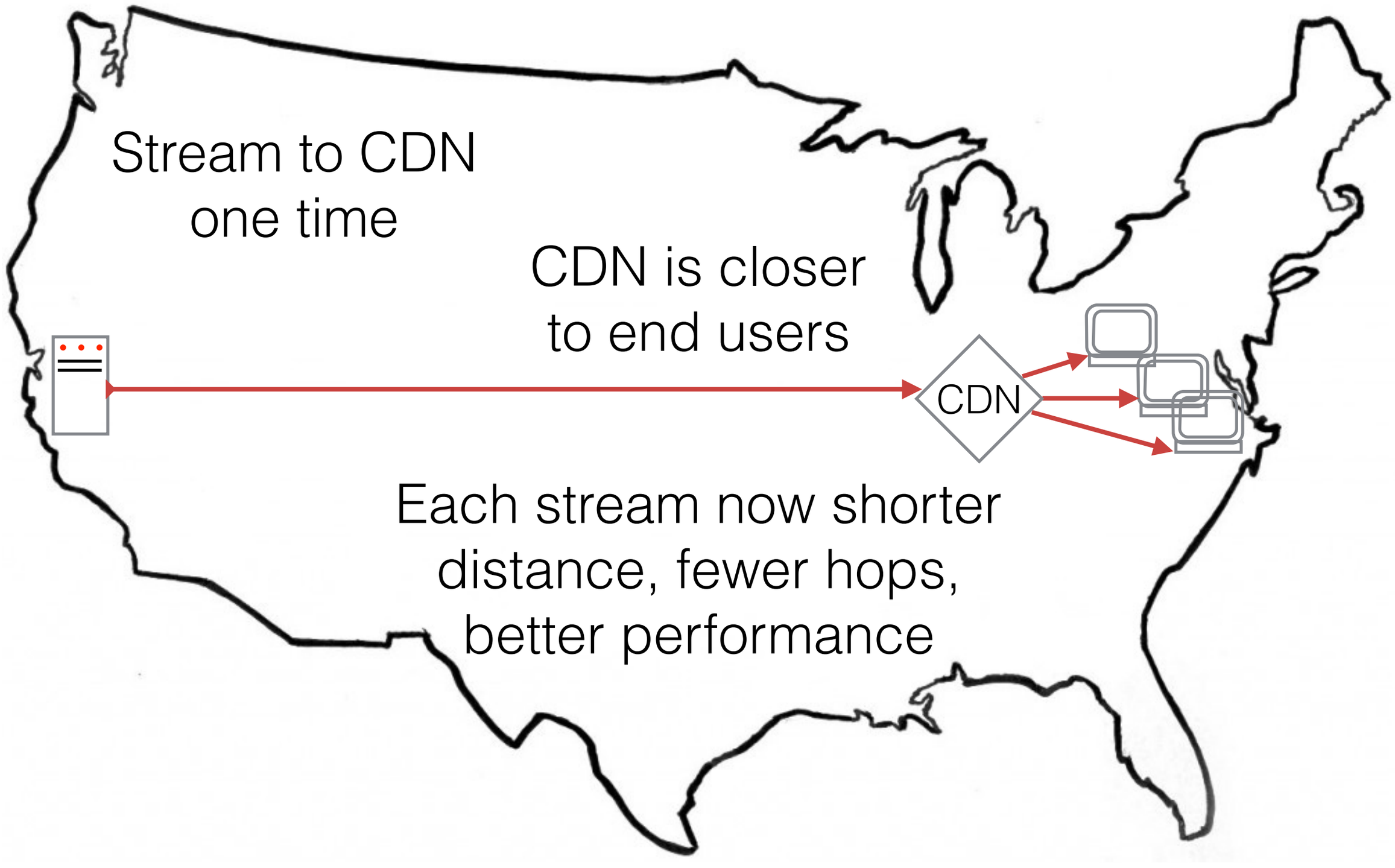
Why CDNs?


A viewer on East coast
requests a Web video stored
in server on West coast
Performance limited by
lightspeed delay, hop delay,
and jitter

Why CDNs?


Each view requires
an additional stream
And each stream must
traverse long distance
and many “hops”

Why CDNs?


Stream to CDN
one time
CDN is closer
to end users
CDN
Each stream now shorter
distance, fewer hops,
better performance

Netflix Argument Is Puzzling

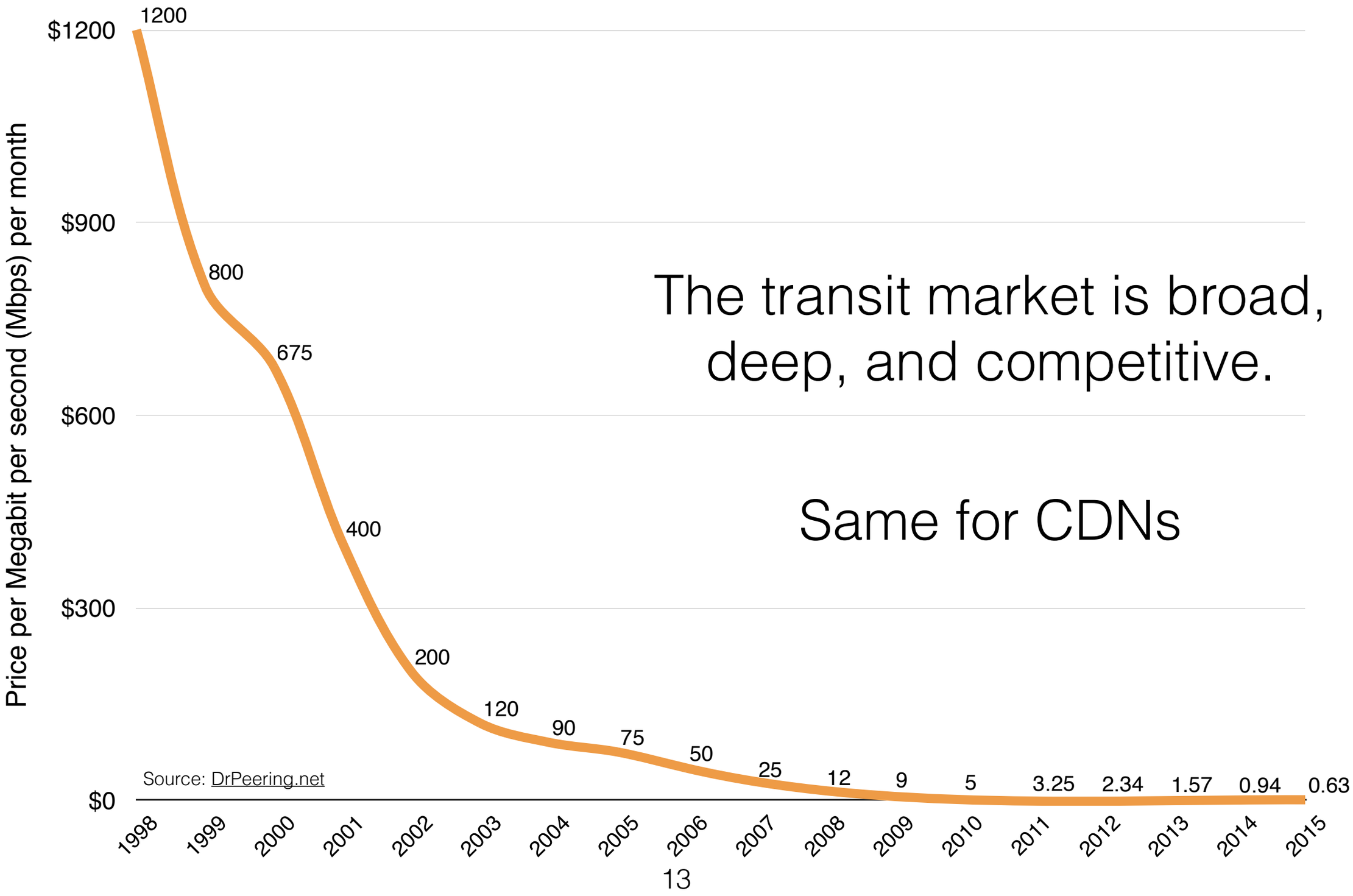
- “Unprecedented”? No. Paid peering and on-net transit are not new. Have been around for 20 years or more. Accelerated use in last 5-10 years.

- Many content firms and all CDNs have such relationships with broadband service providers

- Transit and CDN services are competitive and inexpensive

- More broadband competition — AT&T’s announcement of new fiber networks in 100 cities and towns, Google Fiber, Verizon FiOS, satellite increasingly capable, LTE wireless

Transit Prices Plummet



The transit market is broad, deep, and competitive.

Same for CDNs

Netflix Proposal

- "strong" net neutrality not fully defined
- interconnection "without charge" a radical proposal
- zero price would overturn decades-old practices
- would force both networks and/or consumers to subsidize content companies
- every website gets hosting for free?

Policy

- Prescriptive or proscriptive regulation can't anticipate innovations in hardware, software, content, or business platforms — but can deter or block those innovations

- Net neutrality could have banned CDNs and paid peering had it been in place in late 1990s

- Price regulation used in old world of quasi-government monopoly utilities won't work

- A better standard — demonstration of consumer harm for any government action

The Future

- More video — 4K ultra HD, 8K, and beyond
- Cloud — mobile, wearables especially rely on huge processing and storage of the cloud
- Software Defined Networks — cloud based network functions
- Video conferencing — more symmetrical traffic, big bandwidth
- Exacloud — online gaming, streamed desktops, streamed apps to thin clients — gigantic bandwidth consumption
- More change in hardware, software, content, business models, and thus network interconnection practices

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