CS 40, Lecture 3: Internet economics

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Outline

- Contracts: transit and peer
- Example 1: Peering and pricing
- Example 2: Exchanges
- Example 3: Hot potato routing
- Example 4: 95th percentile pricing
- Example 5: Filtering
- Examples of contracts

Routing: Post-deregulation

When the NSFNet was centrally managed, packet delivery was simple:
Find "cheapest" route from source to destination.

Post-deregulation: How do we guarantee packets find *some* path to their destination, let alone the *best* path?

The Internet today

- Internet = 1000s of ASes
  (autonomous systems)

- An autonomous system is (roughly, not exactly) an *independent administrative domain*
  (ISP, university, content provider, etc.)

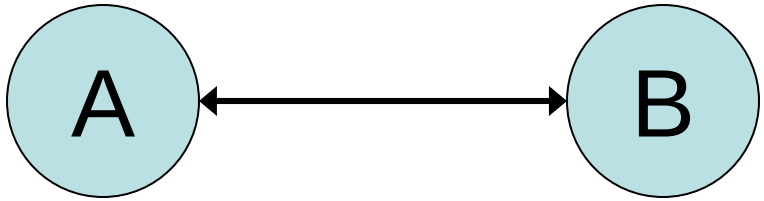
The Internet today

Packets are routed between ASes using an *interdomain routing protocol* called BGP4 (Border Gateway Protocol).

BGP allows ASes to select a *routing policy* consistent with *business contracts.*

Transit contracts

Bilateral contracts between ASes:



Transit contract: A pays B for all connectivity to/from the Internet

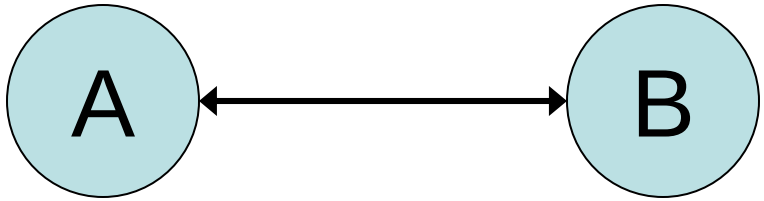
Transit contracts

Transit contracts are what you have with your ISP.

They are usually established between "smaller" providers that "buy transit" from "larger providers."

Peering contracts

Bilateral contracts between ASes:



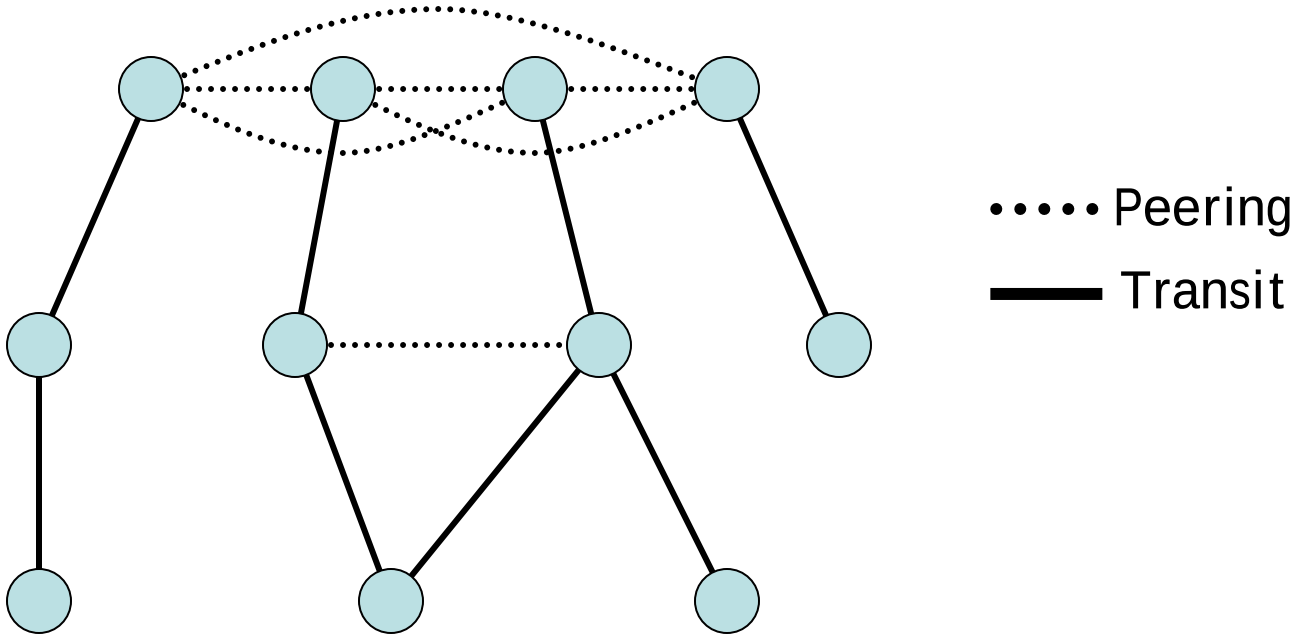
Peer contract: A and B *costlessly* agree to exchange traffic destined for each other

Peering contracts

Peering contracts are typically established between ISPs of similar size, with similar traffic going to each other's network.

The Internet hierarchy

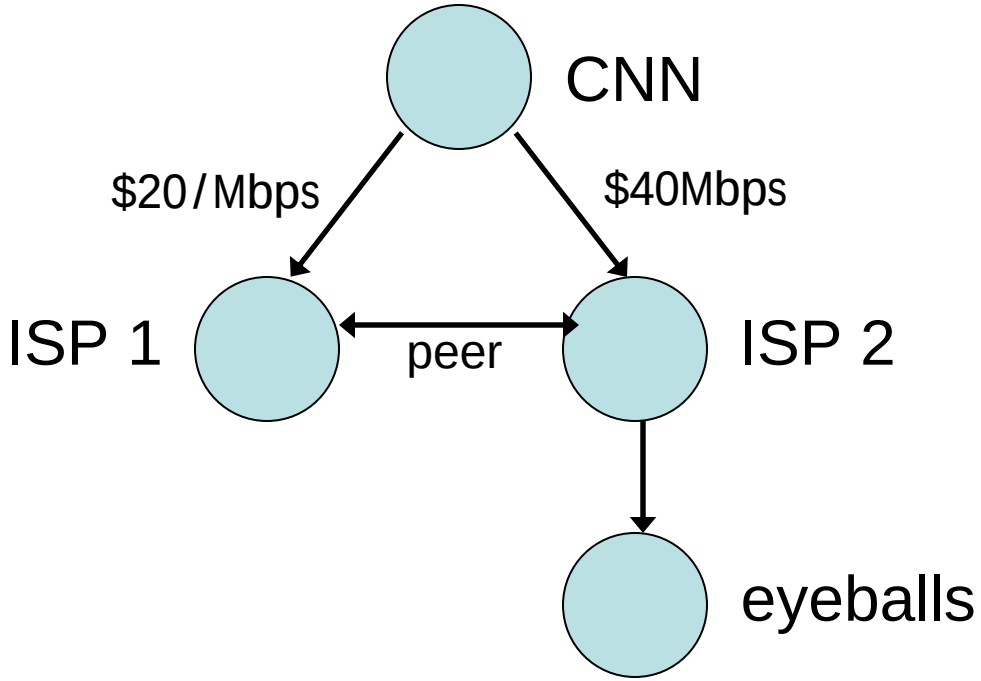
- By many accounts, the Internet looks like a “hierarchy”:



Tiers revisited

- *Tier 1:* Any network that can reach the entire Internet *only* using peering (does not pay for transit)
- *Tier 2:* Network using a mix of transit and peering to reach the entire Internet
- *Tier 3:* Networks who reach the Internet exclusively through transit

Example 1: Peering and pricing



In this scenario,
ISP2 receives no payment from CNN.

Example 1: Peering and pricing

What should happen?

ISP 2 will lower its price.

ISP 1 will lower price in response.

etc. …

…until prices plummet to “near zero.”

Revenues will then no longer cover cost of investment and operation.

Example 1: Peering and pricing

One possible solution:

Why not just identify the *value* of the CNN $\rightarrow$ eyeballs connection,

and share it between ISP 1 and ISP 2?

Example 1: Peering and pricing

Who should pay whom?

- Early peering negotiations
- U.S. vs. the world
- Comcast compared to Akamai

At Tier 1, "value" has been equated with "quantity". Is this a good thing?

- Spam vs. credit card transactions

Verizon peering policy

From Verizon peering rules *(biz.verizon.net/policies/peering_policy.asp):*

1.1 Geographic Scope. .. The Requester also must have a geographically-dispersed network. In the United States, at a minimum, the Requester must have a backbone node in each of the following eight geographic regions: Northeast; Mid-Atlantic; Southeast; North Central; South Central; Northwest; Mid-Pacific; and Southwest.

1.2 Traffic Exchange Ratio. The ratio of the aggregate amount of traffic exchanged between the Requester and the VERIZON Internet Network with which it seeks to interconnect shall be roughly balanced and shall not exceed 1.8:1.

Example 2: Exchanges

An exchange is a single point where many providers and customers can connect to each other.

The exchange provides the infrastructure for the interconnection.

Example 2: Exchanges

Exchanges have a significant impact on price competition.

Without exchanges, moving from one provider to another has a large *switching cost.*

Switching costs prevent prices from plummeting, as in our last example.

Example 2: Exchanges

If exchanges reduce switching costs, then price competition becomes fierce among providers.

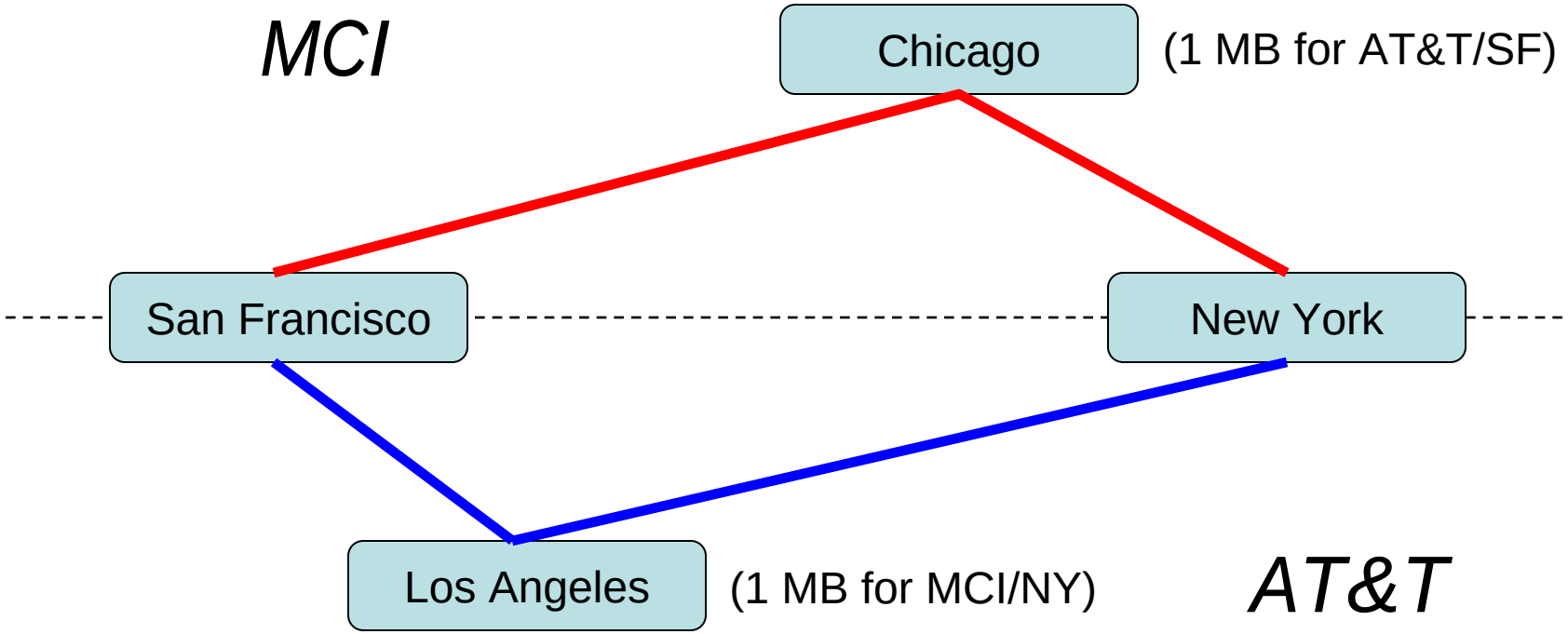
This suggests a world where the exchange becomes a dominant player.

Example 3: Hot potato routing

Routing may not follow “shortest paths” any more.

Why does this happen?

Example 3: Hot potato routing



Costs (per MB): Long links = 2; Short links = 1

Example 3: Hot potato routing

		AT&T: near	AT&T: far
MCI	near	(-4,-4)	(-1,-5)
	far	(-5,-1)	(-2,-2)

(First number is MCI's payoff, second is AT&T's payoff.)

Example 3: Hot potato routing

		AT&T: near	AT&T: far
MCI	near	(-4,-4)	(-1,-5)
	far	(-5,-1)	(-2,-2)

No matter what AT&T does,
MCI prefers nearest exit

Example 3: Hot potato routing

		AT&T: near	AT&T: far
MCI	near	(-4,-4)	(-1,-5)
	far	(-5,-1)	(-2,-2)

Same for AT&T.

Example 3: Hot potato routing

		AT&T: near	AT&T: far
MCI	near	(-4,-4)	(-1,-5)
	far	(-5,-1)	(-2,-2)

So *both* choose nearest exit.

$\Rightarrow$ “Hot potato” routing.

Example 3: Hot potato routing

The players face a *coordination problem.*

They can't communicate value or cost, and so can't agree on a good solution.

Example 4: 95th percentile pricing

In many large volume contracts for service, pricing is based the *95th percentile load:*

(1) Divide a month into 5 minute intervals.

(2) Rank order intervals based on usage

(3) Charge based on the quantity of traffic in the 95th percentile; i.e., throw away top 5% of intervals (about 36 hours worth).

Example 4: 95th percentile pricing

Akamai (the content delivery network) has such a pricing plan with many providers.

Often, this means they prefer *not to serve content from the closest available server.*

Example 4: 95th percentile pricing

Akamai often plays the following game:

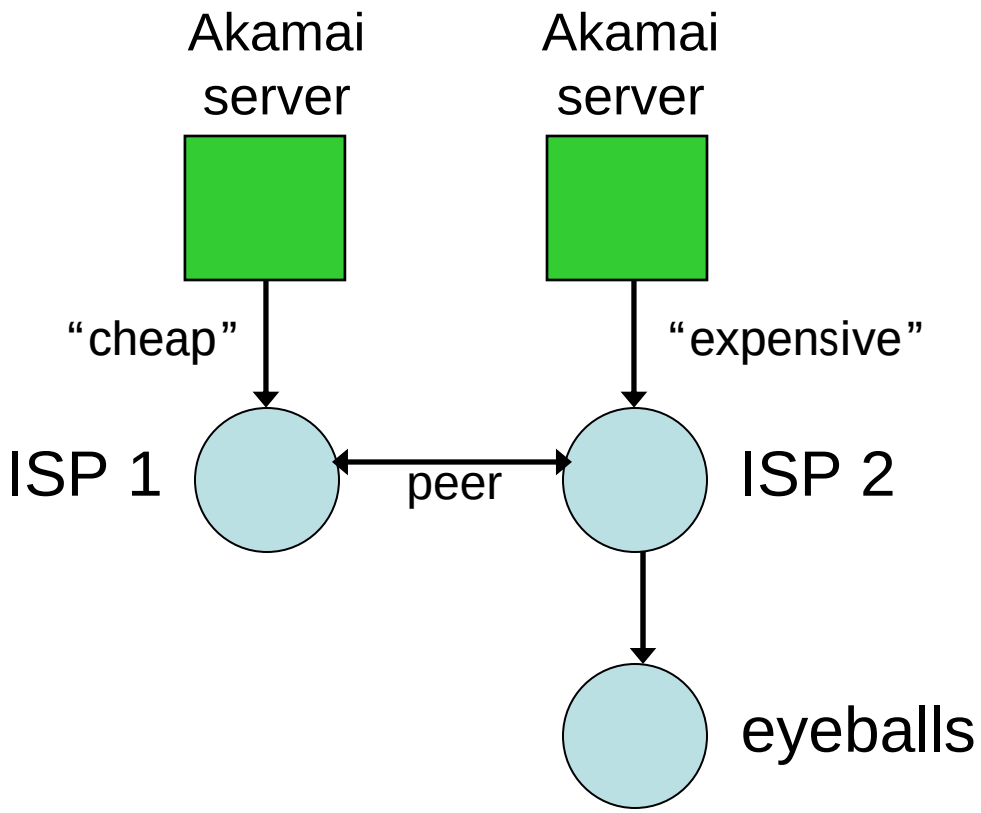
Suppose that a customer requests a CNN page.

That customer is in ISP 2, but Akamai's connection to 2 is currently "expensive."

ISP 1 is nearby, and connected to 2 through a peering link.

So Akamai uses the server in 1 for the page.

Example 4: 95th percentile pricing



Example 4: 95th percentile pricing

Akamai is exploiting the fact that peering is free to balance load across multiple contracts.

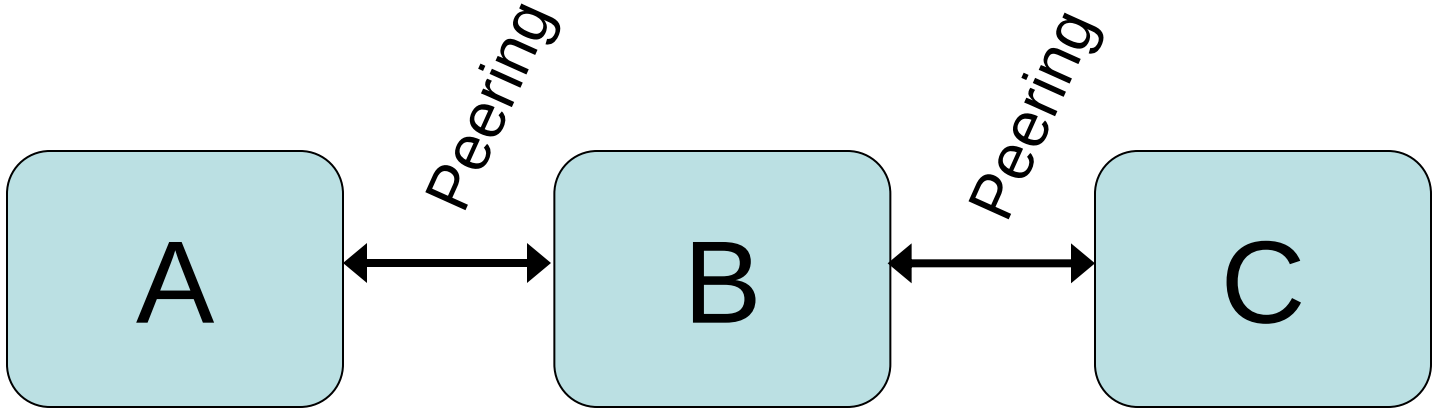
(But the customer may suffer!)

Question: Why can't existing Tier 1 ISPs offer the same service as Akamai?

Example 5: Filtering

Not all links are visible to all providers!

Example: Three peers.



A and B, B and C are peers ⇒
B filters the route B→A from C.

Example 5: Filtering

Filtering is used to enforce business policy.

(Note: Technology meets economics!)

Because of filtering, from any single vantage point in the Internet, many links will never be seen.

Example 5: Filtering

Tier 1 ISPs only have peering contracts with each other, so they filter routes from each other.

Akamai has transit contracts with all Tier 1 ISPs, so it sees every route available.

Implication:

Akamai has a much better "Internet map" than *any* Tier 1 ISP!

Summary of examples

All the examples have one unifying theme:

Contracts *between* ASes gives rise to an interaction between business policy and Internet routing.

This behavior can be unpredictable and undesirable!

We'll conclude with some examples of contractual terms.

Comcast's AUP

From the acceptable use policy *(www.comcast.net/terms/use.jsp):*

[It is prohibited to] resell the Service or otherwise make available to anyone outside the Premises the ability to use the Service (i.e. wi-fi, or other methods of networking), in whole or in part, directly or indirectly, or on a bundled or unbundled basis. The Service is for personal and non-commercial use only and you agree not to use the Service for operation as an Internet service provider or for any business enterprise or purpose, or as an end-point on a non-Comcast local area network or wide area network…

Comcast terms of service

From the terms of service *(www.comcast.net/terms/subscriber.jsp):*

...you shall be entitled upon a request made within sixty (60) days of such interruption, to a pro rata credit for any Service interruption exceeding twenty-four consecutive hours after such interruption is reported to us, or such other period of time as may be specifically provided by law.

AT&T terms of service

From AT&T Yahoo! Internet ToS *(edit.client.yahoo.com/cspcommon/static?page=tos):*

Provisioning of the Service is subject to the availability and the operational limitations of the requisite equipment and associated facilities. You understand and agree that temporary interruptions of the Service may occur as normal events in the provision of the Service and that neither AT&T nor Yahoo! are liable for such interruptions. You further understand and agree that AT&T Yahoo! has no control over third party networks you may access in the course of your use of the Service, and therefore, delays and disruptions of other network transmissions are beyond the control of AT&T and Yahoo!…

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AOL paid peering

Paid peering to AOL Transit Data Network (www.atdn.net/paid_peering.shtml):

Why should I sign up for Paid-Peering?

- With Paid-Peering you get the following benefits:
- Direct access to all AOL Time Warner content.
- Direct access to more than 35 million eyeballs.
- No circuit costs if you choose any carrier neutral ATDN POP locations.
- No traffic volume and restrictive ratio requirements.
- Competitive price with 95th percentile billing.
- Pro-active monitoring by the ATDN NOC (365 x 24 x 7)