Lecture #9: Routing at scale, and with policy
Katrina’s favorite protocol
1970s: ARPAnet  
1978: flexibility and layering  
early 80s: growth → change  
late 80s: growth → problems  
1993: commercialization

hosts.txt  distance-vector routing  
TCP, UDP  OSPF, EGP, DNS  
(a link-state routing protocol)

application  the things that actually generate traffic

transport  sharing the network, reliability (or not)  
examples: TCP, UDP

network  naming, addressing, routing  
examples: IP

link  communication between two directly-connected nodes  
examples: ethernet, bluetooth, 802.11 (wifi)

last time: neither distance-vector nor link-state routing will scale to the size of the Internet, nor do either let us address policy routing

CAIDA's IPv4 AS Core, February 2017  
(https://www.caida.org/research/topology/as_core_network/2017/)
1970s: ARPAnet
1978: flexibility and layering
1980s: growth → change
late 80s: growth → problems
1993: commercialization

application: the things that actually generate traffic
transport: sharing the network, reliability (or not)
examples: TCP, UDP
network: naming, addressing, routing
examples: IP
link: communication between two directly-connected nodes
examples: ethernet, bluetooth, 802.11 (wifi)

this time: scale and policy!
(so we’re thinking about the Internet specifically today, not just any network)

CAIDA’s IPv4 AS Core, February 2017
(https://www.caida.org/research/topology/as_core_network/2017/)

notice that I’m not highlighting the network layer; we’ll talk about why
scalable routing: a few different things allow us to route across the Internet
scalable routing: a few different things allow us to route across the Internet

1. hierarchy of routing: route between ASes, and then within an AS
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2. path-vector routing: advertisements include the path, to better detect routing loops
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1. **hierarchy of routing**: route between ASes, and then within an AS

2. **path-vector routing**: advertisements include the path, to better detect routing loops

3. **topological addressing**: assign addresses in contiguous blocks to make advertisements smaller

\[(A, 2, (B, A))\]

\[18.0.0.0, \ldots ,18.0.0.255\]

\[18.0.0.0/24\]
**scalable routing:** a few different things allow us to route across the Internet

1. **hierarchy of routing:** route between ASes, and then within an AS

2. **path-vector routing:** advertisements include the path, to better detect routing loops

3. **topological addressing:** assign addresses in contiguous blocks to make advertisements smaller

now that we have **scale**, we want a means to implement **policy**
common AS relationships
arrows describe the flow of money; traffic may flow in both directions
customer pays provider for transit

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customer pays provider for transit
makes money whenever any traffic flows on this link

**common AS relationships**

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customer pays provider for transit
makes money whenever any traffic flows on this link!

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typically a provider will charge more money to its customers than it pays its own provider, so E still makes a profit here

makes money whenever any traffic flows on this link

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**peers** allow (free*) mutual access to each other’s customers
*as long as the amount of traffic in each direction is roughly equal
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if a node (E) allows its two peers to send traffic through it to their respective customers, it makes no money.

---

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common AS relationships

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**A** \( \rightarrow \) **B** \( \rightarrow \) **C**

**D** \( \rightarrow \) **E** \( \rightarrow \) **F**

**G**
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these relationships are reflected in **export policies**
which routes to advertise, and to whom
we’re focusing on the middle node (E) right now; ignore the gray nodes

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**providers** tell everyone about themselves and their customers, and tell their customers about everyone
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providers tell everyone about themselves and their customers, and tell their customers about everyone!

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we’re focusing on the middle node (E) right now; ignore the gray nodes
a provider wants its customers to send and receive as much traffic through the provider as possible

we're focusing on the middle node (E) right now; ignore the gray nodes

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this slide represents one “round” of advertisements from node E; other routes will be discovered in subsequent rounds (see next slide)
providers tell everyone about themselves and their customers, and tell their customers about everyone

peers tell each other about their customers

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i can reach

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notice that peers do not tell each other about their own providers; they would lose money providing that transit

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  - *as long as the amount of traffic in each direction is roughly equal*

**these relationships are reflected in export policies**

which routes to advertise, and to whom

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- **peers** tell each other about their customers

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in this example, some of our ASes are **unable** to send traffic to (G) ; they do not know about any routes to it

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**These relationships are reflected in export policies**

which routes to advertise, and to whom

- **Providers** tell everyone about themselves and their customers, and tell their customers about everyone

- **Peers** tell each other about their customers

in fact, there are quite a few ASes here that are disconnected from one another
providers tell everyone about themselves and their customers, and tell their customers about everyone’s peers.

peers allow (free*) mutual access to each other’s customers.
*as long as the amount of traffic in each direction is roughly equal.

these relationships are reflected in export policies, which routes to advertise, and to whom.

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these relationships are reflected in
*export policies*
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*peers* tell each other about their customers
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these relationships are reflected in export policies
which routes to advertise, and to whom

providers tell everyone about themselves and their customers, and tell their customers about everyone's peers tell each other about their customers
on the Internet, all of the top tier ("tier-1") ISPs peer, to provide global connectivity

this is an extremely simplified diagram. you’d expect to see other sorts of peering agreements in this graph, and in fact other sorts of AS relationships

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common AS relationships
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these relationships are also reflected in import policies
which routes to use

on the Internet, all of the top tier (“tier-1”) ISPs peer, to provide global connectivity

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ASes set their own import policies. Typically, if an AS hears about multiple routes to a destination, it will prefer to use its customers first, then peers, then providers.

If that's not enough, a variety of other attributes are provided.

**Common AS relationships**

Arrows describe the flow of money; traffic may flow in both directions.

- **Customer** pays **provider** for transit.
- **Peers** allow (free*) mutual access to each other's customers, as long as the amount of traffic in each direction is roughly equal.

These relationships are also reflected in **import policies**, which routes to use.

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BGP is an application layer protocol, even though it deals with routing

application
the things that actually generate traffic

transport
sharing the network, reliability (or not)
examples: TCP, UDP

network
naming, addressing, routing
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link
communication between two directly-connected nodes
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does BGP scale?
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does BGP scale?

it works on the Internet (which is good), but the size of routing tables, route instability, multihoming, and iBGP all cause scaling issues

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**is BGP secure?**
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**does BGP scale?**

It works on the Internet (which is good), but the size of routing tables, route instability, multihoming, and iBGP all cause scaling issues

**is BGP secure?**

It is not!
on the Internet, all of the top tier ("tier-1") ISPs peer, to provide global connectivity

**does BGP scale?**

It works on the Internet (which is good), but the size of routing tables, route instability, multihoming, and iBGP all cause scaling issues.

**is BGP secure?**

It is not!

BGP basically relies on the honor system.

---

Mark Imbriaco
@markimbriaco

BGP basically relies on the honor system.

---

holly @girlziplocked
What's a dirty secret that everybody in your industry knows about but anyone outside of your line of work would be scandalized to hear?

Show this thread
on the Internet, we have to solve all of the “normal” networking problems (addressing, routing, transport) at massive scale, while supporting a diverse group of applications and competing economic interests.