

Internet Routing

Kai Shen

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IP Packet Format

IP protocol version number
header length (words)
"type" of data
max number remaining hops (decremented at each router)
upper layer protocol to deliver payload to

32 bits

total datagram length (bytes)
for fragmentation/reassembly
e.g. timestamp, record route taken.

IP header size?

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IP Fragmentation & Reassembly

- Network links have MTU - largest possible frame.
 - different link types, different MTUs
- Large IP packet divided ("fragmented") within network
 - one packet becomes several packets
 - "reassembled" only at final destination
 - IP header bits used to identify, order related fragments

fragmentation:
in: one large packet
out: 3 smaller packets

reassemble

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Principles of Internet Routing

Our routing study thus far - idealization

- uniform routing scheme across whole network
- uniform optimization goal
- ... does not work well in practice

scale: with hundreds of millions of destinations:

- can't store all dest's in routing tables!
- routing table exchange would swamp links!

administrative autonomy

- internet = network of networks
- each network admin may want to control routing in its own network

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Hierarchical Routing

- The Global Internet consists of **Autonomous Systems (AS)** interconnected with each other
 - Each AS is usually the network of one organization without internal conflict of interests
- Two-level routing:
 - **Intra-AS:** administrator responsible for choice of routing algorithm within network, typically optimized for performance
 - **Inter-AS:** unique standard to connect all ASes, performance may not be the only goal

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Hierarchical Routing

One path can consist multiple route domains with different routing protocols

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Gateway Routers

Gateways:

- perform inter-AS routing amongst themselves
- perform intra-AS routing with other routers in their AS

inter-AS, intra-AS routing in gateway A.c

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Autonomous Systems in Practice

- Types of **Autonomous Systems (AS)**:
 - **Stub AS:** small corporation: one connection to other AS's
 - **Multihomed AS:** large corporation (no transit): multiple connections to other AS's
 - **Transit AS:** provider, hooking many AS's together
- See a list of ASes

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RIP: An Intra-AS Routing Protocol

RIP (Routing Information Protocol)

- Distance vector routing algorithm
- For scalability, each entry in routing table typically represents a network
- Distance metric: # of hops
- Routing tables exchanged among neighbors periodically (e.g., every 30 secs)
 - this exchange is also called route advertisement

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RIP: Example

Destination Network	Next Router	Num. of hops to dest.
W	A	2
Y	B	2
Z	B	7
X	--	1
....

Routing table in D

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RIP: Example

Dest	Next	hops
w	-	-
x	-	-
z	C	4
....

Advertisement from A to D

Destination Network	Next Router	Num. of hops to dest.
W	A	2
Y	B	2
Z	B A	2 5
X	--	1
....

Routing table in D:

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Routing Table Example

Check routing table at your own workstation:
`netstat -rn`

Destination	Gateway	Interface
128.151.67.0/24	0.0.0.0	eth0
169.254.0.0/16	0.0.0.0	eth0
0.0.0.0	128.151.67.100	eth0

- Local IP network contains two segments of IP addresses
- Routing tables in routers are more complex

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OSPF: Another Intra-AS Routing Protocol

OSPF (Open Shortest Path First)

- Uses Link State algorithm
 - Disseminate link state information to entire AS
 - Complete topology map at each node
 - Route computation using Dijkstra's algorithm
- Solve the scalability problem in OSPF
 - Hierarchical OSPF in large AS

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Hierarchical OSPF

- Two-level hierarchy: local area, backbone.
 - Link-state broadcasts only in area
 - each node has detailed area topology
- Routers:
 - **Area border routers**: run intra-area OSPF routing as well as backbone OSPF routing.
 - **Backbone routers**: run OSPF routing limited to backbone.
 - **Boundary routers**: connect to other AS's.

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Network Routing Architecture within A Host System

- Routing table and routing policy implementation must be protected
 - Kept in the operating system
 - Or managed by protected user process (root-owned daemon)

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Inter-AS Routing in the Internet

- There should be just one inter-AS routing protocol
 - **BGP (Border Gateway Protocol)**
- Inter-AS routing
 - Across multiple administrative domains, which can have conflicting interests

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BGP Routing Protocol

- **Path Vector** protocol:
 - similar to Distance Vector protocol
 - each Border Gateway broadcast to neighbors (peers) entire path (i.e., sequence of AS's) to destination

Flexible routing management in BGP

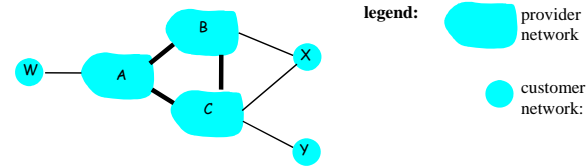
- A router selects routes offered by neighbors based on
 - cost
 - policy (don't route via competitors AS)
- A router can control incoming traffic by manipulating its route advertisements to neighbors:
 - e.g., don't want to route traffic from Z -> don't advertise any routes to Z

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BGP Routing Policy Management



- A,B,C are **provider networks**
- X,W,Y are **customers** (of provider networks), X is **dual-homed**
- X does not want to route transit traffic between B and C
 - ⇒ X advertises nothing to B or C
- A wants to help its customer (W) but not irrelevant traffic
 - ⇒ A tells W everything it knows
 - ⇒ A tells B,C about link to W but not link to C,B

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BGP Routing Table

- BGP routing table at an AS records complete paths to all other ASes
 - See an example
- Possible to construct (almost) complete internet topology (AS-level) with BGP routing tables from several routers

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Why two-level Intra- and Inter-AS routing?

Scale:

- Hierarchical routing saves table size, reduces update traffic


Policy vs. performance:

- Inter-AS: admin wants control over how its traffic routed, who routes through its network. Performance in a global sense is not a major concern for individual service provider.
- Intra-AS: single admin, can focus on performance.

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