The Network Layer: Router Design, Forwarding

CS 352, Lecture 13, Spring 2020

http://www.cs.rutgers.edu/~sn624/352

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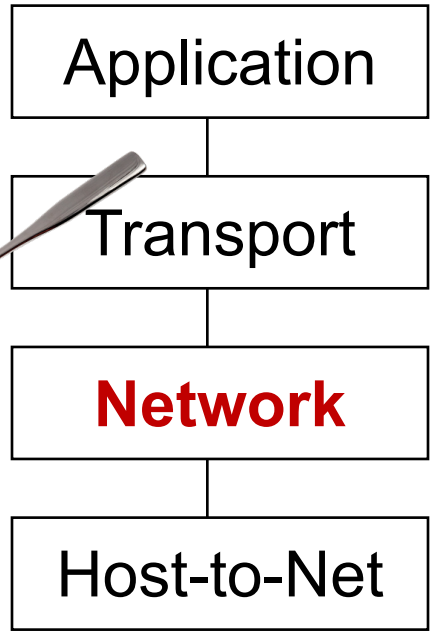
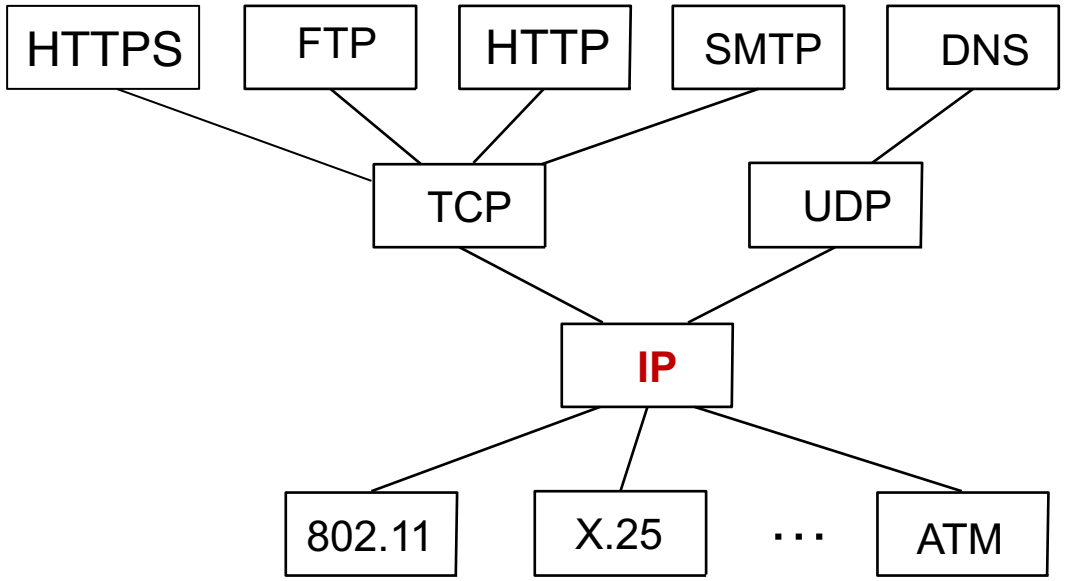
Course announcements

- Project 1 grades available
  - 24/7 grading policy: re-grading considered until 10 PM Sunday 29th
  - TAs have provided feedback on Sakai. Contact TAs for more details

- Lecture and recitation logistics:
  - You will have received WebEx training invitations on Piazza
  - Use a wired connection if possible
  - You can hear me better in a quiet environment
  - Use the chat or Q&A box to ask questions any time
  - Use raise hand feature during time allotted for verbal questions
  - Answer WebEx polls throughout the lecture!

Where we are: The network layer





The network layer exists on every endpoint and router.

Review of concepts

- Forwarding and routing
- Data plane and control plane
  - Control plane can be distributed (this course) or centralized (won't discuss)
- Network-layer addresses (IP addresses)
  - Primary function: identifiers for routing

Poll #1

- An IP address corresponds to:
  - (1) the endpoint
  - (2) the application
  - (3) the point of attachment of the endpoint to the network
  - (4) all of the above

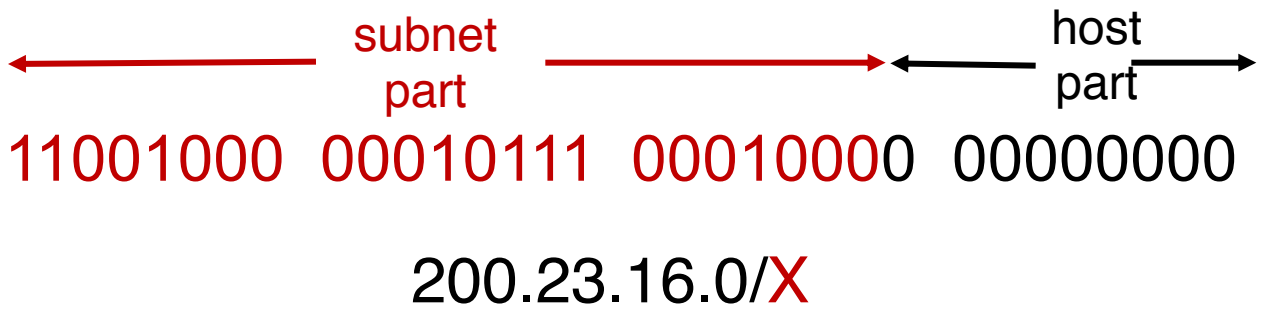
- Please use the WebEx poll feature to answer

Review of concepts

- Forwarding and routing
- Data plane and control plane
  - Control plane can be distributed (this course) or centralized (won't discuss)
- Network-layer addresses (IP addresses): identifiers for routing
- Classful addressing: classes A, B, C, multicast, reserved
  - Distinguished by first few bits
  - Different # bits allotted to network address and host address
- Classless addressing (CIDR):
  - Freely change size of network (host) address
  - Allocate a subset of available addresses using a subnet
- Internet routing scales through hierarchy
  - IP subnetworks are the zip codes of the Internet

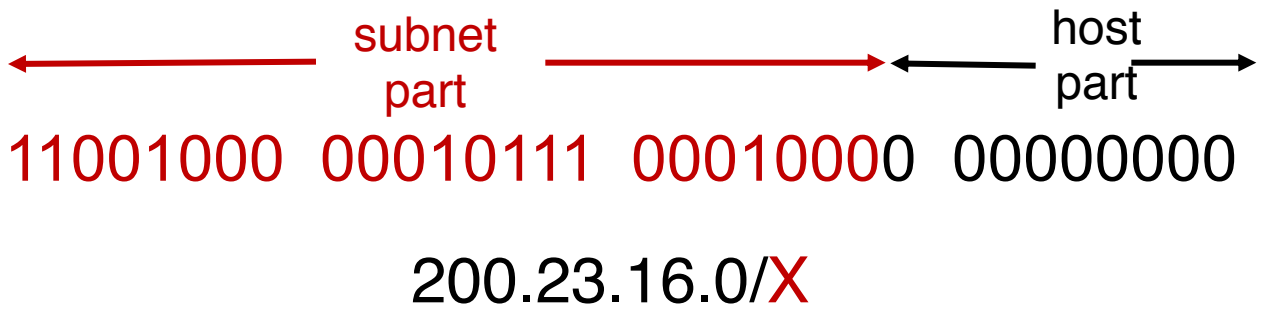
Poll #2

- Given the IP address and subnet below, what is the value of X?
  - (1) 11
  - (2) 23
  - (3) 32
  - (4) none of the above



Poll #3

- How many hosts can this subnetwork support?
  - (1) 2^9
  - (2) 2^{23}
  - (3) 2^{32}
  - (4) none of the above

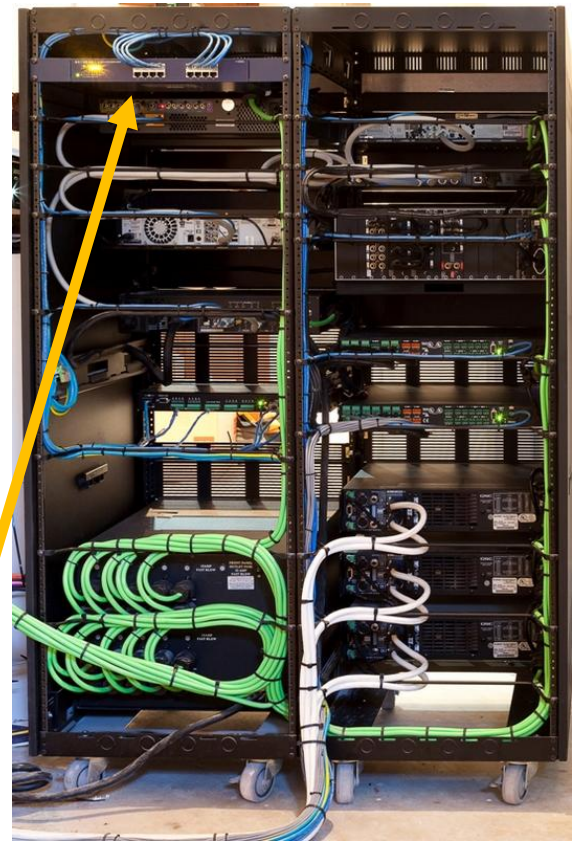


What’s inside a router?

What do routers look like?

Access routers

Core router

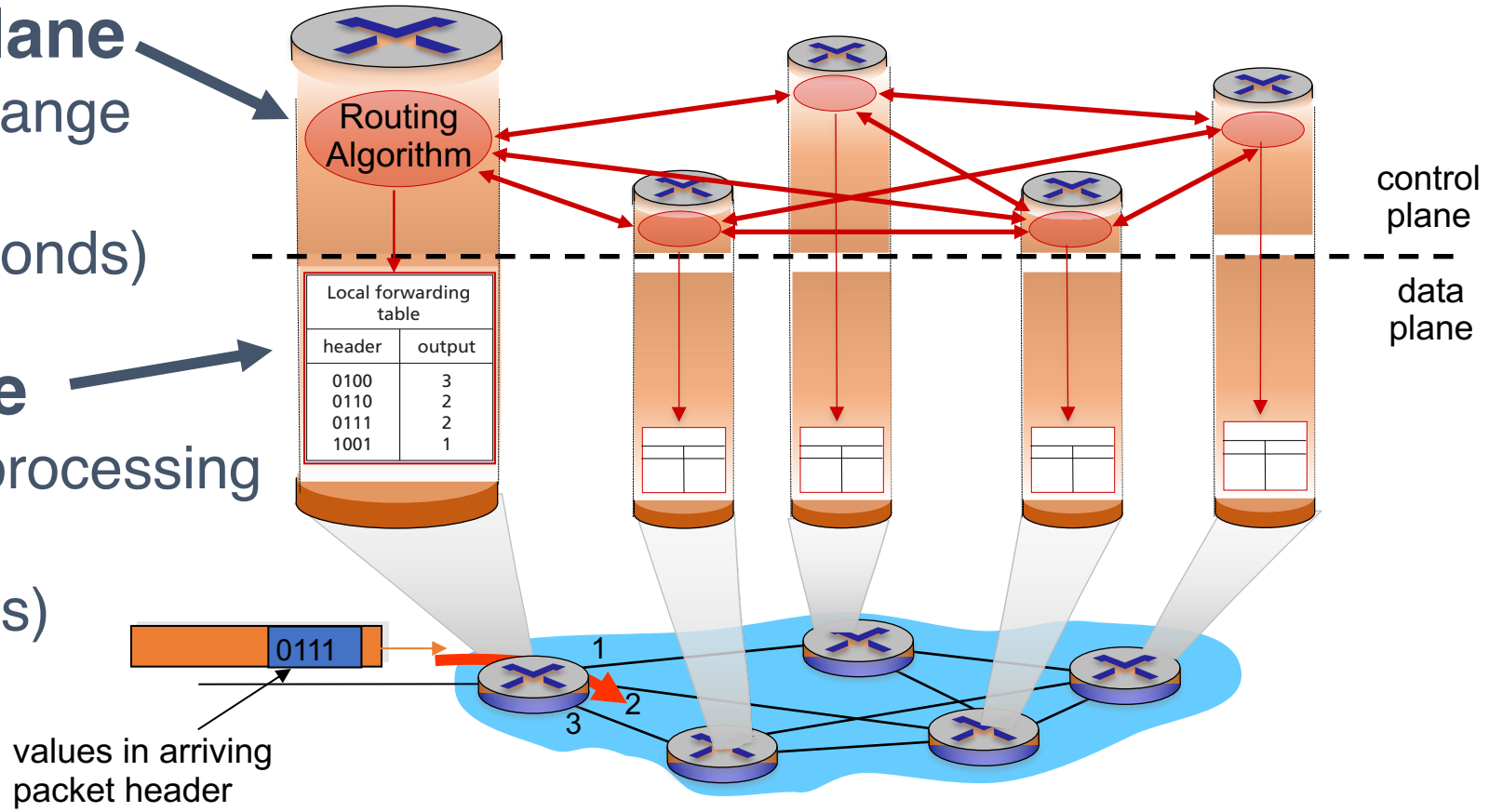


Data center top-of-rack switch

Basic components: Control & Data Planes

Control plane
per route-change processing
(~ a few seconds)

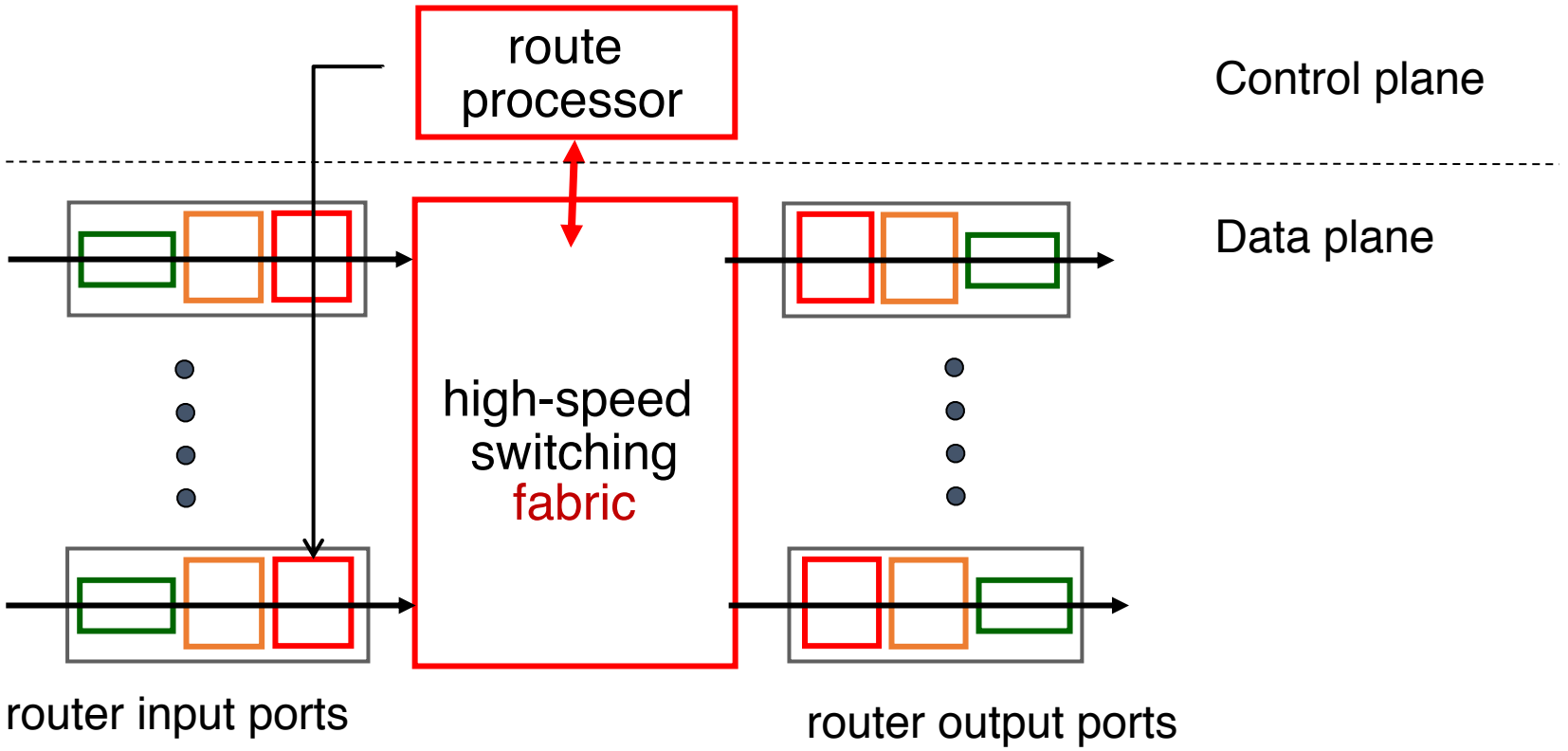
Data plane
per-packet processing
(~ tens of nanoseconds)



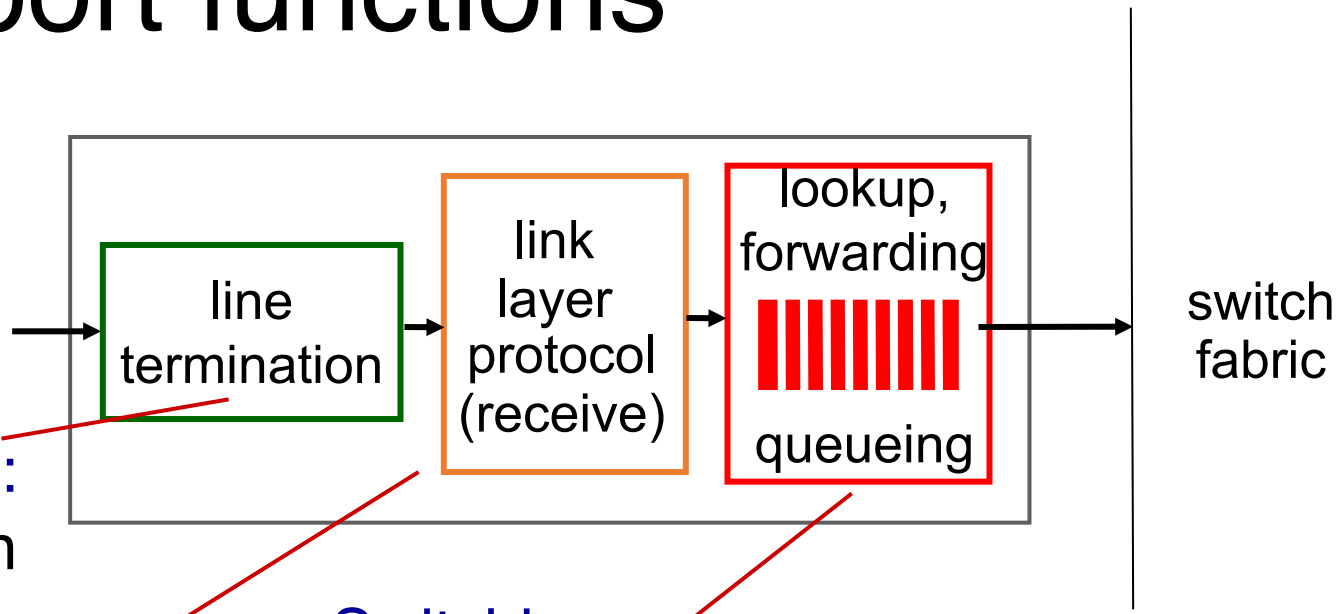
Traditionally:

Individual routing algorithm components *in each and every router* interact in the control plane (Distributed control plane)

Router architecture overview



Input port functions



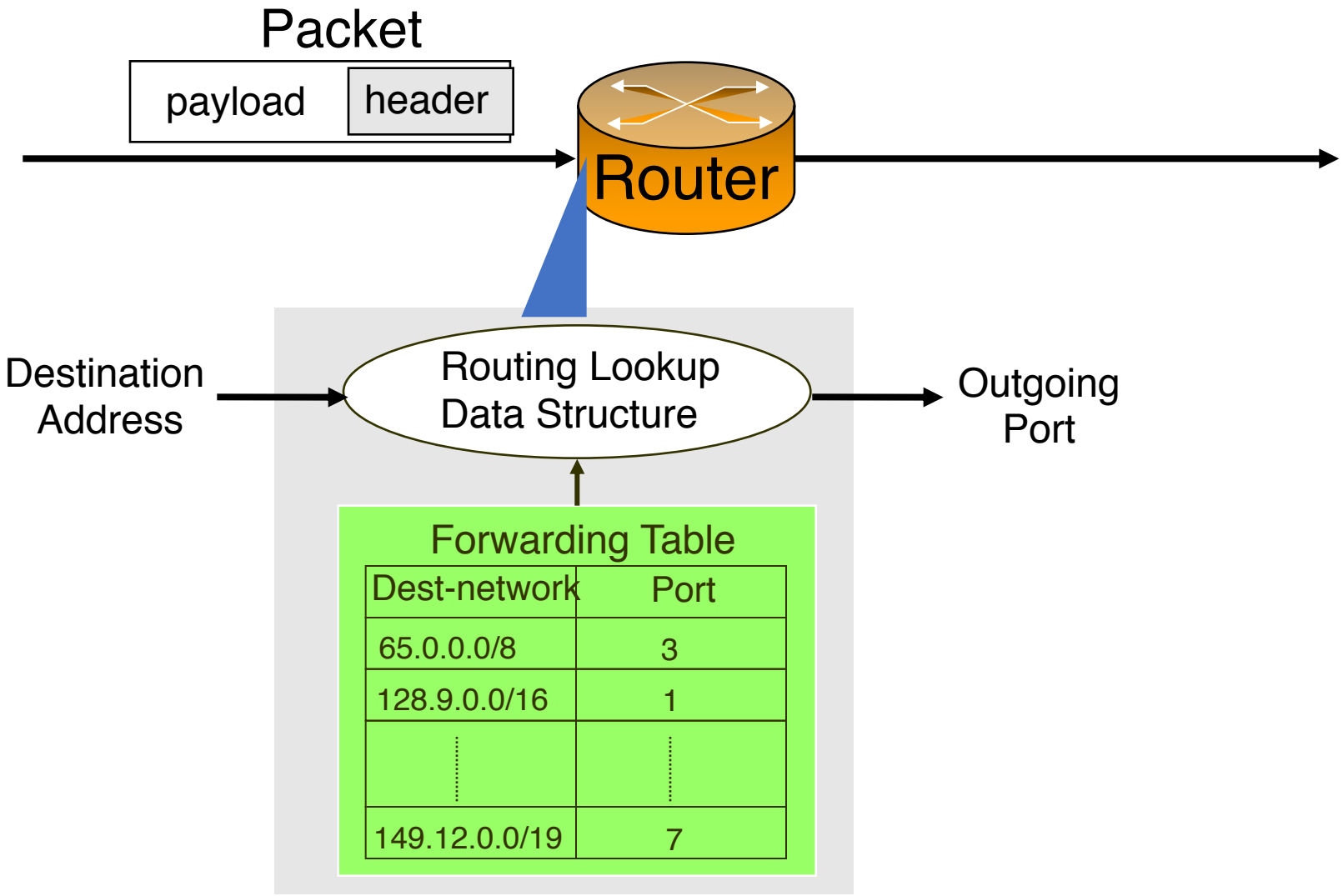
physical layer:
bit-level reception

data link layer:
e.g., Ethernet
(We'll see this later in the course)

Switching:

- using header field values, lookup output port using forwarding table in input port memory
- goal: complete input port processing at line speed (i.e., speed of the interface, say 100 Mbit/s)
- queueing: if datagrams arrive faster than they can be sent via the switch fabric to the output port

Destination-based Forwarding in the Internet

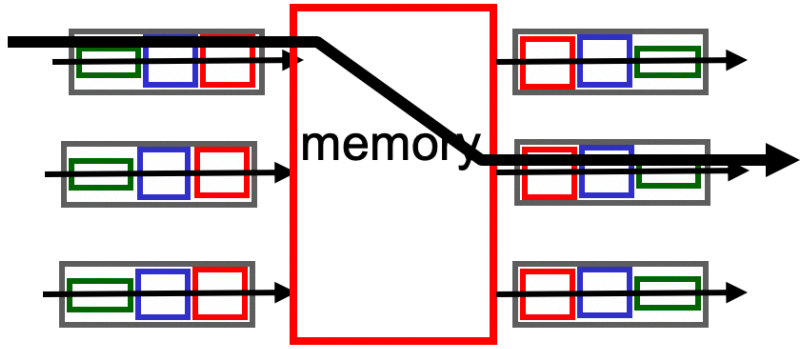


Forwarding in the Internet is based on the destination IP address on packet.

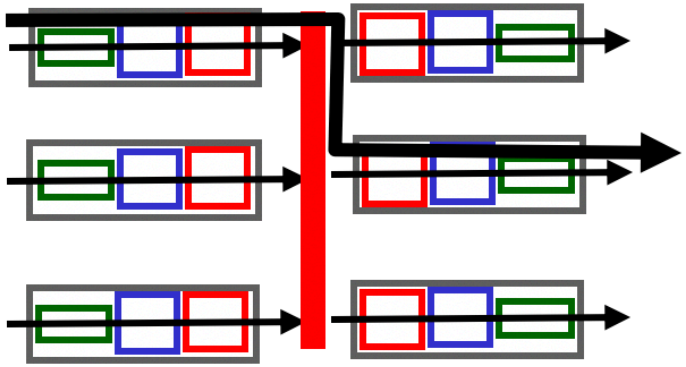
There are exceptions. But Internet forwarding is mostly:

- independent of the source, e.g., legitimate vs. malicious source
- independent of the type of traffic, e.g., Netflix vs. web

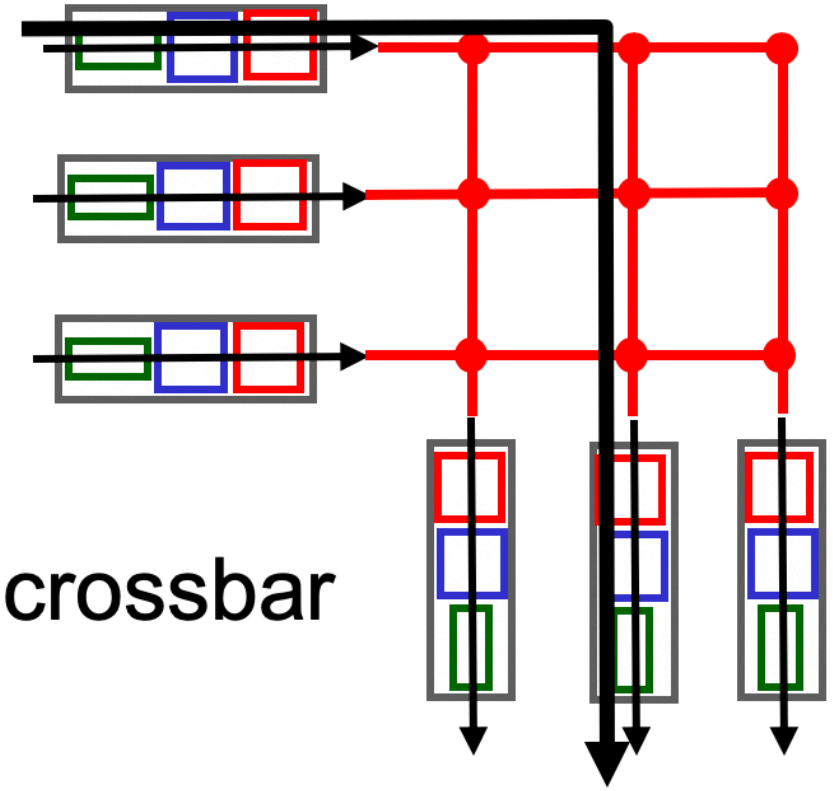
Three types of switching fabrics



memory

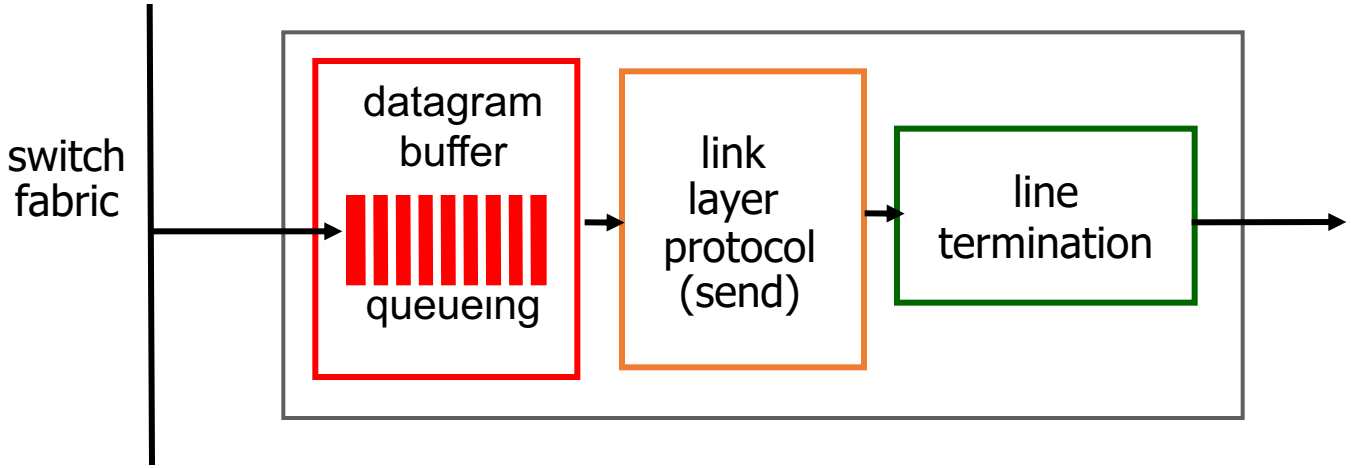


bus



crossbar

Output Ports



- *Buffering* when datagrams arrive from fabric faster than the output port rate
  - If buffers filled up, packets are dropped!
  - Buffer management policy decides which pkts to keep and drop

- *Scheduling discipline* chooses among queued datagrams for transmission
  - Who gets priority is chosen by the scheduler

Poll #4

- Suppose two packets arrive at a router input port. Packet 1 has (src, dst) IP address == (X, Y). Packet 2 has (src, dst) IP address == (Z, Y). Then:
  - (1) The two packets are unlikely to be forwarded out of the same output port
  - (2) The two packets are highly likely to be forwarded out of the same port
  - (3) Not sure

Poll #5

- A packet is waiting to be transmitted at a buffer on the router output port. Who decides when the packet will be transmitted?
  - (1) buffer manager
  - (2) Packet scheduler
  - (3) Forwarding table
  - (4) Line termination

Prefixes and IP lookup

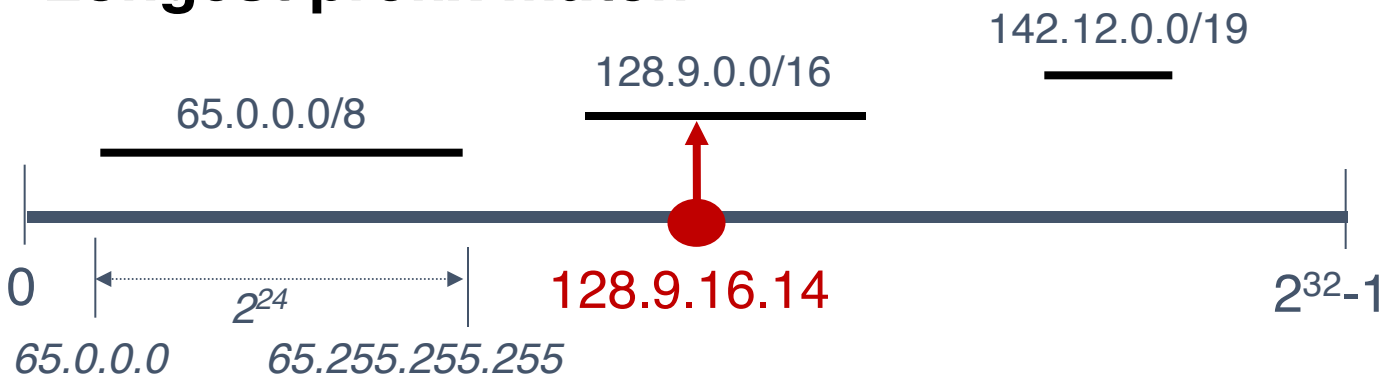
Example Forwarding Table

Destination IP Prefix	Outgoing Port
65.0.0.0/8	3
128.9.0.0/16	1
65.0.0.128/25	4
142.12.0.0/19	7

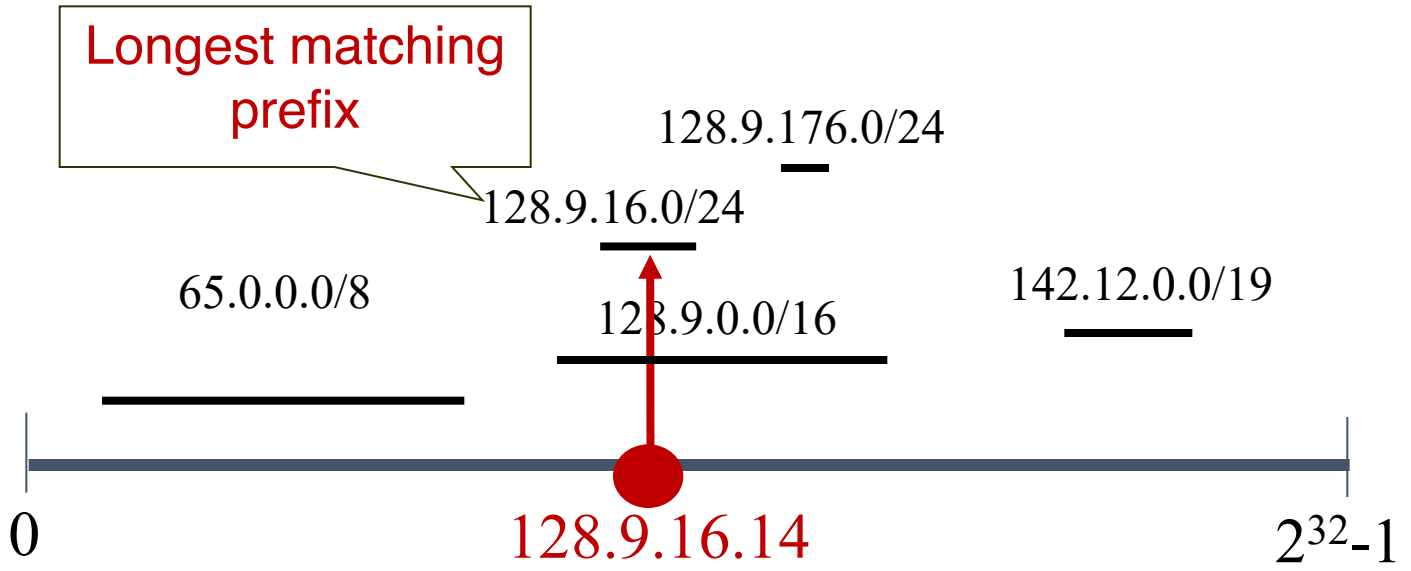
Prefix length

IP prefix: 0-32 bits

Longest prefix match



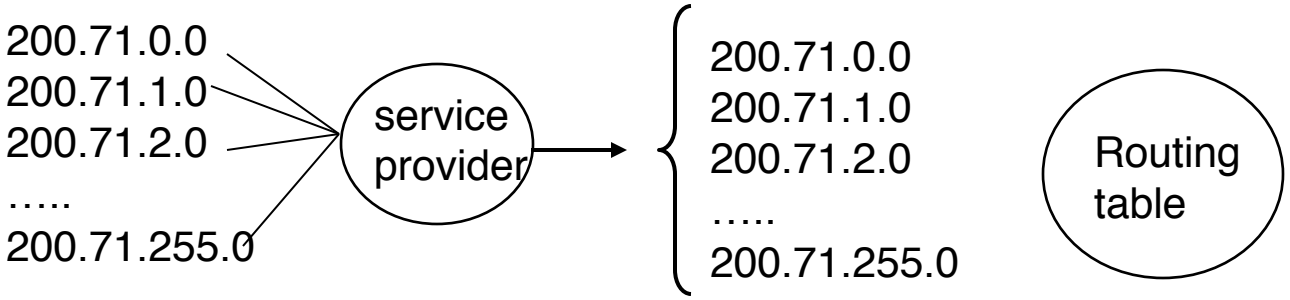
Prefixes can Overlap



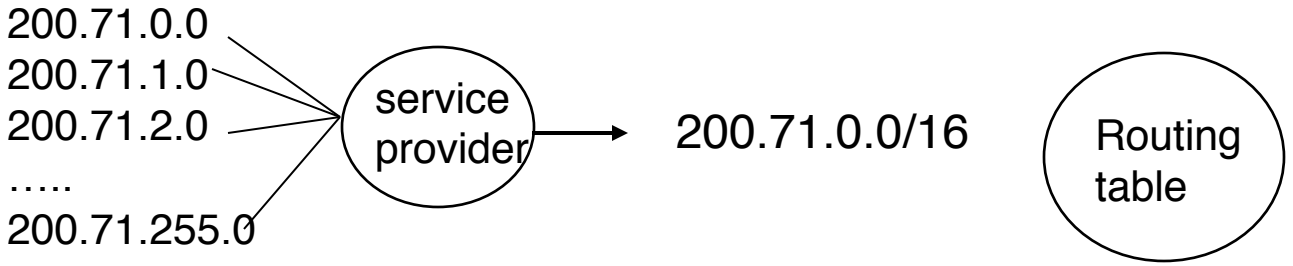
Routing lookup: Find the longest matching prefix (the most specific route) among all prefixes that match the destination address.

Reducing Routing Table Size

Without CIDR:

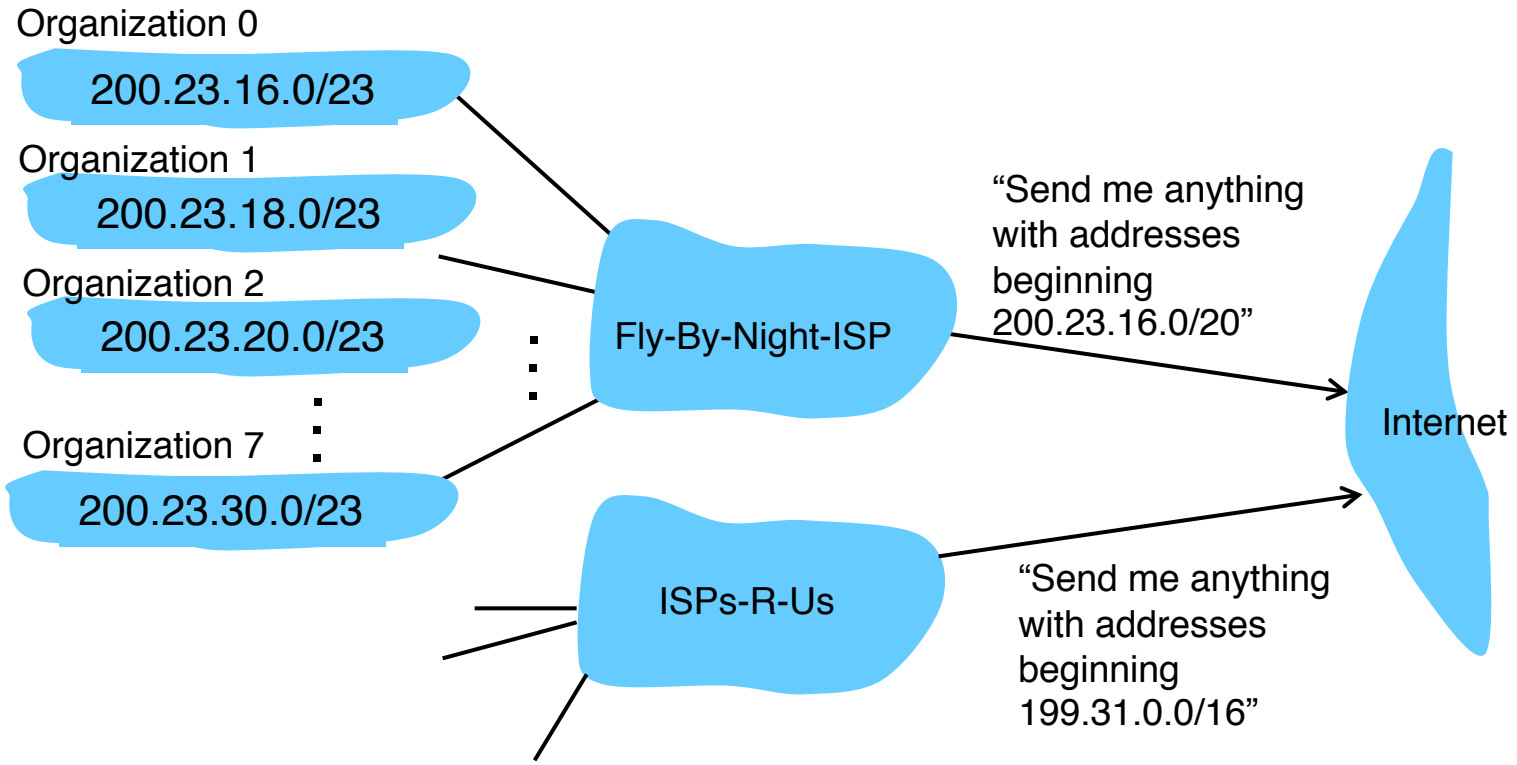


With CIDR:



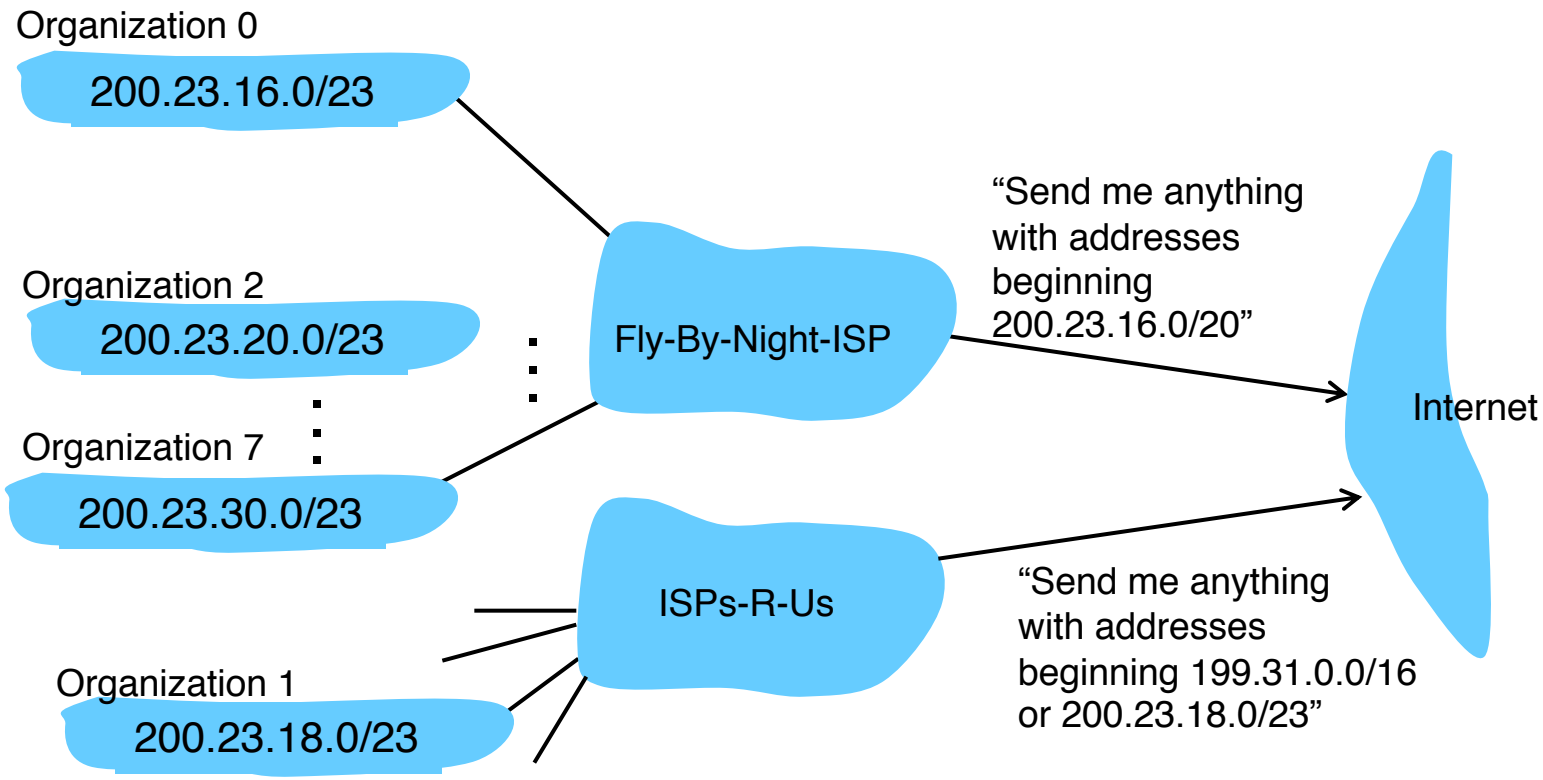
Hierarchical addressing: Route aggregation

Efficient advertisement of routing information!



LPM: Announcing more specific routes

ISPs-R-Us has a more specific route to Organization 1
Longest prefix match will be used to route IP packets



Poll #6

- If the destination IP address of a packet matches three forwarding rules 128.0.0.0/16, 128.0.0.0/20, 128.0.0.0/24, which rule will the router use?
  - (1) 128.0.0.0/16
  - (2) 128.0.0.0/20
  - (3) 128.0.0.0/24
  - (4) None of the above

(1) 128.0.0.0/16

Poll #7

- If an ISP owns two prefixes 128.0.0.0/16 and 128.1.0.0/16, what prefix can it legitimately advertise to the rest of the Internet?
  - (1) 128.0.0.0/8
  - (2) 128.0.0.0/15
  - (3) 128.0.0.0/14
  - (4) None of the above