UIC UNIVERSITY OF ILLINOIS AT CHICAGO Department of Computer Science COLLEGE OF ENGINEERING

CS450 – Introduction to Networking
Lecture 27 – ICMP, IPv6, and Routing

Phu Phung

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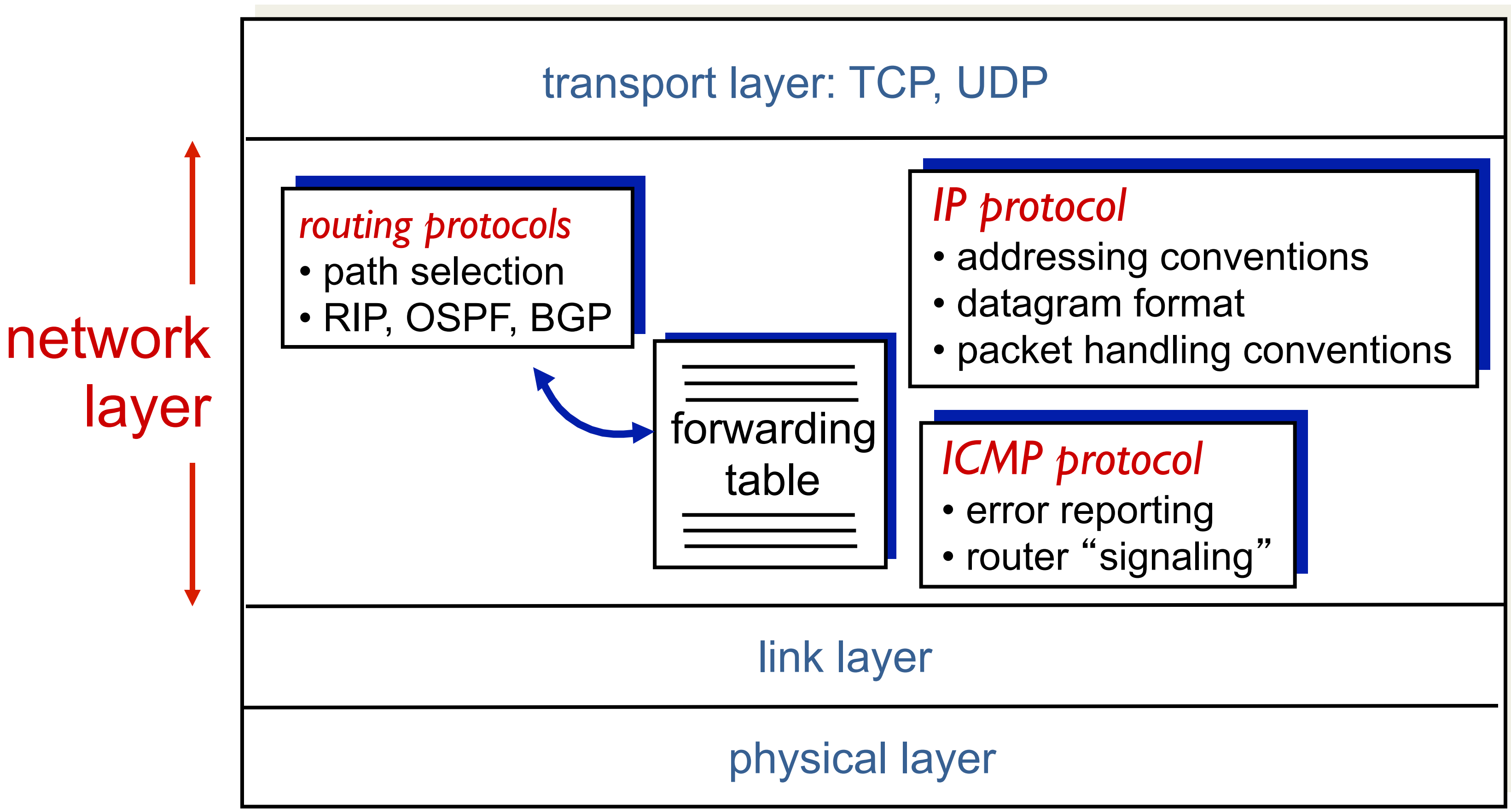
The Internet network layer

host, router network layer functions:



ICMP: internet control message protocol

- used by hosts & routers to communicate network-level information
  - error reporting: unreachable host, network, port, protocol
  - echo request/reply (used by ping)
- network-layer "above" IP:
  - ICMP msgs carried in IP datagrams
- ICMP message: type, code plus first 8 bytes of IP datagram causing error

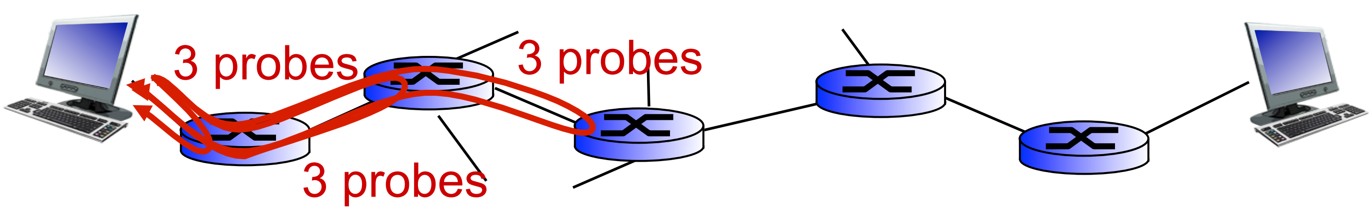
Type	Code	description
0	0	echo reply (ping)
3	0	dest. network unreachable
3	1	dest host unreachable
3	2	dest protocol unreachable
3	3	dest port unreachable
3	6	dest network unknown
3	7	dest host unknown
4	0	source quench (congestion control - not used)
8	0	echo request (ping)
9	0	route advertisement
10	0	router discovery
11	0	TTL expired
12	0	bad IP header

Traceroute and ICMP

- source sends series of UDP segments to dest
  - first set has TTL =1
  - second set has TTL=2, etc.
  - unlikely port number
- when *n*th set of datagrams arrives to nth router:
  - router discards datagrams
  - and sends source ICMP messages (type 11, code 0)
  - ICMP messages includes name of router & IP address
- when ICMP messages arrives, source records RTTs

stopping criteria:

- UDP segment eventually arrives at destination host
- destination returns ICMP "port unreachable" message (type 3, code 3)
- source stops



IP version 6

IPv6 vs IPv4

A. IPv6 increases the size of IP address

B. IPv6 removes header checksum in IP header to reduce processing cost at routers

C. IPv6 does not allow package fragmentation/ reassembly to improve speed/forwarding

D. A and B

E. A, B and C

IPv6: motivation

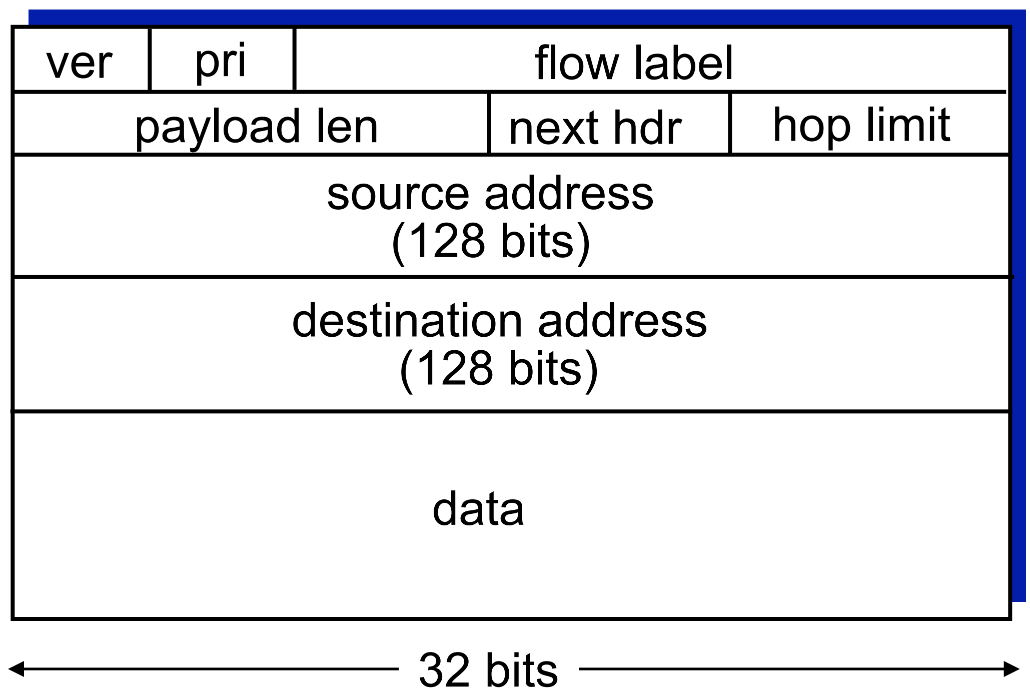
- *initial motivation:* 32-bit address space soon to be completely allocated.
- additional motivation:
  - header format helps speed processing/forwarding
  - header changes to facilitate QoS

IPv6 datagram format:

- fixed-length 40 byte header
- no fragmentation allowed

IPv6 datagram format

priority: identify priority among datagrams in flow
flow Label: identify datagrams in same "flow."
(concept of "flow" not well defined).
next header: identify upper layer protocol for data



Other changes from IPv4

- *checksum:* removed entirely to reduce processing time at each hop
- *options:* allowed, but outside of header, indicated by "Next Header" field
- *ICMPv6:* new version of ICMP
  - additional message types, e.g. "Packet Too Big"
  - multicast group management functions

IPv6 in practice

A. IPv6 is implemented in practice, i.e., in the Internet

B. IPv6 is used in mix with IPv4

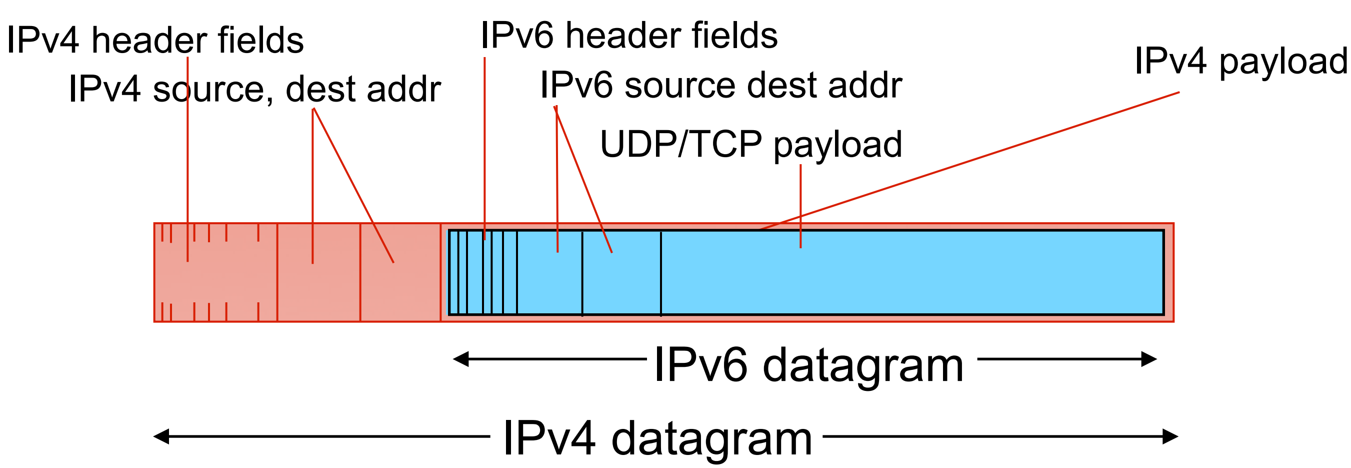
C. IPv4 has been replaced by IPv6

D. A and B

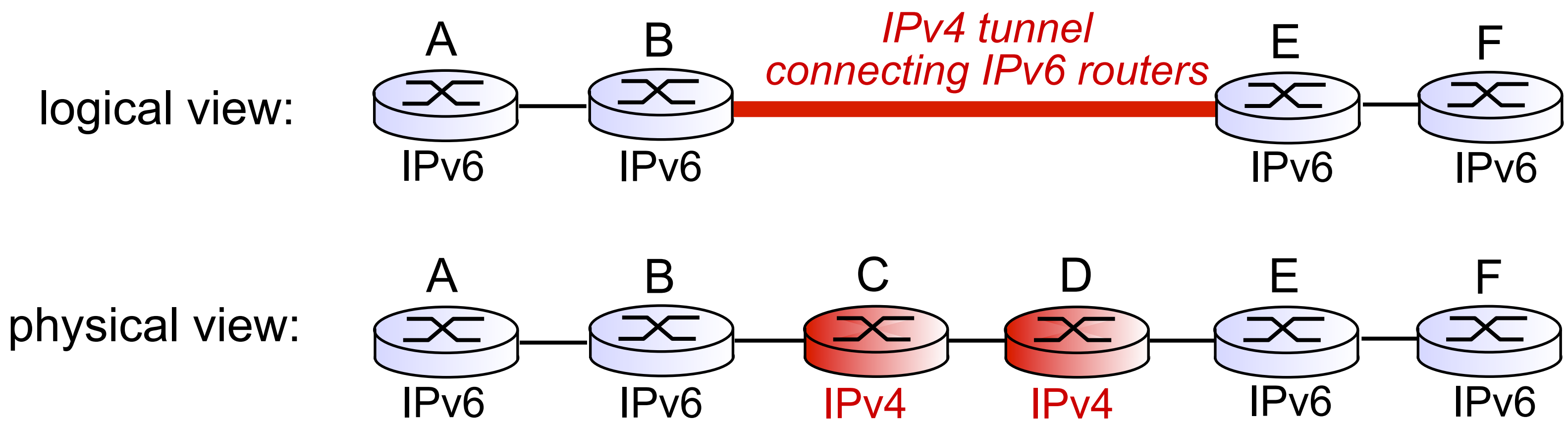
E. A, B and C

Transition from IPv4 to IPv6

- not all routers can be upgraded simultaneously
  - no "flag days"
  - how will network operate with mixed IPv4 and IPv6 routers?
- *tunneling:* IPv6 datagram carried as *payload* in IPv4 datagram among IPv4 routers



Tunneling


logical view:
A
B
IPv4 tunnel
connecting IPv6 routers
E
F
IPv6
IPv6
IPv6
IPv6
physical view:
A
B
C
D
E
F
IPv6
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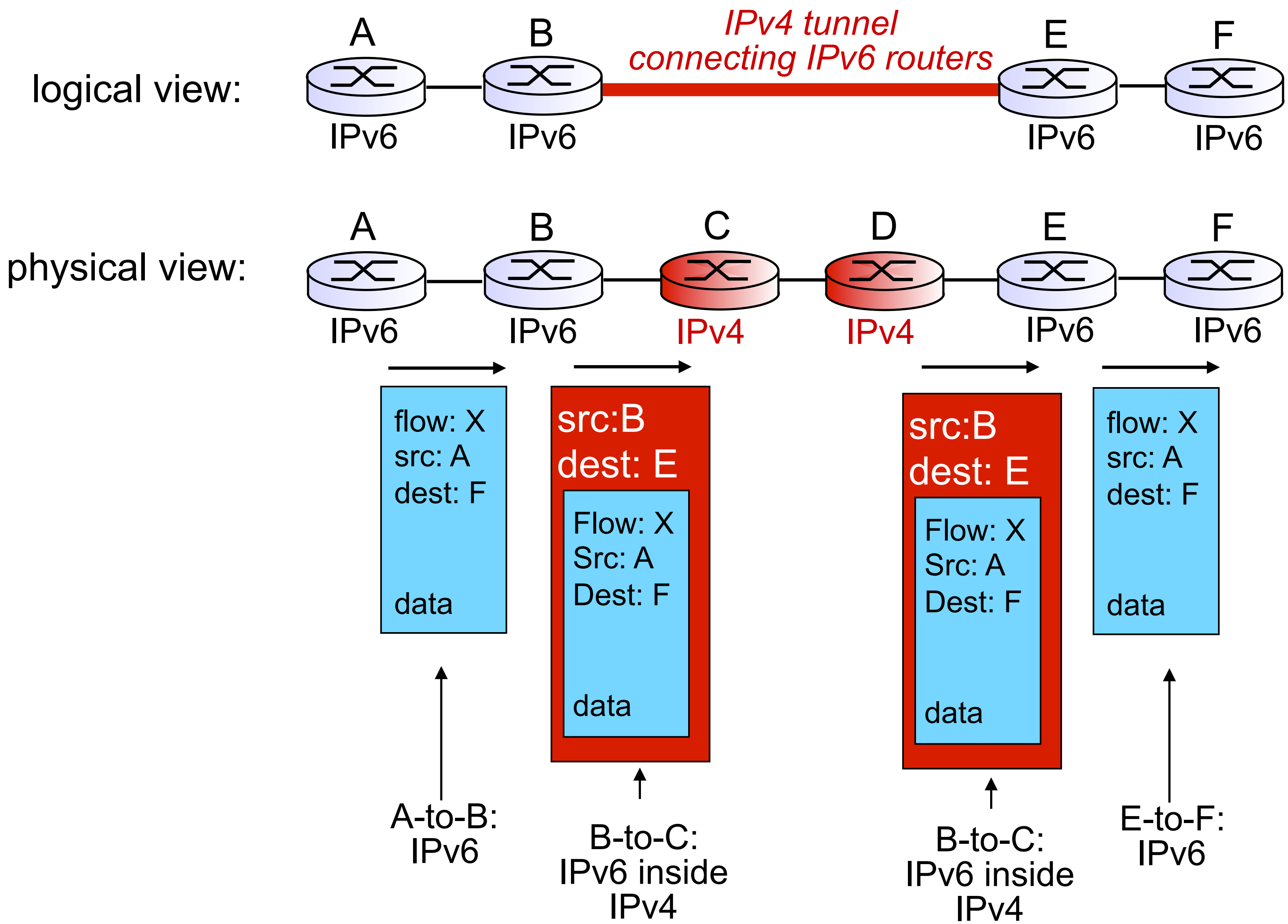
Tunneling



logical view:
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IPv6
IPv6
IPv4
IPv4
IPv6
IPv6
flow: X
src: A
dest: F
data
src:B
dest: E
Flow: X
Src: A
Dest: F
data
src:B
dest: E
Flow: X
Src: A
Dest: F
data
flow: X
src: A
dest: F
data
A-to-B:
IPv6
B-to-C:
IPv6 inside
IPv4
B-to-C:
IPv6 inside
IPv4
E-to-F:
IPv6

IPv6: adoption

- US National Institutes of Standards estimate [2013]:
  - ~3% of industry IP routers
  - ~11% of US gov't routers

- *Long (long!) time for deployment, use*
  - 20 years and counting!
  - think of application-level changes in last 20 years: WWW, Facebook, …
  - *Why?*

Why is it so long to deploy IPv6 in practice?

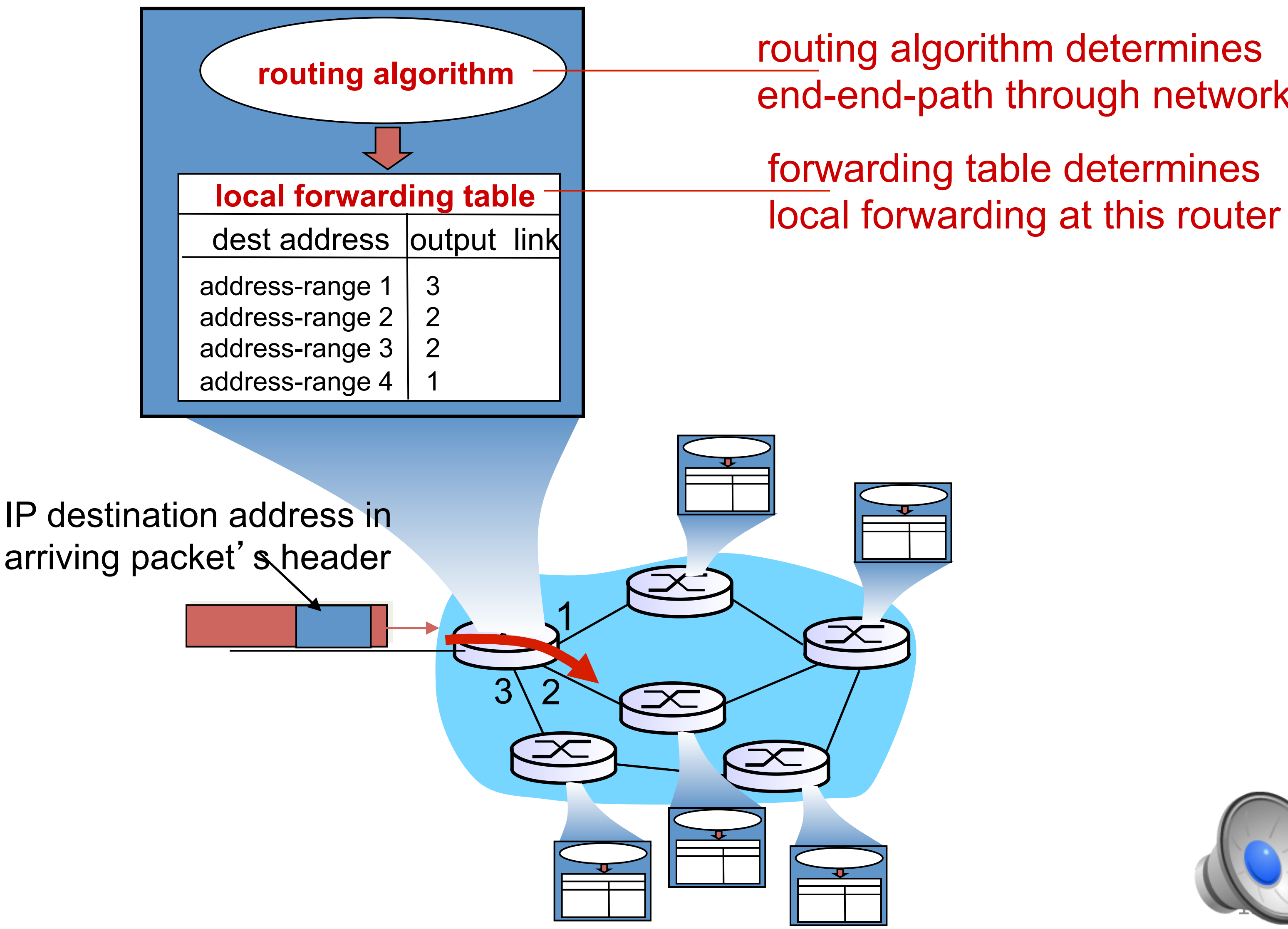
A. Because it is not needed

B. It is too difficult to implement IPv6 protocol

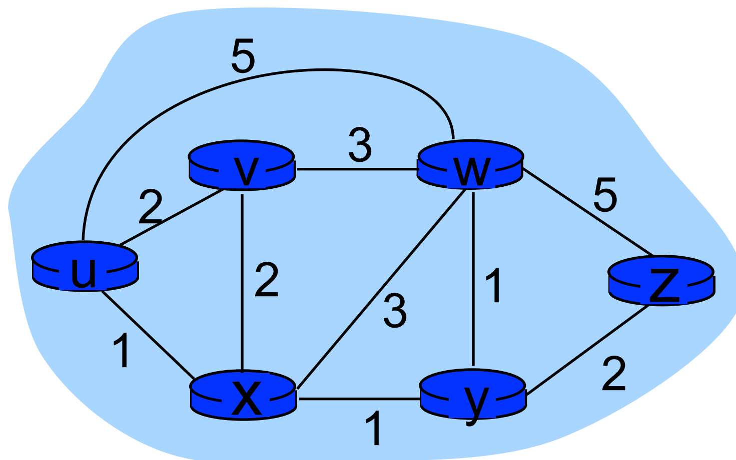
C. Because IPv4 was there

D. Something else (to be discussed)

Interplay between routing, forwarding



Graph abstraction



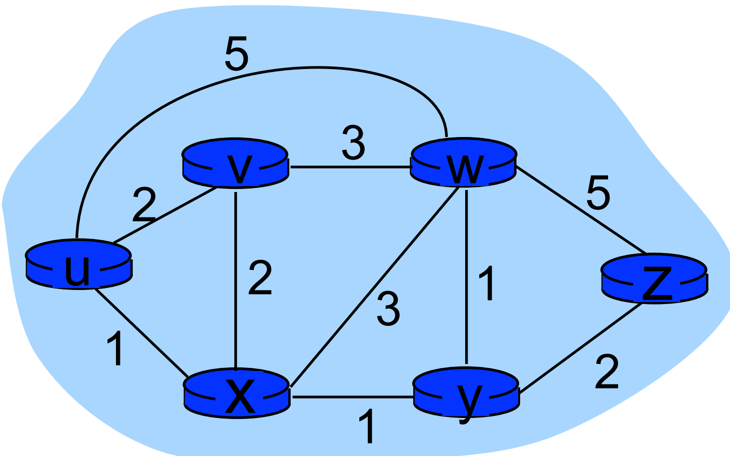
graph: G = (N,E)

N = set of routers = { u, v, w, x, y, z }

E = set of links ={ (u,v), (u,x), (v,x), (v,w), (x,w), (x,y), (w,y), (w,z), (y,z) }

aside: graph abstraction is useful in other network contexts, e.g., P2P, where *N* is set of peers and *E* is set of TCP connections

Graph abstraction: costs



$c(x,x')$ = cost of link (x,x')
e.g., $c(w,z) = 5$

cost could always be 1, or inversely related to bandwidth, or inversely related to congestion

cost of path $(x_1, x_2, x_3, \ldots, x_p) = c(x_1,x_2) + c(x_2,x_3) + \ldots + c(x_{p-1},x_p)$

key question: what is the least-cost path between u and z ?
routing algorithm: algorithm that finds that least cost path

Routing algorithm classification

Q: global or decentralized information?

global:

- all routers have complete topology, link cost info
- "link state" algorithms

decentralized:

- router knows physically-connected neighbors, link costs to neighbors
- iterative process of computation, exchange of info with neighbors
- "distance vector" algorithms

Q: static or dynamic?

static:

- routes change slowly over time

dynamic:

- routes change more quickly
  - periodic update
  - in response to link cost changes

Next lecture

- The Link-State (LS) Routing Algorithm
  - 4.5.1
- The Distance-Vector (DV) Routing Algorithm
  - 4.5.2
- Hierarchical Routing
  - 4.5.3

Assignment 4 submission and grading

- The deadline to submit your assignment 4 is 10 AM Friday March 20.
- The grading will be done in person.
- Your group will download the submitted code, and run to demonstrate the following to get points (Total points are **6**):

Assignment 4 submission and grading

- The DNS resolver can get query from dig client: 1 pt
- The DNS resolver can communicate with other resolver (root resolver, top level resolver): 1 pt
- Can resolve domain www.google.com 1 pt
- Can resolve domain www.uic.edu 0.5 pt
- Can resolve domain www.cs.uic.edu 0.5 pt
- Can get NXDomain answer for domain nonexistent.kaytwo.org 1pt
- Can resolve domain
- www.thelongestdomainnameintheworldandthensomeandthensomemoreandmore.com 0.5 pt
- Can send answer back to dig client correctly 0.5 pt

- There are some random questions to ensure that you have done and understood your code.

Assignment 4 submission and grading

- Your group needs to register to a 15-minutes slot to demo with me or the TA.
- For the TA slots, use this poll: http://doodle.com/hfuuh6dkvadpniri
- For my slots, use this http://doodle.com/vc7gz2f9xpc4bfhp
- I have created slots from 1:00-2:00 just in case your group cannot make the other slots. In these cases, the class on this Friday will be cancelled, but **I strongly recommend that you should avoid these slots** so that we still have class on Friday.