CN-Advanced
L43

Hierarchical Routing

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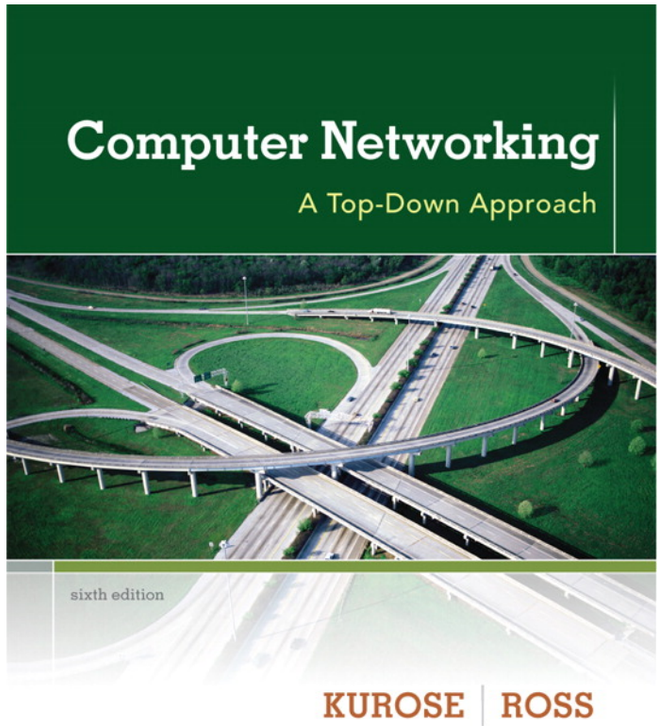
Chapter 4
Wireless and Mobile Networks



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Thanks and enjoy! JFK/KWR

Computer Networking: A Top Down Approach
6th edition
Jim Kurose, Keith Ross
Addison-Wesley
March 2012

Hierarchical routing

- *scale:* with 600 million destinations:
- can't store all dest's in routing tables!
- routing table exchange would swamp links!
- computing cost too high

- our routing study thus far - idealization
  - all routers identical
  - network "flat"
  - … *not* true in practice

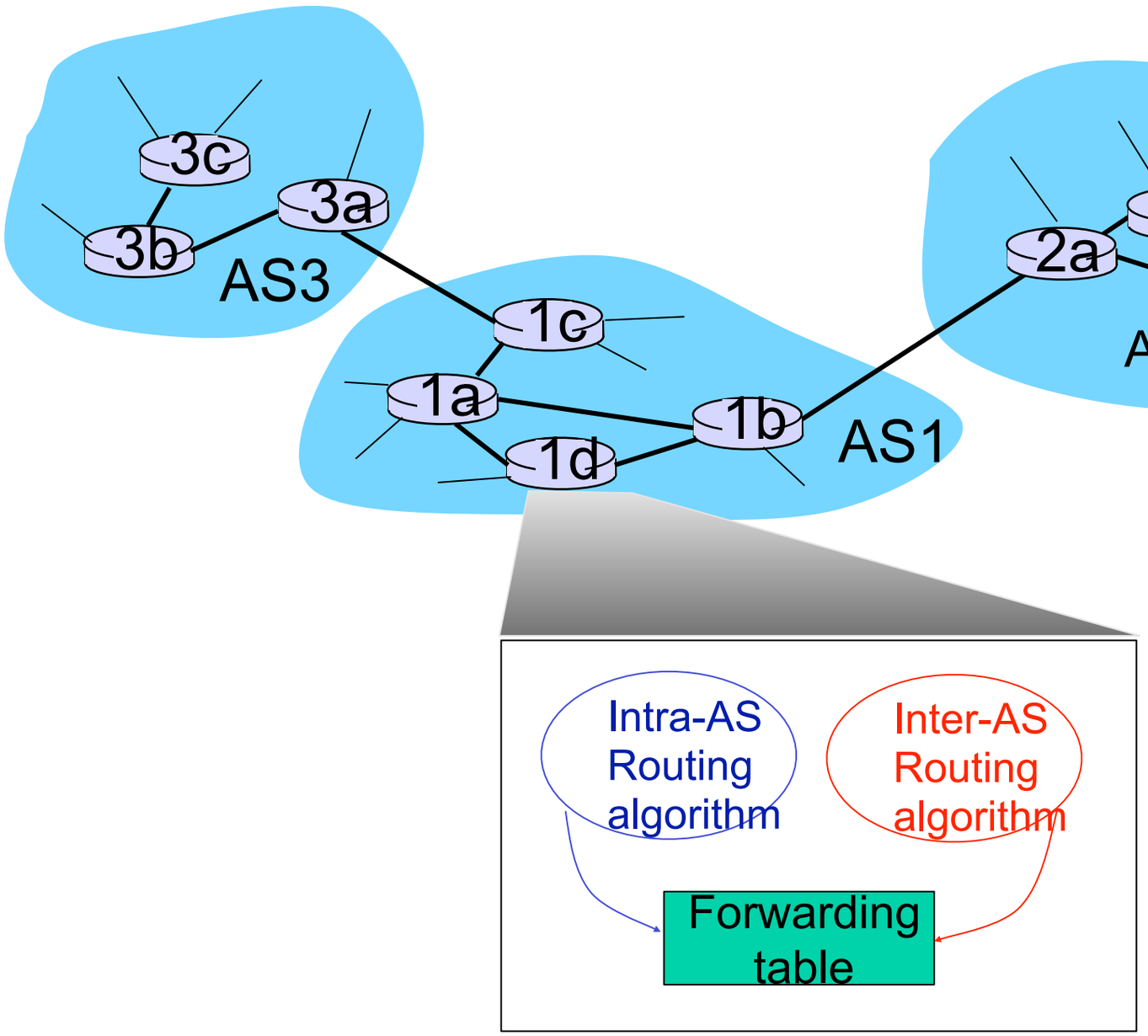
- *administrative autonomy*
  - internet = network of networks
  - each network admin may want to control routing in its own network

Hierarchical routing

- aggregate routers into regions, "autonomous systems" (AS)
- routers in same AS run same routing protocol
  - "intra-AS" routing protocol
  - routers in different AS can run different intra-AS routing protocol

- *gateway router:*
- at "edge" of its own AS
- has link to router in another AS

Interconnected ASes



- forwarding table configured by both intra- and inter-AS routing algorithm
  - intra-AS sets entries for internal dests
  - inter-AS & intra-AS sets entries for external dests

How is AS1 forwarding table different from those of AS2 or AS3?

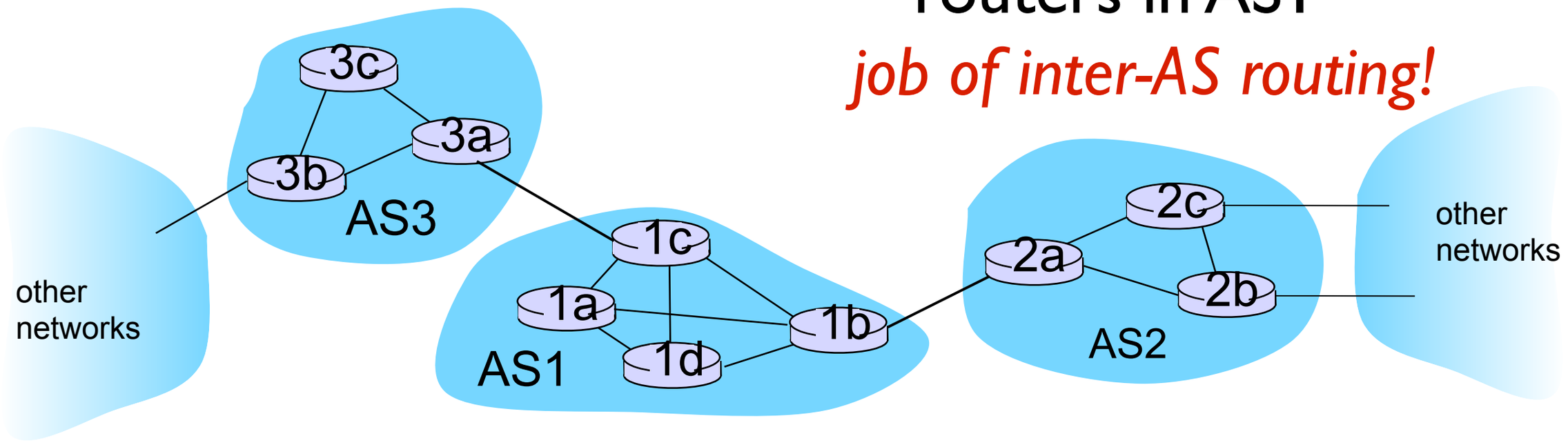
Inter-AS tasks

- suppose router in AS1 receives datagram destined outside of AS1:
  - router should forward packet to gateway router, but which one?

AS1 must:

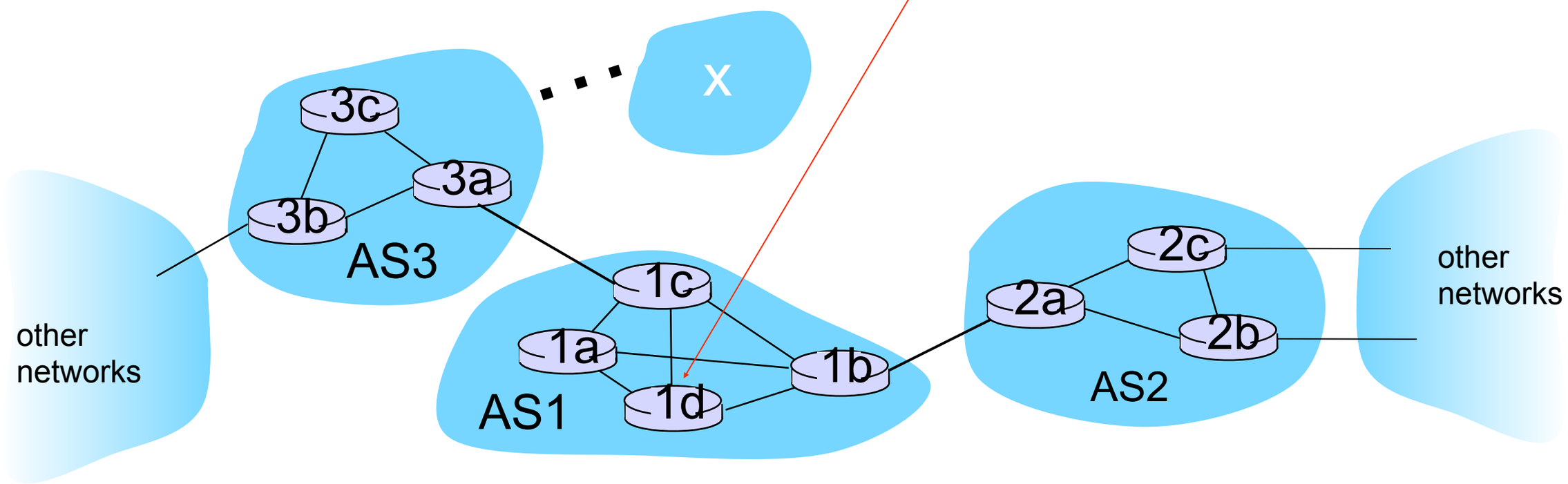
1. learn which dests are reachable through AS2, which through AS3
2. propagate this reachability info to all routers in AS1

job of inter-AS routing!



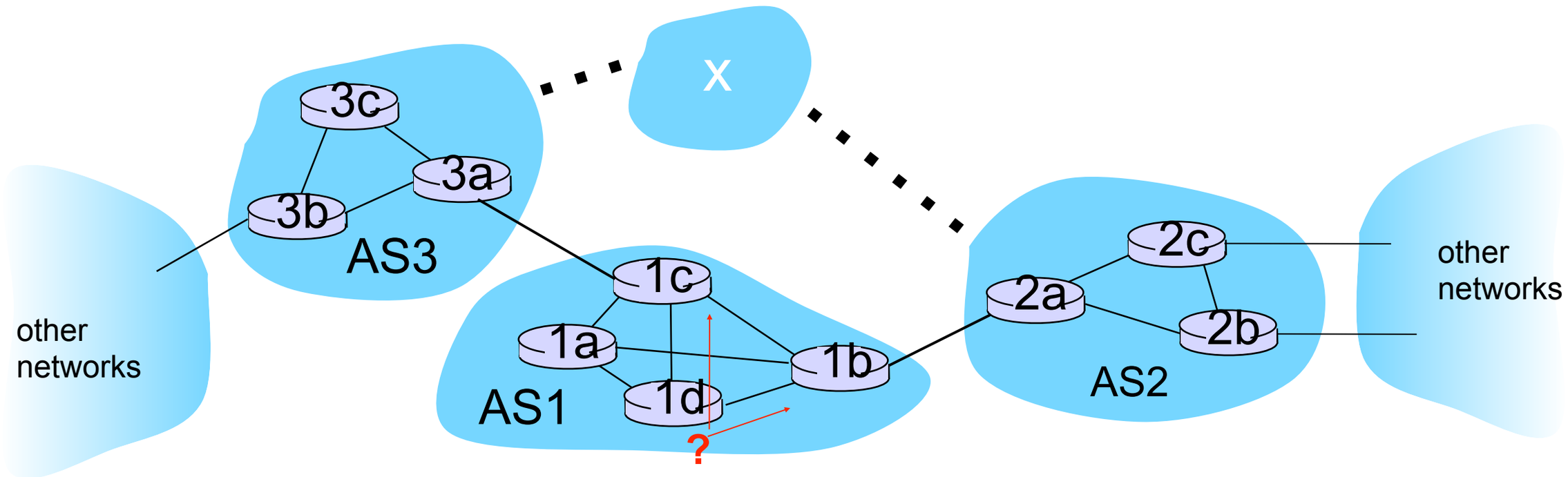
Example: setting forwarding table in router 1d

- suppose AS1 learns (via inter-AS protocol) that subnet *x* reachable via AS3 (gateway 1c), but not via AS2
  - inter-AS protocol propagates reachability info to all internal routers
- router 1d determines from intra-AS routing info that its interface *I* is on the least cost path to 1c
  - installs forwarding table entry *(x,I)*



Example: choosing among multiple ASes

- now suppose AS1 learns from inter-AS protocol that subnet *x* is reachable from AS3 *and* from AS2.
- to configure forwarding table, router `1d` must determine which gateway it should forward packets towards for dest x
- this is also job of inter-AS routing protocol!



Example: choosing among multiple ASes

- now suppose AS1 learns from inter-AS protocol that subnet *x* is reachable from AS3 *and* from AS2.
- to configure forwarding table, router `1d` must determine towards which gateway it should forward packets for dest x
  - this is also job of inter-AS routing protocol!
- *hot potato routing: send* packet towards closest of two routers.

Adding Outside AS info to Forwarding Table

learn from inter-AS protocol that subnet *x* is reachable via multiple gateways

→ use routing info from intra-AS protocol to determine costs of least-cost paths to each of the gateways

↓

hot potato routing: choose the gateway that has the smallest least cost

↓

determine from forwarding table the interface *I* that leads to least-cost gateway. Enter *(x, I)* in forwarding table

ISP and AS

- Does one ISP impley one AS?
  - Some ISP break their network into multiple ASs

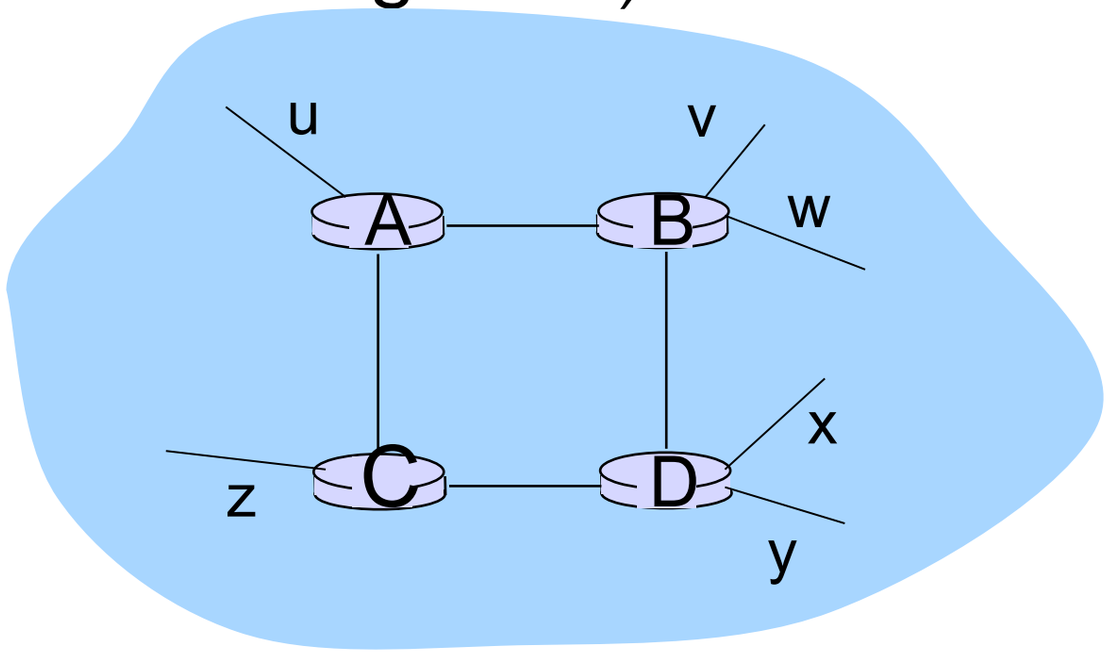
- Summary -
  - What AS achieves
    - Problem of scale
    - Problem of autonomy
  - Routers within AS run same Intra-AS routing protocol
  - Two ASs run same Inter-AS routing protocol
  - Inter AS protocol provides policy support

Intra-AS Routing

- also known as *interior gateway protocols (IGP)*
- most common intra-AS routing protocols:
  - RIP: Routing Information Protocol
    - RFC 1058, RIPv1
    - RFC 2453 RIPv2
  - OSPF: Open Shortest Path First
    - RFC 2328 OSPFv2
  - IGRP: Interior Gateway Routing Protocol (Cisco proprietary)

RIP (Routing Information Protocol)

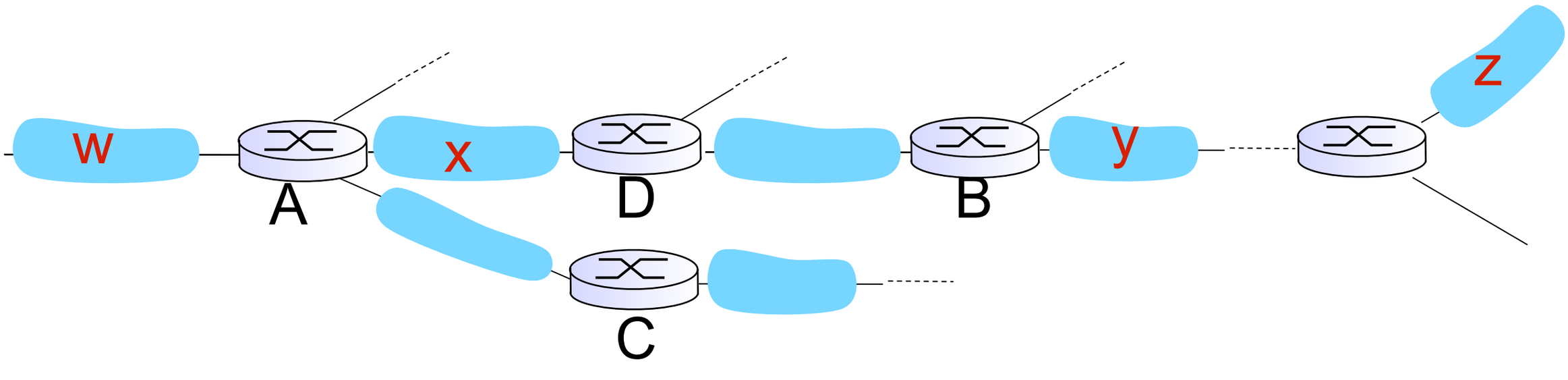
- Included in BSD-UNIX supporting TCP/IP in 1982
  - Reason for widespread distribution
- distance vector algorithm
  - distance metric: # hops (max = `15` hops), each link has cost `1`
  - DVs exchanged with neighbors every 30 sec in response message (aka advertisement)
  - each advertisement: list of up to 25 destination *subnets (in IP addressing sense)*



from router A to destination *subnets:*

subnet	hops
u	1
v	2
w	2
x	3
y	3
z	2

RIP: example



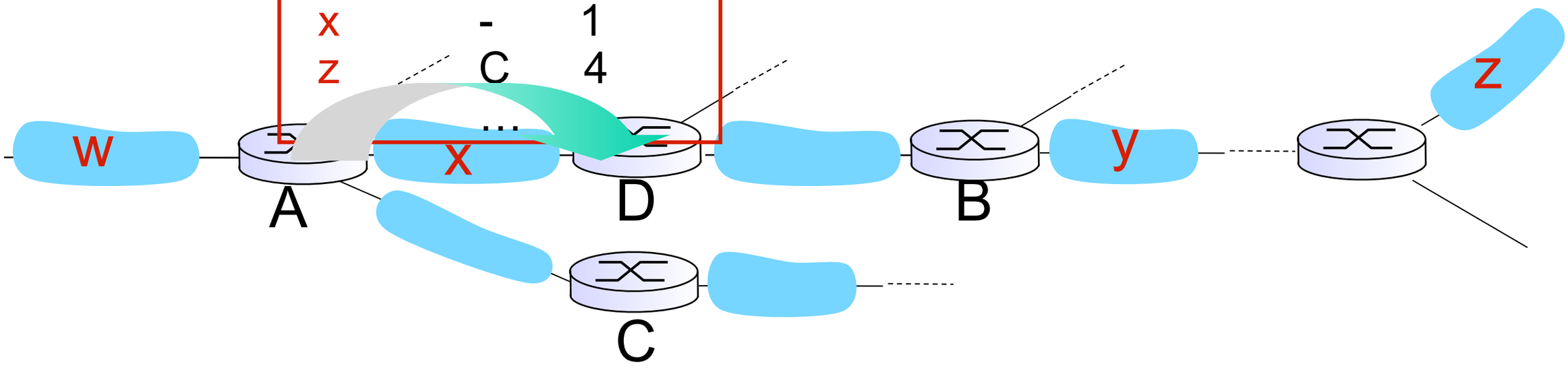
routing table in router D

destination subnet	next router	# hops to dest
w	A	2
y	B	2
z	B	7
x	--	1
….	….	….

RIP: example

A-to-D advertisement

dest	next	hops
w	-	1
x	-	1
z	C	4
	...	



routing table in router D

destination subnet	next router	# hops to dest
w	A	2
y	B	2
z	B A	7 5
x	--	1
....	....	....

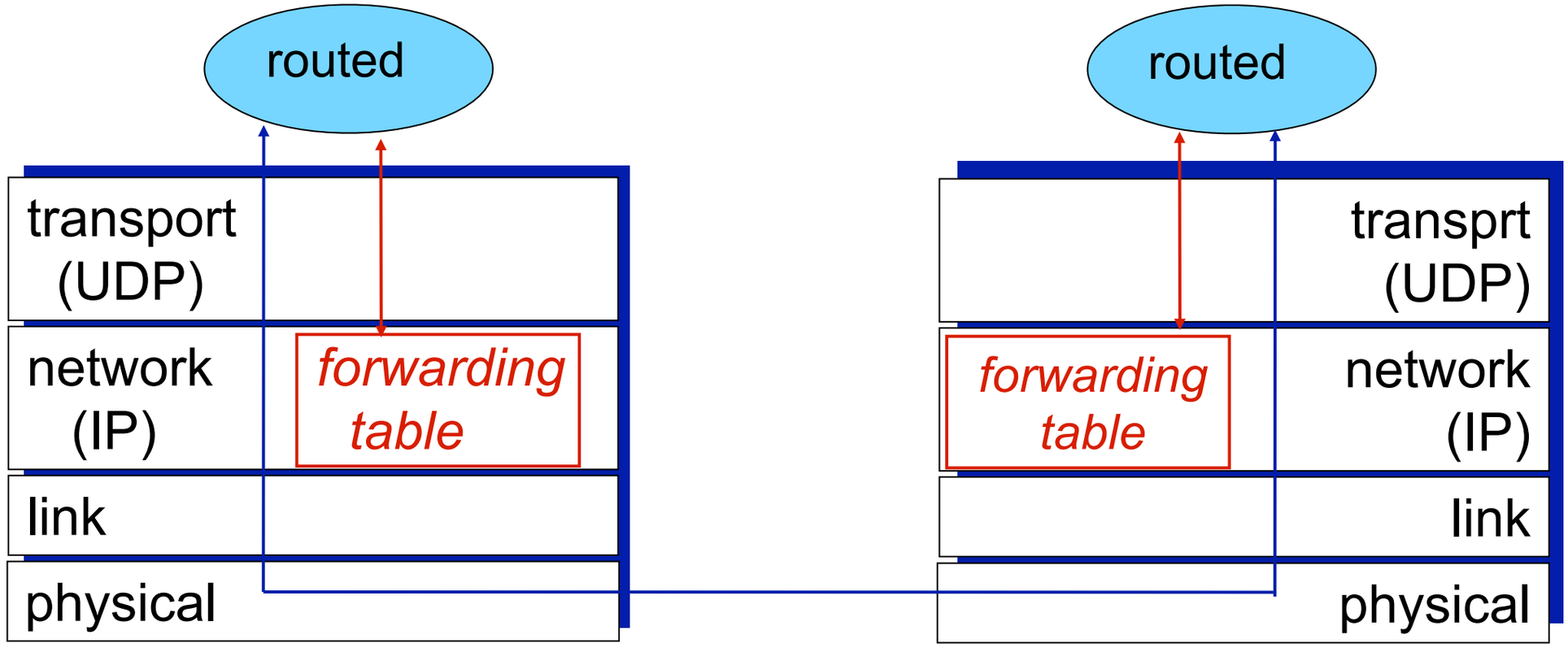
RIP: link failure, recovery

if no advertisement heard after 180 sec --> neighbor/ link declared dead

- routes via neighbor invalidated
- new advertisements sent to neighbors
- neighbors in turn send out new advertisements
  - (if tables changed)
- link failure info quickly (?) propagates to entire net
- *poison reverse* used to prevent ping-pong loops (infinite distance = 16 hops)

RIP table processing

- RIP routing tables managed by *application-level* process called route-d (daemon)
- advertisements sent in UDP packets, periodically repeated



RIP

- RIPv1
  - works with classful networks
- RIPv2
  - works with CIDR
  - communicates network mask along with network number
  - supports aggregation and hierarchical routing

Routing protocols on Linux

- Quagga protocol suite
  - **http://www.quagga.net**

Summary

- Hierarchical Routing
- Interconnected ASes
- Inter AS tasks
- RIP