

# Network Layer

## Part 5

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HIERARCHICAL ROUTING

INTRA DOMAIN ROUTING (RIP, OSPF)

# Hierarchical routing

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our routing study thus far - idealization

- ❖ all routers identical
- ❖ network “flat”

... *not* true in practice

*scale:* with 600 million destinations: *administrative autonomy*

can't store all dest's in routing tables!

routing table exchange would swamp links!

❖ 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

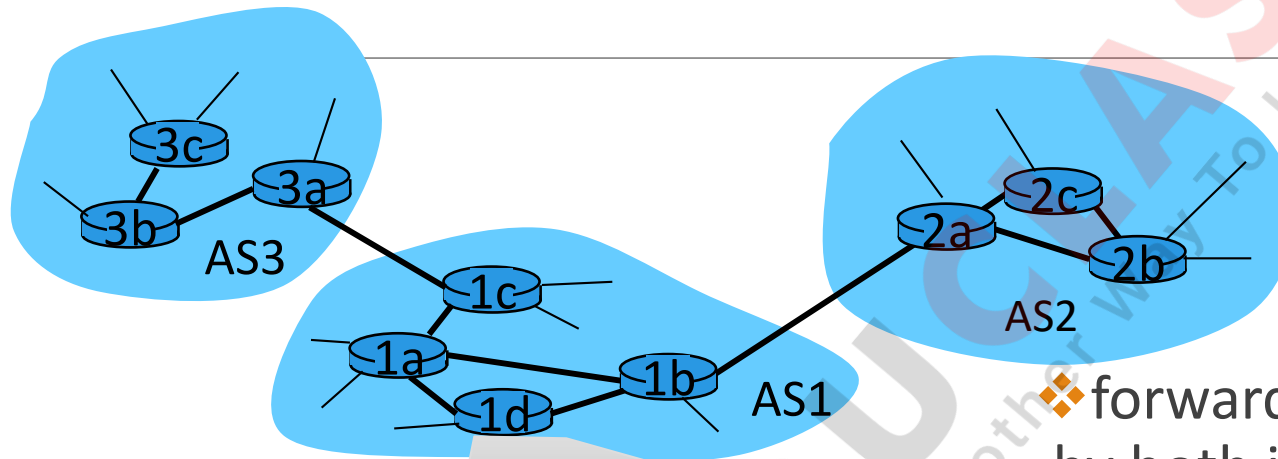
- “intra-AS” routing protocol
- routers in different AS can run  
different intra-AS routing protocol

*gateway router:*

at “edge” of its own AS

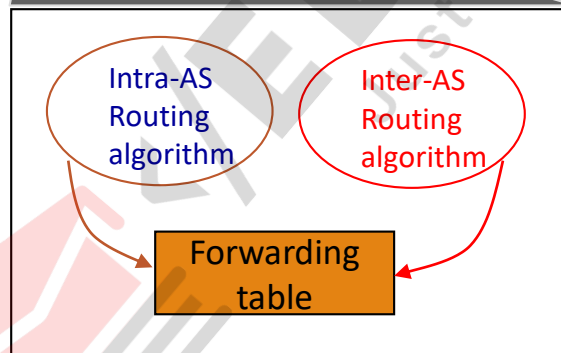
has link to router in another  
AS

# 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



# Inter-AS tasks

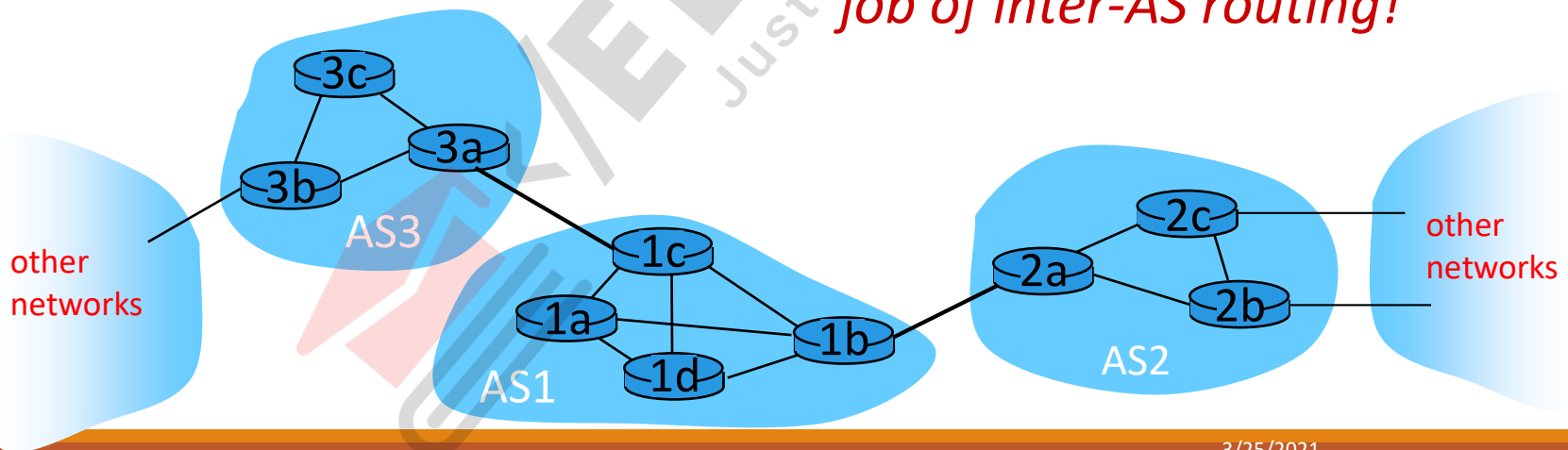
❖ suppose router in AS1 receives datagram destined outside of AS1:

- router should forward packet to gateway router, but which one?

*AS1 must:*

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

*job of inter-AS routing!*



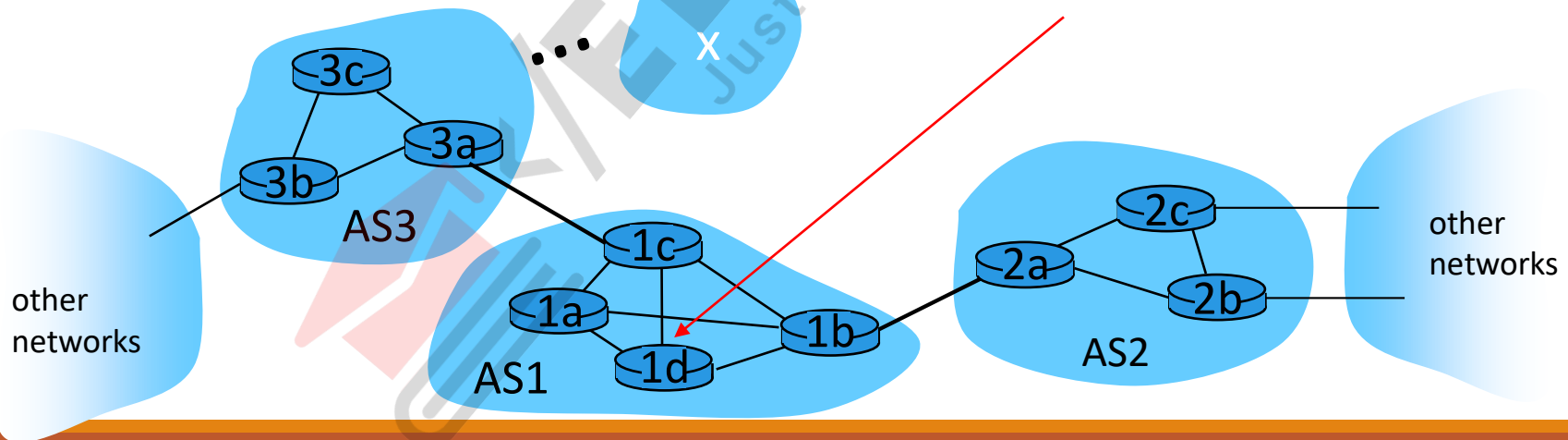
## Example: setting forwarding table in router 1d

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 **l** is on the least cost path to 1c

- installs forwarding table entry **(x, l)**

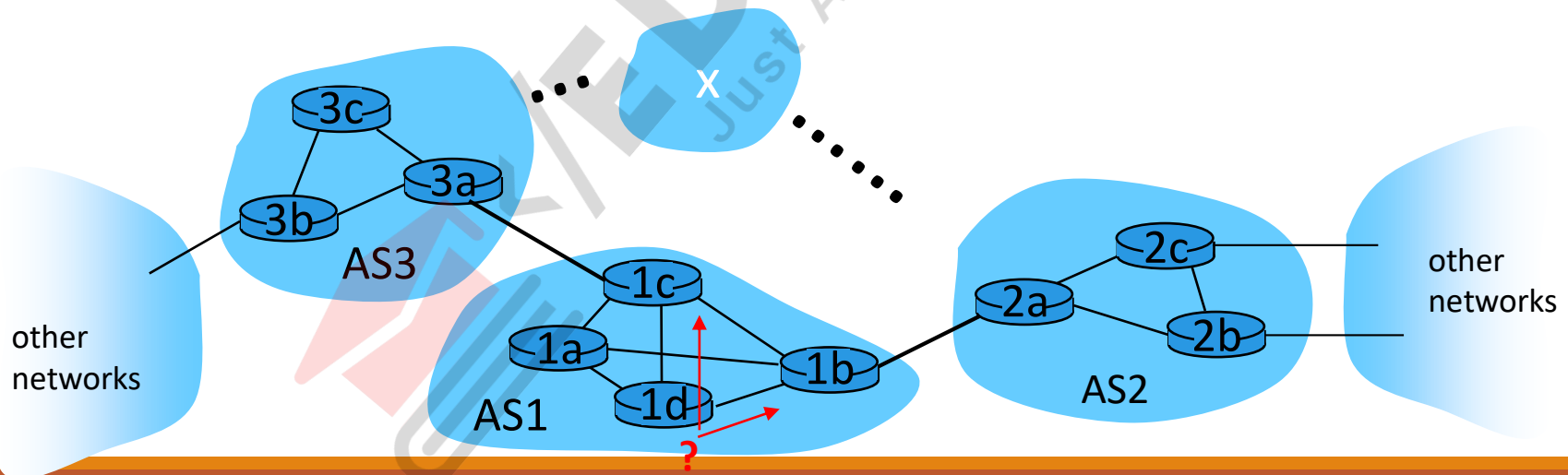


# Example: choosing among multiple ASes

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!



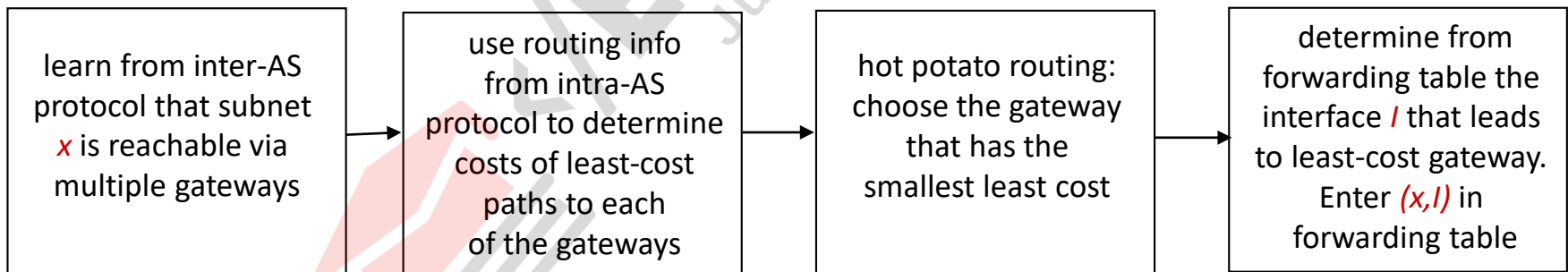
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to configure forwarding table, router 1d must determine towards which gateway it should forward packets for dest **x**

- this is also job of inter-AS routing protocol!

**hot potato routing: send** packet towards closest of two routers.





# Routing in the Internet

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Intra-AS Routing

Inter-AS Routing



# Intra-AS Routing

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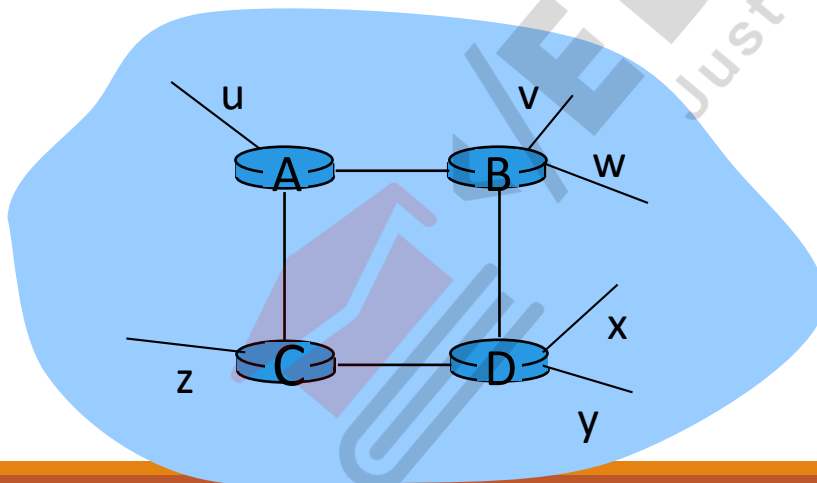
- ❖ also known as *interior gateway protocols (IGP)*
- ❖ most common intra-AS routing protocols:
  - RIP: Routing Information Protocol
  - OSPF: Open Shortest Path First
  - IGRP: Interior Gateway Routing Protocol (Cisco proprietary)

# RIP ( Routing Information Protocol)

included in BSD-UNIX distribution in 1982

distance vector algorithm

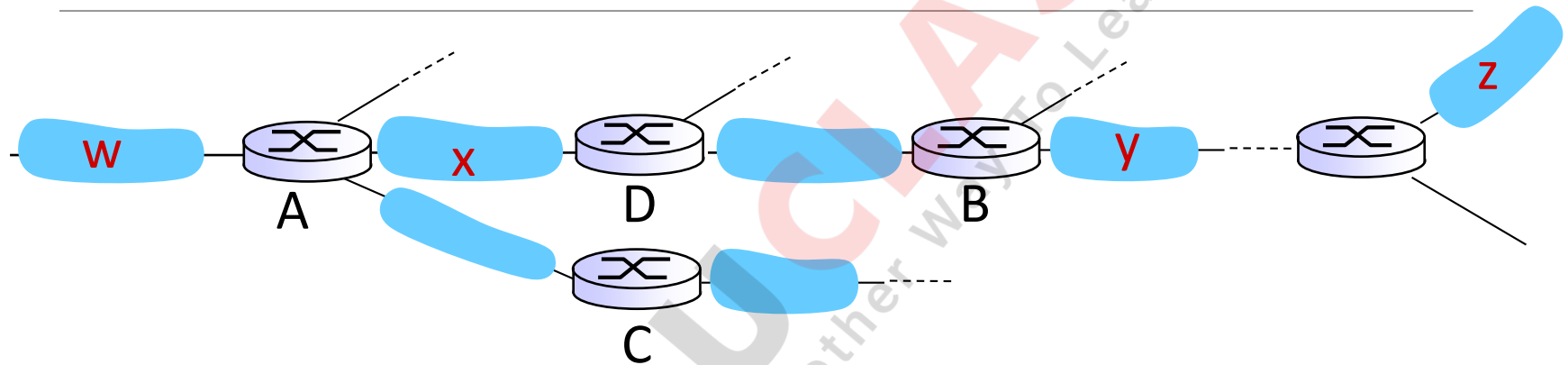
- distance metric: # hops (max = 15 hops), each link has cost 1
- DVs exchanged with neighbors every 30 sec in response message (aka **advertisement**)
- each advertisement: list of up to 25 destination **subnets** (in IP addressing sense)



from router A to destination **subnets**:

<u>subnet</u>	<u>hops</u>
u	1
v	2
w	2
x	3
y	3
z	2

# RIP: example



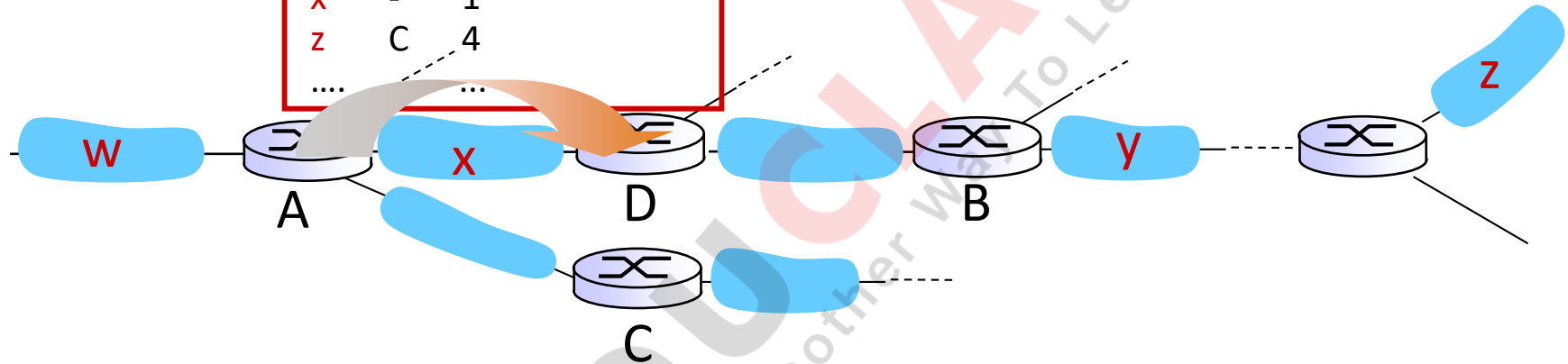
routing table in router D

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	7	
X	--	1	
....	....	....	

→ A

→ 5

# RIP: link failure, recovery

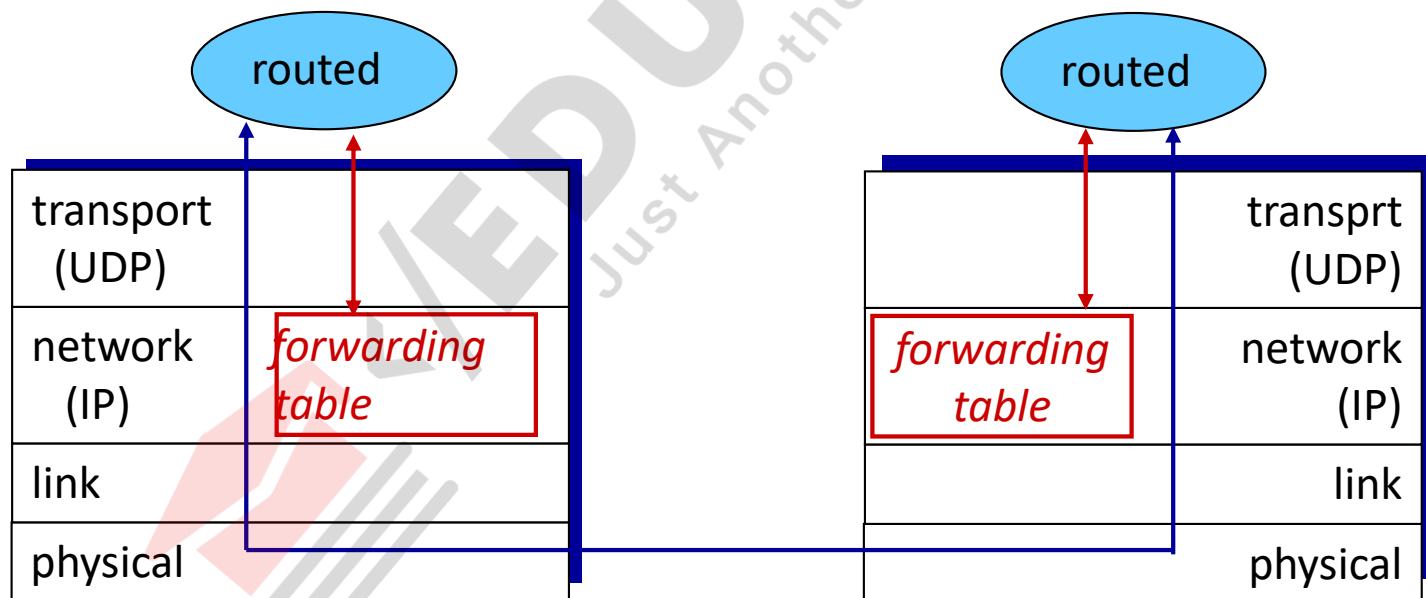
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if no advertisement heard after 180 sec --> neighbor/link declared dead

- 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



# OSPF (Open Shortest Path First)

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“open”: publicly available

uses link state algorithm

- LS packet dissemination
- topology map at each node
- route computation using Dijkstra's algorithm

OSPF advertisement carries one entry per neighbor

advertisements flooded to *entire* AS

- carried in OSPF messages directly over IP (rather than TCP or UDP)

*IS-IS routing* protocol: nearly identical to OSPF



# OSPF “advanced” features (not in RIP)

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**security:** all OSPF messages authenticated (to prevent malicious intrusion)

**multiple same-cost paths allowed** (only one path in RIP)

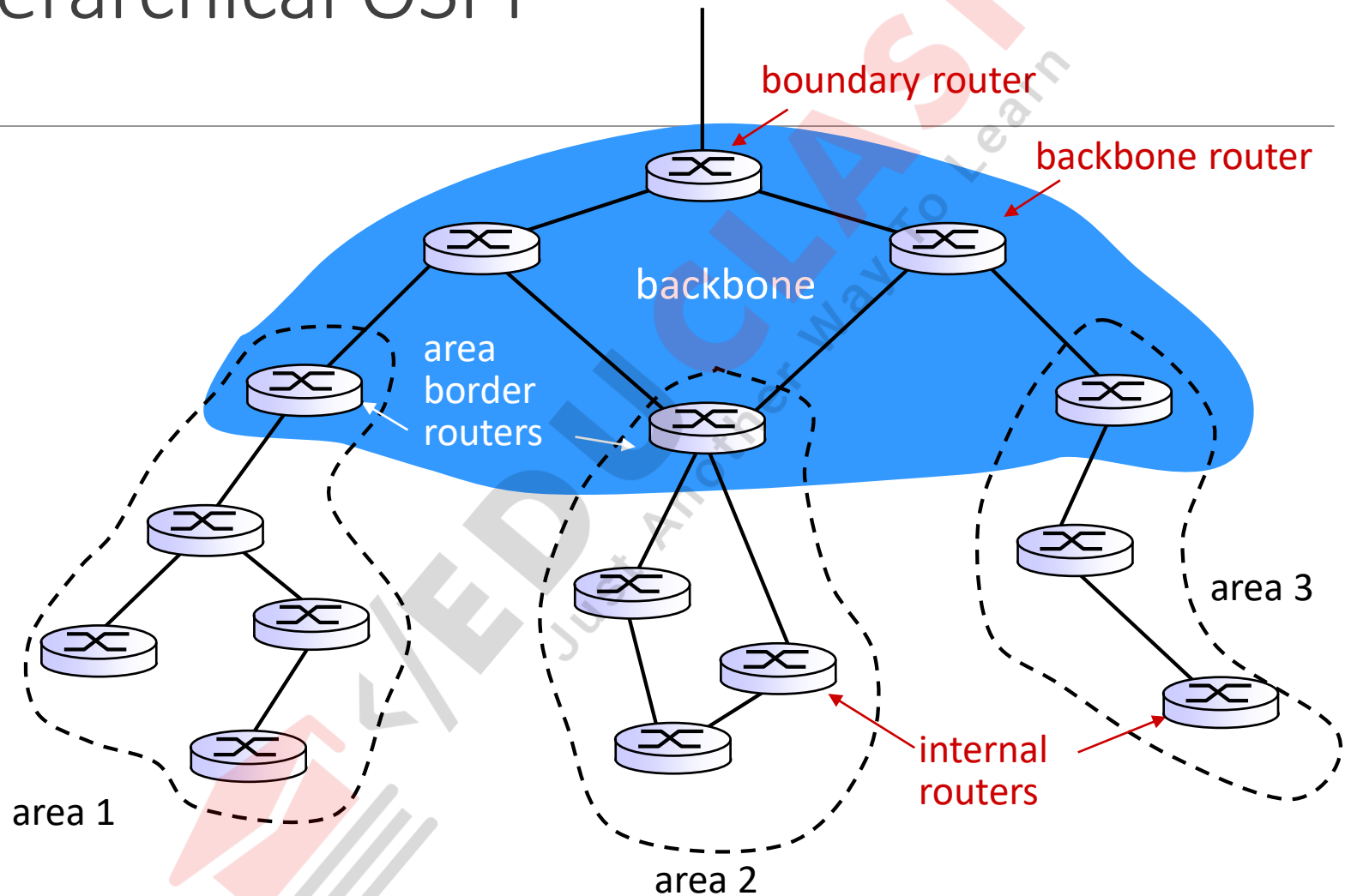
- for each link, multiple cost metrics for different **TOS** (e.g., satellite link cost set “low” for best effort ToS; high for real time ToS)

**integrated uni- and multicast support:**

- Multicast OSPF (MOSPF) uses same topology data base as OSPF

**hierarchical** OSPF in large domains.

# Hierarchical OSPF



# Hierarchical OSPF

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*two-level hierarchy:* local area, backbone.

- link-state advertisements only in area
- each nodes has detailed area topology; only know direction (shortest path) to nets in other areas.

*area border routers:* “summarize” distances to nets in own area, advertise to other Area Border routers.

*backbone routers:* run OSPF routing limited to backbone.

*boundary routers:* connect to other AS' s.