Network Layer
Part 8

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EECS 325/425
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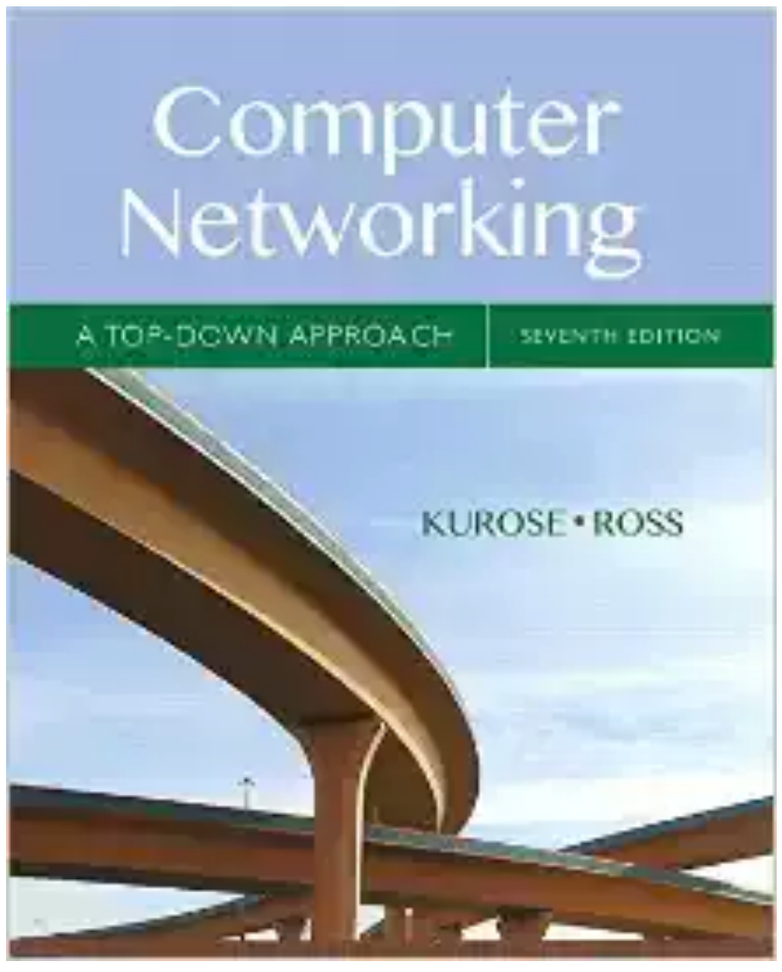
"my, my, my, … these are lawless times …"

These slides are more-or-less directly from the slide set developed by Jim Kurose and Keith Ross for their book "Computer Networking: A Top Down Approach, 5th edition".

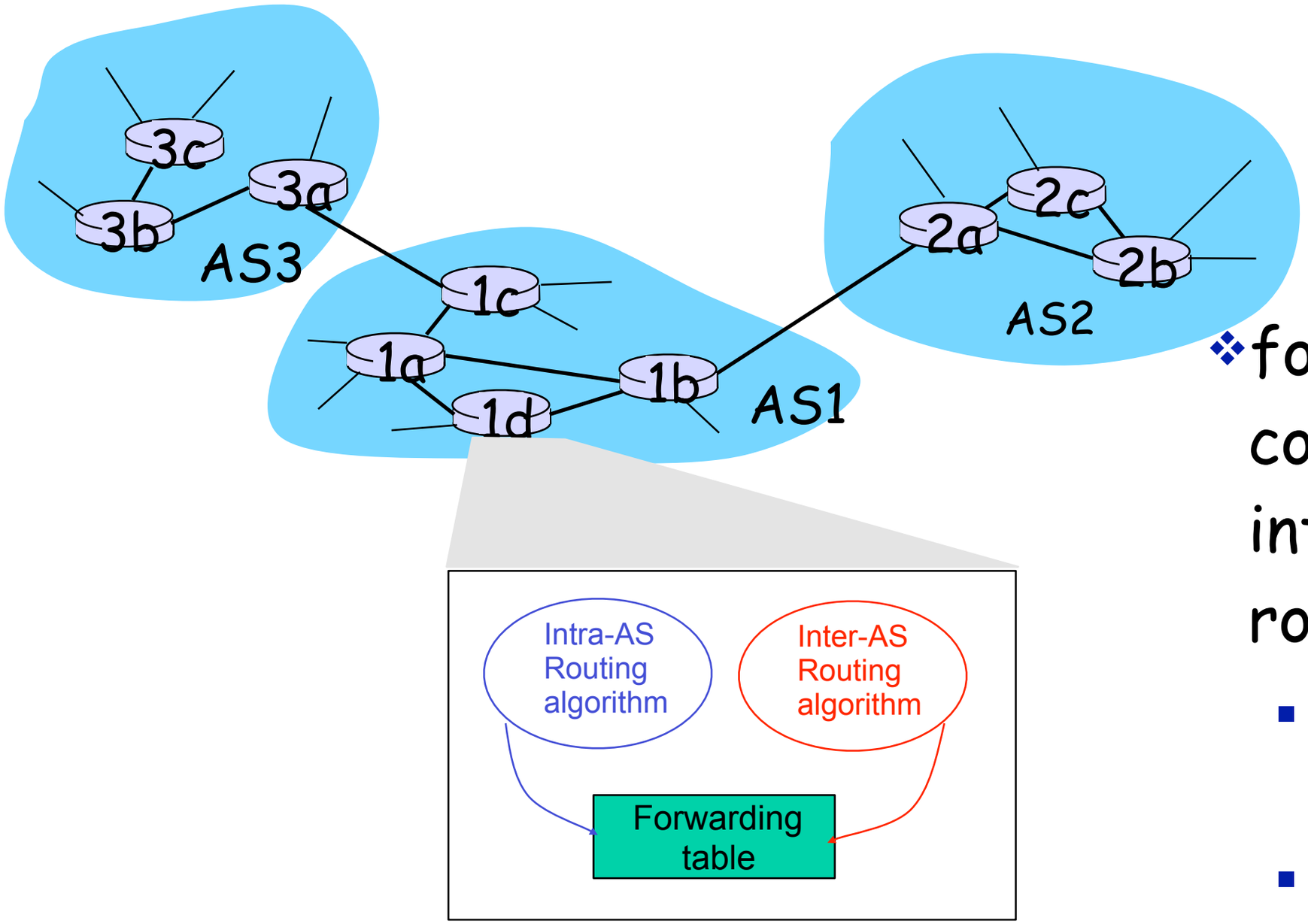
The slides have been lightly adapted for Mark Allman's EECS 325/425 Computer Networks class at Case Western Reserve University.

Reading Along ...



- Network layer is chapters 4 & 5
  - Hierarchical Routing

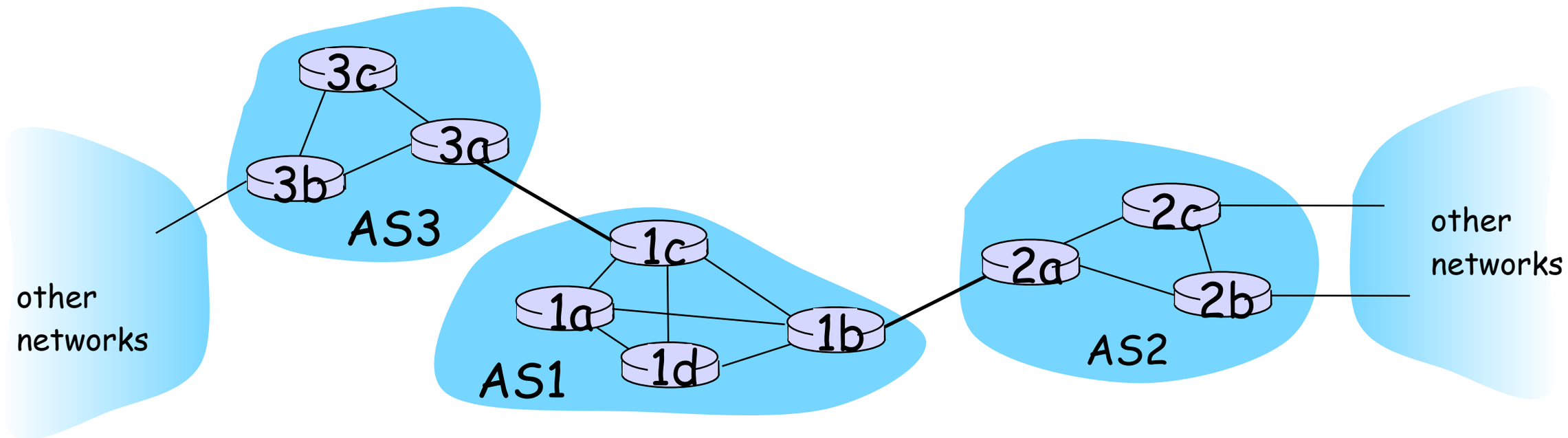
Interconnected ASes



- 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?



Inter-AS tasks

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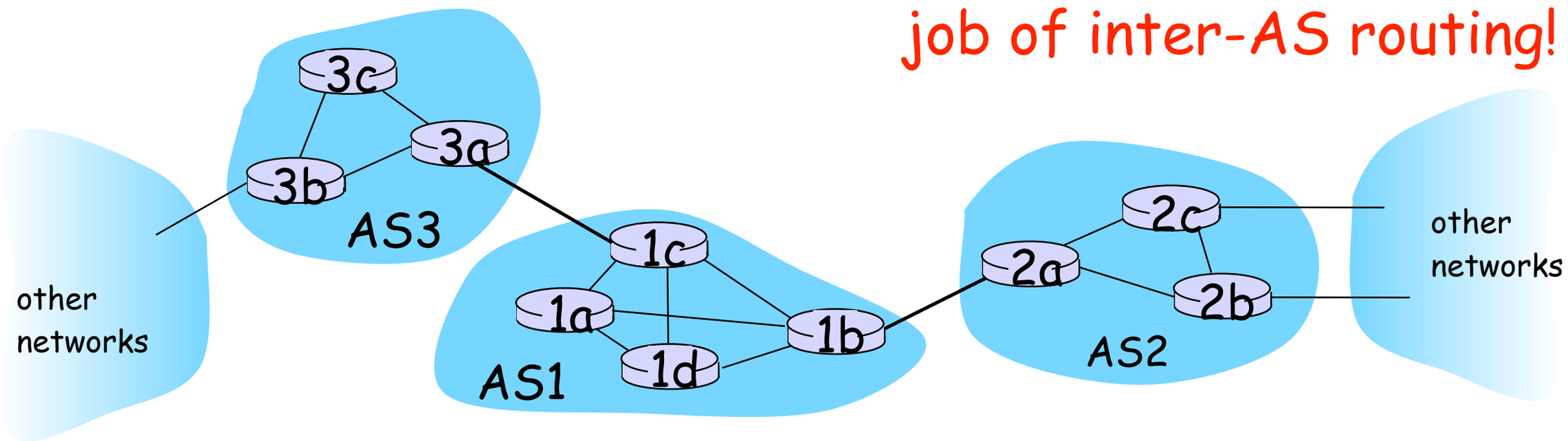
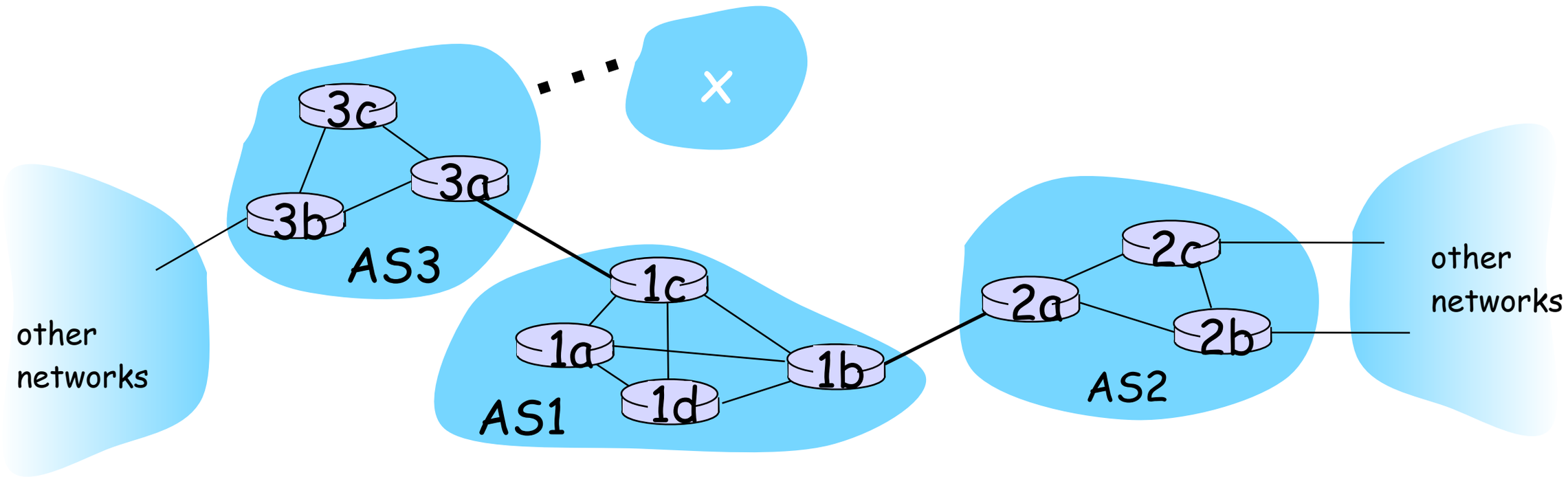
AS1 must:

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



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.
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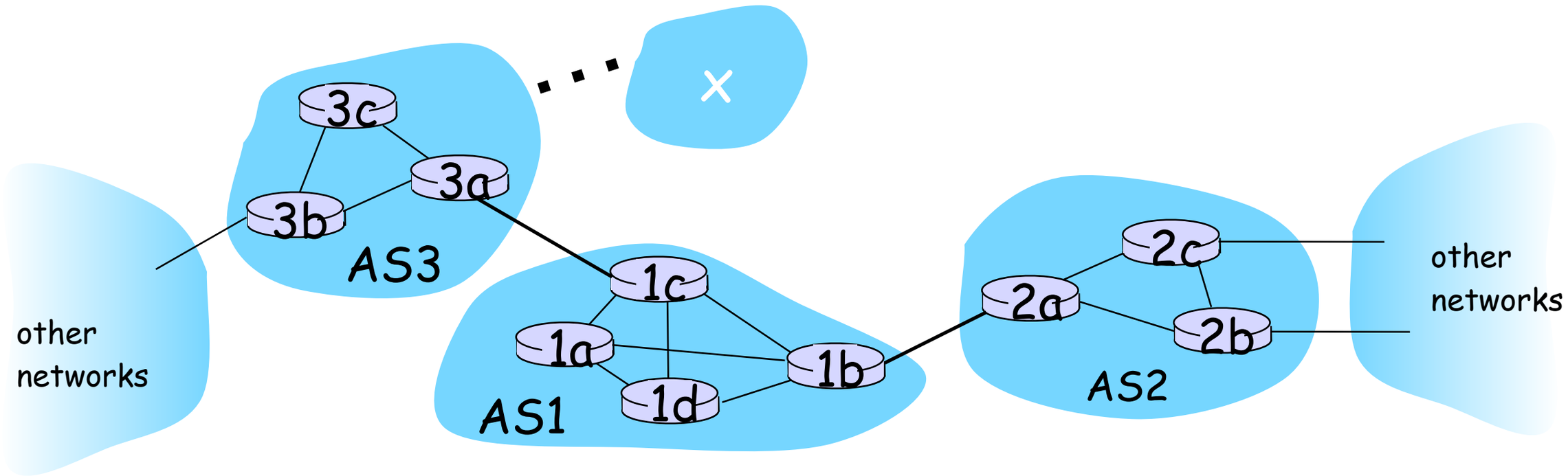

Example: Setting forwarding table in router 1d

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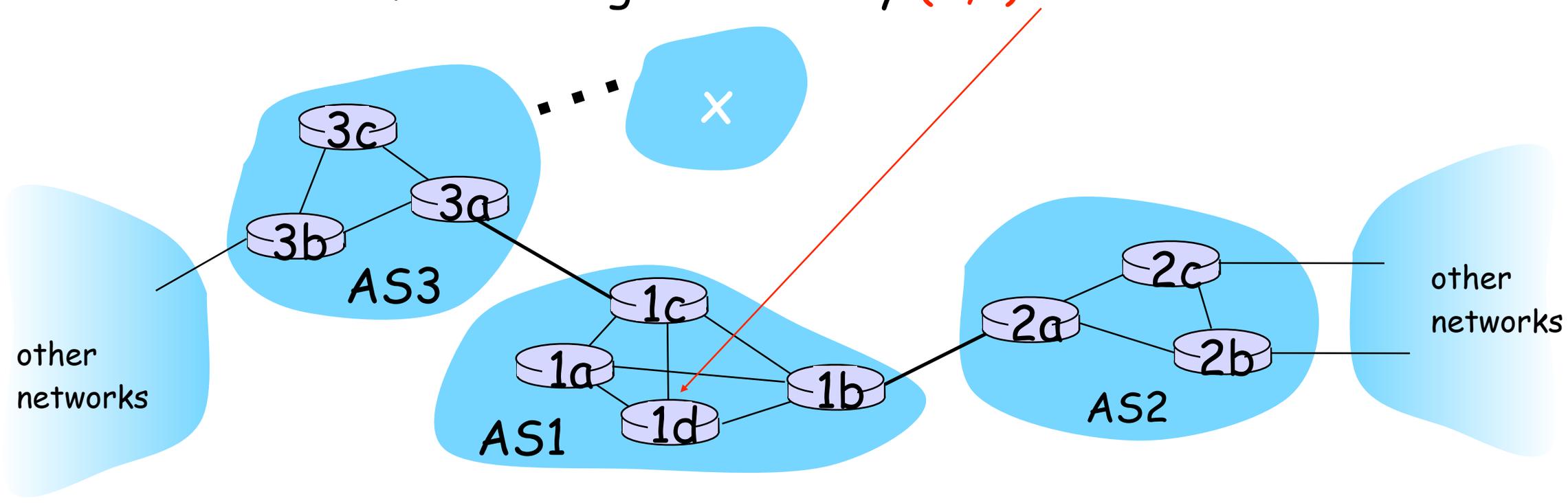
  - inter-AS protocol propagates reachability info to all internal routers
- router 1d determines from intra-AS routing info that its interface I is on the least cost path to 1c.
  - installs forwarding table entry (x,I)



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
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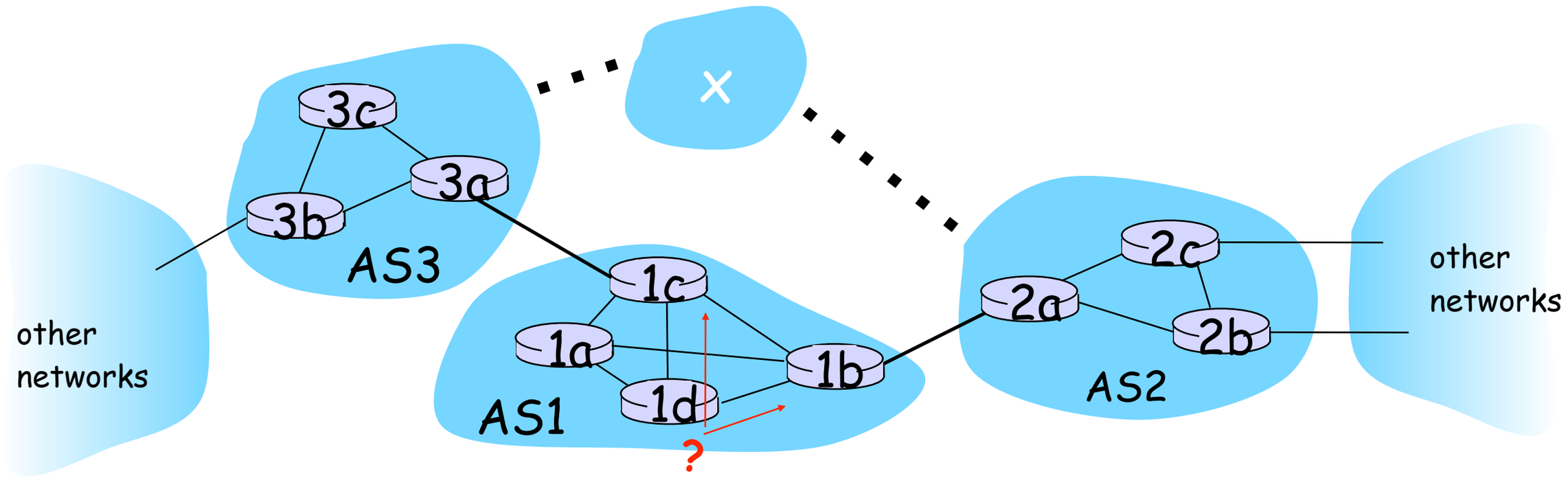

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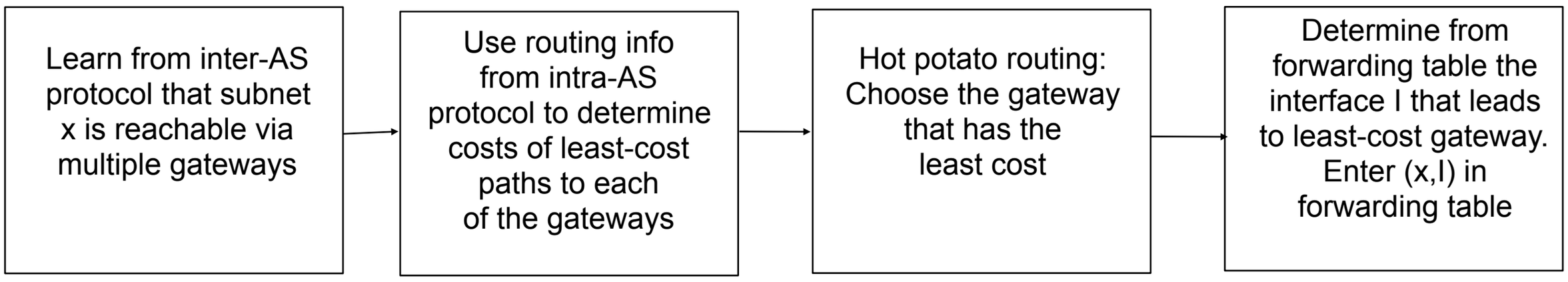
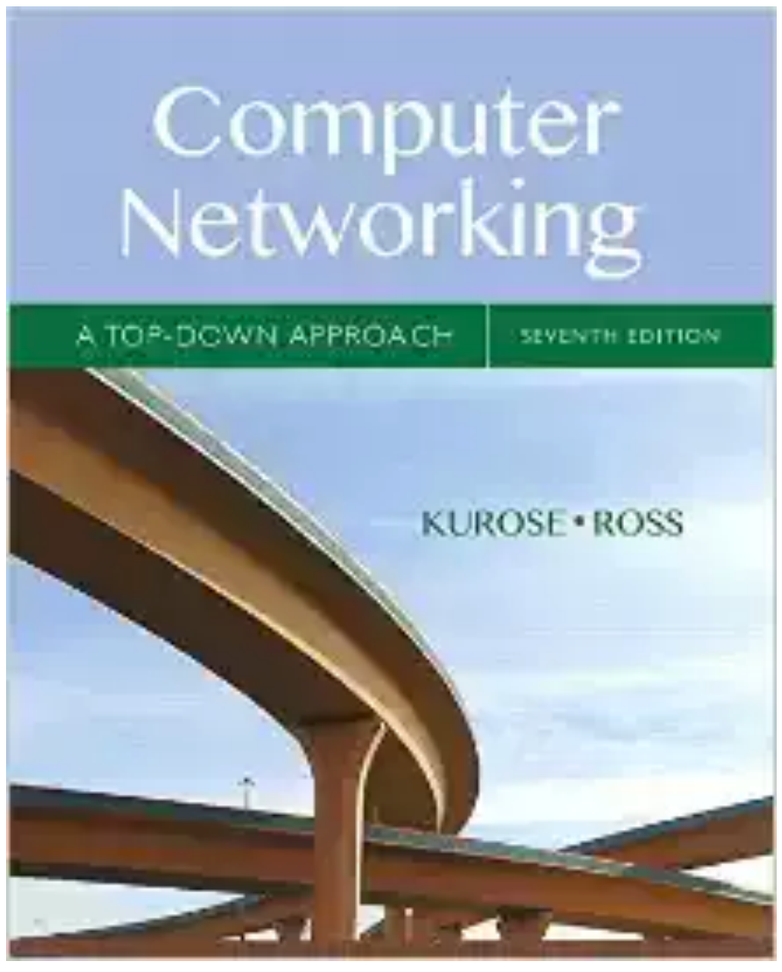
- hot potato routing: send packet towards closest of two routers.



Intra-AS Routing

- 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)

Reading Along ...



- Network layer is chapters 4 & 5
  - Routing Among ISPs

Internet inter-AS routing: BGP

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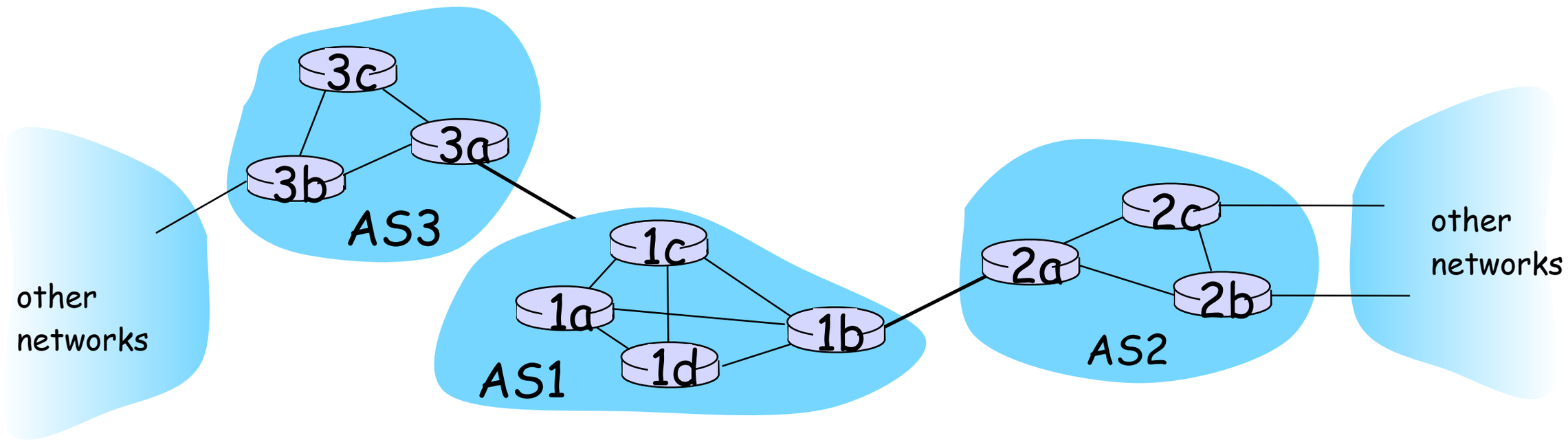
- BGP provides each AS a means to:
  - eBGP: obtain subnet reachability information from neighboring ASs.
  - iBGP: propagate reachability information to all AS-internal routers.
  - determine "good" routes to other networks based on reachability information and policy.

BGP basics

- BGP session: two BGP routers ("peers") exchange BGP messages:
  - advertising paths to different destination network prefixes ("path vector" protocol)
  - exchanged over semi-permanent TCP connections



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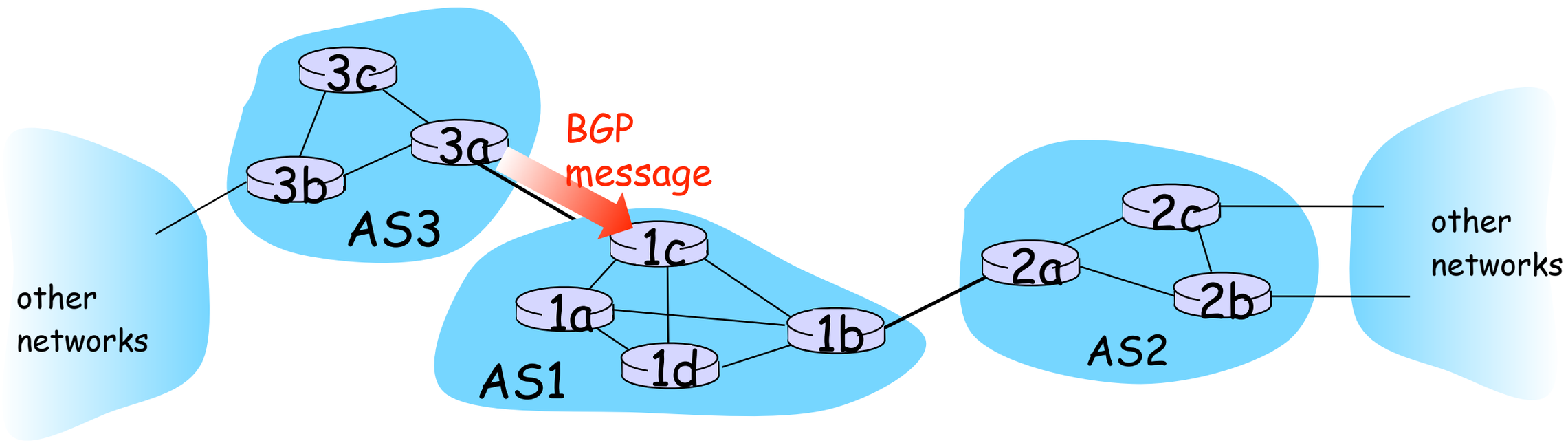
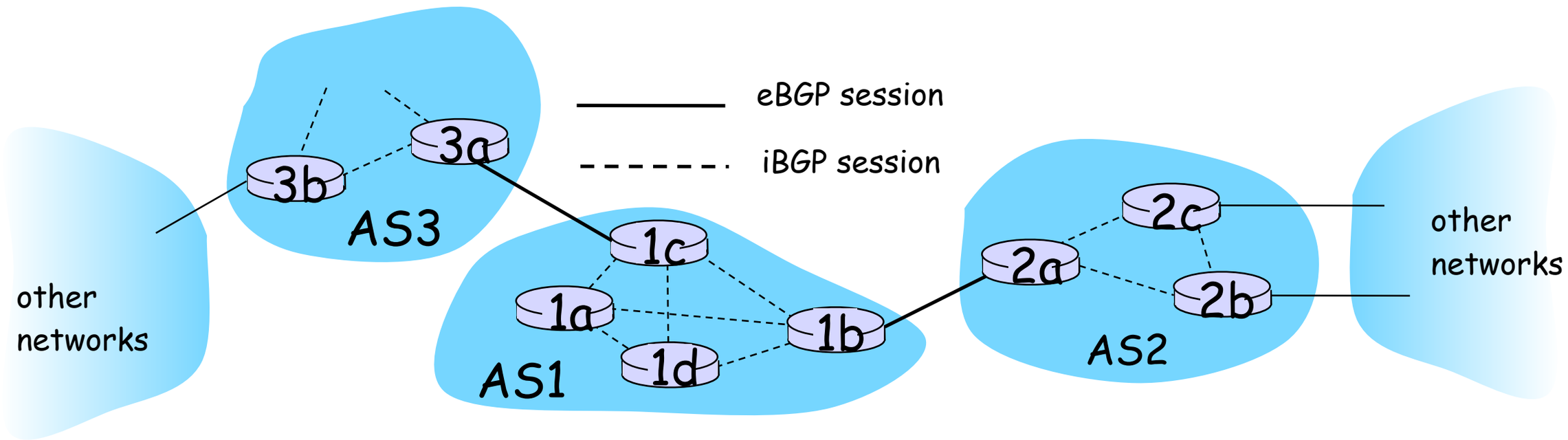
- when AS3 advertises a prefix to AS1:
  - AS3 promises it will forward datagrams towards that prefix
  - AS3 can aggregate prefixes in its advertisement



BGP basics: distributing path information



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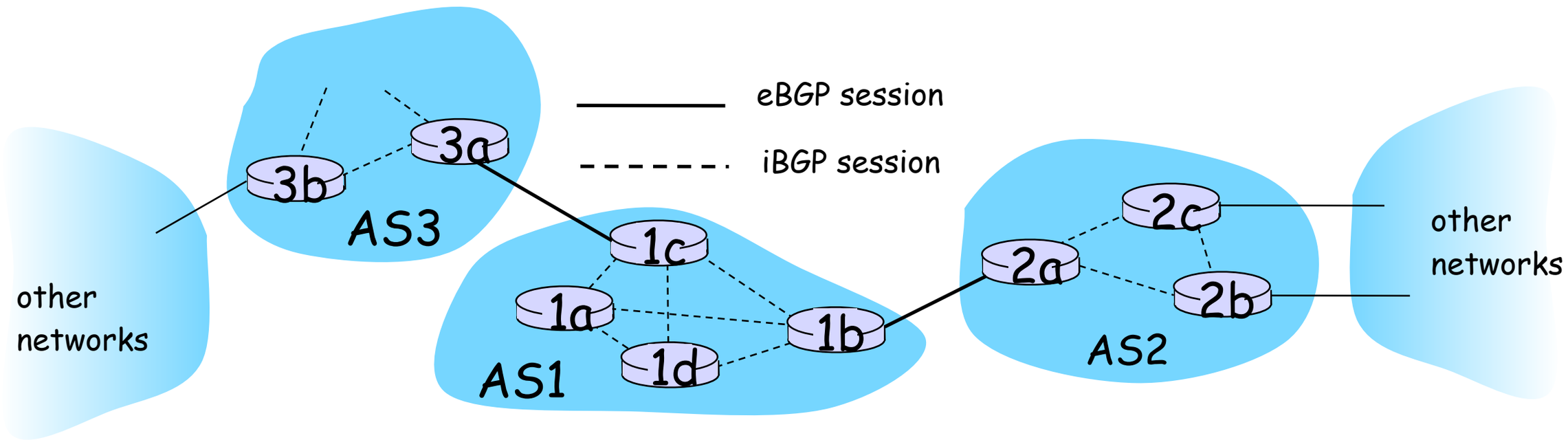
- using eBGP session between 3a and 1c, AS3 sends prefix reachability info to AS1.



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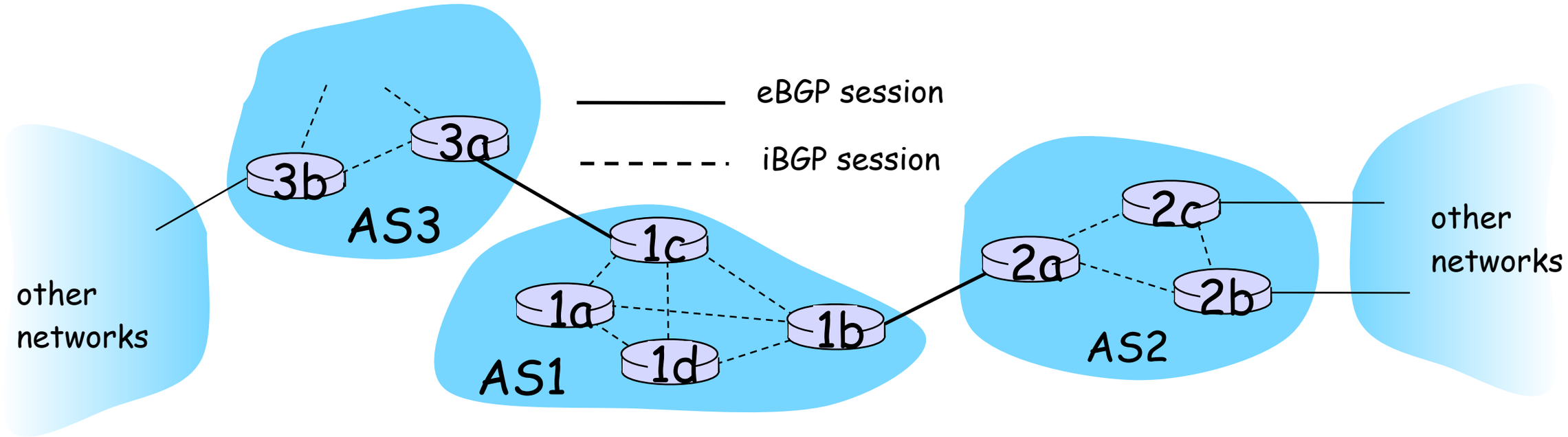

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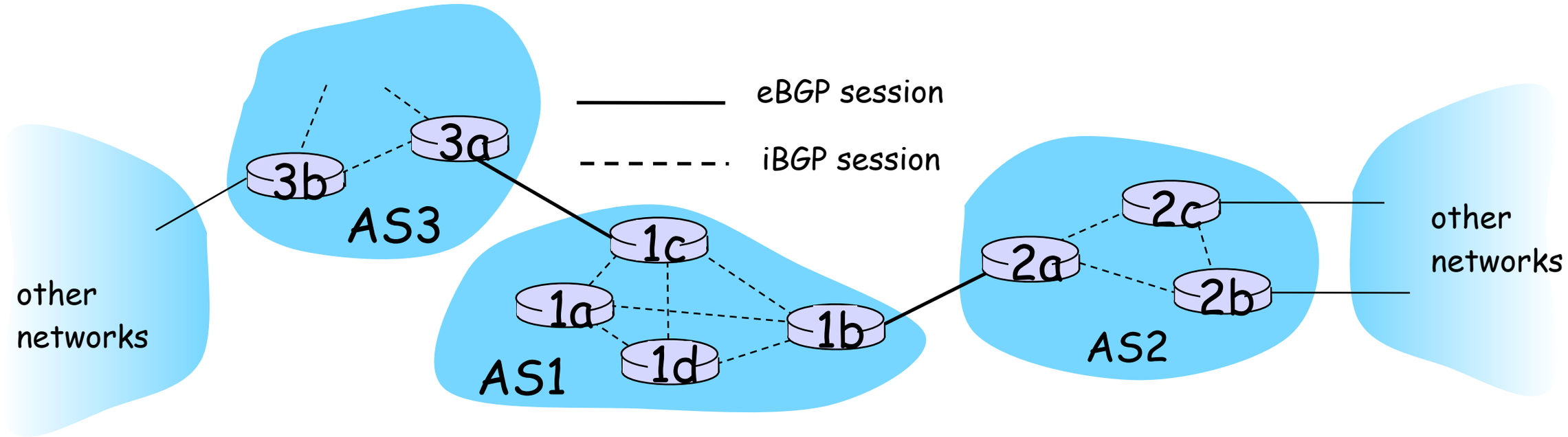

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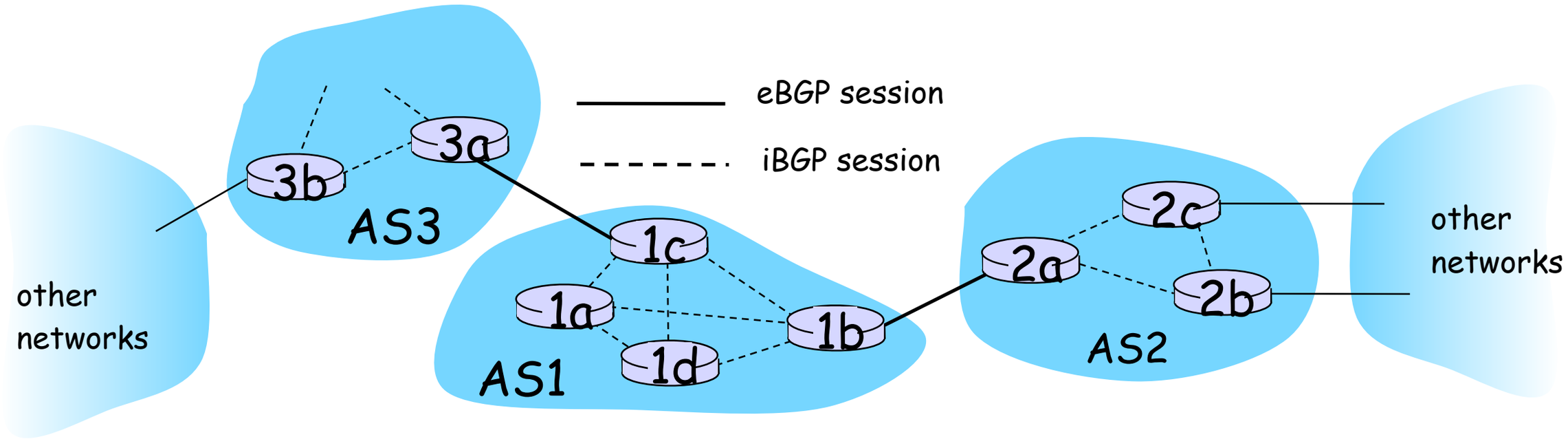
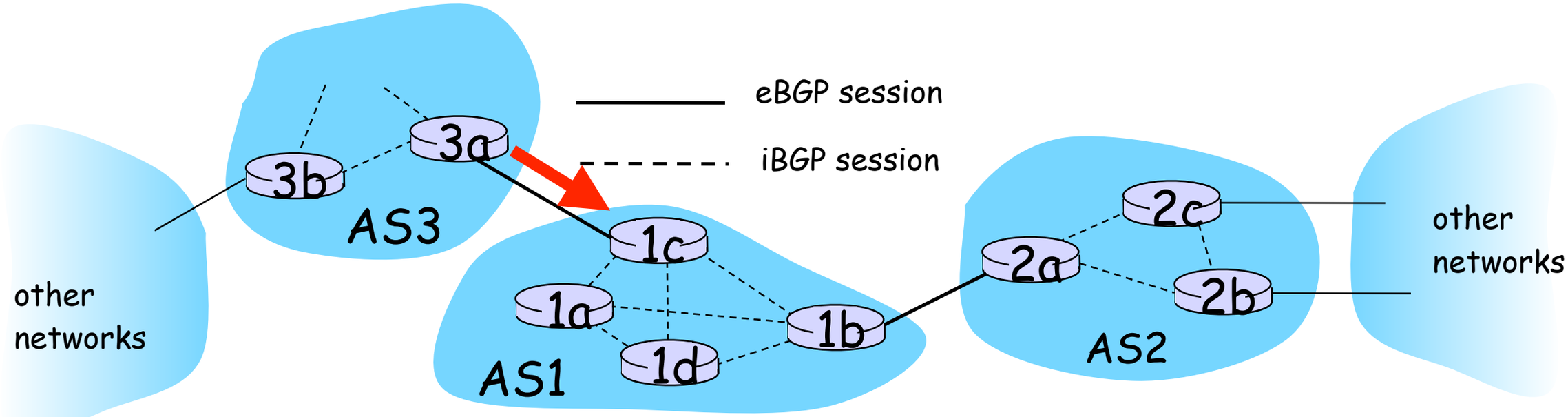
- when router learns of new prefix, it creates entry for prefix in its forwarding table.



Path attributes & BGP routes

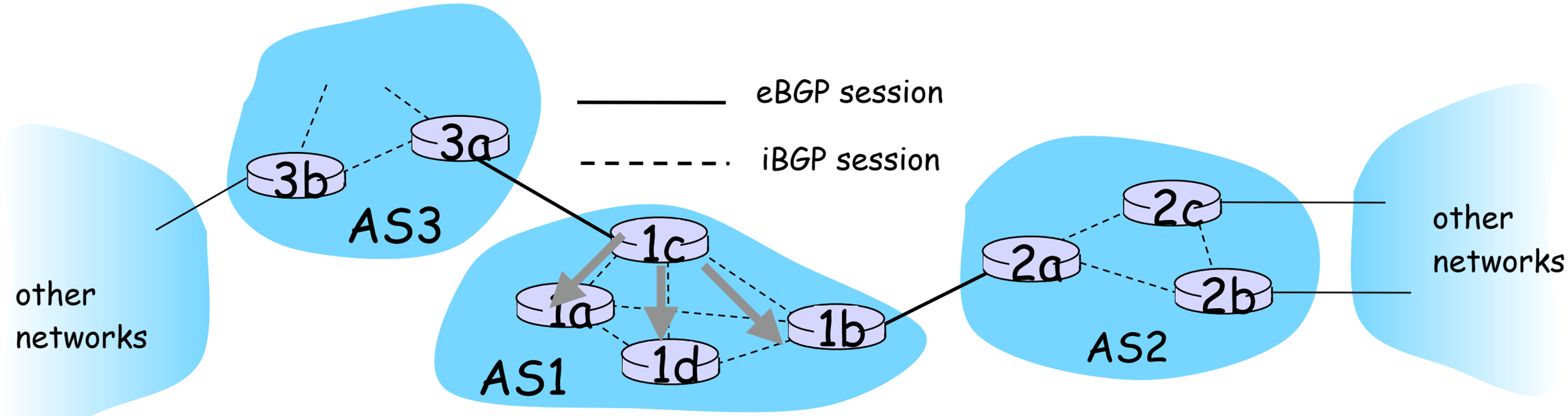
- advertised prefix includes BGP attributes
  - prefix + attributes = "route"
- two important attributes:
  - AS-PATH: contains ASs through which prefix advertisement has passed: e.g., AS 67, AS 17
  - NEXT-HOP: indicates specific internal-AS router to next-hop AS. (may be multiple links from current AS to next-hop-AS)

Path attributes & BGP routes



Prefix: 129.22/16
AS-PATH: AS3

Path attributes & BGP routes



Prefix: 129.22/16
AS-PATH: AS3
NEXT-HOP: 1c

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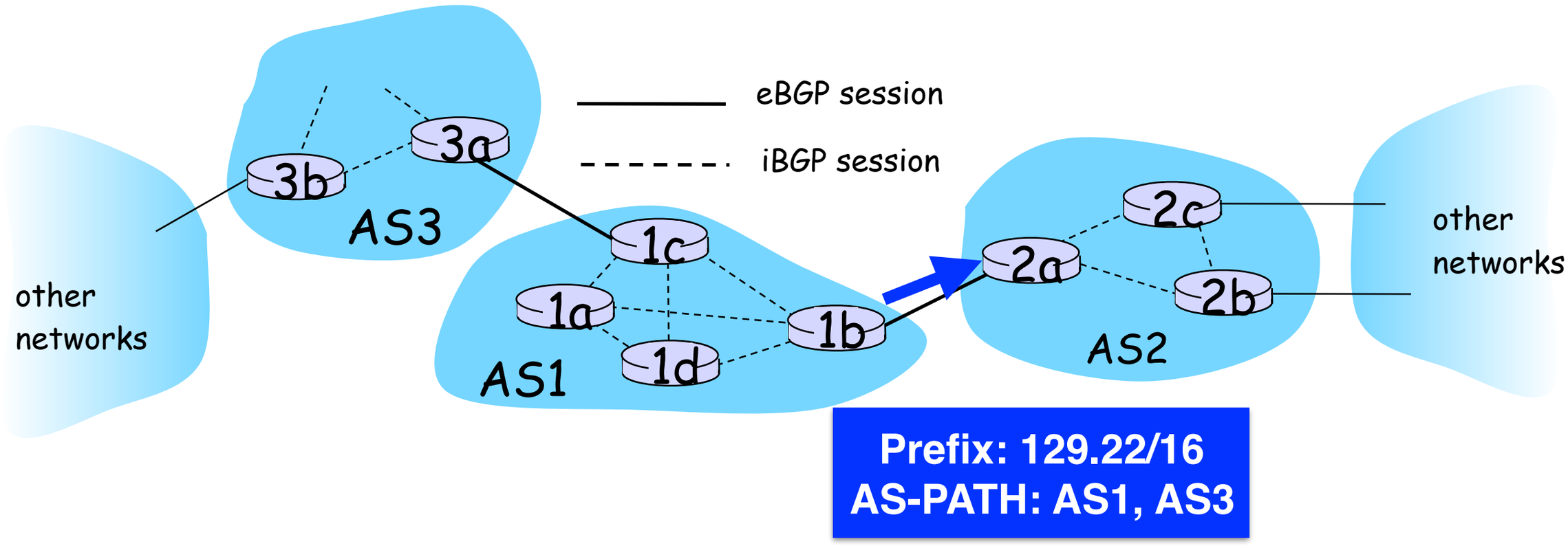


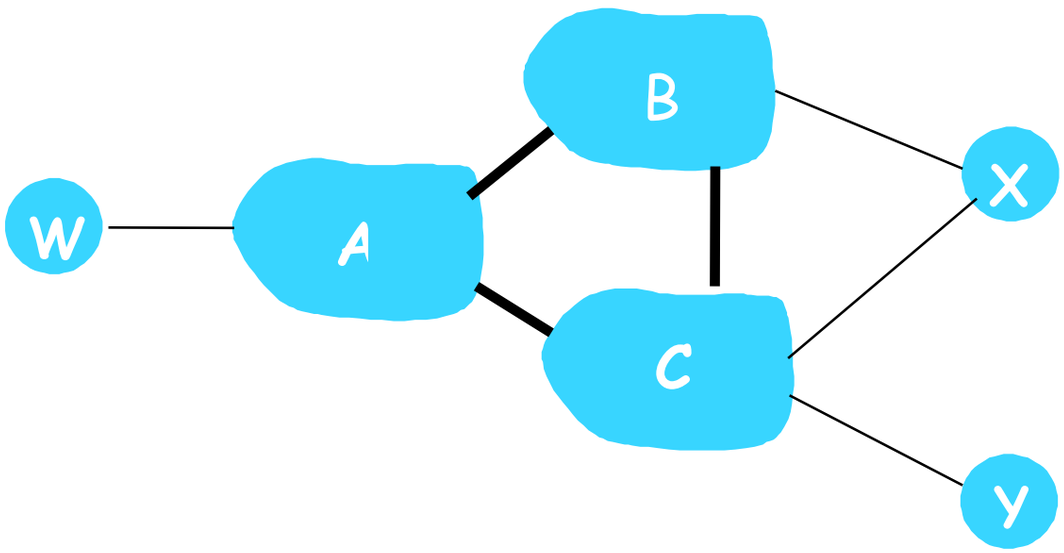
Route Import

- gateway router receiving route advertisement uses import policy to accept/decline
  - e.g., never route through AS x
  - policy-based routing

BGP route selection

- router may learn about more than 1 route to destination AS, selects route based on:
  1. local preference value attribute: policy decision
  2. shortest AS-PATH
  3. closest NEXT-HOP router: hot potato routing
  4. additional criteria

BGP routing policy

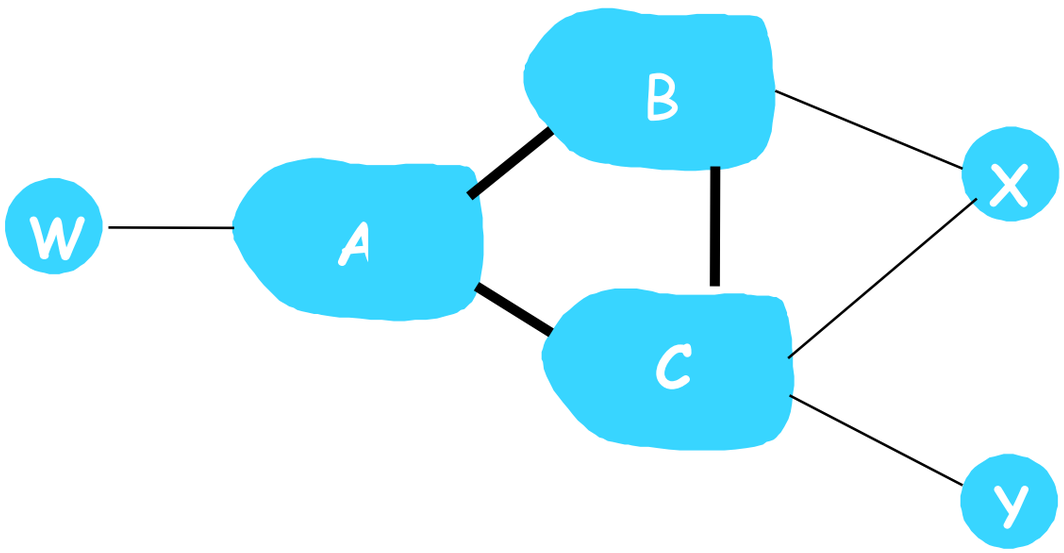


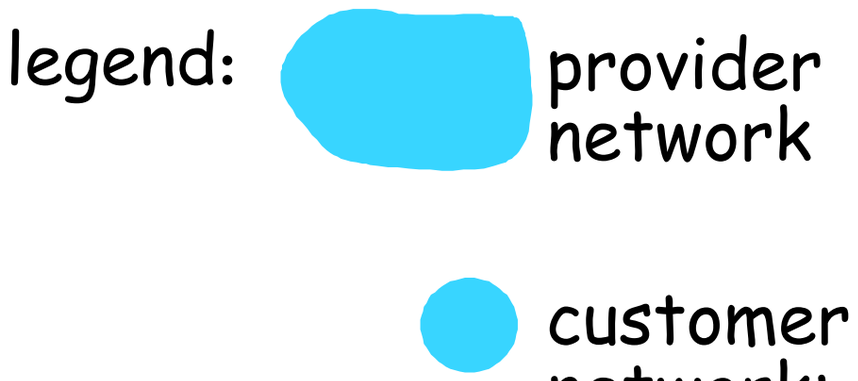
legend:

provider network

customer network:

BGP routing policy





- A,B,C are provider networks
- X,W,Y are customers (of provider networks)

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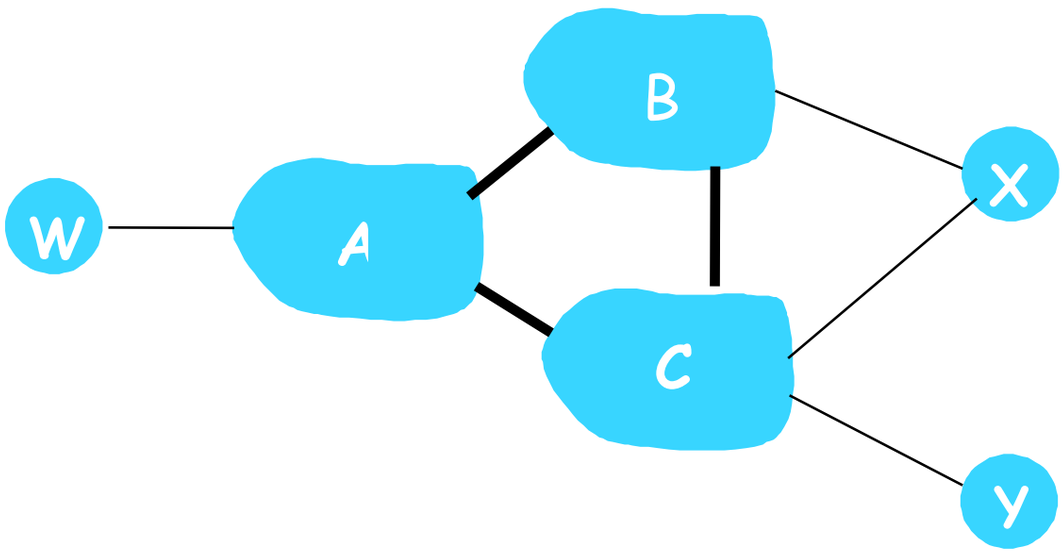

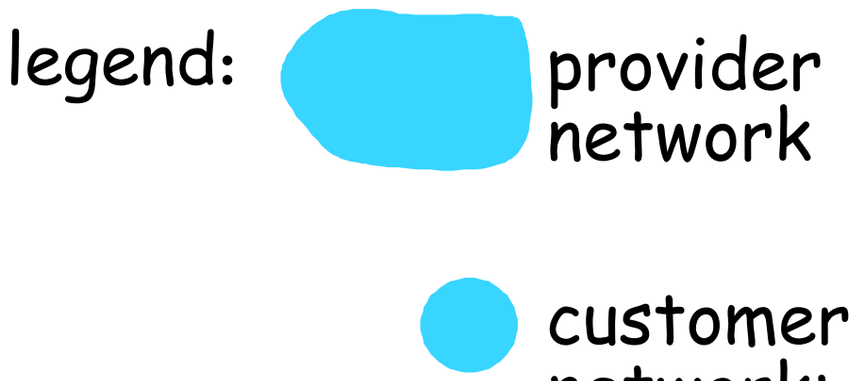

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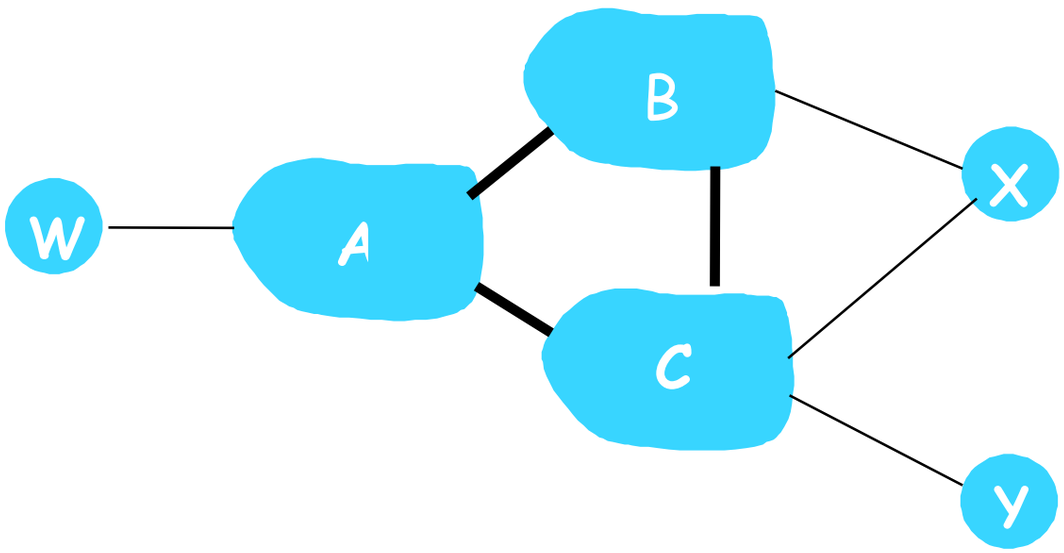

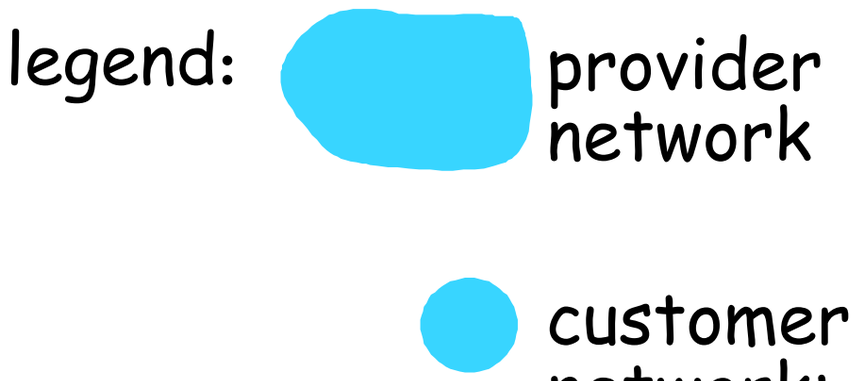

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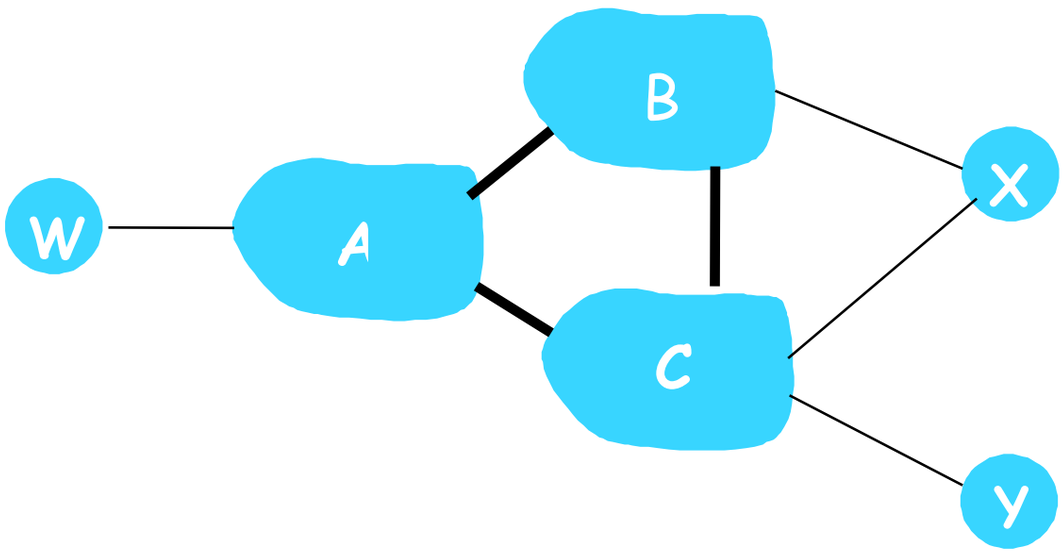
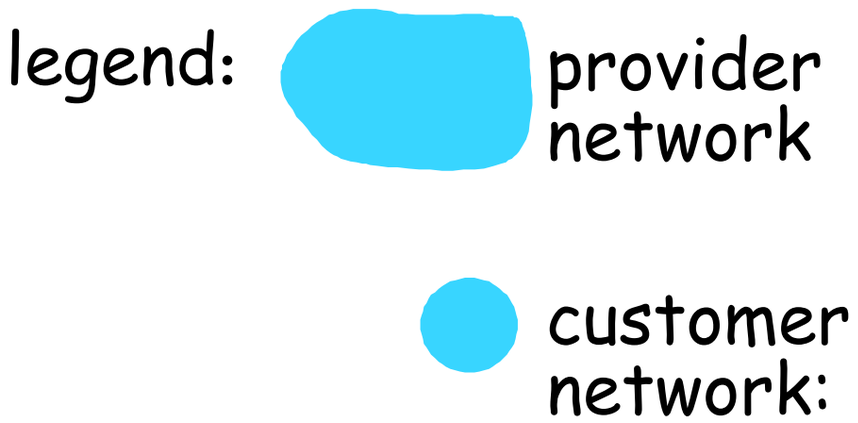
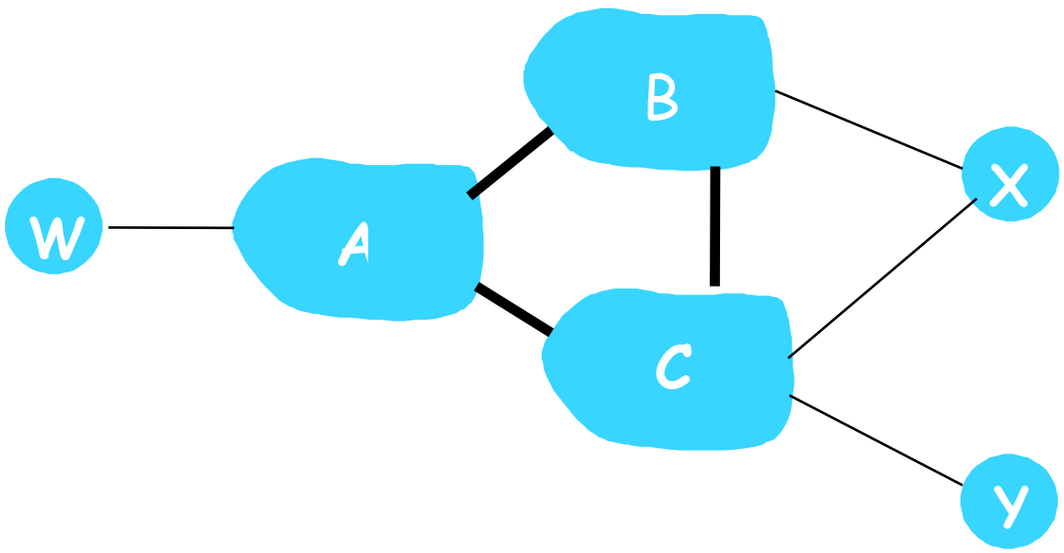




- A,B,C are provider networks
- X,W,Y are customers (of provider networks)
- X is dual-homed: attached to two networks
  - X does not want to route traffic from B to C
  - .. so X will not advertise a route to C in messages to B

BGP routing policy (2)



legend:

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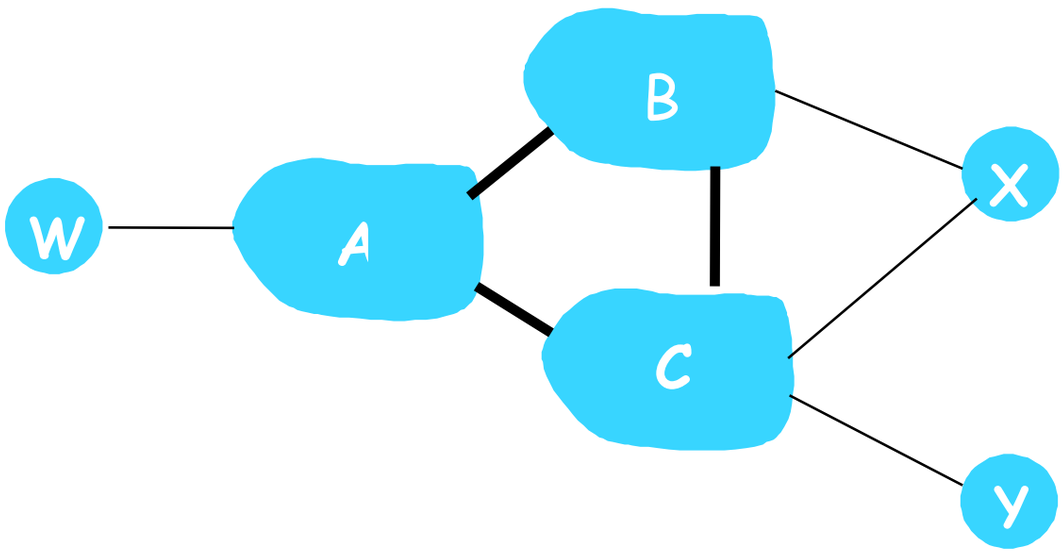

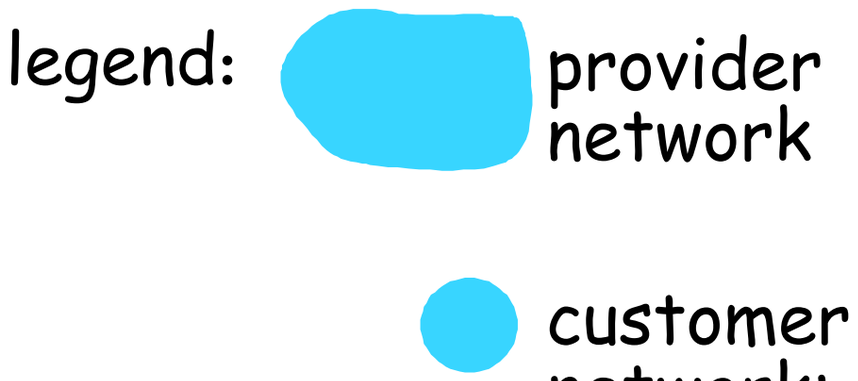

- A advertises path AW to B
- B advertises path BAW to X

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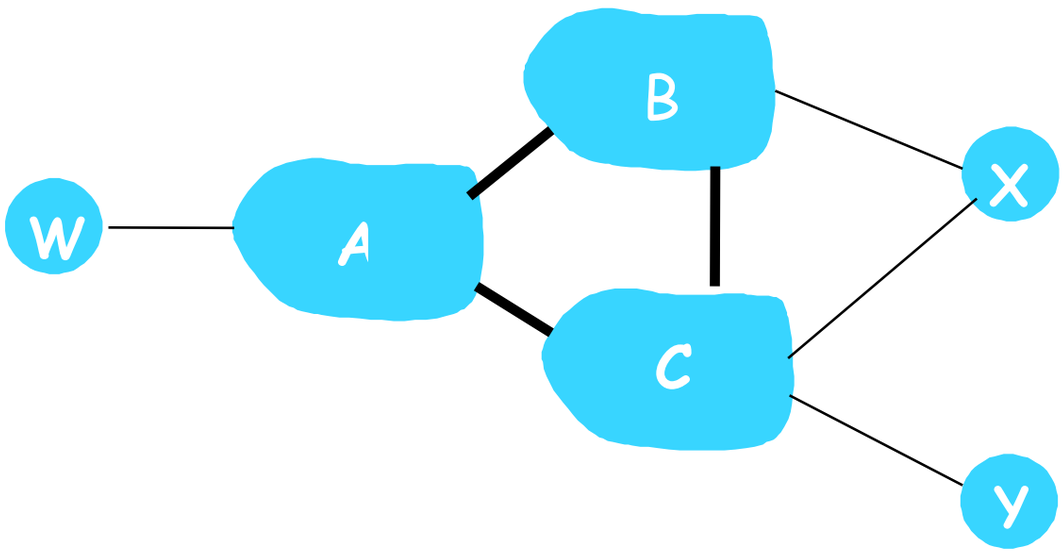

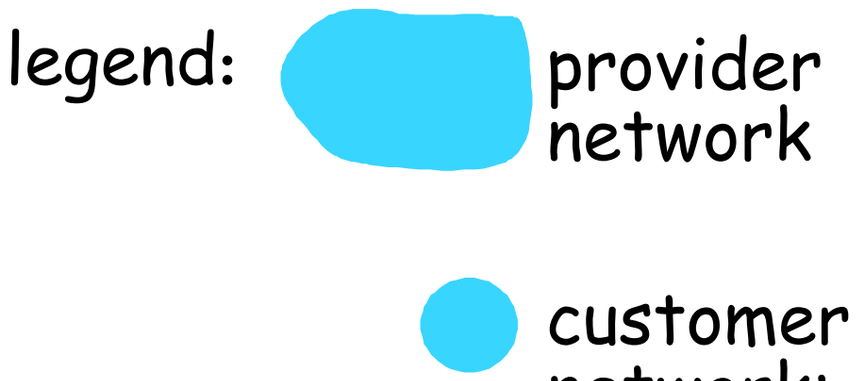

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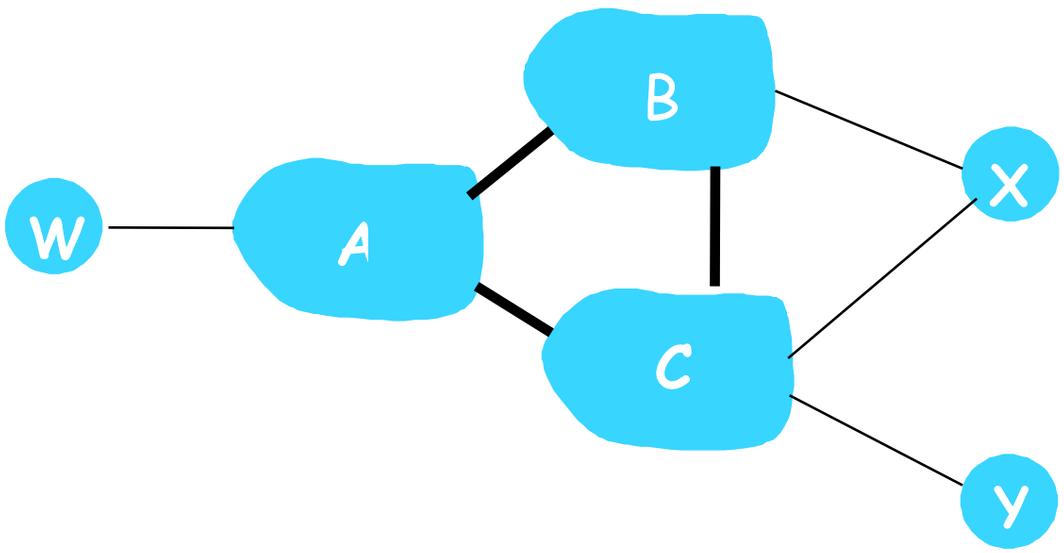
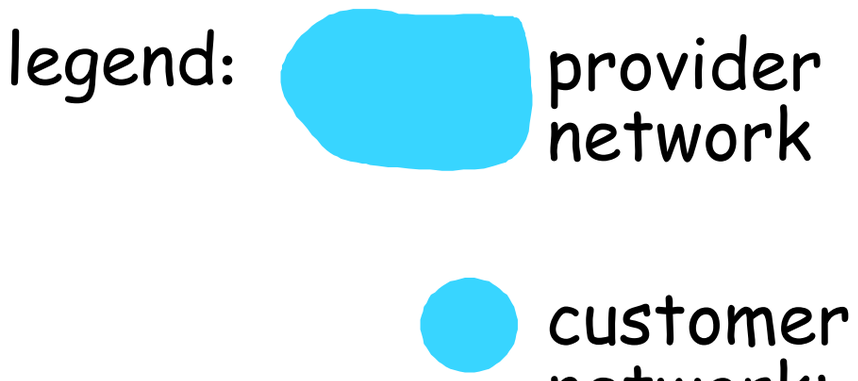
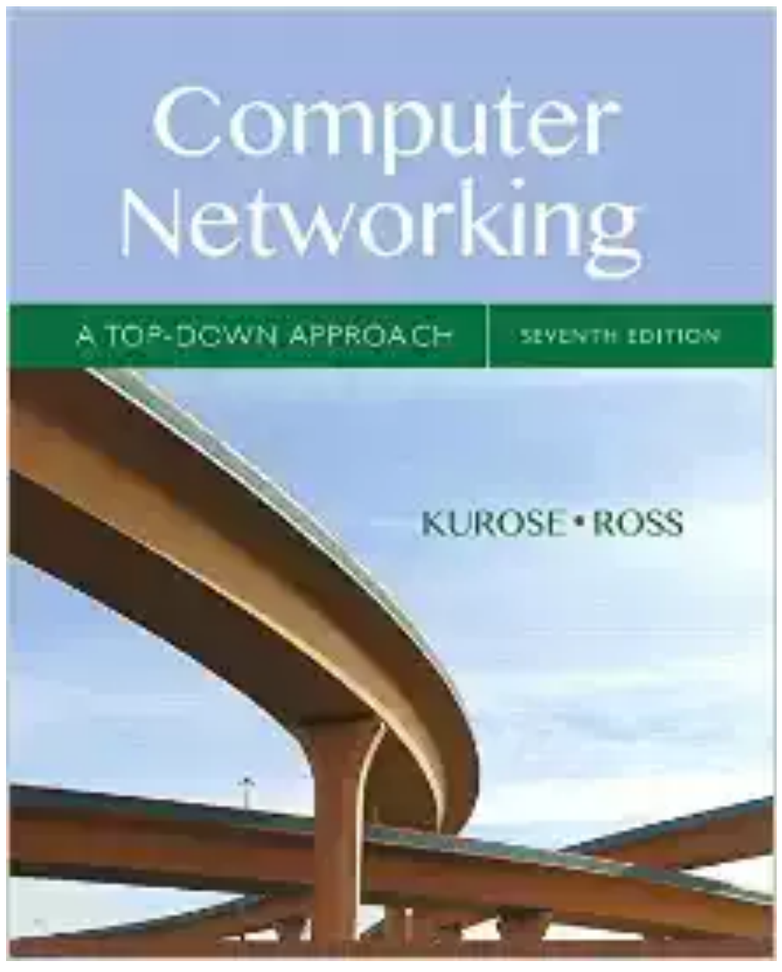




- A advertises path AW to B
- B advertises path BAW to X
- Should B advertise path BAW to C?
  - No way! B gets no "revenue" for routing CBAW since neither W nor C are B's customers
  - B wants to force C to route to w via A
  - B wants to route only to/from its customers!

Reading Along ...



- Network layer is chapters 4 & 5
  - Transmission Classes

Transmission Classes

Transmission Classes

- Unicast
  - send message to a single recipient

Transmission Classes

- Unicast
  - send message to a single recipient
- Broadcast
  - send same message to everyone

Transmission Classes

Transmission Classes

- Multicast

Transmission Classes

- Multicast
  - when sending the same content to multiple destinations
  - … but not everyone!
  - e.g., radio station broadcast

Transmission Classes

Transmission Classes

- Anycast

Transmission Classes

- Anycast
  - for replication of services, any one of which will work
  - e.g., root DNS servers