CSCI 466: Networks

Network Layer – Routing (Control Plane)

Reese Pearsall

Fall 2023

Announcements

Wireshark Lab 3 posted. Due a week from today (11/1)
- It's easy

PA3 Posted. Due on November 8th

Quiz 5 on Friday (due at 5 PM)
→ IP addresses, Subnets, Subnet Masks
→ Private/Public IP addresses, NAT
→ IPv4, IPv6, Tunneling
→ SDN
→ Routing (Link State vs Distance Vector)
→ OSPF, BGP, ICMP

NO CLASS ON FRIDAY AND MONDAY

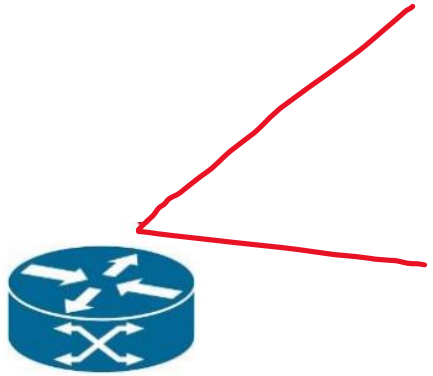
Things to do while reese is gone
- Take quiz 5
- Work on lab 3/PA3
- Watch Monday's lecture
- Party hard

I'll be available via email/DMs if you need anything

Wireshark Lab 3

PA3

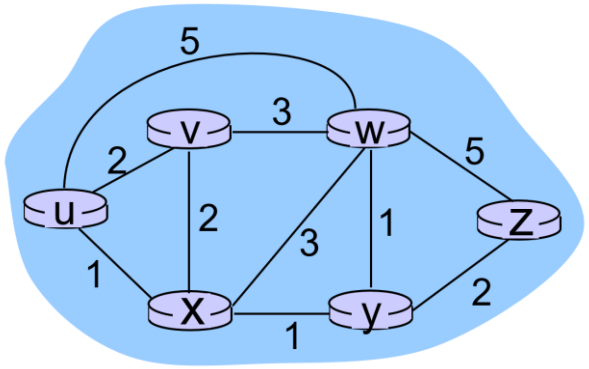
Forwarding refers to moving packets from a **router's input** to appropriate **router output**, and is implemented in the data plane.



Address range	Interface (output link)
128.11.52.0 – 128.11.52.255	1
153.90.2.0 – 153.90.2.255	2
153.90.2.87 – 153.90.2.89	3

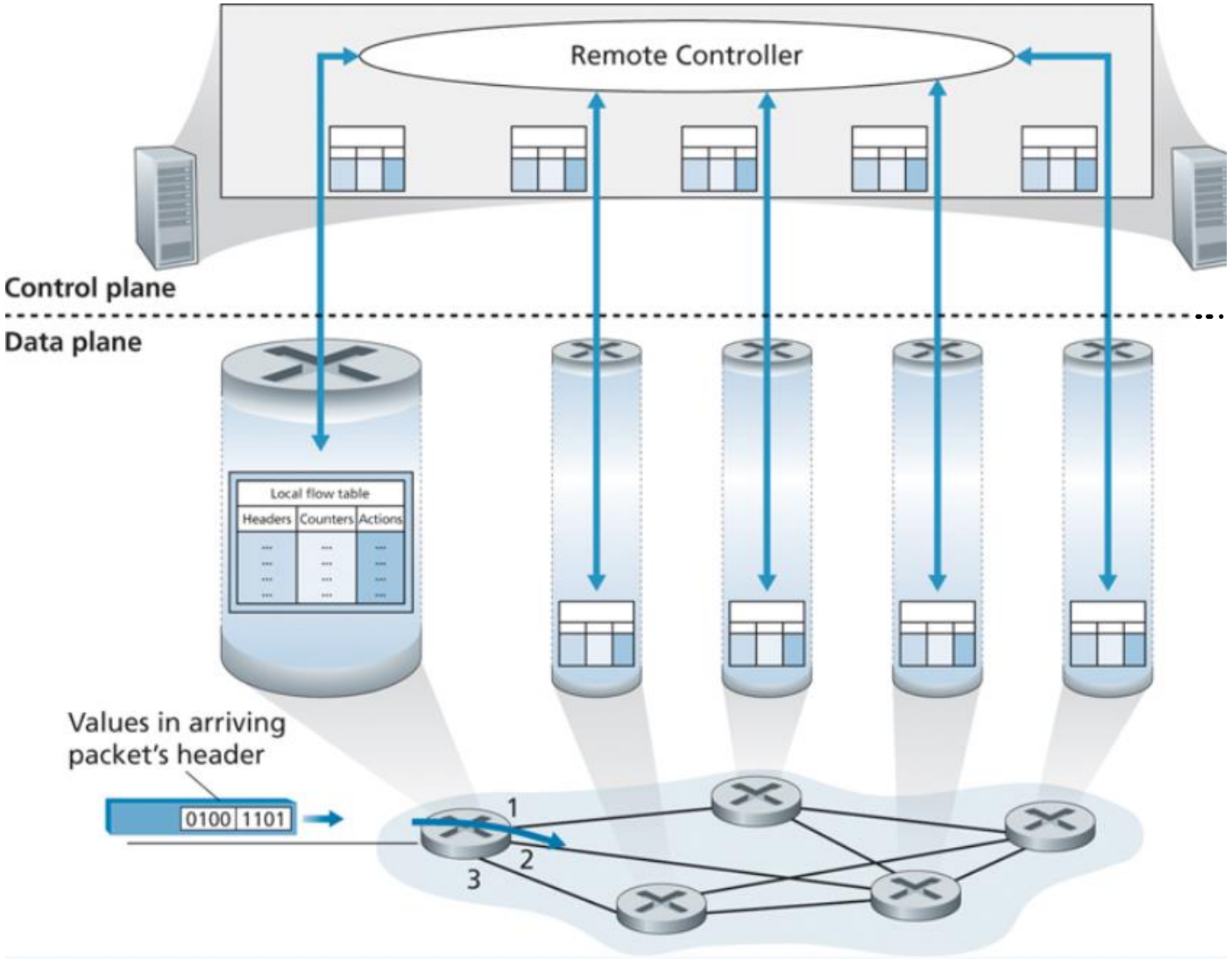
Ideally, this output links are the most optimal path to get to the destination

Routing refers to determining the route taken by packets from **source** to **destination**, and is implemented in the control plane.

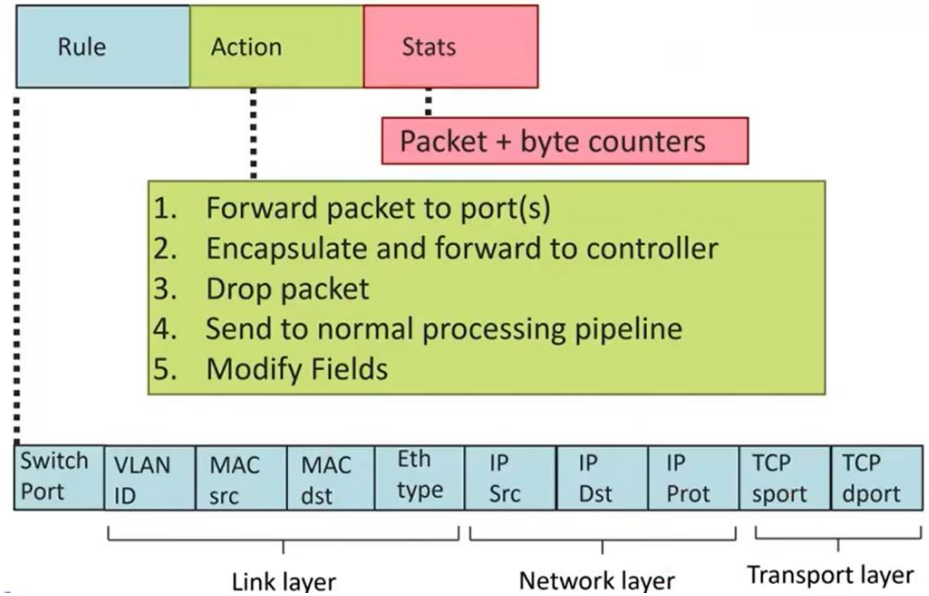


What is the best way to get from **u** to **z**?

Generalized Forwarding and Software Defines Network (SDN)



Control Plane and Data Plane need to work together in order to create efficient routing tables



Routing tables are filled via **routing algorithms**

There are two types of routing algorithms

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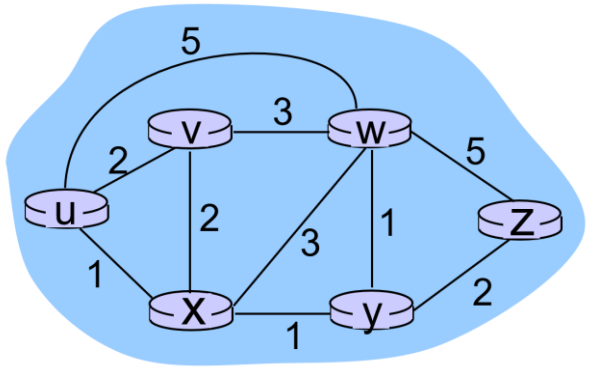
Centralized/Global- we know the edge costs of the network

Link State algorithms

(Dijkstra's Algorithm)



We can compute the shortest path from one node, to all other nodes in roughly O(n^2) time.

Once we know the shortest path from A to B, we can update routing tables to reflect that shortest path

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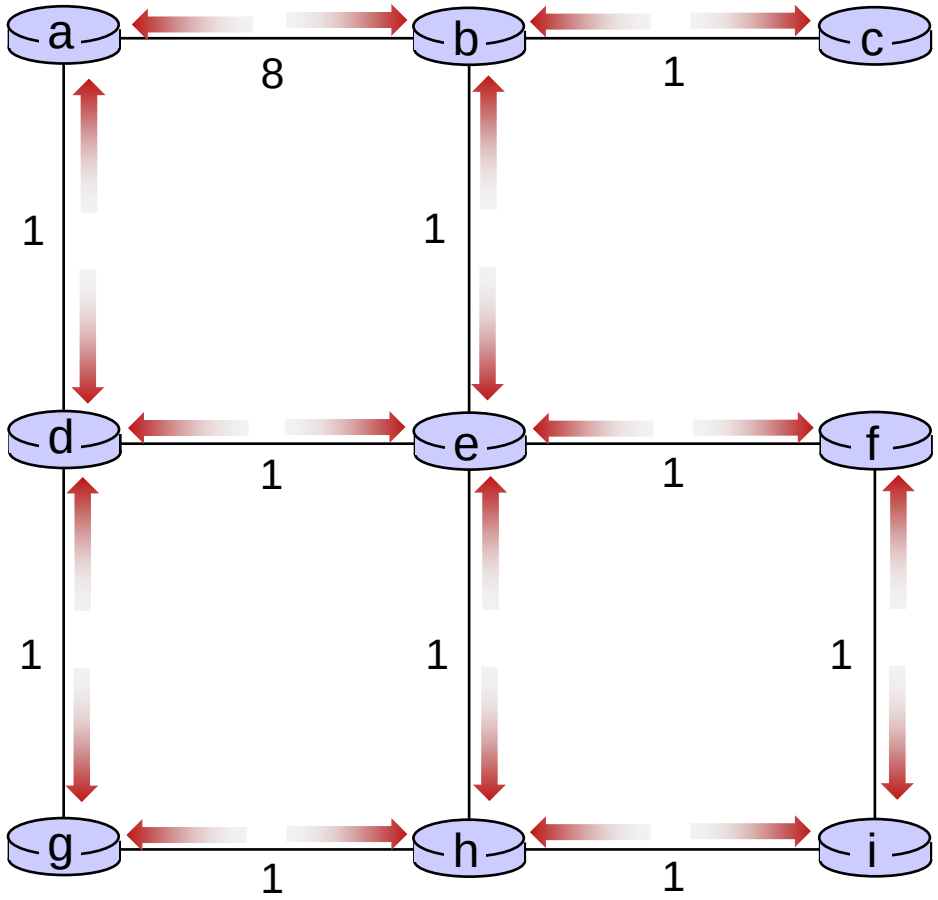

Decentralized- we do not know the edge costs of the entire network.
Only know edge costs to neighbors

Distance Vector algorithms

Routing tables are filled via **routing algorithms**

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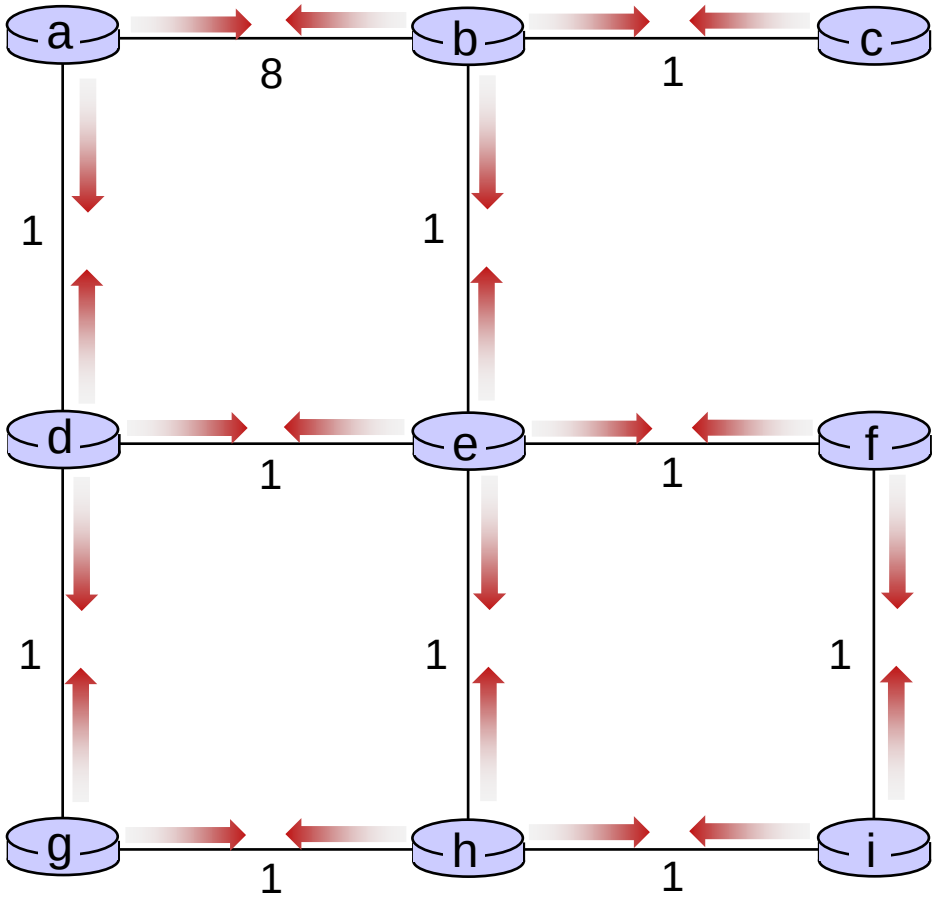

Distance Vector Routing Summary

Every so often, neighbors will exchange their local distances

Using these distances, routers will update their local distances if they find a new shortest path

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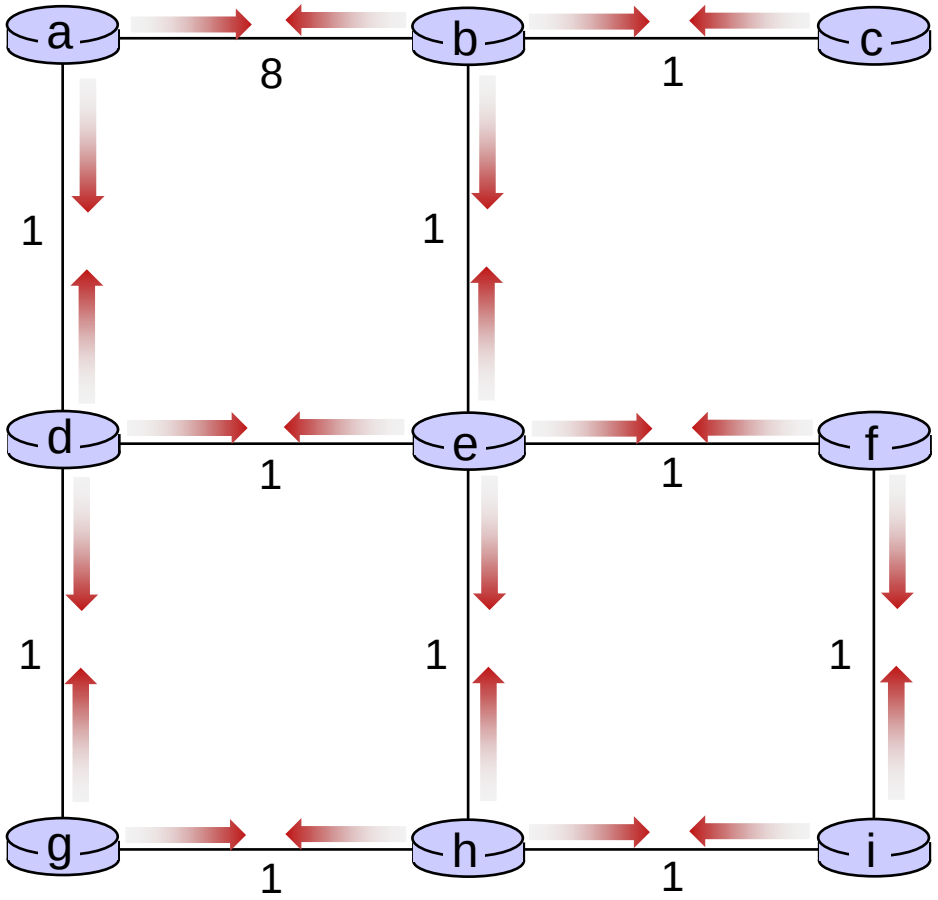

Distance Vector Routing Summary

All nodes:

- receive distance vectors from neighbors
- compute their new local distance vector
- send their new local distance vector to neighbors

"News spreads slowly"

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There are two types of routing algorithms

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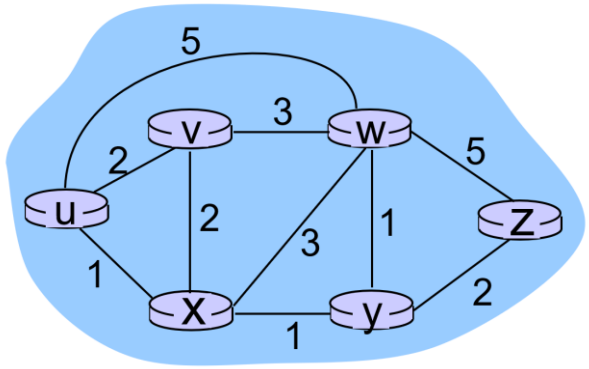
Link State algorithms

(Dijkstra's Algorithm)



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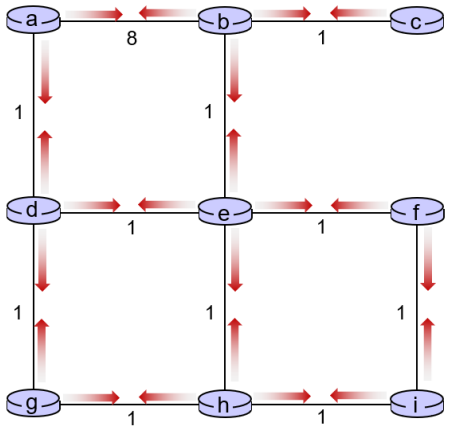

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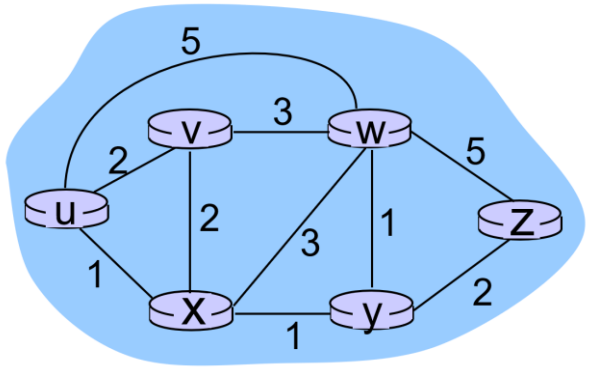

These are not network protocols, these are simply general routing/shortest path algorithms

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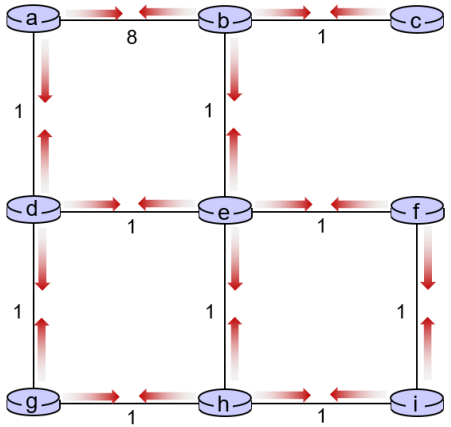
Only know edge costs to neighbors

Distance Vector algorithms



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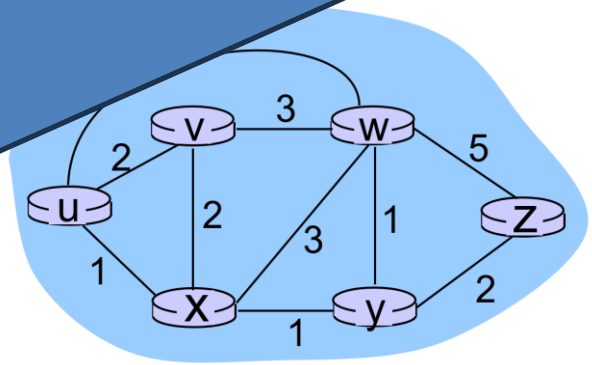
Link State algorithms

OSPF

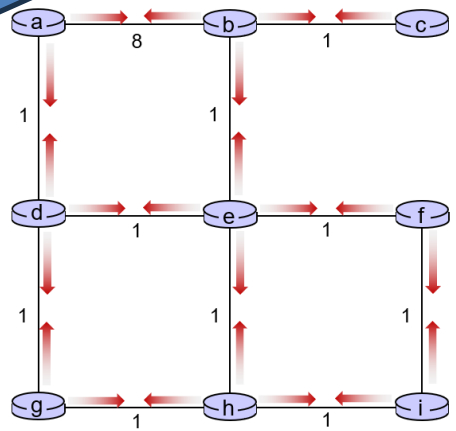


Decentralized- we do not know the edge costs of the network.

Only know neighbors

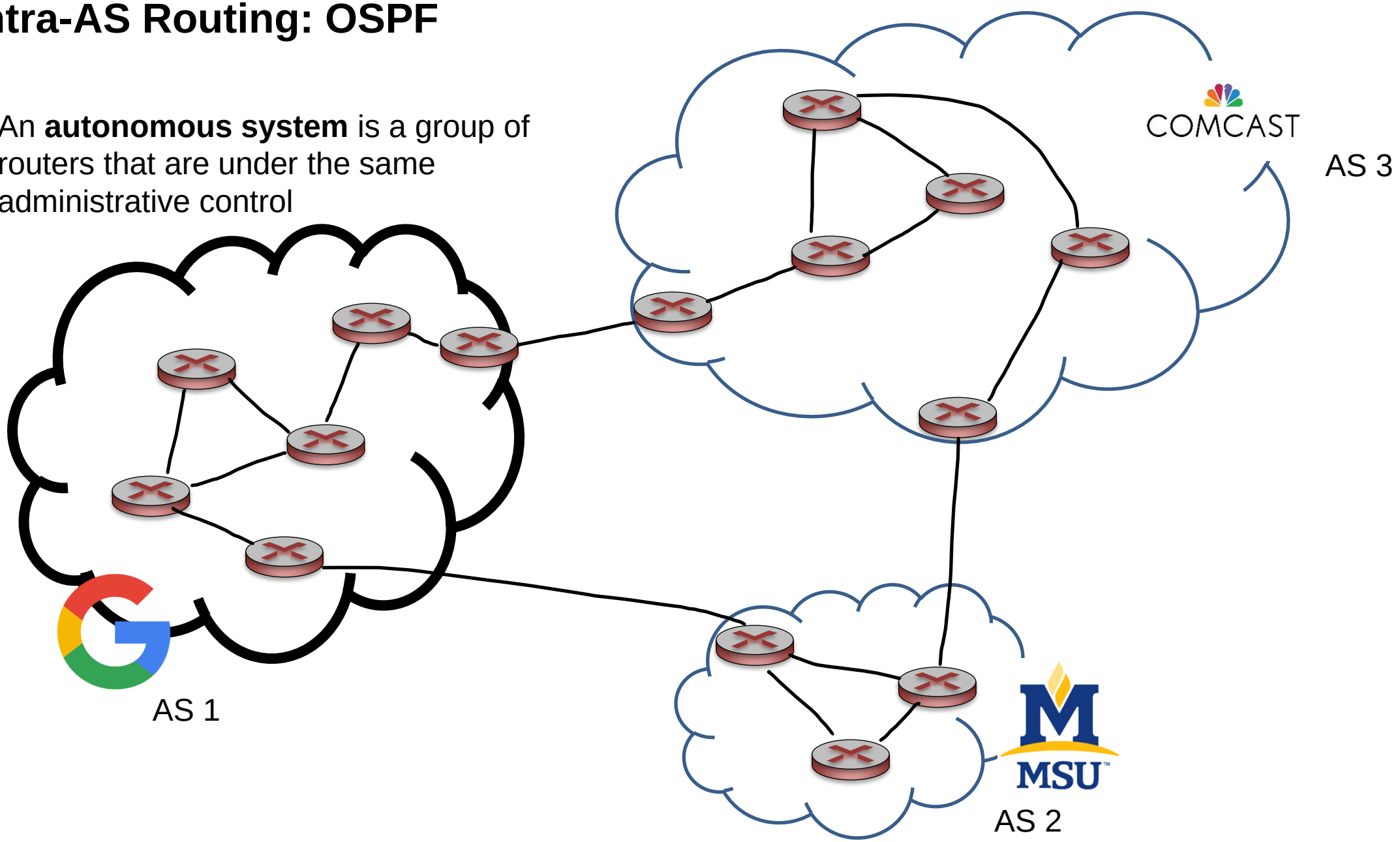
Vector algorithms

BGP



Intra-AS Routing: OSPF

An **autonomous system** is a group of routers that are under the same administrative control



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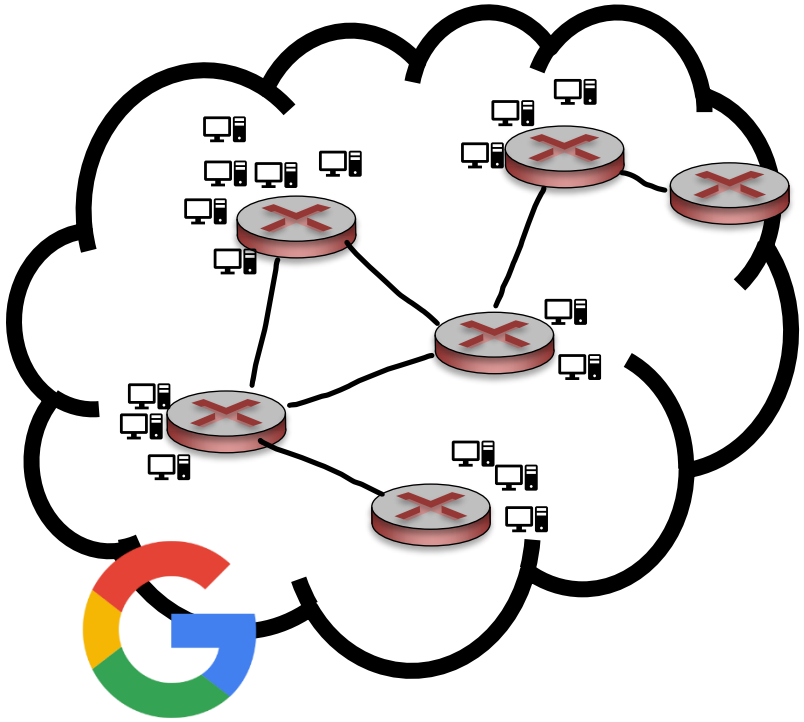

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Open Shortest Path First

OSPF is a link-state protocol that uses flooding of link-state information and Dijkstra's least-cost algorithm

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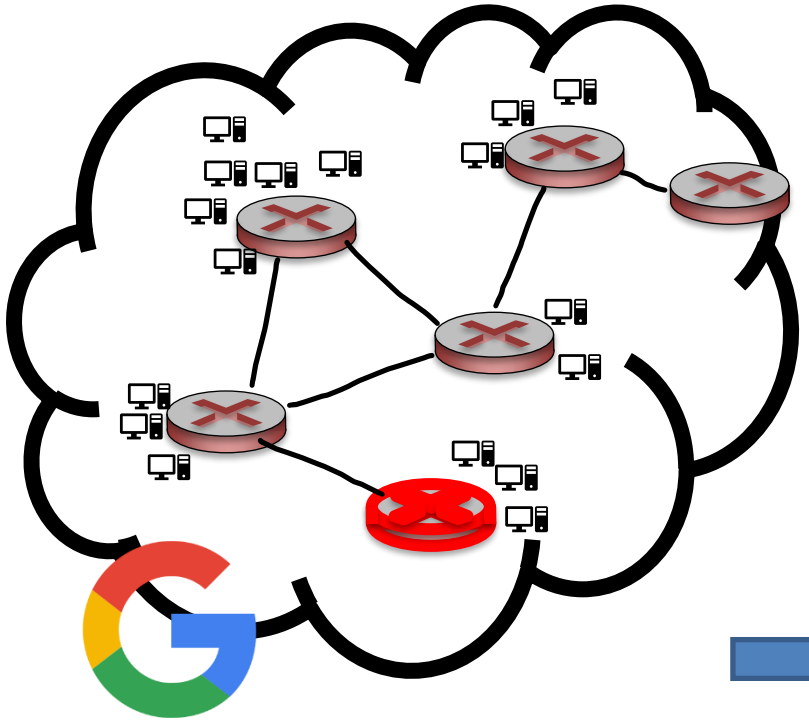
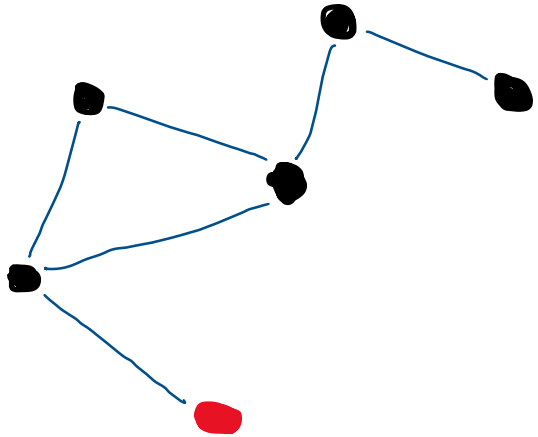


AS 1

1. Each router constructors a topological map of the AS



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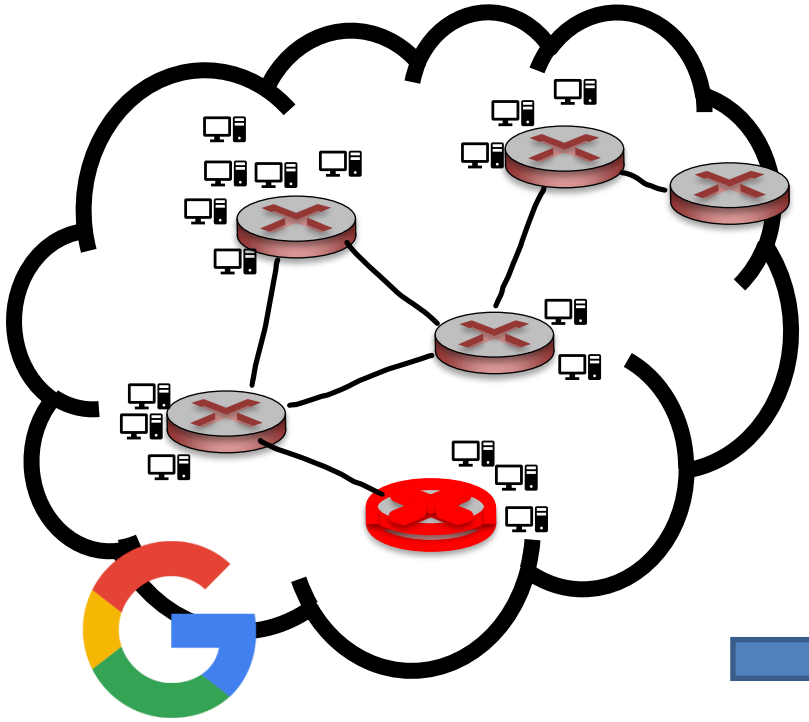

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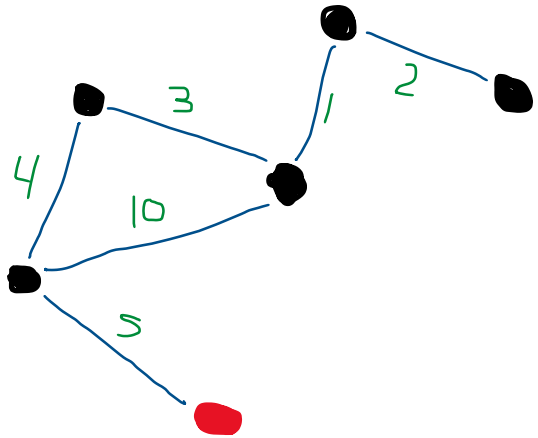

(Edge costs will be set by a network administrator)

If I wanted to find the path with the shortest amount of hops, what should edge cost be?

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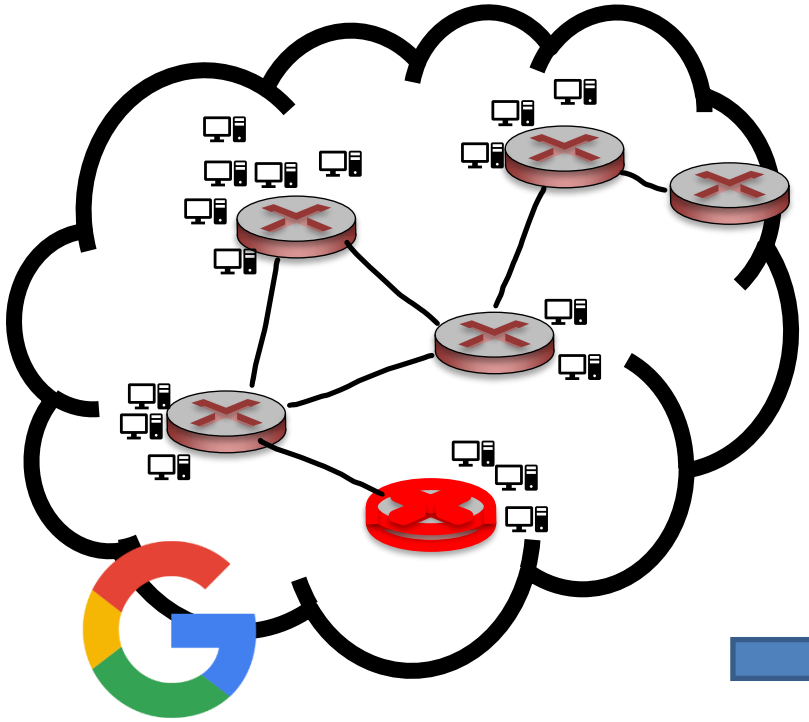

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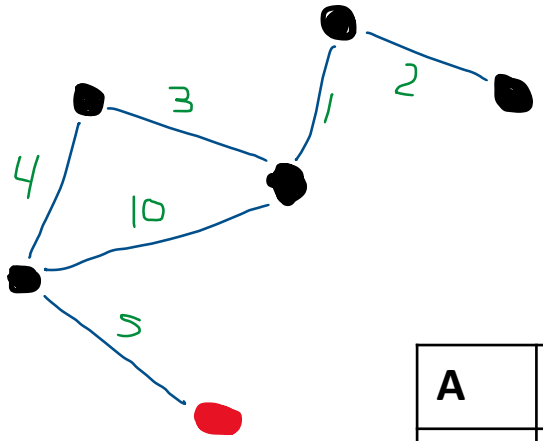


(Edge costs will be set by a network administrator)

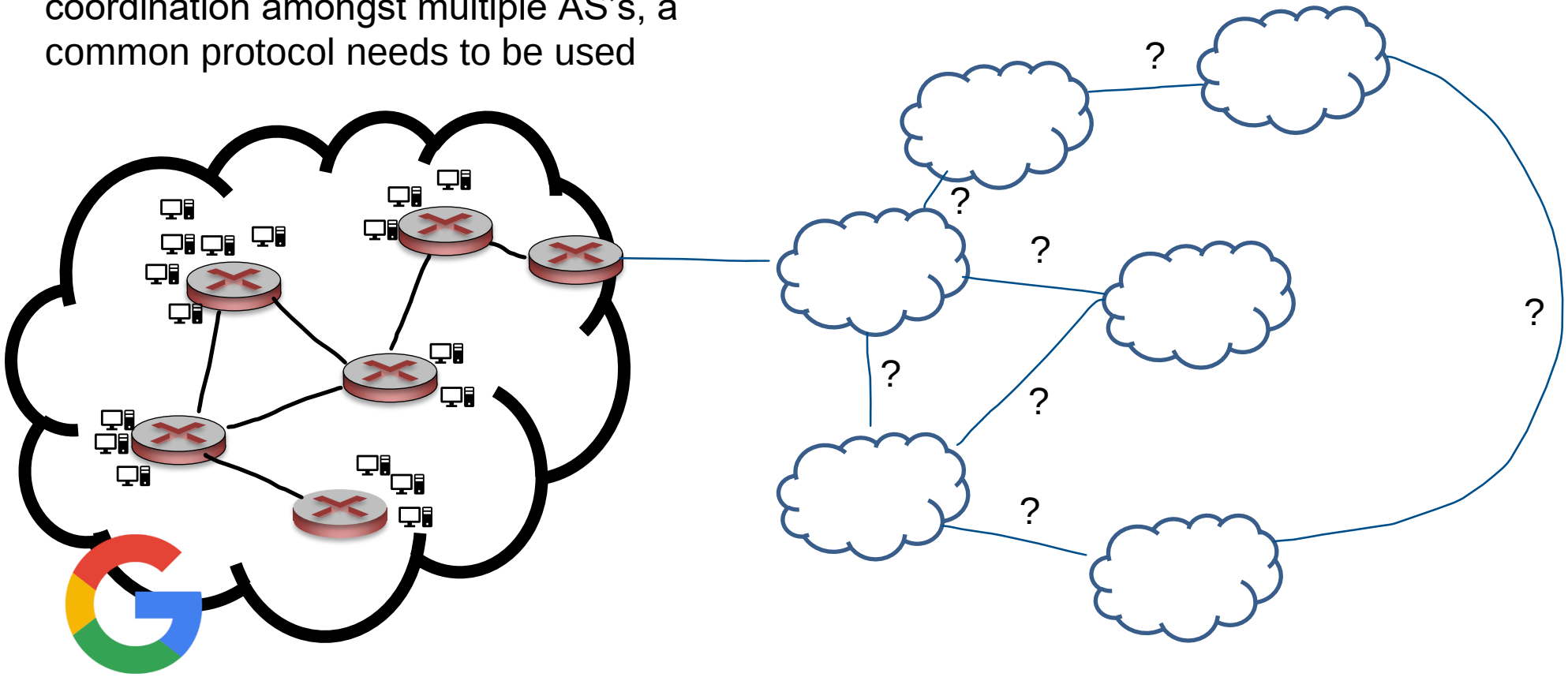
(could set all edges to be a cost of 1)

3. Fill in routing table

A	**1**
B	**2**
C	**3**
…	**…**

Routing Among the ISPs: BGP

Inter-AS routing protocol involves coordination amongst multiple AS's, a common protocol needs to be used



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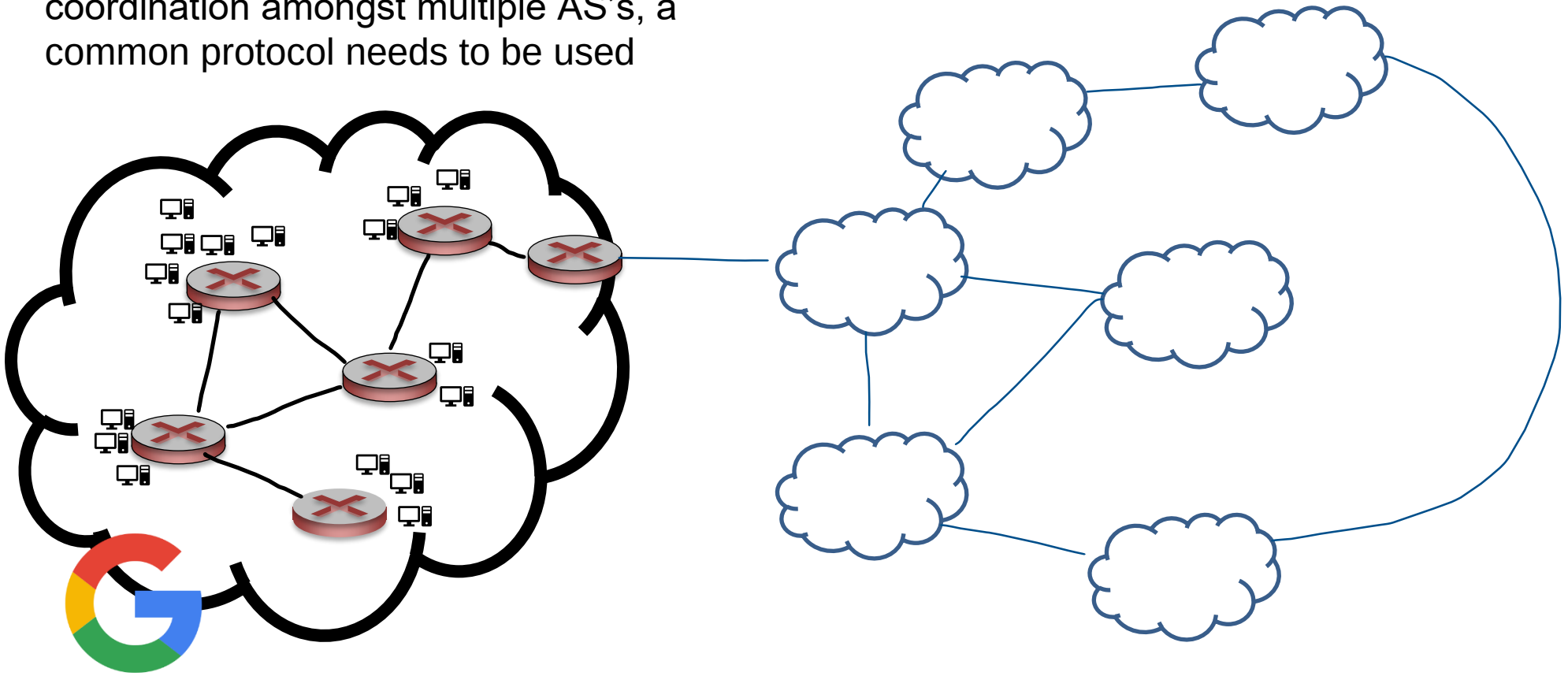

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BGP allows a router to tell other AS's that it exists and needs to be connected

Routing Among the ISPs: BGP

AS consists of **gateway routers** and **internal routers**

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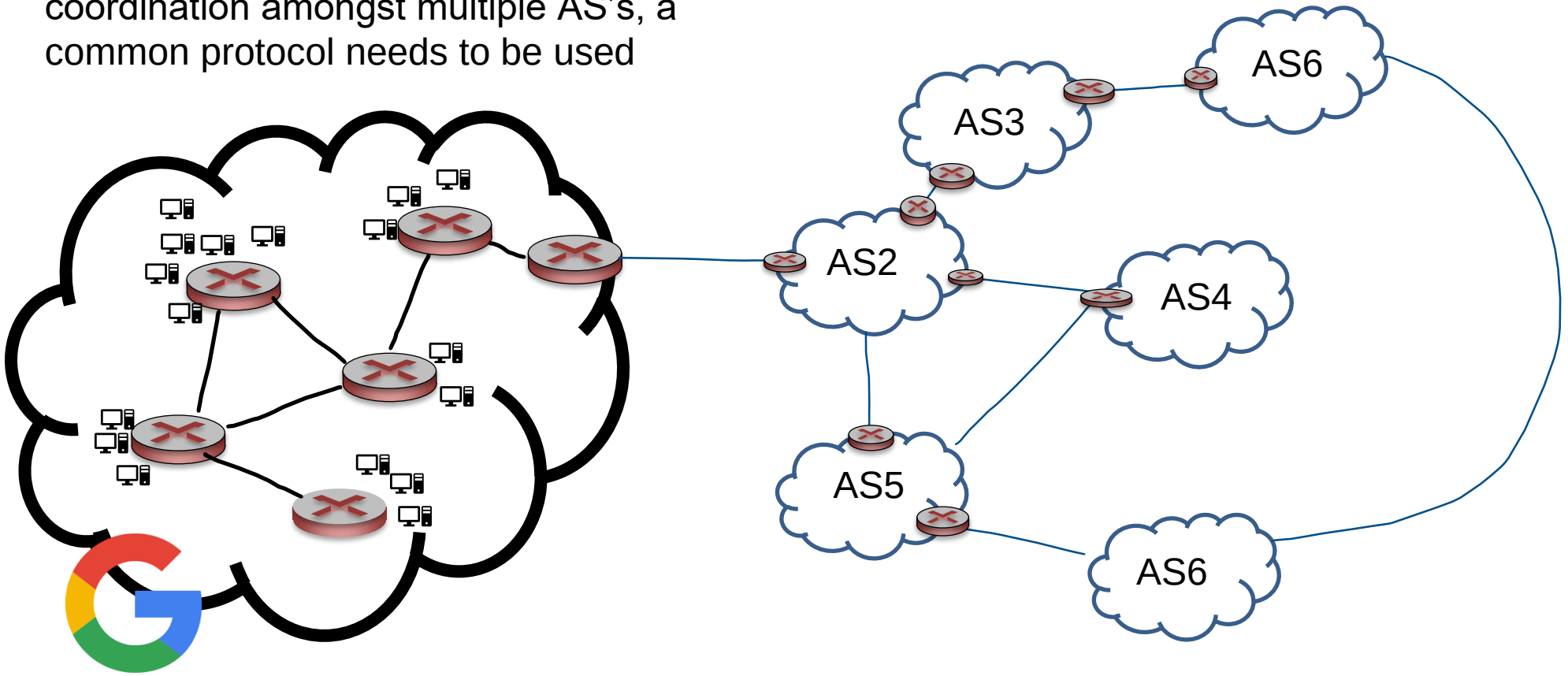

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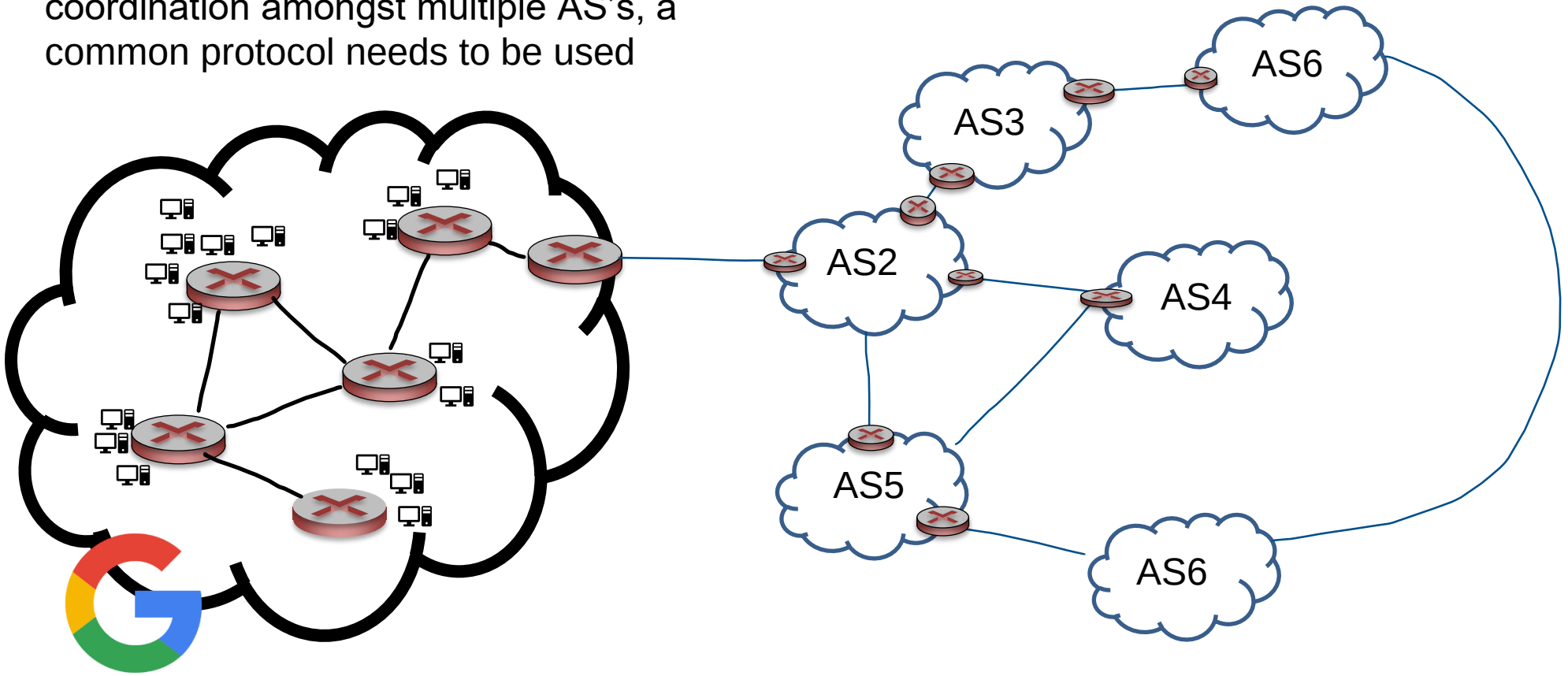

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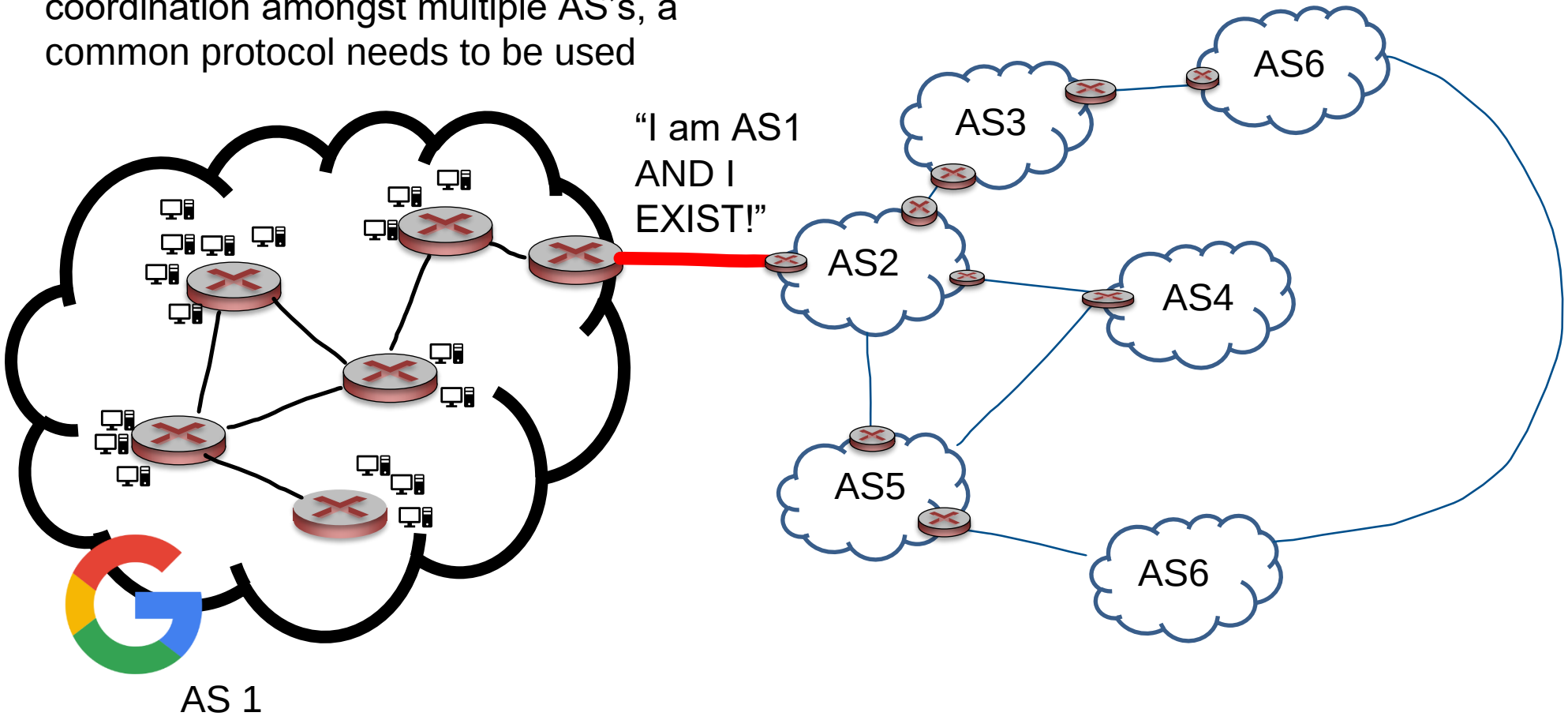

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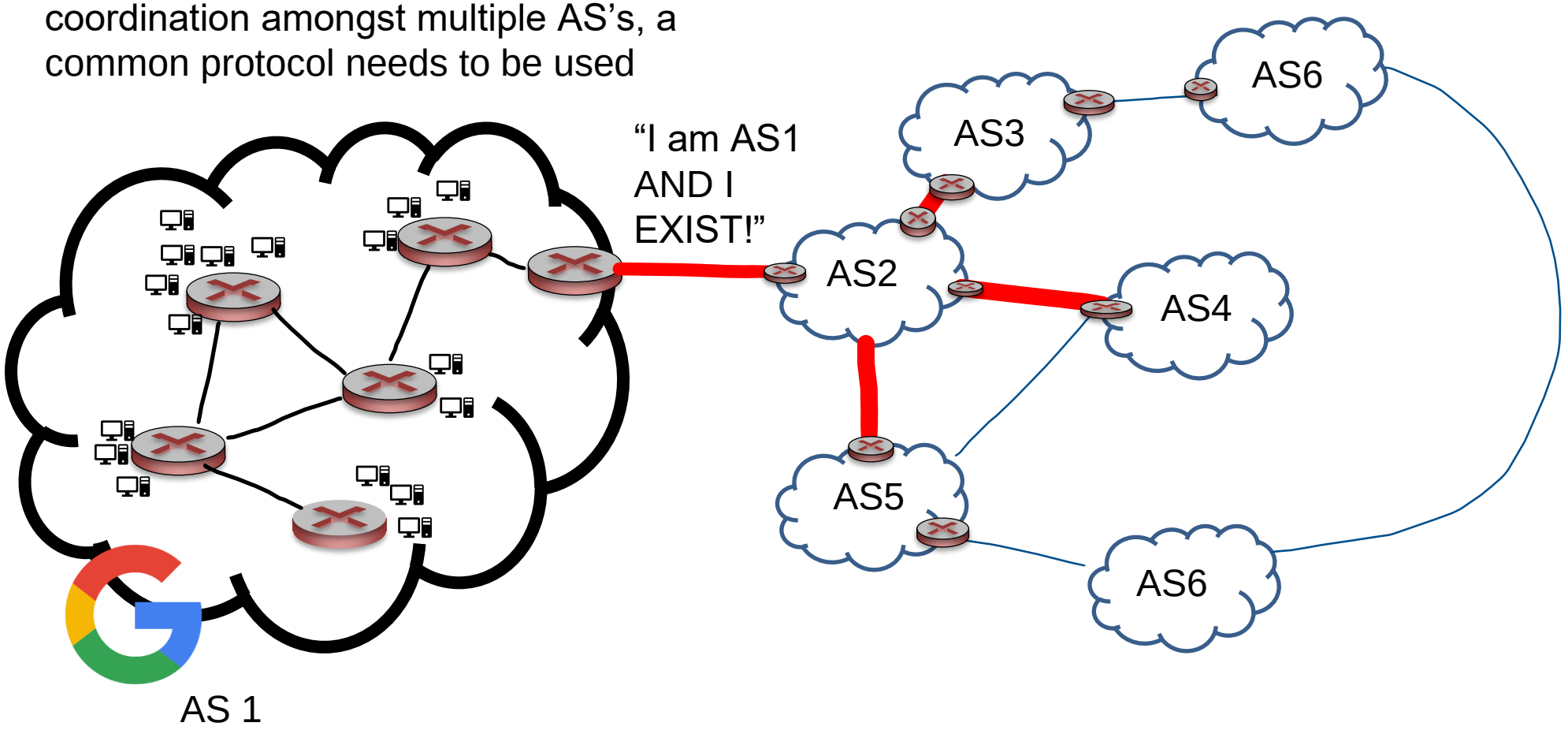


"A1 EXISTS AND FOUND THROUGH AS2"

Internet inter-AS routing: BGP

- BGP (Border Gateway Protocol): *the* de facto inter-domain routing protocol
  - "glue that holds the Internet together"
- allows subnet to advertise its existence, and the destinations it can reach, to rest of Internet: *"I am here, here is who I can reach, and how"*
- BGP provides each AS a means to:
  - obtain destination network reachability info from neighboring ASes (eBGP)
  - determine routes to other networks based on reachability information and *policy*
  - propagate reachability information to all AS-internal routers (iBGP)
  - advertise (to neighboring networks) destination reachability info

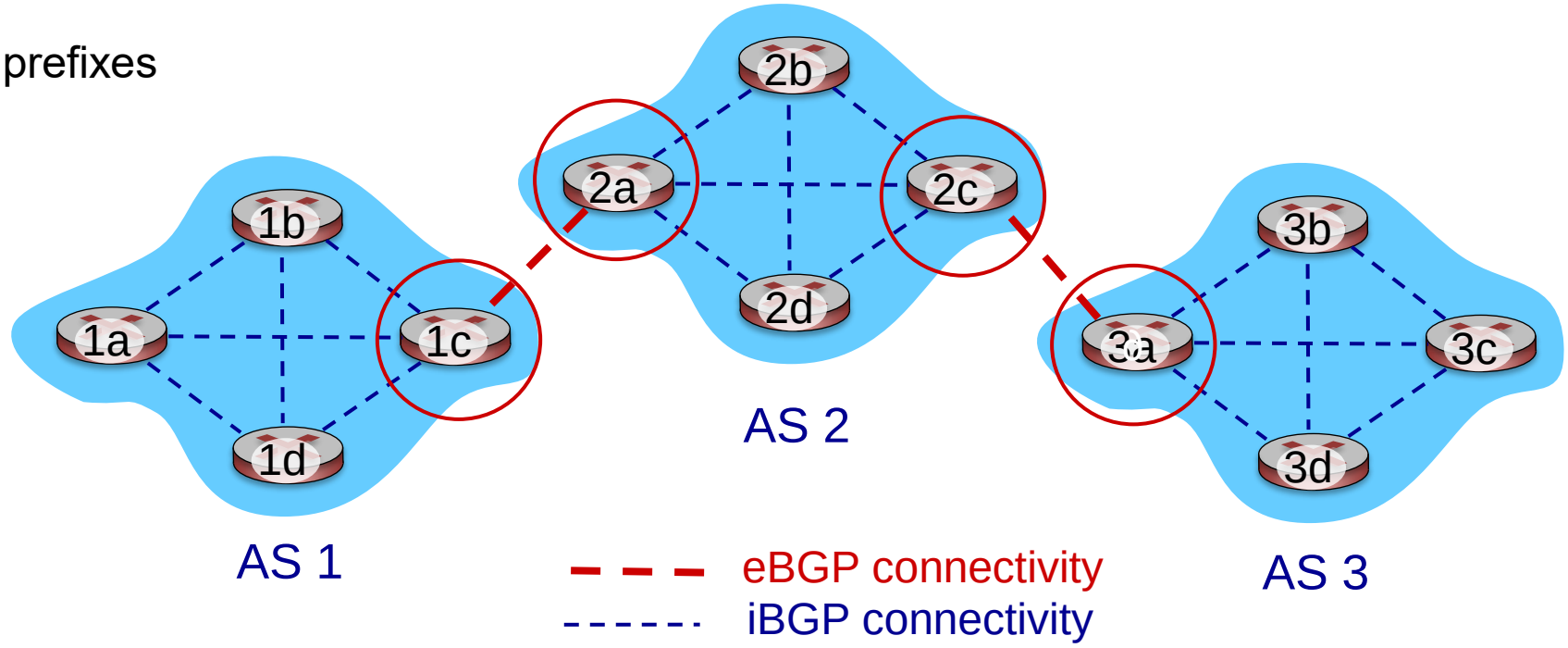
Routing Among the ISPs: BGP

BGP is the routing protocol used for routing amongst different ISPs + AS

Two important functions

→ Obtain prefix reachability information from neighboring ASs (CIDR)

→ Determine the “best” routes to the prefixes



gateway routers run both eBGP and iBGP protools

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Prefix **X** connect

External BGP (eBGP)

3a → 2c “Hey I have X”

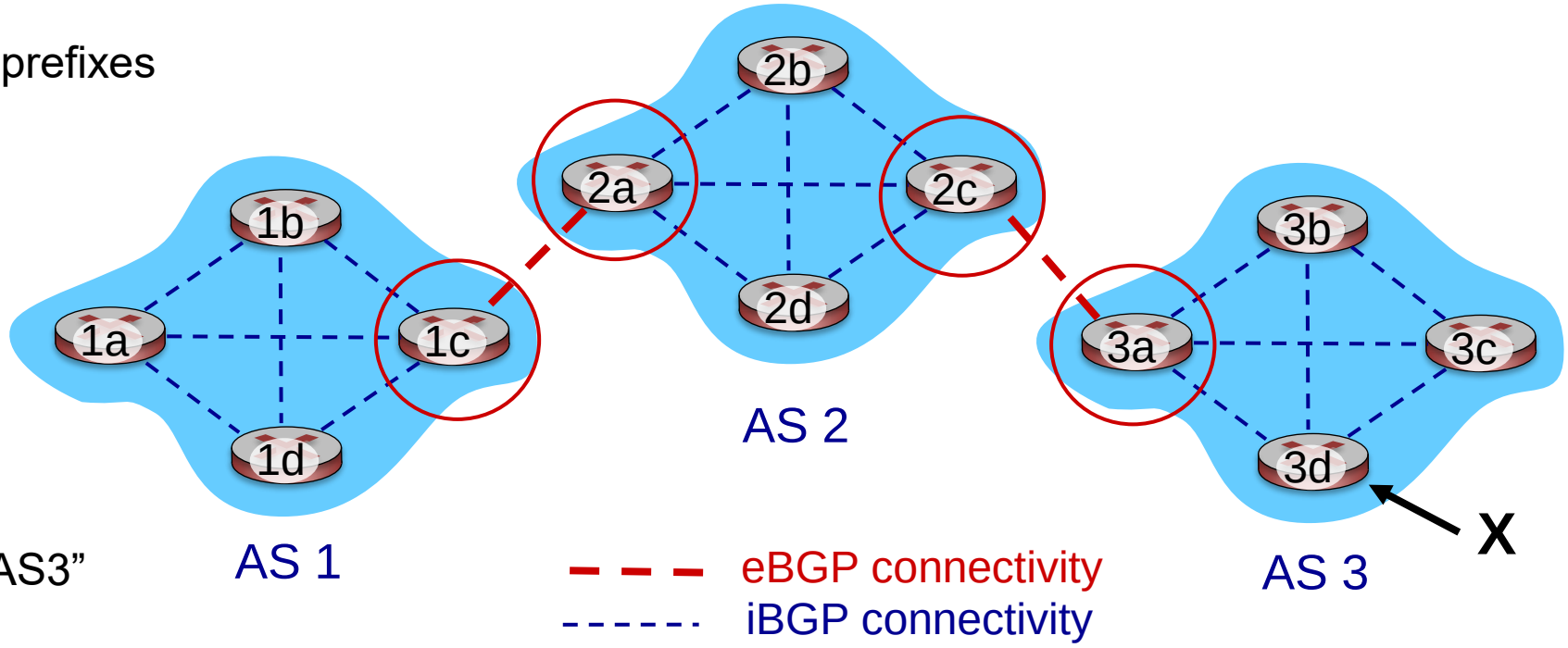
2a → 1c “Hey AS 3 has X and I have AS3”

Internal BGP (iBGP)

2c → 2b

2c → 2d

2c → 2a



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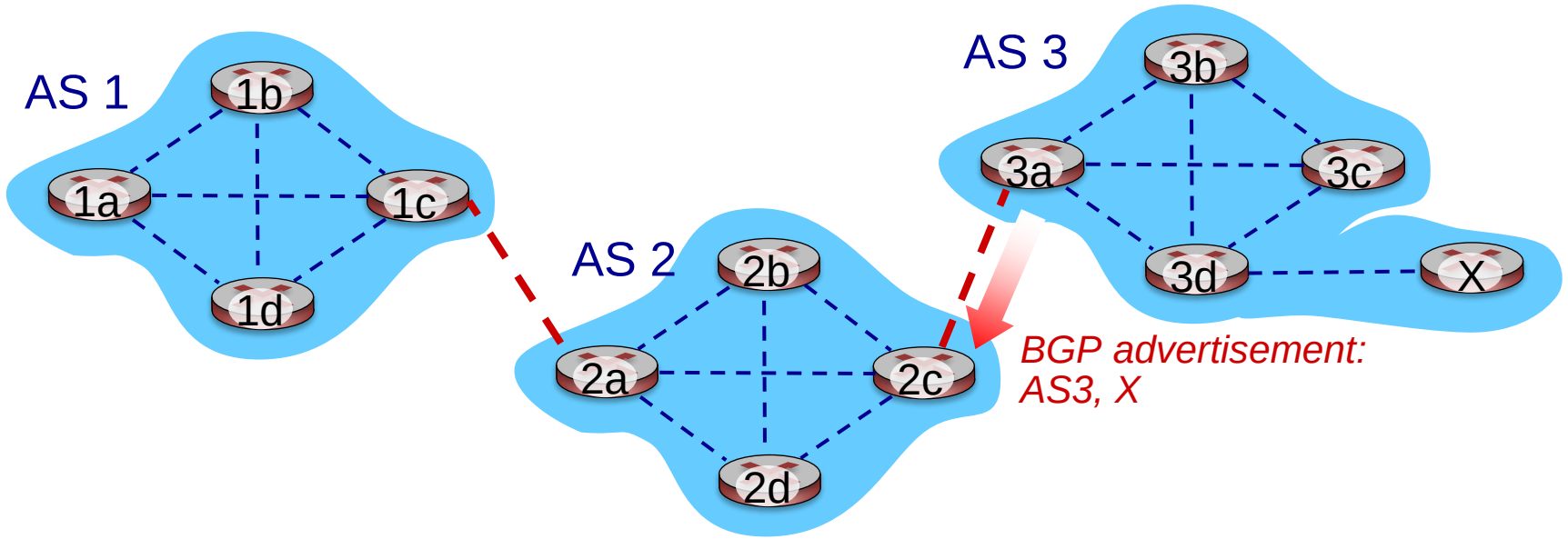
BGP basics

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

when AS3 gateway router 3a advertises path AS3,X to AS2 gateway router 2c:

AS3 *promises* to AS2 it will forward datagrams towards X



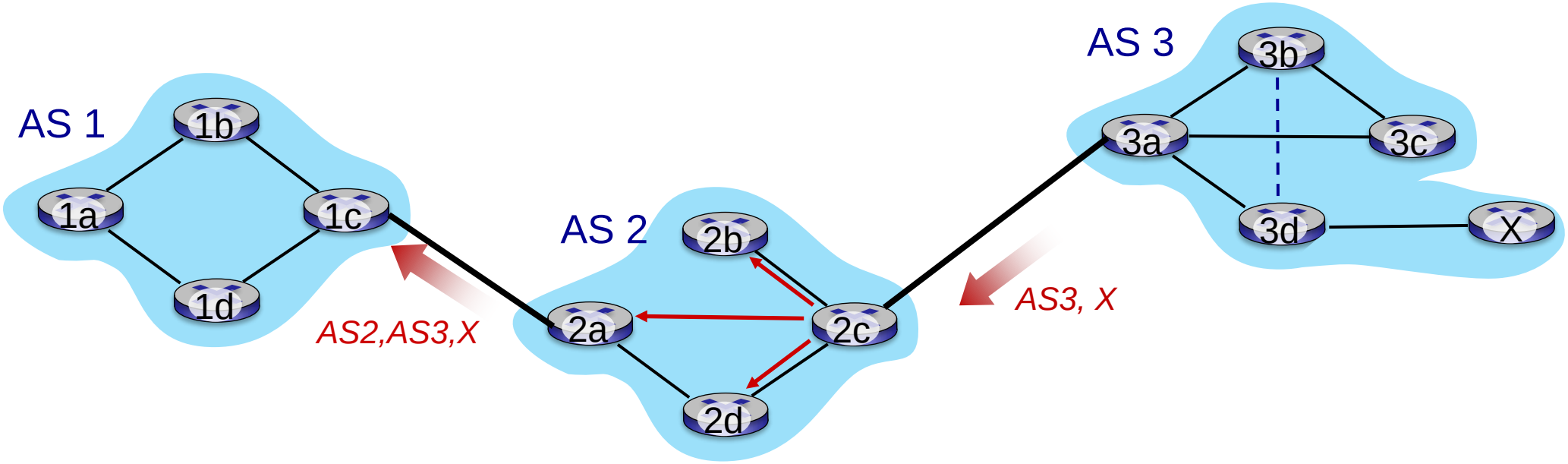
BGP protocol messages

- BGP messages exchanged between peers over TCP connection
- BGP messages [RFC 4371]:
  - OPEN: opens TCP connection to remote BGP peer and authenticates sending BGP peer
  - **UPDATE:** advertises new path (or withdraws old)
  - KEEPALIVE: keeps connection alive in absence of UPDATES; also ACKs OPEN request
  - NOTIFICATION: reports errors in previous msg; also used to close connection

Path attributes and BGP routes

- BGP advertised route: prefix + attributes
  - prefix: destination being advertised
  - two important attributes:
    - AS-PATH: list of ASes through which prefix advertisement has passed
    - NEXT-HOP: indicates specific internal-AS router to next-hop AS
- policy-based routing:
  - gateway receiving route advertisement uses *import policy* to accept/decline path (e.g., never route through AS Y).
  - AS policy also determines whether to *advertise* path to other other neighboring ASes

BGP path advertisement



- AS2 router 2c receives path advertisement AS3,X (via eBGP) from AS3 router 3a
- based on AS2 policy, AS2 router 2c accepts path AS3,X, propagates (via iBGP) to all AS2 routers
- based on AS2 policy, AS2 router 2a advertises (via eBGP) path AS2, AS3, X to AS1 router 1c

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:

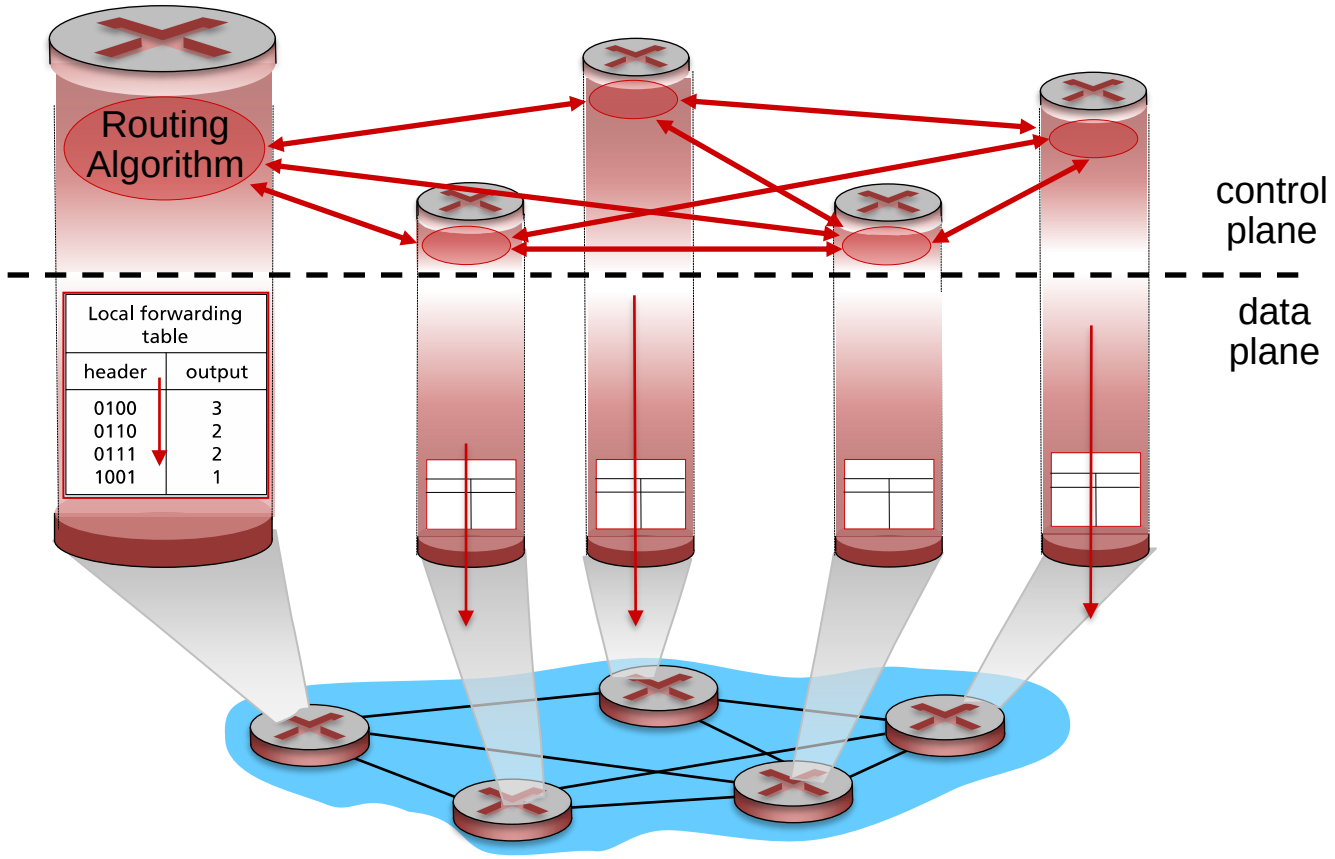
- ICMP msgs carried in IP datagrams

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

Control Plane Wrap up

- approaches to network control plane
  - per-router control (traditional)
  - logically centralized control (software defined networking)
- traditional routing algorithms
  - routing: link state, distance vectors
  - implementation in Internet: OSPF, BGP
- Internet Control Message Protocol



Next:

1. Link Layer
2. Security
3. Random Topics in session, presentation, and physical layers