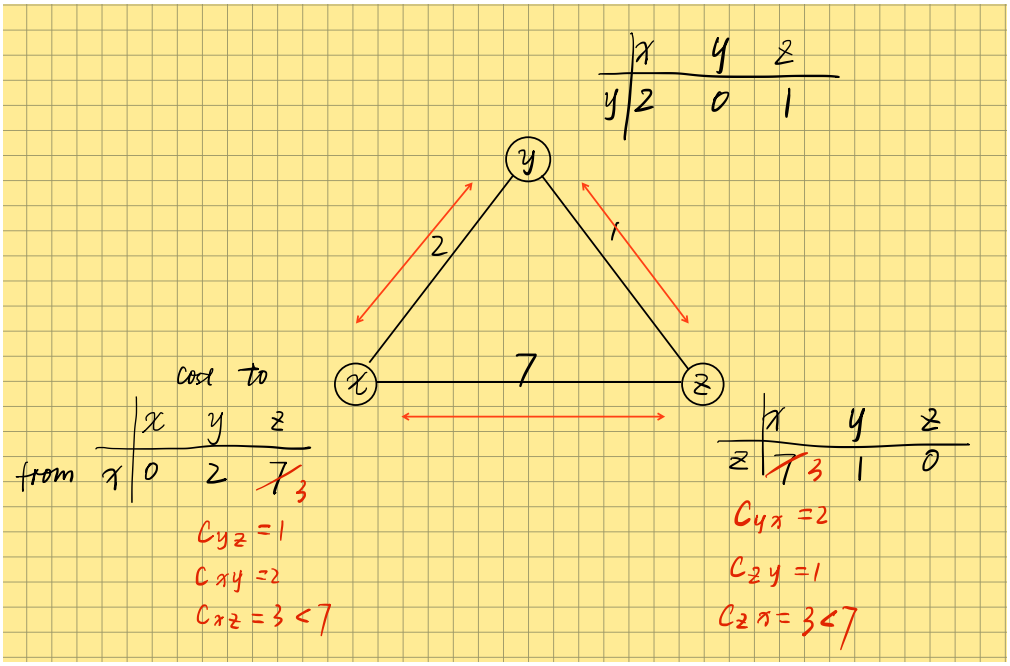
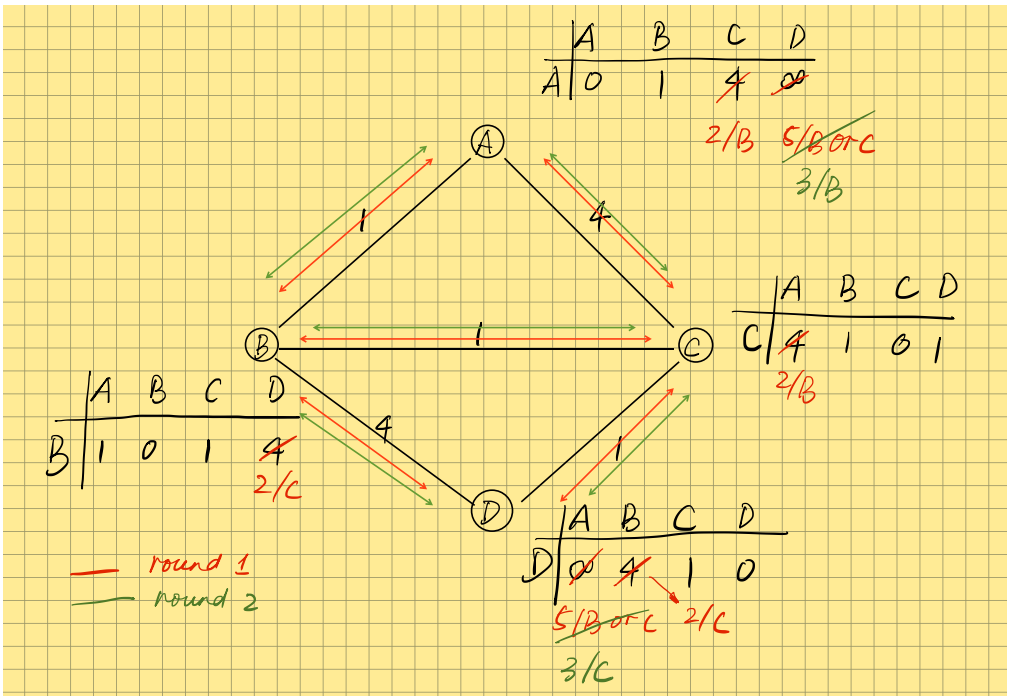
Network Layer (III)

Routing Algorithms - Categories (cont.)

- Distance Vector: decentralized
  - estimates of distances to all nodes in the network sent to all neighbors
  - estimates are improved based on information from neighbors
  - the process is repeated and routing tables are populated based on the estimates



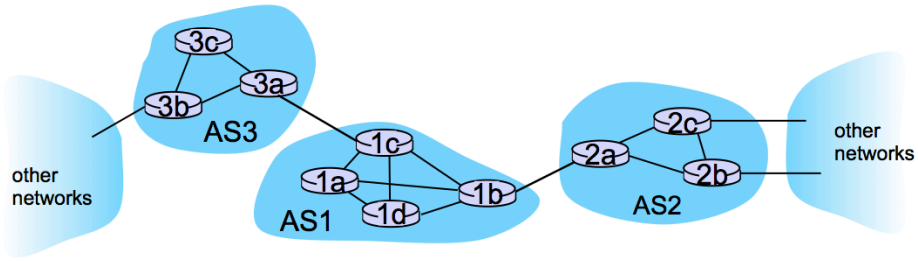


Making Routing Scalable

- Our routing study thus far - idealized
  - all router identical
  - network “flat”
  - but it’s not true in practice
- In practice, the Internet is large …
  - with billions of destinations
  - can’t store all destinations in routing tables!
  - routing table exchange would swamp links!
  - so, scalability needs to be solved
- Administrative autonomy
  - Internet = network of networks
  - each network admin may want to control routing in its own network

Internet Approach to Scalable Routing

- Aggregate routers into regions known as “autonomous systems” (AS) (a.k.a. “domains”)
- The Internet is composed of interconnected ASes



- intra-AS routing - interior gateway routing (IGP)
  - routing among hosts and routers in same AS (“network”)
  - all routers in an AS must run the same intra-domain protocol
    - routers in different AS'es can run different intra-domain routing protocols
  - gateway router: at “edge” of its own AS, has link(s) to router(s) in other AS’es

- inter-AS routing - exterior gateway routing (EGP)
  - routing among AS’es
  - gateways perform inter-domain routing (as well as intra-domain routing)

  - Suppose a router in AS1 receives packet destined outside of AS1 in the above diagram, the router should forward packet to a gateway router, but which one, 1c or 1b?
  - AS1 must:
    - learn which destinations are reachable through AS2 and which through AS3
    - propagate this reachability info to all routers in AS1

- Forwarding table configured by both intra- and inter-AS routing algorithm
  - intra-AS routing determine entries for destinations within AS
  - inter-AS & intra-AS determine entries for external destinations

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Examples of Routing Protocols

	Distance Vector	Link State
IGP	RIP	OSPF
EGP	BGP-4*	

* BGP-4 extends the concept of Distance Vector routing to include the path information and is typically referred to as a **Path Vector** routing protocol

- RIP (Routing Information Protocol)
  - a distance vector routing protocol
  - specify the measure of distance (hops), update interval (30 sec), link failure detect, and recovery.

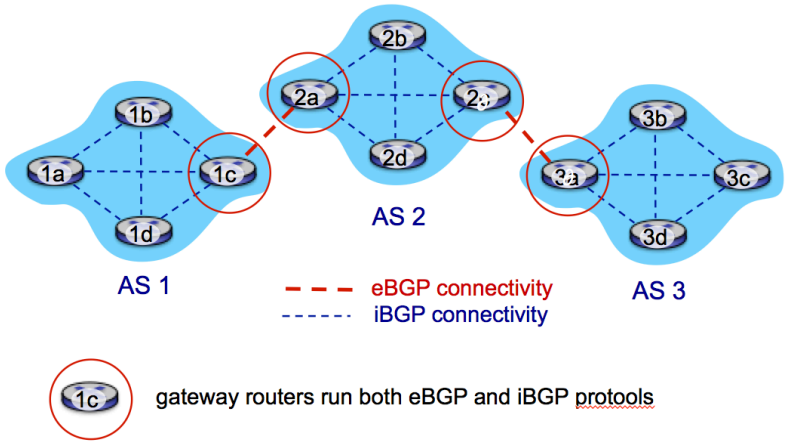
- OSPF (Open Shortest Path First)
  - a link-state algorithm
  - specify the way to require network topology (flood advertisements) and how to define link weights (user defined).

BGP-4

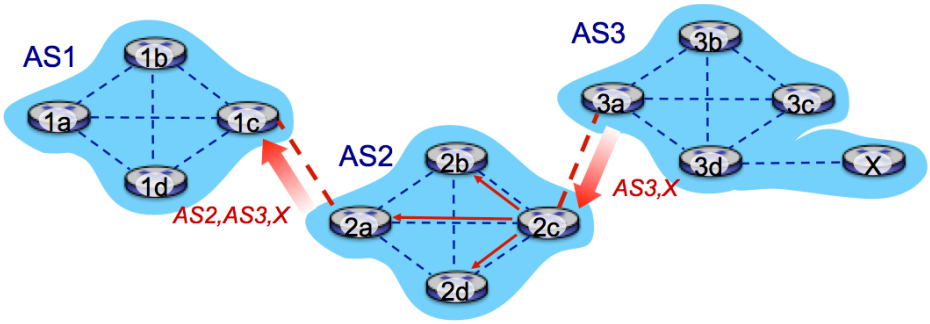
- Border Gateway Protocol
  - exterior gateway routing protocol; “glue that holds the Internet together”
  - path vector routing
  - allows policy based routing
  - AS as a routing hop

- BGP provides each AS two means:
  - eBGP: obtain subnet reachability information from neighboring AS’es
  - iBGP: propagate reachability information to all AS-internal routers
  - determine “good” routes to other networks based on reachability information and policy

- eBGP, iBGP connections

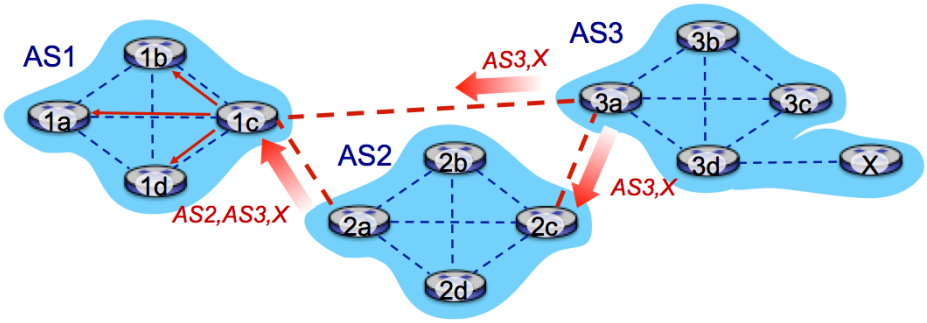


- BGP path advertisement
  - Example 1: receive and propagate a path info into AS1 via AS2, assuming AS2 policy allows AS3 traffic to pass



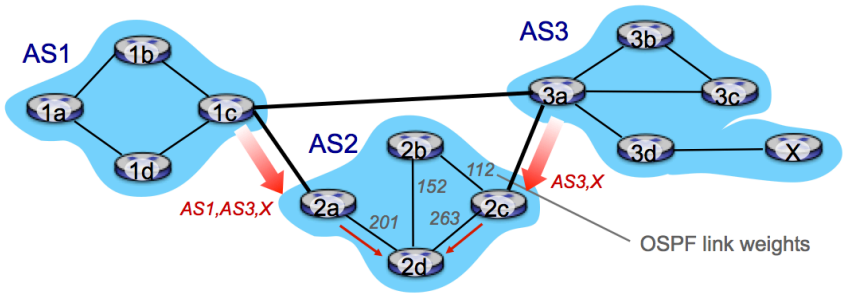
    - AS2 router 2c receives path advertisement AS3,X (via eBGP) from AS3 router 3a
    - Based on AS2 policy, AS2 router 2c accepts path AS3,X, propagates (via iBGP) to all AS2 routers
    - Based on AS2 policy, AS2 router 2a advertises (via eBGP) path AS2, AS3, X to AS1 router 1c

  - Example 2: AS1 receives multiple pieces of path info to the same destination via multiple paths, and AS1 picks a path based on policy.



- gateway routers may learn about multiple paths to destination
- AS1 gateway router 1c learns path *AS2,AS3,X* from 2a
- AS1 gateway router 1c learns path *AS3,X* from 3a
- Based on policy, AS1 gateway router 1c chooses path AS3,X, and advertises path within AS1 via iBGP

- Hot Potato Routing



- 2d learns (via iBGP) it can route to X via 2a or 2c
- *hot potato routing:* choose local gateway that has least intra-domain cost (e.g., 2d chooses 2a, even though more AS hops to *X*): don't worry about inter-domain cost!

Disclaimer: Notes adapted from the textbook and online resources.