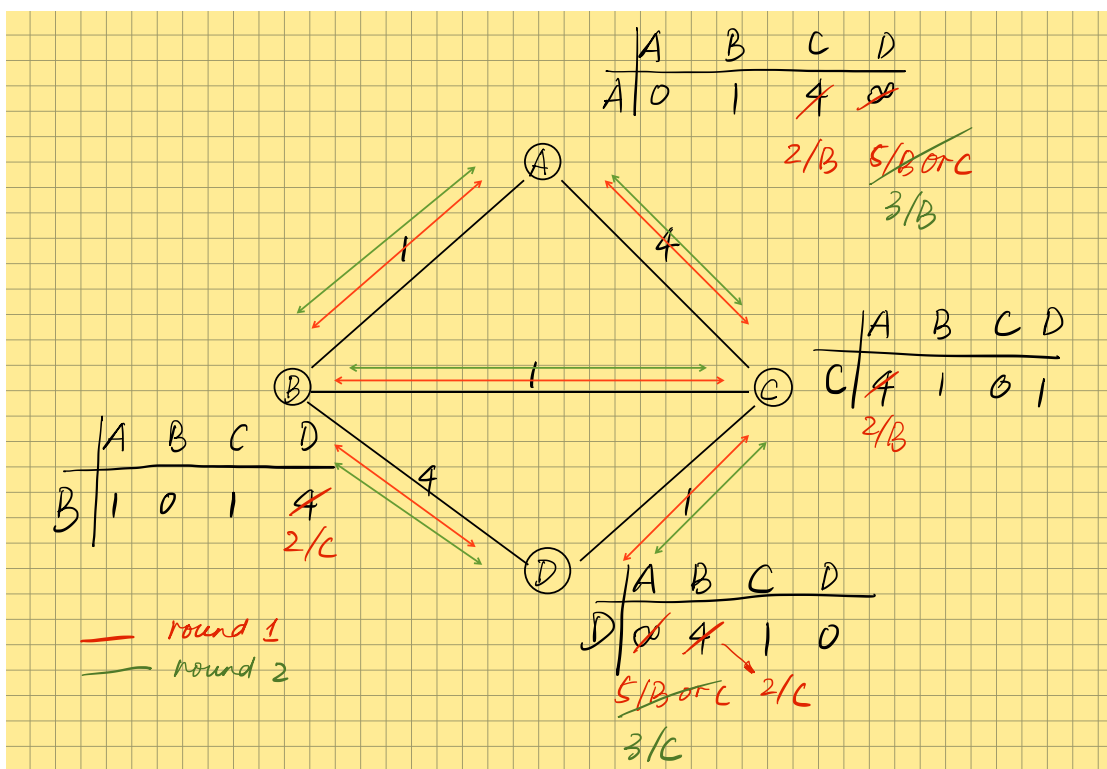
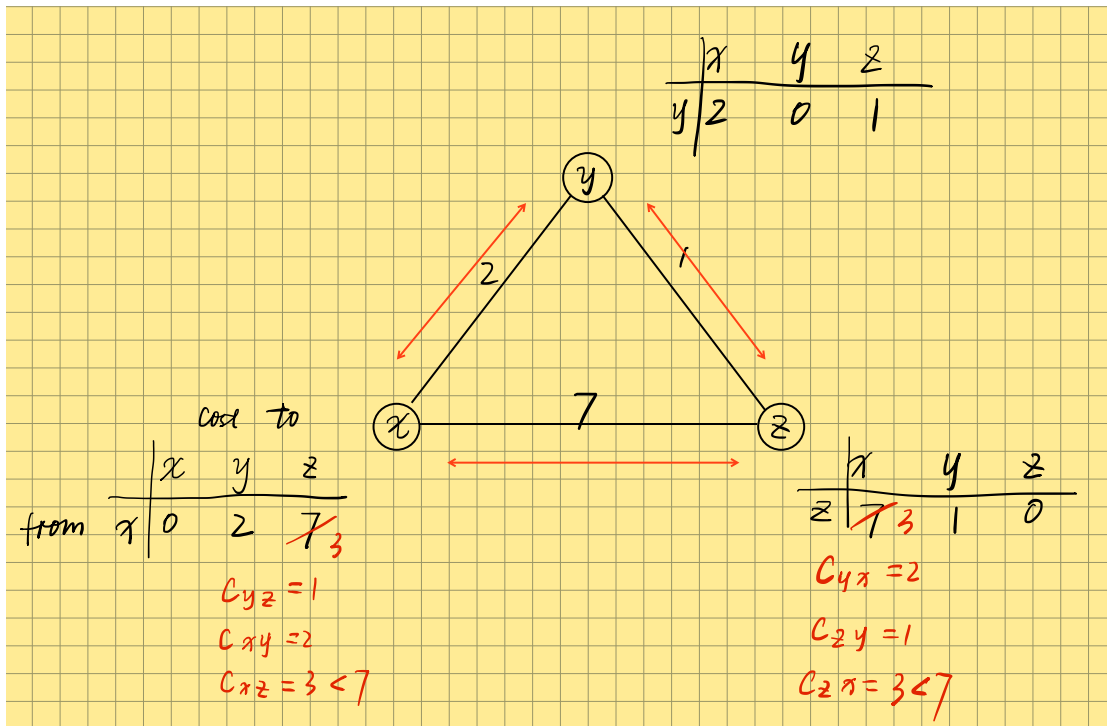


Network Layer (IV)

Routing Protocols - 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**

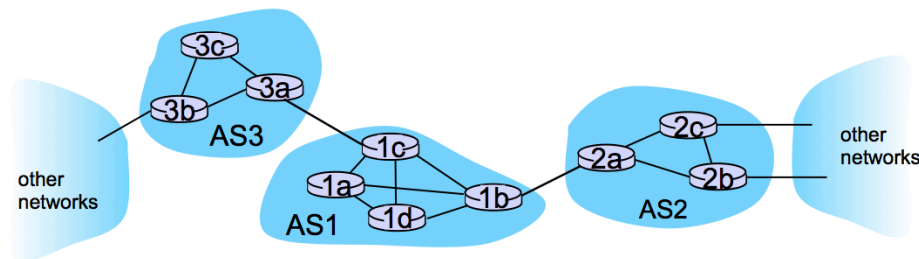


Making Routing Scalable

- 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

Examples of Routing Protocols

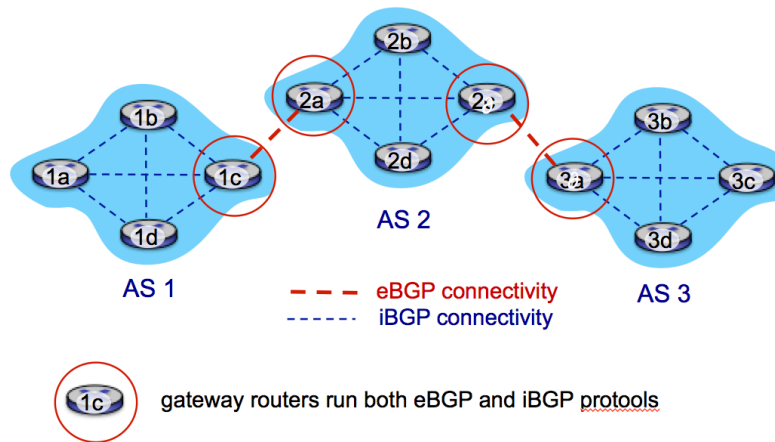
	Distance Vector	Link State
IGP	RIP	OSPF
EGP	BGP-4*	

* 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

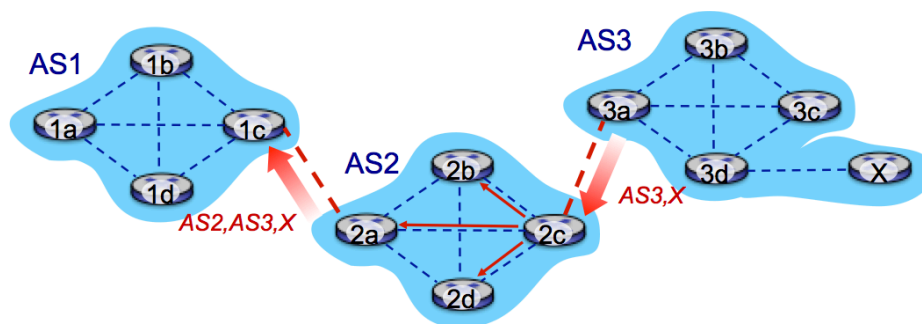
- RIP (Routing Information Protocol)
 - a distance vector routing protocol
 - specify the measure of distance (hops), update interval (30 sec), link failure detect, and recovery.
- OSPF (Open Shortest Path First)
 - a link-state algorithm
 - specify the way to require network topology (flood advertisements) and how to define link weights (user defined).

BGP-4

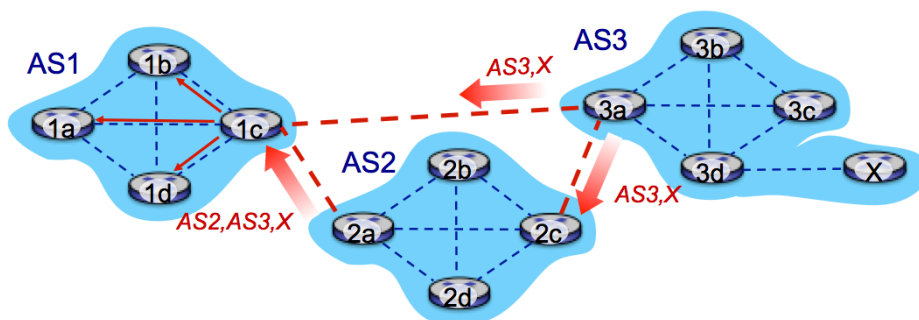
- **Border Gateway Protocol**
 - exterior gateway routing protocol; “glue that holds the Internet together”
 - **path** vector routing
 - allows policy based routing
 - AS as a routing hop
- BGP provides each AS two means:
 - **eBGP**: obtain subnet reachability information from neighboring AS'es
 - **iBGP**: propagate reachability information to all AS-internal routers
 - determine “good” routes to other networks based on reachability information and **policy**
- eBGP, iBGP connections



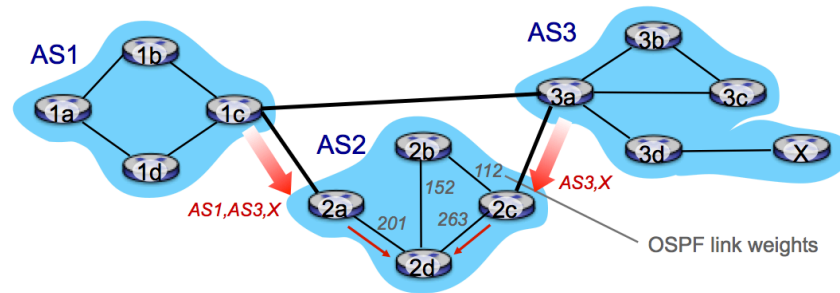
- BGP path advertisement
 - Example 1: receive and propagate a path info into AS1 via AS2, assuming AS2 policy allows AS3 traffic to pass



- 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.