

Distance vector algorithm

iterative, asynchronous:

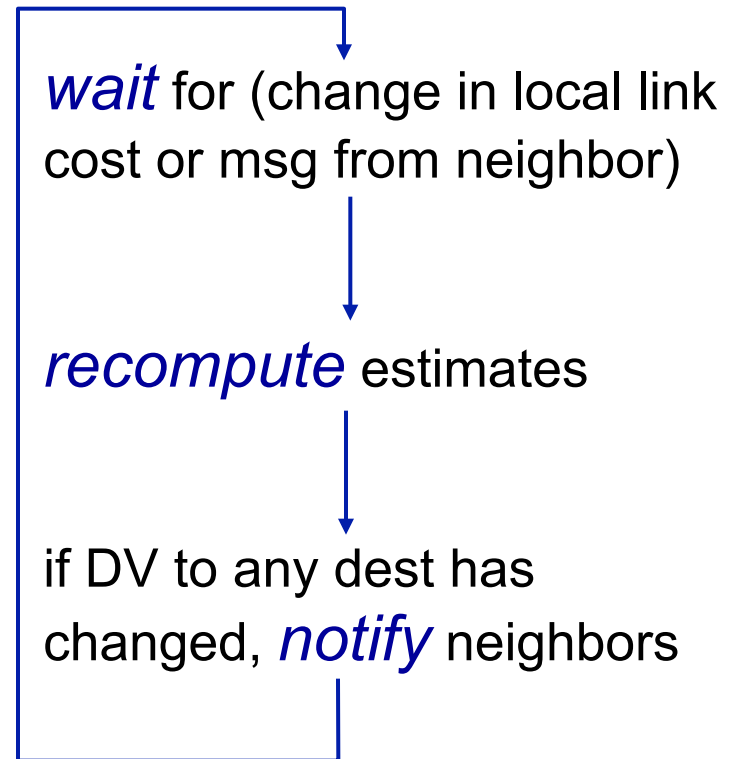
each local iteration
caused by:

- local link cost change
- DV update message from neighbor

distributed:

- each node notifies neighbors *only* when its DV changes
 - neighbors then notify their neighbors if necessary

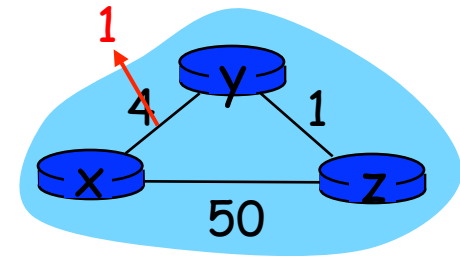
each node:



Distance vector: link cost changes

link cost changes:

- ❖ node detects local link cost change
- ❖ updates routing info, recalculates distance vector
- ❖ if DV changes, notify neighbors



“good
news
travels
fast”

t_0 : y detects link-cost change, updates its DV, informs its neighbors.

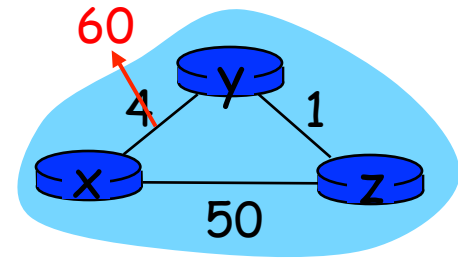
t_1 : z receives update from y, updates its table, computes new least cost to x, sends its neighbors its DV.

t_2 : y receives z's update, updates its distance table. y's least costs do *not* change, so y does *not* send a message to z.

Distance vector: link cost changes

link cost changes:

- ❖ node detects local link cost change
- ❖ *bad news travels slow* - “count to infinity” problem!
- ❖ 44 iterations before algorithm stabilizes: see text



poisoned reverse:

- ❖ If Z routes through Y to get to X :
 - Z tells Y its (Z's) distance to X is infinite (so Y won't route to X via Z)
- ❖ will this completely solve count to infinity problem?

Select a correct statement

- A. A link state routing protocol requires message exchange among all nodes in a network
- B. A distance vector routing protocol requires message exchanges between neighbor nodes only
- C. In link state, each node computes its own routing table while in distance vector, it's node routing table is used by others
- D. A and B
- E. A, B and C

Comparison of LS and DV algorithms

message complexity

- **LS:** with n nodes, E links, $O(nE)$ msgs sent
- **DV:** exchange between neighbors only
 - convergence time varies

speed of convergence

- **LS:** $O(n^2)$ algorithm requires $O(nE)$ msgs
 - may have oscillations
- **DV:** convergence time varies
 - may be routing loops
 - count-to-infinity problem

robustness: what happens if router malfunctions?

LS:

- node can advertise incorrect *link* cost
- each node computes only its own table

DV:

- DV node can advertise incorrect *path* cost
- each node's table used by others
 - error propagate thru network

Hierarchical routing

our routing study thus far - idealization

❖ all routers identical

❖ network “flat”

... *not* true in practice

scale: with 600 million destinations:

- can't store all dest's in routing tables!
- routing table exchange would swamp links!

administrative autonomy

- internet = network of networks
- each network admin may want to control routing in its own network

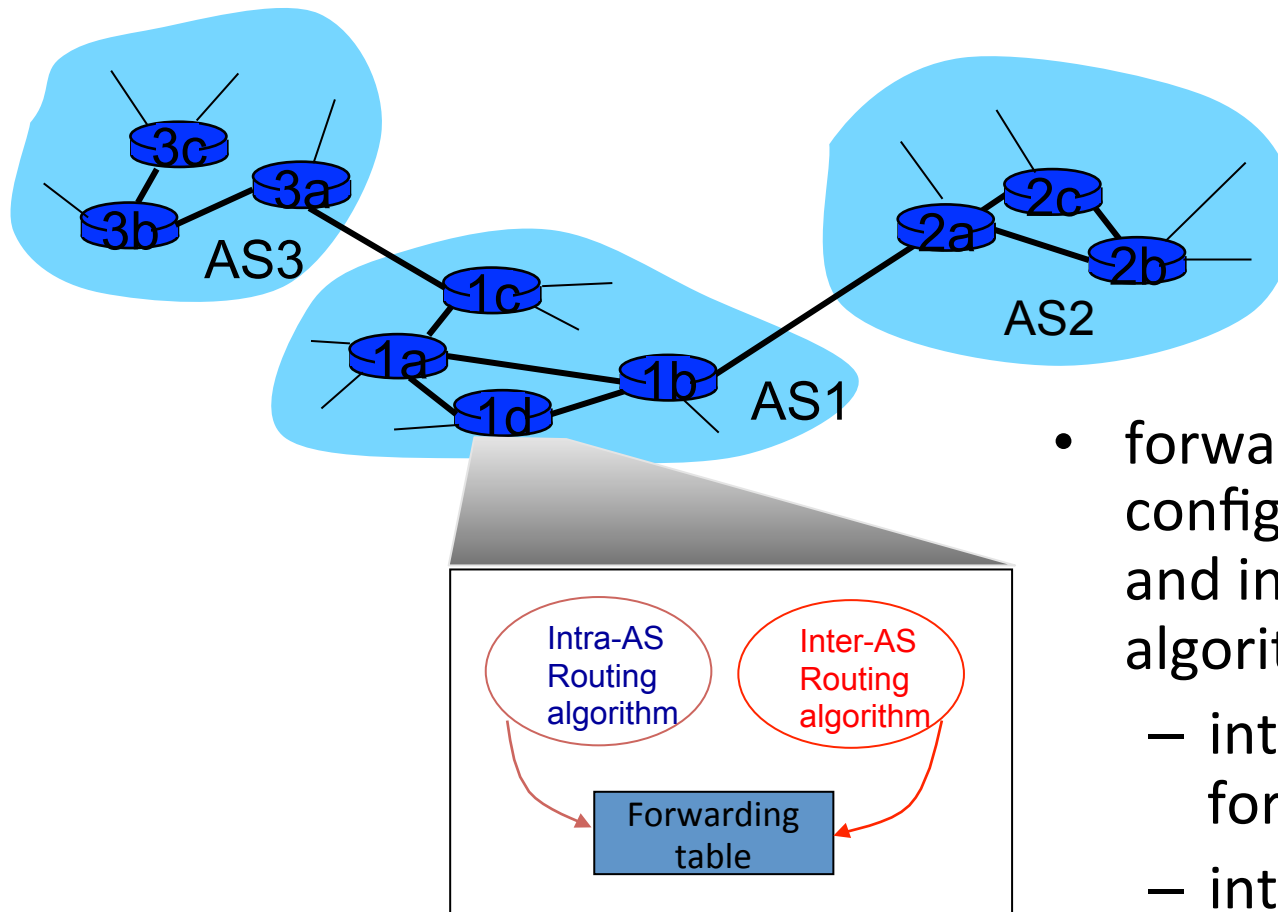
Hierarchical routing

- 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

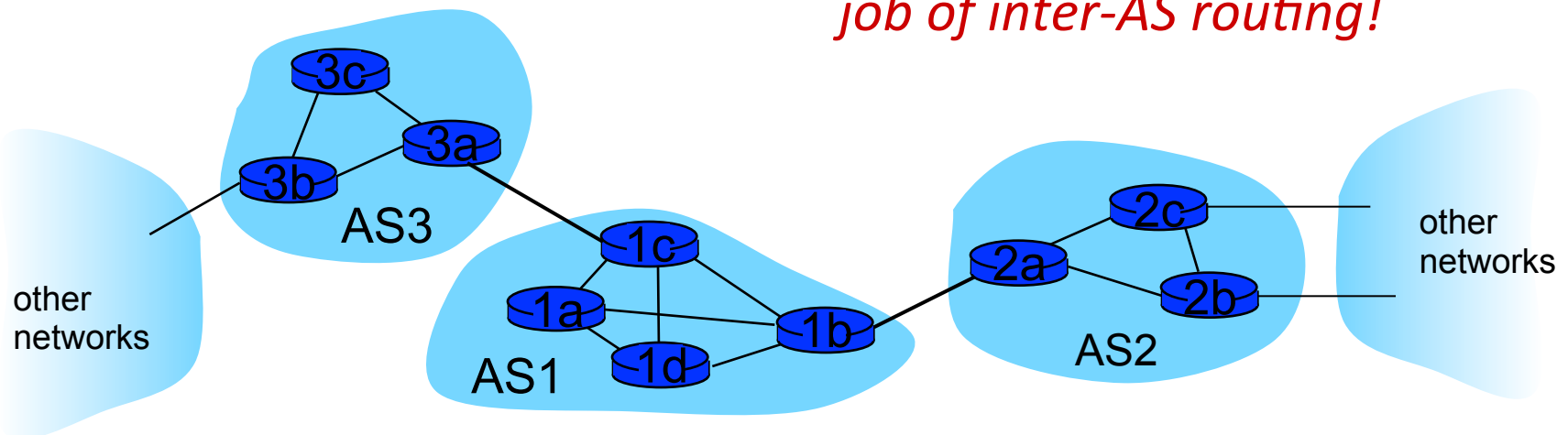
Inter-AS tasks

- suppose router in AS1 receives datagram destined outside of AS1:
 - router should forward packet to gateway router, but which one?

AS1 must:

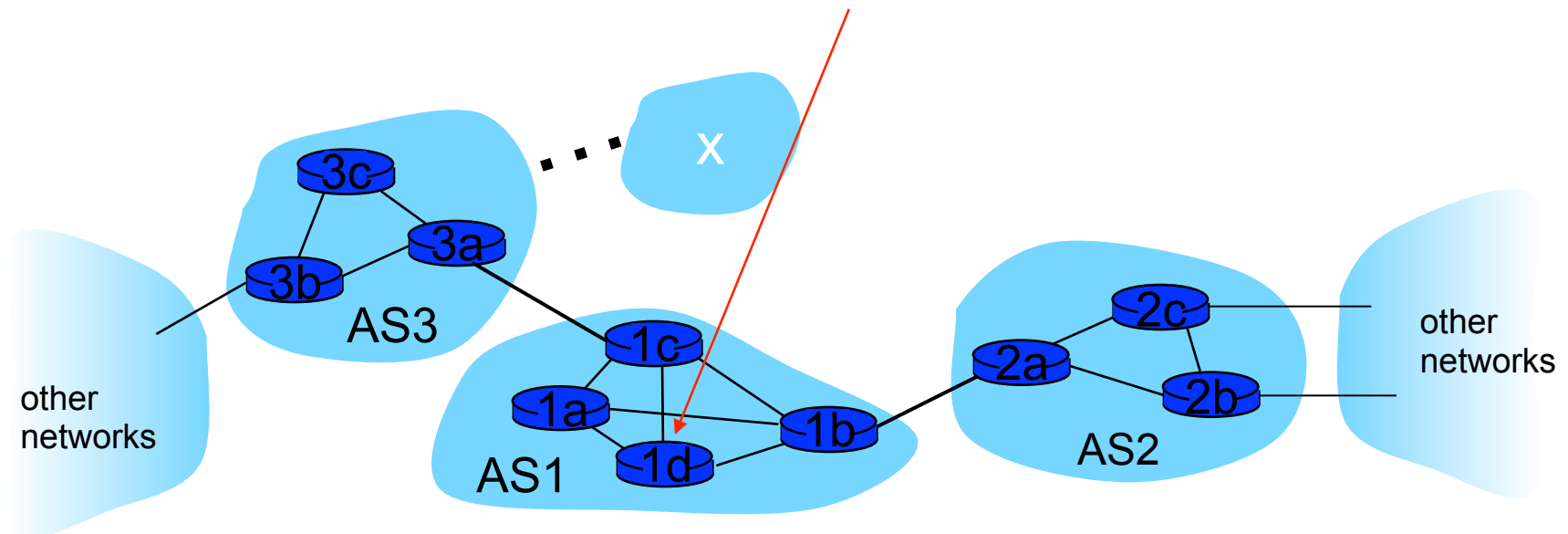
1. learn which dests are reachable through AS2, which through AS3
2. propagate this reachability info to all routers in AS1

job of inter-AS routing!



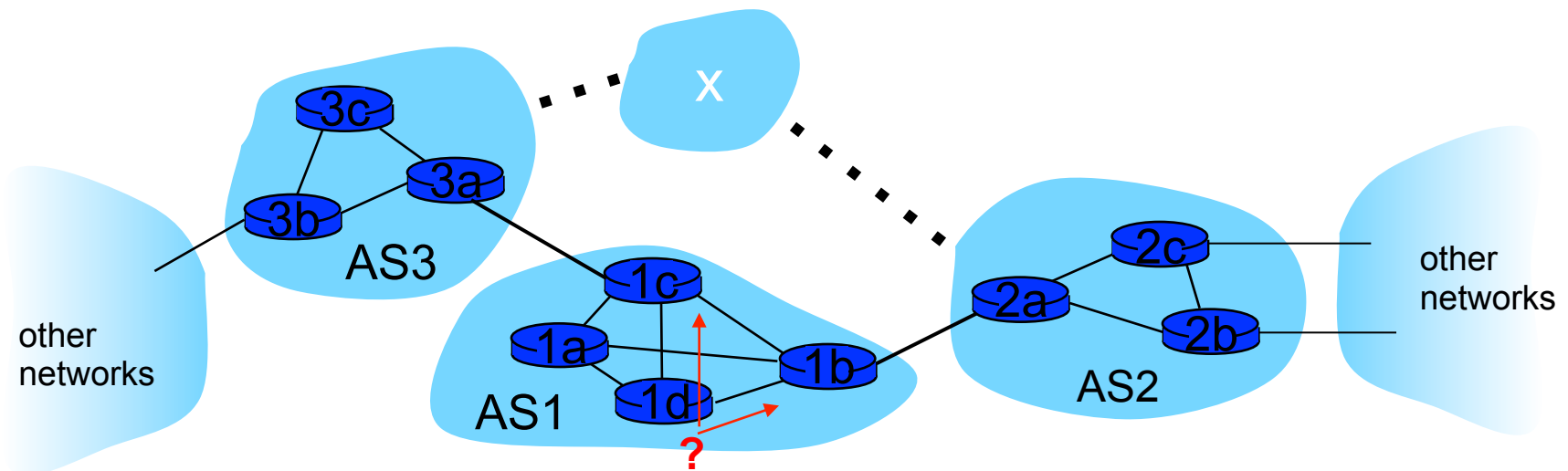
Example: setting forwarding table in router 1d

- 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 **I** is on the least cost path to 1c
 - installs forwarding table entry **(x, I)**



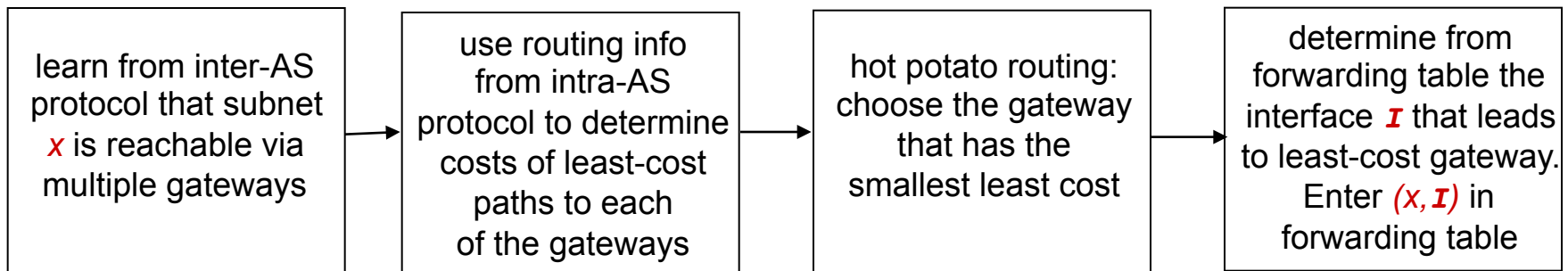
Example: choosing among multiple ASes

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



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 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.



Why is hierarchical routing needed?

- A. Routers are not identical
- B. The real network is too large to run a single routing protocol
- C. The Internet is “flat”
- D. A and B
- E. A, B and C

Routing in the Internet

RIP

OSPF

BGP

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)

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*)

OSPF (Open Shortest Path First)

- “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)

- **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.

Internet inter-AS routing: BGP

- **BGP (Border Gateway Protocol):** *the de facto inter-domain routing protocol*
 - “glue that holds the Internet together”
- 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.
- allows subnet to advertise its existence to rest of Internet: “*I am here*”

Next lecture

- Introduction to the Link Layer
 - Readings 5.1-5.3