Routing

- aggregate routers into regions
  - AS: autonomous systems
- routers in same AS run same routing protocol
- “intra-AS” routing protocol
- routers in different AS can run different intra-AS routing protocol

OSPF

- Link state algorithm
- Main functions
  - Broadcast link state info
  - Link failure detection: Neighbor nodes send HELLO msg to each other periodically

OSPF

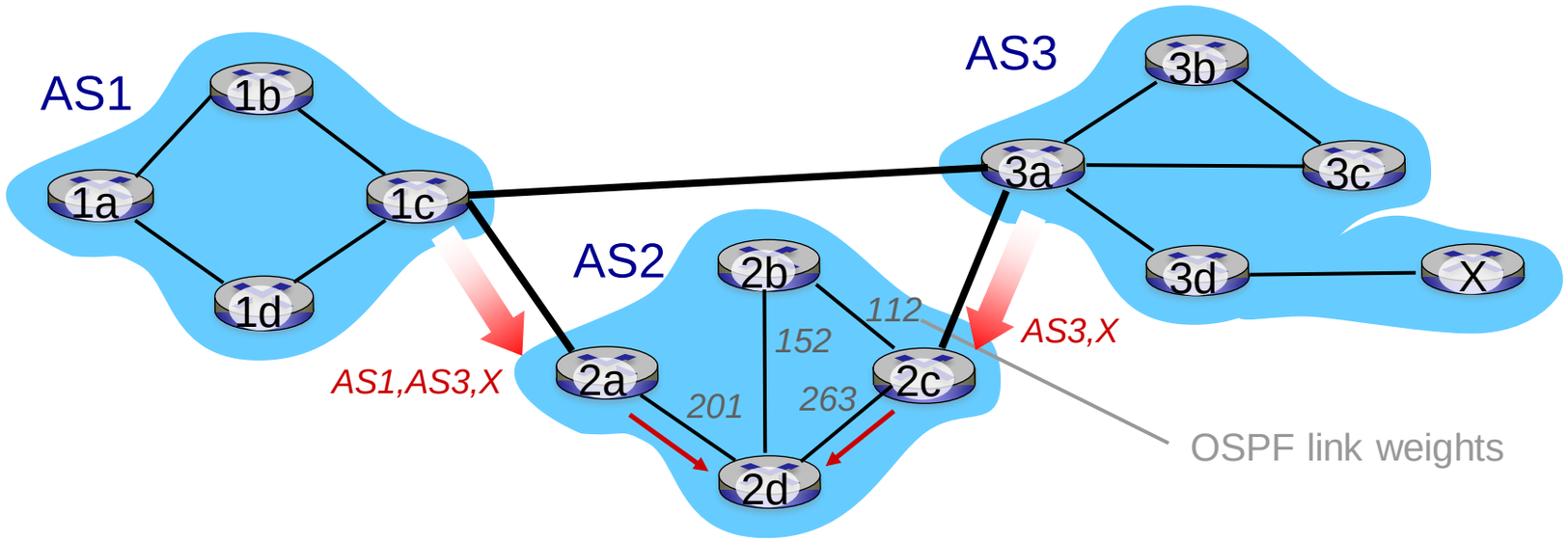
- Message:
  - HELLO message: used as heartbeat to detect failure
  - LSP: information of the node, the list of direct neighbors and link costs
- Generated periodically or upon failure
- Flooding of LSP
  - How to avoid loop? Check the message ID

BGP (Border Gateway Protocol)

- An inter-domain routing protocol; allows subnet to advertise its existence to rest of Internet: “I am here”
- BGP provides each AS a means to:
  - eBGP: obtain subnet reachability information from neighboring ASs.
  - iBGP: propagate reachability information to all AS-internal routers.
- How BGP works with intra-domain routing (e.g. OSPF)

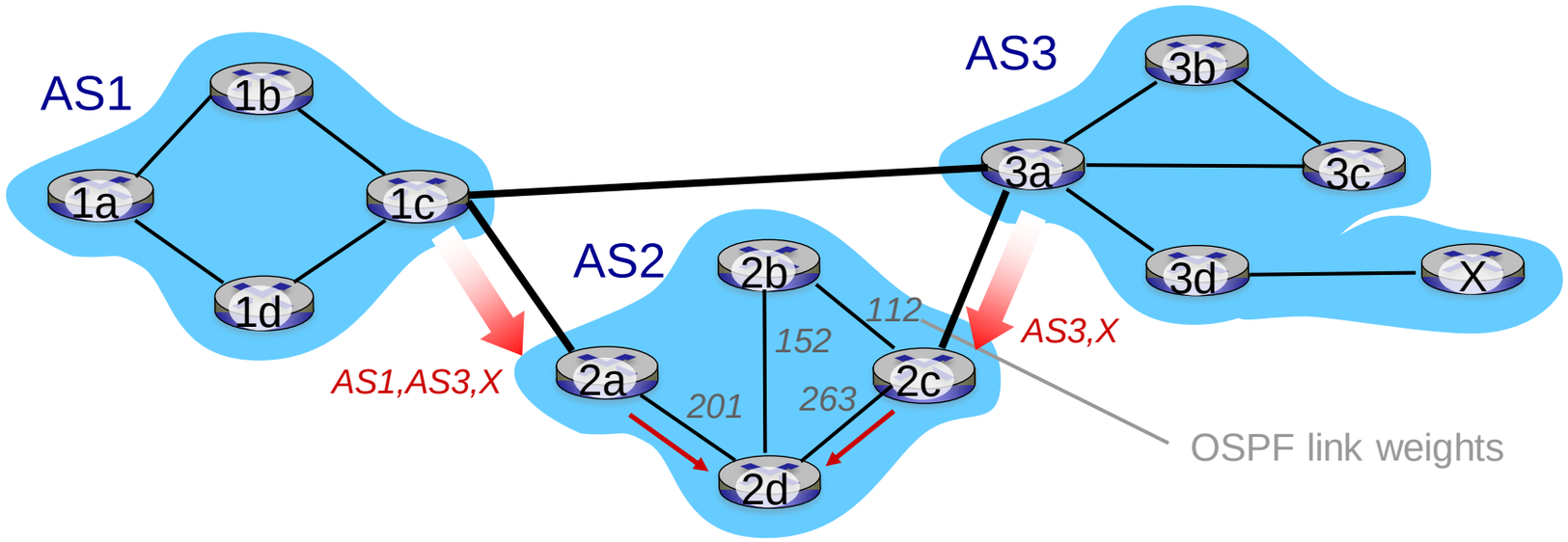
BGP: iBGP and eBGP

- How 2c knows the route to x?
- How 2d knows the route to x?



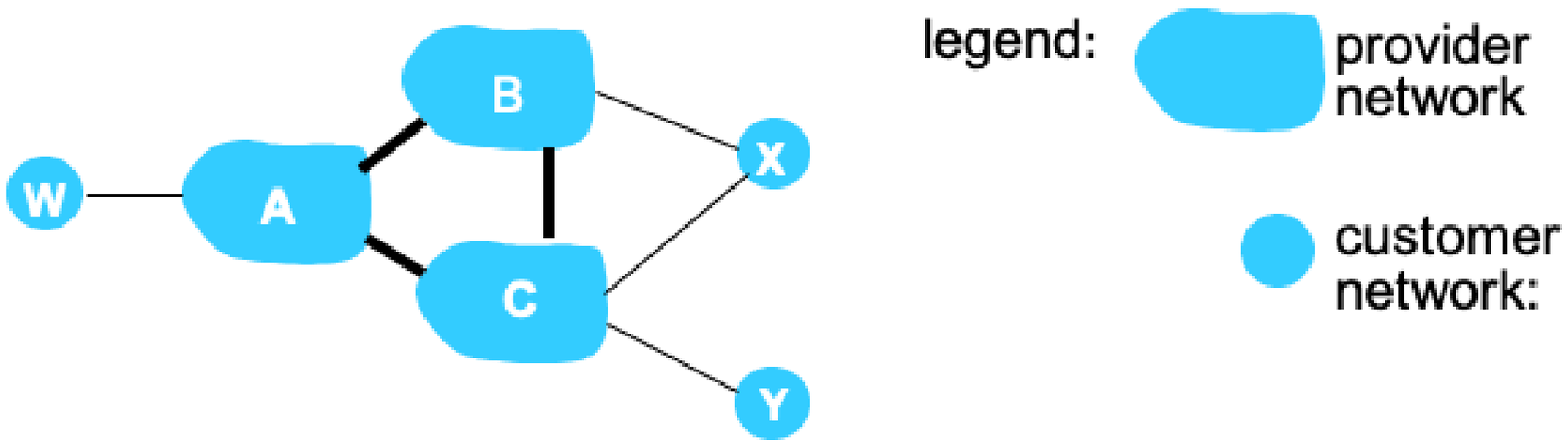
BGP: Hot potato routing

- 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!



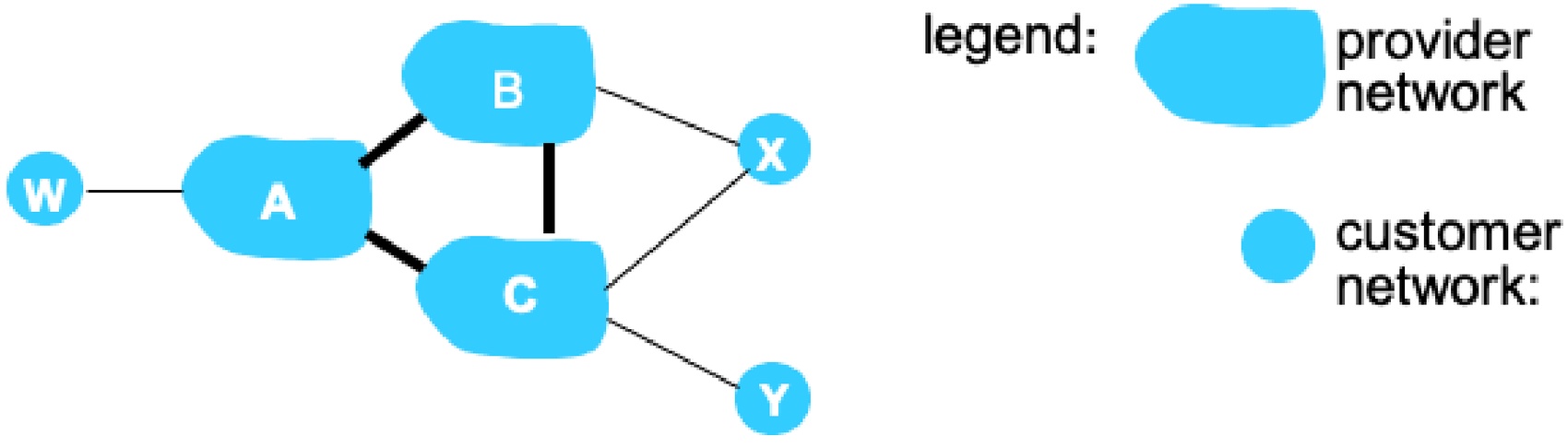
BGP: routing policy

- A,B,C are provider networks
- X,W,Y are customer (of provider networks)
- X is attached to two networks.
- It does not want to route from B via X to C
- … so X will not advertise to B a route to C



BGP: routing policy

- A advertises path AW to B
- B advertises path BAW to X
- Should B advertise path BAW to C?



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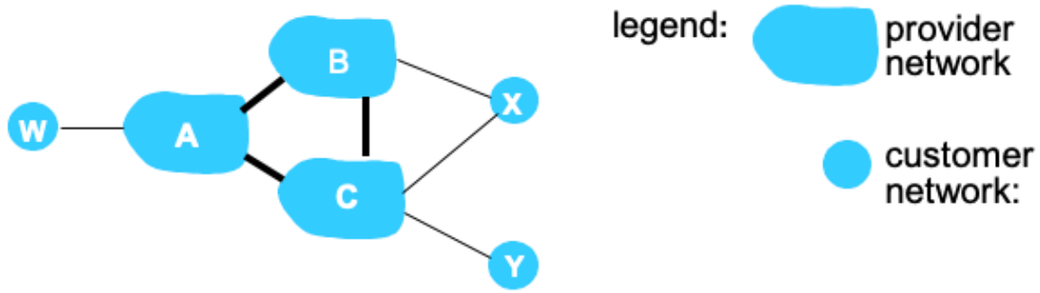

- No! B gets no “revenue” for routing CBAW since neither W nor C are B’s customers
- B wants to force C to route to w via A
- B wants to route only to/from its customers!

BGP: practice problems

- Explain how loops in paths can be detected in BGP.

- BGP advertisements contain complete paths showing the AS's the path passes through, and so a router can easily identify a loop because an AS will appear two or more times.

BGP: practice problems

- Suppose that there is another stub network V that is a customer of ISP A. Suppose that B and C have a peering relationship, and A is a customer of both B and C. Suppose that A would like to have the traffic destined to W to come from B only, and the traffic destined to V from either B or C. How should A advertise its routes to B and C? What AS routes does C receive?

- A should advertise to B two routes: A-W and A-V

- A should advertise to C only one route: A-V

- C receives AS paths: B-A-W, B-A-V, A-V

Routing: summary

- Intra-domain routing V.S. inter-domain routing
  - Performance V.S. policy
  - Scalability: hierarchical routing
- Distance-vector routing V.S. link-state routing
  - Fully-distributed algorithm V.S. decentralized algorithm

ICMP: Internet Control Message Protocol

- Used for feedback, status checking, error reporting at IP layer
- ICMP msgs are carried in IP packets
- `ping`: echo request/reply
- `traceroute`: nth packet has TTL = n

Traceroute: example

```
$ traceroute 8.8.8.8
traceroute to 8.8.8.8 (8.8.8.8), 64 hops max, 52 byte packets
 1  172.30.40.3 (172.30.40.3)  4.055 ms  3.017 ms  3.871 ms
 2  wifi-131-179-60-1.host.ucla.edu (131.179.60.1)  2.545 ms  2.288 ms  2.714 ms
 3  ra00f1.anderson--cr00f2.csb1.ucla.net (169.232.8.12)  3.653 ms  3.506 ms  3.724 ms
 4  cr00f2.csb1--bd11f1.anderson.ucla.net (169.232.4.5)  3.959 ms  4.383 ms  3.483 ms
 5  lax-agg6--ucla-10g.cenic.net (137.164.24.134)  3.951 ms  5.480 ms  3.840 ms
 6  74.125.49.165 (74.125.49.165)  6.558 ms  3.882 ms  3.890 ms
 7  108.170.247.129 (108.170.247.129)  3.192 ms
    108.170.247.193 (108.170.247.193)  93.964 ms
    108.170.247.161 (108.170.247.161)  3.297 ms
 8  108.177.3.127 (108.177.3.127)  3.657 ms
    209.85.255.73 (209.85.255.73)  3.571 ms
    108.177.3.129 (108.177.3.129)  3.261 ms
 9  google-public-dns-a.google.com (8.8.8.8)  5.315 ms  3.770 ms  12.165 ms
```

Traceroute: example