IP addresses: how to get one?

Q: How does *network* get net id part of IP address?

A: gets allocated portion of its provider ISP's address space

ISP's block	11001000 00010111 00010000	00000000	200.23.16.0/20
Organization 0	11001000 00010111 00010000	00000000	200.23.16.0/23
Organization 1	11001000 00010111 00010010	00000000	200.23.18.0/23
Organization 2	11001000 00010111 00010100	00000000	200.23.20.0/23
...	.....	....	....
Organization 7	11001000 00010111 00011110	00000000	200.23.30.0/23

IP addresses: how to get one?

Q: How does a *host* get IP address?

- hard-coded by system admin in a file
  - E.g. in Windows: control-panel -> network-> configuration -> tcp/ip -> properties
- DHCP: Dynamic Host Configuration Protocol: dynamically get address from a server
  - "plug-and-play"

DHCP: Dynamic Host Configuration Protocol

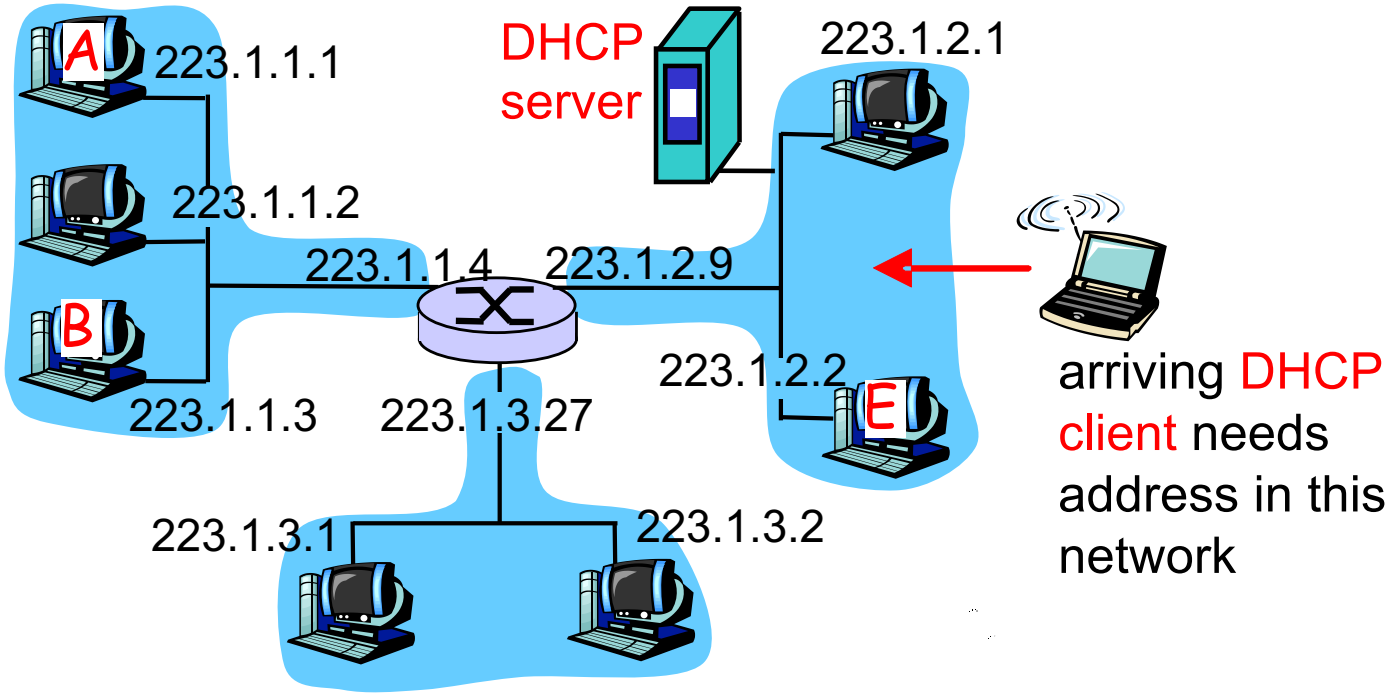
Goal: allow host to *dynamically* obtain its IP address from network server when it joins network

- Can renew its lease on address in use
- Allows reuse of addresses (only hold address while connected and "on")
- Support for mobile users who want to join network

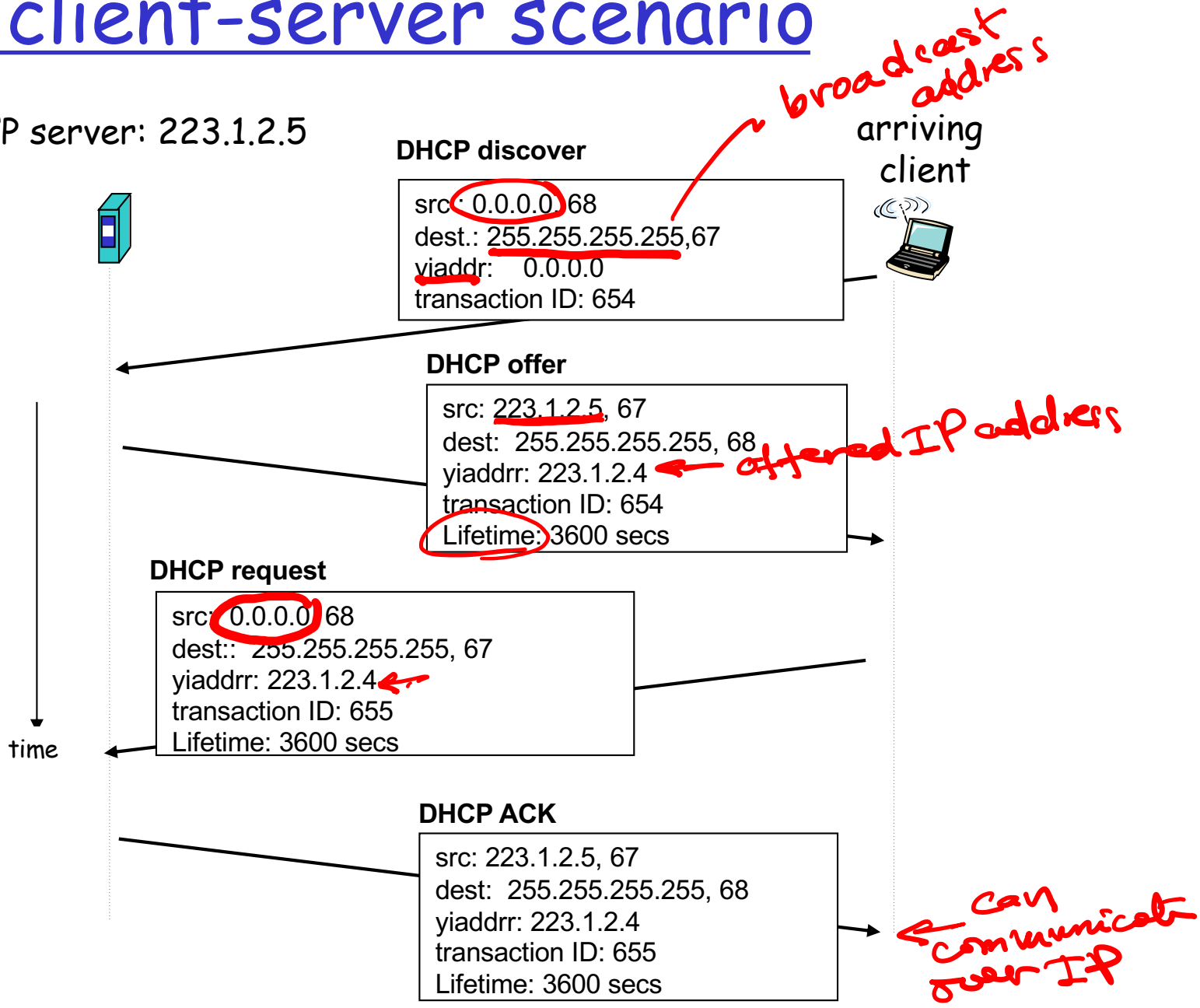
DHCP overview: over UDP

- host broadcasts "DHCP discover" msg
- DHCP server responds with "DHCP offer" msg
- host requests IP address: "DHCP request" msg
- DHCP server sends address: "DHCP ack" msg

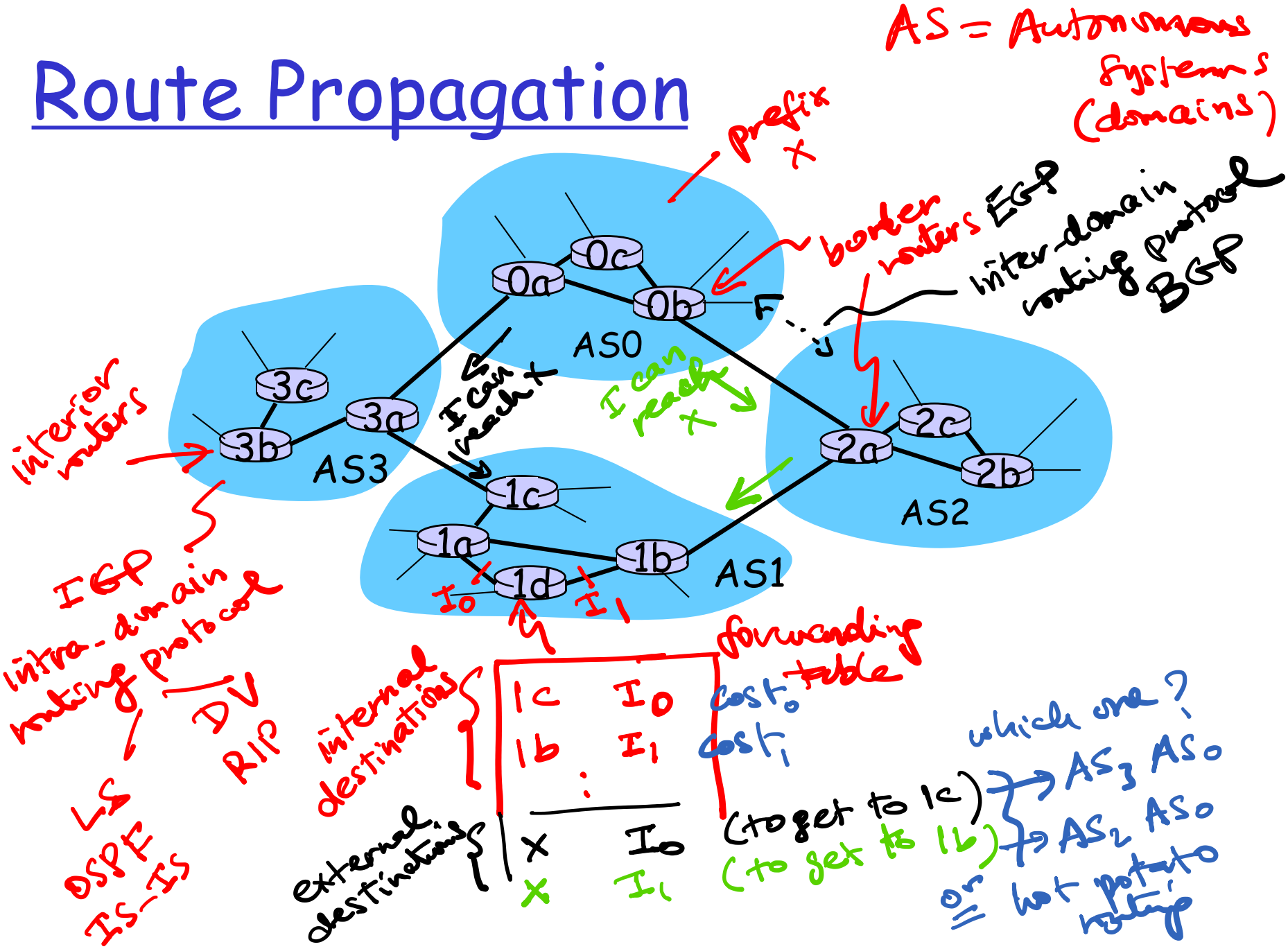
DHCP client-server scenario



DHCP client-server scenario



Route Propagation

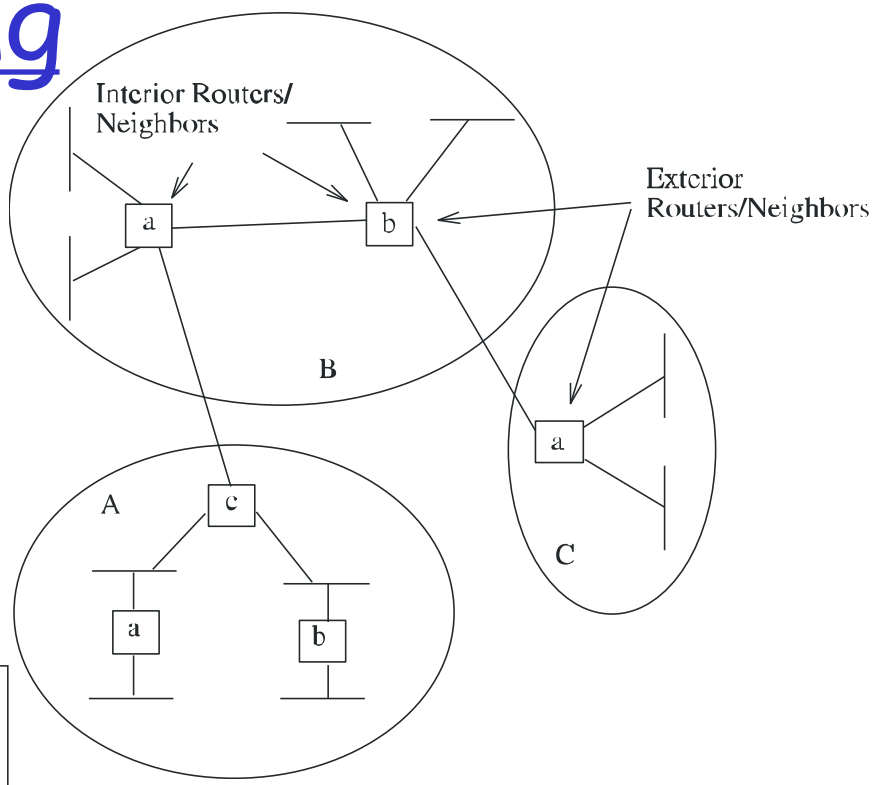


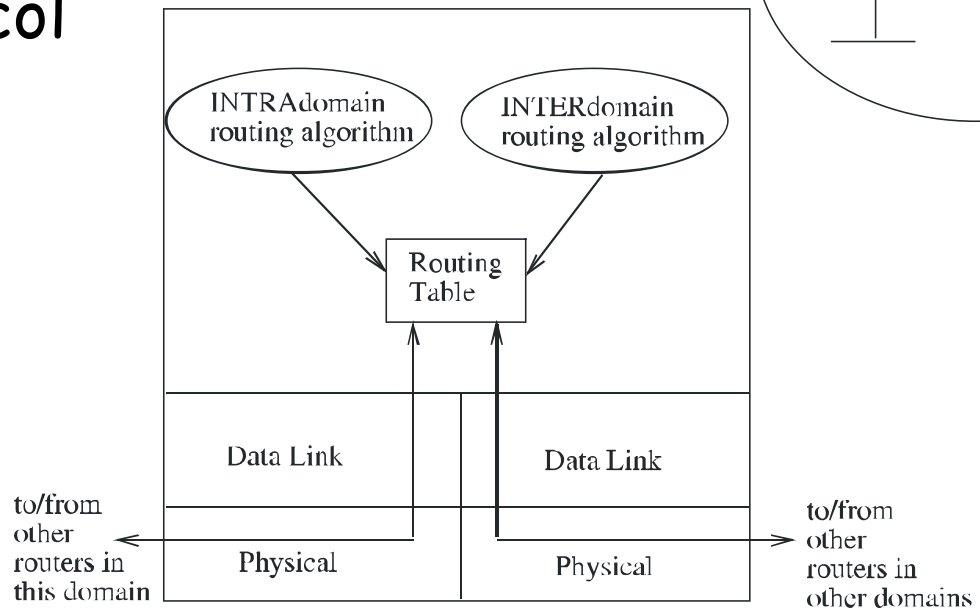
Route Propagation

- Idea: Impose a second hierarchy on the network that limits which routers talk to each other. (The first hierarchy is the address hierarchy that governs how packets are forwarded.)
- Autonomous System (AS)
  - corresponds to an administrative domain/region
  - examples: University, company, backbone network
  - assign each AS a 16-bit number
- Two-level route propagation hierarchy
  - interior gateway protocol (each AS selects its own)
  - exterior gateway protocol (Internet-wide standard)

Hierarchical Routing

- A.a, A.b, A.c run an intradomain routing protocol
- A.c, B.a, B.b, C.a run an interdomain routing protocol





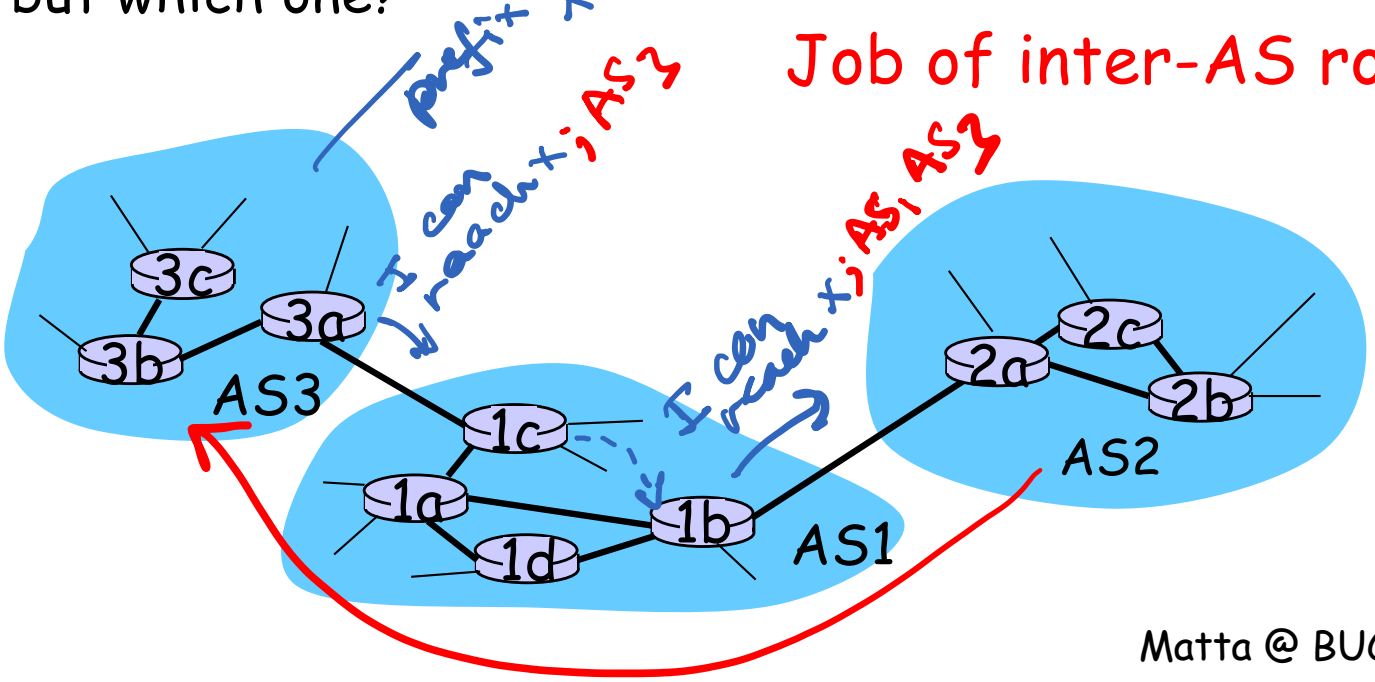
Inter-AS tasks

- Suppose router in AS1 receives datagram for which destination is outside of AS1
  - Router should forward packet towards one of the gateway routers, but which one?

AS1 needs:

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

Job of inter-AS routing!

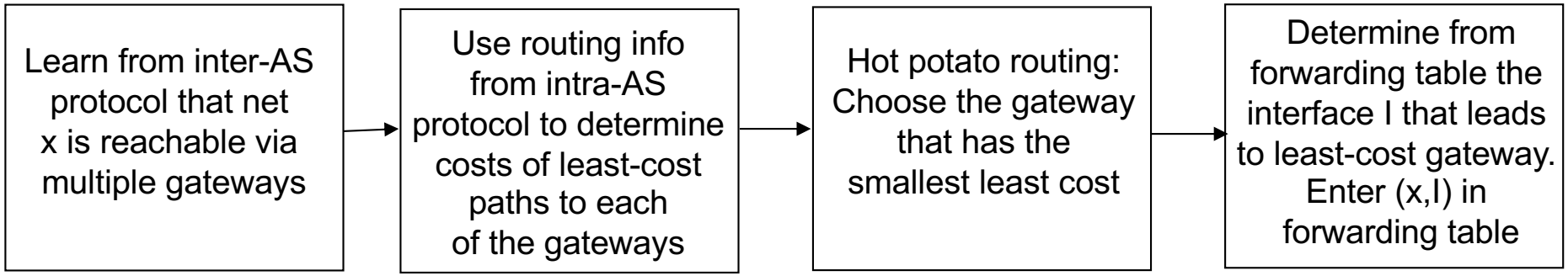


Example: Setting forwarding table in router 1d

- Suppose AS1 learns from the inter-AS protocol that net *x* is reachable from AS3 (gateway 1c) but not from 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
- Puts in forwarding table entry *(x,I)*

Example: Choosing among multiple ASes

- Now suppose AS1 learns from the inter-AS protocol that net *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 the job of inter-AS routing protocol!
- Hot potato routing: send packet towards closest of two routers

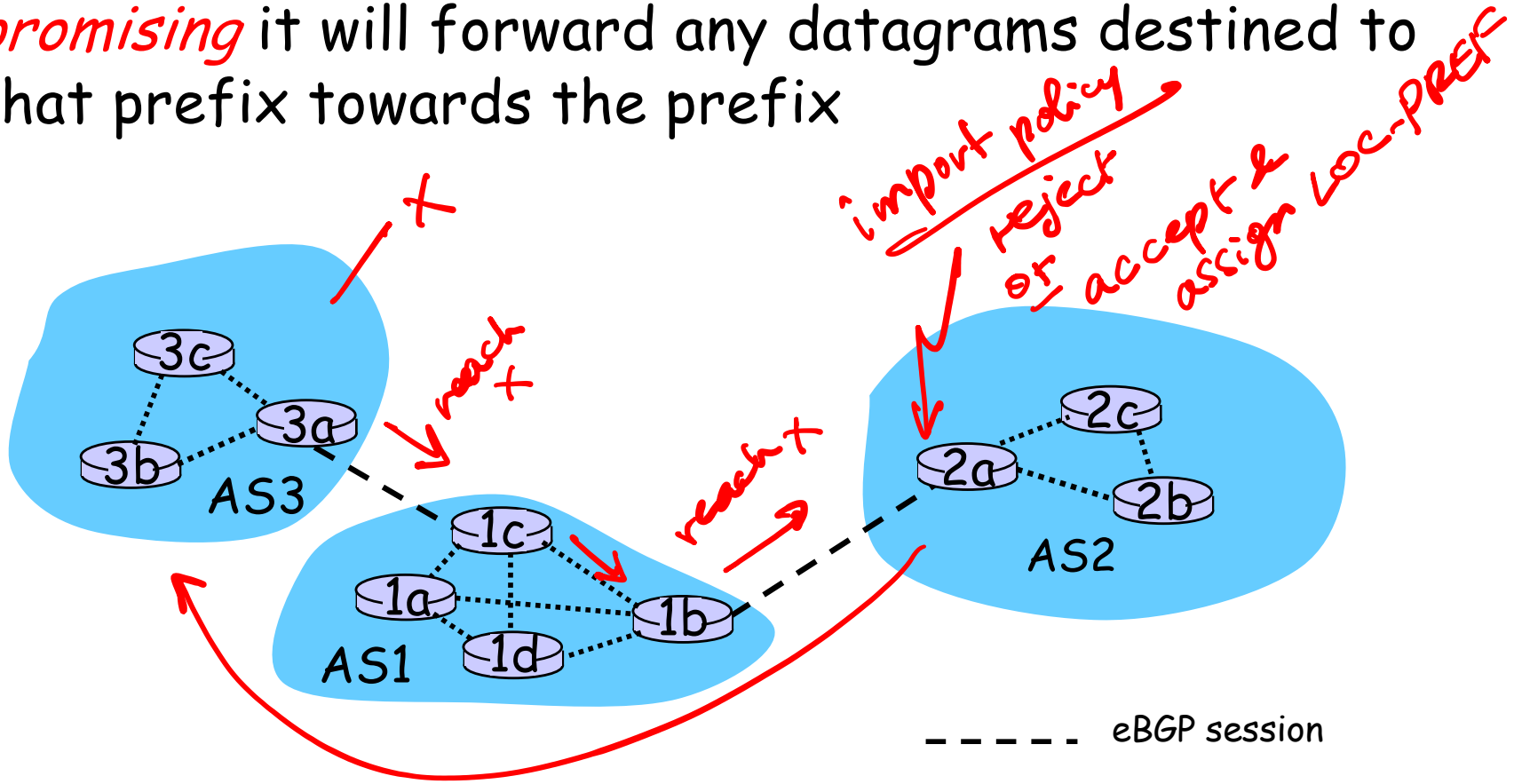


BGP: Border Gateway Protocol

- Assumes the Internet is an arbitrarily interconnected set of AS's
- Define local traffic as traffic that originates at or terminates on nodes within an AS, and transit traffic as traffic that passes through an AS
- AS's classified into three types:
  - Stub AS: an AS that has only a single connection to one other AS; such an AS will only carry local traffic
  - Multihomed AS: an AS that has connections to more than one other AS, but refuses to carry transit traffic
  - Transit AS: an AS that has connections to more than one other AS, and is designed to carry both transit and local traffic

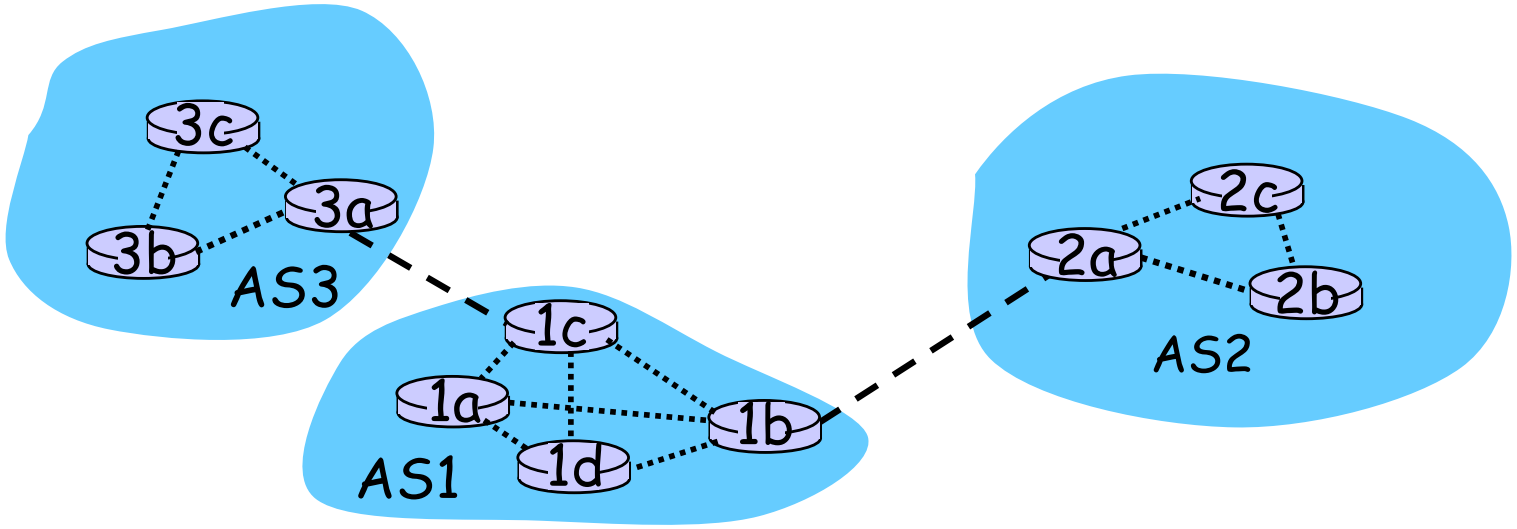
BGP basics

- Pairs of routers (BGP peers) exchange routing info over TCP connections: BGP sessions
- When AS2 advertises a prefix to AS1, AS2 is *promising* it will forward any datagrams destined to that prefix



Distributing reachability info

- With eBGP session between 3a and 1c, AS3 sends prefix reachability info to AS1
- 1c can then use iBGP to distribute this new prefix reach info to all routers in AS1
- 1b can then re-advertise the new reachability info to AS2 over the 1b-to-2a eBGP session
- When router learns about a new prefix, it creates an entry for the prefix in its forwarding table



Path attributes & BGP routes

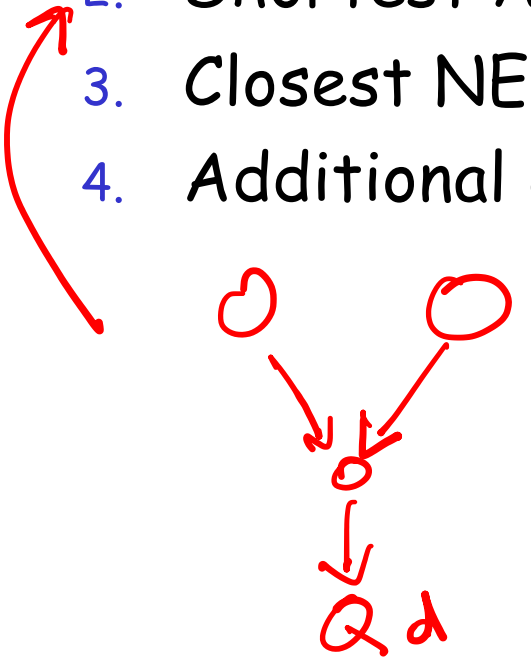
- When advertising a prefix, advertisement includes BGP attributes
  - prefix + attributes = "route"
- Two important attributes:
  - AS-PATH: contains the ASs through which the advertisement for the prefix passed: AS 67 AS 17
  - NEXT-HOP: indicates the specific internal-AS router to next-hop AS (There may be multiple links from current AS to next-hop-AS)
- When gateway router receives route advertisement, uses import policy to accept/decline and attach a LOC_PREF (local preference) value to accepted paths

BGP route selection

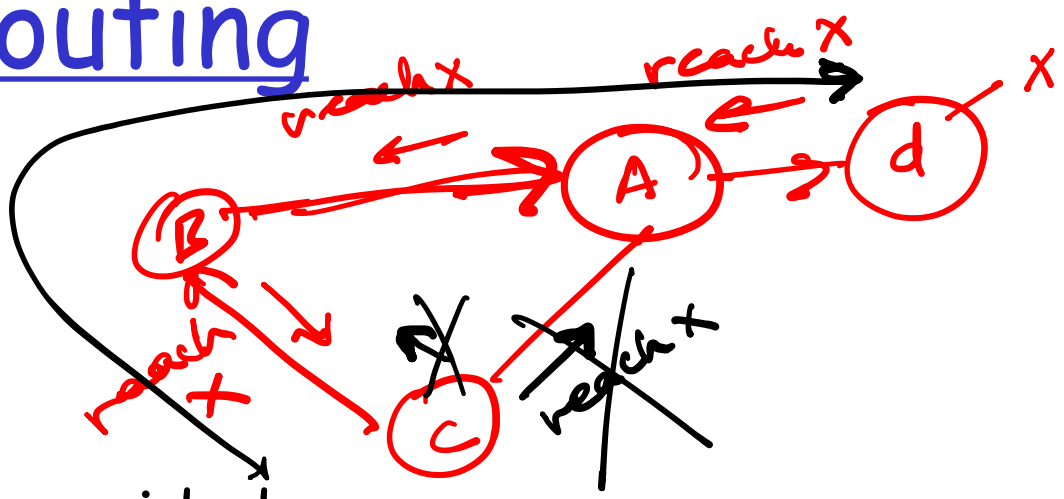
- Router may learn about more than 1 route to some prefix. Router must select route
- Elimination rules:

1. Local preference value attribute: policy decision
2. Shortest AS-PATH
3. Closest NEXT-HOP router: hot potato routing
4. Additional criteria

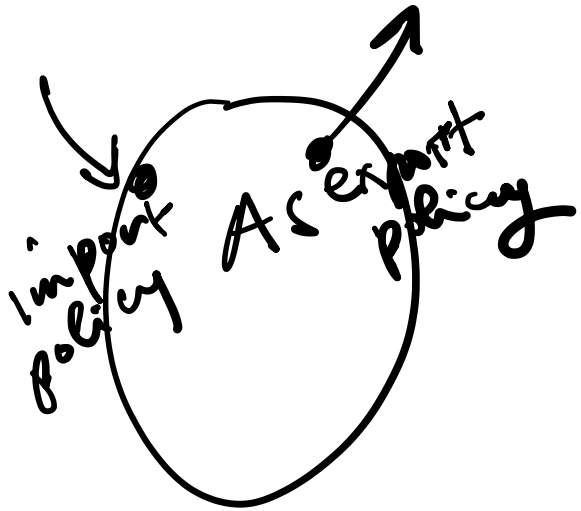
policy-based routing



Path Vector Routing



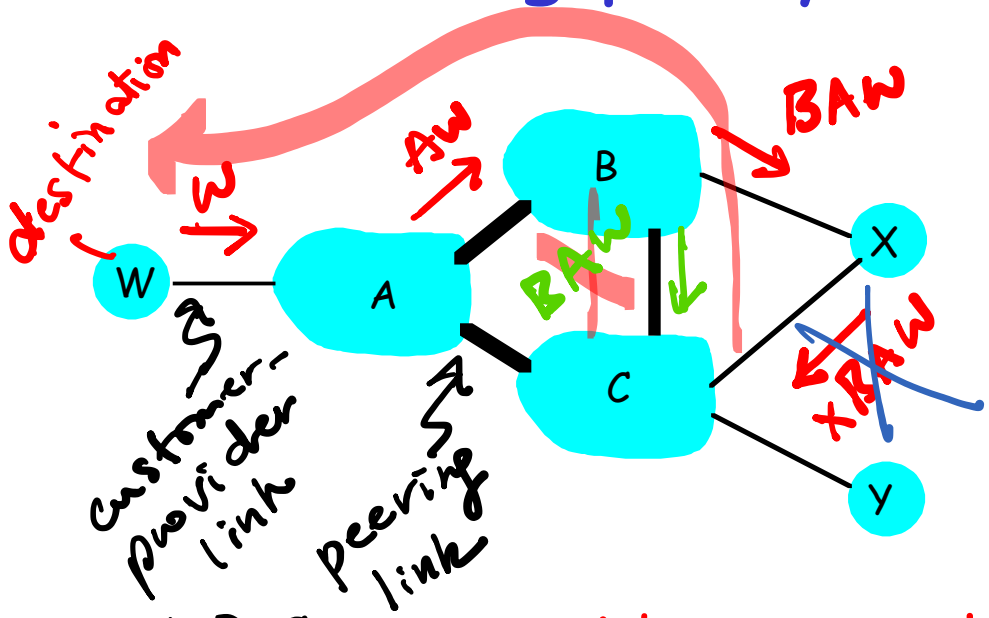
- Loops can be completely avoided
  - Export policy: Do not export chosen path to neighbor if neighbor AS is on the path
- Policy constraints can be imposed
  - Based on ASes on paths
  - Export policy: Do not export a path to a neighbor AS so as not to carry (transit) traffic for that neighbor
  - Import policy: accept (and assign LOC_PREF) or reject

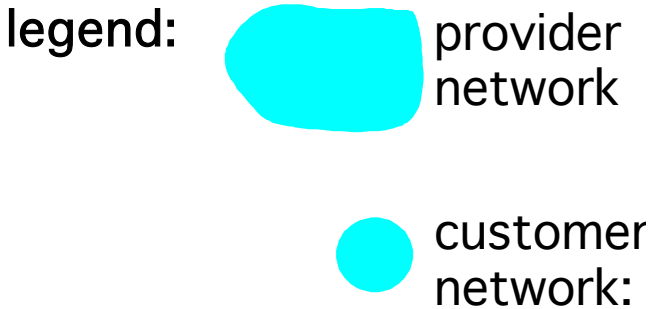


BGP messages

- BGP messages exchanged over TCP
- BGP messages:
  - OPEN: opens BGP peering session with peer and authenticates sender
  - 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 (e.g. unsupported option in OPEN msg); also used to close BGP session

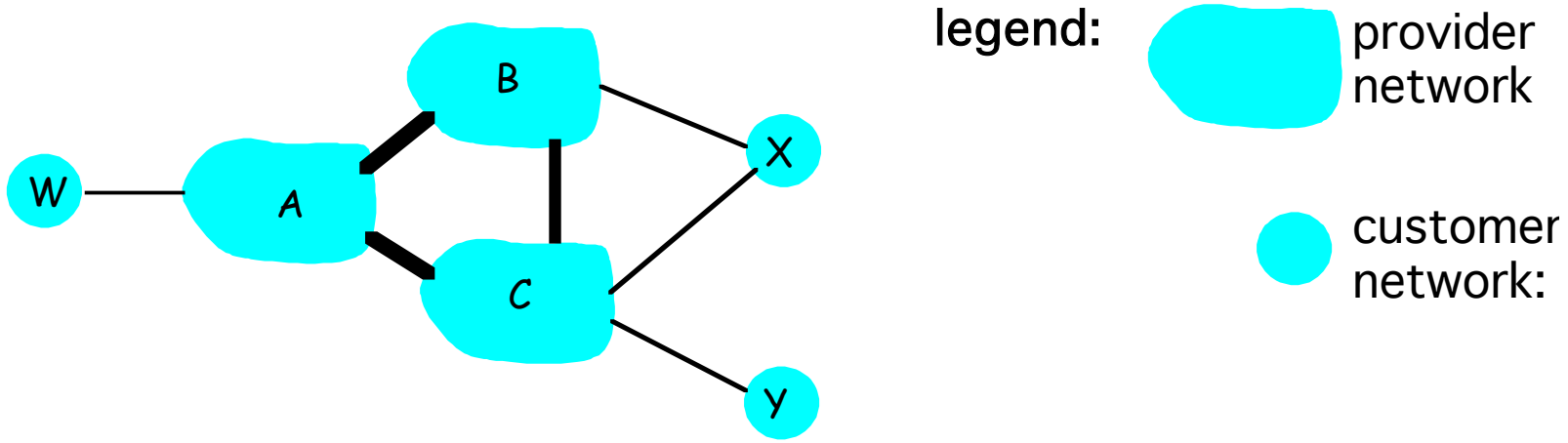
BGP routing policy





- A,B,C are provider networks
- X,W,Y are customers (of provider networks)
- X is dual-homed: attached to two networks
  - X does not want to route from C via X to B
  - .. so X will not advertise to C a route to B
- Gateway router imposes export policy on what route to advertise to other AS's

BGP routing policy (2)



- A advertises to B the path AW
- B advertises to X the path BAW
- Should B advertise to C the path BAW?
  - No way! 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!

Convergence Not Guaranteed!