Computer Networks
COL 334/672

Inter-domain Routing

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Slides adapted from KR

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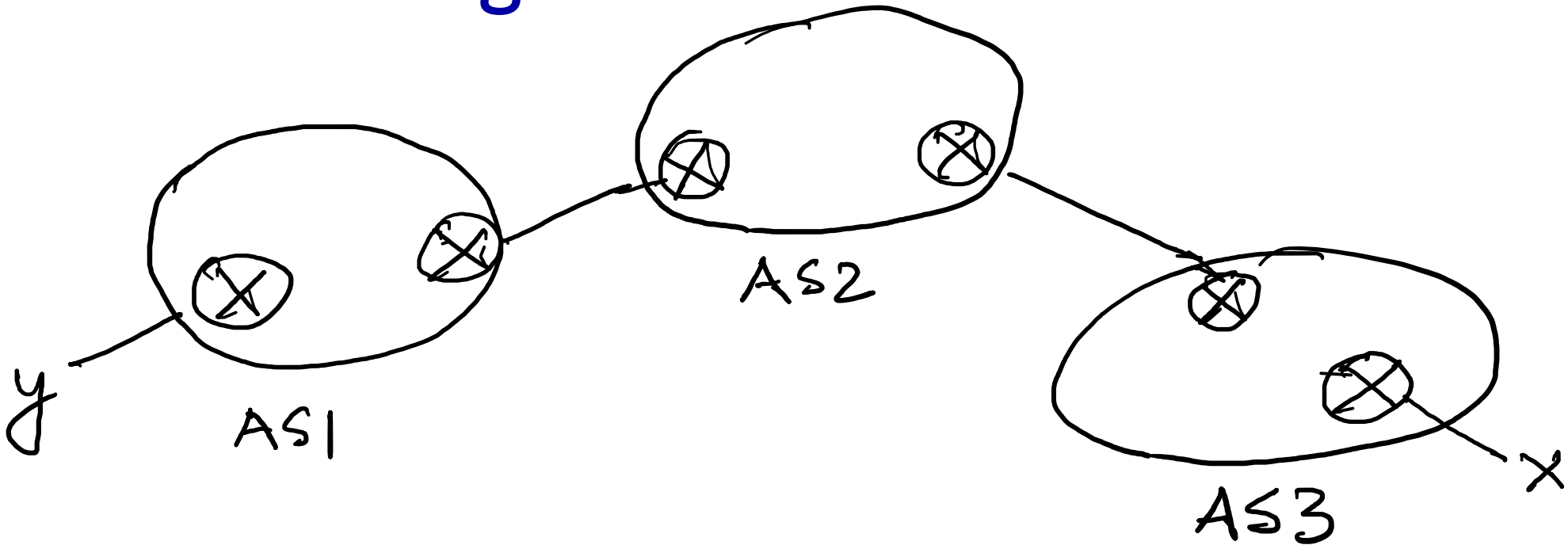
Moodle Quiz: BananaFritters

Recap: Intra-domain routing

Most common protocols for routing within an Autonomous System (AS)

- RIP: Routing Information Protocol [RFC 1723]
  - classic DV: DVs exchanged every 30 secs
  - no longer widely used
- EIGRP: Enhanced Interior Gateway Routing Protocol
  - DV based
  - formerly Cisco-proprietary for decades (became open in 2013 [RFC 7868])
- OSPF: Open Shortest Path First [RFC 2328]
  - link-state routing
  - IS-IS protocol (ISO standard, not RFC standard) essentially same as OSPF

Inter-AS routing



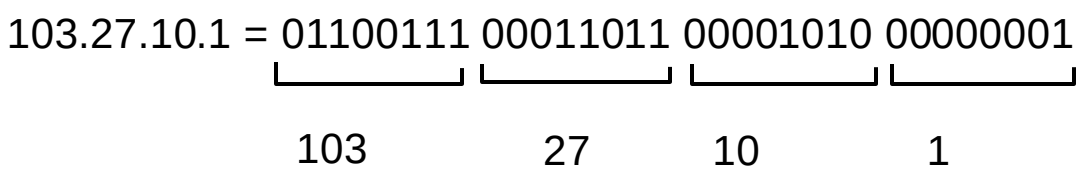
How does Internet route packet from x to y?

What are the requirements for inter-AS routing?

- Common addressing scheme
- Common routing protocol

IP addressing: introduction

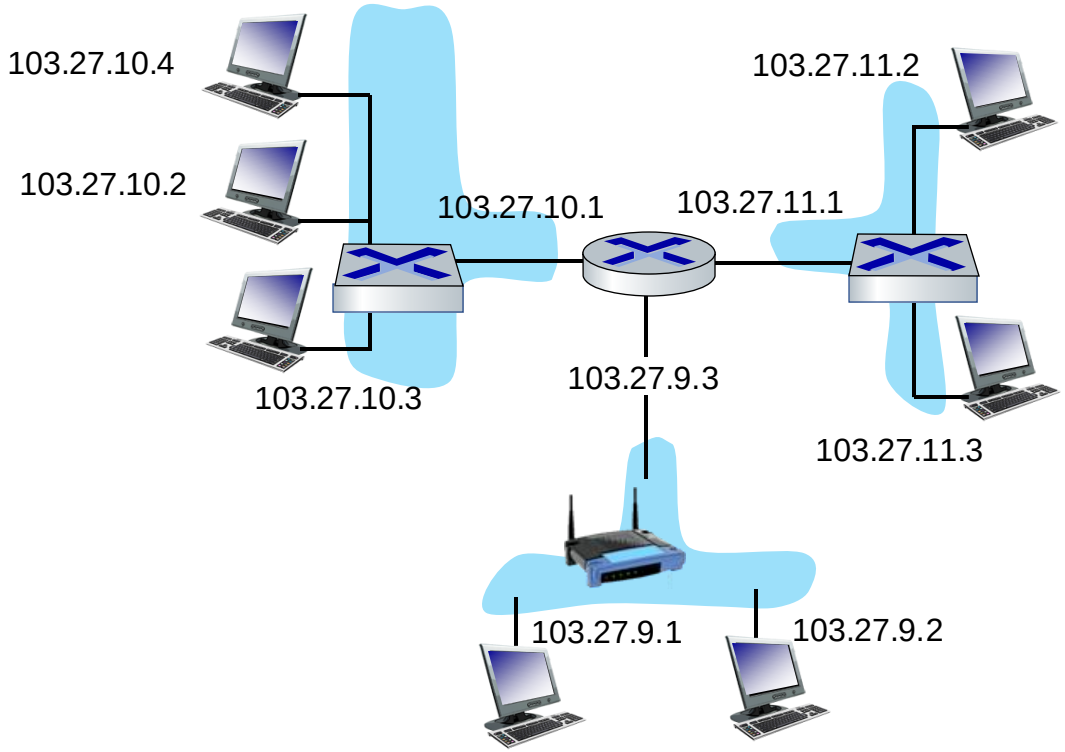
- IP address: 32-bit identifier associated with each host or router *interface*
- dotted-decimal IP address notation:



- How does an AS obtain IP address?
  - Need a coordinating agency
  - Internet Assigned Numbers Authority (IANA) and Internet Corporation for Assigned Names and Numbers (ICANN)

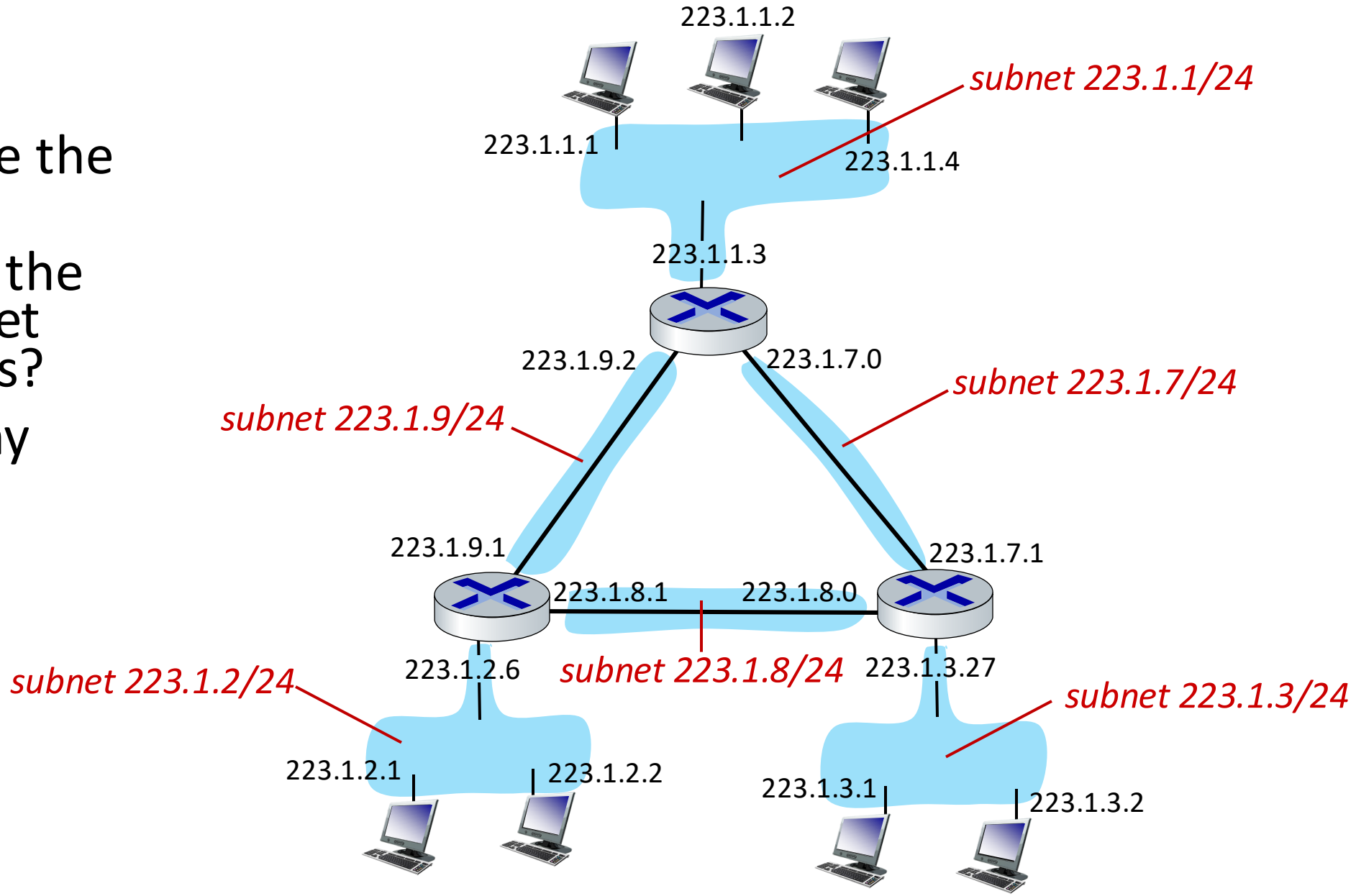
IP addressing: Subnets

- *What's a subnet ?*
  - device interfaces that can physically reach each other without passing through an intervening router
- IP addresses have structure:
  - subnet part: devices in same subnet have common high order bits
  - host part: remaining low order bits



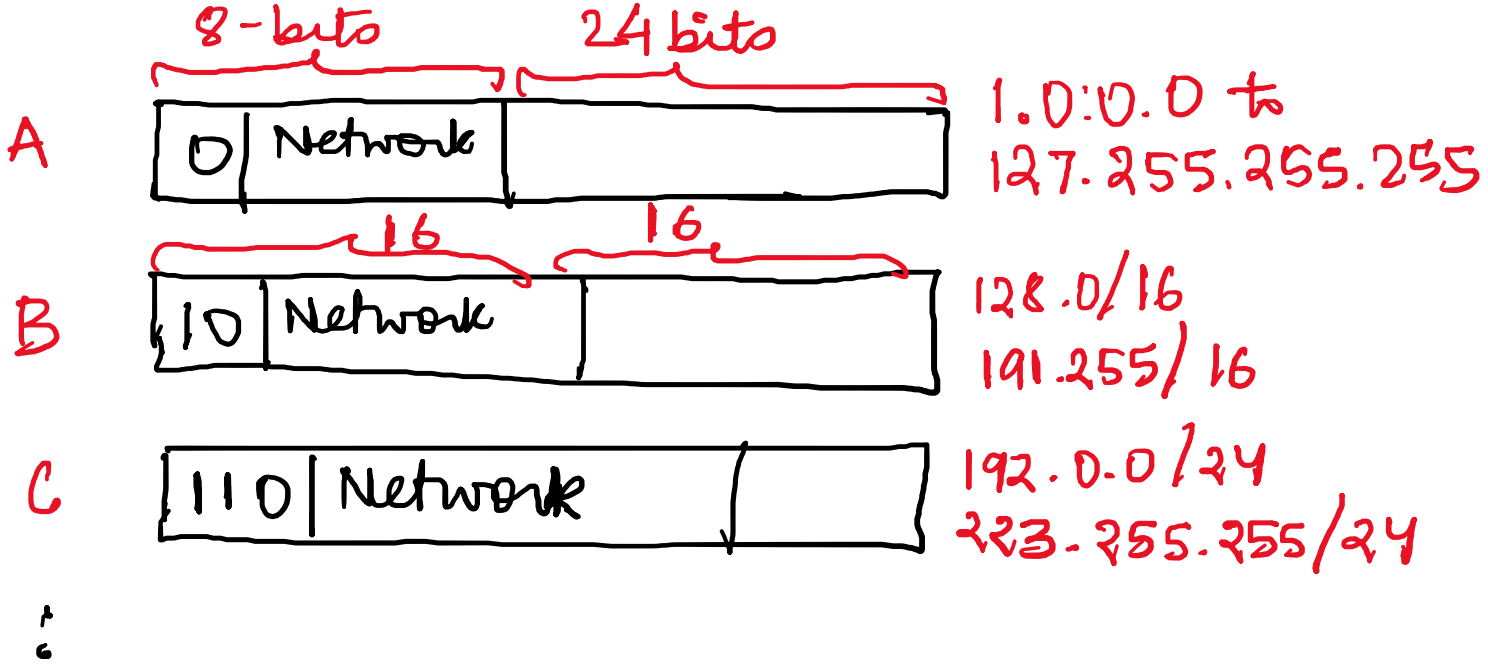
Subnets

- where are the subnets?
- what are the /24 subnet addresses?
- how many subnets?



Classful Addressing

- Why do we split the IP address into 4 parts?
- In the beginning, IP addresses were divided into 5 categories, called classful addressing
  - Classes: A, B, C, D, and E

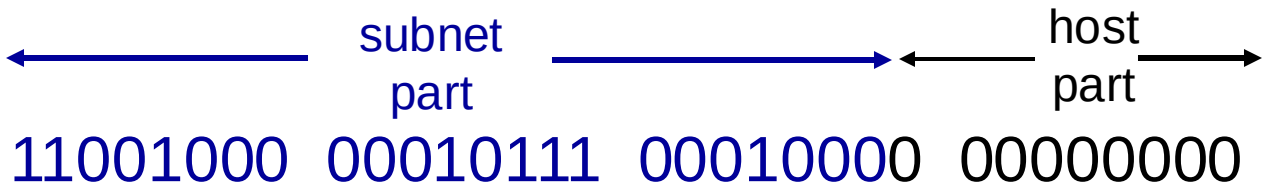


Advantages: **Routing is easier**
Limitations: **Wasteful**

IP addressing: CIDR

CIDR: Classless InterDomain Routing (pronounced “cider”)

- subnet portion of address of arbitrary length
- address format: a.b.c.d/x, where x is # bits in subnet portion of address



200.23.16.0/23

Example: IP Addresses of two AS

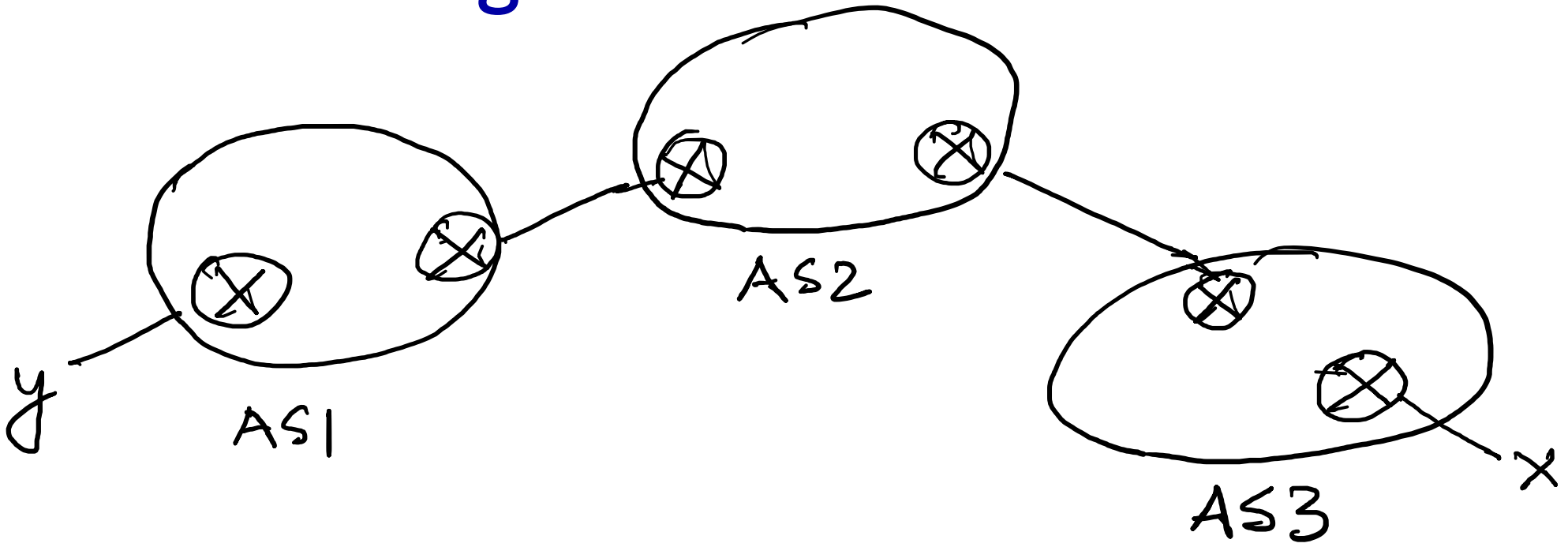
AS3 – Massachusetts Institute of Technology

Country	United States
Website	mit.edu
Hosted domains	718
Number of IPv4	1,836,288
Number of IPv6	6.34×10^{29}
ASN type	Education
Registry	ARIN
Allocated	55 years ago on Jan 01, 1970
Updated	14 years ago on Sep 27, 2010

AS132780 – Indian Institute of Technology Delhi

Country	India
Website	iitd.ac.in
Hosted domains	13
Number of IPv4	1,024
Number of IPv6	1.21×10^{24}
ASN type	Education
Registry	APNIC
Updated	2 years ago on Aug 24, 2022

Inter-AS routing



How does Internet route packet from x to y?

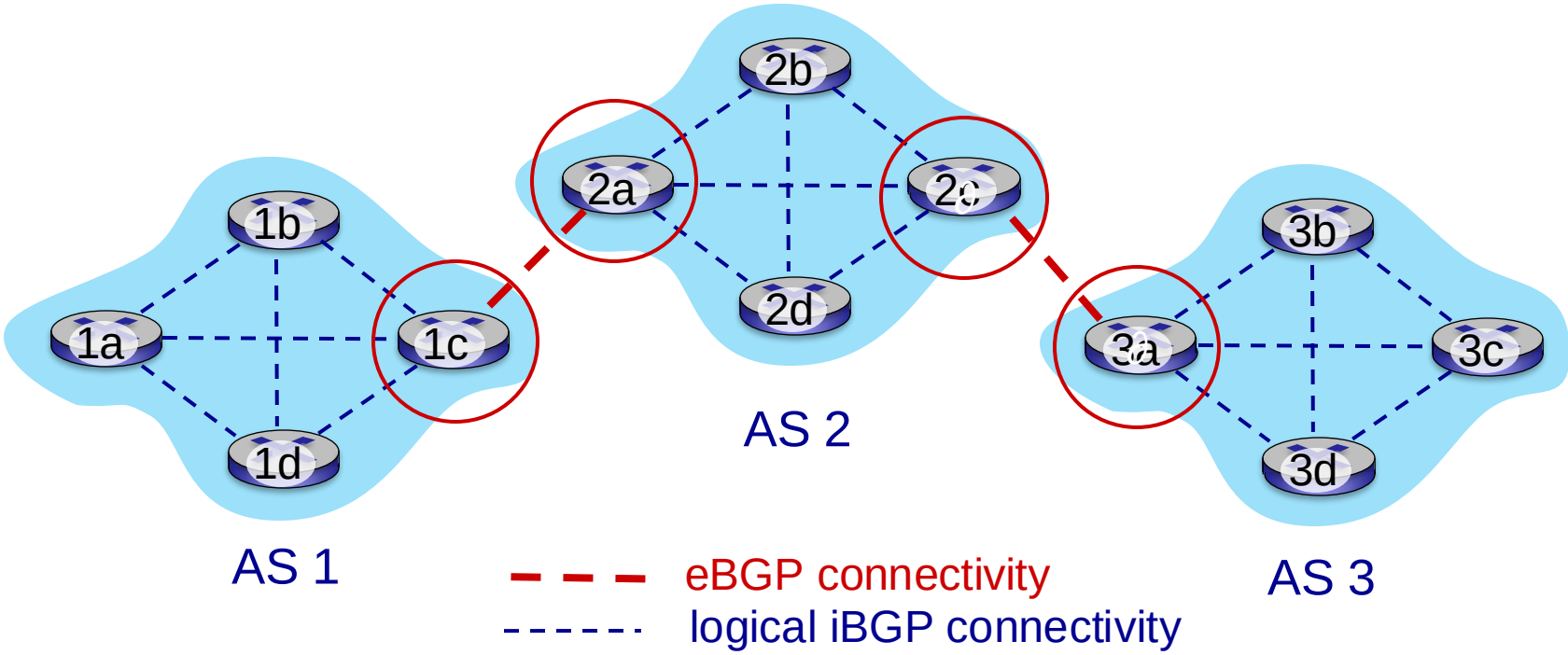
What are the requirements for inter-AS routing?

- Common addressing scheme
- **Common routing protocol**

Internet inter-AS routing: BGP

- BGP (Border Gateway Protocol): *the* de facto inter-domain routing protocol
  - "glue that holds the Internet together"
- allows subnet to advertise its existence, and the destinations it can reach, to rest of Internet: *"I am here, here is who I can reach, and how"*
- BGP provides each AS a means to:
  - obtain destination network reachability info from neighboring ASes (eBGP)
  - determine routes to other networks based on reachability information and *policy*
  - propagate reachability information to all AS-internal routers (iBGP)
  - advertise (to neighboring networks) destination reachability info

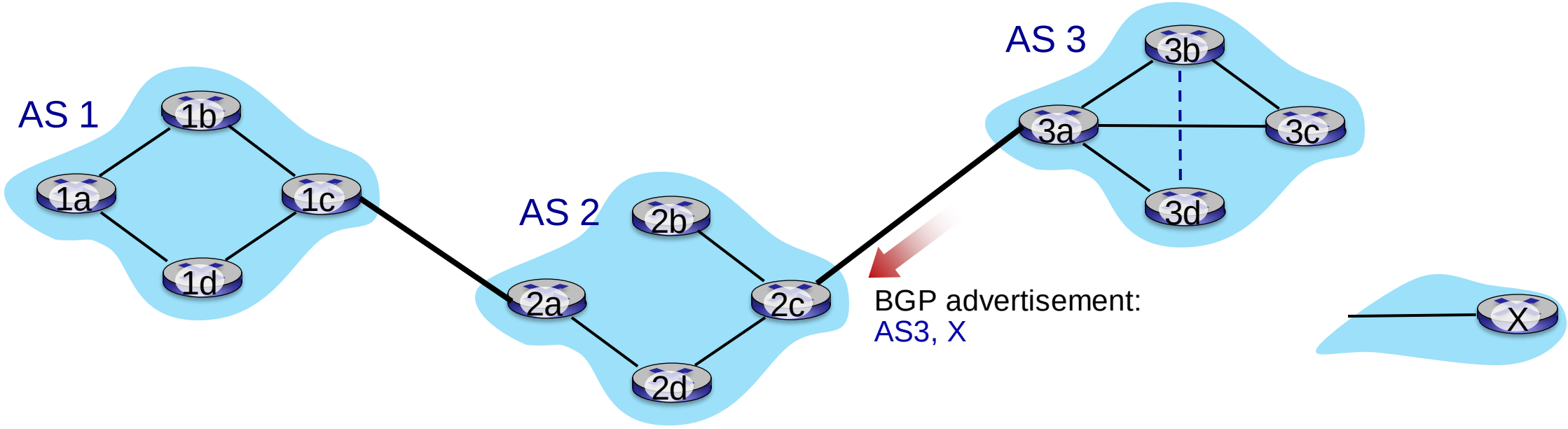
eBGP, iBGP connections



gateway routers run both eBGP and iBGP protocols

BGP basics

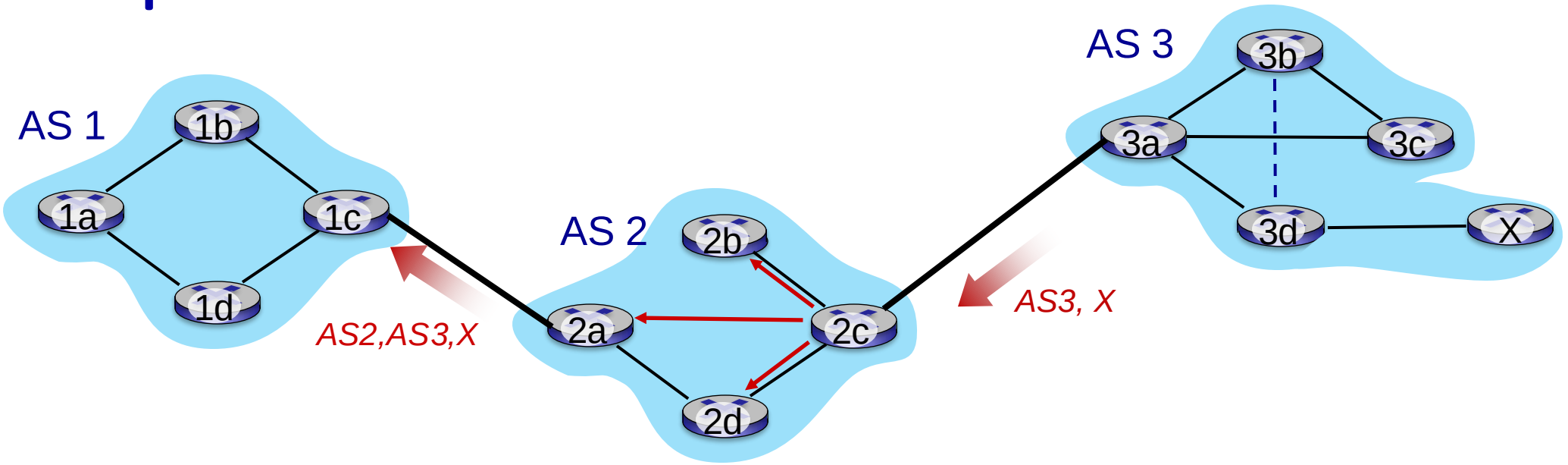
- BGP session: two BGP routers ("peers") exchange BGP messages over semi-permanent TCP connection:
  - advertising *paths* to different destination network prefixes (BGP is a "path vector" protocol)
- when AS3 gateway 3a advertises path AS3,X to AS2 gateway 2c:
  - AS3 *promises* to AS2 it will forward datagrams towards X



Path attributes and BGP routes

- BGP advertised route: prefix + attributes
  - prefix: destination being advertised
  - two important attributes:
    - AS-PATH: list of ASes through which prefix advertisement has passed
    - NEXT-HOP: indicates specific internal-AS router to next-hop AS
- policy-based routing:
  - gateway receiving route advertisement uses *import policy* to accept/decline path (e.g., never route through AS Y).
  - AS policy also determines whether to *advertise* path to other other neighboring ASes

BGP path advertisement



- 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