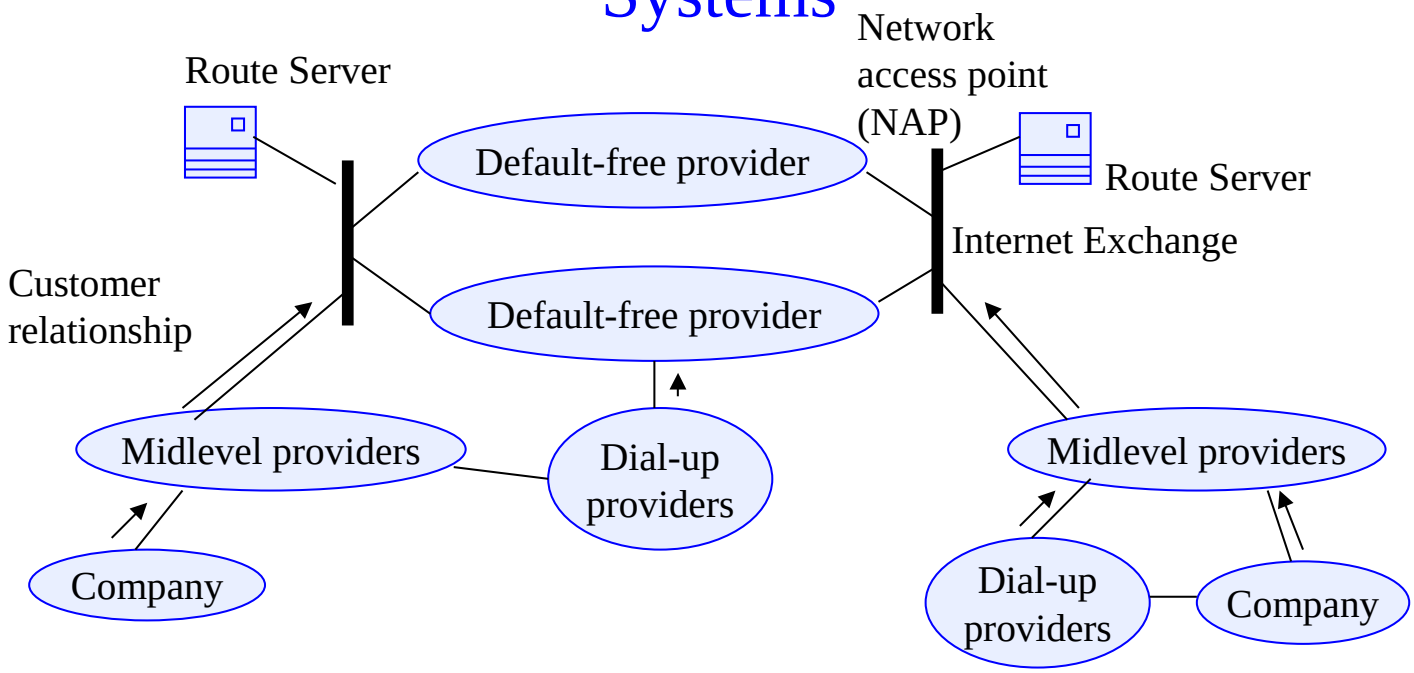
# Introduction to exterior routing



# Autonomous Systems

- An *Autonomous System (AS)* is a part of the Internet owned by a single organization.
- In an AS, usually one *interior routing protocol* is used
  - e.g. OSPF
- An *exterior routing protocol* is used between ASs
  - Currently *Border Gateway Protocol version 4 (BGPv4)* is used.
  - Not discussed in this course

# Organization of the Internet as Autonomous Systems




Peering agreement between providers on the same level define exchange of routing information



# History of the Internet Core

| | | |
|---|---|---|
| …..1985 | Arpanet | |
| …..1987 | NSFNET | 56k lines |
| …..1992 | NSFNET | T1 lines (1.5M) |
| …. 1995 | NSFNET | T3 lines (24M) |
| 1995 | NSFNET | decommissioned |
| 1995… | Commercial (UUNET,MCI, Sprint…) | |

# Internet Addresses are assigned by a hierarchy of registrars


RIPE NCC / Europe
ARIN / North America
APNIC / Asia, Pacific
Internet Service Provider *a*
ISP *b*
ISP *x*
Corporation *a*, *b*, *z*

- This model leads to provider addressing.
- Due to provider addressing, an ISP needs to advertise shorter prefixes, leading to savings in routing table size in the backbone



[http://www.iana.org/ipaddress/ip-addresses.htm]



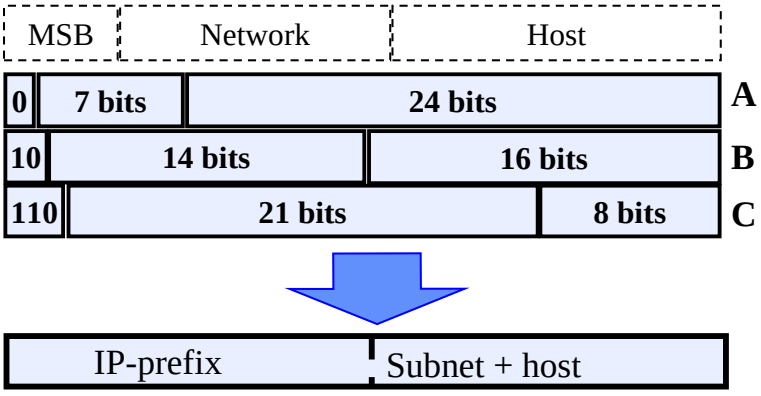
# CIDR – Classless Inter-Domain Routing

# CIDR – Classless Inter Domain Routing

- Problems caused by the growth of the Internet
  - Not enough B-class addresses
    - A few thousands of addresses required for an average organization
    - Class A is too big (16 milj. addresses), class C too small (256 addresses)
    - Only 16384 class B networks
  - Addresses in class B are used inefficiently
    - Class B is usually too big too (65534 addresses)
  - Solution: use several class C networks
  - But: Growth of routing table size
- Internet growth has forced the adoption of CIDR address arithmetic to improve the efficiency of using IP address space. CIDR was adopted 1992.



# CIDR allows splitting 32-bit IP-addresses freely into prefix and tail




- A sequence of C class networks can be represented:

  194.51.120.0 - 194.51.127.255 =

  network = 194.51.120.0

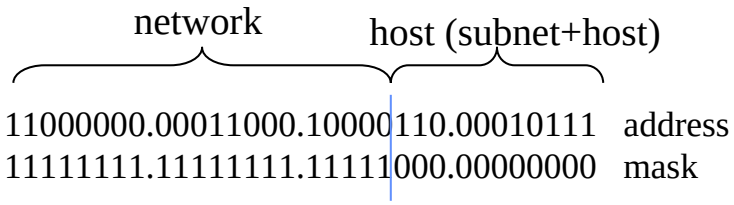
  mask = 255.255.248.0

# Repetition: address arithmetics

- Example

| | | |
|---|---|---|
| | 192.24.134.23 | address |
| AND | 255.255.248.0 | mask |
| | 192.24.128.0 | network |

| | | |
|---|---|---|
| | 192.24.143.23 | address |
| AND | 0.0.7.255 | NOT (mask) |
| | 0.0.6.23 | host |






# CIDR changes the way routes are advertised

- Rule 1:
  - Routing always looks for longest match address with the destination.
    → addresses of multi-homed networks can not be aggregated.
    (multi-homed network connects to many ASs.)
- Rule 2:
  - A network that aggregates a set of routes must delete packets that match with the aggregated prefix but with none of the network addresses that went into the aggregate. This helps to avoid loops.

# Customers are assigned the necessary number of c-class networks, allowing for future growth.

- Customers of the ISP “A”
  - A1: ≤ 2048 addresses (8 class C networks)
  - A2: ≤ 1024 addresses (4 class C networks)
  - A3: ≤ 1024 addresses (4 class C networks)
  - A4: ≤ 4096 addresses (16 class C networks)
  - A5: ≤ 512 addresses (2 class C networks)
  - A6: ≤ 512 addresses (2 class C networks)

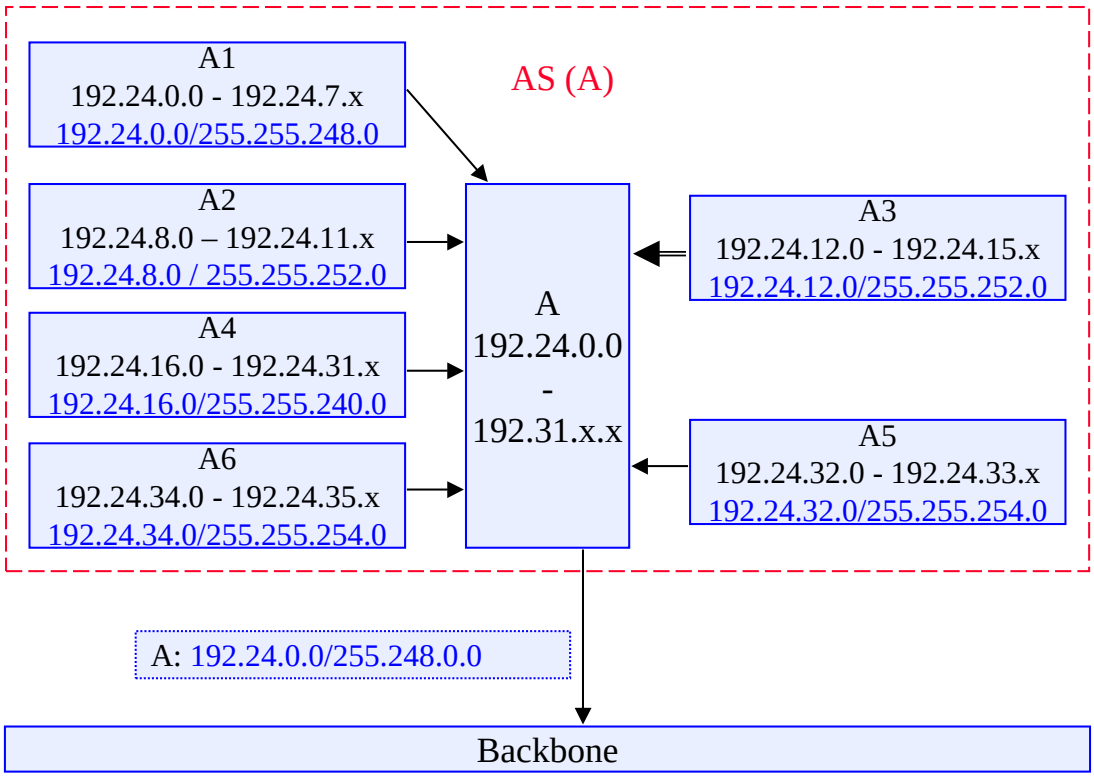


# Addresses are allocated from 192.24.0.0/255.248.0.0

## Aggregation creates a single route to each customer

- Customers of the ISP “A”
  - A1: ≤ 2048 addresses (8 class C networks)
    - 192.24.0 – 192.24.7 192.24.0.0 / 255.255.248.0
  - A2: ≤ 1024 addresses (4 class C networks)
    - 192.24.8 – 192.24.11 192.24.8.0 / 255.255.252.0
  - A3: ≤ 1024 addresses (4 class C networks)
    - 192.24.12 – 192.24.15 192.24.12.0 / 255.255.252.0
  - A4: ≤ 4096 addresses (16 class C networks)
    - 192.24.16 – 192.24.31 192.24.16.0 / 255.255.240.0
  - A5: ≤ 512 addresses (2 class C networks)
    - 192.24.32 – 192.24.33 192.24.32.0 / 255.255.254.0
  - A6: ≤ 512 addresses (2 class C networks)
    - 192.24.34 – 192.24.35 192.24.34.0/255.255.254.0

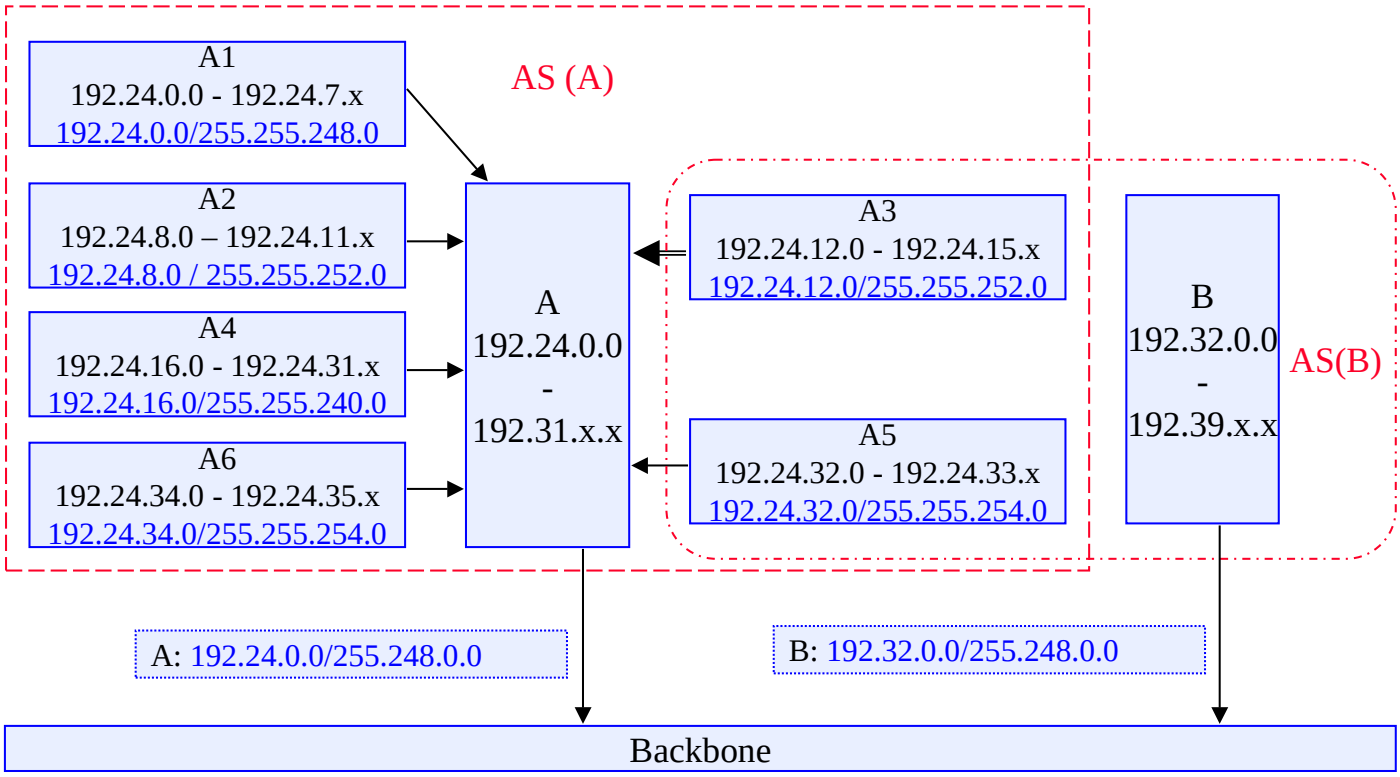
# AS(A) uses aggregation and advertises a single route to the backbone





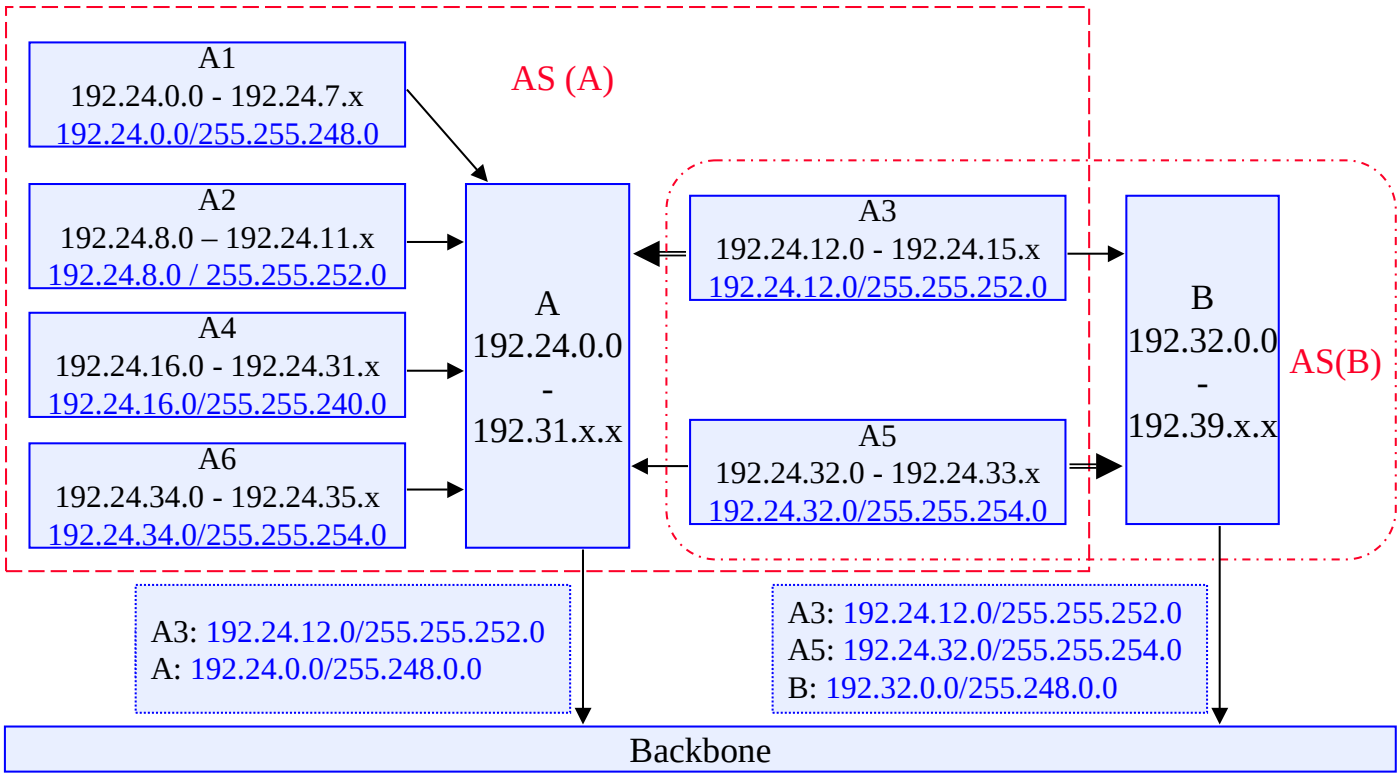

# Let's assume that there is another AS (B)

## (Network 192.32.0.0 / 255.248.0.0)



# A3 and A5 are attached to two ASs

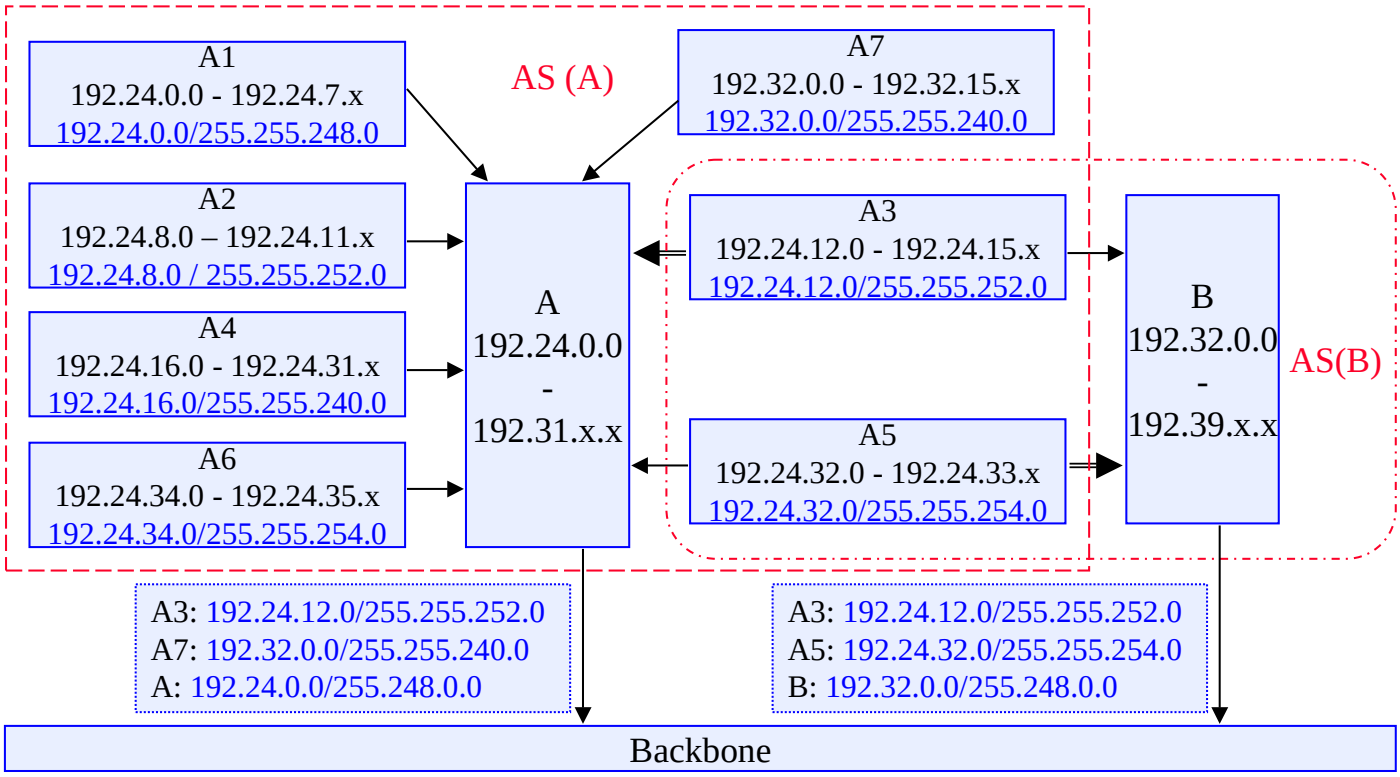
## (A3 is primarily advertised through A, A5 through B)






# A7 has moved from AS (B) to AS (A)

## (A7's addresses belong to B)



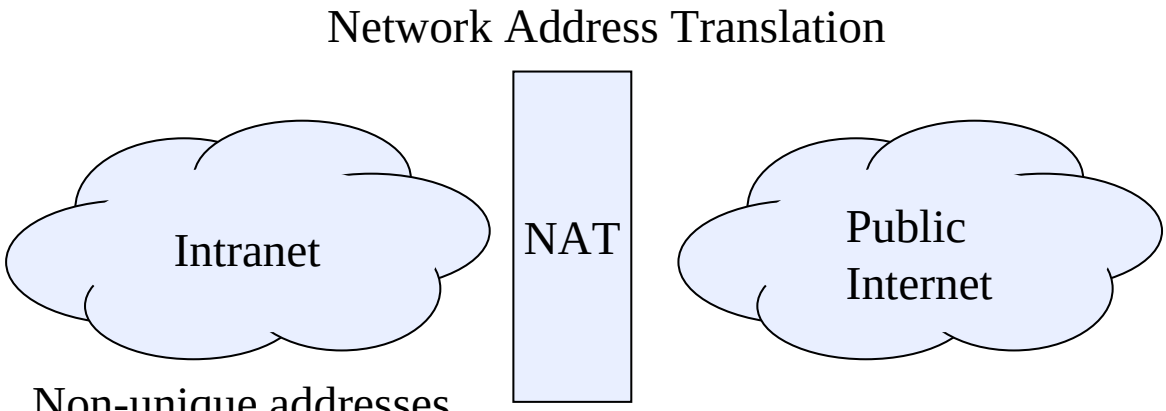
# CIDR affects most routing protocols

Protocols that support CIDR

- Exterior protocols
  - Support: BGP-4
  - No support: EGP, BGP-3
- Interior protocols
  - Support: RIP-2, OSPF, E-IGRP
  - No support: RIP, IGRP



# Network Address Translation (NAT) preserves address space and improves security




Non-unique addresses

- 10/8
- 172.16/12
- 192.168/16

⇒ Not routable in public Internet