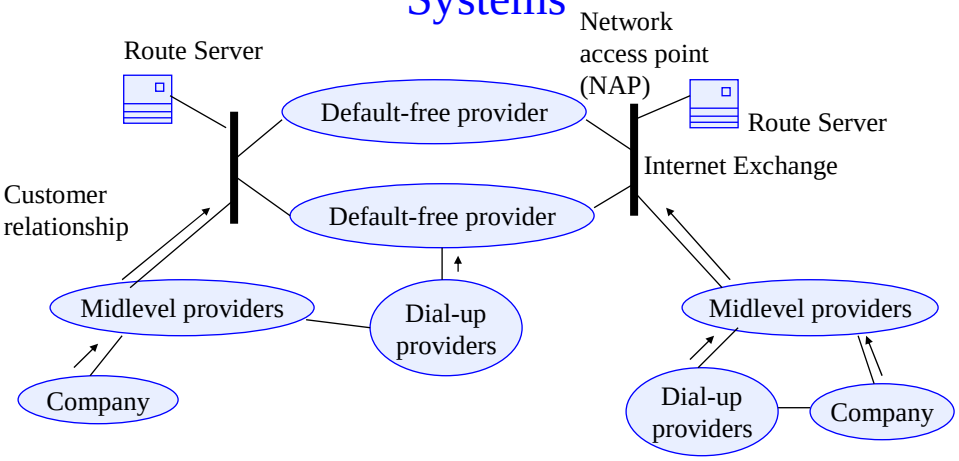
Introduction to exterior routing

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

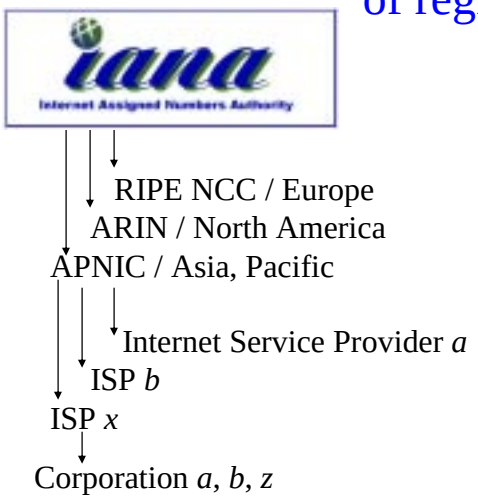


Peering agreement between providers on the same level define exchange of routing information

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



- 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

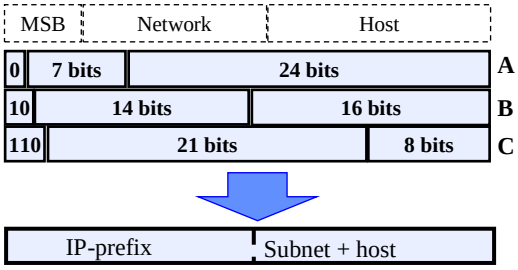
[http://www.iana.org/ipaddress/ip-addresses.htm]

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 or /21

Repetition: address arithmetic

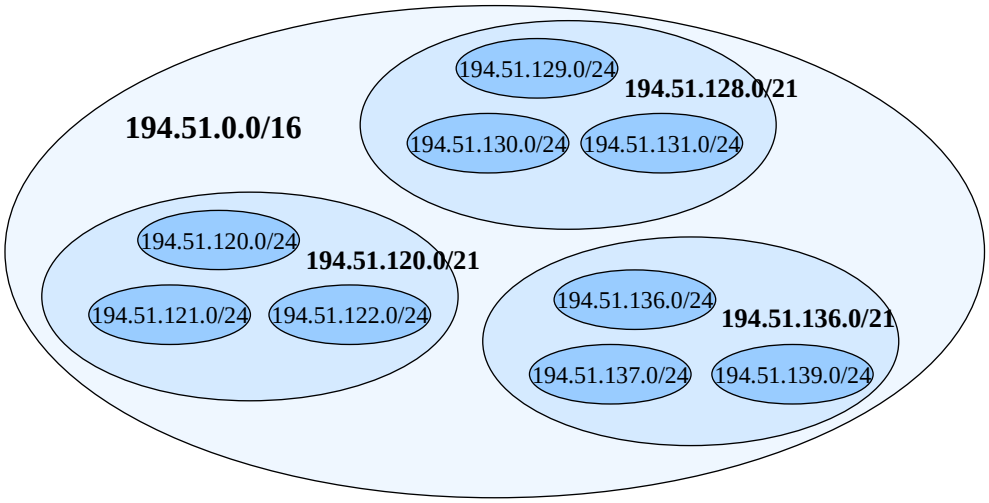
- Example

	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

network host (subnet+host)

11000000.00011000.10000110.00010111 address
11111111.11111111.11111000.00000000 mask

Example of routing hierarchy



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.

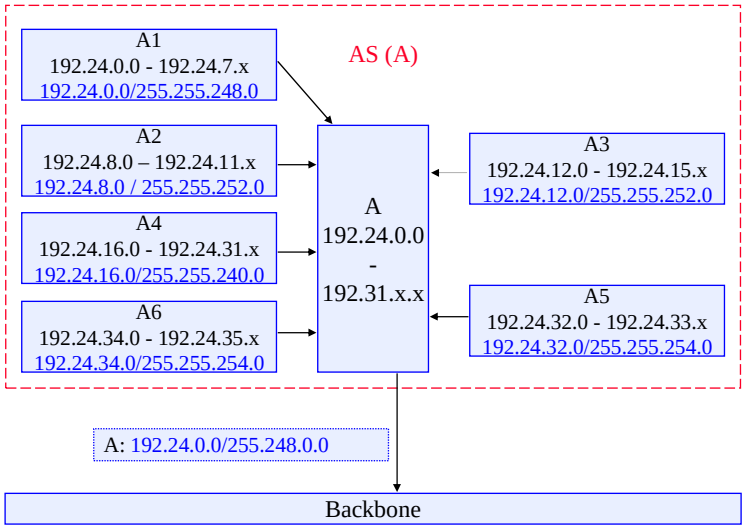
- Customers of the ISP "A"
  - A1: ≤ 2048 addresses (8 class C networks)
  - A2: ≤ 1024 addresses (4 class C networks)
  - A3: ≤ 1024 addresses (4 class C networks)
  - A4: ≤ 4096 addresses (16 class C networks)
  - A5: ≤ 512 addresses (2 class C networks)
  - A6: ≤ 512 addresses (2 class C networks)

Addresses are allocated from 192.24.0.0/255.248.0.0

Aggregation creates a single route to each customer

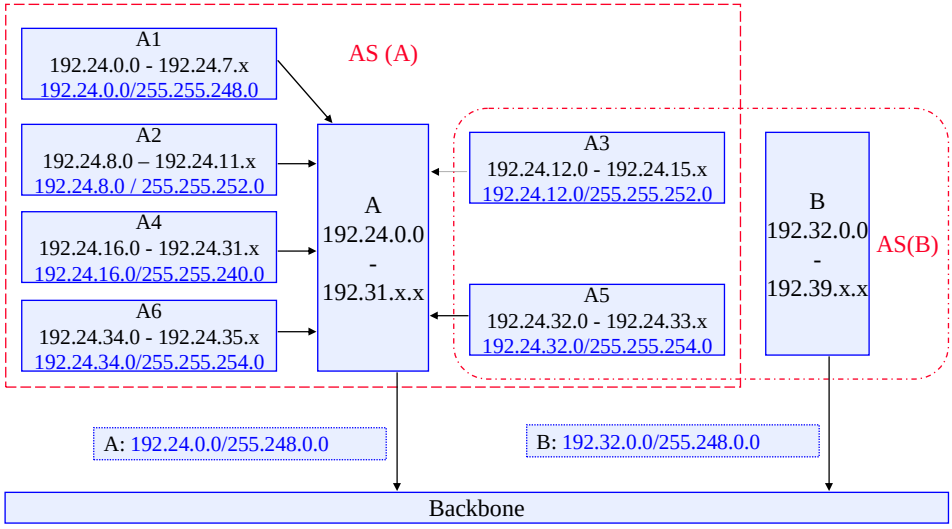
- Customers of the ISP "A"
  - A1: ≤ 2048 addresses (8 class C networks)
    - 192.24.0 – 192.24.7 192.24.0.0 / 255.255.248.0
  - A2: ≤ 1024 addresses (4 class C networks)
    - 192.24.8 – 192.24.11 192.24.8.0 / 255.255.252.0
  - A3: ≤ 1024 addresses (4 class C networks)
    - 192.24.12 – 192.24.15 192.24.12.0 / 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



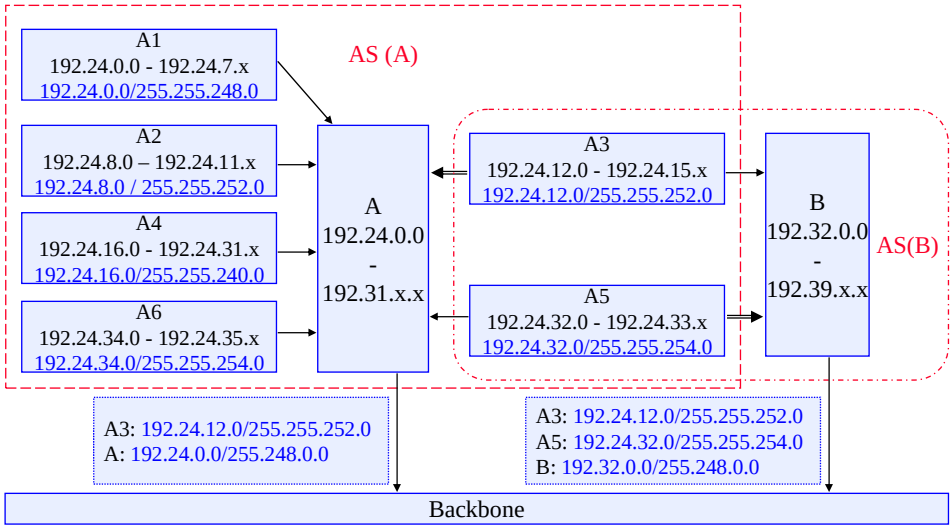
Let's assume that there is another AS (B)

(Network 192.32.0.0 / 255.248.0.0)



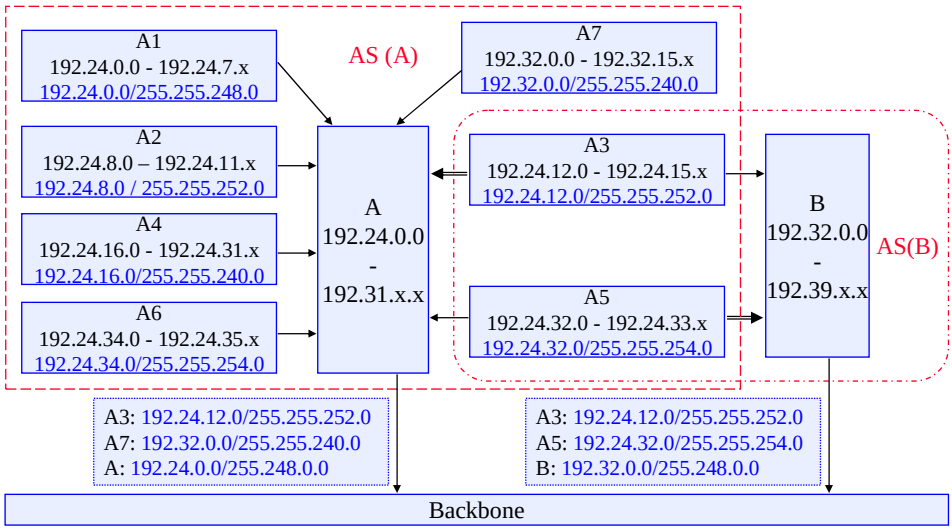
A3 and A5 are attached to two ASs

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



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

(A7's addresses belong to B)

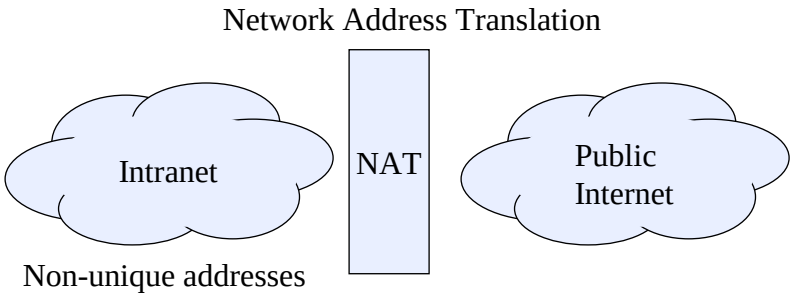


CIDR affects most routing protocols

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