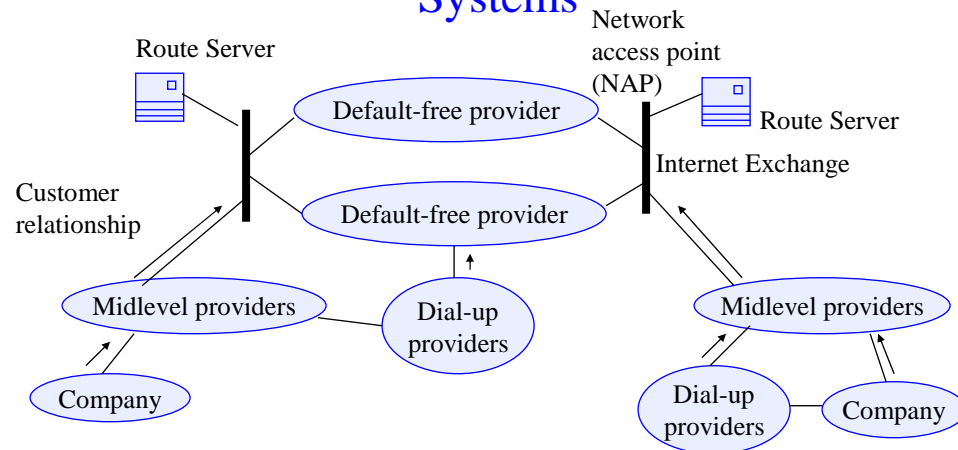


## Introduction to exterior routing

## 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

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CIDR-3

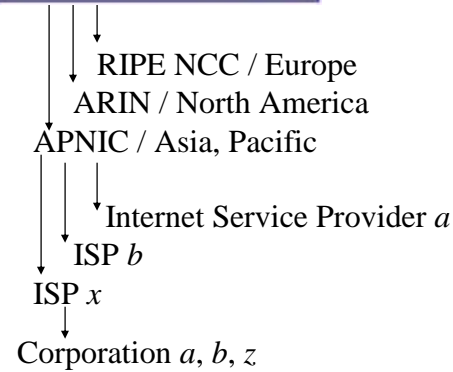
## History of the Internet Core

- .....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...)

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CIDR-4

## 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

## CIDR – Classless Inter-Domain Routing

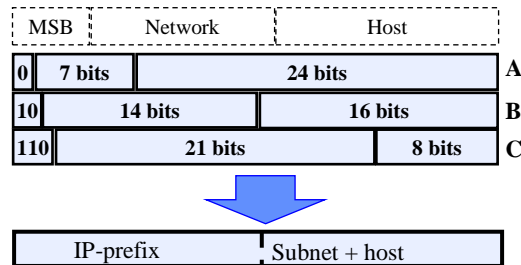
## CIDR – Classless Inter Domain Routing

- 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.

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CIDR-7

## 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

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CIDR-8

## Repetition: address arithmetic

- Example

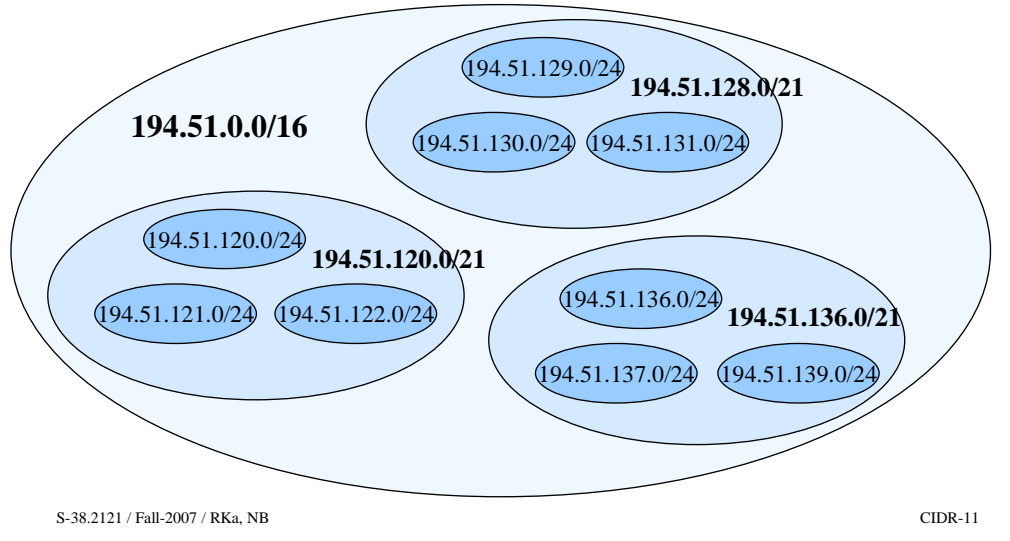
	192.24.134.23	address	
AND	255.255.248.0	mask	
	192.24.128.0	network	
	192.24.143.23	address	
AND	0.0.7.255	NOT (mask)	
	0.0.6.23	host	
	<div style="display: flex; justify-content: space-around; width: 100%;"> <span>network</span> <span>host (subnet+host)</span> </div>		
	11000000.00011000.10000110.00010111	address	
	11111111.11111111.11111000.00000000	mask	

## 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	
	192.24.134.23	address	
-	192.24.128.0	network	
	0.0.6.23	host	(alternative way)

## 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.

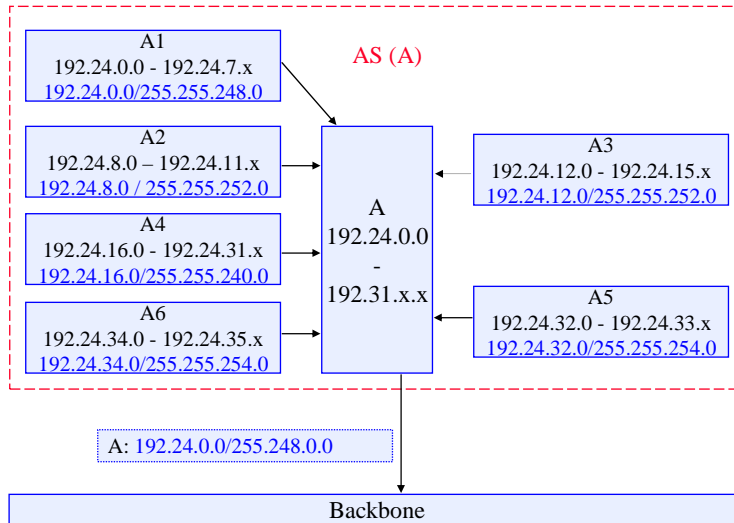
## Customers are assigned the necessary number of c-class networks, allowing for future growth.

- 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](#)

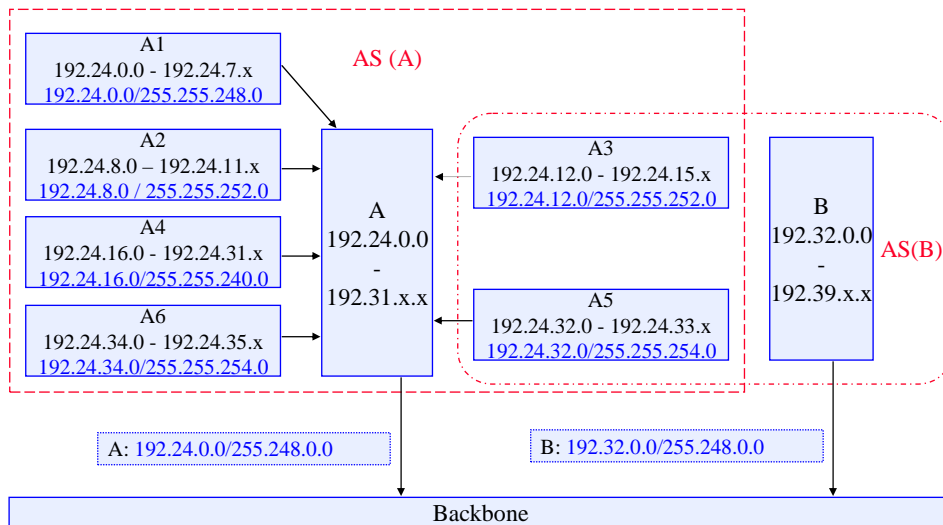
## AS(A) uses aggregation and advertises a single route to the backbone



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CIDR-15

## Let's assume that there is another AS (B) (Network 192.32.0.0 / 255.248.0.0)

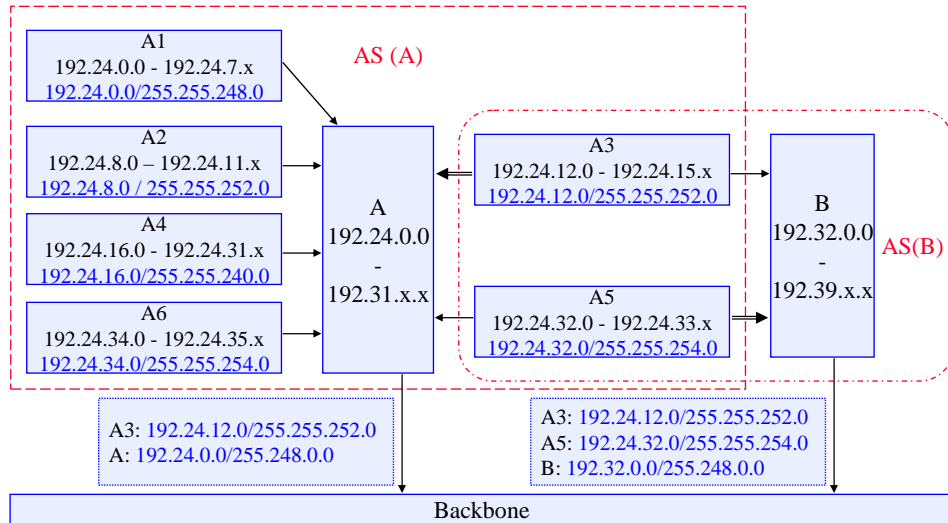


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CIDR-16



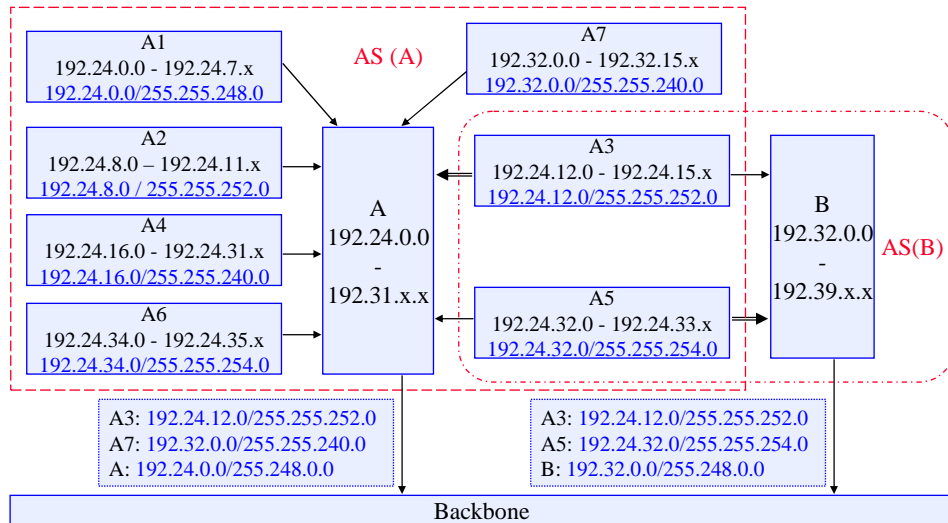
## A3 and A5 are attached to two ASs (A3 is primarily advertised through A, A5 through B)



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CIDR-17

## A7 has moved from AS (B) to AS (A) (A7's addresses belong to B)



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CIDR-18

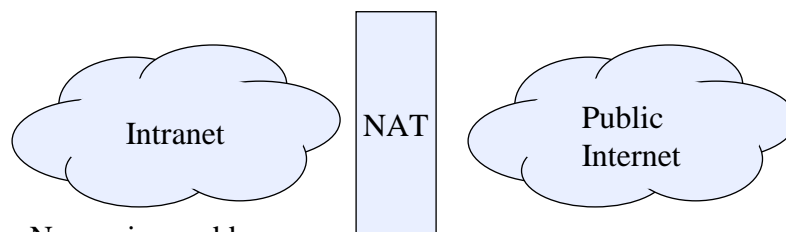
## CIDR affects most routing protocols

### 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

### Network Address Translation



Non-unique addresses

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

⇒ Not routable in public Internet