TELE 302 – Network Design Lecture 21

Addressing Strategies

Source: McCabe 12.1 ~ 12.4

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We Are HERE!

- Requirements analysis
- Flow Analysis
- Logical Design
  - Technology choices
  - Interconnection mechanisms
  - Network Management and security
- Physical Design
- Addressing and Routing

Dividing Up the Space

- Allocation of resources is a fundamental problem in design; it includes issues like
  - Partitioning the design space
  - Preserving high cohesion and weak coupling
  - Ensuring flexibility
- Identify boundaries for routing and addressing
  - Work groups
  - Functional areas (based on work groups)
  - Physical interfaces
  - Administrative domains

Addressing Background

- IPv4 Addressing based on multiple classes ~ Classful Addressing

Class	Set Bits (First Octet)	Natural Mask	Number of Addresses
A	0xxxxxxx	255.0.0.0	2^24-2
B	10xxxxxx	255.255.0.0	2^16-2
C	110xxxxx	255.255.255.0	2^8-2

- Two subtracted from host addresses
  - All 1's is the broadcast address
  - All zeros is the network self-address

Not An Easy Fit

- An average customer
  - May use a small fraction of Class B address.
  - Or uses multiple Class C address.
- E.g., a network with 10,000 computers
  - Can be supported with a Class B address with 2^16-2=65,534 host addresses
  - Or by a minimum of 40 Class C addresses 40*(2^8-2)=10,160

Subnetting

- **Q:** How to make better use of address space?
- **A: Subnetting** involves making the address mask larger, extending by trading host bits for network addresses.
- Hierarchy established, but not advertised outside.

Two Types of Subnetting

- Static Length Subnetting: all the subnetworks in a single network use the same subnet mask
  - Easy to configure but all subnets are the same size
- Variable Length Subnetting: different subnetworks in a single network use different subnet masks
  - Available host addresses are used more efficiently but all the routers must understand this kind of subnetting

Variation of the Mask Length

- Subnetting by trading host bits for network bits → more smaller networks

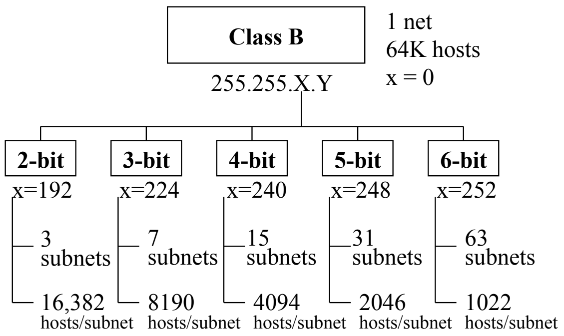
Address (Example)	Natural Mask	
Class B (136.178.0.0)	255.255.0.0	**Classful Addresses**
Class C (198.9.9.0)	255.255.255.0	

Address	Subnet Mask	Size	Subnets	Hosts/Subnet
136.178.0.0	255.255.255.0	8-bit	254	254
	255.255.240.0	4-bit	15	4094

136.178.0.0/24--> subnet mask of 255.255.255.0
136.178.0.0/20--> subnet mask of 255.255.240.0

Classless InterDomain Routing (CIDR /xx notation)

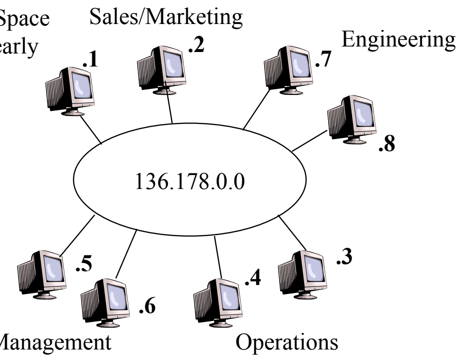
Subnet Mask Length and Subnet Size



Class B Host Address Allocations Linear

Host Address Space
Allocated Linearly

136.178.0.1
255.255.0.0
.2
.3
.4
...

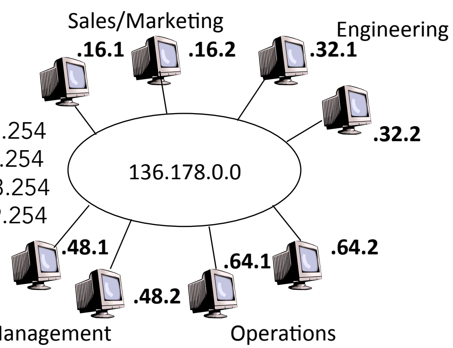


- Difficult to introduce hierarchy into the network design.
- If a random scheme was used for allocating addresses originally then readdressing is required to implement subnetting.

Class B Host Address Allocations Hierarchical

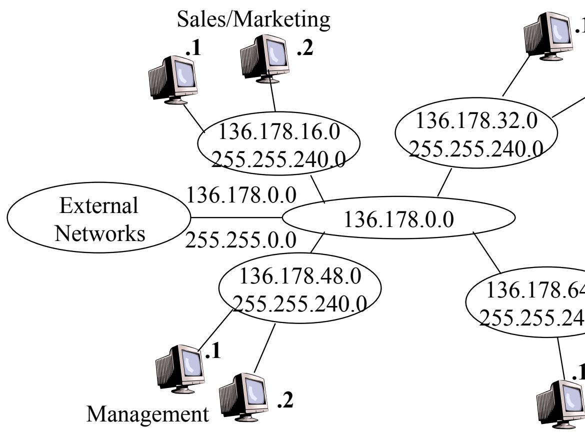
Host Address Space
Allocated Hierarchically
136.178.0.1
255.255.0.0

Sales/Marketing	16.1-31.254
Engineering	32.1-47.254
Management	48.1-63.254
Operations	64.1-79.254



A hierarchical address allocation scheme makes it much easier to introduce subnet addressing when it is needed because no host address changes are needed.

Address Hierarchies Implemented with Address Mask Change



By applying a single subnet mask one gets a number of subnets all the same size. Sometimes one wants subnets of different sizes.

Fixed (Static) Length Subnetting

- Breaks a classful network address space down into a number of fixed length subnets by trading host bits for networks.
- Usually requires a network to have a single subnet mask

Variable Length Subnetting

- Applying multiple subnet masks to a network allows more effective use of the available address space by creating subnets of different sizes called variable length subnetting.
- It involves recognizing multiple subnet masks for the same network address, example …

Work Group	Groups	Size/Group (Hosts)
Engineering	3	400 => /23 (510)
Marketing	1	1950 => /21 (2046)
Administration	1	200 => /24 (254)
Sales	15	35-90 =>/25 (126)
R&D	1	150 =>/24 (254)
Support	22	10-40 =>/26 (62)

Example: Addressing Scheme (Improved)

Work Group	Groups	Size/Group (Hosts)
Engineering	3	400
Marketing	1	1950
Administration	1	200
Sales	15	35 ~ 90
R&D	1	150
Support	22	10 ~ 40

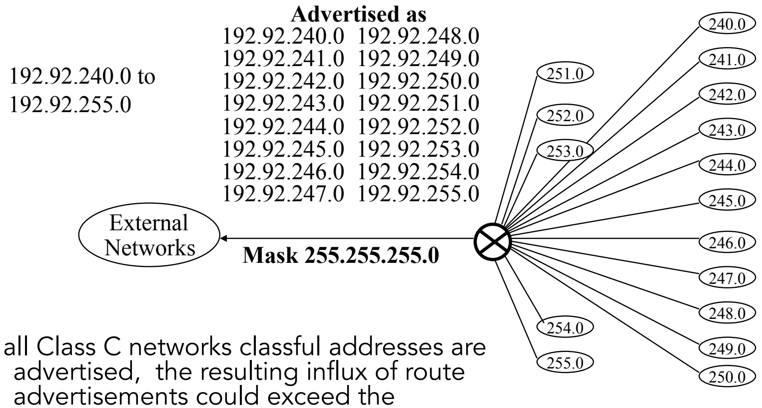
Address Allocations	**4-Bit Mask**	**8-Bit Mask**
Subnets E1-3 (Engineering)	136.178.16.0	
	136.178.32.0	
	136.178.48.0	
Subnet M1 (Marketing)	136.178.64.0	
Subnet A1 (Administration)	136.178.80.0	
Subnets SA1-SA15 (Sales)		136.178.97.0
		…
Subnet R1 (R&D)		136.178.110.0
Subnets SU1-SU22 (Support)	136.178.113.0	
	…	
	136.178.127.0	
	136.178.129.0	
	…	
	136.178.143.0	

Supernetting

- Class A: Too big and too few
- Class B: Too big and too few
- Class C: Numerous but often too small
- The sheer number of Class C networks makes advertising potentially a threat to overload the internet core routers.

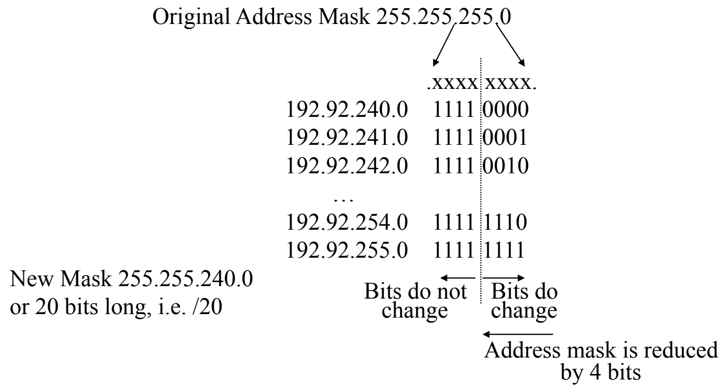
- Subnetting helps to manage networks by breaking things up hierarchically

Allocating and Advertising 16 Class C Addresses

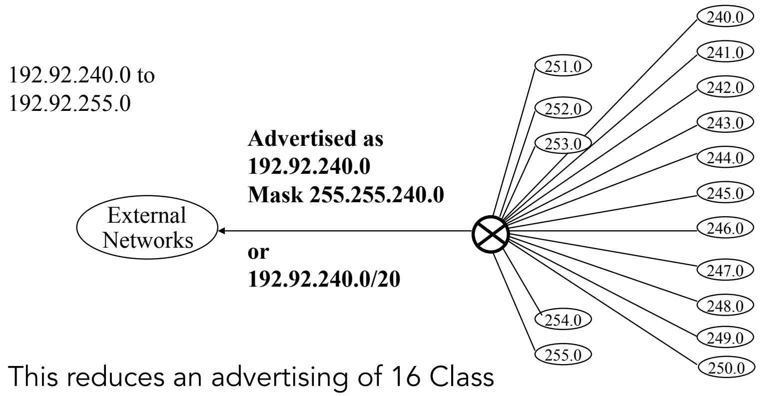


If all Class C networks classful addresses are advertised, the resulting influx of route advertisements could exceed the capability of internet core routers, resulting in performance loss or failure.

Modifying Address Masks to Represent Address Groups



Classless InterDomain Routing (CIDR)



This reduces an advertising of 16 Class C Networks to the advertising of a single CIDR block.

Rules To Observe

- For CIDR to work certain rules must be observed:
  1. Number of addresses in a CIDR block is based on a power of 2 (i.e. 2, 4, 8, … addresses)
  2. The ends of the address block must fall on bit boundaries
  3. Avoid having holes in the address space, the CIDR block should be contiguous.
     - Don't advertise addresses not of your own!
     - There is a workaround for this.

An Example Violating Rule 2

Original Address Mask 255.255.255.0

~~192.92.239.0 to 192.92.255.0~~

192.92.239.0/20?

Invalid CIDR block!

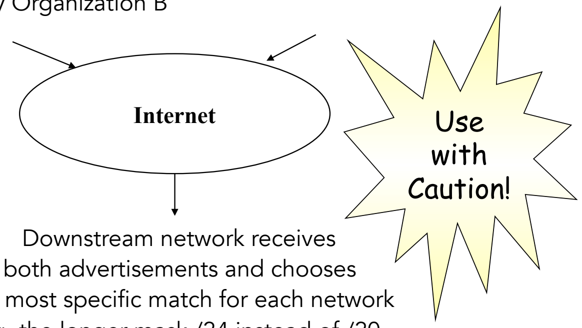
	.xxxx xxxx. (Third octet in binary)
192.92.239.0	1110 1111
192.92.240.0	1111 0000
192.92.241.0	1111 0001
...	
192.92.253.0	1111 1101
192.92.254.0	1111 1110

Bits now change in the fourth bit position.

Holes in CIDR block

Organization A advertises: 198.9.210.0 with natural mask (This address is also in the CIDR block advertised by Organization B

Organization B advertises: 198.9.208.0/20 —A CIDR block of 16 addresses

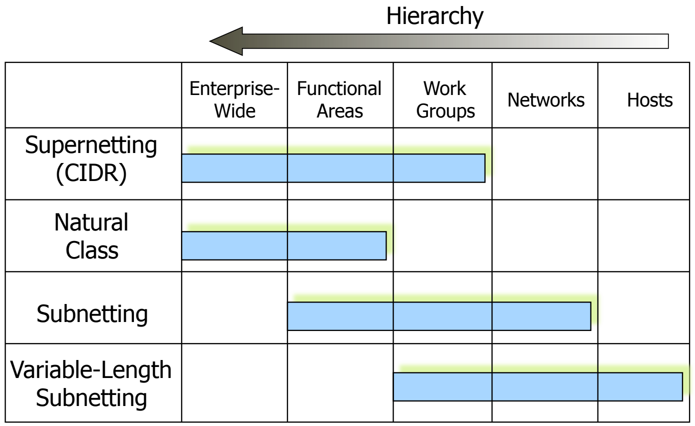


Downstream network receives both advertisements and chooses the most specific match for each network eg. the longer mask /24 instead of /20

Applying Address Strategies

- Scalability: Need to know the NUMBERS of
  - Functional Areas within the system
  - Work Groups within each Functional Area
  - Networks within each Work Group
  - Hosts within each Network
- Establish degree of hierarchies in the network.
- Applying addressing not only system-wide, but also function areas, network groups, and networks.

Best Fit Strategies



Private Addresses

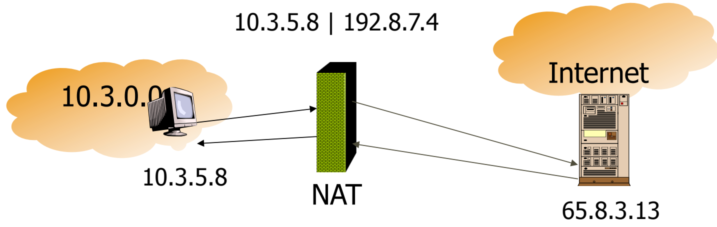
- Defined in RFC 1918.

  Class A: 10.0.0.0 - 10.255.255.255 (10/8 prefix)
  Class B: 172.16.0.0 - 172.31.255.255 (172.16/12 prefix)
  Class C: 192.168.0.0 - 192.168.255.255 (192.168/16 prefix)

- Use NAT (Network Address Translation) to get greater IP savings.
  - LAN uses private IP addresses.
  - Masquerade IP towards WAN (Internet).
  - Difficult for protocols such as FTP, UDP.
  - Efficiency problem.

A NAT Example

- Local host request a connection to 65.8.3.13.
- NAT allocates an external address 192.8.7.4.
- NAT changes source address on outgoing packets to 192.8.7.4.
- Reply packets arriving NAT, with destination address changed to 10.3.5.8, are then forwarded back.



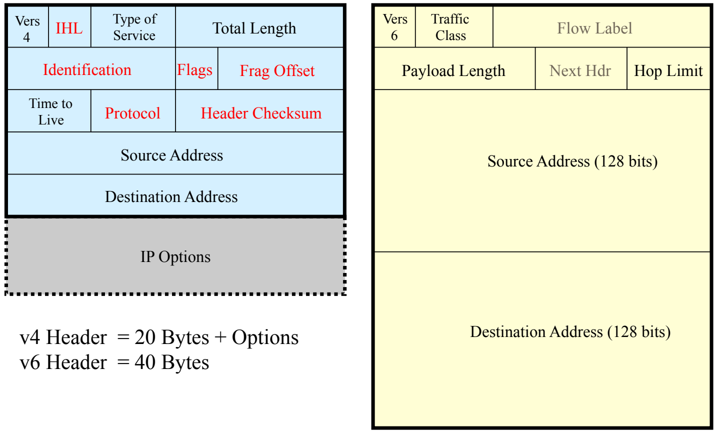
Buggy Patches?

- Workarounds such as NAT, CIDR have their own problems!
  - NATs promote reuse of private address space, but do not provide support to end-to-end packet-level security.
  - CIDR addresses owned by ISPs.
  - Internet still faces the risk of running out of capacity in the global routing tables.
- IPv6 is the solution!

IPv6

- IPv4 uses 32-bit addresses.
  - Theoretically allows 4 billion addresses.
  - Not possible to reach 50% utilisation.
- IPv6 goes to 128-bit addresses.
  - `5f1b:df00:ce3e:e200:0020:0800:2078:e3e3`
- Enables other additions to IP such as:
  - Support for better security (e.g. IPSEC)
  - Support for mobile hosts.
  - Support for real-time services.

IPv4 and IPv6



v4 Header = 20 Bytes + Options
v6 Header = 40 Bytes

IPv6 Address Planning

- Multiple address types for each host: unicast, anycast, multicast
- Format: 16-byte hexadecimal number fields, e.g., 2001:db8:130F:0:0:9c0:876A:130B.
- Normally /64 prefix used for unicast IPv6 addresses and even for point-to-point links (where /126 or /127 can be used)
- Within the system, existing IPv4 addressing schemes can be used, e.g.,
  - Translating subnet numbers into IPv6 subnet IDs
  - Translating VLAN IDs into IPv6 subnet IDs
  - Private addresses in IPv6 are unique!

IPv6 Transition

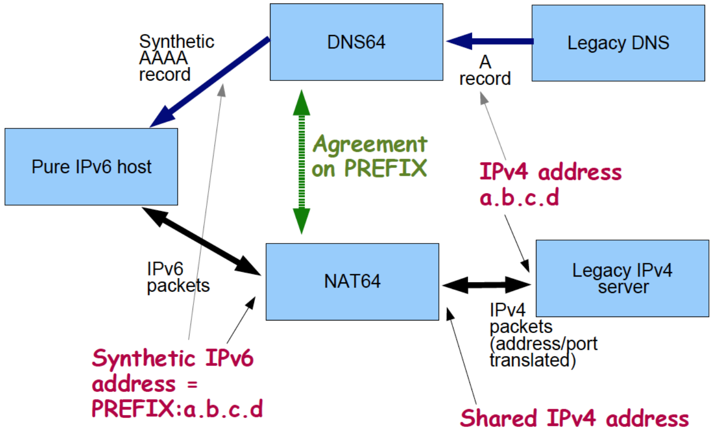
- The Internet clearly must support IPv4 hosts for a *long* time into the future.
- Dual-stack operation:
  - Some nodes and routers will have both IPv4 and IPv6 protocol stacks.
  - The version field will be used to direct a packet to the correct stack.
- Tunneling IPv6 through IPv4.
  - Each IPv6 packet is encapsulated into an IPv4 packet whose address is the address of the other end of the tunnel.

The Long Wait, but Why?

- "By 2004 all implementations will adopt IPv6 as the standard" (NZ e-Government Interoperability Framework e-GIF, 2002).
- IPv4 exhaustion:
  - IANA and ARIN registration exhaustion: 2011 / 2012
  - ISP level: 2015
- NAT
- Too many changes:
  - Apps and API's have to change
  - Domain Name System (DNS) changes
  - Border Gateway Protocol (BGP) changes
  - Routing protocol changes
  - IPv4 over xxx now needs IPv6 over xxx
  - Everything has to change (end-to-end)

NAT64 Technology

http://www.cisco.com/en/US/prod/collateral/iosswrel/ps6537/ps6553/white_paper_c11-676278.html



Summary

- Divide up design space
  - How?
- Subnetting
- Supernetting
- Choose an addressing strategy
- NAT and IPv6
- Refs:
  - CISCO IPv6 Addressing Guide
- Coming next: Routing