IP Addresses & Subnets

Internetworking – M30233

Lecture 2

IP Addresses & Subnets

- IP protocol
- IP functions
- IP notation methods
- IP address structure
- IP addressing
- Subnetting

Layer 3 functionalities

- This layer handles the routing of the data by delivering it to the correct destination

- Layer 3 functionalities are spread all over the network
  - In ad hoc hardware – routers
  - In your PC – routing software by Operating System

The Internet Protocol (IP)

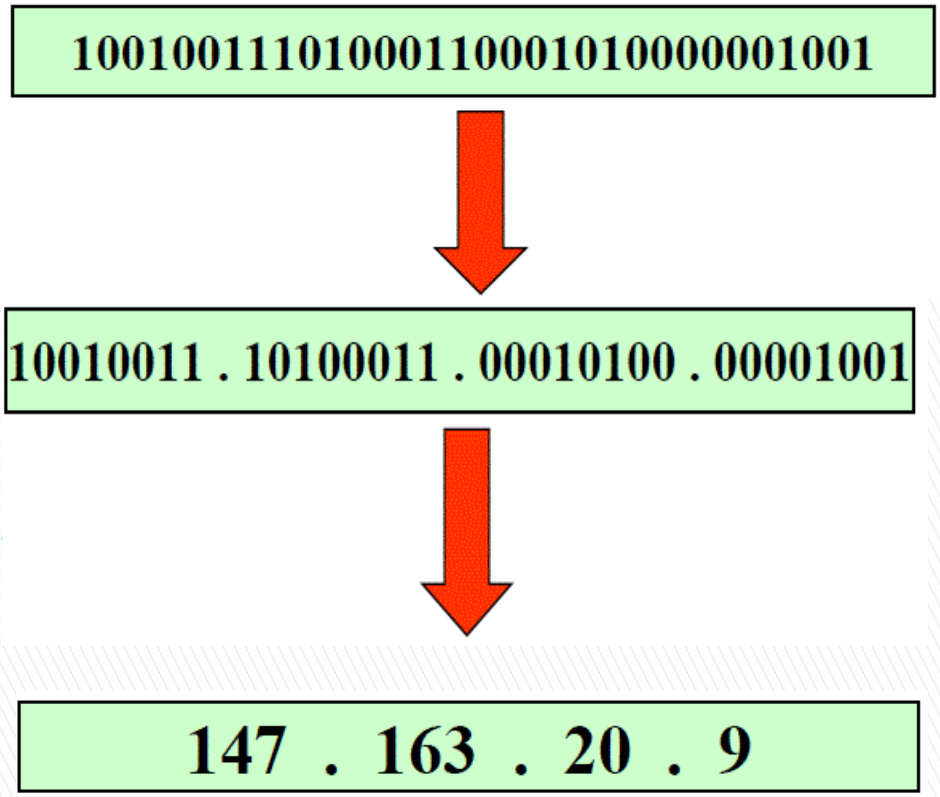
- Connectionless
  - Delivering datagrams
- Best effort
- Unreliable
  - No guarantee of orderly delivery
  - Error-handling algorithm?
    - Buffer is full -> discard
    - Error check failed ->discard

IP functions

- When transmitting:
  - Encapsulates data from transport layer into datagrams
  - Prepare header (src & dest addresses, etc)
  - Apply routing algorithm
  - Forward datagram to network interface card
- When receiving:
  - Check validity of incoming datagrams
  - Read header
  - Check if forwarding is needed
    - If yes ->send to appropriate network interface
    - If no -> pass payload to next upper layer

IP Address

- 32 bit string
  - System notation
- Dotted notation
  - 4 x 1 byte (8 bits)
  - **Each byte** = 0:255 integer
  - 1492.14.2.0 is not an IP address!
  - Intended for humans



Notation conversion

- From binary to decimal
  - E.g. 10101100.11011001.10101001.01010011

Binary	128	64	32	16	8	4	2	1	Decimal
10101100	1	0	1	0	1	1	0	0	172
11011001	1	1	0	1	1	0	0	1	217
10101001	1	0	1	0	1	0	0	1	169
01010011	0	1	0	1	0	0	1	1	83

- 172.217.169.83 (mail.myport.ac.uk)

Notation conversion

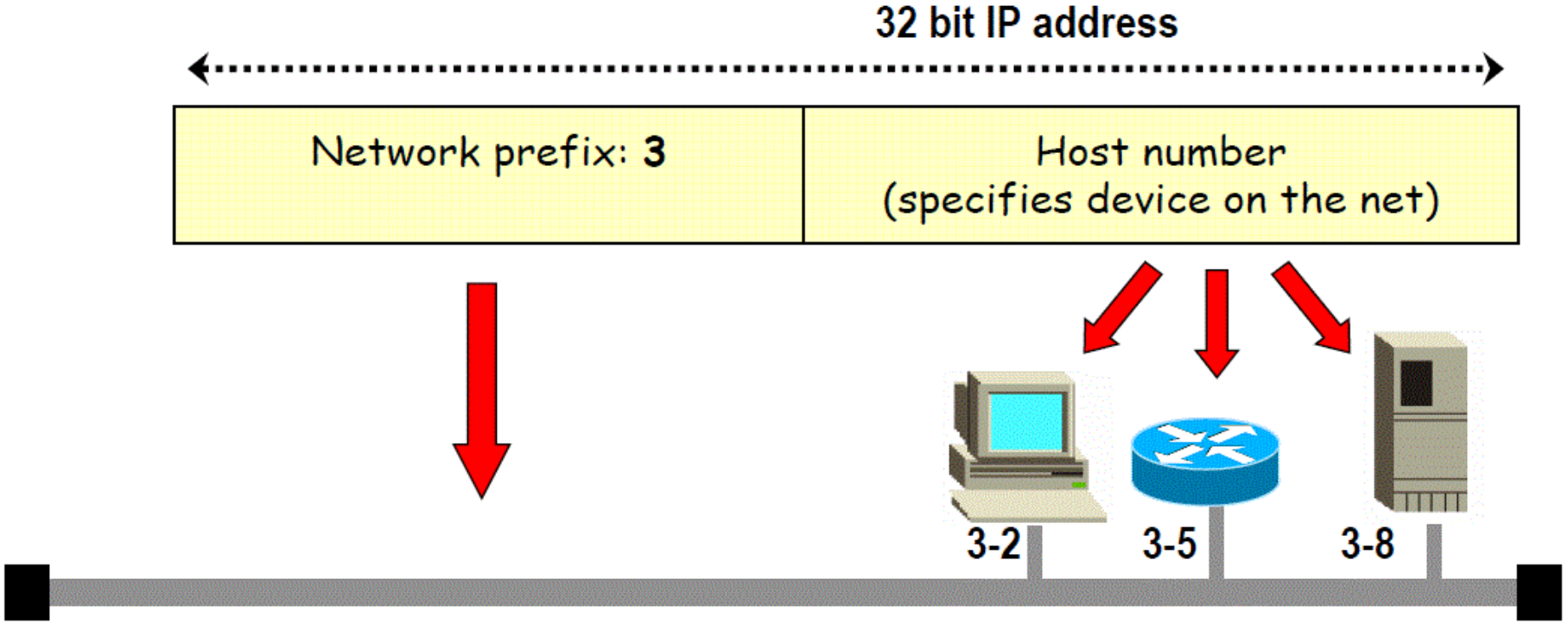
- Decimal to binary
  - E.g. 194.168.4.100

Decimal	128	64	32	16	8	4	2	1	Binary
194	1	1	0	0	0	0	1	0	11000010
168	1	0	1	0	1	0	0	0	10101000
4	0	0	0	0	0	1	0	0	00000100
100	0	1	1	0	0	1	0	0	01100100

  - cache1.service.virginmedia.net

IP Address Structure

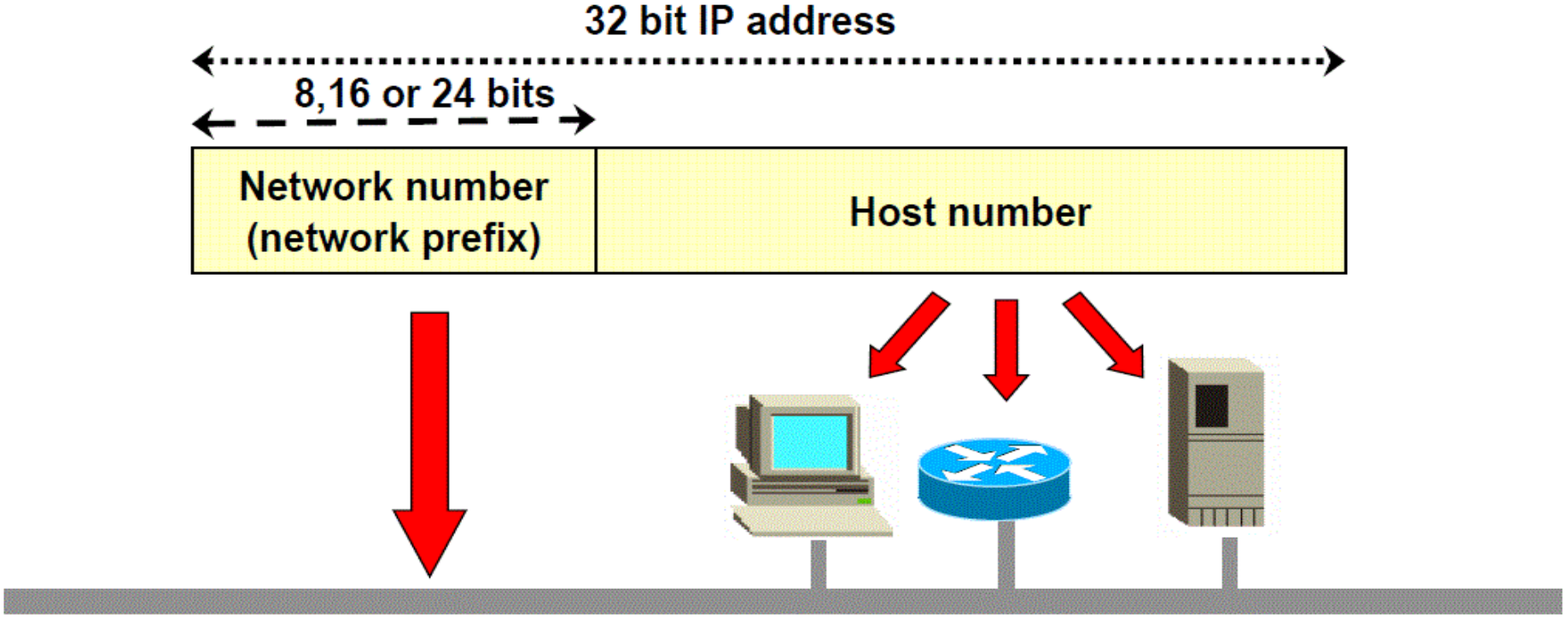
- It is portioned into two fields



Host Addresses
3-8 means: host 8 on network 3

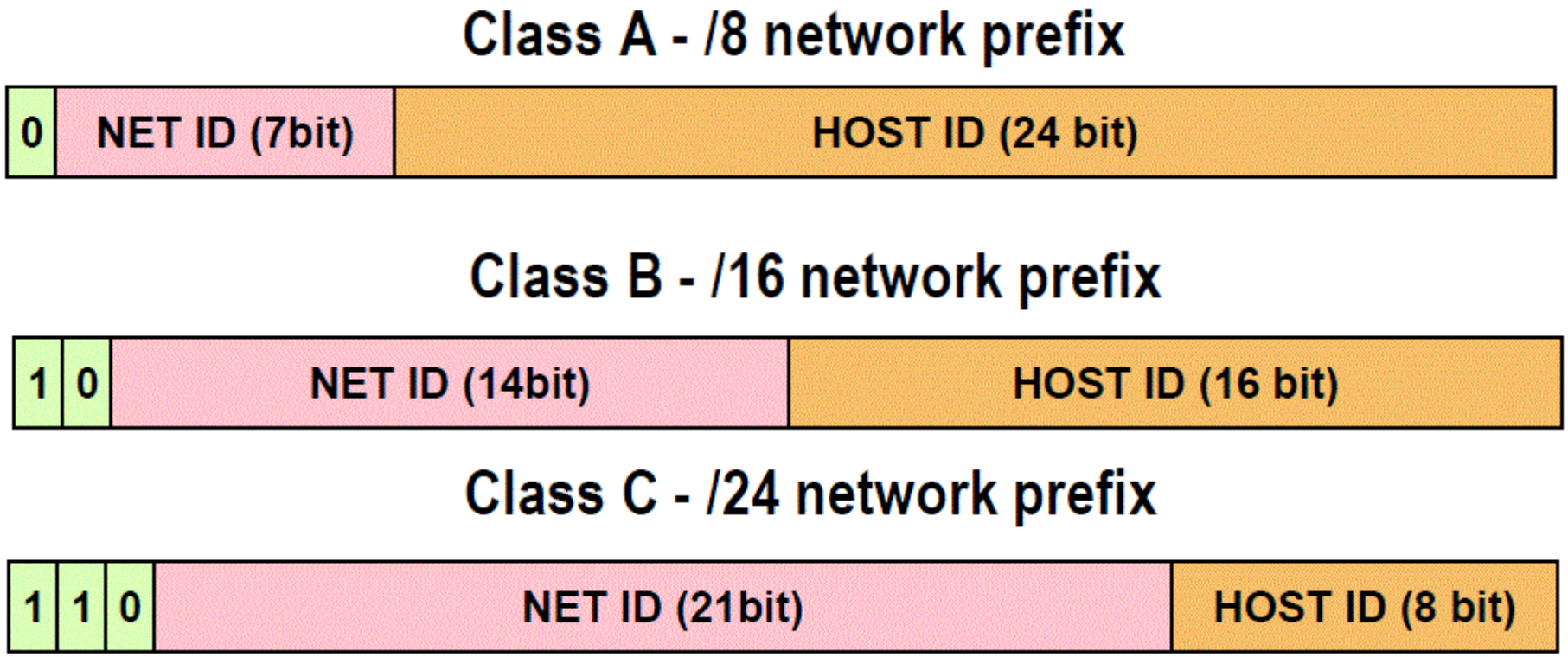
Classful IP Addressing

- It is portioned into two fields
  - Network ID can be 8,16 or 24 bits in length



IP Address Classes – primary

- Three standardised classes



IP Address Classes – extra

Class D: IP multicasting

Class E: reserved for experimental use

IP Address – Decimal Ranges

Address Class	Dotted Decimal ranges
Class A	1.xxx.xxx.xxx through 126.xxx.xxx.xxx
Class B	128.0.xxx.xxx through 191.255.xxx.xxx
Class C	192.0.0.xxx through 223.255.255.xxx
Class D (mcast)	224.xxx.xxx.xxx through 239.xxx.xxx.xxx
Class E (exper)	240.xxx.xxx.xxx through 255.xxx.xxx.xxx

Class A network 127.xxx.xxx.xxx is not part of the list – Why?

IP Address – Decimal Ranges

- Examples:
  - Class A – Default subnet mask = 255.0.0.0
    - 10.25.24.2
    - Network ID = 8 bits & Host ID = 24 bits
  - Class B – Default subnet mask = 255.255.0.0
    - 148.97.52.23
    - Network ID = 16 bits & Host ID = 16 bits
  - Class C – Default subnet mask = 255.255.255.0
    - 198.167.42.85
    - Network ID = 24 bits & Host ID = 8 bits

Addressing Networks

- When you refer to a network address then all host ID bits equal to 0

- Examples:
  - Class A IP address = 12.25.89.124
    - Network address = 12.0.0.0
  - Class B IP address = 132.15.223.17
    - Network address = 132.15.0.0
  - Class C network = 197.211.12.88
    - Network address = 197.211.12.0

Subnetting

- IPv4 provides 2^32 IP addresses
  - 4.294.967.296 (theoretical) maximum
- A class C network provides (2^8-2) assignable host addresses – 254
- A class B network provides $(2^{16}-2)$ assignable host addresses – 65534
- A class A network provides $(2^{24}-2)$ assignable host addresses –16.777.214

Usable host addresses

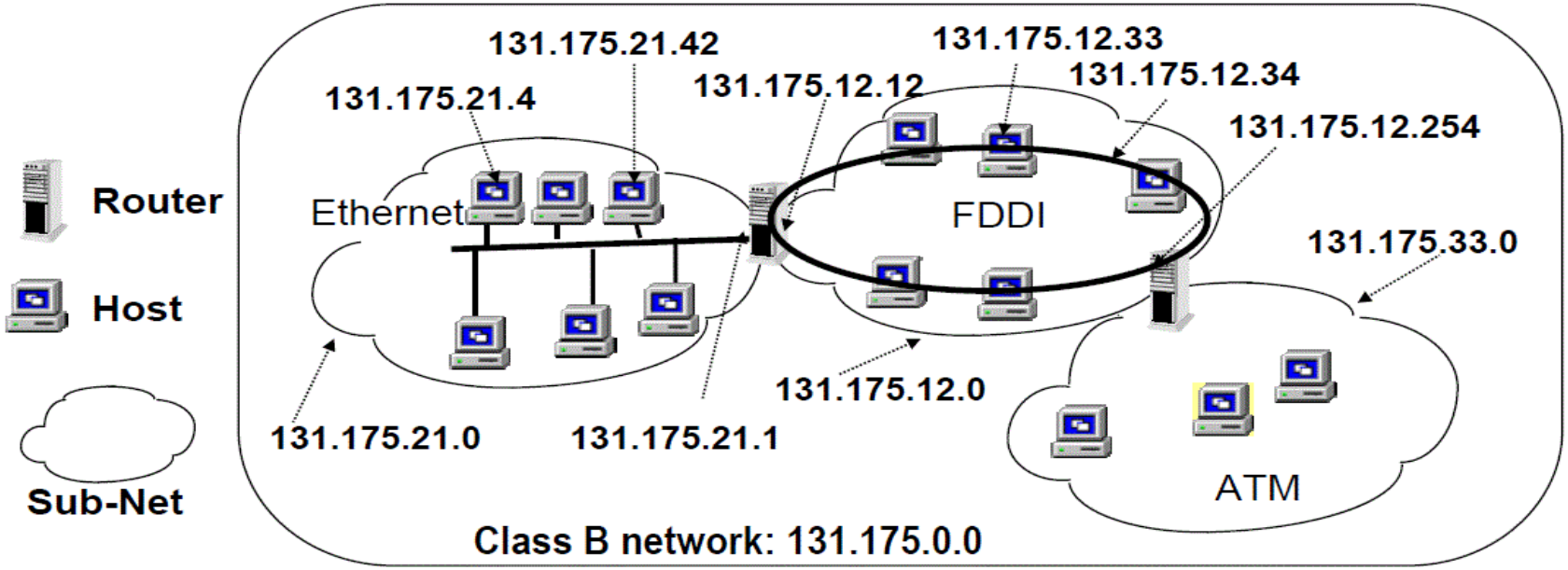
- The x-2 rule
- You have been assigned a Class B network address -> 128.147.0.0
  - IP range: 128.147.0.0 – 128.147.255.255
  - Total addresses available = 65536
  - First assignable address = 128.147.0.1
  - Last assignable address = 128.147.255.254
  - Total assignable addresses = 65534
- Why do we have to deduce 2 from the total addresses?
  - 128.147.0.0 is the network address – not assignable
  - 128.147.255.255 is the network's broadcast address – not assignable

Subnetting – Why?

- If you have been assigned a Class B network address…
- Is it possible to accommodate 65534 hosts on one single physical network?
  - What about management?
  - What about performance?
  - Waste of IP addresses?

Subnetting – Hierarchy

- Divide one big network into several subnetworks
- Each subnet = a physical network



- Solution?
  - We can use the third byte 131.175.**X**.0 as subnet identifier!

Subnetting – Hierarchy

- Network administrator asks for a classful network address – e.g. 128.147.0.0 – Class B
- Create subnetworks within the main network
  - Subnet #1 = 128.147.8.0
  - Subnet #2 = 128.147.12.0

  - Subnet #N = 128.147.x.0
- Flexible for administrator -> Create smaller, manageable networks
- Subnetworks do not require extra routing -> one entry in core router

Subnetting – Example

- Class B without subnetting

- Class B with subnetting

- You reserve host ID bits for subnetting
- The reserved bits are called Subnet ID.

Subnet Address and Mask

- Host IP address
  - 148.197.9.18 -> 10010100.11000101.00001001.00010010
- Class B network with default subnet mask:
  - 255.255.0.0 -> 11111111.11111111.00000000.00000000
- Custom subnet mask (when subnetting)
  - Longer than default class mask. Decided by network admin.
  - Tells where the new boundary between networkID-hostID is
- Example: class B address with a 5 bit subnet ID
  - Subnet mask = /21 ->
  - 255.255.248.0 -> 11111111.11111111.11111000.00000000
  - Network ID = 148.197.0.0 (B class)
  - New (sub)network ID = 10010100.11000101.00001000.00000000 -> 148.197.8.0/21

Class B subnetting – example

- Class B address = /16 network prefix
  - Network address = 148.197.0.0
  - Default subnet mask = 255.255.0.0 = 16 bits long
  - Host ID = 16 bits long

- You can create subnets by extending the network ID with bits you reserve from the Host ID
  - Custom subnet mask = 255.255.**255**.0 (extended by 8 bits)
  - Subnet ID = 8 bits long -> 2^8 (256) number of subnets
  - New Host ID = 8 bits long -> $2^8 - 2$ number of (useable) hosts per subnet

Class C subnetting – example (1)

- You have been assigned a Class C network.
  - 193.1.1.0/24
    - Network ID = 24 bits & Host ID = 8 bits
    - Total number of hosts = $2^8 = 256$
      - Number of usable hosts = 256 – 2 = 254
    - You are asked to create 8 new subnets within the Class C network

Class C subnetting – example (2)

- 193.1.1.0/24
  - Network ID = 24 bits & Host ID = 8 bits
  - You are asked to create 8 new subnets within the Class C network

- The rule $2^x \geq y$ defines how many bits you reserve from the Host ID
  - You need 8 subnets → $2^x \geq 8$ → x=3 bits to reserve
  - You reserve 3 bits from the Host ID
  - (new)Host ID = 5 bits. How many host IP addresses per subnet?
    - Total number of IP address = 2^5= 32 addresses per subnet
    - Usable host addresses = 32-2 = 30 per subnet

Class C subnetting – example (2)

- Why do we need to deduce 2 addresses for every newly created subnet?
  - The first IP address within each subnet is the subnet address – all (new)Host ID bits equals to 0
  - The last IP address within each subnet is the subnet's broadcast address – all (new)Host ID bits equals to 1
  - Every other IP address is a usable address – can be assigned to a host
  - *See next slide for subnet address…*

Class C subnetting – example (2)

Subnet # 0	11000001.00000001.00000001.**000**00000	**193.1.1.0/27**
Subnet # 1	11000001.00000001.00000001.**001**00000	**193.1.1.32/27**
Subnet # 2	11000001.00000001.00000001.**010**00000	**193.1.1.64/27**
Subnet # 3	11000001.00000001.00000001.**011**00000	**193.1.1.96/27**
Subnet # 4	11000001.00000001.00000001.**100**00000	**193.1.1.128/27**
Subnet # 5	11000001.00000001.00000001.**101**00000	**193.1.1.160/27**
Subnet # 6	11000001.00000001.00000001.**110**00000	**193.1.1.192/27**
Subnet # 7	11000001.00000001.00000001.**111**00000	**193.1.1.224/27**

Remember, the rule of $2^x \geq y$ can be applied when you need to create subnets based on the number of required host addresses per subnet

Custom Subnet mask values

128	64	32	16	8	4	2	1	
1	0	0	0	0	0	0	0	= 128
1	1	0	0	0	0	0	0	= 192
1	1	1	0	0	0	0	0	= 224
1	1	1	1	0	0	0	0	= 240
1	1	1	1	1	0	0	0	= 248
1	1	1	1	1	1	0	0	= 252
1	*1*	*1*	*1*	*1*	*1*	*1*	*0*	*= 254*
1	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*= 255*

Special Addresses

- When Host ID is all 1s -> **broadcast address** for this network
  - 134.86.255.255 = Broadcast address for network 134.86.0.0
- 0.0.0.0 -> This host on this network (reserved)
- **127.x.x.x** used for loopback
  - 127.0.0.1 = localhost (same for every PC)
- When address is all 1s -> limited broadcast
  - **255.255.255.255** -> all nodes on this local network

Private IP addresses (RFC 1918)

- Can be used by private organisations not connected to the Internet
  - No need to ask assignment by IANA or InterNIC
  - Internet connectivity? -> use NAT (Network Address Translator)

IANA-Allocated, Non-Internet Routable, IP Address Schemes

Class	Network Address Range
A	10.0.0.0 - 10.255.255.255
B	172.16.0.0 - 172.31.255.255
C	192.168.0.0 - 192.168.255.255

- Next Week
  - Classless Inter-Domain Routing – CIDR