ET0730

Chapter 2
IP Addressing and Subnet Mask

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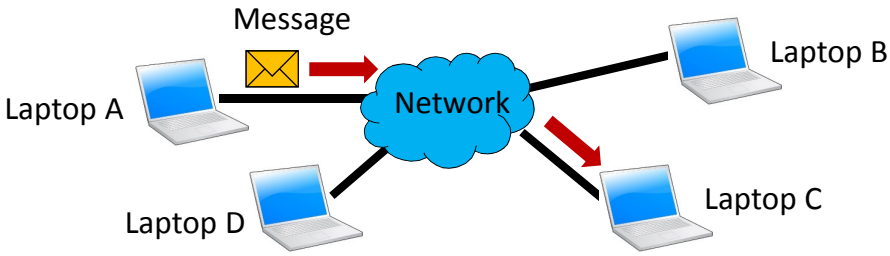
Objectives

- Explain the need of IP address.
- Perform the conversion between binary and decimal formats of IP addresses.
- Describe the use of subnet masks.
- Derive subnet mask.
- Describe Class A, B, C, D, E IP addresses.
- Explain the limitation of Classful IP addresses.
- Explain Classless IP addresses and corresponding subnet mask.

Outline

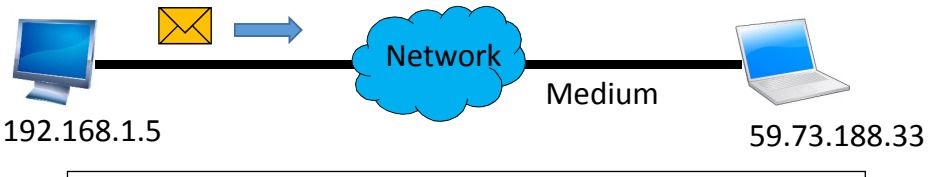
- Format of IP addresses
- Network Portion and Host Portion of IP addresses
- Subnet mask
- Classes of IP addresses
  - Classes A, B, C, D and E
  - Number of host IP addresses
  - Limitations of Classful IP addresses
- CIDR, the Classes IP addresses

Why do we need IP Addresses?



- In one-to-one communications, the "message" coming from the source is expected to be delivered only to the destination.
  - E.g. Laptop A wishes to send a message to Laptop C (not Laptops B and D).
- This is analogue to sending a letter. We need to specify the postal address of the recipient.
- Therefore, every end device in a computer network must have an unique "address".
- Since the network uses "Internet Protocol" (IP) for communications, the address is "IP address".

Format of IP Address



Send a message from 192.168.1.5 to 59.73.188.33.

- IP addresses are generally expressed in the **dotted decimal format**, **x.x.x.x**, where x is any integer from **0 to 255**.
  - Example 1: 153.234.166.200
  - Example 2: 5.6.78.99

Exercise:

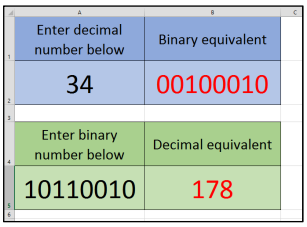
- Determine whether the following are valid IP addresses:
  - (a) 123.234.0.1
  - (b) 5.0.1.2
  - (c) 58.246.111.259
- Answer:
  - (a) Valid
  - (b) Valid
  - (c) Invalid ('259' of "58.246.111.259" exceeds 255.)

Why do we use "Dotted Decimal" format?

- IP addresses are actually 32-bit binary numbers.
- Example:
  - 11010001000110000100110000110101
- Unfortunately, long strings of '0's and '1's are difficult to read.
- Solution:
  - Use **decimal** instead of binary numbers.
- That involves some binary to decimal conversion.

Conversion between Binary and Decimal Formats

- Conversion between binary and decimal Formats is covered in ET1003 Digital Electronics I.
  - It will not be discussed in this module.
- If you have learnt it in ET1003, you may do the conversion manually.
- Else, you may
  - make use of your scientific calculator, or
  - make use of the Excel file **Binary_Decimal_Converter.xlsx** provided on ET0730's Black Board site (under Chapter 02's folder).



Enter decimal number below	Binary equivalent
34	00100010
Enter binary number below	Decimal equivalent
10110010	178

How to obtain IP address in "Dotted Decimal" format?

- Example: Given the 32-bit IP address below:
  - 11010001000110000100110000110101
- How to obtain the "Dotted Decimal" IP address?
  - **Step 1:** Divide the 32 bits into 4 groups of 8 bits.
    - 11010001 00011000 01001100 00110101
  - **Step 2:** Each group of 8-bit binary number is converted into decimal value.
    - 11010001 00011000 01001100 00110101
    - 209 24 76 53
  - **Step 3:** Insert dot (period) between the decimal values.
  - **Result:** IP address = 209.24.76.53 (easier to read compared to binary format. Agree?).

Why is there a limit of "0 to 255"?

- Each group of 8-bit binary number can be any combination of '0's and '1's.
- Example:
  - 00000000 (lowest)
  - 00000001
  - 00000010
  - …… (other combinations of '0's and '1's)
  - 11111101
  - 11111110
  - 11111111 (highest)
- The lowest is 00000000, which equals 0 in decimal.
- The highest is 11111111, which equals 255 in decimal.
- Therefore, the decimal value of the integers representing an IP address must be between 0 to 255 (both inclusive).

Exercise: Binary → Decimal

- Convert the following IP address from binary format to decimal format.

  00110011 11110000 00001111 00001001

- Answer:
  - 00110011 = 51
  - 11110000 =240
  - 00001111 = 15
  - 00001001 = 9
  - Therefore, IP address in decimal format is 51.240.15.9.

Exercise: Decimal → Binary

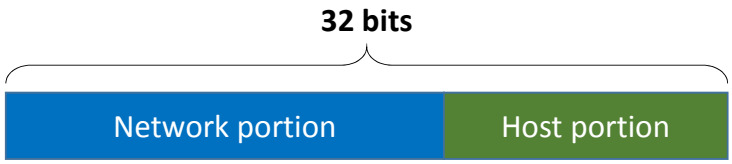
- Convert the following IP address from decimal format to binary format.

  34.56.168.251

- Answer:
  - 34 = 00100010
  - 56 = 00111000
  - 168 = 10101000
  - 251 = 11111011
  - Therefore, IP address in binary format is 00100010001110001010100011111011.

Network Portion & Host Portion

- An 32-bit IP address consists of two portions:
  - **Network portion**
  - **Host portion**



- The "Network portion" represent a groups of IP addresses.
- The "Host portion" is used to uniquely define each IP address within that group of IP addresses.

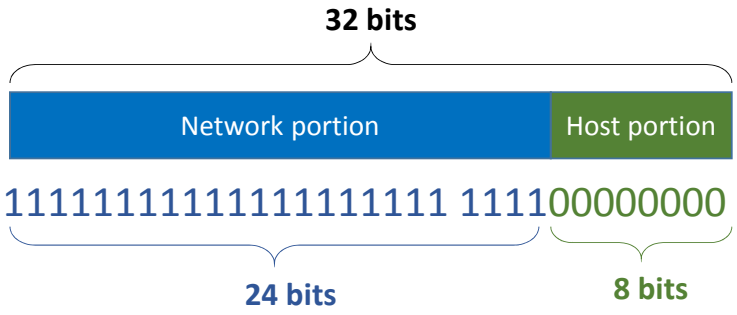
- The number of bits in the Network portion and Host portion depends on the number of unique IP addresses needed in a group of IP addresses.
  - This will be covered in a later chapter.

How to indicate the "Network portion" and "Host portion" of an IP address? (Well, not by colour...)

- To indicate how the 32 bits of an IP addresses are divided between the "Network" and "Host" portions, we use the "**Subnet Masks**".
- Just like the IP addresses, subnet masks are 32-bit binary numbers too.
- Subnet Masks are also generally given in dotted decimal format.
- Four examples of Subnet Masks:
  - 255.255.255.0
  - 255.255.0.0
  - 255.0.0.0

How to derive the Subnet Masks? (1)

- A subnet mask consists of a string of '1's, followed by a string of '0's.
- In a subnet mask,
  - Binary number **'1's** represent the **Network portion**.
  - Binary number **'0's** represent the **Host portion**.
- Example:
  - Network portion=24 bits + Host portion=8 bits



How to derive the Subnet Masks? (2)

- To present a subnet mask in dotted decimal format, follow the steps of converting IP addresses from binary format to decimal format.
- Example:
  - Subnet mask = 11111111111111111111111100000000
  - Divide into groups of 8 bits:
    - 11111111 11111111 11111111 00000000
  - Convert each group of 8-bits into decimal number:
    - **255 255 255 0**
  - Insert dots in between the decimal numbers:
  - Result:
    - Subnet mask in dotted decimal format = **255.255. 255.0**

Exercise: Construct a Subnet Mask

- Construct a subnet mask for indicating the following:
  - Network portion = **16 bits**
  - Host portion = **16 bits**

- Answer:
  - Subnet mask = 11111111 11111111 00000000 00000000
  - Decimal format = **255** **255** **0** **0**
  - Subnet mask = 255.255.0.0

IP Classes

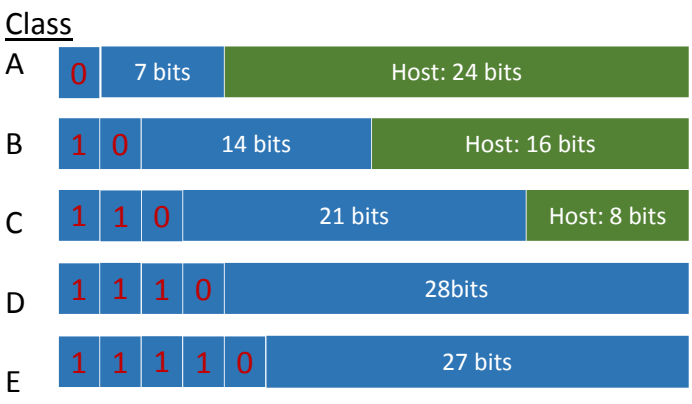
- The **Internet Assigned Numbers Authority (IANA)** devised the hierarchical IP addressing structure.
- The **American Registry of Internet Numbers** (**ARIN**) assigns IP addresses to public, private, and government organisations.

- Five different groups of IP addresses (classes A, B, C, D and E) exist on the Internet.
- Classes A, B, and C are assigned to governments, companies, schools, and public entities for use on the Internet.
- Classes D and E are reserved for multicasting and experimentation.

Formats of IP Classes (1)

- Class A IP addresses start with '0'.
- Class B IP addresses start with '10'.
- Class C IP addresses start with '110'.
- Class D IP addresses start with '1110'.
- Class E IP addresses start with '11110'.

Formats of IP Classes (2)



Range of Net ID	Subnet Mask
1 - 126	255.0.0.0
128.0 – 191.255	255.255.0.0
192.0 – 223.255.255	255.255.255.0
224 - 239	-
240 - 247	-

- Network portion of Class A = 00000001 to 01111110 (i.e. 1 to 126).
- Network portion of Class B = 10000000 00000000 to 10111111 11111111 (i.e. 128.0 to 191.255)
- Network portion of Class C can be derived using same approach as Classes A and B.
- Classes D and E have no Host portion.

Class A

- ARIN reserves Class A IP addresses for governments throughout the world.
- It seems 127.x.x.x (decimal) is the highest assignable Class A address, but that particular address range is reserved for the loopback address.
- Hence, Class A will have 1 to 126 for first octet (octet = byte = 8 bits).

Class B

- Class B IP addresses are assigned to large- and medium-sized companies.
- Class B addresses will lead with pattern "10" when written in binary format.
- This means that the range in decimal notation for the first octet of Class B addresses is 128 through 191.

Binary Place Values								Decimal Equivalent	Description
128	64	32	16	8	4	2	1		
1	0	0	0	0	0	0	0	= 128	First Class B address
1	0	1	1	1	1	1	1	= 191	Last Class B address

Class C

- Class C IP addresses are assigned to groups that do not meet the qualifications to obtain Class A or B addresses.
- The first three binary digits of a Class C address must be "110".
- Hence the first octet of Class C addresses can range from 192 through 223 in decimal notation.

Binary Place Values								Decimal Equivalent	Description
128	64	32	16	8	4	2	1		
1	1	0	0	0	0	0	0	= 192	First Class C address
1	1	0	1	1	1	1	1	= 223	Last Class C address

Class D

- Class D addresses (also known as "Multicast Addresses") are reserved for multicasting.
- Class D addresses must have "1110" as their first four binary digits.
- Hence the range for Class D starts with decimal 224 and ends at 239 in the first octet.

Binary Place Values								Decimal Equivalent	Description
128	64	32	16	8	4	2	1		
1	1	1	0	0	0	0	0	= 224	First Class D address
1	1	1	0	1	1	1	1	= 239	Last Class D address

Class E

- The IANA reserves Class E addresses for research, testing, and experimentation.
- Class E is everything above and including 240 (decimal) as the first octet.

Binary Place Values								Decimal Equivalent	Description
128	64	32	16	8	4	2	1		
1	1	1	1	0	0	0	0	= 240	First Class E address

Exercise:

- What class does IP address 166.74.105.106 belong to?
- Answer:
  - The first octet of the IP address, 166 = 10100110 in binary format.
  - Since the IP address starts with "10", it is a Class B IP address.

Standard (default) Subnet Masks for IP Classes A, B and C

- Standard (default) subnet masks are as follows:
  - Class A subnet mask is 255.0.0.0.
    - 8 bits for Network portion, 24 bits for Host portion.
  - Class B subnet mask is 255.255.0.0.
    - 16 bits for Network portion, 16 bits for Host portion.
  - Class C subnet mask is 255.255.255.0.
    - 24 bits for Network portion, 8 bits for Host portion.

Number of Host Addresses for Classes A, B and C

- If the number of bits in the Host portion is n, the number of different Host Addresses = **$2^n - 2$**.
  - Although n bits can give up to 2^n different patterns, there are two patterns cannot be used (therefore there is a "substrate 2" in the formula) as host IP addresses:
    - All bits of the Host portion are '0's.
    - All bits of the Host portion are '1's.
- Host IP addresses of all '0's and all '1's (i.e. 000…00 and 111…11) are reserved as "Network Address" and "Broadcast Address" respectively.
- "Network Address" and "Broadcast Address" will be introduced in a later chapter,

Exercise:

- How many different host IP addresses can a Class B IP address have?
- Answer:
  - Class B's subnet mask = 255.255.0.0, showing that there are 16 bits in the Host portion (i.e. n=16).
  - Number of different host IP address
    $= 2^{16} - 2$
    $= 65534$

Exercise:

- How many different Class A IP addresses can we have?
- How many different host IP addresses can a Class A IP address have?
- Answer:
  - Class A is from 1 to 126, so we have 126 Class A IP addresses.
    - There are about 196 countries in the world (+/- a few, depending on political reasons). Hence, we don't really have enough Class A IP address for each country in this world.
  - Class A's subnet mask = 255.0.0.0, showing that there are 24 bits in the Host portion (i.e. n=24).
  - Number of different host IP address
    $= 2^{24} - 2$
    $= 16,777,214$ (16.7 millions)
    - Some countries' (e.g. Singapore) population is even less than the number of host IP addresses assigned to the government of that country.

Limitations of Classful IP Addresses

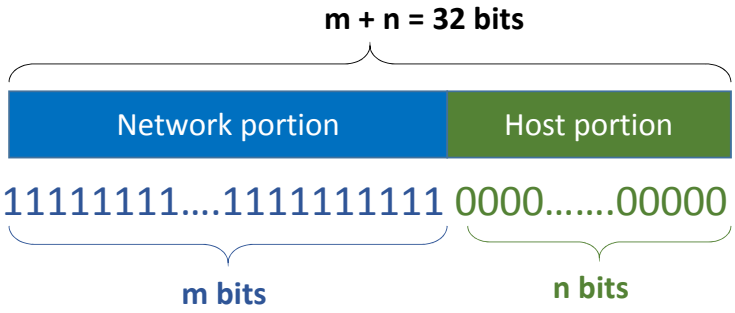
- Classes A, B and C are also called Classful IP Addresses.
- The previous exercise demonstrates that Class A IP addresses are very wasteful.
  - Some countries do not need 16.7 million host IP addresses.
- Root cause:
  - The standard subnet masks of Classful IP Addresses define Network portion as "multiple of 8-bits".
- Question:
  - How about we allow more flexible number of bits in the Network portion? (See next slide for the answer.)

Classless Inter-Domain Routing (CIDR)

- CIDR replaced the old process of assigning IP addresses based on Class A, B and C addresses, by breaking away from the restriction of using Network portion of multiple of 8-bits.
- Advantage of Classless IP Addressing:
  - Replacement of classful addressing with a more flexible and less wasteful class scheme.
- If the Network portion of a Classless IP address is 27 bits long (not a multiple of 8), the CIDR notation for this address is x.x.x.x/27.
- "/27" is the Network Prefix.

How to derive the Subnet Masks for a Classless IP Address? (1)

- There is no change in the way we derive the subnet masks.
  - Binary number **'1's** represent the **Network portion**.
  - Binary number **'0's** represent the **Host portion**.
- m and n do not need to be multiple of 8.



How to derive the Subnet Masks for a Classless IP Address? (2)

- Example:
  - If the Network Prefix is /20, derive the corresponding subnet mask.
- Solution:
  - Network portion=20 bits + Host portion=12 bits
  - Subnet mask = 11111111111111111111000000000000
  - Divide into groups of 8 bits:
    - 11111111 11111111 11110000 00000000
  - Convert each group of 8-bits into decimal number:
    - 255 255 240 0
  - Result:
    - Subnet mask in dotted decimal format = **255.255.240.0**
  - Notice that the subnet mask now may contain decimal number other than 255 and 0.

Exercise: Construct a Subnet Mask

- Construct a subnet mask for an IP address having Network Prefix of /13.

- Answer:
  - Network portion=13 bits + Host portion=19 bits
  - Subnet mask = 11111111 11111000 00000000 00000000
  - Decimal format = **255** **248** **0** **0**
  - Subnet mask = 255.248.0.0

Questions & Answers