Lesson 4 – Network fundamentals

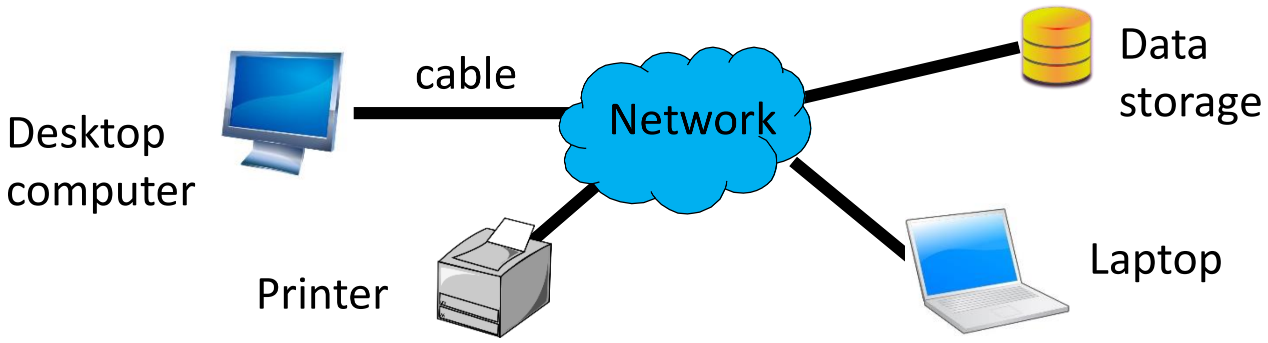
- S.P. Chong

Objectives

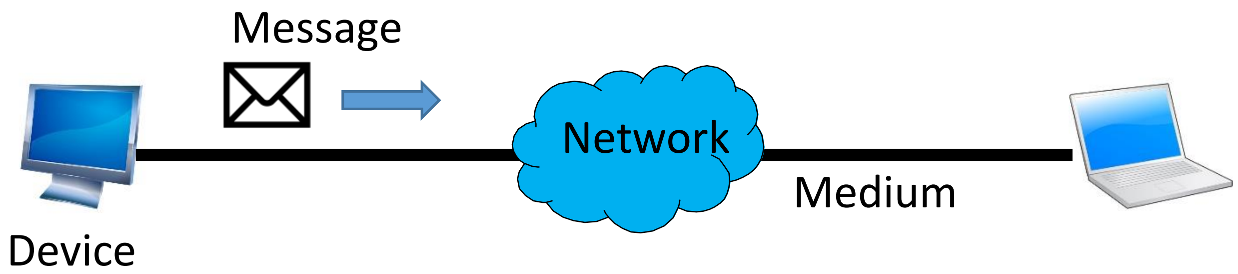
- In this lesson, you will learn the fundamentals of a computer network.
- You will be given an overview of these concepts:
  - PAN vs LAN vs WAN
  - Switches & routers
  - IP addresses (v4, v6) & MAC addresses
  - DHCP
  - NAT & Port Numbers
  - DNS

Computer networks

- Computer networks connect computers, printers, storage devices and other peripherals together, allowing people to **communicate** or **share resources**.
- We use computer networks for **learning, working, playing**, etc.
- The **data transfer** over a computer network includes text, graphics, voice & video.



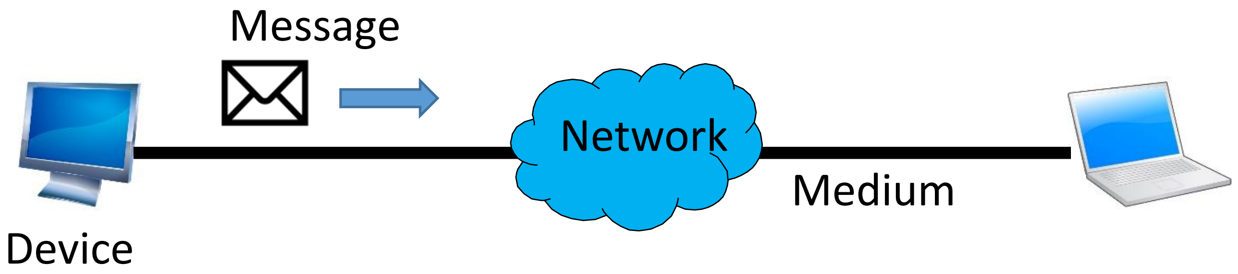
Computer networks (cont.)



- All computer networks have these 4 basic elements:
  - **Devices** - e.g. computers to exchange messages with one another
  - **Media** – wired (copper cables or optical fibres) or wireless (Bluetooth, WiFi, cellular etc.) means of interconnecting devices
  - **Messages** – information that travels from one device to another
  - **Protocols** – rules on how messages are sent, directed, received and interpreted

E.g. max length of message = ?
Message must start with ???
What if fails to send?

Computer networks (cont.) – “Devices”

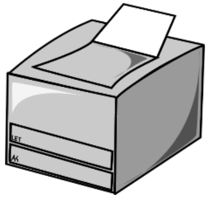


- The types of devices are:
  - **End Devices** - also referred to as “**hosts**”, these are **source or destination** devices that originate or consume messages in communication. E.g. computers, servers, IP phones, network printers, IP cameras
  - **Intermediary Devices** – such as **switches & routers** for **directing & managing** messages across the network

Computer

Server

IP Phone



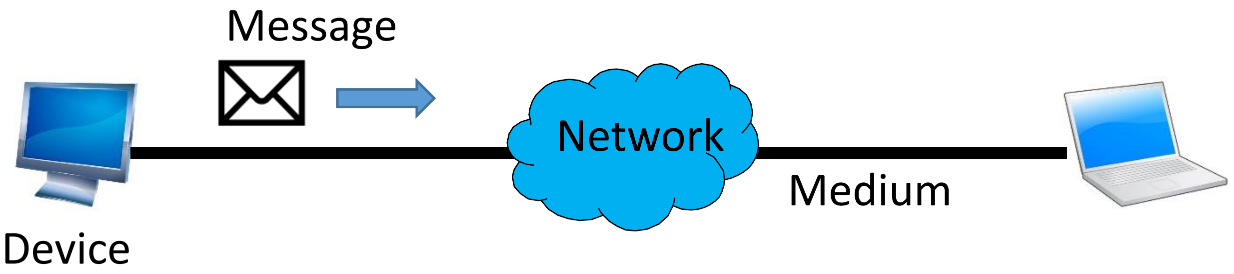
Network printer

IP Camera

Router

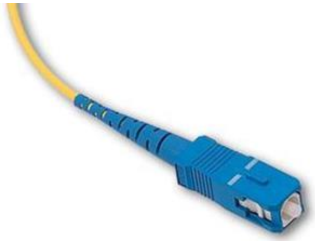
Switch

Computer networks (cont.) – “Media”



- Each wired & wireless medium offers a different **range** (how far the signal can travel), **data rate** (how fast can information be sent) and hence **application** areas.


Copper cables

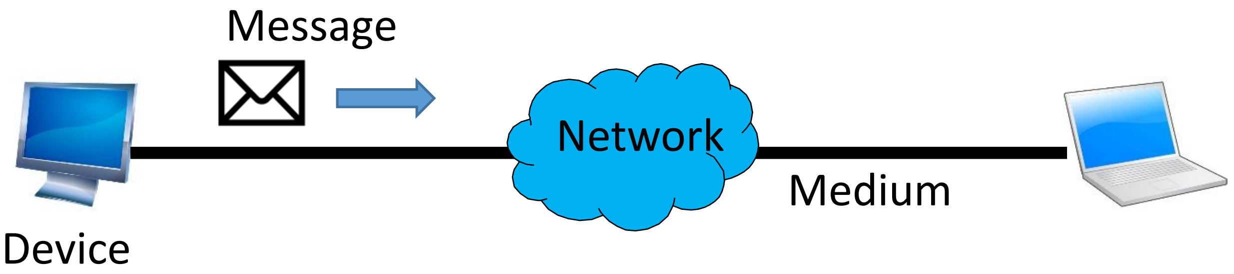

Optical fibre

Bluetooth®

Wi Fi™

Cellular

Computer networks (cont.) – “Messages”



- Messages include web pages, emails, instant messages, telephone calls and other forms of communication enabled by the internet.

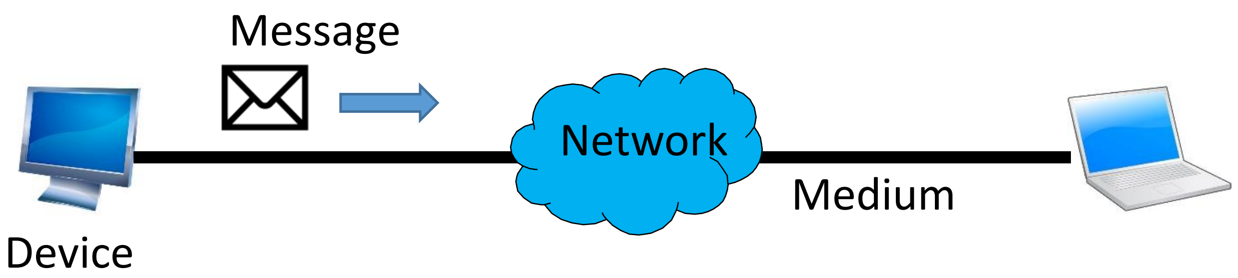
Web page

Email

WhatsApp

Instant message

Computer networks (cont.) – “Protocols”



- Communication between devices is only possible if they follow protocols or rules.
- Example: **TCP/IP** (Transmission Control Protocol/Internet Protocol) which specifies the **formatting**, **addressing** & **routing mechanisms** that ensure the delivery of the messages.
- In this module, you will need to understand a few important protocols (e.g. **DHCP**, **NAT**, **DNS**) to be able to implement an IoT project.

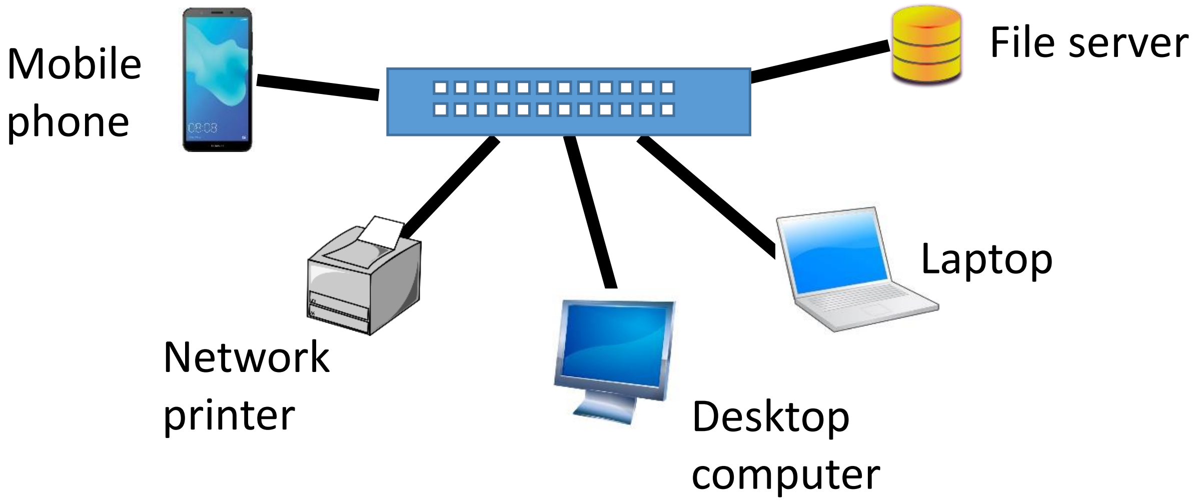
PAN vs LAN vs WAN - PAN

- **Bluetooth** is often used in a **wireless PAN** (Personal Area Network), to allow communication between 2 devices belonging to the **same person**.
- For instance, from his mobile phone to his laptop, or from his laptop to his speakers, or from his mobile phone to his headset.
- The range is typically **under 10m**.

PAN vs LAN vs WAN (cont.) - LAN

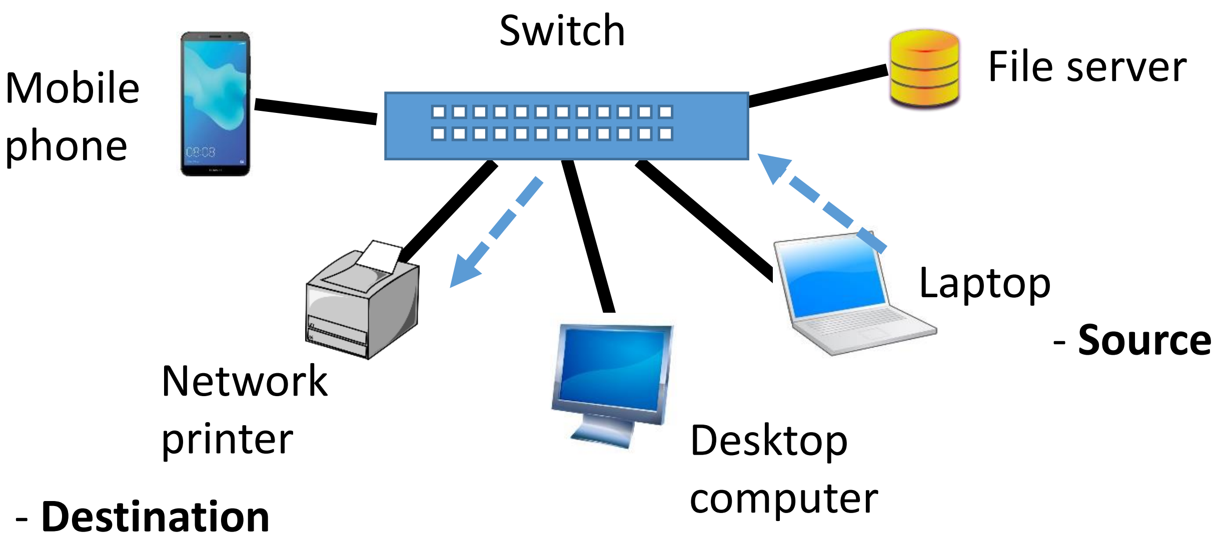
Copper cables

- When devices within a **small geographical area** (e.g. within an office or a building, or a home) are connected (wirelessly or via wires), they form a **LAN** (Local Area Network). These devices often belong to the **same organization or family**.
- **WiFi** is often the wireless medium of choice, but **LAN cables** are also used.
- **Data rate** can be as high as 1Gbps (1 Gigabits per second).



PAN vs LAN vs WAN (cont.) - switch

- A **switch** is used to allow data to move from the **source** device to the **destination** device.
- Every device in the network has a unique "**address**".

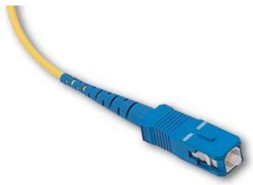


- If a file is sent from a laptop to a network printer, the file (i.e. the "message") is first sent (together with the destination address) to the switch.
- The switch will look at the destination address and forward the file to the correct destination, i.e. the network printer.

PAN vs LAN vs WAN (cont.) - WAN

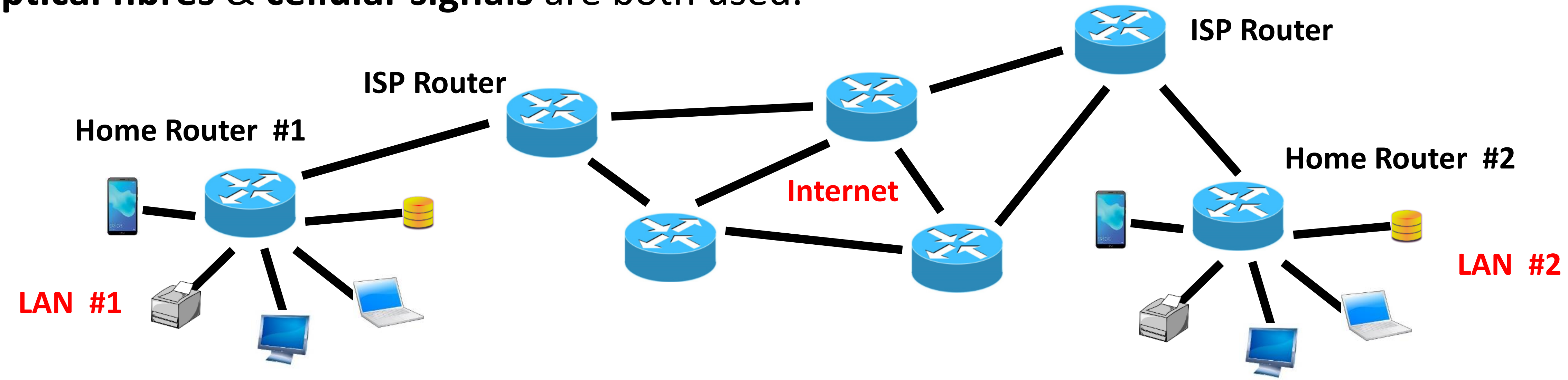
Cellular

Copper cables



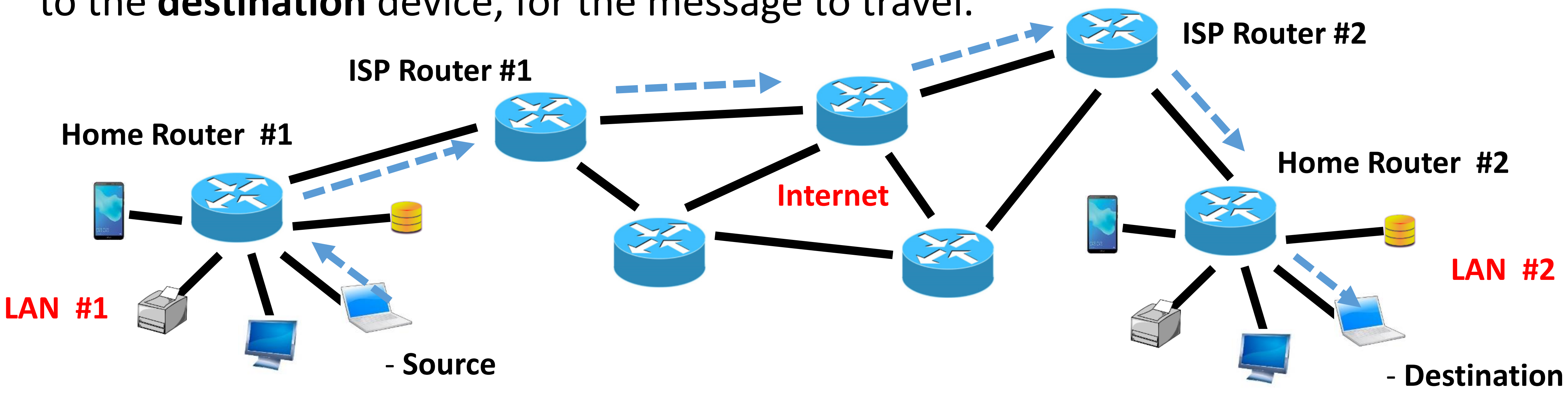
Optical fibre

- For communication across a **large geographical area** (e.g. a city, a state, a nation or the entire world), a **WAN** (Wide Area Network) is needed.
- Communication across WAN can be between branches of an organisation (“**intranet**”), but frequently it is between two different organisations (“**internet**”).
- **Data rate** is often lower than that in LAN, as the distance travelled is longer.
- **Optical fibres** & **cellular signals** are both used.



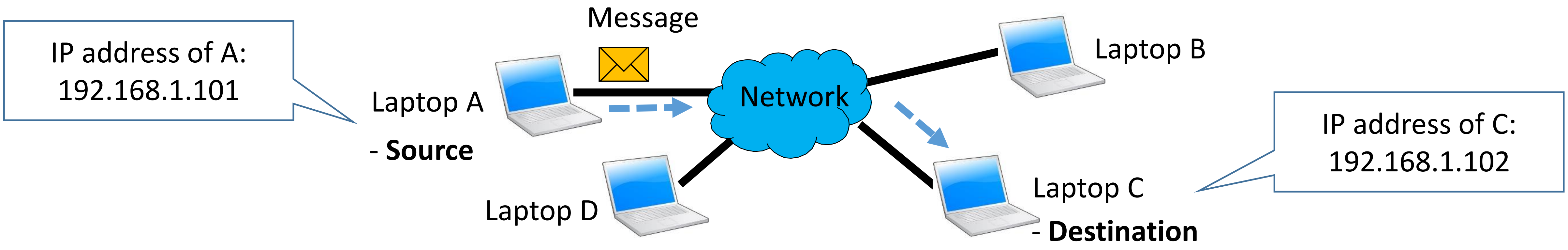
PAN vs LAN vs WAN (cont.) - router

- **Routers** are used to direct / manage “messages” across the WAN.
- The service of an **ISP** (Internet Service Provider, such as Singnet, who has the **infrastructure** needed) must be engaged to access the internet.
- The interconnected routers work together, to find a **path or route** from the **source** device to the **destination** device, for the message to travel.



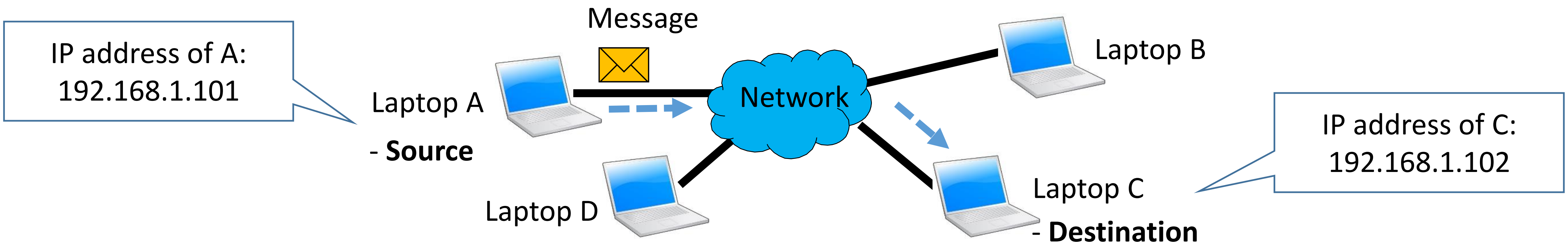
IP address

- Every device in a network must have a **unique** address, called **IP address**.
- Why so?
- Imagine the postal service, the postman will not be able to deliver a letter to your home, if it does not have a unique address.
- In the figure below, Laptop A will be able to send a message to Laptop C via the network, knowing Laptop C's IP address.



IP address (cont.) - format

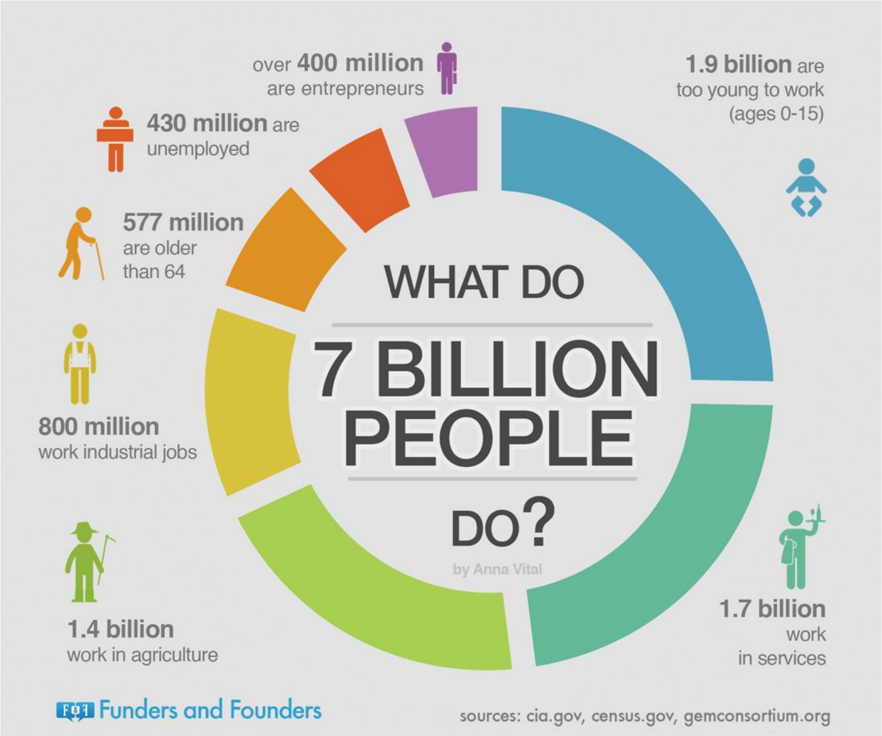
- An example of an IP address (v4 or version 4) is **192.168.1.102** or in general **X.X.X.X**
- Each X is a decimal number **from 0 to 255** (i.e. an 8-bit number, or a byte).
- This is called **dotted decimal notation**.
- You can see that an IP address is **32-bit**, and the number of possible addresses is 2^{32} or **4.29 billions**.
- This may sound like a lot, but some **can't be used** (for some reason) and most have been **used up**.



IP address (cont.) – IPv4 depletion

- Because IPv4 addresses are running out, a new version (**IPv6**, which uses **128 bits**) has been introduced. But we will not go into that.
- There are other methods of tackling the shortage of IPv4 addresses – we will talk about them shortly - such as
  - **DHCP** (Dynamic Host Configuration Protocol)
  - **NAT** (Network Address Translation)

2^{32} or **4.29 billions** IPv4 addresses vs.



IP address (cont.) – network vs host

Note that the mask always consists of a series of 1's on the left, followed by a series of 0's on the right.

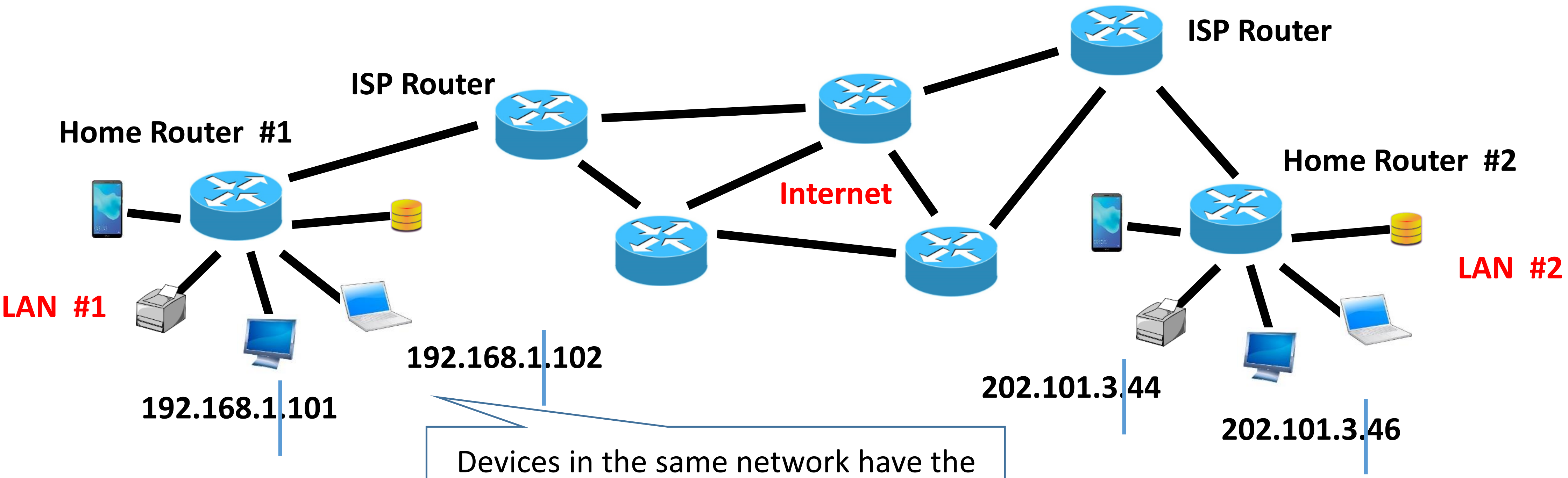
- IP addresses of devices in a network are specified with a "**mask**", such as 255.0.0.0 or 255.255.0.0 or **255.255.255.0**. This mask is also **32 bits**.
- The mask **partitions** the IP address into **2 portions: network + host**
- For instance, if 255.255.255.0 ($11111111_2.11111111_2.11111111_2.00000000_2$ is the mask, the partitioning is as follows:

	Network portion	Host portion
IP address:	192 . 168 . 1	. 102
Mask:	255 . 255 . 255	. 0
In binary:	111……………11	00..0

Why is there a need to have 2 portions?

IP address (cont.) – network vs host

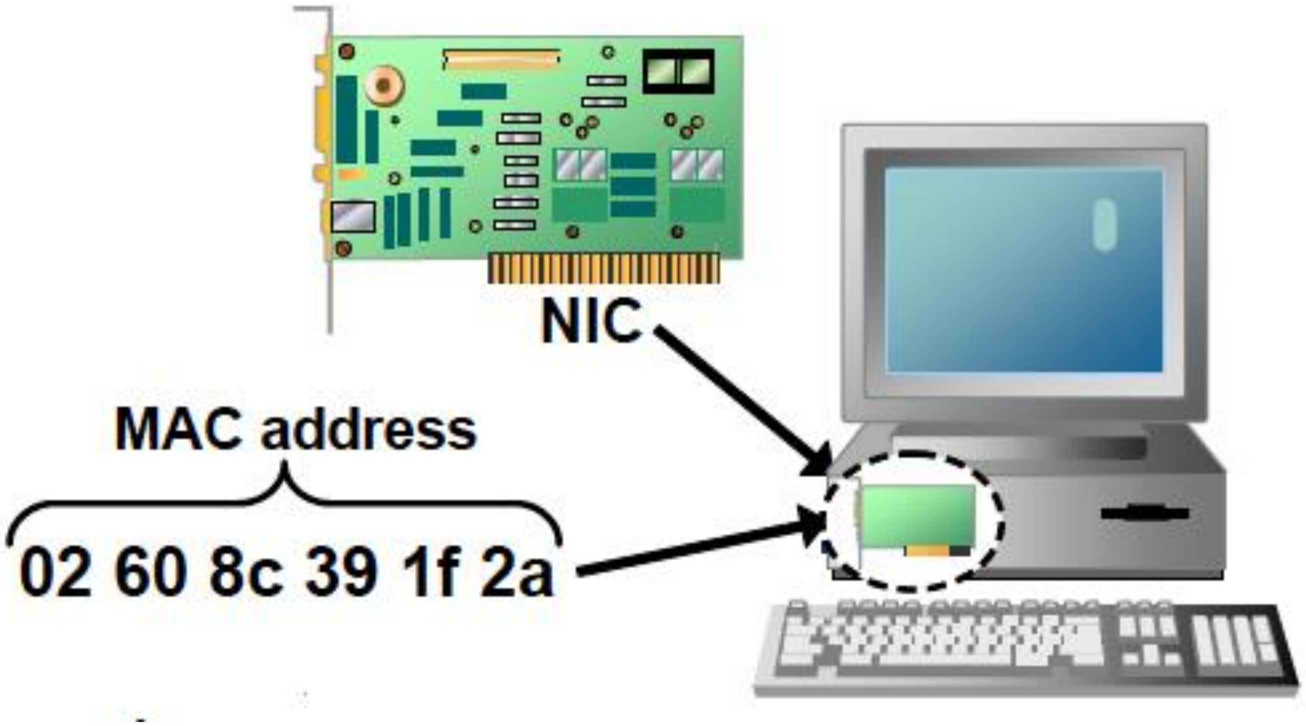
- The **network portion** specifies which network the device belongs to – think of this as the "**block number**" of a HDB flat e.g. Block 123, Clementi Ave 4.
- The **host portion** specifies which particular host within the network – think of this as the "**unit number**" of a HDB flat e.g. #05-67.



Devices in the same network have the same "network portion" in their IP addresses, but different host portions.

IP address (cont.) – IP vs MAC addresses

- Beside IP address (which can be **assigned logically** when setting up the network), networked devices also have unique MAC addresses.
- Each **MAC address** is **48 bits** (12 hexadecimal digits). These are “burnt into” the network cards during manufacturing, and **cannot be changed**.

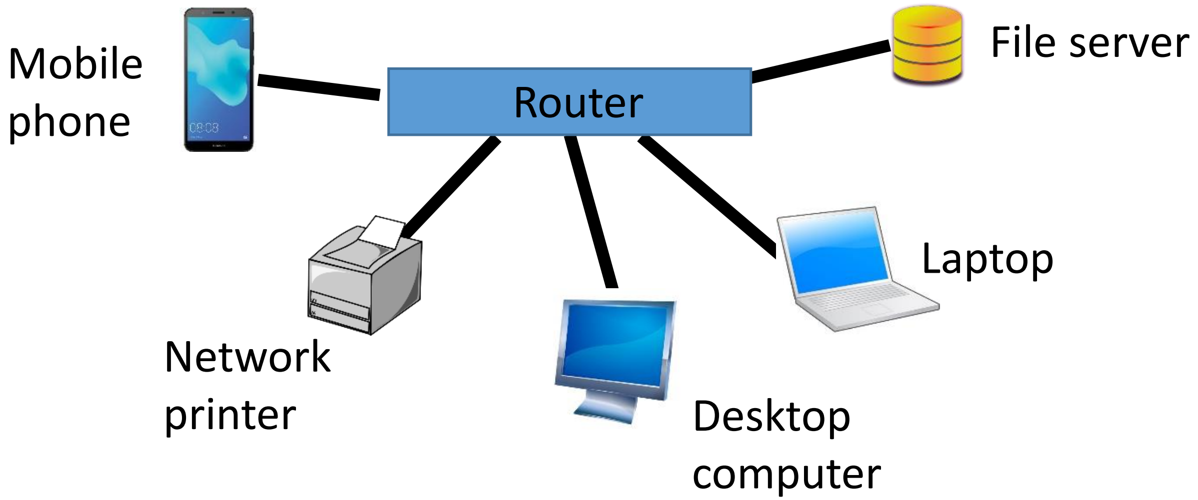


IP address (cont.) – IP vs MAC addresses

- The reason why IP addresses are used is because they can be **assigned logically**.
- For instance, one computer has 192.168.1.102, and another computer in the same network has 192.168.1.103.
- So one glance, you know that both computers belong together. On the other hand, MAC addresses look like some **random** numbers.
- The routers & switches maintain **tables** for associating IP addresses with MAC addresses.
- For instance, the device with the MAC address 02-60-8c-39-1f-2a has been assigned the IP address 192.168.1.102.
- There are protocols (**ARP, RARP**) for the table look up. We will not discuss these.

DHCP (Dynamic Host Configuration Protocol)

- In many organisations, such as companies or schools, **many devices** need network access.
- However, a company using the IP addresses 192.168.1.X (where X is any number from 1 to 254) and the mask 255.255.255.0 only have 254 different addresses to assign.
- It does not make sense to assign a fixed IP address to each device, as they may **not** be **enough** to go around.



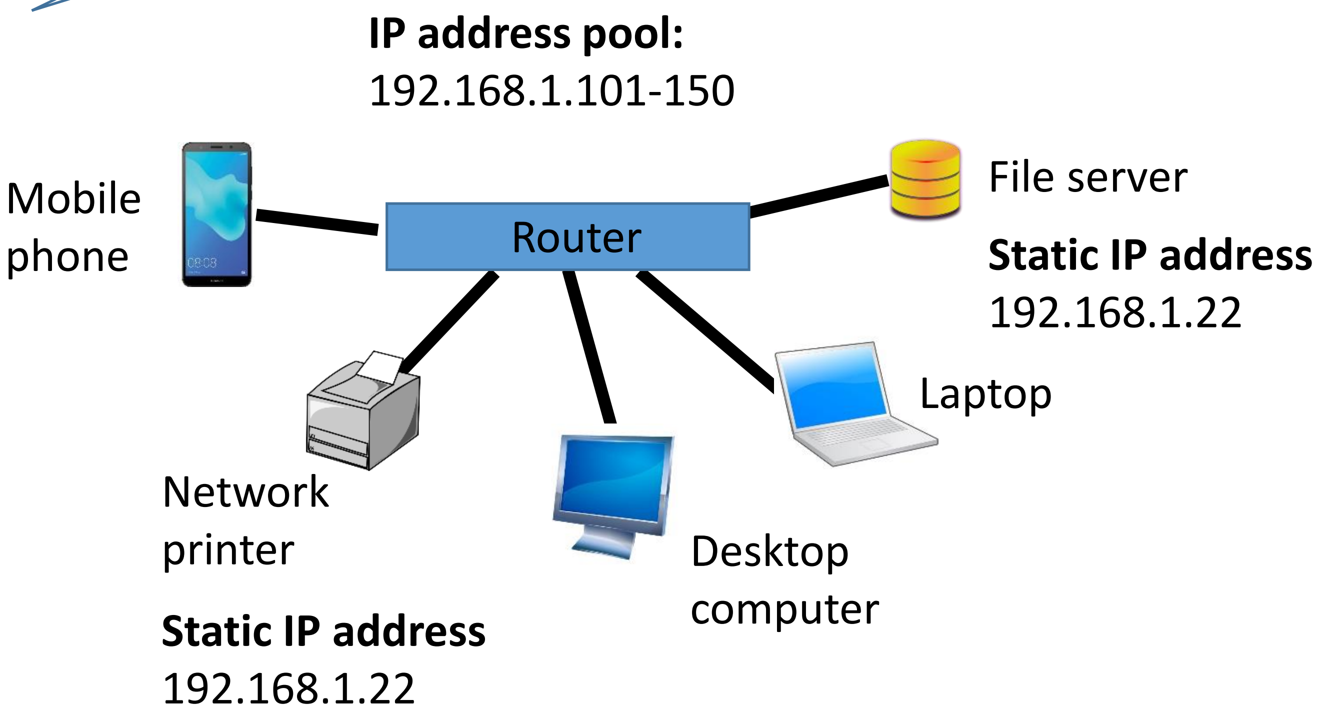
Your lecturer may be able to explain to you why 1 to 254 i.e. why 192.168.1.0 and 192.168.1.255 are not used.

DHCP (Dynamic Host Configuration Protocol) (cont.)

- A better way would be for the **router** to maintain a **pool** of usable IP addresses e.g. 192.168.1.101 to 150, and assign an address **dynamically** to a **host** / device (such as a **laptop** or a **mobile phone**) that has just joined the network.
- "Important" devices such as **network printer** and **file server** can be assigned fixed (or **static**) IP addresses, so that other devices can easily access them.

This is called DHCP.

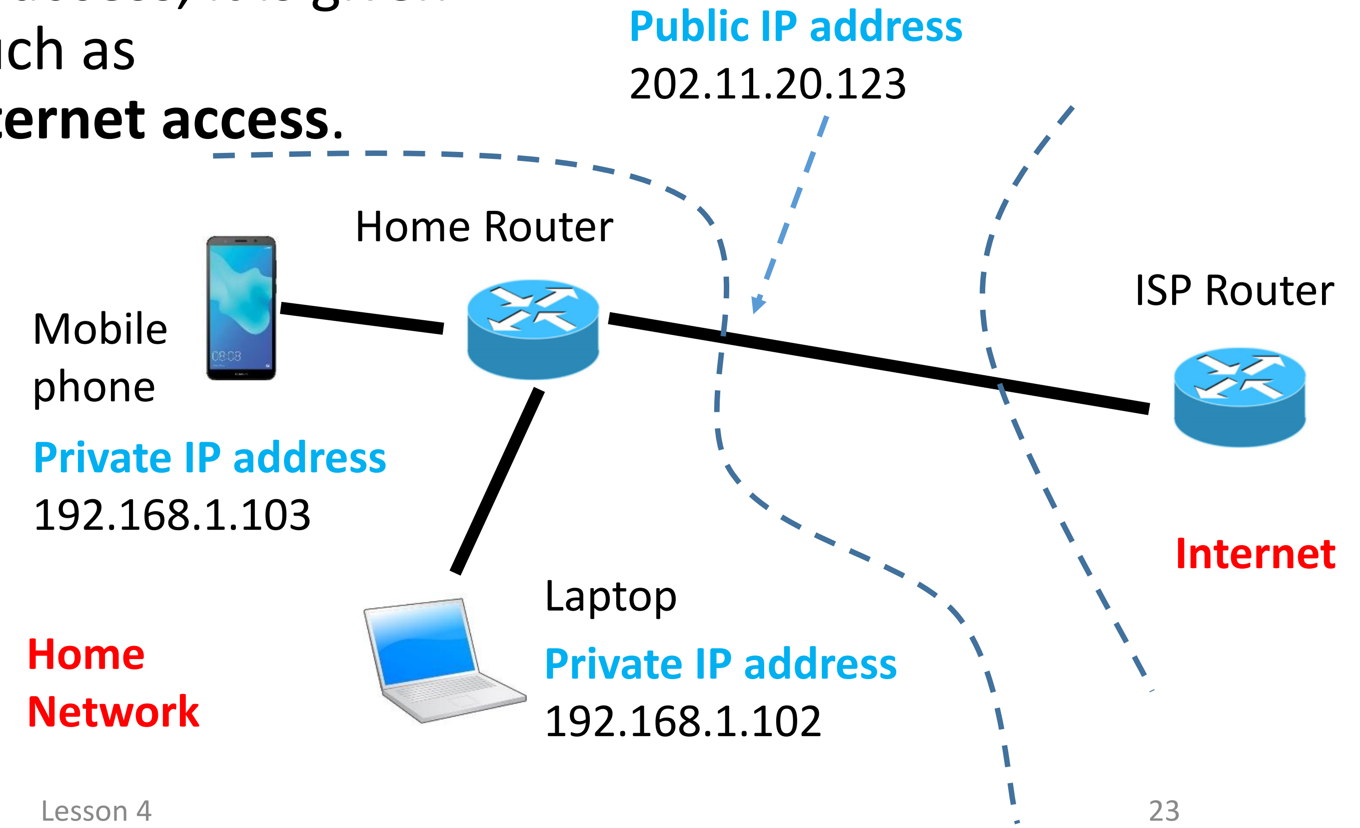
“Time-sharing” (IP addresses from the pool) helps to alleviate the IP address depletion problem.



NAT (Network Address Translation)

There are other ranges of private IP addresses, but we will not discuss them.

- The IP addresses such as 192.168.X.X are known as **private IP addresses**. They can be used within a **LAN**, but cannot be used for internet access.
- When a home (or an organisation) pays the **ISP** (Internet Service Provider) for internet access, it is given one (or more) **public IP address**(es), such as 202.11.30.123. This can be used for **internet access**.
- So how can devices in the LAN, such as a laptop & a mobile phone, with private IP addresses 192.168.1.102 & 192.168.1.103 access internet?

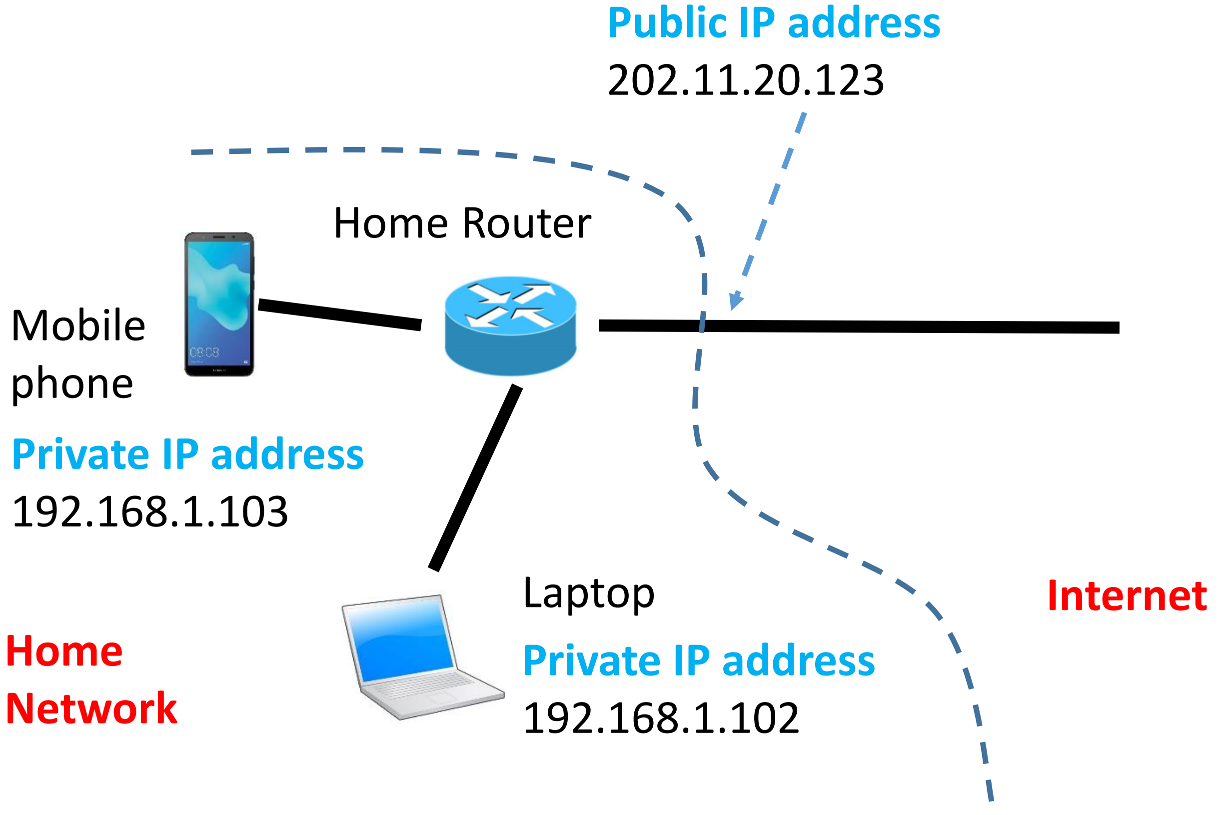


NAT (Network Address Translation) (cont.)

- The answer is **Network Address Translation**.
- Let's assume there is only one public address for the home devices to share.
- Each **application** (such as email application, or browser, or skype) in a device has an associated "**port numbers**" – this is a **16-bit** number (0 to 65535).
- When the "message" from a home device's application goes out to the internet, the device's "private IP address : private port number" pair is **translated** by the router to a "public IP address : public port number" pair.

The router will choose a unique public port no. for each device-application pair.

Private IP Add. : Private Port No.	Public IP Add. : Public Port No.
192.168.1.103 : 77	202.11.20.123 : 1024
192.168.1.102 : 65	202.11.20.123 : 1025



NAT (Network Address Translation) (cont.)

The address fields in the header of the data packets sent will be affected by NAT this way.

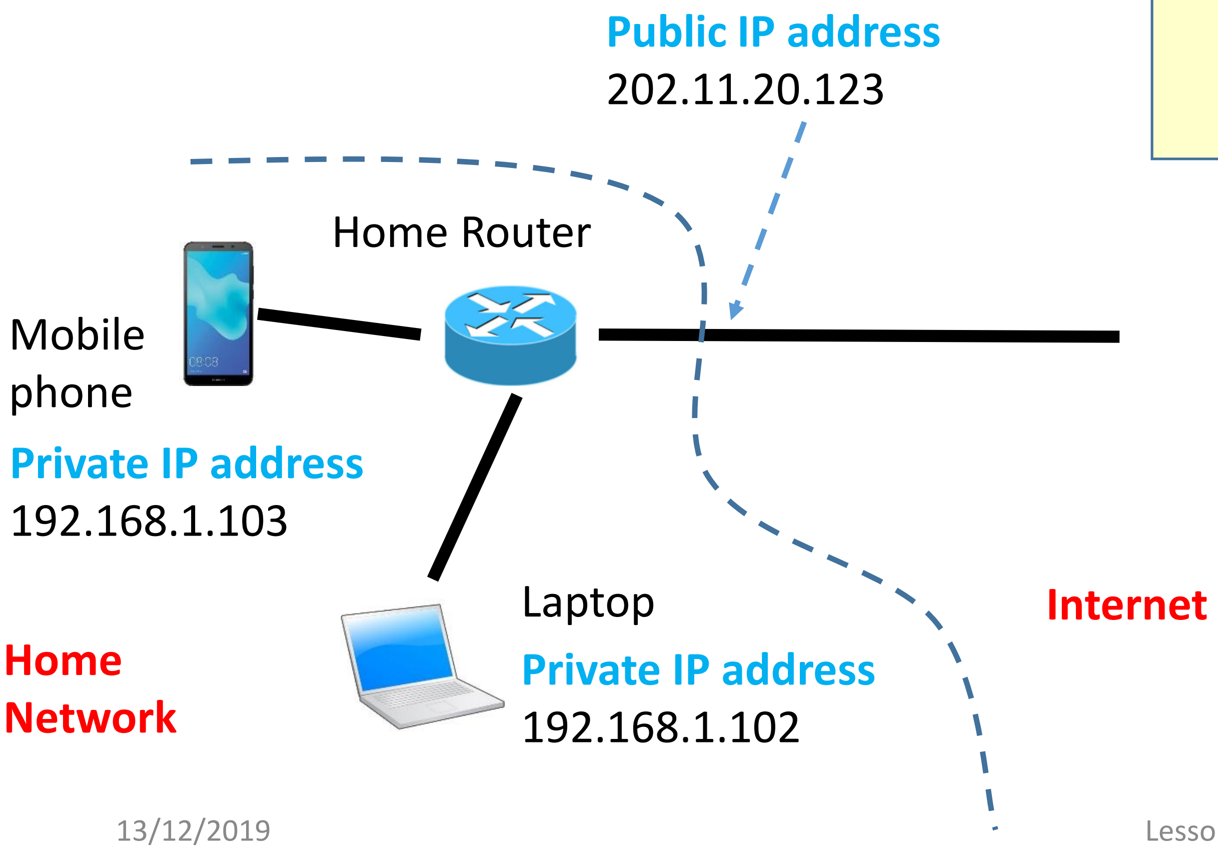
Private IP Add. : Private Port No.	Public IP Add. : Public Port No.
192.168.1.103 : 77	202.11.20.123 : 1024
192.168.1.102 : 65	202.11.20.123 : 1025

Before Translation	After Translation
Source IP Add. : Port No.	**Source IP Add. : Port No.**
192.168.1.103 : 77	202.11.20.123 : 1024

Outgoing traffic to a server in the internet…

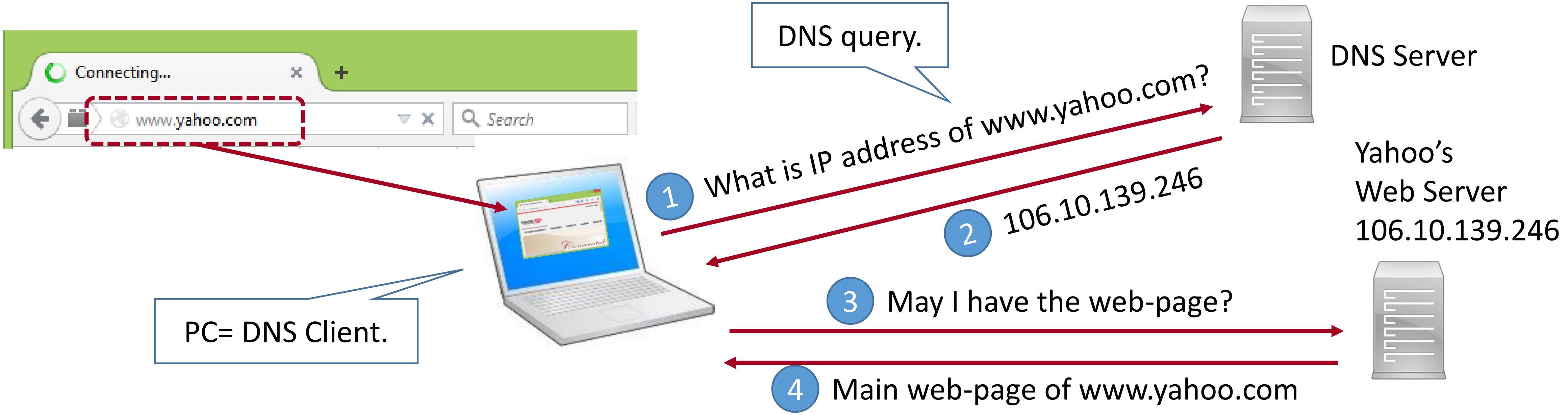
After Translation	Before Translation
Dest. IP Add. : Port No.	**Dest. IP Add. : Port No.**
192.168.1.103 : 77	202.11.20.123 : 1024

Incoming traffic from a server in the internet…

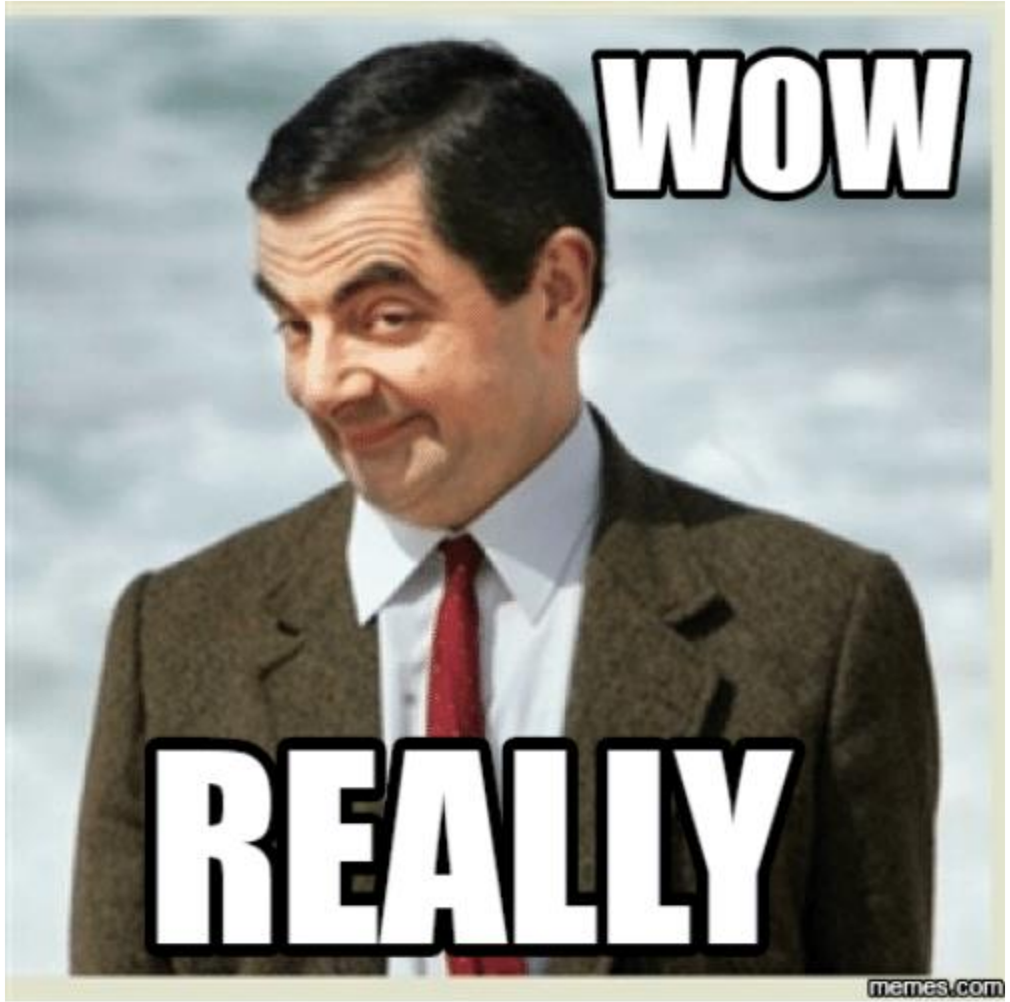


DNS (Domain Name System)

- When you visit a **website**, such as yahoo.com, you don't enter the IP address (106.10.139.246) of the Yahoo's Web Server into the browser.
- Instead, you type yahoo.com and press enter. What happens after that is shown below.
- Note how the **DNS Server** helps to translate **domain name**, such as yahoo.com into the corresponding **IP address**, such as 106.10.139.246



Note: There is no "Lab Exercises" for this lesson.




Thank you