fH2 Computing Summarised Notes (Part 5)

Networking (in a Nutshell)

# Networking Fundamentals

## Part 1: Networks and Nodes

### 1.1 Network

A **network** is a group of devices that are **connected** together and can **communicate** and **share files and peripheral devices** (like printers) between each other.

### 1.2 Node

A **node** is a device or computer that is able to **connect to a network** and **generate, process and transfer data**.

Each node has **addressing information** (MAC address) in order to allow other devices to communicate with it.

#### 1.2.1 Endpoint

An **endpoint** is a node that acts as a **source** or **destination** for data transfer.

#### 1.2.2 Redistribution Point

A **redistribution** point is a node that **transfers data** between other nodes.

(examples: network switches, router)

## Part 2: Local Area Network (LAN)

### 2.1 What is a LAN?

A LAN is a computer network that covers a **small geographical area**.

(examples: home, office, school, a group of buildings)

### 2.2 Characteristics of LAN

A LAN is usually…

* Based in **one** or **more than one** building
* The organisation operating the LAN controls its **speed**
* The organisation operating the LAN is responsible for its **management** and **maintenance**
* There is a **choice of technology**.
* There is **no outside involvement** from telecommunications providers, unlike many WANs.

### 2.3 Network Configurations

A **network configuration** is a design specification for how the nodes of a network are **constructed** to **interact** and **communicate**, by determining the degree by which **communications and processing** are **centralised** and **distributed**.

#### 2.3.1 Centralised Network

A **centralised network** consists of a **central mainframe computer**, which **handles all** the communications and data processing in behalf of clients.

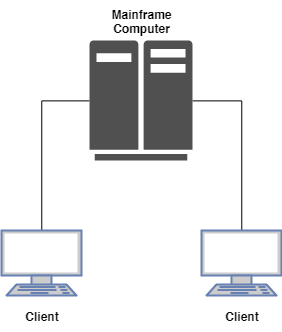
These ‘clients’ connect to the mainframe computer via **dedicated terminals/terminal emulators**.

##### Advantages

* These central mainframe computers are **high performance**.
* It allows for management in the LAN to be **centralised**.

##### Disadvantage

* It is generally **very expensive to implement**, not optimal for smaller businesses.

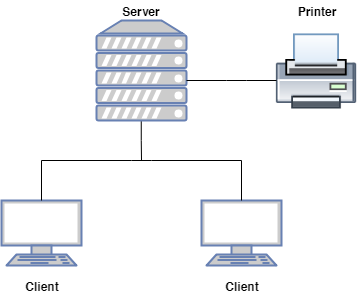


#### 2.3.2 Client/Server Network

A client/server network is one in which **servers provide resources** to **clients**.

Usually, there is at least one server that provides **central authentication services**. Servers also provide access to **shared files, printers, hardware storage** and **applications**.

In client/server networks, processing power, management services, and administrative functions can be concentrated, while clients can still perform many basic end-user tasks on their own.



#### 2.3.3 Peer-to-Peer Networks

A **peer-to-peer network** is a network in which resource sharing, processing, and communications control are **completely decentralised**. There are (at least) **two communication parties** with **equivalent roles and responsibilities** in apeer-to-peer network.

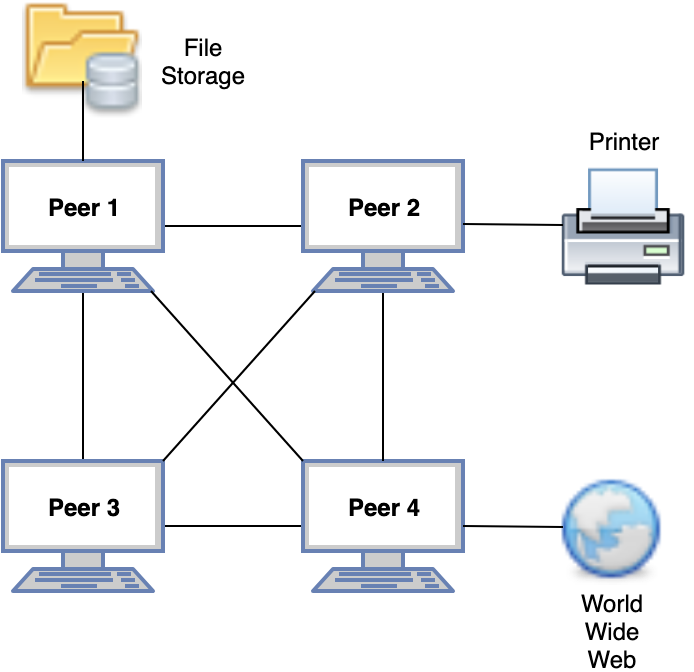
**Services and resources are distributed** on each computer for other computers to access. All clients on the network are equal in terms of providing and using resources, and each individual device authenticates its users.

##### Advantages

* **Easy** and **inexpensive** to implement

##### Disadvantages

* + Data storage and authentication is **not centralised**, hence it is **only practical in very small organisations.**
  + User accounts must be duplicated on every device from which a user accesses resources. This distribution of user information makes **maintaining a peer-to-peer network difficult**, especially **as the network grows**.



### 2.4 Network Topologies?

**These are not required in the A level syllabus.  
Network topologies** are the physical shape of the network. There are three types: **bus**, **star**, and **ring topologies**.

### 2.5 Types of Connections

#### Simplex Connections

A **simplex connection** is a connection that allows **communication in only one direction**, from the transmitter to the receiver.

#### Half-duplex Connections (HDX)

A **half-duplex connection** allows **communication to take place in both directions**, but only at **one direction at a time** (not simultaneously).

##### How half-duplex connections work

Typically, once a party begins receiving a signal, it must wait for the transmitter to stop transmitting before replying. Antennas are of trans-receiver type in these devices (transmitter and receiver) so as to transmit and receive the signal.

#### Full-duplex Connections (FDX)

A **full-duplex connection** allows **communication to take place in both directions simultaneously**.

##### How full-duplex connections work

These connections work by making simultaneous use of **two physical pairs of twisted cable**, where one pair is used for receiving packets (of data) and one pair is used for sending packets, to a directly connected device.

This effectively makes the cable a **collision-free** environment and **doubles the maximum data capacity** for a connection, as compared to a half-duplex connection.

#### Benefits of using full-duplex over half-duplex

##### Time is not wasted

**No frames need to be re-transmitted** using a full-duplex connection as compared to a half-duplex connection, as there are **no collisions**.

(In a half-duplex connection, if two or more stations/nodes transmit at the same time, signals will collide and become garbled.)

##### Full data capacity available in both directions

The **send and receive functions** in a full-duplex connection are **separated**, unlike a half-duplex connections where the same antennae send and receive data.

##### Nodes do not have to wait until others complete their transmission

This is because there is **only one transmitter** for each twisted pair in cables used in a full-duplex connection.

### 2.6 Interconnection of LANs

LANs need to be interconnected for various reasons:

* **Structure an organisation’s network**:

Organisations are generally structured into divisions.  
Each one is likely to have its own LAN.  
To **enable communication** among the divisions, LANs need to be interconnected.

* **Extend maximum distance between stations/nodes**:

A division may be spread over several floors in a building.

Each floor is likely to have its own LAN.

Hence, there is a need to **interconnect these LANs.**

#### 2.6.1 Ways to interconnect LANs

**Ethernet LANs:** Ethernet Hub  
Ethernet Switch  
Bridge

**Different types of LANs:** Bridge

#### 2.6.2 Interconnection using Hub

It is a networking device used to **connect the nodes** in a network to **share files, data, and resources**.

A hub is a ‘non-intelligent’ device and does not manage any data flowing through it, hence it **broadcasts data** that it receives to all nodes in the network – even if the nodes do not request for it.

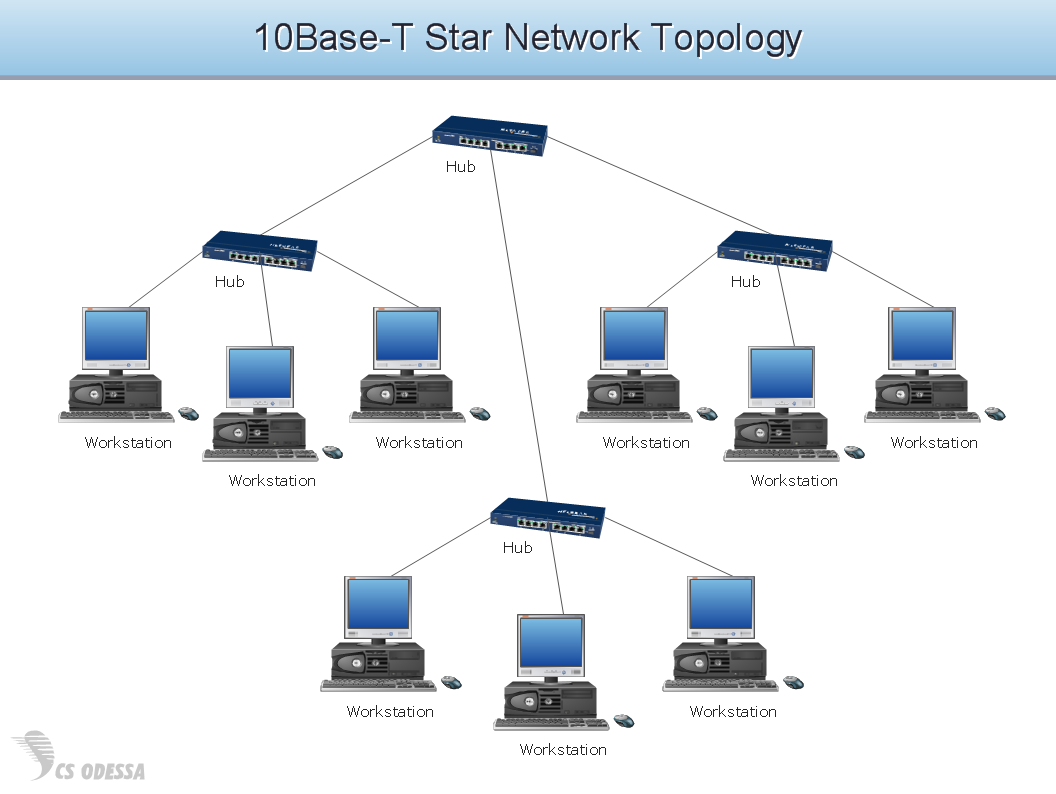
A hub can be connected in a **multi-tier design** with a backbone hub at its top, hence allowing interconnection of entire LANs.

##### Advantage:

* If one hub is down, the remaining network **continues to operate**.

##### Disadvantages:

* **Only one station/node can transmit at a time** in the entire network, otherwise, there would be collisions. (i.e. lack of traffic isolation in the network)
* **Not too many stations** can be connected in the network.



#### 2.6.3 Interconnection using Switch

A switch is a network device that acts as a **common connecting point** for various nodes or segments. It breaks the network into **LAN segments**.

However, switches are more ‘intelligent’ devices as it transmits data around the network more efficiently. This is because it **manages network data** by examining the Media Access Control (MAC) address of the destination node found in the data and **forwards messages** only to the receiving device.

Switches **filter frames**, **isolating traffic** in the network. The frames on the same LAN segment are not usually forwarded onto other segments.

Like hubs, switches can be connected in a **multi-tier design** with a backbone switch as its top. This leads to further performance improvement.

##### 2.6.4 Ethernet Switch

It contains two layers, the **physical** and **MAC layer**.  
It is capable of **buffering frames**.  
It examines **frame headers** and **selectively forwards** the **frame** based on the MAC destination address.  
Other links can be used to switch other frames simultaneously.  
Stations are unaware of the presence of the switch.

#### 2.6.5 Interconnection using Bridge

A bridge has the **same basic functionality** of a **switch**, but it **has fewer ports** and is **software-based**.  
It **passes messages** between two segments of a (bus) LAN.

It can be used to segment a bus networks into two segments.

Bridge also has two layers, just like the switch.

Bridges can **interconnect different LANs together** such that they **act as one single LAN** and allows two LANs to communicate with each other. This is done by converting the frame header according to the LAN on which a frame is being forwarded.

### 2.7 Network Architecture

#### 2.7.1 Client/Server Architecture

##### Roles

**Client/Server**: The client and server are **two communications parties** with **different roles and responsibilities**. Services and resources are placed on the server for the client to access.

**Server**: It **hosts resources** (e.g. files) or **offers services** (e.g. Internet banking).

It is **always on** to wait for connections to come in. However, servers may be turned off during periods of maintenance/fault.

It is usually given **permanent addresses** so that it can be accessed easily.

**Client**: It **communicates with servers** to access services and/or resources.

A client usually **does not communicate with other clients directly**. However, this is possible via a server.

##### What is a client/server architecture?

There is at least **one serving computer (the server)** which provides all the **client** machines with all the facilities they need, which is usually file and printer sharing.

##### Disadvantages

* **Cost**

With client/server computing, there is a need to purchase a **central serving machine** that should be **fast** and have **huge storage capacity**.

* **Reliance on one central system** for provision of services

If this central system (the server) fails, **access** to all information and to the services on this machine **would likely be lost**.

#### 2.7.2 Peer-to-Peer Architecture

In a **peer-to-peer architecture**:

* All nodes are **peer-to-peer**
* **No server** required
* A P2P node **may offer contents to others**. It makes this information available in the network.
* Other P2P nodes may access these contents **via direct communication**.

### 2.8 Intranet

An **intranet** is a **private network** that uses **Internet protocols and services** to share an organisation’s information with its members/staff.

Just like the Internet, these members/staff can access an intranet via a **regular web browser** and **navigate an organisation’s web pages**. An intranet usually contains information that is segregated from the Internet due to **privacy** and **confidentiality** reasons.

Therefore, an **intranet** provides all the features of the World Wide Web, but **access is usually given to a closed group only, normally controlled by a password**.

#### 2.8.1 Benefits of an Intranet

##### Over the Internet

* Access is **controlled**
* **More secure** than the Internet due to only authorised people having access
* **Faster** than the Internet as it usually covers a small area.
* **Less likely to crash** the websites due to less hits

##### Tangible Benefits

* **Inexpensive** to implement
* **Easy to use**, just point and click
* **Saves time and money**
* **Better information**, **faster** too
* Based on **open Internet standards**
* **Scalable** and **flexible**
* **Puts users in control** of their data

##### Intangible Benefits

* Improved **decision making**
* Improved **quality of life**
* Improved **productivity**
* Builds a **culture of sharing and collaboration**
* Facilitates **organisational learning**

### 2.9 Enterprise Networks

It is a network that **includes elements of both LANs and** **WANs**. It is owned and operated by a single organisation to **interlink its devices and resources** so that **users have access whether they are on or off premise** (i.e. allows for remote access).

They are designed for **fast data access**, **email exchange**, and **collaboration**. They are scalable and include **high-end equipment**, **strong security systems**, and **mission-critical applications**.

## Part 3: Wide Area Network (WAN)

### 3.1 What is a WAN?

Definition: a network that covers a **large area**, often across **multiple geographical locations** (e.g. all of an organisation’s offices in a country/among different countries).

## Part 4: Data Transmission

### 4.1 What is Data Transmission?

*Definition:* the **physical transfer of data** (a digital bit stream) **over a point-to-point or point-to-multipoint communication channel**.

### 4.2 Physical Media

**Guided media:** signals propagate in **solid media** (e.g. copper, fiber, coaxial)

**Unguided media:** signals propagate **freely** (e.g. radio)

### 4.3 Digital Signals

Digital signals can have combinations of only two values: **zero** and **one**. These signals can be translated into a **digital waveform**. A waveform can switch between two voltage levels: **0 for zero/ground voltage level** and **1 at a +ve/-ve voltage level**.

### 4.4 Digital Data Transmission

*Definition*: a form of data transmission that makes use of **voltage differences** to represent the ‘1’s and ‘0’s in data.

### 4.5 Unicast & Broadcast Transmission

#### Unicast Transmission

*Definition:* a method of data transfer from **a source address to a destination address**.

In unicast transmission, network nodes not involved in the data transfer ignore the transmission.

#### Broadcast Transmission

*Definition:* a method of data transfer from **a source node to all other nodes in a network**.

### 4.6 Rate & Speed of Data Transmission

#### Rate of Data Transmission

- Megabits per second (Mb/s – 1 million bits/s)  
 - Megabytes per second (MB/s – 1 million bytes/s)

#### Speed of Data Transmission

There are two types of measurements for data measurement speeds: **bit rate** and **baud rate**.

**Bit rate:**  Number of bits that are transmitted per unit of time

**Baud rate:** Number of symbols that are transmitted per unit of time

### 4.7 Transmission Modes

A given transmission on a communications channel between two machines can occur in several different ways. The transmission is characterised by:

* the direction of the exchanges
* the transmission mode: the number of bits sent simultaneously
* synchronisation between the transmitter and the receiver

#### 4.7.1 Simplex, half-duplex, full-duplex connections

##### Simplex Connection

*Definition:* A connection in which data flows in only **one direction**, **from the transmitter to the receiver**.

*Bandwidth:* **Full bandwidth**, as the transmission operates in one direction

*Examples:* Radio, television broadcasts

##### Half-duplex Connection

*Definition:* A connection in which data flows in **one direction** and the **other**, but **not both at the same time**.

*Bandwidth:* **Full bandwidth**, as the transmission operates in one direction at a time

##### Full-duplex Connection

*Definition:* A connection in which data flows in **both directions at the same time**.

*Bandwidth:* **Half bandwidth**, as the transmission can operate in both directions simultaneously.

#### 4.7.2 Serial and Parallel Transmission

The transmission mode refers to the number of elementary units of information (bits) that can be simultaneously translated by the communications channel.

##### Serial Transmission

*Definition:* A form of data transmission where **data are sent one bit at a time over the transmission channel**, as **one per clock cycle**.

*Used in:* Ethernet, keyboards, mice, etc.

However, as most processors process data in parallel, the transmitter has to transform parallel data to serial data and vice versa for the receiver.

##### Parallel Transmission

*Definition:* A form of data transmission where **multiple bits are simultaneously transmitted over multiple transmission channels/lines**.

These bits are sent simultaneously over multiple different lines, which either consists of:

* Multiple physical lines (such as several wires in a ribbon cable), or
* One physical line split up into multiple sub-channels by dividing up the bandwidth. Each bit is sent along the sub-channel at a different frequency.

*Limitation*: For parallel transmission, since conductive wires are close to each other in the ribbon cable (*N* physical lines), **interference may occur** especially at high speeds that may **degrade the signal quality**.

#### 4.7.3 Synchronous and Asynchronous Transmission

Given the problems that arise with a parallel-type connection, serial connections are normally used. However, since a single wire transports the information, the problem is how to synchronise the transmitter and the receiver – the receiver may not necessarily distinguish the characters because the bits are sent one after the other. To address this problem, there are 2 types of transmission that can be used:

##### Asynchronous Transmission

The sender **inserts special start and stop patterns** between each byte of data. By watching for these bit patterns, it **allows the receiver to distinguish between bits** in the data stream.

* **Each individual character is complete in itself** – corruption of a character during asynchronous data transmission does not affect the preceding and succeeding character.
* **Suited for applications where characters are generated at irregular intervals** (e.g. data entry from the keyboard)
* Successful transmission **depends on recognition of start bits** – they can be easily missed
* A **high proportion of the transmitted bits are used for control** (start, stop bits) and carry no useful information (3/11 for ASCII code)
* These distortion effects **limit transmission speeds**.

As a result, this is normally only used for **speeds up to 3000 bits/second**, with only simple, single character error detection.

##### Synchronous Transmission

A byteis sent after a **standardised time interval**. The receiver **assumes that one byte is transmitted every interval**. Two devices must **start and stop their reckoning** of these intervals at **exactly the same time**.

Synchronous devices include a clock chip. A special bit pattern is inserted at specific intervals in the data stream, enabling the receiving device to synchronise its clock with the sender.

* The amount of central information that has to be transmitted is restricted to **only a few characters at the start of each block**.
* The system is **not that prone to distortion** as asynchronous communication and can thus be **used at high speeds.**
* If an error occurs during transmission, the **whole block of data is lost** instead of just a single character (can consist of >100 characters).
* The sender **cannot transmit characters simply as they occur** and consequently **has to store them** until it has built up a block – **unsuitable for applications where characters are generated at irregular intervals**.

As a result, this is normally used for **high-speed communication** between computers.

### Asynchronous Transmission vs Synchronous Transmission

* Serial transmission can be either asynchronous or synchronous.
* In synchronous transmission a receiver and transmitter is synchronised and a block of characters is transmitted along with the synchronisation transmission while asynchronous transmission is character-oriented meaning each character carries start and stop bits
* Synchronous transmission is used for high speed transmission while asynchronous transmission is used for low speed transmission.

### 4.8 Circuit Switching and Packet Switching

#### 4.8.1 Router

*Definition:* A router is a networking device that **connects multiple networks**. It **forwards packets** from one network to another. It allows a LAN and a WAN to be connected.

*Components:* **Routing table:** maps output ports for different network addresses.

**Routing protocol:** exchange routing information, construct routing table.

**Buffer at o/p port:** stores packets before they are transmitted out.

#### 4.8.2 Circuit Switching

*Definition:* Circuit switching provides a **dedicated communications channel** for **two nodes to communicate** with each other. This communications channel is set up **before the nodes communicate**. The circuit guarantees the **full bandwidth** of the channel until the communication session ends.

#### 4.8.3 Packet Switching

##### Process:

**At the sender**

1. The data to be sent is **split up into multiple packets** of a certain size.
2. A header containing the **destination MAC address**, the **length of the data**, and the **packet sequence number** (determines the order to reassemble the packet at the receiver) is added to each packet.
3. The packets get **routed independently to its destination**, following different paths along its way.

**At the router**

1. The packet is **received** and **temporarily stored** (buffered) in the router
2. The packet is then **passed on** to the next router. The next router the packet goes to depends on the destination MAC address.
3. Steps 4 and 5 are repeated until the packet reaches the destination node.

**At the destination**

1. Once all the packets arrive at the destination, the packets are reassembled into the original data in the correct order using the **packet sequence number**.