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EEE116 Multimedia Systems

Topic 3

Television / Communication / Computers
(Digital representation)

↓

Analogue-to-digital conversion
- Sampling
- Quantisation
- Data rate
- Digital Codes

Topic 2

↓

Data Communication

↓

Communication Networks

Topic 3

EEE116 Multimedia Systems

Topic 3

- Learning outcomes:
  - Basic components of a data communication system.
    - How to compute the channel capacity
    - Transmission mediums
  - Application requirements for networks
    - Latency
    - Connectivity
    - Reliability
  - Communication networks fundamentals.

Data Communications Systems

A functional block diagram

Source → **Transmitter** → **Transmission System** → **Receiver** → **Destination**

(Also called Channel or link)

Includes:
data capturing:
- sampling
- quantisation
- digital codes

Source coding: Compression to reduce data size (later in EEE116)

Channel coding: Error control coding to overcome loss of data due to channel errors and noise. (Level 3 & level 4)

Includes:

Channel decoding
Source decoding

Decoding of digital codes

Preparation for displaying (includes digital to analogue conversion (DAC)

Data Communications Systems

Source → **Transmitter** → **Transmission System** → **Receiver** → **Destination**

Transmitter:
Converts the data into a form that is suitable for transmission through the physical transmission system (channel, link).

The data is usually transmitted along a channel using a carrier signal, which is usually a Sinusoidal.

The embedding of data into the carrier signal is called modulation. E.g. Amplitude modulation (AM), Frequency Modulation (FM). (EEE206 module)

Carrier wave has much higher frequency than the maximum frequency of the data signal.

The maximum range of frequencies used by a modulated signal is called the bandwidth of the channel.

Data Communications Systems

Source → **Transmitter** → **Transmission System** → **Receiver** → **Destination**

Receiver:

Function of the Receiver is to recover the data contained in the received modulated signal.

This process is called demodulation.

Data Communications Systems

Source → **Transmitter** → **Transmission System** → **Receiver** → **Destination**

Transmission System (The Channel):

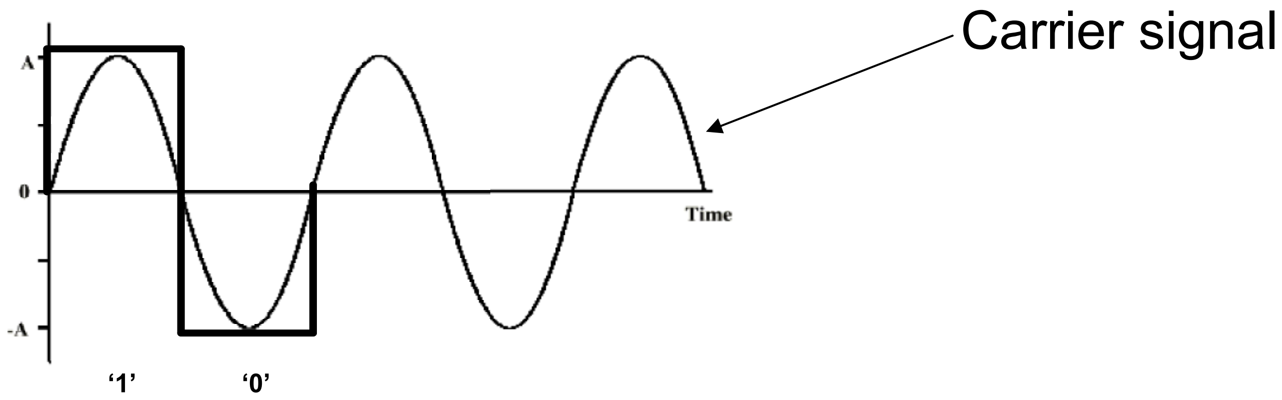
The communications channel is the physical medium that is used to send the modulated signal from the transmitter to the receiver.

Various transmission media include: wire lines, coaxial, fibre optics cables, wireless (free space).

During transmission, the transmitted signal is affected in a random manner by a variety of possible mechanisms. This leads to signal degradation.
e.g., thermal noise and fading (in EEE 206).

There are channel noise models for use in communication systems design. (EEE 206)

Channel Capacity



- Best we can do is two bits per cycle
- Better conservative estimate is one bit per cycle
- So a link (channel) with a bandwidth of 1 MHz is capable of transmitting 1 million bits per second

- We can say the channel capacity is proportional to the available bandwidth.

- What about the effect of noise in the channel?

Channel Capacity

Shannon-Hartley theorem gives the maximum amount of <u>error-free</u> data that can be transmitted over a communication link (channel) with a specified bandwidth in the presence of noise

$$\boxed{\text{Capacity, } C \leq W \log_2 (1 + S/N) \text{ in bits/second}}$$

Bandwidth (in Hz)

Signal Power to Noise Power Ratio

Power (Energy per second) of desired signal

Power (Energy per second) of undesired (random) signals

Usual to express power ratios in logarithmic form

1 Bel = log10 (*Power 1/Power 2*)
1 dB = 10 . log10 (*Power 1/Power 2*)

Class Activity - 1

Local analogue phone line - Bandwidth = 3.4 kHz *(sufficient for voice)*

Signal Power to Noise Power Ratio = 1,000

What is the Channel capacity?

Standard modem = ?

Transmission Medium

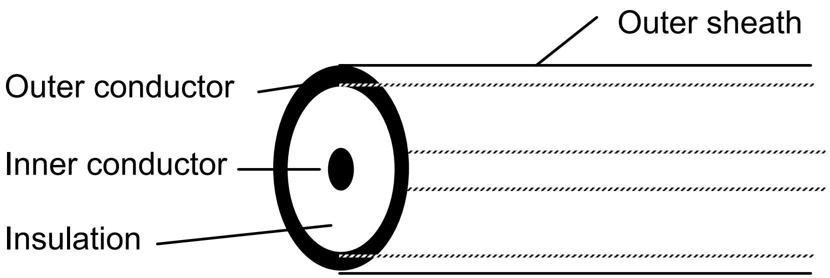
All communication is by electromagnetic waves

Guided media - waves are guided along a solid medium
For example, copper wire, optical fibre

Unguided media *- wireless transmission*

Twisted pair - separately insulated copper cables but twisted together

Low cost; easy to install; often fitted into building during construction



Coaxial cable

Very widespread usage (tv signal distribution)
Used in long-haul telephone circuits

Characteristics of Transmission Media

Bandwidth (channel capacity)	Gives maximum data rate (bits/sec - bps)
Attenuation	How signal reduces with distance Distance between repeaters (amplifiers)
Interference	Effects of other competing signals

An example:

	Maximum data rate	*Repeater spacing*
Twisted pair	10 - 100 Mbps 1 Gbps (short distances)	2 km
Coaxial cable	500 Mbps	10 km

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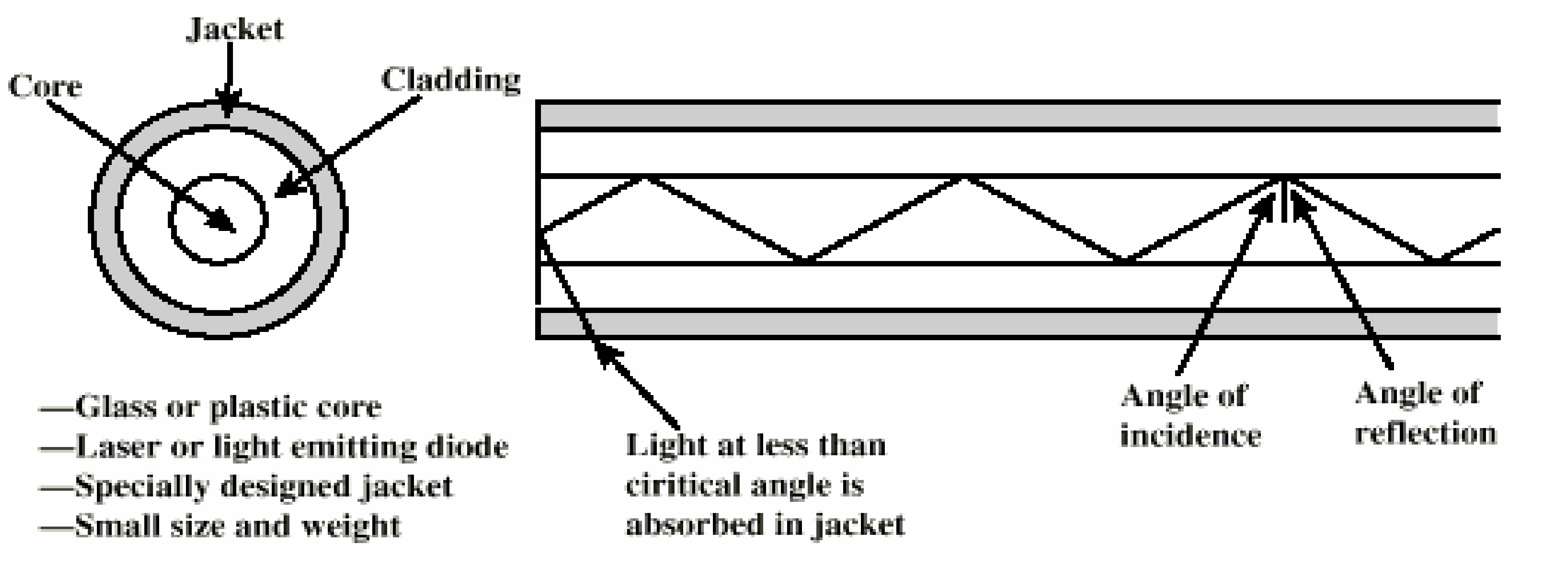
Optical Fibre



1000’s of Gbps (Tbps) over 100’s km

Wireless Links

Any disadvantages of wireless links?

Frequency band	Name	Maximum Digital rate	Applications
300 – 3000 kHz	MF	1000 bps	AM radio
3 – 30 MHz	HF	3000 bps	Shortwave radio
30 – 300 MHz	VHF	100 kbps	FM radio
300 – 3000 MHz	UHF	10 Mbps	UHF television, terrestrial microwave
3 – 30 GHz		100 Mbps	terrestrial microwave, satellite microwave

In general, lower frequencies are omnidirectional, higher frequencies are directional

How can you determine the effect of noise for each of the frequency bands?

Back to data communications

Your needs:

1. Typing - say 20 characters/sec with 8 bits/character = 160 bits/sec
2. Speech conversation - 64K bits/sec
3. Music - ~200K bits/sec
4. Video – 144x176 pixels 15 fps – 256K bits/sec
   - 576x704 pixels 30 fps – 1-5M bits/sec

What you get:

1. Standard modem - $\boxed{}$ bits/sec
2. ADSL modem - $\boxed{}$ bits/sec
3. Mobile phone - $\boxed{}$ bits/sec
4. Computer terminal - $\boxed{}$ bits/sec (peak)

Class Activity - 2

List your experience in data communications networks with regards to the applications listed in the previous slide?.	What are the chief desirable features of data communication networks?

Communication Networks

A computer network must provide:

General purpose, open,
Cost-effective,
Fair,
Robust
and High Performance Connectivity

Networks must adapt to changes in underlying technologies and demands

Priority of needs differs between users, programmers, managers, etc.

Connectivity - Latency - Reliability

Latency

First, consider an example of motorway travelling

- Latency is the time taken to transfer a message across a network – three components
- **Latency = Propagation time + Transmit Time + Queuing Delay**
- **Propagation time** = length of the link / Effective speed of light
- **Transmit time** = Data size / Channel capacity
- **Queuing delays** - network switches generally store (delay) packets prior to forwarding - function of network and its state of congestion

Latency

- (**Propagation time + Queuing Delay)** is called **network delay**

- It measures how long a single bit remains in transit in a network.

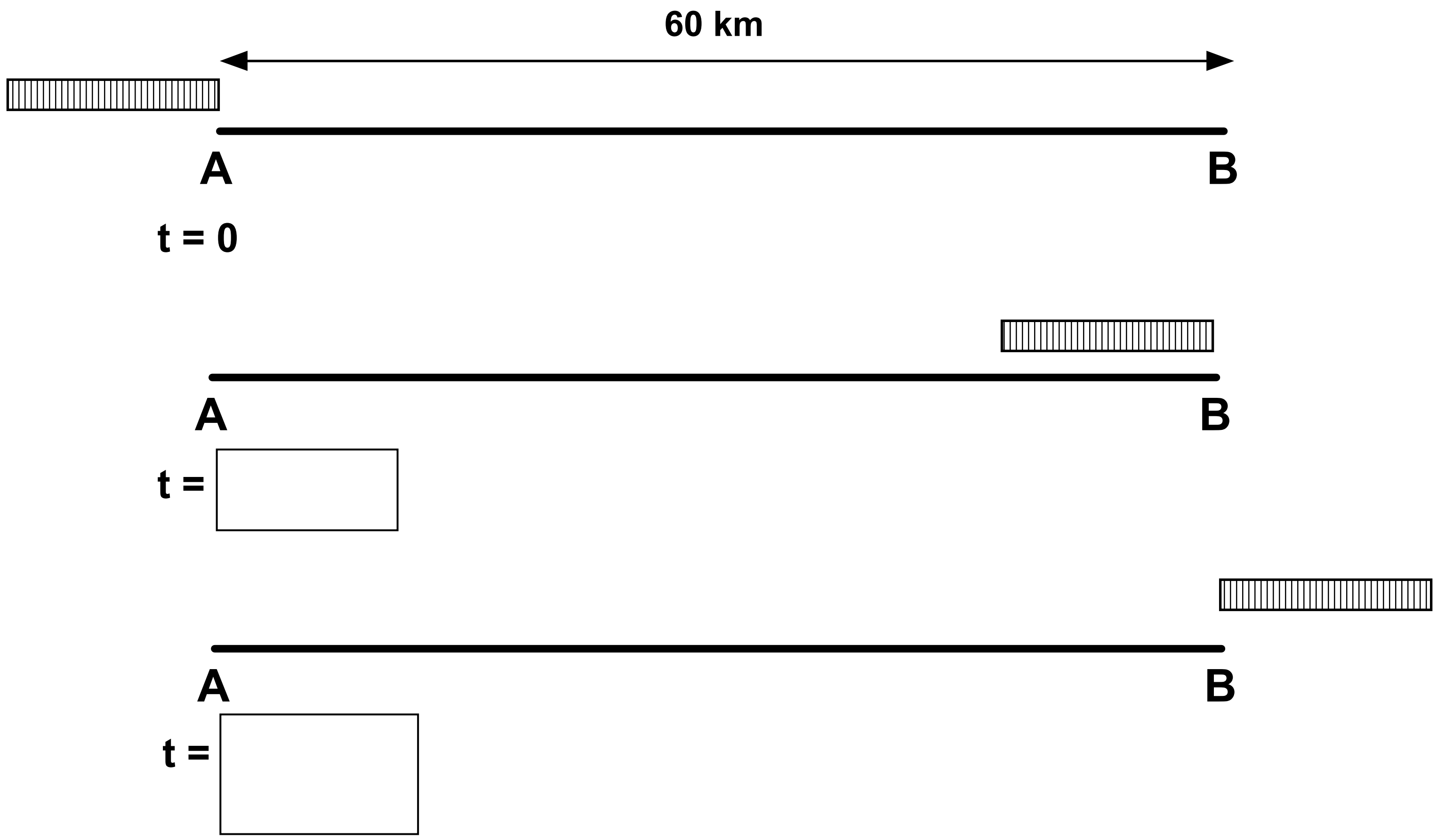
- **Transmit time** = Data size/Channel capacity
  represents the time required to upload/download data to/from the channel from/to transmitting device.

  The channel capacity is also called **throughput.** It specifies how many bits can enter the network per unit time.

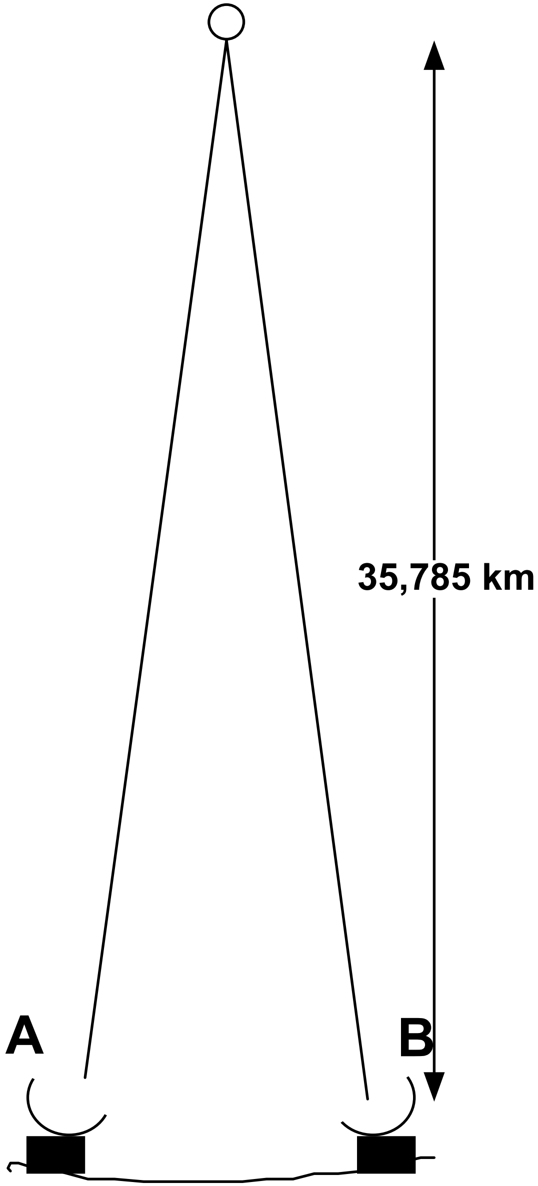
  The upper-limit of it can be computed using the Shannon-Hartley equation. (Slide 8)

Class Activity - 3

Example: Calculate time to send 1K byte message along a 60 km twisted-pair link running at 200 Kbps. Assume speed of "light" is 3×10^8 ms^{-1}



Class Activity - 4



Geosynchronous communications satellite

Assume 256 Kbps link to and from the satellite, and that the satellite takes 50 μs to receive and then retransmit a signal.

Calculate

(i) time to send one bit from A to B

(ii) the time to send a 1Mbyte message from A and B

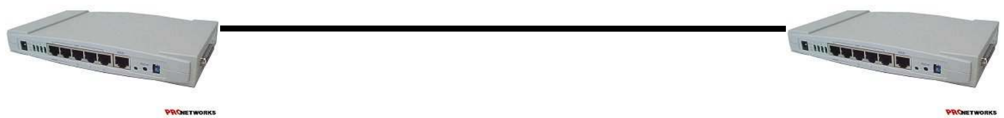
- Tutorial Problems:
  - Now you can attempt Q3 and Q4

Connectivity

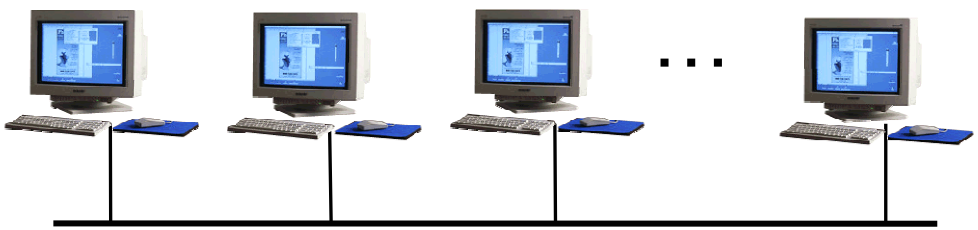
Two types of hardware in communication networks

- Nodes: PC, special-purpose hardware…
  - hosts
  - switches

- Links: co-axial cable, optical fiber, microwave,…
  - point-to-point



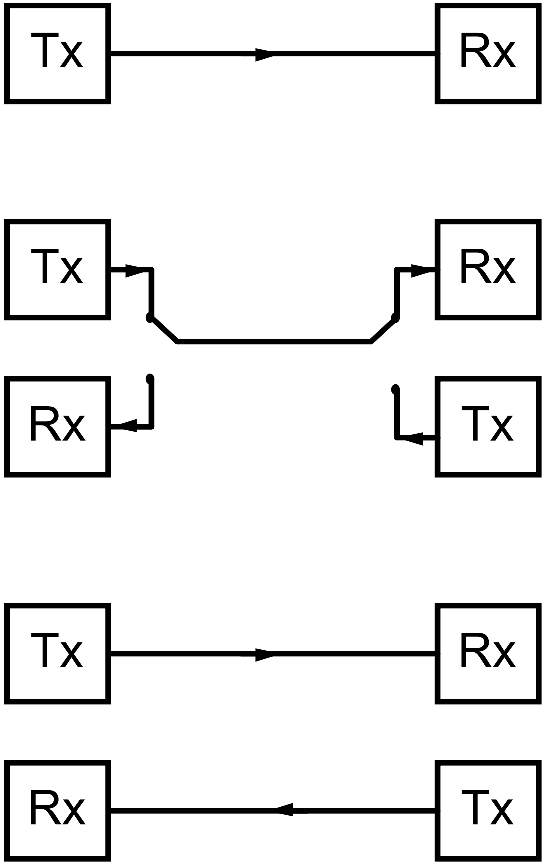
  - multiple access



Point-to-point links

Can logically operate in 3 mode types

Tx - transmitter   Rx - receiver



Simplex — One way communication (e.g., ?

Half duplex — Switched one way communication (e.g., ?

Full duplex — Two way communication (e.g., ?

Multiple access links

- Unicast – source message to single destination node
- (e.g., ?
- Broadcast – source message to all nodes on a network
- (e.g., ?
- Multicast – source message to subset of nodes on a network
- (e.g., ?

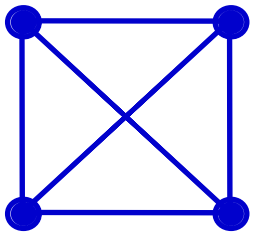
- Sending a message from source to destination requires:
  - Address – character string that identifies a node (usually unique)
    - (e.g., ?
  - Routing – process of forwarding messages to the destination node based on its address
    - (e.g., ?

Network routing

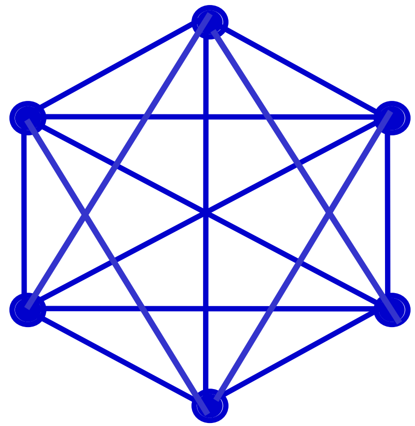
Network routing is the process of ensuring that a link (channel) is made between the appropriate source and destination.

One such method is to have a dedicated, permanent link (L) between all nodes (N).

N = ?
L = ?



N = ?
L = ?



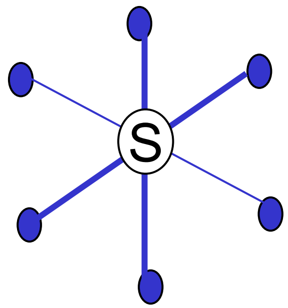
N = ?
L = ?

L=

What is L when N is very large?

- Number of connections quickly becomes excessive!
- Poor utilisation of resources.

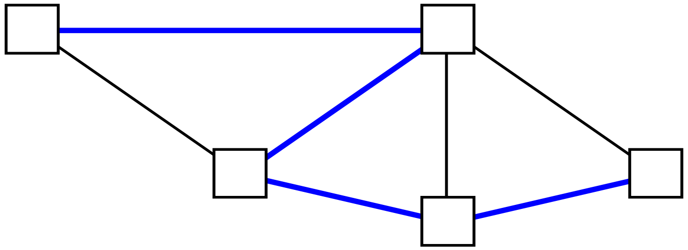
Hence early development of telephone switchboards



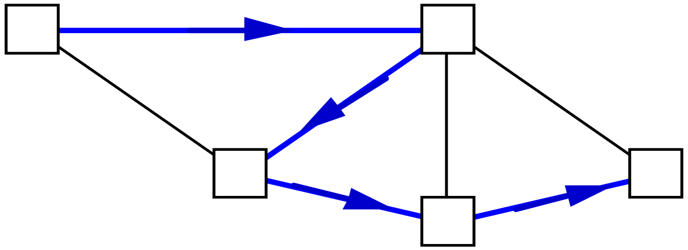
Nodes are connected via a switch.

Switching Strategies

- Circuit switching: carry data on dedicated channel (circuit)
  - E.g., original telephone network

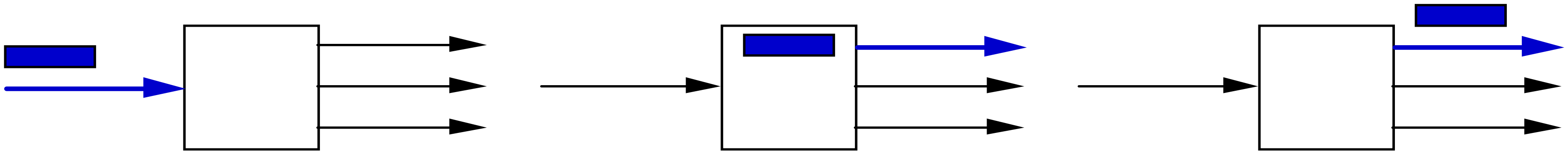


Complete continuous circuit



Send data on dedicated circuit

- Packet switching: take one hop at a time through switches (routers). Can use any available link. Needs to know the destination address.
  - E.g., Nearly all computer networks, Internet



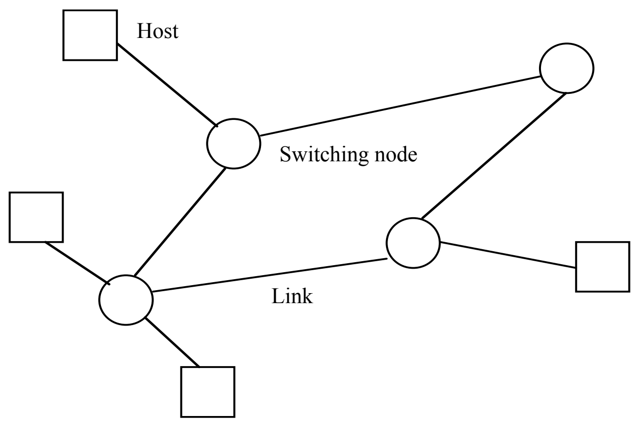
Multiplexing

In packet switching, it needs to combine your message with those of many other users.

In this way the links can be shared.

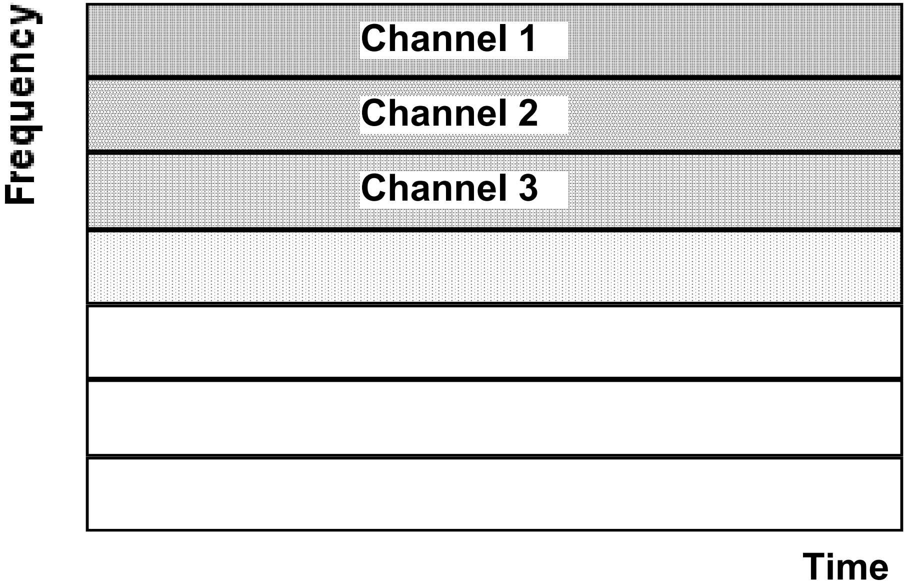
Multiplexing is sending multiple streams of information on a carrier at the same time in the form of a single, complex signal and then recovering the separate streams at the receiving end.

The recovering process is called **Demultiplexing.**



There are two basic types of multiplexing:

Frequency Division Multiplexing



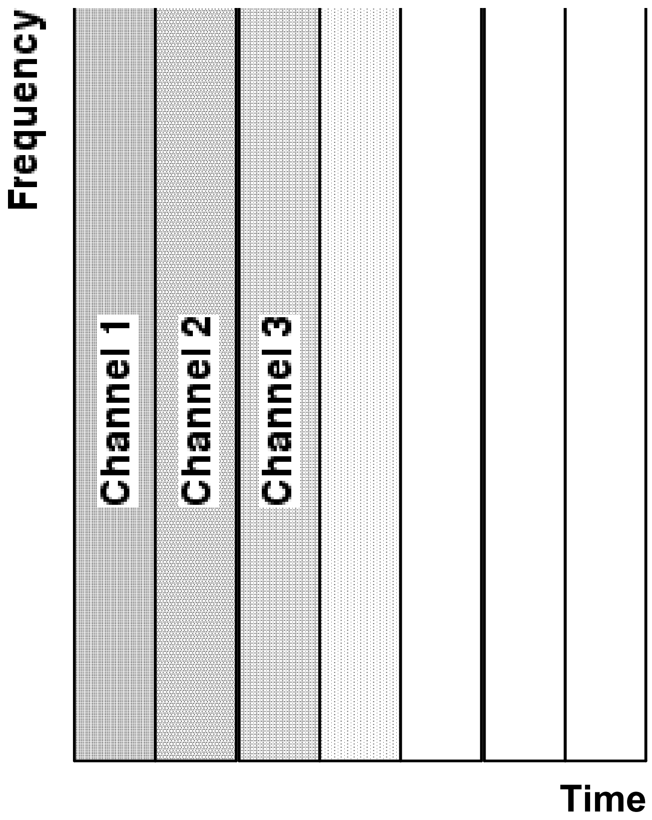
Dedicated band of frequencies for each channel - available for all time.

Each signal is assigned a different carrier frequency (sub-channel) within the main channel.

They are modulated on different frequency carrier waves and added together to create a composite signal.

What type of applications?

Time Division Multiplexing



Dedicated period of time for each channel - all share same band of frequencies.

A method of putting multiple data streams in a single signal by separating the signal into many segments

Each individual data stream is reassembled at the receiving end based on the timing.

What type of applications?

Previous methods are ideal if there is a constant rate at which data is sent

Generally not the case for computer communications

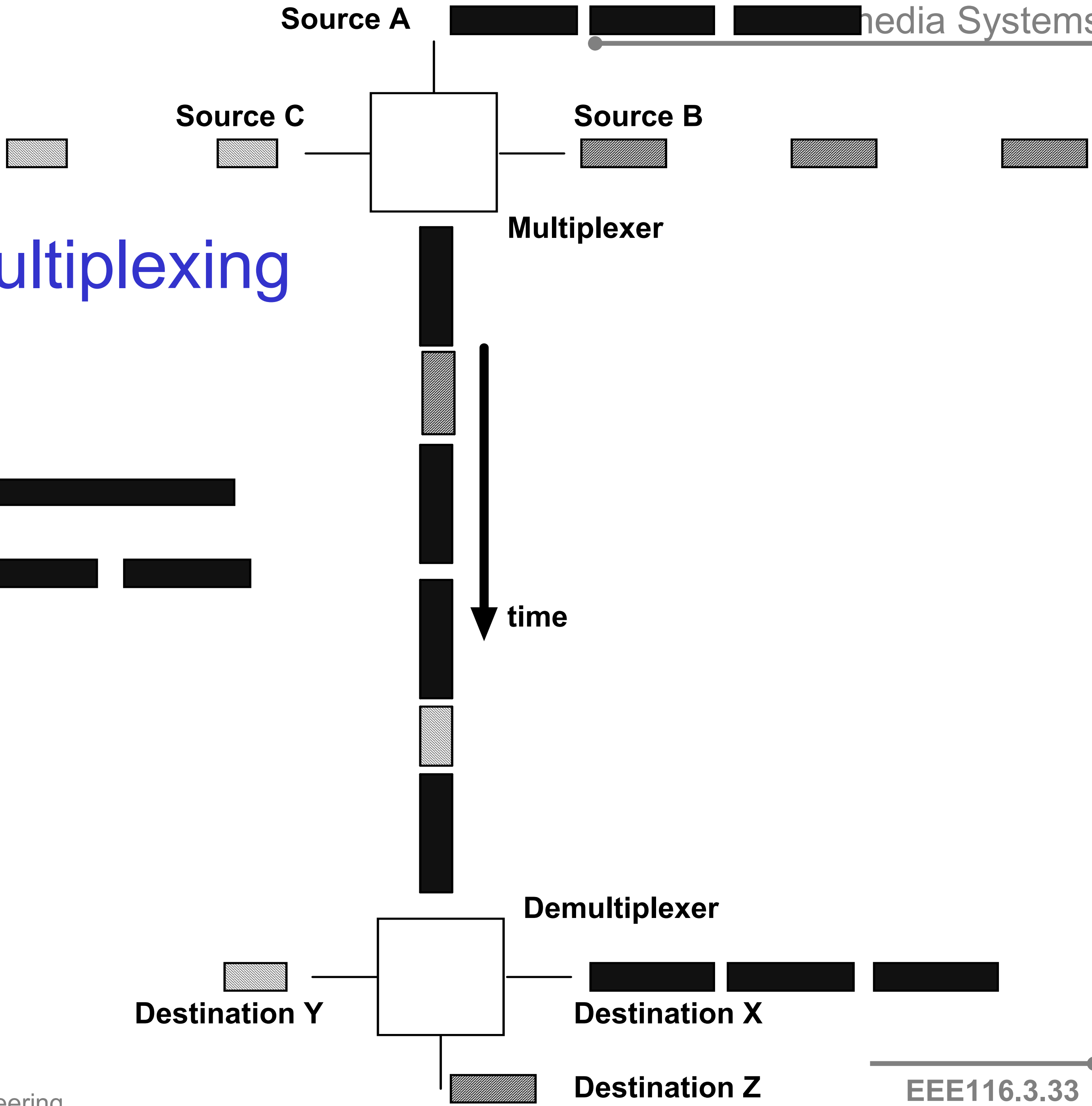
Better utilisation of network resources if each computer gets obtain a fair share of network resources only when needed

The concept of **stochastic multiplexing**

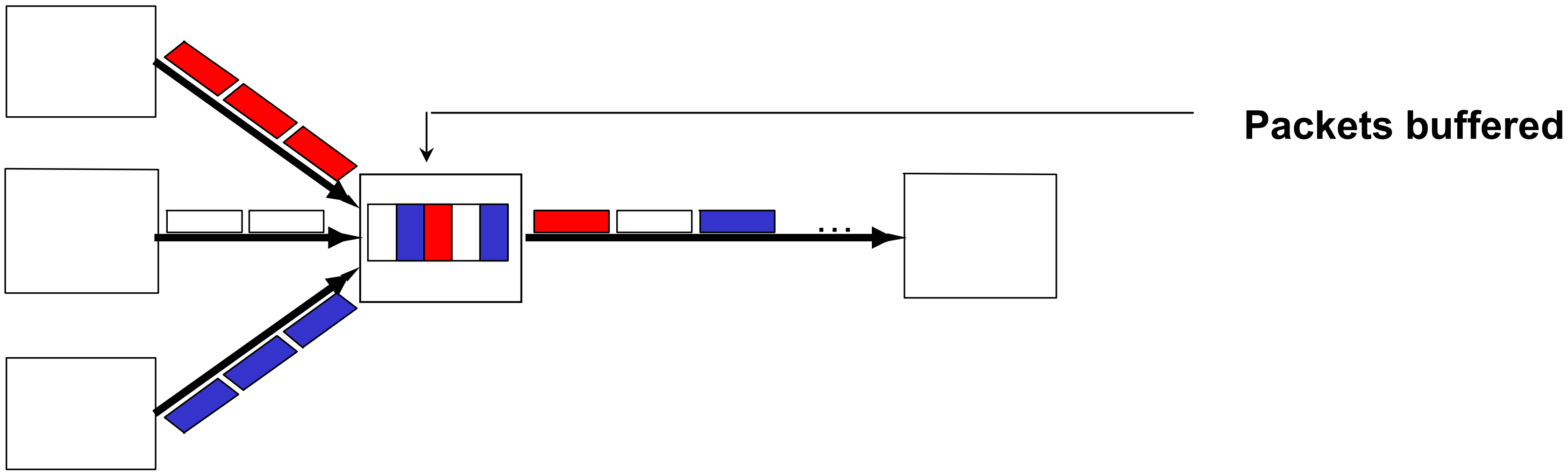
Your complete communication is called a **message** – a long sequence of binary digits (bits)

Break up into smaller sequences - called **packets**

Stochastic Multiplexing



Stochastic or Statistical Multiplexing



- On-demand time-division
- Schedules link on a per-packet basis
- Packets from different sources interleaved on link
- Buffers packets that are contending for the link
- Buffer (queue) overflow is called **congestion**

Reliability
- What Goes Wrong in a Network?

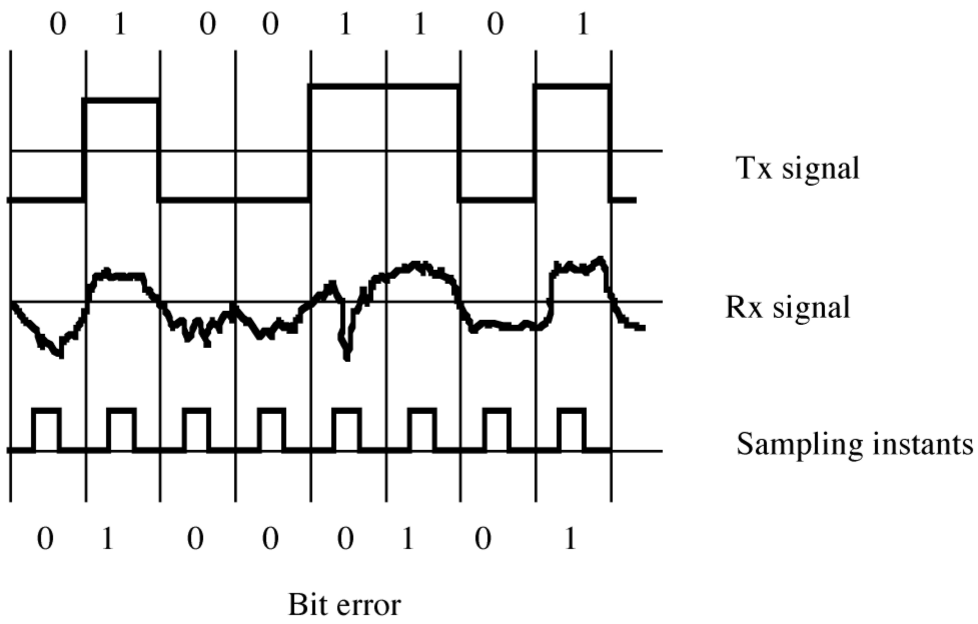
1. Bit-level errors (electrical interference)

Random bits corrupted

Usually burst errors (several consecutive bits corrupted)

All transmitted signals are attenuated and distorted by the transmission medium.

At some stage, the receiver will become unable to reliably distinguish between the '0's and '1's.



The extent of this corruption will depend on

- Type of transmission medium
- Bit rate of data being transmitted
- Distance travelled in medium

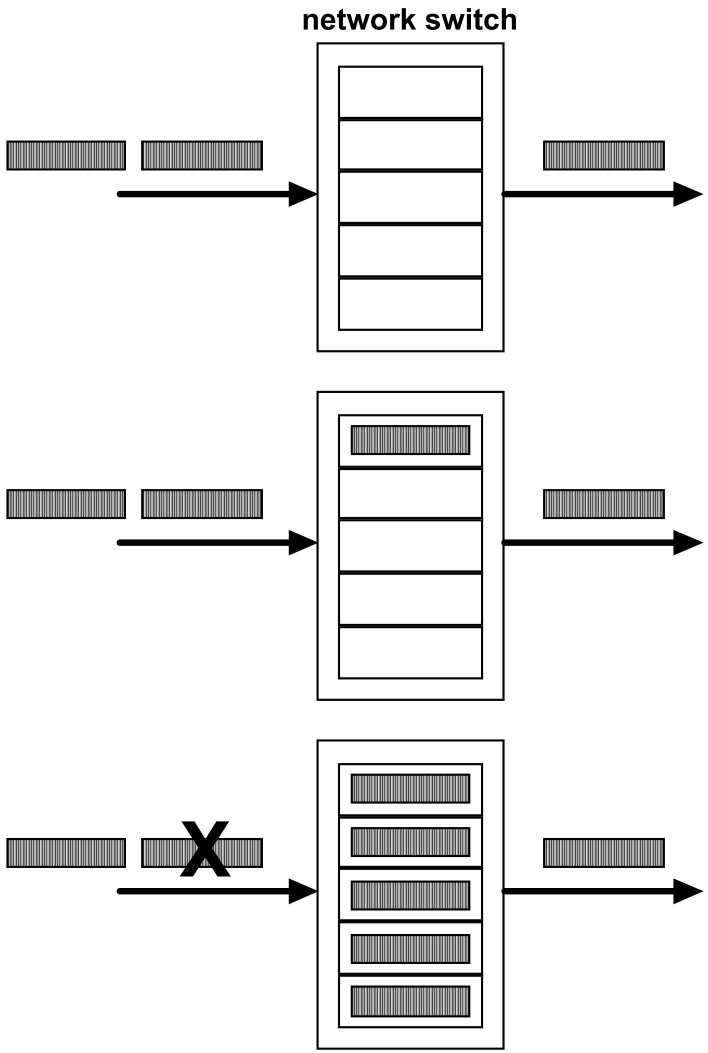
Bit Error Rate (BER) - average probability of 1 bit being corrupted in *n* bits

Optical fibre = 1 in 10^{12} to 10^{14} (or quote as 10^{-12} to 10^{-14})
Copper cable = 1 in 10^{6} to 10^{8}
Cellular radio = 1 in 10^{2} to 10^{4}

I.e., probability of one bit being in error

What Goes Wrong in a Network?

- 2. Packet-level errors
  Packets are lost mainly due to network congestion (sometimes mis-direction). "Excessive" delay can be equivalent to loss



- 3. Link and node failures
  Can have a dramatic effect
- 4. Messages are delayed
- 5. Messages are delivered out-of-order
- 6. Third parties try to eavesdrop

- So far we have discussed
  - -the benefits of digital representation of data,
  - -how to convert analogue data to digital form,
  - -how data is communicated,
  - -Basics of networks,
  - -the limitations of the data communication networks.

We expect
- -. Low latency
- -. Good connectivity
- -. High reliability

from communication networks.

- What is the most important from above from an usage point of view?

Latency (revisited)

- Latency is the time taken to transfer a message across a network.

Latency = Transmit Time + Propagation + Queuing Delay

Revisit --- Tutorial problem Q4
Solutions: (Available on MOLE)

(a)

(b)

(c)

(d)

Class Activity -5

Three main delays contributing to latency

Latency = + +

Which of the following is more controllable to the user?

a) Delays due to network infrastructure

b) Delays due to throughput limitations

Transmit time =

How can we reduce transmit time?

Write down your conclusion

--→ Topic 4