NTNU

Norwegian University of Science and Technology

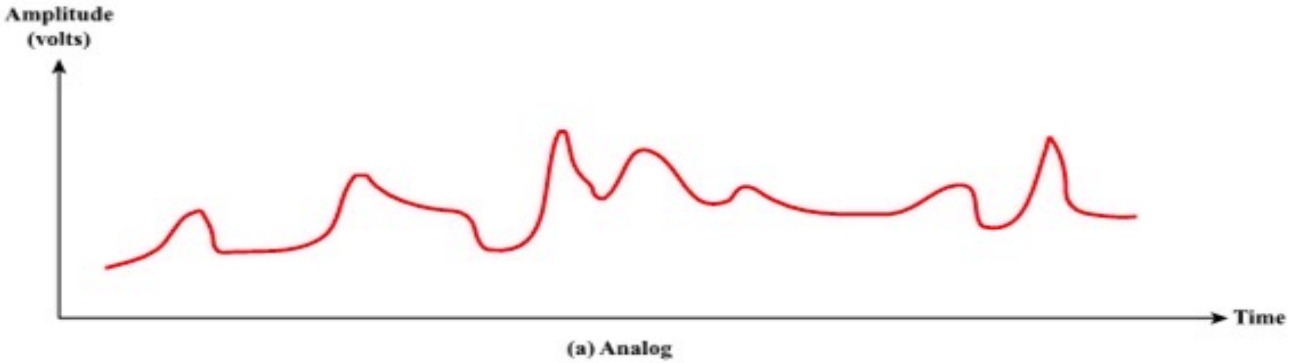
Basics Tutorial

Analog vs Digital signal

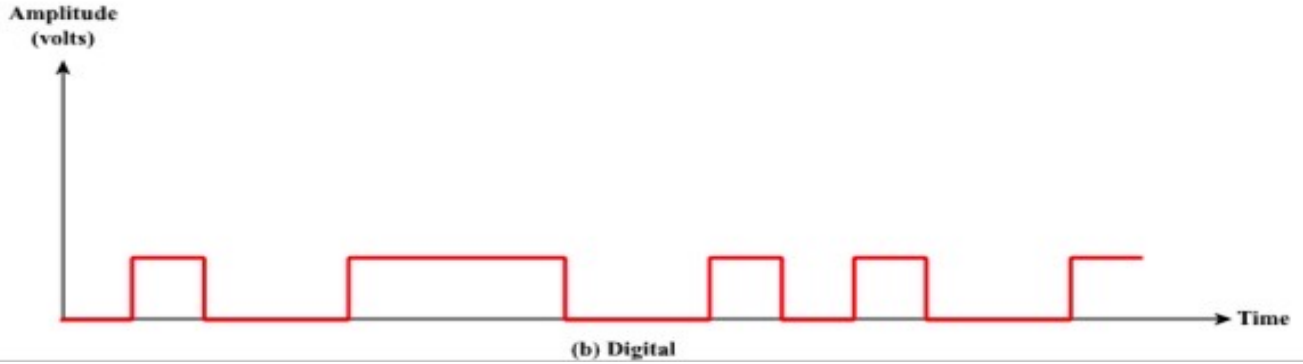
- **Analog signal** - signal intensity varies in a smooth fashion over time
- No breaks or discontinuities in the signal

- **Digital signal** - signal intensity maintains a constant level for some period of time and then changes to another constant level

Analog vs Digital signal



(a) Analog



(b) Digital

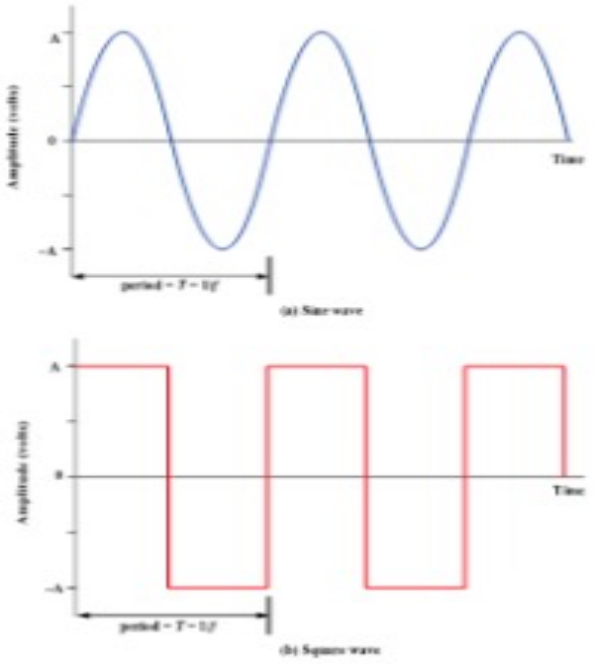
Periodic signal

- **Periodic signal** - analog or digital signal pattern that repeats over time

$$s(t+T) = s(t)$$

$$-\infty < t < +\infty$$

- where T is the period of the signal



Sine Wave Parameters

$$s(t) = A\sin(2\pi ft + \phi)$$

f - frequency

t - given time

A - amplitude

ϕ - phase shift

$\text{Phase}(\phi)$ - measure of the relative position in time within a single period of a signal

Frequency and wavelength

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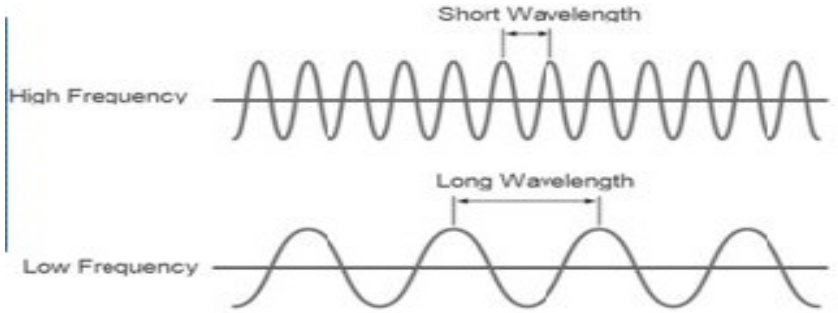
$$f = \frac{1}{T}$$

Frequency	Period
1Hz	1 s
1KHz	1 ms
1MHz	1 μs



- **Frequency (f)** - number of electromagnetic wave cycles that pass a single point per unit time. Measured in hertz (Hz) – number of cycles per second

- **Wavelength (λ)** - distance that the signal travels during 1 complete cycle

- **Period (T)** - is the time taken for one complete oscillation.

Frequency/wavelength relation

- The speed of the wave (v) is the distance that the wave travels per unit time (The speed of a wave is equal to its frequency multiplied by the wavelength)

$$v = \frac{\lambda}{T}$$

$$v = f\lambda$$

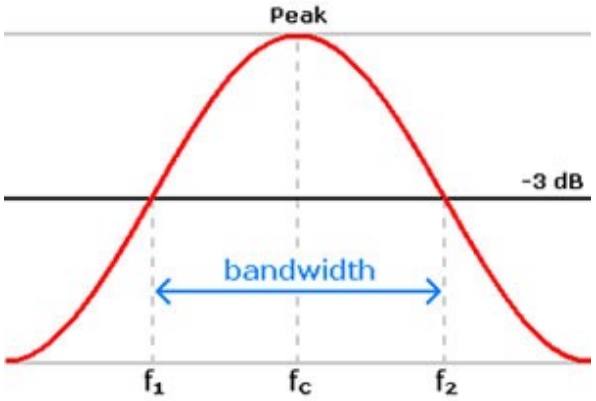
- For electromagnetic travelling through vacuum speed of the wave is 3×10^8 m s-1 (c), the equation written :

$$c = f\lambda$$

- The lightspeed in other substances eg. Glass is lower than vacum

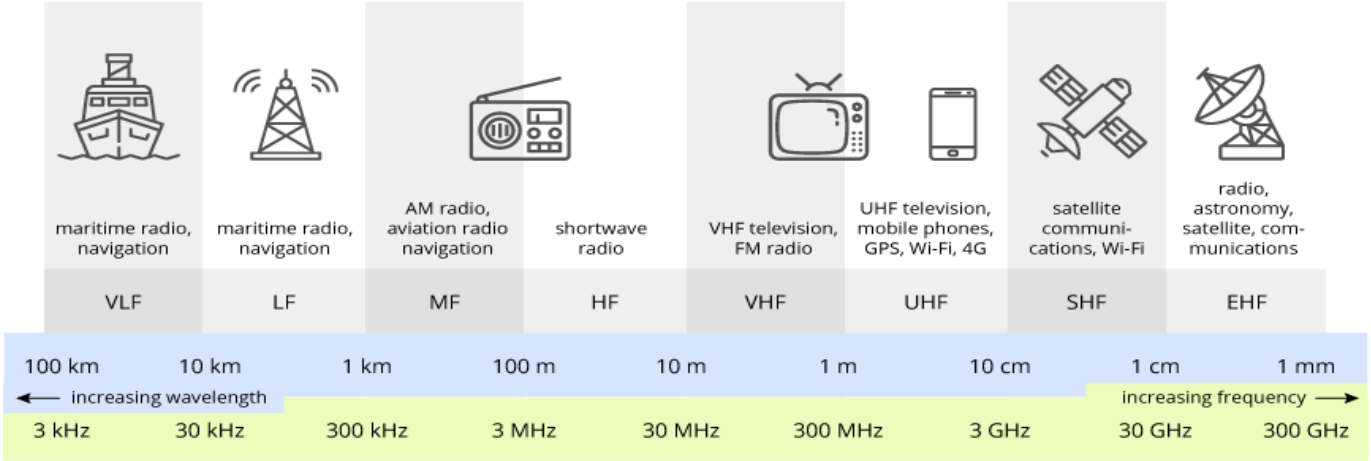
Bandwidth

- Bandwidth (bps) - amount of data transferred
- Bandwidth (Hz) - Size of the transmission channel. The difference between upper and lower frequency



Radio frequency

- Radio frequency (RF) is the oscillation rate of an alternating electric current or voltage or of a magnetic, electric or electromagnetic field or mechanical system in the frequency range from around 20 kHz to around 300 GHz.



Classifications of Transmission Media

Transmission Medium

- Physical path between transmitter and receiver

Guided Media

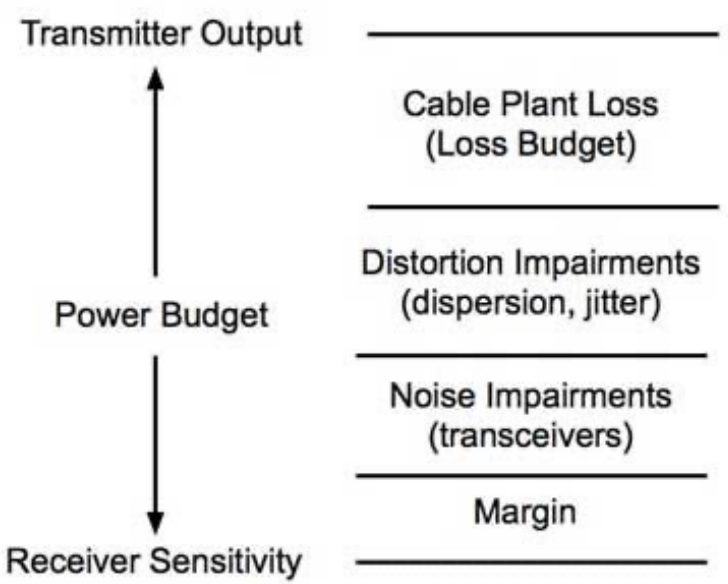
- Waves are guided along a solid medium
- E.g., copper twisted pair, copper coaxial cable, optical fiber

Unguided Media

- Provides means of transmission but does not guide the signals
- Usually referred to as wireless transmission
- Transmission and reception are achieved by means of an antenna
- E.g., atmosphere, outer space

Power Budget

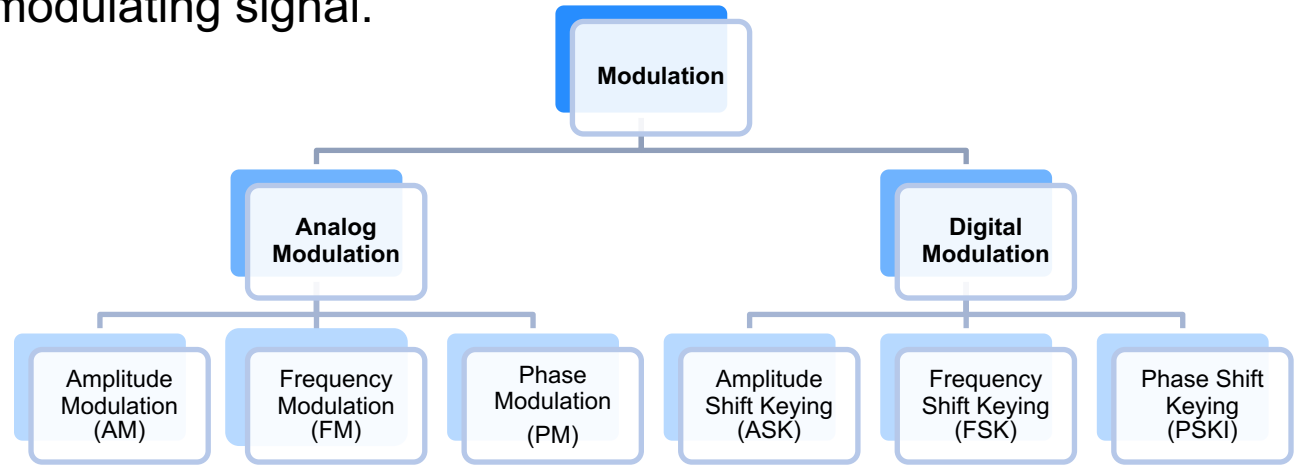
- A receiver needs to receive a minimum strength of the signal
- A receiver does not want to receive a too strong signal, as not to overwhelm/overload the receiver
- Therefore it is important to calculate the amount of loss that a datalink can tolerate and still operate properly
- The power budget is the available power that can be lost from transmission to the lowest power needed at the reciever to operate at a specific bit error level.



Modulation

- Modulation is the process of encoding information from a message source in a way that is suitable for transmission. This is achieved by altering the characteristics of a wave. By superimposing a message on to a high frequency signal known as a carrier wave (or sinusoidal signal), video, voice and other data can be transmitted.

In the modulation process, a parameter of the carrier wave (such as amplitude, frequency or phase) is varied in accordance with the modulating signal.



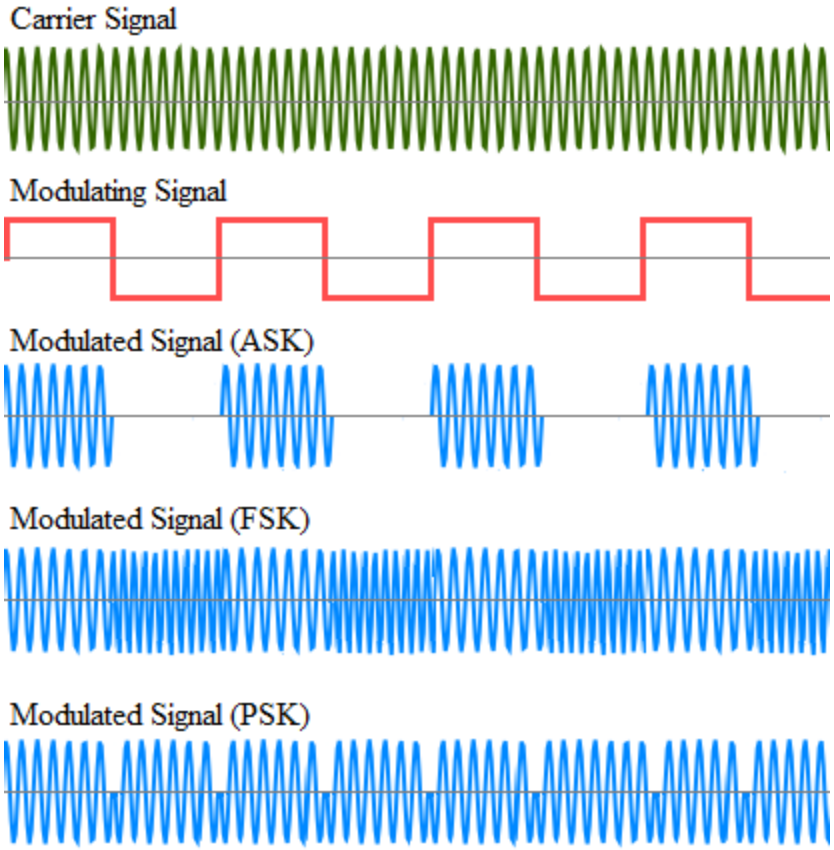
Digital Modulation

- Digital signals cannot be directly transmitted in the radio medium

- Digital modulation: translate digital signals into (baseband) analog signals – Also known as shift keying
  - Amplitude Shift Keying (ASK)
  - Frequency Shift Keying (FSK)
  - Phase Shift Keying (PSK)
  - Quadrature Amplitude Modulation (QAM)

- Changes from 1010110 to a continous (baseband) signal

Digital Modulation



- Digital modulation is similar analog except modulating signal is of discrete amplitude level

Analog Modulation

- Shifts the analog baseband signal into a passband signal that can be transferred on a wireless medium

- Amplitude modulation (AM)
- Frequency modulation (FM)
- Phase modulation (PM)

- Changes to a different analog signal that is better suited for the radio/transfer medium

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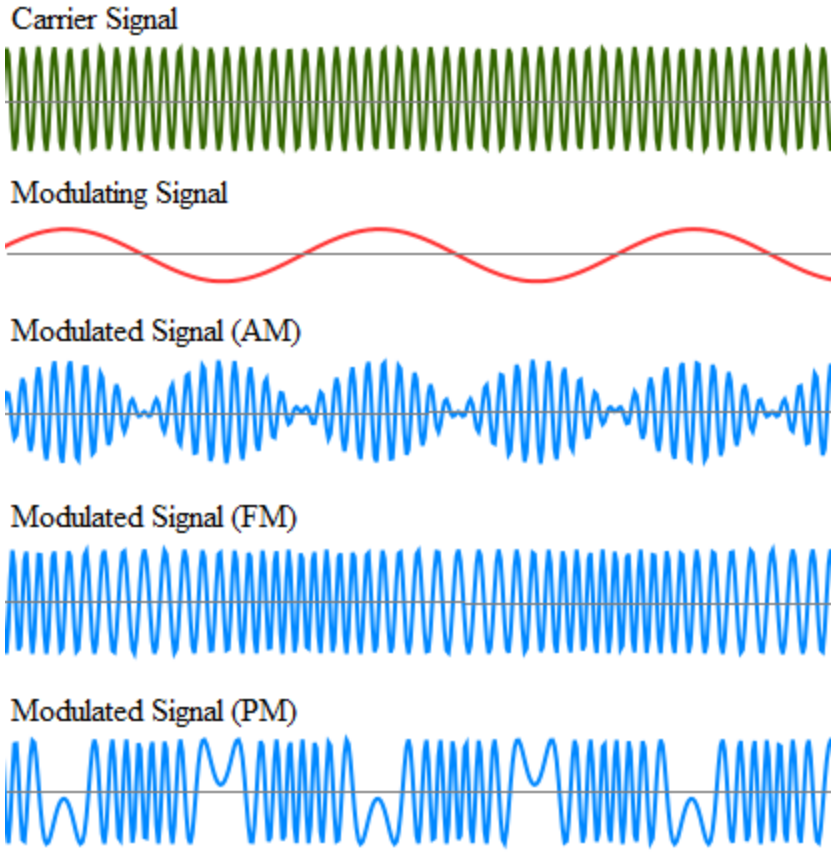
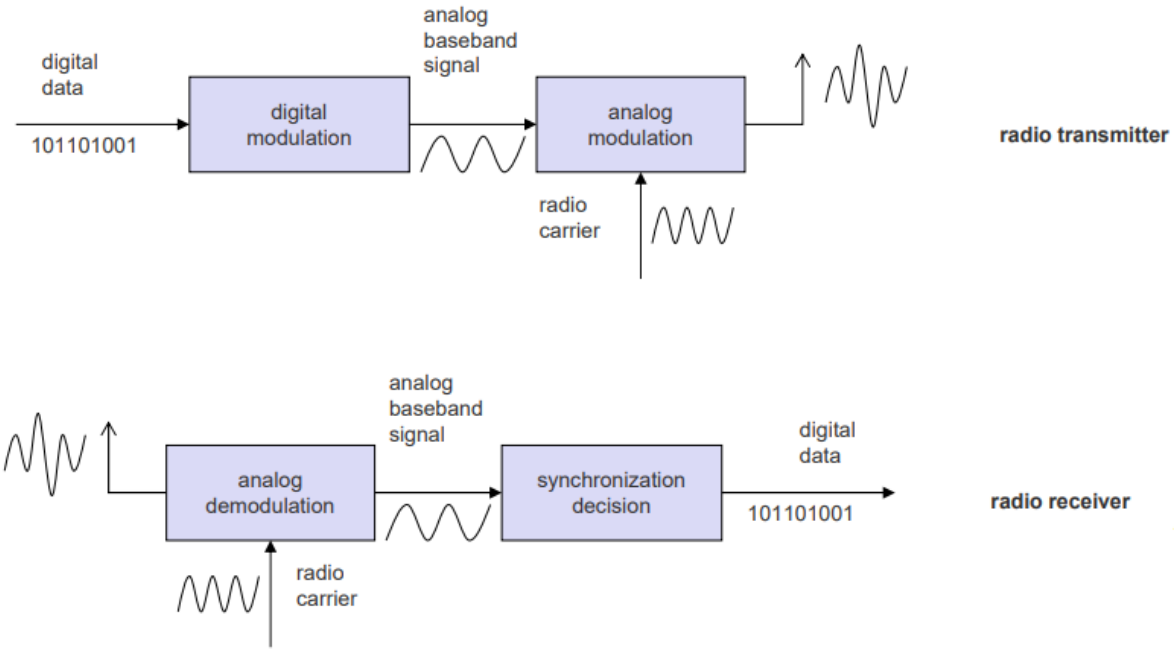
Analog Modulation



Modulation and demodulation



Ethernet at the Data Link Layer

OSI Model

Layer	Name	Example protocols
7	Application Layer	HTTP, FTP, DNS, SNMP, Telnet
6	Presentation Layer	SSL, TLS
5	Session Layer	NetBIOS, PPTP
4	Transport Layer	TCP, UDP
3	Network Layer	IP, ARP, ICMP, IPSec
2	Data Link Layer	PPP, ATM, Ethernet
1	Physical Layer	Ethernet, USB, Bluetooth, IEEE802.11, OTN

- At the data link layer, Ethernet specifies what the data should look like, including the header and trailer. The protocol is defined by IEEE 802.3 and divides the data link layer into two sublayers: the Logical Link Control (LLC) sublayer and the Media Access Control (MAC) sublayer.

- The MAC sublayer is the interface between the Physical layer and the LLC sublayer. At this sublayer, every device is assigned an address. On any given network, each device must have a unique MAC address that can be factory set when the device is manufactured or set manually.
- The Logical Link Control (LLC) sublayer provides the logic for the data link; thus it controls the synchronization, flow control, and error-checking functions of the data link layer.

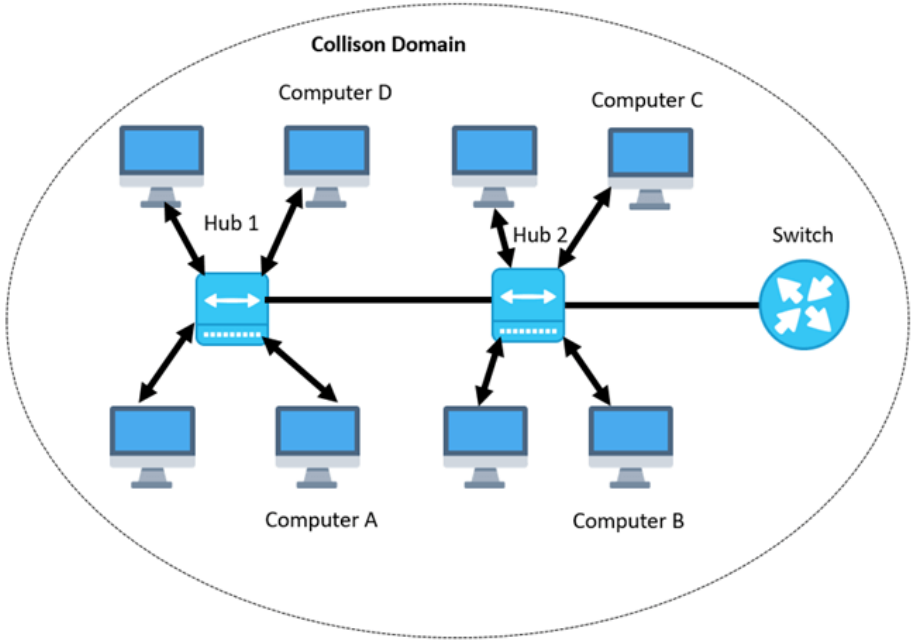
Collision Domain

- The collision domain defines the set of devices on which their frames could collide. It is a network segment connected by a shared medium or using repeaters where real-time data transmissions collide.

- A collision happens when two separate devices simultaneously send a packet on the commonly shared network segment. The packets collide, and both devices require sending the packets again.

- More collisions will happen with many network devices(more traffic) in a Collision domain.

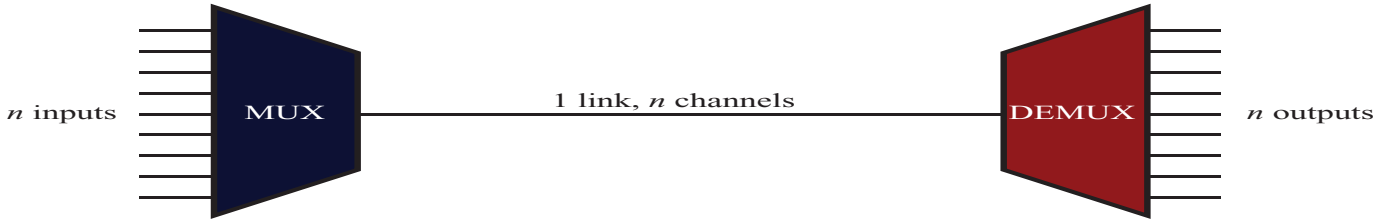
  An increased number of collisions will result in a low-quality network because hosts spend a large amount of time for packet processing and retransmission.



“Computer A” send a data signal to “Computer C.” In the same way, “Computer B” sends a data signal to “Computer D” where a Collision will happen.

Multiplexing

- Capacity of transmission medium usually exceeds capacity required for transmission of a single signal
- Multiplexing - carrying multiple signals on a shared medium
  - "Mux" them together at sender and "demux" them apart on recievers end
  - More efficient use of transmission medium
  - Sharing the medium with minimum or no interference

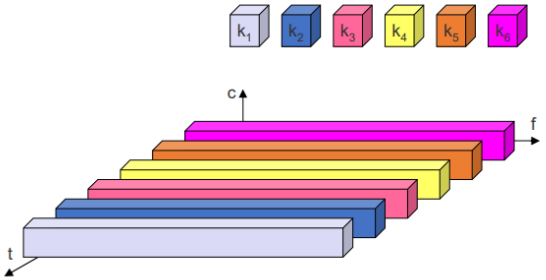


- 5 dimensions:
- **Space**
  - **Time**
  - **Frequency**
  - **Code**
  - **Polarization**
- Guard “spaces” are needed!

Multiplexing examples

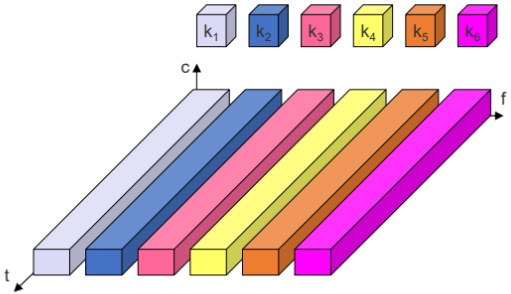
Time division multiplexing

- A channel gets the whole spectrum for a short time



Frequency division multiplexing

- The spectrum is divided into smaller bands

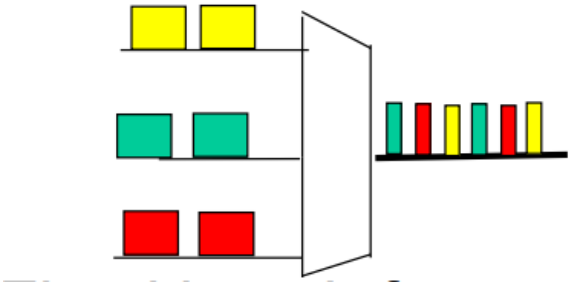


Multiplexing

Static multiplexing-circuit

- Each sender is given dedicated, scheduled ressources according to your service agreement.

-Will always have x Gb/s

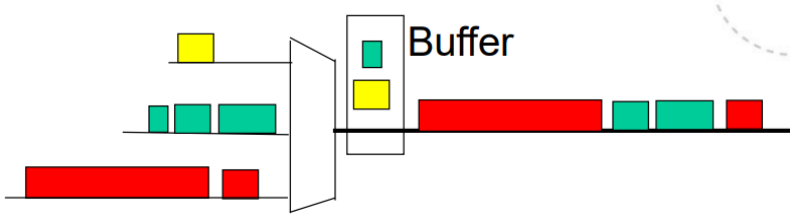


Statistical multiplexing-packet

- All users shares the resources

- Uses statistics to scale the total amount of resources needed

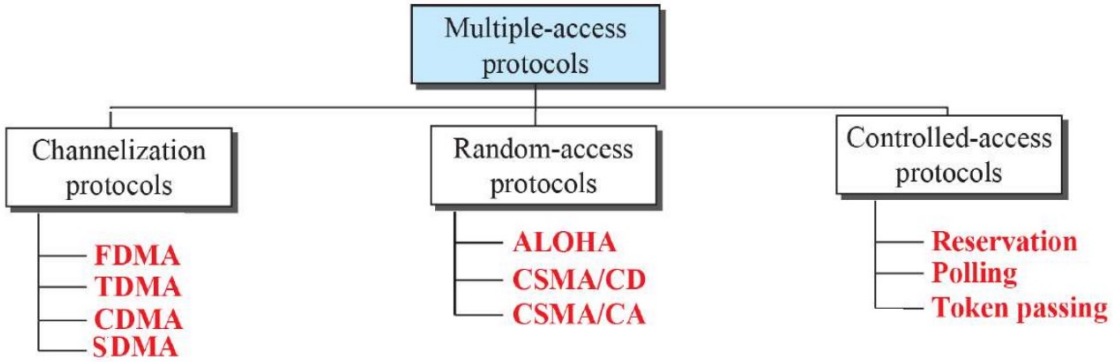
-Will have a variable bitrate depending on the amount of traffic the other users sends and bufferloss



Medium access control (MAC)

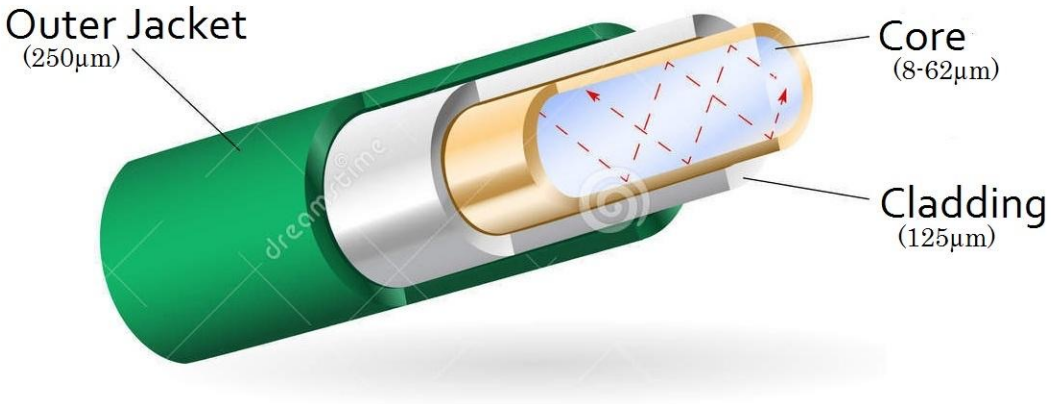
- Mechanism that regulate user access to a medium
- MAC= Multiplexing+Algorithm
- MAC is similar to traffic regulation

- TDM/FDM is about creating channels. Each channel can be given to one person or it can be shared
- When you have a collission domain you need a MAC system to
tell you when you can enter the channel



Principles of an Optical Fibers

- Optical fiber is a guided media made up of transparent dielectric materials, through which the light travel along its length, by total internal reflection.



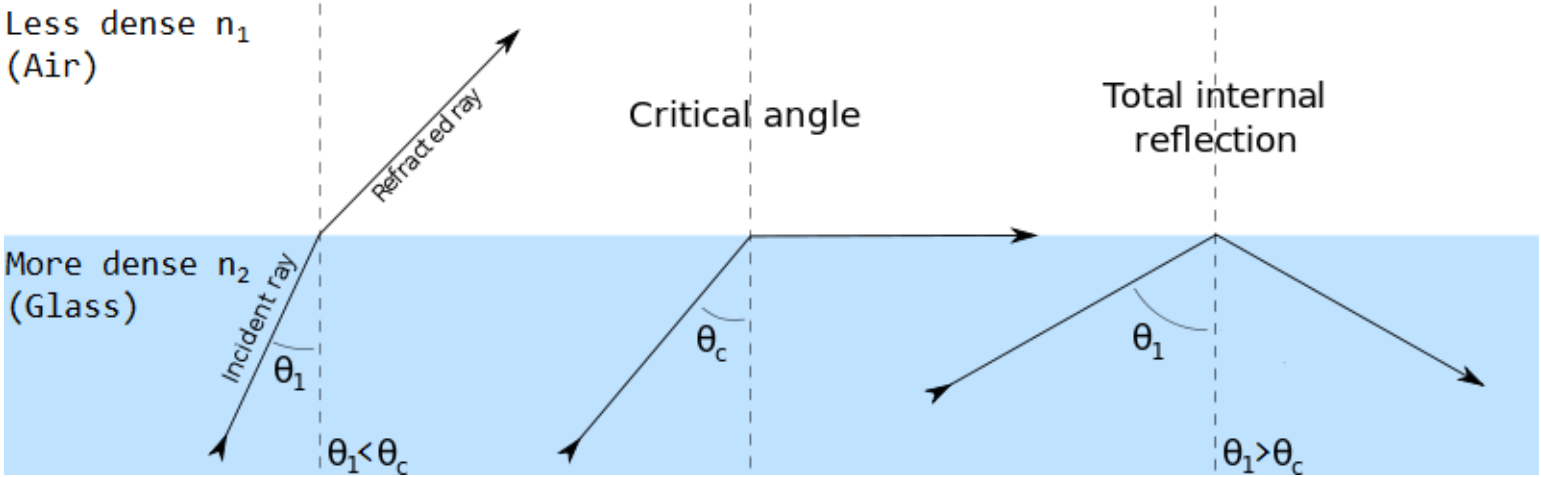
Why Fiber Optics ?

- Greater bandwidth
- Immunity to crosstalk, no electrical hazard
- Lower loss (better reliability)
- Does not generate heat
- High speed
- Long distance communications
- Thinner, lighter than copper or twisted pair
- More Flexibility for the Future
- Lower Total Cost of Ownership

Principles of an Optical Fibers

- Total Internal Reflection

  When light travels from denser medium to rarer medium and if the angle of incidence is greater than critical angle then the light back into same medium.



Light travels faster in air, but slower respectively in glass

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-The speed of light in a medium is given by the formula:

-The refractive index is a measurement on how good the medium is to transmit light.

-High refractive index means worse capability.

-The refractive index of glass is highet than air, so the speed of light will be slower in glass than in air.

$$v = \frac{c}{\mu}$$

v - the speed of light in any medium

c - the speed of light in the vacum

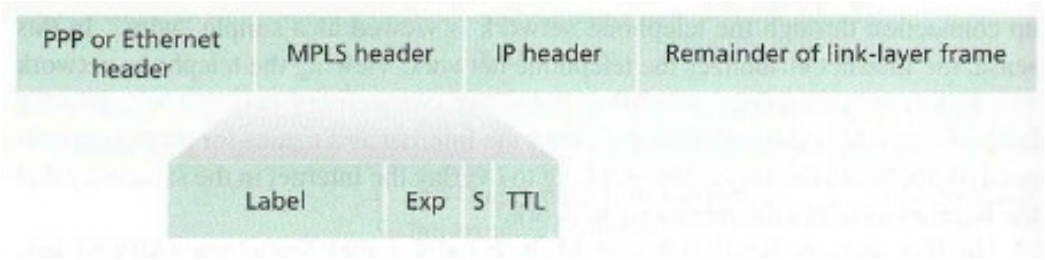
μ - index of refraction

MPLS (Multiprotocol Label Switching)

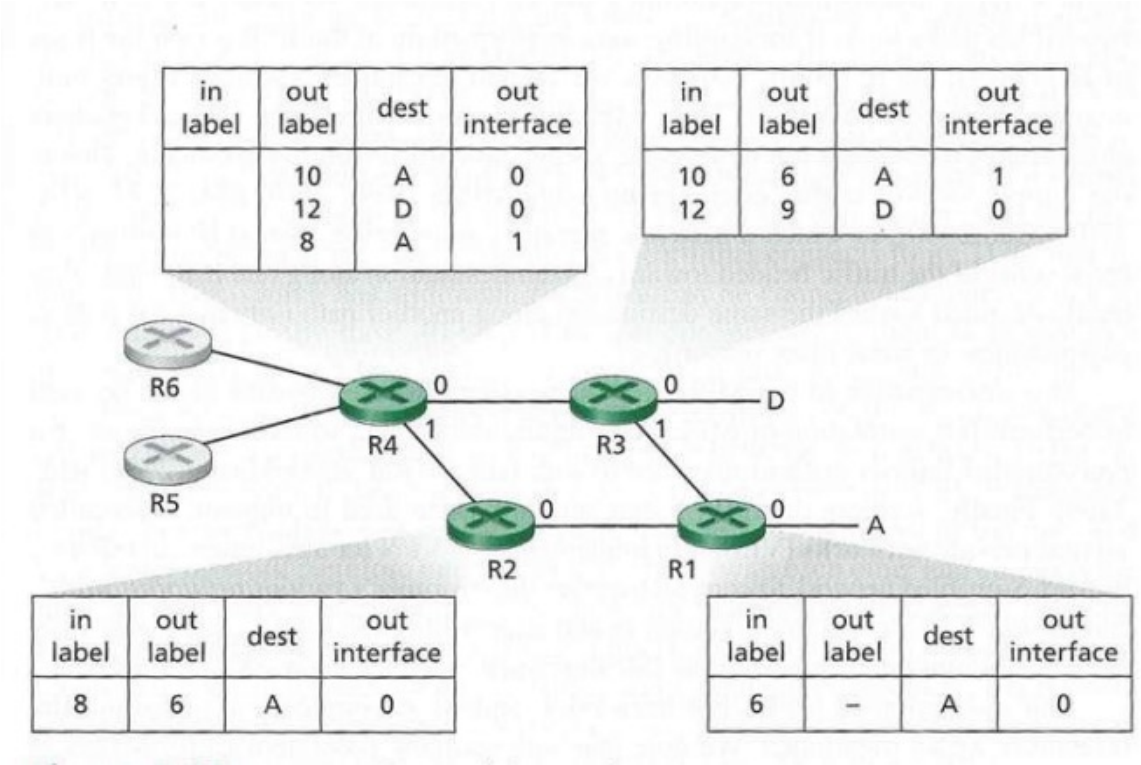
- Multiprotocol Label Switching is a routing technique in telecommunications networks that directs data from one node to the next based on labels rather than network addresses. Whereas network addresses identify endpoints the labels identify established paths between endpoints.

Encapsulation of MPLS

- The MPLS header encapsulates the IP header and remainder of link-layer frame
- Theese headers are of fixed length and increases forwarding speed



MPLS forwarding



R1-4 are MPLS enabled
R5-6 are not
MPLS networks are used in combination with IP networks and in a limited area