Introduction

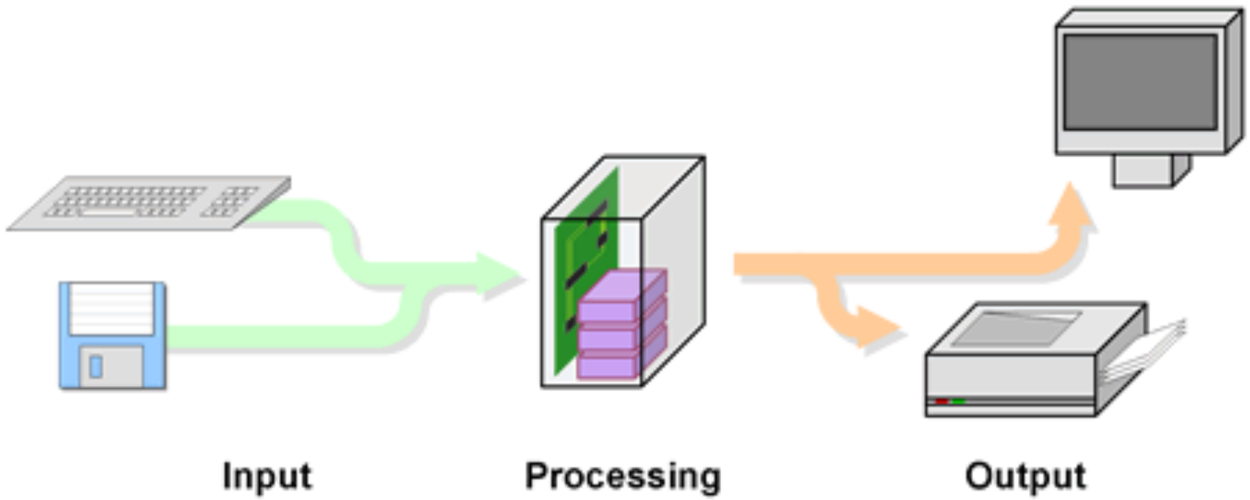
Hardware primitives & services

The O/S

Hardware components

- A computer processes information according to a set of instructions

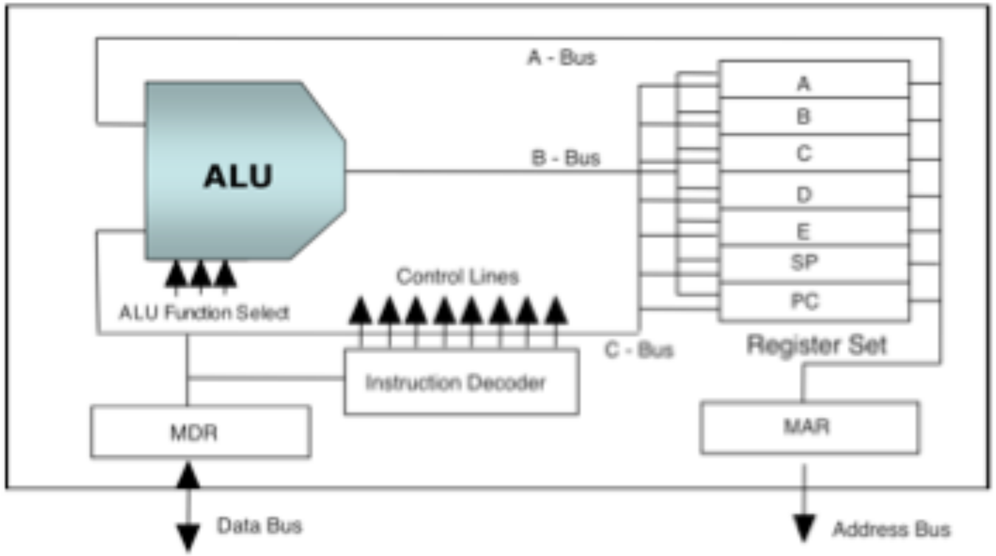
- We would thus expect a computer to have hardware for collecting input, performing ‘processing’ and producing output



CPU

- Central Processing Unit (CPU) fetches, decodes and then executes instructions that perform
  - arithmetic
  - logic comparisons
    - e.g. “is number1 equal to number2 ?”
  - other operations
    - e.g. “skip the next 50 instructions”

CPU

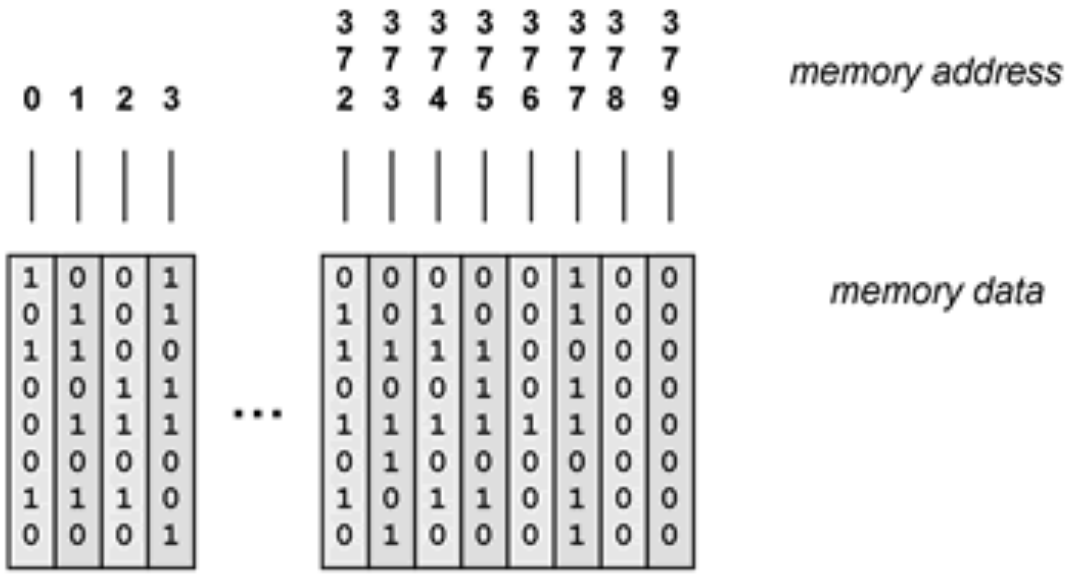


- *Arithmetic Logic Unit* (ALU) performs arithmetic and logic functions
- *Registers* - high speed 'scratch pad' to store data currently being processed
- *Memory Buffer Register* (MBR) – stores data just received from, or about to be written to memory
- Memory Access Register (MAR) – stores address of memory to be accessed next
- *Program Counter* (PC) – stores address of next instruction

Memory

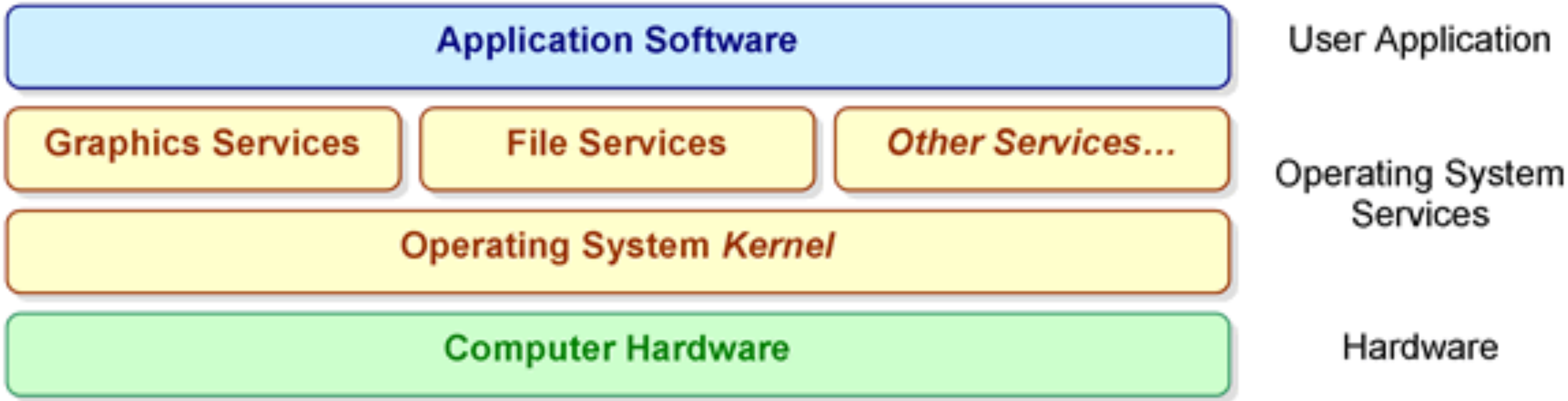
- Each byte of memory has an address
  - numbered sequentially
  - individual bits not addressable, just (usually) bytes

- An address length of N bits can express 2^N numbers ($0..2^{N-1}$)
  - so maximum size of memory limited by length of address



Operating system

- Provides a layer between hardware and user applications
  - attempts to protect hardware from user
  - manages resources in efficient and ‘fair’ manner
  - hides hardware details from user and application programmer



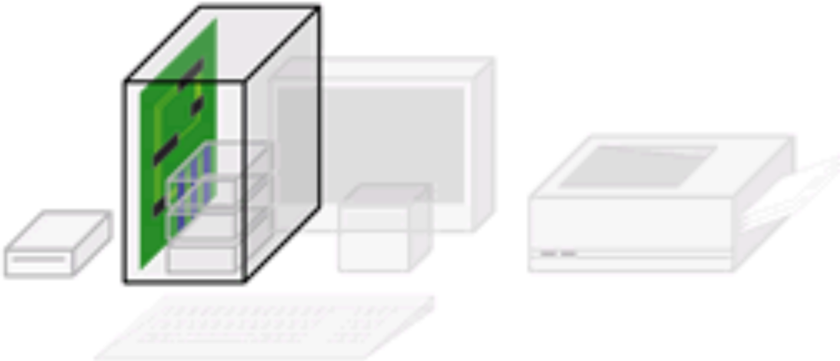
System Basics

Typical desktop system

Desktop motherboard architecture

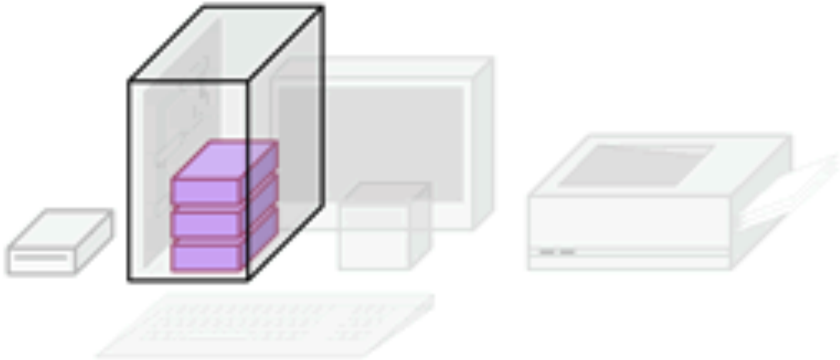
Data links & legacy connections

A computer system



- Motherboard
  - main printed circuit board (PCB)
  - houses CPU socket and slots for main memory
  - expansion slots
  - expansion card functions are increasingly being moved to the motherboard

A computer system

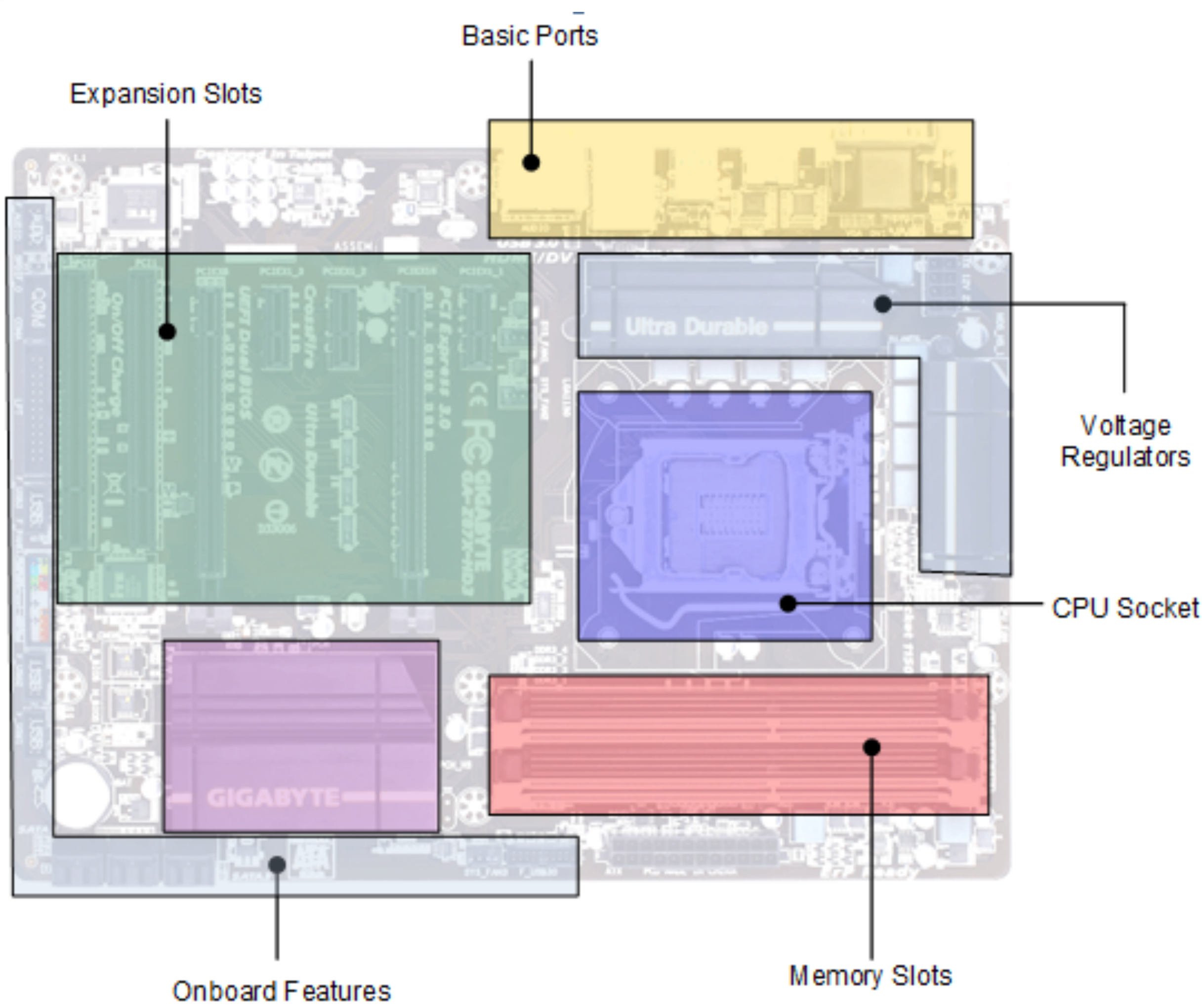


- Internal Expansion
  - inside computer case
  - expansion cards such as network cards, graphics cards etc.
  - internal hard drives

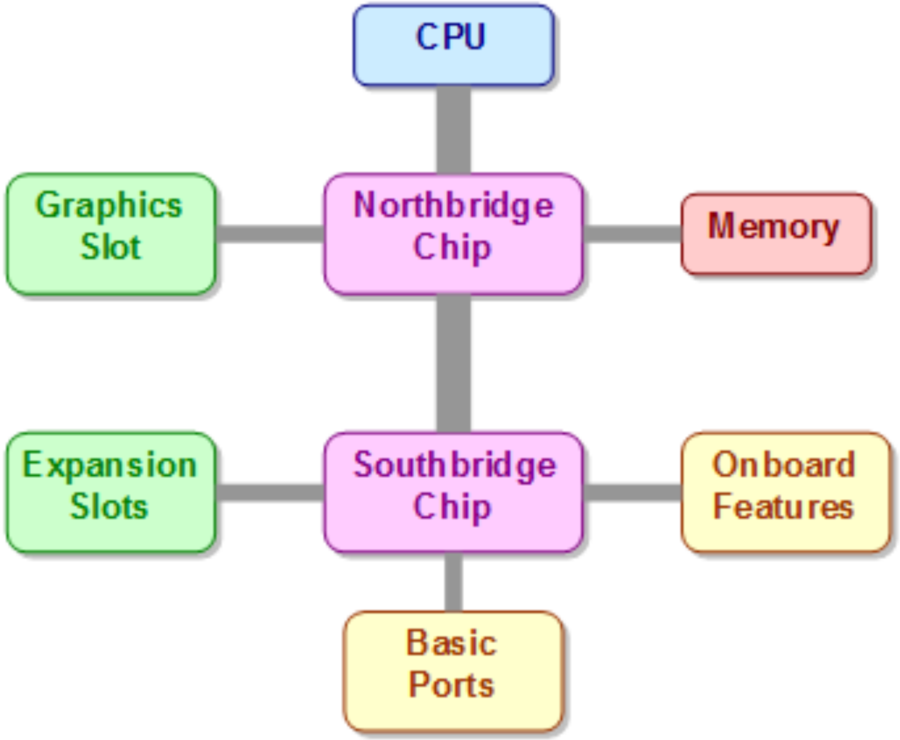
- External Expansion
  - outside computer case
  - non-critical functions
  - peripherals such as keyboards, mice, printers etc.

Desktop motherboard architecture


Photo: Gigabyte Co



Chipset: Legacy



- CPU interacts with many components
- Chipset controls communication between CPU and other components

- Northbridge chip connected directly to CPU (to minimise latency) and handled high-speed components (e.g. RAM)
- Southbridge connected to northbridge and handled slower components (e.g. disk drives)

Chipset: legacy

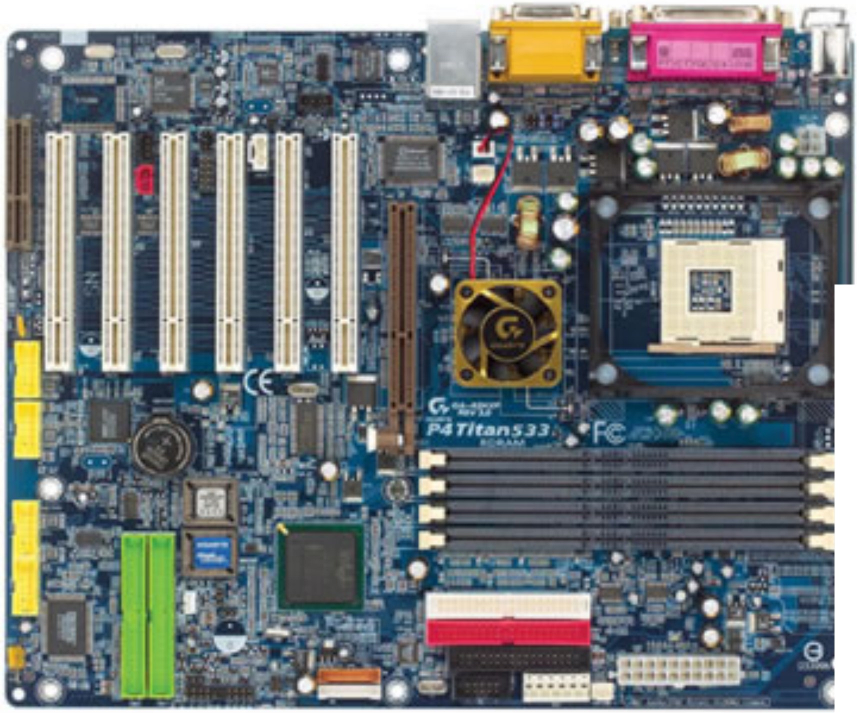
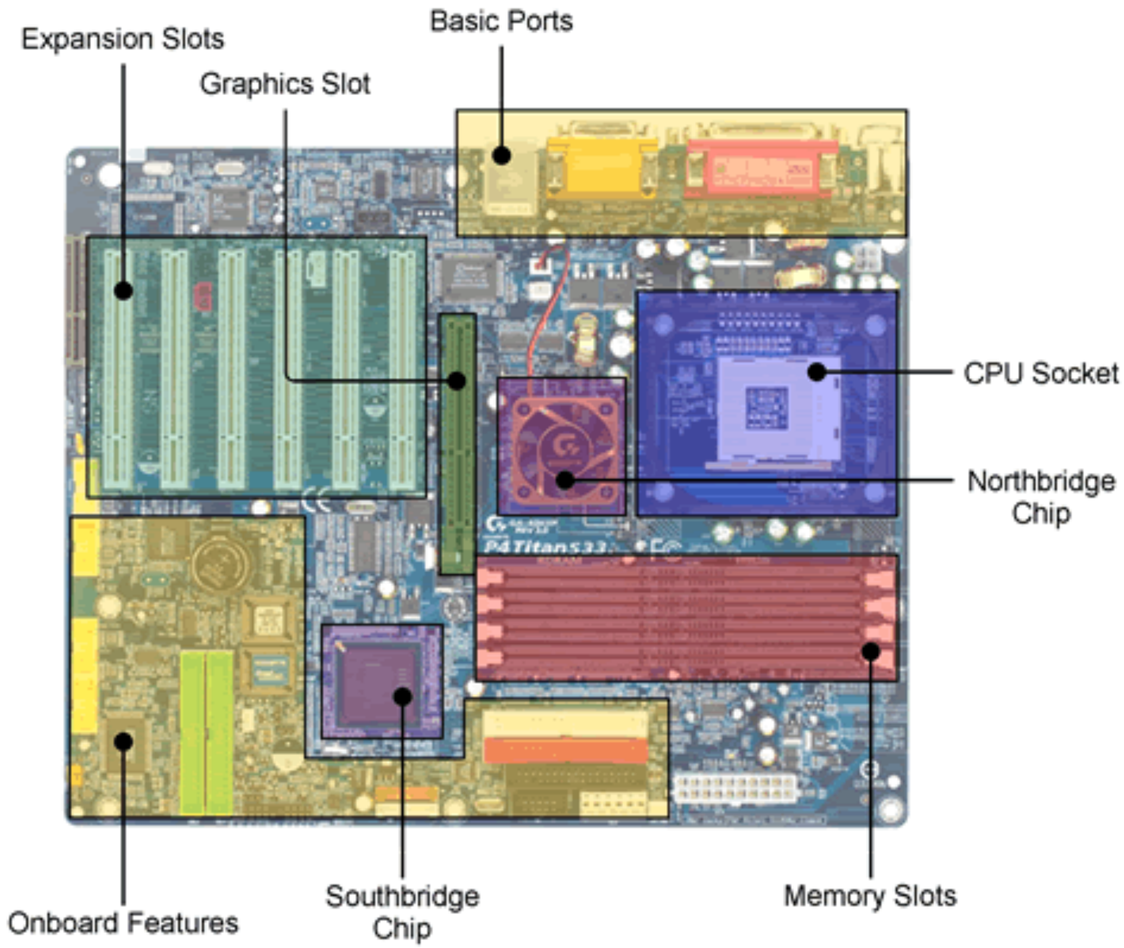
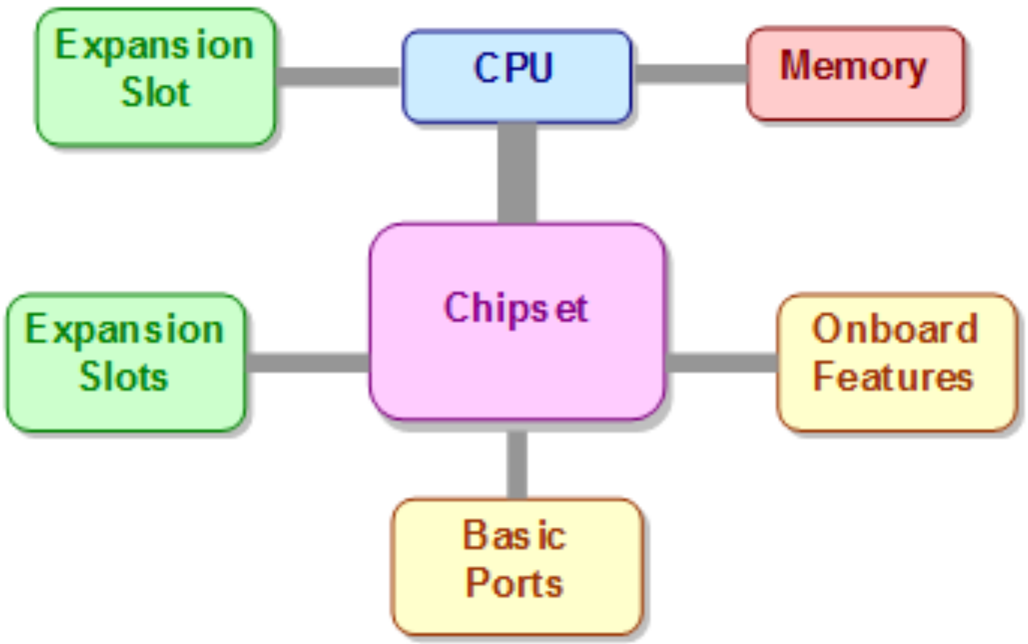


Photo: Gigabyte Co



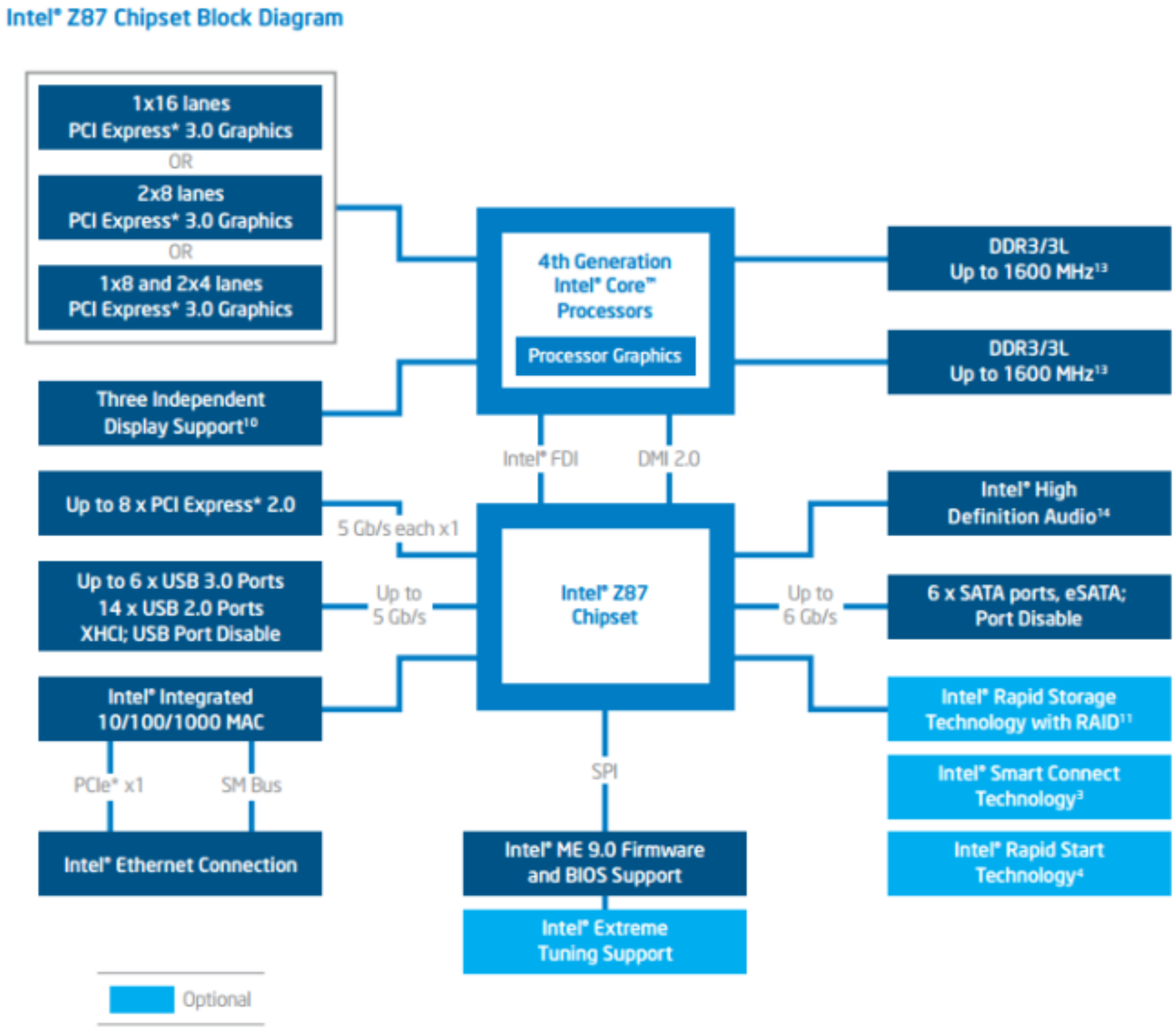
Chipset: modern



- As manufacturing techniques improved and more complex CPUs became possible, control functions migrated to the CPU
  - e.g. memory controller
  - e.g. high speed expansion interfaces

- Northbridge remnants and southbridge merged into a single 'chipset'
- Smartphones etc. use a combined CPU & chipset & memory: 'System on a chip'

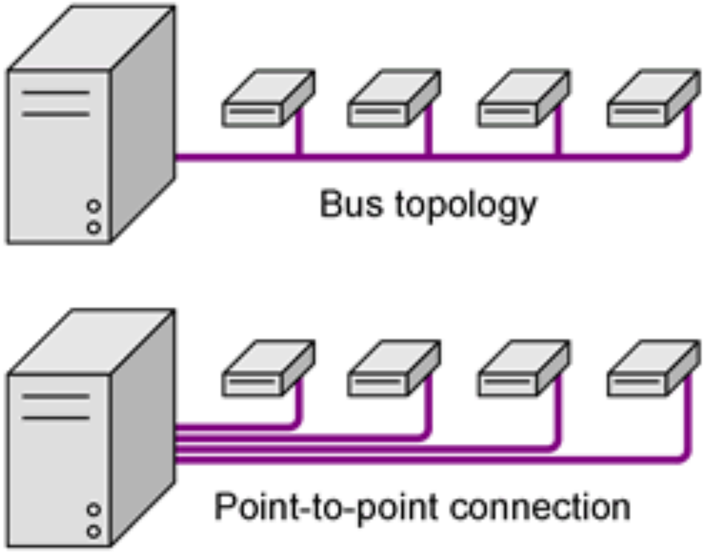
Chipset: modern



- Intel Z87 chipset
  - high level of integration

diagram: Intel Corporation

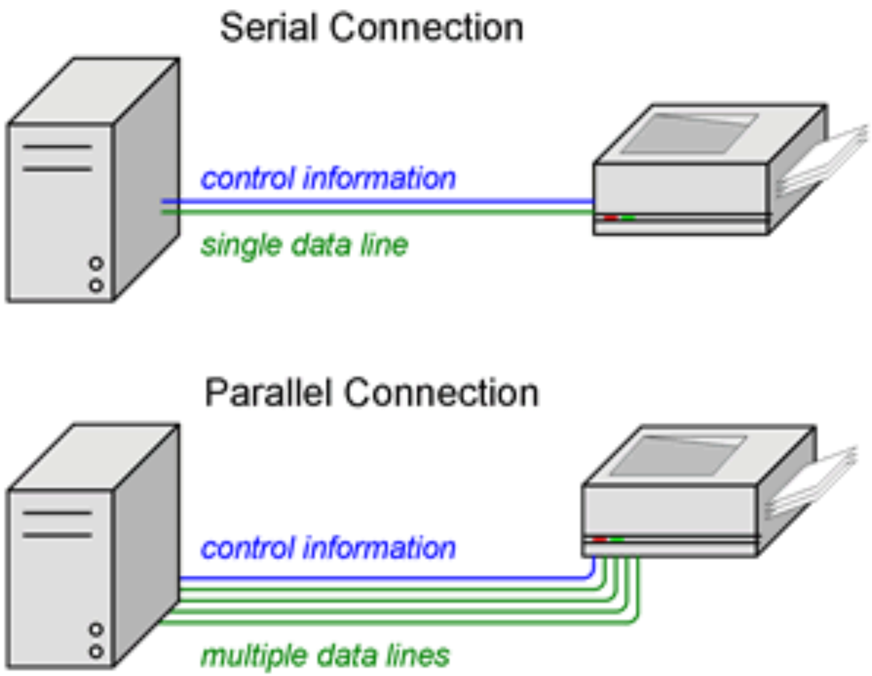
Data links



- Between components are data links
- Typical topologies are bus (most common) verses point-to-point

Data transfer is either:

- Serial: one bit at a time sent on a single wire
- Parallel: multiple wires used to transfer multiple bits at the same time



Data links

- Parallel connections tend to suffer from electrical cross-talk
  - so serial can transfer data reliably over a longer distance
  - serial transfer common now for peripherals due to increased computer interface speeds

Devices differ in when they can be connected:

- *Hot-swappable*: can be plugged in or unplugged while the computer is switched on
- *Warm-swappable*: can be plugged/unplugged when computer is in sleep mode
- *Cold-swappable*: should only be plugged/unplugged after switching off the computer
  - otherwise you risk data loss, or a computer crash, or a dangerous short circuit

Legacy interfaces

- A legacy interface is one that has been superseded but persists for various reasons
  - e.g. large existing stock of devices using it
  - good enough or cheap enough to continue to provide it

- e.g. legacy keyboard & mouse ports
- legacy parallel port

- e.g. legacy AT keyboard connector & PS/2 mouse connector verses more modern USB connector

Legacy interfaces

– e.g. ye olde RS-232 serial port (since the 1960s!)

– e.g. a parallel printer cable

Data Transfers

Data Protocols

Signal Transmission

Communication Mediums

Networks

Data Protocols

- Data is transferred both within and between computer systems. *Protocols* specify how to structure and control those data streams

Protocols define the *structure* (syntax) of the data stream

- Three options for direction of communication:
  1. Simplex
  2. Half duplex
  3. Duplex

Flow Control

- Protocols define how to *control* the data stream
  - prevent receiver being overwhelmed
  - ensure no data is lost

- Stop and wait

  Source transmits frame

  Destination receives frame and replies with ACK

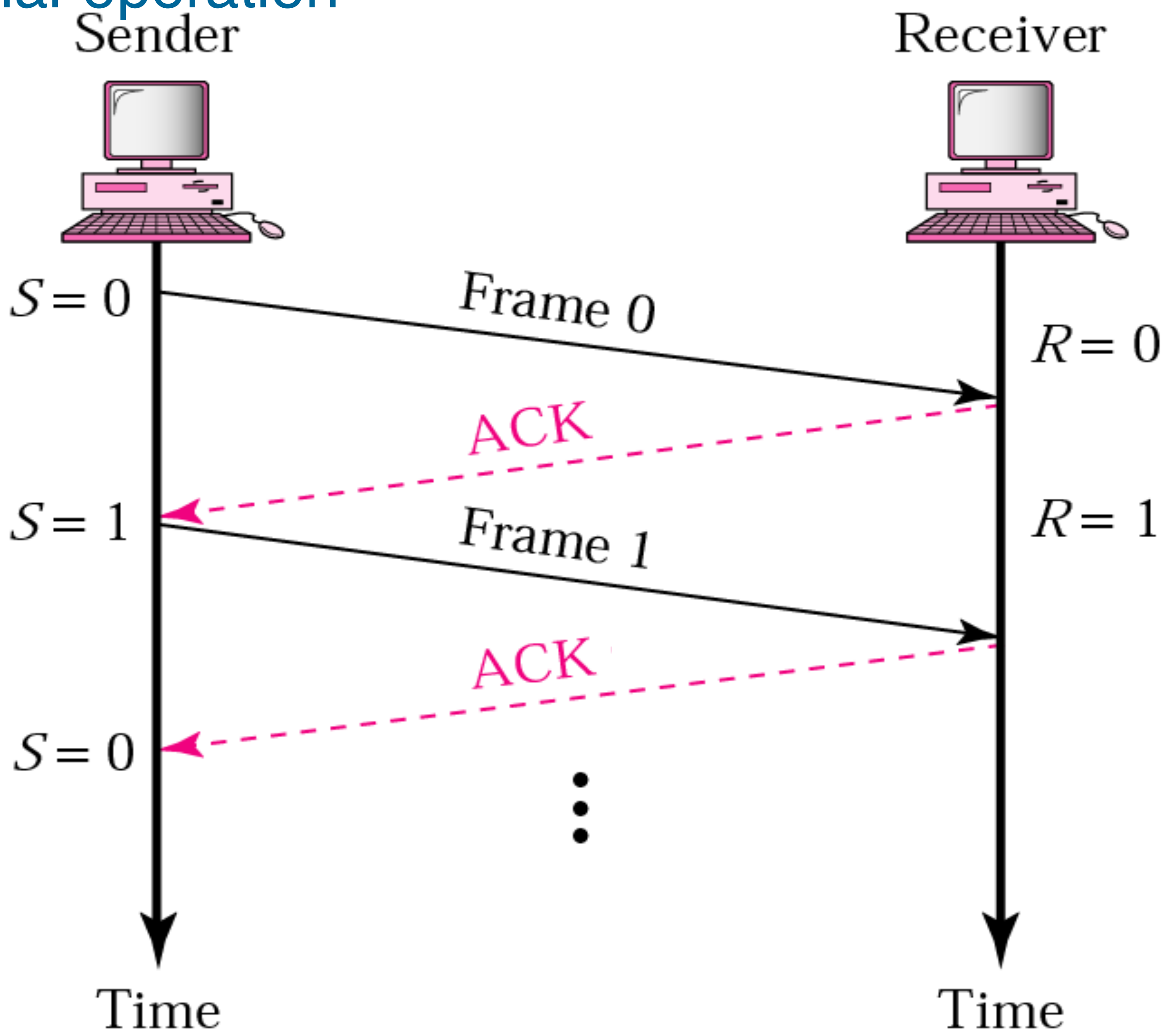
  Source waits for ACK before sending next frame

  Destination can stop flow by not sending ACK

  Works well for a few large frames

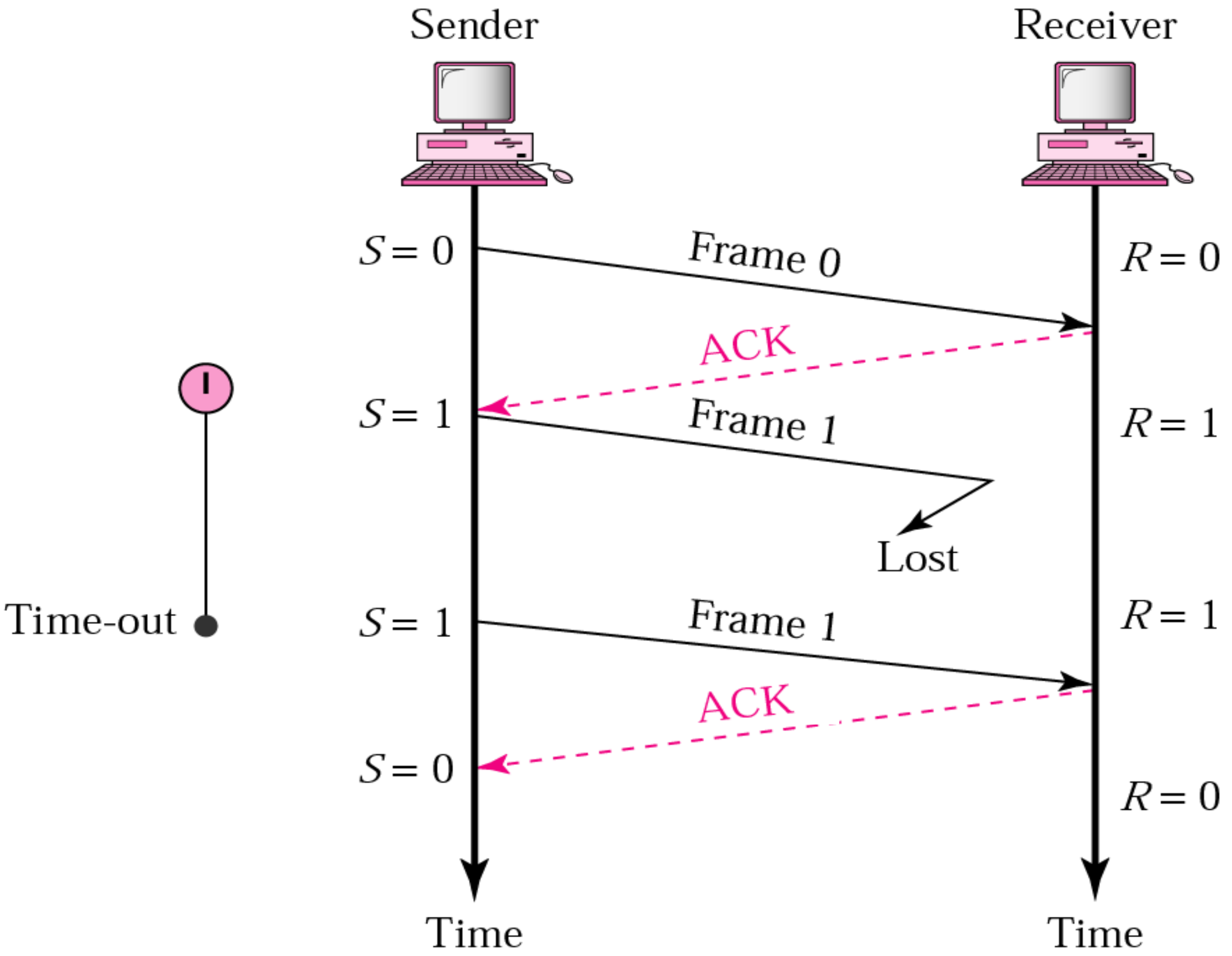
Flow Control

Normal operation



Flow Control

Lost data frame



Flow Control

Stop and wait limitations:

- Inefficient as sender can’t send another frame until either ACK received or timeout – so channel is often empty
- To improve efficiency, multiple frames should be in transition while waiting for acknowledgement (sol: sliding window protocols)

Flow Control

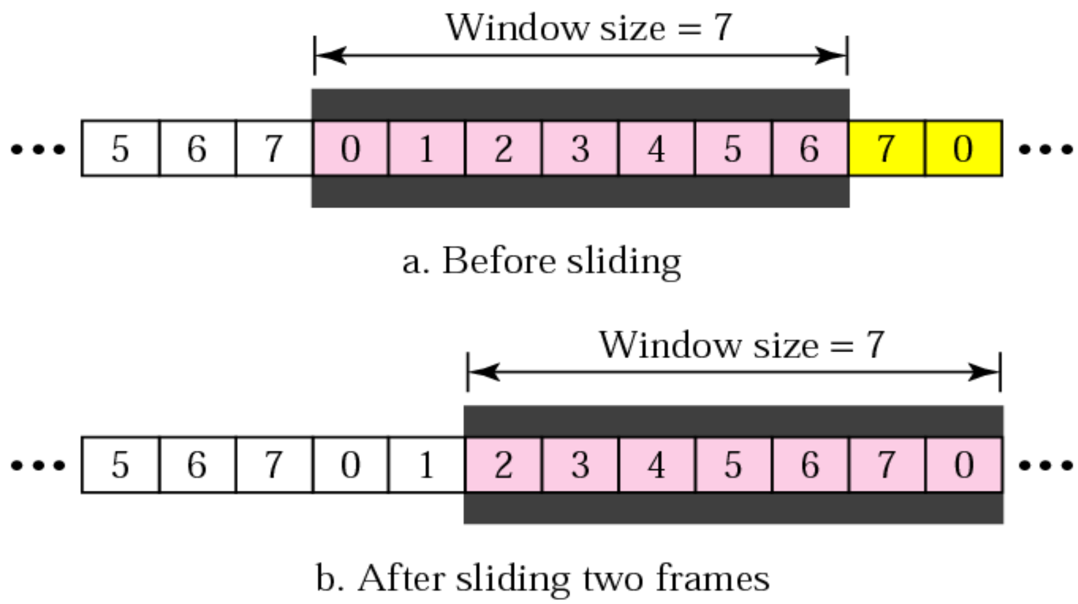
Sliding window

- Allow multiple frames to be in transit
- Receiver has buffer W frames long
- Transmitter can send up to W frames without ACK
- Each frame is numbered
- ACK includes number of next frame expected

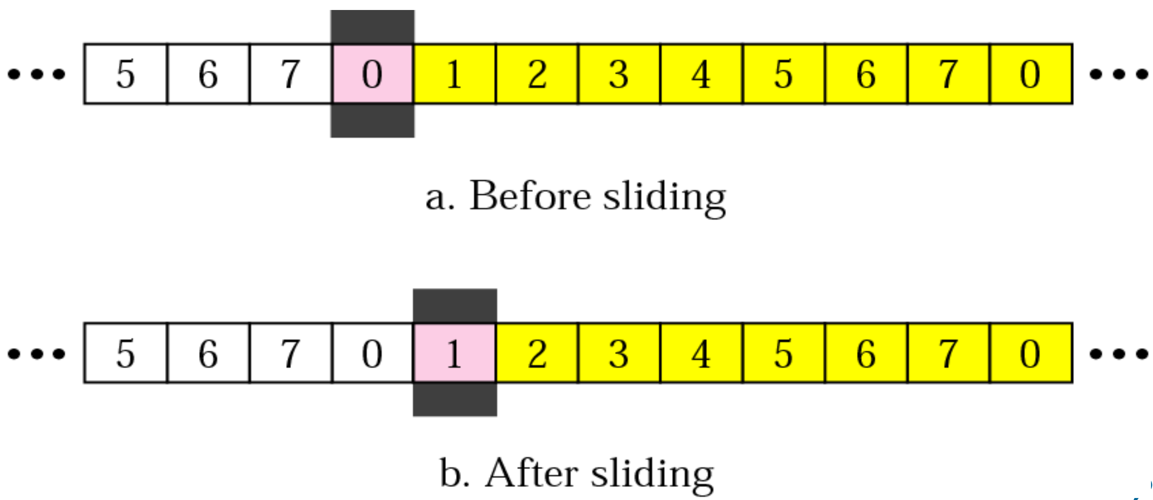
- https://www.youtube.com/watch?v=9BuaeEjIeQI&list=PLVJDTaS7rj9MsS3Rb1reGi4AOTh3gpoP8
-

Sliding window

- Sender window



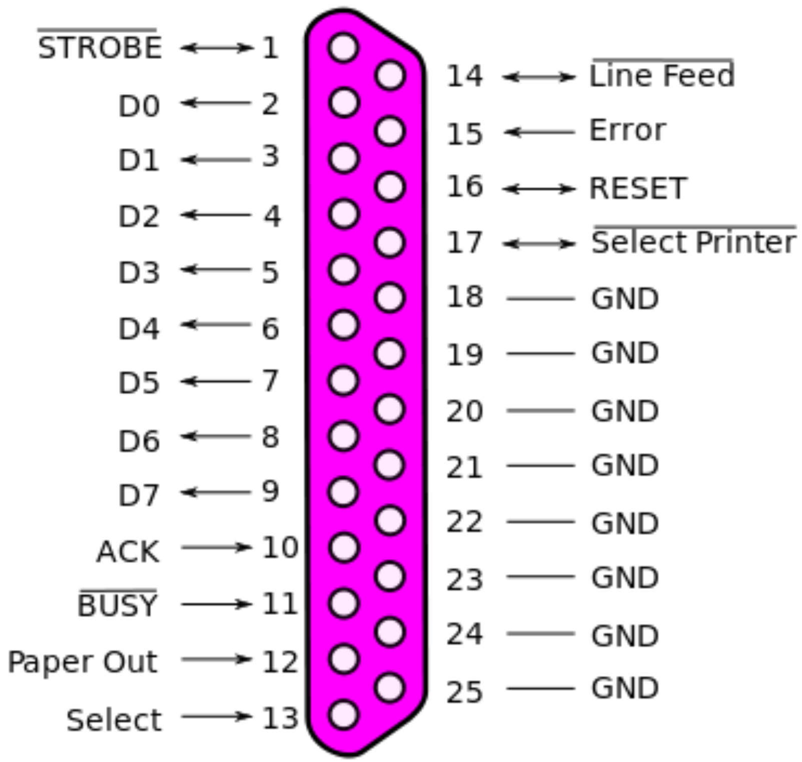
- Receiver window



Flow Control

Hardware for flow control

- could have separate data lines for control



Flow Control & Protocols

Software for flow control

- could have special symbols in data stream used for control

- e.g. ASCII has ACK symbol and device control symbols used for XON, XOFF

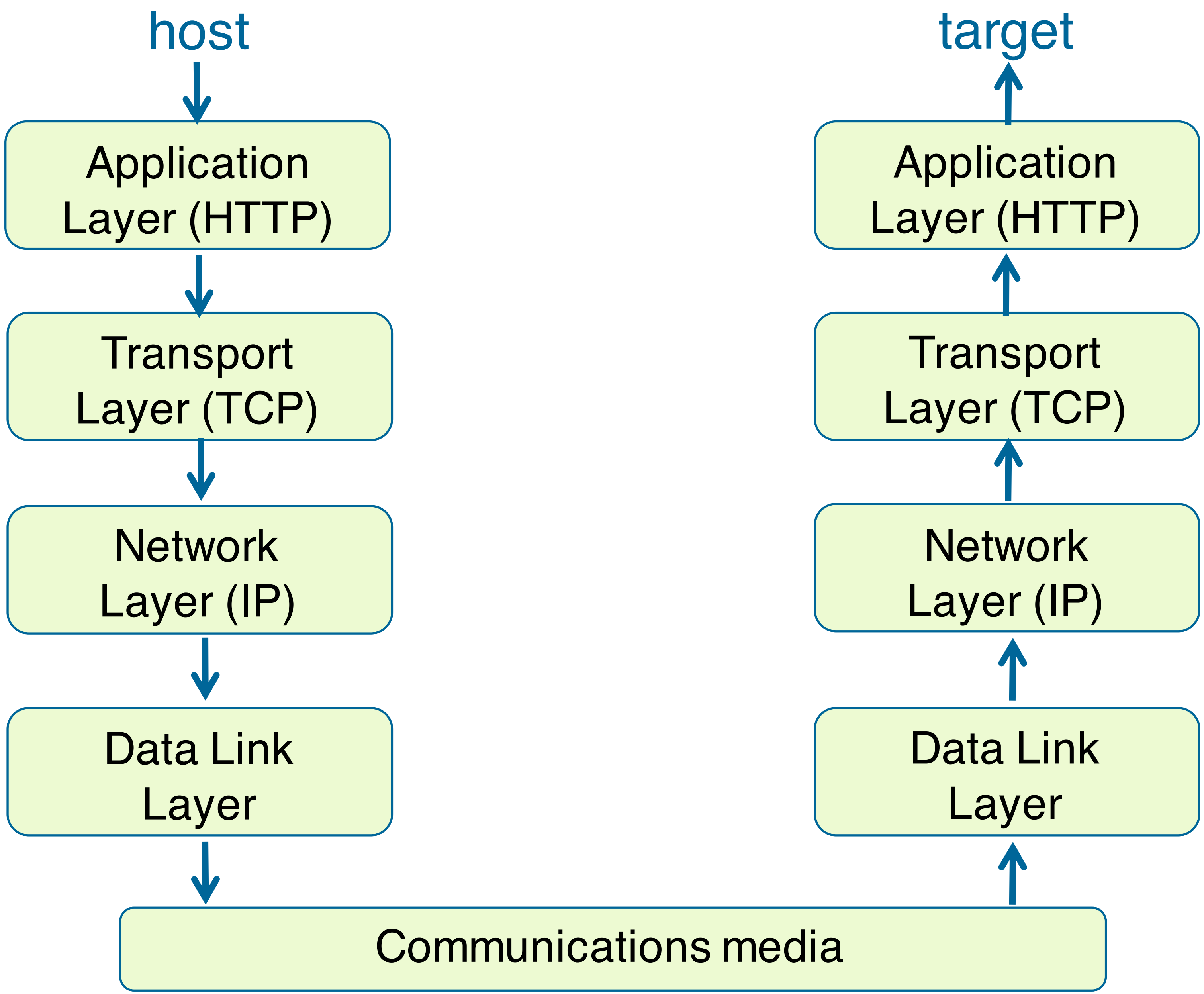
- Common computer network protocols:
  - TCP/IP
  - Ethernet (802.3)
  - WiFi (802.11)

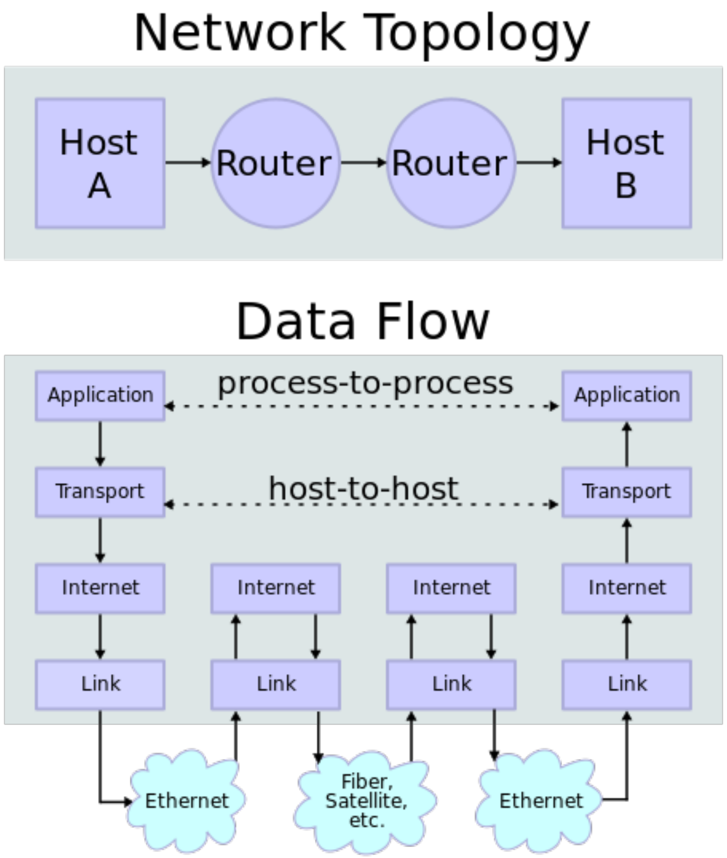
TCP/IP

- TCP/IP are important Internet protocols
- Transmission Control Protocol used by higher protocols to deliver email, transfer files, connect browsers to servers
  - provides high level (transport) interface for performing data transfer
  - provides error checking
  - another protocol, User Datagram Protocol performs data transfer but without error checking and with lower overhead

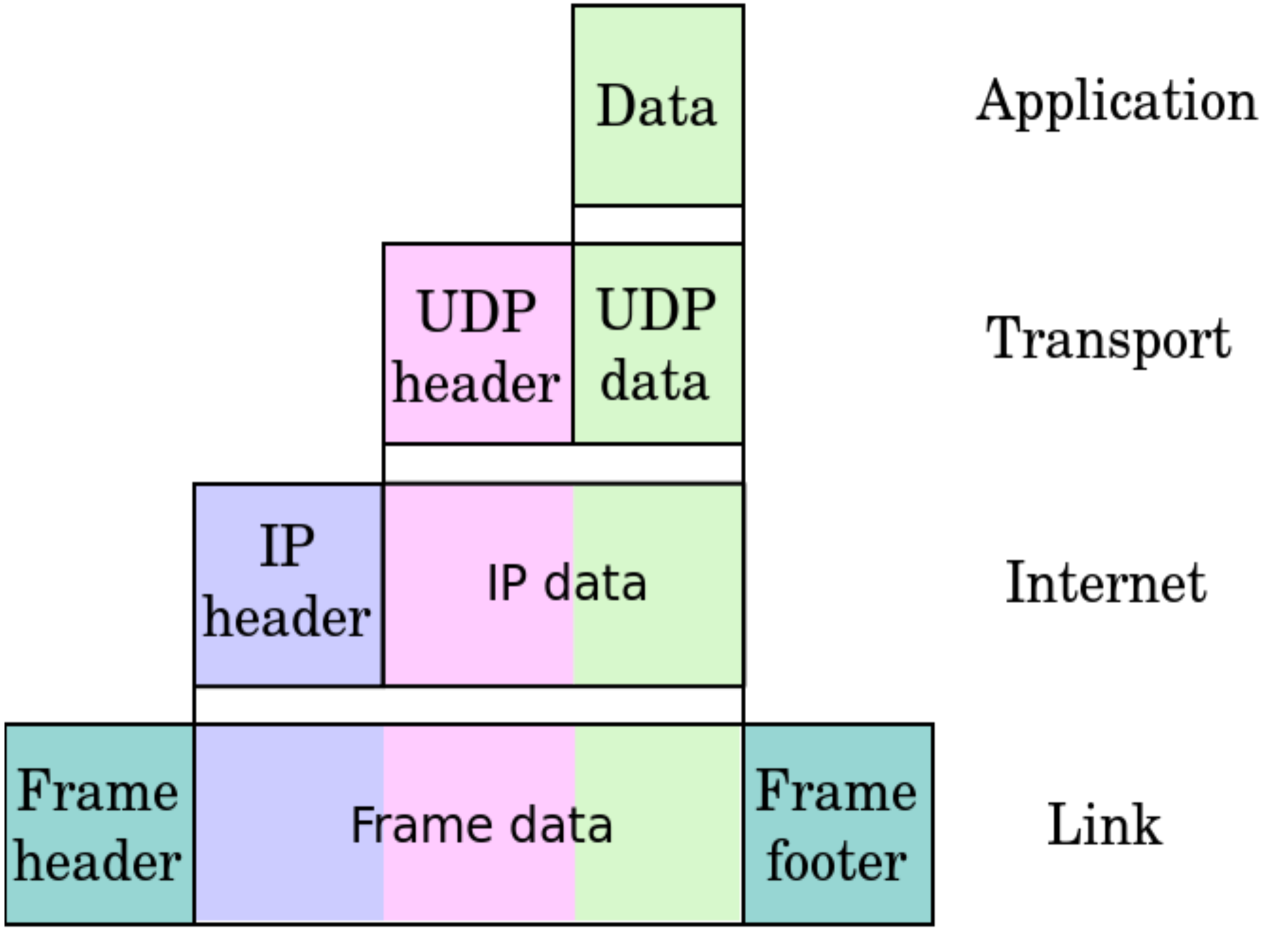
- Internet Protocol
  - lower (network) level protocol:
  - specifies a packet structure for data
  - implements IP addresses
  - routes packets

TCP/IP


host
target
Application Layer (HTTP)
Application Layer (HTTP)
Transport Layer (TCP)
Transport Layer (TCP)
Network Layer (IP)
Network Layer (IP)
Data Link Layer
Data Link Layer
Communications media



"IP stack connections" by en:User:Kbrose - Prior Wikipedia artwork by en:User:Cburnett.



"UDP encapsulation" by en:User:Cburnett

OSI model vs TCP/IP

	OSI	TCP/IP
7	Application	Applications (FTP, SMTP, HTTP, etc.)
6	Presentation	
5	Session	
4	Transport	TCP (host-to-host)
3	Network	IP
2	Data link	Network access (usually Ethernet)
1	Physical	

These type of protocols are used for ”long range” communication

Computer system protocols

Used for things connected directly to the computer (ie short range):

- Peripheral Component Interconnect (PCI) Express
  - general purpose expansion
  - multiple lanes possible, each is a serial point to point connection
    - e.g. WiFi would use 1 lane, a graphics card might use 16
  - full duplex

  - Also PCI (old), AGP
- Universal Serial Bus (USB)
  - used for external connectivity
  - 4 to 5 Gbit/sec (moving to 10 Gbit/sec)
  - can supply power to peripherals

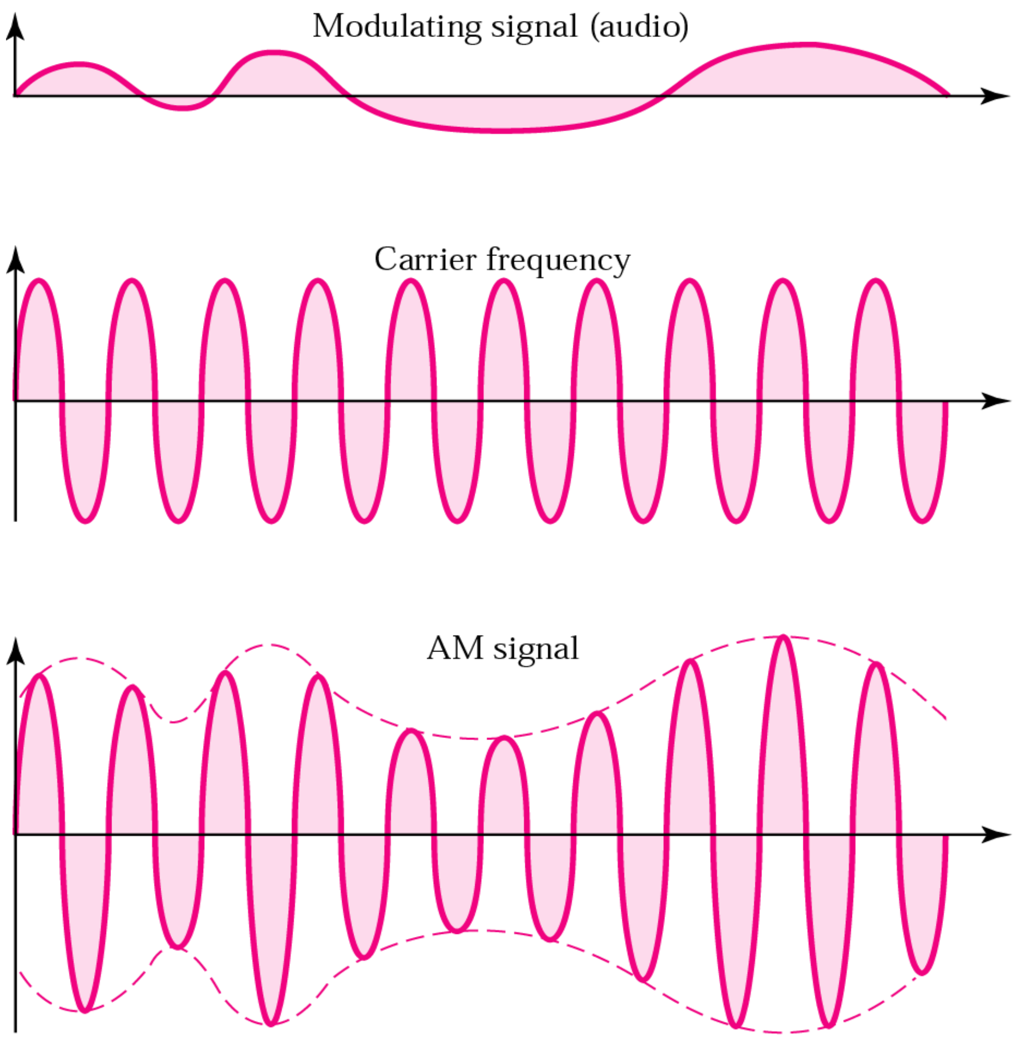
Signal Transmission

- A protocol specifies the logistics for transferring data. How is the transmission physically performed?

- Signal grounding
  – reference to measure signal against

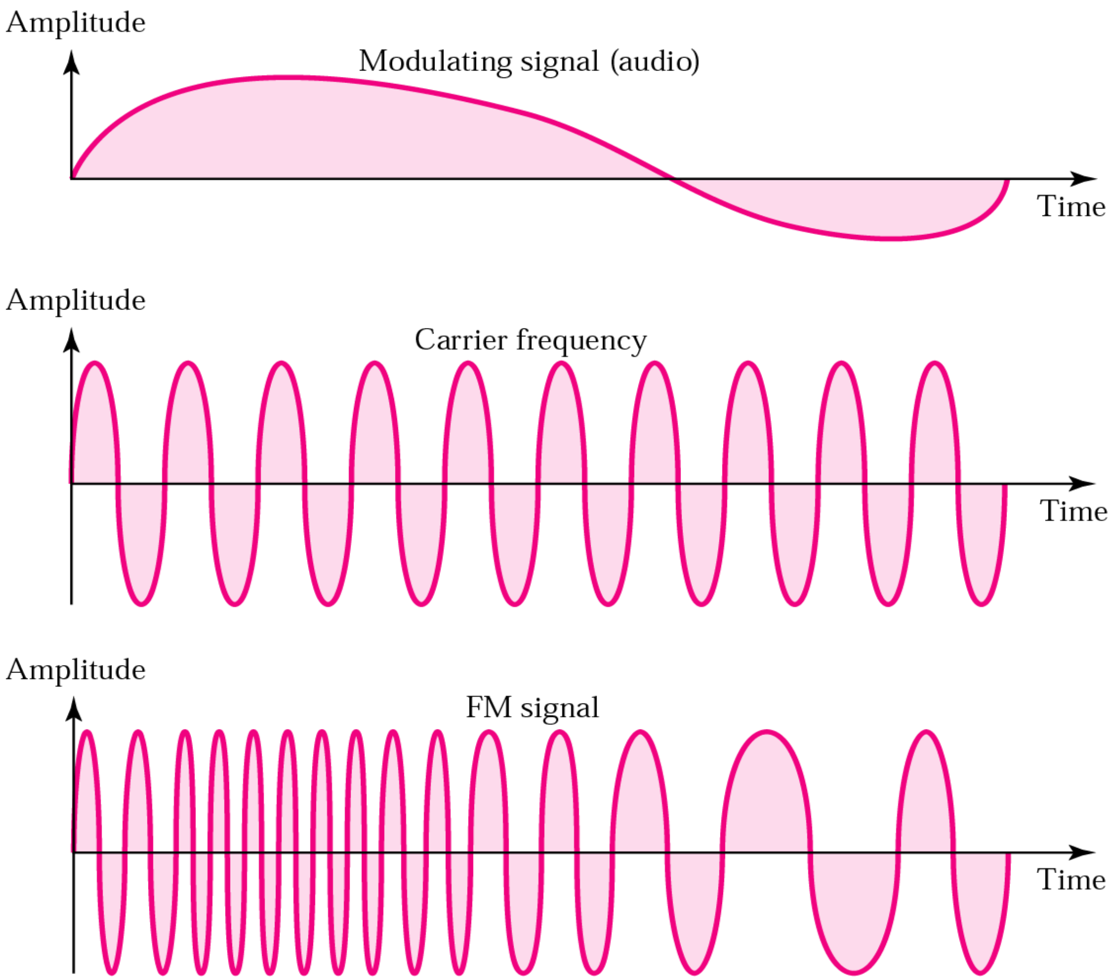
- Analog signals
  – signal values varies continuously
  – many real world signals are analog in nature (e.g. temp)
  – signal modulated (added onto) a carrier frequency
  – main modulations are amplitude (AM) or frequency (FM)

Amplitude modulation (AM)



modulated as a change of amplitude on a carrier signal

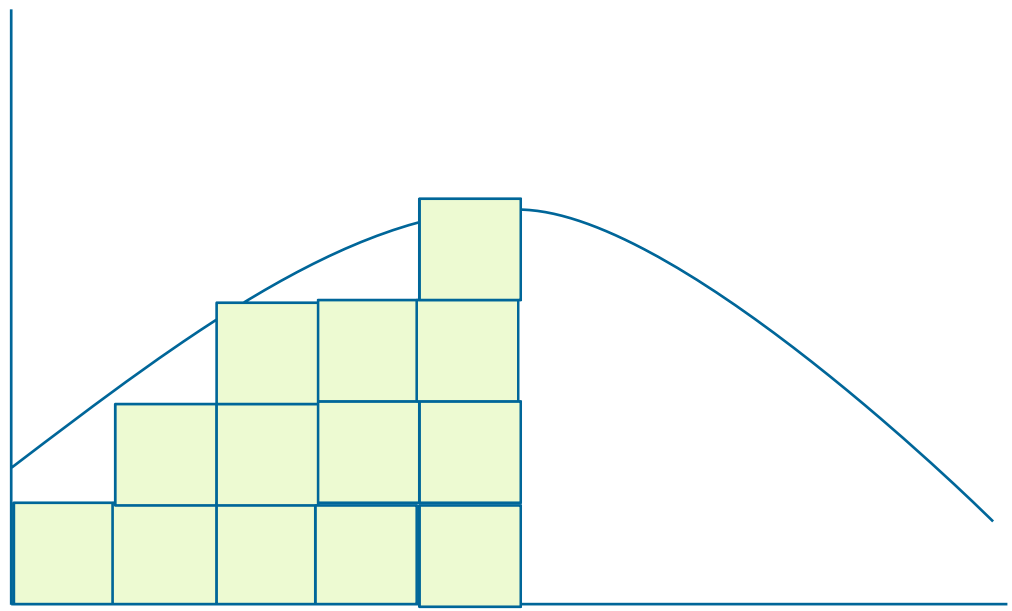
Frequency modulation (FM)



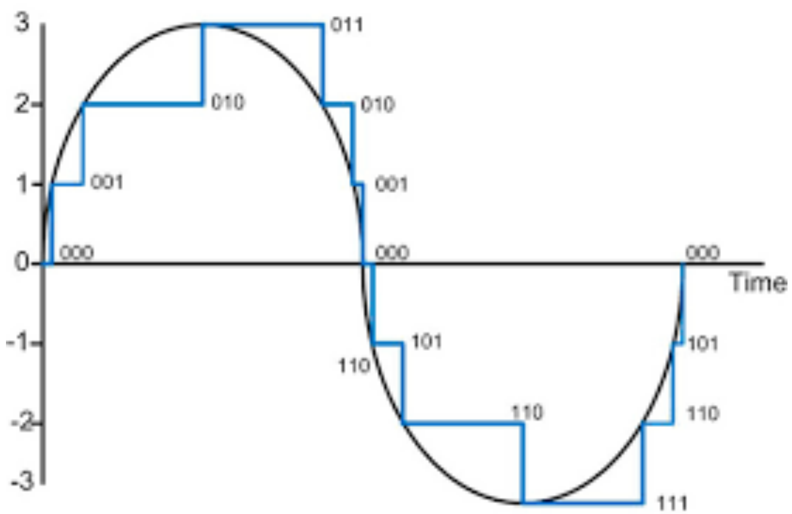
modulated as a change of frequency of a carrier signal

Digital Signals

- Analog signal can be converted to digital signals by quantisation
  - signal sampled at regular intervals and amplitude measured to a certain unit of precision

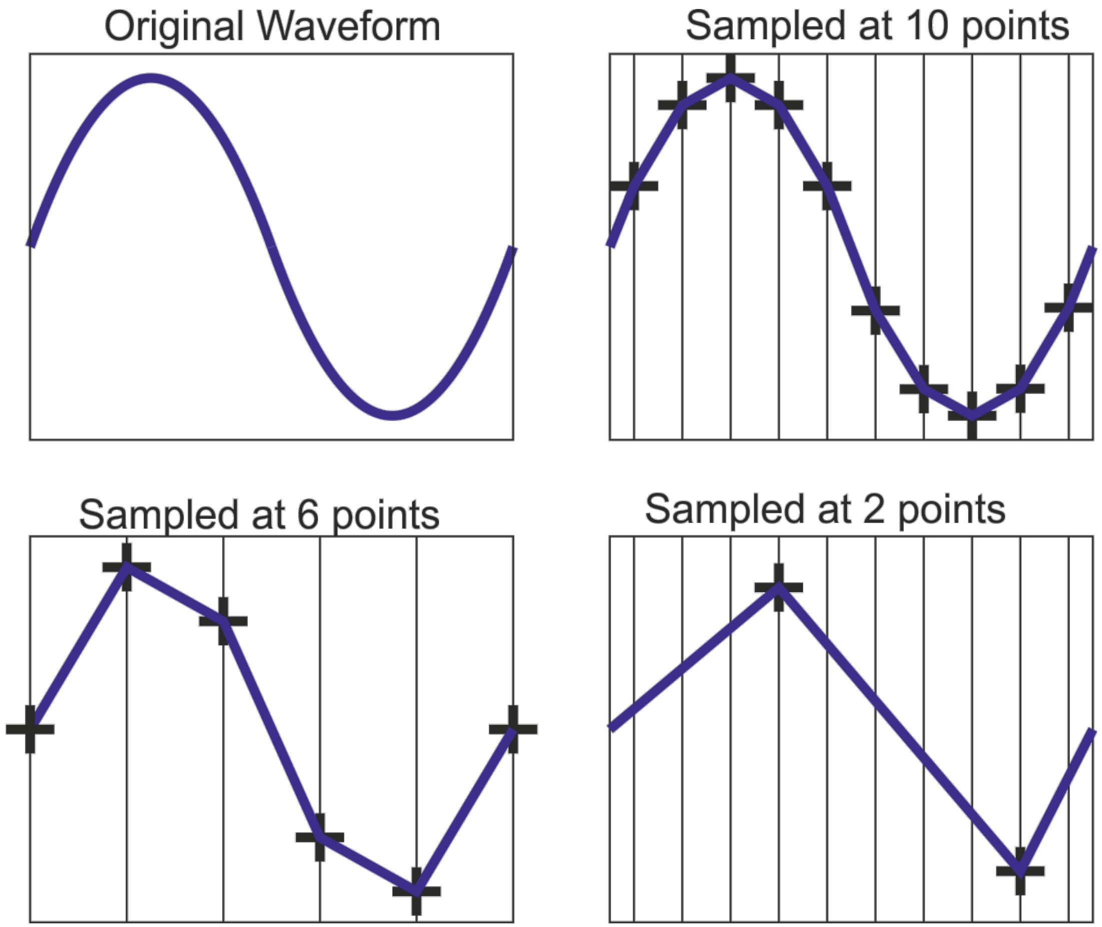


- An analog signal varies continuously
- A digital reading of the signal measures a discrete value at a point in time
- If digital values range from -3 to +3, it can't be 2.5, it has to be 2 or 3



Conversion of Audio Signals to Digital

- The more frequently we sample the signal, the more accurate the digital representation will be:

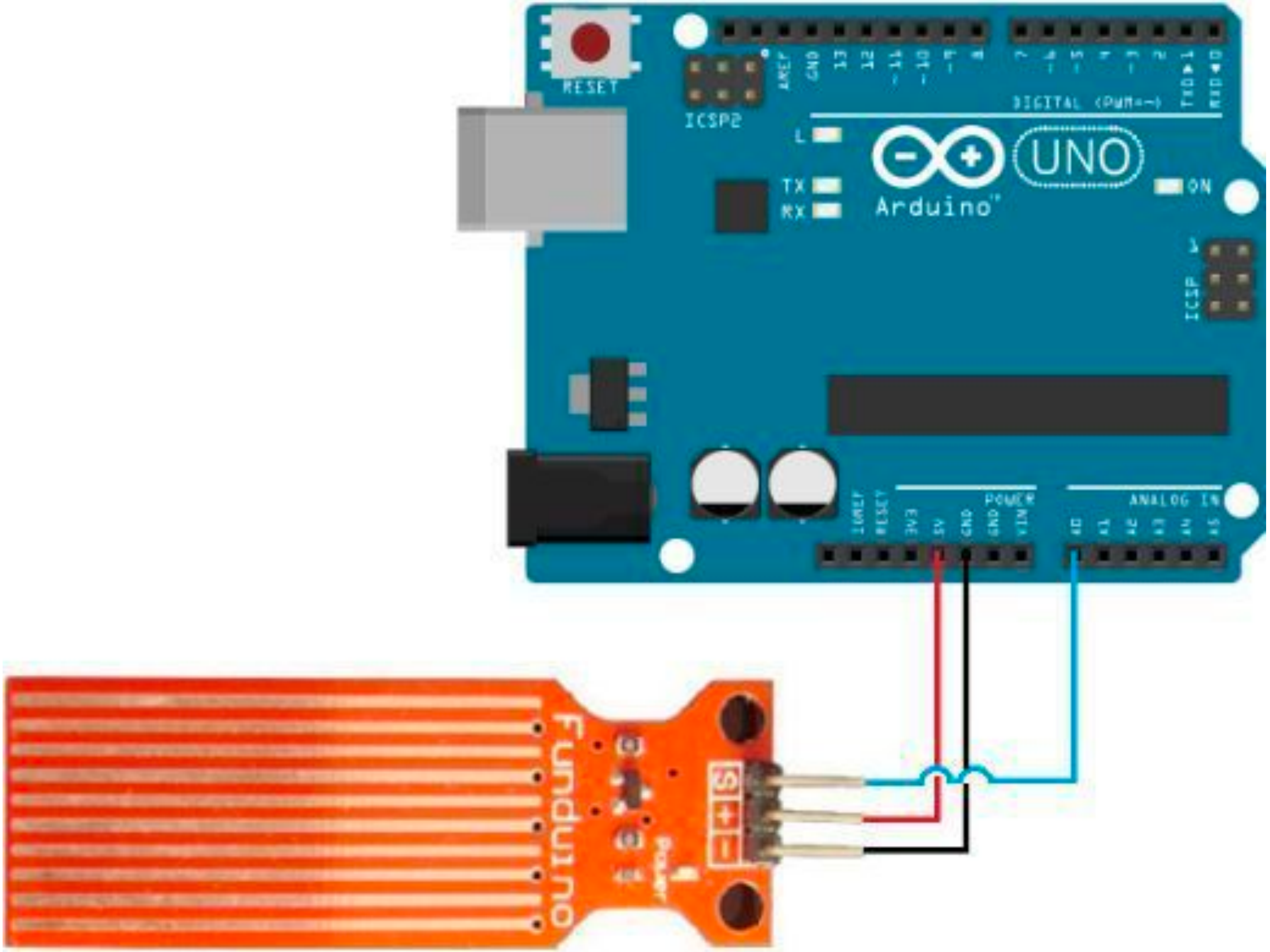


Analog top Digital Converter (ADC)

- A converter measures a signal in terms of an electrical voltage and outputs a number

- Example
- The Arduino boards have an A to D converter that reads a voltage in the range 0 to 5V as input, and outputs a 10 bit result. 0000000000 = 0v and 1111111111 = 5 Volts

Moisture Sensor



Code from Arduino libray

```
int analogPin = 3;     // potentiometer wiper (middle terminal) connected
to analog pin 3
                       // outside leads to ground and +5V
int val = 0;           // variable to store the value read

void setup()
{
  Serial.begin(9600);          //  setup serial
}

void loop()
{
  val = analogRead(analogPin);    // read the input pin
  Serial.println(val);            // debug value
}
```

How do we convert to a Voltage

- 0000000000 = 0v and 1111111111 = 5 Volts
- 1024 values span 0 – 5, so each increase in value represents 5/1024 volts. (a bit less than 0.005 V)
- Any given value n, represents (n / 1024) * 5 Volts
- Eg we measure a value of 0010101010 = 170
- 170/1024 * 5 = 0.83V

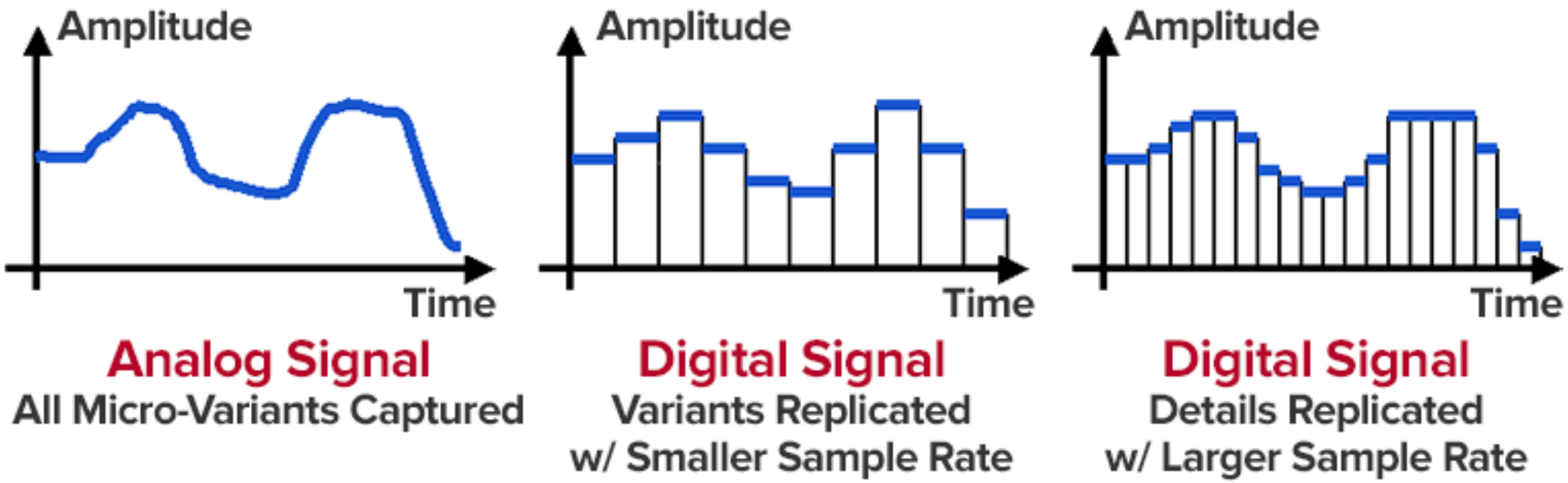
Sampling rate

- If we are converting an audio signal to analog, how often to we need to sample the signal?

- It depends on the frequency of the signal

- A high frequency signal needs to be sampled more often than a low frequency signal to get a “reasonable” representation

- If the sampling rate is too low, then the digital signal will not sound sufficiently similar to the original sound



- For recordings of audio and music, the normal frequency range of the sound is about 50Hz – 20kHz (range of human hearing).

- To get high quality digital sound, the sampling rate is normally around 44kHz – approximately double, which is a consequence of the Nyquist theorem

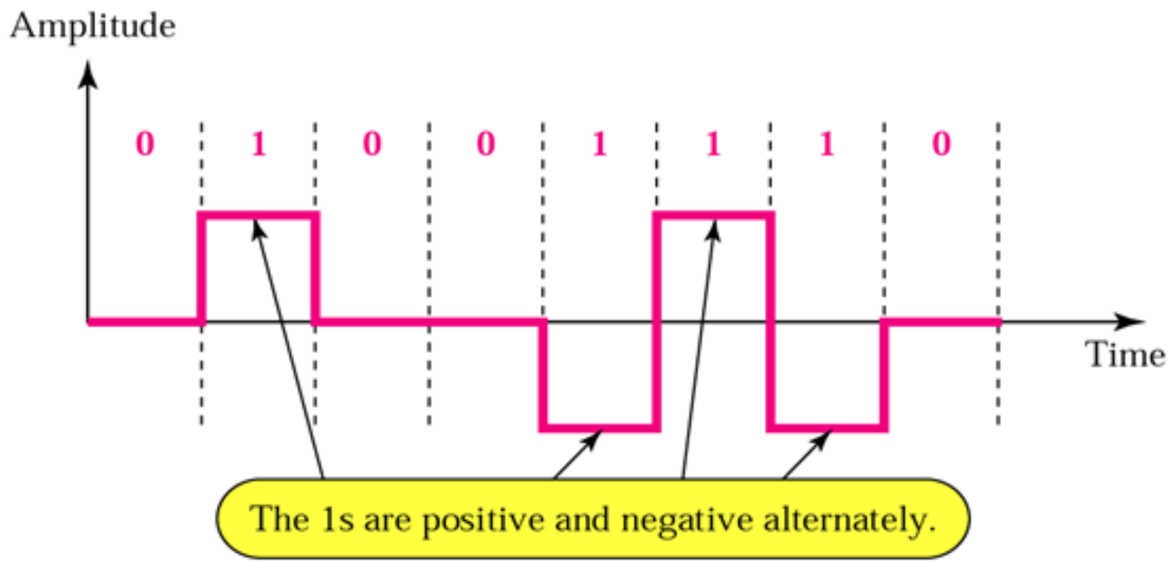
https://en.wikipedia.org/wiki/Nyquist/Shannon_sampling_theorem

Digital signals

- Vary in discrete steps (e.g. binary represented as two different voltage levels)

- Can encode signals ‘as is’ (e.g. 0 = one voltage, 1 = another voltage)
  - called unipolar encoding
  - not popular (other systems result in more reliable transmission)

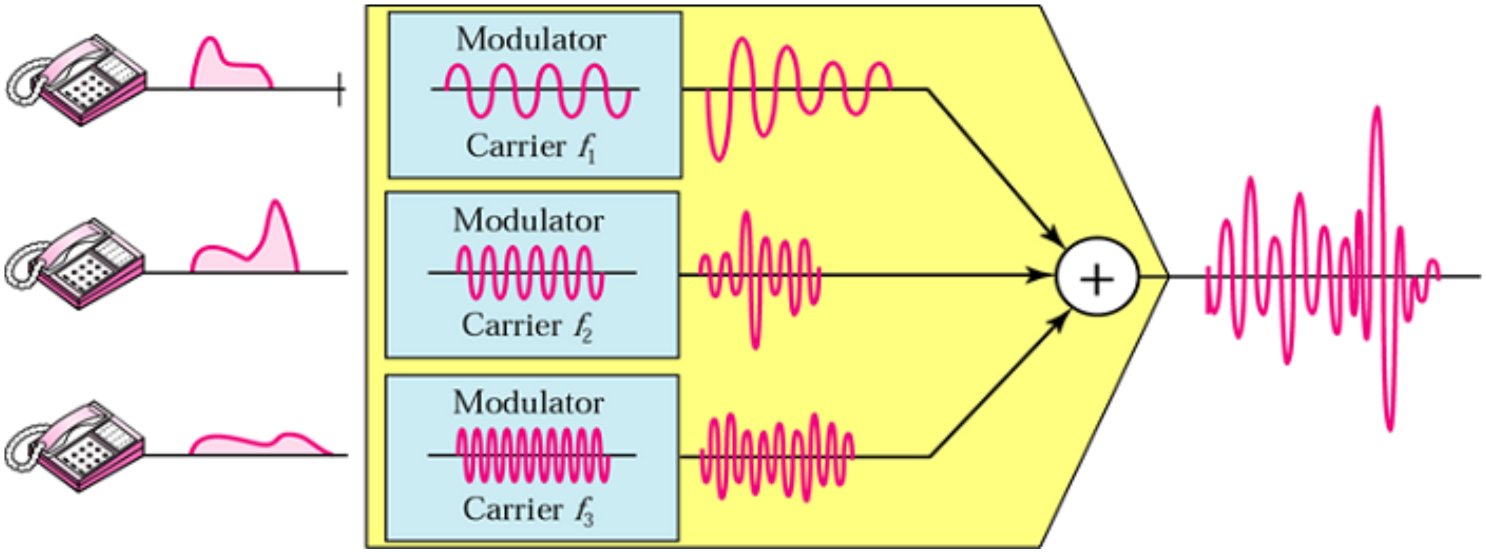
- Bipolar encoding:
  switching between positive and negative voltage



Multiplexing

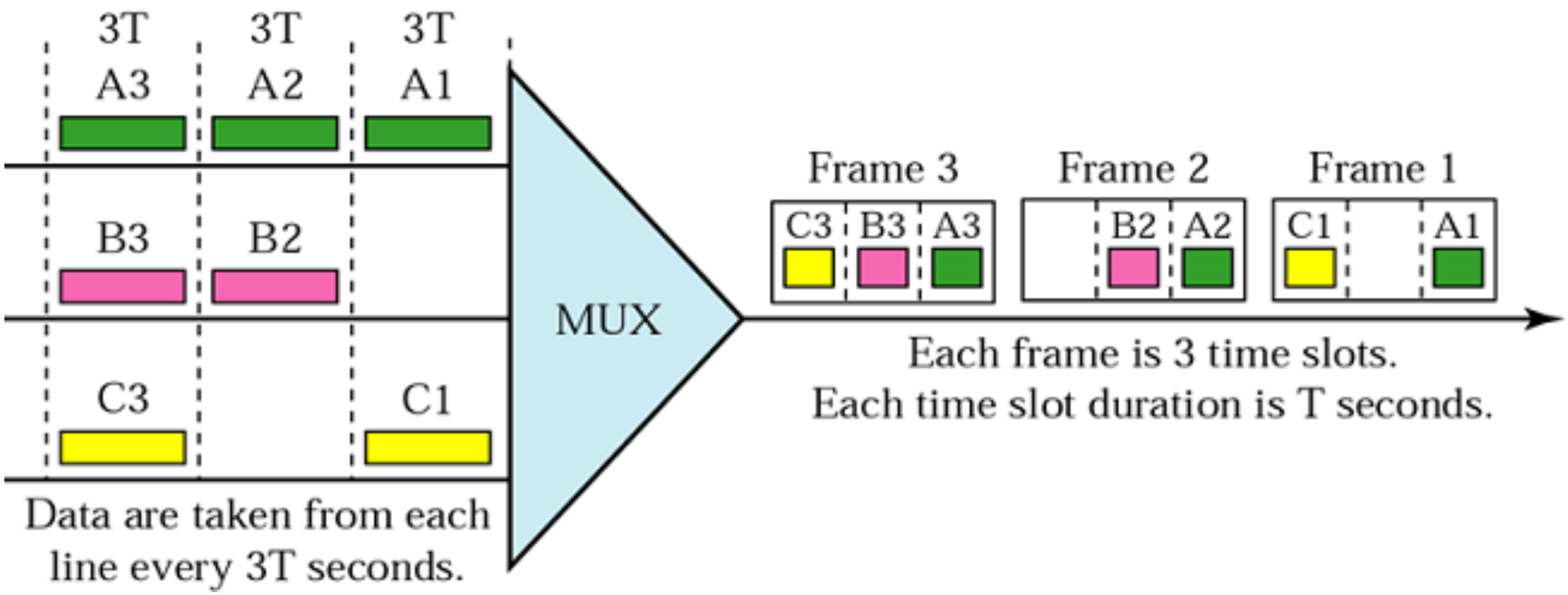
- Multiplexing is the combining of several signals over one link

- Frequency-division multiplexing
  - shift each signal to a different frequency on the link
  - example: radio broadcasts



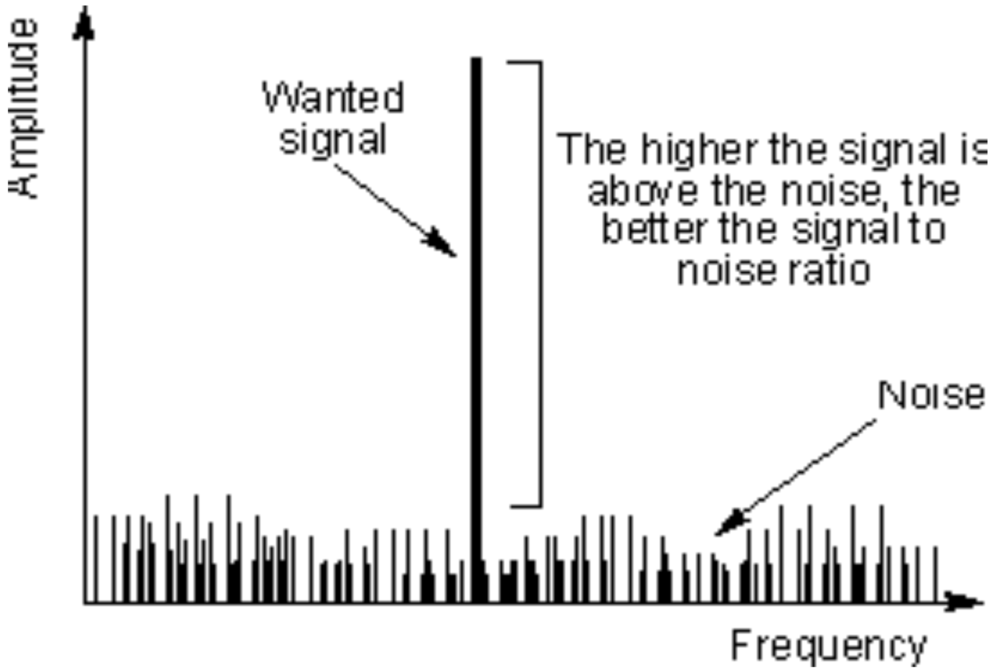
Multiplexing

- Time-division multiplexing
  - break each signal into ‘slices’, and transmit X slices from each signal



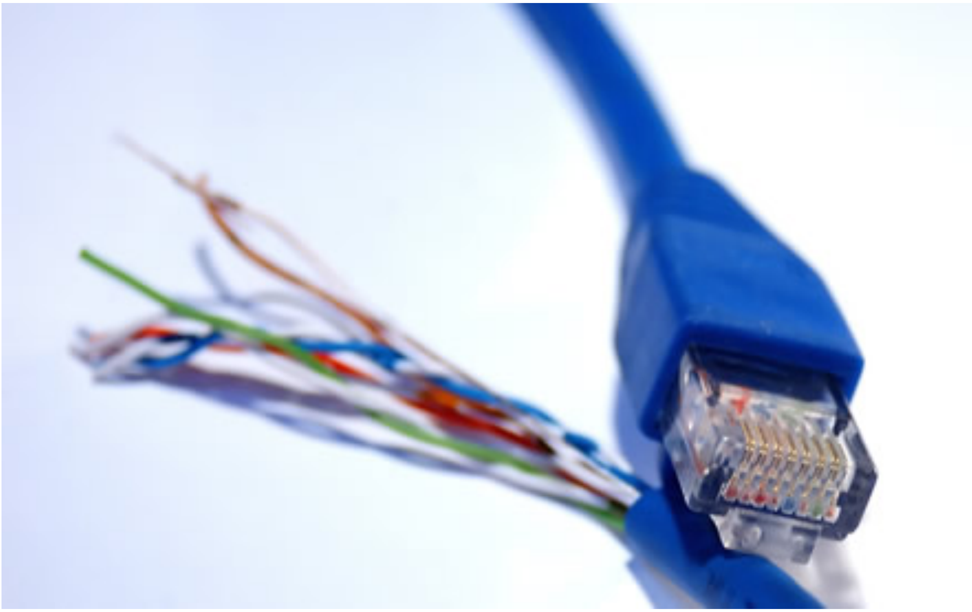
Interference

- Interference is ‘noise’ in a signal
  - can measure the ‘signal to noise’ ratio



Minimising noise

- *Balanced lines* attempt to have the ground and the signal lines equally affected by the noise
  - can subtract the ground noise from the noisy signal to get a clear signal
  - can be implemented by twisting together the signal and ground line (forming a twisted pair line) e.g. in Ethernet cables



Minimising noise

- Spread spectrum
  - spread the signal over a large bandwidth, so noise on one part of the bandwidth won't smother the signal

- Frequency hopping spread spectrum
  - hop between frequencies when transmitting, in a pre-arranged (possibly pseudo-random) fashion
  - transmitter and receiver must stay synchronised

Signal Attenuation

- Attenuation is the reduction in strength of a signal
  - e.g. absorption of signal (e.g. light absorption in fiber optics, radio microwave frequencies absorbed by rain, diffraction or reflection of radio signals by objects)

- Reduce effects of noise due to attenuation by:
  - increasing transmission power or increasing sensitivity of receiver
  - increase shielding of communication medium
  - moving cables or antennas away from RF noisy environments
  - using a directional antenna

Timing issues

- Accurate timing can be vital for correct communication

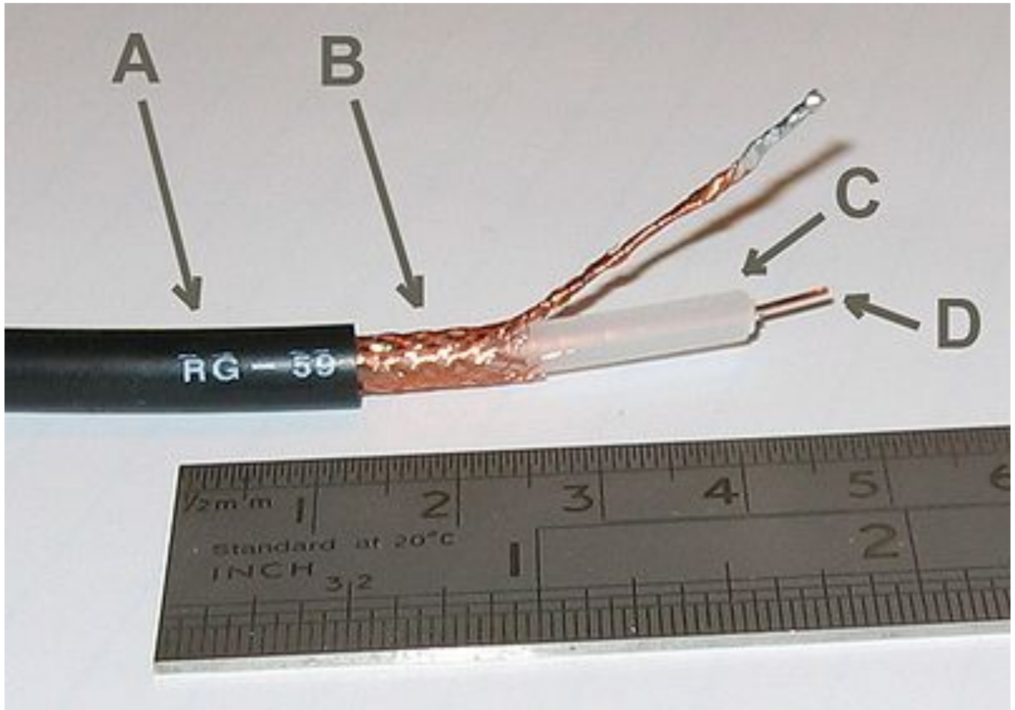
- (Network) Propagation delay
  - time taken for start of a signal to travel from sender to receiver

- Latency
  - time taken for entire data packet to travel from sender to receiver

- If a link is too long:
  - propagation delay/latency over a long link can become too large for a time-based protocol to handle
  - attenuation can degrade a signal until it is unrecognisable

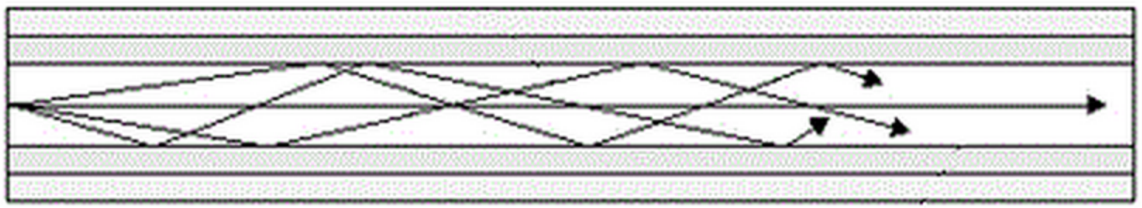
Communication Mediums

- Copper wiring
  - the most common type of wiring
  - often as twisted pair to minimise noise
  - yes, there are standards for wiring (e.g. TIA/EIA-568 category 5 for Ethernet), cat 3 10Mbs, cat 4 20 Mbs cat 5 100Mbs cat 6 10Gb
- Coaxial wiring
  - unbalanced pair
  - often used to connect computers with antennas
  - (A) outer jacket
  - (B) shield
  - (C) insulator
  - (D) signal wire



Communication Mediums

- Optical fibre
  - transparent glass or plastic wire that internally reflects a light signal along the length of the wire
  - can carry orders of magnitude more data than a copper wire
  - used for very high capacity computer networks, trunk telecommunication lines, some broadband networks

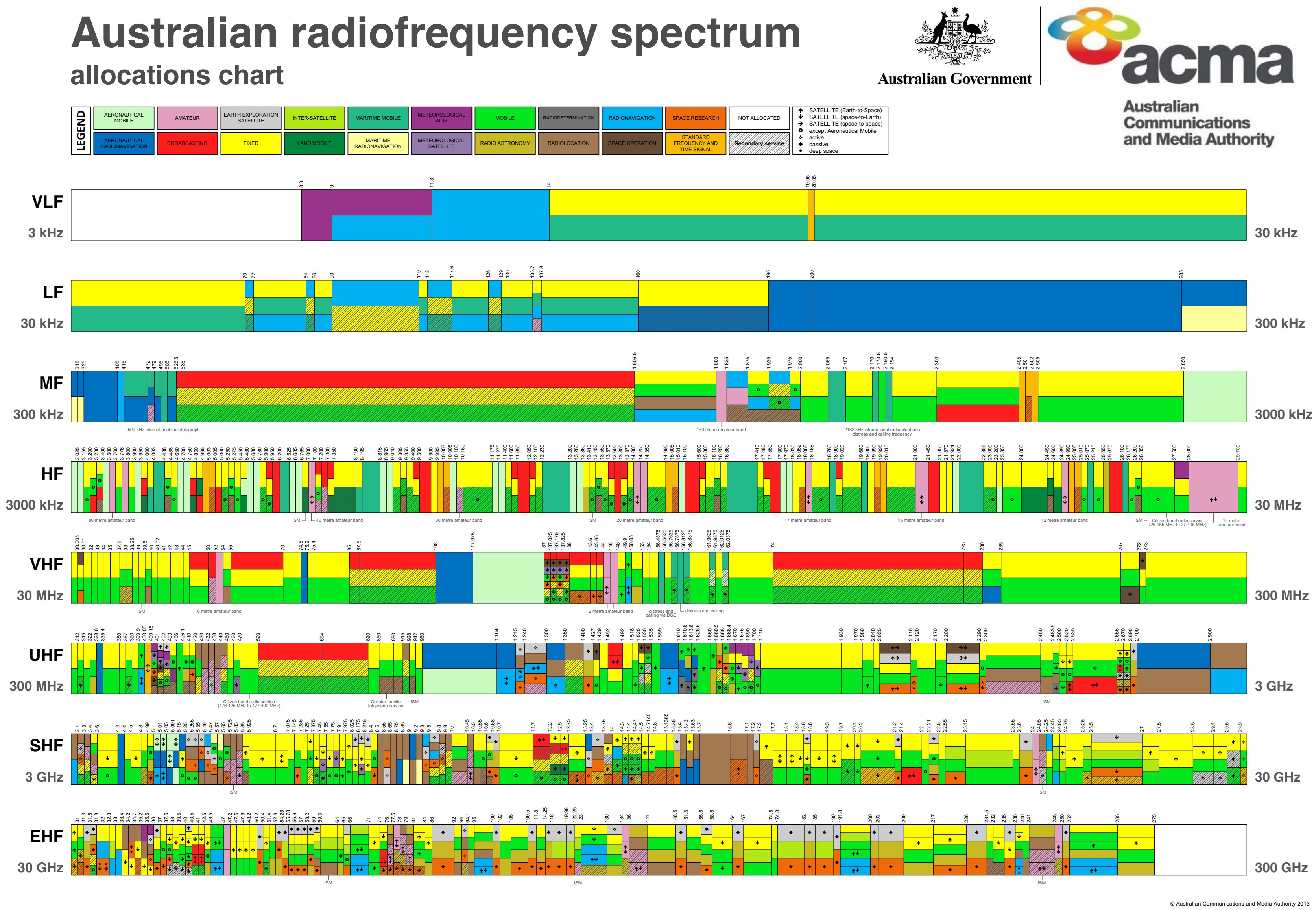


Radio frequency spectrum

- Radio frequency spectrum is a shared environment
  - regulated by government agency to ensure controlled use
  - Australian Communications and Media Authority
  - auctions have been used to sell rights to frequencies
  - auctions for 3G mobile phone bands sold for $1.17 billion

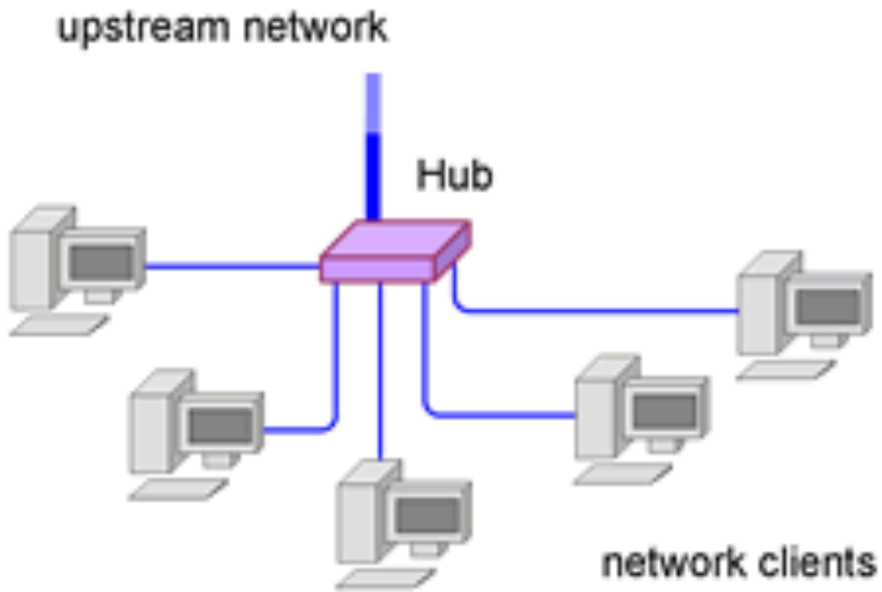
U.S.A spectrum allocation

Radio frequency spectrum



Wired Ethernet (802.3)

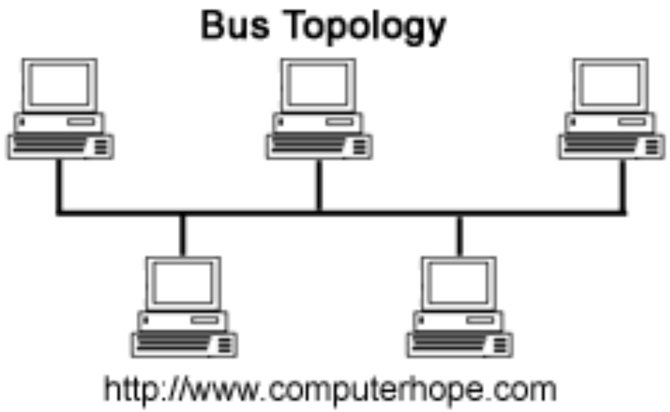
- Ethernet is both a protocol for Data Link layer communication, and a set of associated standards for the Physical Layer.



  – It can use Star topology

Wired Ethernet (802.3)

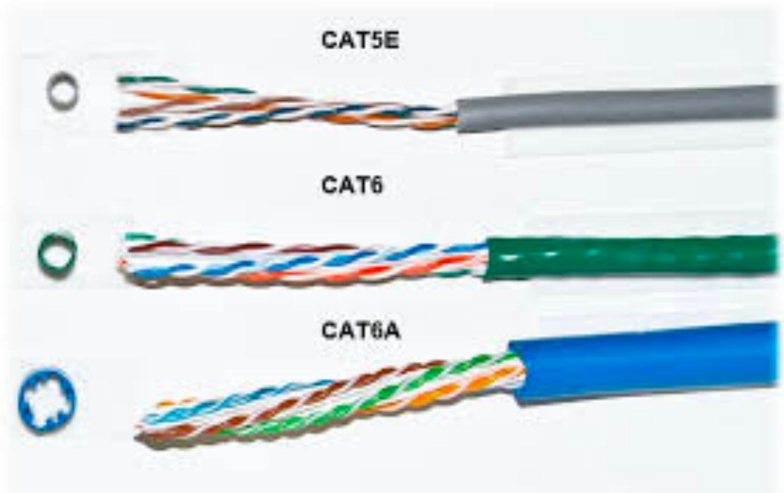
- But can also use “Bus” topology



- Wired Ethernet uses a protocol called CSMA/CD (which stands for Carrier Sense Multiple Access / Collision Detect)

Ethernet

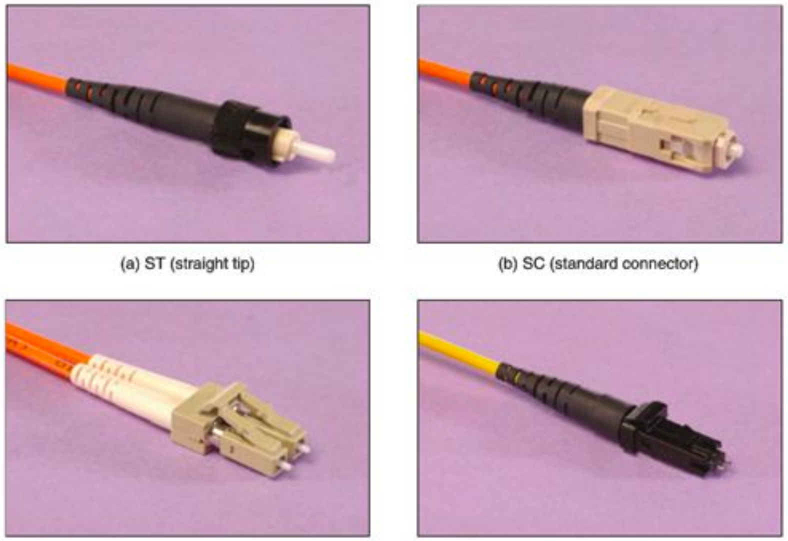
- The Physical layer standards define the type of medium (Coax, twisted pair variation)



- the type of connector:

Types of Ethernet Connectors

- RJ 45
- BNC connector for coax cable
- Fiber optic connectors



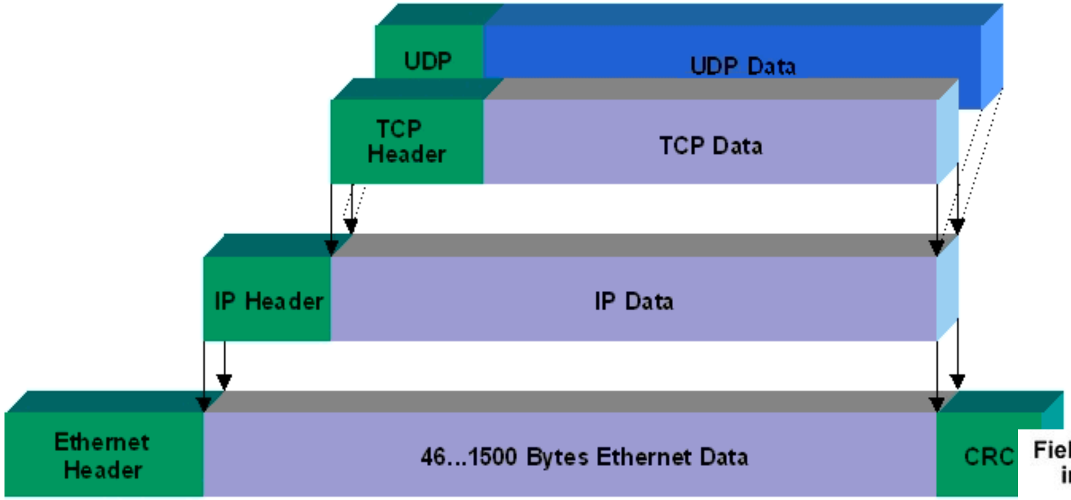
(a) ST (straight tip)
(b) SC (standard connector)
(c) LC (local connector)
(d) MT-RJ (mechanical transfer RJ)
Courtesy Fiber Communications, Inc.

Physical Layer Speeds

Ethernet Standard Cable Length & Speed						
		Distance	Speed			
	10Base-T	100 meters	10 Mbps	Twisted Pair	Copper	CAT 3
	100Base-T	100 meters	100 Mbps	Twisted Pair	Copper	CAT 5
	1000Base-T	100 meters	1 Gbps	Twisted Pair	Copper	CAT 5e
	1000Base-T	55 meters	1 Gbps	Twisted Pair	Copper	CAT 6
	10GBase-T	100 meters	10 Gbps	Twisted Pair	Copper	CAT 6a
Fiber						
	100Base-FX	2 K	100 Mbit	Fiber Pair	Fiber Optic	Muti-mode
	1000Base-X	Used to refer to Gigabit Ethernet transmission over fiber, where options include 1000BASE-SX, 1000BASE-LX, 1000BASE-LX10, 1000BASE-BX10 or the non-standard -EX and -ZX.				
	1000Base-LX	5K or more	1 Gbit	Long (wavelegth) LX	Fiber Optic	Single mode
	1000Base-SX	550 meters	1 Gbit	Short (wavelength) SX	Fiber Optic	Muti-mode
10 Gigabit Fiber						
	10GBase-SR	300 Meters	10 Gbit	Short Range	Fiber Optic	Muti-mode
	10GBase-LR	10K-25K	10 Gbit	Long Range	Fiber Optic	Single Mode
	10Gbase-ER	40K	10 Gbit	Extended Range	Fiber Optic	Single Mode
ISPs/Wans Fiber						
	10GBase-SW	300 meters	10 Gbit	Short WANs	Fiber Optic	Mutimode
	10GBase-LW	10K-25K	10 Gbit	Long WANs	Fiber Optic	Single Mode
	10GBase-EW	40K	10 Gbit	Extended WANs	Fiber Optic	Single Mode
Note:	The above 3 are used to intergrate 10Gig Ethernet into SONET & SDH					

Ethernet Data Link Layer

The Data Link Layer defines the structure of the packets (what the bits mean), and how the protocol works



Ethernet

Field Length, in Bytes	8	6	6	2	46-1500	4
	Preamble	Destination Address	Source Address	Type	Data	FCS

IEEE 802.3

Field Length, in Bytes	7	1	6	6	2	46-1500	4
	Preamble	SOF	Destination Address	Source Address	Length	802.2 Header and Data	FCS

SOF = Start-of-Frame Delimiter
FCS = Frame Check Sequence

learncisco

Wireless Ethernet (802.11)

- WiFi
  - introduced 1997
  - Half Duplex modulation
  - Initially used 2.4Ghz ISM band (now also uses 5.0Ghz)
  - latest standard (2014) allows speeds up to 1Gbit/sec in theory
  - peak rates rare: interference & channel congestion common.
  - In some countries this range can overlap with other uses, such as amateur radio, which can occasionally lead to interference.

Wireless Ethernet (cont)

- 1997 802.11a original standard 1 – 2 Mbits
- 1999 802.11b 11 Mbits
- 2003 802.11g 54Mbits backwards compatible
- 2009 802.11.n introduced MIMO (Multiple Input / Multiple Output) theoretical rates upto 600Mbits
- 2013 802.11.ac wider channels (80 or 160 MHz instead of 40Mhz) – data rates up to 1300Mbits
- These all use 2.4 or 5GHz channels
- Rates depend on slowest component and signal strength.

Wireless Ethernet (cont)

- 2013 802.11ad (not widely used) 60GHz transmission spectrum, date rates upto 7Gbits but very short distance.

- 2016 802.11.ah 347Mbits, increased range

- Nov 2019 (est) 802.1.ay 20Gbits

Wifi throughput

- The actual throughput from a wifi connection will depend on several things
- The speed of the source (Your ISP)
- The speed of the slowest connection, usually, but not always the connection from the wifi transmiter to device
- The strength of the Signal

Signal Strength

- Signal strength is measured in dBm decibel milliwatts
- What signal strength is acceptable?
- Around -70dBm is the minimum
- -50 to -60dBm is good
- > -50dBm is excellent

Measuring Signal strength

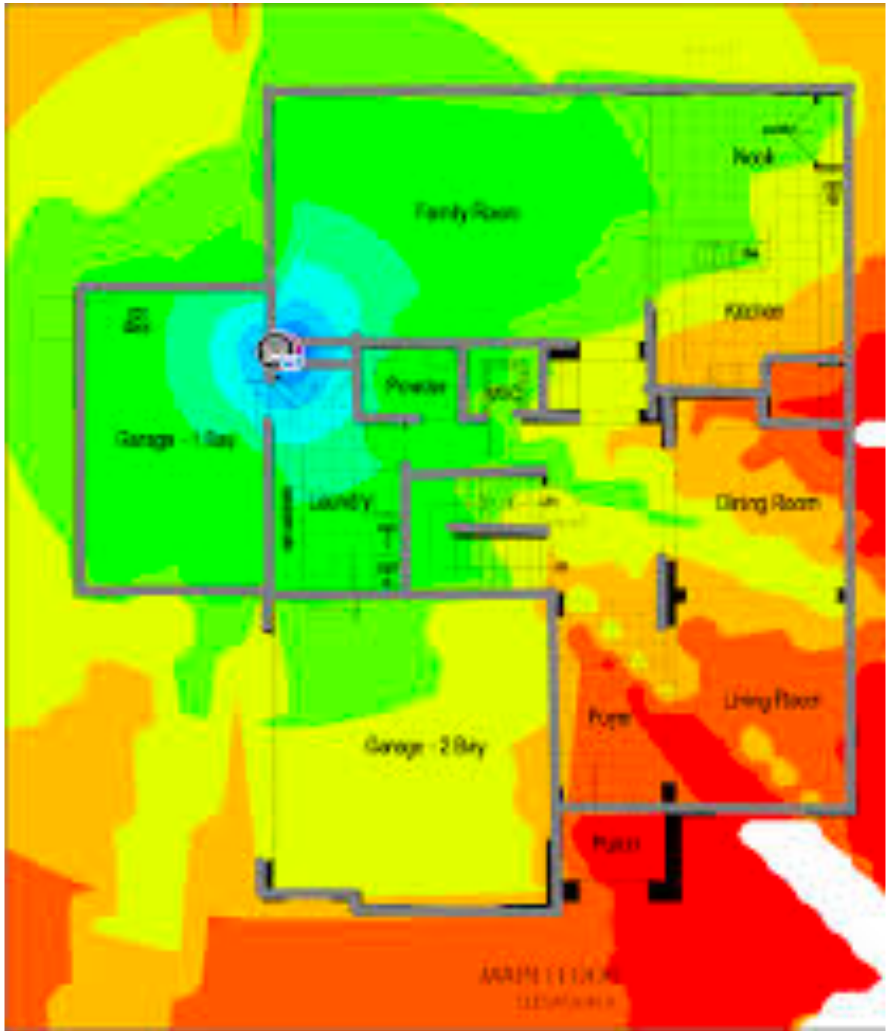
Signal strength can be measured with an RF signal meter

However you can also use your phone or PC.

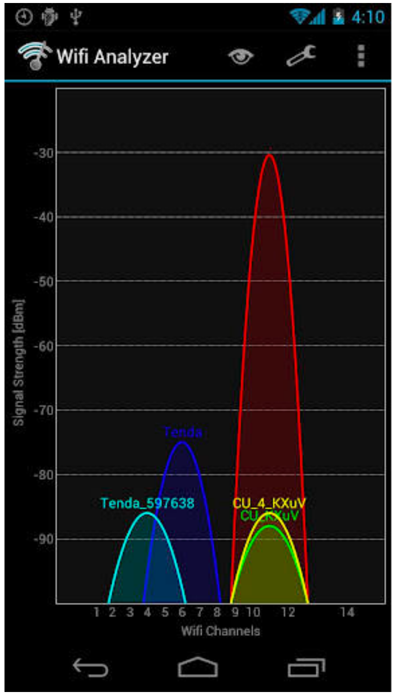
There are many apps available

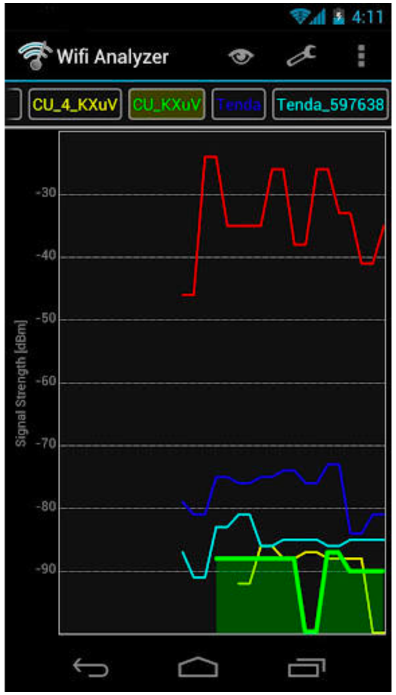
Not all will give you signal strength in dBm however

Wifi Signal reception varies



iPhone and Android apps





How to improve wifi signal strength

- More powerful signal (upgrade router)
- Larger antenna
- Better placement of router
- Use a better Wifi channel
- Quality of Service (QoS)
- Range Extender

Signal Strength

- Influences the strength of the signal sent from the router to wifi devices
- The other factor is antenna design

- Typical figures are 32-100 mW, measured at the source

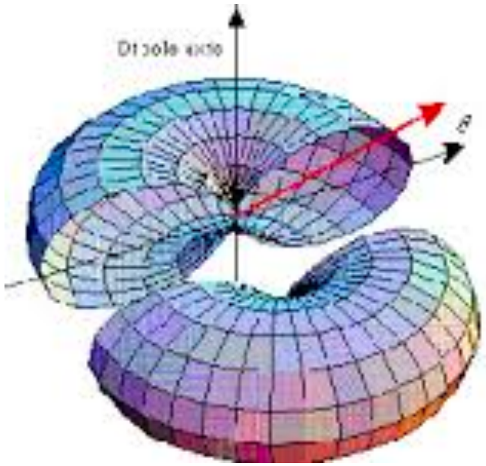
- Manufactures usually don’t provide this information, or possibly provided it in a different way

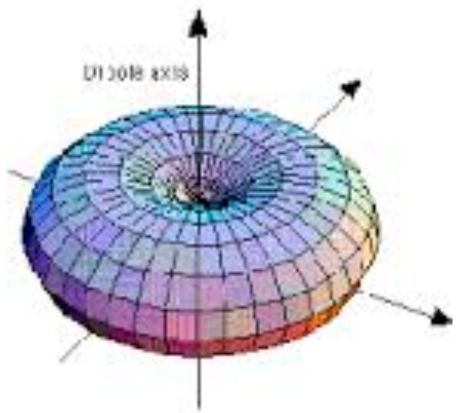
Antenna Design

- Antenna design can influence the strength of the broadcast signal at distance.
- Better antennas will also be able to detect weaker incoming signals
- Antennas can be divided into directional and ominidirectional

Antenna placement

- Although an omnidirectional antenna tries to broadcast the signal in all directions equally, in practice this is not the case.





If you device has more than one antenna, set them at right angles

Wifi Channels

- The 802.11 standard supports upto 23 channels
- If a router is operating on the same channel as another system (eg your neighbor) there will be more interference. This will usually result in the router droping back to a lower speed.
- Solution: Check the channel usage of nearby systems and pick a different one.

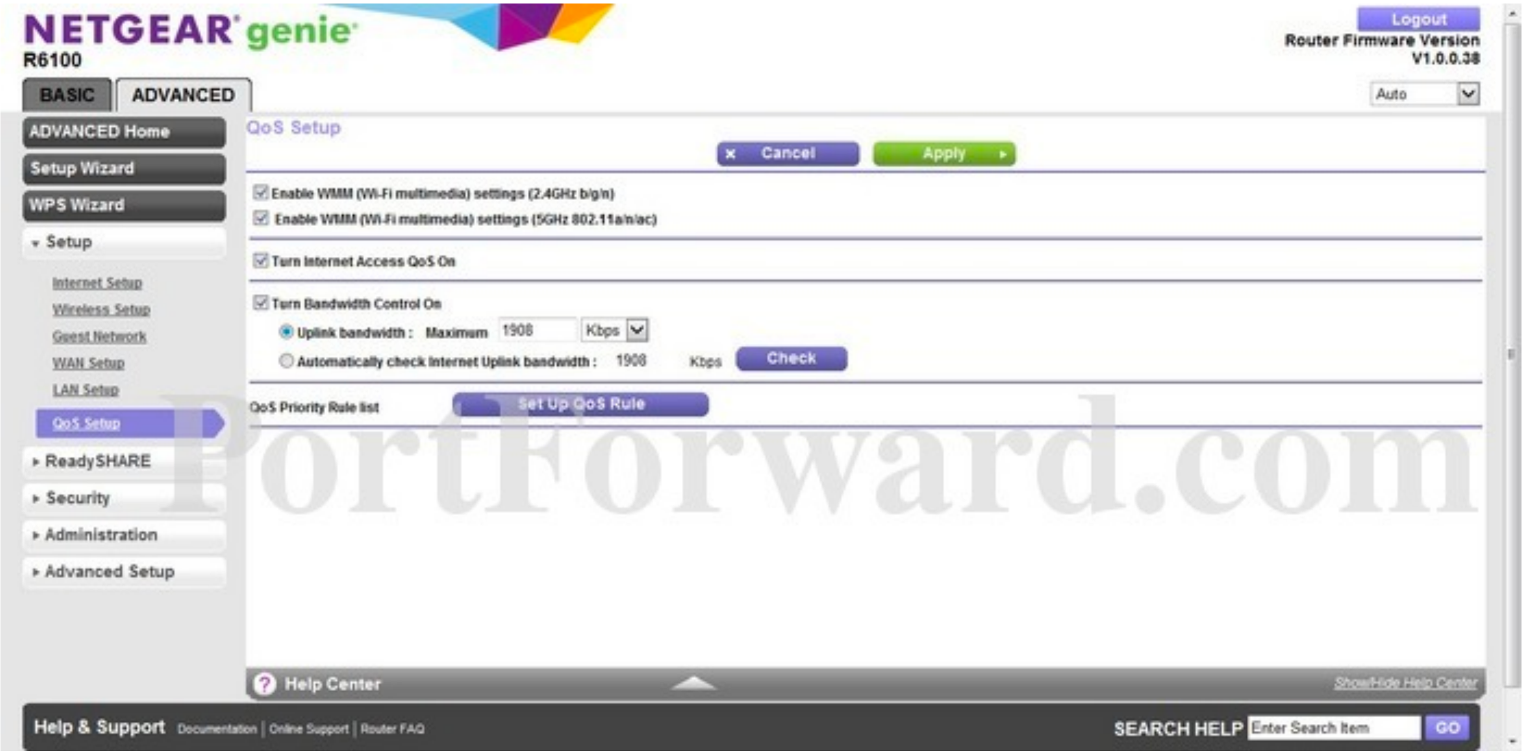
Quality of Service (QoS)

- Part of the 801.11 standard
- Essentially the ability to reserve part of the total bandwidth for a particular connection, application or port.

Priority	802.1p Priority (UP)	802.1p Designation	Traffic Type	Access Category (AC)	Designation
Low	1	BK	Background	AC_BK	Background
	2	-	(spare)	AC_BK	Background
	0	BE	Best Effort	AC_BE	Best Effort
	3	EE	Excellent Effort	AC_BE	Best Effort
	4	CL	Controlled Load	AC_VI	Video
	5	VI	Video	AC_VI	Video
	6	VO	Voice	AC_VO	Voice
High	7	NC	Network Control	AC_VO	Voice

QoS

- Does not increase total bandwidth
- Implemented differently on different routers.
- Some just have low, medium or high



Range Extender

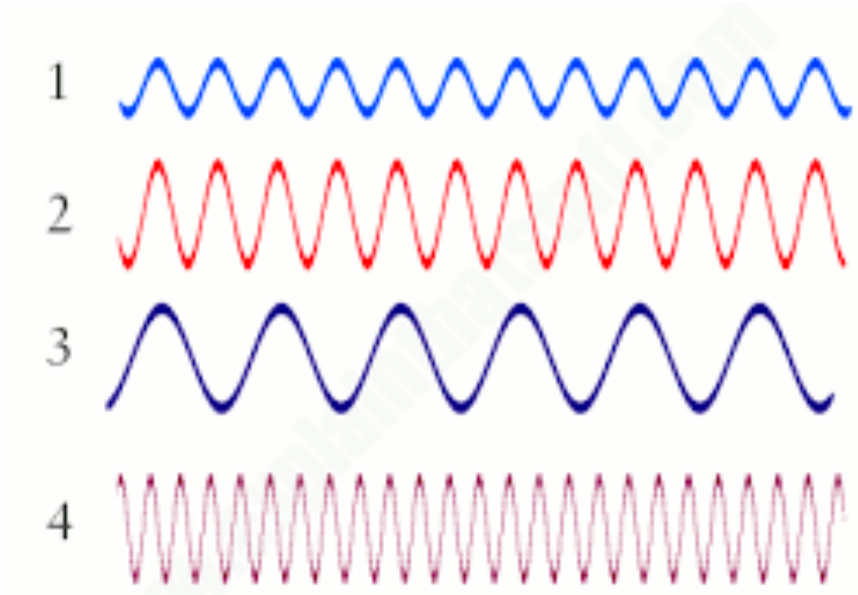
- A Wifi range extender is two routers in one

- One router receives the wifi signal from the base router, while the second router amplifies rebroadcasts the signal, usually on a different channel

Mobile Network Technology 1G to 5G

- Advances in Mobile phone technology have occurred because of changes in transmission methods and use of different parts of the spectrum.

- In general, higher frequency signals (shorter wavelength) can carry more information



Low vs High Frequency

1G - Analog

- Analog transmission using 800Mhz band

- Voice only, no data transmission

Switched off in 1999

2G

- First digital system, also introduced sim cards
- Used GSM (Global System for Mobile communication) which is based on time division multiplexing access(TDMA) - suffers from low range
- Provided a data downlink speed of upto 80kbps – or 10kB/s
- Later also used CDMA technology on 800MHz, mainly for rural locations

- First used 900Mhz spectrum, and later added 1800MHz
- Later added EDGE (Enhanced Data Rates for GSM), giving 29kB/s download.
- Progressively switched off in Australia between Dec 2016 and August 2017

3G

- Introduced in Australia in 2005
- Uses 900 and 2100MHz bands
- Transmission based on Wideband CDMA for greater bandwidth
- Improved signal transmission algorithms allowed more efficient transmission at lower power (250mW cf 2W for 2G)

- Introduced High Speed Packet Access (HSPA), in theory, upto 14.4 Mbps downlink and 5.6 Mbps uplink
- The 2100 MHz band does not have the same range as 900MHz. 900MHZ used more in rural locations

Next –G (3.5 G)

- Introduced late 20066, uses 850MHz spectrum
- Uses HSPA+ as the transmission technology and 64QAM modulation, with theoretical bandwidth of upto 42Mbs (5.25MB/s)

4G and 4G LTE

- The 4G standard was first adopted in 2008
- It proposed speeds of 100M bits/s for high mobility applications such as mobile phones, and 1 G bit/s for low mobility applications (local wireless)

- Several implementations were developed using different signaling technologies, but, while significantly faster than 3G could not achieve the 4G speed specification

- These were named 4G LTE (Long Term Evolution)

- In 2011 the 4G LTE Advanced was released

- This permits true 4G speeds and as sometimes “ True 4G”, or even 4G+

5G

- Testing of 5G networks is now underway and deployment will commence this year (2018) in some countries
- Offers a theoretical performance of 20 G bits/s

- Still working out which parts of the frequency spectrum will be allocated.

- Currently 2.3GHz, 2.5GHz and 3.5GHz are available in Australia, with 3.6GHz to be auctioned soon.

Ministers for the Department of Communications and the Arts

Senator the Hon Mitch Fifield

Deputy Leader of the Government in the Senate
Minister for Communications
Minister for the Arts

Connect:

Contact Bio

Former Minister for Regio
Former Minister for Comn
Former Parliamentary Sec

Government approves auction process for 5G spectrum

Like 0 Tweet G+

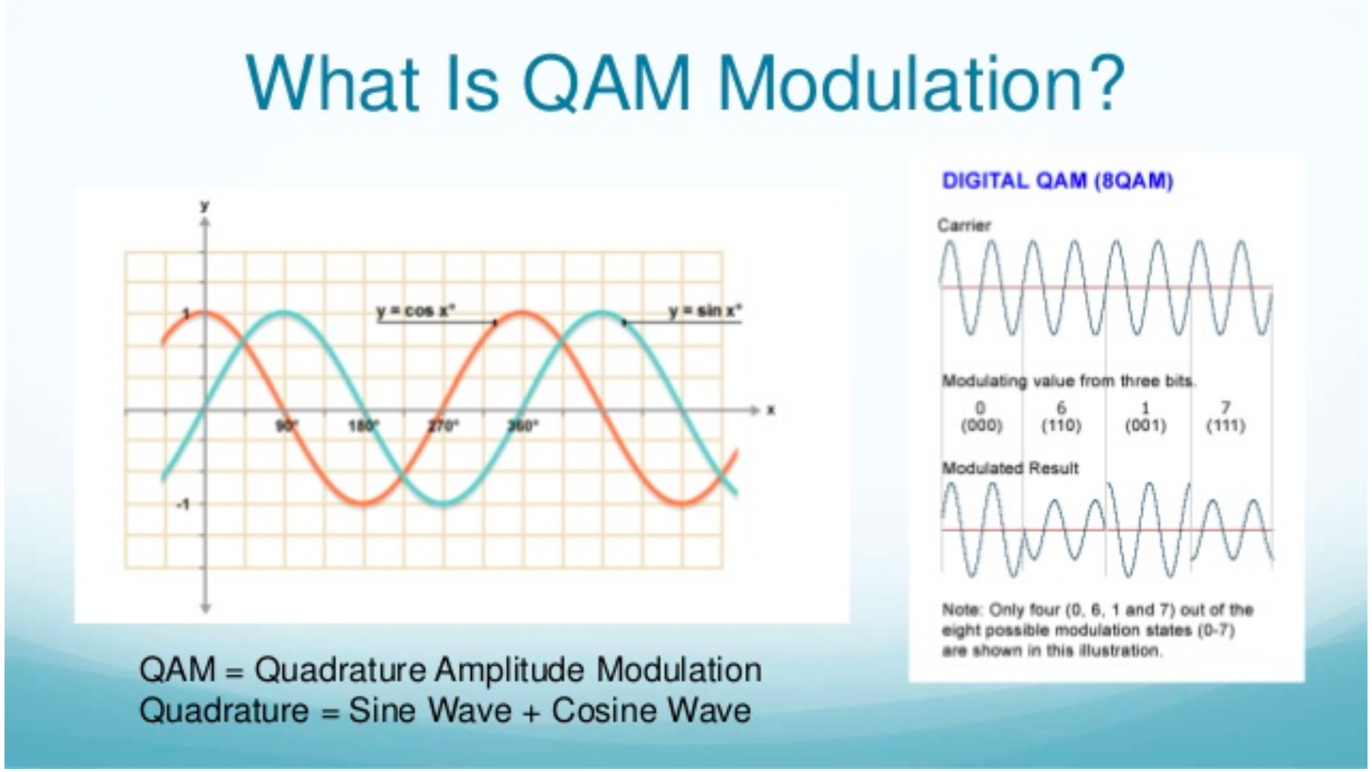
8 March 2018

The Turnbull Government today announced that 125 MHz of spectrum in the 3.6 GHz band will be sold at competitive auction, paving the way for new 5G services in metropolitan and regional Australia.

Spectrum in the 3.6 GHz band is highly valuable, being recognised internationally as a key band for the rollout of 5G services. In Australia, this band is currently used for fixed satellite service earth stations, point-to-point links and site-based wireless broadband services.

5G differences

- Improved modulation techniques mean that more digital bits can be encoded onto a given analog signal



- Advanced modulation techniques account for much of the improvement (eg 1024 QAM)

5G differences

- Uses MIMO Multiple Input Multiple Output , effectively transmitting on several channels at once

- Uses shorter wave lengths (can transmit more data because of higher frequency)

- Shorter wave lengths do not travel as far and do not go through walls as easily as longer wave lengths => more towers / more powerful towers, harder to deploy in non urban locations