DCF255

Lecture 3 | Physical Layer

Agenda

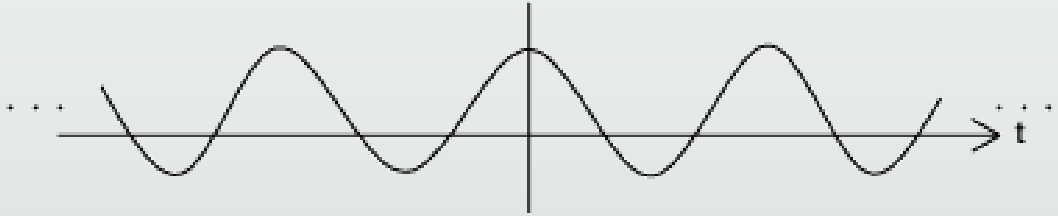
- Signal
  - Characteristics of Signals
- Types of Data & Signals
  - Analog, Digital & Transmission Methods
- Relationship between Bit Rate and Frequency
- Programming with Analog Signals v Digital Signals
- Types of Cables
- DSL Cable Modem and Bell Fibe

Signal

Characteristics of Signals
(Amplitude Frequency Period Phase)

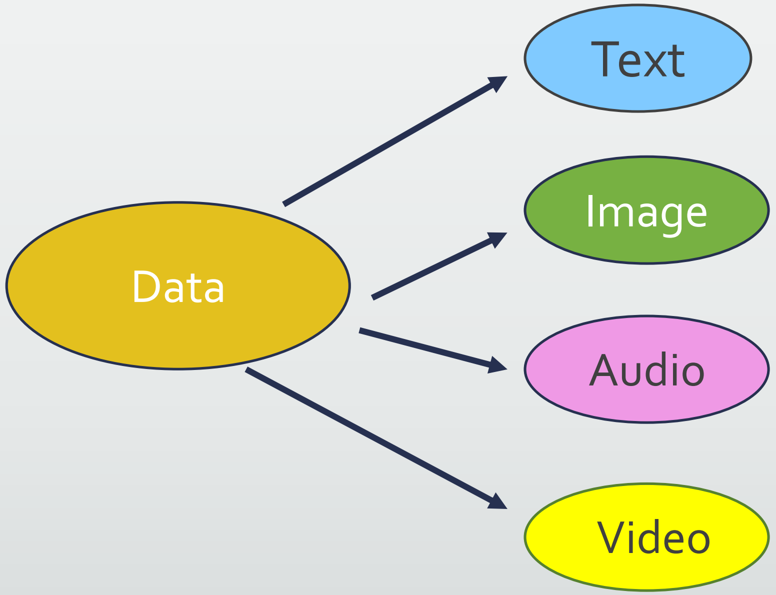
Signal

- A signal is a form in which data is transmitted
- It describes the behavior of data



Data

- Entities that convey information
- Data can be in any of these forms



Amplitude Frequency and Period

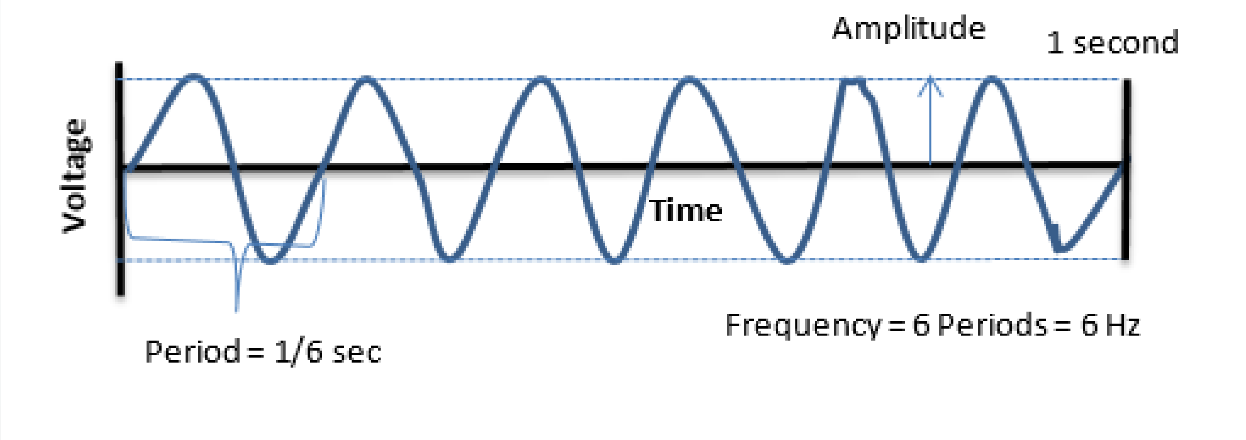
- All signals have 3 attributes Amplitude Frequency and Phase

- Amplitude refers to the height of the waveform, measured in volts or watts
.
- Frequency refers to the number of waveforms completed in a second, measured in hertz.

- Period is the time it takes to complete 1 complete cycle of the waveform

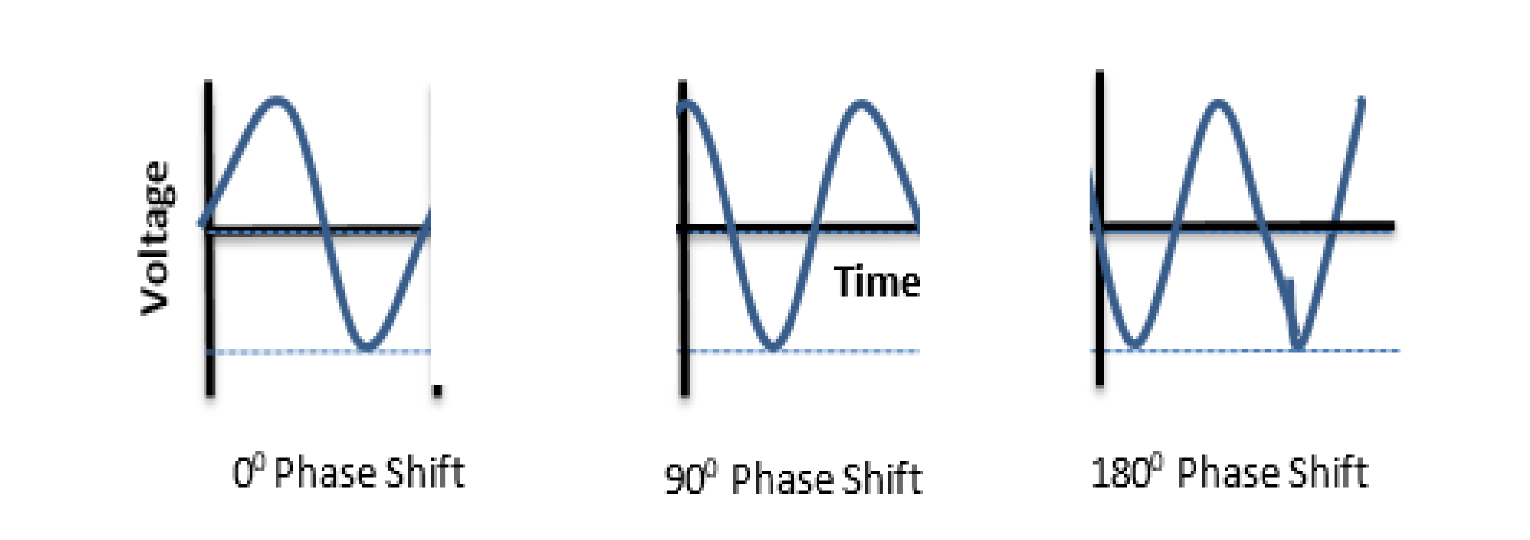
- Frequency and Period are inverse values

- If the frequency is 6, the period is 1/6 of a second.



Phase

- Phase refers to the position of the waveform relative to a point in time
- Technology exists to start a signal with a "phase shift"
- The signals in the last slide all had a phase shift of "o"
- Common phase degrees used in data communications are 90º and 180º

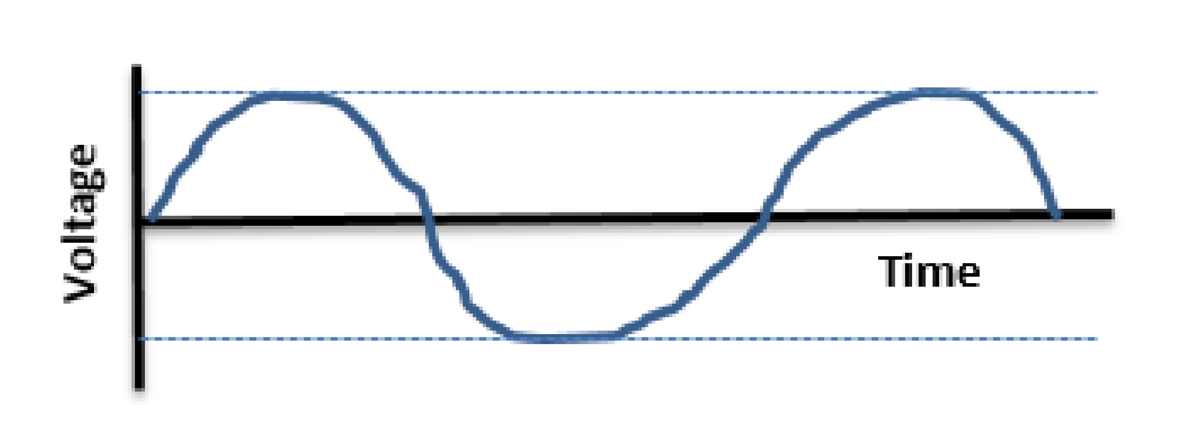


Types of Data & Signals

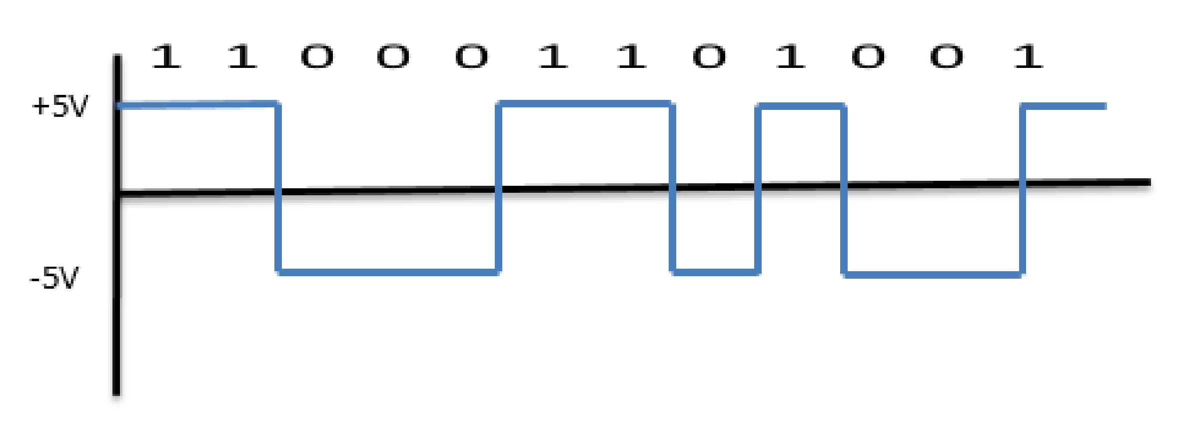
Analog Digital & Transmission Methods

Types of Data & Signals

- **Analog Data**
  - characterized by data with values from a continuous range.
  - they have an indefinite number of values
- **Analog Signal**
  - A sine waveform created with a continuous rising and falling of electromagnetic signal

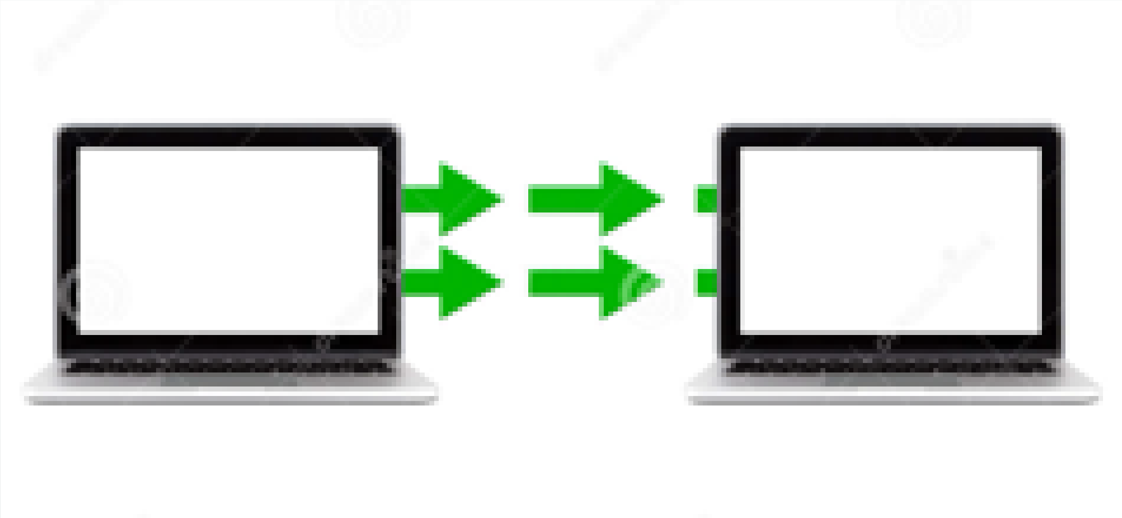


- **Digital Data**
  - constructed from a finite number of symbols.
  - Mostly only a binary message is used
- **Digital Signal**
  - A square waveform created with discrete states in the electromagnetic signal representing a zero or a one



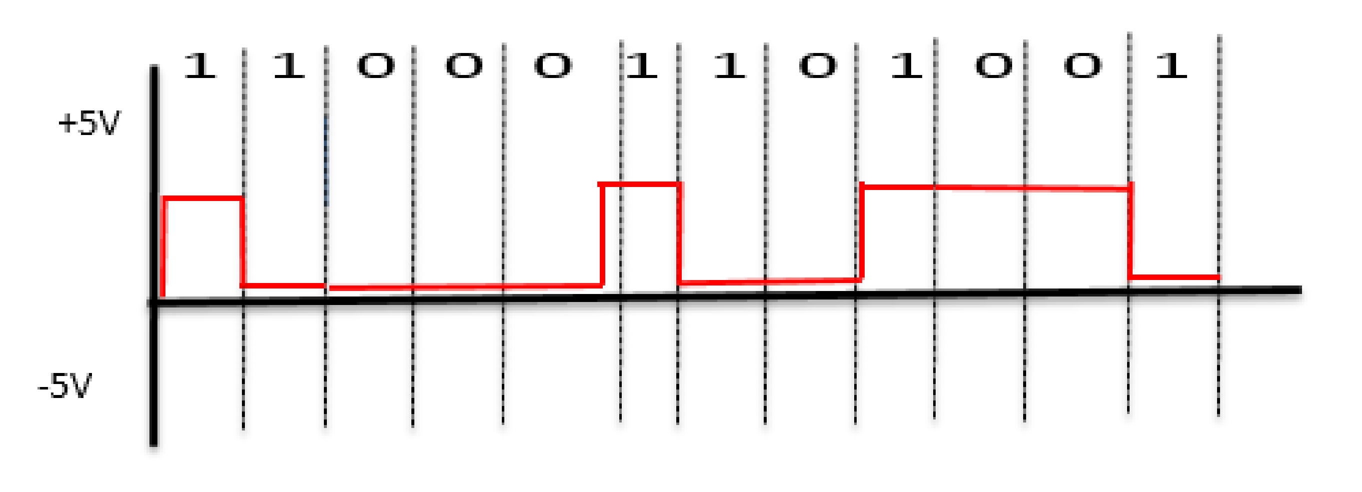
Types of Signals

- The physical layer can produce either analog or digital depending on the type of cable and encoding used
- Transmitting Data
  - Analog Data carried by an Analog Signal
  - Digital Data carried by an Analog Signal
  - Digital Data carried by a Digital Signal
  - Analog Data carried by a Digital Signal



Digital Data carried by a Digital Signal

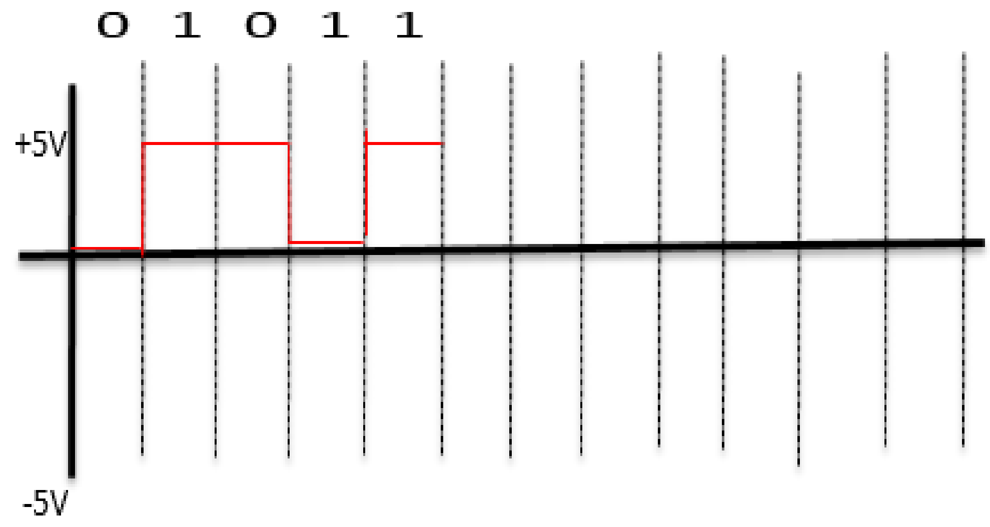
- The physical layer converts the digital data to the proper physical form to be transitted over a wire or airwave
- NRZI (non return to zero – inverted)
- NRZI – a change in voltage at the beginning of a bit period represents a 1 and no change represents a 0
- Long strings of zeros can cause two remote computers to “drift” apart creating errors – because the voltage is kept constant



Digital Data carried by a Digital Signal

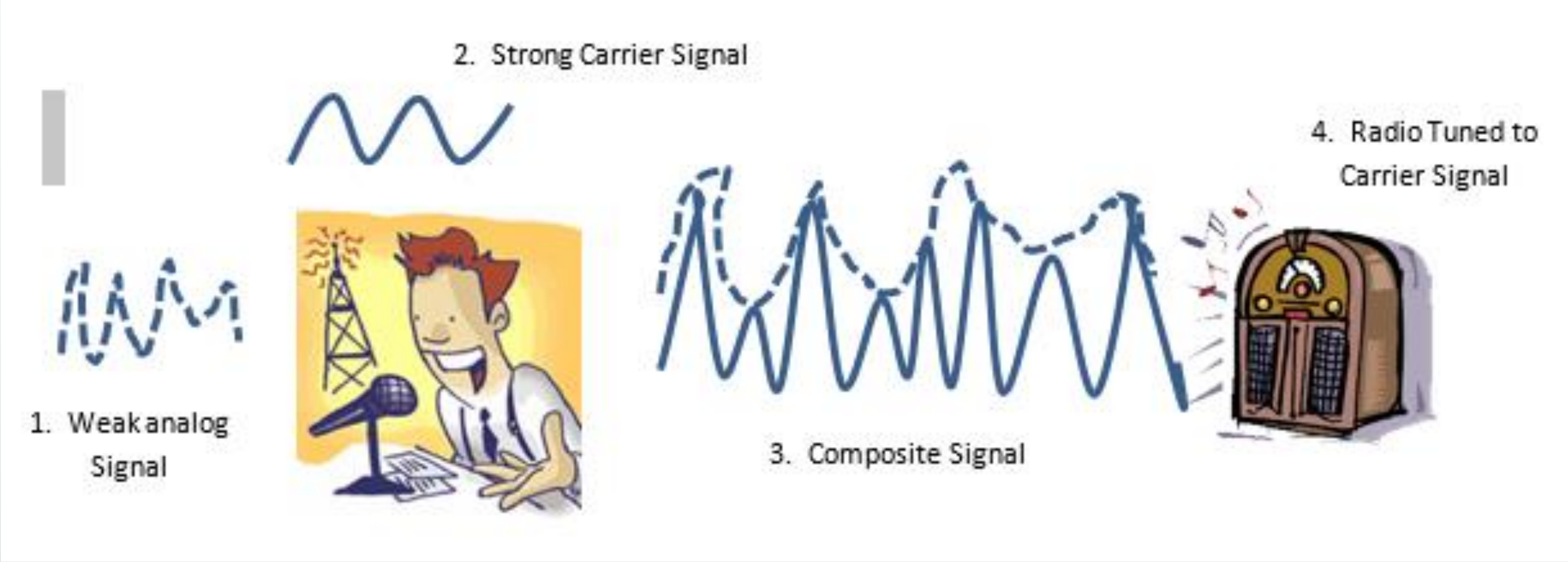
- 4B/5B originally developed for fiber optic cable is now used on many phones and gigabit Ethernet
- The original 4 bits of data are converted into a unique 5 bit transmission code with no more than 2 consecutive zero.
- $2^5 = 32$ possibilities, but only 16 5 bit sequences are used
- The 5 bit transmission code is encoded using NRZI – preventing 2 remote computers from drifting apart

Original Data	New 5 bit Unique Sequence	NRZI
0000	11110	
0001	01001	
0010	10100	
0100	01010	
0101	01011	
0101	01011	



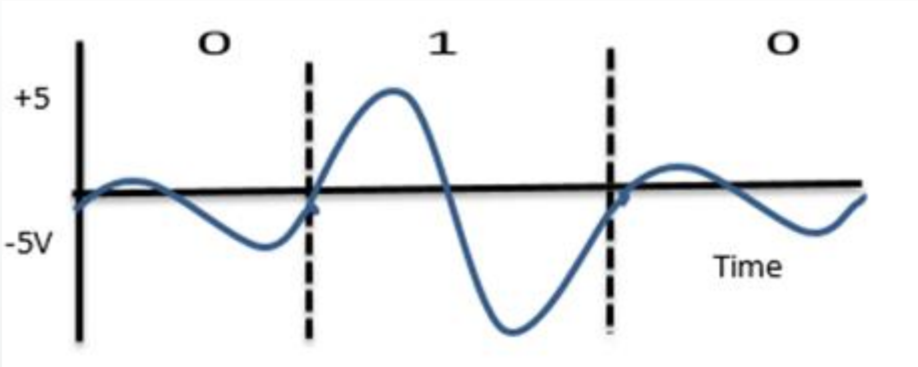
Analog Data carried by an Analog Signal

- For example AM radio station playing music creates a weak signal
- This weak signal is combined with a powerful carrier signal, creating a composite signal
- Tune radio dial to carrier signal frequency to hear the music

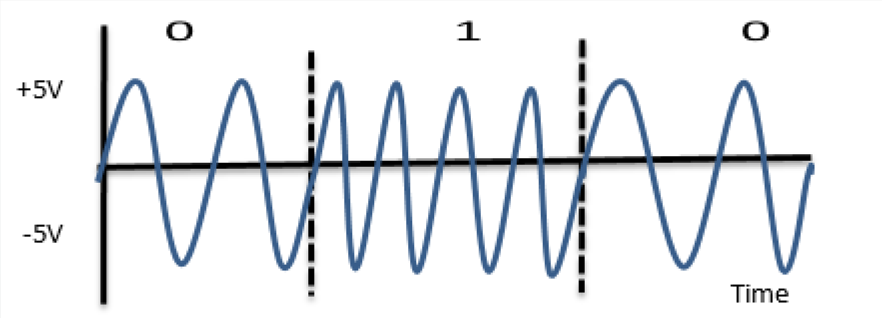


Digital Data carried by an Analog Signal

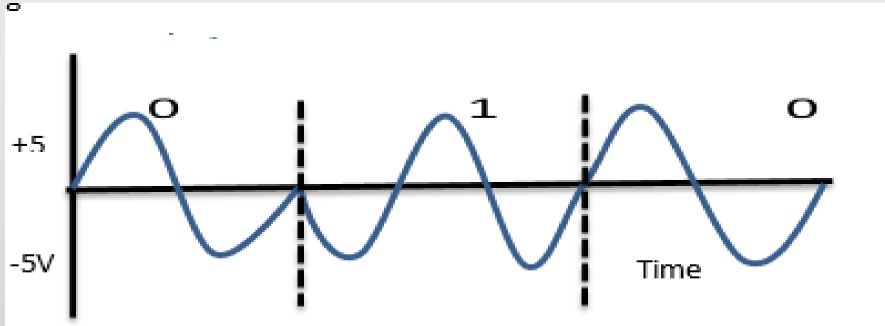
- Amplitude Shift-Keying (ASK) used to represent discrete states of digital data
- Low amplitude = 0 High amplitude = 1



- Frequency Shift-Keying (FSK) used to represent discrete states of digital data
- 2 Hz = 0 4Hz = 1



- Phase Shift-Keying (PSK) used to represent discrete states of digital data
- 0 phase shift = 0 180 Degree phase shift = 1

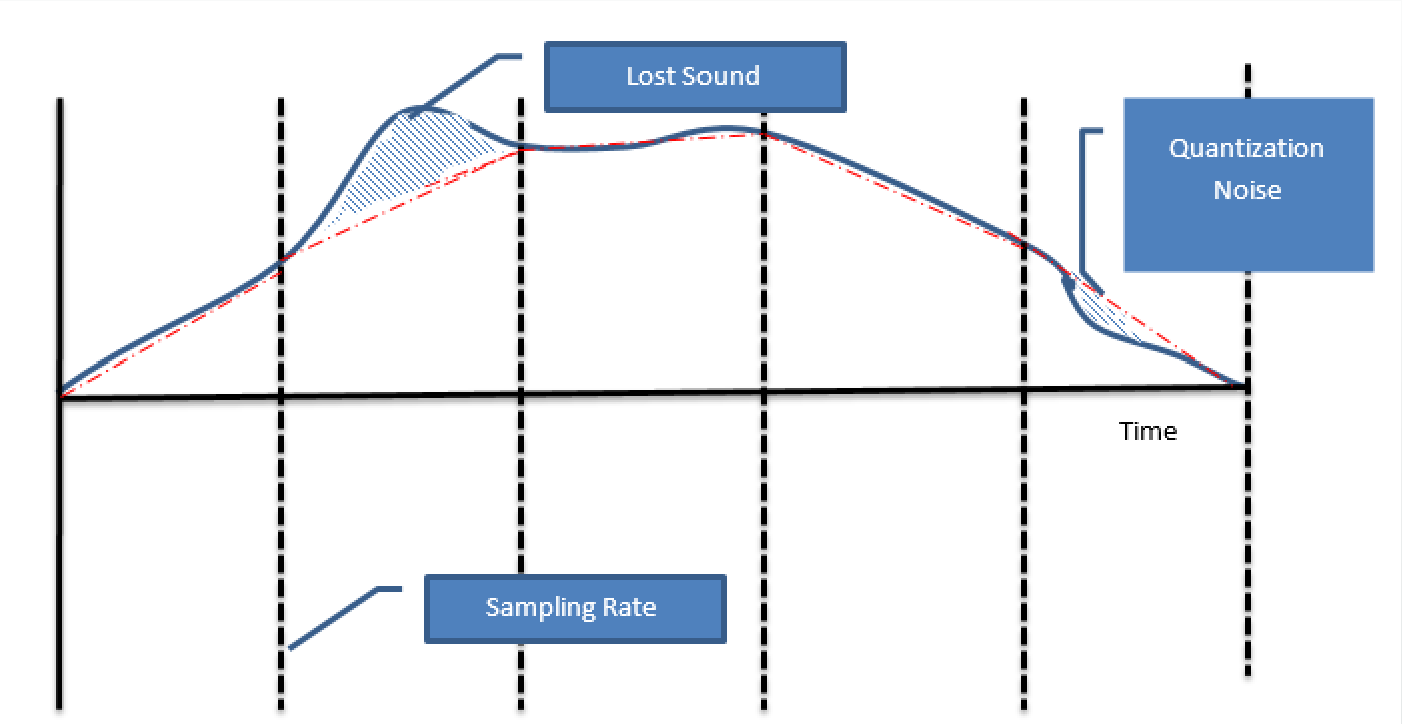


Analog Data carried by Digital Signals

- Analog Data is a continuous wave form, in order to be carried by digital signals it must be converted into digital data

1. The waveform is "Sampled" at discrete intervals and the amplitude is measured
2. The sample waveform is "Quantized" by converted to a 7 bit digital value
3. To convert the digital value back to an analog waveform a special chip called "PAM" is used (Pulse Code Modulation) which converts the 7 bit value to an electromagnetic signal to represent the original waveform

- This can introduce errors (noise not in original waveform or lost of sound that was in the original waveform



Sampling is a compromise between sound quality and performance. CD quality is 2X the highest frequency (Nyquist Theorem). For example 3700 Hz would require a sampling rate of 7400 times per second to get a good representation of the waveform

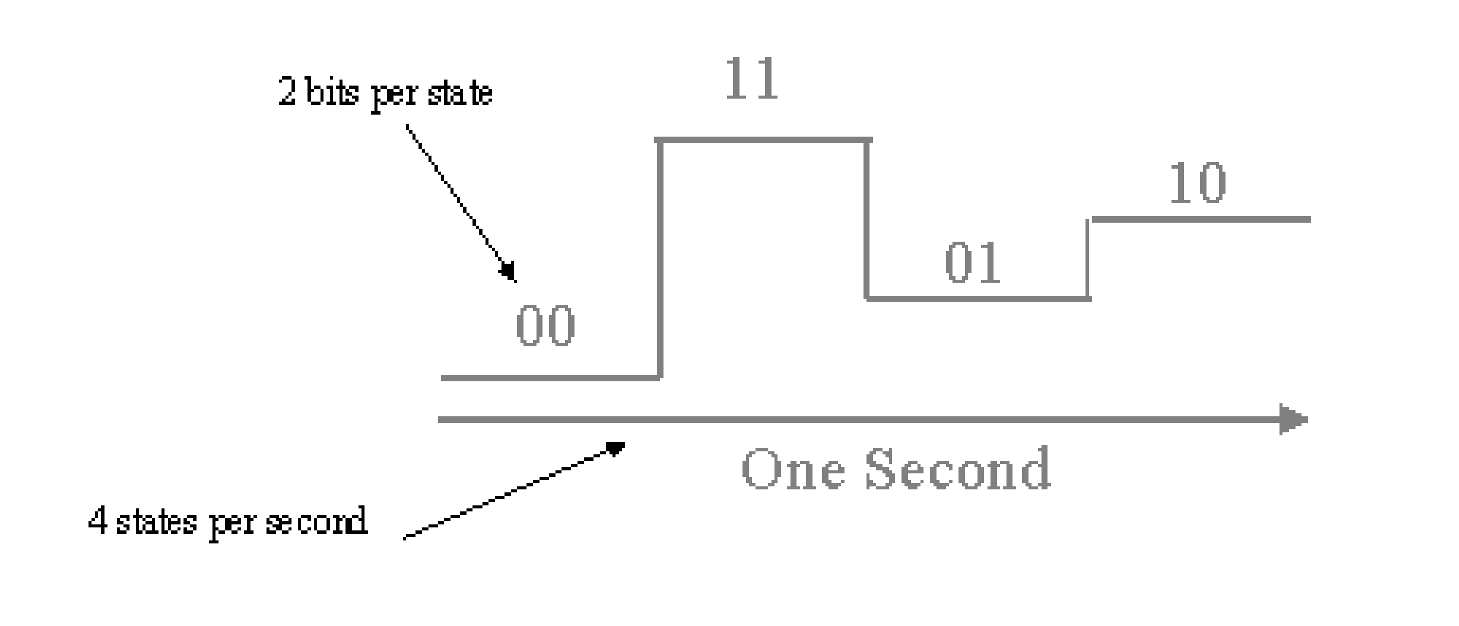
Relationship between frequency and Bit Rate

- Faster network speed can only be created in one of 2 ways:

1. Increase the bit rate by sending more bits per bit cycle and keep the frequency the same, or
2. Increase the frequency of the signal and keep the bit rate the same

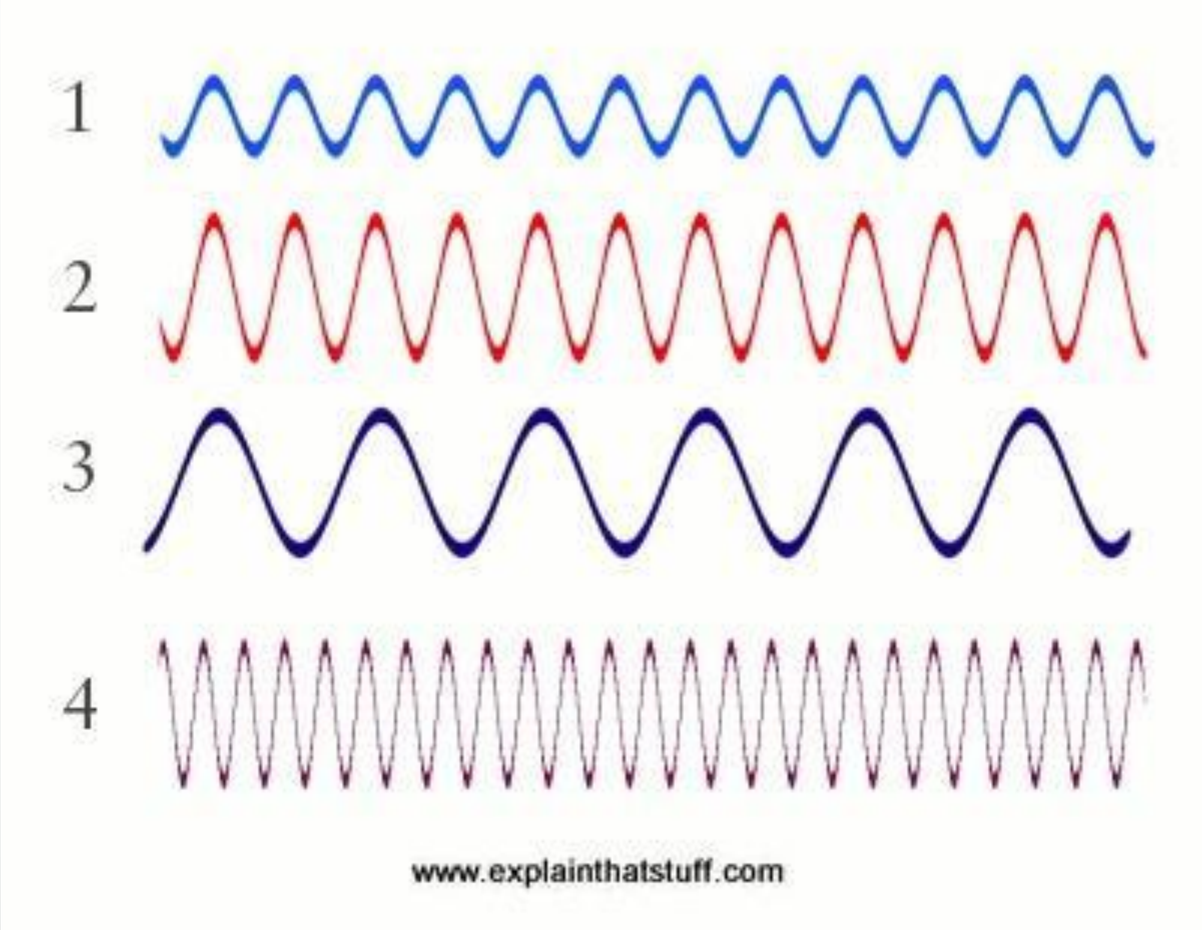
Increase the bit rate – Keep Frequency the same

- Baud rate is how many times the signal changes per second
- Bit Rate is how many bits are sent per second
- Baud rate = 4 Bit rate = 8
- By creating more amplitude levels in a second each amplitude level can represent 2 bits
- This increases throughput, but can increase errors if signal has noise



Increase the frequency – Keep the bit rate the same

- Increasing the frequency sends more bits per second which increases throughput, but can increase errors if signal has noise
- For example, 6 Hz signal sending 1 bit per bit period sends 6 bits per second
- 12 Hz signal would send 12 bits per second doubling throughput
- Medium must be able to support the frequency
- Increasing the frequency also increases noise and electromagnetic interference (EMI)



Shannon's Theorem - Data Rate = f X $\log_2 (1 + S/N)$

- Shannon's Theorem gives the maximum data rate for an analog signal with any number of signal levels and takes noise into account
- f - Bandwidth is the difference between the highest frequency and the lowest frequency
- S – is the power of the signal in watts
- N – is the noise of the signal in watts

Data Rate = f X $\log_2 (1 + S/N)$

f – bandwidth of the signal

S – power of the signal in watts

N – power of the noise in watts

Shannon's Theorem - Data Rate = f X $\log_2 (1 + S/N)$

- . Suppose you were writing an application which will use a dial up modem. If the power of the signal was .5 watts and the noise is .0002 watts. What is the maximum bit rate in bytes per second?
  - Telephone system designed for frequencies of the human voice
  - High 3400 Hz and low 300 Hz
  - Bandwidth = 3400 -300 = 3100 Hz

= 3100 X $\log_2$ (1 + 0.5/0.0002)

= 3100 X $\log_2$ (1 + 2500)

=3100 X $\log_2$ (2501)

= 3100 X 11.289 (DIVIDE LOG_{10} 3.98113/0.301 TO APPROXIMATE LOG_2)

= 34,996 bps / 8

=4,374.5 Bytes per second

Programming

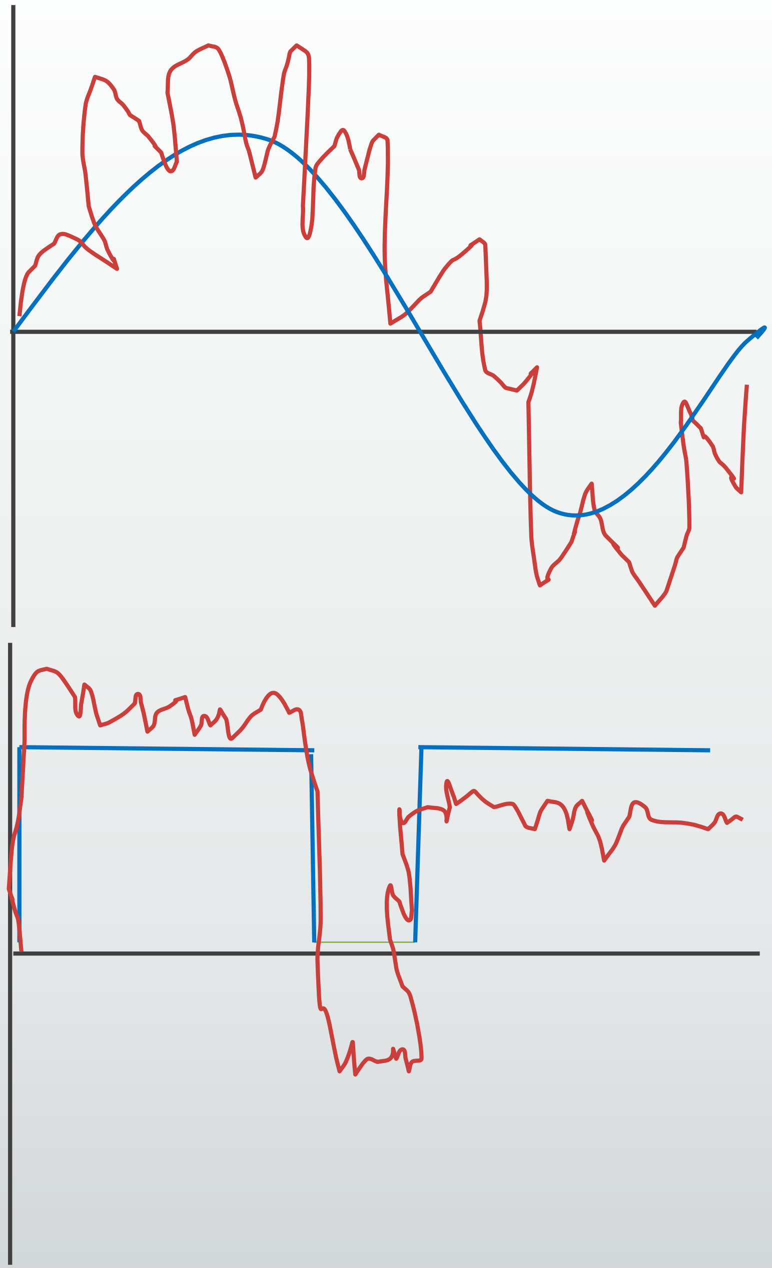
Analog v Digital Signals

Programming with Analog Signals

- Suppose you wrote a simple ATM application using analog signal
- Amplitude of 2 volts = 0
- Amplitude of 4 volts = 1
- Flags
    - Enter Pin – 00 – Authenticate user
    - Success message -01 – Proceed
    - Pushes $100 button – 10 – check account balance
    - If money in account success message -11 returned and $100 dispensed

Programming with Analog Signals

- Same scenario, but suppose lightning hit the line, and the voltage spiked to 8 volts, just after the user hit the cash button and before the account balance was checked
- Server would interpret the 8 voltages as a success message of 11 and dispense $100.00, even if the user did not have the money in the account. Why?
- The major problem with analog signals is that noise is also an analog signal and can be misinterpreted by the receiving computer.
- Same scenario using digital signal. Digital signal uses discrete levels. Therefore, even if the voltage spiked to above 4 volts, it would still be interpreted as a "1", or if the voltage was less than 2 volts, it would still be interpreted as a "0"
- Digital signals less susceptible to noise



Metric Notation

Proper Syntax

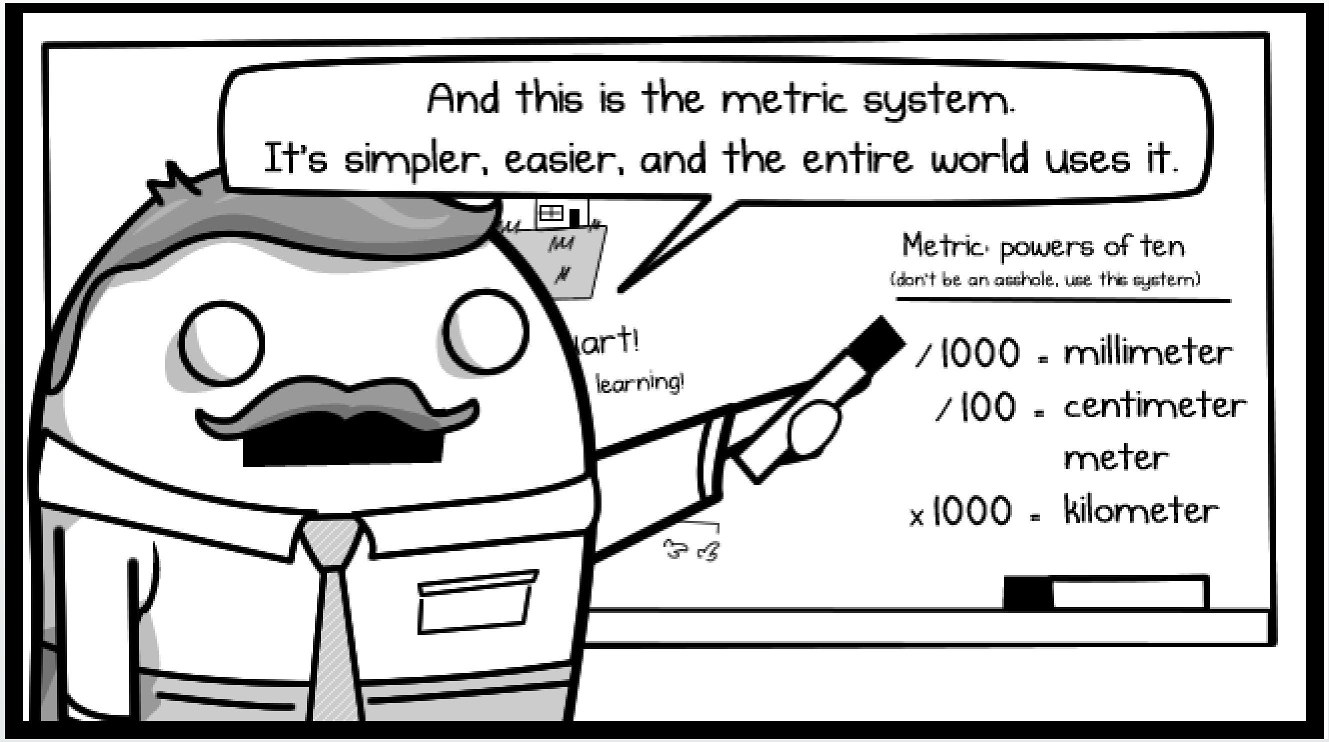
Understanding Metric Notation

Prefix	Name	Example	Description
P	Peta	1,000,000,000,000,000	One thousand trillion
T	Tera	1,000,000,000,000	One trillion
G	Giga	1,000,000,000	One billion
M	Mega	1,000,000	One million
k	kilo	1,000	One thousand

- Many network parameters, such as speed are measured in metric units.
- Notice that all the Prefixes are capitalized, except kilo. (capital K is reserved for measuring Kelvins)
- Petra is one thousand trillion with 15 zeros, Tera is one trillion with 12 zeros, Giga is one billion with 9 zeros and Mega is one million with 6 zeros and kilo is a thousand with 3 zeros.

Writing Metric Notation

- Proper notation is that there must be 1-3 digits before the decimal point
- 8.5 Mbps is good
- 8500.0 kbps is bad
- 0.085 Tbps is bad (leading zeros don't count)
- Import Rule:
  - You can place a space between the number and the metric prefix, but not between the metrix prefix and the base unit
  - 8.5 Mbps – is good
  - 8.5 M bps – is bad

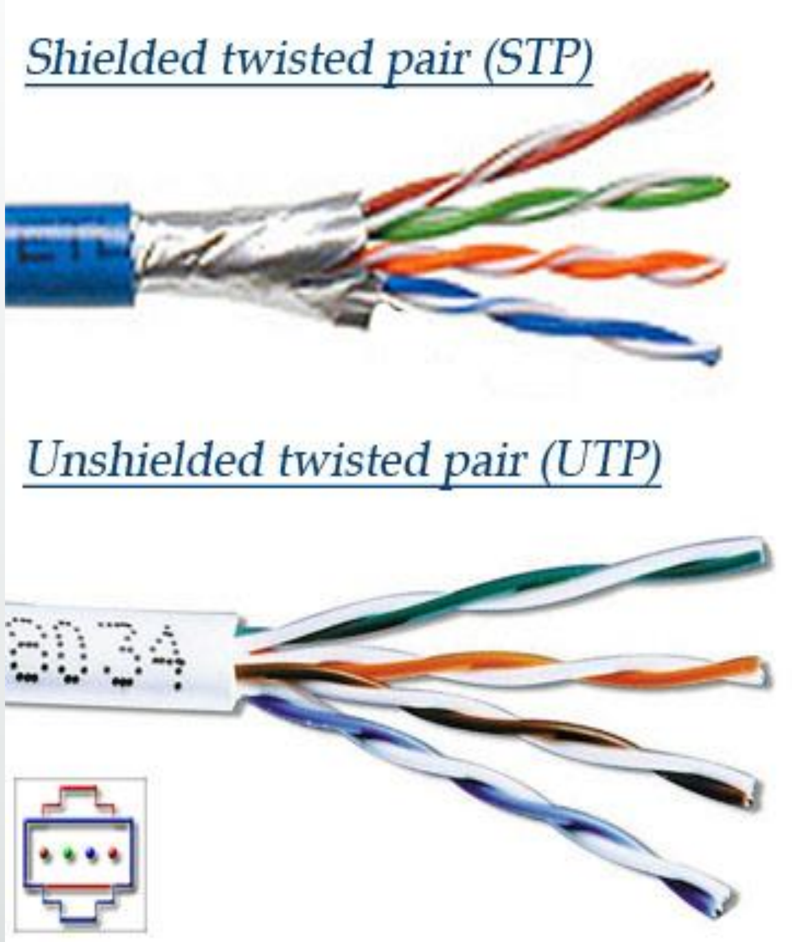


Types of Cable

STP/UTP Coaxial Fiber Optic

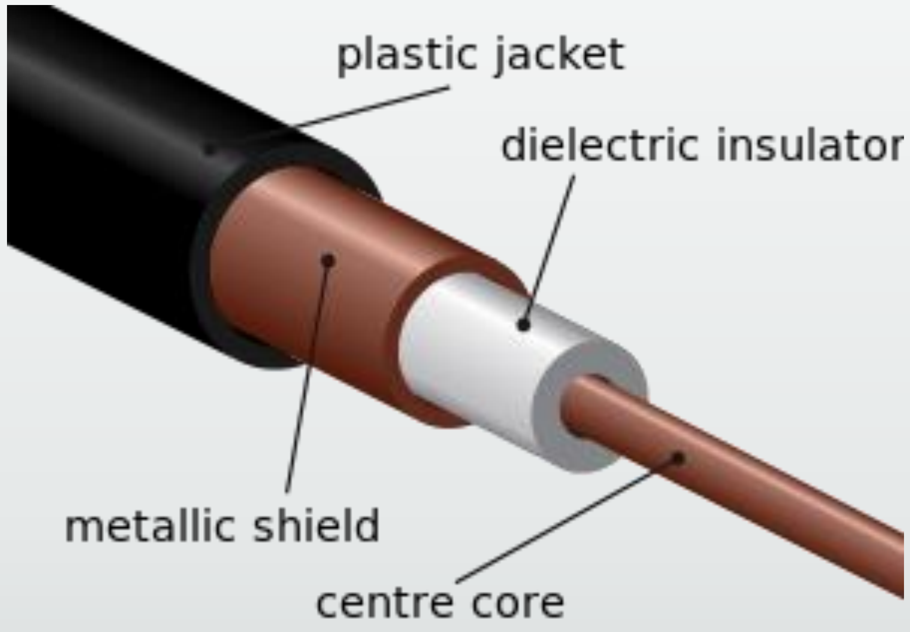
STP/UTP

- UTP - “Unshielded Twisted Pair” cable.
  - Four pairs of wires each twisted around the other, inside a PVC protective jacket. Two wires carry equal but opposite signals; with the cables twisted, the flow of electrons generates opposite electro-magnetic fields minimizing crosstalk.
- STP - “Shielded Twisted Pair”
  - the wires are wrapped in a shielding which protects the signal from external EMI and increases attenuation by having electrons bounce back to the center of the cable.
- The most popular network cables today are CAT5e and CAT6 cables which are specially designed to reduce noise so that they can send information at high speeds(CAT5e -1 Gbps,CAT6- 10G



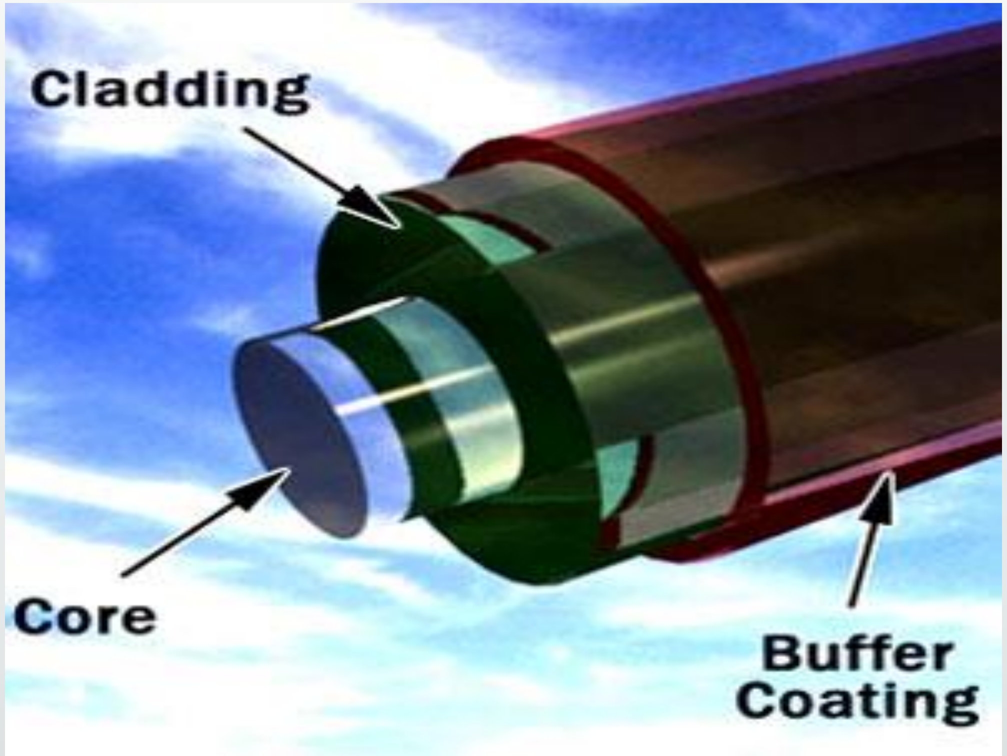
Coaxial

- Coaxial cable conducts electrical signal using a solid copper wire surrounded by an insulating layer and all enclosed by a shield of woven metallic braid which are soldered at the ends to the BNC connectors.
- The shield protects the signal from outside EMI and preventing electron leakage from the centre of the cable.
- This property makes coaxial cable a good choice for carrying weak signals that cannot tolerate interference from the environment or for stronger electrical signals that must not be allowed to radiate or couple into adjacent structures or circuits.
- Coaxial cable is commonly used in CATV and RF installations.



Fiber Optic

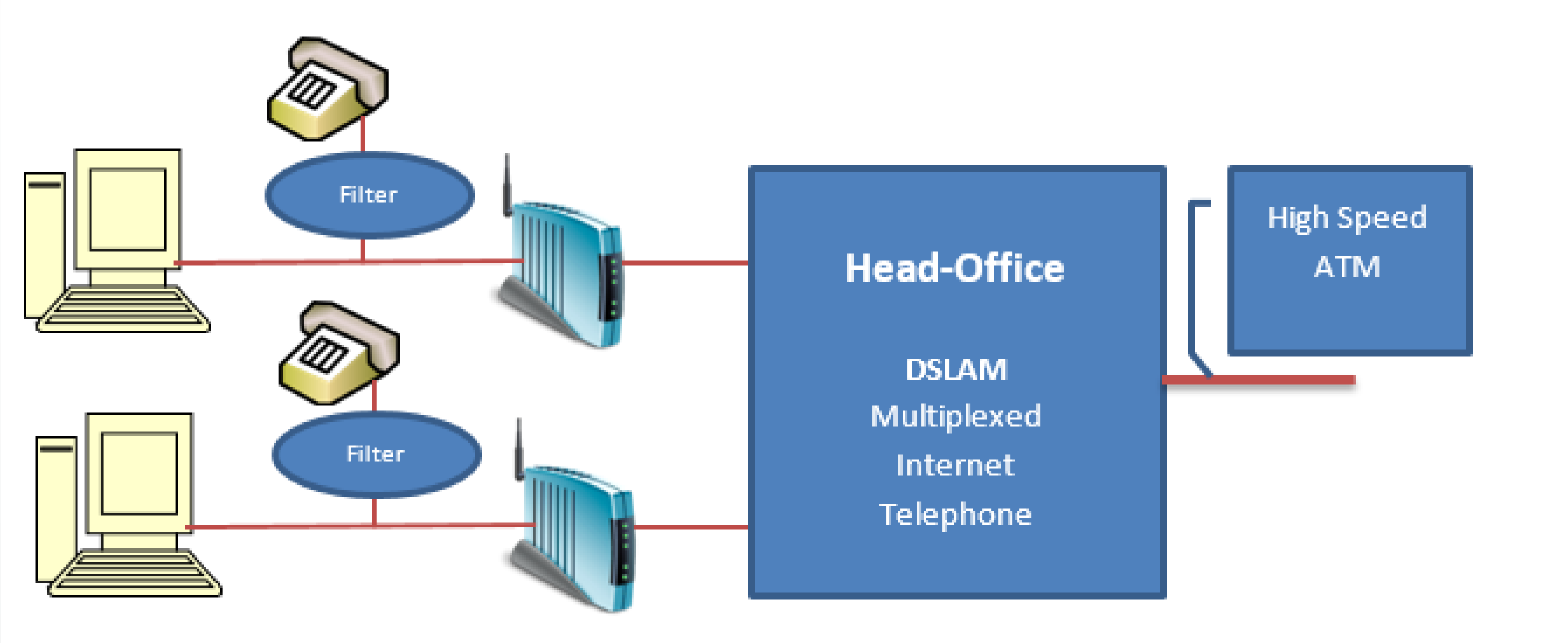
- Fiber optic cables are bundles of glass fibers, smaller than a human hair, which are combined into a single cable
  - Core - Thin glass center of the fiber where the light travels
  - Cladding - Outer optical material surrounding the core that reflects the light back into the core
  - Buffer coating - Plastic coating that protects the fiber from damage and moisture
- Light travels in a straight line and only in one direction at a time.
- The inside of the cable is like a mirror; so that light can travel down the core. Because the cladding does not absorb any light from the core, the light wave can travel great distances.
- Another advantage of fiber optic cables is that it is impervious to EMI and wire tapping.



Types of Connections

DSL Cable Modem Bell Fibe

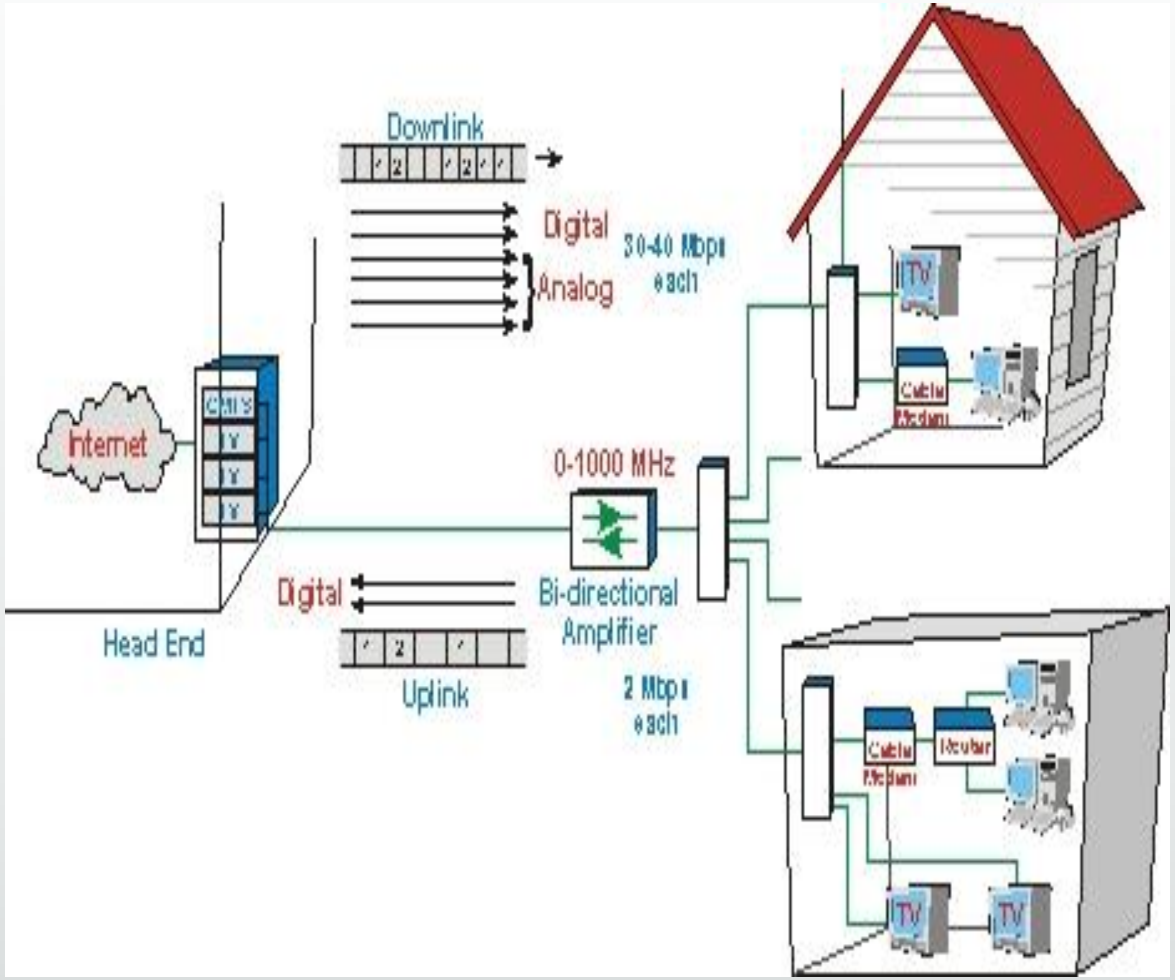
DSL



- UTP used to connect home to telephone switching station (physical limit of copper is 3 miles)
- DSL Modem creates a permanent connection – always on
- DSL Modem divides the frequencies above 3400 Hz into downstream and upstream channels which is why if you have a land line, there must be a splitter on the line to split the telephone frequencies
- DSL uses discrete analog signals to send digital data. At the head office a DSLAM (DSL Access Multiplexer) is installed to convert many DSL transmissions onto one trunk line

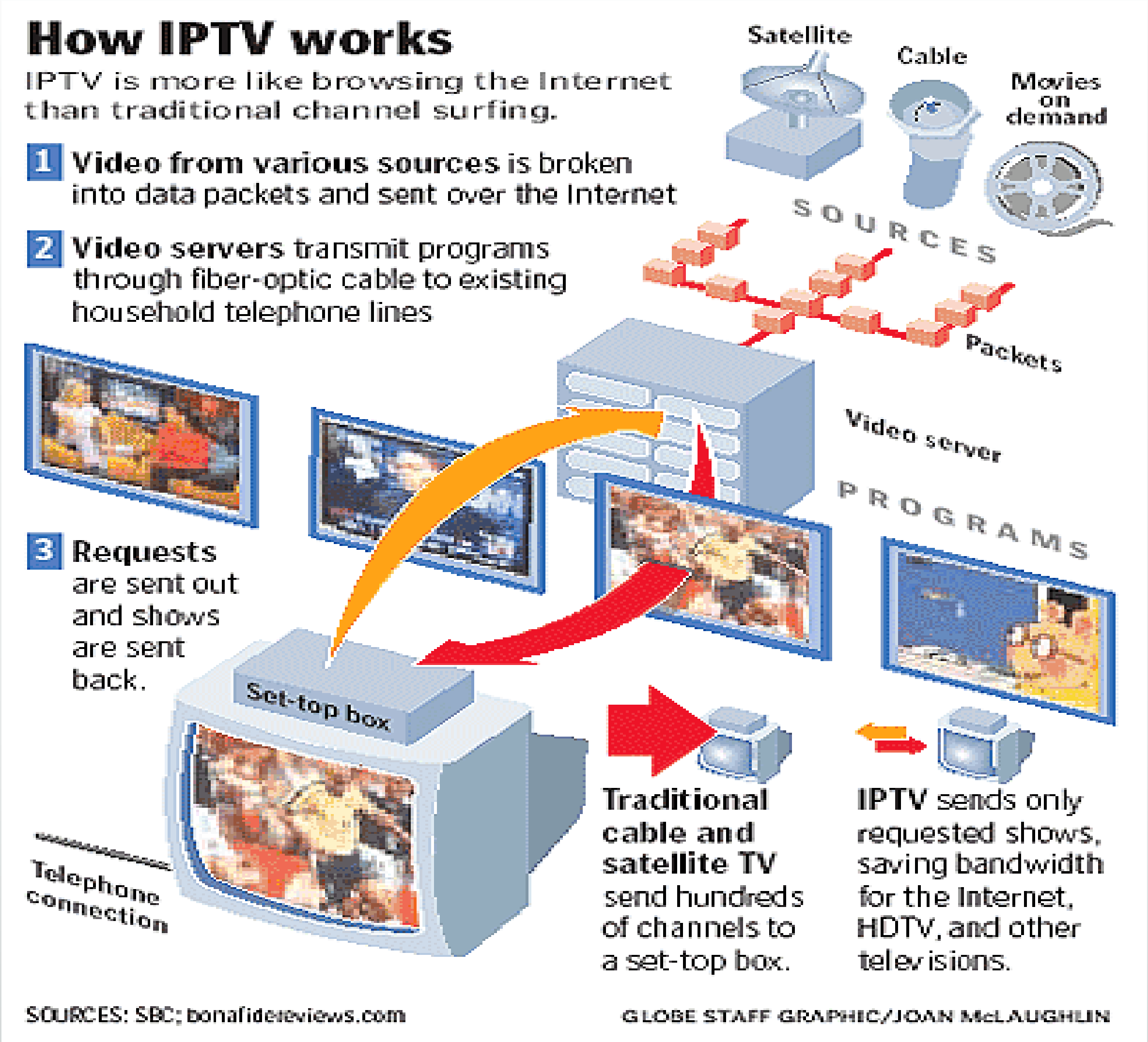
Cable Modem

- CATV divides each TV channel into a 5 MHz channel. The bandwidth is a shared with all other users in the neighbourhood
- Cable modem uses Ethernet to connect to the local network and provides DHCP services to local hosts
- At the head office a CMTS (Cable Modem Termination system) is responsible for connecting a group of customers to an ISP
- Downloaded content is modulated using QAM (Quadrapture Amplitude Modulation) converting 4 bits at a time to discrete digital values.
- Upstream content uses Quadrapture PSK sending 2 bits at a time. QPSK is used because it is least affected by noise



Bell Fibe

- Bell Fibe is a "streaming service" using IP multicasting. Each packet leaves the server only once, but is sent simultaneously to many different destinations using the IGMP (IP Group Membership Protocol.
- One server can send information to many clients as easily as to a single client using the RTSP (Real-Time Streaming Protocol).
- IP multicasting is more efficient in bandwidth because it sends only the selected channel to the appropriate IP group.
- To avoid latency and buffering, caching server farms , known as CDNs, maintain mirrored copies of program content



Summary

1. Electricity and Magnetism are two attributes of an electromagnetic field. A moving magnet will generate an electrical current and an electrical current will generate a magnetic field. The latter will pull electrons from the centre of the medium weakening the signal

2. All signals have phase, amplitude and frequency. Each of these attributes can be used to send discrete digital values. Analog signals are more susceptible to noise than digital signals.

3. It is important to convert metric values correctly. Convention states that there must be 1-3 digits in front of the metric prefix and that there should not be a space between the metric prefix and the base unit.

4. There are 3 types of cables used today in data communications: UTP/STP,. Coaxial and fiber optic. Each of these cables are used in common home connections. DSL uses UTP cable and is an always on circuit to the teleco. Cable modems use coaxial cable and is a shared connection using Ethernet to connect local hosts to the network. Fiber optic cable is used with Bell Fibe. The latter is based on IP multicasting and RSTP protocols.