SEICHE 2022

Introduction to Arduino

Lesson 9 – ESP32 and External Power Sources

POST UPDATED TO MATCH CLASS COVERAGE

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Corporate Sponsor: DXC Technology

REMEMBER!

Immediately copy the latest lesson folder (Lesson9 today) from your USB flash drive to your hard drive where you previously copied the other flash drive files (probably Documents folder)

Lesson Plan Overview

Lesson 1 – Intro and Setup
[may require 2 classes]
- Introduction to class format
- Overview of lesson plan
- Presentation format (monitor, camera, screen, whiteboard)
- Inventory of Arduino kits
- Inventory of USB drives
- Installation of ESP32 serial port drivers (Windows only)
- Installation of Arduino software
- History of Computing

Lesson 2 and 3 – Laptop operation review
- Control panel/Settings location
- Home directories and folder hierarchy
- Arduino file locations
- Search functions
- Open questions and issues
- History of Computing redux

Lesson 4 and 5 – IDE essentials
- The boards manager
- Setting board type
- Installing Libraries
- Loading example sketches
- Finding and selecting the Arduino USB port
- Uploading a sketch to the microcontroller [Example Sketch#1]
- Basic Arduino sketch (program) structure
- Uploading your own sketch [Class Sketch #2]
- History of Telecommunications and Networking – Part 1

Lesson 6 – DC Electricity Basics and DMM Intro
- Quick review: DC vs AC electric currents
- DC current operation
- Voltage vs Amperage (current)
- Ohm's Law
- Series vs parallel circuits
- Introduction to basic DMM functions and usage
- Measuring voltage [DMM usage #1]
- History of Telecommunications and Networking – Part 2

Lesson 7 and 8 – Grounding, ESD, and Connecting LEDs
- Grounding
- The Phantom Menace of ESD
- Resistors!
- LED's [DMM usage #2, maybe]
- Powering LEDs – Ballast and dropping resistors
- Connecting LEDs to microcontrollers
- Parts of an Arduino Sketch
- ESP32 Specifications – Ampacity
- Let there be Light! – Class Sketch #2
- History of Telecommunications and Networking – Part 3

Lesson 9 – ESP32 External power sources [may require 2 classes]
- Capacitors!
- Microcontroller board power requirements
- Board power input options and grounding
- Components with different voltage requirements – level shifting
- External power circuit design

Lesson 10 – Smart LED Strips, Flashing Software
- External device power circuit design recap
- Level shifting recap
- WS2812B and Neopixel connections – Class Sketch #3
- Flashing software binaries

Lesson 11 – Connecting LCD and Matrix Displays
- Simplified serial communication protocols
- One-wire serial communication protocol
- Hardware vs software serial
- The SPI serial protocol
- SPI connections – Class Sketch #5
- SPI device external power design

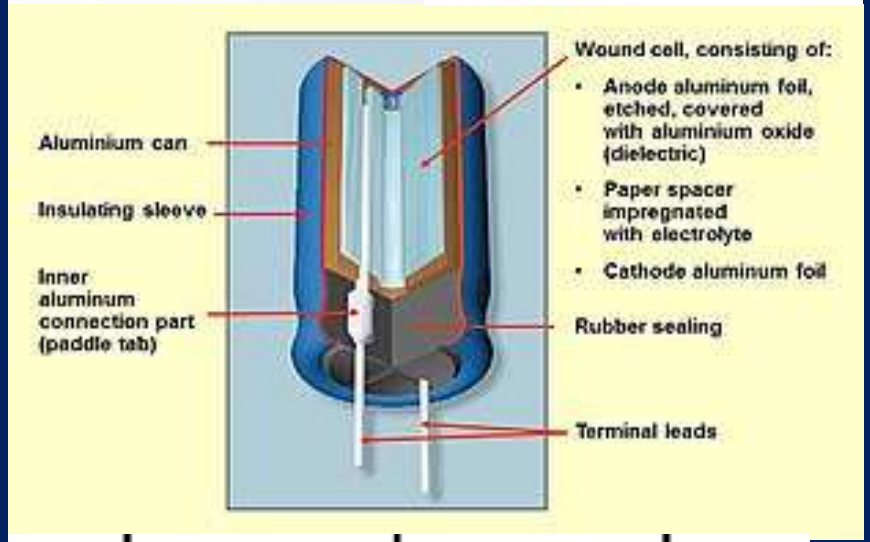
Lesson 12 – Connecting sensors [Time permitting]
- Connecting buttons
- Connecting potentiometers and voltage dividers
- Reading buttons and debouncing
- Reading potentiometers

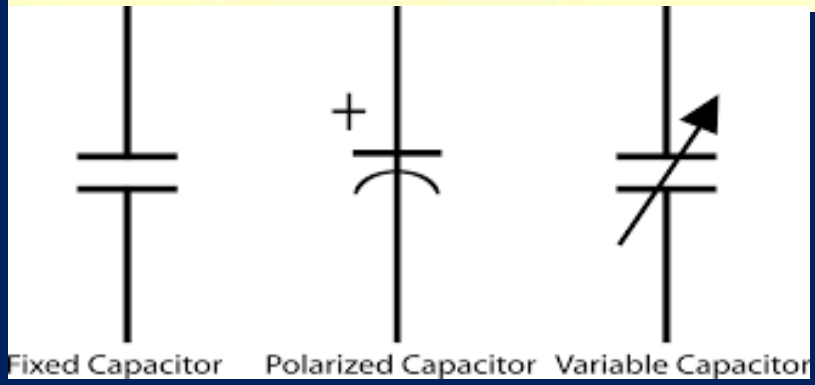
Lesson 9 – ESP32 External Power

- Capacitors!
- Board power input options and grounding
- External and USB Power
- Peripherals with different voltage requirements – level shifting
- External power circuit design
- WS2812B and Neopixel connections
- Class Sketch #3
- History of Telecommunications and Networking
  (Time Permitting)

Our Second Component – Capacitors

- A capacitor is a two-terminal, electrical component. Along with resistors and inductors, they are one of the most fundamental passive components we use. You would have to look very hard to find a circuit which didn't have a capacitor in it. [Sparkfun]
- What makes capacitors special is their ability to store energy; they're like a fully charged electric battery. Caps, as we usually refer to them, have all sorts of critical applications in circuits. Common applications include local energy storage, voltage spike suppression, and complex signal filtering. [Sparkfun]
- Capacitors come in two varieties, polarized and non-polarized. Polarized capacitors have specific leads for positive and negative electrical connections.
- Most polarized capacitors are electrolytic. An electrolytic capacitor is a polarized capacitor whose anode or positive plate is made of a metal that forms an insulating oxide layer through anodization. Due to their very thin dielectric oxide layer and enlarged anode surface, electrolytic capacitors have a much higher capacitance-voltage (CV) product per unit volume than ceramic capacitors or film capacitors, and so can have large capacitance values. [Wikipedia]





Capacitors are critical components, pervasive in electronic devices

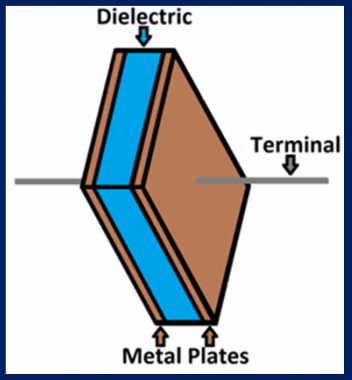
Capacitors - Measurement

Each capacitor is built to have a specific amount of capacitance. The capacitance of a capacitor tells you how much charge it can store, more capacitance means more capacity to store charge. The standard unit of capacitance is called the farad, which is abbreviated F.

It turns out that a farad is a lot of capacitance, even 0.001F (1 milifarad -- 1mF) is a big capacitor. Usually you'll see capacitors rated in the pico- (10-12) to microfarad (10-6) range.

When you get into the farad to kilofarad range of capacitance, you start talking about special caps called super or ultra-capacitors.

[Sparkfun]



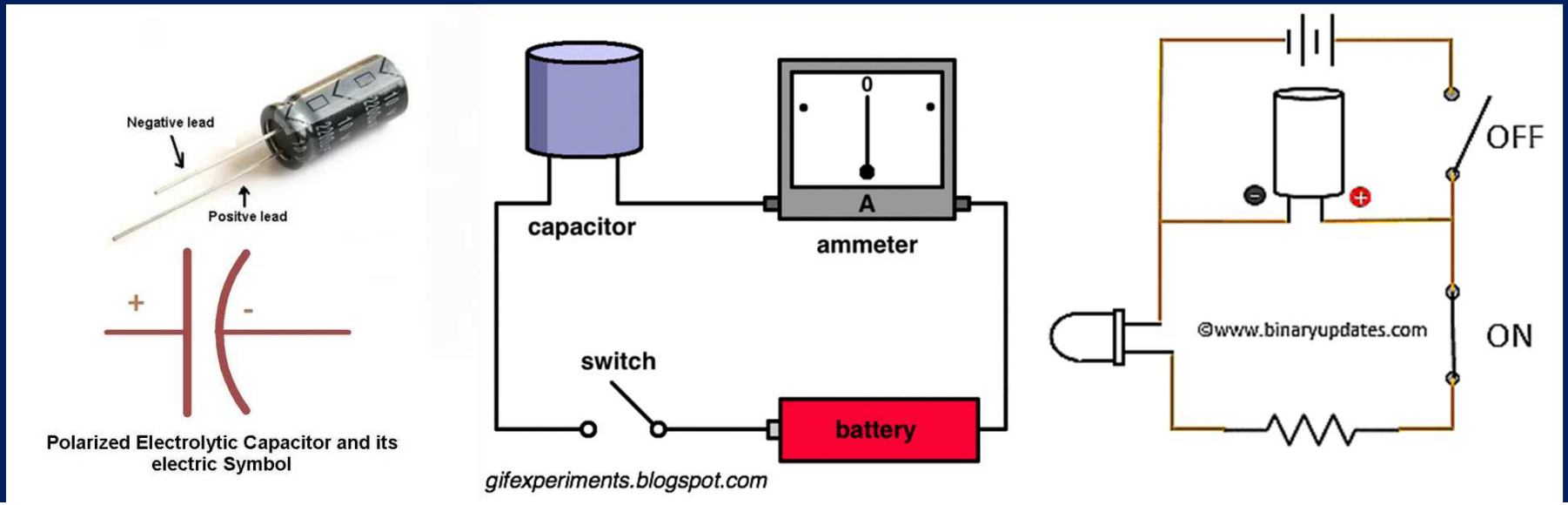
Prefix Name	Abbreviation	Weight	Equivalent Farads
Picofarad	pF	10^{-12}	0.000000000001 F
Nanofarad	nF	10^{-9}	0.000000001 F
Microfarad	µF	10^{-6}	0.000001 F
Milifarad	mF	10^{-3}	0.001 F
Kilofarad	kF	10^{3}	1000 F

Capacitors - Operation

When positive and negative charges coalesce on the capacitor plates, the capacitor becomes charged. A capacitor can retain its electric field -- hold its charge -- because the positive and negative charges on each of the plates attract each other but never reach each other.

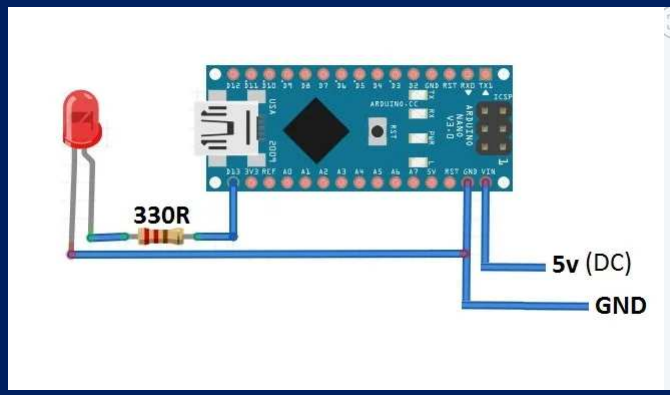
At some point the capacitor plates will be so full of charges that they just can't accept any more. There are enough negative charges on one plate that they can repel any others that try to join. This is where the capacitance (farads) of a capacitor comes into play, which tells you the maximum amount of charge the cap can store.

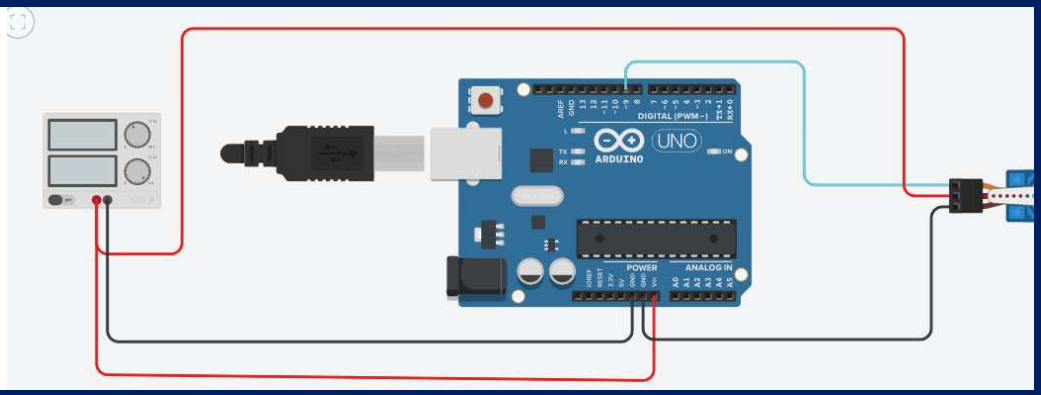
If a path in the circuit is created, which allows the charges to find another path to each other, they'll leave the capacitor, and it will discharge.
[Sparkfun]



Board Power Input Options And Grounding

- All boards can be powered externally, without USB connected.
- Some boards, such as the Arduino Uno, have an external power connector right on the board.
- For other boards, things can get more complicated
- The #1 rule in all cases is that **ALL DEVICES MUST SHARE A COMMON GROUND (RAIL).**
- Failure to provide common ground can, and probably will, cause component damage
- **It is very dangerous to connect USB power and external power rails together. Damage and even fire can result.**





External and USB Power

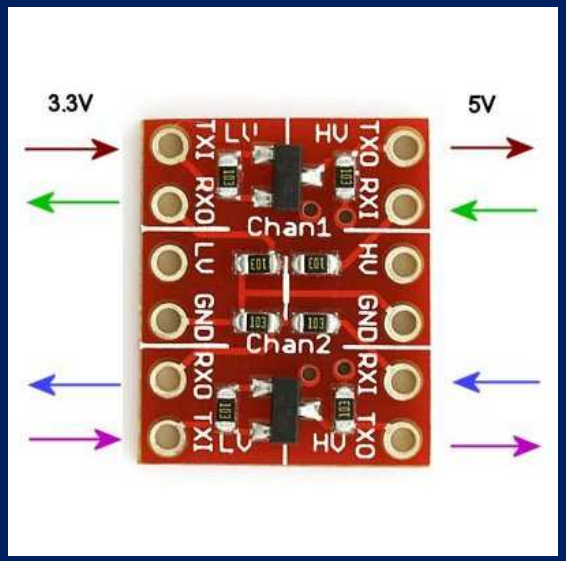
- Connecting USB and external power at the same time will frequently fry a board. This is especially true for the ESP-32, which uses lower capacity power regulation as it uses 3VDC.
- The easiest solution is (obviously) to only have one plugged in at a time.
- BEWARE!: As previously noted, when on USB power many boards will still supply 4.2VDC from the USB connector to the 5 volt rail. This allows peripherals to operate on USB power.
- That's not a problem for low current devices, but quantities of Neopixels will burn out the regulator, the laptop's USB chip, *or both*.
- The solution to this problem is to place a diode in-line between the 5 volt rail and the board's input power pin.
- The diode prevents power from "flowing back" from USB power to the peripherals.

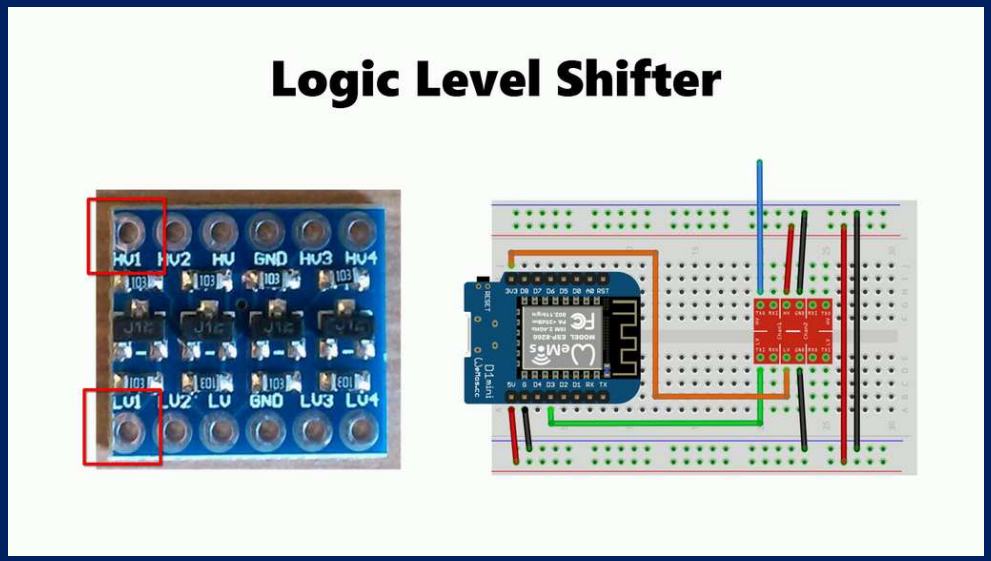
Different Voltage Requirements

- Not all peripherals will run at the same voltage as the microprocessor board you are using
- This results in different signal level tolerances. Not the power rails, *but the control signals themselves* operate at different voltages.
- Transmitting a 5 volt signal into a 3.3 volt device will damage or destroy the receiving device. This is as true for SPI as it is for traditional RS-232C TTL serial connections.
- Transmitting a 3 volt signal into a 5 volt device *sometimes* works. It depends on how well designed the receiving device is.
- The best-practice solution to this problem is to use devices called level shifters. Level shifters provide voltage translation between the two different signal levels.

Level Shifters

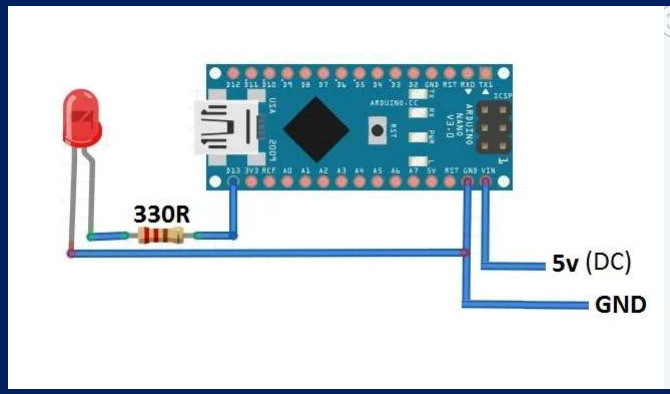
- Level shifters provide bidirectional translation of logical signal voltages between different digital peripherals and devices
- For instance, if you needed to connect a 3.3V microcontroller to a 5V real time clock (RTC), you would use a level shifter on the SPI or I2C serial connections
- Nearly all level shifters are for 5 VDC and 3.3VDC translation
- Level shifters are not self powered; they must have external power connections to the higher voltage (5V) rail

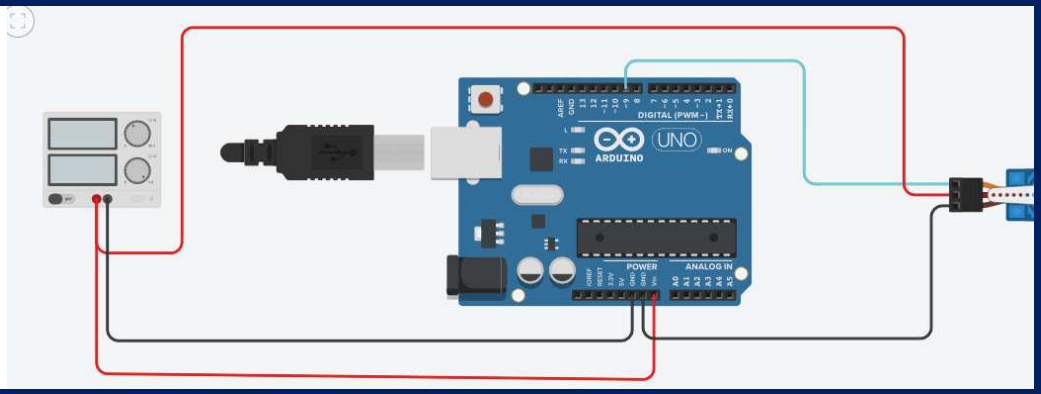




External Power Circuit Design

- All microcontroller boards have a range of external input power they will accept
- Not all boards have direct USB interfaces
- External power should be applied to the board's external power input pin. This is usually shown on the board pinout
- The Heltec Wifi Kit 32 accepts power on the 5V pin
- The maximum external power a Heltec will accept is six (6) volts.
- **Always maintain common grounding between all components, peripherals, and devices!**



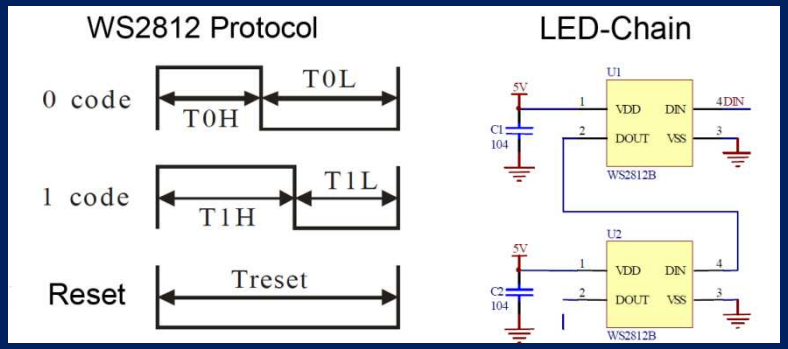


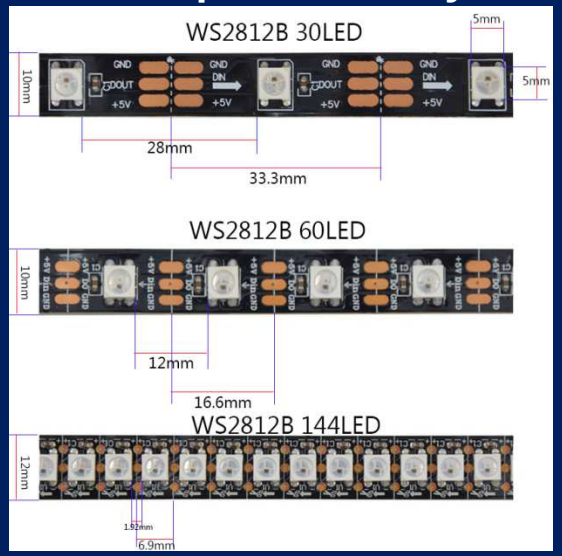
The WS2812B LED aka Neopixel

- The WS2812B is an (integrated) chip and 5050 package (flat, square) RGB LED
- An RGB LED can display 24 bits of color (0-255 red, 0-255 green, 0-255 blue)
- There are RGB LED controllers other than the WS2812B; discussion of those is outside the scope of our class
- “Neopixel” is a proprietary marketing term used by Adafruit Industries for their line of products based on the WS2812B
- RGB LEDs, and their chipsets, can be designed to run at 5VDC and 12VDC
- The chips of “Smart” LEDs make them individually controllable
- Control is by means of a one-wire transmit-only serial data protocol; the signal is directional with an input and an output for each pixel. Usually daisy-chained.

This is the WS2812B chip

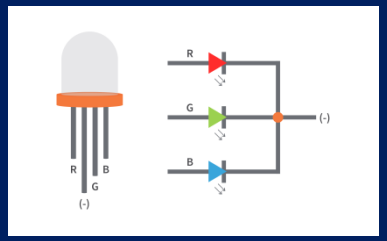
5050 RGB LED package





Types of WS2812B Strips

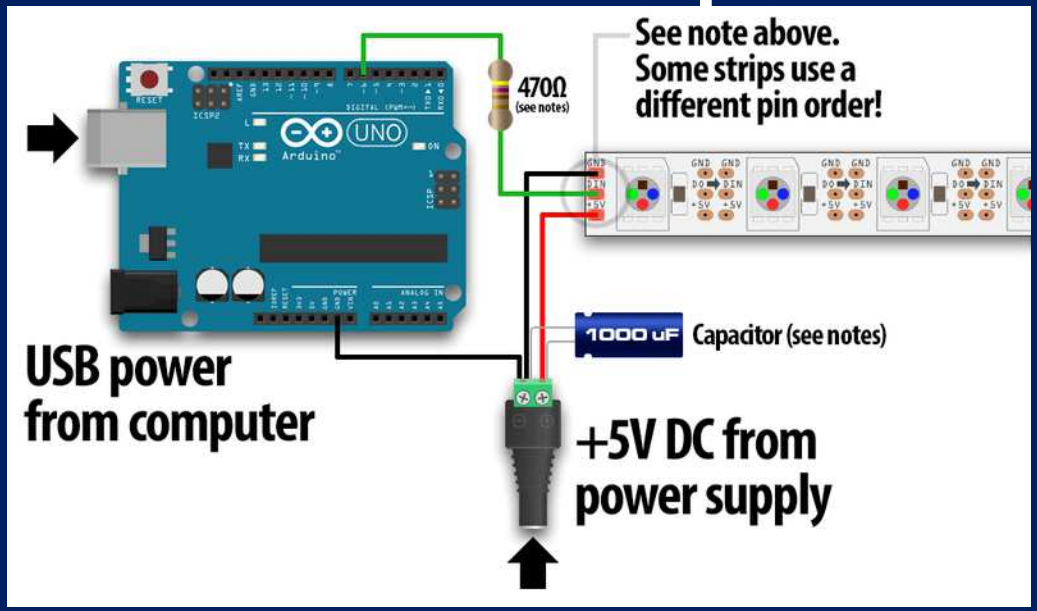
PIXELS ARE DIRECTIONAL!!!



“Traditional” RGB LED (5mm package)

External Power and WS2812B Neopixels

- RGB LEDs of any kind draw *LOTS* of current. 20mA per LED x 3 LEDs = 60 mA of current as a general power budget. *THAT'S PER LED.*
- More than 5 Neopixels will overload most 500mA board power regulators.
- The solution to this problem is to use external power for the LED strip.
- When the external power is 12 or 5 volts and the microcontroller is 3 volts things get very tricky indeed
- It's OK to send 5V to the board input power pin and the LEDs simultaneously
- It's generally NOT OK to connect USB power *at the same time*
- *Level shifting may be required for the serial data line (Data IN) to the Neopixels. This is entirely dependent on the pixel type. YMMV!*



The ability to SAFELY connect USB power and external power at the same time depends on the board!!!

Most boards will attempt to power peripheral devices *using USB power* There is no sanity checking of this action

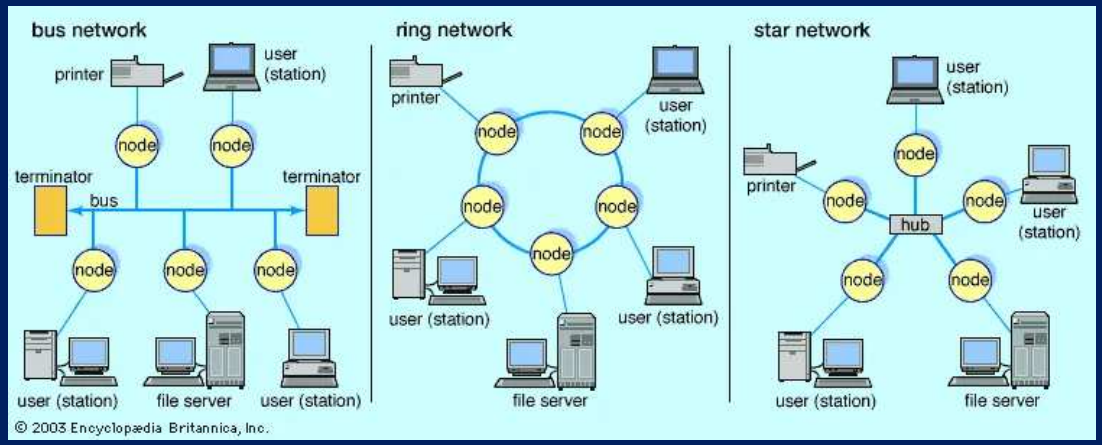
Trying to power numbers of Neopixels from *any* board will overload the onboard regulator

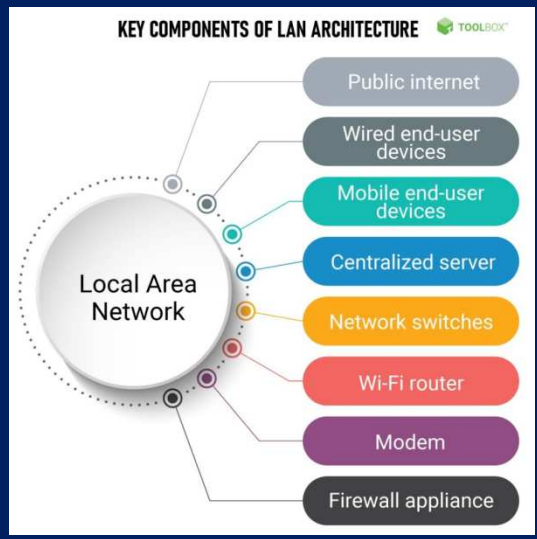
History of Telecommunications Part 2

- Local Area Networks (LANs)
- Wide Area Networks (WANs)
- Wireless LAN (WiFi)
- Cellular Voice Networks
- Cellular data networks
- The Internet - Overview

Local Area Networks

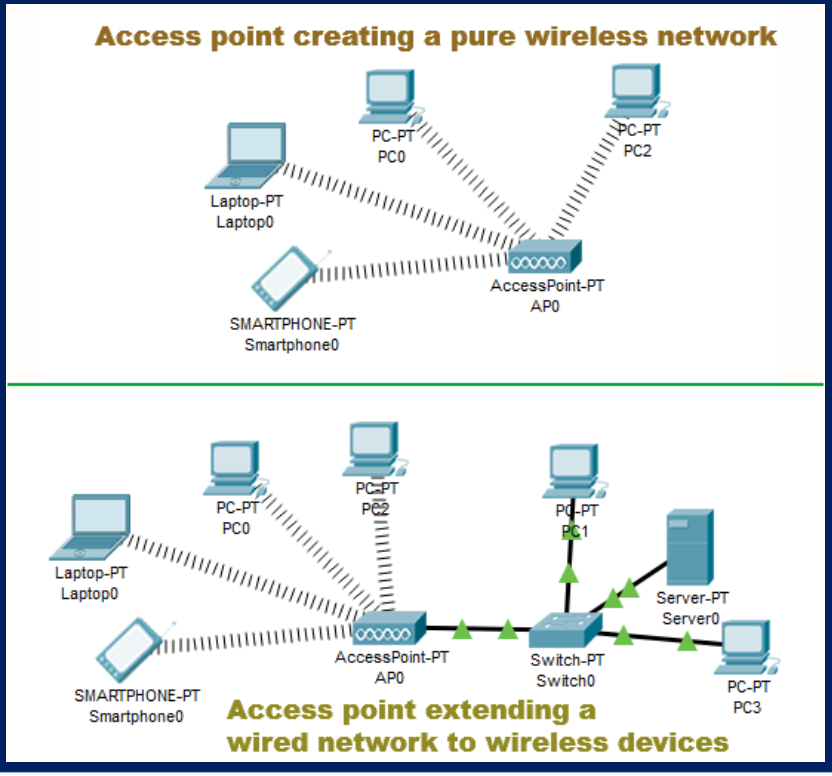
- A local area network (LAN) is a group of computers and peripheral devices that share a common communications line or wireless link to a server within a distinct geographic area. A local area network may serve as few as two or three users in a home office or thousands of users in a corporation's central office.
  Source: TechTarget
- Regardless of size, a LAN's single defining characteristic is that it connects devices that are in a single, limited area. Source: Cisco Systems
- TL;DR a LAN is a group of computers in a single physical location connected together with physical cabling to allow exchange of data





Wireless LAN (WiFi)

- WLAN/Wi-Fi is a family of wireless network protocols, based on the IEEE 802.11 family of standards, which are commonly used for local area networking of devices and Internet access, allowing nearby digital devices to exchange data by radio waves. These are the most widely used computer networks in the world, used globally in home and small office networks to link desktop and laptop computers, tablet computers, smartphones, smart TVs, printers, and smart speakers together and to a wireless router to connect them to the Internet, and in wireless access points in public places like coffee shops, hotels, libraries and airports to provide the public Internet access for mobile devices. Source: Wikipedia
- WLAN is the wireless technology used to connect computers, tablets, smartphones and other devices to the internet. Wi-Fi is the radio signal sent from a wireless router to a nearby device, which translates the signal into data you can see and use. Source: Verizon

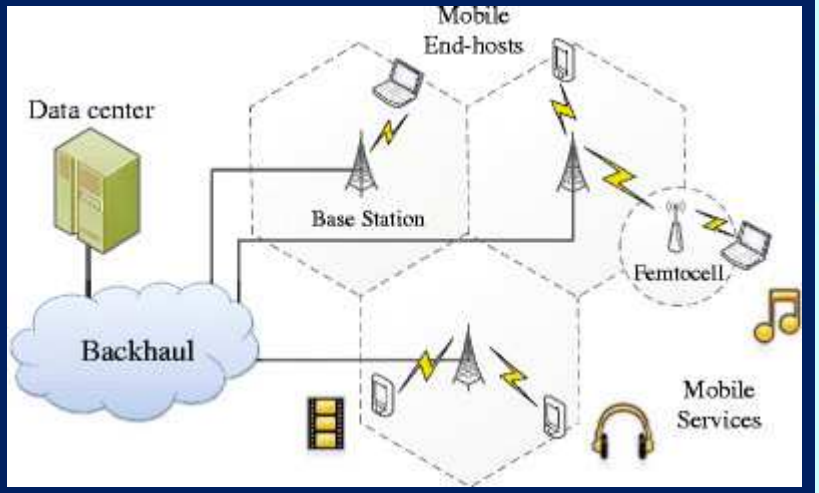


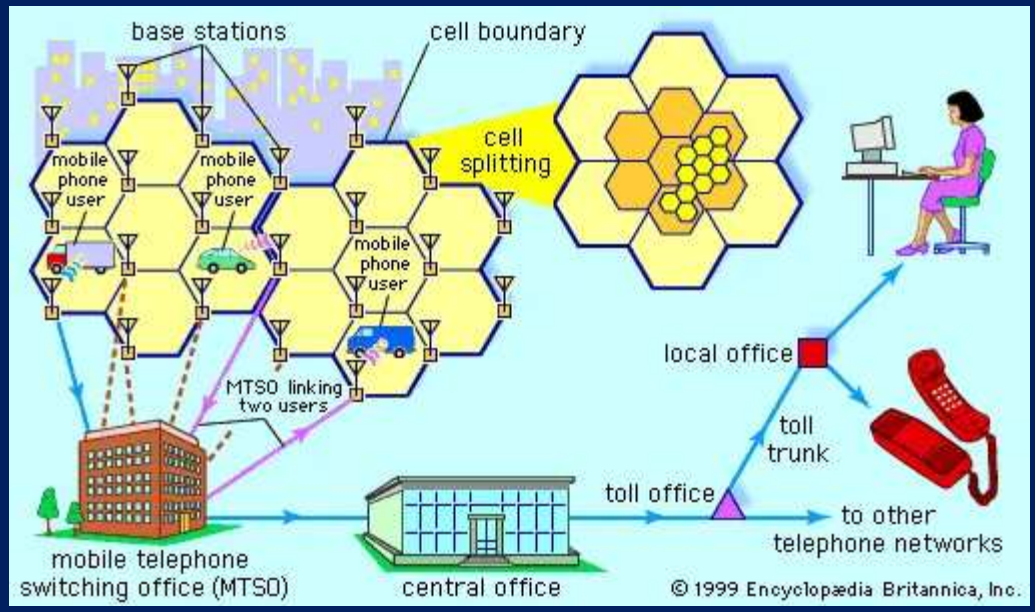
Types of wireless networks

	Wireless LAN (WLAN)	Wireless MAN (WMAN)	Wireless PAN (WPAN)	Wireless WAN (WWAN)
TYPE OF NETWORK	Local area network	Metropolitan area network	Personal area network	Wide area network
GOAL	Provide internet access within a building or limited outdoor area	Provide access outside office and home networks, typically regional	Transmit signals between devices in limited areas, typically 100 meters	Provide access outside the range of WLANs and WMANs
CONNECTIVITY	Cellular	IEEE 802.16 WiMax	Bluetooth, Zigbee and infrared	LTE

Cellular Voice Networks

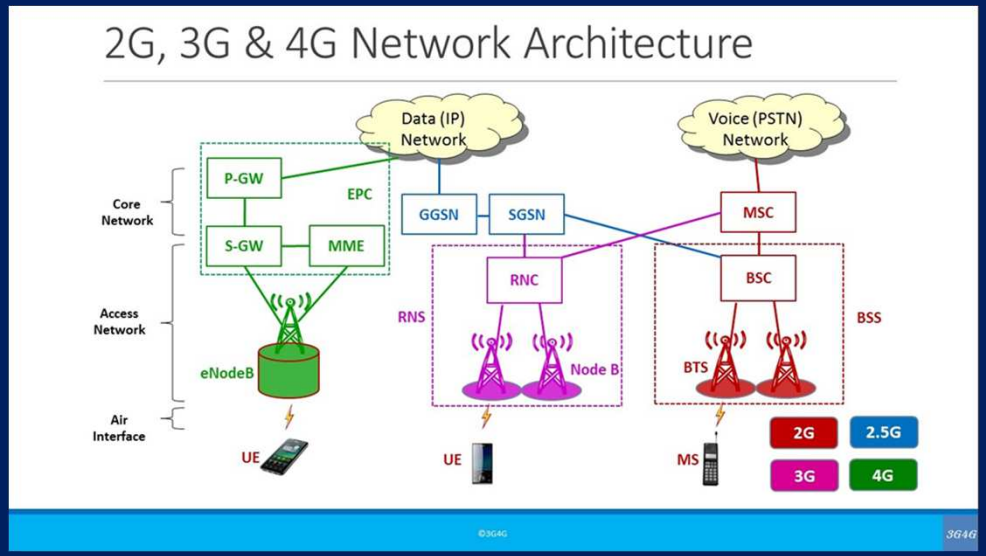
- A cellular network or mobile network is a communication network where the link to and from end nodes is wireless. The network is distributed over land areas called "cells", each served by at least one fixed-location transceiver (typically three cell sites or base transceiver stations). These base stations provide the cell with the network coverage which can be used for transmission of voice, data, and other types of content. A cell typically uses a different set of frequencies from neighboring cells, to avoid interference and provide guaranteed service quality within each cell. When joined together, these cells provide radio coverage over a wide geographic area. Source: Wikipedia
- Cellular networks can be designed to carry voice, data, or both. The earliest cellular networks were voice networks, connecting back to the PSTN (Public Switched Telephone Network).

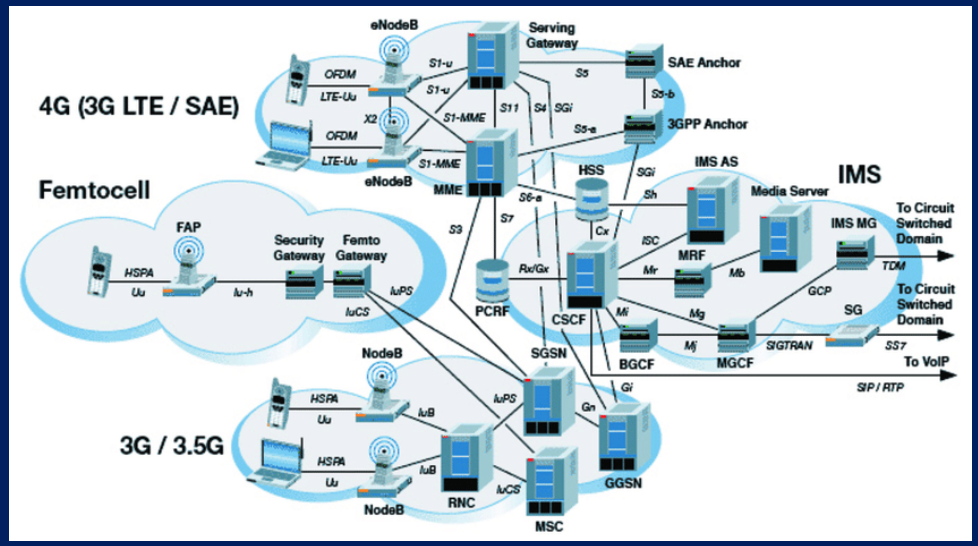




Cellular Data Networks

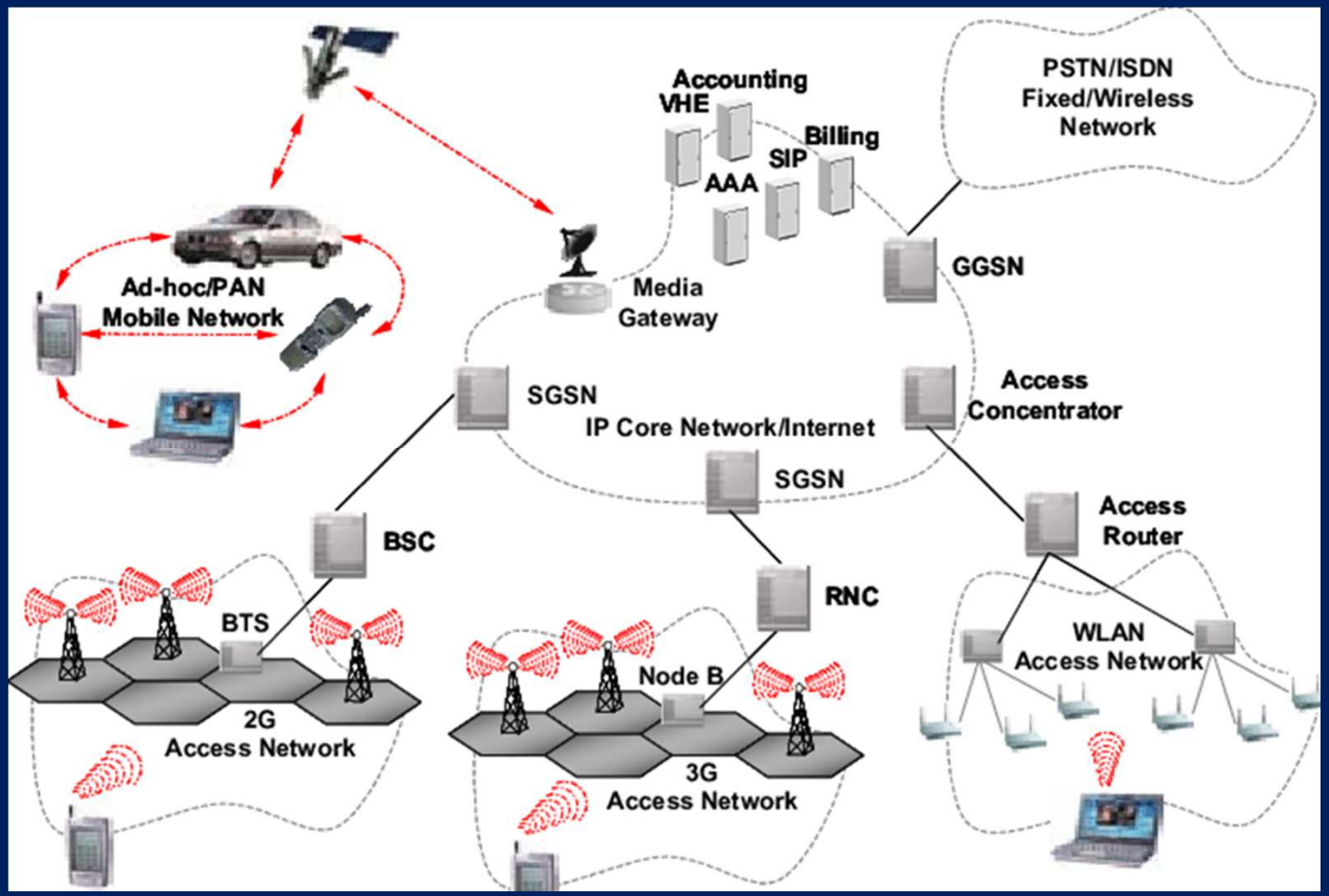
- Cellular Network Data is a *data* connection from the cellular device to the cell site. LTE (4G), 3G and 1X are types of cellular network data connections. Data sessions include, but are not limited to, browsing the Internet such as Google, streaming music, videos and movies, sending and receiving emails, sending and receiving MMS messages, hotspot hosting and application use. While connected to the cellular data network, data usage will pull from the current data plan.
- As with all communications between two computers, “data” refers to information encoded into a bitstream of binary numbers. The method used for encoding varies by network layer, device, and communications protocol.





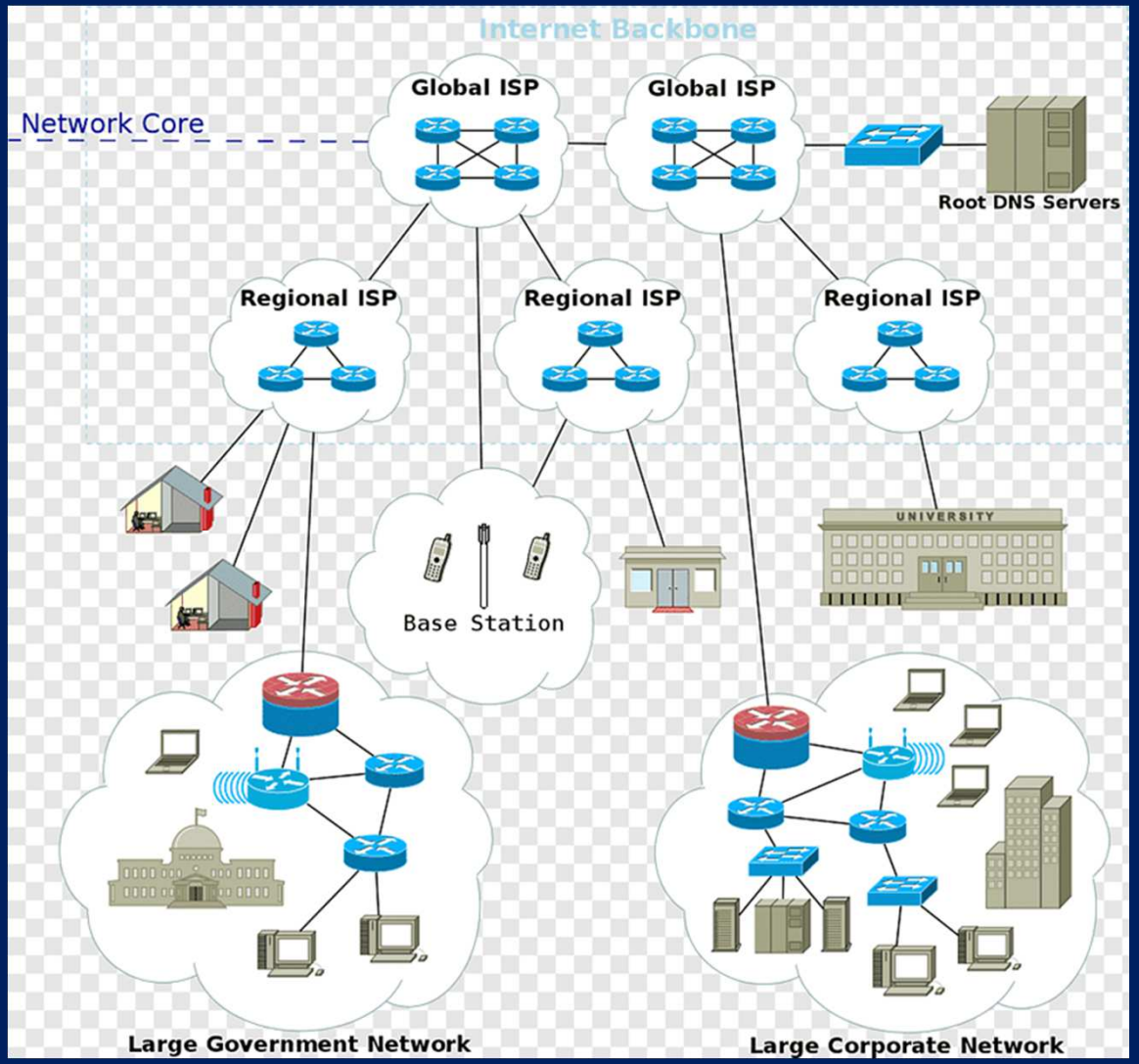
WiFi and Cellular

- WiFi connects to a local router, cellular data connects to a remote router
- WiFi has a limited range, cellular data does not



The Internet - Architecture

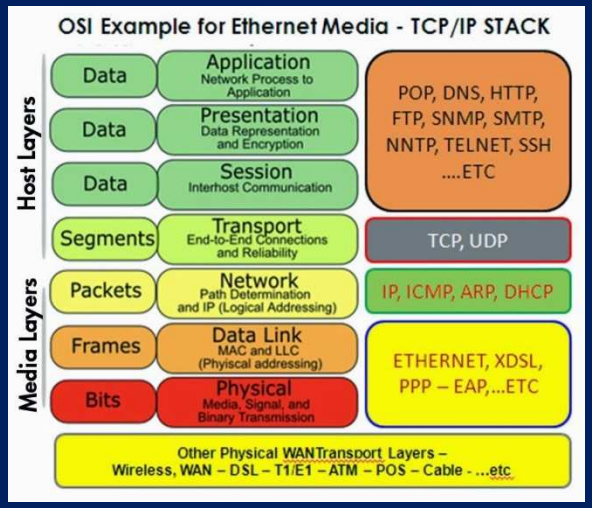
- The Internet is a “network of networks” used to connect many many LANs and WANs together
- Originally the Internet was owned and operated by the US DoD and NSF
- Public connectivity became available in 1992 from a company called PSI

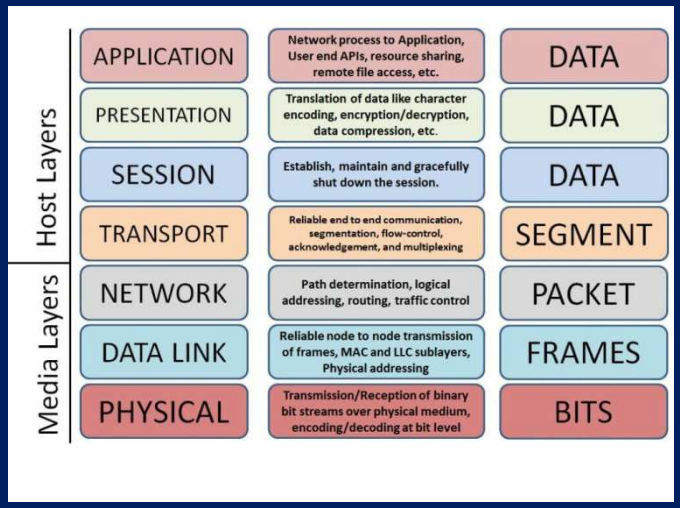


The OSI/ISO Layered Network Model

- In a Quora post asking about the purpose of the OSI model, Vikram Kumar answered this way:
- “The purpose of the OSI reference model is to guide vendors and developers so the digital communication products and software programs they create will interoperate, and to facilitate clear comparisons among communications tools.”
- While some people may argue that the OSI model is obsolete (due to its conceptual nature) and less important than the four layers of the TCP/IP model, Kumar says that “it is difficult to read about networking technology today without seeing references to the OSI model and its layers, because the model’s structure helps to frame discussions of protocols and contrast various technologies.”
- If you can understand the OSI model and its layers, you can also then understand which protocols and devices can interoperate with each other when new technologies are developed and explained.

Source: Network World

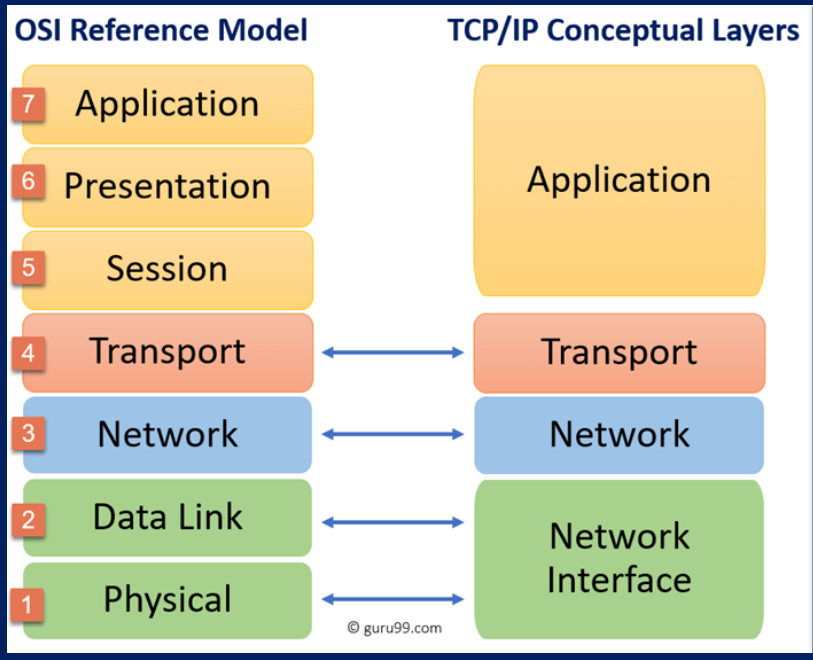


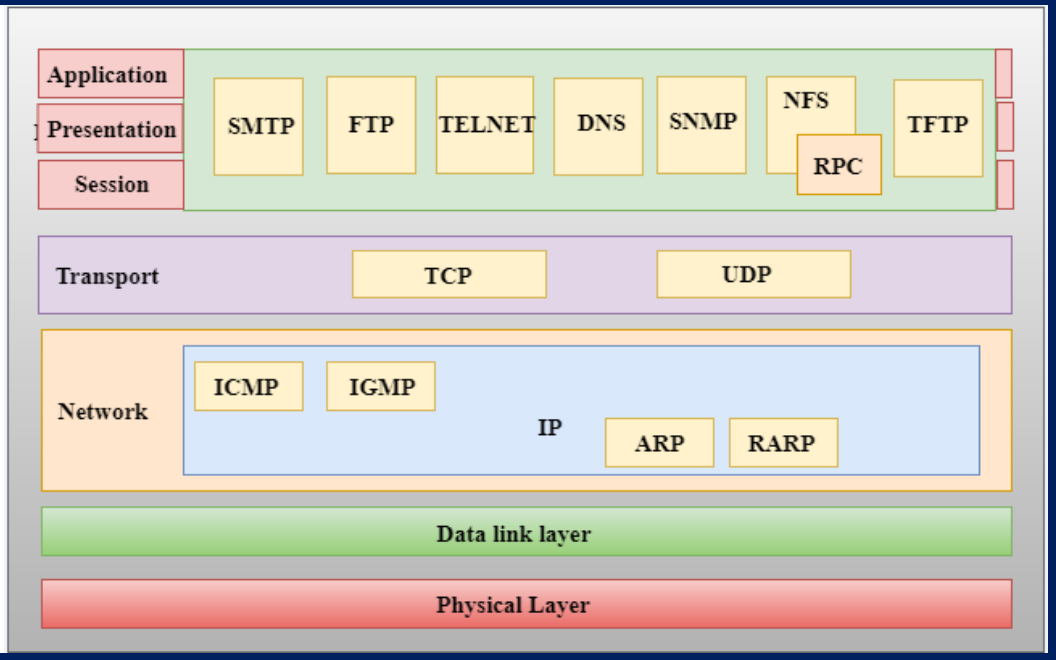


Layer			Protocol data unit (PDU)	Function[21]
Host layers	7	Application	Data	High-level APIs, including resource sharing, remote file access
	6	Presentation		Translation of data between a networking service and an application; including character encoding, data compression and encryption/decryption
	5	Session		Managing communication sessions, i.e., continuous exchange of information in the form of multiple back-and-forth transmissions between two nodes
	4	Transport	Segment, Datagram	Reliable transmission of data segments between points on a network, including segmentation, acknowledgement and multiplexing
Media layers	3	Network	Packet	Structuring and managing a multi-node network, including addressing, routing and traffic control
	2	Data link	Frame	Reliable transmission of data frames between two nodes connected by a physical layer
	1	Physical	Bit, Symbol	Transmission and reception of raw bit streams over a physical medium

ISO/OSI vs The TCP/IP Model

- TCP/IP is the data interchange protocol used by the Internet for computer-to-computer (host-to-host) communications
- It only loosely follows the formal OSI/ISO reference model
- Many consider TCP/IP to be a separate model, but this is not entirely true
- We will not be studying TCP/IP in depth, but it is important to know that it exists and is the underlying protocol used in all web comms





Accurate **Inaccurate**

Formal End of Lesson 9

In next week's exciting episode

- External device power circuit design recap
- Level shifting recap
- WS2812B and Neopixel connections – Class Sketch #3
- Flashing software binaries
- Flashing software on Linux
- Flashing software on Windows
- Flashing WLED software
- Appendices: ESP8266 reference: Pinouts, flashing procedures

Don't forget to return your USB drives!