Wireless Technologies: Wi-Fi

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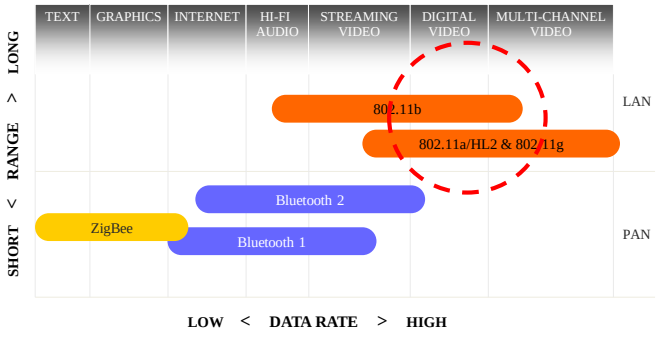
Wireless Technologies

- Wi-Fi
- Bluetooth
- Cellular
- 3G (3rd Generation)
- UWB (Ultra Wide Band)
- FSO (Free Space Optics)
- WiMAX
- ZigBee
- …



Wireless Technologies

Figure 1.

Select the Best Wireless Standard for Your Application

	ZigBee 802.15.4	Bluetooth 802.15.1	Wi-Fi 802.11b	GPRS/GSM 1XRTT/CDMA
System resource	4-32 KB	250 KB+	1 MB ±	16 MB+
Battery life (days)	100-1,000+	1-7	0.1-5	1-7
Nodes per network	255/65,000+	7	30	1-1000
Bandwidth (KBps)	20-250	720	11,000+	64-128
Range (meters)	1-75+	1-10+	1-100	1000+

Figure 2.

Which Wireless Standard?

	Application Focus	Success Metrics
ZigBee	Monitoring and control	Reliable, secure networking Protocol simplicity Low power consumption
Bluetooth	Cable replacement	Low incremental cost Ease of use/convenience Moderate data rate
Wi-Fi	Web, email, and video	High data throughput Flexibility (work and home) Hot Spot connectivity
GPRS / GSM	Wireless voice and data	Broad geographic coverage Datacentric pricing plans Network build-out

Outline

- Wi-Fi
- ESP-01 (ESP8266 circuit) Module
- Example Application + Demo

What is a Wireless LAN?

- **Wireless LAN (WLAN)** - provides all the features and benefits of traditional LAN technologies such as Ethernet, but without the limitations of wires or cables.

Definition of Wi-Fi?

- Wi-Fi (or WiFi) is a local area wireless computer networking technology that allows electronic devices to connect to the network.
- The standard for wireless local area networks (WLANs). It is like a common "language" that all the devices use to communicate to each other. If you have a standard, people can make all sorts of devices that can work with each other.
- The governing body that owns the term Wi-Fi, the Wi-Fi Alliance, defines it as any WLAN products that are based on the Institute of Electrical and Electronics Engineers' (IEEE) 802.11 standards.
- ~~Wireless Fidelity~~

History of Wi-Fi

- In 1985 the FCC allowed the opening of several bands of the wireless spectrum. Allowing those bands to be used without government license.
- The bands were taken from the scientific, medical, and industrial bands of the wireless spectrum.
- The FCC made these bands available for communication purposes.
- Using spread spectrum technology, which spreads a radio signal over wide range of frequencies they were able to steer around interference from other equipment.
- When Ethernet became popular vendors came to the realization that a wireless standard was best.

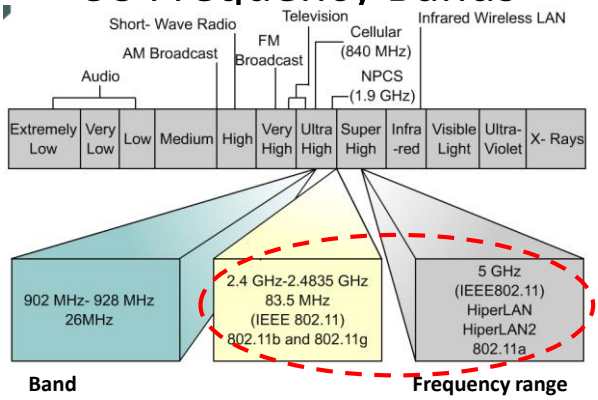
History of Wi-Fi Continued….

- In 1988, the NCR Corporation wanted to use the unlicensed spectrum to hook up wireless cash registers, they looked into getting a standard started.
- Victor Hayes and Bruce Tuch were hired and they went to the IEEE and created the committee known as 802.3.
- Vendors took a while to agree on an acceptable standard due to the fragmented market.
- In 1997 the committee agreed on a basic specification that allowed for a data-transfer rate of two megabits per second.
- Two technologies known as frequency hopping and direct-sequence transmission.

History of Wi-Fi Continued

- The new standard was finally published in 1997, and engineers immediately began working on prototype equipment that was compliant.
- Two variants: 802.11b (operates in 2.4GHz band) and 802.11a (operates in 5.8GHz band) - were ratified in December 1999 and January 2000 respectively.
- In August 1999 the Wireless Ethernet Compatibility Alliance (WECA) was created with the intention to assure compatibility between products from various vendors.
- A consumer friendly name was need for this new technology and the term "Wi-Fi" came to be.
- Apple was the first to supply their computers with Wi-Fi slots on all their laptops, thus sparking the mainstream penetration of Wi-Fi.

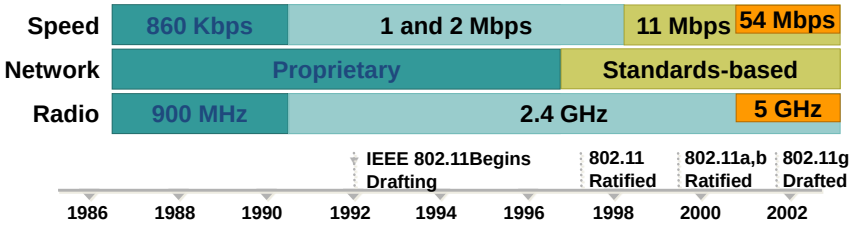
US Frequency Bands



Band	Frequency range
UHF ISM	902-928 MHz
S-Band	2-4 GHz
S-Band ISM	2.4-2.5 GHz
C-Band	4-8 GHz
C-Band satellite downlink	3.7-4.2 GHz
C-Band Radar (weather)	5.25-5.925 GHz
C-Band ISM	5.725-5.875 GHz
C-Band satellite uplink	5.925-6.425 GHz
X-Band	8-12 GHz
X-Band Radar (police/weather)	8.5-10.55 GHz

Wi-Fi Standards

Standard	Speed	Freq. band	Notes
• 802.11	2 Mbps	2.4 GHz	(1997)
• 802.11a	54 Mbps	5 GHz	(1999)
• 802.11b	11 Mbps	2.4 GHz	
• 802.11g	54 Mbps	2.4 GHz	
• 802.11n	600 Mbps	2.4/5 GHz	



IEEE 802.11 Standards Activities

- 802.11a: 5GHz, 54Mbps
- 802.11b: 2.4GHz, 11Mbps
- 802.11d: Multiple regulatory domains
- 802.11e: Quality of Service (QoS)
- 802.11f: Inter-Access Point Protocol (IAPP)
- 802.11g: 2.4GHz, 54Mbps
- 802.11h: Dynamic Frequency Selection (DFS) and Transmit Power Control (TPC)
- 802.11i: Robust Security Network
- 802.11j: Japan 5GHz Channels (4.9-5.1 GHz)
- 802.11k: Measurement
- 802.11n: High throughput standard > 100Mbps. Backwards compatible with a,b,g

Advantages

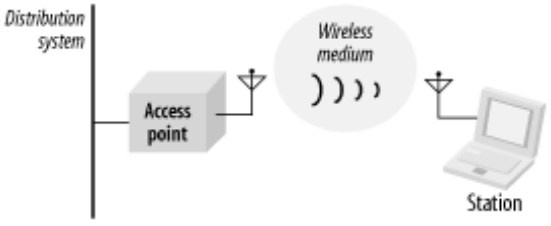
- Freedom – You can work from any location where you can get a signal.
- Setup Cost – No cabling required.
- Flexibility – Quick and easy to setup in temporary or permanent space.
- Scaleable – Can be expanded with growth.
- Mobile Access – Can access the network on the move.

Disadvantages

- Speed – Slower than cable.
- Range – Affected by various mediums.
  - Travels best through open space.
  - Reduced by walls, glass, water, etc.
- Security – Greater exposure to risks.
  - Unauthorized access.
  - Compromising data.
  - Denial of service.

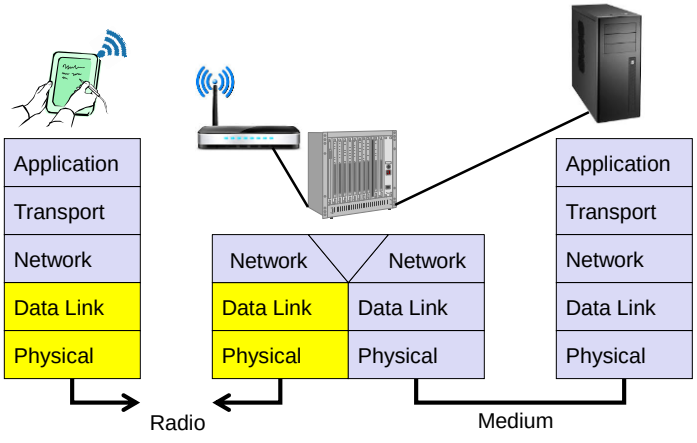
How does Wi-Fi work?

- Wi-Fi works through the use of radio frequency (RF) signals. The ability of radio waves to pass through walls and cover great distances makes wireless a versatile way to build a network.
- The wireless adapter card that is found inside of computers uses the data that is being sent to change it into a radio signal to be transmitted by the antenna.
- A router then receives these signals and decodes them in order to send the information contained within to the Internet via a Local Area Network or a wired Ethernet connection like a cable network connection.



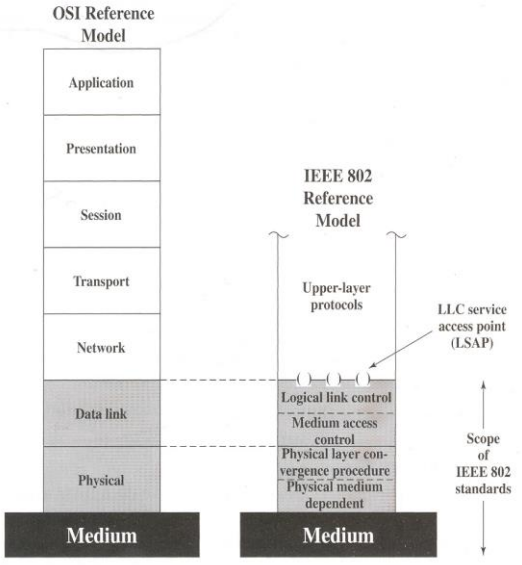
Reference Model

- Standard 802.11 is primarily concerned with the lower layers of the Open Systems Interconnection (OSI) model



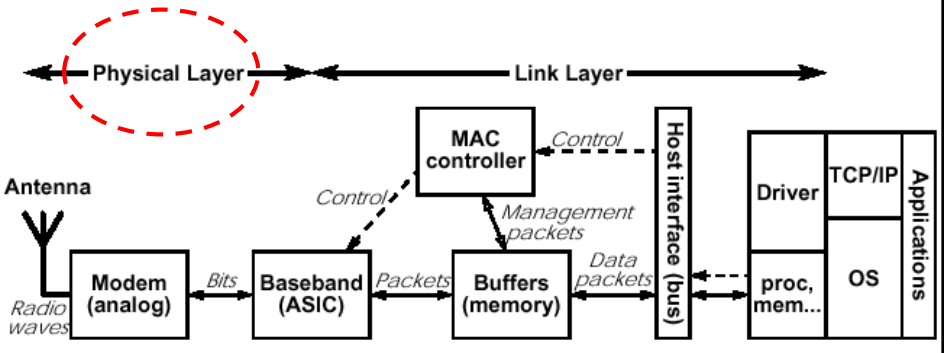
IEEE 802 vs. OSI

- Data Link Layer
  - Logical Link Control (LLC)
  - Medium Access Control (MAC)
- Physical Layer
  - Physical Layer Convergence Procedure (PLCP)
  - Physical Medium Dependent (PMD)



IEEE 802 Protocol Layers Compared to OSI Model

Functional Diagram



802.11 PHY (Physical Layer) Technologies

- Three types of radio transmission within the unlicensed 2.4-GHz frequency bands:
  - Frequency hopping spread spectrum (FHSS) 802.11b (not used)
  - Direct sequence spread spectrum (DSSS) and then Complementary Code Keying (CCK) 802.11b
  - Orthogonal frequency-division multiplexing (OFDM) 802.11g
- One type of radio transmission within the unlicensed 5-GHz frequency bands:
  - Orthogonal frequency-division multiplexing (OFDM) 802.11a

Orthogonal frequency-division multiplexing (OFDM)

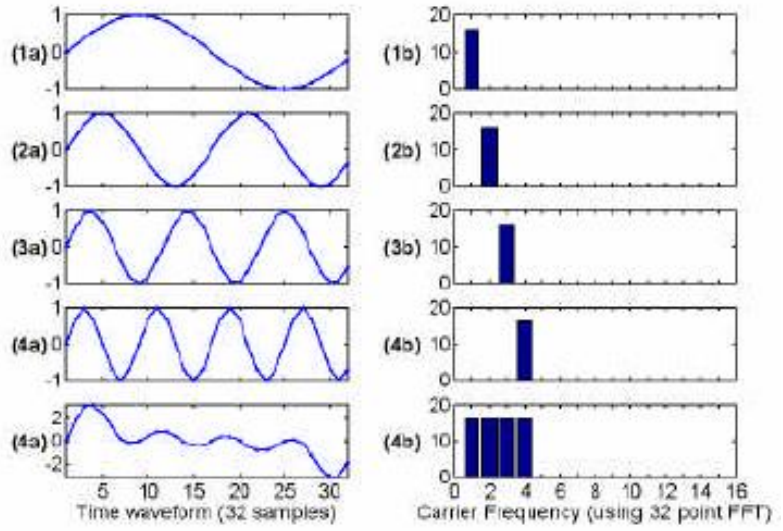
- A method of encoding digital data on multiple carrier frequencies
- Keeps the modulated carriers orthogonal
- Each carrier is modulated using BPSK/QPSK/M-ary QAM
- Do not interfere with each other
- Overlap of frequency response is possible as opposed FDM where inter-carrier spacing is a must
- Frequency responses of the carriers overlap at zero crossings avoiding Inter Carrier Interference (ICI)
- Effectively squeezes multiple modulated carriers tightly together, reducing required bandwidth
- Popular scheme for wideband digital communication (digital television, DSL Internet access, wireless networks, 4G,…)

OFDM Advantages

- Allows carriers to overlap (no guard band), resulting in lesser wasted bandwidth without any Inter Carrier Interference (ICI)
- High data rate distributed over multiple carriers resulting in lower error rate
- Permits higher data rate as compared to FDM
- Increased security and bandwidth efficiency possible using CDMA-OFDM (MC-CDMA)
- Simple guard intervals make the system more robust to multipath effects

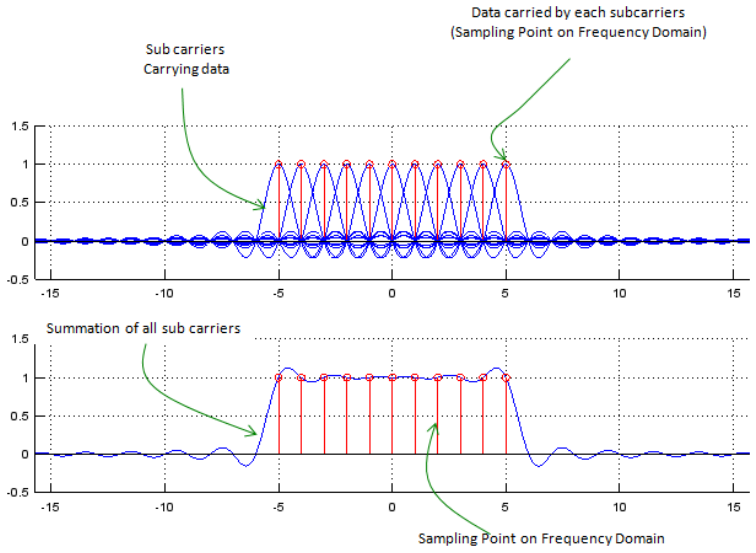
What is OFDM?

Orthogonality in time domain…

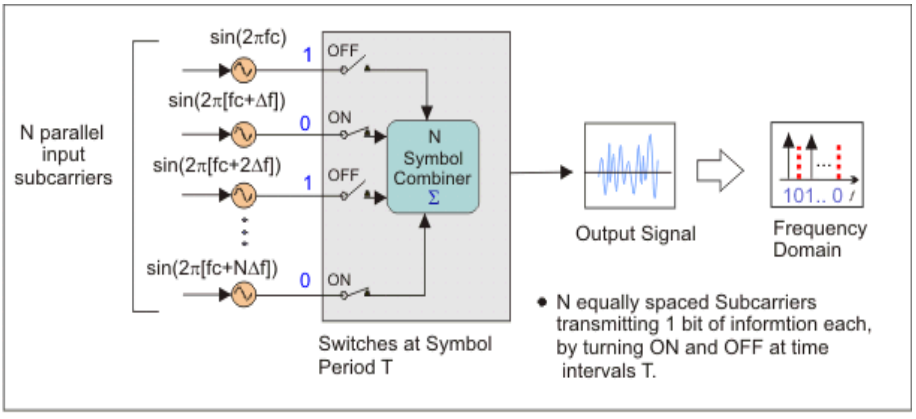


What is OFDM?

Orthogonality in frequency domain…

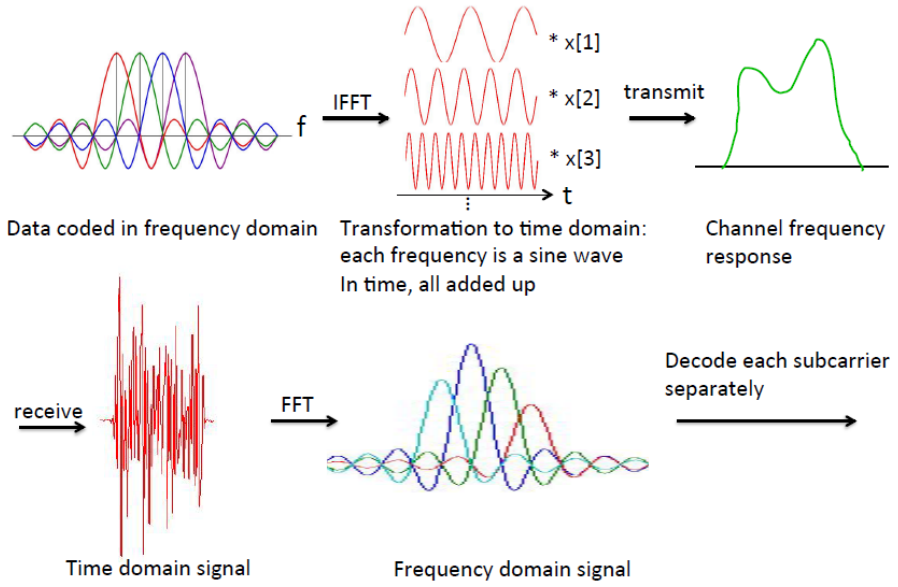


Simplified OFDM Generation

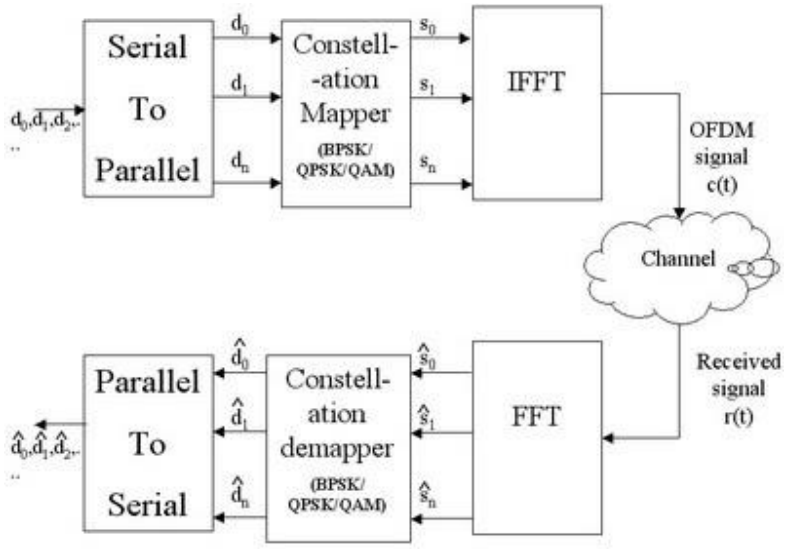


Simple OFDM Generation

OFDM Methodology



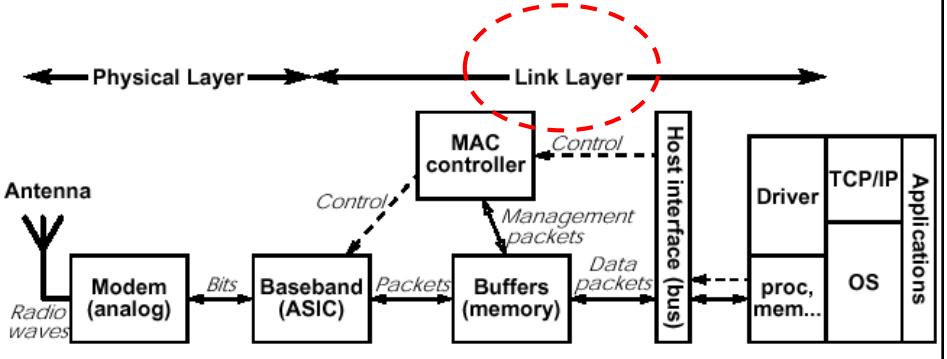
OFDM Transciever



Antennas

- All WLAN equipment comes with a built-in omni-directional antenna, but some select products will let you attach secondary antennas that will significantly boost range
- Antenna
  - 2.4 GHz Antennas
  - 5 GHz Antennas

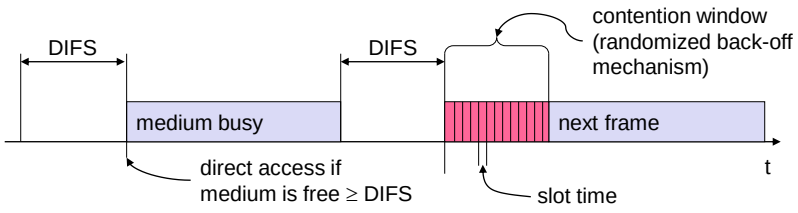
Functional Diagram



802.11 - MAC Layer

- Traffic services
  - Asynchronous Data Service (mandatory) – DCF
  - Time-Bounded Service (optional) - PCF
- Access methods
  - DCF (distributed coordination function) CSMA/CA (carrier sense multiple access with collision avoidance): mandatory
    - Collision Avoidance via randomized back-off mechanism
    - ACK packet for acknowledgements (not for broadcasts)
  - DCF w/ RTS/CTS (optional)
    - Avoids hidden terminal problem
  - PCF (point coordination function): optional
    - Access point polls terminals according to a list

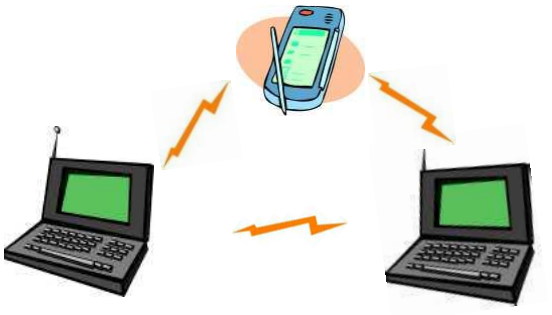
802.11 - CSMA/CA



- station ready to send starts sensing the medium (Carrier Sense based on CCA, Clear Channel Assessment)
- if the medium is free for the duration of an Inter-Frame Space (IFS), the station can start sending (IFS depends on service type)
- if the medium is busy, the station has to wait for a free IFS, then the station must additionally wait a random back-off time (collision avoidance, multiple of slot-time)
- if another station occupies the medium during the back-off time of the station, the back-off timer stops (fairness)

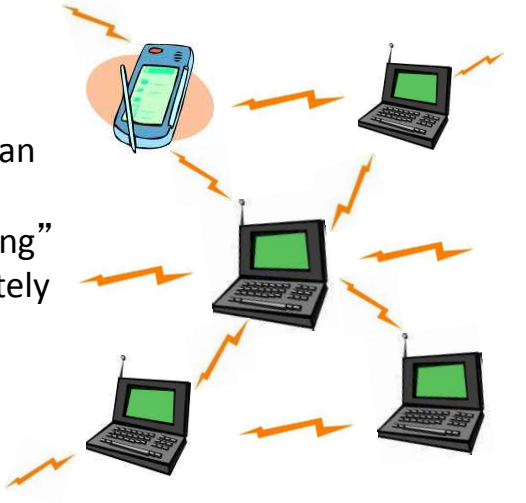
WLAN Architecture - **Ad Hoc Mode**

- Peer-to-peer setup where clients can connect to each other directly. Generally not used for business networks
- Set up for a special purpose and for a short period of time



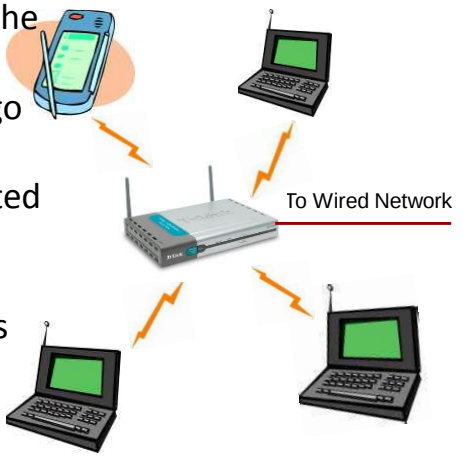
WLAN Architecture - **Mesh**

- Every client in the network also acts as an access or relay point, creating a "self-healing" and (in theory) infinitely extensible network.



WLAN Architecture - **Infrastructure Mode**

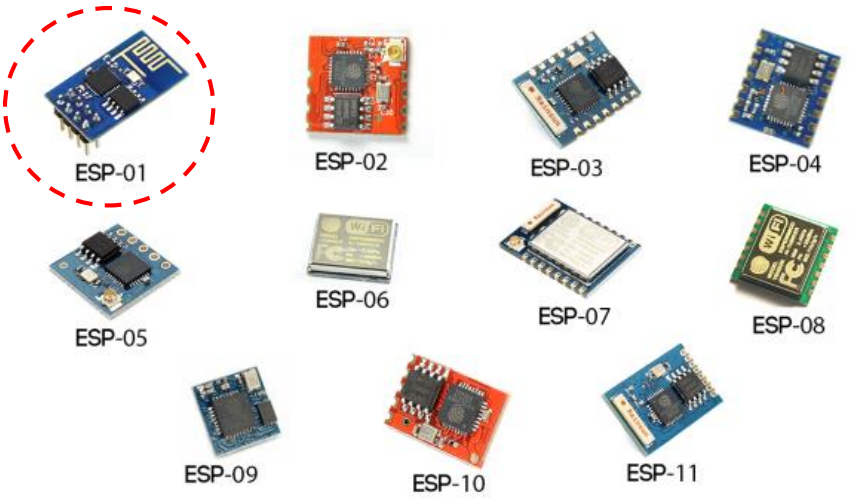
- Access Point (AP) becomes the hub of a "star topology"
- Any communication has to go through AP
- Multiple APs can be connected together to handle a large number of clients
- Majority of WLANs in homes and businesses



Outline

- Wi-Fi
- ESP-01 (ESP8266 circuit) Module
- Example Application + Demo

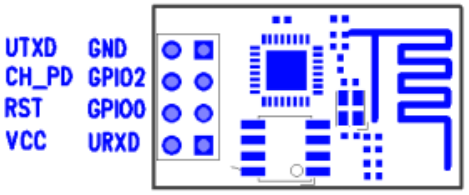
ESP8266 Based Modules

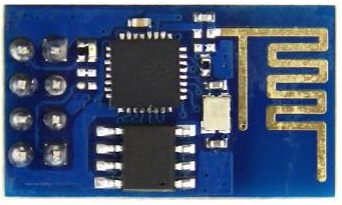


ESP8266 Circuit

- CPU
  - 32 bit
  - 26MHz-52MHz
  - 64KB instruction RAM, 64KB boot ROM
  - 96KB data RAM
- Wi-Fi
  - 802.11b/g/n
  - Access Point or Station
  - WEP
- GPIO, UART, ADC, I2C, SPI, PWM
- Made by Expressif, Dec.2013?

ESP-01 Module





- $US 2...3 @ ebay
- 3.3V - an inconvenience when working with boards like Arduino (5V)
- 115200 baudrate - but can be changed (to be able to use with “software” serial on Arduinos)
- AT commands set
- Firmware can be updated – somewhat painful

ESP8266 AT Commands

- AT+RST
- AT+CWMODE=1
- AT+CWJAP=ssid,password
- AT+CIPMUX=1
- AT+CIPSERVER=1,8888
- AT+CIPSEND=0,13
- ...

Outline

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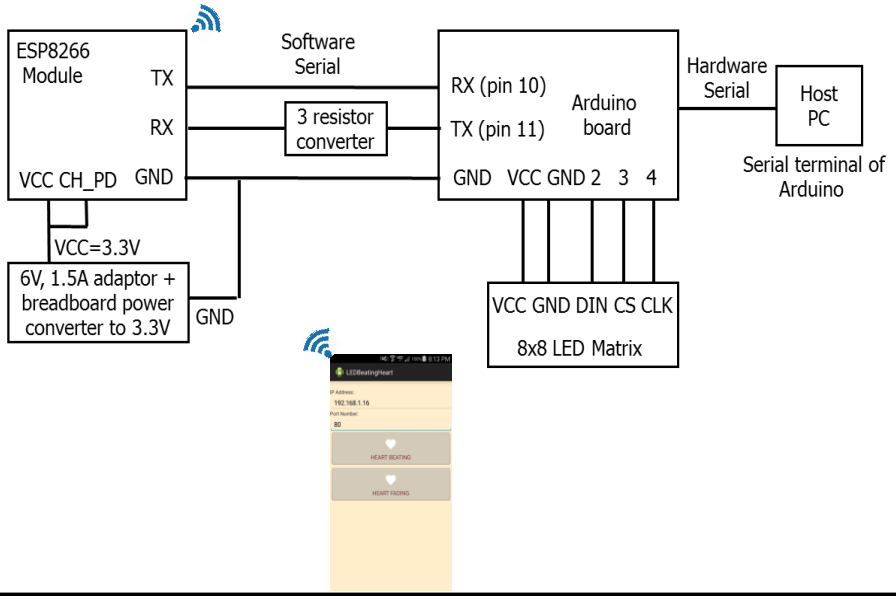
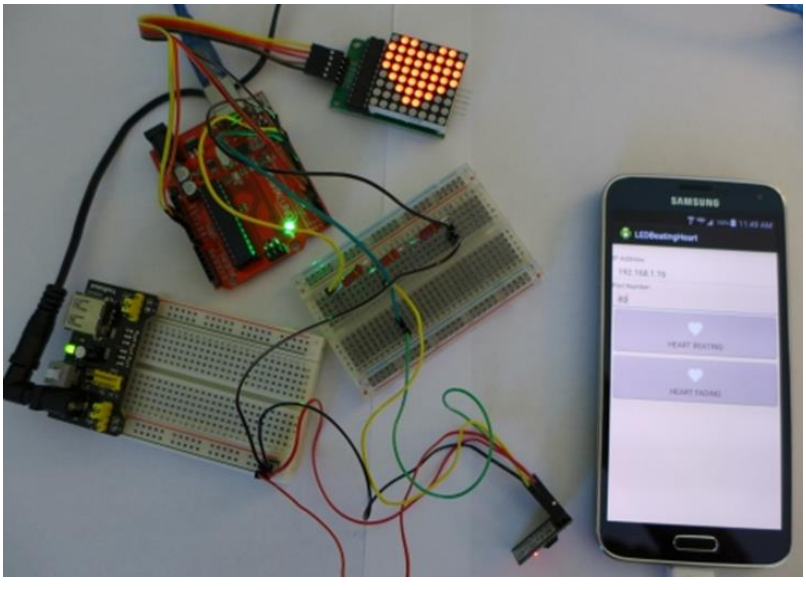
Example Projects that use ESP-01

- Arduino based (can be ported to other MCU boards, such as LandTiger 2.0) examples:
  - Example #1: Request a static page from internet
  - Example #2: ESP8266 module as webserver
  - Example #2 (using an Arduino library): ESP8266 module as webserver
  - Example #3: Log Temperature Data with an Arduino Board (working on)
  - Example #4: ESP8266 Arduino LEDs control from webpage
  - Example #5: ESP8266 Arduino LEDs control from Android app
  - Example #6: ESP8266 Arduino + 8x8 LED matrix control from Android app

Block Diagram



(Not so neat) Experimental Set-up



Credits, References

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