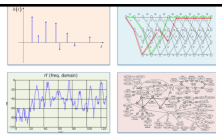


INTRODUCTION TO EECS II

DIGITAL COMMUNICATION SYSTEMS

802.11 Networks for ~~Dummies~~ Professors

Lecture 25

December 6, 2010

6.02 Fall 2010

802.11 (WiFi) physical, link, and subnetwork layer essentials

Application of 6.02 topics and techniques

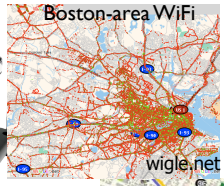
What is 802.11?

- Suite of physical layer (PHY) and link-layer protocols standardized by IEEE
  - Aka "WiFi" (or "wireless ethernet")
  - "Subnetwork" layer functions above link layer (not part of the standard, but important)
- Wildly successful: hundreds of millions in use
  - Most laptops and smartphones have it today
- Multiple possible uses
  - Cellular wireless LANs
  - Mesh networks
  - Mobile ad hoc networks

Example Deployments

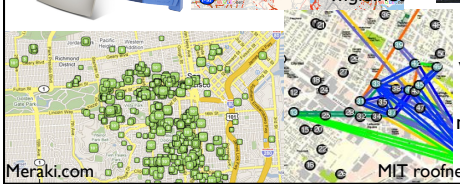
Wireless local area networks

Boston-area WiFi



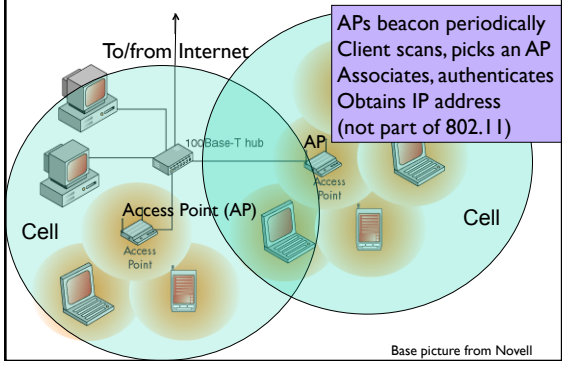
wigle.net

WiFi hotspots



Wireless mesh networks

Cellular Wireless LAN Architecture



802.11 as a Layered Network System

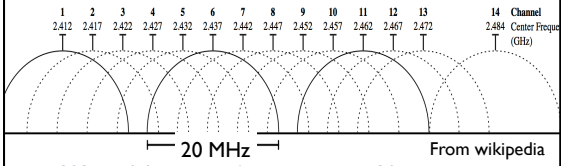
Network layer (IP)	Not part of 802.11
Subnetwork layer	Access point selection Mobility management Mesh routing
Link layer	Framing Stop-and wait rxmit protocol MAC (mainly CSMA) Bit rate adaptation (*non-std*) Power-saving protocol (*non-std*)
Physical layer (PHY)	Channel (freq) allocations Modulation (mainly OFDM) Convolutional coding

Common 802.11 Standards (Alphabet soup: a, b, g, n, …)

802.11 Protocol	Release[4]	Freq. (GHz)	Bandwidth (MHz)	Data rate per stream (Mbit/s)[5]	Allowable MIMO streams	Modulation
–	Jun 1997	2.4	20	1, 2	1	DSSS
a	Sep 1999	5 3.7[y]	20	6, 9, 12, 18, 24, 36, 48, 54	1	OFDM
b	Sep 1999	2.4	20	1, 2, 5.5, 11	1	DSSS
g	Jun 2003	2.4	20	1, 2, 6, 9, 12, 18, 24, 36, 48, 54	1	OFDM, DSSS
n	Oct 2009	2.4/5	20	7.2, 14.4, 21.7, 28.9, 43.3, 57.8, 65, 72.2[z]	4	OFDM
			40	15, 30, 45, 60, 90, 120, 135, 150[z]		

From wikipedia

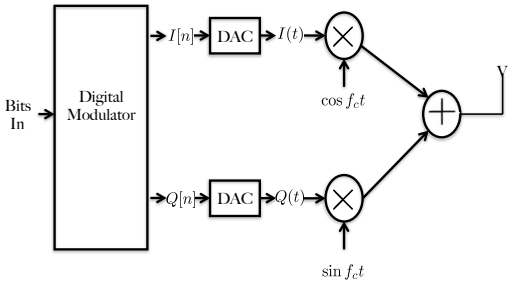
Multiple Frequency Channels



From wikipedia

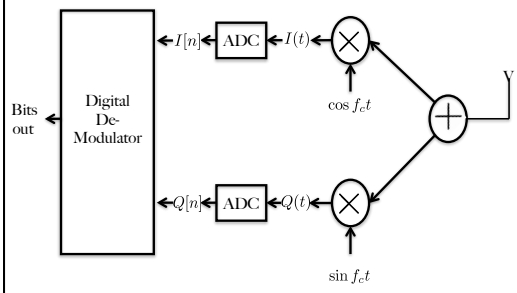
- 802.11b/g/n: up to 14 channels each 20 MHz wide, centered 5 MHz from each other in 2.4 GHz band
  - North America (1-11), Japan (1-14), most of world (1-13)
  - b uses "direct sequence spread spectrum", g uses "orthogonal frequency division multiplexing" (OFDM)
- 802.11a/n: 5 GHz band, 20 channels (in US), OFDM
- "Etiquette rules" set power levels and constraints

In-Phase and Quadrature Transmitter



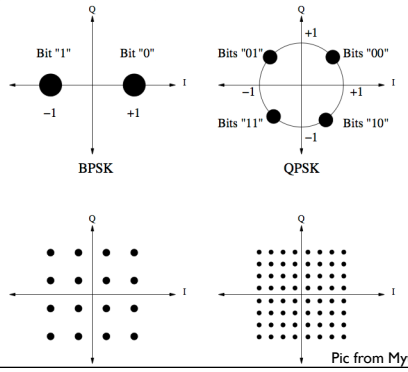
$f_c \approx 2.4$ or 5 GHZ

In-Phase and Quadrature Receiver



$f_c \approx 2.4$ or 5 GHZ

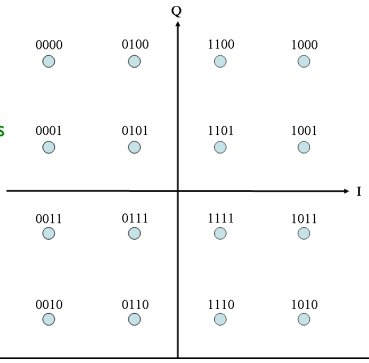
I (cos) and Q (sin) as Constellations



Pic from Mythili Vutukuru

Quadrature Amplitude Modulation (QAM16)

Gray code maps bits to symbols



Multiple Bit Rates

Modulations

Convolutional coding

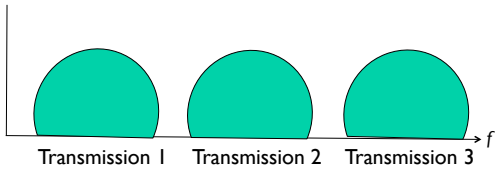
Mod.	Net (Mbit/s)	Gross (Mbit/s)	FEC rate
BPSK	6	12	1/2
BPSK	9	12	3/4
QPSK	12	24	1/2
QPSK	18	24	3/4
16-QAM	24	48	1/2
16-QAM	36	48	3/4
64-QAM	48	72	2/3
64-QAM	54	72	3/4

From wikipedia

802.11g and 802.11a use OFDM (Orthogonal Frequency Division Multiplexing)

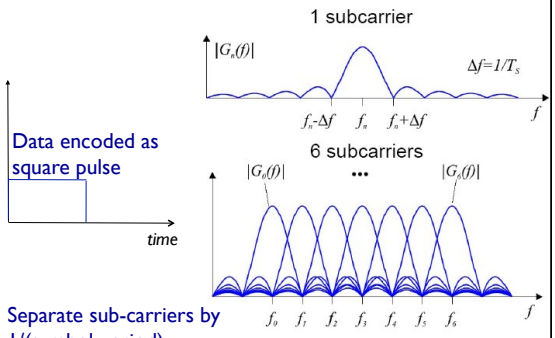
- Recall Frequency Division Multiplexing (FDM)
- Multiple users, each on a different carrier freq.
- Suppose we want to use multiple carriers for a given user's transmission
- Why would we want to do this?
  - To combat "frequency selective fading"
  - Common problem in high-speed wireless – inter-symbol interference caused by reflections interfering with original transmission (aka "multipath effects")
  - Instead of sending each bit over a high speed channel, send each bit over a lower speed one, but send bits in parallel on different *sub-carriers*

(Normal) Frequency Division Multiplexing



- Wastes bandwidth (need gaps between carriers)
- Can we pack carriers tighter?

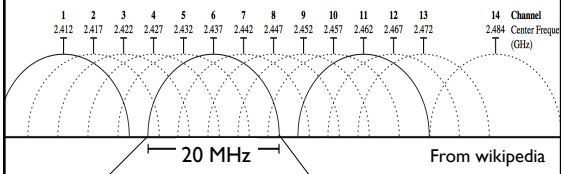
Orthogonal Frequency Division Multiplexing



Separate sub-carriers by 1/(symbol period)

Pic from wimaxcomnet.blogspot.com

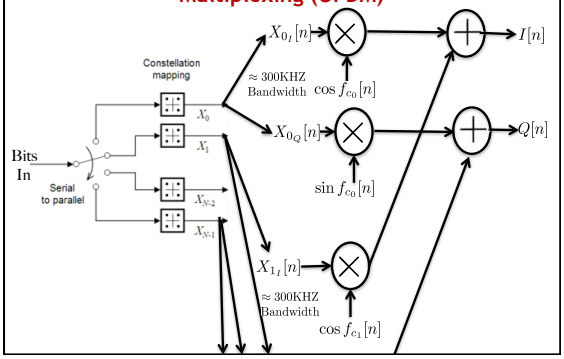
Channels and Sub-carriers



From wikipedia

With OFDM: 52 carriers, 312.5 KHz per carrier
16.25 MHz total used, with some "guard bands"
48 carriers used for data, 4 for control

Digital Modulator for Orthogonal Frequency Division Multiplexing (OFDM)



Layered System

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802.11 MAC

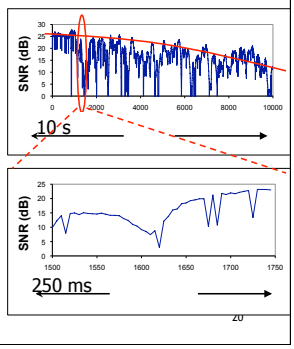
- Radios aren't wires – inherently broadcast
- Receptions aren't perfect like in Ethernet
  - Ethernet: either perfect reception or perfect collision
  - Wireless: probabilistic receptions
- Time-varying channels
- Interference
- How to achieve high throughput?

Time-varying Channel

- Mobility
  - Change in attenuation
  - Multipath fading
- Adapt redundancy by picking best modulation/ code combination

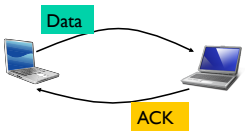
Bit rate adaptation

- Needs accurate and responsive channel estimates



Bit-Rate Adaptation: One Approach

Frame-based



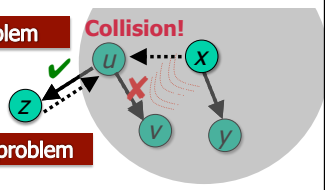
Estimate frame loss rate at each bit rate

Pick bit rate that maximizes throughput: bitrate * (1-lossrate)
Problem: Takes a long time, not good for mobile users

MAC Protocol: Sharing a Wireless Channel

Hidden terminal problem

Problems w/ 802.11 CSMA MAC



Exposed terminal problem

- MAC: decide who transmits when
- Goal: increase spatial concurrency (reuse)
- Carrier Sense Multiple Access (CSMA)
  - Sender senses "busy" → defer
  - "Busy" by energy or preamble detection

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802.11 Summary

Subnetwork layer	**Access point selection** **Mobility management** **Mesh routing**
Link layer	**Framing** **Stop-and wait rxmit protocol** **MAC (mainly CSMA)** **Bit rate adaptation (non-std)** **Power-saving protocol (*non-std*)**
Physical layer (PHY)	**Channel (freq) allocations** **Modulation (mainly OFDM)** **Convolutional coding**

Hundreds of millions of devices
Protocols and designs still evolving
Many open challenges (mobility, "MIMO", energy, video, …)