Spread Spectrum Technologies

COMP3049 – Intermediate Wireless Technology

Chapter 3 - CWNA

Objectives

- List the differences between spread spectrum technologies
- Explain how each SS technology relates to the 802.11 standards PHY clauses
- Identify the underlying concepts of how SS works
- Discuss and apply the concepts which make-up the functionality of SS technology

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Do you know this already?

- The IEEE 802.11 standards apply to which layers of the OSI model?
- Name one of the concepts of 802.11 that differs from other 802 standards.
- Define FHSS and DSSS and outline the key differences between the two.
- What is OFDM and which of the 802.11 amendments employ this modulation technology?

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OSI Model Review

OSI Layer	Layer Name	Functionality	Technology Examples
7	Application	Defines the provision of services to applications, such as checking for resource availability and authenticating users	Most firewalls, FTP, POP3, HTTP, etc.
6	Presentation	Has the primary responsibility of interpreting and presenting data to or from layer 7	Many encryption technologies, compression, protocol conversion, etc.
5	Session	Manages connections between two networked Application layers	RPC, part of the TCP stack

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OSI Model Review

OSI Layer	Layer Name	Functionality	Technology Examples
4	Transport	Where packet delivery confirmation and rebuilding occurs	TCP, UDP, etc.
3	Network	Responsible for routing, relaying and terminating connections between nodes	IP, routers, stateless inspection firewalls or packet filters, etc.
2	Data Link	Detecting and correcting errors in the PHY layer. Transmitting data from one place to another. May be divided into LLC and MAC	Bridges, switches, MAC addresses, IEEE 802 framing, etc.
1	Physical (PHY)	Includes the standards that control the transmission of data streams on the specific medium	FHSS, DSSS, OFDM, Ethernet hubs, 802.11 radios, etc.

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Spread Spectrum and IEEE 802.11

- Clause 14 – FHSS and Clause 15 – DSSS PHY
- Clause 16 – Infrared
- OFDM in 802.11a and ERP 802.11g
- HT (high-throughput) PHY in 802.11n amendment

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Spread Spectrum vs. Narrowband

- Narrowband uses a single frequency center with no redundancy
  - Uses high-power levels to overpower interference
- Spread Spectrum uses a range of frequencies at low power levels
  - Modulation and encoding provide redundancy to get around interference
- OFDM uses multiple frequency centers over a relatively wide band to send multiple copies of data
  - May also send ECCs to evade interference

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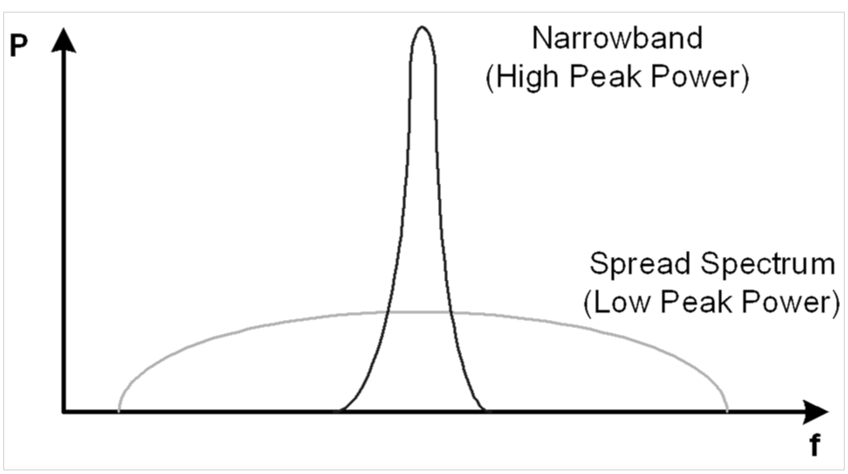
Spread Spectrum vs. Narrowband



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Spread Spectrum vs. Narrowband

- Narrowband communications is used by:
  - Radio stations
  - You tune your radio to a specific frequency
  - Radio stations may transmit with 50,000 Watts of power
- Radio stations using the same frequency must be many kilometres apart
  - Usually hundreds or thousands of Kms apart

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Spread Spectrum vs. Narrowband

- Spread spectrum WLANs using the same frequency range may coexist in the same city block
- By selecting antennas and proper power levels, SS radios using the same frequency range can easily coexist in the same building
- This is due to low power radios
- Multipath is also partially overcome by the use of spread spectrum

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Spread Spectrum vs. Narrowband

- Spread spectrum *spreads* the transmission over a range of frequencies
- Varying wavelengths react differently to the environment through which they propagate
  - i.e.: wavelengths react to different object sizes and materials used in the environment
- The multipath problem in SS is known as *intersymbol interference (ISI)*
- ISI occurs when various signals arrive at the receiver antenna at different times

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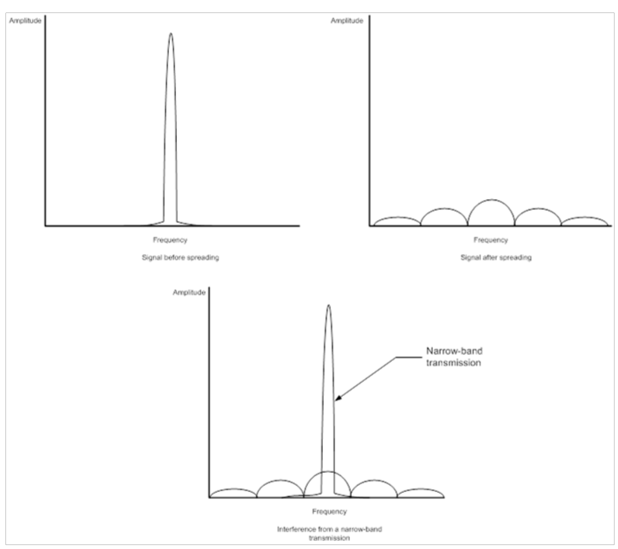
Spread Spectrum vs. Narrowband



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Spread Spectrum vs. Narrowband

- Higher data rates have lower tolerance to delay spread
- Lower data rates have higher tolerance to delay spread
- Balancing data rate, ISI and other signal quality factors is a major reason behind lowering the data rate as distance increases

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FHSS – Frequency Hopping Spread Spectrum

- 1 or 2 Mbps using 2.4 GHz ISM
- 1 MHz channels with 79 MHz allocated
- Each channel follows a specific *hopping sequence*
- Amount of time radio stays in the same frequency is called *dwell time*
- Resists interference through use of small bandwidths and transfer algorithms

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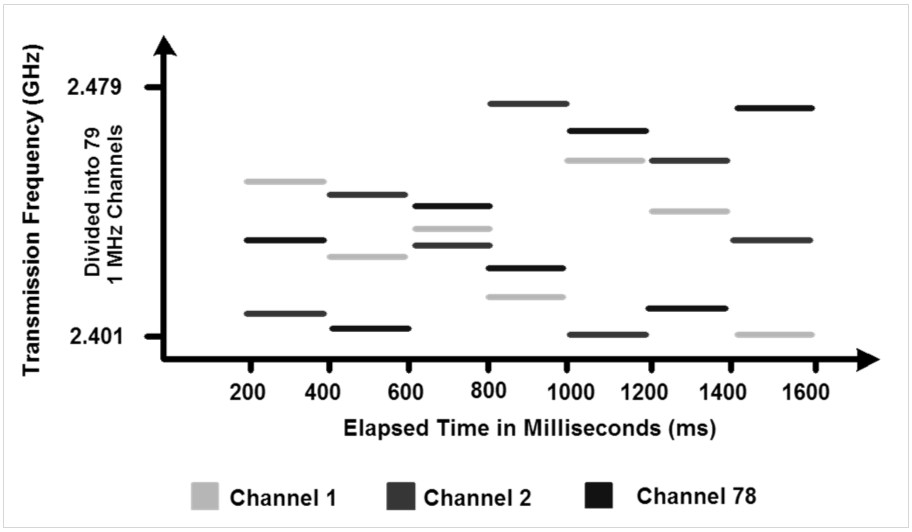
FHSS



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FHSS

- When interference is encountered, radios simply retransmit the same data on the next freq.
  - This reduces speed but increases resilience
- Primarily used in Bluetooth
- BTs *adaptive frequency hopping* (ver. 1.2 and above)
  - Removes a freq. from the channel (hopping sequence)
  - Makes BT more compatible with 802.11

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DSSS – Direct Sequence Spread Spectrum

- In 802.11 supported speeds of 1 and 2 Mbps
- Higher speeds supported in later amendments to 802.11
  - Through different implementations of DSSS
- DBPSK = 1 Mbps & DQPSK = 2 Mbps
- PHY layer divided into:
  - PLCP – Physical layer convergence procedure
  - PMD – Physical medium dependent

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DSSS

- DSSS is more susceptible to interference
  - Because it uses relatively narrow freq. bands and does not change freqs.
  - NB interference usually only affects small part of data (most DSSS systems send multiple copies)

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High-Rate DSSS

- Defined in 802.11b-1999 amendment
- Backward compatible with 802.11 DSSS
- Uses *complementary code keying (CCK)*
- Achieves data rates of 1, 2, 5.5 and 11 Mbps

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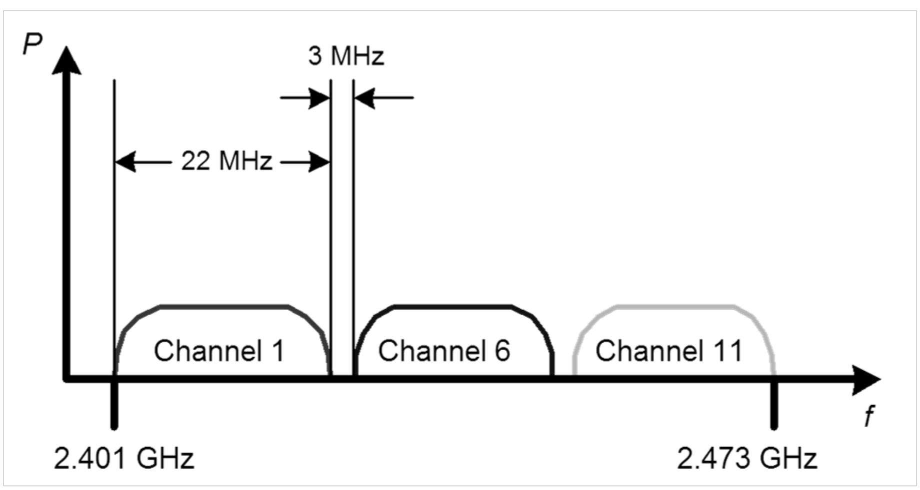
DSSS and HR/DSSS



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OFDM – Orthogonal Frequency Division Multiplexing

- Not a DSSS technology but often called *spread spectrum-like*
- Similar (and better) resistance to interference and data corruption
- Implemented in 802.11a and g
- Digital modulation method
  - Splits signal into multiple narrowband subcarriers
  - Transmits multiple bits of data simultaneously (in parallel), at lower data rates, in different subcarriers

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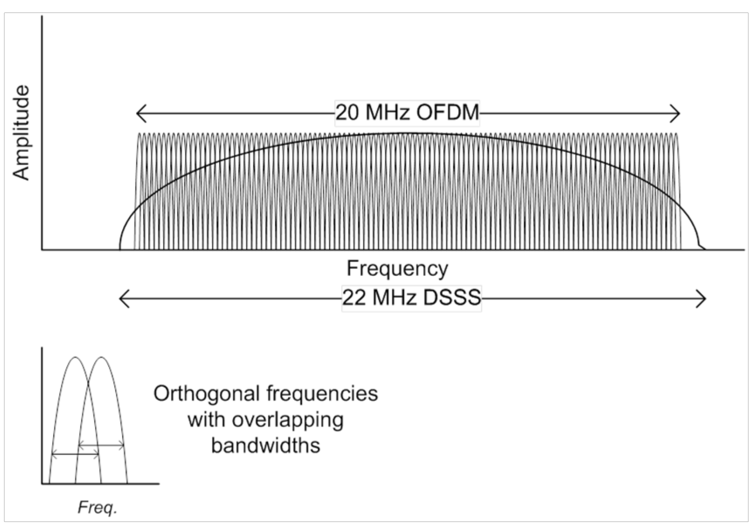
OFDM



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OFDM

- Also used in DSL and WiMAX
- Orthogonal signals reduce *crosstalk*
- Called OFDM in 802.11a
- Called *Extended-Rate PHY (ERP-OFDM)* in 802.11g

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802.11n

- Uses modified version of OFDM
  - High-Throughput OFDM (HT-OFDM)
- Based on 802.11a PHY
- Up to four spatial streams using 20 MHz bandwidth each, in ISM
- Up to four spatial streams using 40 MHz bandwidth each, in U-NII
- Details not yet included in exams

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802.11n

- APs must support both non-HT and 20 MHz HT-OFDM
- Also must support one to four spatial streams to be backwards compatible with 802.11g
- This also allows communications with 802.11a in the U-NII band
- Some new APs and routers support simultaneous 2.4 and 5 GHz bands
  - See Linksys WRT-610N at www.linksys.com

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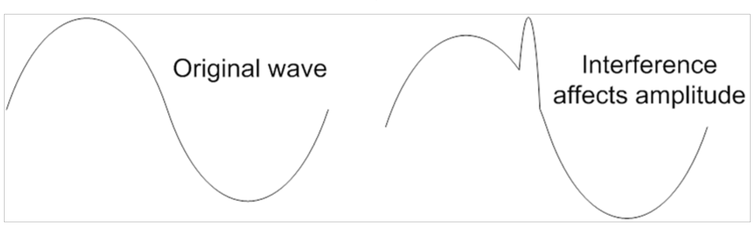
How Spread Spectrum Works

- Modulation
  - WLANs use digital modulation
    - RF signals are modulated to represent 0s and 1s
  - Amplitude, frequency, or phase
  - Interference almost always affects amplitude



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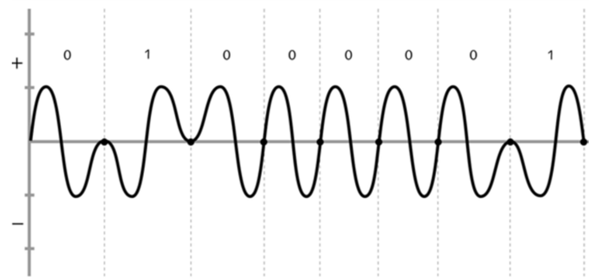
How Spread Spectrum Works

- Modulation (cont'd.)
  - Most common type of modulation for WLANs is one of several varieties of PSK



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How Spread Spectrum Works

- FHSS Modulation
  - 2 level and 4 level Gaussian Frequency Shift keying for 1 and 2 Mbps respectively
- Do not confuse the frequencies in the hopping sequence with the modulation
- Interference affects amplitude, not frequency
- GFSK is resistant but not immune

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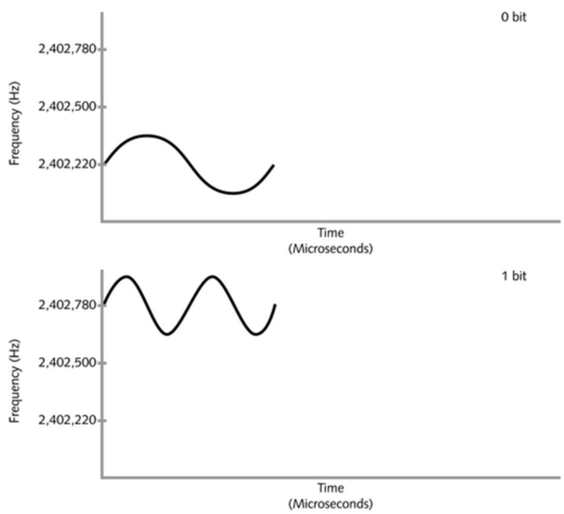
Two Level Gaussian FSK



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How Spread Spectrum Works

- DSSS Modulation
  - DPSK – differential phase shift keying
  - Actual phase does not matter; phase change encodes information
  - Resistant to interference since it does not impact phase
  - DBPSK – differential binary phase shift keying @ 1 Mbps

DBPSK	
Phase Shift in Degrees	Value
0	00
90	01
180	11
270	10

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How Spread Spectrum Works

- DSSS Modulation (cont'd.)
  - DQPSK – differential quadrature phase shift keying @ 2 Mbps
  - DQPSK is more sensitive to multipath
- HR/DSSS Modulation
  - Uses a combination of DQPSK and *complementary code keying (CCK)*
  - Either four or eight bits encoded in each symbol

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How Spread Spectrum Works

- HR/DSSS Modulation (cont'd.)
  - Four bits used for 5.5 Mbps
  - Eight bits used for 11 Mbps
  - CCK is an encoding mechanism
- OFDM Modulation
  - DBPSK, DQPSK, 16-QAM, 64-QAM each used for different data rates

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How Spread Spectrum Works

Modulation Scheme	Data Rate (Mbps)
DBPSK	6
DBPSK	9
DQPSK	12
DQPSK	18
16-QAM	24
16-QAM	36
64-QAM	48
64-QAM	54

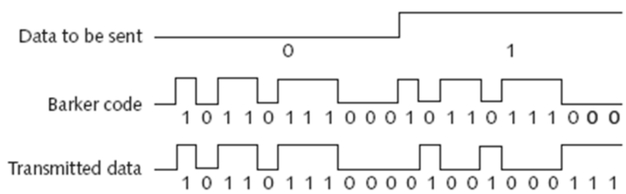
Note: Lower data rates use 802.11 and 802.11b modulations

How Spread Spectrum Works

- FHSS Coding
  - Employs only the hopping sequence
- DSSS Coding
  - Uses 8 or 11 *chips* to transmit each data bit
  - Chip sequence is known as *chipping code* or *Barker code*
  - System is known as *processing gain*
  - Sequence of chips is known as pseudorandom number or PN Code

How Spread Spectrum Works

- DSSS Coding (cont'd.)
  - Encoding happens before the signal is modulated
  - Encoding makes it possible for the receiver to recover data even if some of the chips are lost



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How Spread Spectrum Works

- HR/DSSS Coding
  - CCK uses an 8-chip sequence provides higher data rate
  - Uses different PN codes for different bit sequences
  - 1-to-1 relationship (complementary) between the possible 8-bit sequence and PN code
  - Same is true for 4-bit data
  - DQPSK modulation occurs after ecoding

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How Spread Spectrum Works

- OFDM Coding
  - Convolutional coding (IEEE 802.11g)
  - Forward error correction mechanism
  - Extra bits of data per (encoding) word are used as error correcting code
  - Higher convolution coding rate = lower data rates/Lower convolution coding rate = higher data rate

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Spread Spectrum Fundamentals

- Dwell Time and Hop Time for FHSS
  - Dwell Time is the amount of time spent on any specific frequency
    - Max. 400 ms per carrier frequency, in any 30 sec. interval (FCC)
  - Hop Time – changing frequency, like anything else, takes a certain amount of time
    - Usually rated at 200-300 µs.
  - No station can transmit during the hop time
- FCC regulations specify:
  - Hopping sequence span 75 MHz of the 79 MHz available bandwidth

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Carrier Frequencies, Channel Centers and Widths

- FHSS
  - 2.402 to 2.480 GHz (79 MHz), ISM band
  - IEEE calls for 6 MHz carrier freq. separation between hops
    - Ex.: 2.402, 2.408, 2.414 GHz
  - Frequencies do not have to be sequential
    - Ex.: 2.402, 2.418, 2.404, 2.420 and 2.406 GHz
  - Output power at intentional radiator is dependent on freq. separation
  - FCC rules allow for higher data rates (up to 10 Mbps)

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Carrier Frequencies, Channel Centers and Widths

- DSSS
  - FCC allows 2.400 to 2.497 GHz
  - IEEE specs. 2.400 to 2.4835 GHz
  - Channels are 22 MHz wide
  - Centers are spaced by 5 MHz
  - Only 3 channels available that do not interfere
    - 1, 6, and 11

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Carrier Frequencies, Channel Centers and Widths

- OFDM
  - 5.15 to 5.25 and 5.25 to 5.35 GHz in U-NII bands provide 8 channels
  - Extended 5.470 to 5.725 GHz provides 11 channels (not assigned by IEEE)
  - 20 MHz of spacing between channels in U-NII (see table 3.7 in the book)
  - 802.11g and n use the same channels and separation in ISM band as 802.11 and 802.11b
  - 5.745 to 5.850 GHz band provides 5 channels but 5.825 to 5.850 GHz band conflicts with ISM

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Co-Location

- Ability to place multiple devices in the same RF (signal reach) area while causing minimal interference
- FHSS
  - Co-located by using a different hopping sequence
  - A freq. conflict, it only lasts for one dwell time
  - When co-located it is theoretically possible to achieve up to 158 Mbps (79 x 2 Mbps)
  - This is easier to achieve with OFDM

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Co-Location

- DSSS
  - Usable channels spaced 25 MHz (5 channels) apart (ISM)
  - In NA 3 non-overlapping channels (ISM)
  - 3 channels x 11 Mbps = 33 Mbps
- OFDM
  - Same 3 non-overlapping channels can provide up to 163 Mbps
  - 802.11a: 8 channels x 54 Mbps = 432 Mbps

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Co-Location

- Technology comparison
  - Decision is not simple
  - 802.11a throttles back to lower rates before 802.11g
  - 802.11a antennas are smaller, signals have lower power and higher freqs. attenuate more
  - Understanding basic functionality of the different technologies is important

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Throughput vs. Data Rate

- Data rate is derived from the entire bandwidth (i.e.: 54 Mbps)
- Throughput is the amount of useful information that can be effectively transferred
- Example: a 50 KB word document will generate more than 50 KB of network traffic
- Data rate may be 54 Mbps but throughput is only between 20 – 28 Mbps

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Throughput vs. Data Rate

PHY	IEEE PHY Standard	Data Rate	Est. Throughput
FHSS	802.11-1997	1-2 Mbps	0.7-1 Mbps
DSSS	802.11-1997	1-2 Mbps	0.7-1 Mbps
HR/DSSS	802.11b-1999	1, 2, 5.5 and 11 Mbps	3-6 Mbps
ERP/OFDM	802.11g-2003	1-54 Mbps	3-29 Mbps
OFDM	802.11a-1999	6-54 Mbps	3-29 Mbps
HT/OFDM	802.11n-2009(?)	1-600 Mbps	Untested

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Throughput vs. Data Rate

- Bandwidth
  - Frequency space available (i.e.: 22 MHz for 802.11g)
  - Sometimes used to define *space* available for data transfer (in purely digital systems)
    - i.e.: 100 Mbps for Fast Ethernet

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Communication Resilience

- FHSS and OFDM provide the best resistance to interference
- FHSS is the most resilient but has lower data rates
- OFDM is second today
- HT/OFDM is coming in 802.11n but needs to be broadly implemented before we know *for sure*

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