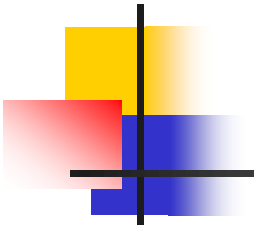
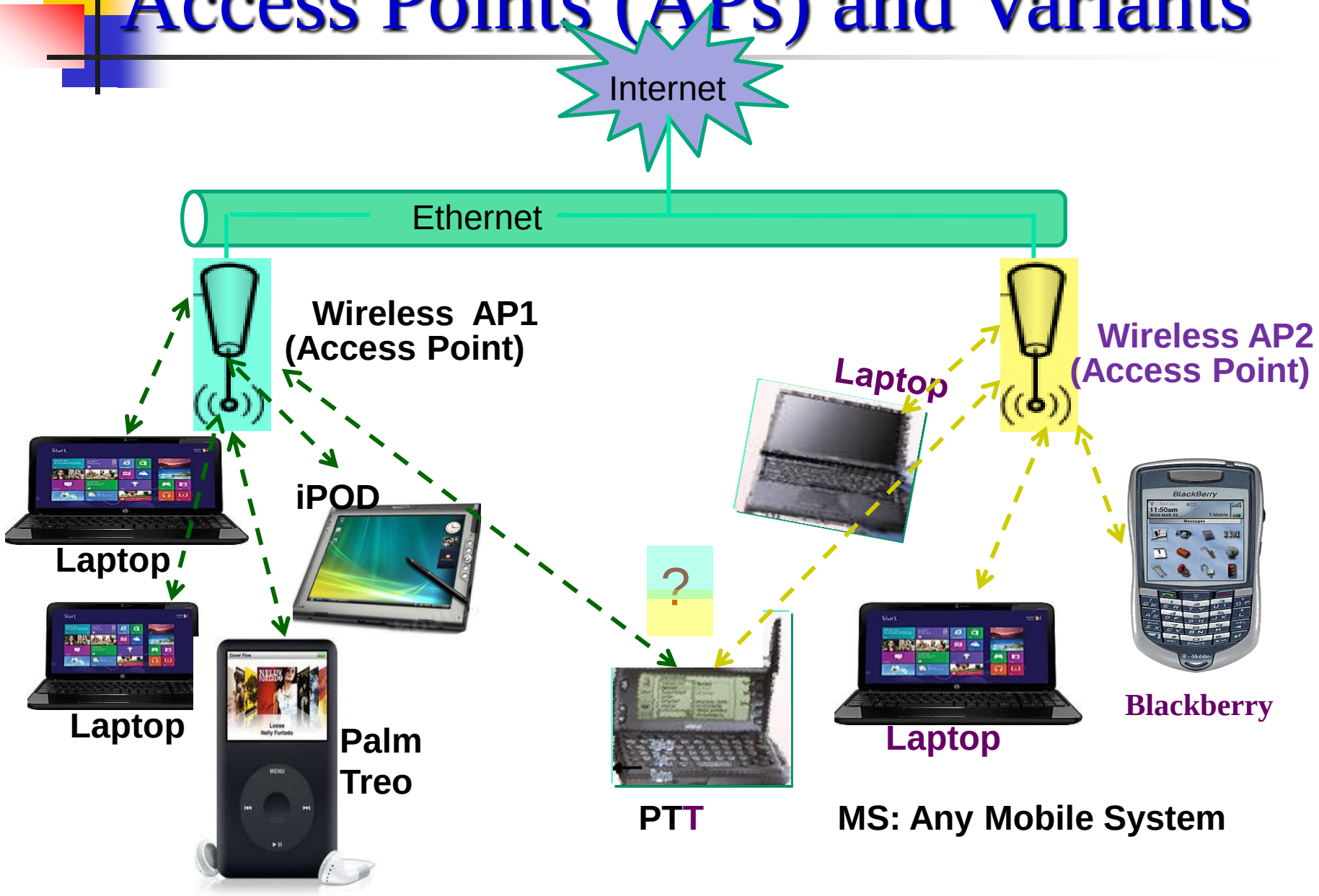


Chapter 12

Access Points and Variants

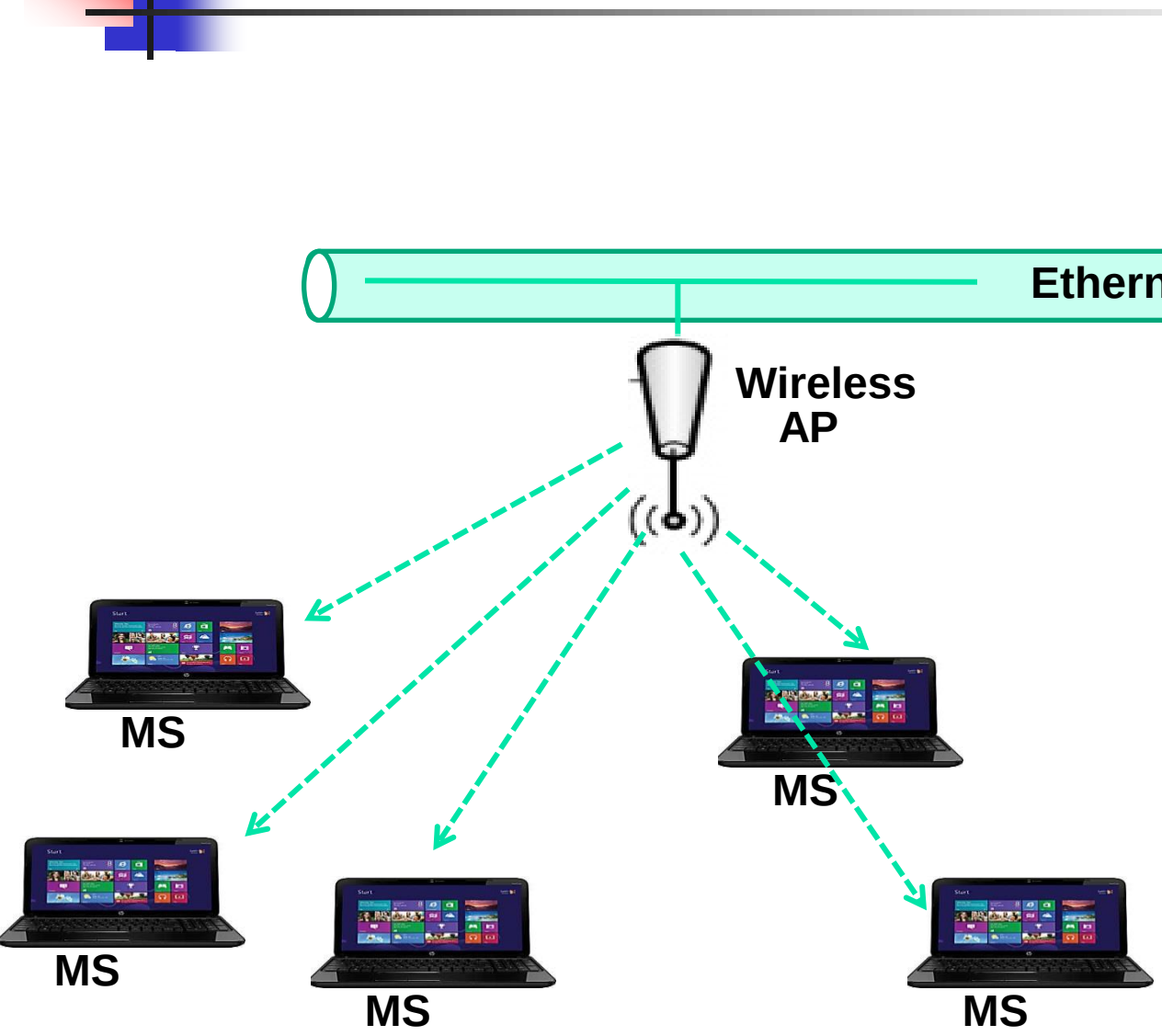
Access Points (APs) and Variants



Access Point (AP)

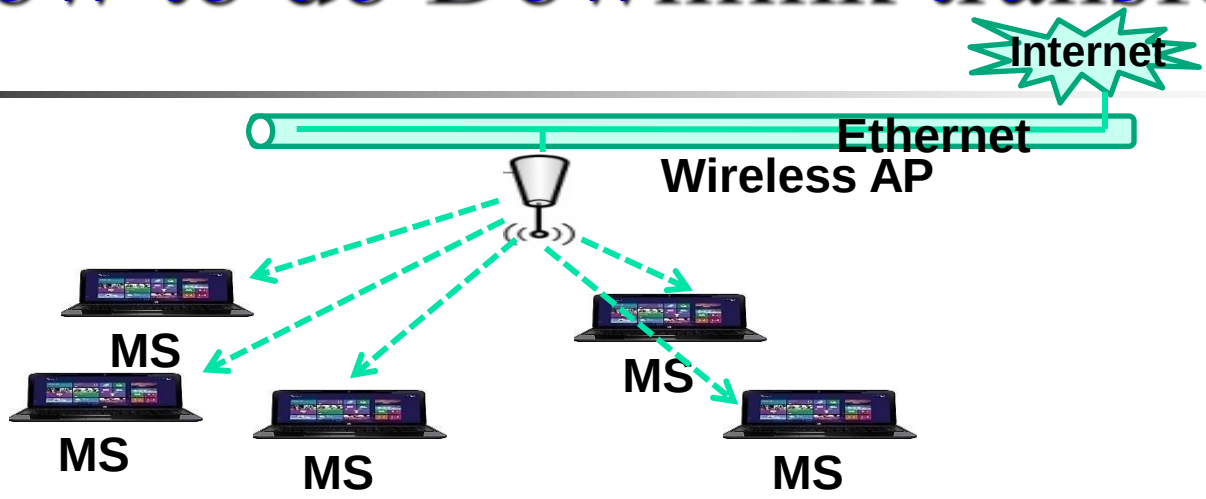
- Short for *Access Point*, is a hardware device that acts as a communication hub for users of a wireless device to connect to a wired LAN
- APs are important for providing wireless security and for extending the physical range of service a wireless user has access to
- MS connects to basic service set (BSS) over a wireless local-area network (WLAN) using unique basic service set identification (BSSID) number

Downlink transferring of Data



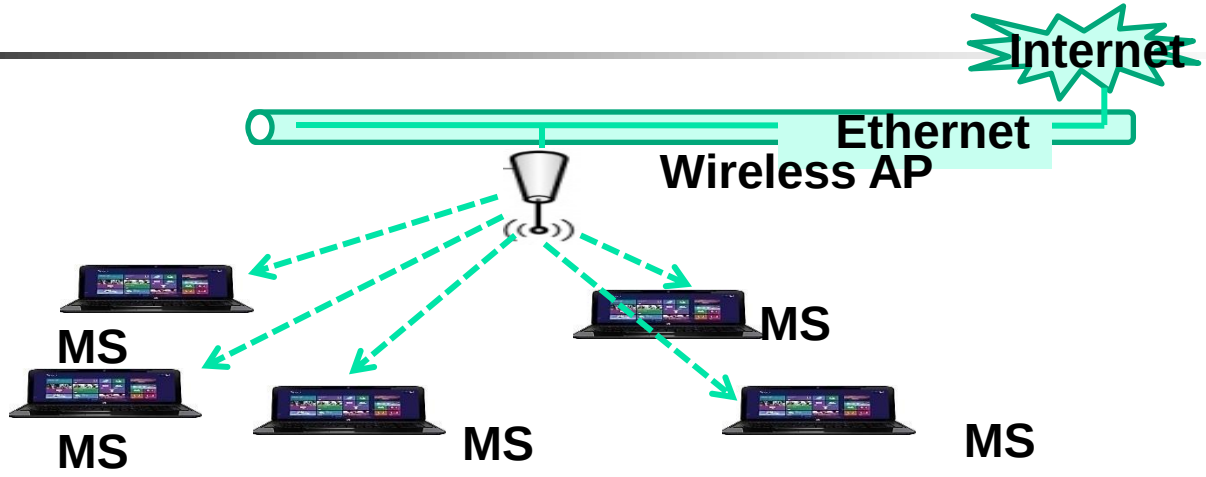
- Sending down data can be done using TDMA
- But, the number of user will keep on changing
- So, what to do??
- The user may be in sleep mode??

How to do Downlink transfer??



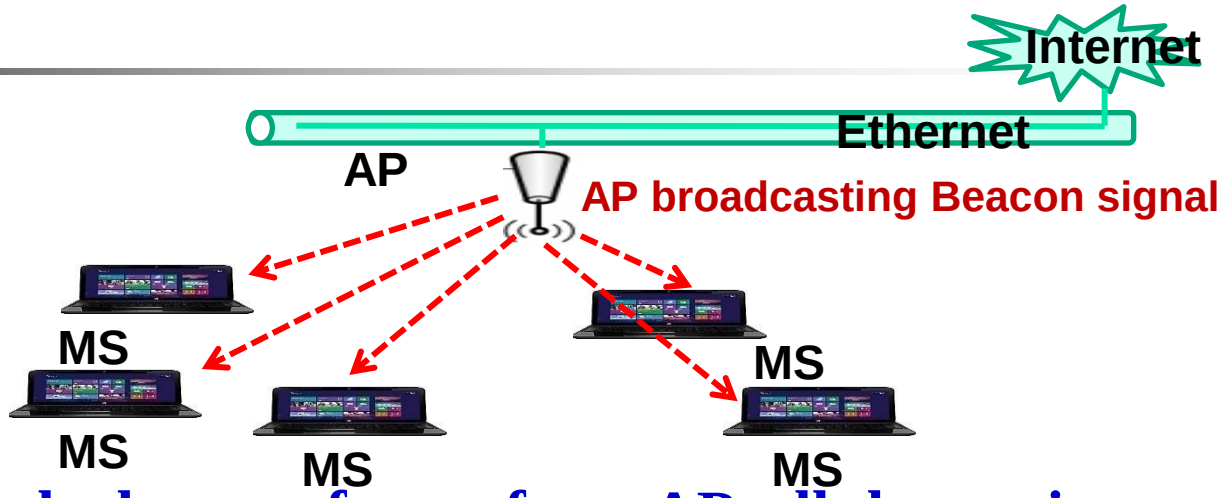
- Assign whole bandwidth to one user (802.11b)
- Multiplex equally among all users- FAIR???
- Time for multiplexing matrix W is a function of the channel conditions between the AP and the clients, based on interference avoidance and/or signal-to-interference and noise ratio (SINR)
- Each client sends an acknowledgement (ACK) of all correctly received packets during an allocated time slot
- A client with low data rate requirements may be allocated less bandwidth by the AP, by adjusting multiplexing matrix and/or after using other amplitude adjustment method for the distance

AP-MS Signal Exchange



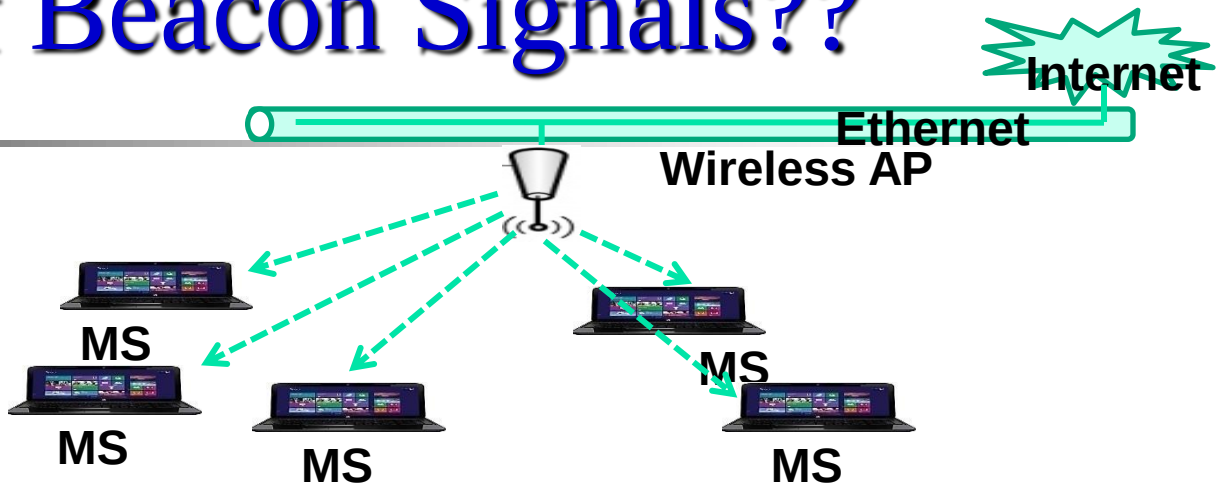
- During this time, other devices are unable to transmit data and the Time Frame is selected using MAC mechanisms provided by existing WLAN specifications
- AP determines whether new Channel State Information has been received from one of the clients and is added by adjusting the time allocation matrix module
- This is done by having Beacon frame for management
- Beacon frames are transmitted periodically by AP to announce its presence

Downlink Channels



- **Timestamp:**
  - **After receiving the beacon frame from AP, all the stations change their local clocks to this time. This helps with synchronization within the range of 4 ms + propagation time**
- **Beacon interval (every 100 ms with 50 byte frame)**
  - **This is the time interval between beacon transmissions and typically configured at 100 ms Time Units**
- **Capability information**
  - **Capability information field spans to 16 bits and contain information about speed and modulation capability. It announces the support for polling and encryption**

Use of Beacon Signals??



- Users listen to known beacon channels from all APs in the building and select the one AP with strongest signal
- Two power saving modes of Stations: awake and sleeping
- Users need to inform AP before going to sleeping mode
- In sleeping mode, device cannot receive any packets
- However, each station ought to **wake up** periodically to listen to AP's beacon signals that indicate message queue at AP
- The delivery traffic indication message (DTIM) indicates clients that are currently in low-power mode that have data buffered on the access point awaiting pickup
- This looks like |Element ID|Length|DTIM count|DTIM period|Bitmap control|PVM| with PVM: Partial Virtual Bitmap

802.11 Packet Format

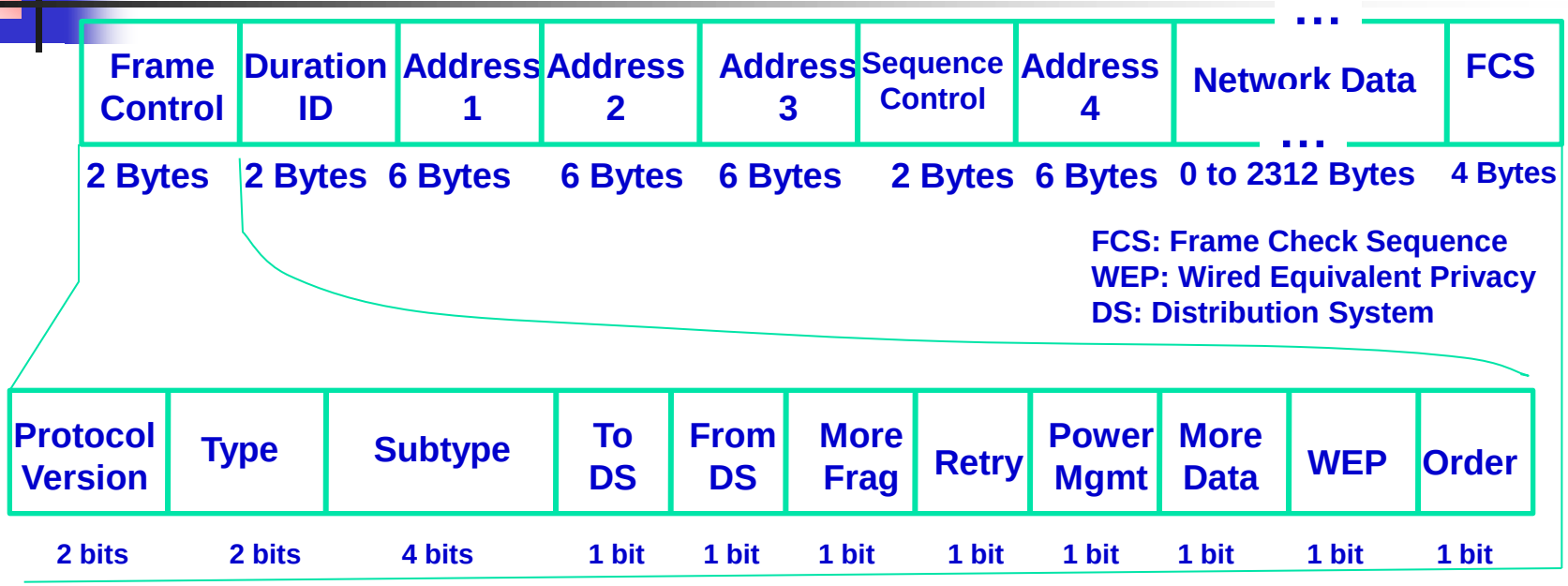
OSI Physical (PHY) layer	OSI Data Link layer		Higher CGI layers	Packet trailer	
PLCP Pre-emble header	MAC Header	LLC (opt)	Network Data	FCS	End Delimiter

- **802.11 WLANs must be able to form and re-form their membership constantly**
- **As radio transmission conditions themselves can change, coordination becomes a large issue in WLANs. Management and control packets are dedicated to these coordination functions**
- **In addition, headers of ordinary data packets contain a great deal more information about network conditions and topology than, for example, the headers of Ethernet data packets would contain**

802.11 MAC downlink header (WLAN)							802.3 MAC header (Ethernet)		
Frame Control	Duration ID	Address 1	Address 2	Address 3	Sequence Control	Address 4	Dest. Address	Source Address	Type or Length
2 Bytes	2 Bytes	6 Bytes	6 Bytes	6 Bytes	6 Bytes	6 Bytes	6 Bytes	6 Bytes	2 Bytes

http://www.wildpackets.com/resources/compendium/wireless_lan/wlan_packets

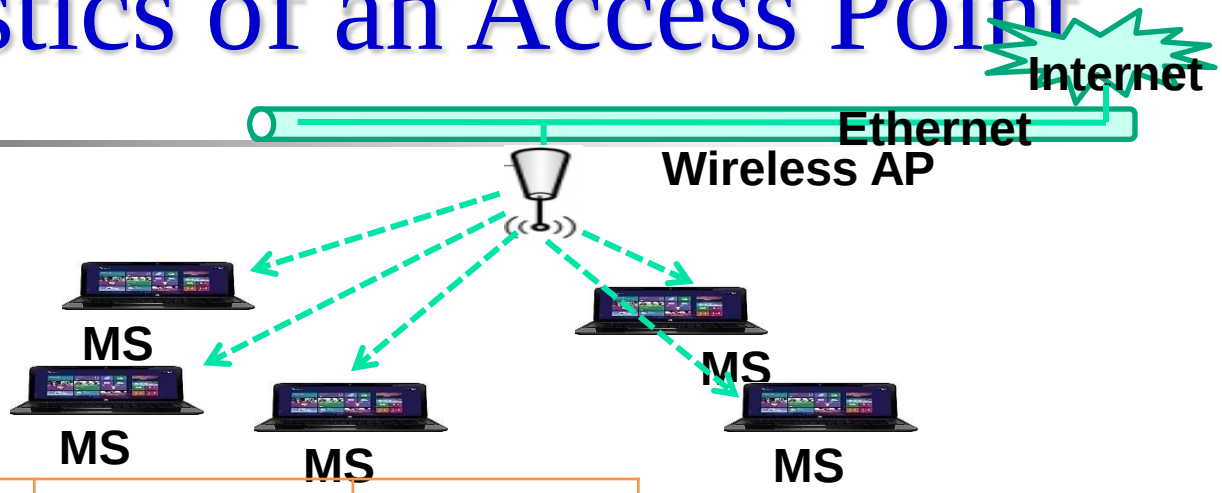
802.11 MAC Header



- The bit-wise breakdown of the Frame Control field is as follows:
- The first two bits are the Protocol Version and tell which version of 802.11 is to follow
- The Type field (2 bits) and the Sub Type field (4 bits) work together to describe the type of frame and its function
- To AP and From AP fields are one bit each and are set to 1 for true and 0 for false, indicating whether the packet was sent to or from the Distribution System
- For messages within a single BSS (Basic Service Set), both of these fields would be set to 0
- More Fragments bit would be set to 1 if there were more fragments of the current packet

http://www.wildpackets.com/resources/compendium/wireless_lan/wlan_packets

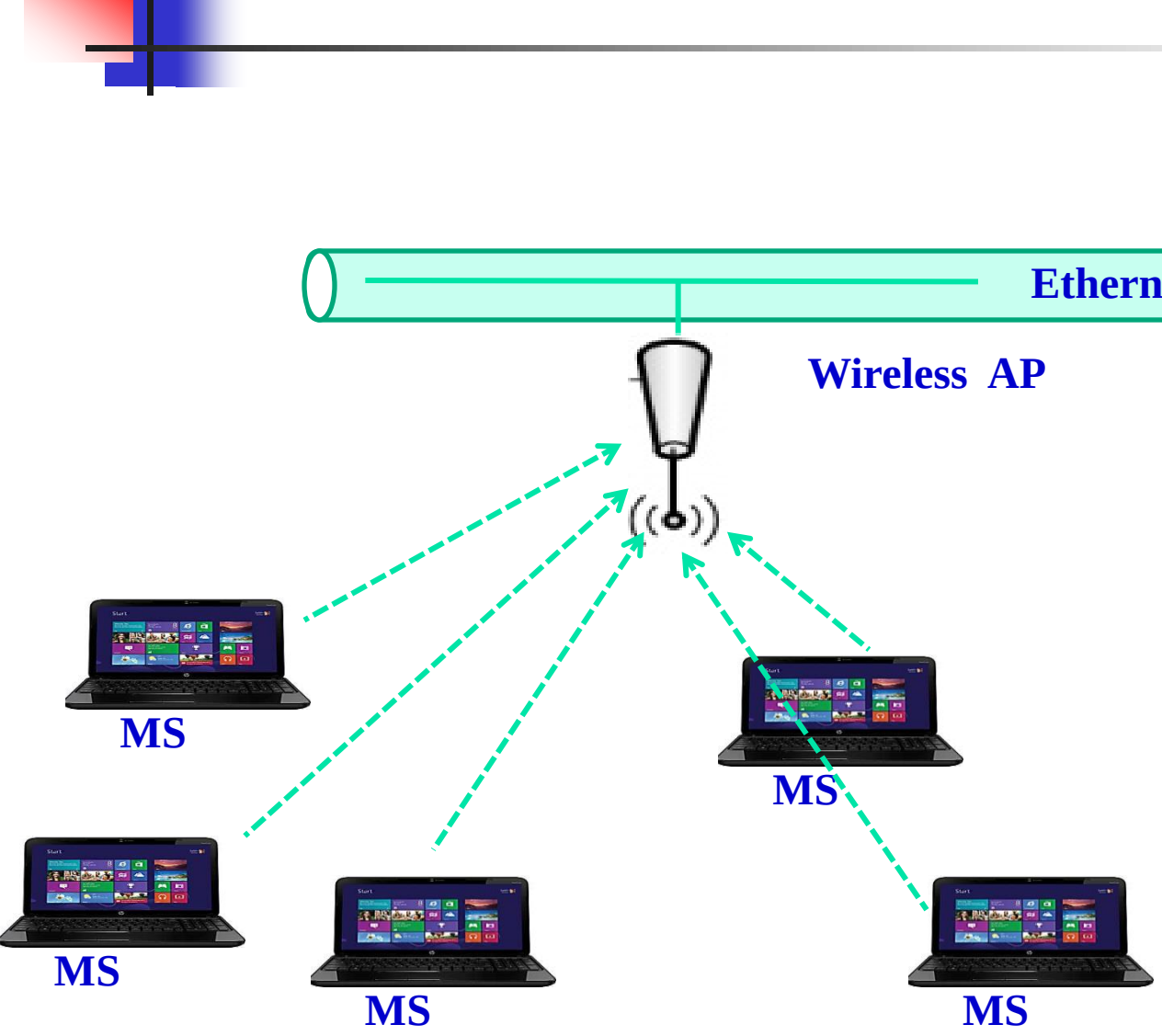
Characteristics of an Access Point



Channel bandwidth	20MHz	20MHz	40MHz	40MHz
Guard Interval	400ms (short)	800ms (long)	400ms (short)	800ms (long)
Data Rates	7.2 Mbps	6.5 Mbps	14.4Mbps, 21.7Mbps, 28.9Mbps, 43.3Mbps, 57.8Mbps, 65Mbps, 72.2Mbps	13.5Mbps, 27Mbps, 40.5Mbps, 54Mbps, 81Mbps, 108Mbps, 121.5Mbps, 135Mbps
Mode	Static, legacy mode	Dynamic	Static	Dynamic
Throughput	Least throughput	Compatibility mode	High-throughput mode	Compatibility mode
Encryption	• 64 bits WEP: Standard WEP encryption, using 40/64 bit encryption • 128 bits WEP Standard WEP encryption, using 104/128 bit encryption • 152 bits WEP Proprietary mode that works only with other wireless devices that support this mode			

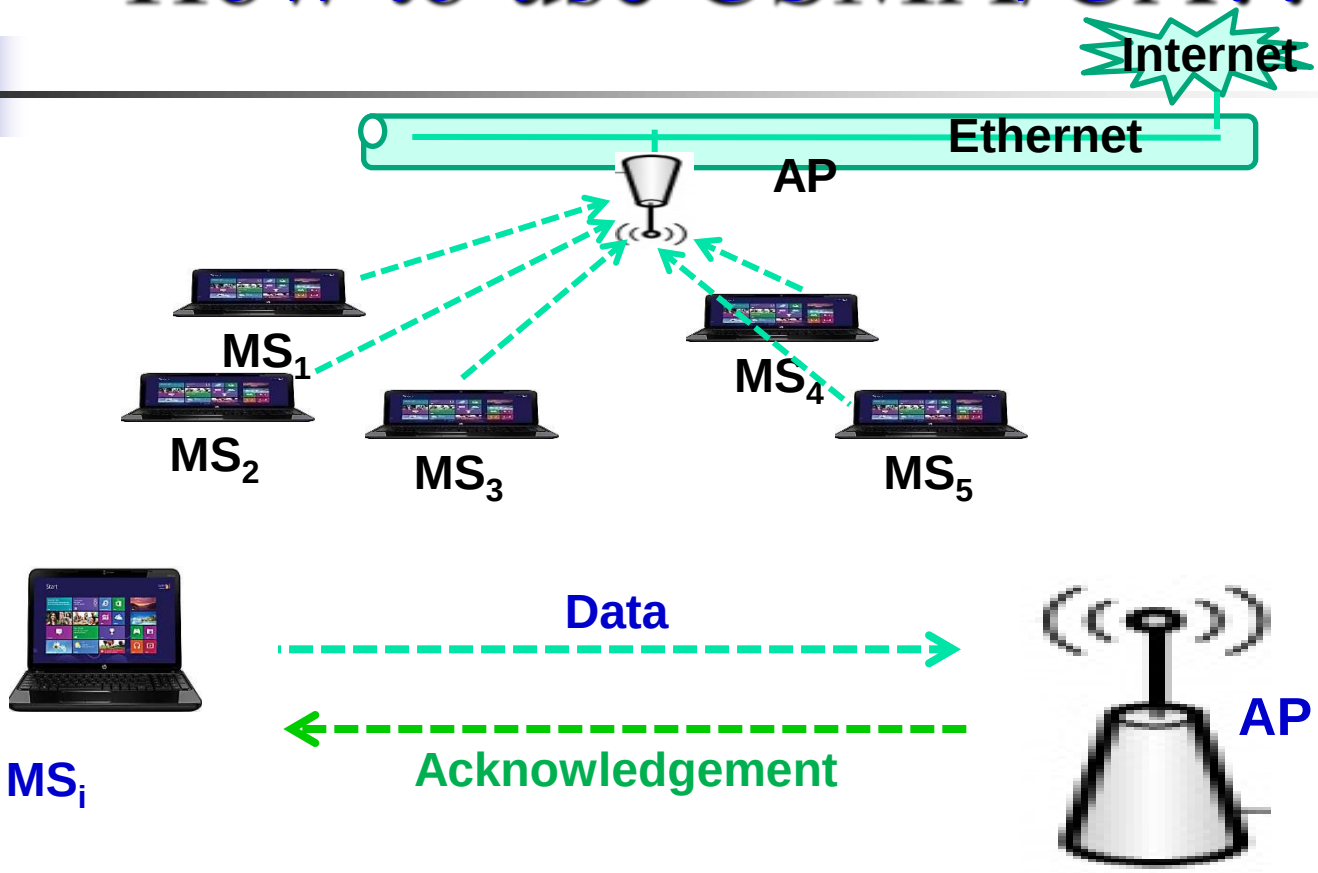
http://www.downloads.netgear.com/files/GDC/WN604/WN604_UM_14Oct11.pdf

Uplink transfer of Data



- Can we do time multiplexing similar to downlink data transfer???
- Not appropriate as data may not be ready at each station at the allocated time
- CSMA-CA technique used

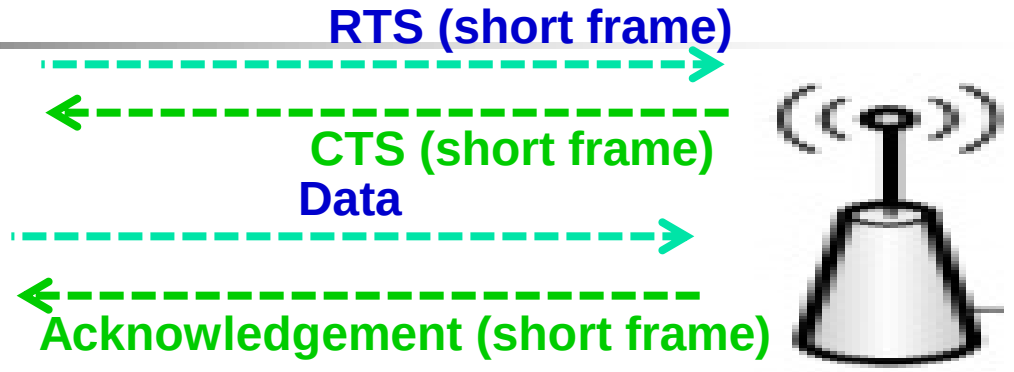
How to use CSMA/CA??



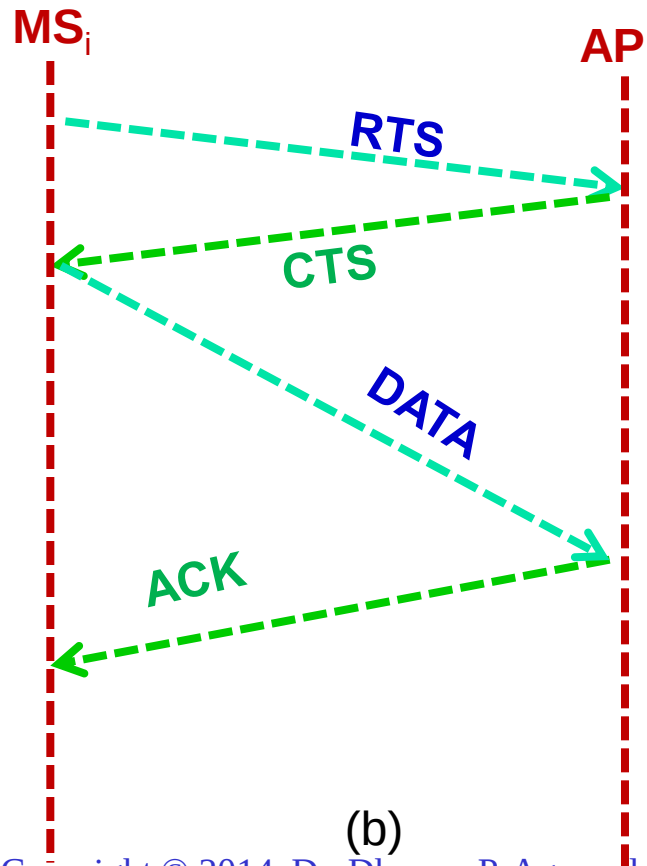
- Collision may be possible, determined by not receiving ACK signal within pre-specified period
- Carrier Sense Multiple Access/Collision Avoidance used, a network contention protocol that listens to a network in order to avoid collisions

How to use CSMA/CA??

MS_i



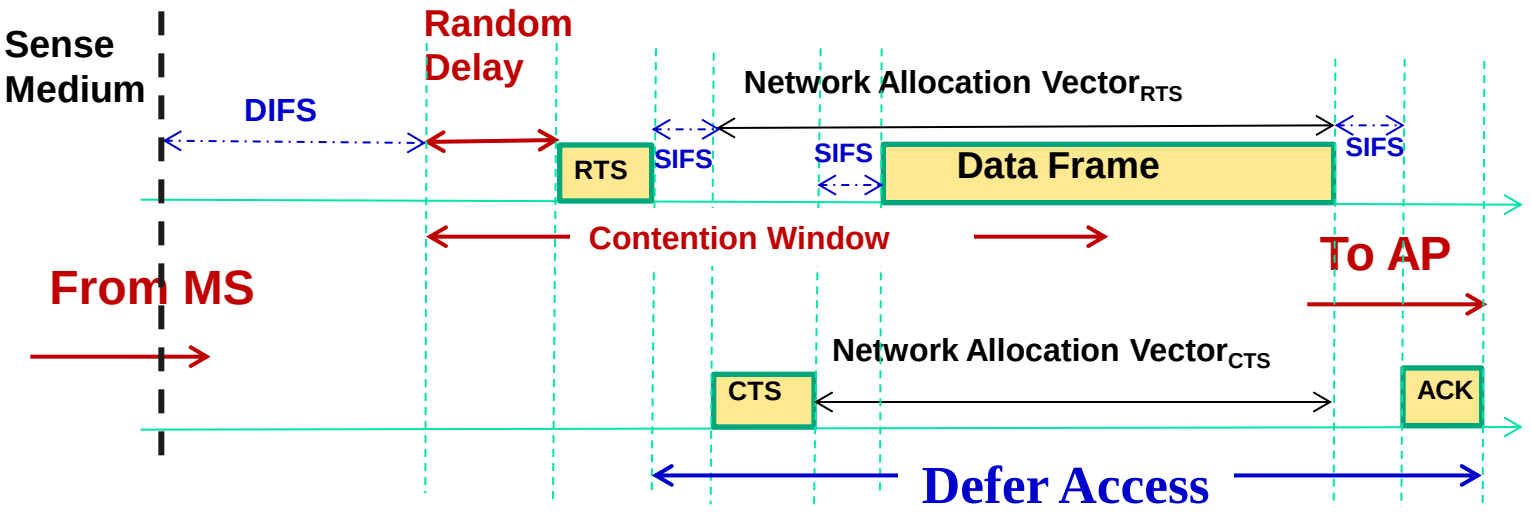
(a)



(b)

- **If collision occurs, double the contention window**

CSMA/CA with RTS/CTS and CW



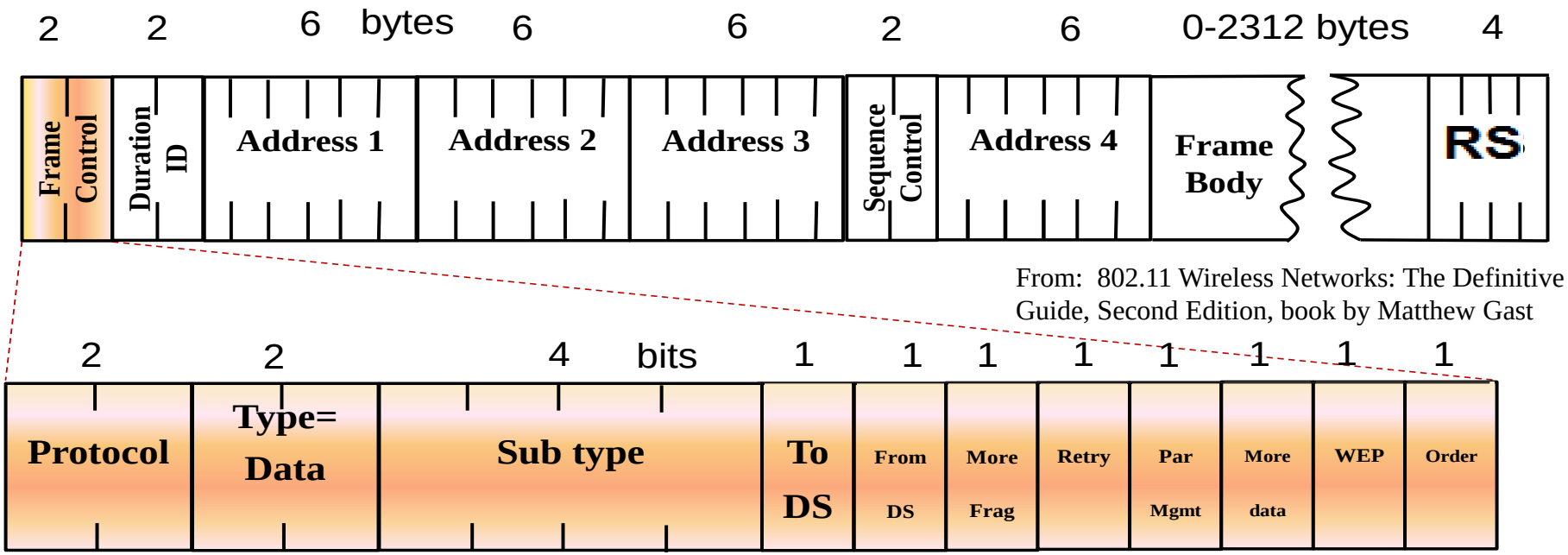
Network Allocation Vector (NAV)
maximum of 32,767 ms

- **Time intervals**
  - **The slot time (=20μs), defined in the PHY layer**
  - **The short interframe space (SIFS=10μs) defined by the PHY layer**
  - **The distributed interframe space (DIFS=50μs)**
  - **The extended interframe space (EIFS=78μs)**

Uplink Data Format

OSI Physical (PHY) layer	OSI Data Link Layer		Higher CGI layers	Packet trailer	
PLCP Premble header	MAC Header	LLC (opt)	Network Data	FCS	End Delimiter

http://www.wildpackets.com/resources/compendium/wireless_lan/wlan_packets



From: 802.11 Wireless Networks: The Definitive Guide, Second Edition, book by Matthew Gast

802.11a Data Rate

Data Rate (Mbit/s)	Modulation Type	Coding Rate (Convolution Encoding & Puncturing)	Coded bits per sub-carrier symbol	Coded bits per OFDM symbols	Data bits per OFDM symbol
6*	BPSK	½	1	48	24
9	BPSK	¾	1	48	36
12*	QPSK	½	2	96	48
18	QPSK	¾	2	96	72
24*	16-QAM	½	4	192	96
36	16-QAM	¾	4	192	144
48	64-QAM	2/3	6	288	192
54	64-QAM	¾	6	288	216
* Support for these data rates is required by the IEEE 802.11a standard					

- OFDM can eliminate inter-symbol interference at no bandwidth cost
- However, OFDM is very sensitive to frequency offsets and timing jitter

Recommended distance between an AP and household devices

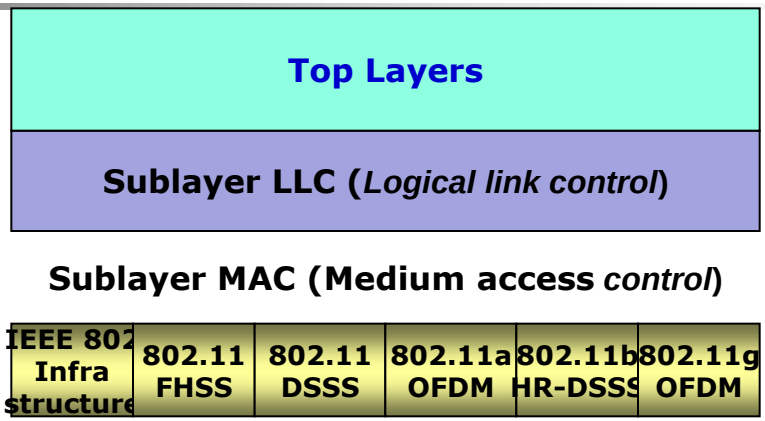
Household Appliance	Recommended Minimum Distance (in feet / meters)
Microwave ovens	30 feet / 9 meters
Baby Monitor - Analog	20 feet / 6 meters
Baby Monitor - Digital	40 feet / 12 meters
Cordless phone - Analog	20 feet / 6 meters
Cordless phone - Digital	30 feet / 9 meters
Bluetooth devices	20 feet / 6 meters
ZigBee	20 feet / 6 meters

[http://www.downloads.netgear.com/files/GDC/WN604/WN604_UM_14Oct11.pdf]

Various IEEE 802.11

- 802.11a 5GHz, 54Mbps
- 802.11b 2.4GHz, 11Mbps
- 802.11c Protocol for *bridges*
- 802.11d World Mode (Europa 20 dB, EUA-BR 36dB)
- 802.11e Quality of Service
- 802.11f Inter-Access Point Protocol
- 802.11g 2.4GHz, 54Mbps, modulated digital OFDM
- 802.11h Dynamic Frequency Selection
- 802.11i Authentication and Security
- 802.11n (MIMO)
- 802.11ac (multiple antennas)

Various IEEE 802.11



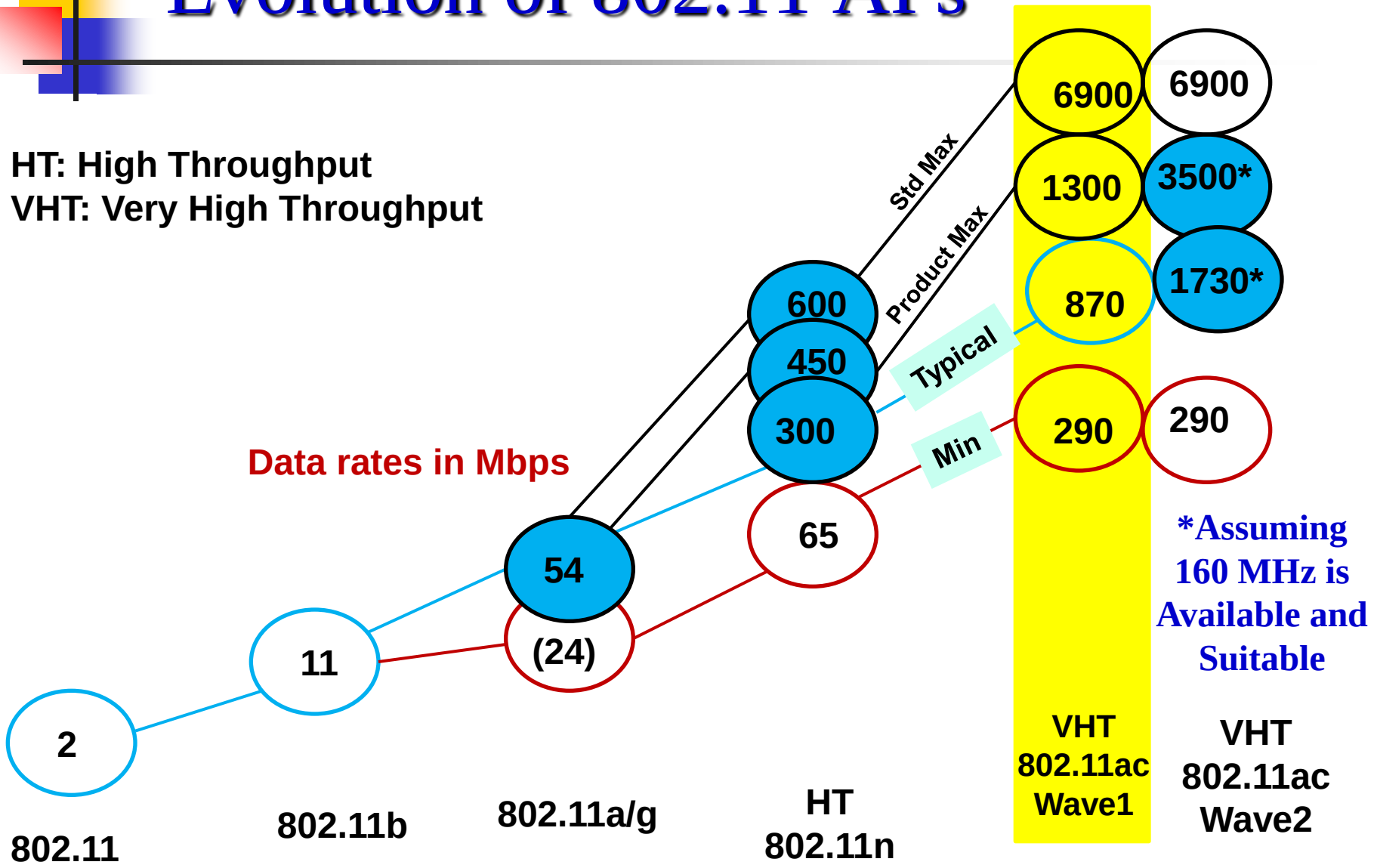
- **LLC:**
  - **Multiplexing protocols transmitted over the MAC layer (when transmitting) and decoding them (when receiving)**
  - **Providing node-to-node flow and error control**
- **MAC:**
  - **Manages and maintains communications between 802.11 stations and APs by coordinating access to a shared radio channel and utilizing protocols that enhance communications over a wireless medium**
- **Physical (PHY) Layer**
  - **Performs the tasks of carrier sensing, transmission, and receiving of 802.11 frames**

Variations in IEEE 802.11

- CSMA
  - A network contention protocol that listens to a network in order to avoid collisions
- DSSS
  - It is a transmission technology used in WLAN transmissions where a data signal at the sending station is combined with a higher data rate bit sequence, or chipping code, that divides the user data according to a spreading ratio
  - The chipping code is a redundant bit pattern for each bit that is transmitted, which increases the signal's resistance to interference
  - If one or more bits in the pattern are damaged during transmission, the original data can be recovered due to the redundancy of the transmission
- Complementary Code Keying
  - A set of 64 eight-bit code words used to encode data for 5.5 and 11Mbps data rates in the 2.4GHz band of 802.11b wireless networking
  - The code words have unique mathematical properties that allow them to be correctly distinguished from one another by a receiver, even in the presence of substantial noise and interference
  - CCK works only in conjunction with the DSSS technology that is specified in the original 802.11 standard

Evolution of 802.11 APs

HT: High Throughput
VHT: Very High Throughput



http://www.cisco.com/en/US/prod/collateral/wireless/ps5678/ps11983/white_paper_c11-713103.html

Communication/Computation Technology Projection

Characteristics		1999 Bluetooth	1999 802.11a	2003 802.11g	2009 802.11n	2013 802.11ac
Communication	Energy per bit	150nJ/bit	120 nJ/bit	5 nJ/bit	60.6 nJ/bit to 14.2 nJ/bit	11.1 nJ/bit
	Total energy	1.5mW	30 mW	50 mW	120 nJ/bit	100 mW
	Speed	1 Mb/s	1-5 Mb/s	22 M/s	54 Mb/s to 600 Mb/s	1Gbps
Microprocessor speed in a given year	MIPS	2,054 MIPS at 600 MHz		9,726 MIPS at 3.2 GHz	42,820 MIPS at 3.0 GHz	9,726 MIPS at 3.2 GHz
	Energy/OP	2.53 pJ/OP		5 pJ/OP	13 pJ/OP	10 pJ/OP

1-100 Gigabit Ethernet commercially available

Large cost of communications relative to computation continues

Variants of 802.11 protocols and their important characteristics

Variant of 802.11	a	b	g	n	ac
Frequency Range	5GHz, 54Mbps	2.4GHz, 11Mbps	2.4GHz, 54Mbps, modulated digital OFDM	MIMO	1 to 8 Antennas
Bandwidth	54 Mbps	11 Mbps	54 Mbps	248 Mbps	6.77 Gbit/s
Channel	20 MHz	20 MHz	20 MHz	20 or 40 MHz	20-160 MHz
Energy Consumption	120-14.2 nJ/bit	11.1nJ/bit	5 nJ/bit	60.6-14.2 nJ/bit	11.1 nJ/bit
Range	120m	140m	140m	250m	70-100m
Modulation Technique and coding	BPSK, QPSK, 16-QAM, 64-QAM, OFDM	DBPSK, DBQPS, CCK, DSSS	DBPSK, DBQPSK, 16-QAM, 64-QAM, OFDM	64-QAM, Alamouti, OFDM	BPSK, QPSK, 16QAM, 64QAM 256QAM

*BPSK: Binary Phase-Shift Keying
QPSK: Quadrature Phase-Shift Keying
DBPSK: Differential Binary Phase-Shift Keying
DQPSK: Differential Quadrature Phase-Shift Keying

*QAM: Quadrature Amplitude Modulation
Alamouti: Alamouti space–time block code
CCK: Complementary Code Keying
OFDM: Orthogonal Frequency-Division Multiplexing
DSSS: Direct-Sequence Spread Spectrum Phase-Shift Keying

OFDM

OFDM: Orthogonal Frequency-Division Multiplexing

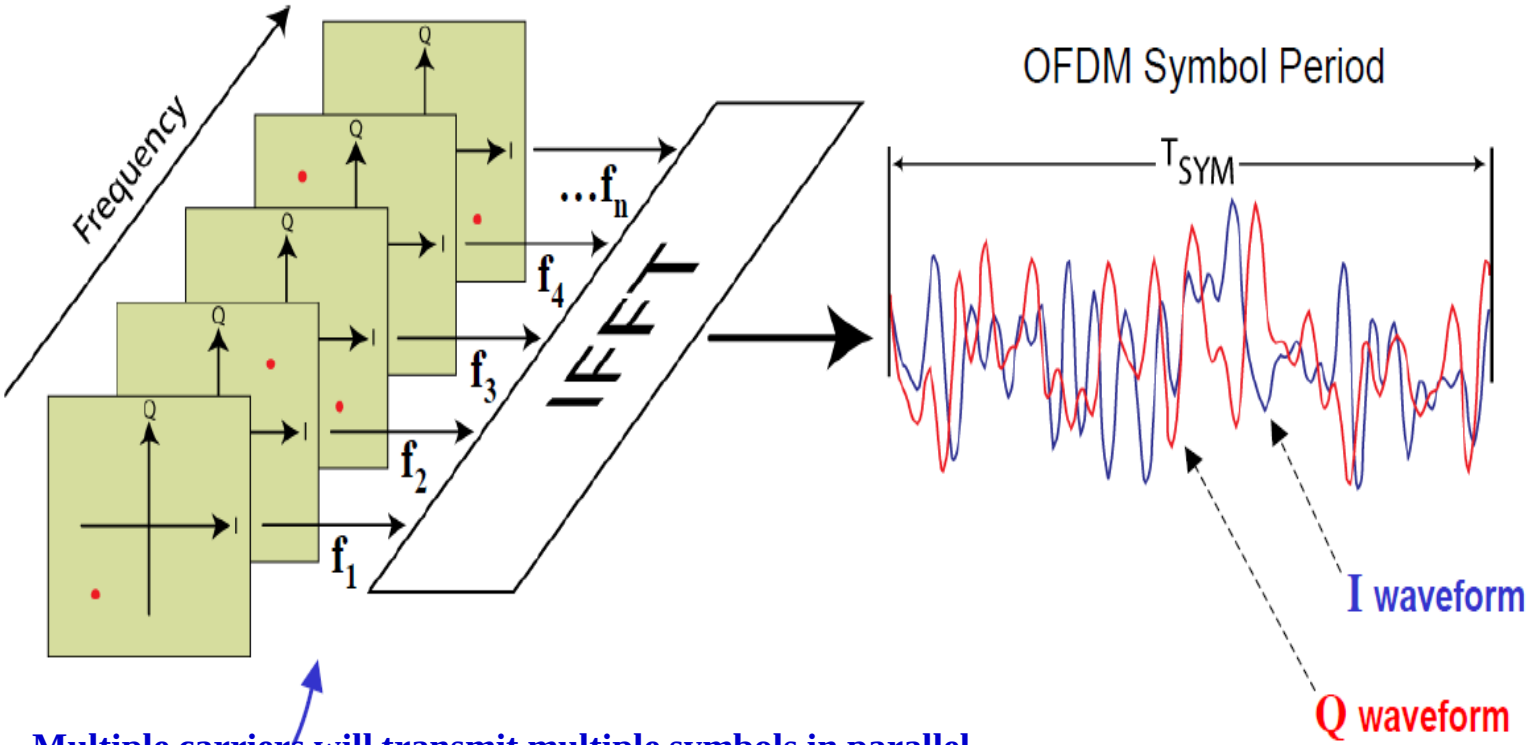
- Orthogonal Frequency Division Multiplexing (OFDM) is a multiple-carrier (MC) modulation technique which creates frequency diversity
- A high-speed data stream is converted into multiple low-speed data streams via Serial-to-Parallel (S/P) conversion
- Each data stream is modulated by a subcarrier
- That way, instead of having a frequency-selective fading wireless channel, where each frequency component of the signal is attenuated and phase-shifted in different amount, we have multiple flat-fading sub-channels

- Efficiently Deals With Multi-path Fading
- Efficiently Deals With Channel Delay Spread
- Enhanced Channel Capacity
- Adaptively Modifies Modulation Density
- Robustness to Narrowband Interference

OFDM

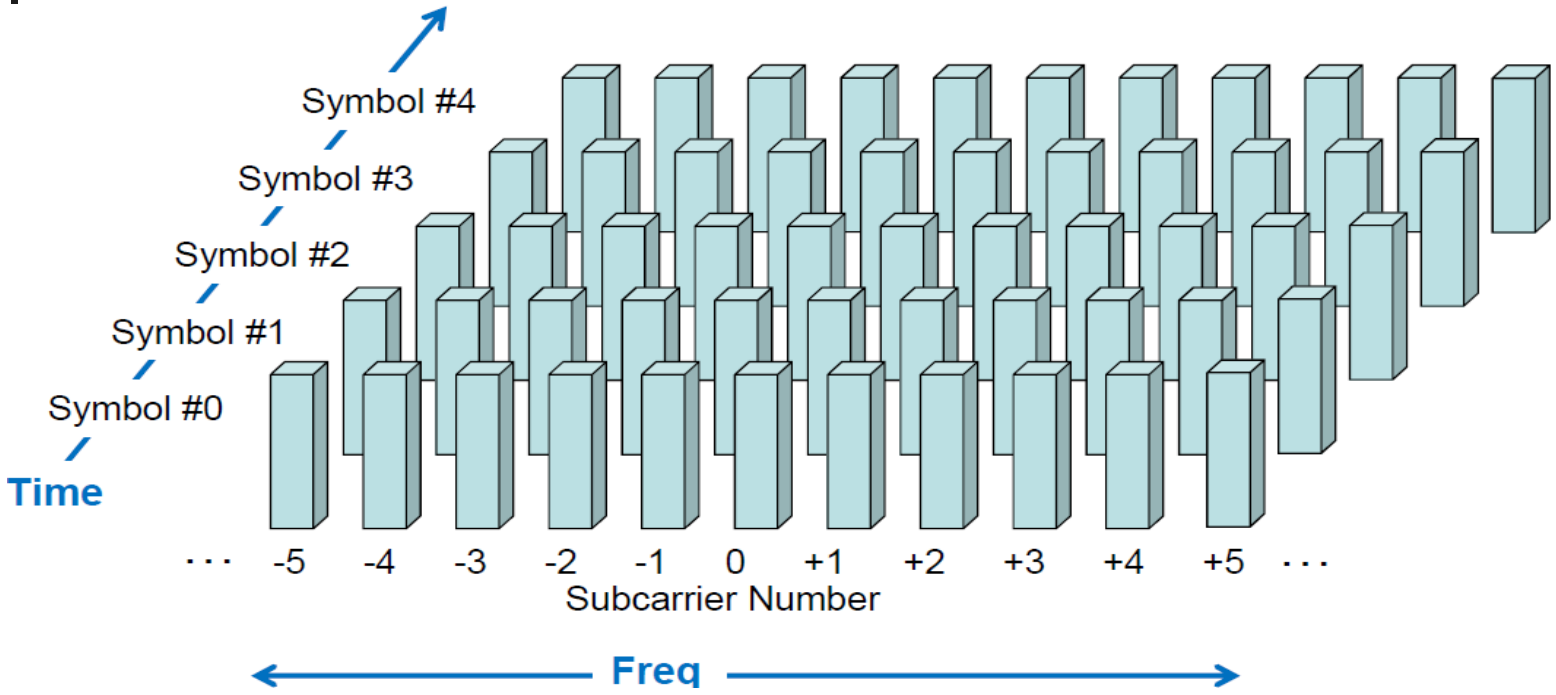
OFDM: Orthogonal Frequency-Division Multiplexing

I: In-phase
Q: Quadrature Phase



Multiple carriers will transmit multiple symbols in parallel.
Carriers may have different modulations – BPSK, QPSK… 64QAM.

OFDM



http://www.keysight.com/upload/cmc_upload/All/2_Flexible_OFDM_Signal_Generation_Analysis_and_Troubleshooting.pdf?cmpid=1-3660333773&cc=US&lc=eng

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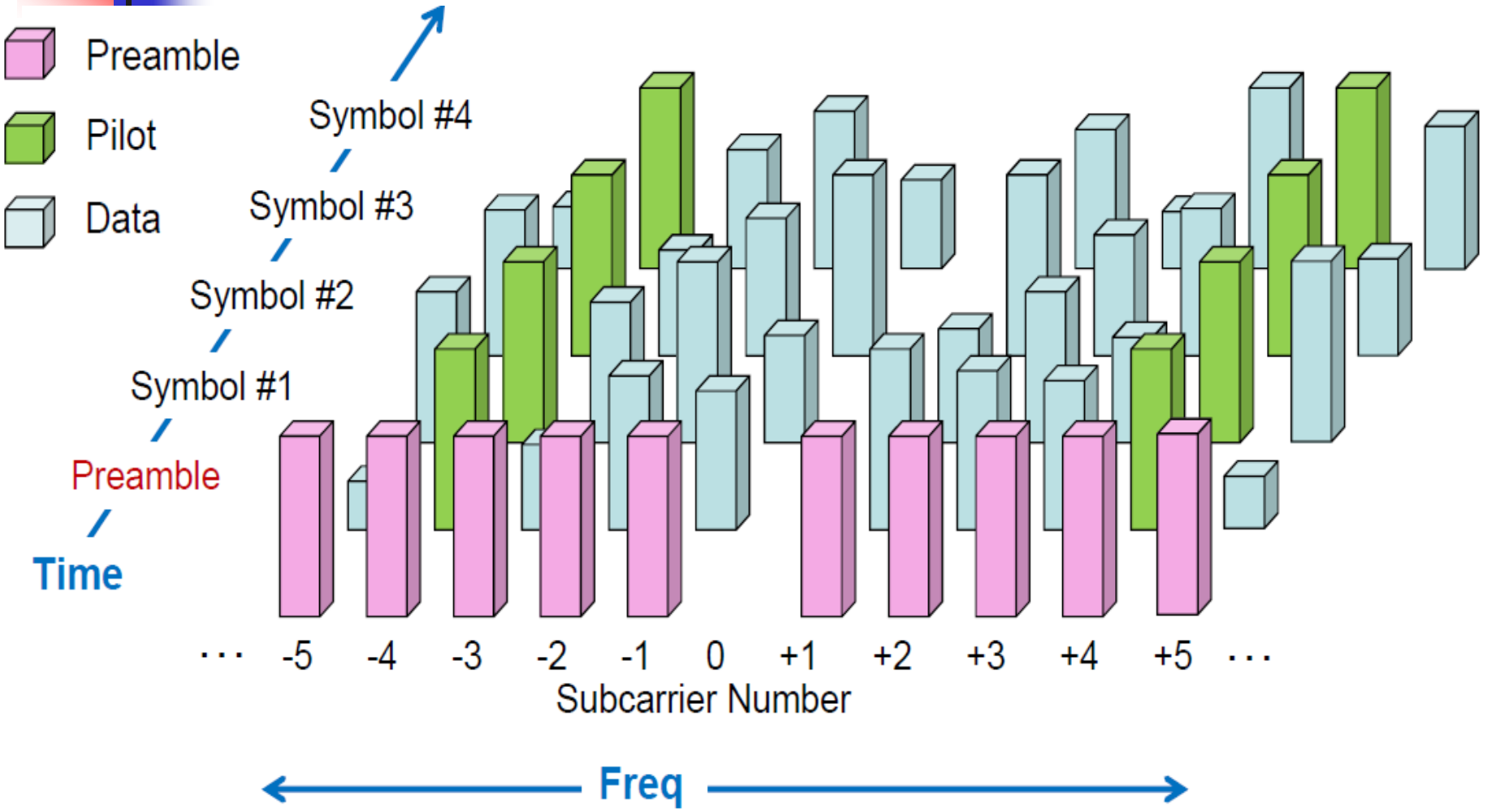
OFDM

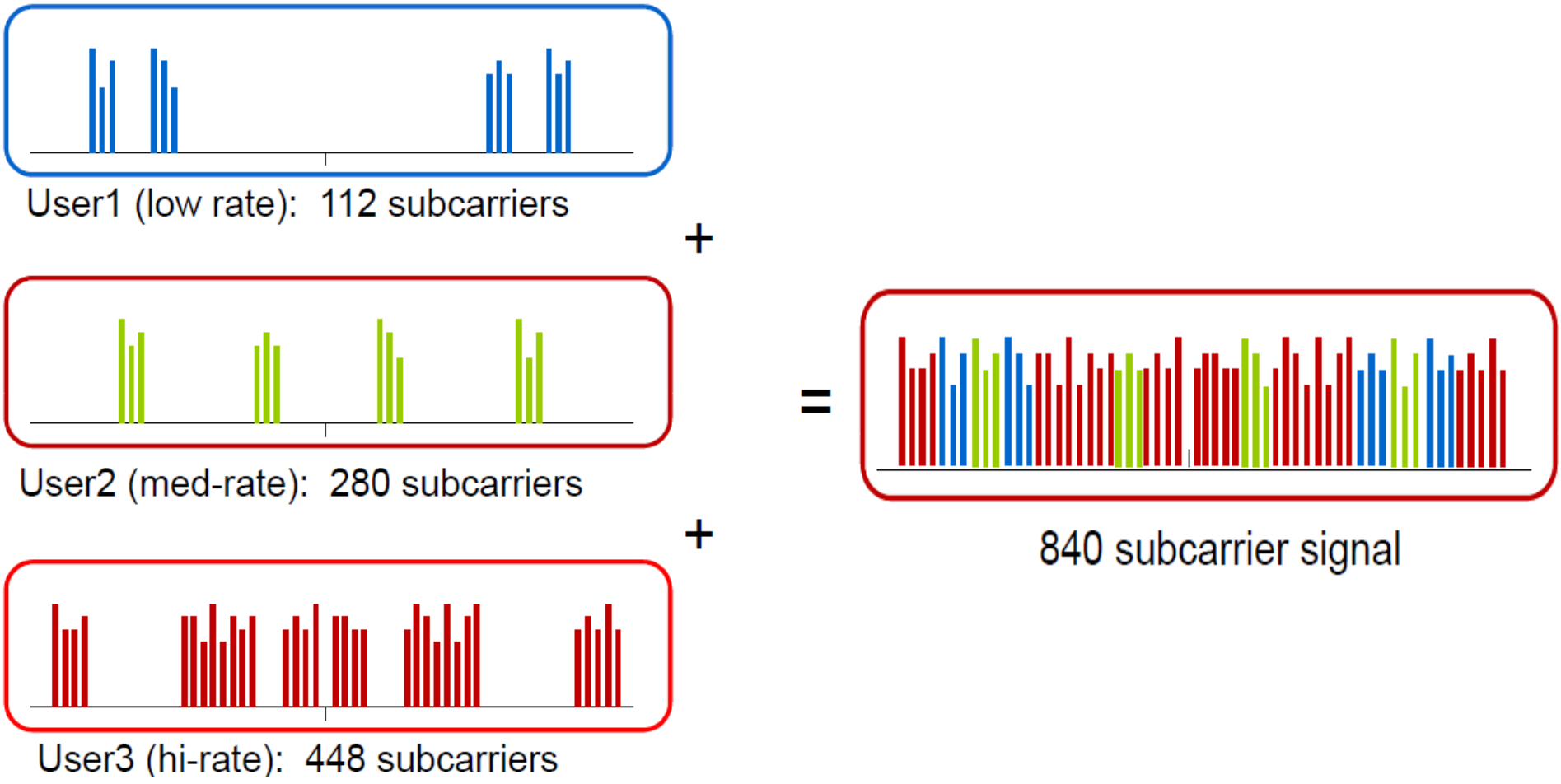


http://www.keysight.com/upload/cmc_upload/All/2_Flexible_OFDM_Signal_Generation_Analysis_and_Troubleshooting.pdf?cmpid=1-3660333773&cc=US&lc=eng

Multiple carriers will transmit multiple symbols in parallel.

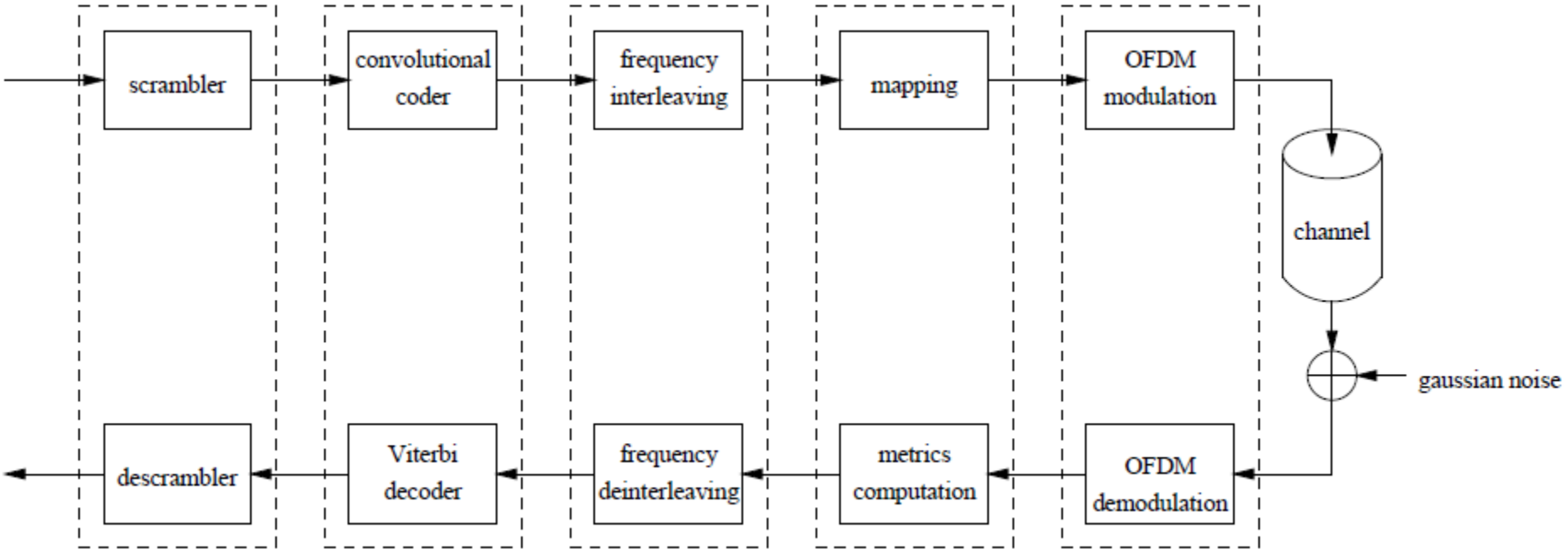
Carriers may have different modulations – BPSK, QPSK… 64QAM.

OFDM sharing of Resources



OFDM

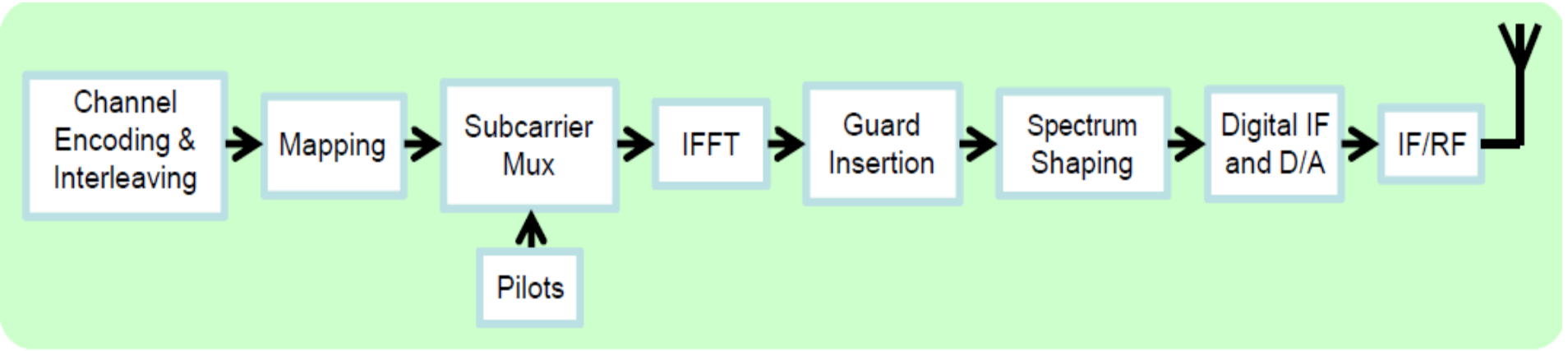
OFDM: Orthogonal Frequency-Division Multiplexing



Coded Orthogonal Frequency Division Multiplexing COFDM

OFDM

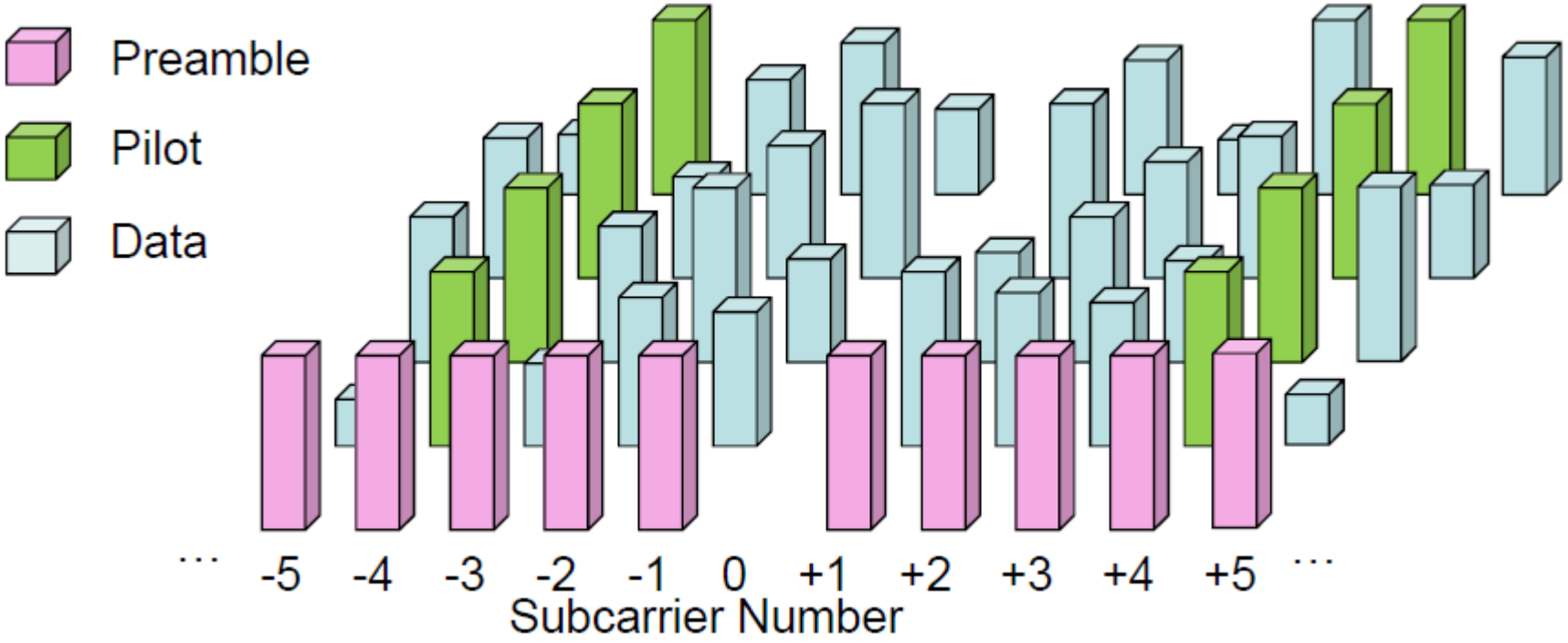
OFDM: Orthogonal Frequency-Division Multiplexing



Coded Orthogonal Frequency Division Multiplexing COFDM

OFDM

OFDM: Orthogonal Frequency-Division Multiplexing



Coded Orthogonal Frequency Division Multiplexing COFDM

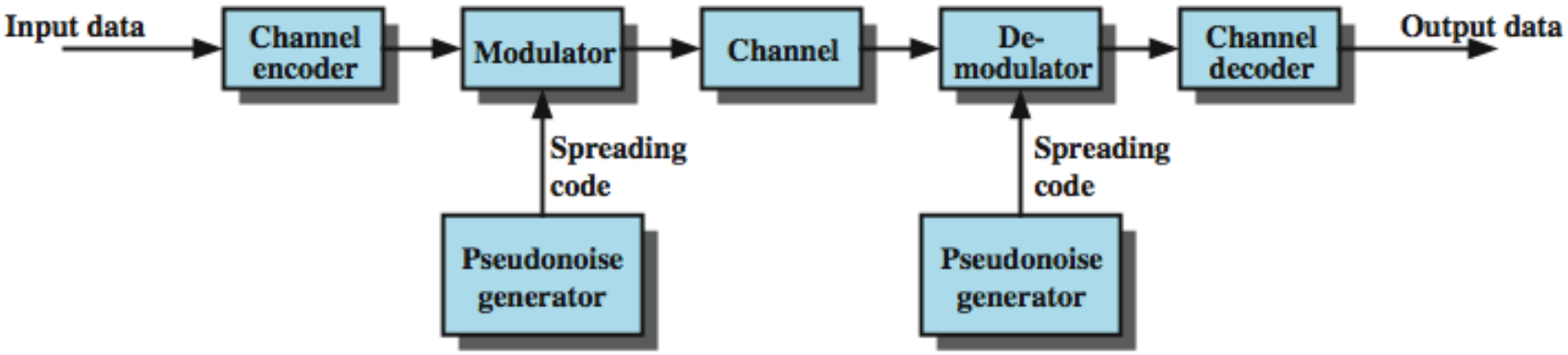
Spread Spectrum

- Important encoding method for wireless communications
- Analog & digital signal
- Spreads data over wide bandwidth
- Makes jamming and interception harder
- Two approaches, both in use:
  - Frequency Hopping
  - Direct Sequence

Spread Spectrum Advantages

- Immunity from noise and multipath distortion
- Can hide / encrypt signals
- Several users can share same higher bandwidth with little interference
  - CDM/CDMA Mobile telephones

General Model of Spread Spectrum System



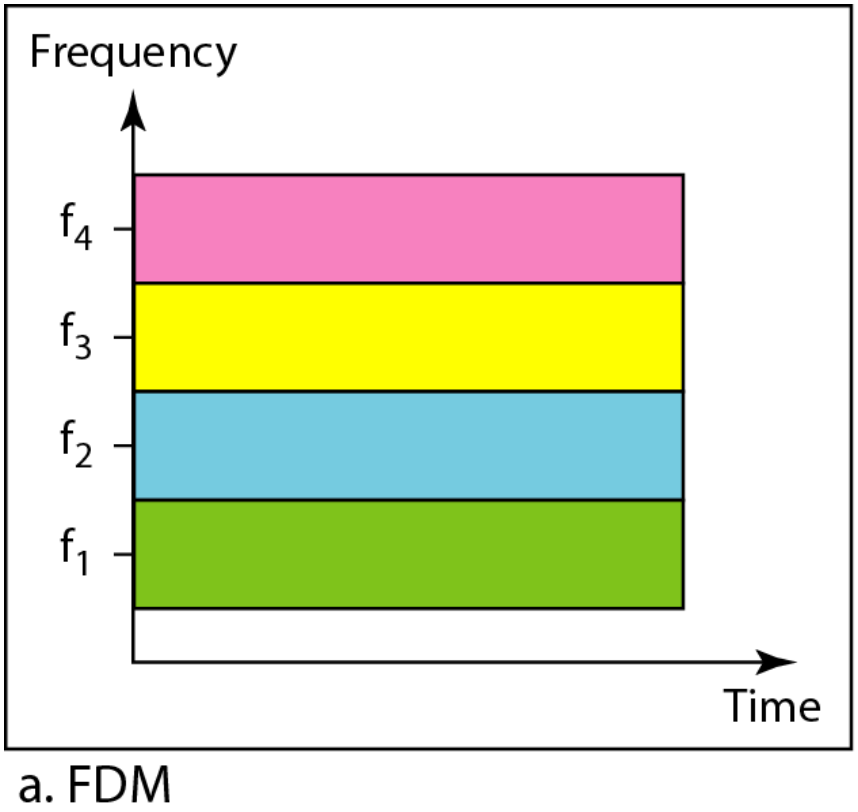
Pseudorandom Numbers

- Generated by a deterministic algorithm
  - Not actually random
  - But if algorithm good, results pass reasonable tests of randomness
- Starting from an initial seed
- Need to know algorithm and seed to predict sequence
- Hence, only receiver can decode signal

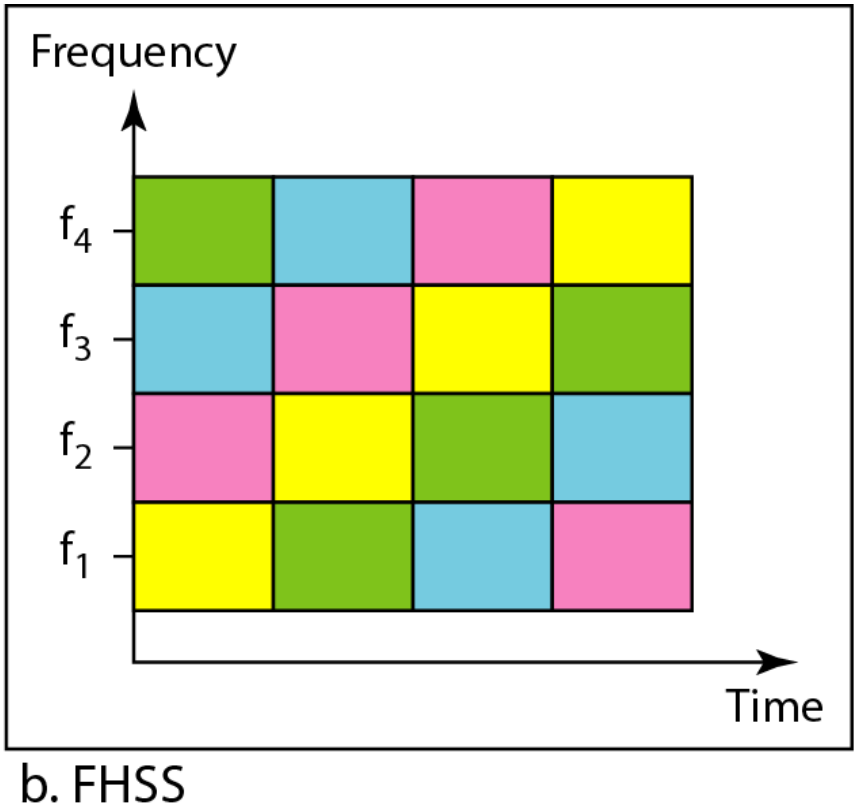
Frequency Hopping Spread Spectrum (FHSS)

- Signal is broadcast over seemingly random series of frequencies
- Receiver hops between frequencies in sync with transmitter
- Eavesdroppers hear unintelligible blips
- Jamming on one frequency affects only a few bits

Bandwidth sharing

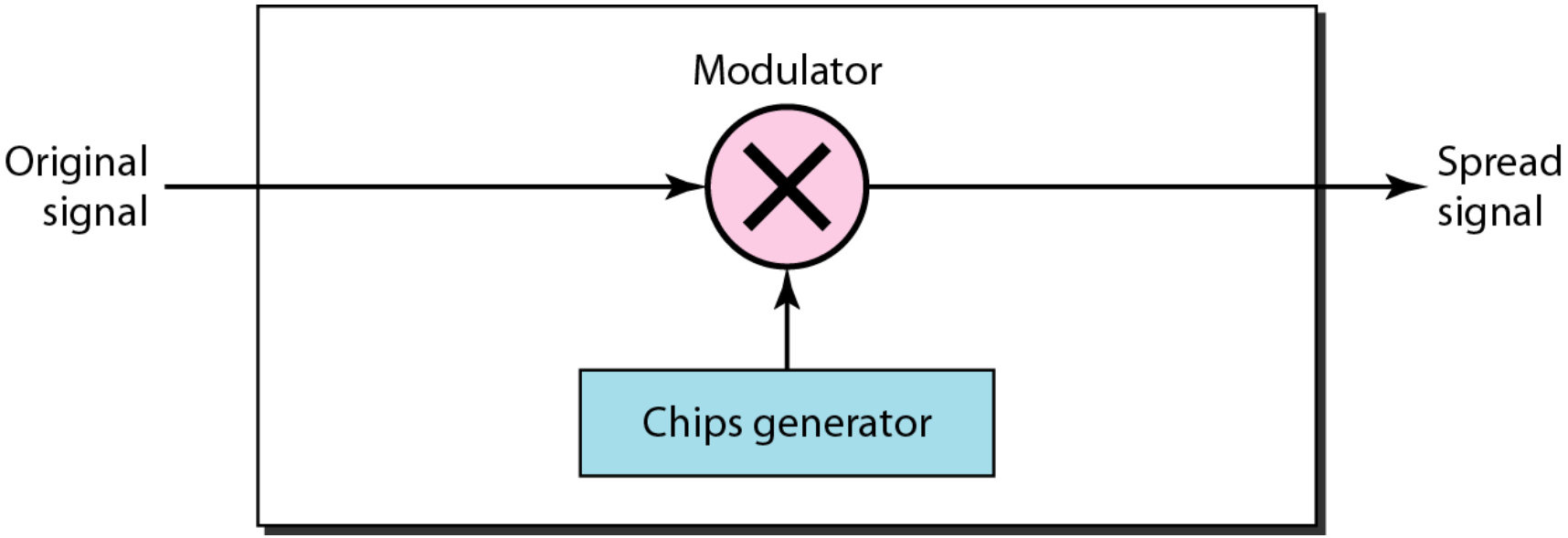


a. FDM

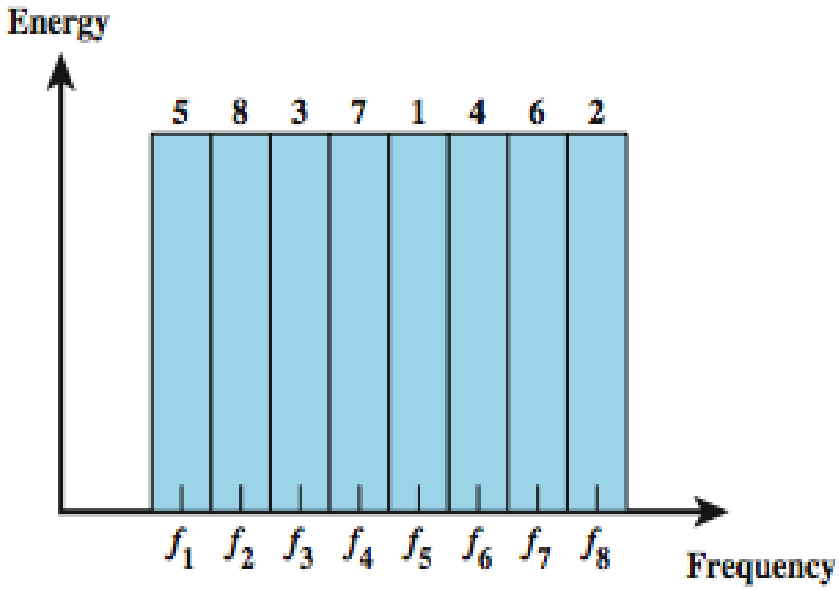


b. FHSS

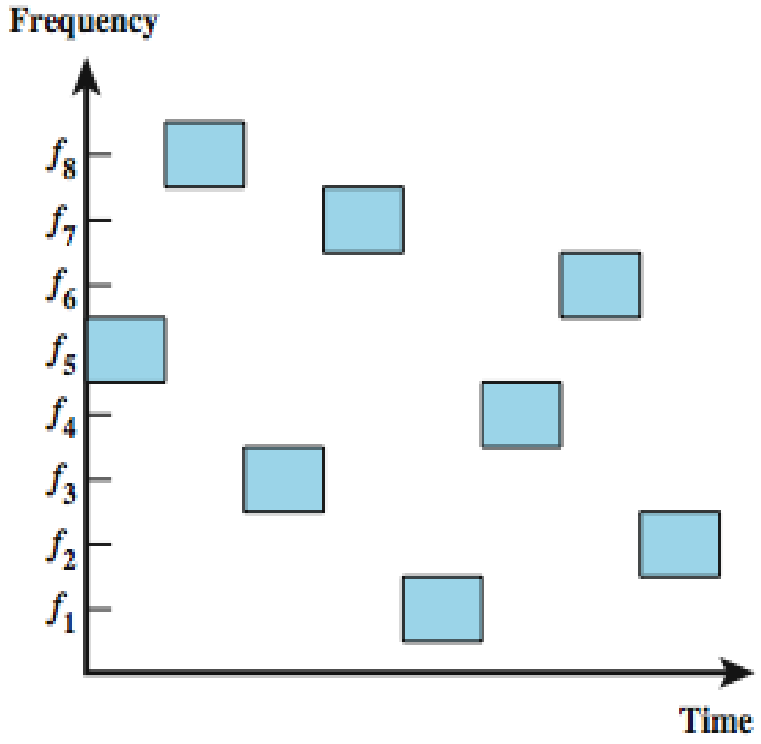
DSSS



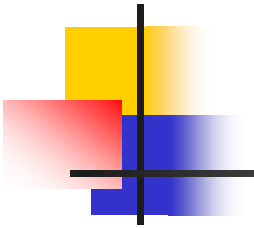
Frequency Hopping Example



(a) Channel assignment



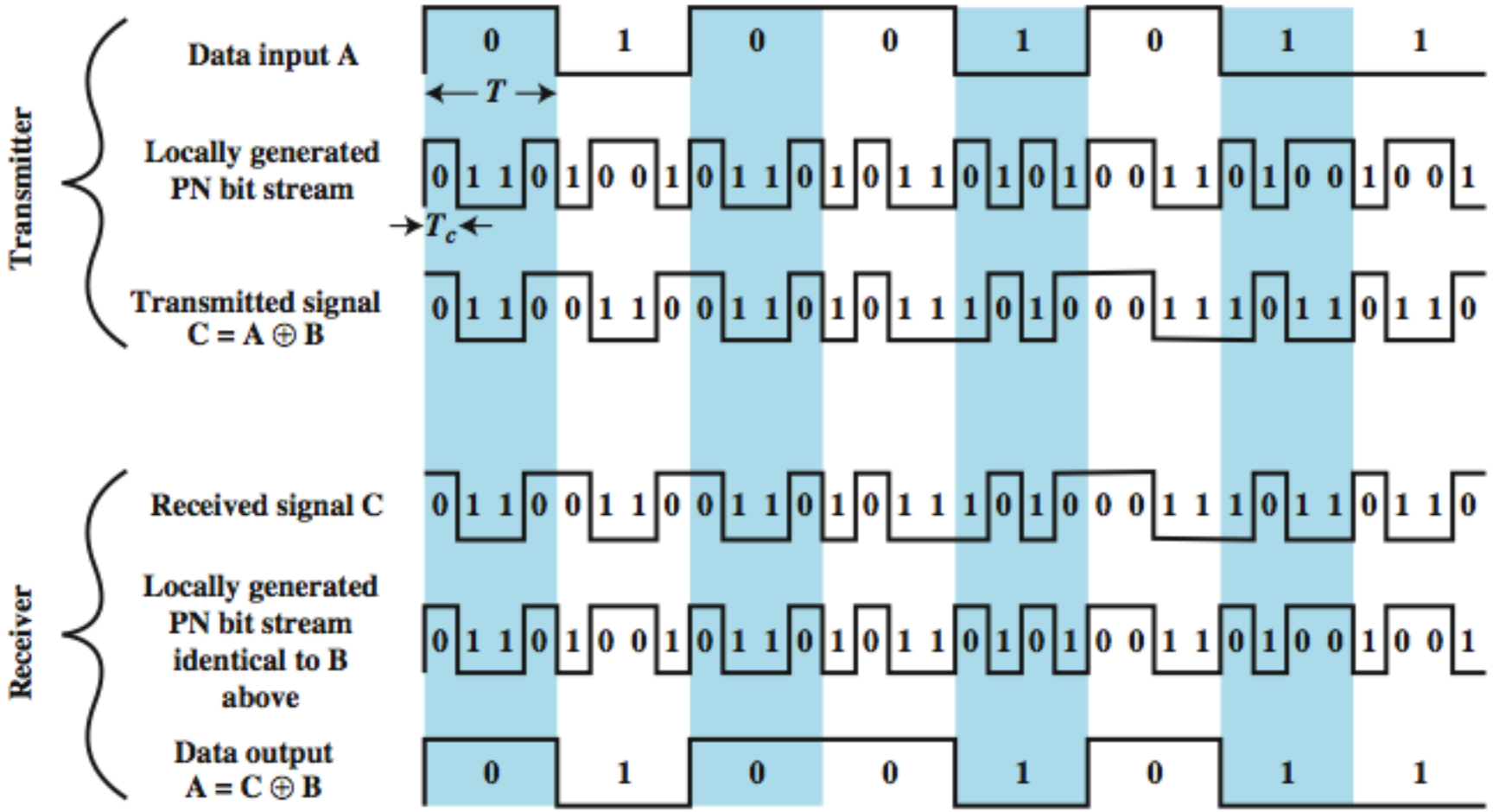
(b) Channel use



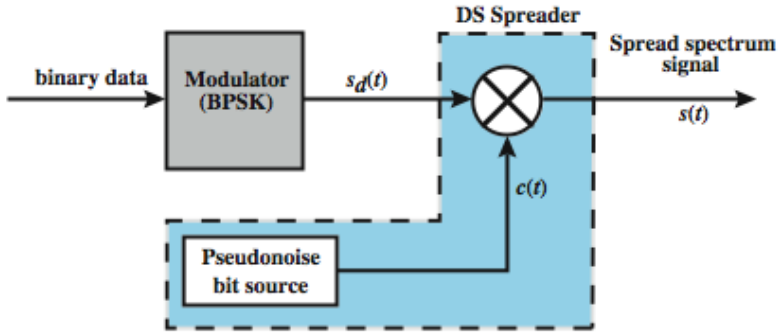
Direct Sequence Spread Spectrum (DSSS)

- Spread Spectrum (SS) techniques convert a low-speed data stream into a high-speed data stream
- The bandwidth of the modulated carrier becomes much larger than the minimum required transmission bandwidth
- This is like Frequency Modulation (FM): Trade transmission bandwidth with Signal-to-Noise (S/N) ratio, meaning that we can have error-free communication transmitting lower-power signals
- Each bit is represented by multiple bits using a spreading code
- This spreads signal across a wider frequency band
- Has performance similar to FHSS

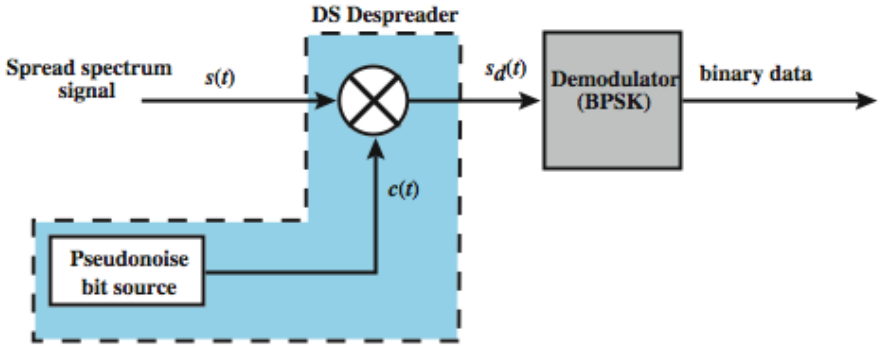
Direct Sequence Spread Spectrum Example



Direct Sequence Spread Spectrum System



(a) Transmitter

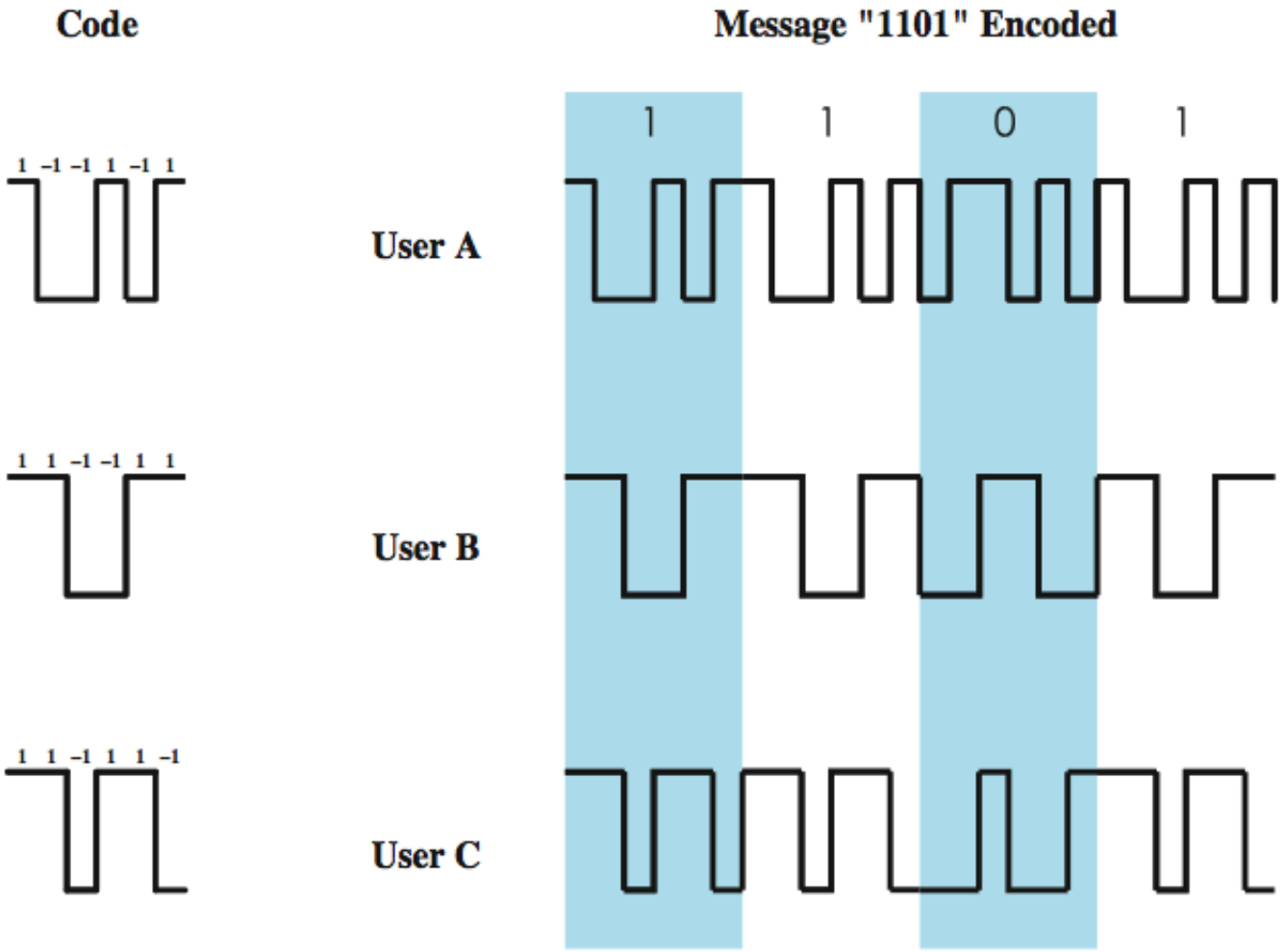


(b) Receiver

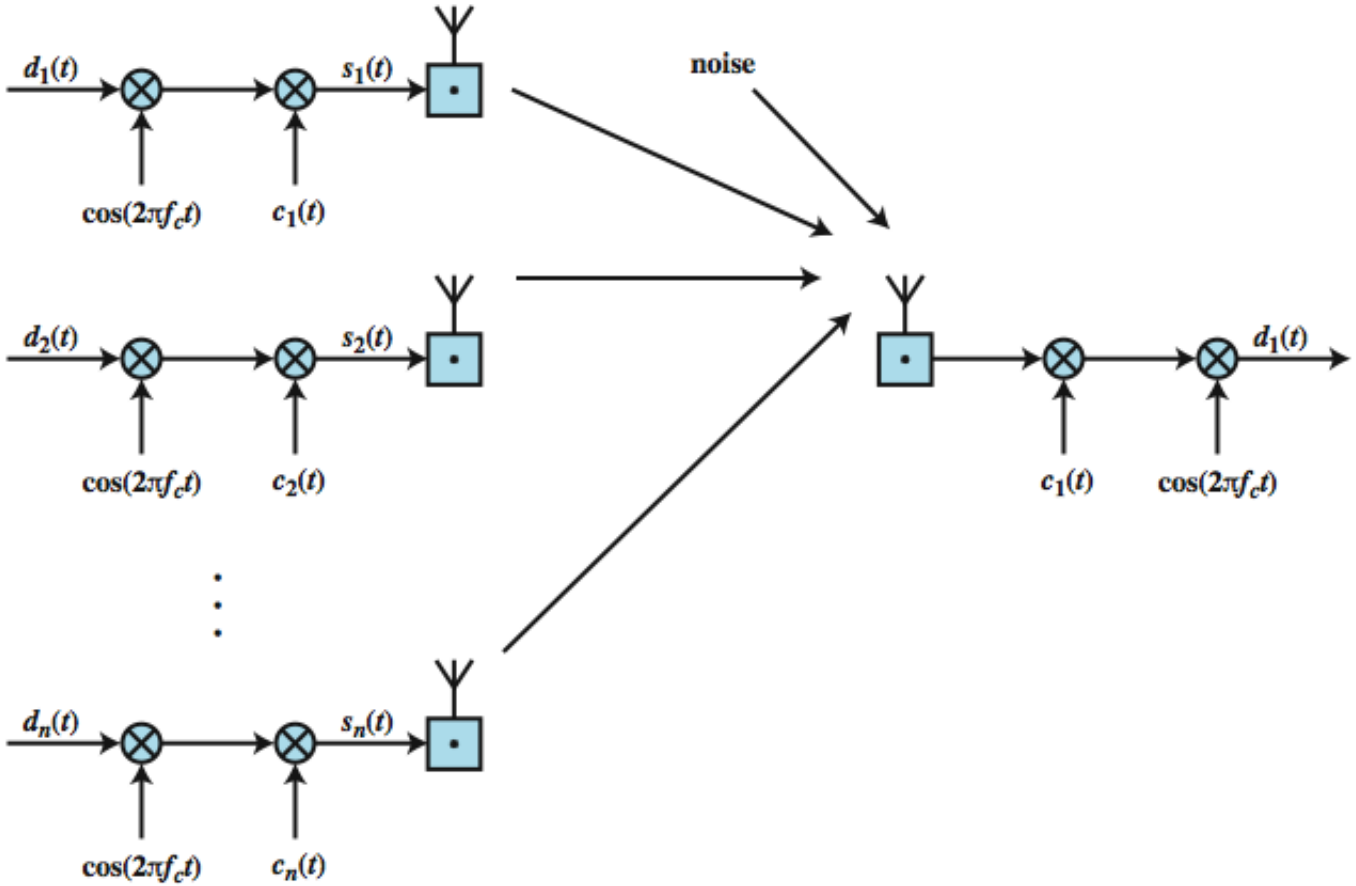
Code Division Multiple Access (CDMA)

- Multiplexing technique used with spread spectrum
- Given a data signal rate D
- Break each bit into *k* chips according to a fixed chipping code specific to each user
- Resulting new channel has chip data rate *kD* chips per second
- Can have multiple channels superimposed

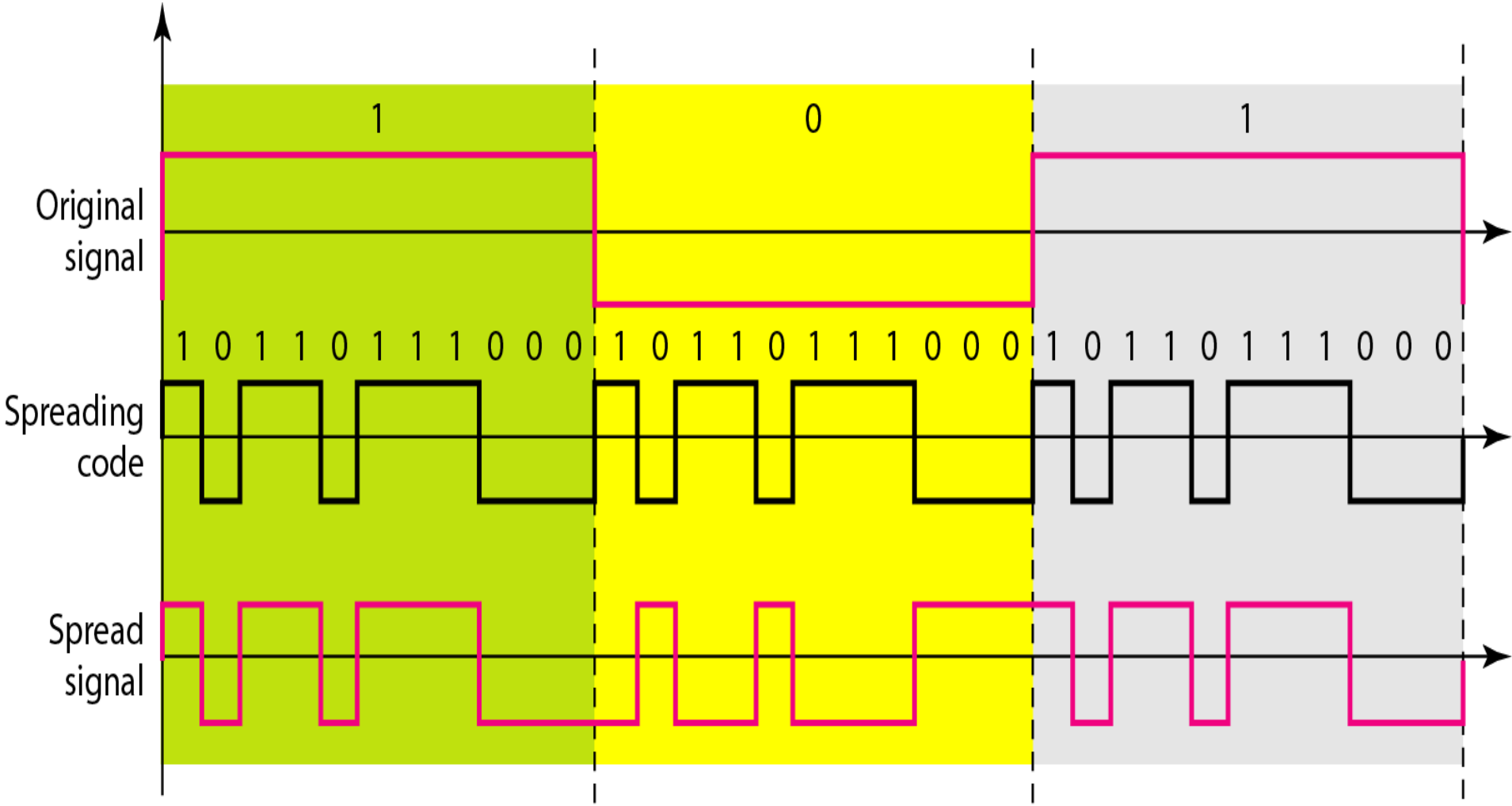
CDMA Example



CDMA using DSSS



DSSS example



Comparison between 802.11 a/b/g/n/ac

Mode	802.11a	802.11b	802.11g	802.11n	802.11ac
Operating frequencies	5 GHz UNII/ ISM bands	2.4 GHz ISM band	2.4 GHz ISM band	2.4 GHz and 5 GHz UNII/ ISM bands	5.0 GHz ISM band
Modulation techniques	OFDM	Barker code/CCK	Barker code/CCK/ OFDM	OFDM 4 MIMO streams	Multiuser MIMO
Data rates	6, 9, 12, 18, 24, 36, 48, 54	1, 2, 5, 5, 11	1, 2, 5.5, 11, 6, 9, 12,18, 24, 36, 48, 54	20 or 40 MHz	500 Mbit/s
Slot time	9 ms	20 ms	20 ms 9 ms (optional)	< 9µs	48µs
Preamble	OFDM	Long Short (optional)	Long/Short/ OFDM	High Throughput (HT), Non-HT, and HT Mixed	0^0 phase shift on LSIG (Legacy SIGNAL) at 16-20 ms/ 20-24ms; or 90^0 phase shift at 24-28 ms

802.11b (WiFi)

- In 1999, a Wireless Ethernet compatibility alliance (WECA) formed to promote the IEEE 802.11 high-rate standard
- This eventually became IEEE 802.11b- commercial product WiFi
- 802.11b uses only DSSS
- 802.11b was a 1999 ratification to the original 802.11 standard, allowing wireless functionality comparable to Ethernet
- Data Rate: Up to 11Mbps in 2.4GHz band
- Modulation scheme: DSSS (direct-sequence spread spectrum) with CCK (*Complementary Code Keying*)
- Security: WEP (Wired Equivalent Privacy) & WPA (Wi-Fi Protected Access)
- These are considered "Wi-Fi Certified." Not interoperable with 802.11a. Requires fewer access points than 802.11a for coverage of large areas
- As the coverage is larger, 802.11b requires fewer access points than 802.11a for a given areas

802.11b (Wi-Fi)

- Offers high-speed access to data at up to 300 feet from base station
- 14 channels available in the 2.4GHz band (only 11 of which can be used in the U.S. due to FCC regulations) with only three non-overlapping channels

802.11a X 802.11b	802.11a	802.11b
Speed (data rate)	54 Mbps (54, 48, 36, 24,18, 12, 6 Mbps) Real: 28 Mbps	11 Mbps (11, 5.5, 2, 1 Mbps) Real: 5.2Mbps
Area	50 Meters	100 Meters
Frequency Band	ISM (5 GHz)	ISM (2.4 GHz)
Modulation	Technology OFDM	Technology DSSS

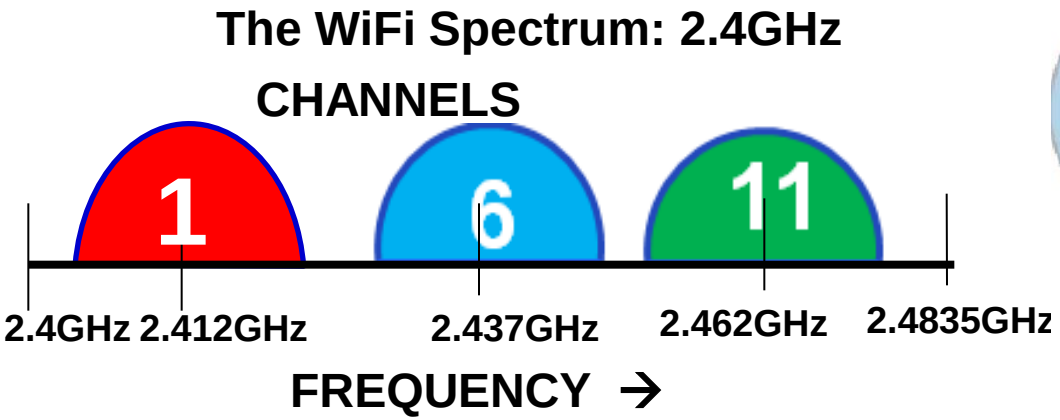
IEEE 802.11g (High Speed 2.4GHz)

- **Pros/Cons & More Info:**
  - **Products that adhere to this standard are considered "Wi-Fi Certified"**
  - **May replace 802.11b as compatible with 802.11b**
  - **14 channels available in the 2.4GHz band (only 11 of which can be used in the U.S. due to FCC regulations) with only three non-overlapping channels**
- **Data Rate: Up to 54Mbps in the 2.4GHz band**
- **Modulation Scheme:**

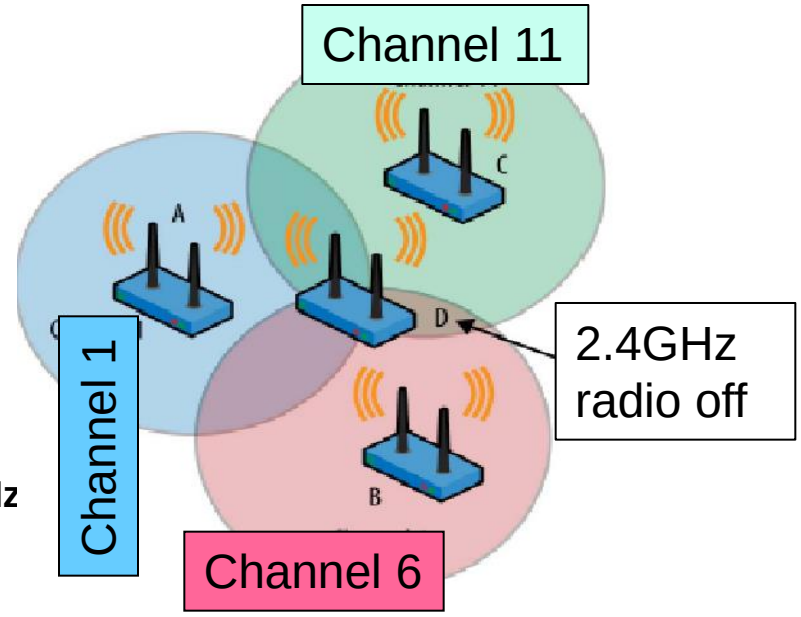
  OFDM above 20Mbps
  DSSS with CCK below 20Mbps
- **Security: WEP & WPA & WPA2 (Wi-Fi Protected Access) (IEEE 802.11i)**

802.11g

- In 2003, operating in 2.4G like IEEE 802.11b., can achieve higher throughput of up to 54Mbps
- Although 14 channels are available in the 2.4GHz band, only 11 of which can be used in the U.S. due to FCC regulations

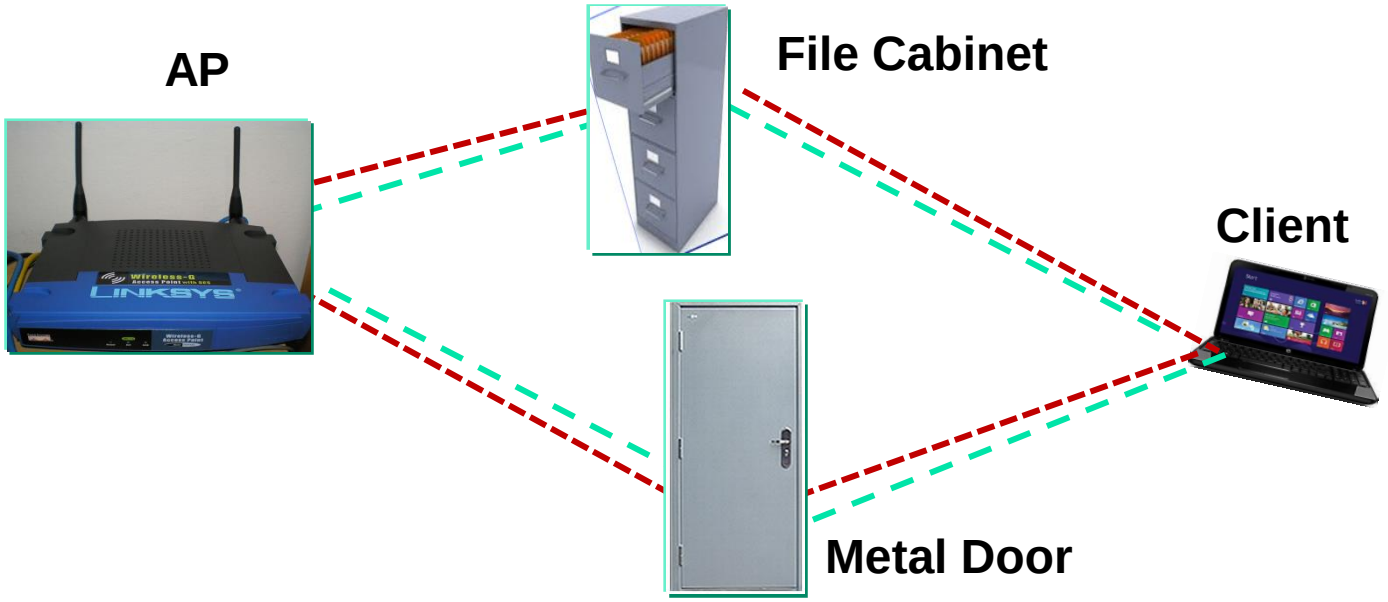


http://www.4gon.co.uk/solutions/introduction_to_802_11_wifi.php



http://chimera.labs.oreilly.com/books/1234000001739/ch05.html#coverage_and_capacity_estimates

802.11n Wireless Access Point



en.wikipedia.org/wiki/Access_point

Multiple-input multiple-output (MIMO) technology added

802.11 MAC Header

Address Fields in 802.11 MAC header

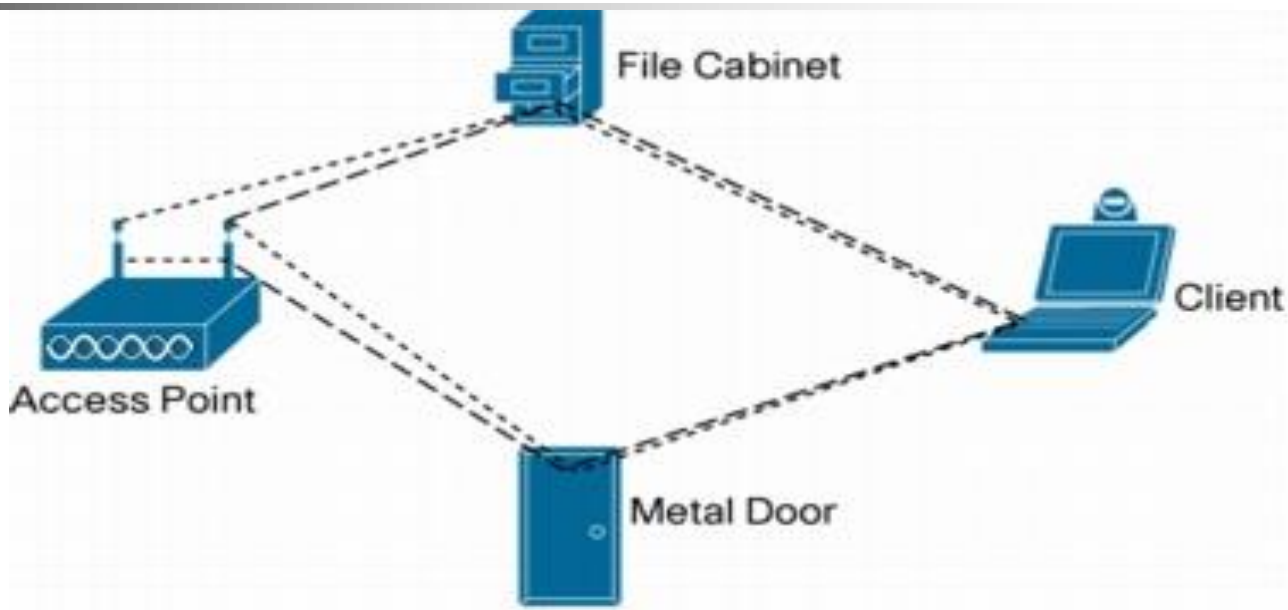
To AP	From AP	Address 1	Address 2	Address 3	Address4
0	0	Destination	Source	BSSID	N/A
0	1	Destination	BSSID	Source	N/A
1	0	BSSID	Source	Destination	N/A
1	1	Receiver	Transmitter	Destination	Source

- MAC (Media Access Control) address is the physical address of a particular Network Interface Card (NIC)
- Retry bit is set to 1 if the current packet is a retransmission of a previous attempt
- Power Management bit is set to 1 if the node will enter power save mode after the current transmission or 0 if the node will be active
- More Data bit is set to 1 if packets have been buffered and are waiting to be delivered to the destination node
- WEP (Wired Equivalent Privacy) bit is set to 1 if the content (payload) of the packet has been encrypted using the WEP algorithm
- Order bit is set to 1 if the packets must be strictly ordered, for example voice over IP

(BSSID):Basic service set identification (MAC address of WAP)

http://www.wildpackets.com/resources/compendium/wireless_lan/wlan_packets

802.11n Wireless Access Point



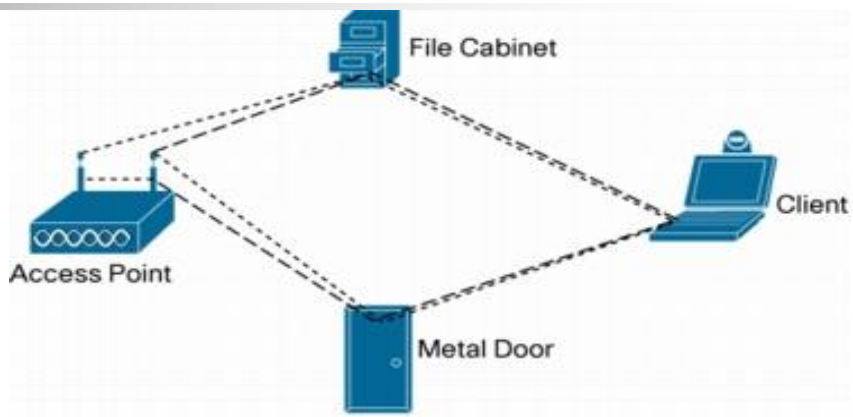
- Multiple transmit antennas are used to focus transmissions in the direction of the client, increasing downlink signal-to-noise ratio and the data rate over range
- MIMO has multiple separate receive and transmit paths, 2x1 refers to a system with two transmitters and one receiver, 2x2 to 4x4

L-G700AP > High Speed 2.4GHz (802.11g) Wireless Access Point

Product Features:

- **Up to 54Mbps**
- **WPA for Enhanced Wireless Security**
- **Quickly Add Wireless Access to the Network**
- **Web-based Configuration and Management**

802.11n Wireless Access Point



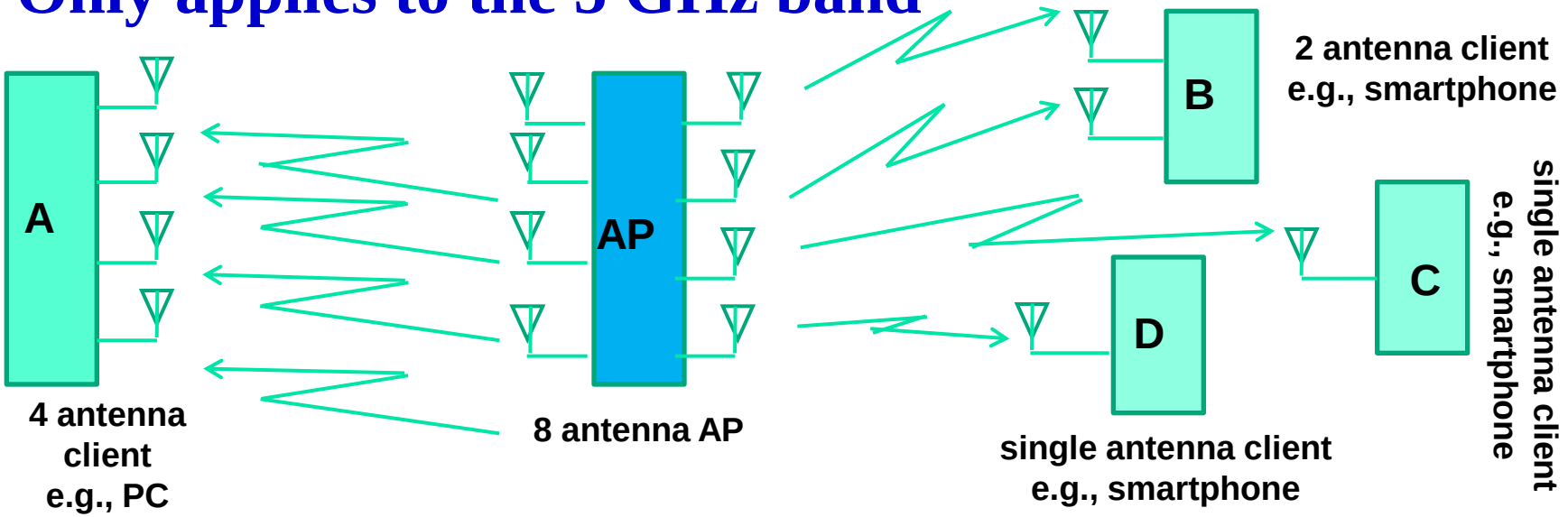
- Takes advantage of multipath by sending multiple radio signals at the same time called spatial diversity
- In addition to sending multiple streams, multiple transmitters can also be used to achieve a higher SNR
- Clients operating near cell boundaries, the technology improves performance on both the uplink and downlink during web browsing, email, and file downloads

802.11ac Wireless Access Point

- Developed from 2011 to 2013 by Wi-Fi Alliance and approved in Jan. 2014
- Allows AP to transmit separate streams to each client simultaneously, similar to MIMO except the transmissions are to antennas on different receivers
- The number of spatial streams is limited to the number of transmit chains on the AP
- Downlink multi-user MIMO requires some MAC layer enhancements and beam forming
- This feature will only work when the AP is transmitting to the client (uplink)
- Client devices will not be able to leverage this feature when they are transmitting to the AP (downlink)

802.11ac Wireless Access Point

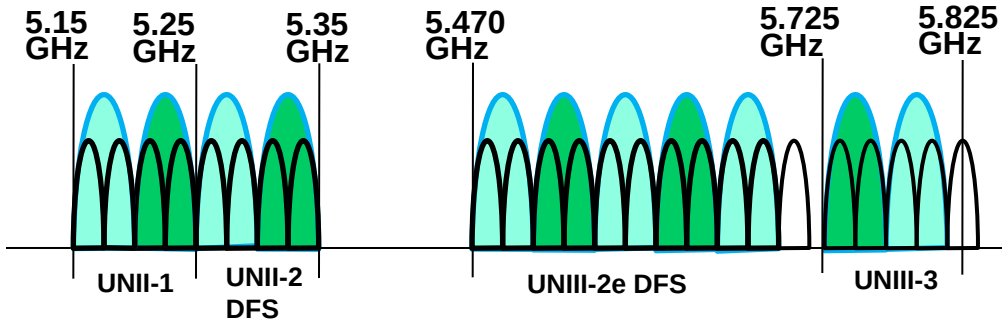
- Downlink multi-user MIMO should allow significantly improved throughput when multiple single and dual stream clients are connected to the AP
- Most smartphones and tablets are single stream devices
- With 11n, only 1 single stream device can download at a time
- Only applies to the 5 GHz band



http://www.arubanetworks.com/pdf/support/80211ac_FAQ.pdf

802.11ac Wireless Access Point

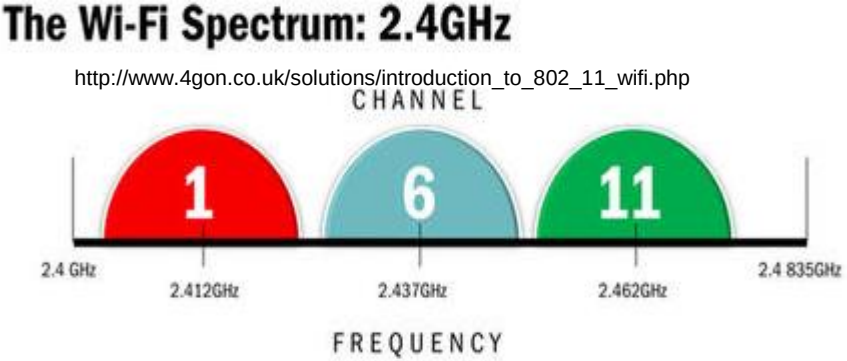
The 802.11ac Spectrum use in 5GHz Range

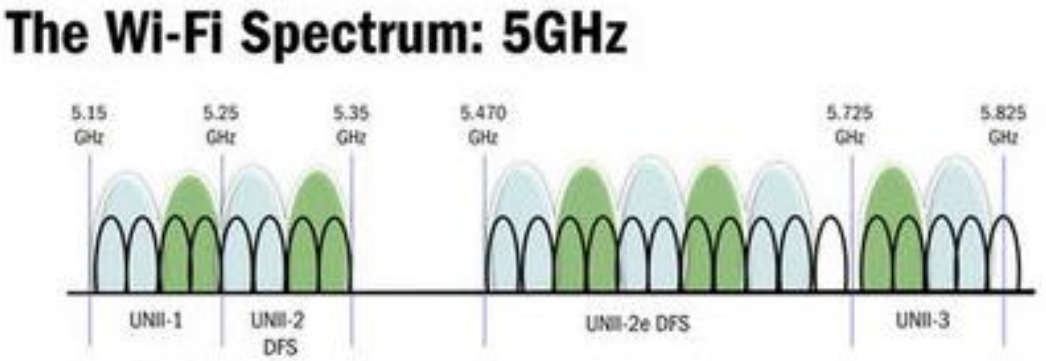


- **Approved in Jan. 2014**
- **Extend the concept of 802.11n RF bandwidth to 160 MHz**
- **Have up to 8 MIMO spatial streams serving multiple users and use high-density modulation such as up to 256-QAM (Quadrature Amplitude Modulation)**

www.dataconnectors.com/events/2013/07denver/pres/ruckus.ppsx

802.11ac Wireless Access Point

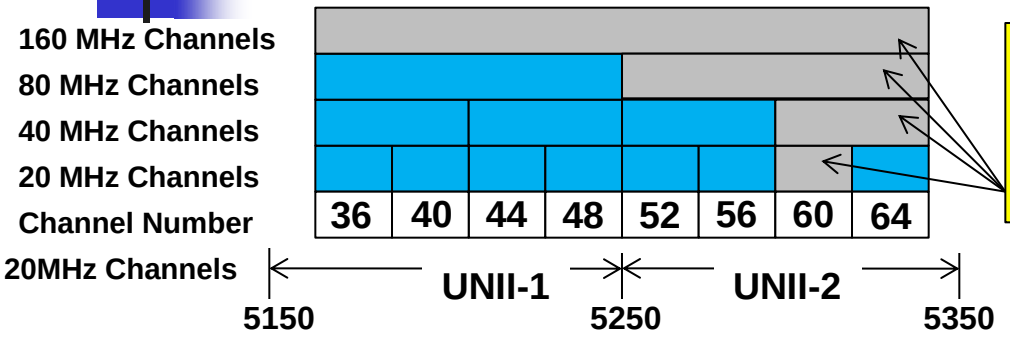




- A 20 MHz-wide 802.11g/n network has four such channels, while a 40 MHz-wide 802.11n network has just two
- 802.11ac Offers 23 non-overlapping channels
- In the US, there are 5 contiguous 80 MHz channels
- Likely to support up to 3 streams and 80 MHz channels
- With an oscillation roughly twice that of 2.4 GHz, a 5.0 GHz signal was more likely to die in less distance than its competitor
- So, 802.11b/g went on to become the dominant public wireless communication standard

http://www.arubanetworks.com/pdf/support/80211ac_FAQ.pdf

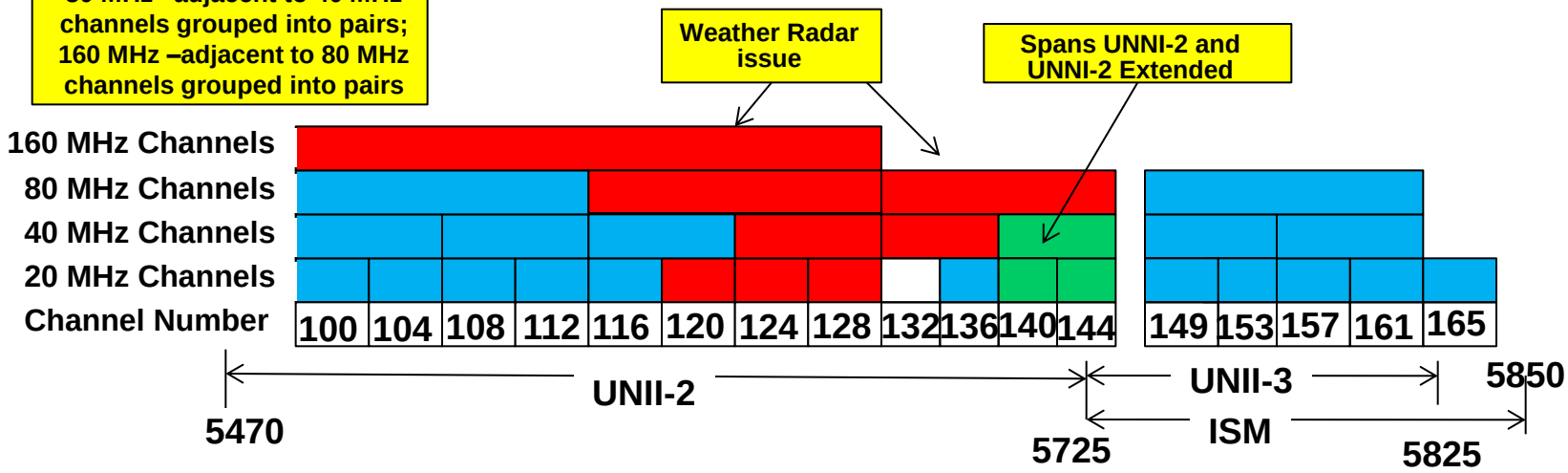
802.11ac Wireless Access Point



Example of a channel-set for a BSS
-primary 20MHz on ch60 (beacons, virtual carrier sense and 802.11a devices)
-primary 40 MHz on ch60+64 (802.11n devices)
-primary 80 MHz on ch52-64 and 160 MHz on ch36-64 (802.11ac devices)

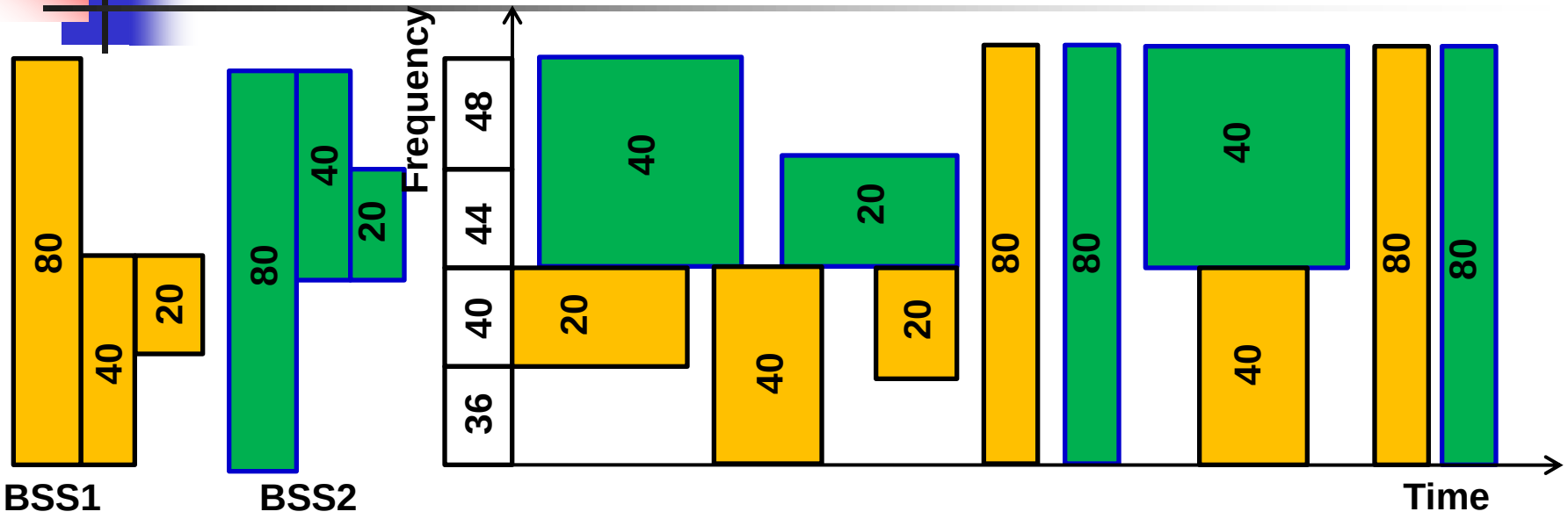
http://www.cisco.com/en/US/prod/collateral/wireless/ps5678/ps11983/white_paper_c11-713103.html

40 MHz –adjacent to 20 MHz channels grouped into pairs;
80 MHz –adjacent to 40 MHz channels grouped into pairs;
160 MHz –adjacent to 80 MHz channels grouped into pairs



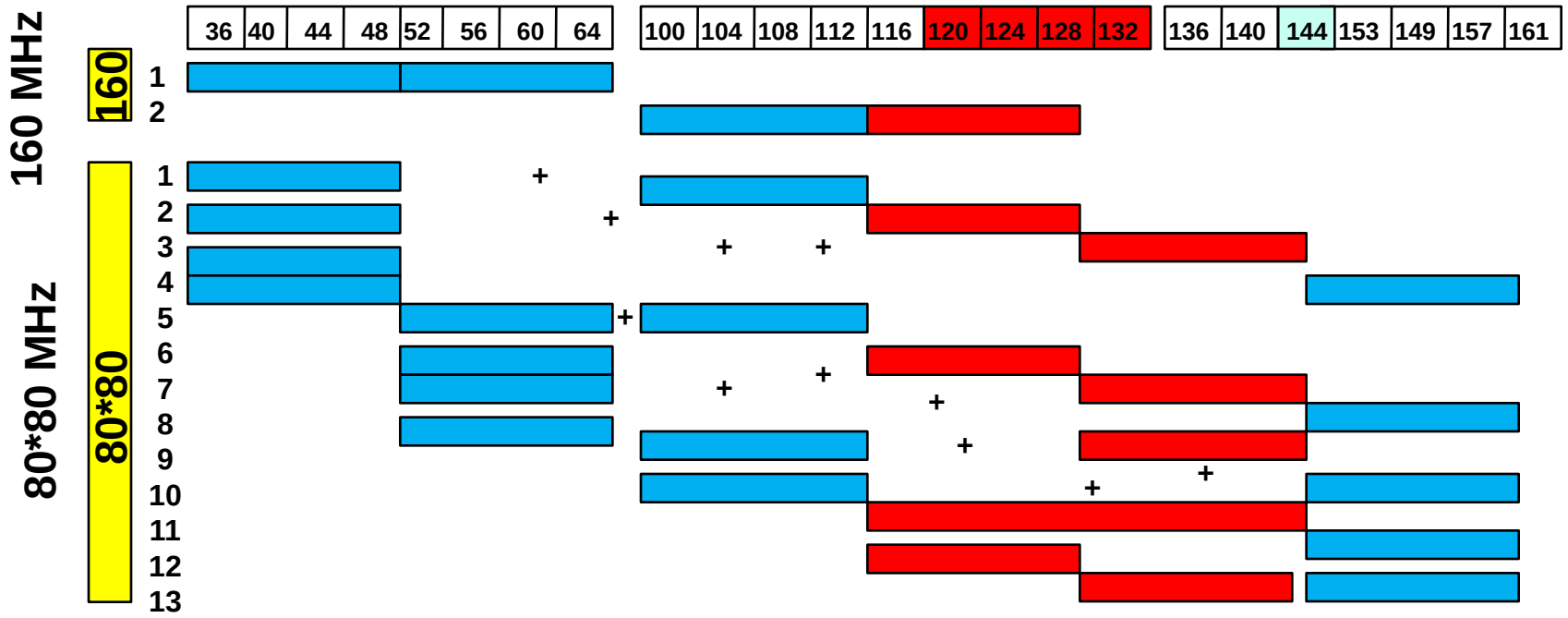
In the United States, there are 20 to 25 20-MHz channels, 8 to 12 40-MHz channels, 4 to 6 80-MHz channels, and 1 or 2 160-MHz channels

802.11ac Wireless Access Point



- Two BSSs on the Same 80 MHz but with Different Primary 20-MHz Subchannels
- The minimum allowed 802.11ac product is 4x4, faster than the corresponding 802.11n product
- Mid-tier and high-end wave 1 products are nearly 3× faster, reaching up to 1.3 Gbps PHY data rates
- A 20 MHz-wide 802.11g/n network has four such channels, while a 40 MHz-wide 802.11n network has just two

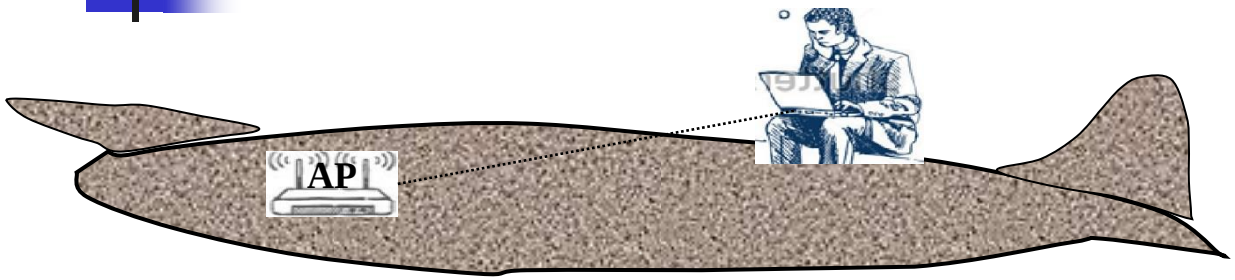
Channel Options for 802.11ac in US

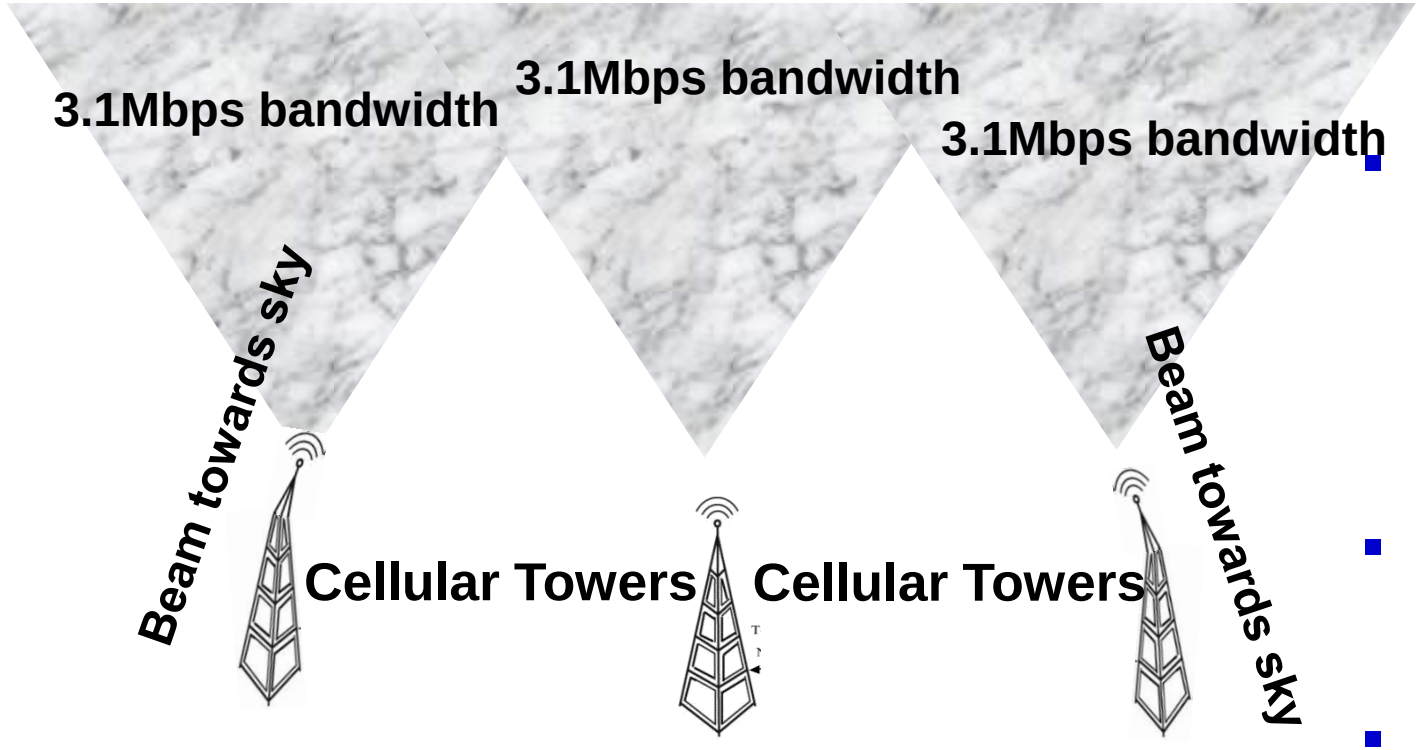


Channel Options for 160-MHz and 80+80 MHz

http://www.cisco.com/en/US/prod/collateral/wireless/ps5678/ps11983/white_paper_c11-713103.html

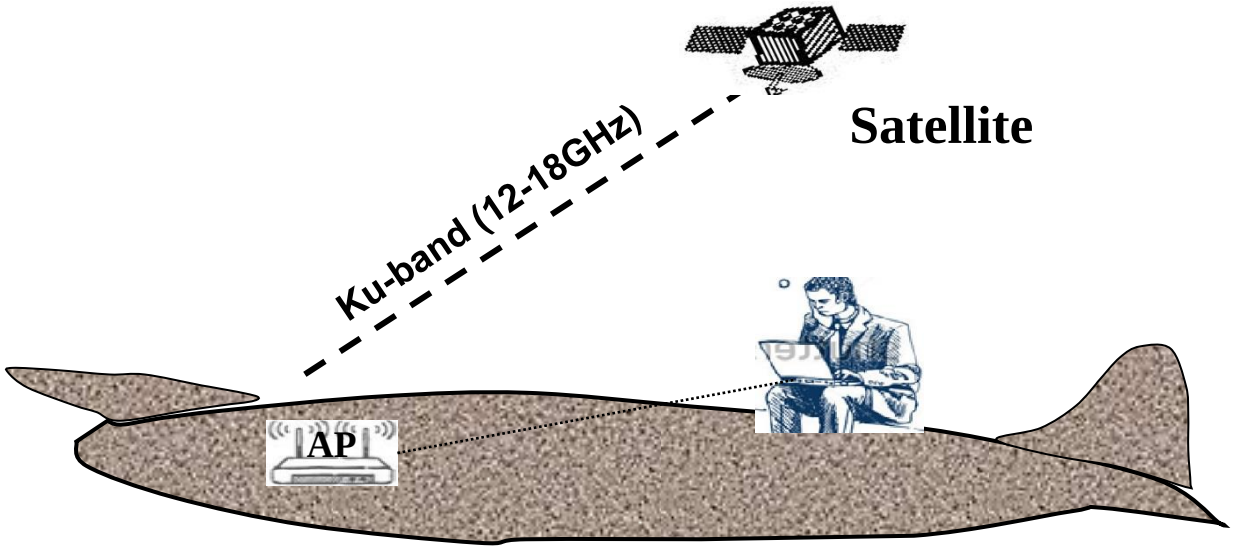
WiFi access inside an Airplane





- Each AP has a bandwidth of 3 Mbps that can support 500–600 Kbps for downloads and 300 Kbps for uploads
- One scheme is to project electromagnetic signals towards the sky using existing cell-phone towers
- There are over 160 such towers used in North America
- What about sea??

WiFi access inside an Airplane in sea area



- The second scheme being planned is to utilize Inmarsat's satellite communication link that could have a peak speed of 60 Mbps
- Ku-band (12-18GHz) is to be used (considerable delay)

Airplane mode of Cellphones

- Airplane mode is a setting available on cell phones to suspend Wi-Fi and Bluetooth while keeping games, built-in camera, MP3 player active
- It is possible to activate Bluetooth in airplane mode
- Some cell phones allow writing text or sending E-mail messages
- Some cell phones allow making an emergency call
- Other names include flight mode, aeroplane mode, offline mode, and standalone mode