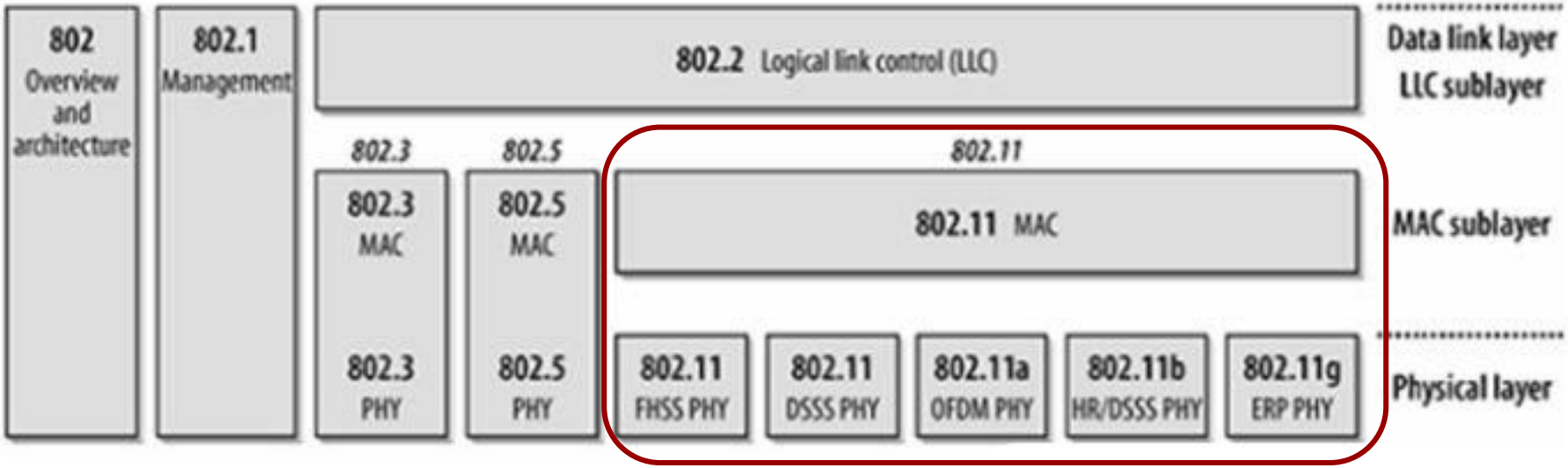
UNIVERSIDAD
COMPLUTENSE
MADRID

Networks and Protocols 1

Wifi (IEEE 802.11b/g/n/ac)

IEEE 802

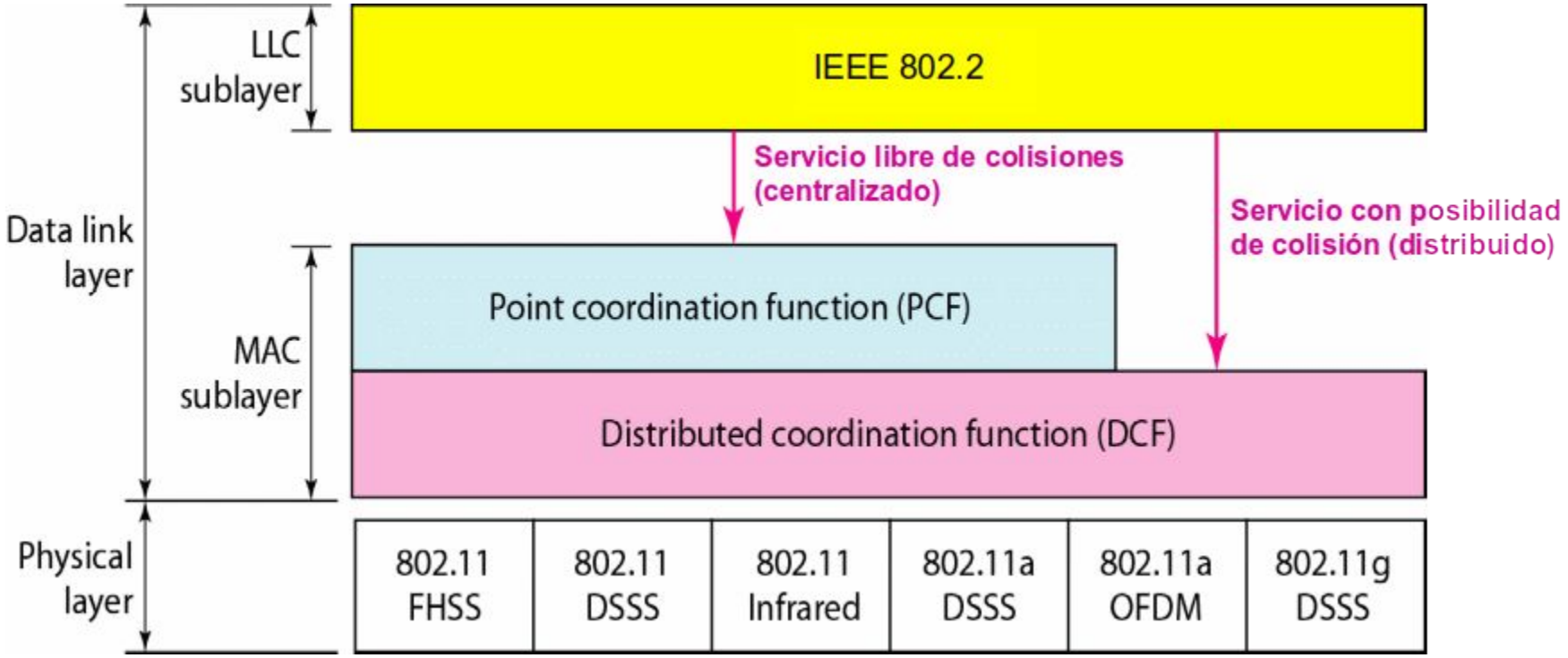


WIFI

Wifi networks: IEEE 802.11

- WiFi (Wireless Fidelity) is a WLAN technology standardized by the IEEE 802.11
- The standard defines
  - The supported WiFi network types
    - With infrastructure (with Access Point)
    - Without infrastructure (ad-hoc)
  - The set of services available
    - Basic Service Set (BSS)
    - Extended Service Set (ESS)
  - The medium access protocols involved
    - Distributed Coordination Function (DCF), based on CSMA/CA
    - Point Coordination Function (PCF), based on polling
  - The physical implementations supported
    - 802.11a, 802.11b, 802.11g, 802.11n, 802.11ac, ...
  - The frame format

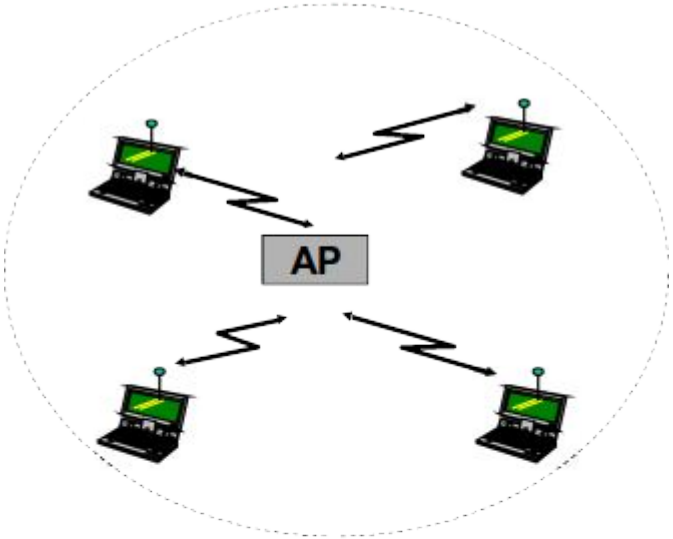
Wifi 802.11 protocol set architecture



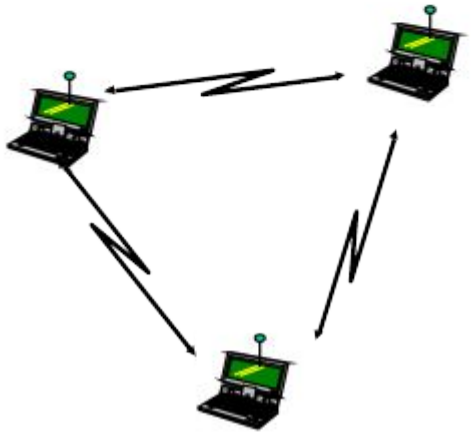
Types of wifi networks

- WiFi network with infrastructure
  - Communication through a wireless Access Point (AP)
    - Each AP has an id (MAC address)
    - The connection of a station to an AP is called association
  - The AP works as a wireless hub
    - The emitter station send its frames the AP
    - The AP retransmits the frame to the destination station
- WiFi network without infrastructure (ad-hoc)
  - The wireless stations communicate with each other directly, no intermediary AP is needed

WiFi con infraestructura

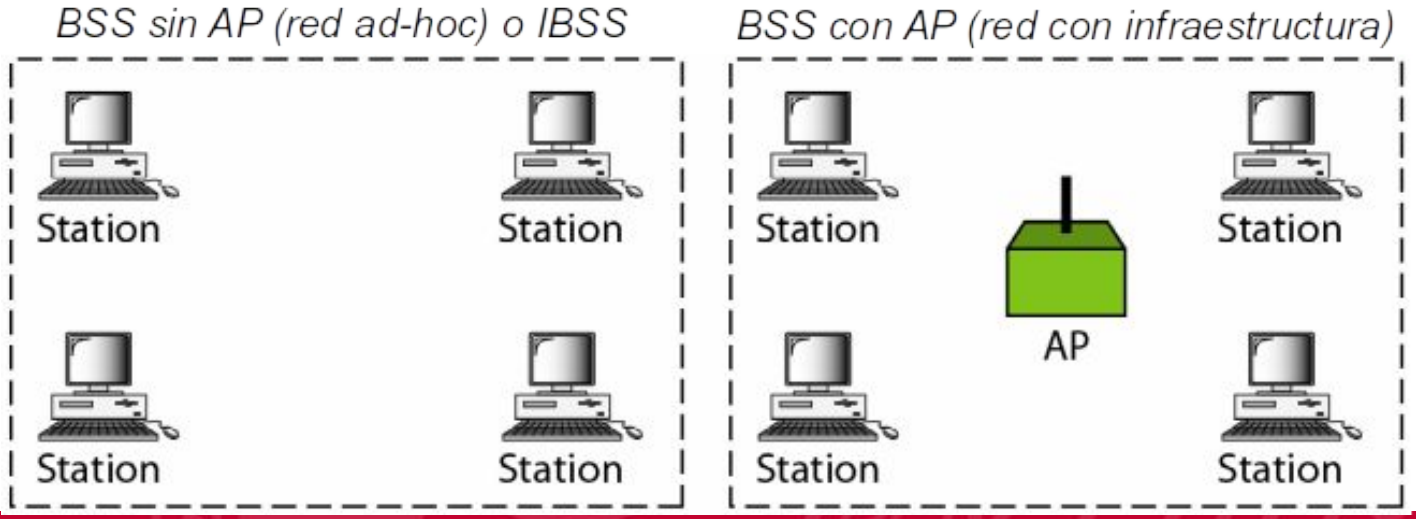


WiFi sin infraestructura (ad-hoc)



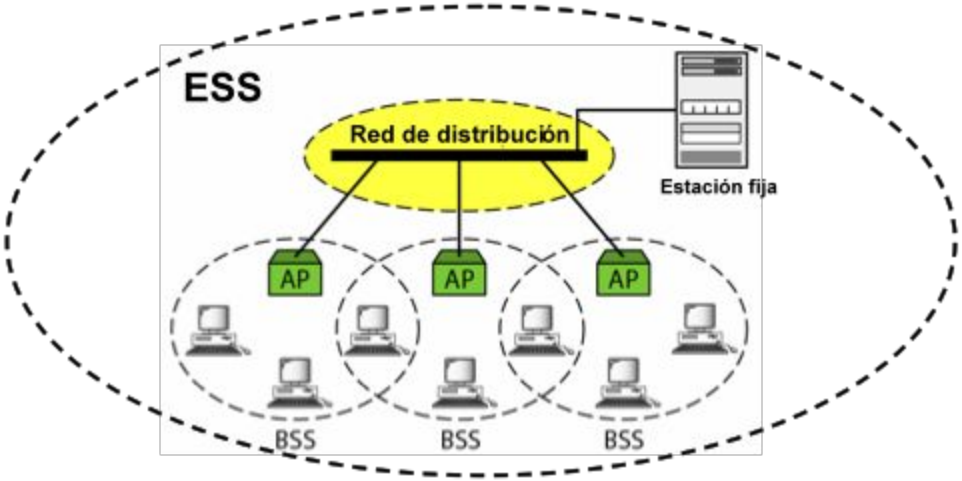
Basic Service Set (BSS)

- A BSS is the basic block on a WLAN
  - It is formed by a set of mobile stations and, optionally, an AP
- A BSS can be a WLAN with or without infrastructure
  - Without infrastructure (ad-hoc): isolated net, cannot communicate with others
    - Also called an Independent BSS (IBSS)
  - With infrastructure, can communicate with stations outside through the AP
- Each BSS has an identifier known as its BSSID
  - In the case of a BSS with AP, the BSSID is the MAC address of the AP
  - In the case of an IBSS, the BSSID is randomly generated
  - It is recognized externally by a SSID, which is a text string



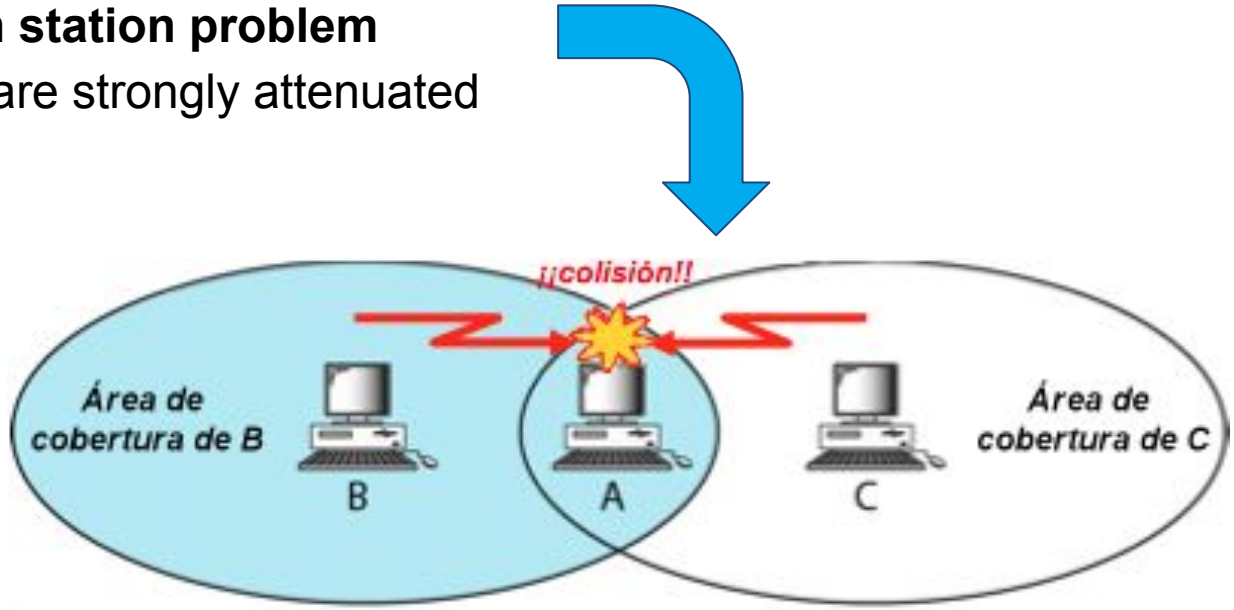
Extended Service Set (ESS)

- An ESS is composed of several BSS with their AP joined by a Distribution System (DS)
  - The distribution system is usually a wired network, that can use any technology (e.g. Ethernet)
  - The ESS can be formed by mobile or static stations
- An ESS is identified by an ESSID (or SSID)
  - It is an ASCII string of maximum 32 characters, also known as the “name of the network”



Medium Access Control

- Collisions cannot be detected -> ~~CSMA/CD~~
  - WiFi cards cannot receive and transmit simultaneously
  - **Hidden station problem**
  - Signal are strongly attenuated



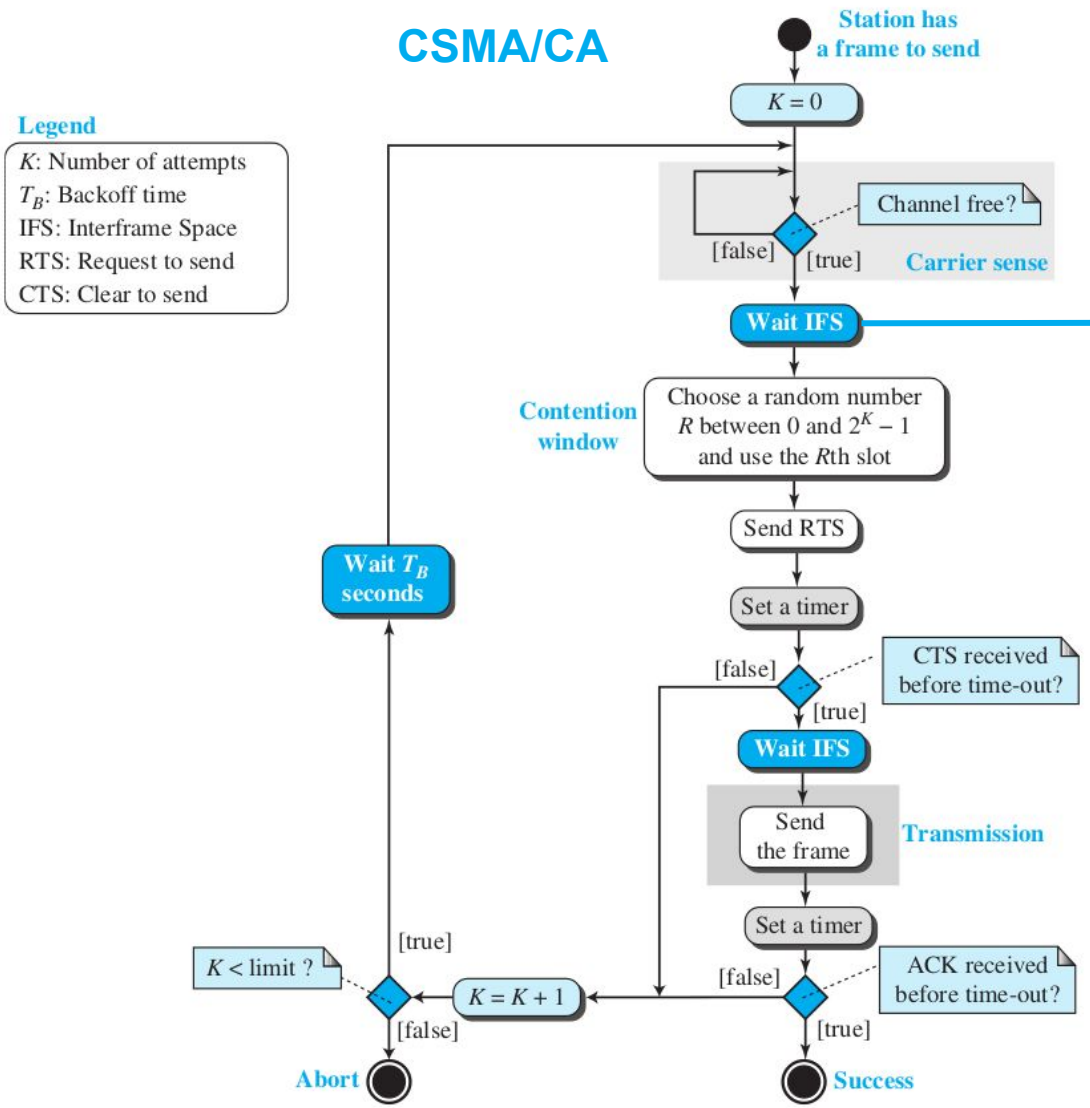
B and C cannot see each other:
- B transmits to A
- C detects a free medium and also sends to A

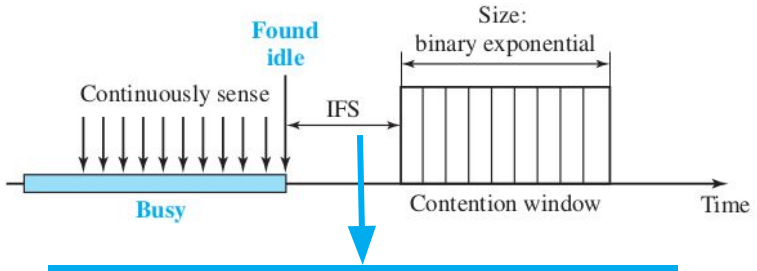
MAC in WLAN 802.11

- Distributed Coordination Function (DCF)
  - The decision of who can send is distributed across all the nodes that want to send
  - It is based on the CSMA with Collision Avoidance (CSMA/CA) protocol
  - Can be used with or without infrastructure
- Punctual Coordination Function (PCF)
  - The decision on who can send is controlled by the AP
  - Only for networks with infrastructure (AP)

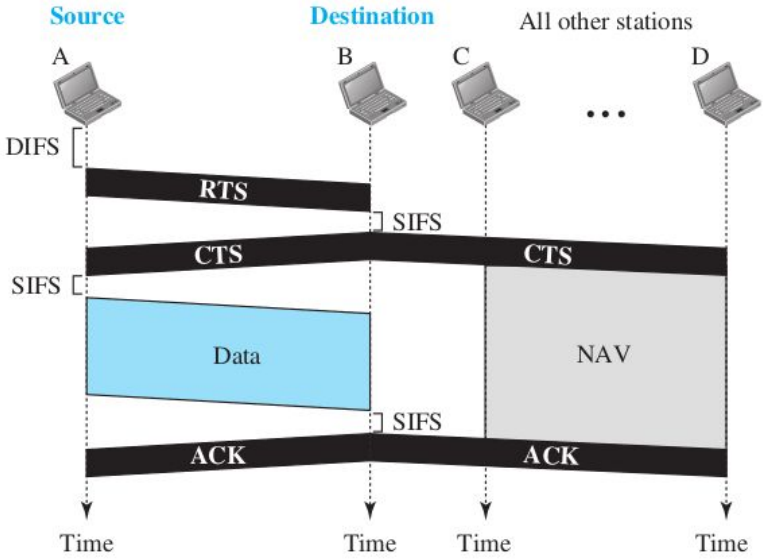
Distributed Coordination function (DCF)

CSMA/CA



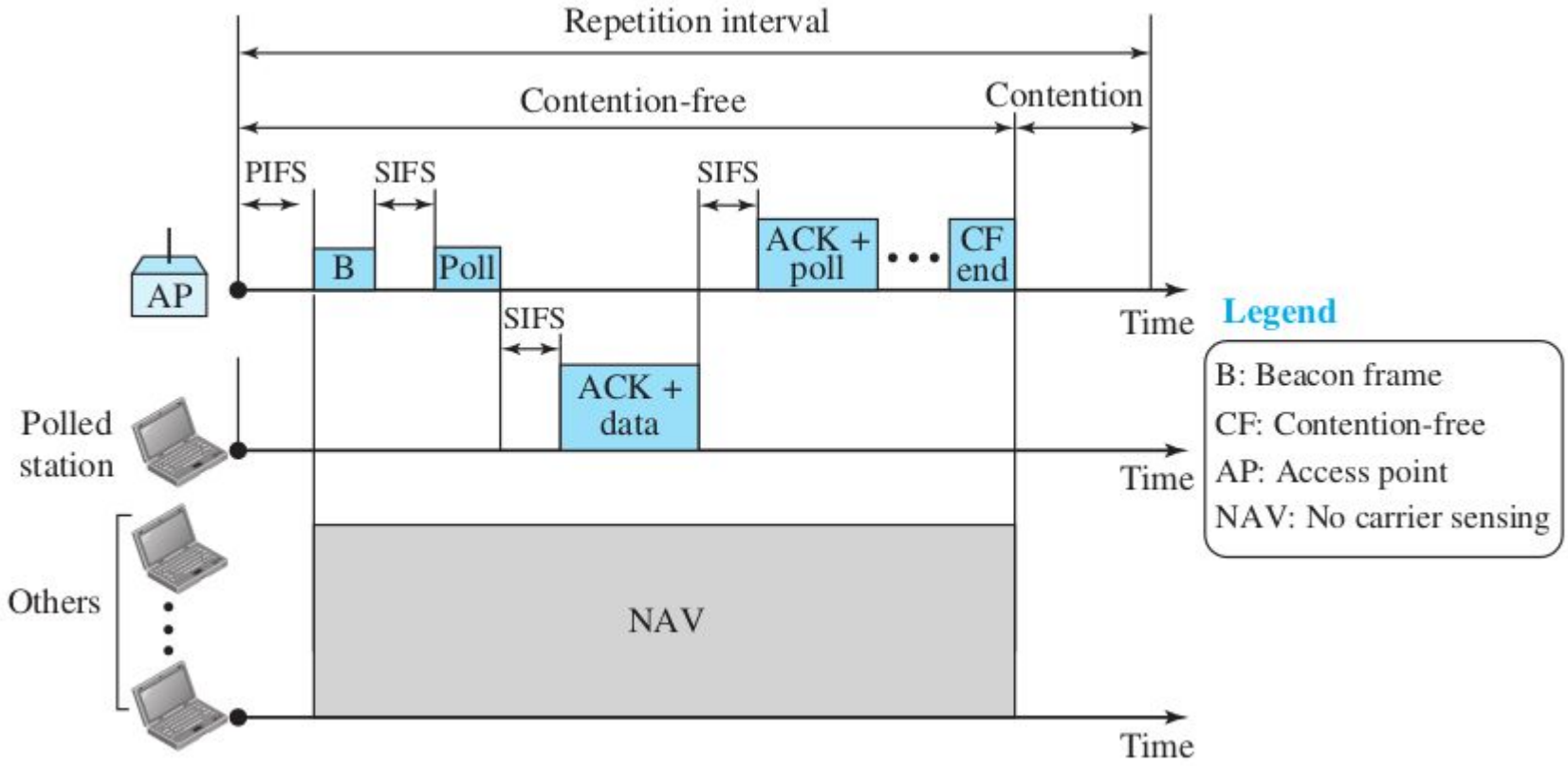


SIFS (short inter-frame spacing)
PIFS (PCF inter-frame spacing)
DIFS (DCF inter-frame spacing)

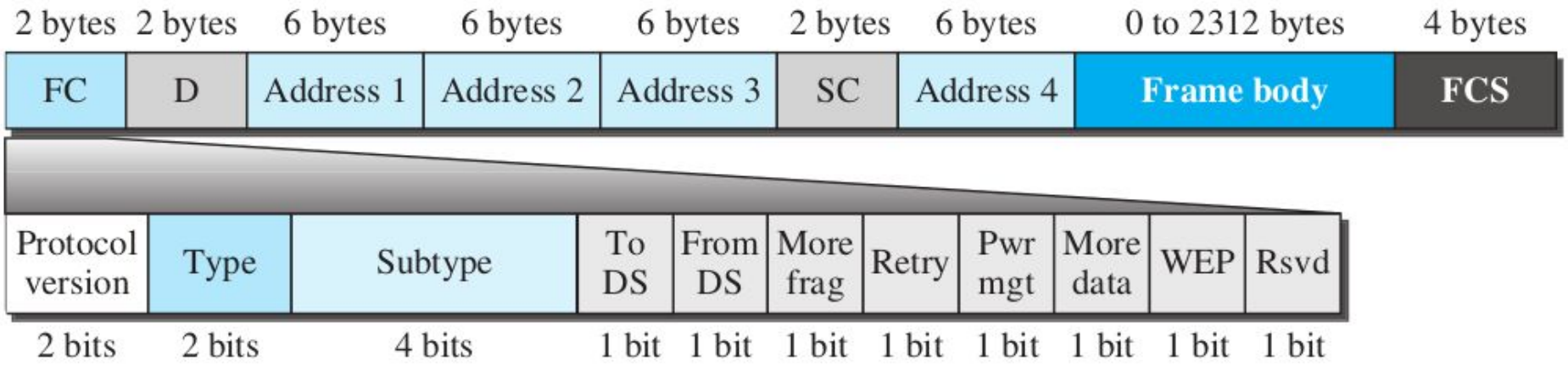


RTS: Request To Send (petición para enviar)
CTS: Clear To Send (permiso para enviar)
NAV: Network Allocation Vector

Point Coordination Function (PCF)



802.11 Frame format

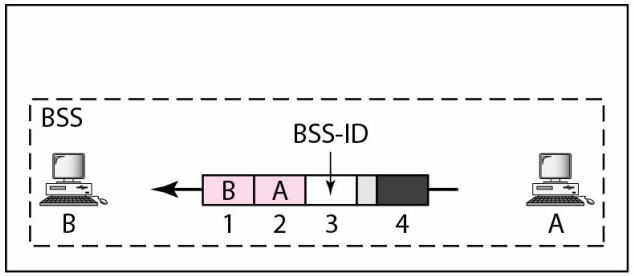


- Frame types
  - Management Frames (00) (e.g. AP association request)
  - Control Frames (01) (e.g. RTS, CTS y ACK)
  - Data Frames (10)
- Subtype:
  - e.g.: RTS (=1011), CTS (=1100) o ACK (=1001)
- D: Duration in μs that the medium will be occupied
  - Used to compute the NAV
- SC: identification (4 bits fragment and 12 seq number)

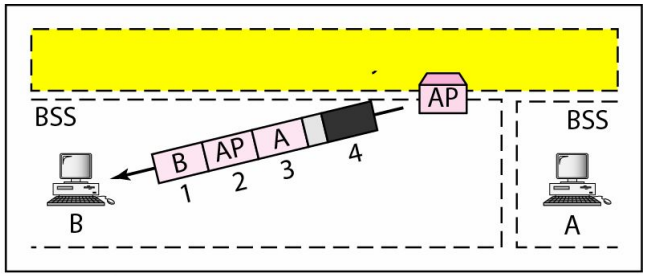
802.11 frame addressing

To DS	From DS	Add 1	Add 2	Add 3	Add 4
0	0	Destination	Source	BSSID	not used
0	1	Destination	emitter AP	Source	not used
1	0	receiver AP	Source	Destination	not used
1	1	receiver AP	emitter AP	Destination	Source

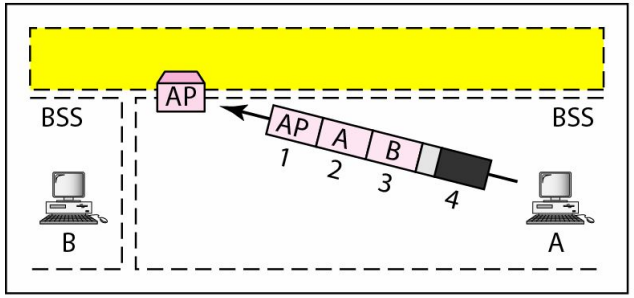
case 1



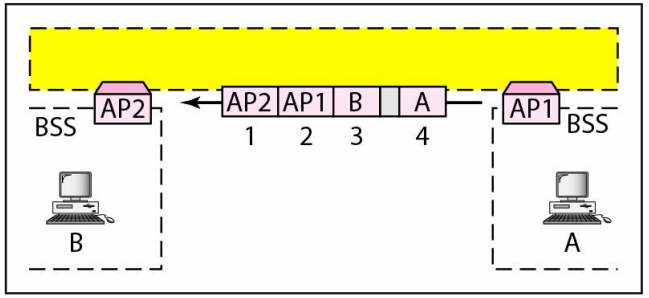
case 2



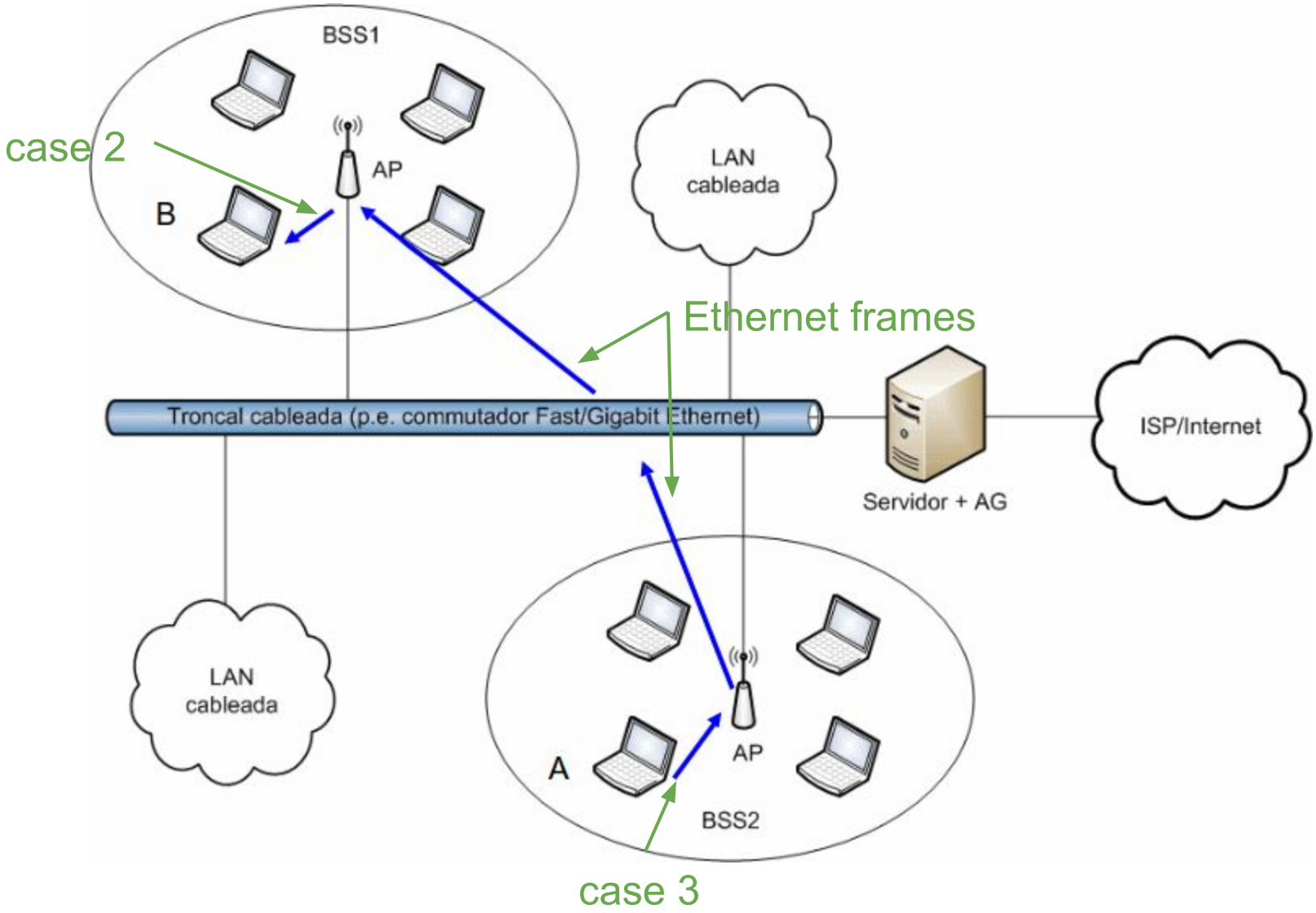
case 3



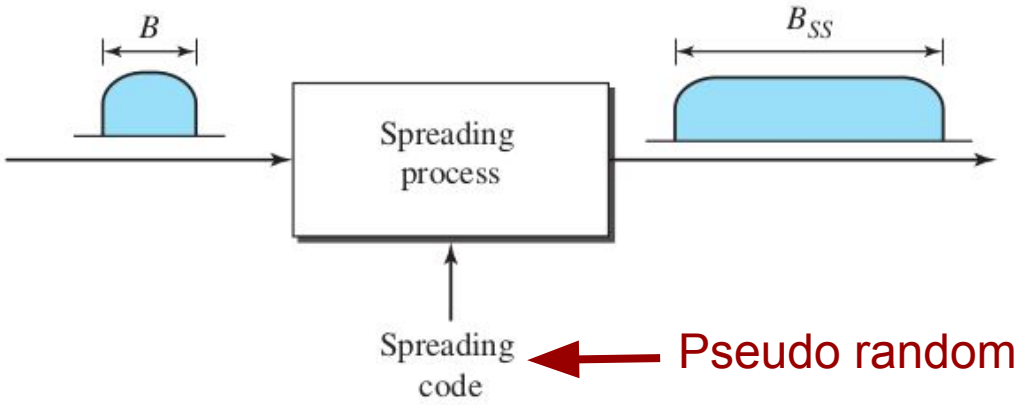
case 4



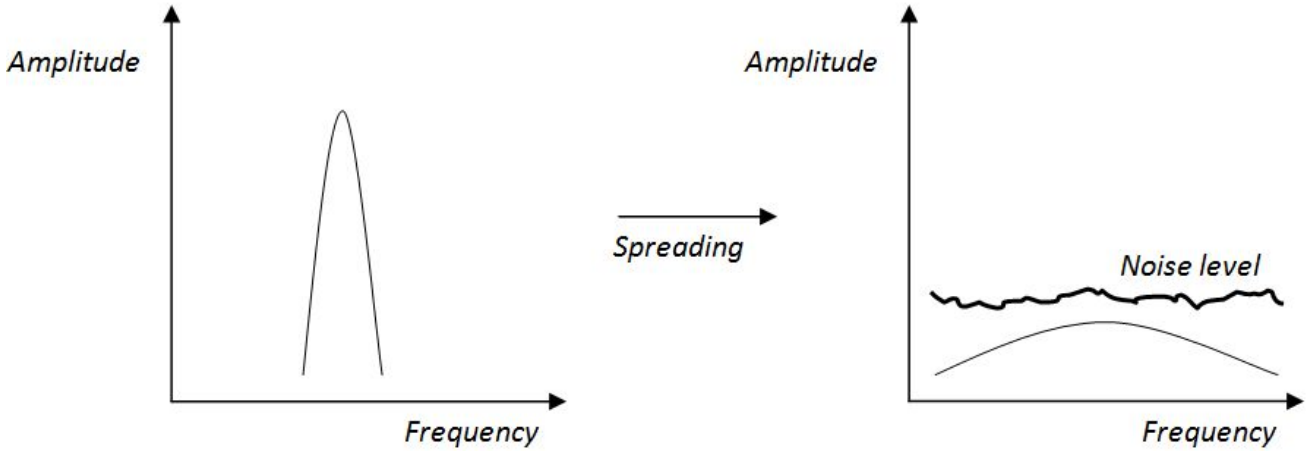
802.11 Frame addressing



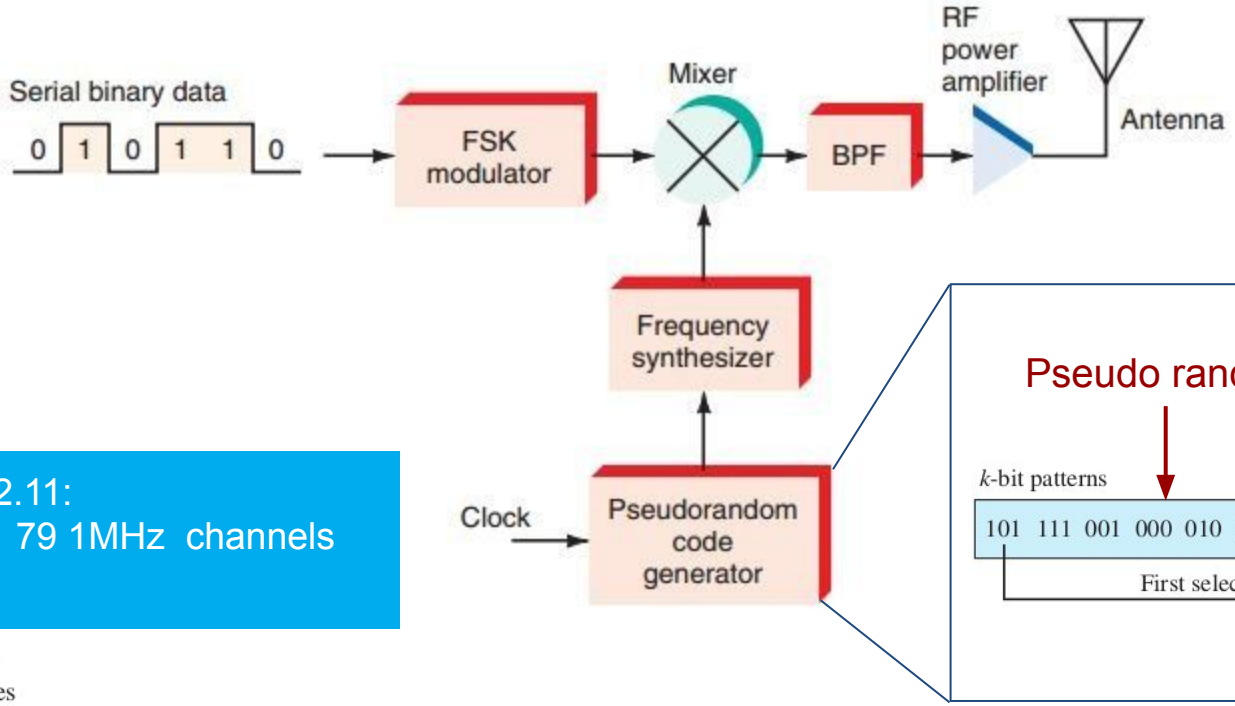
Transmission techniques: Spread Spectrum (SS)



- Less susceptibility to interference
- Greater security, harder for an intruder to decode the signal
  - Can be similar to noise
  - Kind of encryption at the phy level

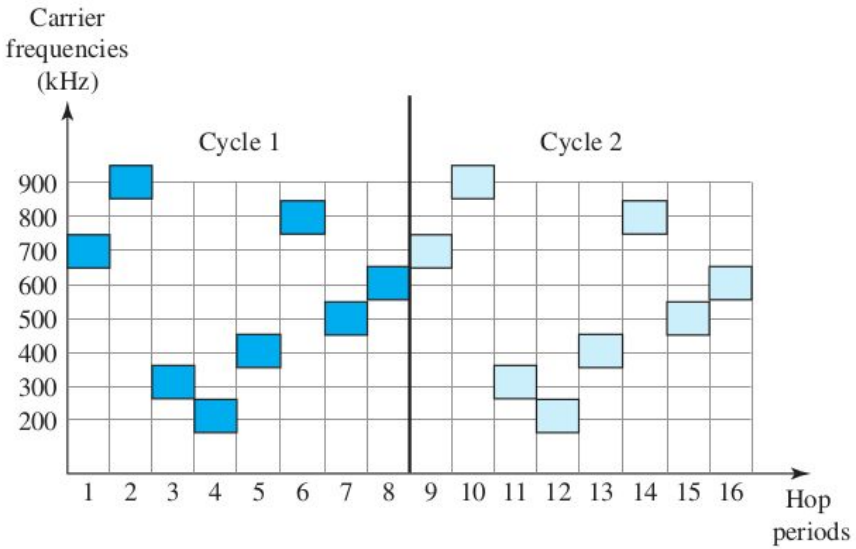


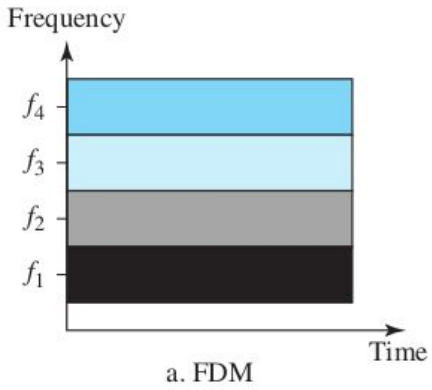
Frequency Hopping SS (FHSS)

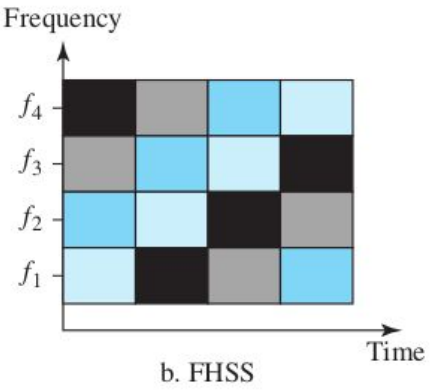


In 802.11:

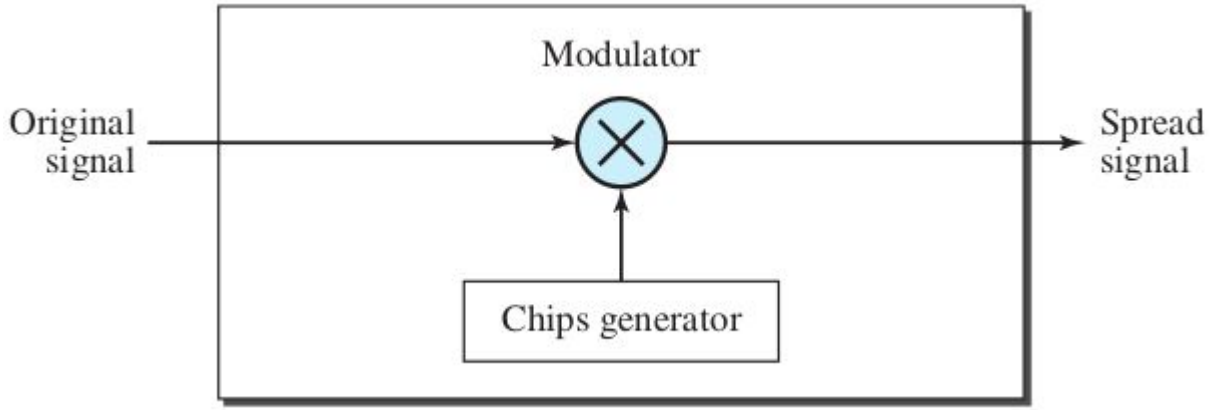
- 79 1MHz channels

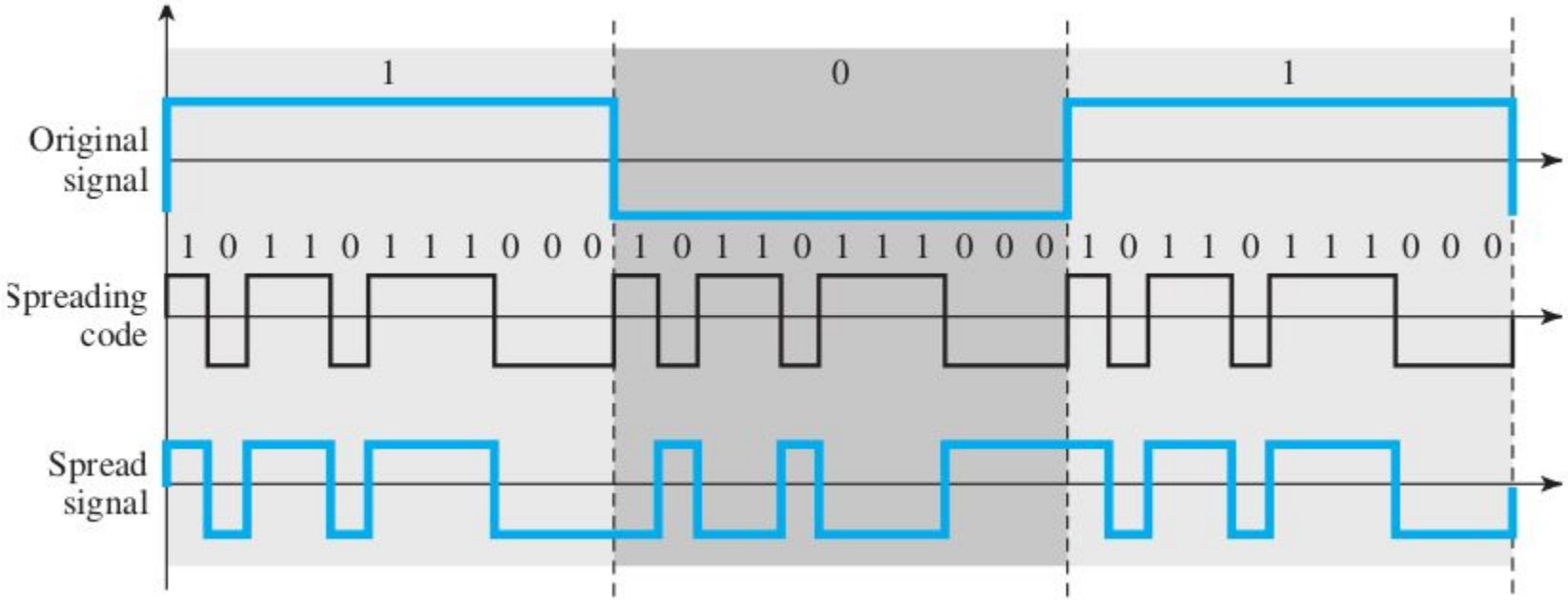




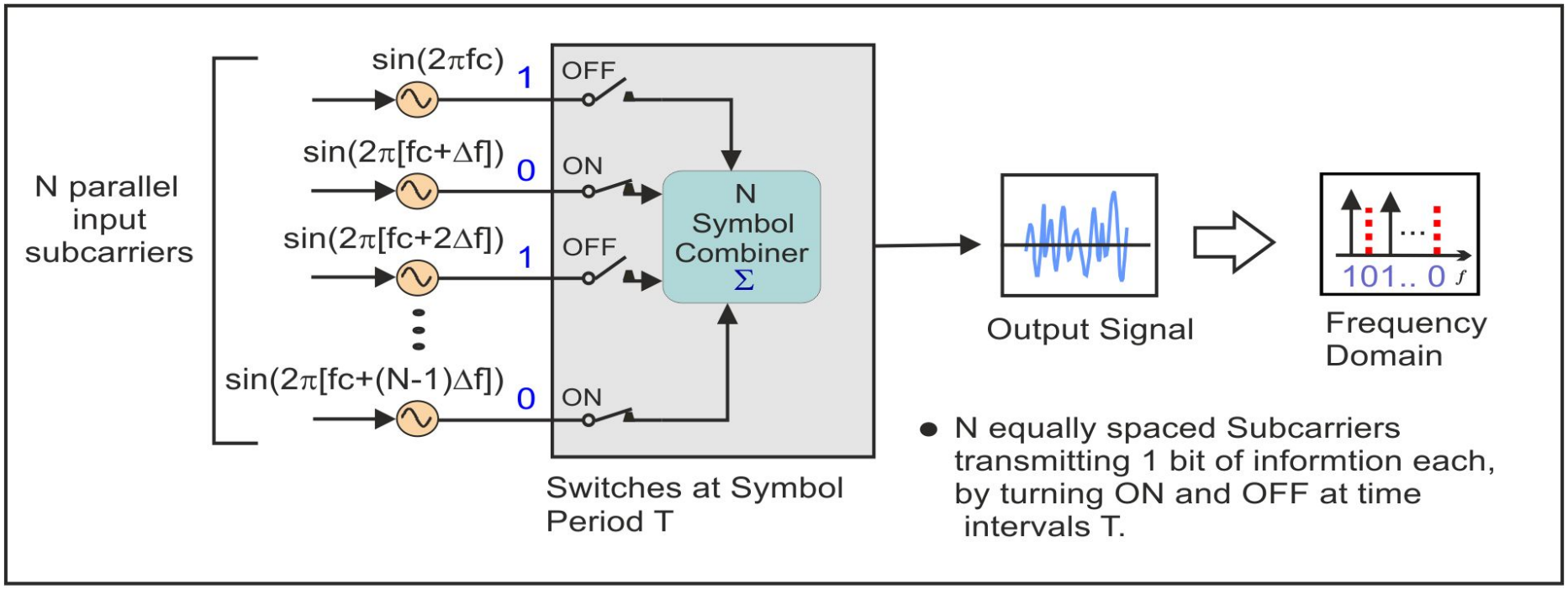


Direct Sequence SS (DSSS)



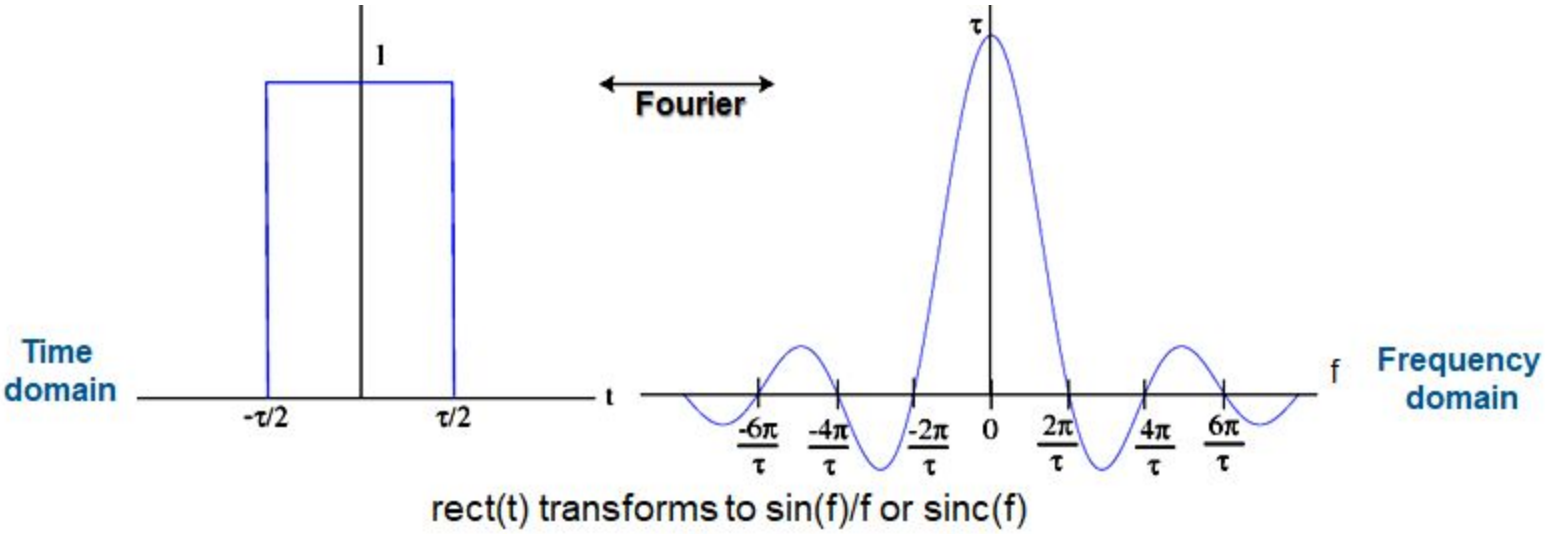


Orthogonal FDM (OFDM) - time domain -

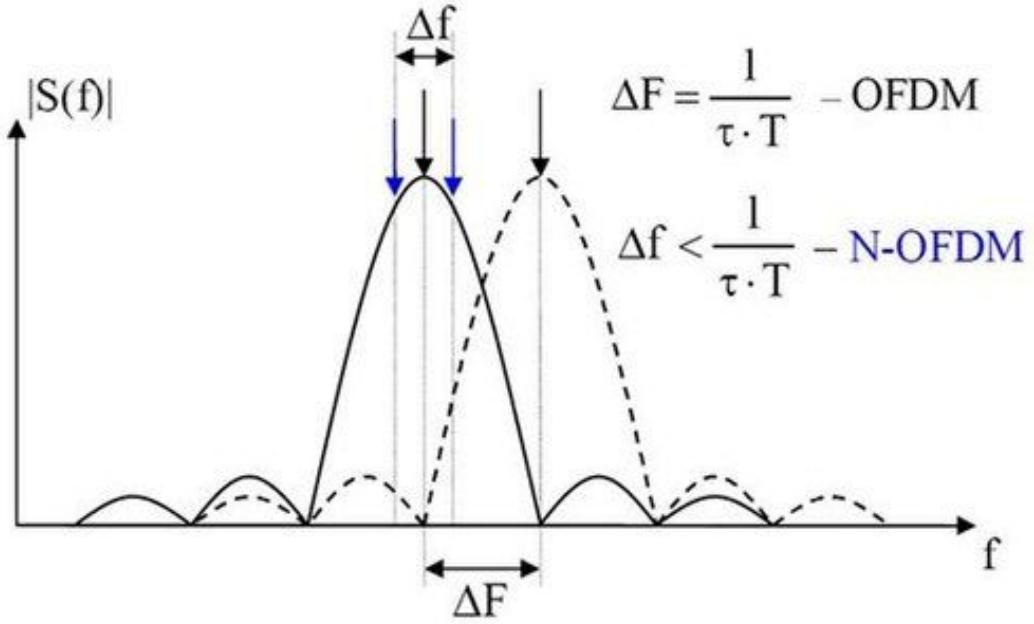


Simple OFDM Generation

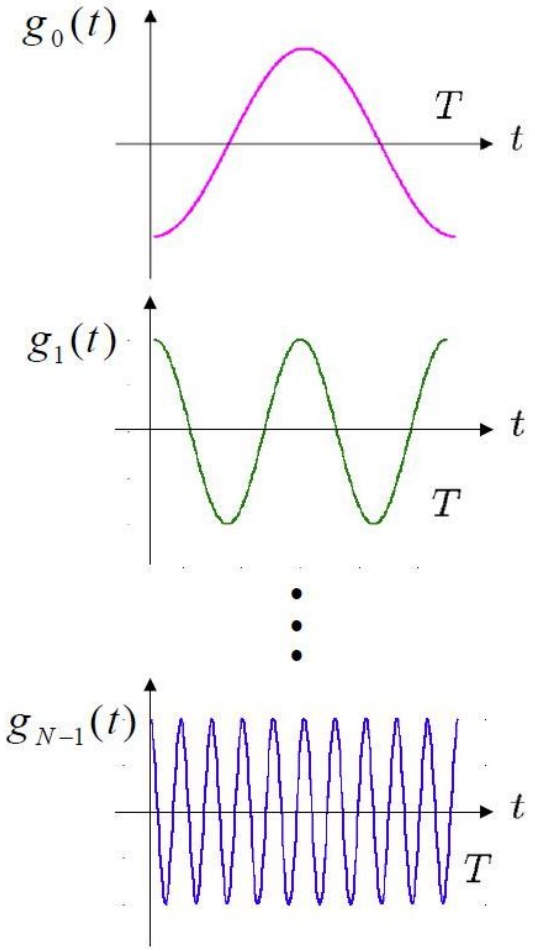
Orthogonal FDM (OFDM) - freq. domain -

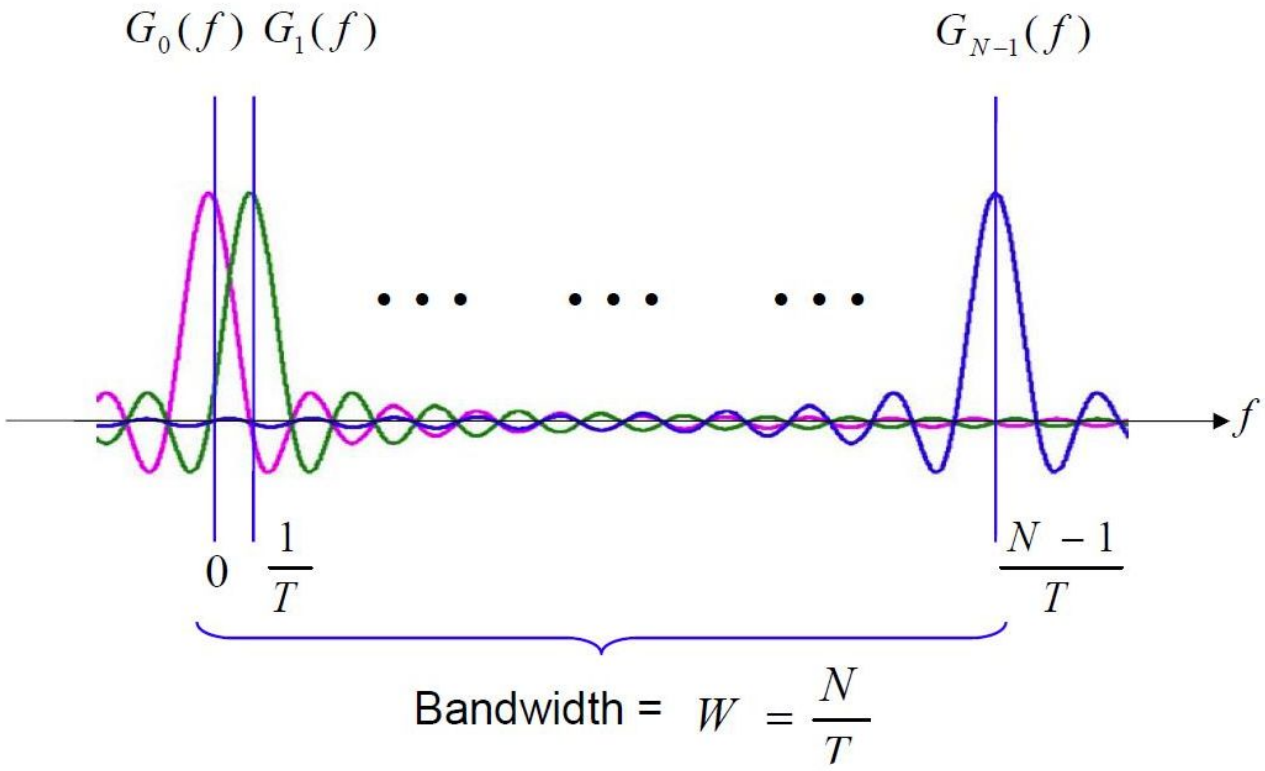


rect(t) transforms to sin(f)/f or sinc(f)

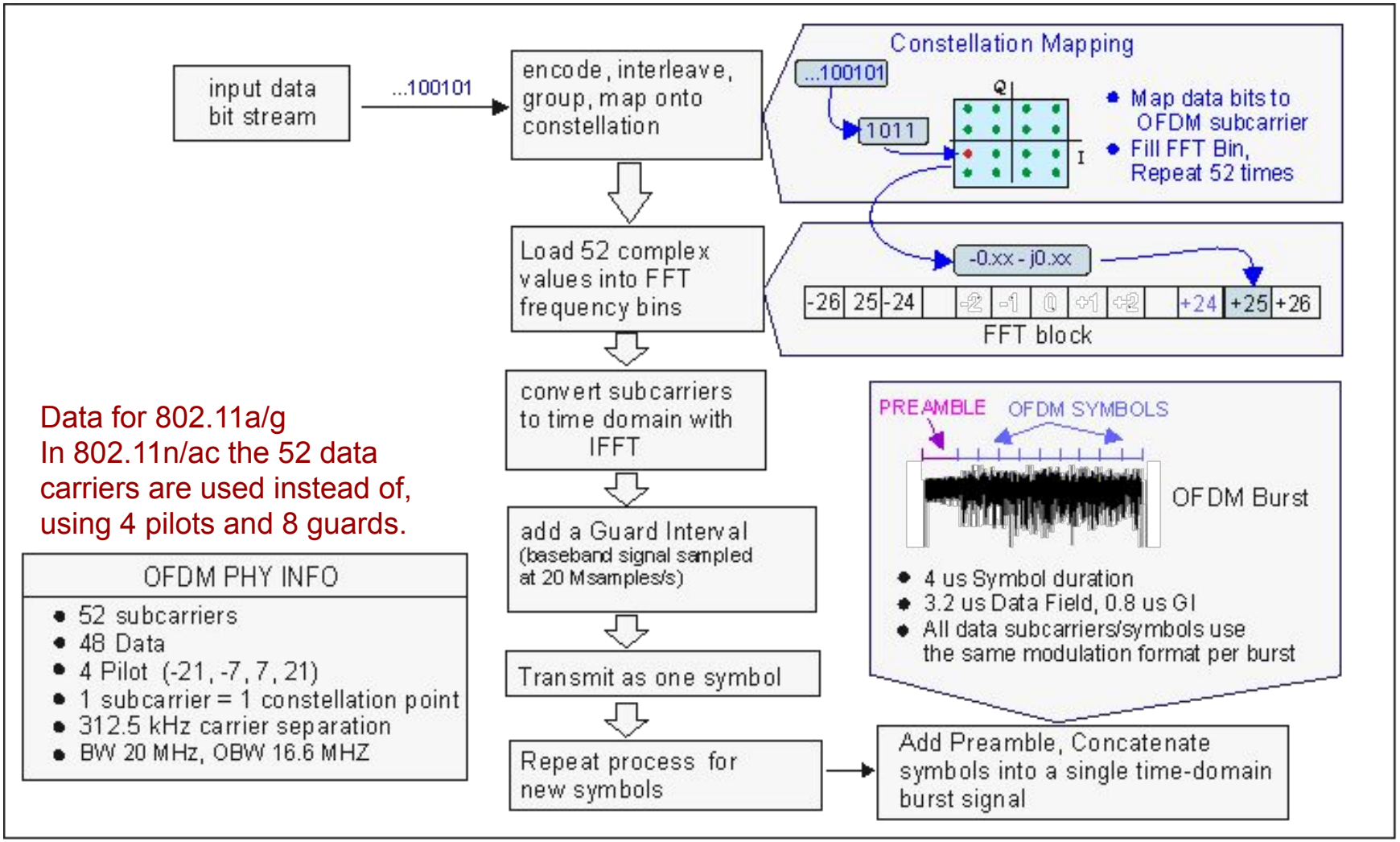


Orthogonal FDM (OFDM) - freq. domain -





OFDM symbol



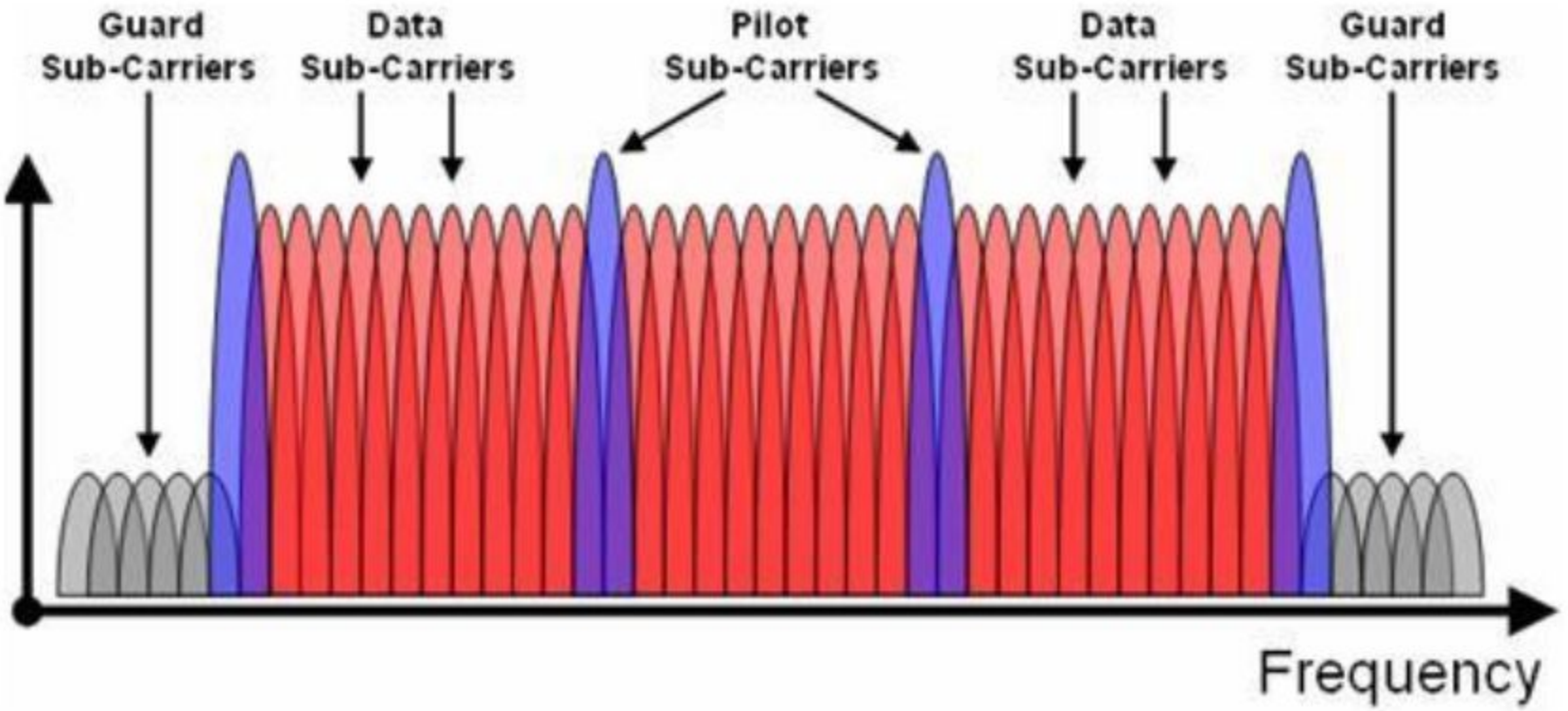
Data for 802.11a/g
In 802.11n/ac the 52 data carriers are used instead of, using 4 pilots and 8 guards.

OFDM PHY INFO

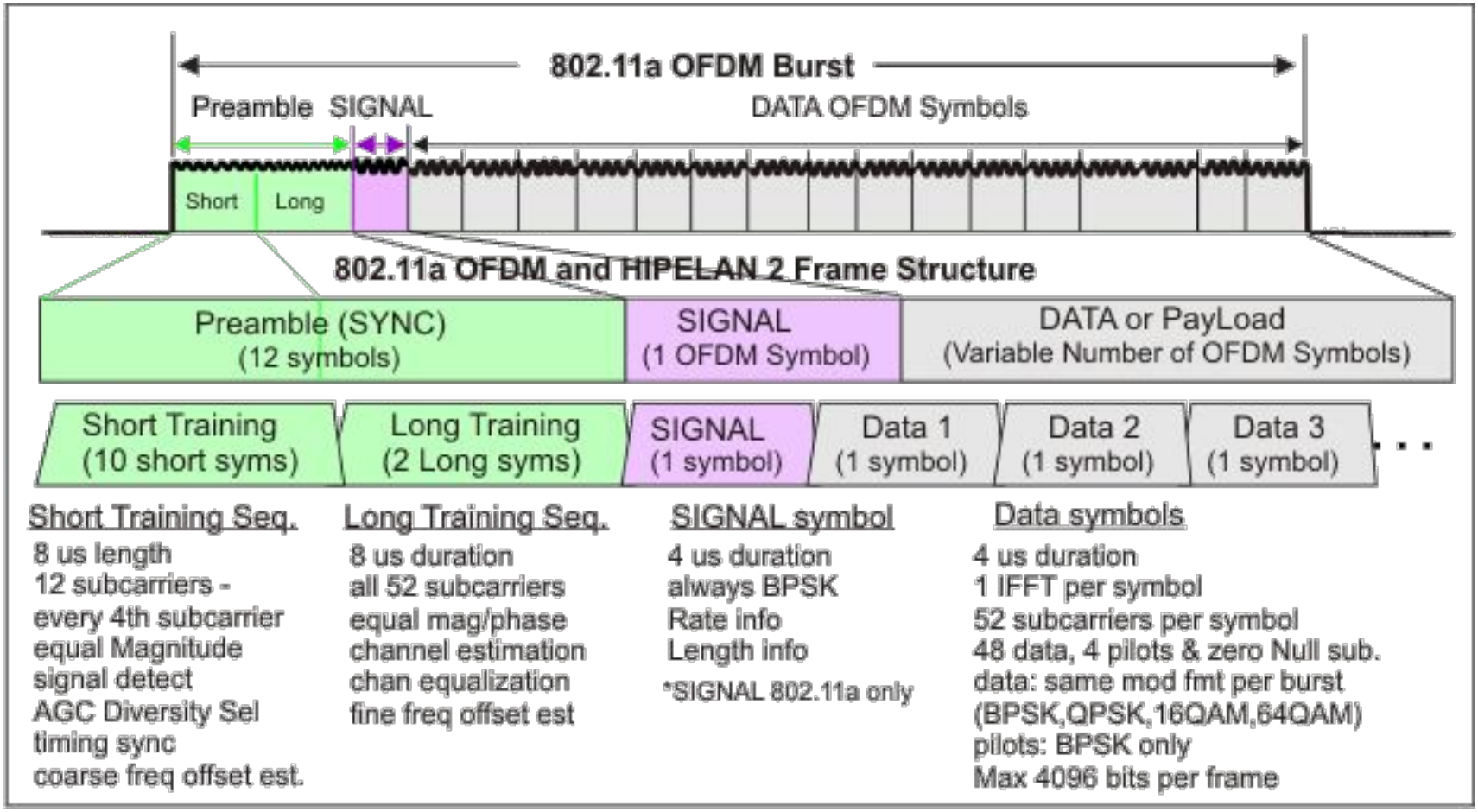
- 52 subcarriers
- 48 Data
- 4 Pilot (-21, -7, 7, 21)
- 1 subcarrier = 1 constellation point
- 312.5 kHz carrier separation
- BW 20 MHz, OBW 16.6 MHZ

802.11a OFDM Signal Generation Process

OFMD: subcarriers, pilots y guards

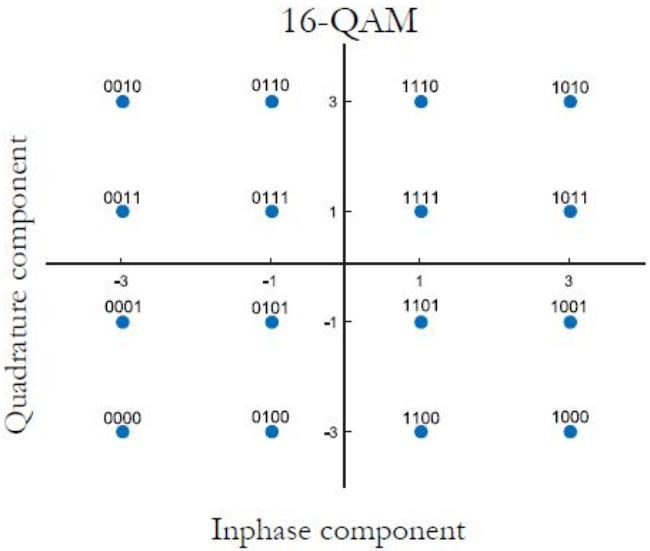


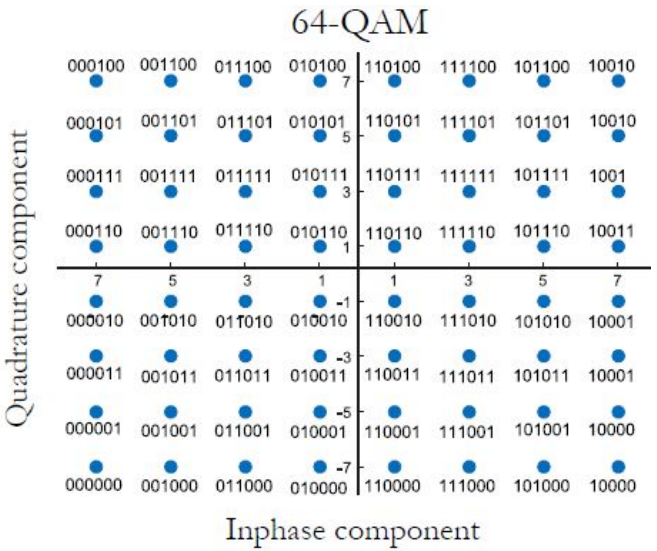
802.11a frame

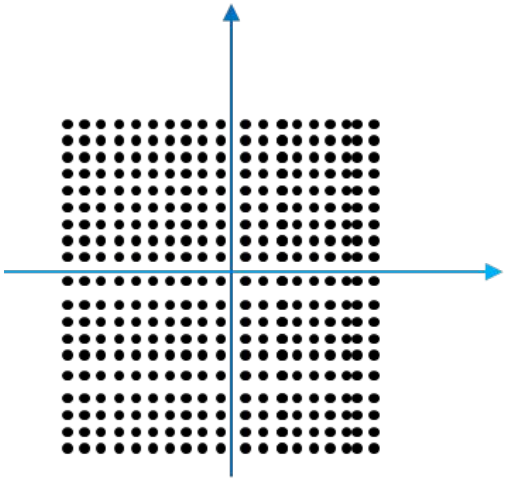


802.11a and HIPERLAN/2 Frame Structure

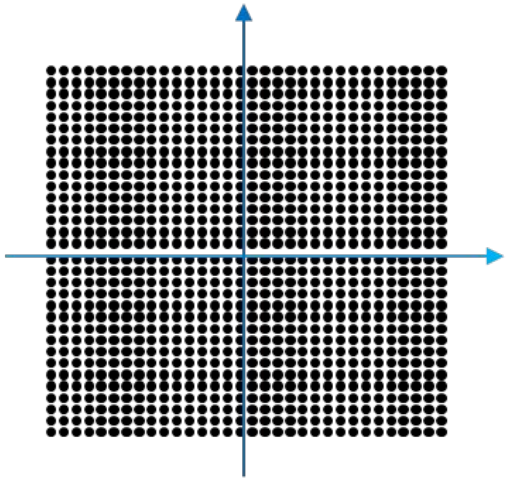
Modulation schemes





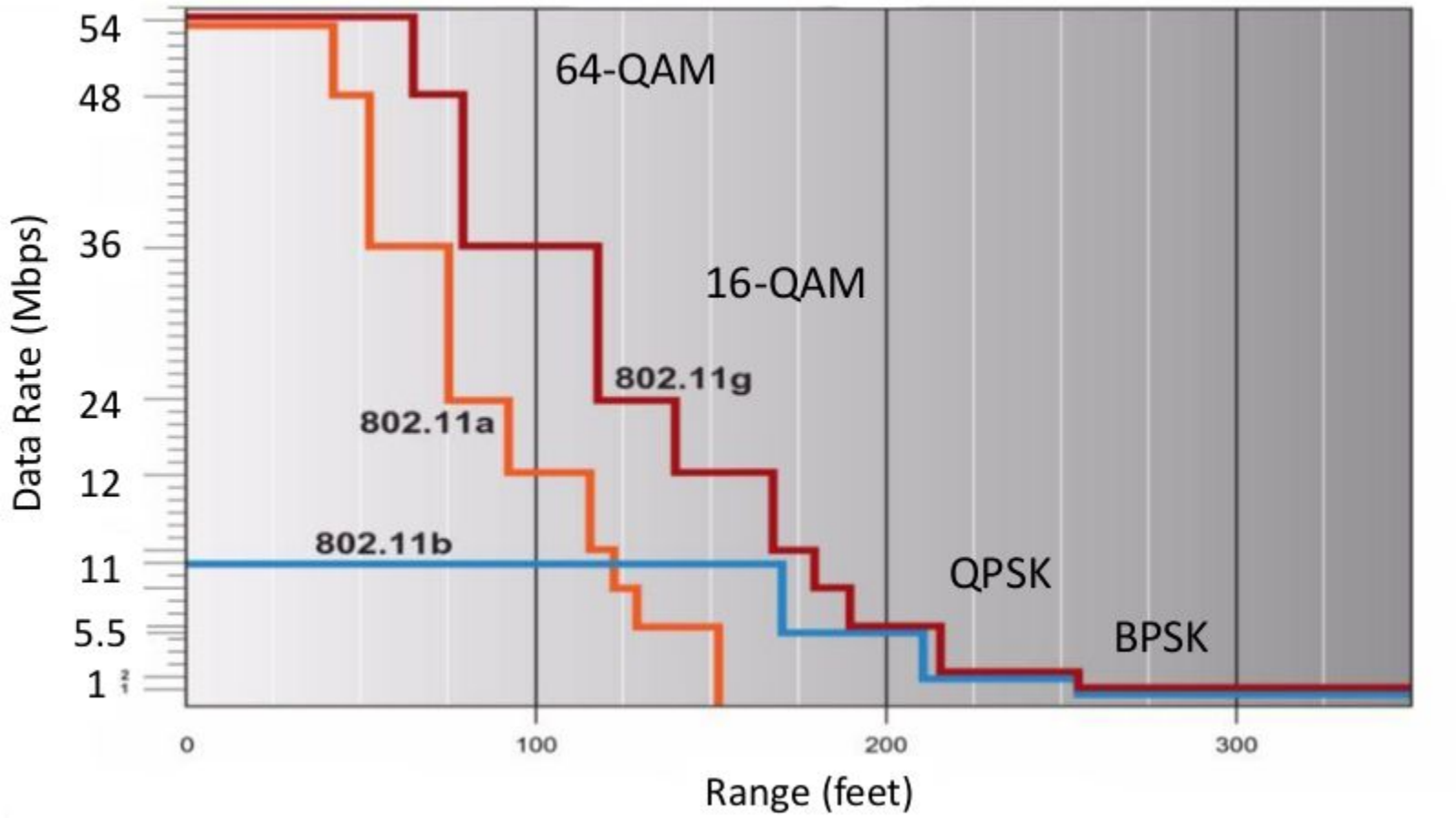


802.11ac
256-QAM



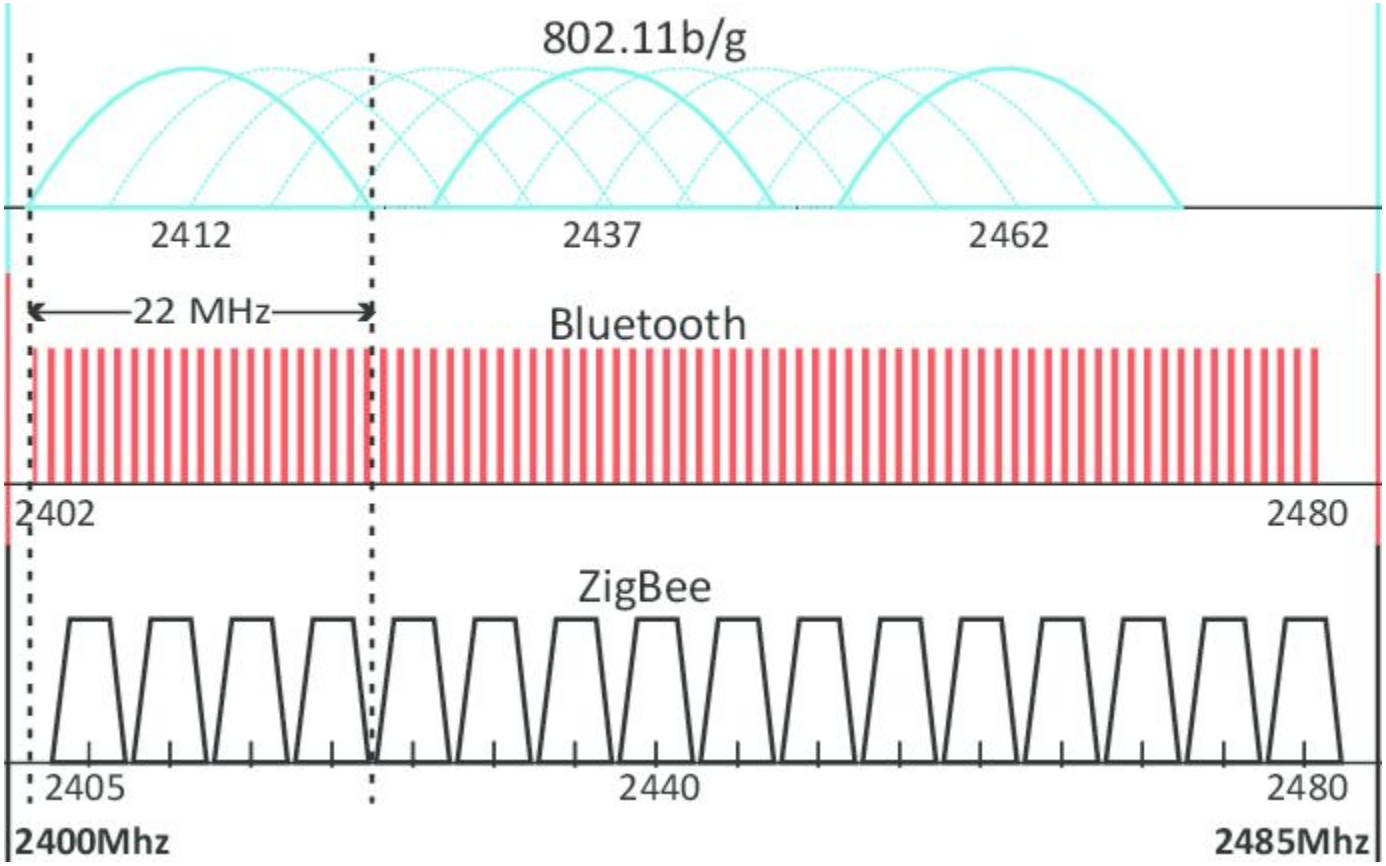
802.11ax
1024-QAM

802.11a/b/g range vs data rate

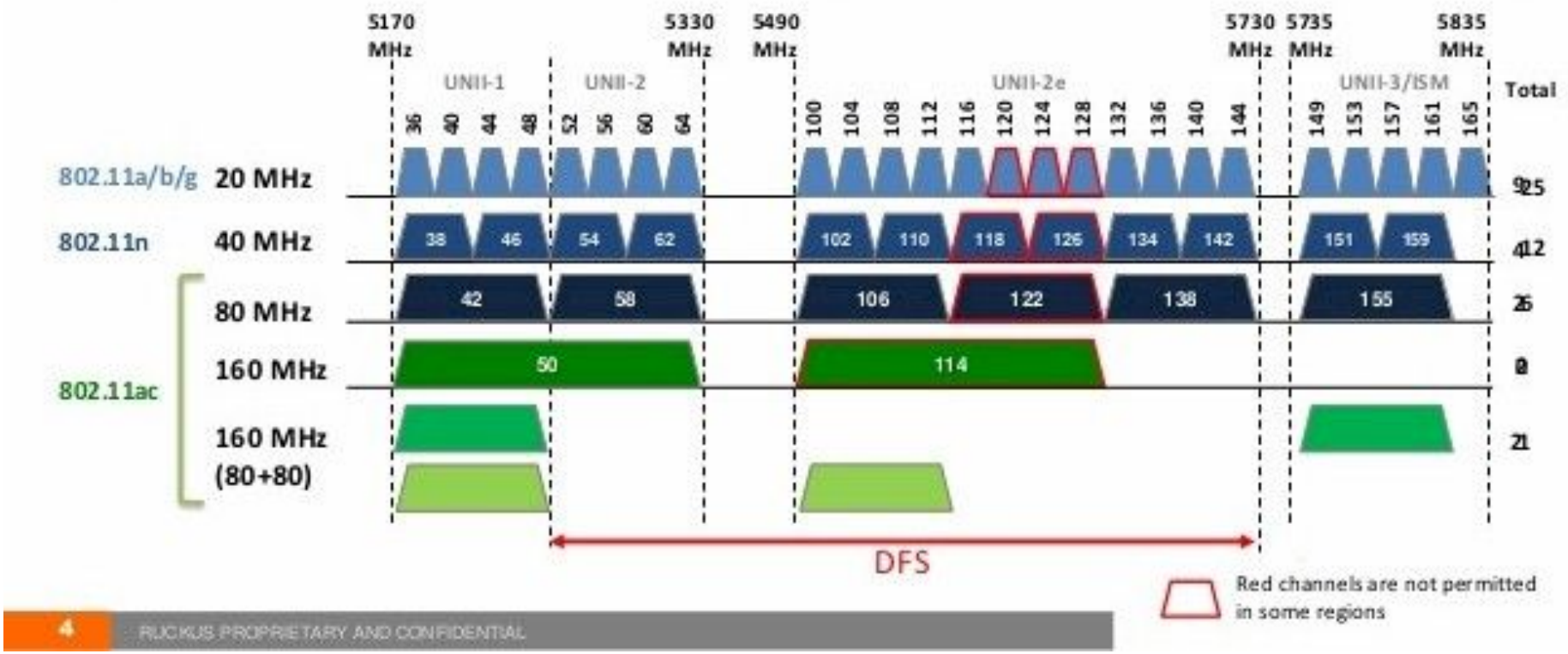


As the distance to the AP increases the achievable data rate is reduced (lower SNR at larger distances -> larger symbol separation)

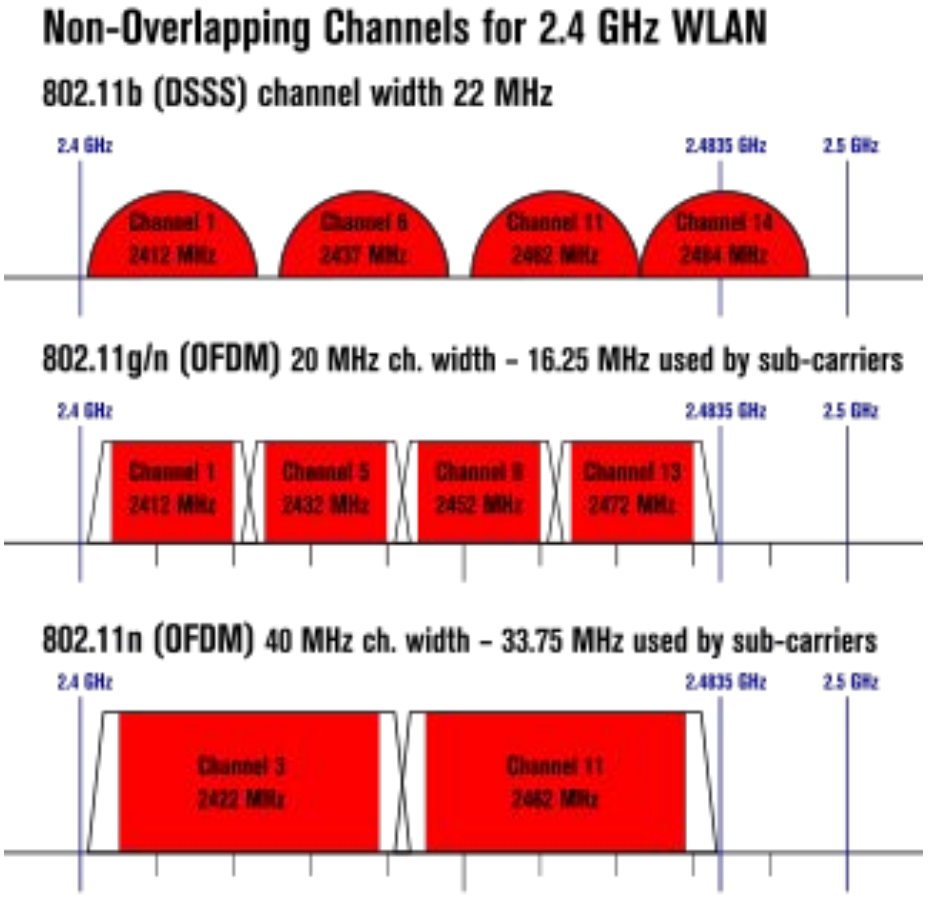
2.4GHz is a disputed band



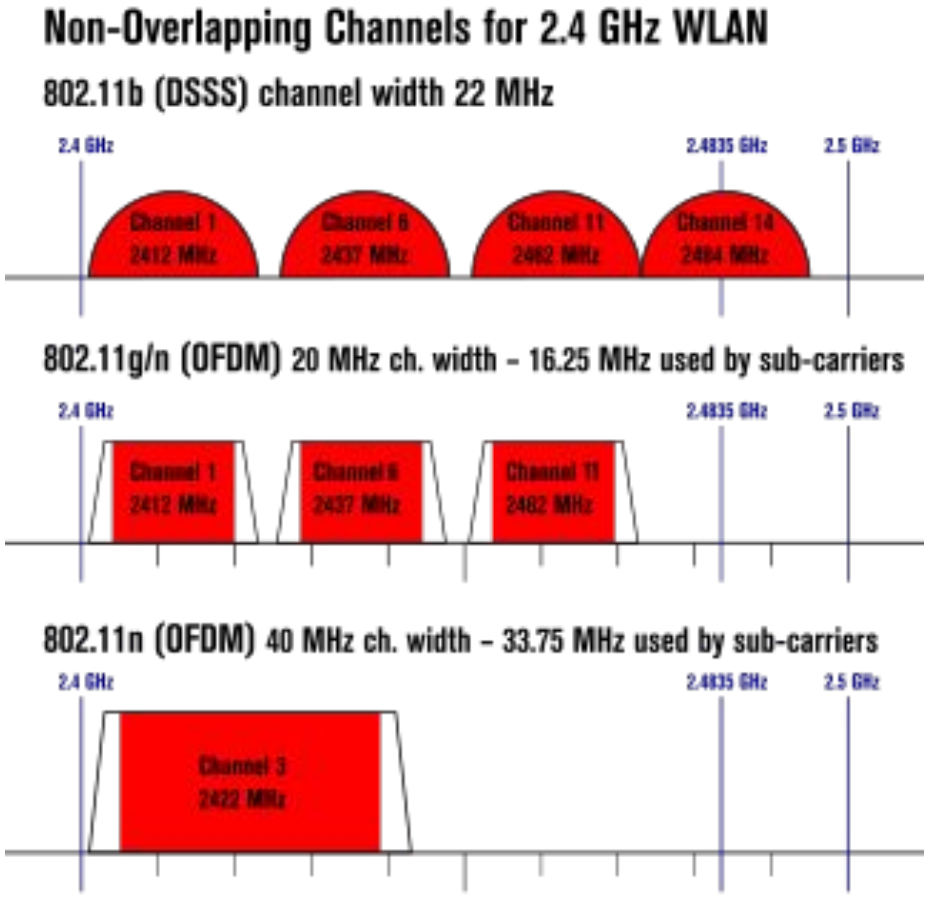
More channels available in 5G band



Non overlapping channels in 2.4 G band



Europa



USA

802.11 PHY

	802.11 (Legacy)	802.11b (Legacy)	802.11a (Legacy)	802.11g (Legacy)	802.11n (HT)	802.11ac (VHT)	802.11ax (HE)
Year Ratified	1997	1999	1999	2003	2009	2014	2019 (Expected)
Operating Band	2.4 GHz/IR	2.4 GHz	5 GHz	2.4 GHz	2.4/5 GHz	5 GHz	2.4/5 GHz
Channel BW	20 MHz	20 MHz	20 MHz	20 MHz	20/40 MHz	20/40/80/160 MHz	20/40/80/160 MHz
Peak PHY Rate	2 Mbps	11 Mbps	54 Mbps	54 Mbps	600 Mbps	6.8 Gbps	10 Gbps
Link Spectral Efficiency	0.1 bps/Hz	0.55 bps/Hz	2.7 bps/Hz	2.7 bps/Hz	15 bps/Hz	42.5 bps/Hz	62.5 bps/Hz
Max # SU Streams	1	1	1	1	4	8	8
Max # MU Streams	NA	NA	NA	NA	NA	4 (DL only)	8 (UL & DL)
Modulation	DSSS, FHSS	DSSS, CCK	OFDM	OFDM	OFDM	OFDM	OFDM, OFDMA
Max Constellation / Code Rate	DQPSK	CCK	64-QAM, 3/4	64-QAM, 3/4	64-QAM, 5/6	256-QAM, 5/6	1024-QAM, 5/6
Max # OFDM tones	NA	NA	64	64	128	512	2048
Subcarrier Spacing	NA	NA	312.5 kHz	312.5 kHz	312.5 kHz	312.5 kHz	78.125 kHz

- 802.11a/g/n/ac: 64 subcarriers, with a separation of 312.5KHz
  - 802.11a/g: 48 data subcarriers, 4 pilots and 12 guards
  - 802.11n/ac: 52 data subcarriers, 4 pilots and 8 guards