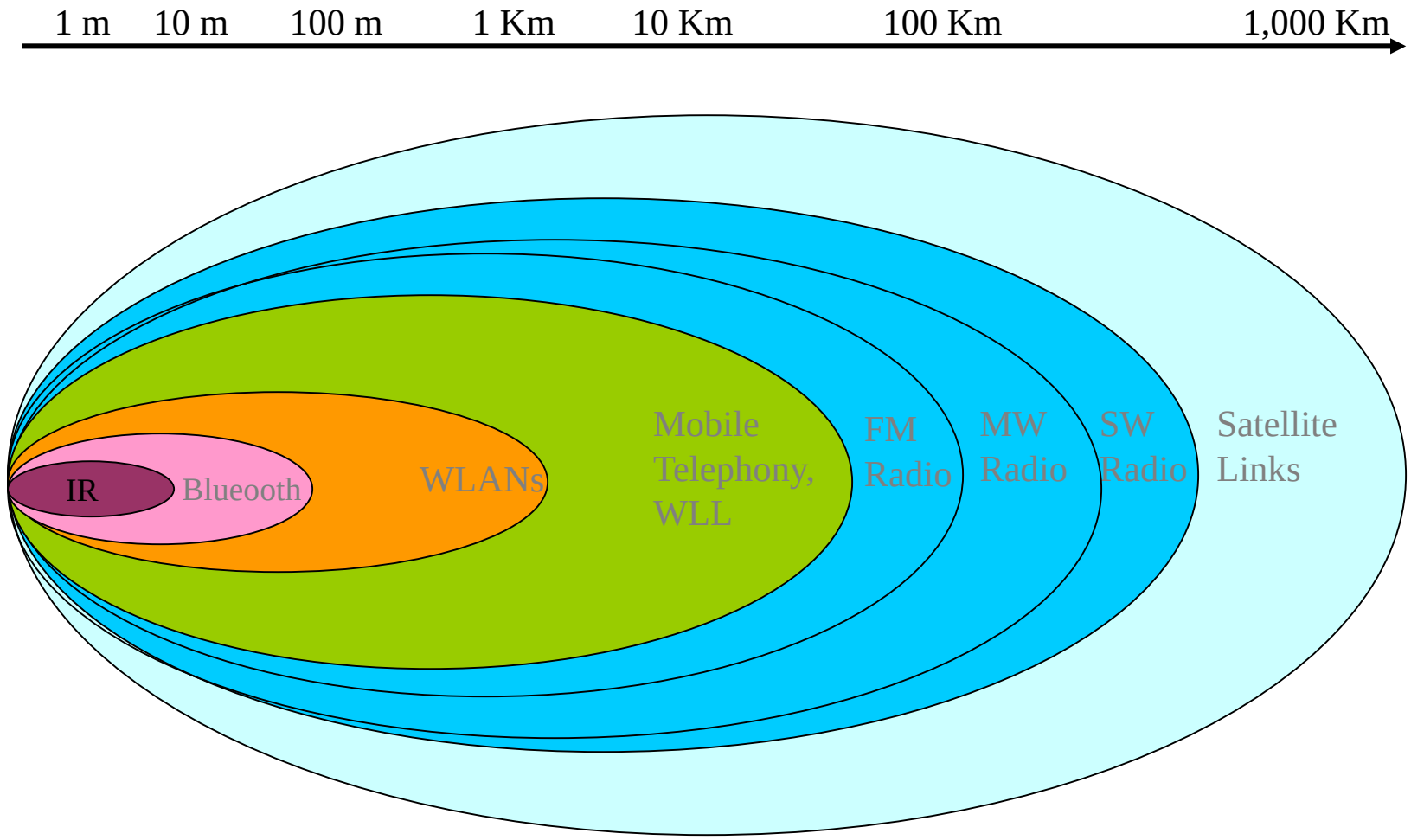
Wireless Communication and Networking

CMPT 371

Wireless Systems:

✓ AM, FM Radio ✓ TV Broadcast ✓ Satellite Broadcast	Broadcast (analog)
✓ 2-way Radios ✓ Cordless Phones	2-way communication (analog)
✓ Satellite Links ✓ Mobile Telephony Systems ✓ Wireless Local Loop (WLL) ✓ Microwave Links ✓ Wireless LANs ✓ Infrared LANs	2-way communication (digital)

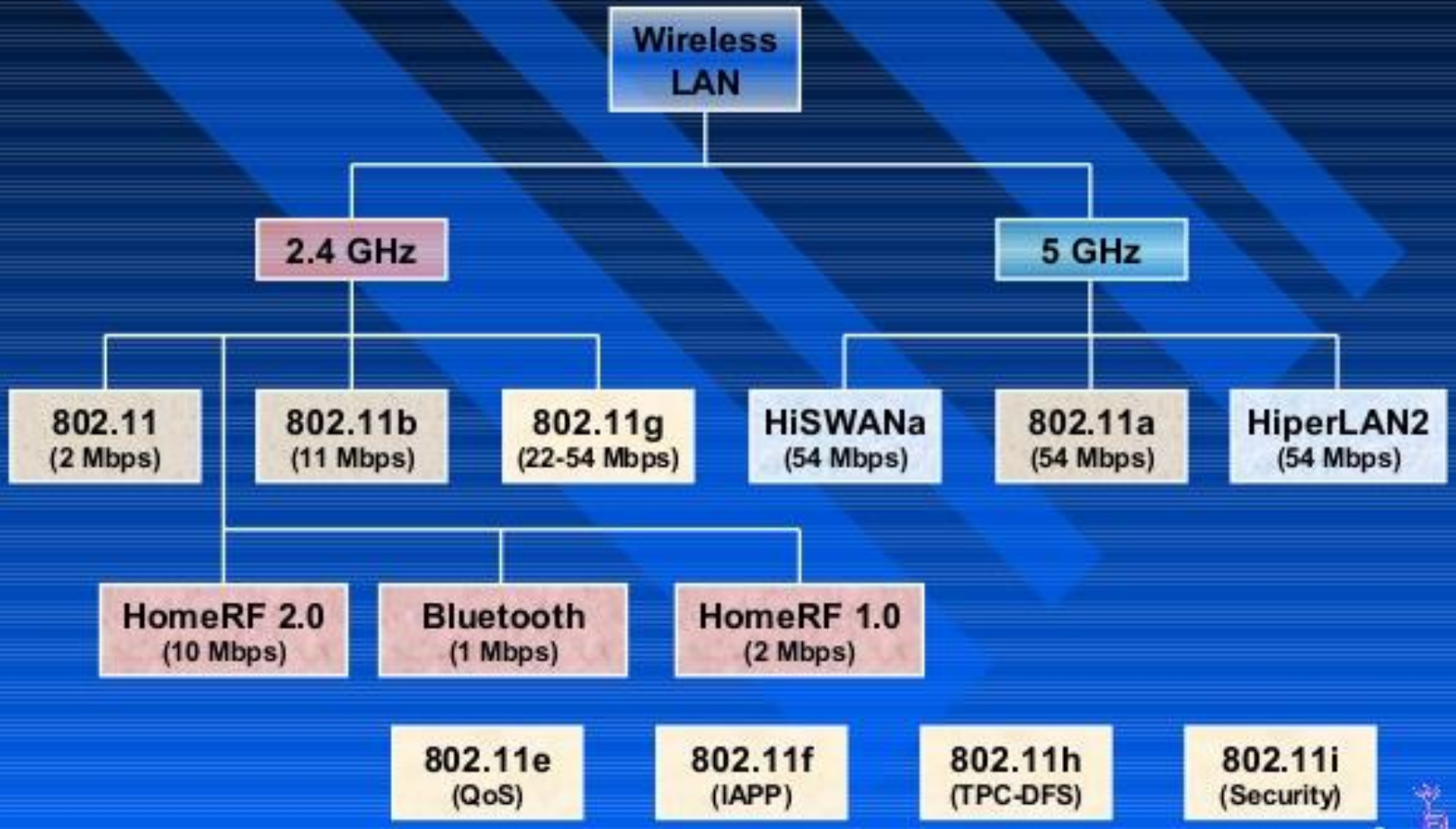
Wireless Systems: Range Comparison



1G to 5G - Overview

Feature	1G	2G	3G	4G	5G
Deployment	1980	1990	2001	2010	2020 or beyond (www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-2020/Pages/default.aspx)
Frequency band	800 MHz	900 MHz	2,100 MHz	2,600 MHz	3–90 GHz[15]
Speed	2 Kbps	64 Kbps	2 Mbps	1 Gbps	Higher than 1 Gbps
Technology	Analogue cellular	Digital cellular	Code division multiple access, Universal Mobile Telecommunications System	Long-Term Evolution Advanced, Wi-Fi	Multi-radio access technology, Wi-Fi, Wi-Gig[16]
Services	Voice	Digital voice, SMS, packet (General Packet Radio Service), low-rate data	Higher quality audio and video calls, mobile broadband	High data rate, wearable devices	Very high data rate[13] to fulfill extreme user demands, device-to-device, machine-to-machine, Internet of Things
Multiplexing	Frequency division multiple access	Time division multiple access	Code division multiple access	Orthogonal frequency-division multiple access	Orthogonal frequency-division multiplexing, filter bank multicarrier, nonorthogonal multiple access[14]
Handover	No	Horizontal	Horizontal	Horizontal/vertical	Horizontal/vertical
Switching	Circuit	Circuit/packet	Packet	All packet	All packet[17]
Core network	Public switched telephone network	Public switched telephone network	Packet network	Internet	Internet

WLAN Standards



IEEE 802.11 Standard

	Standard approved	Bandwidth	Frequency	non over lapping channel	data rate (Mb/s)	Range	Modulation
802.11	1997	83.5 MHz	2.4-2.4835G	3	1,2	20m	DSSS, FHSS
802.11a	1999	300 MHz	5.15-5.35G 5.725-5.825G	23, 12	6,12,24,36,48, 54	30m	OFDM
802.11 b	1999	83.5 MHz	2.4-2.4835G	3	1, 2, 5.5, 11	35m	DSSS/CCK
802.11 g	2003	83.5 MHz	2.4-2.4835G	3	1, 2, 5.5, 11, 6, 9, 12, 18, 24, 36, 48, 54	100m	OFDM, DSSS/CCK
802.11 n	2009	83.5 MHz	2.4-2.4835G 5 GHz	3	600	300m	Modified OFDM

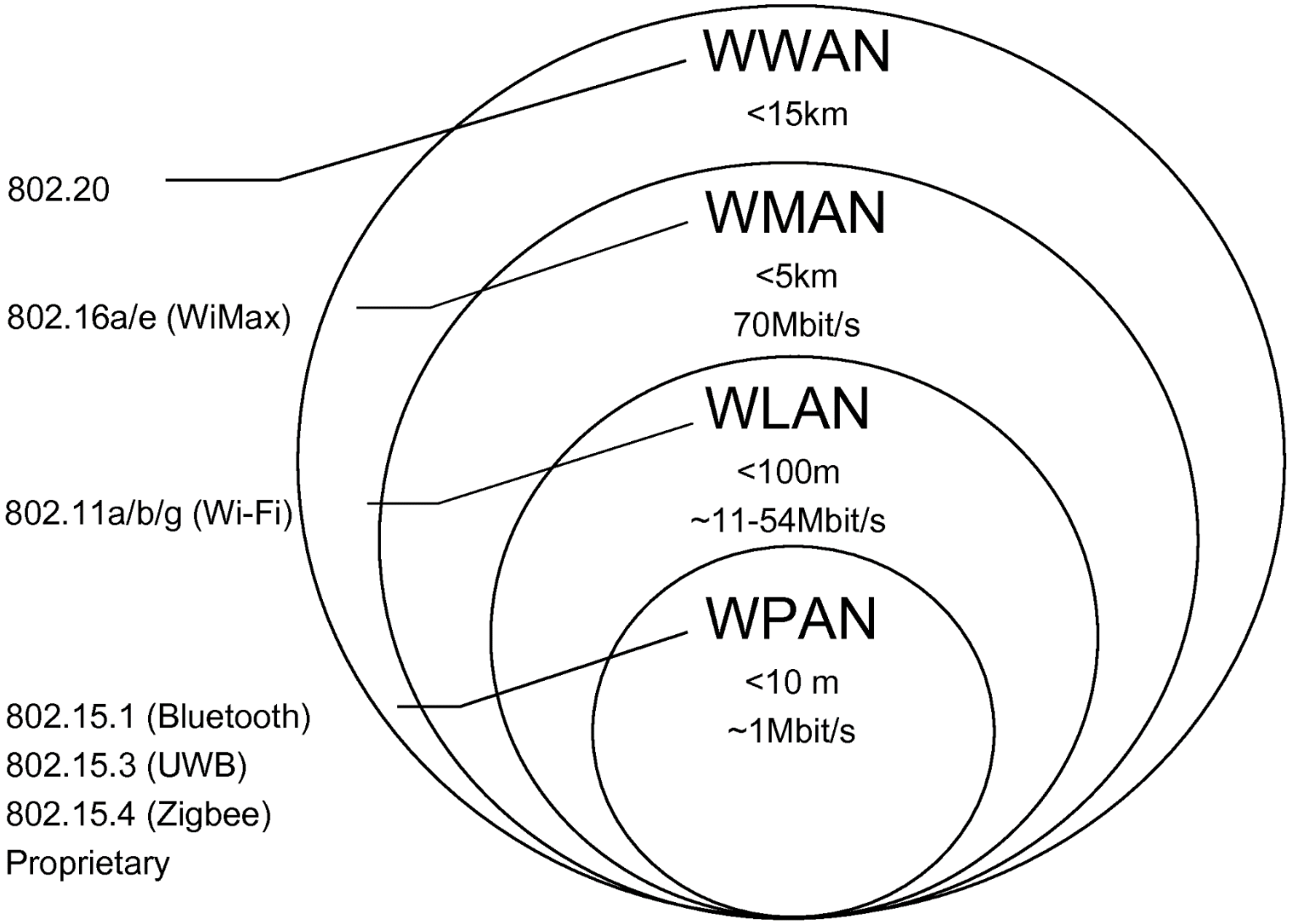
Faster 802.11x Protocols

	802.11n	802.11ac	802.11ad
Throughput	600 Mbps	3.2 Gbps	Up to 7 Gbps
Coverage	Home, 70 m	Home, 30 m	Room, <5m
Freq. Band	2.4/5 GHz	5 GHz	2.4/5/60 GHz
Antennas	4 x 4 MIMO	8 x 8 MIMO	>10 x 10 MIMO
Applications	Data, Video	Video	Uncompressed Video

Communication Channels

802.11 protocol	Release date[1]	Frequency (GHz)	Bandwidth (MHz)	Stream data rate[2] (Mbit/s)	Allowable MIMO streams	Modulation	Approximate range[citation needed] Indoor (m)	Indoor (ft)	Outdoor (m)	Outdoor (ft)
802.11-1997	Jun 1997	2.4	22	1, 2	N/A	DSSS, FHSS	20	66	100	330
a	Sep 1999	5	20	6, 9, 12, 18, 24, 36, 48, 54	N/A	OFDM	35	115	120	390
		3.7[A]					—	—	5,000	16,000[A]
b	Sep 1999	2.4	22	1, 2, 5.5, 11	N/A	DSSS	35	115	140	460
g	Jun 2003	2.4	20	6, 9, 12, 18, 24, 36, 48, 54	N/A	OFDM	38	125	140	460
n	Oct 2009	2.4/5	20	400 ns GI : 7.2, 14.4, 21.7, 28.9, 43.3, 57.8, 65, 72.2 [B] 800 ns GI : 6.5, 13, 19.5, 26, 39, 52, 58.5, 65 [C]	4	MIMO-OFDM	70	230	250	820[3]
			40	400 ns GI : 15, 30, 45, 60, 90, 120, 135, 150 [B] 800 ns GI : 13.5, 27, 40.5, 54, 81, 108, 121.5, 135 [C]			70	230	250	820[3]
ac	Dec 2013	5	20	400 ns GI : 7.2, 14.4, 21.7, 28.9, 43.3, 57.8, 65, 72.2, 86.7, 96.3 [B] 800 ns GI : 6.5, 13, 19.5, 26, 39, 52, 58.5, 65, 78, 86.7 [C]	8		35	115[4]		
			40	400 ns GI : 15, 30, 45, 60, 90, 120, 135, 150, 180, 200 [B] 800 ns GI : 13.5, 27, 40.5, 54, 81, 108, 121.5, 135, 162, 180 [C]			35	115[4]		
			80	400 ns GI : 32.5, 65, 97.5, 130, 195, 260, 292.5, 325, 390, 433.3 [B] 800 ns GI : 29.2, 58.5, 87.8, 117, 175.5, 234, 263.2, 292.5, 351, 390 [C]			35	115[4]		
			160	400 ns GI : 65, 130, 195, 260, 390, 520, 585, 650, 780, 866.7 [B] 800 ns GI : 58.5, 117, 175.5, 234, 351, 468, 702, 780 [C]			35	115[4]		

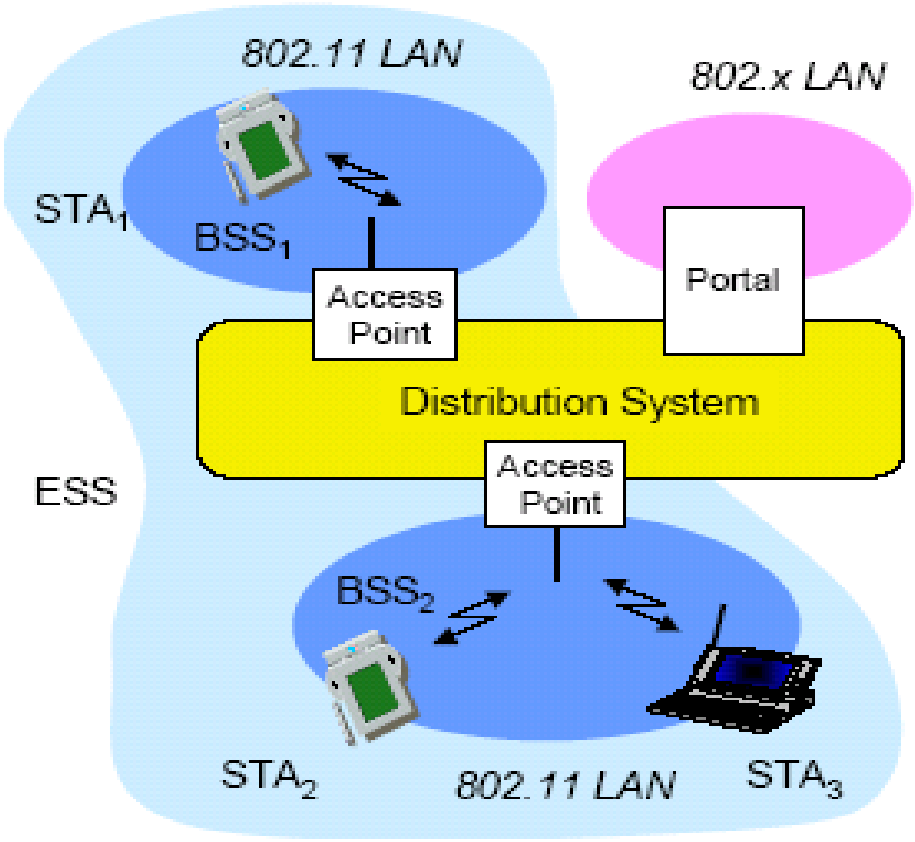
WWAN: Wireless Wide area network



Wireless LAN -Architecture

- ✓ IEEE has defined the specifications for a wireless LAN, called IEEE 802.11, which covers the physical and data link layers.

Basic Service Set (BSS)
Access Point (AP)
Distribution System (DS)
Extended Service Set (ESS)
Portal



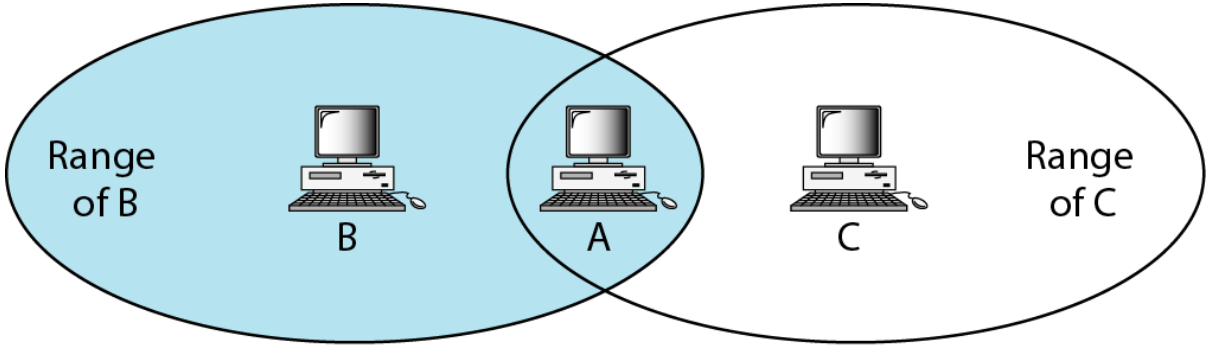
WIRELESS LAN- Architecture elements

- An 802.11 LAN is based on a cellular architecture where the system is divided into cells called basic Service set (BSS) and each cell is Controlled by a base station called Access point (AP).
- The WLAN can be formed by a single cell or several cells, where the access points are connected through some kind of backbone called distribution system (DS) typically Ethernet.
- The whole interconnected WLAN including different cells, their access points and the distribution system is seen to upper layers of OSI model as a single 802 network and it is called in the standard as Extended service set (ESS).
  - ESS is a set of BSSs interconnected by a distribution system (DS)
- The standard defines the concept of portal, a portal is a device that interconnects between 802.11 and another 802 LAN.

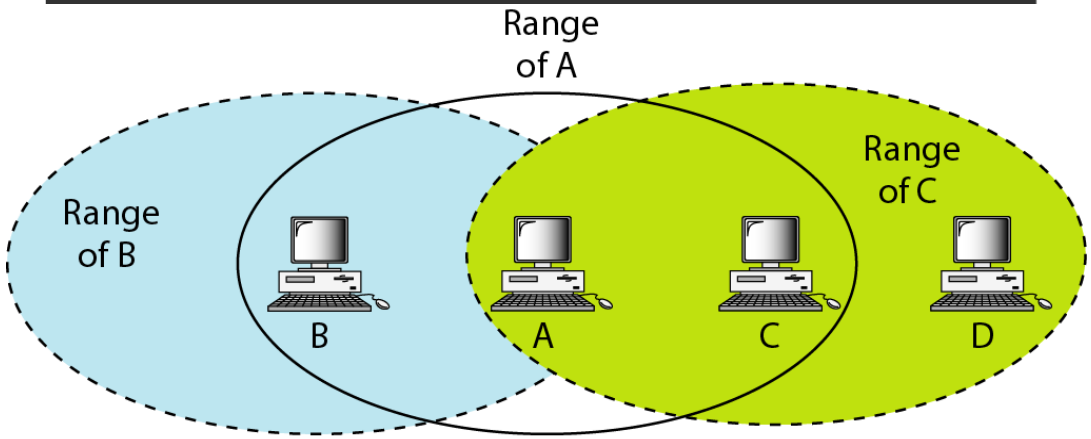
IEEE 802.11 - MAC Sublayer

- ✓ Wireless LANs cannot implement *CSMA/CD for three reasons:*
  - For collision detection a station must be able to send data and receive collision signals at the same time. This can mean costly stations and increased bandwidth requirements.
  - Collision may not be detected because of the hidden station problem.
  - The distance between stations can be great. Signal fading could prevent a station at one end from hearing a collision at the other end.
- ✓ IEEE 802.11 defines two MAC sublayers:
  - DCF: Distributed coordination function (DCF uses *CSMA/CA)*
  - PCF: point coordination function (uses polling by access point)

Hidden & Exposed Station Problem

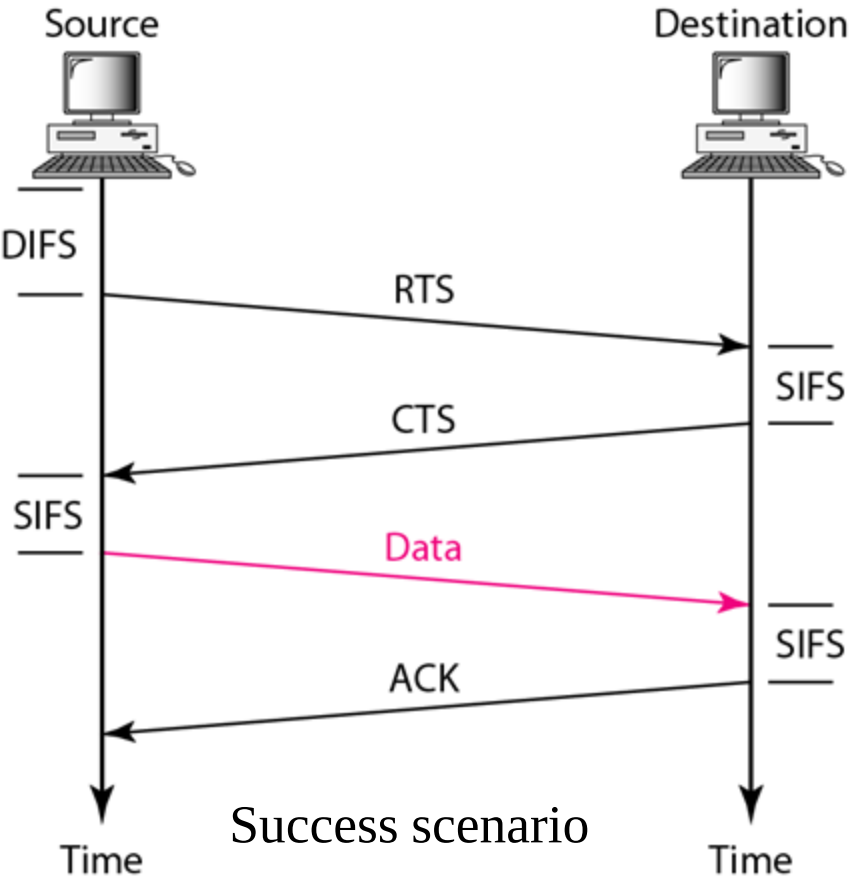


B and C are hidden from each other with respect to A.



C is exposed to transmission from A to B.

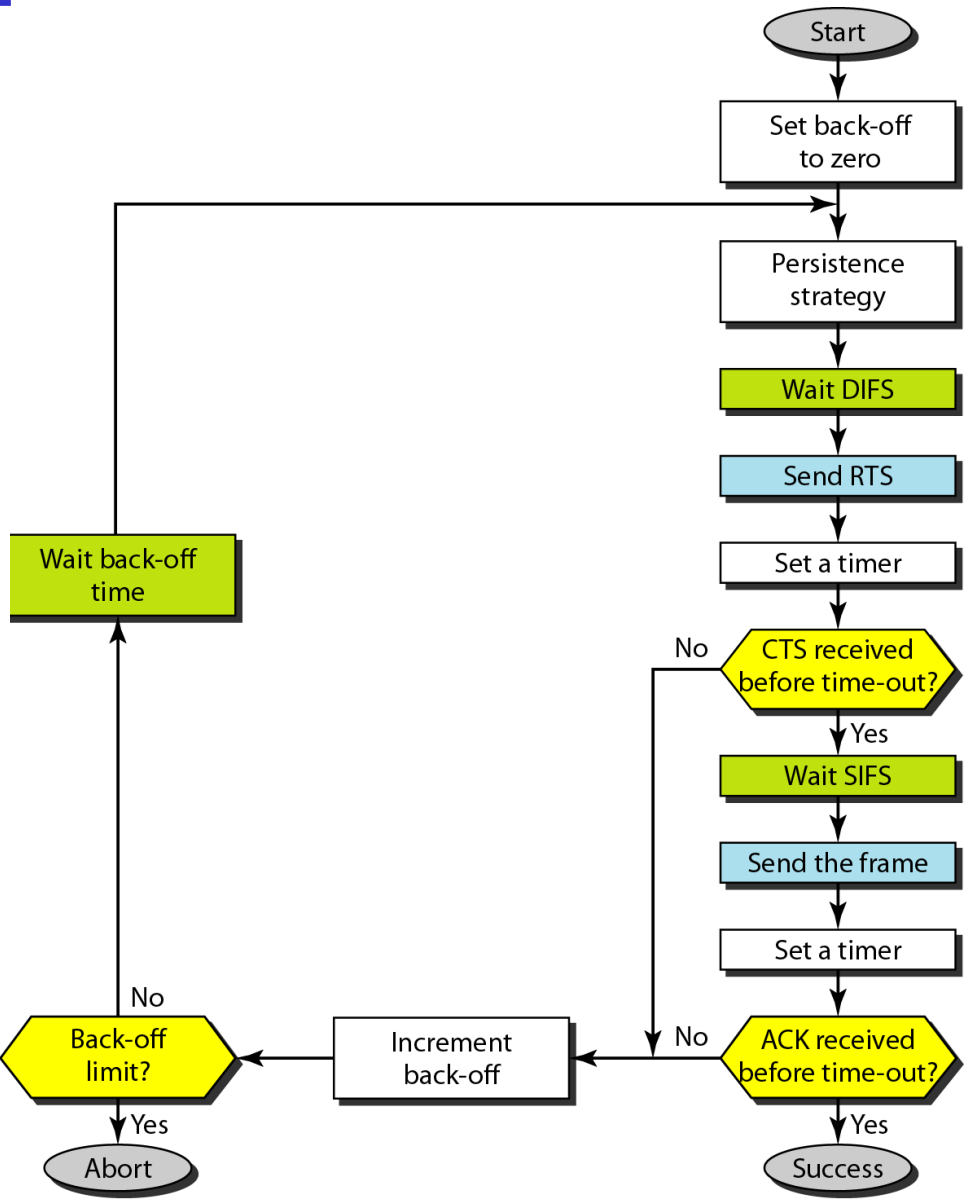
CSMA/CA – DCF mode



Success scenario

distributed interframe space (DIFS)

short interframe space (SIFS)



CSMA/CA- DCF mode (Cont.)

- 1. Before sending a frame, the source station senses the medium
  - a. The channel uses a persistence strategy with back-off until the channel is idle.
  - b. If the channel is idle, the station waits for a period of time called the distributed interframe space (DIFS);
- 2. Then the station sends a control frame called RTS (request to send)
  - After receiving the RTS and waiting a period of time called the short interframe space (SIFS), the destination station sends a control frame, called CTS (clear to send), to the source station. (i.e. the destination station is ready to receive data.)
- 3. The source station sends data after waiting SIFS time period.
- 4. The destination station, after waiting SIFS, sends an Ack to show that the frame has been received. Acknowledgment is needed in this protocol because the station does not have any means to check for the successful arrival of its data at the destination.

DCF- Network Allocation Vector

- Questions
  - How do other stations defer sending their data if one station acquires access? In other words, how is the *collision avoidance* accomplished?
- Answer:
  - The key is a feature called NAV.
  - When a station sends an RTS frame, it includes the duration of time that it needs to occupy the channel. The stations that are affected by this transmission create a timer called a network allocation vector (NAV) that shows how much time must pass before these stations are allowed to check the channel for idleness.
  - Each time a station accesses the system and sends an RTS frame, other stations start their NAV. In other words, each station, before sensing the physical medium to see if it is idle, first checks its NAV to see if it has expired.

DCF- Collision During Handshaking

- Question:
  - What happens if there is collision during the time when RTS or CTS control frames are in transition, often called the handshaking period?
- Answer:
  - Two or more stations may try to send RTS frames at the same time. These control frames may collide. However, because there is no mechanism for collision detection, the sender assumes there has been a collision if it has not received a CTS frame from the receiver.
  - The back-off strategy is employed, and the sender tries again.

PCF (Point Coordination Function)

- ✓ The Access point polls the other stations, asking them if they have any frames to send. Since transmission order is completely controlled by the access point in PCF mode, no collisions ever occur.
- ✓ The basic mechanism is for the access point to broadcast a beacon frame periodically(10 to 100 times per second)
- ✓ The beacon frame contains system parameters. It also invites new stations to sign up for polling service.
- ✓ Once a station has signed up for polling service at a certain rate, it is effectively guaranteed a certain fraction of the bandwidth, thus making it possible to give quality-of service guarantees

WLAN Services

- ✓ Each wireless LAN must provide nine services. These services are divided into two categories:
  - Distribution Services
    - Distribution services relate to managing cell membership and interacting with stations outside the cell. These services are provided by the access point and deal with station mobility as they enter and leave cells, attaching themselves to and detaching themselves from access points.
  - Station Services
    - Station services relate to activity within a single cell.

Distribution Services

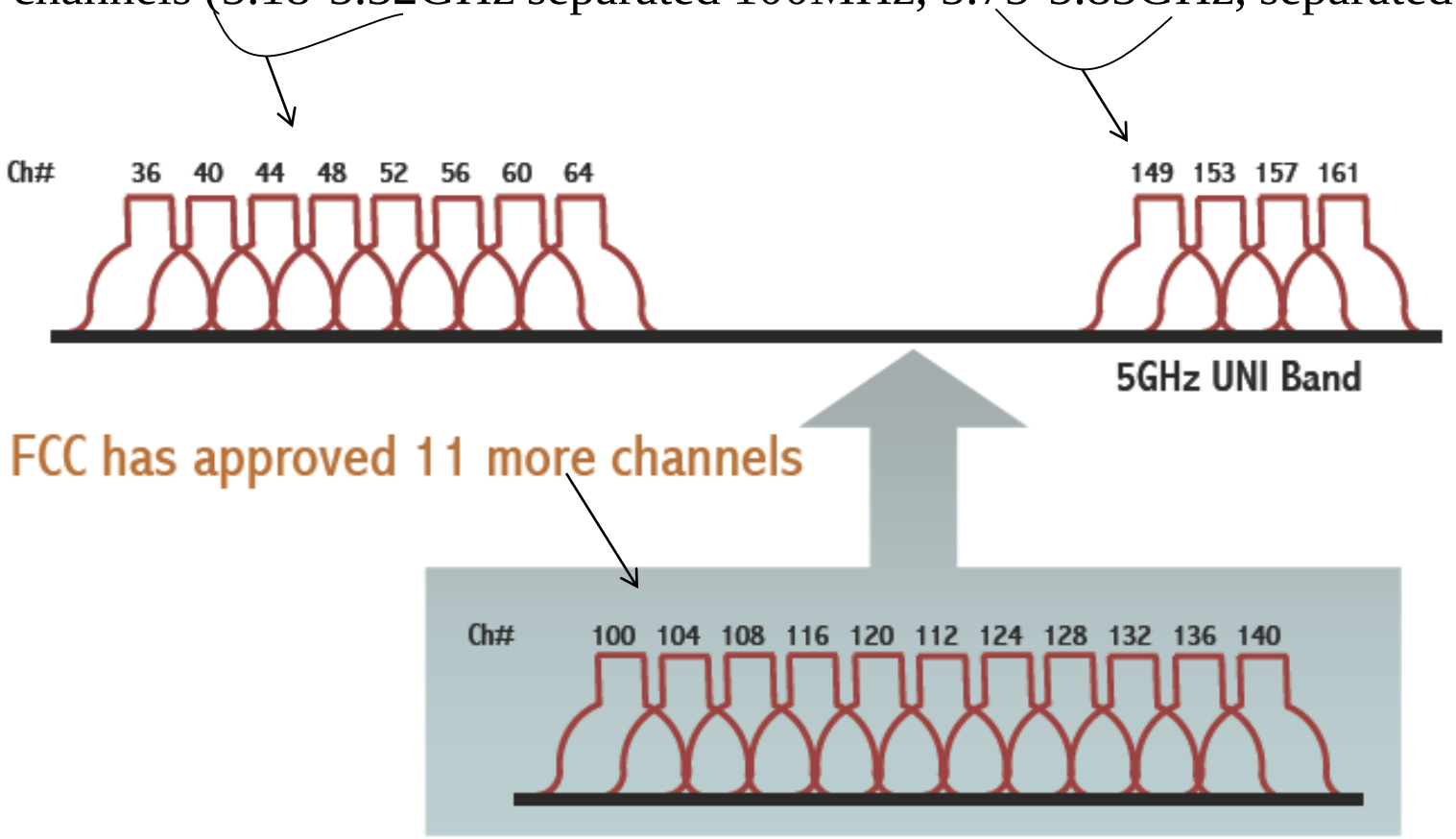
- **Association:** Establishes initial association between station and AP
  - Used by mobile stations to connect themselves to access point
  - Mobile station announces its identity and capabilities (data rates supported, need for PCF services (i.e., polling), and power management requirements.
- **Re-association:** transfer of association from one AP to another (move to another BSS)
  - If it is used correctly, no data will be lost as a consequence of the handover.
- **Disassociation:** Association termination notice from stations or access point
  - A station should use this service before shutting down or leaving
  - The access point may also use it before going down for maintenance.
- **Distribution:** Used to exchange MAC frames from station in one BSS to station in another BSS
- **Integration:** Transfer of data between station on IEEE 802.11 LAN and station on integrated IEEE 802.x LAN
  - If a frame needs to be sent through a non-802.11 network with a different addressing scheme or frame format, this service handles the translation

Station Services

- **Authentication:** Establishes identity of stations to each other;
  - Access point sends a special challenge frame to see if the mobile station knows the secret key (password) that has been assigned to
- **De-authentication:** Invoked when existing authentication is terminated
  - When a previously authenticated station wants to leave the network, it is de-authenticated.
- **Privacy:** Prevents message contents to be read by unintended recipient
  - The encryption algorithm specified is RC4, invented by Ronald Rivest
- **Delivery of data**
  - Finally, data transmission is what it is all about

Channels in 802.11 a

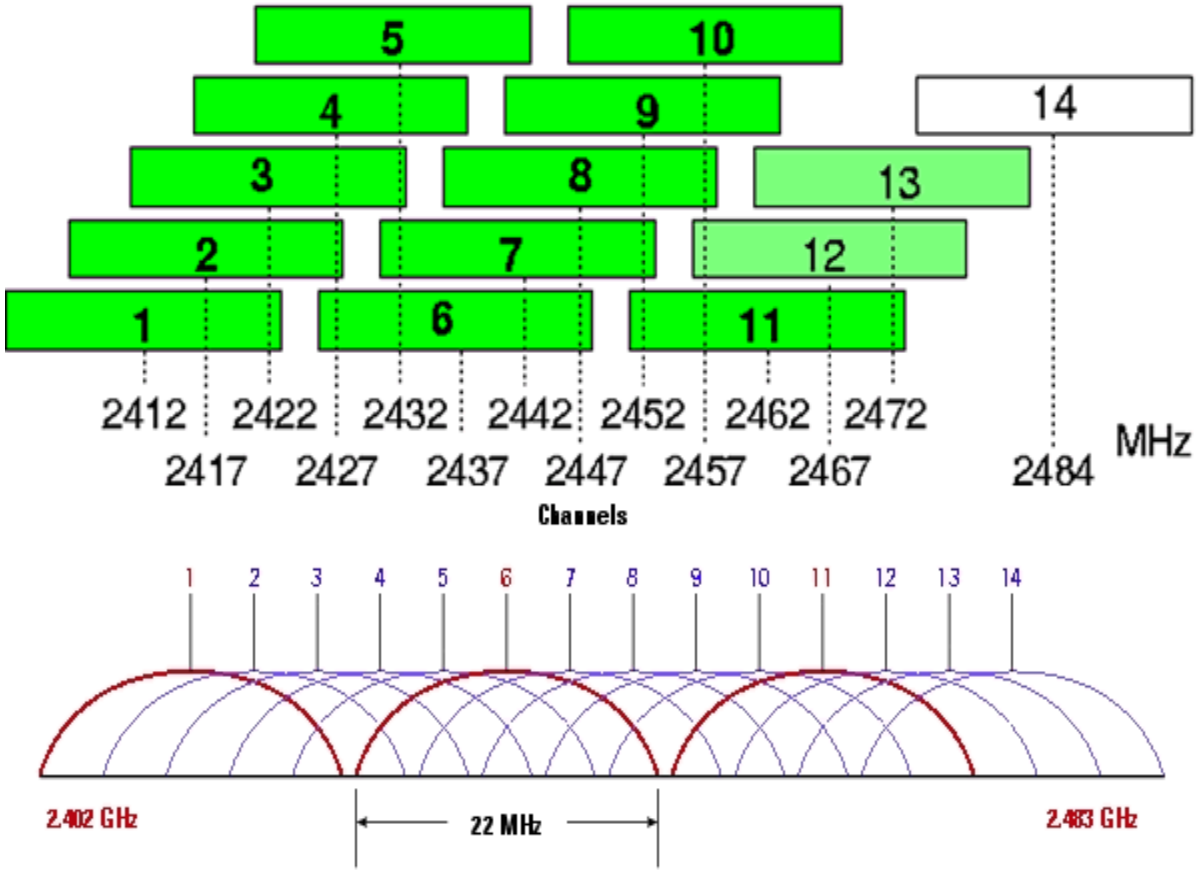
- ✓ 12 channels (5.18-5.32GHz separated 100MHz, 5.75-5.83GHz, separated 200MHz)



Channels in 802.11 b/ g

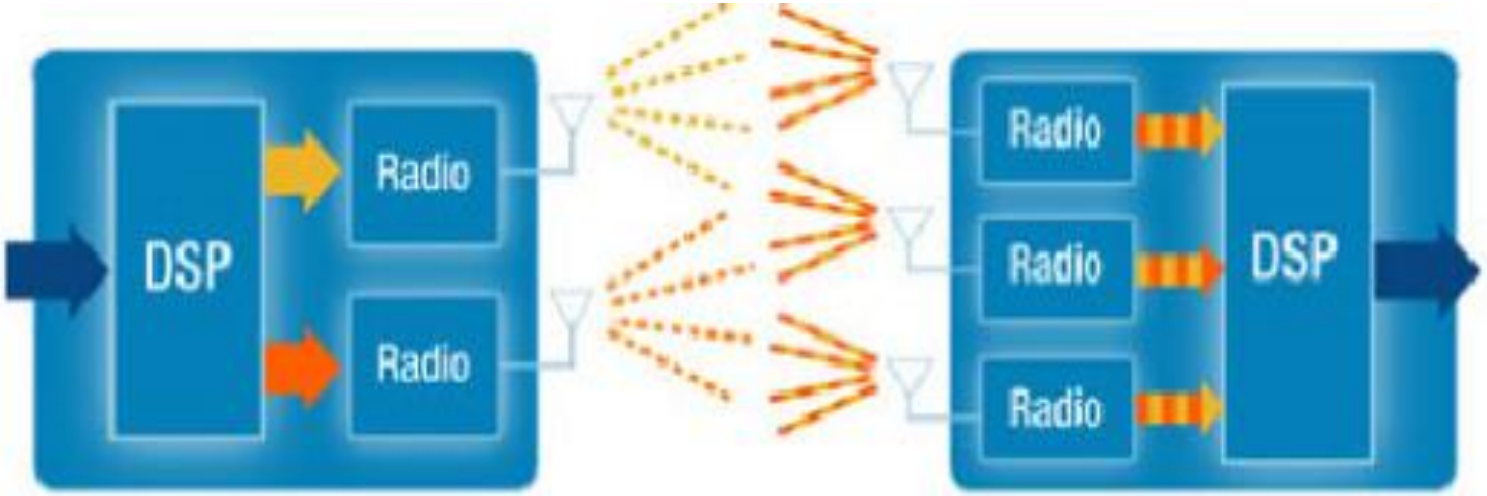
✓ 3 non overlapping channels

Channel Number	Channel in GHz
1	2.412
2	2.417
3	2.422
4	2.427
5	2.432
6	2.437
7	2.442
8	2.447
9	2.452
10	2.457
11	2.462

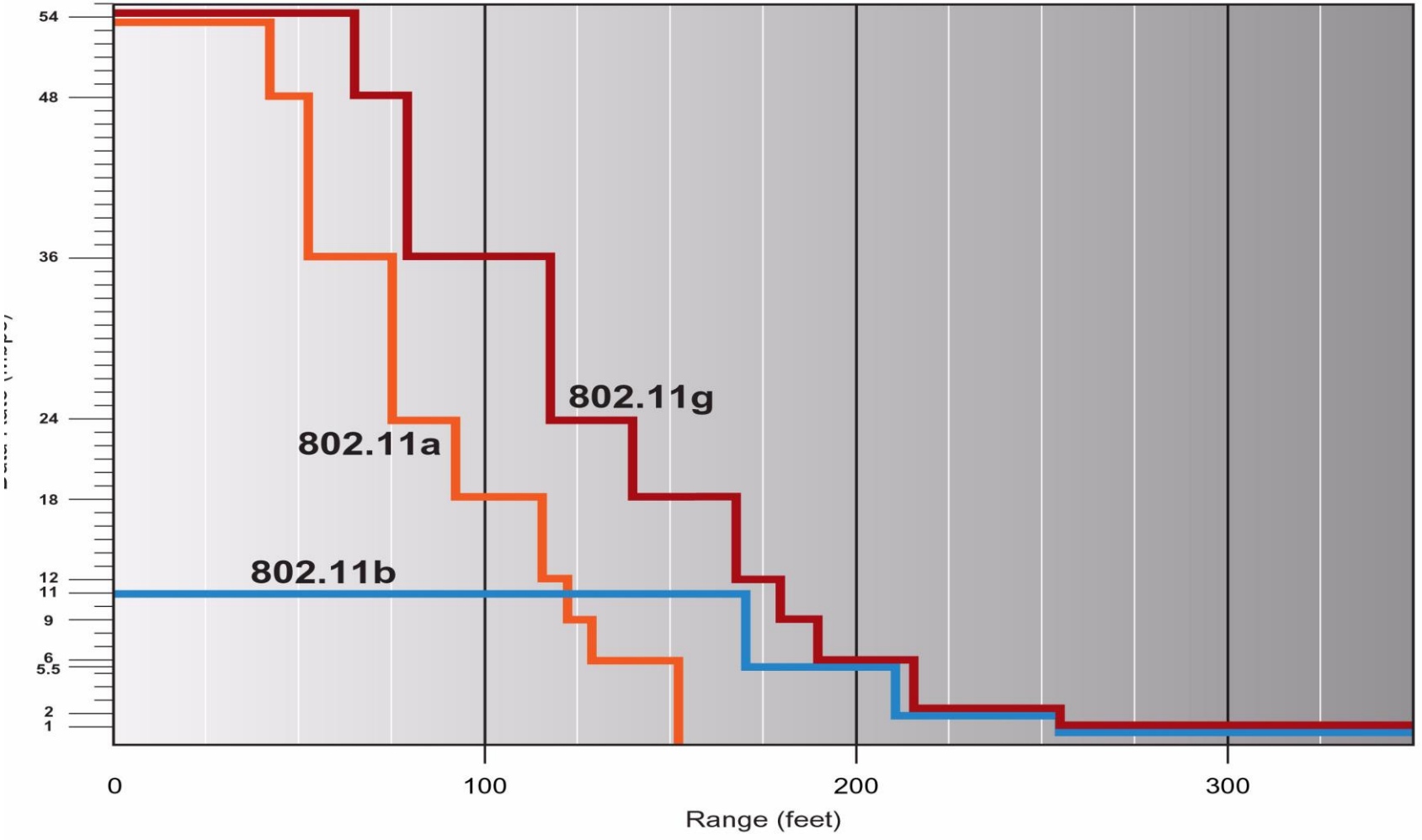


Multi- Input, Multi Output (MIMO)

- ✓ MIMO divide a data stream into multiple unique streams
- ✓ MIMO transmits data streams in same radio channel at same time
- ✓ MIMO use the advantage of multipath (reflections of the signals)
- ✓ MIMO receiver combines all streams
- ✓ MIMO enables 802.11n to operate at much higher data rates than the PHY would otherwise normally be able to operate for a given transmission.

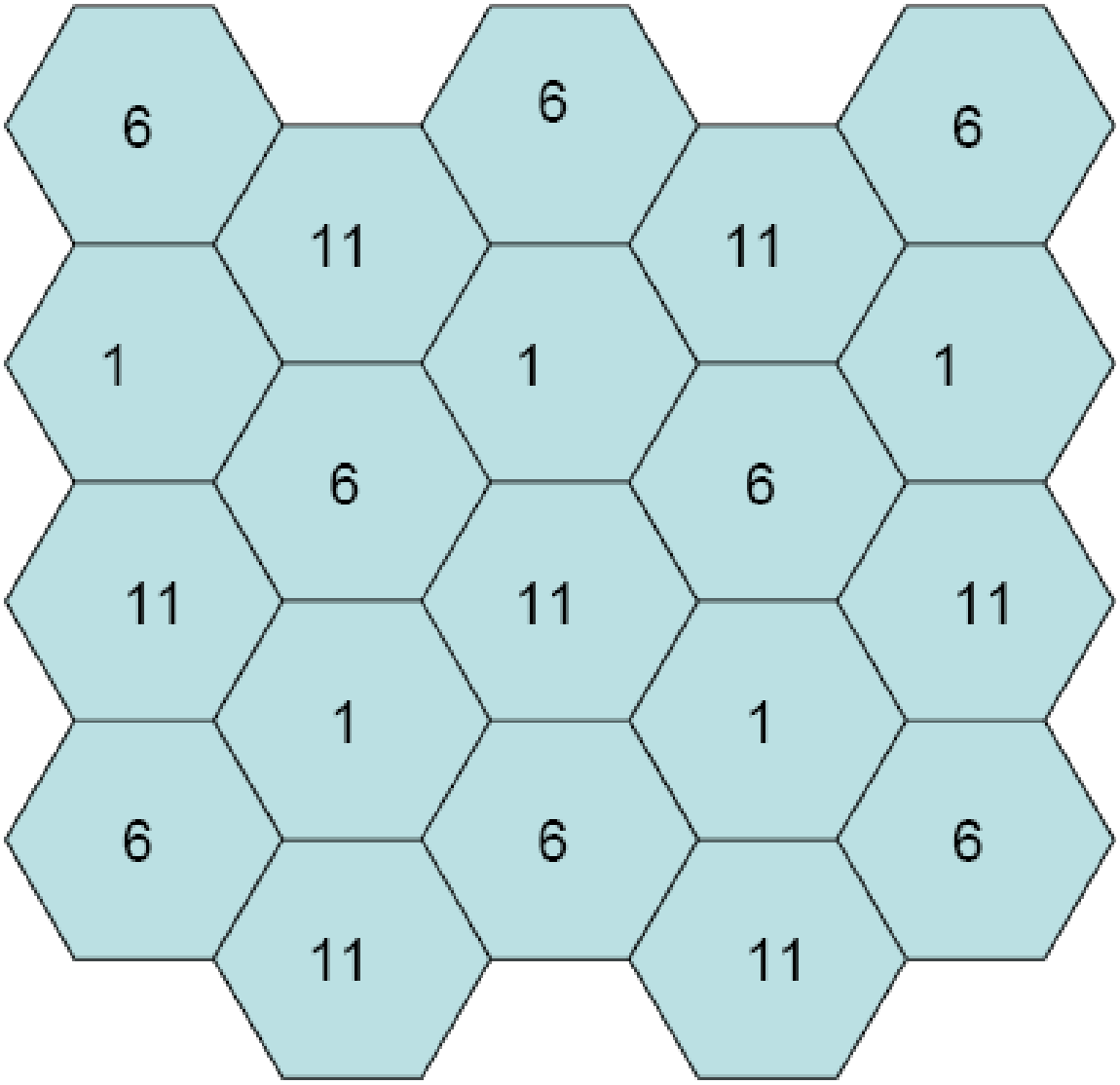


RANGE AND DATA RATE

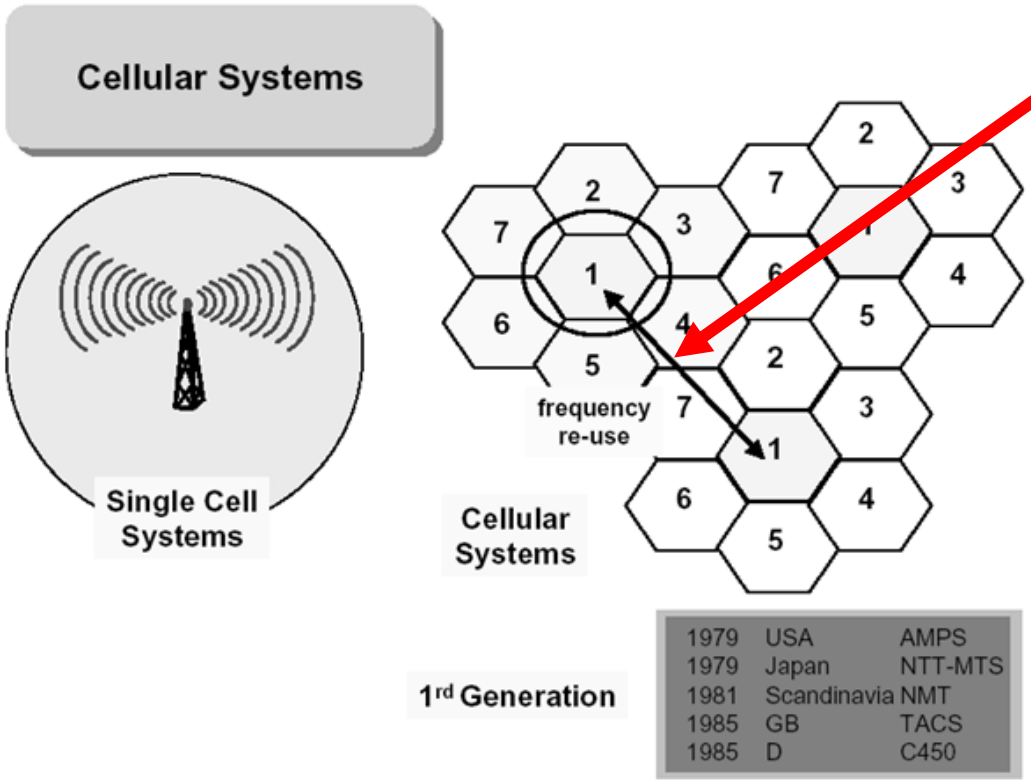


- ✓ As distance from the access point increases, 802.11 products provide reduced data rates to maintain connectivity.

Channel Reuse



Co-Channel and Adjacent Channel in Cellular Networks



Co Channel: 1-1, 2-2, ..etc
Same frequency Range

Adjacent Channels: 1-2, 2-3, ..etc
Frequency Range is very close to each other