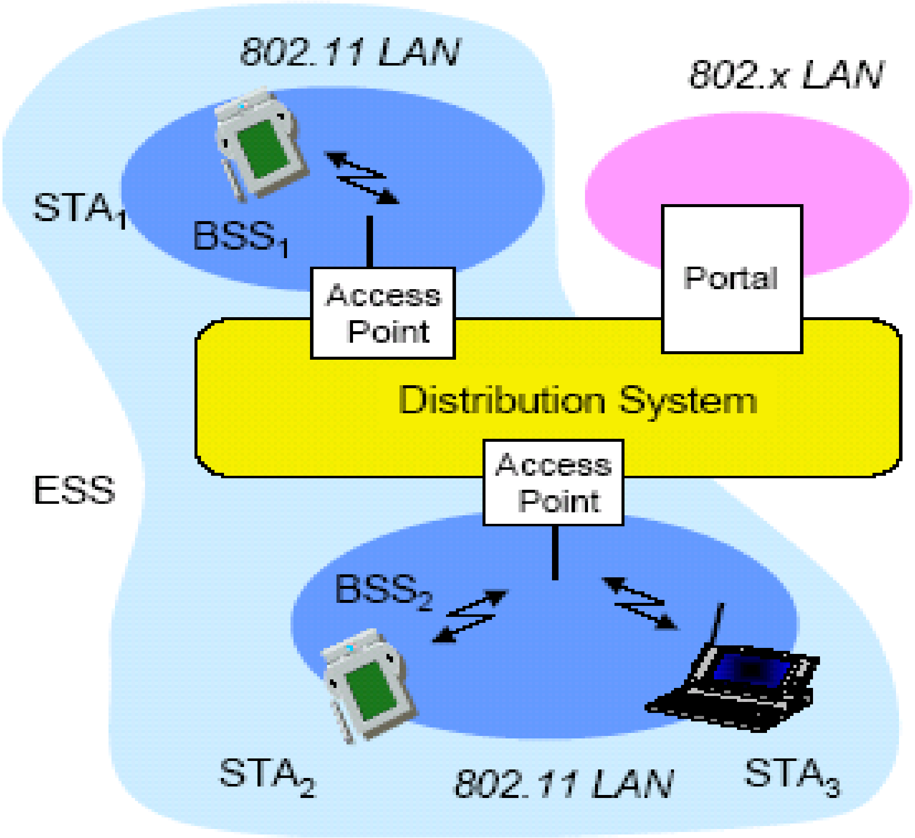
Wireless LAN -Architecture

- ✓ 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



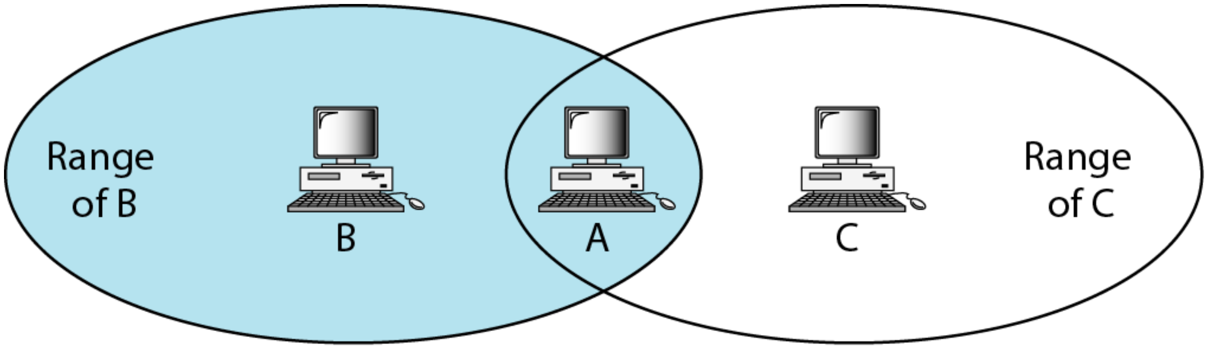
WIRELESS LAN- Architecture elements

- 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.

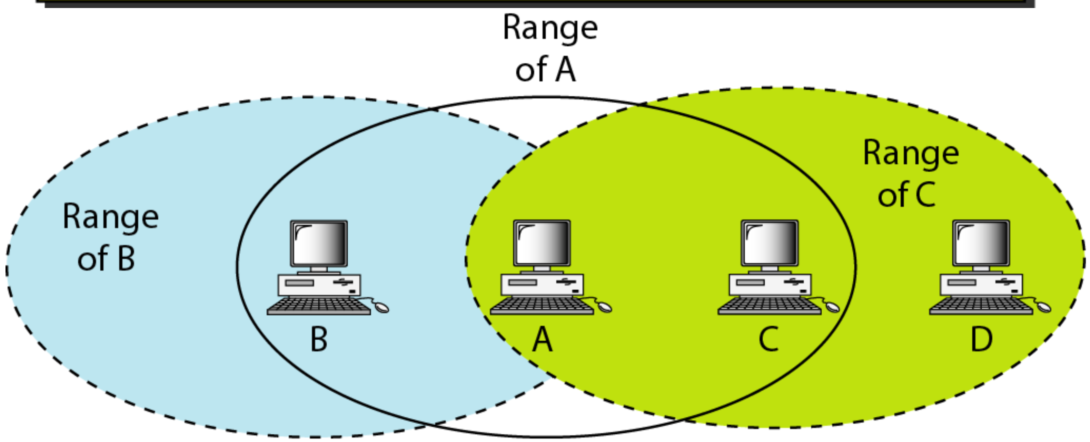
IEEE 802.11 - MAC Sublayer

- 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

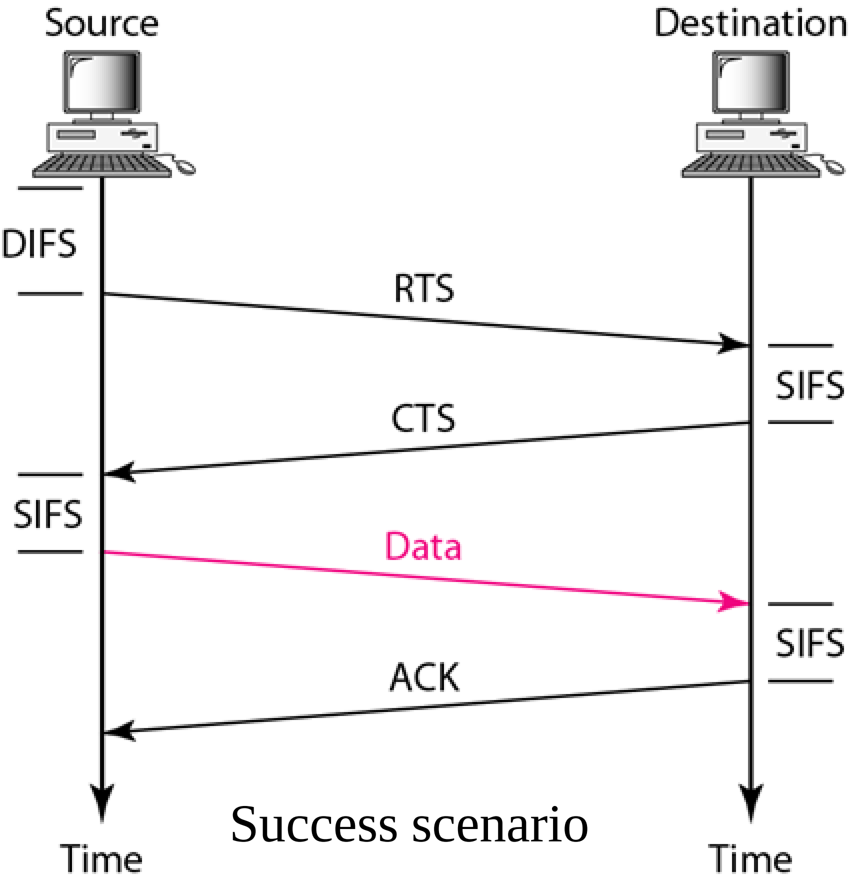


B and C are hidden from each other with respect to A.

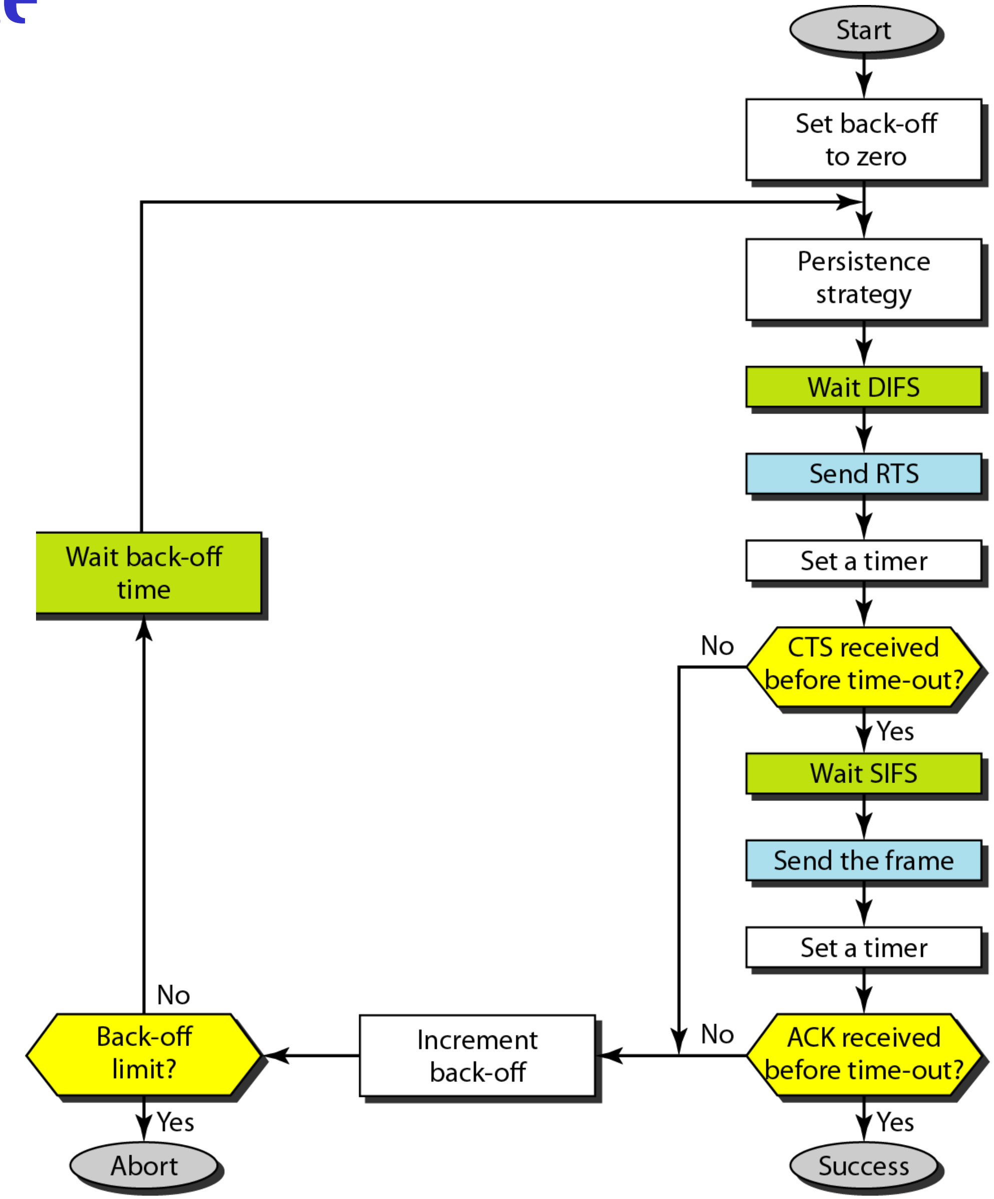


C is exposed to transmission from A to B.

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

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
802.11 AC	Expected Dec 2013	80-160 MHz	< 6 GHz	?	1000	?	**LDPC** – Low Density Parity Check **STPC** – Space-Time Block Coding **TxBF** – Transmit Beam Forming **SGI** – 400ns Short Guard Interval
802.11 AD	2003	83.5 MHz	60 GHz	?	Up to 7 Gbps	?	OFDM, DSSS/CCK

802.11ac

Type	2.4 GHz Mbit/s[d]	5 GHz Mbit/s
AC600	150	433
AC750	300	433
AC1200	300	867
AC1300	400	867
AC1450	450	975
AC1600	300	1,300
AC1750	450	1,300
AC1900	600[e]	1,300
AC2350	600[e]	1,733
AC3200	600[e]	2,600[f]

Multiple Antenna Scenarios

Scenario	Typical client form factor	PHY link rate	Aggregate capacity (speed)
One-antenna AP, one-antenna STA, 80 MHz	Handheld	433 Mbit/s	433 Mbit/s
Two-antenna AP, two-antenna STA, 80 MHz	Tablet, laptop	867 Mbit/s	867 Mbit/s
One-antenna AP, one-antenna STA, 160 MHz	Handheld	867 Mbit/s	867 Mbit/s
Two-antenna AP, two-antenna STA, 160 MHz	Tablet, laptop	1.69 Gbit/s	1.69 Gbit/s
Four-antenna AP, four one-antenna STAs, 160 MHz (MU-MIMO)	Handheld	867 Mbit/s to each STA	3.39 Gbit/s
•Eight-antenna AP, 160 MHz (MU-MIMO) one four-antenna STA •one two-antenna STA •two one-antenna STAs	Digital TV, Set-top Box, Tablet, Laptop, PC, Handheld	•3.39 Gbit/s to four-antenna STA •1.69 Gbit/s to two-antenna STA •867 Mbit/s to each one-antenna STA	6.77 Gbit/s
Eight-antenna AP, four 2-antenna STAs, 160 MHz (MU-MIMO)	Digital TV, tablet, laptop, PC	1.69 Gbit/s to each STA	6.77 Gbit/s

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

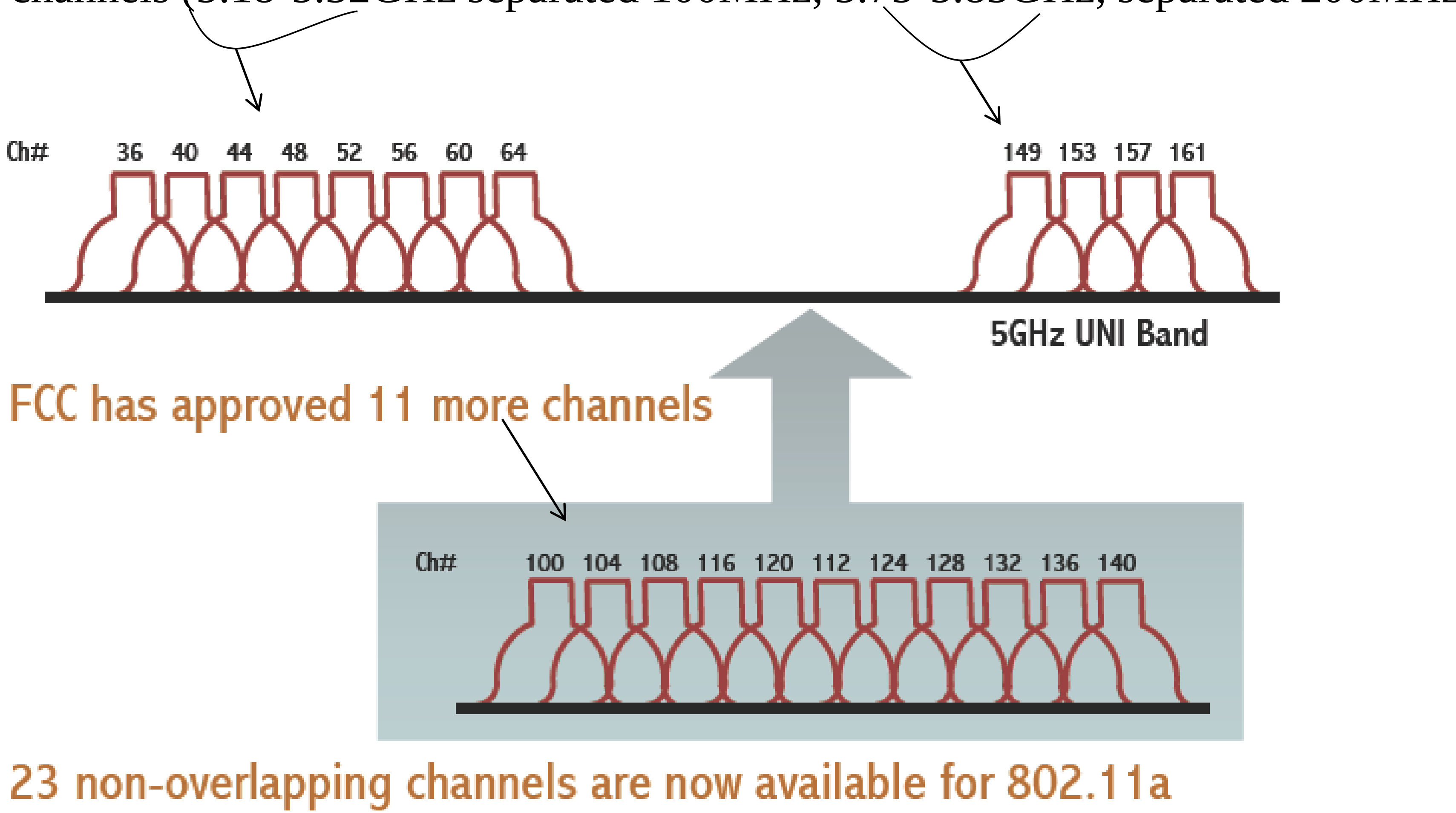
- ✓ **Association:** Establishes initial association between station and AP
  - ❑ Used by mobile stations to connect themselves to access point
  - ❑ Mobile station announces its identity and capabilities (data rates supported, need for PCF services (i.e., polling), and power management requirements.
- ✓ **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

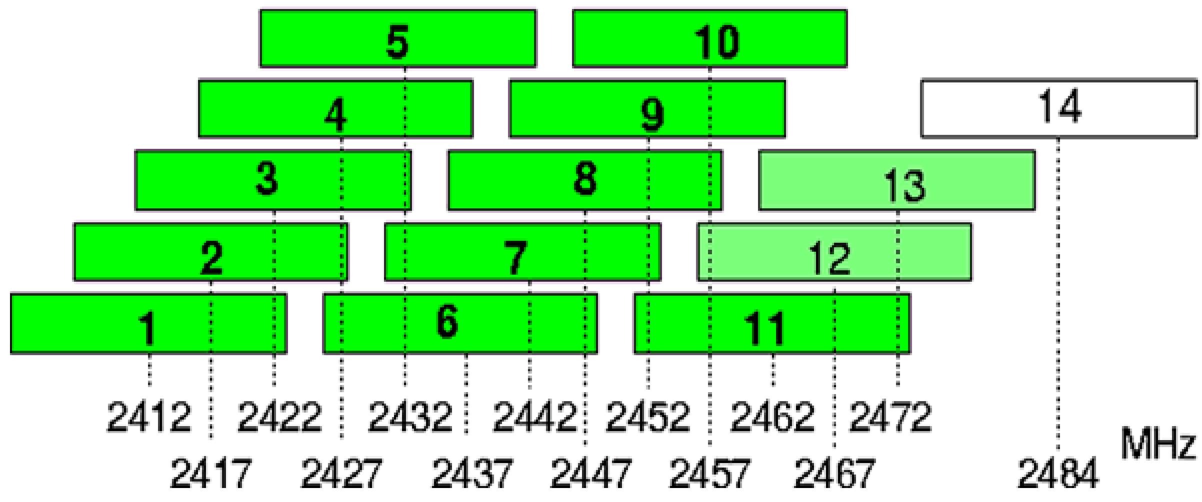
- ✓ 12 channels (5.18-5.32GHz separated 100MHz, 5.75-5.83GHz, separated 200MHz)

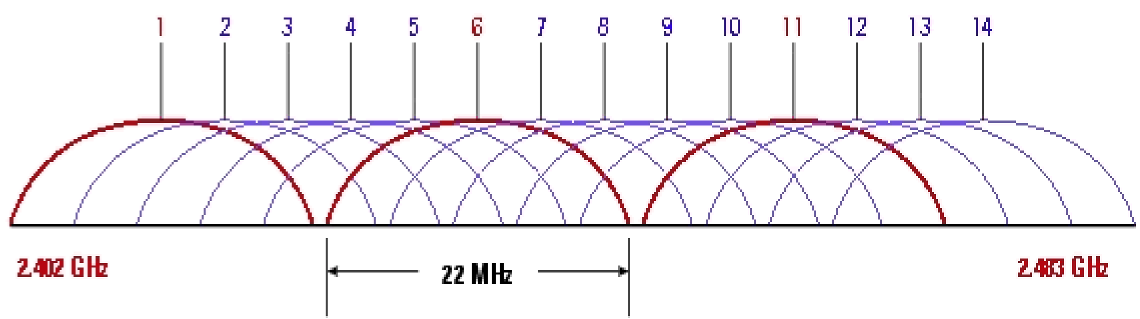


Channels in 802.11 b/ g

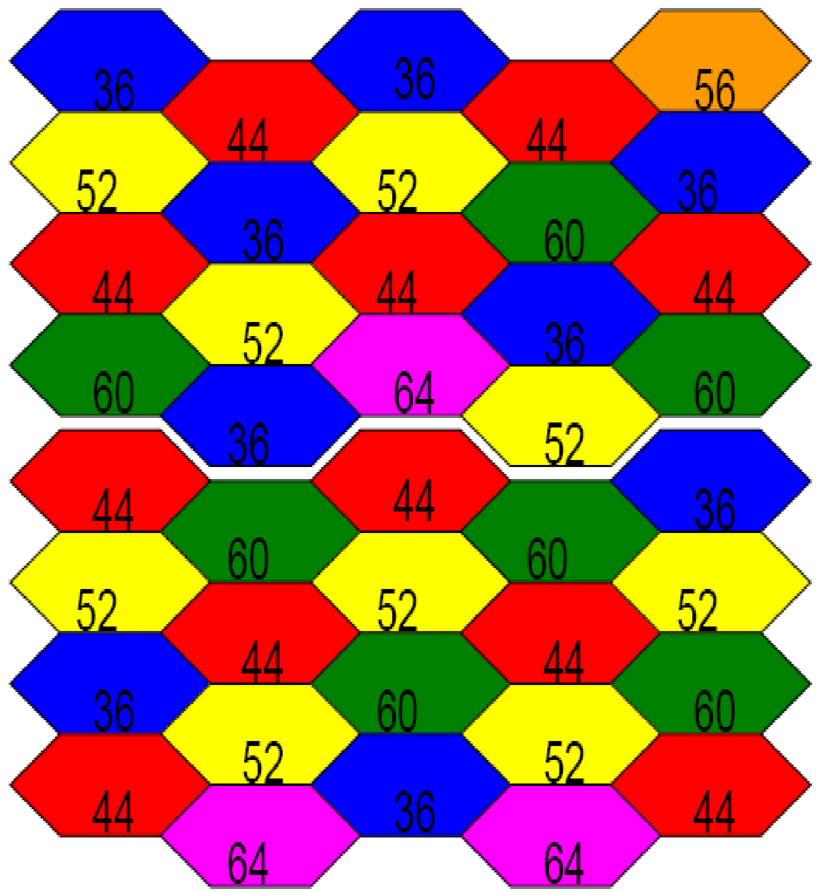
✓ 3 non overlapping channels

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



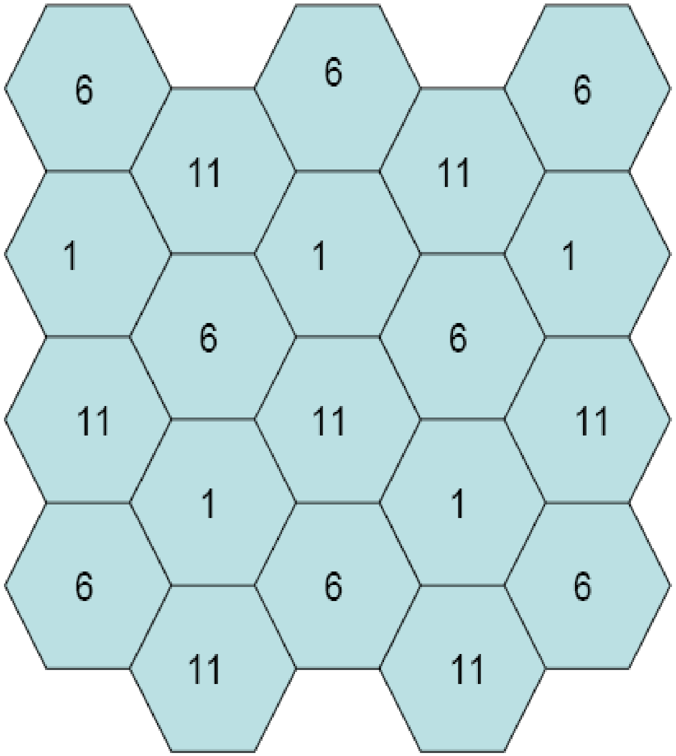


Channel Reuse- 802.11a



Channel Reuse- 802.11b/g

- Due to the small number of non-overlapping channels (3) in the 802.11b specification, deployments of wireless sites that use multiple APs require careful design consideration.
- In order to minimize interference between APs and maximize network throughput it is necessary to keep APs that communicate in the same channel away from each other.
- The honeycomb pattern is a suggested configuration. Which channel is placed in each slot is not important as long as you keep APs operating in the same channel as far away from each other as possible.



802.11n

- ✓ Significantly improve PHY layer transmission rate over previous standards
- ✓ Maintain backward compatibility with existing (802.11a/b/g)
- ✓ Becomes more reliable in performance

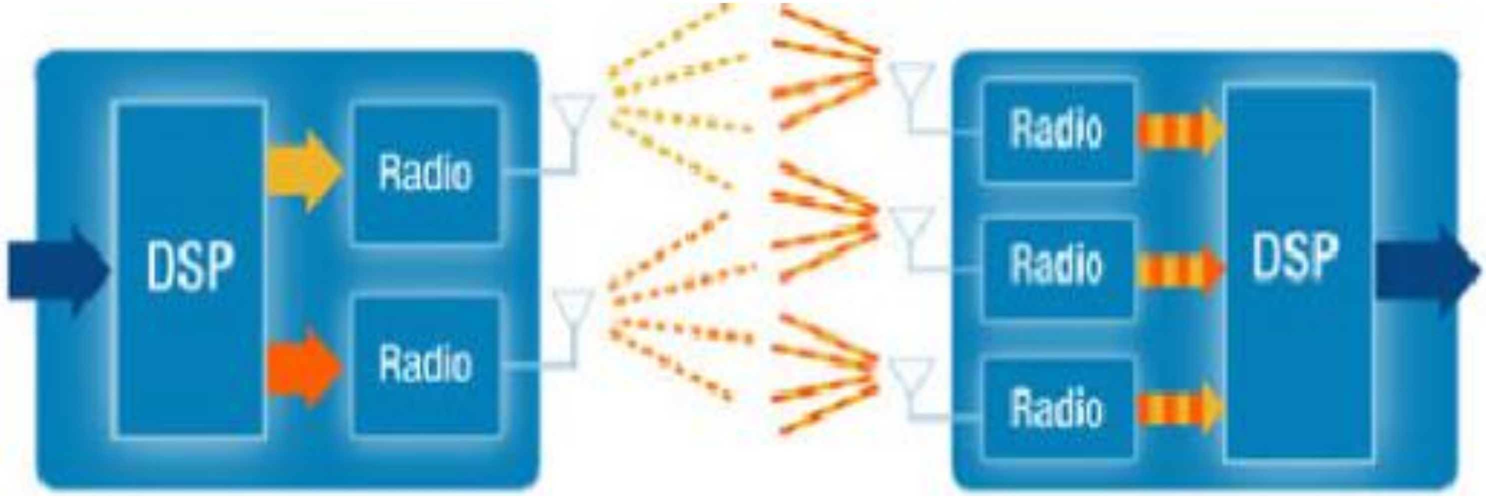
Release date	Nov. 2009
Bit rate	600 Mb/s
Range (indoor)	300m
Frequency	2.4 GHz, 5GHz

802.11n- How the objectives are met

- Modified OFDM
  - The number of OFDM data sub-carriers is increased from 48 to 52.
    - improves the maximum throughput from 54 to 58.5 Mbps
- MAC Enhancement
  - Reduce the protocol overhead.
    - boosts the link rate from 58.5 to 65 Mbps
- Shorter Guard Interval (GI)
  - The GI between OFDM symbols is reduced from 800ns to 400ns
    - increases throughput from 65 to 72.2 Mbps
- Channel Bonding
  - Doubling channel bandwidth from 20 to 40 MHz
    - more than doubles data rate from 72.2 to 150 Mbps
- Spatial multiplexing
  - Support of up to four spatial streams (MIMO)
    - increases throughput up to 4 times 150 to 600 Mbps

Multi- Input, Multi Output (MIMO)

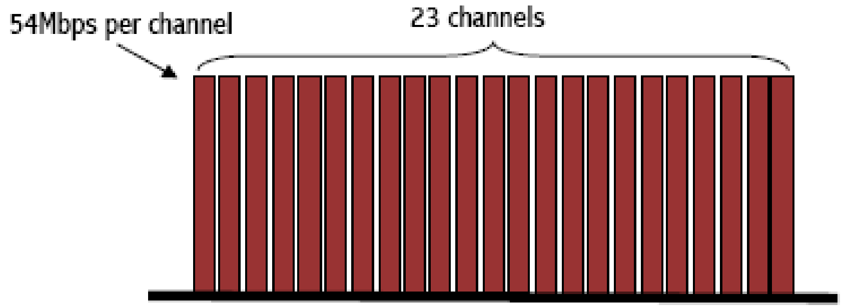
- ✓ MIMO divide a data stream into multiple unique streams
- ✓ MIMO transmits data streams in same radio channel at same time
- ✓ MIMO use the advantage of multipath (reflections of the signals)
- ✓ MIMO receiver combines all streams
- ✓ MIMO enables 802.11n to operate at much higher data rates than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



Capacity Comparison

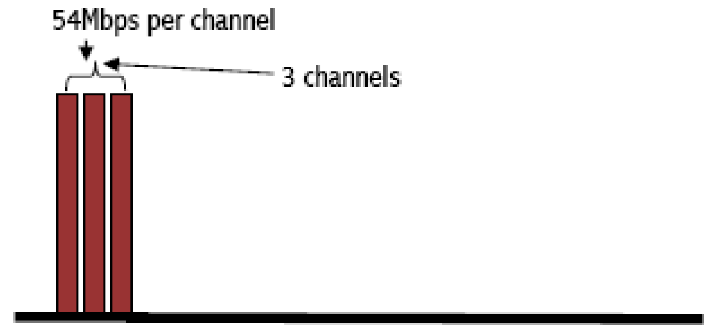
802.11a Capacity

- 23 channels * 54Mbps = 1.24Gbps of RF capacity



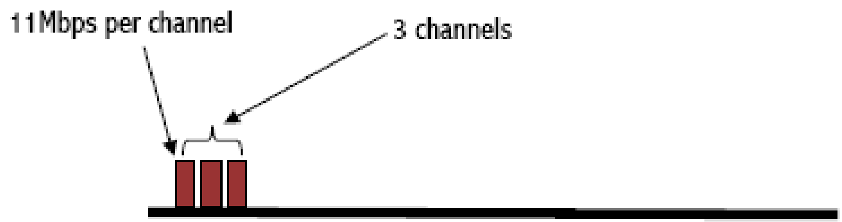
802.11g Capacity

- 3 channels * 54Mbps = 162Mbps of RF capacity

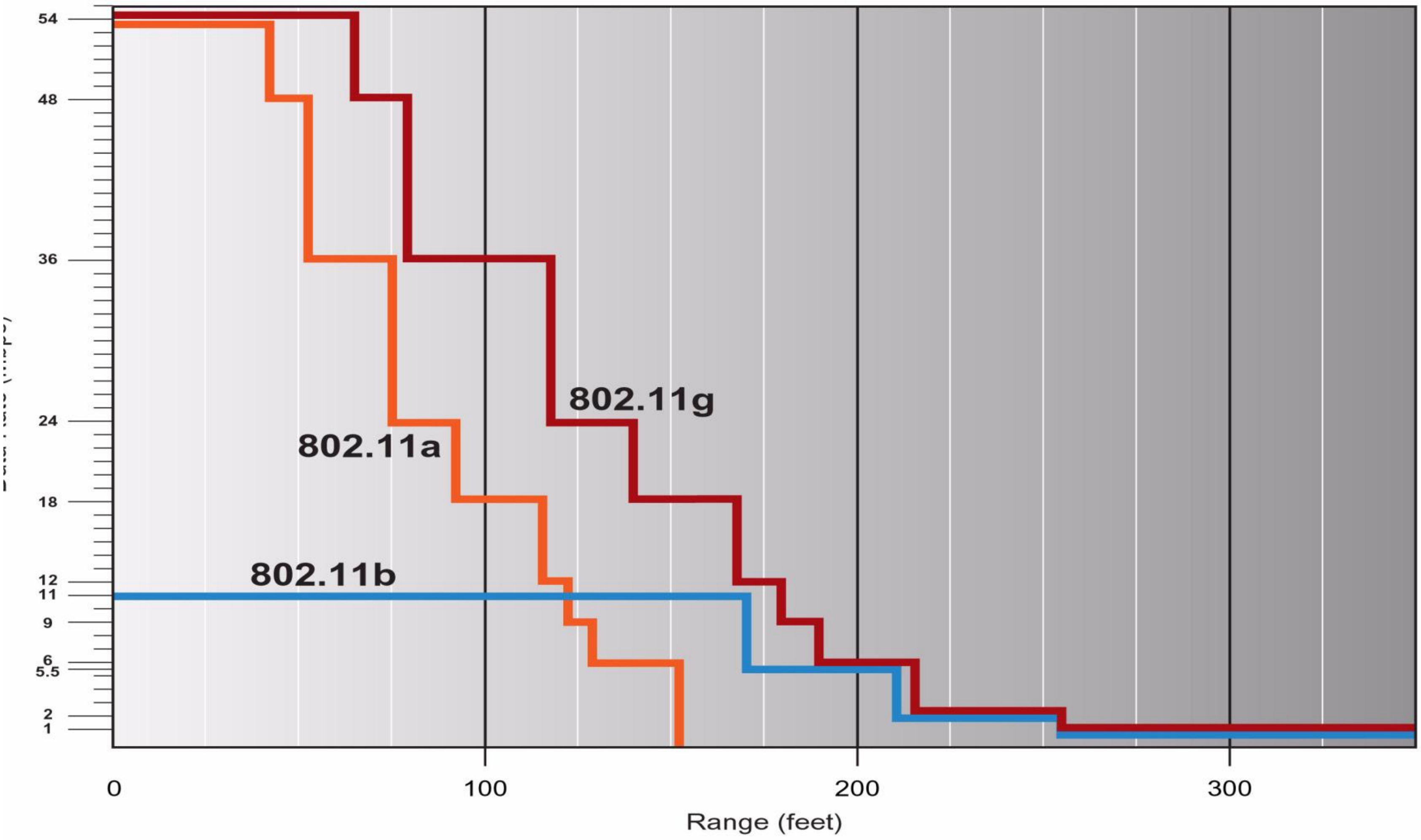


802.11b Capacity

- 3 channels * 11Mbps = 33Mbps of RF capacity



RANGE AND DATA RATE

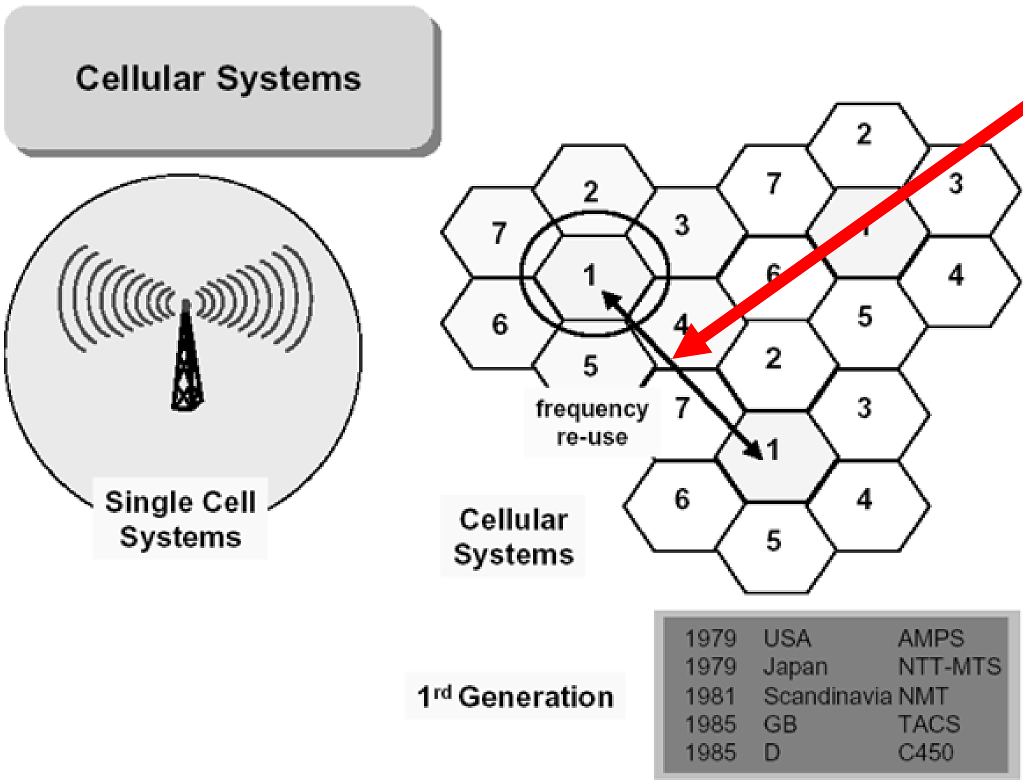


- ✓ As distance from the access point increases, 802.11 products provide reduced data rates to maintain connectivity.

IEEE 802.i, e & f

- **802.11i**
  - New security standard
  - Replaces WEP (which was found to have some problems)
- **802.11e**
  - Provides QOS support for a, b, & g standards.
- **802.11f**
  - Recommended practice document for AP inter-operabilit

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