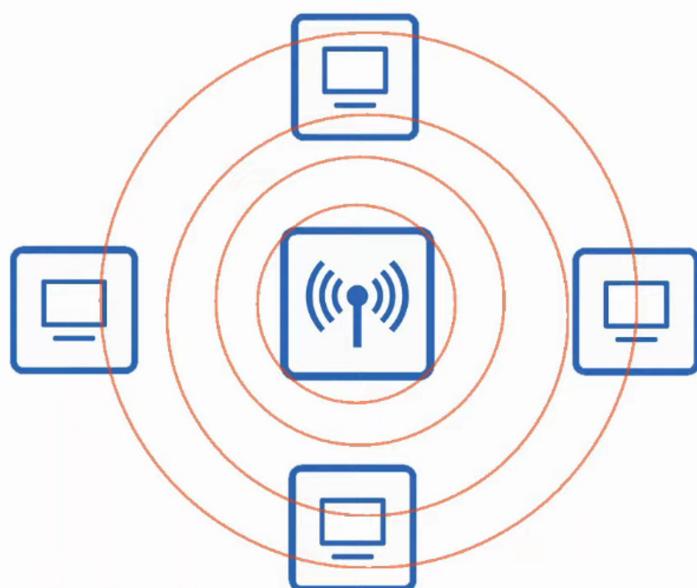


## WIRELESS FUNDAMENTALS

- Although we will briefly look at other types of WIRELESS NETWORKS, in this section of the course we will be focusing on WIRELESS LANs using WI-FI
- The STANDARDS we use for WIRELESS LANs are defined in IEEE 802.11
- The term WI-FI is a trademark of the WI-FI ALLIANCE, not directly connected to the IEEE
- The WI-FI ALLIANCE tests and certifies equipment for 802.11 standards compliance
- However, WI-FI has become the common term that people use to refer to 802.11 WIRELESS LANs and that term will be used through the course videos

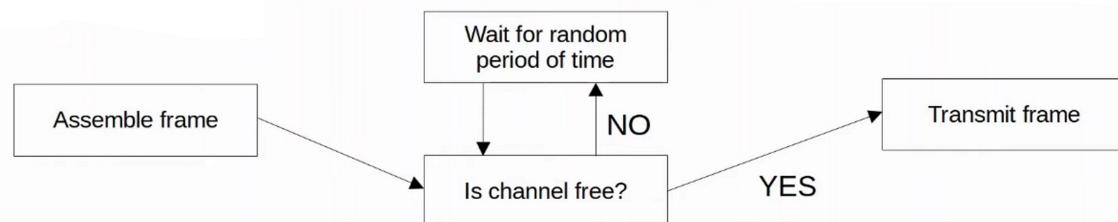
## WIRELESS NETWORKS

- WIRELESS NETWORKS have some issues that we need to deal with



### 1. ALL DEVICES within range receive ALL FRAMES, like DEVICES connected to an ETHERNET HUB

- Privacy of DATA within the LAN is a greater concern
- CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) is used to facilitate HALF-DUPLEX communications
- CSMA / CD is used in WIRED NETWORKS to detect and recover from COLLISIONS
- CSMA / CA is used in WIRELESS NETWORKS to avoid COLLISIONS
- When using CSMA / CA, a DEVICE will wait for other DEVICES to STOP TRANSMITTING before it TRANSMITS DATA itself.



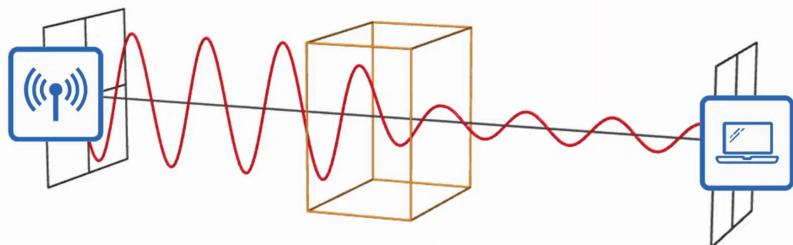
### 2. WIRELESS COMMUNICATIONS are regulated by various INTERNATIONAL and NATIONAL bodies

### 3. WIRELESS SIGNAL COVERAGE AREA must be considered

- Signal Range
- Signal ABSORPTION, REFLECTION, REFRACTION, DIFFRACTION, and SCATTERING

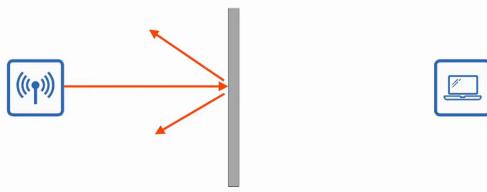
#### SIGNAL ABSORPTION

- ABSORPTION happens when a WIRELESS SIGNAL PASSES THROUGH a material and is converted into HEAT, weakening the SIGNAL



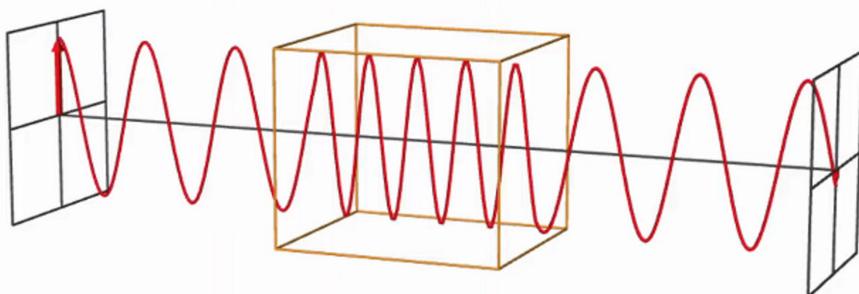
#### SIGNAL REFLECTION

- REFLECTION happens when a SIGNAL BOUNCES off a material (like metal)
  - This is why WI-FI reception is usually POOR in elevators. The SIGNAL bounces off the metal and very little penetrates into the elevator



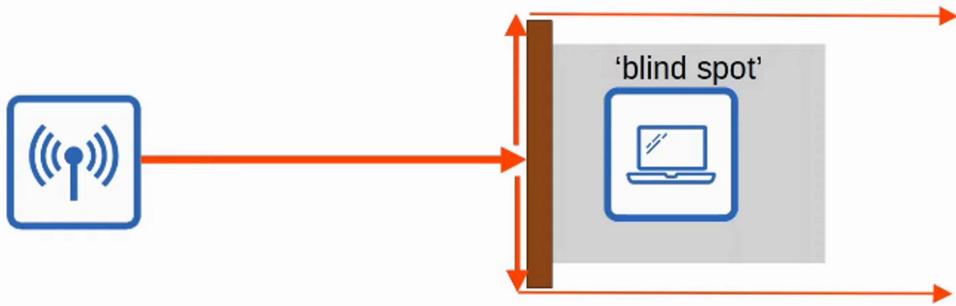
#### SIGNAL REFRACTION

- REFRACTION happens when a WAVE is BENT when entering a medium where the SIGNAL travels at a different speed
  - For example, glass and water can refract waves



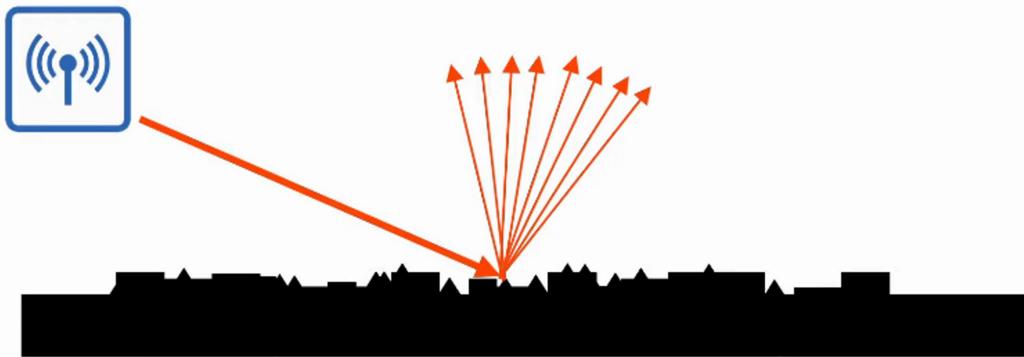
#### SIGNAL DIFFRACTION

- DIFFRACTION happens when a WAVE encounters an OBSTACLE and travels AROUND it
  - This can result in “BLIND SPOTS” behind the obstacle



## SIGNAL SCATTERING

- SCATTERING happens when a material causes a SIGNAL to SCATTER in all directions
  - Dust, smog, uneven surfaces: concrete, Tree etc. can cause scattering
  - Raindrop > Signal scatter

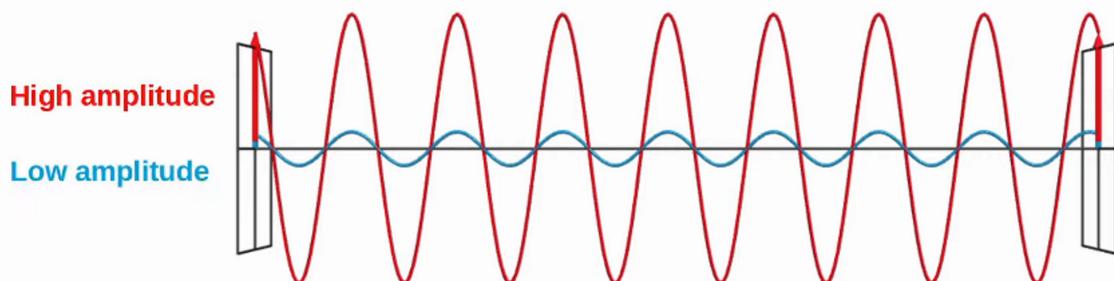


## 4. Other DEVICES using the SAME CHANNELS can cause INTERFERENCE

- For example, a WIRELESS LAN in your neighbor's house / apartment

## RADIO FREQUENCY (RF)

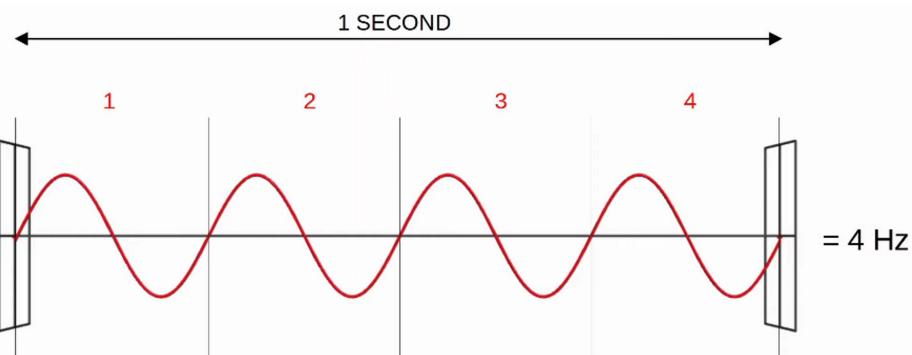
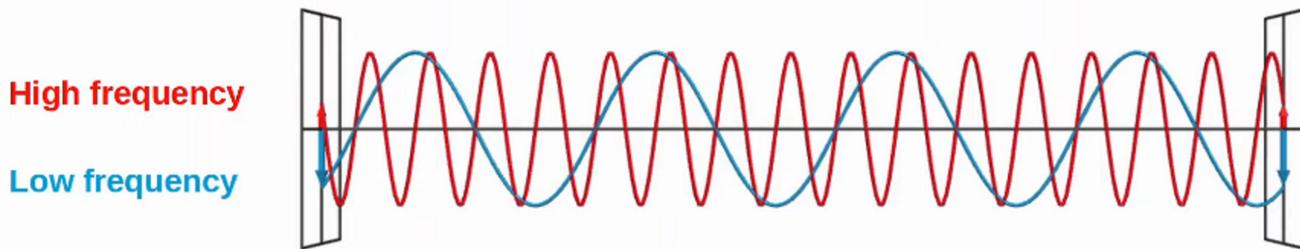
- To send WIRELESS SIGNALS, the SENDER applies an ALTERNATING CURRENT to an antenna
  - This creates ELECTROMAGNETIC WAVES which propagate out as WAVES
- ELECTROMAGNETIC WAVES can be measured in multiple ways - for example AMPLITUDE and FREQUENCY
- AMPLITUDE is the MAXIMUM STRENGTH of the ELECTRIC and MAGNETIC FIELDS



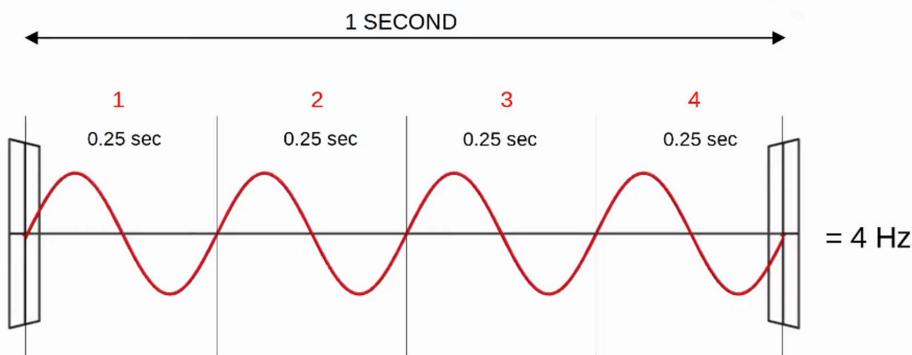
- FREQUENCY measures the number of UP / DOWN CYCLES per a GIVEN UNIT of TIME
- The most COMMON measurement of FREQUENCY is HERTZ
  - Hz (HERTZ) = cycles per second

- kHz (KILOHERZ) = 1,000 cycles per second
- MHz (MEGAHERZ) = 1,000,000 cycles per second
- GHz (GIGAHERTZ) = 1,000,000,000 cycles per second
- THz (TERAHERTZ) = 1,000,000,000,000 cycles per second

4 CYCLES per 1 SECOND = 4 HERTZ



- Another important term is PERIOD, the amount of TIME of ONE CYCLE
  - If the FREQUENCY is 4 Hz, the PERIOD is 0.25 SECONDS



- The VISIBLE FREQUENCY RANGE is ~400 THz to 790 THz
- The RADIO FREQUENCY RANGE is 30 Hz to 300 GHz and is used for many purposes.

|                      |     |    |                          |  |
|----------------------|-----|----|--------------------------|--|
| Ultra high frequency | UHF | 9  | 300–3,000 MHz<br>1–0.1 m | Television broadcasts, microwave oven, microwave devices/communications, radio astronomy, mobile phones, wireless LAN, Bluetooth, ZigBee, GPS and two-way radios such as land mobile, FRS and GMRS radios, amateur radio, satellite radio, Remote control Systems, ADSB. |
| Super high frequency | SHF | 10 | 3–30 GHz<br>100–10 mm    | Radio astronomy, microwave devices/communications, wireless LAN, DSRC, most modern radars, communications satellites, cable and satellite television broadcasting, DBS, amateur radio, satellite radio.  |

## RADIO FREQUENCY BANDS

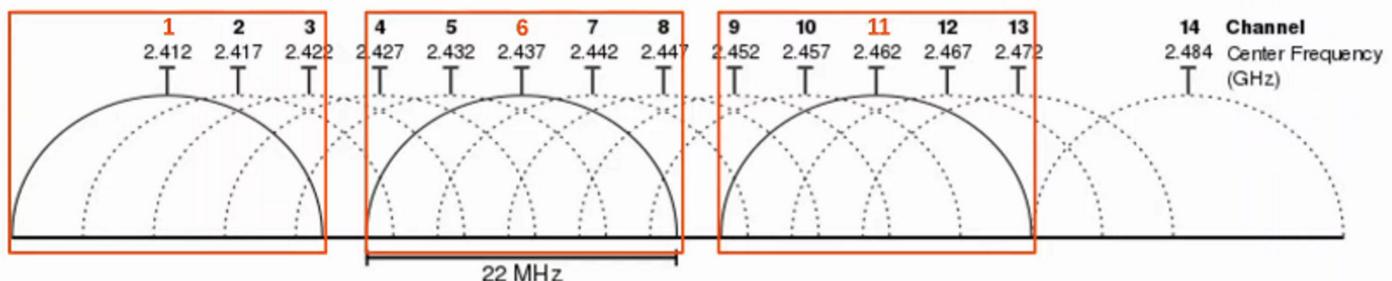
- WI-FI uses TWO MAIN BANDS (FREQUENCY RANGES)
- **2.4 GHz band**
  - Range is 2.400 - 2.4835 GHz

- **5 GHz band**

- Range is 5.150 - 5.825 GHz
- Divided into FOUR SMALLER BANDS:
  - 5.150 - 5.250 GHz
  - 5.250 - 5.350 GHz
  - 5.470 - 5.725 GHz
  - 5.725 - 5.825 GHz
- The 2.4 GHz band typically provides FURTHER REACH in open space and BETTER PENETRATION of obstacles such as walls.
- HOWEVER, more DEVICES tend to use the 2.4 GHz BAND so INTERFERENCE can be a BIGGER PROBLEM compared to 5GHz
- \*\* WI-FI 6 (802.11ax) has EXPANDED the spectrum range to include a band in the 6 GHz RANGE

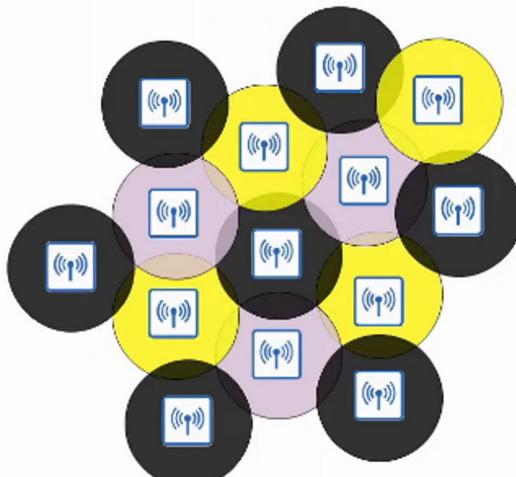
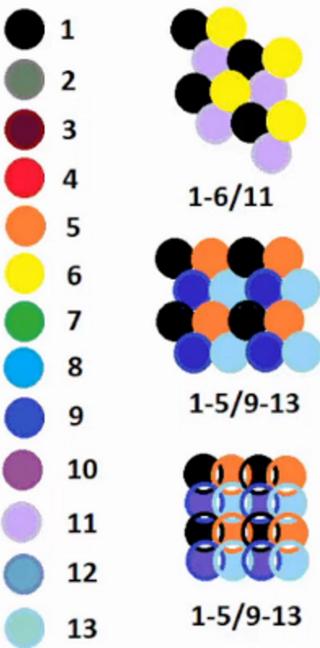
## CHANNELS

- Each BAND is divided up into MULTIPLE “CHANNELS”
  - DEVICES are configured to TRANSMIT and RECEIVE traffic on one (or more) of these CHANNELS
- The 2.4 GHz BAND is divided into several CHANNELS, each with a 22 MHz RANGE
- In a SMALL WIRELESS LAN with only a single ACCESS POINT (AP), you can use ANY channel
- However, in larger WLANs with multiple APs, it’s important that adjacent APs don’t use OVERLAPPING CHANNELS. This helps avoid INTERFERENCE
- In the 2.4 GHz BAND, it is recommended to use CHANNELS 1, 6 and 11



Outside of North America you could use other combinations, but for the CCNA exam remember **1, 6, and 11**.

- The 5 GHz BAND consists of NON-OVERLAPPING channels so it’s much EASIER to avoid INTERFERENCE between adjacent APs
- Using CHANNELS 1, 6, 11, you can place APs in a “HONEYCOMB” pattern to provide COMPLETE coverage of an area without INTERFERENCE between CHANNELS



## WI-FI STANDARDS (802.11)

| Standard | Frequencies     | Max Data Rate (theoretical) | Alternate Name |
|----------|-----------------|-----------------------------|----------------|
| 802.11   | 2.4 GHz         | 2 Mbps                      |                |
| 802.11b  | 2.4 GHz         | 11 Mbps                     |                |
| 802.11a  | 5 GHz           | 54 Mbps                     |                |
| 802.11g  | 2.4 GHz         | 54 Mbps                     |                |
| 802.11n  | 2.4 / 5 GHz     | 600 Mbps                    | 'Wi-Fi 4'      |
| 802.11ac | 5 GHz           | 6.93 Gbps                   | 'Wi-Fi 5'      |
| 802.11ax | 2.4 / 5 / 6 GHz | 4*802.11ac                  | Wi-Fi 6'       |

## SERVICE SETS

- 802.11 defines different kinds of SERVICE SETS which are groups of WIRELESS NETWORK DEVICES
- There are THREE MAIN TYPES:
  - INDEPENDENT
  - INFRASTRUCTURE
  - MESH
- ALL DEVICES in a SERVICE SET share the same SSID (Service Set Identifier)
- The SSID is a HUMAN-READABLE NAME which identifies the SERVICE SET
- The SSID does NOT have to be UNIQUE

## SERVICE SETS : IBSS

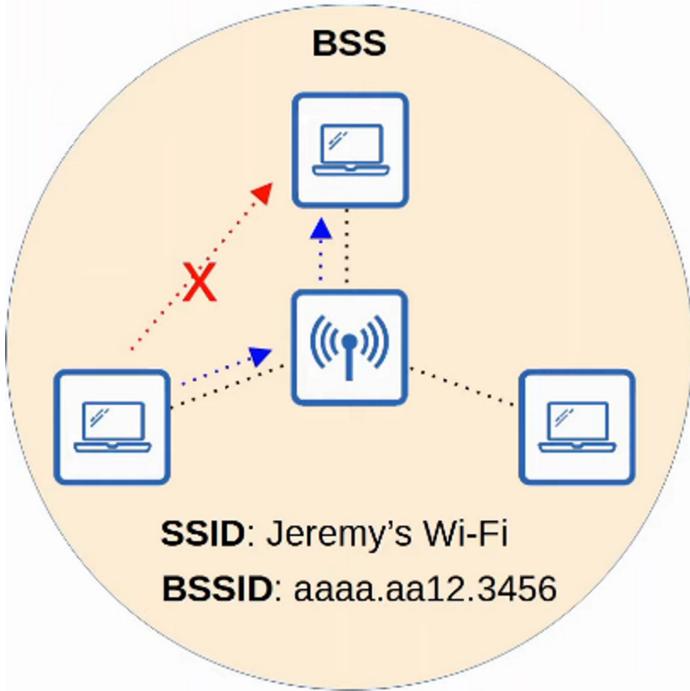
- An IBSS (INDEPENDENT BASIC SERVICE SET) is a WIRELESS NETWORK in which TWO or MORE WIRELESS DEVICES connect directly without using an AP (**ACCESS POINT**)
- Also called an AD HOC NETWORK

- Can be used for FILE TRANSFER (ie: AirDrop)
- Not scalable beyond a few DEVICES



### SERVICE SETS : BSS

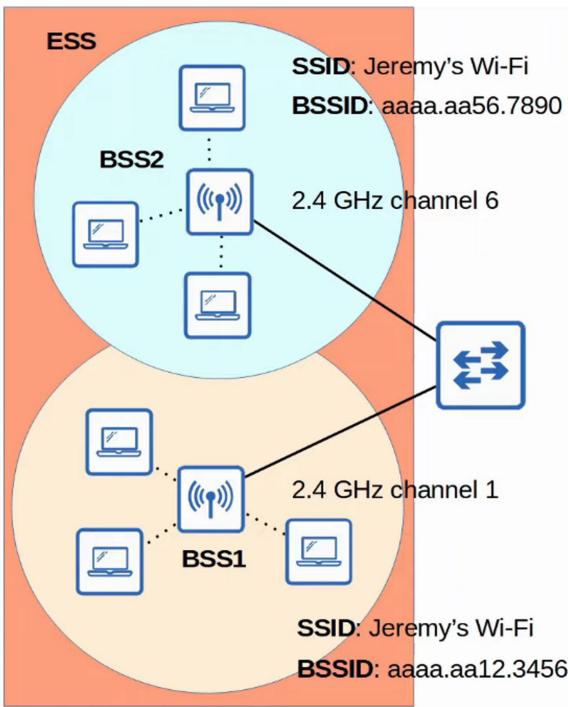
- A BSS (BASIC SERVICE SET) is a kind of infrastructure SERVICE SET in which CLIENTS connect to each other via an AP (ACCESS POINT) but not DIRECTLY to each other
- A BSSID (BASIC SERVICE SET ID) is used to uniquely identify the AP
  - Other APs can use the SAME SSID but NOT THE SAME BSSID
  - The BSSID is the MAC ADDRESS of the AP's RADIO
- WIRELESS DEVICES request to *associate* with the BSS
- WIRELESS DEVICES that have associated with the BSS are called “CLIENTS” or “STATIONS”
- The AREA around an AP where its SIGNAL is usable is called a BSA (BASIC SERVICE AREA)



### SERVICE SETS: ESS

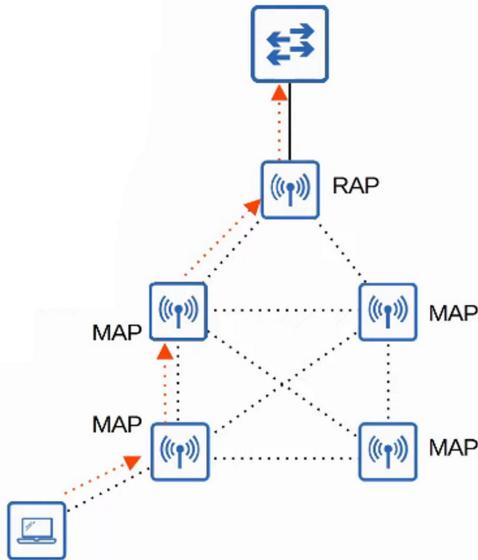
- To create LARGER WIRELESS LANs beyond the range of a SINGLE AP, we use an ESS (EXTENDED SERVICE SET)
- APs with their own BSSs are connected by a WIRED NETWORK
  - Each BSS uses the SAME SSID
  - Each BSS has a UNIQUE BSSID
  - Each BSS uses a DIFFERENT channel to avoid INTERFERENCE
- CLIENTS can pass between APs without having to RECONNECT, providing a SEAMLESS WI-FI experience when moving between APs

- This is called ROAMING
- The BSAs should overlap about 10-15%



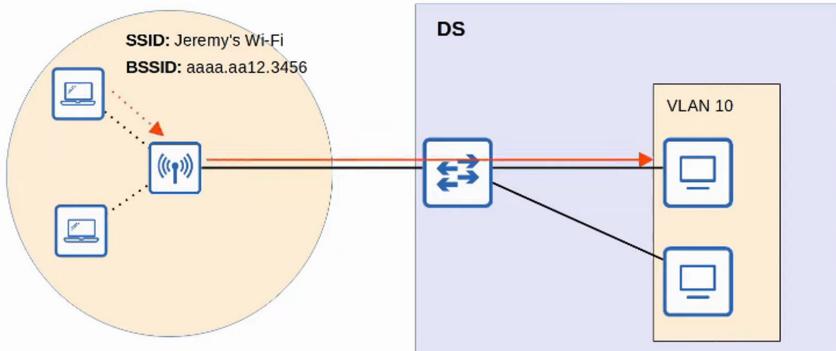
#### SERVICE SETS: MBSS

- An MBSS (MESH BASIC SERVICE SET) can be used in situations where it's difficult to run an ETHERNET connection to every AP
- MESH APs use TWO RADIOS:
  - ONE provides BSS to WIRELESS CLIENTS
  - ONE forms a “BACKHAUL NETWORK” which is used to BRIDGE traffic from AP to AP
- At least ONE AP is connected to the WIRED NETWORK and it is called the RAP (ROOT ACCESS POINT)
- The OTHER APs are called MAPs (MESH ACCESS POINTS)
- A PROTOCOL is used to determine the BEST PATH through the MESH (similar to how DYNAMIC ROUTING PROTOCOLS are used to determine the BEST PATH to a DESTINATION)

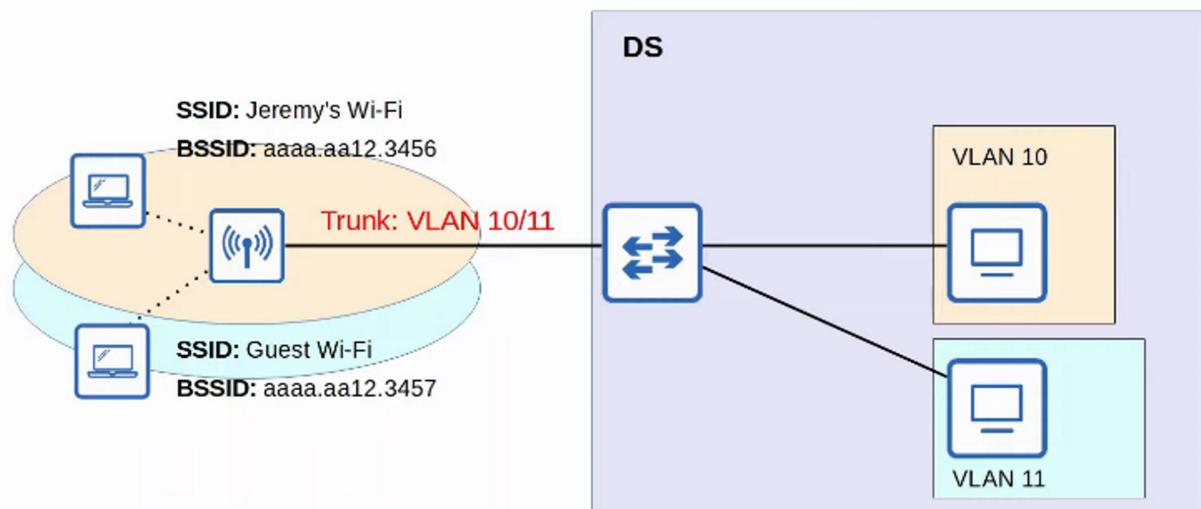


#### DISTRIBUTION SYSTEM

- Most WIRELESS NETWORKS are not STANDALONE NETWORKS
  - Rather, they are a way for WIRELESS CLIENTS to connect to the WIRED NETWORK INFRASTRUCTURE
- In 802.11, the UPSTREAM WIRED NETWORK is called the DS (DISTRIBUTION SYSTEM)
- Each WIRELESS BSS or ESS is mapped to a VLAN in the WIRED NETWORK

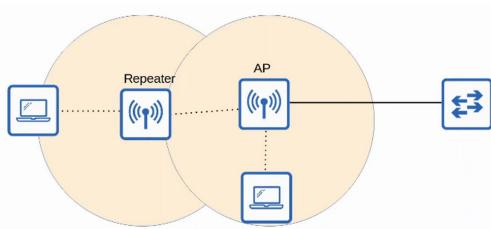


- It is possible for an AP to provide MULTIPLE WIRELESS LANs, each with a unique SSID
- Each WLAN is mapped to a separate VLAN and connected to the WIRED NETWORK via a TRUNK
- Each WLAN uses a UNIQUE BSSID, usually by INCREMENTING the LAST digit of the BBSID by one



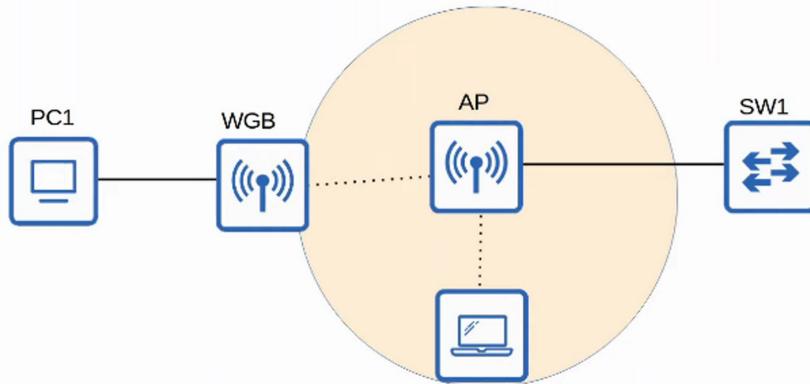
## ADDITIONAL AP OPERATIONAL MODES

- APs can operate in ADDITIONAL MODES beyond the ones we've introduced so far
- An AP in REPEATER MODE can be used to EXTEND the RANGE of a BSS
- The REPEATER will re-transmit ANY SIGNAL it receives from the AP
  - A REPEATER with a SINGLE RADIO must operate on the SAME CHANNEL as the AP, but this can drastically reduce the overall THROUGHPUT on the CHANNEL
  - A REPEATER with TWO RADIOS can receive on ONE CHANNEL and then retransmit on ANOTHER CHANNEL



- A WORKGROUP BRIDGE (WGB) operates as a WIRELESS CLIENT of another AP and can be used to CONNECT WIRED DEVICES to the WIRELESS NETWORK
- In the example below, PC1 does NOT have WIRELESS CAPABILITIES, and also DOES NOT have ACCESS to WIRED CONNECTIONS to SW1
- PC1 has a WIRED CONNECTION to the WGB, which has a WIRELESS CONNECTION to the AP

There are two kinds of WGBs:  
**Universal WGB (uWGB)** is an 802.11 standard that allows one device to be bridged to the wireless network.  
**WGB** is a Cisco-proprietary version of the 802.11 standard that allows multiple wired clients to be bridged to the wireless network.



- AN OUTDOOR BRIDGE can be used to connect NETWORKS over LONG DISTANCES without a PHYSICAL CABLE connecting them
- The APs will use SPECIALIZED ANTENNAS that focus most of the SIGNAL POWER in one direction, which allows the WIRELESS CONNECTION to be made over LONGER DISTANCES than normally possible
- The CONNECTION can be POINT-TO-POINT as in the diagram below, or POINT-TO-MULTIPOINT in which MULTIPLE SITES connect to one CENTRAL SITE

