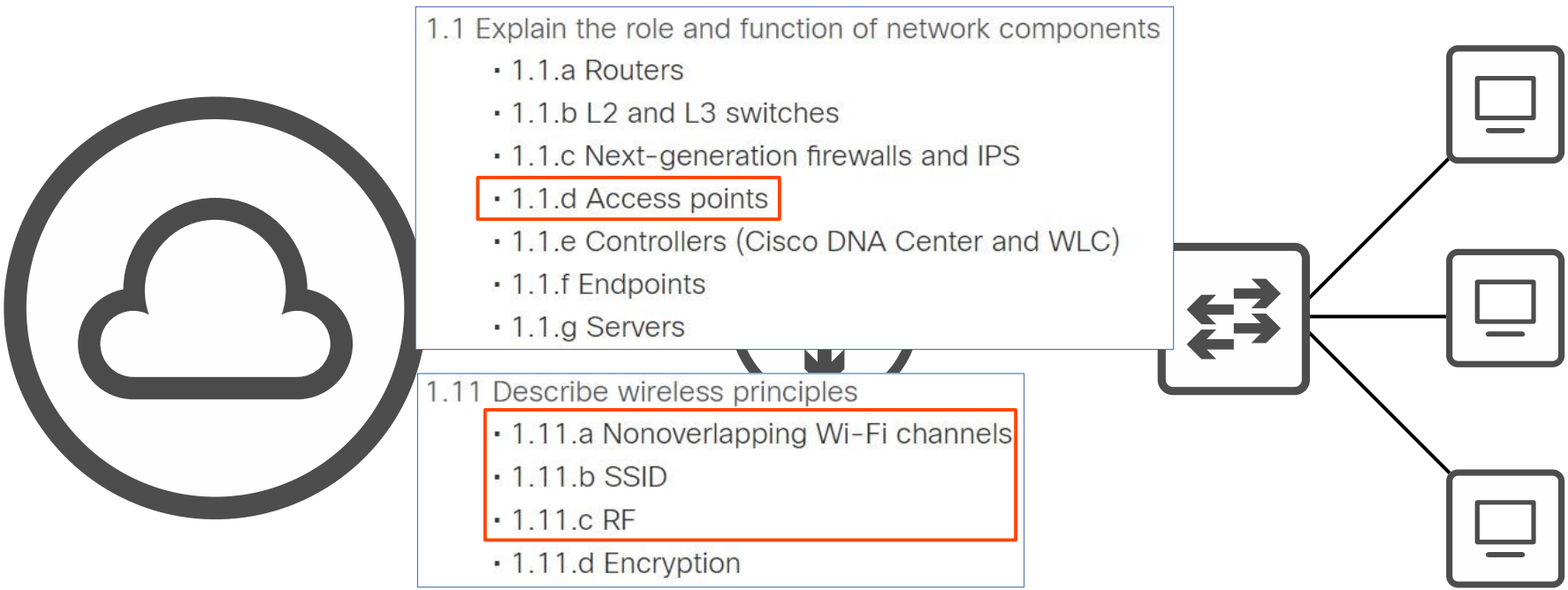
JEREMY'S IT LAB

CCNA Day 55

Wireless Fundamentals



Things we'll cover

- Radio Frequency (RF)
- Wi-Fi Standards
- Wireless LAN Fundamentals

Wireless Networks

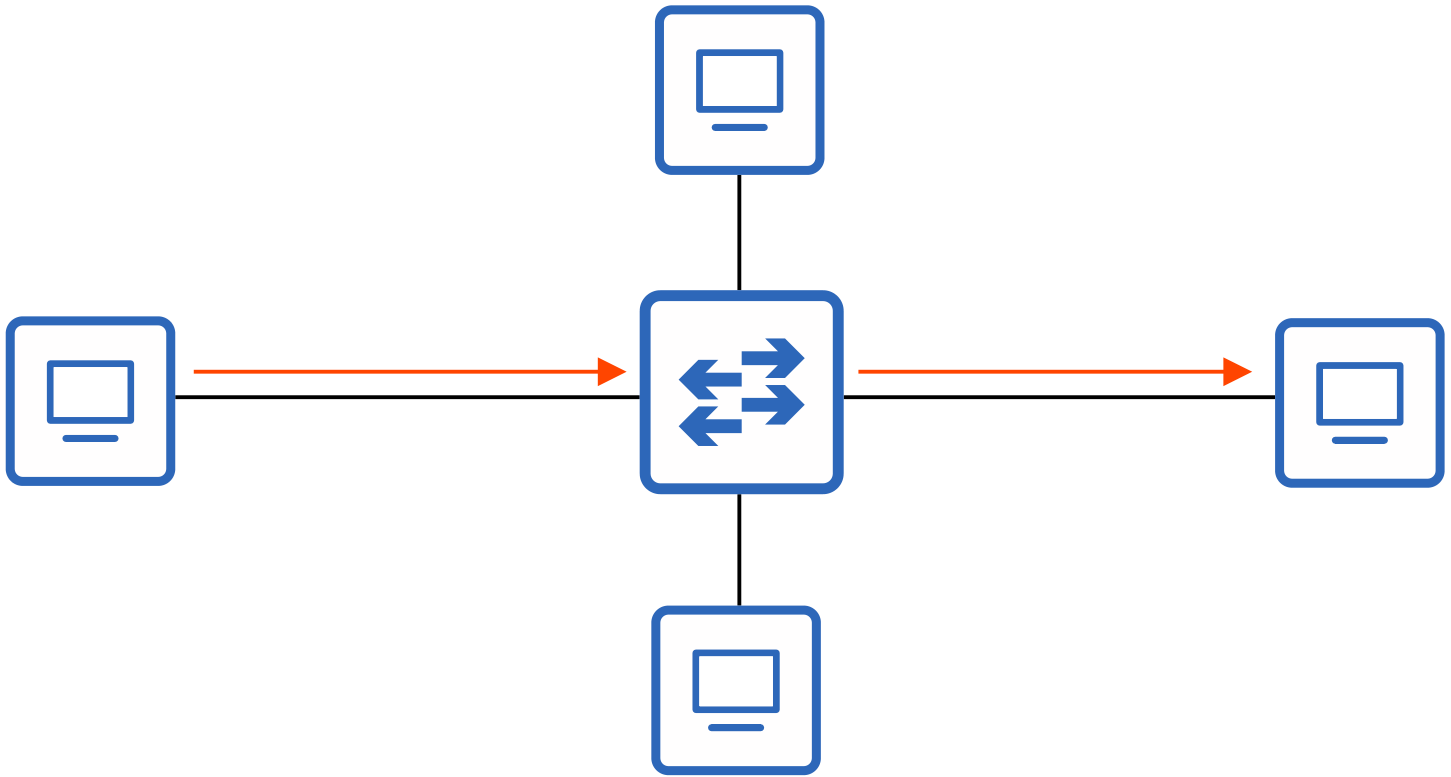
- Although we will briefly look at other types of wireless networks, in this section of the course we will be focusing on wireless LANs using Wi-Fi.
- The standards we use for wireless LANs are defined in IEEE 802.11.
- The term **Wi-Fi** is a trademark of the **Wi-Fi Alliance**, not directly connected to the IEEE.
- The Wi-Fi Alliance tests and certifies equipment for 802.11 standards compliance interoperability with other devices.
- However, Wi-Fi has become the common term that people use to refer to 802.11 wireless LANs, and I will use both terms throughout these videos.

Wi Fi CERTIFIED

Wireless Networks

- Wireless networks have some issues that we need to deal with.

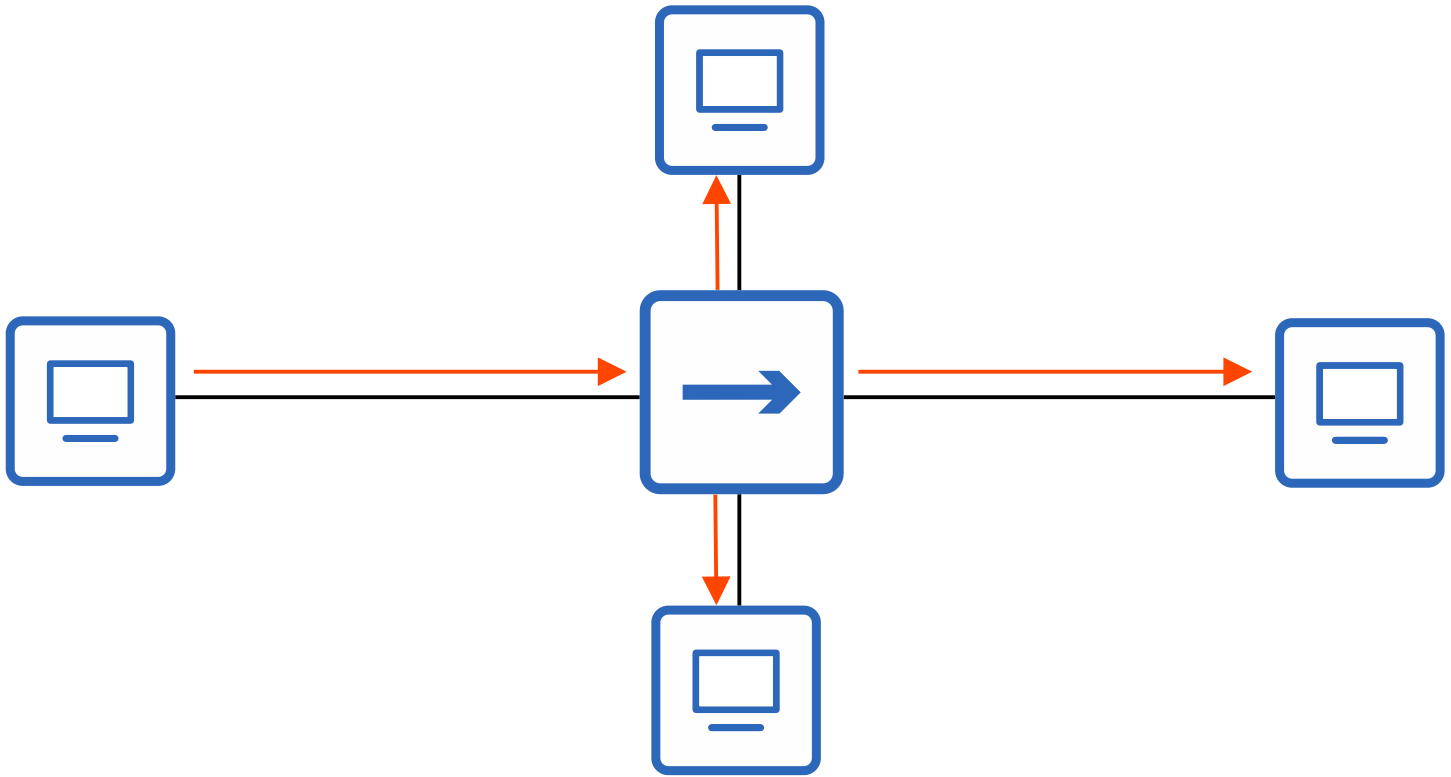
1) All devices within range receive all frames, like devices connected to an Ethernet hub.



Wireless Networks

- Wireless networks have some issues that we need to deal with.

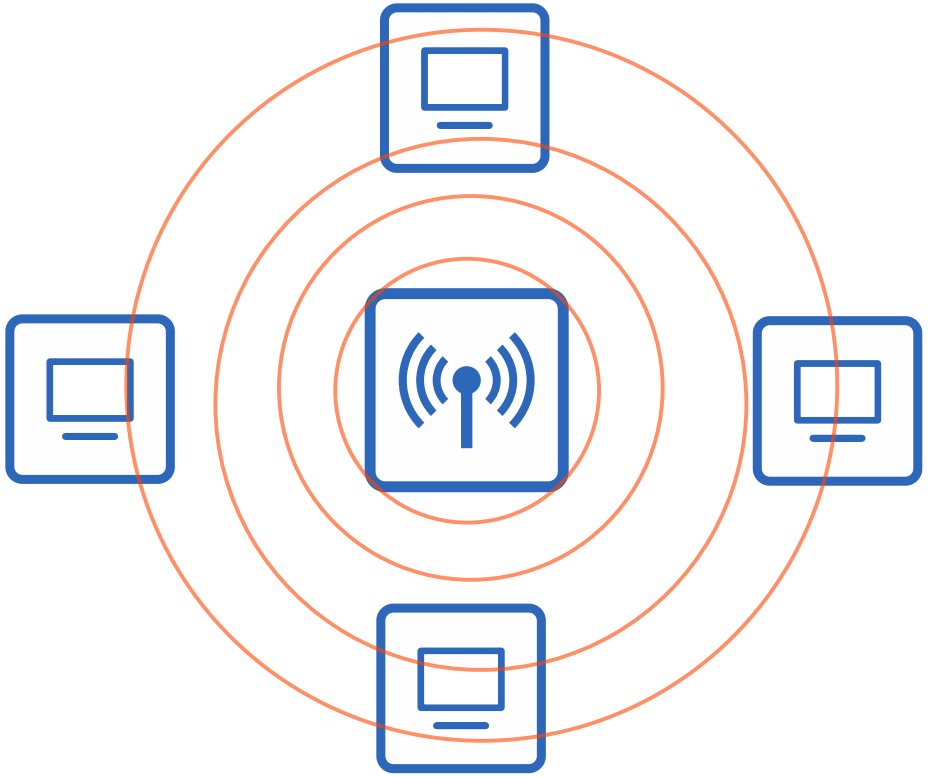
1) All devices within range receive all frames, like devices connected to an Ethernet hub.



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.



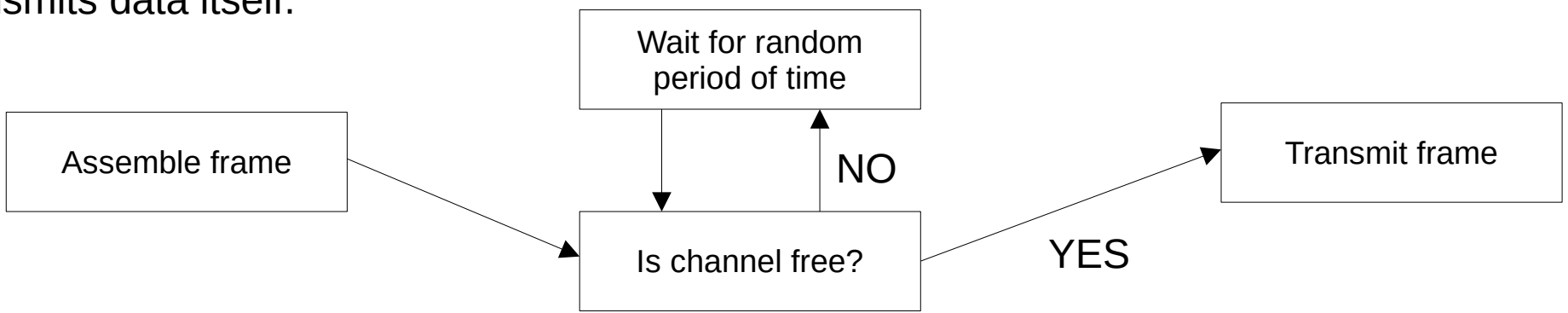
Wireless Networks

- 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.



Wireless Networks

- Wireless networks have some issues that we need to deal with.

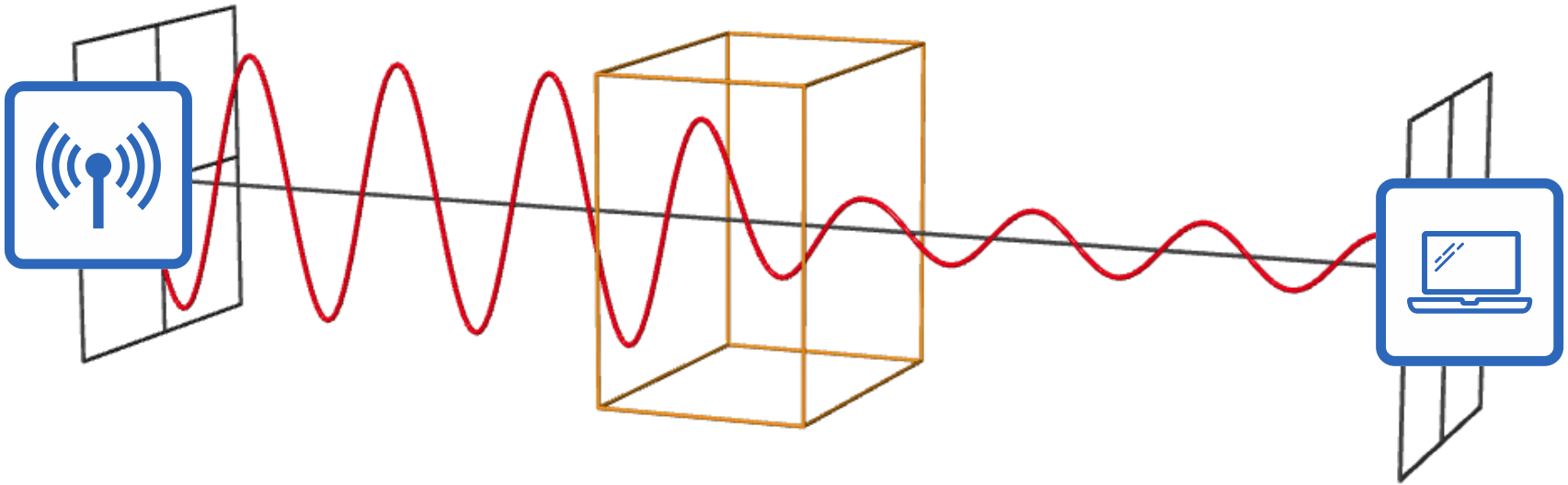
1) All devices within range receive all frames, like devices connected to an Ethernet hub.
   → Privacy of data within the LAN is a greater concern.
   → CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) is used to facilitate half-duplex communications.

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

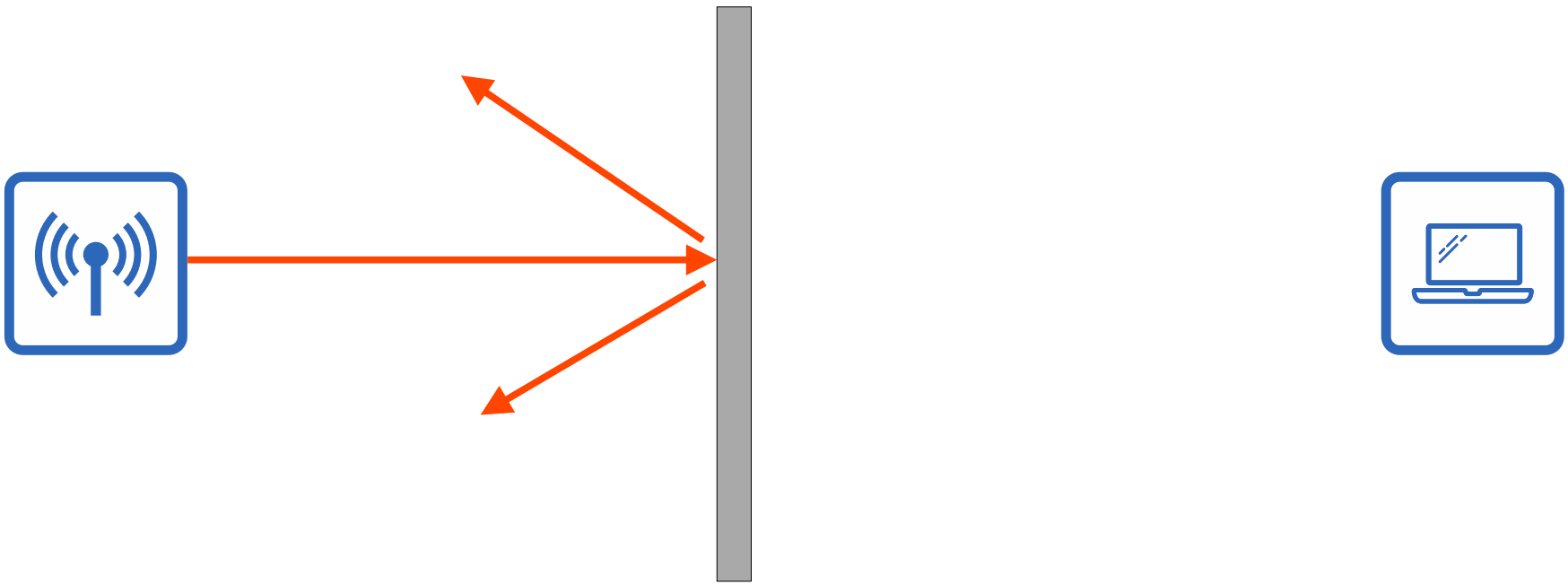
- **Absorption** happens when a wireless signal passes through a material and is converted into heat, weakening the original signal.



https://emanim.szialab.org/

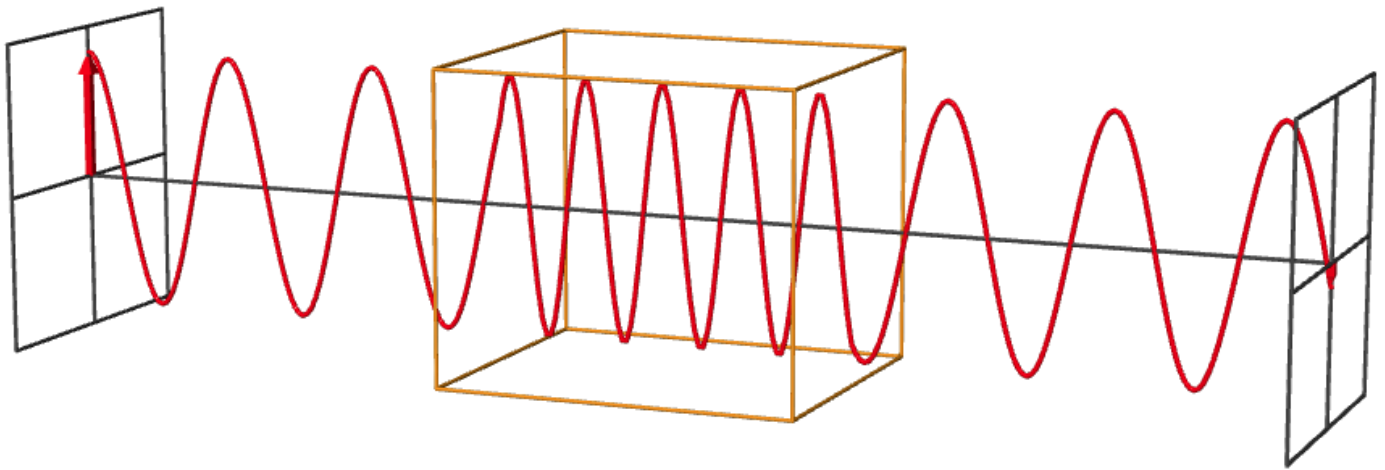
Signal Reflection

- **Reflection** happens when a signal bounces off of a material, for example 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.



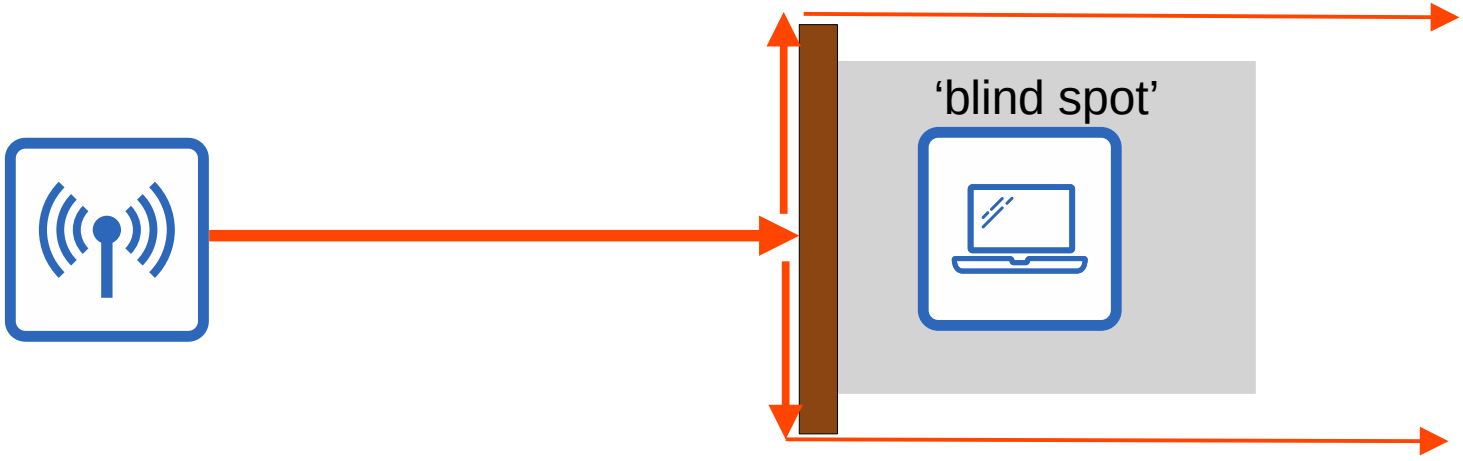
Signal Refraction

- **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.



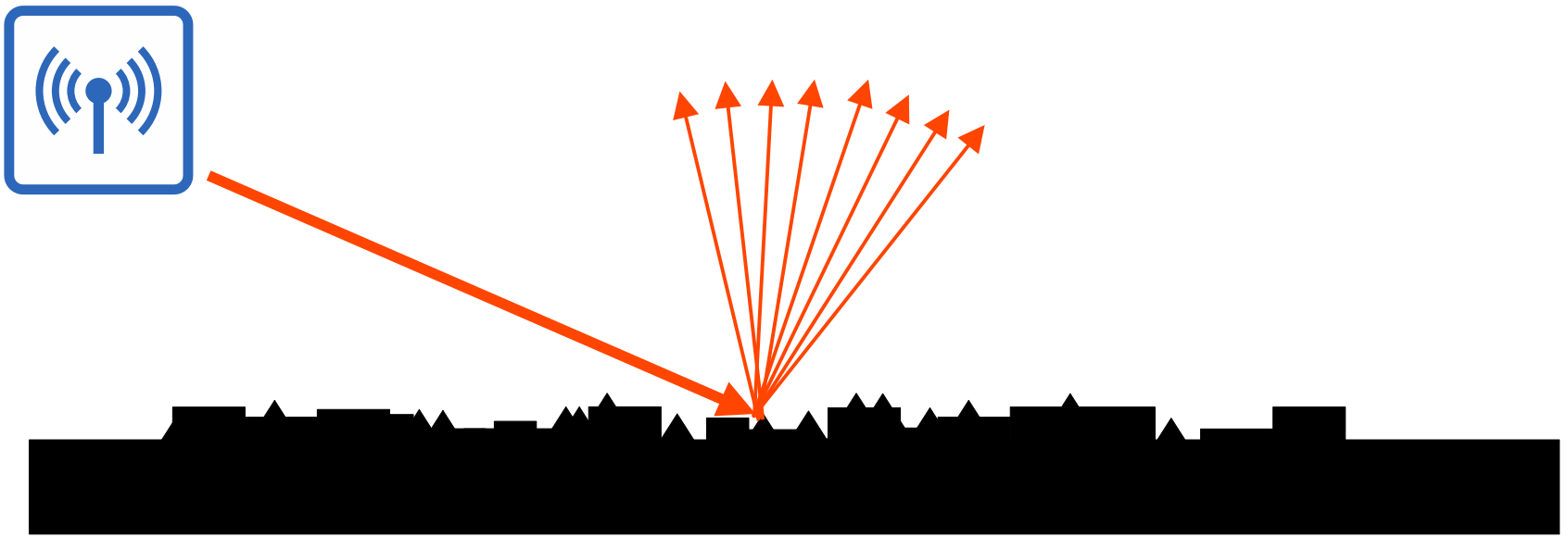
Signal Diffraction

- **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, etc. can cause scattering.



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.

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**.

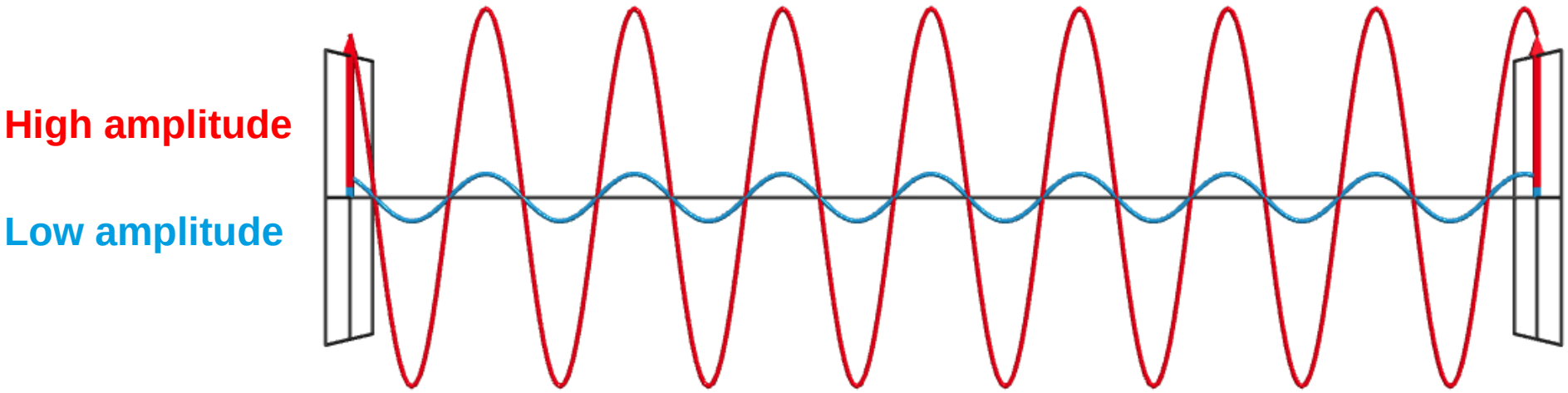
4) Other devices using the same channels can cause interference.
   → For example, a wireless LAN in your neighbor's house/apartment.

Radio Frequency

- To send wireless signals, the sender applies an alternating current to an antenna.
  → This creates electromagnetic fields 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.



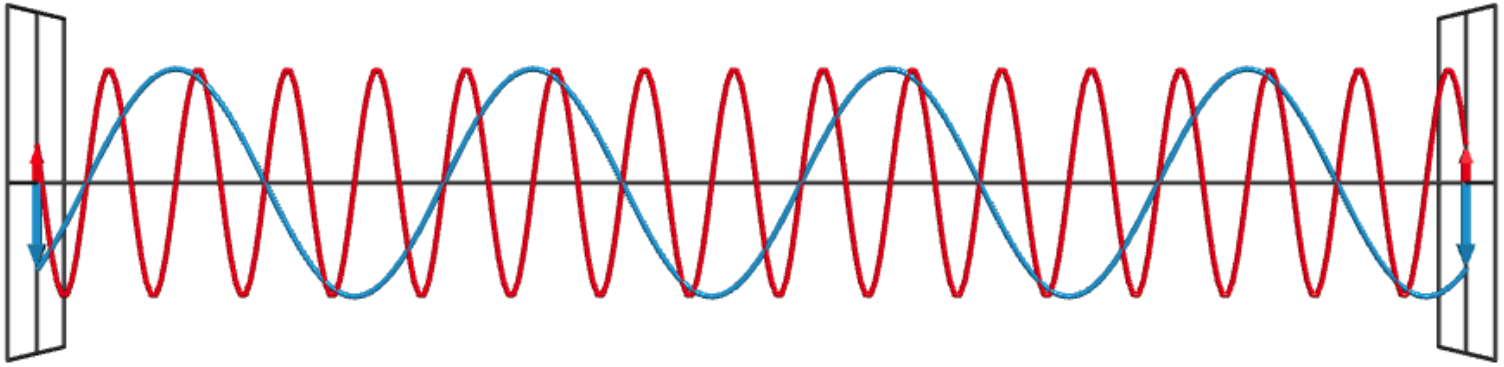
Radio Frequency

- **Frequency** measures the number of up/down cycles per a given unit of time.

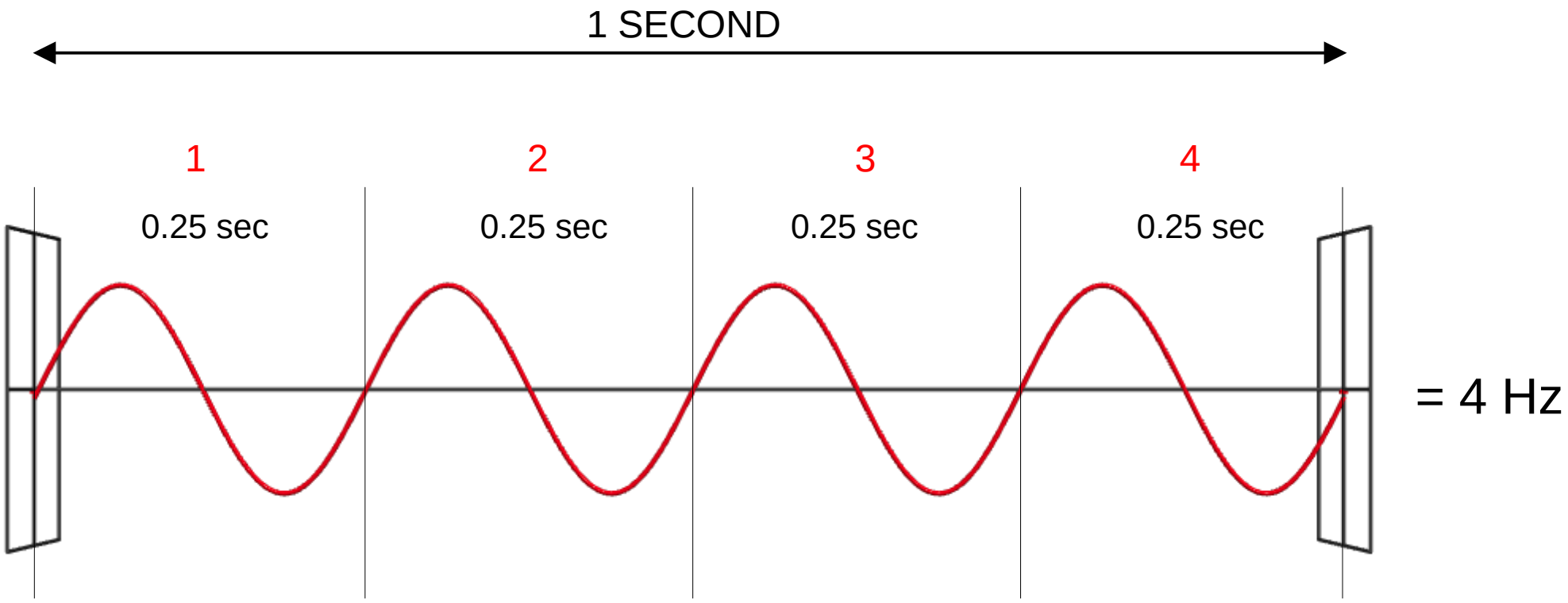
- The most common measurement of frequency is **hertz**.
  - → Hz (Hertz) = cycles per second
  - → kHz (Kilohertz) = 1,000 cycles per second
  - → MHz (Megahertz) = 1,000,000 cycles per second
  - → GHz (Gigahertz) = 1,000,000,000 cycles per second
  - → THz (Terahertz) = 1,000,000,000,000 cycles per second

High frequency

Low frequency



Radio Frequency



- Another important term is **period**, the amount of time of one cycle.
  → If the **frequency** is 4 Hz, the **period** is 0.25 seconds.

Radio Frequency

- The visible frequency range is about 400 THz to 790 THz.
- The radio frequency range is from 30 Hz to 300 GHz and is used for many purposes.

Band name	Abbreviation	ITU band number	Frequency and Wavelength	Example Uses
Extremely low frequency	ELF	1	3–30 Hz 100,000–10,000 km	Communication with submarines
Super low frequency	SLF	2	30–300 Hz 10,000–1,000 km	Communication with submarines
Ultra low frequency	ULF	3	300–3,000 Hz 1,000–100 km	Submarine communication, communication within mines
Very low frequency	VLF	4	3–30 kHz 100–10 km	Navigation, time signals, submarine communication, wireless heart rate monitors, geophysics
Low frequency	LF	5	30–300 kHz 10–1 km	Navigation, time signals, AM longwave broadcasting (Europe and parts of Asia), RFID, amateur radio
Medium frequency	MF	6	300–3,000 kHz 1,000–100 m	AM (medium-wave) broadcasts, amateur radio, avalanche beacons
High frequency	HF	7	3–30 MHz 100–10 m	Shortwave broadcasts, citizens band radio, amateur radio and over-the-horizon aviation communications, RFID, over-the-horizon radar, automatic link establishment (ALE) / near-vertical incidence skywave (NVIS) radio communications, marine and mobile radio telephony
Very high frequency	VHF	8	30–300 MHz 10–1 m	FM, television broadcasts, line-of-sight ground-to-aircraft and aircraft-to-aircraft communications, land mobile and maritime mobile communications, amateur radio, weather radio
Ultra high frequency	UHF	9	300–3,000 MHz 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 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.
Extremely high frequency	EHF	11	30–300 GHz 10–1 mm	Radio astronomy, high-frequency microwave radio relay, microwave remote sensing, amateur radio, directed-energy weapon, millimeter wave scanner, Wireless Lan 802.11ad.
Terahertz or Tremendously high frequency	THz or THF	12	300–3,000 GHz 1–0.1 mm	Experimental medical imaging to replace X-rays, ultrafast molecular dynamics, condensed-matter physics, terahertz time-domain spectroscopy, terahertz computing/communications, remote sensing

Radio Frequency Bands

- Wi-Fi uses two main *bands* (frequency ranges)

- **2.4 GHz** band
  → The actual range is **2.400 GHz** to **2.4835 GHz**

- **5 GHz** band
  → The actual range is from **5.150 GHz** to **5.825 GHz**
  → Divided into four smaller bands: **5.150 GHz** to **5.250 GHz**
  5.250 GHz to **5.350 GHz**
  5.470 GHz to **5.725 GHz**
  5.725 GHz to **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 the 5 GHz band.

- *__Wi-Fi 6__ (802.11ax)has expanded the spectrum range to include a band in the **6 GHz** range.

Channels

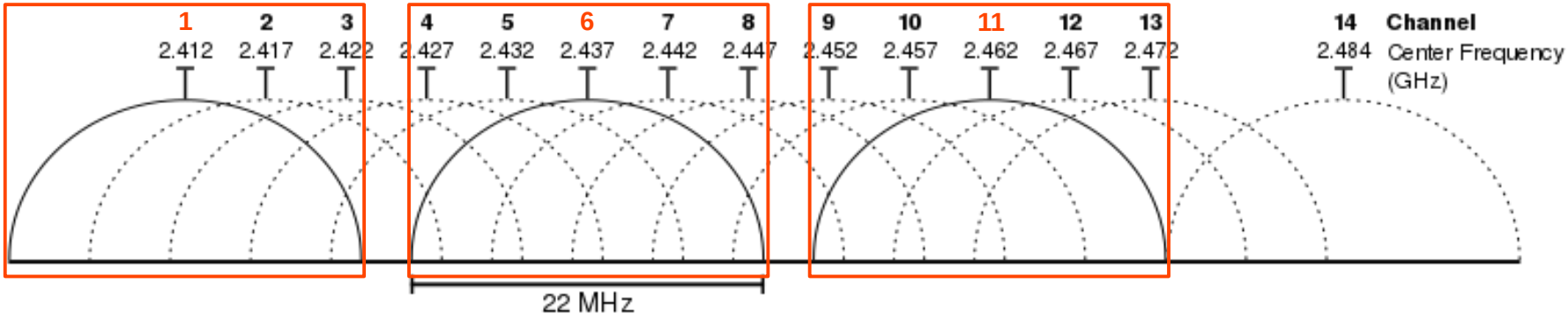
- Each band is divided up into multiple ‘channels’.
  → Devices are configured to transmit and receive traffic on one (or more) of these channels.

- The 2.4 GHz band is divided into several channels, each with a 22 MHz range.

Channel	F_0 (MHz)	Frequency Range (MHz)	North America[8]	Japan [8]	Most of world [8][9][10][11] [12][13][14][15]
1	2412	2401–2423	Yes	Yes	Yes
2	2417	2406–2428	Yes	Yes	Yes
3	2422	2411–2433	Yes	Yes	Yes
4	2427	2416–2438	Yes	Yes	Yes
5	2432	2421–2443	Yes	Yes	Yes
6	2437	2426–2448	Yes	Yes	Yes
7	2442	2431–2453	Yes	Yes	Yes
8	2447	2436–2458	Yes	Yes	Yes
9	2452	2441–2463	Yes	Yes	Yes
10	2457	2446–2468	Yes	Yes	Yes
11	2462	2451–2473	Yes	Yes	Yes
12	2467	2456–2478	No[B] except CAN	Yes	Yes
13	2472	2461–2483	No[B]	Yes	Yes
14	2484	2473–2495	No	11b only[C]	No

Channels

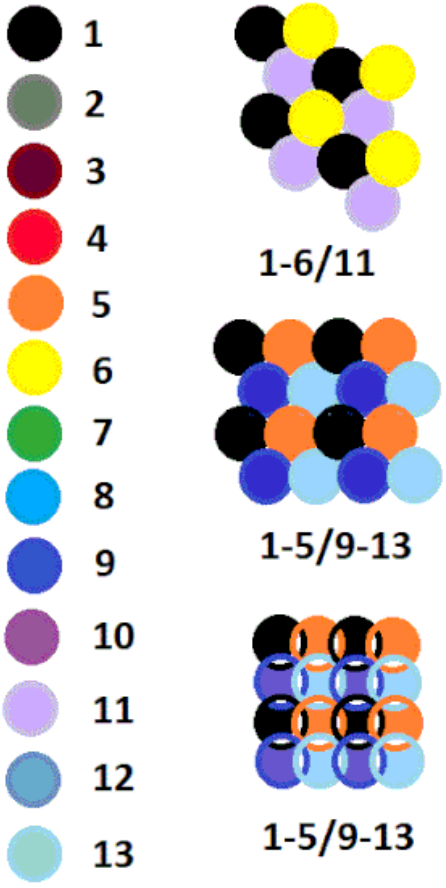
- In a small wireless LAN with only a single AP, you can use any channel.
- However, in larger WLANs with multiple APs, it's important that adjacent APs don't use overlapping channels. This helps avoid interference.
- In the 2.4 GHz band, it is recommended to use channels **1, 6, and 11**.

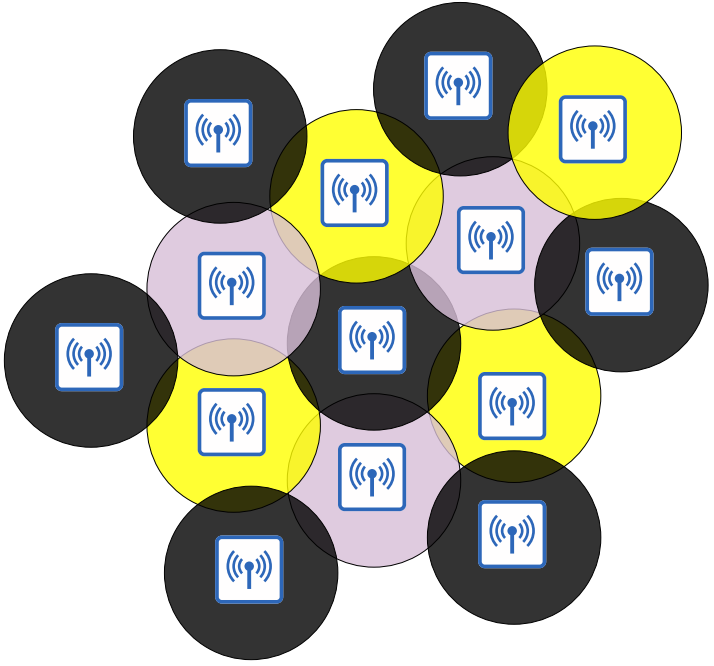


- Outside of North America you could use other combinations, but for the CCNA exam remember **1, 6, and 11**.
- The 5 GHz band consists of non-overlapping channels, so it is much easier to avoid interference between adjacent APs.

Channels

- Using channels 1, 6, and 11, you can place APs in a ‘honeycomb’ pattern to provide complete coverage of an area without interference between channels.





802.11 Standards

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’

Wi-Fi specifications for iPhone X

The table below details the Wi-Fi specifications for all iPhone X models: iPhone X, iPhone XR, iPhone Xs, and iPhone Xs Max.

802.11 standard, name, frequency	Maximum PHY data rate	Maximum channel bandwidth	Maximum MCS index	Maximum spatial streams
ac@5 GHz	866 Mbps	80 MHz	9 (VHT)	2/MIMO
a/n@5 GHz	300 Mbps	40 MHz	7 (HT)	2/MIMO
b/g/n@2.4 GHz	144 Mbps	20 MHz	7 (HT)	2/MIMO

Service Sets

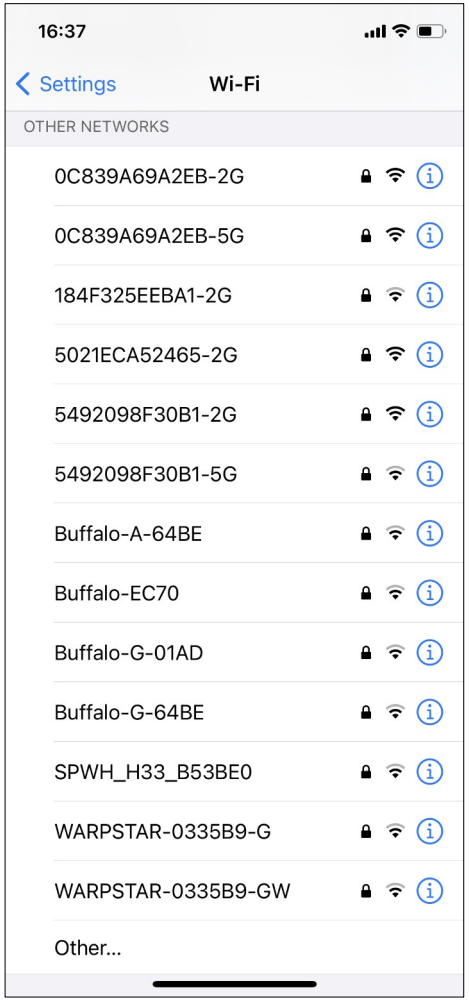
- 802.11 defines different kinds of **service sets** which are groups of wireless network devices.

- There are three main types:
  → Independent
  → Infrastructure
  → Mesh

- All devices in a service set share the same **SSID** (**service set identifier**).

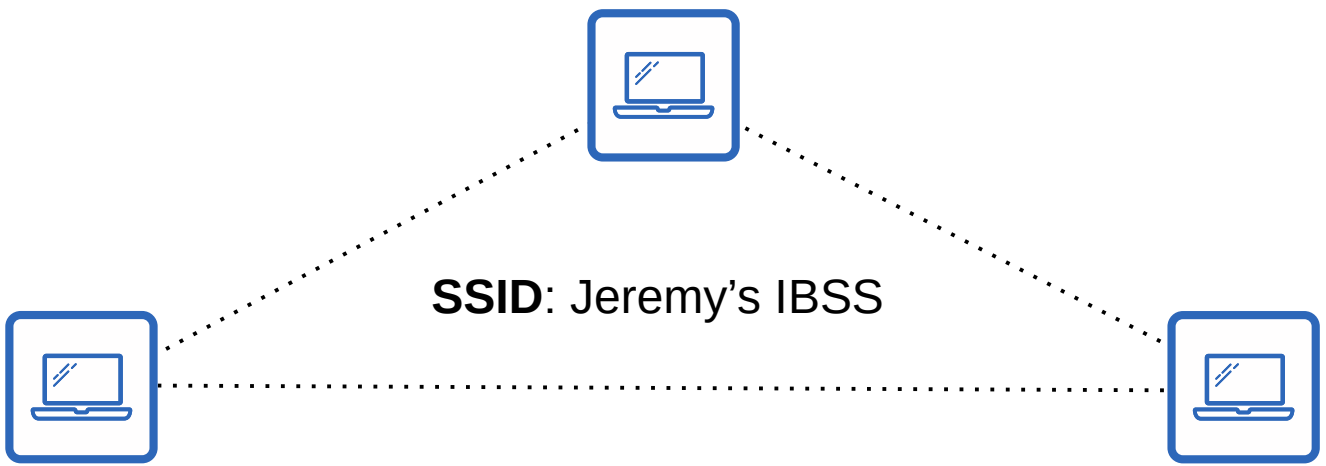
- The SSID is a human-readable name which identifies the service set.

- The SSID does **not** have to be unique.



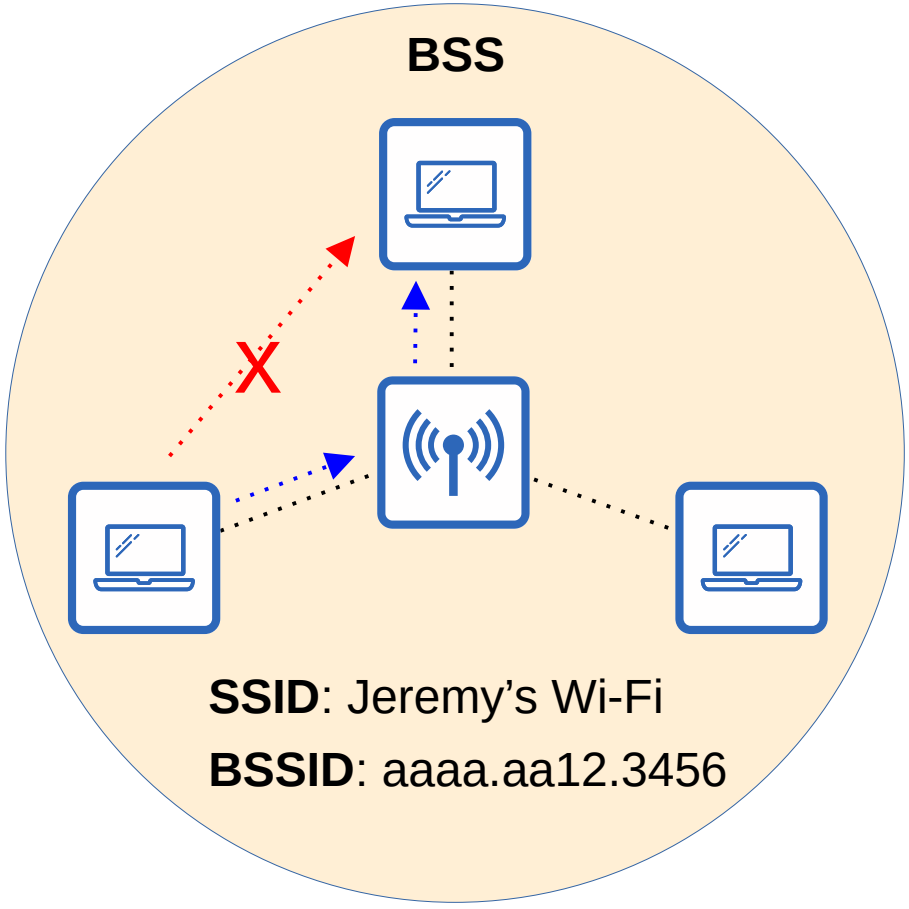
Service Sets: IBSS

- 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**).
- *Clients must communicate via the AP, not directly with each other.



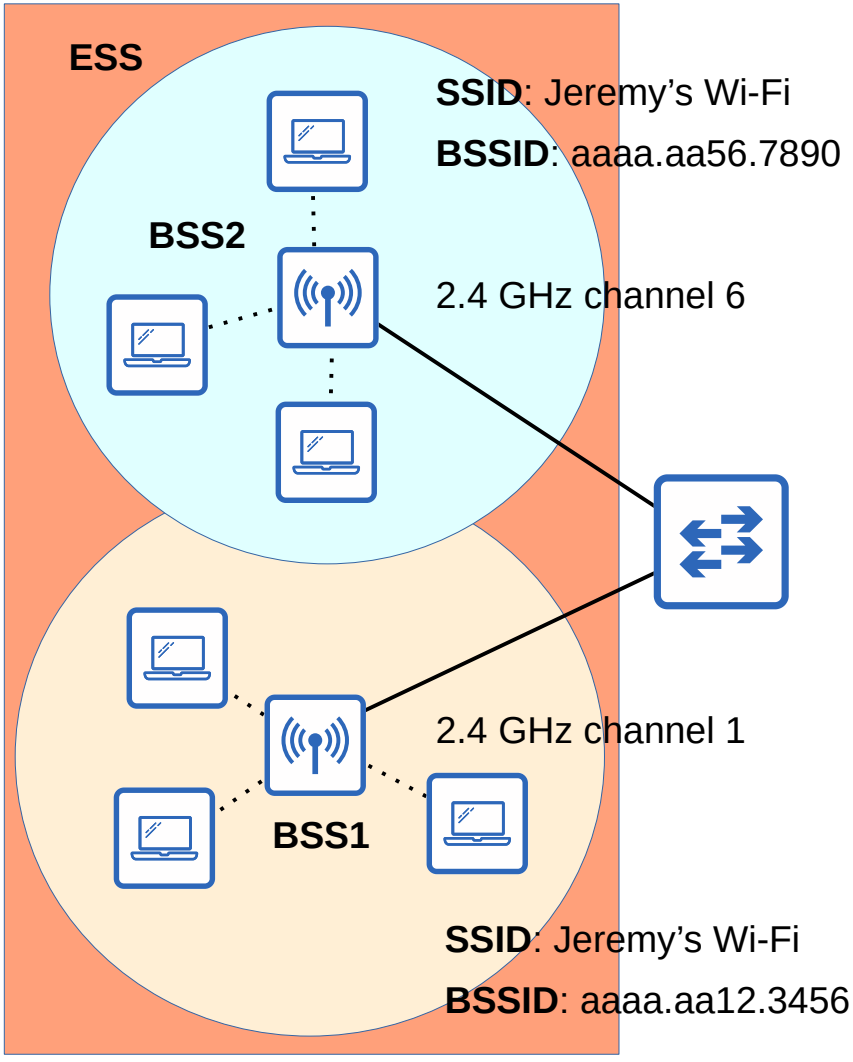
Service Sets: ESS

- 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.

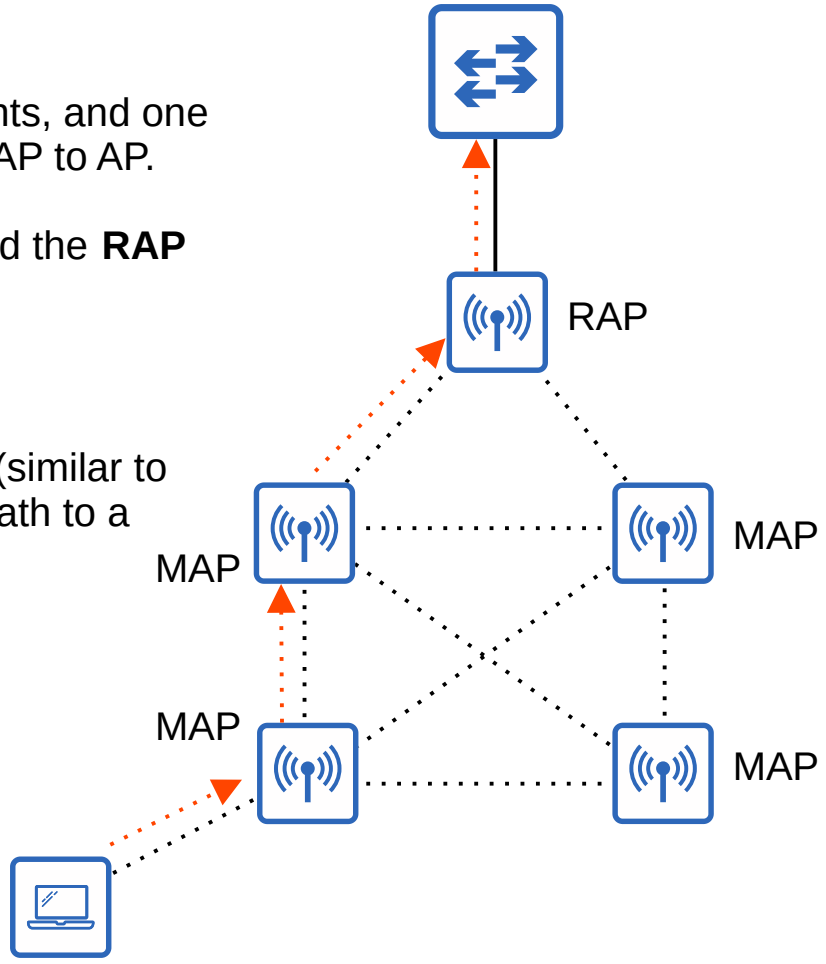
- Clients can pass between APs without having to reconnect, providing a seamless Wi-Fi experience when moving between APs.
  → This is called **roaming**.

- The BSAs should overlap about 10-15%.



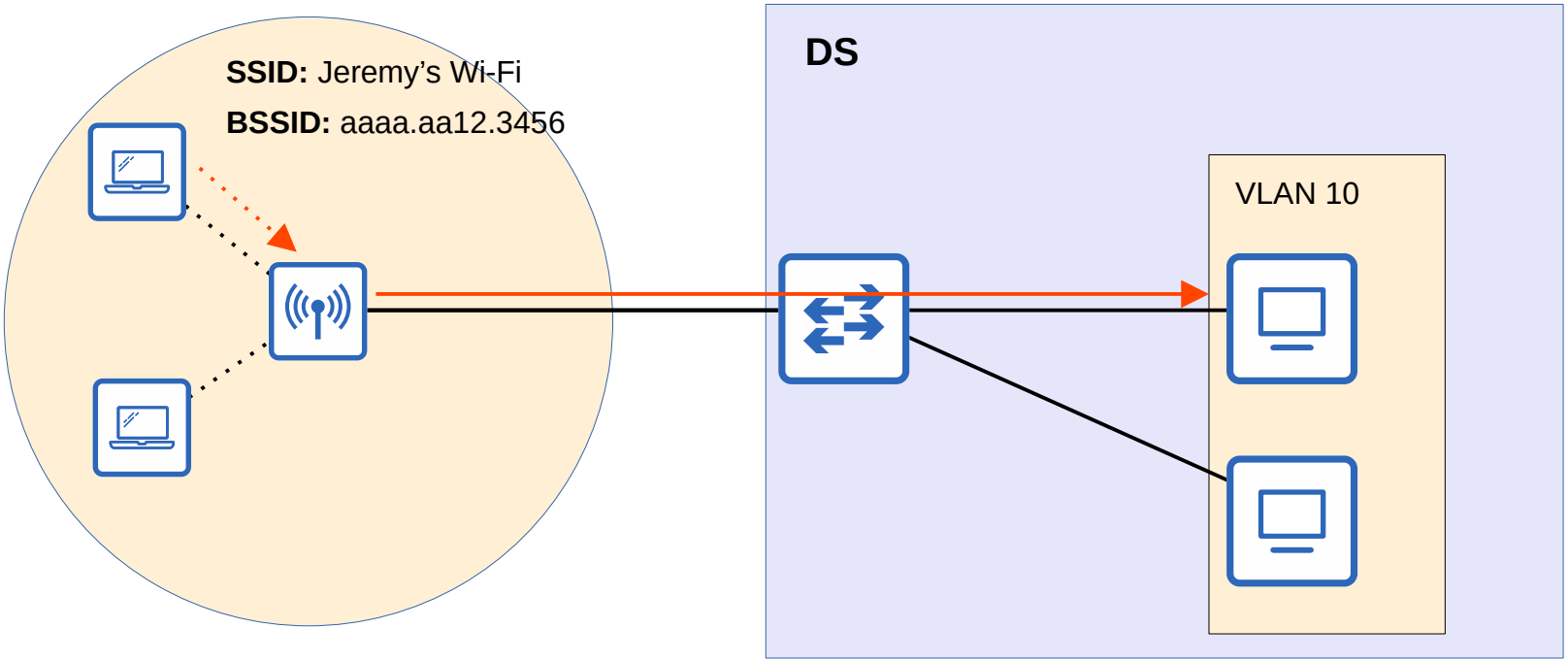
Service Sets: MBSS

- 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 to provide a BSS to wireless clients, and one to form 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 **MAP**s (**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).



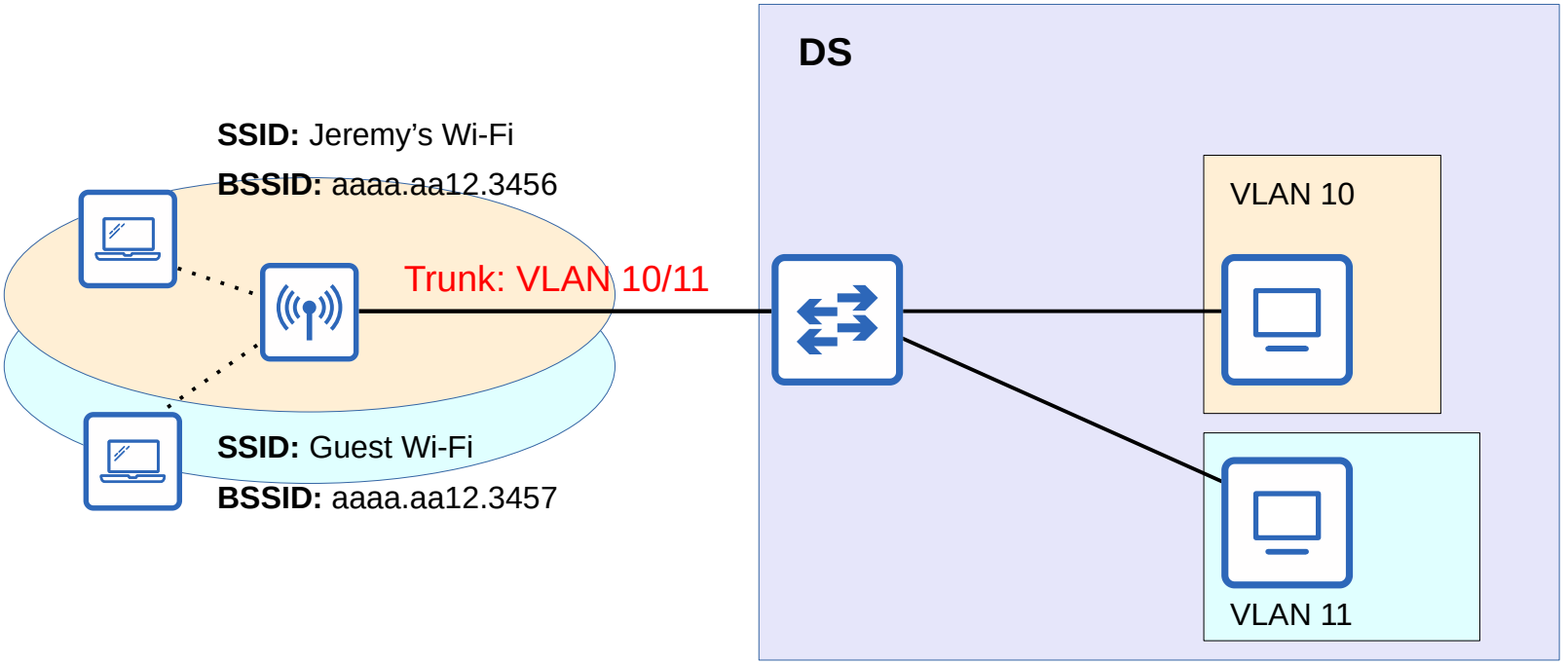
Distribution System

- Most wireless networks aren't 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.



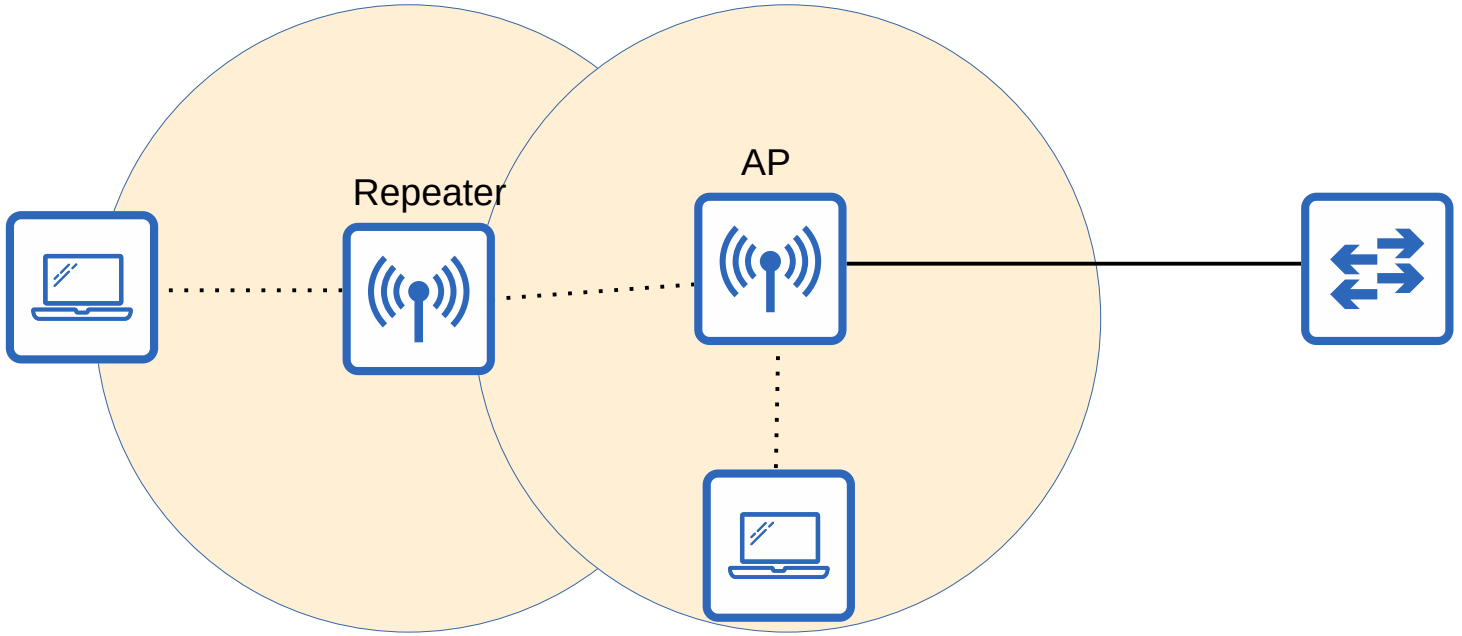
Distribution System

- It's 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 BSSID 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 simply retransmit 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.

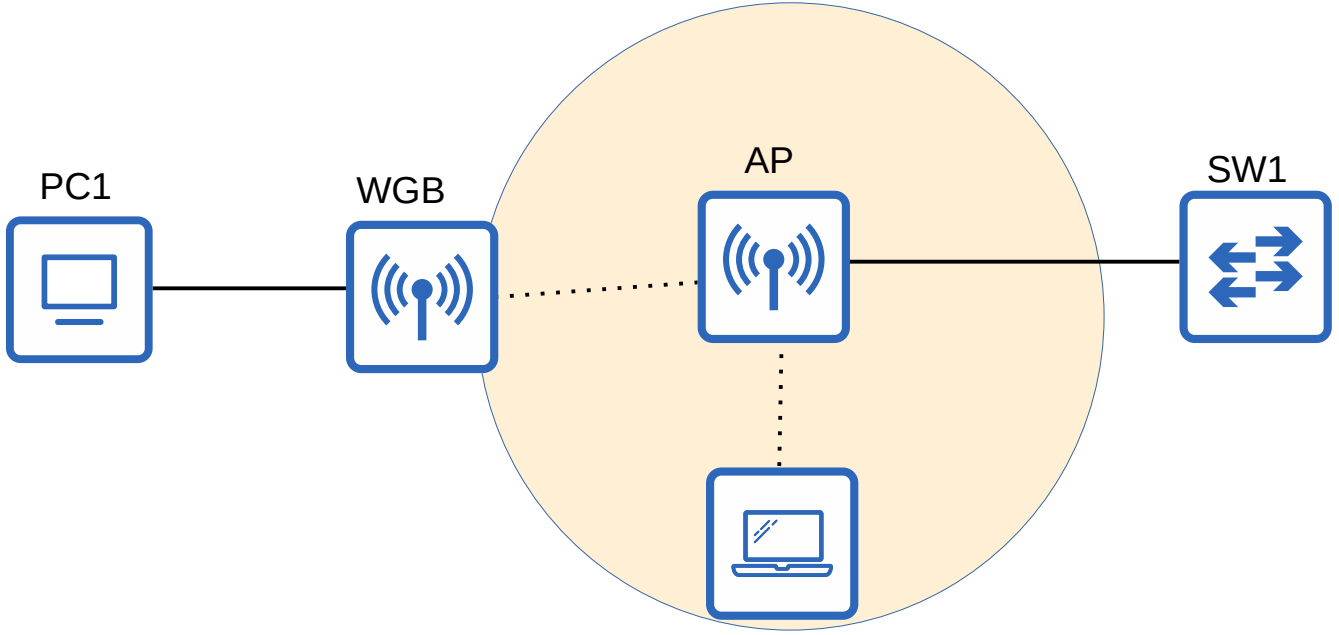


Additional AP Operational Modes

- 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 a wired connection 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.



Additional AP Operational Modes

- 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.

Review

- Wireless LANs are defined in 802.11.
- Operate in half duplex using CSMA/CA
- Wireless signals can be affected by **absorption, reflection, refraction, diffraction, and scattering.**
- Various aspects of waves can be measured, such as **amplitude, frequency,** and **period.**
- Frequency is measured in **hertz** (Hz).
- Wireless LANs use two frequency ranges: the **2.4 GHz** band and **5 GHz** band.
  → Wi-Fi 6 (802.11ax) can use the **6 GHz** range too.
- Bands are divided into channels.
- 5 GHz band consists of non-overlapping channels.
- 2.4 GHz band channels overlap. To avoid overlapping, use channels 1, 6, and 11 (in North America).
- 802.11 standards (802.11b, 802.11a, etc) and their frequencies/theoretical max data rates.
- Service sets are groups of wireless devices. Three types:
  → Independent (**IBSS**, also called **ad hoc**)
  → Infrastructure (**BSS**, **ESS**)
  *passing between APs in an ESS is called **roaming**.
  → Mesh (**MBSS**)
- Service sets are identified by an **SSID** (non-unique, human-readable) and **BSSID** (unique, MAC address of AP).
- The area around an AP where its signal is usable is called a **BSA**.
- The upstream wired network is called the **DS**.
- When multiple WLANs are used, each is mapped to a separate VLAN on the wired network.
- APs can also operate as a **repeater**, **workgroup bridge**, or **outdoor bridge**.

*Although this summarizes the topics in this video, make sure you know the details of each topic that we covered.

Things we covered

- Radio Frequency (RF)
- Wi-Fi Standards
- Wireless LAN Fundamentals

Quiz 1

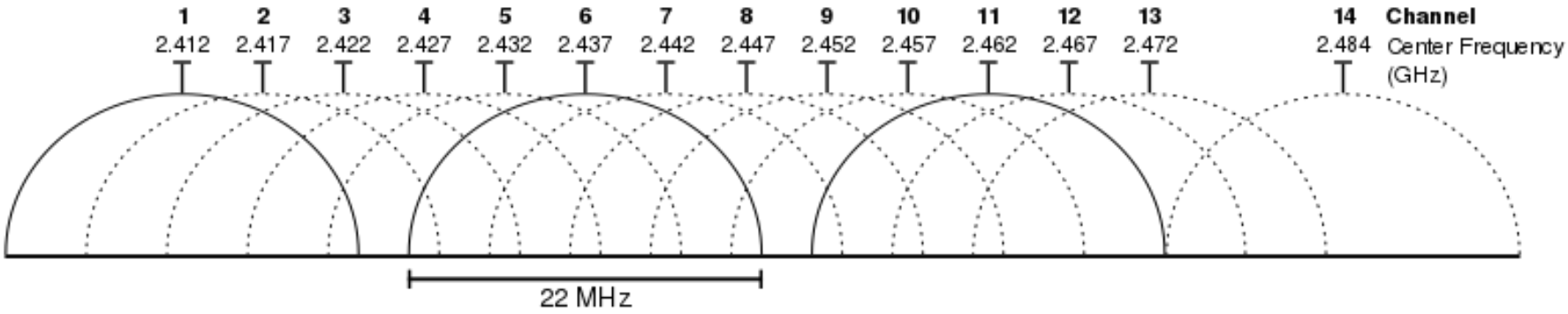
When using the 2.4 GHz band, which channels should be selected when using multiple APs?

a) 2, 6, 10

b) 1, 6, 11

c) 11, 12, 13

d) 2.4 GHz channels do not overlap, so any channels can be used.



Quiz 2

If an enterprise’s network is mostly wired, what is the purpose of an AP in the network?

a) To connect wireless devices to the wired network.

b) To centrally manage all wireless devices.

c) To provide additional security for wireless clients.

c) To create additional VLANs in the network.

Quiz 3

Which of the following bands are commonly used by wireless LANs? (select two)

a) 2.4 GHz

b) 2.5 GHz

c) 4.5 GHz

d) 5 GHz

Quiz 4

Which of the following statements about an ESS are true? (select two)

a) Each BSS uses a unique SSID.

b) Each BSS uses a unique BSSID.

c) Roaming can provide seamless connectivity when moving between APs.

d) Each BSS uses the same channel.

Quiz 5

Which of the following statements is **not** true about an AP that provides multiple BSSs?

a) Each BSS can use a unique SSID.

b) Each BSS shares the same BSSID.

c) Each BSS is mapped to a separate VLAN on the wired network.

d) The AP should connect to the switch via a trunk.