COMMUNITY TECH RESOURCES · COMMUNITY CLASS 1 OF 10

How Do Networks Work?

The internet, IP addresses, the OSI model, and wireless

Everyone | 60 min | 3 parts | 13 pictures



Free class handout from Numu Communications. The interactive class, slides, and poster are at www.numu.tech/learning-center/networks.html

START HERE Welcome

Every time you open a website or watch a video, the information takes a trip. It starts in a big building full of computers, maybe a thousand miles away, and ends in your hand. Along the way it is cut into small labeled pieces, passed from network to network, found by its address, and carried the last few feet by radio waves. Numu Communications builds and runs these networks for tribal and rural communities. This class follows that trip in three parts: the internet and IP addressing, the OSI model, and wireless.

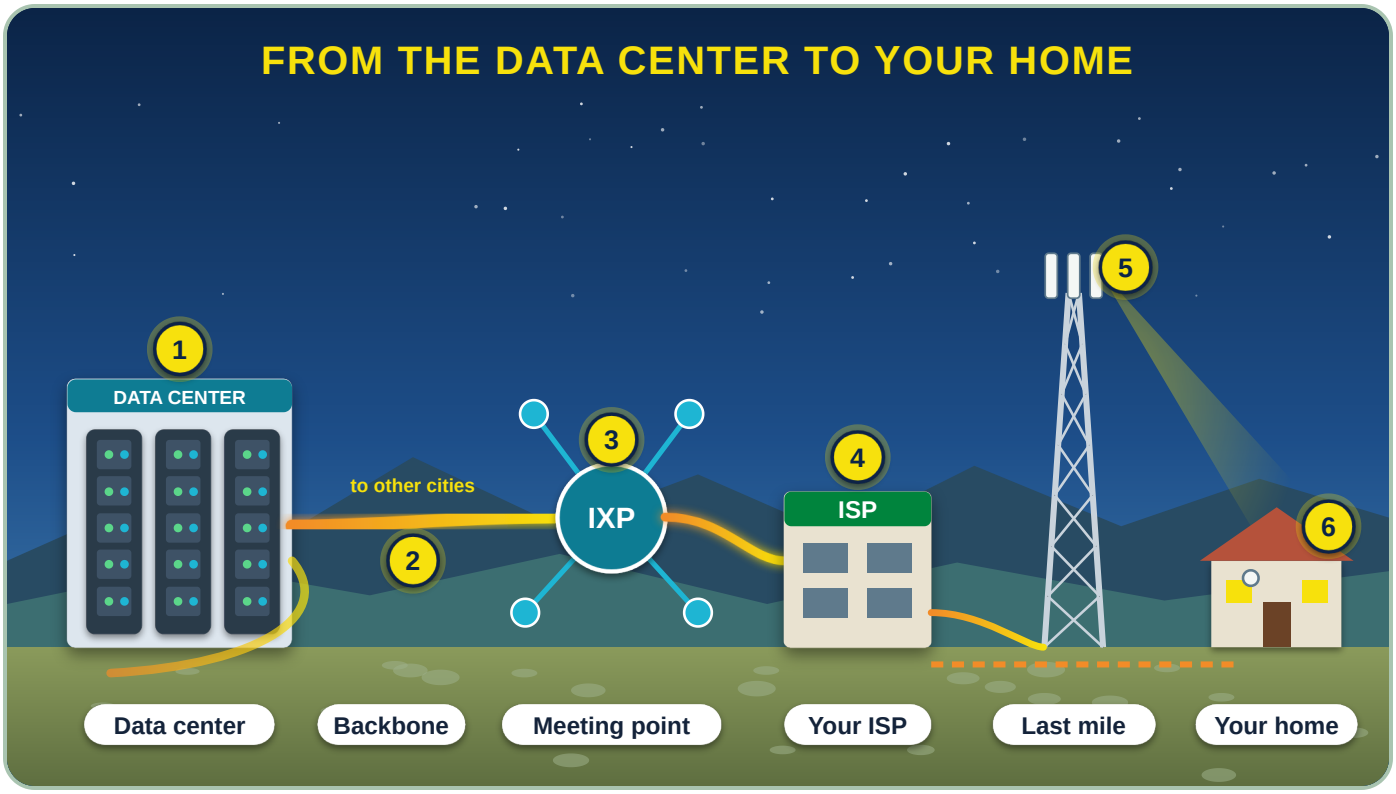
WHAT YOU WILL LEARN

- Explain how information travels from a data center to your home in small labeled packets

- Describe what a router does and why every device needs an IP (Internet Protocol) address
- Name the seven layers of the OSI (Open Systems Interconnection) model using a mailing analogy
- Explain frequency, call signs, and why Wi-Fi has 2.4, 5, and 6 GHz (gigahertz) bands

PART 1 Internet and IP Addressing

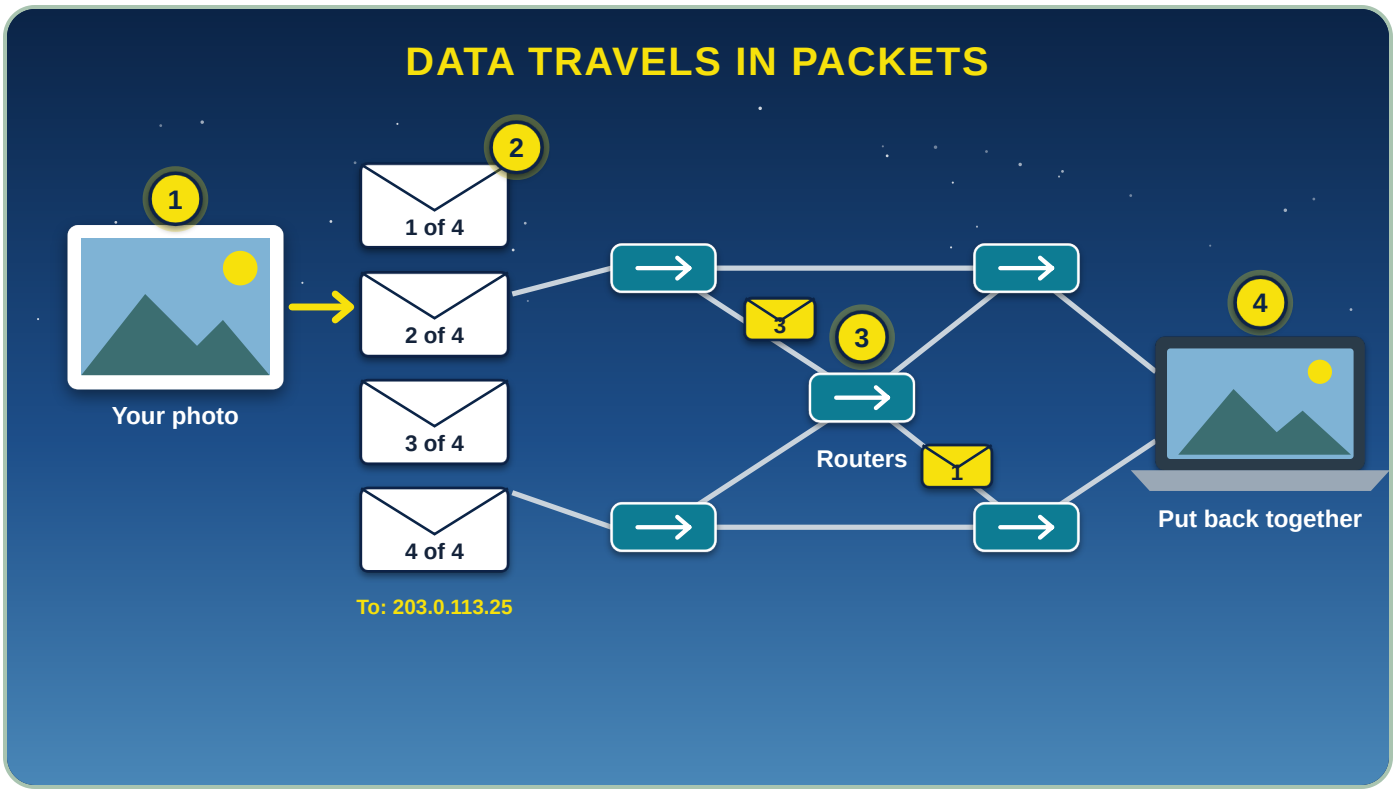
The internet is a network of networks. Follow the trip from a data center to your home, then see how your router gives every device its own address.



Read all 6 details

1. **Data center.** Websites, videos, and apps live on powerful computers called servers. Thousands of servers sit together in large buildings called data centers.
2. **Backbone.** Very large fiber optic cables carry internet traffic between cities, across the country, and even under the ocean. Together they are called the internet backbone.

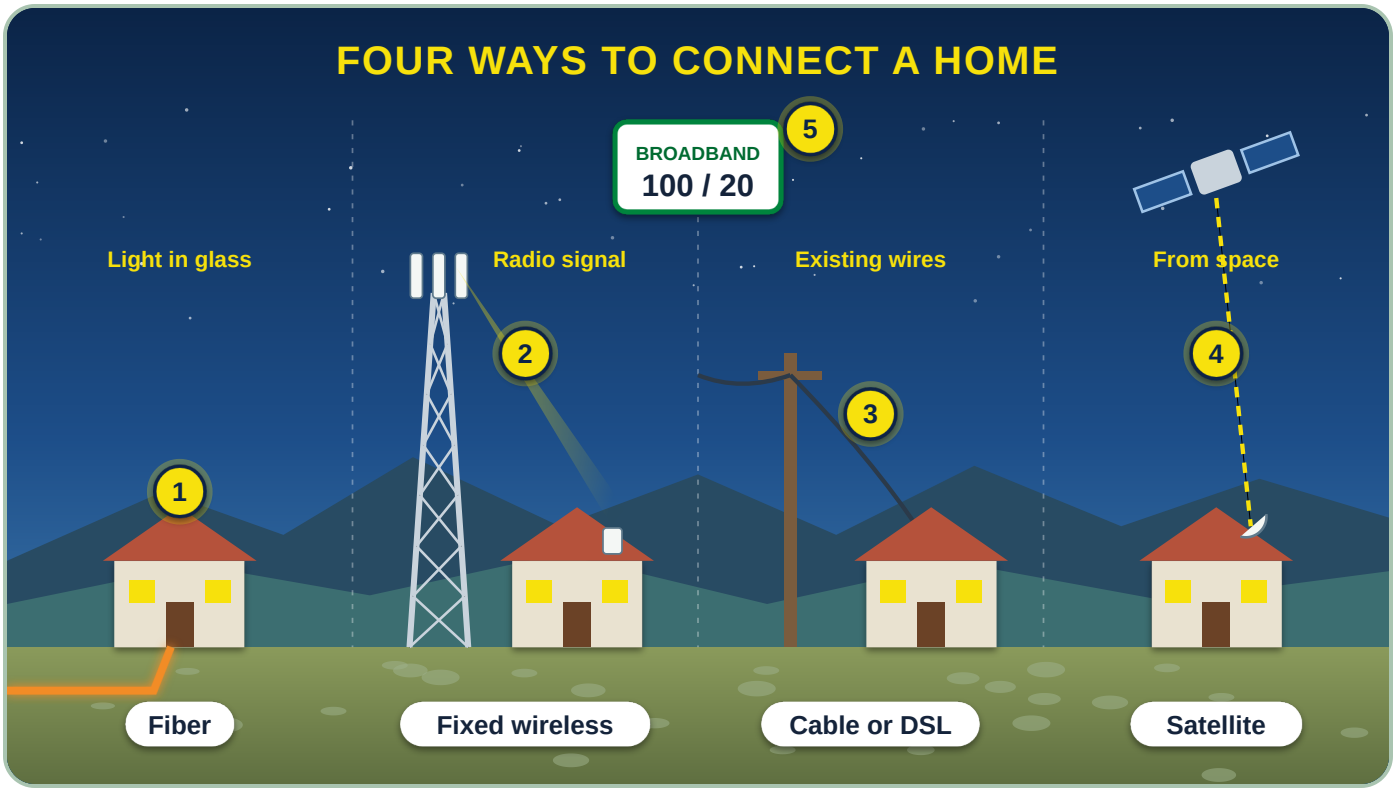
3. **Meeting point.** Networks meet at places called Internet Exchange Points (IXPs) to trade traffic. That is why people call the internet a network of networks: no single company owns it all.
4. **Your ISP.** Your internet service provider (ISP) connects to the backbone and carries traffic to your area over "middle mile" lines.
5. **Last mile.** The last mile is the final link to each home or business. It can be a fiber cable in the ground or a radio signal from a tower. In rural and tribal areas it is often the hardest and most expensive part to build, because homes are far apart.
6. **Your home.** At home, a modem or radio receiver brings the connection inside, and a router shares it with your phone, laptop, and TV over Wi-Fi, the short-range wireless signal inside your home.



Read all 4 details

1. **Break it up.** A photo, video, or message is too big to send in one piece. Your device cuts it into many small pieces called packets.
2. **Label every piece.** Each packet gets a label, like an envelope. The label says where it is going, where it came from, and which piece it is, such as "2 of 4."
3. **Routers pick the road.** Routers are like post offices at every crossroads. They read each label and send the packet down the best open road. Pieces of the same photo can take different roads.

4 **Put it back together.** The receiving device puts the packets back in order and asks again for any that went missing. All of this usually happens in a fraction of a second.



Read all 5 details

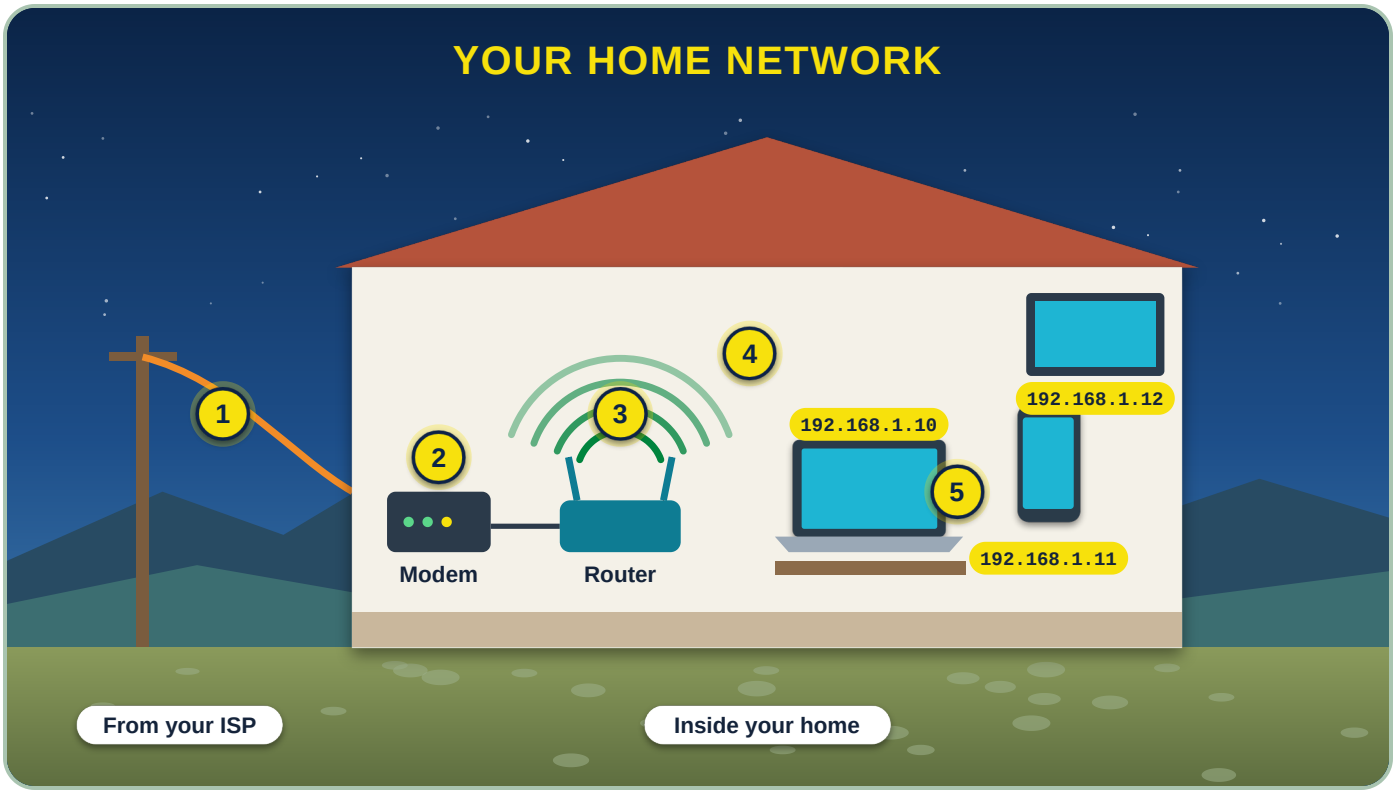
1 **Fiber.** Fiber sends pulses of light through thin strands of glass. It is the fastest and most reliable option, and it lasts for decades, but laying cable to every far-apart home costs a lot.

2 **Fixed wireless.** A radio on a tower sends the internet through the air to a small receiver on your home, much like a radio station, except the signal goes both ways. It can reach spread-out rural homes faster and at lower cost than digging a trench to each one. Numu is building this kind of network in Fort McDermitt now, with service estimated for spring 2027.

3 **Cable or DSL.** Cable internet uses TV cable lines, and DSL (Digital Subscriber Line) uses old telephone lines. Both reuse wires already in place, so they are only an option where those lines exist.

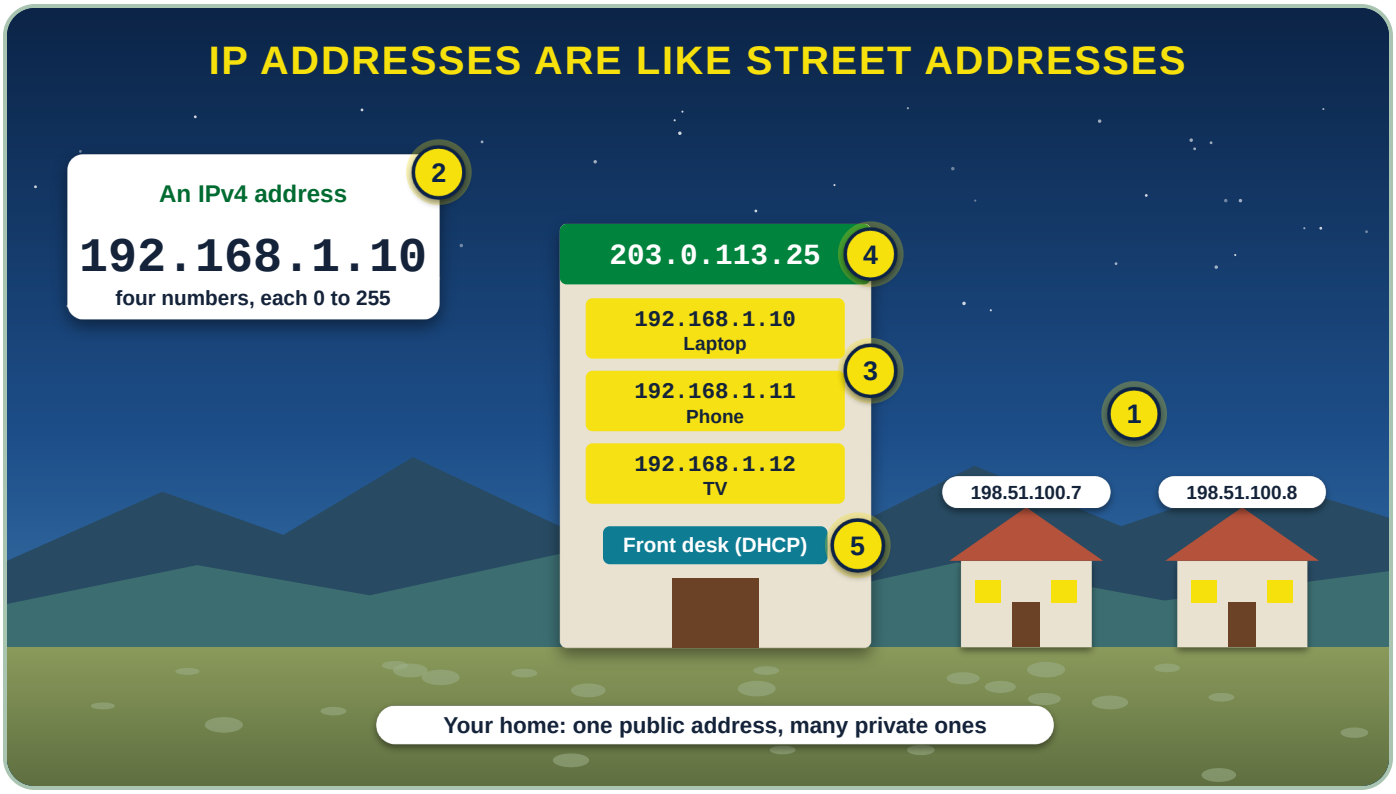
4 **Satellite.** A dish on your home talks to a satellite in space. It can reach almost anywhere. Newer low-orbit satellites are much quicker than older ones that sit far above the Earth, but weather and trees can still get in the way.

5 **What counts as broadband.** The Federal Communications Commission (FCC), the U.S. agency that oversees communications, counts a connection as broadband when it gives at least 100 megabits per second (Mbps) down and 20 Mbps up. Download is how fast you receive things, like a video. Upload is how fast you send things, like a video call.



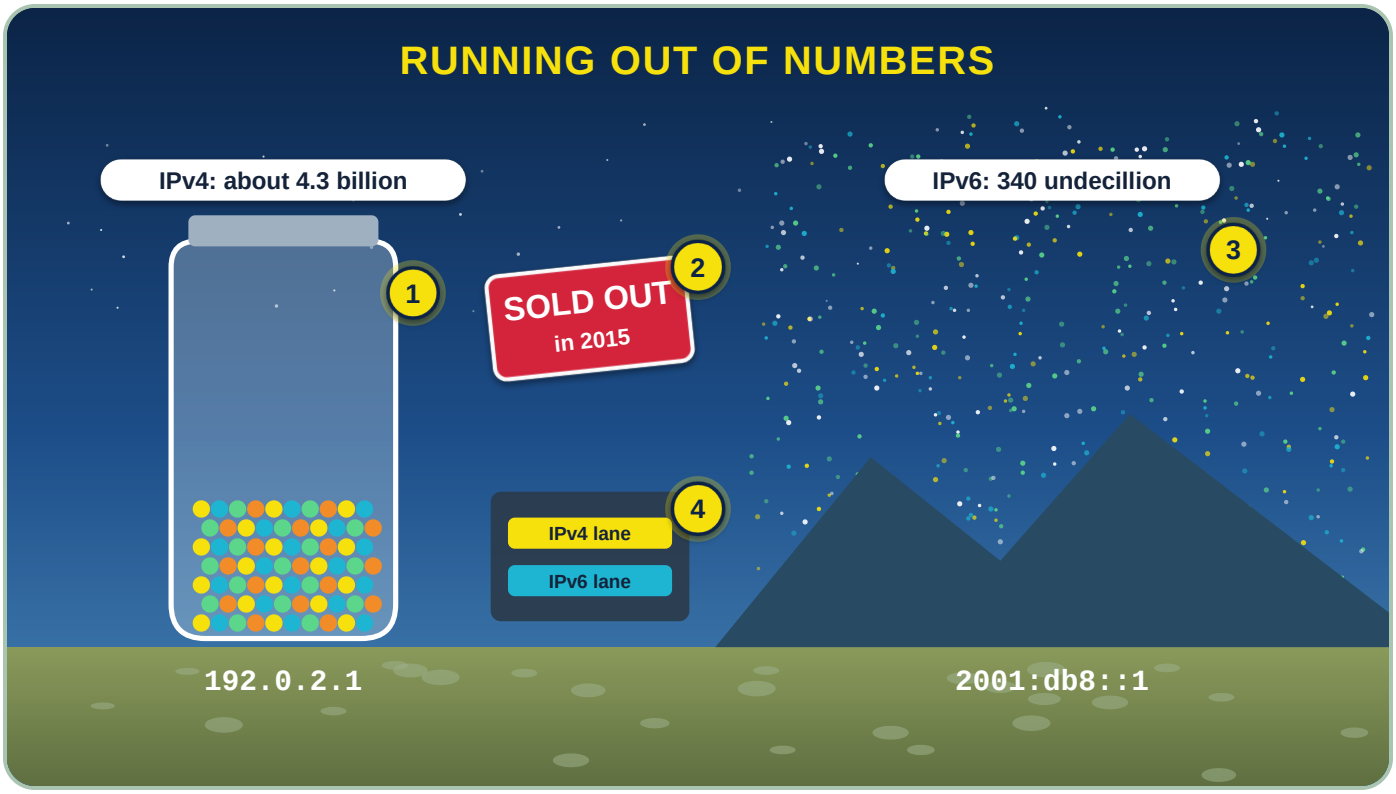
Read all 5 details

1. **The line from your provider.** The connection reaches your home by fiber, cable, phone line, or a radio receiver on the roof. This is your link to the rest of the internet.
2. **Modem.** The modem (short for modulator-demodulator), or a fiber or radio box, translates the signal from your provider into something your home network can use. Some homes have one box that is both a modem and a router.
3. **Router.** The router is the traffic director for your home. It gives each device its own address on your home network, called an IP (Internet Protocol) address, and sends every packet to the right device.
4. **Wi-Fi.** Wi-Fi is a short-range radio signal from your router, like a tiny radio station inside your home. It lets devices connect without cables. Walls and distance make it weaker, so a router near the middle of the home works best.
5. **Your devices.** Phones, laptops, TVs, and printers all join the network. Each one gets its own address so the router knows who asked for what.



Read all 5 details

1. **Every device needs an address.** To send a packet, the network needs to know where it is going. An IP (Internet Protocol) address is that address, like a street address on a mailbox.
2. **Four numbers.** The common kind of address, IPv4 (Internet Protocol version 4), is written as four numbers separated by dots, such as 192.168.1.10. Each number is between 0 and 255.
3. **Private addresses inside.** Inside your home, the router gives devices private addresses, often starting with 192.168 or 10. Millions of homes reuse these same private numbers, and that is fine because they never leave the home.
4. **One public address.** Your router shares one public address with the whole internet, like an apartment building with one street address and many apartment numbers inside. This sharing is called network address translation (NAT).
5. **The front desk.** Devices get their address automatically from the router through a service called DHCP (Dynamic Host Configuration Protocol), like a front desk handing out room numbers when guests arrive.



Read all 4 details

1. **IPv4.** IPv4 has been in use since the early 1980s. Its addresses are 32 bits long (a bit is a single 1 or 0), which allows about 4.3 billion addresses. That sounded like plenty before phones, TVs, and doorbells all went online.

2. **Sold out.** There are now more connected devices than IPv4 addresses. In North America, the American Registry for Internet Numbers (ARIN), which hands out addresses, gave out its last free IPv4 addresses on September 24, 2015. Sharing tricks like network address translation (NAT) help stretch the supply.

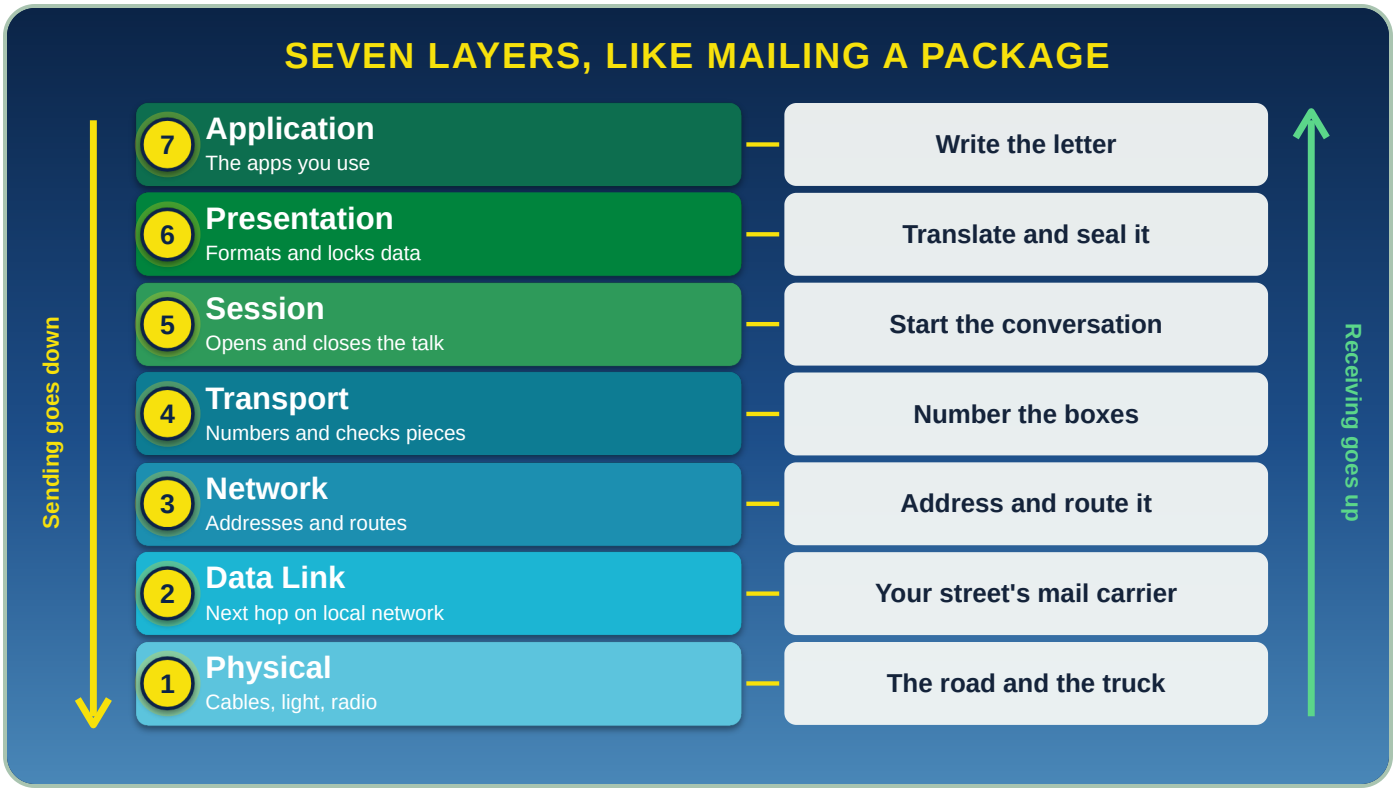
3. **IPv6.** IPv6 (Internet Protocol version 6) addresses are 128 bits long and use numbers and letters separated by colons, such as 2001:db8::1. There are about 340 undecillion of them: 340 followed by 36 zeros. That is enough for every grain of sand many times over.

4. **Both at once.** Most networks today run IPv4 and IPv6 side by side, like a road with two lanes. Your devices use whichever one works best, and you usually never notice.

PART 2 The OSI Model

Engineers describe every network the same way, in seven layers. Mailing a package is a

good way to remember them.



Read all 7 details

7 **Application.** This is the app you are using, like a web browser, email, or a video call. It is like writing the letter you want to send.

6 **Presentation.** Data is put into a shared format both sides understand, and it can be locked with encryption so others cannot read it. It is like translating the letter and sealing the envelope.

5 **Session.** Two devices open a conversation, keep it going, and close it when done. It is like starting and ending a phone call.

4 **Transport.** Data is split into numbered pieces and checked so every piece arrives. TCP (Transmission Control Protocol) does this careful checking. It is like numbering boxes "1 of 3" and tracking each one.

3 **Network.** Each piece gets an IP (Internet Protocol) address and a route between networks. Routers work here. It is like writing the street address and letting the post office choose the route.

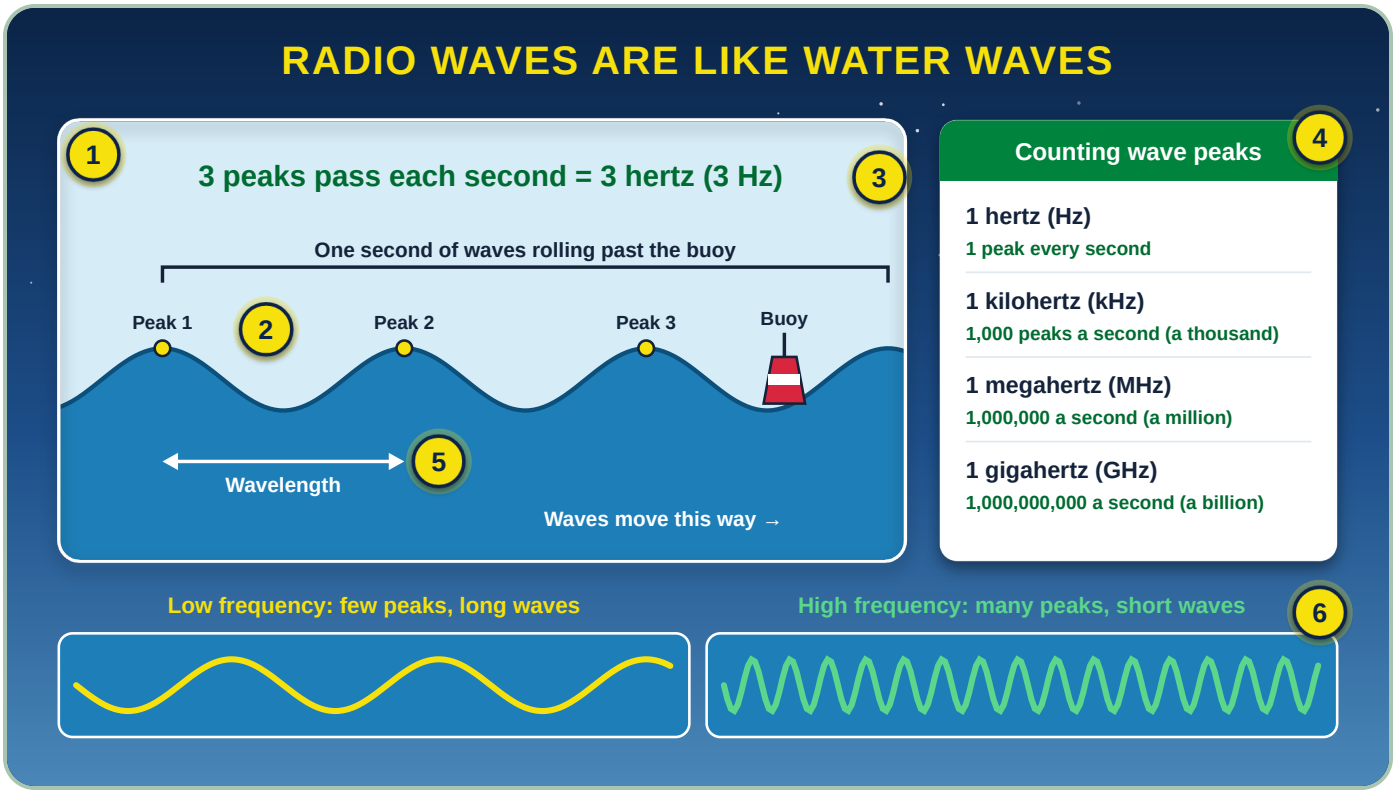
2 **Data Link.** Data moves one hop at a time across the local network using hardware addresses called MAC (Media Access Control) addresses. Switches and Wi-Fi work here. It is like the mail carrier on your street.

1 **Physical.** The actual cables, pulses of light in fiber, or radio waves that carry 1s and 0s. It is the road and the truck.

Real networks mostly follow a simpler four-layer model called TCP/IP, named after its two main rules, TCP and IP. The seven OSI layers are still the most common way to learn networking and to talk about where a problem is, such as "it's a layer 1 problem" when a cable is unplugged.

PART 3 Wireless

Your car radio, your cell phone, and your Wi-Fi all send and catch invisible radio waves. If you can tune a car radio, you already understand most of wireless.



Read all 6 details

1. **Like ripples on a lake.** Drop a stone in a lake and ripples spread out in every direction. A radio antenna sends out radio waves the same way, except radio waves are invisible and travel at the speed of light.

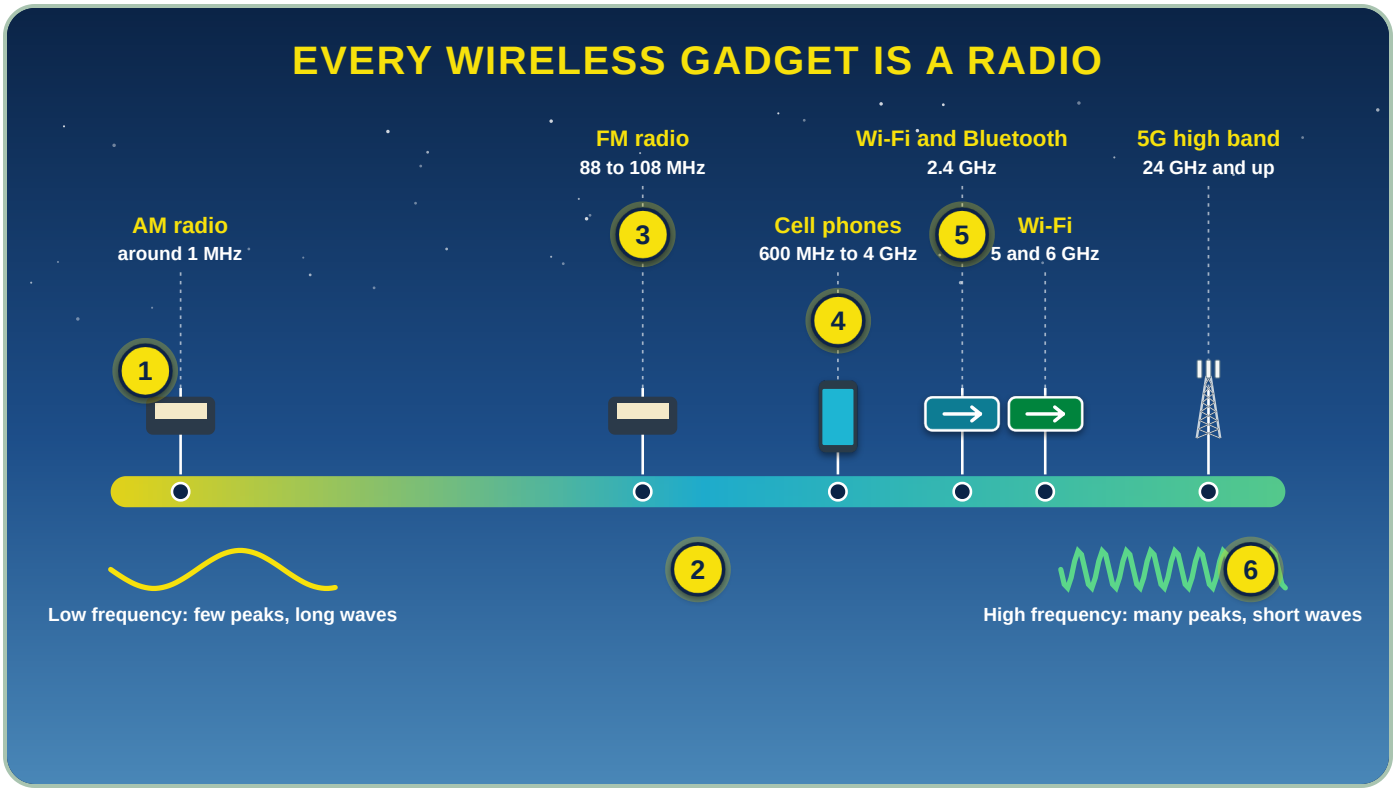
2. **Wave peaks.** Every wave has high points, called peaks. Watch the buoy bob up and down and count how many peaks roll past it each second. That count is the wave's frequency.

3. **Hertz.** One peak per second is called 1 hertz (Hz), named for Heinrich Hertz, the German scientist who proved radio waves exist in the late 1880s. In this picture, 3 peaks pass the buoy every second, so the frequency is 3 hertz.

4 **Kilo, mega, and giga.** Radio waves wiggle much faster than lake waves, so we use bigger units. Kilo means a thousand, mega means a million, and giga means a billion. KWNA at 92.7 FM (frequency modulation) sends 92.7 million wave peaks every second. 2.4 GHz Wi-Fi sends 2.4 billion.

5 **Wavelength.** Wavelength is the distance from one peak to the next. More peaks per second means the peaks are packed closer together. An AM (amplitude modulation) radio wave is hundreds of meters long, an FM wave about 3 meters, and a 2.4 GHz Wi-Fi wave only about 12 centimeters, or 5 inches.

6 **Where the comparison stops.** Water waves need water, but radio waves do not need anything to travel through. They cross empty space, which is how signals from GPS (Global Positioning System) satellites reach your phone.



Read all 6 details

1 **It is all radio.** Car radios, cell phones, Wi-Fi, Bluetooth headphones, and garage door openers all send invisible radio waves through the air. They travel at the speed of light.

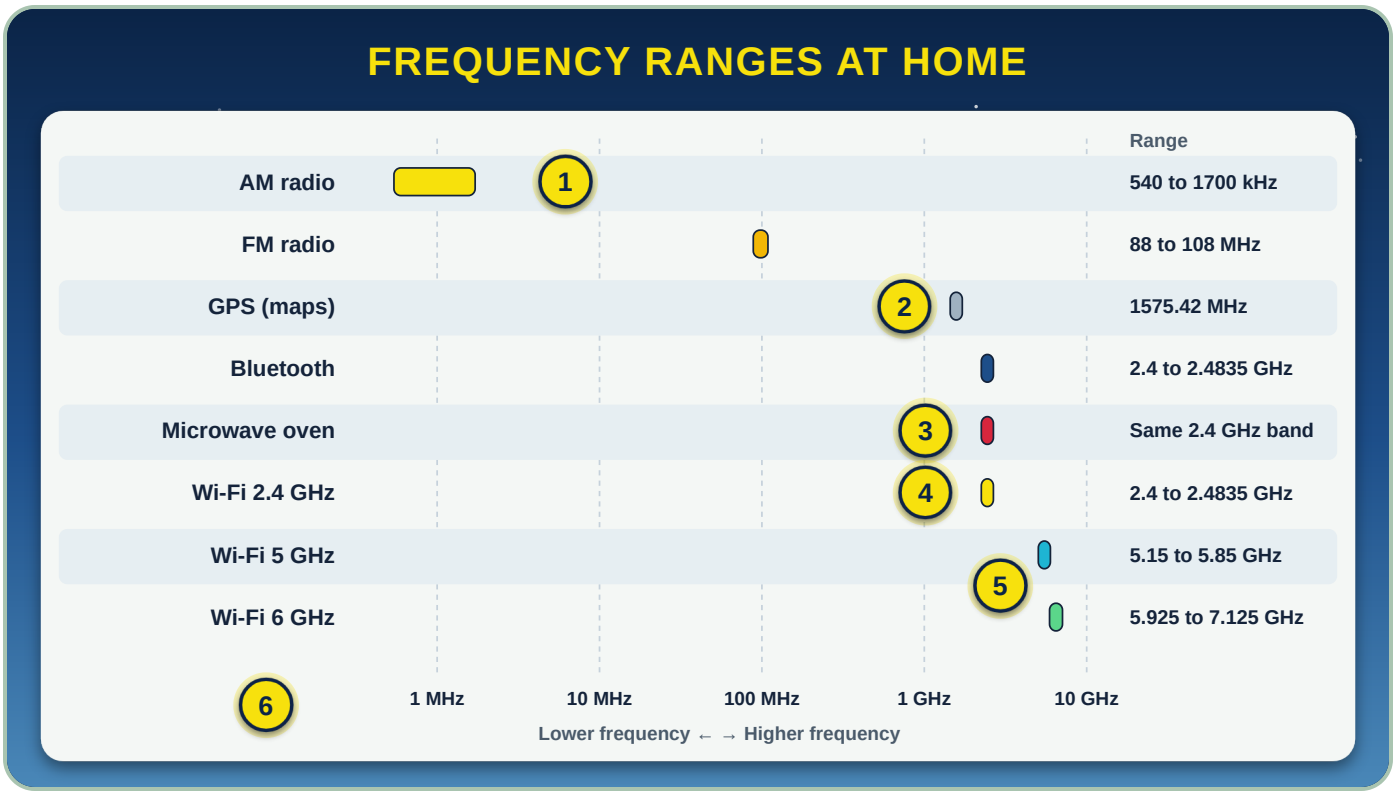
2 **Frequency.** Remember the lake: frequency is how many wave peaks pass each second, counted in hertz. Low frequencies, on the left, have few peaks and long waves. High frequencies, on the right, have many peaks and short waves.

3 **Your car radio.** When you tune your car radio to 92.7 FM in Winnemucca, you are choosing KWNA, the station that broadcasts at 92.7 megahertz. AM stations sit much lower, around one megahertz, which is one reason AM can be heard so far away.

4 **Your cell phone.** Cell phones use frequencies from about 600 MHz up to about 4 GHz. Phone companies hold licenses for blocks of these frequencies, just like a radio station holds a license for its spot on the dial.

5 **Wi-Fi and Bluetooth.** Wi-Fi and Bluetooth use frequencies around 2.4 GHz, and Wi-Fi also uses 5 GHz and 6 GHz. These are shared, unlicensed bands, so many gadgets use them at once.

6 **The trade-off.** Lower frequencies travel farther and pass through walls and hills. Higher frequencies carry more data but fade faster. Every wireless network balances distance against speed.



Read all 6 details

1 **Car radio.** AM radio sits way down near 1 megahertz (MHz). FM radio runs from 88 to 108 MHz, which is why your car radio dial reads 88 at one end and 108 at the other. Each FM station gets a slice 0.2 MHz wide.

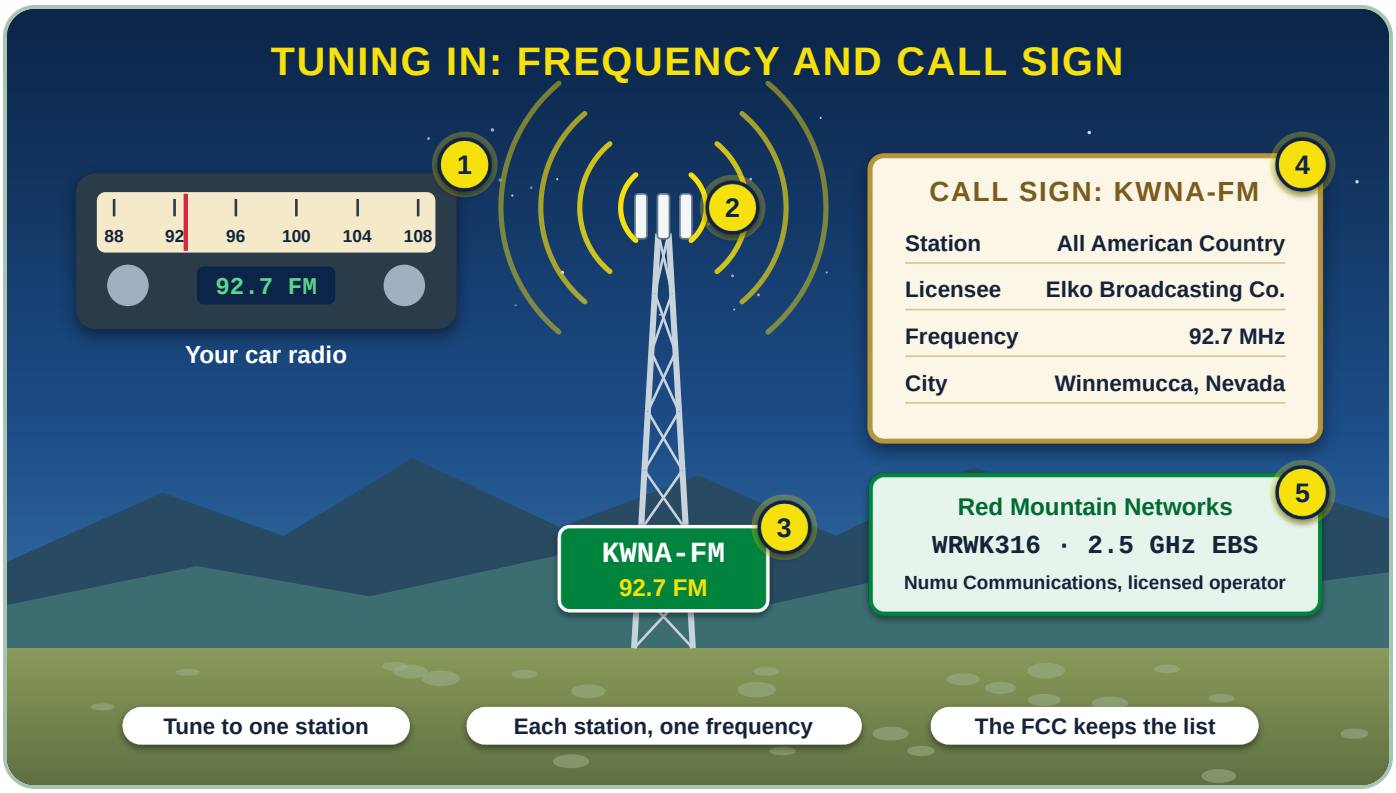
2 **GPS.** The Global Positioning System (GPS) that powers your map app listens for satellites broadcasting at 1575.42 MHz. Your phone only receives this signal; it never transmits on it.

3 **Bluetooth and the microwave.** Bluetooth headphones, microwave ovens, and many other gadgets all share the same unlicensed 2.4 gigahertz (GHz) band. That is why a running microwave can slow down nearby 2.4 GHz Wi-Fi.

4 **Wi-Fi 2.4 GHz.** The 2.4 GHz Wi-Fi band runs from 2.4 to 2.4835 GHz, 83.5 MHz in all. It reaches farthest through walls, but it is shared by the most devices.

5 **Wi-Fi 5 and 6 GHz.** Wi-Fi also uses 5 GHz (about 5.15 to 5.85 GHz) and, since 2020, 6 GHz (5.925 to 7.125 GHz). The 6 GHz band alone is 1,200 MHz wide, so it has room for many more fast channels.

6 **Why the bars look so thin.** This chart uses a stretched scale so AM radio and Wi-Fi fit on one picture: each grid line is 10 times the one before it. On a normal ruler, the 2.4 GHz Wi-Fi band (83.5 MHz) would be about four times wider than the whole FM dial (20 MHz).



Read all 5 details

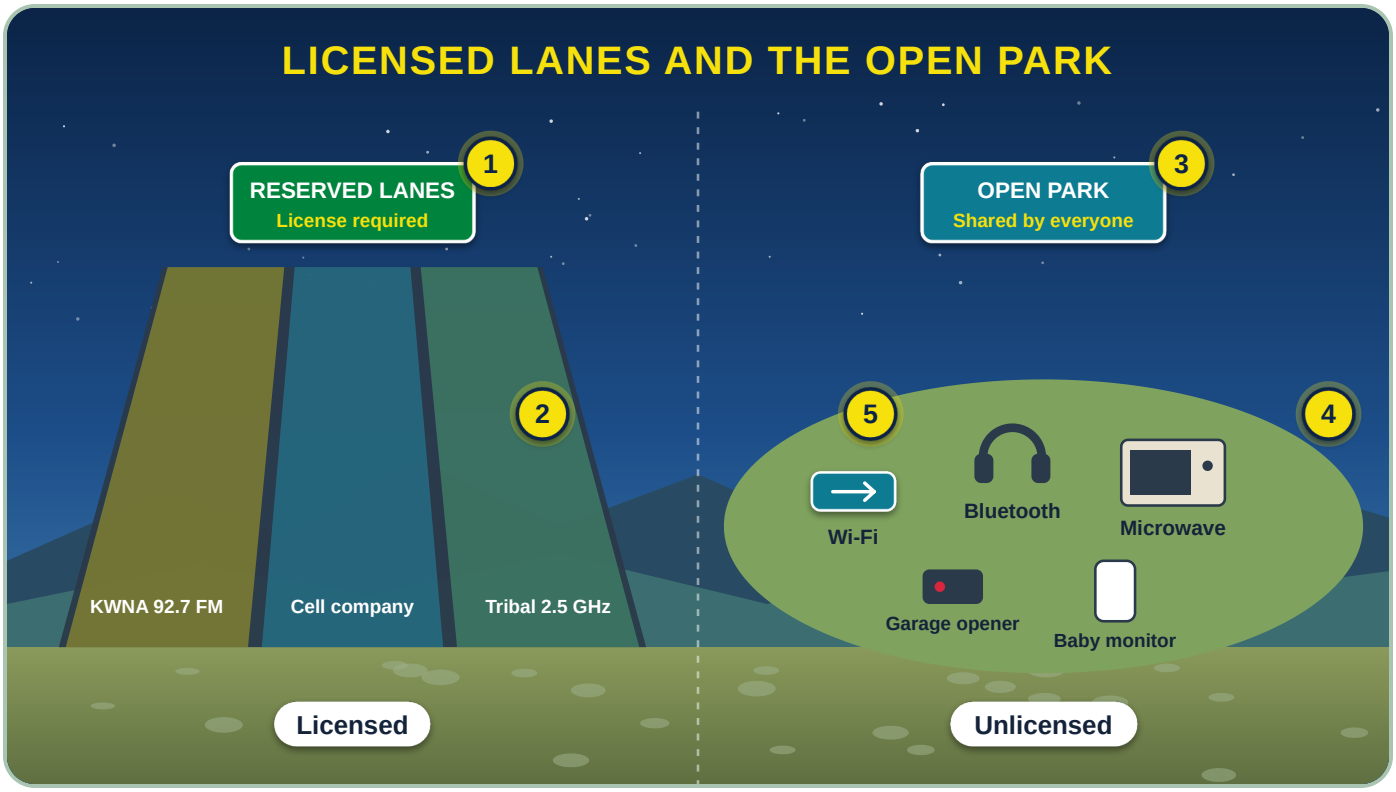
1 **Tuning.** Turning the dial picks one frequency, such as 92.7 FM in Winnemucca, Nevada. Your radio listens only to that frequency and ignores every other station in the air around you.

2 **The station.** Each radio station sends its signal on one assigned frequency from a tall tower. If two nearby stations used the same frequency, you would hear both garbled together, which is called interference.

3 **The call sign.** Every station has a call sign, like a name tag. 92.7 FM in Winnemucca is KWNA-FM. In the United States, call signs start with K west of the Mississippi River and W east of it, with a few older exceptions, and the -FM on the end tells you it is an FM station. Stations must say their call sign at the top of every hour.

4 **The call sign is the license.** The Federal Communications Commission (FCC), the U.S. agency in charge of the airwaves, gives each station a license, and the call sign is that license's name. Look up KWNA-FM and you find its owner, Elko Broadcasting Company, its frequency, 92.7 MHz, its city, Winnemucca, and how much power it may use, so stations do not step on each other.

5 **Wireless networks have call signs too.** Cell phone companies, internet providers, and tribes hold FCC licenses for blocks of frequencies in a specific area, and each license has its own call sign. Red Mountain Networks in Fort McDermitt holds call sign WRWK316 in the 2.5 GHz Educational Broadband Service (EBS), with Numu Communications as its licensed operator. In 2020, the FCC opened a Rural Tribal Priority Window so tribes could get 2.5 GHz licenses over their own lands.



Read all 5 details

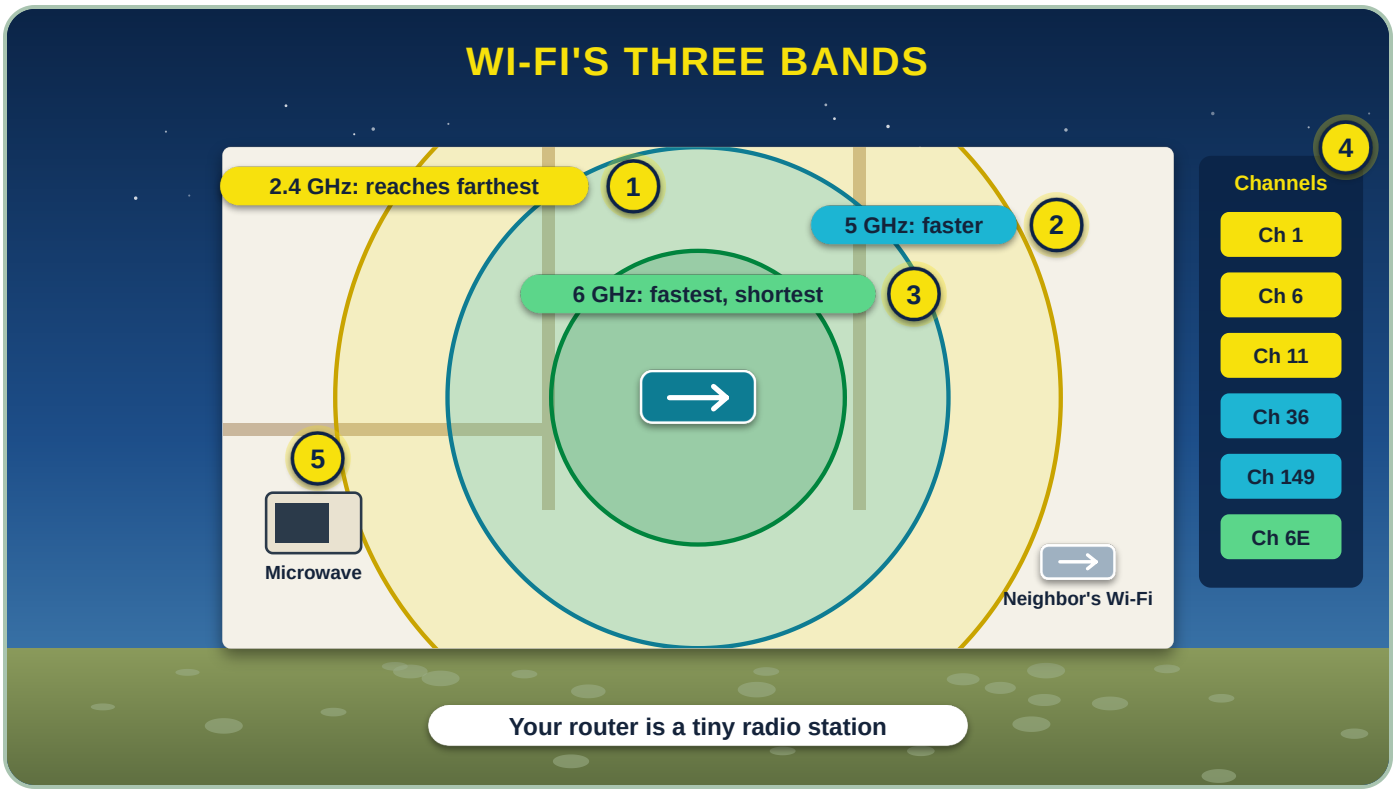
1 **Licensed.** Some frequencies are like reserved highway lanes. Only the license holder may use that lane in that area: radio and TV stations, cell phone companies, and tribes with 2.5 GHz licenses.

2 **Protection.** Because the lane is reserved, nobody else is supposed to use it. If someone causes interference, the FCC can step in. That protection is why licensed networks can cover wide areas reliably.

3 **Unlicensed.** Other frequencies are like an open public park. Anyone may use them without a license: Wi-Fi, Bluetooth, cordless phones, baby monitors, and garage door openers all share this space.

4 **Rules still apply.** Unlicensed does not mean no rules. Devices must stay at low power and be approved by the FCC. Look for the "FCC ID" label on the bottom of your router or phone.

5 **It can get crowded.** Because everyone shares the park, it can get busy. Your neighbor's Wi-Fi, Bluetooth headphones, and even a running microwave oven can slow your 2.4 GHz Wi-Fi.



Read all 5 details

1 **2.4 GHz.** The 2.4 GHz band reaches the farthest and goes through walls best. But it is the most crowded: Bluetooth, microwave ovens, baby monitors, and your neighbors' Wi-Fi all share it.

2 **5 GHz.** The 5 GHz band is faster and has more channels, so it is less crowded. Its signal does not reach as far or pass through walls as well.

3 **6 GHz.** The FCC opened the 6 GHz band to Wi-Fi in 2020, adding 1,200 MHz of new room. It is the fastest and least crowded, but it has the shortest reach and needs a newer device labeled Wi-Fi 6E or Wi-Fi 7.

4 **Channels.** Each band is split into channels, like stations on a radio dial. Your router picks a channel to broadcast on. If a neighbor's router uses the same channel, the two take turns, which slows both down.

5 **2.4 is not 2.5.** The numbers look alike, but 2.4 GHz Wi-Fi is unlicensed and short-range, made for inside a home. The 2.5 GHz band next to it is licensed, like a radio station, and is used for wide-area wireless networks, including the tribal licenses.

REVIEW

Practice and quiz

TRY IT AT HOME

Ten minutes with your own phone or computer:

1. Find your router. Look for a sticker with its name and the network name (SSID, for Service Set Identifier).
2. On your phone, open Wi-Fi settings and tap your network. Find your device's IP address. Does it start with 192.168 or 10?
3. Search the web for "what is my IP address." The number you see is your home's public address, shared by every device in the house.
4. Stand close to the router and run a free speed test, then try again in the farthest room. Write down both numbers.
5. Look up the call sign of your favorite radio station on the FCC (Federal Communications Commission) website.

REMEMBER



The internet is a network of networks, sending small labeled packets



Every device has an IP address; your router hands them out



Wireless is radio: frequency is wave peaks per second

CHECK WHAT YOU LEARNED

1. What is a packet?



A small labeled piece of data ANSWER



A kind of cable

Why: Big files are cut into small labeled pieces called packets, sent separately, and put back together.

2. What hands out addresses to devices on your home network?



The website



The router, using DHCP ANSWER

Why: Your router's DHCP (Dynamic Host Configuration Protocol) service gives each device an address when it joins, like a front desk assigning rooms.

3. Which OSI (Open Systems Interconnection) layer is the cable or Wi-Fi signal itself?



Layer 1, Physical ANSWER



Layer 7, Application

Why: Layer 1 is the physical road: cables, light in fiber, and radio waves. Layer 7 is the app you use.

4. If 5 wave peaks pass the buoy every second, what is the frequency?

5 miles

5 hertz **ANSWER**

Why: Frequency counts wave peaks per second. 5 peaks a second is 5 hertz (Hz).

5. Which Wi-Fi band can a running microwave oven slow down?

2.4 GHz **ANSWER**

6 GHz

Why: Microwave ovens, Bluetooth, and many other gadgets share 2.4 GHz (gigahertz). The 6 GHz band is newer and much less crowded.

RESOURCES Words and resources

WORDS TO KNOW

ISP

Internet Service Provider. The company or tribal utility that connects your home to the internet.

IXP

Internet Exchange Point. A building where many networks plug into each other to trade traffic.

IP, IPv4, IPv6

Internet Protocol, versions 4 and 6. The addressing system every device uses. IPv4 looks like 192.0.2.1; IPv6 looks like 2001:db8::1.

DHCP

Dynamic Host Configuration Protocol. The rule your router uses to hand each device an IP address automatically.

NAT

Network Address Translation. How your router lets many devices share one public IP address.

MAC address

Media Access Control address. A permanent ID number built into each network chip, like a serial number.

TCP

Transmission Control Protocol. The rule that numbers packets and re-sends any that get lost.

OSI model

Open Systems Interconnection model. A seven-layer way to describe how any network works, from wires up to apps.

Wi-Fi

A brand name, not an acronym. Short-range wireless internet in homes and buildings, using the shared 2.4, 5, and 6 GHz bands.

Bluetooth

A short-range radio (a few feet to a few dozen feet) for headphones, speakers, and watches. It uses the shared 2.4 GHz band.

Hz, kHz, MHz, GHz

Hertz, kilohertz, megahertz, gigahertz. How many wave peaks pass each second: one, a thousand, a million, or a billion.

Wavelength

The distance from one wave peak to the next. Higher frequencies have shorter wavelengths.

Spectrum

The full range of radio frequencies, shared by radio, TV, cell phones, Wi-Fi, and more.

Call sign

The official name of an FCC license, such as KWNA-FM, the 92.7 FM station in Winnemucca. Radio stations, cell companies, and internet providers all have them.

FCC

Federal Communications Commission. The U.S. agency that licenses radio, TV, and cell frequencies and assigns call signs.

Mbps

Megabits per second. How fast data moves. 100 Mbps is 100 million bits every second.

Broadband

Fast internet that is always on, as opposed to old dial-up service.

LEARN MORE

Code.org: How the Internet Works ↗
Short, friendly videos on wires, Wi-Fi, packets, addresses, and routing.

Cloudflare: How does the Internet work? ↗
A plain-language article on packets, routers, and protocols.

Cloudflare: What is the OSI model? ↗
Each of the seven layers explained with examples.

NTIA: United States Frequency Allocation Chart ↗
The official chart showing who uses every slice of the radio spectrum.

FCC: Look up a wireless call sign ↗

Search the FCC's Universal Licensing System, for example call sign WRWK316.

FCC National Broadband Map ↗

Look up which internet services are reported at your address.

For teachers and digital navigators: how to run this class (two 45-minute sessions)

Lesson plan

Session 1 Start here, then Internet and IP Addressing.

10 min Read the story together. Ask: where do you think a video is stored?

20 min Internet and IP Addressing: explore the trip, packets, and connection pictures. Have a volunteer tap each number.

15 min Still in Internet and IP Addressing: pass around a router and find its sticker. Do steps 1 to 3 of Try it at home.

Session 2 The OSI Model and Wireless, then Practice and quiz.

15 min The OSI Model: act out the mailing analogy, one volunteer per layer.

20 min Wireless: the lake and buoy picture, then call signs and Wi-Fi bands.

10 min Practice and quiz: answer together with a show of hands, then review the three Remember cards.

What you need

- Projector or large TV for the slides
- A home Wi-Fi router to pass around (unplugged is fine)
- Printed handouts, one per person
- Optional: a phone with a free speed test app

Talk about it

- Where in your home is the Wi-Fi weakest? What might be in the way?
- Why do you think it costs more to bring internet to homes that are far apart?

- What radio stations, phones, or radios do you use that share the airwaves?

The PowerPoint slides follow this plan, with the story and every picture detail in the speaker notes.

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