CS 484/504
Computer Networks I
Wireless Physical Layer

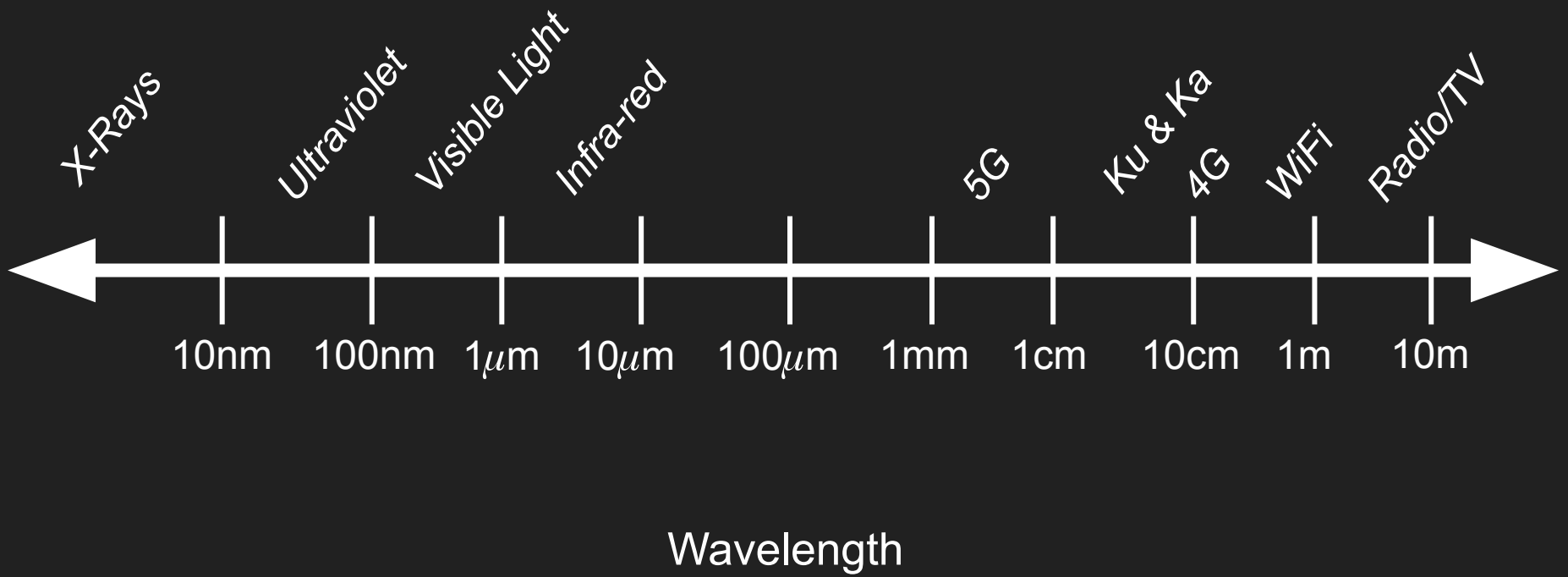
Fall 2022

Joshua Reynolds

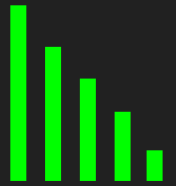
Wireless Networking

Antennae - Creating and Detecting Electromagnetic Ripples

The Electro-Magnetic Spectrum



Measurement of Signal Strength



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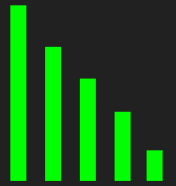

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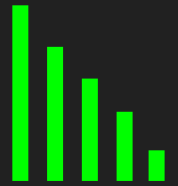

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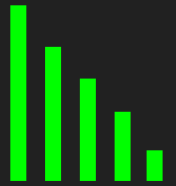

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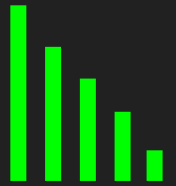

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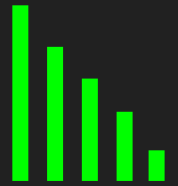

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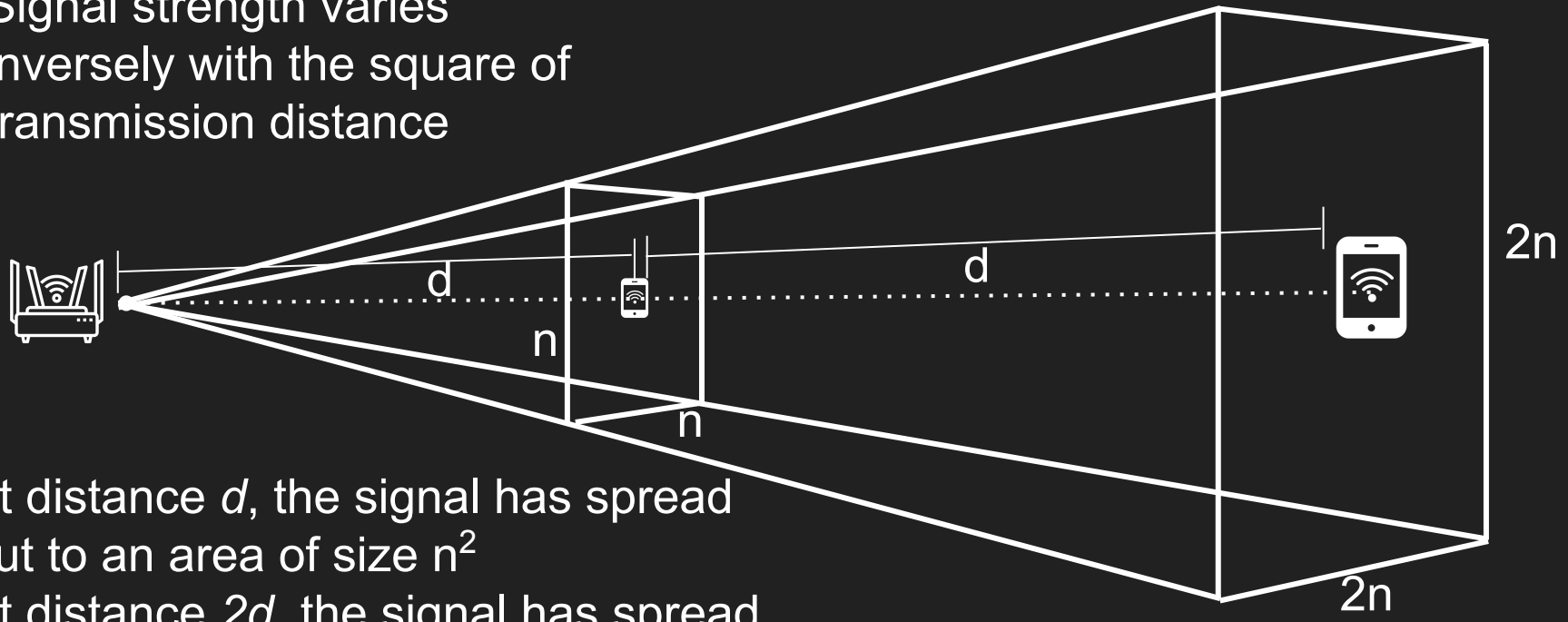
Received Signal Strength Indicator (**RSSI**): A scale of “goodness” created by the receiver manufacturer. Usually a scale of 1-100 ish.

The Inverse Square Law (Geometry Just Happened)

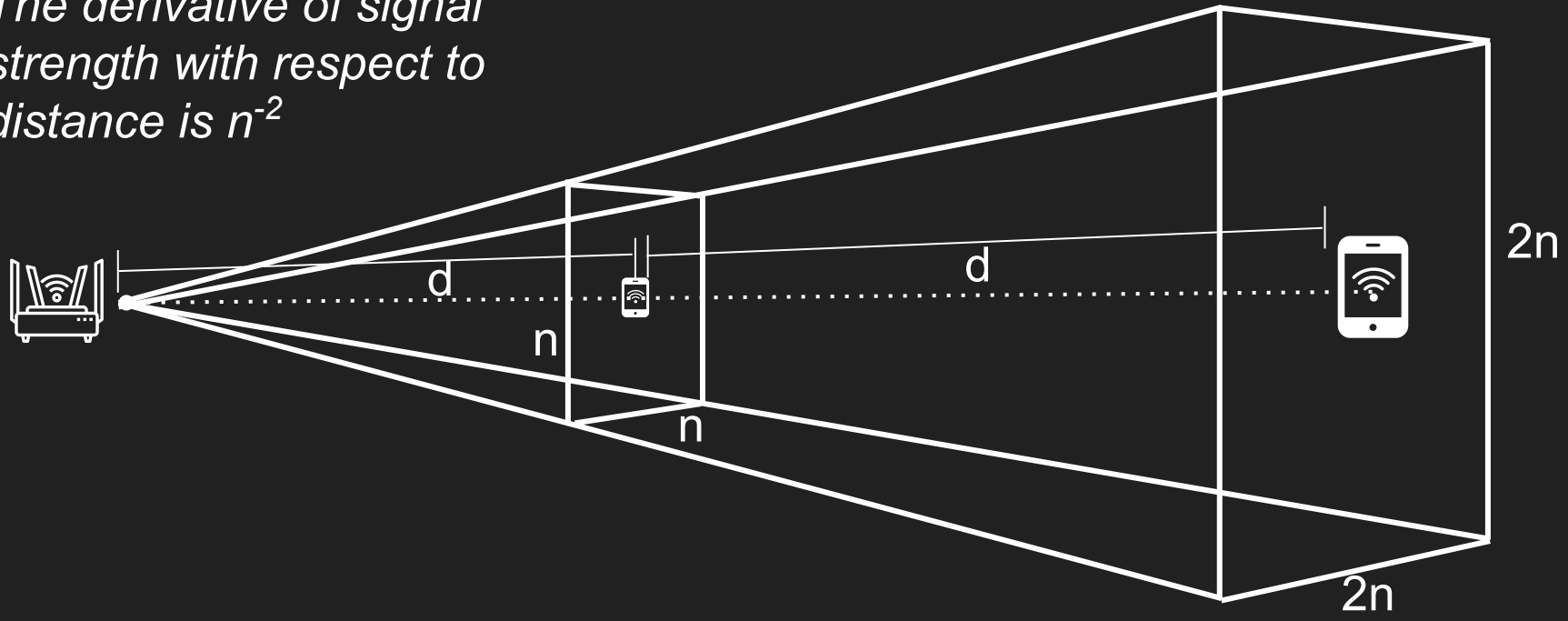
Signal strength varies inversely with the square of transmission distance



At distance *d*, the signal has spread out to an area of size n^2
At distance *2d*, the signal has spread to an area of size 2^2n^2

The Inverse Square Law (Calculus just happened)

The derivative of signal strength with respect to distance is n^{-2}



Applying the Inverse Square Law: Predict Transmission Strength

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At 50 meters we would expect to have $10^{-5} \times (50/3)^{-2}$ mW = 3.6×10^{-8} mW

Applying the Inverse Square Law: Predict Transmission Strength

Consider a wifi router in an open space:

Assume the signal strength 3 m away is 10^{-5} mW (-50 dBm)

At n meters of distance, we expect $10^{-5} \times (n/3)^{-2}$ mW of signal strength

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At 50 meters we would expect to have $10^{-5} \times (50/3)^{-2}$ mW = 3.6×10^{-8} mW

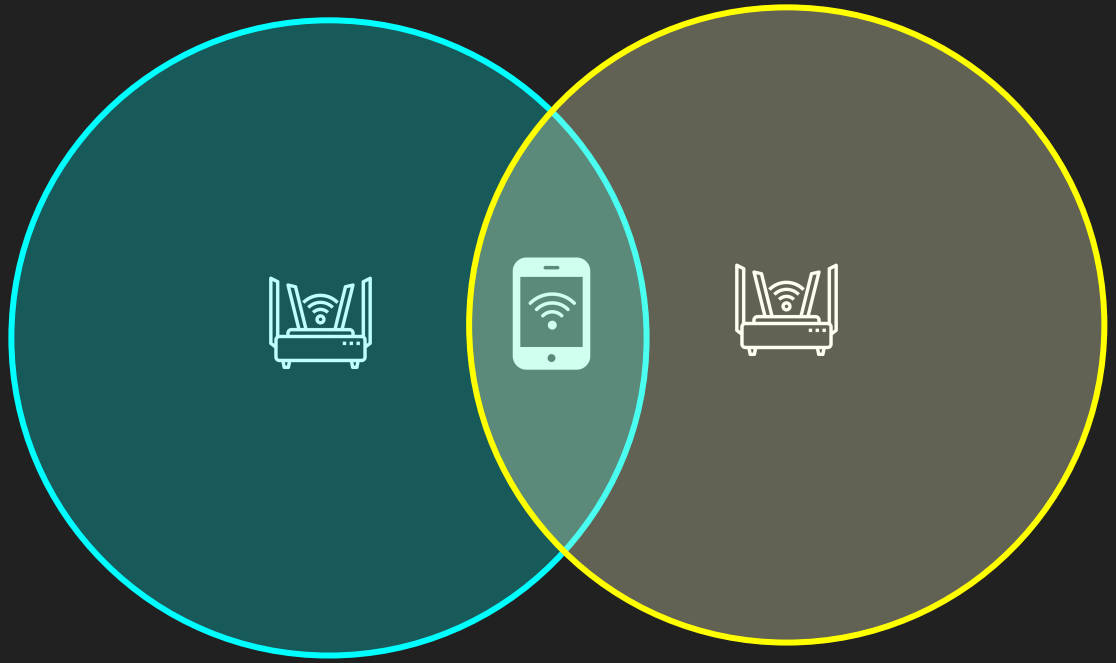
Real-world WiFi has a range of about 25m indoors, considering obstacles

Collisions

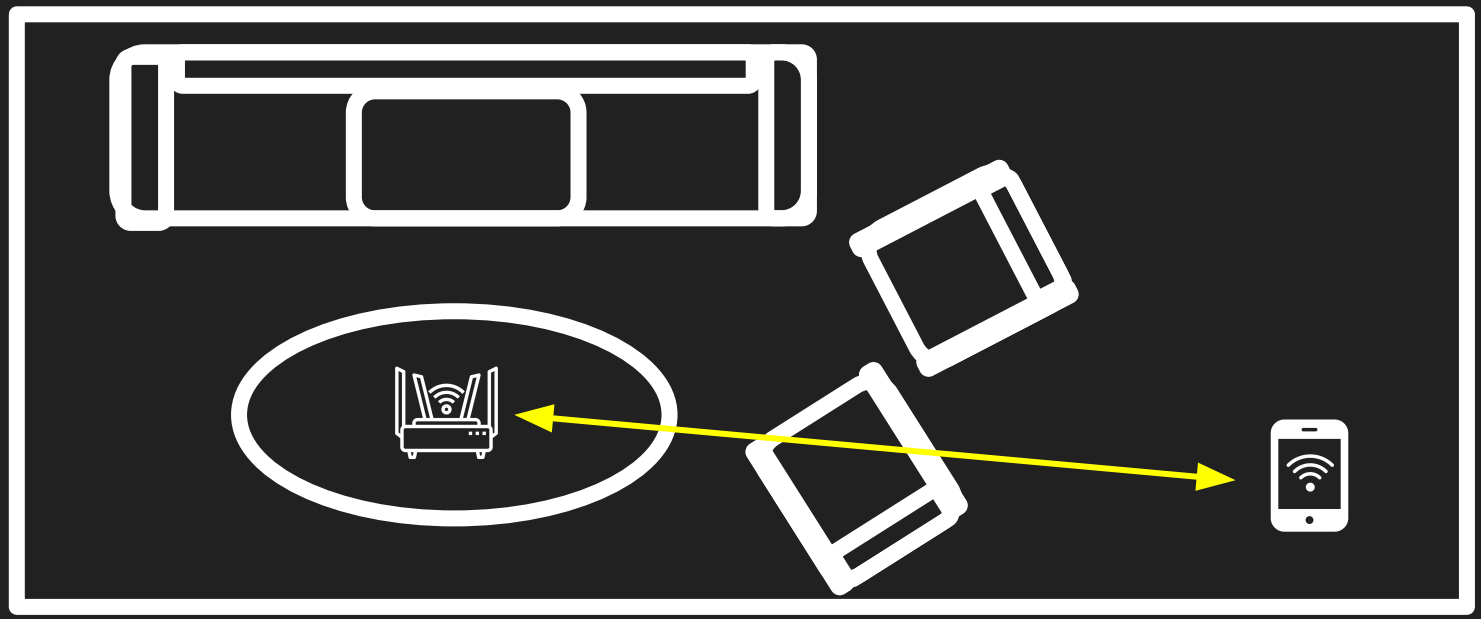
Transmission is so much more powerful than receiving that the same antenna cannot transmit and receive simultaneously.

Radio waves from two simultaneous transmissions interfere with each other and cause information loss.

Hidden Node Collisions



Reflection: Not only visible light reflects!



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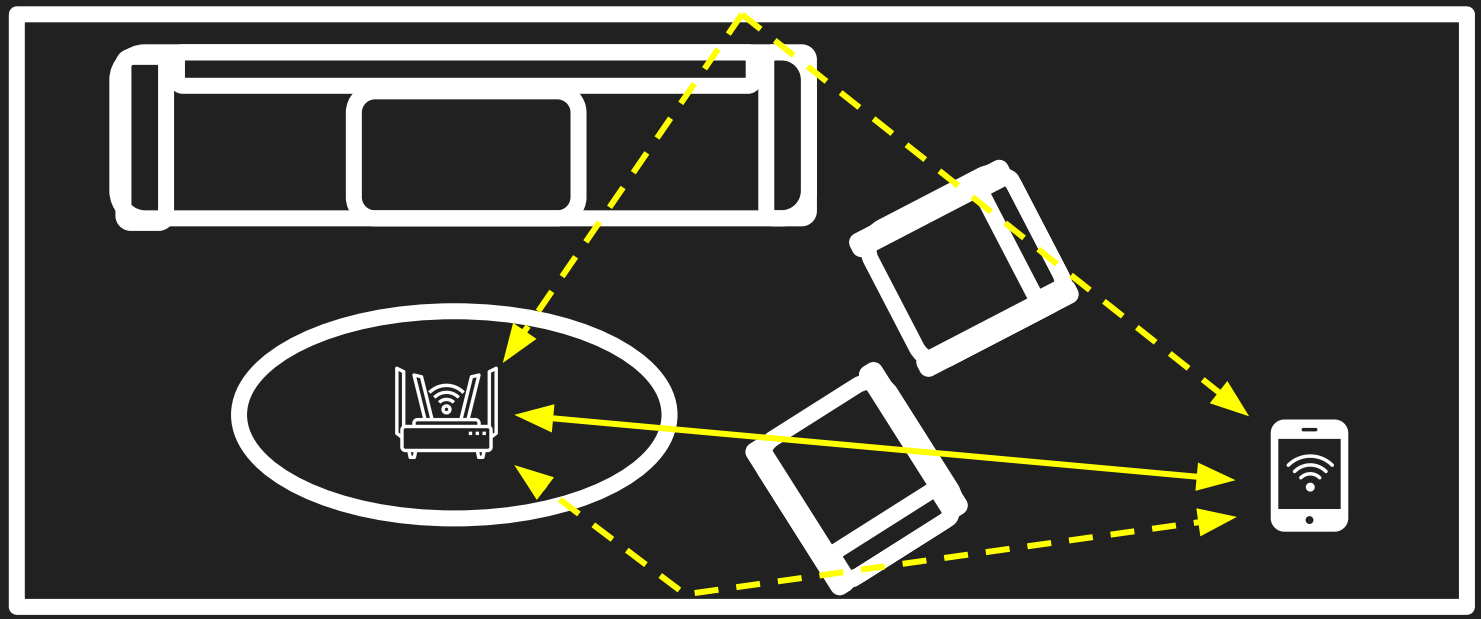

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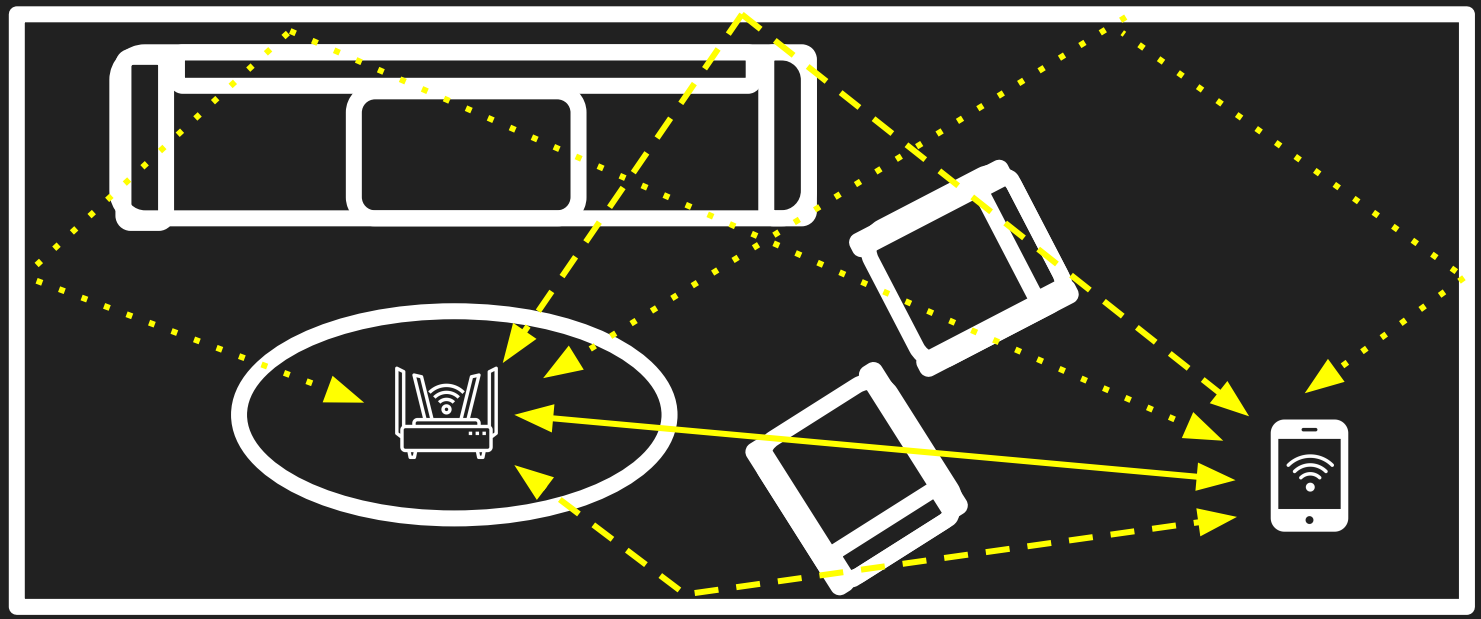

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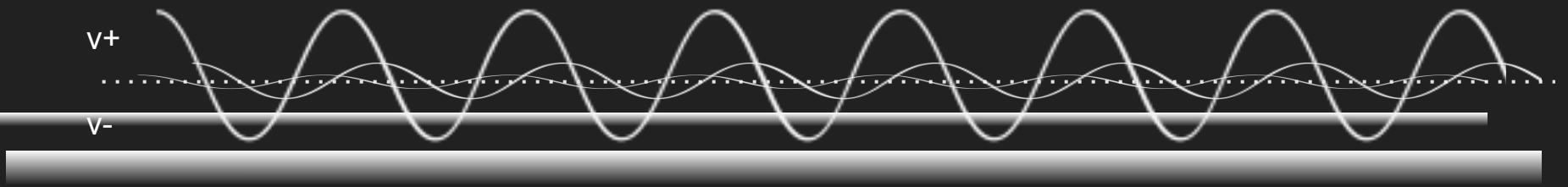

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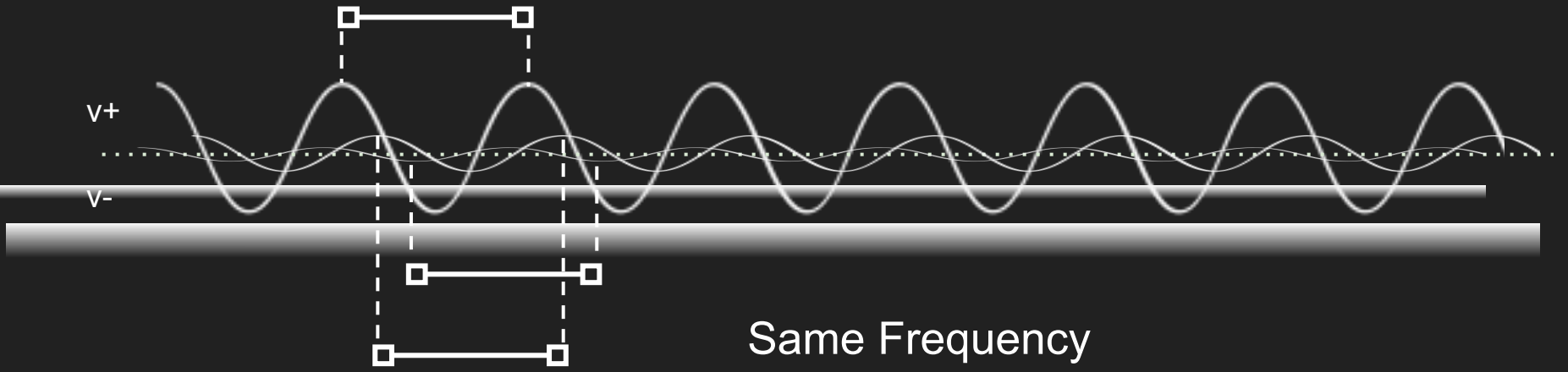

Same Frequency
Lower Power
Out of Phase

Multiple Input Multiple Output (MIMO)

Allows for reception even when there are collisions.

Uses out-of-phase echoes as alternatives for receiving the signal

- In empty space, it would not help, because it relies on bouncing signals.

Uses more than one antenna to transmit and receive.

- An antenna in a different position may receive a stronger signal or catch a better echo

Wireless Fidelity (WiFi)

Every country can choose which part of the EM spectrum to use for WiFi

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Every country can choose which part of the EM spectrum to use for WiFi

14 channels at ~2.4 GHz

- USA’s Federal Communication Commission only allows 11 of these
- Each 5MHz apart in frequency

24 channels at ~5 Ghz

- USA’s Federal Communication Commission only allows 21 of these
- Other countries are different

WiFi, WiFi 5, WiFi 6, WiFi 6e

WiFi 5 uses only the 5 GHz band

- 4 device MU-MIMO before interference

WiFi 6 uses both 2.4 GHz and 5GHz simultaneously

- 8 device MU-MIMO before interference

WiFi 6e will use an extra 6 GHz band

- Will require an antenna able to listen/transmit on this band

WiFi specifications also include 2nd network layer rules we will learn later (like encryption, collision detection, and framing)

Cellular Networks - Longer Distance Radios

4G LTE (Long Term Evolution) - 100Mbps reasonable top speeds

5G 1Gbps+ speeds

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Challenges to solve at layer 2 and 3:

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Challenges to solve at layer 2 and 3:

- What happens if you are driving between towers while using the Internet?
- Saving power by limiting transmissions by phones
- Transmissions that get lost and never received
- Too many phones for one cell tower to support

5G

More frequency channels

Lower latency

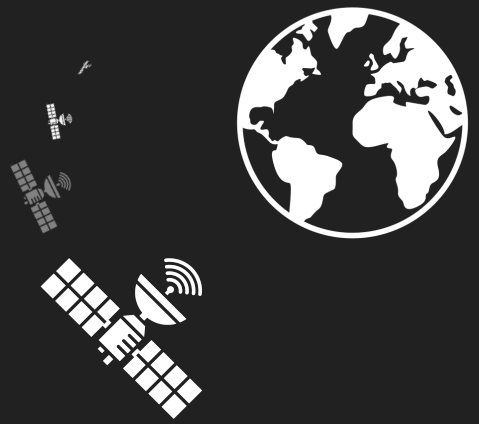
More simultaneous connections per cell

4G in perfect conditions can reach gigabit speeds

5G in perfect conditions can reach 20 gigabit speeds

Could compete with ISPs without laying and maintaining cables!

Traditional Satellite Internet (Viasat, Hughesnet)



Relays in geo-stationary orbit

Stays still relative to Earth’s spinning surface

35,800 km over Earth’s surface

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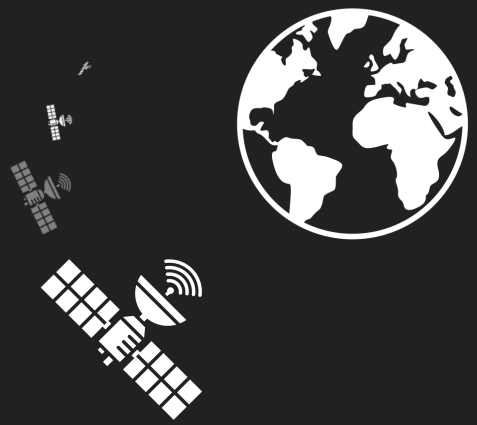

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Latency:

At least .2 seconds RTT

Real life ~.5 seconds RTT

Starlink Low Latency Satellite Internet

Low Earth Orbit (~550km)

More, small satellites

Lower Latency

Less Signal Loss

Higher Atmospheric Drag

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We cannot solve *jamming* when someone transmits gibberish constantly at high power to drown out legitimate signals

Wireless protocols have to know that they may lose information

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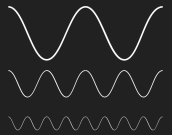
Earth by mungang kim from Noun Project 

Satellite by tezar tantular from Noun Project 

Smartphone by IconHome from Noun Project 

Sine Waves by Davo Sime from Noun Project 

cell tower by Rifai from Noun Project 

Satellite Dish by Vectors Market from Noun Project