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Wireless Technical Basics

What is wireless (radio) ?

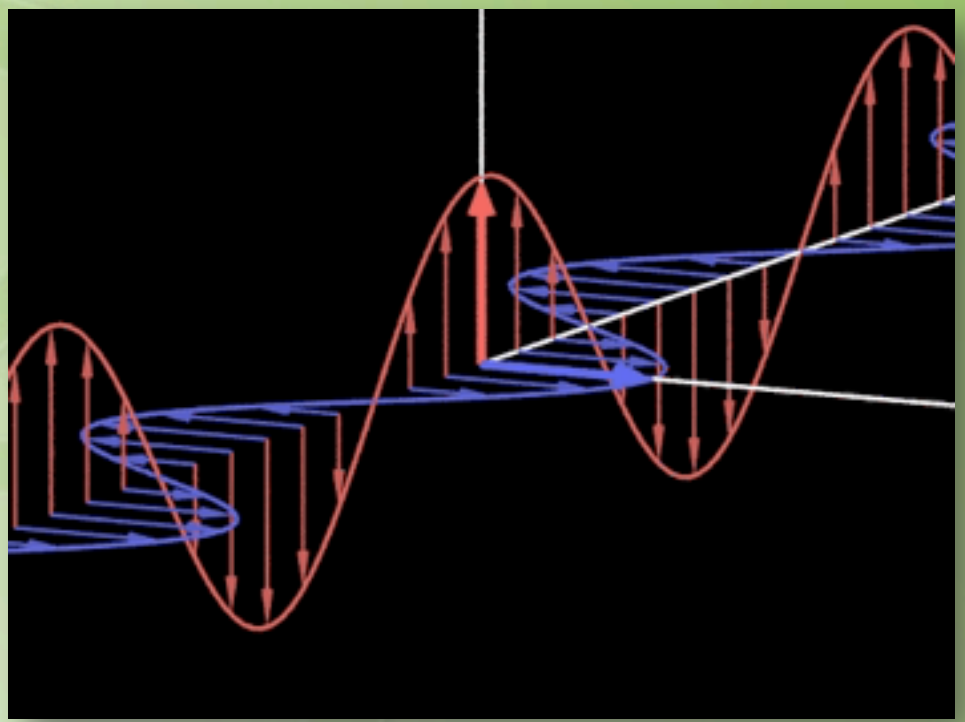
Albert Einstein described radio this way

– *"You see, wire telegraph is a kind of a very, very long cat. You pull his tail in New York and his head is meowing in Los Angeles. Do you understand this? And radio operates exactly the same way: you send signals here, they receive them there. The only difference is that there is* ***no cat****."*

From NoCat.net

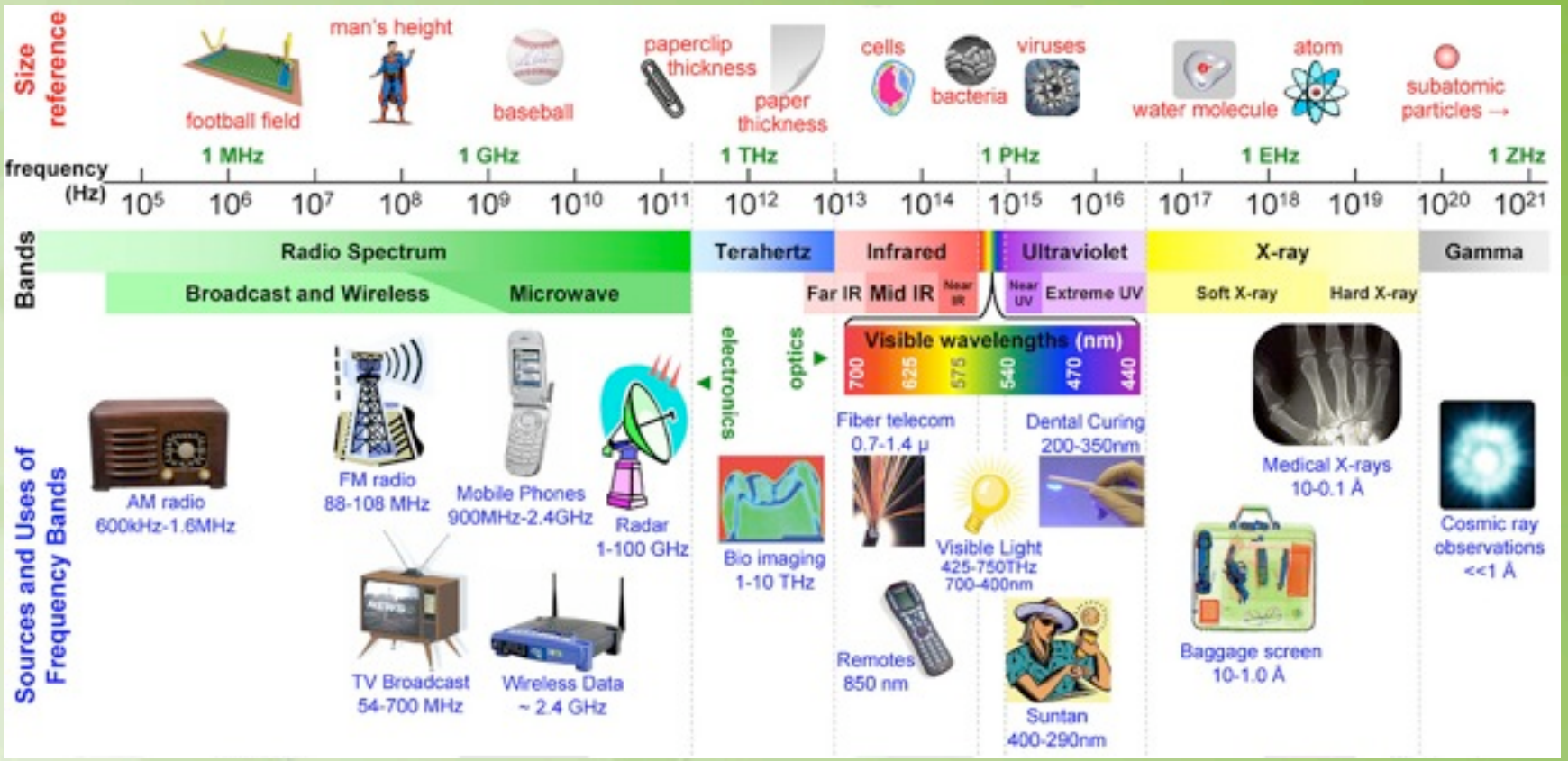
Electromagnetic Waves

- Radio waves are half electric, half magnetic
- Each half pushes the other half forward



The Electromagnetic Spectrum

Radio broadcasts, cell phones, wireless networking, visible light and x-rays are all electromagnetic waves, just at different frequencies.



Licensed/Unlicensed Bandwidth

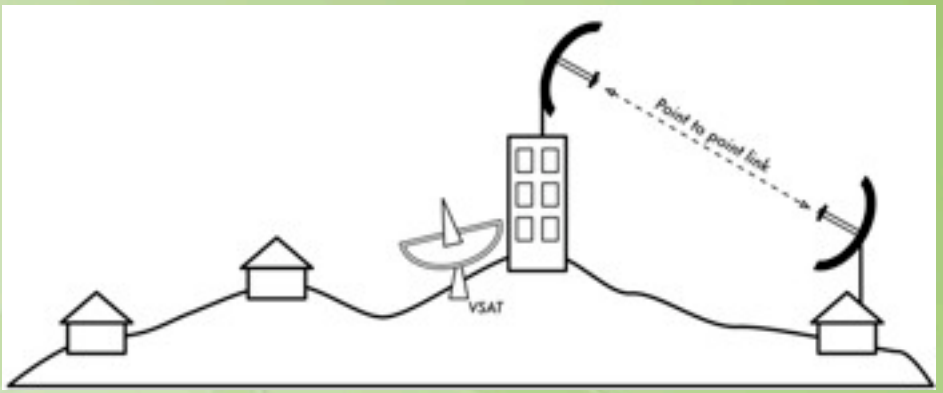
- In some countries, the government limits what parts of the spectrum you can use without special permission.
- Don’t get in trouble: make sure you know the law.

Wireless Network Layout

Wireless network design has three basic modes that can be combined as needed:

- Point-to-Point
- Point-to-Multipoint
- Multipoint-to-Multipoint

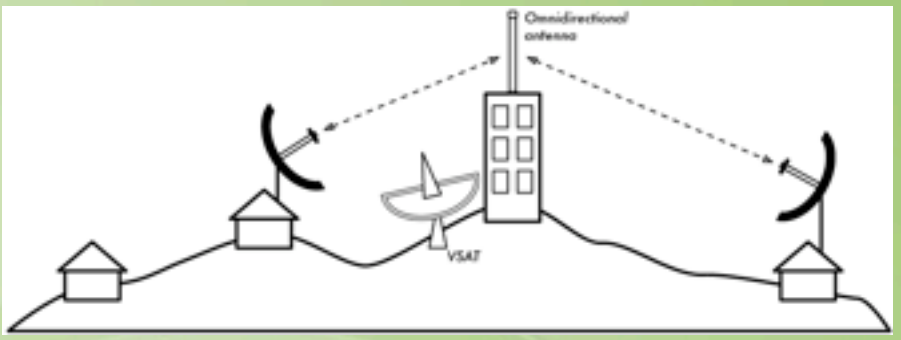
Point-to-Point (P2P)

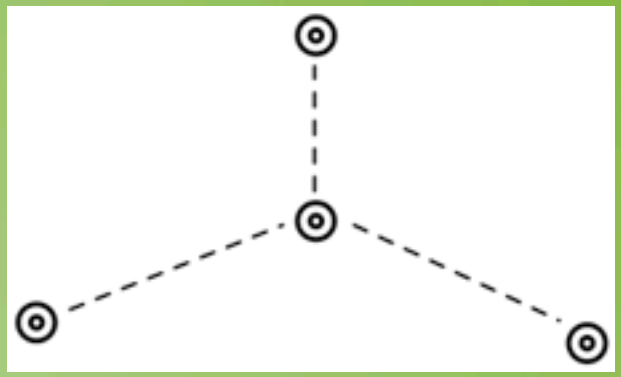


Advantages: Long range, less interference, simplicity

Disadvantages: Antenna aim is critical, Two radios for each field location (cost)

Point-to-Multipoint (P2MP)

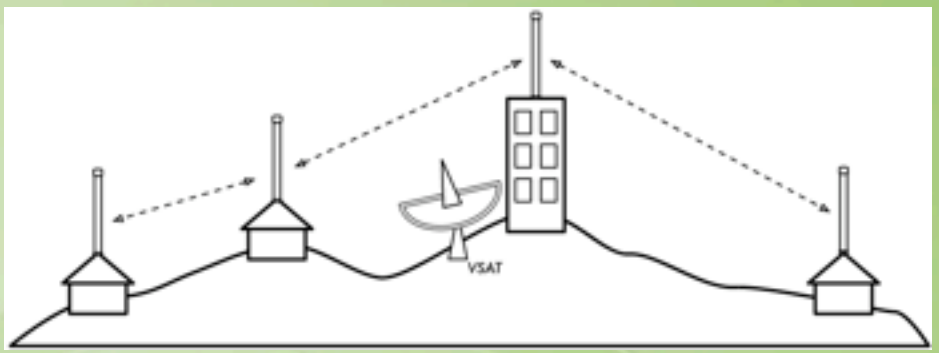


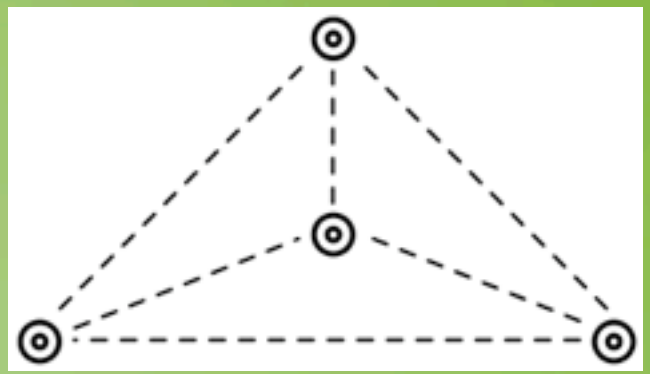


Advantages: Cost effective (less equipment), simple design

Disadvantages: Single point of failure, less bandwidth (only one radio at a time can transmit), shorter range than P2P

Multipoint-to-Multipoint (MP2MP)





Advantages: Redundancy, less planning required, less configuration, good for short distance

Disadvantages: Less bandwidth, many variables impacting quality

Antenna Basics

Antennas convert between electromagnetic waves (in the air) and electrical currents (on a wire)

Frequency range: *What frequencies is the antenna designed for?*

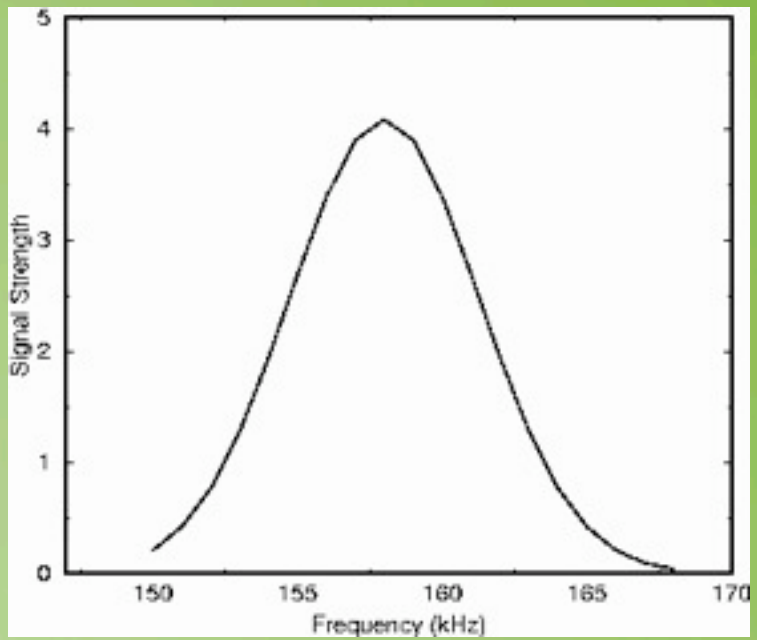
Gain: *How powerful is the antenna?*

Beamwidth: *How focused is the beam of the antenna?*

Polarization: *Does the antenna polarize the signal?*

Frequency Range

- Every antenna has a ‘perfect’ or center frequency, and is effective for a range of frequencies on either side.
- WiFi Frequencies:
  - 802.11b/g: 2400 – 2484 MHz
  - 802.11a: 5725 – 5825 MHz
- Choose your antenna for frequencies important to you



Gain

- An antenna does not add power to a signal, it focuses existing power
- An antenna with no gain sends energy in all directions equally and is called an *ideal isotropic radiator*
- Gain measures the ratio of power received from our antenna to power received from an ideal isotropic radiator at the same location

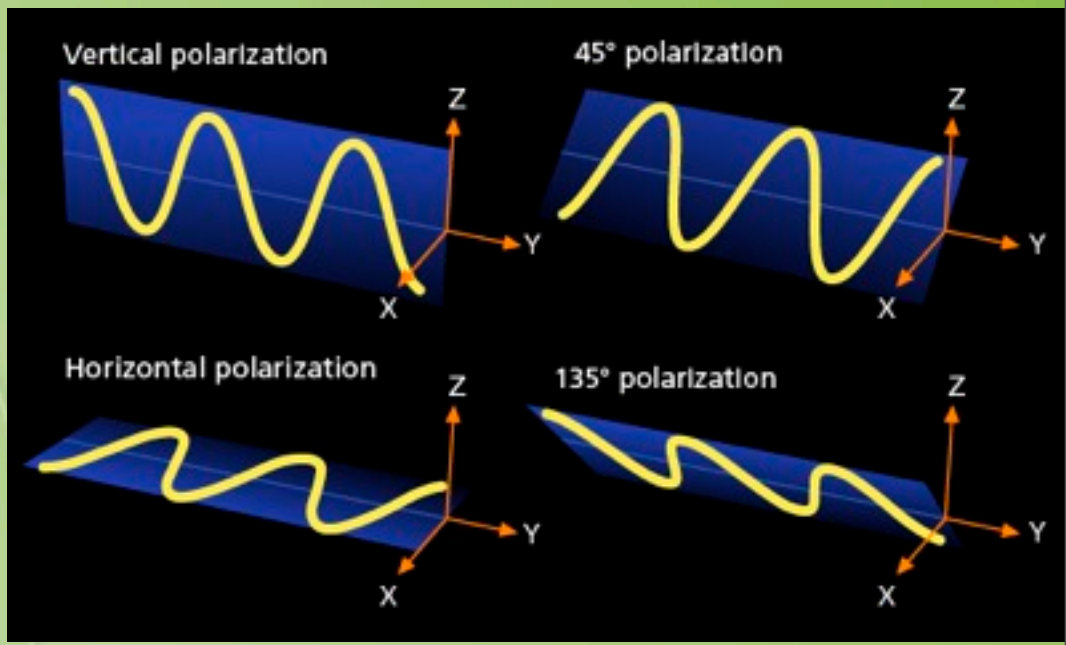
$$dBi = 10\log_{10}\left(\frac{P_{antenna}}{P_{isotropic}}\right)$$

Beamwidth

- Antennas take energy from where we don't want it, and concentrate it where we do.
- How wide is the area where you need coverage?
  - Point-to-Point: Narrow beamwidth
  - Point-to-Multipoint: Broad beamwidth

Polarization

- Antennas can *polarize* the signal
- Polarization direction refers to the orientation of the electric component of the EM wave
- Polarization of your transmitting and receiving antennas **must** match!

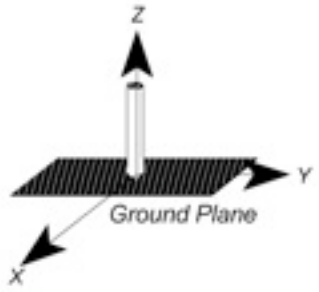
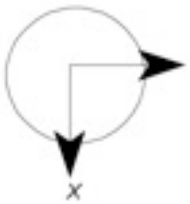


Antenna types

- Omni-directional
- Directional
  - Patch
  - Yagi
  - Reflective / Parabolic
  - Cantenna (circular aperture waveguide)

Omni-directional

- Distributes energy in a 360° circle
- The “circle” is flat like a plate, not round like a ball
- Good for P2MP and MP2MP
- Not good for long distance
- Typical gain 3 - 8 dBi

Antenna Type	Radiation Pattern	Characteristics
MONOPOLE 	Elevation:  Azimuth: 	***Polarization: Linear*** *Vertical as shown* ***Typical Half-Power Beamwidth*** *45 deg x 360 deg* ***Typical Gain:*** *2-6 dB at best* ***Bandwidth:*** *10% or 1.1:1* ***Frequency Limit*** ***Lower:*** *None* ***Upper:*** *None*

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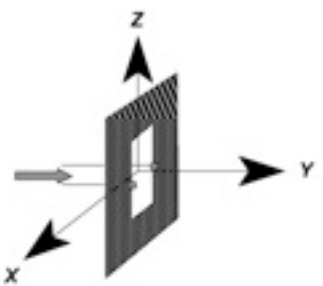
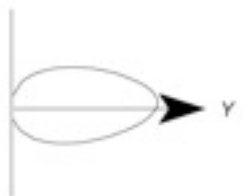
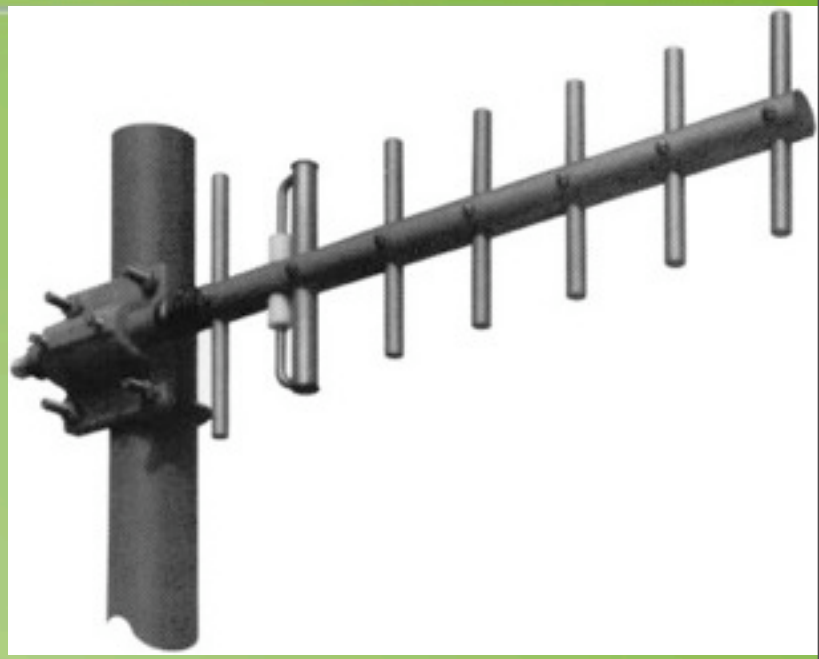
Patch

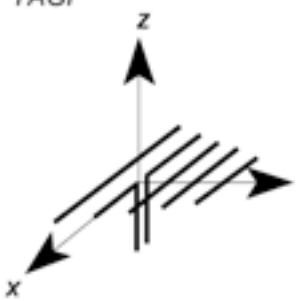
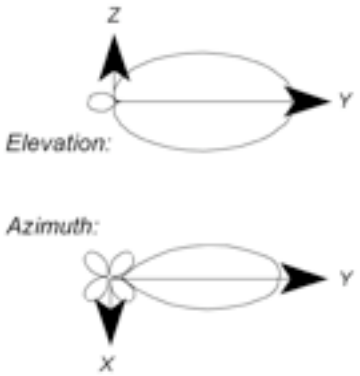
- Directional (30° to 160° Beamwidth)
- Low cost
- Easy to mount
- 6 - 15 dBi gain
- Good for P2P and P2MP
- Medium range (2 - 10 km)

Antenna Type	Radiation Pattern	Characteristics
PATCH 	***Elevation & Azimuth*** 	***Polarization:*** *Linear, vertical as shown* ***Typical Half-Power Beamwidth:*** *80 deg x 80 deg* ***Typical Gain:*** *6 dB* ***Bandwidth:*** *Narrow* ***Frequency Limit:*** ***Lower:*** *50 MHz* ***Upper:*** *18 GHz*

Yagi



- Directional (30° to 160° Beamwidth)
- Low cost
- Easy to mount
- 6 - 15 dBi gain
- Good for P2P and P2MP
- Medium range (2 - 10 km)

Antenna Type	Radiation Pattern	Characteristics
YAGI 		***Polarization:*** *Linear Horizontal as shown* ***Typical Half-Power Beamwidth*** *50 deg X 50 deg* ***Typical Gain:*** *5 to 15 dB* ***Bandwidth:*** *5% or 1.05:1* ***Frequency Limit:*** ***Lower:*** *50 MHz* ***Upper:*** *2 GHz*

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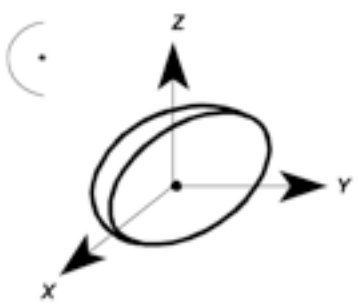
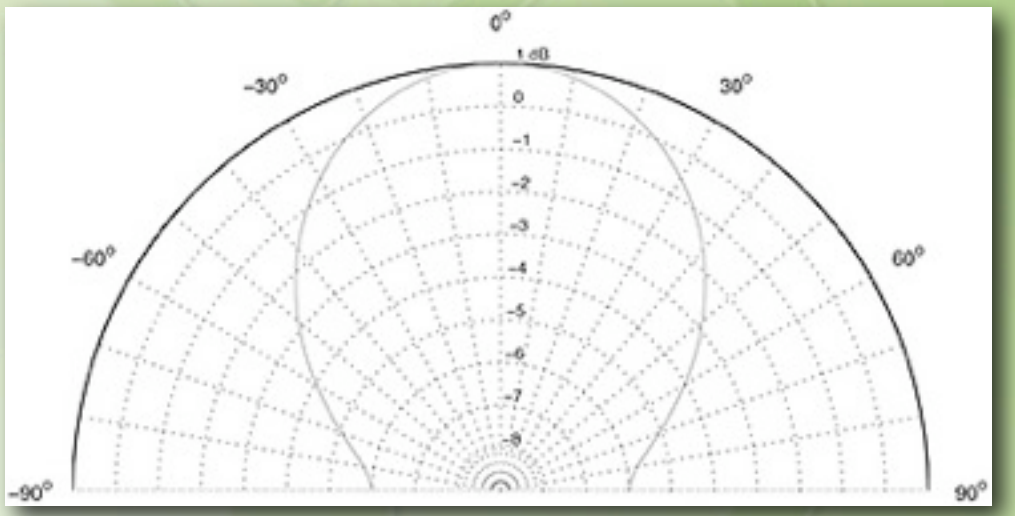
Reflective / Parabolic

- Highly Directional (1° to 10° Beamwidth)
- Expensive
- Must be precisely aimed
- 20 - 30 dBi gain
- Best for P2P
- Long range (Up to 200+ km)

Antenna Type	Radiation Pattern	Characteristics
PARABOLIC 	Elevation & Azimuth 	**Polarization:** *Takes polarization of feed* **Typical Half-Power Beamwidth:** *1 to 10 deg* **Typical Gain:** *20 to 30 dB* **Bandwidth:** *33% or 1.4:1 limited mostly by feed* **Frequency Limit:** **Lower:** *400 MHz* **Upper:** *13+ GHz*

Cantenna

- Directional
- Inexpensive (~USD $7)
- Can be difficult to construct
- 6 - 15 dBi gain
- Good for P2P and P2MP
- Medium range (2 - 10 km)



Radio Configuration

802.11 modes

- Infrastructure
- Ad-hoc
- Monitor

Standards

- 802.11b/g (b: 11 Mbps / g: 54 Mbps) - 2.4 Ghz
- 802.11a (54Mbps) - 5.8 Ghz

Radio Configuration

Channel: What channel to use (1-11)

SSID: Service Set Identifier (Network name)

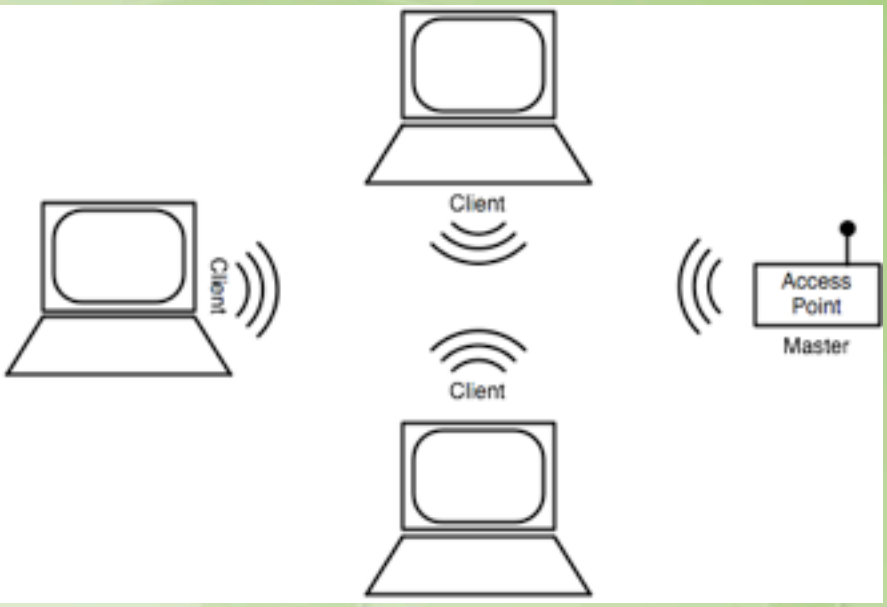
Broadcast SSID?

- -Yes: Announce network name
- -No: Keep it secret

Encryption:

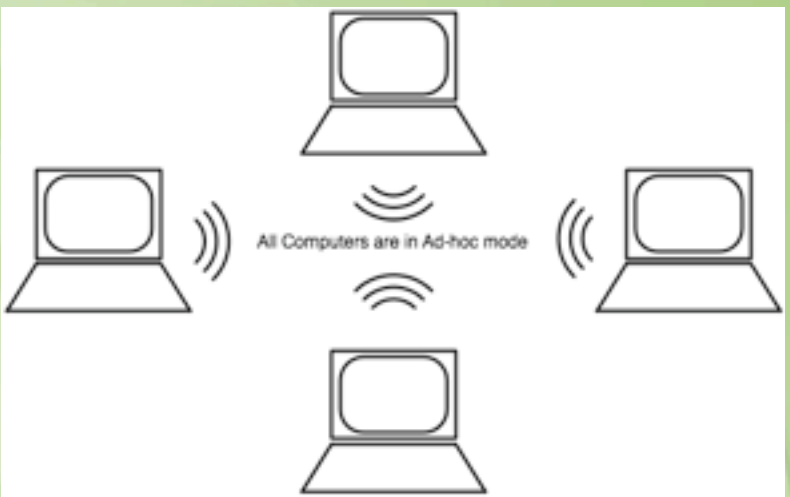
- -WEP: Common, but with flaws
- -WPA/WPA2: More secure than WEP

Infrastructure Network



- Most common wifi network configuration for homes and offices
- Computers connect (associate) to an access point to use network resources (Internet, printers, servers)
- Access point operates in **master** mode, computers operate in **managed** mode.

Ad-hoc Network



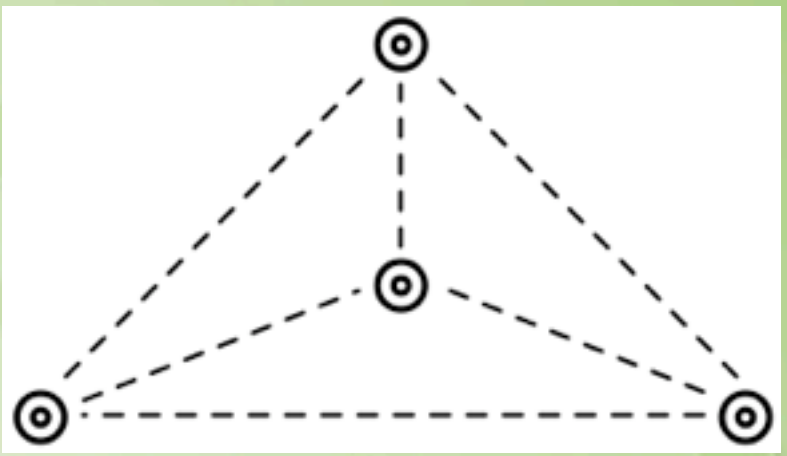
- In *ad-hoc* network nodes communicate directly with no access point in between
- All nodes use the same SSID
- Nodes can be removed or added with no impact on other nodes
- An ad-hoc network has no center, it is a network of peers

Monitor Mode

- Nodes in **Monitor mode** listen to all wifi traffic
- Not used for traditional networking, a special mode useful for solving problems

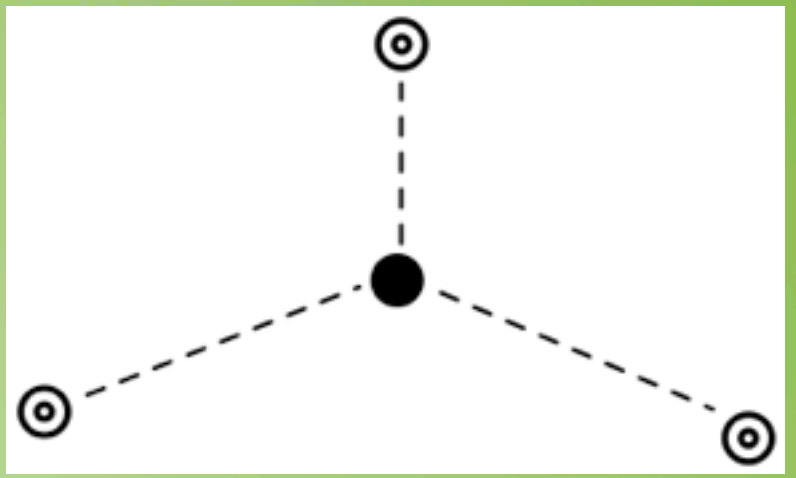
Logical Network Diagram

Ad-hoc



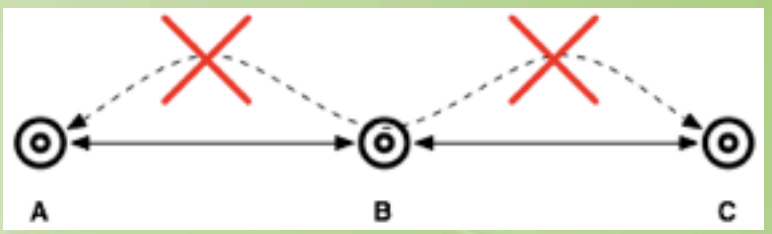
An ad-hoc network is a multipoint to multipoint network

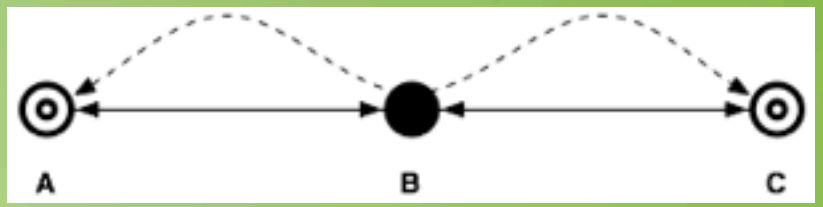
Infrastructure



An infrastructure network is a point to multipoint network

Relaying Traffic





Nodes A and C are in range of B but not each other

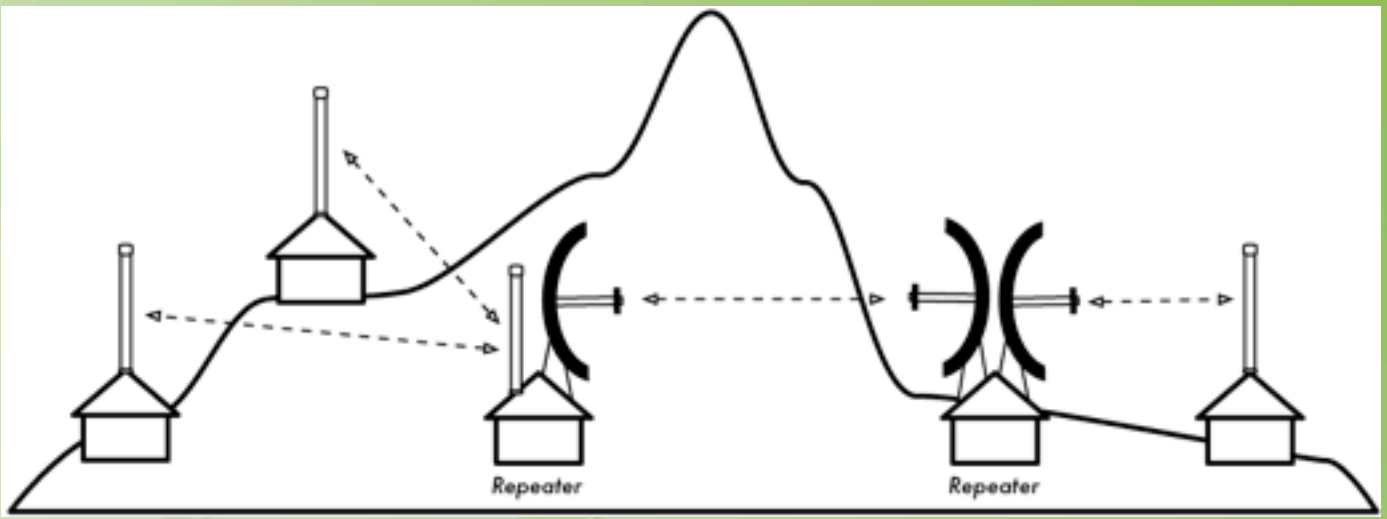
In an **ad-hoc** network, A can communicate with B and B with C but not A with C. Node B will **NOT relay** traffic for other nodes.

In an **infrastructure** network, B **will relay** traffic from A to C. A and C cannot communicate directly without B in the middle.

Growing Networks

- When networks grow beyond the range of a single radio or need to cover multiple separate areas, things get more complicated
- Good design is important to make sure the growing network works efficiently
- Multiple access points provide service to clusters of clients
- Access points are interconnected so clients in different clusters can communicate and share services (Internet access, printers, etc.)

Repeaters



- A *repeater* is a location with two or more radios
- Traffic *received* on one radio is *transmitted (repeated)* by the other
- Radios can be networked together in different ways

Bridged (wireless) Networks

Bridging is an easy way to extend a small network (i.e. to provide a larger coverage area)

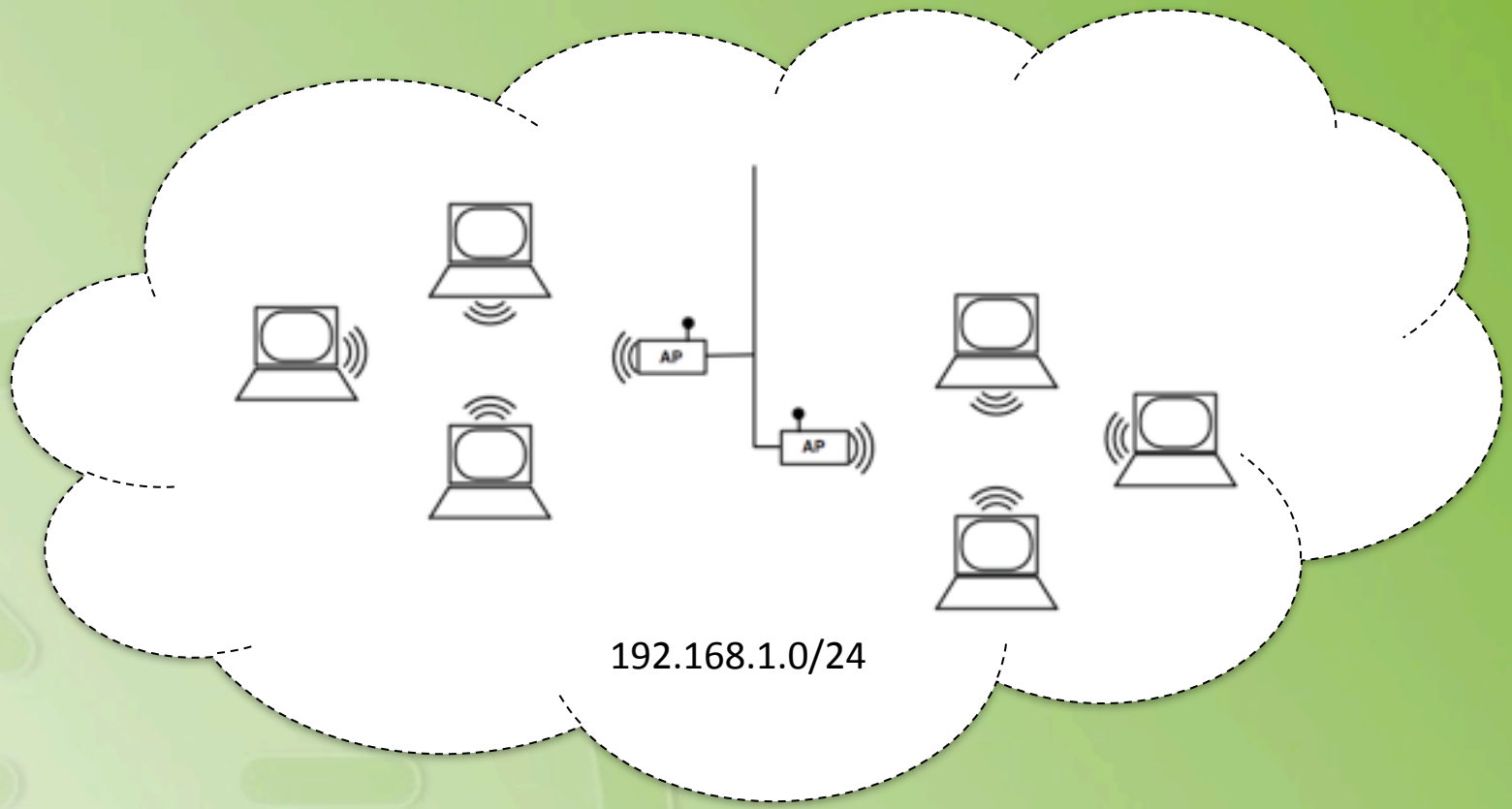
Advantages:

- Easy to configure
- Roaming (moving from one AP to another AP) works well

Disadvantages:

- Doesn't scale well – less efficient with more nodes
- Broadcast traffic is repeated
- Troubleshooting is difficult

Bridged Access Points



- The range of the network is extended by adding a second access point
- Client nodes don't notice any change before and after bridging
- When two networks are *bridged* all traffic from one is visible on the other: they become a single network

Routed (wireless) Networks

Routing allows a network to grow without flooding the network with rebroadcasts

Advantages:

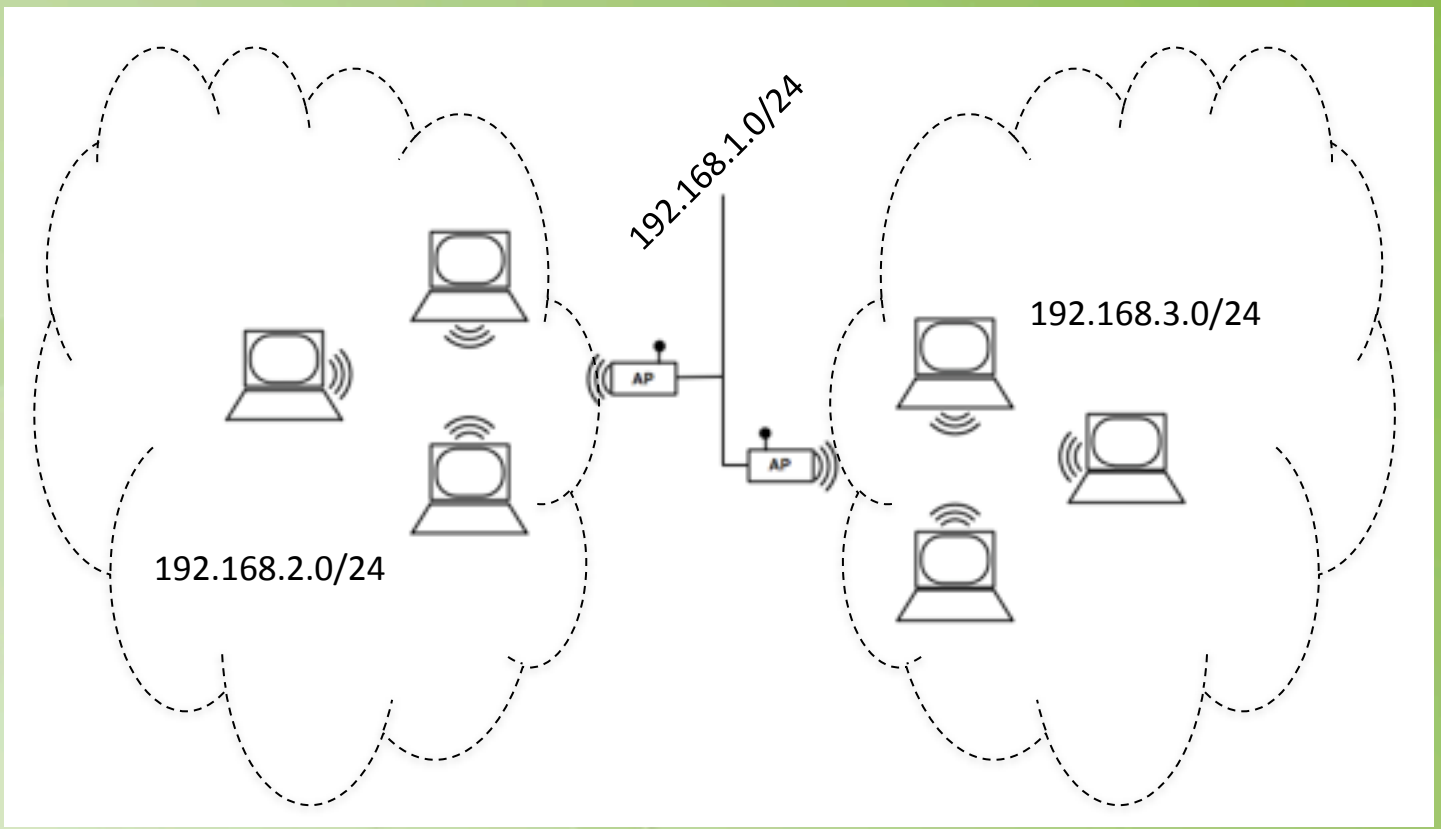
- Efficient - No unnecessary rebroadcasts
- Troubleshooting is easier
- Scales well

Disadvantages:

- Takes more planning/ knowledge to implement
- Roaming (moving from one AP to another) is more complicated

- Static - Only good for small networks, gets confusing quickly
- Dynamic - Self-configuring networks (OSPF, RIP)

Routed Access Points



- Network 192.168.2.0 is extended by adding a second access point and creating a second network (192.168.3.0)
- The two wireless networks are linked through a third network (192.168.1.0)
- The linking network can be an ethernet cable or a wireless link (e.g. point to point)

Credits

WirelessU.org

WNDW.net – Wireless networking for the developing world

Rob Flickenger – Hackerfriendly.com

www.itrainonline.org

Abdus Salam International Centre for Theoretical Physics (ICTP) (www.ictp.it)

Granite Island Group - www.tscm.com