Limitations of the mobile environment

- Limitations of the Wireless Network
  - limited communication bandwidth
  - frequent disconnections
  - heterogeneity of fragmented networks

- Limitations Imposed by Mobility
  - route breakages
  - lack of mobility awareness by system/applications

- Limitations of the Mobile Device
  - short battery lifetime
  - limited capacities

Wireless v/s Wired networks

- Regulations of frequencies
  - Limited availability, coordination is required
  - useful frequencies are almost all occupied
- Bandwidth and delays
  - Low transmission rates
    - few Kbits/s to some Mbit/s.
  - Higher delays
    - several hundred milliseconds
  - Higher loss rates
    - susceptible to interference, e.g., engines, lightning
- Always shared medium
  - Lower security, simpler active attacking
  - radio interface accessible for everyone
  - secure access mechanisms important

Wireless LANs vs. Wired LANs

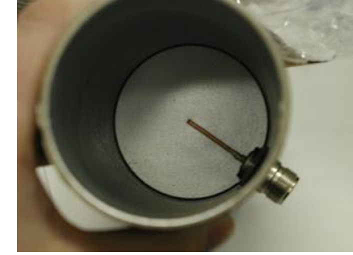
- Destination address does not equal destination location (mobility)
- The media impact the design
  - wireless LANs intended to cover reasonable geographic distances must be built from basic coverage blocks
- Impact of handling mobile (and portable) stations
  - Propagation effects
  - Mobility management
  - Power management

Wireless Media

- Physical layers used in wireless networks
  - have neither absolute nor readily observable boundaries outside which stations are unable to receive frames
  - are unprotected from outside signals
  - communicate over a medium significantly less reliable than the cable of a wired network
  - have dynamic topologies
  - lack full connectivity and therefore the assumption normally made that every station can hear every other station in a LAN is invalid (i.e., STAs may be "hidden" from each other)
  - have time varying and asymmetric propagation properties

Antennas

Antennas



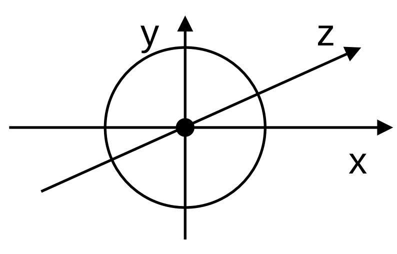
- An antenna is an electrical conductor or system of conductors to send/receive RF signals
  - Transmission - radiates electromagnetic energy into space
  - Reception - collects electromagnetic energy from space
- In two-way communication, the same antenna can be used for transmission and reception

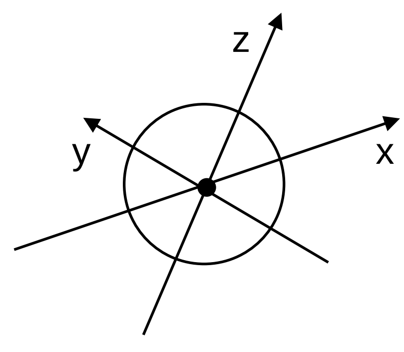
Omnidirectional Antenna
(lower dBi)

Directional Antenna (higher dBi)

Antennas: isotropic radiator

- Radiation and reception of electromagnetic waves, coupling of wires to space for radio transmission
- Isotropic radiator: equal radiation in all directions (three dimensional) - only a theoretical reference antenna
- Real antennas always have directive effects (vertically and/or horizontally)
- Radiation pattern: measurement of radiation around an antenna

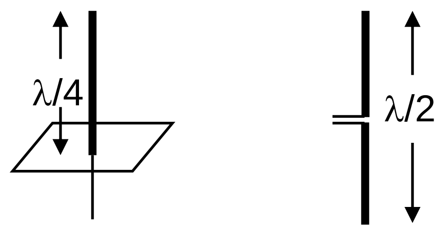


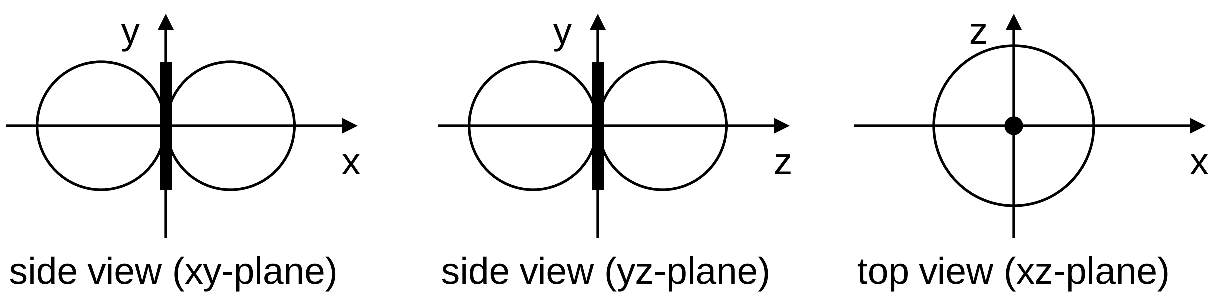


ideal isotropic radiator

Antennas: simple dipoles

- Real antennas are not isotropic radiators
  - dipoles with lengths $\lambda/4$ on car roofs or $\lambda/2$ (Hertzian dipole)
    ➔ shape of antenna proportional to wavelength
- Gain: maximum power in the direction of the main lobe compared to the power of an isotropic radiator (with the same average power)

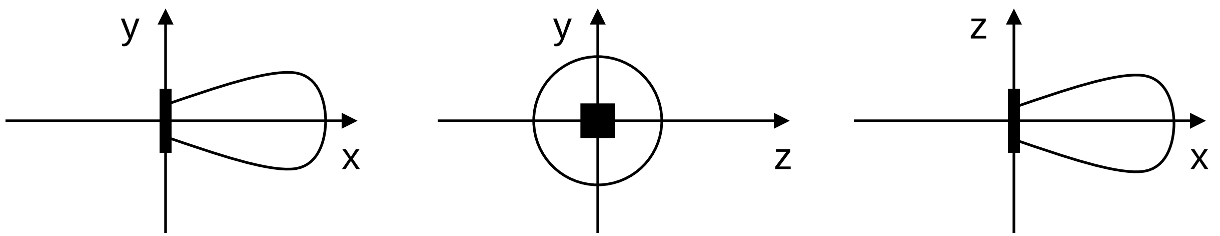




simple dipole

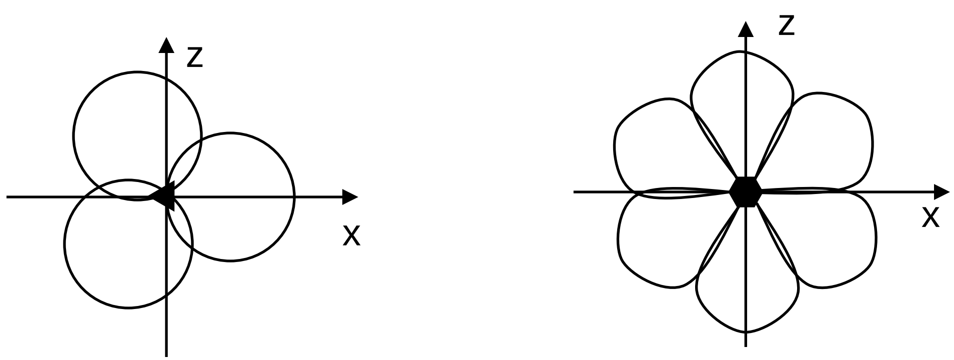
Antennas: directed and sectorized

- Often used for microwave connections or base stations for mobile phones (e.g., radio coverage of a valley)



side view (xy-plane) side view (yz-plane) top view (xz-plane)

directed antenna



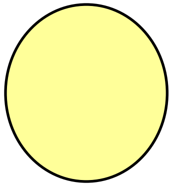
top view, 3 sector top view, 6 sector

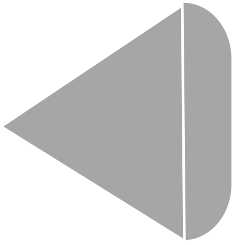
sectorized antenna

Antenna models

In Omni Mode:

- Nodes receive signals with gain $\mathbf{G^o}$



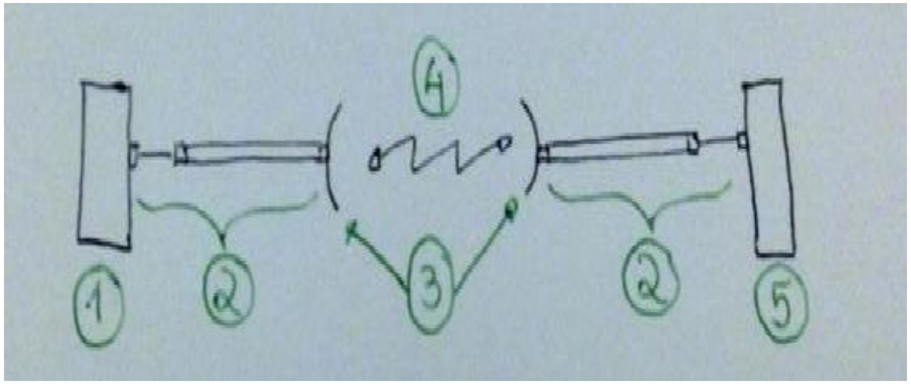


In Directional Mode:

- Capable of beamforming in specified direction
- Directional Gain $\mathbf{G^d}$ $\mathbf{(G^d > G^o)}$

Question?

Consider a standard wireless link, where we have a transmitter (1) and a receiver (5), Antennas (3), Cables, Jumpers and Connectors (2) and Free Space propagation media (4).



Using real values, let's do the math and see, from the transmitted power, how much power we have at receiver. So with values close to reality, we have:

Transmitter Power = 40 Watts

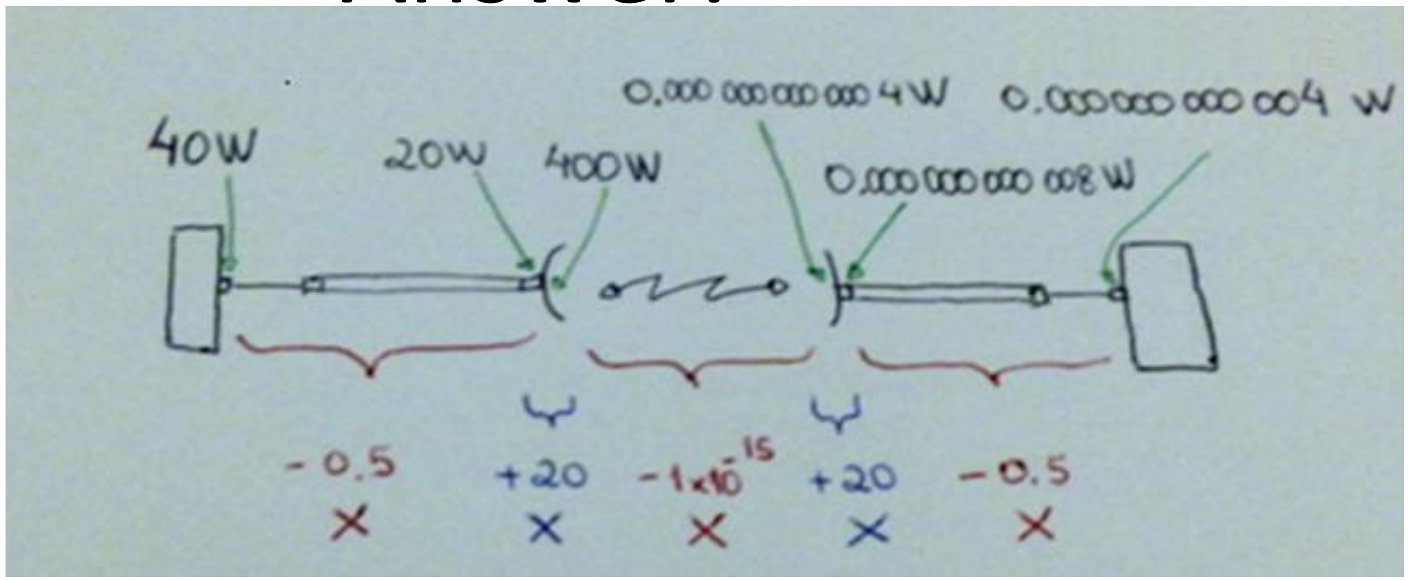
Cables and connectors loss = - 0.5 (Half Power)

Antenna Gain = 20 + times in the Power

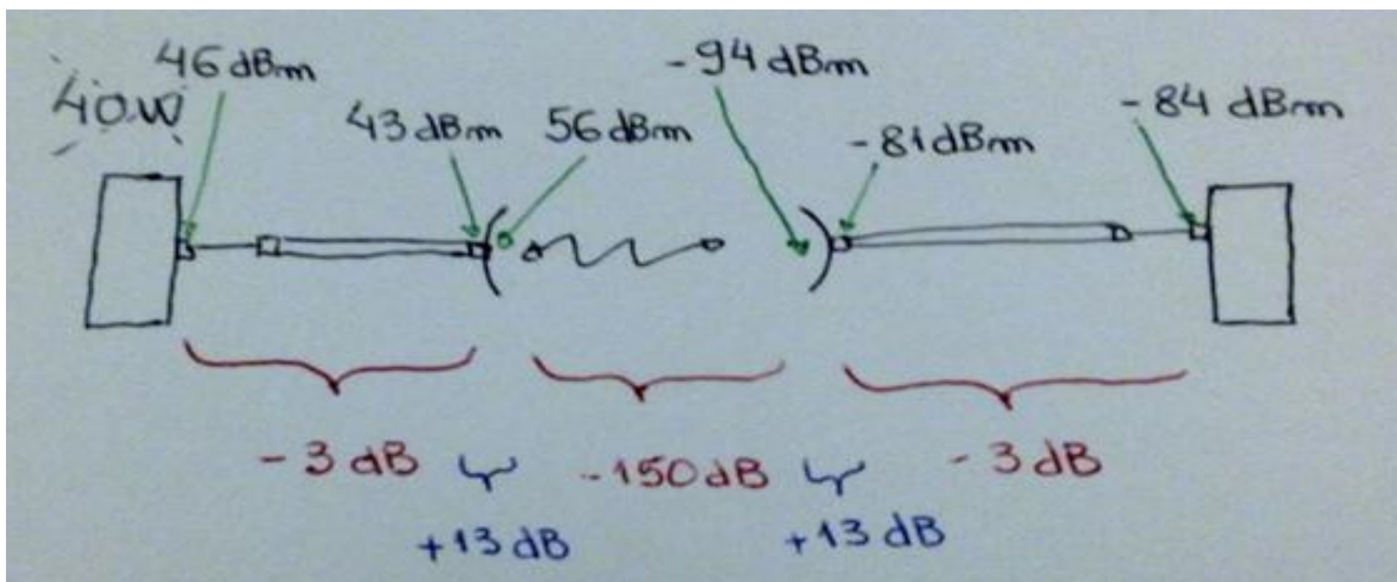
Free Space Loss = - 0.000 000 000 000 000 1 times of Power

Answer:

By power (w)



By power(dbm)



Directional communication

Received Power $\propto$ (Transmit power)

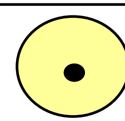
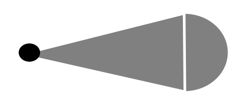
*(Tx Gain) * (Rx Gain)

Directional gain is higher

Directional antennas useful for:

- Increase “range”, keeping transmit power constant
- Reduce transmit power, keeping range comparable with omni mode

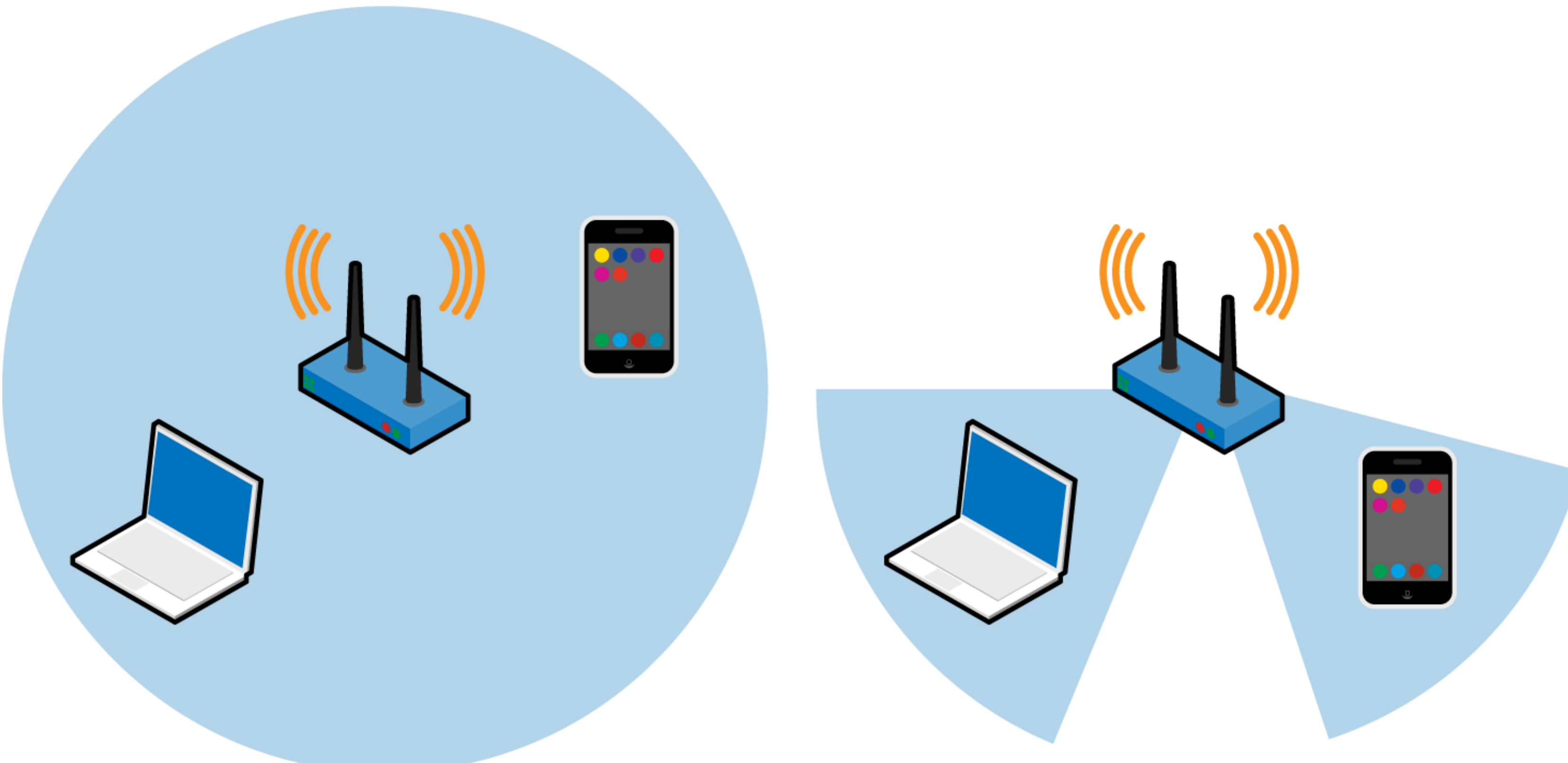
Comparison of omni and directional

Issues	Omni	Directional
Spatial Reuse	Low	High
Connectivity	Low	High
Interference	high	low
Radiation shape		
Cost & Complexity	Low	High

Spatial reuse

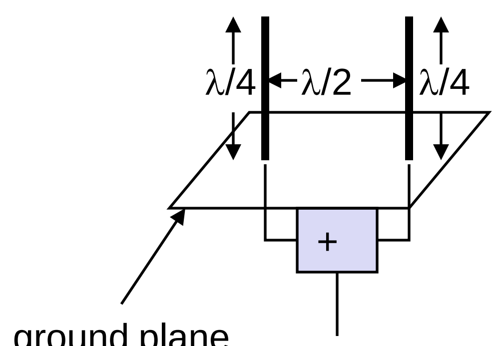
(a) Spatial reuse per AP

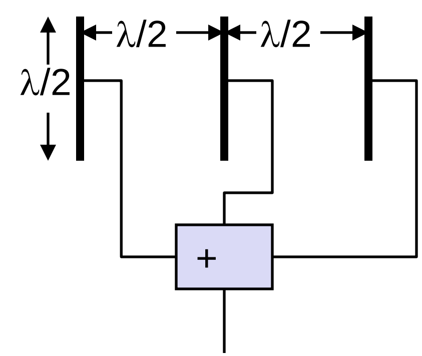
(b) Spatial reuse per receiver



Antennas: diversity

- Grouping of 2 or more antennas
  - multi-element antenna arrays
- Antenna diversity
  - switched diversity, selection diversity
    - receiver chooses antenna with largest output
  - diversity combining
    - combine output power to produce gain
    - Co-phasing needed to avoid cancellation





Signal Propagation

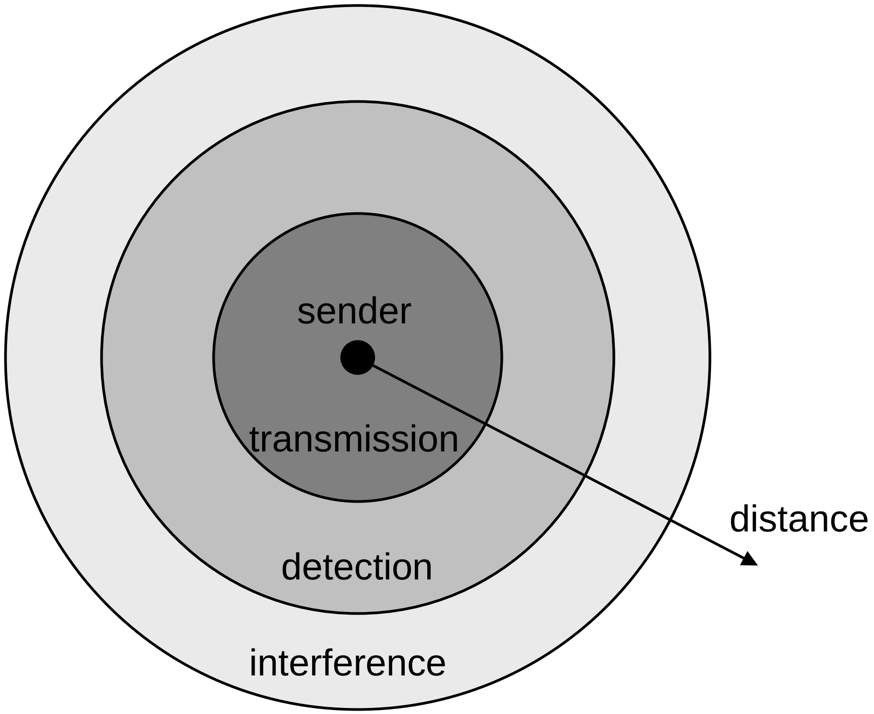
Signals

- physical representation of data
- function of time and location
- signal parameters: parameters representing the value of data
- classification
  - continuous time/discrete time
  - continuous values/discrete values
  - analog signal = continuous time and continuous values
  - digital signal = discrete time and discrete values
- signal parameters of periodic signals:
  period T, frequency f=1/T, amplitude A, phase shift φ
  - sine wave as special periodic signal for a carrier:

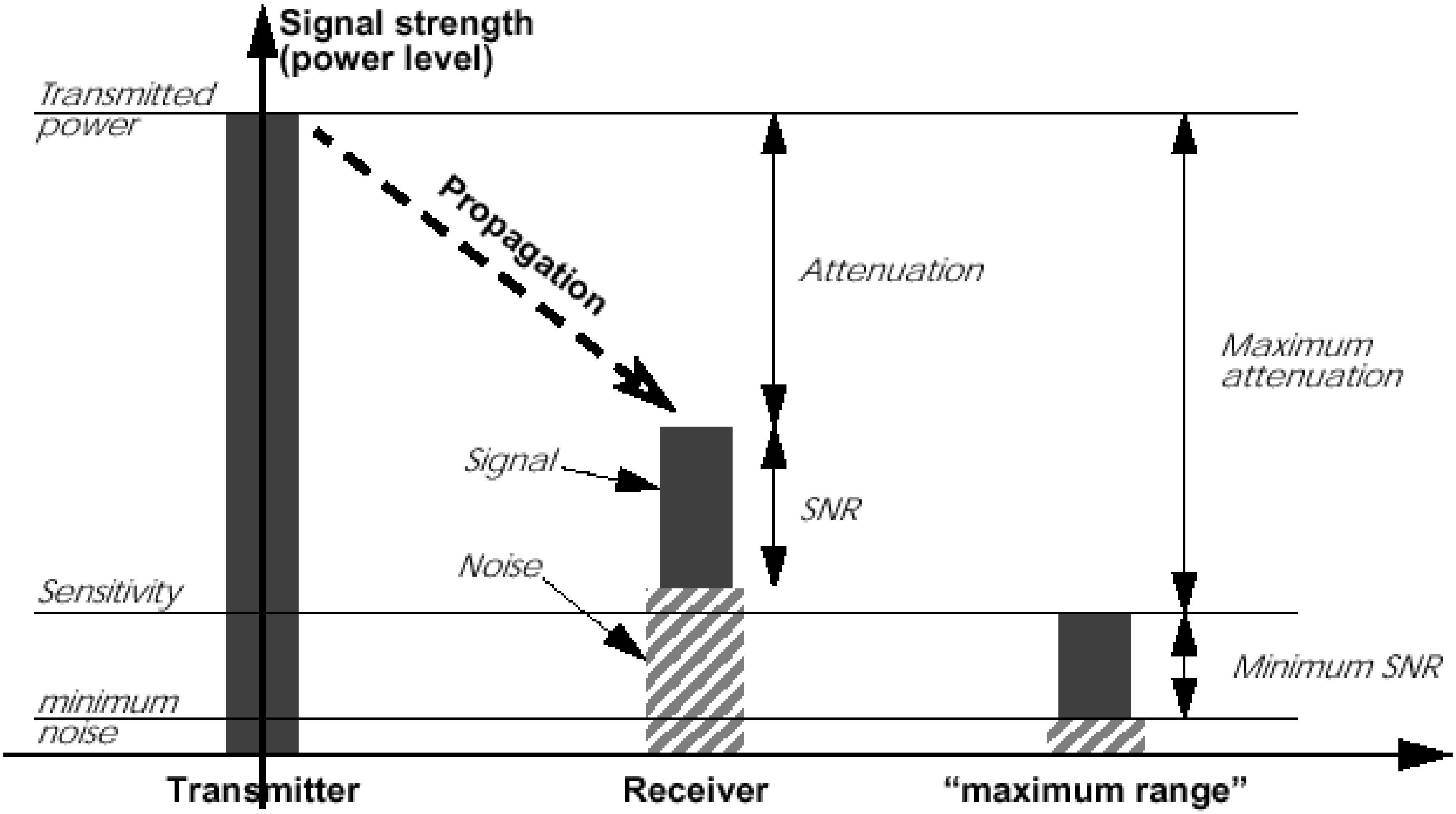
$$s(t) = A_t \sin(2 \pi f_t t + \varphi_t)$$

Signal propagation ranges

- Transmission range
  - communication possible
  - low error rate
- Detection range
  - detection of the signal possible
  - no communication possible
- Interference range
  - signal may not be detected
  - signal adds to the background noise



Attenuation: Propagation & Range

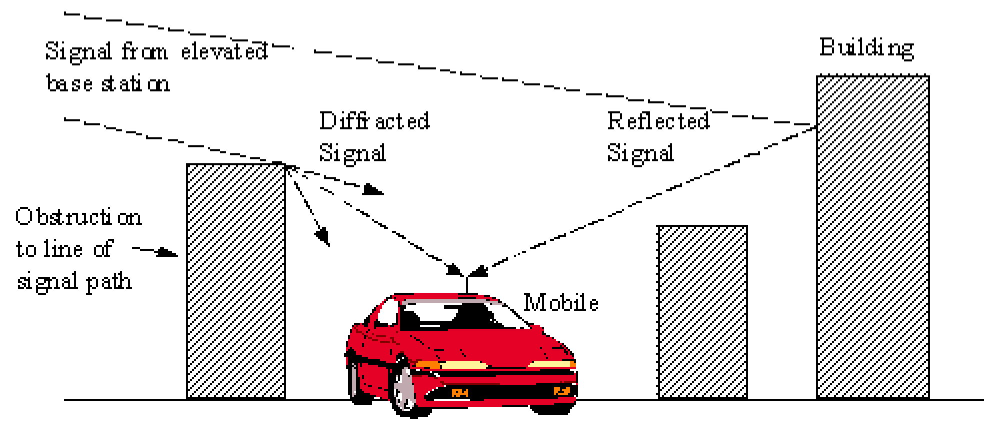


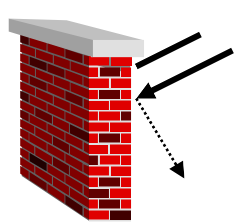
Attenuation

- Strength of signal falls off with distance over transmission medium
- Attenuation factors for unguided media:
  – Received signal must have sufficient strength so that circuitry in the receiver can interpret the signal
  – Signal must maintain a level sufficiently higher than noise to be received without error
  – Attenuation is greater at higher frequencies, causing distortion
- Approach: amplifiers that strengthen higher frequencies

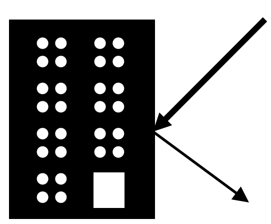
Signal propagation

- Propagation in free space always like light (straight line)
- Receiving power proportional to $1/d^2$
  (d = distance between sender and receiver)
- Receiving power additionally influenced by
  - fading (frequency dependent)
  - shadowing
  - reflection at large obstacles
  - refraction depending on the density of a medium
  - scattering at small obstacles
  - diffraction at edges

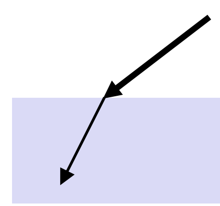




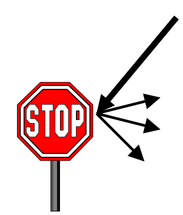
shadowing



reflection



refraction

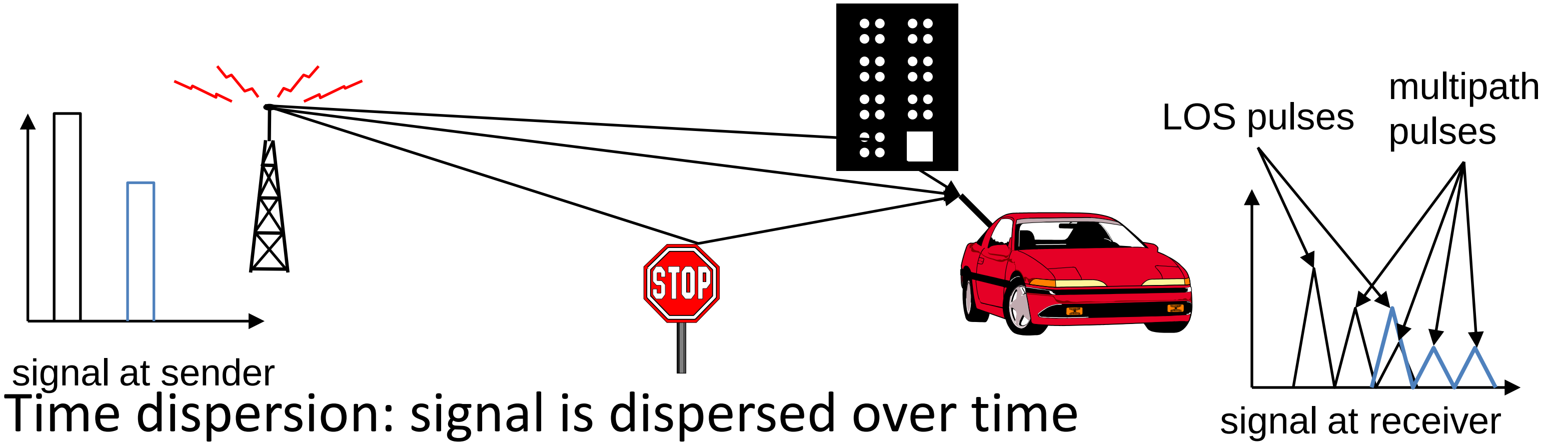


scattering

diffraction

Multipath propagation

- Signal can take many different paths between sender and receiver due to reflection, scattering, diffraction

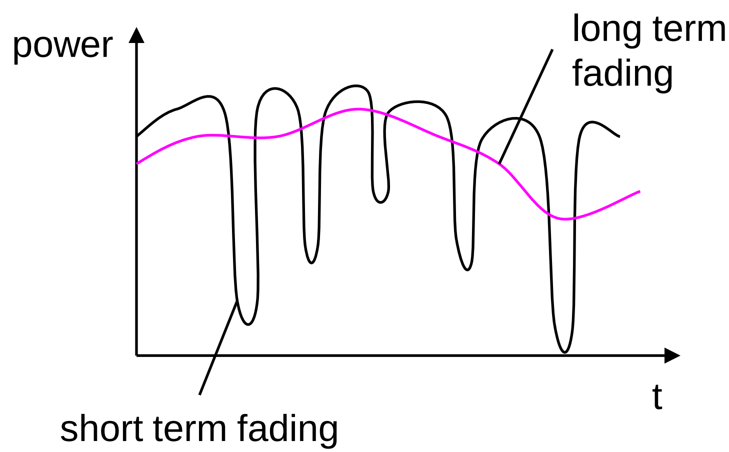


- Time dispersion: signal is dispersed over time
- ➔ interference with "neighbor" symbols, Inter Symbol Interference (ISI)
- The signal reaches a receiver directly and phase shifted
- ➔ distorted signal depending on the phases of the different parts

Effects of mobility

- Channel characteristics change over time and location
  - signal paths change
  - different delay variations of different signal parts
  - different phases of signal parts
- ➔ quick changes in the power received

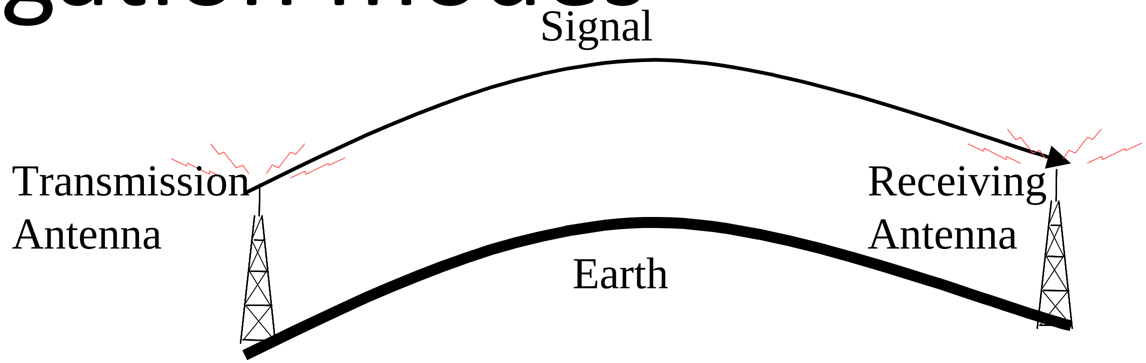
(short term fading)



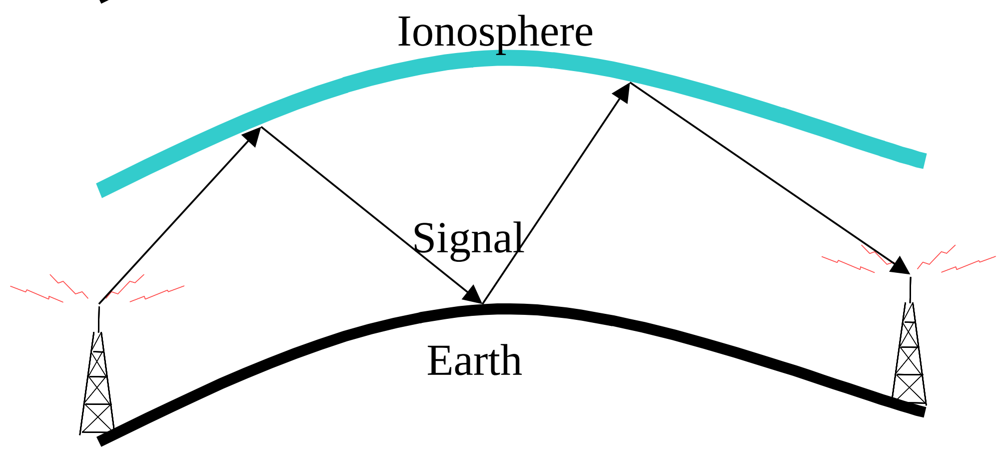
- Additional changes in
  - distance to sender
  - obstacles further away
- ➔ slow changes in the average power received (long term fading)

Propagation modes

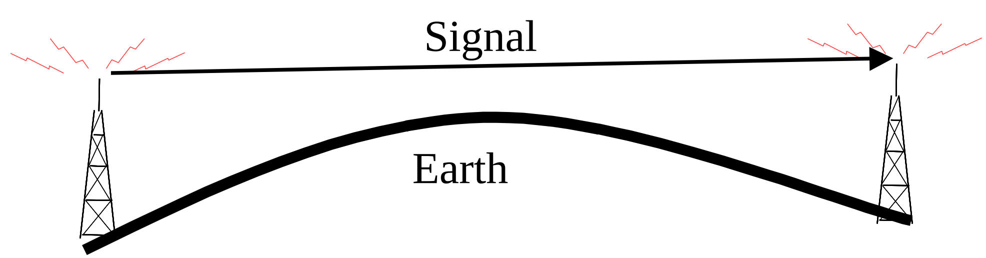
a) Ground Wave Propagation



b) Sky Wave Propagation



c) Line-of-Sight Propagation

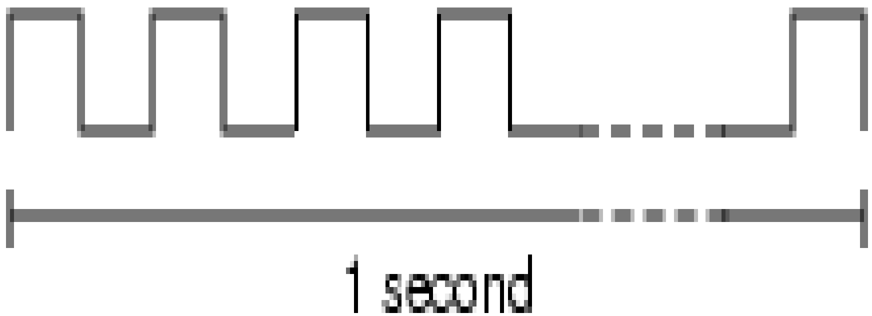


Bandwidth and Delay

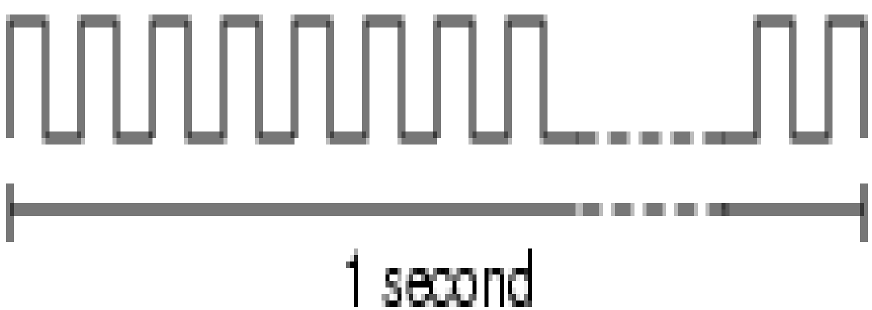
Bandwidth

- Amount of data that can be transmitted per unit time
  - expressed in cycles per second, or Hertz (Hz) for analog devices
  - expressed in bits per second (bps) for digital devices
  - KB = 2^{10} bytes; Mbps = 10^6 bps
- Link v/s End-to-End

Bandwidth v/s bit width



1Mbps
(each bit 1 microseconds wide)



2 Mbps
(each bit 0.5 microseconds wide)

Latency (delay)

- Time it takes to send message from point A to point B
  - Latency = Propagation + Transmit + Queue
  - Propagation = Distance / SpeedOfLight
  - Transmit = Size / Bandwidth

- Queueing not relevant for direct links
- Bandwidth not relevant if Size = 1 bit
- Software overhead can dominate when Distance is small

- RTT: round-trip time

Delay X Bandwidth product

- Relative importance of bandwidth and delay
- Small message: 1ms vs 100ms dominates 1Mbps vs 100Mbps
- Large message: 1Mbps vs 100Mbps dominates 1ms vs 100ms

Delay X Bandwidth product

100ms RTT and 45Mbps Bandwidth = 562.5 KB of data

Planning

Planning the Wireless LAN

- There needs to be a well-documented plan before a wireless network can be implemented.
- Number of Users:
  - Not a straightforward calculation.
  - Depends on the geographical layout of your facility (how many bodies and devices fit in a space),
- Data Rates:
  - RF is a shared medium and the more users there are the greater the contention for RF.
  - Use non-overlapping channels in an ESS.
- You will have sufficient wireless support for your clients if you plan your network for proper RF coverage in an ESS.

Planning the Wireless LAN

- Location of Access Points:
  - You may not be able to simply draw coverage area circles and drop them over a plan.
  - Do access points use existing wiring?
  - Position access points:
    - Above obstructions.
    - Vertically near the ceiling in the center of each coverage area, if possible.
    - In locations where users are expected to work. For example, conference rooms are typically a better location for access points than a hallway.

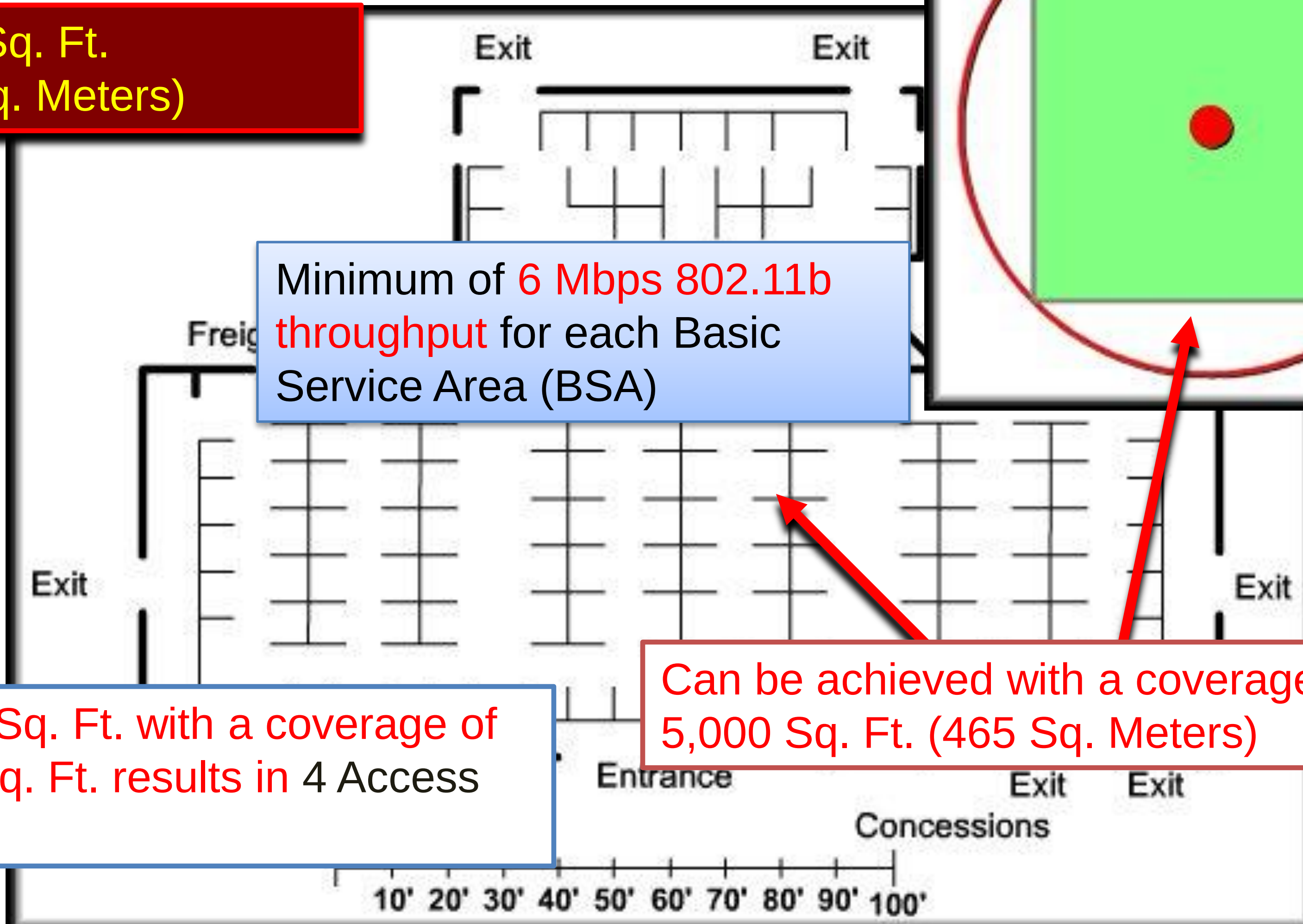
Planning the Wireless LAN

- Coverage Area of Access Points:
  - Estimate the expected coverage area of an access point.
  - This value varies depending on:
    - The WLAN standard or mix of standards that you are deploying.
    - The nature of the facility.
    - The transmit power that the access point.
- Based on your plan, place access points on the floor plan so that coverage circles are overlapping.

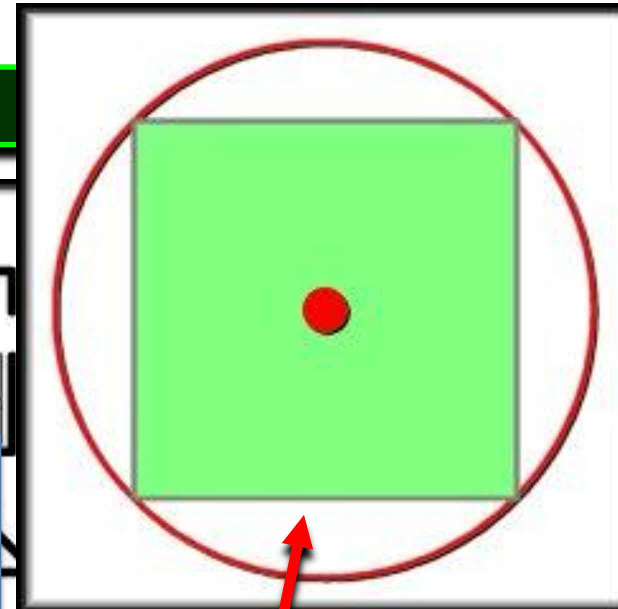
Planning the Wireless LAN

Number of Access Points

20,000 Sq. Ft.
(1860 Sq. Meters)



Minimum of 6 Mbps 802.11b throughput for each Basic Service Area (BSA)



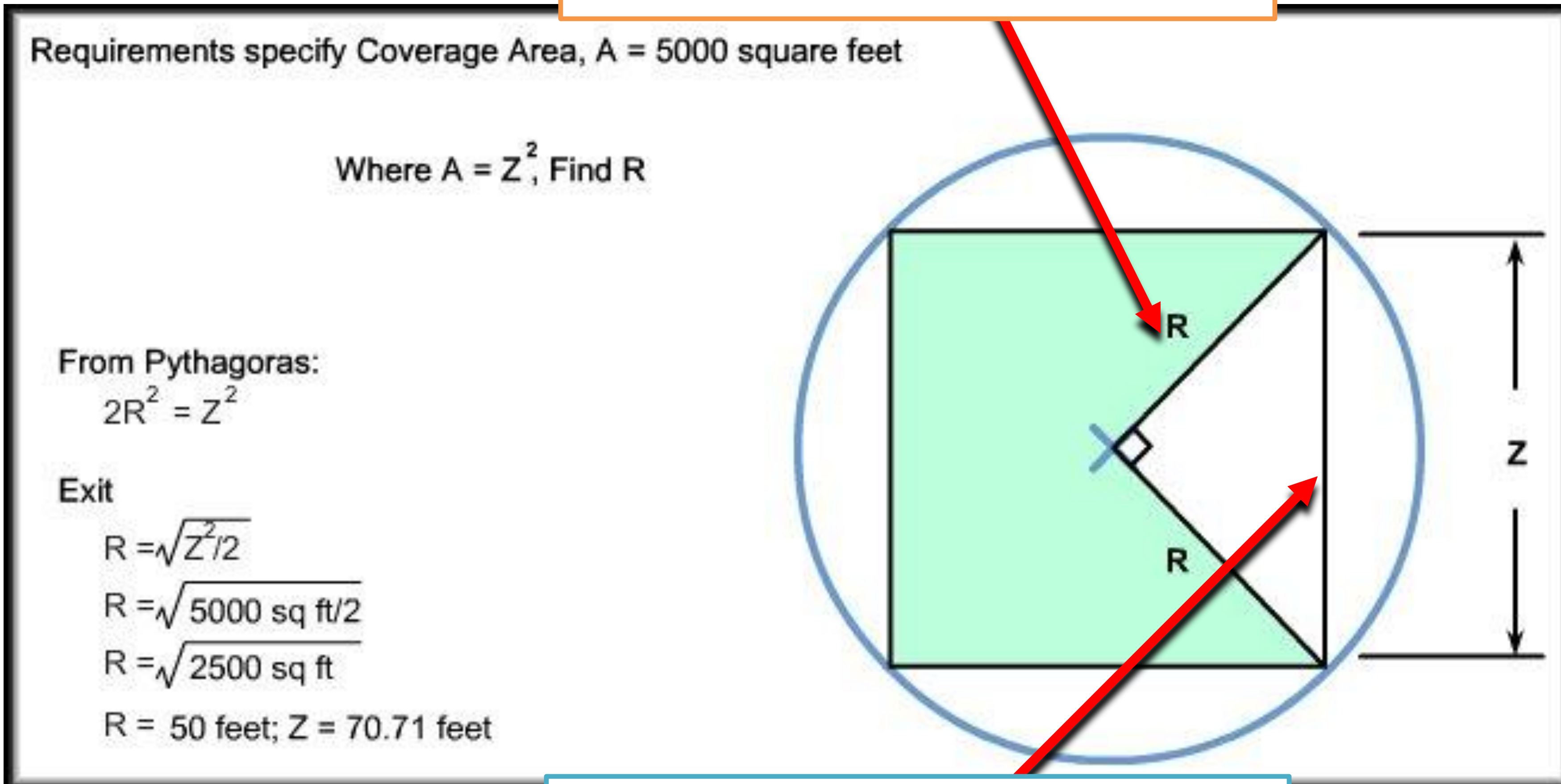
Can be achieved with a coverage area of 5,000 Sq. Ft. (465 Sq. Meters)

20,000 Sq. Ft. with a coverage of 5,000 Sq. Ft. results in 4 Access Points.

Planning the Wireless LAN

Dimension of Coverage Area

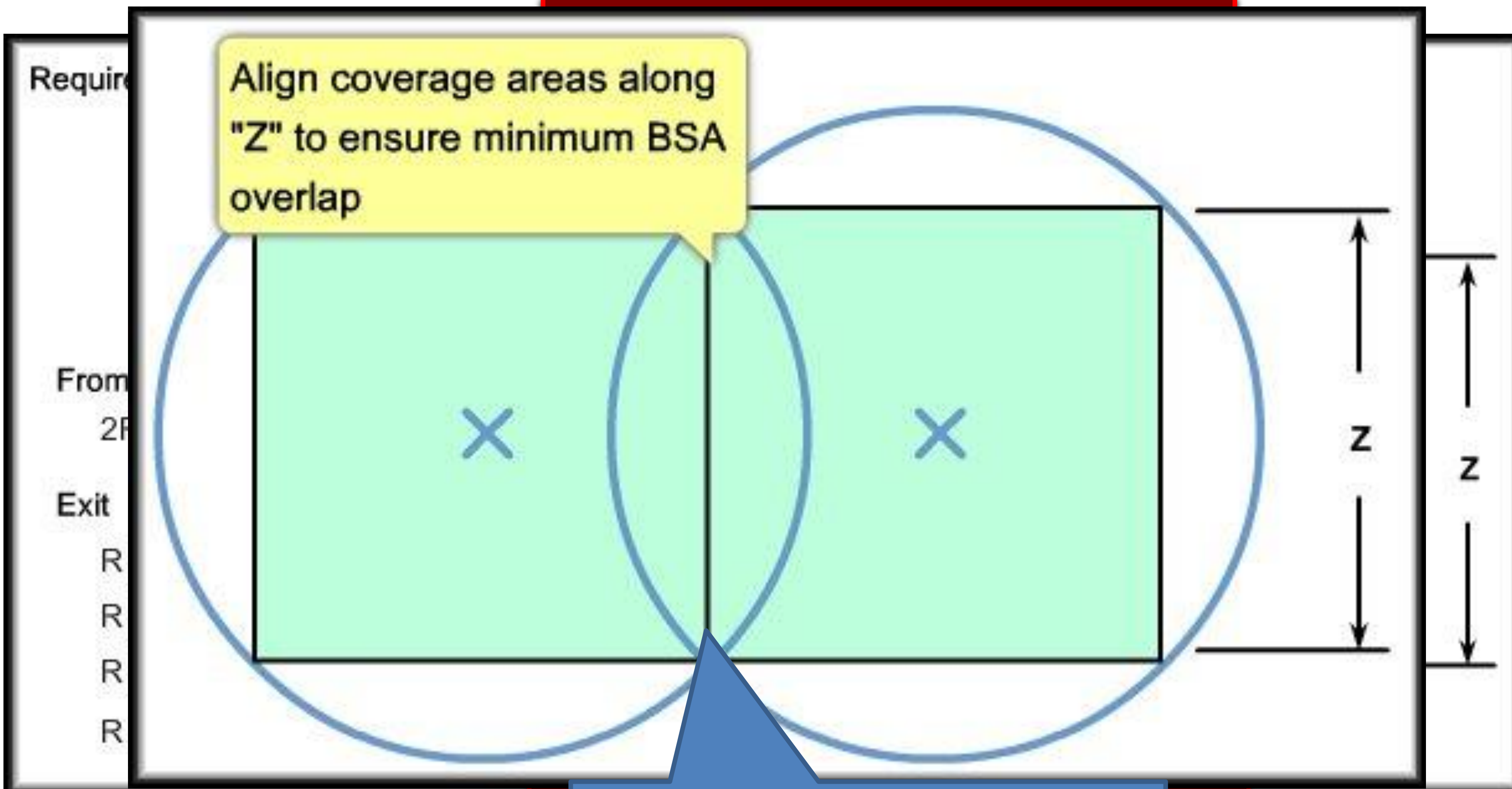
50 foot (15 Meter) Radius



71 foot (22 Meter) Square

Planning the Wireless LAN

Dimension of Coverage Area



Overlapping is essential for rooming

Planning the Wireless LAN

Location of Access Points