Backgroud:
Signal, Signal, and Signal

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Lecture 02

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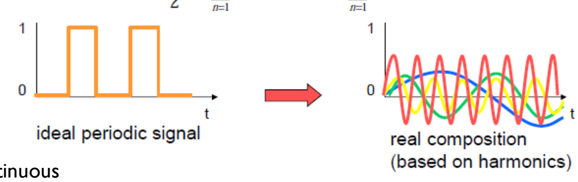
Referred and adapted partially from Mobile Computing, Wireless communications & Networks, and "You Believe You Understand What You Think I Said…" – The Truth About 802.11 Signal And Noise Metrics

Signals

- Physical representation of data
  - Function of time and location
- Classification:
  - continuous time/discrete time
  - continuous values/discrete values
  - analog signal?
    - continuous time and continuous values
  - digital signal?
    - discrete time and discrete values
- Digital signals (sequence of 0 or 1) need,
  - Infinite frequencies for perfect transmission
  - Modulation with a carrier signal for transmission

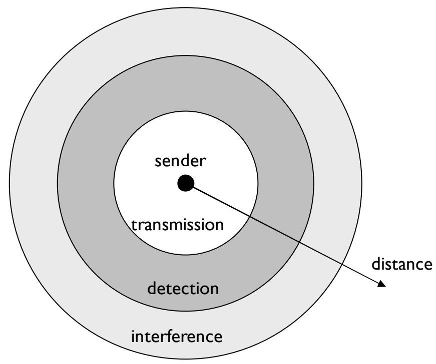
$$g(t) = \frac{1}{2}c + \sum_{n=1}^{\infty} a_n \sin(2\pi n f t) + \sum_{n=1}^{\infty} b_n \cos(2\pi n f t)$$



Fourier Representation of Periodic Signals

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



Signal Propagation: Fading

- Propagation in free space always like light (straight line)
- Strength of the signal decreases with distance between transmitter and receiver: **path loss**
- Receiving power proportional to $1/d^2$ in vacuum:
  - Inverse square law (d = distance between sender and receiver)
  - much more in real environments, usually assumed inversely proportional to distance to the power of 2.5 to 5
- Fading
  - the attenuation of the transmitted signal power due to various variables during wireless propagation

Signal Propagation: Fading (cont.)

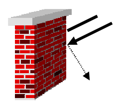
- Radio waves can also penetrate objects:
  - Depending on the frequency
  - The lower the frequency, the better the penetration
  - For example,
    - Long waves? Transmitted through the oceans to a submarine
    - High frequencies can be blocked by a tree
  - The higher the frequency, the more the behavior of the radio waves resemble that of light

Signal Propagation

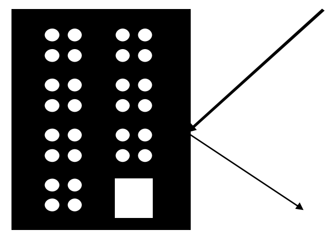
- Propagation behaviors:
  - Ground wave (< 2MHz):
    - Submarine communication or AM radio
  - Sky wave (2-30MHz):
    - Many international broadcasts and amateur radio
  - Line-of-sight (> 30MHz):
    - Mobile phone systems, satellite systems, cordless telephones, etc

Signal Propagation Effects

- **Shadowing** (or blocking):
  - Even small obstacles, e.g. truck on the street, or trees
- **Reflection** at large obstacles:
  - If an object is large compared to the wavelength of the signal, e.g. huge buildings, mountains, etc
  - The more often the signal is reflected, the weaker it becomes



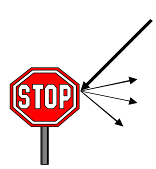
shadowing



reflection

Signal Propagation Effects (cont.)

- **Scattering** at small obstacles:
  - If the size of an obstacle is in the order of the wavelength or less
  - Several weaker outgoing signals
- **Diffraction** at edges:
  - Propagate in different directions

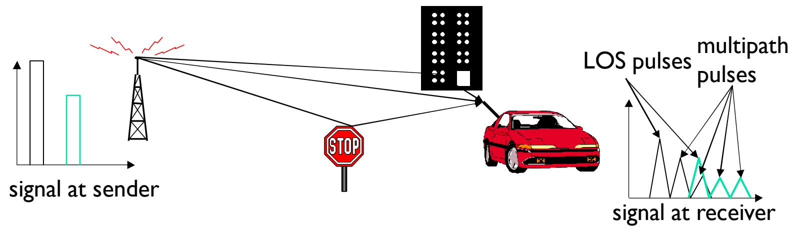


scattering

diffraction

Multipath Propagation

- Signal can take many different paths between sender and receiver due to?
  - reflection, scattering, diffraction, etc
  - lead to severe radio channel impairment, multi-path propagation
    - This effect is called delay spread



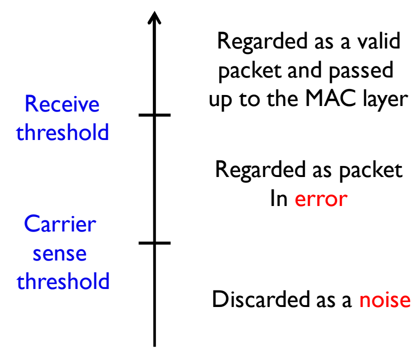
Transmitting Radio Signal

- Free space model:
  - No matter exists between the sender and the receiver
  - Signal power is attenuated as $1/d^2$
- Ground reflection model,
  - Signal power is attenuated as $1/d^4$
  - In short space, free space model applies

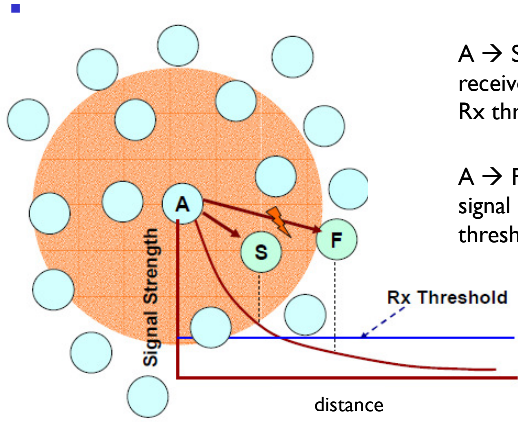
- Longer radio range requires much stronger power

Receiving Radio Signal

- The power level of a received signal (e.g. packet) is compared to two values,



Receiving Radio Signal



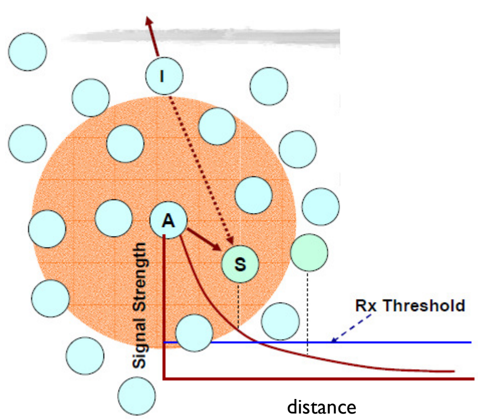
A → S is successful because the received signal is stronger than the Rx threshold

A → F fails because the received signal is weaker than the Rx threshold

Physical Impairments: Noise/Interference

- Unwanted signals added to the message signal
- May be due to signals generated by natural phenomena such as lightning or man-made sources, including transmitting and receiving equipment as well as spark plugs in passing cars, wiring in thermostats, etc.
- Signal-to-noise ratio (SNR)
  - often used as a metric in the assessment of channel quality
- Signals generated by communications devices operating at roughly the same frequencies may interfere with one another
  - e.g. IEEE 802.11b and Bluetooth devices, microwave ovens, some cordless phones
- Signal to interference and noise ratio (SINR)
  - another metric used in assessment of channel quality

Carrier Sense Threshold



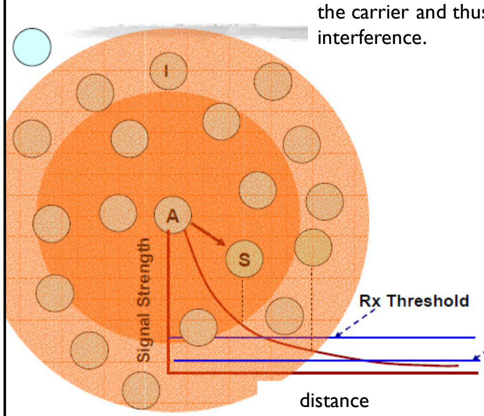
A → S is successful only when its neighbors do not cause interference.

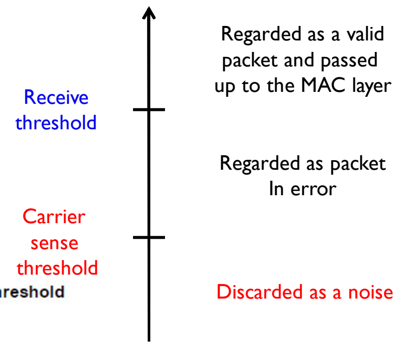
When 'I' hears something, 'I' waits until the current communication is completed.
→ carrier sense mechanism

Carrier sense threshold is used for this purpose
→ check the medium for received signal power before transmission to be less than a certain threshold

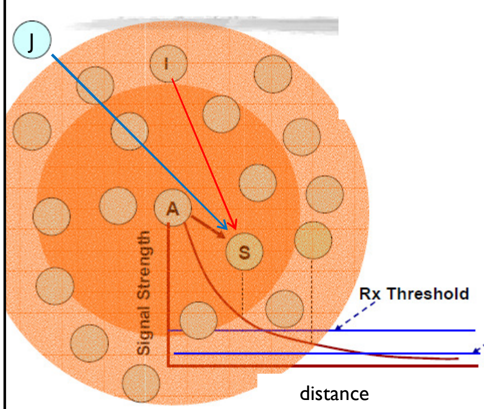
Carrier Sense Threshold (cont.)

When A transmits, node 'I' is not able to decode the packet but it will sense the carrier and thus will not make any interference.





Capture Threshold



A → S is strong enough to tolerate **J's** transmission (SNR)

A → S is NOT strong enough to tolerate **I's** transmission

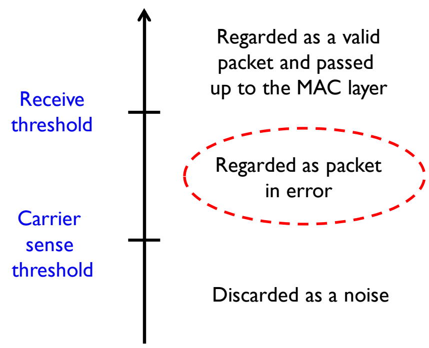
The corresponding SNR requirement is called capture threshold (e.g. 10 dB)

A → S is strong enough to tolerate J's transmission
P(A→S)/P(J→S) > 10dB

A → S is NOT strong enough to tolerate I's transmission
P(A→S)/P(I→S) < 10dB

Receiving Radio Signal: Revisit

- The power level of a received signal (e.g. packet) is compared to two values,



If the receiver receives one signal while receiving another (conflict),

P(old)/P(new)>10dB, can still receive the old one (new packet is dropped) → signal capturing

Otherwise, it is a "collision" and both packets are dropped