Wireless Communication

Mobile Computing

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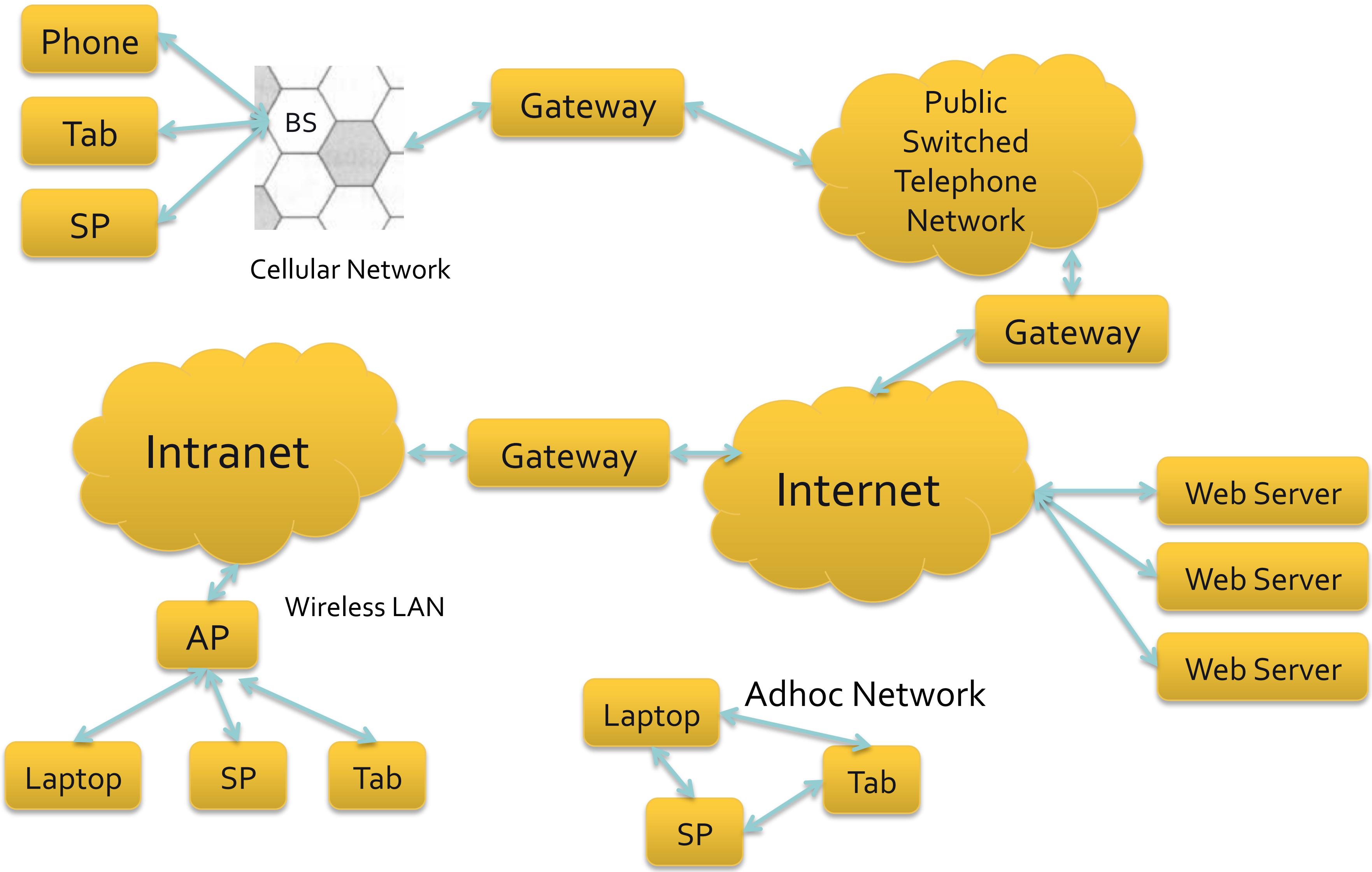
Wireless & Internet



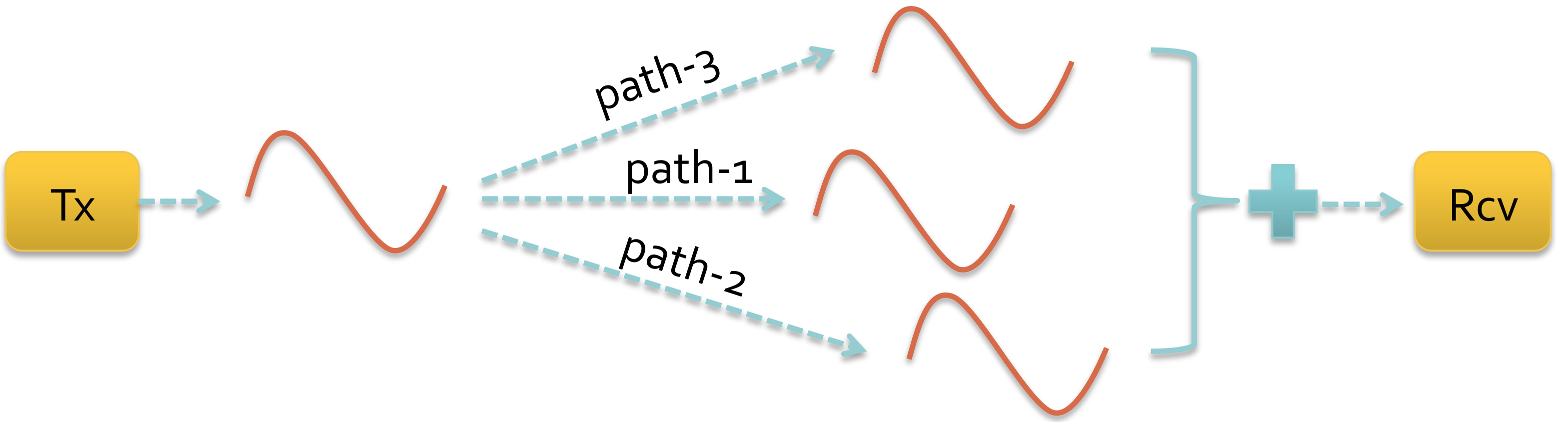
Radio Communication

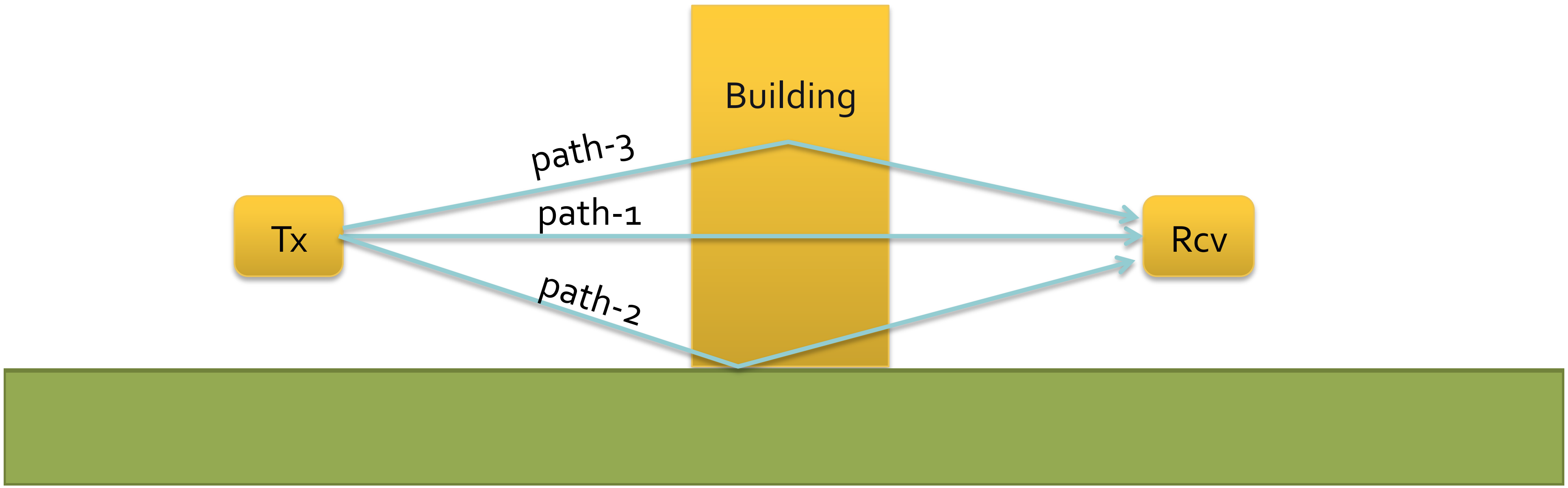
- Communication: Transmitter sends Receiver information through Channel (Medium)
- Channel distorts original information

Simplest Channel

- Additive White Gaussian Noise (AWGN)
- Wireless communication model in deep space (e.g., stationary station on earth and geostationary sattelites or spacecrafts)
- No reflection
- $y(t) = x(t) + z(t)$
  - $x(t)$: input signal
  - $z(t)$: Gaussian noise
  - $y(t)$: output signal

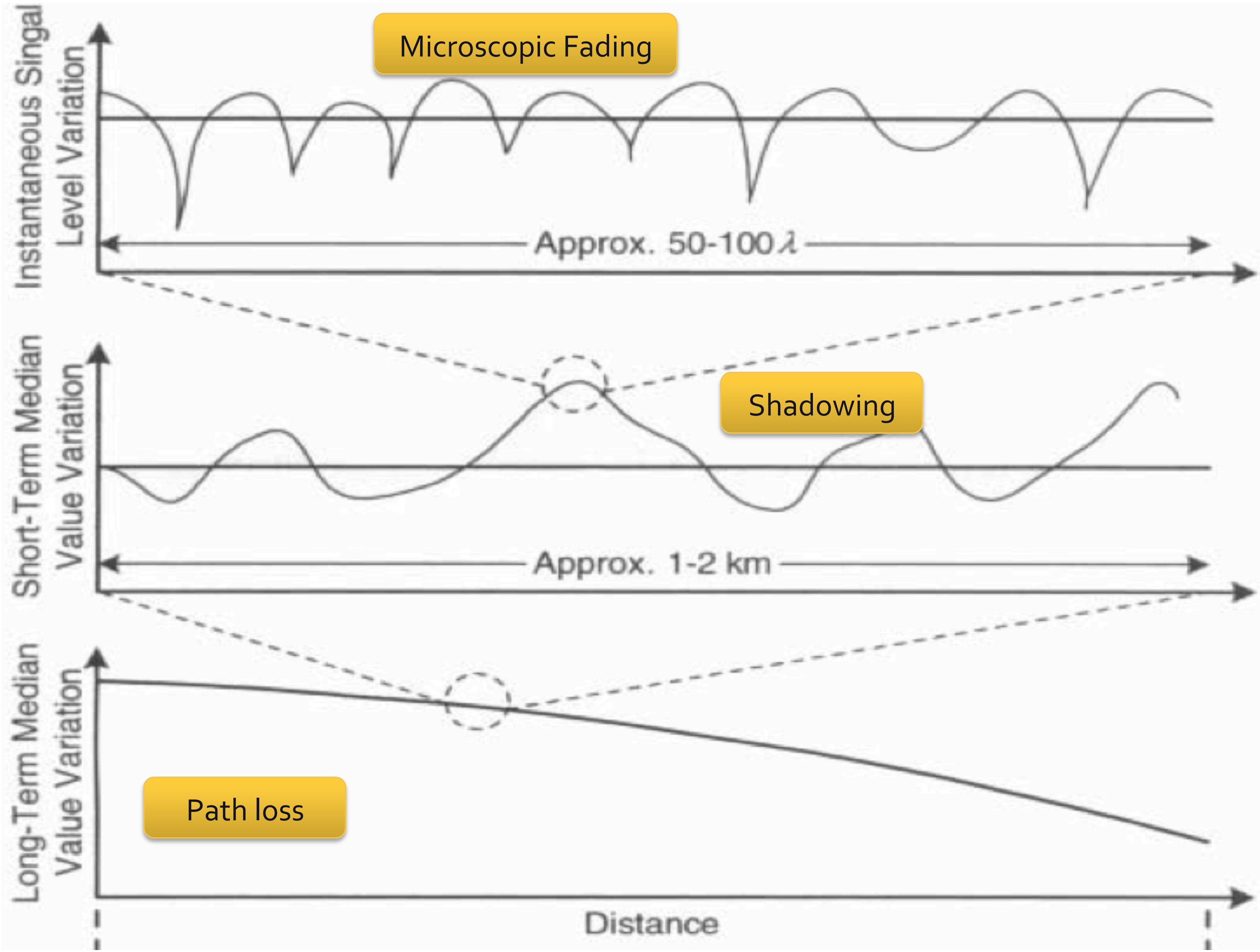
Terrestrial Wireless Comm.





Terrestrial Wireless Comm.

- Multipath: there are multiple paths for the signal to reach the receiver
- Each path superimpose (overlap) each other
- Different path length causes different phase
- Superposition can be constructive/destructive
  - Constructive: signal strengthens (diff = n * wavelength)
  - Destructive: signal weakens (diff = (n + 1/2) * wavelength)


Microscopic Fading
Instantaneous Singal
Level Variation
Approx. 50-100 λ
Shadowing
Short-Term Median
Value Variation
Approx. 1-2 km
Long-Term Median
Value Variation
Path loss
Distance

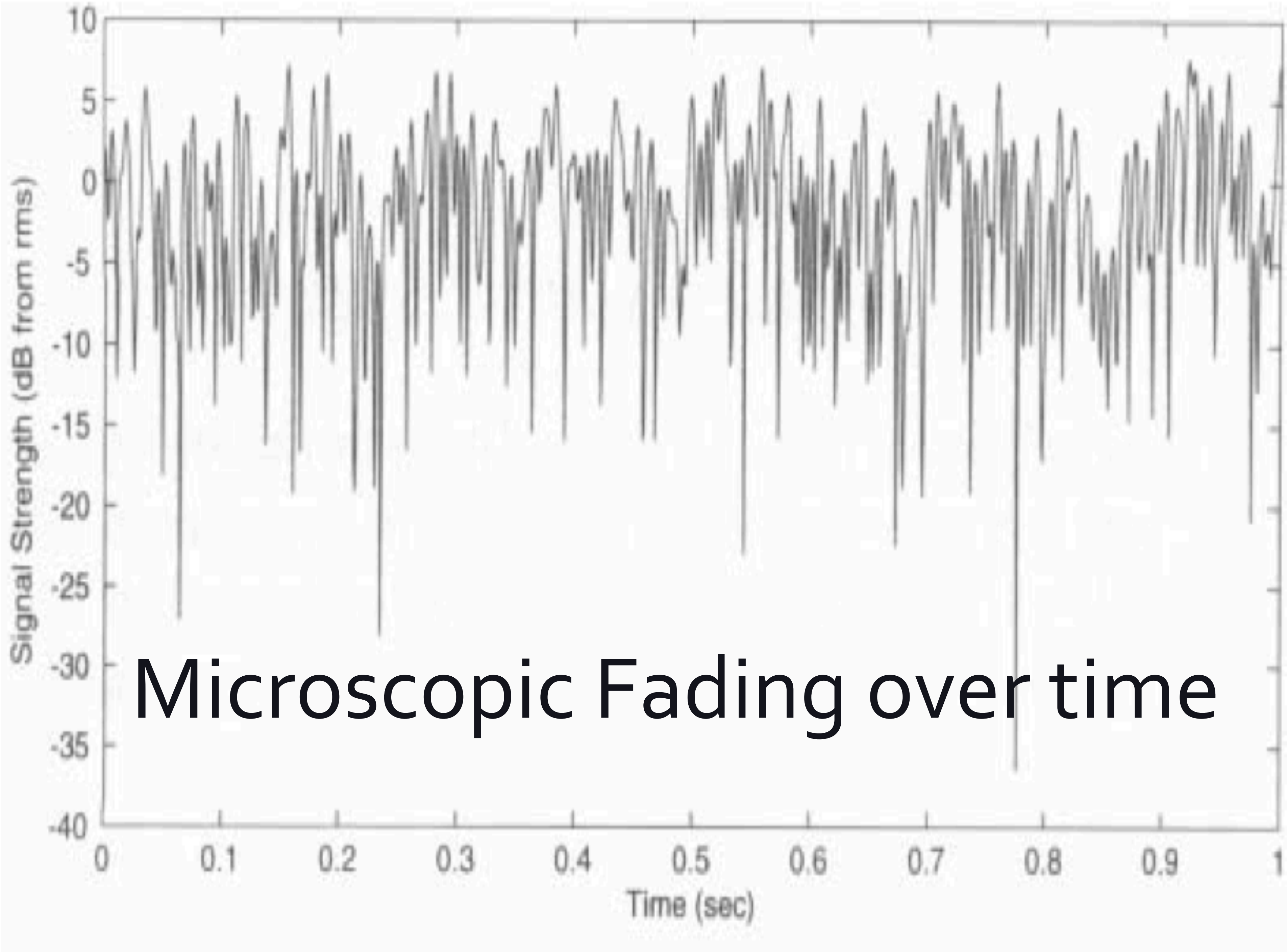
Channel Distortion Model

- Path Loss: : signal variation due to distance

$$P_r = \frac{P_t G_t G_r c^2}{16\pi^2 d^2 f^2}$$

- Shadowing: signal variation due to terrain features and man-made obstacles
  - Reflection
  - Diffraction
- Microscopic Fading: interference of multipath and fluctuation over time

Microscopic Fading over time



More about Path Loss

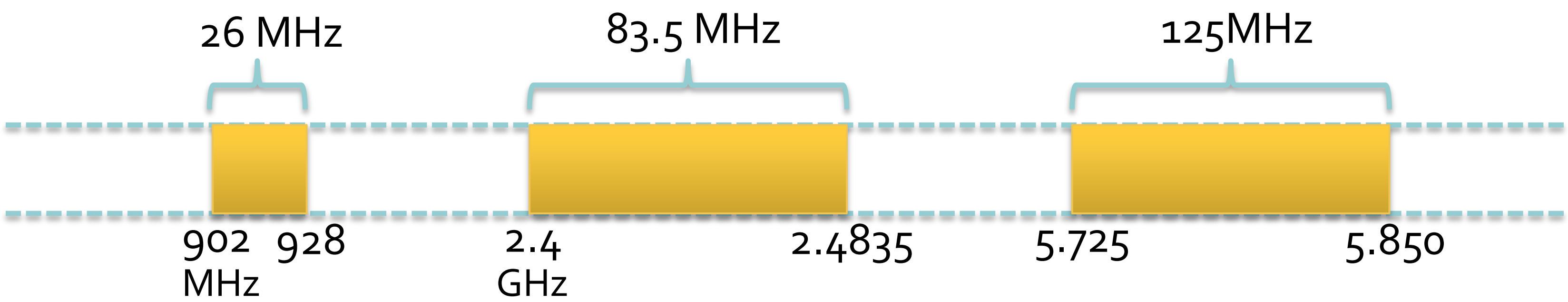
- High path loss is bad for point-to-point communication
- High path loss is good for cellular systems
  - Prevents interference between cells using the same frequency

Why Wireless LAN?

- Wireless extension of wired LAN (Ethernet)
- Mobility with high bandwidth
- Use unlicensed spectrum: ISM band

ISM bands

- In 1985, FCC allows wireless products without FCC license
  - Can operate under 1-watt transmission power
- Called ISM (Industrial, Scientific, and Medical) bands
- ISM is crowded:
  - Microwave (2.45GHz), Cordless phone (915MHz/2.45GHz/5.8GHz), Wireless Sensor Networks (868MHz/915MHz/2.45GHz), Bluetooth (2.45GHz), IEEE802.15.4(ZigBee) (915MHz/2.45GHz),…



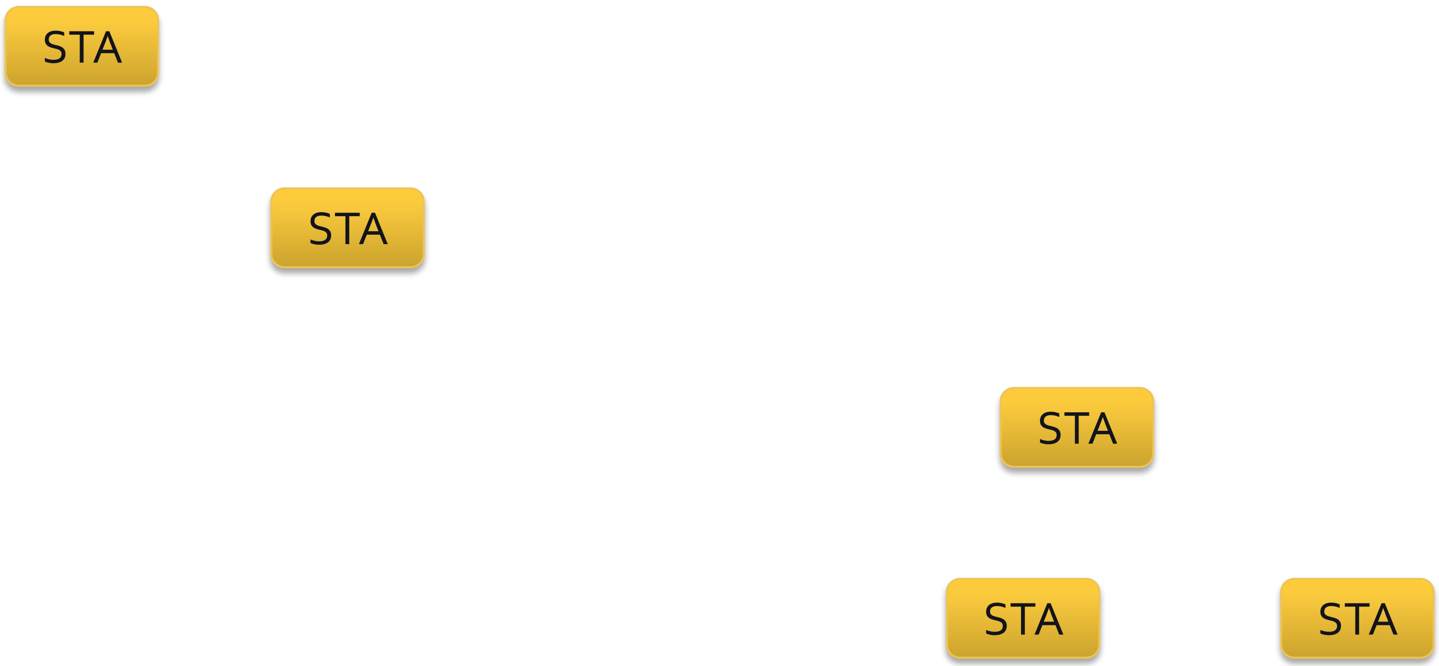
Birth of WLAN

- WLAN has been in widespread deployment for several years
- Vendors developed their own WLAN products based on their own ideas (proprietary)
- So serious problem of incompatibility between wireless devices.
- First IEEE 802.11 standard was introduced in 1997 for *interoperability*

Design goal of WLAN

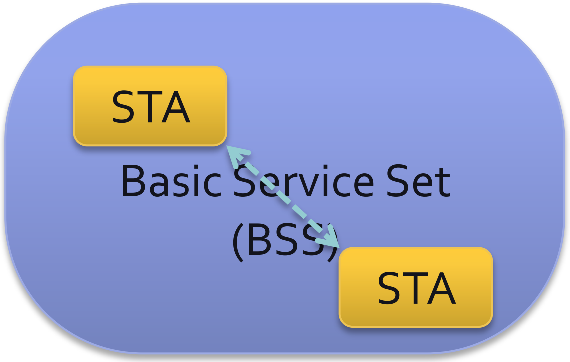
- Interoperability between WLAN and wired LAN
  - Connect Wired LAN and Wireless LAN with an Access Point (AP)
- Interoperability between WLAN devices
  - Standardize Medium Access Control (MAC) and Physical links (PHY)
- Low cost
  - Use unlicensed band (ISM) for free → coexistence with other wireless technologies
  - Simple design for low cost mass production of devices

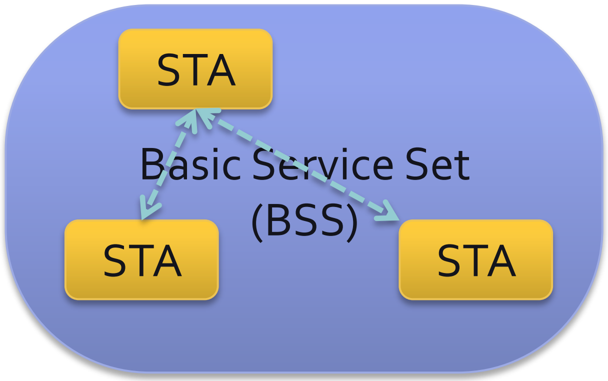
Building Blocks of 802.11



- Station (STA): device with 802.11 MAC/PHY

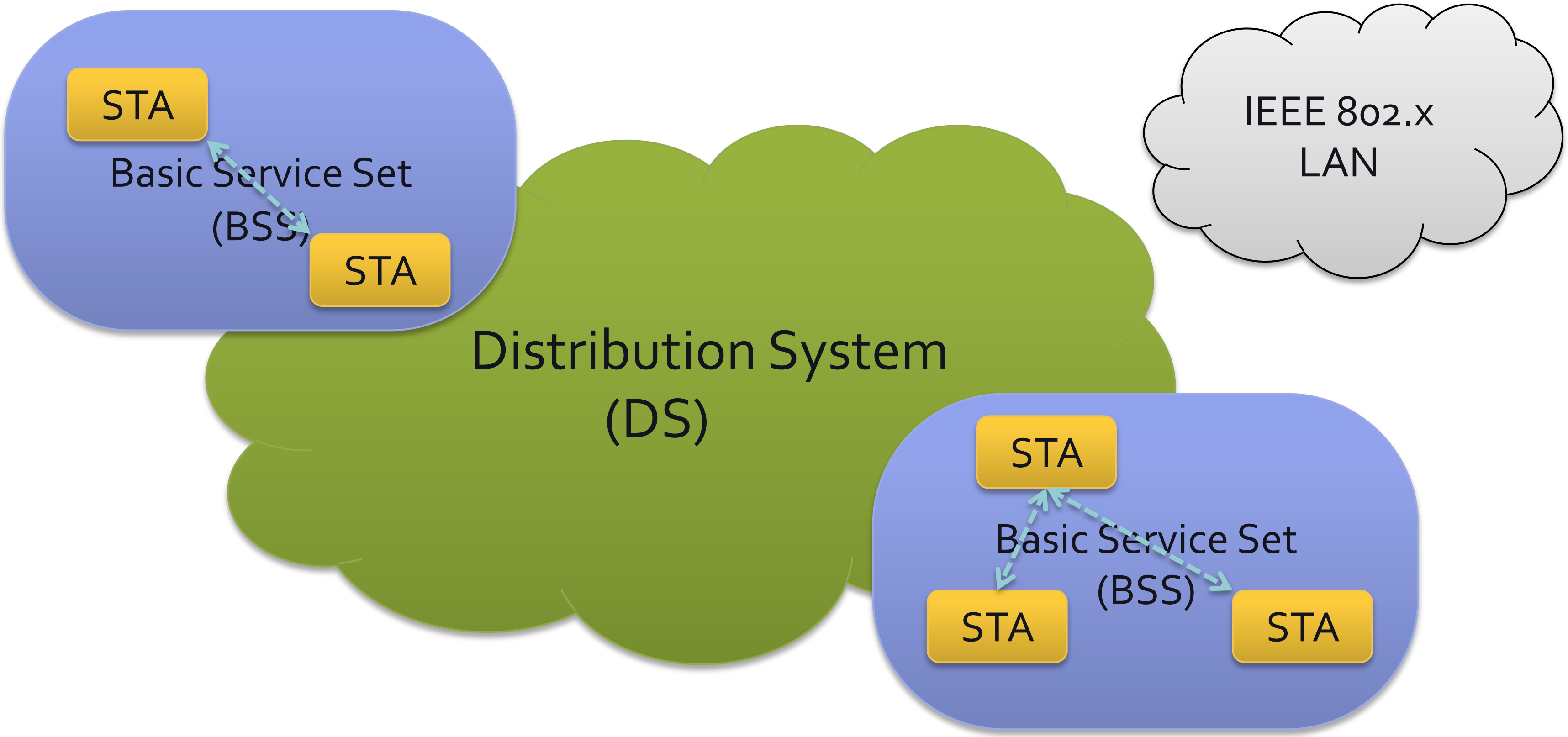
Building Blocks of 802.11





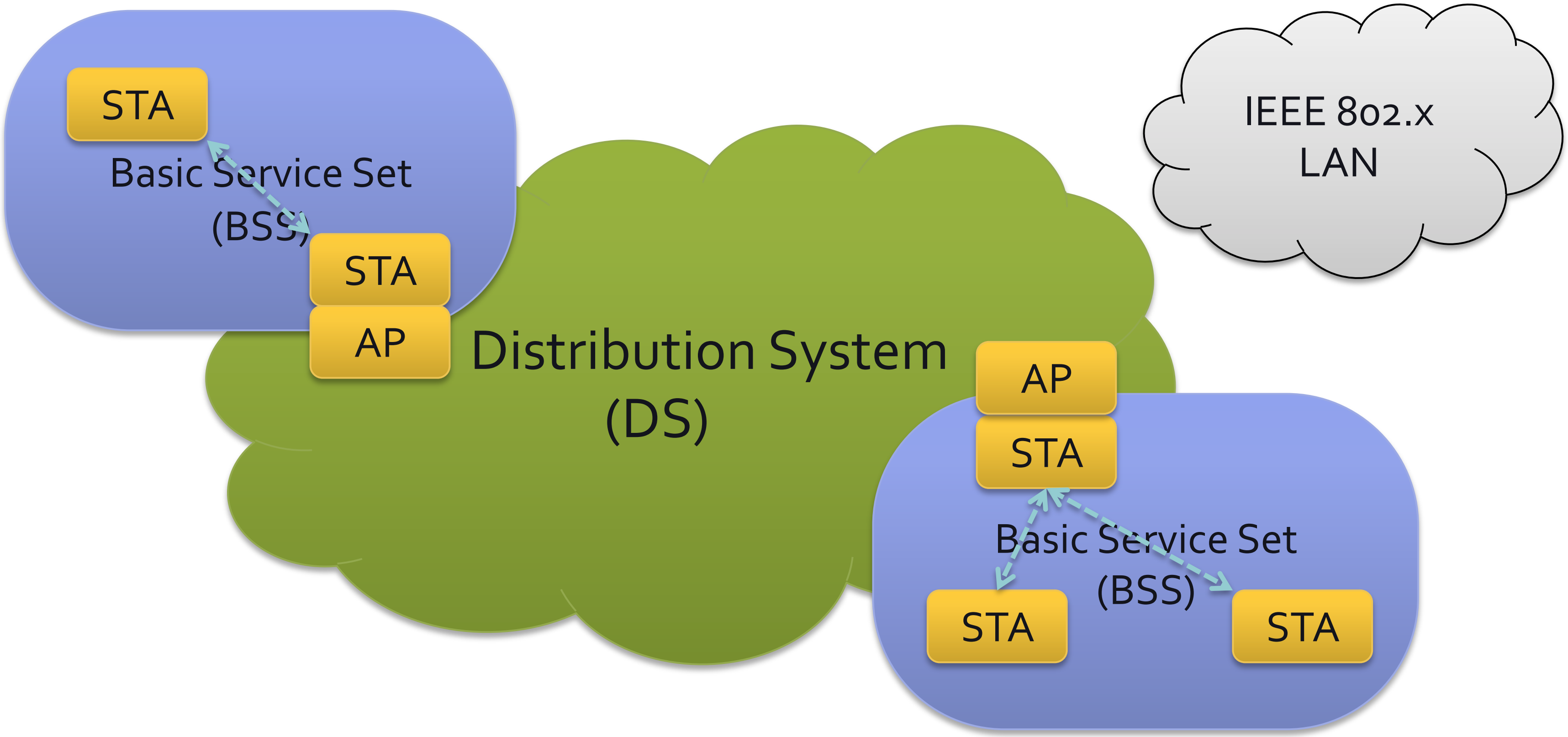
- Basic Service Set (BSS): a group of connected STAs

Building Blocks of 802.11



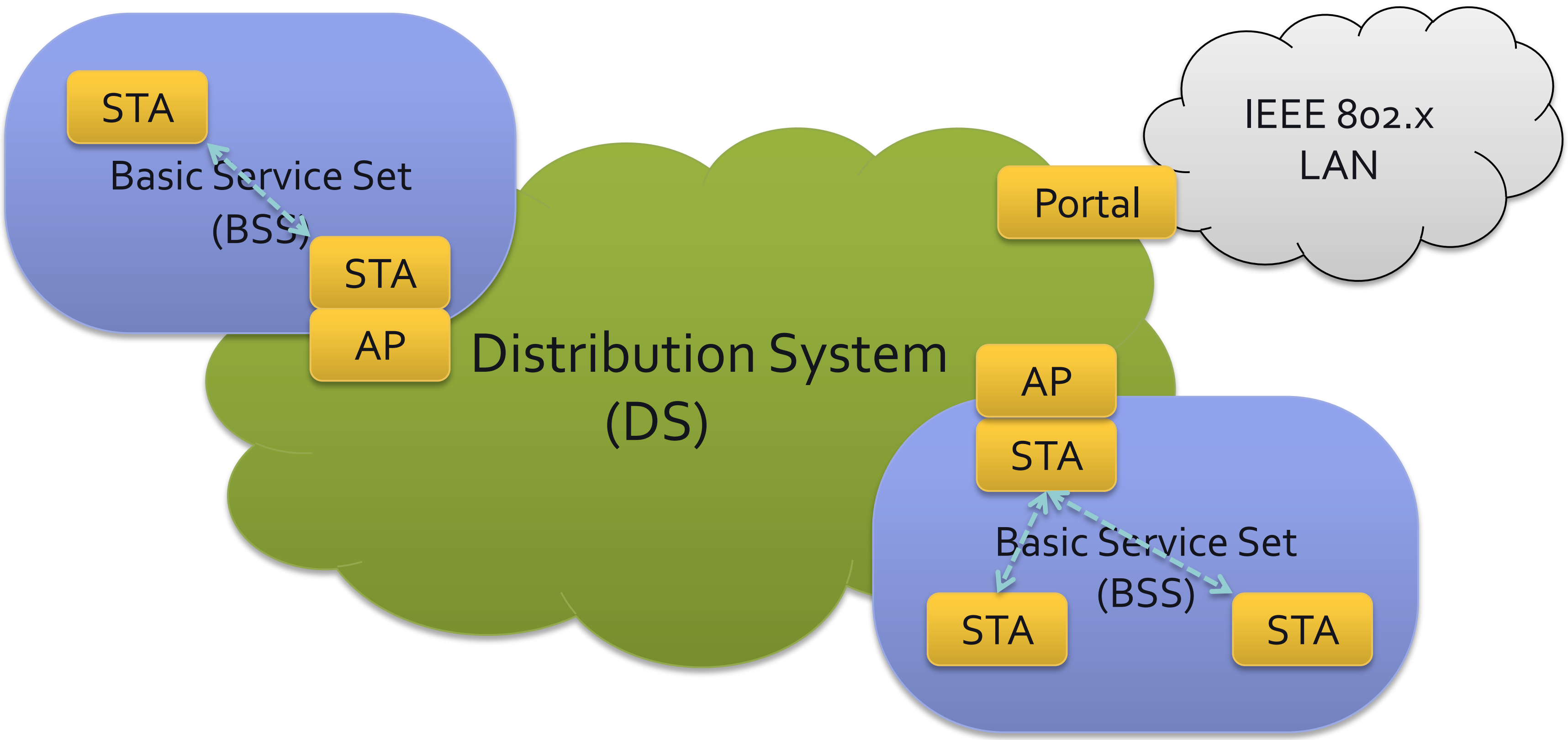
- Distribution System(DS): system connecting BSSs and other 802.x LANs

Building Blocks of 802.11



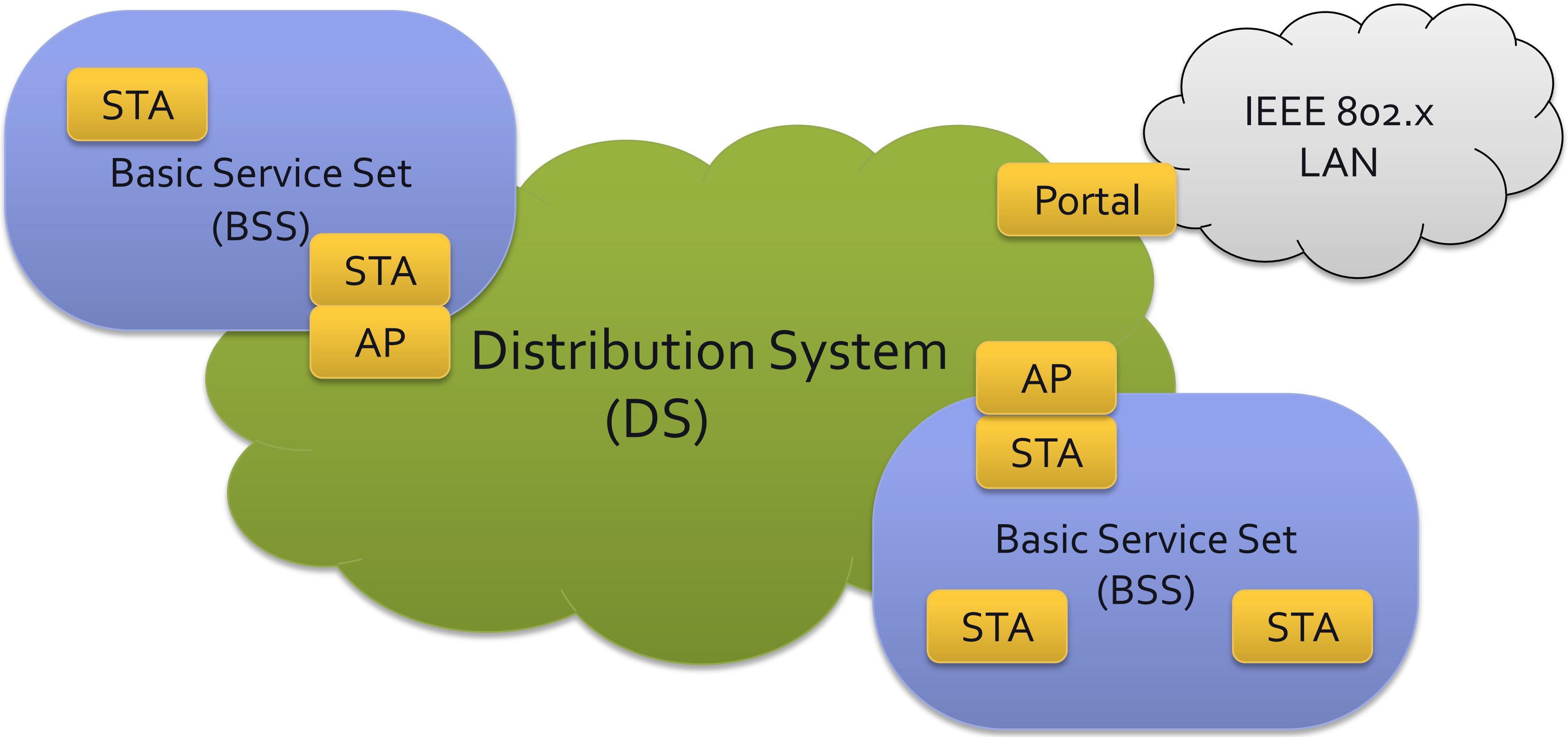
- Access Point (AP): connects STA to DS
  - An access point has both STA and AP functionality

Building Blocks of 802.11



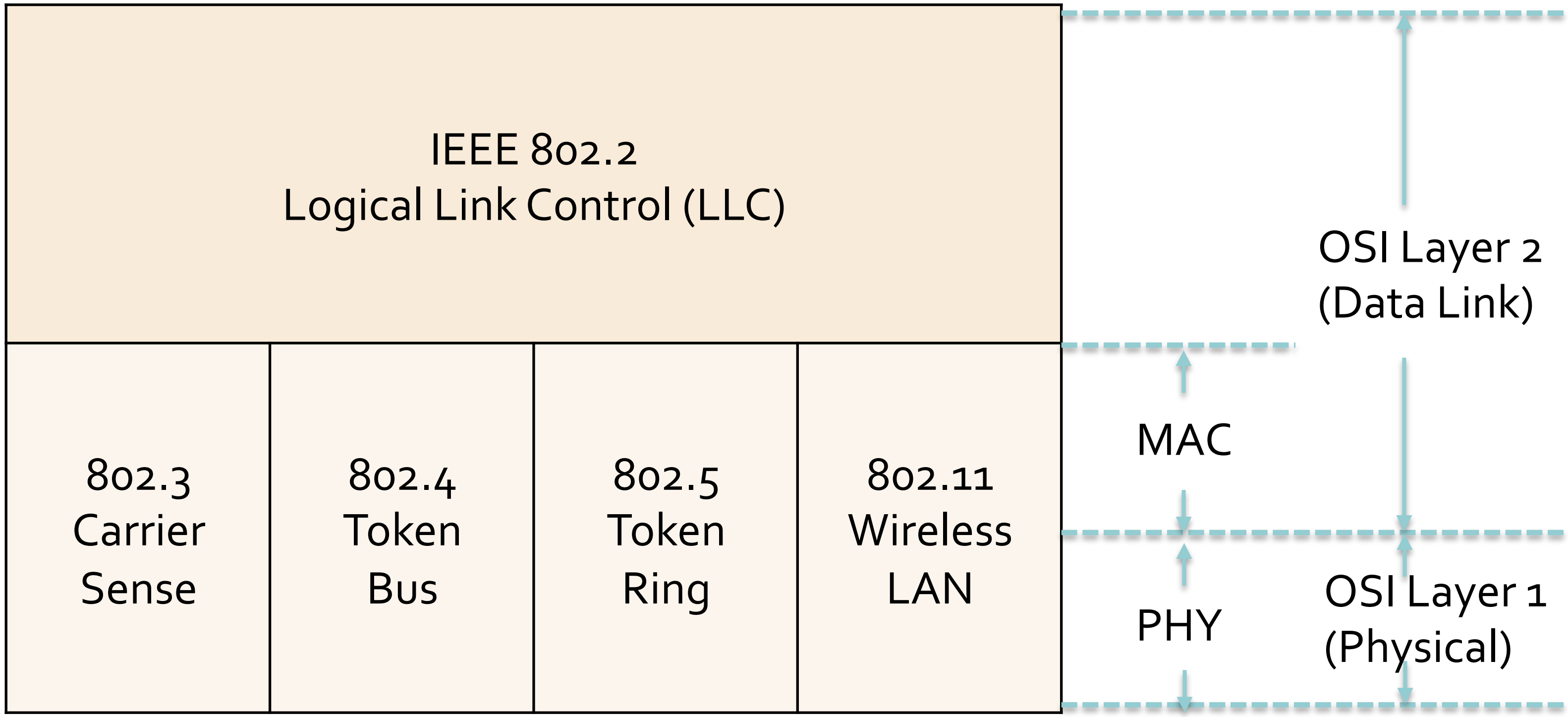
- Portal: connects DS with other LANs

Building Blocks of 802.11



- Extended Service Set (ESS): all of these

IEEE 802.x Standards



802.11 MAC Layer

- Communication medium (wired or wireless) is shared by multiple nodes
- Receiver cannot receive if senders simultaneously transmit
- MAC service allows for devices to access the communication medium without conflicting with others
- 802.11 defines two Coordination Function mechanisms: DCF/PCF

Coordination Functions

- Distributed Coordination Function (DCF)
  - Most WLAN uses DCF
  - Stations contend for wireless medium: CSMA/CA
- Point Coordination Function (PCF)
  - Centralized approach: AP tells which STA to send (like TDMA)
  - Mixed with PCF phase and DCF phase
  - Rarely implemented, WiFi exclude PCF: vague on mixing method

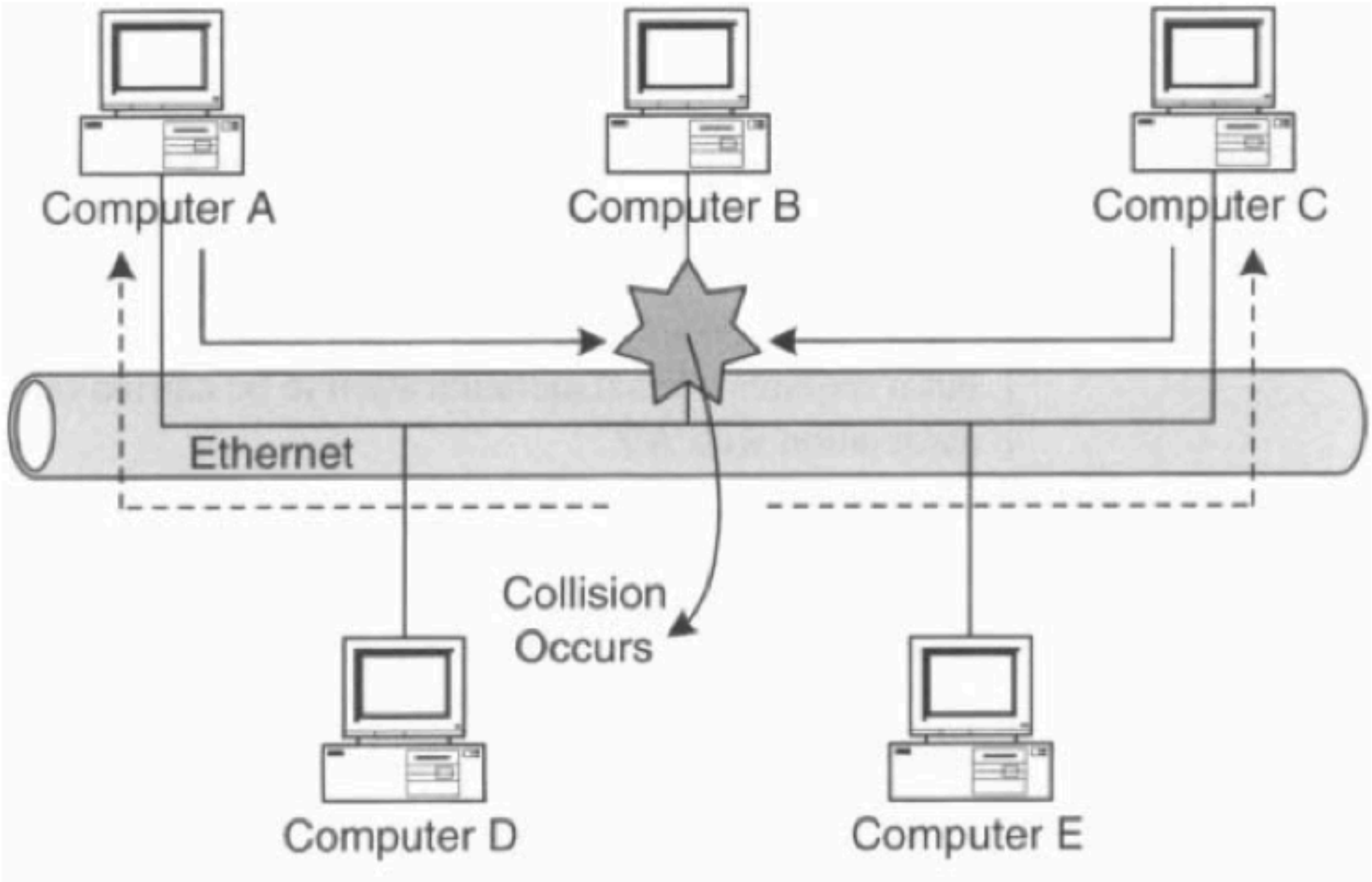
Wireless MAC Layer Problems

- Communication medium (wired or wireless) is shared by multiple nodes
- Receiver cannot receive if senders simultaneously transmit
- MAC service allows for devices to access the communication medium without conflicting with others
- Three problems to solve:
  - Collision Detection Problem
  - Hidden Terminal Problem
  - Exposed Terminal Problem

Collision Detection

- In Wired LAN (Ethernet), MAC is done by CSMA/CD (Carrier Sense Multiple Access/ Collision Detection)
- To send a packet
  - Senses if the medium is busy (Carrier Sense)
  - If busy, wait until become idle
  - If not busy, send a packet
  - While sending, detect if collision occurs (Collision Detection)
  - If collide, stops sending, and retry after random wait

CSMA/CD in Wired LAN

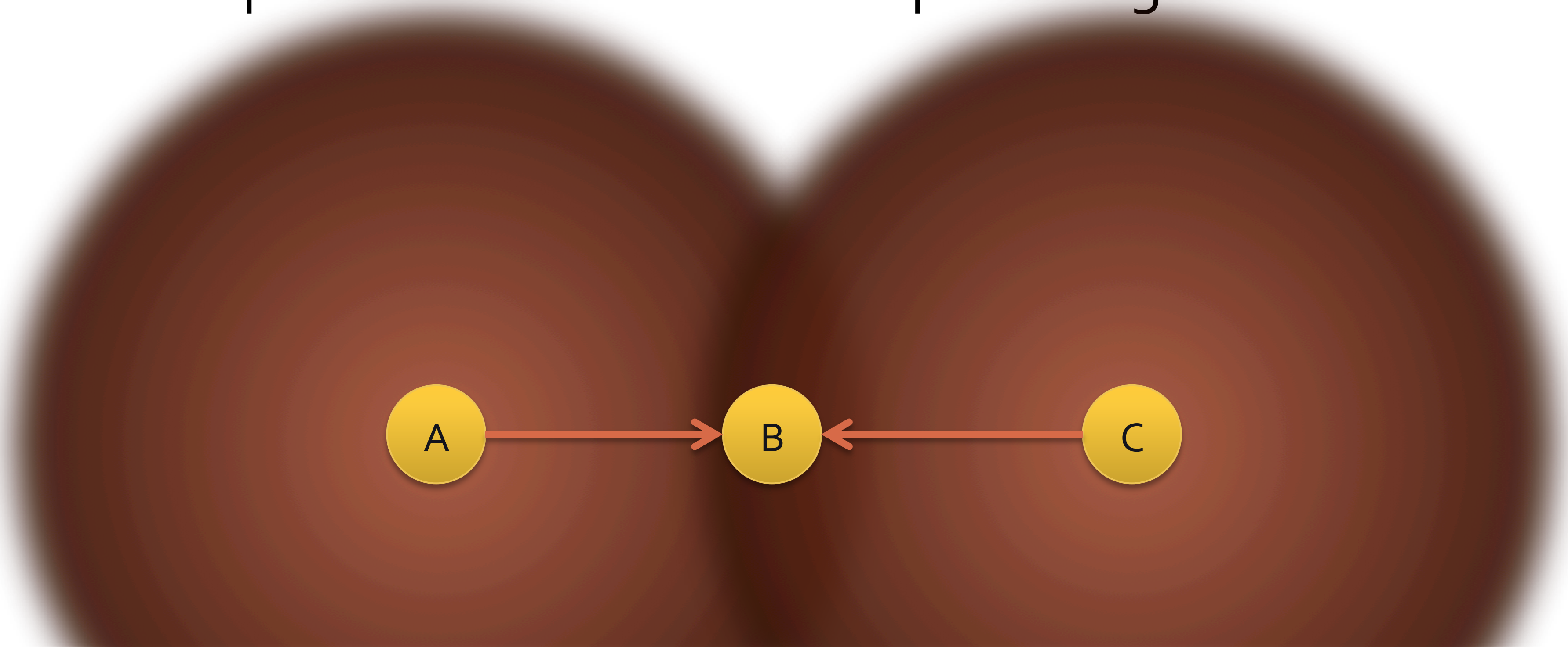


CSMA/CA of WLAN

- Instead of detecting collision, try to avoid collision
  - Carrier Sense Multiple Access with Collision Avoidance
- Each STA obtains the medium to send as follows
  - When a STA has a packet to send
  - Senses the medium if it is busy
  - If busy, wait for a random period within exponentially growing time window: binary exponential backoff
  - If not busy, also do exponential backoff and send

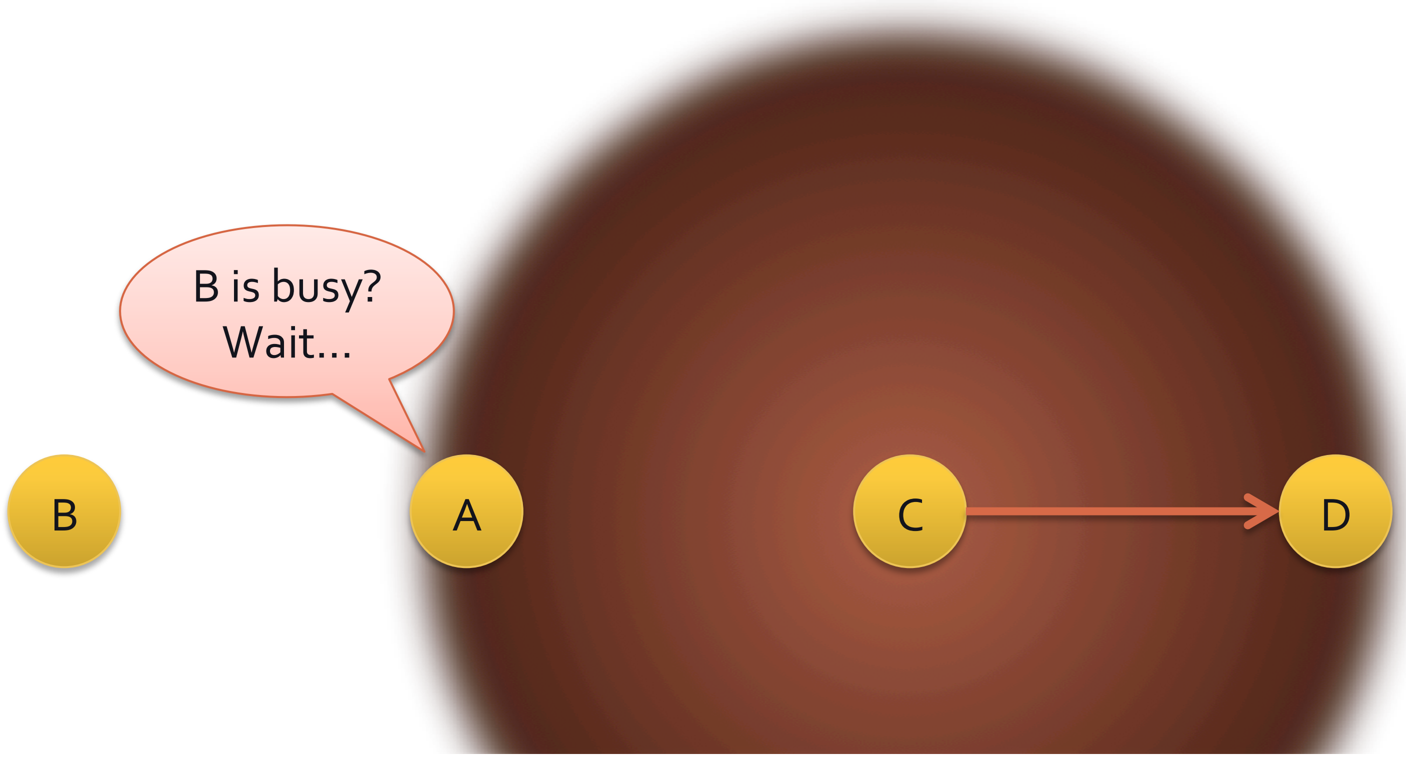
Hidden Terminal Problem

- Sender is unsure if there is no hidden node simultaneously sending packets to the receiver
- False positive carrier sense: keep sending



Exposed Terminal Problem

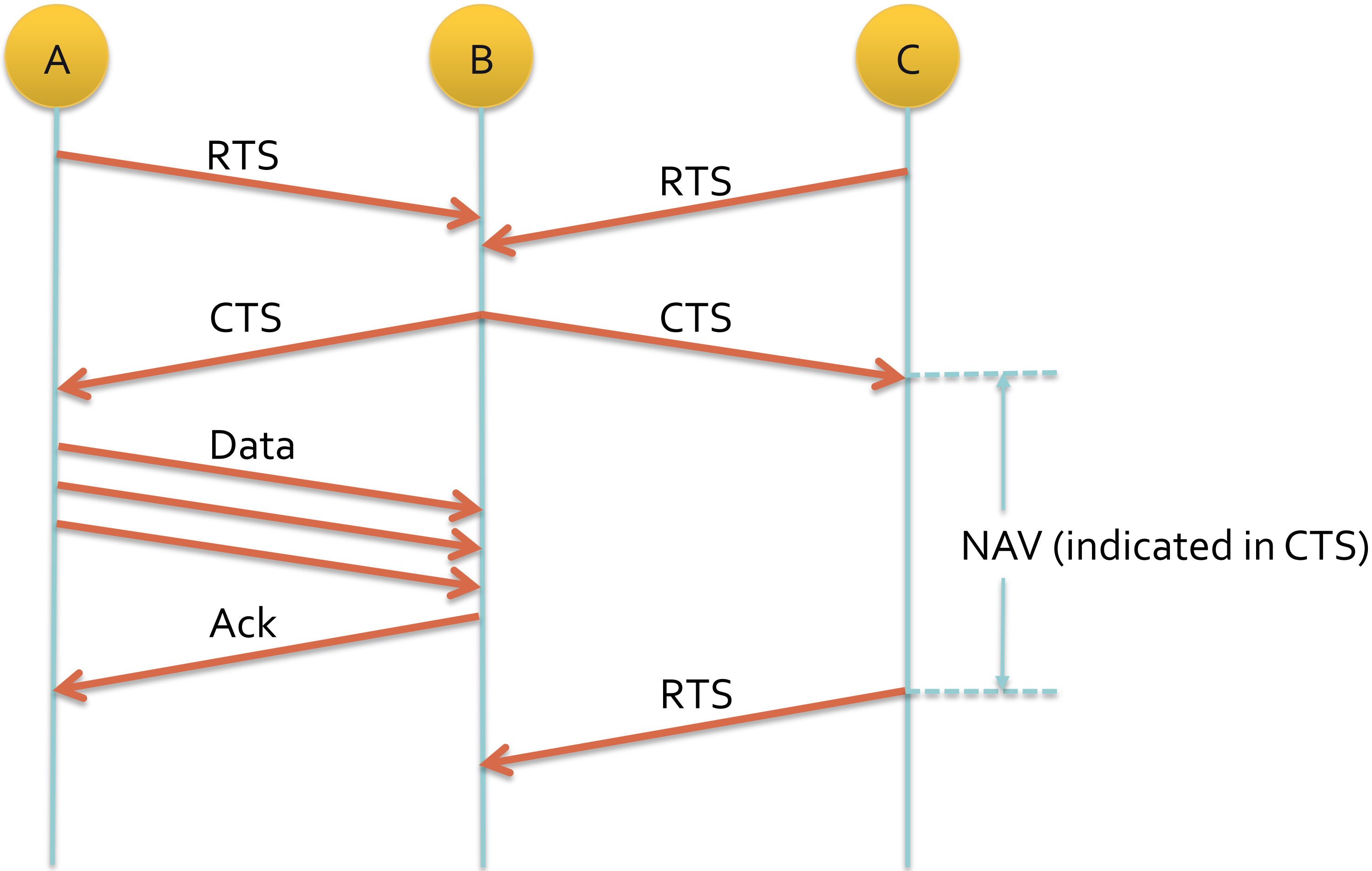
- Sender is unsure if there is a near-by node but unreachable to the receiver sending packets
- False negative: unnecessary waits



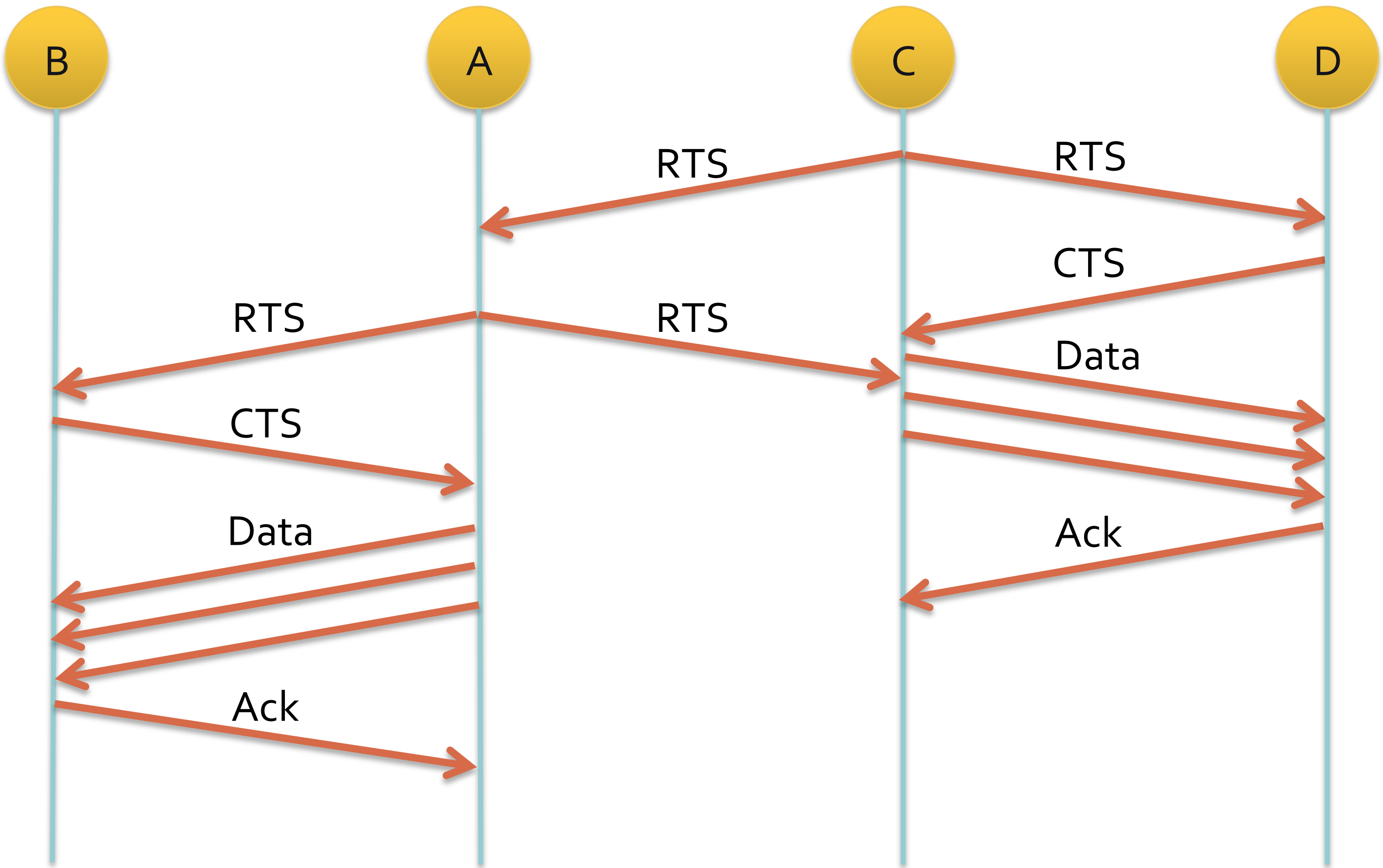
Solution: RTS/CTS

- Potential sender and receiver publicly announce their immediate medium use by CTS/RTS mechanism
- To send a packet
  - Sender broadcasts Request-to-Send (RTS)
    - nearby nodes hold transmission for a while or until CTS arrives
  - Upon receiving RTS, receiver sends Clear-To-Send (CTS)
    - other nodes receiving CTS hold transmission for a while
  - Sender transmits data
  - Receiver replies with Acknowledgement packet

Hidden Terminal Resolved



Exposed Terminal Resolved

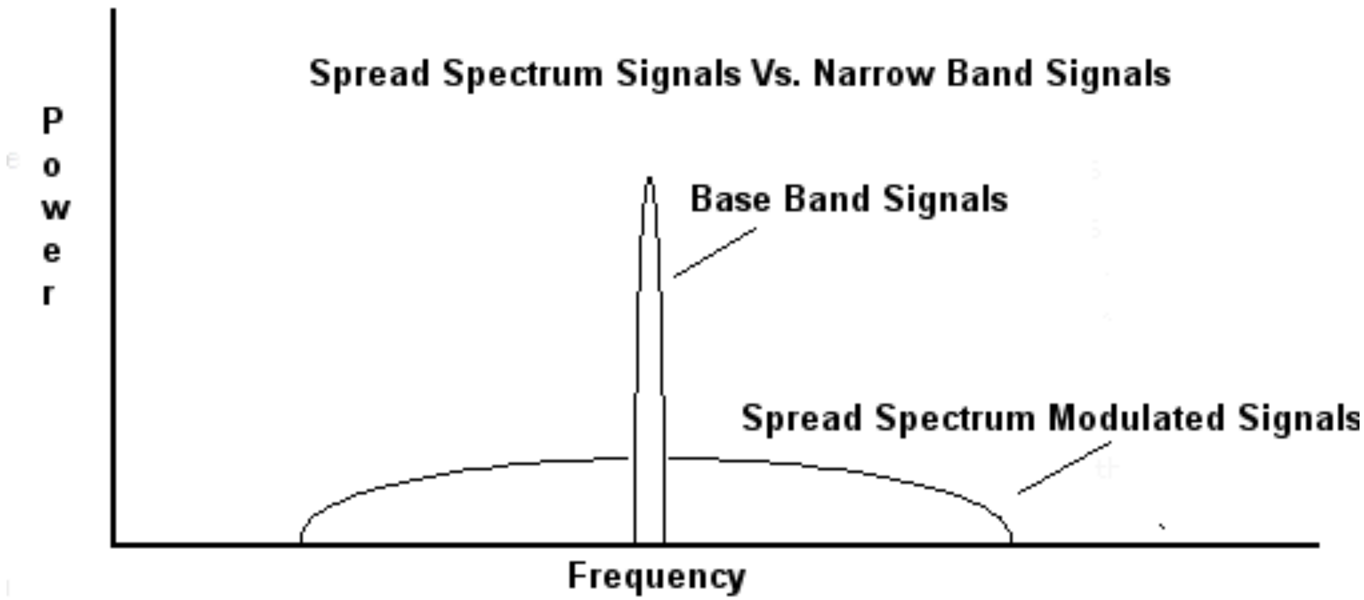


802.11 PHY Layer

- As physical link type of WLAN, 802.11-1997 proposed
  - Infrared (Diffused): up to 2 Mbps (not discussed)
  - FHSS (Frequency Hopping Spread Spectrum)
  - DSSS (Direct Sequence Spread Spectrum)

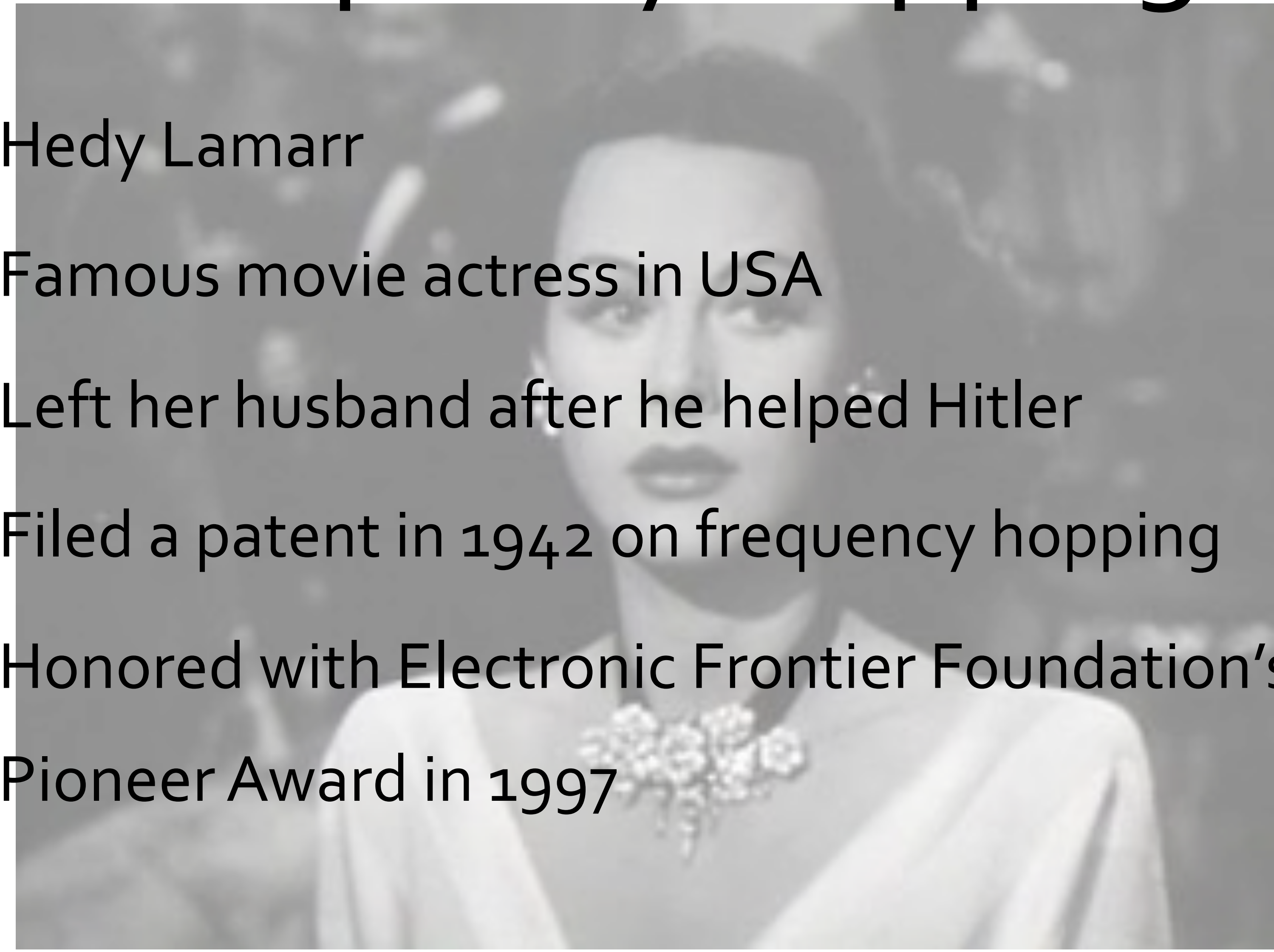
Spread Spectrum

- Spreads a signal's power over a wider band of frequencies, sacrificing bandwidth, but robust against noise/interference



Frequency Hopping

Frequency Hopping



- Hedy Lamarr
- Famous movie actress in USA
- Left her husband after he helped Hitler
- Filed a patent in 1942 on frequency hopping
- Honored with Electronic Frontier Foundation's Pioneer Award in 1997

Frequency Hopping Spread Spectrum

- Divides 2.4 GHz ISM band into 1 MHz frequency slots.
  - Channel 1 centered at 2.401 GHz
  - # of channels depend on country: from 23 (Jap) to 78 (US,Europe)
- Each STA keeps on changing channels staying on each not more than .4 sec following the predefined hopping sequence set by regulation
- 1MB with two-level GFSK/ 2 Mbps four-level GFSK modulation
- Robust against inference, cost effective, but low bandwidth

Direct Sequence Spread Spectrum

- Each data bit is divided into 11 chips (chipping code)
  - 0 = 11101100011
  - 1 = 00010011100
- Divide 2.4 ISM bands into 14 channels, 5MHz apart, each 22MHz bandwidth
  - To be orthogonal, channels need to be apart at least 3 channels
- 1Mbps with DBPSK, and 2 Mbps using DQPSK modulation (1997 version)

IEEE 802.11b

- Proposed in 1999
  - 2.4 GHz ISM
  - Three orthogonal channels
- use Complementary Code Keying (CCK): eight-bit seq for 4bit/8bit data, supporting 5.5 Mbps/ 11 Mbps, respectively

IEEE 802.11a

- Proposed in 1999
  - 5 GHz unlicensed band
  - larger bandwidth, less crowded than 2.4 GHz ISM
- with OFDM, 13 (original) + 11 (new) = 24 channels
- more complicated modulations : BPSK, QPSK, 16-QAM, 64-QAM for higher throughput capacity
  - data rates from 6 Mbps to 54 Mbps