CPE348: Introduction to Computer Networks

Lecture #7: Chapter 2.5

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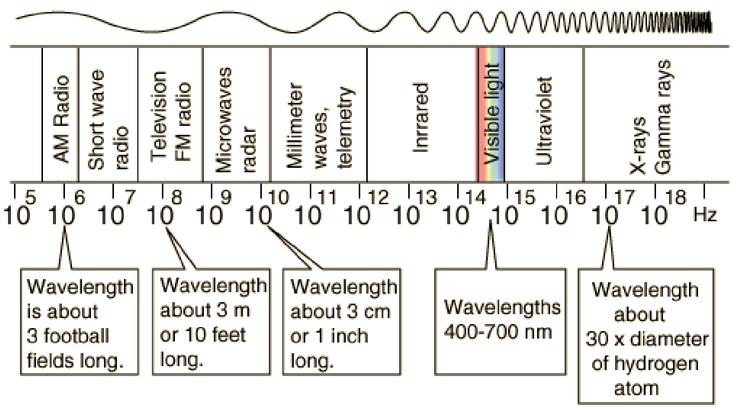
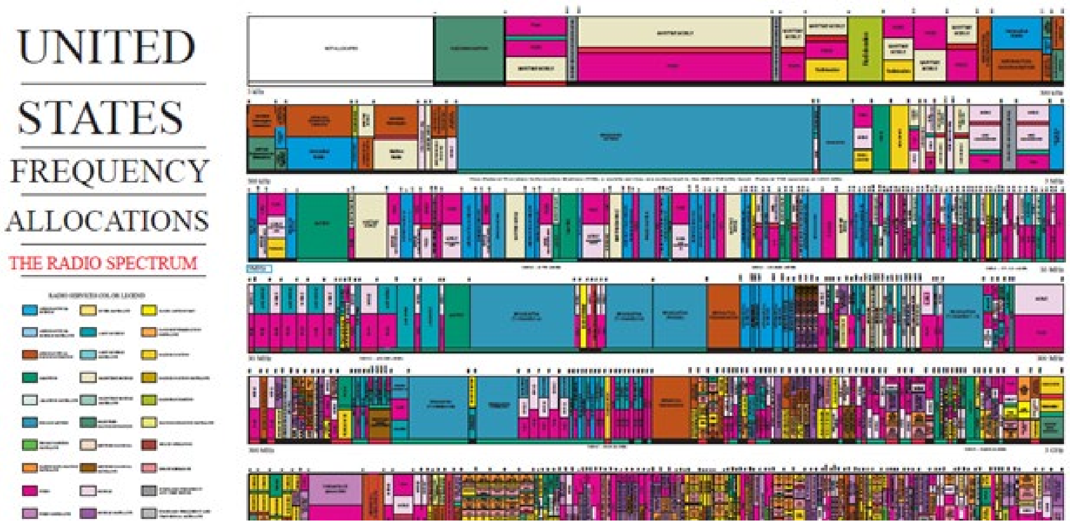
Wireless Links

- Wireless data transmission is based on EM wave propagation in the free space.



Wireless Links

- A Specific frequency band is allocated to a specific entity.
- These allocations are determined by FCC (Federal Communications Commission) in USA.



Wireless Networks

- Several wireless networks
  - Bluetooth (802.15)
  - Wi-Fi (more formally known as 802.11)
  - 2G, 3G, 4G/LTE cellular systems and beyond

Wireless Networks

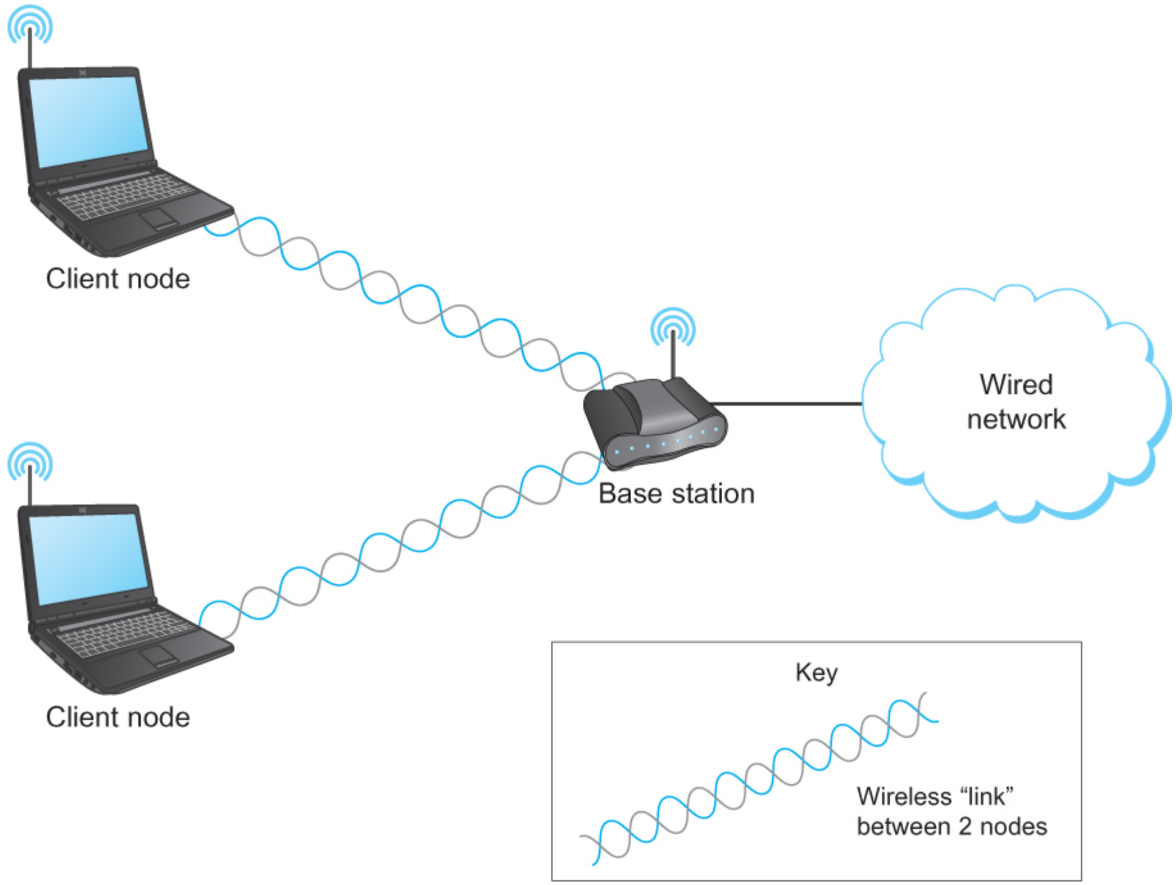
- Considerations upon designing or updating a wireless system:
  - Connectivity
  - data rate (uplink & downlink)
  - Latency
  - Energy efficiency

Capability	5G target
Peak data rate	20 Gbit/s
User experienced data rate	1 Gbit/s
Latency	1 ms
Mobility	500 km/h
Connection density	$10^6/km^2$
Energy efficiency	Equal to 4G
Spectrum efficiency	3–4x 4G
Area traffic capacity	1000 (Mbit/s)/m^2

- How to achieve these specs:
  - Architecture design
  - Resource allocation (bandwidth, power, time, device)
  - Scheduling and control design

Computer Engineer!

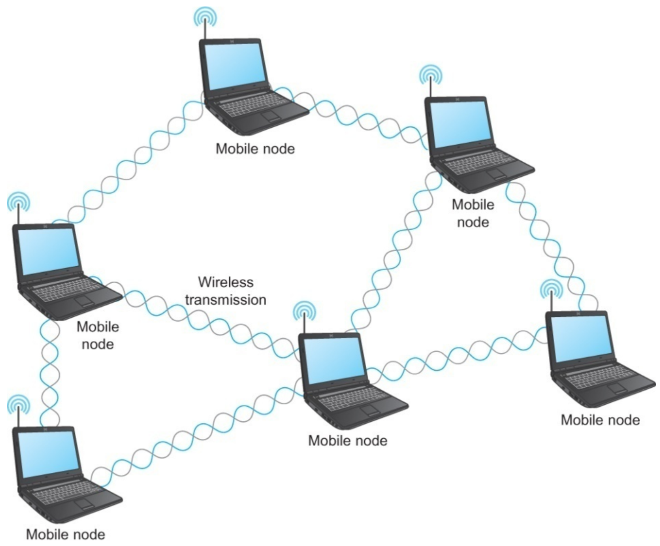
Wireless Networks – centralized



A wireless network using a base station, e.g. cellular

Wireless Networks – distributed

- Mesh or Ad-hoc network
  - Nodes are peers
  - Messages may be forwarded via a chain of peer nodes
  - Multiple paths are available



A wireless mesh network, e.g. wireless sensor network

Wireless Networks

Too many wireless networks!

Let's just study WiFi as an example!

IEEE 802.11 – overview

- Also known as Wi-Fi
- 802.11 defines a suite of protocols to build a wireless local area network (WLAN)
- Its version evolves to support different applications.

IEEE 802.11 – history

- Original 802.11 standard defined two radio-based physical layer standard
  - One using the frequency hopping
    - Over 79 1-MHz-wide frequency bandwidths
  - Second using direct sequence
    - Using 11-bit chipping sequence
  - Both standards run in the 2.4-GHz and provide up to 2 Mbps

IEEE 802.11 – history

- Then physical layer standard 802.11b was added
  - Using a variant of direct sequence 802.11b provides up to 11 Mbps
  - Uses license-exempt 2.4-GHz band
- Then came 802.11a which delivers up to 54 Mbps using OFDM (Orthogonal FDM)
  - Runs on license-exempt 5-GHz band – less interference
- Then came 802.11g which is backward compatible with 802.11b
  - Uses 2.4 GHz band, OFDM and delivers up to 54 Mbps
- Then came 802.11n which delivers up to 600 Mbps
  - Uses multiple antennas – MIMO (multiple input multiple output)
- Story continues…

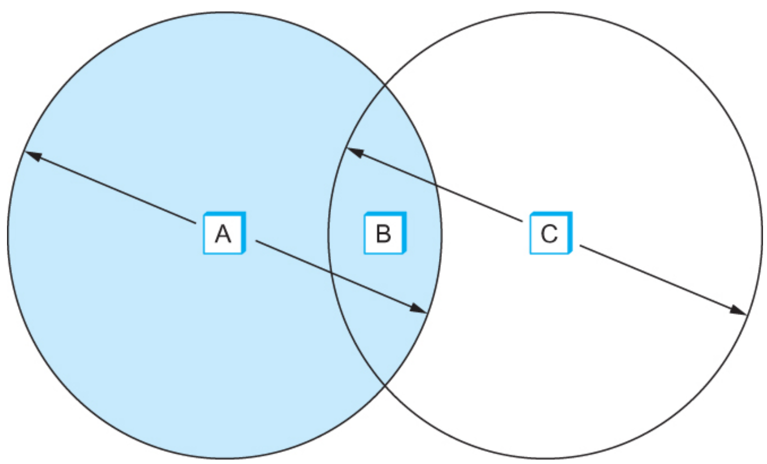
IEEE 802.11 – Collision Avoidance

Let's look into an important issue in WiFi networks!

IEEE 802.11 – Collision Avoidance

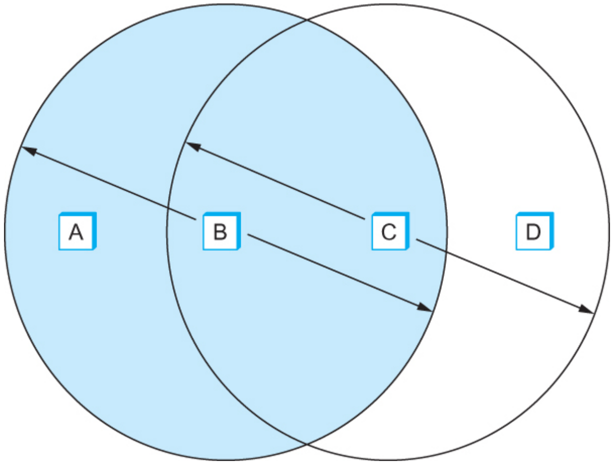
- Suppose both A and C want to communicate with B
  - A and C are unaware of each other
  - These two frames collide with each other at B
  - But unlike an Ethernet, neither A nor C is aware of this collision

- A and C are said to *hidden nodes* with respect to each other – see next slide



IEEE 802.11 – Collision Avoidance

- Another problem called *exposed node* problem occurs
  - Suppose B is sending to A. Node C is aware of this communication
  - Suppose C wants to transmit to node D.
  - It would be a mistake for C to conclude that it cannot transmit.
  - Waste of resources!



IEEE 802.11 – Collision Avoidance

- 802.11 addresses these two problems with an algorithm called Multiple Access with Collision Avoidance (MACA).
  - Sender and receiver exchange control frames with each other before data communications;
  - This exchange informs all nearby nodes that a transmission is about to begin;
  - Sender transmits a *Request to Send* (RTS) frame to the receiver.
    - Includes a field that indicates how long the sender wants to hold the medium

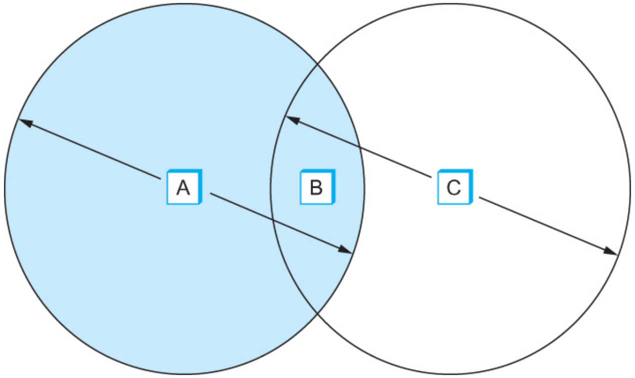
    - Includes length of the data frame to be transmitted
  - Receiver replies with a *Clear to Send* (CTS) frame
    - This frame echoes the length field back to the sender

IEEE 802.11 – Collision Avoidance

- Any node that sees the CTS frame knows that
  - it is close to the receiver, therefore
  - cannot transmit for the period of time it takes to send a frame of the specified length
- Any node that sees the RTS frame but not the CTS frame
  - is not close enough to the receiver to interfere with it, and
  - so is free to transmit to a node other than the node originating the RTS

IEEE 802.11 – Collision Avoidance

- If two or more nodes detect an idle link and try to transmit an RTS frame at the same time
  - Their RTS frame will collide with each other
  - So the senders realize the collision when they do not receive the CTS frame after a period of time
  - In this case, they each wait a random amount of time before trying again.
  - The amount of time a given node delays is defined by the same *exponential backoff* algorithm used on the Ethernet.



IEEE 802.11 – Collision Avoidance

802.11 does not support collision detection! Why?

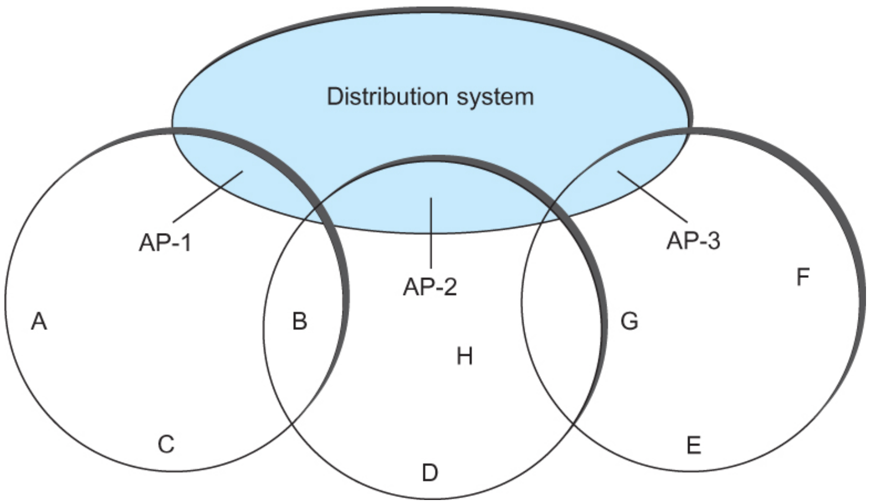
IEEE 802.11 – Distribution System

- WiFi devices are free to move around

- To deal with this mobility and partial connectivity,
  - Some nodes are stable, like an anchor, which are connected to a wired network infrastructure
    - they are called *Access Points* (AP) and they are connected to each other by a so-called *distribution system*

IEEE 802.11 – Distribution System

- Three local area networks (LANs) severed by three Aps;
- APs are connected to the distribution system (in most cases Ethernet).

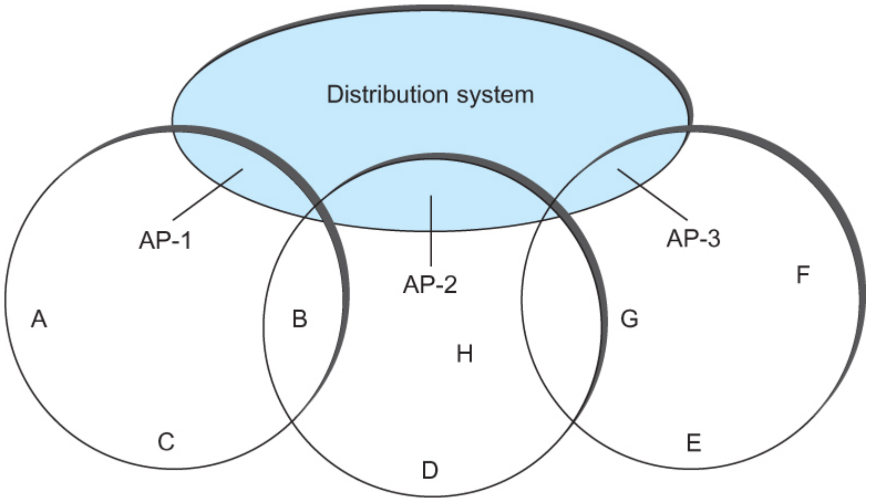


Access points connected to a distribution network

IEEE 802.11 – Distribution System

- For example, if A tries to talk with E,

A first sends a frame to its AP-1 which forwards the frame across the distribution system to AP-3, which finally transmits the frame to E



A -> AP-1 -> AP-3 -> E

IEEE 802.11 – Distribution System

When a node is moving, how to associate with an appropriate AP?

This is called, handover!

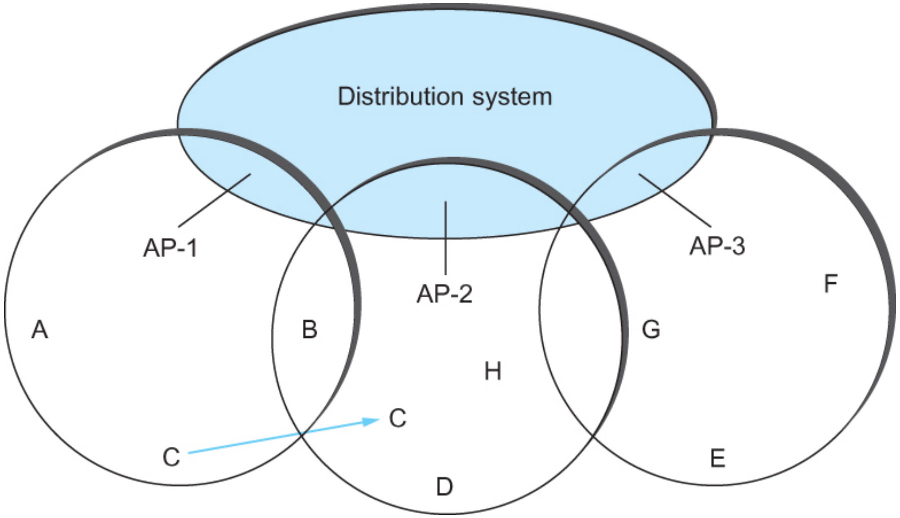
- *Active scanning*
  - The node initiates a *Probe* frame
  - All APs within reach reply with a *Probe Response* frame
  - The node selects one of the APs, based on signal strength, and sends that AP an *Association Request* frame
  - The AP replies with an *Association Response* frame

IEEE 802.11 – Distribution System

- Active scanning – node is actively searching for an access point
- Passive scanning
  - performed by access points
  - AP's periodically send Beacon Frames
  - AP's advertise their capabilities in Beacon Frames
  - Nodes can decide to change AP's based on Beacon Frames

IEEE 802.11 – Distribution System

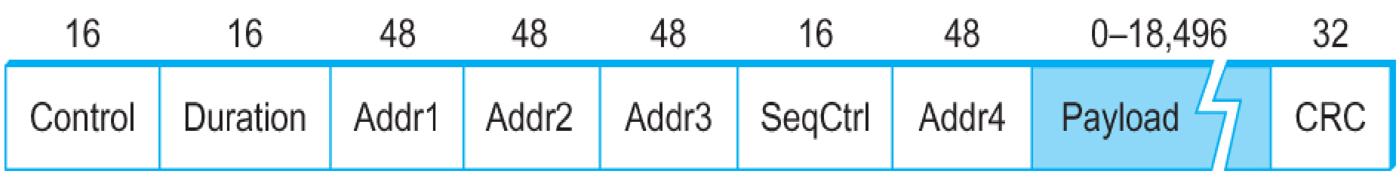
- For example



Node Mobility

IEEE 802.11 – Frame Format

- Source and Destination addresses: each 48 bits
- Data: up to 2312 bytes
- CRC: 32 bit
- Control field: 16 bits
  - Contains three subfields (of interest)
    - 6 bit **Type** field: indicates whether the frame is an RTS or CTS frame or being used by the scanning algorithm
    - A pair of 1 bit fields : called **ToDS** and **FromDS**



Frame Format

Chapter Summary

- Physical layer (L1) and Link layer (L2) techniques.

- We looked into five key issues in L1&L2
  - Encoding
  - Framing
  - Error Detecting
  - Reliability
  - Multiple Access Links
    - Ethernet
    - Wireless 802.11