MOBILE COMPUTING

CSE 40814/60814
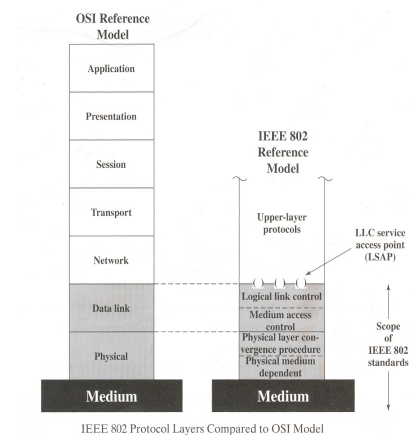
Spring 2021

Wi-Fi

- Wi-Fi:
  - name is NOT an abbreviation
  - play on "Hi-Fi" (high fidelity)
- **Wireless Local Area Network (WLAN)** technology
- WLAN and Wi-Fi often used synonymous
- Typically **in 2.4 and 5 GHz bands**
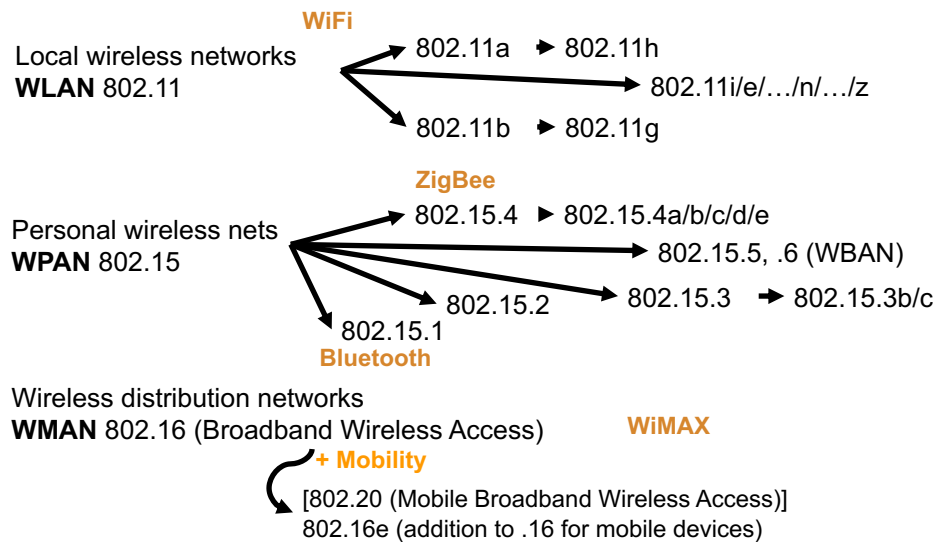- Based on **IEEE 802.11** family of standards

IEEE

- IEEE (Institute of Electrical and Electronics Engineers) established the 802.11 Group in 1990. Specifications for standard ratified in 1997.
- Initial speeds were 1 and 2 Mbps.
- IEEE modified the standard in 1999 to include:
  - 802.11b
  - 802.11a
  - 802.11g
  - 802.11n
  - **802.11ac (150Mbps (2.4GHz) and 433Mbps (5GHz or more))**
  - 802.11...

IEEE 802.11 Standard

- 802.11 is primarily concerned with the **lower layers of the OSI model**
- **Data Link Layer**
  - Logical Link Control (LLC).
  - Medium Access Control (MAC).
- **Physical Layer**
  - Physical Layer Convergence Procedure (PLCP).
  - Physical Medium Dependent (PMD).

OSI Reference Model

Application

Presentation

Session

Transport

Network

Data link

Physical

Medium

IEEE 802 Reference Model

Upper-layer protocols

LLC service access point (LSAP)

Logical link control

Medium access control

Physical layer convergence procedure

Physical medium dependent

Medium

Scope of IEEE 802 standards

IEEE 802 Protocol Layers Compared to OSI Model

3/7/21

IEEE Standards

WiFi

Local wireless networks
WLAN 802.11

802.11a → 802.11h

802.11i/e/…/n/…/z

802.11b → 802.11g

ZigBee

Personal wireless nets
WPAN 802.15

802.15.4 → 802.15.4a/b/c/d/e

802.15.5, .6 (WBAN)

802.15.2

802.15.3 → 802.15.3b/c

802.15.1
Bluetooth

Wireless distribution networks
WMAN 802.16 (Broadband Wireless Access)

WiMAX

+ Mobility

[802.20 (Mobile Broadband Wireless Access)]
802.16e (addition to .16 for mobile devices)

Wi-Fi Alliance Mission Statement

- Non-profit organization
- Certify the interoperability of products and services based on IEEE 802.11 technology
- Grow the global market for **Wi-Fi® CERTIFIED** products and services across all market segments, platforms, and applications
- Rigorous interoperability testing requirements
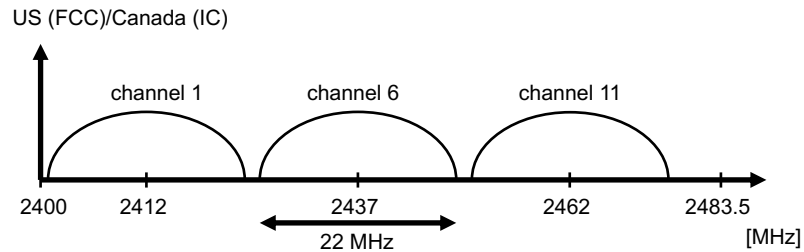
Certificate & Logo

Certificate inside packaging (optional)

- Logo on product packaging (mandatory)
- Helps retailers and consumers

IEEE 802.11b (obsolete)

- **2.4 GHz range** (very "busy" part of spectrum)
- **ISM bands:** industrial, scientific and medical (now unlicensed use)
- Prone to **interference from other devices** (microwave ovens, cordless phones, etc.) and also has security disadvantages
- Limits the number of access points in range of each other to three
- Has **11 channels** (**3 non-overlapping**) and supports rates from **1 to 11 Mbps**, but realistically about 4-5 Mbps max
- Range: **100-300ft** (indoors/outdoors)

Channel Selection (non-overlapping)

US (FCC)/Canada (IC)

channel 1   channel 6   channel 11

2400   2412   2437   2462   2483.5

22 MHz

[MHz]

- Width of band: 22MHz
- Channel 1 center: 2412MHz
- Channel center distance: 5MHz (2412, 2417, 2422, 2427, 2432, 2437, ...)

802.11g Standard

- Extension of 802.11b, with the same disadvantages (security and interference).
- Has a shorter range than 802.11b.
- Is backwards compatible with 802.11b so it allows or a smooth transition from 11b to 11g.
- Flexible because multiple channels can be combined for faster throughput.
- Runs at **54 Mbps**, but realistically about 20-25 Mbps and about 14 Mbps when b associated
- Uses frequency division multiplexing

IEEE 802.11a

- Completely different from 11b (& 11g)
- Flexible because multiple channels can be combined for faster throughput and more access points can be co-located
- Shorter range than 11b
- Runs in the **5 GHz range**, so less interference from other devices
- Has 12 channels (8 non-overlapping)
- Rates from **6 to 54 Mbps** (realistically ~27 Mbps max)
- Uses frequency division multiplexing

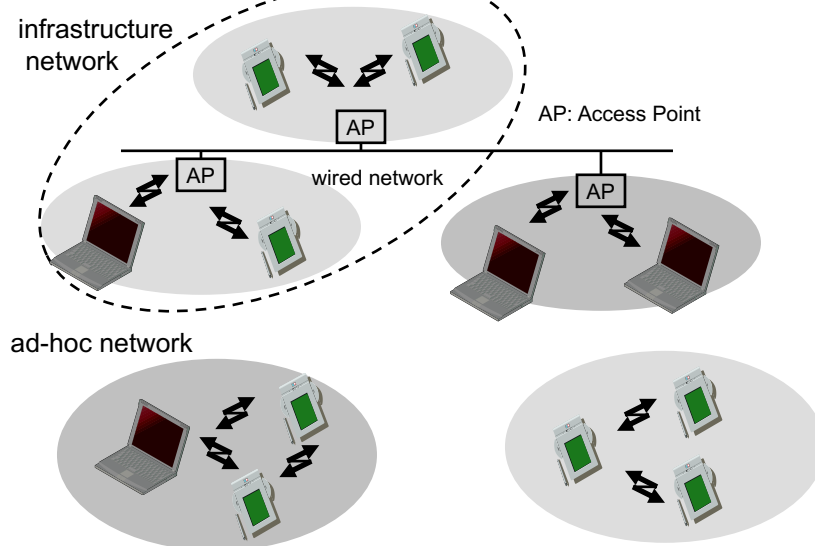# OFDM = Orthogonal Frequency Division Multiplexing

- 52 subcarriers (64 in total)
  - 48 data + 4 pilot
    - (plus 12 virtual subcarriers)
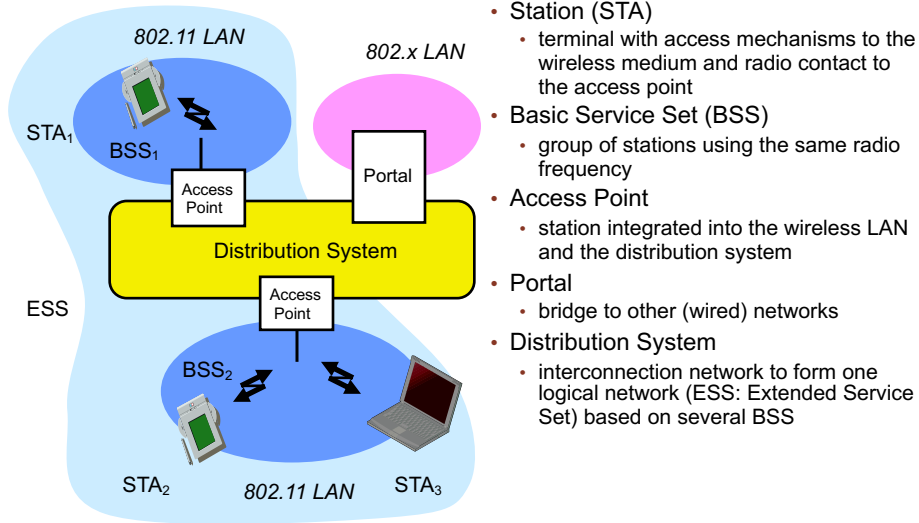 - 312.5 kHz spacing
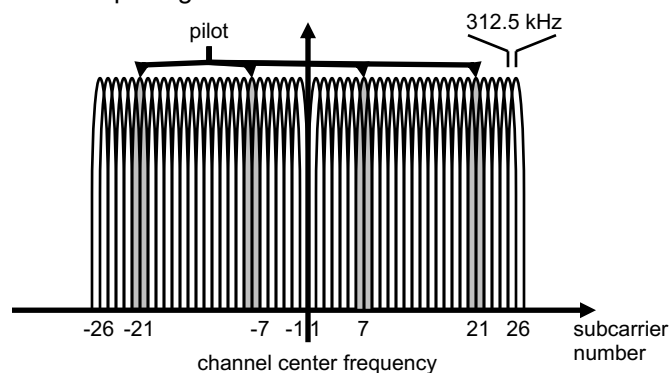
IEEE 802.11n & ac

- **IEEE 802.11n:**
  - **MIMO**: Multiple Input Multiple Output (multiple antennas)
  - 2.4 & 5GHz
  - Data rates up to 150Mbps (single antenna)
  - Range: 230-820 ft (indoor/outdoor)

- **IEEE 802.11ac:**
  - 5GHz
  - Data rates of 150 (2.4GHz) – 433 (5GHz) Mbps (single antenna)
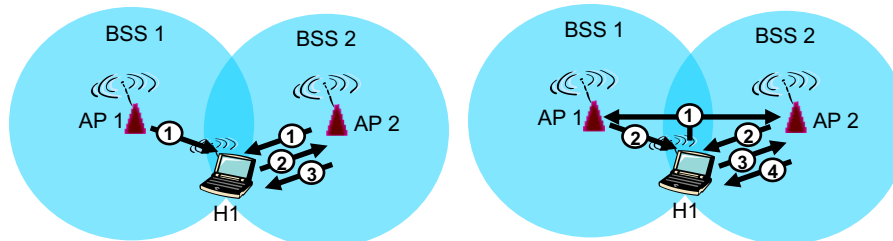 - Range: 115 ft indoor

Infrastructure vs. Ad-Hoc Networks

infrastructure network

AP: Access Point

AP

wired network

AP

AP

ad-hoc network

802.11 - Architecture of an Infrastructure Network

802.11 LAN

802.x LAN

STA$_1$

BSS$_1$

Portal

Access Point

Distribution System

Access Point

ESS

BSS$_2$

STA$_2$ *802.11 LAN* STA$_3$

- Station (STA)
  - terminal with access mechanisms to the wireless medium and radio contact to the access point
- Basic Service Set (BSS)
  - group of stations using the same radio frequency
- Access Point
  - station integrated into the wireless LAN and the distribution system
- Portal
  - bridge to other (wired) networks
- Distribution System
  - interconnection network to form one logical network (ESS: Extended Service Set) based on several BSS

Wi-Fi (802.11)

BSS 1

BSS 2

AP 1 ① ② ③ AP 2

H1

BSS 1

BSS 2

AP 1 ① ② ③ ④ AP 2

H1

Passive Scanning
(1) Beacons sent from APs
(2) Association Request sent from H1 to selected AP
(3) Association Response sent from AP to H1

Active Scanning
(1) Probe Request (broadcast) sent from H1
(2) Probe Response sent from APs
(3) Association Request sent from H1 to selected AP
(4) Association Response sent from AP to H1

Infrastructure Network

- There is an **Access Point (AP)**, which becomes the hub of a "star topology".
- **Any communication has to go through AP!**
  - MS1 -> AP -> MS2
- Multiple APs can be connected together and handle a large number of clients (WLAN consisting of multiple APs).
  - MS1 -> AP1 -> AP2 -> MS2
  - AP1 -> AP2 typically wired (Ethernet), otherwise "mesh network"

Roaming

- In an extended service area, a mobile station (MS) can roam from one BSS (Basic Service Set) to another.
- Roughly speaking, the MS keeps checking the **beacon signal** sent by each AP and selects the strongest one and connects to that AP.
- If the BSSs overlap, the connection will not be interrupted when an MS moves from one set to another. If not, the service will be interrupted.
- Two BSSs coverage areas can largely overlap to increase the capacity for a particular area. If so, the two access points will use different channels (why?).
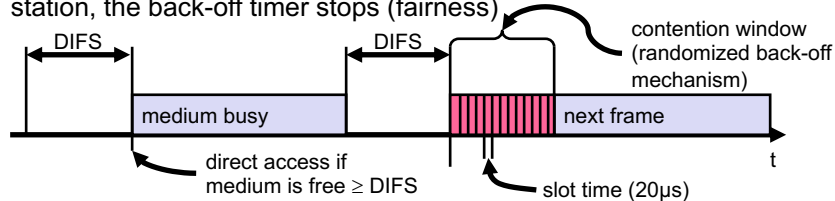
802.11 – MAC Layer

- **Priorities**
  - defined through different inter frame spaces
  - no guaranteed, hard priorities
  - **SIFS** (Short Inter Frame Spacing)
    - highest priority, for ACK, CTS, polling response
  - PIFS (PCF IFS)
    - medium priority, for time-bounded service using PCF
  - **DIFS** (DCF, Distributed Coordination Function IFS)
    - lowest priority, for asynchronous data service
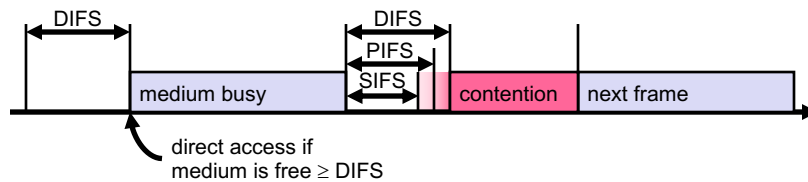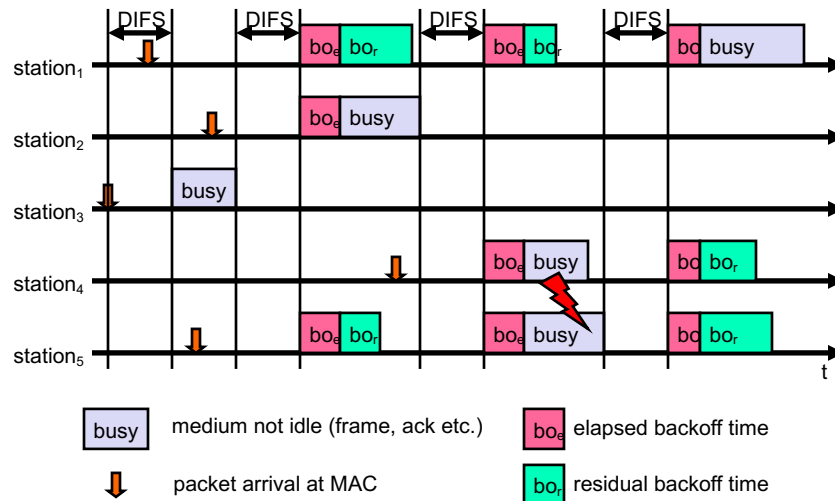

802.11 - CSMA/CA Access Method

- Station ready to send starts sensing the medium (Carrier Sense based on CCA, Clear Channel Assessment)
- If the medium is free for the duration of an Inter-Frame Space (IFS), the station can start sending (IFS depends on service type)
- If the medium is busy, the station has to wait for a free IFS, then the station must additionally wait a random back-off time (collision avoidance, multiple of slot-time)
- If another station occupies the medium during the back-off time of the station, the back-off timer stops (fairness)

802.11 – Competing Stations

| busy | medium not idle (frame, ack etc.) | bo_e | elapsed backoff time |

packet arrival at MAC bo_r residual backoff time
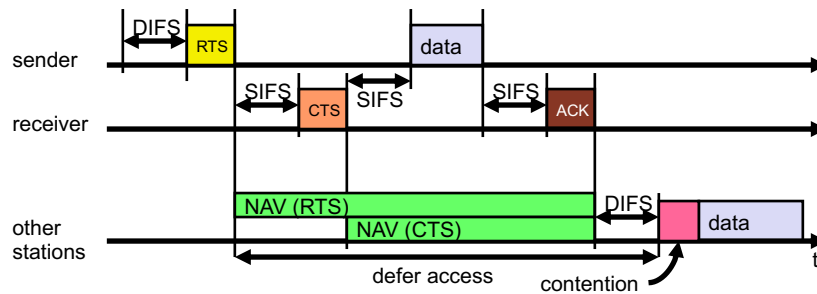
802.11 - CSMA/CA Access Method

- Sending unicast packets
  - station has to wait for DIFS before sending data
  - receivers acknowledge at once (after waiting for SIFS) if the packet was received correctly (CRC)
  - automatic retransmission of data packets in case of transmission errors
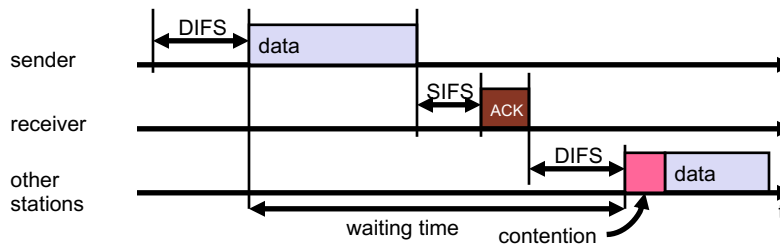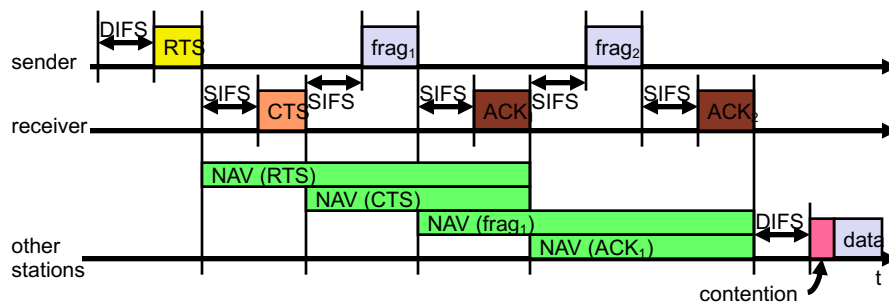
802.11 - CSMA/CA Access Method

- Sending unicast packets
  - station can send RTS with reservation parameter after waiting for DIFS (reservation determines amount of time the data packet needs the medium)
  - acknowledgement via CTS after SIFS by receiver (if ready to receive)
  - sender can now send data at once, acknowledgement via ACK
  - other stations store medium reservations distributed via RTS **and** CTS

Fragmentation

Synchronization using Beacons

beacon interval
(20ms – 1s)

access
point

medium

▽ value of the timestamp   B beacon frame
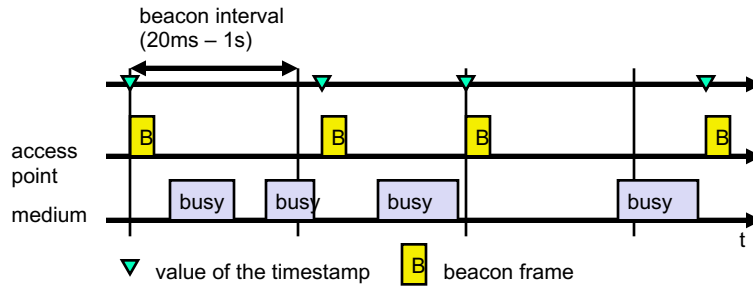
WLAN (Wi-Fi)

802.11 Wireless Standards

IEEE Standard	802.11a	802.11b	802.11g	802.11n	802.11ac
Year Adopted	1999	1999	2003	2009	2014
Frequency	5 GHz	2.4 GHz	2.4 GHz	2.4/5 GHz	5 GHz
Max. Data Rate	54 Mbps	11 Mbps	54 Mbps	600 Mbps	1 Gbps
Typical Range Indoors*	100 ft.	100 ft.	125 ft.	225 ft.	90 ft.
Typical Range Outdoors*	400 ft.	450 ft.	450 ft.	825 ft.	1,000 ft.