

# EEN 1043/EE452

# Wireless and Mobile Communication

Multiple Access

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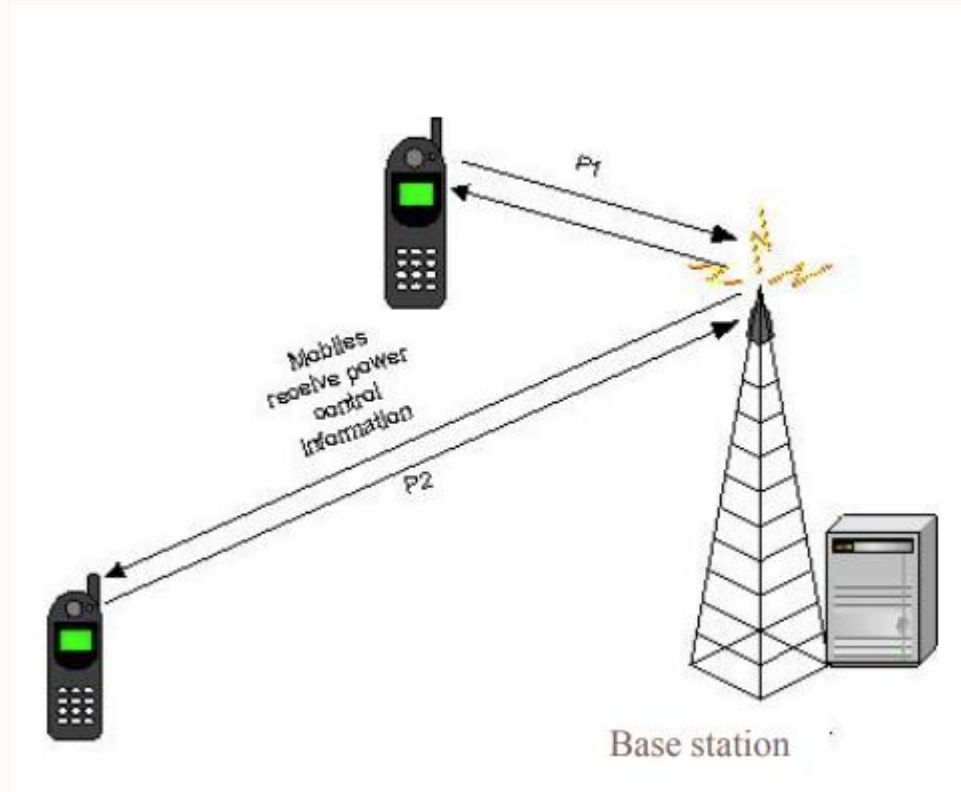
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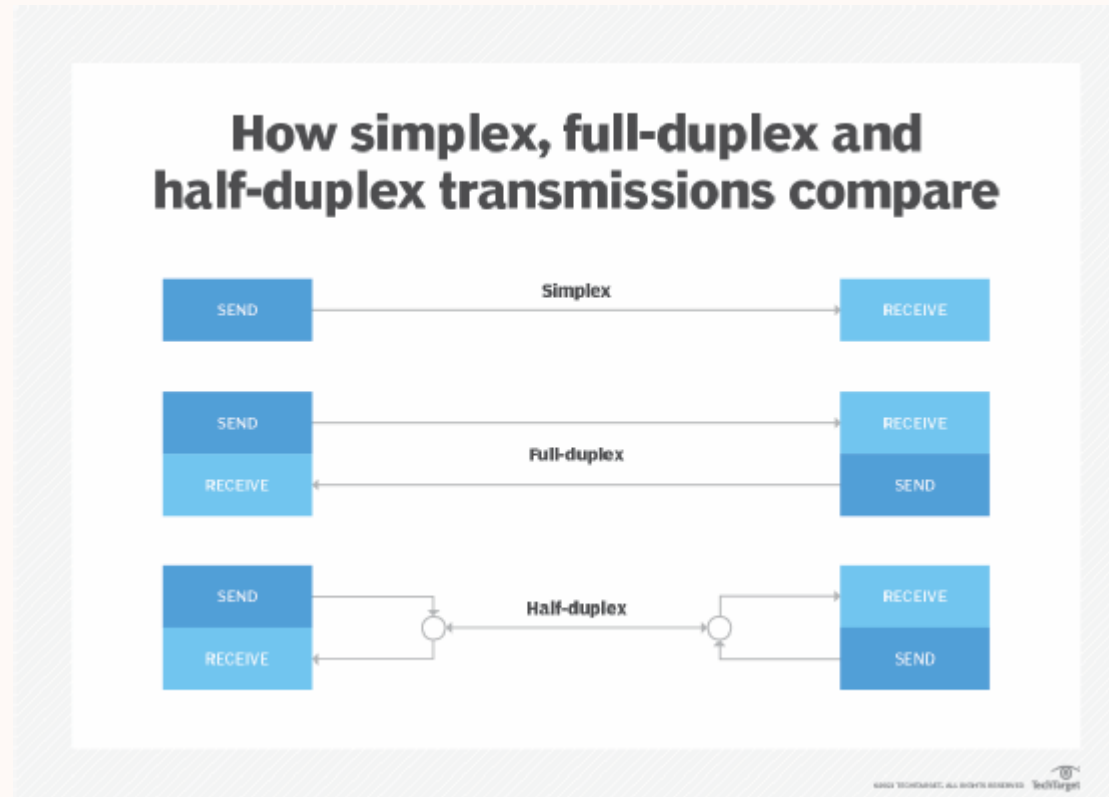
# Outline

- What is medium access?
  - Who gets to transmit? How? When?
- Multiplexing
  - How many stations can share a single link n FDMA, TDMA, CDMA in circuit switched voice networks
- CSMA/CD in Ethernet (simplicity)
- Duplexing
  - How communication from station A to station B is separated from the communication from station B to station A n FDD or TDD
- Impact of architectures
  - Infrastructure – centralized, fixed base station
  - Ad hoc – distributed, peer-to-peer

# Need for medium access control



# Duplexing



# Duplexing

- Simplex – one way communication (e.g., broadcast AM)
- Duplex – two way communication
- TDD – time division duplex
  - Users take turns on the channel
- FDD – frequency division duplex
  - Users get two channels one for each direction of communication
  - For example one channel for uplink (mobile to base station) another channel for downlink (base station to mobile)
- Half-duplex
  - As in 802.11, a device cannot simultaneously be transmitting and receiving

# Medium Access Control

- Centralized Access Control
  - Cellular
- Distributed Access Control (Random Access)
  - Adhoc Network of Peer Workstations
  - Wireless LAN



# Centralized Access Control

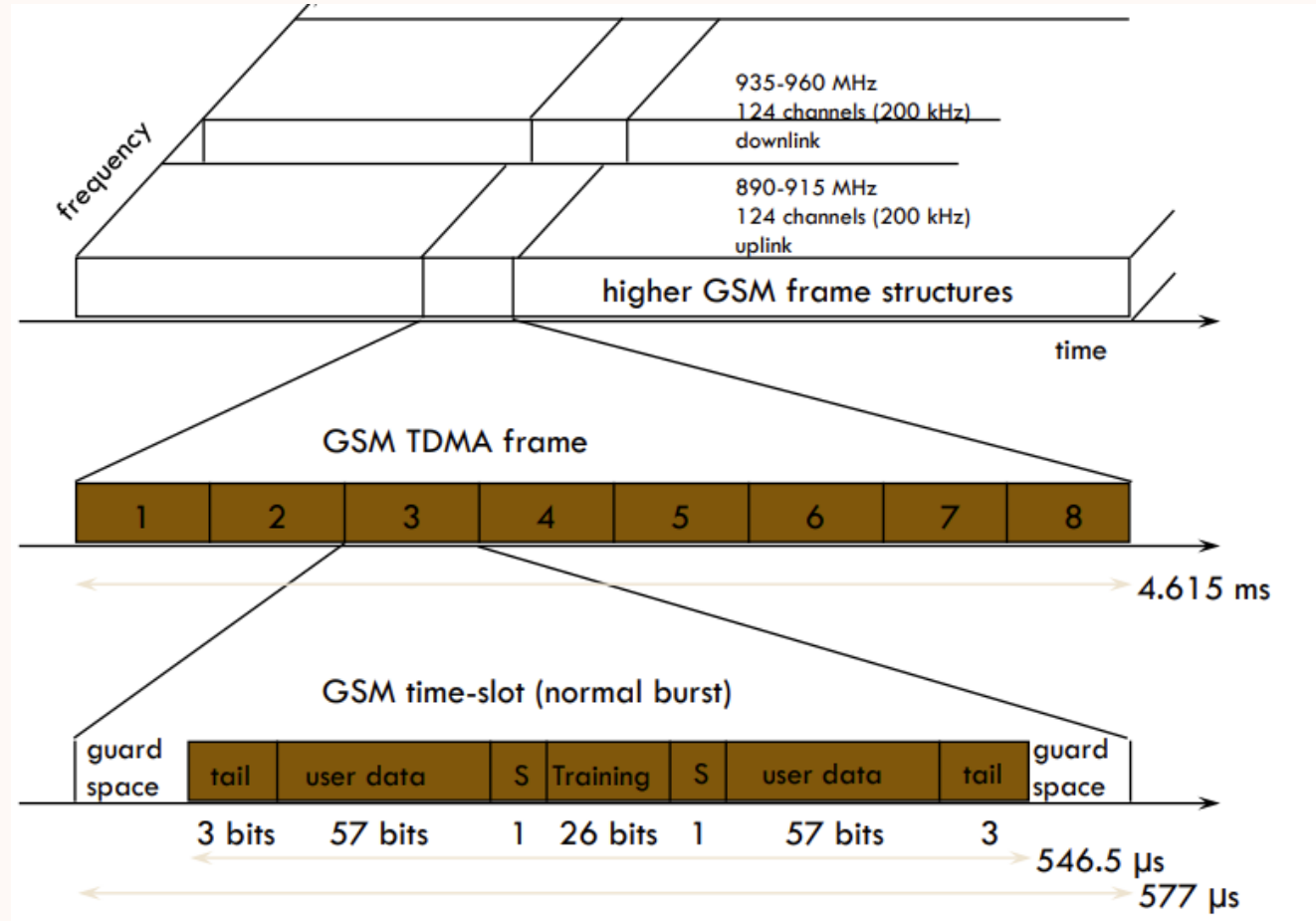
# Centralized Multiple Access Schemes

- FDMA (frequency division multiple access)
  - Separate spectrum into non-overlapping frequency bands
  - Assign a certain frequency to a transmission channel between a sender and a receiver
  - Different users share use of the medium by transmitting on non-overlapping frequency bands at the same time
- TDMA (time division multiple access)
  - Assign a fixed frequency to a transmission channel between a sender and a receiver for a certain amount of time (users share a frequency channel in time slices)
- CDMA (code division multiple access)
  - Assign a user a unique code for transmission between sender and receiver, users transmit on the same frequency at the same time

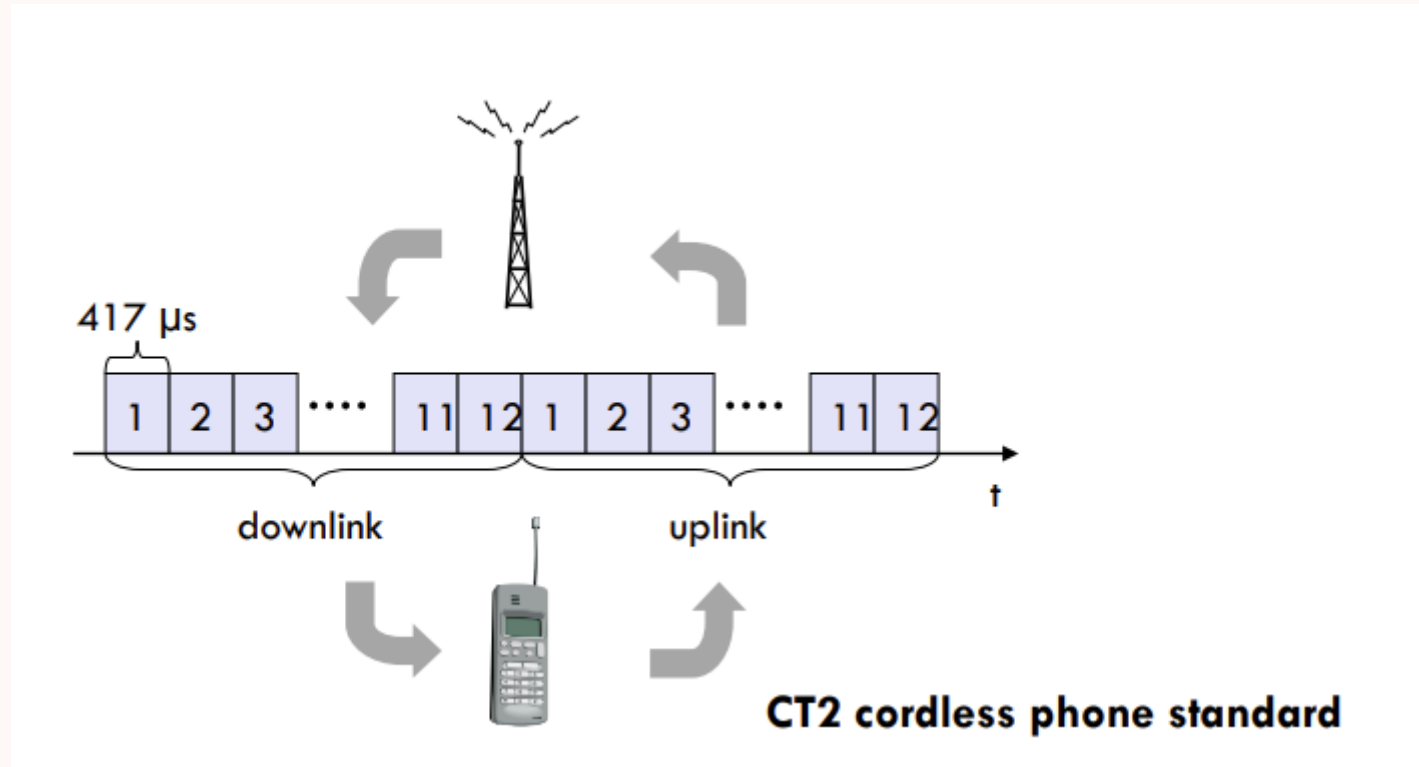
# Centralized Multiple Access Schemes

- OFDMA (orthogonal frequency division multiple access)
  - Separate spectrum into orthogonal frequency bands

# FDD/TDMA



# TDD/TDMA



# OFDMA

- OFDM essentially divided the spectrum into sub-channels.
  - So far, we have considered the use of all of the subchannels by a single user.
  - There is no reason that different subchannels cannot be assigned to different users.
- OFDMA stands for Orthogonal Frequency Division Multiple Access.
  - Technique to allow multiple users to share the spectrum.
  - Uses a combination of FDMA and TDMA.
  - Bit rate implications.
  - Allows subcarriers to be shared according to which subcarrier has the strongest signal.

# OFDMA

- Users are allocated *groups* of subcarriers (referred to as a *subchannel*).
  - A single subcarrier does not have enough capacity, and there are too many to schedule individually.
- Subchannels can be allocated in three ways:
  - **Adjacent subcarriers**: contiguous block of frequencies.
    - SINR roughly equal across block.
    - System must try to choose best block.
      - Requires system to have good knowledge of channel characteristics.
    - Used by WiMAX and LTE.
  - **Regularly spaced subcarriers**: distributed periodically through spectrum.
    - Good frequency diversity, so system doesn't need to worry as much about channel characteristics.
    - Used by LTE
  - **Randomly Spaced Subcarriers**:
    - Also good frequency diversity.
    - Used by WiMAX

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# OFDMA Example LTE

- On the downlink, LTE uses OFDM combined with either
  - QPSK
  - 16 QAM
  - 64 QAM
- So, the number of bits per signalling element varies according to channel conditions.
  - A signalling element is contained in a resource block
    - $\Delta f = 15\text{kHz}$  band
    - 0.5 msec ( $1/\Delta f$  + cyclic prefix)

# OFDMA Example LTE

- OFDM symbols grouped into resource blocks
  - 180kHz in frequency domain, 0.5msec in time domain.
  - Users allocated a number of resource blocks in the time-frequency grid.
  - How many resources granted based on QoS negotiation with network.
    - Considerations include:
      - Efficiency: improve SINR
      - Fairness (or proportional fairness)
        - All users should get some resources
      - Application requirements
      - Priority

# OFDMA Example LTE

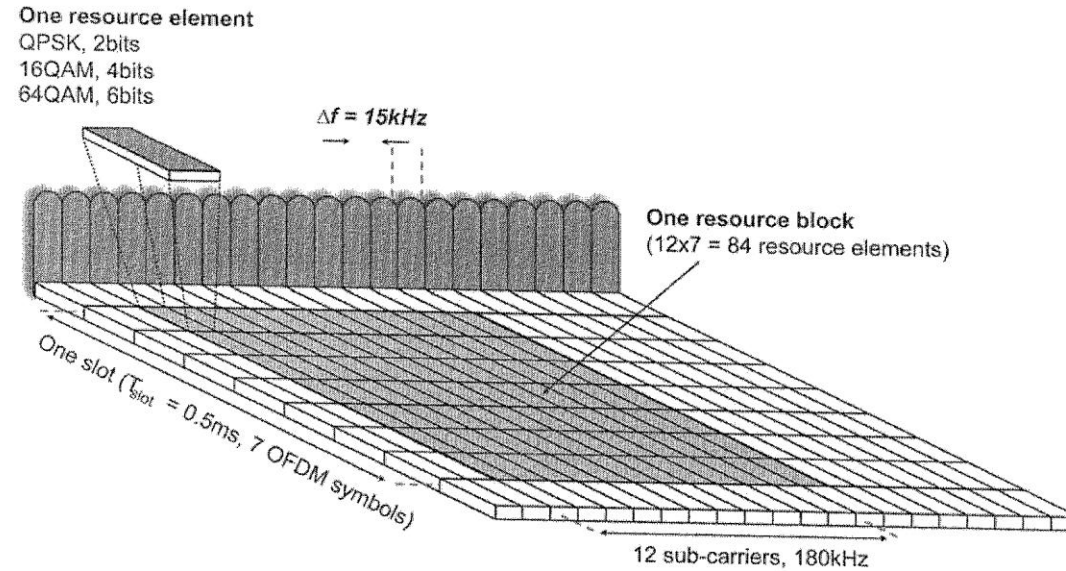


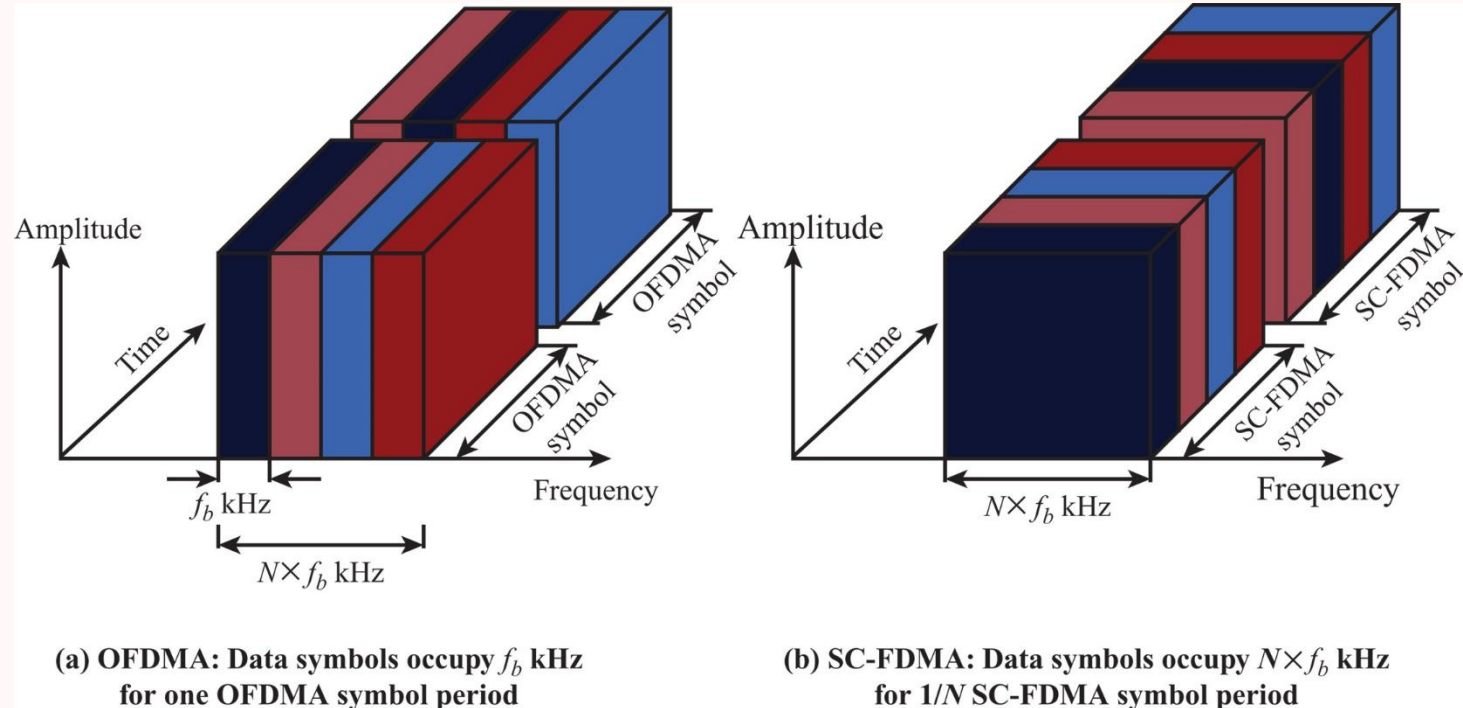
Figure 4: The LTE downlink physical resource based on OFDM

# OFDMA Example LTE

- On the uplink, LTE uses Single Carrier Frequency Division Multiple Access (SC-FDMA)
  - Precoded version of OFDM
  - Resources grouped to optimise power control.

# SC-FDMA

- SC-FDMA despite what the name implies, does not use FDMA.
- Multiple access is achieved via TDMA.
  - Symbols transmitted at a higher rate, but over greater frequency bandwidth.
  - Source data stream replicated  $N$  times, copies sent on all subcarriers.



# OFDM vs. CDMA

- Advantages of OFDM
  - It is robust when combatting narrow-band co-channel interference. As only some of the channels will be affected, not all data is lost and error coding can combat this.
    - This advantage lessens as less channels assigned.
  - Intersymbol interference, ISI is less of a problem with OFDM than CDMA because low data rates are carried by each carrier.
  - Provides higher levels of spectral efficiency than CDMA.

# OFDMA vs. CDMA

OFDMA	CDMA
<ul style="list-style-type: none"><li>• OFDM can combat multipath interference with greater robustness and less complexity. Equalisation can be undertaken on a carrier by carrier basis.</li><li>• OFDMA can achieve higher spectral efficiency with MIMO than CDMA using a RAKE receiver.</li><li>• Cell breathing does not occur as additional users connect to the base station.</li><li>• Can be used to provide a single frequency network.</li><li>• It is relatively easy to aggregate spectrum.</li><li>• It can be scaled according to the requirements relatively easily</li></ul>	<ul style="list-style-type: none"><li>• Not as complicated to implement as OFDM based systems</li><li>• As CDMA has a wide bandwidth, it is difficult to equalise the overall spectrum - significant levels of processing would be needed for this as it consists of a continuous signal and not discrete carriers.</li><li>• Not as easy to aggregate spectrum as for OFDM</li></ul>

# Random Access

# Random Access

- ALOHA
  - Any terminal is allowed to transmit without considering whether channel is idle or busy. If packet is received correctly, the base station transmits an acknowledgement. If no acknowledgement is received by the mobile, it retransmits the packet after waiting a random time.
- Carrier Sensing
  - " Listen before talk ": no new packet transmission is initiated when the channel is busy. This reduces collisions.

# ALOHA

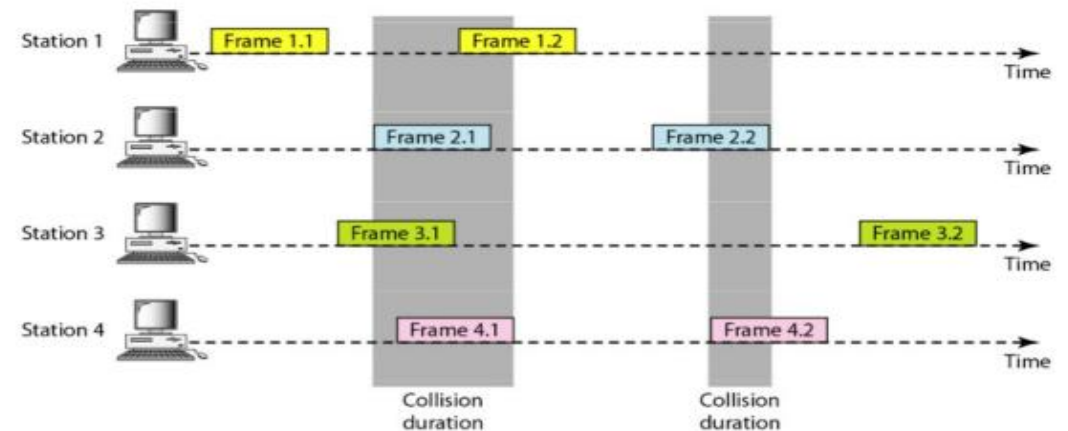
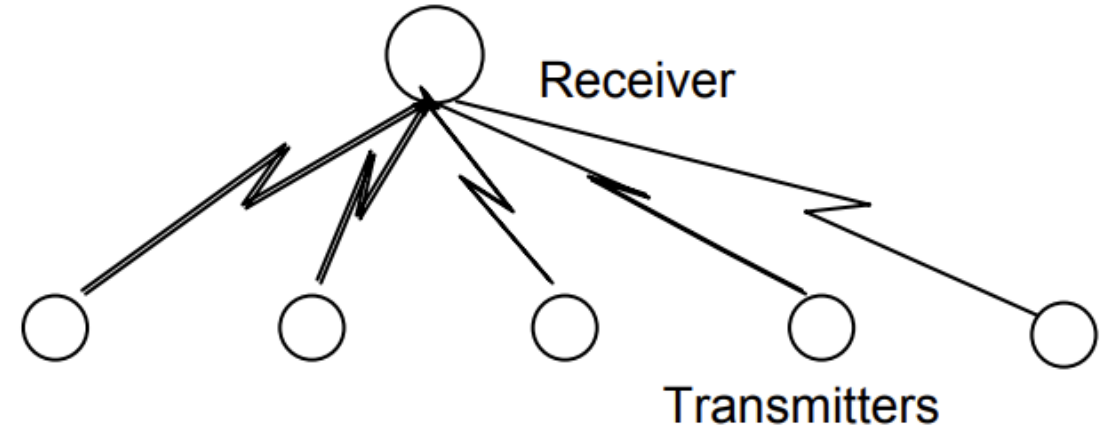
- ALOHA (Additive Links On-line Hawaii Area)
- Transmit whenever you want
  - If you are acknowledged, everything is fine
  - Otherwise retransmit packets
- Low throughput (18%) ( $1/2e$ )
- Slotted versions are slightly better
  - Transmission attempts can take place only at discrete points of time
- Works efficiently when less number of nodes

# ALOHA

- Single receivers, many transmitters
- The probability of k arrivals during a time interval of length t is given by

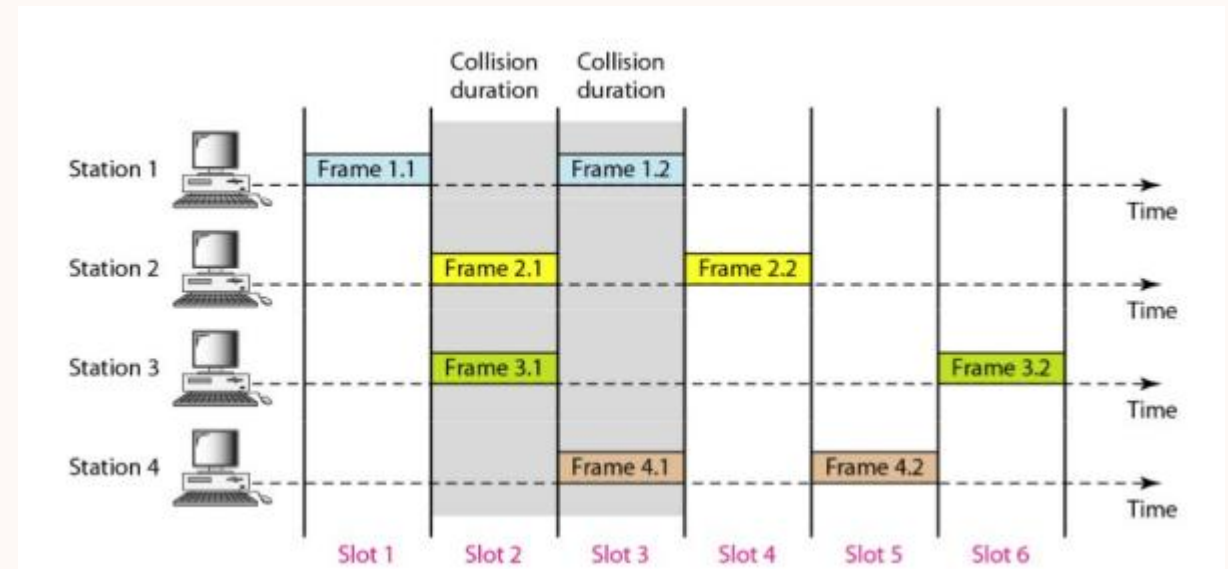
- $$P_k(t) = \frac{(\lambda t)^k e^{-\lambda t}}{k!}$$

- $\lambda$  is the arrival rate



# Slotted ALOHA

- A station is allowed to send only at the beginning of the synchronized time slot
- if a station misses this moment, it must wait until the beginning of the next time slot.
- This means that the station which started at the beginning of this slot has already finished sending its frame.
- Throughput is 36.8%



Probability of successful transmission of a specific node

$$P(\text{success}) = p(1 - p)^{N-1}$$

Probability of successful transmission of any node

$$P(\text{success}) = Np(1 - p)^{N-1}$$

As  $N$  approaches infinity  $P(\text{success}) = 1/e$

# Carrier Sensing Multiple Access

- Carrier Sense Multiple Access With Collision Avoidance (CSMA/CA)
- Carrier Sense Multiple Access With Collision Detection (CSMA/CD)

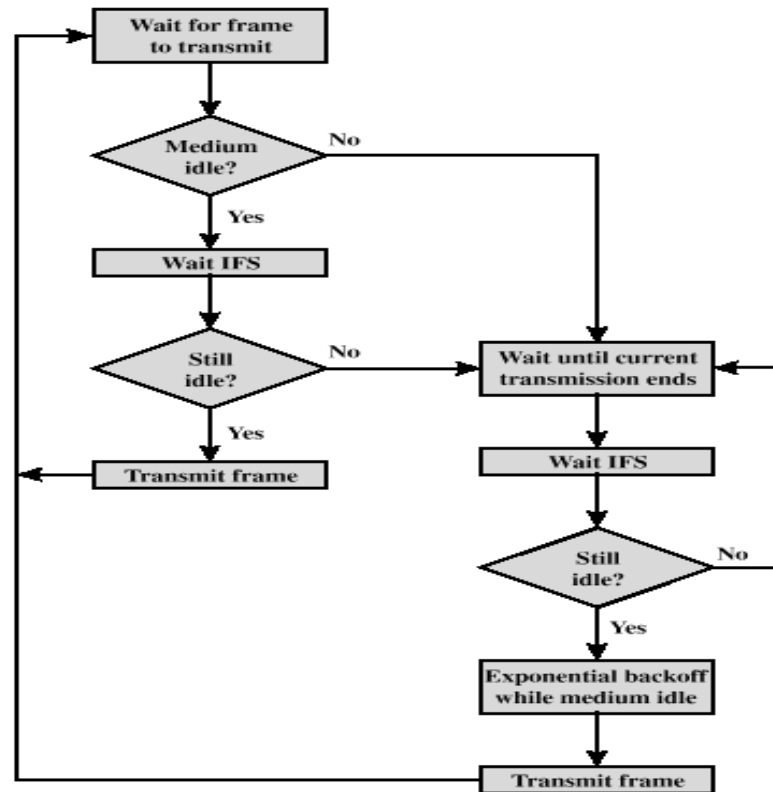
# CSMA

- Multiple access protocol used in 802.11 for sharing of the medium (Radio channel)
- Goal is to prevent/minimise interference
- Operation when node wants to transmit
  - Sense the channel
  - If idle, start transmitting, if not backoff
  - If collision occurs, backoff random time
  - Then Sense Channel ... Repeat

# CSMA/CA

- All terminals listen to the same medium as CSMA/CD.
- Terminal ready to transmit senses the medium.
- If medium is busy, it waits until the end of current transmission.
- It again waits for an additional predetermined time period DIFS (Distributed inter frame Space).
- Then picks up a random number of slots (the initial value of backoff counter) within a contention window to wait before transmitting its frame.
- If there are transmissions by other terminals during this timeperiod (backoff time), the terminal freezes its counter.
- It resumes count down after other terminals finish transmission + DIFS. The terminal can start its transmission when the counter reaches to zero.

# CSMA/CA



**Figure 14.6 IEEE 802.11 Medium Access Control Logic**

# CSMA/CD

- Carriers sense multiple access with collision detection (CSMA/CD) augments the algorithm to handle the collision.
- In this method, a station monitors the medium after it sends a frame to see if the transmission was successful.
  - If so, the station is finished.
  - If, however, there is a collision, the frame is sent again.
- CSMA/CD
  - Step 1: If the medium is idle, transmit
  - Step 2: If the medium is busy, continue to listen until the channel is idle then transmit
  - Step 3: If a collision is detected during transmission, cease transmitting
  - Step 4: Wait a random amount of time and repeats the same algorithm

# CSMA/CD

