Lecture 3 Wireless LAN (07/03)

1. Introduction	
2. Wireless LAN Protocols	a. MACA; b. MACAW
3. Wireless communication protocol stack	
4. MAC 802.11 Sublayer Protocol	
5. CSMA/CA	
6. The 802.11 Frame Structure	
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9. TCP/UDP over 802.11b Wireless Networks	
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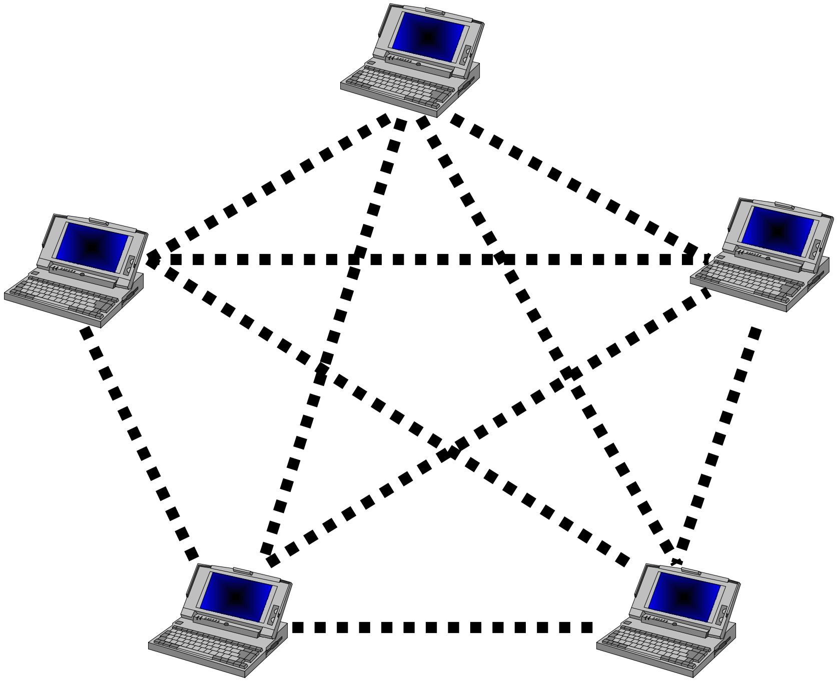
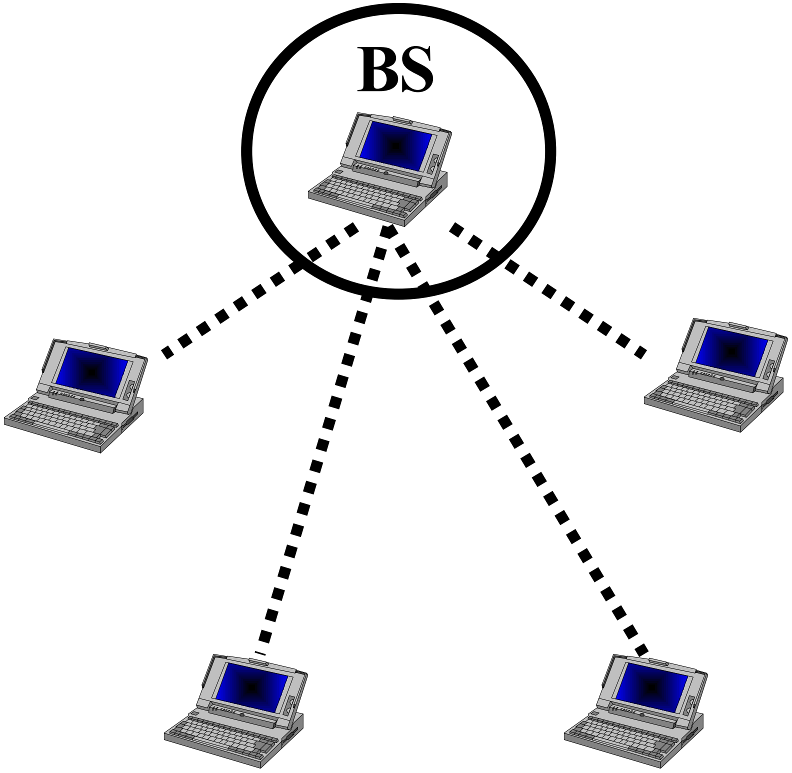
(Recommended: T. 68-71,134-137, 267-270, 292-310 208-211, 462-464, 553-555

802.11 Wireless LAN Configurations

1. Ad-Hoc Networking



2. Peer-to-peer Networking



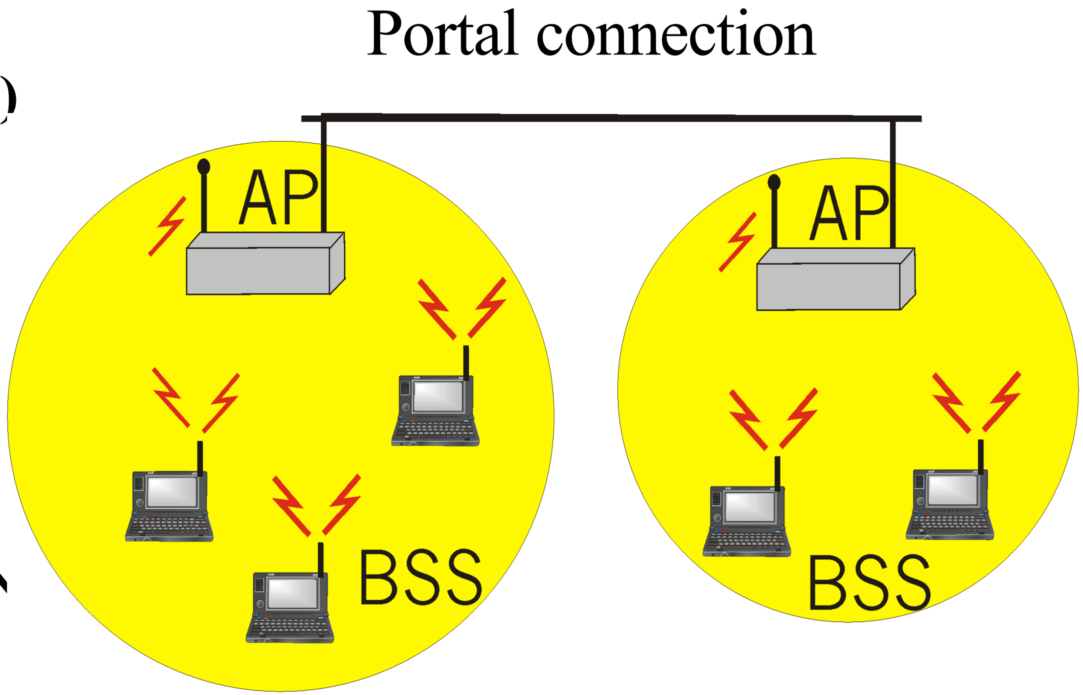
Standardized 802.11 (Wi-Fi="Wireless Fidelity”) (mid 1990) compatible with Ethernet above the DLL to send an IP packet over the WLAN.

IEEE 802.11 Wireless LAN

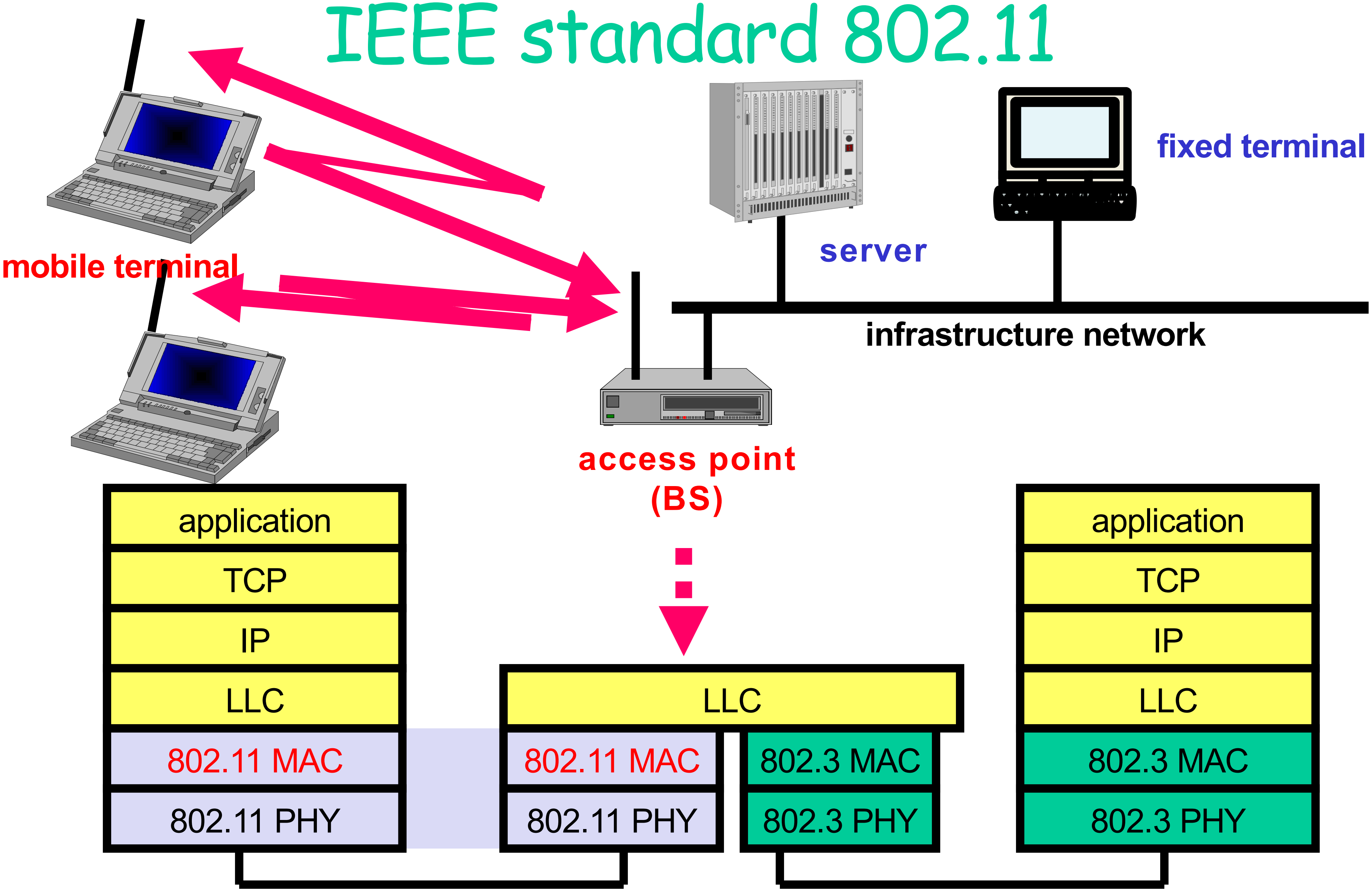
- Applications:

  Internet access, portable connection, Ad Hoc networking **(multi-hopping)**
- Unlicensed frequency spectrum bands: 900Mhz,

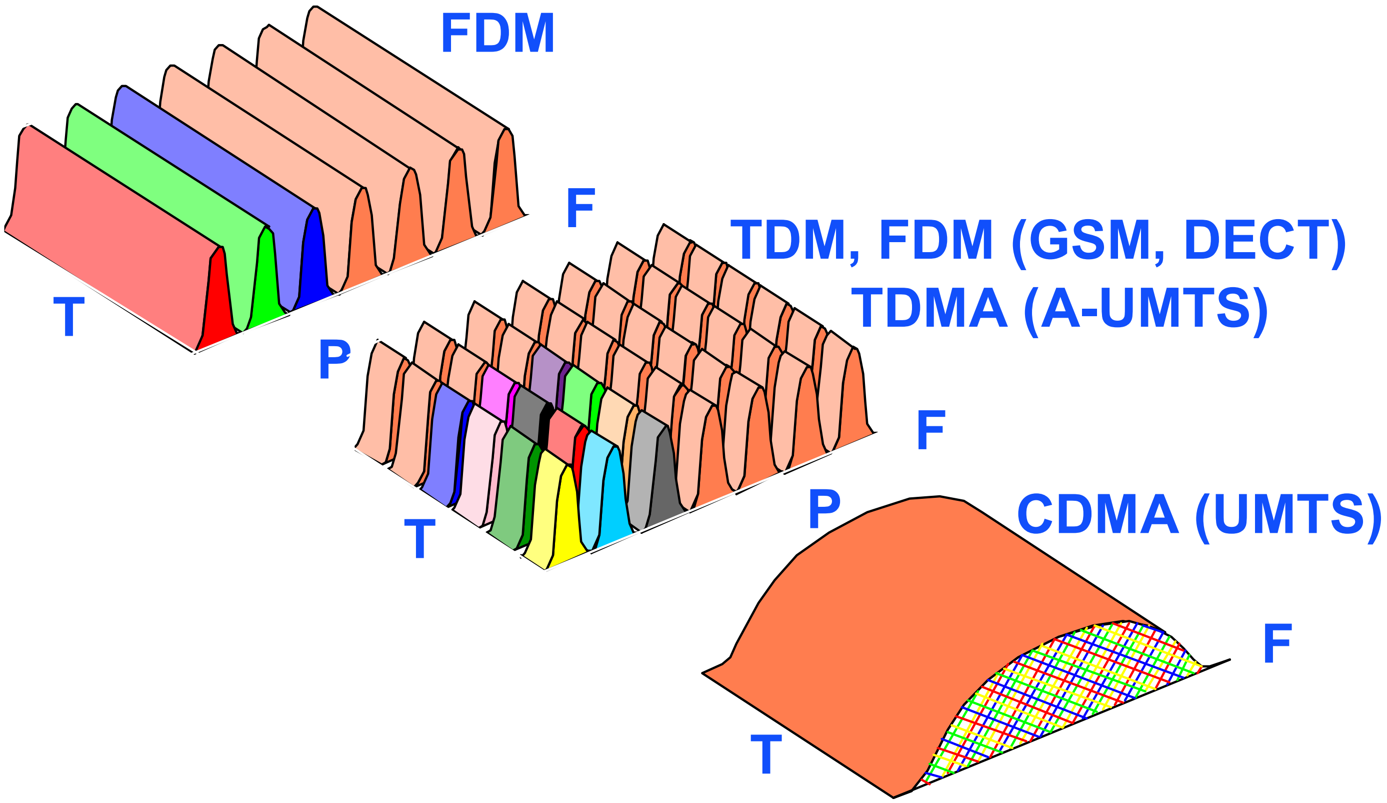
  2.4 GHz -5.7 GHz
- **AP** Like a bridged LAN



IEEE standard 802.11



Each LAN cell has only one channel, Unlike cellular systems, **covering the entire available bandwidth and covering all the stations in this cell. Typically, its Bit Rate is 11 to 54 Mbps.**



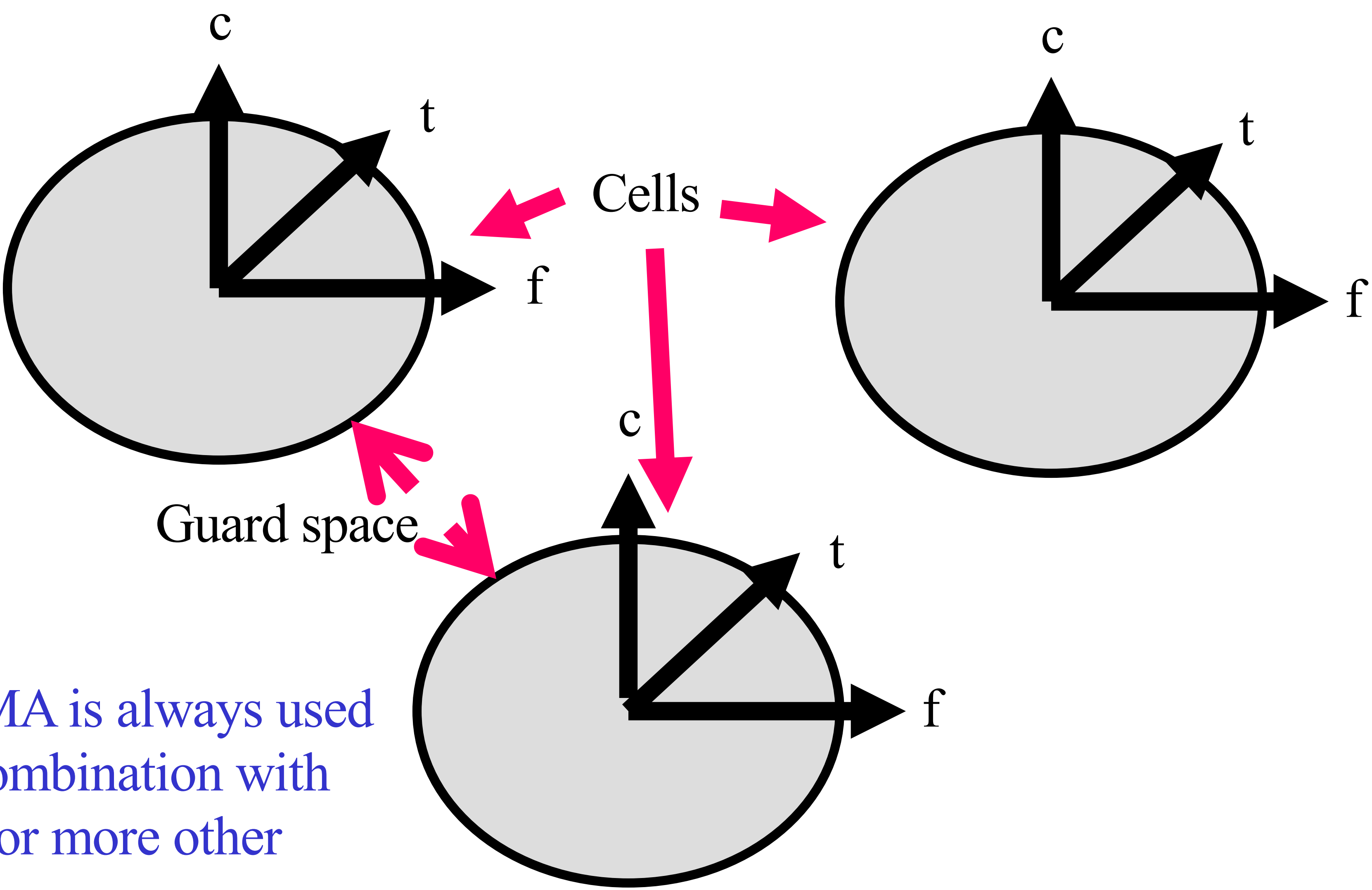
FDM

TDM, FDM (GSM, DECT)

TDMA (A-UMTS)

CDMA (UMTS)

SDMA

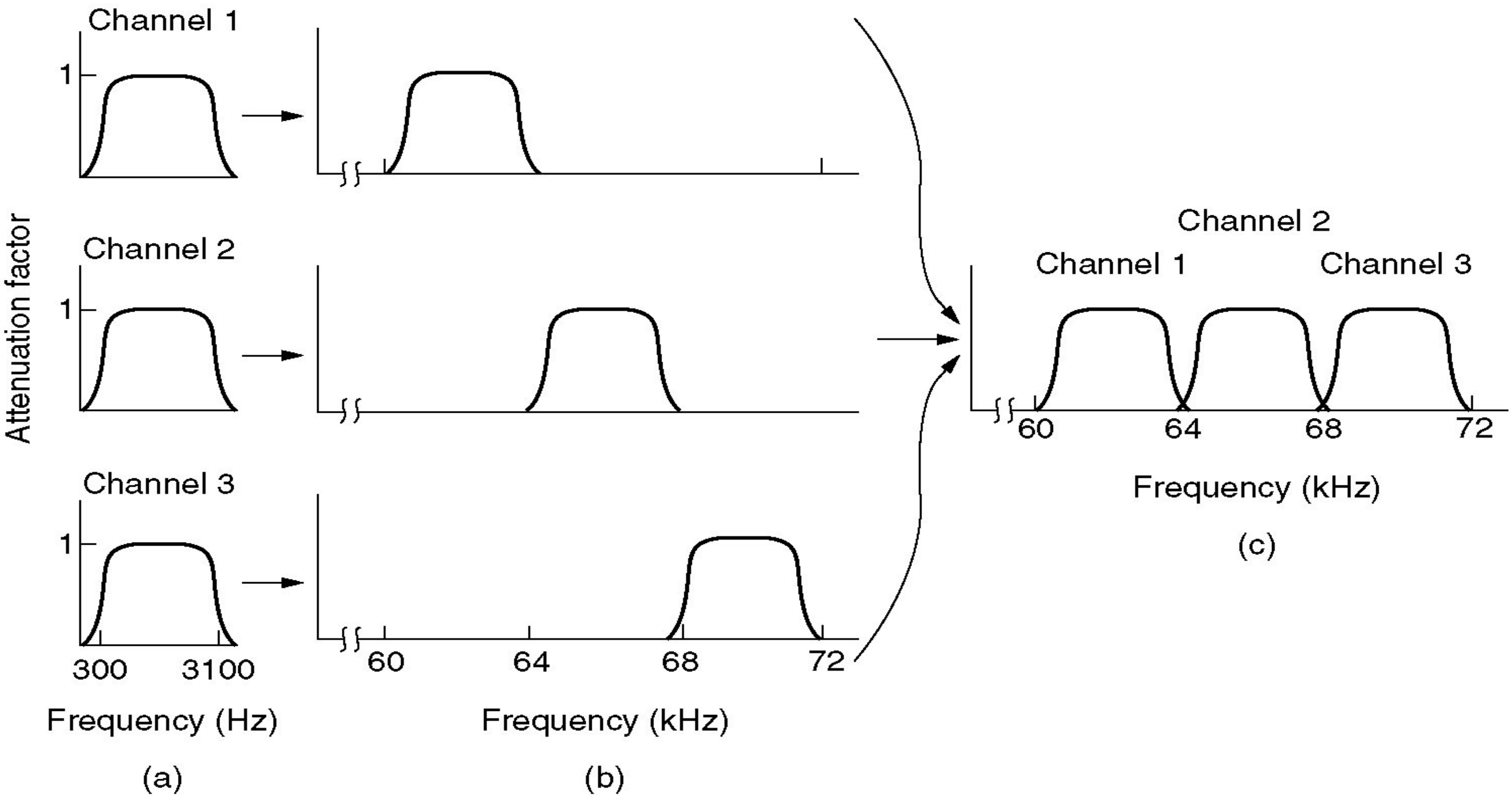


Cells

Guard space

SDMA is always used in combination with one or more other schemes.

FDMA



(a) The original bandwidths.

(b) The bandwidths raised in frequency.

(b) The multiplexed channel.

Random Access protocols (Review)

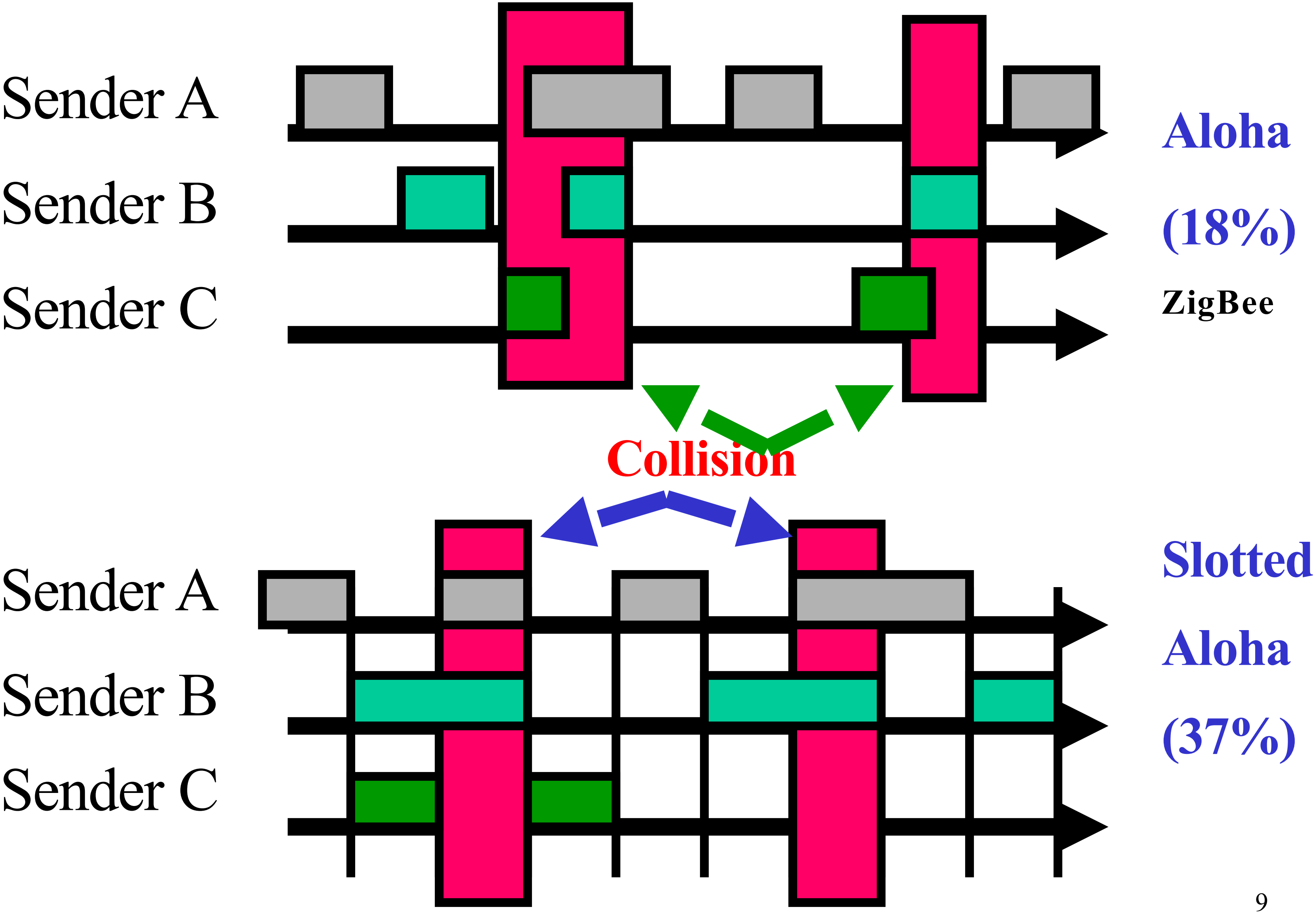
- Ethernet
- A node transmits **at random** (no priority among nodes).
- If "**collide**", they retransmit at random times
- The **random access MAC** protocol specifies how to detect **collisions** and how to recover from them (via delayed retransmissions, "binary back off")
- Random access MAC protocols:

(a) ALOHA

(b) SLOTTED ALOHA

(c) CSMA/CA and CSMA/CD

Aloha Multiple Access



CSMA (Carrier Sense Multiple Access)

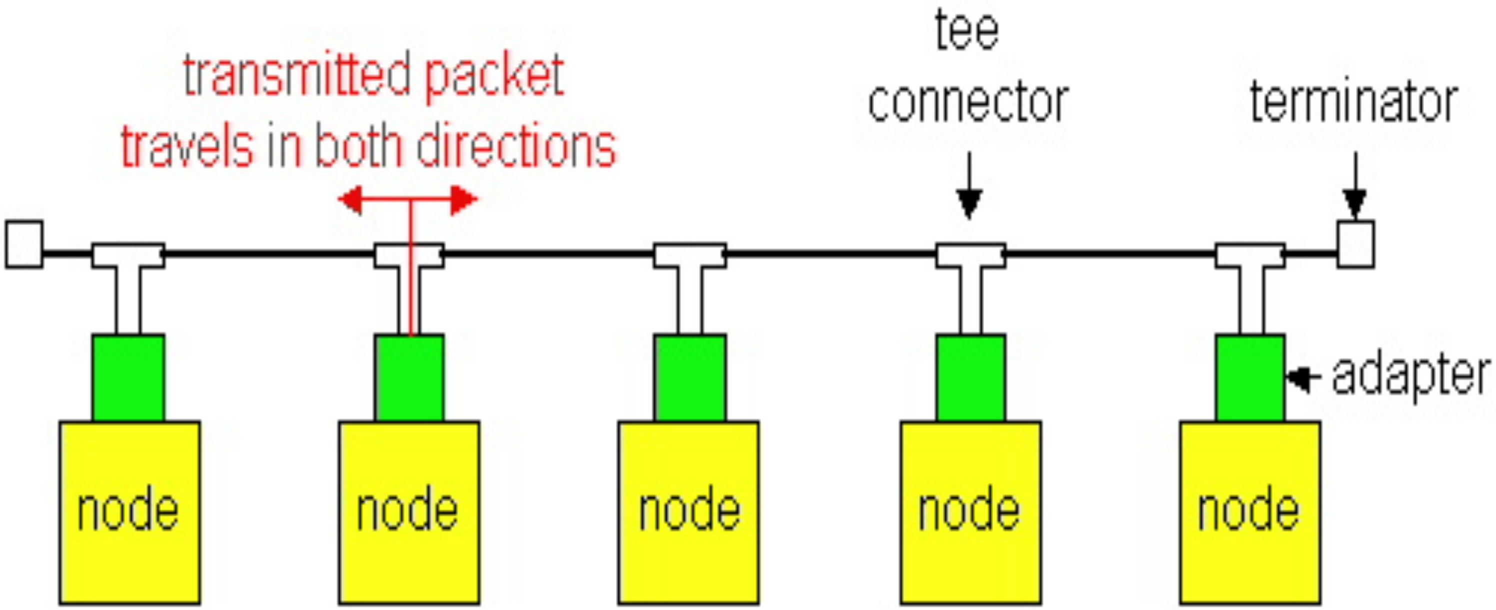
- **CSMA**: **listen** before transmit. If channel is sensed **busy**, **listens again. (Leonard Kleinrock, 1975).**
- **Persistent CSMA**: retry immediately when **collide** (this may cause instability. Note: collisions may still exist, since two stations may sense the channel idle at the same time)
- **Non persistent CSMA:** retry after random interval

- **CDMA with Collision Avoidance (CA)** access schemes used in wireless LANs. Here sensing the carrier combined with a **back-off** scheme. (MACA)

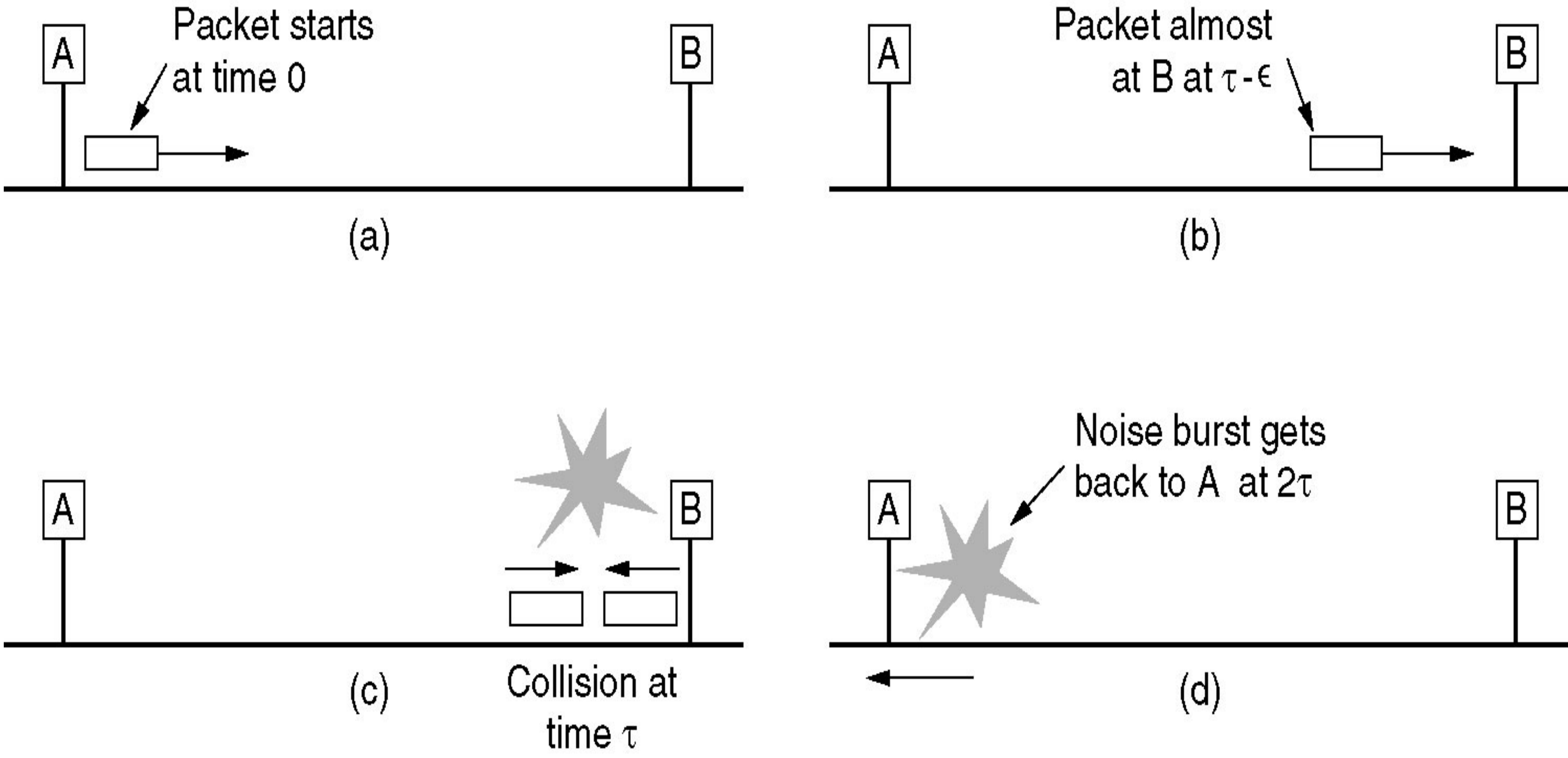
Ethernet Technologies: 10Base2 (IEEE 802.3)

- 10Mbps, under 200 meters max cable length
- Thin coaxial cable in a bus topology
- **Ethernet** operates with **CSMA/CD** protocol.

S/N =1000



Limitations



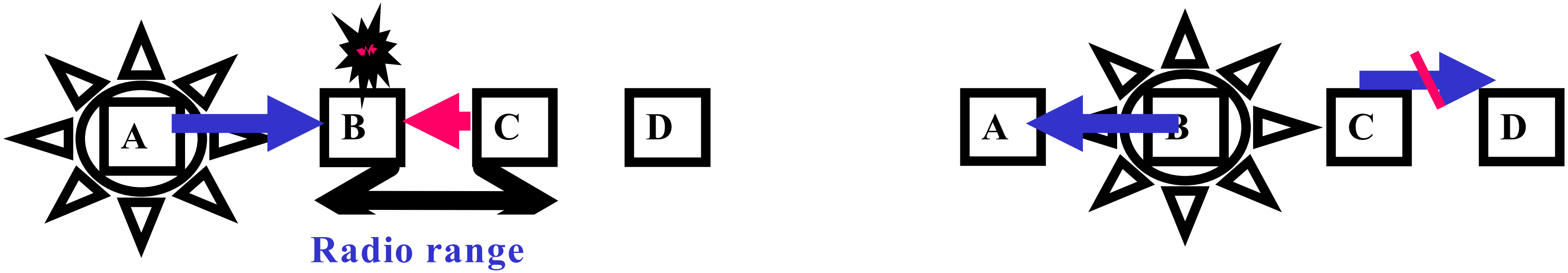
Differences with Ethernet

- **Ethernet** operates with **CSMA/CD** protocol.
- With **wireless LANs** that idea does not work well.

1. Problems with **multipath fading** of a radio signal
2. **Mobility** of wireless communication stations.
3. Base station-to-base station **movement**.
4. **Exposed** and **hidden** stations problems

- From the outside, the entire system should look like a single Ethernet.
- **S/N <<100, can not listen during a transmission**
- **CSMA/CA**

Wireless LAN Protocols



Possible interference at B

a

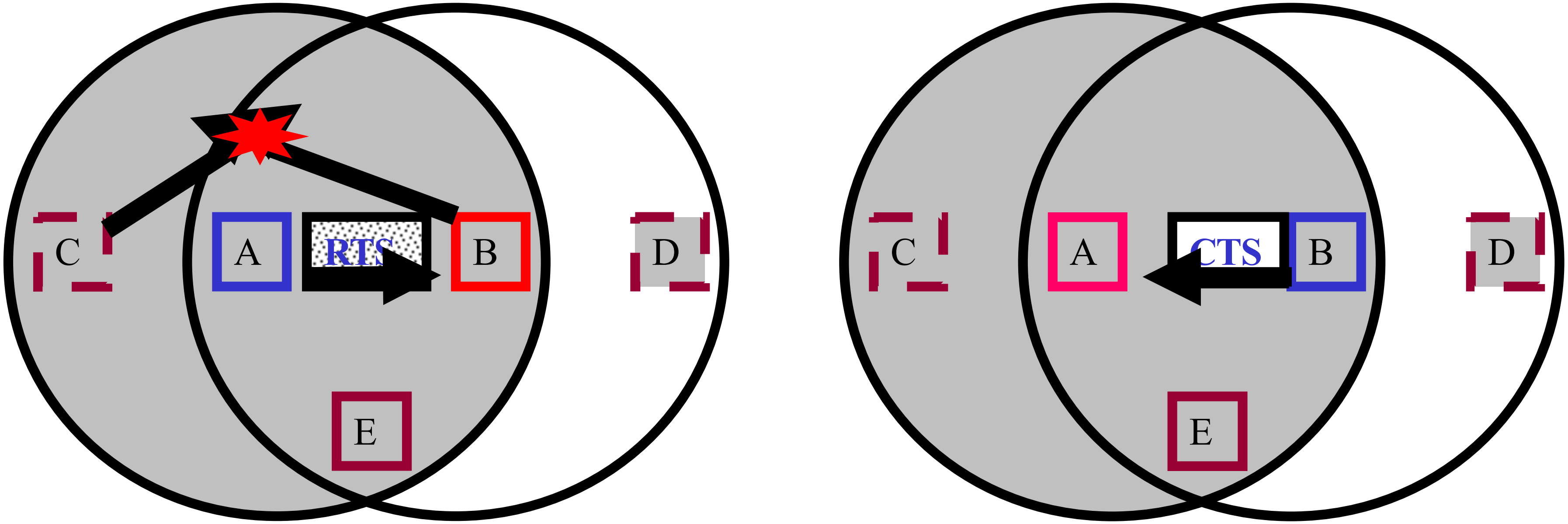
b

Hidden station problem

Exposed station problem

Two Major Problems

The MACA protocol



A sending an RTS to B; B responding with a CTS to A.

After CTS is received, A begins transmission

Anyone hearing RTS must remain silent until CTS to be transmitted back to A. Anyone hearing

CTR must remain silent during the upcoming data transmission, whose t determined from CTS. C is within of A, but not within of B. So, it hears RTS from A, but not CTS from B. Since it does not interfere with the CTS, it is free to transmit while the data frame is being sent. D is within of B but not A. It does not hear RTS but hear CTS. Hearing CTS, it waits about to receive a frame, so it holds sending anything until that is expected to be finished. E hears both control messages and must be silent until the data frame is complete.

Medium Access with CSMA/CA

When many users are located in the same area, and use the same wireless LAN at the same time, **two different access methods** are defined for signal multiplexing:

1. Distributed Coordination Function (DCF)

1a. Physical channel sensing

1b. Virtual channel sensing

2. Point Coordination Function (PCF) (BS control cell)

The basic access mechanism, called the **DCF**, Two modes:

1a. & 1b Using CSMA/CA

Medium Access with CSMA/CA (Cont)

The basic access mechanism:

- 1. DCF = CSMA/CA algorithm = 2 methods.

1a). Physical channel sensing.

1b). Virtual channel sensing

DCF- 1a. Physical channel sensing:

Like Ethernet

- **It does not sense the channel while transmitting,**

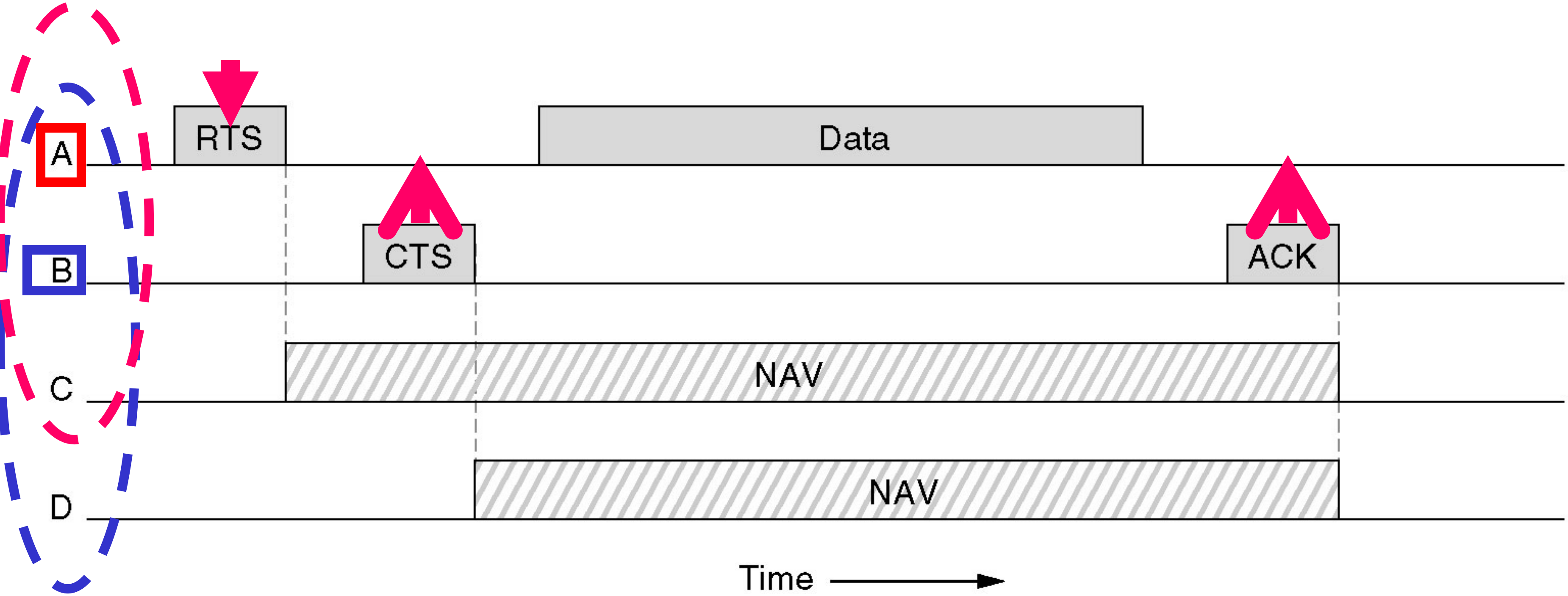
  CSMA/CD needs full-duplex channel

  802.11 all stations cannot hear each other

802.11 - Positive Acknowledge Scheme

The 802.11 MAC Protocol (Cont)

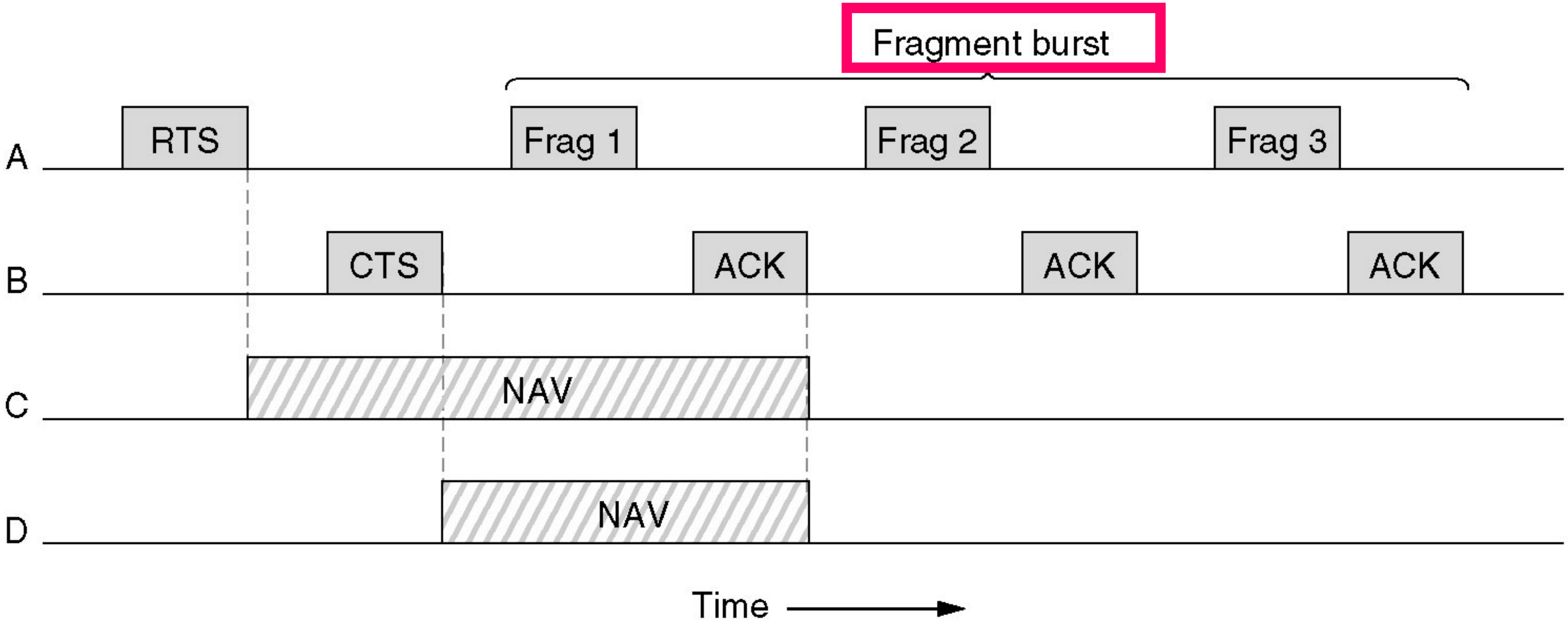
DCF- 1b. Virtual Carrier Sense (VCS)



NAV-Network Allocation Vector -keeps other stations silent

The 802.11 MAC Protocol (Cont) : fragments

1b. DCF-The use of virtual channel sensing using CSMA/CA.

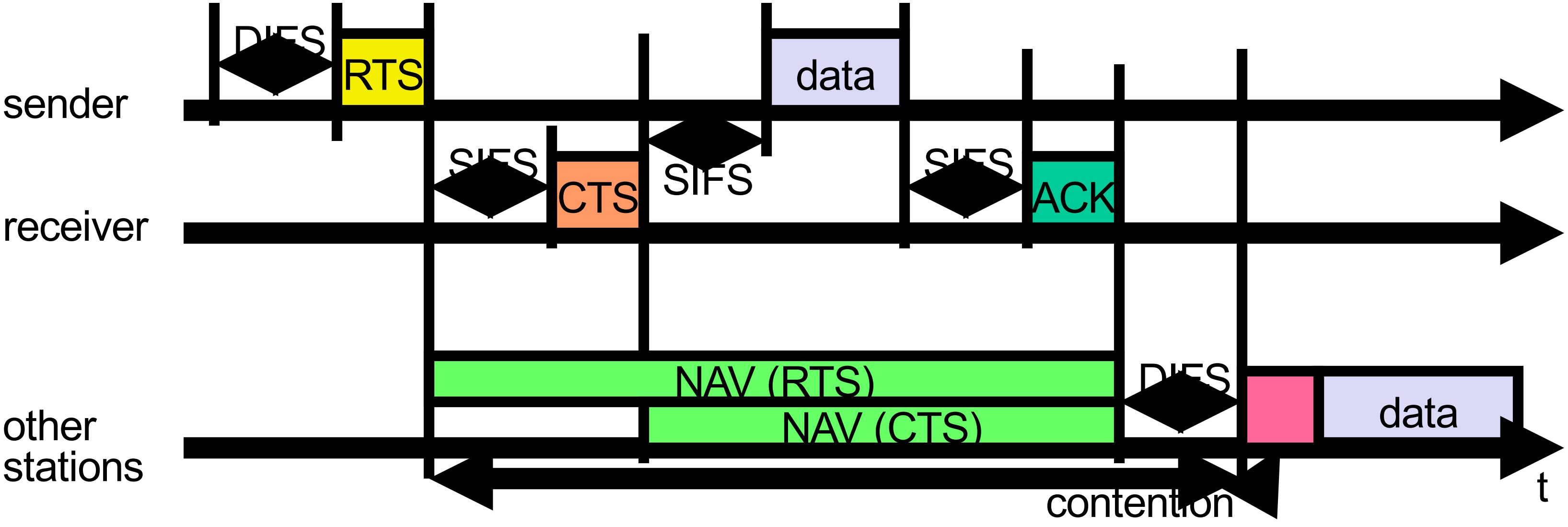


stop-and-wait protocol

802.11 - CSMA/CA (cont)

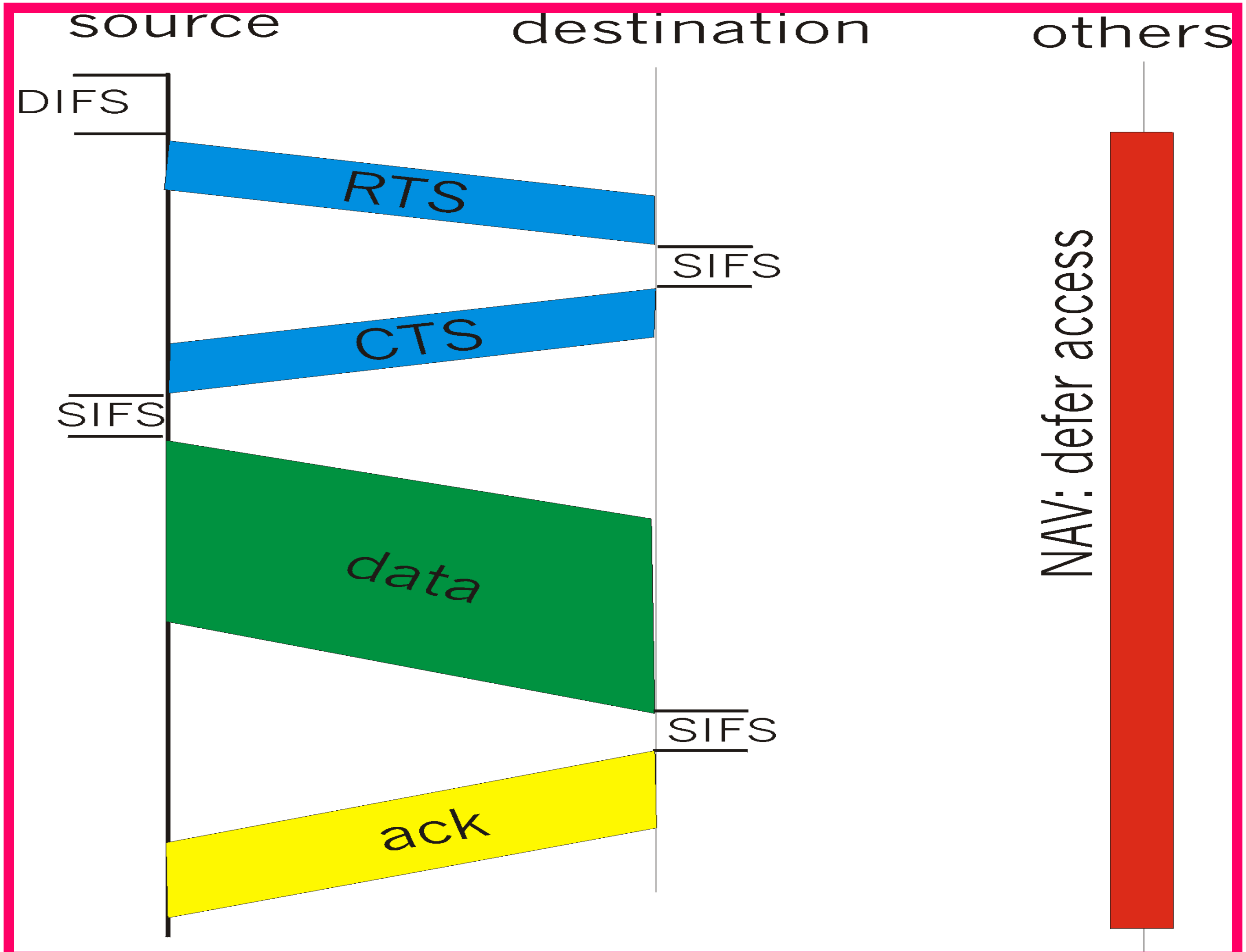
1b. Virtual Channel Sensing

- It works by carefully defined the interframe time interval
- After waiting for **DIFS**-(**DCF Inter Frame Spacing**) sends **RTS**
- after **SIFS** (Short IFS) sends **CTS** as a ACK by if ready to receive
- Sender can now send data at once, ACK via CTS
- Medium reservations for other stations announced by **RTS**/**CTS**
- **Network Allocation Vector-** for silent stations



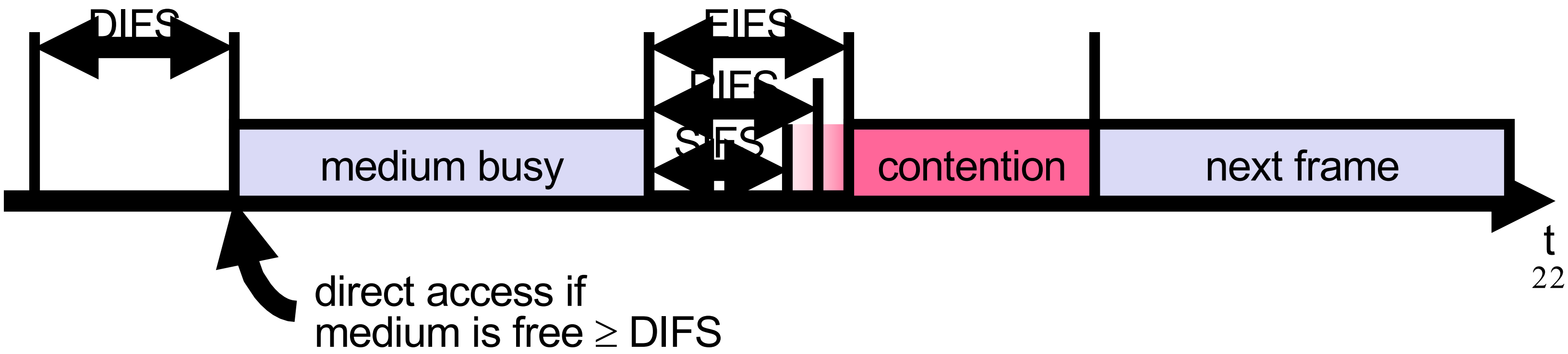
1b. CSMA/CA (cont)

- **CTS** "freezes" stations within range of receiver (but possibly hidden from transmitter); this prevents collisions by hidden (from transmitter) station during data.



1b. 802.11 - MAC layer (cont)

- Priorities
  - Defined through different inter frame spaces
  - **SIFS** (Short Inter Frame Spacing) **single dialog the chance to go first**
    - Highest priority, for ACK, CTS, polling response
  - **PIFS** (Point Coordination Function IFS) **station sending a data frame or fragment sequence to finish its frame without anyone else getting in the way**
    - Medium priority, for time-bounded service using PCF
  - **DIFS** (Distributed Coordination Function IFS) **other stations requesting the medium**
    - Lowest priority, for asynchronous data service
    - **EIFS** (Extended IFS) **to report the bad frame**



2 -Point Coordination Function

BS polls MSs, asking stations to send. **no collision**.

Base mechanism –

- BS broadcasts a **beacon frame** (10 to 100 times per second). The beacon frame contains system parameters, such as **hopping sequences** and **dwell times, clock synchronization**, etc. (for FHSS),
- It also invites new stations to sign up for **polling service**.
- 802.11 **power management** -BS can direct a MS to go into sleep state until awakened by the BS or the user. In this time the BS has the responsibility for **buffering** any frames directed at it while the MS is asleep.
- **PCF** and **DCF** can coexist within one cell.

Full process steps:

1. A station that wants to transmit will first sense the medium. If the medium is idle, waits for a specified **time-Distributed Inter Frame Space**, or **DIFS**). If no other station transmits, then the station will transmit a short **RTS** packet. (**Includes the source address, destination address, and duration of the following transmission**). The duration = the total transmission time for all further packets that will be transmitted (CTS, data, ACK, plus inter-frame spaces).

2. The **Access Point** responds with a response control packet called **CTS**, which includes the same **duration** information. Receipt of the CTS packet indicates to the transmitter that no collision occurred, and permission is granted to start the **data transmission**. If the transmitter does not receive a **CTS** packet, then it repeats part 1 until it either receives ACK or times out after a given number of re-transmissions.

3 The **CTS** frame is received by all the stations in the cell, notifying them that another unit will transmit during the following **X** microseconds. These stations record this information so they will know when the medium will again be available. Some of these stations may not have received the **RTS** packet because the original transmitting unit is out of range.

4. The transmitting station sends its **data frame** to the access point. After the data frame is transmitted, the access point checks the **CRC** of the packet end, if correct, returns an **ACK** packet to confirm successful transmission.

5. If the final destination is another station on the WLAN, the access point then **reserves** the medium with a RTS packet (step 1). It proceeds to retransmit the data frame. The destination station checks the **CRC** of the packet end, if correct, returns an **ACK** to the access point

- Because the **RTS and CTS are very short packets**, this mechanism also reduces the overhead of collisions.
- If the **data packet** is **very short**, the RTS packet may include all the **data** to be transmitted. If the **RTS** contains data, the CTS packet contains a duration of **zero**, and simply acts as an **ACK** to the transmitter that the **RTS** packet with data was received.
- Typical **WLAN protocols** use packets several hundred bytes long (up to **1518 bytes**). These packets << than Ethernet packets. It is preferable to use smaller packets in a wireless environment for several reasons:

1. Due to the higher **BER** of a radio link, the probability of a packet getting corrupted increases with the packet size.
2. In the case of packet corruption (due to collision or noise), a smaller the packet requires less overhead if it is necessary to re-transmit.

Voice support in IEEE 802.11

- DCF mode, with CSMA
- voice has priority over data (**S**hort **IFS**)
- positive ACK guarantees success (no hidden terminal)

Possible Improvement:

- instead of positive ACK, **negative ACK**
- receiver "invites" the sender with negative ACK if did not receive packet after time out

The 802.11 standard specifies transmission techniques allowed in the physical layer

1. Use short-range radio, techniques of **FHSS 79 hops, 1 MHz wide, PN seq., Dwell time 400 msec,**
2. Use short-range radio **DSSS**. 1-2 Mbps, similar to CDMA.

- Modifications: **802.11a--54 Mbps;**
  802.11b--11 Mbps;
  802.11g--54 Mbps ??
- Both of **FHSS** and **DSSS** use a part of the unlicensed spectrum **(2.4 GHz) ISM (Industrial, Scientific, and Medical) application** band.

The 802.11 Protocol Stack

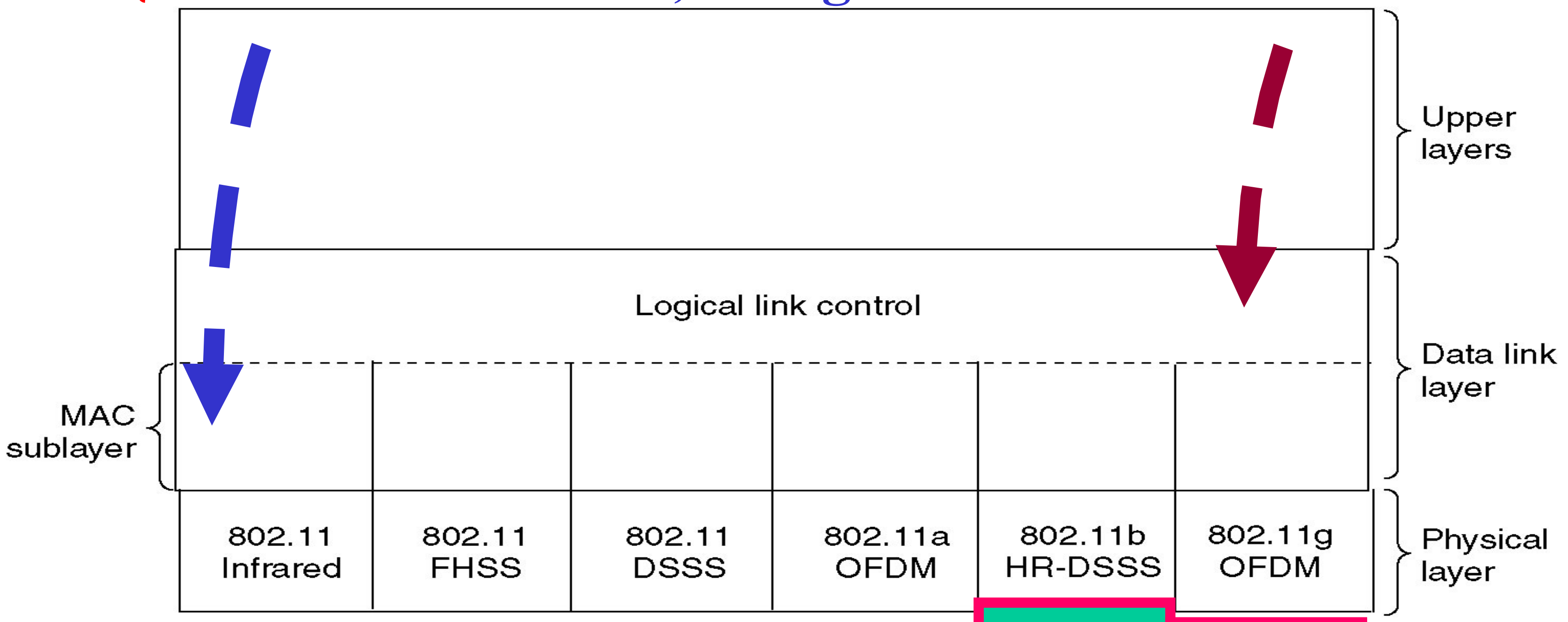
DLL

LLC

MAC

LLC sublayer, hides the differences between the different 802 variants and make them indistinguishable for the network .

The MAC sublayer determines how the channel is allocated, who gets to transmit next.



operate at 1 to 2 Mbps,

Orthogona
54Mb

High rate
11Mb

High rate
54Mb

802.11 Modifications

11	**1 Mbps or 2 Mbps,** so was too slow.
11a	**FHSS; 5-GHz band**; **54 Mbps**; **OFDM (48 data+4 Sync) ch. 18-54 Mbps, =With Europ. HiperLAN/2**
11b	DSSS; Uses the **same frequency band as 802.11**, but uses **different modulation technique** achieve **11 Mbps**.
11g	Uses the **OFDM modulation= of 802.11a** but the **frequency band =of 802.11b**. (Theory-54 Mbps)??

802.11 Frame Structure: Frames Classes

1. Data frame.

Preamble	PLCP Header	MAC Data Frame	Header CRC

2. Control frame= RTS, CTS, ACK

2 bytes	2 bytes	6 bytes	6 bytes	4 bytes
Frame Control	Duration	Receiver Address	Transmitter Address	CRC

← MAC Header →

RTS

CTS

2 bytes	2 bytes	6 bytes	4 bytes
Frame Control	Duration	Receiver Address	CRC

← MAC Header →

ACK

3. Management

Exchange management information and are transmitted in the same manner as data frames, but are not forwarded to upper layer.

These frames are used for synchronization, authentication, and power management.

comparison of the four basic multiple access versions

Apprch	SDMA	TDMA	FDMA	CDMA
Idea	Segment space in cells/sectors	Segment sending time in disjoint slots,	Segments the frequency band	Spread the spectrum using orthogonal codes
Terminals	one terminal can be active in one cell	terminals are active for short time on the same frequency	Every terminal has its own frequency, uninterrupted	All terminals can be active at the same place at the same moment,
Signal separation	Cell structure directed anten	Synchronization in the time domain	Filtering in the frequency domain	Code plus special receivers
Advantages		Established, fully digital, flexible	Simple, established, robust	Simple, less planning needed, soft handover
Disadvantages	Inflexible, antennas typically fixed	Guard space needed (multi-path propagation difficult	Inflexible, frequencies are a scarce resource	Complex receivers, needs more complicated power control for sender
Comment	Only in combination with TDMA, FDMA or CDMA useful	Standard in fixed networks, together with FDMA/SDMA used in many mobile networks	Typically combined with TDMA (frequency hopping patterns) and SDMA frequency reuse	Used in many 3G systems, higher complexity, lower expectations; integrated with TDMA/FDMA

CSMA/CA Protocol: Congestion control

Networks with wireless and other **lossy links** suffer from significant losses from **congestion**, due to **interference, fading**, **multipath effects**, and other wireless medium characteristics.

TCP responds to **all such** losses, by **invoking congestion control and congestion avoidance algorithms**,

TCP seeks to meet the following **four primary goals**:

1. Reliable transport,
2. High network utilization,
3. Avoidance of network congestion, and
4. Sharing of bandwidth

Congestion control (Cont)

- TCP uses a sliding window mechanism-**congestion window** with **cumulative ACKs** to implement the above four goals:

1. In an ideal scenario without any other competing TCP flows, the TCP sender sets **congestion window** that should **equal** to the total **number of packets** that can be pipelined between the sender and receiver.

2. **The rate of the TCP sender is simply the size of this window over the total RTT**: **Source rate = window size / RTT**

2a. Thus, can be used to approximate the size of the ideal congestion window: **Window size = bandwidth x RTT**

2b. In reality a given TCP flow can never know the actual bandwidth of the network, the TCP source must somehow share the network with other competing flows. As a result, TCP employs a set of congestion control algorithms to attempt to **set the window size over time**

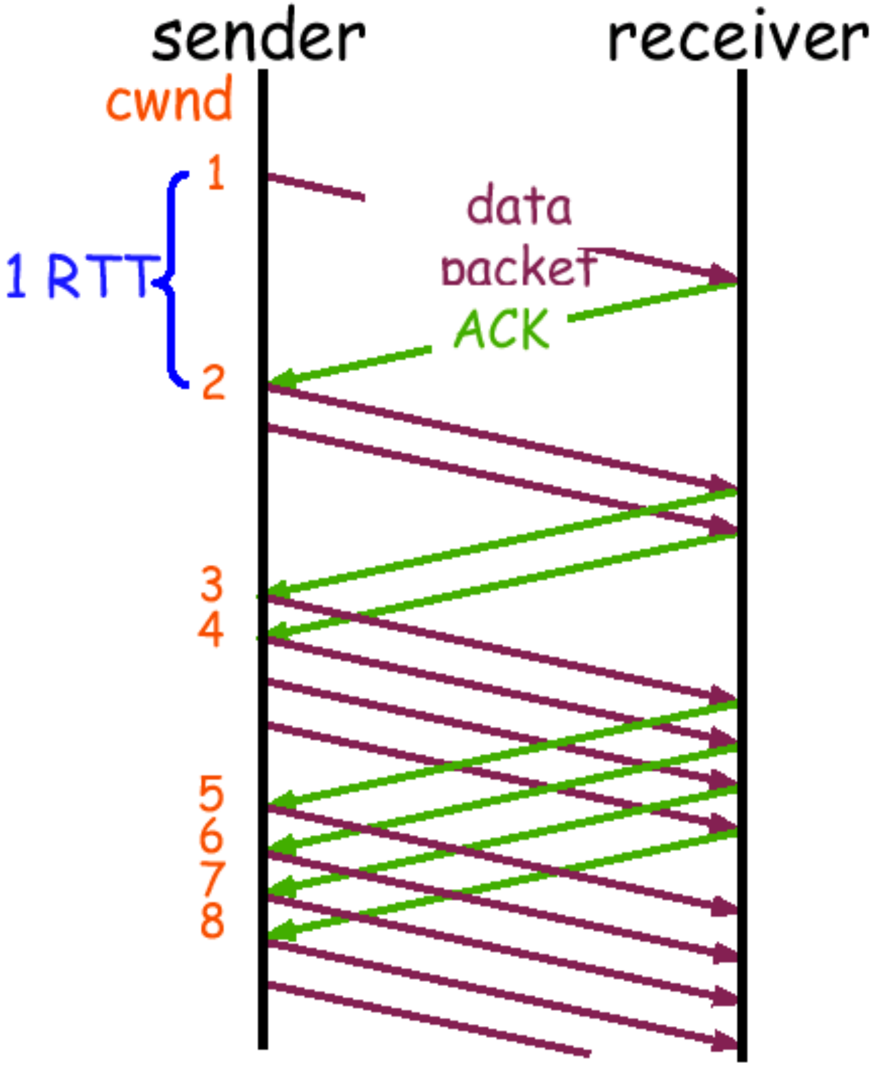
Congestion control (Cont)

3. Traditional **TCP** **congestion control** (TCP Reno) has four key phases:

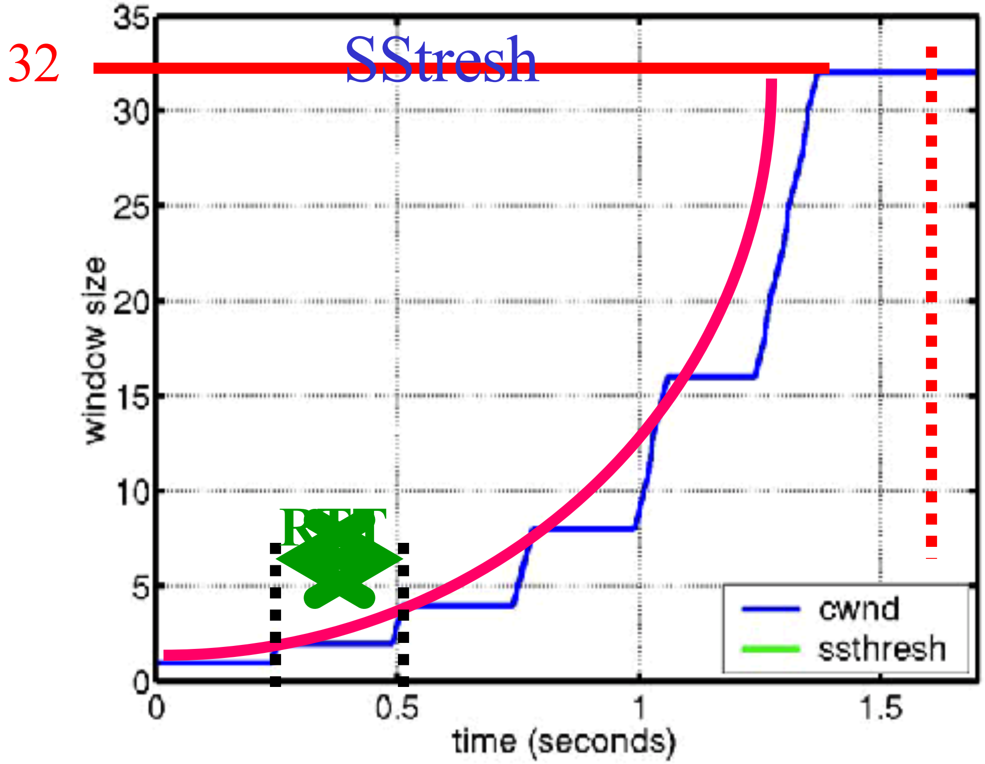
- **Slow Start (SS),**
- **Congestion Avoidance (CA),**
- **Fast Retransmit (FT),** and
- **Fast Recovery (FR).**
- In addition to have a **varying** **Contention Window (CWIN),** TCP also employs a value called the **"Slow Start Threshold" (SSTresh)** to decide between SS and **CA** phases.

4. A TCP sender initially begins in the SS phase, which begins with **CWIN** set to 1. On each successful ACK, we increment our CWIN by 1. Thus, this results in the **exponential growth** of the CWIN because in each RTT, **CWIN = 2 * CWIN**. When the CWIN finally exceeds SSTresh, TCP enters the **CA** phase

Congestion control (Cont)

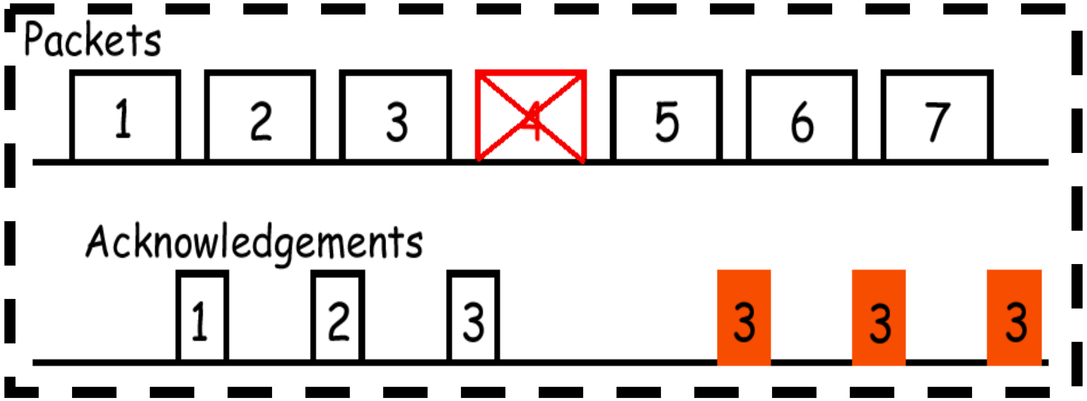


In each RTT, CWIN = 2 x CWIN.



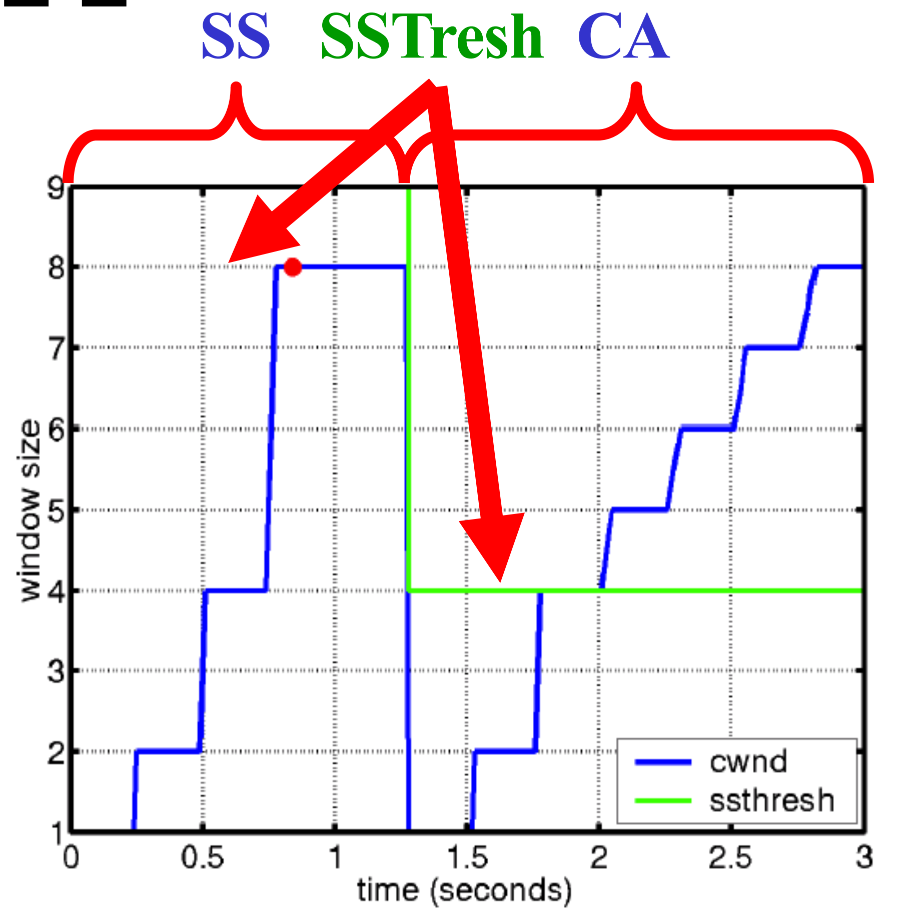
cwnd ← cwnd + 1 (for each ACK)

Congestion control (Cont)



packet loss: (a) timeout,

(b) duplicate ACK

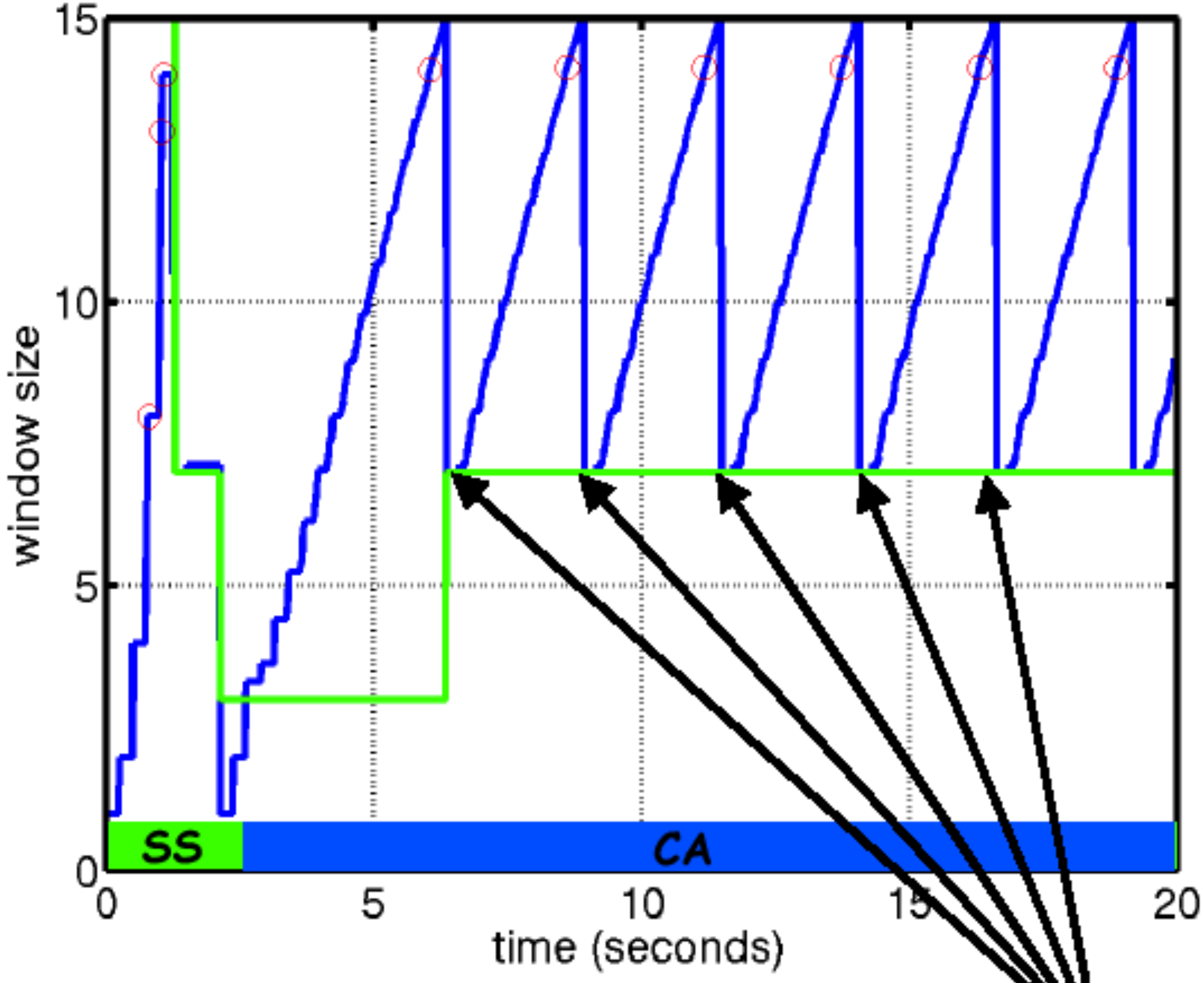


ssthresh ← cwnd/2

cwnd = 1

TCP assumes that the packet loss is due to network congestion, TCP sets the SSTresh to half the current CWIN, and the CWIN back to 1 and re-enters the SS phase

Congestion control (Cont)



Fast retransmission/fast recovery

The Internet has two main protocols in the transport layer:

- **Connectionless protocol (User Datagram Protocol- UDP).**
- **Connection-oriented (Transport Control Protocol- TCP).**

a. User Datagram Protocol. Because UDP is basically just IP with a short header added.

Applications of UDP. The IP supports is connectionless transport protocol, UDP sends datagram without having to establish a connection.

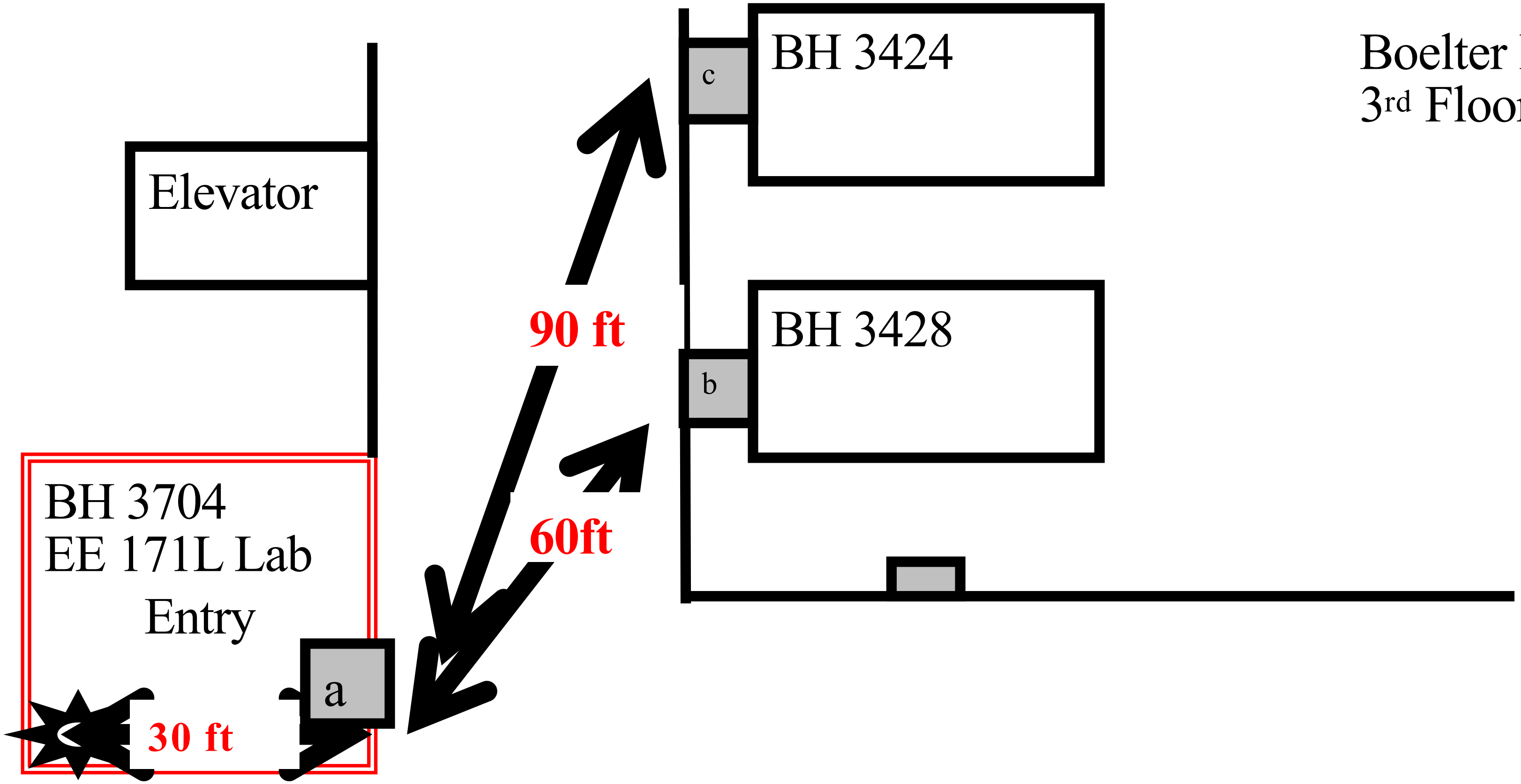
b. Transport Control Protocol provides a reliable end-to-end byte stream over an unreliable internetwork.

TCP provides multiplexing, demultiplexing, and error detection in exactly the same manner as UDP. Nevertheless, TCP and UDP differ in many ways. The most fundamental difference is that:

UDP is connectionless, while

TCP is connection-oriented.

Boelter Hall
3rd Floor



Elevator

BH 3424

BH 3428

BH 3704
EE 171L Lab
Entry

a

b

c

90 ft

60ft

30 ft

THANK YOU!

APPENDIX
The 802.11 Services

- Each wireless LAN must provide **nine services** divided **into two** categories:

1. **Five distribution services** (provided by **BS**) **and**
2. **Four station services** (provided by **MS**).

- **Distribution services** relate to managing **cell membership** and **interacting with stations outside the cell.**
- **Station services** relate to **activity within a single cell**.

802.11 Services

Distribution Services (BS) deal with station mobility as they enter and leave cells, **attaching themselves to BS** and **detaching themselves from BS**. They are as follows:

- **Association**
- **Disassociation**
- **Re-association**
- **Distribution**
- **Integration**

Distribution services (BS Services (Cont))

1. **Association**. Used by **MS** to **connect** themselves to **BS**. It is used just after a **MS** moves within the **radio range** of the **BS**. Upon arrival, it announces its **identity** and **capabilities**. The capability include the **data rates supported**, need for **PCF** services and **power management** requirements. The **BS** may accept or reject the **MS**. If the **MS** is accepted, it must then **authenticate** itself.
2. **Disassociation.** The **MS** or the **BS** may disassociate, thus, **breaking the relationship**. A **MS** should use this service before shutting down or leaving, but the **BS** may also use it before going down for maintenance.
3. **Re-association**. A **MS** may **change** its **preferred** **BS** using this service. This facility is useful for **MS moving** from one cell to another.
4. **Distribution.** Determines how to **route frames** sent to the **BS**. If the destination is local to the **BS**, the frame can be sent out directly over the air. Otherwise, they will have to be forwarded over the wired network.
5. **Integration.** Handles the translations from the 802.11 format to the format required by the destination network.

802.11 Station Services

Intra-cell Services, **by MS**

- Authentication
- De-authentication
- Privacy
- Data Delivery

Intra-cell Services (Cont) (MS services)

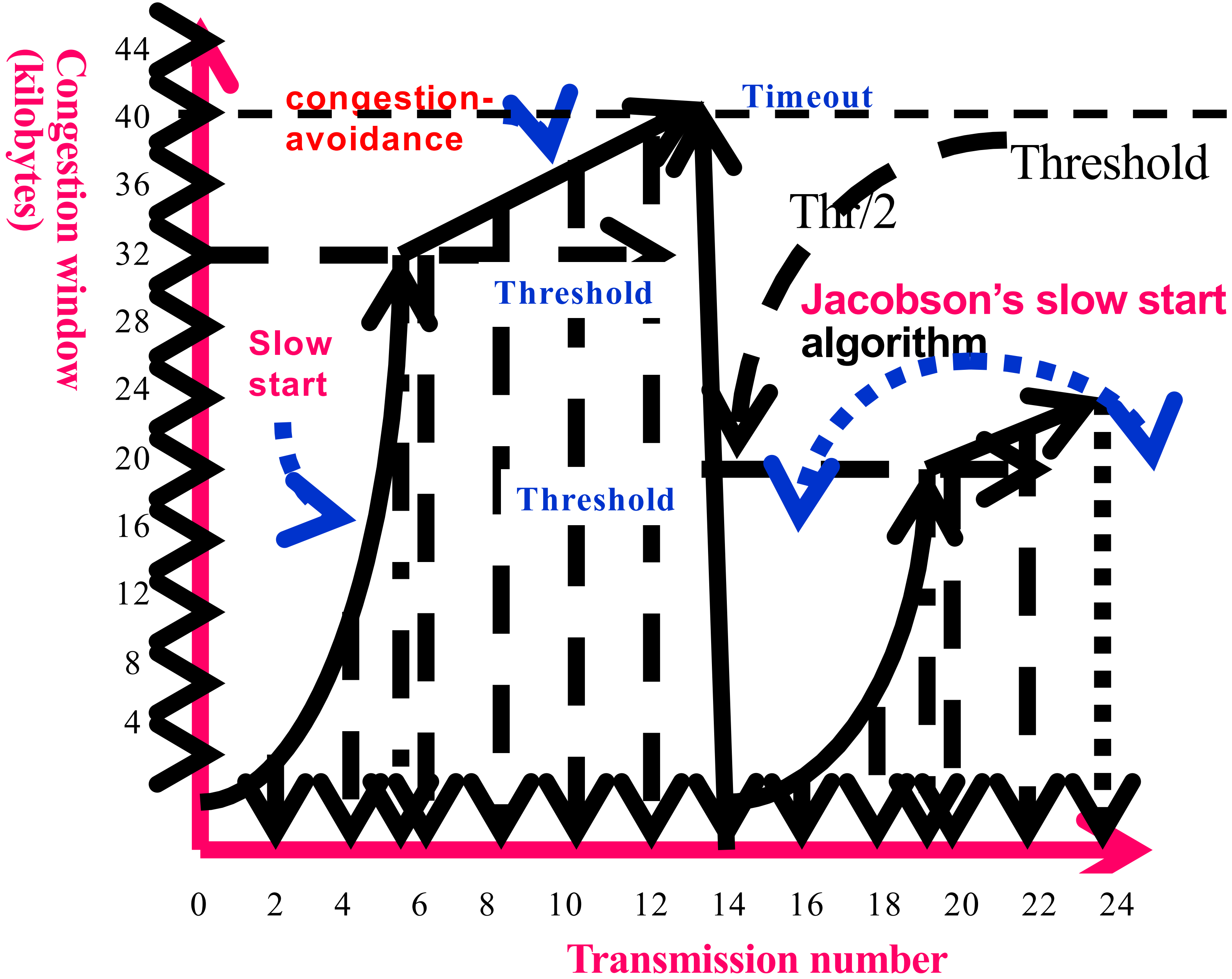
1. **Authentication**. Because wireless connection can easily used by unauthorized stations, a **MS** must **authenticate** itself before it is permitted to send or receive data. **MS** must know the secret **password.**

2. **De-authentication.** When a previously authenticated station wants to leave the network, it is **de-authenticated.**

3. **Privacy**. For information sent over a wireless LAN to be kept **confidential,** it must be **encrypted.** This service manages the **encryption** and **description**.

4. **Data delivery**. 802.11 naturally provides a way to **transmit** and **receive data**. Since 802.11 is modeled on Ethernet and transmission over Ethernet is not guaranteed to be 100% reliable, transmission over 802.11 is not guaranteed to be reliable either. An **802.11 cell has some parameters that can be inspected** and, in some cases, **adjusted**. They relate to **encryption, timeout intervals, data rates, beacon frequency, and so on.**

TCP Slow Start for reliable comm.



Congestion Control

- Since the number of nodes attempting to transmit simultaneously may change with time, some mechanism to manage congestion is needed

- IEEE 802.11 DCF: Congestion control achieved by dynamically adjusting the contention window *cw*

Binary Exponential Backoff in DCF

- When a node fails to receive CTS in response to its RTS, it increases the **contention window**, it is **doubled** (up to an upper bound – typically **5 times**)
- When a node successfully completes a data transfer, it restores ***cw*** to **CWmin**
- ***Contention:***

1. A condition that arises when two or more data stations attempt to transmit at the same time over a shared channel.

2. Competition by users of a system for use of the same facility at the same time.

IEEE 802.1 DCF Congestion Avoidance

- Before transmitting a packet, randomly choose a **backoff interval** in the range [0, cont.wind].
- **Count down** the backoff interval if medium is idle: Count-down is stopped if medium becomes busy.
- When backoff interval reaches 0, transmit packet.
- Choosing a ***large cw*** (contention window) leads to large backoff intervals and can result in larger overhead
- Choosing a ***small cw*** leads to a larger number of collisions (more likely that two nodes count down to 0 simultaneously)