Medium Access Control

EE450: Introduction to Computer Networks

Professor A. Zahid

之前讲的都是point to point link所以用不到

Medium Access Control

- Single shared broadcast channel
- Two or more simultaneous transmissions by nodes: interference
  - collision if node receives two or more signals at the same time

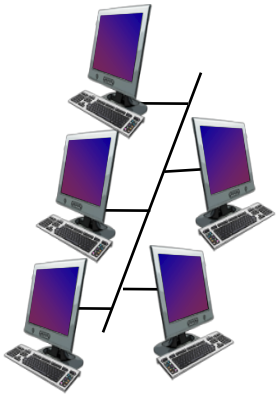
Multiple Access Protocol

need to implement in every node,implement in layer 2

- Distributed algorithm that determines how nodes share channel, i.e., determine when node can transmit
- Communication about channel sharing must use channel itself!

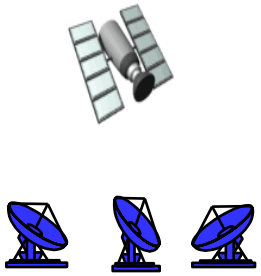
多于两个设备同时send data会有traffic

Multiple Access Links



shared wire (e.g., cabled Ethernet)

shared RF (e.g., 802.11 Wi-Fi)

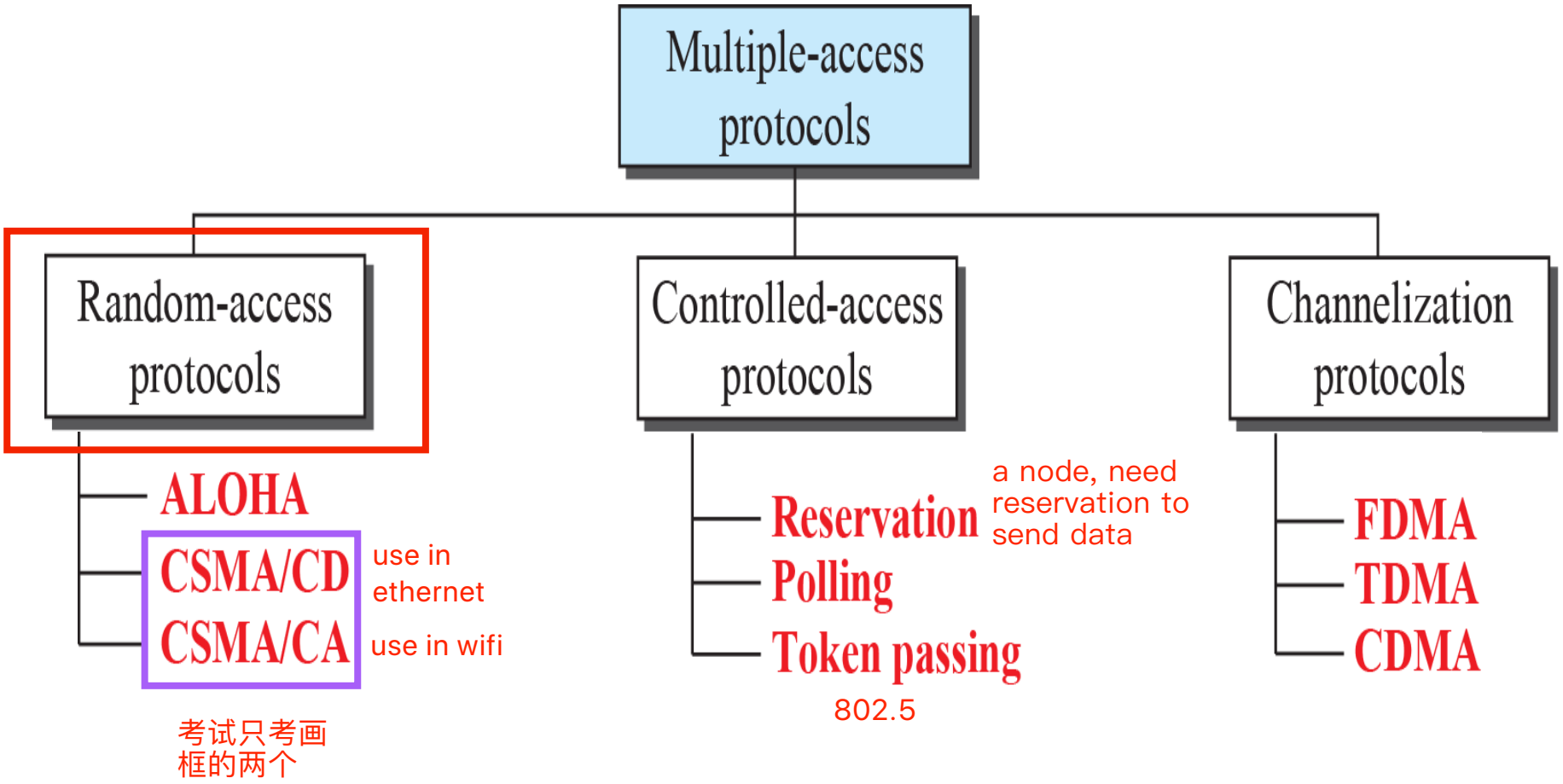


shared RF (satellite)

humans at a cocktail party (shared air, acoustical)

- Old-fashioned Ethernet
- Upstream HFC (In Cable Access Networks)
- Wi-Fi: 802.11 wireless LAN

Taxonomy of MAC Protocols



Classifications of MAC Protocols

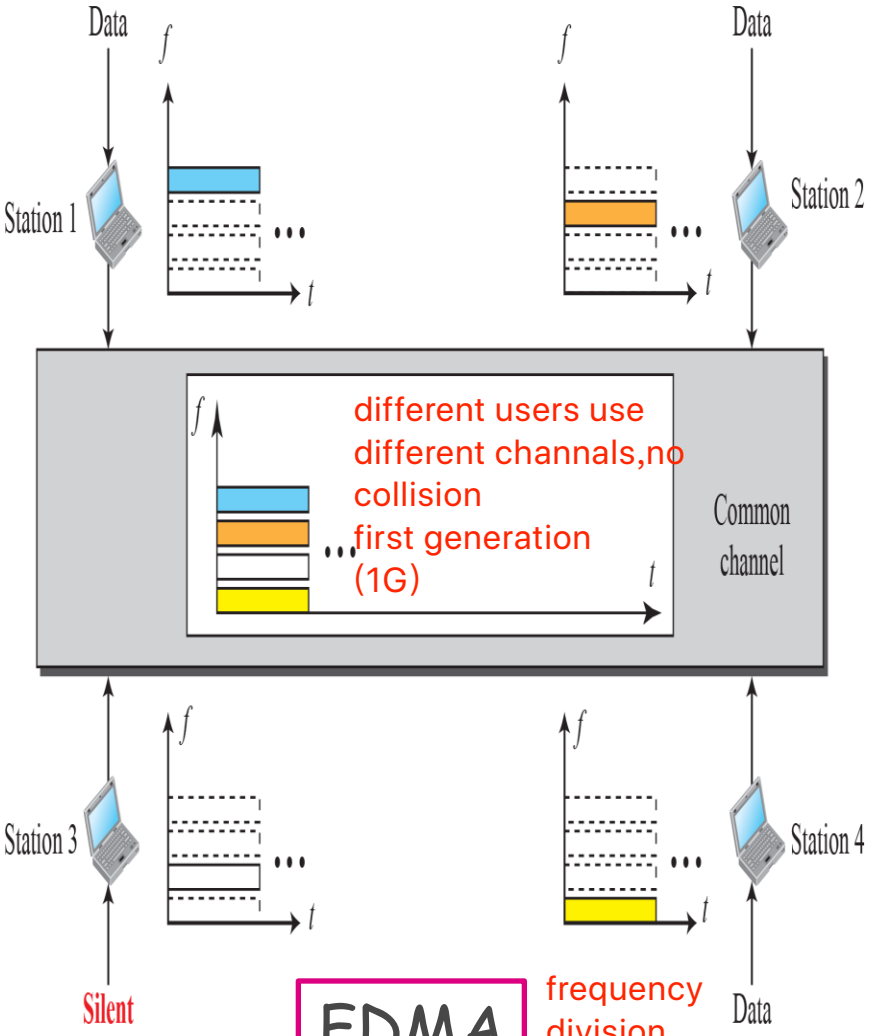
Three broad classes:

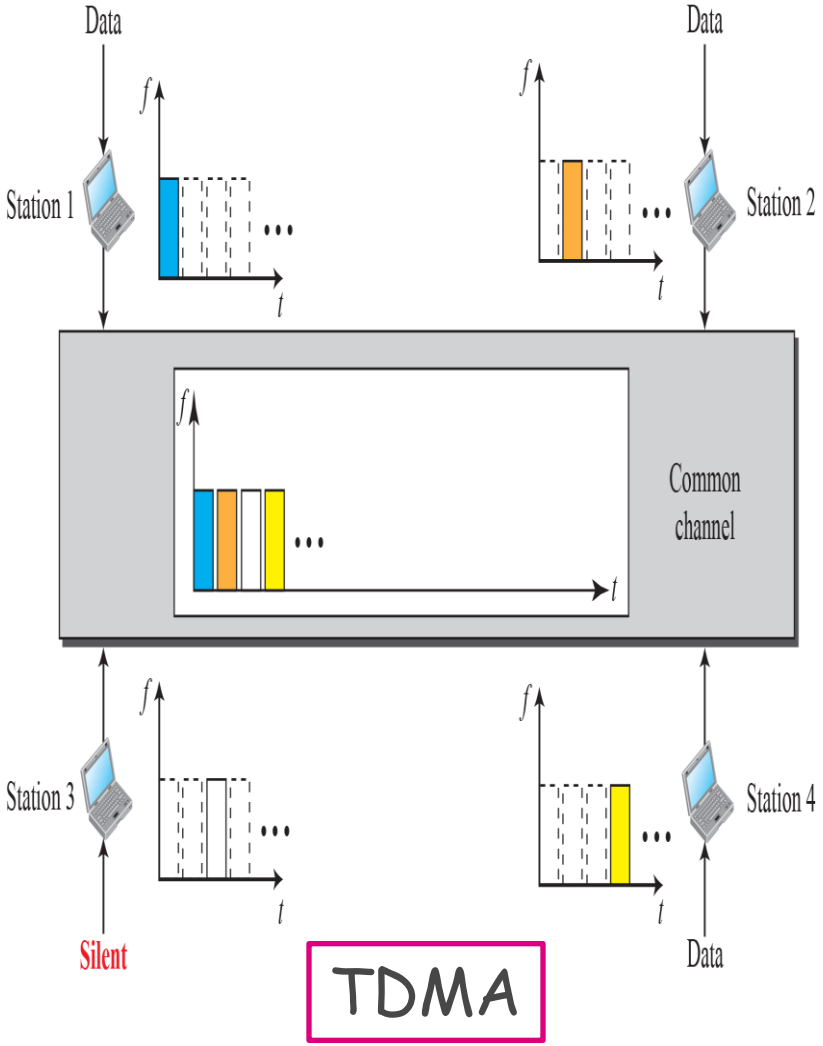
- Channel Partitioning
  - Divide channel into smaller "pieces" (time slots, frequency, code) for example TDMA, FDMA or CDMA
  - Allocate a piece to each node for exclusive use

code division
mutlplex access
2G/3G

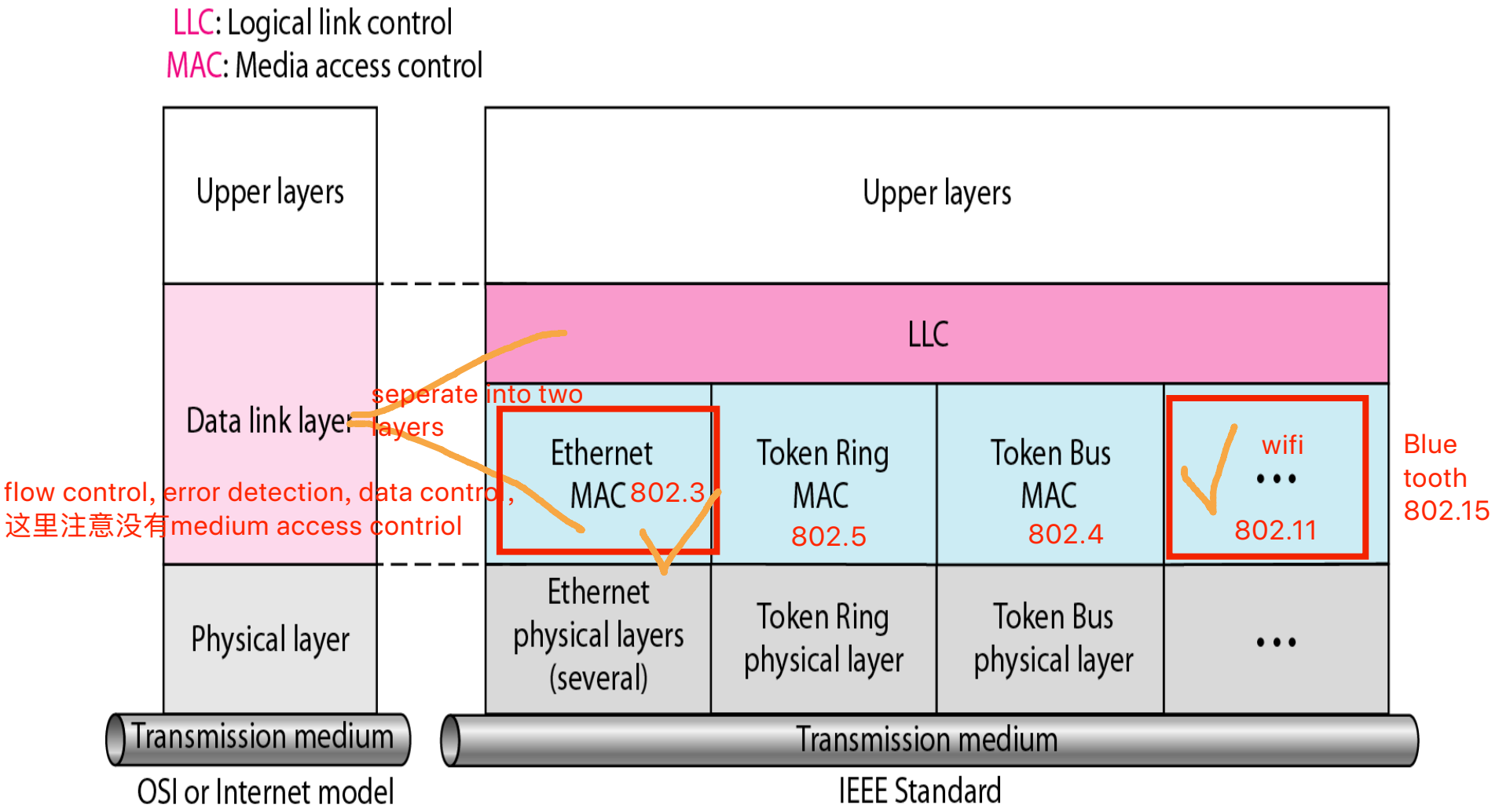
- Random Access
  - Channel not divided, allow collisions. Examples: ALOHA, CSMA/CD, CSMA/CA
  - "Recover" from collisions for example via delayed retransmissions
- "Taking turns"
  - Nodes take turns, but nodes with more to send can take longer turns. Examples: Polling, Token Passing

Channel Partitioning: FDMA/TDMA



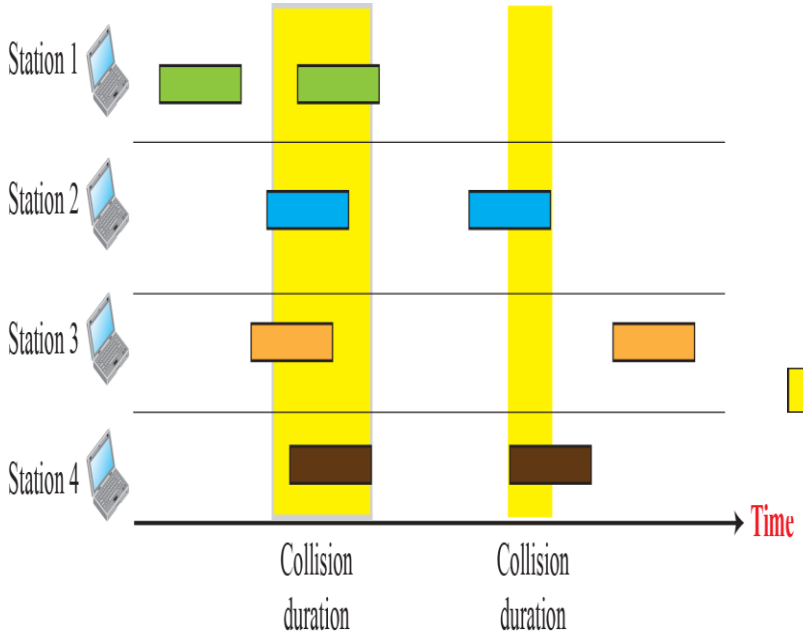


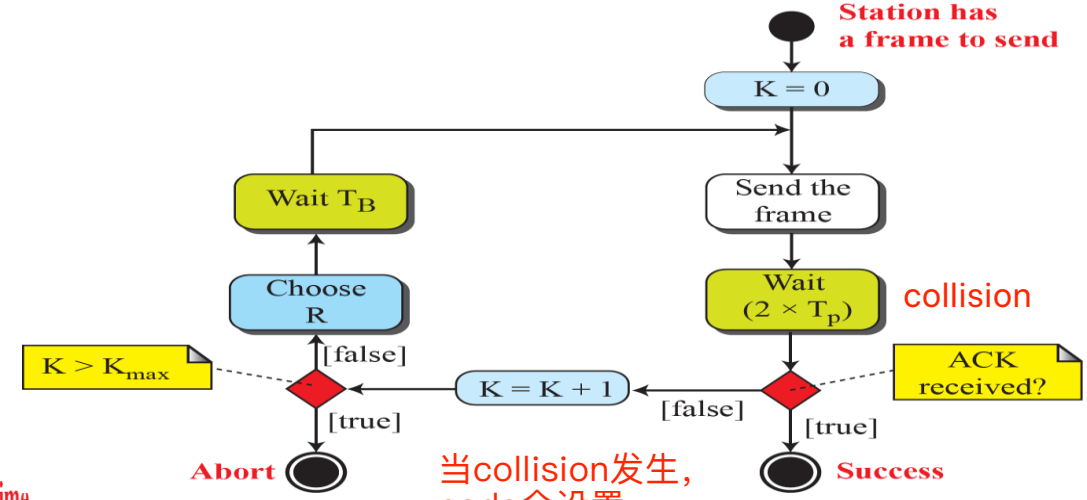
IEEE802 Standards for LANs



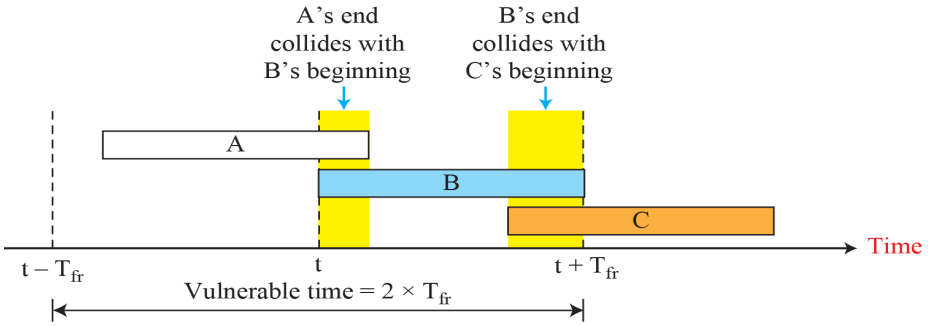
Random Access Protocols: ALOHA

no rules





当collision发生，node会设置random的时间重传



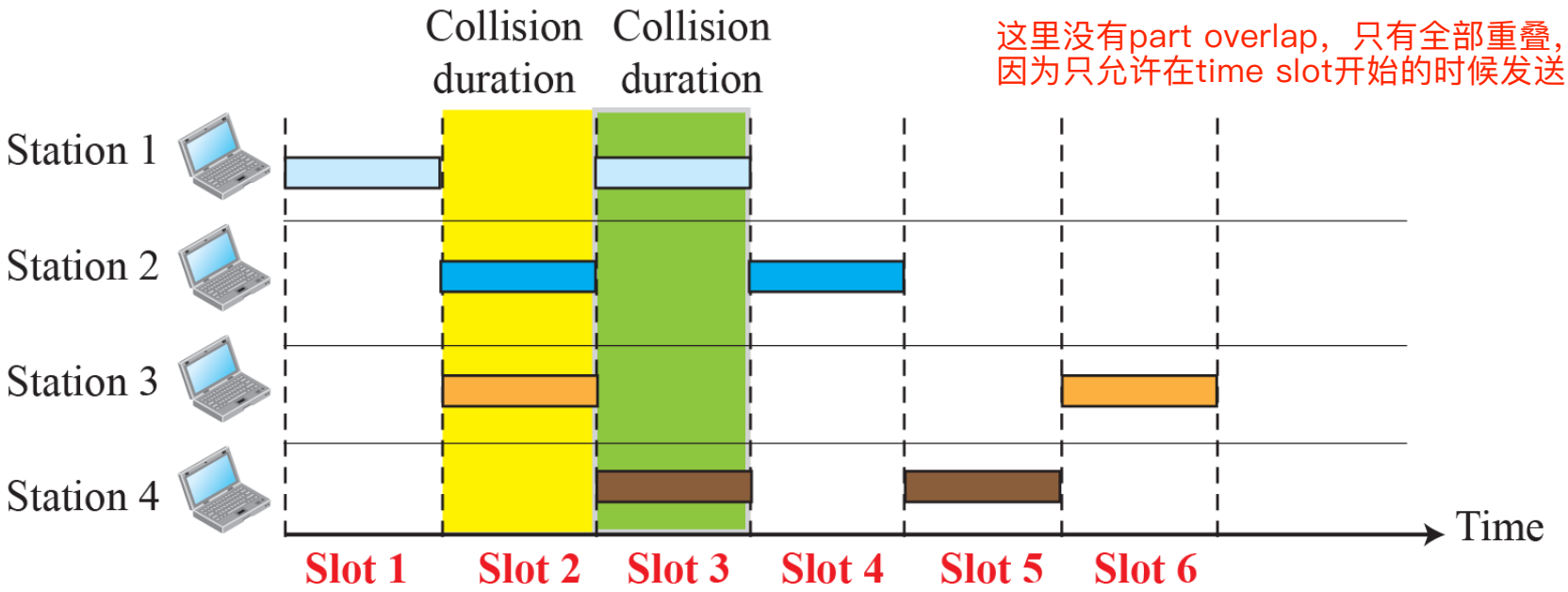
Legend

- K : Number of attempts retransmition
- T_p : Maximum propagation time
- T_{fr}: Average transmission time
- T_B: (Back-off time): $R \times T_p$ or $R \times T_{fr}$
- R : (Random number): 0 to $2^K - 1$

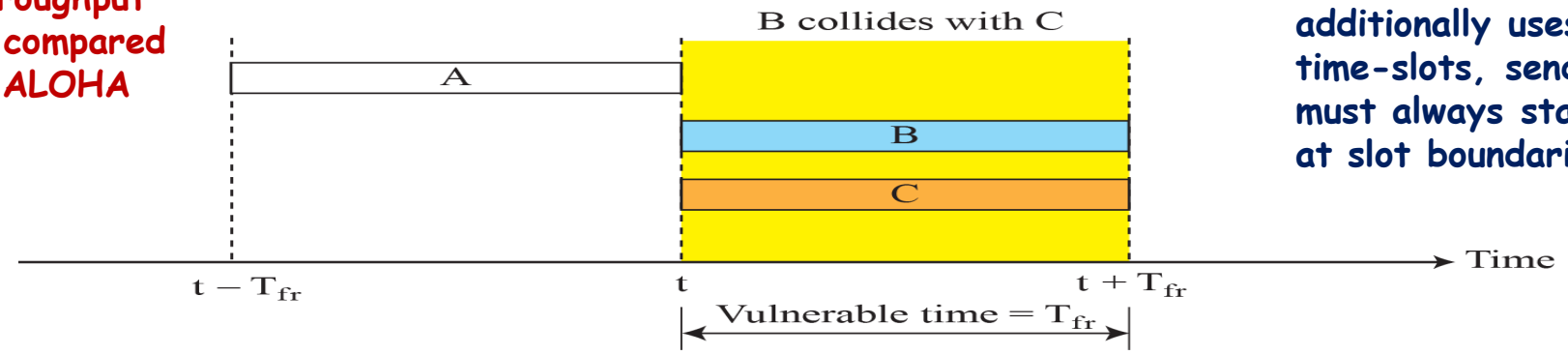
link utiliazation:18%

Slotted ALOHA

link utilization:36%



Double the Throughput as compared to ALOHA



Slotted Aloha additionally uses time-slots, sending must always start at slot boundaries

IEEE802.3 (Based on Ethernet)
"Carrier Sense Multiple Access"

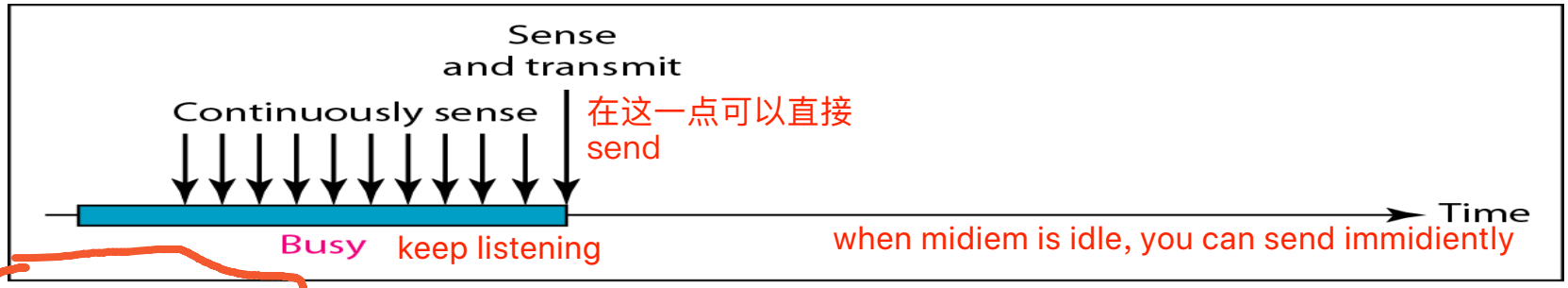
with collision detection

CSMA/CD

Carrier Sense Multiple Access

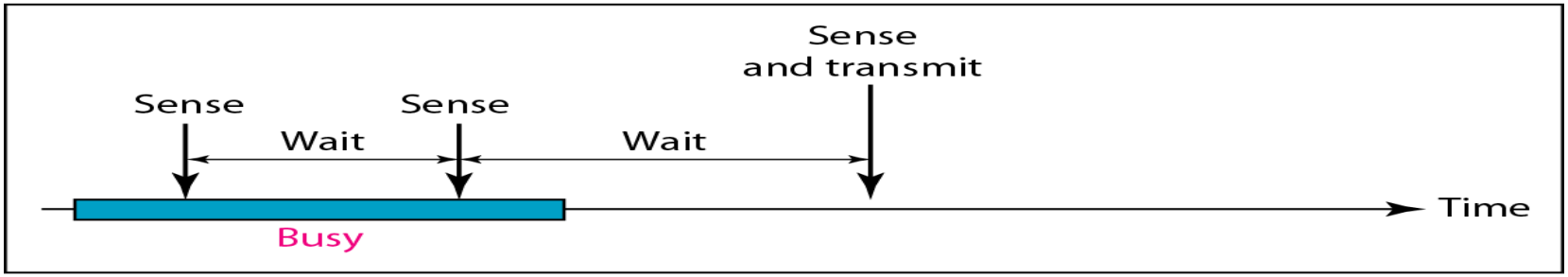
- CSMA/CD: Carrier sense, multiple access with collision detection
  - collisions detected within short time
  - colliding transmissions aborted, reducing waste
  - Persistent, non-persistent and P-persistent retransmission
- Collision Detection:
  - On baseband bus, collision produces much higher signal voltage than transmitted signal
  - For twisted pair (Hub-topology) activity on more than one port is collision

Behavior of Three Persistent Scenarios

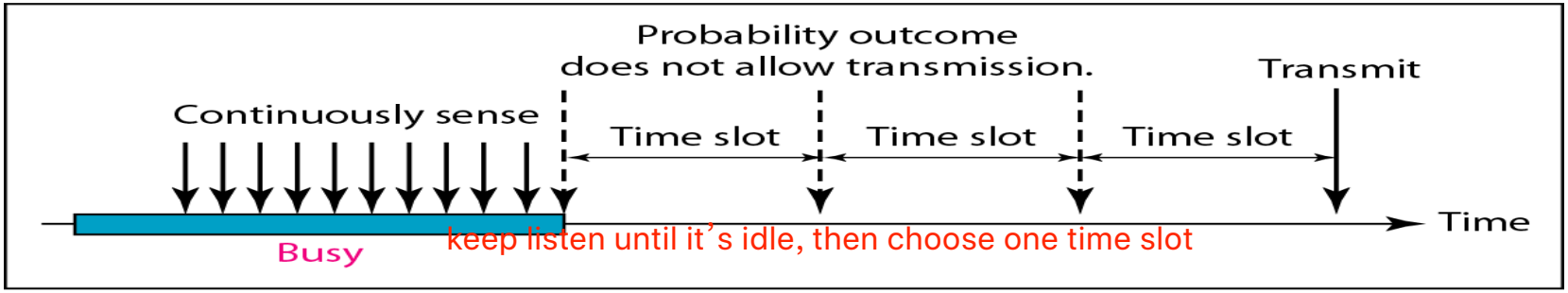


a. 1-persistent

better



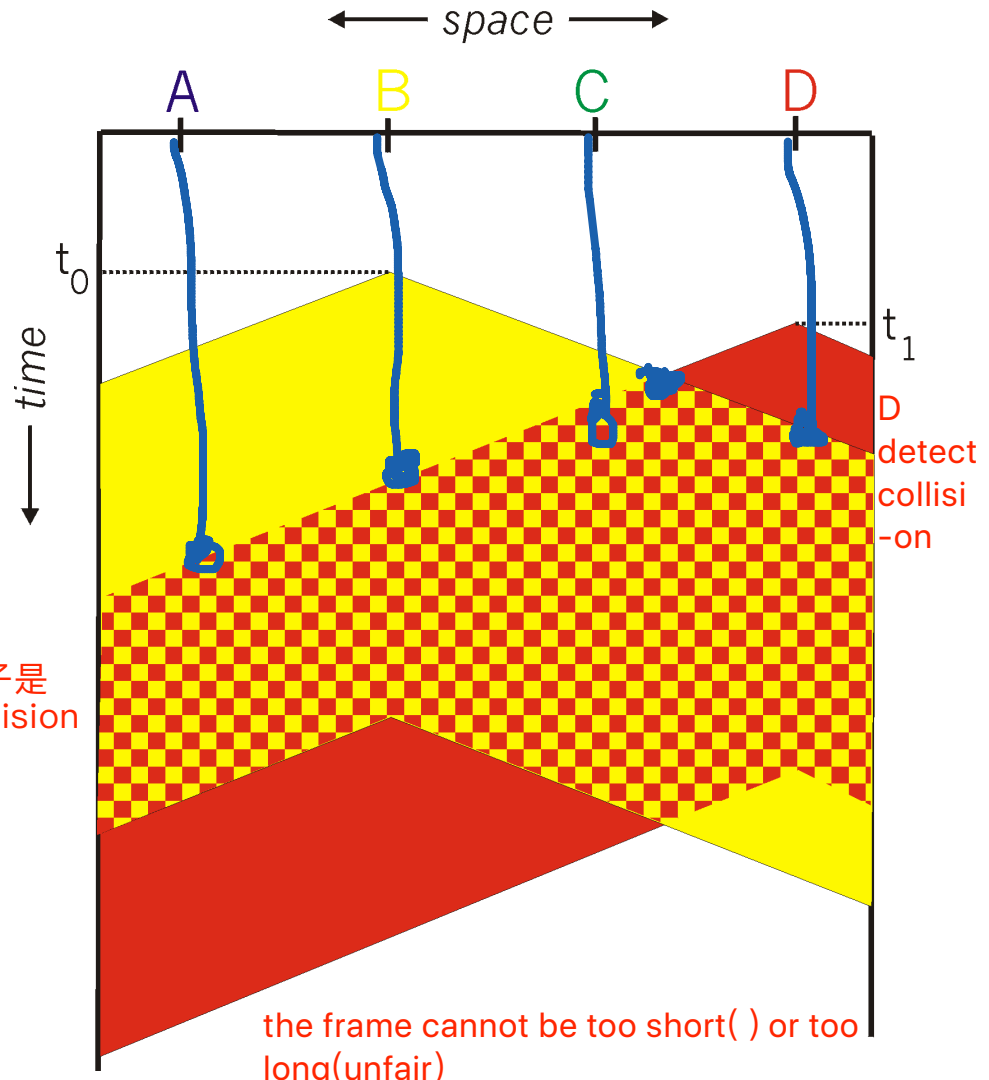
b. Nonpersistent



c. p-persistent

Collisions in CSMA/CD

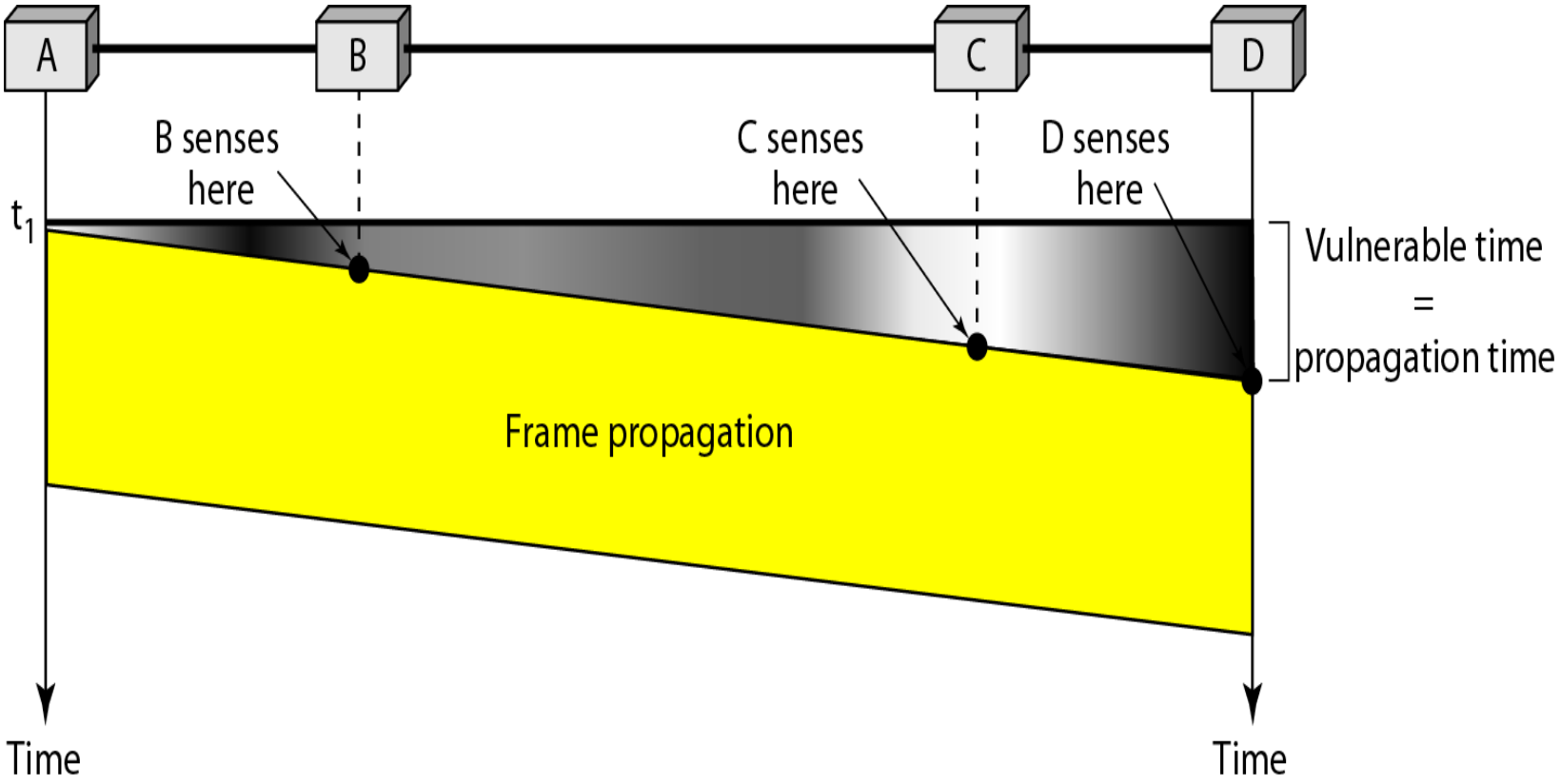
- Collisions can still occur: propagation delay means two nodes may not hear each other's transmission
- When collision occur, entire frame is wasted
- Collision is detected by comparing transmitted and received signal strengths (Hard to do in WLANs, TBD)



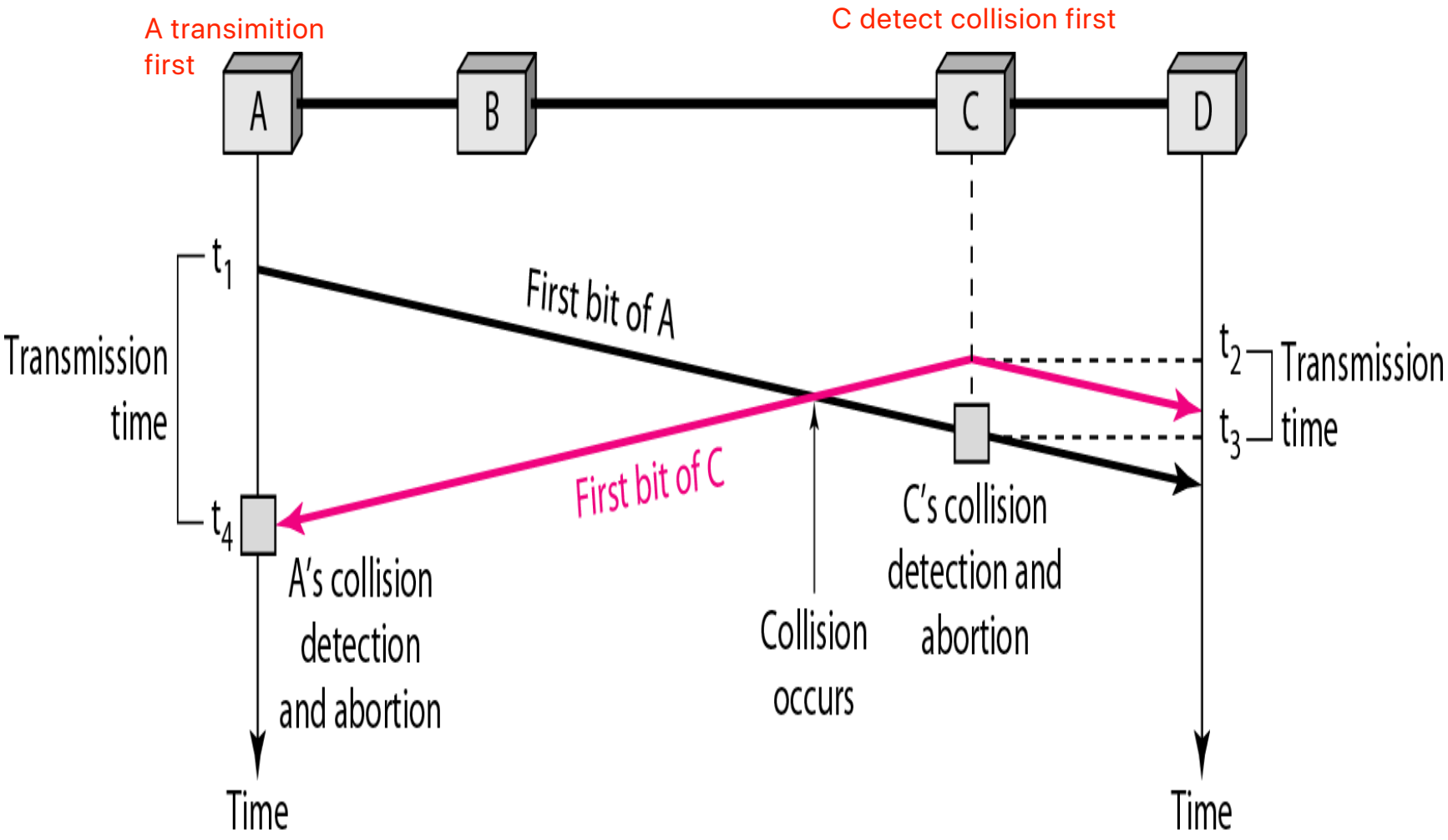
collision can be detected between 0 to Tp
Tf = frame transmition time >= 2Tp
a node should not finishtransmitting frame before a possible collision can be detected

the frame cannot be too short( ) or too long(unfair)

Vulnerable Time in CSMA

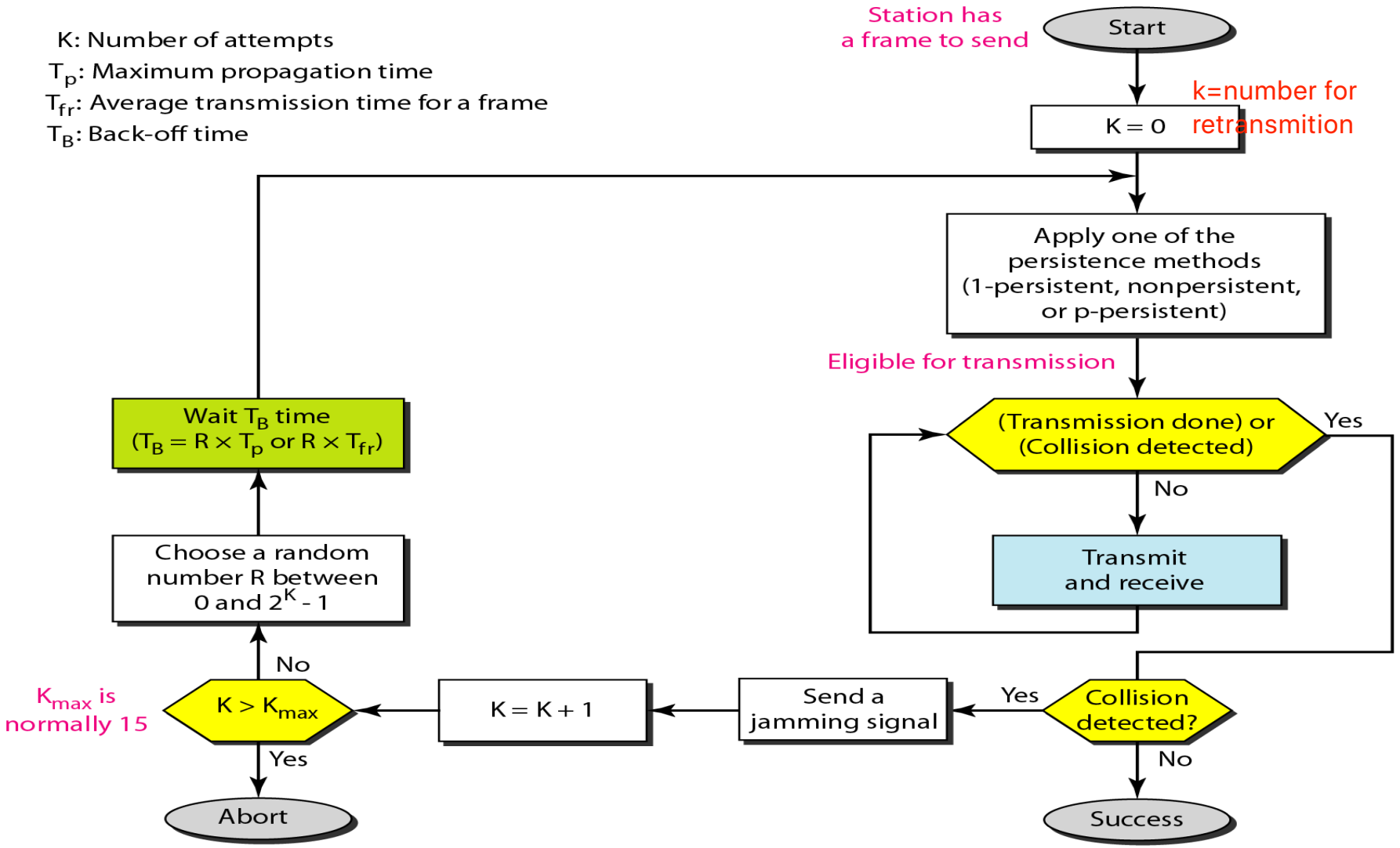


Collision Detection



for transmitter

Flow Chart of CSMA/CD

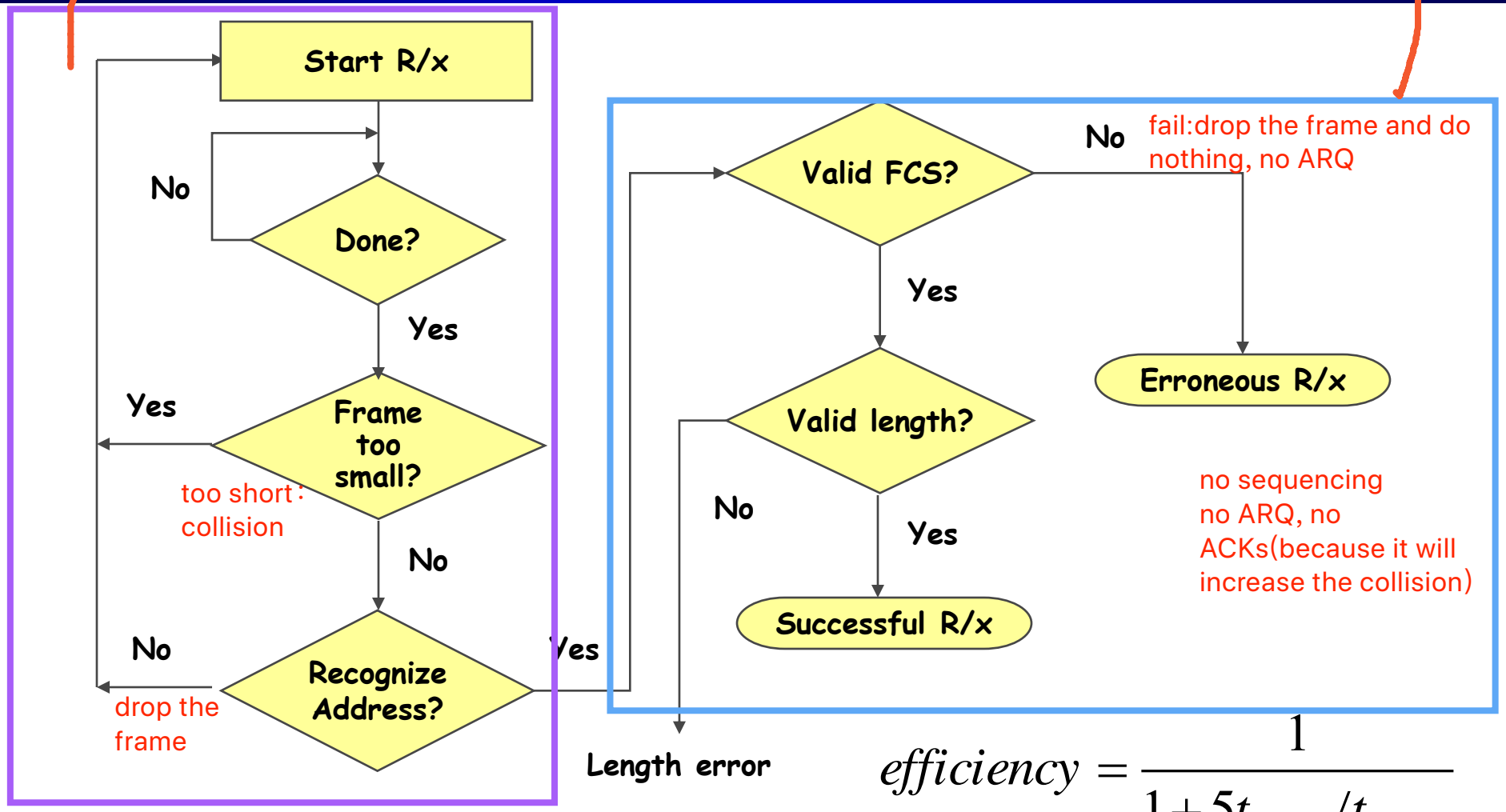


这里的receiver是除了sender之外所有nodes，只要能收到bits都可以视为receiver

只有当有frame send的时候才会listen，其他时候是receive mode

这边的receiver是真正的receiver

Receive Process in IEEE802.3



$$efficiency = \frac{1}{1 + 5t_{prop}/t_{trans}}$$

in layer 4, sender will know whether the frame was received, in layer2, receiver and sender do nothing when errors detected or collision

in ethernet 没有sequence of frame，没有ARQ，在frame最后也没有flag，因为frame不能transimitt back to back

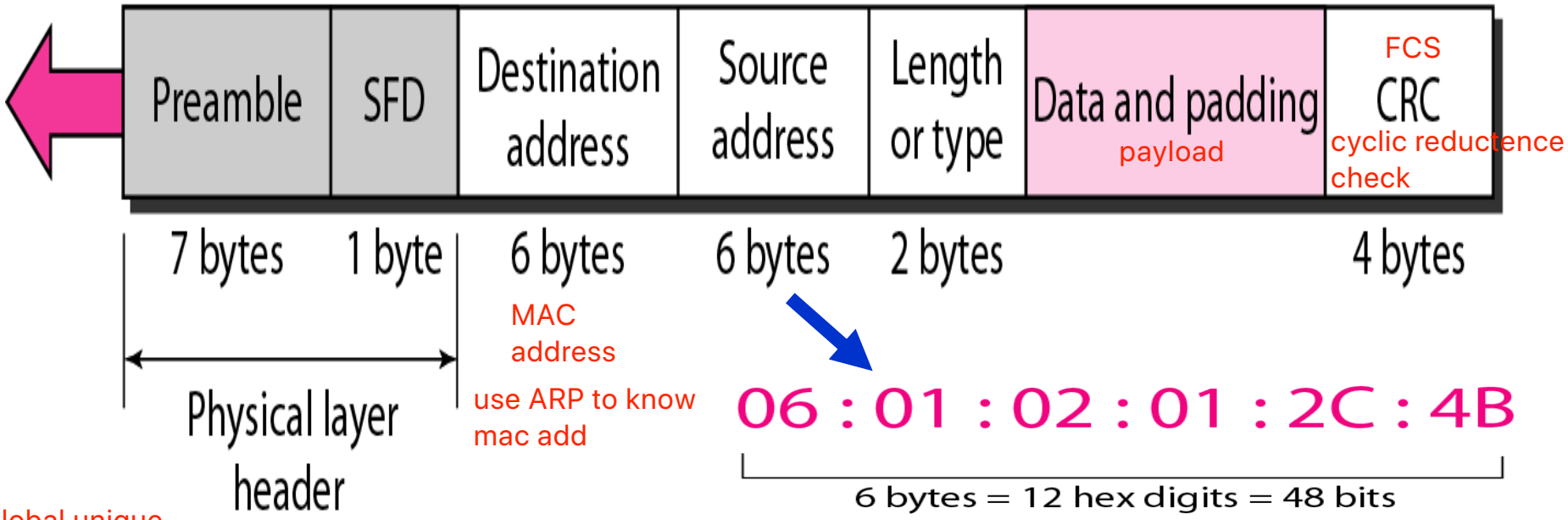
IEEE802.3 MAC Frame

to allow receiver have time to sychnical(同步)

Preamble: 56 bits of alternating 1s and 0s.

SFD: Start frame delimiter, flag (10101011)

Sending adapter encapsulates IP Packet in Ethernet frame



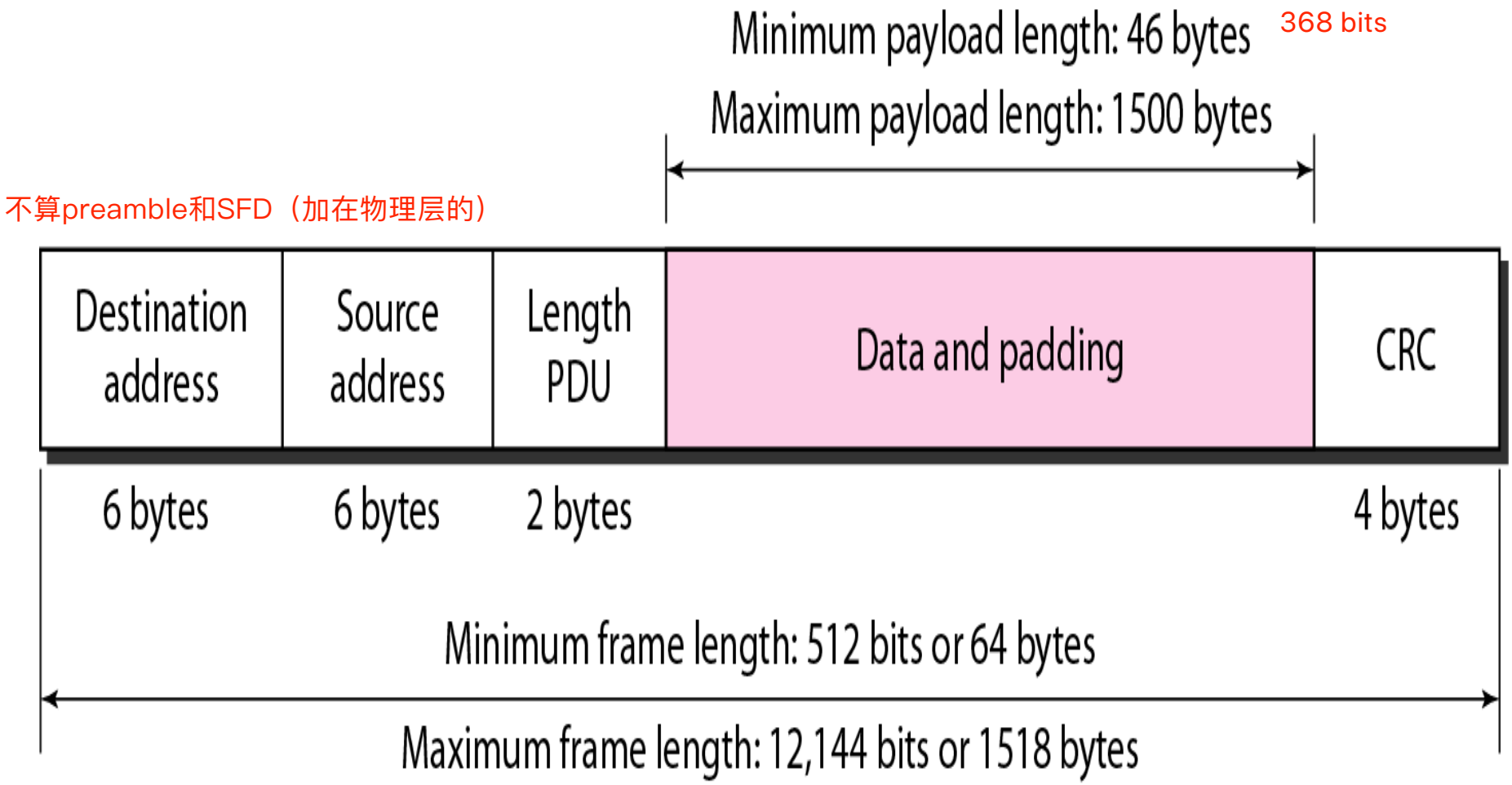
global unique

MAC address is burned in NIC ROM (sometimes software settable)

Type: Indicate Network Layer Protocol (mostly IP)

let receiver know where to pass

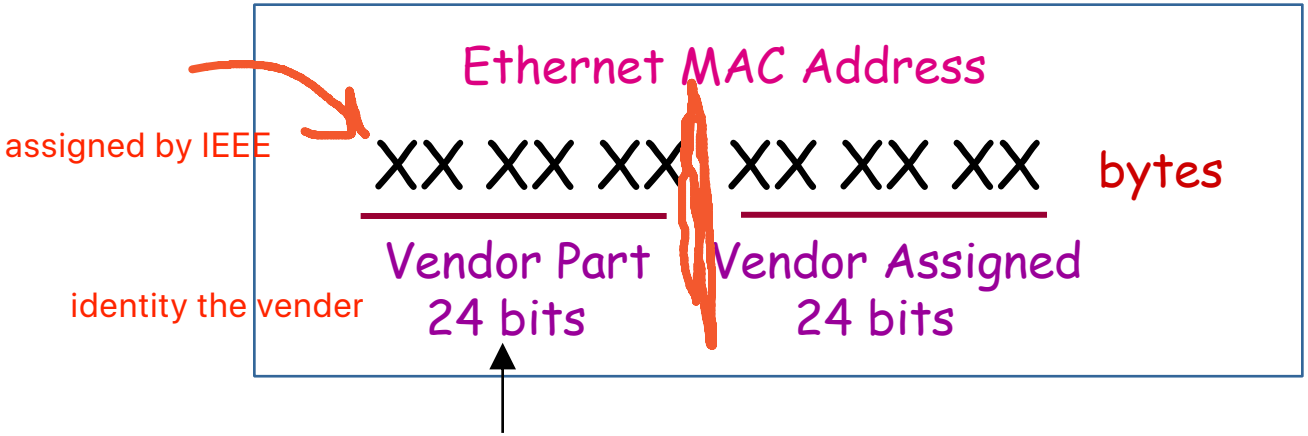
IEEE802.3 Frame Length Limits



If errors are detected,
Frame is dropped

MAC Addresses

- Source and destination MAC addresses. These are the hardware addresses. They are 48-bits long each



IEEE Organizationally Unique Identifier (OUI)
- allows vendor to build hardware with unique addresses

http://standards.ieee.org/regauth/oui/
http://www.cavebear.com/CaveBear/Ethernet/

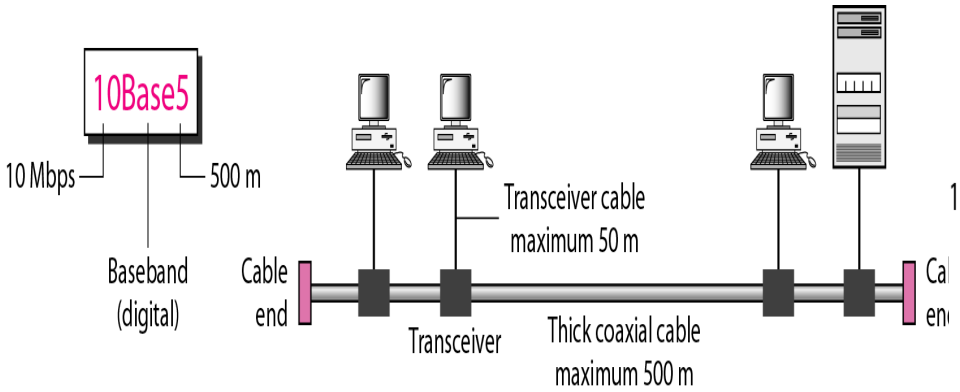
recreate不等于process:广播的时候每个node都会recreate
frame去知道mac add，但是不process

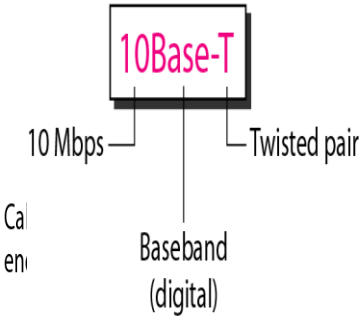
Types of MAC Addresses

- **Unicast**: one interface to one interface
- **Broadcast**: all 1's destination address means that every attached interface to a LAN should read the frame.
  - MAC Address: FF:FF:FF:FF:FF:FF
- **Multicast**: an interface can be configured to read frames sent to one or more multicast addresses.

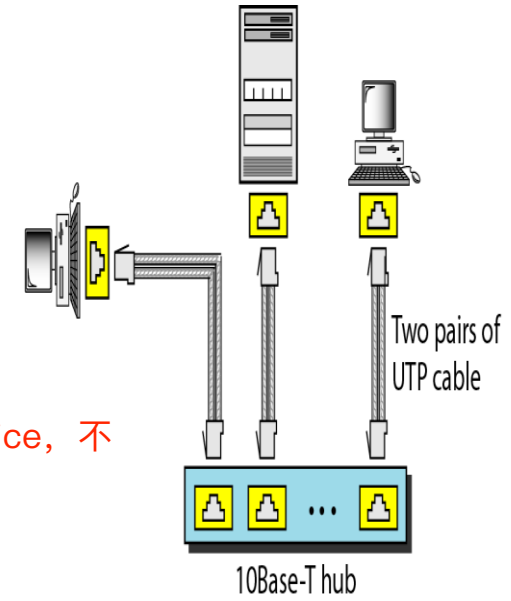
group of nodes

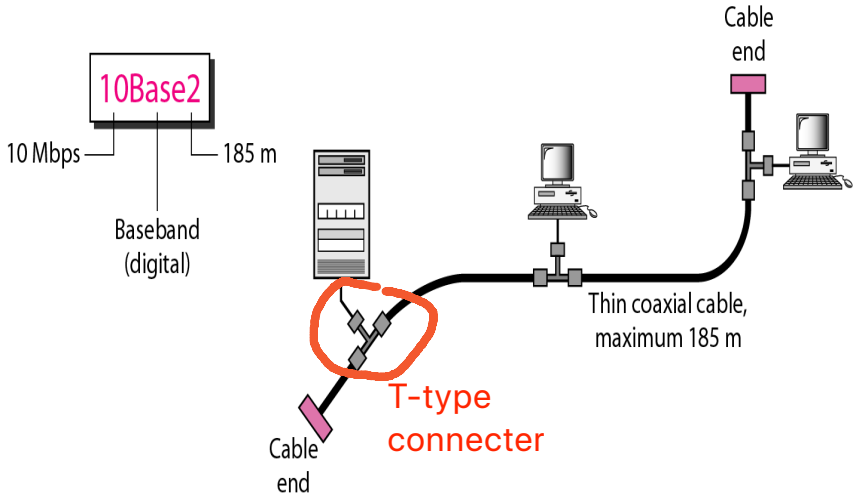
10Base? Implementations

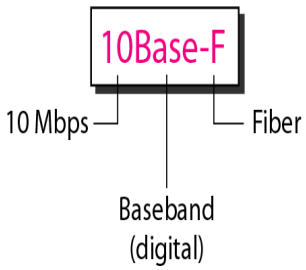


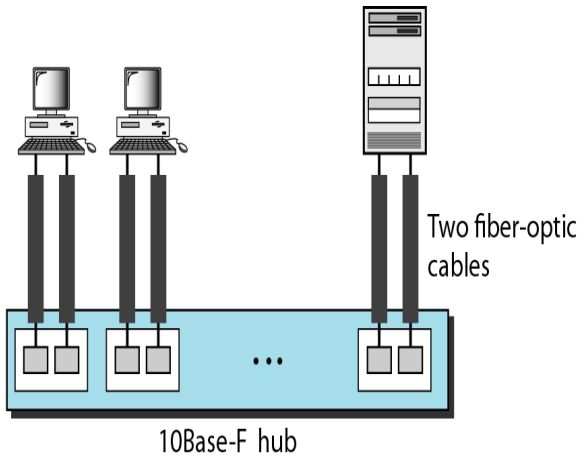


hub: is a physical device，不识别只转发

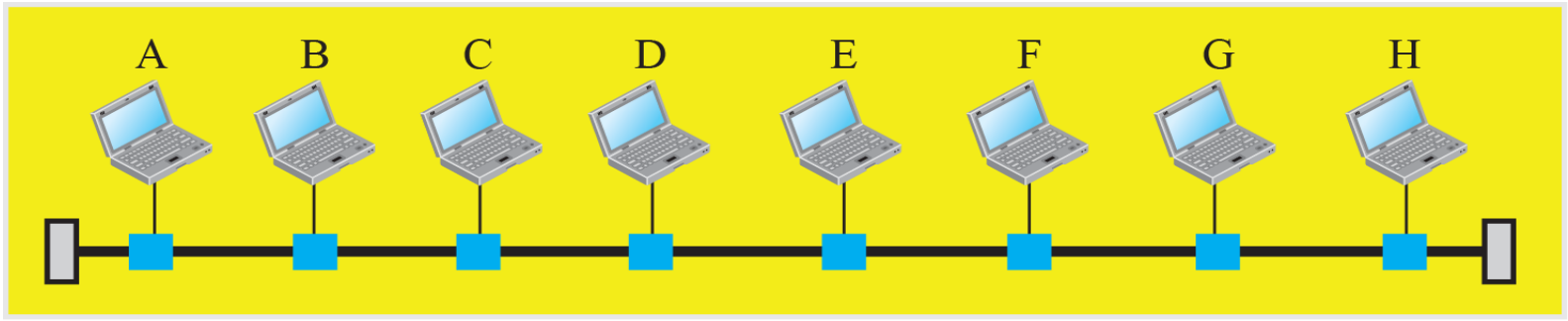




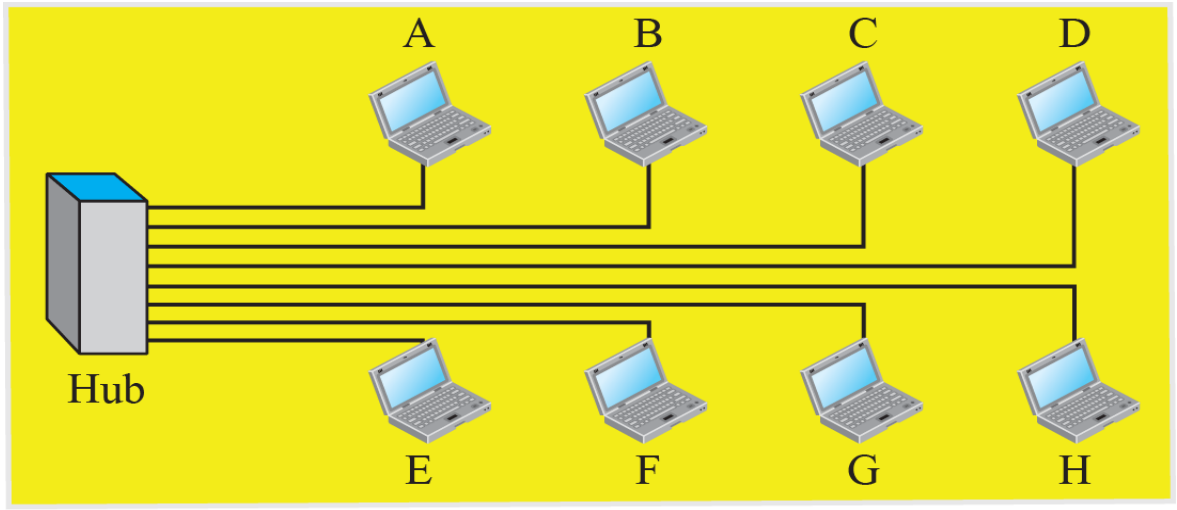




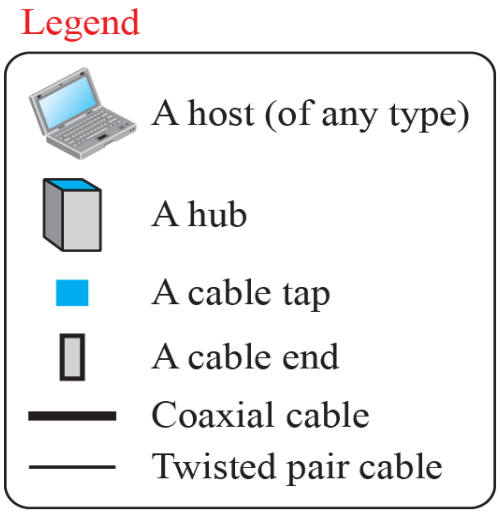
Shared Ethernet Implementations



a. A LAN with a bus topology using a coaxial cable



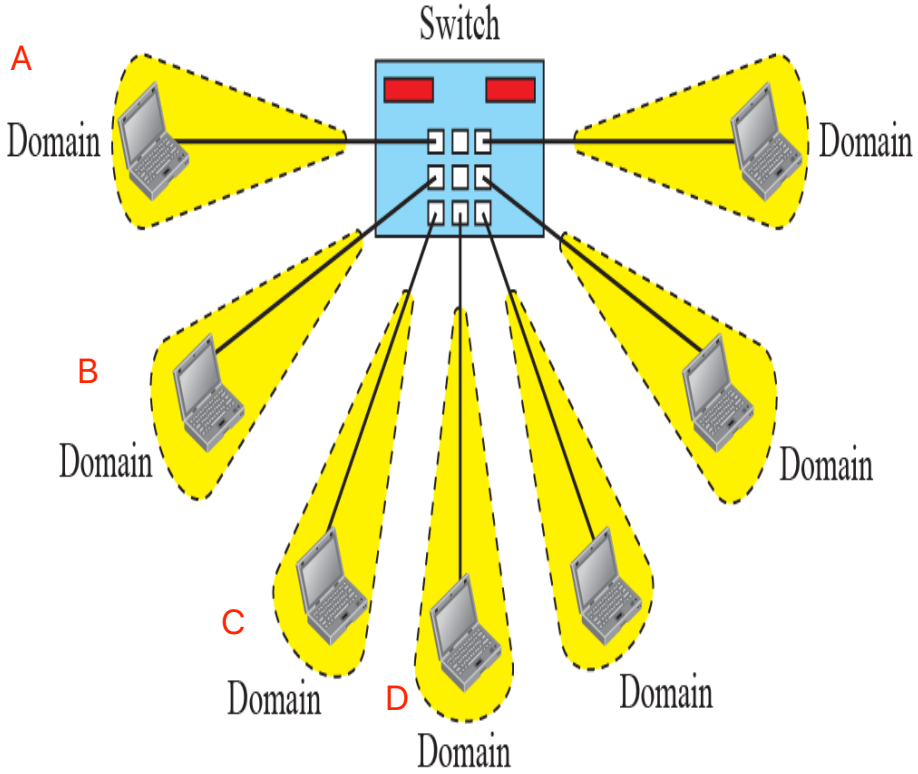
b. A LAN with a star topology using a hub



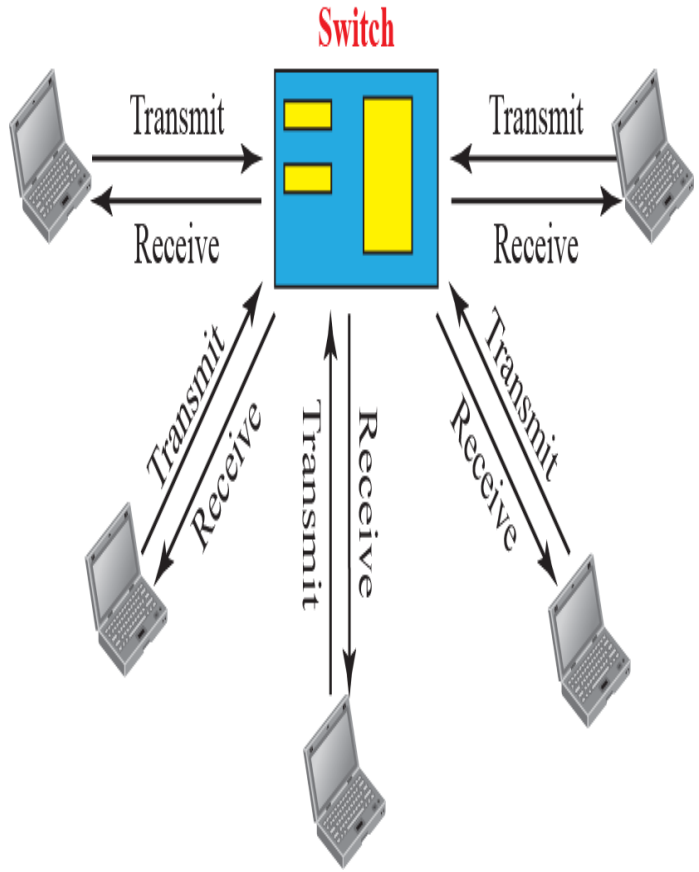
replace hub to L2 switch
L2 switch: recongnize MAC address

Switched Ethernet

if A send to B, CandD will not receive the bits
同时C可以向D send frame without collision



No Collisions



Support FDX

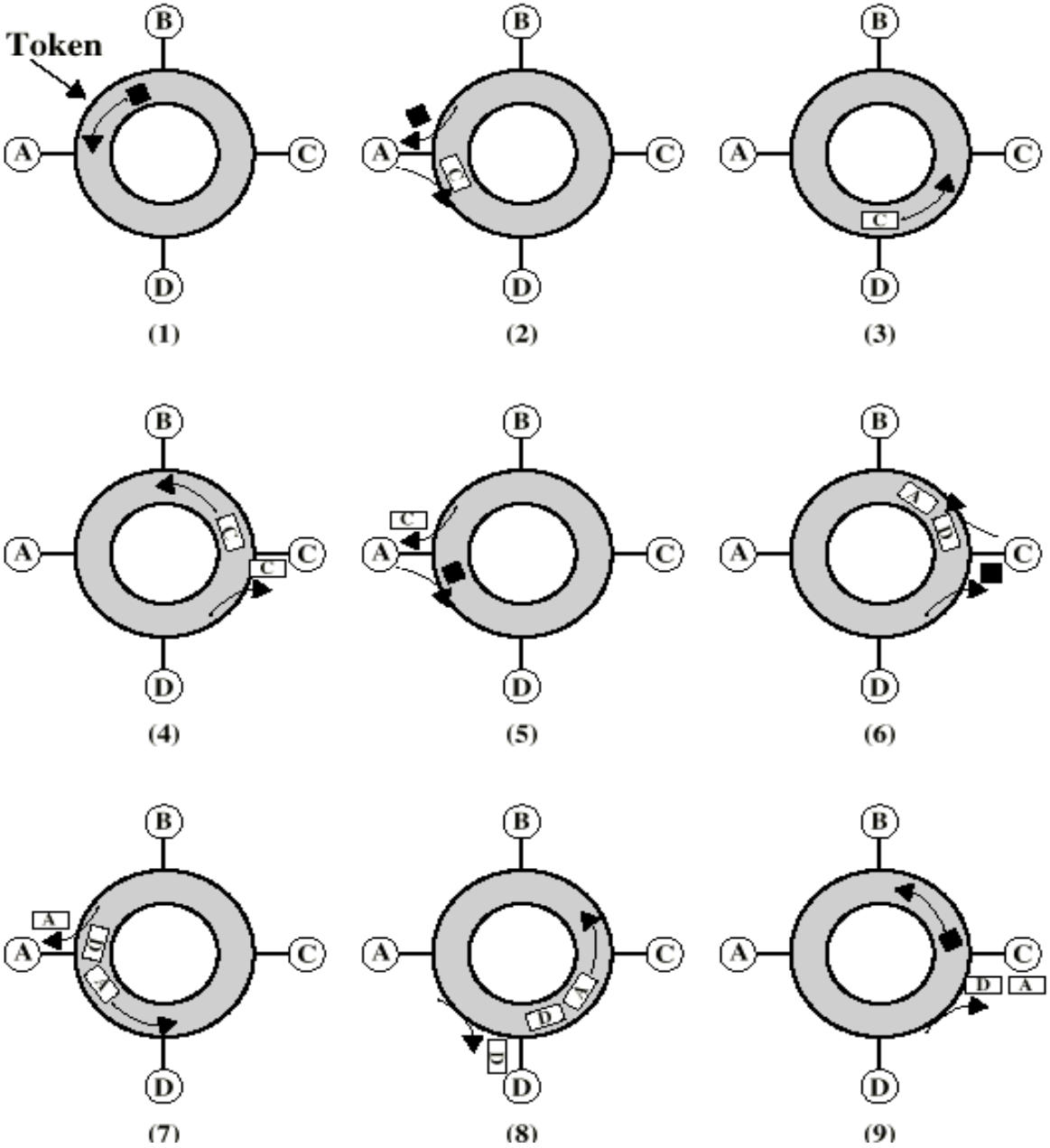
IEEE802.5 (Based on IBM) "Token-Passing Rings"

IEEE802.5 Token-Passing Rings

- Frames flow in one direction
- Special bit pattern (token) rotates around ring. The token is 24-bit long
- Node having a frame to transmit must capture token first
- Node must release token after done transmitting
- Node remove frame when it comes back around
- Stations get round-robin service

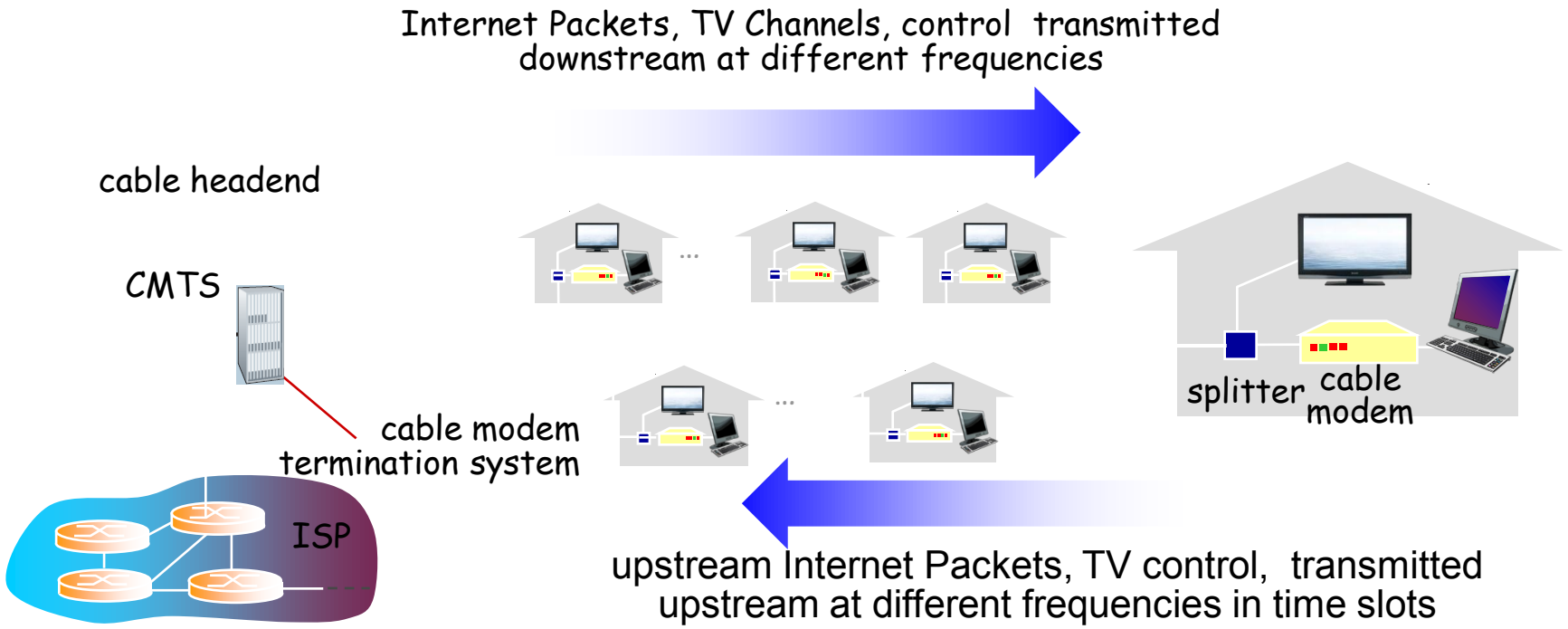
Token Ring

- Supports 4Mbps (UTP), 16 Mbps (STP) and 100 Mbps (Fiber)
- Token Holding Timer ~ 10 msec which limits the frame length ~ 4500 Bytes for the 4Mbps Rings and ~ 18,000 Bytes for the faster Rings



Cable Access Network

downlinkm没有problem，
因为只是cable company
给users
on the downlink, the
company broadcast



- multiple 40Mbps downstream (broadcast) channels
  - single CMTS transmits into channels
- multiple 30 Mbps upstream channels
  - multiple access: all users contend for certain upstream channel time slots (others assigned)

uplink is share, so you need to make reservation to cable company
when you make reservation, it can be collision

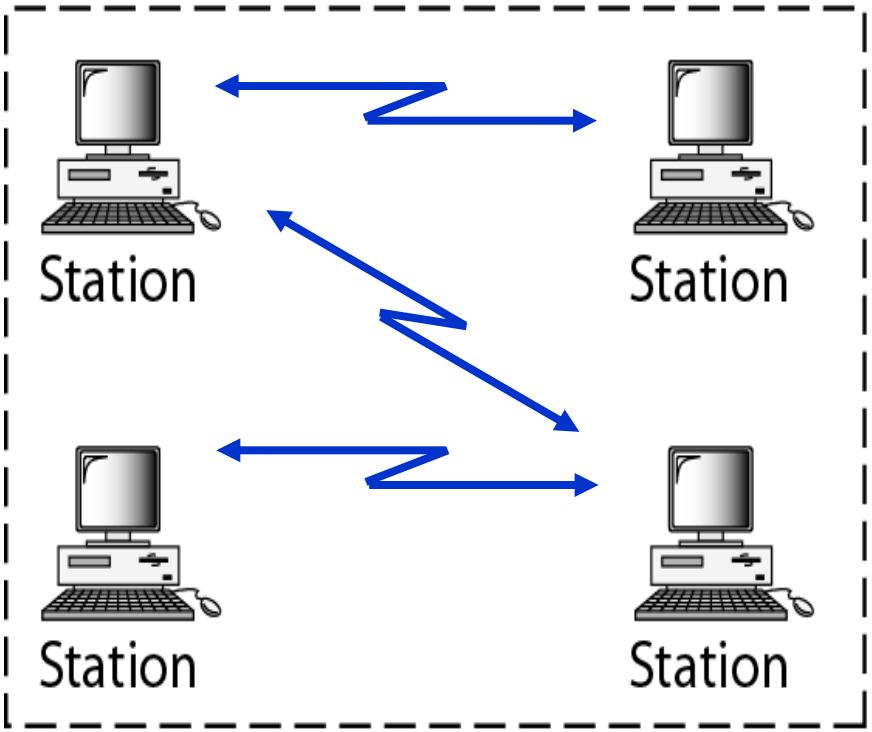
IEEE 802.11
Wireless LANs (Wi-Fi)

Ad-hoc vs. Infrastructure WLANs

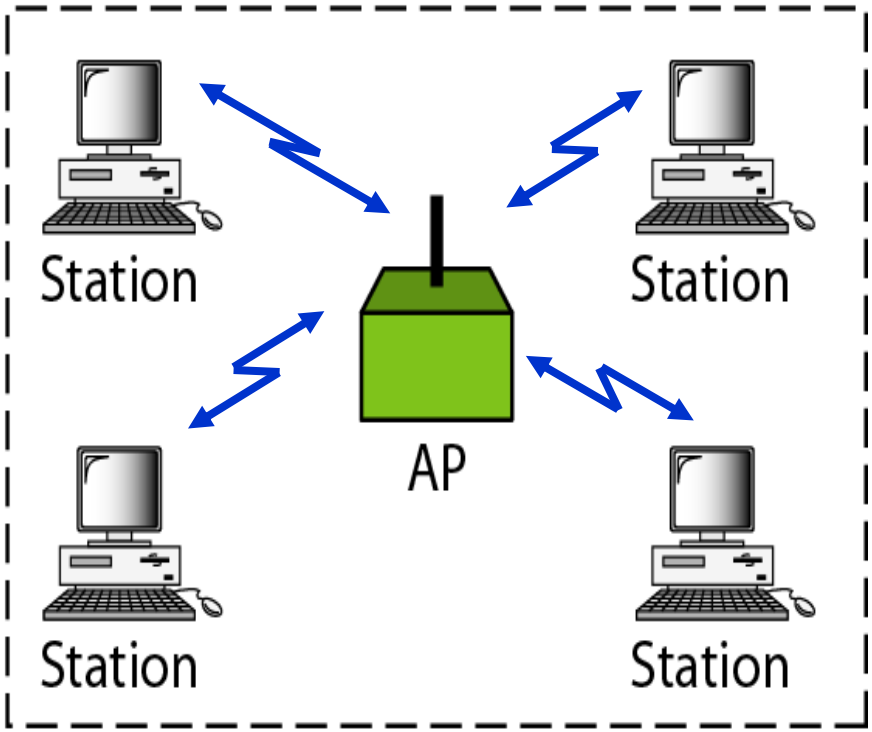
BSS: Basic service set

AP: Access point

只关注这边



Ad hoc network (BSS without an AP)



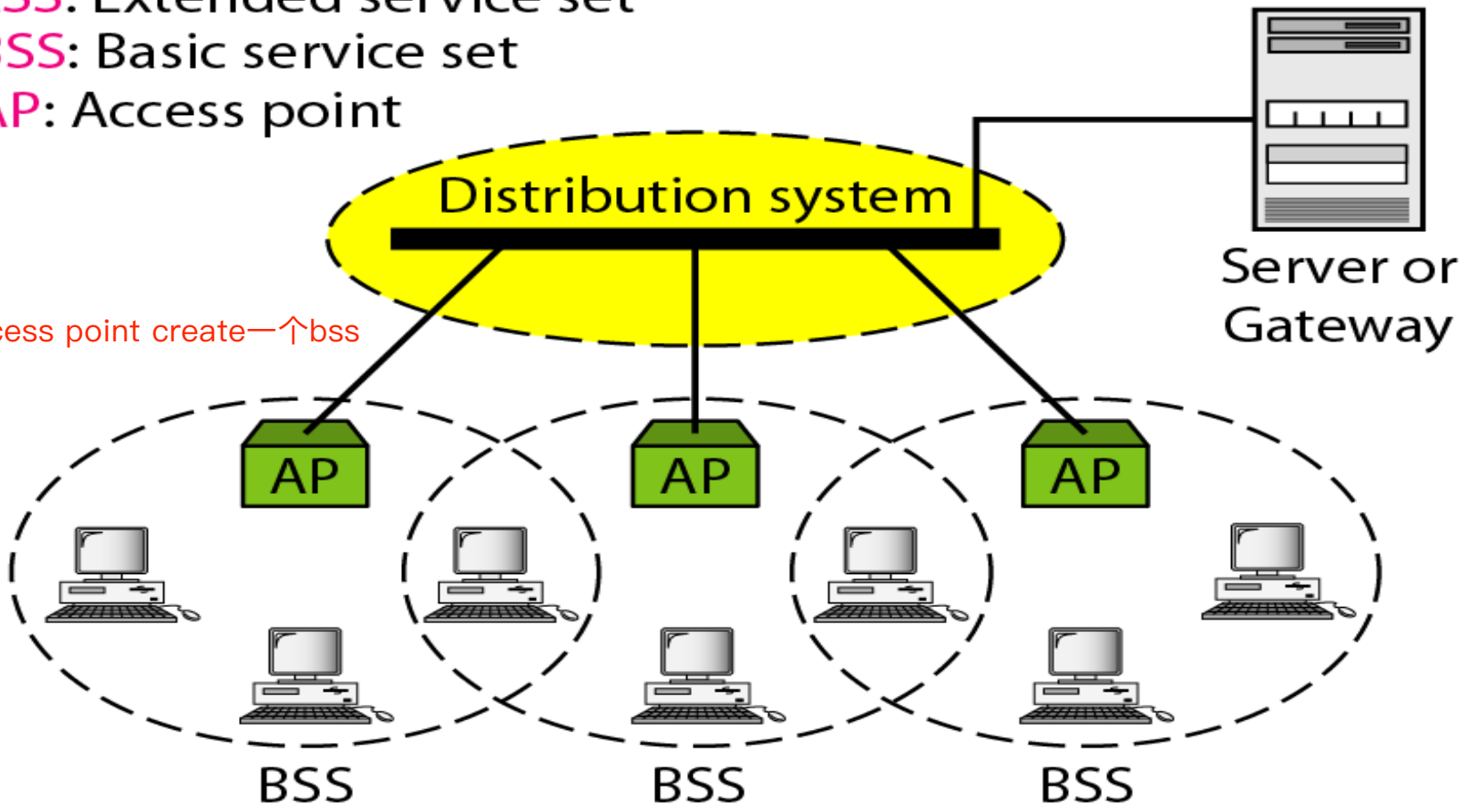
Infrastructure (BSS with an AP)

on the fly
—eg：bluetooth/zigbee

家用的AP embed在router里边

Extended Service Sets

ESS: Extended service set
BSS: Basic service set
AP: Access point



一个access point create一个bss

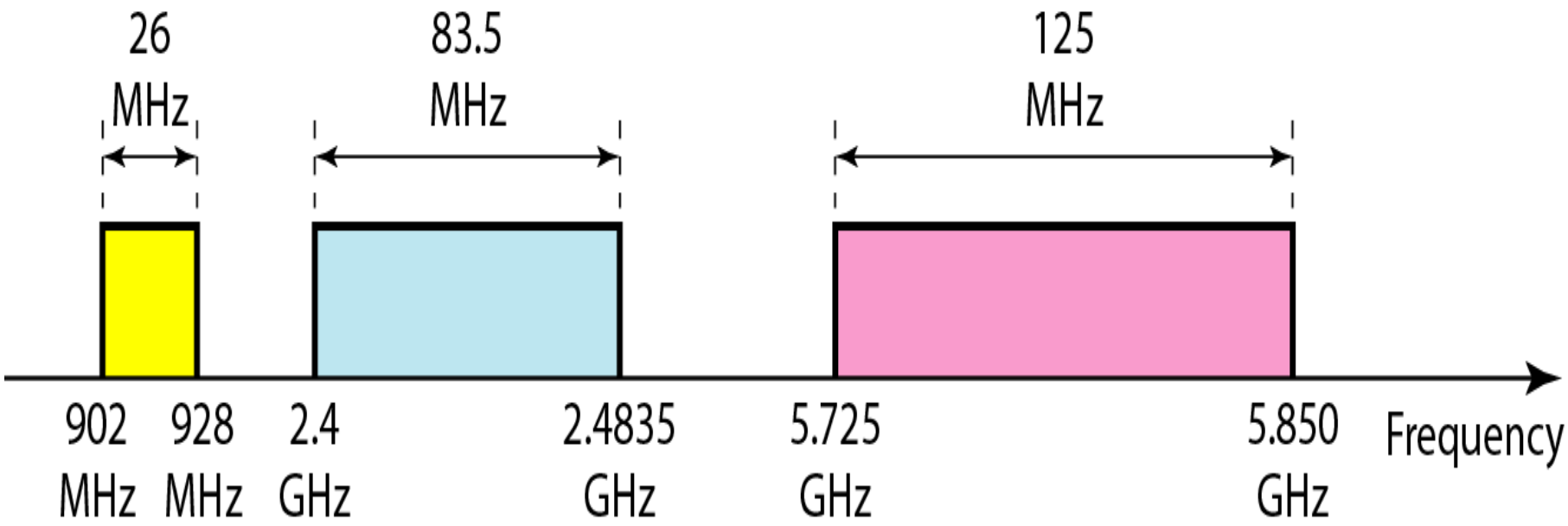
这几个BSS可以belong不同人

一个bss一个frequency

every BSS use one frequency

unlicensed

~~Unregulated~~ Band (ISM)



ISM: Industrial, Scientific and Medical band

wider bandwidth—>faster

wifi: 2.4-5.5

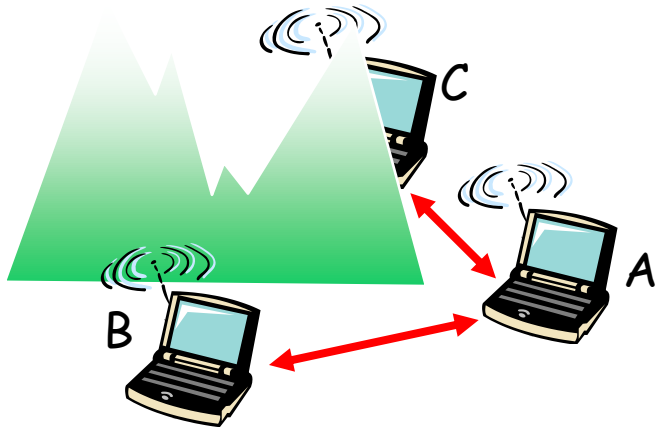
Wireless Link Characteristics

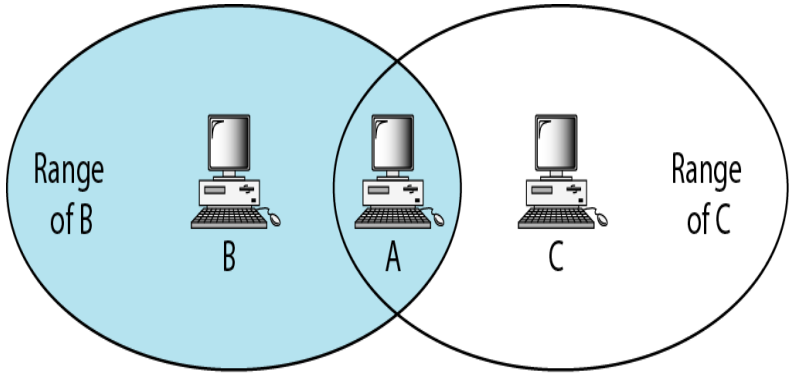
- Differences from wired link ….
  - Decreased Signal Strength: Radio signal attenuates as it propagates through matter (path loss) signal fading
  - Interference from other sources: standardized wireless network frequencies (e.g., 2.4 GHz) shared by other devices (e.g., phone); devices (motors) interfere as well
  - Multipath propagation: Radio signal reflects off objects ground, arriving ad destination at slightly different times

csma/cd fail in wireless: because wireless cannot listen and send at the same time

Hidden Terminal Problem

- Hidden terminal problem
  - B, A hear each other
  - C, A hear each other
  - B, C can not hear each other
  - Means B, C unaware of their interference at A

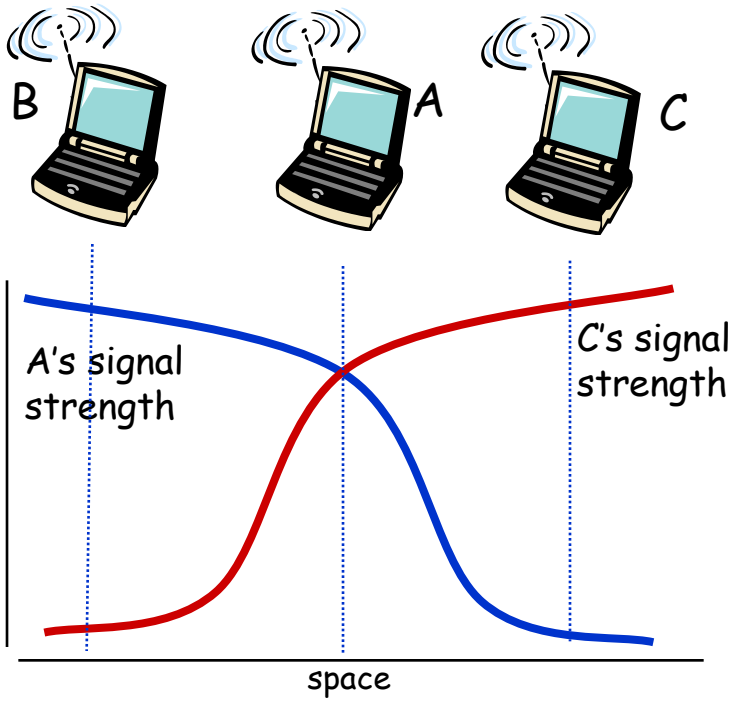




B and C are hidden from each other with respect to A.

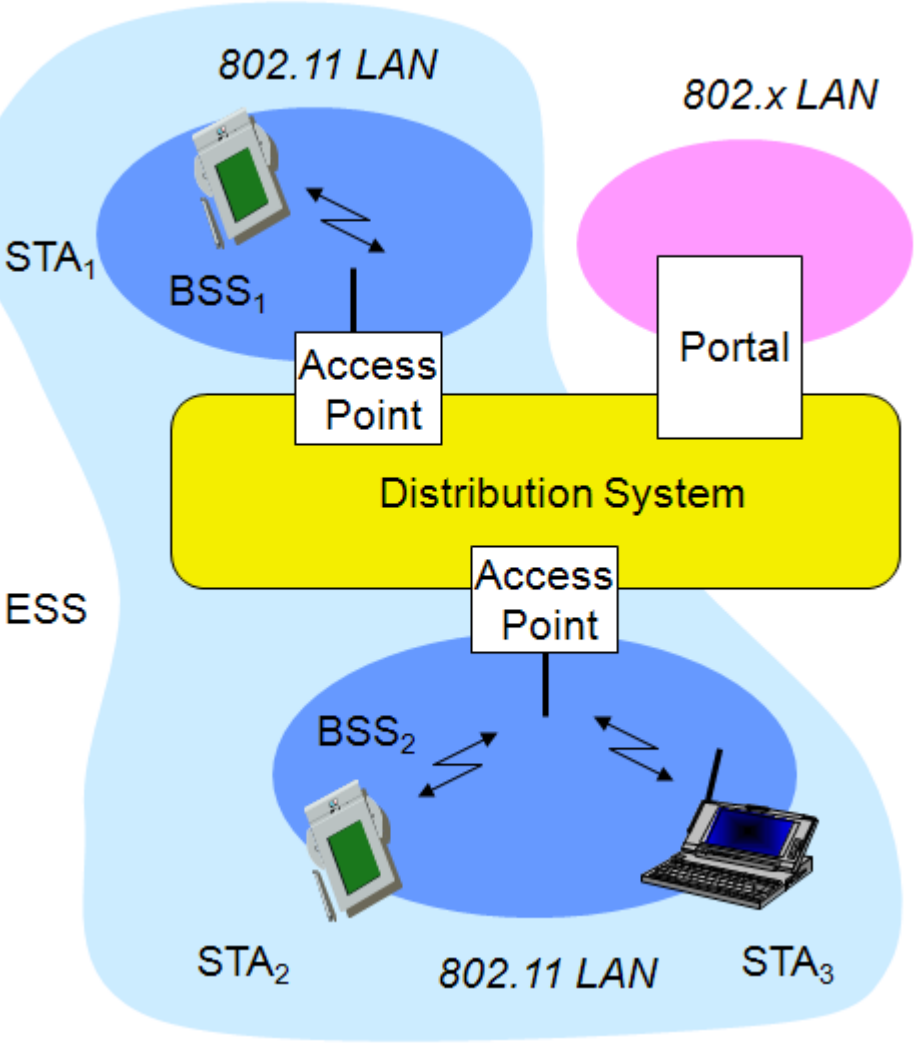
Signal Fading

- Signal fading:
  - A, B can hear each other
  - A, C can hear each other
  - B, C can not hear each other interfering at A
  - Signal losses its strength as distance increases



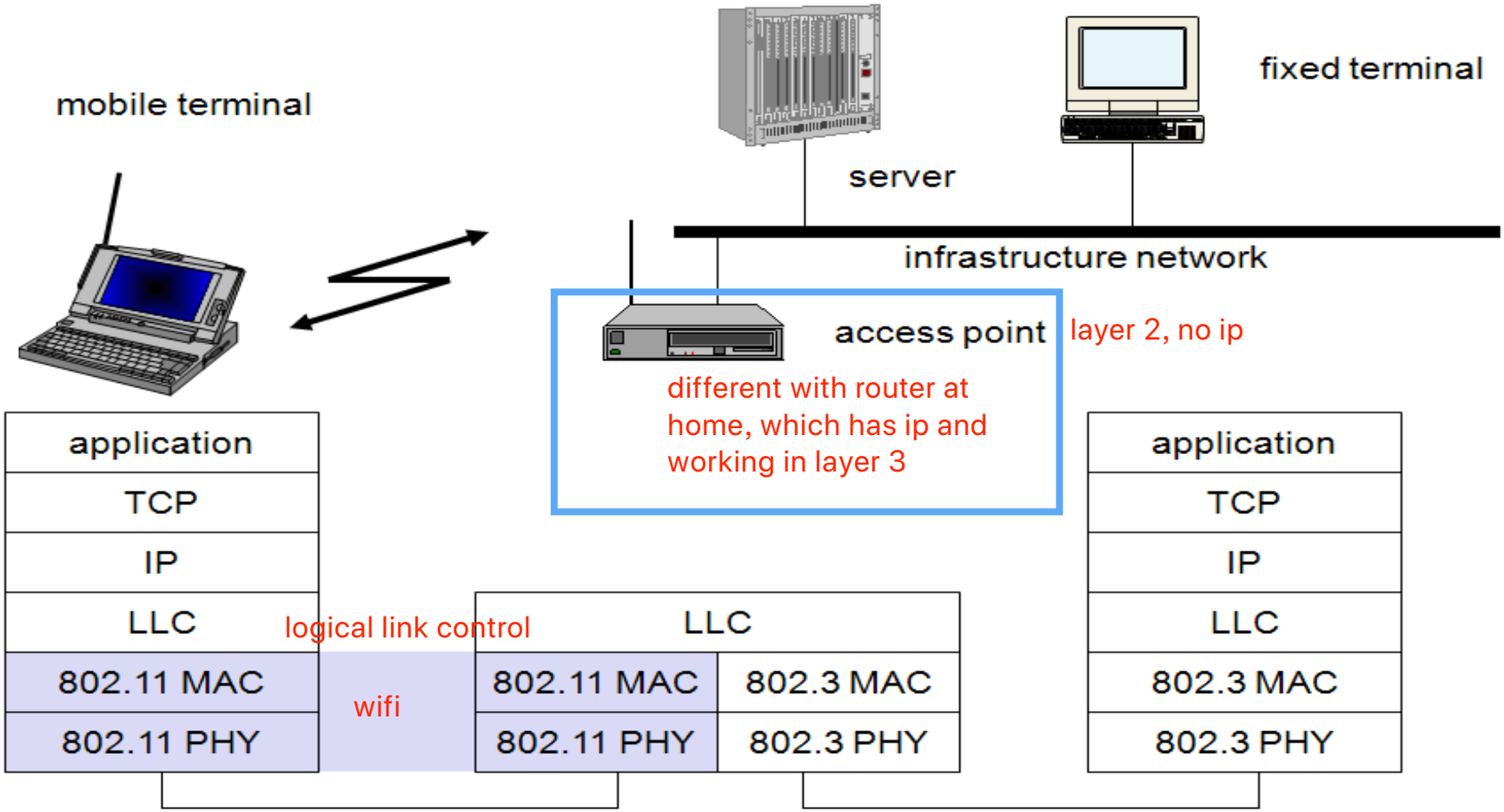
ap identify bss
wifi has ssid (server side identify)

802.11 Infrastructure Network



- 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/Router)
  - to other (wired) networks
- Distribution System
  - interconnection network to form one logical network (EES: Extended Service Set) based on several BSS

802.11 in the TCP/IP Stack



802.11ac 5G 500Mbps
802.11ax 6G 1Gbps

wireless channel可用：11个
no gradband, 只有1,6,11这三个不重叠each other， 默认是channel6（可以自己改）

IEEE 802.11 Wireless LAN

802.11b 1G

- 2.4-5 GHz unlicensed spectrum
- up to 11 Mbps
- direct sequence spread spectrum (DSSS) in physical layer
  - all hosts use same chipping code

802.11a 2G

- 5-6 GHz range
- up to 54 Mbps

802.11g 3G

- 2.4-5 GHz range
- up to 54 Mbps

802.11n: multiple antennae 4G

- 2.4-5 GHz range
- up to 200 Mbps

- all use CSMA/CA for multiple access
- all have base-station and ad-hoc network versions

upgrade wifi at home， you need to upgrade conection to ISP

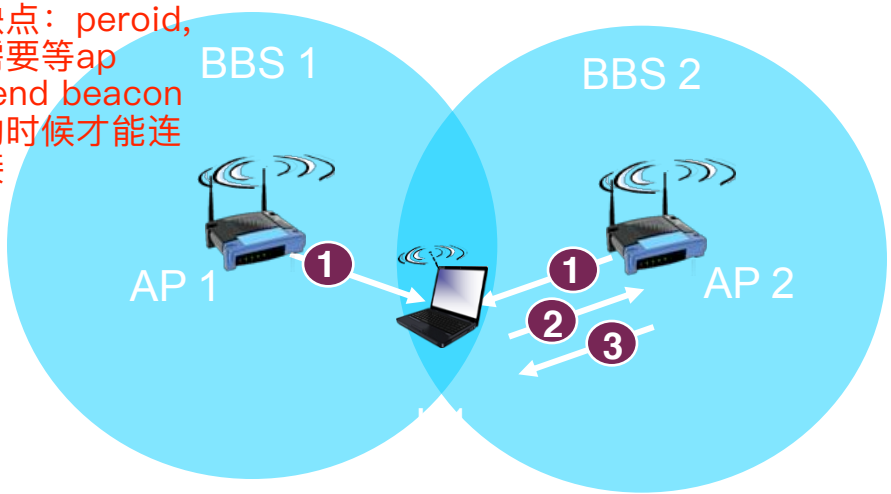
Channel Association

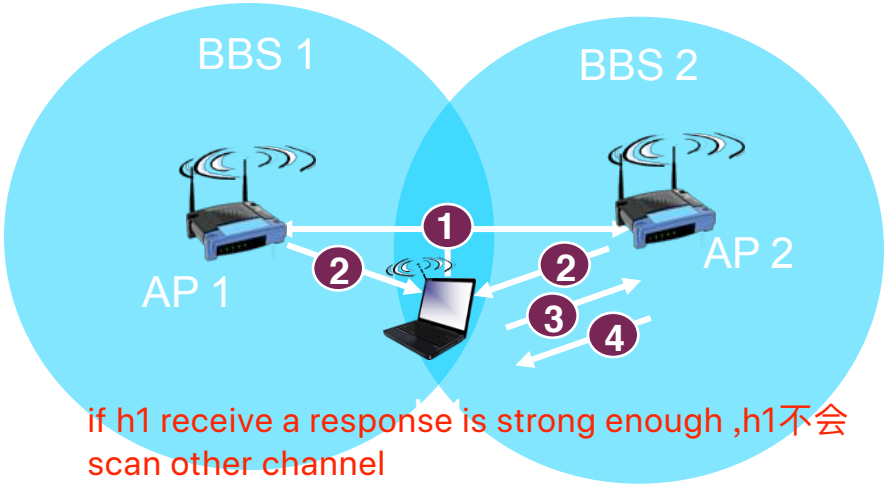
- 802.11b: 2.4GHz-2.485GHz spectrum divided into 11 channels at different frequencies
  - AP admin chooses frequency for AP
  - Interference possible: channel can be same as that chosen by neighboring AP!
- Host: must *associate* with an AP
  - Scans channels, listening for Beacon frames containing AP's name (SSID) and MAC address
  - Selects AP to associate with
  - May perform authentication
  - Run DHCP to get IP address in AP's subnet

hot spot: wifi donot belong to you

802.11: Passive/Active scanning

缺点：peroid, 需要等ap send beacon 的时候才能连接





if h1 receive a response is strong enough ,h1不会 scan other channel

passive scanning:

(1) beacon frames sent from APs

(2) association Request frame sent: H1 to selected AP

(3) association Response frame sent from selected AP to H1

ap broadcast a short frame(called beacon): i'm ap, my ssid is xx my mac add is xxx

device scan all frequency(channels), 如果接到多个beacon选最强的信号

active scanning:

(1) Probe Request frame broadcast from H1

wireless unit send probe on each channel,

(2) Probe Response frames sent from APs

(3) Association Request frame sent: H1 to selected AP

(4) Association Response frame sent from selected AP to H1

csma/cd fail resaon: hiden terminal problem/ signal fade

IEEE802.11 MAC Protocol

- Avoid collisions: 2+ nodes transmitting at same time

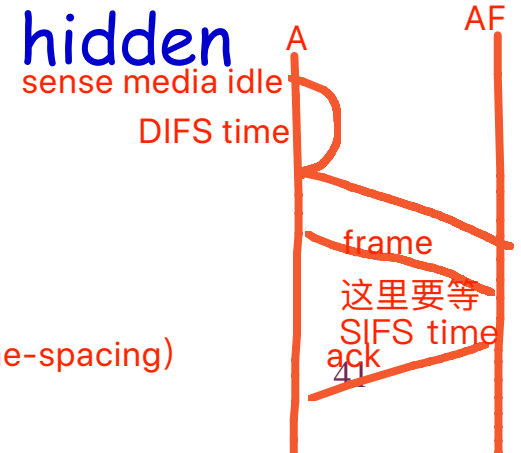
CSMA/CA: collision avoid

- 802.11: CSMA - sense before transmitting
  - Don't collide with other transmissions
- 802.11: No collision detection!

wifi如何知道collision：no response from ap

no looking back：只要传了必须传完

  - Difficult to receive (sense collisions) when transmitting due to weak received signals (fading)
  - Can't sense all collisions in any case: hidden terminal, fading
  - Goal: avoid collisions: CSMA/C(ollision)A(voidance)



in wifi, no frame can be transimitted back-to-back, there must be IFS(inter-frame-spacing)

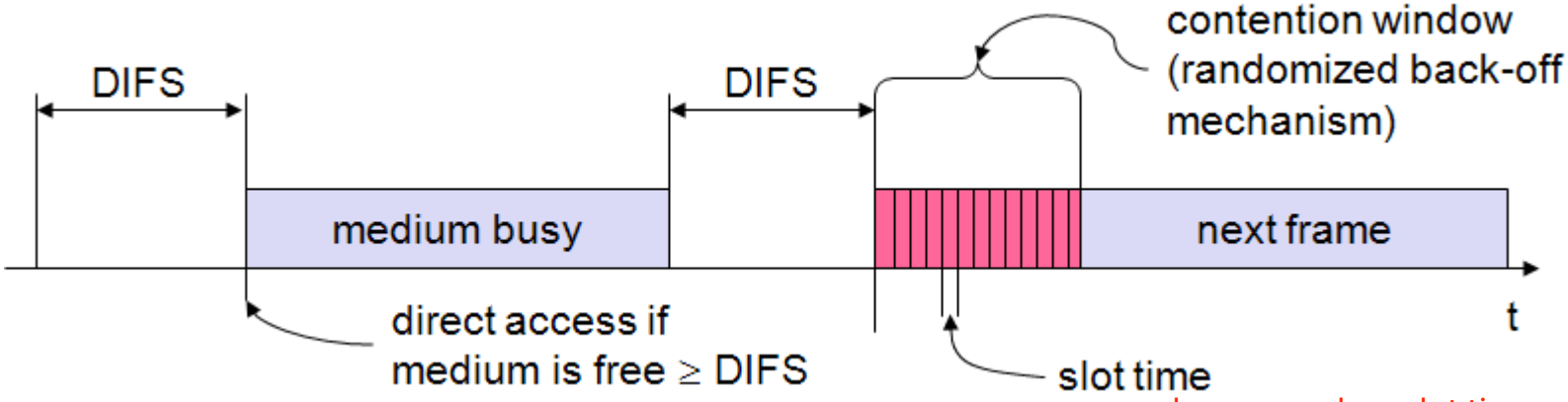
IFS包括：DIFS（distributed IFS）/ SIFS（short IFS）

802.11 MAC Procedures

- Traffic services
  - Asynchronous Data Service (mandatory) – DCF
  - Time-Bounded Service (optional) - PCF
- Access methods
  - DCF CSMA/CA (mandatory)
    - collision avoidance via randomized back-off mechanism
    - ACKs for data frames (not for broadcasts)
  - DCF w/ RTS/CTS (optional)
    - avoids hidden terminal problem
  - PCF (optional)
    - access point polls terminals according to a list

try best to avoid collision

DCF: CSMA/CA



choose random slot time

- 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)

media is idle: counter work;
media is busy: counter freeze

Avoiding Collisions

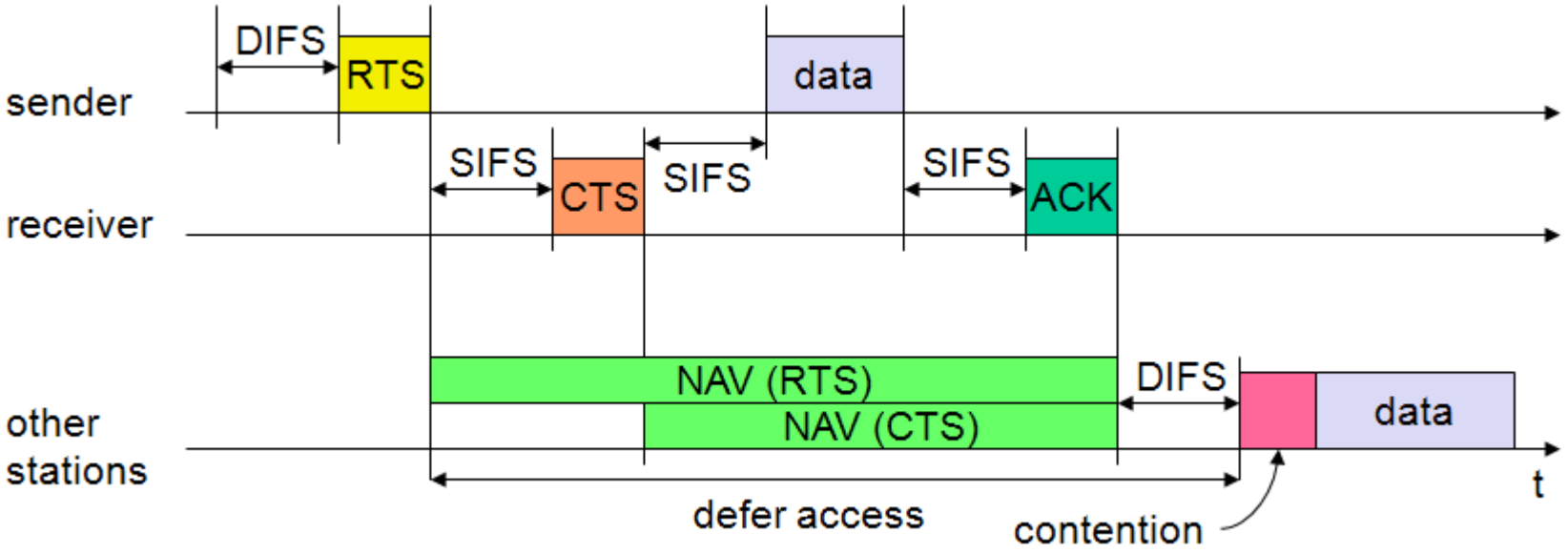
- Idea: allow sender to "reserve" channel rather than random access of data frames: avoid collisions of long data frames
- Sender first transmits small request-to-send (RTS) frames to BS using CSMA
  - RTSs may still collide with each other (but they're short)
- BS broadcasts clear-to-send CTS in response to RTS
- CTS heard by all nodes
  - Sender transmits data frame
  - Other stations defer transmissions

avoid data frame collisions completely using small reservation packets!

optional原因：large overhead

NAV:network access vector

DCF w/RTS & CTS



- Station send RTS with reservation parameter (amount of time the data frame needs the medium) after waiting for DIFS
- 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

一些情况下cts是broadcast的

Collision Avoidance using RTS/CTS

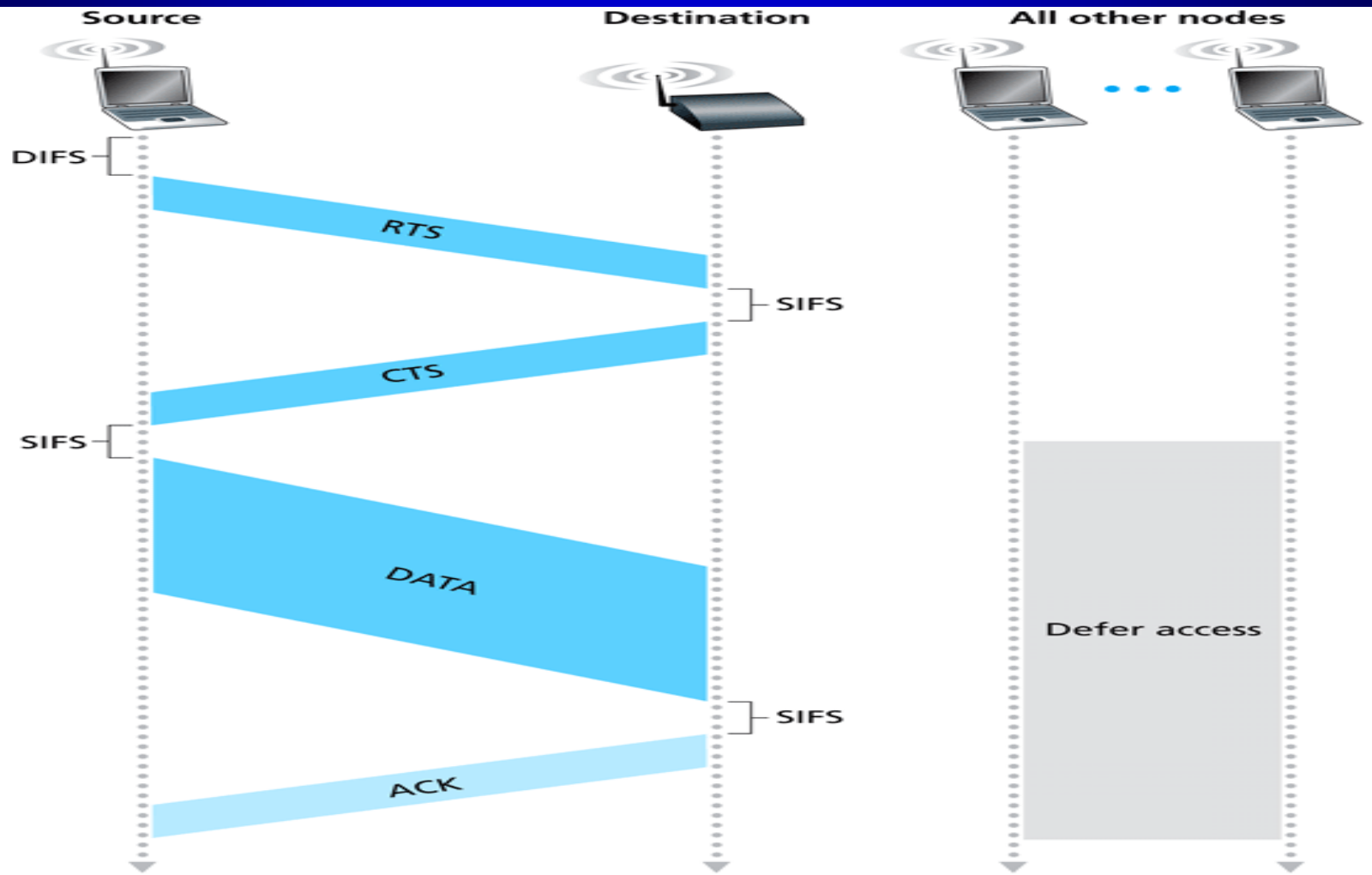
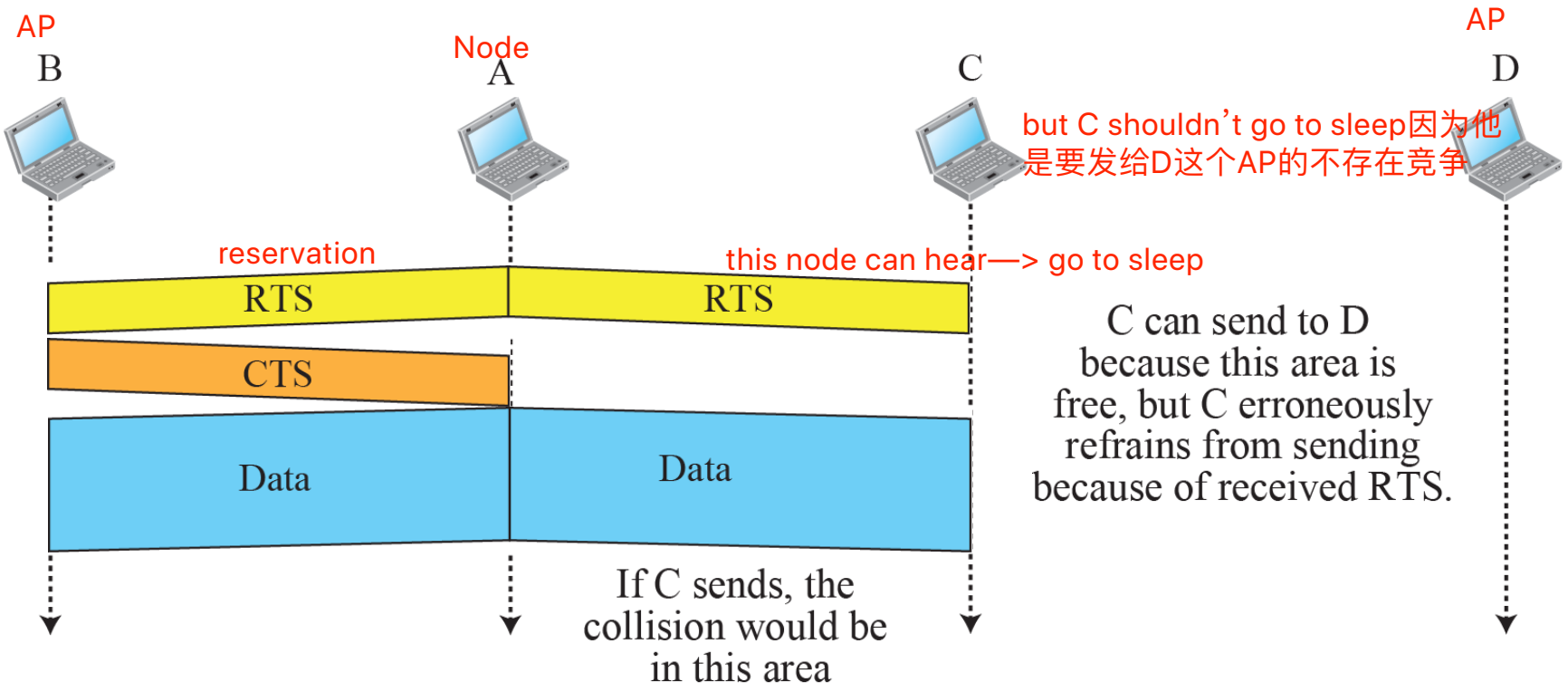


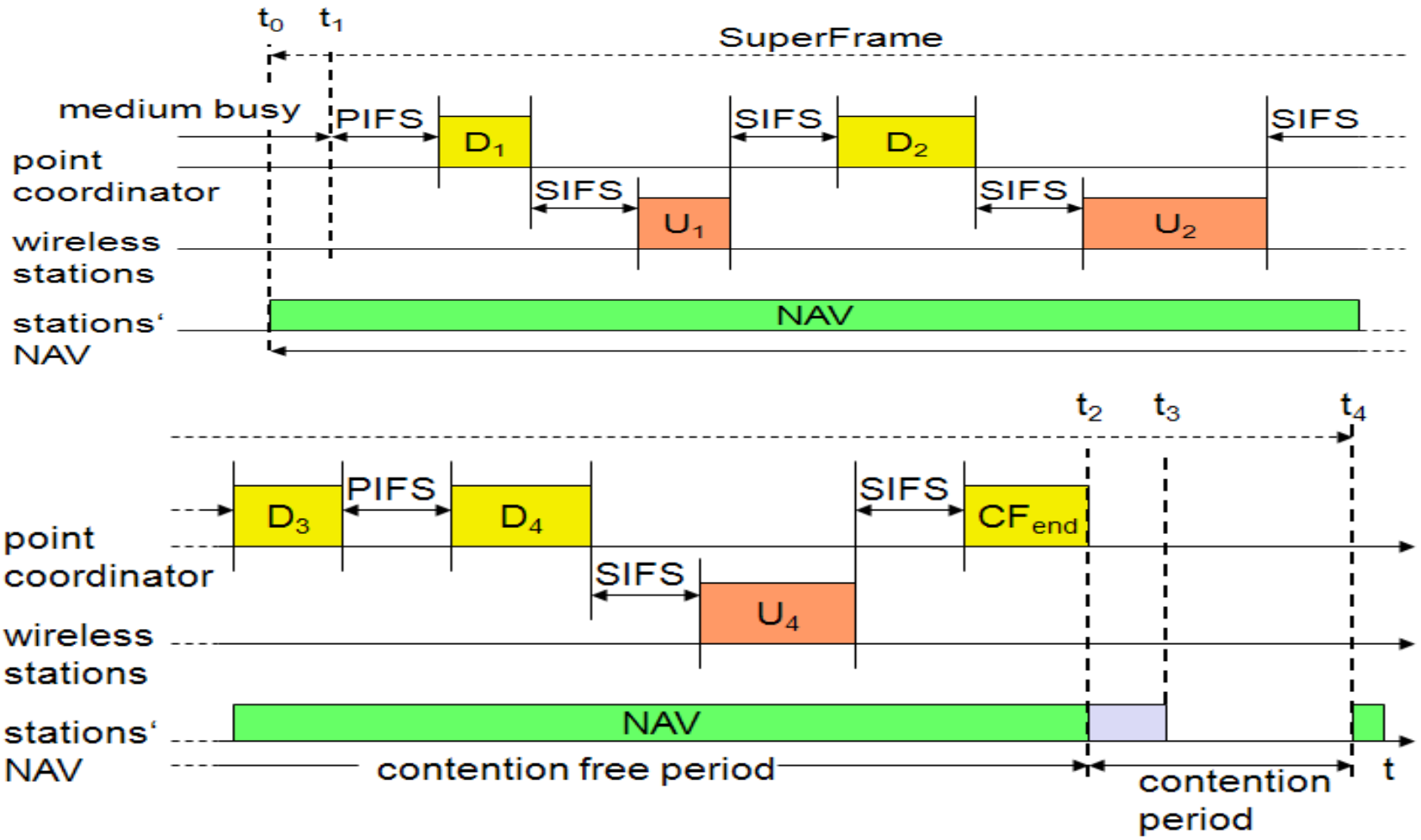
Figure 6.12 ◆ Collision avoidance using the RTS and CTS frames

Exposed Terminal Problem

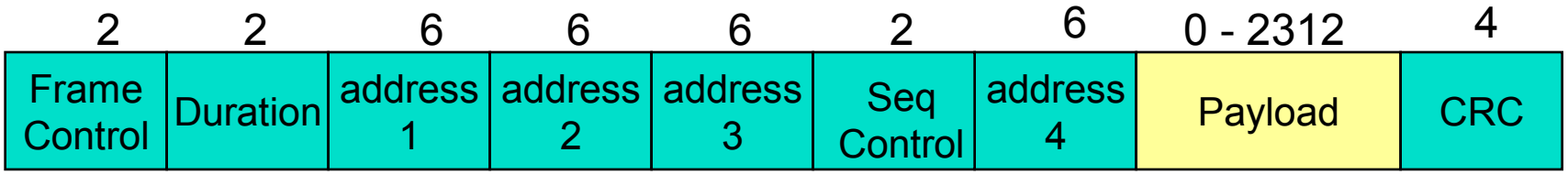


rarely use

802.11 PCF (Point Coordination Function)



IEEE802.11 Frame Structure



next hoop whoever receive the frame
uplink:AP
downlink:your device

Address 1: MAC address of wireless host or AP to receive this frame

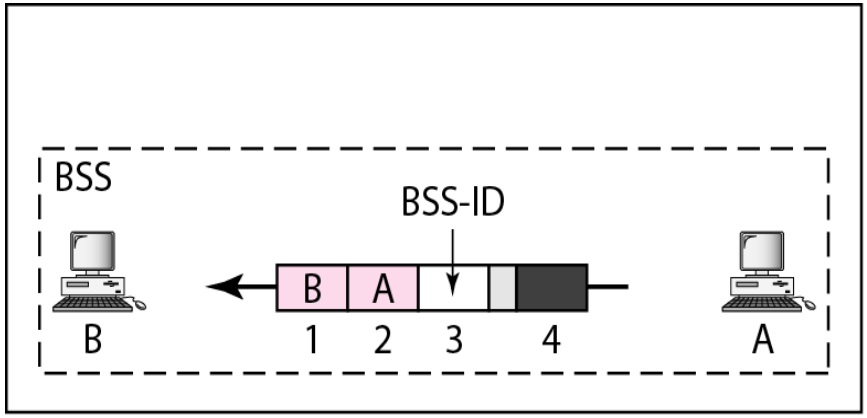
Address 2: MAC address of wireless host or AP transmitting this frame

Address 3: MAC address of router interface to which AP is attached

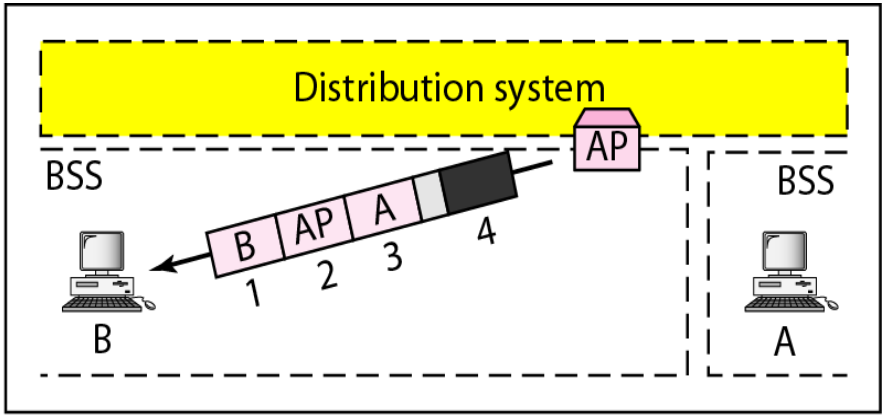
ethernet router

Address 4: used only in ad hoc mode

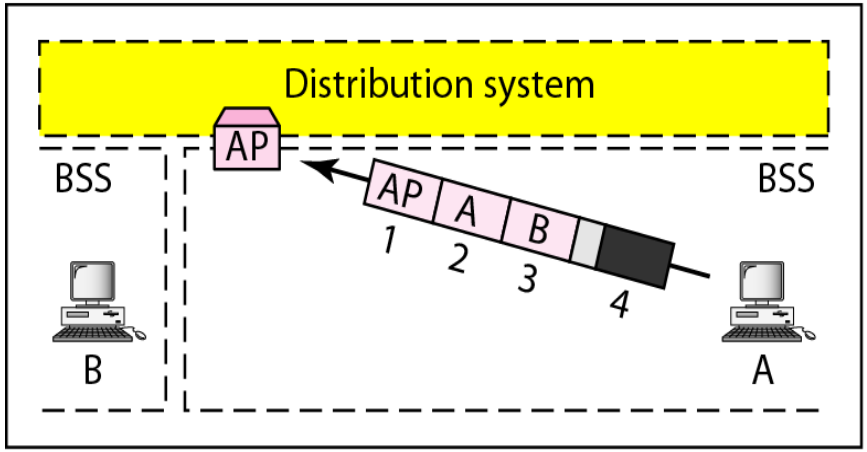
Addressing Mechanisms



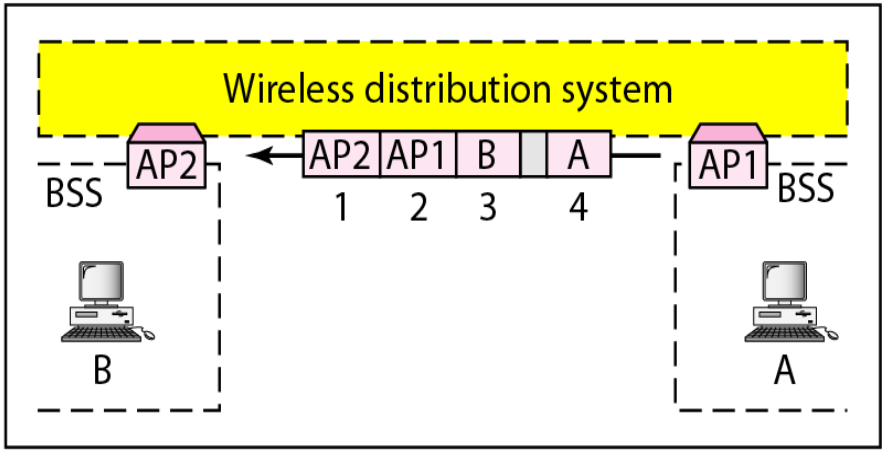
a. Case 1



b. Case 2



c. Case 3



d. Case 4

IEEE802.11 Frame Addressing