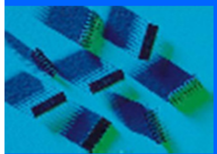


Lecture 5

Medium Access Control (MAC) Protocols

Textbook: Ch.12

We are still in Data Link Layer . . .

Main Topics

- 12.1 Random Access
  - **ALOHA Protocol**
    - **Pure ALOHA and Slotted ALOHA**
  - **CSMA - Carrier Sense Multiple Access**
    - **Non-persistent CSMA**
    - **1-persistent CSMA**
  - **CSMA/CD**
    - **Collision Detection Procedure**
    - **Collision Detection Timing**

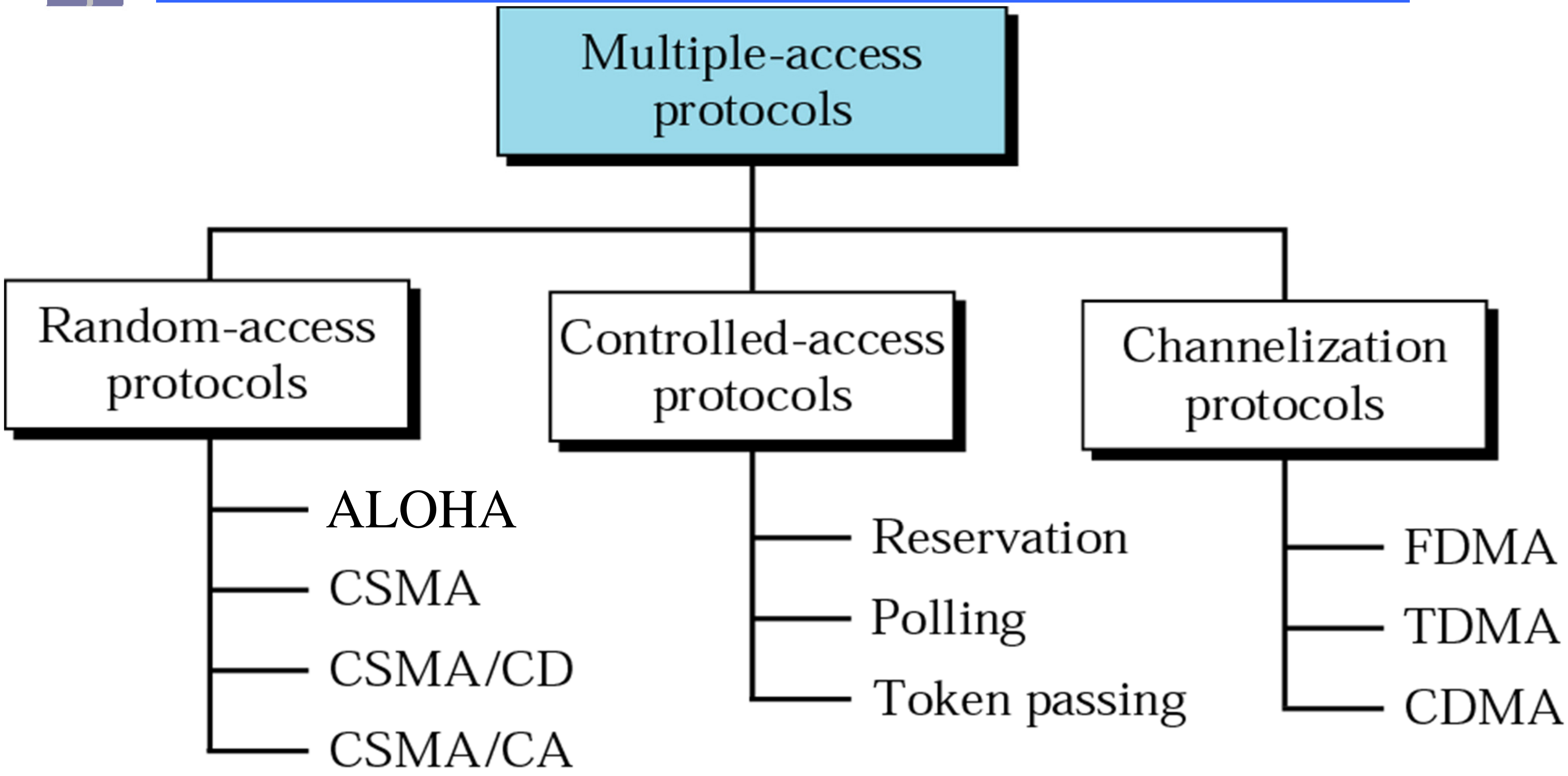
Local Area Network (LAN)

- A network used to interconnect distributed computers located within a single building or localized group of buildings ***in a limited geographic area***
- Wired LAN & wireless LAN
- Classified by
  - Topology
  - Transmission media
  - Multiple Access Control (MAC) protocols

Multiple Access Control Protocols

- The protocols used to determine who can transmit next on a ***multiaccess channel*** (i.e. the network is in a bus topology, usually also a ***broadcast channels***)
- Also called ***media access control protocols***
- A protocol must be used to ensure that the transmission medium is accessed and used in a fair way

Multiple Access Protocols



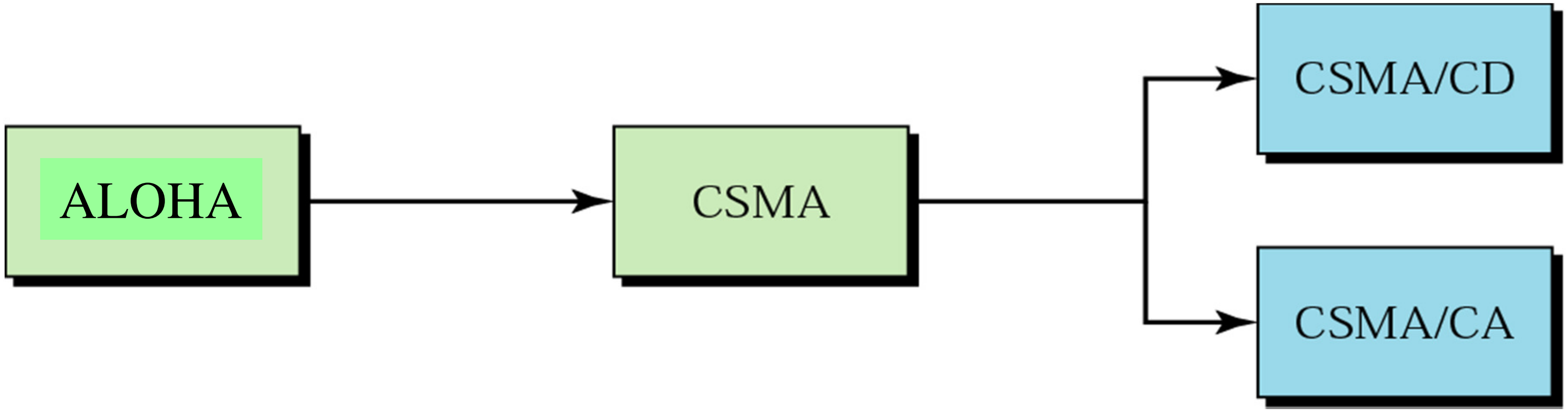
RANDOM ACCESS

*In random-access or contention **no station** is **superior** to another station and none is assigned control over another.*

*At each instance, a station that has data to send uses a procedure defined by the protocol to make a decision on **whether or not to send.***

*This decision depends on the **state** of the medium (idle or busy).*

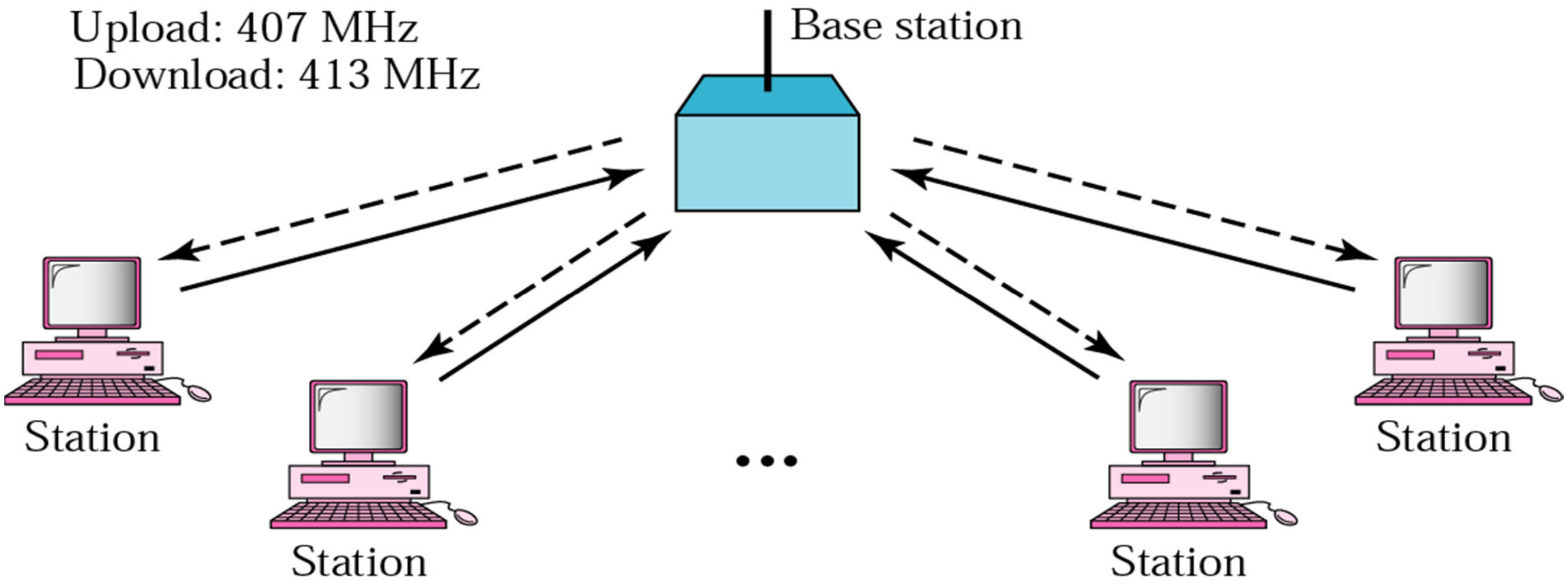
Evolution of random access protocols



If two or more stations send at the same time, there is a **collision** *in the common channel* and all the data frames will be destroyed (since the network is a bus topology)

12.1.1 ALOHA Network

A wireless radio network in a bus topology, developed by University of Hawaii,



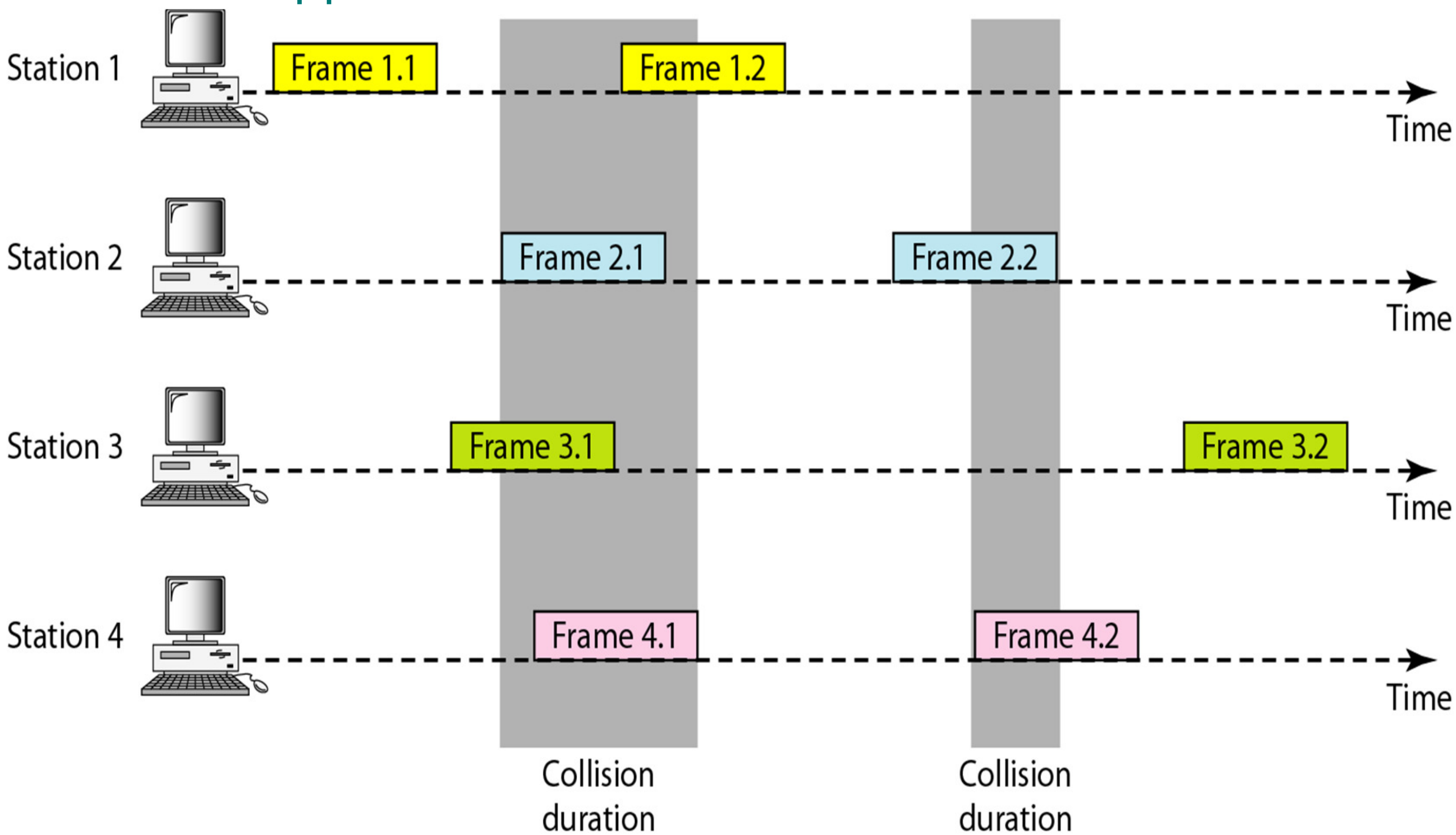
- ALOHA is the earliest random access protocol (in early 1970)

Pure ALOHA
(Random Access Protocol)

- It can be used on any shared medium
- The network is in a bus topology
- Each station makes its own decision
- Transmit whenever the data is ready
- If collided, retry (re-transmit) after a random delay (called ***back-off time***)
- The collision is known by ACK operation; if no ACK receives, then assume collision

Pure ALOHA

- Idea: Each station sends a frame whenever it has a frame to send.
  - What will happen? ➔ Collision



Frames in a pure ALOHA network

Procedure for ALOHA protocol

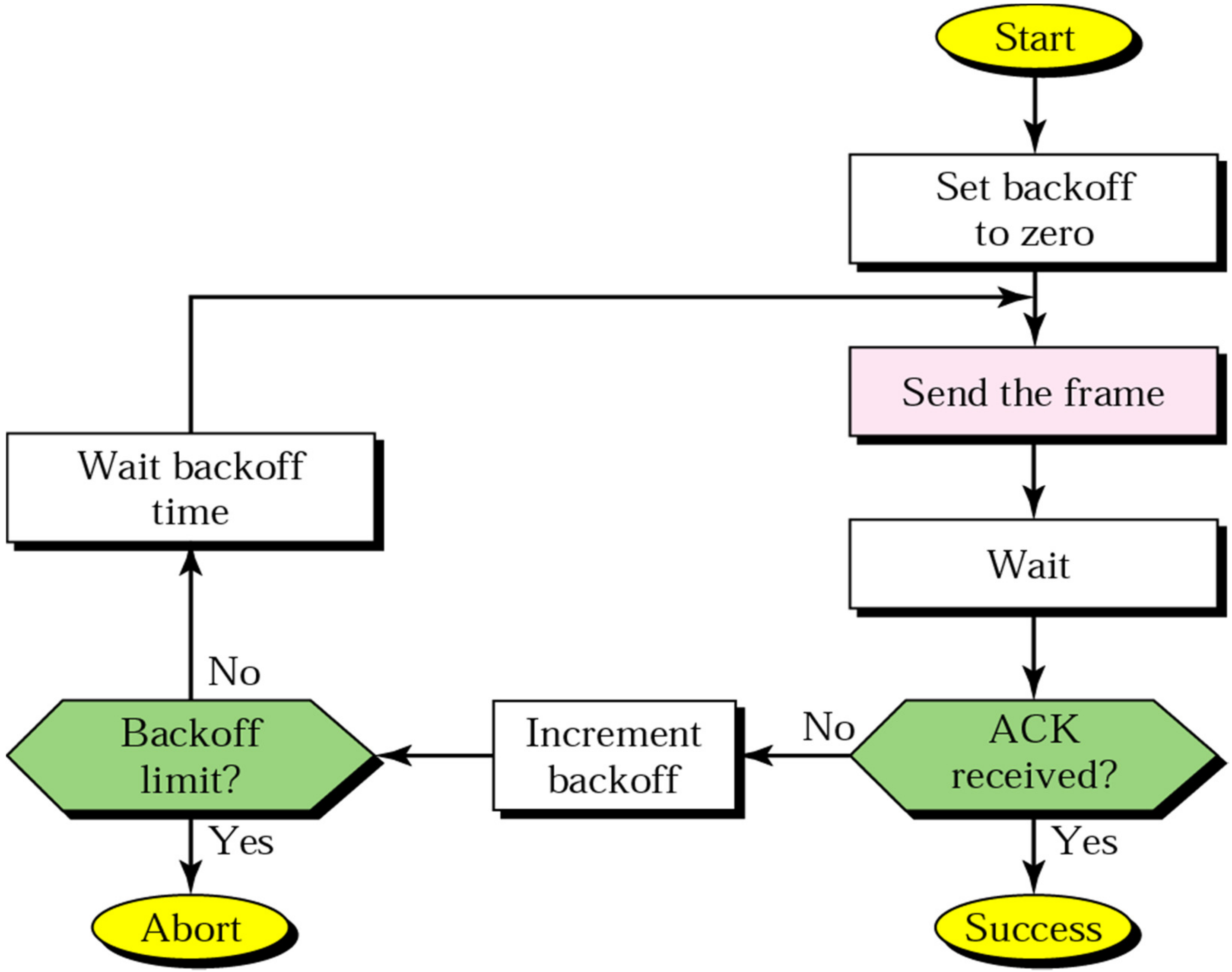
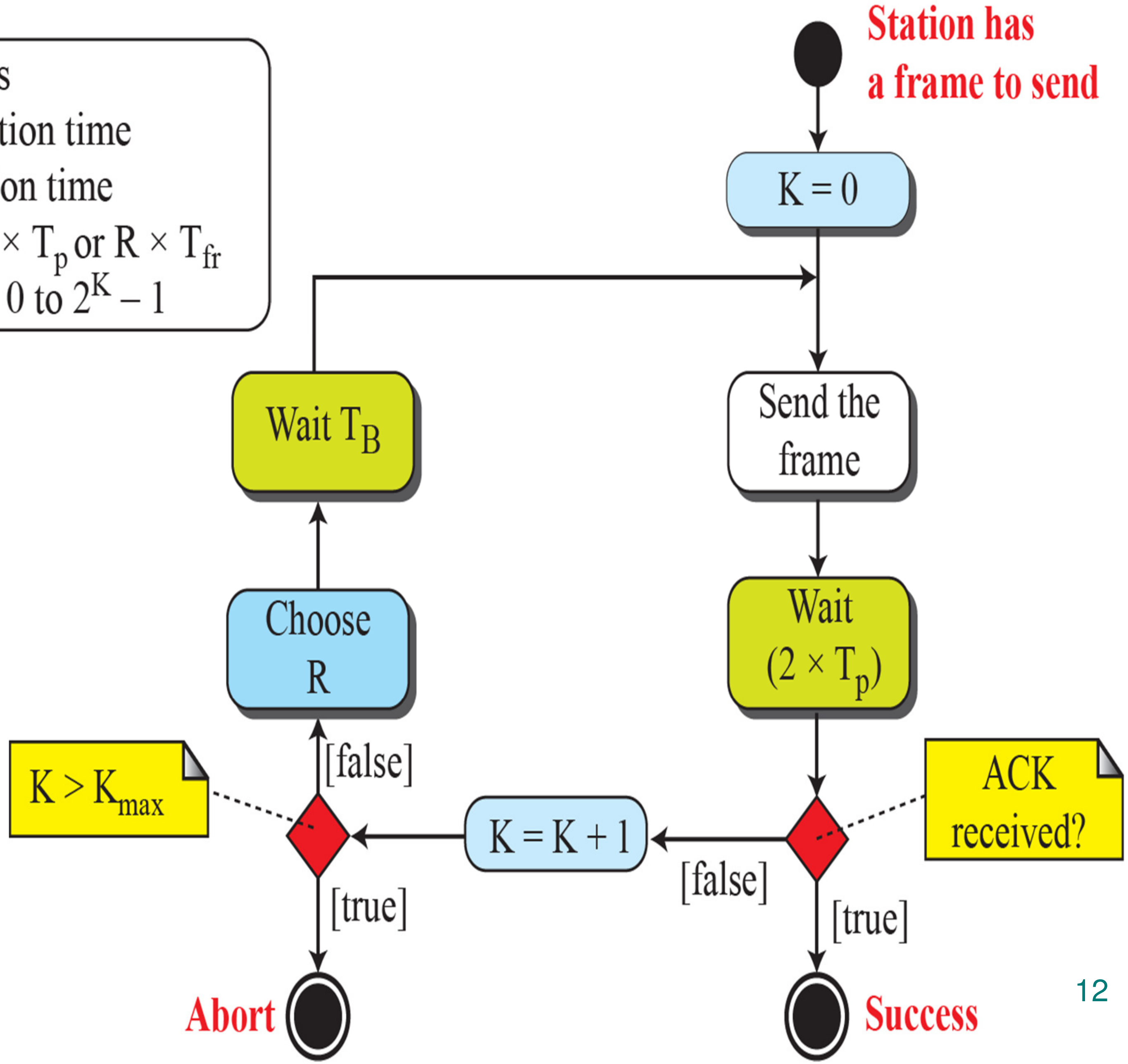


Figure 12.3: Procedure for pure ALOHA protocol

Legend

K : Number of attempts
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 $2^K - 1$



Example 12. 1

The stations on a wireless ALOHA network are a maximum of 600 km apart.

If we assume that signals propagate at 3×10^8 m/s,

we find $T_p = (600 \times 10^3) / (3 \times 10^8) = 2$ ms.

For $K = 2$, the range of R is $\{0, 1, 2, 3\}$.

This means that T_B can be 0, 2, 4, or 6 ms, based on the outcome of the random variable R.

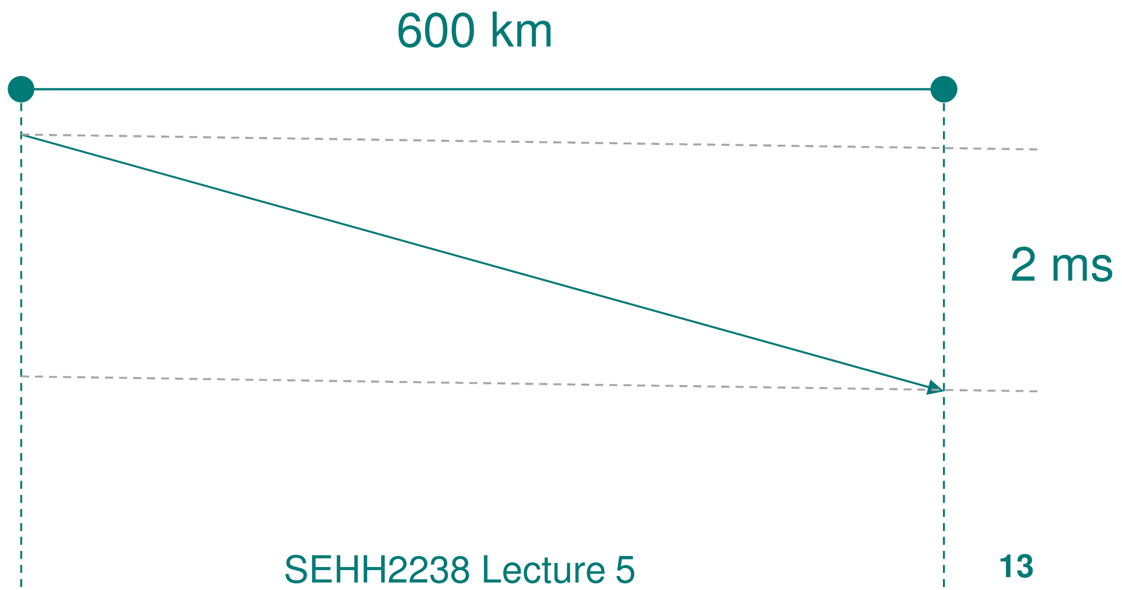
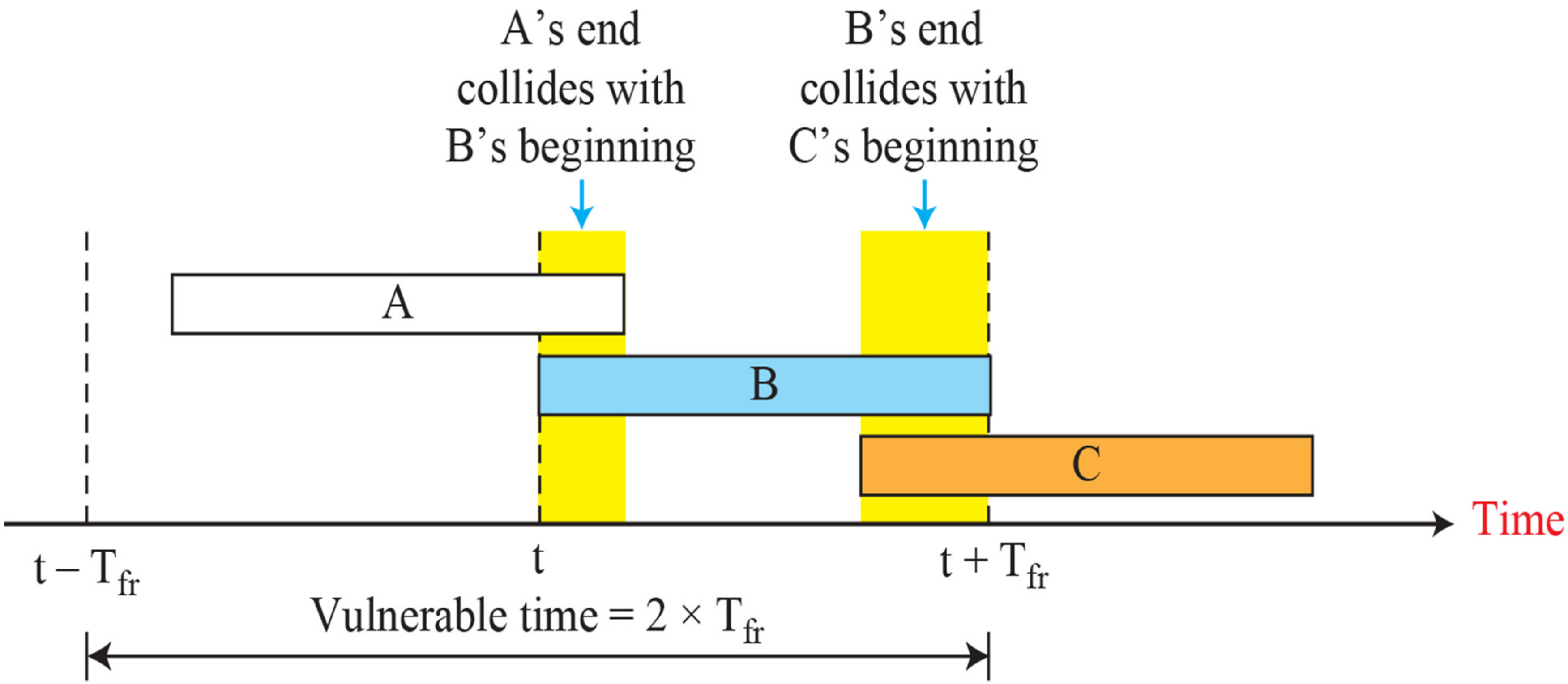


Figure 12.4 *Vulnerable time for pure ALOHA protocol*

The length of time in which collisions may occur

T_{fr} – frame size in seconds



Example 12.2

A pure ALOHA network transmits 200-bit frames on a shared channel of 200 kbps. What is the requirement to make this frame collision-free?

Solution

Average frame transmission time T_{fr} is 200 bits/200 kbps or 1 ms. The vulnerable time is 2×1 ms = 2 ms. This means no station should send later than 1 ms before this station starts transmission and no station should start sending during the period (1 ms) that this station is sending.

Throughput

- Throughput is **the portion of data frames reaching the destination *successfully***
- *In pure Aloha, the maximum throughput is only 0.18*

Proof (optional, could be skipped):

It is known that the average number of ***successful*** transmission for pure Aloha is

$$\mathbf{S = G \times e^{-2G}}$$

- where G is the average number of frames generated by the system in one frame transmission time (may be collided)
- by differentiation, we can find that S_{max} occurs at G =1/2 and the corresponding S_{max} is 0.18

Example 12. 3

A pure ALOHA network transmits 200-bit frames on a shared channel of 200 kbps. What is the throughput if the system (all stations together) produces

a. 1000 frames per second?

b. 500 frames per second?

c. 250 frames per second?

transfer frames per second ==> frames per frame time

Solution

The frame transmission time is 200/200 kbps or 1 ms.

a. If the system creates 1000 frames per second, or 1 frame per millisecond, then G = 1. In this case $S = G \times e^{-2G} = 0.135$ (13.5 percent). This means that the throughput is $1000 \times 0.135 = 135$ frames. Only 135 frames out of 1000 will probably survive.

Example 12. 3 (continued)

b. If the system creates 500 frames per second, or 1/2 frames per millisecond, then $G = 1/2$. In this case $S = G \times e^{-2G} = 0.184$ (18.4 percent). This means that the throughput is $500 \times 0.184 = 92$ and that only 92 frames out of 500 will probably survive. Note that this is the maximum throughput case, percentage-wise.

c. If the system creates 250 frames per second, or 1/4 frames per millisecond, then $G = 1/4$. In this case $S = G \times e^{-2G} = 0.152$ (15.2 percent). This means that the throughput is $250 \times 0.152 = 38$. Only 38 frames out of 250 will probably survive

Slotted ALOHA

- Adopt the same fixed packet length (data frame length) for all stations
- Divide time into discrete intervals (**slots**) of duration equals to the packet length (in terms of transmission time)
- All stations follow the same synchronized time system
- Transmit only at the beginning of the next time slot
- If collided, retry after a random delay
- *Maximum throughput is doubled to 0.36*

Figure 12.5 *Frames in a slotted ALOHA network*

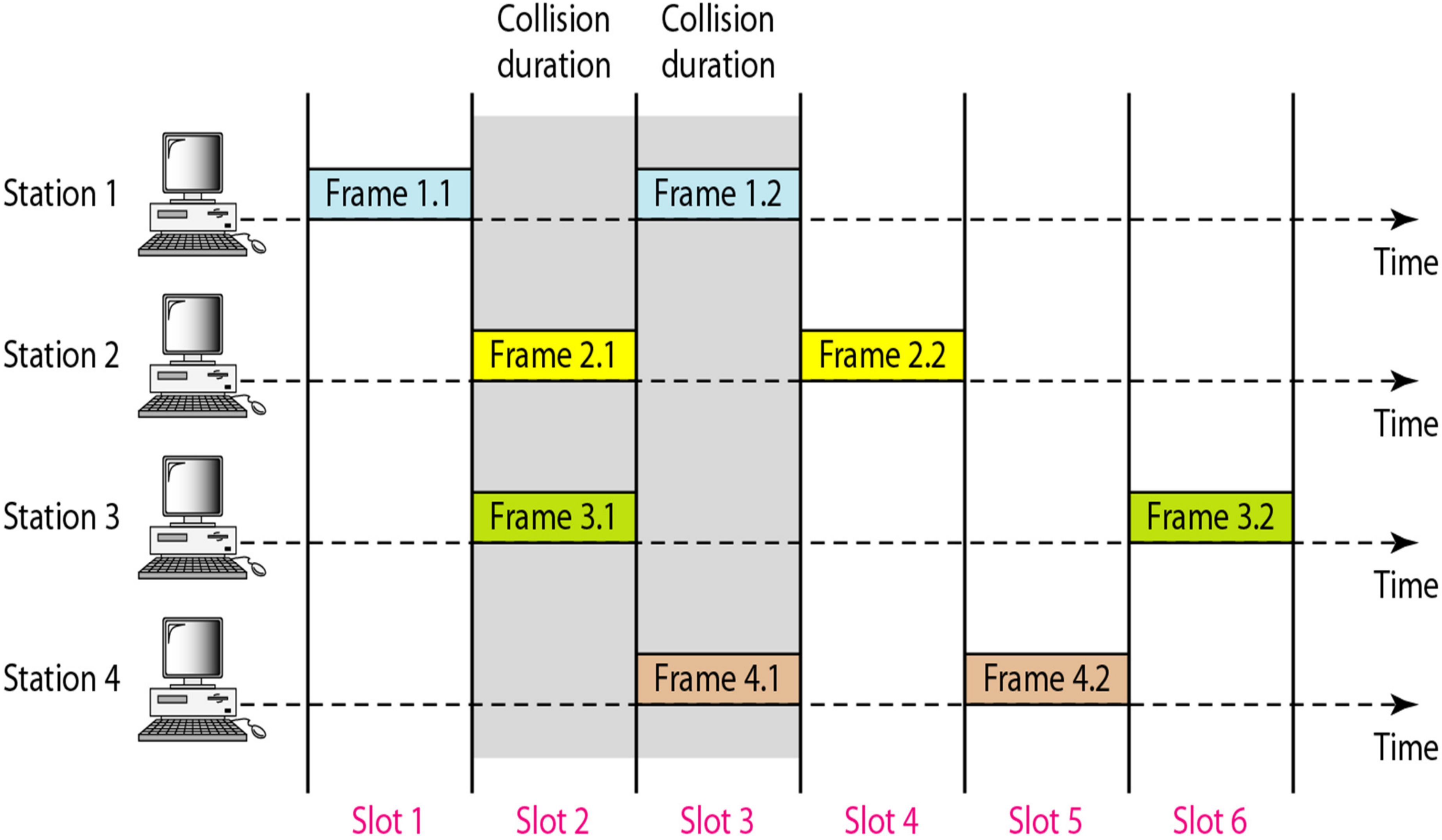
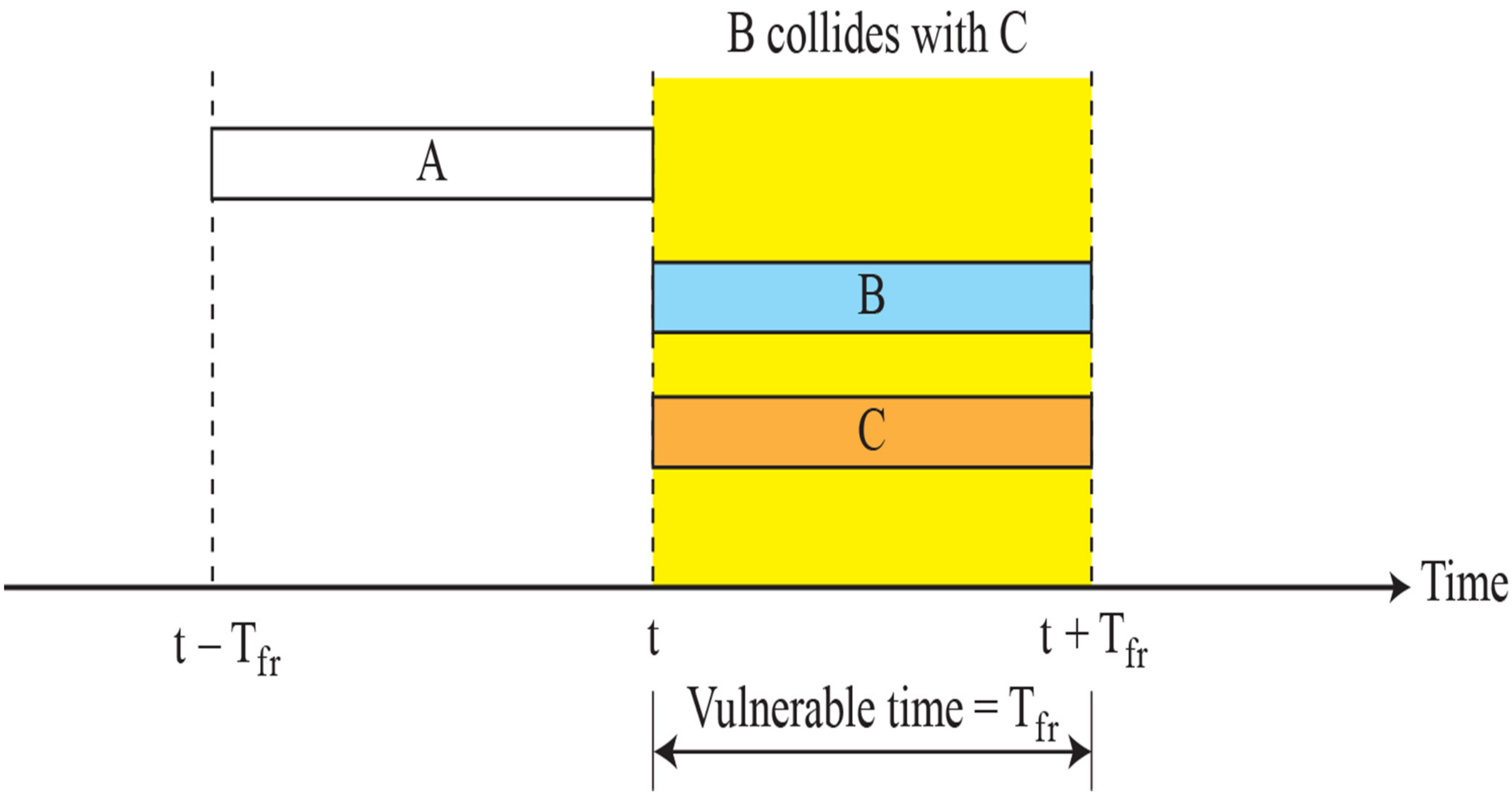


Figure 12.6 *Vulnerable time for slotted ALOHA protocol*



12.1.2 Carrier Sense Multiple Access (CSMA)

- Allow variable packet length
- Listen to the channel (sense the carrier) before transmission
- If the channel is idle then transmit *otherwise*
  - **non-persistent CSMA**

    - (if channel is busy) retry after a random delay
  - **1-persistent CSMA**

    - (if channel is busy) wait until the channel becomes idle and then transmit
- If collided, retry after a random delay

Collision in CSMA

(The collision is known by receiving and checking the ACK)

The network should be a bus topology

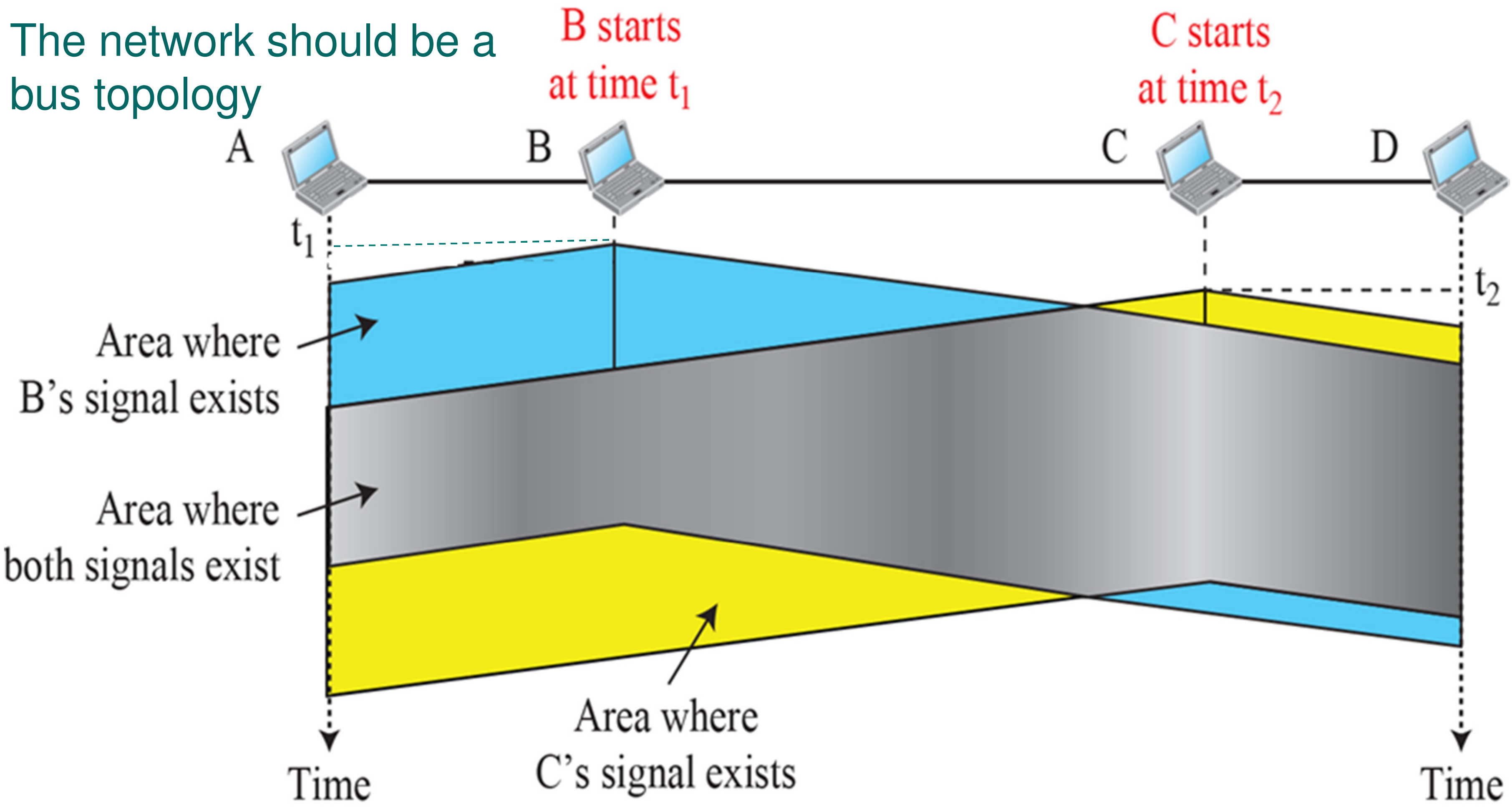
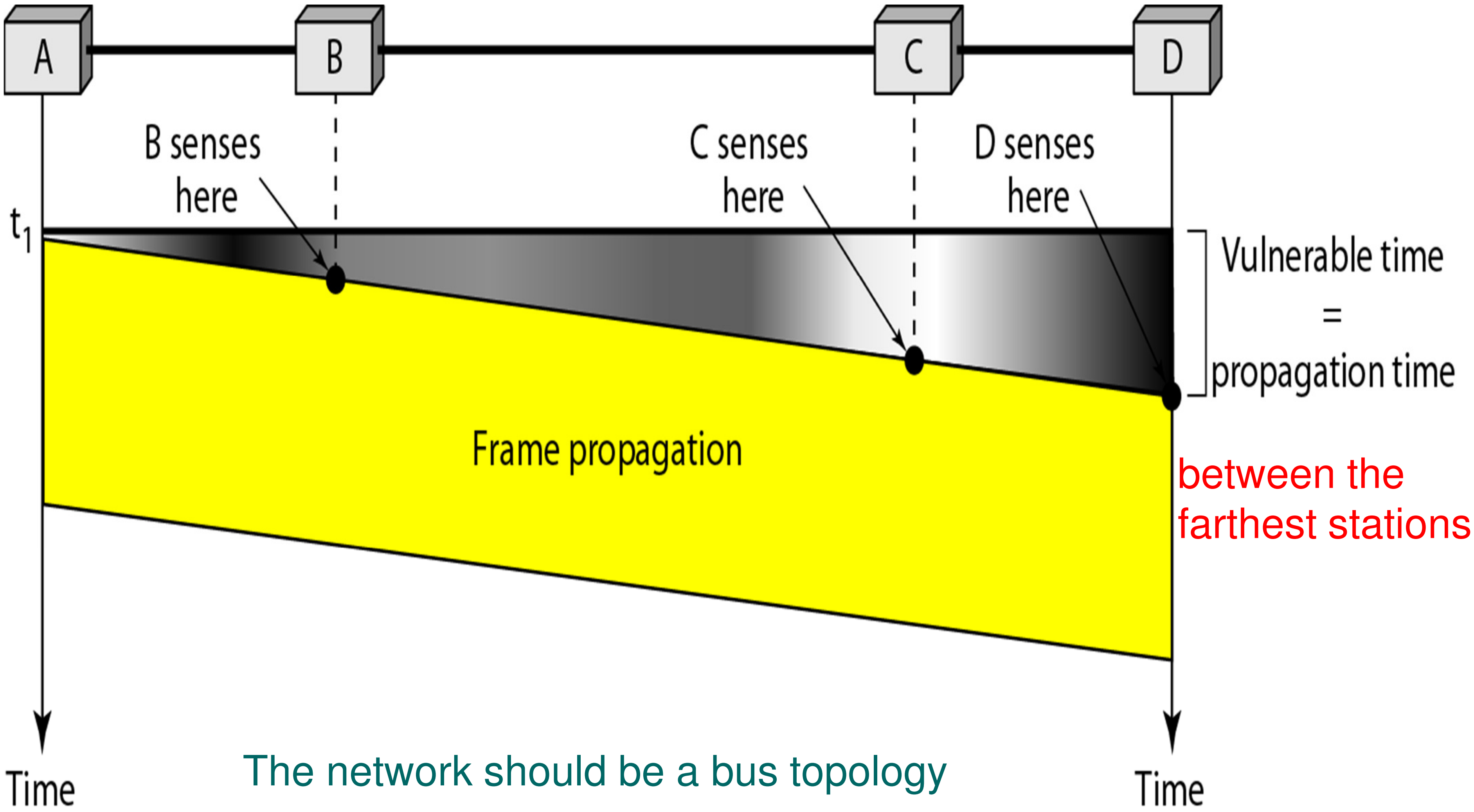


Figure 12.8 *Vulnerable time in CSMA*



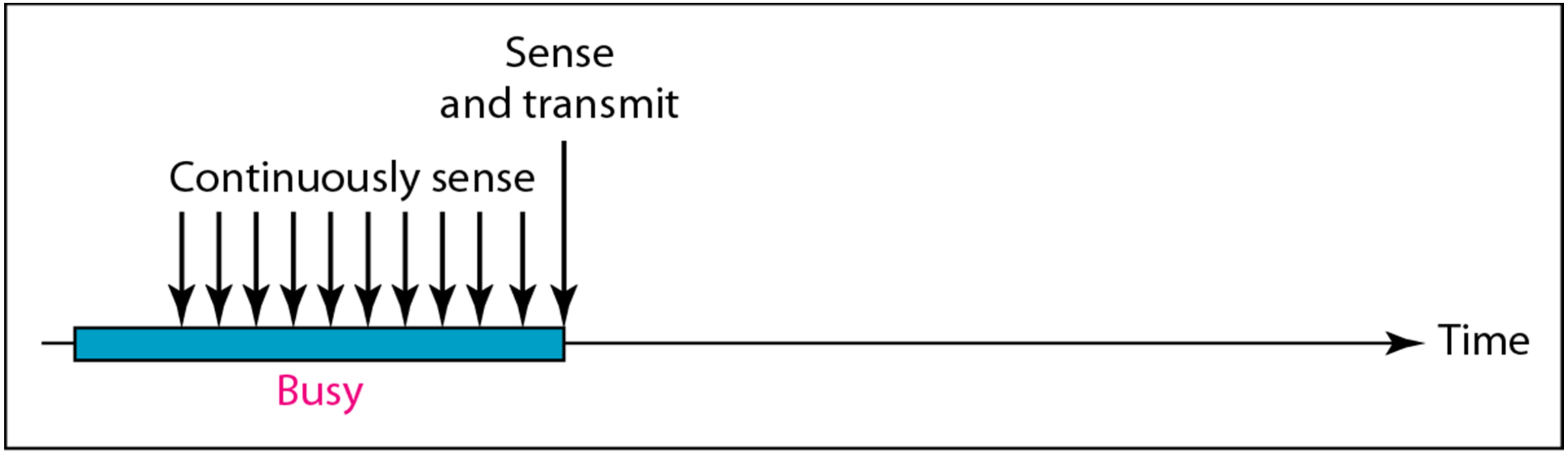
between the farthest stations

The network should be a bus topology

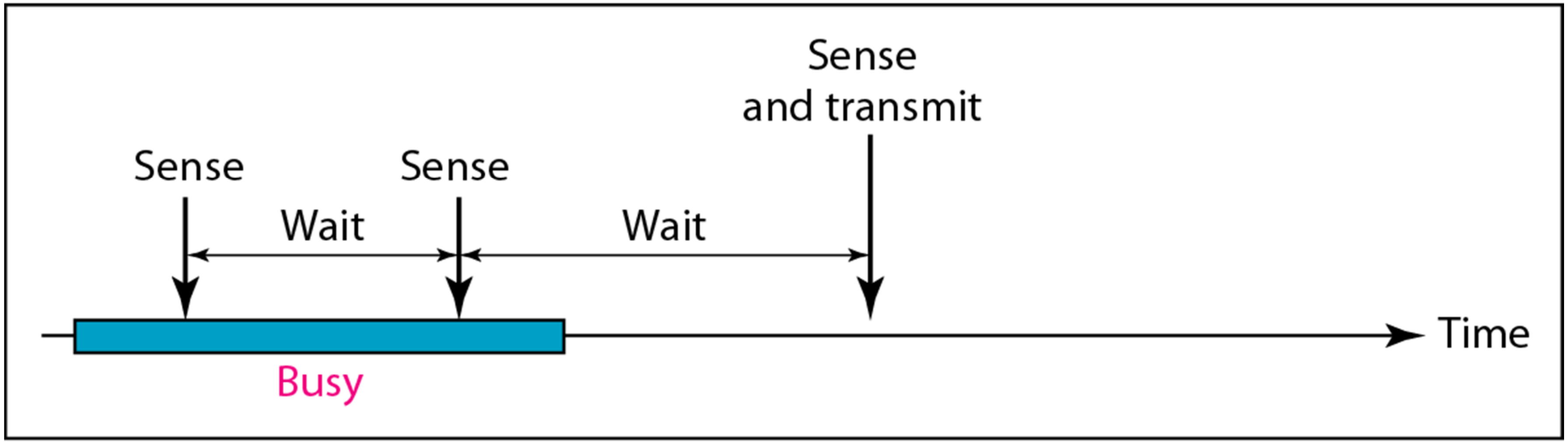
Persistence Methods

- Persistence method defines the procedure for a station that senses a busy medium
- **non-persistent CSMA**
- **1-persistent CSMA**
- **p-persistent CSMA (skip)**

Figure 12.9 *Behavior of persistence methods*

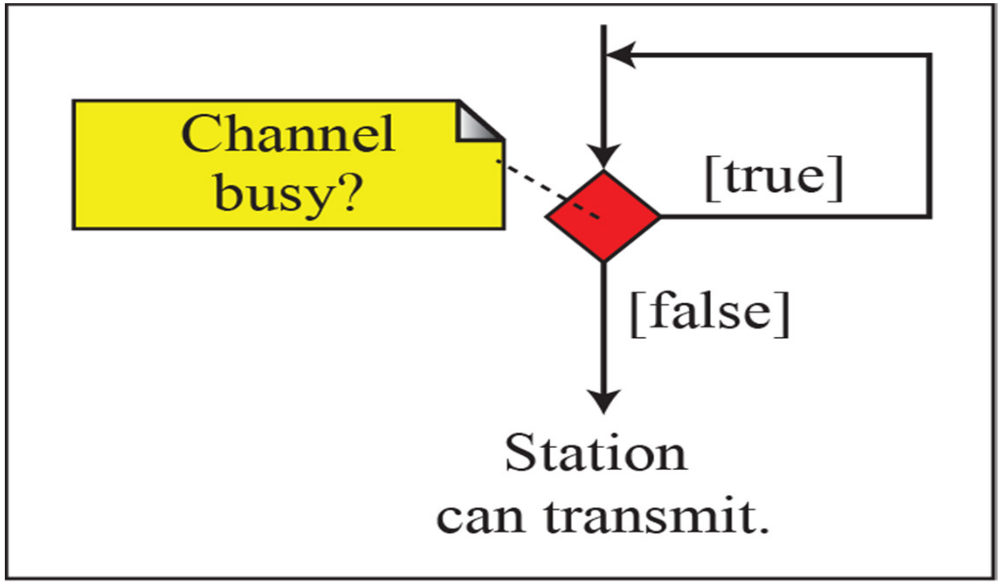


a. 1-persistent

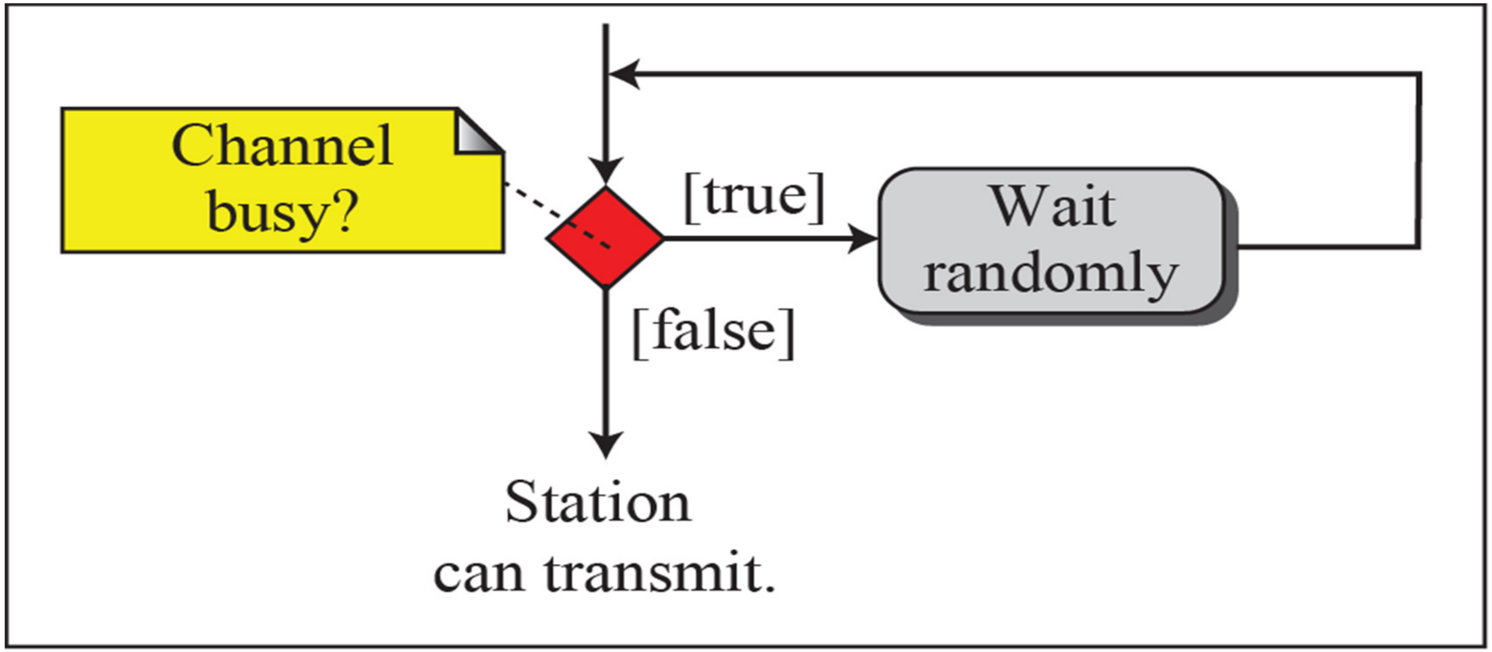


b. Nonpersistent

Figure 12.10: Flow diagram for persistence methods



a. 1-persistent



b. Nonpersistent

Non-persistent CSMA

- A station senses the channel when it has a frame ready to send
- If the channel is idle, the station sends the frame immediately
- If the channel is busy, it waits a random period of time and senses the channel again (and repeat the process)
- If collided, retry after a random delay

1-Persistent CSMA

- A station senses the channel when it has a frame ready to send
- If the channel is busy, the station senses the channel again and again until the channel becomes idle
- When the channel is idle, the station sends the frame immediately
- If collided, retry after a random delay

12.1.3 CSMA/CD Protocol

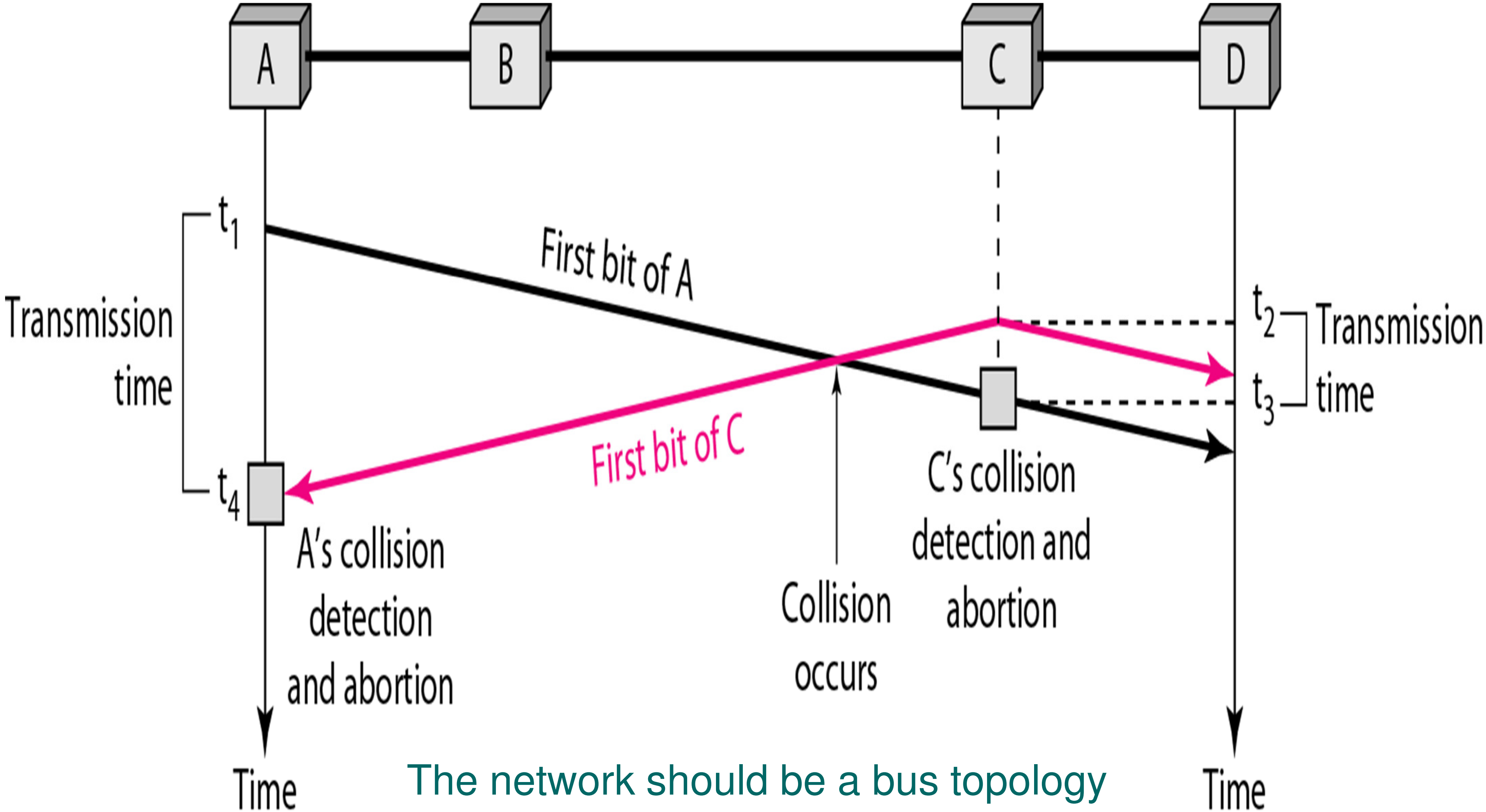
- Carrier Sense Multiple Access with Collision Detection
- Listen *before & while* transmission
- Before transmission, the source station first listen to the channel
- If the channel is idle, transmit
- If collided, retry after a random delay
- What is more …

Collision Detection in CSMA/CD

- It is possible that 2 stations detect the channel idle at the same time and start transmission simultaneously and hence data collided
- *To check whether collision occurs*, the station *simultaneously monitors* the data signal actually present on the channel *when transmitting* a frame
- *If transmitted & monitored signals are different then collision detected (CD).* The station then *stops* transmitting the current frame *immediately*

Collision Detection

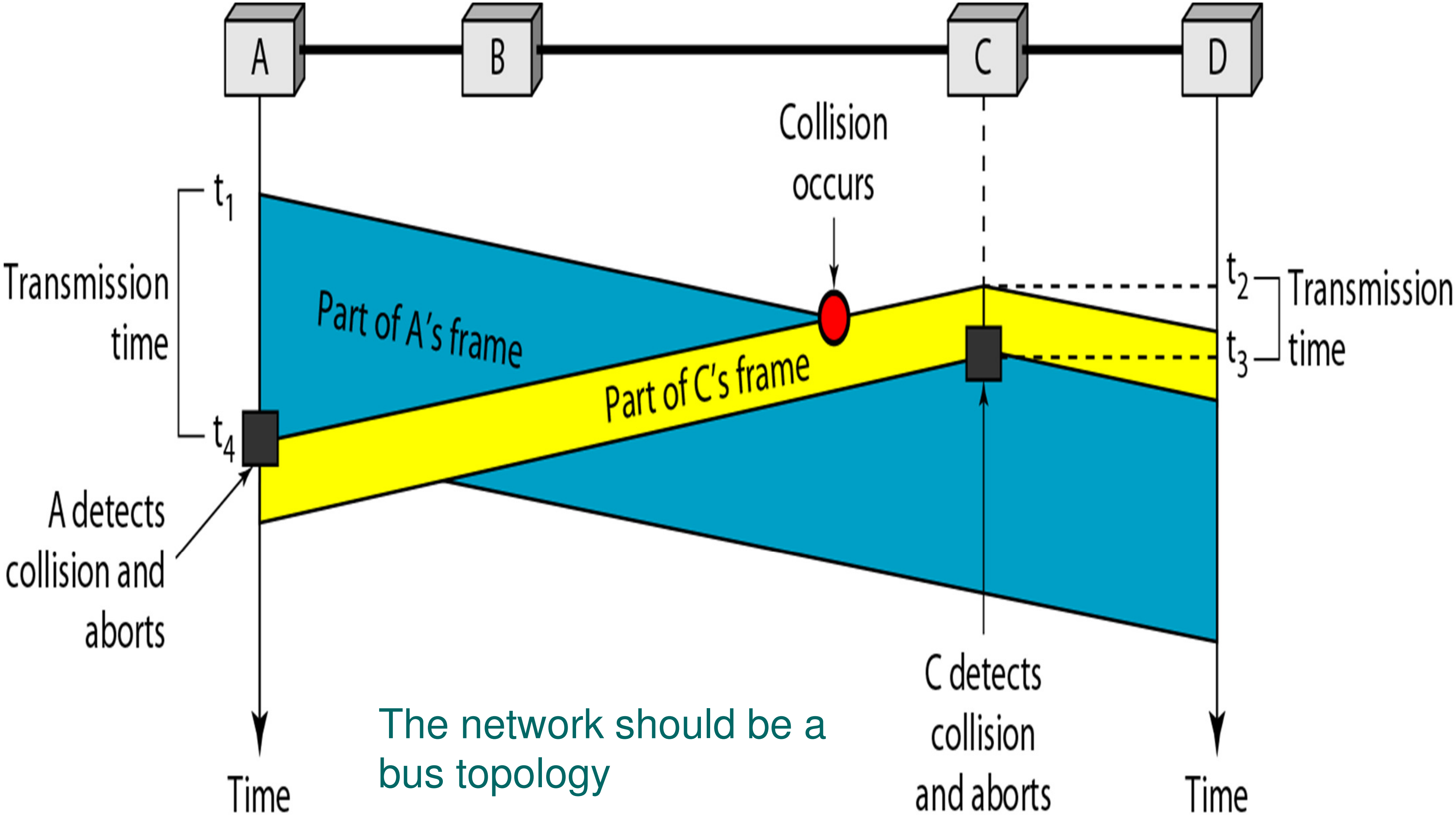
Figure 12.11 ***Collision of the first bit in CSMA/CD***



The network should be a bus topology

Collision Detection

Figure 12.12 ***Collision and abortion in CSMA/CD***



The network should be a bus topology

CSMA/CD (Cont.)

- To tell other stations that collision has occurred, the station continues to send a random bit pattern (known as **jam sequence/signal**) for a short period of time before stopping transmission
- The stations involved then wait for a random delay (**the back-off time**) before trying to retransmit the affected frames (i.e. those collided)
- For 1-persistent method the max throughput of using CSMA/CD is around 0.5
- For non-persistent method, the max throughput of CSMA/CD can go up to 0.9

CSMA/CD procedure -Summary

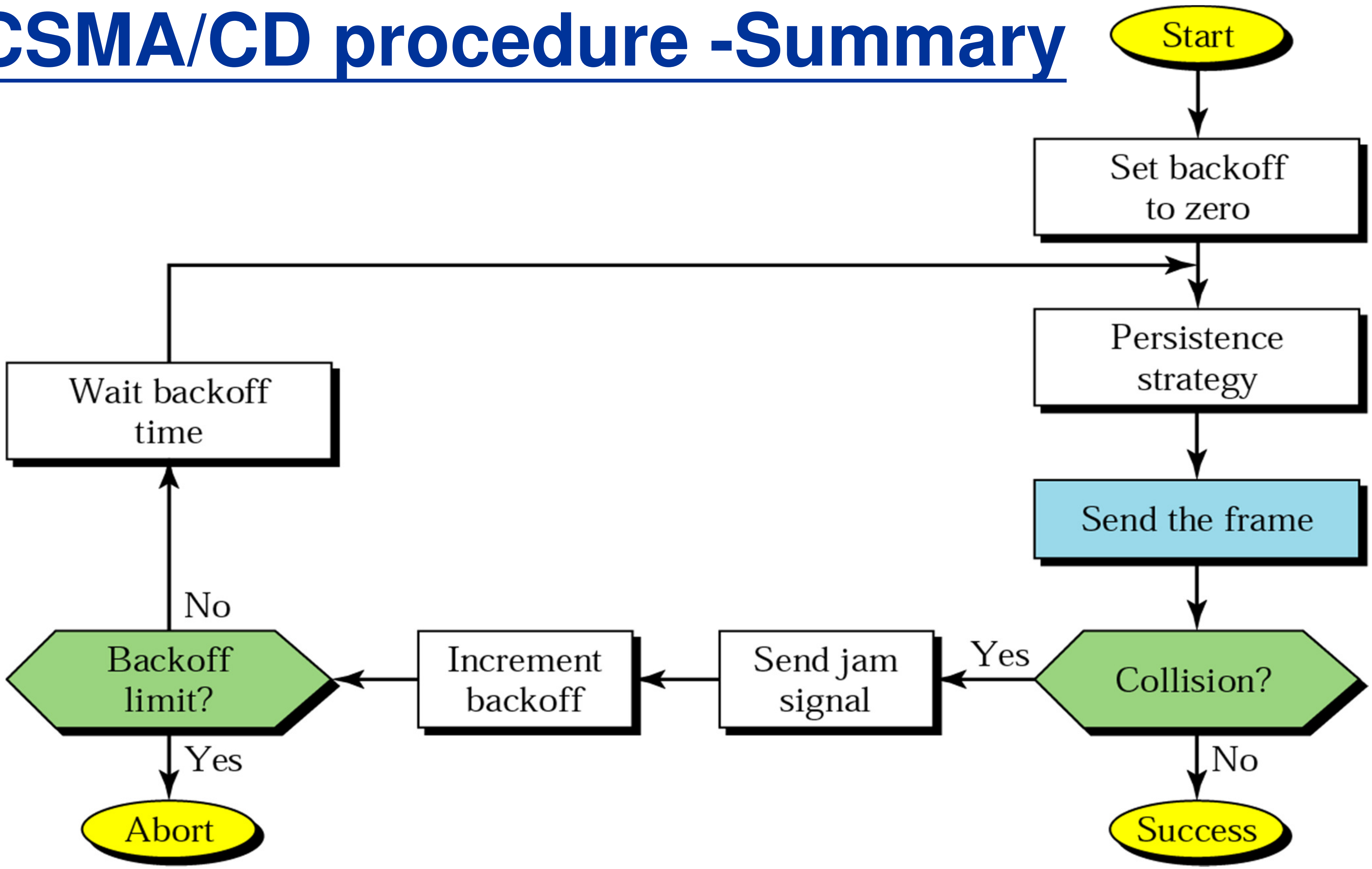


Fig12.13 Flow diagram for the CSMA/CD

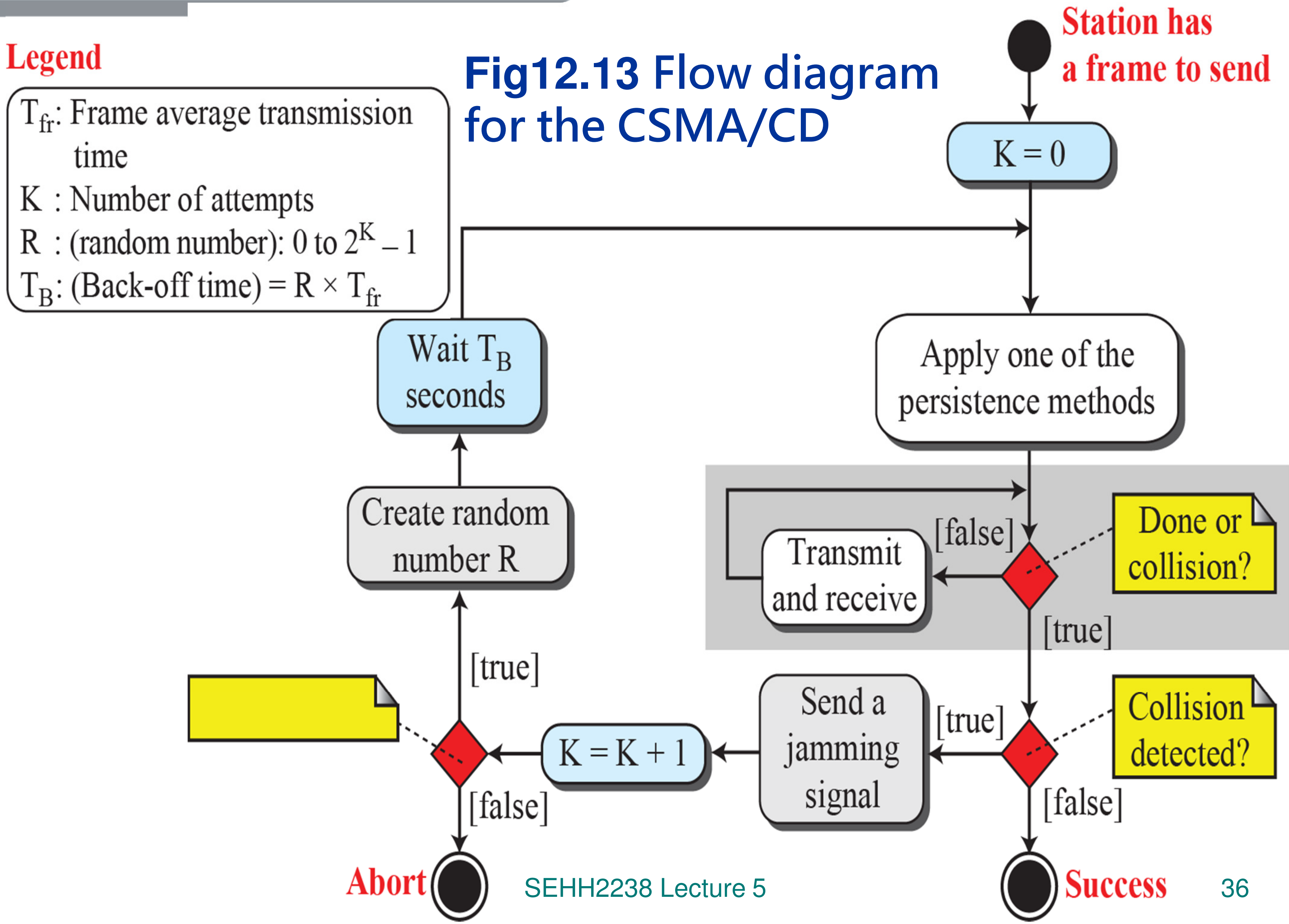
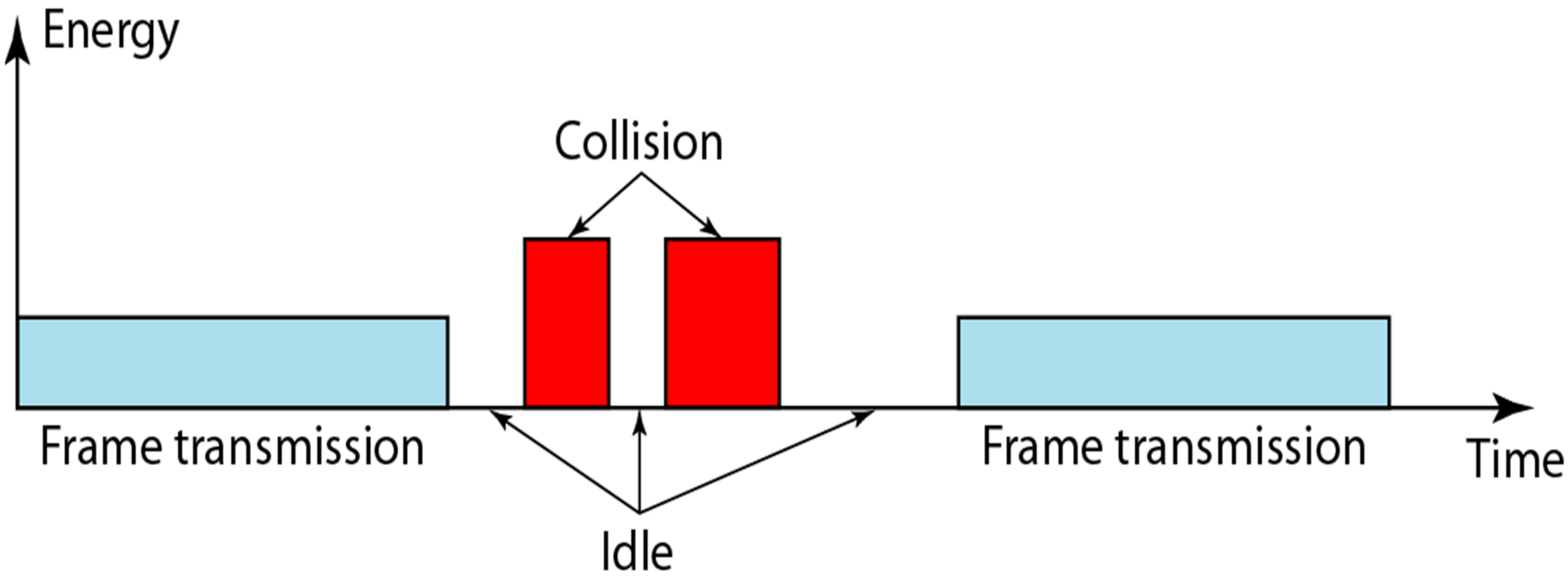


Figure 12.14 *Energy level during transmission, idleness, or collision*



A station can also monitor the energy level to determine the channel is idle, busy, or in collision

Time for detecting collision

- T_p is the time for a signal to propagate between the ***farthest*** stations
- In the ***worst case*** a station cannot be sure that it has seized the channel until it has transmitted for $2T_p$ without hearing a collision
- Therefore the longest time to detect collision is **the maximum round trip delay = $2T_p$**
- **$2T_p$** is also the minimum frame size (transmission time) required for proper operation of CSMA/CD

Example 12.5

A network using CSMA/CD has a bandwidth of 10 Mbps. If the maximum propagation time (including the delays in the devices and ignoring the time needed to send a jamming signal) is 25.6 μs, what is the minimum size of the frame?

Solution

- The frame transmission time is $T_{fr} = 2 \times T_p = 51.2$ μs.
- This means, in the worst case, a station needs to transmit for a period of 51.2 μs to detect the collision.
- The minimum size of the frame is 10 Mbps × 51.2 μs = 512 bits or 64 bytes.
- This is actually the minimum size of the frame for ***Standard Ethernet***.

Back-off Time (optional, skip)

- How much is enough?
- Simplest: just double the back-off time if collide again
- Exponential back-off
  - In K^{th} attempt,
  - the station waits a random amount of time between: **0 to $(2^K - 1) \times T_{fr}$**
  - where T_{fr} is the average frame transmission time
- Back-off Limit
  - If the number of retry exceeds the pre-set limit in back-off (usually 15), the station has tired enough and abort the procedure

Summary

- MAC protocols to be use in a bus channel
  - Pure ALOHA – max throughput 0.18
  - Slotted ALOHA – max throughput 0.36
  - CSMA - Carrier Sense Multiple Access
    - Listen before transmission
  - 1-persisten CSMA/CD – max throughput ≈ 0.5

- All – If collided, retry after a random delay

- **Revision Quiz**
  - http://highered.mheducation.com/sites/0073376221/student_view0/chapter12/quizzes.html