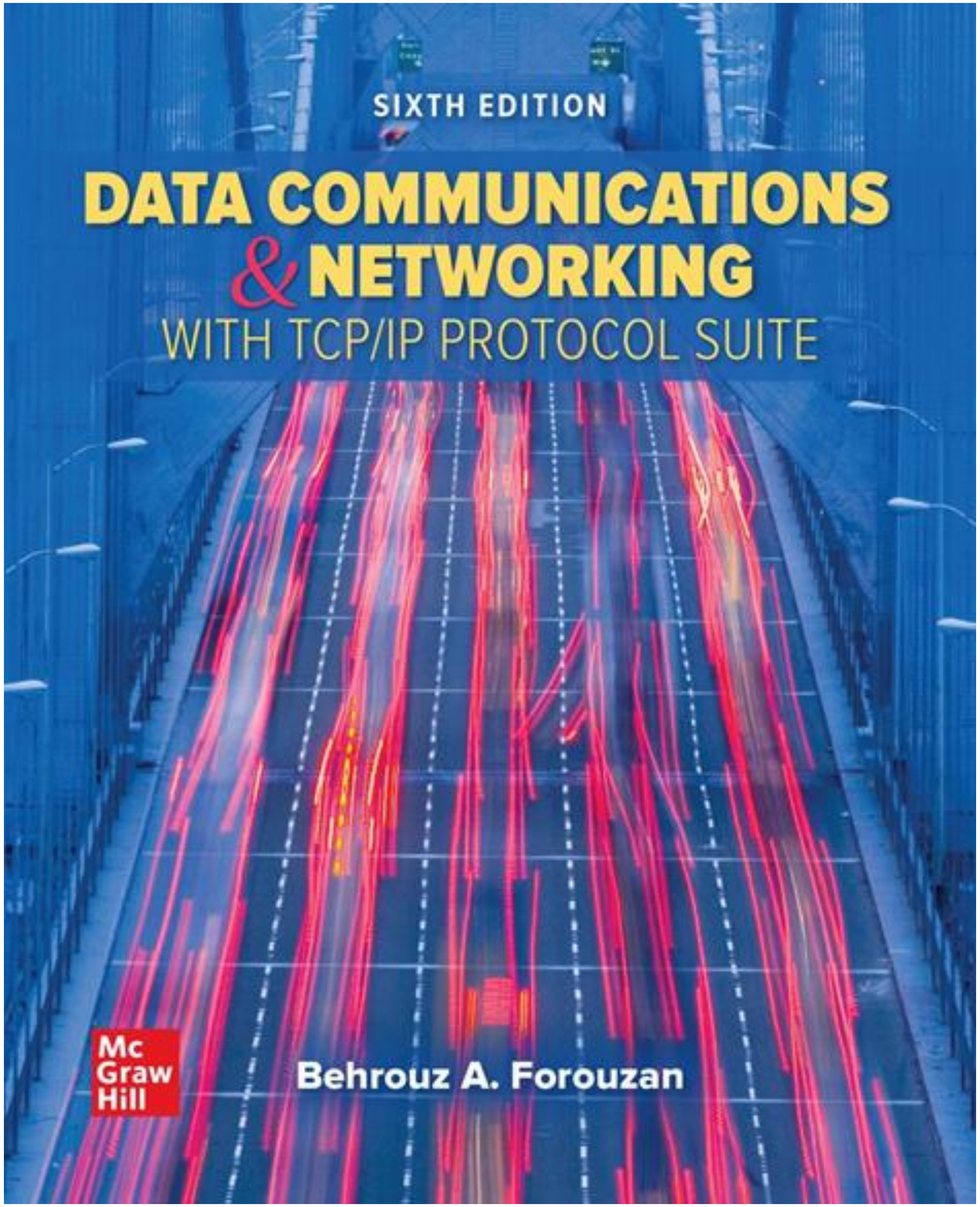
Chapter 03

Data-Link Layer

- Data Communications and Networking, With TCP/IP protocol suite Sixth Edition
- Behrouz A. Forouzan



Chapter Outline

RANDOM ACCESS

CONTROLLED ACCESS

CHANNELIZATION

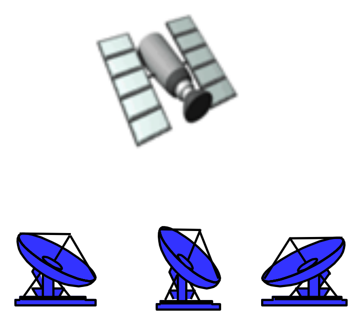
Multiple Access

- **Broadcast (shared) link** consists of multiple sending and receiving nodes connected to or use a single shared link

Shared links Examples

shared wire (e.g., cabled Ethernet)

shared RF (e.g., 802.11 WiFi)



shared RF (satellite)

shared radio: 4G/5G

Multiple Access

- **Problem**: When two or more nodes transmit at the same time, their frames will collide and the link bandwidth is **wasted** during collision
  - How to coordinate the access of multiple sending/receiving nodes to the shared link**???**
- **Solution**: We need a **protocol** to coordinate the transmission of the active nodes
- These protocols are called **Medium or Multiple Access Control (MAC) Protocols** belong to a **sublayer** of the data link layer called **MAC** (Medium Access Control)

Figure ***Data link layer divided into two functionality-oriented sublayers***

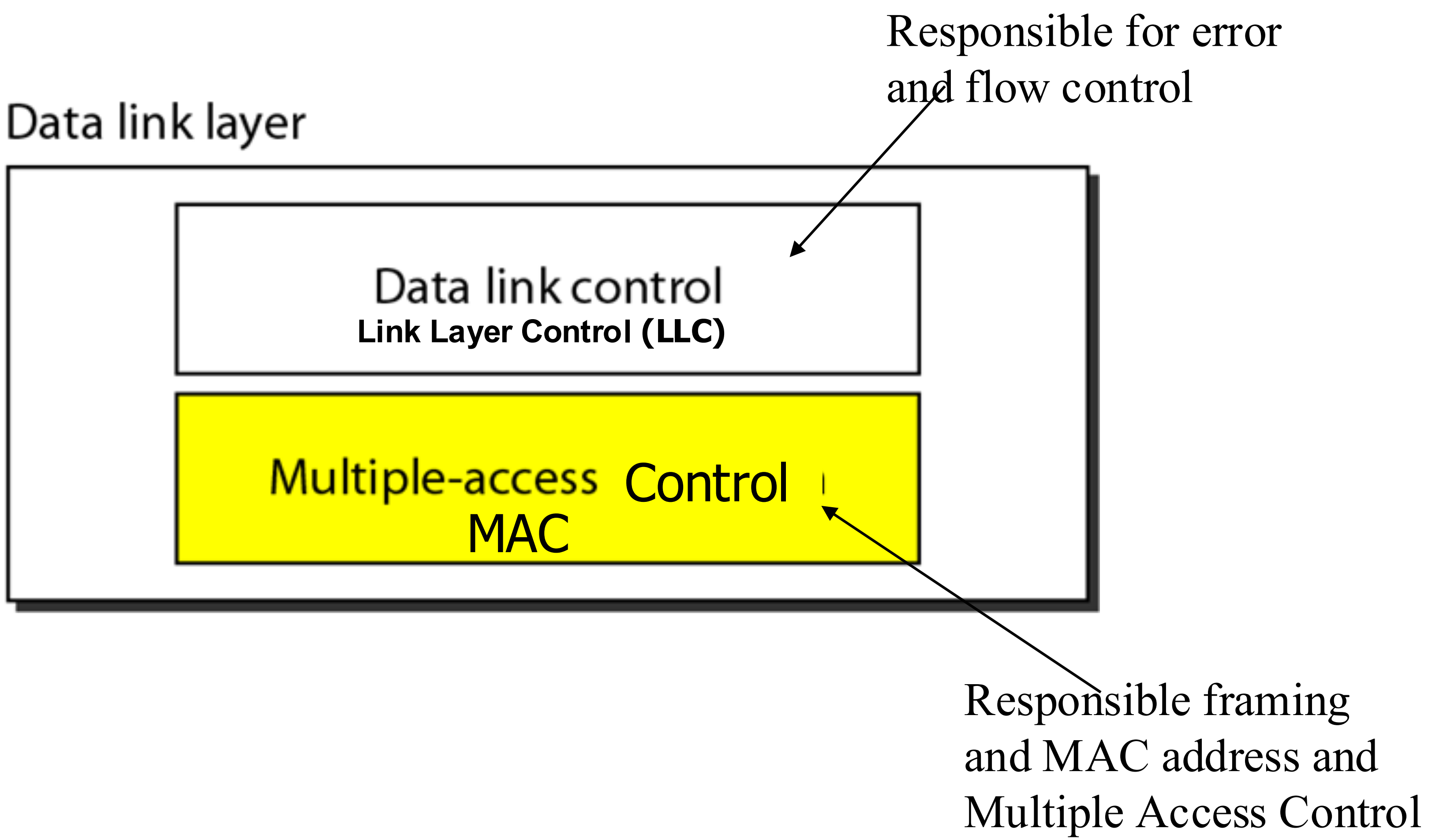
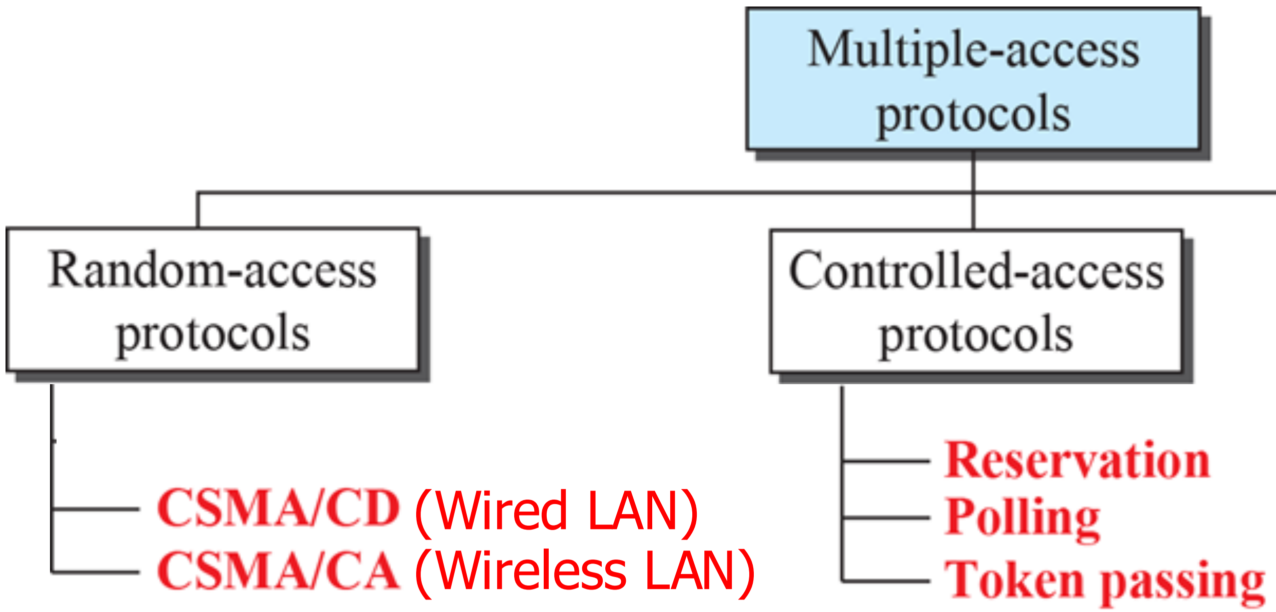


Figure : Taxonomy of multiple-access protocols

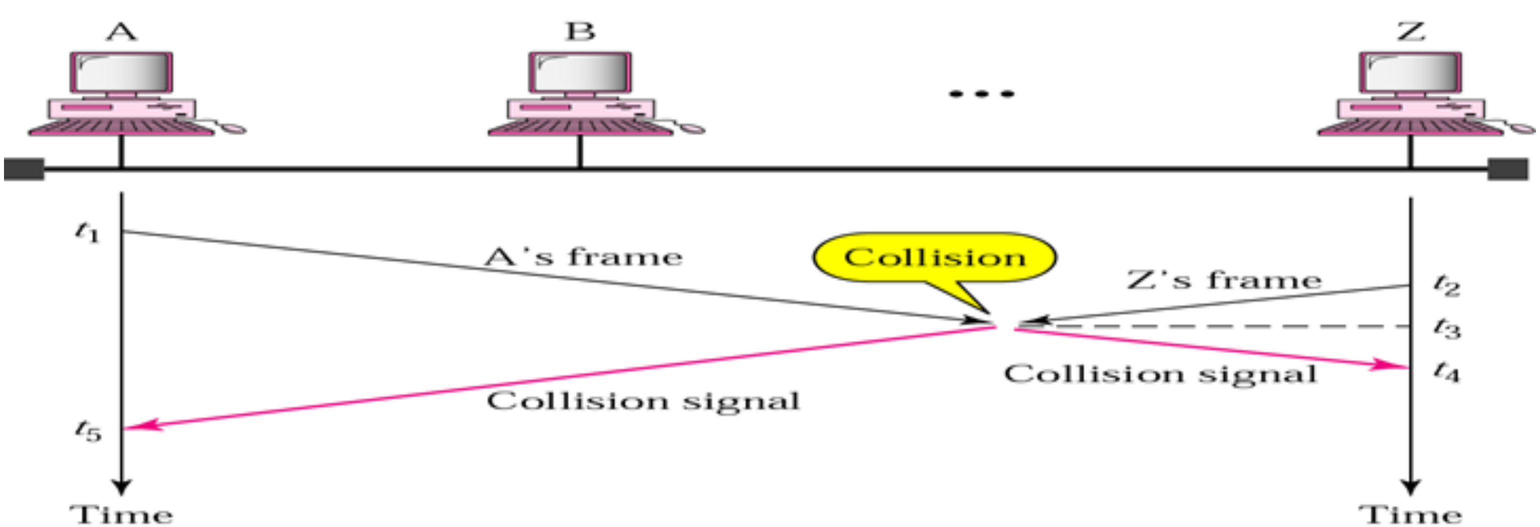


Random Access

- **Random Access Protocols:**
  - No station is superior to another station and none is assigned the control over another.
  - A station with a frame to be transmitted **can use the link directly based** on a procedure defined by the protocol to make a decision on whether or not to send.

Random Access – Carrier Sense Multiple Access (CSMA)

- Based on the fact that in LAN propagation time is **very small**
- □ If a frame was sent by a station, All stations **knows immediately** so they can **wait before start sending**
  - □ A station with frames to be sent, should **sense the medium** for the presence of another transmission (carrier) before it starts its own transmission
- This can **reduce** the possibility of collision but it <u>cannot eliminate</u> it.
  - Collision can only happen when more than one station begin transmitting within a short time (the **propagation time** period)

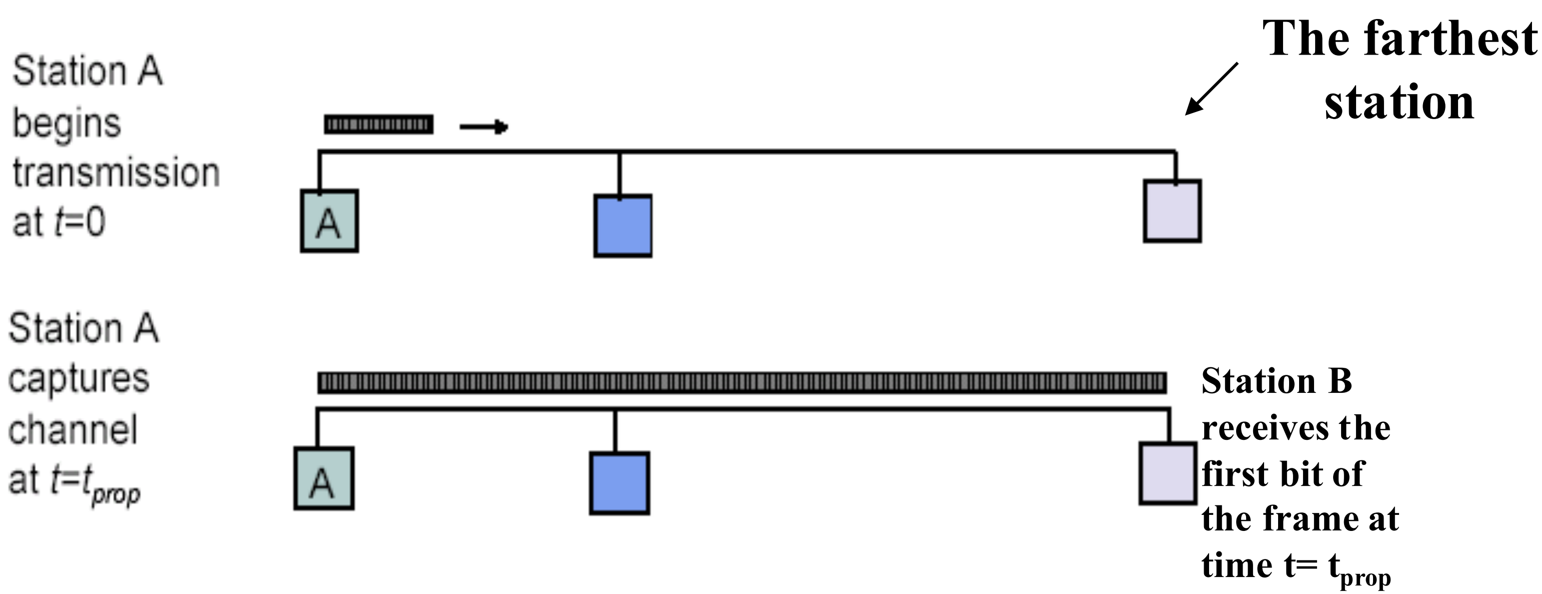


Random Access – Carrier Sense Multiple Access (CSMA)

- Vulnerable (Unsafe) time for CSMA is the **maximum propagation time**

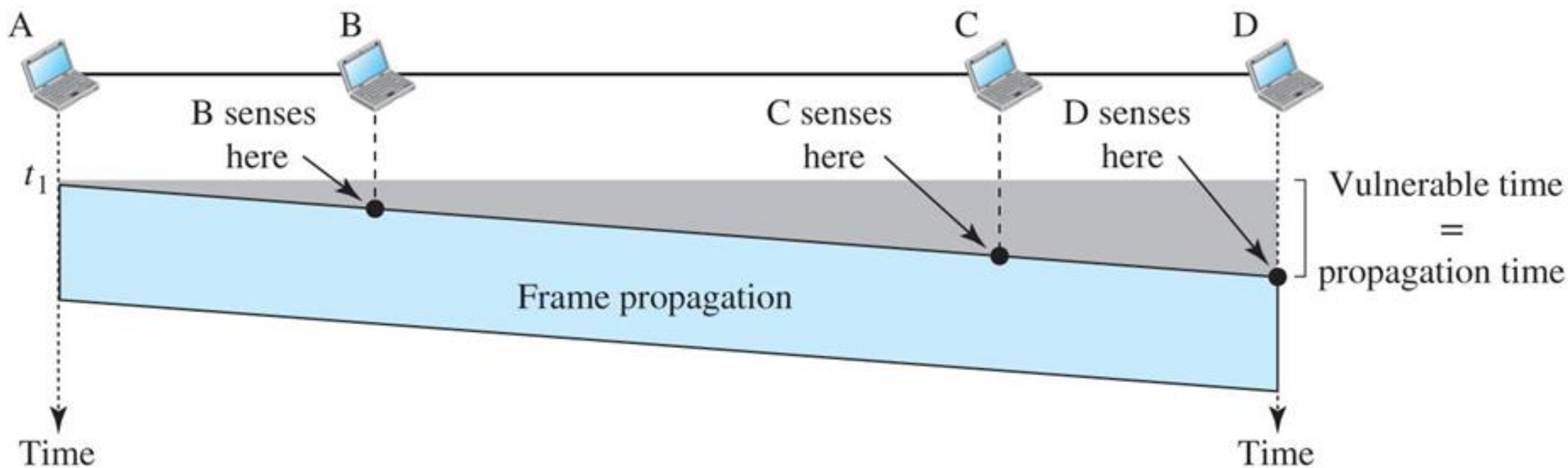
- **What is Maximum Propagation Time?**

- **Maximum propagation delay**(t_{prop}): time it takes for a bit of a frame to travel between the **two most widely** separated stations.



Random Access – Carrier Sense Multiple Access (CSMA)

- The longer the propagation delay, the worse the performance of the protocol because of the above case.



Types of CSMA Protocols

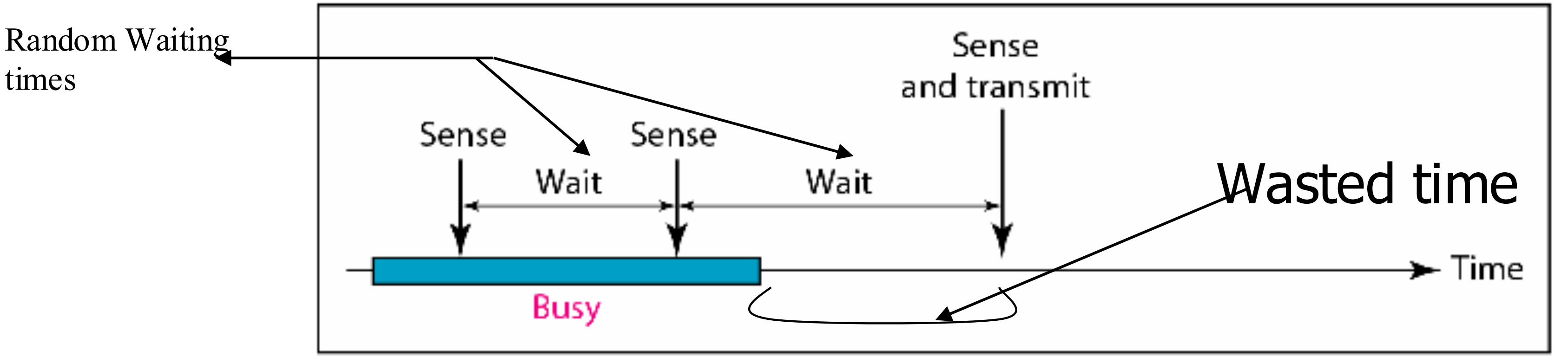
Different CSMA protocols that determine:

- What a station should do when the medium is **idle**?
- What a station should do when the medium is **busy**?

1. Non-Persistent CSMA
2. 1-Persistent CSMA
3. p-Persistent CSMA

Nonpersistent CSMA

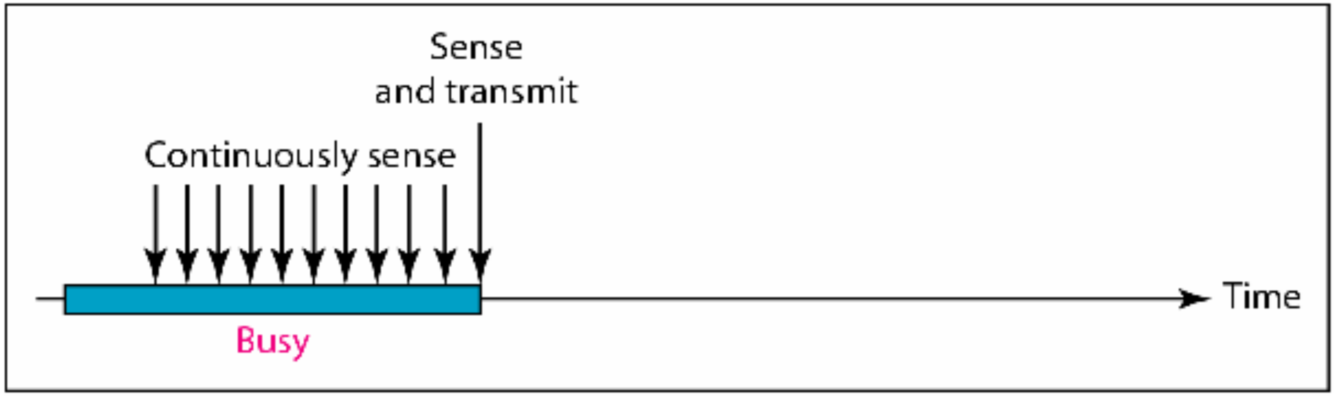
- A station with frames to be sent, should sense the medium
  1. If medium is idle, **transmit**; otherwise, go to 2
  2. If medium is busy, (**backoff**) wait a ***random* amount of time** and repeat **1**
- Non-persistent Stations are **deferential (respect others)**
- Performance:
  - Random delays reduces probability of collisions because two stations with data to be transmitted will wait for different amount of times.
  - Bandwidth is **wasted** if waiting time (backoff) is large because medium will remain idle following end of transmission even if one or more stations have frames to send



b. Nonpersistent

1-persistent CSMA

- To avoid idle channel time, 1-persistent protocol used
- Station wishing to transmit listens to the medium:
  1. If medium idle, **transmit** immediately;
  2. If medium busy, **continuously listen** until medium becomes idle; then transmit immediately with probability 1
- Performance
  - 1-persistent stations are **selfish**
  - If two or more stations becomes ready at the same time, **collision guaranteed**

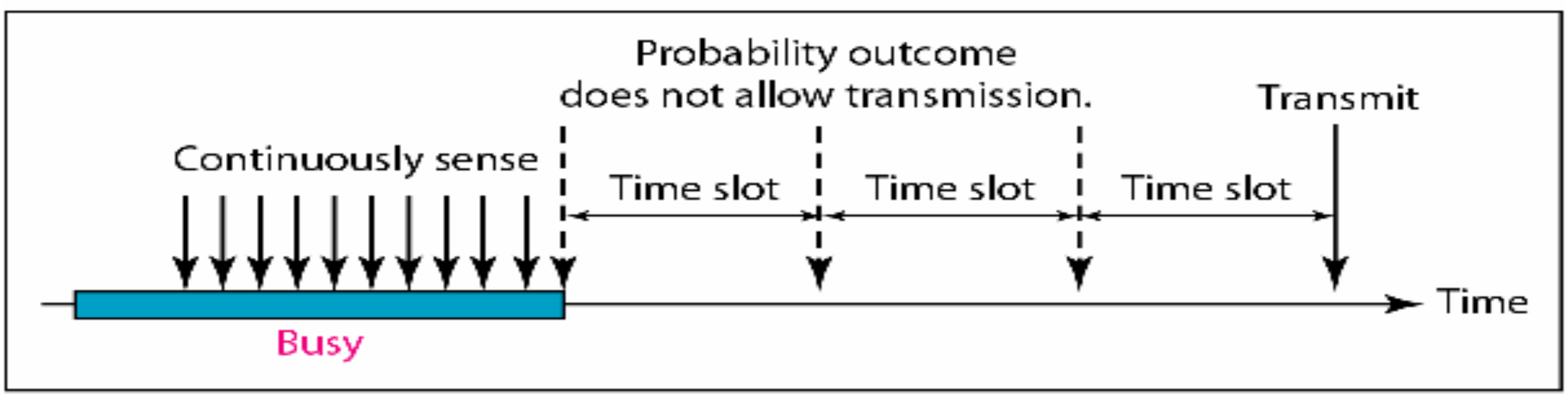


a. 1-persistent

P-persistent CSMA

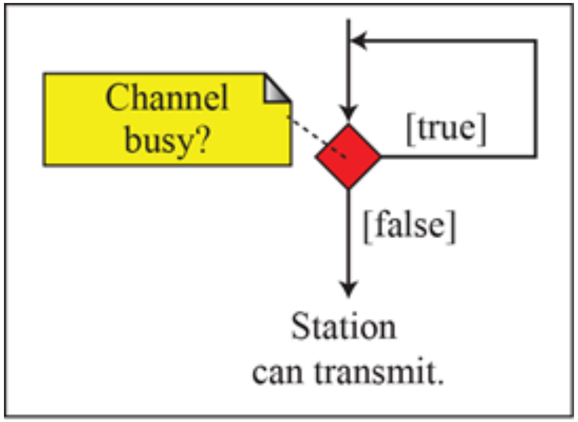
- Time is divided to slots where each Time unit (slot) typically equals **maximum propagation delay**
- Station wishing to transmit listens to the medium:

1. If medium **idle,**
   - transmit with probability (**p**), OR
   - wait **one time unit (slot)** with probability (**1 – p**), then **repeat listening to the medium.**
2. If medium **busy**, **continuously listen until idle** and repeat step **1**
3. Performance
   - Reduces the possibility of collisions like **nonpersistent**
   - Reduces channel idle time like **1-persistent**

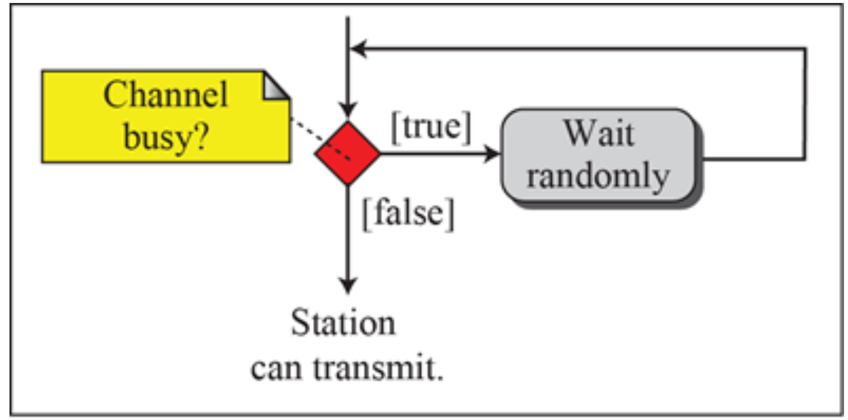


c. p-persistent

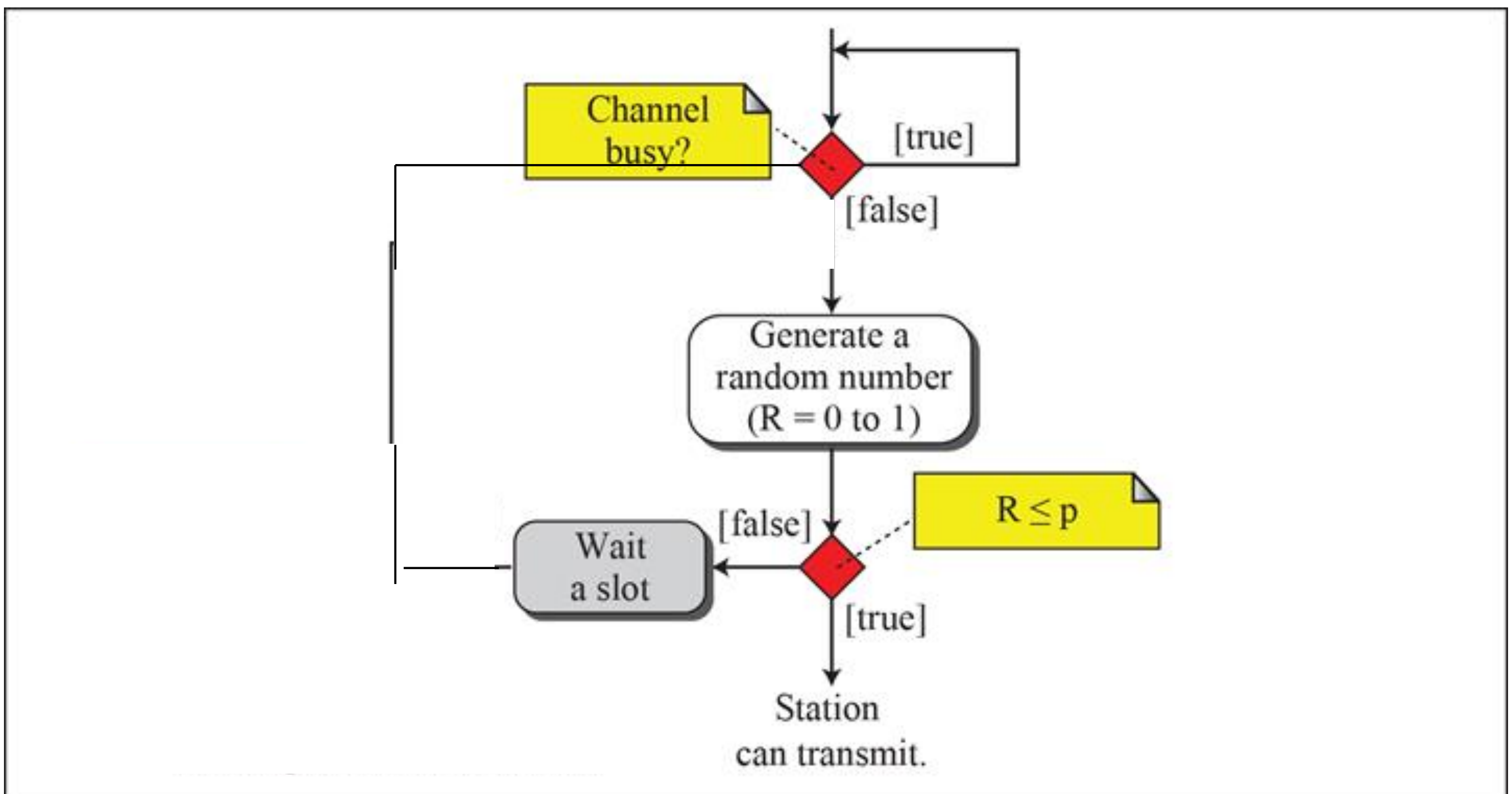
Figure : Flow diagram for three persistence methods



a. 1-persistent

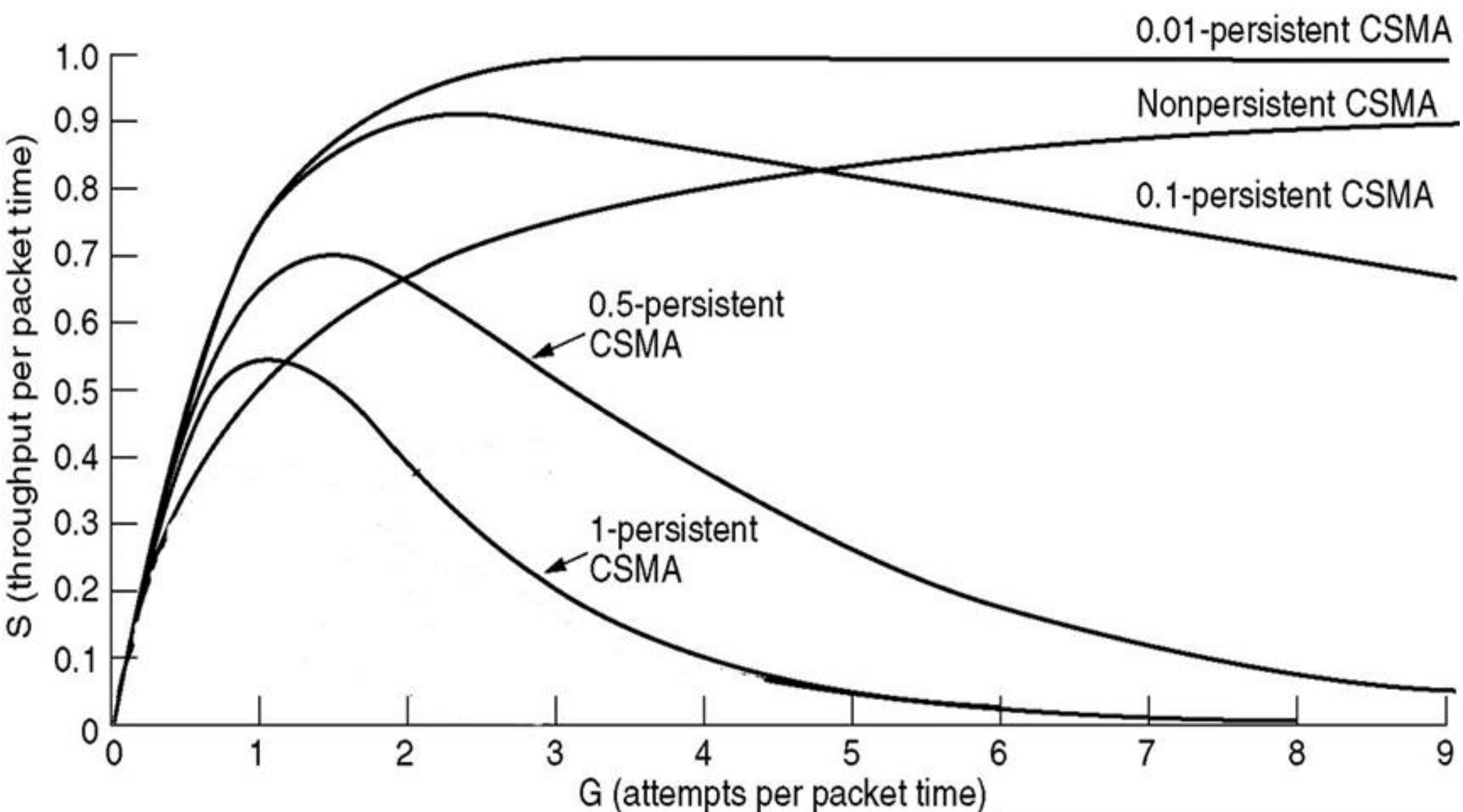


b. Nonpersistent



c. *p*-persistent

Persistent and Nonpersistent CSMA



Comparison of the channel utilization versus load for various random access protocols.

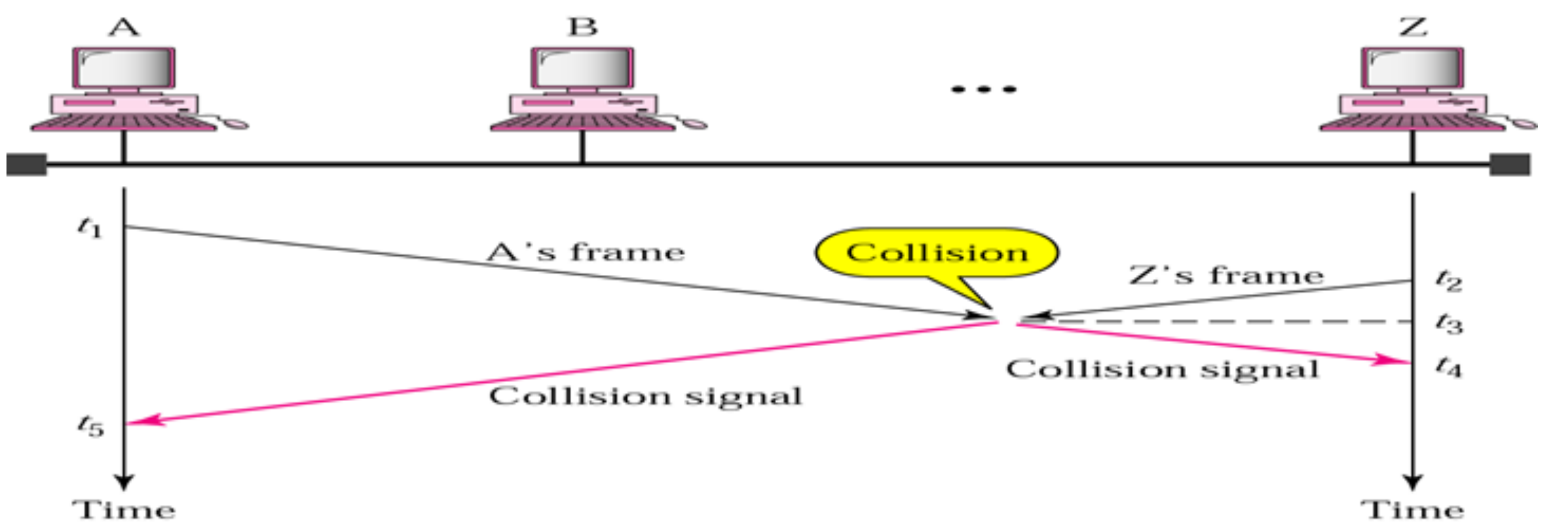
CSMA/CD (Collision Detection)

- ***CSMA (all previous methods) has an inefficiency:***
  - If a collision has occurred, the channel is **unstable** until colliding packets have **been fully transmitted**
- ***CSMA/CD*** *(Carrier Sense Multiple Access with Collision Detection)* ***overcomes this as follows:***
  - While transmitting, the sender is **listening to medium** for collisions.
  - Sender **stops transmission** if collision has occurred **reducing channel wastage** .

CSMA/CD is Widely used for in star topology if **Hub is used** (IEEE 802.3, Ethernet).

How does a node detect a collision?

Transceiver: **A node monitors the media while transmitting. If the observed power is more than transmitted power** of its own signal, it means collision occurred



CSMA/CD Protocol

- Use one of the CSMA persistence algorithm *(non-persistent, 1-persistent, p-persistent)* for transmission
- If a collision is detected by a station during its transmission then it should do the following:
  - **Abort transmission** and
  - **Transmit** a ***jam signal*** (48 bit) to notify other stations of collision so that they will **discard the transmitted fra**me also to make sure that the collision signal will stay until detected by <u>the furthest station</u>
  - After sending the ***jam signal***, **backoff (wait) for a *random*** amount of time, then
  - Reapply the used CSMA persistent algorithm

Performance of Random Access Protocols

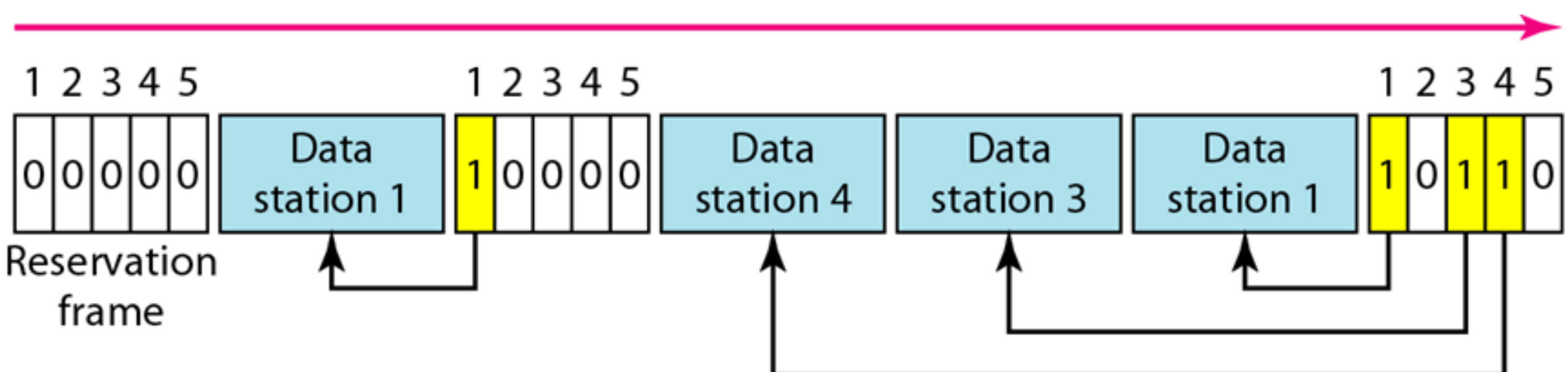
- Simple and easy to implement
- Decentralized (no central device that can fail and bring down the entire system)
- In low-traffic, packet transfer has low-delay
- However, in heavier traffic, packet delay has no limit.
- In some cases, a station may never have a chance to transfer its packet. (**unfair protocol**)
- A node that has frames to be transmitted can **transmit continuously** at the **full rate of channel (R)** if it is the **only node with frames**
- If (M) nodes want to transmit, many collisions can occur and the **maximum average throughput** for each node will **not be R/M**

13.2 Controlled Access or Scheduling

- Provides **in order access** to shared medium so that every station has chance to transfer (**fair protocol**)
- It is fair protocol. A node is limited to throughput equal **R/M**
- ***Eliminates*** collision completely
- **Three methods** for controlled access:
  - Reservation
  - Polling
  - Token Passing

1-Reservation access method

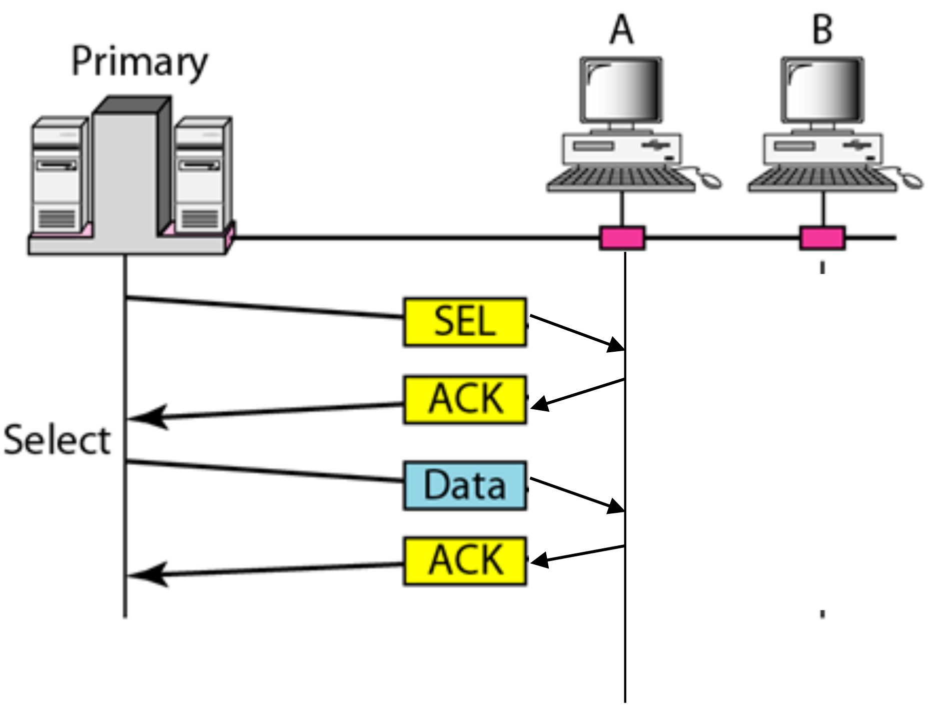
- Stations **take turns transmitting a single frame** at a **full rate (R) bps**
- Transmissions are organized into **variable length** cycles
- Each cycle **begins** with a reservation frame that consists of (N) minislots. One minislot for each of the N stations
- When a station needs to send a data frame, it makes a **reservation** in its own minislot.
- By listening to the reservation interval, every station knows which stations will transfer frames, and in **which order**.
- The stations that made reservations can send their data frames after the reservation frame.



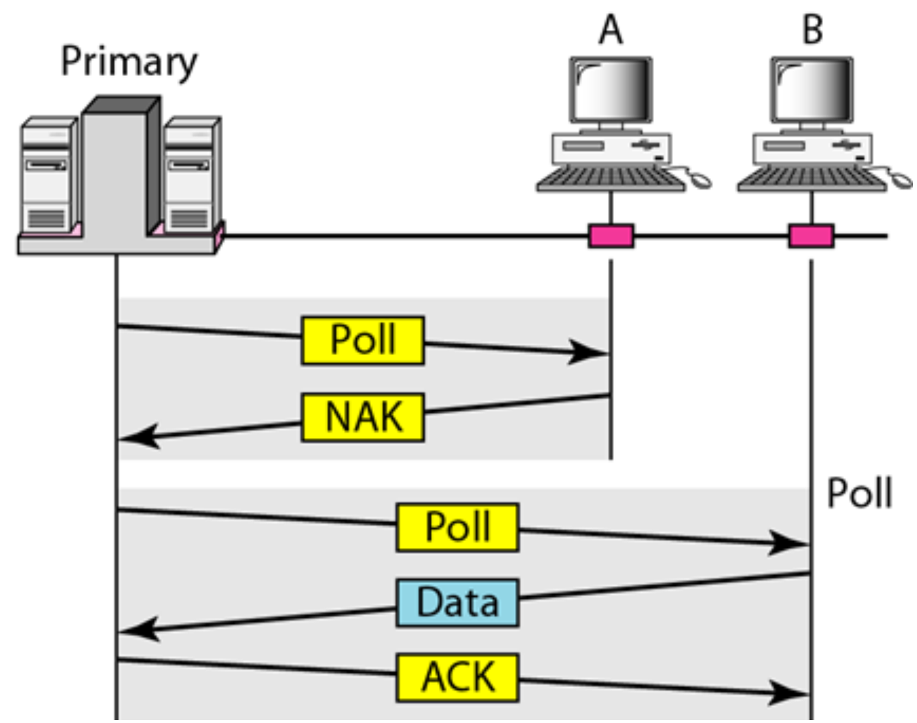
2- Polling

- Stations take turns accessing the medium
- Two models: **Centralized** and **distributed** polling
- **Centralized polling**
  - One device is assigned as **primary station** and the others as **secondary stations**
  - All data exchanges are done through the **primary**
  - When **the primary has a frame to send,** it sends a **select** frame that includes the address of the intended secondary
  - When **the primary is ready to receive** data it sends a **Poll** frame for each device to ask if it has data to send or not. If yes, **data** will be transmitted otherwise **NAK (Negative Acknowledgement)** is sent.
  - Polling can be done <u>in order</u> (Round-Robin) or based on <u>predetermined order</u>
- **Distributed polling**
  - **No primary and secondary**
  - Stations have a **known polling order** list which is made based on some protocol
  - **station with the highest priority** will have the access right first, then it passes the access right to the **next station (it will send a pulling message to the next station in the pulling list)**, which will passes the access right to the following next station, … (**Reservation and Token Passing** are examples of **Distributed Polling**)

Figure 12.19 *Select and poll functions in polling access method*

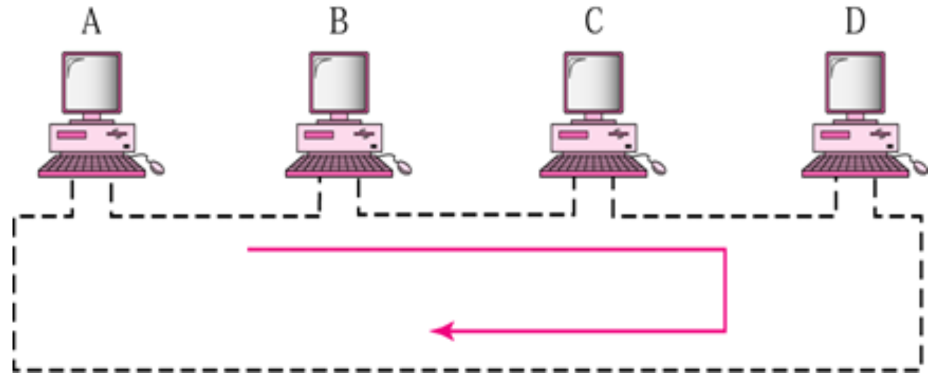


Primary is sending to Secondary



Secondary is sending to Primary

3- Token-Passing network



Implements **Distributed Polling** System

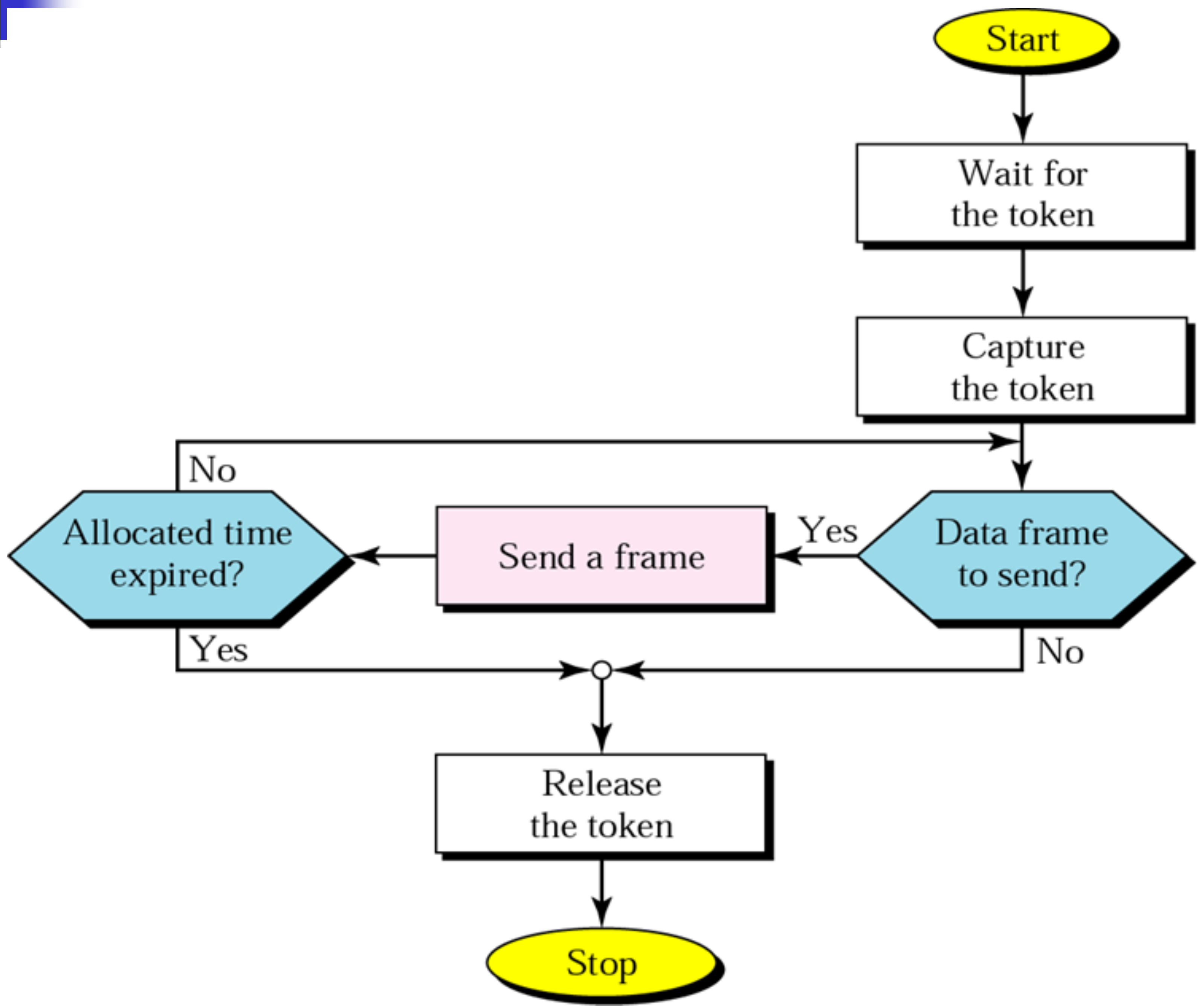
There is a special frame rotating in the ring called token.

Any station that wants to send data has to wait for free token to arrive.

The station makes the token busy by inserting its data in the token and puts the destination address.

The destination station receive the data and change the token to free

Figure 13.13 Token-passing procedure



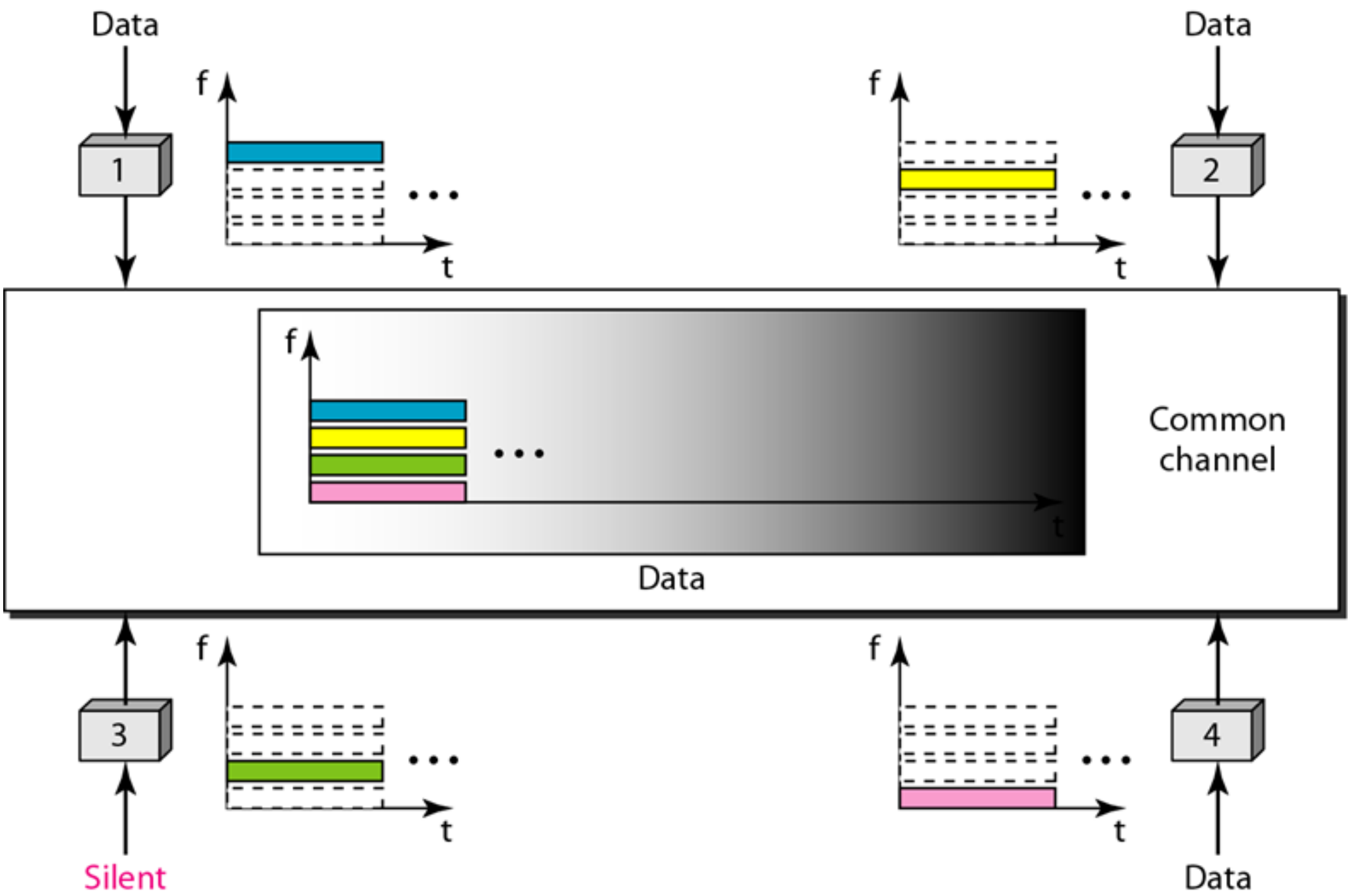
12-3 CHANNELIZATION

***Channelization* is a multiple-access method in which the available bandwidth of a link is shared in time, frequency, or through code, between different stations. In this section, we discuss three channelization protocols.**

Topics discussed in this section:

Frequency-Division Multiple Access (FDMA)
Time-Division Multiple Access (TDMA)
Code-Division Multiple Access (CDMA)

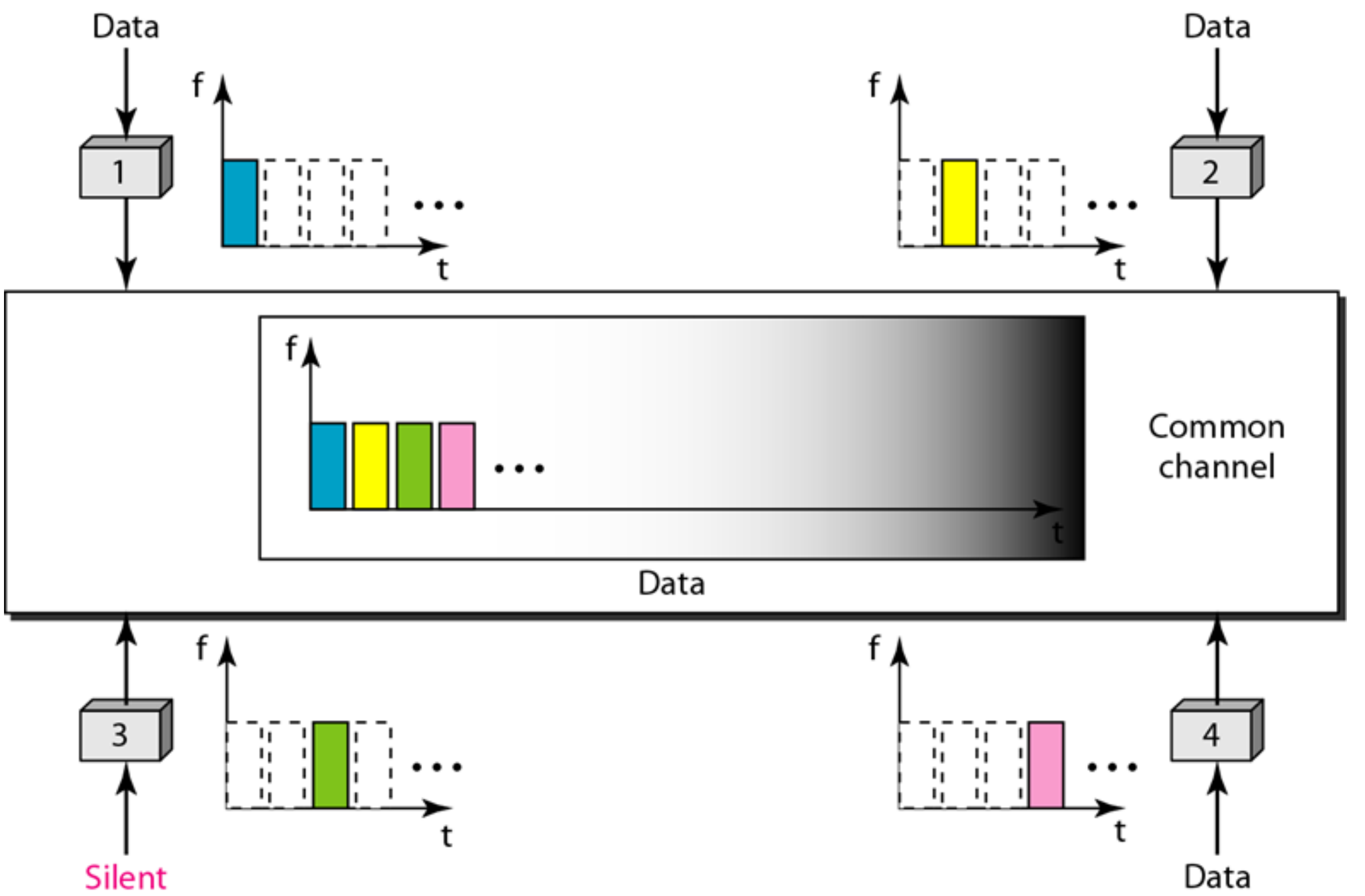
Figure 12.21 *Frequency-division multiple access (FDMA)*



12-3 CHANNELIZATION - FDMA

- **FDMA:** Frequency Division Multiple Access:
  - Transmission medium is divided into **M** separate frequency bands
  - Each station transmits **continuously** on the assigned band at an average rate of **R/M**
  - A node is **limited** to an average throughput equal **R/M** (where M is number of nodes) even when it is **the only node with frame** to be sent

Figure 12.22 *Time-division multiple access (TDMA)*



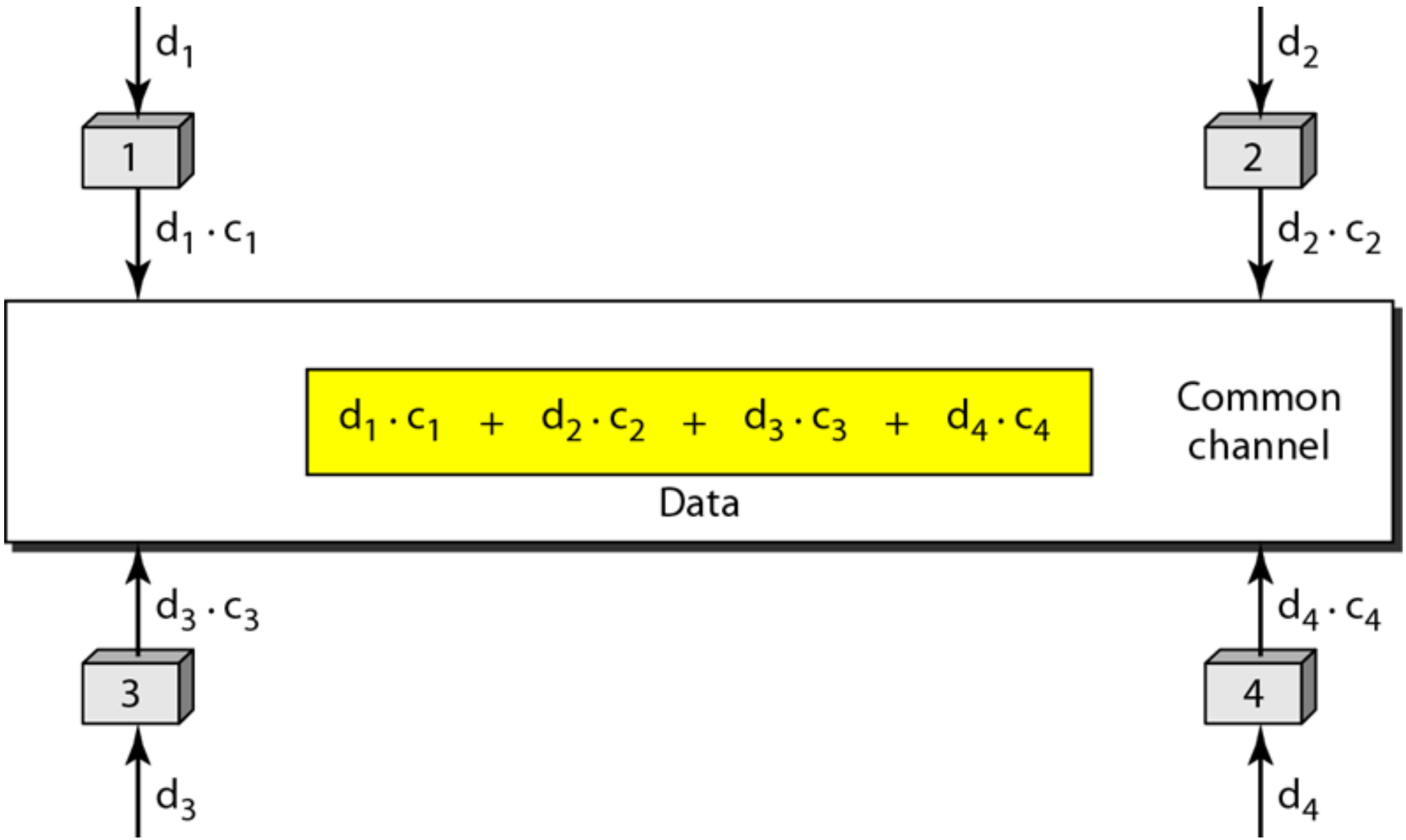
12-3 CHANNELIZATION - TDMA

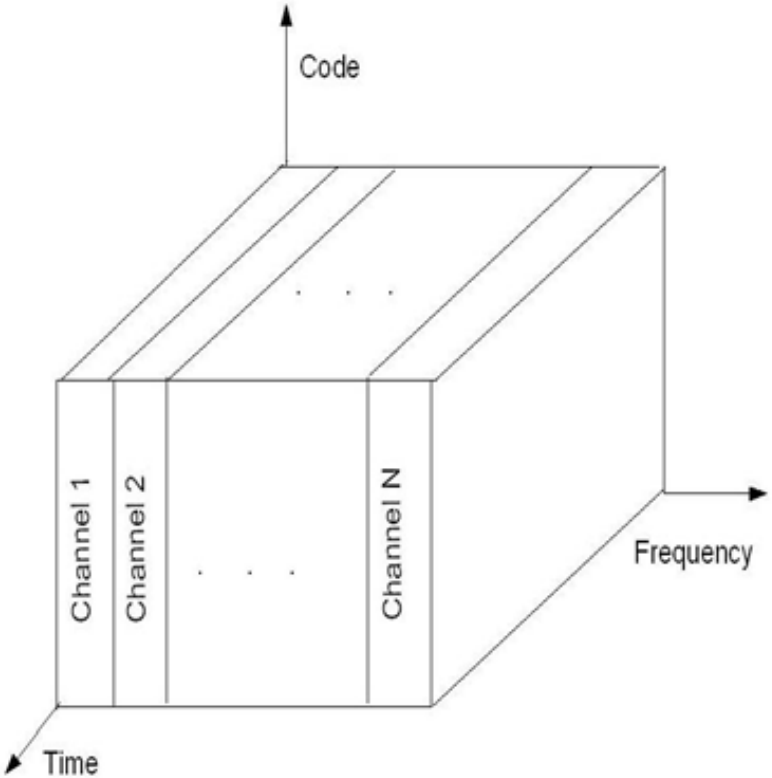
- **TDMA: Time Division Multiple Access**
  - The entire bandwidth capacity is a **single channel** with its capacity shared **in time** between **M** stations
  - A node must **always wait for its turn** until its slot time arrives even when it is the **only node** with frames to send
  - A node is limited to an average throughput equal **R/M** (where M is number of nodes) even when it is the only node with frame to be sent

12-3 CHANNELIZATION - CDMA

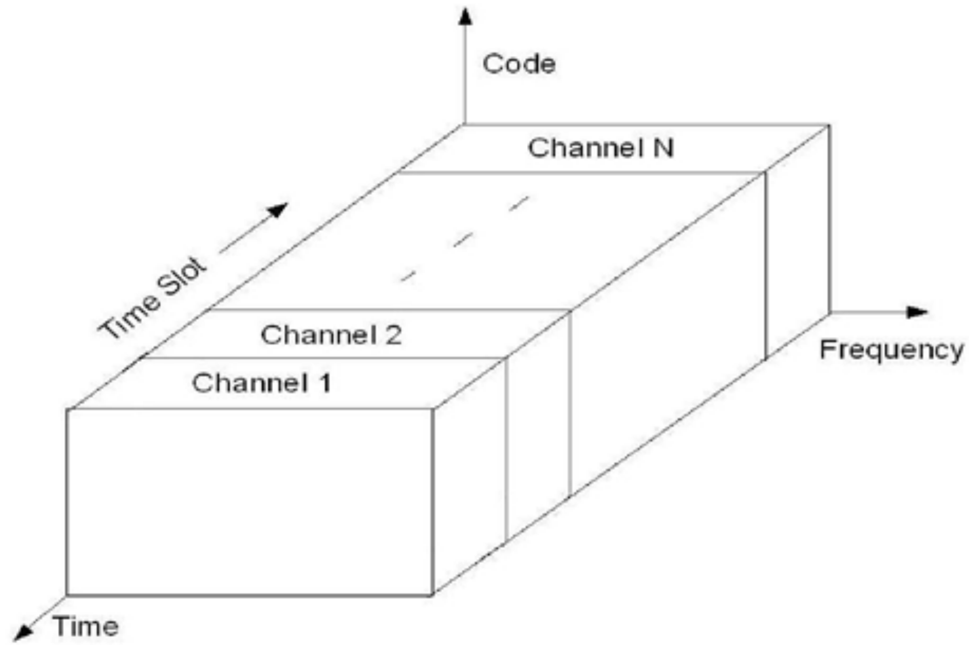
- **CDMA: Code Division Multiple Access**
  - In CDMA, **one channel** carries all transmissions **simultaneously**
  - Each station codes its data signal by a specific codes before transmission
  - The stations receivers use these codes to recover the data for the desired station

Figure 12.23 Simple idea of communication with code

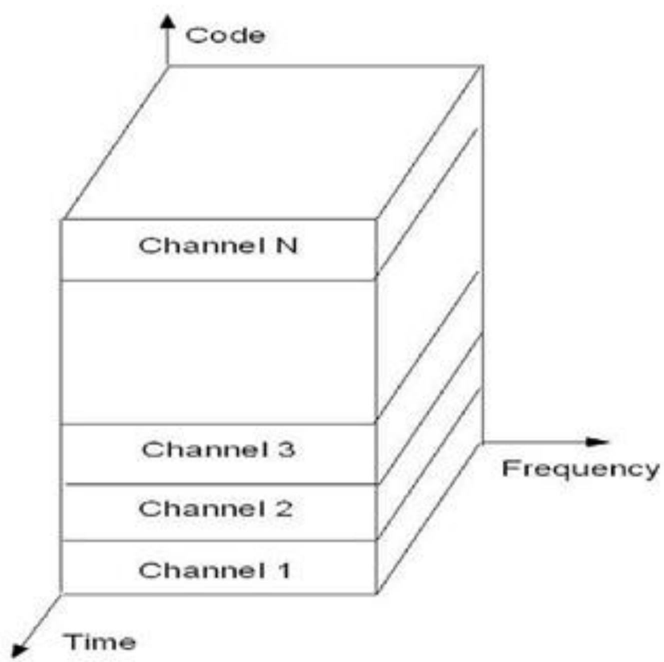




FDMA



TDMA



CDMA