

Overview

- Link Layer
 - Error Detection
 - Flow Control
 - HDLC – Frames/Control Bytes
 - PPP – Lifecycle/State Diagram
 - Medium Access Control
 - 802.11 DCF & PCF
 - CDMA & Ethernet
 - Bridges & Switches
- Network Layer

Overview

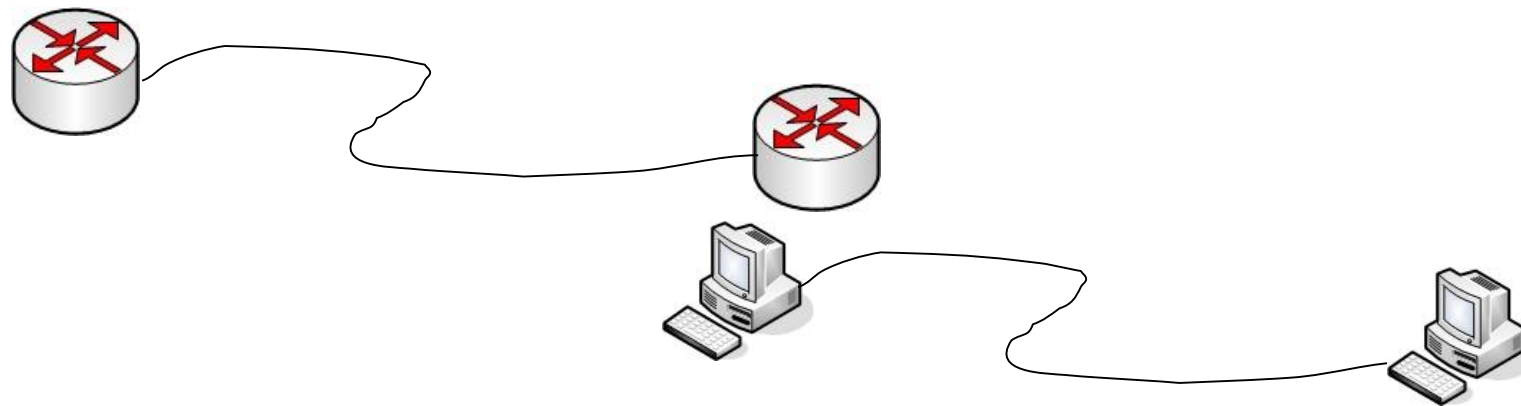
- Link Layer
 - ~~Error Detection~~
 - ~~Flow Control~~
 - ~~HDLC — Frames/Control Bytes~~
 - ~~PPP — Lifecycle/State Diagram~~
 - Medium Access Control
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 - Bridges & Switches
- Network Layer

CS2031

Telecommunications II

Medium Access Control

HDLC / PPP



a. Point-to-point



b. Multipoint

* Figure is courtesy of B. Forouzan

Analogy: Point-to-Point Communication



Alice

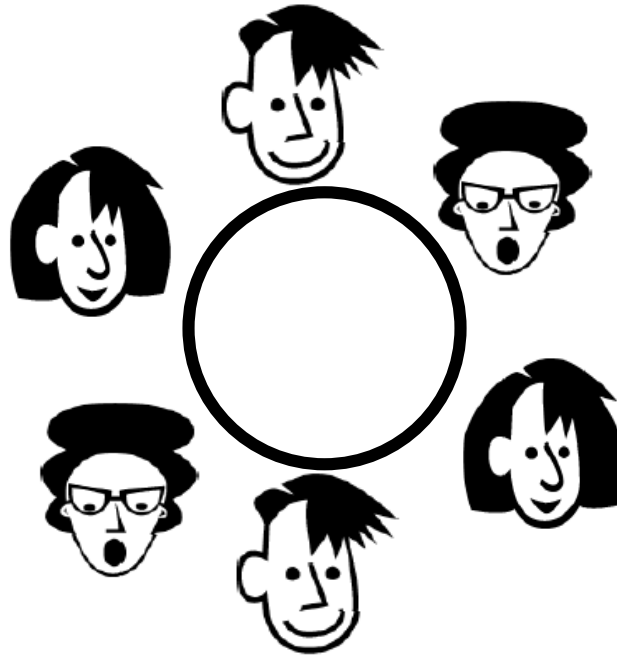
Phone conversation



Bob

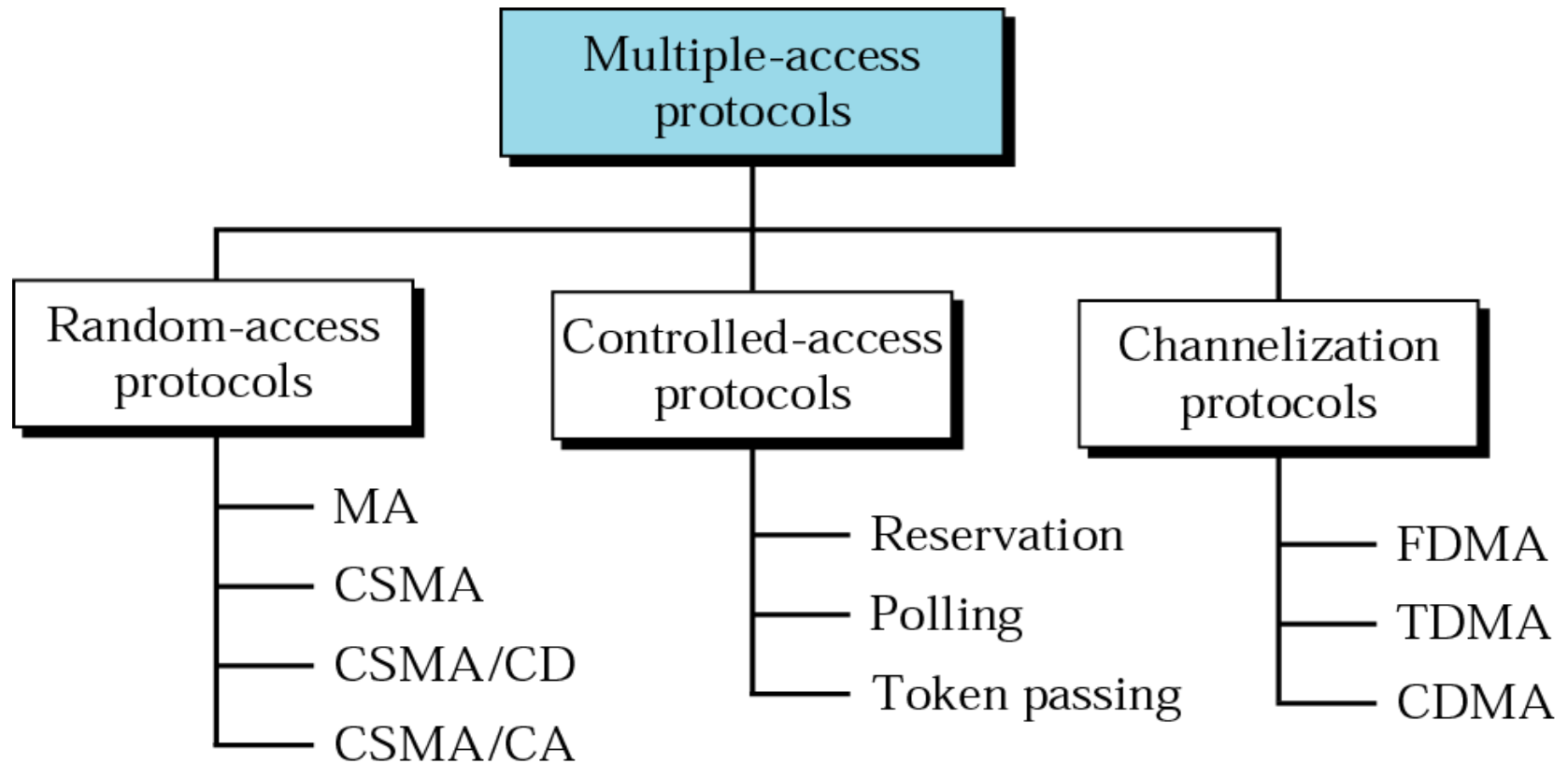
- Synchronization: Simple!

Analogy: Shared Medium



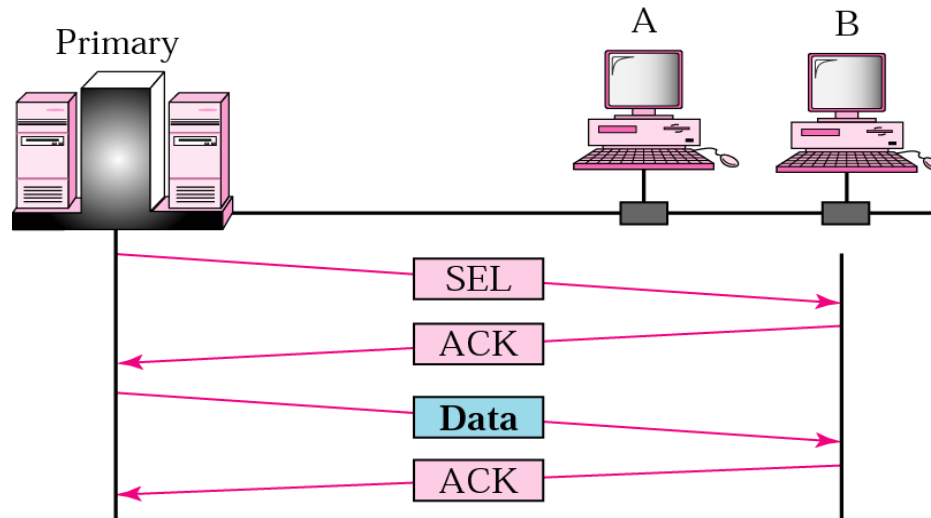
- Synchronisation: More complex

Multiple-Access Protocols



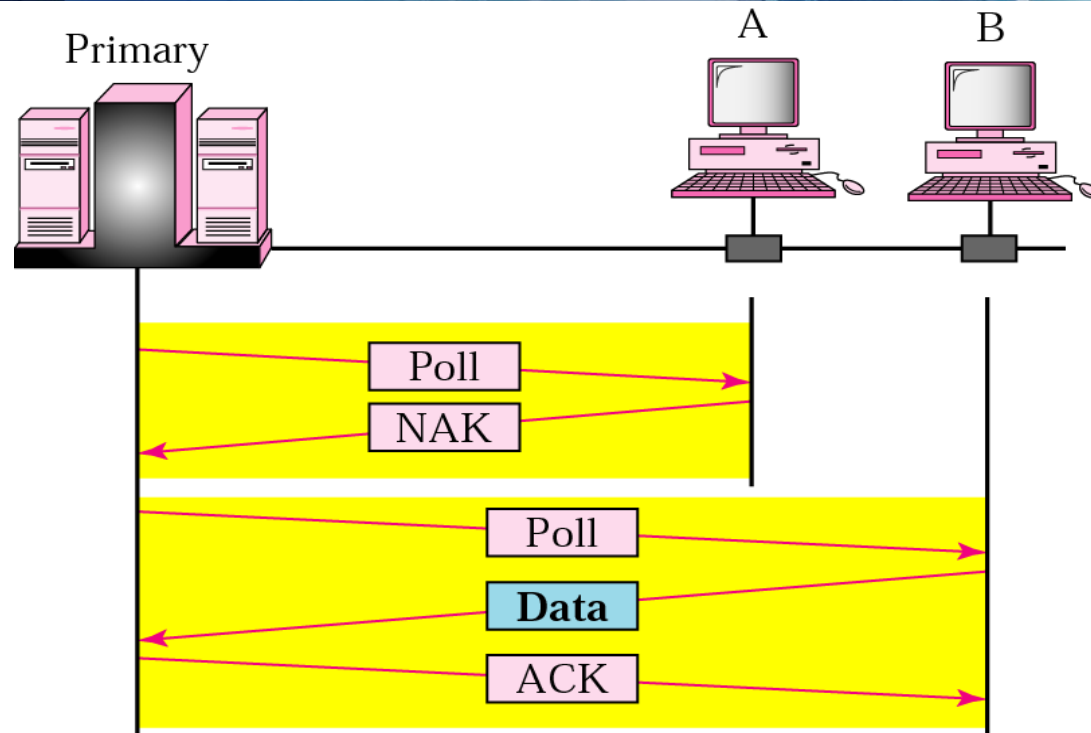
* Figure is courtesy of B. Forouzan

Select / Push



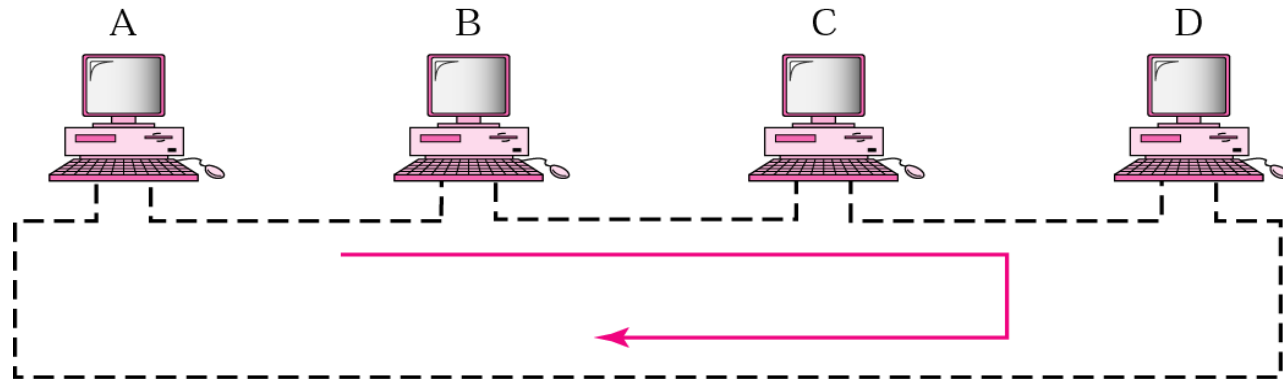
- Primary co-ordinates all communication
- Primary selects station that is destination then transmits data

Poll



- Primary contacts stations to determine if they have data to transmit

Token-Passing Network

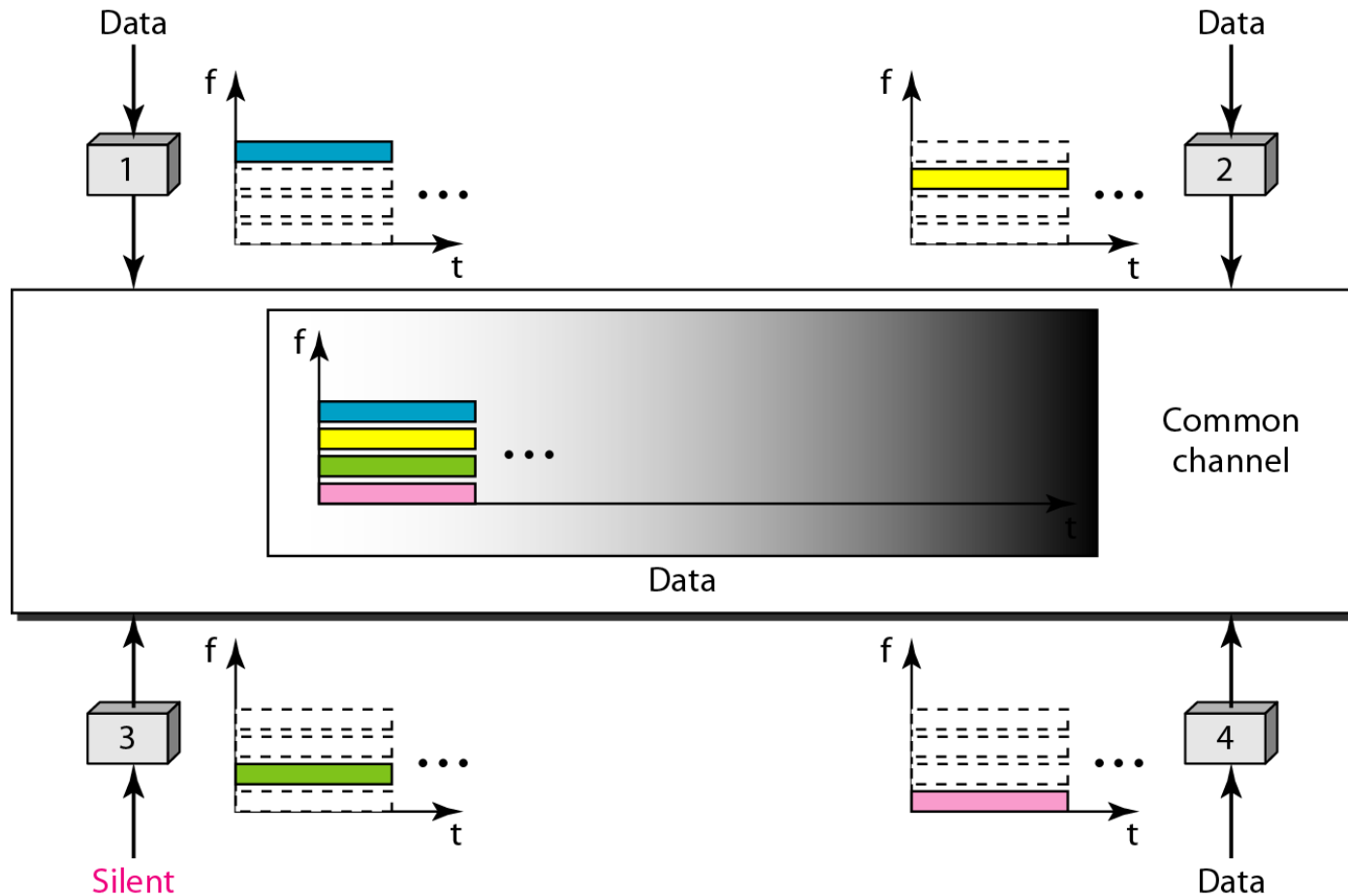


- Token passes around a network
- Machine with token is allowed to transmit data

Static Channel Allocation

- Frequency Division Multiplexing (FDM)
 - N users get $1/N$ of the total bandwidth
 - $\ll N$ users \Rightarrow wasted bandwidth
 - $> N$ users \Rightarrow denial of service
 - Bursts cannot be accommodated
- Time Division Multiplexing (TDM)
 - N users get full bandwidth $1/N$ of the time
 - Same arguments apply

Frequency Division Multiple Access (FDMA)

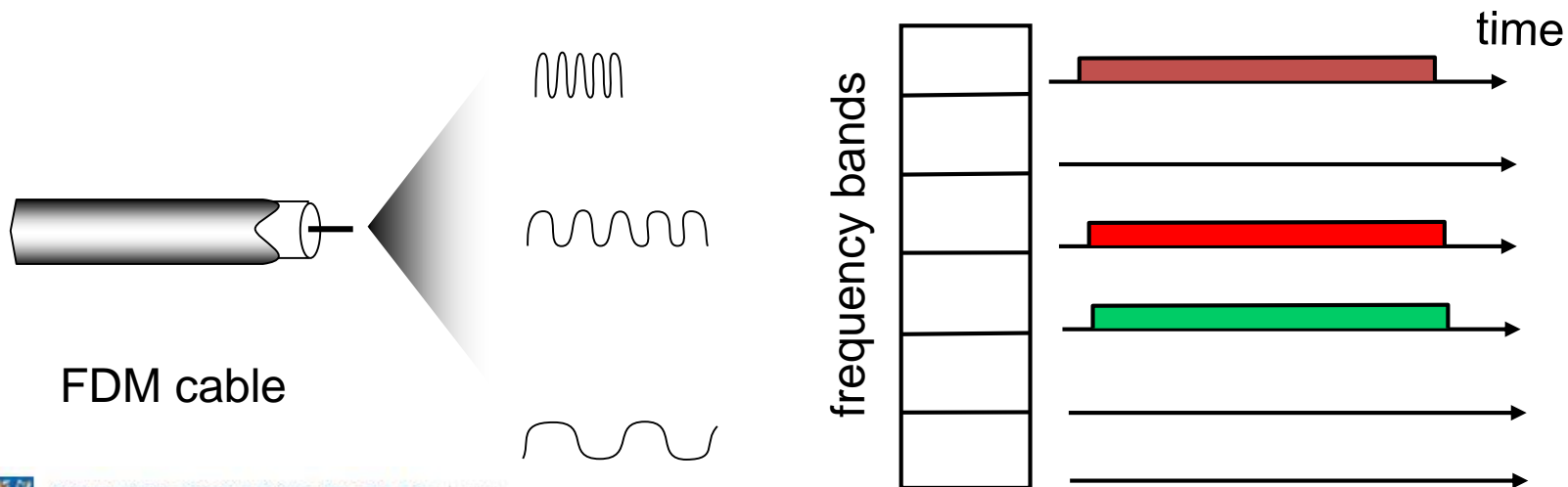


* Figure is courtesy of B. Forouzan

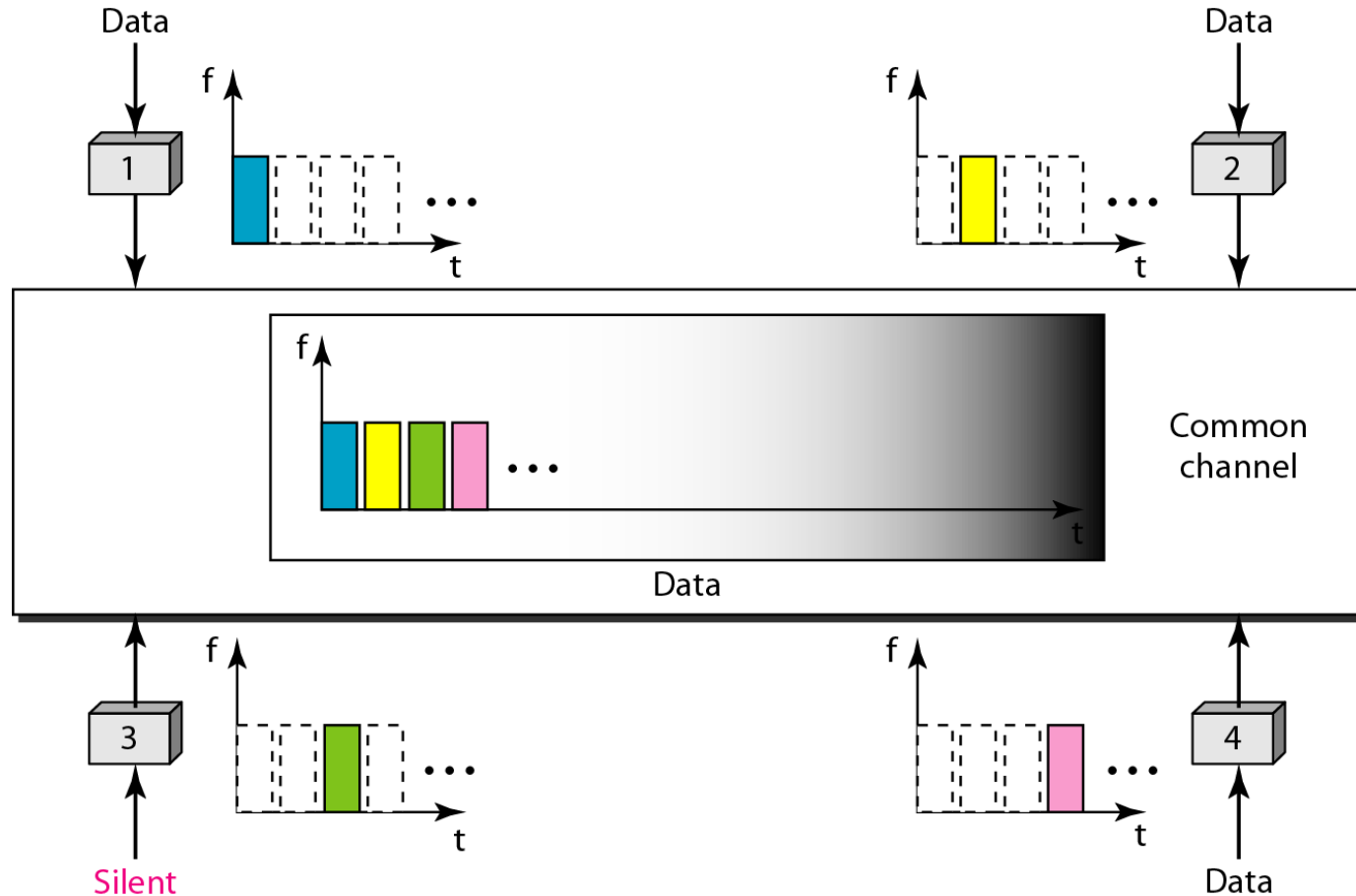
Channel Partitioning MAC protocols: FDMA

FDMA: frequency division multiple access

- channel spectrum divided into frequency bands
- each station assigned fixed frequency band
- unused transmission time in frequency bands go idle
- example: 6-station LAN, 1,3,4 have pkt, frequency bands 2,5,6 idle



Time Division Multiple Access (TDMA)

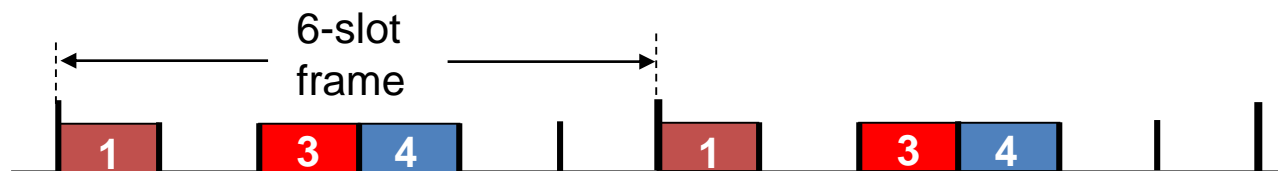


* Figure is courtesy of B. Forouzan

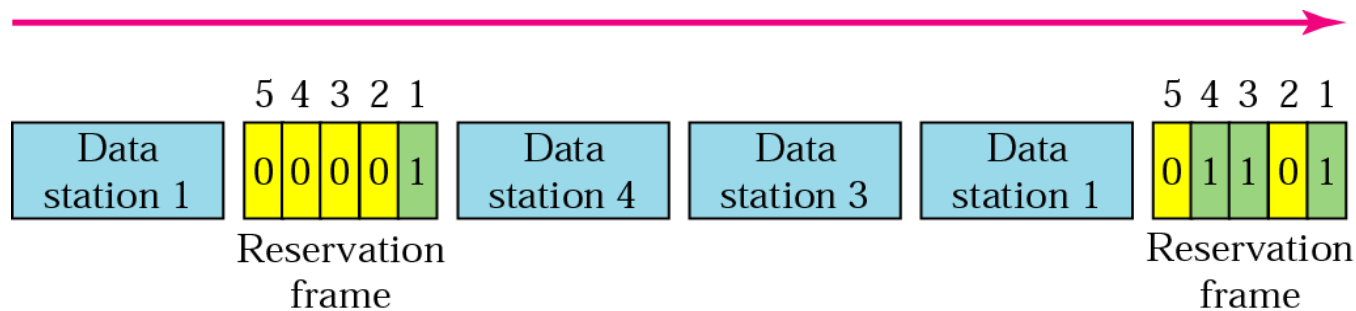
Channel Partitioning MAC protocols: TDMA

TDMA: time division multiple access

- access to channel in "rounds"
- each station gets fixed length slot (length = pkt trans time) in each round
- unused slots go idle
- example: 6-station LAN, 1,3,4 have pkt, slots 2,5,6 idle



Reservation Access Method

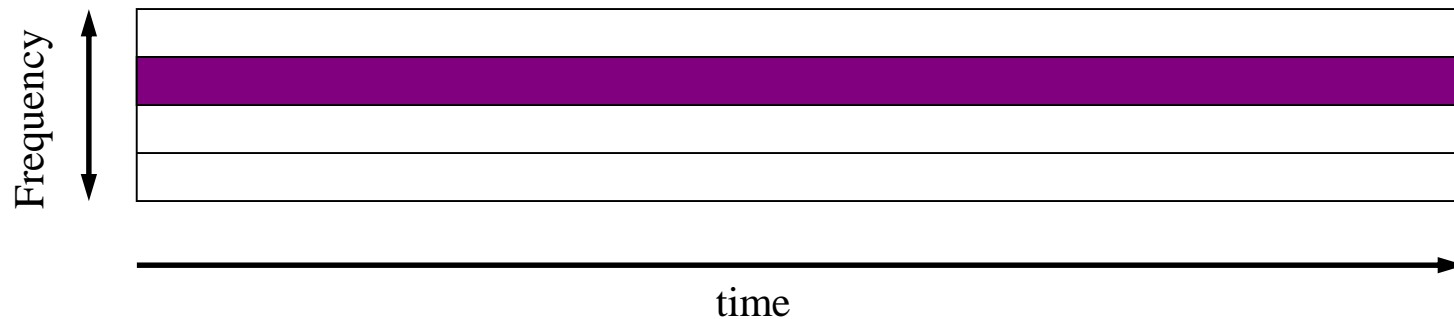


- Station that wants to transmit data
 - transmits 1 during its slot in the reservation frame
- All stations are informed about all planned communication
- Limited number of pre-allocated slots/stations

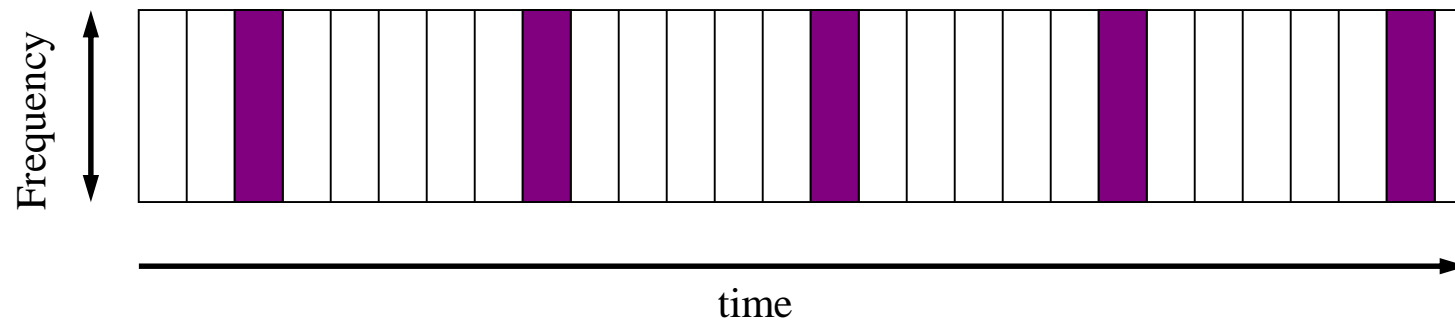
* Figure is courtesy of B. Forouzan

Static Channel Allocation

- Frequency Division Multiplexing (FDM)

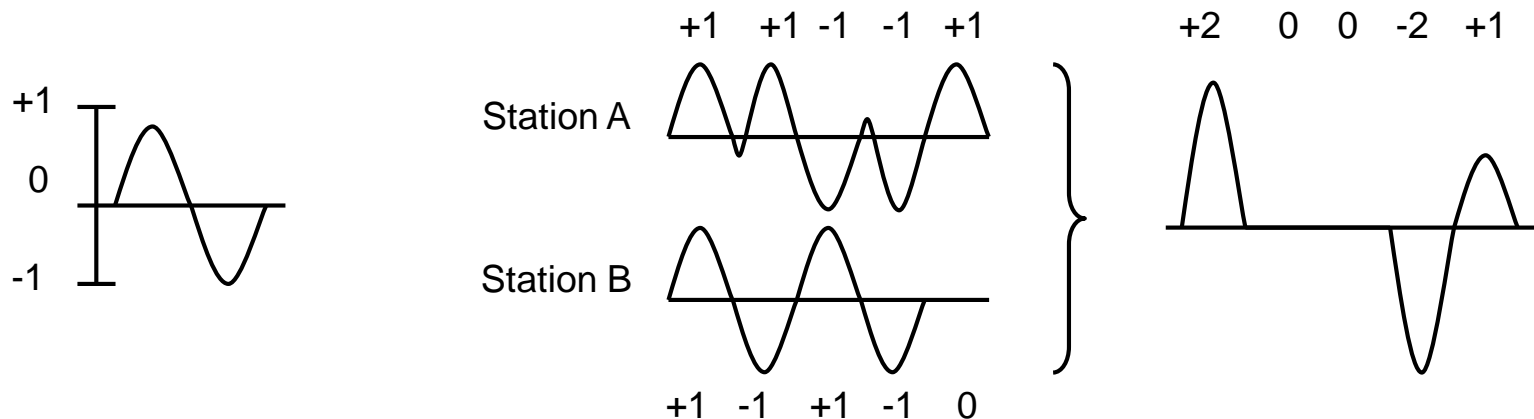


- Time Division Multiplexing (TDM)



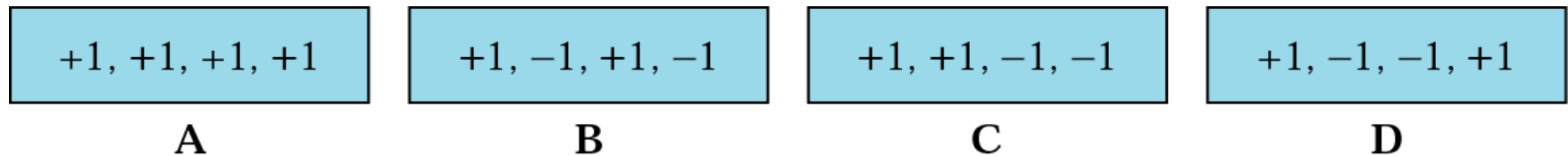
Code Division Multiple Access (CDMA)

- Makes use of physical properties of interference
 - If two stations send signals in phase, they will "add up" to give twice the amplitude
 - If the signals are out of phase, they will "subtract" and give a signal that is the difference
- Difficult to implement because control of exact power strength is essential



Chip Sequences

- Every station is identified by an individual chip sequence



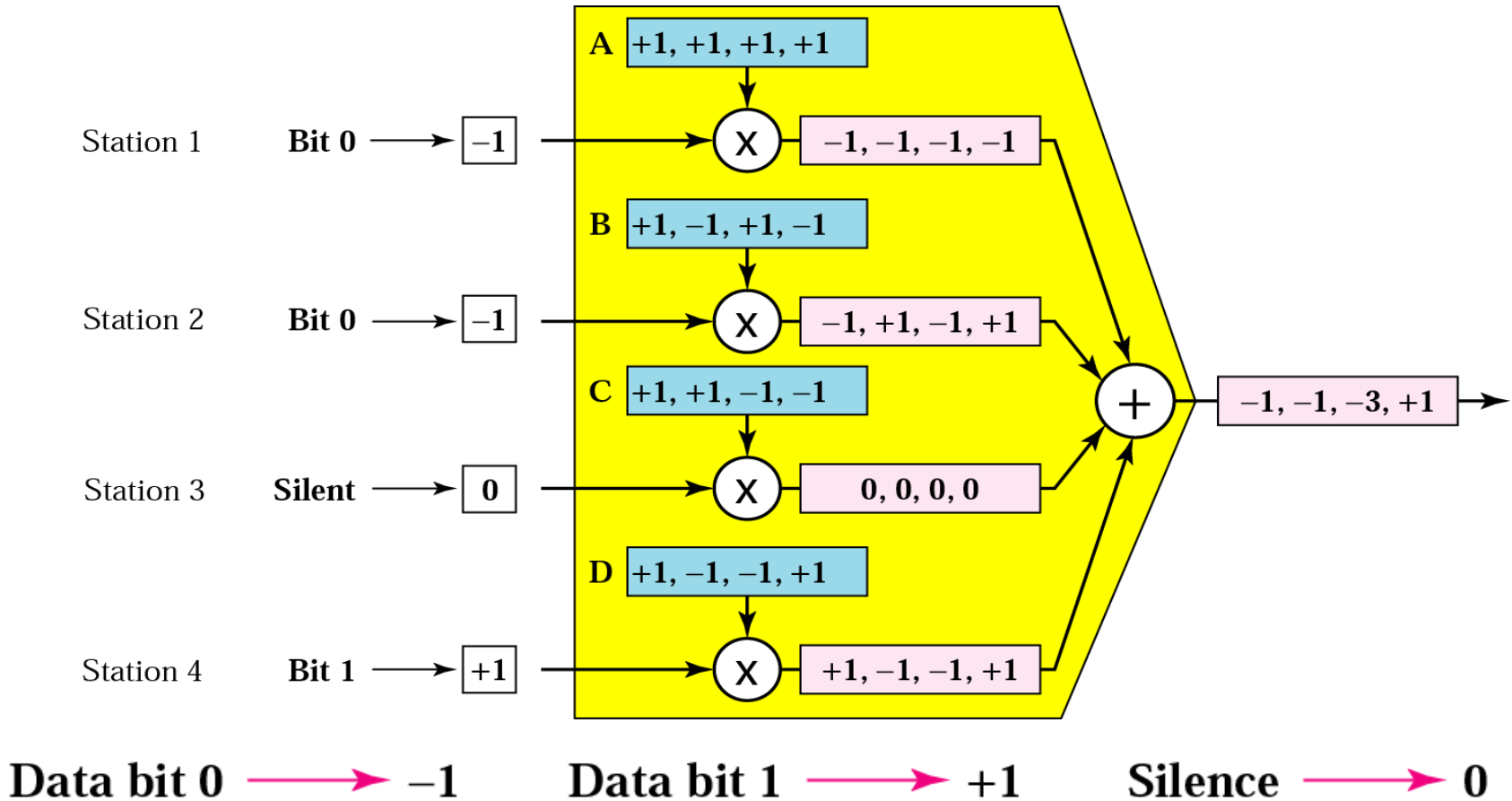
- Data bits are encoded as either +1, 0, or -1:

Data bit 0 \longrightarrow -1 Data bit 1 \longrightarrow +1 Silence \longrightarrow 0

Databit \otimes Chip Sequence = Transmission

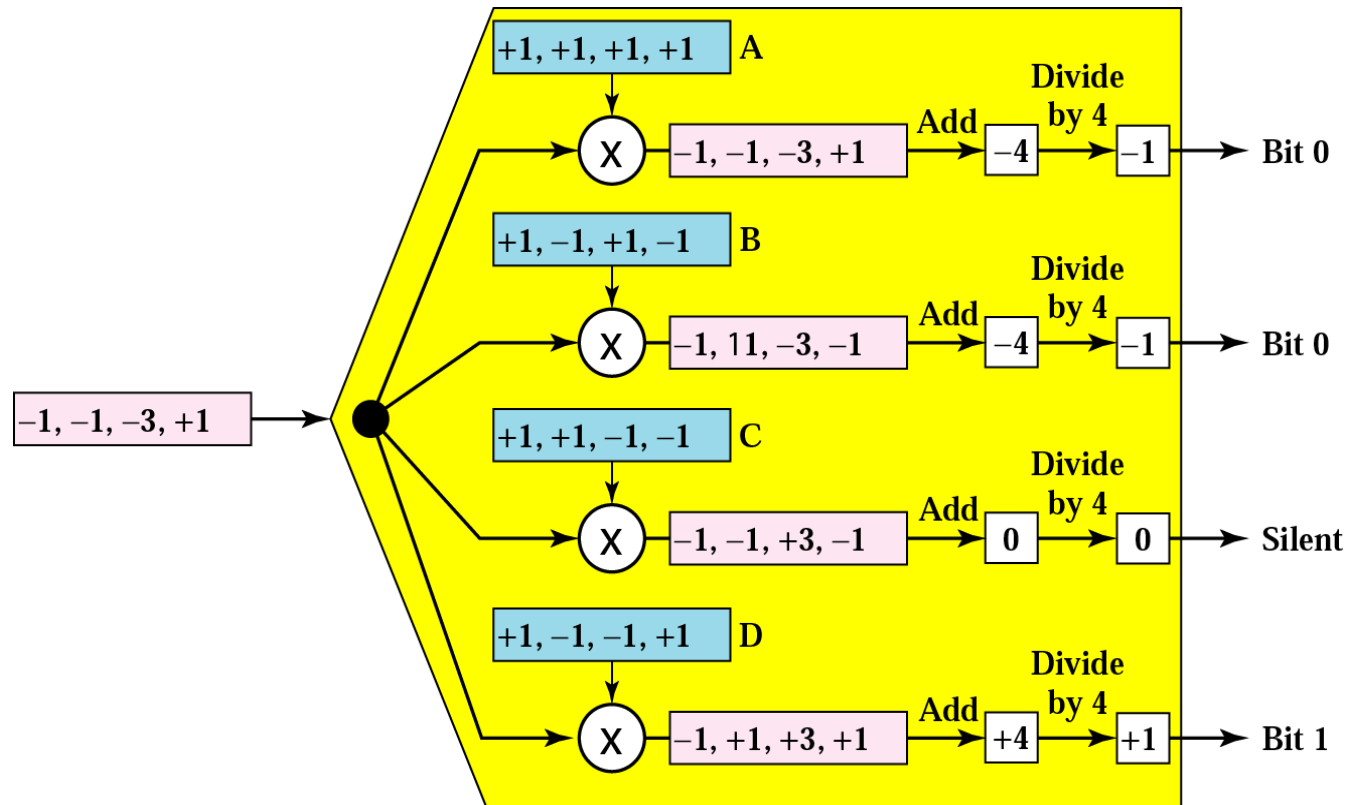
$$-1 \otimes \boxed{+1, +1, -1, -1} \longrightarrow \boxed{-1, -1, +1, +1}$$

CDMA Multiplexer



* Figure is courtesy of B. Forouzan

CDMA De-Multiplexer



Decoding of received signal

* Figure is courtesy of B. Forouzan

Walsh Tables

$$W_1 = \begin{bmatrix} +1 \end{bmatrix}$$

$$W_{2N} = \begin{bmatrix} W_N & W_N \\ W_N & \overline{W_N} \end{bmatrix}$$

$$W_1 = \begin{bmatrix} +1 \end{bmatrix}$$

$$W_2 = \begin{bmatrix} +1 & +1 \\ +1 & -1 \end{bmatrix}$$

$$W_4 = \begin{bmatrix} +1 & +1 & +1 & +1 \\ +1 & -1 & +1 & -1 \\ +1 & +1 & -1 & -1 \\ +1 & -1 & -1 & +1 \end{bmatrix}$$

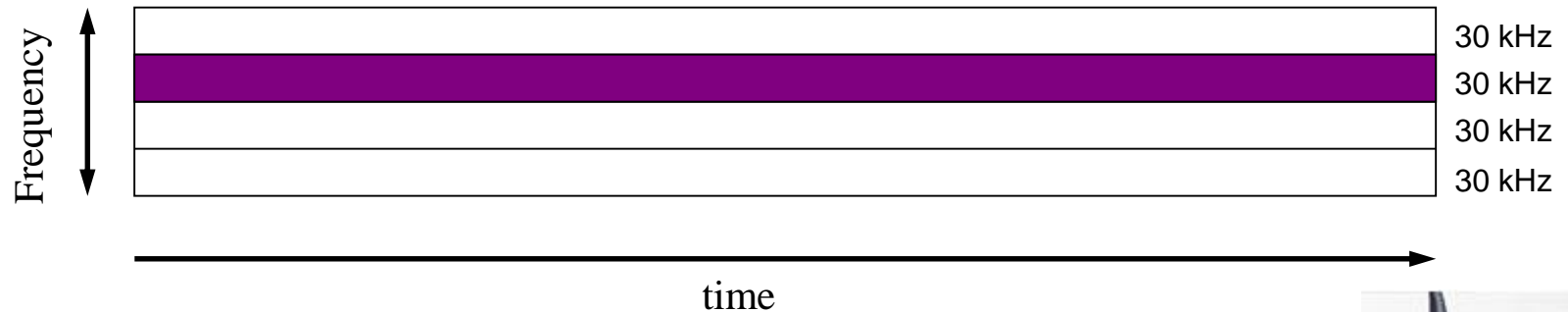
* Figure is courtesy of B. Forouzan

Summary: Synchronous CDMA

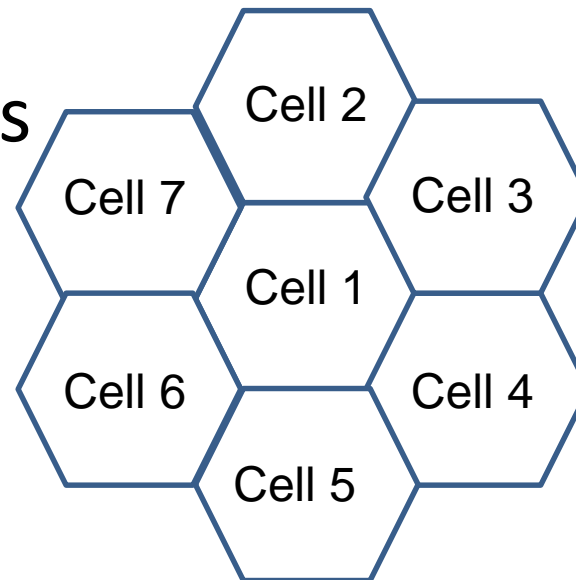
- Makes use of physical properties of interference
- All stations use whole bandwidth
- Computational requirements at stations
- Stations hold individual chip sequences

FDMA in AMPS

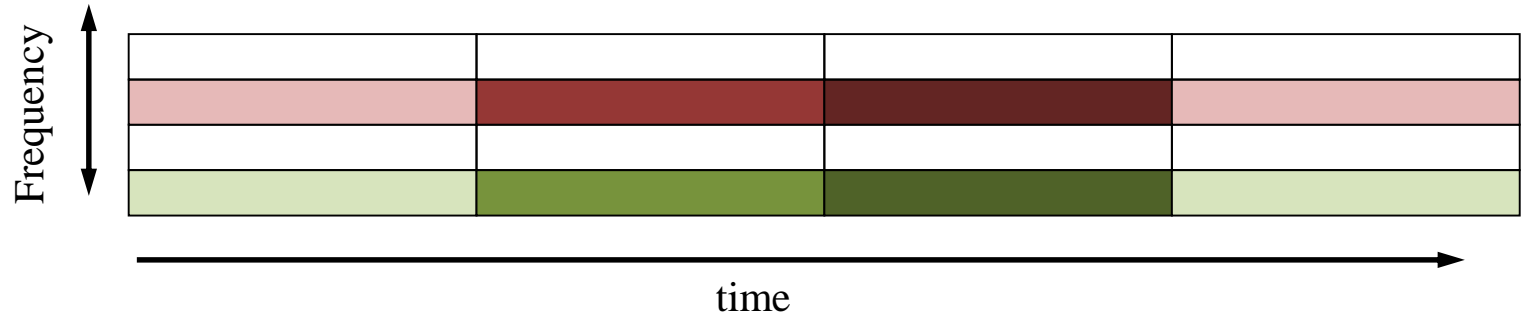
- FDMA



- Non-overlapping channels



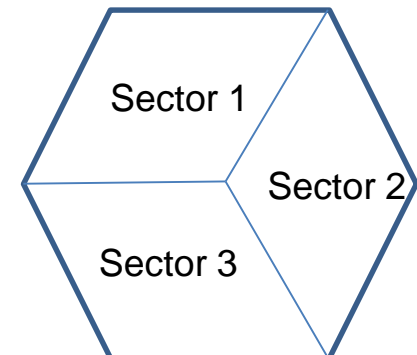
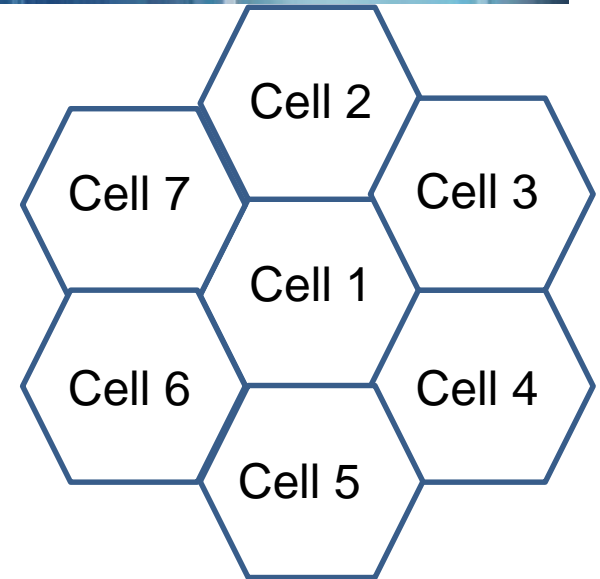
TDMA in GSM



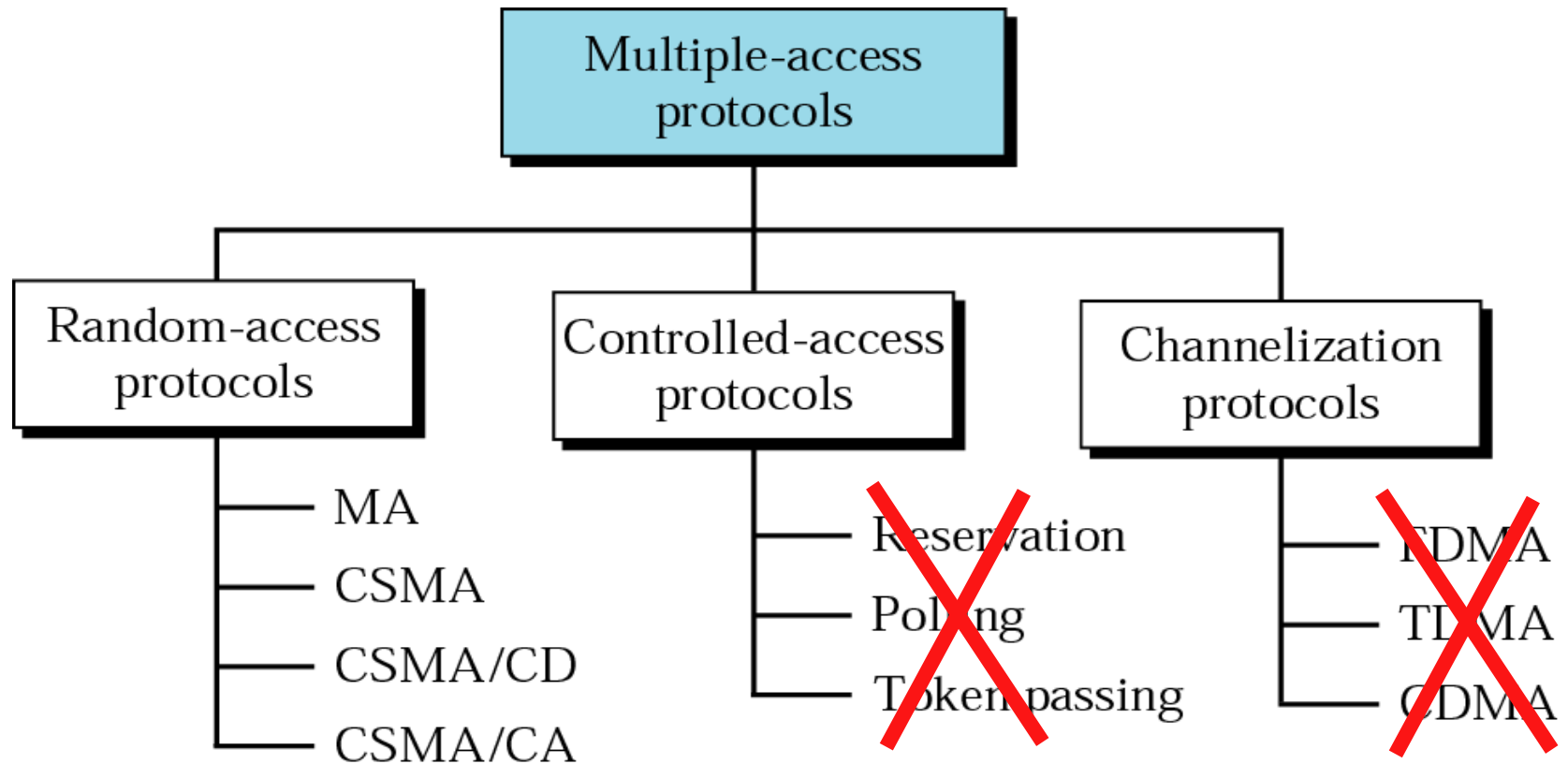
- Mixture of TDMA and FDMA

CDMA in Mobile Phones

- Asynchronous CDMA
- Cells use same frequencies
- Directional antennae used to split cell into sectors
 - 3x capacity

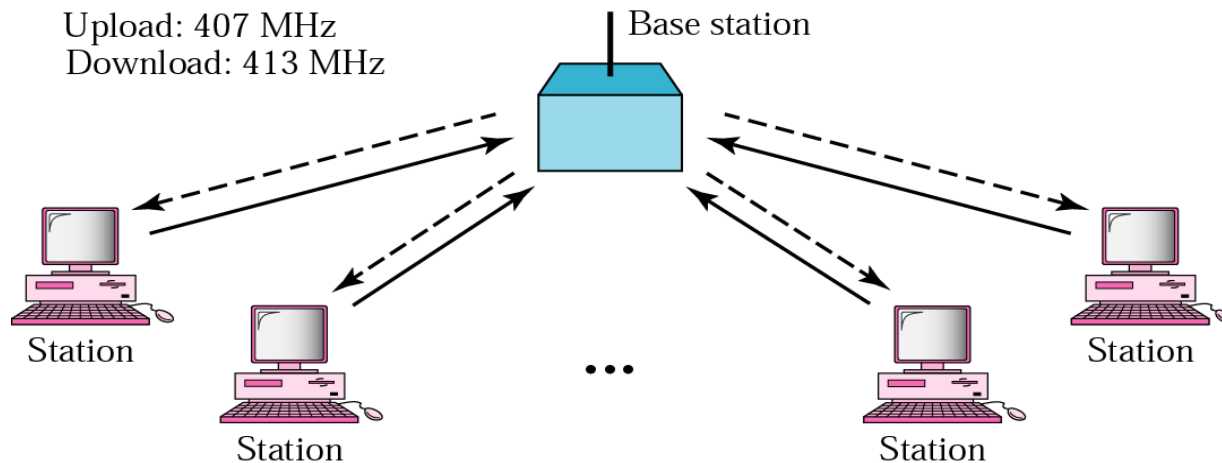


Multiple-Access Protocols



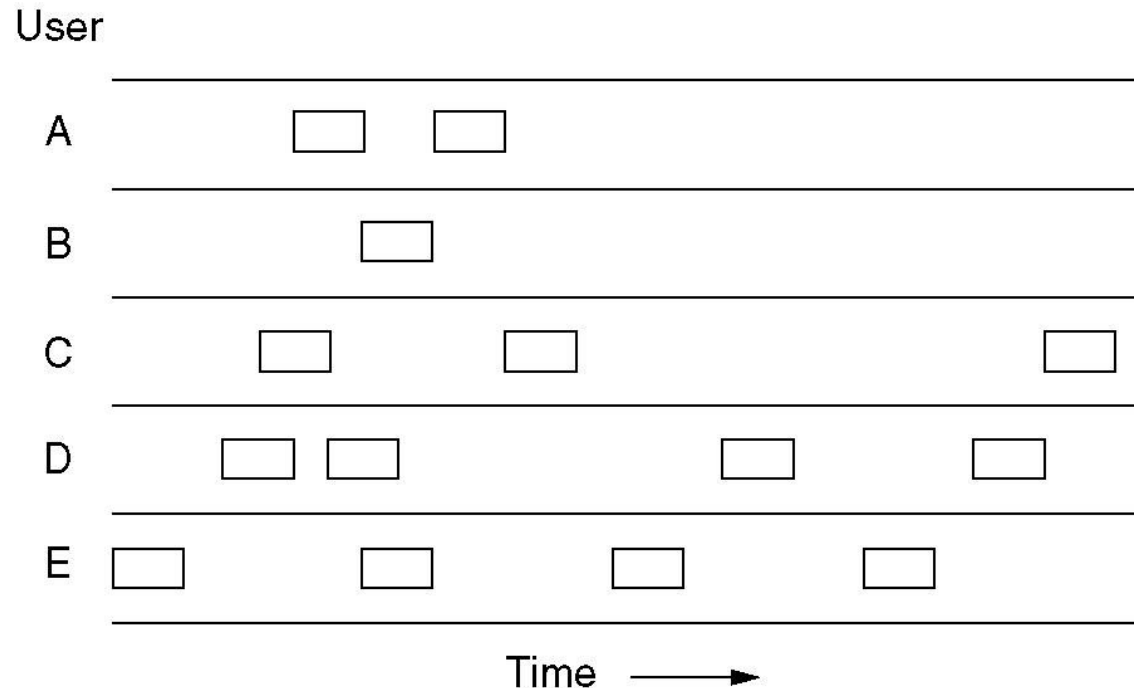
* Figure is courtesy of B. Forouzan

ALOHA Network



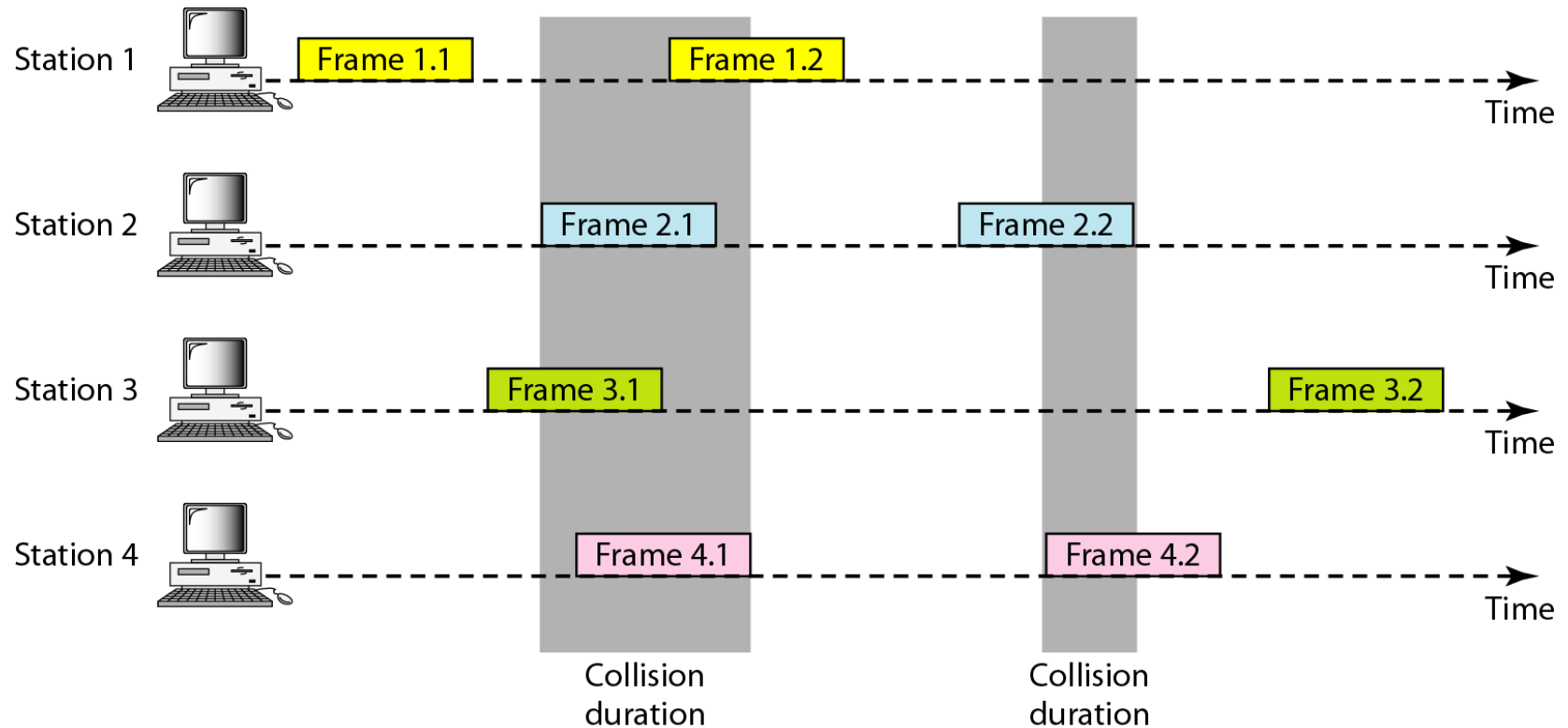
* Figure is courtesy of B. Forouzan

Pure ALOHA



- Assuming all frames of equal length
- Frames are transmitted at completely arbitrary times

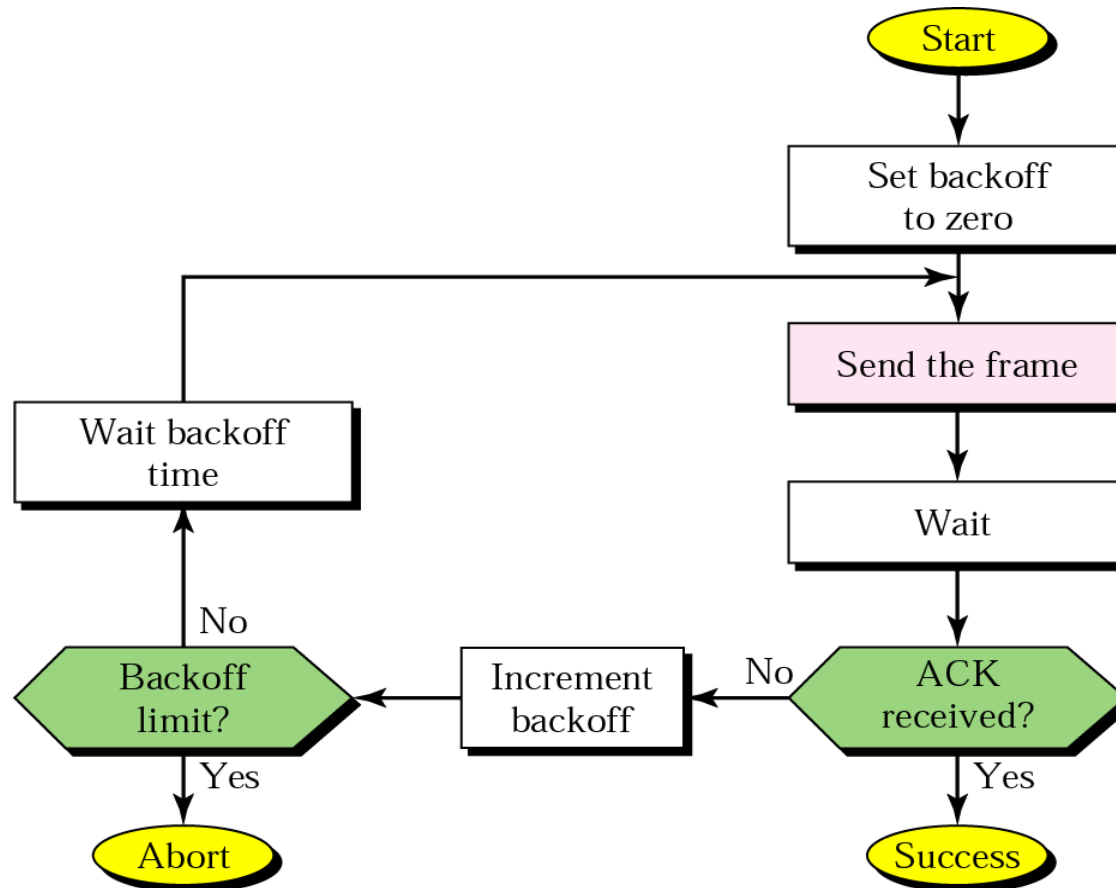
Pure Aloha II



- Collision occurs when frames are transmitted by stations at the same time

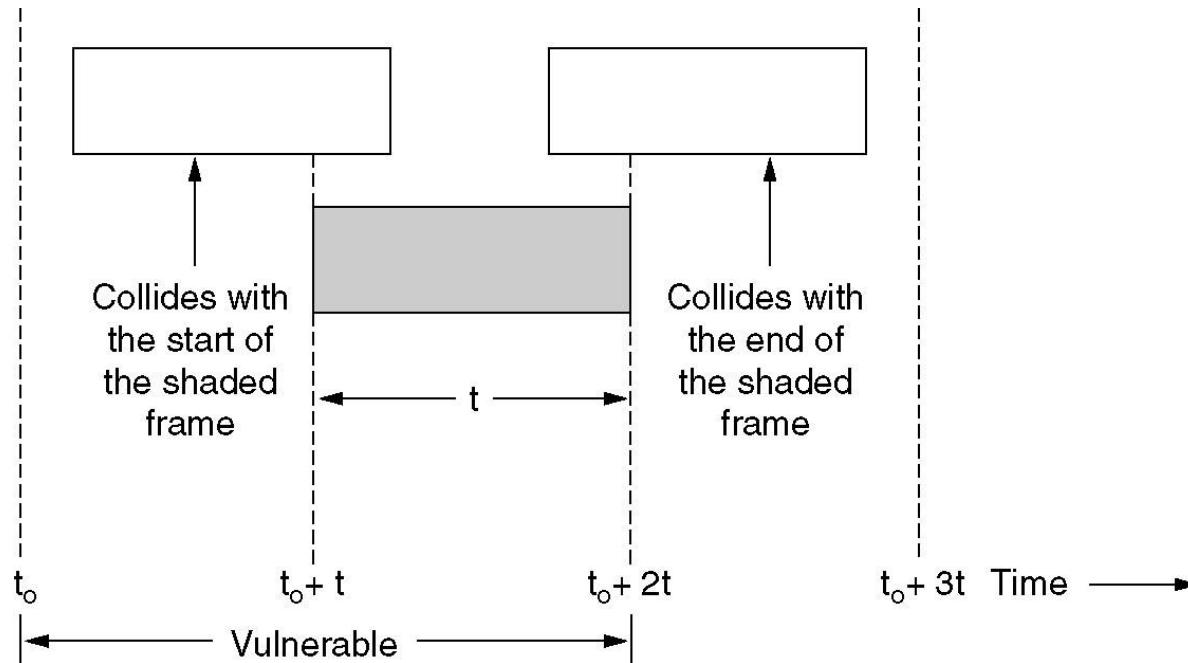
* Figure is courtesy of B. Forouzan

Procedure for ALOHA Protocol



* Figure is courtesy of B. Forouzan

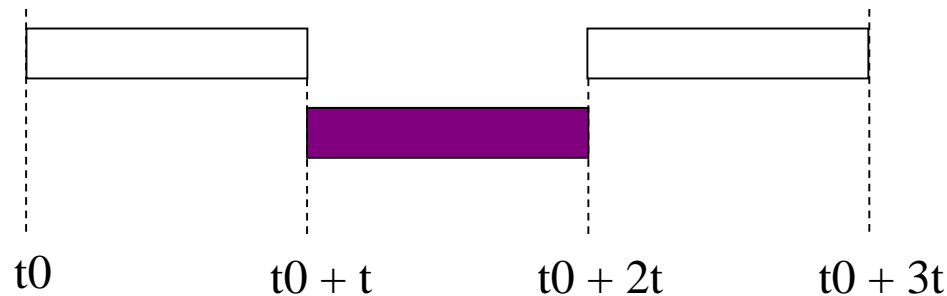
Vulnerable Period for Frame



Maximum utilization around 18%

Slotted Aloha

Divide time into intervals (timeslots)



Algorithm:

when data ready wait for next timeslot

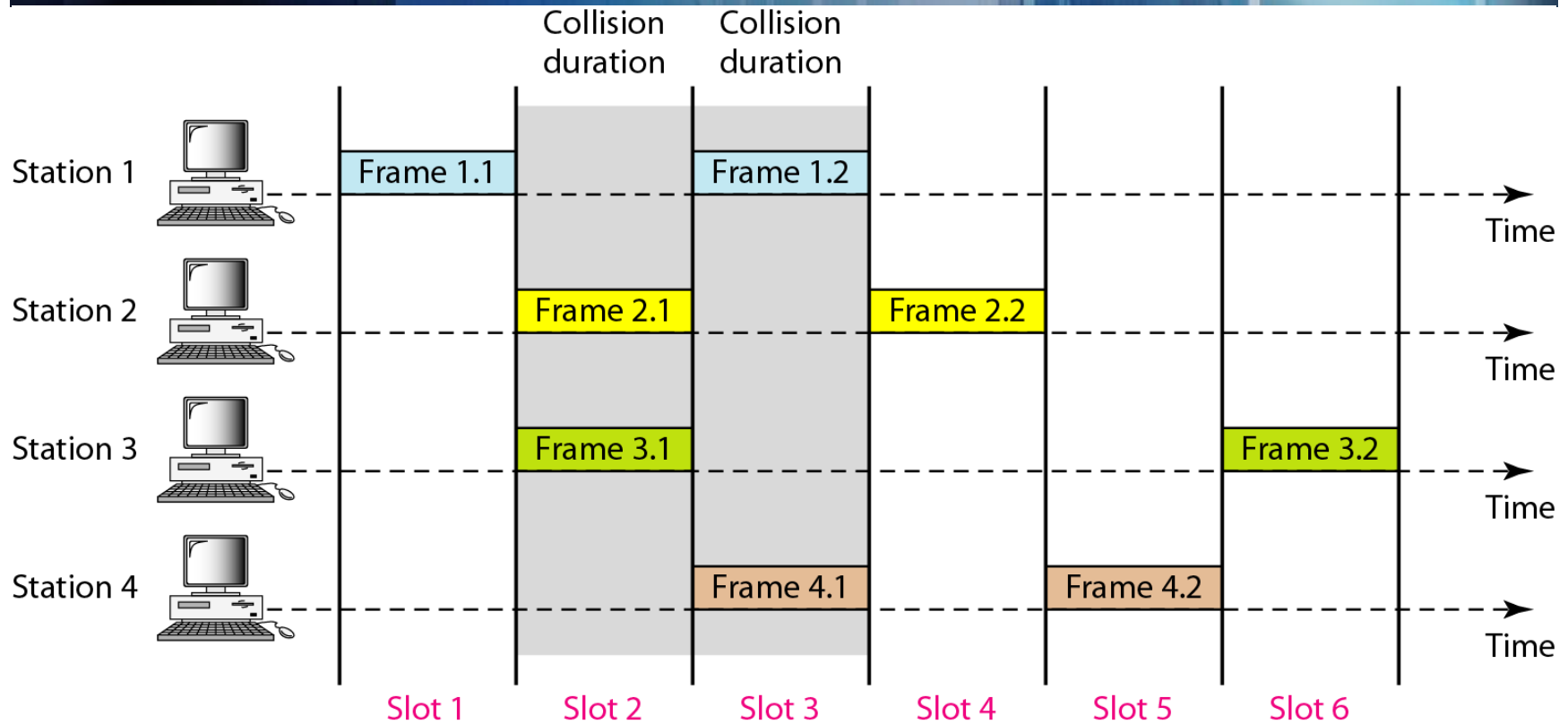
transmit

if (collision)

wait and retransmit

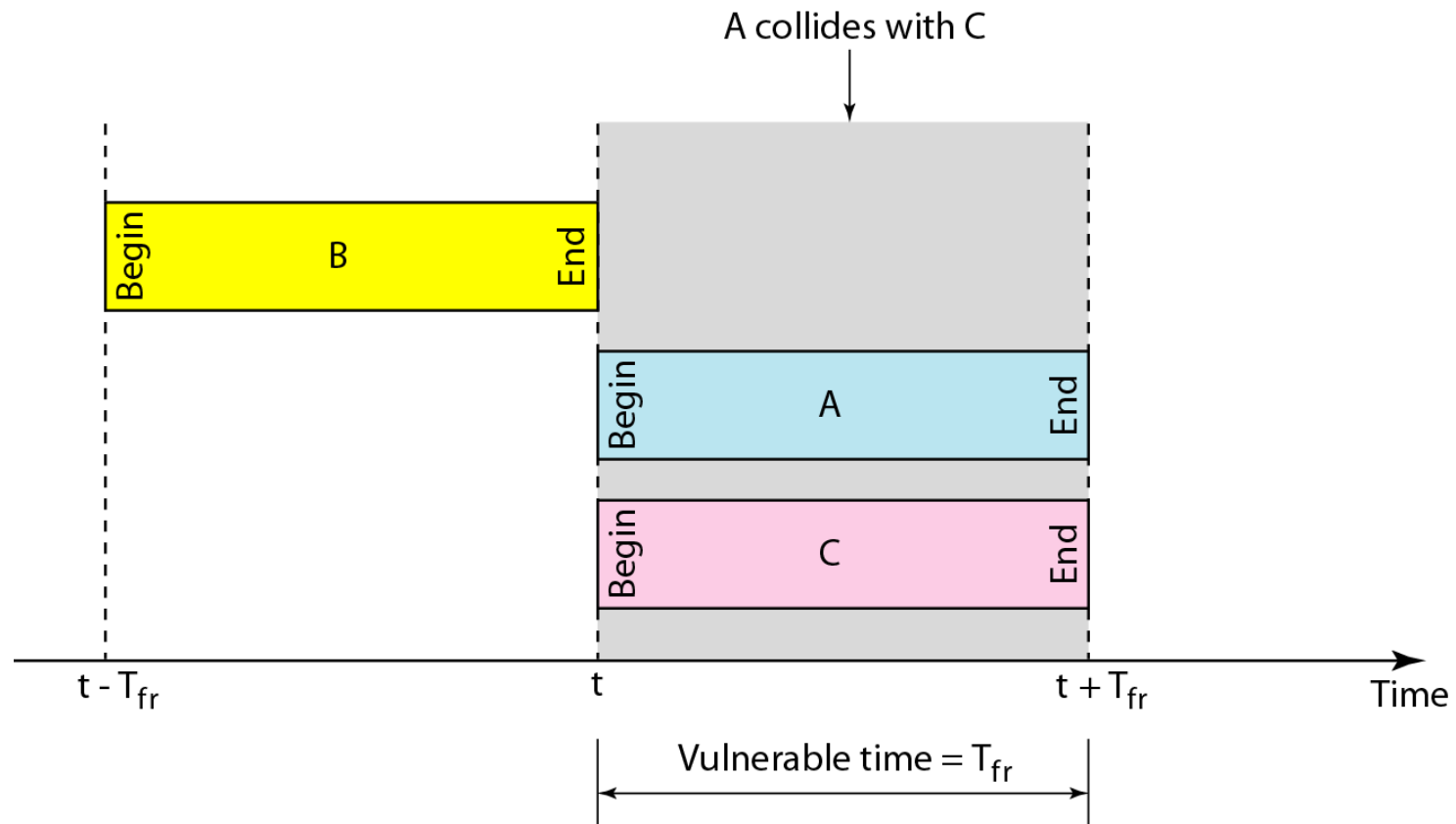
Maximum utilization
is $2 \times$ Pure Aloha

Frames in Slotted Aloha



* Figure is courtesy of B. Forouzan

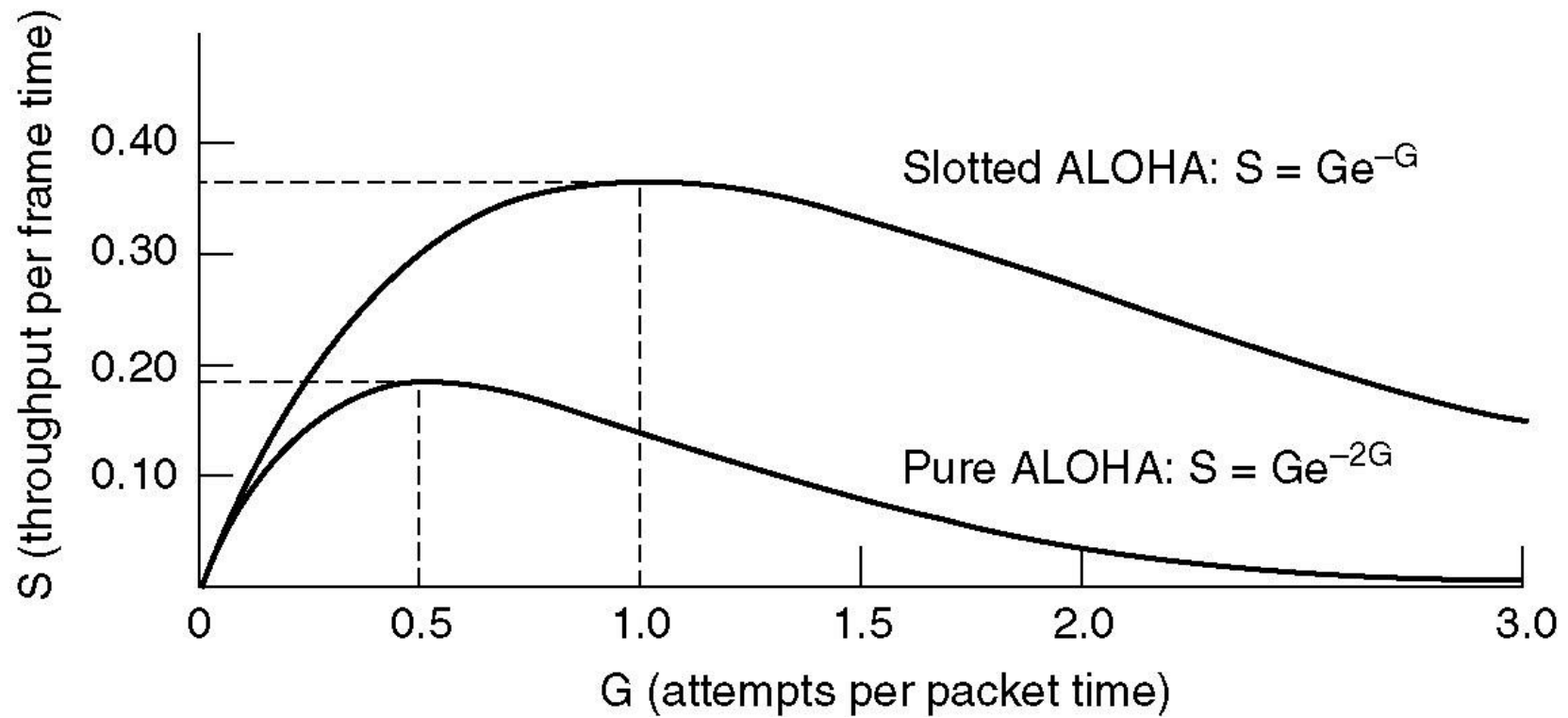
Advantage of Slotted Aloha



- Collisions can only occur within a slot

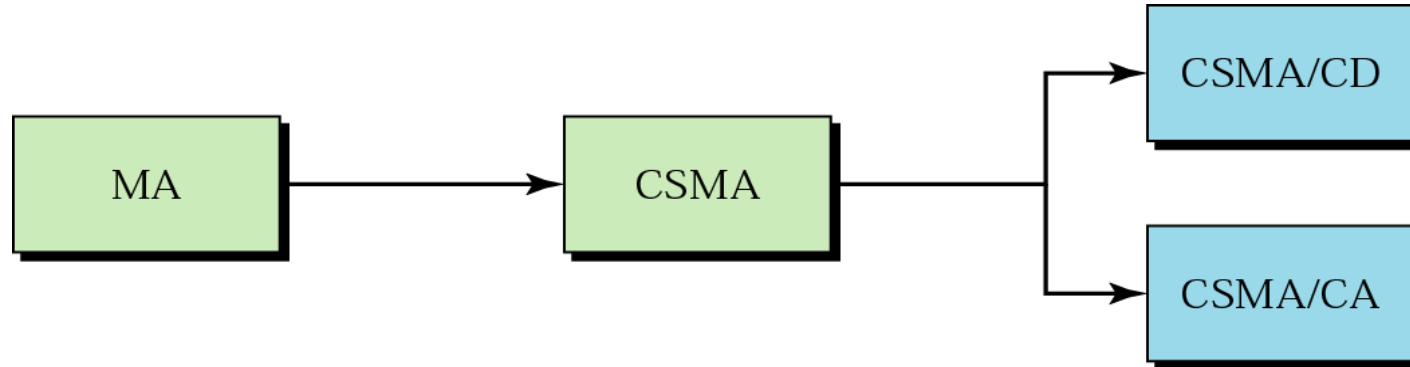
Performance of ALOHA

Throughput versus offered traffic for ALOHA systems.



* Figure is courtesy of A. Tannenbaum

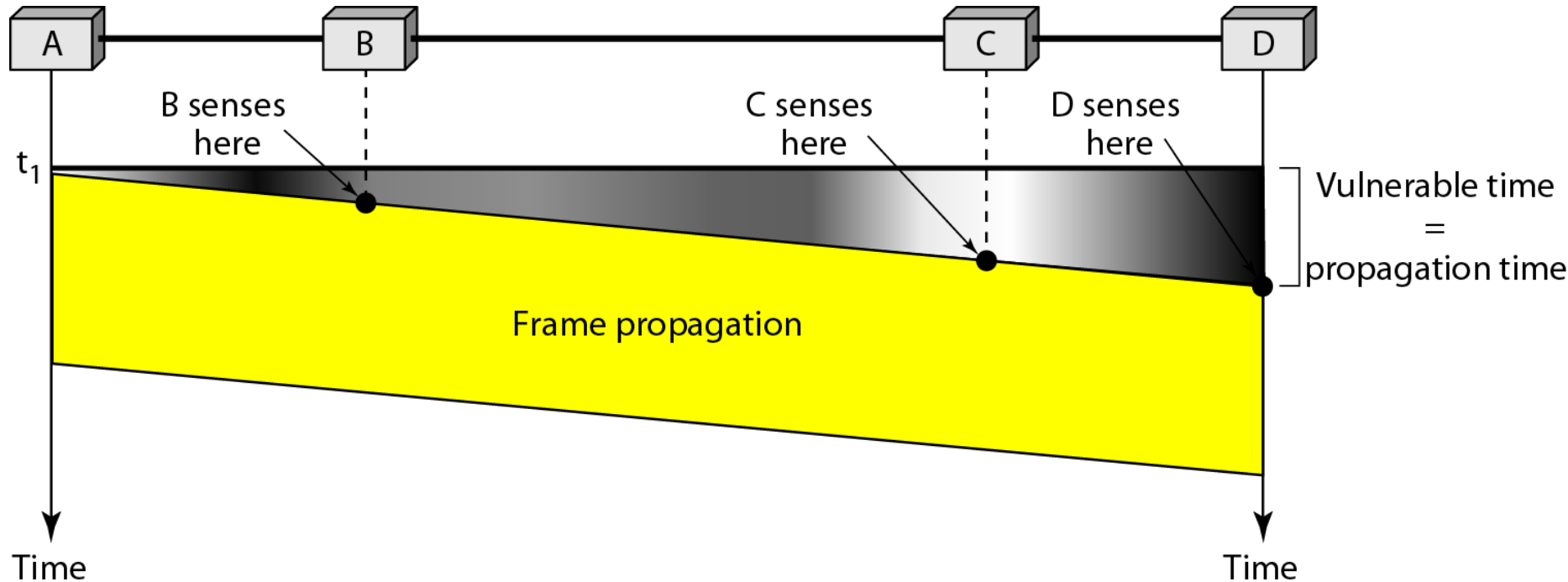
Random-Access Methods



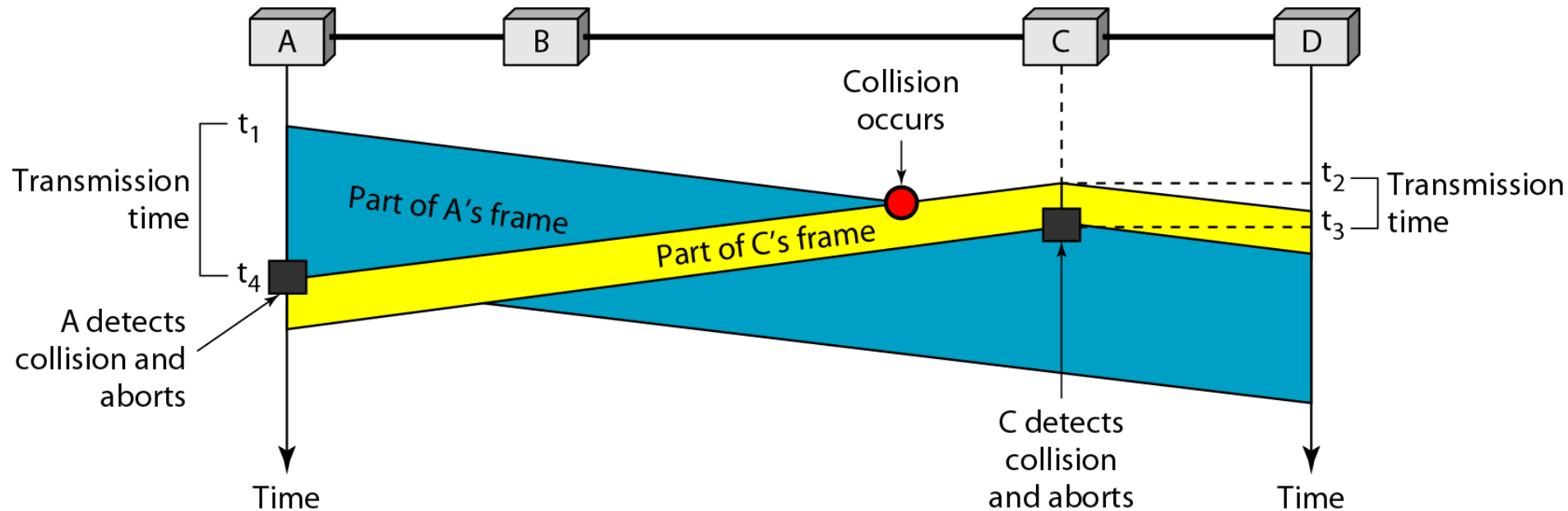
- CS \Rightarrow Carrier Sense
- MA \Rightarrow Multiple Access
- CD \Rightarrow Collision Detection
- CA \Rightarrow Collision Avoidance

* Figure is courtesy of B. Forouzan

CSMA

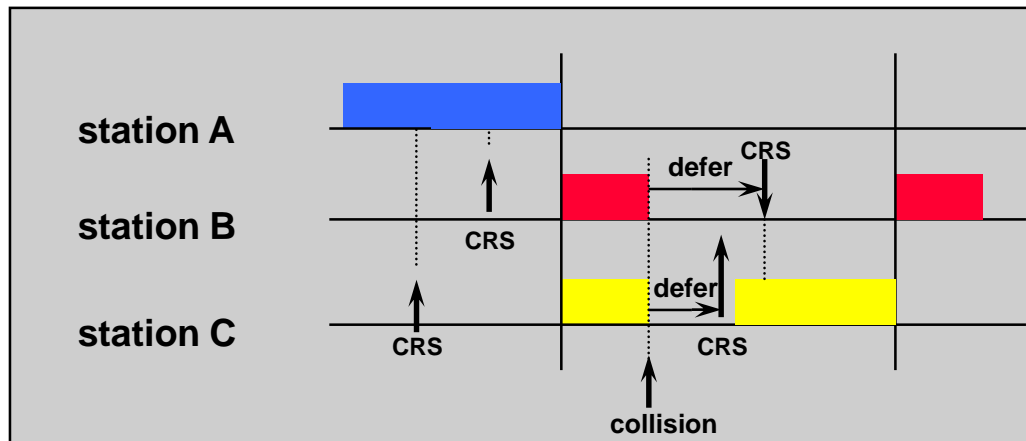


Collision in CSMA/CD



- Both stations will realize that a collision has taken place
- Backoff and attempt to send later

Binary Exponential Backoff

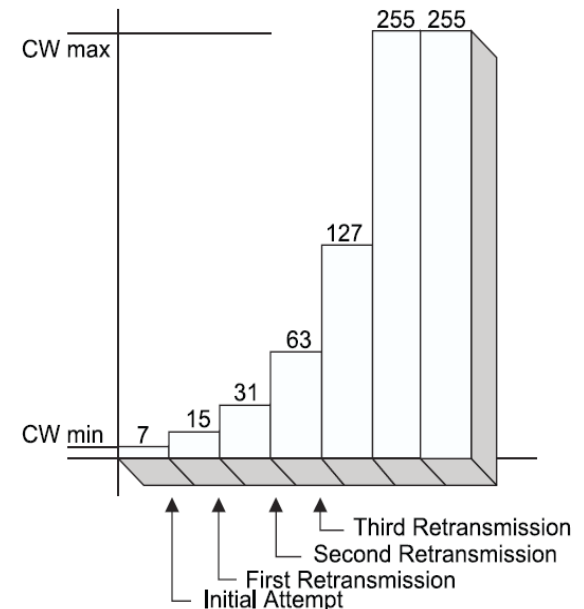


$$\text{Backoff Time} = \text{Random}() \times \text{aSlotTime}$$

where

$\text{Random}()$ = Pseudorandom integer drawn from a uniform distribution over the interval $[0, CW]$, where CW is an integer within the range of values of the PHY characteristics aCW_{\min} and aCW_{\max} , $aCW_{\min} \leq CW \leq aCW_{\max}$. It is important that designers recognize the need for statistical independence among the random number streams among STAs.

$aSlotTime$ = The value of the correspondingly named PHY characteristic.



An Alternative Representation

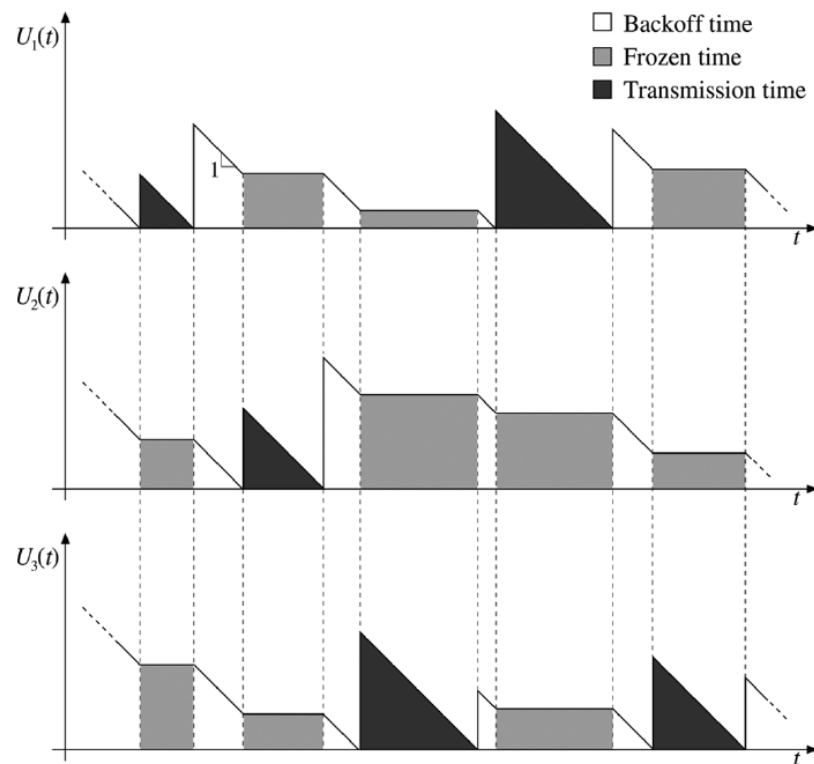
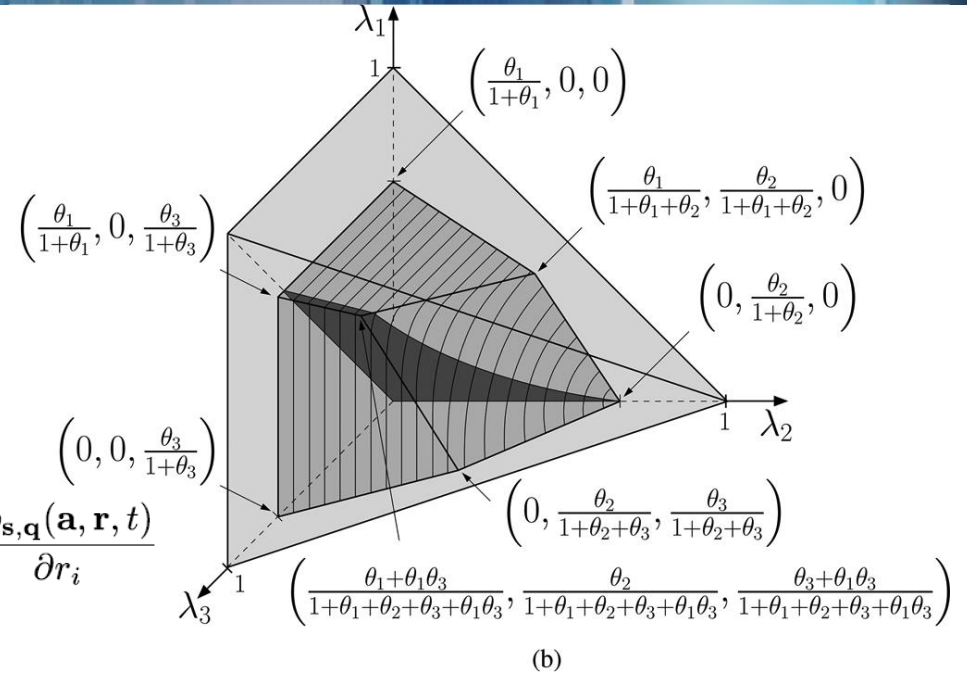


Fig. 1. The operation of three saturated links within carrier-sense range. The graphs show the unfinished work $U_i(t)$ of each transmitter τ_i at time t , which can be either the remaining backoff or the remaining transmission time.

Rafael Laufer and Leonard Kleinrock, The Capacity of Wireless CSMA/CA Networks,
IEEE/ACM TRANSACTIONS ON NETWORKING, vol. 24, no. 3, pp 1518-1532, JUNE 2016

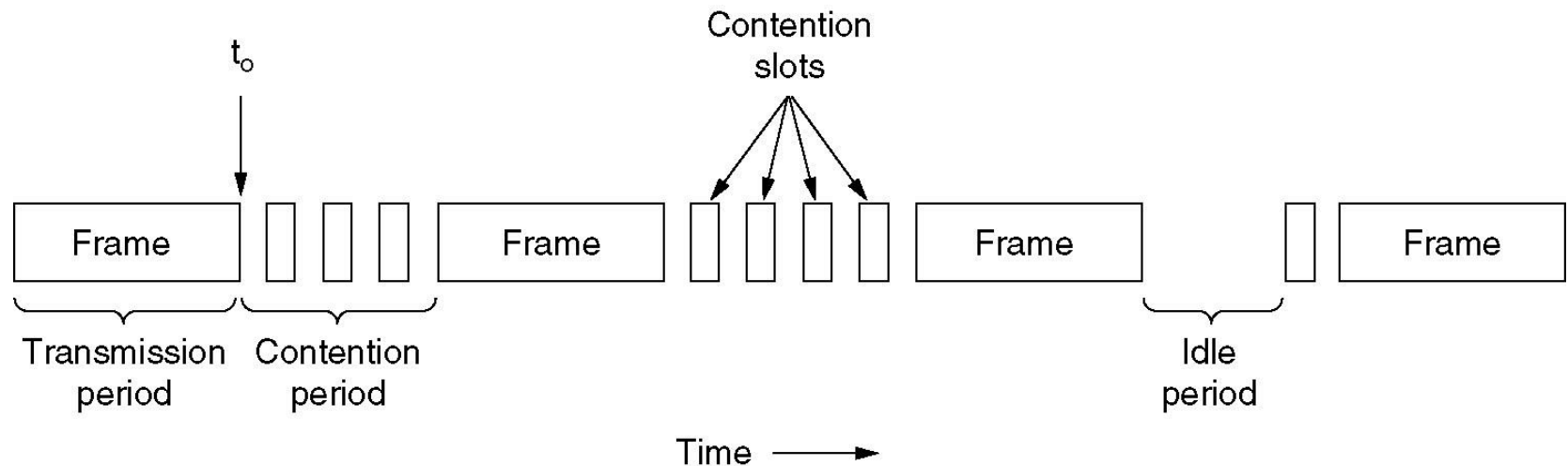
Capacity of Networks

$$\begin{aligned}
 \frac{\partial p_{\mathbf{s}, \mathbf{q}}(\mathbf{a}, \mathbf{r}, t)}{\partial t} = & \sum_{i \notin F(\mathbf{s})} \frac{\partial p_{\mathbf{s}, \mathbf{q}}(\mathbf{a}, \mathbf{r}, t)}{\partial a_i} + \sum_{i \in C(\mathbf{s}, \mathbf{q})} \frac{\partial p_{\mathbf{s}, \mathbf{q}}(\mathbf{a}, \mathbf{r}, t)}{\partial r_i} \\
 & + \sum_{i \in A(\mathbf{s}, \mathbf{q})} p_{\mathbf{s}, \mathbf{q} - \mathbf{e}_i}(\tilde{\mathbf{a}}_i, \mathbf{r}, t) f_{A_i}(a_i) \\
 & + \sum_{i \in T(\mathbf{s})} p_{\mathbf{s} - \mathbf{e}_i, \mathbf{q}}(\mathbf{a}, \tilde{\mathbf{r}}_i, t) f_{T_i}(r_i) \\
 & + \sum_{i \in B(\mathbf{s})} p_{\mathbf{s} + \mathbf{e}_i, \mathbf{q} + \mathbf{e}_i}(\mathbf{a}, \tilde{\mathbf{r}}_i, t) f_{B_i}(r_i). \quad (31)
 \end{aligned}$$



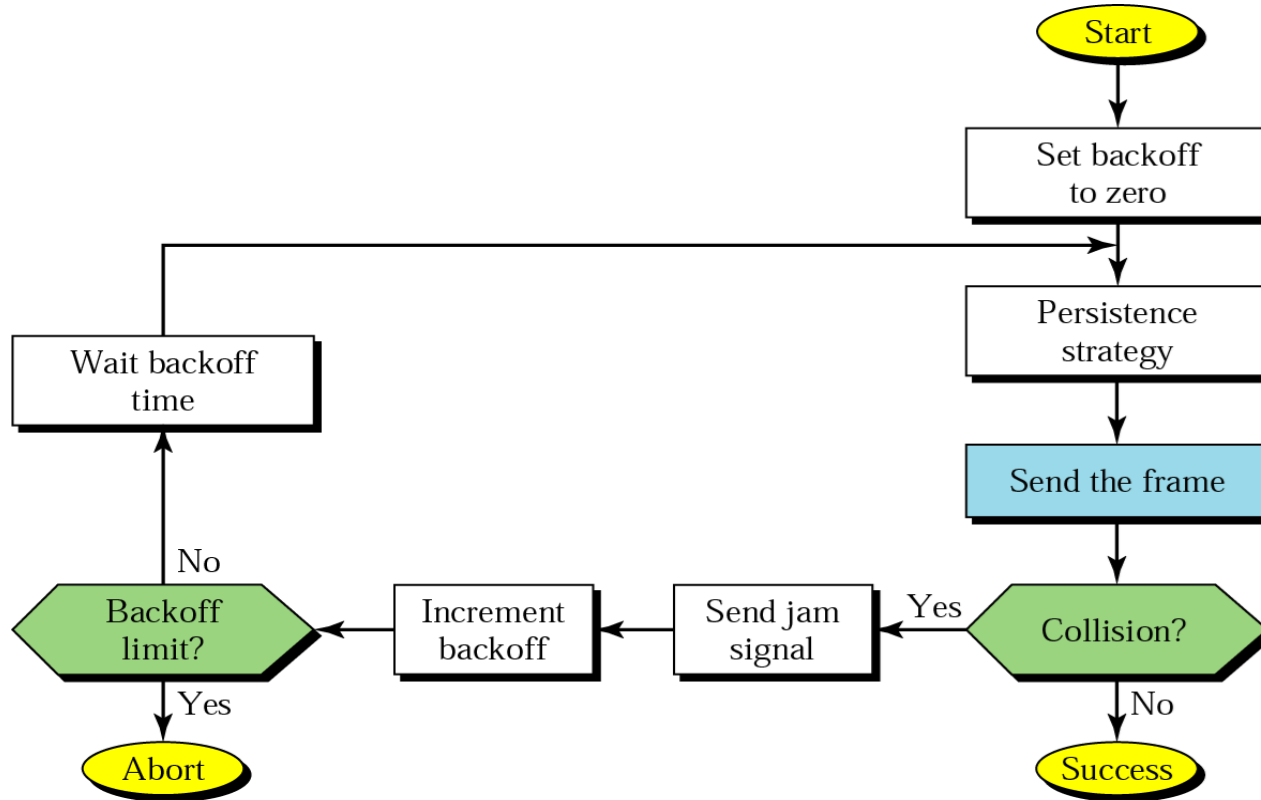
Rafael Laufer and Leonard Kleinrock, The Capacity of Wireless CSMA/CA Networks,
IEEE/ACM TRANSACTIONS ON NETWORKING, vol. 24, no. 3, pp 1518-1532, JUNE 2016

CSMA with Collision Detection



CSMA/CD can be in one of three states:
contention, transmission, or idle.

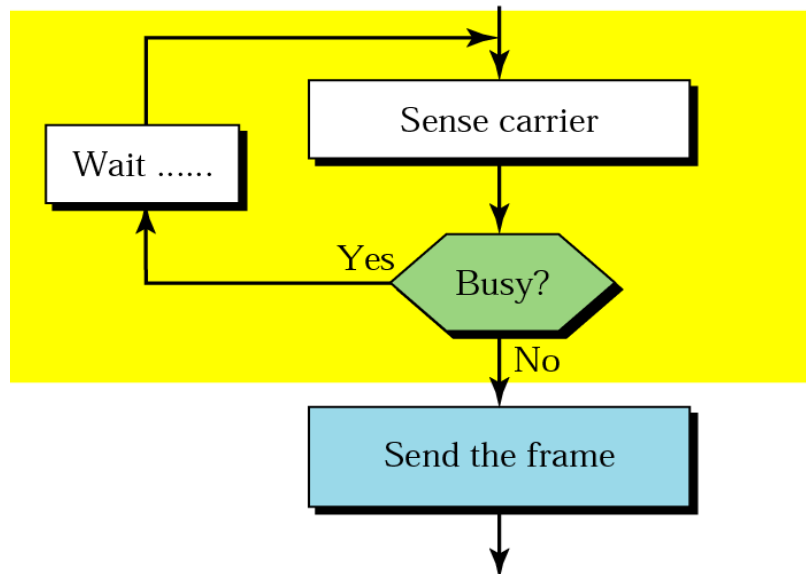
CSMA/CD Procedure



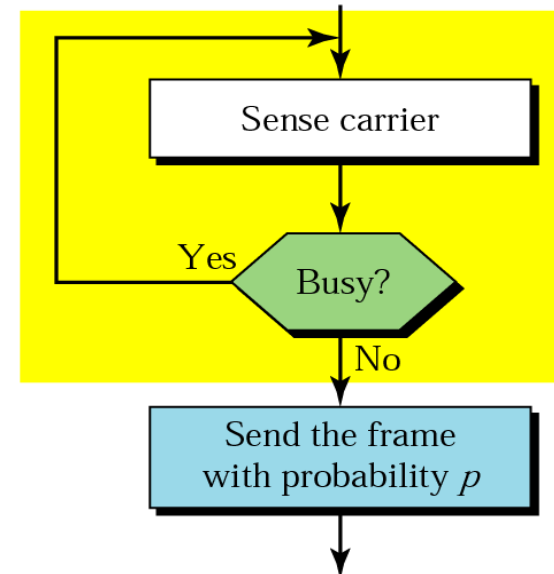
* Figure is courtesy of B. Forouzan

Persistence Strategies

Nonpersistent strategy



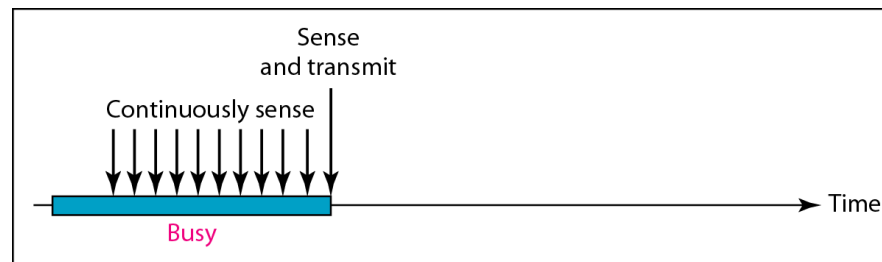
Persistent strategy



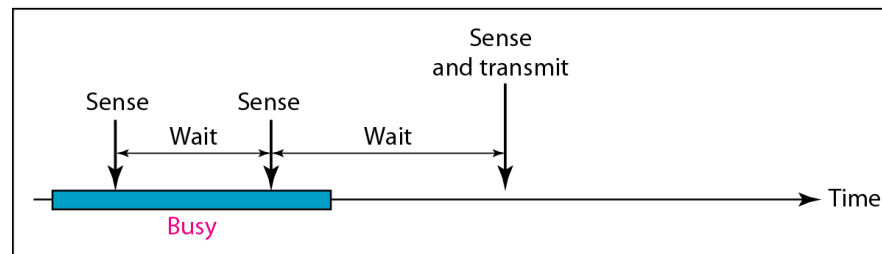
- 1-persistent CSMA
 - if medium idle send immediately
- p-persistent CSMA
 - if medium available station may send depending on probability
 - reduces chance of collision and improves efficiency

* Figure is courtesy of B. Forouzan

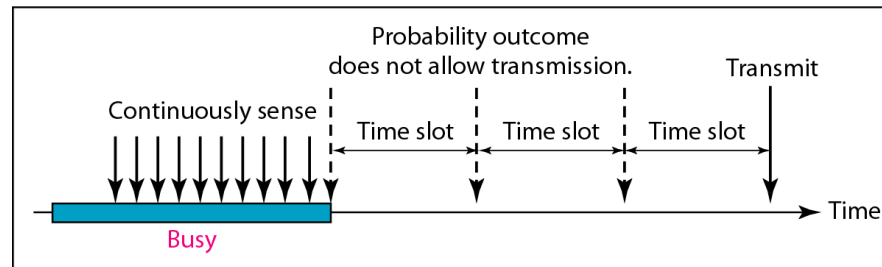
Persistence Strategies II



a. 1-persistent



b. Nonpersistent

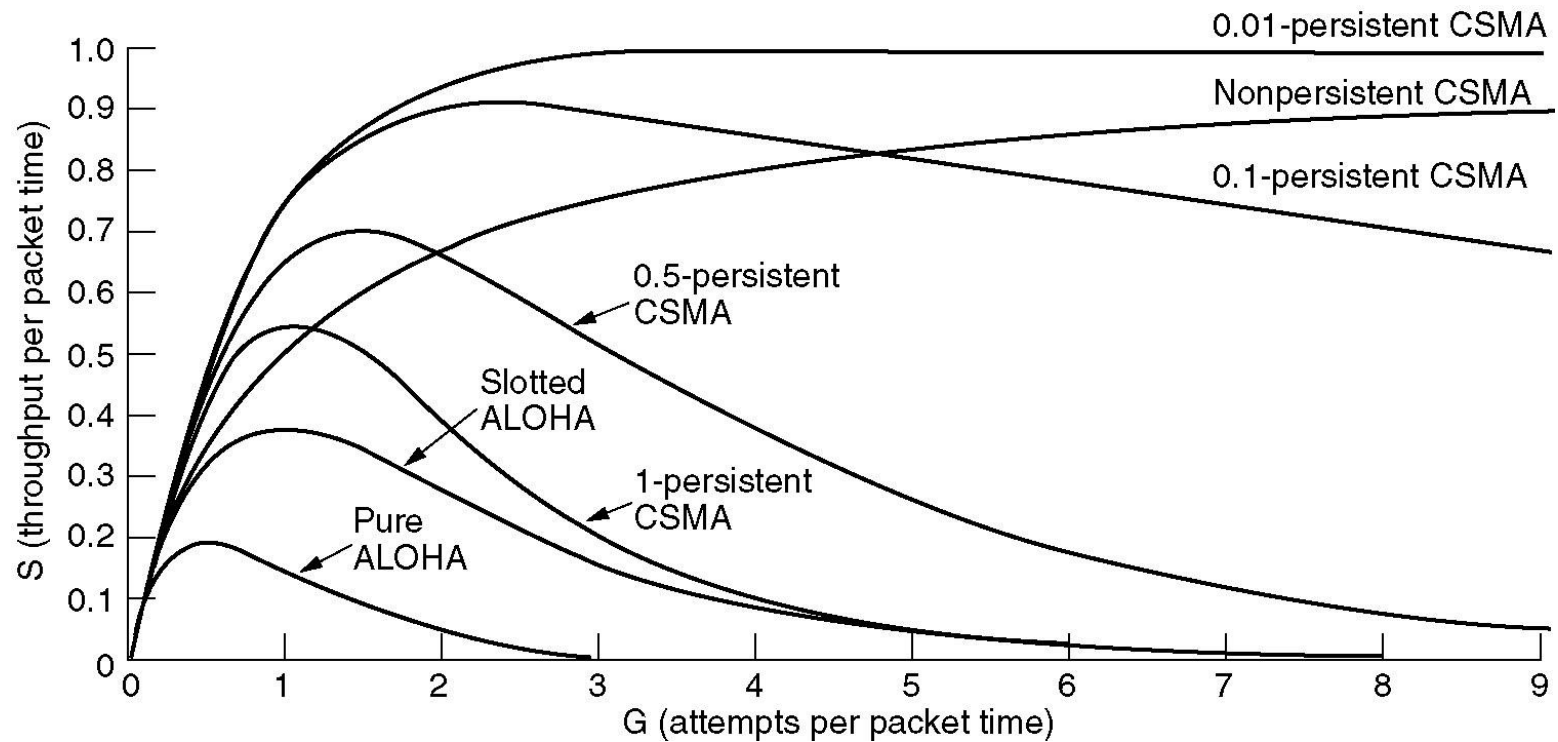


c. p-persistent

* Figure is courtesy of B. Forouzan

Persistent and Non-Persistent CSMA

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

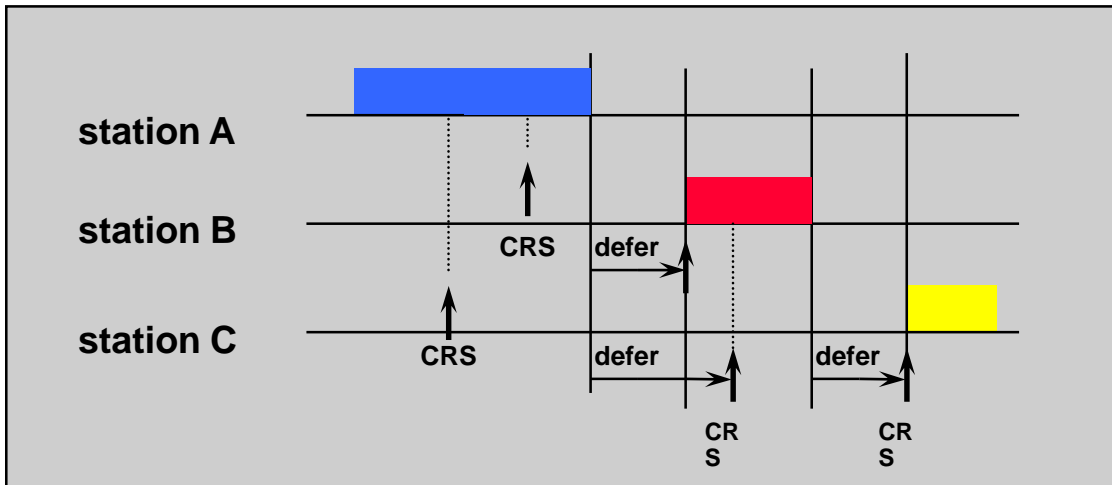


* Figure is courtesy of A. Tanenbaum

CSMA in Wireless Media

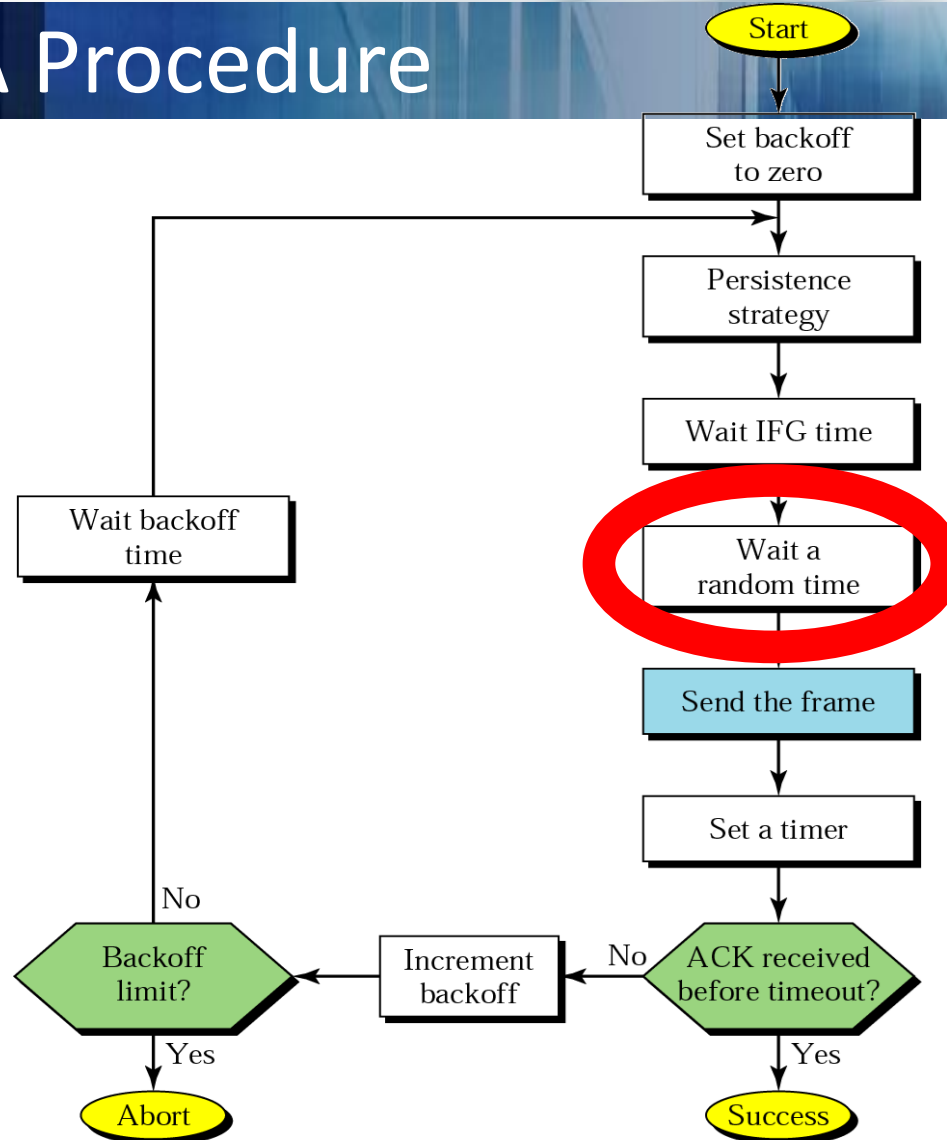


Collision is at the receiver !!!



- Sense carrier to determine if medium is free
 - Once free pick a random number
 - then start sending
- * Figure is courtesy of Ayaya Corp

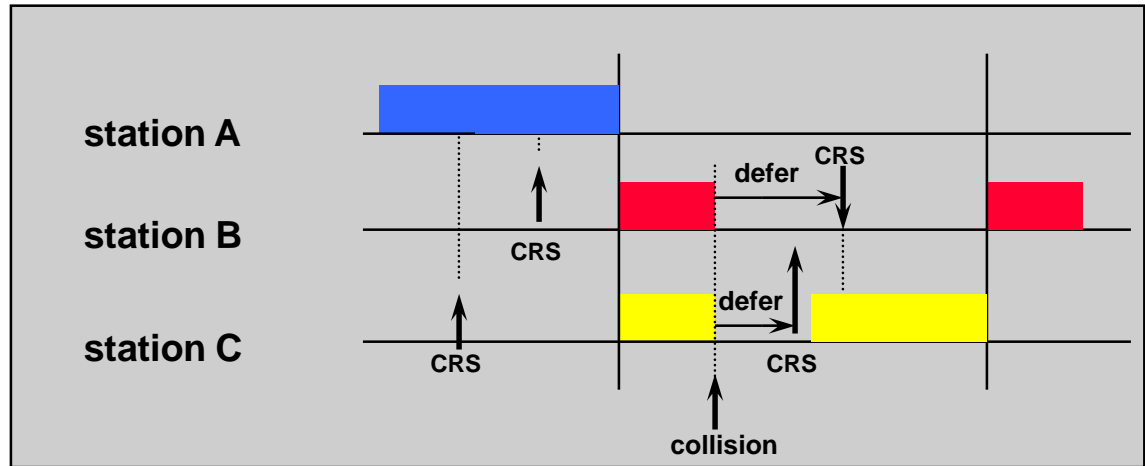
CSMA/CA Procedure



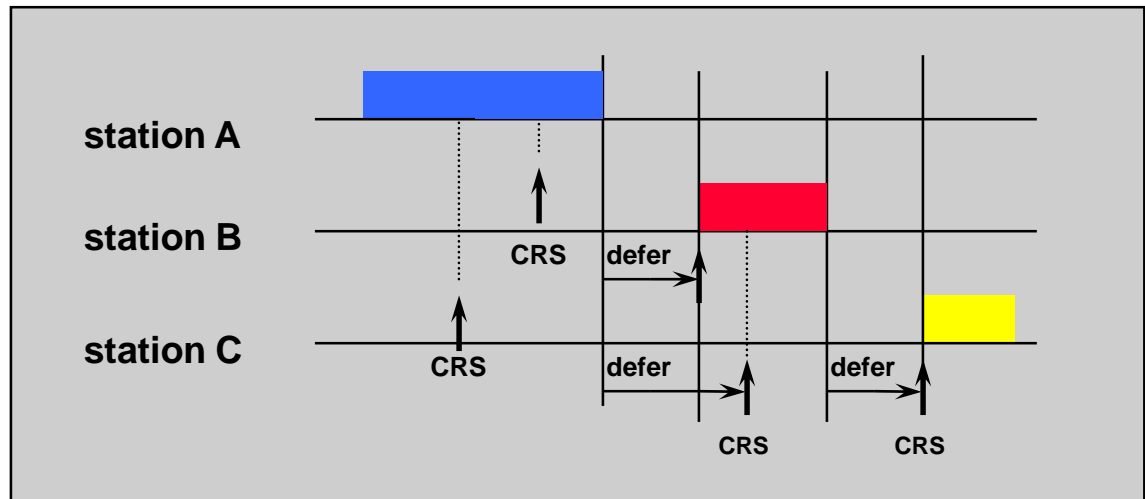
* Figure is courtesy of B. Forouzan

CSMA/CD and CSMA/CA

- CSMA/CD



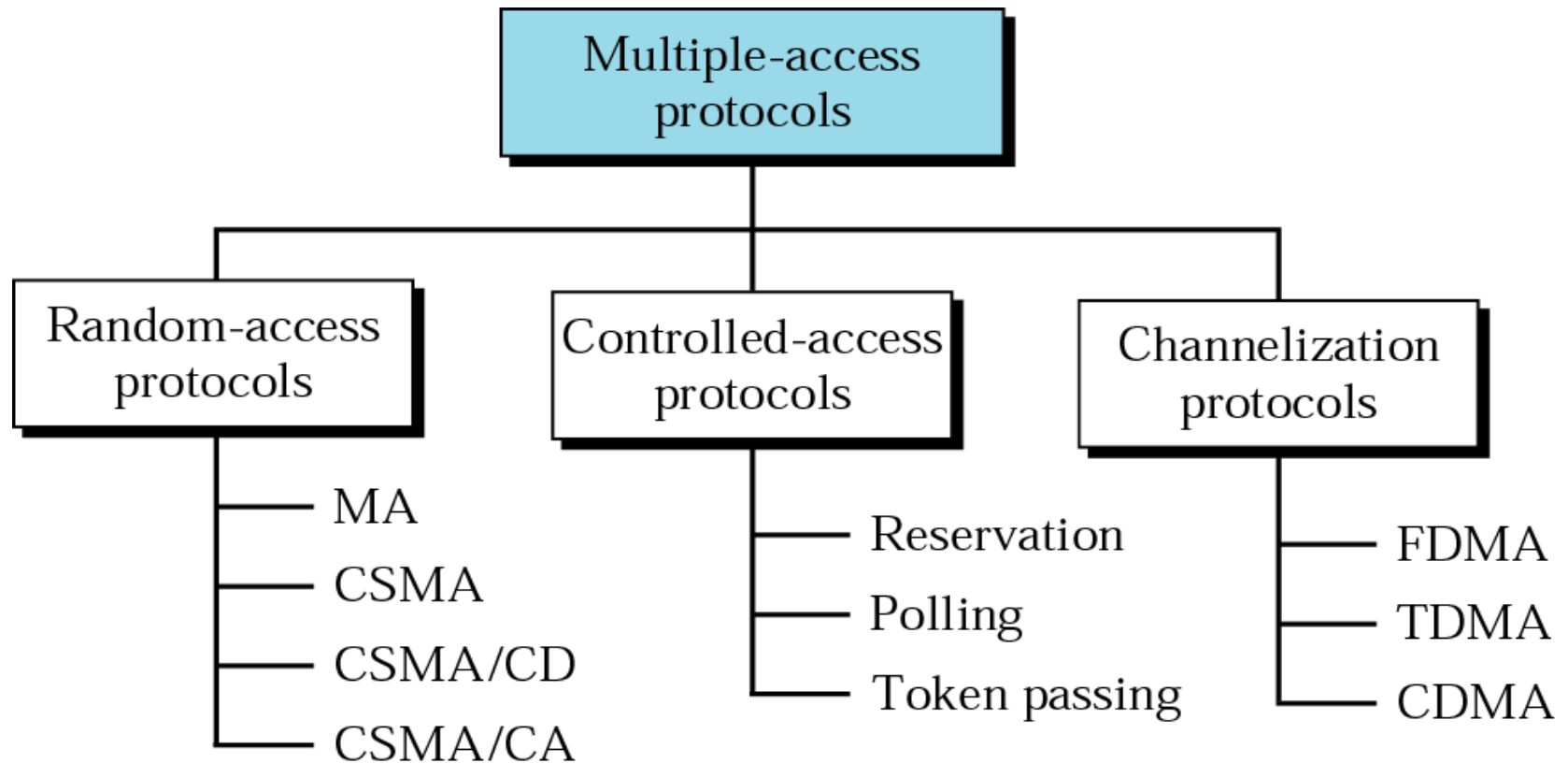
- CSMA/CA



CRS = Carrier Sense

* Figure is courtesy of Avaya Communications Inc

Multiple-Access Protocols



* Figure is courtesy of B. Forouzan



That's all
folks