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

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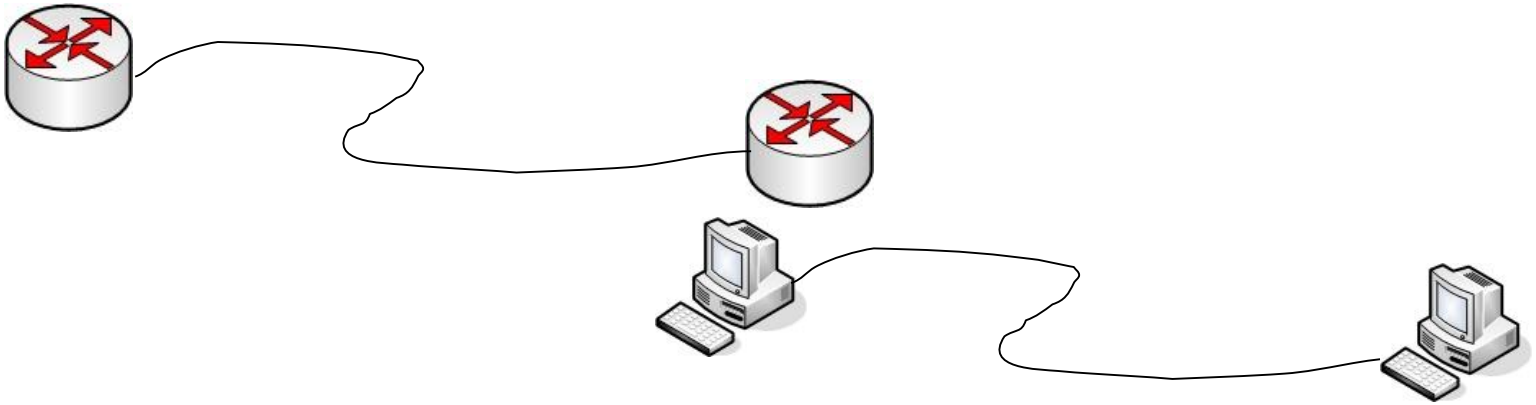
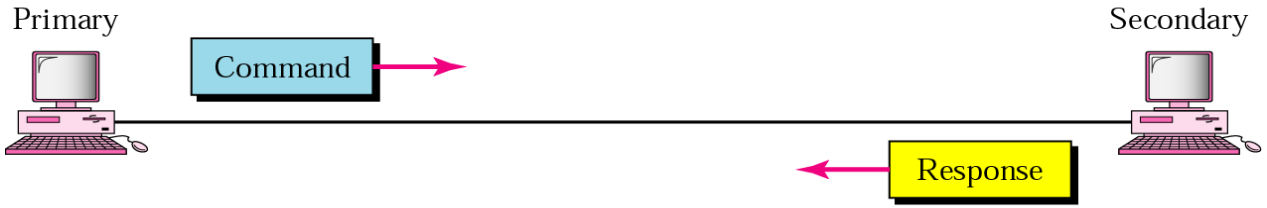
CS2031
Telecommunications II

Medium Access Control

HDLC / PPP



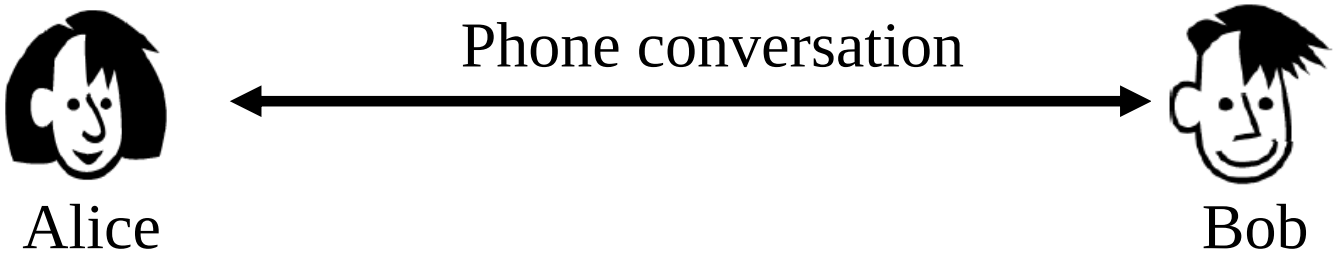


a. Point-to-point

b. Multipoint

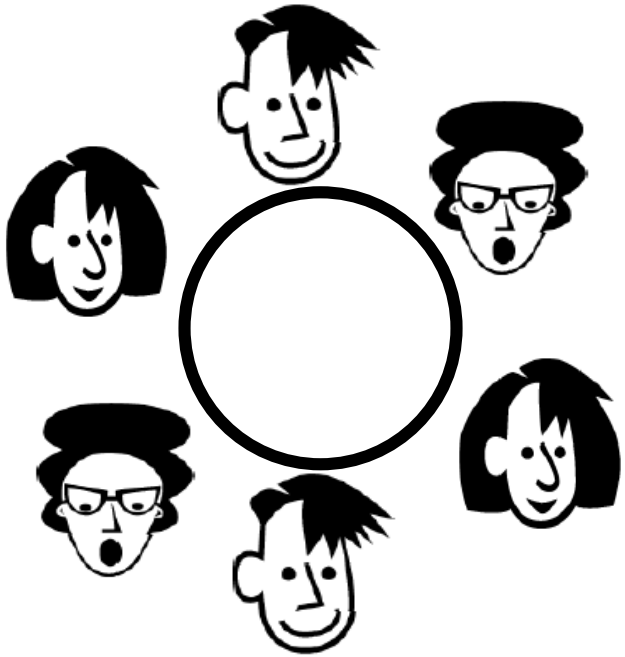
* Figure is courtesy of B. Forouzan

Analogy: Point-to-Point Communication



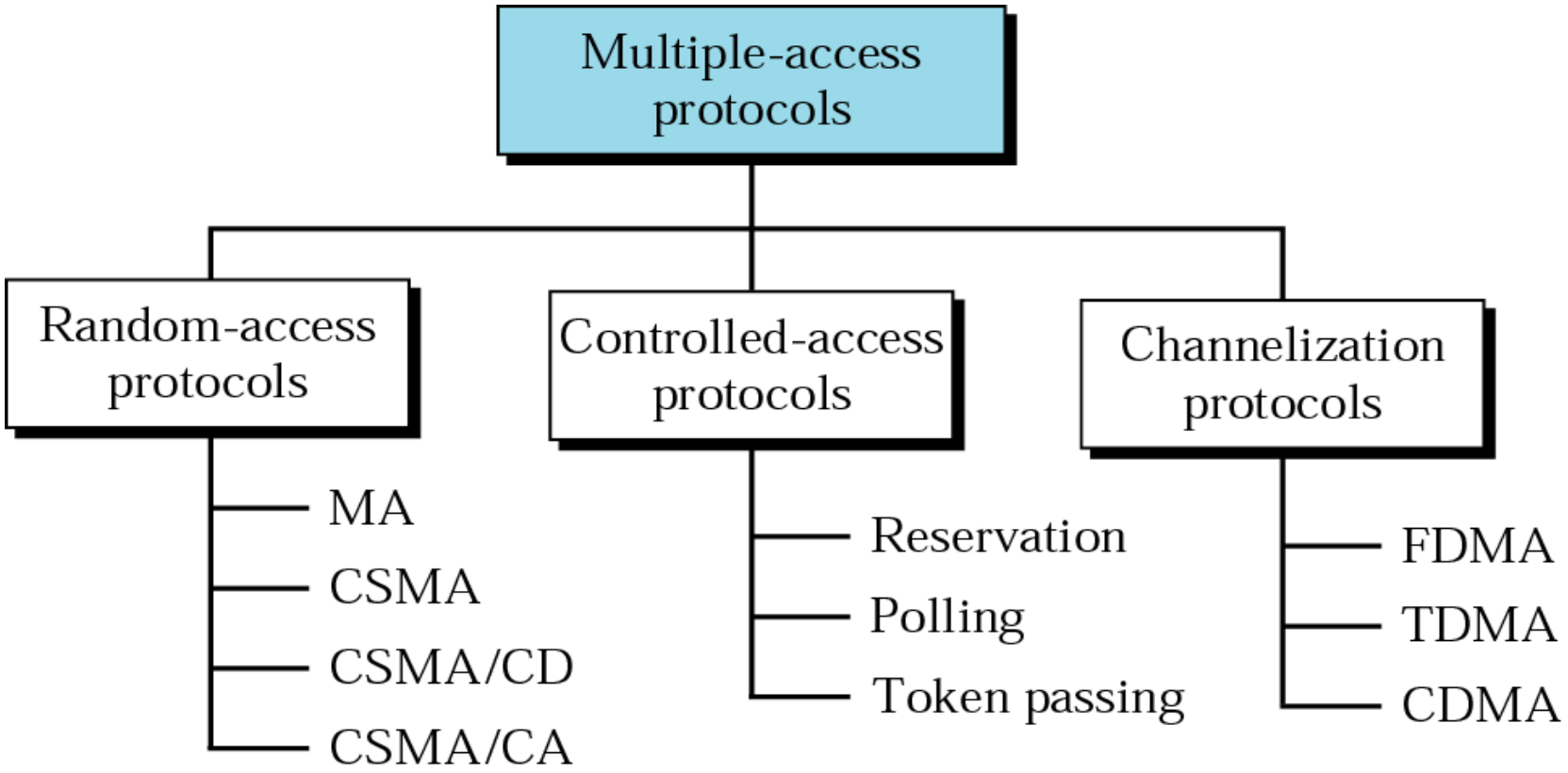
- Synchronization: Simple!

Analogy: Shared Medium



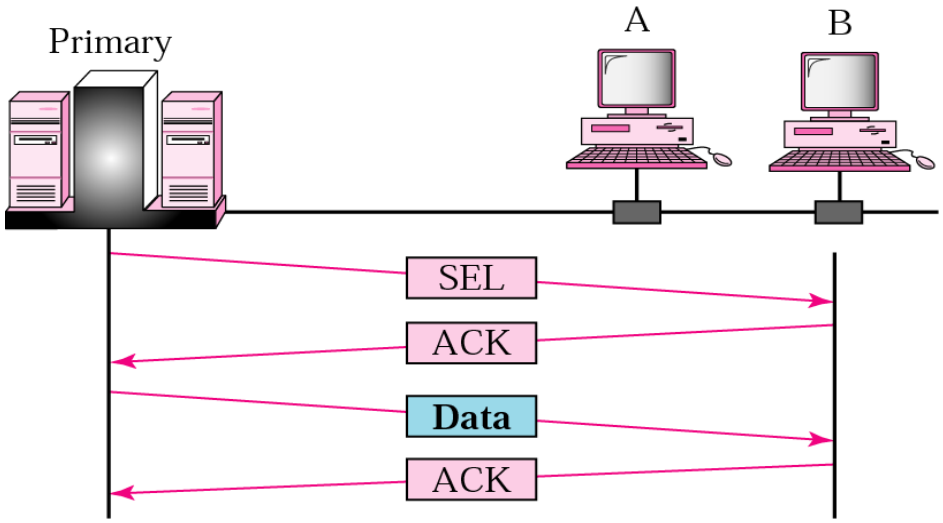
- Synchronisation: More complex

Multiple-Access Protocols



* Figure is courtesy of B. Forouzan

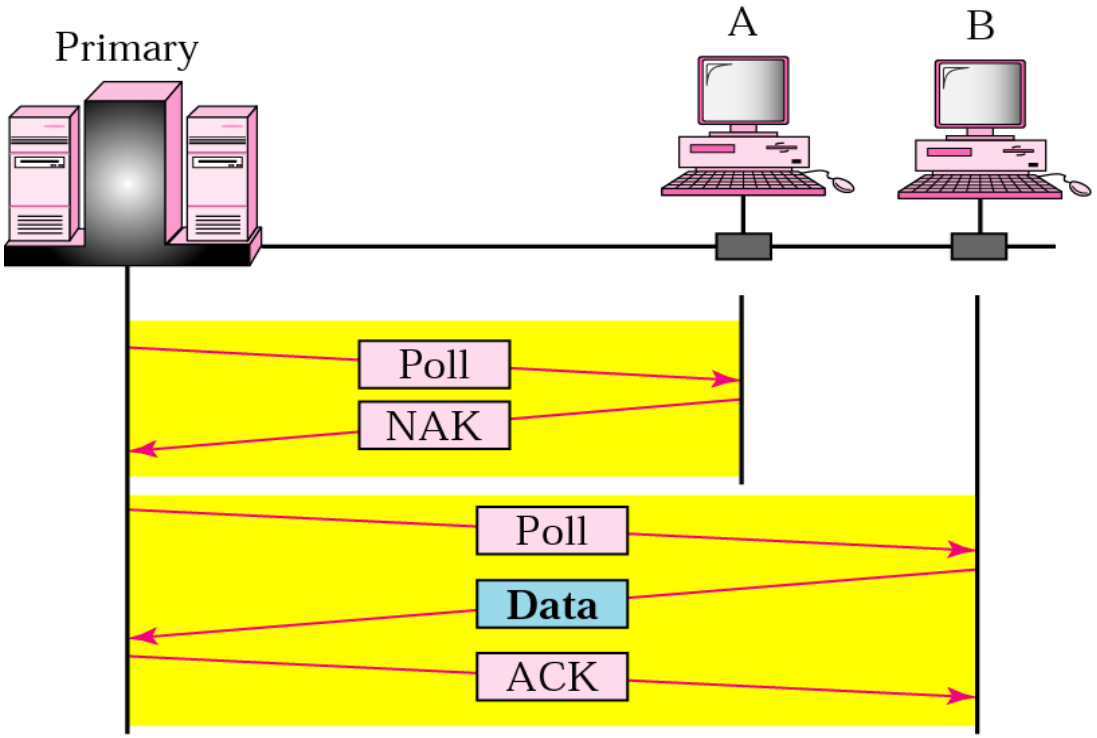
Select / Push



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

* Figure is courtesy of B. Forouzan

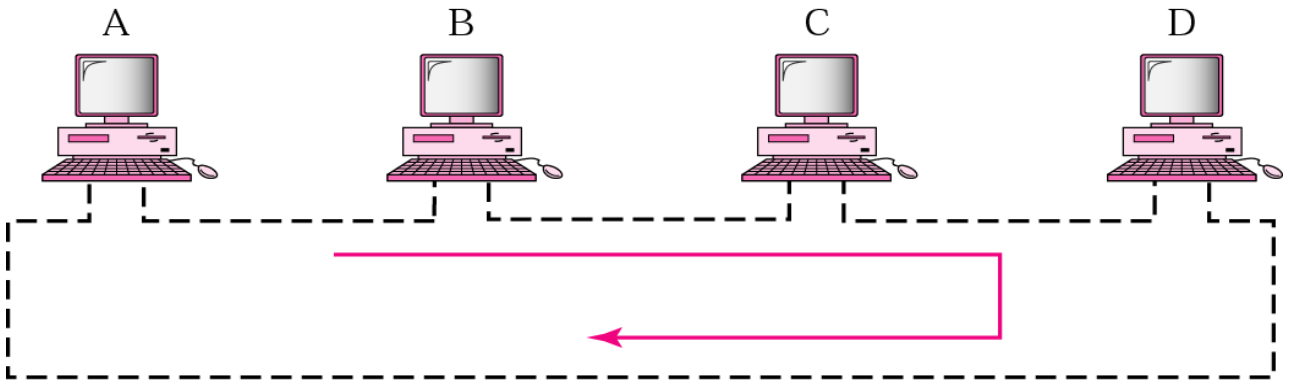
Poll



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

* Figure is courtesy of B. Forouzan

Token-Passing Network



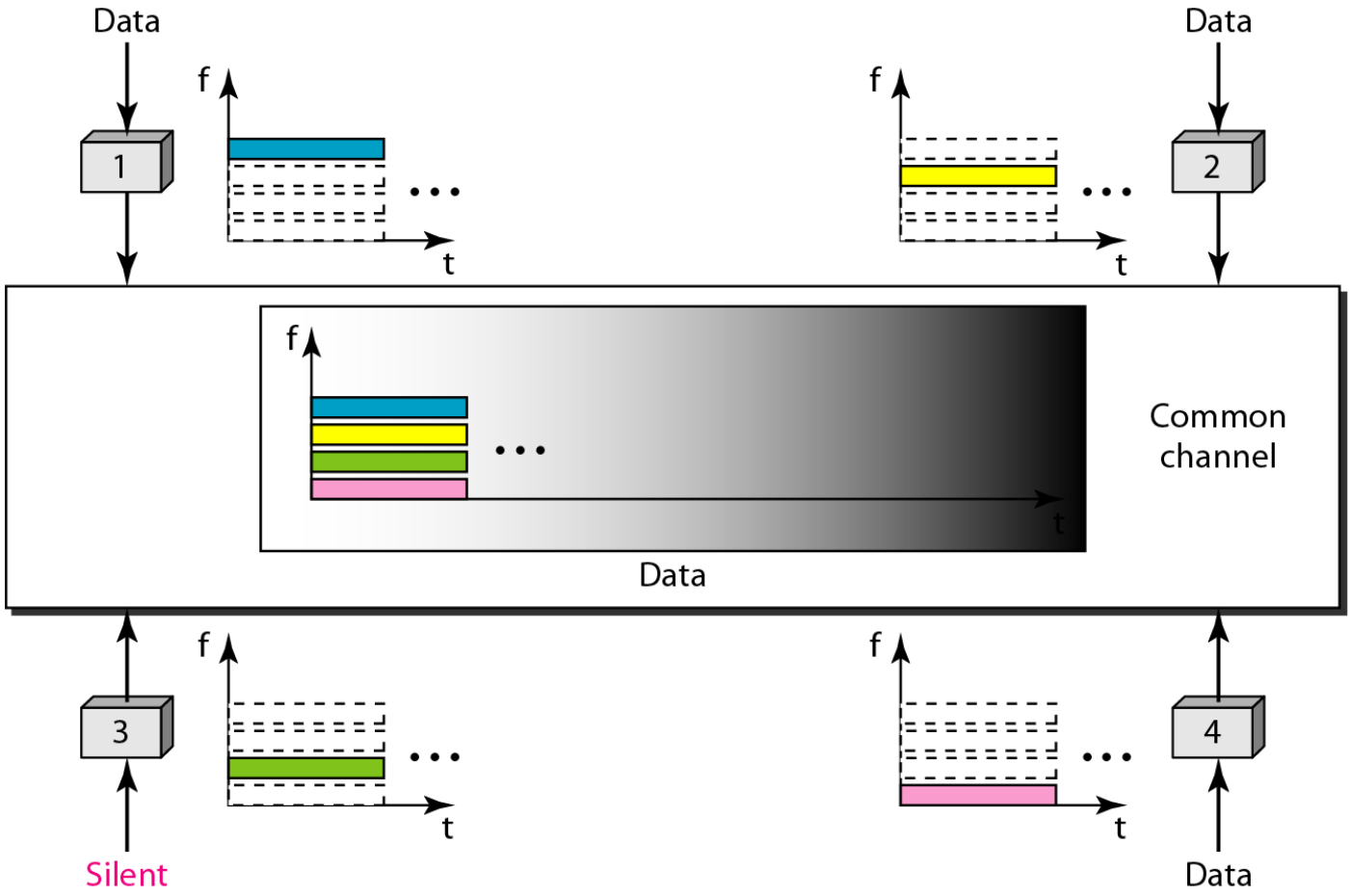
- Token passes around a network
- Machine with token is allowed to transmit data

* Figure is courtesy of B. Forouzan

Static Channel Allocation

- Frequency Division Multiplexing (FDM)
  - N users get 1/N of the total bandwidth
  - << N users ⇨ wasted bandwidth
  - > N users ⇨ 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)

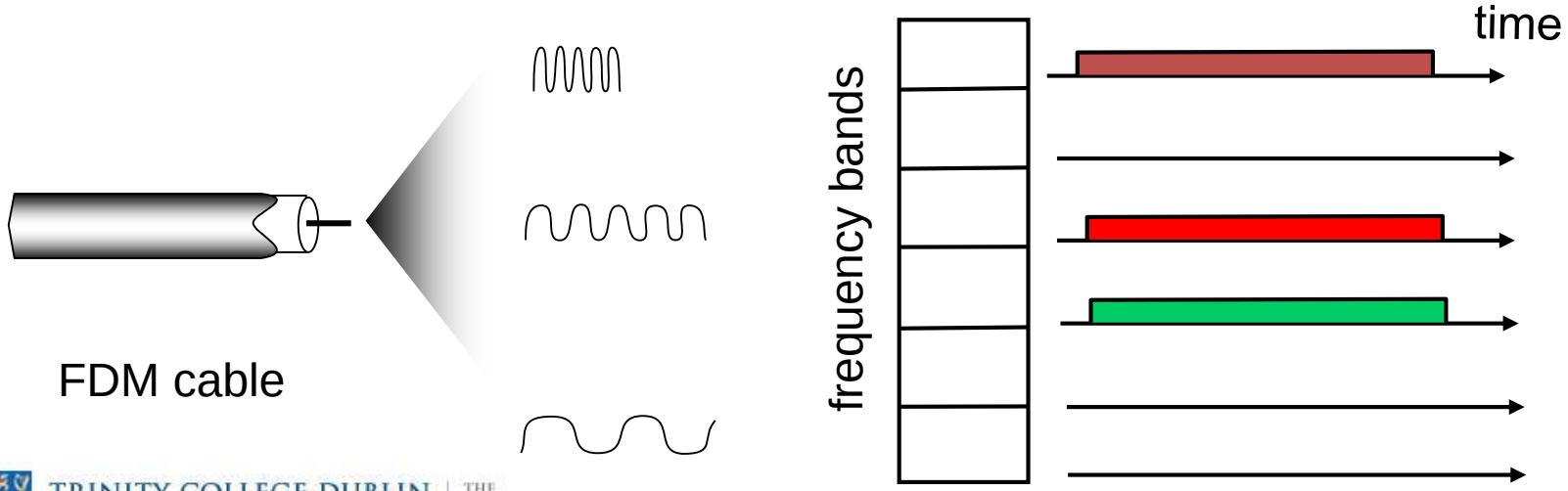


* Figure is courtesy of B. Forouzan

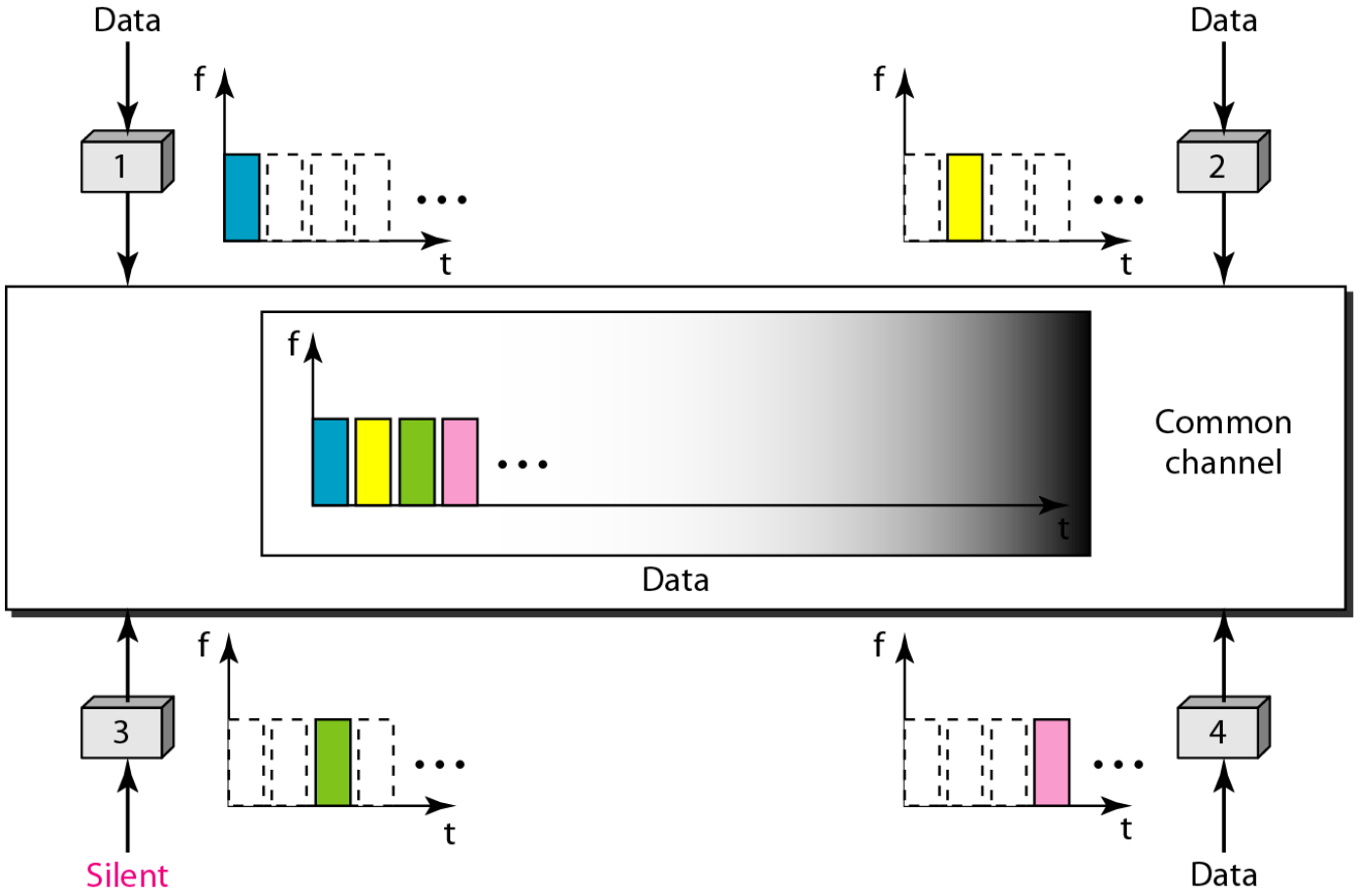
Channel Partitioning MAC protocols: FDMA

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)

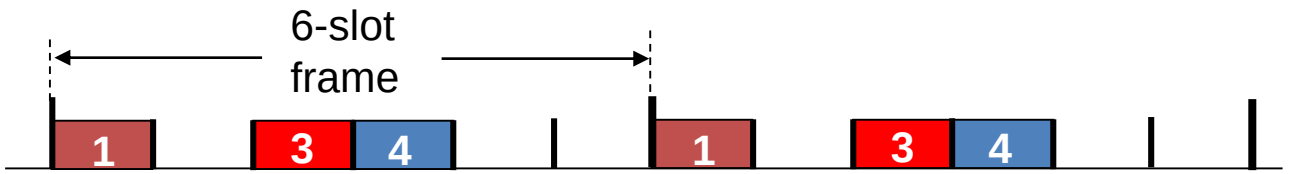


* Figure is courtesy of B. Forouzan

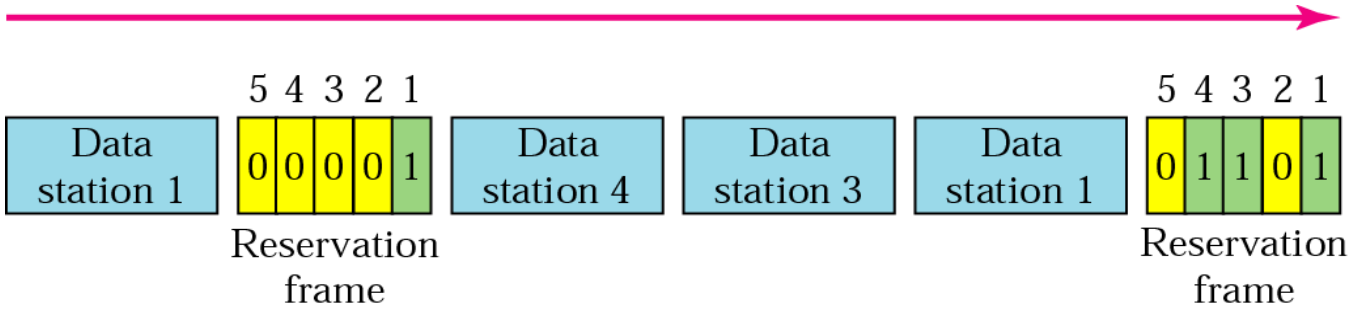
Channel Partitioning MAC protocols: TDMA

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

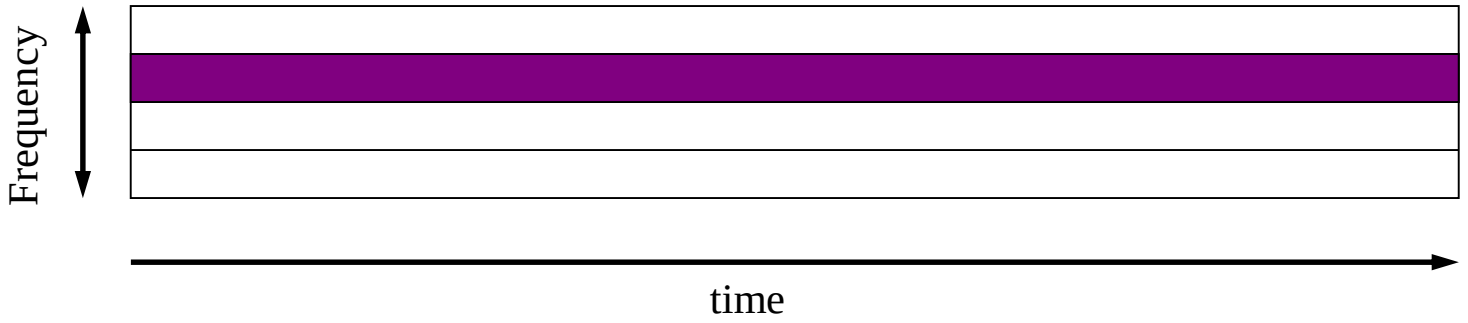


- Station that wants to transmit data
  - transmits 1 during its slot in the reservation frame
- All stations are informed about all planned communication
- Limited number of pre-allocated slots/stations

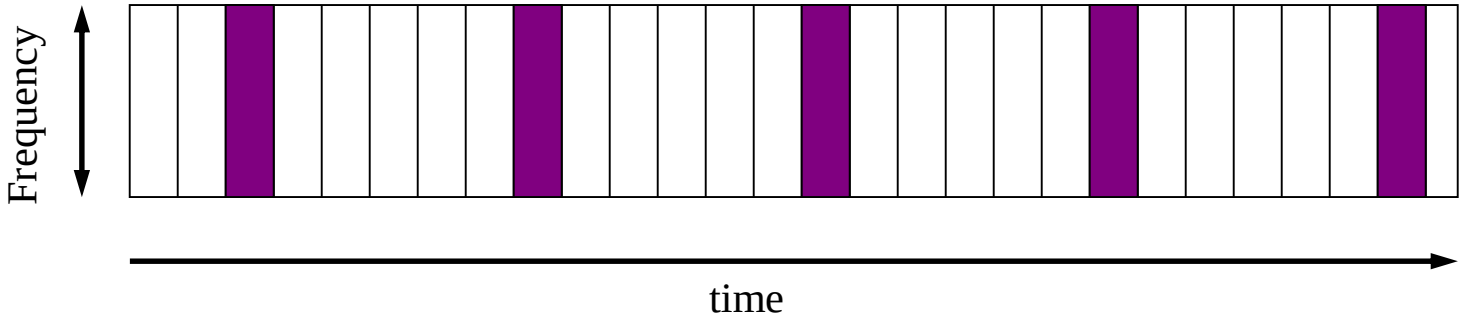
* Figure is courtesy of B. Forouzan

Static Channel Allocation

- Frequency Division Multiplexing (FDM)



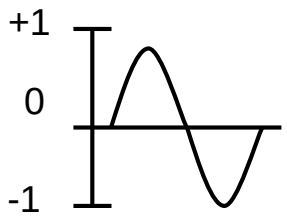
- Time Division Multiplexing (TDM)

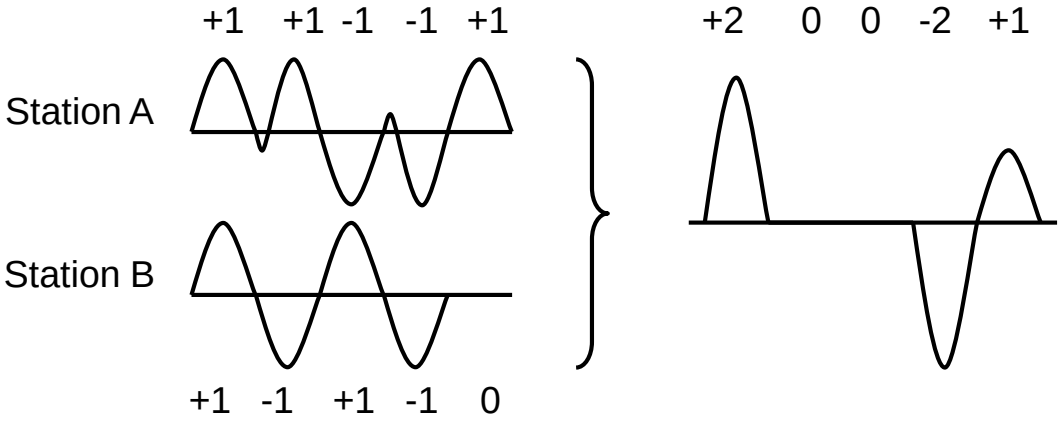


Code Division Multiple Access (CDMA)

- 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

A	B	C	D
+1, +1, +1, +1	+1, −1, +1, −1	+1, +1, −1, −1	+1, −1, −1, +1

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

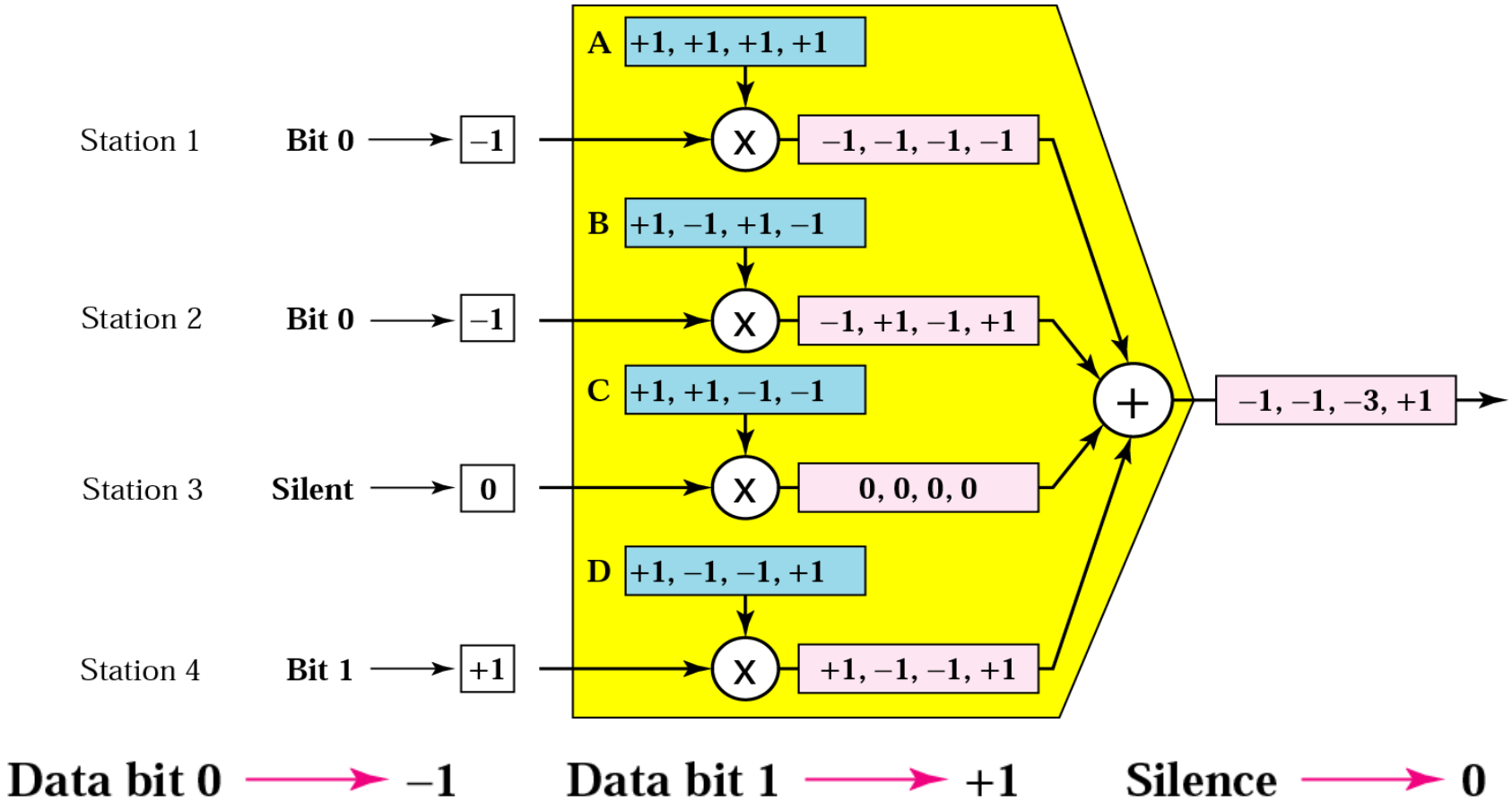
Data bit 0 → **−1** **Data bit 1** → **+1** **Silence** → **0**

Databit ⊗ Chip Sequence = Transmission

-1 ⊗ +1, +1, -1, -1 → -1, -1, +1, +1

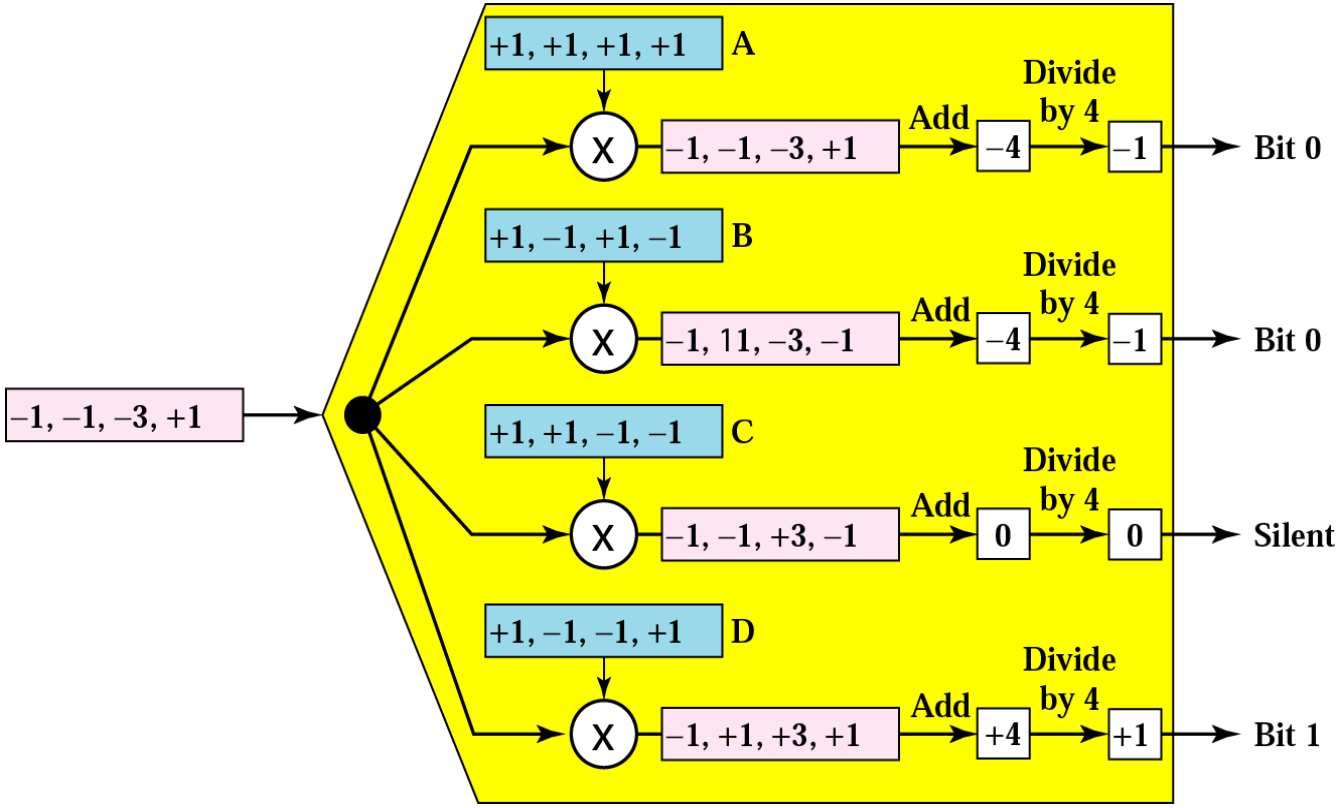
* Figure is courtesy of B. Forouzan

CDMA Multiplexer



* Figure is courtesy of B. Forouzan

CDMA De-Multiplexer



Decoding of received signal

* Figure is courtesy of B. Forouzan

Walsh Tables

$$W_1 = \begin{bmatrix} +1 \end{bmatrix} \qquad W_{2N} = \begin{bmatrix} W_N & W_N \\ W_N & \overline{W_N} \end{bmatrix}$$

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

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

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

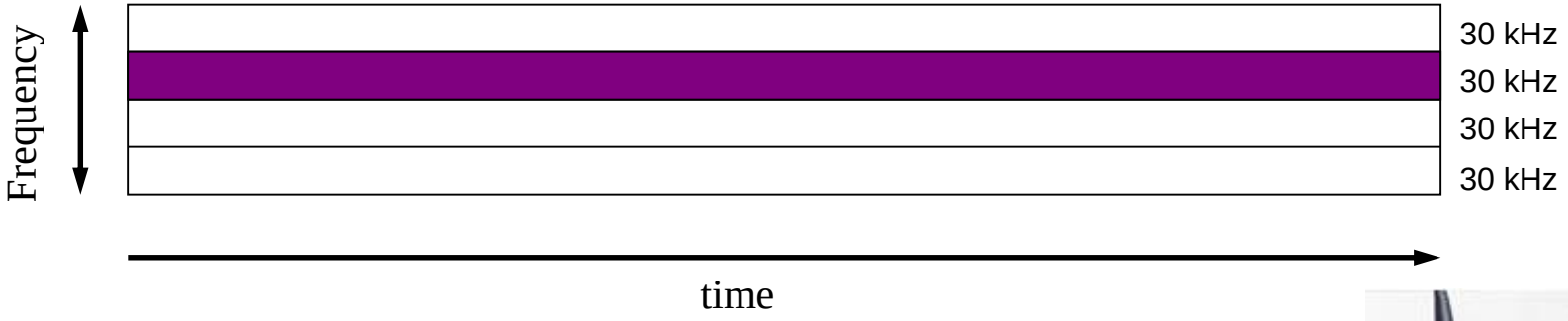
* Figure is courtesy of B. Forouzan

Summary: Synchronous CDMA

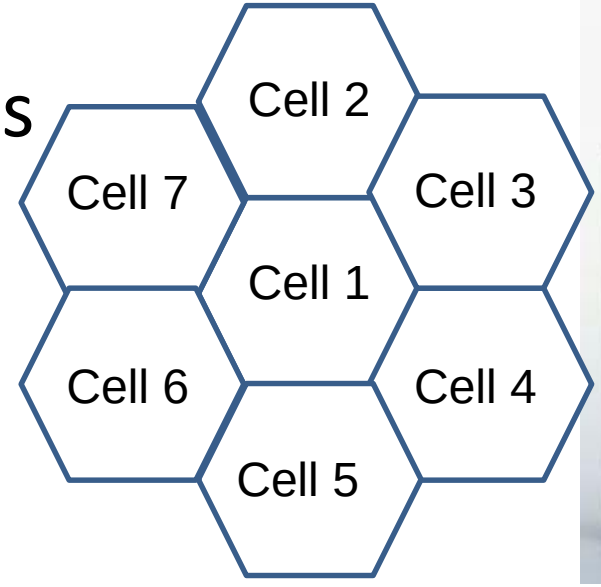
- Makes use of physical properties of interference
- All stations use whole bandwidth
- Computational requirements at stations
- Stations hold individual chip sequences

FDMA in AMPS

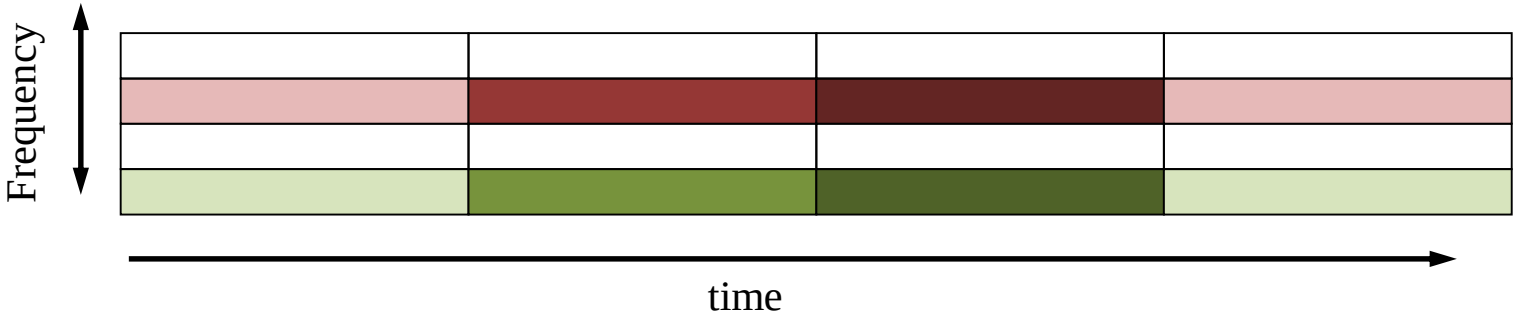
- FDMA



- Non-overlapping channels



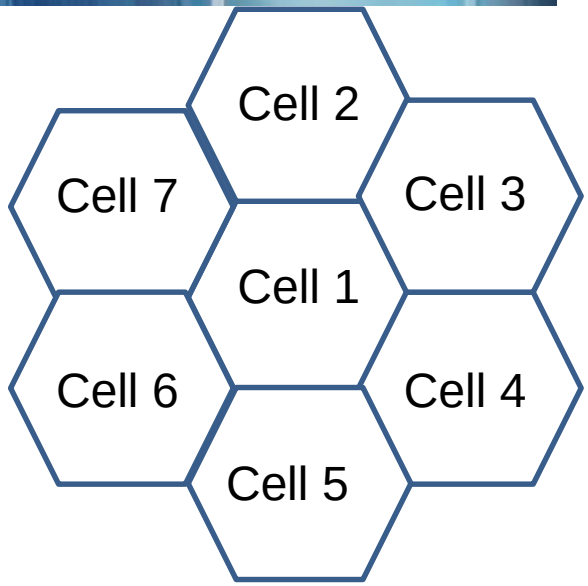
TDMA in GSM

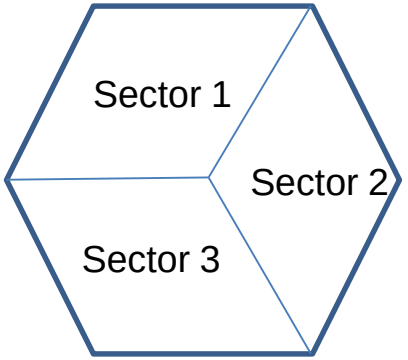


- Mixture of TDMA and FDMA

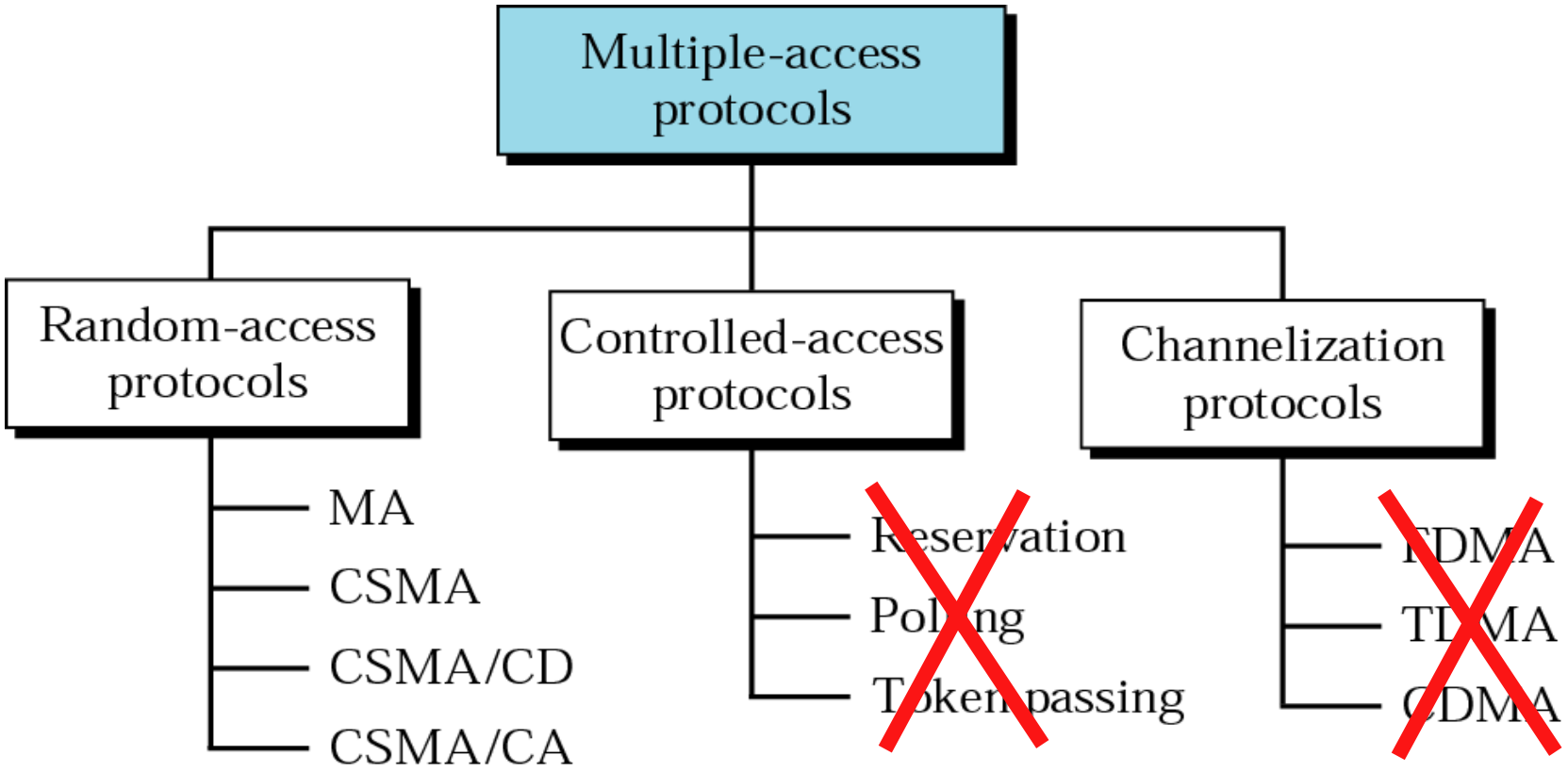
CDMA in Mobile Phones

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



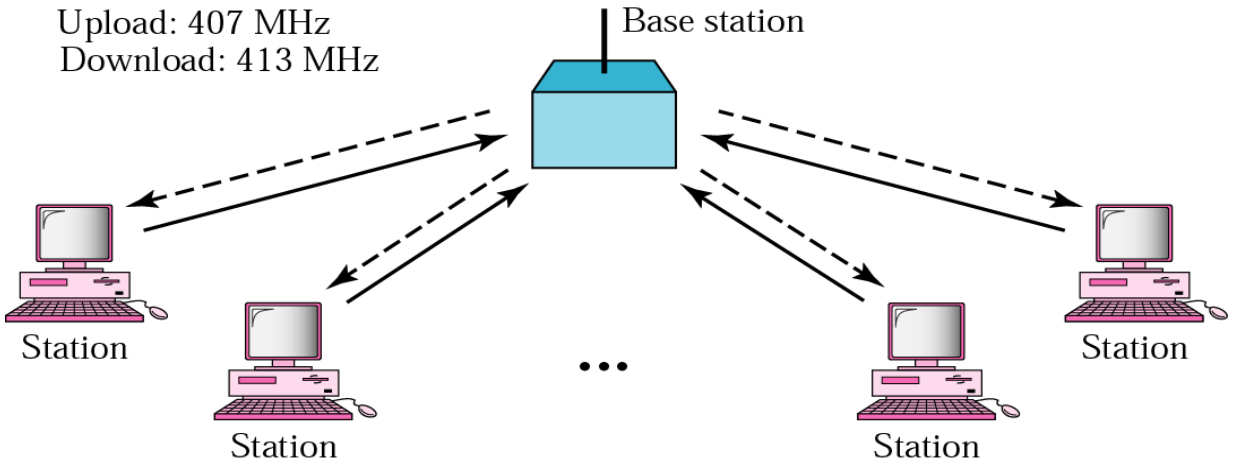


Multiple-Access Protocols



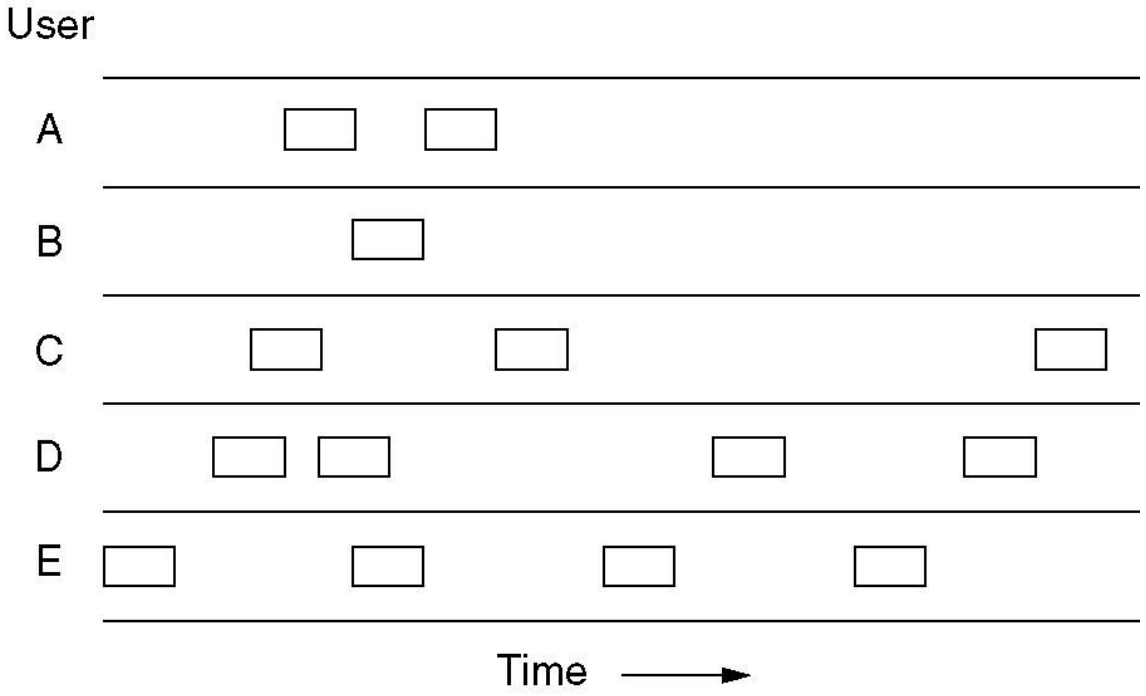
* Figure is courtesy of B. Forouzan

ALOHA Network



* Figure is courtesy of B. Forouzan

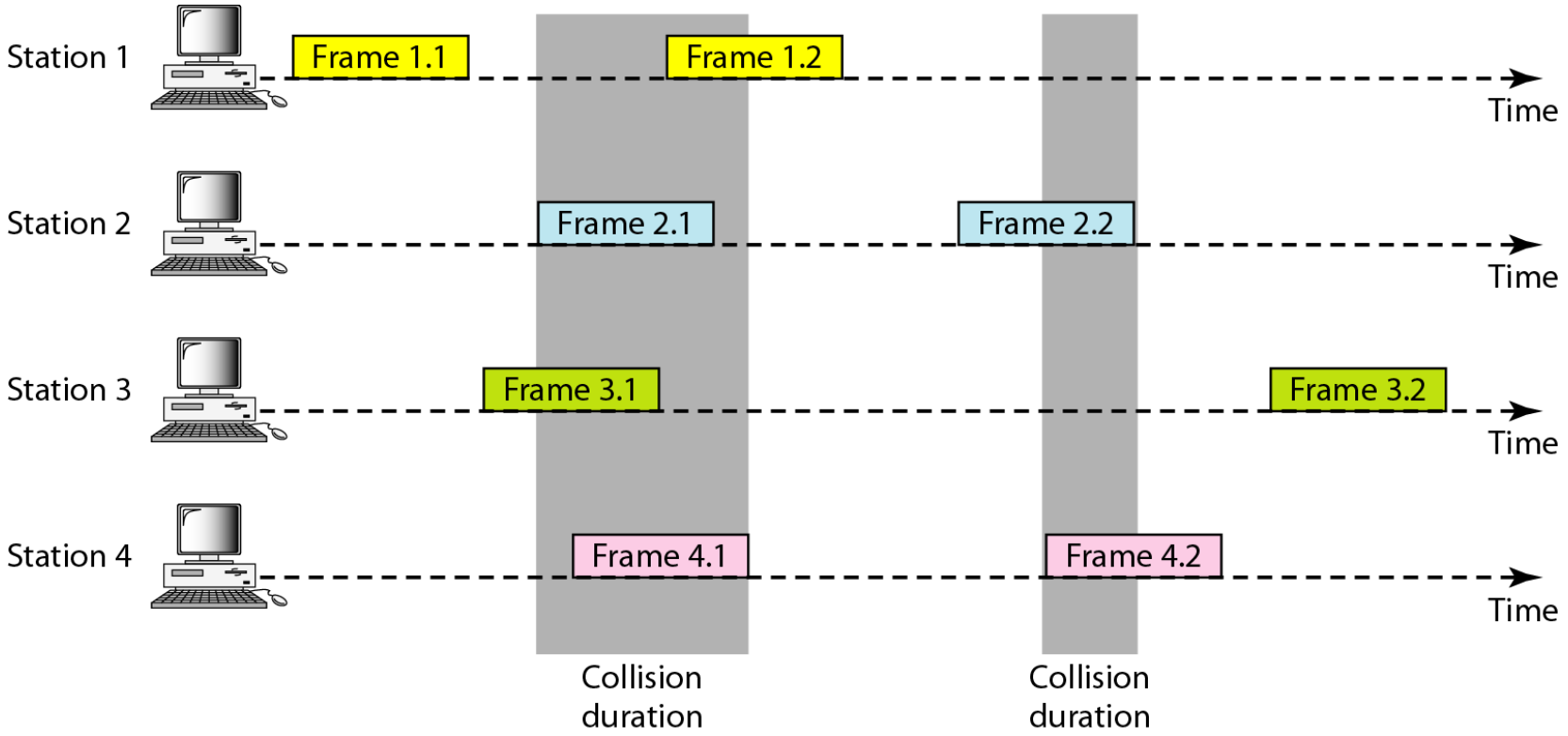
Pure ALOHA



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

* Figure is courtesy of A. Tannenbaum

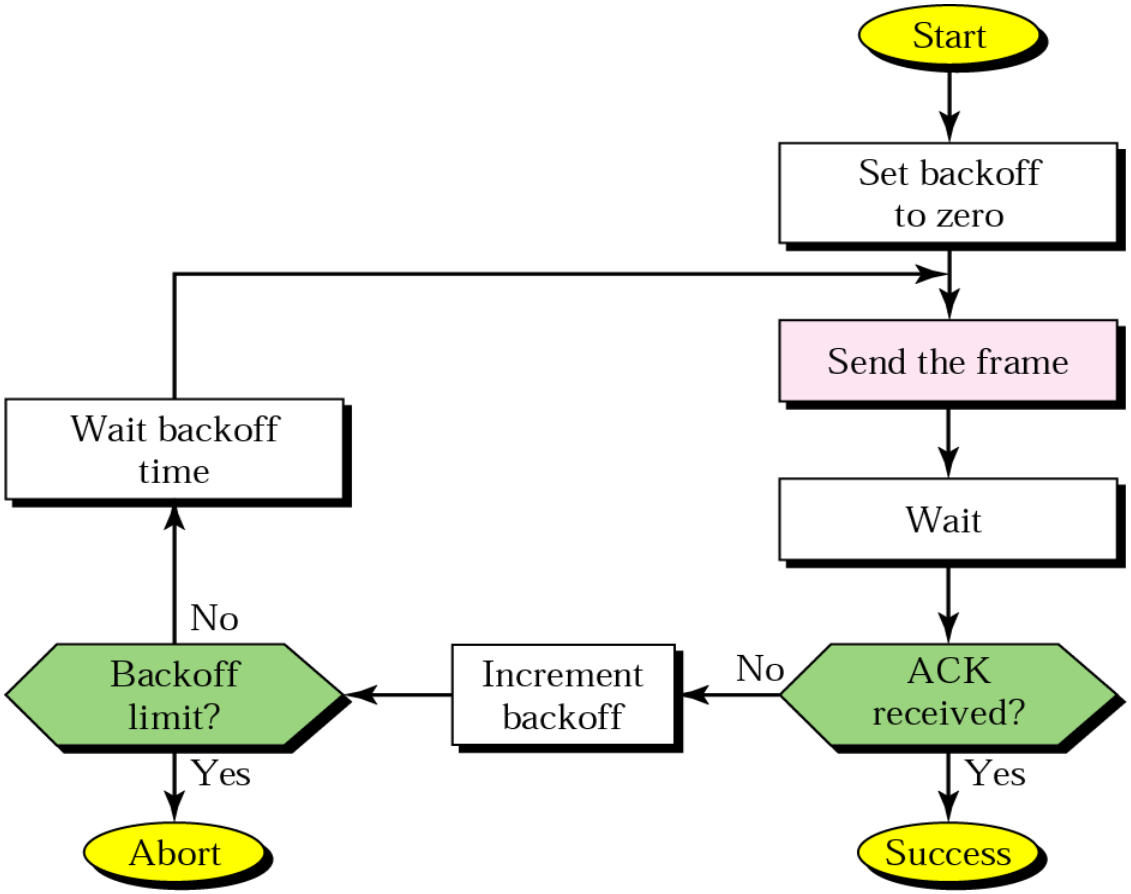
Pure Aloha II



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

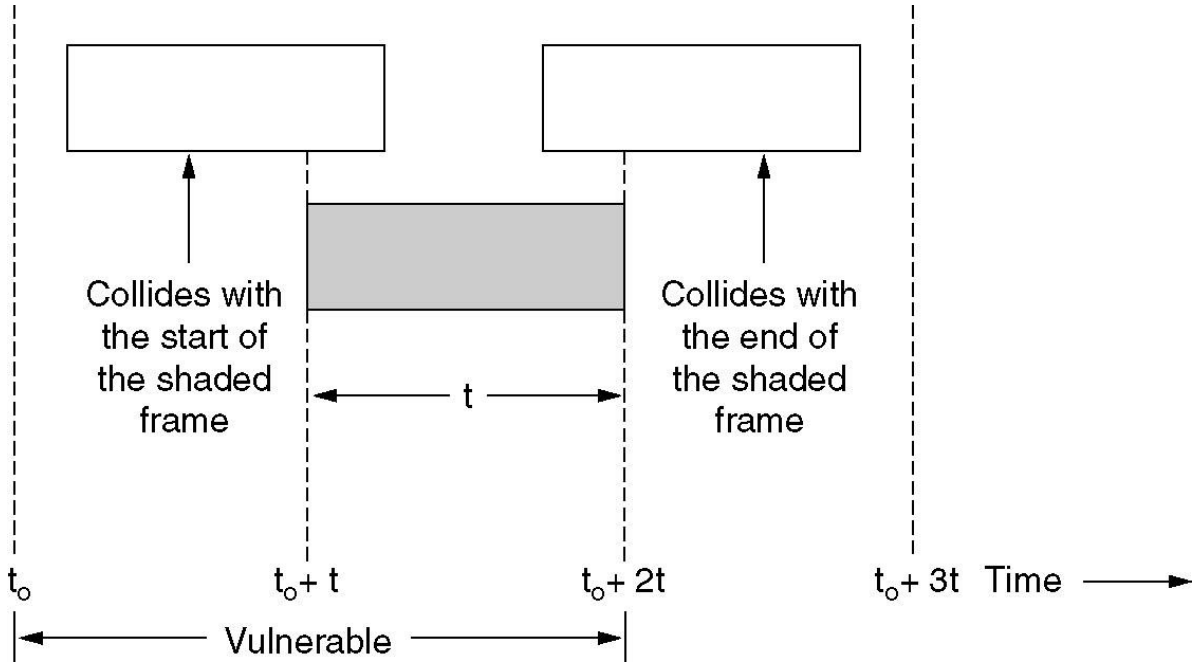
* Figure is courtesy of B. Forouzan

Procedure for ALOHA Protocol



* Figure is courtesy of B. Forouzan

Vulnerable Period for Frame

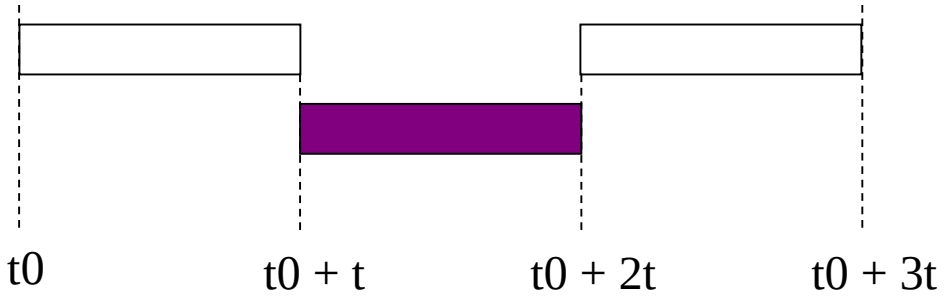


Maximum utilization around 18%

* Figure is courtesy of A. Tannenbaum

Slotted Aloha

Divide time into intervals (timeslots)

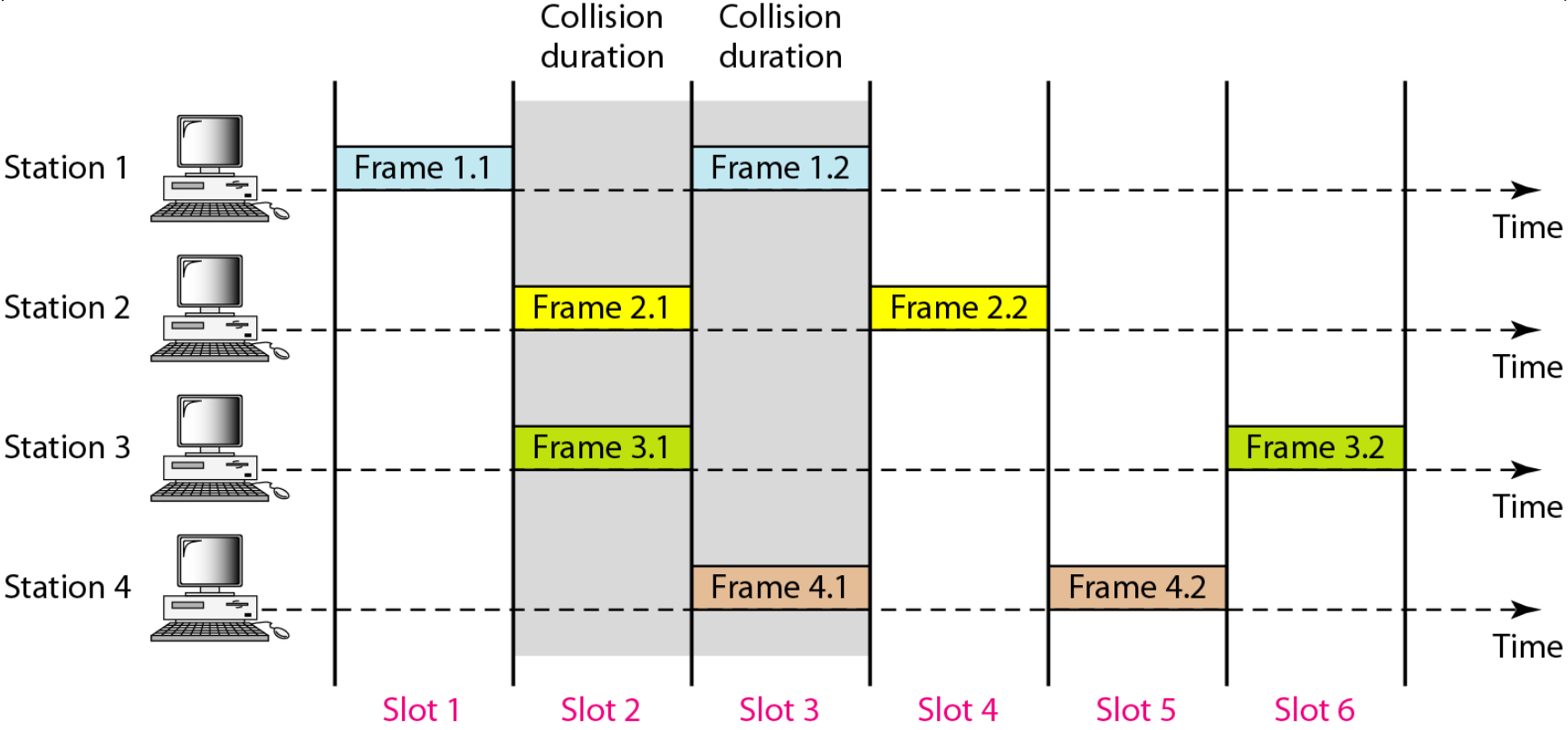


Algorithm:

when data ready wait for next timeslot
transmit
if (collision)
    wait and retransmit

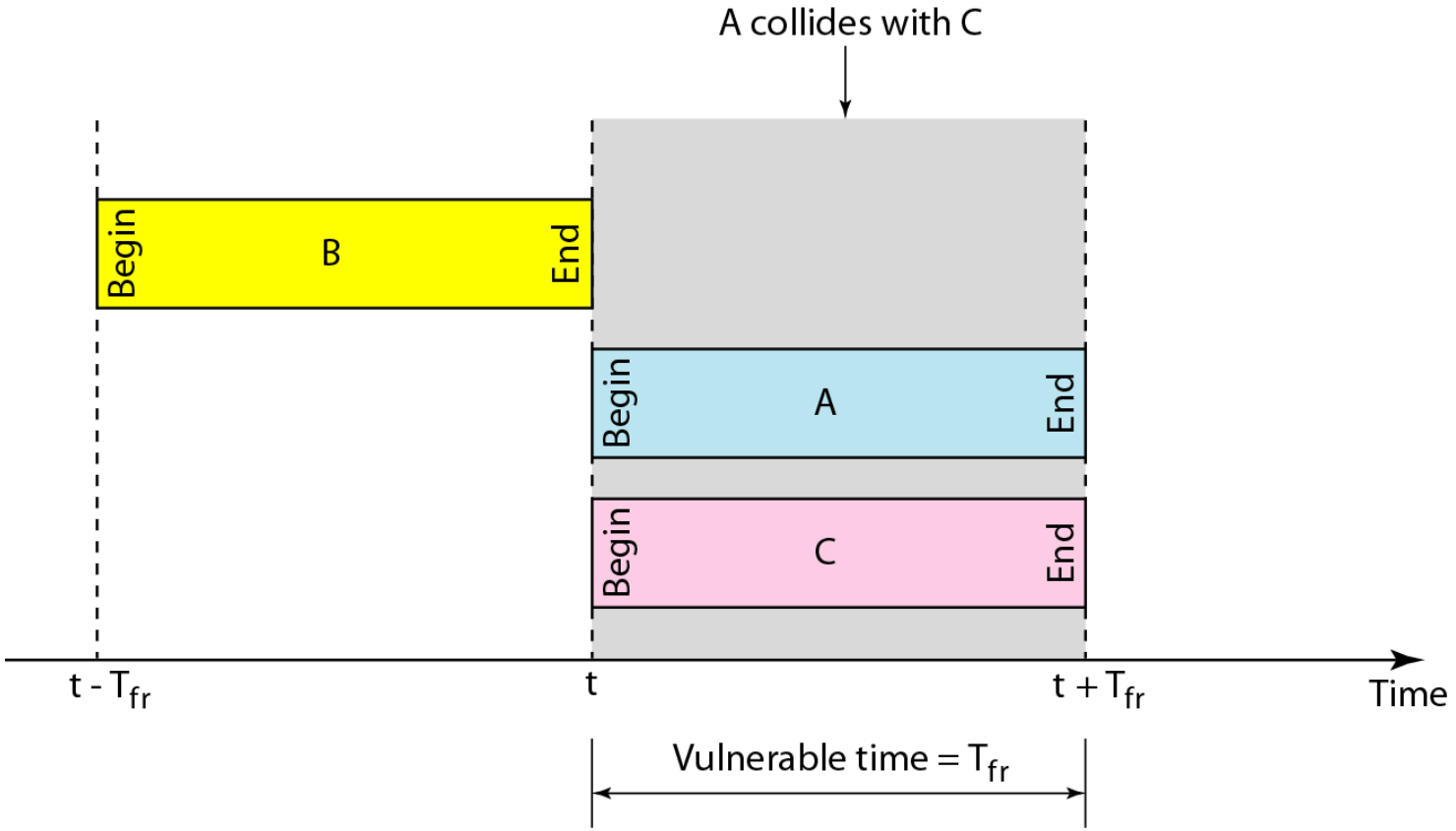
Maximum utilization is 2 × Pure Aloha

Frames in Slotted Aloha



* Figure is courtesy of B. Forouzan

Advantage of Slotted Aloha

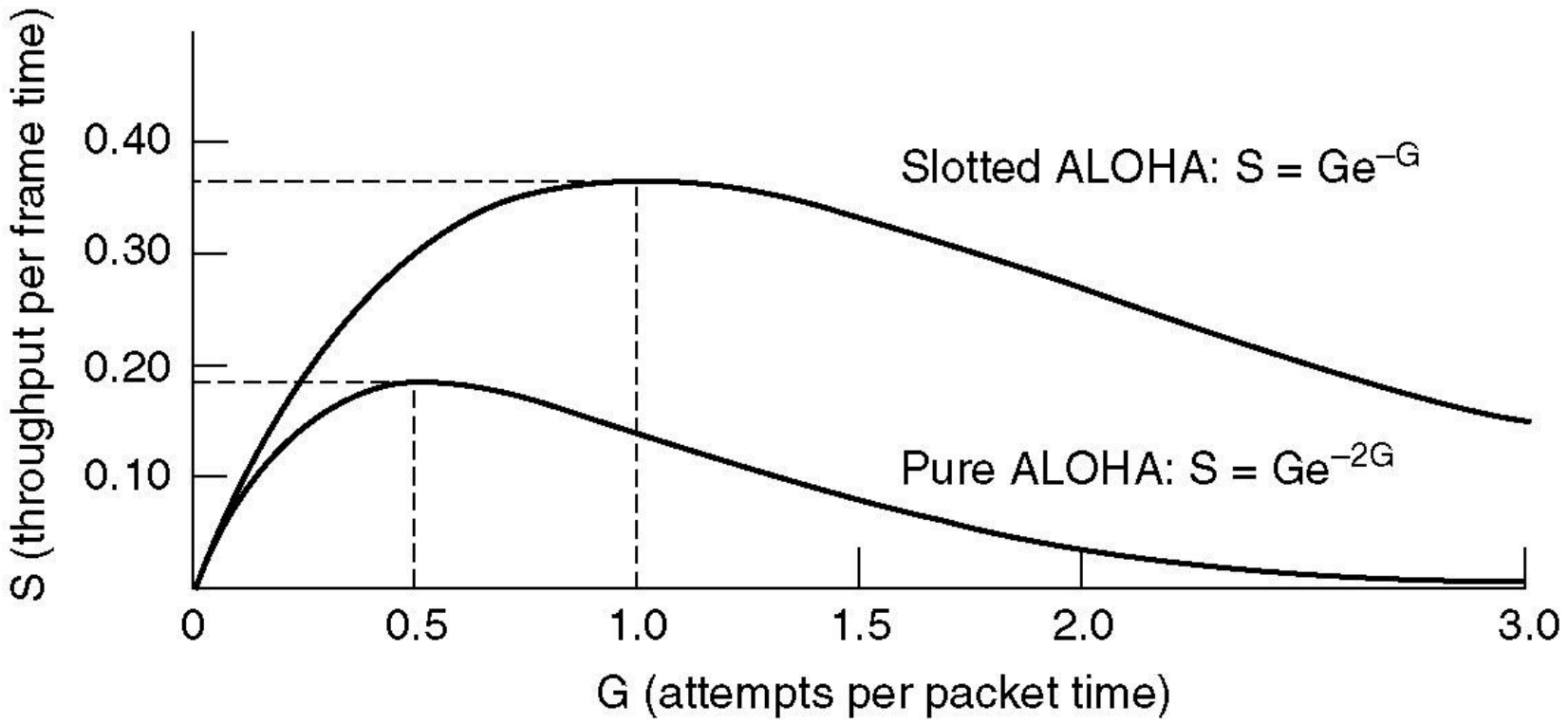


- Collisions can only occur within a slot

* Figure is courtesy of B. Forouzan

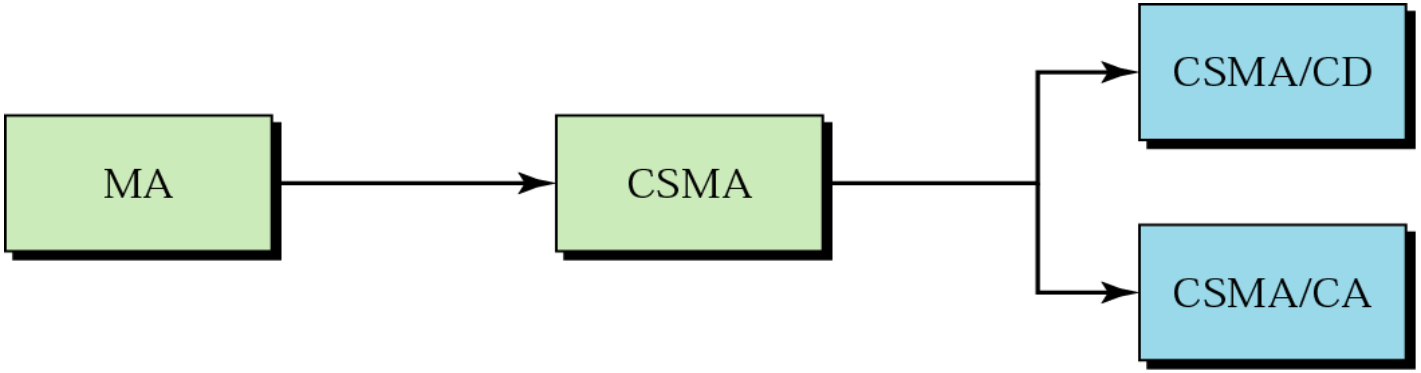
Performance of ALOHA

Throughput versus offered traffic for ALOHA systems.



* Figure is courtesy of A. Tannenbaum

Random-Access Methods

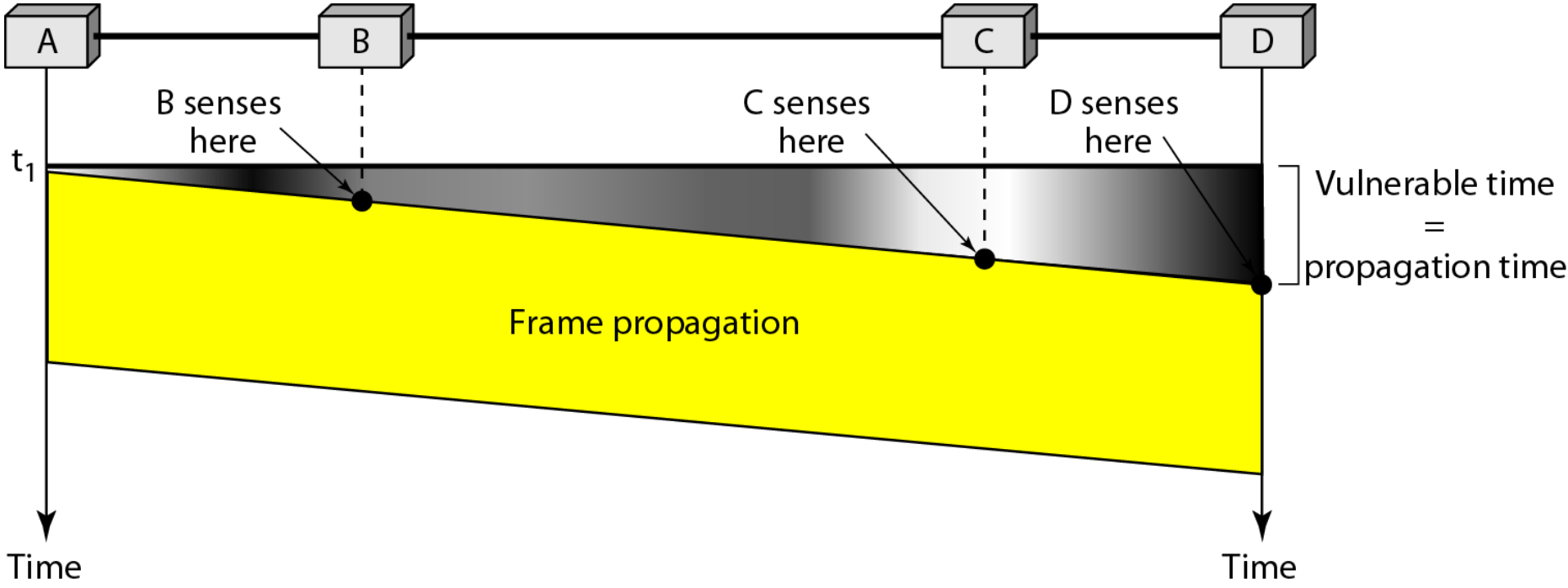


- CS ⇨Carrier Sense
- MA ⇨Multiple Access

- CD ⇨ Collision Detection
- CA ⇨ Collision Avoidance

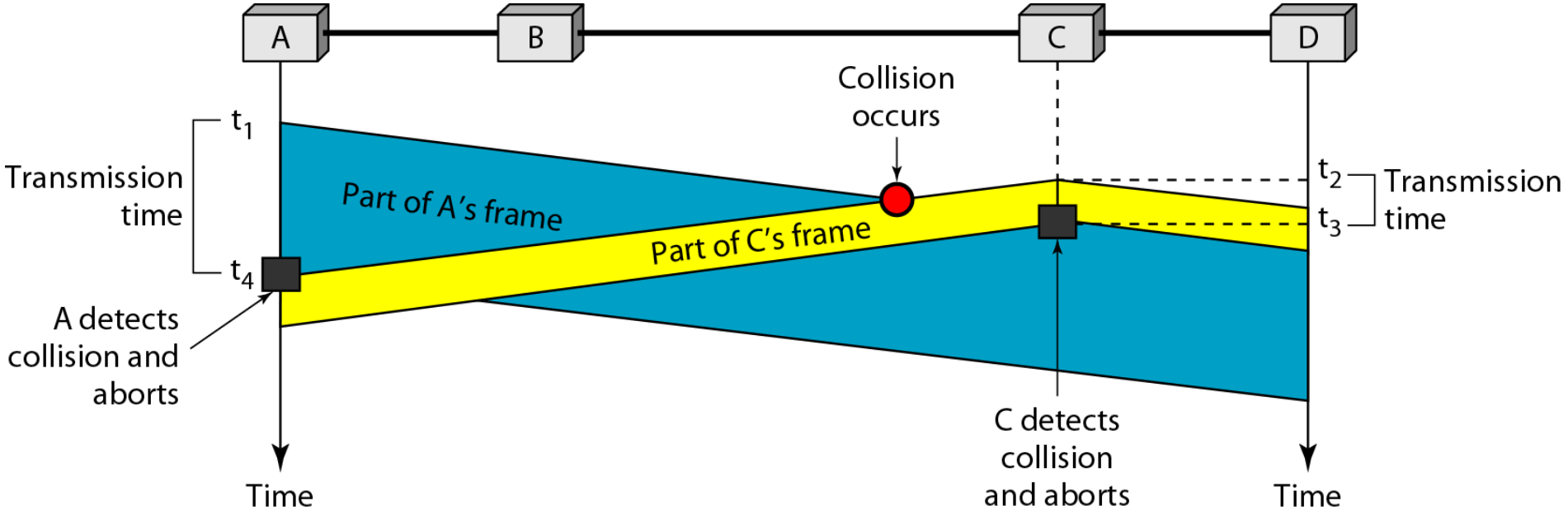
* Figure is courtesy of B. Forouzan

CSMA



* Figure is courtesy of B. Forouzan

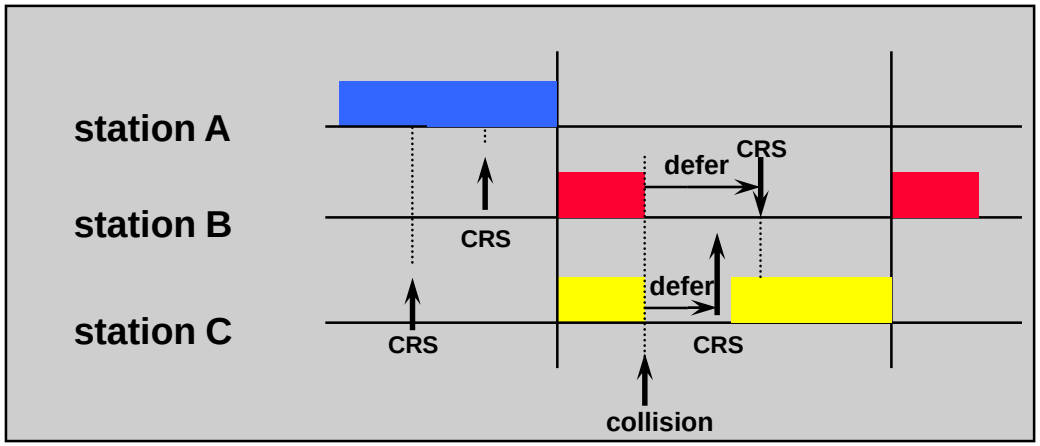
Collision in CSMA/CD

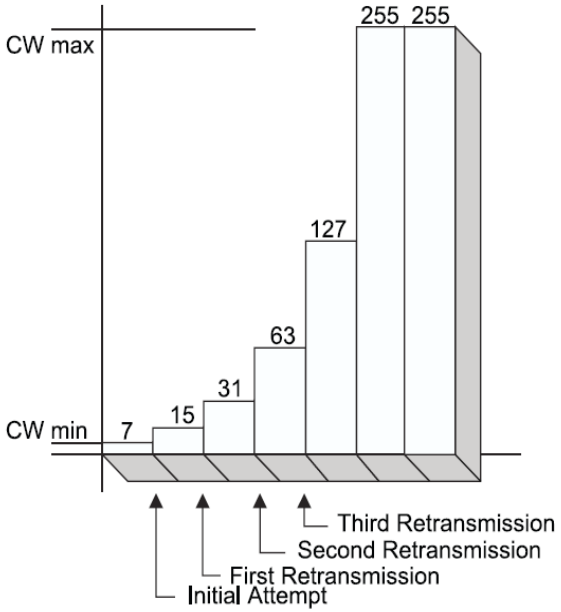


- Both stations will realize that a collision has taken place
- Backoff and attempt to send later

* Figure is courtesy of B. Forouzan

Binary Exponential Backoff





Backoff Time = Random() × aSlotTime

where

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 aCWmin and aCWmax, aCWmin ≤ CW ≤ aCWmax. 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.

* Figure is courtesy of ANSI/IEEE Std 802.11 & Avaya Communications Inc

An Alternative Representation

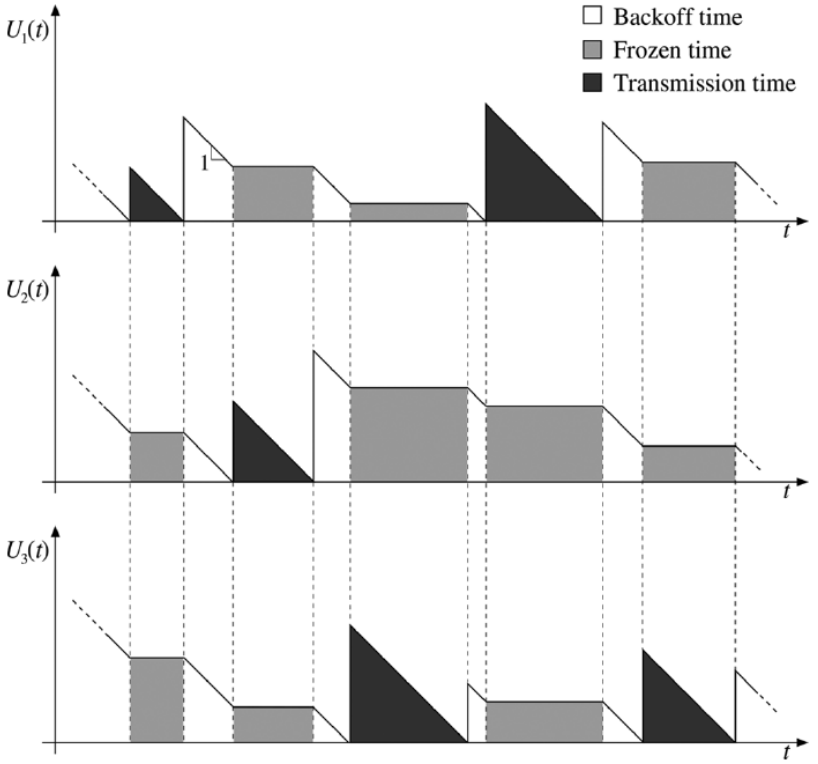
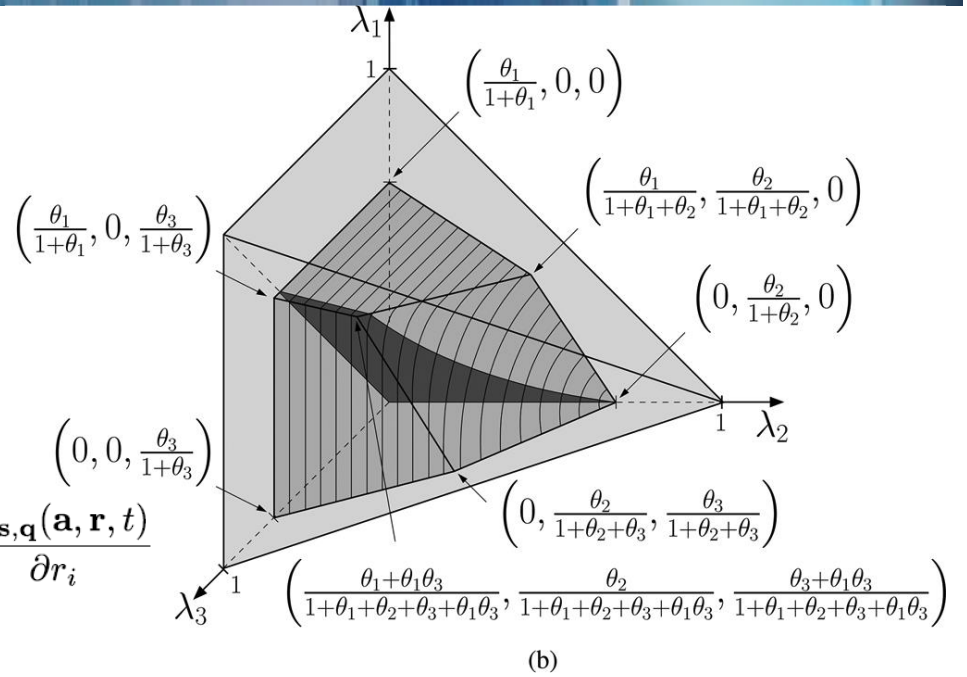


Fig. 1. The operation of three saturated links within carrier-sense range. The graphs show the unfinished work $U_i(t)$ of each transmitter τ_i at time t, which can be either the remaining backoff or the remaining transmission time.

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

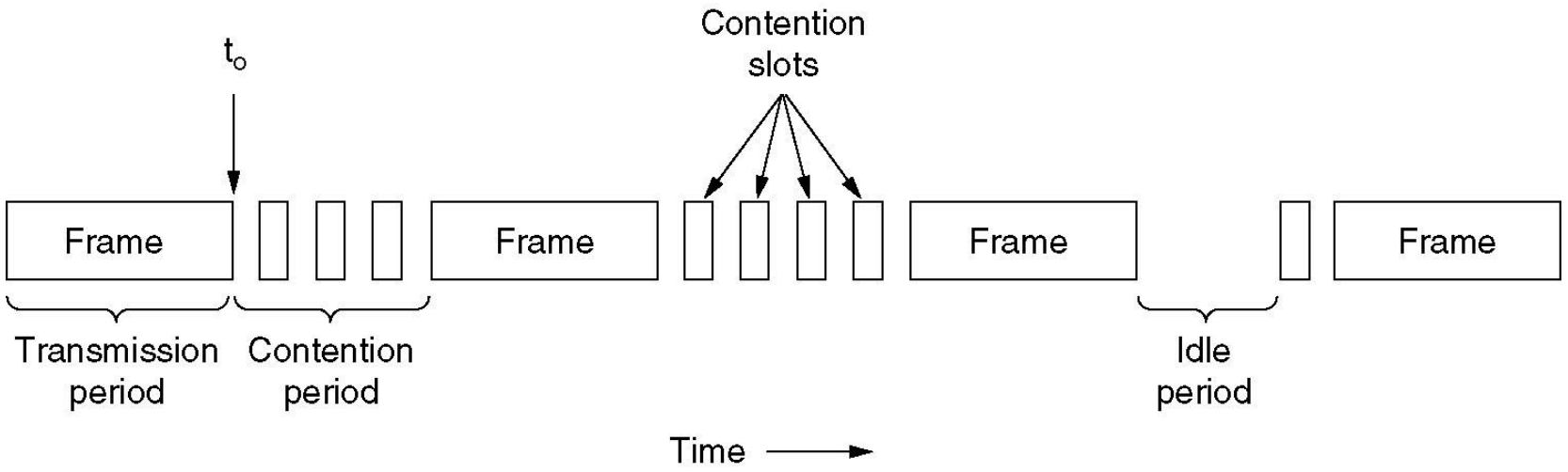
$$\frac{\partial p_{\mathbf{s},\mathbf{q}}(\mathbf{a},\mathbf{r},t)}{\partial t} = \sum_{i\notin F(\mathbf{s})} \frac{\partial p_{\mathbf{s},\mathbf{q}}(\mathbf{a},\mathbf{r},t)}{\partial a_i} + \sum_{i\in C(\mathbf{s},\mathbf{q})} \frac{\partial p_{\mathbf{s},\mathbf{q}}(\mathbf{a},\mathbf{r},t)}{\partial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



(b)

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

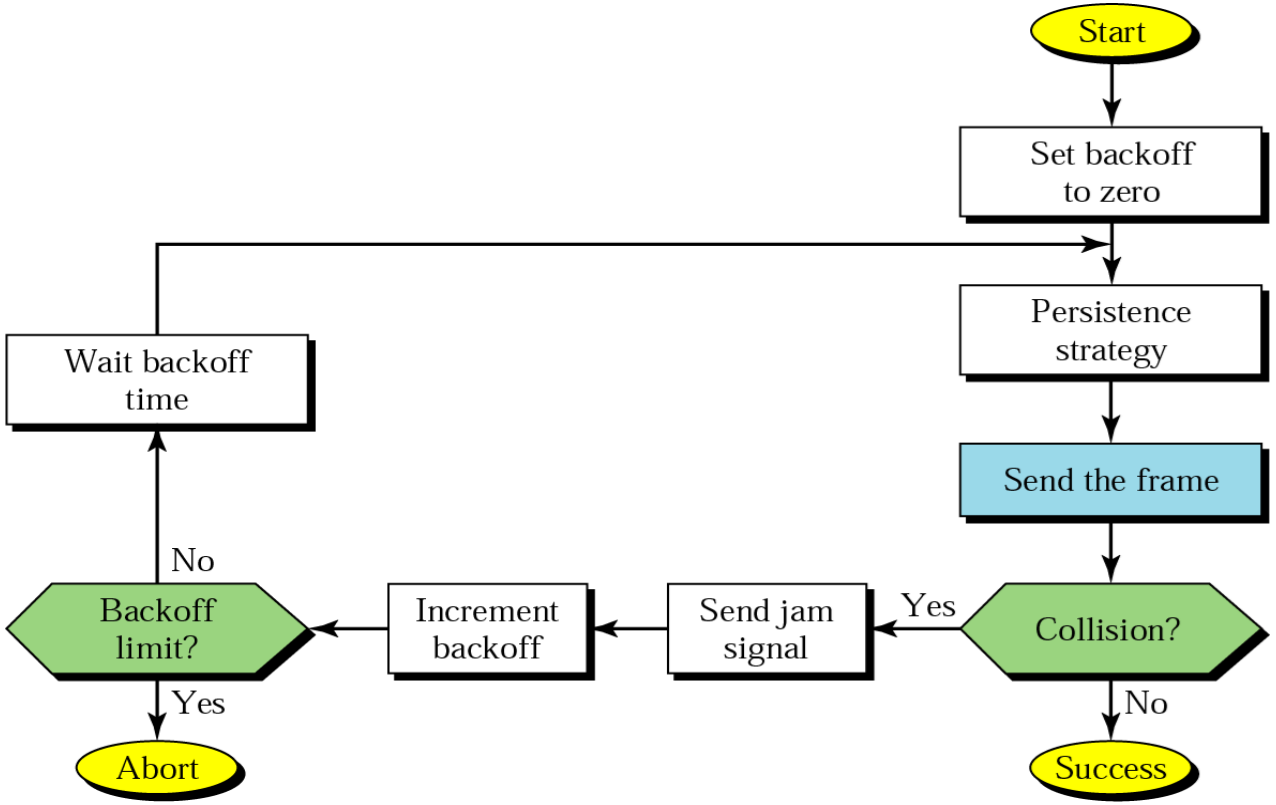
CSMA with Collision Detection



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

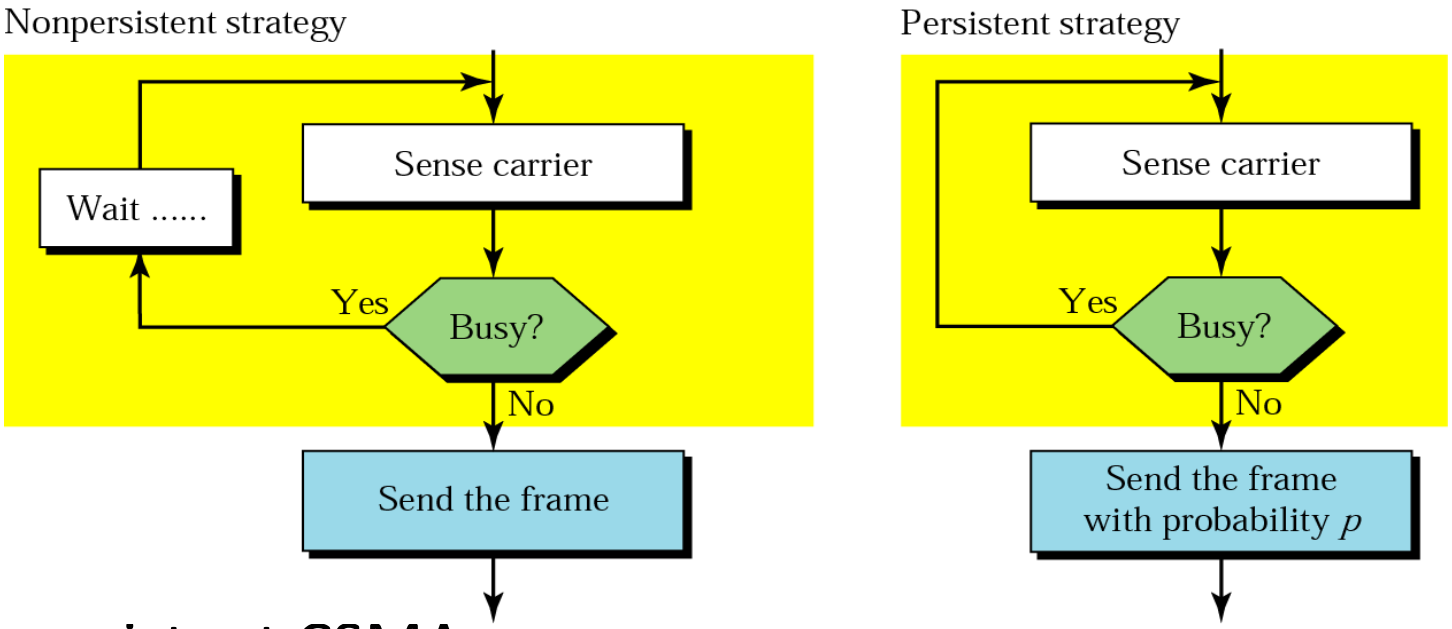
* Figure is courtesy of A. Tannenbaum

CSMA/CD Procedure



* Figure is courtesy of B. Forouzan

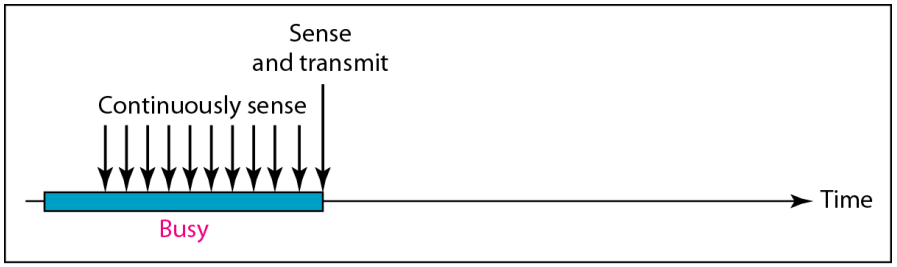
Persistence Strategies



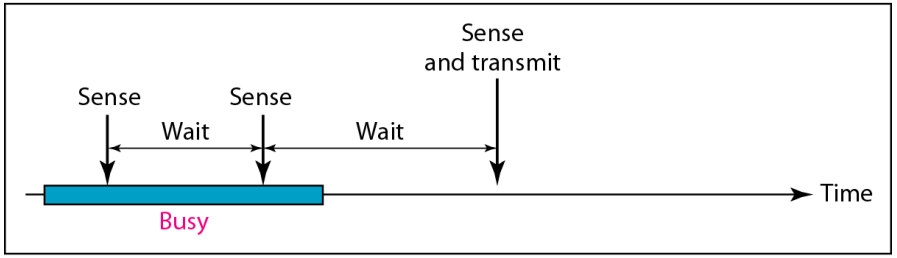
- 1-persistent CSMA
  - if medium idle send imidiately
- p-persistent CSMA
  - if medium available station may send depdending on probability
  - reduces chance of collison and improves efficiency

* Figure is courtesy of B. Forouzan

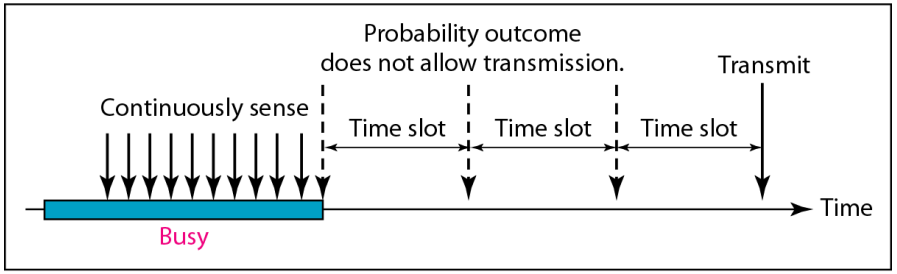
Persistence Strategies II



a. 1-persistent



b. Nonpersistent

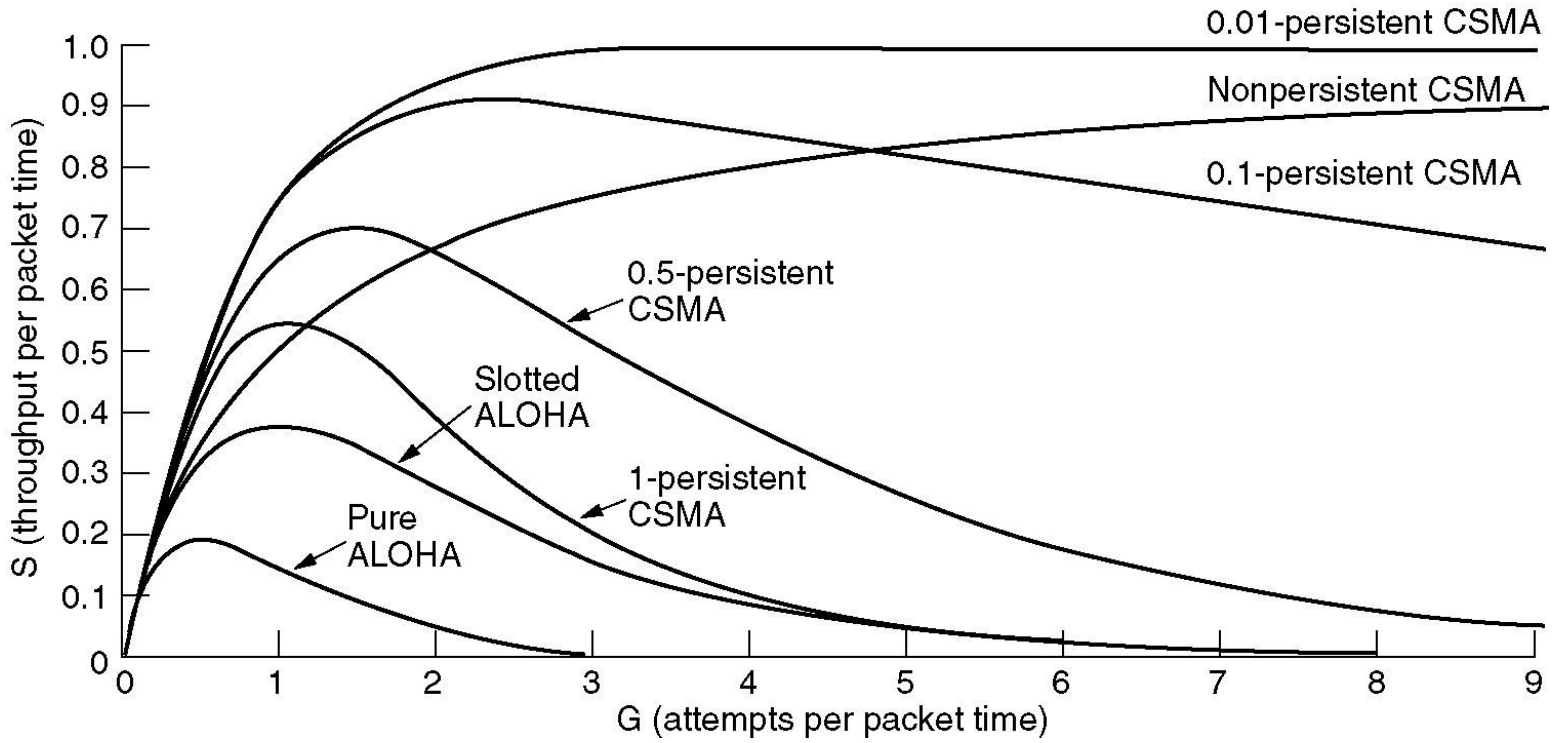


c. p-persistent

* Figure is courtesy of B. Forouzan

Persistent and Non-Persistent CSMA

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

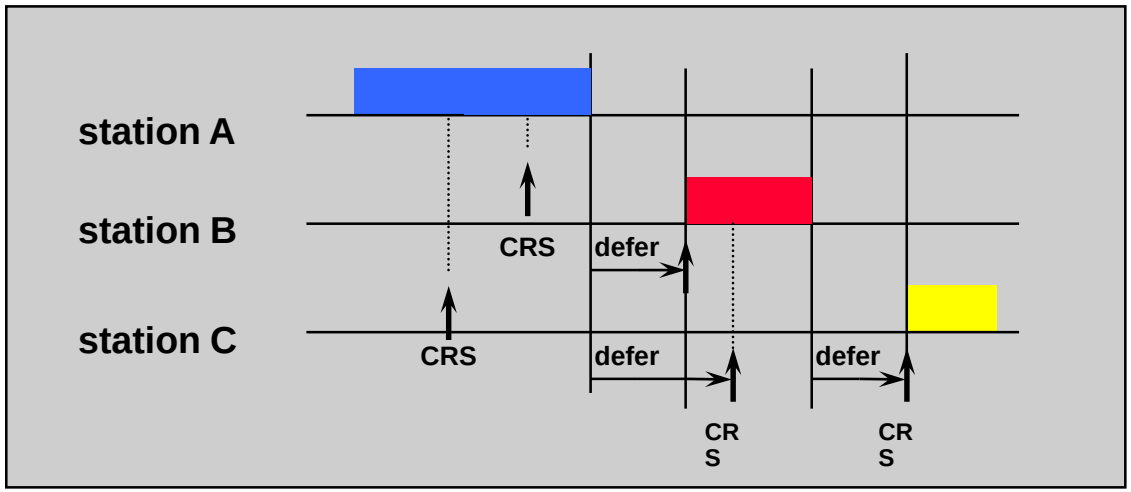


* Figure is courtesy of A. Tanenbaum

CSMA in Wireless Media

Station B Station A Station C

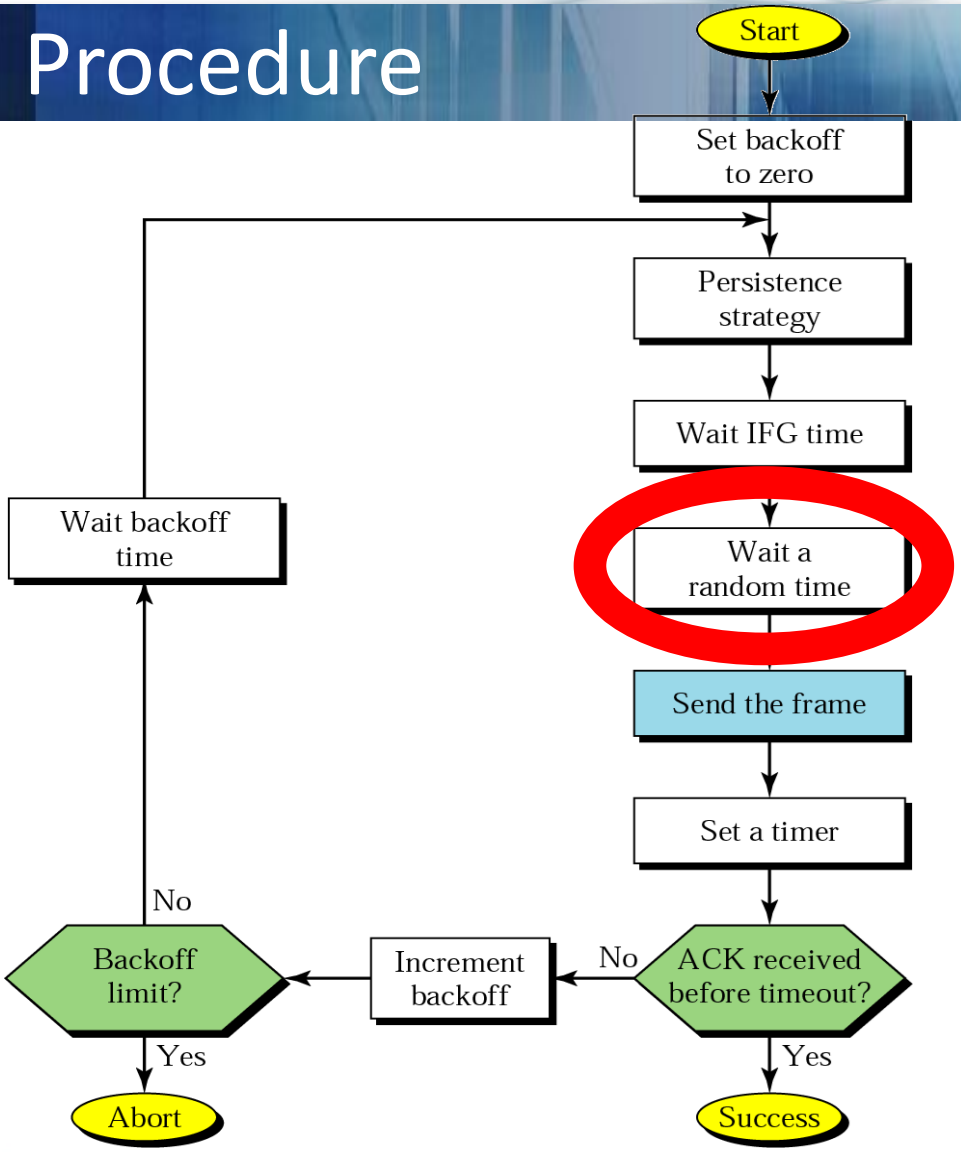
Collision is at the receiver !!!



- Sense carrier to determine if medium is free
- Once free pick a random number
  - then start sending

* Figure is courtesy of Avaya Communications Inc

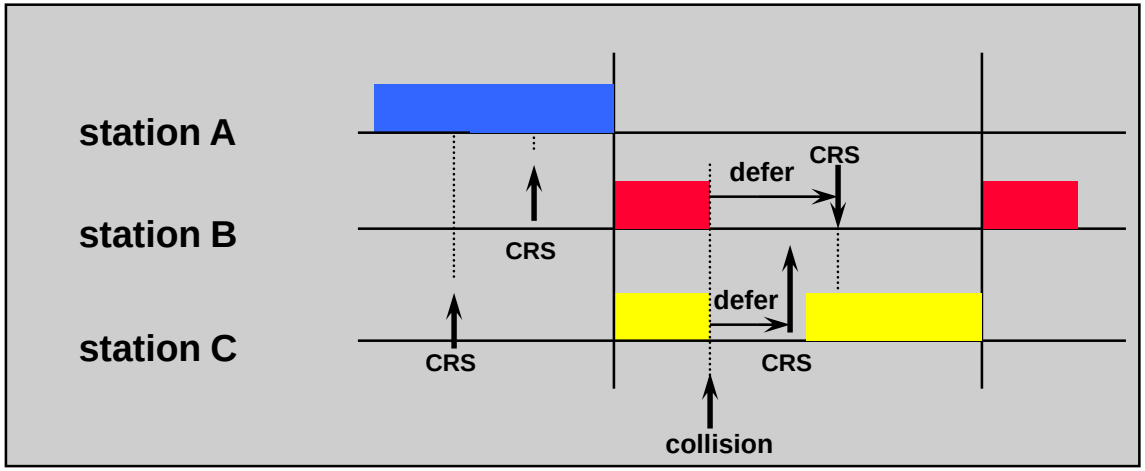
CSMA/CA Procedure



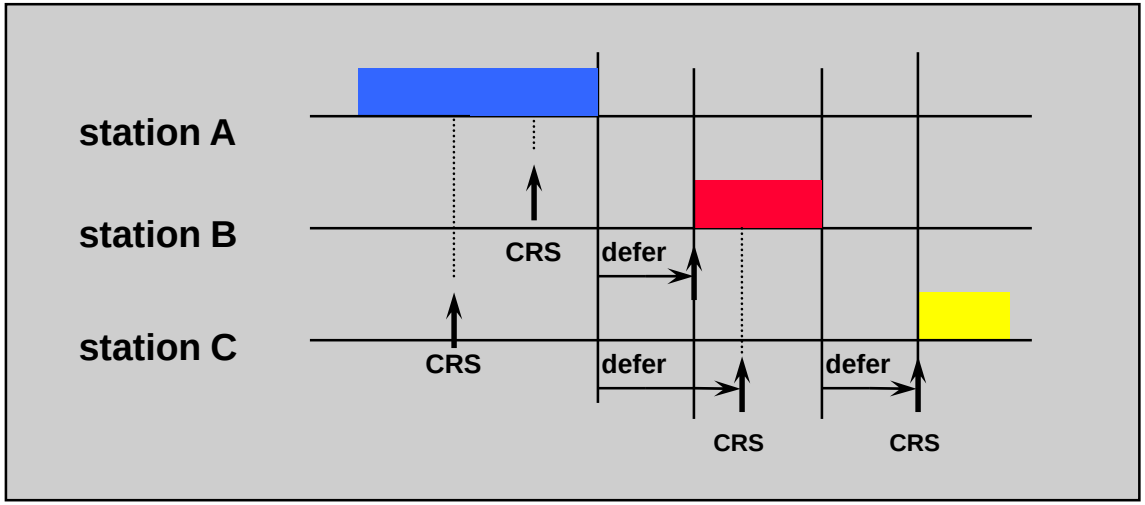
* Figure is courtesy of B. Forouzan

CSMA/CD and CSMA/CA

- CSMA/CD



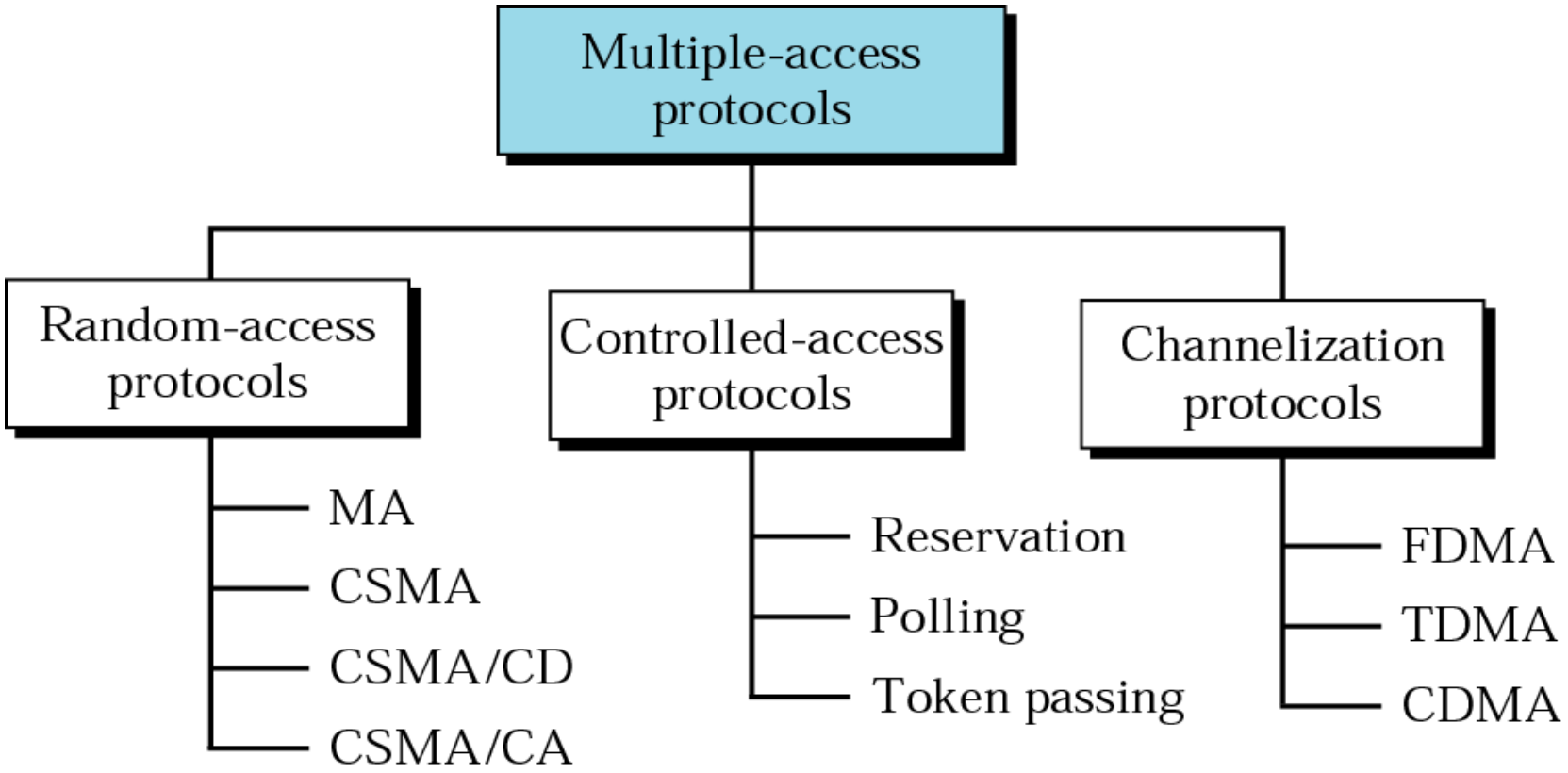
- CSMA/CA



CRS = Carrier Sense

* Figure is courtesy of Avaya Communications Inc

Multiple-Access Protocols



* Figure is courtesy of B. Forouzan


That's all folks
Telecomms II