The Medium Access Control Sublayer

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Reading Material for this topic

- Computer Networks, Fourth Edition by Andrew S Tanenbaum
  - Chapter 4, Topic 4.1, 4.2.1, 4.2.2, 4.2.6

Network categories:

1. Those using point-to-point channels
2. Those using broadcast channels

- In broadcast network, key issue is to determine who gets to use channel when there is competition for it.
- Broadcast channels = multiaccess channels
- Eg. conference call – chaos in who goes next
- Eg. Face to face meeting – raise hands when you want to speak
- protocols used to determine who goes next on a multiaccess channel belong to a sublayer of data link layer called MAC (Medium Access Control) sublayer

Static Channel Allocation in LANs and MANs

- Static channel – FDM
- N users BW divided into N equal size portion
- All users may not access channel – a waste
- More than N users want to communicate some may be denied due to lack of BW
- OK for small fixed no. users with heavy load
- When users more and traffic bursty – not ok
- computer systems peak : mean traffic = 1000:1
- Channel idle for most of time
- Same for TDM – user may not use allotted time

Dynamic Channel Allocation in LANs and MANs

- Key assumptions
- **Station Model**
- Consists of N independent stations, each generates frames for transmission.
- Once a frame has been generated, station is blocked and does nothing until the frame has been successfully transmitted

- **Single Channel Assumption**
- Single channel is available for all communication
- All stations can transmit on it and all can receive from it.
- Hardware at all stations are equivalent,
- Protocol software may assign priorities to them.

- **Collision Assumption.**
- If 2 frames are transmitted simultaneously, they overlap in time and resulting signal is garbled.
- This event is called a collision.
- All stations can detect collisions.
- A collided frame must be transmitted again later.
- There are no errors other than those generated by collisions.

- Carrier = electrical signal on cable
- **Continuous Time.** Frame transmission can begin at any instant. No master clock dividing time into discrete intervals.
- **Slotted Time.** Time is divided into discrete intervals (slots). Frame transmissions always begin at start of a slot. A slot may contain 0, 1, or more frames, corresponding to an idle slot, a successful transmission, or a collision, respectively.
- **Carrier Sense.** Stations can tell if channel is in use before trying to use it. If channel is sensed as busy, no station will attempt to use it until it goes idle.
- **No Carrier Sense.** Stations cannot sense channel before trying to use it. They just go ahead and transmit. Only later can they determine whether transmission was successful.

Multiple Access Protocols

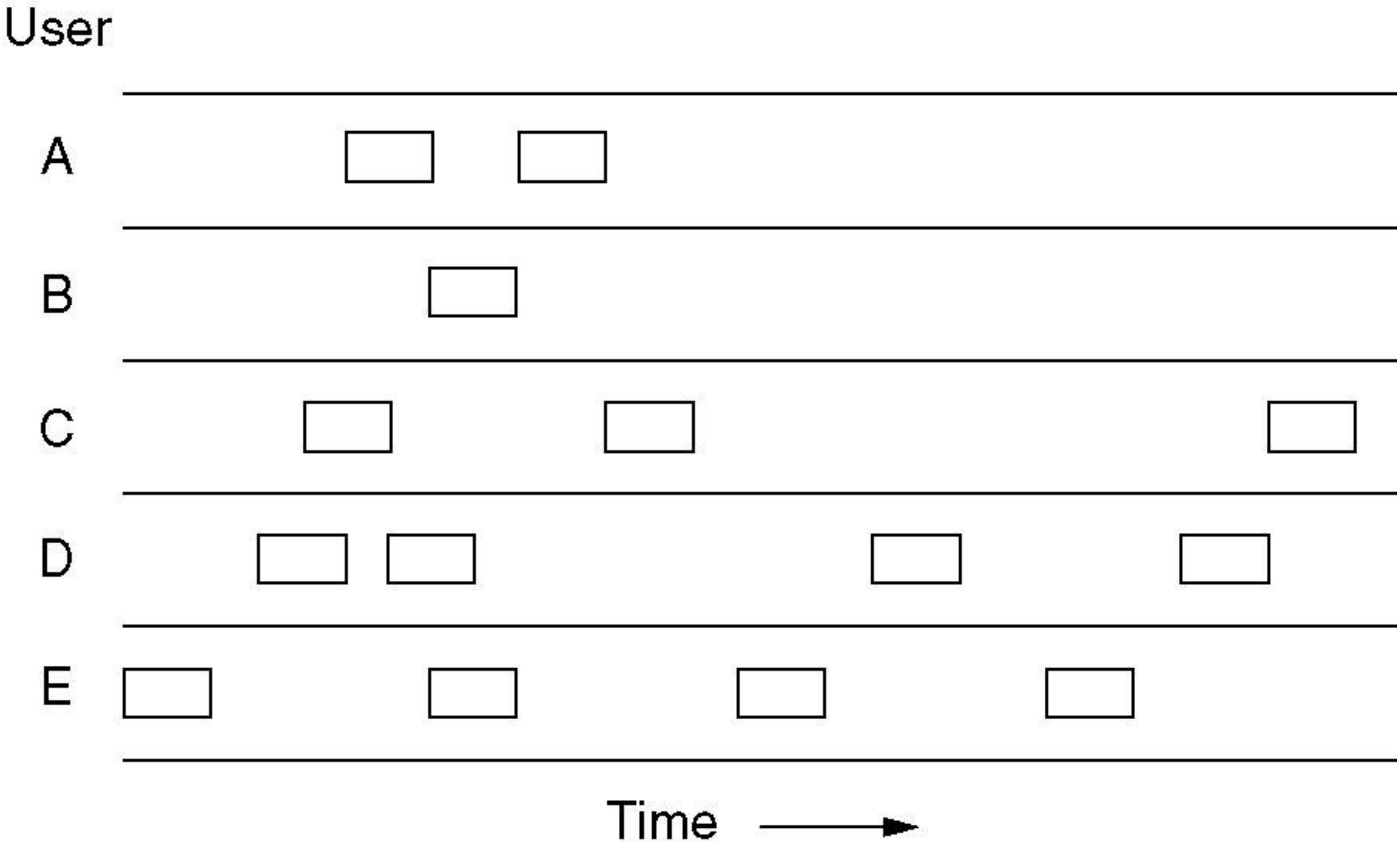
- ALOHA
- In 1970s, Norman Abramson, University of Hawaii devised method to solve channel allocation problem.
- Work used ground-based radio broadcasting
- Basic idea is applicable to any system in which uncoordinated users are competing for use of a single shared channel.
- Two versions of ALOHA here: pure and slotted.

Pure ALOHA

- Let users transmit whenever they have data to be sent.
- There will be collisions, colliding frames will be damaged.
- Due to feedback property of broadcasting, sender can always find out whether its frame was destroyed by listening to channel
- If listening while transmitting is not possible for some reason, acknowledgements are needed.
- If frame was destroyed, sender just waits a random amount of time and sends it again.
- Waiting time must be random or same frames will collide over and over, in lockstep.

Frame generation in an ALOHA system

- Frames of same length

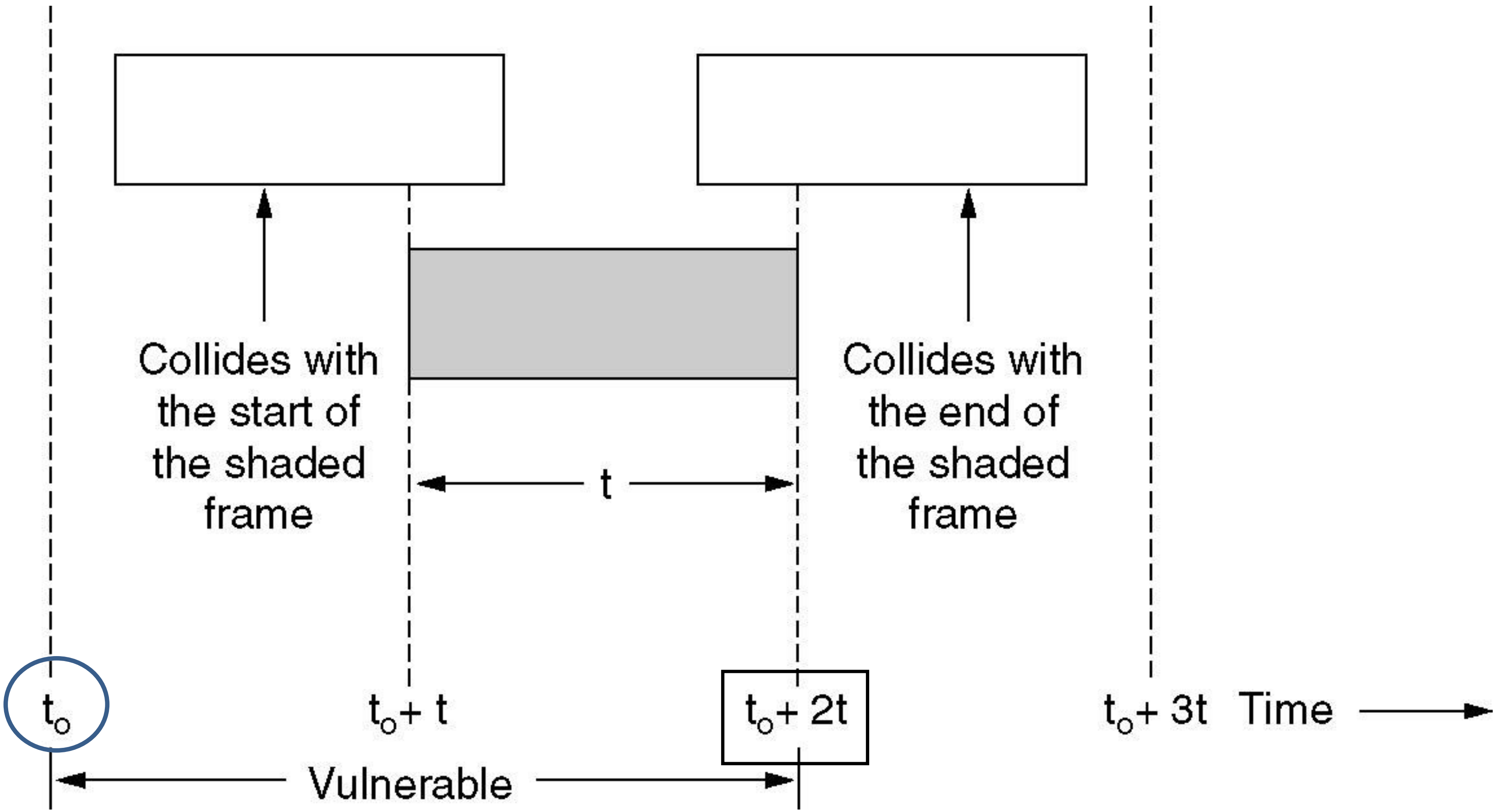


Efficiency of an ALOHA channel

- Frame time = amount of time needed to transmit standard, fixed-length frame
- Frame time = Frame length/bit rate
- Infinite number of users generates new frames according to Poisson's distribution with average N frames per frame time
- If N > 1, users generating frames at a higher rate than channel can handle and most frames will suffer a collision
- To reduce collision we would expect 0 < N < 1

- In addition to new frames, stations also generate retransmissions of frames that previously suffered collisions.
- Let there be k transmission attempts (including retransmissions) per frame time.
- The probability of k transmissions per frame time is also Poisson.
- Let the mean of these transmissions be G per frame time.
- Clearly, $G \geq N$ (old (duplicate) and new frames will be more than new frames)
- At low load ($N \approx 0$), few collisions, few retransmissions, so $G \approx N$.
- At high load there will be many collisions, so $G > N$
- For all loads, Throughput per frame time = S = G x Probability that a frame doesn't suffer collision = GP_0
- We find P_0

Vulnerable time for the shaded frame



- What is the condition for shaded frame to arrive undamaged without collision? (for finding P_0)

- t = time required to send a frame
- If any other user has generated a frame between time t_0 and $t_0 + t$, end of that frame will collides with beginning of shaded one
- any other frame started between $t_0 + t$ and $t_0 + 2t$, beginning of that frame will collide with end of shaded frame
- Vulnerable period = $\boxed{t_0 + 2t} - t_0 = 2t$

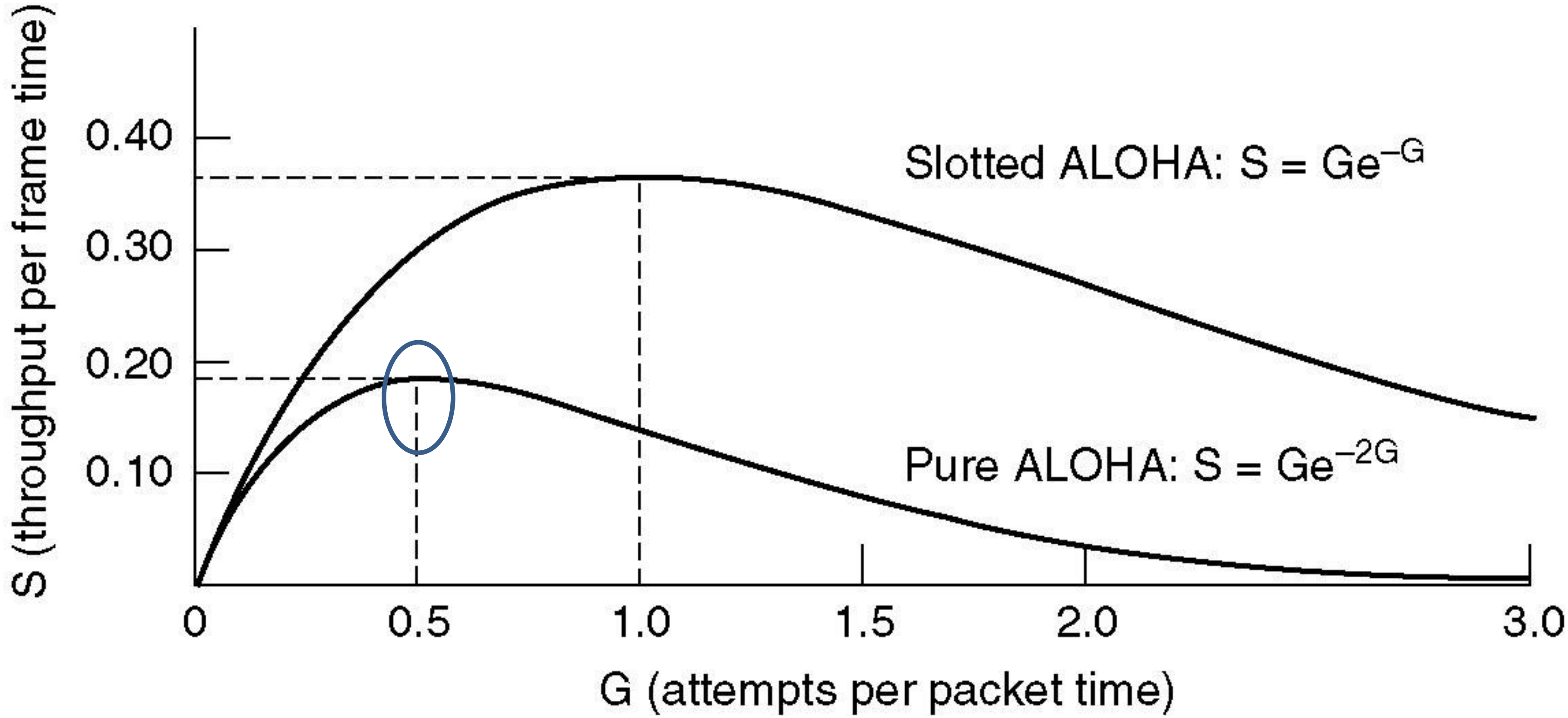
Generalized Poisson Distribution for frame generation

- Probability that k frames are generated during time t is given by Poisson distribution
- $P[k]=[G^k \; e^{-G}]/k!$
- Probability of generating zero frames i.e. k= 0 (when 0 frame generated no collision and so no frame damaged)
- $P[k]=[G^0 \; e^{-G}]/0!$
- $P[k]= e^{-G}$ (i.e 0!=1)

Poisson Distribution for frame generation during vulnerable period

- If interval is two frame time long (2t, vulnerable period), mean number of frames generated will be 2G (t-> G frames, 2t->2G frames)
- Probability of generating zero frames i.e. k= 0 during 2t (no collision and so no frame damaged when 0 frame generated)
- $P_0=[(2G)^0 e^{-2G}]/0!$
- $P_0 = e^{-2G}$
- Using $S = GP_0$,
- Throughput per frame time = $S=G e^{-2G}$

Offered traffic (G) and throughput (S)



Pure ALOHA

- maximum throughput (S) occurs at G = 0.5,

$$S = G\, e^{-2G}$$

$$S = 0.5 \times e^{-2 \times 0.5}$$
$$= 0.5 \times e^{-1}$$
$$= 0.184$$
$$= 18.4\%$$

- e = constant=2.71828
- We get efficiency of 18 percent in Pure Aloha

Example

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 = frame length/bit rate = 200 bits/200 kbps = 1 ms.

Vulnerable time = 2t = 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 one 1-ms period that this station is sending.

Example

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

a. 1000 frames per second   b. 500 frames per second

Solution

The frame transmission time = 200 (frame length)/200 kbps (bit rate)=1 ms.

a. If system creates 1000 frames per second, this is 1 frame per millisecond. The load offered by system i.e G is 1. Thus $S = G \times e^{-2G}$ ***or*** $S = 1 \times e^{-2*1} = 1/(2.71828)^2 = 0.135$ ***(13.5 percent). From 100 frames 13.5 will not collide, how many from 1000 frames will be successfully transmitted without collision. Throughput = 1000 × 13.5/100 = 135 frames. Only 135 frames out of 1000 will probably survive.***

Example 12.3 (continued)

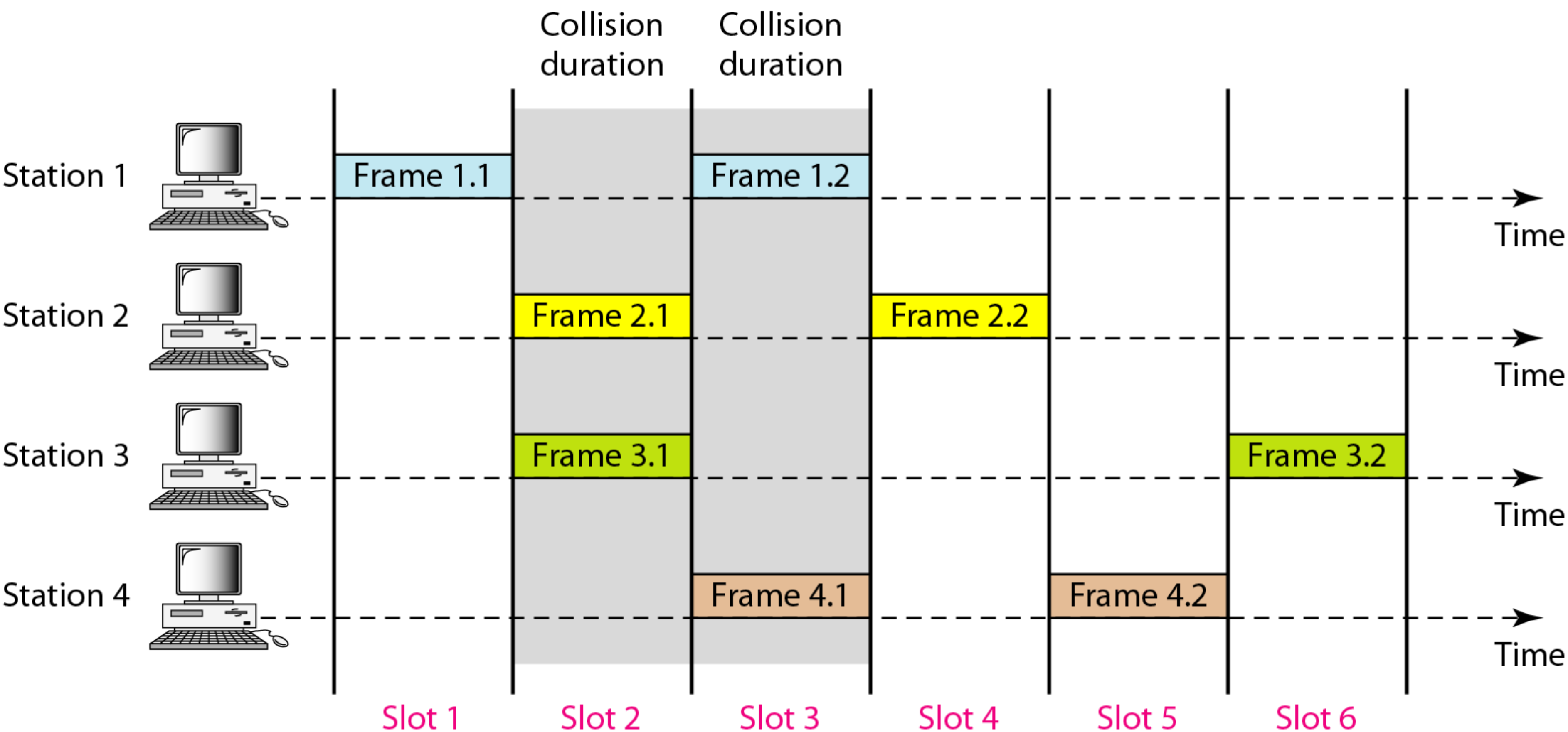
b. *If system creates 500 frames per second, this is (1/2) frame per millisecond. The load is (1/2). In this case $S = G \times e^{-2G}$ or $S = 0.184$ (18.4 percent). This means that the throughput is $500 \times 0.184 = 92$ and that only 92 frames out of 500 will probably survive. Note that this is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

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

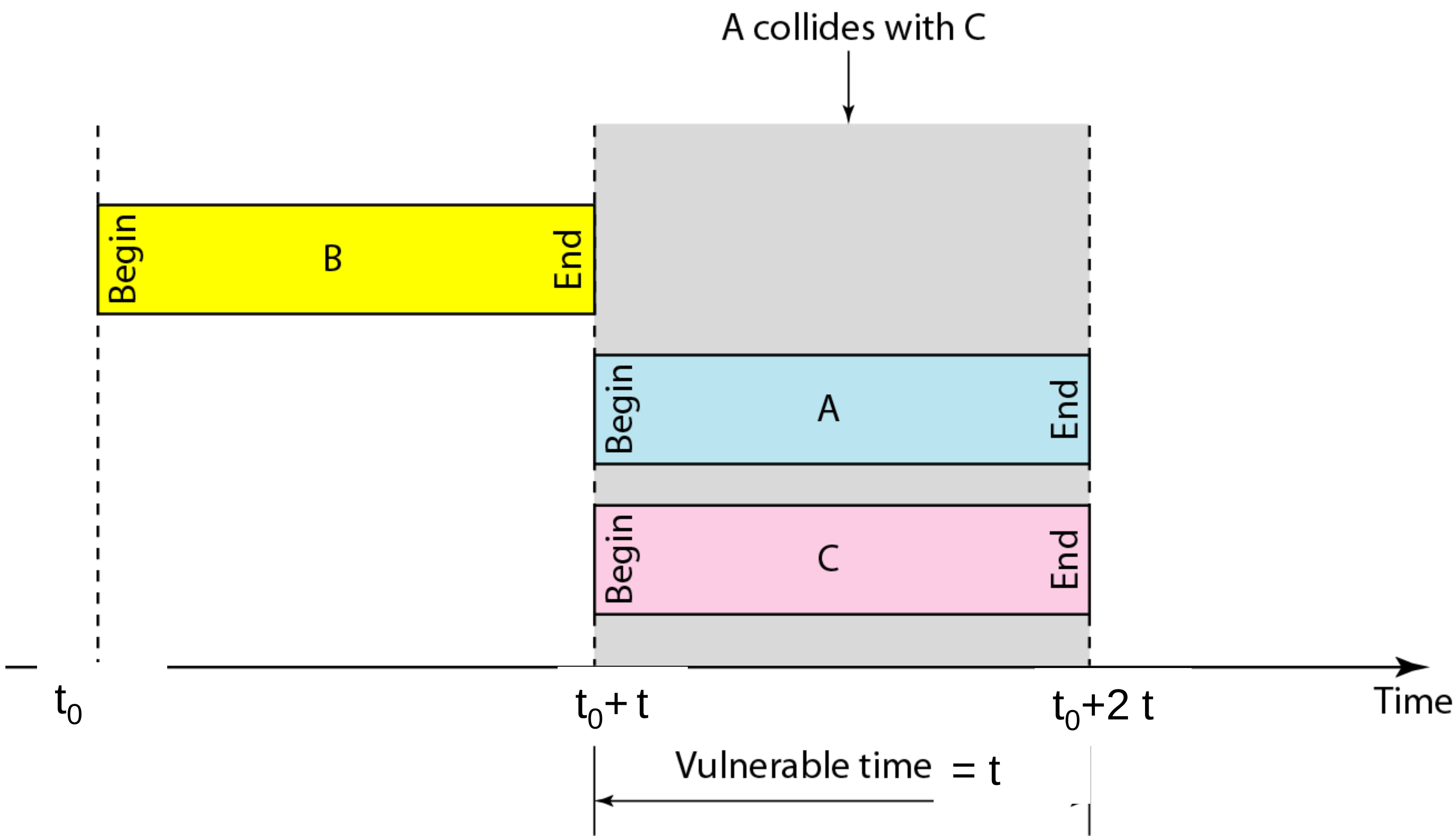
Slotted ALOHA

- In 1972, Roberts published a method for doubling efficiency of an ALOHA system
- Divide time into discrete intervals, each interval corresponding to one frame
- All users are to agree on slot boundaries.
- For synchronization one special station transmit a signal at the start of each interval, like a clock.
- User is not permitted to send whenever he wants
- it is required to wait for beginning of the next slot
- If misses to start at start of slot wait for begin of next slot

Frames in a slotted ALOHA network

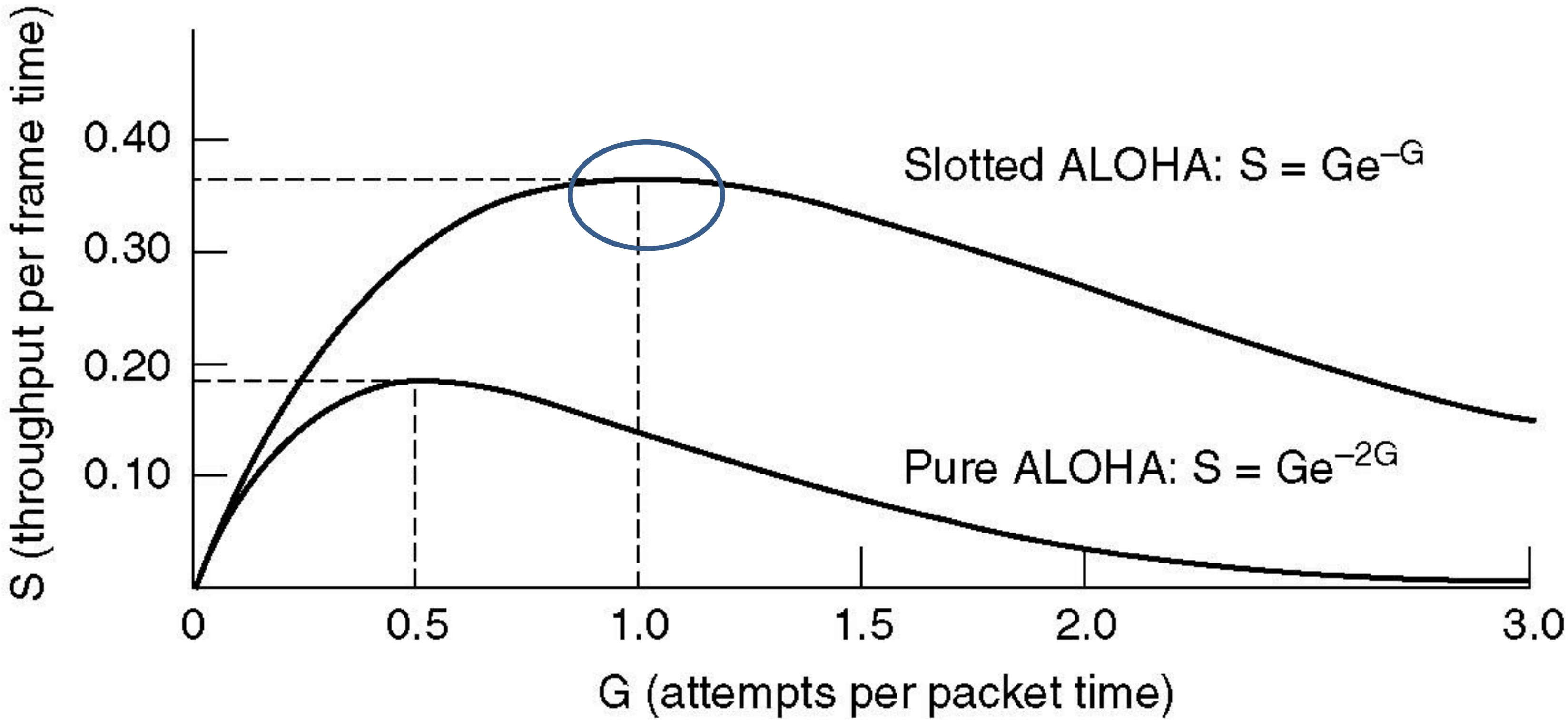


Vulnerable time for slotted ALOHA protocol



- If interval is one frame time long (t, vulnerable period), mean number of frames generated will be G (transmission attempts)
- Probability of generating zero frames i.e. k= 0 during t (when 0 frame generated no collision and so no frame damaged)
- $P_0=[(G)^0 e^{-G}]/0!$
- $P_0 = e^{-G}$
- Using $S = GP_0$,
- $S=G e^{-G}$

offered traffic (G) and throughput (S)



Slotted ALOHA

- maximum throughput (S) occurs at G = 1,

$$S=G\,e^{-G}$$

$$S=1/e^{-1}$$

- e = constant=2.71828

$$S = 1/2.71828 = 0.3678$$

- We get efficiency of 37 percent in Slotted Aloha, twice that of pure ALOHA.

Carrier Sense Multiple Access Protocols

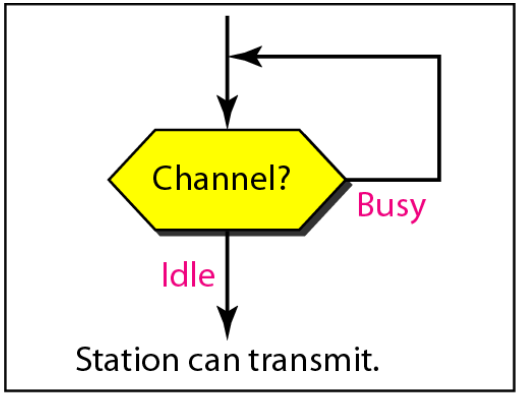
- In LAN, it is possible for stations to detect what other stations are doing, and adapt their behavior accordingly.
- Protocols in which stations listen for a carrier (i.e., a transmission) and act accordingly are called carrier sense protocols.
- CSMA is based on the principle "sense before transmit" or "listen before talk”

Persistence Methods

- What should a station do if channel is busy?
- What should a station do if channel is idle?
- Three methods have been devised to answer these questions: 1-persistent method, nonpersistent method, p-persistent method.

1-Persistent CSMA

- When a station has data to send, it first listens to channel to see if anyone else is transmitting
- If channel is busy, station continuously senses it waiting for it to becomes idle
- When station detects an idle channel, it transmits a frame (with probability 1)
- If a collision occurs, station waits a random amount of time and starts all over again.
- Has highest chance of collision because two or more stations may find channel idle and send their frames immediately

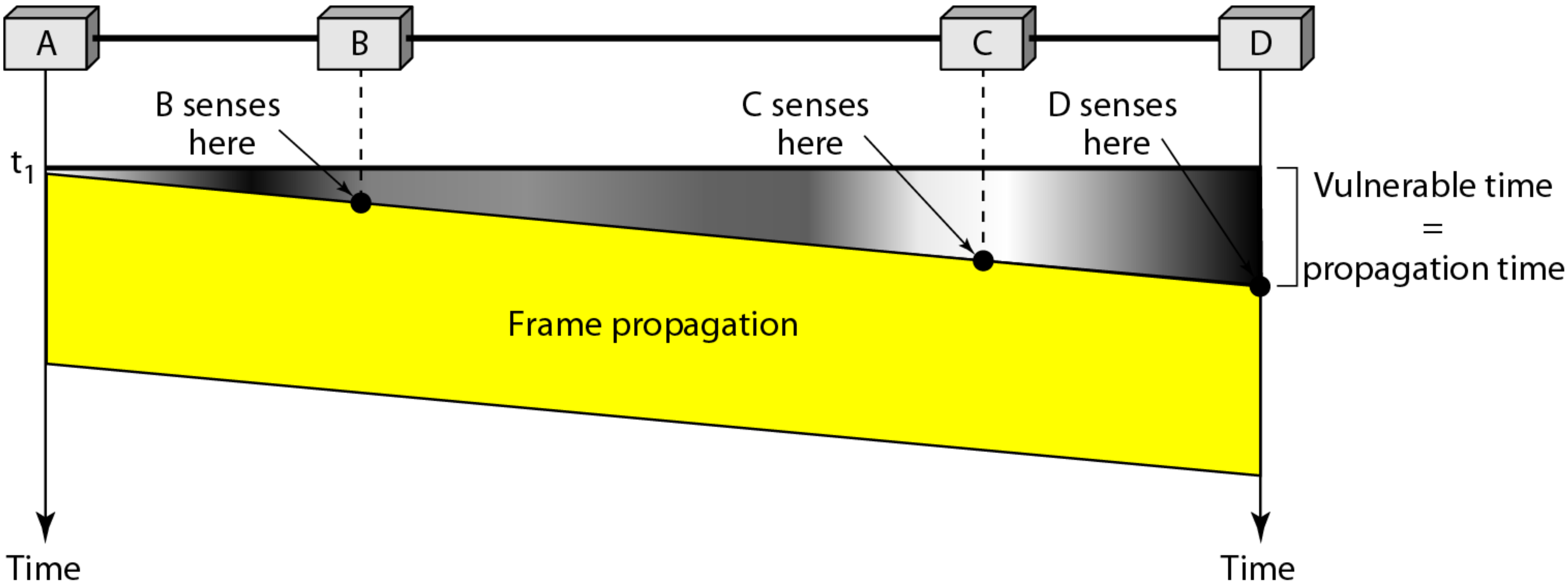


a. 1-persistent

Role of propagation delay in CSMA

- propagation delay has an important effect on performance CSMA
- just after a station begins sending, another station becomes ready to send and sense the channel.
- If first station's signal has not yet reached second one, latter will sense an idle channel and will also begin sending, resulting in a collision.
- longer propagation delay, more important this effect becomes, and worse the performance of the protocol
- Even if propagation delay is zero, two stations become ready in middle of a third station's transmission, both will wait until transmission ends and then both will begin transmitting exactly simultaneously, resulting in a collision

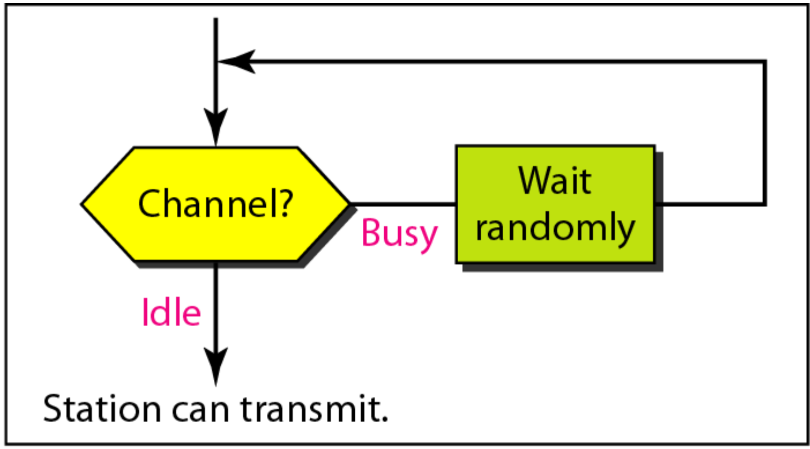
Vulnerable time in CSMA = Propagation time



longer propagation delay, more important this effect becomes, and worse is the performance of the protocol

nonpersistent CSMA

- attempt is made to be less greedy
- Before sending, a station senses the channel.
- If no one else is sending, the station begins doing so itself.
- However, if channel is already in use, station does not continually sense it for purpose of seizing it immediately upon detecting end of previous transmission.
- Instead, it waits a random period of time and then repeats the algorithm.
- Consequently, this algorithm leads to better channel utilization but longer delays than 1-persistent CSMA



b. Nonpersistent

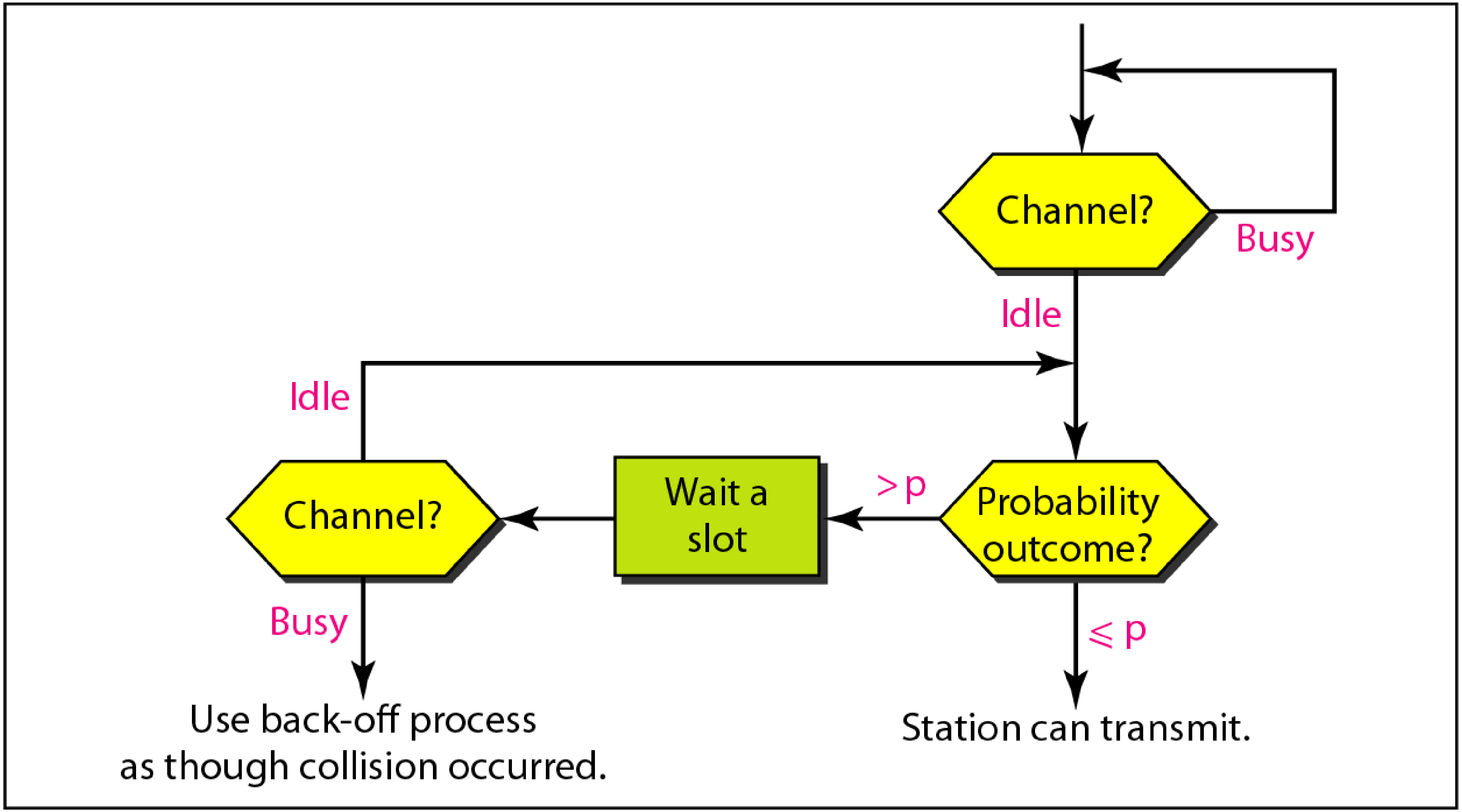
p-persistent CSMA

- Used if channel has time slots with a slot duration ≥ maximum propagation time
- When a station becomes ready to send, it senses the channel.
- If station finds channel idle it follows these steps:

1. With probability p, the station sends its frame.
2. With probability $q = 1 - p$, the station waits for the beginning of the next time slot and checks the line again.
   a. If the line is idle, it goes to step 1.
   b. If the line is busy, it acts as though a collision has occurred and uses the back-off procedure.

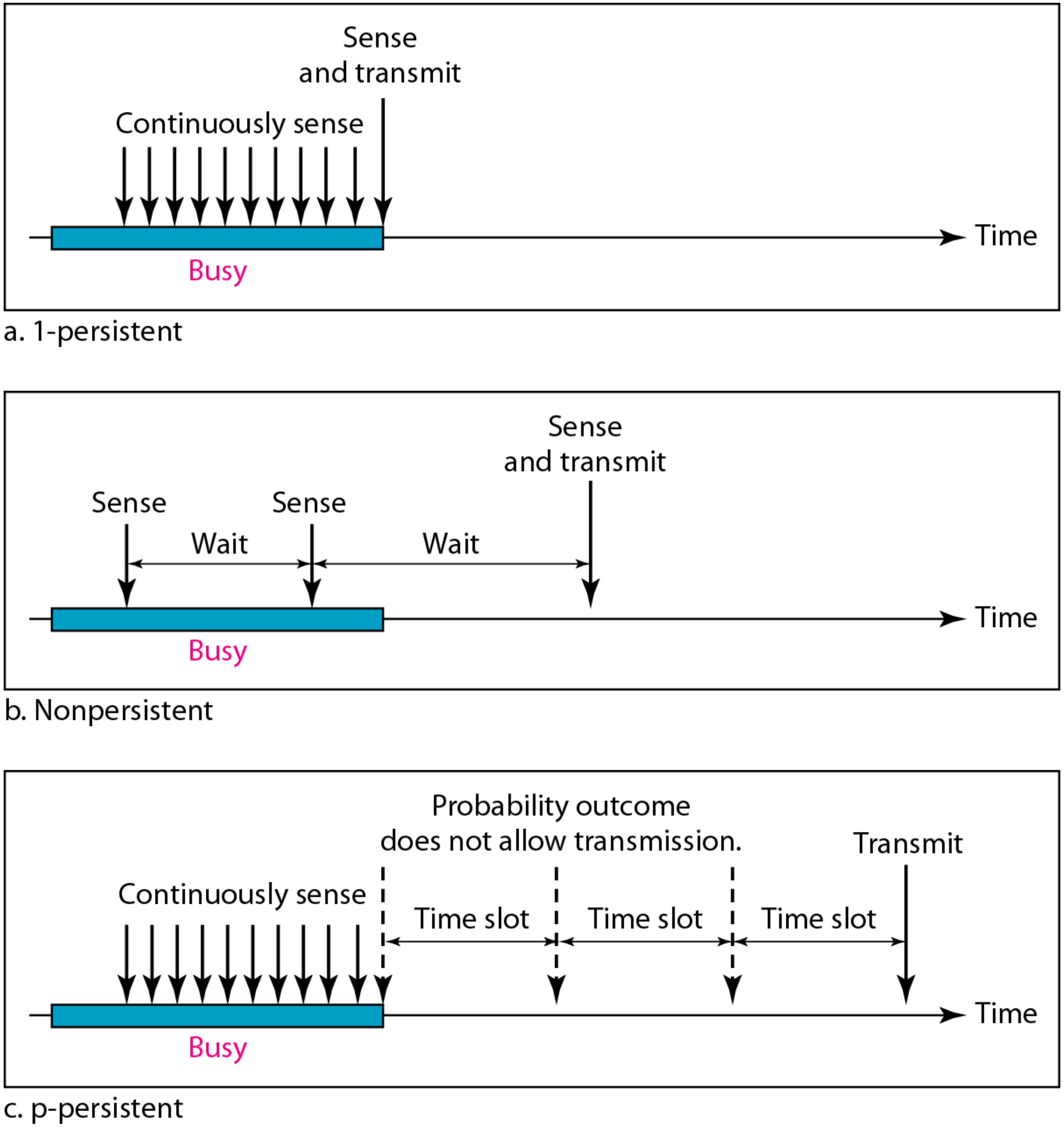
- If station initially senses the channel busy, it waits until the next slot and applies the above algorithm.

Flow diagram of p-persistence method

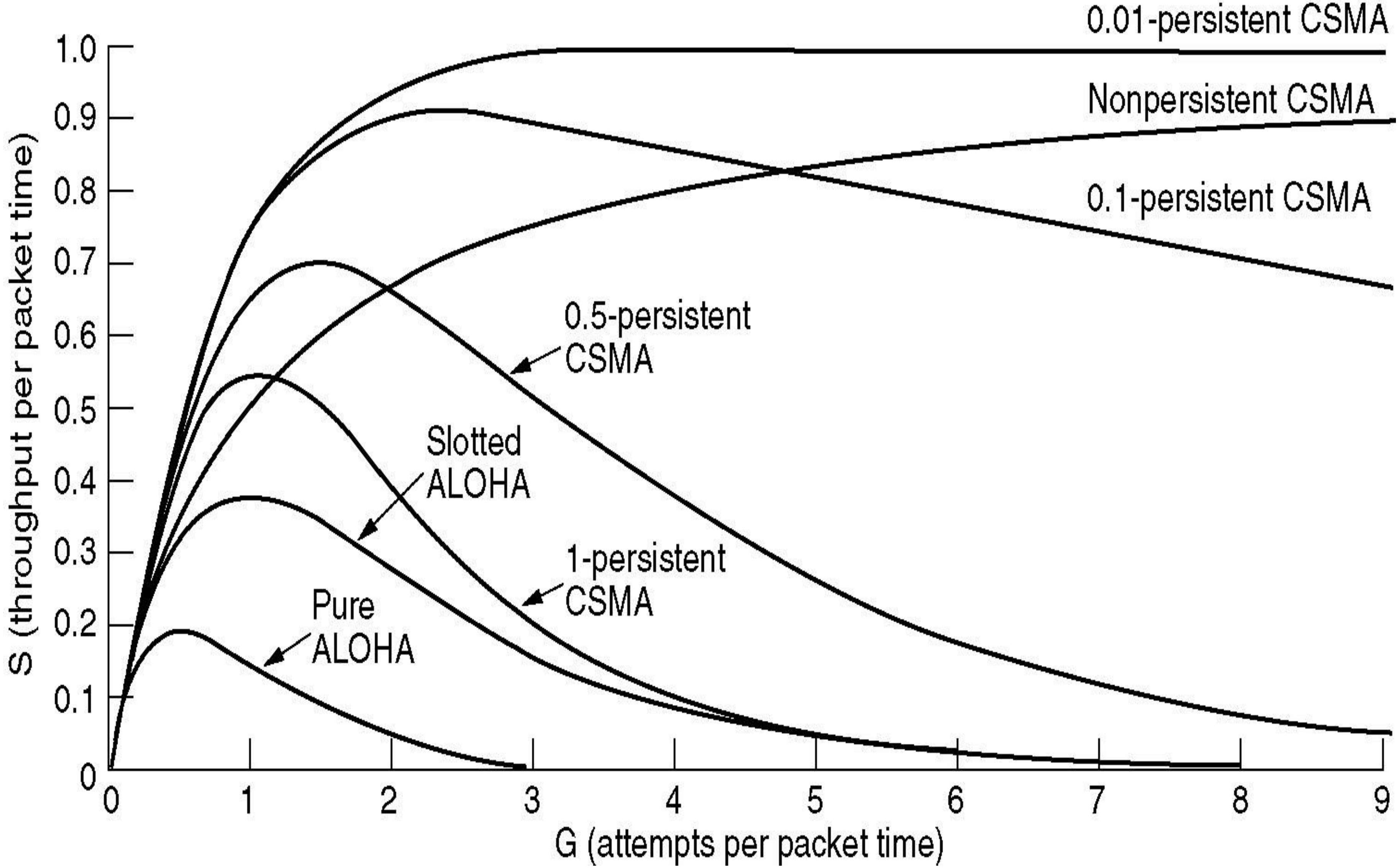


c. p-persistent

Behavior of three persistence methods



computed throughput versus offered traffic



CSMA with Collision Detection

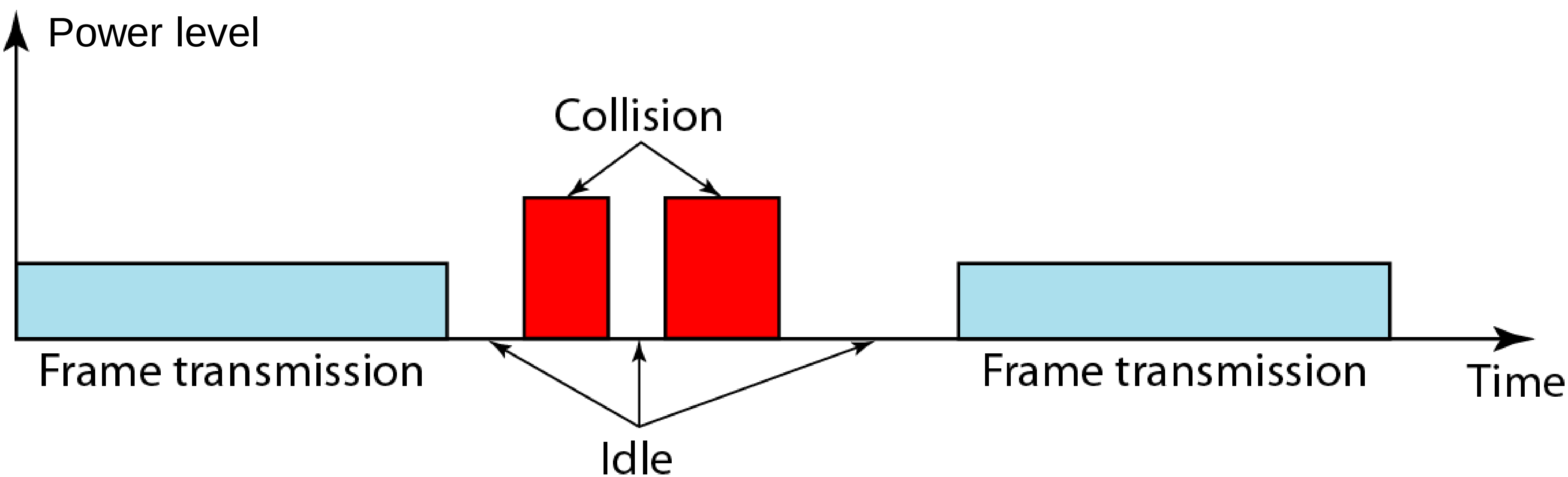
- Augmentation to handle collision
- station monitors channel after it sends a frame to see if transmission was successful
- If so, the station is finished.
- If, there is a collision, the frame is sent again.
- stations to abort their transmissions as soon as they detect a collision
- widely used on LANs in the MAC sublayer.
- Ethernet LAN uses it

Collision Detection

- station's hardware must listen to the channel while it is transmitting.
- If what it reads back is different from what it is putting out, it knows that a collision is occurring.
- Signal encoding must allow collisions to be detected (e.g., a collision of two 0-volt signals cannot be detected, 1 = 5 V, 0=0 V is better).
- a sending station must continually monitor the channel, listening for noise bursts that might indicate a collision.

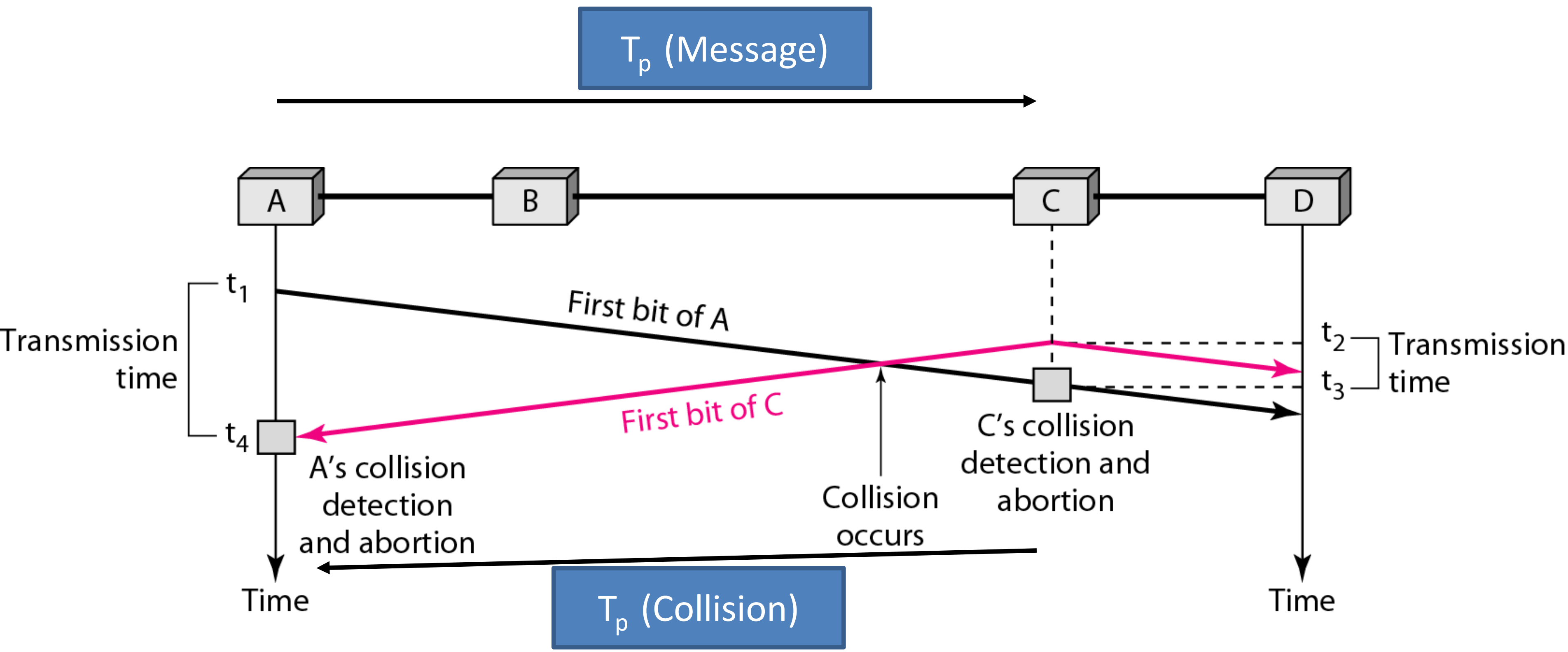
Collision Detection

- Collisions can be detected by looking at power or pulse width of received signal and comparing it to transmitted signal
- After station detects a collision, it aborts its transmission, waits a random period of time, and then tries again



Minimum Frame Size

- If two stations involved in a collision are maximum distance apart, signal from first takes time T_p (propagation time) to reach second
- Effect of collision takes another time T_p to reach the first
- So requirement is that first station must still be transmitting after $2T_p$ (i.e. active to know collision has occurred)



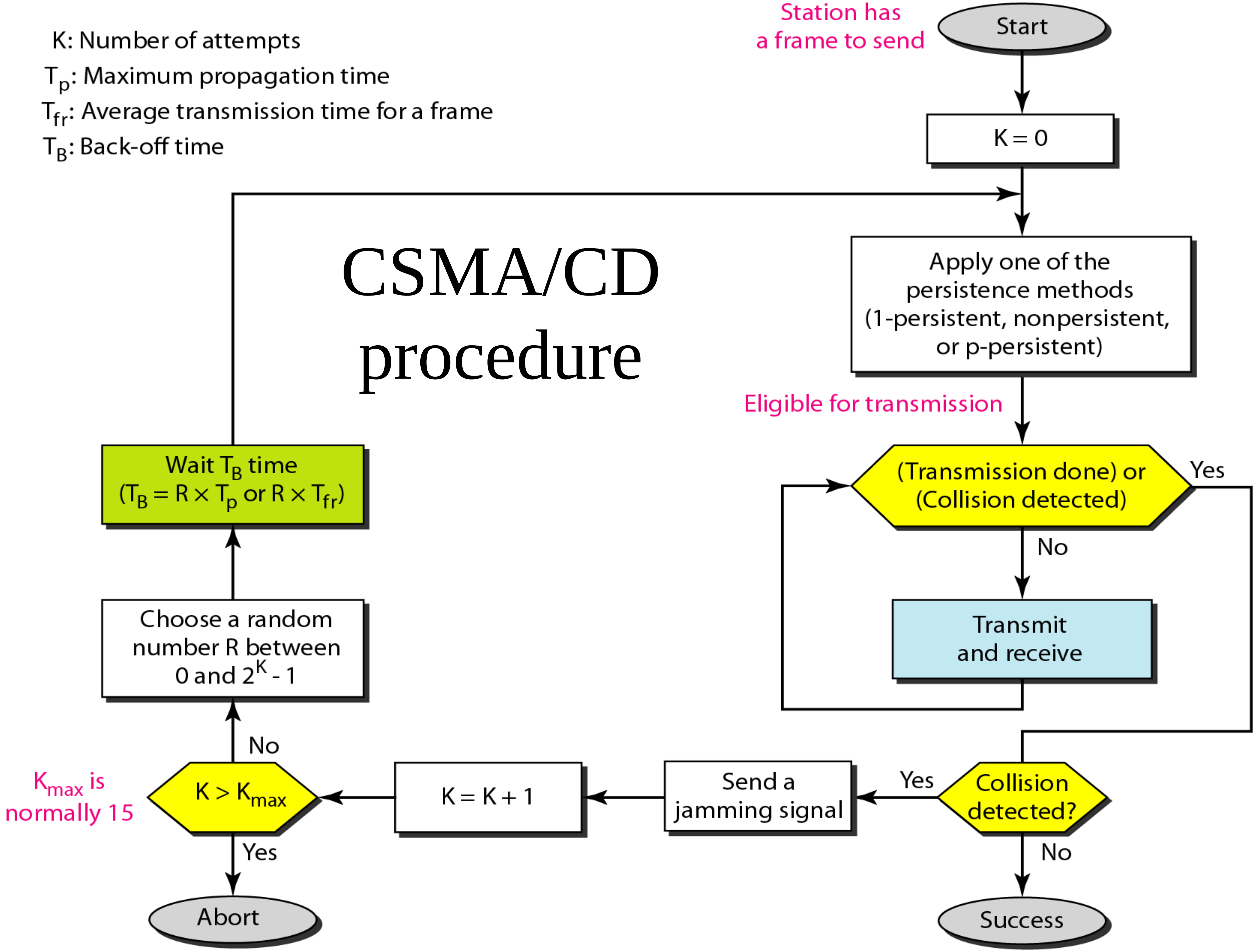
Example

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

Solution

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

CSMA/CD procedure



Thank You!