Part I Syllabus

Lecture	Date	Subject
1	10/08/2016	Introduction
2	10/08/2016	Layered network architecture & Physical resilience
3	17/08/2016	Data link layer – flow control
4	17/08/2016	Data link layer – error control
5	24/08/2016	Data link layer – HDLC
6	24/08/2016	Local area network – introduction
7	**31/08/2016**	**Local area network – MAC**
8	31/08/2016	Local area network – Ethernet
9	07/09/2016	Local area network – WLAN
10	07/09/2016	Packet switch network - Introduction
11	14/09/2016	Packet switch network – queue analysis
12	14/09/2016	Review and examples

How to mingle among cocktail

1) When to start speaking?
2) What to speak?
3) Whether/How to detect interruption?
4) How to act upon interruption?

Lecture 7
Medium Access Control (MAC) Protocols

Contents

- **Medium Access Control Protocol**
  - Ideal MAC Protocol
  - MAC Taxonomy
- **ALOHA Protocols**
  - Slotted ALOHA
  - Pure ALOHA
- **CSMA Protocol**
  - Vulnerable time in CSMA
  - CSMA Variants
- **CSMA/CD Protocol**
  - Collision Detection

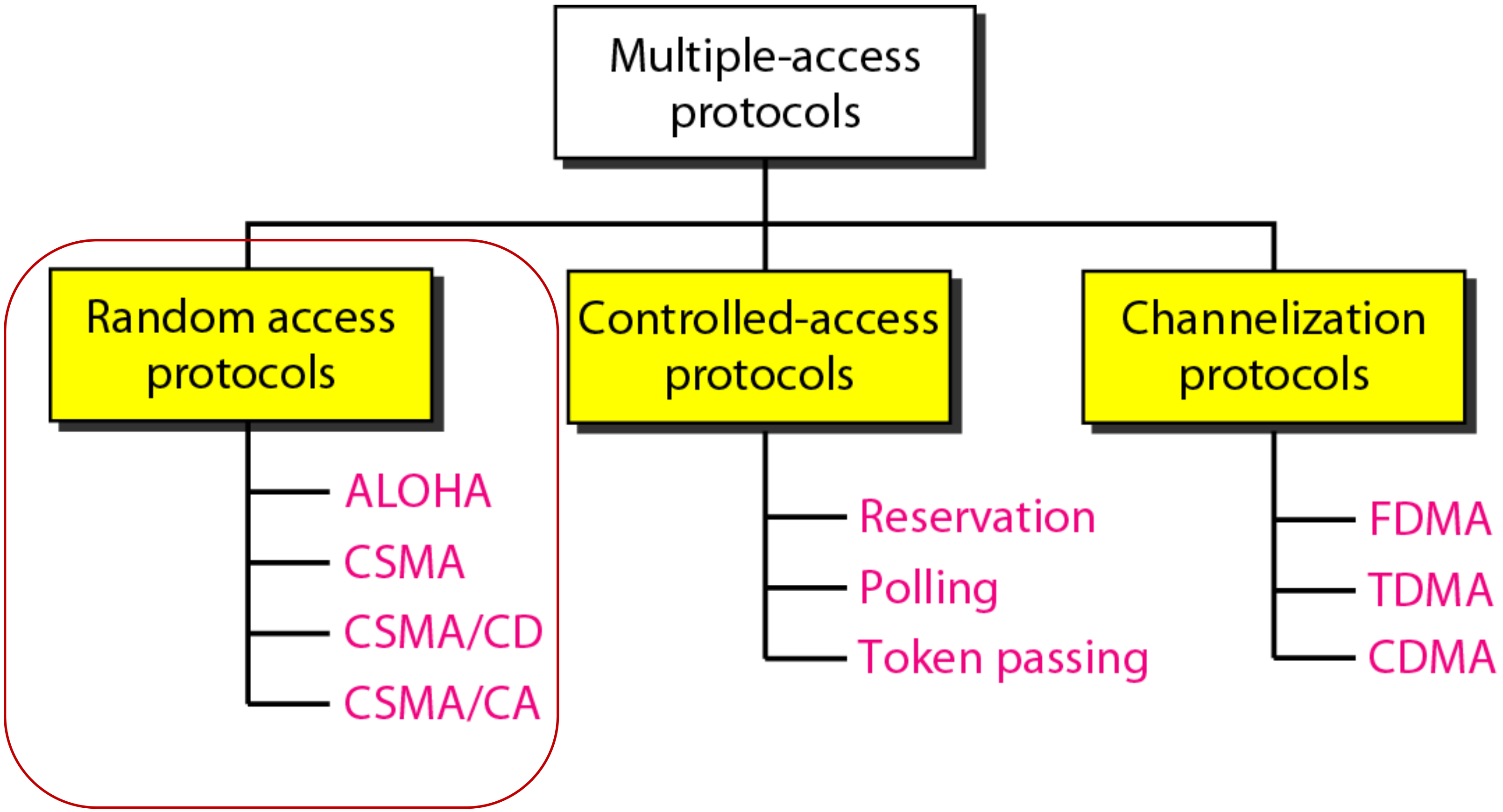
Medium Access Control Protocols

- **Single shared broadcast channel**
- **Two or more simultaneous transmissions by noises: interference**
  - Collision if node receives two or more signals at the same time
- **MAC Protocol**
  - Distributed algorithm to share the channel
  - Communication about channel sharing must use channel itself
    - No out-of-band channel for coordination

Ideal MAC Protocols

- **Broadcast Channel of Rate *R*-bps**
  - When one node transmits, it can send at rate *R*
  - When *M* nodes want to transmit, each can send at average rate *R/M*
  - Full decentralized
    - No special node to coordinate transmissions
    - No synchronization of clocks, slots
  - Simple
  - We call this ideal protocol as "*genie-aided*" MAC

MAC Taxonomy



Random Access Protocols

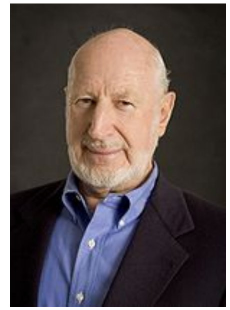
- **When node has packet to send**
  - Transmits at full channel data rate of *R*
  - No a-priori coordination among nodes
- **Two or more transmitting nodes**
  - Collision
- **Random MAC consists of 4 stages**
  - Whether to sense channel status
  - How to transmit frames
  - Whether/How to detection collision
  - How to recover from collision (e.g., via delayed retransmissions)

ALOHA Protocols

aloha
/əˈləʊhə/
exclamation & noun
a Hawaiian word used when greeting or parting from someone.

Slotted ALOHA

- **Inventor**
  - Norm Abramson
- **Assumptions**
  - All frames of the same size
  - Time is divided into equal size slots, time to transmit 1 frame
  - Nodes start to transmit frames only at beginning of slots
  - Nodes are synchronized
  - If 2 or more nodes transmit in slot, all nodes detect collision



Norman M. Abramson	
Born	April 1, 1932 (age 83) Boston, Massachusetts
Nationality	American
Fields	Electrical Engineering and Computer Sciences
Institutions	University of Hawaii
Alma mater	Stanford University Harvard University
Doctoral advisor	Willis Harman
Doctoral students	Thomas M. Cover Robert A. Scholtz
Notable awards	IEEE Alexander Graham Bell Medal (2007)

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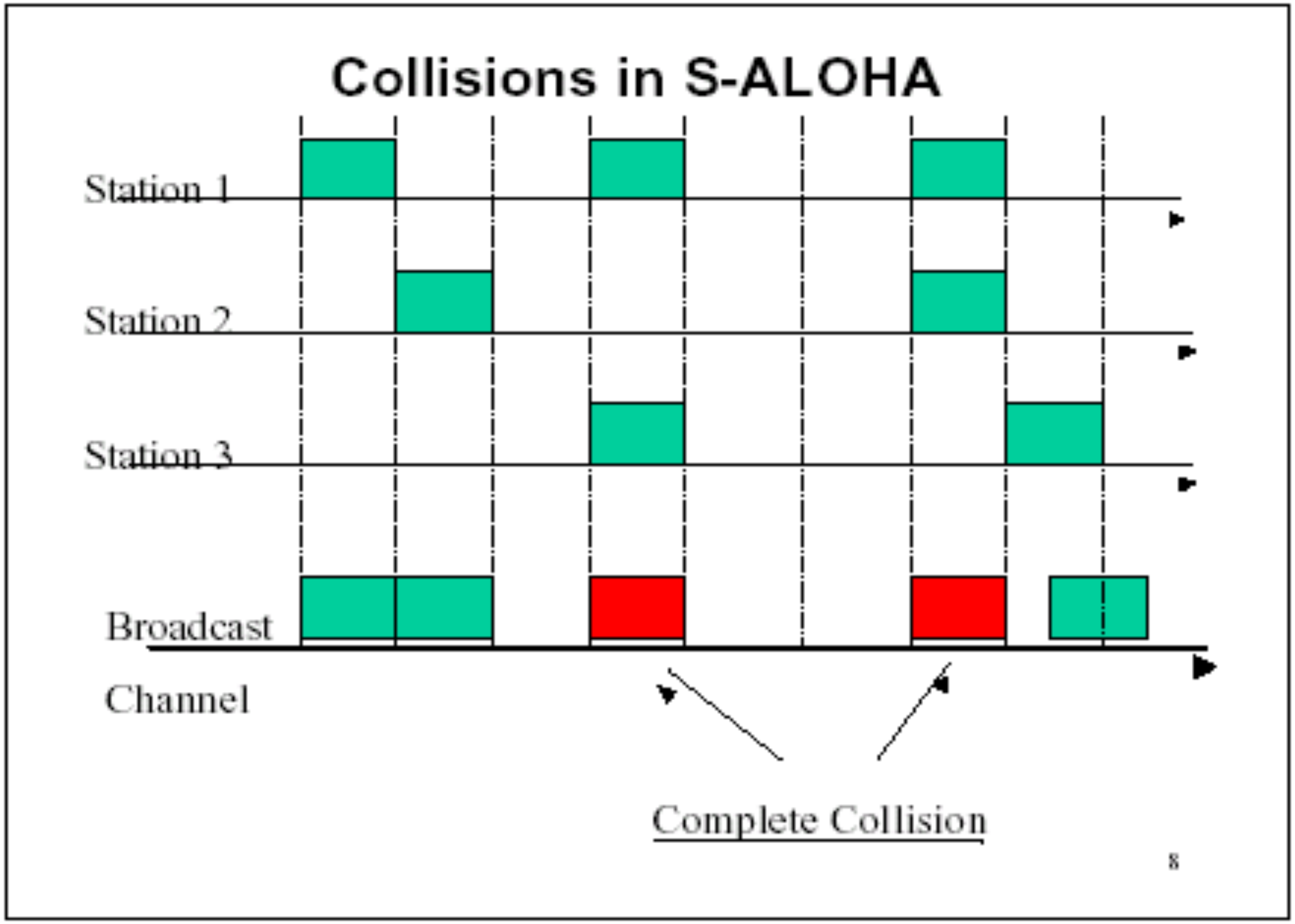
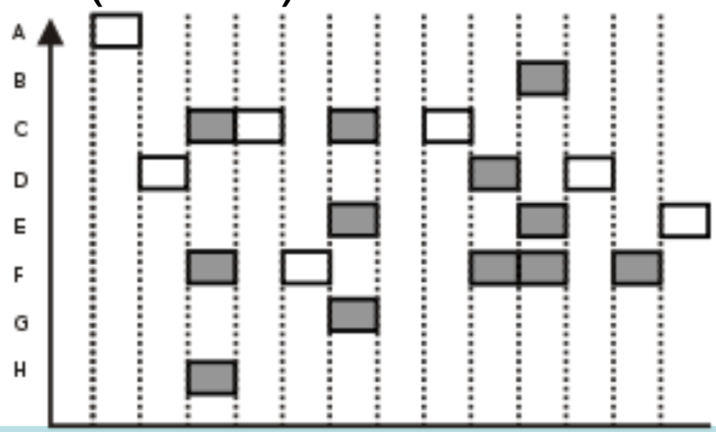
Slotted ALOHA



Slotted Aloha Efficiency

- **Slotted ALOHA**
  - If N stations have frames to send, and each transmits in a slot with a probability p:
  - For a particular station, $\Pr(S) = p\,(1-p)^{(N-1)}$
  - So for the network, $\Pr(S) = N\,p\,(1-p)^{(N-1)}$
  - $\Pr(S) = Ge^{-G}$ where $G=Np$ is the offer load
  - For very large N, Pr(S) = 1/e ($\approx$ 0.37)*



Slotted ALOHA protocol (shaded slots indicate collision)

*Tutorial 3.4

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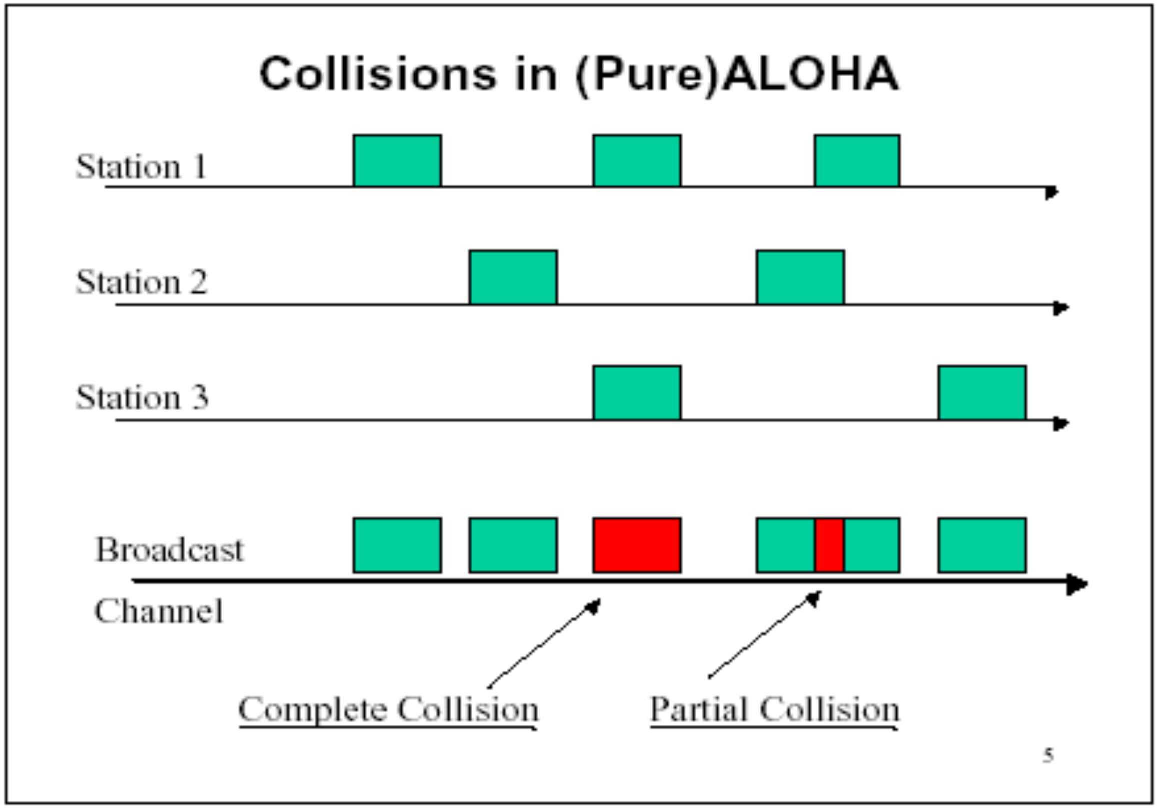
Pros and Cons of Slotted ALOHA

- **Pros**
  - Single active node can continuously transmit at full rate of channel
  - Highly decentralized: only slots need to be sync
  - Simple
- **Cons**
  - Collisions, wasting slots
  - Idle slots
  - Nodes may be able to detection in less time than to transmit packet
  - Clock synchronization

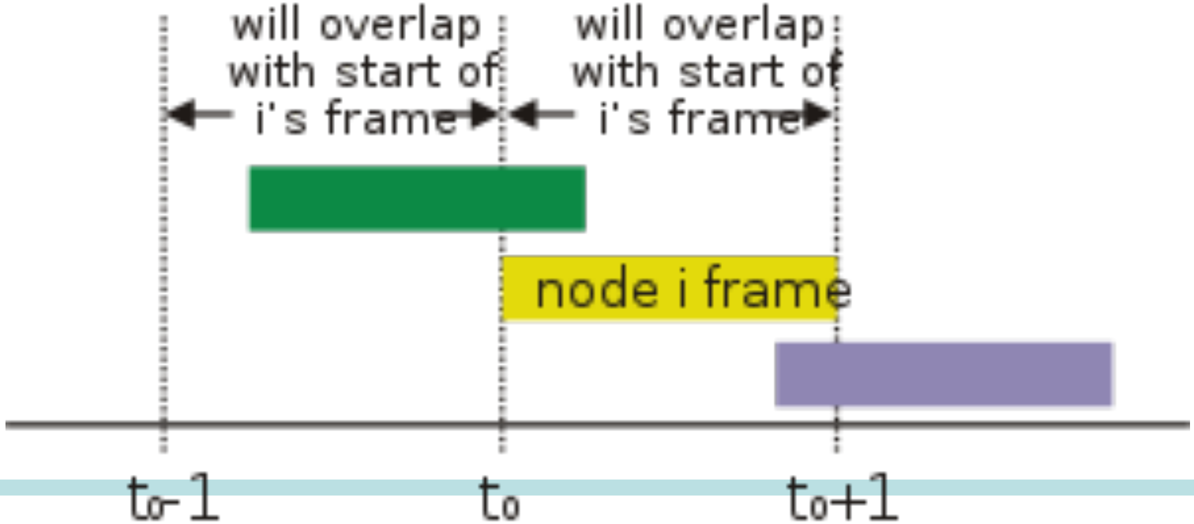
Pure ALOHA

- **In pure ALOHA, frames are transmitted at completely arbitrary times**



Pure ALOHA

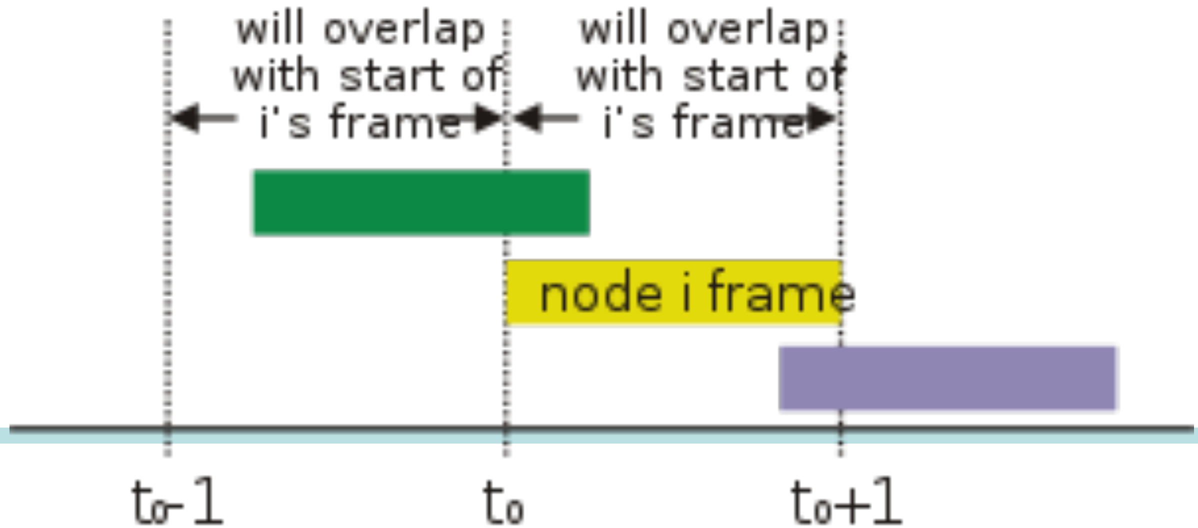
- **Unslotted Aloha: simpler, no synchronization**
- **When frame first arrives**
  - Transmit immediately
- **Collision probability increases:**
  - Frame sent at t_0 collides with other frames sent in $[t_0-1, t_0+1]$



Aloha Efficiency: Pure ALOHA

Pure Aloha: Partial transmission collision can occur (ie. my 1st half of the transmission collides with your 2nd half)

- **Pr(success by given node) = P(node transmit) * P(no other node transmits in [t0-1, t0]) * P(no other node transmit in [t0, t0+1])**
  $= p \times (1-p)^{(N-1)} \times (1-p)^{(N-1)}$
  $= p\,(1-p)^{(2N-2)}$
- **$Pr(S) = Ge^{-2G}$ where $G=Np$ is the offer load**
- **For very large N, $Pr(S) = 1/(2e) = 18.4\%$**



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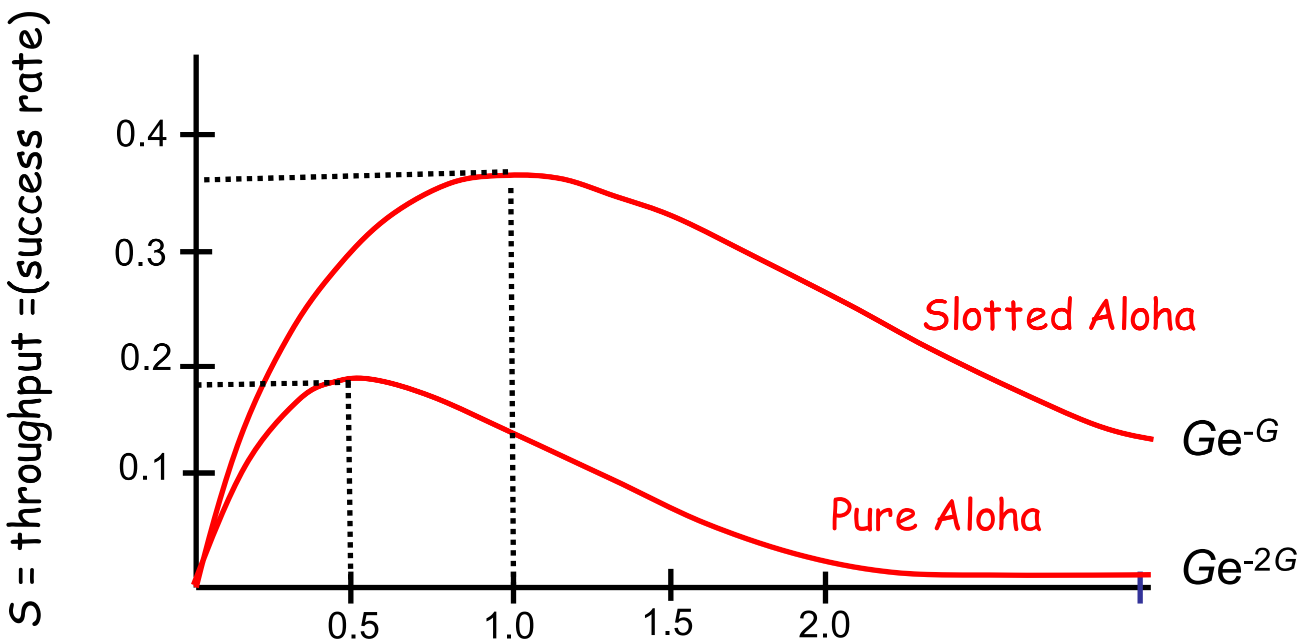
ALOHA Efficiency Comparison



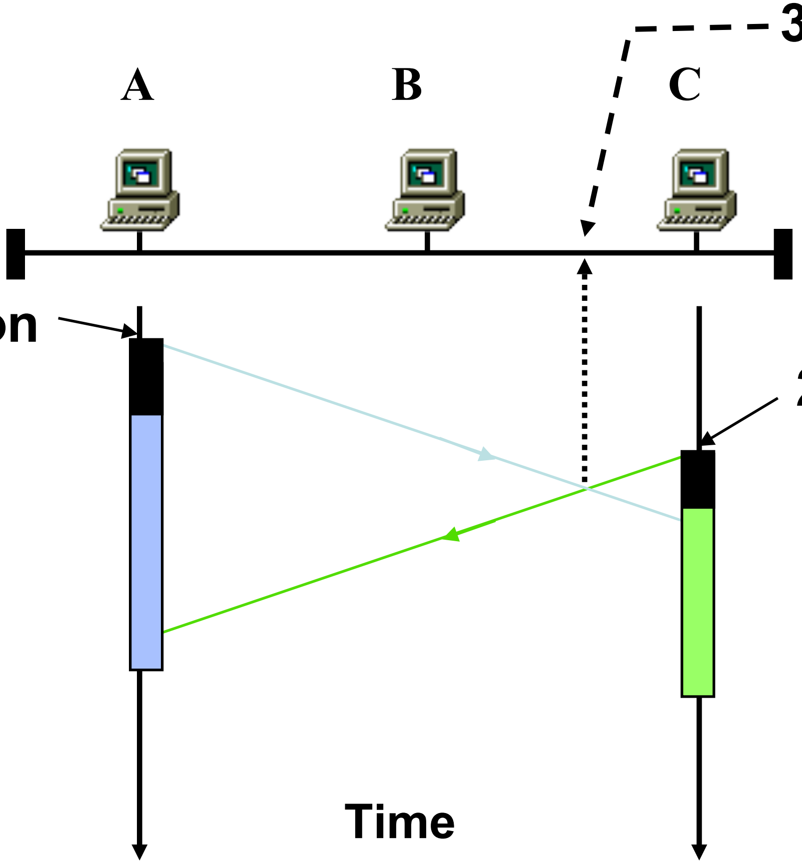
G = offered load rate= new frames+ retransmitted
= Total frames presented to the link per the transmission time of a single frame

Carrier-Sense Multiple-Access (CSMA)

Carrier-Sense Multiple-Access

- **To improve performance, avoid transmissions that are certain to cause collisions**
- **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 cannot eliminate it.**
  - Collision can only happen when more than one station begin transmitting within a short time (the **propagation time** period)

Collision in CSMA



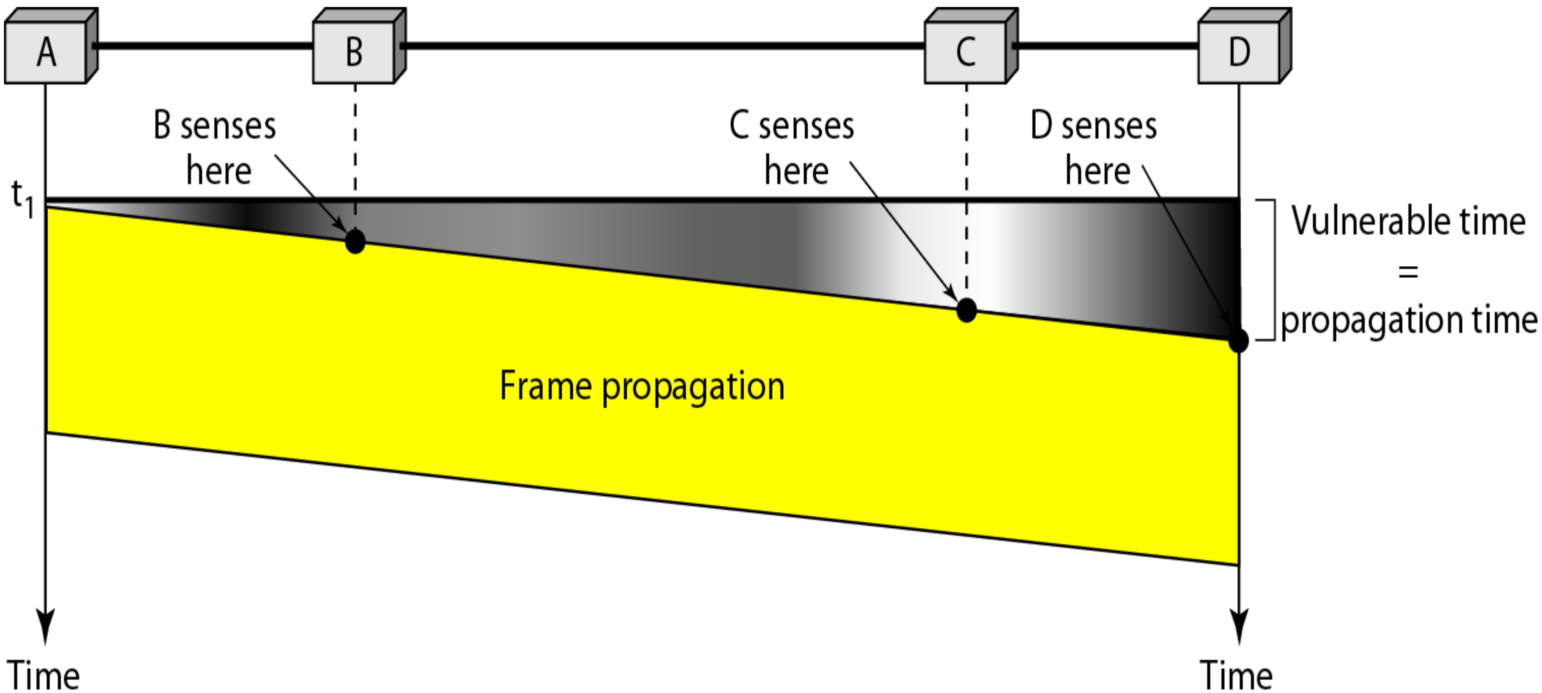
1. *A* senses the medium idle and starts transmission

2. *C* senses the medium idle and starts transmission

3. Collision occurs at this place on the medium

Vulnerable Time in CSMA

- **Vulnerable time for CSMA is the <u>maximum propagation time</u>**
- **The longer the propagation delay, the <u>worse the performance</u> of the protocol.**

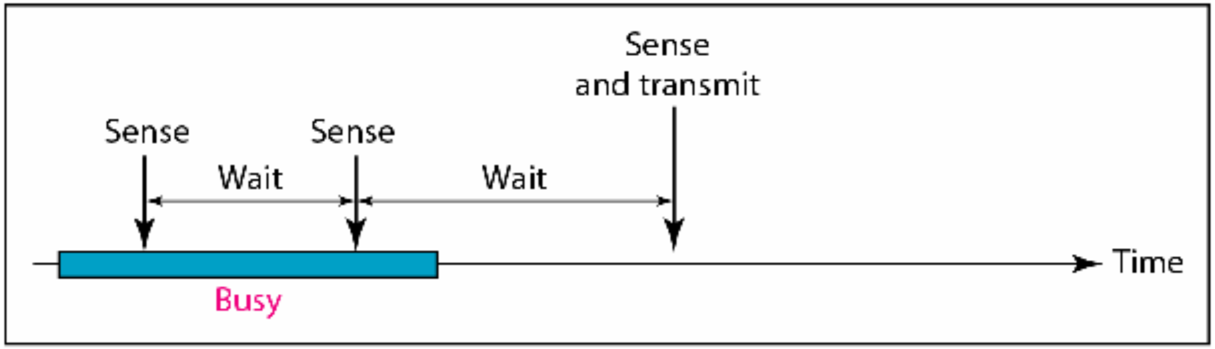


CSMA Variants

- **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?
- **Three Types of CSMA Protocols**
  – Non-persistent CSMA
  – 1-Persistent CSMA
  – P-Persistent CSMA

Non-persistent CSMA

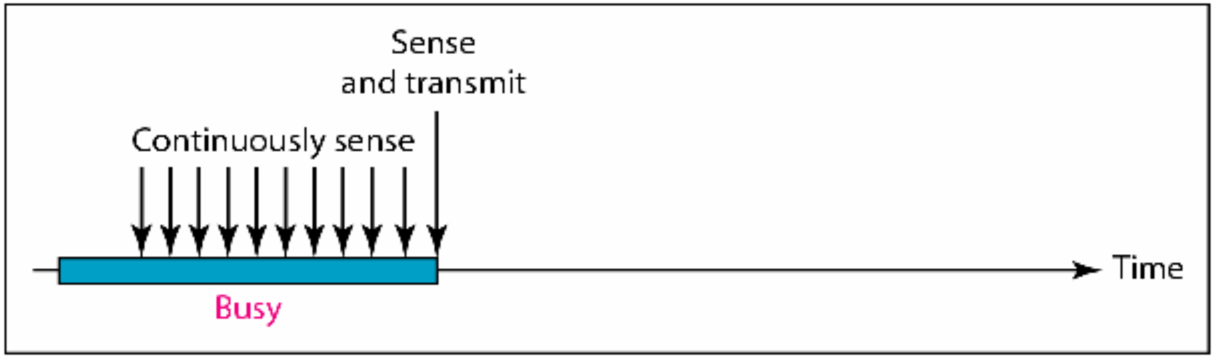
- **A station with frames to be sent, should sense the medium**
  1. If medium is idle, **transmit**; otherwise, go to 2
  2. If medium is busy, (**backoff**) wait a ***random*** **amount of time** and repeat **1**
- **Non-persistent Stations are deferential (respect others)**
- **Performance:**
  - Random delays reduces probability of collisions because two stations with data to be transmitted would 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

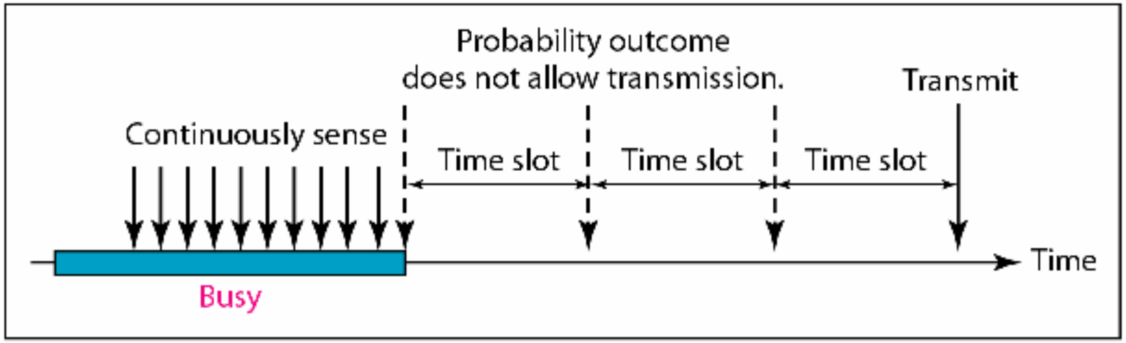
- **To avoid idle channel time, 1-persistent protocol used**
- **Station wishing to transmit listens to the medium:**
  1. If medium idle, **transmit** immediately;
  2. If medium busy, **continuously listen** until medium becomes idle; then transmit immediately with probability 1
- **1-persistent stations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



a. 1-persistent

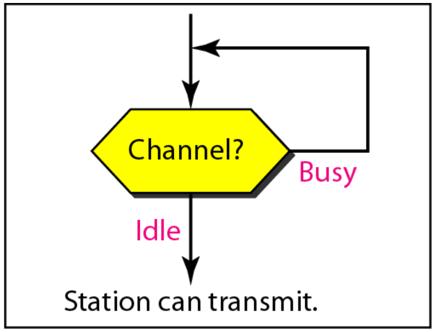
P-Persistent CSMA

- **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 1.
  2. If medium busy, continuously listen until idle and repeat step 1
- **Performance**
  - Reduces the possibility of collisions like **non-persistent**
  - Reduces channel idle time like **1-persistent**

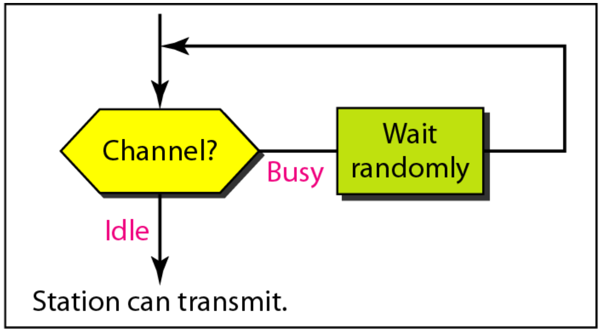


c. p-persistent

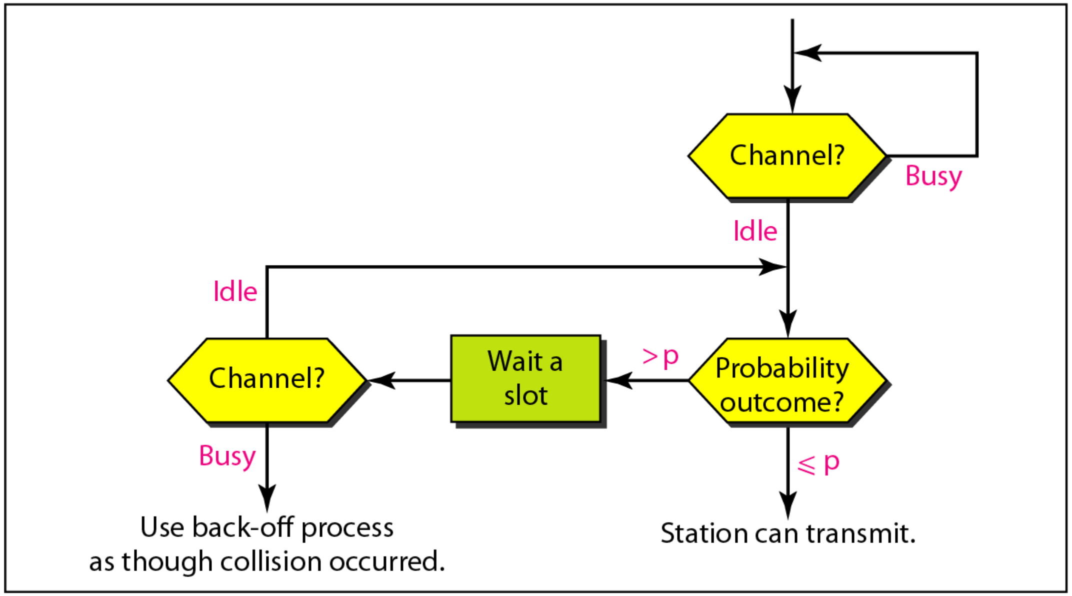
Flow Diagrams for CSMA



a. 1-persistent



b. Nonpersistent



c. p-persistent

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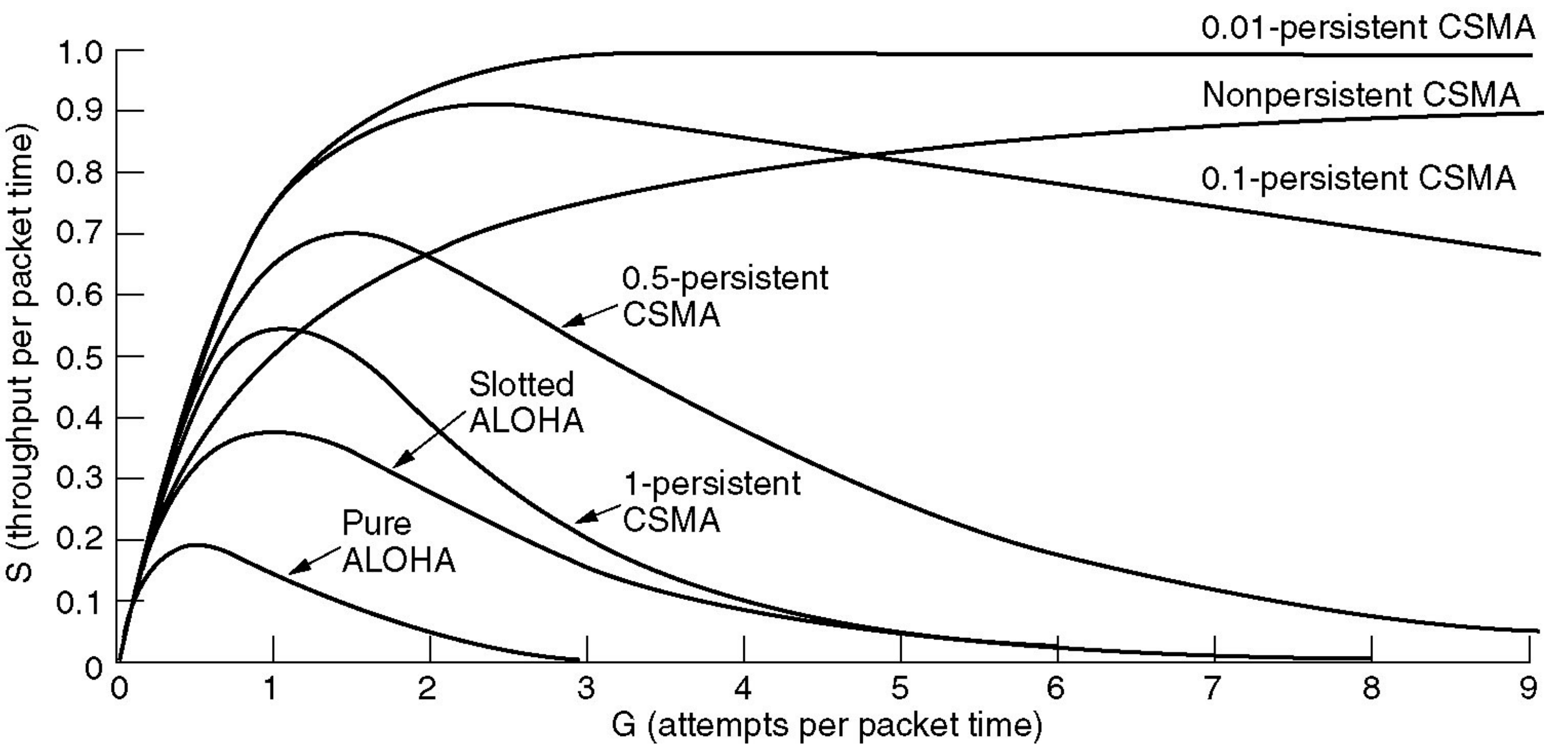
CSMA Efficiency



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

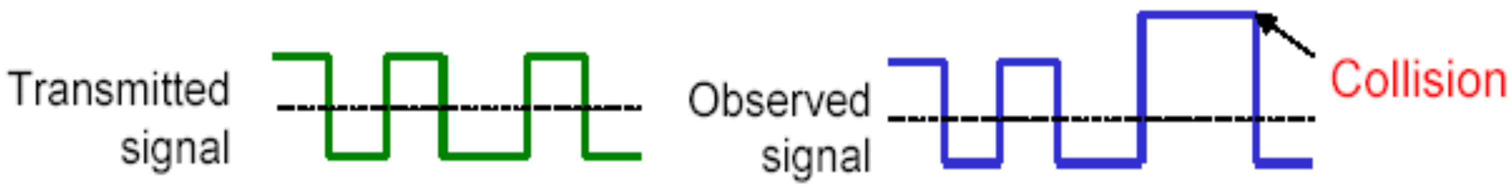
CSMA/CD Protocol

CSMA/CD (Collision Detection)

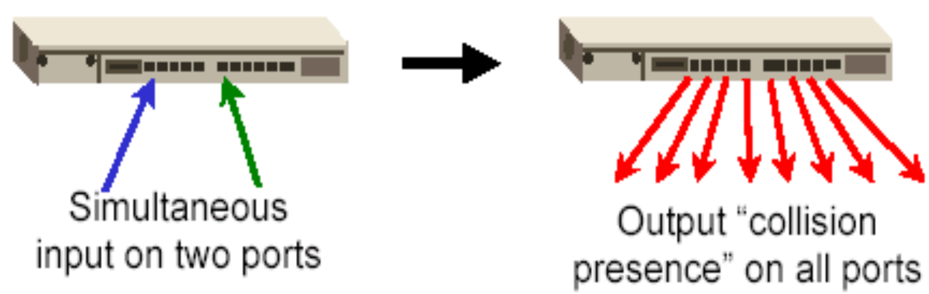
- **CSMA has an inefficiency**
  - If a collision has occurred, the channel is unstable until colliding packets have been fully transmitted.
- **CSMA/CD (*Carrier Sense Multiple Access with Collision Detection*) overcomes this:**
  - While transmitting, the sender is listening to medium for collisions.
  - Sender stops transmission if collision has occurred reducing channel wastage.
- **CSMA/CD is widely used for bus topology LANs (IEEE 802.3, Ethernet)**

How to detect a Collision?

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



- **Hub**
  - If input occurs simultaneously on two ports, it indicates a collision. Hub send a collision presence signal on all ports.



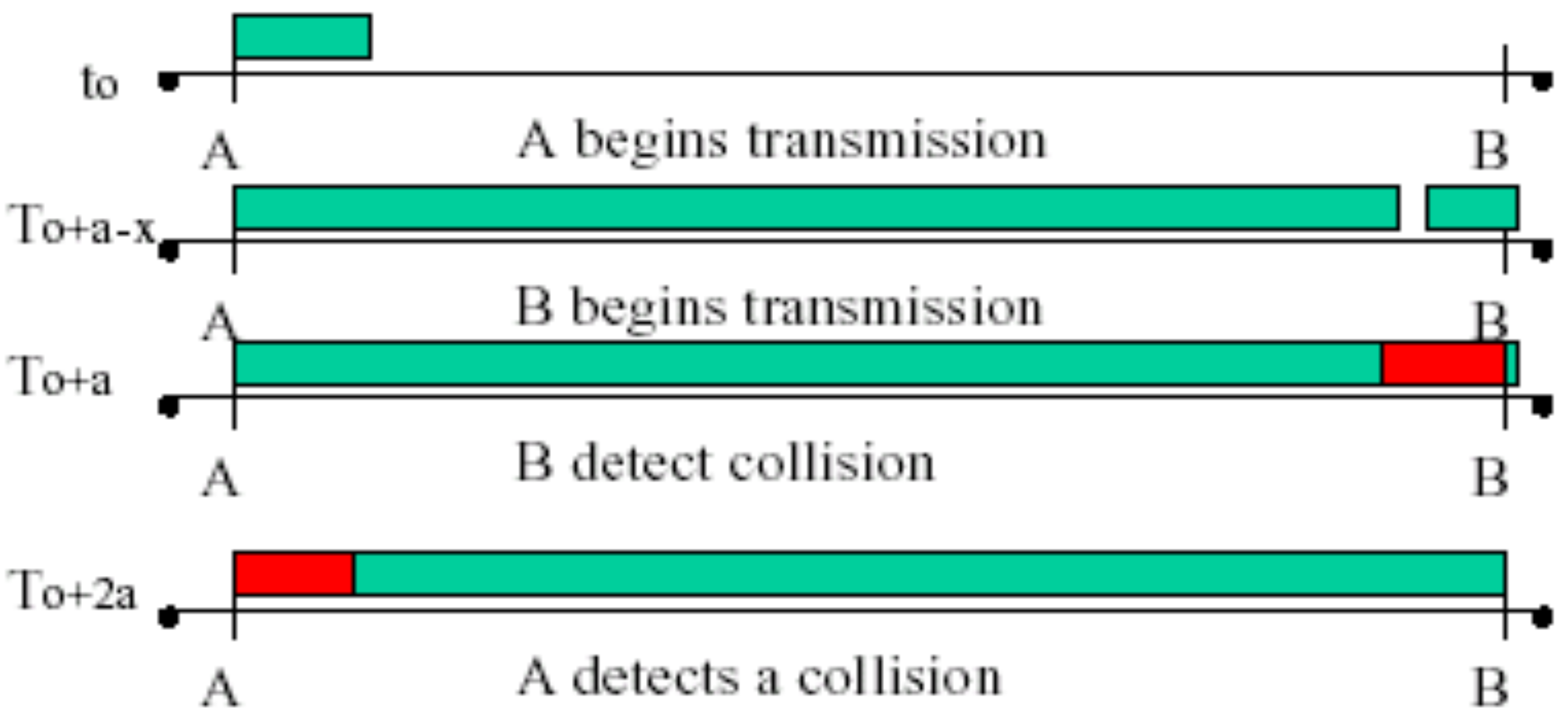
CSMA/CD Protocol

- **Transmission protocol**
  - use one of the CSMA persistent algorithms
- **If a collision is detected by a station during its transmission, it should do the following**
  - **Abort transmission**, and
  - Transmit a *jam signal* (48 bits) to notify other stations of collision so that they will **discard the transmitted frame** also to make sure that the collision signal will stay until detected by the furthest station
  - After sending the *jam signal*, **backoff (wait) for a *random*** amount of time, then
  - Transmit the frame again

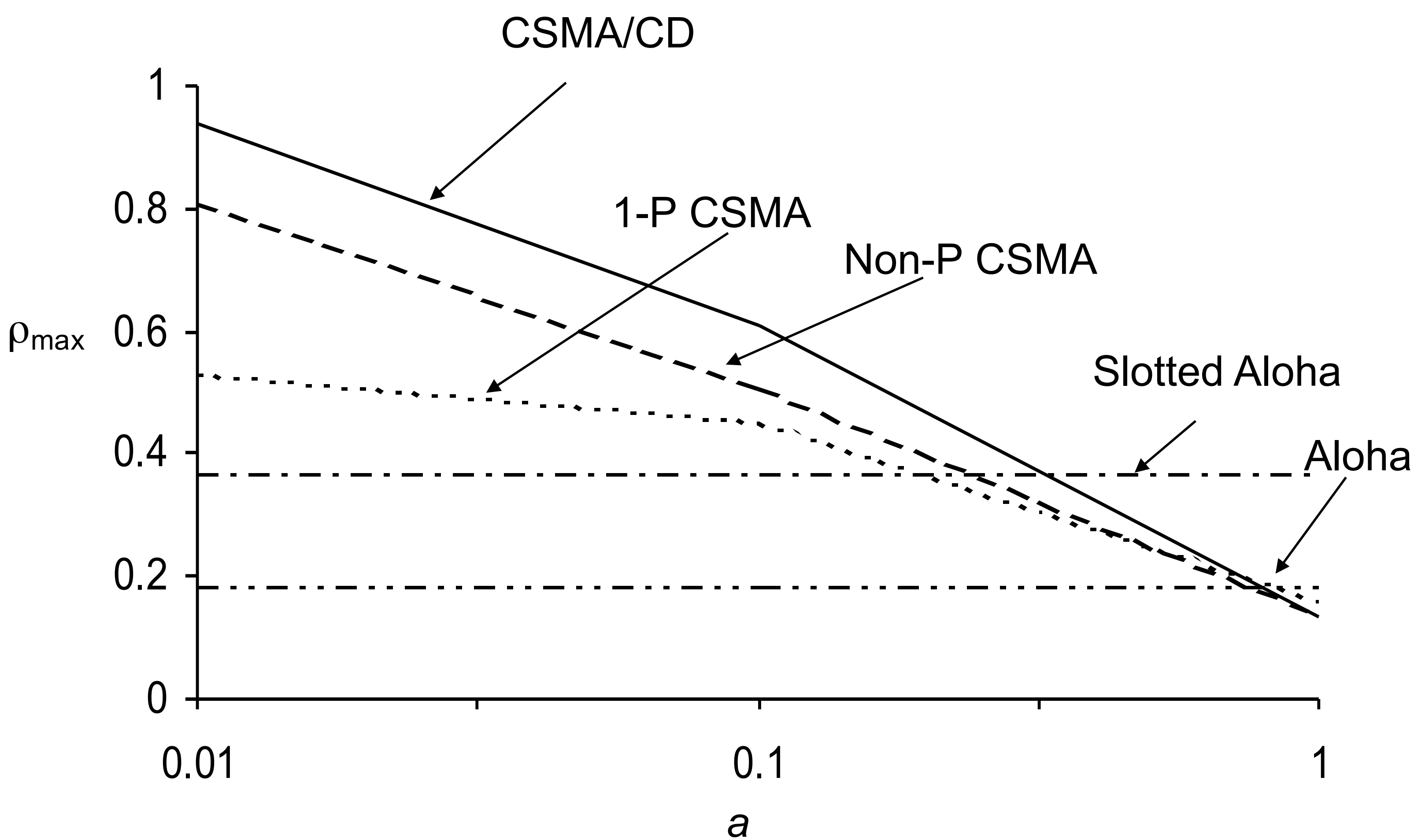
Collision Detection

- ***Question:*** **How long does it take to detect a collision?**
- ***Answer: In the worst case*****, twice the maximum propagation delay of the medium**

Note: **a = maximum propagation delay**



Achievable Throughputs



Learning Objectives

- **ALOHA Protocol**
  - Calculate throughput for ALOHA
  - Maximize throughput
- **CSMA Protocol**
  - Protocol comparison for three flavors
- **CSMA/CD Protocol**
  - Maximum duration for collision detection