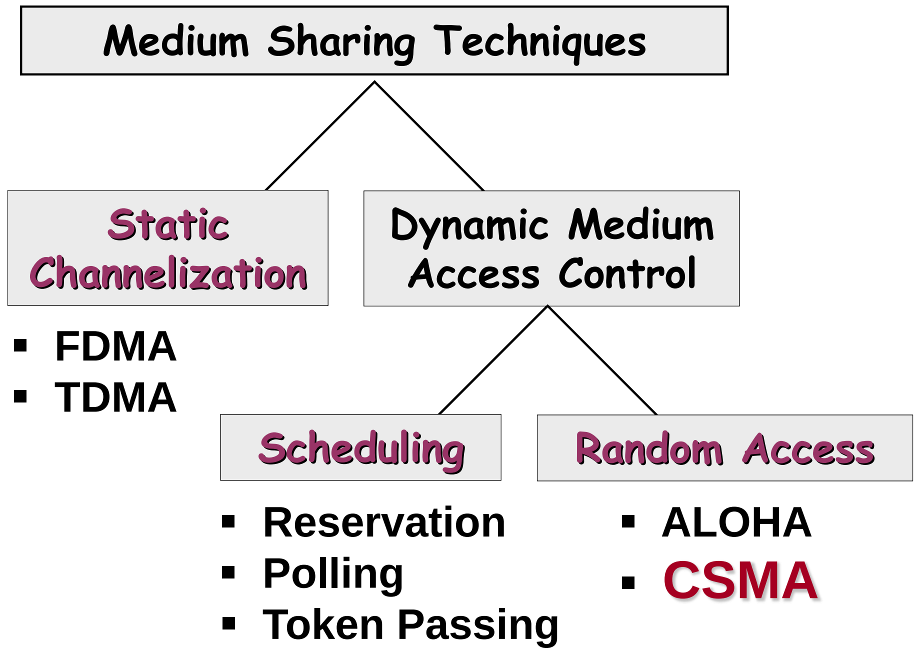
Multiple Access (2)

Required reading:
Forouzan 12.1.2, 12.1.3, 12.1.4
Garcia 6.2.3, 6.2.4

CSE 3213, Fall 2015
Instructor: N. Vlajic


Medium Sharing Techniques
Static Channelization
Dynamic Medium Access Control
FDMA
TDMA
Scheduling
Random Access
Reservation
Polling
Token Passing
ALOHA
CSMA

Carrier Sense Multiple Access

ALOHA Disadvantages – node decides to transmit independently of other nodes attached to broadcast channel

- node does not pay attention whether another node is transmitting (CSMA does)
- node does not stop transmitting if another node node begins to interfere with its transmission (CSMA/CD does)

CSMA – 'polite version of ALOHA' – decreases the probability of collision by implementing the following rule:

- carrier sensing – node listens to the channel before transmitting
  - if sensed channel idle $\Rightarrow$ transmit entire frame
  - if sensed channel busy $\Rightarrow$ back-off (defer transmission), and keep sensing or sense the channel again after a random amount of time

Does carrier sensing completely eliminate the probability of collision?!

Carrier Sense Multiple Access (cont.)

Vulnerable Period – **suppose station A begins transmission at one extreme end of a broadcast medium**

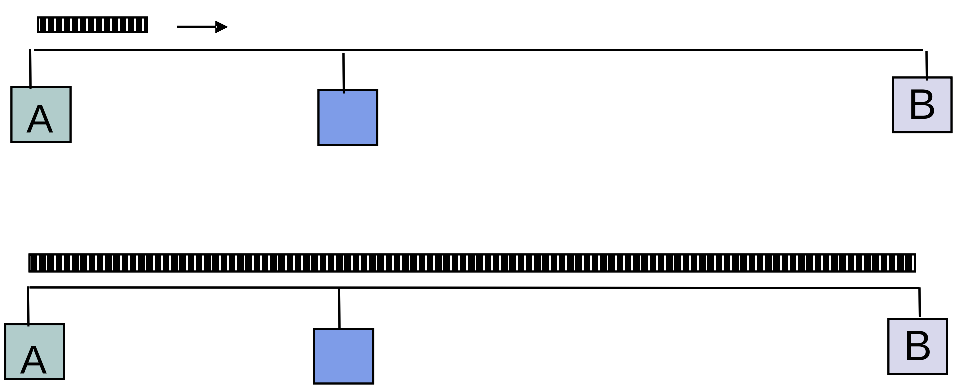
- **as signal propagates through the medium, stations become aware of A's transmission**
- **at time $t = t_{prop}$ A's transmission reaches the other end of medium – if no other station initiates transmission during that period, station A will successfully capture the channel**

vulnerable period = t_{prop}

- **NOTE: if $t_{prop} > t_{frame}$, CSMA provides no advantage over slotted ALOHA**

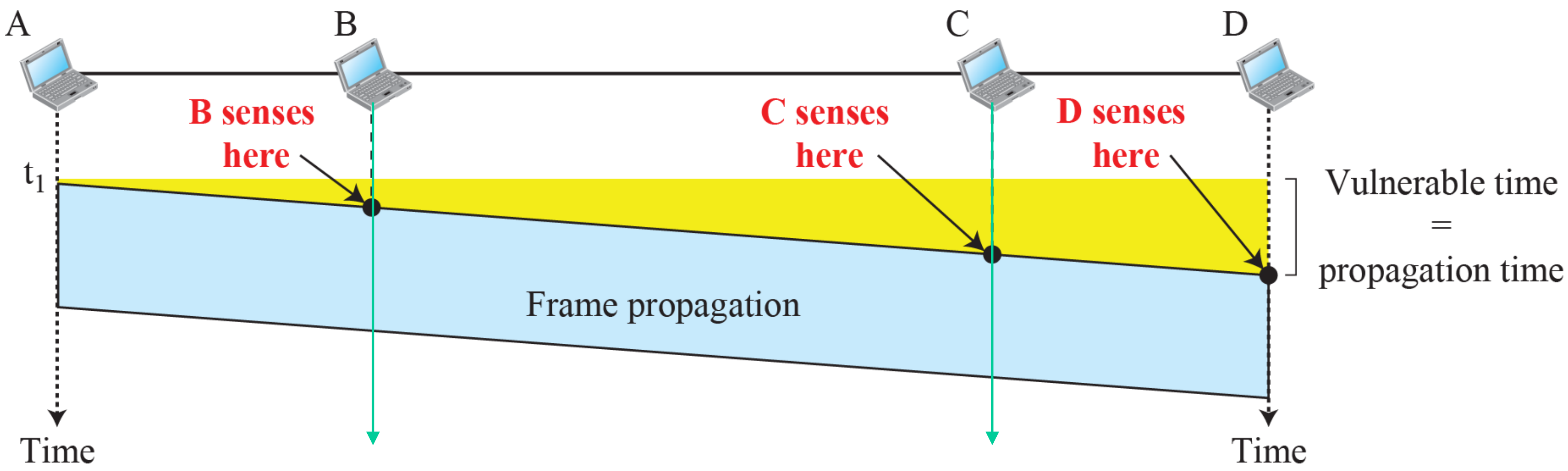
Station A begins transmission at $t = 0$

Station A captures channel at $t = t_{prop}$



Carrier Sense Multiple Access (cont.)

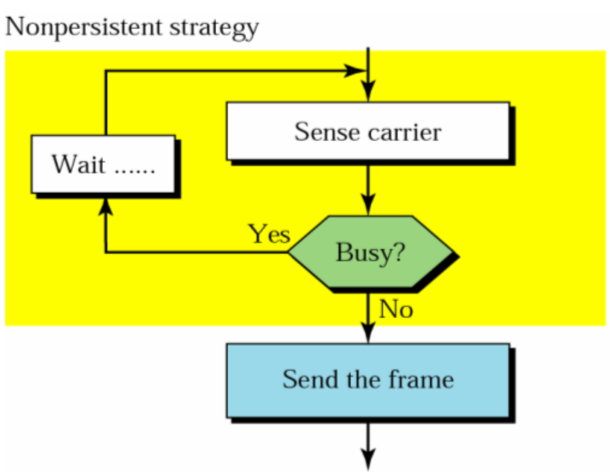
Example **[Vulnerable Time in CSMA]**

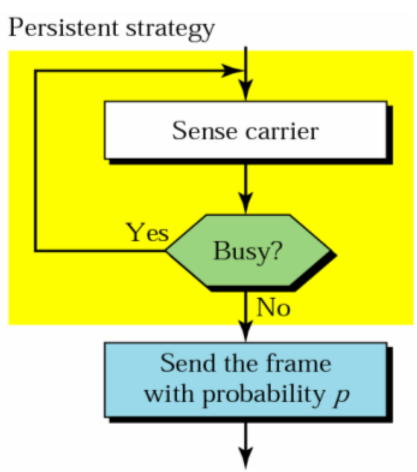


Carrier Sense Multiple Access (cont.)

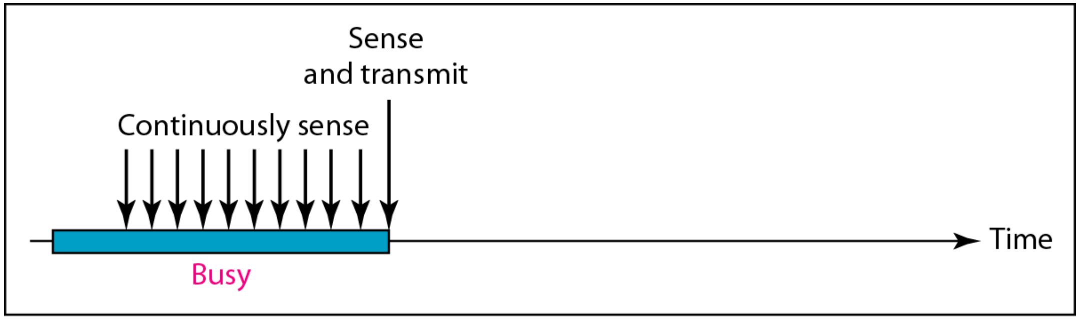
CSMA Options – **various CSMA schemes employ various types of node behaviour when channel is busy**

- **Non-Persistent CMSA** (least greedy)
  - **wait entire back-off period before sensing channel again**
  - **high efficiency ☺, high delay ☹**
- **1-Persistent CMSA** (most greedy)
  - **start transmission as soon as channel becomes idle**
  - **low delay ☺, low efficiency ☺**
- **P-Persistent CMSA** (adjustable greedy)
  - **wait until channel idle, then transmit with probability p**
  - **spread out transmission attempts by stations that have been waiting ⇒ delay and efficiency can be balanced**

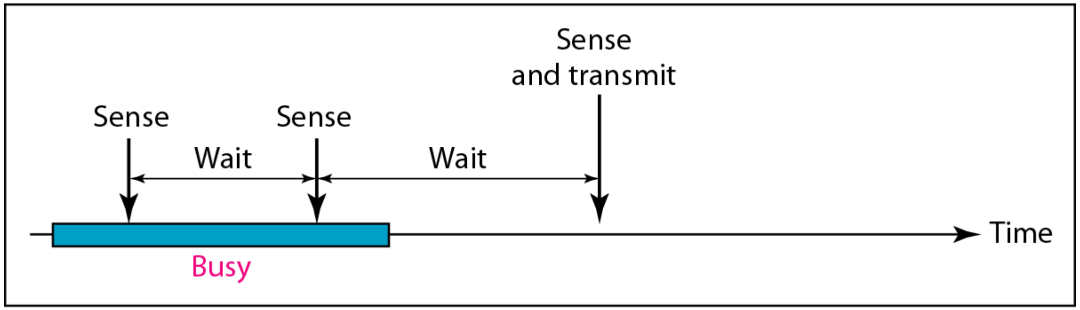




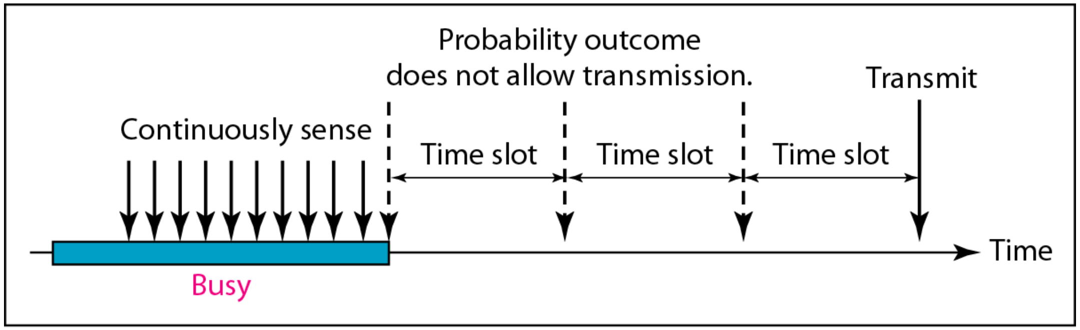
Carrier Sense Multiple Access (cont.)



a. 1-persistent



b. Nonpersistent

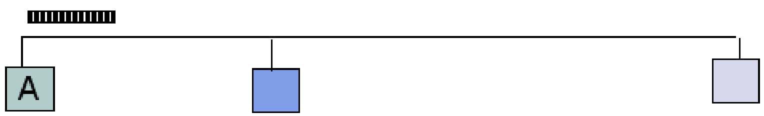


c. p-persistent

Carrier Sense Multiple Access (cont.)

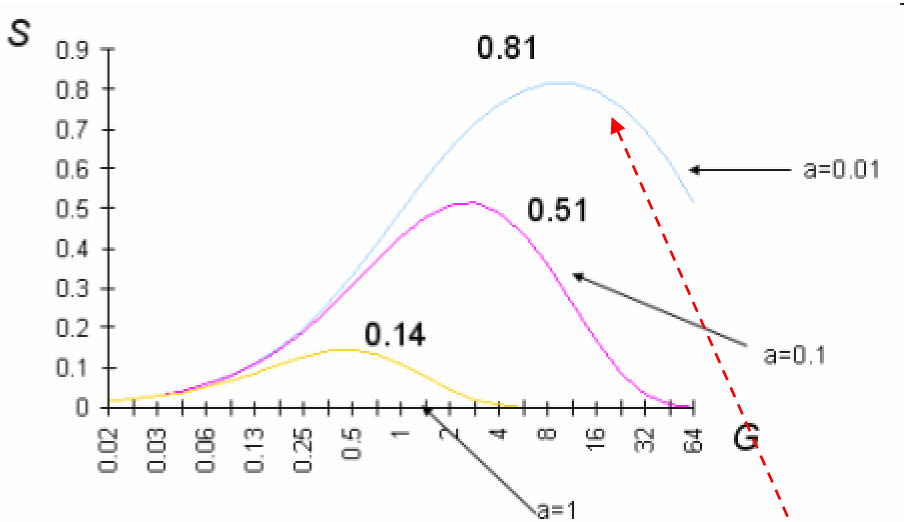
S vs. G

- ***a* annotates '*propag. delay normalized to frame transmission time*' or so called '*normalized bandwidth-delay product*'**



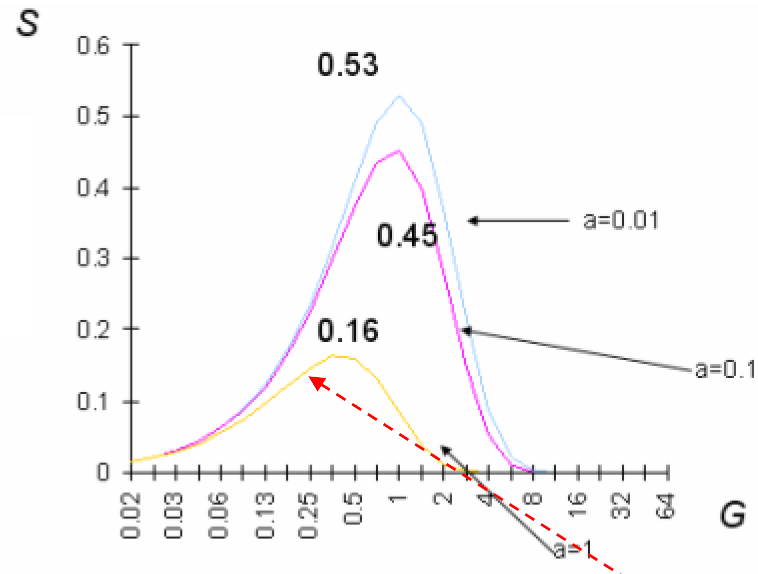
$$\mathbf{a} = \frac{\mathbf{t_{prop}}}{\mathbf{t_{frame}}} = \frac{t_{prop}}{L/R} = \frac{\mathbf{t_{prop}} \cdot \mathbf{R}}{\mathbf{L}}$$

Bigger a, longer time to detect and resolve collision !!!



Non-Persistent CSMA
"polite CSMA"

for high loads non-persistent CSMA performs better



1-Persistent CSMA
"aggressive CSMA"

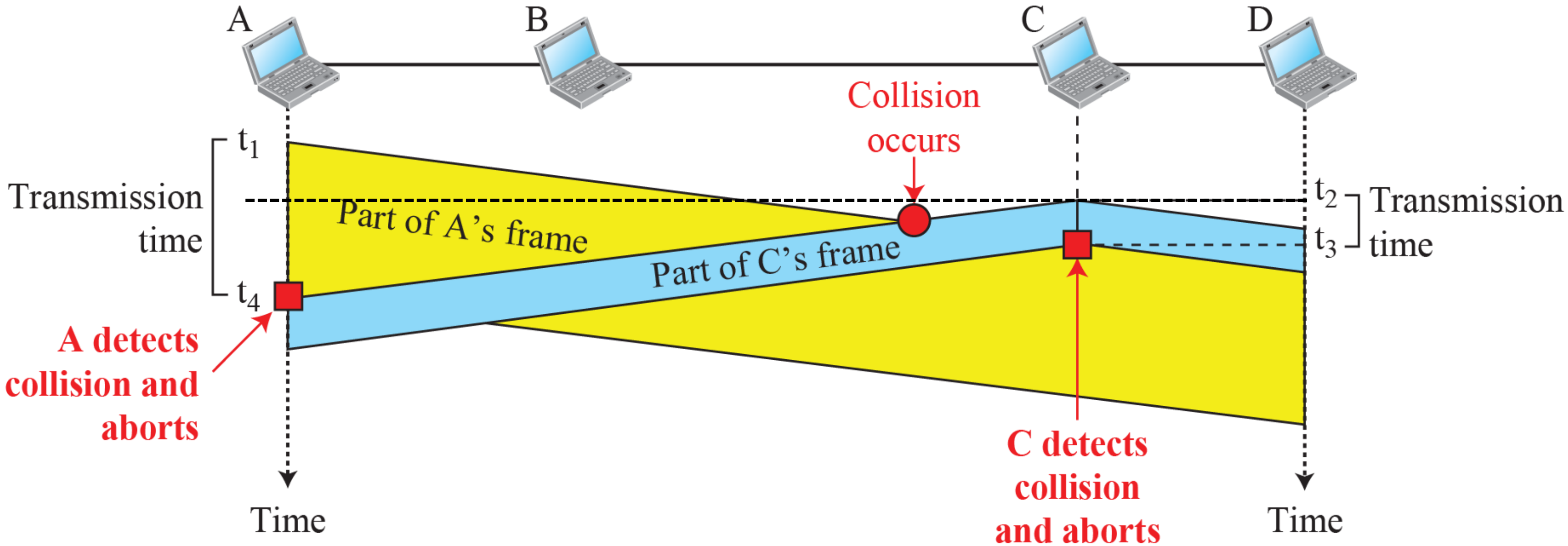
for small loads 1-persistent CSMA performs better

Parameter a has a significant impact on max achievable throughput.
Throughput of 1-Persistent CSMA drops off much more sharply with increased G.

Carrier Sense Multiple Access (cont.)

Collision Detection & Resolution – **basic CSMA does not specify procedure dealing with collision detection**

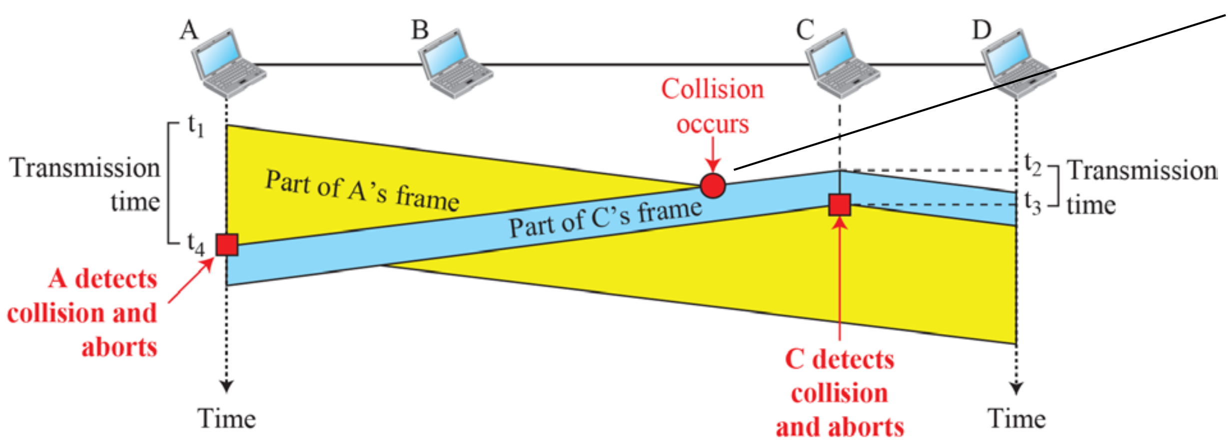
- **basic CSMA only tries to prevent collisions from happening**
- **CSMA/CD - deals with collision detection**
- **CSMA/CA - aims to avoid collision in wireless domain**



CSMA with Collision Detection

C **CSMA/CD** – 'collision detection' is **another level of sophistication** of CSMA

- CSMA collisions result in wastage of X seconds spent transmitting an entire frame
- in CSMA/CD
  - station <u>listens while transmitting</u>
  - **if a station hears something different than what it is sending, it immediately stops** (this happens when 2 or more transmitting signals garble each other)
  - in addition, if a collision is detected, a short **jamming signal** is subsequently sent to ensure that other stations know that collision has occurred (all stations discard the part of frame received)



Note: **Collision detection is easy in wired LANs** - measure signal strengths, compare transmitted and received signals.

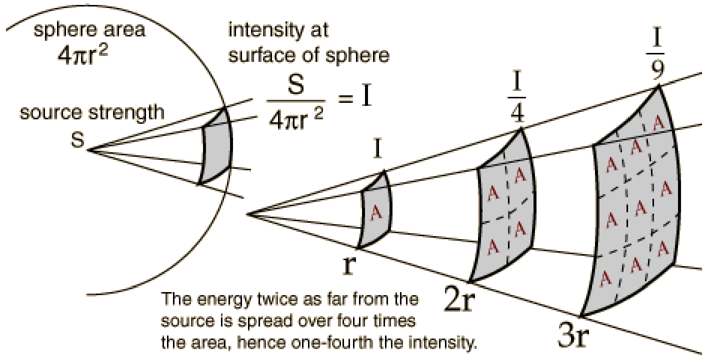
However, **collision detection is difficult in wireless LANs** – signal of sending antenna overwhelms any other signal at the receiving antenna.

Power in a wire is lost "linearly". When the length of a wired link is doubled, the power loss is doubled. This occurs because the size of the wire and therefore the area of the wire (the cross-sectional area) remain constant from the beginning to the end of the wire. As the signal power travels forward through the wire, it only expands in one direction - along the length of the wire.

In contrast to the wired link, the power traveling across a wireless link expands in all directions. Like a flashlight shining on the inside of a ball, the wireless power spreads out left and right and up and down as it travels forward. The further the wireless power travels, the more it spreads out, the larger the area it travels through, and the quicker the power level decreases. Because the wireless power spreads out in all directions, it decreases much faster than linearly - it decreases logarithmically, according to the "inverse-square" law.

Start with 1-mile links	Link distance = 2 miles	Link distance = 3 miles	Link distance = 4 miles	Link distance = 5 miles
Wired link	1/2	1/3	1/4	1/5
Wireless link	1/4	1/9	1/16	1/25

Percentage of Remaining Energy When Extending the Link Distance



CSMA with Collision Detection (cont.)

CSMA/CD Reaction Time
(Time to Detect Collision)

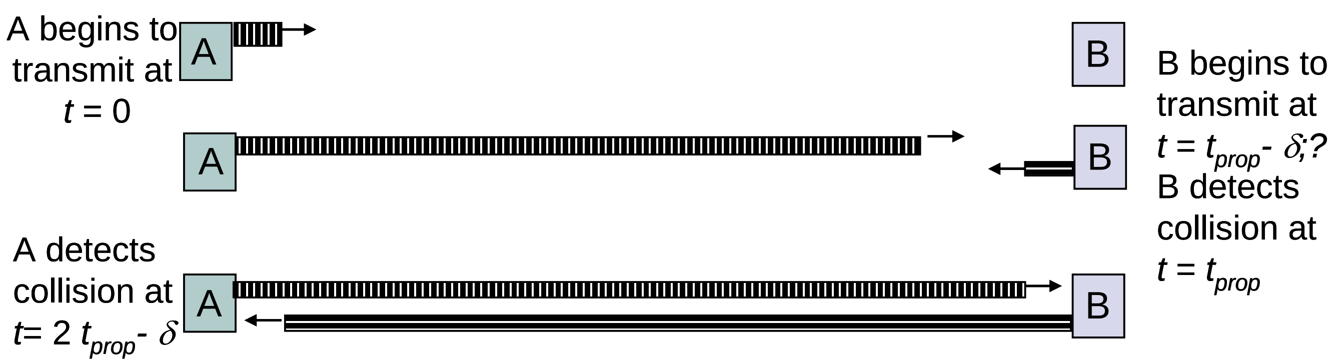
– **because of 'propagation' latency, collisions cannot be detected immediately**

- **suppose nodes A and B are placed at two extreme ends of the network, and B initiates a transmission just before the transmission arrival from A**
- **station A will not be aware of the collision until time 2*t_{prop}**

$$\text{reaction time} = 2 \cdot t_{prop}$$

- **<u>note</u>: collision detection works <u>only</u> as long as frame-size is sufficiently long to require more than a round-trip time for transmission**

$$\frac{\text{frame size}}{R} > 2 \cdot t_{prop} \quad \Rightarrow \quad \text{frame size} > 2 \cdot t_{prop} \cdot R$$



CSMA with Collision Detection (cont.)

Analysis of p-persistent CSMA/CD

– **channel can be in three states:**

- **busy transmitting / idle / contention period**
- **contention period – stations attempt to capture the channel by transmitting and listening if they have successfully captured the channel**

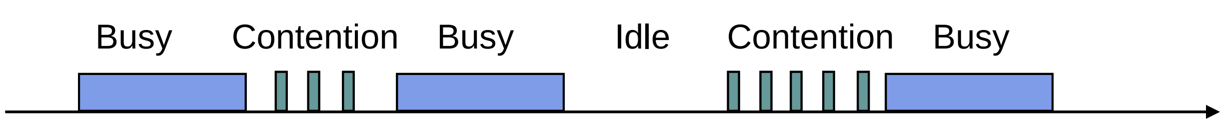
each contention interval (minislot) = 2*t_{prop}

- **assume n stations contend for the channel, and each station transmits during a contention minislot with probability p**
⇒ probabiltiy that 'some host' acquires the slot and transmits successfully:

$$P_{succ} = n \cdot p \cdot (1-p)^{n-1}$$

- **p that maximizes P_{succ} can be obtained from** $\frac{\partial P_{succ}}{\partial p} = 0$

$$p_{optimal} = \frac{1}{n} \quad \Rightarrow \quad \max(P_{succ})\Big|_{p_{optimal}\ \text{and}\ n \to \infty} = \frac{1}{e}$$



CSMA with Collision Detection (cont.)

Average Contention Period in p-persistent CSMA/CD

- **average # of minislots until <u>some</u> station successfully captures the channel:**

$$\text{average \# of contention minislots} = \frac{1}{P_{succ}} = e = 2.718$$

- **average contention interval:**

$$\text{average contention interval} = e \cdot 2t_{prop}$$

- **average time to transmit a frame:**

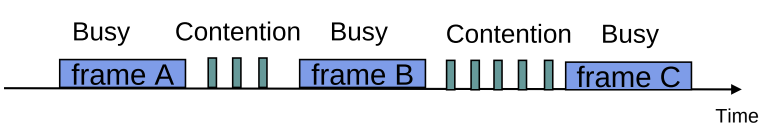
$$t_d = \text{average cont. interval} + X + t_{prop} = X + (e \cdot 2 + 1) \cdot t_{prop} \approx X + 7 \cdot t_{prop}$$

contention

frame transmission

waiting to confirm successful transmission

- **max throughput is achieved when all of channel time is spent in frame transmission followed by contention**



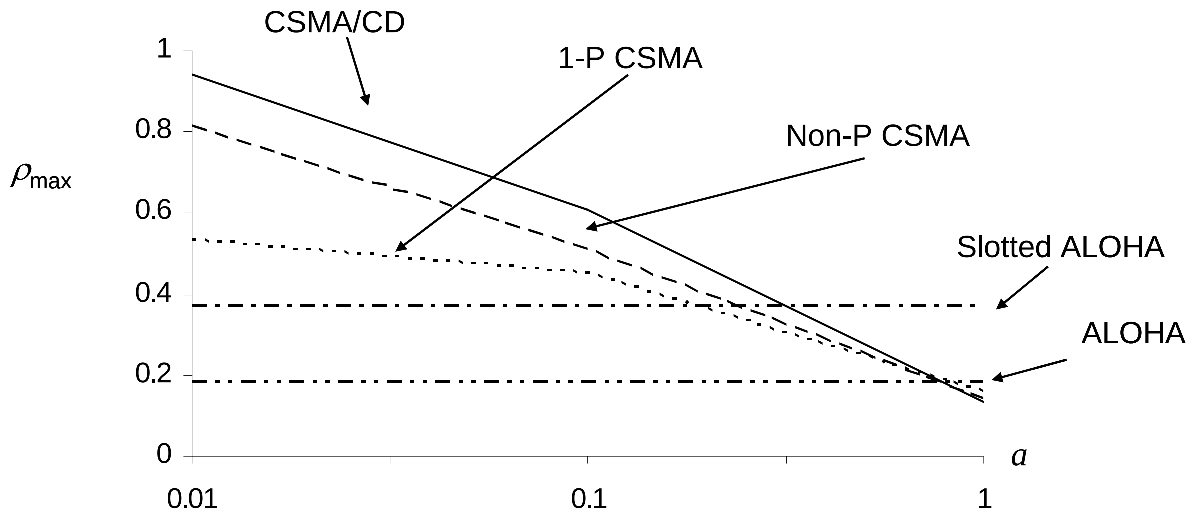
$$\rho_{max} = \frac{X}{X + 7 \cdot t_{prop}} = \frac{1}{1 + 7 \cdot \frac{t_{prop} \cdot R}{L}}$$

$\frac{t_{prop} \cdot R}{L}$ **=a**

CSMA-CD throughput → 1, when a → 0 (i.e. bandwidth delay product << L)

Comparison of MAC Schemes

Maximum Achievable Throughputs of Random Access Schemes



CSMA/CD performance is sensitive to a (propagation delay).

Increased propagation delay ⇒ increased chance of collisions. **(vuln. period = t_{prop})**

Increased propagation delay ⇒ increased time loss when a collision occurs.

- For small *a:* CSMA-CD has best throughput
- For larger *a:* Aloha & slotted Aloha better throughput

CSMA/CD in Wireless Domain

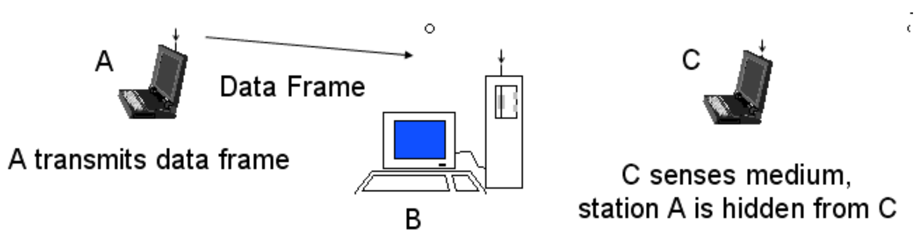
Why NOT Wireless CSMA/CD!?

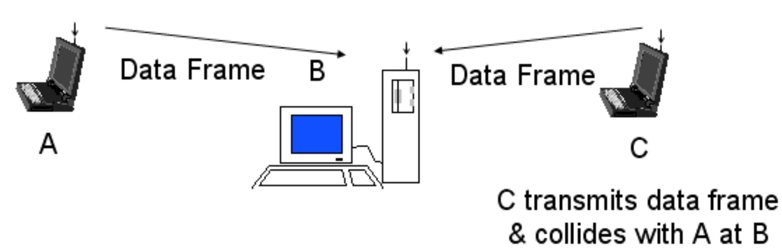
– **two main reasons:**

(1) difficult to detect collision in radio environment – transmitting power overwhelms receiving power at the same station

(2) 'hidden terminal problem' – transmitting stations out of each other's range

- **A and C want to send to B**
- **A starts transmitting – C cannot hear and assumes medium available**
- **C starts transmitting as well, signals collide at B !**

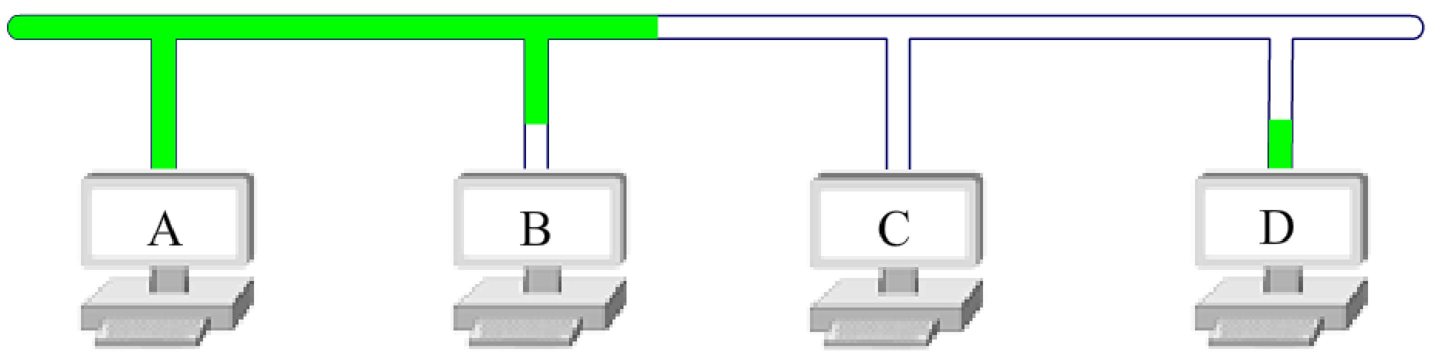




Carrier Sense Multiple Access (cont.)

Example [CSMA Applet]

CSMA- Collision Detection (CSMA/CD)



http://www.netbook.cs.purdue.edu/animations/CSMA-CD.html