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Wireless Networks

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Medium Access Control

- Required for any shared medium

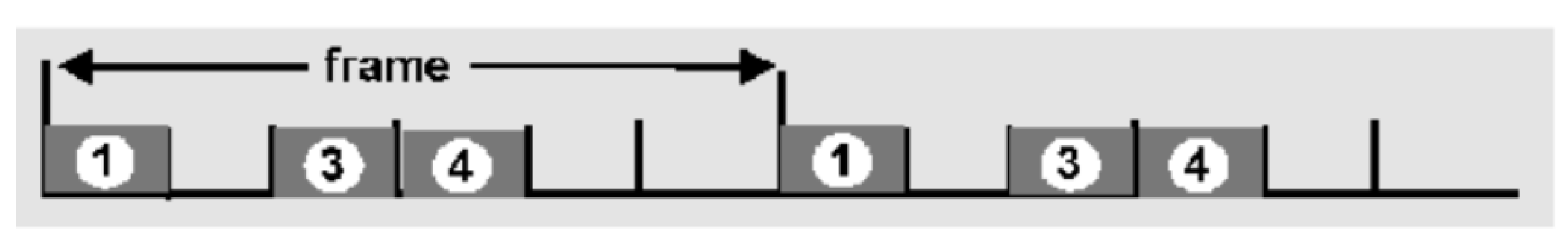
- Goals:
  - Maximize channel utilization
  - Minimize delay

- Static
  - FDMA
  - TDMA
  - CDMA

- Dynamic
  - Centralized vs. Distributed
  - Contention-based vs. Contention-free

Static MAC Protocols: TDMA

- TDMA: time division multiple access
- Access to channel in "rounds"
- Each station gets fixed length slot (length = x*packet transmission time) in each round (e.g.: x=1, one packet each round)
- Unused slots go idle



Static 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

Dynamic: Contention-Based vs. Contention-Free

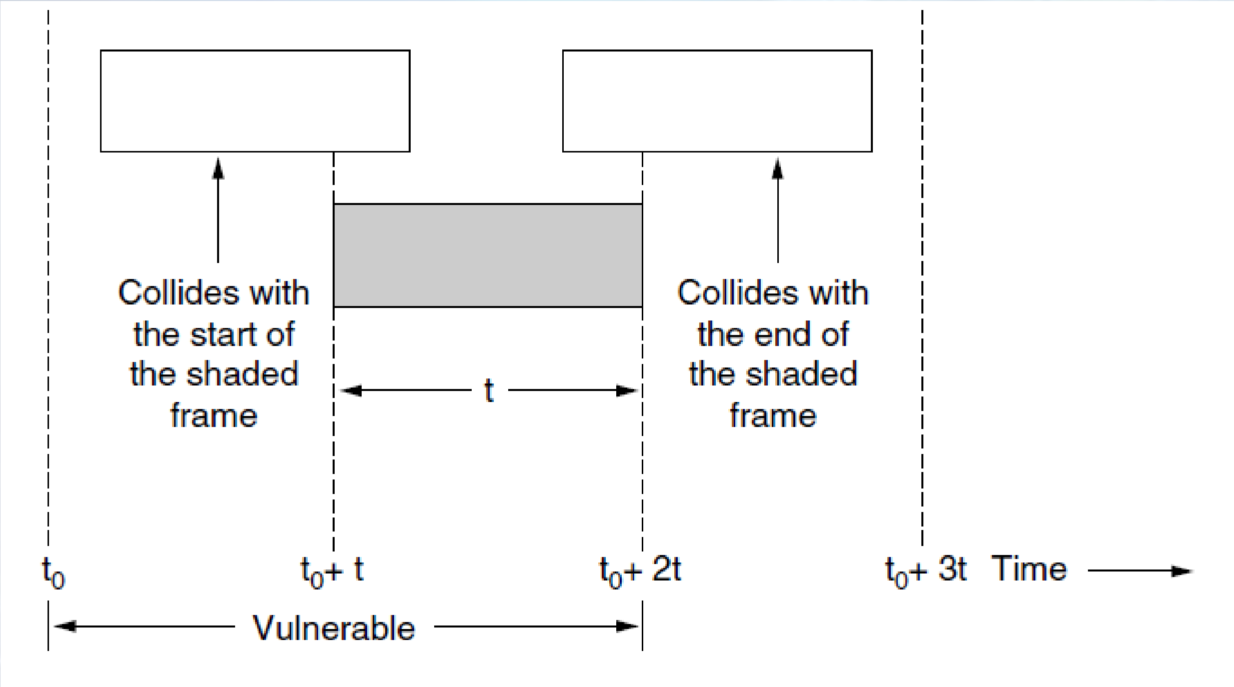
- Contention-Based (Random Access)
  - stations compete, sometimes leading to collisions
  - “**recover**” from collisions
  - typically a **distributed** scheme

Unslotted ALOHA	Slotted ALOHA
CSMA	CSMA/CD

- Contention-Free
  - tightly coordinate shared access to **avoid** collisions
  - each node is granted temporary exclusive access to the medium
  - usually a **centralized** scheme

Unslotted ALOHA

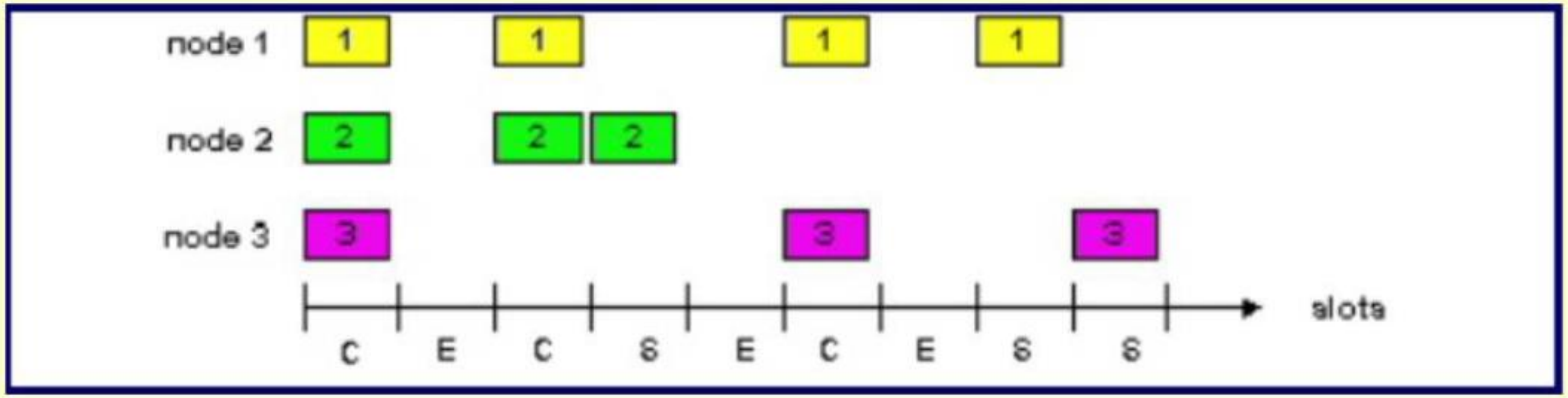
- No synchronization
- Packet needs transmission:
  - Send without awaiting for beginning of slot



- Vulnerability period (time where collision can happen)=**2t**

Slotted ALOHA

- Time is divided into equal size slots
- Transmits only at the **beginning of the slot**
  - Still does not check if other stations are transmitting before it transmits
- Vulnerability period (time where collision can happen)=**t**



Success (S), Collision (C), Empty (E) slots

Carrier Sense Multiple Access (CSMA)

- Listen to the channel before transmitting
  - If the channel is sensed busy, then the user waits until the channel becomes idle

- This avoids collision with ongoing transmission.

- Collisions may still occur

Why??

If two stations become ready in the middle of a third station's transmission, both will wait until the transmission ends, and then both will begin transmitting exactly **simultaneously** (when the channel becomes free), resulting in a collision.

CSMA with Collision Detection (CSMA/CD)

- Listen to the channel before transmitting
  - If idle, start transmitting
- Listen to the channel while transmitting
  - If collision is detected:
    - Abort immediately
    - Back off for some time then retry
      - ➢ Randomized back off interval to avoid repeated collisions
- Maximum time to detect collision (Contention slot) = twice maximum propagation delay

Why??

Consider the following worst-case scenario. Let the time for a signal to propagate between the two farthest stations be τ. At t_0, one station begins transmitting. At $t_0 + \tau - \varepsilon$, an instant before the signal arrives at the most distant station, that station also begins transmitting. Of course, it detects the collision almost instantly and stops, but the little noise burst caused by the collision does not get back to the original station until time $2\tau - \varepsilon$. In other words, in the worst case a station cannot be sure that it has seized the channel until it has transmitted for 2τ without hearing a collision.

Back-off Algorithm

CW is the contention window

- After undergoing the collision:
  - Transmitting station chooses a **random number** in the range $\boxed{[0, 2^n-1]}$ if the packet is undergoing collision for the **n^{th}** time.
  - If station chooses a number k, then $\boxed{\textbf{Back off time = k x Time slot}}$ (Time slot=2t)

- Consider the following scenario: (for simplicity set Time slot=1)

1] 1^{st} data packet of both stations A and D:

- Both A and D start transmitting their 1^{st} data packet simultaneously.

→This leads to a collision.

- The collision on both the packets is occurring for the 1^{st} time.

→n for the 1^{st} data packet of both stations = 1.

- At station A: after detecting the collision:
  - Station A randomly chooses a number in the range $[0, 2^1-1] = [0,1]$.
  - If station A chooses the number K_A, then back off time = K_A units.
- At station D: after detecting the collision:
  - Station D randomly chooses a number in the range $[0, 2^1-1] = [0,1]$.
  - If station D chooses the number K_D, then back off time = K_D units.

Back-off Algorithm

- 4 possible cases:

K_A	K_D	Remarks
0	0	• In this case, both the stations start retransmitting their data immediately. • This case leads to a collision again.
0	1	• In this case, station A starts retransmitting its data immediately while station D waits for 1 unit of time. • This case leads to A successfully retransmitting its data after the 1^{st} collision.
1	0	• In this case, station A waits for 1 unit of time while station D starts retransmitting its data immediately. • This case leads to D successfully retransmitting its data after the 1^{st} collision.
1	1	• In this case, both the stations wait for 1 unit of time and then starts retransmitting their data simultaneously. • This case leads to a collision again.

- Probability of A to successfully retransmit its data after the 1^{st} collision = 1/4
- Probability of D to successfully retransmit its data after the 1^{st} collision = 1/4
- Probability of occurrence of collision again after the 1^{st} collision = 2/4 = 1/2

Back-off Algorithm

2] Consider case2 (A successfully retransmits its 1st packet after the 1st collision):

Now we have 2nd data packet of A and 1st data packet of D:

- A starts transmitting its 2nd packet and D starts transmitting its 1st packet simultaneously.

→This leads to a collision.

- For A collision of the 2nd packet for the 1st time

→n for the 2nd data packet = 1.

  - Station A randomly chooses a number in the range $[0, 2^1-1] = [0,1]$.
  - If station A chooses the number K_A, then back off time = K_A units.

- For D collision of the 1st packet for the 2nd time

→n for the 1st data packet = 2.

  - Station D randomly chooses a number in the range $[0, 2^2-1] = [0,3]$.
  - If station D chooses the number K_D, then back off time = K_D units.

Back-off Algorithm

- 8 possible cases:

K_A	K_D	Remarks
0	0	• In this case, both the stations start retransmitting their data immediately. • This case leads to a collision again.
0	1	• In this case, station A starts retransmitting its data immediately while station D waits for 1 unit of time. • This case leads to A successfully retransmitting its data after the 2^{nd} collision.
0	2	• In this case, station A starts retransmitting its data immediately while station D waits for 2 unit of time. • This case leads to A successfully retransmitting its data after the 2^{nd} collision.
0	3	• In this case, station A starts retransmitting its data immediately while station D waits for 3 unit of time. • This case leads to A successfully retransmitting its data after the 2^{nd} collision.
1	0	• In this case, station A waits for 1 unit of time while station D starts retransmitting its data immediately. • This case leads to D successfully retransmitting its data after the 2^{nd} collision.
1	1	• In this case, both the stations wait for 1 unit of time and then starts retransmitting their data simultaneously. • This case leads to a collision again.
1	2	• In this case, station A waits for 1 unit of time while station D waits for 2 unit of time. • This case leads to A successfully retransmitting its data after the 2^{nd} collision.
1	3	• In this case, station A waits for 1 unit of time while station D waits for 3 unit of time. • This case leads to A successfully retransmitting its data after the 2^{nd} collision.

- Probability of A to successfully retransmit its data after the 2^{nd} collision = 5/8
- Probability of D to successfully retransmit its data after the 2^{nd} collision = 1/8
- Probability of occurrence of collision again after the 2^{nd} collision = 2/8 = 1/4

Back-off Algorithm

3] Consider case3 (A successfully transmits its 2nd packet after the 2nd collision):

Now we have 3rd data packet of A and 1st data packet of D:

- A starts transmitting its 3rd packet and D starts transmitting its 1st packet simultaneously.

→This leads to a collision.

- For A collision of the 3rd packet for the 1st time

→n for the 3rd data packet = 1.

  - Station A randomly chooses a number in the range $[0, 2^1-1] = [0,1]$.
  - If station A chooses the number K_A, then back off time = K_A units.

- For D collision of the 1st packet for the 3rd time

→n for the 1st data packet = 3.

  - Station D randomly chooses a number in the range $[0, 2^3-1] = [0,7]$.
  - If station D chooses the number K_D, then back off time = K_D units.

Back-off Algorithm

- 16 possible cases:

K_A	K_D	Remarks
0	0	• In this case, both the stations start retransmitting their data immediately. • This case leads to a collision again.
0	1	• In this case, station A starts retransmitting its data immediately while station D waits for 1 unit of time. • This case leads to A successfully retransmitting its data after the 3rd collision.
0	2	• In this case, station A starts retransmitting its data immediately while station D waits for 2 unit of time. • This case leads to A successfully retransmitting its data after the 3rd collision.
0	3	• In this case, station A starts retransmitting its data immediately while station D waits for 3 unit of time. • This case leads to A successfully retransmitting its data after the 3rd collision.
0	4	• In this case, station A starts retransmitting its data immediately while station D waits for 4 unit of time. • This case leads to A successfully retransmitting its data after the 3rd collision.
0	5	• In this case, station A starts retransmitting its data immediately while station D waits for 5 unit of time. • This case leads to A successfully retransmitting its data after the 3rd collision.
0	6	• In this case, station A starts retransmitting its data immediately while station D waits for 6 unit of time. • This case leads to A successfully retransmitting its data after the 3rd collision.
0	7	• In this case, station A starts retransmitting its data immediately while station D waits for 7 unit of time. • This case leads to A successfully retransmitting its data after the 3rd collision.
1	0	• In this case, station A waits for 1 unit of time while station D starts retransmitting its data immediately. • This case leads to D successfully retransmitting its data after the 3rd collision.
1	1	• In this case, both the stations wait for 1 unit of time and then starts retransmitting their data simultaneously. • This case leads to a collision again.
1	2	• In this case, station A waits for 1 unit of time while station D waits for 2 unit of time. • This case leads to A successfully retransmitting its data after the 3rd collision.
1	3	• In this case, station A waits for 1 unit of time while station D waits for 3 unit of time. • This case leads to A successfully retransmitting its data after the 3rd collision.
1	4	• In this case, station A waits for 1 unit of time while station D waits for 4 unit of time. • This case leads to A successfully retransmitting its data after the 3rd collision.
1	5	• In this case, station A waits for 1 unit of time while station D waits for 5 unit of time. • This case leads to A successfully retransmitting its data after the 3rd collision.
1	6	• In this case, station A waits for 1 unit of time while station D waits for 6 unit of time. • This case leads to A successfully retransmitting its data after the 3rd collision.
1	7	• In this case, station A waits for 1 unit of time while station D waits for 7 unit of time. • This case leads to A successfully retransmitting its data after the 3rd collision.

- Probability of A to successfully retransmit its data after the 3rd collision = 13/16
- Probability of D to successfully retransmit its data after the 3rd collision = 1/16
- Probability of occurrence of collision again after the 3rd collision = 2/16 = 1/8

Back-off Algorithm

- Known as **Binary Exponential Back Off Algorithm:**

1. It works for only **two** stations.

   With each successive collision:

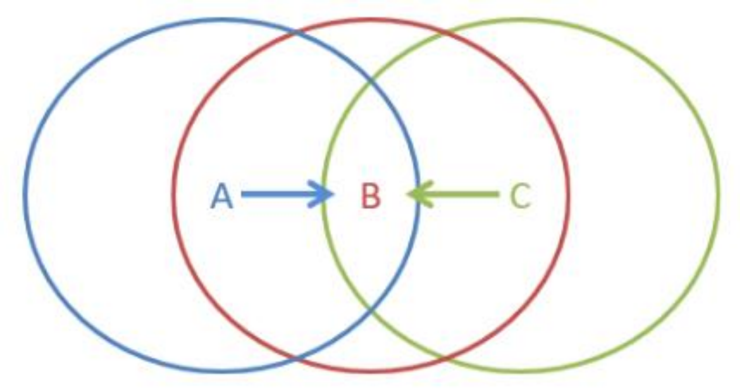
2. The back off time **increases exponentially**.
3. Collision probability **decreases exponentially**.

- One disadvantage of Back Off Algorithm:

If a particular station wins the collision one time, then its probability of winning the successive collisions increases exponentially.

A Problem with CSMA: the Hidden Terminal Problem

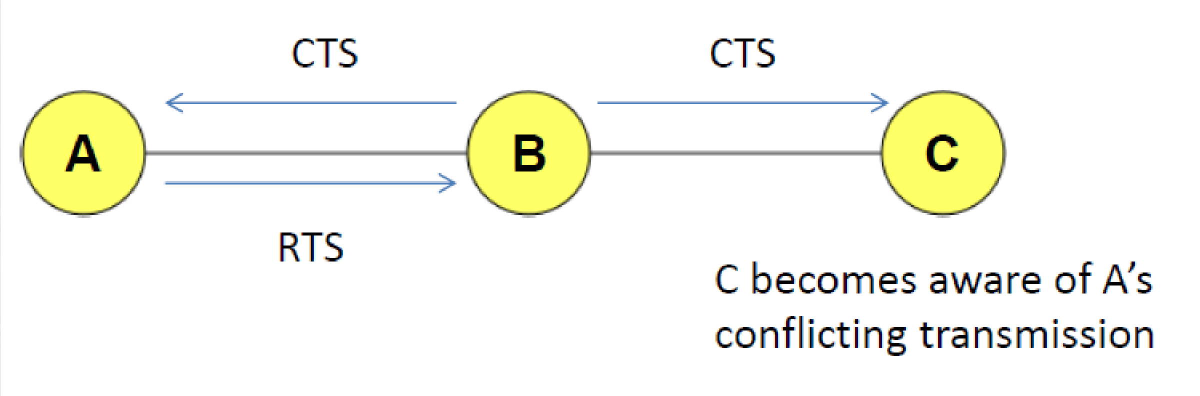
- It is a transmission problem that arises when two or more stations who are **out of range of each other transmit simultaneously to a common recipient**.
  - E.g.: This occurs when a station is visible from a wireless access point (AP), but is hidden from other stations that communicate with the AP.



- Nodes A and C cannot hear each other.
  - Out of the sensing range.
- Transmissions by nodes A and C can collide at node B.
- Nodes A and C are hidden from each other.

The Hidden Terminal Solution

- **RTS/CTS** is the mechanism used to resolve the hidden terminal problem.
- Sender first sends a **Request-to-Send (RTS)**
- If ready, receiver responds with **Clear-to-Send (CTS)**
- All nodes hearing RTS or CTS **keep quiet** for the duration of the transfer
  - Transfer duration included in both RTS and CTS.

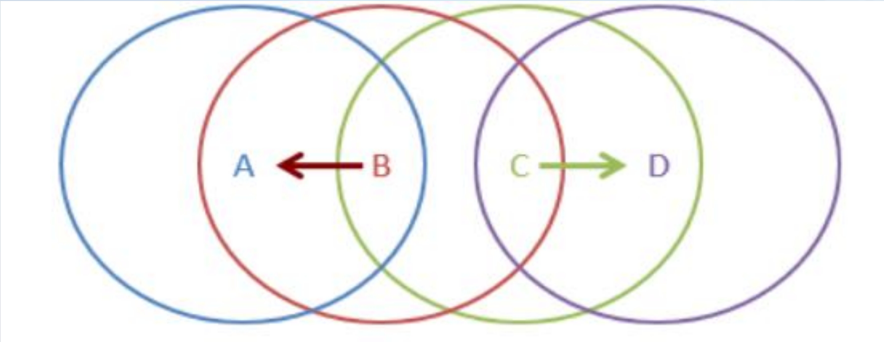


The Exposed Terminal Problem

- A data transmission which **do not interfere may be blocked.**

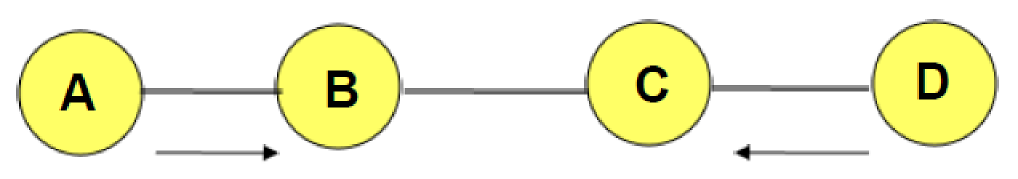
➢B is sending to A and C wants to send to D.

- Both transmissions can happen without interference.
- But C remains silent since it is in the sensing range of B and received its RTS.



➢A is sending to B and D wants to send to C.

- Both transmissions can happen without interference.
- But C remains silent since it is in the sensing range of B and received its CTS.
- So even if D sends RTS to C, C won't respond with CTS.



Virtual Carrier Sense

- **Network Allocation Vector (NAV)** is a virtual carrier-sensing mechanism used with wireless network protocols such as IEEE 802.11 (Wi-Fi).

- The virtual carrier-sensing is a logical abstraction which **limits the need for physical carrier-sensing** to save power.

- The MAC layer frame headers contain a **duration field** that specifies the transmission time required for the frame: time the medium will be busy.

- The stations listening on the wireless medium read the duration field and set their NAV, which is an indicator for a station on how long it must defer from accessing the medium


Thank You