Computer Communication
&
Networking

Data Link Control - MAC

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Medium Access Control Techniques

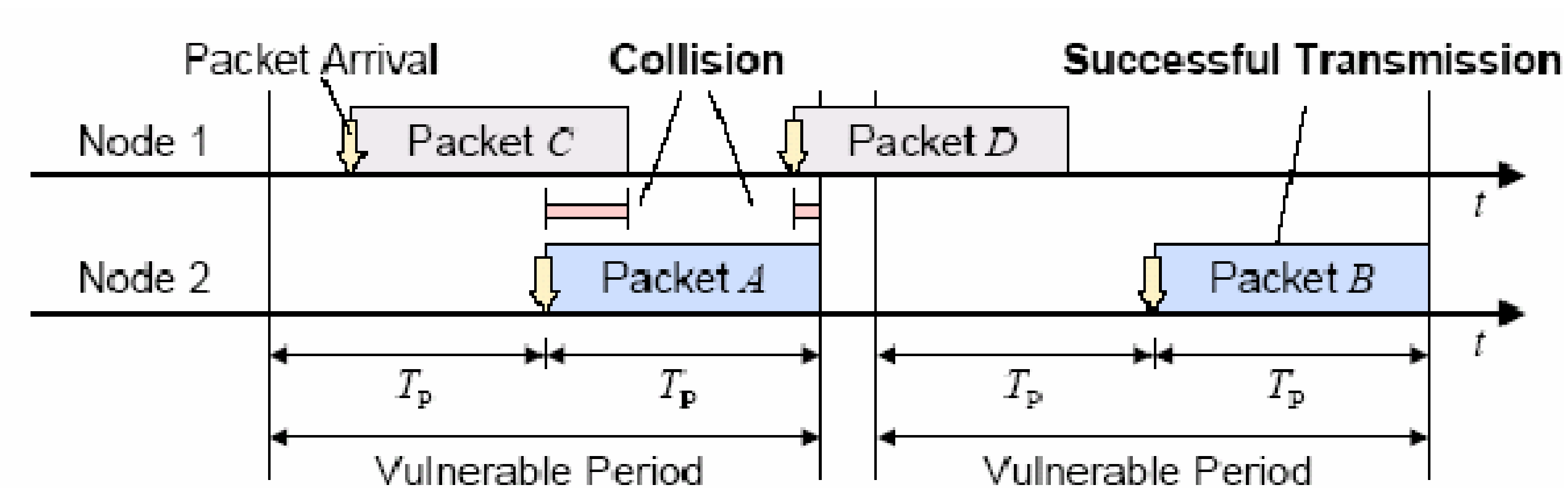
- **Important in distributed channels.**
- **ALOHA Protocol**
  - **Pure ALOHA**
  - **Slotted ALOHA**
- **CSMA**
  - **One persistent**
  - **Non persistent**
  - **p-persistent – Slotted channels**
- **CSMA/CD**
- **CSMA/CA**

Definitions

- Medium Access: A station wants to put a data frame into the shared medium or channel.
- Contention Resolution: Multiple stations trying to access the medium simultaneously.
- Collision: Transmissions by two or more stations overlap in time.
- Carrier: An unmodulated signal.
- Jamming signal: In telecommunication, this is a signal that carries a bit pattern sent by a data station to inform the other stations that they must not transmit.

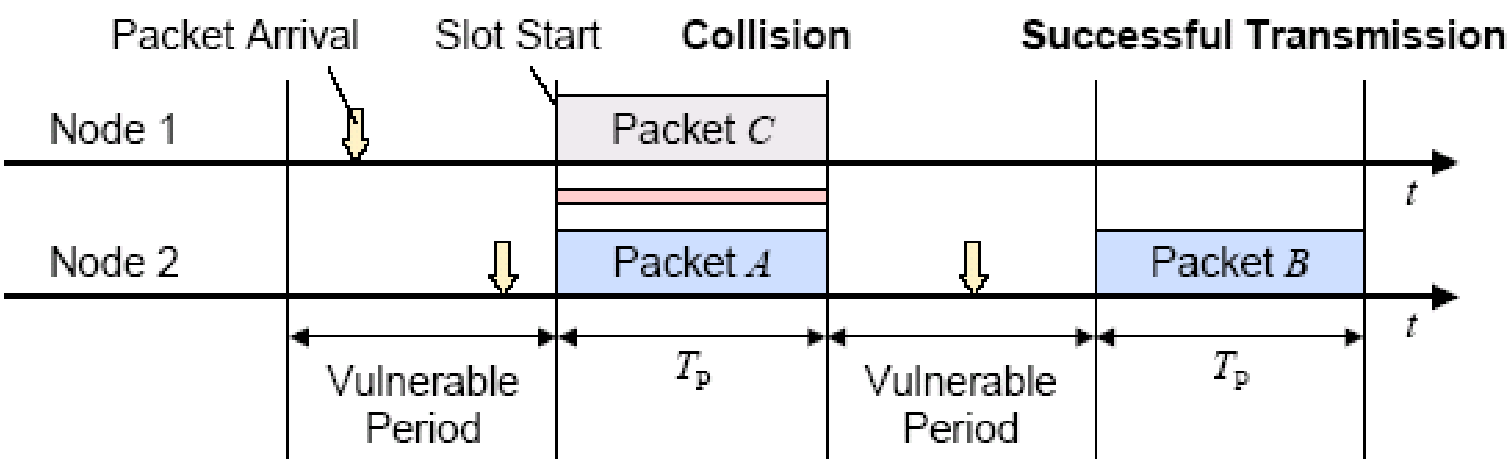
ALOHA Protocol

- Pure ALOHA
- A node transmits a packet whenever it has one to send.
- In case of collision the packet is retransmitted after a random time interval.



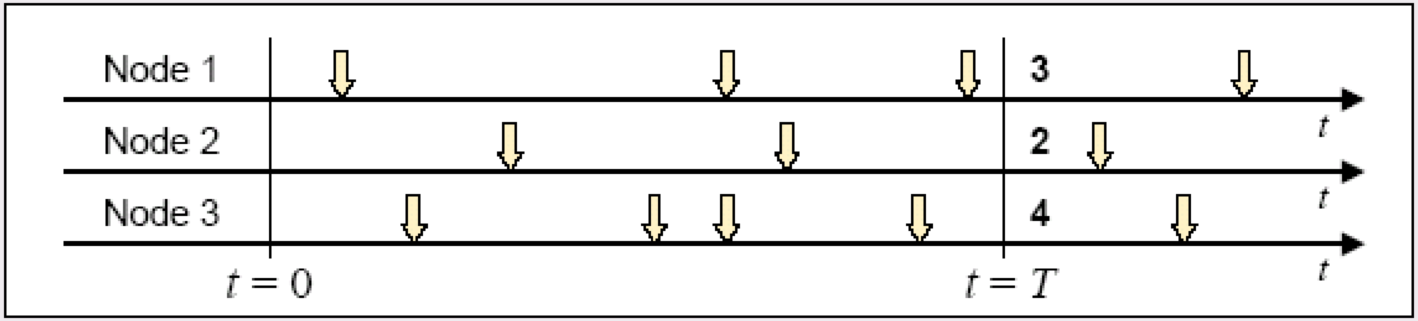
Slotted ALOHA

- The time is divided into slots of fixed length (equal to the packet duration Tp).
- All the nodes start their transmission only at the beginning of a new time slot.



Throughput Analysis

Question: How many packets $n(T)$ arrive within the Interval $t = [0,T]$?



Modeling of Packet Arrivals

- Arrival Process: **Poisson**
- Rate of Arrivals: λ

Poisson Process $n(T)$

- $n(T)$ counts the number of packet arrivals that have occurred from t=0 up to time T
- The time between arrivals is a statistically independent, identically (*exponentially*) distributed random variable

Poisson Distribution

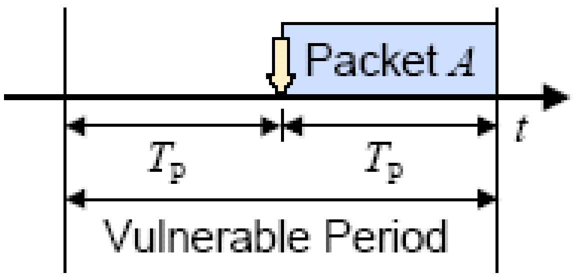
$$P_n(T) = \frac{(\lambda \cdot T)^n}{n!} e^{-\lambda \cdot T}$$

Throughput Analysis

Traffic: $G = \lambda_t T_P$
(Transmitted packets per time slot)

Throughput: $S = G\,P_S$
(Successful packets per time slot)

Probability of successful transmission using **Pure ALOHA**



Packet A is successfully transmitted, if **no** other packet arrives within the vulnerable period of **two** packet durations:

$$P_S = P_0(2T_P) = e^{-2\lambda_t \cdot T_P} = e^{-2G}$$

Throughput Analysis (Contd.)

- Throughput Analysis
  - Assumptions:
    - Packet duration=Tp
- Packet transmission rate = λ
- Pr[Successful transmission]=Ps
- Increase in transmission rate due to retransmissions=λr
- Total packet transmission rate observed
    - λt =λ+λr.
  - Definitions:
    - Traffic, G=λtTp.

At low load, S$\approx$G, at high load G>S.

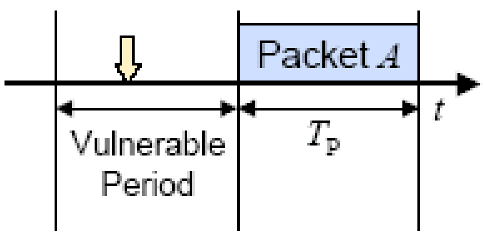
- Throughput, S=GPs.
- Pr[Success in k attempts]=$P_0(1-P_0)^{k-1}$ = $\sum_{k=1}^{\infty} k e^{-G}(1-e^{-G})^{k-1}$
- Expected number of transmissions= e^{G}

Throughput Analysis (Slotted Aloha)

Traffic: $G = \lambda_t T_P$
(Transmitted packets per time slot)

Throughput: $S = G\,P_S$
(Successful packets per time slot)

Probability of successful transmission using **Slotted ALOHA**

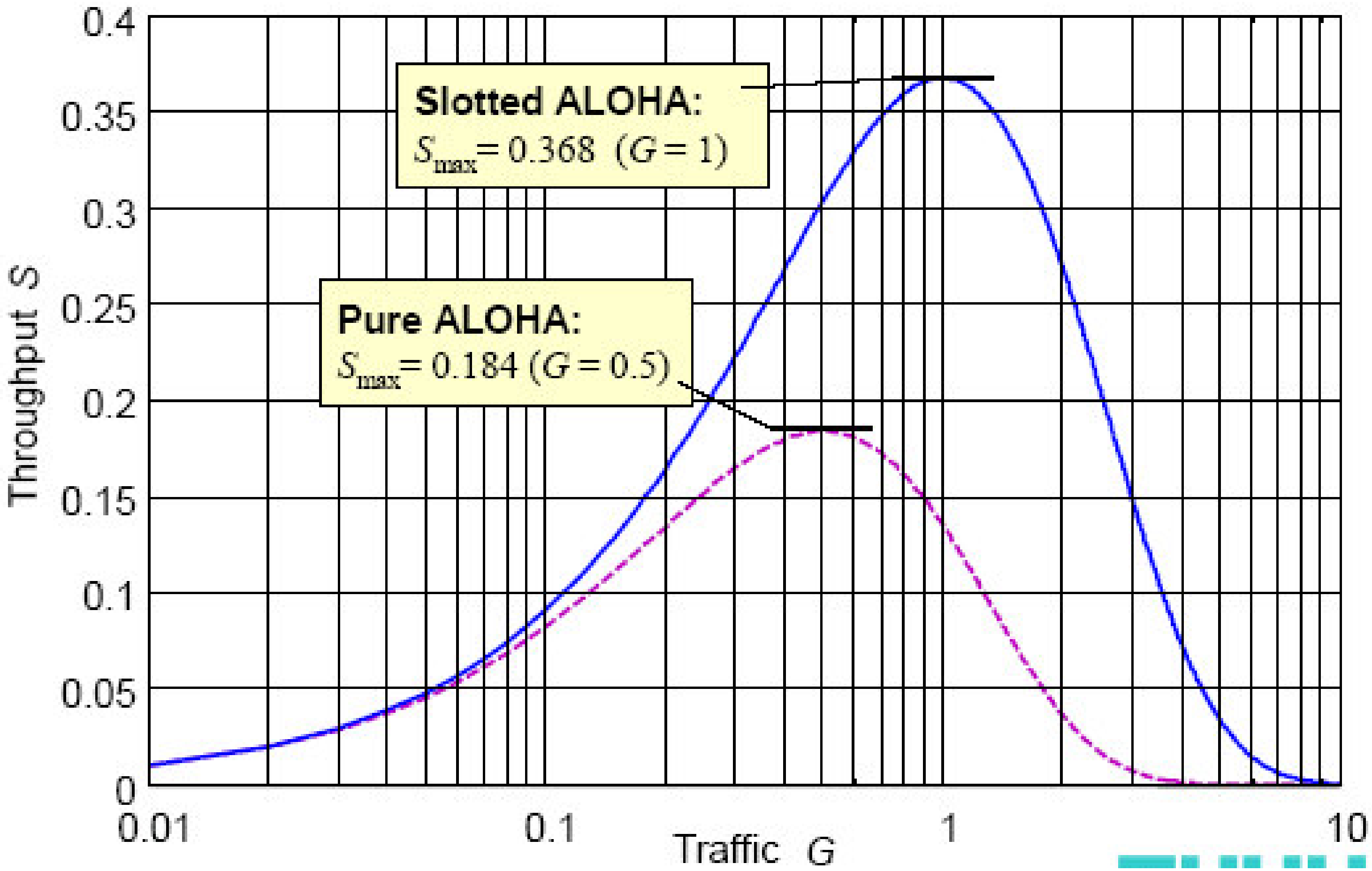


Packet A is successfully transmitted, if **no** other packet arrives within the vulnerable period of **one** packet duration:

$$P_S = P_0(T_P) = e^{-\lambda_t \cdot T_P}$$

$$\begin{aligned} S &= G \cdot P_S \\ &= G \cdot e^{-\lambda_t \cdot T_P} = \boxed{G \cdot e^{-G}} \end{aligned}$$

Analytical Throughput curve



Carrier sense multiple access (CSMA)

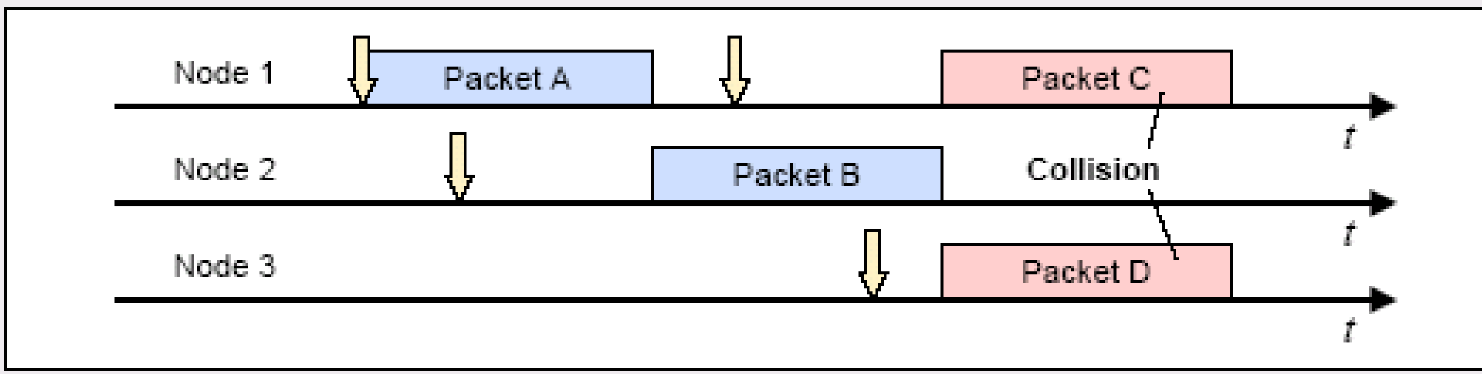
- **A refinement of the ALOHA protocol that is used in Ethernet.**
- **Improves performance when there is a higher medium utilisation.**
- **When a NIC has data to transmit, it *first* listens to the cable (using a transceiver) to see if a carrier (signal) is being transmitted by another node.**
- **This may be achieved by monitoring whether a current is flowing in the cable (each bit corresponds to 18-20 mA of current).**

CSMA (Contd.)

- Station willing to transmit senses the medium (**carrier sensing**)
- If a busy medium is detected, the transmission is deferred:

1-persistent CSMA	If medium is idle, transmit directly, otherwise wait until it becomes idle and then transmit directly
nonpersistent CSMA	If medium is idle, transmit directly, otherwise defer for a random interval and try again
p-persistent CSMA	If medium is idle, transmit directly with probability of p, otherwise defer for a random interval and try again

Example: Multiple Access using the **1-persistent CSMA** Method



Non persistent CSMA

1. If the medium id idle, transmit; otherwise, go to step 2.
2. If the channel is busy, wait for a random amount of time and repeat step1.

1-persistent CSMA

1. If the medium id idle, transmit; otherwise, go to step 2.
2. If the channel is busy, continue to sense the channel until it is sensed to be idle; then transmit immediately.

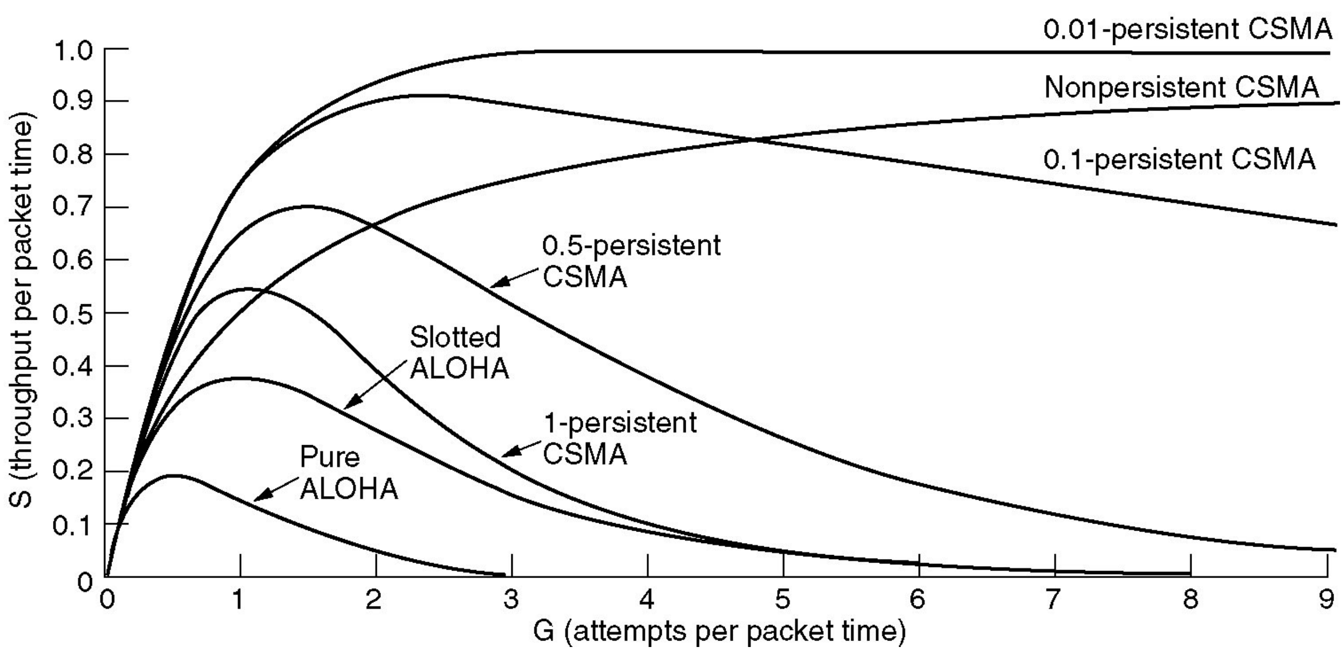
p-persistent CSMA

A compromise that attempts to reduce collisions while ensuring less idle time.

1. If the medium id idle, transmit with a probability of p, and delay for one time unit with probability (1-p); typically, the time unit is set equal to the maximum propagation delay.
2. If the channel is busy, continue to sense the channel until it is sensed to be idle; then repeat step 1.
3. If transmission is delayed by one time unit, repeat step 1.

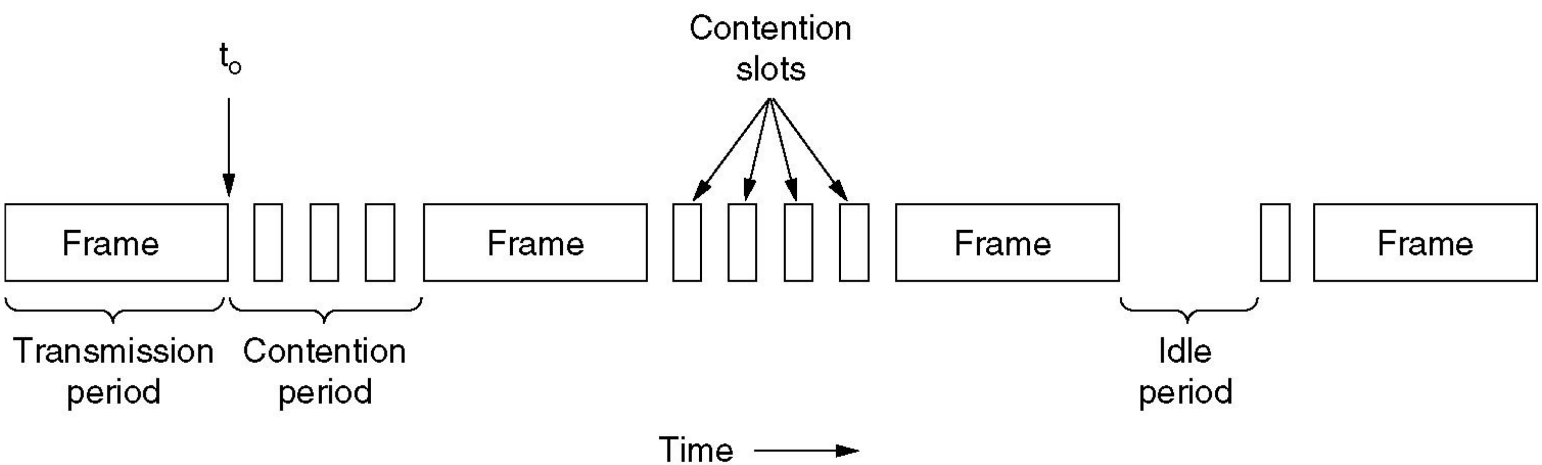
Throughput Curve

Analytical Throughput Results



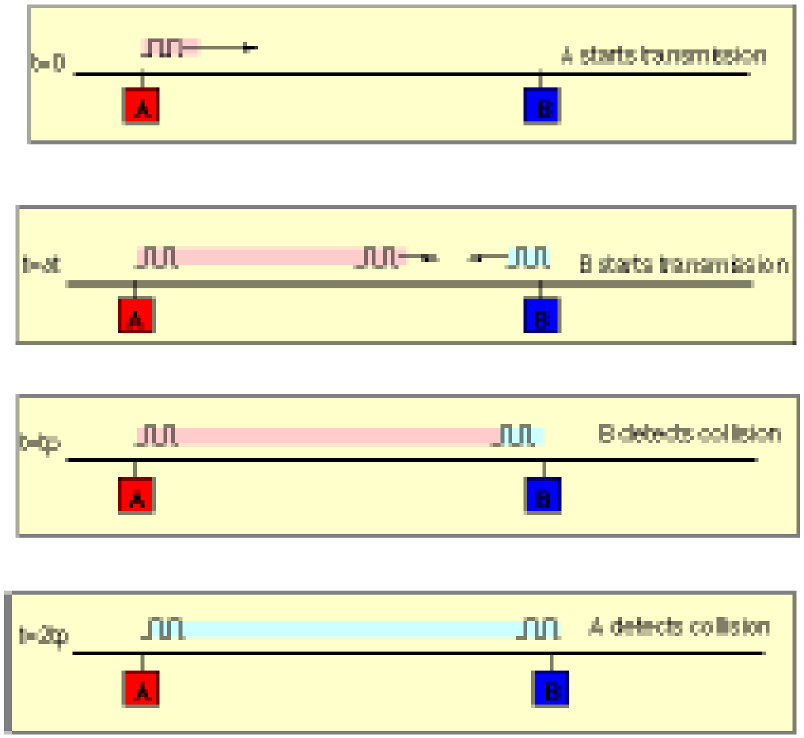
MAC Protocol used in IEEE 802.3

- **CSMA with Collision Detection (CSMA/CD)**
- The Channel can be in one of three states:
  (i) Transmission (ii) Contention (iii) Idle



CSMA/CD?

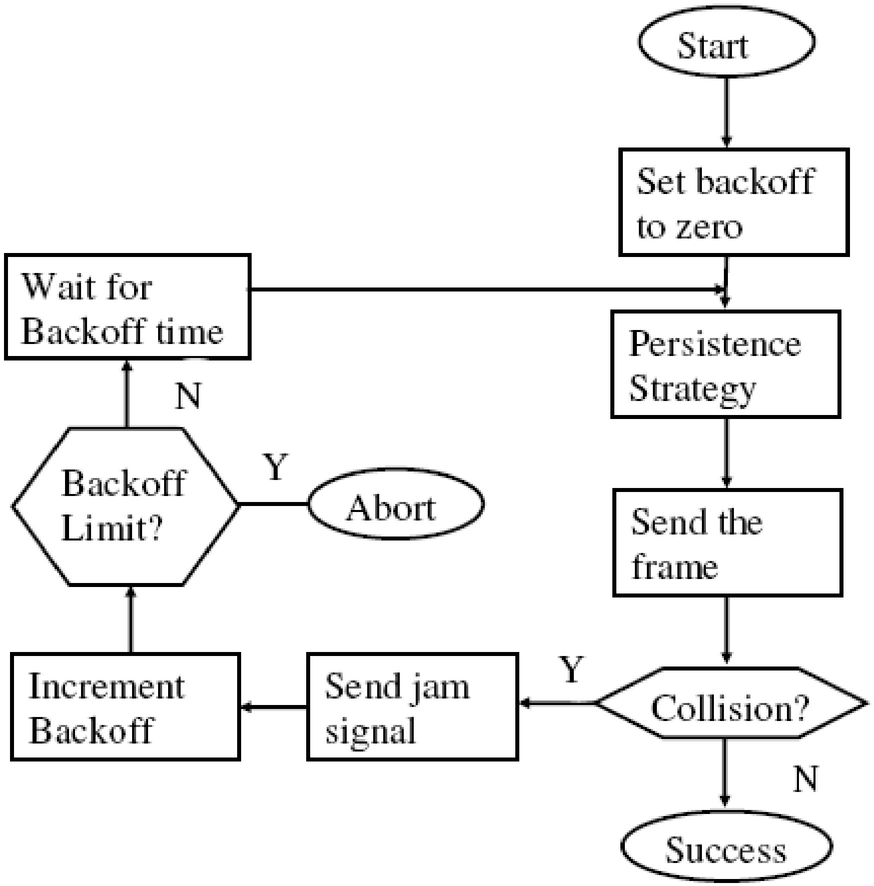
- Collision detection logic is embedded in the transceiver interfacing a node to the medium.



CSMA/CD Operation

- **A station that detects a collision:**
  - ➢ **Abruptly stops transmission.**
  - ➢ **Puts a jamming signal into the channel.**
  - ➢ **Chooses a retransmission time using the Binary exponential Backoff algorithm.**

CSMA/CD Operation



Source: Forouzan - DCN

Binary exponential Backoff Algorithm

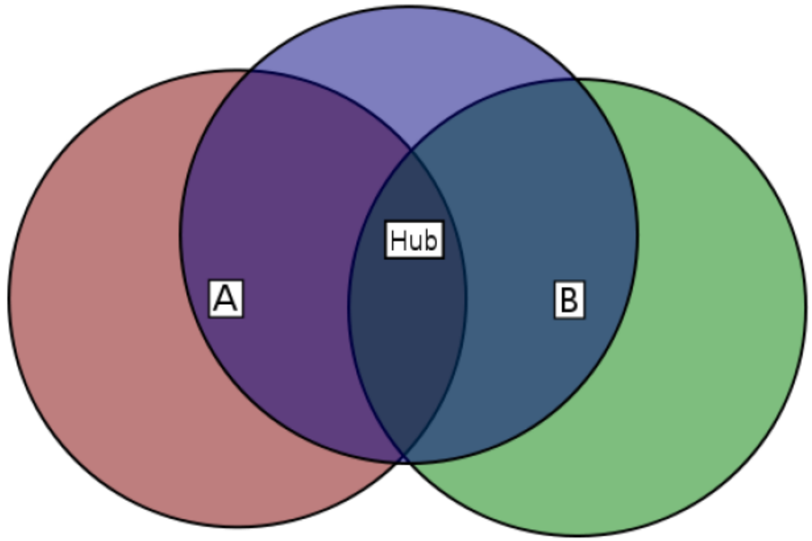
Slotted Channel

- **After the first collision, each station waits for either 0 or 1 time slots.**
- **After second collision, each station waits for either 0, 1, 2, or 3 time slots at random.**
- **After I collisions, a random number is chosen between 0 and 2^i-1 and that many slots are skipped.**
- **After 10 collisions, the randomization interval is frozen at 1023 slots.**
- **After 16 collisions, failure is reported and now it's the job of higher layers to ensure recovery.**

CSMA/CA

- **CSMA/CA is used in 802.11 based wireless LANs.**
- **In wireless LANs, CSMA/CD cannot be implemented as here it is not possible to listen while sending.**
- **Thus, collision detection is not possible.**
- **Another reason is the hidden terminal problem, whereby a node A, in range of the receiver R, is not in range of the sender S, and therefore cannot know that S is transmitting to R.**
- **Still another problem is the exposed terminal problem.**

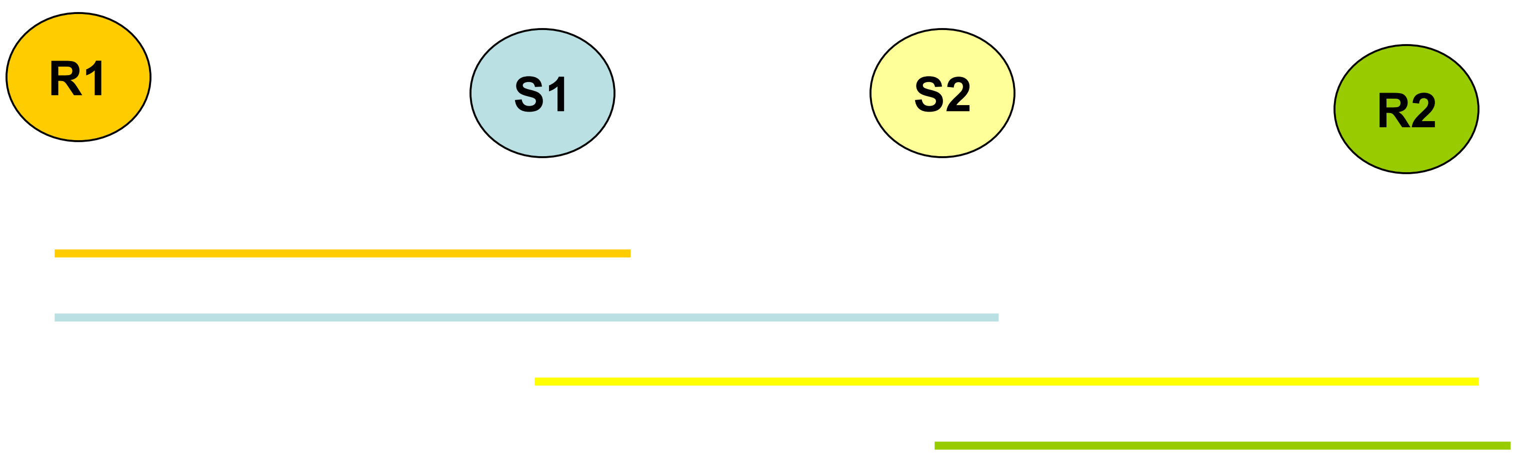
Hidden terminal problem



- **In wireless networking, the hidden node problem occurs when a node is visible from a wireless access point (AP), but not from other nodes communicating with the said AP.**
- **In the above figure, nodes A and B can each communicate with the hub, but one can not know when the other one is transmitting.**

Exposed terminal problem

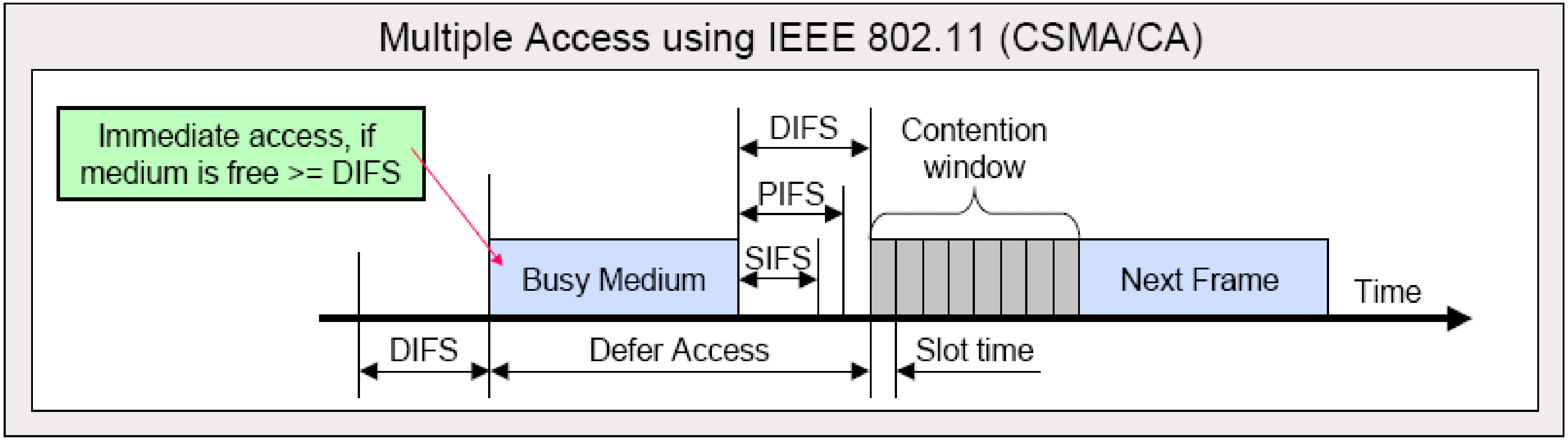
- **In the following figure, S2 can not transmit to R2 as it hears S1 transmitting to R1, though R2 is not in the range of S1.**



CSMA/CA Protocol

- **CSMA/CA: explicit channel reservation**
  - **sender: send short RTS: request to send**
  - **receiver: reply with short CTS: clear to send**
- **CTS reserves channel for sender, notifying (possibly hidden) stations**
- **Avoids hidden station collisions**

CSMA/CA: IEEE 802.11



IEEE 802.11 Multiple Access Principle:

- Station willing to transmit senses the medium (**carrier sensing**)
- If medium is idle for a duration longer than the priority-dependant *Interframe Space* (**IFS**), the station directly accesses the medium
- Otherwise, the station waits for the next idle **IFS** and additionally defers its access by a random backoff time
- If the medium is accessed during the backoff phase by other stations, the backoff-counter is stopped

CSMA/CA Operation