# Chapter 6
# Multiple Radio Access

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# Outline

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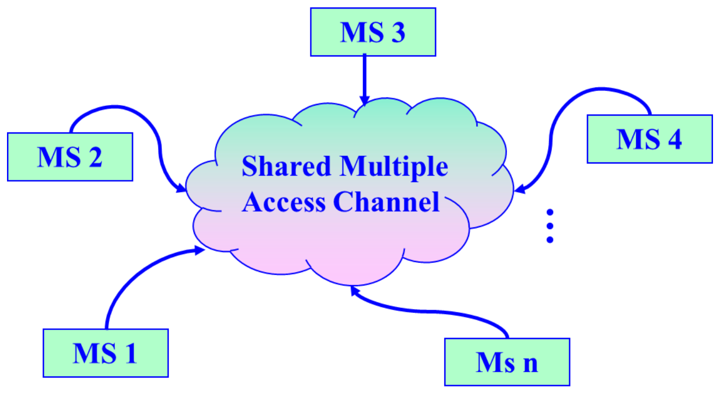
# 6.1 Introduction

- In cellular wireless network, MSs need to use a control channel to inform the BS before using the traffic channel or the information channel.
  - Uses shared access of a control channel ⇒ competition!
  - Such contention is implicitly present in MANETs wherein the same frequency is used.
- Multiple access of shared channel in a wireless network
  - Each Mobile Station (MS) communicates with other MSs using a single channel shared by others.
  - Transmission from any MS is received by other MSs.

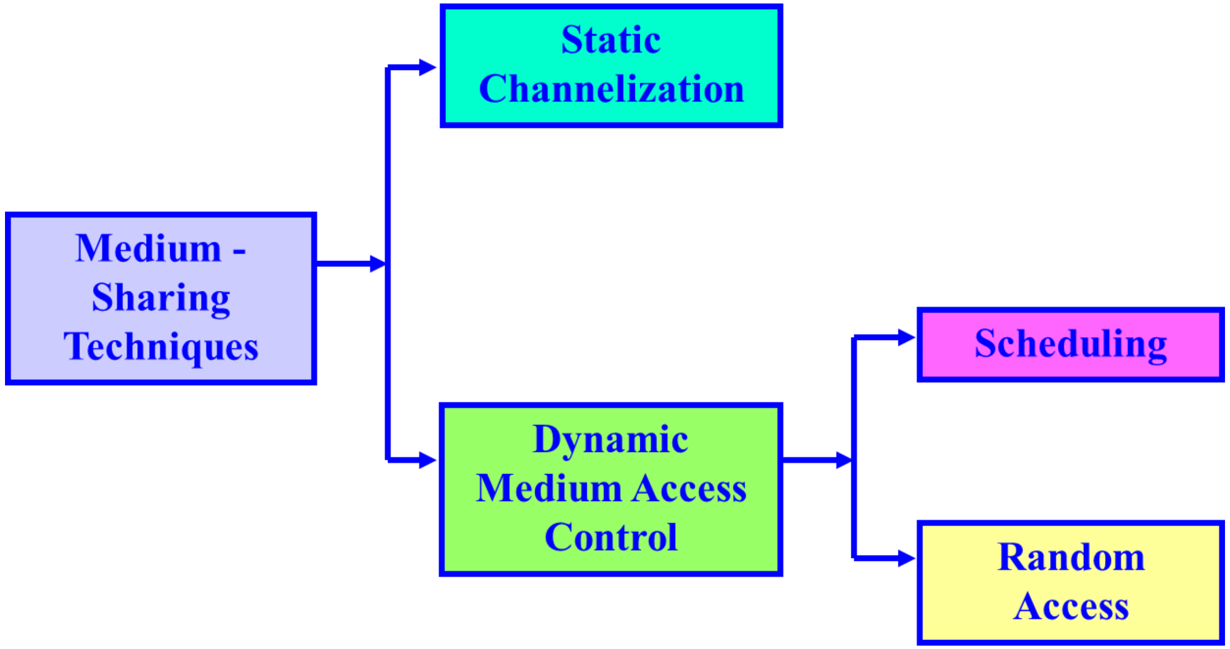


# 6.1 Introduction

- Collisions in the Channel (or Multiple Access Issues)
  - If more than one MS attempts to transmit at one time, using the shared channel ⇒ **collision occurs.**
    ⇒ MSs receiving the information cannot interpret or differentiate what is being transmitted.
- Multiple Access Protocols
  - Handles multiple access issues
  - Two different types:
    - **Contention-based protocol**:
      - Resolve a collision after it occurs.
      - These protocols execute a collision resolution protocol after each collision
    - **Conflict-free (or Collision-free) protocol:**
      - Ensures that a collision can never occur
      - e.g., a bit-map protocol and binary countdown

# 6.1 Introduction

- Channel Sharing Techniques
  - **Static allocation**: the channel assignment is done in a prespecified way and does not change with time.
  - **Dynamic allocation**: the channel is allocated as needed and changes with time.

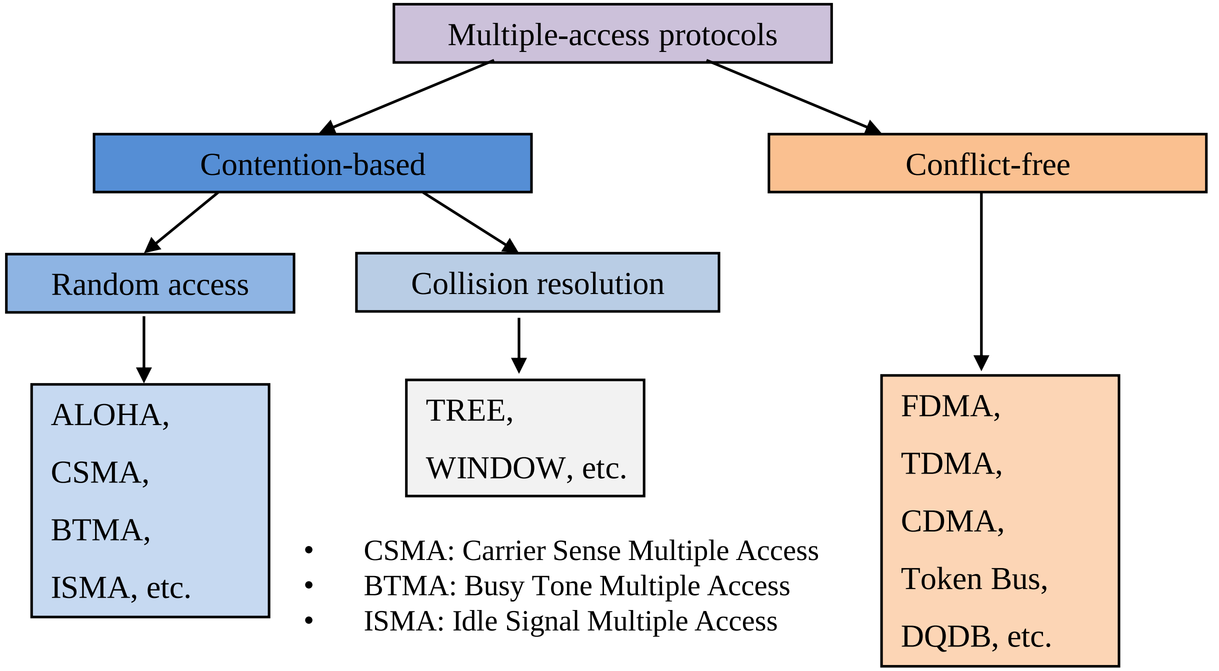


# 6.2 Multiple Radio Access Protocols

- For computer networks, a seven-layer ISO (International Standards Organization) OSI (Open Systems Interconnection) reference model is widely used.
- The communication subnetwork can be described by the lower three layers (i.e., physical, data link, and network layers)
- A simple modification of OSI model is done by adding the **MAC (Medium Access Control) sublayer** in data link layer.
- MAC sublayer protocols
  - Usually known as the multiple-access protocols
  - A set of rules that communicating MSs need to follow
  - Numerous multiple-access protocols have been proposed in the literature.

# 6.2 Multiple Radio Access Protocols

- Classification of Multiple-Access Protocols for a Shared Channel.




- CSMA: Carrier Sense Multiple Access
- BTMA: Busy Tone Multiple Access
- ISMA: Idle Signal Multiple Access

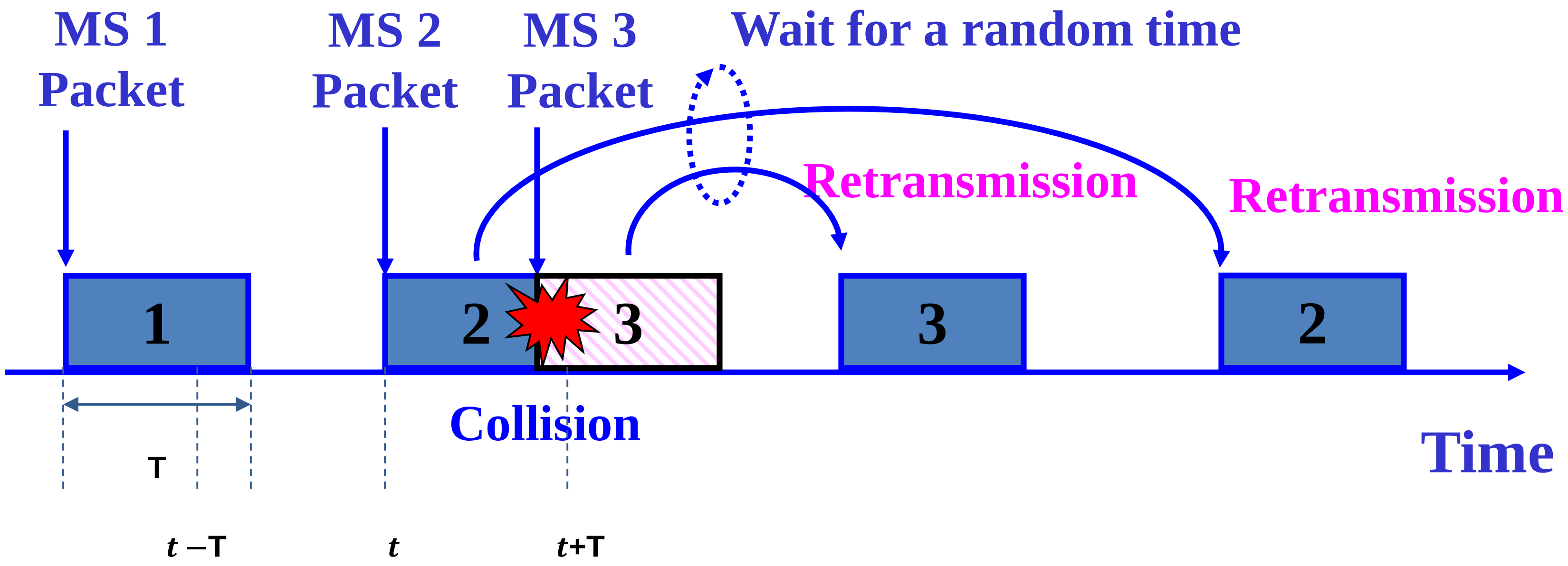
- Random Access:
  a MS is allowed to transmit the collided message only after a random delay.
- Collision Resolution:
  employ a more sophisticated way to control the retransmission process.

# 6.3.1 Pure ALOHA

- Developed by Abramson in the 1970s for a packet radio network between remote terminals and the central computer at the University of Hawaii.
- A contention-based protocol
  - A MS in the system may use the shared channel to transmit its message at any time it wishes, hoping that no other terminals will transmit at the same time.
  - Whenever a terminal (MS) has data, it transmits.
  - Sender finds out whether transmission was successful or experienced a collision by listening to the broadcast from the destination station. If there is a collision, sender retransmits after some random time

# 6.3.1 Pure ALOHA

- Collision Mechanism in Pure ALOHA




Collision mechanism in ALOHA

# 6.3.1 Pure ALOHA

- Traffic Model
  - Each user generates packets according to a Poisson process with arrival rate $\lambda$ (packets/sec)
  - All packets have the same fixed length $T$.
  - If the presence of a collision is determined by the sender, it retransmits after some random wait time.
  - Let the rate of the scheduling: $\boldsymbol{g}$ (packets/sec)

    $\Rightarrow$ referred to as **the offered load** to the channel
  - Since some packets are transmitted more than once before they are successfully transmitted

    $\Rightarrow g > \lambda$
  - For tractable analysis of ALOHA, assume that the scheduling process is also a Poisson process with arrival rate $g$.

# 6.3.1 Pure ALOHA

- The probability of successful transmission $P_s$
  - The probability no other packets scheduled between the instants $t-T$ and $t+T$ (interval of length $\mathbf{2T}$**: vulnerable period**)
  - $P_s = P(\text{no collision}) = P(\text{no transmission in } 2T) = e^{-2gT}$
- The rate of successful transmission = $gP_s$ (successful packets/sec)
- **Throughput $S_{th}$** is defined as "the fraction of time during which the useful information is carried on the channel."
  - $S_{th} = T \cdot gP_s = gTe^{-2gT}$
- Defining normalized offered load to the channel: $G = gT$
  - $S_{th} = Ge^{-2G}$
  - $\frac{dS_{th}}{dG} = -2Ge^{-2G} + e^{-2G} = 0 \quad \Rightarrow S_{th\,max}$ occurs at $G = \frac{1}{2}$
  - **Maximum throughput of pure ALOHA: $S_{th\,max} = \frac{1}{2e} \approx 0.184$**

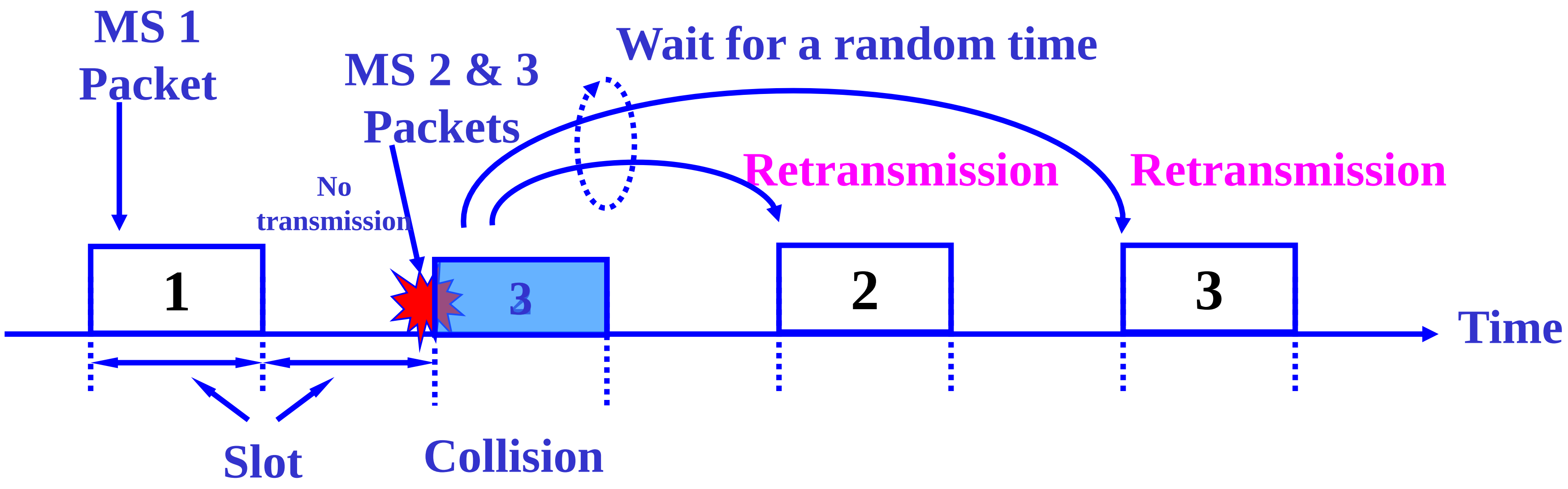
# 6.3.2 Slotted ALOHA

- Slotted ALOHA
  - A modification of pure ALOHA
  - Time is slotted and a packet can only be transmitted only at the beginning of one slot.
    - The slot size = the duration of packet $T$
  - A transmission will be successful if and only if exactly one packet is scheduled for transmission for the current slot.
    - No partial collision is possible.

⇒ Reduces the <u>vulnerable period</u> for packet collision to a single slot $\boldsymbol{T}$

⇒ Thus, it can reduce the collision duration.

# 6.3.2 Slotted ALOHA

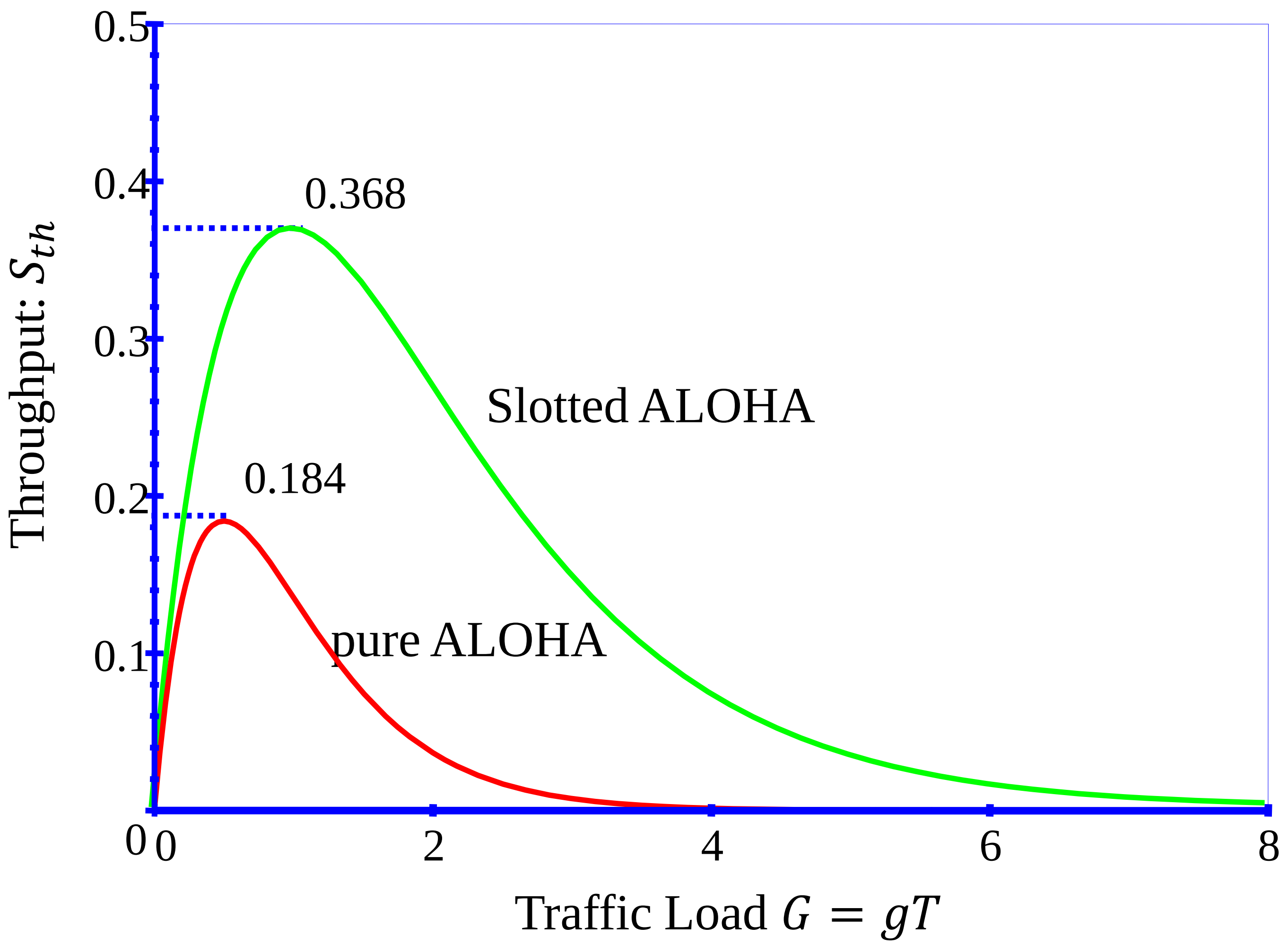



Collision mechanism in slotted ALOHA

# 6.3.2 Slotted ALOHA

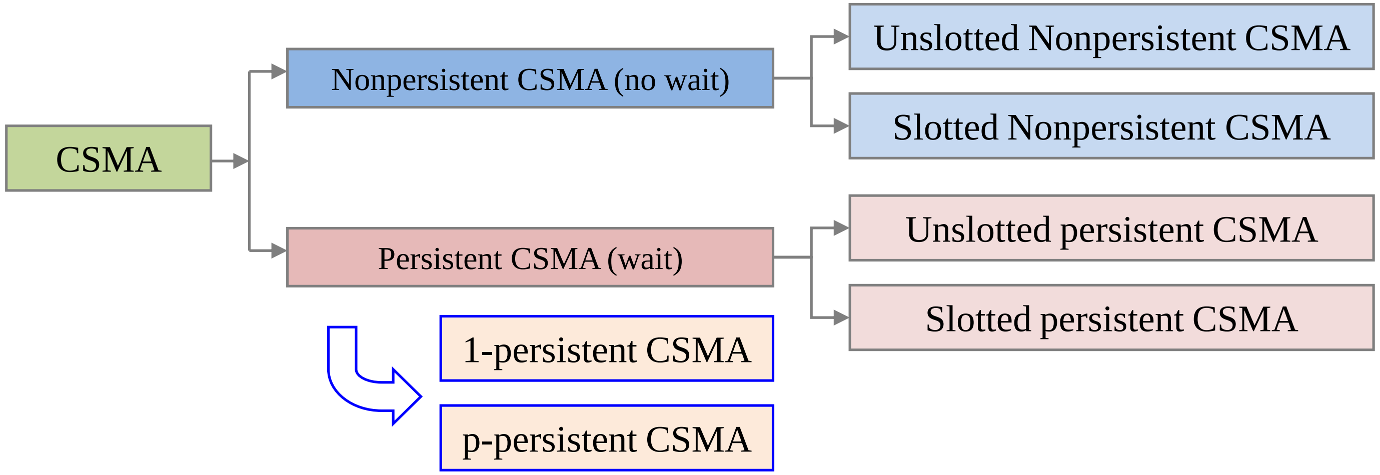
- The probability of successful transmission $P_s$
  - The probability no other packets scheduled between the instants $t$ and $t+T$ (interval of length $\boldsymbol{T}$: **vulnerable period**)
  - $P_s = P(\text{no collision}) = P(\text{no transmission in } T) = e^{-gT}$
- The rate of successful transmission = $gP_s$ (successful packets/sec)
- **Throughput $\boldsymbol{S_{th}}$**
  - $S_{th} = T \cdot gP_s = gTe^{-gT}$
- Defining normalized offered load to the channel: $G = gT$
  - $S_{th} = Ge^{-G}$
  - $\frac{dS_{th}}{dG} = -Ge^{-G} + e^{-G} = 0 \quad \Rightarrow S_{th\,max}$ occurs at $G = 1$
  - **Maximum throughput of slotted ALOHA: $\boldsymbol{S_{th\,max} = \frac{1}{e} \approx 0.368}$**

# Throughputs of ALOHA vs. Slotted SLOHA



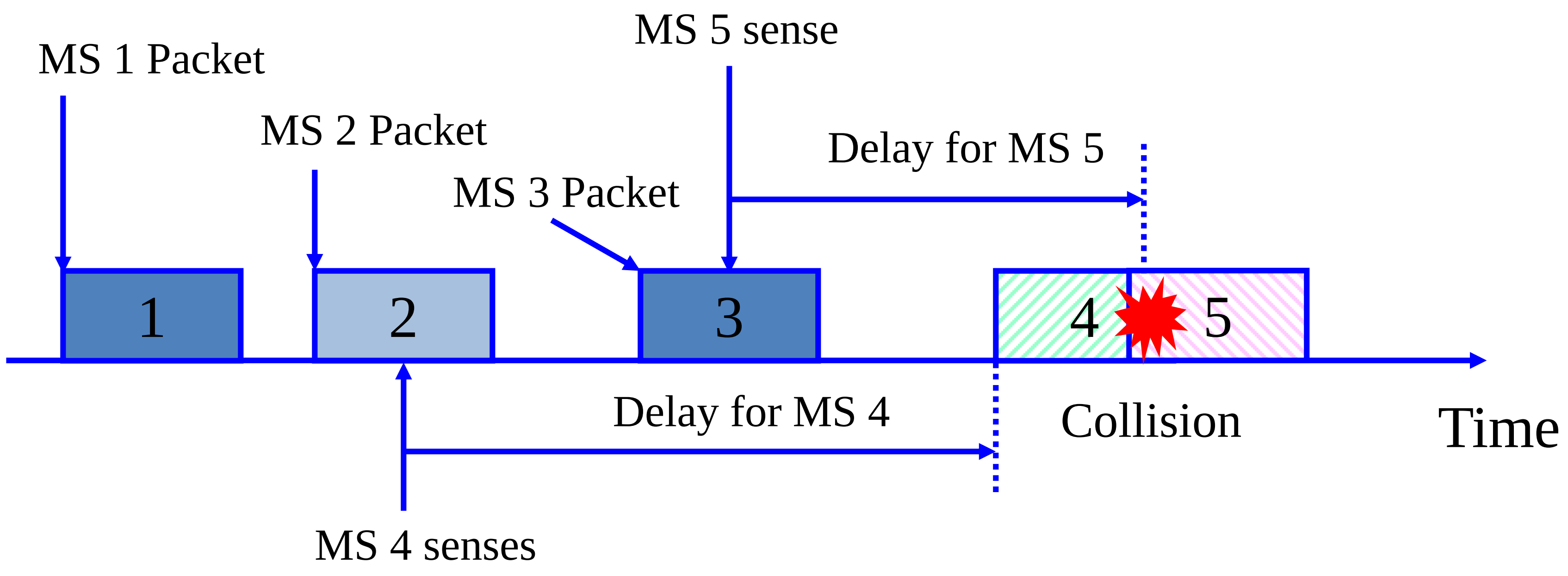
# 6.3.3 CSMA

- **Max throughput achievable by slotted ALOHA is 0.368**
  **⇒ Need to find another way of improving throughput**
- CSMA (Carrier Sense Multiple Access)
  - Prevents potential collision in a shared channel by simply listening to the channel before transmitting a packet.
  - Collisions could be avoided.
  - CSMA gives improved throughput compared to ALOHA & slotted ALOHA.



# 6.3.3 CSMA

- Collision Mechanism in CSMA



# 6.3.3 CSMA

- Nonpersistent CSMA Protocol
  - MS senses the medium first whenever the MS has a packet to send
  - If the shared medium is busy, the MS **waits for** a random amount time and senses the medium again.
  - If the channel is idle, the MS transmits the packet immediately.
  - If a collision occurs, the MS waits for a random amount of time and starts all over again.
  - The packet can be sent during a slotted period or any arbitrary time.
    - Slotted nonpersistent CSMA
    - Unslotted nonpersistent CSMA

# 6.3.3 CSMA

- 1-Persistent CSMA Protocol
  - MS senses the medium first whenever the MS has a packet to send
  - If the shared medium is busy, the MS **keeps listening to** the medium and transmits the packet immediately after the medium becomes idle.
  - Called **1-persistent** because the MS transmits with probability of 1 whenever it finds the medium to be idle.
  - A collision occurs if two or more MSs have ready packets, are waiting for the channel to become free, and start transmitting at the same time.

# 6.3.3 CSMA

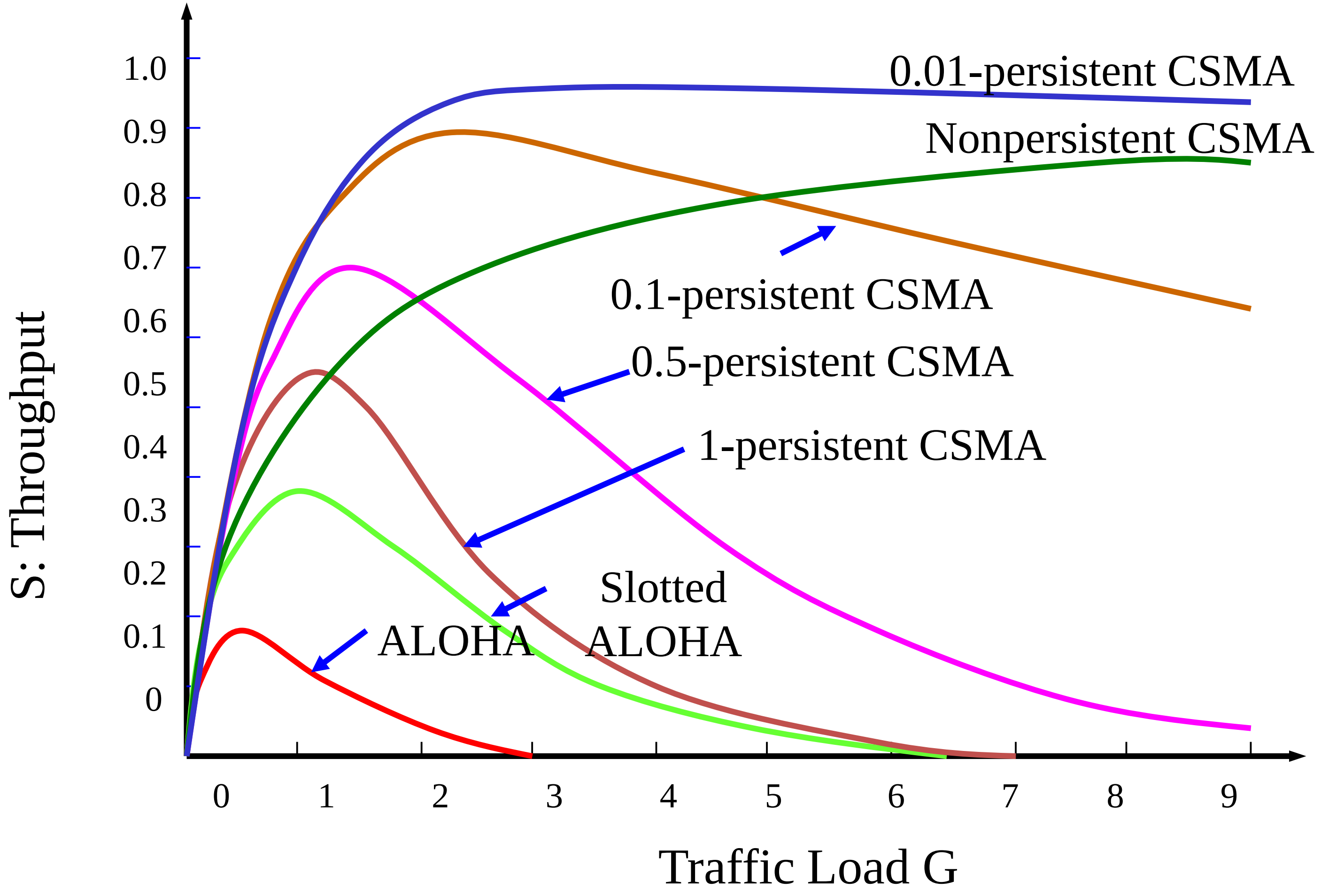
- *p*-Persistent CSMA Protocol
  - The time is slotted.
  - MS senses the medium first whenever the MS has a packet to send
  - If the shared medium is busy, the MS **waits until the next slot** and checks the meduim again.
  - If the medium is idle, the MS transmits with probability of *p* or defers transmission with probability (1-*p*) until the next slot.
  - If collision occurs the MS waits for a random amount of time and starts all over again.
  - Intuitively, this protocol is considered as an optimal access strategy for a shared channel.

# 6.3.3 CSMA

- How to select $p$ for the $p$-persistent CSMA?
  - Assume that $N$ nodes have a packet to send and the medium is busy.
  - Then, $Np$ is the expected number of nodes that will attempt to transmit once the medium becomes idle.
  - If $Np > 1$, then a collision is expected to occur
  - Therefore, network must make sure that $\boldsymbol{Np \leq 1}$ to avoid collision.

# 6.3.3 CSMA

- Throughput for different ALOHA and CSMA protocols

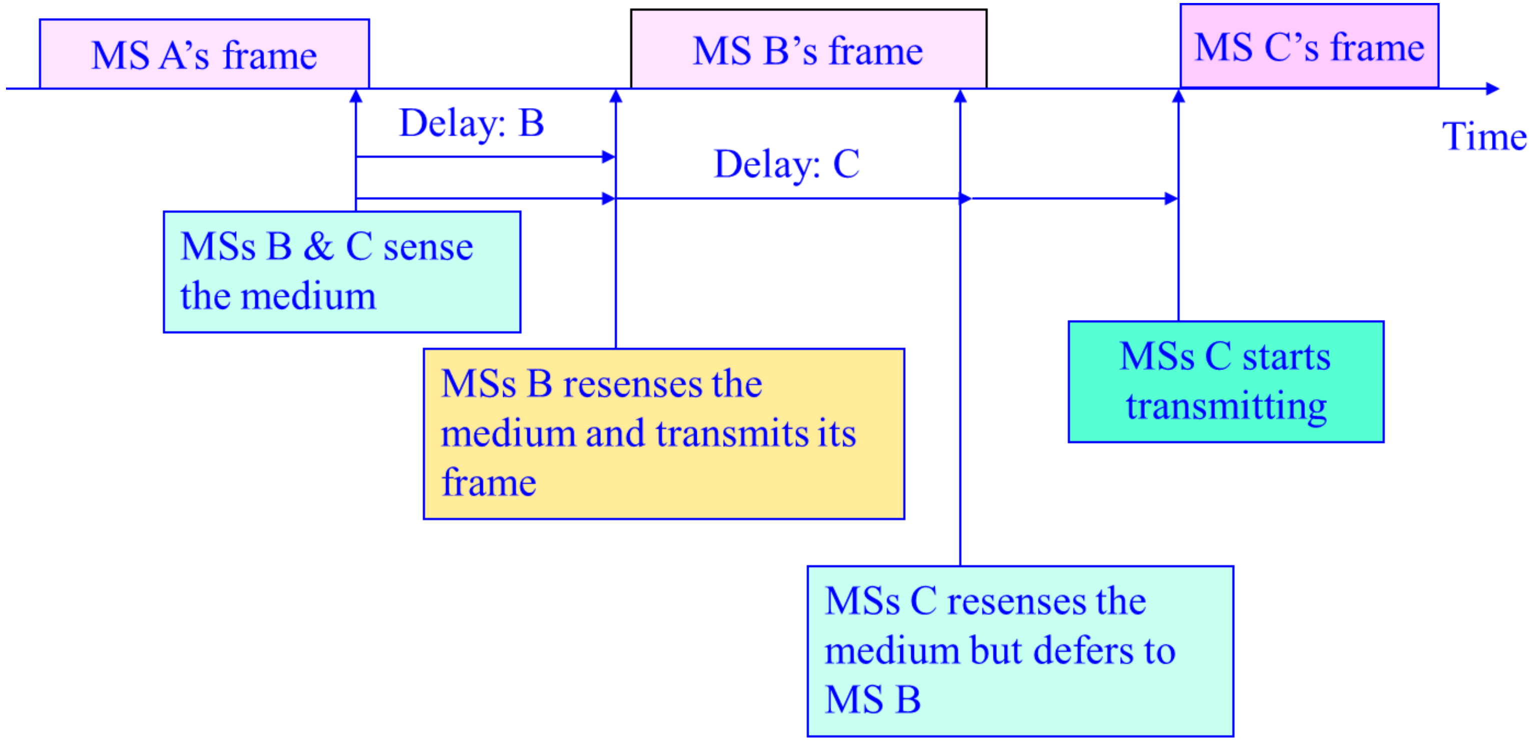


# 6.3.4 CSMA/CD

- In CSMA, if two terminals begin sending packet at the same time, each will transmit its complete packet (although collision is taking place).
  ⇒ Wasting medium for an entire packet time
  ⇒ CSMA with collision detection (CSMA/CD) is needed!
- The main idea of CSMA/CD
  - To terminate transmission immediately after detection of a collision.

# 6.3.5 CSMA/CA

- CSMA with Collision Avoidance (CSMA/CA)
  - Wait a random time and try again when carrier is quiet.
  - If still quiet, then transmit



# Thank You !