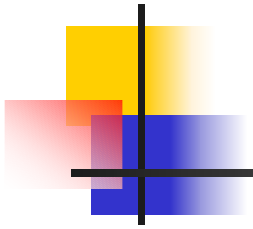
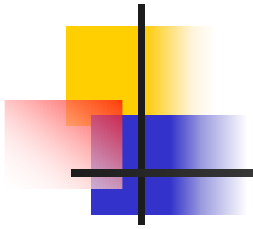


Chapter 6

Multiple Radio Access

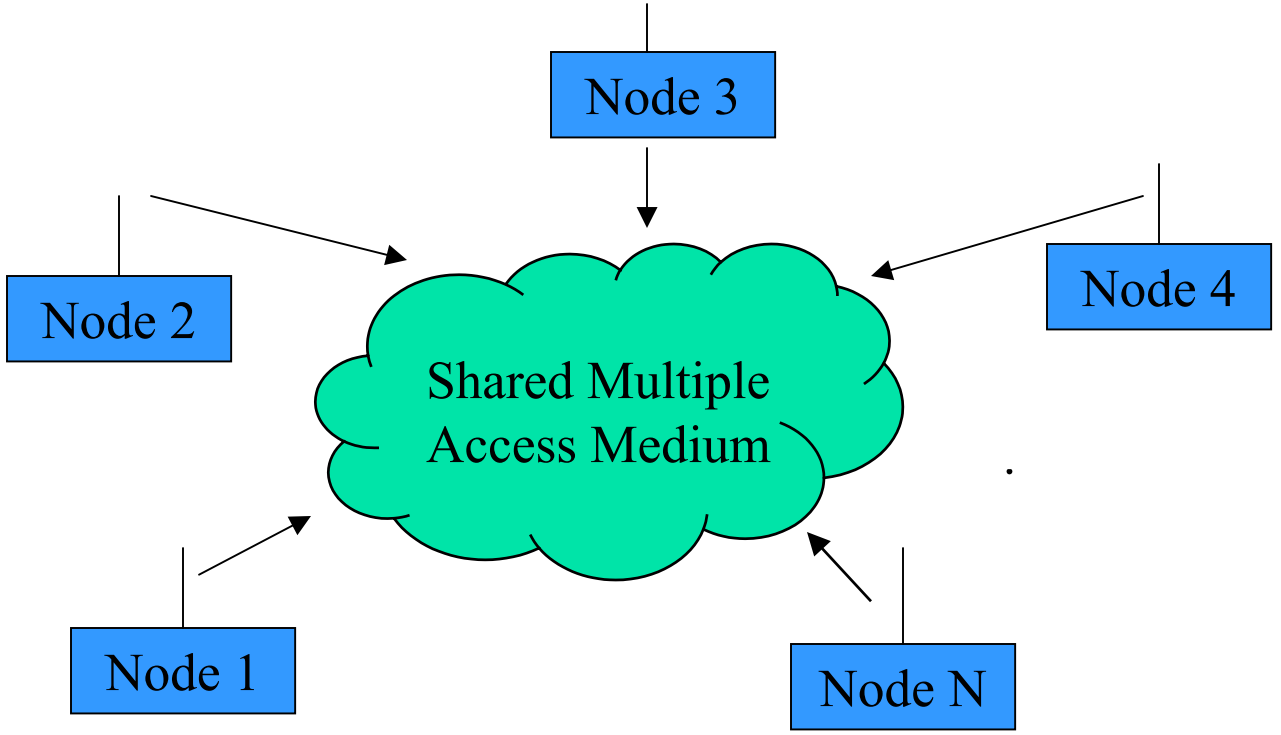


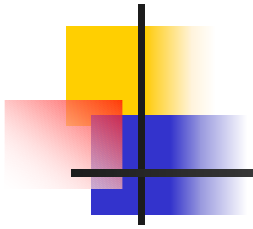
Outline

- Introduction
- Contention Protocols
- ALOHA
- Slotted ALOHA
- CSMA (Carrier Sense Multiple Access)
- CSMA/CD (CSMA with Collision Detection)
- CSMA/CA (CSMA with Collision Avoidance)

Introduction

- Multiple access networks
  - Each node is attached to a transmitter/receiver which communicates via a medium shared by other nodes
  - Transmission from any node is received by other nodes

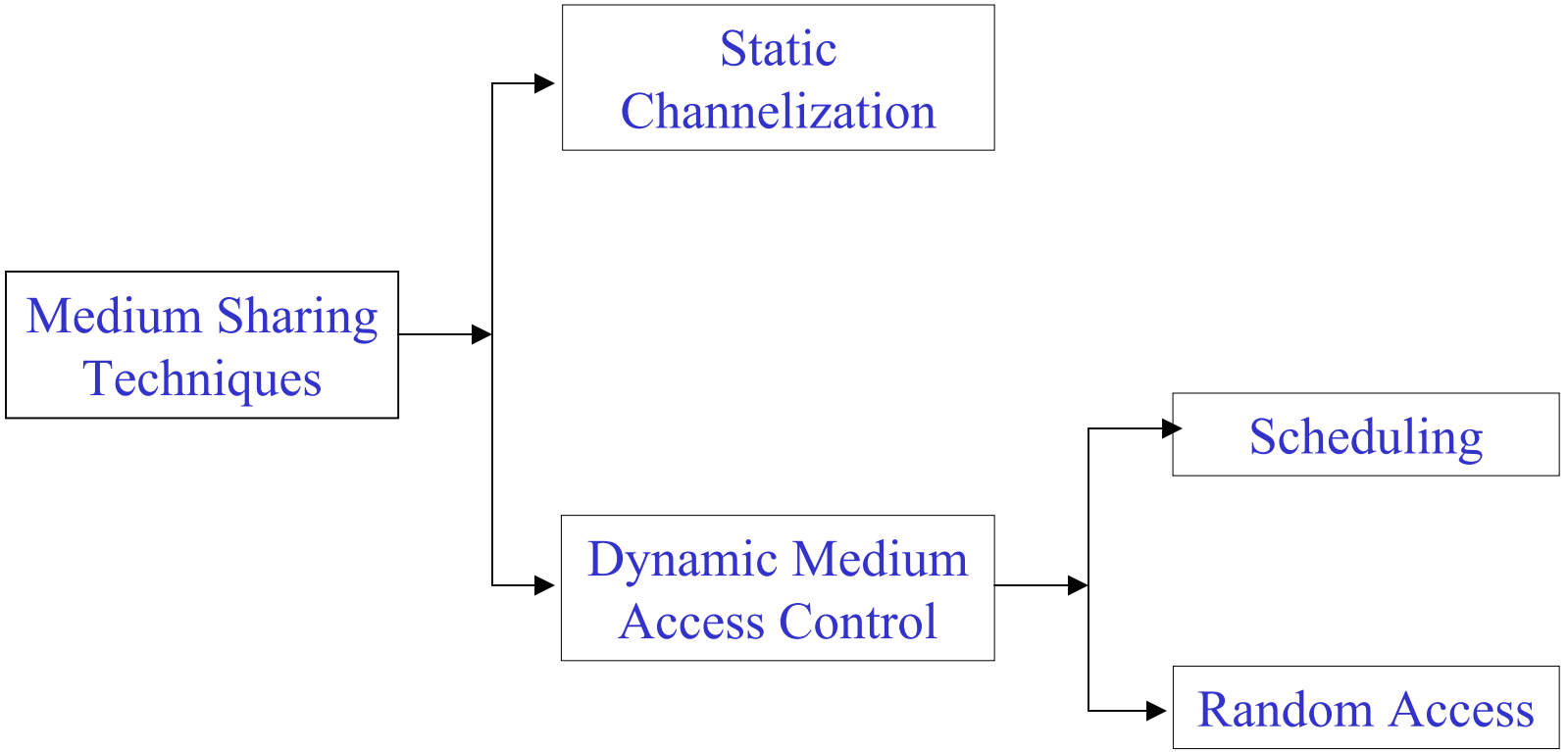


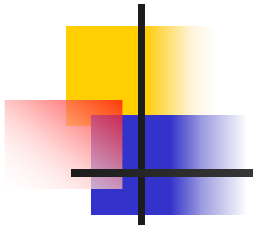


Introduction (Cont'd)

- Multiple access issues
  - If more than one node transmit at a time on the broadcast channel, a collision occurs
  - How to determine which node can transmit?
- Multiple access protocols
  - Solving multiple access issues
  - Different types:
    - Contention protocols resolve a collision after it occurs. These protocols execute a collision resolution protocol after each collision
    - Collision-free protocols (e.g., a bit-map protocol and binary countdown) ensure that a collision can never occur.

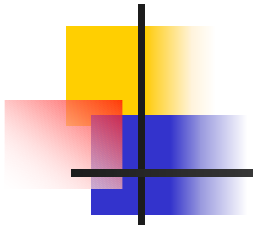
Medium Sharing Techniques





Contention Protocols

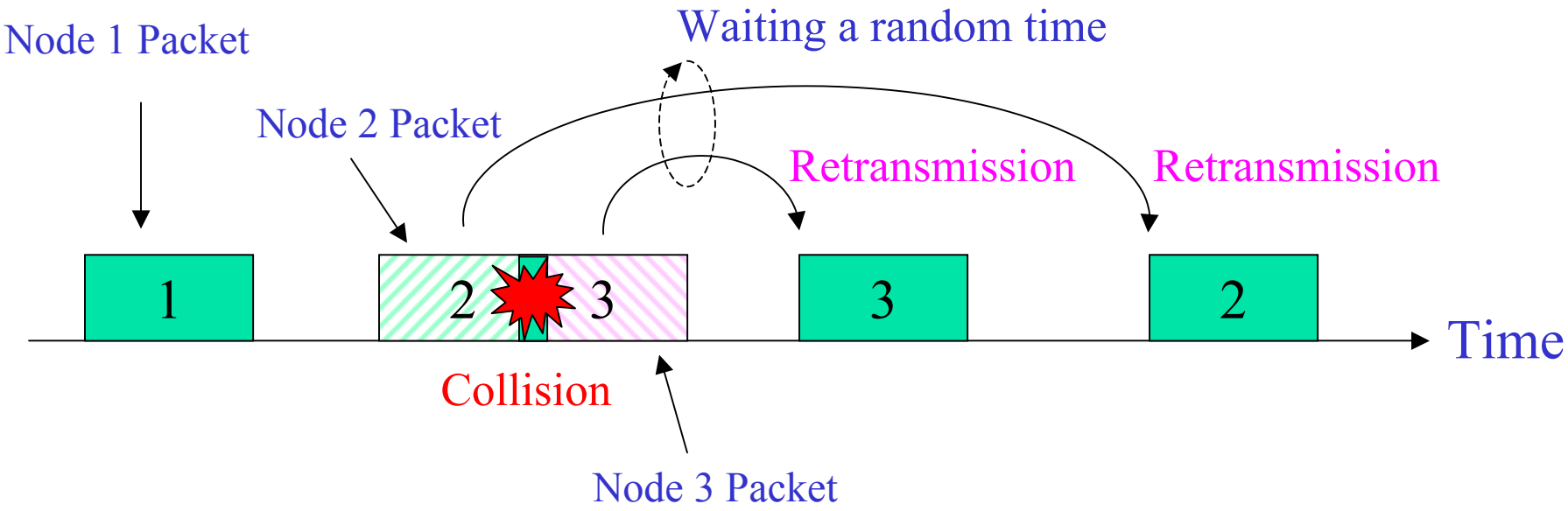
- **ALOHA**
  - Developed in the 1970s for a packet radio network by Hawaii University.
  - Whenever a station has a data, it transmits. Sender finds out whether transmission was successful or experienced a collision by listening to the broadcast from the destination station. Sender retransmits after some random time if there is a collision.
- **Slotted ALOHA**
  - Improvement: Time is slotted and a packet can only be transmitted at the beginning of one slot. Thus, it can reduce the collision duration.



Contention Protocols (Cont'd)

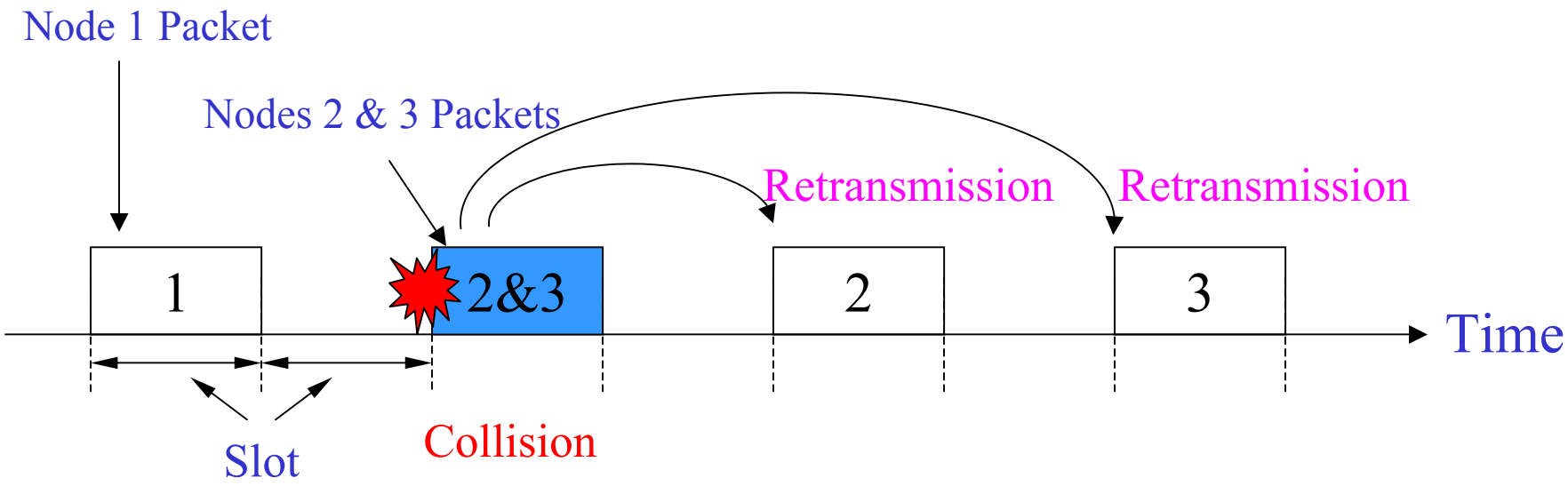
- **CSMA** (Carrier Sense Multiple Access)
  - Improvement: Start transmission only if no transmission is ongoing
- **CSMA/CD** (CSMA with Collision Detection)
  - Improvement: Stop ongoing transmission if a collision is detected
- **CSMA/CA** (CSMA with Collision Avoidance)
  - Improvement: Wait a random time and try again when carrier is quiet. If still quiet, then transmit
- **CSMA/CA with ACK**
- **CSMA/CA with RTS/CTS**

ALOHA



Collision mechanism in ALOHA

Slotted ALOHA



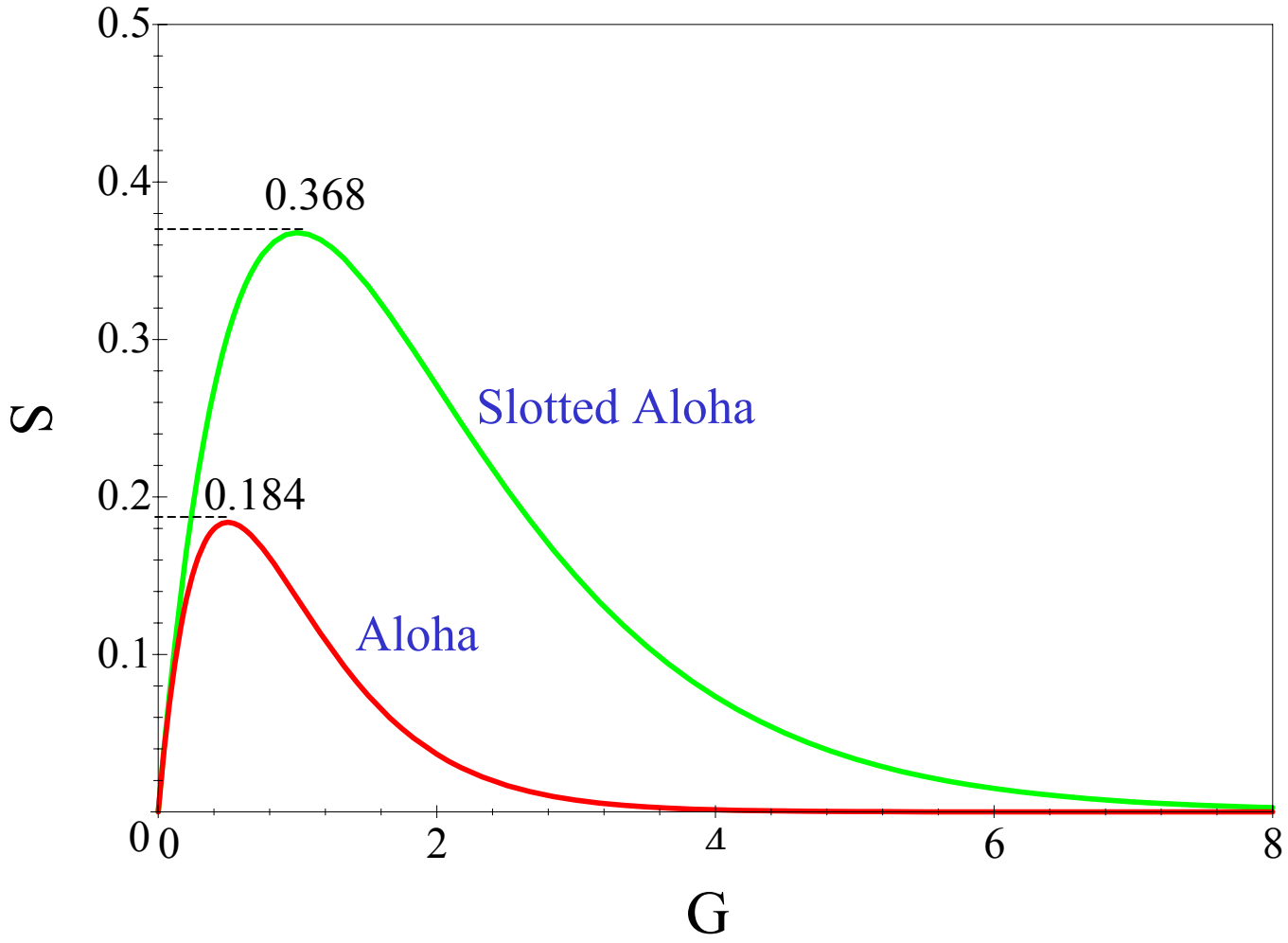
Collision mechanism in slotted ALOHA

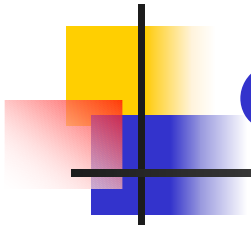
Performances of ALOHA and Slotted ALOHA

- Throughput ***S***:
  - Number of packets transmitted successfully per unit of time
- Model
  - Fixed packet length
  - Offered load *G*
  - Poisson arrival

- ALOHA: $S = G \cdot e^{-2G}$
- Slotted ALOHA: $S = G \cdot e^{-G}$

Throughput

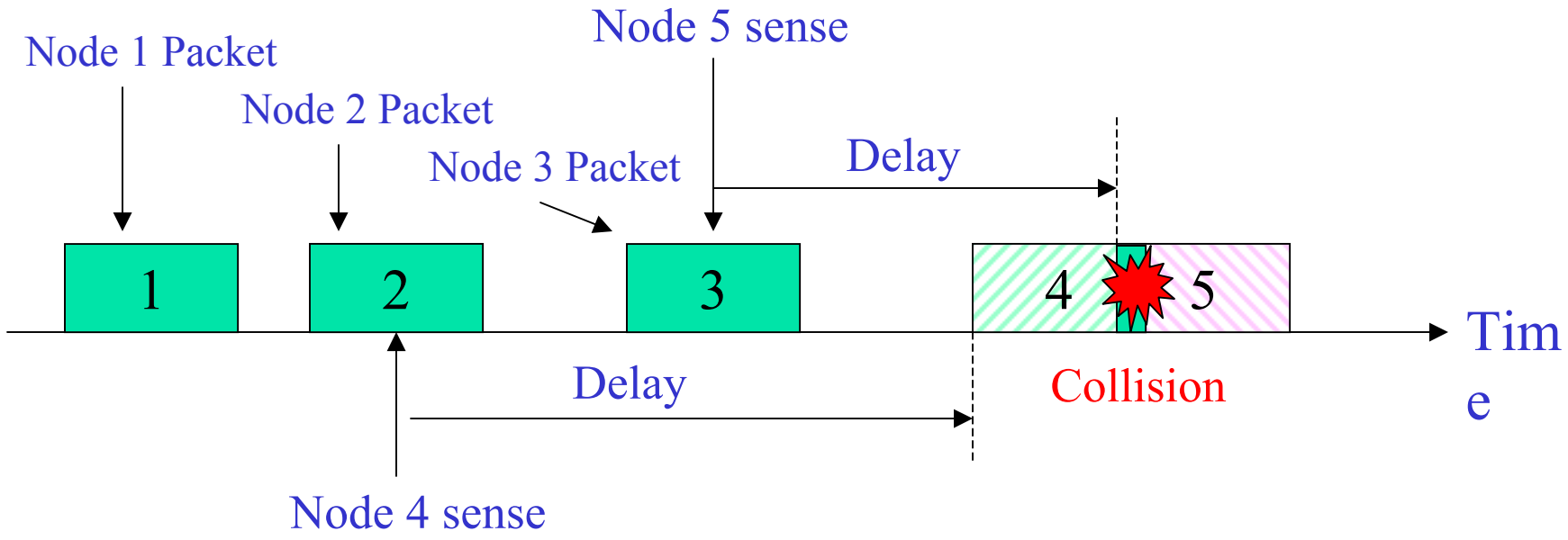




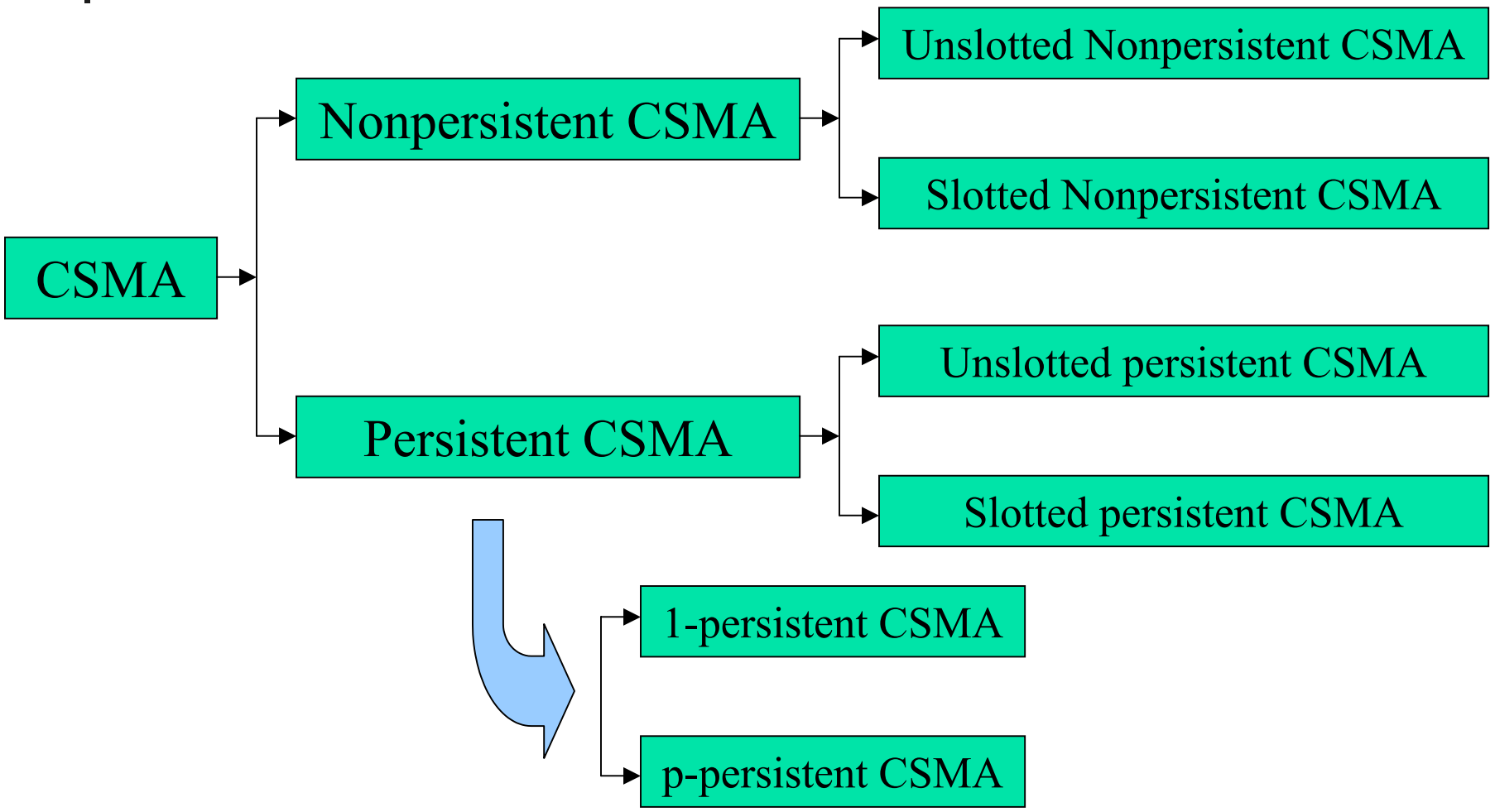
CSMA (Carrier Sense Multiple Access)

- Max throughput achievable by slotted ALOHA is 0.368.
- CSMA gives improved throughput compared to Aloha protocols.
- Listens to the channel before transmitting a packet (avoid avoidable collisions).

Collision Mechanism in CSMA



Kinds of CSMA



Nonpersistent/x-persistent CSMA Protocols

- Nonpersistent CSMA Protocol:

Step 1: If the medium is idle, transmit immediately

Step 2: If the medium is busy, wait a random amount of time and repeat **Step 1**

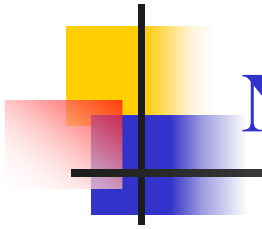
  - Random backoff reduces probability of collisions
  - Waste idle time if the backoff time is too long

- 1-persistent CSMA Protocol:

Step 1: If the medium is idle, transmit immediately

Step 2: If the medium is busy, continue to listen until medium becomes idle, and then transmit immediately

  - There will always be a collision if two nodes want to retransmit



Nonpersistent/x-persistent CSMA Protocols

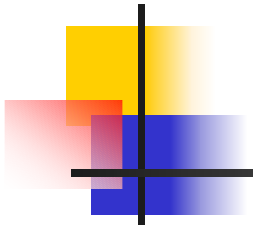
- p-persistent CSMA Protocol:

  Step 1: If the medium is idle, transmit with probability p, and delay for one propagation delay with probability (1-p)

  Step 2: If the medium is busy, continue to listen until medium becomes idle, then go to **Step 1**

  Step 3: If transmission is delayed by one time slot, continue with **Step 1**

  - A good tradeoff between nonpersistent and 1-persistent CSMA

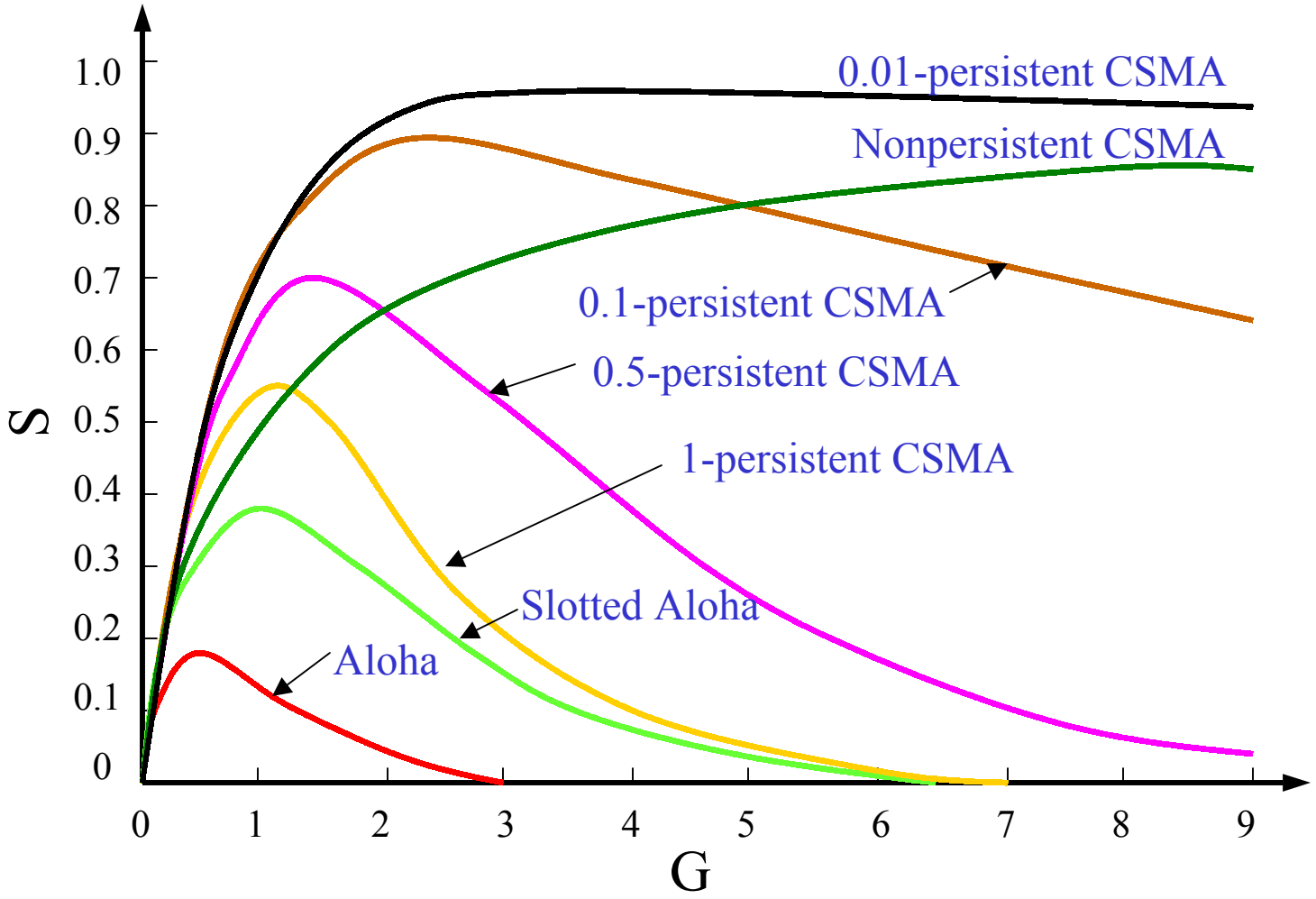


How to Select Probability *p* ?

- Assume that *N* nodes have a packet to send and the medium is busy
- *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 $Np < 1$, where *N* is the maximum number of nodes that can be active at a time

Throughput



CSMA/CD (CSMA with Collision Detection)

- In CSMA, if 2 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/CD

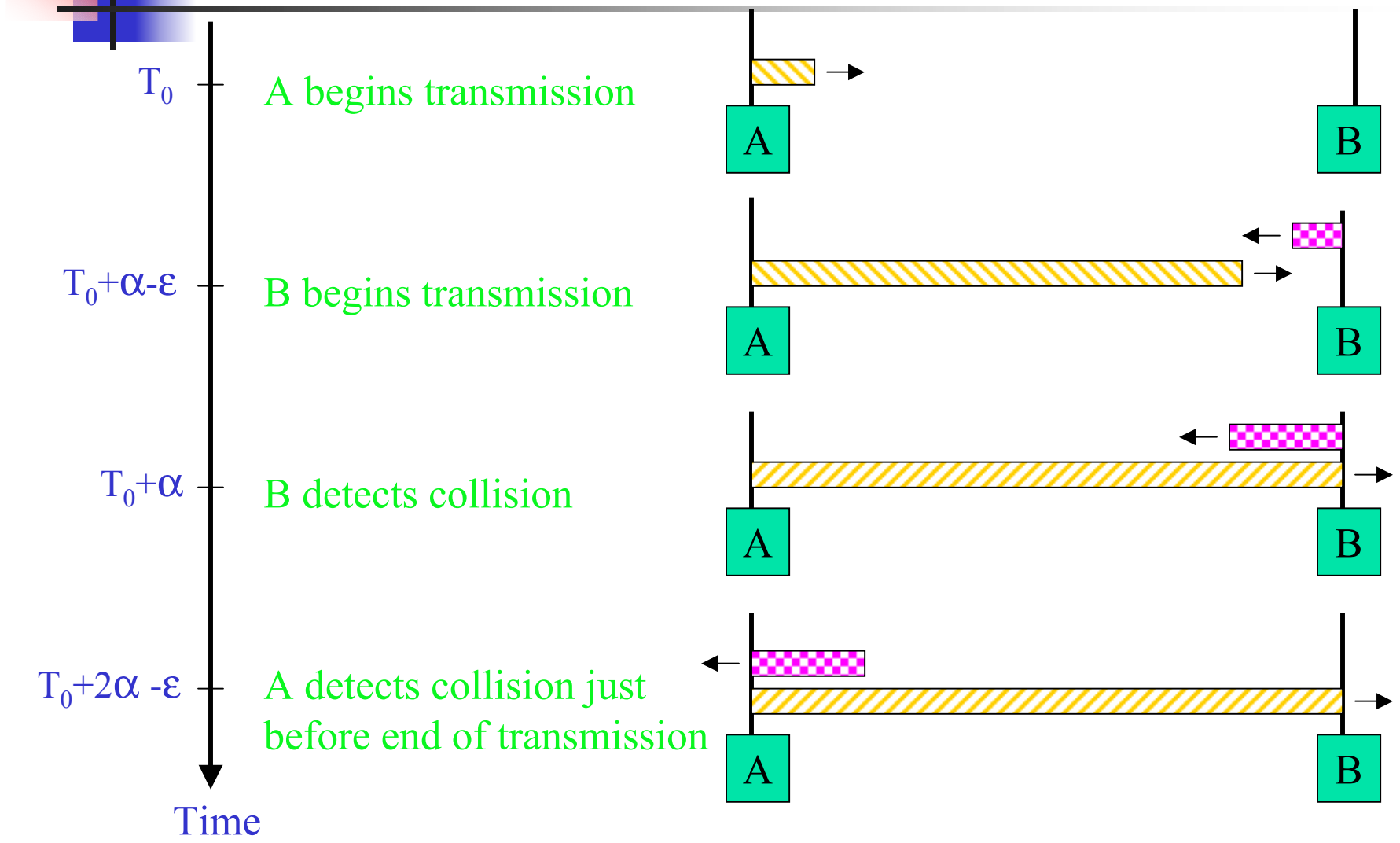
  Step 1: If the medium is idle, transmit

  Step 2: If the medium is busy, continue to listen until the channel is idle then transmit

  Step 3: If a collision is detected during transmission, cease transmitting

  Step 4: Wait a random amount of time and repeats the same algorithm

CSMA/CD (Cont'd)

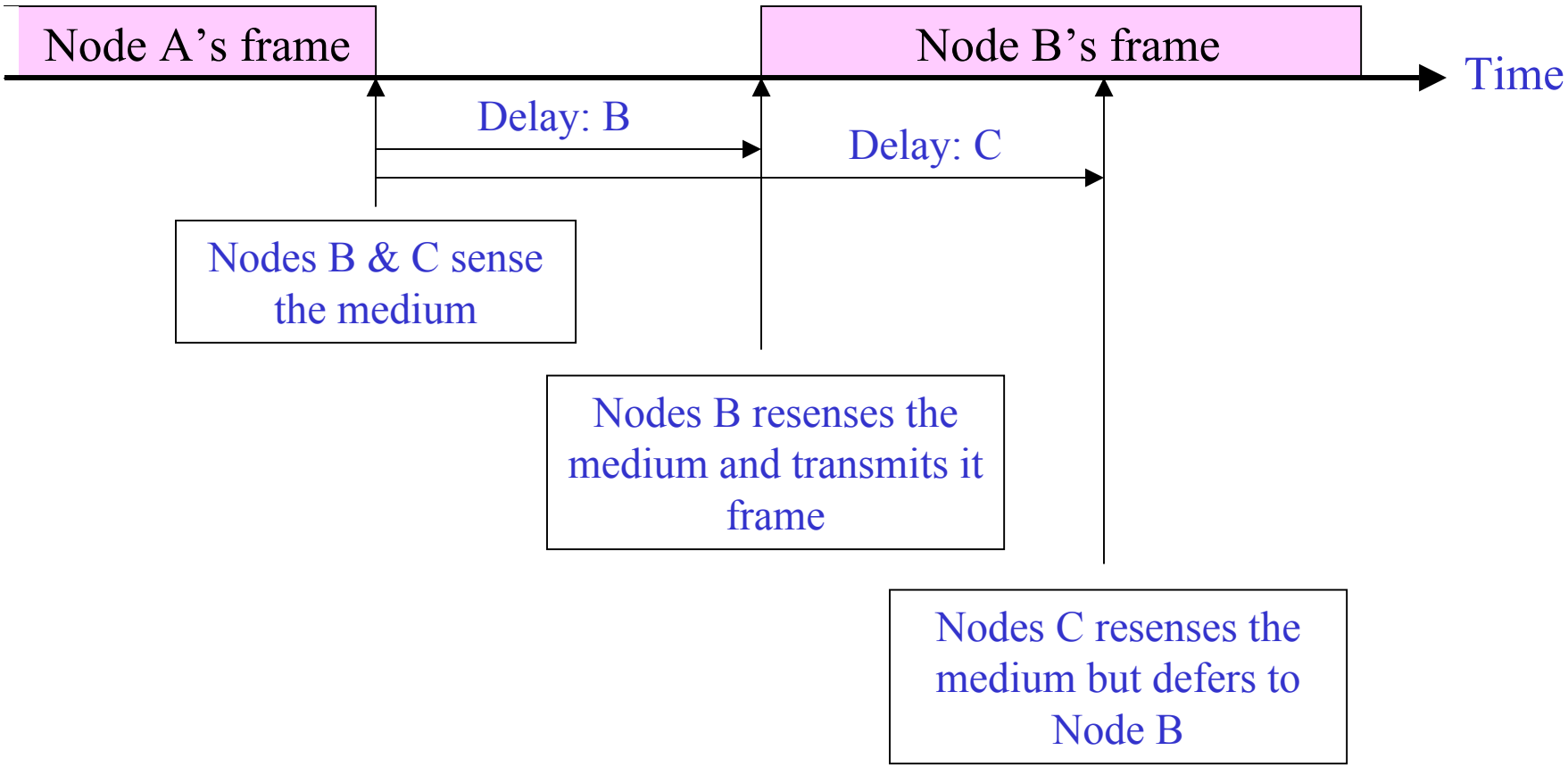


(α is the propagation time)

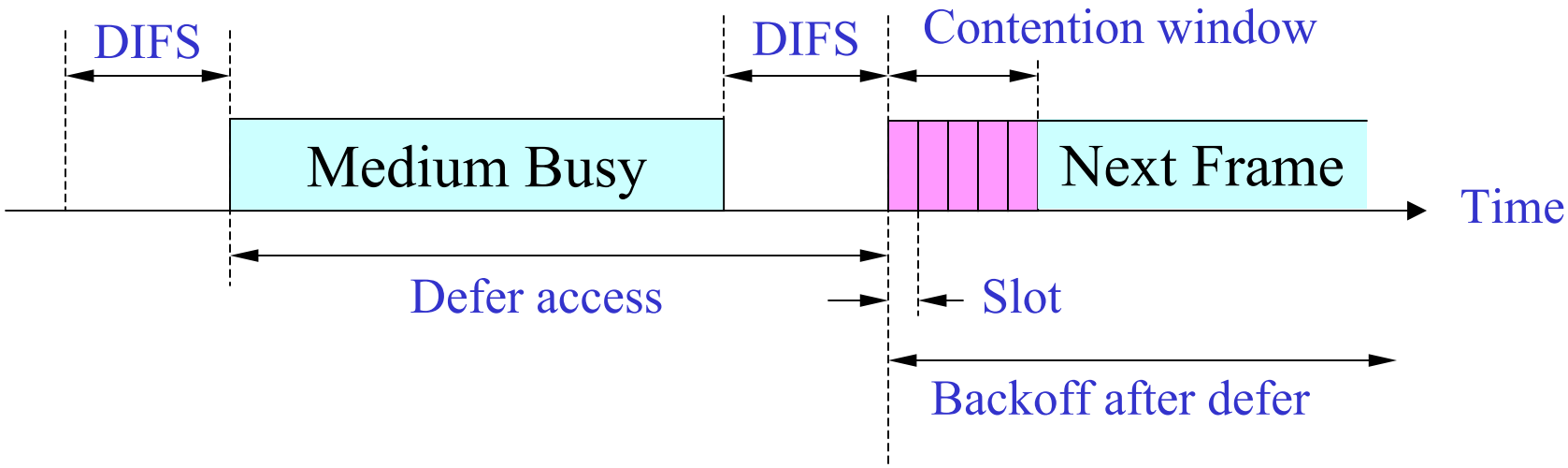
CSMA/CA (CSMA with collision Avoidance)

- All terminals listen to the medium same as CSMA/CD.
- Terminal ready to transmit senses the medium.
- If medium is busy it waits until the end of current transmission.
- It again waits for an additional predetermined time period DIFS (Distributed inter frame Space).
- Then picks up a random number of slots (the initial value of backoff counter) within a contention window to wait before transmitting its frame.
- If there are transmissions by other terminals during this time period (backoff time), the terminal freezes its counter.
- It resumes count down after other terminals finish transmission + DIFS. The terminal can start its transmission when the counter reaches to zero.

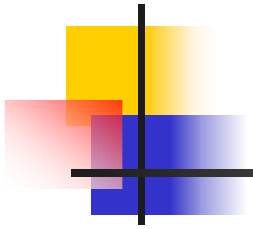
CSMA/CA (Cont'd)



CSMA/CA Explained



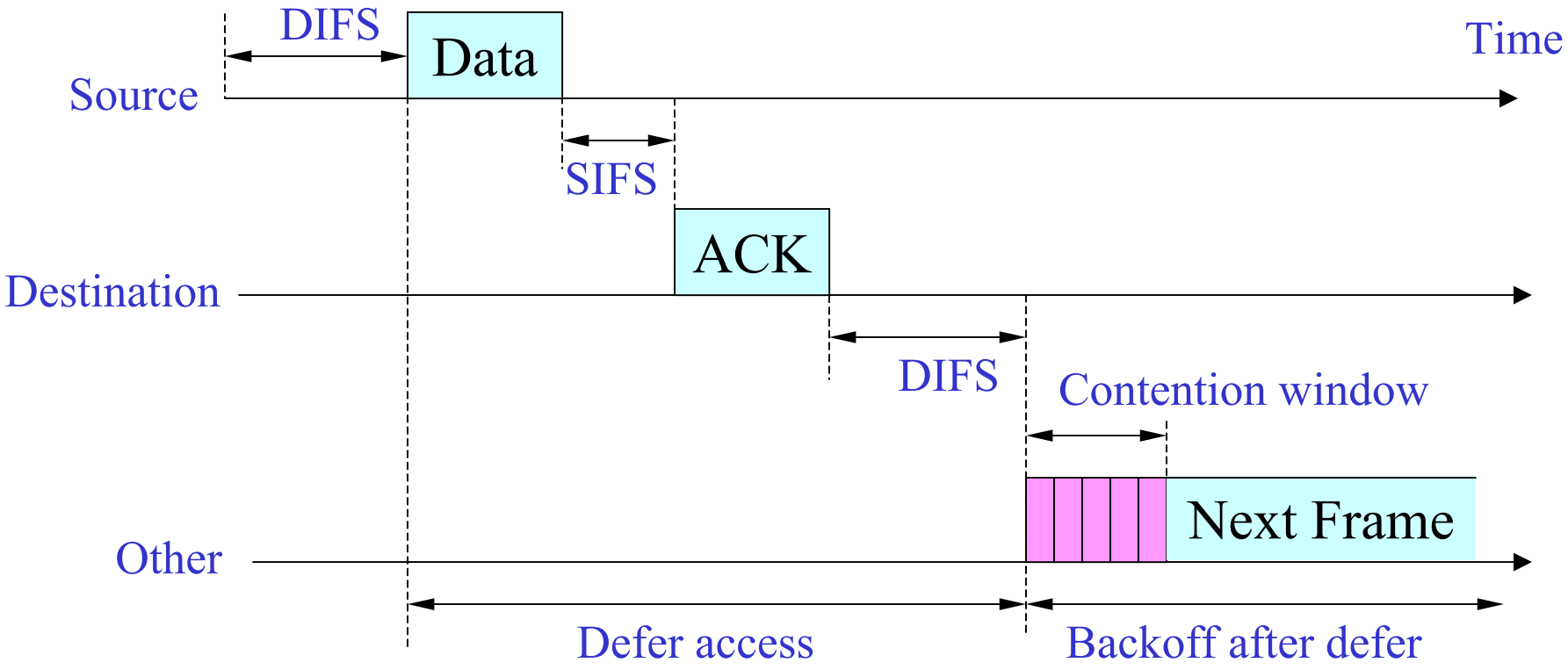
DIFS – Distributed Inter Frame Spacing



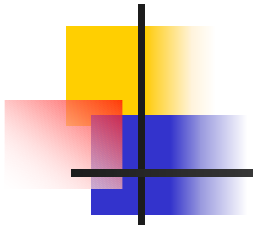
CSMA/CA with ACK

- Immediate Acknowledgements from receiver upon reception of data frame.
- ACK frame transmitted after time interval SIFS (*Short Inter-Frame Space*) (*SIFS < DIFS*)
- Receiver transmits ACK without sensing the medium.
- If ACK is lost, retransmission done.

CSMA/CA/ACK



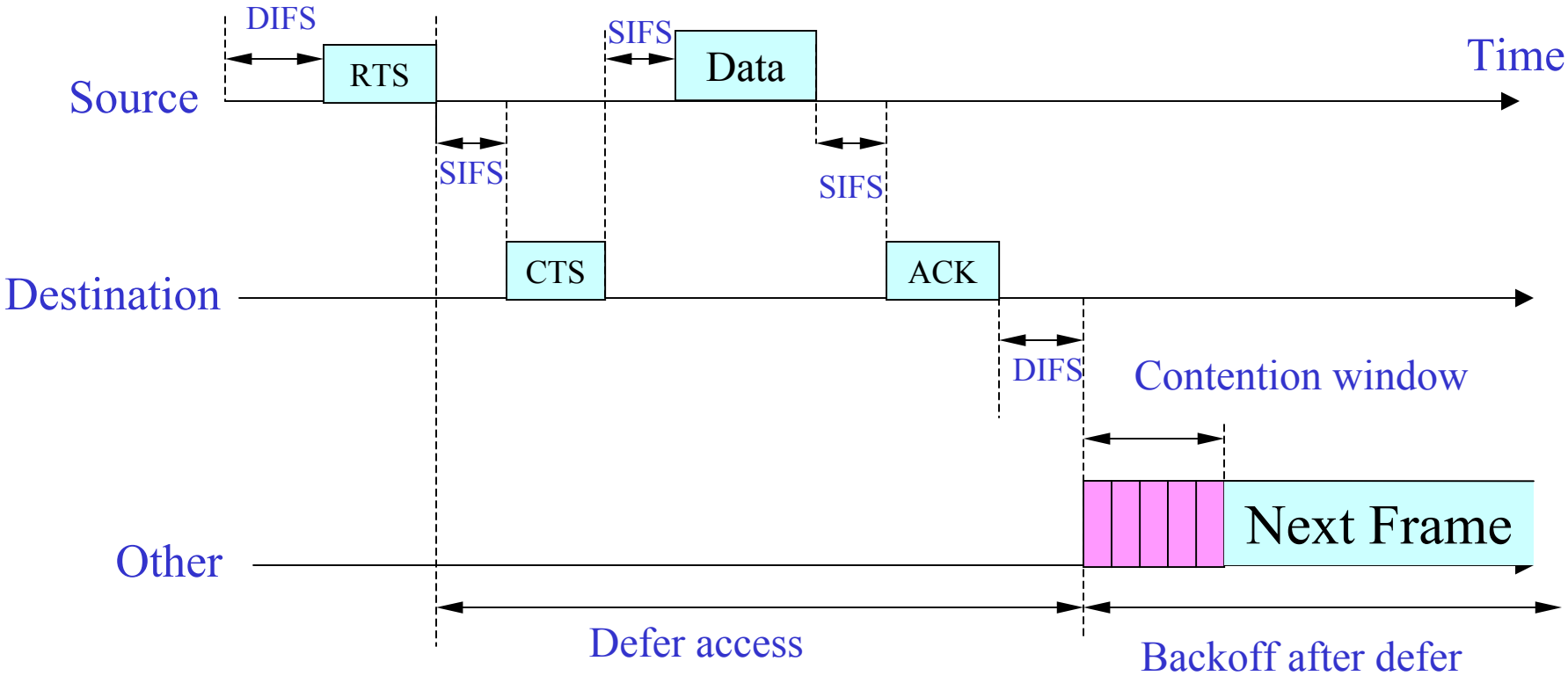
SIFS – Short Inter Frame Spacing



CSMA/CA with RTS/CTS

- Transmitter sends an RTS (request to send) after medium has been idle for time interval more than DIFS.
- Receiver responds with CTS (clear to send) after medium has been idle for SIFS.
- Then Data is exchanged.
- RTS/CTS is used for reserving channel for data transmission so that the collision can only occur in control message.

CSMA/CA with RTS/CTS (Cont'd)



RTS/CTS