CN (IT-3001)

Data Link Layer: MAC Protocol

Prof. Amit Jha

School of Electronics Engineering (SOEE)

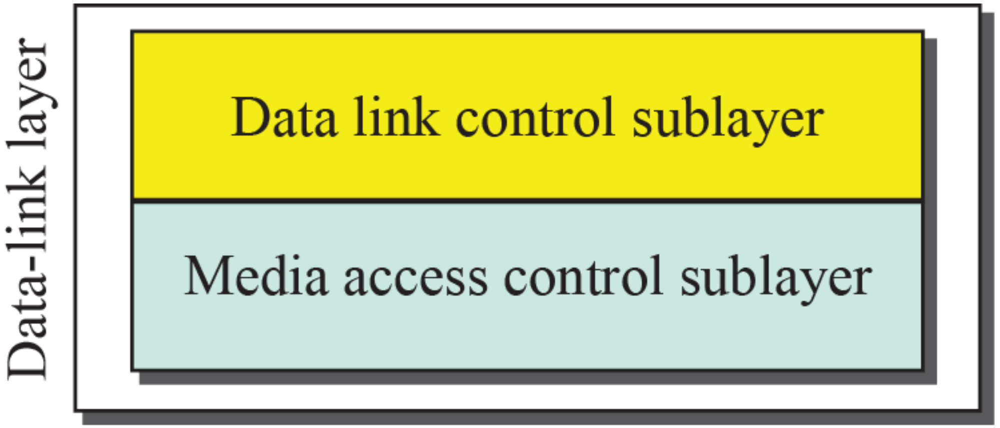
KIIT Deemed to be University

Objective

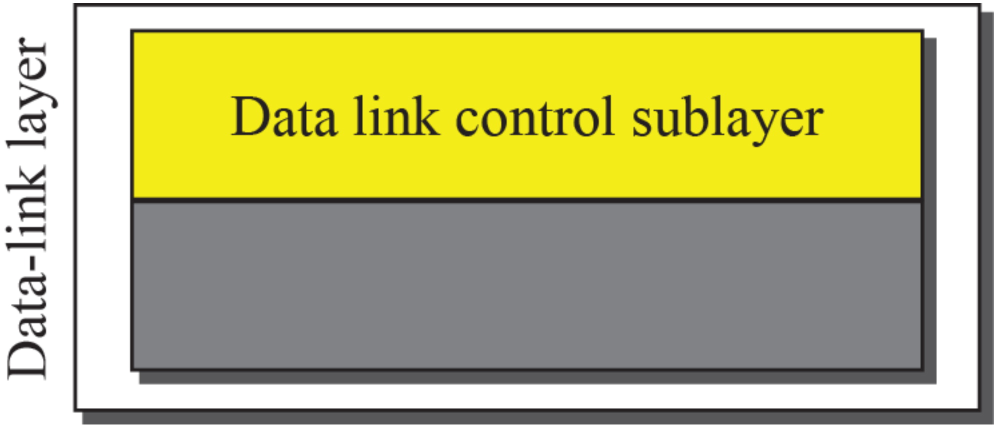
- Media Access/Multiple Access
  - Random Access
    - ALOHA
    - CSMA
    - CSMA/CD
    - CSMA/CA
- Controlled Access
  - Resevation
  - Polling
  - Token passing
- Cahnnelization
  - FDMA
  - TDMA
  - CDMA

Two Sublayers of the Data-Link-Layer

- The data link layer is divided into two sublayers as shown below.
  1. Data Link Control (DLC) sublayer
  2. Media Access Control (MAC) Sublayer



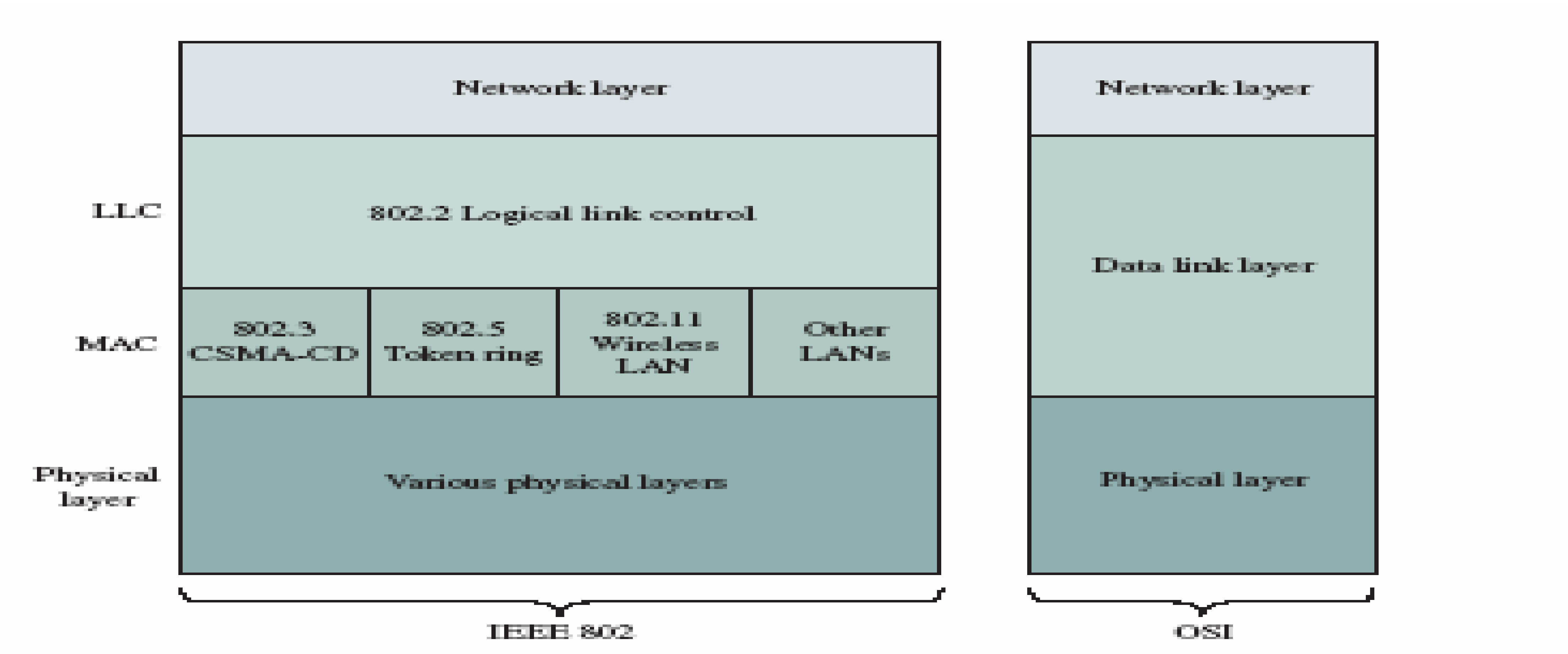
a. Data-link layer of a broadcast link



b. Data-link layer of a point-to-point link

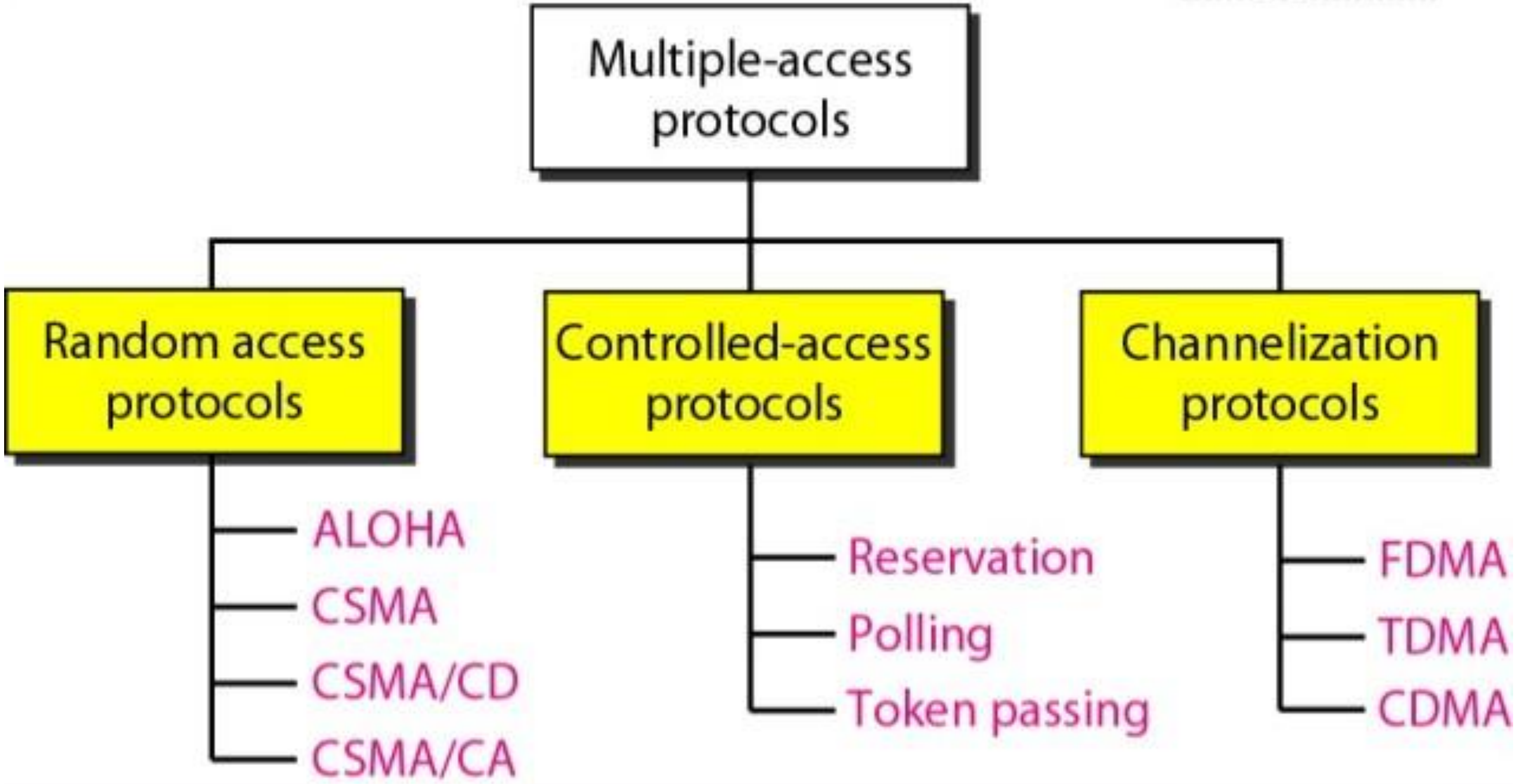
- The upper sublayer that is responsible for flow and error control is called the ***logical link control*** (LLC) layer.
- The lower sublayer that is mostly responsible for multiple access resolution is called the ***media access control*** (MAC) layer.
- **Why do we need multiple-access protocol?**

Ans: In a broadcast or multipoint, nodes use a common link. To use this common link efficiently, we need a multiple-access protocol to coordinate access to the link.



Network layer
LLC
802.2 Logical link control
MAC
802.3 CSMA-CD
802.5 Token ring
802.11 Wireless LAN
Other LANs
Physical layer
Various physical layers
IEEE 802
Network layer
Data link layer
Physical layer
OSI

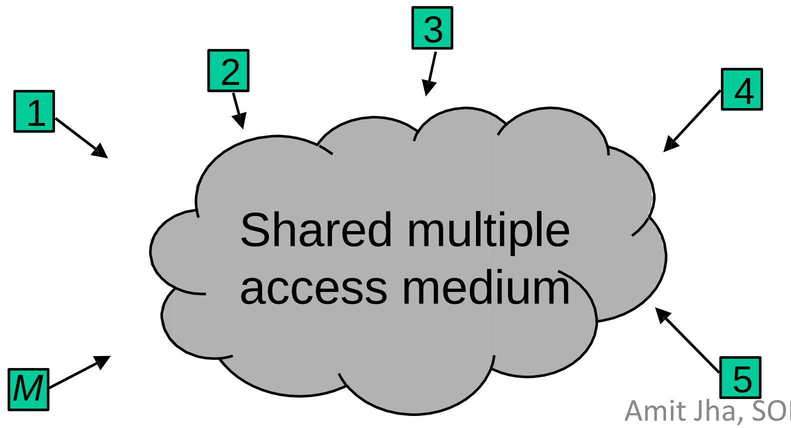
Types of Multiple-Access Protocol/ MAC Protocol



Random Access Protocol

- Why the name *random access*?
  - There is no scheduled time for a station to transmit.
  - Transmission is random among the stations.
  - No station is superior to another station and none is assigned the controlled over another.
- In a random access method, each station has the right to the medium without being controlled by any other station. However, if more than one station tries to send, there is an access conflict-collision-and the frames will be either destroyed or modified.

- To avoid access conflict or to resolve it when it happens, each station follows a procedure that answers the following questions:
  - When can the station access the medium?
  - What can the station do if the medium is busy?
  - How can the station determine the success or failure of the transmission?
  - What can the station do if there is an access conflict?



ALOHA: Pure ALOHA

- Based upon the simplest solution: **just do it**
  - A station transmits whenever it has data to transmit.
  - If more than one frames are transmitted, they interfere with each other (collide) and are lost.
  - If ACK not received within timeout, then a station picks **random back-off time** (to avoid repeated collision).
  - Station retransmits frame after back-off time denoted as T_B
- **Note:** A collision involves two or more stations. If all these stations try to resend their frames after the time-out, the frames will collide again.
- After a maximum number of retransmission attempts K_{max} a station must give up and try later.

Four stations transmitting 2 frames each.

Out of all the frames, only two frames survive: frame 1.1 and frame 3.2

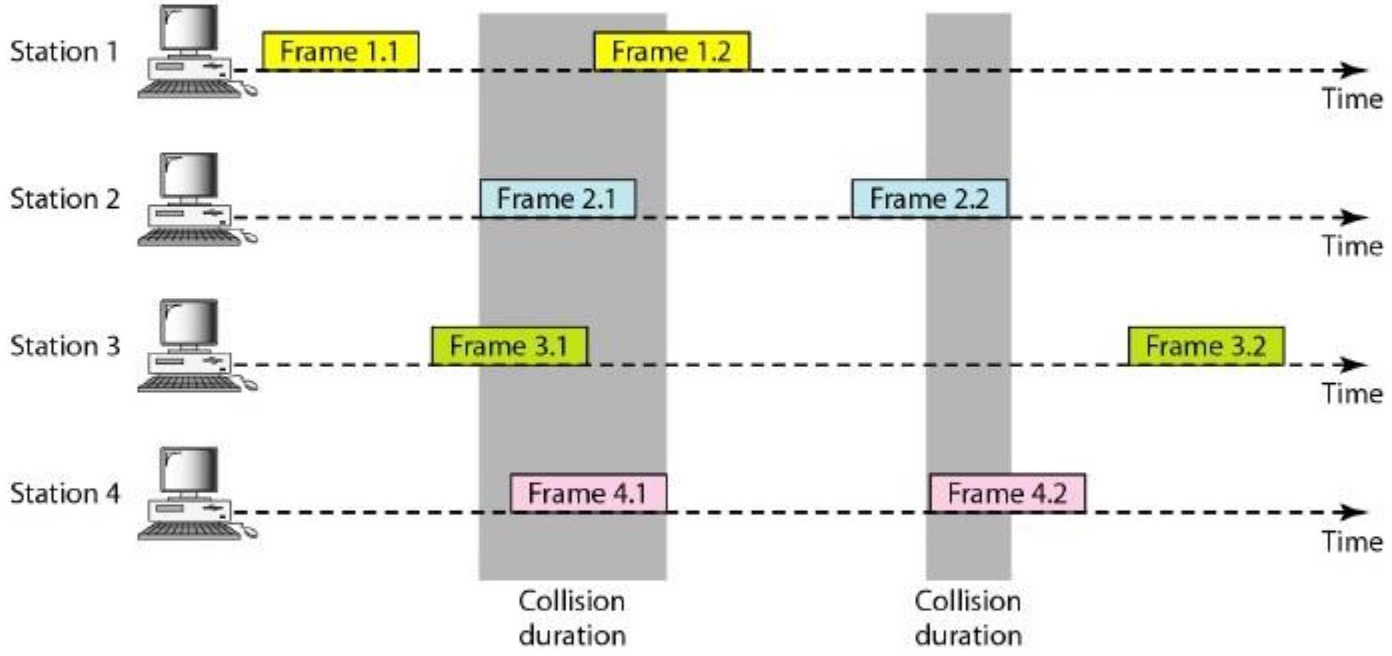
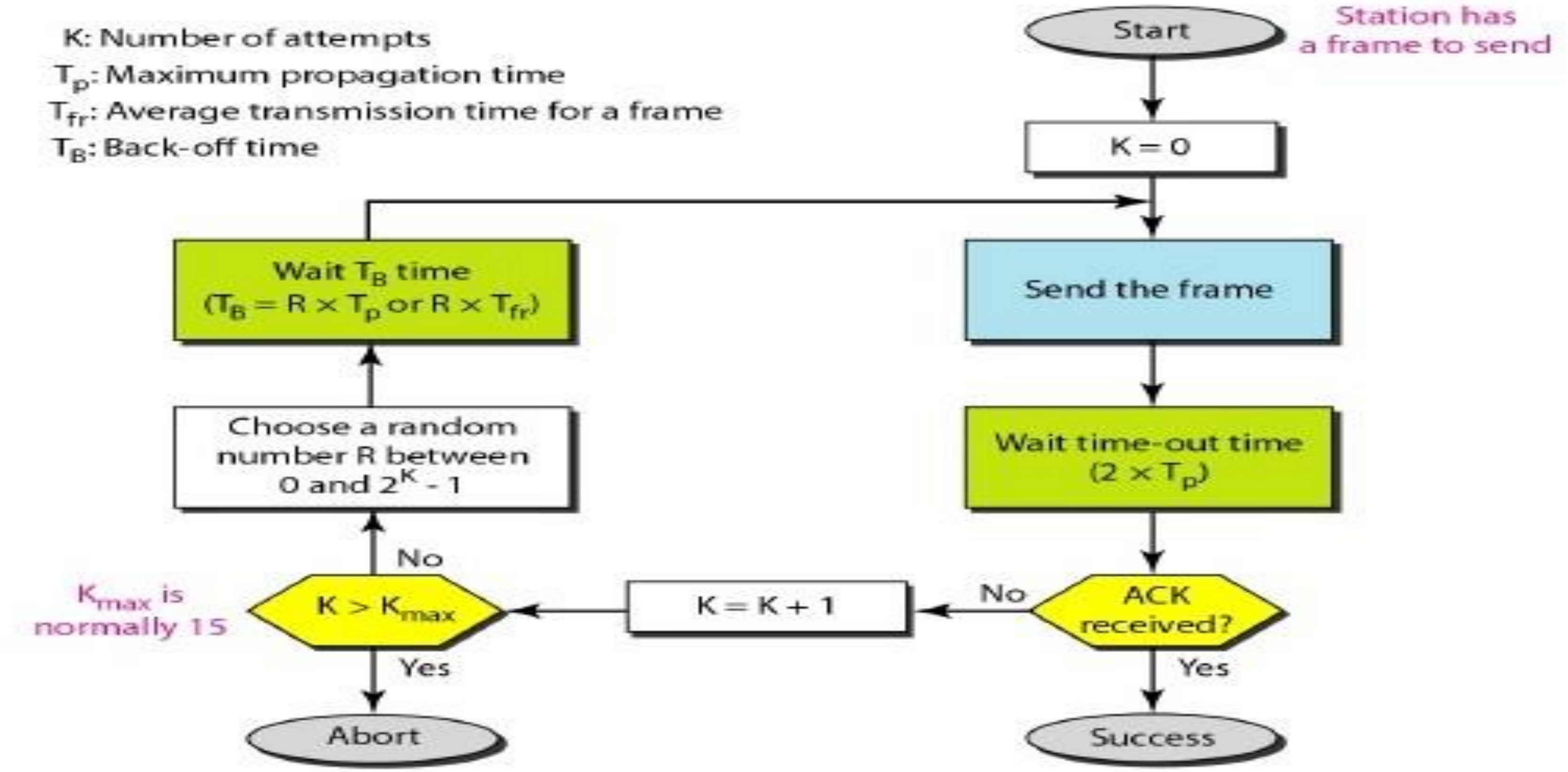


Fig. Example of frame collisions in pure ALOHA

Procedure for pure ALOHA protocol



Note: R is a random number chosen from the range 0 to $2^k - 1$, and value of the random number increases after each collision.

Example 1: The stations on a wireless ALOHA network are a maximum of 600 km apart. If we assume that signals propagate at $3 \times 10^8\ m/s$, we find T_P = (600 x 10^3) / (3 x 10^8) = 2 *ms*. Now we can find the value of T_B for different values of *K*.

a) *For K=1, the range of R is {0, 1}. The station needs to generate a random number with value 0 or 1. So,* T_B *is either 0 or 2ms, based on outcome of the random variable.*
b) *For K=2, the range of R is {0, 1, 2, 3}. So,* T_B *can be 0, 2, 4 or 6ms, based on outcome of the random variable.*
c) *For K=3, the range of R is {0, 1, 2, 3, …, 7}. So,* T_B *is can be 0, 2, 4, 6, 8, 10, 12, or 14ms, based on outcome of the random variable.*
d) *So on……………*
e) *We need to mention that if k >10, it is normally set to 10.*

Vulnerable time: It is the time duration , in which there is a possibility of collision. **Vulnerable time in pure ALOHA = $2 \times T_{fr}$**

$T_{fr} = frame\ transmission\ time$

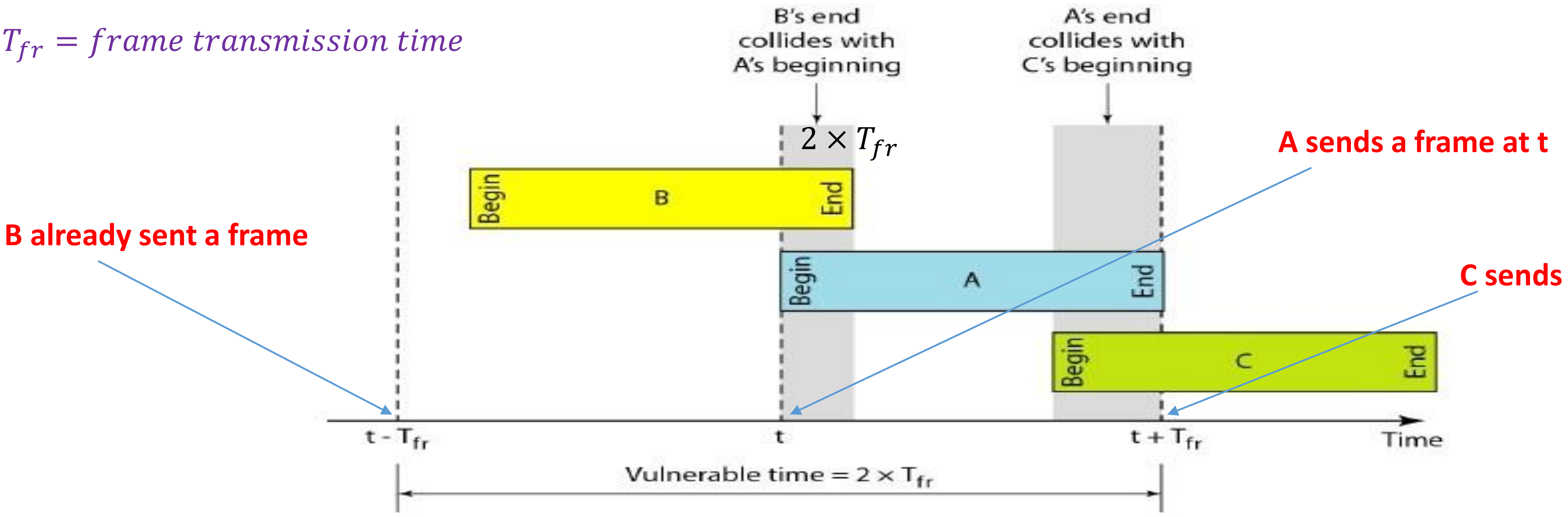


Fig: Vulnerable time for pure ALOHA

Example 2: A pure ALOHA network transmits 200-bit frames on a shared channel of 200 kbps. What is the requirement to make this frame collision-free?

Sol:

Average frame transmission time T_{fr} *is 200 bits/200 kbps or 1 ms. The vulnerable time is 2 x1 ms =2 ms.*
This means no station should send later than 1 ms before this station starts transmission and no station should start sending during the one 1-ms period that this station is sending.

Pure ALOHA Model

- Definitions and assumptions
  - T_{fr} frame transmission time (assume constant)
  - S: throughput (average # successful frame transmissions per T_{fr} seconds)
  - G: load (average # transmission attempts per T_{fr} sec.)
  - $P_{success}$: probability a frame transmission is successful

Note: Any transmission that begins during vulnerable period leads to collision. Success if and only if no arrivals during 2 T_{fr} seconds.

Throughput is given by,

$$\boxed{S = GP_{success}}$$

Abramson's assumption for calculation of $P_{Success}$

- *What is probability of no arrivals in vulnerable period?*

- **Abramson's assumption:** Effect of back-off algorithm is that frame arrivals are equally likely to occur at any time interval.

- G is avg. # arrivals per T_{fr} seconds
- Divide T_{fr} into n intervals of duration $\Delta = T_{fr}/n$
- p = probability of arrival in Δ interval, then

$G = n\,p$ since there are n intervals in T_{fr} seconds

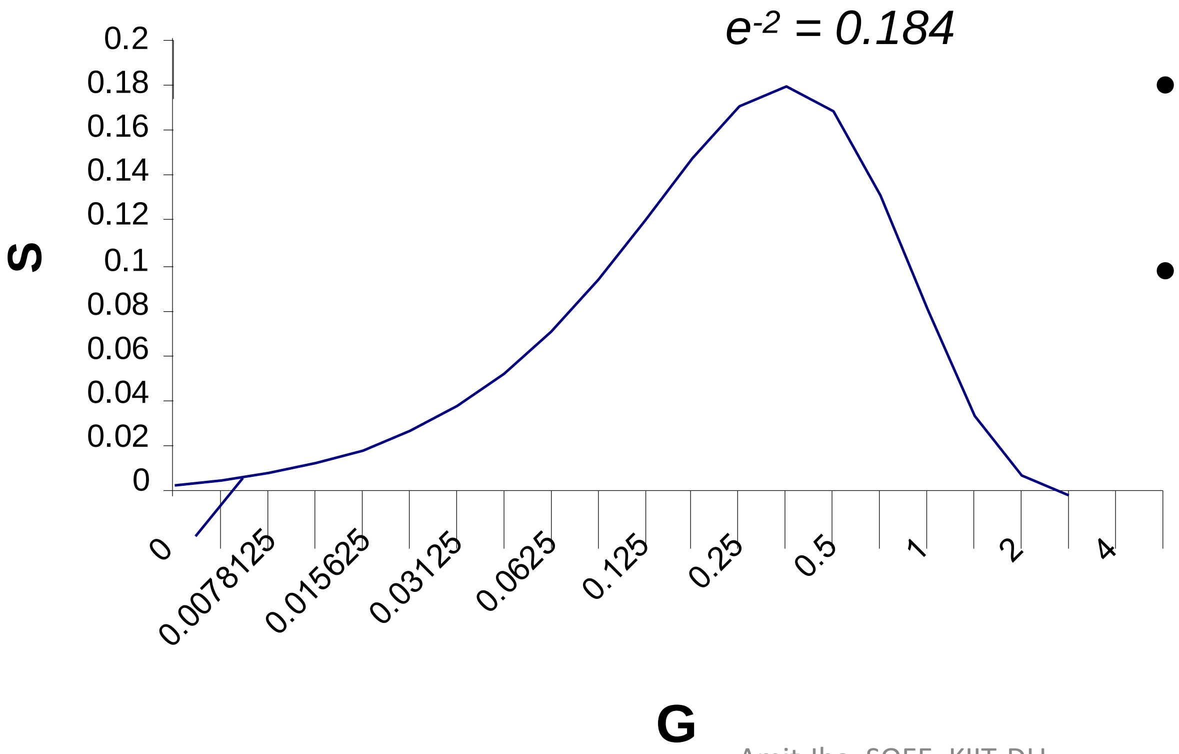
$$P_{success} = P[0 \text{ arrivals in } 2T_{fr} \text{ seconds}] =$$

$$= P[0 \text{ arrivals in 2n intervals}]$$ ....**Abramson's assumption:**

$$= (1-p)^{2n} = \left(1 - \frac{G}{n}\right)^{2n} \rightarrow \boldsymbol{e}^{-2G} \quad \text{as n} \rightarrow \infty$$

Throughput of ALOHA

$$S = GP_{success} = Ge^{-2G}$$



- Collisions are means for coordinating access
- Max throughput is $\rho_{max} = 1/2e$ *(18.4%)*
- Bimodal behavior:
  Small G, S≈G
  Large G, S↓0

Use basic maths

Example 3: A pure ALOHA network transmits 200-bit frames on a shared channel of 200 kbps. What is the throughput if the system (all stations together) produces

a. 1000 frames per second

b. 500 frames per second

c. 250 frames per second

Sol: $Here,\ T_{fr}$ *is 200 bits/200 kbps or 1 ms.*

a. If the system creates 1000 frames per second, this is 1 frame per millisecond. The load is 1. In this case S = $G \times e^{-2G}$ or S =0.135 (13.5 percent). This means that the throughput is 1000 X 0.135 =135 frames. Only 135 frames out of 1000 will probably survive.

b. If the system creates 500 frames per second, this is (1/2) frame per millisecond. The load is *(1/2)*. In this case S = $G \times e^{-2G}$ or S = 0.184 (18.4 percent). This means that the throughput is 500 x 0.184 = 92 and that only 92 frames out of 500 will probably survive. Note that this is the maximum throughput case, percentagewise.

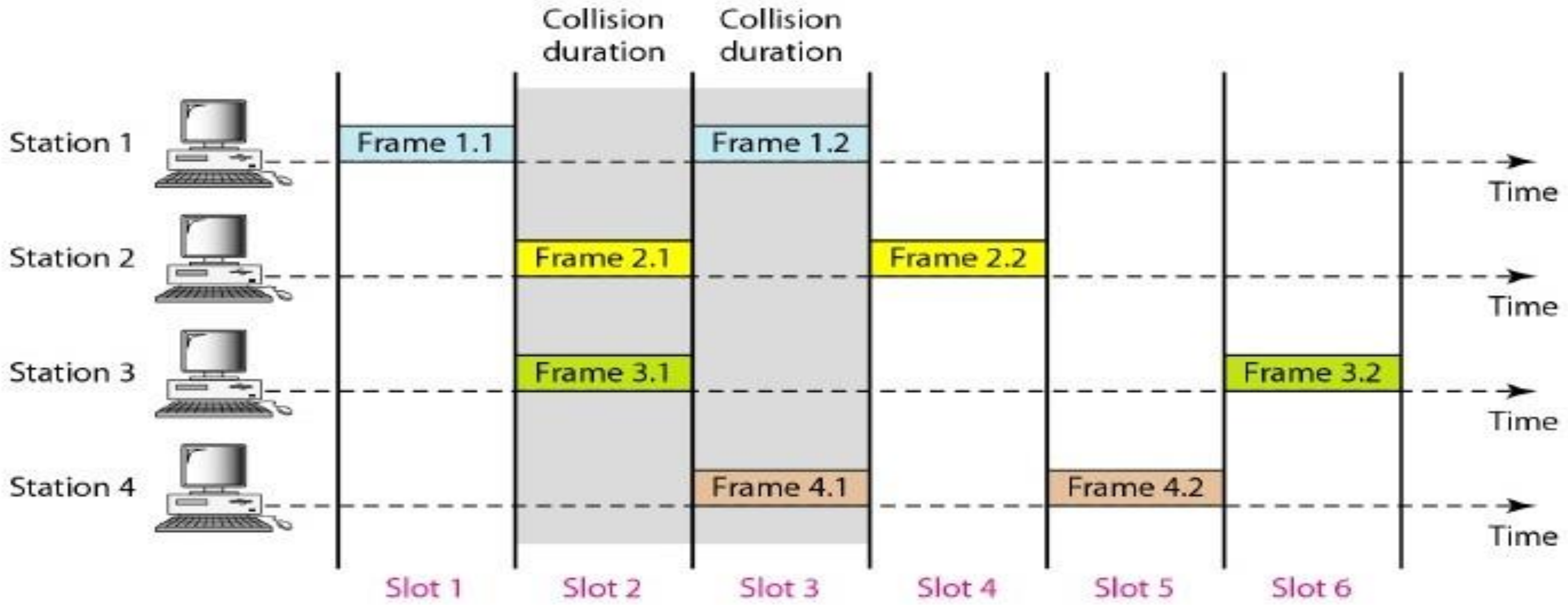
c. If the system creates 250 frames per second, this is (1/4) frame per millisecond. The load is (1/4). In this case S = $G \times e^{-2G}$ or S =0.152 (15.2 percent). This means that the throughput is 250 x 0.152 = 38. Only 38 frames out of 250 will probably survive.

Slotted ALOHA

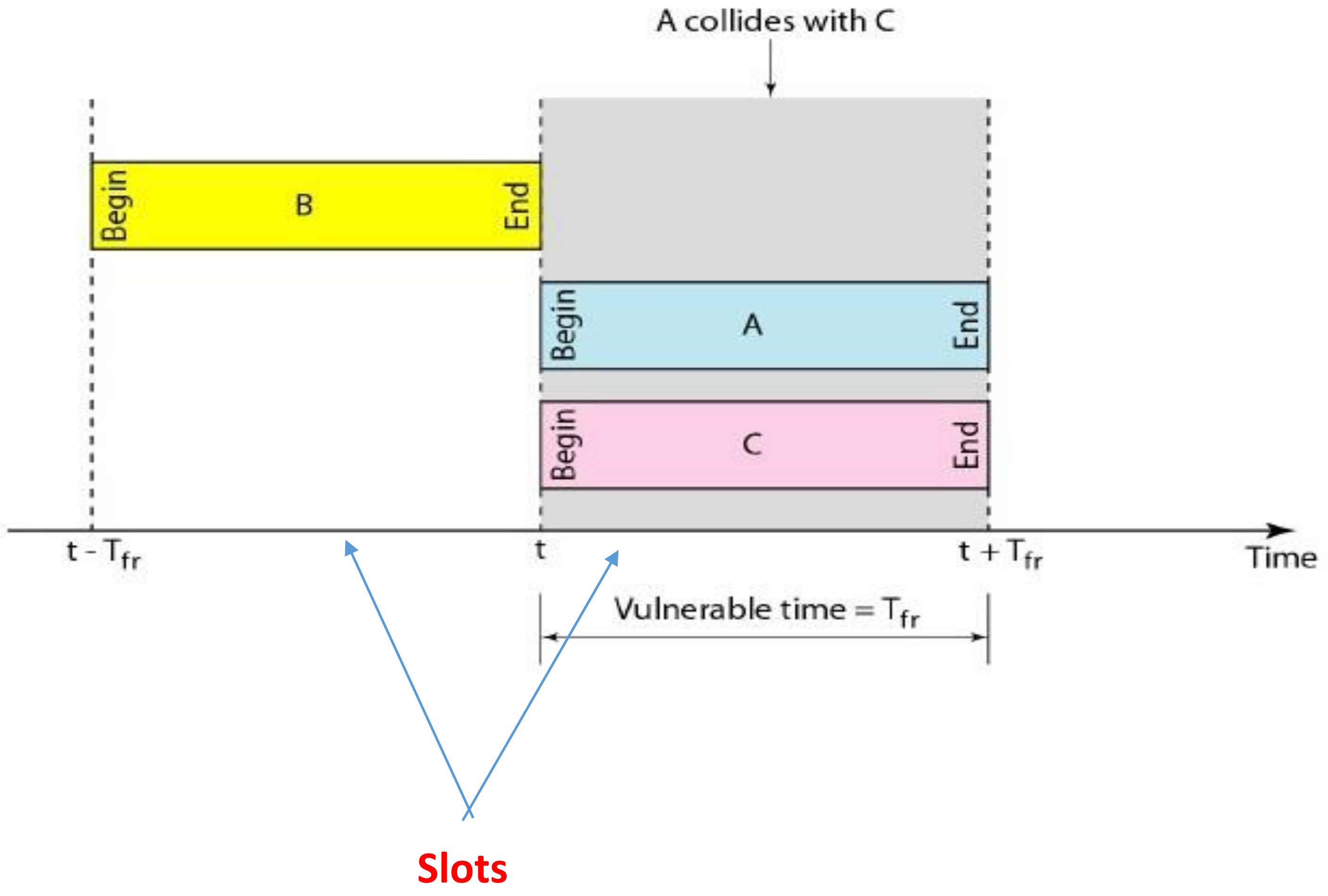
Time is slotted in T_{fr} seconds slots Stations synchronized to frame times

Stations transmit frames in first slot after frame arrival

Backoff intervals are in multiples of slots



Vulnerable time for slotted aloha



Throughput of Slotted ALOHA

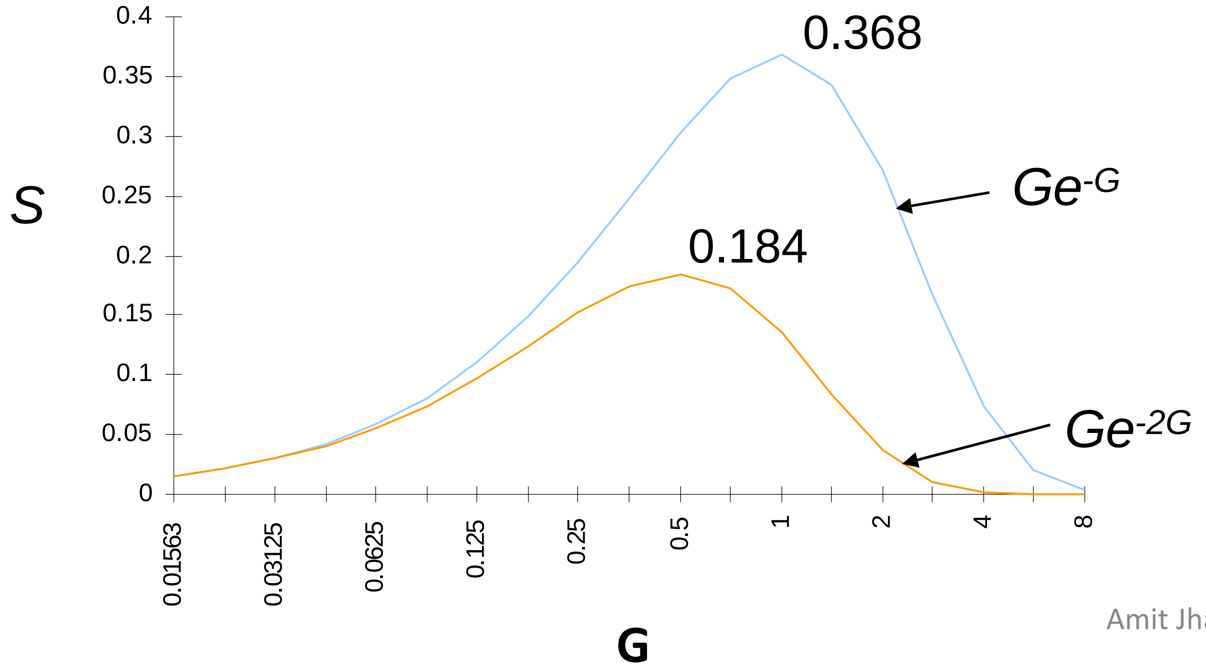
$$P_{success} = P[0 \text{ arrivals in } T_{fr} \text{ seconds}]$$

$$= P[0 \text{ arrivals in n intervals}] \quad \ldots\textbf{Abramson's assumption}$$

$$= (1-P)^n = \left(1 - \frac{G}{n}\right)^n$$

$$\rightarrow \boldsymbol{e^{-G}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{as } n \rightarrow \infty$$

$$\boxed{\therefore S = GP_{Success} = Ge^{-G}}$$



Limitations of ALOHA

The throughput for pure ALOHA is S =G x *e*-*2G*.
The maximum throughput S_{max} = 0.184 when G =(1/2).

The throughput for slotted ALOHA is *S* = G x *e*-G.
The maximum throughput S_{max} = 0.368 when G =1.

Homework:1) Repeat Example 3 for slotted ALOHA, and observe the conclusion.
2) Derive the formulae for the maximum throughput for Pure and Slotted ALOHA.