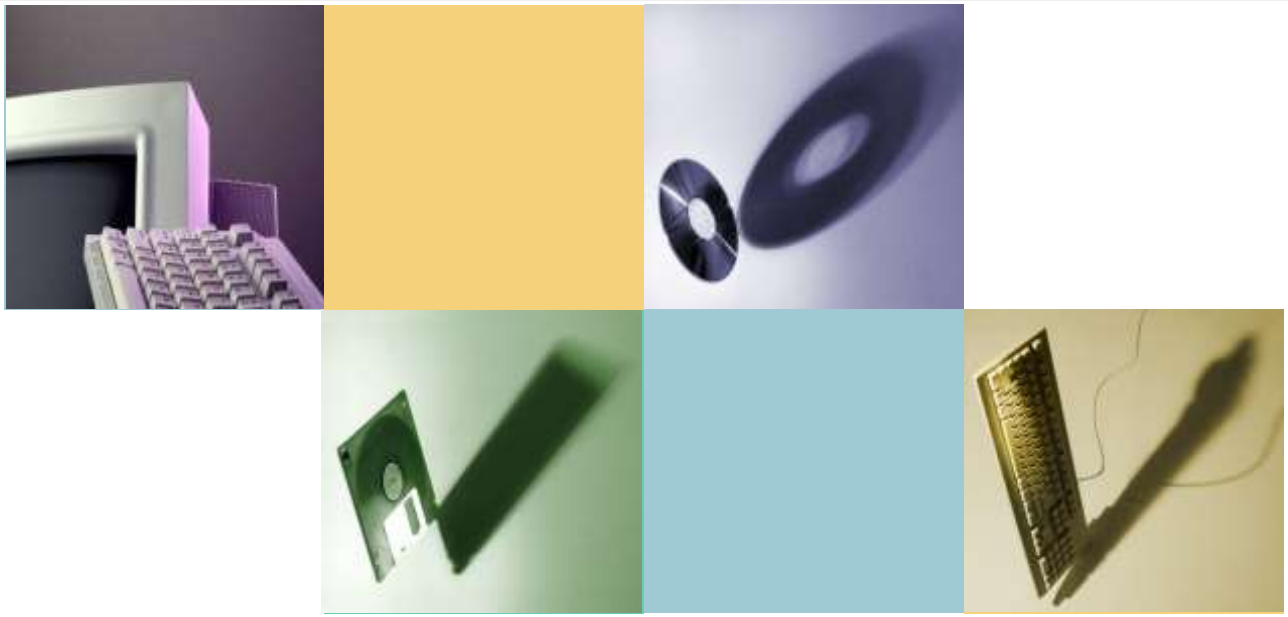
A Medium Access Protocol: ALOHA



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ALOHA : Meaning[1]

It has been derived from a compound of the Hawaiian words:

- ALO means "share".
- HA means "essence of life"



History[1]

- Development of the ALOHA network was begun in 1968 at the University of Hawaii under the leadership of ***Norman Abramson.***

- The goal was to use low-cost commercial radio equipment to connect users on Oahu(an island of Hawaii) and the other Hawaiian islands with a central time-sharing computer on the main Oahu campus.

- ALOHAnet became operational in June, 1971, providing the first public demonstration of ***a wireless packet data network.***

- Although ALOHAnet was designed for wireless communication, there were two other media available for the application of an ALOHA channel – ***cables and satellites.***

- In the 1970s ALOHA random access was employed in the widely used Ethernet cable based network and then in the satellite network.



ALOHA: A family of Contention Protocols

- **Contention** is a media access method that is used to share a broadcast medium.

- In contention, any computer in the network can transmit data at any time (first come-first served).

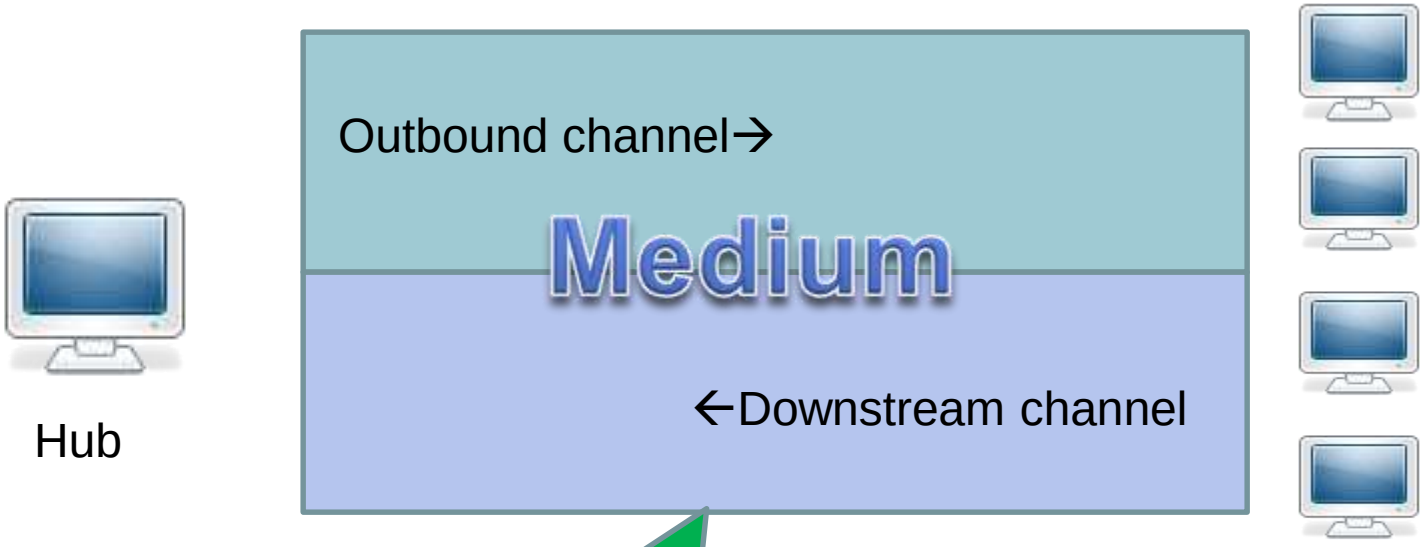
- The ALOHAnet solution was to allow each client to send its data without controlling when it was sent, with an acknowledgment/retransmission scheme used to deal with collisions.



Basic Idea Behind ALOHA

- Use of two distinct frequencies in a hub/star configuration.
- The hub machine broadcasting packets to everyone on the "outbound" channel.
- Various client machines sending data packets to the hub on the "inbound" channel.
- If data was received correctly at the hub, a short acknowledgment packet was sent to the client.
- if an acknowledgment was not received by a client machine after a short wait time, it would automatically retransmit the data packet after waiting a randomly selected time interval.
- This acknowledgment mechanism was used to detect and correct for "collisions" created when two client machines both attempted to send a packet at the same time.

Basic Idea Behind ALOHA



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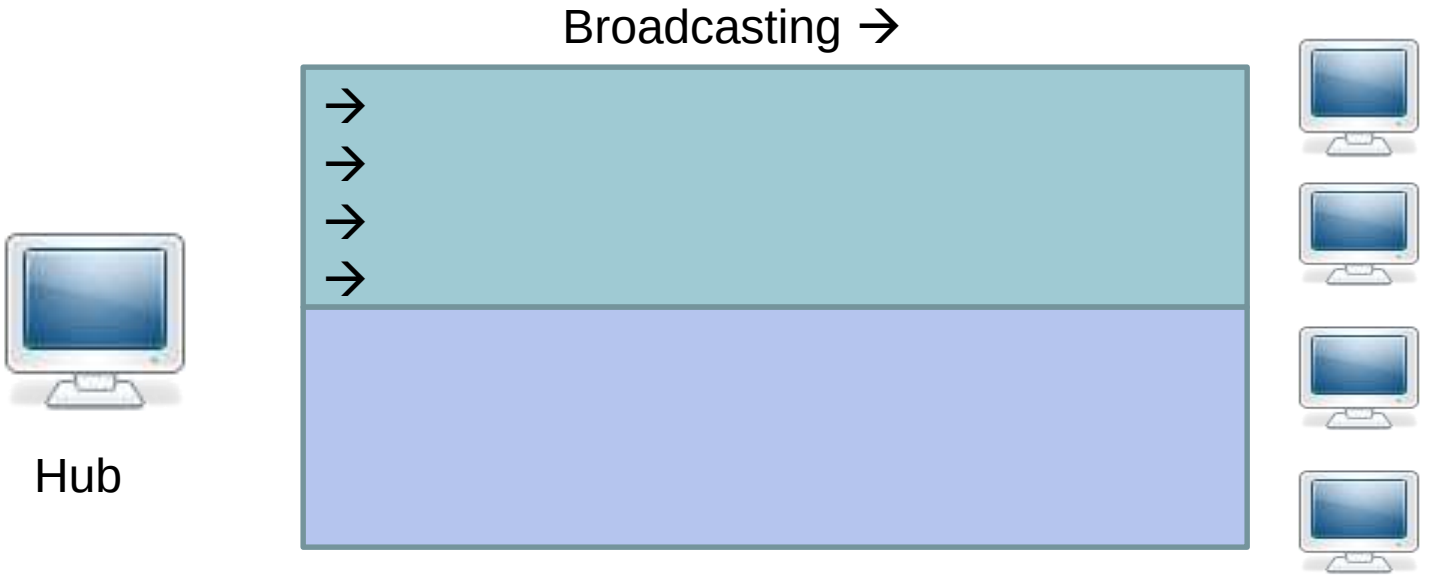

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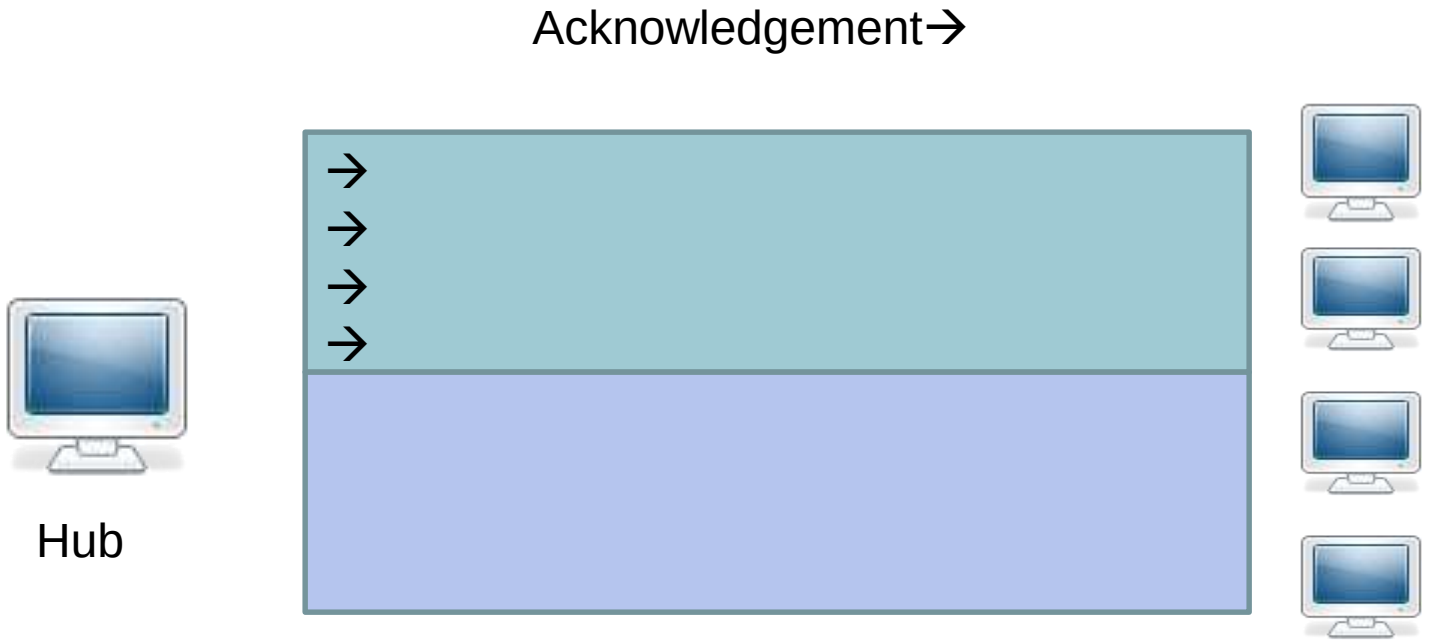
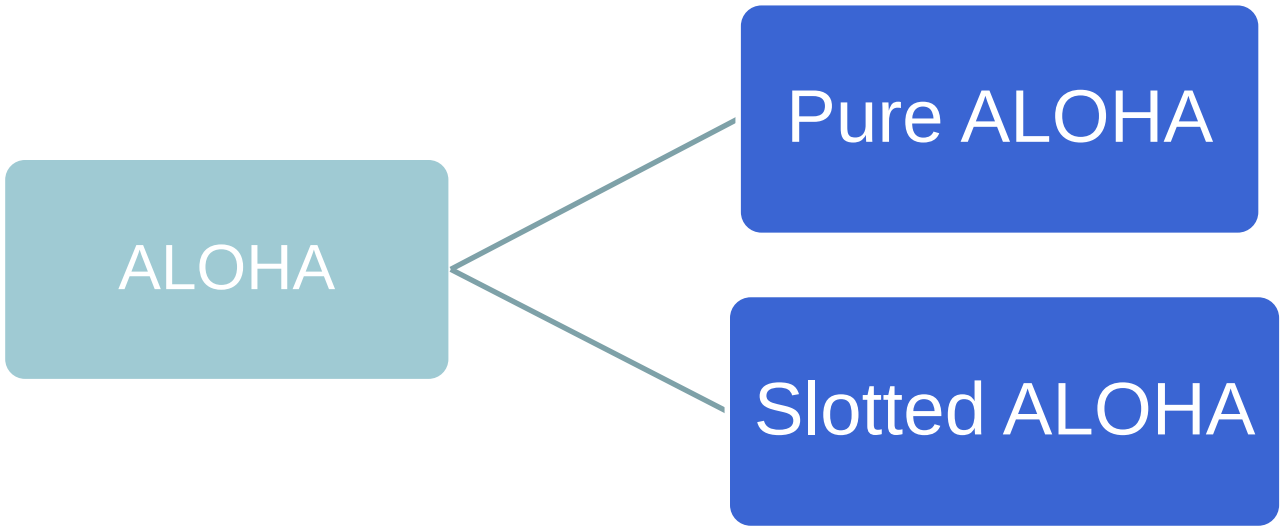


Versions Of ALOHA Protocol





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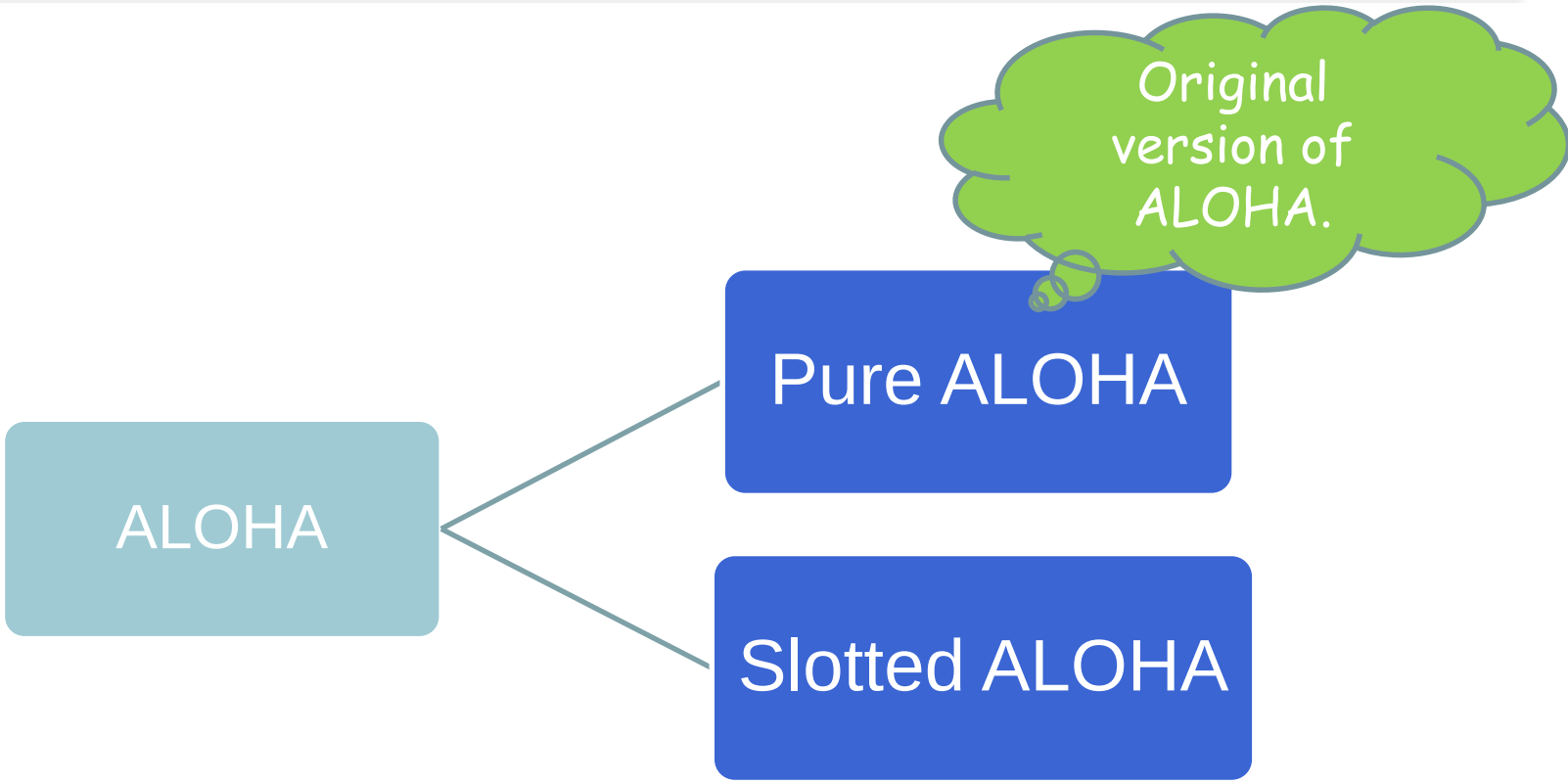



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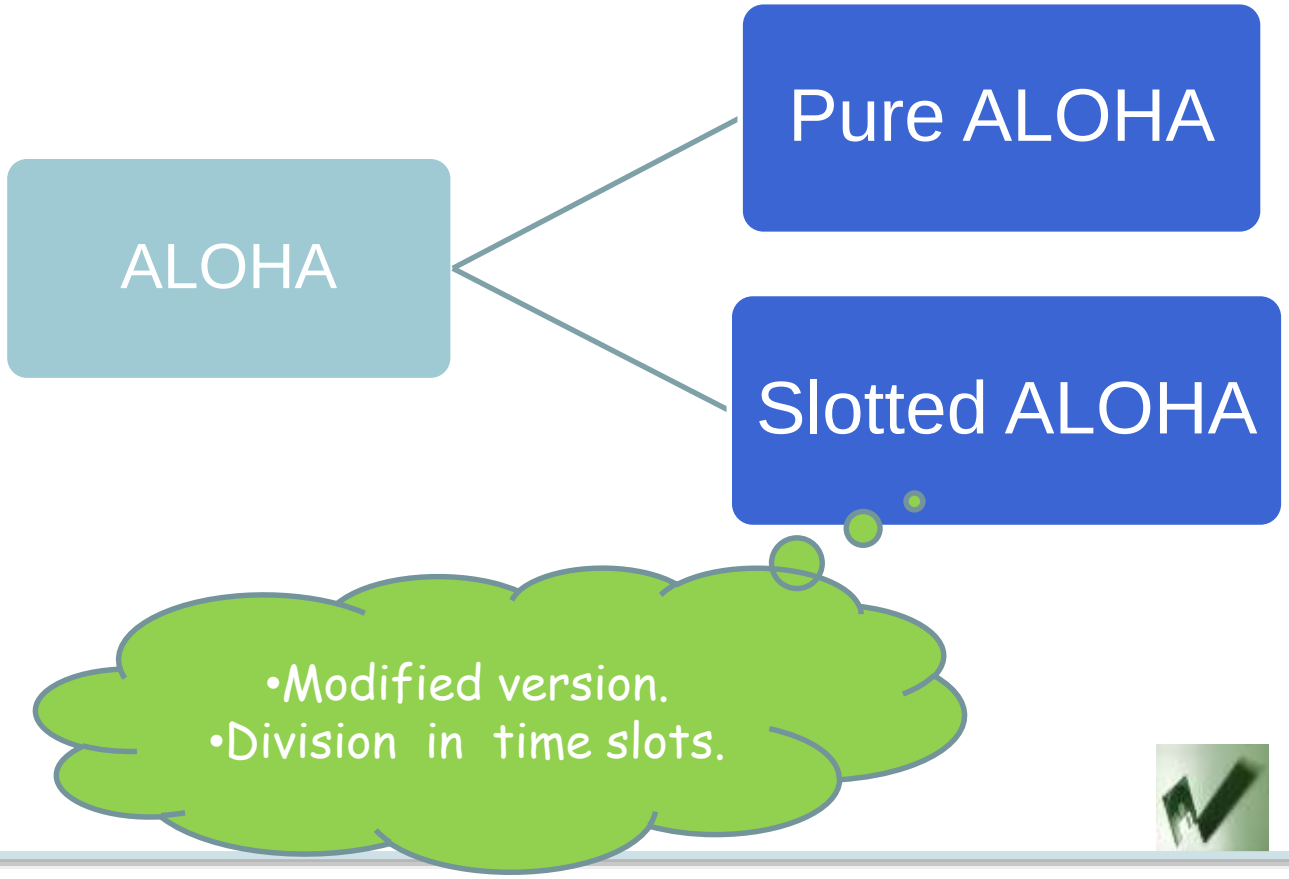


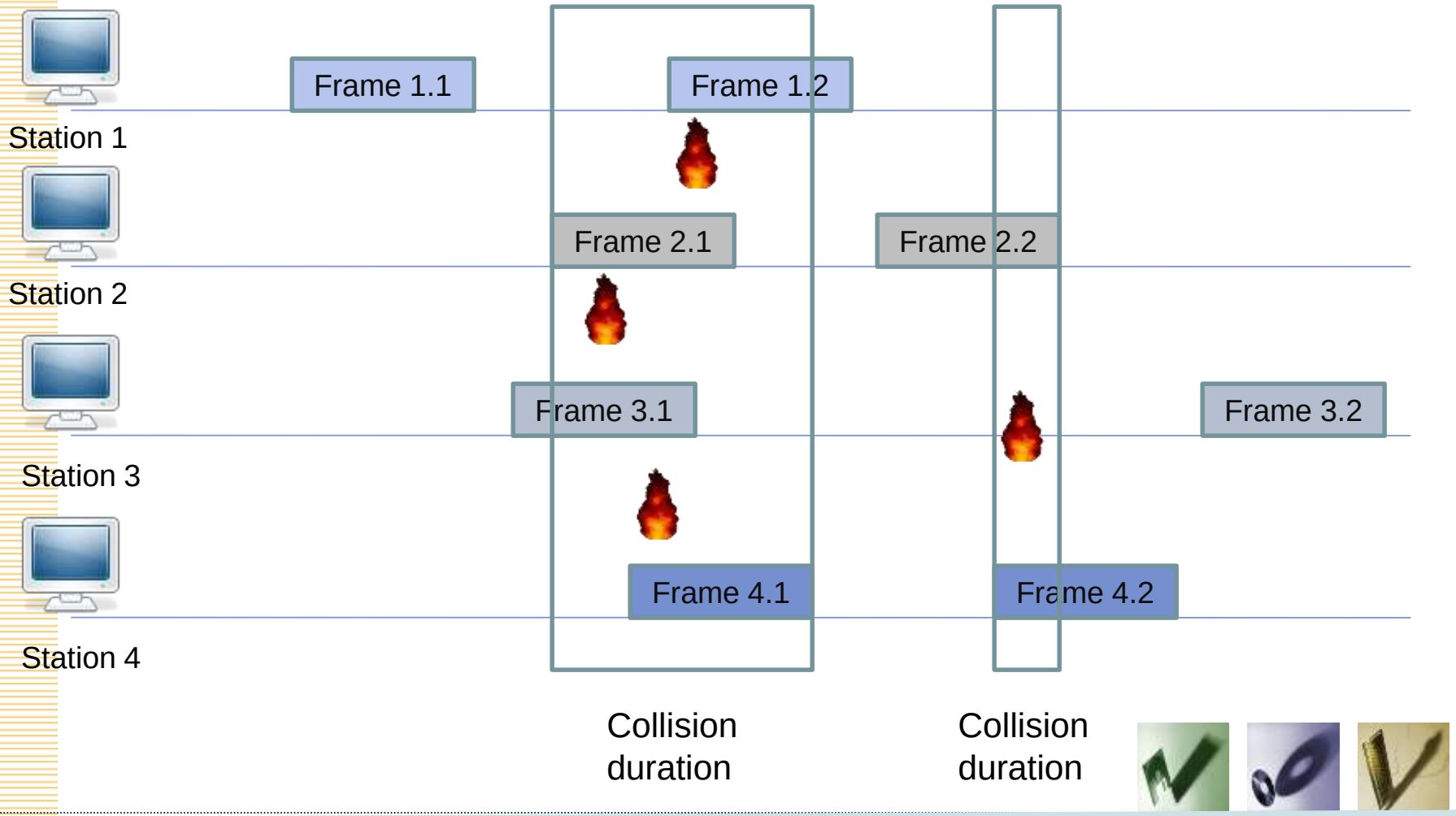
Pure ALOHA

• Whenever a station has a data, it transmits i.e. frames are transmitted at completely arbitrary times.

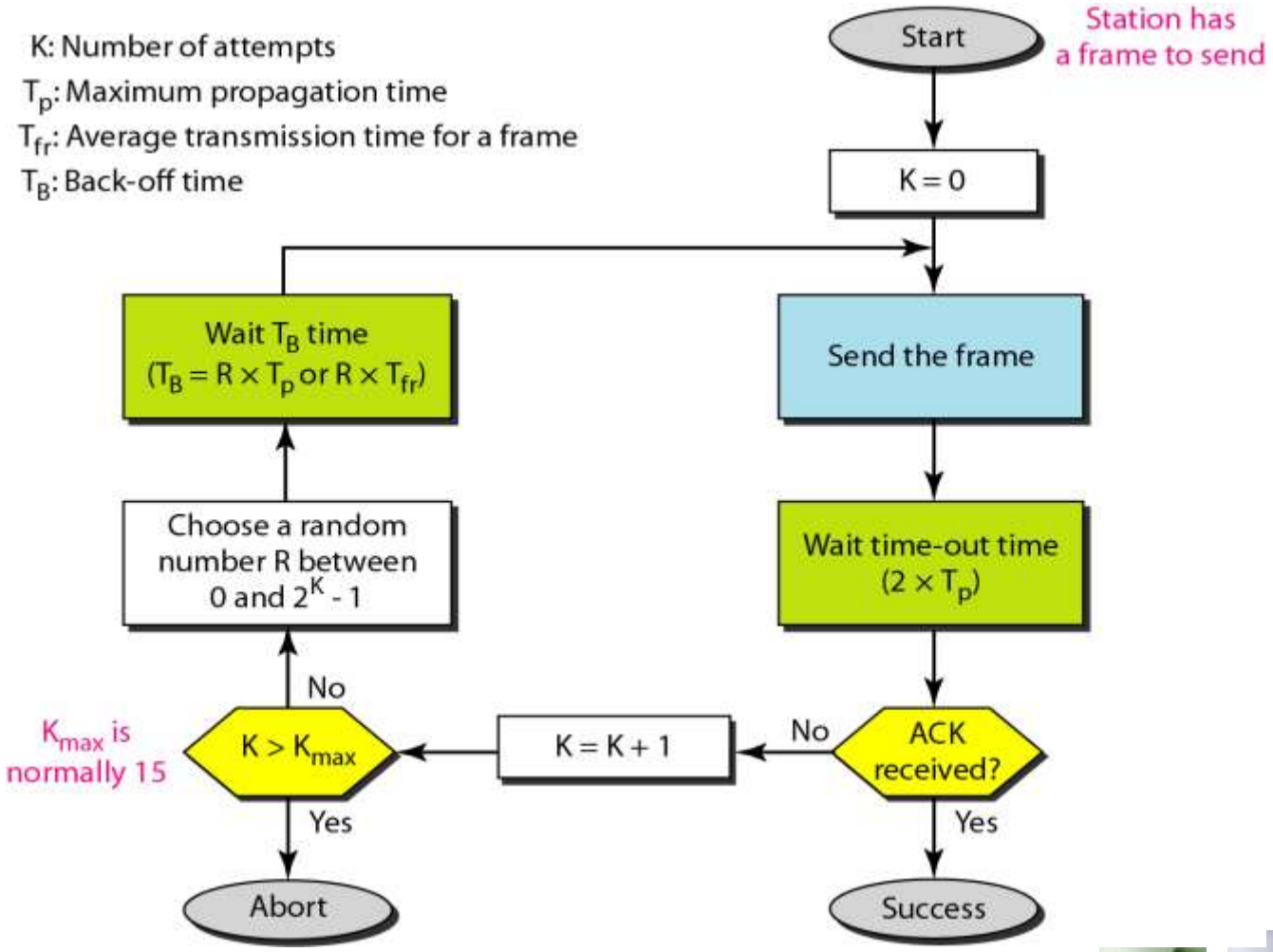
•Sender finds out whether transmission was successful or experienced a collision by listening to the broadcast from the destination station.

•Sender retransmits after some random time if there is a collision.

Frames in a pure ALOHA network



Procedure for pure ALOHA protocol



Analysis of Pure ALOHA...

- Notation:
  - T_f : Frame time (processing, transmission, propagation)
  - *S* : Average number of successful transmissions per T_f; that is, the *throughput* or *efficiency*.
  - *G* : Average number of total frames transmitted per T_f
  - *D* : Average delay between the time a packet is ready for transmission and the completion of successful transmission.

….Analysis Of Pure ALOHA….

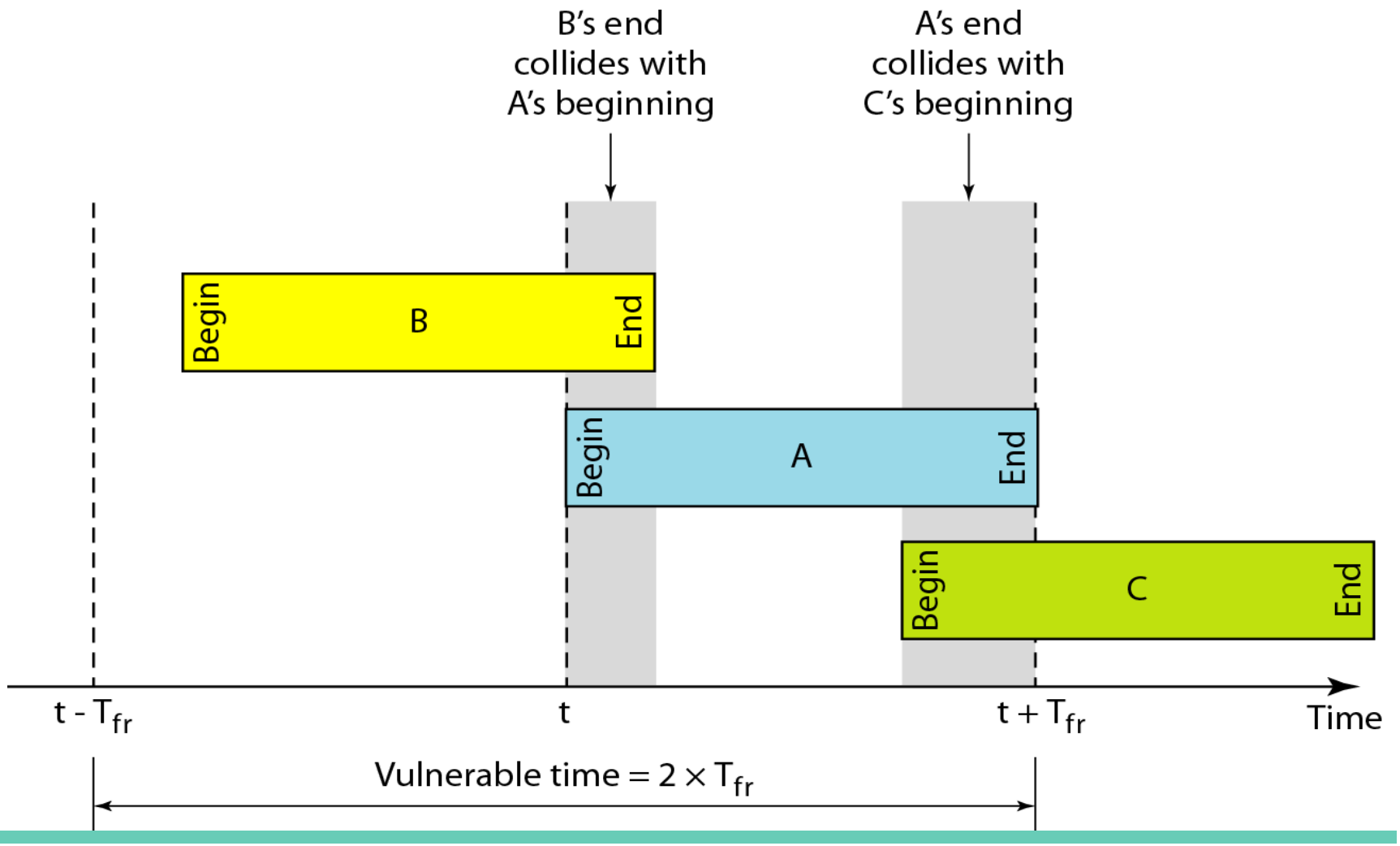
We will make the following assumptions:

- All frames are of constant length
- The channel is noise-free; the errors are only due to collisions.
- Frames do not queue at individual stations
- The channel acts as a Poisson process.

Since *S* represents the number of "good" or "succeed" transmissions per *frame time*, and *G* represents the total number of attempted transmissions per *frame time*, then we have:

$S = G$ * (Probability of good transmission)

Vulnerable time for pure ALOHA protocol:



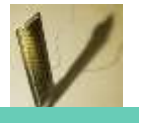
….Analysis Of Pure ALOHA….

- The probability of having *k* arrivals during a time interval of length *t* is given by:

$$P_k(t) = \frac{(\lambda t)^k e^{-\lambda t}}{k!}$$

- where λ is the arrival rate.





- The vulnerable time for a successful transmission is $2T_f$ *i.e.* collision probability increases

- So, the probability of good transmission is not to have an "arrival" during the vulnerable time .

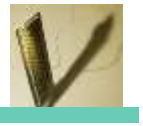
$$P_k(t) = \frac{(\lambda t)^k e^{-\lambda t}}{k!}$$

- And setting $t = 2T_f$ and $k = 0$, we get,

$$P_0(2T_f) = \frac{(\lambda \cdot 2T_f)^0 e^{-\lambda 2T_f}}{0!} = e^{-2G}$$

$$\text{becasue } \lambda = \frac{G}{T_f}. \quad \text{Thus, } S = G \cdot e^{-2G}$$





….Analysis Of Pure ALOHA….

- For PURE ALOHA, the probability of a successful transmission is e^{-2G} .

- Expected number of transmissions = e^{2G}

- Which means that a small increase in the channel load, that is G, can drastically reduce its performance.

The throughput for pure ALOHA is

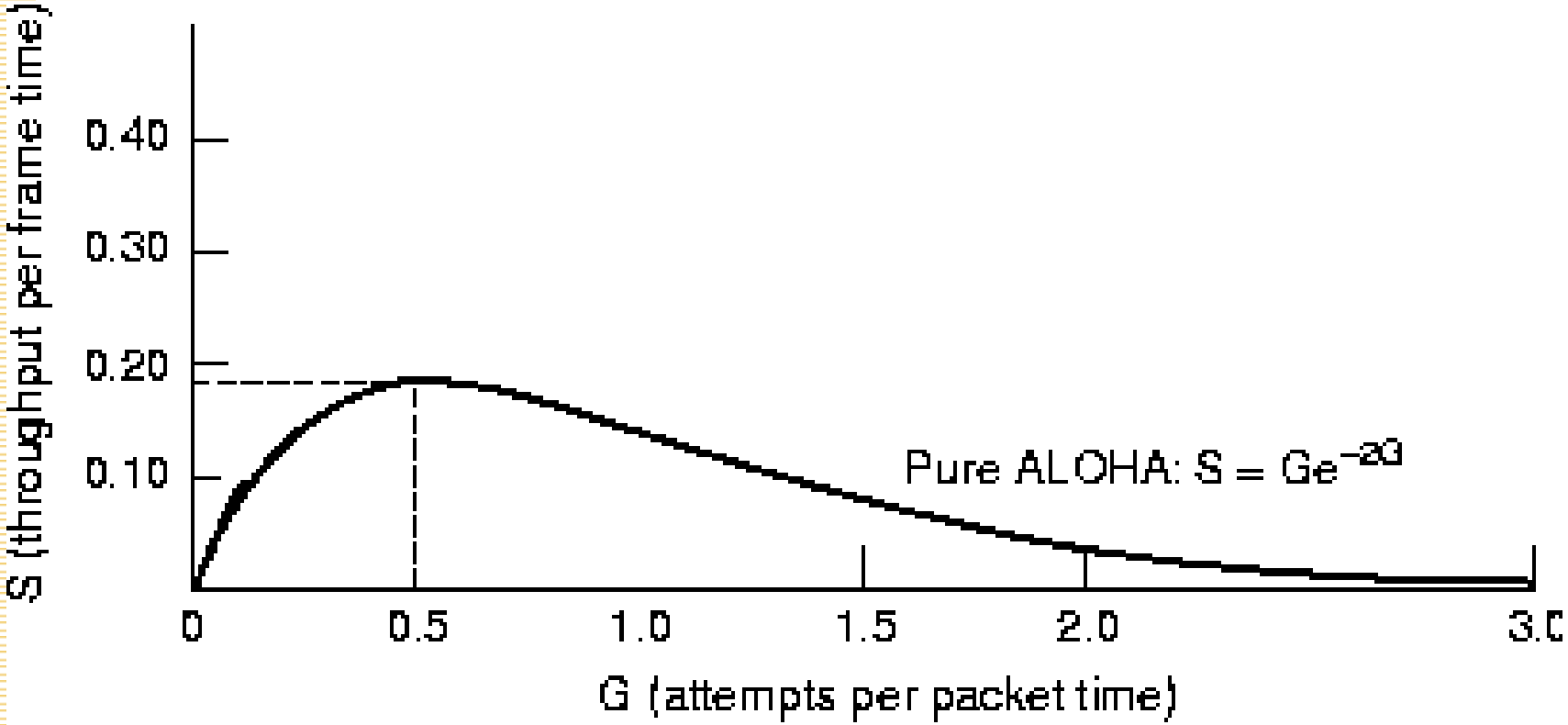
$$S = G \times e^{-2G} .$$

The maximum throughput

$S_{max} = 0.184$ when G= (1/2).

- The ALOHA protocol is an example of an *unstable* protocol.

Pure ALOHA Offered Load vs. Throughput



- Max at $G = 0.5$, $S = 1/2e$, only about 0.184 (18%)!
  - Can we do better?

Slotted ALOHA

- Slotted ALOHA was invented to improve the efficiency of pure ALOHA as chances of collision in pure ALOHA are very high.
- In slotted ALOHA, there is still a possibility of collision if two stations try to send at the beginning of the same time slot
- Slotted ALOHA still has an edge over pure ALOHA as chances of collision are reduced to one-half.

Assumptions Made In Slotted ALOHA

- All frames consist of exactly L bits.
- Time is divided into slots of size L/R seconds (i.e., a slot equals the time to transmit one frame).
- Nodes start to transmit frames only at the beginnings of slots.
- The nodes are synchronized so that each node knows when the slots begin.
- If two or more frames collide in a slot, then all the nodes detect the collision event before the slot ends.

Procedure for slotted ALOHA

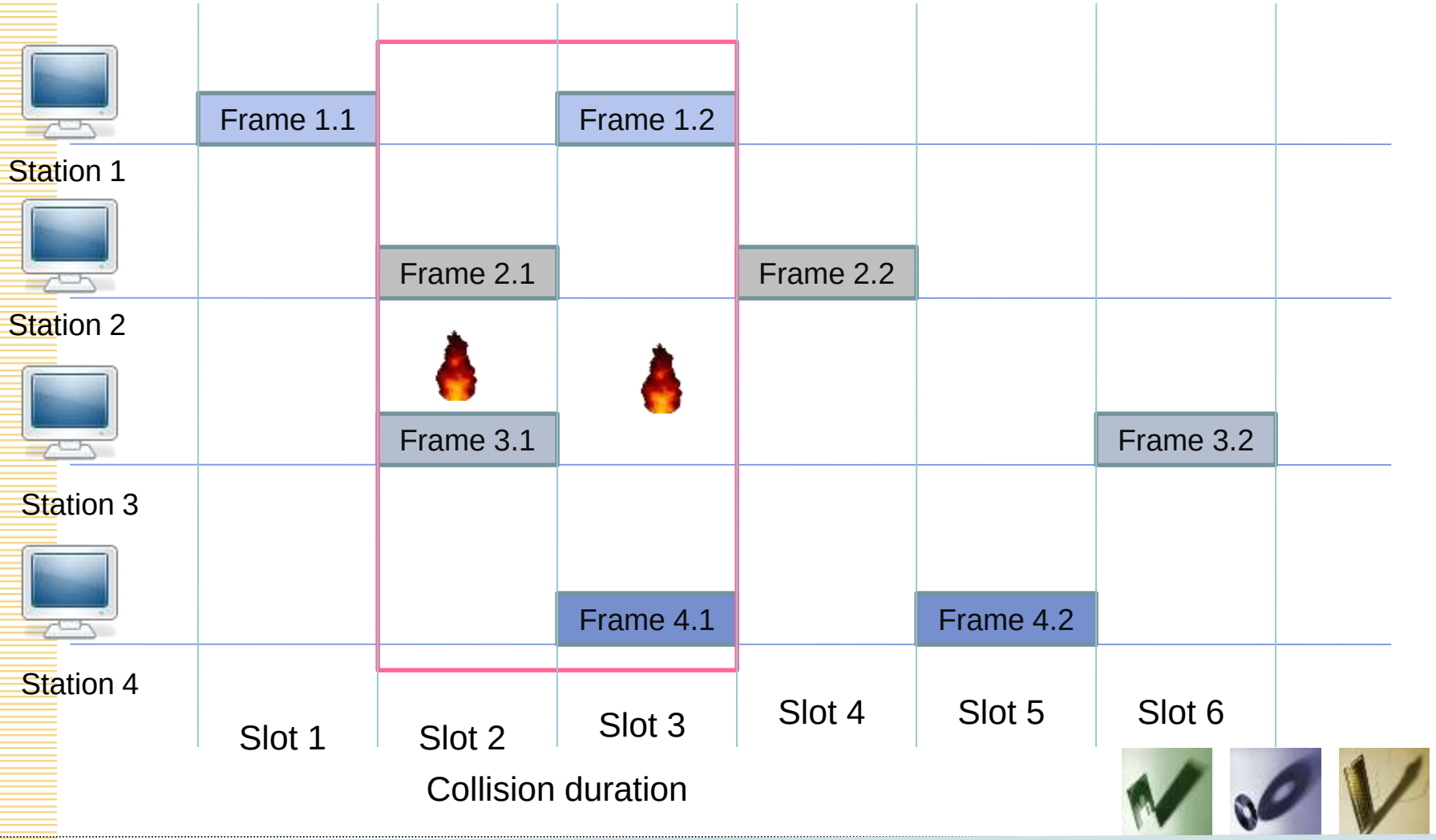
While there is a new frame A to send do

1. Send frame A at a slot boundary and wait for ACK
2. If after "some" time ACK is received, successful transmission of frame.
3. If there is a collision, the node detects the collision before the end of the slot.
4. wait a random amount of time and go to 1

End

The node retransmits its frame in each subsequent slot with probability *p* until the frame is transmitted without a collision

Frames in a Slotted ALOHA network



Analysis of Slotted ALOHA....

Suppose N stations have packets to send,

→each transmits in slot with probability *p*

→probability of successful transmission *S* is:

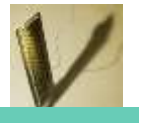
- by any specific single node: $S = p(1-p)^{(N-1)}$
- by any of N nodes

S = Prob (only one transmits)
$= N p (1-p)^{(N-1)}$

for optimum p as N -> infty ...

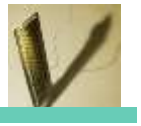
$S = 1/e = .37$



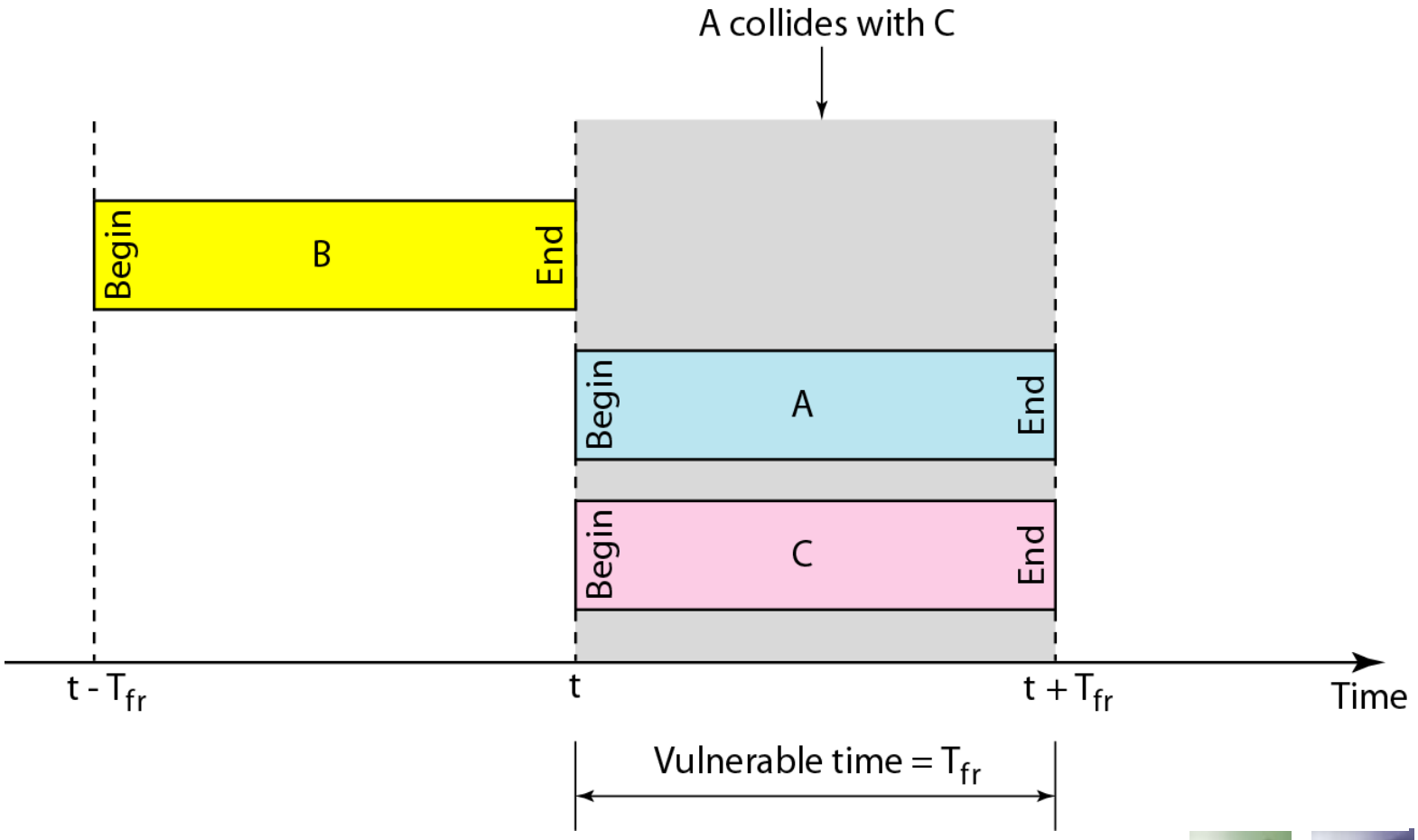


At best: channel use for useful transmissions 37% of time!!!!!





Vulnerable time for slotted ALOHA protocol



..Analysis of Slotted ALOHA…

- Note that the vulnerable period is now reduced in half.

Hence,

$$P_k(t) = \frac{(\lambda t)^k e^{-\lambda t}}{k!}$$

And putting $t = T_f$ and $k = 0$, we get

$$P_0(T_f) = \frac{(\lambda \cdot T_f)^0 e^{-\lambda T_f}}{0!} = e^{-G}$$

because $\lambda = \frac{G}{T_f}$. Thus, $S = G \cdot e^{-G}$

Throughput of Slotted ALOHA

- The probability of no collision is given by

$$P(0) = e^{-G}$$

- The throughput *S* is

$$S = G \cdot P(0) = G \cdot e^{-G}$$

- The Maximum throughput of slotted ALOHA is

$$S_{\max} = \frac{1}{e} \approx 0.368$$

..Analysis of Slotted ALOHA…

- Best ($G = 1$):
  - 37% empty
  - 37% success
  - 26% collisions
- Raising G, reduces empties but increases collisions exponentially
- Expected transmissions (includes original)

  $$E = e^{G}$$

  - G=0, then 1 transmission; G=1 then 2*X transmissions.
- Small increase in load, big decrease in performance.

Pros and Cons of Slotted ALOHA

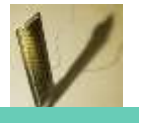
Pros

- single active node can continuously transmit at full rate of channel
- highly decentralized: only slots in nodes need to be in sync
- Simple protocol

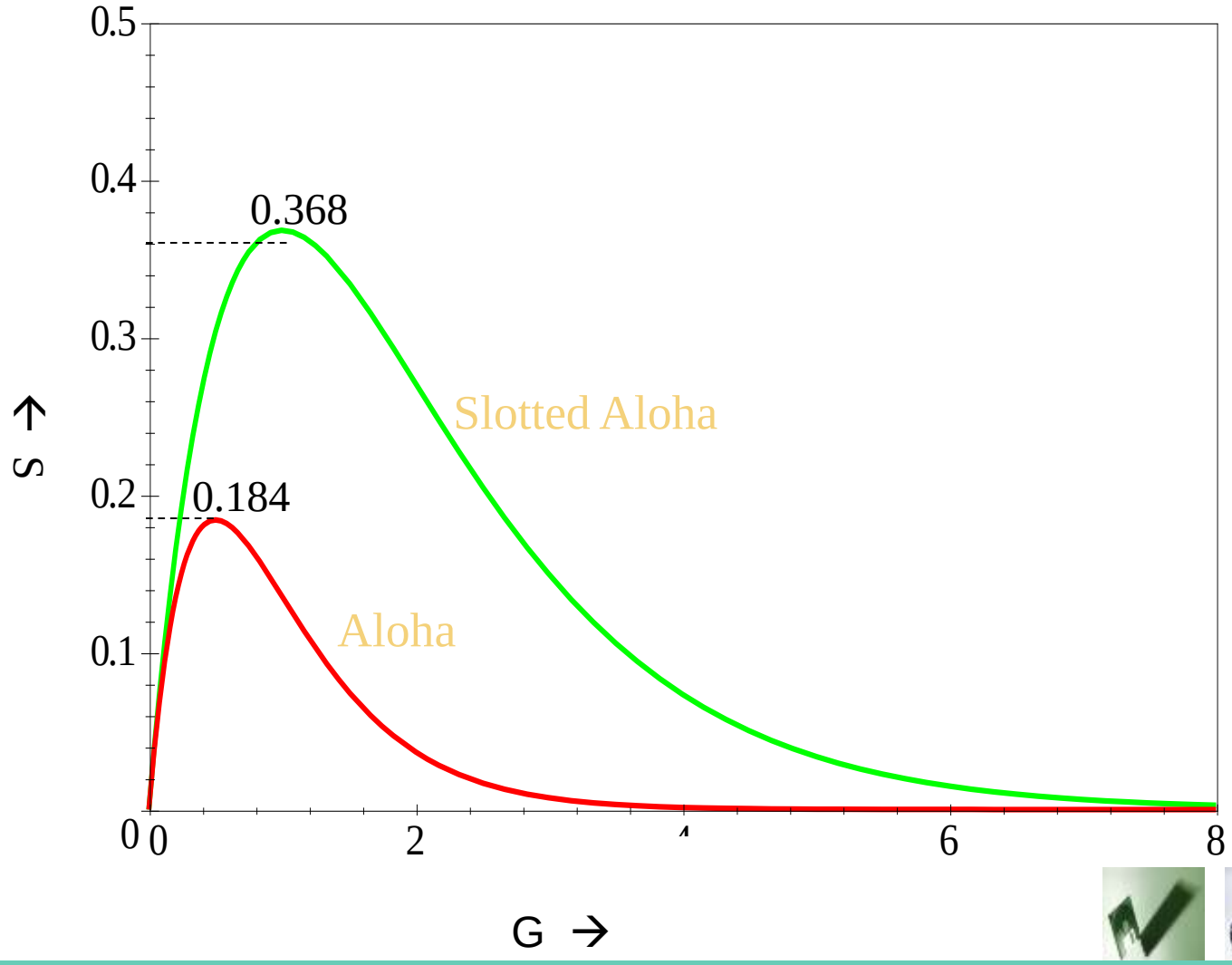
Cons

- collisions, wasting slots
- idle slots
- nodes may be able to detect collision in less than time to transmit packet
- clock synchronization





Throughput versus offered traffic for ALOHA systems.



Summary

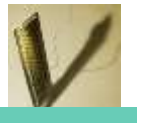
ALOHA is one of the random access protocol implemented at link layer.

Chances of collisions are more in pure ALOHA as compared to Slotted ALOHA , but still it is least efficient as compared to other random access protocol such as CSMA(CD/CA).

These protocols works efficiently when there are less active nodes.

Modified versions of ALOHA are being used in some services such as Mobile Slotted ALOHA[1].

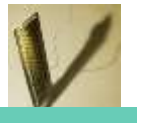


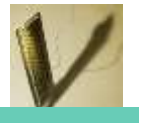


References

[1] Wikipedia
[2] http://www.cse.iitk.ac.in/users/dheeraj/cs425/lec04.html/index.html
[3] Data Communication and Networking by Behrouz A Forouzan
[4] computer networks and the internet by Ross & Kurose








Thank You!