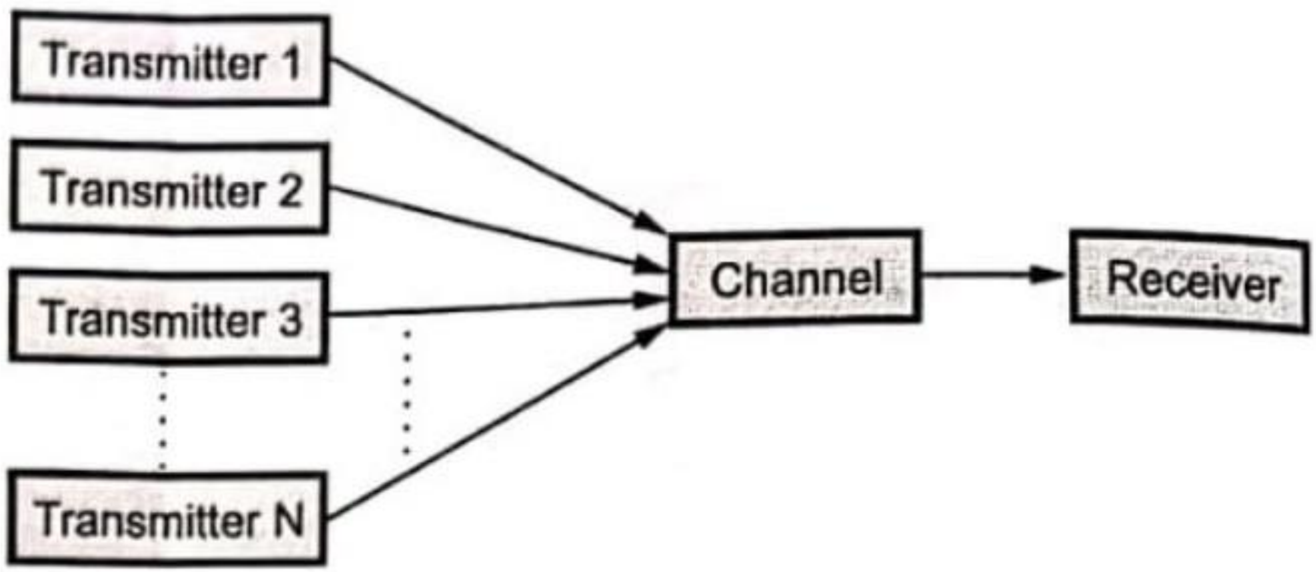
SRM
Institute of Science and Technology

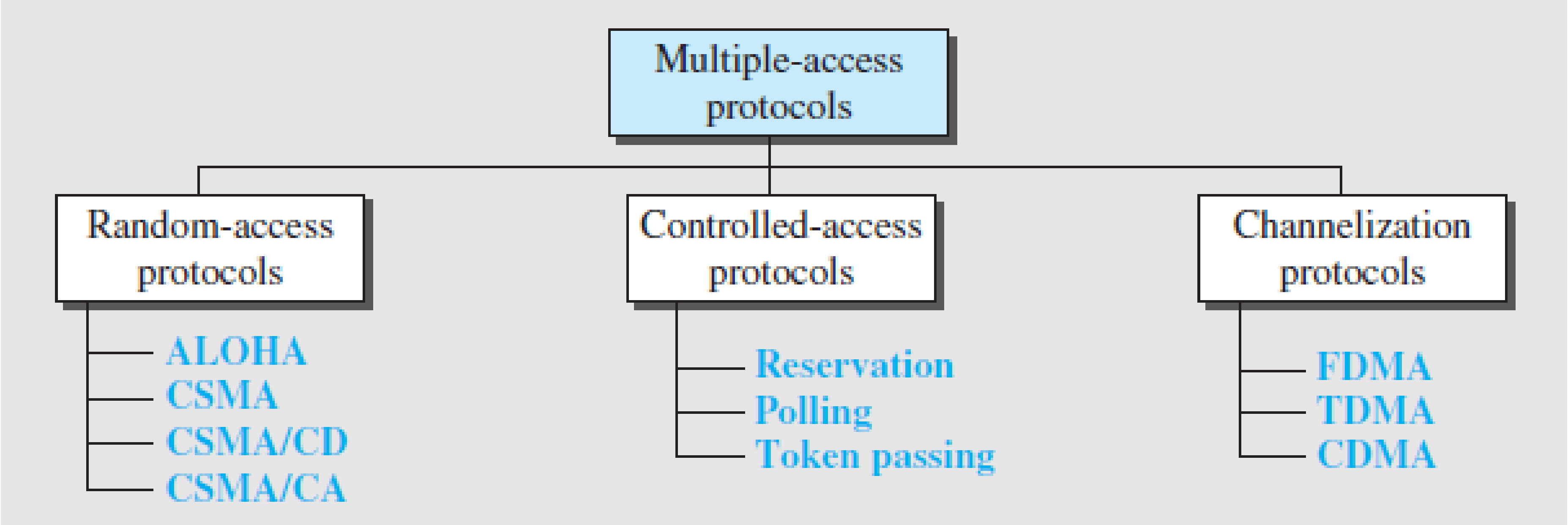
21CSC302J-COMPUTER NETWORKS

Unit- IV

Medium Access Control



Random Access



- In random-access or contention methods,
  - ***no station is superior to another station and***
  - ***none is assigned control over another.***

- At each instance, a station that has data to send ***uses a procedure defined by the protocol to make a decision on whether or not to send.***

- ***This decision depends on the state of the medium (idle or busy).***

- Each station can transmit when it desires on the condition that it follows the predefined procedure, including testing the state of the medium.

- **Two features give this method its name.**

- First,
  - ***there is no scheduled time for a station to transmit.***
  - ***Transmission is random among the stations.***
  - ***That is why these methods are called random access.***

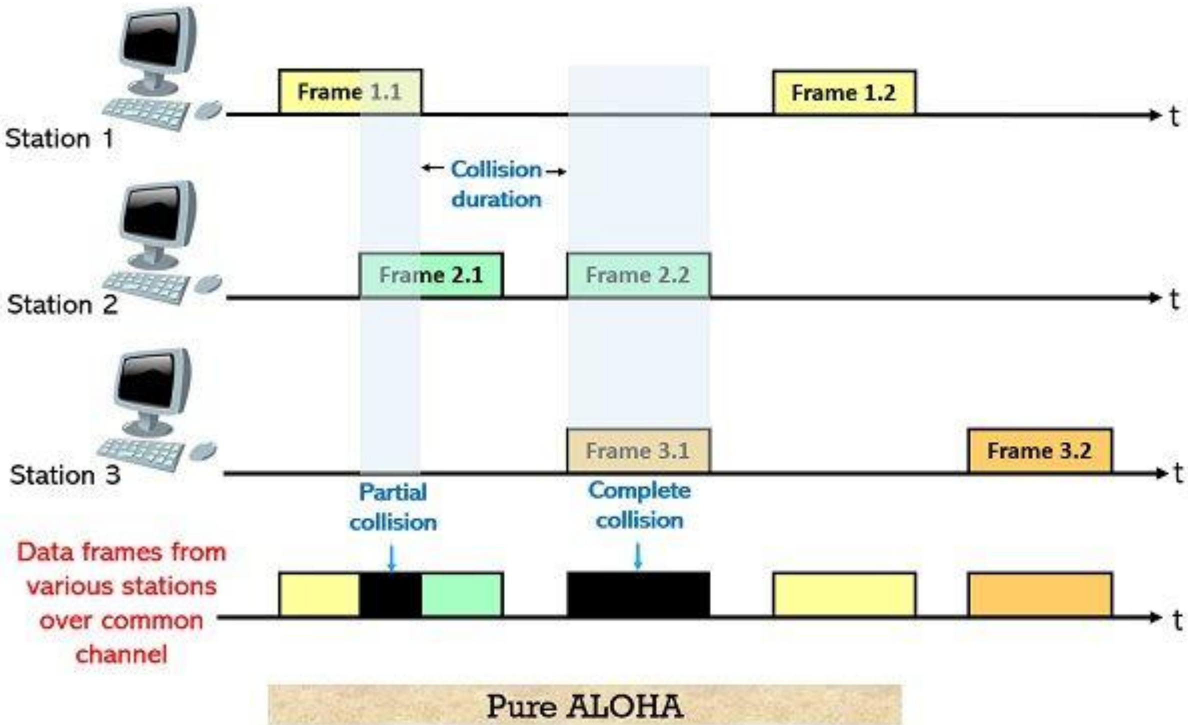
- Second,
  - ***no rules specify which station should send next.***
  - ***Stations compete with one another to access the medium.***
  - ***That is why these methods are also called contention methods.***

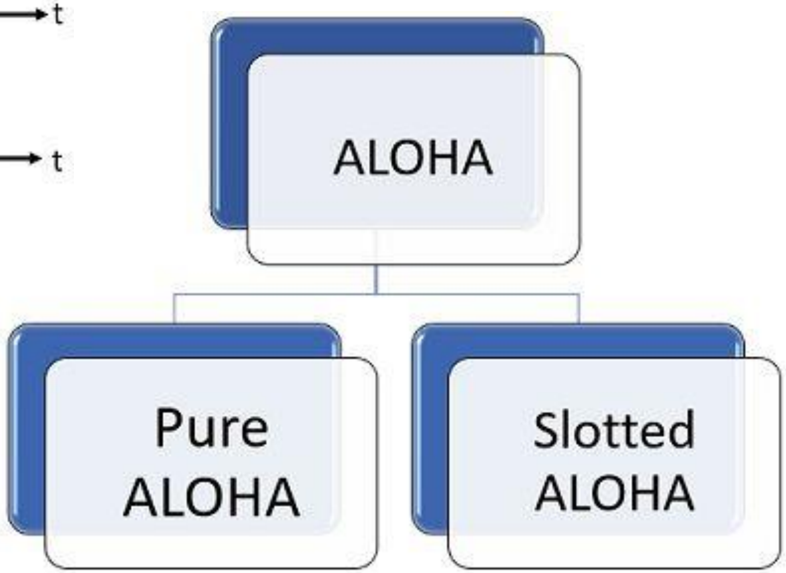
- In a random-access method,
  - ***each station has the right to the medium without being controlled by any other station.***
  - ***If more than one station tries to send, there is an access conflict—collision—and the frames will be either destroyed or modified.***

- 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?***

- The random-access methods have evolved from a very interesting protocol known as ALOHA,
  - *used a very simple procedure called multiple access (MA).*
- **The method was improved with the addition of a procedure *that forces the station to sense the medium before transmitting.***
- This was called carrier sense multiple access (CSMA).
- This method later evolved into two parallel methods:
  - ***carrier sense multiple access with collision detection (CSMA/CD), which tells the station what to do when a collision is detected,***
  - ***carrier sense multiple access with collision avoidance (CSMA/CA), which tries to avoid the collision.***

ALOHA


Frame 1.1
Frame 1.2
t
Station 1
Collision
duration
Frame 2.1
Frame 2.2
Station 2
Frame 3.1
Frame 3.2
Station 3
Partial
collision
Complete
collision
Data frames from
various stations
over common
channel
Pure ALOHA


ALOHA
Pure ALOHA
Slotted ALOHA

ALOHA

- The ***earliest random access method***, was developed at the University of Hawaii in early 1970.
- ***Designed for a radio (wireless) LAN***, but it can be used on any shared medium.
- There are *potential collisions in this arrangement*.
- ***The medium is shared between the stations.***
- **When a station sends data,** ***another station may attempt to do so at the same time.***

Pure Aloha

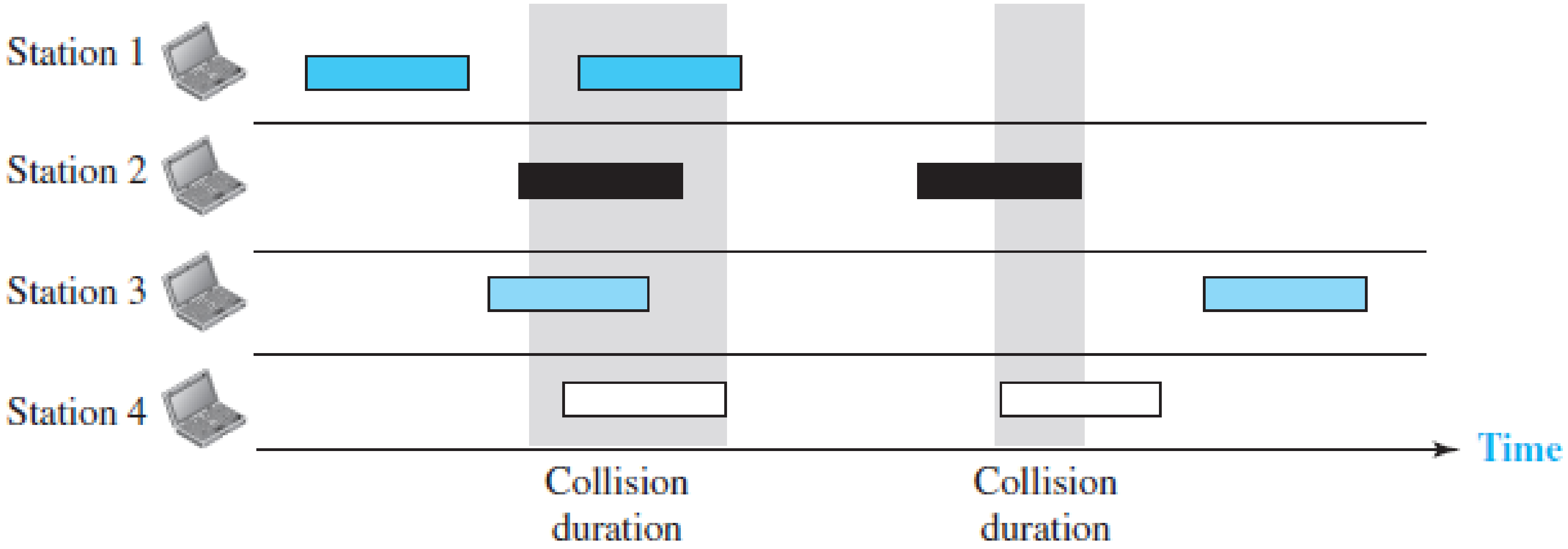
- The data from the ***two stations collide*** and become garbled.

- **The original ALOHA protocol is called *pure ALOHA.***

- This is a simple but elegant protocol.

- **The idea is** - ***each station sends a frame whenever it has a frame to send (multiple access).***

- **There is only one channel to share,**
  - ***The possibility of collision between frames from different stations.***


Station 1
Station 2
Station 3
Station 4
Time
Collision duration
Collision duration

Pure Aloha

- There are four stations (unrealistic assumption) that contend with one another for access to the shared channel.
- The figure shows that each station sends two frames; there are a total of eight frames on the shared medium.
- Some of these frames collide because multiple frames are in contention for the shared channel.
- Figure shows that only two frames survive: one frame from station 1 and one frame from station 3.

Pure Aloha

- Even if one bit of a frame coexists on the channel with one bit from another frame,
  - ***a collision and both will be destroyed.***

- ***Resend the frames*** **that have been destroyed during transmission.**

- ***Relies on acknowledgments from the receiver.***

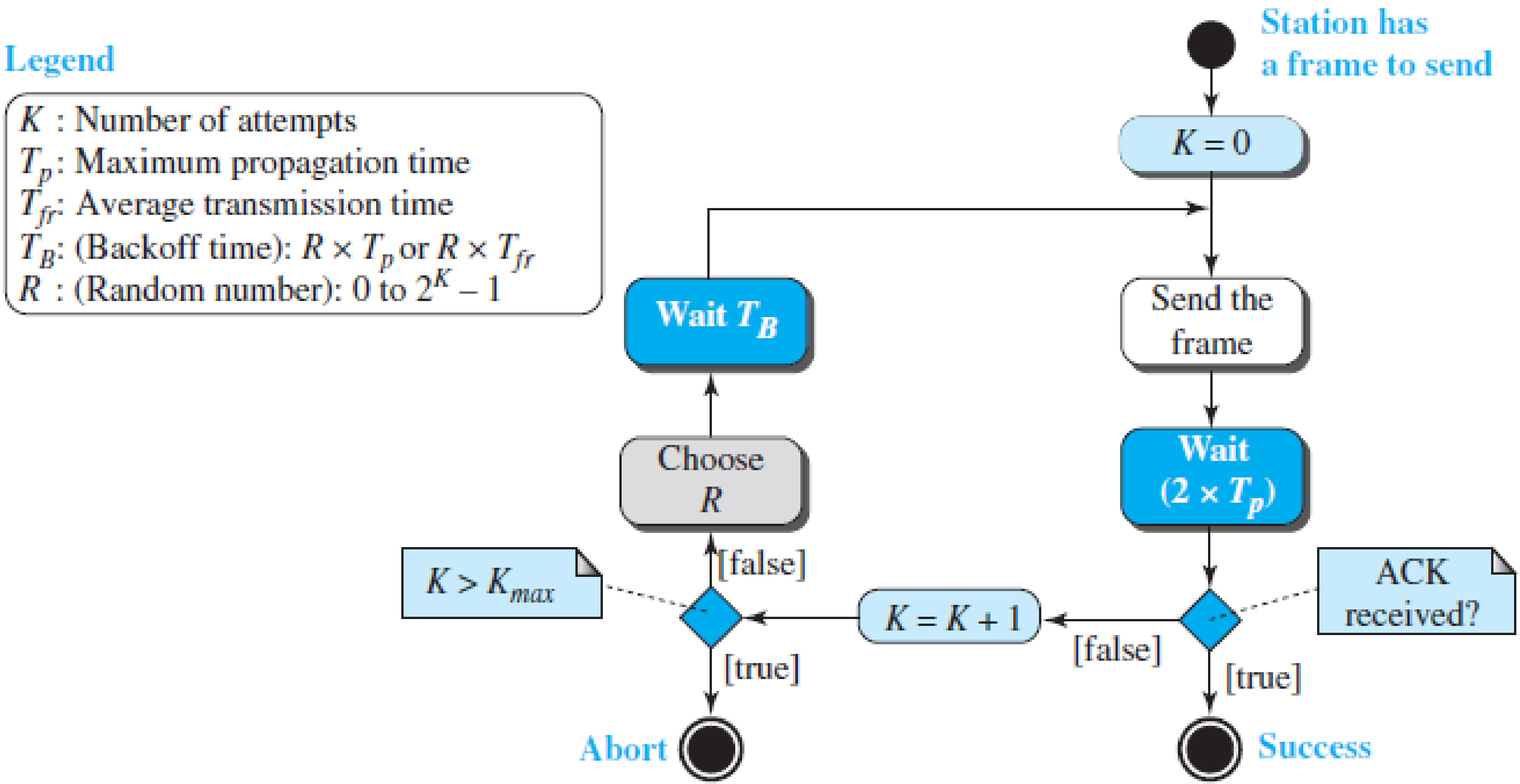
- When a station sends a frame, it expects the receiver to send an acknowledgment.

Pure Aloha

- **If the acknowledgment does not arrive after a time-out period,**
  - ***The station assumes that the frame has been destroyed and resends the frame.***
- 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.
- Pure ALOHA dictates
  - ***When the time-out period passes, each station waits a random amount of time before resending its frame.***

Pure Aloha

- *The randomness will help avoid more collisions.*
- ***backoff time T_B.***
- Pure ALOHA has a **second method to prevent congesting the channel with retransmitted frames.**
- ***After a maximum number of retransmission attempts K_{max}, a station must give up and try later.***
- Figure shows the procedure for pure ALOHA based on the above strategy.


Legend
K : Number of attempts
T_p: Maximum propagation time
T_{fr}: Average transmission time
T_B: (Backoff time): $R \times T_p$ or $R \times T_{fr}$
R : (Random number): 0 to $2^K - 1$
Station has a frame to send
$K = 0$
Send the frame
Wait ($2 \times T_p$)
ACK received?
[true]
Success
[false]
$K = K + 1$
$K > K_{max}$
[true]
Abort
[false]
Choose R
Wait T_B

Pure Aloha

- **The time-out period is equal to the maximum possible round-trip propagation delay,**
  - ***twice the amount of time required to send a frame between the two most widely separated stations ($2 \times T_p$).***

- **The backoff time T_B is a random value** ***that normally depends on K*** (the number of attempted unsuccessful transmissions).

- The formula for T_B depends on the implementation.

- **One common formula is** ***the binary exponential backoff.***

Pure Aloha

- In this method, for each retransmission,
  - ***a multiplier R = 0 to 2^{K-1} is randomly chosen and multiplied by Tp (maximum propagation time) or***
  - ***T_{fr} (the average time required to send out a frame) to find T_B.***

- The range of the random numbers increases after each collision.

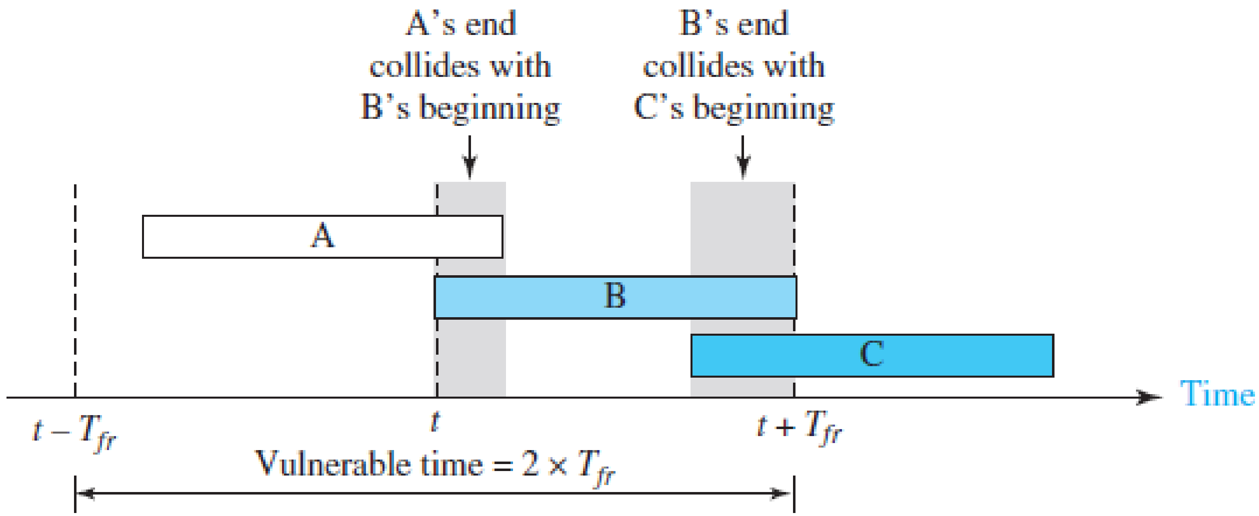
- The value of K_{max} is usually chosen as 15.

Vulnerable time

- **The length of time** ***there is a possibility of collision.***

- The stations send fixed-length frames with each frame taking T_{fr} seconds to send.

- Figure shows the vulnerable time for station B.



Vulnerable time

- Station B starts to send a frame at time t.
- Station A has started to send its frame after $t - T_{fr}$.
- This leads to a collision between the frames from station B and station A.
- On the other hand, suppose that station C starts to send a frame before time $t + T_{fr}$.
- There is also a collision between frames from station B and station C.

Vulnerable time

- The vulnerable time during which a collision may occur in pure ALOHA is 2 times the frame transmission time.

$$\text{Pure ALOHA vulnerable time} = 2 \times T_{fr}$$

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?

Average frame transmission time T_{fr} is 200 bits/200 kbps or 1 ms.

The vulnerable time is 2×1 ms $= 2$ ms.

- *No station should send later than 1 ms before this station starts transmission and*
- *No station should start sending during the period (1 ms) that this station is sending.*

Throughput

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

- G ***the average number of frames generated by the system during one frame transmission time***.
- The average number of successfully transmitted frames for pure ALOHA is S
- The maximum throughput S_{max} is 0.184, for G = 1/2.

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?

The frame transmission time is 200/200 kbps or 1 ms.

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

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?

The frame transmission time is 200/200 kbps or 1 ms.

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

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?

The frame transmission time is 200/200 kbps or 1 ms.

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

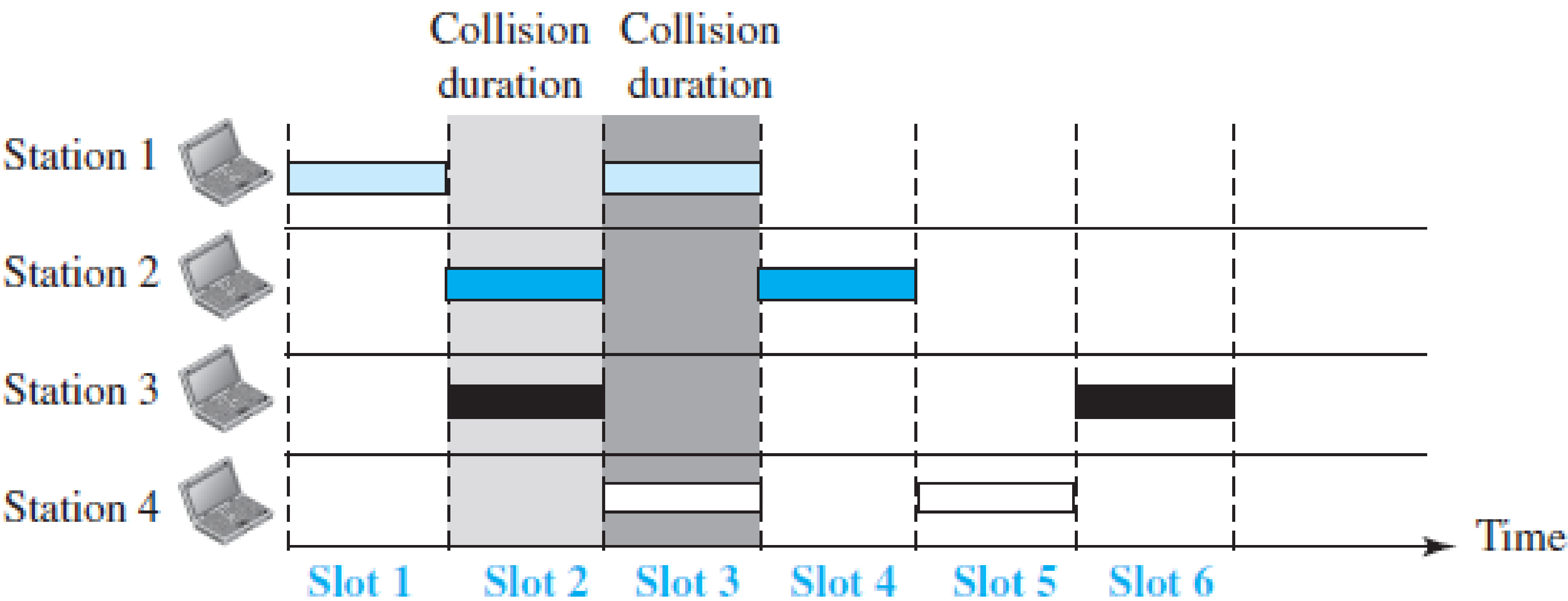
Slotted ALOHA

Slotted Aloha

- Pure ALOHA has a vulnerable time of $2 \times T_{fr}$.
- There is no rule that defines when the station can send.
- **A station may send soon after another station has started or just before another station has finished.**
- Slotted ALOHA was invented ***to improve the efficiency of pure ALOHA.***
- In slotted ALOHA
  - ***Divide the time into slots of T_{fr} seconds and***
  - ***Force the station to send only at the beginning of the time slot.***

Slotted Aloha

- Figure shows an example of frame collisions in slotted ALOHA.



Slotted Aloha

- ***A station is allowed to send only at the beginning of the synchronized time slot,***

- ***If a station misses this moment, it must wait until the beginning of the next time slot.***

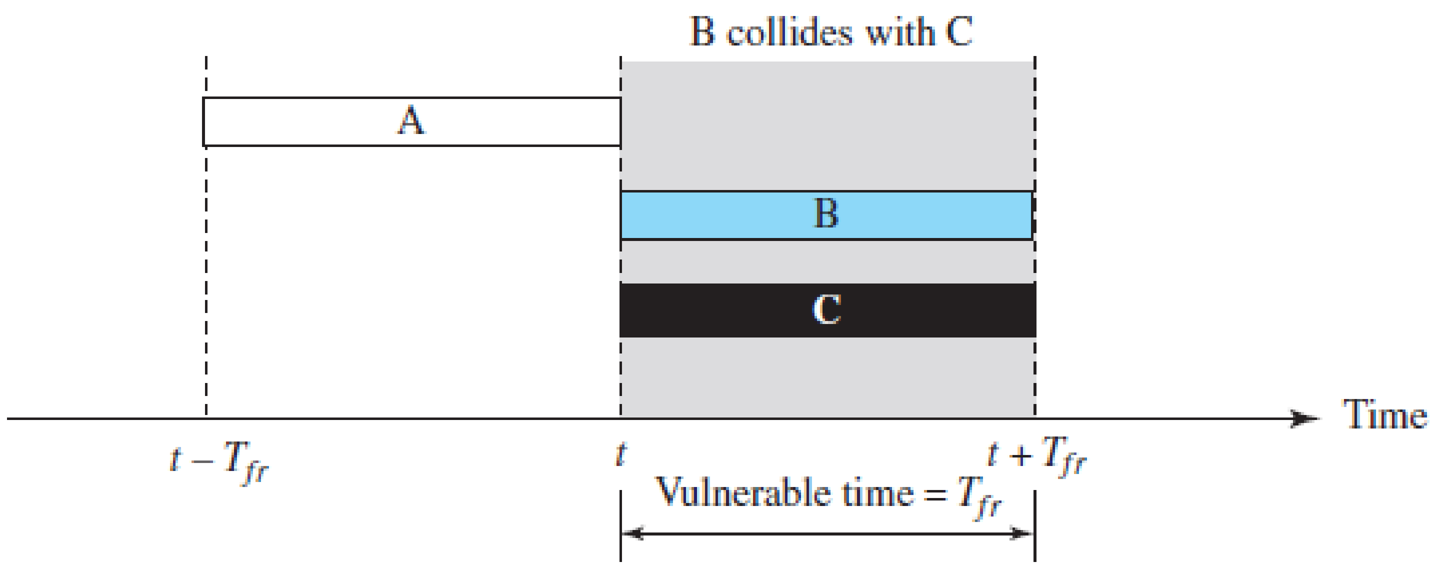
- This means that the station which started at the beginning of this slot has already finished sending its frame.

- Still the possibility of collision if two stations try to send at the beginning of the same time slot.

- ***The vulnerable time is now reduced to one-half, equal to T_{fr}***

Slotted Aloha

- Figure shows the situation.



Slotted ALOHA vulnerable time = T_{fr}

The throughput for slotted ALOHA is $S = G \times e^{-G}$.
The maximum throughput $S_{max} = 0.368$ when $G = 1$.

A Slotted 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?

The frame transmission time is 200/200 kbps or 1 ms.

a. In this case G is 1. So $S = G \times e^{-G} = 0.368$ (36.8 percent). This means that the throughput is $1000 \times 0.0368 = 368$ frames. Only 368 out of 1000 frames will probably survive. Note that this is the maximum throughput case, percentagewise

A Slotted 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?

The frame transmission time is 200/200 kbps or 1 ms.

Here G is 1/2. In this case S = G × e−G = 0.303 (30.3 percent). This means that the throughput is 500 × 0.0303 = 151. Only 151 frames out of 500 will probably survive.

A slotted 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?

The frame transmission time is 200/200 kbps or 1 ms.

C. Now G is 1/4. In this case $S = G \times e^{-G} = 0.195$ (19.5 percent). This means that the throughput is $250 \times 0.195 = 49$. Only 49 frames out of 250 will probably survive.

CSMA

- The CSMA method was developed.
  - ***To minimize the chance of collision and Increase the performance***

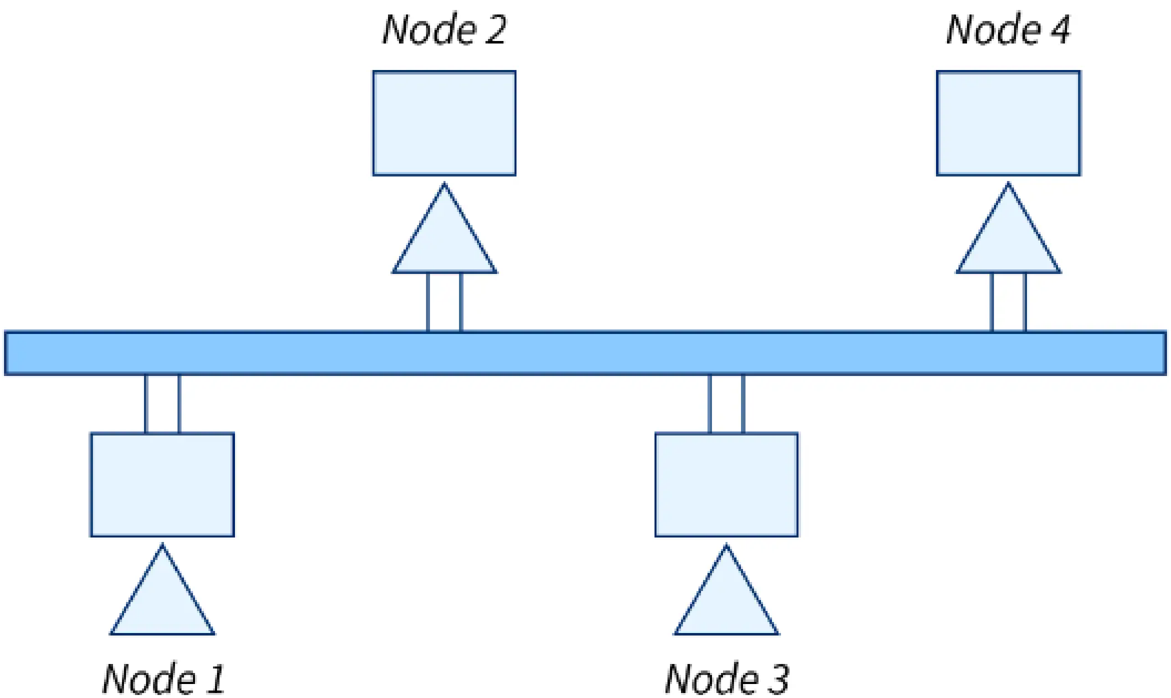
- **The chance of collision can be reduced** ***if a station senses the medium before trying to use it.***

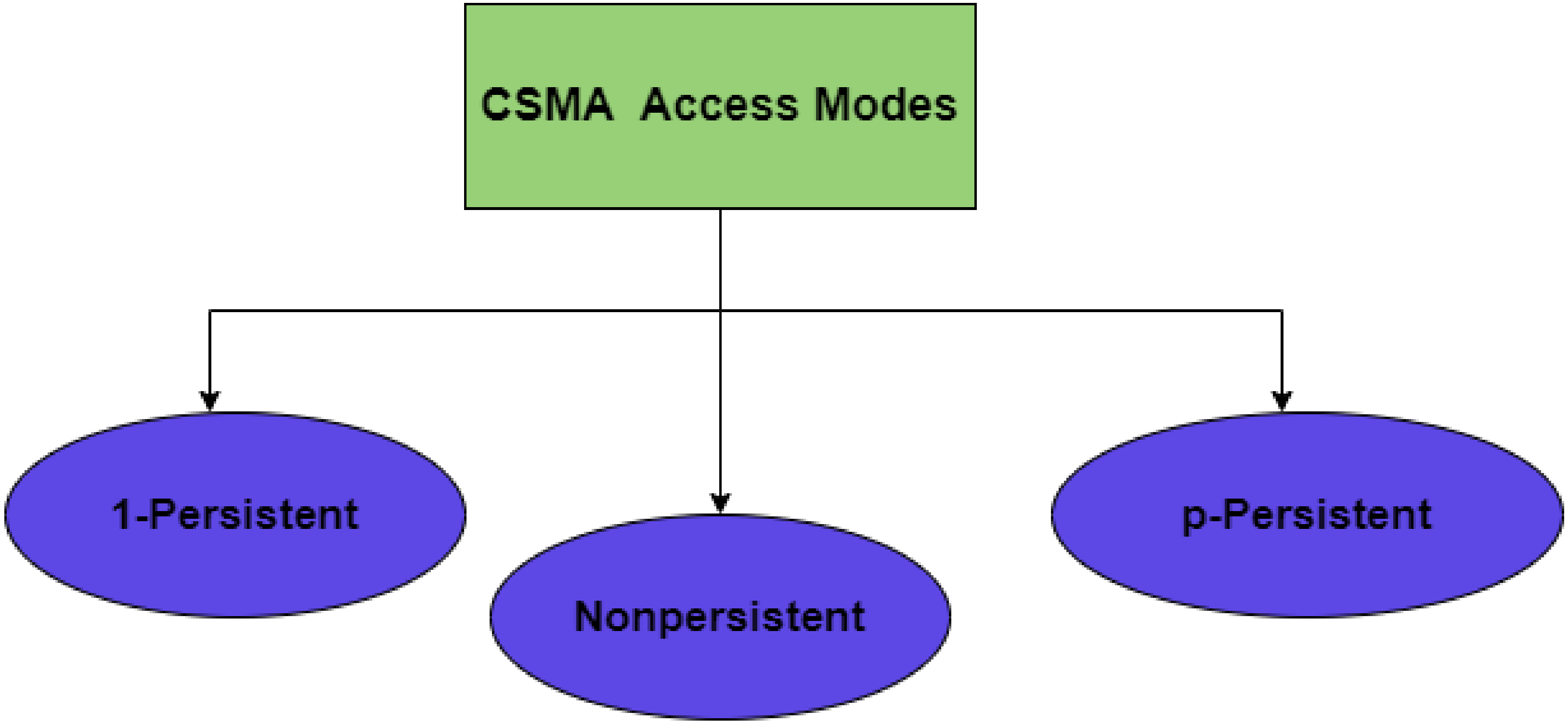
- ***Requires that each station first listen to the medium before sending.***

- **CSMA is based on the principle** ***"sense before transmit" or "listen before talk."***

- ***It cannot eliminate it.***
- Stations are connected to a shared channel
- The possibility of collision still exists because of propagation delay;
- When a station sends a frame, it still takes time for the first bit to reach every station and for every station to sense it.

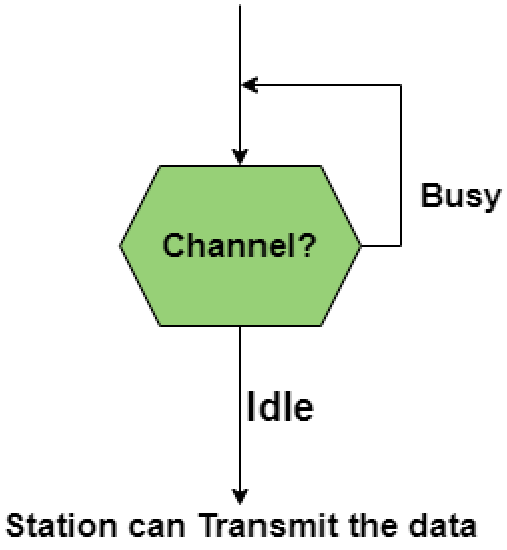
- A station may sense the medium and find it idle, only because the first bit sent by another station has not yet been received.

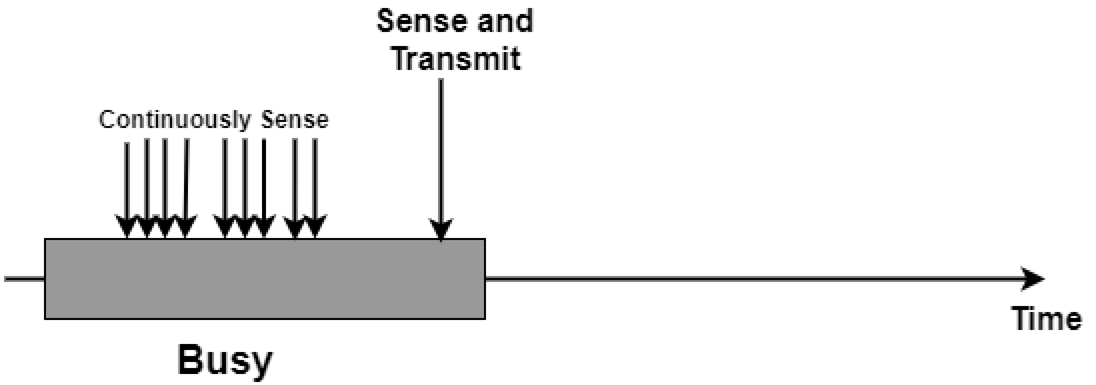



CSMA Access Modes
1-Persistent
Nonpersistent
p-Persistent

1-Persistent CSMA

- This is one of the simplest and straightforward methods.
- **Once the station finds the medium is idle *then it immediately sends the frame.***
- ***Higher chances for collision***
- It is possible that two or more stations find the shared medium idle at the same time
  - ***Send their frames immediately.***



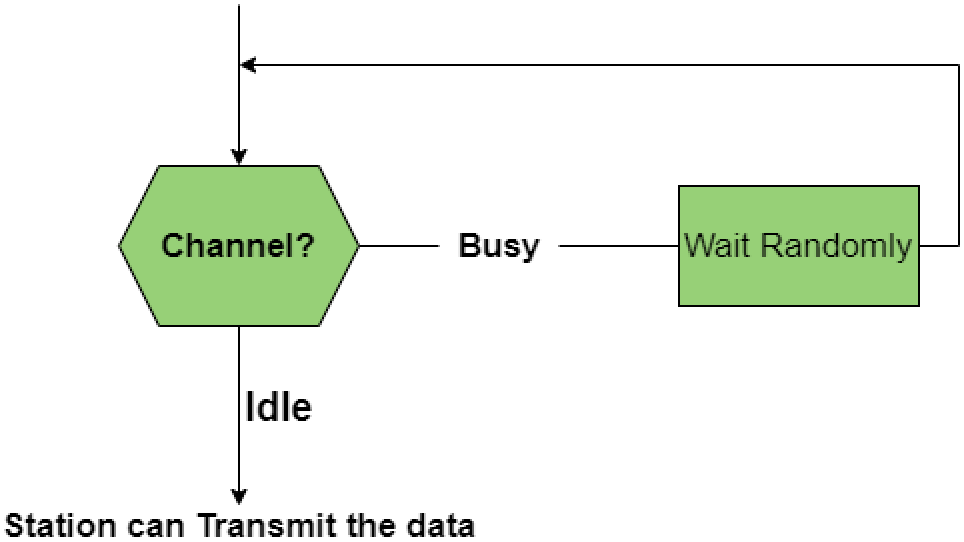


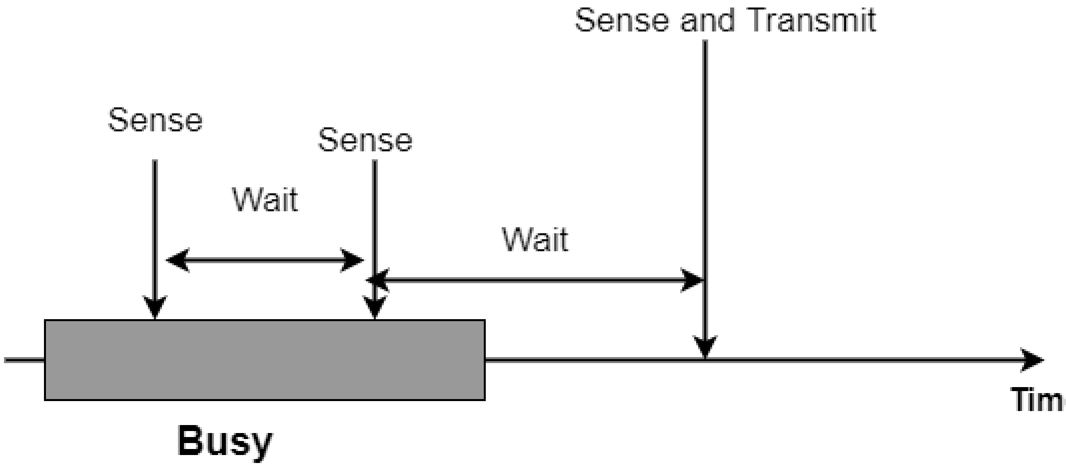
1-persistent

Non-persistent CSMA

- A station has a frame to send senses the line.
- If the line is idle then the station will send the frame
- If the line is not idle
  - The station will ***wait for a random amount of time***
  - **It then senses the line again.**
- **The chances of collision get reduced**
- ***The efficiency of the network gets reduced***
  - ***The medium stays idle when there may be stations having frames to send***

Non-persistent CSMA





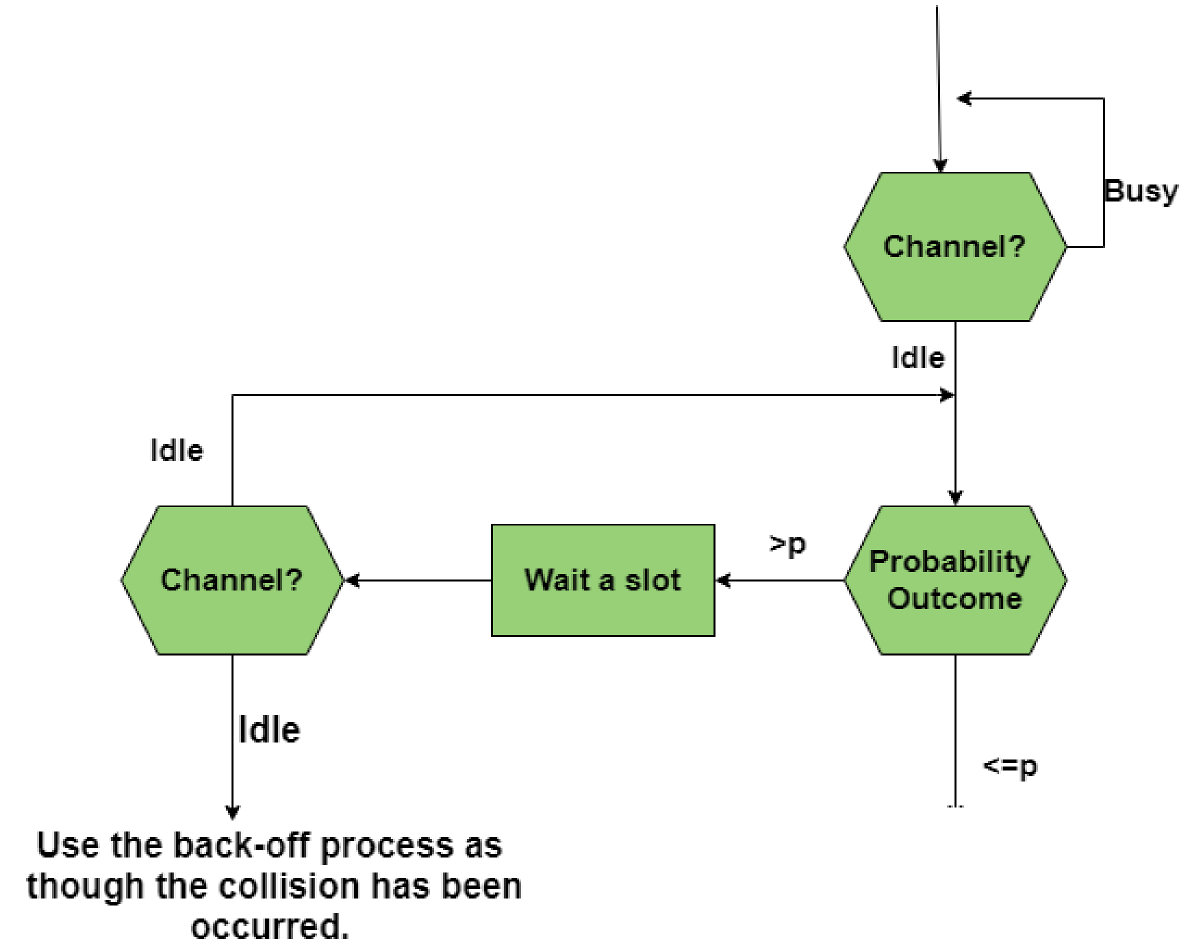
NonPersistent Approach

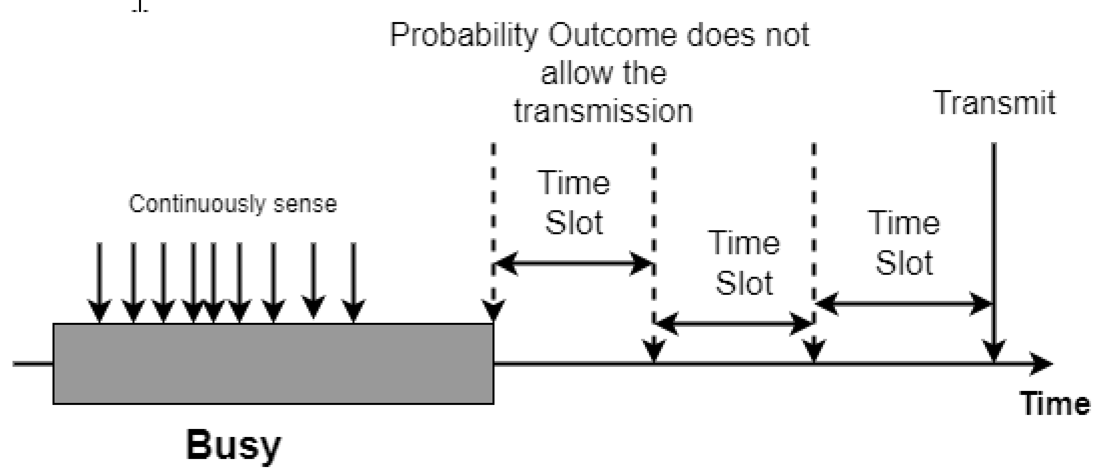
p-Persistent CSMA

- **If the channel has time slots with a slot duration**
  - ***Equal to or greater than the maximum propagation time.***
- ***Combines the advantages of 1-persistent and Nonpersistent CSMA.***
- **The chances of collision get reduced** and ***there is increased efficiency.***
- If the station finds the line idle then it follows the given below steps
- With the probability p, the station sends its frame.

p-Persistent CSMA

- With the probability q=1-p,
  - ***the station mainly waits for the beginning of the next time slot and***
  - ***then checks the line again.***
- In case if the line is found idle then go to step 1.
- In case if the line is found busy then it acts as though a collision has been occurred and then it makes use of the back-off procedure.





p-Persistent

CSMA/CD

- ***Carrier Sense Multiple Access with Collision Detection,*** is a MAC protocol.

- **Specifies how network devices should react**
  - ***When two devices try to use the same data channel at the same time and experience a data collision.***

- **Once the collision was detected, *the CSMA/CD immediately stops the transmission by sending the signal***
  - ***so that the sender does not waste all the time to send the data packet.***

- Suppose a collision is detected from each station while broadcasting the packets.

  - ***Immediately sends a jam signal to stop transmission***

  - ***waits for a random time context before transmitting another data packet.***

  - ***If the channel is found free, it immediately sends the data and returns it.***

Algorithm

- The transmitting station determines whether the channel is busy or idle when a frame is ready.
- If the channel is occupied, the station waits till it is free.
- The station begins transmitting and continuously scans the channel for collisions if the channel is empty.
- The station begins the ***collision resolution mechanism*** **when a collision is detected.**
- After finishing frame transmission, the stations reset the retransmission counters.

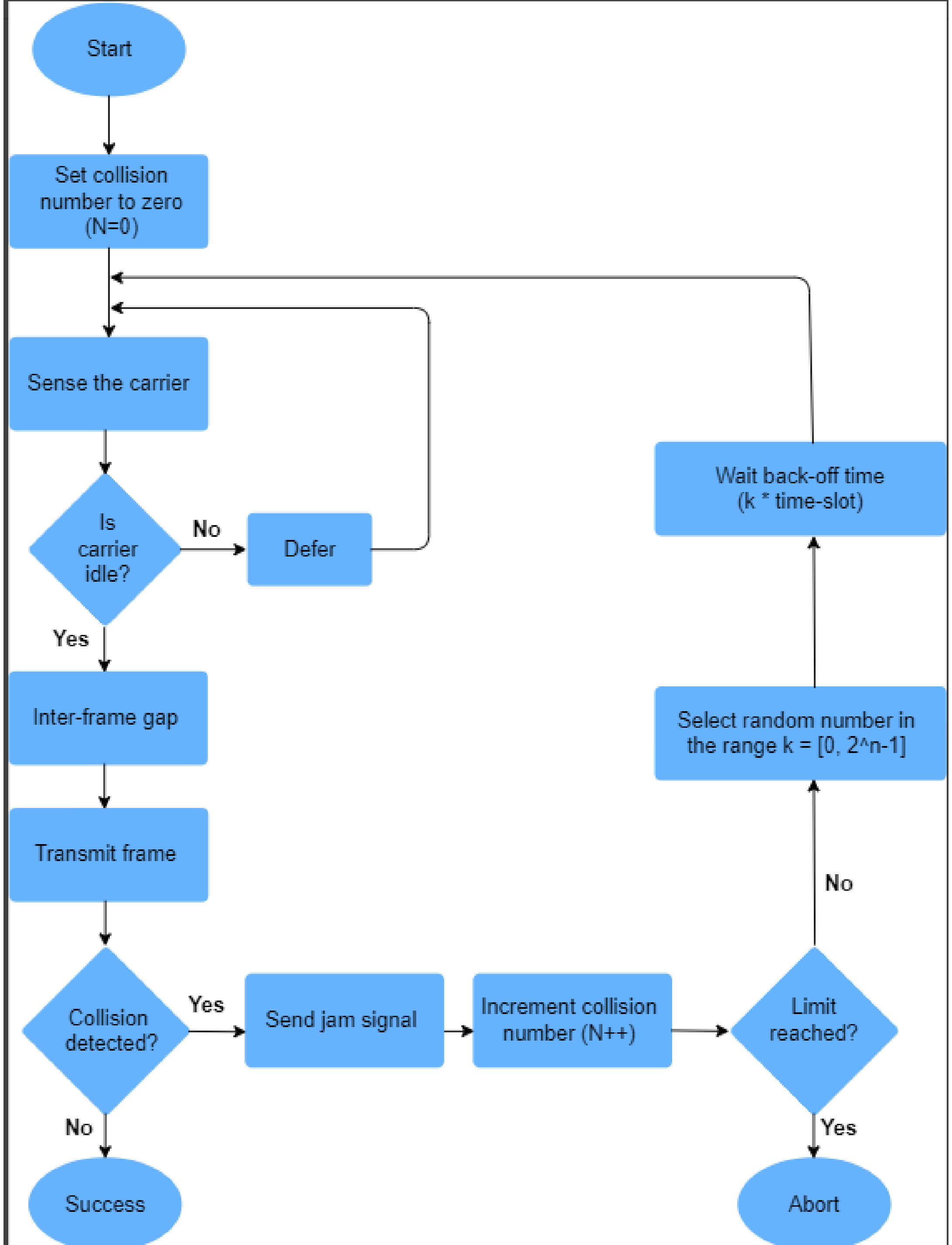
Collision resolution algorithm

- **To make sure that all other stations notice a collision,**
  - ***Station keeps transmitting the current frame for a predetermined amount of time while also sending out a jam signal.***

- The station increases the retransmission counter.

- The station stops transmission if the allotted number of retransmission attempts has been used.

- In the absence of a restart main algorithm, the station waits for a backoff period, which is often a function of the number of collisions.



Start
Set collision number to zero (N=0)
Sense the carrier
Is carrier idle?
No
Defer
Yes
Inter-frame gap
Transmit frame
Collision detected?
Yes
Send jam signal
Increment collision number (N++)
Limit reached?
No
Select random number in the range k = [0, 2^n-1]
Wait back-off time (k * time-slot)
Yes
Abort
No
Success

Efficiency

- CSMA/CD is more efficient than CSMA,

- **The efficiency of CSMA/CD decreases** ***with increase in distance.***

- Even if efficiency improves with a larger packet size, there is still a limit as to how it can be. The packets can only be a maximum of 1500 bytes long.

Advantages

- For collision detection, CSMA/CD is better than CSMA.
- It is used for quick collision detection on a shared channel.
- Compared to CSMA/CA, it has lesser overhead.
- Using CSMA/CD helps prevent the waste of transmission in any way.
- Whenever mandatory, it consumes or shares all of the bandwidth.

Disadvantages

- After reaching the maximum distance, collision detection is impossible.
- Not ideal for larger networks as collision detection is difficult to detect.
- The performance gets considerably disrupted when more devices are added.

CSMA/CA

- CSMA/CA has been specially designed for wireless networks

- three types of strategies:
  - ***InterFrame Space (IFS):*** ***When the station finds a channel to be idle it waits for a period of time called IFS time. IFS can also be used to define the priority of a station or a frame. Higher the IFS lower is the priority.***

  - ***Contention Window:*** ***It is the amount of time divided into slots. A station is ready to send frames chooses a random number of slots as wait time.***

- three types of strategies:
  - ***Acknowledgments: The positive acknowledgments and time-out timer can help guarantee a successful transmission of the frame***

- CSMA/CA is a protocol for carrier transmission in 802.11 networks.

- Developed to minimize the potential of a collision occurring when two or more stations send their signals over a data link layer.

Interframe Space (IFS)

- **Whenever the channel is found idle, *the station does not transmit immediately.***
  - ***waits for a period of time called interframe space (IFS).***

- When channel is sensed to be idle, it may be possible that same distant station may have already started transmitting and the signal of that distant station has not yet reached other stations.

- The purpose of IFS time is to allow this transmitted signal to reach other stations.

- **If after this IFS time, the channel is still idle, the station can send, *but it still needs to wait a time equal to contention time.***

Interframe Space (IFS)

- IFS variable can also be used to define the priority of a station or a frame.

Contention Window

- Contention window is ***an amount of time divided into slots.***

- **A station is ready to send** ***chooses a random number of slots as its wait time.***

- The number of slots in the window changes according to the binary exponential back-off strategy.

- It means that it is set of one slot the first time and then doubles each time the station cannot detect an idle channel after the IFS time.

Contention Window

- This is very similar to the p-persistent method except that a random outcome defines the number of slots taken by the waiting station.

- In contention window the station needs to sense the channel after each time slot.

- If the station finds the channel busy, it does not restart the process.

- It just stops the timer & restarts it when the channel is sensed as idle.

- CSMA/CA reduces the frequency of collisions and comes with a plan to continue if a collision does occur.
- The CSMA/CA protocol creates a decentralized network where all participants follow a predefined set of rules and organize transmissions accordingly.
- CSMA/CA has its limitations.

Characteristics of CSMA/CA

- Carrier Sense:
  - ***The device listens to the channel before transmitting, to ensure that it is not currently in use by another device.***
- Multiple Access:
  - ***Multiple devices share the same channel and can transmit simultaneously.***
- Collision Avoidance:
  - ***If two or more devices attempt to transmit at the same time, a collision occurs. CSMA/CA uses random backoff time intervals to avoid collisions.***
- Acknowledgment (ACK):
  - ***After successful transmission, the receiving device sends an ACK to confirm receipt.***

Characteristics of CSMA/CA

- Fairness:
  - ***The protocol ensures that all devices have equal access to the channel and no single device monopolizes it.***

- Binary Exponential Backoff:
  - ***If a collision occurs, the device waits for a random period of time before attempting to retransmit. The backoff time increases exponentially with each retransmission attempt.***

- Interframe Spacing:
  - ***The protocol requires a minimum amount of time between transmissions to allow the channel to be clear and reduce the likelihood of collisions.***

Characteristics of CSMA/CA

- RTS/CTS Handshake:
  - *__In some implementations, a Request-To-Send (RTS) and Clear-To-Send (CTS) handshake is used to reserve the channel before transmission. This reduces the chance of collisions and increases efficiency.__*

- Wireless Network Quality:
  - *__The performance of CSMA/CA is greatly influenced by the quality of the wireless network, such as the strength of the signal, interference, and network congestion.__*

- Adaptive Behavior:
  - *__CSMA/CA can dynamically adjust its behavior in response to changes in network conditions, ensuring the efficient use of the channel and avoiding congestion.__*

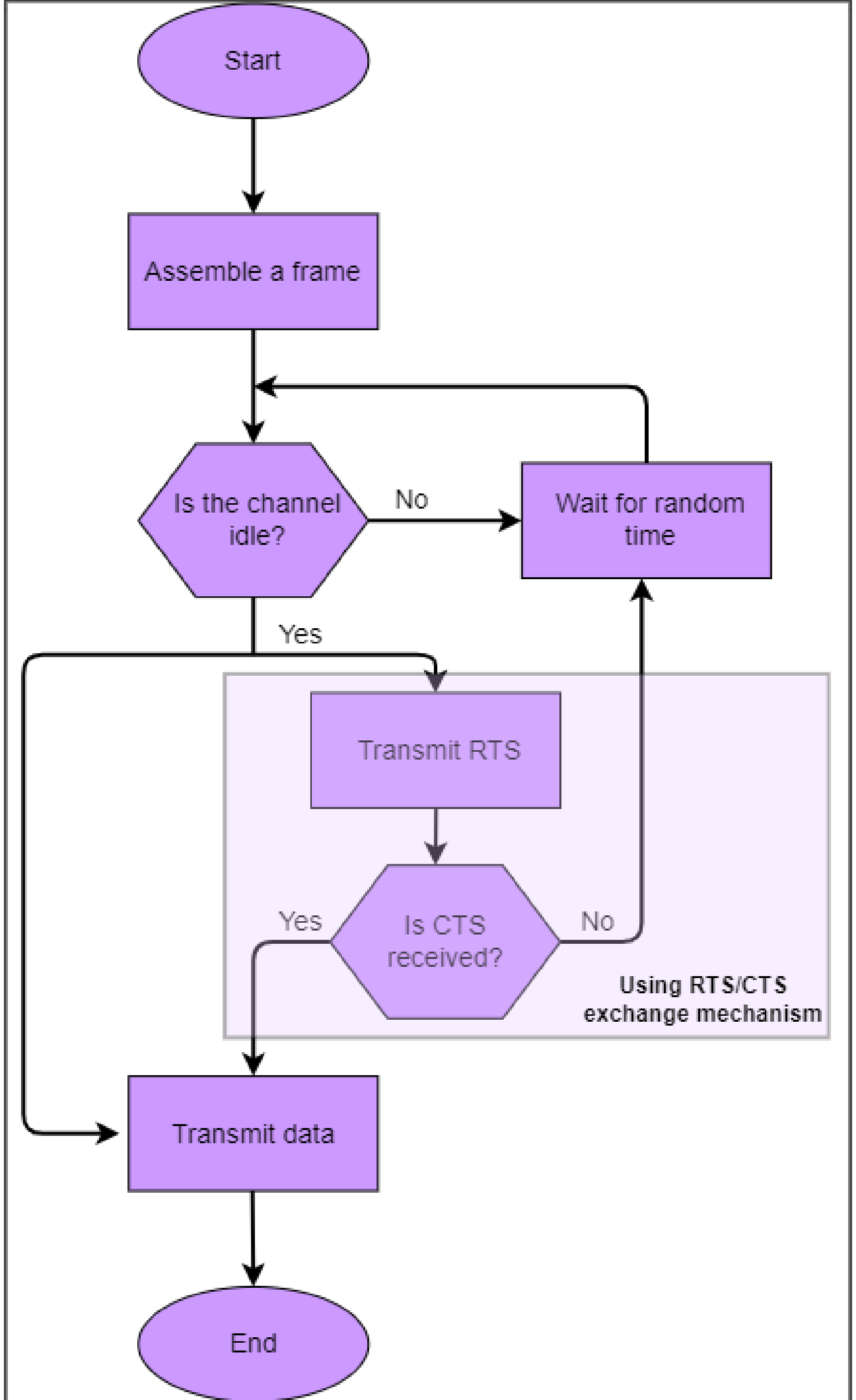
Algorithm

- When a frame is ready, the transmitting station checks whether the channel is idle or busy.
- If the channel is busy, the station waits until the channel becomes idle.
- **If the channel is idle,**
  - ***the station waits for an Inter-frame gap (IFG) amount of time and***
  - ***sends the frame.***
- After sending the frame, it sets a timer.

Algorithm

- The station then waits for acknowledgement from the receiver. If it receives the acknowledgement before expiry of timer, it marks a successful transmission.

- Otherwise, it waits for a back-off time period and restarts the algorithm.


Start
Assemble a frame
Is the channel idle?
No
Wait for random time
Yes
Transmit RTS
Is CTS received?
Yes
No
Using RTS/CTS exchange mechanism
Transmit data
End

Advantages

- CMSA/CA prevents collision.
- Due to acknowledgements, data is not lost unnecessarily.
- It avoids wasteful transmission.
- It is very much suited for wireless transmissions

Disadvantages

- The algorithm calls for long waiting times.

- It has high power consumption.

Thank You