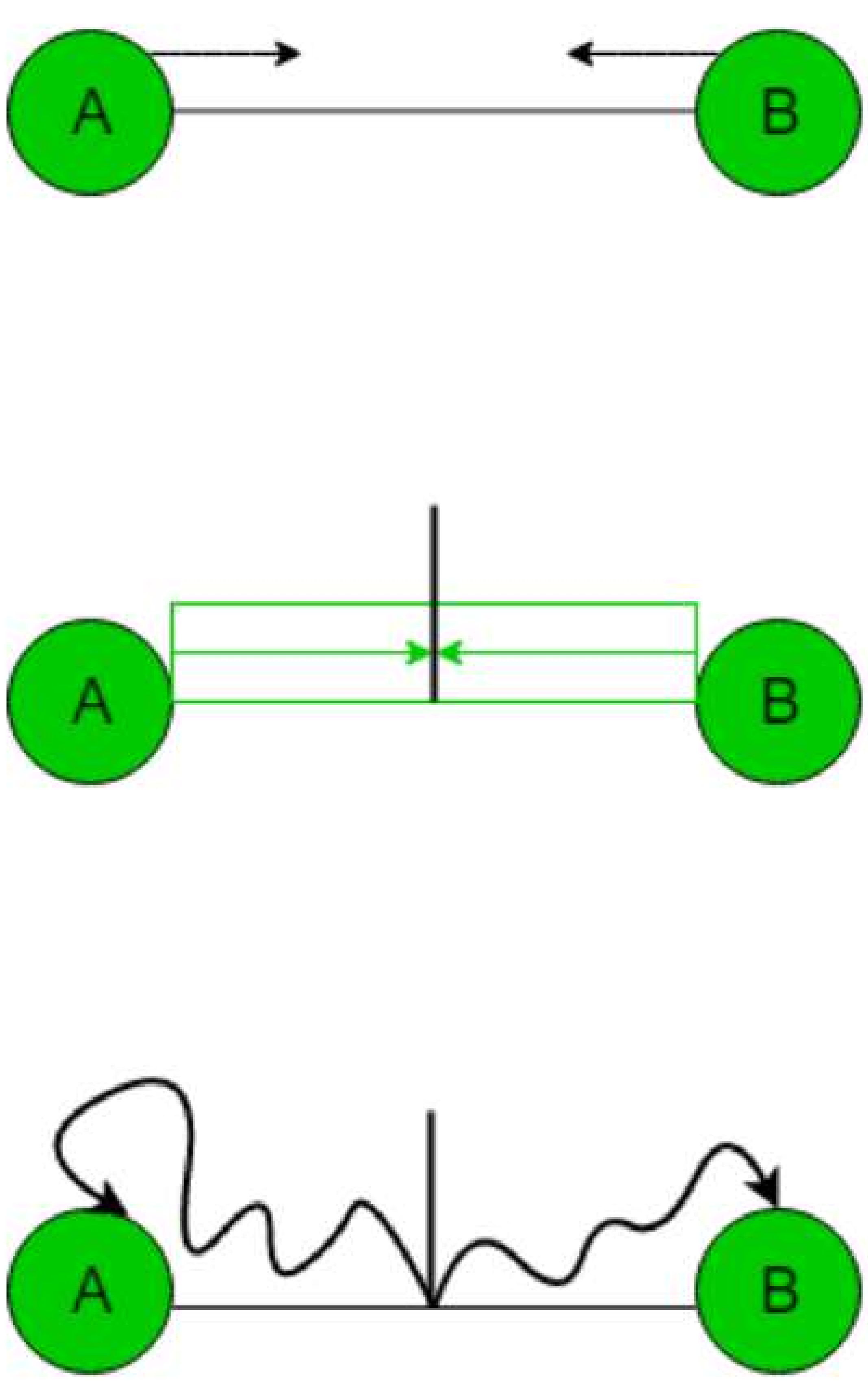
Back-off Algorithm for CSMA/CD

Back-off algorithm is a **collision resolution** mechanism which is used in random access MAC protocols (CSMA/CD). This algorithm is generally used in Ethernet to schedule re-transmissions after collisions.

If a collision takes place between 2 stations, they may restart transmission as soon as they can after the collision. This will always lead to another collision and form an infinite loop of collisions leading to a deadlock. To prevent such scenario back-off algorithm is used.

Let us consider an scenario of 2 stations A and B transmitting some data:



At t = 0 , both A and B start transmission

Packets of both A and B collide

Both stations A and B detect collision

After a collision, time is divided into discrete slots (T_{slot}) whose length is equal to 2t, where t is the maximum propagation delay in the network.

The stations involved in the collision randomly pick an integer from the set K i.e {0, 1}. This set is called the contention window. If the sources collide again because they picked the same integer, the contention window size is doubled and it becomes {0, 1, 2, 3}. Now the sources involved in the second collision randomly pick an integer from the set {0, 1, 2, 3} and wait that number of time slots before trying again. Before they try to transmit, they listen to the channel and transmit only if the channel is idle. This causes the source which picked the smallest integer in the contention window to succeed in transmitting its frame.

So, Back-off algorithm defines a *waiting time for the stations involved in collision*, i.e. for how much time the station should wait to re-transmit.

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Waiting time = back-off time

Let n = collision number or re-transmissi

Then,

Waiting time = K * Tslot

where K = [0, 2n - 1 ]
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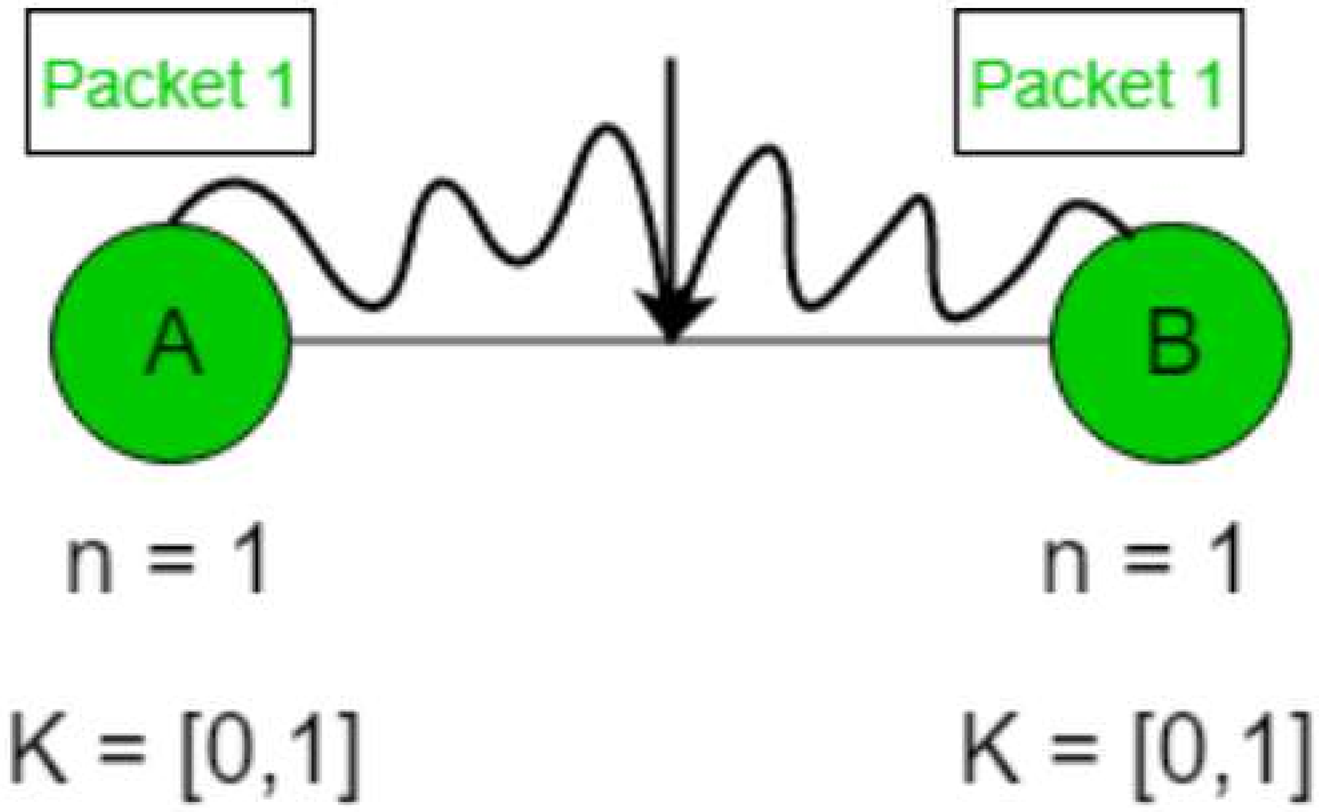
$$\text{Waiting time} = K * T_{slot}, \quad K = [0, 2^n - 1]$$

Example –

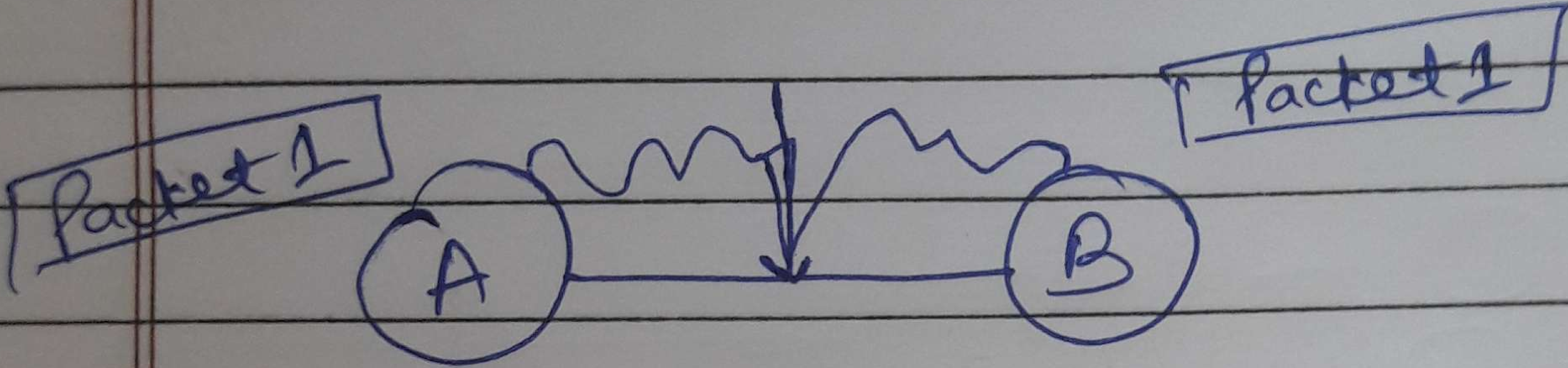
Case-1 :

Suppose 2 stations A and B start transmitting data (Packet 1) at the same time then, collision occurs. So, the collision number n for both their data (Packet 1) = 1. Now, both the station randomly pick an integer from the set K i.e. {0, 1}.



Value of K

A	B
0	0
0	1
1	0
1	1



$n=1$

$n=1$ → no. of collisions for packet 1.

$k=[0, 2^n - 1]$

$k=[0, 1]$

∴ Put $n=1$ in above range

$k=[0, 2^1 - 1]$

$k=[0, 1]$

- **When both A and B choose K = 0**

  –> Waiting time for A = 0 * T_{slot} = 0

  Waiting time for B = 0 * T_{slot} = 0

  Therefore, both stations will transmit at the same time and hence collision occurs.

- **When A chooses K = 0 and B chooses K = 1**

  –> Waiting time for A = 0 * T_{slot} = 0

  Waiting time for B = 1 * T_{slot} = T_{slot}

  Therefore, A transmits the packet and B waits for time T_{slot} for transmitting and hence A wins.

- **When A chooses K = 1 and B chooses K = 0**

  –> Waiting time for A = 1 * T_{slot} = T_{slot}

  Waiting time for B = 0 * T_{slot} = 0

Therefore, B transmits the packet and A waits for time T_{slot} for transmitting and hence B wins.

- **When both A and B choose K = 1**
  –> Waiting time for A = 1 * T_{slot} = T_{slot}
  Waiting time for B = 1 * T_{slot} = T_{slot}
  Therefore, both will wait for the same time T_{slot} and then transmit. Hence, collision occurs.

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Probability that A wins = 1/4

Probability that B wins = 1/4

Probability of collision  = 2/4
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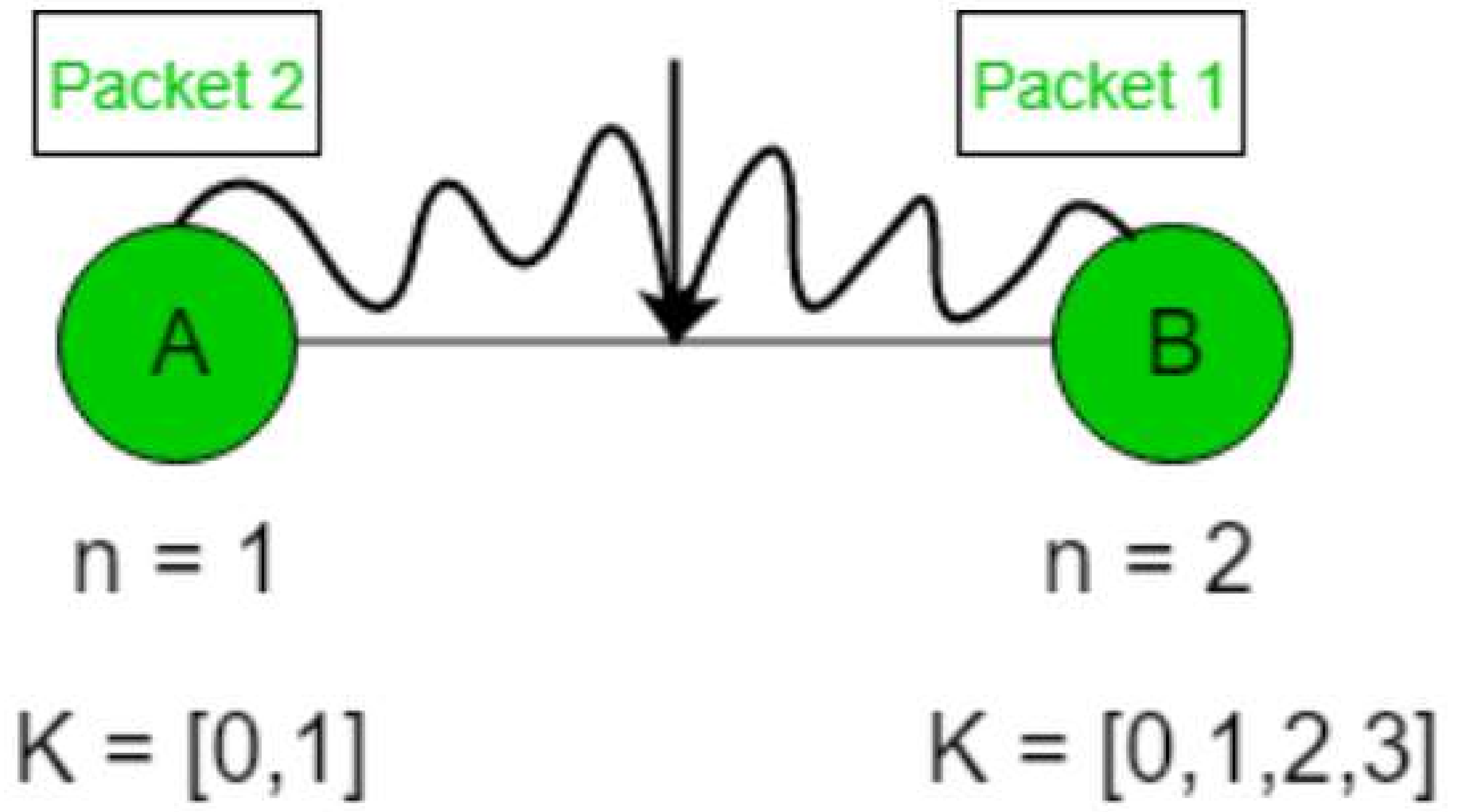
Case-2 :

Assume that A wins in Case 1 and transmitted its data(Packet 1). Now, as soon as B transmits its packet 1, A transmits its packet 2. Hence, collision occurs. Now collision no. n becomes 1 for packet 2 of A and becomes 2 for packet 1 of B.

For packet 2 of A, K = {0, 1}

For packet 1 of B, K = {0, 1, 2, 3}

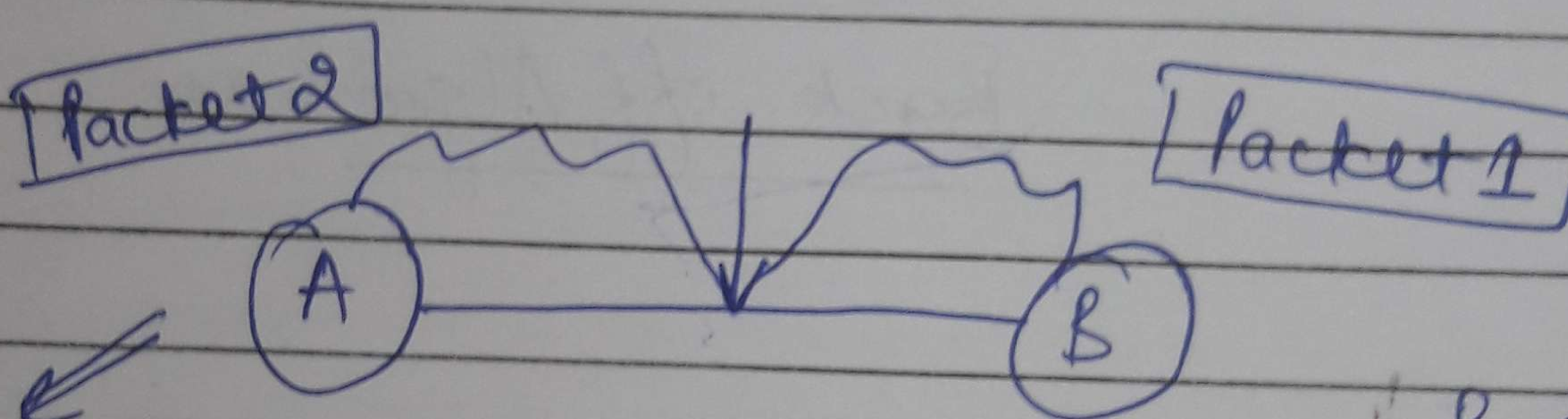


Value of K

A	B
0	0
0	1
0	2
0	3
1	0
1	1
1	2
1	3

Now, Ist packet of A has been transmitted & B is waiting for its Ist packet to transmit.

Now, A has to transmit its 2nd Packet.



A के Packet 2 का एक बार collision हुआ है so $n=1$

$n = 1$

B के $n = 2 \Rightarrow$ Packet 1 का दो बार collision हो गया है so $n=2$

$k = [0, 2^n - 1]$ $\quad$ $k = [0, 2^n - 1]$

$k = [0, 2^1 - 1]$ $\quad$ $k = [0, 2^2 - 1]$

$k = [0, 1]$ $\quad$ $k = [0, 1, 2, 3]$

	A	B	
	0	0	Both send data packet at same time so collision.
A retransmit immediately & B waits for 1 time slot.	0	1	A wins (1)
B waits for 2 time slots	0	2	A wins (2)
B waits for 3 time slots.	0	3	A wins (3)
	1	0	B wins (A waits)
	1	1	collision
(4) A wins	1	2	B waits for longer time
(5) A wins	1	3	(B waits for longer time)

Total chances = 8

$P(A) = 5/8$ $P(C) = 2/8$ $P(B) = 1/8$

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Probability that A wins = 5/8

Probability that B wins = 1/8

Probability of collision  = 2/8
```

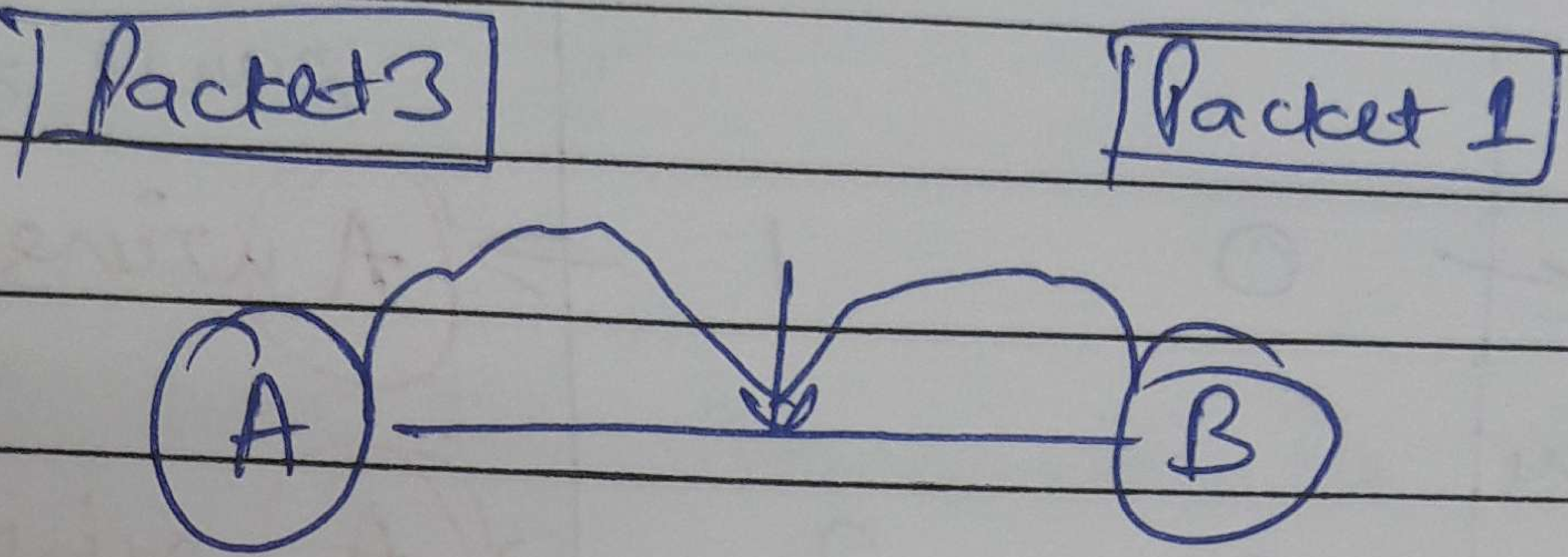
So, probability of collision decreases as compared to Case 1.

Advantage –

- Collision probability decreases exponentially.

Disadvantages –

- **Capture effect:** Station who wins ones keeps on winning.
- Works only for 2 stations or hosts.



$n = 1$ $\quad$ $n = 3$

$(0, 1)$ $\quad$ $(0, 1, 2, 3, 4, 5, 6, 7)$

No. of combinations will be
($2 \times 8 = 16$).

$W_t = K * T_{slot}$

T_{slot} = ~~random~~ / fixed time acc. to the network.

Note → ① If A has won in the first case after collision, then A's probability of winning keeps on increasing.

Disadvantage – ① If one station wins once, then it will keep on winning many no. of times (which decreases the ~~...~~ chances of winning for other station).

Capture effect

∘ Probabilities increase or decrease exponentially.

∘ Binary exponential back-off algorithm.

↓

Another name

2. Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) –

The basic idea behind CSMA/CA is that the station should be able to receive while transmitting to detect a collision from different stations. In wired networks, if a collision has occurred then the energy of received signal almost doubles and the station can sense the possibility of collision. In case of wireless networks, most of the energy is used for transmission and the energy of received signal increases by only 5–10% if a collision occurs. It can’t be used by the station to sense collision. Therefore **CSMA/CA has been specially designed for wireless networks.**

These are three types of strategies:

1. **InterFrame Space (IFS)** – When a station finds the channel busy, 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.
2. **Contention Window** – It is the amount of time divided into slots.A station which is ready to send frames chooses random number of slots as **wait time**.
3. **Acknowledgements** – The positive acknowledgements and time-out timer can help guarantee a successful transmission of the frame.

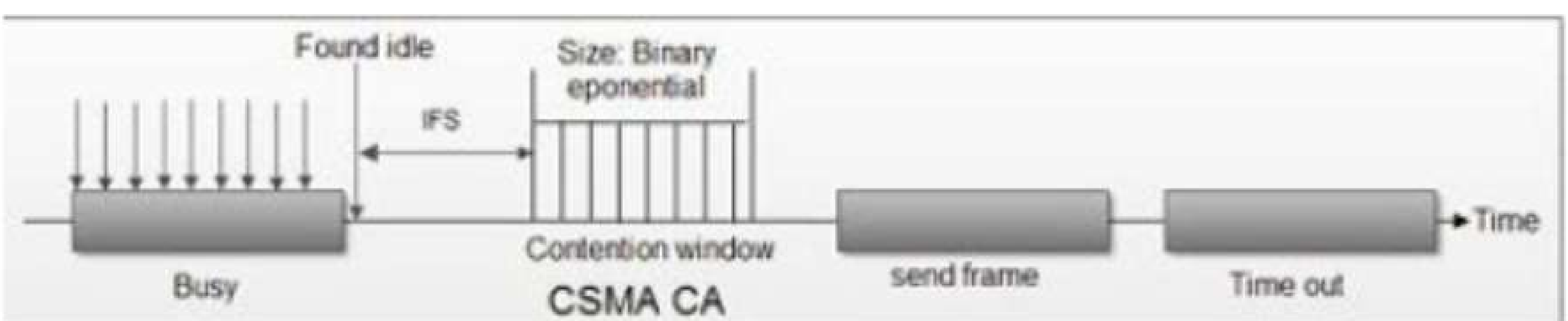
• CSMA/CA protocol is used in wireless networks because they cannot detect the collision so the only solution is collision avoidance.

• CSMA/CA avoids the collisions using three basic techniques.

(i) Interframe space

(ii) Contention window

(iii) Acknowledgements



1. Interframe Space (IFS)

- Whenever the channel is found idle, the station does not transmit immediately. It 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.

- Therefore 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.

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

2. Contention Window

• Contention window is an amount of time divided into slots.

• A station that 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.

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

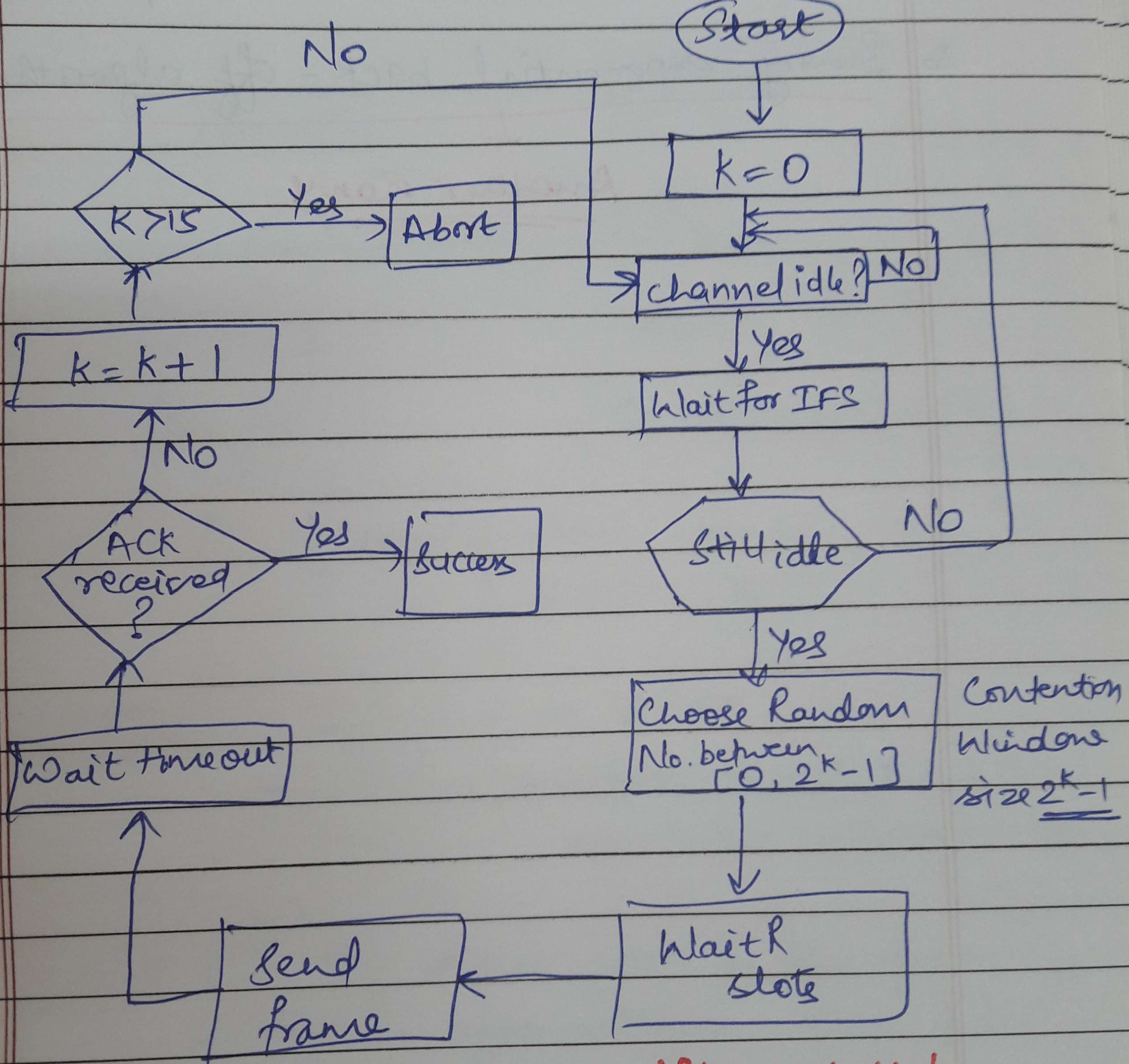
• In contention window the station needs to sense the channel after each time slot.

• 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.

3. Acknowledgement

- Despite all the precautions, collisions may occur and destroy the data.

- The positive acknowledgment and the time-out timer can help guarantee that receiver has received the frame.



k = No. of attempts to send a frame

After each slot check channel — if idle then continue; if Busy then halt for some time & continue when idle.

- This is the CSMA protocol with collision avoidance.
- The station ready to transmit, senses the line by using one of the persistent strategies.
- As soon as it find the line to be idle, the station waits for an IFG (Interframe gap) amount of time.
- If then waits for some random time and sends the frame.
- After sending the frame, it sets a timer and waits for the acknowledgement from the receiver.
- If the acknowledgement is received before expiry of the timer, then the transmission is successful.
- But if the transmitting station does not receive the expected acknowledgement before the timer expiry then it increments the back off parameter, waits for the back off time and resenses the line.