21ES614 – Internet of Things

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Syllabus

Unit 1

Introduction to IoT - Definitions, frameworks and key technologies. Functional blocks of IoT systems: hardware and software elements- devices, communications, services, management, security, and application. Challenges to solve in IoT

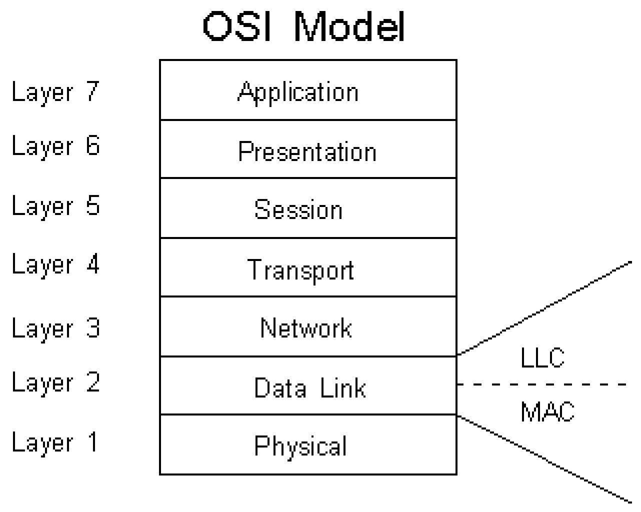
Unit 2

Basics of Networking & Sensor Networks - Applications, challenges - ISO/OSI Model, TCP/IP Model, Sensor network architecture and design principles, IoT technology stack, Communication models. Communication Protocols - Overview of protocols in each layer, Application protocols for the transfer of sensor data, Infrastructure for IoT: LoRa-Wan, 6LoWPAN, 5G and Sigfox.

Unit 3

Introduction to Cloud, Fog and Edge Computing. Modern trends in IoT – Industrial IoT, Wearable. Applications of IoT - Smart Homes/Buildings, Smart Cities, Smart Industry, and Smart Medical care, Smart Automation etc.

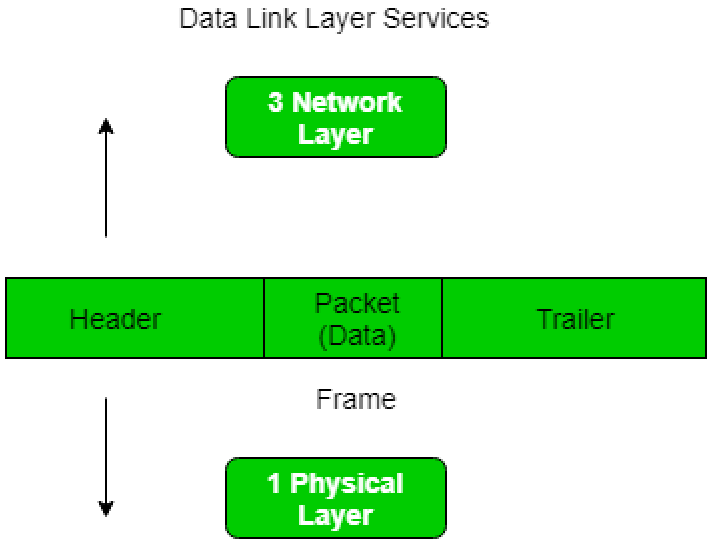
Data Link Layer

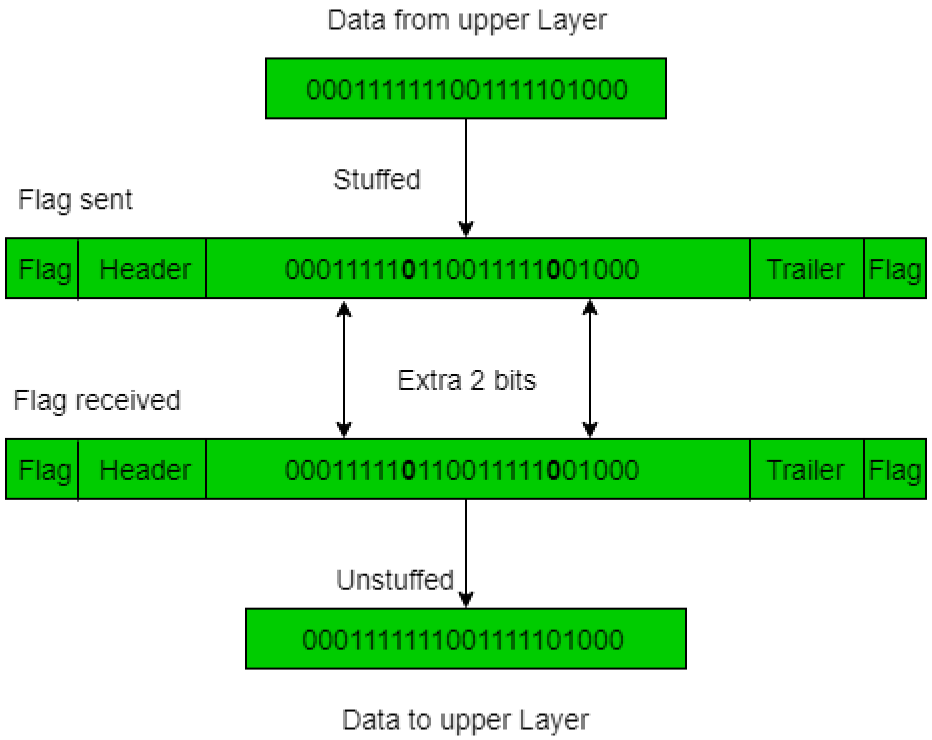


- Framing
- Link Management
- Physical addressing
- Flow control
- Error control
- Multiplexing of multiple protocols at a higher layer
- Access control of channel by the devices
- Data Link Layer devices - Switch & Bridge

Ref: https://networkhope.in/iso-osi-basic-reference-model/
http://cs.uok.edu.in/Files/79755f07-9550-4aeb-bd6f-5d802d56b46d/Custom/ADC%20unit%202.pdf
https://www.studytonight.com/computer-networks/complete-osi-model
https://www.geeksforgeeks.org/layers-of-osi-model/

Data Link Layer - Framing





Ref: https://www.geeksforgeeks.org/framing-in-data-link-layer/
https://www.geeksforgeeks.org/various-kind-of-framing-in-data-link-layer/

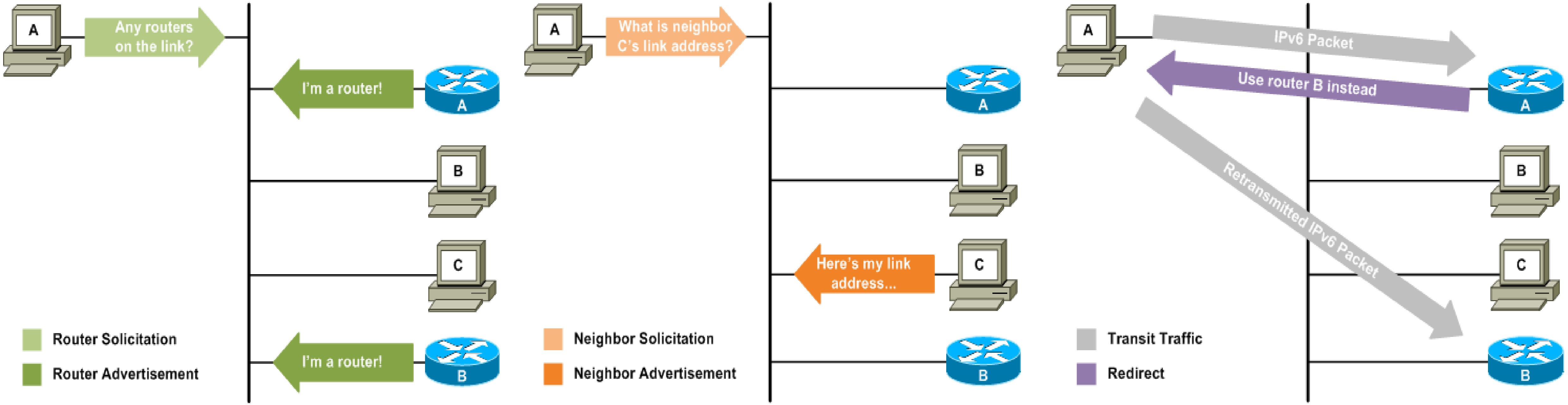
Data Link Layer – Link Management

- Creation of link
  - Hand shaking messages
- Maintenance of link
  - Quality of link
  - Bit/Word Error rate
- Destruction of link
  - On persistent noise
  - Termination of link/network

Ref:

Data Link Layer – Link Management

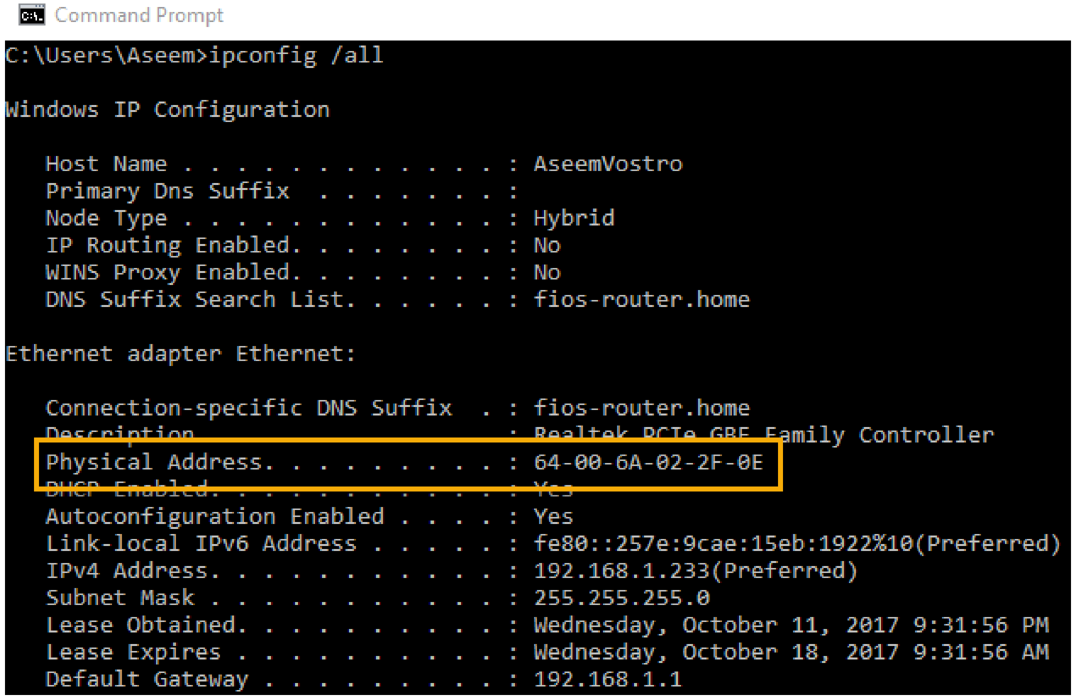
- Neighborhood Discovery Protocol

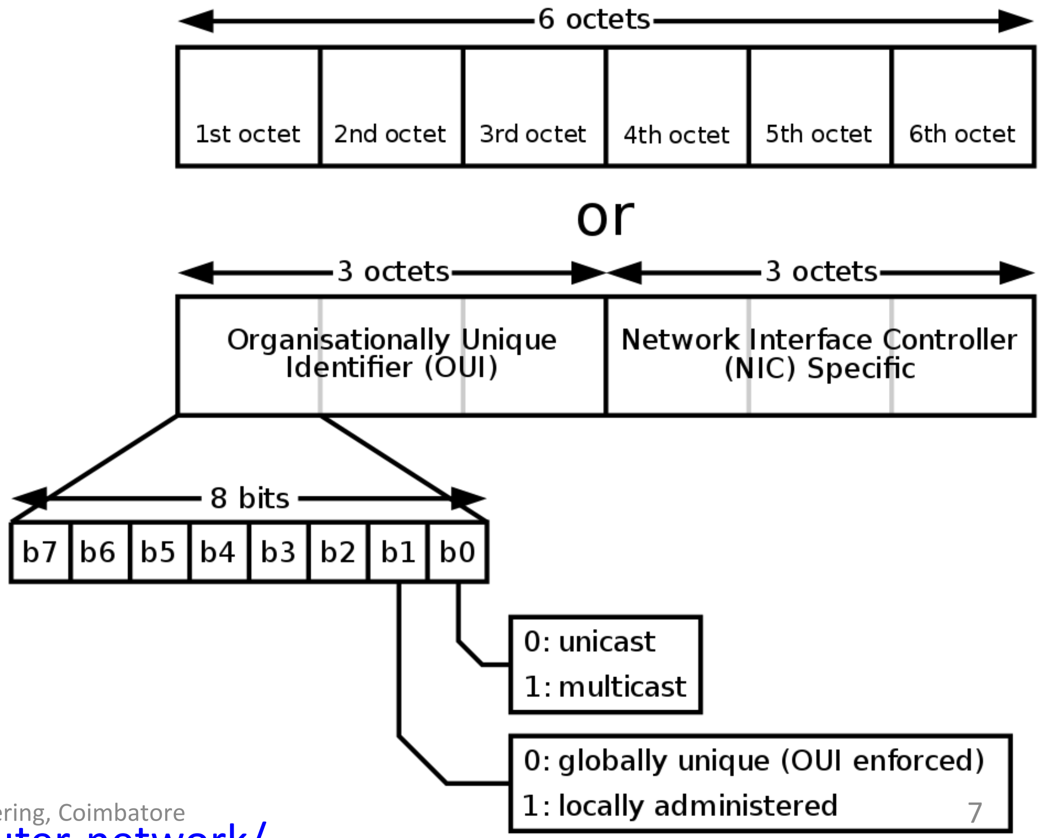


Ref: https://packetlife.net/blog/2008/aug/28/ipv6-neighbor-discovery/
https://en.wikipedia.org/wiki/Neighbor_Discovery_Protocol

Data Link Layer – Physical Addressing

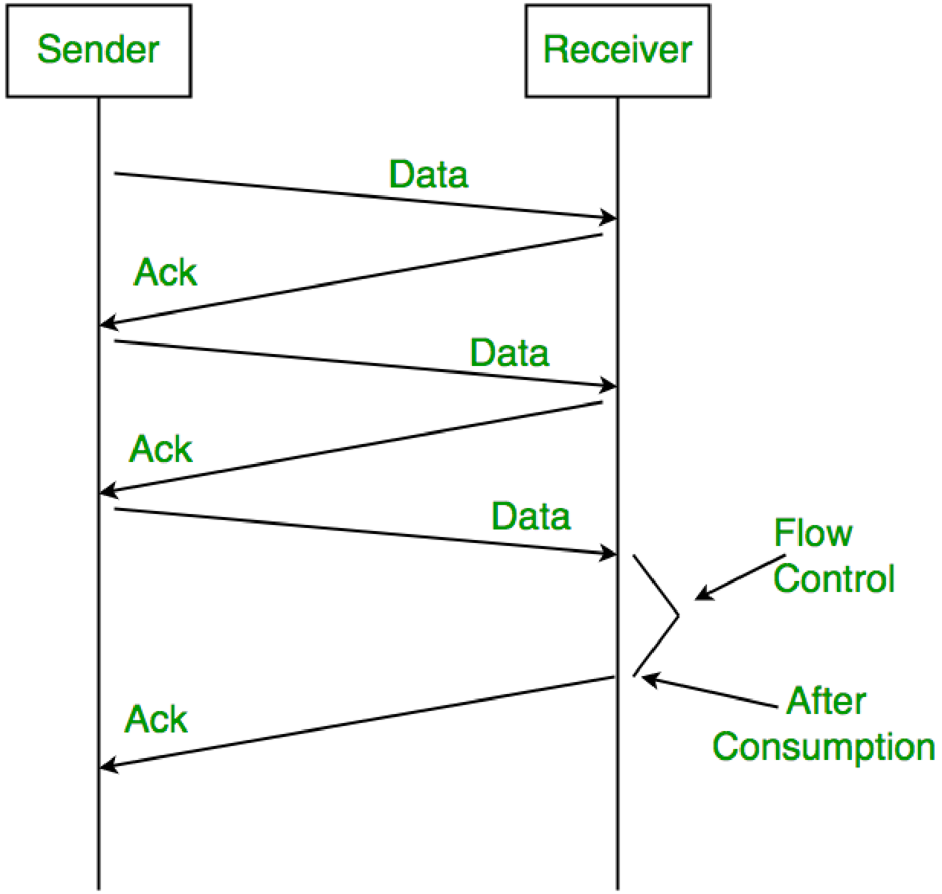
- Unique identifier assigned to an NIC
- Primarily assigned by device manufacturers

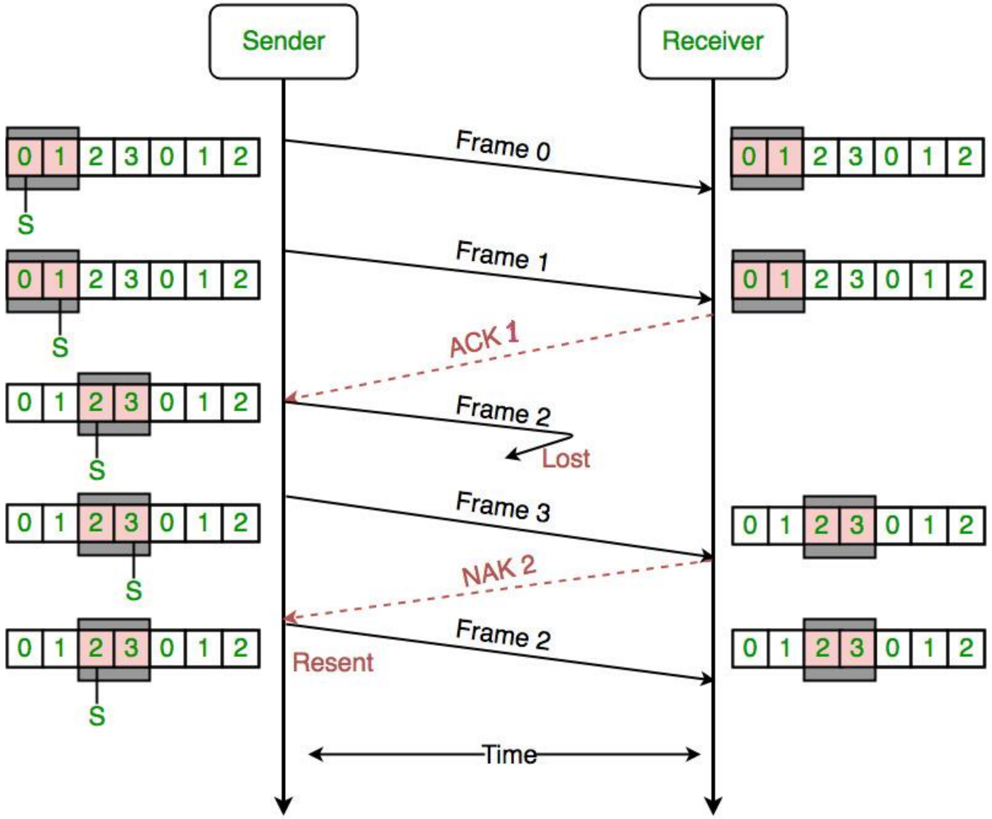




Ref: https://en.wikipedia.org/wiki/MAC_address
https://www.geeksforgeeks.org/introduction-of-mac-address-in-computer-network/

Data Link Layer – Flow Control

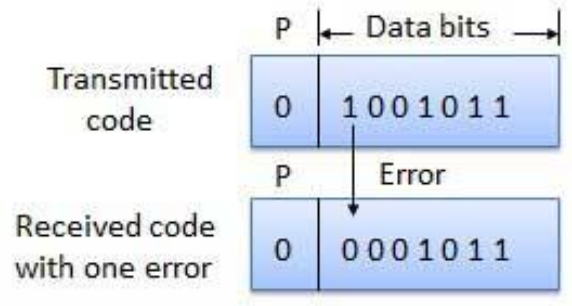


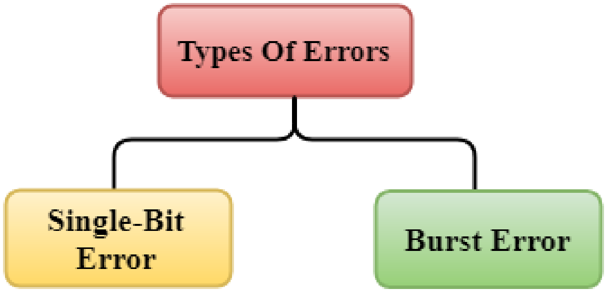


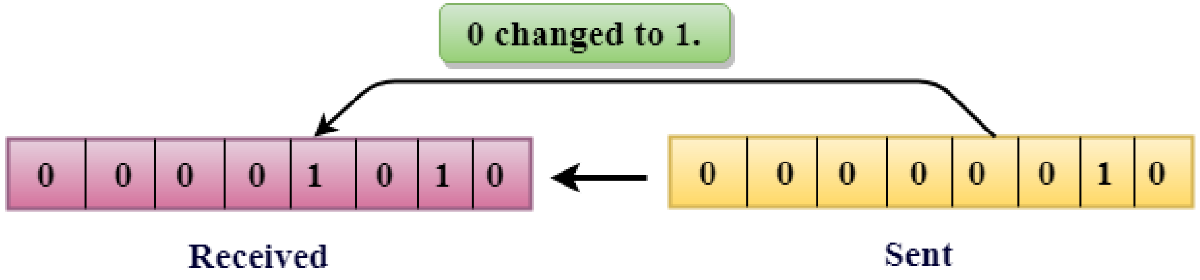
Ref: https://www.geeksforgeeks.org/stop-and-wait-arq/
https://www.geeksforgeeks.org/sliding-window-protocol-set-3-selective-repeat/

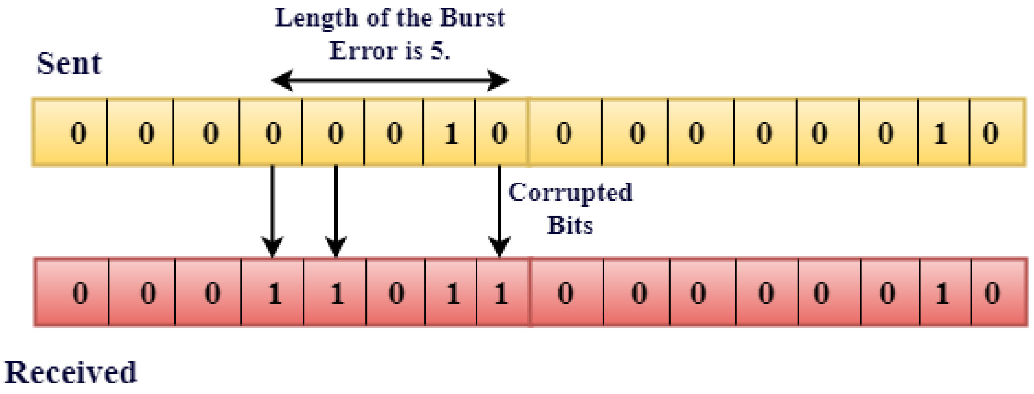
Data Link Layer – Error Control

- Error Detection
  - Single Parity Check
  - 2D Parity Check
  - Checksum
  - CRC



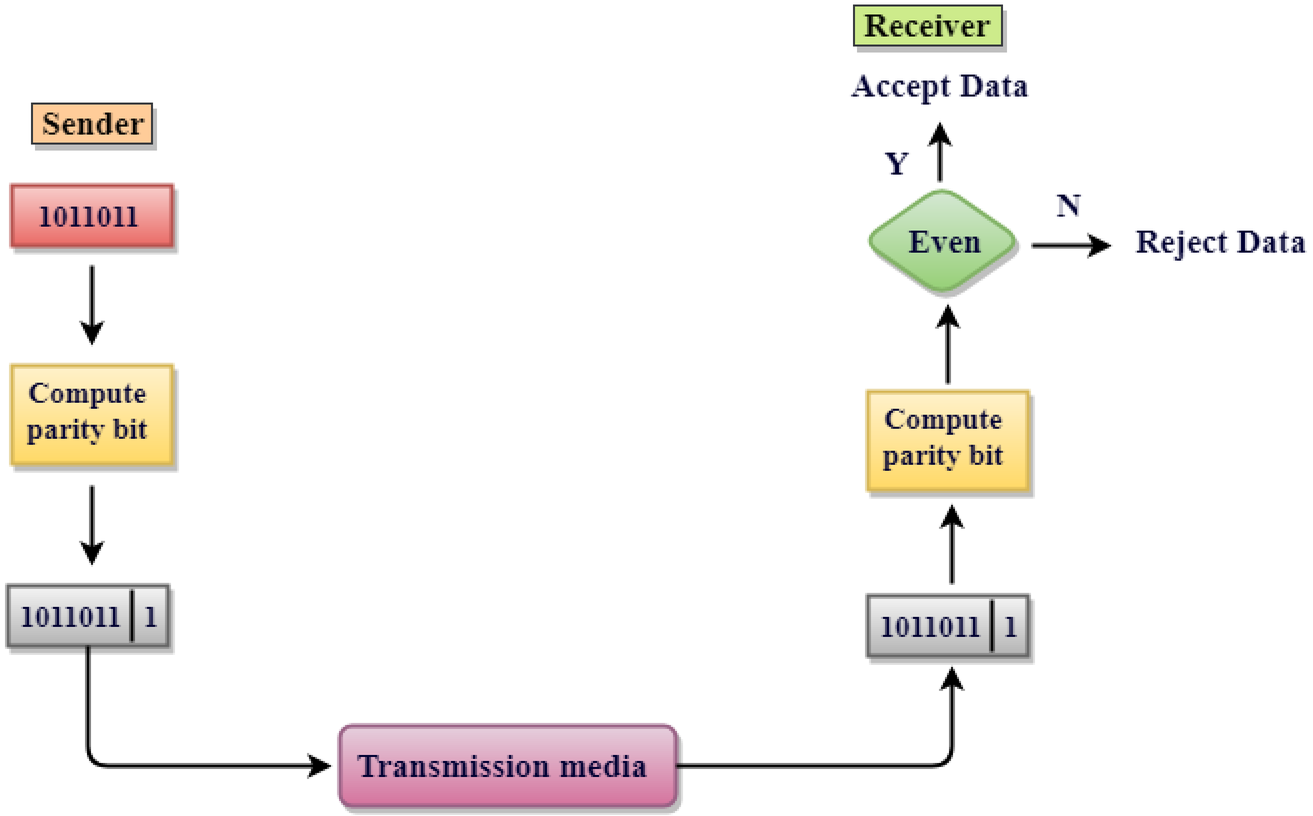


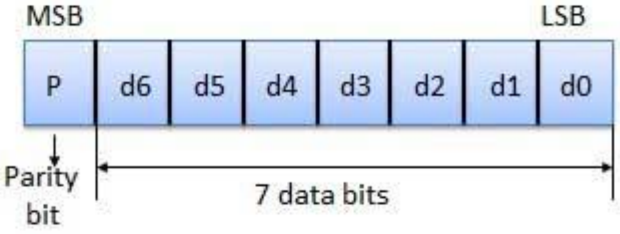




Ref: https://www.tutorialspoint.com/computer_logical_organization/error_codes.htm
https://www.javatpoint.com/computer-network-error-detection
https://www.geeksforgeeks.org/error-detection-in-computer-networks/

Error Detection – Single Parity Check





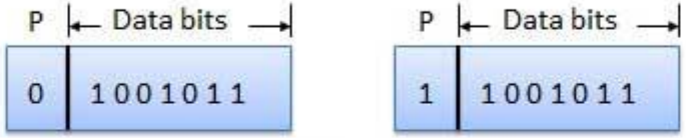


Fig. (a)

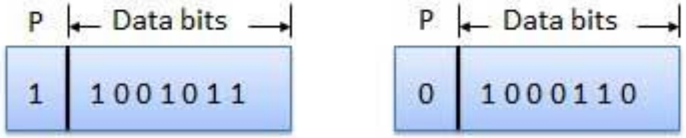
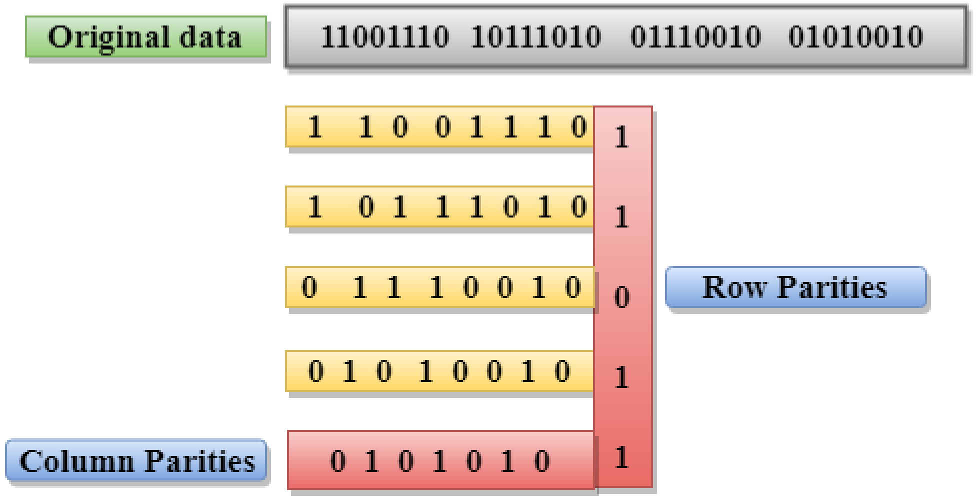
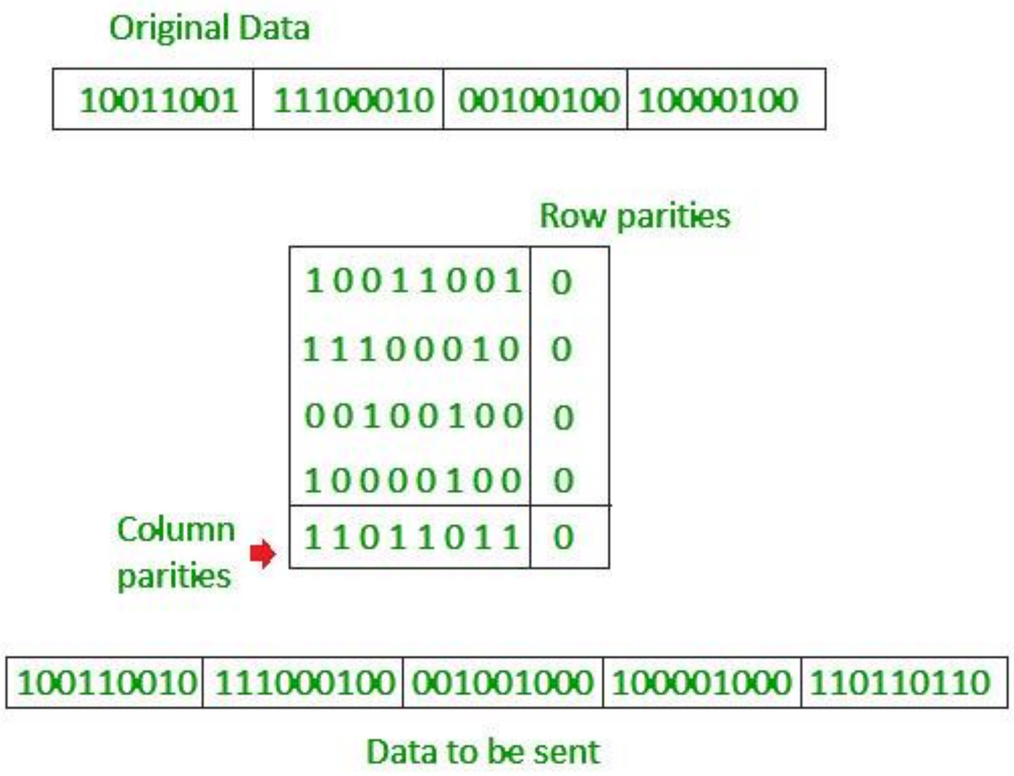


Fig. (b)

Ref: https://www.tutorialspoint.com/computer_logical_organization/error_codes.htm
https://www.javatpoint.com/computer-network-error-detection
https://www.geeksforgeeks.org/error-detection-in-computer-networks/

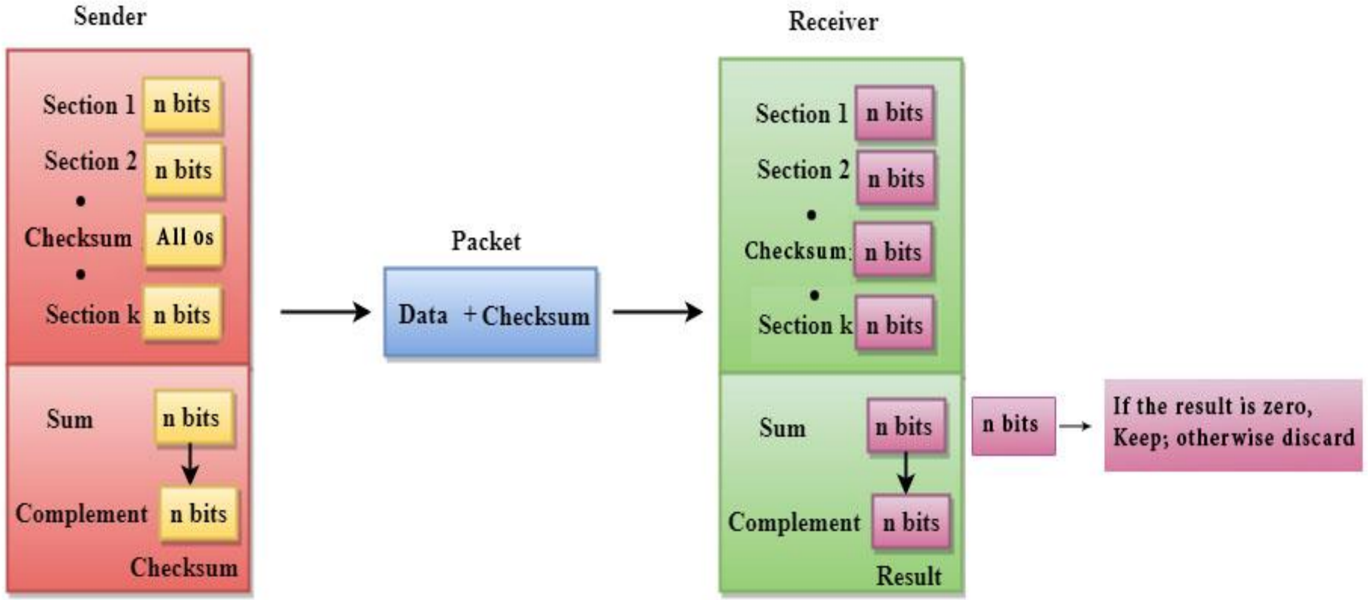
Error Detection – 2D Parity Check

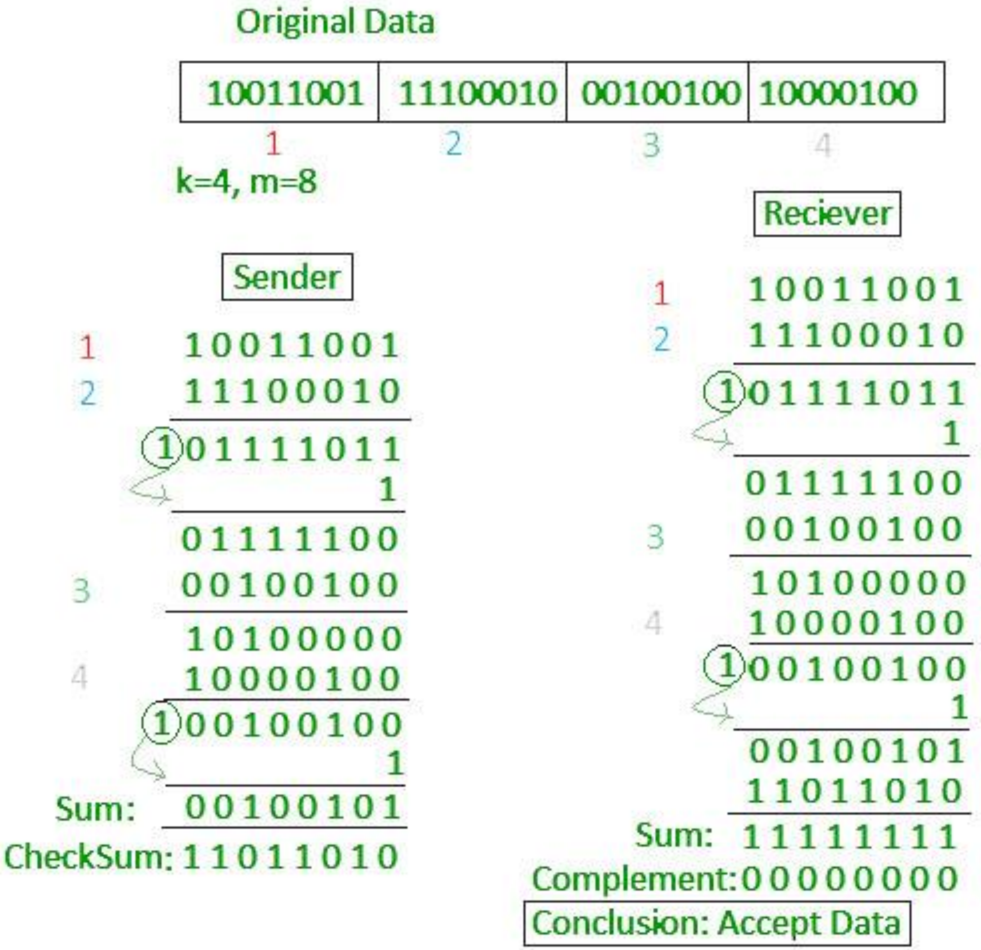




Ref: https://www.javatpoint.com/computer-network-error-detection
https://www.geeksforgeeks.org/error-detection-in-computer-networks/

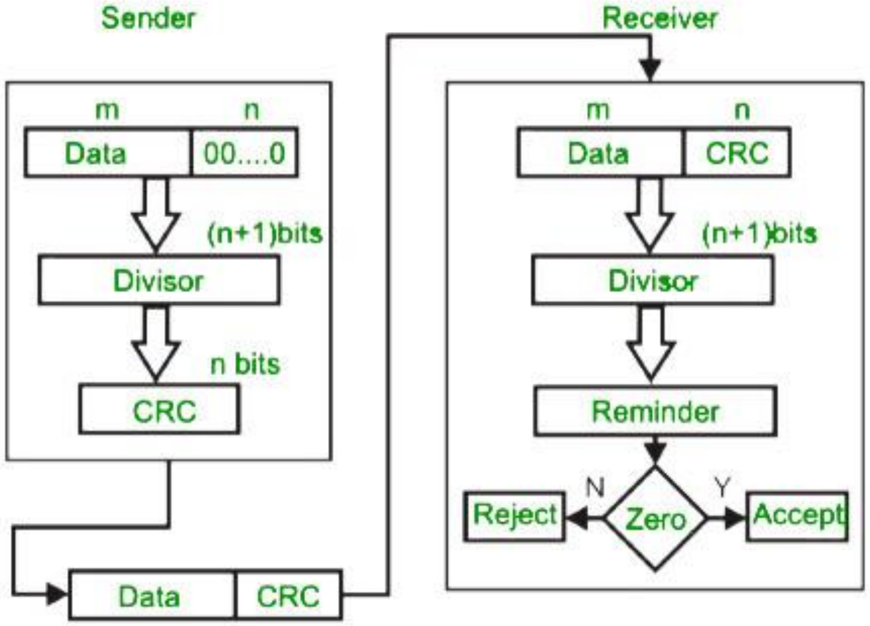
Error Detection – Checksum

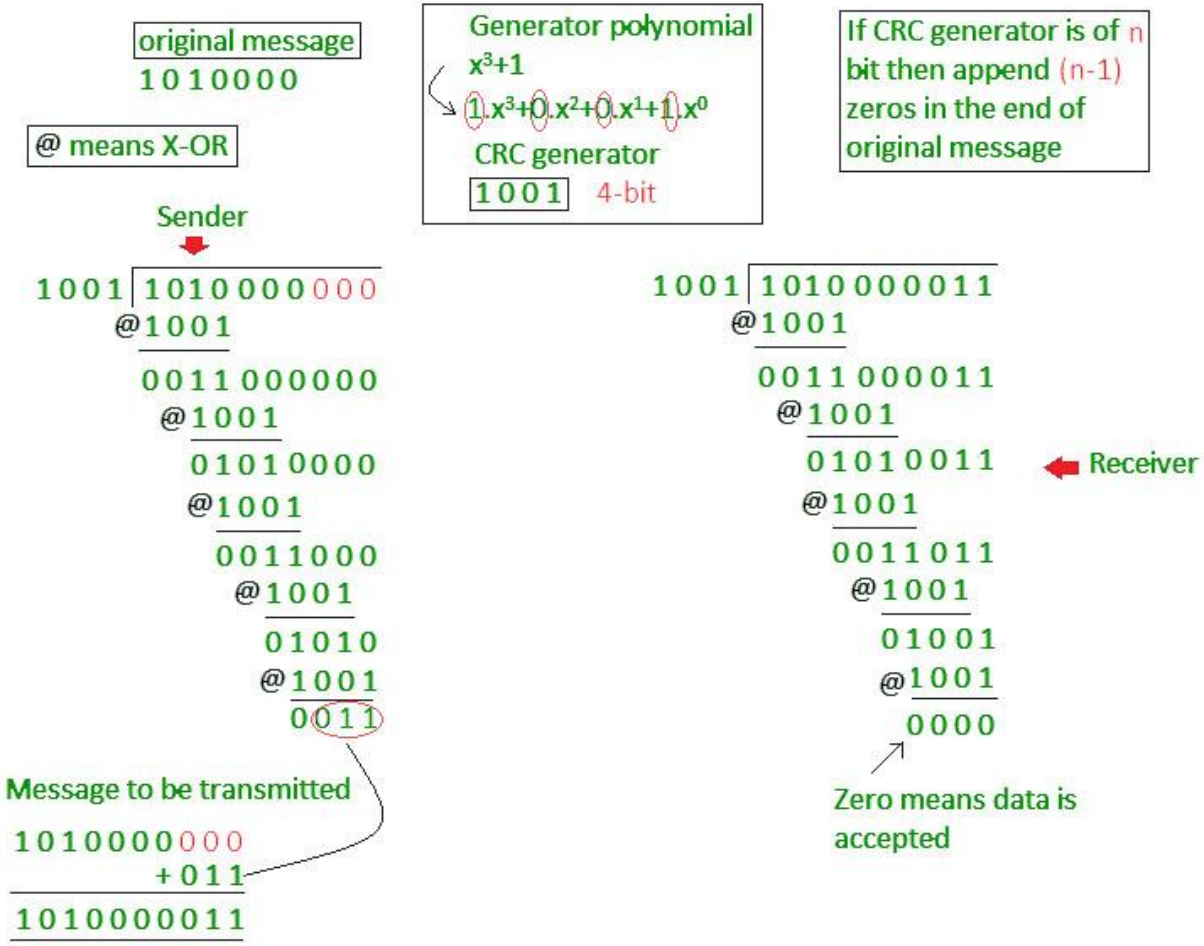




Ref: https://www.javatpoint.com/computer-network-error-detection
https://www.geeksforgeeks.org/error-detection-in-computer-networks/

Error Detection – CRC





Ref: https://www.javatpoint.com/computer-network-error-detection
https://www.geeksforgeeks.org/error-detection-in-computer-networks/
https://info.support.huawei.com/info-finder/encyclopedia/en/CRC.html

Error Correction - CRC

```
          10001100
1001 | 10011101000
       1001
       00001
        0000
        00011
         0000
         00110
          0000
          01101
           1001
           01000
            1001
            00010
             0000
             00100
              0000
              0100  <- CRC
```

```
          10101000
1001 | 10111101100
       1001
       00101
        0000
        01011
         1001
         00100
          0000
          01001
           1001
           00001
            0000
            00010
             0000
             00100
              0000
              0100  <- Remainder
```

```
 100000000
----------- = 100100, Remainder = 100
   1001
```

```
           100100
         ----------
1001 )  100000000
        1001
        ----
         00100000
           1001
           ----
              100
```


Ref: https://www.gatevidyalay.com/cyclic-redundancy-check-crc-error-detection/

Error Correction – Hamming Code

Bit Designation Bit Location Binary Location Number	D7 7 111	D6 6 110	D5 5 101	P4 4 100	D3 3 011	P2 2 010	P1 1 001
Parity Bits (Pn)				—		—	—
Data Bits (Dn)	—	—	—		—		

$$2^P \geq n + P + 1$$

- n – data bits; P – parity bits

1. Number the bits starting from 1: bit 1, 2, 3, 4, 5, etc.
2. Write the bit numbers in binary. 1, 10, 11, 100, 101, etc.
3. All bit positions that are powers of two (have only one 1 bit in the binary form of their position) are parity bits.
4. All other bit positions, with two or more 1 bits in the binary form of their position, are data bits.

Ref: https://www.electronicshub.org/error-correction-and-detection-codes/
https://www.electrically4u.com/hamming-code-with-a-solved-problem/
https://www.studytonight.com/post/hamming-code-error-detection-and-error-correction

Error Correction – Hamming Code

- Each data bit is included in a unique set of 2 or more parity bits, as determined by the binary form of its bit position.
  - Parity bit 1 covers all bit positions which have the least significant bit set: bit 1 (the parity bit itself), 3, 5, 7, 9, 11, etc.
  - Parity bit 2 covers all bit positions which have the second least significant bit set: bit 2 (the parity bit itself), 3, 6, 7, 10, 11, etc.
  - Parity bit 4 covers all bit positions which have the third least significant bit set: bits 4–7, 12–15, 20–23, etc.
  - Parity bit 8 covers all bit positions which have the fourth least significant bit set: bits 8–15, 24–31, 40–47, etc.
- In general each parity bit covers all bits where the binary AND of the parity position and the bit position is non-zero.

Ref: https://www.electronicshub.org/error-correction-and-detection-codes/
https://www.electrically4u.com/hamming-code-with-a-solved-problem/
https://www.studytonight.com/post/hamming-code-error-detection-and-error-correction

Error Correction – Hamming Code

Example: - Consider 7 bit data, 4 redundancy bits, codeword is 11 bits

- message bits are numbered 3, 5, 6, 7, 9, 10, 11
- redundancy bits are numbered 1, 2, 4, 8

check bit 1 checks error in bits 1, 3, 5, 7, 9, 11

check bit 2 checks error in bits 2, 3, 6, 7, 10, 11

check bit 4 checks error in bits 4, 5, 6, 7

check bit 8 checks error in bits 8, 9, 10, 11

Ref: https://www.electronicshub.org/error-correction-and-detection-codes/
https://www.electrically4u.com/hamming-code-with-a-solved-problem/
https://www.studytonight.com/post/hamming-code-error-detection-and-error-correction

Error Correction – Hamming Code

	[1]	[2]	3	[4]	5	6	7	[8]	9	10	11
1	X		X		X		X		X		X
2		X	X			X	X			X	X
4				X	X	X	X				
8								X	X	X	X

Check bit in position 1 is even parity on 1, 3, 5, 7, 9, 11

ASCII a = 1 1 0 0 0 0 1 => _ _ 1 _ 1 0 0 _ 0 0 1

- 10111001001 – Even parity
- 01101000001 – Odd parity

Ref: https://www.electronicshub.org/error-correction-and-detection-codes/
https://www.electrically4u.com/hamming-code-with-a-solved-problem/
https://www.studytonight.com/post/hamming-code-error-detection-and-error-correction

Error Correction – Hamming Code

X	X	1	X	1	0	0	X	0	0	1

	1	2	3	4	5	6	7	8	9	10	11	Even	Odd
1	X		1		1	0	0				1	1	0
2		X	1			0	0				1	0	1
4				X	1	0	0					1	0
8								x	0	0	1	1	0

- 10111001001 – Even parity
- 01101000001 – Odd parity

Ref: https://www.electronicshub.org/error-correction-and-detection-codes/
https://www.electrically4u.com/hamming-code-with-a-solved-problem/
https://www.studytonight.com/post/hamming-code-error-detection-and-error-correction

Error Correction – Hamming Code

- Encode a binary word 11001 into the even parity hamming code.

Bit Location	9	8	7	6	5	4	3	2	1
Bit designation	D5	**P4**	D4	D3	D2	**P3**	D1	**P2**	**P1**
Binary representation	1001	1000	0111	0110	0101	0100	0011	0010	0001
Information bits	1		1	0	0		1		
Parity bits		1				1		0	1

- Let us assume on transmission of 111001101 (111110011) the received code is 110001101 (110110011).

Ref: https://www.electronicshub.org/error-correction-and-detection-codes/
https://www.electrically4u.com/hamming-code-with-a-solved-problem/
https://www.studytonight.com/post/hamming-code-error-detection-and-error-correction

Error Correction – Hamming Code

Bit Location	9	8	7	6	5	4	3	2	1
Bit designation	D5	**P4**	D4	D3	D2	**P3**	D1	**P2**	**P1**
Binary representation	1001	1000	0111	0110	0101	0100	0011	0010	0001
Received code	1	1	0	0	0	1	1	0	1

The corrected code is 111001101
(111110011)

- For P1 : Check the locations 1, 3, 5, 7, 9. There is three 1s in this group, which is wrong for even parity. Hence the bit value for P1 is 1.
- For P2 : Check the locations 2, 3, 6, 7. There is one 1 in this group, which is wrong for even parity. Hence the bit value for P2 is 1.
- For P3 : Check the locations 4, 5, 6, 7. There is one 1 in this group, which is wrong for even parity. Hence the bit value for P3 is 1.
- For P4 : Check the locations 8, 9. There are two 1s in this group, which is correct for even parity. Hence the bit value for P4 is 0.
- The resultant binary word is 0111 (0011). It corresponds to the bit location 7 (3) in the above table. The error is detected in the data bit D4. The error is 0 and it should be changed to 1.

Ref: https://www.electronicshub.org/error-correction-and-detection-codes/
https://www.electrically4u.com/hamming-code-with-a-solved-problem/
https://www.studytonight.com/post/hamming-code-error-detection-and-error-correction

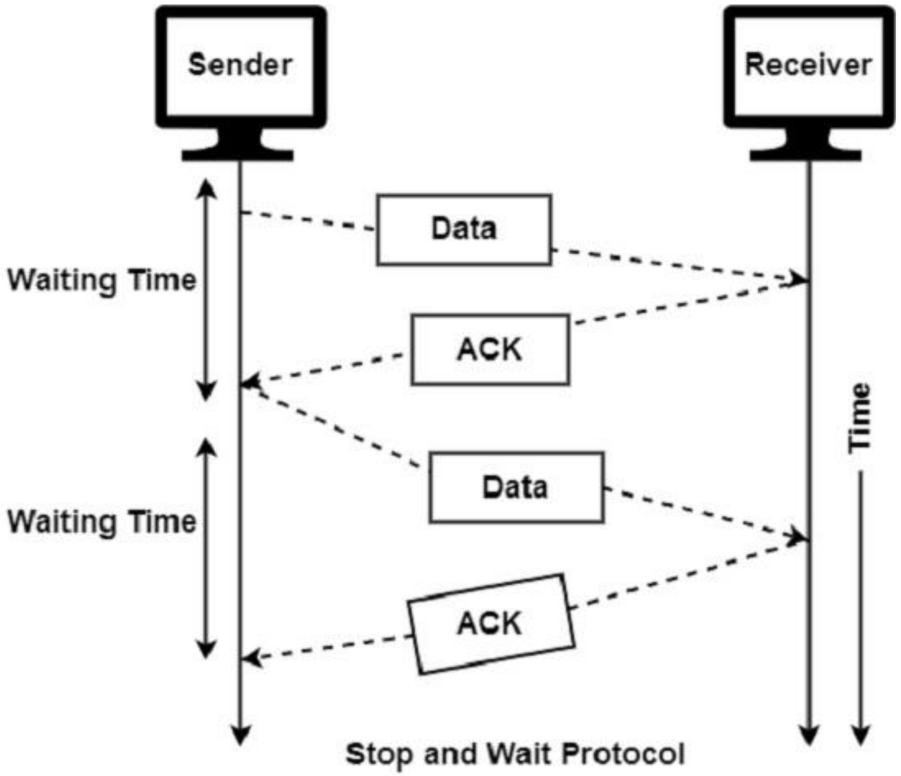
Error Correction – Re-transmission - ARQ

- Receiver requests the retransmission of missing packets or packets with errors

Ref: https://www.tutorialspoint.com/automatic-repeat-request-arq

Error Correction – Re-transmission – Stop and Wait ARQ

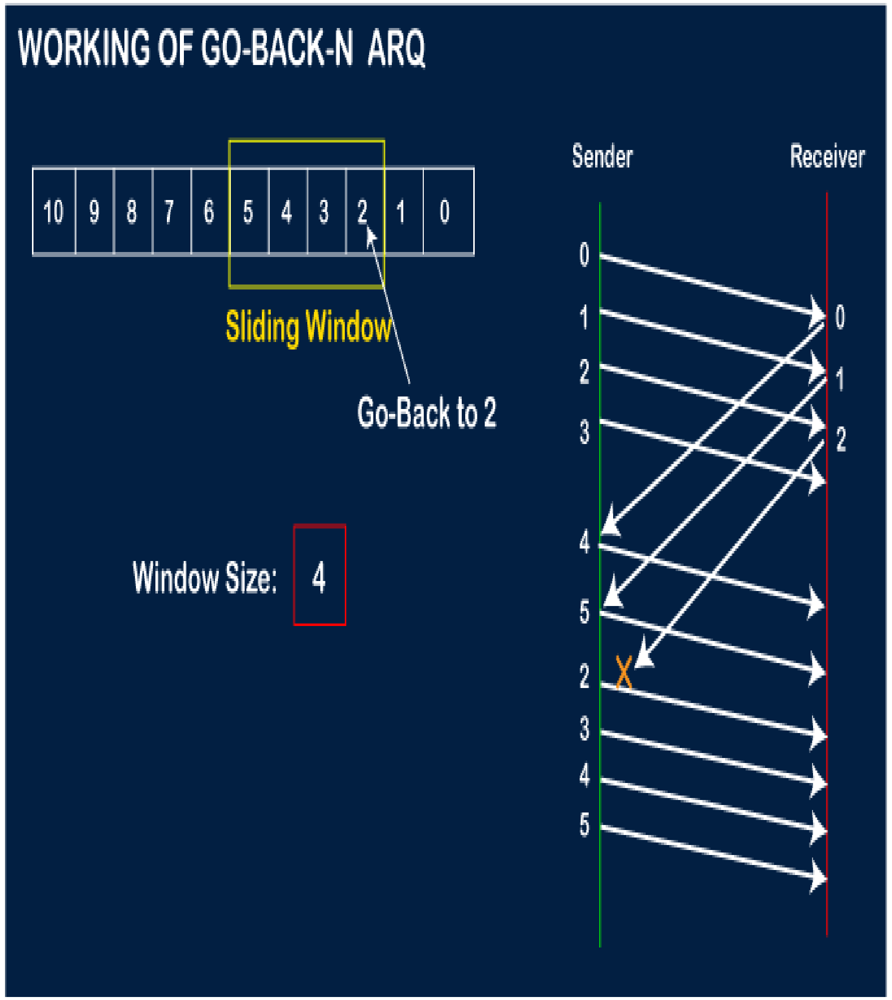
- Provides unidirectional data transmission with flow control and error control mechanisms, appropriate for noisy channels.
- Sender keeps a copy of the sent frame. It then waits for a finite time to receive a positive acknowledgement from receiver.
- If the timer expires or negative acknowledgement comes, the frame is retransmitted.
- If a positive acknowledgement is received then the next frame is sent.
- Buffer size: Sender – 1, Receiver -1



Ref: https://www.tutorialspoint.com/what-is-the-stop-and-wait-protocol-in-computer-network
https://www.javatpoint.com/stop-and-wait-protocol

Error Correction – Re-transmission – Go-Back-N ARQ

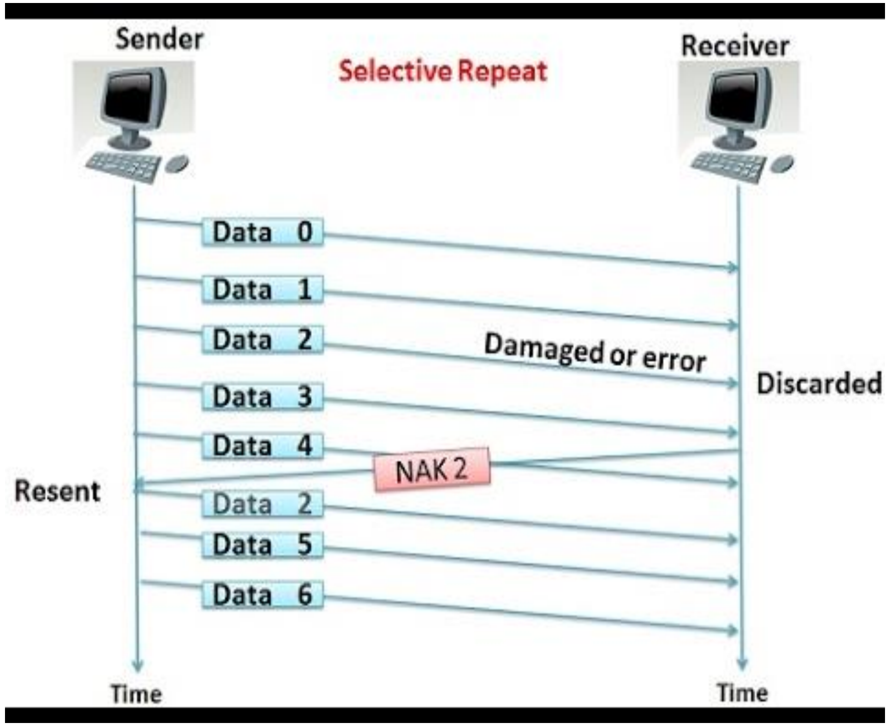
- Sends multiple frames before receiving the acknowledgement for the first frame.
- Uses the concept of sliding window.
- The frames are sequentially numbered and a finite number of frames are sent.
- If the acknowledgement of a frame is not received within the time period or negative acknowledgement is received, all frames starting from that frame are retransmitted.
- Buffer Size: Sender – n, Receiver - 1



Ref: https://www.tutorialspoint.com/go-back-n-arq
https://www.javatpoint.com/go-back-n-arq
https://www.javatpoint.com/sliding-window-protocol

Error Correction – Re-transmission – Selective Repeat ARQ

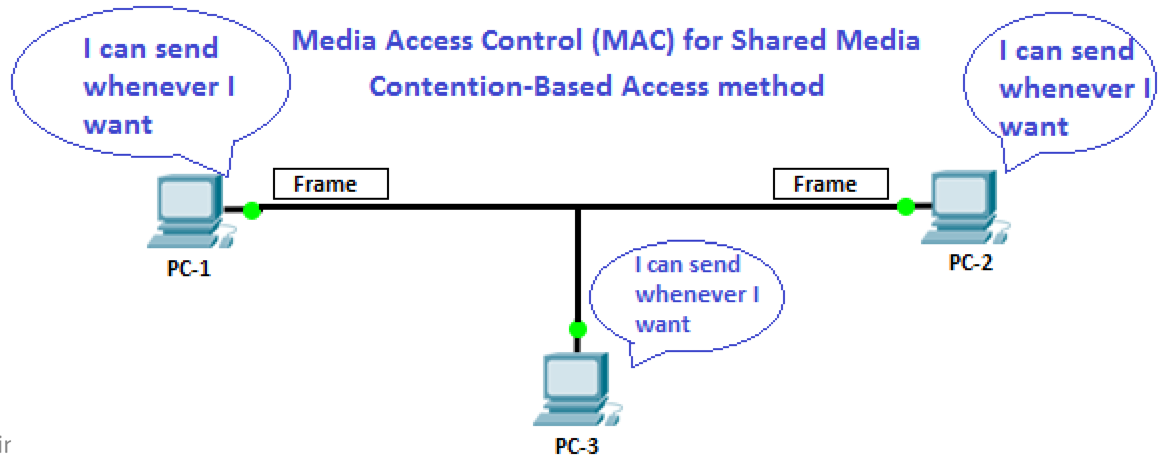
- Sends multiple frames before receiving the acknowledgement for the first frame.
- Uses the concept of sliding window.
- The frames are sequentially numbered and a finite number of frames are sent.
- If the acknowledgement of a frame is not received within the time period or negative acknowledgement is received, only the erroneous or lost frames are retransmitted, while the good frames are received and buffered.
- Buffer Size: Sender – n, Receiver - n



Ref: https://www.tutorialspoint.com/a-protocol-using-selective-repeat
https://www.javatpoint.com/sliding-window-protocol

Data Link Layer – Medium Access Control

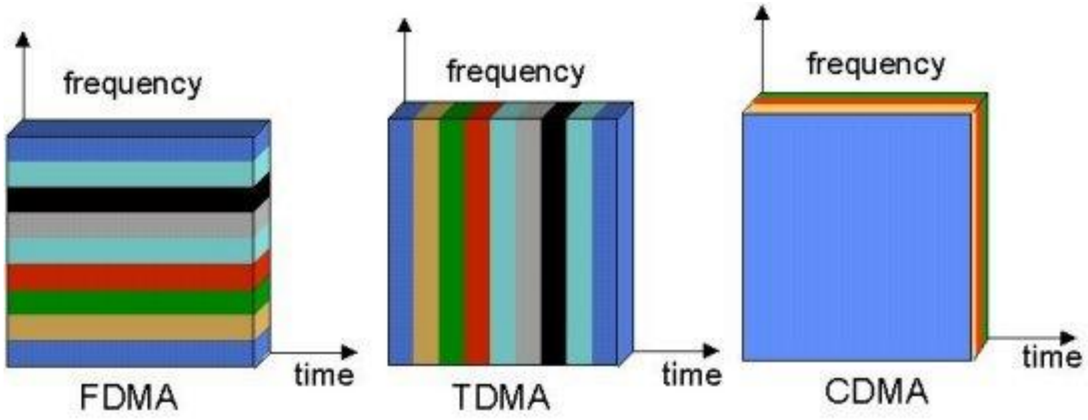
- Nodes of the network can transmit at any time
- Can result in,
  - Collision leading to data loss
  - Re-transmission resulting in higher energy, time and cost factor
  - Need a synchronized strategy among networked nodes



Ref: http://www.cnt4all.com/2016/10/mac-technniques.html

Data Link Layer – Medium Access - Revisiting

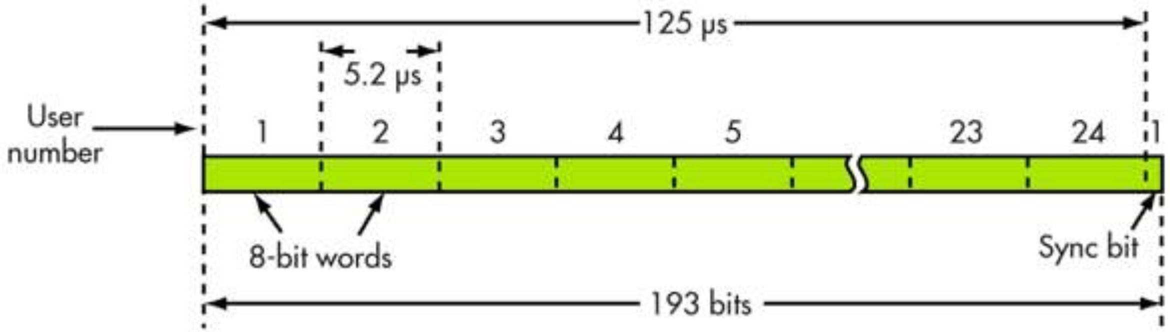
- Collision free protocols
  - TDMA, FDMA, CDMA
- Contention based Protocols
  - Aloha, Slotted Aloha
  - CSMA, CSMA/CD, CSMA/CA



Ref: https://www.geeksforgeeks.org/multiple-access-protocols-in-computer-network/

Data Link Layer – Medium Access - TDMA

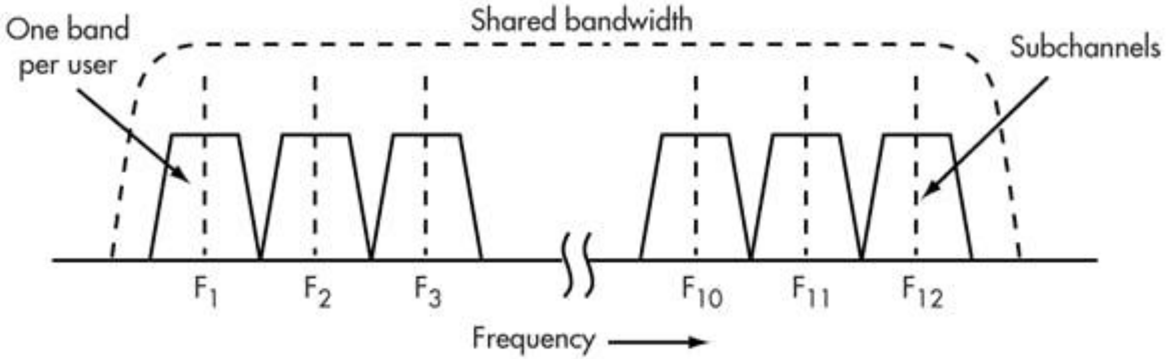
- TDMA shares a single carrier frequency with several users where each users makes use of non-overlapping time slots.
- Data transmission in TDMA is not continuous, but occurs in bursts.
- TDMA uses different time slots for transmission and reception thus duplexers are not required.
- TDMA has an advantage that is possible to allocate different numbers of time slots per frame to different users.
- Bandwidth can be supplied on demand to different users by concatenating or reassigning time slot based on priority.



Ref: https://www.tutorialspoint.com/wireless_communication/wireless_communication_multiple_access.htm
https://www.electronicdesign.com/technologies/communications/article/21802209/electronic-design-fundamentals-of-communications-access-technologies-fdma-tdma-cdma-ofdma-and-sdma

Data Link Layer – Medium Access - FDMA

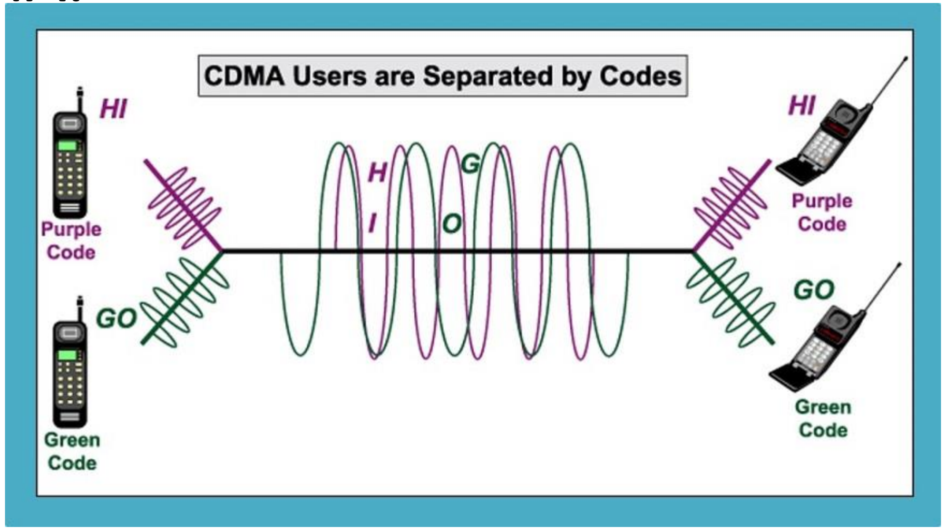
- FDMA allots a different sub-band of frequency to each different user to access the network.
- If FDMA is not in use, the channel is left idle instead of allotting to the other users.
- FDMA is implemented in Narrowband systems and it is less complex than TDMA.
- Tight filtering is done here to reduce adjacent channel interference.
- The base station BS and mobile station MS, transmit and receive simultaneously and continuously in FDMA.



Ref: https://www.tutorialspoint.com/wireless_communication/wireless_communication_multiple_access.htm
https://www.electronicdesign.com/technologies/communications/article/21802209/electronic-design-fundamentals-of-communications-access-technologies-fdma-tdma-cdma-ofdma-and-sdma

Data Link Layer – Medium Access - CDMA

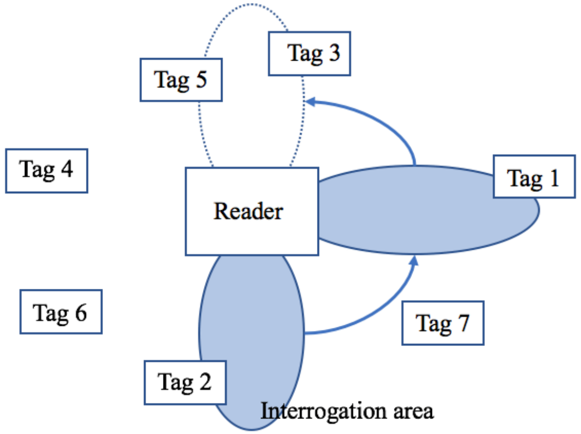
- In CDMA every user uses the full available spectrum instead of getting allotted by separate frequency.
- CDMA is much recommended for voice and data communications.
- While multiple codes occupy the same channel in CDMA, the users having same code can communicate with each other.
- CDMA offers more air-space capacity than TDMA.

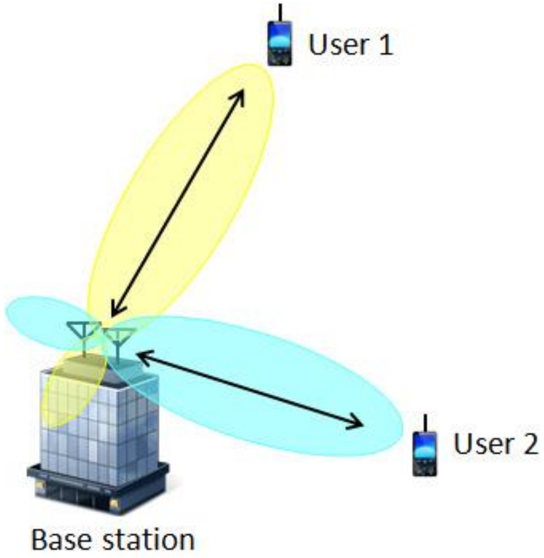


Ref: https://www.tutorialspoint.com/wireless_communication/wireless_communication_multiple_access.htm
https://chrisbell.com/SNHU/IT-640-Telecommunications-and-Networking/CDMA-code-division-multiple-access-protocol.php

Data Link Layer – Medium Access - SDMA

- All users can communicate at the same time using the same channel.
- SDMA can be made completely free from interference.
- The directional spot-beam antennas are used and hence the base station in SDMA, can track a moving user.
- Controls the radiated energy for each user in space

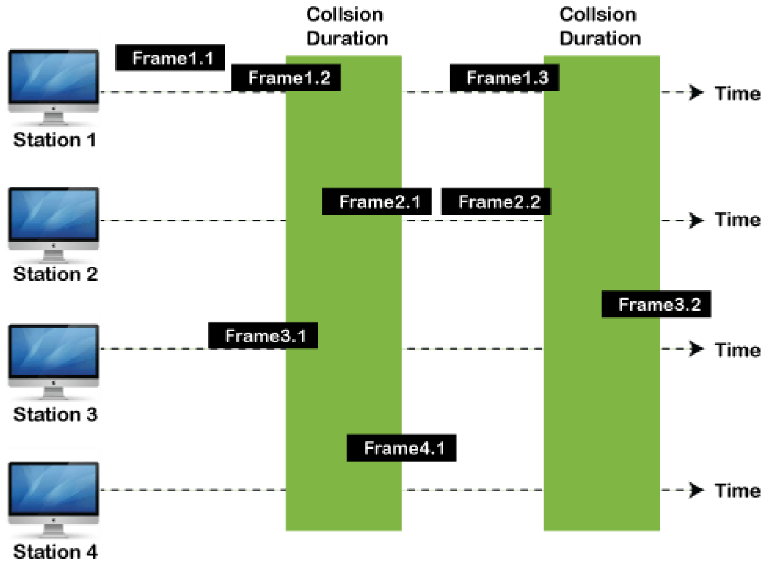




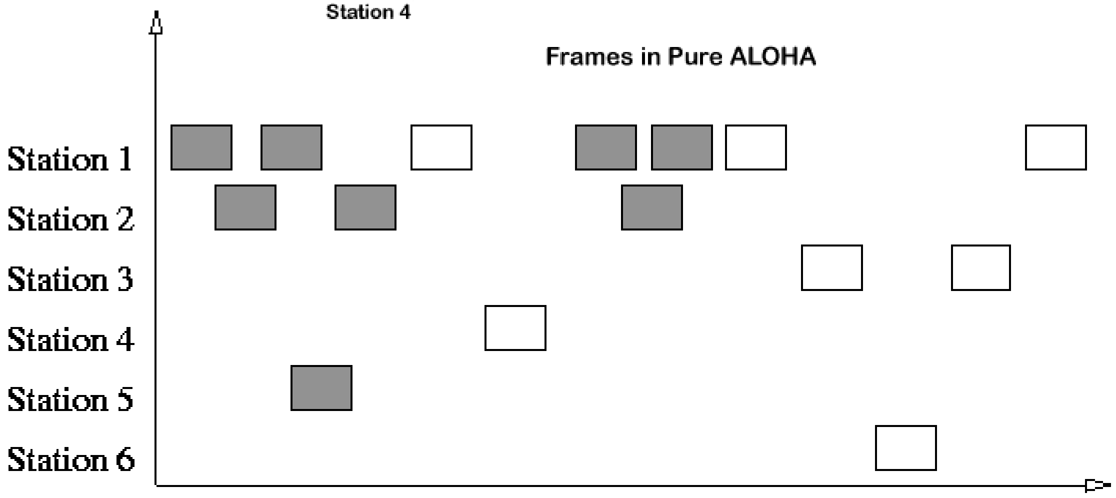
Ref: http://dx.doi.org/10.3390/app8081282
https://www.tutorialspoint.com/wireless_communication/wireless_communication_multiple_access.htm
https://www.ieice.org/eng/about_ieice/new_honorary_members_award_winners/2013/gyouseki_03e.html

Data Link Layer – Medium Access - ALOHA

- Each station transmits data to a channel without checking whether the channel is idle or not.
- Chance of collision may occur, and the data frame can be lost.
- If no acknowledge is received within the specified time, the station waits for a random amount of time, called the backoff time.
- Transmitter may assume the frame has been lost or destroyed.
- Therefore, it retransmits the frame.



Frames in Pure ALOHA

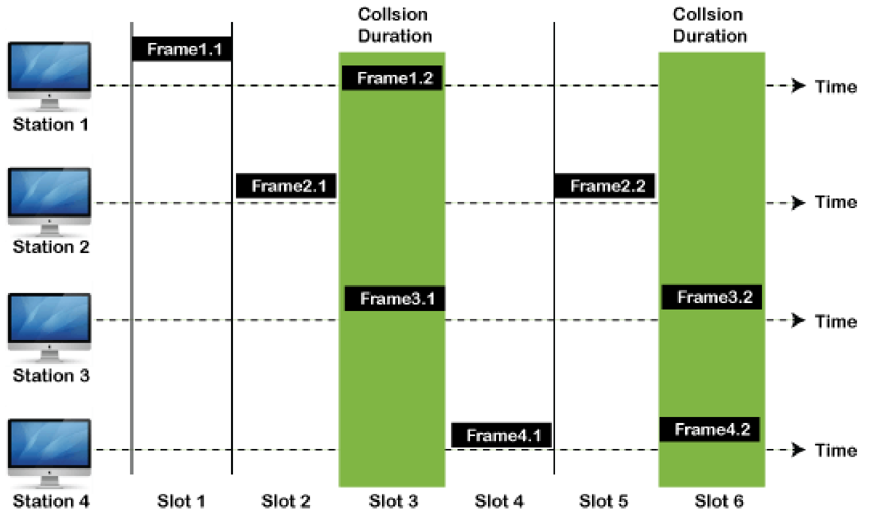


Time (shaded slots indicate collisions)

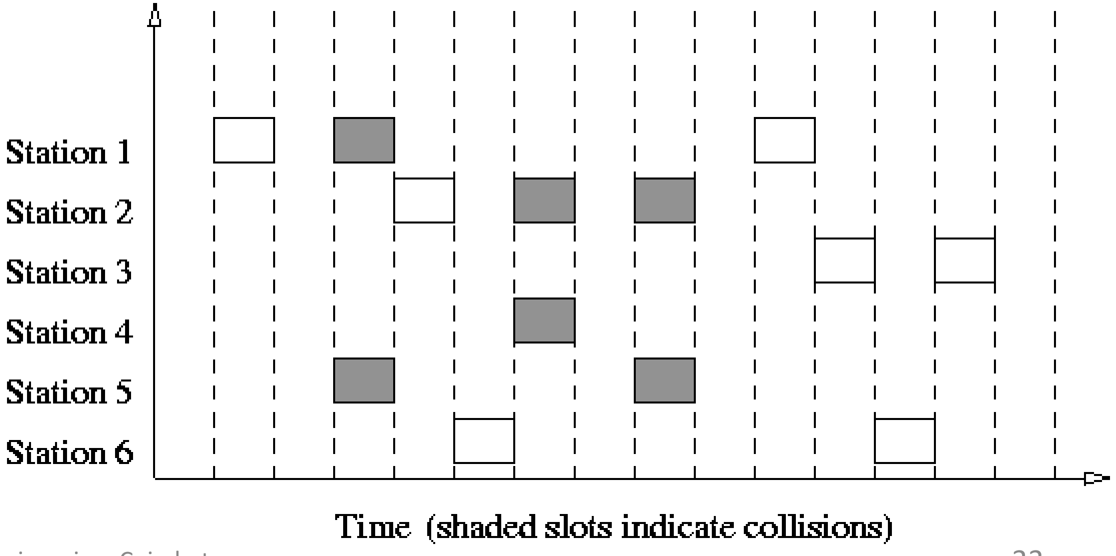
Ref: https://www.cse.iitk.ac.in/users/dheeraj/cs425/lec04.html
https://www.javatpoint.com/multiple-access-protocols

Data Link Layer – Medium Access – Slotted ALOHA

- The shared channel is divided into a fixed time interval called slots.
- If a station wants to send a frame to a shared channel, the frame can only be sent at the beginning of the slot.
- Only one frame is allowed to be sent to each slot.
- If the stations are unable to send data to the beginning of the slot, the station will have to wait until the beginning of the slot for the next time



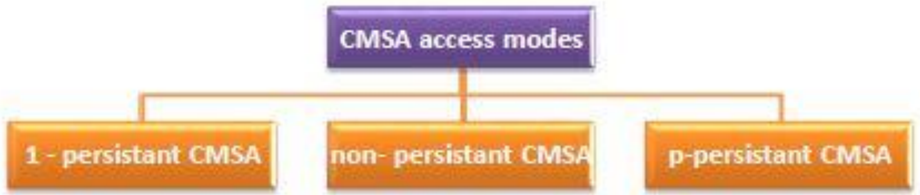
Frames in Slotted ALOHA



Ref: https://www.cse.iitk.ac.in/users/dheeraj/cs425/lec04.html
https://www.javatpoint.com/multiple-access-protocols

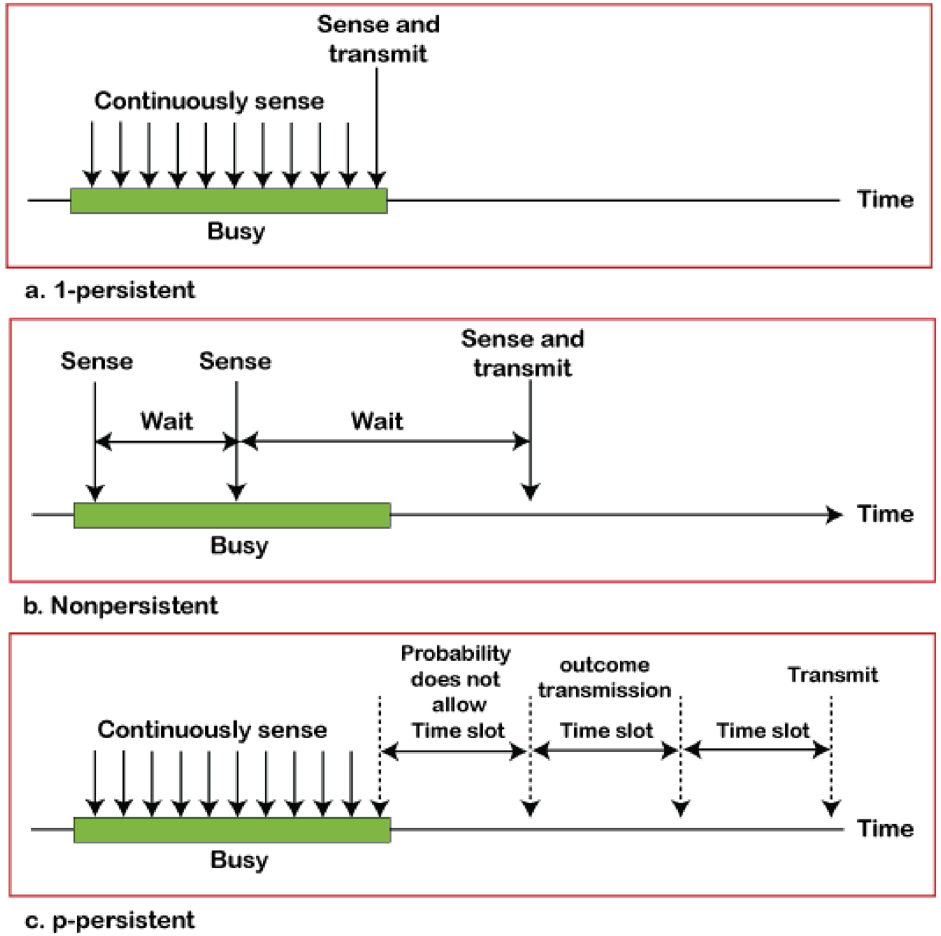
Data Link Layer – Medium Access – CSMA

- CSMA – Carrier Sense Multiple Access
- A media access protocol that senses the traffic on a channel (idle or busy) before transmitting the data
- If the channel is idle, the station can send data to the channel. Otherwise, it must wait until the channel becomes idle
- Since, the nodes detect for a transmission before sending their own frames, collision of frames is reduced.
- However, if two nodes detect an idle channel at the same time, they may simultaneously initiate transmission. This would cause the frames to garble resulting in a collisior



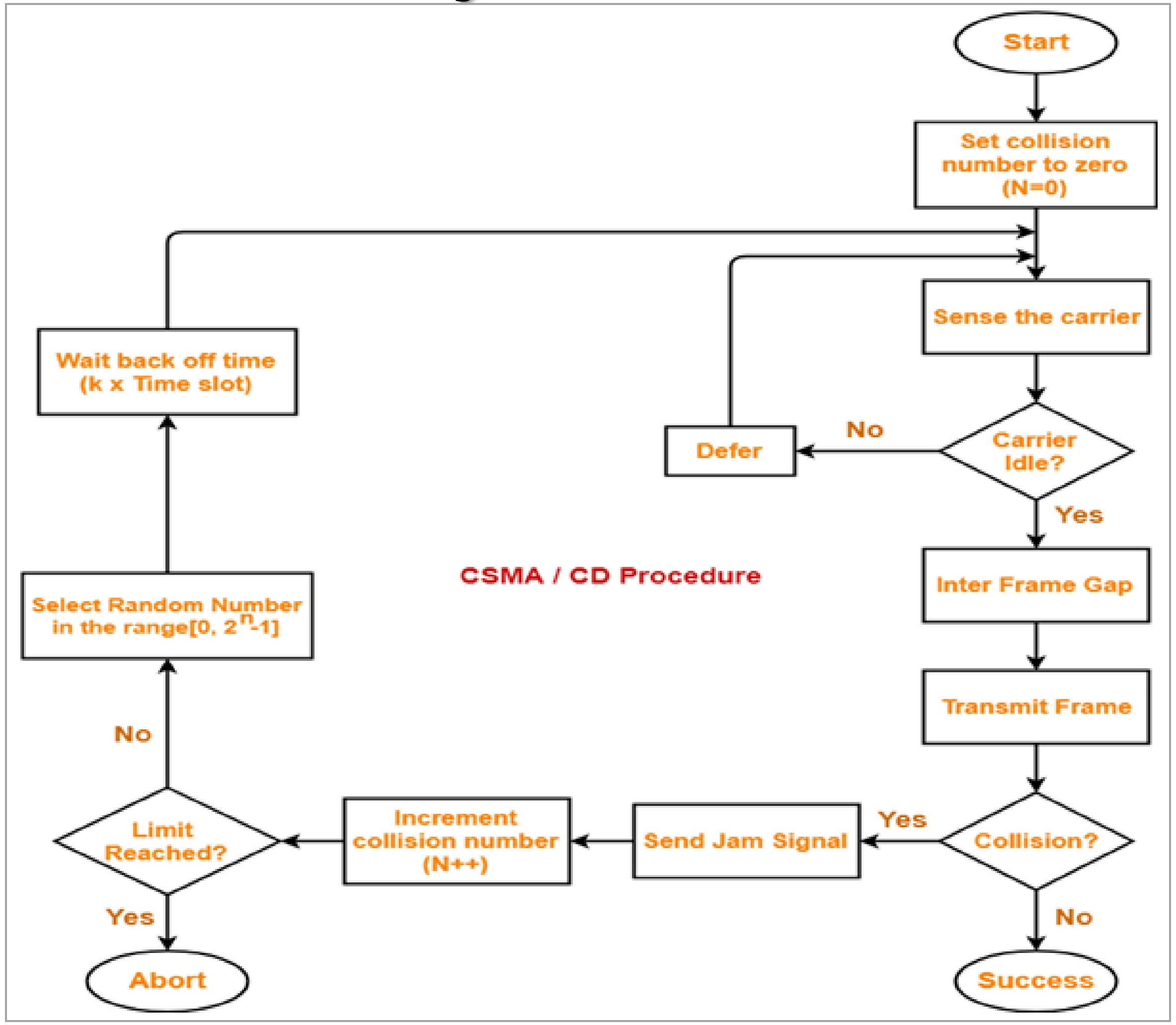
Ref: https://www.javatpoint.com/multiple-access-protocols
https://www.tutorialspoint.com/what-is-carrier-sense-multiple-access-csma

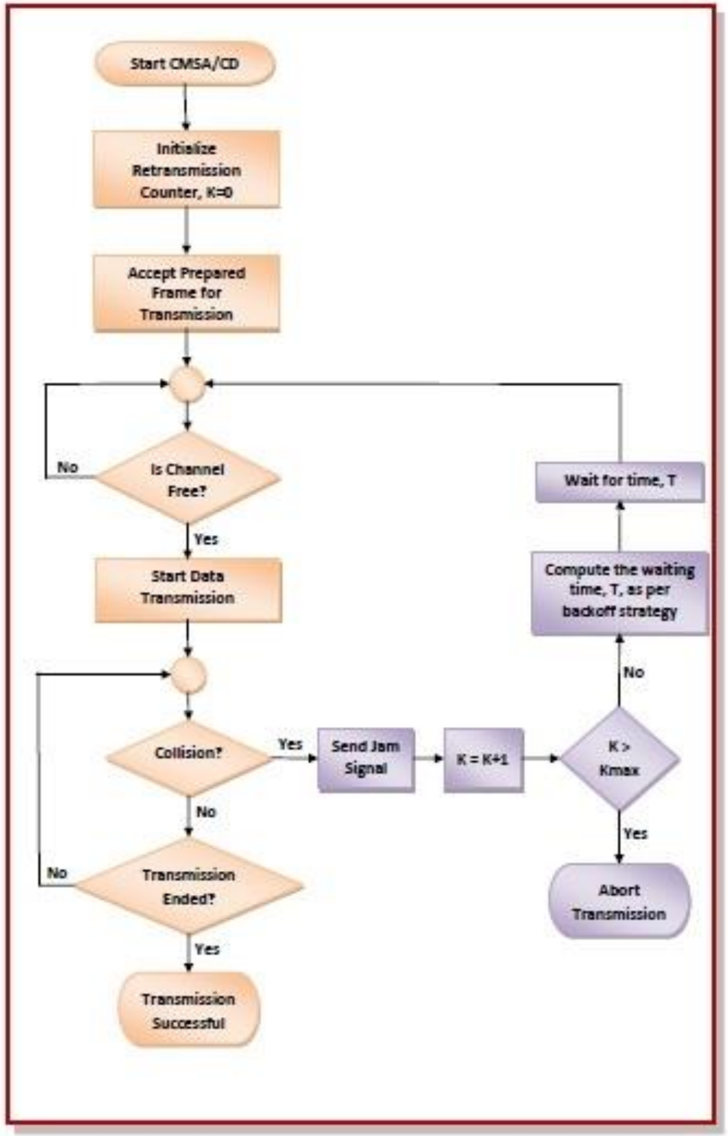
Data Link Layer – Medium Access – CSMA Types



Ref: https://www.javatpoint.com/multiple-access-protocols
https://www.tutorialspoint.com/what-is-carrier-sense-multiple-access-protocols

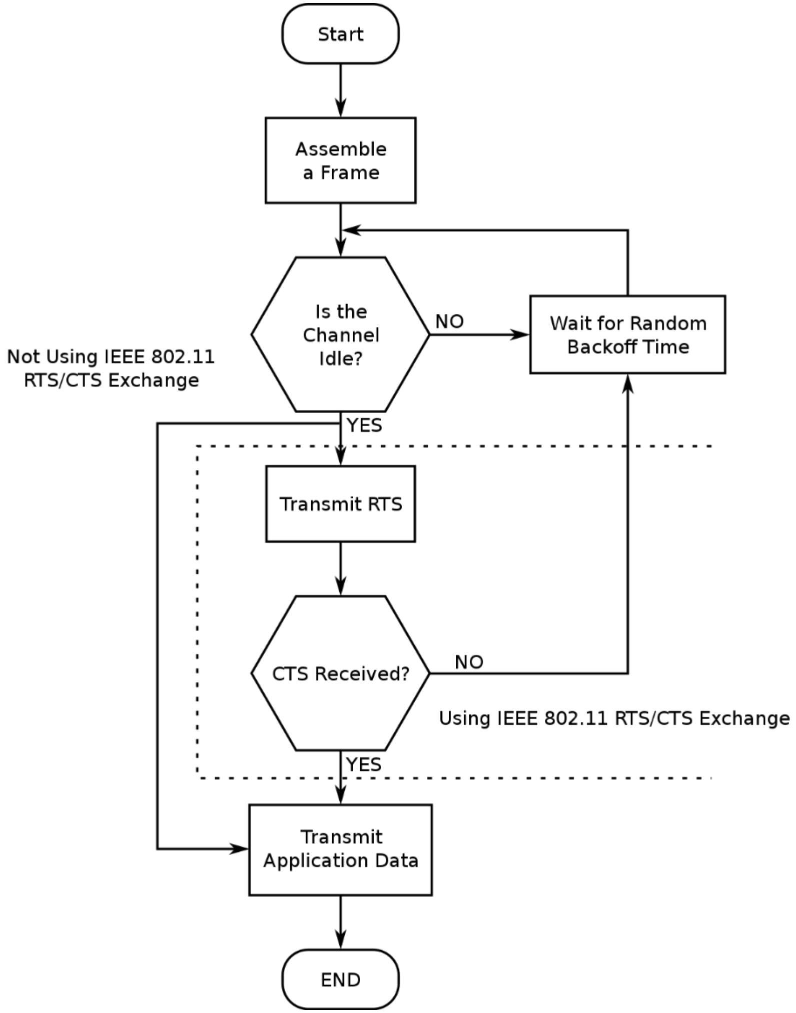
Data Link Layer – Medium Access – CSMA/CD

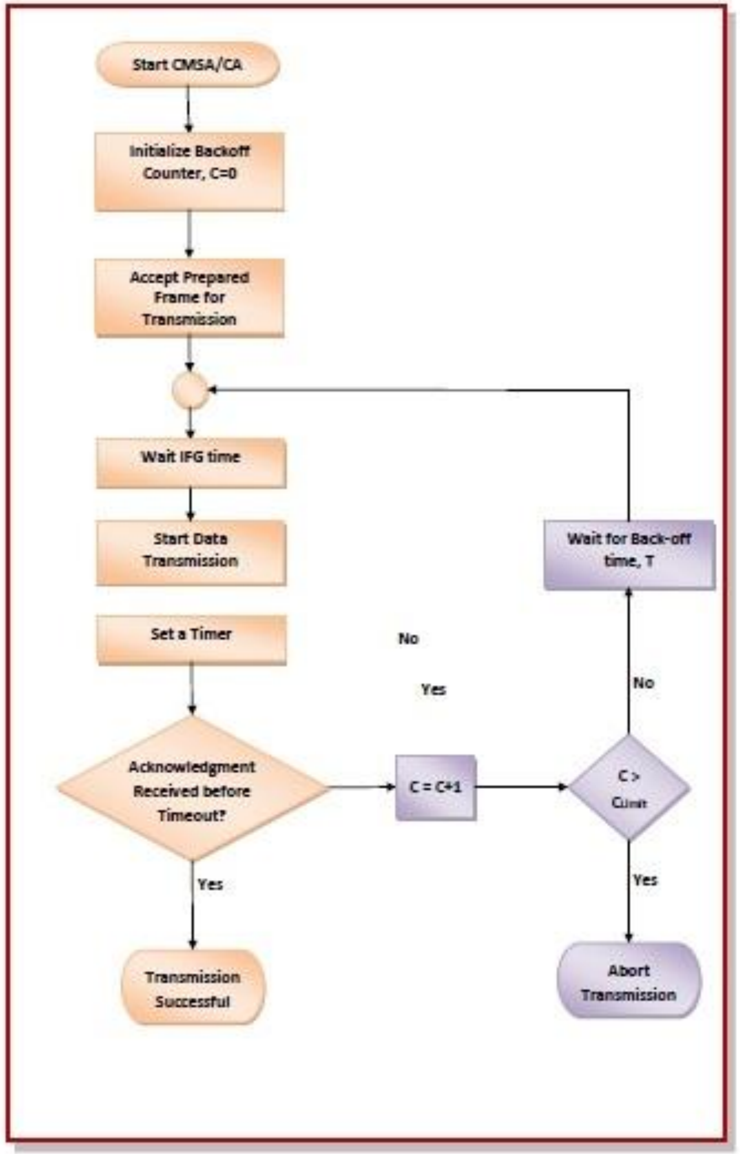




Ref: https://www.javatpoint.com/multiple-access-protocols
https://www.tutorialspoint.com/csma-with-collision-detection-csma-cd
https://www.softwaretestinghelp.com/what-is-csma-cd/

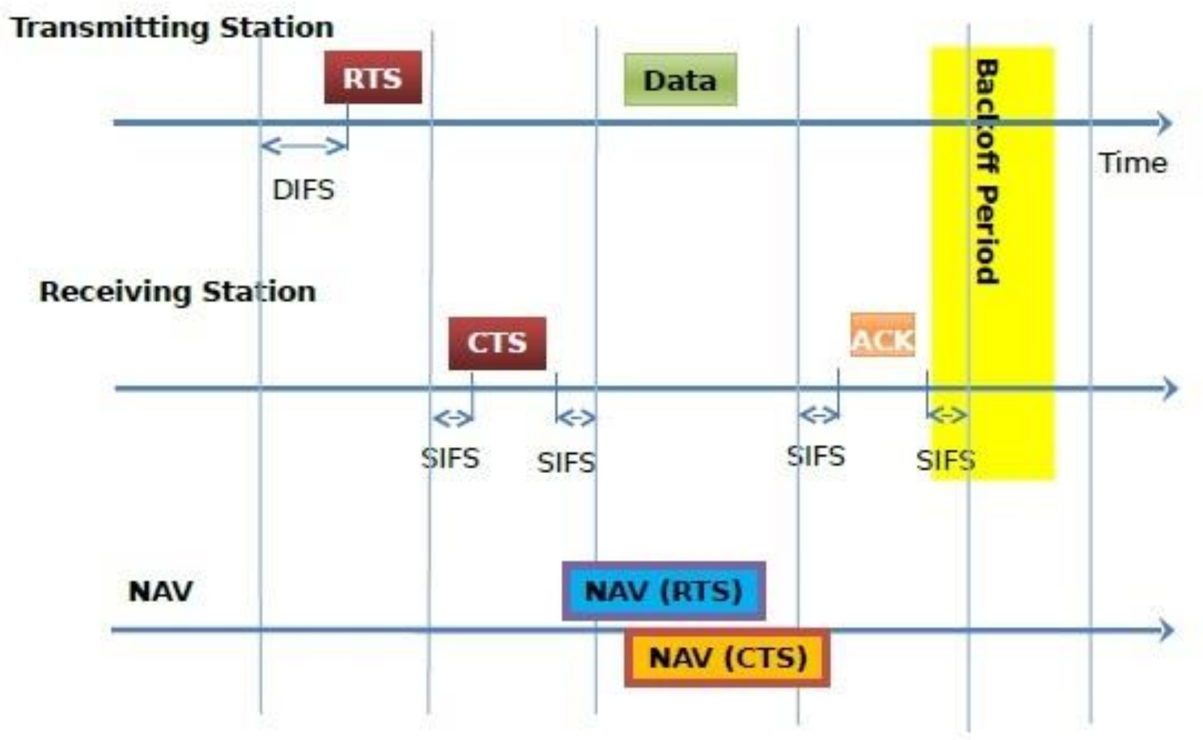
Data Link Layer – Medium Access – CSMA/CA





Ref: https://www.javatpoint.com/multiple-access-protocols
https://www.tutorialspoint.com/csma-with-collision-avoidance-csma-ca
https://en.wikipedia.org/wiki/Carrier-sense_multiple_access_with_collision_avoidance

Data Link Layer – Medium Access – CSMA/CA



NAV in wireless communication

Ref: https://www.javatpoint.com/multiple-access-protocols
https://www.tutorialspoint.com/virtual-channel-sensing-using-csma-ca

Thank You…