Open system Interconnection (OSI)

DataLink Layer Polling & CSMA/CD

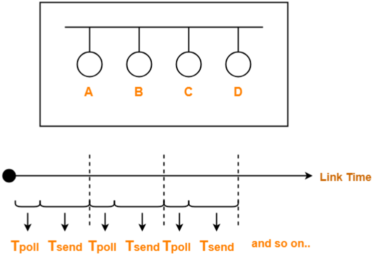
Munesh Singh

Indian Institute of Information Technology, Design and Manufacturing Kancheepuram,
Chennai, Tamil Nadu 600127

October 11, 2020

Access Control: Polling

- In this access control method
  - A polling is conducted in which all the stations willing to send data participates.
  - The polling algorithm chooses one of the stations to send the data.
  - The chosen station sends the data to the destination.
  - After the chosen station has sent the data, the cycle repeats.



Polling Access Control Method

1. Tpoll = Time taken for polling
2. Tsend = Time taken for sending the data = Transmission delay + Propagation delay = Tt + Tp

Efficiency

- Efficiency (η) = Useful Time / Total Time
    - Useful time = Transmission delay of data packet = Tt
    - Useless time = Time wasted during polling + Propagation delay of data packet = Tpoll + Tp

$$\boxed{\text{Efficiency } (\eta) = \frac{T_t}{T_{poll} + T_t + T_p}}$$

- **Advantages**
    - Unlike in Time Division Multiplexing, no slot is ever wasted.
    - It leads to maximum efficiency and bandwidth utilization.
- **Disadvantage**
    - Time is wasted during polling.
    - Link sharing is not fair since each station has the equal probability of winning in each round.
    - Few stations might starve for sending the data.

Important Formulas-

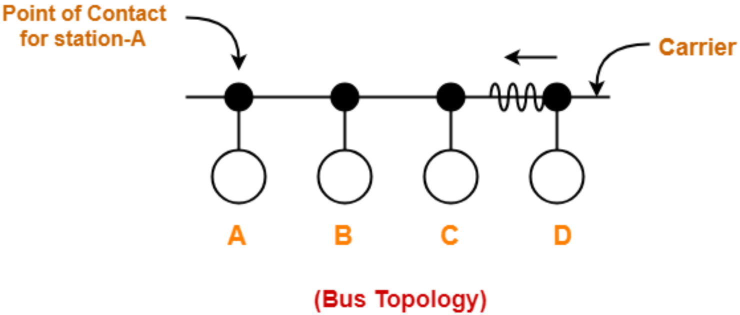
- Efficiency (η) = Tt / (Tpoll + Tt + Tp)
- Effective Bandwidth / Bandwidth Utilization / Throughput = Efficiency(η) x Bandwidth
- Maximum Available Effective Bandwidth = Total number of stations x Bandwidth requirement of 1 station

CSMA/CD

- CSMA / CD stands for Carrier Sense Multiple Access / Collision Detection.
- This access control method works as follows-
  - Step-01: Sensing the Carrier-
    - Any station willing to transmit the data senses the carrier.
    - If it finds the carrier free, it starts transmitting its data packet otherwise not.
  - **How?**
    - Each station can sense the carrier only at its point of contact with the carrier.
    - It is not possible for any station to sense the entire carrier.
    - Thus, there is a huge possibility that a station might sense the carrier free even when it is actually not.

Example-

- At the current instance,
  - If station A senses the carrier at its point of contact, then it will find the carrier free.
  - But the carrier is actually not free because station D is already transmitting its data.
  - If station A starts transmitting its data now, then it might lead to a collision with the data transmitted by station D.



Step-02: Detecting the Collision-

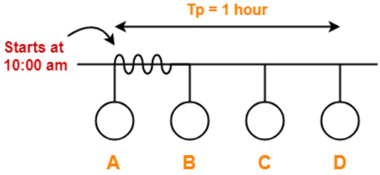
- In CSMA / CD,
  - It is the responsibility of the transmitting station to detect the collision.
  - For detecting the collision, CSMA / CD implements the following condition.
  - This condition is followed by each station-
    - **Transmission delay** $>=$ **2 x Propagation delay**
  - Meaning-According to this condition,
    - Each station must transmit the data packet of size whose transmission delay is at least twice its propagation delay.
    - If the size of data packet is smaller, then collision detection would not be possible.

Length Of Data Packet

- As we know:
  - Transmission delay = Length of data packet (L) / Bandwidth (B)
  - Propagation delay = Distance between the two stations (D) / Propagation speed (V)
- Substituting values in the above condition, we get-
  - **L / B >= 2 x D / V**
  - **L >= 2 x B x D / V**

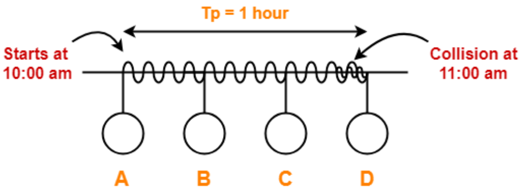
Understanding the Condition To Detect Collision With Example

- Consider at time 10:00 am, station A senses the carrier.
- It finds the carrier free and starts transmitting its data packet to station D.
- Let the propagation delay be 1 hour.



- Let us consider the scenario at time 10:59:59:59 when the packet is about to reach the station D.

- At this time, station D senses the carrier.
- It finds the carrier free and starts transmitting its data packet.
- Now, as soon as station D starts transmitting its data packet, a collision occurs with the data packet of station A at time 11:00 am.



- After collision occurs, the collided signal starts travelling in the backward direction.
- The collided signal takes 1 hour to reach the station A after the collision has occurred.
- For station A to detect the collided signal, it must be still transmitting the data.

- So, transmission delay of station A must be $>=$ 1 hour $+$ 1 hour $>=$ 2 hours to detect the collision.
- That is why, for detecting the collision, condition is Tt $>=$ 2Tp.
- **Two cases are possible-**
  - **Case-01:** If no collided signal comes back during the transmission,
    - It indicates that no collision has occurred.
    - The data packet is transmitted successfully.
  - **Case-02:** If the collided signal comes back during the transmission,
    - It indicates that the collision has occurred.
    - The data packet is not transmitted successfully.
    - Step-03 is followed.

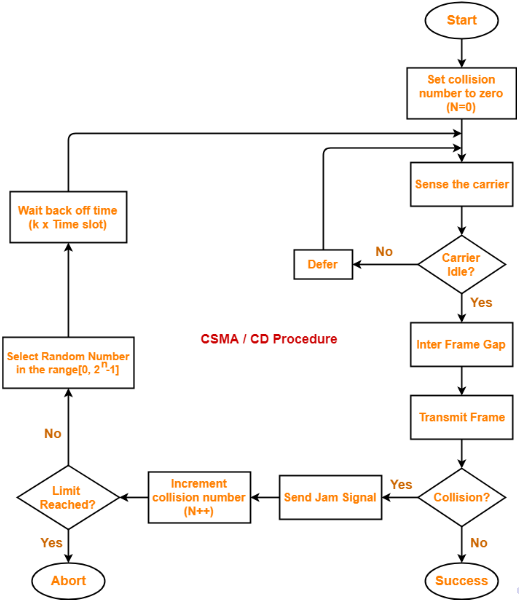
Step-03: Releasing Jam Signal

- Jam signal is a 48 bit signal.
- It is released by the transmitting stations as soon as they detect a collision.
- It alerts the other stations not to transmit their data immediately after the collision.
- Otherwise, there is a possibility of collision again with the same data packet.
- Ethernet sends the jam signal at a frequency other than the frequency of data signals.
- This ensures that jam signal does not collide with the data signals undergone collision.

Step-04: Waiting For Back Off Time

- After the collision, the transmitting station waits for some random amount of time called as back off time.
- After back off time, it tries transmitting the data packet again.
- If again the collision occurs, then station again waits for some random back off time and then tries again.
- The station keeps trying until the back off time reaches its limit.
- After the limit is reached, station aborts the transmission.
- Back off time is calculated using Back Off Algorithm.

CSMA / CD Flowchart



Efficiency

- Efficiency (η) = Useful Time / Total Time
- Before a successful transmission,
  - There may occur many number of collisions.
  - 2 x Tp time is wasted during each collision.
- **Thus,**
  - Useful time = Transmission delay of data packet = Tt
  - Useless time = Time wasted during collisions + Propagation delay of data packet = c x 2 x Tp + Tp
  - Here, c = Number of contention slots / collision slots.

$$\text{Efficiency } (\eta) = \frac{T_t}{c \times 2 \times T_p + T_t + T_p}$$

- Here,c is a variable.
- This is because number of collisions that might occur before a successful transmission are variable.

Probabilistic Analysis shows-

- Average number of collisions before a successful transmission = e
- Substituting c = e in the above relation, we get-

$$\text{Efficiency } (\eta) = \frac{T_t}{e \times 2 \times T_p + T_t + T_p}$$

OR

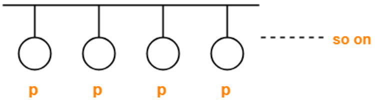
$$\text{Efficiency } (\eta) = \frac{T_t}{T_t + 6.44 \times T_p}$$

OR

$$\text{Efficiency } (\eta) = \frac{1}{1 + 6.44 \times a}, \text{ where } a = T_p / T_t$$

Prababilistic Analysis

- Consider-Number of stations connected to a CSMA / CD network = n
- Probability of each station to transmit the data = p
- According to the statement Binomial Distribution can help us to know the probability of success.

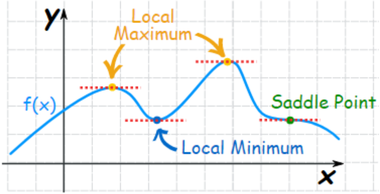


- A binomial distribution can be thought of as simply the probability of a SUCCESS or FAILURE outcome in an experiment or survey that is repeated multiple times.
  - A coin is tossed 10 times, what is the probability of getting exactly 6 heads.
  - n=10,x=6, p_s=0.5,p_f=0.5
  - P(x)=${}_n^x\mathbf{C} * p^x * (1-p)^{n-x}$

- Transmission will be successful only when-
  - One station transmits the data
  - Other (n-1) stations do not transmit the data.
- Thus, Probability of successful transmission is given by-

$$\boxed{P_{\text{successful transmission}} = {}^{n}C_{1} \times p \times (1-p)^{n-1}}$$

- Now, let us find the maximum value of Psuccessful transmission.
- As we don't know the fixed value of n and x, we take the help of maxima and minima.
  - In a smoothly changing function a maximum or minimum is always where the function flattens out (slope is zero) (except for a saddle point).



- Where is the slope zero? The Derivative tells us!
  - For maximum value, we put-

$$\frac{dP_{\text{successful transmission}}}{dp} = 0$$

  - On solving, At p = 1/n, we get the maximum value of Psuccessful transmission
  - Thus substitute the value of p in

$$P_{\text{successful transmission}} = {}^{n}C_{1} \times p \times (1-p)^{n-1}$$

    - **(Psuccessful transmission)max** $= (1 - 1/n)^{n-1}$
  - If there are sufficiently large number of stations i.e. $n -> \infty$, then we have-

$$\lim_{n\to\infty} \left(P_{\text{successful transmission}}\right)_{max} = \lim_{n\to\infty} \left(1 - \frac{1}{n}\right)^{n-1}$$
$$= \frac{1}{e}$$

- Number of times a station must try before successfully transmitting the data packet = 1 / Pmax (Using Poissons distribution)
- = 1 / (1/e) = e
- From here, we conclude-
  - Average number of collisions that might occur before a successful transmission = e
- **Important Notes-**
  - CSMA / CD is used in wired LANs.
  - CSMA / CD is standardized in IEEE 802.3
  - CSMA / CD only minimizes the recovery time.
  - It does not take any steps to prevent the collision until it has taken place.
- **Important Formulas-**
  - Condition to detect collision: Transmission delay >= 2 x Propagation delay
  - Minimum length of data packets in CSMA / CD = 2 x Bandwidth x Distance / Speed
  - Efficiency of CSMA / CD = 1 / (1 + 6.44 x a) where a = Tp / Tt
  - Probability of successful transmission = nC1 x p x (1-p)n-1
  - Average number of collisions before a successful transmission = e

Thank You