Rechnernetze – Computer Networks

Problem Set 5: Direct Link Networks & Medium Access Control

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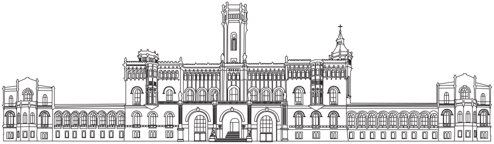

Institute of Communications Technology
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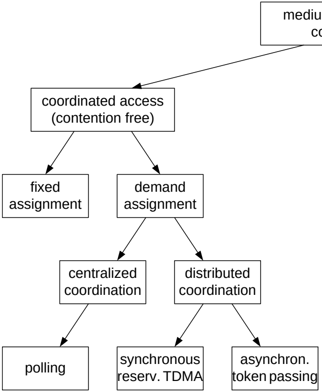
Mai 13, 2024

Medium Access Control - Classification



1. Fixed Assignment

Consider the following examples. Would you recommend the usage of an FDMA system with a service rate of 100 frames per second? Why or why not?

1. 10 users, each user generates 15 frames per second
2. 10 users, 5 users generate 1 frame per second, the other 5 generate 15 frames per second
3. 10 users, each user generates 9 frames per second

1. Fixed Assignment

10 users, each user generates 15 frames per second

- number of sub-channels is 10
- with each sub-channel having a service rate of 10 frames per second
- system can't cope with the generation of 15 frames per second!

1. Fixed Assignment

10 users, 5 users generate 1 frame per second, the other 5 generate 15 frames per second

- number of sub-channels is 10
- with each sub-channel having a service rate of 10 frames per second
- we can't share channels across users
- the 5 users with rate 1 frame per second can be supported but it is a waste of channel time!
- but system can't cope with the generation of 15 frames per second!

1. Fixed Assignment

10 users, each user generates 9 frames per second

- number of sub-channels is 10
- with each sub-channel having a service rate of 10 frames per second
- since each user generates frames at a rate smaller than the service rate, the system can support it
- since the number of frames generated is close to the service rate, not too much channel time is wasted

ALOHA

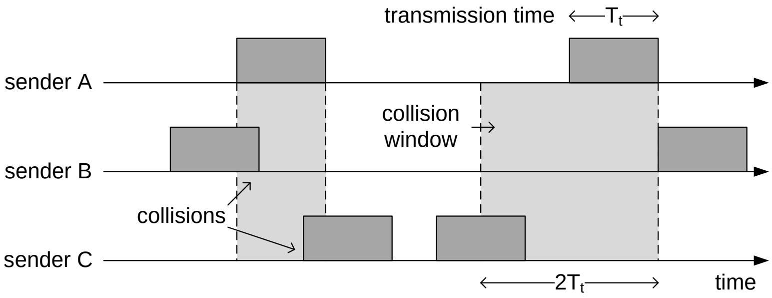
The ALOHA protocol was developed by Abramson for a wireless computer network between the Hawaii islands. It is widely used today, e.g., for the LTE Random Access Channel.

A number of hosts share a wireless channel

- if a host has data for transmission it sends the data immediately
- the hosts do not consider other potentially sending hosts
- if two or more frames are transmitted at the same time they are destroyed
- these frames are retransmitted after a random time (can detect collisions from missing ack)

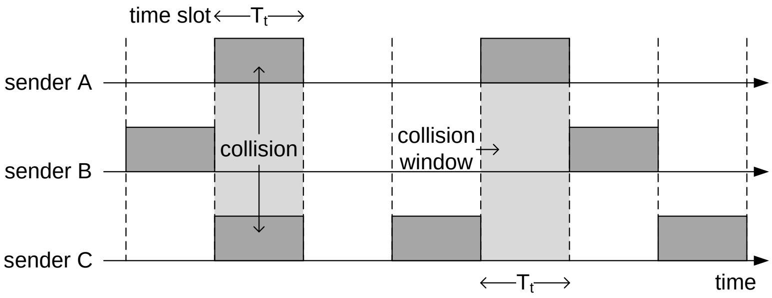
What is the impact of frame collisions on the performance, i.e. what is the maximally achievable throughput?

Pure ALOHA - Collision window



Pure ALOHA

- constant sized frames with transmission time T_t
- collision window $2T_t$
- a frame is transmitted without collision if no other frame starts transmission in the collision window



Slotted ALOHA

- TDM scheme with slot time T_t
- requires global time synchronization among all stations
- constant sized frames with transmission time T_t
- the collision window is reduced to T_t

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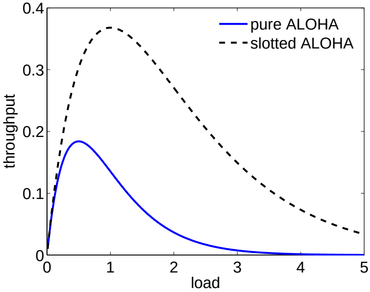
- A large population of ALOHA users manages to generate 50 requests/sec, including both originals and retransmissions. Time is slotted in units of 40 msec. What is the throughput S of the system?

  There are two ways to calculate the throughput S of the system:

  1. $\lambda = 50\ (requests/s) \cdot 4 \cdot 10^{-2}\ (s/slot) = 2\ requests/slot$
     $S = \lambda \cdot e^{-\lambda T}$ (slotted ALOHA, T=1)
     $S = 2 \cdot e^{-2} \approx 0.27\ requests/slot \rightarrow \dfrac{0.27\ requests/slot}{40\ ms/slot} \approx$
     $6.75\ requests/s$
  2. $\lambda = 50\ requests/s\ ,\ T = 40\ ms$
     $S = \lambda \cdot e^{-\lambda T}$ (slotted ALOHA)
     $S = 50\ requests/s \cdot e^{-50 \cdot 4 \cdot 10^{-2}} = 50 \cdot e^{-2} \approx 6.75\ requests/s$

The figures show the throughput of ALOHA for different loads.



The simple model neglects retransmissions respectively retrials.

- A group of N stations share a 56-kbps pure ALOHA channel. Each station outputs a 1000-bit frame on average once every 100 sec, even if the previous one has not yet been sent (e.g., the stations can buffer outgoing frames). What is the maximum value of N?

$$\text{system throughput} = N \cdot \text{station througput} \rightarrow N = \frac{\text{system throughput}}{\text{station throughput}}$$

$$\text{station throughput} = \frac{1000\text{bit}}{100s} = 10 \text{ bps}$$

$$\text{system throughput} = \frac{1}{2e} \cdot 56 \text{ kbps} \approx 10.3 \text{ kbps}$$

$$N = \frac{10.3 \text{ kbps}}{10 \text{ bps}} = 1030$$

With pure ALOHA, this channel can accommodate up to N = 1030 stations.

- 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?

  transmission time $T_t = \frac{200\text{bit}}{200\text{kbps}} = 1\text{ms}$

  Collision window $= 2T_t = 2\text{ms}$

  A frame is transmitted without collision if no other frame starts transmission in the collision window.

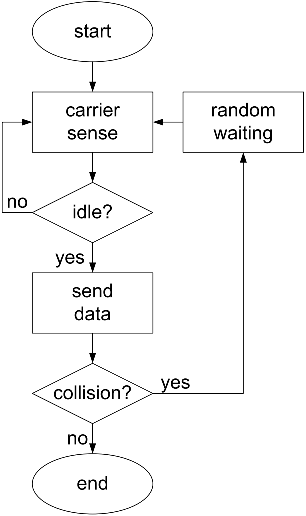
- Consider the delay of pure ALOHA versus slotted ALOHA at low load. Which one is less? Explain your answer.

  With common sense: low load implies:

  - probability for collisions is low
  - there are hardly any retransmissions
  - pure ALOHA:
    - nodes can transmit immediately
    - delay $\approx T_t + 2T_p$
  - slotted ALOHA:
    - nodes have to wait until the next slot starts
    - delay $\approx T_t/2 + T_t + 2T_p$

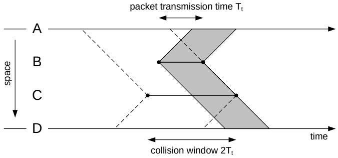
CSMA

- stations sense the channel before transmitting
  - if the station finds the channel idle it starts sending
  - if the station finds the channel busy it defers sending
    - non-persistent: try again after random waiting time
    - 1-persistent: try again immediately
    - p-persistent: try again, if idle send with probability p, wait one slot with $1-p$
- is used e.g. in LAN and WLAN, i.e. IEEE 802.3 and 802.11

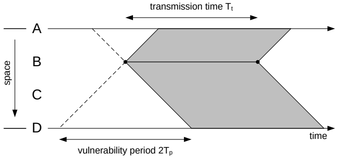


- Specify the vulnerability times, i.e., the time span in which transmitted frames can collide with previously transmitted frames, for ALOHA and CSMA.

pure ALOHA



CSMA



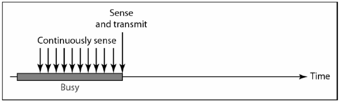
  - collision window (Pure ALOHA and Slotted ALOHA): $2T_t$ and T_t respectively
  - vulnerability period (CSMA): $2T_p$

- “CSMA always outperforms ALOHA.“ Is this statement true?

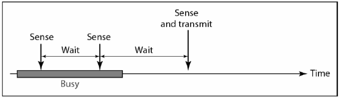
  No. In case of very long propagation delays compared to the transmission time, CSMA doesn’t outperform ALOHA anymore, i.e., if carrier sensing yields only ”old” information

4.1 CSMA Access Modes

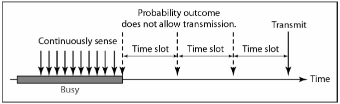
- Consider the three CSMA access modes 1-, non-, and p-persistent. Sketch the timing of sensing and transmitting data for these three cases and the according flow charts.



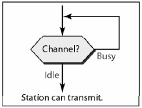
a. 1-persistent



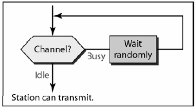
b. Nonpersistent



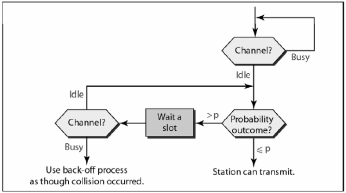
c. p-persistent



a. 1-persistent



b. Nonpersistent

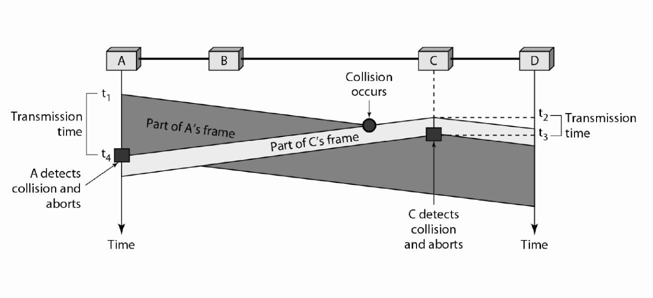


c. p-persistent

- What is the relationship between non-persistent and 1-persistent CSMA regarding throughput and delay?
  - 1-persistent (most greedy) : after the station finds the line idle, it sends its frame immediately (with probability 1)
    - less delay since channel is accessed as soon as possible
    - low throughput: highest chance of collision because two or more stations may find the line idle and send their frames immediately
  - non-persistent (least greedy): station senses the line. If the line is idle, it sends immediately. otherwise, it waits a random amount of time and then senses the line again
    - delay is more when it waits for random amount of time and reduces the efficiency of the network because the medium remains idle while stations are waiting
    - throughput is high: reduced chance of collisions, because it is unlikely that two or more stations will wait the same amount of time and retry to send simultaneously

- Which scheme of CSMA offers balance regarding throughput and delay?
  - P-Persistent CMSA (adjustable greedy): When the channel is free during current slot, it may transmit with probability p or may defer until next slot with probability $1 - p$

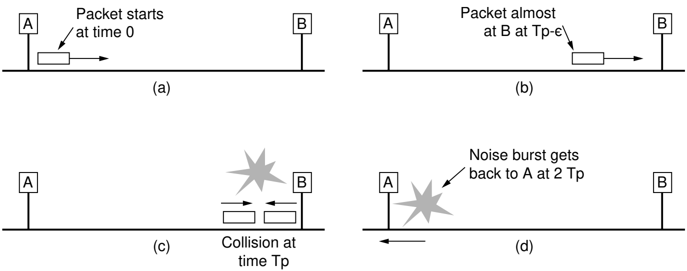
- What does the CD stand for in CSMA/CD? In which systems is it applied? And what does a node do in case of a collision?
  - CD: collision detection
  - applied in wired systems since transmitting stations can detect ongoing transmissions of other stations, e.g., Ethernet
  - reaction to collision: stop transmitting data and send jam signal instead in order to notify others



- At t1, station A has executed its persistence procedure and starts sending its frame.
- At t2, station C has not sensed the first bit of A, executes its persistence procedure and starts sending its frame.
- Station C detects a collision at t3, it immediately aborts transmission.
  - Node C transmits for the duration t3-t2.
- Station A detects collision at t4 and aborts immediately the transmission.
  - Node A transmits for the duration t4-t1.

- Which requirement has to be met in order to detect a collision and why?

  - $T_t > 2T_p$
  - One T_p duration to let the signal from the first station signal reach the second one.
  - One T_p duration to let the collision reach the first station.
  - So, the first station must still be transmitting after $2T_p$



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- A network using CSMA/CD has a bandwidth C of 10 Mbps. If the maximum propagation time (including the delays in the devices) is 25.6 μs, what is the minimum size L of the frame?

$$T_t > 2T_p \qquad \frac{L}{C} > 2T_p \qquad L > 2T_p \cdot C$$

$$L > 51.2 \cdot 10^{-6}s \cdot 10 \cdot 10^{6}s^{-1} = 512$$

The minimum size of the frame is 512 bits or 64 Bytes. This is actually the minimum size of the frame for Standard Ethernet.