Medium Access Control (MAC)

1) Time Division Multiple Access (TDMA)

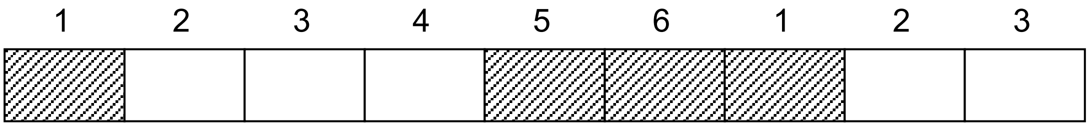
   A network employing TDMA uses 50ms time slots. The available slots are split up between 6 stations. During a period of 3 seconds, stations 1, 5 and 6 have data to transmit. Calculate the usage of the available bandwidth for TDMA with and without a reservation access method. Assume that it takes 60us for the reservation frame to be transmitted and that it is negligible in the calculation of the bandwidth usage. Demonstrate the usage in a diagram.

   Usage:

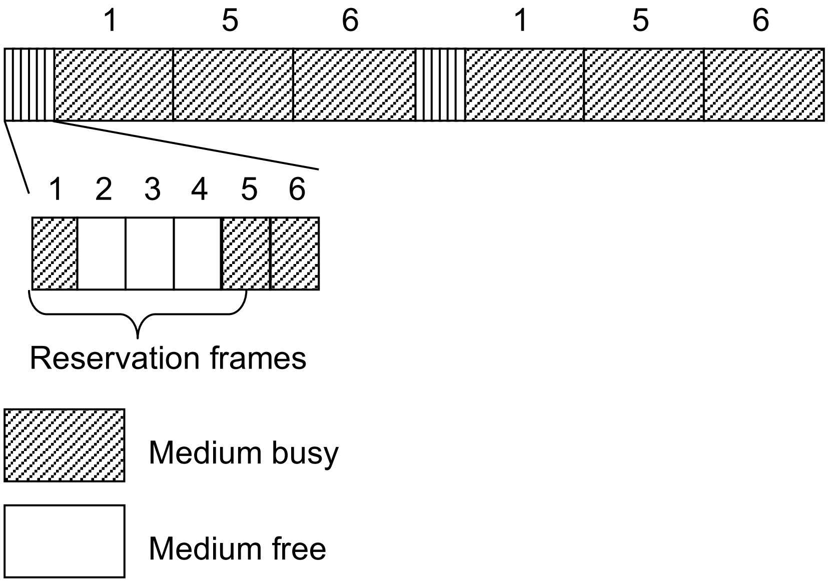
   Statically assigned TDMA: 50% of the bandwidth

   TDMA with reservation: close to 100%

Statically assigned TDMA



TDMA with reservation



2) Carrier Sense Multiple Access (CSMA)

Both, CSMA with Collision Detection (CSMA/CD) and CSMA with Collision Avoidance (CSMA/CA) use binary exponential backoff. Assume that four stations 1, 2, 3 and 4 want to send data and the transmission of a frame has just been completed. Show in a diagram how the four stations compete for the medium and the times that are involved, using both CSMA/CD and CSMA/CA.

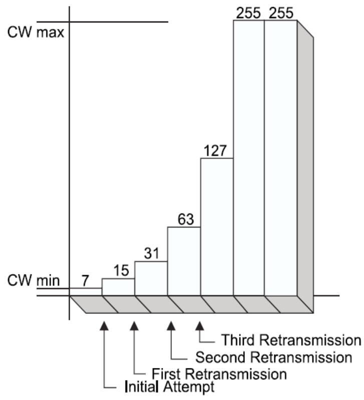
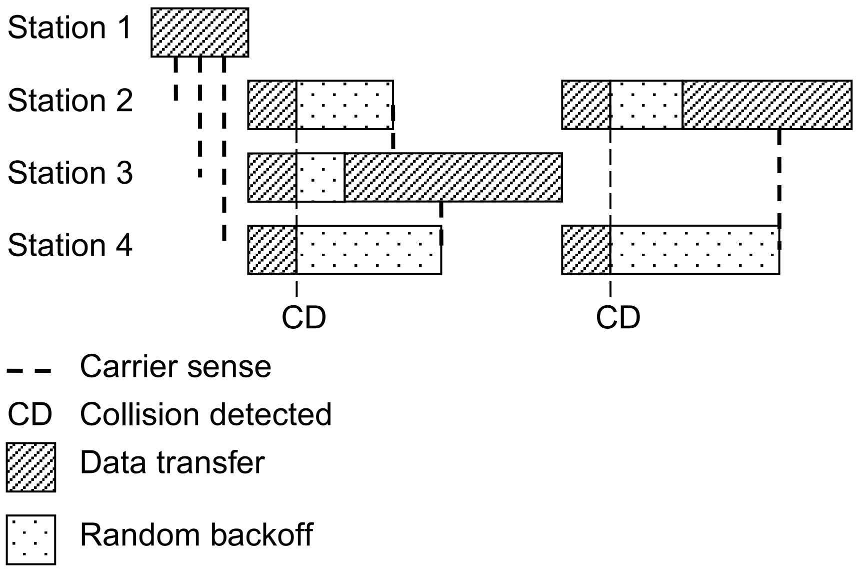
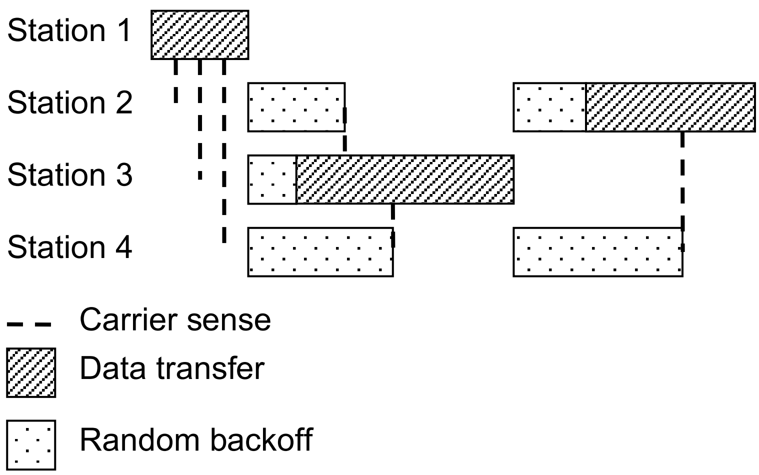


Figure 1: Binary Exponential Backoff

CSMA/CD

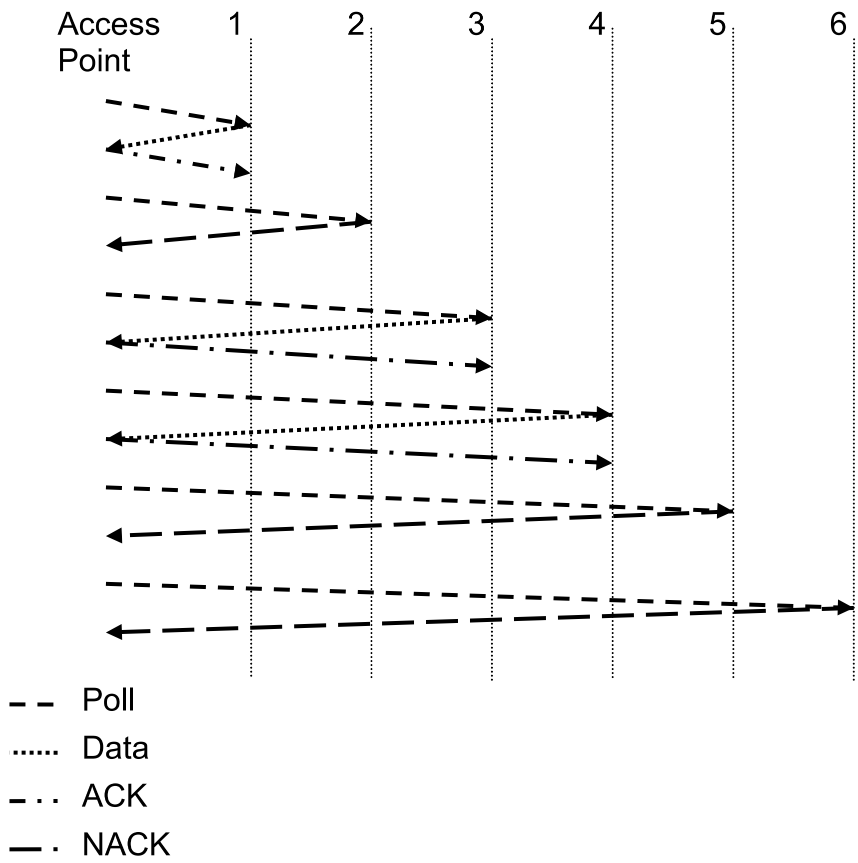


CSMA/CA



3) Poll

Assume that a wireless network consists of a wireless access point and a set of 6 mobile stations. The wireless access point polls the individual mobile stations for data to transmit. Stations 1, 3, and 4 have data to transmit; stations 2, 5 and 6 have no data to transmit. Show in a diagram the traffic that is exchanged over the wireless medium between the access points and the stations.



4) Code Division Multiple Access (CDMA)

Assume a network with three mobile phones, stations 1, 2 and 4, and a base station, station 3. The three mobile phones want to send 011, 101 and 100 respectively; the base station is silent. A 0 is encoded as -1, a 1 is encoded as +1 and silence is represented by 0. Give the signal that the base station receives.

Chip Sequences:

Station 1: +1 +1 −1 −1
Station 2: +1 −1 +1 −1
Station 3: +1 +1 +1 +1
Station 4: +1 −1 −1 +1

Station	Bit	Code	Chip Sequence				Signal
1			+1	+1	-1	-1	
	0	-1					-1 -1 +1 +1
2			+1	-1	+1	-1	
	1	+1					+1 -1 +1 -1
3			+1	+1	+1	+1	
	-						0 0 0 0
4			+1	-1	-1	+1	
	1	+1					+1 -1 -1 +1
							+1 -3 +1 +1

Station	Bit	Code	Chip Sequence				Signal
1			+1	+1	-1	-1	
	1	+1					+1 +1 -1 -1
2			+1	-1	+1	-1	
	0	-1					-1 +1 -1 +1
3			+1	+1	+1	+1	
	-						0 0 0 0
4			+1	-1	-1	+1	
	0	-1					-1 +1 +1 -1
							-1 +3 -1 -1

Station	Bit	Code	Chip Sequence				Signal
1			+1	+1	-1	-1	
	1	+1					+1 +1 -1 -1
2			+1	-1	+1	-1	
	1	+1					+1 -1 +1 -1
3			+1	+1	+1	+1	
	-						0 0 0 0
4			+1	-1	-1	+1	
	0	-1					-1 +1 +1 -1
							+1 +1 +1 -3

The signal received by the base station is

+1 -3 +1 +1 -1 +3 -1 -1 +1 +1 +1 -3

802.11 Wireless Networking

5) An access point uses the Point Coordination Function (PCF) of 802.11 to communicate with 10 laptops that are associated with it. After the contention free period has been completed, the laptops attempt to communicate with one another directly using the Distributed Coordination Function (DCF) of 802.1 – see figure 2 for a possible topology. Assume that at least a number of transmission attempts lead to collisions.

   Describe the frames that are exchanged by the stations and the inter frame spaces that are involved in this exchange. Use diagrams to visualise the chronological exchange of the frames and the inter frame spaces.

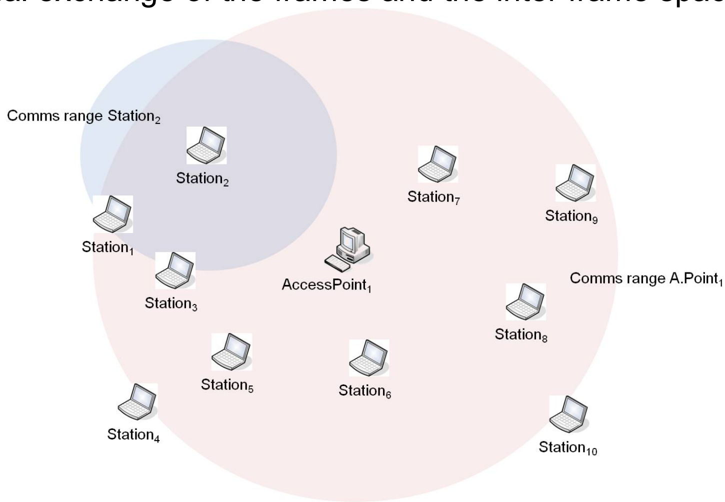


Figure 2: Possible 802.11 topology

Figure 2) and 3) give examples of communication using PCF and DCF; figure 4) presents an example of DCF extended to 10 nodes.

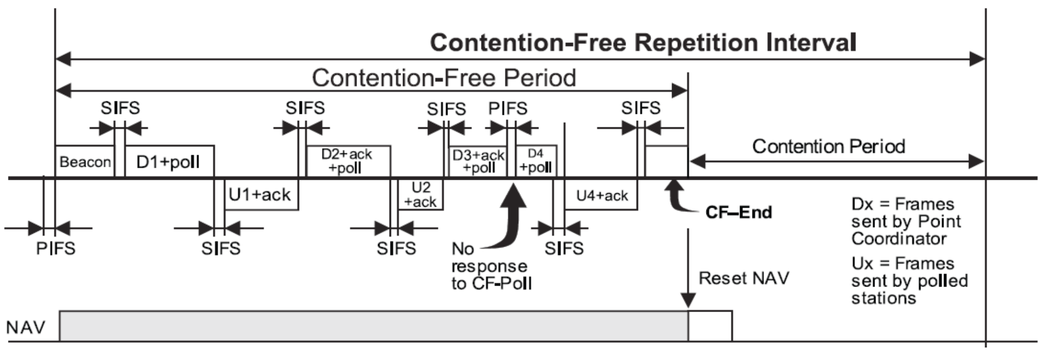


Figure 3: Example for a Contention-Free Period using PCF

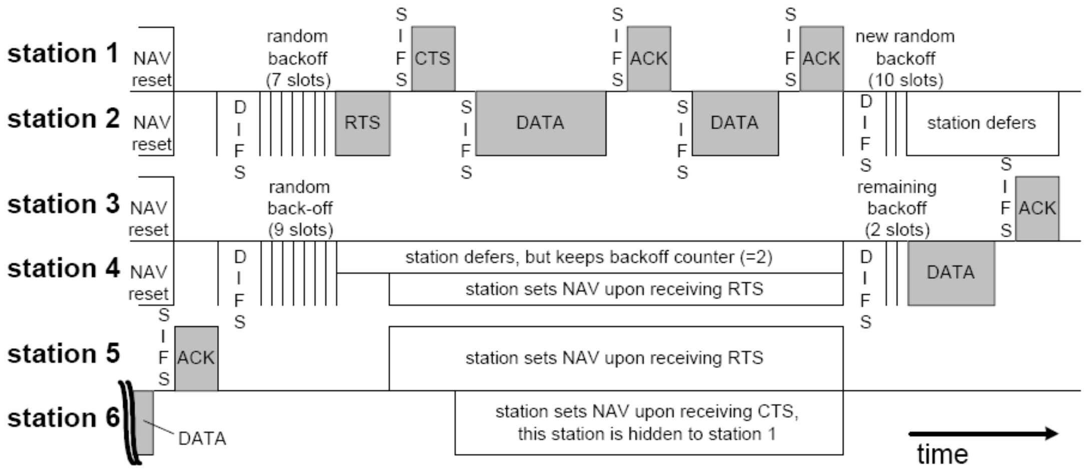


Figure 4: Example for a Contention Period using DCF

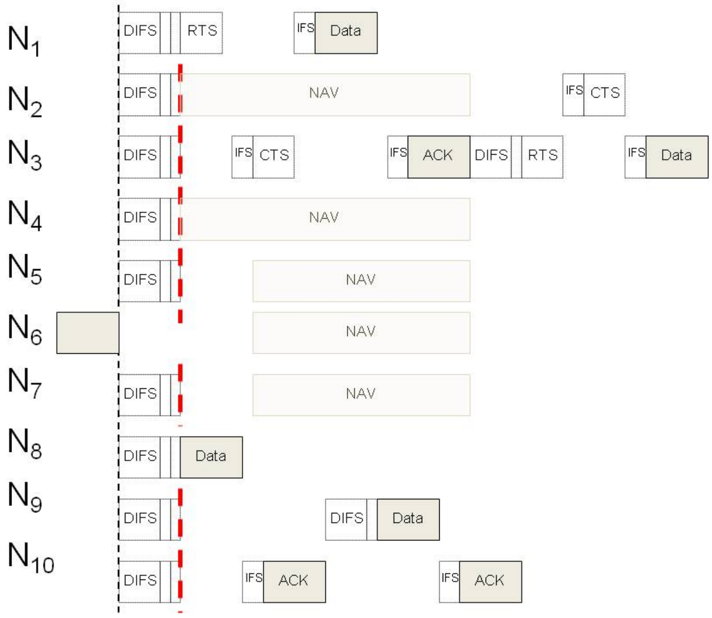


Figure 5: A possible arrangement of communication between 10 nodes using DCF

6) Three stations using 802.11 intent to transmit each 3 data frames to an access point. The times for the transmission for data frames and the Beacon are 190us, for RTS and Poll 180us, for CTS, ACK and CF-End 132us.

> with 802.11a:
> slot: 9us
> SIFS: 16us
> PIFS: 25us
> DIFS: 34us
> AIFS: >=34us

i) Calculate the total time for the transmissions if the stations use DCF. Assume that the random numbers for backoff slots received by the stations are different for all the stations ie. that no collisions occur because of the same random numbers received by two or more stations. Indicate the random numbers that you are using for your calculations.

ii) Calculate the total time for the transmissions if the stations use PCF. Assume that the access point uses only one contention free period for polling each station 3 times.

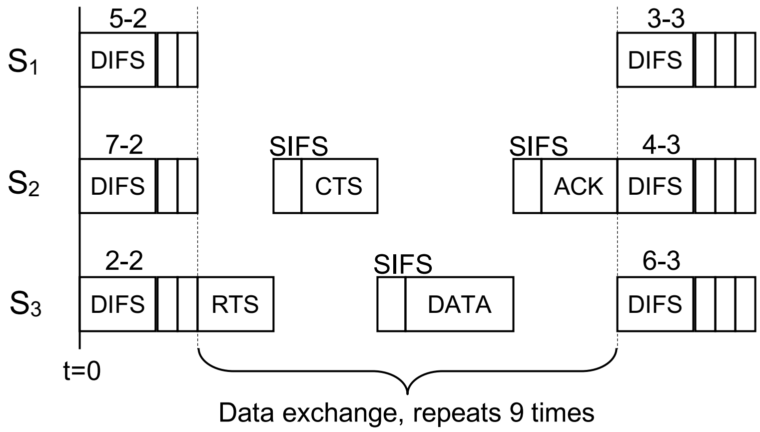
i)

Random back-off numbers – chosen as I went through the exercise:

S_1: 5, 4

S_2: 7, 5, 2

S_3: 2, 6,



First, all stations wait for the DIFS period; then they pick random numbers for their back-off e.g. 5, 7, 2. The station that returns first – in this case S_3 – transmits an RTS frame. The addressed station – in this case I randomly picked S_2 – waits an SIFS period to be sure that the previous transmission has ended and no one is using the medium; then it transmits a CTS frame. S3 then waits an SIFS period and transmits the data. S2 waits another SIFS period and responds with an acknowledgement.

So every data exchange will consist at least of a DIFS period, an RTS and a CTS frame, a data frame and an acknowledgement and 3 SIFS periods.

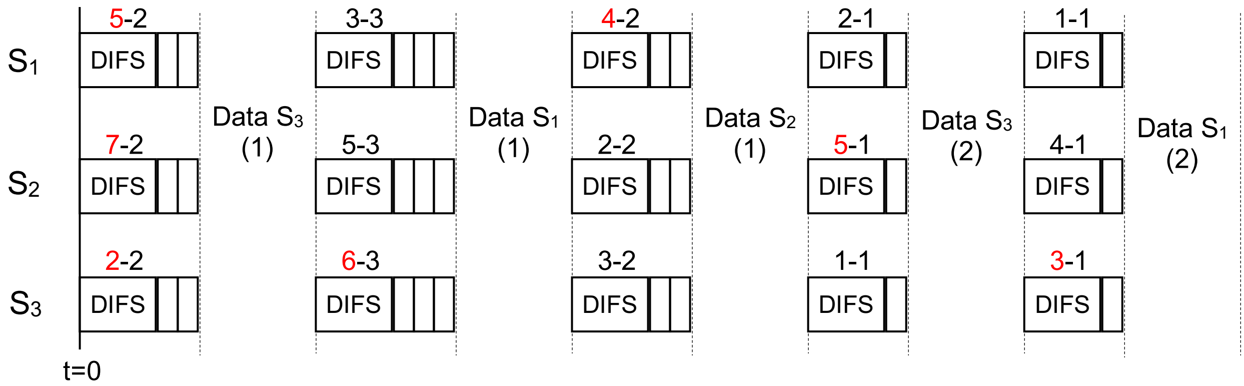
Dx= DIFS+RTS+CTS+data+ack+3*SIFS

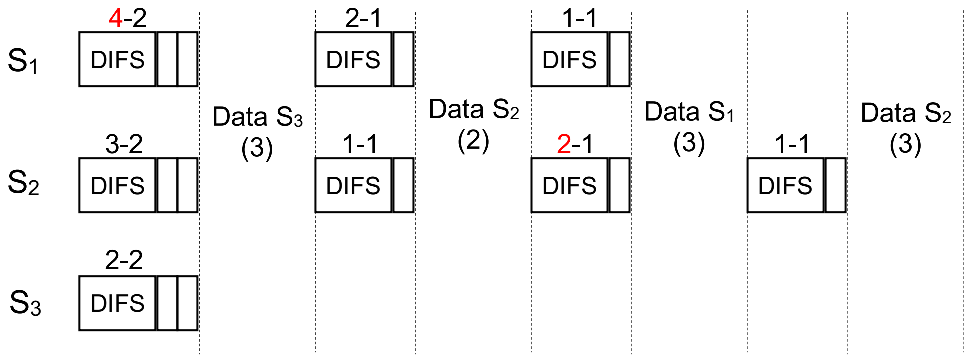
= 34us+180us+132us+190us+132us+3*16us

= 716us

Now, because whoever sat this questions, said each station would transmit 3 data frames, we'll have to play through this scenario 9 times in order to determine the number of slots that stations wait before transmission.

In the following, I've indicated a random back-off number in red, followed by the number of slots that the stations waited before a transmission by one of them e.g. 3-2 indicates that the station picked 3 as a random number of slots and that the station waited 2 slots before a transmission took place. The data exchanges show the station that is transmitting and the number of the transmission e.g. Data S3 (2) indicates the 2nd transmission of a data frame by station 3.

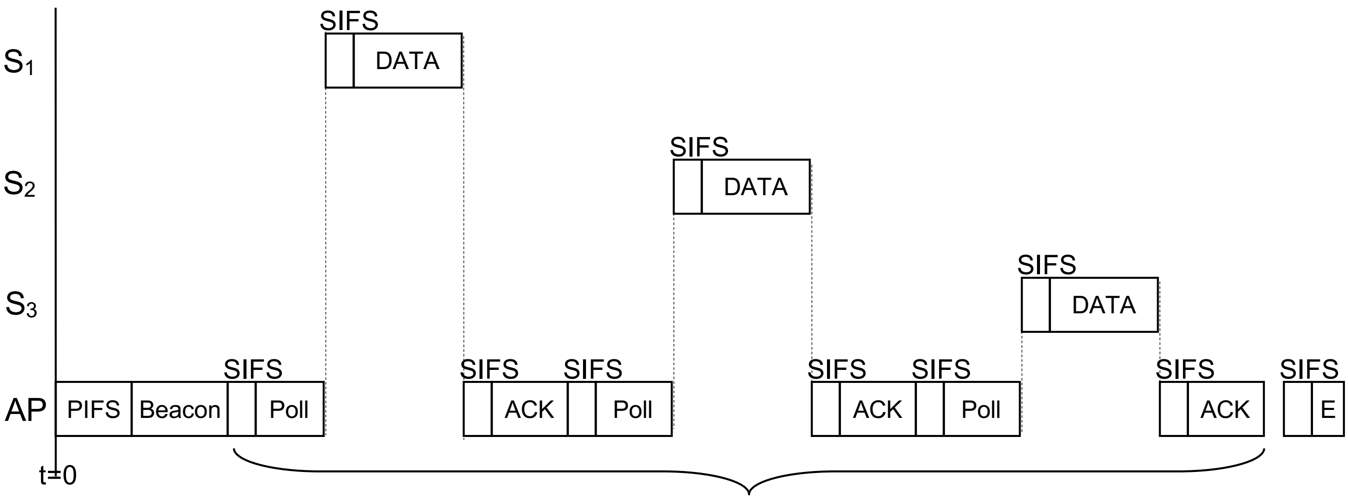




This means that 2+3+2+1+1+2+1+1+1 = 14 slots were used before a transmission took place.

So, the total time for the transmission of the 9 data frames is:
Tx= 9*Dx + 14*slots
= 9*716 + 14*9us
= 6,570us = ~0.006ms

ii)



1 cycle through polling all 3 stations, repeats 3 times

In the PCF mode, the access point AP initially waits a PIFS period after the last transmission and then transmits a beacon frame. Following that, it waits SIFS time and then transmits a frame to poll a station – in this case S_1. S_1 waits an SIFS period and then transmits a data frame. The access points waits SIFS time, transmits an acknowledgement and then polls the next station e.g. S_2 and then the next, S_3. So, every cycle of polling all stations consists of 9 SIFS periods, 3 poll frames, 3 data frames and 3 acknowledgements:
Dx= 9*SIFS + 3*poll + 3*data + 3*ack
= 9*16us + 3*180us + 3*190us + 3*132us
= 1,650us

A contention free period includes one PIFS period, a beacon frame and a final SIFS period and a CF-End frame at the end:
Tx= PIFS + beacon + 3*Dx + SIFS + CF-End
= 25us +190us + 3*1650us + 16us +132us
= 5,313us = ~0.005ms

802.3 Ethernet

7) IEEE 802.3 Ethernet defines a frame format as shown in figure 1 and may include a IEEE 802.2 Link Layer Control (LLC) protocol frame. Figure 2 shows layout of the control field for the types of frames of 802.2 that can be used to implement flow control.

   a) Draw the exchange of the frames in much detail as possible for a Stop-and-Wait approach and for a Selective-Repeat approach. Your diagram should be accompanied by an explanation of the process and of assumptions in case you made any.

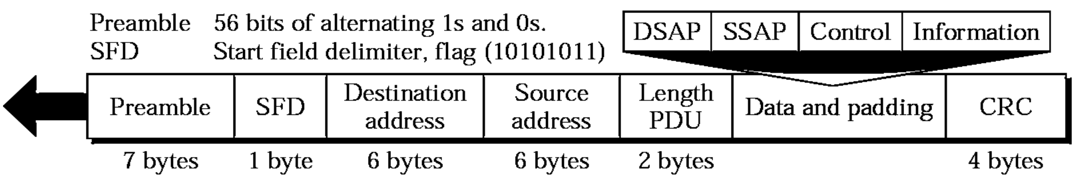


Figure 6: Layout of an 802.3 Ethernet frame

LLC PDU control field bits

	1	2	3	4	5	6	7	8	9	10–16
Information transfer command/response (I-format PDU)	0	N(S)							P/F	N(R)
Supervisory commands/responses (S-format PDUs)	1	0	S	S	X	X	X	X	P/F	N(R)
Unnumbered commands/responses (U-format PDUs)	1	1	M	M	P/F	M	M	M		

Figure 7: Layout of 802.2 LLC information

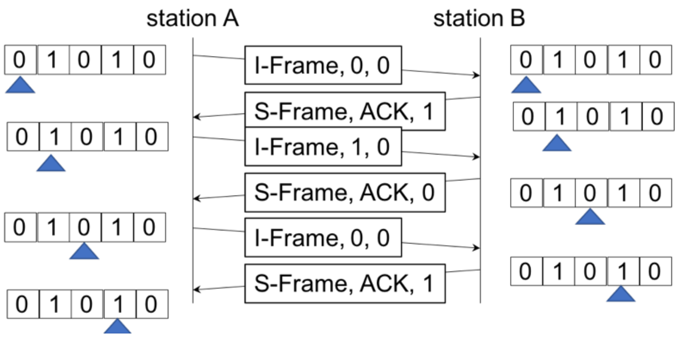
The description of the exchange of frames below has been copied from the HDLC solution ☺ – because in the end, LLC is an updated version of HLDC. In order to adapt this to Ethernet & LLC, the frames will need to be defined:

As addresses for station A and B, I assume random addresses, 0xAABBCC and 0xDDEEFF respectively. The first 7 bytes will be the preamble i.e. 10101010, or 0xAA, followed by the start-field delimiter 10101011, 0xAB. As CRC, I assume a random number, e.g. 0xCCDDBBAA; this would usually be vary with every frame. As Destination and Source Subnet Access Protocol (DSAP and SSAP) I used 0x06 for IPv4. The content of the length, control and information field are dependent on the frame.
Frame from A to B:
Preamble & SFD Dest. Source DSAP SSAP
0xAAAAAAAAAAAAAAAB 0xDDEEFF 0xAABBCC <length> 0x06 0x06
Ctrl bytes Payload. CRC
<control> <information> 0xCCDDBBAA

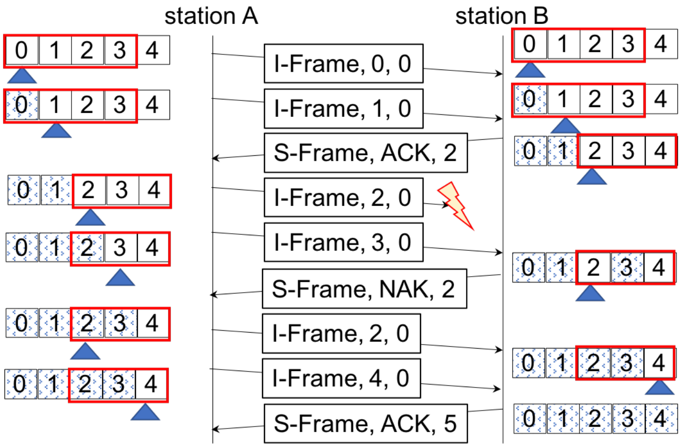
The code in S-Frames for an acknowledgement (RR) is 00 and for a negative acknowledgement (REJ) is 01.

The bit sequences for the control field would look like the following:
IFrame: 0 <7-bit seq#> 0 <7-bit ack#>
SFrame ACK: 10 00 0000 0 <7-bit ack#>
SFrame NAK: 10 01 0000 0 <7-bit ack#>

For Stop&Wait, the sender will send I-frames, carrying the sequence number of the frame, and the receiver will respond to this with an S-frame carrying an acknowledgement.



For Selective Repeat, I-frames will carry sequence numbers of the frame and the receiver will reply with S-frames either as acknowledgements or negative acknowledgements. On the transmission and reception of an acknowledgement, the station A and station B will move their windows forward to the sequence number indicated in the acknowledgement.



8) Assume that you have 2, 20 and 200 stations sharing an Ethernet segment. All stations intent to send frames at some stage during a 5 second window.
   a) Draw a diagram that visualizes the attempts by each station over times to acquire the medium to transmit and how the back-off times for the individual stations develop. Where times etc are not given, use your best judgement and state the assumptions that you are making.
   b) What is the effect of a scenario where stations send large frames e.g.1536 bytes compared against a scenario where stations send very short frames e.g. 64 bytes?

a) 2, 1 transmission after another, no collision – 20 some collision, back-offs, 200 continuous collisions, multiple back-offis, same random numbers etc<diagram to come>

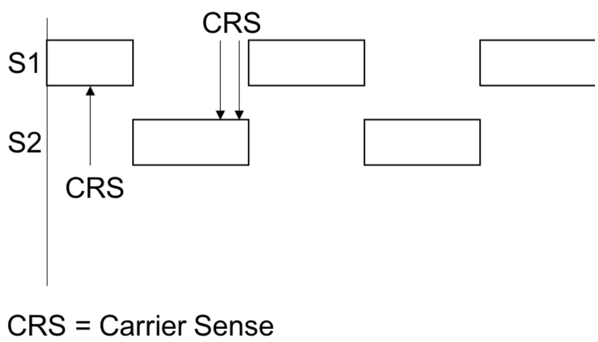


Figure 8: With 2 stations transmitting, - in the best case - the stations should detect each other's transmissions and no collisions will occur.

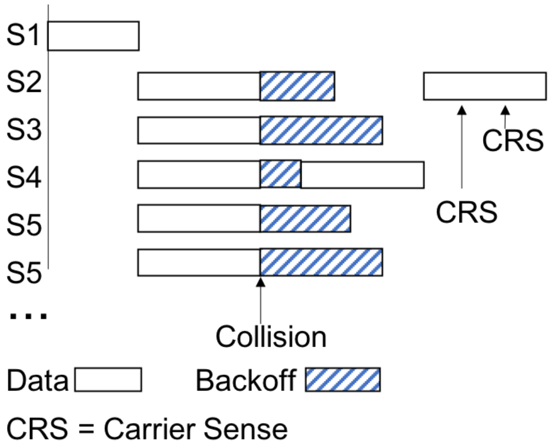


Figure 9: In the case of 20 stations attempting to transmit, stations are likely to experience collisions and will use a back-off. Collisions may occasionally occur more than once, so some stations may increase their back-off time exponentially e.g. from choosing a random number from 0...7 to choosing a random number from 0...15 and 0…31.

In the case of 200 stations attempting to transmit, repeated collisions and numerous increases in back-off times will be unavoidable. Once a station has exceeded the maximum number of back-offs, it may not re-attempt to transmit a frame.

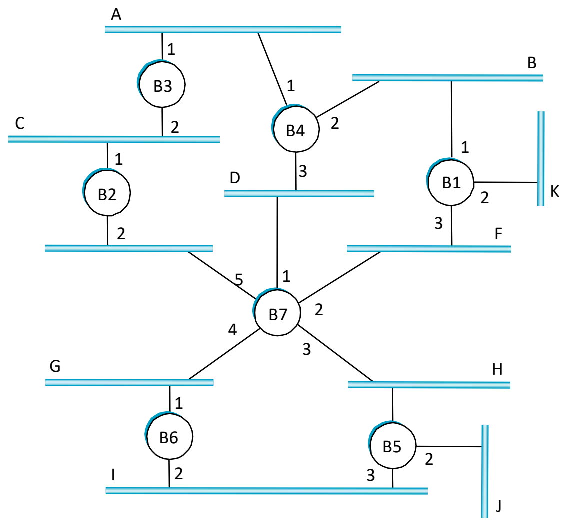
b) In the case of the transmission of large frames, the ratio of transmission periods to contention periods should be high and the utilization of the medium should be high. In the case of the transmission of small frames, the contention periods may be larger than the transmission period, so the utilization of the medium would be low.

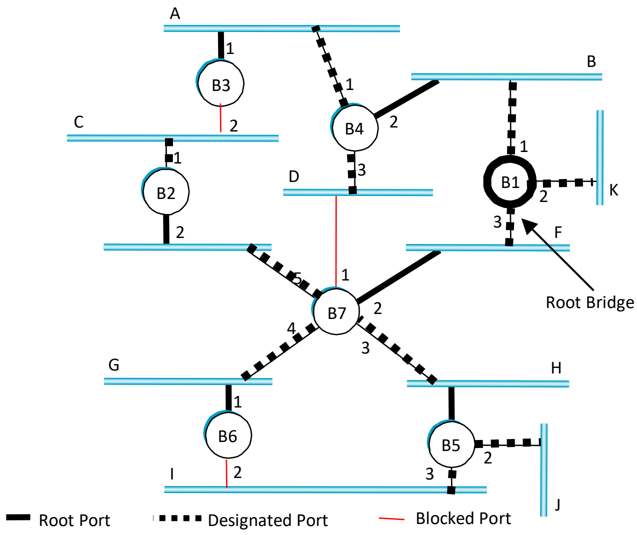
Spanning Tree

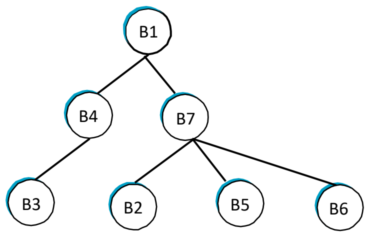
The Spanning Tree Algorithm is used to remove loops from local area networks that employ a set of bridges. Apply the algorithm to the following network and give the resulting spanning tree.

Short description of the algorithm:

1. Bridge with smallest ID is selected as root bridge.
2. Mark port on each bridge with least-cost to root bridge as root port.
3. Select designated bridge for each LAN that has root port with least-cost to root bridge – if two bridges have the same cost, select bridge with lowest ID.
4. Mark root ports and designated ports as forwarding ports; other ports as blocking ports.




A
B
C
D
F
G
H
I
J
K
B1
B2
B3
B4
B5
B6
B7
Root Bridge
Root Port
Designated Port
Blocked Port


B1
B4
B7
B3
B2
B5
B6