Access Networks and Shared Media: A Collection of Problems

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4 septiembre 2023

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Preface

This book contains the problems for the Access Network and Shared Media Course. Problems are either created by the authors of this book or taken from the books by Stallings [1], Forouzan [2], and Tanenbaum[3].

Contents

Fundamentals | 1

1.1 Topologies

Exercise 1.1.1 In a network with n devices, what is the number of links needed for the following topologies:

Sol: $n(n-1)/2$, $n-1$,1,n

A full mesh.
b. A ring.
c. A bus.
d. A star.

Exercise 1.1.2 For each of the following network topologies, explain what happens if a link is broken:

a. Five devices in a full mesh topology.
b. Five devices in a star topology (without considering the hub).
c. Five devices in a bus topology.
d. Five devices in a ring topology.

1.2 Information transfer

Exercise 1.2.1 In *circuit switching* a direct and dedicated path is established between the source and destination devices, while in *packet switching* each information unit is divided into packets for transmission, which can be transmitted independently. Discuss the advantages and disadvantages of these paradigms.

Exercise 1.2.2

How long will it take to transmit a 1-GB file from one VSAT to another using a hub as shown in Figure 1.1? Assume that the uplink is 1 Mbps, the downlink is 7 Mbps, and circuit switching is used with 1.2 sec circuit setup time. Assume that the distance between the satellites and the hub is 35800 Km, and the propagation speed is 300000 km/s

Sol: 8193.68 s.

Exercise 1.2.3

Calculate the transfer time in the previous problem if packet switching is used instead. Assume that the packet size is 64 KB, the switching delay in the satellite and hub is 10 microseconds, and the packet header size is 32 bytes.

Sol: 8196.48 s.

Exercise 1.2.4 Imagine that you have trained your St. Bernard, Bernie, to carry a box of three 8-mm tapes instead of a flask of brandy. (When your disk fills up, you consider that an emergency.) These tapes each

Sol: x2, x2, x0.5

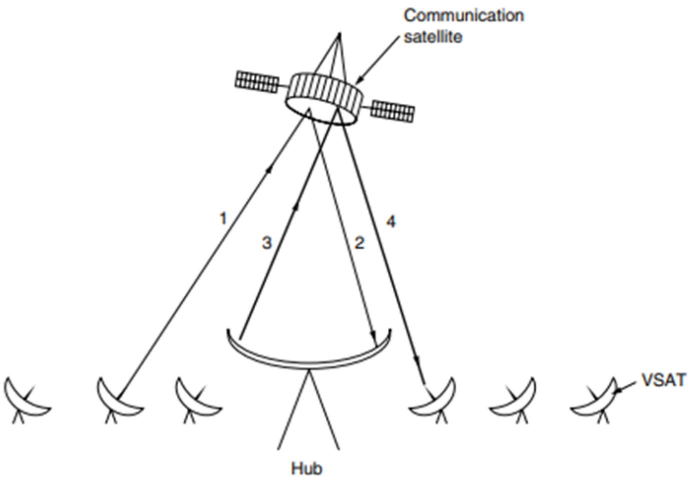


Figure 1.1: A Satellite Network.

contain 7 gigabytes. The dog can travel to your side, wherever you may be, at 18 km/hour. For what range of distances does Bernie have a higher data rate than a transmission line whose data rate (excluding overhead) is 150 Mbps? How does your answer change if

Bernie's speed is doubled;
b. each tape capacity is doubled
c. the data rate of the transmission line is doubled.

1.3 Layering

Exercise 1.3.1 The president of the Specialty Paint Corp. gets the idea to work with a local beer brewer to produce an invisible beer can (as an anti-litter measure). The president tells her legal department to look into it, and they in turn ask engineering for help. As a result, the chief engineer calls his counterpart at the brewery to discuss the technical aspects of the project. The engineers then report back to their respective legal departments, which then confer by telephone to arrange the legal aspects. Finally, the two corporate presidents discuss the financial side of the deal. What principle of a multilayer protocol in the sense of the OSI model does this communication mechanism violate?

Exercise 1.3.2 A system has an n-layer protocol hierarchy. Applications generate messages of length M bytes. At each of the layers, an h-byte header is added. What fraction of the network bandwidth is filled with headers.

Exercise 1.3.3 Map the following concepts with one or more layers in the OSI model:

a. Reliable delivery between processes
b. Route selection
c. Frame definition.
d. Service provisioning such as File Transfer and e-mail.

e. Transmission of a bit sequence over a physical media.

Exercise 1.3.4 In the information transfer processes between the different OSI or TCP/IP models, what are headers and tails, and how are they added and removed?

Physical Layer 2

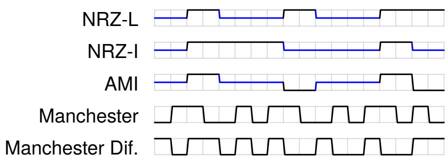
2.1 Coding

Exercise 2.1.1 Draw a line chart with the signal transmitted for the sequence

$$010010011 \tag{2.1}$$

according to these modulation schemes: NRZ-L, NRZ-I, AMI, Manchester, and Differential Manchester.

Sol:



Exercise 2.1.2 What is the minimum bandwidth needed to achieve a data rate of B bits/sec if the signal is transmitted using

a. NRZ coding
b. Manchester coding

Sol: $B/2$,B

2.2 Noisy Channels

Exercise 2.2.1 A signal is transmitted with a transmission power equal to 200 mW. It goes through 2 devices, and in each device there is a 3 dB power attenuation and an additional 10 mW noise. What is the received signal-to-noise ratio?

Sol: 5.23 dB

Exercise 2.2.2

We measured a coaxial cable, and we find that the attenuation follows this rule:

$$Att = 2f^2 \frac{dB}{km \cdot KHz} \tag{2.2}$$

Where Att is the measured attenuation in dB/Km and f is the frequency in KHz. Assuming that a traffic generator sends BPSK signals with a power of 10 mW, compute:

a. The received power on the other end of a 100 m cable if the sine wave signal has a frequency of 10 KHz.
b. The minimum frequency of the sine wave signal to get farther than (i) 100 m and (2) 2.5 km. Assume a receiver with sensitivity equal to 60 dBm.

Sol: 18.71 kHz, 3.74 kHz

Exercise 2.2.3 If a binary signal is sent over a 3-kHz channel whose signal-to-noise ratio is 20 dB, what is the maximum achievable data rate?

Sol: 6 Kbps

2.3 Noiseless Channels

Exercise 2.3.1 In a 3 kHz wide channel, that transmits a signal with 2 levels:

a. What is the maximum transmission capacity?
b. What is the maximum transmission capacity if we employ 2 bits (i.e., 4 levels)?

Sol: 6 Kbps, 12 Kbps

Exercise 2.3.2 A noiseless 4-kHz channel is sampled every 1 msec.

a. What is the maximum data rate?
b. How does the maximum data rate change if the channel is noisy, with a signal-to-noise ratio of 30 dB?

Sol: arbitrarily large, 39.86 kbps

Exercise 2.3.3

We want to send a 256 Kbps flow using a noiseless digital channel, with a bandwidth equal to 20 KHz. How many signal levels are needed?

Sol: 85

Exercise 2.3.4 The Shannon theorem sets the maximum capacity of a channel to:

$$R = B\log_2(1 + SNR) \tag{2.3}$$

While Hartley's law sets the capacity of the channel according to the number of used signal levels M and the bandwidth M

$$R = 2B\log_2(M) \tag{2.4}$$

Given an SNR of 10 dB

a. What is the maximum recommendable M?
b. What is the maximum recommendable M if the SNR is 24 dB?

Sol: 4, 16

Exercise 2.3.5 We want to send a video signal with 480×500 píxels, where each pixel has up to 32 intensity values. The video is sent at 30 images per second rate.

a. Compute the needed transmission rate.
b. We want to send the signal over a 4.5 Mhz wide channel with a SNR o 35 dB. Is it possible? If not, what changes to the signal coding can be done to make it possible?

Sol: 36 Mbps,possible

Exercise 2.3.6 Television channels are 6 MHz wide. How many bits/sec can be sent if four-level digital signals are used? Assume a noiseless channel.

Sol: 24 Mbps

Exercise 2.3.7 We want to use a 4 KHz to transmit 100 kbps. What is the minimum SNR needed?

Sol: 75 dB.

2.4 Network Deployment

Exercise 2.4.1

Radio antennas are usually designed in a way such that the diameter is equal to the wavelength. If the dimension range of the antennas goes from 1 cm to 5 m, what is the frequency range?

Sol:60 MHz

Exercise 2.4.2 A telephone company has 10 million users. Every phone connects with the central station with a copper twisted pair. The mean length of these cables is 10 km. If the copper wire has a 1 mm diameter, its density is 9 g/cm^3, and the price of the copper is 5.76 $/kg, what is the economic value of the infrastructure employed by the company?

Sol:8 138,88 M$

Error Control and CRC 3

3.1 Error Control

Exercise 3.1.1 An upper-layer packet is split into 10 frames, each of which has an 80% chance of arriving undamaged. If no error control is done by the data link protocol, how many times must the message be sent on average to get the entire thing through?

Sol: 9.31

Exercise 3.1.2 To provide more reliability than a single parity bit can give, an error-detecting coding scheme uses one parity bit for checking all the odd-numbered bits and a second parity bit for all the even-numbered bits. What is the Hamming distance of this code?

Sol: 2

Exercise 3.1.3

Suppose that data are transmitted in blocks of sizes 1000 bits. What is the maximum error rate under which error detection and retransmission mechanism (1 parity bit per block) is better than using Hamming code? Assume that bit errors are independent of one another and no bit error occurs during retransmission.

Sol: <0.009

Exercise 3.1.4 Suppose that a message `1001 1100 1010 0011` is transmitted using Internet Checksum (4-bit word). What is the value of the checksum?

Sol: `1011`

3.2 CRC

Exercise 3.2.1 What is the remainder obtained by dividing $x^7 + x^5 + 1$ by the generator polynomial $x^3 + 1$?

Sol: $x^2 + x + 1$.

Exercise 3.2.2 A bit stream `10011101` is transmitted using the standard CRC method described in the slides. The generator polynomial is $x^3 + 1$.

a. Show the actual bit string transmitted.
b. Suppose that the third bit from the left is inverted during transmission. Show that this error is detected at the receiver's end.
c. Give an example of bit errors in the bit string transmitted that will not be detected by the receiver.

Sol: `10011101100`, remainder `100`, all zeros

Exercise 3.2.3 A 1024-bit message is sent that contains 992 data bits and 32 CRC bits. CRC is computed using the IEEE 802 standardized, 32-degree CRC polynomial ($x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x^1 + 1$). For each of the following, explain whether the errors during message transmission will be detected by the receiver:

a. There was a single-bit error.
b. There were two isolated bit errors.
c. There were 18 isolated bit errors.
d. There were 47 isolated bit errors.
e. There was a 24-bit long burst error.
f. There was a 35-bit long burst error.

Sol: ✓,✓,×,✓,✓,×

Exercise 3.2.4 Given the word `10100111` and the divisor `10111`, show the generation of the CRC codeword at the sender site.

Sol: `10100111`**`0001`**

Exercise 3.2.5 Apply the following operations on the corresponding polynomials:

$(x^3 + x^2 + x + 1) + (x^4 + x^2 + x + 1)$
b. $(x^3 + x^2 + x + 1) - (x^4 + x^2 + x + 1)$
c. $(x^3 + x^2)(x^4 + x^2 + x + 1)$
d. $(x^3 + x^2 + x + 1)(x^2 + 1)$

Sol: $x^4 + x^3$,$x^4 + x^3$,$x^7 + x^6 + x^5 + x^2$,0

Exercise 3.2.6 Answer the following questions

a. What is the polynomial representation of `101110`?
b. What is the result of shifting `101110` three bits to the left?
c. Repeat part b using polynomials
d. What is the result of shifting `101110` four bits to the right?
e. Repeat part d using polynomials.

Sol: $x^5+x^3+x^2+x$,`101110`**`000`**,($x^8+x^6+x^5+x4$),`10`,x

Exercise 3.2.7 Which of the following CRC generators guarantee the detection of a single bit error?

$x^3 + x + 1$
b. $x^4 + x^2$
c. 1
d. $x^2 + 1$

a,d

Exercise 3.2.8 For P = `110011` and M = `11100011`, find the CRC

`11010`

Exercise 3.2.9 A CRC is constructed to generate a 4-bit FCS for an 11-bit message. The generator polynomial is $X^4 + X^3 + 1$.

a. Encode the data bit sequence `10011011100` (leftmost bit is the least significant) using the generator polynomial and give the codeword.
b. Now assume that bit 7 (counting from the LSB) in the codeword is in error and show that the detection algorithm detects the

error.

Sol: `1110110010100`

Exercise 3.2.10

In a CRC error-detecting scheme

a. Chose the generator polynomial is $x^4 + x + 1$. Encode the bits `10010011011`.
b. Suppose the channel introduces an error pattern `100010000000000` (i.e., a flip from 1 to 0 or from 0 to 1 in position 1 and 5). What is received? Can the error be detected?
c. Repeat the above with error pattern `100110000000000`.

`100100110111100`,`000110110111100` yes,`000010110111100` no

4 Flow control

4.1 Efficiency analysis

Exercise 4.1.1

Perform a comparative study of the effective flow rate and the efficiency obtained by applying the stop-and-wait, go-back-n, and selective repeat techniques on a given link using the following parameters. Assume that receiving an erroneous frame always sends a NACK.

a. propagation delay: 10 ms
b. physical throughput of the link: 2400 bps
c. 1-bit error probability: 10^{-4}
d. Number of bits per information frame: 1024 bits
e. Number of bits per ACK frame: 24 bits
f. Number of bits per NACK frame: 16 bits

Sol: 84.4%, 89.7%, 90.3%, 2025.5 bps, 2153.4 bps, 2166.5 bps

Exercise 4.1.2 A 128 Kbps physical channel has a propagation delay of 10 ms. Determine the range of frame sizes to obtain an efficiency of at least 40% using a stop-and-wait based protocol without considering errors produced in the channel. Consider that the processing delay of the data frames and control is 100 μs in each system and the size of the acknowledgment frames (ACKs) negligible.

Sol: > 216 bytes

4.2 Stop and Wait

Exercise 4.2.1

Consider the following variation of the stop-and-wait ARQ protocol:

- Each frame is sent 2 times
- Custom positive/negative acknowledgments are used for each submission
- If a positive ACK is received for the first transmission, it proceeds directly to send the next frame without waiting for the acknowledgment of the second transmission. The next frame is also duplicated.
- If the ACK of the first submission is negative, the ACK of the second is expected. If this is positive, the next frame is sent (in duplicate). If it isn't, it retransmits the frame (also in duplicate)

Sol: $U = \frac{T}{T_{tot}} = \frac{1-P_e^2}{(1+2a)(1-P_e)+(2+2a)P_e} = \frac{1-P_e}{(2+2a)-(1-P_e)}$

Assume that:

- Each transmission arrives in error with probability P_e
- ACKs do not suffer from errors
- The transmission delay of an information frame is equal to T
- Propagation delay is equal to T_{prop}

- The transmission delay of ACKs is negligible

is requested

a. Calculate the time taken and probability for the case in which a frame has to be sent once for it to arrive correctly (see Figure 4.1).
b. Repeat the above calculation for cases where a frame has to be sent twice, three times, times, and four times respectively (see Figures below).
c. Calculate the efficiency of the protocol.

Observations:

$$P^{2i} = (P^2)^i \tag{4.1}$$

$$P^{2i+1} = P(P^2)^i \tag{4.2}$$

$$\sum_{i=1}^{\infty} iP^{i-1} = \frac{1}{(1-P)^2} \tag{4.3}$$

$$\sum_{i=1}^{\infty} P^{i-1} = \frac{1}{(1-P)} \tag{4.4}$$

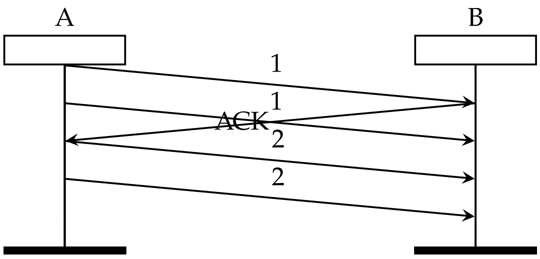


Figure 4.1

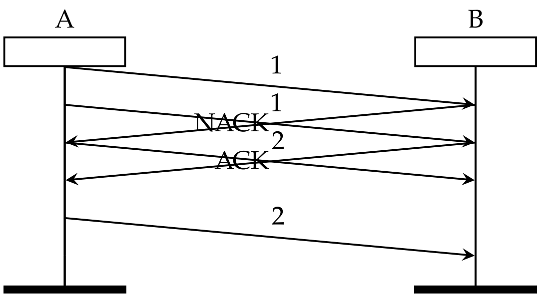


Figure 4.2

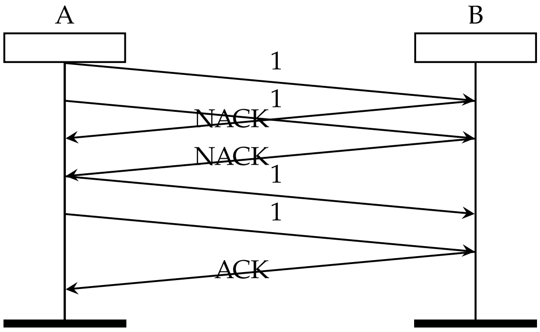


Figure 4.3: E3

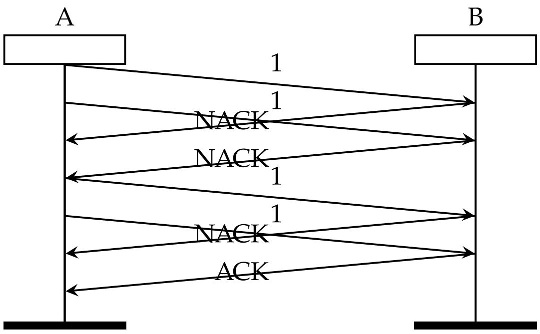


Figure 4.4

Exercise 4.2.2

The following ARQ protocol is considered (see figure below):

- The transmitter sends the same frame continuously.
- On receiving an incorrect frame, the receiver does not send an acknowledgment.
- Upon receiving a successful frame, the receiver sends a positive acknowledgment.
- Upon receiving a positive acknowledgment, the sender proceeds to send the next frame, also continuously.
- For acknowledgments, the transmission time and the probability of error are negligible.

Sol: $U = \frac{T}{T_{tot}} = \frac{1-P_e}{1+2a(1-P_e)}$, $P_e > 0$, $D = \frac{T}{1-P_e} + T_{Prop}$

Answer the next questions:

a. Calculate the efficiency of this protocol based on the probability of error of a frame (P_e) and of ($a = T_{prop}/T_{tx}$).
b. Is the efficiency of this protocol greater or less than the efficiency of the Stop and Wait? Reason your answer.
c. For what values of P_e is the efficiency greater than that of the Go-Back-N ARQ protocol?
d. Calculate the average value of the time that elapses since the transmitter starts sending a frame until the receiver receives it correctly (time D in the figure).

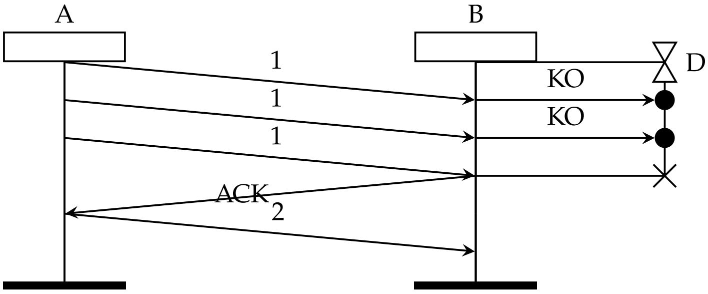


Figure 4.5

Exercise 4.2.3

The stop-and-wait ARQ protocol is used on a channel where errors occur in bursts of according to the following model:

$U = \frac{1}{1.2\times(1+2a)}$

- ► If the transmission of the previous frame was not erroneous, the probability that a error in the transmission of the current frame is 0.1.
- ► If the transmission of the previous frame failed, the probability of an error occurring new error in the current frame is 0.5.

Answer the next questions:

a. Compute the probability that a total of i transmission attempts will have to be made for a frame to arrive correctly. Calculate the total time used for the transmission of a frame in this case.
b. Calculate the efficiency of the stop-and-wait ARQ protocol for the described channel model.
c. Qualitatively describe the degree of improvement that would be obtained in efficiency if the ARQ protocols of Go-Back-N and ARQ of Selective Repeat with a channel of these characteristics.

Exercise 4.2.4

Consider a variation of the stop-and-wait ARQ protocol in which each transmission attempt x copies of a frame are sent. The receiver waits to receive all the copies and sends a NACK if all are incorrect, or an ACK otherwise. See the example in the attached figure. NOTE: The example in the figure illustrates the delay suffered by a frame, which is defined as the time that elapses from when a frame begins to be sent until it successfully arrives at the receiver. It is requested:

$U = \frac{T_{tx}(1-P_e^x)}{2T_{prop}+xT_{tx}}$

a. Calculate the efficiency of the protocol based on x, a and P_e.
b. If the T_{tx} is negligible, $P_e = 0.1$ and it is desired that the delay suffered by the frame does not exceed $3T_{prop}$ with a probability of 0.9999, what value should x have?
c. Qualitatively explain what impact the choice of x has on efficiency and delay, and Propose a strategy for setting x if certain delay requirements are to be met and while maximizing efficiency.

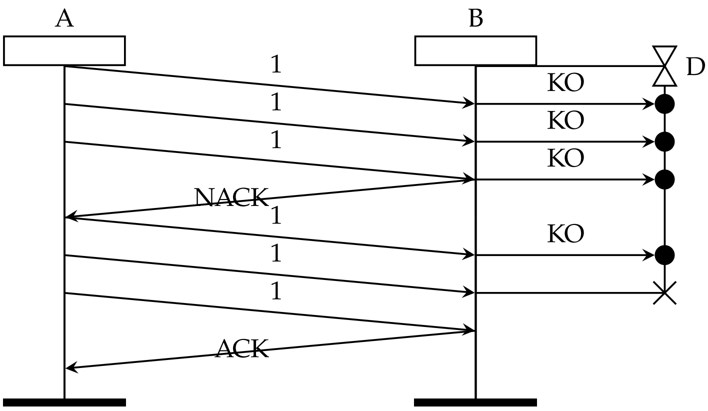


Figure 4.6: An example for $x = 3$.

Exercise 4.2.5 The aim is to analyze the performance of the ARQ stop-and-wait protocol without neglecting the error probability of the ACK frames.

Sol.: $\frac{l(1-P_{e,bit})^{l+l_{ACK}}}{(l+2T_{Prop}C+l_{NACK})}$

It is requested:

a. Compute the probability that only one transmission attempt needs to be made for a frame as a function of: the length of the data frame (l), the length of the Ack frame (l_{ACK}) and the probability bit error ($P_{e,bit}$).
b. Compute the probability that i transmission attempts have to be made for a frame.
c. Calculate the time spent in case of i retransmissions, based on the transmission time of a data frame (T), the transmission time of an Ack (T_{ACK}), and the propagation time (T_{prop}).
d. Calculate the efficiency of the protocol.
e. Qualitatively describe the impact of increasing and decreasing l for efficiency. What will be the efficiency for very large values of l? For very small values? And for intermediate values?

Exercise 4.2.6

Consider the following variation of the stop-and-wait ARQ protocol:

Sol.: $\frac{1-P_e^2}{2+2a}$

- The sender sends a duplicate frame (that is, it sends the same frame twice) and waits for a response from the receiver.
- The receiver waits to receive the two transmissions and sends a NACK in case both are incorrect and an ACK in any other case.
- Upon receiving an ACK, the sender proceeds to send the next frame (also duplicated).
- Upon receiving a NACK, the receiver resends the frame, also in duplicate.
- The frame error probability is P_e, the transmission time of a frame T_{tx} and the delay of spread T_{prop}. The transmission time of the ACKs and NACKs is considered to be negligible.

It is requested:

1) Calculate the efficiency of the proposed protocol as a function of P_e and a = T_{prop}/T_{tx}.
2) We want to compare the efficiency of the proposed protocol with that of the stop ARQ protocol and traditional wait:
   a) In case the values of a and P_e are very large, which of the two protocols will provide higher efficiency? Justify your answer qualitatively.
   b) If $P_e = 0$, which of the two protocols is more efficient?
   c) If $P_e = 0.1$, for what values of a will the proposed protocol provide an efficiency superior to traditional stop-and-wait ARQ?

The following figure shows an example of how the proposed protocol works:

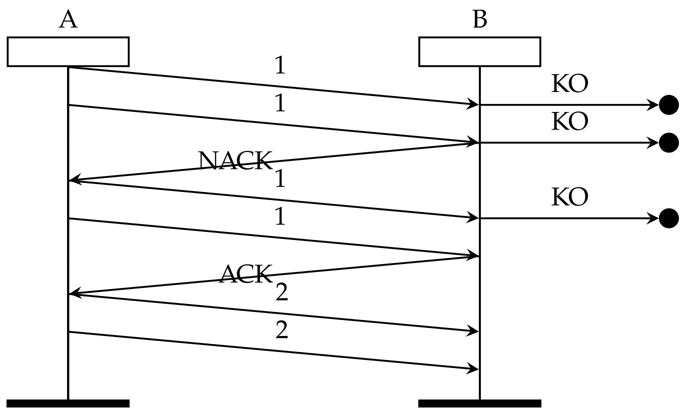


Figure 4.7

4.3 Go Back N

Exercise 4.3.1

The Go-Back-N ARQ protocol is used for communication between two terminals that are connected through an intermediate node:

Sol.: $\frac{(1-P_e^2)}{2}\eta_{GBN}$

- The transmitter and receiver implement the simple reject ARQ protocol.
- The intermediate node only retransmits the data frames sent by the transmitter, as well as the positive and negative assents that the receiver sends.
- The transmission and propagation times of both links (the one that joins the transmitter to the internal node) intermediate, and the one that joins the intermediate node with the receiver) are T_{tx} and T_{prop}, and the probability of error of both links is P_e.

Exercise 4.3.2 We modify a continuous sending ARQ protocol in the following way:

- A frame will be retransmitted if a NACK of that frame is received.
- A rejection will be received for two reasons: that the received frame is wrong or that the frame is lost.

Assume that:

- Custom positive/negative acknowledgments are used for each frame of information (ACK/NACK).
- Control frames are not erroneous or lost.
- Continuous sending is not interrupted for reasons related to the size of the transmission and reception windows.
- Frames contain n bits. The probability that a frame will not reach its destination is P_p (probability that the frame is lost on the link). The probability of error of a data frame is P_e (probability that a frame sent arrives with errors).
- The acknowledgment time (time from when an acknowledgment frame is transmitted information until an ACK or NACK is received from the receiver) is equal to four times the transmission time of a data frame.
- The timer is set to the minimum possible value.

It is requested to calculate the efficiency of the protocol in the case that Go-Back-N is used.

4.4 Selective Repeat

Exercise 4.4.1

The following variation of the selective repeat ARQ protocol is considered

- On the first transmission attempt, the frame is transmitted only once.
- In successive attempts the frames are transmitted duplicates (that is, the same frame is transmitted twice in a row).
- After making a duplicate transmission, the two corresponding acknowledgments are expected and if both are negative, the duplicate frames are sent again.

The following figure shows an example of the protocol operation in the case where i transmission attempts to send frame 1.

Sol.: $T(i = 1) = T$, $Pr(i) = P_e(P_e^2)^(1 - 2)(1 - P_e^2)$,$T(i) = T + 2T(i - 1)$,$U = \frac{1-P_e^2}{1+2Pe-Pe^2}$

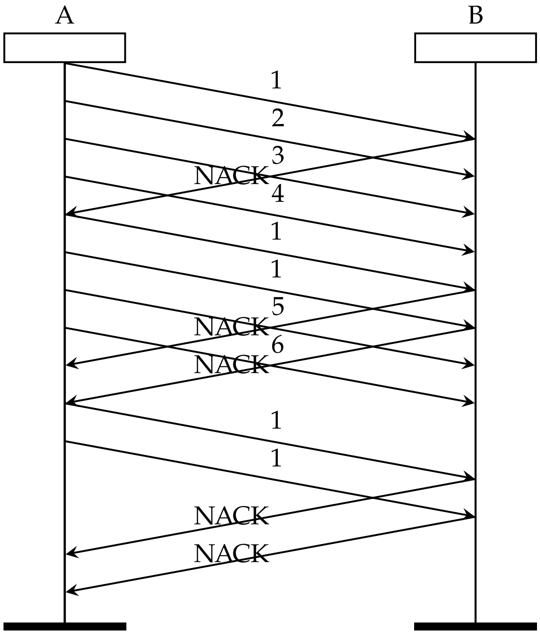


Figure 4.8

Answer the following questions using depending on the parameters transmission time (T_{tx}), propagation time (T_{prop}) and frame error probability (P_e).

a. Indicate the total time that is used for a frame in case it is successfully transmitted in the first attempt.
b. Compute the probability that a total of i transmission attempts will have to be made for a frame to arrive correctly.
c. Calculate the total time that is used for the transmission of a frame in this of having to make a total of i transmission attempts to get a frame to arrive correctly. mind.
d. Calculate the efficiency of the protocol.
e. Describe the benefits that duplicate transmissions can bring.

4.5 Sliding Windows

Exercise 4.5.1

Consider a full-duplex link of 4000 km length, physical throughput of 128 Kbps and propagation delay of 10 μs/km. If this link is used for the transmission of frames of 1000 bits, it is requested:

Sol.: 9, 71%, 26%

a. Calculate the minimum window size W for the channel efficiency to be greater than 80% in the flow control with a sliding window. Suppose no errors exist.
b. What would be the efficiency that would be obtained if the frames had only 3 bits for enumeration? Assume that there are no errors.
c. Suppose the window size is $W = 15$. Calculate the efficiency of the simple reject ARQ protocol if the frame error probability is 0.2. NOTE: with this window size we have continuous transmission.

Shared Access 5

5.1 Aloha

Exercise 5.1.1 We have a pure Aloha network with 100 stations. If $T_{tx} = 1\ \mu$s, what is the number of frames/s each station can send to achieve the maximum efficiency.

Sol: 5000

Exercise 5.1.2 Repeat previous problem for slotted Aloha.

Sol: 10000

Exercise 5.1.3 One hundred stations on a pure Aloha network share a 1 Mbps channel. If frames are 1000 bits long, find the throughput if each station is sending 10 frames/s.

Sol: 135 Kbps

Exercise 5.1.4 Repeat previous problem for slotted Aloha.

Sol: 360 Kbps

Exercise 5.1.5 A group of N stations share a 56-kbps pure Aloha channel. Each station outputs a 1000-bit frame on an average of once every 100 s, even if the previous one has not yet been sent (i.e. the stations can buffer outgoing frames). What is the maximum value of N?

Sol: 2800

Exercise 5.1.6 Ten thousand airline reservation stations are competing for the use of a single slotted Aloha channel. The average station makes 18 requests/hour. A slot is 125 μs. What is the approximate total channel load?

Sol: 6.21e−3

5.2 CSMA

Exercise 5.2.1 In a CSMA/CD network with a data rate of 10 Mbps, the minimum frame size is found to be 512 bits for the correct operation of the collision detection process. What should be the minimum frame size if we increase the data rate to:

a. 100 Mbps
b. 1 Gbps
c. 10 Gbps

Sol: 5120, 51200, 512000

Exercise 5.2.2 In a CSMA/CD network with a data rate of 10 Mbps, the maximum distance between any station pair is found to be 2500 m for the correct operation of the collision detection process. What should be the maximum distance if we increase the data rate to:

a. 100 Mbps
b. 1 Gbps
c. 10 Gbps

Sol: 250, 25, 2.5

Exercise 5.2.3 Consider building a CSMA/CD network running at 1 Gbps over a 1-km cable. The signal speed in the cable is 200000 km/s. What is the minimum frame size?

Sol: 10000 bits

Exercise 5.2.4 In the figure below, the data rate is 10 Mbps, the distance between nodes A and C is 2000 m, and the propagation speed is 2e8 m/s. Node A starts sending a long frame at time t_1=0; mode C starts sending a long frame at time t_2=3 μs. The size of the frame is long enough to guarantee the detection of collision by both stations. Find

1) The time when station C hears the collision.
2) The time when station A hears the collision.
3) The number of bits station A has sent before detecting the collision.
4) The number of bits station C has sent before detecting the collision.

Sol: 10ms, 13ms, 130 bits, 100 bits

Figure 5.1: The network topology.

Interconnection 6

6.1 Forwarding

Exercise 6.1.1 In the network depicted in the figure below, where B1 and B2 are learning bridges, answer the following question:

1) Draw the forwarding tables of the bridges after that B receives a frame from A
2) Draw the forwarding tables of the bridges after that H receives a frame from I
3) Draw the forwarding tables of the bridges after that H receives a frame fromA
4) Draw the forwarding tables of the bridges after that I receives a frame from A
5) How many times E and G forward frames originated in A, if:
    a) G sends a frame to E
    b) A sends a frame to G
    c) B sends a frame to A
    d) A sends a frame to B
    e) A sends a frame to D
6) How many frames with source A were processed by D
7) How many frames with source A were processed by I
8) How many frames with source A were processed by E
9) How many frames with source A were processed by H

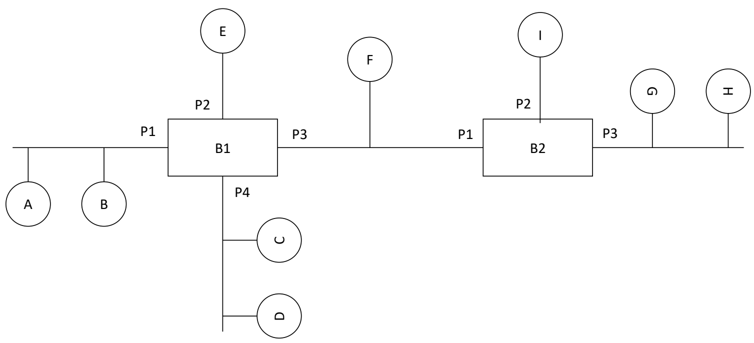


Figure 6.1: The Topology.

Exercise 6.1.2 In the network depicted in the figure below, where B1 to B10 are bridges that interconnect the diferentes LAN. Assume that A and B are in LAN 1, node C is in LAN 2, and node D in LAN8. Initially, all the forwarding tables are empty.

1) What is the forwarding table status after each of these steps?:
    a) Step 1. A sends a frame to D

b) Step 2. C sends a frame to A
c) Step 3. D sends a frame to C
d) Step 4. A sends a frame to D

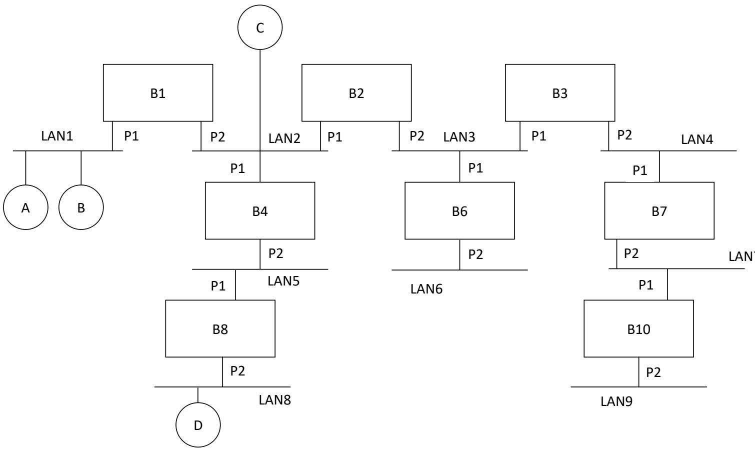


Figure 6.2: The Topology.

Exercise 6.1.3 Given the network in the figure, composed by 7 Ethernet segments, where R1, R2, and R3 are layer 3 routers, B1 is a bridge, SW1 is a switch. To identify an interface of an interconnection device we use this notation: `<Device Name . attached segment>`. So R1 interfaces are `R1.S1` and `R1.S2`

Answer the following questions:

1) Identify the broadcast domains of the network and the segments that compose them.
2) Identify the collision domains of the network and the segments that compose them.

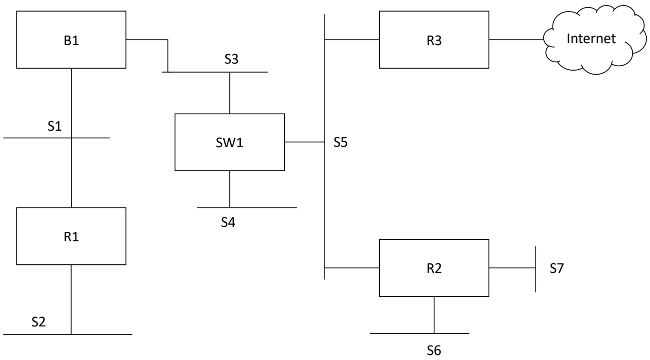


Figure 6.3: The Topology.

Exercise 6.1.4 The figure shows a Fast Ethernet network used by an enterprise. S_x represents a Switch and H_x a Hub.

Compute

1) The number of broadcast domains in the network and the end systems that belong to them.

2) The number of collision domains in the network and the end systems that belong to them.
3) Before converging to a stable state, node B sends a frame to node D, which will be processed by several interconnection devices. Detail for each of them what are the entries that shall be added to the forwarding table.
4) Immediately after receiving the frame from B, D sends a frame to B. Detail for each interconnection device what are the entries that shall be added to the forwarding table.

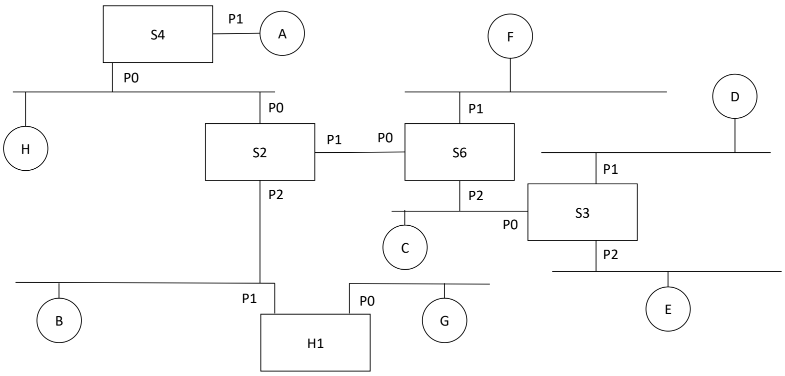


Figure 6.4: The Topology.

6.2 Spanning Tree

Exercise 6.2.1 In the network below B_x is a bridge, and R_x is a Hub. Consider:

1) All the LANs use Ethernet (802.3) and links have the same capacity.
2) The number x attached to each device is the device id. For instance B_{50} is the bridge with ID 50.
3) Learning bridges are used.
4) Circles represent end node.

Answer the following questions:

1) Represent the protocol architecture of each component.
2) Detail what end nodes share the same collision domain.
3) Detail what end nodes share the same broadcast domain.
4) Compute the resulting Spanning Tree
5) Compute the forwarding table for each bridge once the network has reached a stable state.
6) Describe the path for the frames originating in A with destination C and for the ones originating in A with destination E once the network has converged to a stable state.

Exercise 6.2.2 In the network below B_x is a bridge, and R_x is a Hub. Consider:

1) All the LANs use Ethernet (802.3) and links have the same

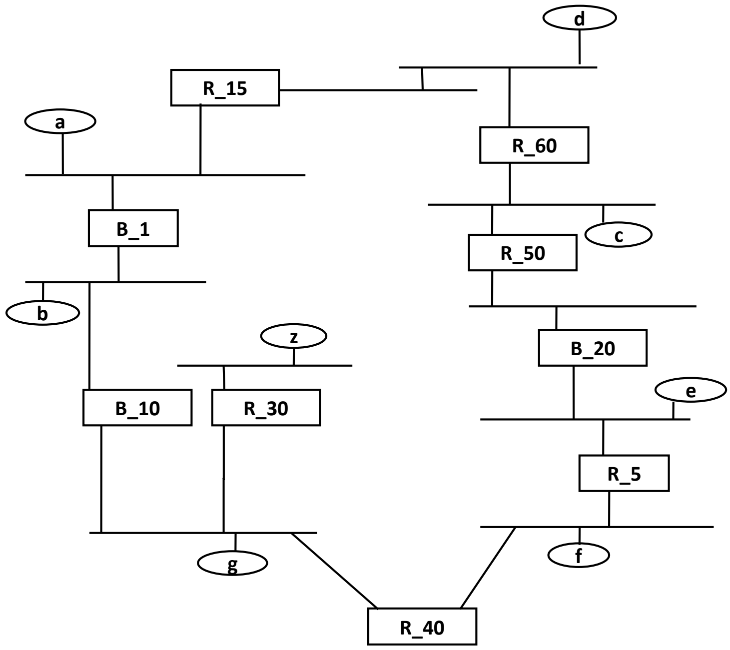


Figure 6.5: The Topology.

capacity.

2) The number x attached to each device is the device id. For instance B_{50} is the bridge with ID 50.
3) Learning bridges are used.
4) Circles represent end node.

Answer the following questions:

1) Represent the protocol architecture of each component.
2) Detail what end nodes share the same collision domain.
3) Detail what end nodes share the same broadcast domain.
4) Compute the resulting Spanning Tree
5) Compute the forwarding table for each bridge once the network has reached a stable state.
6) Assume that B_{10} stops working. Re-compute the spanning tree and the forwarding tables.
7) Detail the path followed by frames with source A and destination E before and after B_{10} stops working.

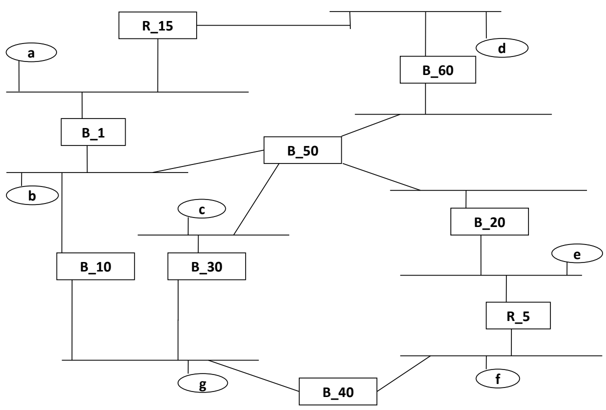


Figure 6.6: The Topology.

Exercise 6.2.3 The network below uses Fast Ethernet and has 3 segments connected through a switch. Considering the Switch id and the port numbers depicted in Figure 6.7:

1) Depict the broadcast and collision domains.
2) Explain how the interconnection device work and compute the spanning tree.
3) Compute the forwarding table achieved once the network has converged.
4) A new switch is introduced between `LAN_1` y `LAN_3` as depicted in Figure 6.8. Compute the forwarding table for the new network topology.

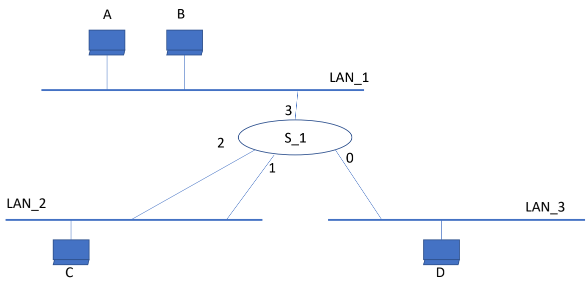


Figure 6.7: The Topology.

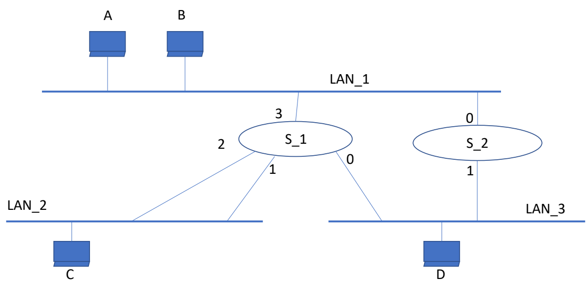


Figure 6.8: The updated Topology.

6.3 VLAN

Exercise 6.3.1 Given the following network where:

- The ethernet segments speed is 100Mbps and are named SEG-x, where x is the indentifier
- Routers have 4 interfaces but not all of them are configured. Their name is Rx, where x is the indentifier
- Bridges are named BridgeX, being x their identifier
- Servers or PCs are marked with letter
- The center switch has 8 ports

1) Supposing that VLANs are not defined in the switch compute
   a) The number of collision domains.
   b) The number of broadcast domains.
2) Supposing that we defined Port Based VLANs:
   - VLAN 1: 2, 3, 4, 5
   - VLAN 2: 6, 7, 8, 1

   compute
   a) The number of collision domains.
   b) The number of broadcast domains.
   c) If all the broadcast domains shall be connected among them using the switch, what connection shall be added?

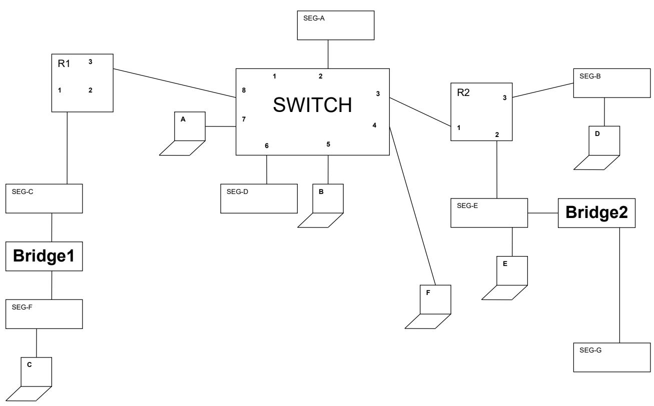


Figure 6.9: The Topology.

Exercise 6.3.2 Given the network in the following figure where:

- S1, S2, S3, S4, S5, S6 y S7 are Ethernet network segments.
- R1, R2 y R3 are routers with some free interfaces.
- B1 is a bridge.
- Rep is a repeater.
- SW1 is a 10 ports cut-through switch
- A and B are two nodes connected to the network.

Answer:

1) How many collision domains there are in the networks? Which segments are they encompassing? To which ports of SW1 they are connected?
2) How many broadcast domains there are in the networks? Which segments are they encompassing? To which ports of SW1 they are connected?

We then configure 4 port-based VLANs in SW1 as follows:

- VLAN1: 1,2,3
- VLAN2: 4,5,6
- VLAN3: 7,8
- VLAN4: 9,10

In this new context:

1) How many collision domains there are in the networks? Which segments are they encompassing? To which ports of SW1 they are connected?
2) How many broadcast domains there are in the networks? Which segments are they encompassing? To which ports of SW1 they are connected?
3) How are VLAN1 and VLAN4 connected?
4) How can we connect VLAN2 and VLAN3 with the rest?
5) In communication between A and B how many Ethernet addresses are used?

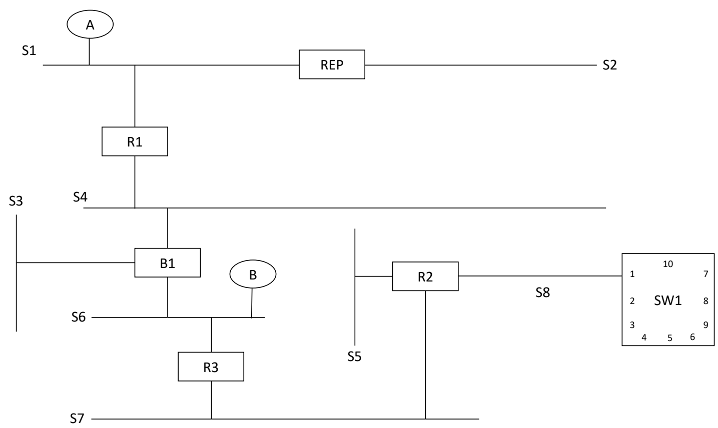


Figure 6.10: The Topology.

Exercise 6.3.3 The network administrator creates two VLANs out of the network depicted below Specifically:

- Bridges 0 (ports 0,3,6,5) 1 (ports 0 and 3) 2 (ports 1,4 and 3) 4 (all ports),7 (all ports),8 (all ports) are in VLAN 1
- Bridges 0 (ports 1,2,4) 1 (ports 1 and 2) 2 (ports 0 and 2) 3 (all ports),6 (all ports),5 (all ports) are in VLAN 2

Then the STP is turned on. Once the protocol has converged, clearly indicate for the network

1) The root bridge
2) For each bridge, its root, designated and blocked ports

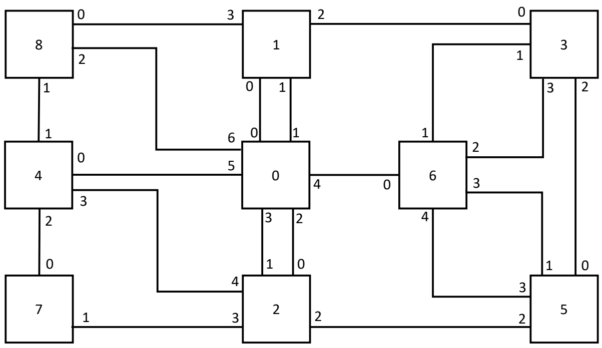


Figure 6.11: The Topology. All links have cost 10, besides the links between 8 and 10 and 1 and 3, that have cost 1.

7 Wireless LANs

7.1 Time Diagrams

Exercise 7.1.1 In an IEEE 802.11 DCF network, there are two stations (A and B) that are connected to the same access point. The following events take place in the network:

1) At t = 0 A receives a frame to be transmitted from the upper layer
2) At t = 5 B receives a frame to be transmitted from upper layers

Knowing that

- DIFS = 4
- SIFS = 1
- The transmission time for both frames is 6
- Acknowledgements, RTS and CTS frames last 2
- The propagation time is 0

Answer the following questions

1) Compute the entire time diagram when A and B are not hidden nodes and RTS/CTS is not used
2) Repeat 1) with A and B hidden nodes and RTS/CTS is activated

Exercise 7.1.2 In an IEEE 802.11 DCF network, there are two stations (A and B) that are connected to the same access point. The following events take place in the network:

1) At t = 0 A receives a frame to be transmitted from the upper layer
2) At t = 8 B receives a frame to be transmitted from upper layers

Knowing that

- DIFS = 4
- SIFS = 1
- The transmission time for both frames is 8
- Acknowledgements, RTS and CTS frames last 2
- The propagation time is 0

Answer the following questions

1) Compute the entire time diagram when A and B are not hidden nodes and RTS/CTS is not used
2) Repeat 1) with A and B hidden nodes and RTS/CTS is not used
3) Repeat 1) with A and B hidden nodes and RTS/CTS is used

Bibliography

[1] William Stallings. *Data and Computer Communications*. Prentice Hall Press, 2013 (cited on page ii).

[2] Behrouz A. Forouzan. *Data Communications and Networking (McGraw-Hill Forouzan Networking)*. McGraw-Hill Higher Education, 2007 (cited on page ii).

[3] Andrew S. Tanenbaum and David Wetherall. *Computer Networks*. Prentice Hall, 2011 (cited on page ii).