Name …...ID …............................... Section …........Seat No..........

Sirindhorn International Institute of Technology
Thammasat University

Midterm Examination Answers: Semester 1/2010

Course Title : ITS323 Introduction to Data Communications

Instructor : Dr Steven Gordon

Date/Time : Friday 6 August 2010; 13:30 – 16:30

Instructions:

- This examination paper has 19 pages (including this page).
- Condition of Examination
  Closed book (No dictionary; Non-programmable calculator is allowed)
- Students are not allowed to be out of the exam room during examination. Going to the restroom may result in score deduction.
- Turn off all communication devices (mobile phone etc.) and leave them under your seat.
- Write your name, student ID, section, and seat number clearly on the answer sheet.
- The space on the back of each page can be used if necessary.
- Assume bits are ordered from left to right: 1st bit, 2nd bit, 3rd bit, …, nth bit
- Unless otherwise stated in the question, assume the speed of transmission is $3x10^8$m/s
- Free space propagation path loss:

$$\frac{P_t}{P_r} = \frac{(4\pi d)^2}{G_t G_r \lambda^2}$$

- Antenna gain for parabolic antenna with area *A*:

$$G = \frac{4\pi A}{\lambda^2}$$

Questions [100 marks]

Question 1 [9 marks]

a) Draw the layered stack in the TCP/IP protocol architecture. [3 marks]

Answer

Application

Transport

Network

Data Link

Physical

b) Which layer from the above TCP/IP protocol architecture does the following address belong to? [4 marks]

i. IPv4, e.g. 203.45.16.23 Layer: ______________________________

ii. Email, e.g. steve@siit.tu.ac.th Layer: ______________________________

iii. IEEE, e.g. 13:45:f5:e9:51:b9 Layer: ______________________________

iv. Web server port, e.g. 80 Layer: ______________________________

Answer

Network

Application

Data Link

Transport

c) Protocols from which two layers are normally implemented in the operating system? [2 marks]

Answer

Transport and Network

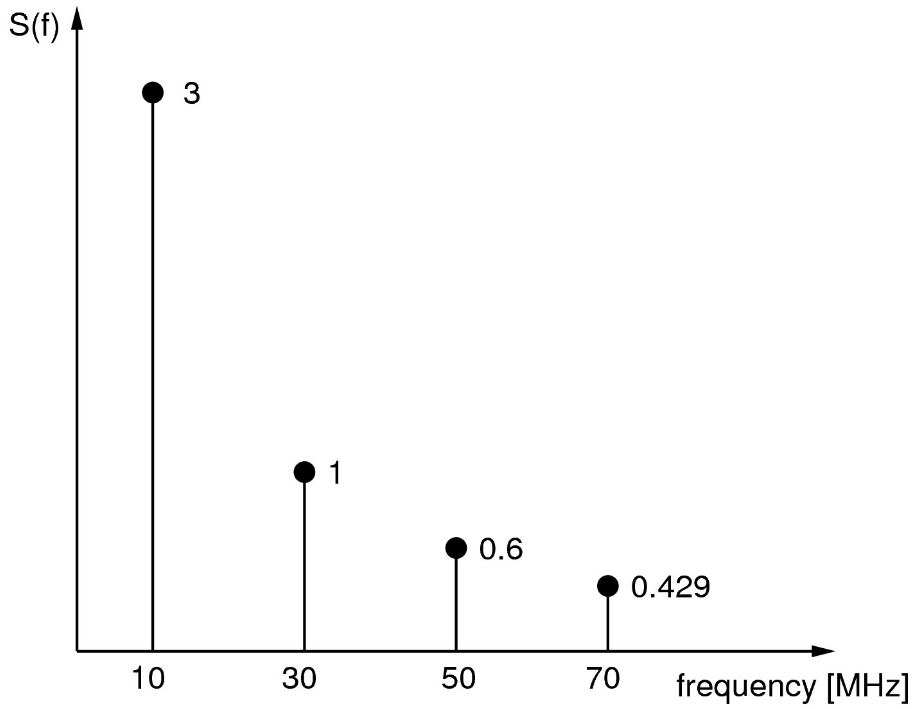
Question 2 [9 marks]

Consider the following communications signal:[NOTE: Missing "sin" n exam]

$$s_1(t)=3.000\sin(2\times10^7\pi t)+1.000\sin(6\times10^7\pi t)+0.600\sin(1\times10^8\pi t)+0.429\sin(1.4\times10^8\pi t)$$

a) Draw a plot of the signal in the frequency domain. [3 marks]

Answer



b) What is the period of $s_1(t)$? [1 mark]

Answer

The fundamental frequency is 10MHz, therefore the period is 0.1us.

c) Write an equation for a signal, $s_2(t)$, that uses the same absolute bandwidth as $s_1(t)$, has the same peak amplitude as $s_1(t)$, but only uses 3 sine components. [3 marks]

Answer

[Note: the question is not well written – I was supposed to say also a fundamental frequency]

The absolute bandwidth is 60MHz. If we use three sine components then their frequencies are i, 3*f* and 5*f*, giving an absolute bandwidth of 4*f*. Therefore the fundamental frequency should be 15MHz.

$$s_1(t)=3.000\sin(3\times10^7\pi t)+1.000\sin(9\times10^7\pi t)+0.600\sin(1.5\times10^8\pi t)$$

d) Explain an advantage of $s_1(t)$ compared to $s_2(t)$ if both are used to transmit digital data. [1 mark]

Answer

Signal $s_1(t)$ can more accurately represent the digital data – less impact of errors.

e) Explain a disadvantage of $s_1(t)$ compared to $s_2(t)$ if both are used to transmit digital data. [1 mark]

Answer

Signal $s_1(t)$ uses a lower fundamental frequency, therefore longer period. The maximum data rate is therefore less than that with $s_2(t)$.

Question 3 [10 marks]

The free space path loss model is:

$$P_r = \frac{P_t G_t G_r}{L}$$

where the absolute power loss is: $L = \frac{(4\pi d)^2}{\lambda^2}$

However this model is inaccurate in indoor environments, as it does not consider obstructions such as floors, ceilings, walls and office furniture. A more accurate model of indoor environments is the ITU Indoor Propagation model, where the path loss between two antenna's is calculated as:

$$L = 20\log_{10}(f) + N\log_{10}(d) + P_f(n) - 28$$

where:

- L is the path loss measured in dB
- f is the signal frequency in Megahertz (MHz)
- d is the distance in metres (m)
- N is the distance power loss coefficient, with values depending on frequency and environment
- $P_f(n)$ is floor penetration loss factor which depends on the number of floors (*n*) and frequency.

For an office environment using signals at frequency of 2.4GHz, N = 30. To cover 3 floors (n=2), $P_f(2)$ = 19.

Consider an IEEE 802.11 wireless LAN (Wi-Fi) device with the following characteristics:

- Transmit power: 12.5mW
- Receive threshold: -60dBm
- Frequency: 2.4GHz

Each device has the choice of three different types of antenna:

- Antenna 1: 5dBi gain; cost 500 Baht
- Antenna 2: 10dBi gain; cost 2000 Baht
- Antenna 3: 15dBi gain; cost 4000 Baht

a) What is the transmit power of the wireless device, measured in dBm? [2 marks]

Answer

$dBm = 10\log_{10}(12.5) = 11\text{dBm}$

b) What is the value of the wavelength of the signal being transmitted? [1 mark]

Answer

$$\lambda=\frac{c}{f}=\frac{3\times10^{8}}{2.4\times10^{9}}=0.125\text{m}$$

c) Assuming two wireless devices (both with identical characteristics as above) are to communicate in the office environment over a maximum distance of 20m, which antenna type should be purchased? You must assume both devices will use the same antenna type and the ITU Indoor propagation model applies. You must show your calculations. [7 marks]

Answer

The general path loss model, using dB, can be expressed as:

$$P_{r_{dBm}}=P_{t_{dBm}}+G_{t_{dBi}}+G_{r_{dBi}}-L_{dB}$$

From the ITU model:

$$L_{dB}=20\log_{10}(2400)+30\log_{10}(20)+19-28=97.6\text{dB}$$

Therefore, assuming the antenna gains must be the same:

$$G_{dBi}=\frac{P_{r_{dBm}}-P_{t_{dBm}}+L_{dB}}{2}=\frac{-60-11+97.6}{2}=13.3\,dBi$$

Therefore antenna type 3 (with gain 15dBi) should be used. A gain of 10dBi or less will be insufficient with a path loss of 97.6dB.

Question 4 [12 marks]

Figure 1 illustrates a portion of analog input data at a source computer. The analog data is to be transmitted to the destination computer using digital signalling. A 10KHz 3-bit PCM codec is used, as well as the NRZ-Invert encoding scheme. The minimum and maximum possible signal levels are marked on the figure.

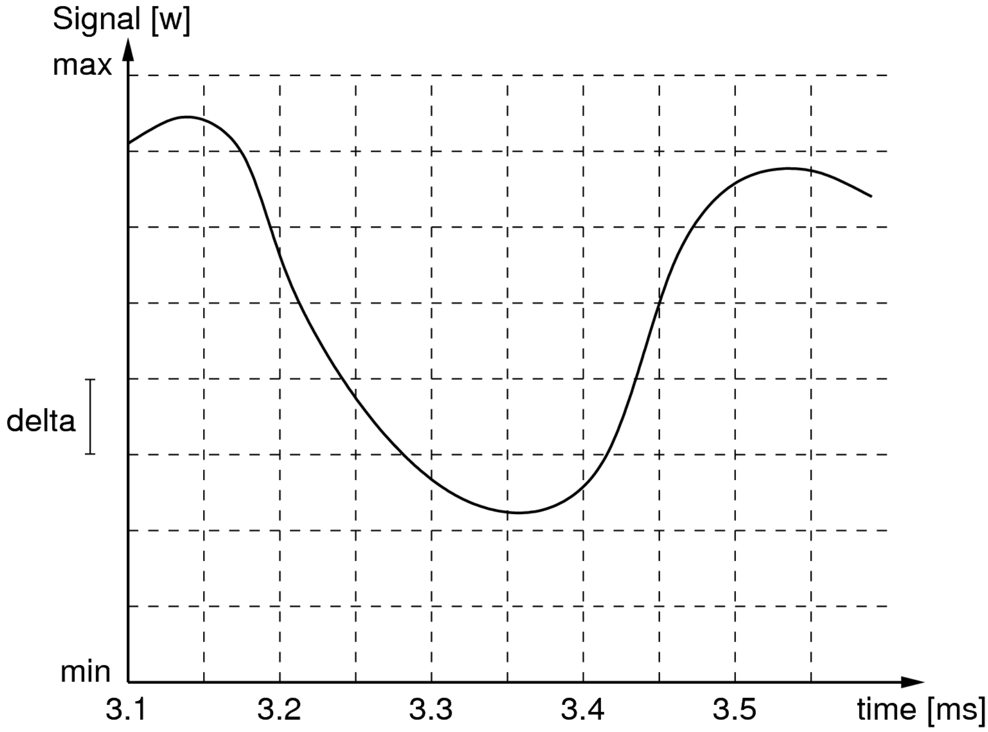


Figure 1

a) What is the digital data to be transmitted? [4 marks]

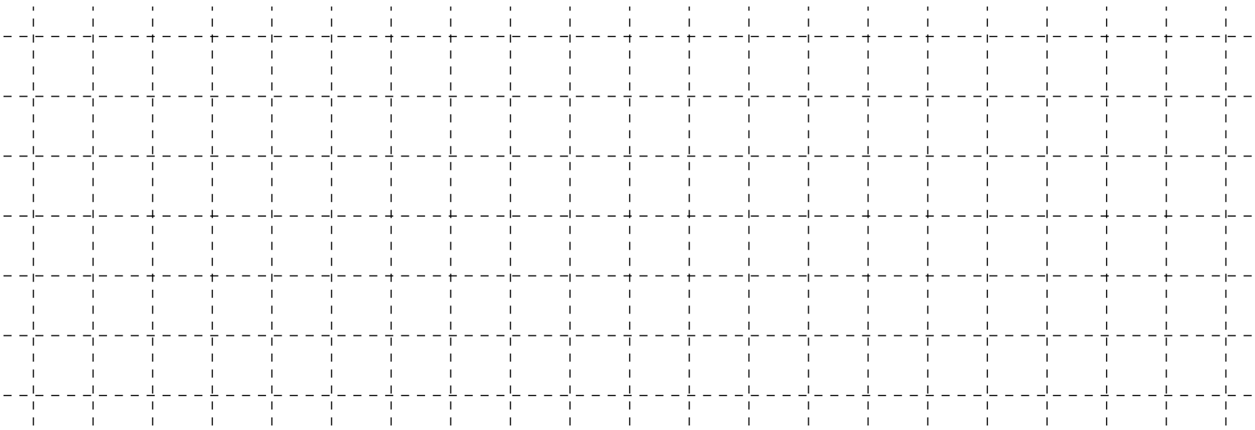
Answer

With 3-bit PCM, there are 8 code levels. With a sample rate of 10KHz, the sample interval is 0.1ms. Therefore assume the first sample is at 3.1ms. The sampled values in decimal and binary are:

7	5	2	2	6
111	101	010	010	110

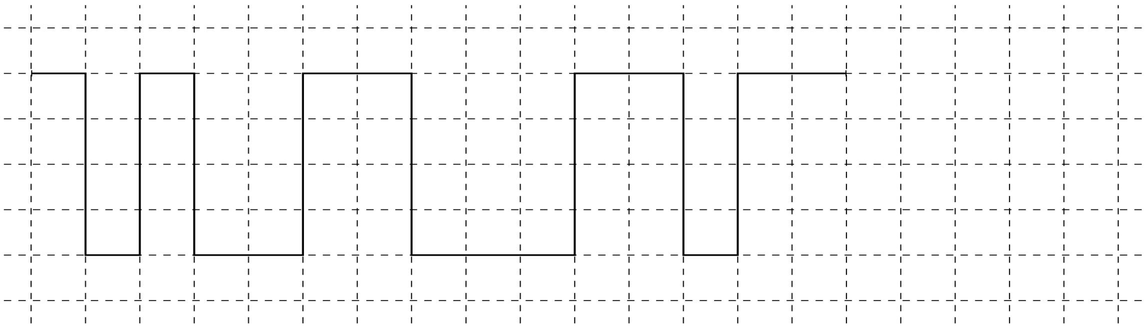
Hence the data to be transmitted is: 111101010010110.

b) Draw the transmitted digital signal. [3 marks]

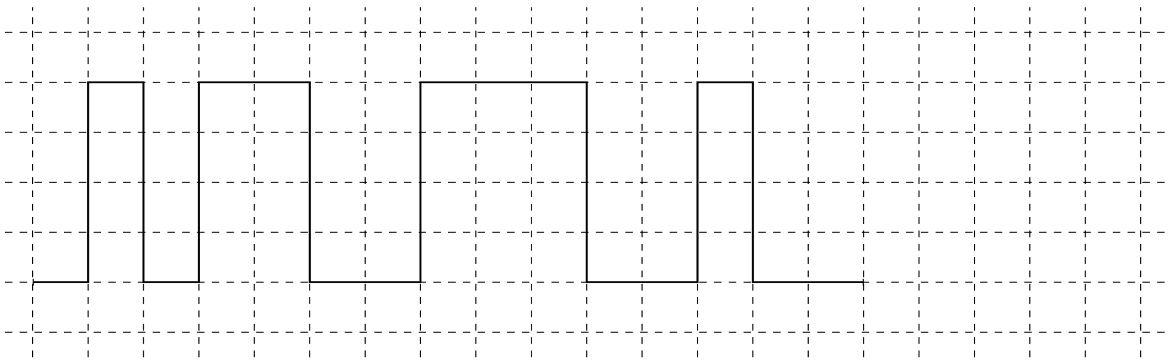


Answer

Assuming the first level is positive for bit 1, the digital signal is:



However, if you assume the first level was negative, the inverted signal would be obtained:



An alternative to PCM is Delta Modulation (DM). In DM, a “staircase” function is created based on the analog input data. When the analog input is sampled, if the analog input value is greater than the previous staircase value, then the staircase goes up one level; else, the staircase goes down one level. The digital output is derived directly from the staircase function: if the staircase level goes down, a bit 0 is output; if the staircase level goes up, a bit 1 is output. The step size of the staircase is called delta, δ. The figure below gives an example of Delta Modulation. Assume that the first staircase level is the level below the sampled analog input at time 3.1ms, and produces a bit 0 as output.

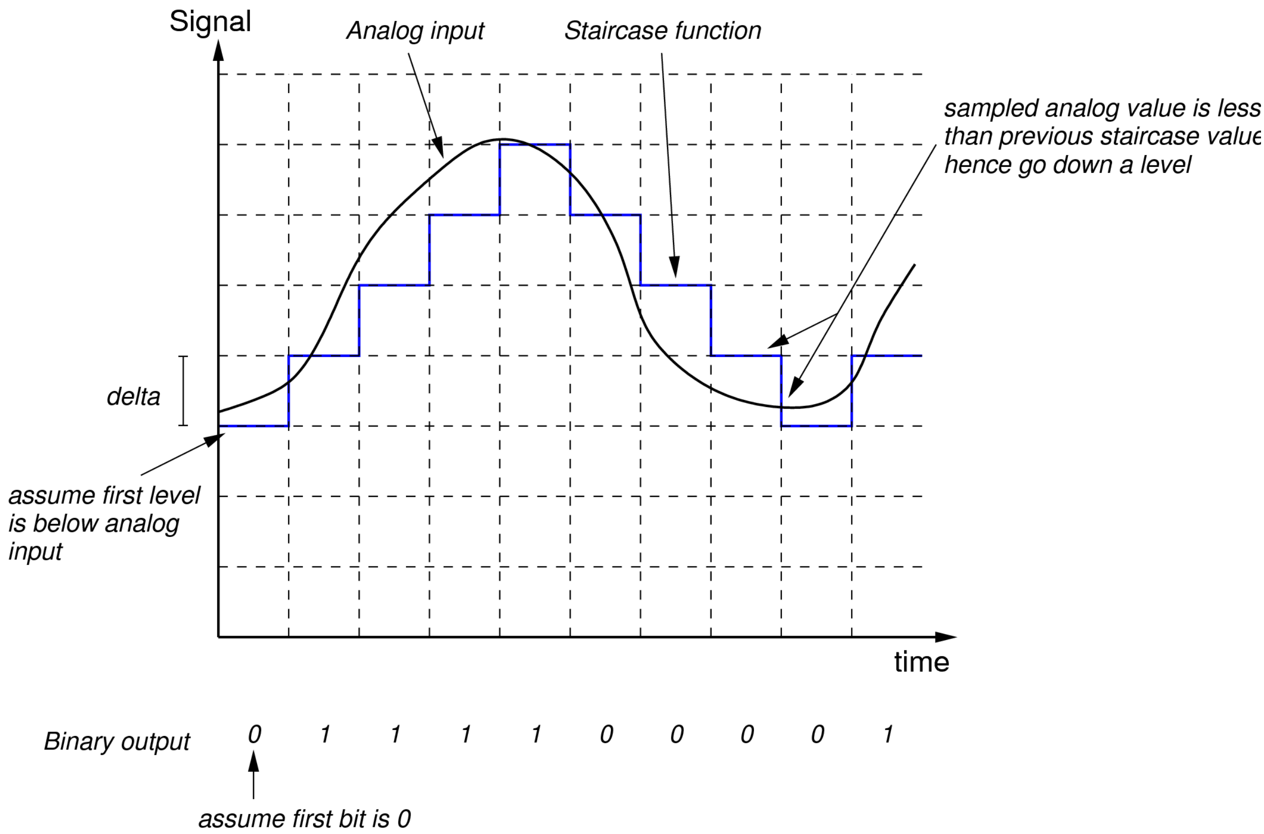
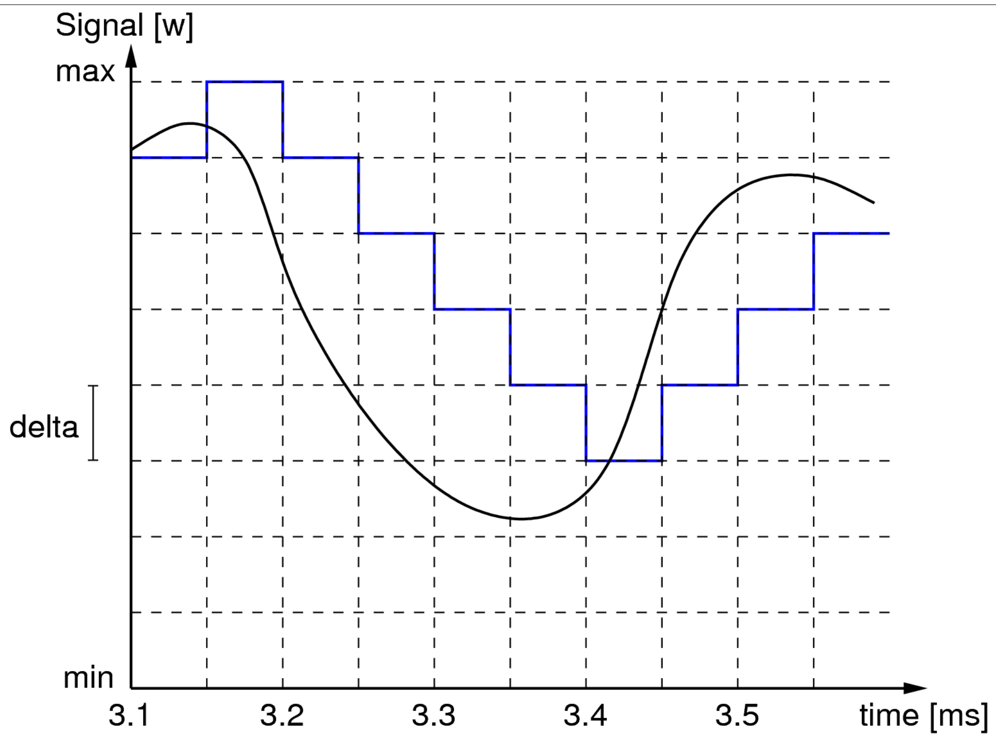


Figure 2

c) For the analog input data in Figure 1, what is the digital data to be transmitted if 20KHz DM is used with delta as shown on the figure? [3 marks]

Answer

Using DM, the staircase is shown below:



The first bit is assumed 0. Therefore the digital data is:

0 100000111

d) Explain an advantage of using DM (compared to PCM). [2 marks]

Answer

Fewer bits need to be transmitted. In this example, to send 0.5ms of data, with PCM 15 bits are sent, but with DM only 10 bits are sent. Therefore DM uses the link more efficiently than PCM.

Question 5 [8 marks]

Consider the network in Figure 3 where computer A is to send a single 1MB message to computer B.

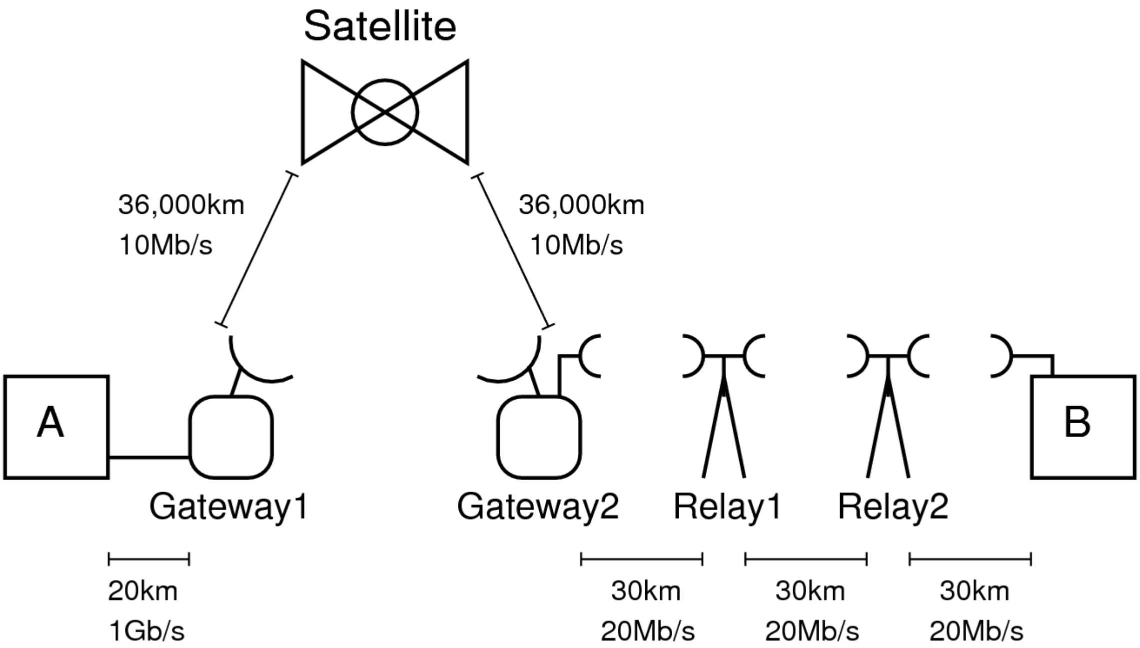


Figure 3

Assume the following:

- The geostationary satellite orbits the Earth at an altitude of 36,000km
- The transmission speed from Earth to satellite is 3×10^8m/s
- The transmission speed over the wireless links (between Gateway2, relays and B) is 3×10^8m/s
- The transmission speed over optical fibre (between A and Gateway1) is 2×10^8m/s
- There is a processing delay of 3ms at each gateway, 0.8ms at each wireless relay, as well as a processing delay of 4ms at the satellite. There is no processing delay in the computers.
- There is a queuing delay of 20ms at each gateway. There is no queuing delay at the satellite, wireless relays or in the computers.
- Segmentation is not used.

a) What is the propagation delay from computer A to the first gateway? [1 mark]

Answer

Distance of 20km, speed of 2×10^8m/s, gives a propagation delay of $(2 \times 10^4 / 2 \times 10^8) = 1 \times 10^{-4}$ or 0.1ms

b) What is the transmission delay from gateway to satellite? [1 mark]

Answer

Message size of 1MB, data rate of 10Mb/s, gives transmission delay of ($8x10^6/10x10^6$) = 0.8 or 800ms.

c) What is the total delay for the message from computer A to computer B? [6 marks]

Answer

Propagation delay

A to gateway 1: 0.1ms

Satellite link: $36x10^6$ / $3x10^8$ = $12x10^{-2}$ = 120ms

Wireless link: $30x10^3$ / $3x10^8$ = $10x10^{-5}$ = 0.1ms

Total propagation = 0.1 + 120 + 120 + 0.1 + 0.1 + 0.1 = 240.4ms

Transmission delay

A to gateway 1: $8x10^6$ / $1x10^9$ = $8x10^{-3}$ = 8ms

Satellite link: $8x10^6$ / $10x10^6$ = 0.8 = 800ms

Wireless link: $8x10^6$ / $20x10^6$ = 400ms

Total transmission = 8 + 800 + 800 + 400 + 400 + 400 = 2808ms

Processing delay = 0 + 3 + 4 + 3 + 0.8 + 0.8 + 0 = 11.6ms

Queuing delay = 20 + 20 = 40ms

Total delay = 240.4 + 2808 + 11.6 + 40 = 3100ms = 3.1sec

Question 6 [7 marks]

HDMI is a standard interface for sending uncompressed video from a video player or computer to a screen or monitor. The capacity of HDMIv1.3 is 10.2Gb/s.

A common HDTV format is a 1920x1080 pixel frame with 24-bit colour and 25Hz frame rate. A higher quality format used in cinemas is called "4K", with the same colour depth, but 4096x2304 pixels with 50Hz frame rate.

a) Can a HDMIv1.3 connection support uncompressed 4K video? Show your calculations. [3 marks]

Answer

With 4K each frame has 4096x2304 pixels, each pixel is 24 bits and a frame is generated 50 times per second, therefore the necessary data rate is 11,324,620,800 bits per second (approx. 11.3Gb/s). This is greater than the capacity of HDMIv1.3, so no, 4K is not supported by HDMIv1.3.

To transfer video over a network, compression is usually applied. Assume video (in either format) can be compressed to 1% of its original size.

b) How long would it take to download a 2 hour movie in 4K compressed video if the data rate from the server was 100Mb/s? (Ignore any overheads) [4 marks]

Answer

1% of the original size brings 4K down to 113,246,208 bits per second (approx. 113Mb/s). 2 hours of video at this rate is approx. 815Mb. Sent at a rate of 100Mb/s this would take 8,154 seconds or 2 hours 15 minutes.

Question 7 [7 marks]

An encoding scheme maps 8 bits of digital data into 1 signal element.

a) In a noise-free environment with a bandwidth of 10MHz, what is the maximum theoretical data rate possible? [3 marks]

Answer

With 8-bits to 1 signal element, 256 different levels (signal elements) are needed to represent any sequence of bits. Therefore with Nyquist capacity:

$$C = 2B\log_2(M) = 2 \times 10 \times 10^6 \times \log_2(256) = 160\text{Mb}/s$$

b) If the level of noise was measured to be -27dBm and the received signal strength of 2.041mw for a communications channel with bandwidth of 10MHz, what is the maximum theoretical data rate possible? [4 marks]

Answer

A noise level of -27dBm is equivalent to $10^{-2.7}$ mW. Therefore using Shannon capacity:

$$C = Blog_2(1+SNR) = 10 \times 10^6 \times \log_2(1 + \frac{2.041}{10^{-2.7}}) = 100\text{Mb}/s$$

Question 8 [16 marks]

In this question you need to complete the sentence using only one of the following:

Amplitude Shift Keying	Bandwidth	Baud rate
Coaxial cable	Cyclic Redundancy Check	Delay
Errors	Flow control	Forward Error Correction
Frequency Modulation	Frequency Shift Keying	Full-duplex
Half-duplex	Hamming distance	IEEE
Jitter	Manchester encoding	Optical fibre
Parity check	Pulse Code Modulation	Signal rate
Simplex	Standard	TCP/IP
Throughput	Twisted pair	

Although there may be more then one correct answer, you must only give one answer (giving two or more will result in 0 marks). Each correct answer is worth 2 marks. You may use the above words/phrases more than once.

a) The **Hamming distance** between 0101001 and 1101010 is 3.

b) **Frequency Modulation** involves varying the frequency of the output signal as the amplitude of the input analog data changes.

c) With a **half-duplex** link, data can be sent in both directions, but not at the same time.

d) **Flow control** is used to ensure the buffer at the receiver does not overflow.

e) **Amplitude/Frequency Shift Keying** is used to transmit digital data as an analog signal.

f) **Forward Error Correction** provides mechanisms for both detecting and correcting errors.

g) **Twisted Pair** is the most common wired technology for LANs and in-building communications.

h) File transfer applications cannot tolerate any **errors**.

Question 9 [13 marks]

Consider the sliding window flow control protocol being used over a single link from A to B. DATA frames carrying 900 Bytes of data (plus 100 Bytes of header) have a transmission delay of 10ms. ACK frames (100 Bytes of header) have a transmission delay of 1ms. The link propagation delay is 50ms. Assume the source A always has data ready to send, and B immediately sends an ACK frame after receiving a DATA frame (there is no processing delay and no errors).

First, consider a 3-bit sequence number is used. Assume A sends its 1st DATA frame at time 0s.

a) What is the maximum number of bytes of original data that A can send without having received an ACK frame? [2 marks]

Answer

With a 3-bit sequence number the maximum window size is 2^3-1. Therefore 7 frames may be sent before having to wait for an ACK. Each frame contains 900 Bytes of data, therefore 6300 Bytes.

b) At what time is the ACK of the 1st DATA frame received by A? [2 marks]

Answer

The DATA frame has a transmission delay of 10ms, and then takes 50ms to propagate to B. B transmits the ACK which has a delay of 1ms, and takes another 50ms to propagate to A. Therefore the ACK is received at time 111ms.

c) Does A spend any time at which it is not transmitting DATA frames? If yes, then how much time? If no, then explain why not. [2 marks]

Answer

Yes. It takes 70ms to transmit the allowed 7 DATA Frames. A must wait another 41ms before it receives the first ACK.

d) What is the maximum throughput that can be achieved across the link from A to B? [2 marks]

Answer

6300 Bytes are delivered every 111ms, therefore the throughput is 56756 B/s or 454,054 b/s.

Now consider the same scenario as above, but a 4-bit sequence number is used instead.

e) Does A spend any time at which it is not transmitting DATA frames? If yes, then how much time? If no, then explain why not. [3 marks]

Answer

No. With a 4-bit sequence number, A is allowed to transmit 15 frames before waiting for an ACK. This will take 150ms. But the first ACK is received after only 111ms. Therefore once A has transmitted the 15 frames, it can immediately start transmitting subsequent frames.

f) What is the maximum throughput that can be achieved across the link from A to B? [2 marks]

Answer

As there is no time spent waiting (i.e. DATA frames are always being transmitted, and also arriving at B), every 10ms 900 Bytes are received, giving a throughput of 90KB/s or 720Kb/s.

Question 10 [9 marks]

Table 1 shows a set of frames received by the Data Link layer of a computer (including the time when it is received). Each frame contains a header plus data. The amount of data in each frame is shown in the Data column. The Data Link layer header contains five fields:

1. A 16-bit timestamp, which indicates the time when the frame was sent
2. Address of the source, in the format of a 48-bit IEEE address
3. Address of the destination, in the format of a 48-bit IEEE address
4. A 32-bit sequence number
5. A 2 byte field to indicate the type of protocol used.

Time received [ms]	*Sequence number*	*Timestamp [ms]*	*Data [Bytes]*
7	0	0	100
11	1	3	120
14	2	6	150
16	3	9	125
22	4	12	100
23	5	15	125

Table 1: Frames Received

Answer the following questions considering only the frames in the table.

a) What is the average delay from source to destination? [2 marks]

Answer

Delay of packets are: 7, 8, 8, 7, 10, 8. Average delay is 48/6 = 8ms

b) What is the jitter between source and destination? [2 marks]

Answer

The difference between delays is: 1, 0, 1, 3, 2. Jitter is 7/5 = 1.4ms

c) What is the throughput for the received data? [2 marks]

Answer

There is 720 Bytes of data received over a period of 16ms. Throughput is 45000 Bytes/second or 360kb/s.

d) Consider the source sending the frames. Assume the Physical layer at the source adds an additional 80 bits to each frame. What is the average rate at which bits are sent by the source Physical layer? [3 marks]

Answer

Each frame contains data plus 20 byte Data Link layer header plus 10 byte Physical layer header. A total of 720 + 6x30 = 900 Bytes are sent over a period of 15ms, giving a sent rate of 60KB/s. Alternatively, we could say the frames are sent every 3ms. The average data sent per frame is 900/6 = 150B, therefore sent rate of 50KB/sec.