PC Metrics - Solutions

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1. The size of a windows batch file is 100 bytes. What is the file size in bits?

   File size = 100 x 8 = 800 bits = 800 b

2. The size of a windows system file is 7200 bits. What is the file size in bytes?

   File size = 7200 / 8 = 900 bytes = 900 B

3. What is the file size - in bytes - of an image which is 1250 pixels by 1000 pixels, with the colour information encoded as 16 bits per pixel?

   File size = (1250 x 1000 x 16) / 8 = 2,500,000 = 2.5 MB

4. What is the aspect ratio of a monitor capable of displaying an image of 2560 x 1440?

   The aspect ratio is the of number of horizontal pixels to number of vertical lines, reduced to their lowest terms; i.e. written as a fraction such that the numerator and denominator have no common factors - e.g. in this case both numbers can be divided by 160 reducing the fraction to 16:9

   $2560:1440 \equiv 16:9$

5. A monitor with an aspect ratio of 4:3 is capable of displaying 2048 pixels horizontally. How many lines does the monitor display?

   $$4 : 3 = 2048 : y$$

   $$\frac{4}{3} = \frac{2048}{y}$$

   $$y = \frac{2048 \times 3}{4}$$

   $$y = 1536$$

6. A 2 TB hard drive has 5 platters, what is the storage capacity of each platter?

   $$\text{Capacity} = \frac{2 \times 10^{12}}{5}$$

7. Capacity = 400×10^9
8. Capacity = 400 GB

9. For the following hard drives, what is the precise percentage of the cache to the disk capacity?
   i. 2 TB, 200 MB cache

$$\frac{200 \times 10^6}{2 \times 10^{12}} \times 100$$

   ii. = 0.01 %

   iii. 4 TB, 600 MB cache

$$\frac{600 \times 10^6}{4 \times 10^{12}} \times 100$$

   iv. = 0.015 %

   v. 8 TB, 1024 MB cache

$$\frac{1024 \times 10^6}{8 \times 10^{12}} \times 100$$

   vi. = 0.0128 %

10. Three hard drives spin at the following speeds. How long does it take for each of them to complete one revolution of their platters?
   i. 5400 RPM

   Revolutions per second = 5400 / 60 = 90

   T = 1/90 = 11.11 ms

   ii. 7200 RPM

   Revolutions per second = 7200 / 60 = 120

   T = 1/120 = 8.3 ms

   iii. 10,000 RPM

   Revolutions per second = 10,000 / 60 = 166.67

   T = 1/166.67 = 6 ms

11. A hard drive with a spin speed of 7200 RPM, commences spinning at time = 0, at time = 1.326 ms what is the angle that the disk has rotated by relative to it's start position?
   i. In degrees

   Revolutions per second = 7200 / 60 = 120

   T = 1 / 120 = 8.333 ms

$$\frac{\theta}{360} = \frac{1.326 \times 10^{-3}}{8.333 \times 10^{-3}}$$

$$\theta = 57.28^0$$

ii. In Radians

$$\theta / 2\pi = 57.28 / 360$$

$$\theta = 1 \text{ radian}$$

12. A computer's memory chip takes 166.6 ps to read/write data per cycle. What is the clock frequency of the memory?

$$f = 1 / 166.6 \times 10^{-12} = 6 \text{ GHz}$$

13. Three single core micro processors have the following clock speeds. For each of them, what is the duration of a one clock cycle?
    i. 1 MHz

$$T = 1 / 1 \times 10^{6} = 1 \ \mu s$$

    ii. 4 GHz

$$T = 1 / 4 \times 10^{9} = 250 \text{ ps}$$

    iii. 2 THz

$$T = 1 / 2 \times 10^{12} = 500 \text{ fs}$$

14. An optical storage disk can store 10 PB of data, the disk is 1 mm in thickness. For every moment since you have been born, a High Definition (HD) video (1,280×720 pixels with the colour information encoded as 24 bits per pixel and a frame rate of 24 fps) of your life has been recorded. How high is the stack of optical storage disks used to store the video of your life to date?

For a student who is exactly 20 years old, the age in seconds is 60 x 60 x 24 x 365.25 x 20 = 631152000 s

1 second of video data = 1280 x 720 x 24 x 24 = 530841600 b

20 years of data = (631152000 x 530841600) / 8 = 41.88 PB

Number of disks = 41.88 x 10^{15} / 10 x 10^{15} = 4.18 disks. Therefore 5 disks are required and the height of the disks = 5 mm

Communication Metrics - Solutions

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1. How long would it take an image which is 1024 pixels by 768 pixels with 16 bit colour encoding to transfer via:-
   i. GSM - 9.6 kbps

   File size = 1024 x 768 x 16 = 12582912 bits

   t = 12582912 / 9600 = 1310.72 s

   ii. UMTS - 2 Mbps

   File size = 1024 x 768 x 16 = 12582912 bits

   t = 12582912 / 2 x 10^6 = 6.29 s

   iii. 802.11g - 54 Mbps

   File size = 1024 x 768 x 16 = 12582912 bits

   t = 12582912 / 54 x 10^6 = 233.02 ms

2. How long would a 10 MB animation take to transfer via:-
   i. 56 kbps Modem

   t = (10x10^6 x 8) / 56 x 10^3 = 1428.57 s

   ii. 1 Gbps LAN

   t = (10x10^6 x 8) / 1 x 10^9 = 80 ms

3. A High Definition (1920×1080 resolution, 24 bit colour encoding per pixel, 24 frames per second) film of 1 hour and 45 minutes duration, is to be transmitted over a communication channel in under 12 s. What is the minimum transmission speed of the system?

   File size = 1920 x 1080 x 24 x 24 x (60 + 45) x 60 = 7.525 Tb

   Minimum data rate = 7.525 x 10^{12} / 12 = 627.08 Gbps

4. A floppy disk stores 1.4 MB of data and weighs 30g. If an airliner carries 30,000 kg of these floppies at a speed of 1000 km/hr over a distance of 5000 km, what is the data rate achieved?

   Number of disks = 30,000 x 10^3 / 30 = 1 x 10^6

   Size of data = 1.4 x 10^6 x 1 x 10^6 = 1.4 TB

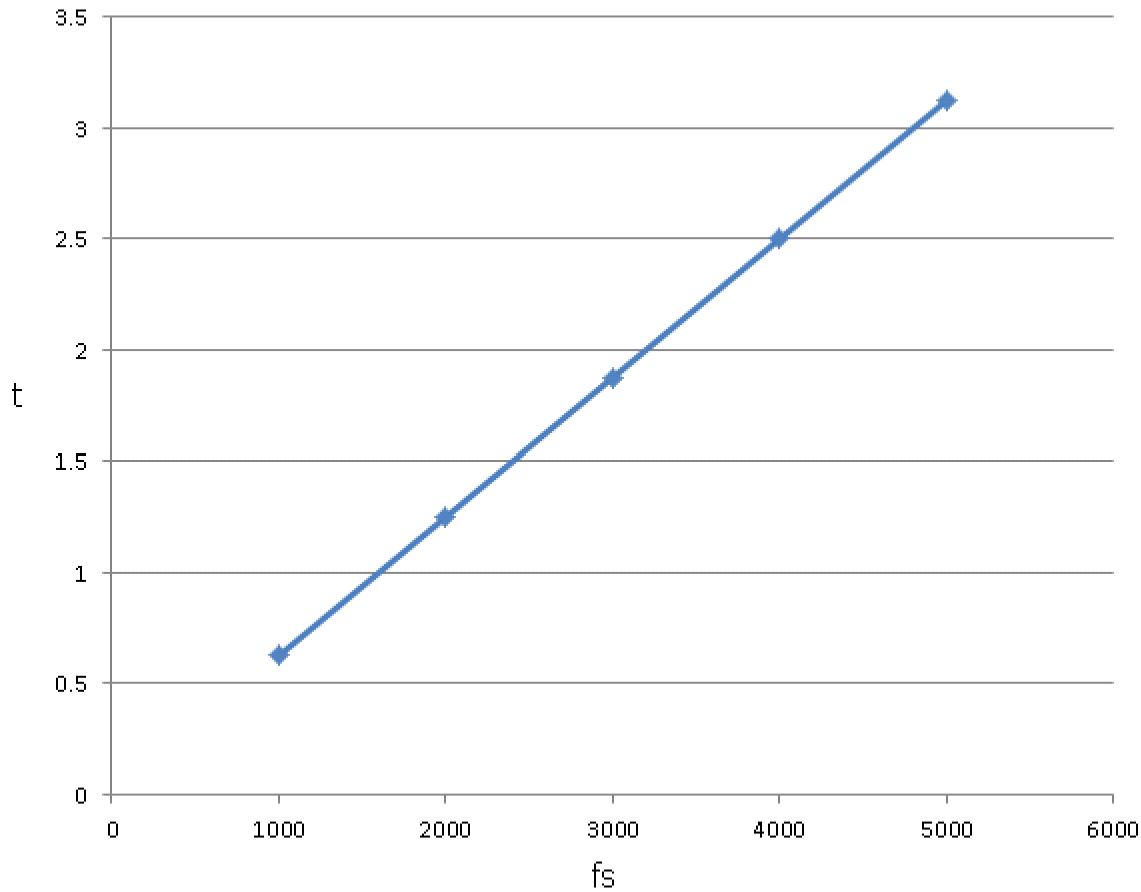
Journey time = 5000 / 1000 = 5 hours = 5 x 60 x 60 = 18000 s

Data rate = $(1.4 \times 10^{12} \times 8) / 18000 = 622.22$ Mbps

5. The following files were sent over a communication link and their transmission time recorded.

	File α	File β	File γ	File δ	File ε
File Size	125 B	250 B	375 B	500 B	625 B
Transmission Time	0.625 s	1.250 s	1.875 s	2.500 s	3.125 s

6. Plot the data on a graph. Transmission Time on the y axis and file size in bits on the x axis)



7.

i. Using the graph, determine how long it will take to transfer a file of 300 B

300 B = 300 x 8 = 2400 b, from the graph transmission time = 1.5 s

ii. What is the gradient?

$$m = \Delta y / \Delta x$$

$$m = (3.125 - 0.625) / (5000 - 1000) = 2.5 / 4000 = 625 \times 10^{-6}$$

iii. What is the equation of the line?

$$t = m.fs$$

$$t = 625 \times 10^{-6} fs$$

iv. What is the reciprocal of the gradient?

$$1 / 625 \times 10^{-6} = 1600$$

v. What is the transmission speed of the system?

1600 bps

Communication Fundamentals - Solutions

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1. What is the IPv4 dotted decimal address 192.168.0.1 in binary?

   11000 000 . 1010 1000 . 0000 0000 . 0000 0001

2. Calculate how many IP address can be formed with the 32 bits of IPv4

   $$2^{32} = 4294967296$$

3. Calculate how many IP address can be formed with the 128 bits of IPv6

   $$2^{128} = 340.3 \times 10^{36}$$

   $$= 340282366920938000000000000000000000000$$

4. The island of Lilliput has a very small population, and has decided that a 10 bit IP address scheme will be sufficient to accommodate the requirements of the population. How many 10 bit IP address can be formed?

   $$2^{10} = 1024$$

5. Convert the following dotted decimal IPv4 address to binary. By examining the binary patterns, distinguish which is Class A, Class B and Class C.

   i. 10.8.78.40

   0000 1010 . 0000 1000 . 01001110 . 0010 1000 Class A

   ii. 190.20.8.60

   1011 1110 . 0001 0100 . 00001000 . 0011 1100 Class B

   iii. 200.12.5.6

1100 1000 . 0000 1100 . 0000 0101 . 0000 0110 Class C

6. What is the IPv6 Hexadecimal address 2001:0DB8:85A3:0000:0000:8A2E:0370:7334 in binary?

0010 0000 0000 0001 : 0000 1101 1011 1000 : 1000 0101 1010 0011 : 0000 0000 0000 0000 : 0000 0000 0000 0000 : 1000 1010 0010 1110 : 0000 0011 0111 0000 : 0111 0011 0011 0100

Introduction to signals

1. The frequency of a periodic signal is 20 MHz, state it's period.

$T = 1/f = 1 / 20 \times 10^6 = 50$ ns

2. A signal has a period T of 0.033 µs, state it's frequency.

$f = 1/T = 1/ 0.033 \times 10^{-6} = 30.3$ MHz

3. Calculate the period of the UK's 50 Hz mains electricity supply.

$T = 1 / f = 1 /50 = 20$ ms

4. Calculate the frequency of the rotation of the Earth.

$$f = 1 / T = 1 / (24 \times 60 \times 60) = 11.57\ \mu Hz$$

5. Calculate the frequency of the orbit of the Earth around the Sun

$$f = 1 / T = 1 / (365.25 * 24 \times 60 \times 60) = 31.69\ nHz$$

6. Calculate the angular velocity ω for the following format of vinyl records
   i. 78's

$$\text{Revolutions per second} = 78 / 60 = 1.3$$

$$\omega = 2.\pi.\ f = 2 * \pi * 1.3 = 8.168\ rad/s$$

   ii. 45's

$$\text{Revolutions per second} = 45 / 60 = 0.75$$

$$\omega = 2.\pi.\ f = 2 * \pi * 0.75 = 4.712\ rad/s$$

   iii. LP's

$$\text{Revolutions per second} = 33\tfrac{1}{3} / 60 = 0.5555$$

$$\omega = 2.\pi.\ f = 2 * \pi * 0.555 = 3.49\ rad/s$$

7. What is the instantaneous amplitude of a sinusoidal signal with period T = 5 ns and peak amplitude of 1.141 V at t = 26.8 ns.

$$f = 1 / T = 1 / 5 \times 10^{-9} = 200\ MHz$$

$$V(t) = A\ .\sin(2.\pi.f.t)$$

$$V(t) = 1.141 \sin(2 \times \pi \times 200 \times 10^{6} \times 26.8 \times 10^{-9})$$

$$V(t) = 1.141 \sin(33.678)$$

$$V(t) = 1.141 \times 0.77$$

$$V(t) = 0.8785\ V$$

8. Calculate for a sinusoidal signal with an angular velocity of 314.1593 radians/s and a peak voltage of 340 V
   - The instantaneous amplitude at t = 15 ms

$$V(t) = A.\sin(\omega.t)$$

$$V(t) = 340 \sin(314.1593 \times 15 \times 10^{-3})$$

$$V(t) = 340 \sin (4.71)$$

$$V(t) = 340 * -1 = -340 \text{ V}$$

- The amplitude at an angular rotation of 7.0669 radians.

$$V(t) = 340 \sin (7.0669)$$

$$V(t) = 340 * 0.7059$$

$$V(t) = 240 \text{ V}$$

- The period of the signal.

$$T = 2.\pi / \omega$$

$$T = (2 * \pi) / 314.1593 = 20 \text{ ms}$$

- The frequency of the signal.

$$f = 1 / T$$

$$f = 1 / 20 \times 10^{-3} = 50 \text{ Hz}$$

9. BBC Radio 4 transmits on 93.5 MHz FM and 198 kHz LW. Calculate the wavelengths at which the signals are broadcast
   - 93.5 MHz

$$\lambda = c / f$$

$$\lambda = 299792458 / 93.5 \times 10^{6}$$

$$\lambda = 3.206 \text{ m}$$

   - 198 kHz

$$\lambda = c / f$$

$$\lambda = 299792458 / 198 \times 10^{3}$$

$$\lambda = 1514 \text{ m}$$

10. The BBC world service transmits in the short wave radio spectrum to Western Europe at wavelength 31.8589 m. Calculate the frequency the signal is transmitted at.

$$f = c / \lambda$$

$$f = 299792458 / 31.8589$$

$$f = 9.41 \text{ MHz}$$

11. Calculate the period T for a signal in the ultra violet with a wavelength of 450 nm

$$f = c / \lambda$$

$$f = 299792458 / 450 \times 10^{-9}$$

$$f = 666.2 \text{ THz}$$

$$T = 1 / f$$

$$T = 1 / 666.2 * 10^{12}$$

$$T = 1.5 \text{ fs}$$

12. What bandwidth would be required to transmit the following signal V(t)?

$$V(t) = \cos(2.\pi.f.t) - \cos(6.\pi.f.t) + \cos(10.\pi.f.t)$$

$$V(t) = \cos(2.\pi.f.t) - \cos(2.\pi.3.f.t) + \cos(2.\pi.5.f.t)$$

Therefore Bandwidth = 5f - f = 4.f Hz

If the available transmission bandwidth were to be decreased by 30%, what would happen to the signal

Modulation and Coding - Solutions

---

1. A co-axial cable has a bandwidth of 1000 MHz. The cable is to be used in a Frequency Division Multiplexing system to carry simultaneous music channels. The base bandwidth for the music has been restricted to 15 kHz. How many music channels can the cable support?

Number of channels = 1000×10^6 / 15×10^3 = 66666

2. A fibre optic cable can carry 450 independent channels, each using a different wavelength of light - Wavelength Division Multiplexing (WDM). Each channel can support 200 Gbps. A single telephone connection requires 64 kbps. How many simultaneous telephone connections can the cable carry?

   Number of telephone channels = $(450 \times 200 \times 10^9) / 64 \times 10^3$ = 1406250000

3. A radio station transmitting on 12095 kHz using Full AM, has it's base bandwidth restricted to 7 kHz.
   i. What is the transmission bandwidth?

      Full AM has two sidebands, therefore transmission bandwidth = 2 x 7 kHz = 14 kHz

   ii. What is the lowest radio frequency transmitted?

      $12095 \times 10^3 - 7 \times 10^3$ = 12.088 MHz

   iii. What is the highest radio frequency transmitted?

      $12095 \times 10^3 + 7 \times 10^3$ = 12.102 MHz

4. A file of 10,000 characters is to be sent over a 2,400 bps transmission line. Calculate the percentage overhead and the time taken to send the file over the line using asynchronous transmission with 8 bit ASCII coding, 1 start bit, 1.5 stop bits and 1 parity bit.

   Percentage overhead = ((1 + 1.5 + 1) / (8 + 1 + 1.5 + 1)) * 100

   = (3.5 / 11.5) * 100

   = 30.43%

   Number of bits = 11.5 x 10,000 = 115000 b

   Transmission time = 115000 / 2400 = 47.917 s

5. The Baud rate of a communication channel with 8 signalling states is 120 Bd. What is the bit rate?

   8 signalling states can encode 3 bits per state ($2^3 = 8$)

   Therefore bit rate = 120 x 3 = 360 bps

6. A communication channel has a capacity of 2400 Bd. The throughput of the system is required to be 12000 bps. How many signalling states are required?

   Bits per Baud = 12000 / 2400 = 5

Quantization and Noise - Solutions

---

1. The bandwidth of a music system has been measured and found to be 20 kHz. What is the Nyquist frequency?

$$N_f = 2 \text{ x } 20 \text{ x } 10^3 = 40 \text{ kHz}$$

2. What is the data rate of a sampled analogue signal which has a bandwidth of 50 kHz and uses 8 bit quantization?

$$\text{Data rate} = 2.n.f_{max}$$

$$\text{Data rate} = 2 \text{ x } 8 \text{ x } 50 \text{ x } 10^3 = 800 \text{ kbps}$$

3. An analogue signal has a 15 kHz bandwidth, and is quantized into 32 levels. What is the data rate of the system?

$$\text{Number of bits} = 5 \text{ as } 2^5 = 32$$

$$\text{Data rate} = 2.n.f_{max}$$

$$\text{Data rate} = 2 \text{ x } 5 \text{ x } 15 \text{ x } 10^3 = 150 \text{ kbps}$$

4. What is the bandwidth of the analogue signal that has been sampled quantized into 65,536 levels and has a data rate of 100 kbps

$$\text{Number of bits} = 16 \text{ as } 2^{16} = 65536$$

$$f_{max} = \text{Data rate} / (2.\ n)$$

$$f_{max} = 100 \text{ x } 10^3 / (2 \text{ x } 16) = 3.125 \text{ kHz}$$

5. A sharp spike of energy of 0.01 s duration appears in a line transmitting digital data with the rate of 2400 bps. How many ASCII characters could be affected?

$$\text{Duration of 1 bit} = 1 / 2400 = 416.67\ \mu\text{s}$$

$$\text{No of bit affected} = 0.01 / 416.67 \text{ x } 10^{-6} = 24$$

Assuming 8 bit ASCII, 3 characters will be affected

6. A telephone line has an input power of 120 mW and an output power of 45 mW. What is the loss of the line in dB?

$$\text{Loss} = 10 \text{ x } \log_{10}(45 \text{ x } 10^{-3} / 120 \text{ x} 10^{-3})$$

$$\text{Loss} = 10 \text{ x } \log_{10}(0.375)$$

$$Loss = -4.26\ dB$$

7. Calculate the maximum capacity C, in bps for a transmission channel with a bandwidth of 10 kHz and a signal to noise ratio of 1000

$$C = B \log_2(1 + S/N)$$

$$C = 10 \times 10^3 \times \log_2(1 + 1000)$$

$$C = 10 \times 10^3 \times (\log_{10}(1001) / \log_{10}(2))$$

$$C = 10 \times 10^3 \times (3.000434 / 0.30103)$$

$$C = 99.67\ kbps$$

8. Calculate the maximum capacity C, in bps for a transmission channel with a bandwidth of 500 Hz and a signal to noise ratio of 10 dB

$$N\ dB = 10\log_{10} (P_o/P_i)$$

$$10 = 10 \times \log_{10}(S/N)$$

$$1 = \log_{10}(S/N)$$

$$10^1 = S/N$$

$$S/N = 10$$

$$C = B \log_2(1 + S/N)$$

$$C = 500 \times \log_2(1 + 10)$$

$$C = 500 \times (\log_{10}(11) / \log_{10}(2))$$

$$C = 500 \times (1.041393 / 0.30103)$$

$$C = 1.73\ kbps$$

9. Data is to be transmitted over a LAN at 100 Mbps. Measurements on the system show that the S/N ratio is 90 dB. Calculate the Bandwidth required to transmit the data at the required rate.

$$N\ dB = 10\log_{10} (P_o/P_i)$$

$$90 = 10 \times \log_{10} (S/N)$$

$$9 = \log_{10} (S/N)$$

$$S/N = 10^9$$

$$C = B \log_2(1 + S/N)$$

$$100 \times 10^6 = B \times \log_2(1 + S/N)$$

$$100 \times 10^6 = B \times \log_2(1 + 10^9)$$

$$100 \times 10^6 = B \times (\log_{10}(1 + 10^9) / \log_{10}(2))$$

$$100 \times 10^6 = B \times (9 / 0.30103)$$

$$B = 3.34 \text{ MHz}$$

Error Detection and Control

10. The maximum through put on a digital radio channel of 5 kHz bandwidth is found to be 7 kbps. Calculate the signal to noise ratio in dB.

$$C = B \log_2(1 + S/N)$$

$$7 \times 10^3 = 5 \times 10^3 \times \log_2(1 + S/N)$$

$$1.4 = \log_2(1 + S/N)$$

$$S/N + 1 = 2^{1.4}$$

$$SN = 1.639$$

$$N = 10 \times \log10(1.639)$$

1. Take the second letter of your first name and convert it to 7-bit ACSII binary code. What bit do you need to add to have even parity?

It depends on the name of the student and whether he/she chooses to use the lowercase or uppercase character.
If the character has odd number of 1s, the bit to add is 1. Otherwise 0. For example, if the name is G**e**orge, the character e is 1100101 and the bit to add is 0.

2. Take the first two letters of your country of birth and the first two letters of your first name and convert them in ASCII binary. You should now have a sequence of 28 bits. What bits do you need to add and where for LRC with odd parity

Again the same, but this time we are seeking odd parity across all rows and columns.

Example: If the country of birth is **Ch**ina and the name is **Ri**hanna,

C 1000011-**0**
h 1101000-**0**
R 1010010-**0**
i 1101111-**1**
1101001-1

Note that the parity bit in the last row is determined by the row, not the column.

Final answer: 1000011-**0**-1101000-**0**-1010010-**0**-1101111-**1**-**1101001**-**1**

We need to add the bits marked in bold.

3. In a stop-and-wait error control system, Station A sends packet 0, it arrives without error, and an ACK is returned, but the ACK is lost. What happens next?

Station A will keep waiting. In practice, after a timeout delay, station A will retransmit packet 0.

4. What is the hamming distance between 1000110 and 0011110?

They differ by three bits. So, **3**.

5. i) What is the hamming distance of the following code:

A	010010
B	110100
C	011001
D	101010
E	111111
F	000000
G	010101

ii) For the code above, is it possible for an error control system to detect and correct two errors?

i) The minimum difference is 2. So, the hamming distance of the code is **2**.

ii) **No.** With hamming distance of two, one can detect up to one error and correct none.

Lans Networks

1. How many frames per second can
i) half-duplex traditional gigabit Ethernet handle? (frames can be between 64 and 1,518 bytes)
ii) half-duplex frame bursting gigabit Ethernet handle? (frames can be between 512 and 8,192 bytes)
iii) full-duplex gigabit Ethernet handle? (frames tend to be about 9,000 bytes)

i) Between 10^9 / (64 * 8) = **1,953,125** and 10^9 / (1,518 * 8) = **82,345** frames per second

ii) Between **244,140** and **15,258** frames per second

iii) Around **13,888** frames per second

IP routing

1. i) What class is the IP address 168.59.107.145?
ii) What is the default subnet mask for this class?

i) class B
ii) 255.255.0.0

2. Taking into account only the structure of the IPv4 packet header:
i) What is the maximum permittable size (in bits) for an IPv4 packet?
ii) How many IPv4 addresses can exist?

i) The total length field is 16 bits. So, the largest possible number in that field is 1111111111111111 (= 2^16 – 1) = 65,535, which means that a packet can't be larger than 65,535 bytes = 524,280 bits
ii) 2 ^ 32 = 4,294,967,296 addresses

3. Suppose that a router uses the following routing table:

SubnetNumber	SubNetMask	NextHop
128.96.39.0	255.255.255.128	Interface 0
128.96.39.128	255.255.255.128	Interface 1
128.96.40.0	255.255.255.128	Interface 2
192.4.153.0	255.255.255.192	Interface 3
default	-	Interface 4

Which interface will the router use for the next hop for each of the following destination addresses:
i) 128.96.39.10
ii) 128.96.40.12
iii) 128.96.39.151
iv) 192.4.153.17
v) 192.4.153.90
Tip: Apply each subnet mask (logical AND of the binary addresses) and if the corresponding subnet number matches the SubnetNumber column, then use the entry in Next-Hop.

i) Interface 0

ii) Interface 2

iii) Interface 1

iv) Interface 3

v) Interface 4

4. How many subnets and hosts per subnet can you get from the network 174.20.0.0 / 255.255.240.0?

174.20.0.0 is class B. So, the defaults subnet mask would be 255.255.0.0.

However, we are using 255.255.**240**.0 instead:

11111111.11111111.**1111**0000.0000

So, we stole four bits from the host part to use for our subnets (the bold 1s) and left only 12 bits for the hosts in each subnet (the 0s).

2^4 – 2 = 14 subnets

2^12 – 2 = 4,094 hosts per subnet

2. Suppose that a 10-Mbps wireless station is transmitting 50-byte frames one immediately after the other.

i) How many frames is it transmitting per second?

ii) If the probability of a frame being damaged (having at least one wrong bit) is 0.004, approximately how many frames will be damaged in one hour?

i) 10,000,000 / (50 * 8) = **25,000** frames per second

ii) 25,000 * 3600 * 0.004 = **3,600,000** frames

WAN

1. Draw a network with 7 nodes (A, B, C, D, E, F, G) and the following duplex links: AB, AF, AE, BC, CF, CD, CG, DF, DG, EF, EG, FG
i) How many more links would you need to have a fully-connected mesh?
ii) If there is a network hop limit of 2, using flooding, will all nodes receive a copy of a packet sent from B?

i) For fully connected mesh we need 7 * (7-1) / 2 = 21 links, which is 9 more than the 12 that we have.
ii) All nodes will receive it, because all nodes can be reached from B in two hops.

2. Draw a network with four nodes (A, B, C and D) and five duplex links, each with the following weights (costs):

AB	2
BC	1
CD	5
AC	5

BD	7

Find the least-cost path from A to D using Dijkstra's algorithm. Show all steps you took in detail.

Iteration	Permanent nodes up to now	B's Distance from A L(B)	Path	C's Distance from A L(C)	Path	D's Distance from A L(D)	Path
1	{A}	2	A,B	5	A, C	∞	-
2	{A, B}	2	A, B	3	A, B, C	9	A, B, D
3	{A, B, C}	2	A, B	3	A, B, C	8	A, B, C, D

In detail:

All distances are set to ∞.

I start from A and update the distances of the direct neighbours. For B, it is L(B)=2 and for C, it is L(C)=5. The nearest to A is B. So, I label it as permanent and continue from B.

I look at B and update the distances of the direct neighbours of B from A through B. For C, it is L(C)=3. For D, it is L(D) = 9. The nearest non-permanent node to A is C. So, I label it permanent and continue from C.

I look at C and update the distances of the direct neighbour s of C from A through C. For D, it is L(D)=8. It is the last one, so I label it as permanent.

The answer is 8 and the path is A, B, C, D.

3. In 2-3 sentences, describe a case where circuit-switching is better than packet-switching.

A circuit-switched network can guarantee a certain amount of end-to-end bandwidth for the duration of a call. Most packet-switched networks today (including the Internet) cannot make any end-to-end guarantees for bandwidth.

A circuit-switched network is also better when an application involves long sessions with steady bandwidth requirements. If the transmission rate is fixed and known, bandwidth can be reserved for each communication. Overhead is also less, as circuit switching does not need as much extra control information. In packet-switching, we need IP headers, MAC headers, transport headers, various update messages (e.g. for routing) and other control information that is sent alongside the real data.

4. If the queuing delay is 12 ms, the processing delay is insignificant, the transmission delay is 60 ms, the link is 50 m and the propagation speed of the link is 1 km/s, what is the total packet transfer delay for one packet?

Propagation delay = d / s = 50 m / 1,000 m/s = 50 * 10^{-3} s = 50 ms

Packet transfer delay = transmission + propagation + queuing + processing = 60 + 50 + 12 + 0 = 122 ms

Mobile

1. Consider a geographical area divided (for mobile phone coverage purposes) into 36 hexagonal cells, without gaps or overlaps between them. Each cell has a radius of 2 km. The reuse factor is 5. There are 350 channels in total.

i) What is the total area covered?

ii) What is the number of channels per cell?

iii) What is the maximum number of concurrent calls that can be handled?

iv) Would the answers to (i), (ii) or (iii) change if the radius of each cell was 1 km and there were 144 cells in total?

i) 36 * 10.39 = **374** square km

ii) 350 / 5 = **70** channels per cell

iii) 70 * 36 = **2,520** calls in total

iv) Area would be the same, number of channels per cell would be the same, but max number of calls would change to 144 * 70 = 10,080 calls