ITS 323 – ASSIGNMENT 1

Due Wednesday 15 August 2007, 5pm

10% of the final course mark

Instructions

1. This is an individual assignment. You must complete the assignment *on your own*. You should not work with others on this assignment – if you need help, then you should ask the lecturer!
2. The assignment can be neatly handwritten or typed on a computer.
3. You must give the final answers for questions on the Answer Sheet at the back of this handout. This should also be the cover sheet of your submitted assignment. You must attach the necessary calculations to the Answer Sheet.
4. Failing to show your calculations for a question may result in reduced or 0 marks, even if the answer is correct.
5. Your explanations of answers for Question 5 can be short (e.g. using bullet points), but must be clear. Space is given on the Answer Sheet – if you need more, then attach further sheets.
6. Copying and other forms of plagiarism (e.g. copying answers from the Internet or textbooks) will be penalised.
7. You must submit a hardcopy of the assignment, with the Answer Sheet as the first page, and the calculations attached. Staple at the top left hand corner. Do not include plastic covers or bind the assignment in other ways. Email submission is not accepted.
8. Hints and/or clarifications of questions may be posted on the ITS323 mailing list.

Assumptions

Unless it is stated in the question, you can make the following assumptions:

1. Speed of transmission is the speed of light: 3×10^8 m/s
2. 1GB = 1000MB; 1MB = 1000KB; 1KB = 1000B; 1B = 8 bits
3. b = bit; B = Byte

Question 0 (Preliminaries)

You must correctly complete this step, as answers in the remainder of the assignment depend upon it. You do not receive any marks for this question, *but you may be penalised if you make mistakes.*

a) The last 3 digits of your ID number will be referred to as X. Record the value in both decimal and as a 10-bit binary number on the answer sheet. Pad the binary number with zeros on the left.

Example:

If your ID is 4822771234, X = 234. In binary, this is: 0011101010.

Question 1 [21 marks]

You want to create a wireless connection from your dormitory building at Thammasat Rangsit to your friend's house nearby. You are lucky that the antenna on the dormitory building and the antenna on your friend's house are within line-of-sight. Both antennas that you buy are the same. The antennas:

- Are circular, with a radius of 0.2 metres
- Have a receive power threshold of -60dBm (that is, it can only successfully receive a signal with power above this threshold)

The distance between the two antennas is, d = 5000 + X, where X is the value generated from your ID in Question 0. The distance is measured in metres.

Since they are cheap, you decide to use IEEE 802.11g wireless LAN cards for the wireless transmission system. This operates at a frequency of 2.4GHz and provides a Physical layer data rate of 54Mb/s.

a) Assuming the free-space loss model, determine the minimum power you need to transmit at in order to successfully receive at your friend's house. Give a final answer in milliWatts (mW), rounded to the nearest mW. [9 marks]

b) How much power is lost between transmitter and receiver due to free-space propagation? Give your answer in decibel milliWatts (dBm), rounded to three decimal place (e.g. 23.456dBm). [6 marks]

You transmit at the power calculated and discover your friend *cannot* receive your transmission. After further measurements, you realise that, in addition to the free-space loss, there is another loss of 10dBm (due to for example, imperfections of the antenna, loss over cables and so on).

c) Given the 10dBm of power loss in addition to the free-space propagation loss, what is the transmit power required to reach your friends house? Again, give a final answer in mW. [6 marks]

Answers

Part (a)

The free space loss equation from the lecture notes is:

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

Where the gain (from the same slide in the lecture notes) is:

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

We know the radius (and hence area, A, and gain, G) of the antenna, frequency (and hence wavelength, λ), and distance. The receive power threshold tells us the minimum power that we can receive with. Therefore if we set P_r to this value, then we can calculate the minimum transmit power needed as:

$$P_t = \frac{P_r(4\pi d)^2}{\left(\frac{4\pi A}{\lambda^2}\right)^2 \lambda^2}$$

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

$$= \frac{P_r d^2 \lambda^2}{\pi^2 r^4}$$

$$= P_r \left(\frac{d\lambda}{\pi r^2}\right)^2$$

$$= P_r \left(\frac{dc}{f\pi r^2}\right)^2$$

We know d = 5000 + X; c = 3 x 10^8; f = 2.4 x 10^9; r = 0.2 and P_r is given in dBm, so need to convert to Watts:

$$P_{dBm} = 10\log(P_{mW})$$

$$\therefore P_r = 10^{-60/10}$$

$$= 10^{-6} mW$$

$$= 10^{-9} W$$

So now we can calculate Pt. If we assume X = 0, then Pt = 25mW.

Part (b)

The amount of power lost, in dBm, is the ratio of Pt to Pr:

$$Loss_{dBm} = 10\log\left(\frac{P_t}{P_r}\right) \text{where } P_t \text{ and } P_r \text{ are in mW}$$

With X = 0, loss = 74dB.

Another way to calculate (and more useful for part (c)): Convert P_t from mW to dBm using the logarithm equation, to find 25mW is 14dBm. Therefore the power goes from 14dBm to -60dBm: loss of 74dBm.

Part (c)

So the free-space propagation loss is 74dBm, and now we know there is an additional 10dBm loss. Since our receive threshold is -60dBm, that means our transmit power needs to be: 24dBm (since 24 – 74 – 10 = -60). This equates to 251mW.

Question 2 [12 marks]

So now you can communicate with your friend over the wireless link. The main application you will use is file sharing. Your friend has many home DVDs burnt to their hard drive, and you want to copy them to your hard drive, via the wireless link.

Your computer is setup to use a set of simple protocols at each layer in the Internet layered model. The protocols only add headers; they perform no retransmissions and send no control messages. The header sizes are:

- Application protocol: 40 bytes
- Transport protocol: 30 bytes
- Network protocol: 20 bytes
- Data link protocol: 25 bytes
- Physical protocol: 10 bytes

The only complexity is at the Network layer, where the network protocol fragments packets into a maximum size of 2000 bytes (and then adds its header to each fragment).

a) What throughput can be achieved when transferring a single 4.7GB DVD movie with the simple set of protocols? Ignore any propagation, queuing or processing delays. Give the answer to the nearest tenth of a Mb/s (e.g. 23.1Mb/s) [7 marks]

Now assume that there is a propagation delay, as well as a processing delay of 0.01 seconds at both transmitter and receiver. There is no queuing delay.

b) How many seconds does it take to transmit 1 DVD? Give your answer to the nearest second. [5 marks]

Answers

Part (a)

The 4.7GB is the original data. The application protocol and transport protocol add a total of 70 bytes to this. Then the network protocol breaks this 4,700,000,070 bytes into 2,350,001 fragments of 2000 bytes and adds 20 bytes to each fragment (2020 bytes now). Then the DL and PHY protocols both add 25 and 10 bytes respectively to each fragment. So the total data is 2,350,001 fragments of 2055 bytes in length. A total of 4,829,252,055. But useful data is 4,700,000,000 bytes. Given our data rate is 54Mb/s, our throughput is:

54Mb/s * (4,700,000,000 / 4,829,252,055) = 52.6Mb/s

Part (b)

We need to calculate the propagation delay (distance/speed of light), transmission delay (data size/rate) and add the processing delay.

Propagation delay = $(5000 + X)/3 \times 10^{8} = 1.6\times10^{-5}$ (if X = 0)

Transmission delay = $4{,}829{,}252{,}055 \times 8 / (54\times10^{6}) = 715.44$sec

Processing delay = 0.02

Therefore (independent of X, since the propagation is very small, about 2 usec) total delay is 715 seconds.

Question 3 [17 marks]

The simple set of protocols you used in Question 2 performed no error or flow control. But you know that all physical links (and especially wireless links) are prone to bit errors.

Lets assume you use a single-bit even parity check to perform error detection at the data link layer. The parity check is applied to 7-bit characters. Assume the 7-bit character being transmitted is the last 7-bits of X (where X is generated from your ID). If X as a 10-bit binary number is $x_1\ x_2\ x_3\ x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}$ then the character will be $x_4\ x_5\ x_6\ x_7\ x_8\ x_9\ x_{10}$

a) What is the sequence of bits sent by the transmitter? [2 marks]

b) If the middle bit of the 7-bit character (x_7) is in error on transmission (that is, it is changed from 1 to 0 or from 0 to 1), then explain what the receiver does? [5 marks]

c) If the middle bit of the 7-bit character and the bit to the right (that is, bits x_7 and x_8) are in error, then explain what the receiver does? [5 marks]

d) If the middle bit of the 7-bit character and the bit to the right and the parity bit are in error (that is, bits x_7, x_8 and the parity bit), then explain what the receiver does? [5 marks]

Your explanations of what the receiver does should answer: is the error detected? If yes, then how? If no, then why not? Provide your explanations on the answer sheet.

Answers

Part (a)

Even parity check adds a bit to the front of the 7-bit character such that the resulting 8-bits has an even number of 1's. If the 7-bit character originally has an even number of 1's, then the parity bit will be 0. If the 7-bit character originally has an odd number of 1's, then the parity bit will be 1.

Lets use the example of 0101010.

There are three 1's (odd), so we add another 1 to make the total even:

Data transmitted: 1 0101010 (where the first bit is the parity bit)

Part (b)

If the middle bit is in error then the receiver receives: 10100010. The receiver counts the number of 1's to be three (odd) and therefore assumes an error since it is expecting an even number of 1's. The error is successfully detected.

Part (c)

If the 2 middle bits are in error then the receiver receives: 10100110. The receiver counts the number of 1's to be four (even) and therefore assumes no error since it is expecting an even number of 1's. The error is undetected.

Part (d)

If the 2 middle bits are in error, as well as the parity bit, then the receiver receives: 00100110. The receiver counts the number of 1's to be three (odd) and therefore assumes error, since it is expecting an even number of 1's. The error is detected. (Note that it doesn't matter that it is the parity bit that is in error – the receiver just looks at all bits received).

Question 4 [26 marks]

Of course, detecting errors is not enough – you must also do something to fix the errors once detected. After investigation of different Forward Error Correction schemes, you find one that works well for your link. In fact, after applying Forward Error Correction, the number of errors that will be uncorrected is very small, and those undetected and uncorrected even smaller. So in the following, lets assume there are no errors on the link (all possible errors are detected and corrected).

But you still have a problem: the computer at your friends house is a high performance Pentium Quad Core computer, while your computer receiving the files is an old Intel 486. Data is sent too fast for your computer to handle, so you need some flow control. You have two options:

- Stop and Wait Flow Control
- Sliding Window Flow Control

Although we said in Question 2 that each layer adds a header, lets simplify things and look only at the performance of the Data Link layer. That is, ignore the headers and operations from all the other layers (Physical, Network, Transport, Application).

You should make the following assumptions:

- The size of each message to be sent by the Data link layer is: 1000 + X bytes, where X is generated from your ID number
- Each data message has a 25 byte header added to it to create the DATA frame (so the size of the DATA frame is 1025 + X bytes)
- The total size of an ACK frame is 25 bytes
- When using Sliding Window, the window size used is: $W = 2^{(1+\mathrm{mod}(X,6))}$ where mod(X,6) is the remainder when X is divided by 6.
- The transmitter always has data ready to send.
- There are no processing delays at the transmitter or receiver.

a) What is the utilisation (or efficiency) of the Stop and Wait flow control protocol? [10 marks]

b) What is the throughput of the Stop and Wait flow control protocol? [3 marks]

c) What is the utilisation (or efficiency) of the Sliding Window flow control protocol? [10 marks]

d) What is the throughput of the Sliding Window flow control protocol? [3 marks]

For utilisation, give your answers as percentages, rounded to two decimal points (e.g. 63.78%). For throughput, give your answer in Mb/s, rounded to one decimal point (e.g. 23.5Mb/s).

Answers

Part (a)

Stop and Wait flow control protocol involves transmission of a DATA frame, and then an ACK frame response. Since the transmitter always has data ready to send, the next DATA frame will be sent as soon as the ACK frame is received.

We don't have to consider all frames of our 4.7GB file, since we will have somewhere between 2,000,000 and 4,000,000 messages all of the same size (1000 + X bytes). The utilisation is the time spent sending useful data, divided by the total time to send the data:

$$U = \frac{T_{UsefulData}}{T_{Data} + T_{prop} + T_{Ack} + T_{prop}}$$

where:

$$T_{UsefulData} = \frac{1000 + X \text{ bytes}}{54 \text{ Mb/s}}$$

$$T_{Data} = \frac{1000 + 25 + X \text{ bytes}}{54 \text{ Mb/s}}$$

$$T_{Ack} = \frac{25 \text{ bytes}}{54 \text{ Mb/s}}$$

$$T_{prop} = \frac{5000 + X \text{ metres}}{3 \times 10^{8} \text{ m/s}}$$

If we assume X is 0, then the result is U = 78.43%

Part (b)

Given a data rate of 54Mb/s, and utilisation U = 78.43%, the throughput is 42.4Mb/s

Part (c)

With Sliding Window, the transmitter sends W DATA frames and then waits for an ACK frame. Upon receipt of the ACK frame, it sends the next W DATA frames.

$$U = \frac{W \times T_{UsefulData}}{W \times (T_{Data}) + T_{prop} + T_{Ack} + T_{prop}}$$

W is calculated as $2^{(1+\mathrm{mod}(X,6))}$. If X = 0, W = $2^{(1+0)}$ = 2. Using our values U = 86.97%

Part (d)

Throughput for Sliding Window is 47.0Mb/s.

Question 5 [24 marks]

So now we can transfer our video files across our wireless link in an efficient manner. Lets consider some of the design decisions made, and other issues that need to be considered.

a) We assumed Forward Error Correction was used for error control in our link. Lets assume it was the algorithm described in the lecture, where we took 2 bits of data and sent a 5 bit codeword.

   i. Explain the advantages and disadvantages of this algorithm compared to the Go-Back-N ARQ protocol. [6 marks]

   ii. If the number of errors on the link is very small, then which scheme is more efficient? Explain your choice. [Hint: do not perform detailed calculations;

instead consider the approximate efficiency of the FEC scheme, and note Go-Back-N uses a sliding window scheme] [6 marks]

b) Not everyone is as lucky to have their friend's house within line-of-sight of their house for wireless LAN to work. If you could not use wireless LAN to connect, two common alternatives may be to: 1. use a land-based ADSL Internet connection at both houses or 2. use a dedicated satellite connection (e.g. satellite dish at your dorm, and satellite dish at friends house). Compare the three different alternatives for the intended application (that is, transferring large video files). [12 marks]

Answers

Part (a.i)

The advantages of FEC (versus Go-Back-N) are based on the fact errors can be corrected without retransmissions. Therefore if many frames contain errors, using FEC most of the frames can be correctly received (after error correction) without additional transmissions. Whereas using Go-Back-N, for each frame that has an error, at least one re-transmission is needed. And in fact the re-transmitted frames may contain errors, resulting in more re-transmissions (and so on).

The disadvantages of FEC are that additional information is sent with each frame. If there are few errors, then many frames will be received without errors, and the additional information sent is wasted overhead.

In summary, the efficiency of FEC is mainly dependant on the encoding rate (data bits to transmitted bits). The efficiency of Go-Back-N depends on the number of retransmissions (and hence the number of errors).

Part (a.ii)

One answer may be from Part (a) we see that if the number of errors on the link is small, then it would generally be better to use Go-Back-N, since we would have few (if any) retransmissions, and hence very low overhead (compared to around 40% efficiency for FEC).

However, you could also argue that with Go-Back-N, if there are errors, then the entire window must be retransmitted (e.g. with a window of 32 frames, on average 16 frames will be retransmitted), significantly reducing the efficiency of Go-Back-N. With this explanation, you could say FEC was more efficient.

The following is not needed in the answer, but explains the reasoning in more detail.

Lets consider a simple example. In the best case, when the FEC can detect and correct all errors, we will achieve an efficiency of 40% (since 5 bits are sent for 2 bits of data: 2/5 = 0.4).

Now consider very simple analysis of Go-Back-N. Lets assume if there are no errors (retransmissions), then efficiency is 70% (this is just an example – in fact we would have to calculate the efficiency based on transmission and propagation times). And now assume if we have a frame in error, we need to retransmit once. So an error will result in 35% efficiency.

Lets consider Go-Back-N with the following number of errors:

- 0 of the frames are in error: overall efficiency will be 70%
- 1 out of every 10 frames is in error: for 1 frame efficiency will be 35% and the other 9 frames will be 70%. Overall efficiency is 0.1*35 + 0.9*70 = 66.5%
- 2 out of every 10 frames is in error: for 2 frames efficiency will be 35% and the other 8 frames will be 70%. Overall efficiency is 0.2*35 + 0.8*70 = 63%
- 8 out of every 10 frames is in error: for 8 frames efficiency will be 35% and the other 2 frames will be 70%. Overall efficiency is 0.8*35 + 0.2*70 = 42%
- 9 out of every 10 frames is in error: for 9 frames efficiency will be 35% and the other 1 frame will be 70%. Overall efficiency is 0.9*35 + 0.1*70 = 38.5%

So now lets compare FEC with Go-Back-N. The efficiency of FEC is 40%, no matter the number of errors. But for Go-Back-N, the efficiency is greater than 40% of the number of frames in error is less than 80%. In summary, Go-Back-N is more efficient than FEC if the number of frames in error is less than 80%. Of course, this makes some unrealistic assumptions, but illustrates the main trade-off between FEC and Go-Back-N.

Part (b)

Some advantages and disadvantages of the three options for transferring large video files:

Wireless LAN

- Advantages:
  - o Low cost and installation; in many cases can be installed by yourself. Antennas plus access points are on the order of several thousand baht.
  - o Free to use once setup. No monthly cost or data cost.
  - o Good speed (in practice 10's of Mb/s)
- Disadvantages:
  - o Requires line of sight transmission; obstructions such as buildings or large trees may make it impossible to communicate.
  - o More errors than terrestrial link, leading the lower performance.
  - o Security may be a problem

ADSL

- Advantages:
  - o Does not require line of sight or close proximity of two houses; in fact, houses can be in most cities in the world
  - o Reliable connection, low number of errors
  - o Very easy installation, relatively low cost to setup
  - o Also provides connection to the Internet
- Disadvantages:
  - o Requires both houses to have telephone line
  - o Requires both houses to connected to ADSL enabled telephone exchange

  - Regular monthly cost, as well as data cost (in some countries)
  - Traffic is routed through ISPs network (and possibly Internet), resulting in unpredictable performance
  - Low data rate, about 1Mb/s (unless using ADSL2)

Satellite

- Advantages:
  - Coverage from almost anywhere in world;
  - Does not require telephone line or line of sight
- Disadvantages:
  - High setup cost (installation is expensive and complex)
  - Very expensive (for dedicated connection); similar but slightly higher cost than ADSL for standard Internet connection
  - Significant transmission delay (though shouldn't effect file transfer) and large number of errors