LINKS, NETWORK AND PROTOCOLS – LAB SCRIPTS

Version 0.05 – 3rd February 2011
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This document contains the lab scripts for the first term of the Links, Networks and Protocols first year option. (There are no lab scripts for the summer term.)

There are seven labs[1]:

- Installing and running the simulator
- Configuring the simulator and analysing results
- Investigating the physical layer
- Lab Four: TBD
- Lab Five: TBD
- Lab Six: TBD
- Lab Seven: TBD

Please note: this is the first time this module has been run, and the first time this simulator has been used in a teaching situation. There will probably be some bugs identified in the software and the documentation, all of which I will fix as soon as I can.

If you find (or think you've found) a bug or an error, no matter how small, please first check the list of known issues on the website, and if it's not there, please send me an email and let me know.

The same goes for good ideas for improvements, I'd really like to hear them. Accurate bug-reporting and good ideas will be rewarded.

I'll send round an email telling everyone when a new version of anything is available on the module web-site:

http://www.elec.york.ac.uk/internal_web/meng/yr1/modules/Links_Networks_Protocols/

Please keep your copies up-to-date.

Thanks.

[1] At least that's the current plan. This front-page is subject to change as we go along.

1 Lab Three: The Physical Layer

In this lab, we'll be looking at how to calculate the transmit powers required for transmitting signals over a known distance, and the energy consequences of choosing frame sizes and modulation schemes[2].

1.1 Aims of this Lab

After doing this lab, you should be familiar with the use of the dBm to express powers and the dB to express power ratios, and understand the issues involved in choosing transmit power levels, modulation schemes and frame sizes.

1.2 Step One: Updating the Simulator

Please go to the course web-site and download an updated version of the DANSE simulator zip file, save it somewhere on your computer and extract the files into a folder. Double-click on the simulator itself, and the main window should appear.

http://www.elec.york.ac.uk/internal_web/meng/yr1/modules/Links_Networks_Protocols/

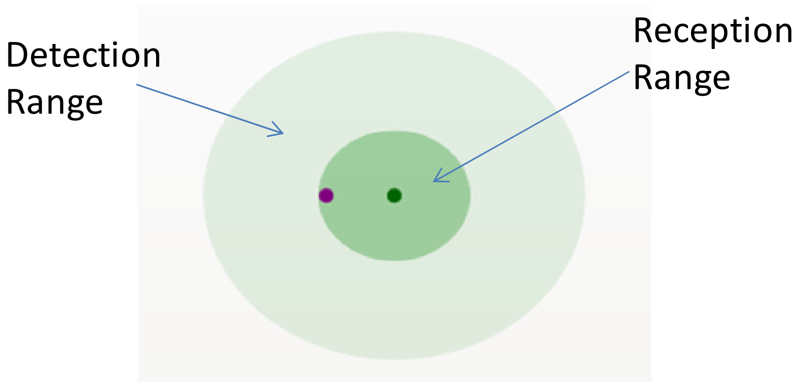
Also download the configuration files for lab three, and store these in your local workspace.

1.3 Step Two: Determining Transmit Powers

Load up the configuration file "Lab_3_1.xml". This simulation uses two nodes and attempts to send a packet from one to the other. Run the simulation.

What happens? Does the packet get to the destination?

Run the simulation in real-time mode, and pause when the packet is being transmitted[3]: note that there are two green circles around the transmitting node, an inner darker circle (the reception range: any node within this circle may be able to receive the frame) and an outer lighter circle (the detection range: any node within this circle will detect the transmission).



[2] (Most real nodes can't do pre-emption, so we won't be looking at that subject in these labs. We'll look at the effects of the detection threshold in the lab on MAC protocols.)

[3] If this is difficult, try pressing the "Next Tx" button on the main window. This advances the simulator to the next packet to be transmitted, and then pauses it.

In the "Physical Layer" control box on the "Setup Simulation" tab, change the bit rate to 500 bit/s, and run the simulation again (still in real-time mode).

What happens to the size of the circles, and why?

Leaving the bit-rate at 500 bit/s, change the "Detect (dB)" parameter to 10.0 and run the simulation again.

What happens to the circles now? Can you explain what you see?

Note: the table of signal-to-interference plus noise ratio (SINR) required for each bit rate is provided below (taken from the User Instructions). These SINR requirements are for a bit error rate of 1e-3 (in other words, with this SINR value, on average one in every thousand bits received is wrong).

Bit rate	SINR required for BER = 1e-3
500 bit/s	4 dB
1 kb/s	10 dB
2 kb/s	16 dB
4 kb/s	22 dB

1.3.1 Calculating Minimum Transmit Powers

What is the distance between these two nodes?

Hint: if you put the cursor over the nodes, the x and y co-ordinates of the nodes are shown in the top line of the Infobox (bottom right of the "Main" tab). Alternatively, look at the "Raw Nodes" output on the "Outputs" tab; the x- and y-coordinates are in the second and third columns respectively.

With the bit-rate set to 1000 bit/s, determine the minimum power required to achieve a bit error rate of 1e-3 in dBm.

Note that there is a noise of 10 nW = -50 dBm at every node, and that the loss of the channel can be assumed to be:

$$\text{Loss} = 0.001 \times d^4$$
$$\text{Loss}(\text{dB}) = -30 + 40\log_{10}(d)$$

Set the bit-rate to 1000 bit/s and the transmit power to your result[4], and run the simulation again. Did the packet arrive?

Try this a few times. Does the packet arrive (or not) every time? If not, why not?
(Hint: it should arrive some of the time, but not all of the time. If it always arrives or always doesn't arrive, you've probably got the transmit power set wrong.)

[4] Note you will not be able to set the transmit power to the exact value, you can only set the transmit power accurate to two decimal places. Just set it to the closest value you can.

1.4 Frame Error Rates

Load up the configuration “Lab_3_2.xml”. This has the same two nodes, and is configured to transmit 998 packets each 100 bytes long from one to the other at regular intervals, one per second. The bit rate is set to 1000 bit/s, and the transmit power is set so that the frame arrives a bit error rate of approximately 1e-3.

Run the simulation.

What percentage of the packets arrived?

(Hint: look at the Statistics item on the “Output” tab.)

1.4.1 The Effect of Transmit Power

Now change the transmit power in the range from -14 to -20 dB.

In each case, what proportion of the packets arrives, and what is the total energy used in the simulation?

(Hint: you can get the total energy used from the Statistics outputs on the “Outputs” tab.)

Transmit Power (dBm)	Percentage of Frames That Arrive	Total Energy Used
-14		
-15		
-16		
-17		
-18		
-19		
-20		

Clearly, the higher the transmit power, the more likely it is that a frame will arrive. However, higher transmit powers also take more energy to transmit.

1.5 The Effect of Frame Size

Set the transmit power to -18.0 dBm, and change the size of the packets to 10 bytes (the "Packet Size" control on the "Application" control box in the "Setup Simulation" screen), and run the simulation again.

What percentage of the packets arrived now?

Now try 1000 byte packets.

What percentage of the packets arrived now?

Can you explain the difference? Why should longer frames be less likely to arrive?

1.5.1 Optimum Frame Size

Suppose you had a 200 byte message to send. You could send it in one 200-byte packet, or two 100-byte packets, or 20 ten-byte packets, or even 200 one-byte packets. Which would take the least energy?

Clearly the one 200-byte packet would take the least energy to transmit initially, but it is also the least likely to be delivered correctly. What if the logical link layer were reliable, so it re-transmitted lost packets? Then one 200-byte packet might no longer take the least energy, since you would be more likely to have to send it twice (or even three or more times).

So, what is the best packet size to use?

Load up the configuration "Lab_3_3.xml". This configuration uses a reliable logical-link layer, and sends 200-packet packets. Run the simulation, and look at the physical layer activity – notice how many packets are being re-transmitted.

Note the total energy used by the nodes (look at the "Statistics" output on the "Outputs" tab).

What is the total energy required to send these 200-byte packets, and how many packets are sent?

Now, try the simulation again with 10 byte packets, and then one-byte packets (change the "Mean Size" of packets in the "Application" control box on the "Setup Simulation" tab).

What is the total energy required to send these 10-byte packets, and how many packets are sent?

What is the total energy required to send these 1-byte packets, and how many packets are sent?

Now, set the "Mean Rate" of generating packets to zero (the control is in the Application control box on the "Setup Simulation" tab) and work out the total energy that the nodes use even when no packets are sent (just listening takes energy too).

How much energy is used when no packets at all are sent?

Therefore, how much energy is required to successfully receive each 200-byte packet?

And how much energy is required to successfully receive twenty 10-byte packets?

And how much energy is required to successfully receive 200 one-byte packets?

Which is the lowest energy solution for transmitting a 200-byte message?

(Note: if you have time, you could try the same thing for sending 200 one-byte packets, and then investigating if there is an optimum size for the packets.)

1.6 The Effect of Bit Rate

Load up the configuration "Lab_3_4.xml".

How much transmit power is required for approximately 90% (within 2% will do) of the packets to be received correctly?

(This might take a bit of trial and error, but it is possible to get a good estimate for 100-byte packets by calculating the transmit power required for a bit error ratio of 1e-3 and then adding 1.6 dB.)

What is the total energy used by the nodes in this case?

Now change the bit rate to 500 bit/s, and run the simulation again (with the same level of transmit power).

What is the total energy used by the nodes in this case?

Clearly this requires more energy, since the nodes are transmitting for twice as long. However, the SINR requirement for 500 bit/s is different...

Determine what the transmit power should be for approximately 90% (within 2% will do) of the packets to be received correctly at a bit rates of 500 bit/s, 1000 bit/s, 2000 bit/s and 4000 bit/s.

Bit Rate	Transmit Power	Total Energy Used
500		
1000	-16.4 dB	
2000		
4000		

It takes more power to transmit at the higher transmit powers, so how can you explain these results?

1.7 Finishing and Writing Up

In this third lab, you should have been writing your answers on the lab script itself, there is no need to do any further writing up.

1.8 If You Have More Time...

In this lab we've looked at the effects of choosing the optimum transmit power for a given bit rate and frame size. We've also looked at the effects of choosing different bit rates for a given frame size and transmit power. We've even looked at choosing the best frame size for a given transmit power and bit rate.

What if you were allowed to pick any bit rate, transmit power and frame size you wanted? What bit rate, transmit power and frame size scheme would reliably transmit a 10,000 byte message between these two nodes using the least amount of energy?