Path Loss Parameters in Wi-Fi Networks

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1. Introduction:

1.1 Context/Background

Traditional network security is tough enough, but with wireless networks such as Wi-Fi, the very nature of the medium is a hacker's dream come true. The open air around us carries the radio signals with few restrictions, and this peculiarity of wireless networks makes them vulnerable to stealth attackers camouflaging their location to avoid detection and retribution. But it's possible to track down these hackers by the clues they leave behind: the strength of their transmission signal when it is received by other devices.

The first goal of this project was to conduct an outdoor experiment on campus to examine the signal propagation characteristics of a mobile device. The data collected from this experiment helped to determine if the mobile device's location could be pinpointed from the received signal strength.

The second goal was to correlate the experimental data using linear regression techniques to determine the signal propagation path loss parameters

1.2 Definition of the problem

The first goal of this project was to conduct an outdoor experiment on campus to examine the signal propagation characteristics of a mobile device. The data collected from this experiment helped to determine if the mobile device's location could be pinpointed from the received signal strength.

The second goal was to correlate the experimental data using linear regression techniques to determine the signal propagation path loss parameters.

1.3. Summary of the result

The result of this project presents a document explaining the graphs created from the data sent by the broadcast utility and captured by wireshark.

1.4 Outline of the report

Detailed background information about the hardware and software required is provided in Section 2. The development setup is reviewed in Section 3. The results of this work are presented in Section 4. The results of the project execution are presented in Section 5. The contributions of each team member in this project are described in Section 6.

2. Detailed context/background information:

Wi-Fi

Wi-Fi, also unofficially known as Wireless Fidelity, is a wireless technology brand owned by the Wi-Fi Alliance intended to improve the interoperability of wireless local area network products based on the IEEE 802.11 standards.

Common applications for Wi-Fi include Internet and VoIP phone access, gaming, and network connectivity for consumer electronics such as televisions, DVD players, and digital cameras.

Path Loss

When a computer sends a packet it sends it with specific signal strength, but at the receiver end the original signal strength is reduced to some lower signal strength. This loosing of strength refers to path loss. The goal of this project is to do an experiment to find a relation between path loss and position of the computers sending the signal.

3. Development setup:

3.1 Required Equipments

For this project we used four desktop computers with special network cards which can talk to wireshark software and a laptop computer.

3.2 WireShark

Wireshark (formerly known as Ethereal) is a free software protocol analyzer, or "packet sniffer" application, used for network troubleshooting, analysis, software and protocol development, and education. It has all of the standard features of a protocol analyzer.

The functionality Wireshark provides is very similar to tcpdump, but it has a GUI front-end, and many more information sorting and filtering options. It allows the user to see all traffic being passed over the network (usually an Ethernet network but support is being added for others) by putting the network card into promiscuous mode.

Wireshark is a software that "understands" the structure of different network protocols. Thus it's able to display encapsulation and single fields and interpret their meaning. Wireshark uses pcap to capture packets, so it can only capture on networks supported by pcap.

3.3 Simulation

The plan is to set those 5 machines in a common place where internet access is available in school (The quad seemed perfect for that). Before we start we have to make sure all the desktops has wireshark up and running. Then we have to filter the capture packets only from our source (the Laptop). We have to then place the desktops in four corners of the quad. Then one has to take the laptop and stand somewhere in between those corners and we have to measure the distances from the laptop to the desktops (as we need the distances to correlate the data). Then we have to send packets (browse internet) from the laptop for certain period (5 minutes) and change the position of the laptop and do the same thing again. In the mean time we have to save those data in wireshark in a dump file which will later be used to correlate. Once we get all those data from 5- 10 repetitions of the experiment we will process those dump files to some java readable format, and using java we will make a graphics representation of linear regression.

3.4 Broadcast Utility

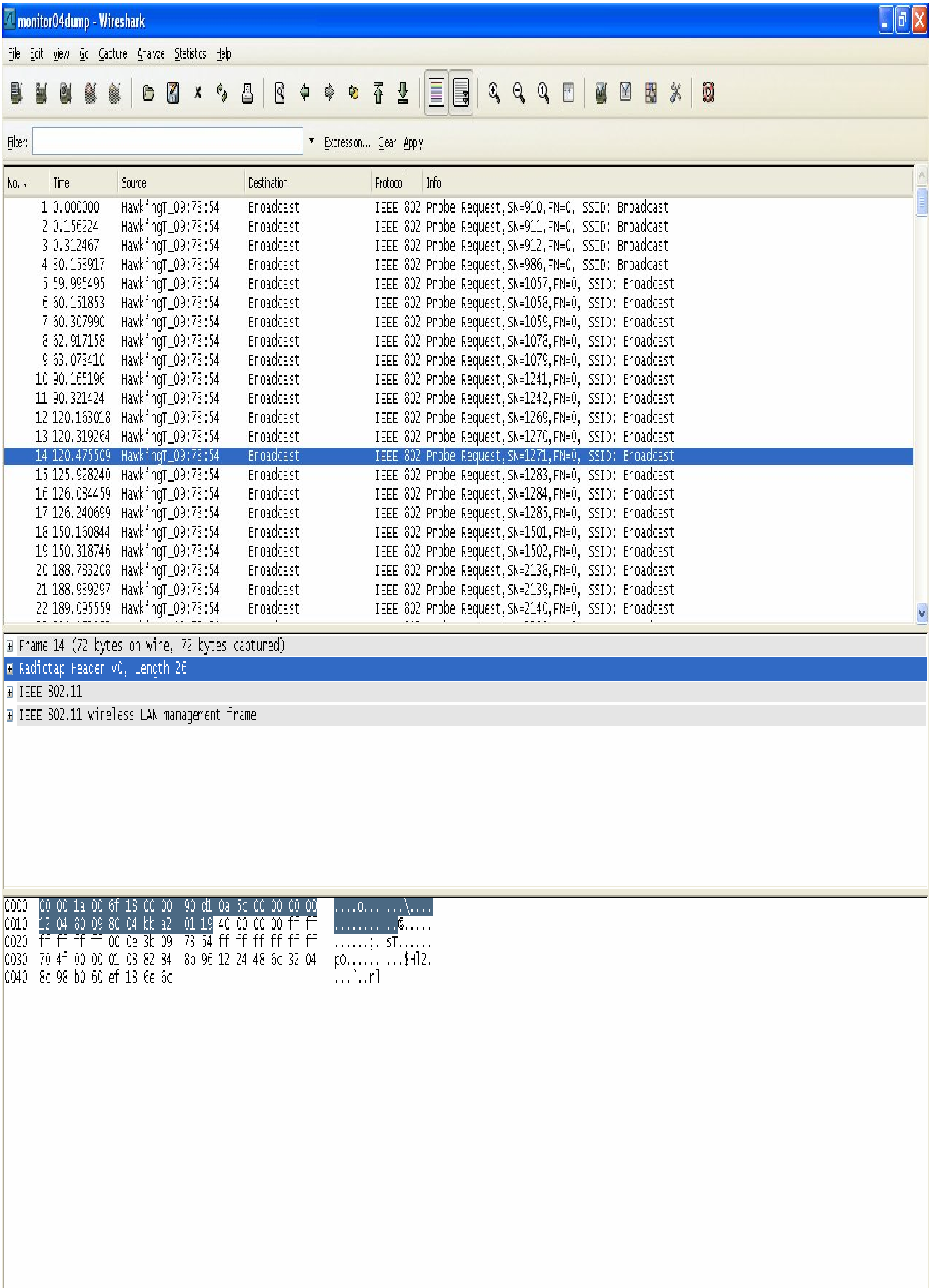
From the laptop thousands of broadcast messages were sent using a utility which uses UDP to do that. The simple C program opens a socket and sends thousands of broadcast packets over UDP and closes the socket once it's done sending packets. The program is as follow.

```
#include <winsock.h>
#include <stdio.h>

main()

{

WSADATA ws;
WSAStartup(0x0101,&ws);
int i;
```

```
SOCKET udp_socket;
struct sockaddr_in peer;
int peerlen;

peer.sin_family = AF_INET;
peer.sin_port = htons(2555);
peer.sin_addr.s_addr = inet_addr("192.168.1.255");

udp_socket = socket(AF_INET, SOCK_DGRAM, 0);

for(i= 0; i<2000;i++)
	{
	sendto(udp_socket, "Have a nice day!\n", 17, 0, (struct sockaddr *)&peer,
sizeof(peer));

	}

close(udp_socket);

return(0);

}
```

4. Description of the result:

The result of the execution of socket.c (source code for running the program to Send broadcast packets over the network) is given below. It’s the screenshot from wireshark capture window.


monitor04dump - Wireshark
File Edit View Go Capture Analyze Statistics Help
Filter:
Expression... Clear Apply
No. Time Source Destination Protocol Info
1 0.000000 HawkingT_09:73:54 Broadcast IEEE 802 Probe Request,SN=910,FN=0, SSID: Broadcast
2 0.156224 HawkingT_09:73:54 Broadcast IEEE 802 Probe Request,SN=911,FN=0, SSID: Broadcast
3 0.312467 HawkingT_09:73:54 Broadcast IEEE 802 Probe Request,SN=912,FN=0, SSID: Broadcast
4 30.153917 HawkingT_09:73:54 Broadcast IEEE 802 Probe Request,SN=986,FN=0, SSID: Broadcast
5 59.995495 HawkingT_09:73:54 Broadcast IEEE 802 Probe Request,SN=1057,FN=0, SSID: Broadcast
6 60.151853 HawkingT_09:73:54 Broadcast IEEE 802 Probe Request,SN=1058,FN=0, SSID: Broadcast
7 60.307990 HawkingT_09:73:54 Broadcast IEEE 802 Probe Request,SN=1059,FN=0, SSID: Broadcast
8 62.917158 HawkingT_09:73:54 Broadcast IEEE 802 Probe Request,SN=1078,FN=0, SSID: Broadcast
9 63.073410 HawkingT_09:73:54 Broadcast IEEE 802 Probe Request,SN=1079,FN=0, SSID: Broadcast
10 90.165196 HawkingT_09:73:54 Broadcast IEEE 802 Probe Request,SN=1241,FN=0, SSID: Broadcast
11 90.321424 HawkingT_09:73:54 Broadcast IEEE 802 Probe Request,SN=1242,FN=0, SSID: Broadcast
12 120.163018 HawkingT_09:73:54 Broadcast IEEE 802 Probe Request,SN=1269,FN=0, SSID: Broadcast
13 120.319264 HawkingT_09:73:54 Broadcast IEEE 802 Probe Request,SN=1270,FN=0, SSID: Broadcast
14 120.475509 HawkingT_09:73:54 Broadcast IEEE 802 Probe Request,SN=1271,FN=0, SSID: Broadcast
15 125.928240 HawkingT_09:73:54 Broadcast IEEE 802 Probe Request,SN=1283,FN=0, SSID: Broadcast
16 126.084459 HawkingT_09:73:54 Broadcast IEEE 802 Probe Request,SN=1284,FN=0, SSID: Broadcast
17 126.240699 HawkingT_09:73:54 Broadcast IEEE 802 Probe Request,SN=1285,FN=0, SSID: Broadcast
18 150.160844 HawkingT_09:73:54 Broadcast IEEE 802 Probe Request,SN=1501,FN=0, SSID: Broadcast
19 150.318746 HawkingT_09:73:54 Broadcast IEEE 802 Probe Request,SN=1502,FN=0, SSID: Broadcast
20 188.783208 HawkingT_09:73:54 Broadcast IEEE 802 Probe Request,SN=2138,FN=0, SSID: Broadcast
21 188.939297 HawkingT_09:73:54 Broadcast IEEE 802 Probe Request,SN=2139,FN=0, SSID: Broadcast
22 189.095559 HawkingT_09:73:54 Broadcast IEEE 802 Probe Request,SN=2140,FN=0, SSID: Broadcast
Frame 14 (72 bytes on wire, 72 bytes captured)
Radiotap Header v0, Length 26
IEEE 802.11
IEEE 802.11 wireless LAN management frame
0000 00 00 1a 00 6f 18 00 00 90 d1 0a 5c 00 00 00 00 ....o... ...\....
0010 12 04 80 09 80 04 bb a2 01 19 40 00 00 00 ff ff ....@.....
0020 ff ff ff ff 00 0e 3b 09 73 54 ff ff ff ff ff ff ......;. sT......
0030 70 4f 00 00 01 08 82 84 8b 96 12 24 48 6c 32 04 pO...... ...$Hl2.
0040 8c 98 b0 60 ef 18 6e 6c ...`..nl

For every file five distances were divided and Frame Check Sequences were noted down. After capturing four files like above the data was parsed to get the SSI Signal and Frame Check Sequence of every packets. Here is the parsed data.

output - Notepad

File Edit Format View Help

Sequece #	D(M1)	SSI	D(M2)	SSI	D(M3)	SSI	D(M4)	SSI
0x3d154b09	27	-56	51	-59	60	-55	35	-56
0x3335957a	27	-55	51	-58	60	-54	35	-52
0xd9d76b98	27	-59	51	-59	60	-57	35	-57
0xc54cd1be	27	-54	51	-59	60	-59	35	-57
0xbe71133b	27	-56	51	-61	60	-57	35	-59
0xcf1a242f	27	-58	51	-61	60	-56	35	-57
0x48674876	27	-56	51	-60	60	-57	35	-54
0x703c8ab9	27	-58	51	-62	60	-59	35	-62
0x9741c039	27	-55	51	-60	60	-54	35	-58
0xb80a420b	27	-57	51	-58	60	-56	35	-59
0x0d167a8b	27	-57	51	-59	60	-54	35	-56
0xf79b3424	27	-53	51	-60	60	-56	35	-56
0x04264bc1	27	-55	51	-59	60	-55	35	-56
0x4156ad39	27	-55	51	-58	60	-56	35	-57
0xf6463b6e	27	-57	51	-60	60	-57	35	-55
0xeca6d078	27	-57	51	-58	60	-57	35	-57
0xba06ecdc	27	-58	51	-60	60	-57	35	-55
0x262bd35b	27	-51	51	-60	60	-54	35	-55
0x2e72f413	27	-55	51	-62	60	-55	35	-59
0xd03f201d	27	-52	51	-59	60	-54	35	-56
0xa232d3d2	27	-55	51	-57	60	-58	35	-57
0xcc122b78	27	-56	51	-58	60	-54	35	-55
0xfc1266f4	27	-54	51	-57	60	-57	35	-54
End Of Distance #1								
0x1e1eda18	40	-54	45	-62	45	-58	38	-53
0x92334a5b	40	-52	45	-59	45	-57	38	-49
0xf053a1d2	40	-50	45	-59	45	-55	38	-49
0xd808ccd9	40	-52	45	-59	45	-57	38	-48
0x413866b5	40	-51	45	-59	45	-52	38	-49
0xbb6e2edb	40	-52	45	-59	45	-53	38	-50
0xed1514be	40	-52	45	-60	45	-59	38	-50
0x0a685e3e	40	-49	45	-58	45	-58	38	-52
0xf0e7b89a	40	-52	45	-60	45	-58	38	-50
0x779ad4c3	40	-52	45	-58	45	-58	38	-50

This data table shows the different distances and relevant SSI Signal strength of every packets matched by the frame check sequence number of each packets.

4.1 Linear Regression

The captured data for every monitor was used to use linear regression technique to find the best fit for n where

path loss = path loss at d0 + 10*n*log10(d/d0)

where d0 is our reference distance .001 Km(1m), and d = relevant distance.and

path loss at d0 in free space = 32.45 + 20*log10(f) + 20*log10(d0)

where f is the frequency expressed in MHz ,and for our wifi experiment it was 2.4 GHz= 2400 MHz. After putting the values for f and d0 we get

path loss at d0 in free space = 40.05.

After that all the theoretical pathlosses were drawn against the relevant distances for each monitor separately and one with all the monitor's pathloss was drawn too. We considered n=1, 2, 3, 4, 5 as those values cover all the points in the graph. Below is a sample of representation of the graphs which were drawn from the data taken for every desktop separately. This graph represents the distance and path loss (SSI Signal strength) co-relation while horizontal bar represents log of each distances for a certain desktop and vertical bar represents the path loss (17db- actual SSI Signal captured live).

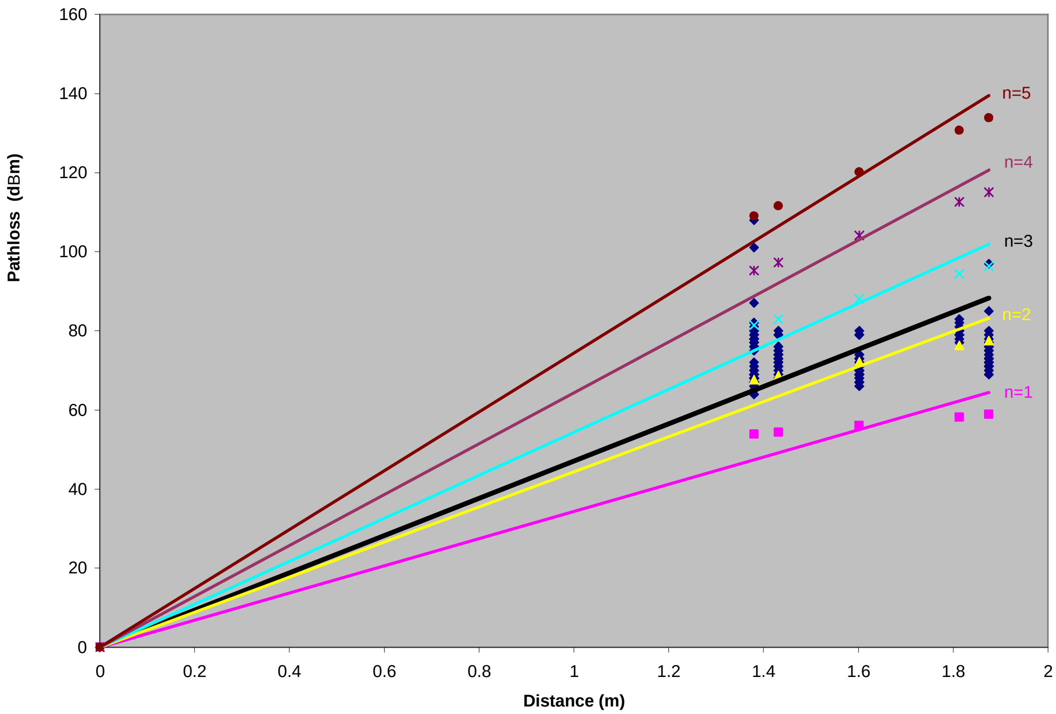


Fig 1: Monitor 1

Best Fit: The thick black line shows the best linear fit for monitor one which is 2.2.

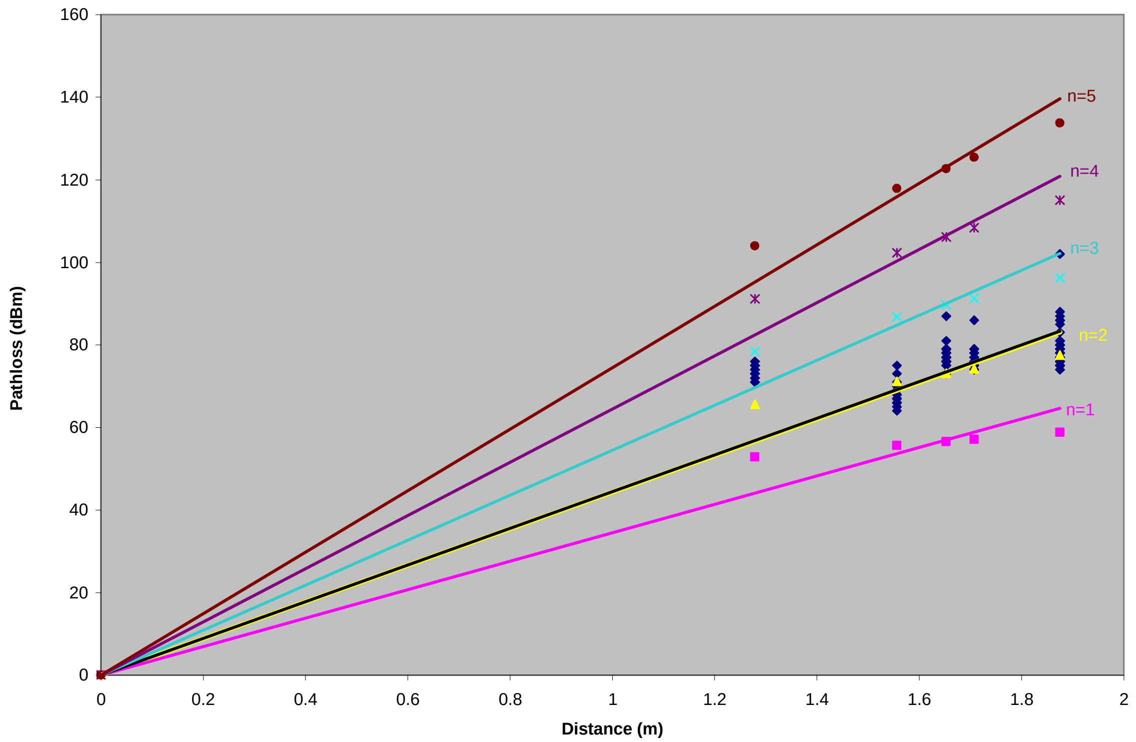


Fig2: Monitor 2

Best Fit: The thick black line on top of yellow line shows the best linear fit for monitor two which is 2.

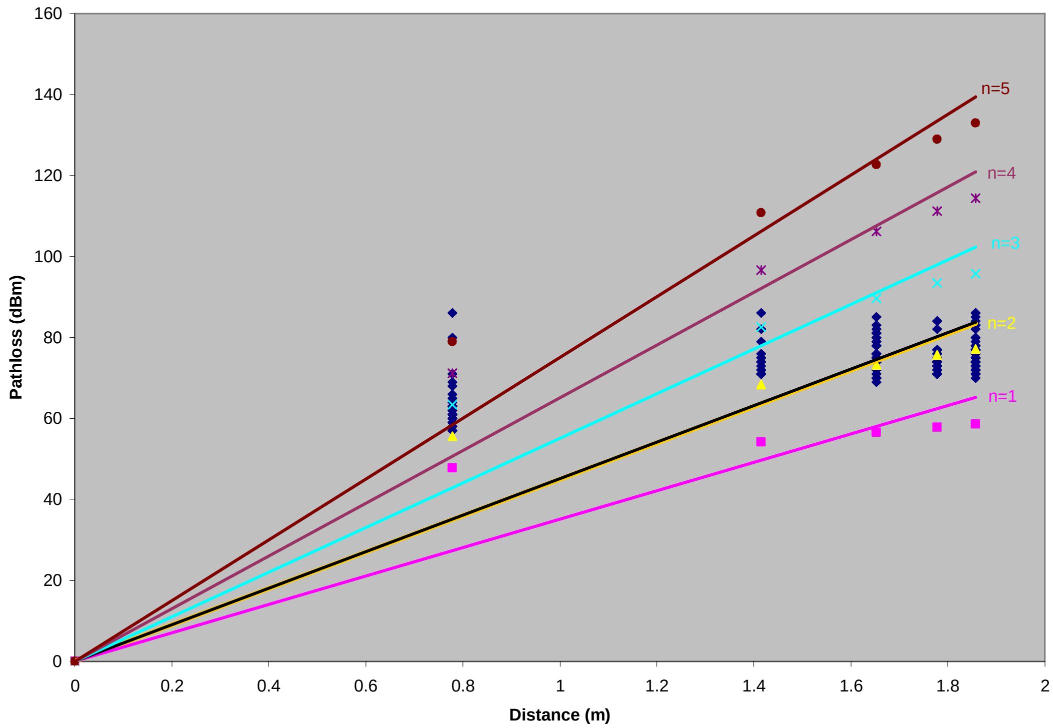


Fig 3 : Monitor 3

Best Fit: The thick black line on top of yellow line shows the best linear fit for monitor three which is 2.

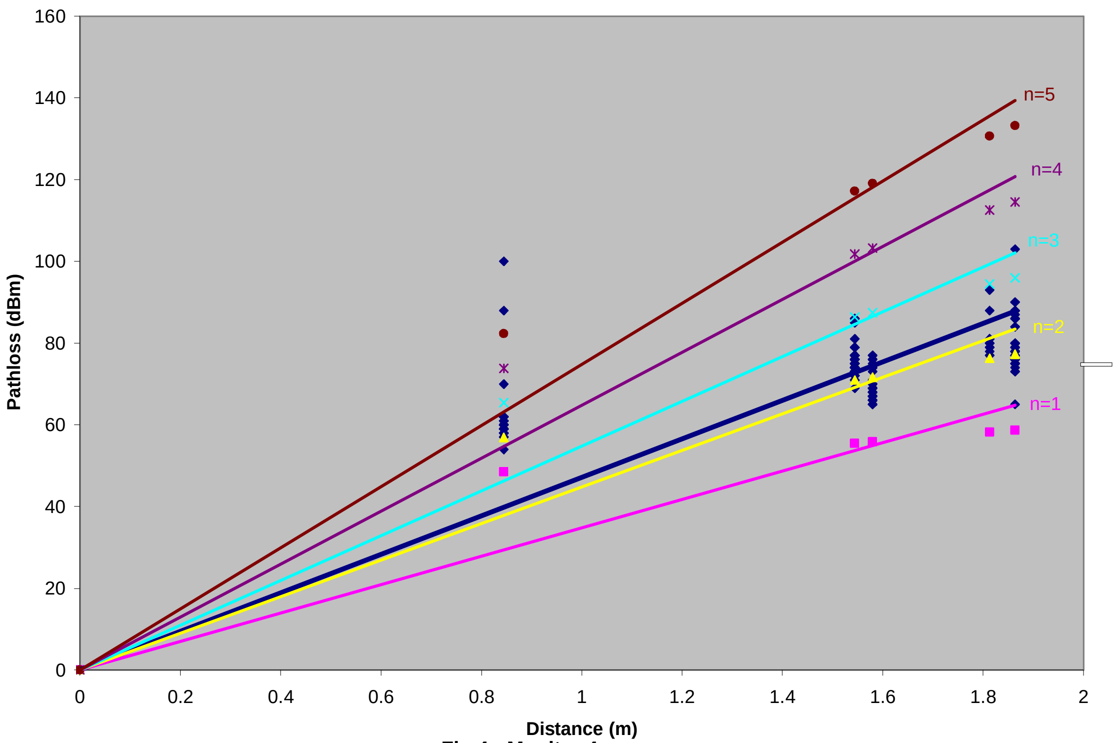


Fig 4 : Monitor 4

Best Fit: The thick blue line shows the best linear fit for monitor four which is 2.2.

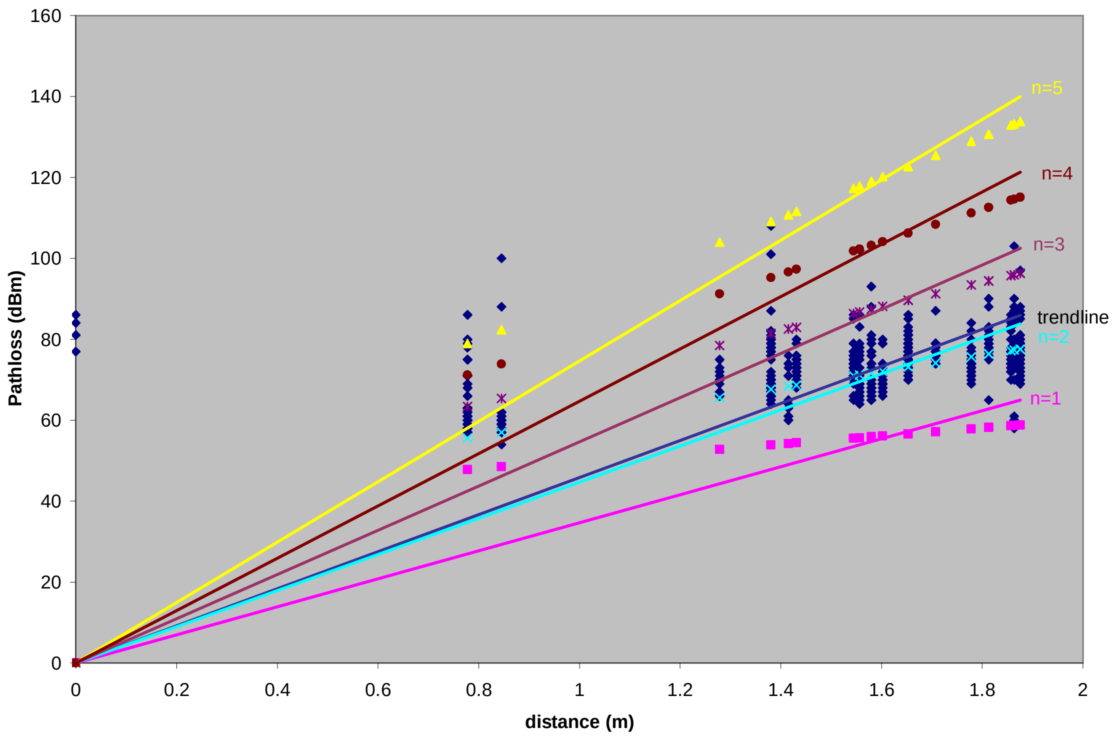


Fig 5: All monitors

Best Fit: The thick blue line shows the best linear fit for all monitor which is 2.2.

5. Evaluation of the result:

The graph drawn from the data captured suggests that there is a definite co-relation between the distance and the signal strength of the transmission. The thick black line in figure 5 shows the best linear regression fit to the data and indicates that average wifi path loss increases as distance to the power 2.2. This best fit was found by using least square method on the data captured for every distance for every monitor. So we could conclude saying that it is possible to track down a hacker's location from the clue he leaves behind, SSI Signal strength.

6. Contributions of team member:

Marufur Rahman wrote the broadcast utility, Set up all those desktops to capture data sent by the utility, parsed the data and represented the graph.

7. Acknowledgement:

I would love to convey my sincere appreciation to Dr Michel Barbeau for inspiring me to find this interesting open topic and providing all necessary assistance.

I thank Chirtine Laurendeau, a PhD In Carleton who was also the co-supervisor of the project .I would also like to thank Chen Guang Lee (a Master's student at carleton university) and my intimate friends for giving me continuous supports

8. References:

[1] Wireshark Tutorial. http://www.wireshark.org, 2007.

[2] Wikipedia. http://www.wikipedia.org, 2007