LAB 1 (Measuring the influence of attenuation of radio signal on network performance for different radio propagation models)

Fatema Mirza & Mohammad Newaj Jamil

D7030E Advanced Wireless Networks

LAB 1 (Measuring the influence of attenuation of radio signal on network performance for different radio propagation models)

by

Fatema Mirza & Mohammad Newaj Jamil

Submission Deadline:	September 20, 2021	
Teachers:	Dr. Evgeny Osipov,	LULEÅ TEKNISKA UNIVERSITET
	Ahmed Afif Monrat,	LULEÅ TEKNISKA UNIVERSITET

Contents

List of Tables

List of Figures

1

PART 1 – The Effect of Signal Attenuation on Communication Ranges in WiFi Networks

Kumar, 2015 Werner Mohr and Hans-Peter, 2015 The Effect of Signal Attenuation on Communication Ranges in WiFi Networks will be studied and experimented upon on the basis of three loss models:

1. Two-Ray Ground Propagation Loss Model
2. Cost231 Propagation Loss Model
3. Friis Propagation Loss Model

1.1. Experimental Setup

Radio signals are known to decrease with distance. To demonstrate this behavior measurements of bitrate is taken by varying distance between two nodes. The IEEE 802.11 ad hoc mode (also known as independent basic service set, IBSS) is used. During all experiments node(0) is the transmitter and node(1) is the receiver. The MAC settings is set to comply with the IEEE 802.11a specification, with UDP traffic and payload size of 1000 Bytes. It is important to note that this experiment should be performed in ns-3.30, because some of the specifications have been deprecated after ns-3.32.

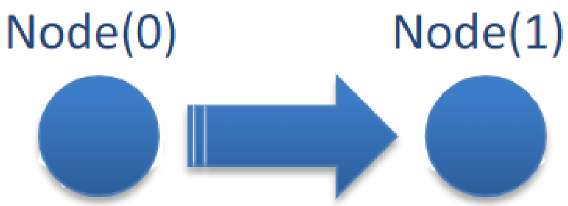


Figure 1.1: Topology of the network

First, the initial distances for the 3 loss models are calculated. Once the initial distance has been measured, the distances were decreased by 1/8th for each iteration and the bit rate was calculated for each distance for each of the models.

1.1.1. Initial Distance Calculation for Two-Ray Ground Propagation Loss Model

$$d_i = \sqrt[4]{\frac{P_t * G_t * G_r * (h_t h_r)^2}{P_r * L}}$$

where

$$P_t = \text{Transmission power (W)} = \text{16dB} = \text{39.811 W}$$

$$P_r = \text{Reception power (W)} = \text{-80dB} = 10^{-8} W$$

$$G_t = \text{Transmission gain (no unit)}$$

$$G_r = \text{Reception gain (no unit)}$$

$$d_i = \text{distance (m)}$$

$$L = \text{system loss (no unit) =1 (According to Rappaport's book)}$$

According to the source code provided in the ns-3.30 src directory, the gains are ignored.

Substituting the values in the equation the initial distance is found out to be **251.1 metres** for Two-Ray Ground Propagation Loss Model. The equation is explained in the source code folder of ns-3.30 (ns3, 2021c).

1.1.2. Initial Distance Calculation for Cost231 Propagation Loss Model

$$d_m = 10^{C_A} / 1e - 3$$

where

$$C_A = (L_b - C_G - C_H - C_m) / C_I$$

$$C_G = 46.3 + (33.9 * \log_{10}(f_{MHz})) - (13.82 * \log_{10}(m_{h_b}))$$

$$C_H = 0.8 + ((1.11 * \log_{10}(f_{MHz})) - 0.7) * m_{h_r} - (1.56 * \log_{10}(f_{MHz}))$$

$$C_I = 44.9 - 6.55 * \log_{10}(m_{h_b})$$

$$f_{MHz} = \text{Frequency of Transmission (MHz) = 2.3e9 * 1e-6}$$

$$m_{h_b} = \text{Base station antenna effective height (m) = 50.0}$$

$$m_{h_r} = \text{Mobile station antenna effective height (m) = 3.0}$$

$$C_m = \text{Constant offset (dB) = 10.0}$$

$$L_b = \text{Median path loss (dB) = 95.914}$$

$$d_m = \text{Link distance (m)}$$

Substituting the values in the equation, the initial distance is found out to be **42.8 metres** for Cost231 Propagation Loss Model. The equation is explained in the source code folder of ns-3.30 (ns3, 2021a) and Wikipedia (Wikipedia, 2021).

1.1.3. Initial Distance Calculation for Friis Propagation Loss Model

$$d_i = \sqrt[2]{\frac{P_t * (\lambda)^2}{P_r * (4 * \pi)^2}}$$

where

$$P_t = \text{Transmission power (W)} = \text{16dB} = \text{39.811 W}$$

$$P_r = \text{Reception power (W)} = \text{-80dB} = 10^{-8} W$$

$$\lambda = \frac{C}{f} \text{ where C = 299792458 m/s and f=5.15 GHZ}$$

Substituting the values in the equation the initial distance is found out to be **292.2 metres** for Friis Propagation Loss Model. The equation is explained in the source code folder of ns-3.30 (ns3, 2021b).

1.1.4. Set the distance between nodes at decreasing 1/8th distance for Two-Ray Ground Propagation Loss Model

Table 1.1: Set the distance between nodes at decreasing 1/8th distance for Two-Ray Ground Propagation Loss Model

Distance	D	(D*7)/8	(D*6)/8	(D*5)/8	(D*4)/8	(D*3)/8	(D*2)/8	(D*1)/8
Distance (m)	251.1	219.7125	188.325	156.9375	125.55	94.1625	62.775	31.3875

1.1.5. Set the distance between nodes at decreasing 1/8th distance for Cost231 Propagation Loss Model

Table 1.2: Set the distance between nodes at decreasing 1/8th distance for Cost231 Propagation Loss Model

Distance	D	(D*7)/8	(D*6)/8	(D*5)/8	(D*4)/8	(D*3)/8	(D*2)/8	(D*1)/8
Distance (m)	42.8	37.45	32.1	26.75	21.4	16.05	10.7	5.35

1.1.6. Set the distance between nodes at decreasing 1/8th distance for Friis Propagation Loss Model

Table 1.3: Set the distance between nodes at decreasing 1/8th distance for Friis Propagation Loss Model

Distance	D	(D*7)/8	(D*6)/8	(D*5)/8	(D*4)/8	(D*3)/8	(D*2)/8	(D*1)/8
Distance (m)	292.2	255.675	219.15	182.625	146.1	109.575	73.05	36.525

1.2. Bitrate Calculation

The bitrate was calculated by taking size of packet in bits (8512 bits) and divide it by time difference between LAST packet received by receiver and LAST packet sent by sender. The values were extracted from wireshark.

$$Bitrate(bits/sec) = \frac{\text{Packet size in bits}}{\text{Time for packet received by receiver in seconds} - \text{Time for packet sent by sender in seconds}}$$

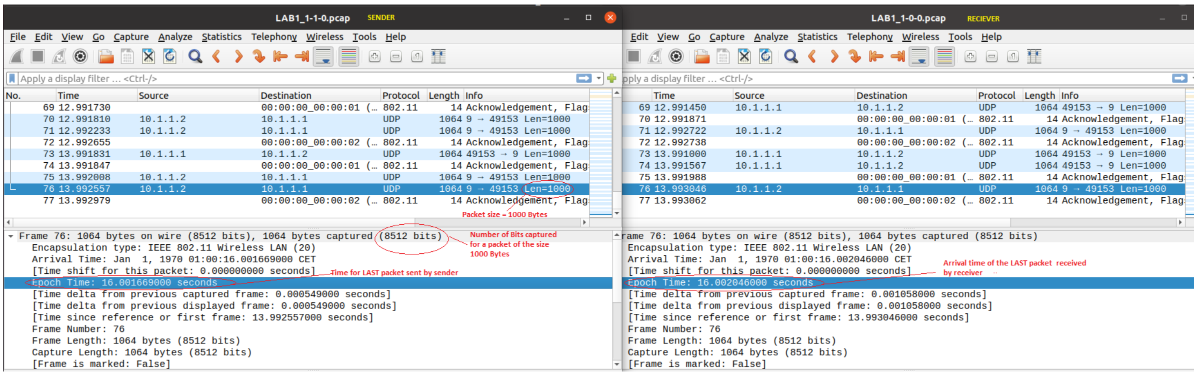


Figure 1.2: Detailed calculation for bitrate

1.3. Results

The results were tabulated and demonstrated graphically.

1.3.1. Two-Ray Ground Propagation Loss Model

Table 1.4: Bitrate calculation for each distance using Two Ray Ground Propagation Loss Model

Distance (m)	Time for LAST packet received by receiver (s)	Time for LAST packet sent by sender (s)	Time (s)	Bitrate (bits/s)
251.1	16.002046	16.001669	0.000377	22578249.3
219.7125	16.001577	16.001316	0.000261	32613026.8
188.325	16.001586	16.001325	0.000261	32613026.8
156.9375	16.001586	16.001325	0.000261	32613026.8
125.55	16.001344	16.001144	0.0002	42560000
94.1625	16.000501	16.000321	0.00018	47288888.9
62.775	16.000501	16.000321	0.00018	47288888.9
31.3875	16.000501	16.000321	0.00018	47288888.9

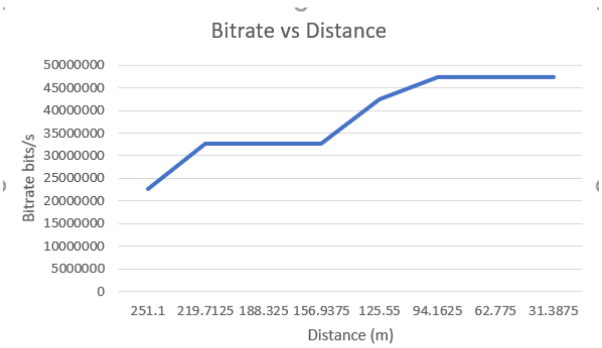


Figure 1.3: Bitrate versus distance plot for two ray ground propagation loss model

1.3.2. Cost231 Propagation Loss Model

Table 1.5: Bitrate calculation for each distance using Cost231 Propagation Loss Model

Distance (m)	Time for LAST packet received by receiver (s)	Time for LAST packet sent by sender (s)	Time (s)	Bitrate (bits/s)
42.8	16.002045	16.001669	0.000376	22638297.9
37.45	16.006949	16.006689	0.000377	22578249.3
32.1	16.001585	16.001325	0.00026	32738461.5
26.75	16.003159	16.002959	0.0002	42560000
21.4	16.000501	16.000321	0.00018	47288888.9
16.05	16.000501	16.000321	0.00018	47288888.9
10.7	16.000501	16.000321	0.00018	47288888.9
5.35	16.000501	16.000321	0.00018	47288888.9

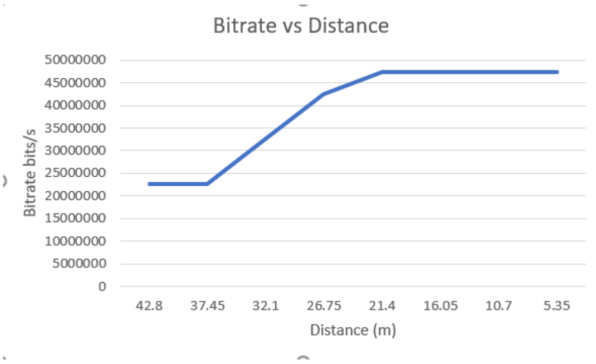


Figure 1.4: Bitrate versus distance plot for cost231 propagation loss model

1.3.3. Friis Propagation Loss Model

Table 1.6: Bitrate calculation for each distance using Friis Propagation Loss Model

Distance (m)	Time for LAST packet received by receiver (s)	Time for LAST packet sent by sender (s)	Time (s)	Bitrate (bits/s)
292.2	16.002046	16.001669	0.000377	22578249.3
255.675	16.002046	16.001669	0.000377	22578249.3
219.15	16.001586	16.001325	0.000261	32613026.8
182.625	16.001586	16.001325	0.000261	32613026.8
146.1	16.001585	16.001325	0.00026	32738461.5
109.575	16.000501	16.000321	0.00018	47288888.9
73.05	16.000501	16.000321	0.00018	47288888.9
36.525	16.000501	16.000321	0.00018	47288888.9

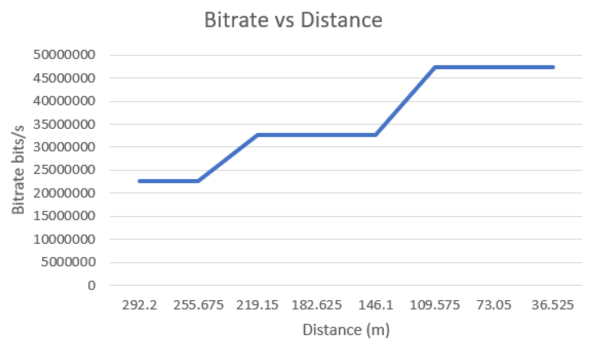


Figure 1.5: Bitrate versus distance plot for friis propagation loss model

2

PART II: Practical Scenario: Measurements in Real Environment

2.1. Experimental Setup

An adhoc network was created using mobile hotspot established in one of the laptop. The second laptop was connected to this network. WifiInfoView was used to monitor received-signal strength indication (RSSI) values.

Figure 2.1: Adhoc network using two laptops

The RSSI was measured (using ping from one laptop to another for precise measurements) by changing the positions of the second laptop increasing the distance in each experiment by 1 metre - first along a straight corridor and then around a corner. The experiment was repeated for 50 metres where 30 metres were along a straight corridor and 20 metres around the corner of a corridor.

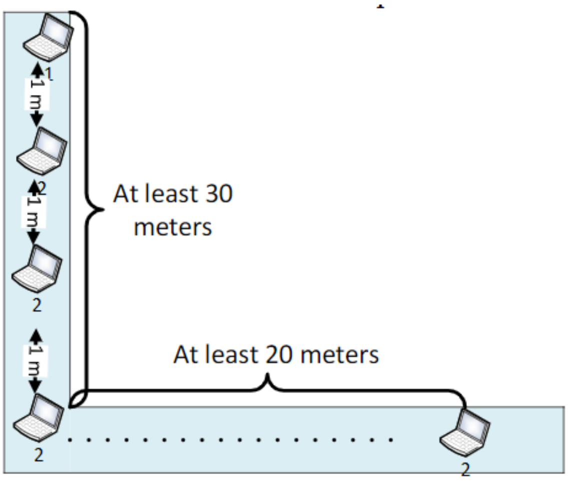


Figure 2.2: Experimental setup diagram

Calculate the path loss:

For actual measurement path loss:

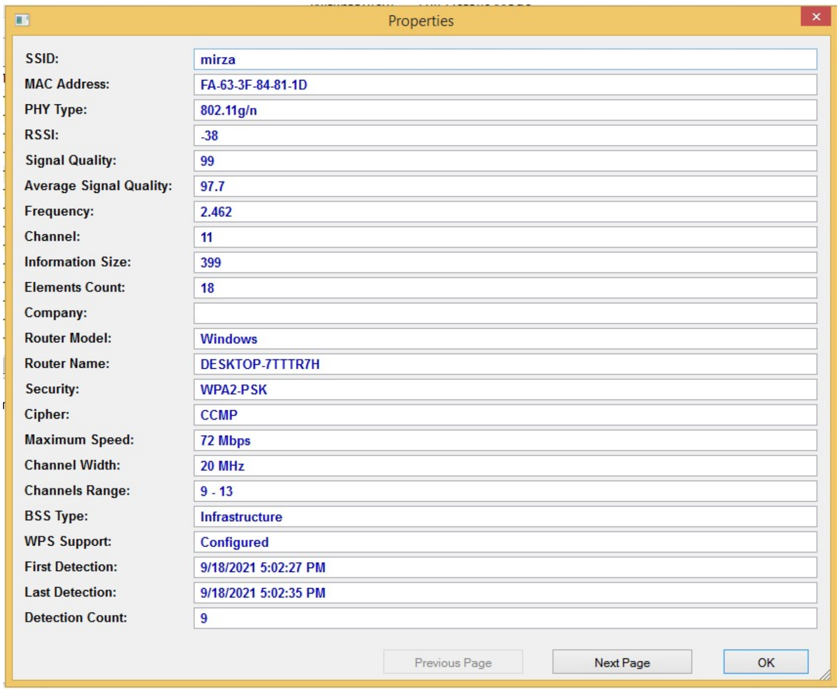
$$L(dB) = Tx\ power(dB) - RSSI(dBm)$$

where Tx power is equal to 20 dB.

For Friis path loss:

$$L(dB) = 20 * \log_{10}(d) + 20 * \log_{10}(f) - 27.55$$

where d is the distance in meters and f is the frequency which is equal to 2462 MHz.



SSID:	mirza
MAC Address:	FA-63-3F-84-81-1D
PHY Type:	802.11g/n
RSSI:	-38
Signal Quality:	99
Average Signal Quality:	97.7
Frequency:	2.462
Channel:	11
Information Size:	399
Elements Count:	18
Company:	
Router Model:	Windows
Router Name:	DESKTOP-7TTTR7H
Security:	WPA2-PSK
Cipher:	CCMP
Maximum Speed:	72 Mbps
Channel Width:	20 MHz
Channels Range:	9 - 13
BSS Type:	Infrastructure
WPS Support:	Configured
First Detection:	9/18/2021 5:02:27 PM
Last Detection:	9/18/2021 5:02:35 PM
Detection Count:	9

Figure 2.3: Properties of the network

2.2. Results

The results for the experiment have been tabulated and demonstrated as a graph. RRSI decreases with distance whereas both the pathloss (extracted and friis) increases with distance.

The following graph demonstrates a comparison between the actual measurement for path loss and Friis path loss where it can be observed that the values for actual measurement for path loss is greater than the values for Friis path loss.This is because Friis path loss assumes an ideal environment which can not be mimicked in real life and thus the actual measurement experiences higher loss.

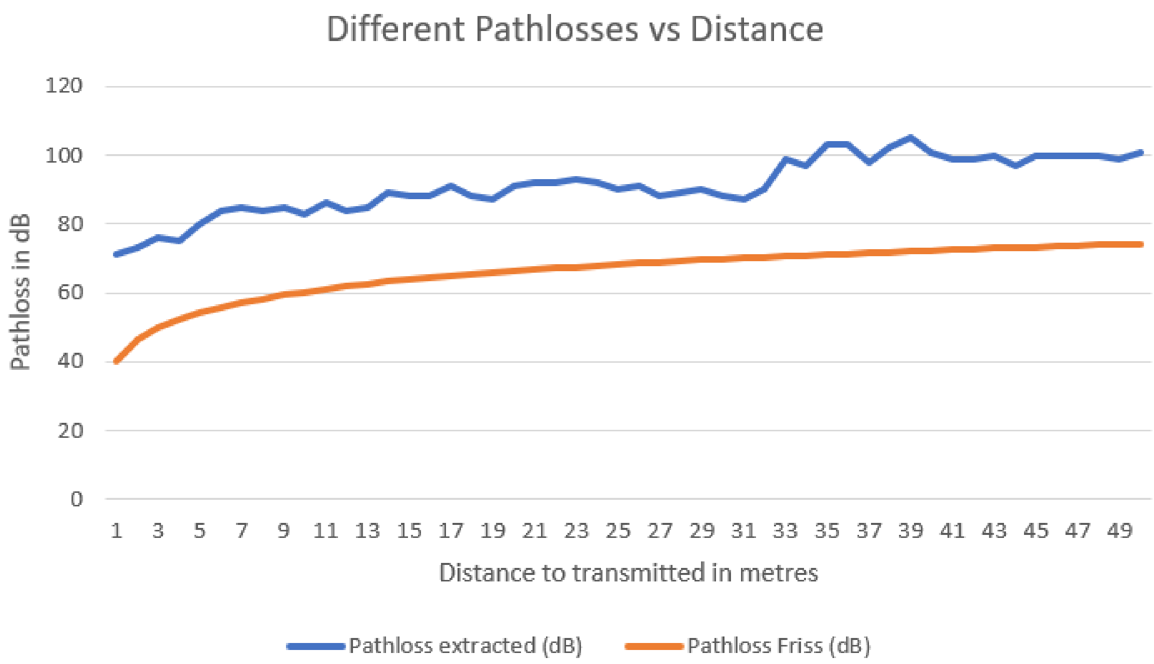


Figure 2.4: Different types of pathloss plot versus increasing distance

Table 2.1: Different Pathlosses per distance

Distance to transmitter (m)	RSSI (dBm)	Pathloss extracted (dB)	Pathloss Friss (dB)
1	-51	71	40.27576
2	-53	73	46.29636
3	-56	76	49.81819
4	-55	75	52.31696
5	-60	80	54.25516
6	-64	84	55.83879
7	-65	85	57.17772
8	-64	84	58.33756
9	-65	85	59.36061
10	-63	83	60.27576
11	-66	86	61.10361
12	-64	84	61.85939
13	-65	85	62.55463
14	-69	89	63.19832
15	-68	88	63.79759
16	-68	88	64.35816
17	-71	91	64.88474
18	-68	88	65.38121
19	-67	87	65.85083
20	-71	91	66.29636
21	-72	92	66.72015
22	-72	92	67.12421
23	-73	93	67.51032
24	-72	92	67.87999
25	-70	90	68.23456
26	-71	91	68.57523
27	-68	88	68.90304
28	-69	89	69.21892
29	-70	90	69.52372
30	-68	88	69.81819
31	-67	87	70.10299
32	-70	90	70.37876
33	-79	99	70.64604
34	-77	97	70.90534
35	-83	103	71.15712
36	-83	103	71.40181
37	-78	98	71.6398
38	-82	102	71.87143
39	-85	105	72.09705
40	-81	101	72.31696
41	-79	99	72.53144
42	-79	99	72.74075
43	-80	100	72.94513
44	-77	97	73.14481
45	-80	100	73.34001
46	-80	100	73.53092
47	-80	100	73.71772
48	-80	100	73.90059
49	-79	99	74.07968
50	-81	101	74.25516

Friis Free Space Propagation Loss Model works on the basis of Line of sight (LOS) path loss in an ideal environment (without any objects that create diffraction, absorption, reflection and so on). Therefore, Friis model can be used to model the propagation loss for the straight corridor, however it fails around the corner because the wave is obstructed by objects which can cause wave characteristic altering actions. So to conclude, Friis can not fully mimic behavior of measured path loss (Mathuranathan, 2013).

Bibliography

Kumar, N. (2015). *security in gsm 2g and umts 3g networks*. Retrieved October 13, 2021, from https://www.slideshare.net/NaveenKumar11/security-in-gsm2g-and-umts3g-networks

Mathuranathan. (2013). *Friis Free Space Propagation Model*. Retrieved September 20, 2021, from https://www.gaussianwaves.com/2013/09/friss-free-space-propagation-model/

ns3. (2021a). *Cost231 Propagation Loss Model*. Retrieved September 20, 2021, from https://www.nsnam.org/docs/release/3.21/doxygen/classns3_1_1_cost231_propagation_loss_model.html#a66a71d3fdabd10ff7a90a5447e656f47

ns3. (2021b). *Friis Propagation Loss Model*. Retrieved September 20, 2021, from https://www.nsnam.org/docs/release/3.21/doxygen/classns3_1_1_friis_propagation_loss_model.html

ns3. (2021c). *Two Ray Ground Propagation Loss Model*. Retrieved September 20, 2021, from https://www.nsnam.org/docs/release/3.21/doxygen/classns3_1_1_two_ray_ground_propagation_loss_model.html

Werner Mohr, L. J., & Hans-Peter. (2015). *PhD Course: UMTS and IP based mobile networks*. Retrieved October 13, 2021, from https://slideplayer.com/slide/5013116/

Wikipedia. (2021). *COST Hata model*. Retrieved September 20, 2021, from https://en.wikipedia.org/wiki/COST_Hata_model