Department of Computer Science, Electrical and Space Engineering

D7030E: Advanced Wireless Networks

Lab 1: Behavior of WiFi with ns3

Students:

Manasik Hassan

Pavan Kalyan Reddy Karnati

PART 1 – The effect of signal attenuation on communication ranges in WiFi networks

1. Calculate the initial distance between nodes (d_i), which equals the value corresponding to the border of the transmission range for all the following propagation models.
2. Calculate the set of distances D = {d_i, $7d_i/8$, $6d_i/8$, ..., $d_i/8$} between node(0) and node(1) (totally 8 values).
3. For each value in D run an experiment. In each experiment measure the bit-rate.
4. Plot the bit-rate against the distance.

Figure 1. Topology of our Scenarios

1- Two-Ray Ground Model:

The following equation represents the mathematical formulation of the two-ray ground model:

$$P_{r_{\mathrm{dBm}}} = P_{t_{\mathrm{dBm}}} + 10\log_{10}(Gh_t^2 h_r^2) - 40\log_{10}(d)$$

Where:

- *Pr* is the power of the received signal in dBm.
- *Pt* is the transmitted power in dBm.
- *G* is the product of the transmit and receive antenna gains (unitless).
- *Ht* and Hr are the height of the transmitter and the receiver in meters.
- *d* is the distance between the transmitter and the receiver in meters.

Parameters values from the script*:*

*Pt=16 dbm, Pr=-80 dbm, G=Gt*Gr =0 db = 1, Ht=Hr=1 m*

By substituting in two ray model equation => ***d = 251.1 m***

The following table shows the corresponding Bit rate (Mb/s) for each distance in the set D = {*di, 7di/8, 6di/8, ..., di/8*}.

Table 1. Simulation results for the Two-ray ground model

Distance	Distance (m)	Time at Sender (s)	Time at Receiver (s)	Total time (s)	Sent Bits	Bit rate (Mb/s)
d	251.1	16.000454	16.00083	0.000376	8512	22.63829787
7d/8	219.7125	16.005548	16.005808	0.00026	8512	32.73846154
6d/8	188.325	16.002264	16.002464	0.0002	8512	42.56
5d/8	156.9375	16.000034	16.000214	0.00018	8512	47.28888889
4d/8	125.55	16.000034	16.000214	0.00018	8512	47.28888889
3d/8	94.1625	16.000034	16.000214	0.00018	8512	47.28888889
2d/8	62.775	16.000034	16.000214	0.00018	8512	47.28888889
d/8	31.3875	16.000034	16.000214	0.00018	8512	47.28888889

The results shown in the previous table are plotted in the following graph.

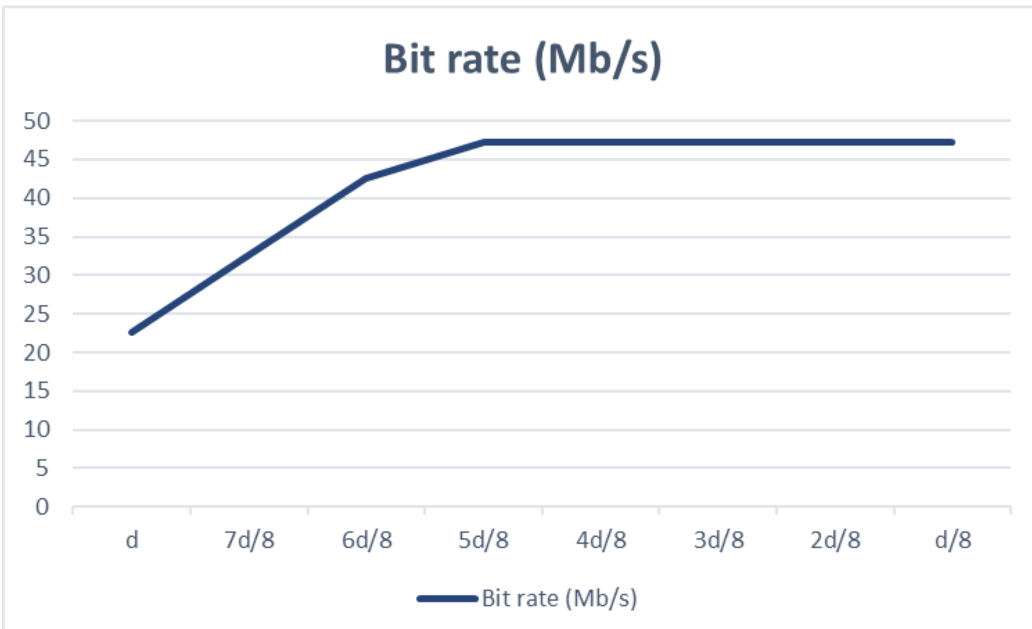


Figure 2. Bit-rate vs Distance for the Two-ray ground model

2- Cost231 Propagation Loss Model:

The following equation represents the mathematical formulation of the Cost231 model:

$$L_b = 46.3 + 33.9 \log_{10} \frac{f}{\mathrm{MHz}} - 13.82 \log_{10} \frac{h_B}{\mathrm{m}} - a(h_R, f) + \left(44.9 - 6.55 \log_{10} \frac{h_B}{\mathrm{m}}\right) \log_{10} \frac{d}{\mathrm{km}} + C_m$$

$$a(h_R, f) = \left(1.1 \log_{10} \frac{f}{\mathrm{MHz}} - 0.7\right) \frac{h_R}{\mathrm{m}} - \left(1.56 \log_{10} \frac{f}{\mathrm{MHz}} - 0.8\right)$$

Where:

- *Lb* is the transmission path loss in dB.
- *f* is the frequency of the transmission in MHz.
- *Hb* is the base station antenna's effective height in meters.
- *Hr* is the mobile station antenna's effective height in meters.
- *d* is the link distance in Km.
- *Cm* is the constant offset for shadowing in dB.

The default values in the script for the *Hb* and *Hr* were 50 m and 3 m respectively. This is because the cost231 model estimates the path loss in urban and suburban areas, and it applies to macro cells where a BTS antenna is installed in a tower and the link distance between BTS and the mobile user ranges between 1 – 20 Km. This macro cells scenario will also require higher transmission power levels than the configured 16 dBm.
Since our Scenario is a Wi-Fi network with a transmission power of 16 dBm, the antenna heights were modified in the model to 3.5 and 1 meters for the transmitter and receiver respectively to reflect a convenient Wi-Fi environment and further investigate whether this model can give reasonable results for our Wi-Fi scenario.

Parameters values from the script*:*

Lb=96 db, f=2.3 GHz,Cm=10 db, Hb=3.5 m, Hr=1 m

By substituting in Cost231 equation => ***d = 22.45 m***

The following table shows the corresponding Bit rate (Mb/s) for each distance in the set D = {*di, 7di/8, 6di/8, ..., di/8*}.

Table 2. Simulation results for the Cost231 model

Distance	Distance (m)	Time at Sender (s)	Time at Receiver (s)	Total time (s)	Sent Bits	Bit rate (Mb/s)
d	22.45	16.000454	16.00083	0.000376	8512	22.63829787
7d/8	19.64375	16.002404	16.002664	0.00026	8512	32.73846154
6d/8	16.8375	16.000356	16.000536	0.00018	8512	47.28888889
5d/8	14.03125	16.000034	16.000214	0.00018	8512	47.28888889
4d/8	11.225	16.000034	16.000214	0.00018	8512	47.28888889
3d/8	8.41875	16.000034	16.000214	0.00018	8512	47.28888889
2d/8	5.6125	16.000034	16.000214	0.00018	8512	47.28888889
d/8	2.80625	16.000034	16.000214	0.00018	8512	47.28888889

The results shown in the previous table are plotted in the following graph.

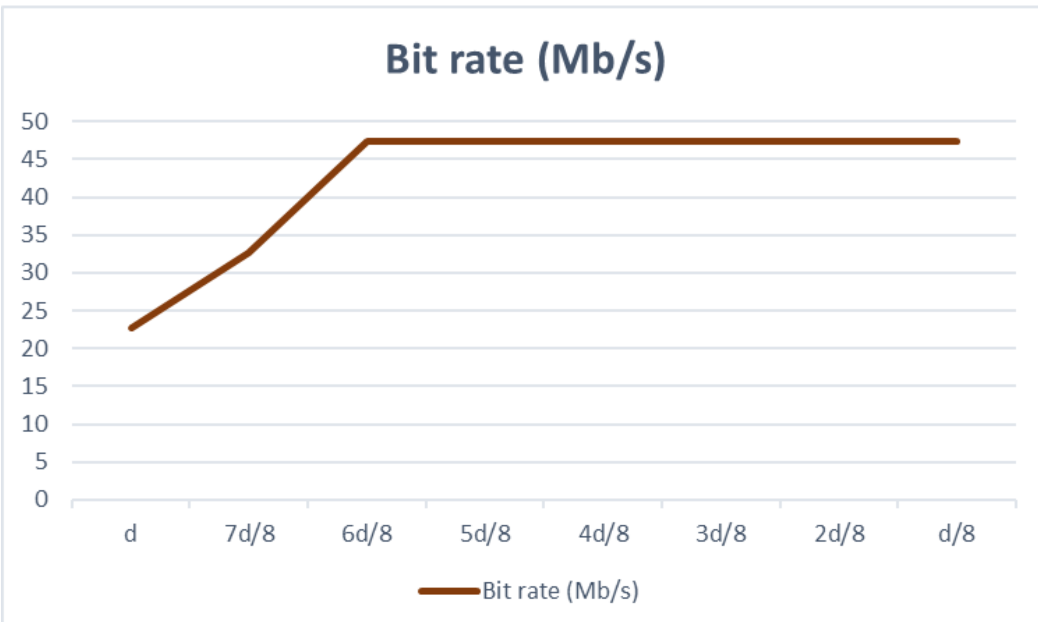


Figure 3. Bit-rate vs Distance for the Cost231 model

3- Friis Propagation Loss Model:

The following equation represents the mathematical formulation of the Friis propagation model:
Where:

$$P_r^{[\text{dB}]} = P_t^{[\text{dB}]} + G_t^{[\text{dBi}]} + G_r^{[\text{dBi}]} + 20\log_{10}\left(\frac{\lambda}{4\pi d}\right)$$

- *Pr* is the power of the received signal in dBm.
- *Pt* is the transmitted power in dBm.
- *Gt & Gr* are the antenna gains for the transmitter and receiver respectively
- λ is the wavelength for the transmission in meters.
- *d* is the distance between the transmitter and the receiver in meters.

Parameters values from the script*:*

Pr=-80dbm, Pt=16dbm, Gt=Gr=0 db, f=5.15 GHz, lambda = 0.058 m

By substituting in Friis equation => ***d = 292 m***

The following table shows the corresponding Bit rate (Mb/s) for each distance in the set D = {*di, 7di/8, 6di/8, ..., di/8*}.

Table 3. Simulation results for the Friis model

Distance	Distance (m)	Time at Sender (s)	Time at Receiver (s)	Total time (s)	Sent Bits	Bit rate (Mb/s)
d	292	16.000454	16.00083	0.000376	8512	22.63829787
7d/8	255.5	16.000454	16.00083	0.000376	8512	22.63829787
6d/8	219	16.002404	16.002664	0.00026	8512	32.73846154
5d/8	182.5	16.000392	16.000592	0.0002	8512	42.56
4d/8	146	16.000034	16.000214	0.00018	8512	47.28888889
3d/8	109.5	16.000034	16.000214	0.00018	8512	47.28888889
2d/8	73	16.000034	16.000214	0.00018	8512	47.28888889
d/8	36.5	16.000034	16.000214	0.00018	8512	47.28888889

The results shown in the previous table are plotted in the following graph.

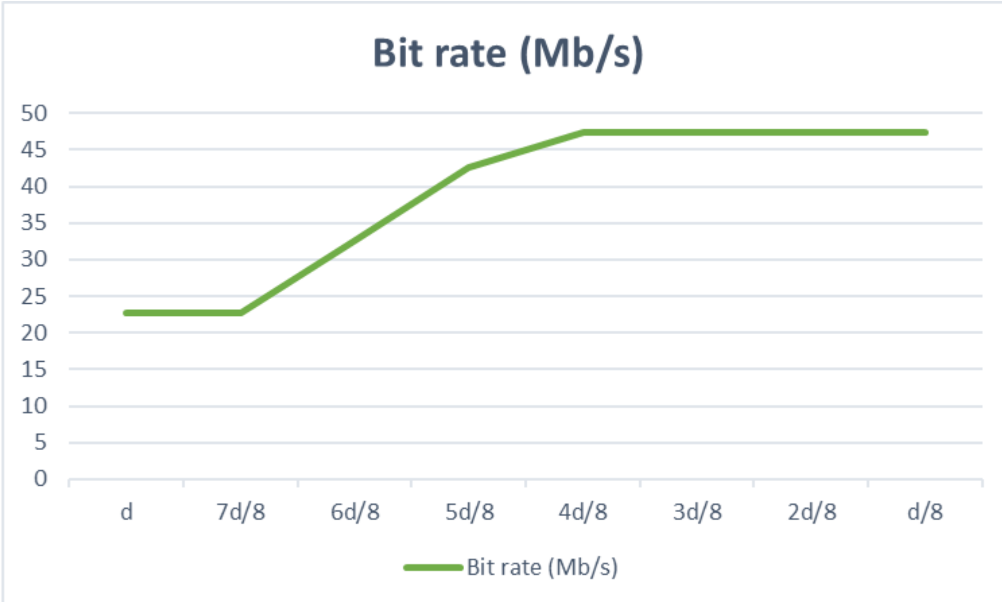
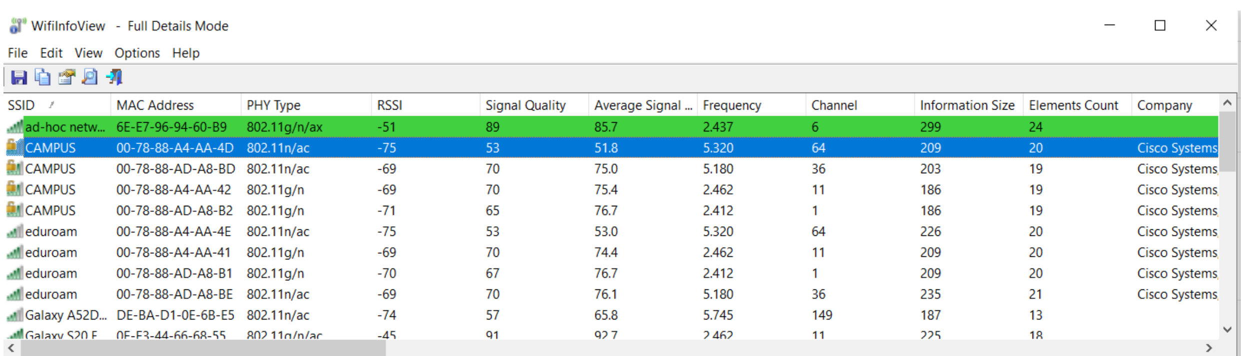


Figure 4. Bit-rate vs Distance for the Friis model

PART II: Practical Scenario: measurements in a real environment

Our experiment was conducted based on the steps below:

1. Creating a hotspot on a Samsung S22 Ultra phone with a transmission power level of 24 dBm, and connecting to the network using a Lenovo laptop.
2. Wifiinfoview software was installed on the laptop to measure the RSSI, as shown in the following snap.



WifiInfoView - Full Details Mode

File Edit View Options Help

SSID	MAC Address	PHY Type	RSSI	Signal Quality	Average Signal ...	Frequency	Channel	Information Size	Elements Count	Company
ad-hoc netw...	6E-E7-96-94-60-B9	802.11g/n/ax	-51	89	85.7	2.437	6	299	24	
CAMPUS	00-78-88-A4-AA-4D	802.11n/ac	-75	53	51.8	5.320	64	209	20	Cisco Systems
CAMPUS	00-78-88-AD-A8-BD	802.11n/ac	-69	70	75.0	5.180	36	203	19	Cisco Systems
CAMPUS	00-78-88-A4-AA-42	802.11g/n	-69	70	75.4	2.462	11	186	19	Cisco Systems
CAMPUS	00-78-88-AD-A8-B2	802.11g/n	-71	65	76.7	2.412	1	186	19	Cisco Systems
eduroam	00-78-88-A4-AA-4E	802.11n/ac	-75	53	53.0	5.320	64	226	20	Cisco Systems
eduroam	00-78-88-A4-AA-41	802.11g/n	-69	70	74.4	2.462	11	209	20	Cisco Systems
eduroam	00-78-88-AD-A8-B1	802.11g/n	-70	67	76.7	2.412	1	209	20	Cisco Systems
eduroam	00-78-88-AD-A8-BE	802.11n/ac	-69	70	76.1	5.180	36	235	21	Cisco Systems
Galaxy A52D...	DE-BA-D1-0E-6B-E5	802.11n/ac	-74	57	65.8	5.745	149	187	13	
Galaxy S20 F...	0E-F3-44-66-68-55	802.11g/n/ac	-45	91	92.7	2.462	11	225	18	

Figure 5. wifiinfoview software

3. The RSSI levels were measured at different transmission distances while moving at steps of 1 meter at a time. The experiment was conducted following the same path illustrated in figure 6 (30 measurements for 30 meters straight along the corridor & one measurement 10 meters after turning).

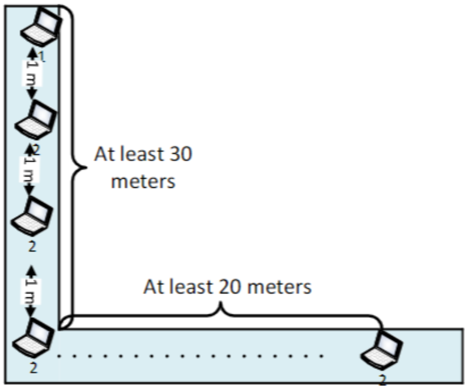


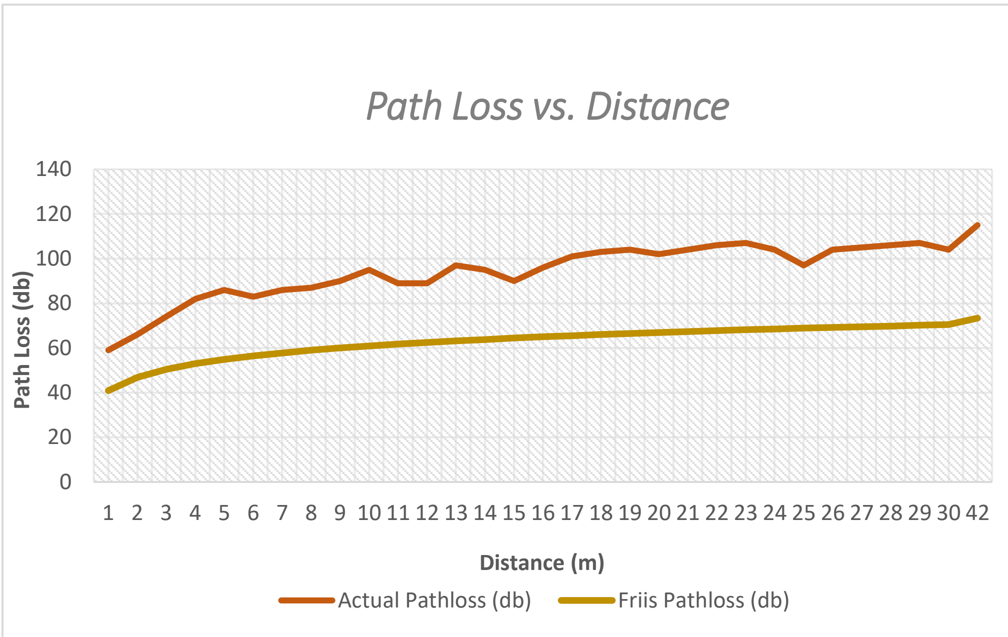
Figure 6. Setup for the experiment

Table 4. Measured RSSI levels & Path loss values for different distances.

Disatnce (m)	RSSI (dbm)	Actual Pathloss (db)	Friis Pathloss (db)
1	-35	59	40.8909729
2	-42	66	46.91157281
3	-50	74	50.43339799
4	-58	82	52.93217272
5	-62	86	54.87037298
6	-59	83	56.4539979
7	-62	86	57.7929337
8	-63	87	58.95277264
9	-66	90	59.97582308
10	-71	95	60.8909729
11	-65	89	61.7188266
12	-65	89	62.47459782
13	-73	97	63.16983994
14	-71	95	63.81353361
15	-66	90	64.41279808
16	-72	96	64.97337255
17	-77	101	65.49995132
18	-79	103	65.996423
19	-80	104	66.46604491
20	-78	102	66.91157281
21	-80	104	67.33535879
22	-82	106	67.73942651
23	-83	107	68.12552962
24	-80	104	68.49519773
25	-73	97	68.84977307
26	-80	104	69.19043986
27	-81	105	69.51824818
28	-82	106	69.83413352
29	-83	107	70.13893285
30	-80	104	70.43339799
42	-91	115	73.3559587

4. The actual path loss values were calculated from the RSSI measurements using the following formula: *path loss* (dB)= *Tx power* (dB) – *RSSI*(dBm). Additionally, the Friis model formula was used to calculate the theoretical path loss for each distance. The values for RSSI, Actual, and theoretical path losses are shown in table 4.

The following graph illustrates the path loss values at different distances for our experiment as well as the friis propagation model.



Does the Friis model mimic the behavior of measured path loss? If not, why?

The actual path loss and Friis path loss trends are similarly increasing with distance. However, the Friis propagation model shows lower path loss values compared to our measured values for each distance. The reason behind this is as follows: the Friis model only considers the free space LOS path loss, antenna gains, and the wavelength when relating the received and the transmitted powers, it doesn't consider the existence of any surrounding buildings and objects that create diffraction, scattering, absorption, and reflections. The presence of these objects leads to multipath propagation and shadowing which will have a destructive impact on the signal power level as seen by the receiver antenna, as demonstrated in our experiment.