ITIS 6010/8010 Wireless Network Security

Project 1: Feasibility and accuracy of indoor localization through WLAN

Assignment Submitted By:

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I. Software and Tools Used:

- Netspot Application in the Receiver(Laptop) - Arbitrary node.
- Android Phones as Anchor Nodes
- Matlab R2018b for multi-dimensional scaling

II. First Phase - Readings & Calculation of Alpha (α):

We set up 4 anchor nodes namely **A1, A2, A3** and **A4** at 4 different locations inside a classroom and we used another laptop with Netspot application installed as a receiver to recorded the signal strength(dBm) between the anchor nodes and the receiver at 9 different locations. In addition to that, we also recorded the actual distance(inch) of the receiver node from the Anchor nodes using a measuring tape.

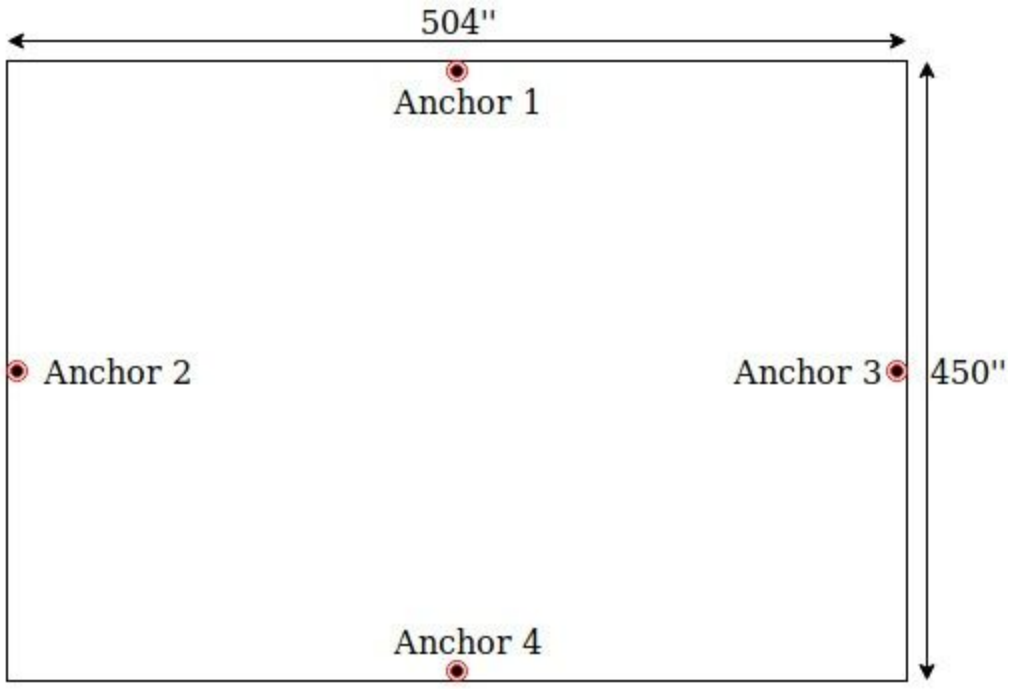
$$P_{(dBm)} = 10 \cdot \log_{10}(P_{(mW)} / 1mW)$$

We converted the signal strength from dBm to milliwatts using the following formula:

We used the readings to calculate values of Alpha(α) corresponding to those readings using the formula assuming that the “Transmitted signal strength is 1”:

$$Received\ Signal\ Strength = 1/ d^{\alpha}$$

The Environment:



We measured readings of 9 different nodes placing them at different locations in the environment. The readings are as follows:

Distance of the receiver nodes 1-9 from Anchor 1:

Nodes	Signal 1 (dBm)	Signal 1 (mW)	Noise 1	Distance 1	Alpha
1	-44	0.00003981071706	-92	169.25	1.9744
2	-50	0.00001	-92	113	2.43537
3	-44	0.00003981071706	-92	169.25	1.9744
4	-48	0.00001584893192	-92	258.75	1.98932
5	-46	0.00002511886432	-92	226	1.95403
6	-45	0.0000316227766	-92	258.75	1.86499
7	-48	0.00001584893193	-92	361.66	1.8762
8	-54	0.000003981071706	-92	334	2.13968
9	-53	0.000005011872336	-92	361.66	2.07169

Distance of the receiver nodes 1-9 from Anchor 2:

Nodes	Signal 2 (dBm)	Signal 2 (mW)	Noise 2	Distance 2	Alpha
1	-44	0.00003981071706	-92	187.61	1.93555
2	-48	0.00001584893192	-92	287.8	1.95194
3	-51	0.000007943282347	-92	402.75	1.95775
4	-41	0.00007943282347	-92	126	1.95204
5	-40	0.0001	-92	252	1.66569
6	-49	0.00001258925412	-92	378	1.90107
7	-46	0.00002511886432	-92	169.92	2.0625
8	-50	0.00001	-92	276.59	2.04764
9	-53	0.000005011872336	-92	394.82	2.04129

Distance of the receiver nodes 1-9 from Anchor 3:

Nodes	Signal 3 (dBm)	Signal 3 (mW)	Noise 3	Distance 3	Alpha
1	-42	0.00006309573445	-92	394.24	1.618
2	-49	0.00001258925412	-92	275.79	2.007
3	-48	0.00001584893193	-92	168.58	2.1555
4	-50	0.00001	-92	378	1.9398
5	-43	0.00005011872336	-92	252	1.7906
6	-41	0.00007943282347	-92	126	1.952
7	-49	0.00001258925412	-92	393.96	1.8879
8	-46	0.00002511886432	-92	275.36	1.8853
9	-43	0.00005011872336	-92	167.92	1.9325

Distance of the receiver nodes 1-9 from Anchor 4:

Nodes	Signal 4 (dBm)	Signal 4 (mW)	Noise 4	Distance 4	Alpha
1	-51	0.000007943282347	-92	359.78	1.99528
2	-54	0.000003981071706	-92	337	2.13639
3	-53	0.000005011872336	-92	359.78	2.07352
4	-55	0.00000316227766	-92	257	2.28222
5	-53	0.000005011872336	-92	224	2.25508
6	-54	0.000003981071706	-92	257	2.24073
7	-50	0.00001	-92	167.92	2.24709
8	-49	0.00001258925412	-92	116	2.3735
9	-56	0.000002511886432	-92	167.92	2.51674

Then, using the above values of Alpha, we calculated the average Alpha as “2.03”.

Avg Alpha:	
A1	2.03112
A2	1.946163333
A3	1.907622222
A4	2.235616667
Average :	2.030130556

III. Second Phase (Localization and Error calculation using Matlab)

We then recorded the signal strength and distance between the anchor nodes and the receiver for 5 random points (R1 - R5). Then, using the values of Signal strength (mW) the calculated Alpha value, we also calculated the distance between anchor nodes and receiver using the previously used formula.
The readings are as follows:

Nodes	Signal 1 (dBm)	Signal 2 (dBm)	Signal 3 (dBm)	Signal 4 (dBm)
R1	-52	-50	-48	-50
R2	-53	-51	-48	-38
R3	-55	-54	-38	-52
R4	-45	-51	-40	-55
R4	-50	-45	-48	-59

Converting these values to milliwatts (mW), we calculated the distances from the receiver nodes to the Anchor nodes. Following is a table of the Actual distances VS the Calculated distances.

Nodes	Actual Dist. (A1)	Calc. Dist. (A1)	Actual Dist. (A2)	Calc. Dist. (A2)	Actual Dist. (A3)	Calc. Dist (A3)	Actual Dist. (A4)	Calc. Dist. (A4)
R1	79.404	364.6	190.41	146.7	260.21	237.8	414.61	146.7
R2	445.61	408.6	300.62	362.2	368.42	237.8	45.54	76.5
R3	455.29	408.16	493.96	457.19	185.29	74.46	212.81	364.39
R4	289.7	164.72	432.004	325.32	72.02	93.42	286.58	512.11
R4	131.03	290.44	213.96	164.72	404.62	231.49	408.13	806.13

Multidimensional Scaling:

We used MATLAB for multidimensional scaling and we used an inbuilt function (cmdscale). This function takes an N*N matrix as input and scales it thereby providing coordinates of N nodes as the output.

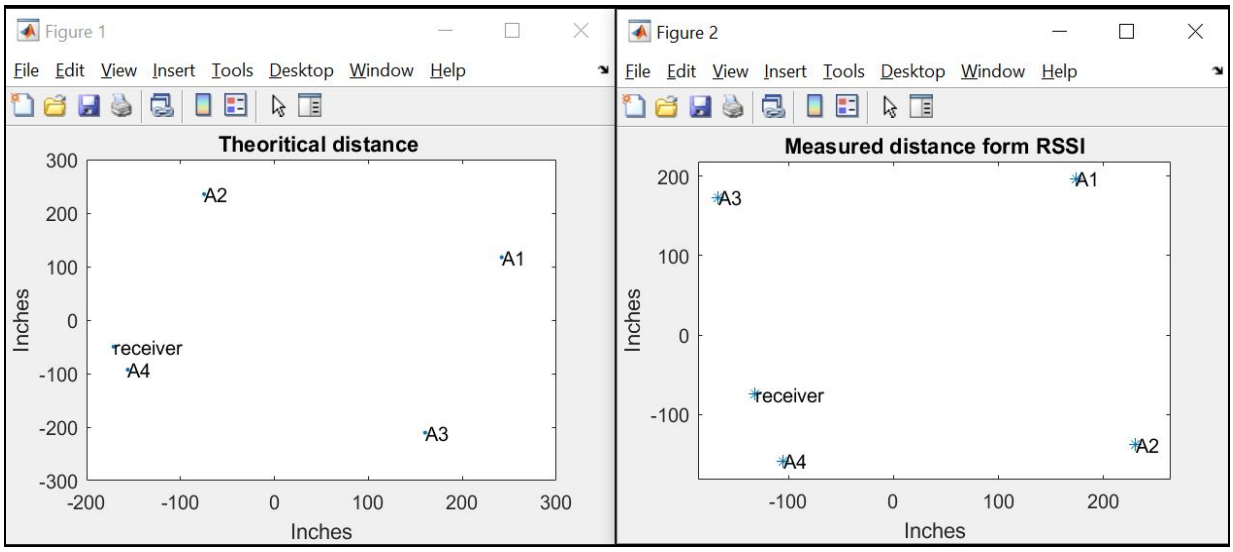
Below are the matrices of R2 - Actual distances and Measured distances from RSSI that we used in Matlab.

Readings for R2:

Theoretical Dist.	R2	A1	A2	**A3**	A4
R2	**0**	**445.61**	**300.62**	**368.42**	**45.54**
A1	**445.61**	0	337.8	337.8	450
A2	**300.62**	337.8	0	504	337.8
A3	**368.42**	337.8	504	0	337.8
A4	**45.54**	450	337.8	337.8	0

Measured Dist.	R2	A1	A2	**A3**	A4
R2	**0**	**408.64**	**362.2**	**237.8**	**76.5**
A1	**408.6**	0	337.8	337.8	450
A2	**362.2**	337.8	0	504	337.8
A3	**237.8**	337.8	504	0	337.8
A4	**76.5**	450	337.8	337.8	0

The Matlab Scaling output:



Localization Error:

Along with the scaling, Matlab also provided X and Y coordinates as shown below. We used these numbers to calculate the error using the distance formula **d=sqrt((x2−x1)^2+(y2−y1)^2)**

Errors	**x**	**y**		**x**	**y**	**d**	**d'**	**| d - d' |**
R2	-171.21	-49.664	**R2**	-131.99	-74.201			
A1	241.85	117.45	**A1**	173.57	196.82	445.48	408.3	37.18
A2	-74.862	235.27	**A2**	230.24	-137.63	300.67	367.6	67
A3	160.38	-210.47	**A3**	-166.81	173.03	368.4	249.6	118.8
A4	-156.15	-92.589	**A4**	-105.01	-158.02	45.47	88.02	42.55
								Average = 66.38

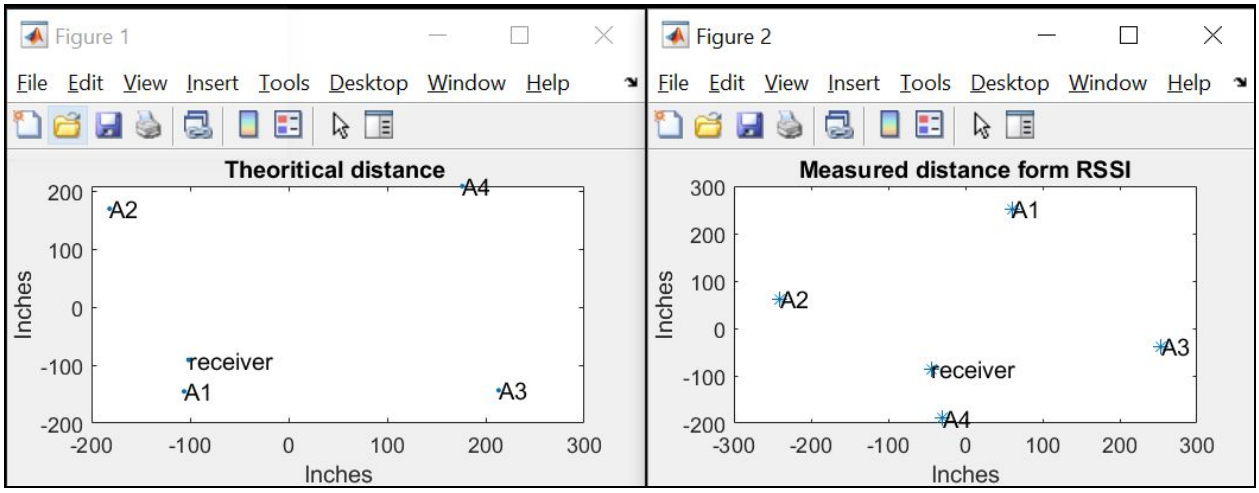
Thus we found a **localization error of 66.38 inches for R2**.

Similarly, we calculated the errors for other receiver points. Below are the screenshots for the readings of R1, R3, R4, and R5.

Readings for R1:

Theoretical Dist.	R1	A1	A2	**A3**	A4
R1	**0**	**79.404**	**190.41**	**260.21**	**414.61**
A1	**79.404**	0	337.8	337.8	450
A2	**190.41**	337.8	0	504	337.8
A3	**260.21**	337.8	504	0	337.8
A4	**414.61**	450	337.8	337.8	0

Measured Dist.	R1	A1	A2	**A3**	A4
R1	**0**	**364.6**	**146.7**	**237.8**	**146.7**
A1	**364.6**	0	337.8	337.8	450
A2	**146.7**	337.8	0	504	337.8
A3	**237.8**	337.8	504	0	337.8
A4	**146.7**	450	337.8	337.8	0

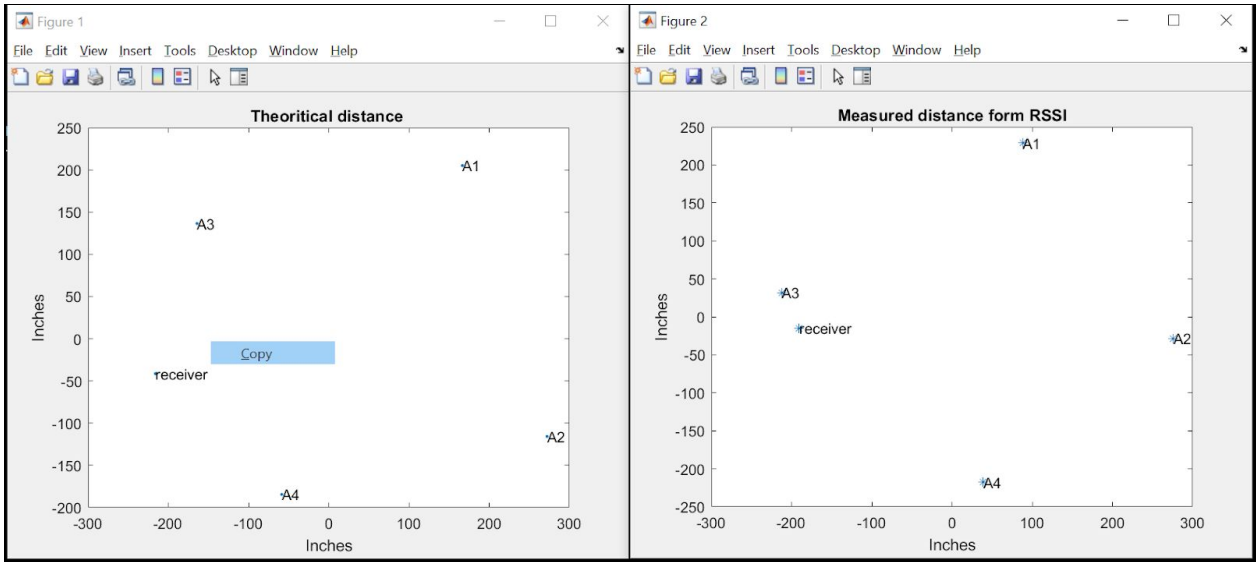


Errors	x	y		x	y	d	d'	| d - d' |
R1	-101.58	-90.723	**R1**	-44.228	-85.716			
A1	-106.01	-145.18	**A1**	60.529	251.93	54.63	353.52	298.89
A2	-181.73	170.07	**A2**	-240.31	61.899	272.83	245.43	27.4
A3	213.15	-143.23	**A3**	253.64	-38.569	319.07	301.58	17.49
A4	176.18	209.06	**A4**	-29.633	-189.55	408.68	104.85	303.83
								Average = 161.9

Readings for R3:

Theoretical Dist.	R3	A1	A2	**A3**	A4
R3	**0**	**455.29**	**493.96**	**185.29**	**212.81**
A1	**455.29**	0	337.8	337.8	450
A2	**493.96**	337.8	0	504	337.8
A3	**185.29**	337.8	504	0	337.8
A4	**212.81**	450	337.8	337.8	0

Measured Dist.	R3	A1	A2	**A3**	A4
R3	**0**	**408.16**	**457.19**	**74.46**	**364.39**
A1	**408.16**	0	337.8	337.8	450
A2	**457.19**	337.8	0	504	337.8
A3	**74.46**	337.8	504	0	337.8
A4	**364.39**	450	337.8	337.8	0

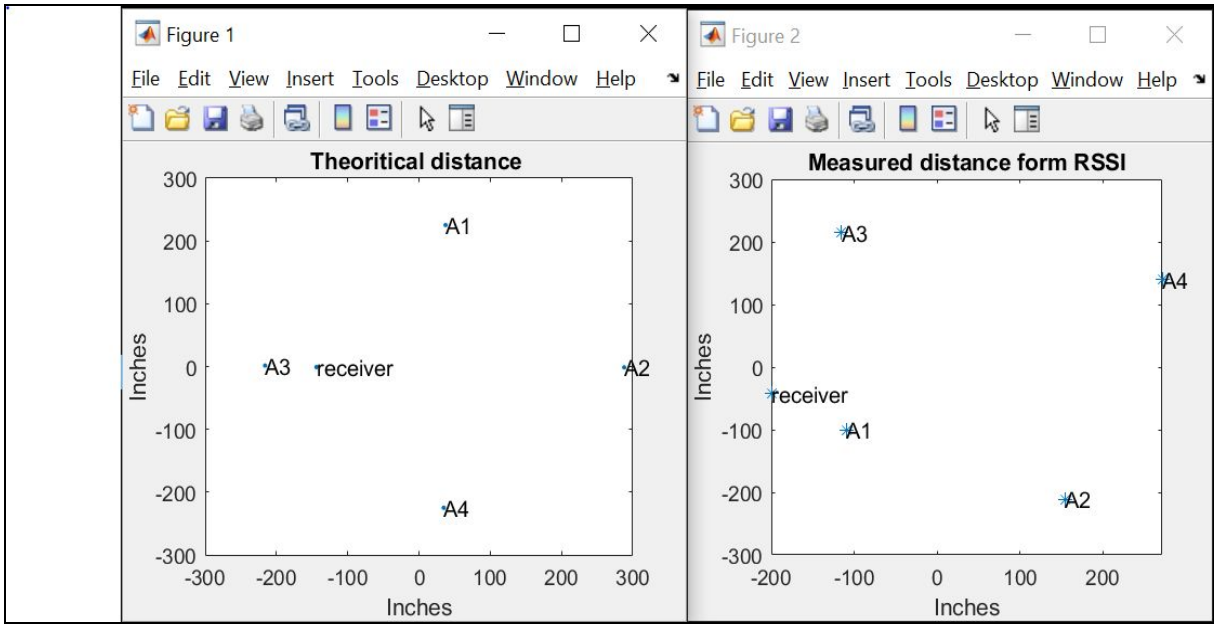


Errors	x y		x y	d	d’	| d - d’ |
R3	-216.08 -41.324		-190.55 -14.89			
A1	166.64 205.12		88.05 229.03	455.2	351.39	103.81
A2	272.18 -115.81		275.89 -28.351	493.91	466.63	27.28
A3	-164.14 136.47		-212.2 31.755	185.22	51.42	133.8
A4	-58.6 -184.45		38.811 -217.54	212.8	306.06	93.26
						Average = 89.54

Readings for R4:

Theoretical Dist.	R4	A1	A2	**A3**	A4
R4	**0**	**289.7**	**432.004**	**72.02**	**286.58**
A1	**289.7**	0	337.8	337.8	450
A2	**432.004**	337.8	0	504	337.8
A3	**72.02**	337.8	504	0	337.8
A4	**286.58**	450	337.8	337.8	0

Measured Dist.	R4	A1	A2	**A3**	A4
R4	**0**	**164.72**	**325.32**	**93.42**	**512.11**
A1	**164.72**	0	337.8	337.8	450
A2	**325.32**	337.8	0	504	337.8
A3	**93.42**	337.8	504	0	337.8
A4	**512.11**	450	337.8	337.8	0



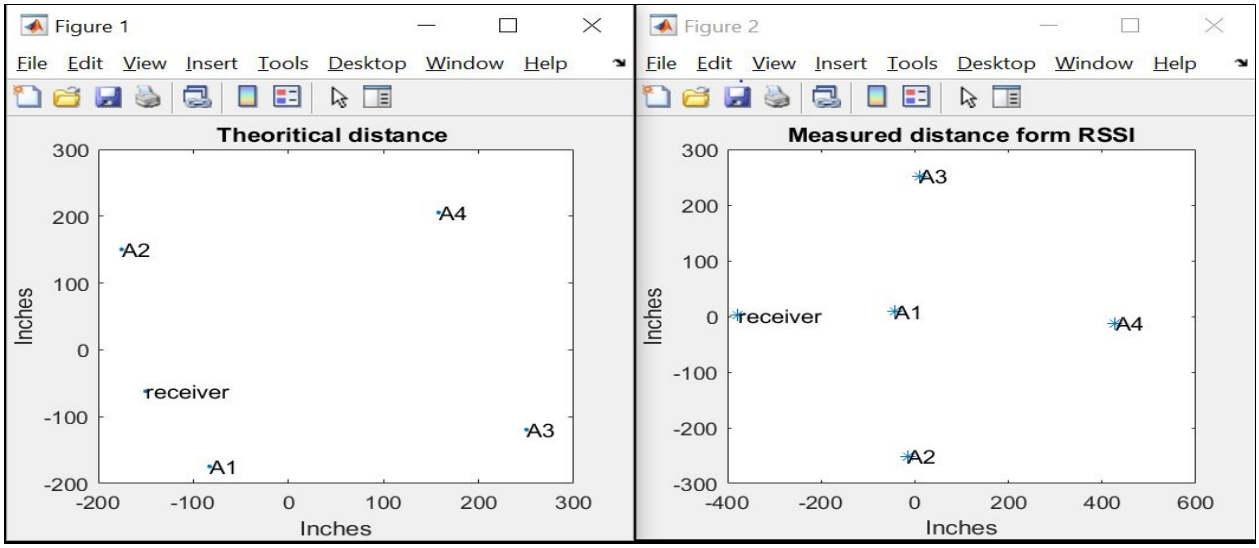
Errors	x	y		x	y	d	d'	| d - d' |
R4	-144	-0.81684		-200.41	-42.655			
A1	37.28	225.2		-109.67	-100.56	249.95	107.64	142.31
A2	288	-1.2343		154.23	-211.14	144	392.63	248.63
A3	-215.99	1.6428		-115.65	214.96	359.99	271	88.99
A4	34.711	-224.79		271.5	139.39	249.21	505.8	256.59
								Average = 184.13

Readings for R5:

Theoretical Dist.	R5	A1	A2	**A3**	A4
R5	**0**	**131.03**	**213.96**	**404.62**	**408.13**
A1	**131.03**	0	337.8	337.8	450
A2	**213.96**	337.8	0	504	337.8
A3	**404.62**	337.8	504	0	337.8
A4	**408.13**	450	337.8	337.8	0

Measured Dist.	R5	A1	A2	**A3**	A4
R5	**0**	**290.44**	**164.72**	**231.49**	**806.13**
A1	**290.44**	0	337.8	337.8	450
A2	**164.72**	337.8	0	504	337.8

A3	**231.49**	337.8	504	0	337.8
A4	**806.13**	450	337.8	337.8	0



Errors	**x**	**y**		**x**	**y**	**d**	**d'**	**| d - d' |**
R5	-150.14	-62.051		-378.53	1.879			
A1	-82.901	-174.54		-42.984	8.6062	131.05	335.61	204.56
A2	-175.33	150.4		-15.587	-250.94	213.94	442.34	228.4
A3	250.39	-119.38		9.2245	252.52	404.61	461.7	57.09
A4	157.97	205.57		427.88	-12.059	402.85	806.53	403.68
								Average= 223.43

Conclusion:

Thus the Average errors that we got are 161.9, 66.38, 89.54, 184.13 and 223.43. If we average all these errors, we get the **Average error as 145.07 inches.** The readings tell us that currently, the accuracy and feasibility isn't as expected as a modern localization technique should be. This can be due to various factors viz. - device errors, environment errors and human errors. We have compiled a list of sources that the current errors should be induced from.

Sources of the Errors:

We notice that the theoretically measured location values and the values calculated by using RSSI and Alpha differ to the actual values with an average error of around 145.07 inches. The potential reasons for this are as follows:

1. **Device errors:** The devices used for setting up as Anchor nodes are different and have some differences. This can lead to different values of depreciation of the signal. The

device battery might also play a role in the errors as the device might be programmed to lower the propagation power of the WiFi signal when the battery falls lower than a certain percentage.

2. **Environmental errors:** The air, as a medium is quite inconsistent and this can lead to varying values of signal loss on a time scale t. Also, there might be other RF signals interfering with the WiFi signals. Thus, this can easily induce an error on the calculation of the location using RSSI.
3. **Obstacles:** Obstacles act as a hindrance to the propagation of signals. A human body in the path of the signal will also affect the readings, especially if a person's back is facing the Anchor node in the line of communication while holding the receiver.
4. **Device positioning:** Different angles of a device, thereby resulting in different angles of the device antenna, result in varying signal propagation and reception. This can easily lead to errors in measurements like the one we did.