FFinal- 659 - Assignment 3(Q4.)

August 3, 2021

[1]:
```python
# Importing all neccessary liberaries
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
%matplotlib inline
from sklearn import metrics
import math
from mpl_toolkits import mplot3d
```

0.0.1 Received Signal Strength Indicator (RSSI):

This technology is commonly used for wireles indoor localization or postioning systems. In this, a log-distance path loss model is built. This model is obtained by curve fitting and the locations are determined by wighted least square algorithms. Another RSSI-based methods includes Fingerprint lacalization. The logarithmic-distance pathh loss model of RSSI is represented as: #### RSSI = -10 n log(d/do) + A + X where, d is distance between transmitter and receiver , n is path-loss parameter, A is the RSSI with distance do from the transmitter, and X is the random variable of Gaussian-distribution with mean as 0 and sigma**2. Usually, do value is assumed as 1m, So, the above equation can also be written as: #### RSSI = -10 n log(d) + A

0.1 Part 1):

In this part , the values for path-loss parameter and A is known, So, using the simplified second equation above, the RSSI mean readings will be calculated ranging from distance d=1 to d=140. Here, a function named RSSI_profile will be created which will return the list of RSSI values of varying distance range.

0.1.1 Calculating RSSI values varying from d = 1 to 140:

[2]:
```python
# Function that returns the RSSI profile varying from d=1 to 140 at fixed n, A_
↪and standard deviation as 0
def RSSI_profile(n,A_):
    RSSI_list =[]
    for d in range(1,141):
        RSSI_ = -10 * n * math.log(d) + A_
        RSSI_list.append(RSSI_)
    return RSSI_list
```

```python
# setting n and A_ values
n= 4
A_ = -50

# Retreiving values of RSSI
RSSI_ = RSSI_profile(n,A_)

# Converting list of RSSI values in dataframe with respective distances
RSSI_df = pd.DataFrame(np.arange(1,141),columns= ['distance(d)'])
RSSI_df['RSSI']=RSSI_

# Displaying the dataframe
print('The RSSI profile from distance 1 to 140 is as following table:')
display(RSSI_df)
```

```
The RSSI profile from distance 1 to 140 is as following table:

     distance(d)        RSSI
0              1  -50.000000
1              2  -77.725887
2              3  -93.944492
3              4 -105.451774
4              5 -114.377516
..           …          …
135          136 -246.506195
136          137 -246.799237
137          138 -247.090147
138          139 -247.378957
139          140 -247.665697

[140 rows x 2 columns]
```

0.2 Part 2):

- The first step in this part is to calculate the co-ordinates of tiles. As, provided in instructions that, the tiles are square shaped and the distance will calculated from their centers. Thus, a function tile_co() is created to return center values of x and y co-ordinates(As , z is zero on floor of tiles).
- Then, from the calculated co-ordinates , the distance from three devices will be calculated using least square algorithm, which is : #### d^2 = (x1-x)^2 + (y1-y)^2 + (z1-z)^2
- Therefore, the distances will be returned by function dist().
- Furthermore, the RSSI values with random variable having standard deviation of 5.1 , will be calculated calling fingerprint() function and appended in a list.
- Atlast, for better view of results, a table will be created having tile no. , x and y co-ordinates , RSSI values of all three devices at that particular location and tile.

0.2.1 Creating x and y co-ordinates of tile centers:

[3]:
```
# Function that returns x and y center coordinates
def tile_co(x,y):
    x_ ,y_ =[],[]

    # for x-axis center coordinates
    for i in range(1,x*2,2):
        x_.append(i/2)

    # for y-axis center coordinates
    for j in range(1,y*2,2):
        y_.append(j/2)
    return x_ ,y_

# calling function to get x and y centers given particular values
x_cent , y_cent =tile_co(100,60)
```

0.2.2 Calculating distance of all three devices from different tile's centers:

[4]:
```
# settinf values of co=ordinates of three devices
X1, Y1, Z1 = 0 , 30, 3
X2, Y2, Z2 = 50 , 60, 4
X3, Y3, Z3 = 100 , 30, 3

# Function that returns distance of given coordinates from list of center␣
↪coordinates calculated above
def dist(x,y,z,xcent,ycent):
    dist=[]
    for i in xcent:
        for j in ycent:
            dist.append(math.sqrt((i-x)**2 + (j-y)**2 + (0-z)**2))
    return dist

# Getting distance values for first device
first_dist= dist(X1, Y1, Z1,x_cent,y_cent)

# Getting distance values for second device
second_dist= dist(X2, Y2, Z2,x_cent,y_cent)

# Getting distance values for third device
third_dist= dist(X3, Y3, Z3,x_cent,y_cent)
```

0.2.3 Calculating RSSI of all three devices from different tile's centers:

[5]:
```
# Generating random number for normal distribution with mean as 0 and standard␣
↪deviation as 5.1
x_rand =np.random.normal(scale = 5.1)

# Function that returns the RSSI values provided distances for given device
def fingerprint(dist,xrand):
    RSSI_list =[]
    for d in dist:
        RSSI_ = -10 * n * math.log(d) + A_ + x_rand
        RSSI_list.append(RSSI_)
    return RSSI_list

# Getting RSSI values for first device
first_fp= fingerprint(first_dist,x_rand)

# Getting RSSI values for second device
second_fp= fingerprint(second_dist,x_rand)

# Getting RSSI values for third device
third_fp= fingerprint(third_dist,x_rand)
```

0.2.4 Creating table 2) consisting of RSSI values and their locations:

[6]:
```
# Getting x and y values for df
x=[]
y=[]
for i in range(1,100*2,2):
    for j in range(1,60*2,2):
        x.append(i/2)
        y.append(j/2)

# Creating table that shows RSSI values of all three devices with grid tile␣
↪number and respective x and y co-ordinates.
RSSI_device = pd.DataFrame(np.arange(1,len(first_fp)+1),columns = ['Grid_tile'])
RSSI_device['X']= x
RSSI_device['Y']=y
RSSI_device['RSSI1'] = first_fp
RSSI_device['RSSI2'] = second_fp
RSSI_device['RSSI3'] = third_fp

# Displaying the table
print('The table that shows RSSI values of all three devices with their grid␣
↪tile number and,respective x and y co-ordinates is as follows: ')
display(RSSI_device)
```

```
The table that shows RSSI values of all three devices with their grid tile
```

```
number and,respective x and y co-ordinates is as follows:

      Grid_tile     X     Y       RSSI1       RSSI2       RSSI3
0             1   0.5   0.5 -184.621888 -223.046767 -234.742846
1             2   0.5   1.5 -183.257456 -222.649949 -234.634944
2             3   0.5   2.5 -181.845401 -222.252028 -234.530207
3             4   0.5   3.5 -180.382325 -221.853099 -234.428689
4             5   0.5   4.5 -178.864456 -221.453265 -234.330441
…           …     …     …           …           …           …
5995       5996  99.5  55.5 -234.330441 -205.407445 -178.864456
5996       5997  99.5  56.5 -234.428689 -205.342993 -180.382325
5997       5998  99.5  57.5 -234.530207 -205.294518 -181.845401
5998       5999  99.5  58.5 -234.634944 -205.262136 -183.257456
5999       6000  99.5  59.5 -234.742846 -205.245925 -184.621888

[6000 rows x 6 columns]
```

0.3 Part 3):

- Here, a roaming device is given with its location co-ordinates. So, its distance from all other three devices will be calculated.
- Once, distance is known , the RSSI values can be retreived by using RSSI equation mentioned.
- Here also, the random variable of gaussian distribution is added in calculation of RSSI values.
- Moreover, for better view of the three devices and the roaming device , a figure is plotted which also tells the distances between all roaming device and all other three devices.
- The function roaming_device_RSSI is implemented to perform above operations.

0.3.1 Calculating RSSI readings of roaming device from all three devices:

[7]:
```
# Settind co-ordinates of roaming device
XR, YR, ZR = 30, 45, 0
# Generating random number for normal distribution with mean as 0 and standard␣
↪deviation as 5.1
x_rand =np.random.normal(scale = 5.1)

# Function that returns RSSI of roaming device from given device
def roaming_device_RSSI(x,y,z,xrand):
    # Getting distance value of roaming device from given device
    roaming_device_dist = math.sqrt(((XR-0.5)-x)**2 + ((YR-0.5)-y)**2 +␣
↪(ZR-z)**2)
    # Getting RSSI value of roaming device from given device
    roaming_device_RSSI = -10 * n * math.log(roaming_device_dist) + (A_) + xrand
    return roaming_device_RSSI , roaming_device_dist

# Getting RSSI value of roaming device from first device
roaming_first_RSSI, roaming_first_dist = roaming_device_RSSI(X1, Y1, Z1,x_rand)

# Getting RSSI value of roaming device from second device
```

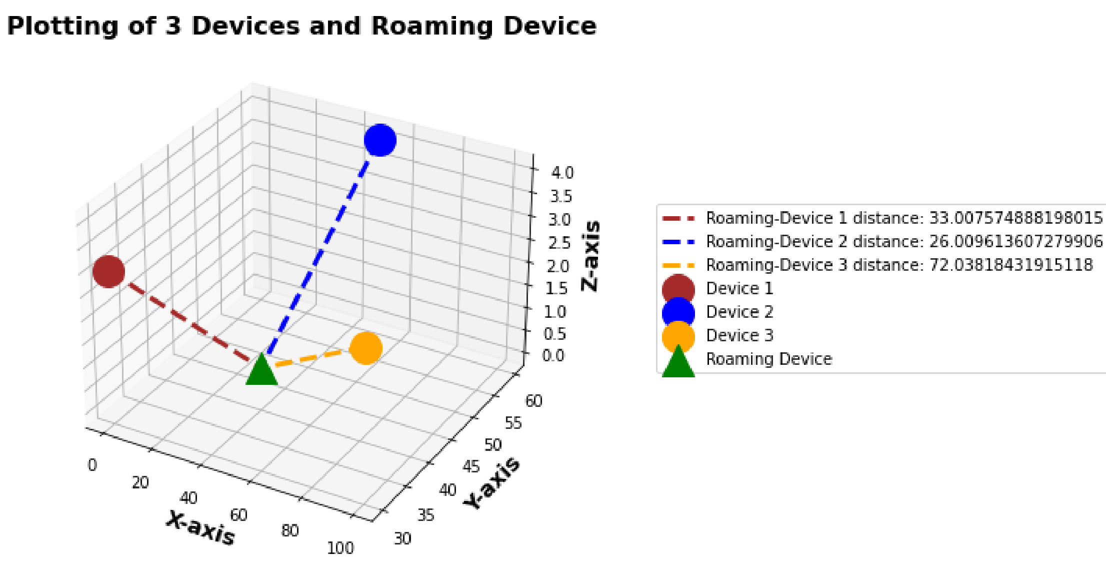
```
roaming_second_RSSI, roaming_second_dist = roaming_device_RSSI(X2, Y2,␣
↪Z2,x_rand)

# Getting RSSI value of roaming device from third device
roaming_third_RSSI, roaming_third_dist = roaming_device_RSSI(X3, Y3, Z3,x_rand)

# Displaying the values
print('1) Iteration')
print('The RSSI of roaming device from first device is {}'.
↪format(roaming_first_RSSI))
print('The RSSI of roaming device from second device is {}'.
↪format(roaming_second_RSSI))
print('The RSSI of roaming device from third device is {}'.
↪format(roaming_third_RSSI))
```

```
1) Iteration
The RSSI of roaming device from first device is -195.2173463580812
The RSSI of roaming device from second device is -185.68651222260456
The RSSI of roaming device from third device is -226.4357159184946
```

0.3.2 Visual representation of location of 3 Devices and Roaming device:

[8]:
```
plt.figure(figsize=(10,6))
ax = plt.axes(projection = '3d')
ax.scatter(X1,Y1,Z1, color='brown', s = 400 ,label='Device 1')
ax.plot([X1,XR],[Y1,YR],[Z1,ZR], color = 'brown', linestyle ='dashed',linewidth␣
↪=3,
        label ='Roaming-Device 1 distance: {}'.format(roaming_first_dist) )
ax.scatter(X2,Y2,Z2, color='blue', s = 400 ,label='Device 2')
ax.plot([X2,XR],[Y2,YR],[Z2,ZR], color = 'blue', linestyle ='dashed',linewidth␣
↪=3,
        label ='Roaming-Device 2 distance: {}'.format(roaming_second_dist) )
ax.scatter(X3,Y3,Z3, color='orange', s = 400 ,label='Device 3')
ax.plot([X3,XR],[Y3,YR],[Z3,ZR], color = 'orange', linestyle␣
↪='dashed',linewidth =3,
        label ='Roaming-Device 3 distance: {}'.format(roaming_third_dist) )
ax.scatter(XR,YR,ZR, color='green' , marker='^', s = 400 ,label='Roaming␣
↪Device')
ax.legend(bbox_to_anchor = (2.1,0.7))
ax.set_xlabel('X-axis',fontweight='bold',fontsize=14)
ax.set_ylabel('Y-axis',fontweight='bold',fontsize=14)
ax.set_zlabel('Z-axis',fontweight='bold',fontsize=14)
ax.set_title('Plotting of 3 Devices and Roaming Device',fontweight='bold',␣
↪fontsize=16)
```

[8]:
```
Text(0.5, 0.92, 'Plotting of 3 Devices and Roaming Device')
```



0.4 Part 4):

- In this part, the calculated RSSI value of roaming device from each device will be matched with the table created in part 2.
- This matching process will occur for 10 times which will return a different value everytime it runs because of random variable.
- Thus, all the values will be added in a list.
- Apart from the RSSI values, we also created list of tile no. , x and y co-ordinates of respective RSSI values.
- To view them better, these values will be stored in dataframe or table.
- atlast , their means(RSSI , x and y co-ordinates) will be computed.

0.4.1 Calculating RSSI readings of roaming device from all three devices (10 times):

[9]:
```
# initializing list to store tile no, x-axis, y-axis and RSSI values computed␣
↪with with random variable
grid1 , grid2, grid3 = [], [], []
x_axis1, x_axis2, x_axis3 = [], [], []
y_axis1, y_axis2, y_axis3 = [], [], []
value1, value2, value3 = [], [], []

# computing values for 10 times
for iter in range(1,11):

    # Getting RSSI value of roaming device from first device
    roaming_first_RSSI, roaming_first_dist  = roaming_device_RSSI(X1, Y1,␣
↪Z1,x_rand)
```

```
    # Getting RSSI value of roaming device from second device
    roaming_second_RSSI, roaming_second_dist = roaming_device_RSSI(X2, Y2,␣
↪Z2,x_rand)

    # Getting RSSI value of roaming device from third device
    roaming_third_RSSI,roaming_third_dist = roaming_device_RSSI(X3, Y3,␣
↪Z3,x_rand)

    # Generating random number for normal distribution with mean as 0 and␣
↪standard deviation as 5.1
    x_rand =np.random.normal(scale = 5.1)

    # Displaying the values
    print('{}) Iteration'.format(iter))
    print('The RSSI of roaming device from first device is {}'.
↪format(roaming_first_RSSI))
    print('The RSSI of roaming device from second device is {}'.
↪format(roaming_second_RSSI))
    print('The RSSI of roaming device from third device is {}'.
↪format(roaming_third_RSSI))

    # iterating through table created in part 2)
    for i in range(len(RSSI_device)):
        # matching the values of roaming device with first device
        if round(RSSI_device['RSSI1'][i], 0) == round(roaming_first_RSSI, 0):
            val1 = round(RSSI_device['RSSI1'][i], 1)
            grid_tile1 = RSSI_device['Grid_tile'][i]
            x1 = RSSI_device['X'][i]
            y1= RSSI_device['Y'][i]
    for i in range(len(RSSI_device)):
        # matching the values of roaming device with second device
        if round(RSSI_device['RSSI2'][i],0) == round(roaming_second_RSSI,0):
            val2 = round(RSSI_device['RSSI2'][i],1)
            grid_tile2 = RSSI_device['Grid_tile'][i]
            x2 = RSSI_device['X'][i]
            y2= RSSI_device['Y'][i]
    for i in range(len(RSSI_device)):
        # matching the values of roaming device with third device
        if round(RSSI_device['RSSI3'][i],0) == round(roaming_third_RSSI,0):
            val3 = round(RSSI_device['RSSI3'][i],1)
            grid_tile3 = RSSI_device['Grid_tile'][i]
            x3 = RSSI_device['X'][i]
            y3= RSSI_device['Y'][i]

    # Displaying all the values retreived
```

```
    print('''The RSSI of roaming device matched with first device at grid tile:␣
↪{}
    and x and y co-ordinates as: ({},{}), with value: {}'''.format(grid_tile1␣
↪,x1, y1, val1))
    print('''The RSSI of roaming device matched with third device at grid tile:␣
↪{}
    and x and y co-ordinates as: ({},{}), with value: {}'''.format(grid_tile2␣
↪,x2, y2, val2))
    print('''The RSSI of roaming device matched with third device at grid tile:␣
↪{}
    and x and y co-ordinates as: ({},{}), with value: {}'''.format(grid_tile3␣
↪,x3, y3, val3))
    print('\n')

    # Appending lists for first device
    grid1.append(grid_tile1)
    x_axis1.append(x1)
    y_axis1.append(y1)
    value1.append(val1)

    # Appending lists for second device
    grid2.append(grid_tile2)
    x_axis2.append(x2)
    y_axis2.append(y2)
    value2.append(val2)

    # Appending lists for third device
    grid3.append(grid_tile3)
    x_axis3.append(x3)
    y_axis3.append(y3)
    value3.append(val3)
```

```
1) Iteration
The RSSI of roaming device from first device is -195.2173463580812
The RSSI of roaming device from second device is -185.68651222260456
The RSSI of roaming device from third device is -226.4357159184946
The RSSI of roaming device matched with first device at grid tile: 2315
    and x and y co-ordinates as: (38.5,34.5), with value: -195.5
The RSSI of roaming device matched with third device at grid tile: 4860
    and x and y co-ordinates as: (80.5,59.5), with value: -186.1
The RSSI of roaming device matched with third device at grid tile: 1380
    and x and y co-ordinates as: (22.5,59.5), with value: -225.8



2) Iteration
The RSSI of roaming device from first device is -194.89800055223571
The RSSI of roaming device from second device is -185.36716641675906
```

```
The RSSI of roaming device from third device is -226.11637011264912
The RSSI of roaming device matched with first device at grid tile: 2315
    and x and y co-ordinates as: (38.5,34.5), with value: -195.5
The RSSI of roaming device matched with third device at grid tile: 4800
    and x and y co-ordinates as: (79.5,59.5), with value: -184.8
The RSSI of roaming device matched with third device at grid tile: 1380
    and x and y co-ordinates as: (22.5,59.5), with value: -225.8


3) Iteration
The RSSI of roaming device from first device is -193.1129435191131
The RSSI of roaming device from second device is -183.58210938363646
The RSSI of roaming device from third device is -224.3313130795265
The RSSI of roaming device matched with first device at grid tile: 2195
    and x and y co-ordinates as: (36.5,34.5), with value: -193.4
The RSSI of roaming device matched with third device at grid tile: 4738
    and x and y co-ordinates as: (78.5,57.5), with value: -183.6
The RSSI of roaming device matched with third device at grid tile: 1620
    and x and y co-ordinates as: (26.5,59.5), with value: -223.9


4) Iteration
The RSSI of roaming device from first device is -187.7279120916617
The RSSI of roaming device from second device is -178.19707795618507
The RSSI of roaming device from third device is -218.9462816520751
The RSSI of roaming device matched with first device at grid tile: 1952
    and x and y co-ordinates as: (32.5,31.5), with value: -188.5
The RSSI of roaming device matched with third device at grid tile: 4500
    and x and y co-ordinates as: (74.5,59.5), with value: -177.5
The RSSI of roaming device matched with third device at grid tile: 2280
    and x and y co-ordinates as: (37.5,59.5), with value: -218.5


5) Iteration
The RSSI of roaming device from first device is -190.25538899781694
The RSSI of roaming device from second device is -180.7245548623403
The RSSI of roaming device from third device is -221.47375855823034
The RSSI of roaming device matched with first device at grid tile: 2017
    and x and y co-ordinates as: (33.5,36.5), with value: -190.4
The RSSI of roaming device matched with third device at grid tile: 4620
    and x and y co-ordinates as: (76.5,59.5), with value: -180.6
The RSSI of roaming device matched with third device at grid tile: 2040
    and x and y co-ordinates as: (33.5,59.5), with value: -220.5


6) Iteration
The RSSI of roaming device from first device is -189.12405932964583
The RSSI of roaming device from second device is -179.5932251941692
```

```
The RSSI of roaming device from third device is -220.34242889005924
The RSSI of roaming device matched with first device at grid tile: 1958
    and x and y co-ordinates as: (32.5,37.5), with value: -189.5
The RSSI of roaming device matched with third device at grid tile: 4556
    and x and y co-ordinates as: (75.5,55.5), with value: -179.7
The RSSI of roaming device matched with third device at grid tile: 2160
    and x and y co-ordinates as: (35.5,59.5), with value: -219.5


7) Iteration
The RSSI of roaming device from first device is -194.65257650337185
The RSSI of roaming device from second device is -185.12174236789522
The RSSI of roaming device from third device is -225.87094606378525
The RSSI of roaming device matched with first device at grid tile: 2315
    and x and y co-ordinates as: (38.5,34.5), with value: -195.5
The RSSI of roaming device matched with third device at grid tile: 4800
    and x and y co-ordinates as: (79.5,59.5), with value: -184.8
The RSSI of roaming device matched with third device at grid tile: 1380
    and x and y co-ordinates as: (22.5,59.5), with value: -225.8


8) Iteration
The RSSI of roaming device from first device is -188.7879574451143
The RSSI of roaming device from second device is -179.25712330963768
The RSSI of roaming device from third device is -220.0063270055277
The RSSI of roaming device matched with first device at grid tile: 1958
    and x and y co-ordinates as: (32.5,37.5), with value: -189.5
The RSSI of roaming device matched with third device at grid tile: 4560
    and x and y co-ordinates as: (75.5,59.5), with value: -179.1
The RSSI of roaming device matched with third device at grid tile: 2160
    and x and y co-ordinates as: (35.5,59.5), with value: -219.5


9) Iteration
The RSSI of roaming device from first device is -194.59758468224433
The RSSI of roaming device from second device is -185.0667505467677
The RSSI of roaming device from third device is -225.81595424265774
The RSSI of roaming device matched with first device at grid tile: 2315
    and x and y co-ordinates as: (38.5,34.5), with value: -195.5
The RSSI of roaming device matched with third device at grid tile: 4800
    and x and y co-ordinates as: (79.5,59.5), with value: -184.8
The RSSI of roaming device matched with third device at grid tile: 1380
    and x and y co-ordinates as: (22.5,59.5), with value: -225.8


10) Iteration
The RSSI of roaming device from first device is -193.43207120038286
The RSSI of roaming device from second device is -183.90123706490624
```

```
The RSSI of roaming device from third device is -224.65044076079627
The RSSI of roaming device matched with first device at grid tile: 2195
    and x and y co-ordinates as: (36.5,34.5), with value: -193.4
The RSSI of roaming device matched with third device at grid tile: 4738
    and x and y co-ordinates as: (78.5,57.5), with value: -183.6
The RSSI of roaming device matched with third device at grid tile: 1500
    and x and y co-ordinates as: (24.5,59.5), with value: -224.9
```

0.4.2 Tables displaying matched values of roaming device with three different devices:

[10]:
```python
# Function that create and returns table of matched value's tile no., x and y␣
 ↪axis
def create_table(grid,x,y,val,name):
    df= pd.DataFrame(grid,columns=['Grid_tile_no.'])
    df['X']=x
    df['Y']=y
    df['RSSI_value']=val
    return df

# Creating table for all three devices
device1=create_table(grid1, x_axis1, y_axis1, value1,'first')
device2=create_table(grid2, x_axis2, y_axis2, value2,'second')
device3=create_table(grid3, x_axis3, y_axis3, value3,'third')

# Displaying the created tables
print('\n The table for matches with first device is as follows:')
display(device1)
print('\n The table for matches with second device is as follows:')
display(device2)
print('\n The table for matches with third device is as follows:')
display(device3)
```

 The table for matches with first device is as follows:

	Grid_tile_no.	X	Y	RSSI_value
0	2315	38.5	34.5	-195.5
1	2315	38.5	34.5	-195.5
2	2195	36.5	34.5	-193.4
3	1952	32.5	31.5	-188.5
4	2017	33.5	36.5	-190.4
5	1958	32.5	37.5	-189.5
6	2315	38.5	34.5	-195.5
7	1958	32.5	37.5	-189.5
8	2315	38.5	34.5	-195.5
9	2195	36.5	34.5	-193.4

```
The table for matches with second device is as follows:

   Grid_tile_no.     X     Y  RSSI_value
0           4860  80.5  59.5      -186.1
1           4800  79.5  59.5      -184.8
2           4738  78.5  57.5      -183.6
3           4500  74.5  59.5      -177.5
4           4620  76.5  59.5      -180.6
5           4556  75.5  55.5      -179.7
6           4800  79.5  59.5      -184.8
7           4560  75.5  59.5      -179.1
8           4800  79.5  59.5      -184.8
9           4738  78.5  57.5      -183.6


The table for matches with third device is as follows:

   Grid_tile_no.     X     Y  RSSI_value
0           1380  22.5  59.5      -225.8
1           1380  22.5  59.5      -225.8
2           1620  26.5  59.5      -223.9
3           2280  37.5  59.5      -218.5
4           2040  33.5  59.5      -220.5
5           2160  35.5  59.5      -219.5
6           1380  22.5  59.5      -225.8
7           2160  35.5  59.5      -219.5
8           1380  22.5  59.5      -225.8
9           1500  24.5  59.5      -224.9
```

0.4.3 Calculating the mean RSSI , x and y co-ordinates of all three devices:

[11]:
```python
# Calculating mean values of RSSI , x and y co-ordinates for first device
mean_val1=(device1['RSSI_value'].values).mean()
mean_x1=(device1['X'].values).mean()
mean_y1=(device1['Y'].values).mean()

# Calculating mean values of RSSI , x and y co-ordinates for second device
mean_val2=(device2['RSSI_value'].values).mean()
mean_x2=(device2['X'].values).mean()
mean_y2=(device2['Y'].values).mean()

# Calculating mean values of RSSI , x and y co-ordinates for third device
mean_val3=(device3['RSSI_value'].values).mean()
mean_x3=(device3['X'].values).mean()
mean_y3=(device3['Y'].values).mean()

# Displaying the calculated mean values of RSSI, x and y co-ordinates
```

```
print('The mean RSSI value of roaming device matched with first device is: {}'.
 ↪format(mean_val1))
print('The mean (x,y,z) of roaming device matched with first device is:␣
 ↪({},{},0) \n'.format(mean_x1,mean_y1))
print('The mean RSSI value of roaming device matched with second device is: {}'.
 ↪format(mean_val2))
print('The mean (x,y,z) of roaming device matched with second device is:␣
 ↪({},{},0)\n'.format(mean_x2,mean_y2))
print('The mean RSSI value of roaming device matched with third device is: {}'.
 ↪format(mean_val3))
print('The mean (x,y,z) of roaming device matched with third device is:␣
 ↪({},{},0)\n'.format(mean_x3,mean_y3))
```

```
The mean RSSI value of roaming device matched with first device is:
-192.67000000000002
The mean (x,y,z) of roaming device matched with first device is: (35.8,35.0,0)

The mean RSSI value of roaming device matched with second device is:
-182.45999999999998
The mean (x,y,z) of roaming device matched with second device is: (77.8,58.7,0)

The mean RSSI value of roaming device matched with third device is: -223.0
The mean (x,y,z) of roaming device matched with third device is: (28.3,59.5,0)
```

0.5 Part 5):

- Once the mean values of x and y co-ordinates are calculated, the, they will be compared to table in part 2).
- In this comparision, the difference between mean x and x values of table in part 2) will be calculated.
- Similarly, the difference between mean y and y values of table in part 2) will be calculated.
- After, getting the difference values, the minimum value among them will computed.
- The computed minimum value of x and y co-ordinated of all three devices will be defined as the Location Error.

0.5.1 Calculating the location error between true and estimated values (using the tables in part 2)):

[12]:
```
# initializing lists to store the location errors of computed mean coordinates␣
 ↪values and true table created in 2).
loc_x1, loc_y1=[],[]
loc_x2, loc_y2 =[],[]
loc_x3, loc_y3 = [], []

# iterating through table 2) and appendinf difference values of x-coordinates
for i in RSSI_device['X'].values:
```

```
    loc_x1.append(abs(i-mean_x1))
    loc_x2.append(abs(i-mean_x2))
    loc_x3.append(abs(i-mean_x3))

# iterating through table 2) and appendinf difference values of y-coordinates
for j in RSSI_device['Y'].values:
    loc_y1.append(abs(j-mean_y1))
    loc_y2.append(abs(j-mean_y2))
    loc_y3.append(abs(j-mean_y3))

# Getting the minimum location-error value of first device
loc_error_x1 = min(loc_x1)
loc_error_y1 = min(loc_y1)

# Getting the minimum location-error value of second device
loc_error_x2 = min(loc_x2)
loc_error_y2 = min(loc_y2)

# Getting the minimum location-error value of third device
loc_error_x3 = min(loc_x3)
loc_error_y3 = min(loc_y3)

# Displaying the location-error values
print('The location error of true and predicted values of first device is ({},{}) '.format(loc_error_x1, loc_error_y1))
print('The location error of true and predicted values of second device is ({},{}) '.format(loc_error_x2, loc_error_y2))
print('The location error of true and predicted values of third device is ({},{}) '.format(loc_error_x3, loc_error_y3))
```

```
The location error of true and predicted values of first device is
(0.29999999999999716,0.5)
The location error of true and predicted values of second device is
(0.29999999999999716,0.20000000000000284)
The location error of true and predicted values of third device is
(0.1999999999999993,0.0)
```

0.6 Part 6):

- In this part of the problem , estimated location values of roaming device will be calculated and then, will be comapred to its true position.
- In order to do so, firstly, the distance will be calculated using the RSSI value of roaming device calculated in part 3) and the RSSI model equation. This will be done for all three devices.
- Once , the distances are retreived, then using trilateration method the estimated location of roaming device will be found.
- Trilateration method stated that: #### AX = B

where A = [[-2(x1-xn), -2(y1-yn), -2(z1-zn)],……….[-2(x(n-1)-xn), -2(y(n-1)-yn), -2(z(n-1)-zn)]] and,

B = [[(d1^2 - dn^2) - (X1^2 - Xn^2) - (Y1^2 - Yn^2) - (Z1^2 - Zn^2)]…….[(d(n-1)^2 - dn^2) - (X(n-1)^2 - Xn^2) - (Y(n-1)^2 - Yn^2) - (Z(n-1)^2 - Zn^2) here, Aim is to find X =[[x,y,z]] - So, using above method , first A and B is calculated , then X can be represented as: #### X = (A ^-1)B - Once, X matrix is calculated through above computation, their x , y and z values can be retreived and comapred to the true actual values provided in part 3). - Here, a huge difference is noticed in the locations of estimated and true values . Also, their distance is calculated to see their difference. - At the end, the figure is plotted visualizing the actual and estimated locations in 3-D plane and their distance difference. - This comparision also proves that, RSSI is not a good candidate for solving localization or positioning problems. But, still in many cases of real world, it is used.

0.6.1 Calculating the estimated distance of roaming device from devices (Using part 3. readings and RSSI model):

[13]:
```
# The distance value of three devices calculated by part 3) reading and RSSI␣
↪model
d1 = 2**((roaming_first_RSSI + 50 - x_rand)/(-10*4))
d2 = 2**((roaming_second_RSSI + 50- x_rand)/(-10*4))
d3 = 2**((roaming_third_RSSI + 50- x_rand)/(-10*4))

# Displaying the values
print('The distance value of first device calculated by part 3) reading and␣
↪RSSI model is: {}'.format(d1))
print('The distance value of second device calculated by part 3) reading and␣
↪RSSI model is: {}'.format(d2))
print('The distance value of third device calculated by part 3) reading and␣
↪RSSI model is: {}'.format(d3))
```

```
The distance value of first device calculated by part 3) reading and RSSI model
is: 11.957060546161669
The distance value of second device calculated by part 3) reading and RSSI model
is: 10.136727094831008
The distance value of third device calculated by part 3) reading and RSSI model
is: 20.538374552225523
```

0.6.2 Calculating the estimated location of roaming device using ' Trilateration Method' :

[14]:
```
# Calculating the value elements of matrix A and B
A00 = -2*(X1-X3)
A01 = -2*(Y1-Y3)
A02 = -2*(Z1-Z3)
A10 = -2*(X2-X3)
A11 = -2*(Y2-Y3)
A12 = -2*(Z2-Z3)
B00 = (d1**2 - d3**2) - (X1**2 - X3**2) - (Y1**2 - Y3**2) - (Z1**2 - Z3**2)
```

```
B10 = (d2**2 - d3**2) - (X2**2 - X3**2) - (Y2**2 - Y3**2) - (Z2**2 - Z3**2)

# Creating matrix A and B
A = np.matrix([[A00, A01, A02], [A10, A11, A12]])
B = np.array([[B00], [B10]])

# Calculating the estimated co-ordinates values of roaming device or matrix X
X = np.linalg.pinv(A)*B

# Retreiving values as (x,y,z) co-ordinates
x_roaming_estimated = X[0,0]
y_roaming_estimated = X[1,0]
z_roaming_estimated = X[2,0]

# printing the estimated values
print('The estimated values of co-ordinates(x,y,z) of roaming device are:\n␣
↪({},{},{})'.format(x_roaming_estimated,
                                                                                        ␣
↪    y_roaming_estimated,z_roaming_estimated))
```

```
The estimated values of co-ordinates(x,y,z) of roaming device are:
 (48.605732338285364,6.436928305454387,0.21456427684847945)
```

0.6.3 Comparing True and Estimated values of roaming device:

[15]:
```
# Creating comparision table of True and estimated values
Comparision_table = pd.DataFrame([XR,YR,ZR], columns= ['True_values'])
Comparision_table['Estimated_values'] = X[:,0]
Comparision_table['Location_error']=␣
↪[(abs(XR-x_roaming_estimated)),(abs(YR-y_roaming_estimated)),(abs(ZR-z_roaming_estimated))]

# Computing difference through distance
roam_loc_err_dist = math.sqrt((x_roaming_estimated - XR)**2 +␣
↪(y_roaming_estimated- YR)**2 + (z_roaming_estimated - ZR)**2)

# Displaying the comparision
print('The location error and difference through distance is: {}m \n'.
↪format(roam_loc_err_dist))
print('The Comparision of both true and estimates values is as below:')
display(Comparision_table)
```

```
The location error and difference through distance is: 42.81740081078582m

The Comparision of both true and estimates values is as below:
```

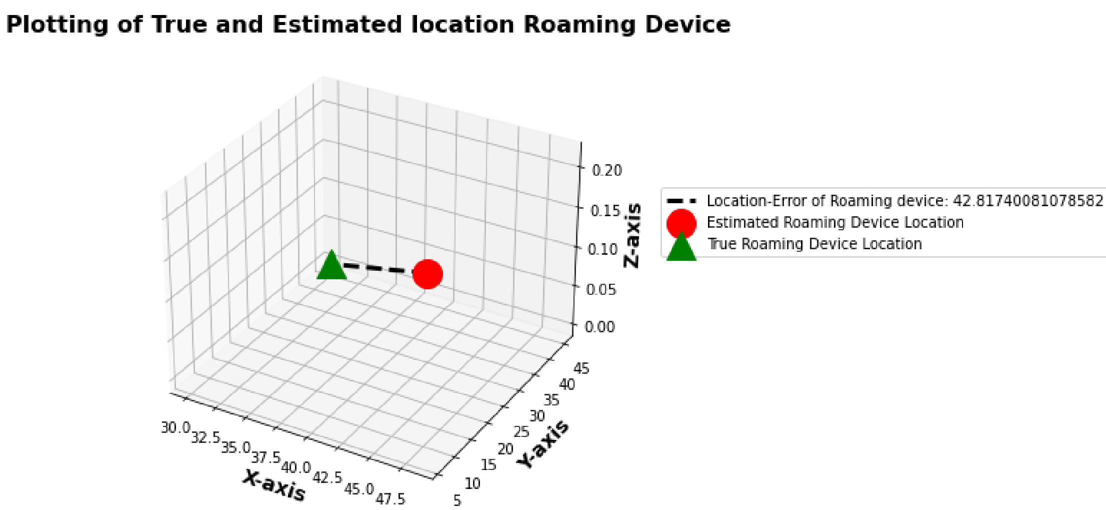
	True_values	Estimated_values	Location_error
0	30	48.605732	18.605732
1	45	6.436928	38.563072

```
2            0            0.214564          0.214564
```

0.6.4 Visual representation of comparision:

[16]:
```
plt.figure(figsize=(10,6))
ax1 = plt.axes(projection = '3d')
ax1.scatter(x_roaming_estimated,y_roaming_estimated,z_roaming_estimated, color='red', s = 400 ,
           label='Estimated Roaming Device Location')
ax1.scatter(XR,YR,ZR, color='green' , marker='^', s = 400 ,label='True Roaming Device Location')
ax1.plot([x_roaming_estimated,XR],[y_roaming_estimated,YR],[z_roaming_estimated,ZR], color = 'black', linestyle ='dashed',
         linewidth =3,label ='Location-Error of Roaming device: {}'.format(roam_loc_err_dist) )
ax1.legend(bbox_to_anchor = (2.1,0.7))
ax1.set_xlabel('X-axis',fontweight='bold',fontsize=14)
ax1.set_ylabel('Y-axis',fontweight='bold',fontsize=14)
ax1.set_zlabel('Z-axis',fontweight='bold',fontsize=14)
ax1.set_title('Plotting of True and Estimated location Roaming Device',fontweight='bold', fontsize=16)
```

[16]:
```
Text(0.5, 0.92, 'Plotting of True and Estimated location Roaming Device')
```



[ ]: