Question 1

- Here the network we are using is: the dataset of 'circles' (or 'friends lists') from Facebook.
- Here's the link for the same: https://snap.stanford.edu/data/ego-Facebook.html.

RAW DATA TO CSV DATA

We are given the network in a `.txt` file containing raw data in the format: `node1 node2`, representing an undirected edge between `node1` and `node2`.
To process this data efficiently, we convert it into a `.csv` file with two columns: `u` and `v`.

```
import pandas as pd

with open("facebook_combined.txt") as file:
    filtered_data=[]
    data=file.readlines()
    for item in data:
        item=item.strip()
        item=item.split(' ')
        filtered_data.append([item[0],item[1]])
    dataframe=pd.DataFrame(filtered_data)
    dataframe.columns=["u","v"]
    dataframe.to_csv("facebook_network.csv",index=False)
```

Part(a)

Adjacency Matrix and Edge List Representation

After obtaining the `.csv` file, we create an adjacency matrix for the network.

Steps for Adjacency Matrix:

1. **Find the Maximum Node:**
   - Iterate over the `.csv` file to find the maximum node number.
   - Add 1 to account for the `0` node.
2. **Create a 2D Matrix:**
   - Initialize a 2D matrix filled with `0`s, where the size is `[max_node][max_node]`.
3. **Fill the Matrix:**
   - Iterate over the `.csv` file and for each node pair, update the matrix by setting the corresponding positions to `1`.

Steps for Edge List

1. **Empty List Creation:**
   - We first create a empty list to represent a edge list.
2. **Fill the list:**
   - Now, we simply again iterate over the `.csv` file and add a tuple as `(node1,node2)` to our list.

Lastly we print both the adjacency matrix and edge list

Note: I have only printed the adjacency matrix for some specified rows and column, if you want to change this, then change the values of `ROW_TO_PRINT` and `COL_TO_PRINT`.

```
# adj matrix

import pandas as pd

def print_the_adj_matrix(row,col,matrix):
    for i in range(row):
        print("[",end=" ")
        for j in range(col):
            print(matrix[i][j],end=" ")
        print("]")
```

```
def print_the_edge_list(edge_list):
    for i in range(len(edge_list)):
        print(edge_list[i][0],"------",edge_list[i][1],sep="")


datafarme=pd.read_csv("facebook_network.csv")

# obtain size of the matrix
max_num=-10000000000

for index,row in datafarme.iterrows():
    u=row.iloc[0]
    v=row.iloc[1]
    max_num=max(max_num,u,v)


# add +1 to account for 0 as well
max_num=max_num+1

ADJ_MATRIX=[]
ADJ_ROW=[]
for i in range(max_num):
    ADJ_ROW.append(0)

for i in range(max_num):
    ADJ_MATRIX.append(list(ADJ_ROW))

for index,row in datafarme.iterrows():
    u=row.iloc[0]
    v=row.iloc[1]
    ADJ_MATRIX[u][v]=1
    ADJ_MATRIX[v][u]=1

# now with edge list
EDGE_LIST=[]
for index,row in datafarme.iterrows():
    u=row.iloc[0]
    v=row.iloc[1]
    EDGE_LIST.append((u,v))


ROW_TO_PRINT=50
COL_TO_PRINT=50

#print the adj_matrix till a specified row and a specfied column
print("------------------:ADJ_MATRIX:-------------------")
print_the_adj_matrix(50,50,ADJ_MATRIX)
print("\n------------------:EDGE_LIST:-------------------")
print_the_edge_list(EDGE_LIST)
```

```
------------------:ADJ_MATRIX:-------------------
[ 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 ]
[ 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 ]
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```

```
[ 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 ]
[ 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 ]
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[ 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 ]

------------------:EDGE_LIST:-------------------
0------1
0------2
0------3
0------4
```

Part(b)

Visualization of the network using Cytoscape

For this we use our `.csv` file and open it using cytoscape and then visualized the network. Image is saved as `q1_part(b)_facebook_network.png`.

Image

Part(c)

To compute the sparseness and to derive some conclusions about it, we first find the number of edges in our network, by simply summing across each row in adjacency matrix.

Next we also compute the maximum possible number of edges in our network, by using the formula, `N*(N-1)/2`.

Next we find the percentage of edges actaully present in our network.

Conclusions

- The network is really very sparse, the number of edges are very smaller as compared to maximum possible edges in the same graph.
- **Number of Edges**: 88234
- **Maximum Edges Possible**: 8154741
- Hence only `1%` of maximum possible edges are present.
- For this network, `L` <<< `Lmax`.

```
def compute_sparseness(adj_matrix):
    num_edges=0
    for  i in range(len(adj_matrix)):
        for j in range(i,len(adj_matrix)):
            if adj_matrix[i][j] == 1:
                num_edges += 1

    return num_edges

# compute Lmax
num_nodes=len(ADJ_MATRIX)
num_edges=compute_sparseness(ADJ_MATRIX)
L_MAX = (num_nodes*(num_nodes-1))/2
sparsness_in_percent = (num_edges/L_MAX)*100

print("Maximum Edges Possible: ",L_MAX)
print("Number of Actual Edges: ",num_edges)
```

```
print("Percentage of Edges: ",sparsness_in_percent,"%")
```

```
Maximum Edges Possible:  8154741.0
Number of Actual Edges:  88234
Percentage of Edges:  1.0819963503439287 %
```

Part(d)

As this network is a undirected graph, hence we directly use the formula to calculate the average degree of the network.

Formula Used

`2*(No. of edges)/No. of nodes`

```
# avg degree

AVG_DEGREE = (2*(num_edges))/num_nodes
print("The Average Degree is: ",AVG_DEGREE)
```

```
The Average Degree is:  43.69101262688784
```

Part(e)

To obtain the probabilites that a node has degree `k`, we first find the maximum possible degree in our network, by simply summing across each row in adjacency matrix and then finding the maximum across them.

Next, we precompute the degrees of each node by the same logic as used in the previous step and store them at `kth` index in a array.

Now, we run a simple for loop across the array and get the total number of nodes for that degree and then we divide this by total number of nodes present in out network.

Effective Formula: `P(k) = Nk/N`

Next, we simply plot this data using matplotlib and label th axes as well.

```
# degree distribution
import matplotlib.pyplot as plt

# first get the max_possible degree
def max_possible_degree(adj_matrix):
    degrees=[]
    for i in range(len(adj_matrix)):
        my_degree=0
        for j in range(len(adj_matrix)):
            if(adj_matrix[i][j]==1):
                my_degree+=1
        degrees.append(my_degree)
    max_val = max(degrees)
    return max_val

def calculate_nodes_with_degree(adj_matrix):
    degrees=[0]*len(adj_matrix)
    for i in range(len(adj_matrix)):
        for j in range(len(adj_matrix)):
            if(adj_matrix[i][j]==1):
                degrees[i]+=1
    return degrees



max_degree_in_network=max_possible_degree(ADJ_MATRIX)

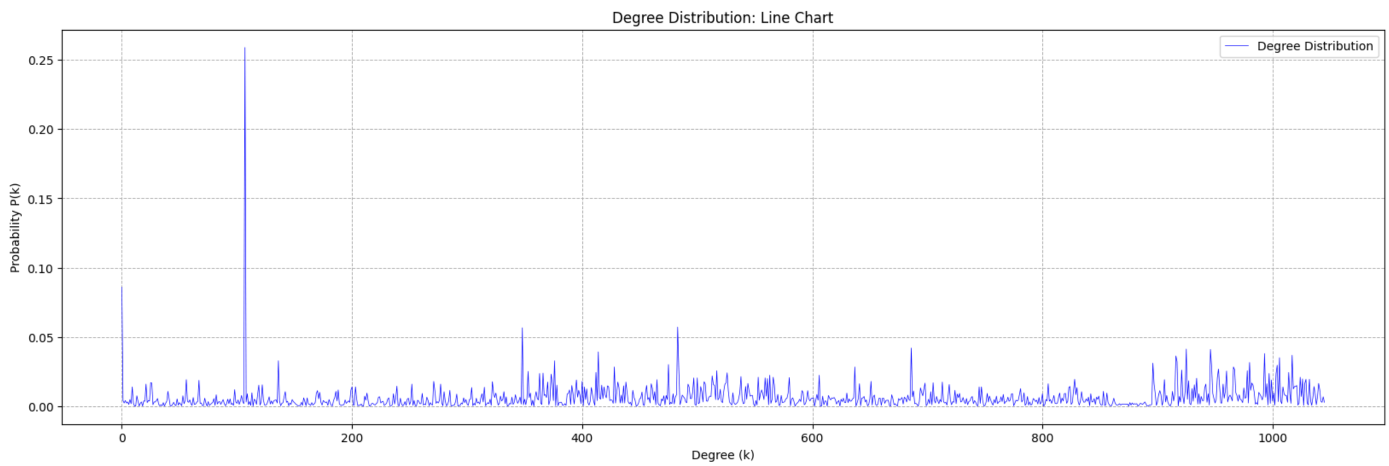
node_degrees=calculate_nodes_with_degree(ADJ_MATRIX)
probabiltiy_and_degree_data=[]

for i in range(max_degree_in_network+1):
    num_nodes=node_degrees[i]
    pk=num_nodes/len(ADJ_MATRIX)
    probabiltiy_and_degree_data.append([pk,i])
```

```
probabilities, degrees = zip(*probabiltiy_and_degree_data)

plt.figure(figsize=(20, 6))
plt.plot(degrees, probabilities, color='b', linewidth=0.5, label='Degree Distribution')

plt.title('Degree Distribution: Line Chart')
plt.xlabel('Degree (k)')
plt.ylabel('Probability P(k)')
plt.grid(True, linestyle='--', linewidth=0.7)
plt.legend()
plt.savefig('q1_part(e)_degree_distribution.png', dpi=1000, bbox_inches='tight')
plt.show()
```



Part(f)

To calculate the avg path length we use the following formula:-

- Average Path Length = Total Distance / Number of Valid Pairs

```
from collections import deque
import pandas as pd
import matplotlib.pyplot as plt
dataframe = pd.read_csv("facebook_network.csv")


def bfs(source, num_nodes,adj_list):
    distances={}
    for i in range(num_nodes):
        distances[i]=float('inf')
    distances[source] = 0
    queue = deque([source])

    while queue:
        node = queue.popleft()
        for neighbor in adj_list[node]:
            if distances[neighbor] == float('inf'):
                distances[neighbor] = distances[node] + 1
                queue.append(neighbor)

    return distances


num_nodes=len(ADJ_MATRIX)
ADJ_LIST = {}

for i in range(num_nodes):
    ADJ_LIST[i]=[]
```

```
for index, row in dataframe.iterrows():
    u= row.iloc[0]
    v= row.iloc[1]
    ADJ_LIST[u].append(v)
    ADJ_LIST[v].append(u)

TOTAL_DISTANCE=0
PAIRS=0

max_path_length=-1
for node in range(num_nodes):
    temp_list=[]
    distance_array = bfs(node,num_nodes,ADJ_LIST)
    for dst in range(num_nodes):
        if((node!=dst) and (distance_array[dst]!=float('inf'))):
            TOTAL_DISTANCE+=distance_array[dst]
            PAIRS+=1
    for dist in distance_array.values():
        if dist != float('inf'):
            temp_list.append(dist)
    max_path_length=max(max_path_length,max(temp_list))

path_length_freq={}
for i in range(1, max_path_length + 1):
    path_length_freq[i]=0

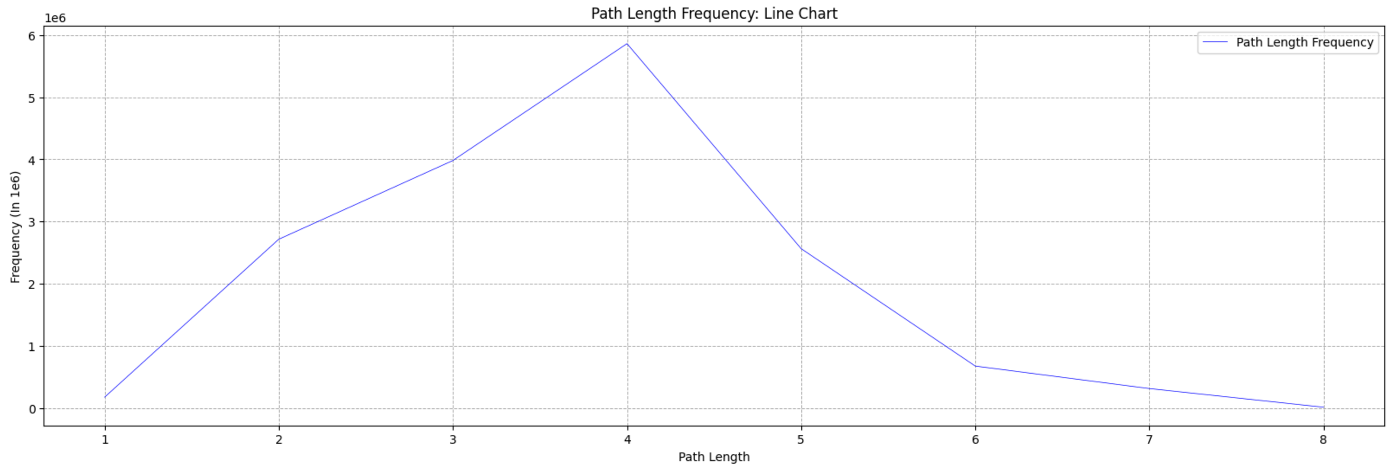
for node in range(num_nodes):
    distance_array = bfs(node, num_nodes, ADJ_LIST)
    for dist in distance_array.values():
        if dist != float('inf') and dist > 0:
            path_length_freq[dist] += 1

sorted_lengths = sorted(path_length_freq.keys())
sorted_freq = []
for length in sorted_lengths:
    sorted_freq.append(path_length_freq[length])


avg_path_length=TOTAL_DISTANCE/PAIRS
print("Average Path Length is: ",avg_path_length)

plt.figure(figsize=(20, 6))
plt.plot(sorted_lengths, sorted_freq, color='b', linewidth=0.5, label='Path Length Frequency')
plt.title('Path Length Frequency: Line Chart')
plt.xlabel('Path Length')
plt.ylabel('Frequency (In 1e6)')
plt.grid(True, linestyle='--', linewidth=0.7)
plt.legend()
plt.savefig('q1_part(f)_path_length_distribution.png', dpi=1000, bbox_inches='tight')
plt.show()
```

```
Average Path Length is:  3.6925068496963913
```



Part(g)

Formula used:-

- Clustering Coefficient (C) = (2 * Number of Actual Edges Between Neighbors) / (Degree of Node * (Degree of Node - 1))

Where:

- **Number of Actual Edges Between Neighbors** is the number of edges that actually exist between the neighbors of the node.
- **Degree of Node** is the number of neighbors connected to the node.

The clustering coefficient measures how interconnected the neighbors of a node are to each other. A high clustering coefficient indicates that the node's neighbors are densely connected.

```
import matplotlib.pyplot as plt
from collections import defaultdict
import numpy as np
def find_clustering_coefficient(adj_matrix):
    num_nodes=len(adj_matrix)

    all_data=[] # coefficient,degree
    for src in range(num_nodes):
        degree=0
        neighbours=[]
        comman_edge=0
        for dst in range(num_nodes):
            if(adj_matrix[src][dst]==1):
                degree+=1
                neighbours.append(dst)

        if(degree < 2):
            all_data.append([0,degree])
            continue

        for i in range(degree):
            for j in range(i + 1, degree):
                if adj_matrix[neighbours[i]][neighbours[j]] == 1:
                    comman_edge += 1

        coefficinet=(2*(comman_edge))/(degree*(degree-1))
        all_data.append([coefficinet,degree])

    return all_data


coefficients=find_clustering_coefficient(ADJ_MATRIX)
sorted_list = sorted(coefficients, key=lambda x: x[1])
sum_coefficient=0
```

```
sorted_coefficinets=[]
sorted_degrees=[]
for i in sorted_list:
    sum_coefficient+=i[0]
    sorted_coefficinets.append(i[0])
    sorted_degrees.append(i[1])


grouped = defaultdict(lambda: [0, 0])

for first, second in sorted_list:
    grouped[second][0] += first
    grouped[second][1] += 1
means = {key: total / count for key, (total, count) in grouped.items()}

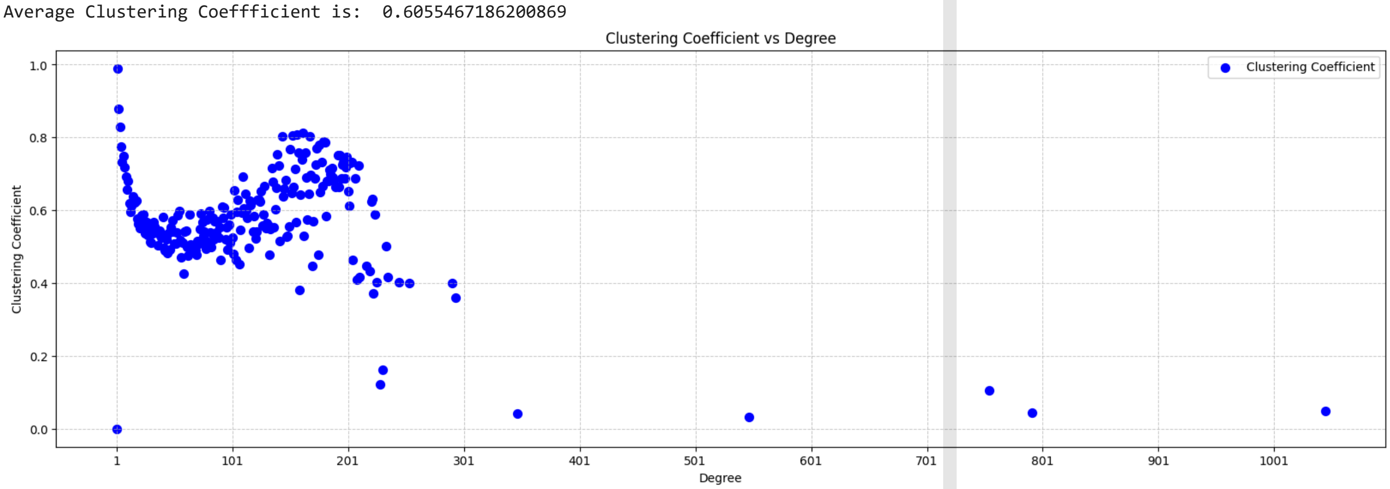
avg_clustering_coefficient=sum_coefficient/len(coefficients)
print("Average Clustering Coeffficient is: ",avg_clustering_coefficient)
sorted_degrees=[]
sorted_coefficinets=[]
for key,val in means.items():
    sorted_degrees.append(key)
    sorted_coefficinets.append(val)
plt.figure(figsize=(20, 6))

plt.scatter(sorted_degrees, sorted_coefficinets, color='b', s=50, label='Clustering Coefficient')

x_min, x_max = min(sorted_degrees), max(sorted_degrees)
plt.xticks(np.arange(x_min, x_max , step=100))
plt.title('Clustering Coefficient vs Degree')
plt.xlabel('Degree')
plt.ylabel('Clustering Coefficient')
plt.grid(True, linestyle='--', linewidth=0.7, alpha=0.7)
plt.legend()

plt.savefig('q1_part(g)_clustering_coefficient_distribution.png', dpi=1000, bbox_inches='tight')
plt.show()
```

```
Average Clustering Coeffficient is:  0.6055467186200869
```



Question2

- The graph used here represents the network of wikipedia votes.
- This is a directed unweighted graph.
- The Link for reference for the network is: https://snap.stanford.edu/data/wiki-Vote.html

Importing Necessary Libraries

```
import pandas as pd
import matplotlib.pyplot as plt
from collections import defaultdict
```

Making the Data frame from wikipedia_vote_network.csv file which was generated from wikipedia_vote_network.txt file.

```
file_path = "wikipedia_vote_network.csv"
df = pd.read_csv(file_path)
```

Printing the Data frame.

```
df
```

Initializing Dictionaries for In-Degree and Out-Degree

in_degree: Stores the count of incoming edges for each node.

out_degree: Stores the count of outgoing edges for each node.

Both dictionaries are initialized with defaultdict(int), meaning if a key (node) does not exist, it starts with a value of 0.

```
in_degree = defaultdict(int)
out_degree = defaultdict(int)
```

Iterating Through the DataFrame to Compute Degrees

Iterates over each row of the DataFrame. from_node represents the starting node of a directed edge. to_node represents the ending node of a directed edge. out_degree[from_node] += 1: Increments the count of outgoing edges for from_node. in_degree[to_node] += 1: Increments the count of incoming edges for to_node.

```
for index, row in df.iterrows():
    from_node, to_node = row["FromNodeId"], row["ToNodeId"]
    out_degree[from_node] += 1
    in_degree[to_node] += 1
```

Converts the in_degree and out_degree dictionaries into Pandas DataFrames.

```
in_degree_df = pd.DataFrame(in_degree.items(), columns=["NodeId", "InDegree"])
out_degree_df = pd.DataFrame(out_degree.items(), columns=["NodeId", "OutDegree"])
```

Plotting In-Degree Distribution

```
plt.figure(figsize=(12, 6))
plt.hist(in_degree.values(), bins=50, color='skyblue', alpha=0.7, label="In-Degree")
plt.xlabel("Degree")
plt.ylabel("Frequency")
plt.title("In-Degree Distribution")
plt.legend()
plt.grid(True)
plt.savefig('q2_in_degree_distribution.png', dpi=1000, bbox_inches='tight')
plt.show()
```

Plotting Out-Degree Distribution

```
plt.figure(figsize=(12, 6))
plt.hist(out_degree.values(), bins=50, color='orange', alpha=0.7, label="Out-Degree")
plt.xlabel("Degree")
plt.ylabel("Frequency")
plt.title("Out-Degree Distribution")
plt.legend()
plt.grid(True)
plt.savefig('q2_out_degree_distribution.png', dpi=1000, bbox_inches='tight')
plt.show()
```

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt

csv_file = "genes_network.csv"
df = pd.read_csv(csv_file)

numofnodes = set(df['node1']).union(set(df['node2']))
n = len(numofnodes)

adj = np.zeros((n, n))

for i in df.itertuples(index=False):
    adj[i.node1, i.node2] = i.weight
    adj[i.node2, i.node1] = i.weight

wdegrees = adj.sum(axis=1)

cluster_cof = np.zeros(n)

for i in range(n):
    neigh = np.nonzero(adj[i])[0]
    k_neigh = len(neigh)

    if k_neigh < 2:
        cluster_cof[i] = 0
    else:
        total_weight = 0
        for l in range(k_neigh):
            for p in range(l + 1, k_neigh):
                j, m = neigh[l], neigh[p]
                if adj[j, m] > 0:
                    w_ij = adj[i, j]
                    w_im = adj[i, m]
                    w_jm = adj[j, m]
                    total_weight += ((w_ij + w_im) / 2) * w_jm

        cluster_cof[i] = total_weight / (k_neigh * (k_neigh - 1))

cluster_cof = np.clip(cluster_cof, 0, 1)
for i in range(n):
    print(f"{i} | {wdegrees[i]} | {cluster_cof[i]}")
plt.figure()
plt.hist(wdegrees, bins=10, color='blue')
plt.xlabel("Weighted degree")
plt.ylabel("Frequency")
plt.title("Weighted degree distribution")
plt.savefig('q3_part(a)_degree_distribution.png')
plt.show()

plt.figure()
plt.scatter(wdegrees, cluster_cof, color='purple')
plt.xlabel("Degree of network")
plt.ylabel("Clustering coefficient")
plt.title("Clustering coefficient vs Degree of network")
plt.savefig('q3_part(b)_clustering_coefficient.png')
plt.show()
```

```
0 | 19.653167482633812 | 0.16545967751391558
1 | 2.94585497615587 | 0.0
2 | 5.718057257041989 | 0.0
3 | 32.385328536273065 | 0.17121147200694306
4 | 2.94585497615587 | 0.0
5 | 8.50917063096242 | 0.0
6 | 11.27425039921332 | 0.0
7 | 10.87409565499815 | 1.0
8 | 2.98578258722189 | 0.0
9 | 8.39320365238115 | 0.0
10 | 5.73137847629301 | 0.0
11 | 34.42804690500526 | 0.0
12 | 17.06591969144985 | 0.0
13 | 1.40673049935764 | 0.0
14 | 184.28169541585083 | 0.0
15 | 2.39705450780215 | 0.0
16 | 159.40983798072568 | 0.0
17 | 2.85799281775087 | 0.0
18 | 28.490879089221572 | 0.0
19 | 11.545435494639179 | 0.0
20 | 2.9741087782552 | 0.0
21 | 5.89232851670208 | 0.0
22 | 5.65642684141896 | 0.0
23 | 31.891888320474422 | 0.08554195217182818
24 | 11.6115104209083 | 1.0
25 | 5.8755624990608 | 1.0
26 | 11.6115104209083 | 1.0
27 | 11.505787292317141 | 0.692426895022829
28 | 8.72585812583171 | 1.0
29 | 55.15417884174089 | 0.0
30 | 5.65642684141896 | 0.0
31 | 10.758875500190939 | 0.0
32 | 2.84564225261916 | 0.0
33 | 2.84564225261916 | 0.0
34 | 2.84564225261916 | 0.0
35 | 2.84564225261916 | 0.0
36 | 2.84564225261916 | 0.0
37 | 13.53820392183546 | 0.39404741458079057
38 | 2.84564225261916 | 0.0
39 | 2.84564225261916 | 0.0
40 | 10.953589340219349 | 0.0
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42 | 2.84564225261916 | 0.0
43 | 2.84564225261916 | 0.0
44 | 2.84564225261916 | 0.0
45 | 2.84564225261916 | 0.0
46 | 2.84564225261916 | 0.0
47 | 2.84564225261916 | 0.0
48 | 2.84564225261916 | 0.0
49 | 8.515960153445 | 1.0
50 | 42.68088621254696 | 0.032685797015024706
51 | 8.51596015344501 | 1.0
52 | 8.72585812583169 | 1.0
53 | 17.18829307420505 | 0.8334262775660167
54 | 5.855952691057411 | 0.0
55 | 11.720595289270829 | 0.0
56 | 5.86313706341011 | 0.0
57 | 8.70885752252562 | 1.0
58 | 11.589616483314899 | 1.0
59 | 8.70885752252563 | 1.0
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62 | 2.90167902881037 | 0.0
63 | 2.93771260067026 | 0.0
64 | 22.03200987940695 | 0.2791525692876972
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66 | 2.98578258722189 | 0.0
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69 | 37.10624454722954 | 0.0
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71 | 5.99964198566498 | 0.0
72 | 10.91859094724764 | 1.0
73 | 10.36463647646399 | 1.0
74 | 10.480622656553042 | 0.5593772441250258
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76 | 30.003352278631098 | 0.36424432867373924
77 | 11.860107584296 | 0.0
78 | 8.8177139096206 | 0.0
79 | 37.05712131132847 | 0.0
80 | 20.71775002916068 | 0.43415908949388765
81 | 21.30056373313933 | 0.16302344906585894
82 | 8.07131625639766 | 0.0
83 | 11.43490684135259 | 0.18623676694574134
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91 | 1.40673049935764 | 0.0
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93 | 3.01895150003729 | 0.0
94 | 2.93771260067026 | 0.0
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96 | 3.01895150003729 | 0.0
97 | 3.01895150003729 | 0.0
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99 | 14.293307091560798 | 0.0
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106 | 2.99982099283249 | 0.0
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144 | 2.94585497615587 | 0.0
145 | 2.94585497615587 | 0.0
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214 | 2.87595765123462 | 0.0
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237 | 5.817920698897 | 1.0
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246 | 3.01895150003729 | 0.0
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405 | 8.72755783277724 | 1.0
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416 | 8.66661124226137 | 1.0
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422 | 2.95450848109683 | 0.0
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439 | 3.01895150003729 | 0.0
440 | 3.01895150003729 | 0.0
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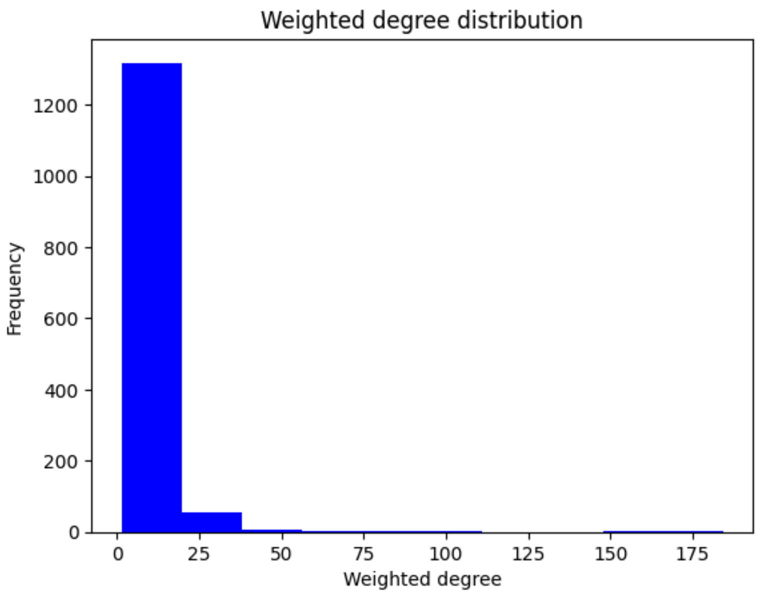
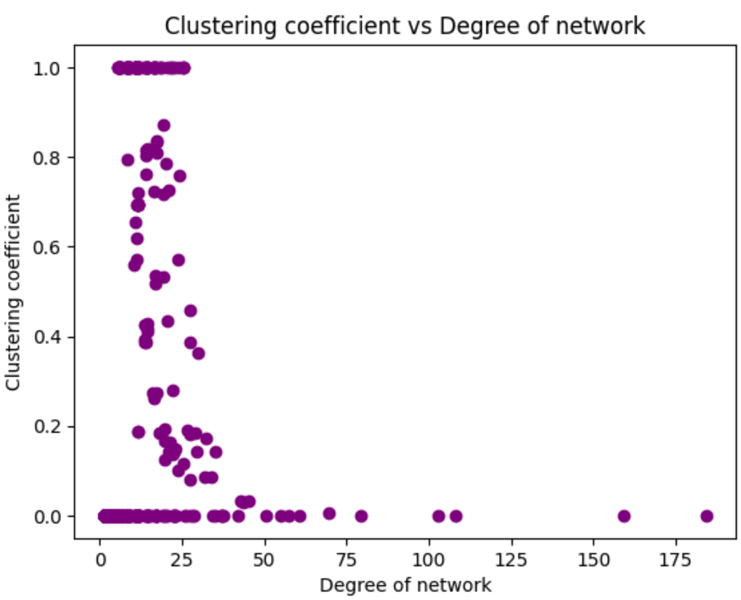




```
import numpy as np
import matplotlib.pyplot as plt
import pandas as pd
import random

def read(g):
    df = pd.read_csv(g)
    edge = []
    for i in range(len(df)):
        edge.append((df.loc[i, 'u'], df.loc[i, 'v']))
    node = set(df['u']).union(set(df['v']))
    return node, edge

def gilbert(n, p):
    node = list(range(n))
    edge = []

    for u in node:
        for v in node:
            if u < v and random.random() < p:
                edge.append((u, v))

    return node, edge


def degree_dist(n, e):
    degree_count = {}

    for i in n:
        degree_count[i] = 0


    for u, v in e:
        degree_count[u] += 1
        degree_count[v] += 1
    degree = list(degree_count.values())

    if degree:
        maxi = max(degree)
    else:
        maxi = 0

    hist = np.bincount(degree, minlength=maxi + 1)

    return hist / sum(hist)


def avg_random_dist(n, p, iter):
    distributions = []
    for i in range(iter):
        node, edge = gilbert(n, p)
        distribution = degree_dist(node, edge)
        distributions.append(distribution)

    max_len = 0
    for d in distributions:
        if len(d) > max_len:
            max_len = len(d)

    padded_distributions = []
    for di in distributions:
        padded_dist = np.pad(di, (0, max_len - len(di)))
        padded_distributions.append(padded_dist)

    return np.mean(padded_distributions, axis=0)


graphs = "facebook_network.csv"
nodes_real, edges_real = read(graphs)

n = len(nodes_real)
m = len(edges_real)
p = 2 * m / (n * (n - 1))

real_distribution = degree_dist(nodes_real, edges_real)
random_distribution = avg_random_dist(n, p,100)
```

```
plt.figure(figsize=(10, 8))
plt.plot(real_distribution, marker='*', label='facebook graph')
plt.plot(random_distribution, marker='s', label='Gilbert graph (Avg of 100 graphs)')
plt.xlabel("Degree")
plt.ylabel("Normalized frequency")
plt.legend()
plt.title("Degree distribution comparison")
plt.savefig("q4_degree_distribution_comparison.png")
plt.show()

distributions_100 = []

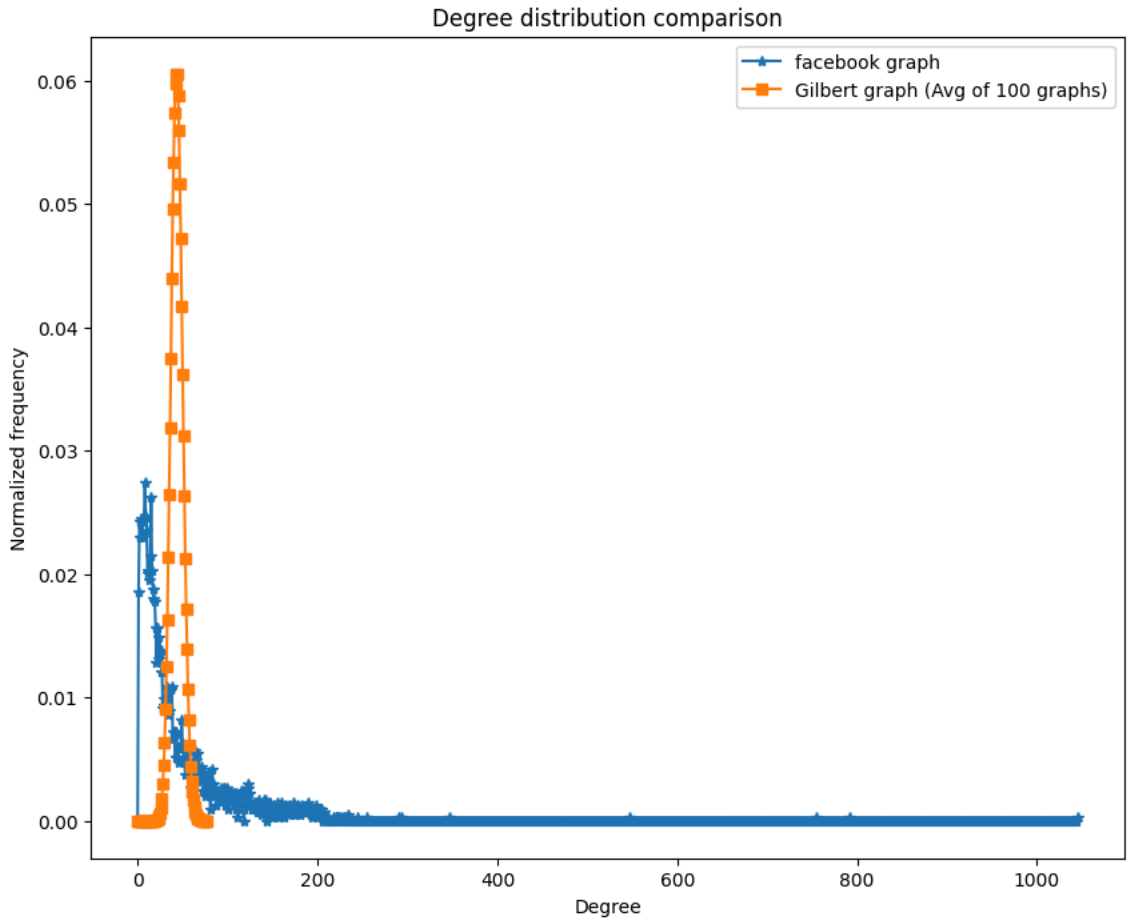
for i in range(100):
    node, edge = gilbert(n, p)
    distribution = degree_dist(node, edge)
    distributions_100.append(distribution)

max_len_100 = 0
for o in distributions_100:
    if len(o) > max_len_100:
        max_len_100 = len(o)

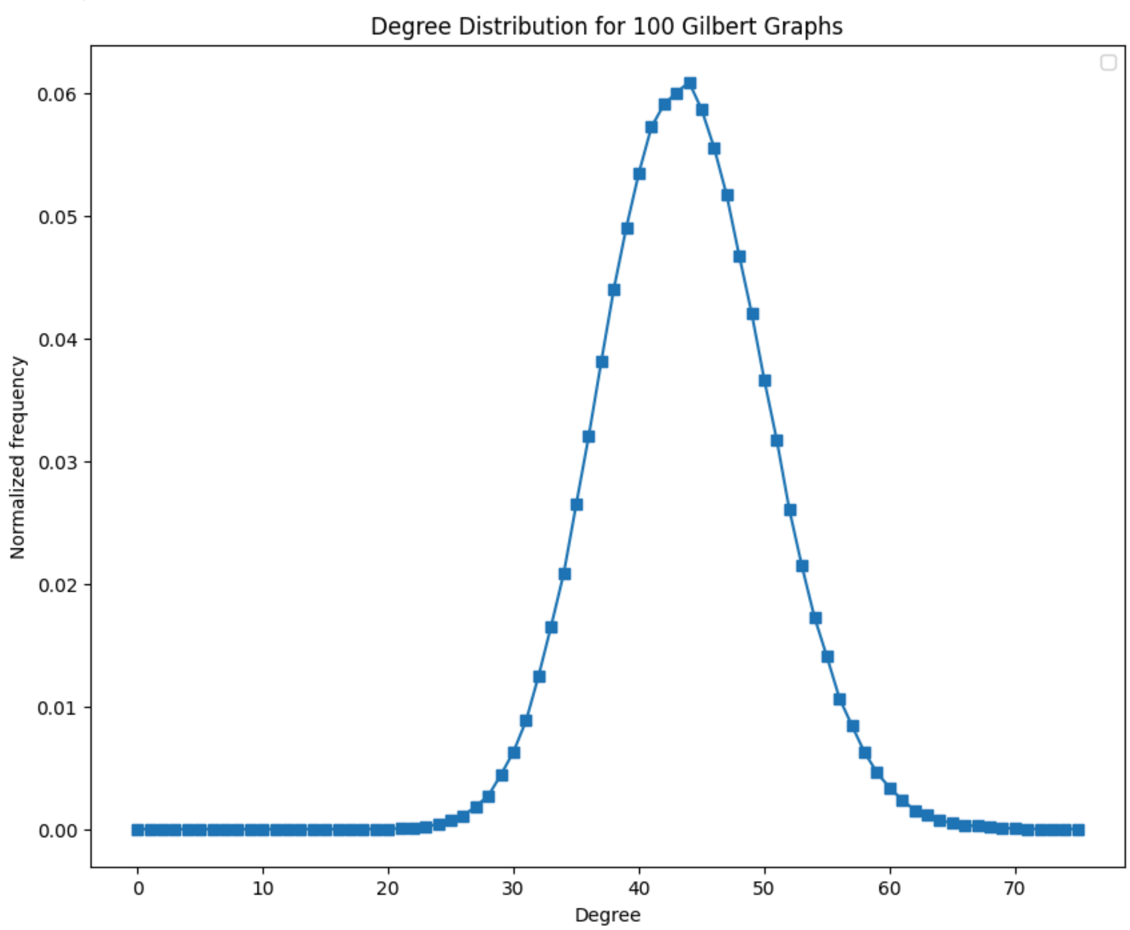
padded_distributions_100 = []
for l in distributions_100:
    padding_needed = max_len_100 - len(l)
    padded_distribution = np.pad(l, (0, padding_needed))
    padded_distributions_100.append(padded_distribution)

avg_distribution_100 = np.mean(padded_distributions_100, axis=0)


plt.figure(figsize=(10, 8))
plt.plot(avg_distribution_100, marker='s')
plt.xlabel("Degree")
plt.ylabel("Normalized frequency")
plt.legend()
plt.title("Degree Distribution for 100 Gilbert Graphs")
plt.savefig('q4_gilbert_100_graph.png')
plt.show()
```




```
C:\Users\DELL\AppData\Local\Temp\ipykernel_1988\213367749.py:113: UserWarning: No artists with labels found to put in legend.  Note that
  plt.legend()
```



Network Visualization In Cytoscape

- Here we visualize two networks - The facebook Network as used in Question-1 and genes association network as used in Question-3.
- There were three layouts visualized, namely: Default Layout(Grid Layout), Circular Layout and y_Organic_layout.
- The Images and the pdf file for these are present in the `Question5-Images&PDF`.

Facebook Network

- Default Network

Default Layout

- Circular Layout

Circular Layout

- y_Organic Layout

Organic Layout

Genes Association Network

- Default Network

Default Layout

- Circular Layout

Circular Layout

- y_Organic Layout

Organic Layout