GAM Assignment-1

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Table of Contents

In [ ]:

Import of Required Libraries

In [85]:
```
#for Graph Modelling
import networkx as nx
import random

#for plotting of Graphs
import matplotlib.pyplot as plt
%matplotlib inline

import warnings
warnings.filterwarnings(action = 'ignore')
```

A. Random Connected Graph Generation

Generate random graphs of at least 100 node connected graphs.

Random Graphs are mathematical structures that model random connections between nodes or vertices. They are widely studied in graph theory & have applications in various fields, including computer science, social networks, and biology.

Below are few popular models for generating random graphs:

1. Erdős-Rényi model (also known as the random graph model)
2. Barabási-Albert model
3. Watts-Strogatz model
4. Random geometric graph

Generation of Random Connected Graph using simple networkx.Graph() followed by random edge generation

In [86]:
```
def generate_random_connected_graph(num_nodes, num_edges):
    grph = nx.Graph()
    grph.add_nodes_from(range(num_nodes))

    while nx.number_of_edges(grph) < num_edges:
        node1 = random.randint(0, num_nodes - 1)
        node2 = random.randint(0, num_nodes - 1)

        if node1 != node2 and not grph.has_edge(node1, node2):
            grph.add_edge(node1, node2)

    # Extract largest connected component
    largest_component = max(nx.connected_components(grph), key=len)
```

```
    grph = grph.subgraph(largest_component)

    return grph
```

In [87]:
```
# Generate a random connected graph
G = generate_random_connected_graph(num_nodes=150, num_edges=300)
```

Below are some alternative methods for Random Graph generation via API calls:

- Random Regular Graph
- connected_watts_strogatz_graph
- Erdős-Rényi graph

In [88]:
```
# Random Regular Graph
G_rand_reg = nx.random_regular_graph(d=4, n=150, seed=42)
```

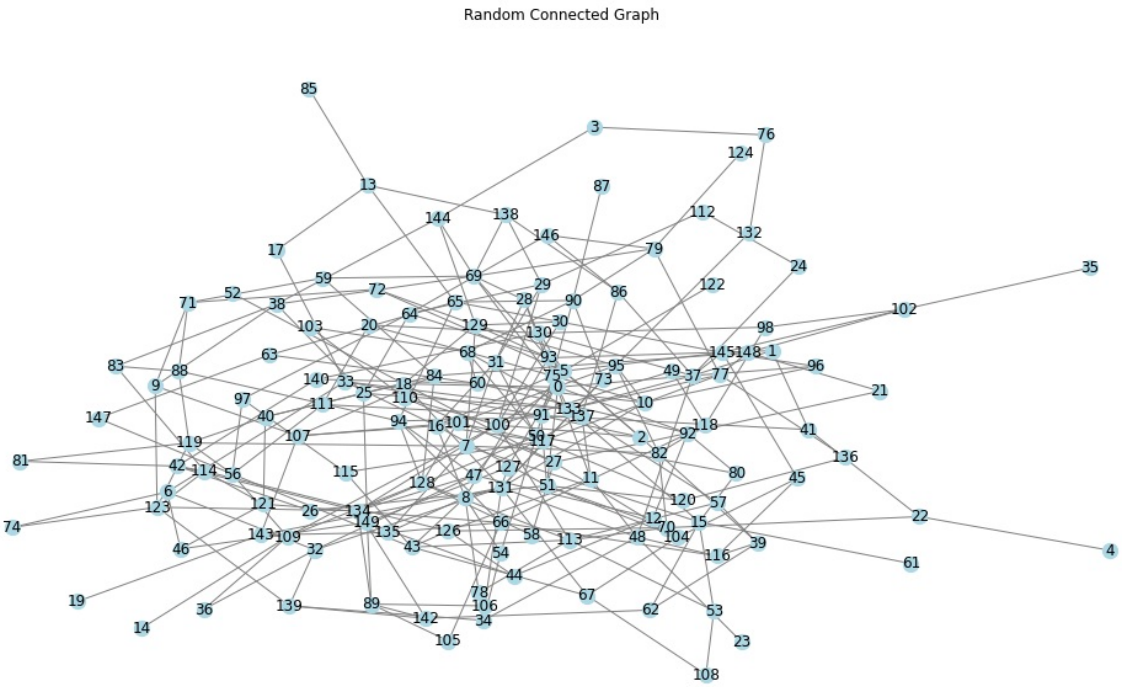
In [89]:
```
# connected_watts_strogatz_graph
G_watts_strogatz = nx.connected_watts_strogatz_graph(n=150, k=2, p=0.3, seed=42)
```

In [90]:
```
# Generate a random connected graph using Erdős-Rényi model

G_erdos_renyi = nx.erdos_renyi_graph(n=120, p=0.2)

# Ensure the graph is connected
if not nx.is_connected(G_erdos_renyi):
    G_erdos_renyi = max(nx.connected_components(G_erdos_renyi), key=len)
    G_erdos_renyi = G_erdos_renyi.subgraph(G_erdos_renyi)
```

Drawing of Graph

In [91]:
```
def draw_graph(G, width=10, height=5):
    fig = plt.figure(figsize=(width,height))
    pos = nx.spring_layout(G)
    nx.draw(G, pos, with_labels=True, node_size=150, node_color='lightblue', edge_color='gray')
    plt.title("Random Connected Graph")
    plt.show()
```

In [92]:
```
# Visualize the graph

draw_graph(G, 15, 8)
# draw_graph(G_rand_reg, 15, 8)
# draw_graph(G_watts_strogatz, 15, 8)
# draw_graph(G_erdos_renyi, 15, 8)
```



B. Network Measurement on graph

Perform Following activities (Network Measurements) on above graph:

B.1 Eccentricity, Diameter

Eccentricity

Eccentricity of a vertex in a graph is maximum distance (number of edges) between that vertex and any other vertex in the graph. It measures how far vertex is from the farthest vertex in the graph.

In [93]:
```
ecentricity = nx.eccentricity(G)
```

In [94]:
```
# len(ecentricity)
ecentricity_sorted = sorted(ecentricity.items(), key=lambda X: X[1], reverse=True)
for node, ecen in ecentricity_sorted:
    print(f'Ecentricity of Node {node} is : {ecen}')
```

```
Ecentricity of Node 4 is : 8
Ecentricity of Node 87 is : 8
Ecentricity of Node 3 is : 7
Ecentricity of Node 19 is : 7
Ecentricity of Node 22 is : 7
Ecentricity of Node 35 is : 7
Ecentricity of Node 63 is : 7
Ecentricity of Node 74 is : 7
Ecentricity of Node 76 is : 7
Ecentricity of Node 85 is : 7
Ecentricity of Node 90 is : 7
Ecentricity of Node 108 is : 7
Ecentricity of Node 111 is : 7
Ecentricity of Node 124 is : 7
Ecentricity of Node 132 is : 7
Ecentricity of Node 6 is : 6
Ecentricity of Node 9 is : 6
Ecentricity of Node 12 is : 6
Ecentricity of Node 13 is : 6
Ecentricity of Node 14 is : 6
Ecentricity of Node 17 is : 6
Ecentricity of Node 20 is : 6
Ecentricity of Node 21 is : 6
Ecentricity of Node 23 is : 6
Ecentricity of Node 24 is : 6
Ecentricity of Node 25 is : 6
Ecentricity of Node 26 is : 6
Ecentricity of Node 27 is : 6
Ecentricity of Node 28 is : 6
Ecentricity of Node 29 is : 6
Ecentricity of Node 30 is : 6
Ecentricity of Node 32 is : 6
Ecentricity of Node 33 is : 6
Ecentricity of Node 34 is : 6
Ecentricity of Node 36 is : 6
Ecentricity of Node 38 is : 6
Ecentricity of Node 39 is : 6
Ecentricity of Node 40 is : 6
Ecentricity of Node 41 is : 6
Ecentricity of Node 42 is : 6
Ecentricity of Node 43 is : 6
Ecentricity of Node 44 is : 6
Ecentricity of Node 45 is : 6
Ecentricity of Node 46 is : 6
Ecentricity of Node 50 is : 6
Ecentricity of Node 52 is : 6
Ecentricity of Node 53 is : 6
Ecentricity of Node 54 is : 6
Ecentricity of Node 56 is : 6
Ecentricity of Node 57 is : 6
Ecentricity of Node 58 is : 6
Ecentricity of Node 59 is : 6
Ecentricity of Node 60 is : 6
Ecentricity of Node 61 is : 6
Ecentricity of Node 62 is : 6
Ecentricity of Node 64 is : 6
Ecentricity of Node 65 is : 6
Ecentricity of Node 66 is : 6
Ecentricity of Node 67 is : 6
Ecentricity of Node 68 is : 6
Ecentricity of Node 70 is : 6
Ecentricity of Node 71 is : 6
Ecentricity of Node 73 is : 6
Ecentricity of Node 77 is : 6
Ecentricity of Node 78 is : 6
Ecentricity of Node 79 is : 6
Ecentricity of Node 80 is : 6
Ecentricity of Node 81 is : 6
Ecentricity of Node 82 is : 6
Ecentricity of Node 83 is : 6
Ecentricity of Node 88 is : 6
Ecentricity of Node 89 is : 6
Ecentricity of Node 91 is : 6
Ecentricity of Node 95 is : 6
Ecentricity of Node 97 is : 6
```

```
Ecentricity of Node 98 is : 6
Ecentricity of Node 102 is : 6
Ecentricity of Node 103 is : 6
Ecentricity of Node 105 is : 6
Ecentricity of Node 106 is : 6
Ecentricity of Node 110 is : 6
Ecentricity of Node 112 is : 6
Ecentricity of Node 114 is : 6
Ecentricity of Node 115 is : 6
Ecentricity of Node 116 is : 6
Ecentricity of Node 118 is : 6
Ecentricity of Node 119 is : 6
Ecentricity of Node 120 is : 6
Ecentricity of Node 121 is : 6
Ecentricity of Node 122 is : 6
Ecentricity of Node 123 is : 6
Ecentricity of Node 126 is : 6
Ecentricity of Node 130 is : 6
Ecentricity of Node 134 is : 6
Ecentricity of Node 136 is : 6
Ecentricity of Node 137 is : 6
Ecentricity of Node 138 is : 6
Ecentricity of Node 139 is : 6
Ecentricity of Node 140 is : 6
Ecentricity of Node 142 is : 6
Ecentricity of Node 143 is : 6
Ecentricity of Node 144 is : 6
Ecentricity of Node 146 is : 6
Ecentricity of Node 147 is : 6
Ecentricity of Node 148 is : 6
Ecentricity of Node 149 is : 6
Ecentricity of Node 1 is : 5
Ecentricity of Node 2 is : 5
Ecentricity of Node 5 is : 5
Ecentricity of Node 7 is : 5
Ecentricity of Node 8 is : 5
Ecentricity of Node 10 is : 5
Ecentricity of Node 11 is : 5
Ecentricity of Node 15 is : 5
Ecentricity of Node 16 is : 5
Ecentricity of Node 18 is : 5
Ecentricity of Node 31 is : 5
Ecentricity of Node 37 is : 5
Ecentricity of Node 47 is : 5
Ecentricity of Node 48 is : 5
Ecentricity of Node 49 is : 5
Ecentricity of Node 51 is : 5
Ecentricity of Node 69 is : 5
Ecentricity of Node 72 is : 5
Ecentricity of Node 75 is : 5
Ecentricity of Node 84 is : 5
Ecentricity of Node 86 is : 5
Ecentricity of Node 92 is : 5
Ecentricity of Node 93 is : 5
Ecentricity of Node 94 is : 5
Ecentricity of Node 96 is : 5
Ecentricity of Node 100 is : 5
Ecentricity of Node 101 is : 5
Ecentricity of Node 104 is : 5
Ecentricity of Node 107 is : 5
Ecentricity of Node 109 is : 5
Ecentricity of Node 113 is : 5
Ecentricity of Node 117 is : 5
Ecentricity of Node 127 is : 5
Ecentricity of Node 128 is : 5
Ecentricity of Node 129 is : 5
Ecentricity of Node 131 is : 5
Ecentricity of Node 133 is : 5
Ecentricity of Node 135 is : 5
Ecentricity of Node 145 is : 5
Ecentricity of Node 0 is : 4
```

Diameter

Diameter of a graph is maximum eccentricity among all the vertices in the graph. It's the longest shortest path between any two vertices of graph.

In [95]:
```
diameter = nx.diameter(G)
```

In [96]:
```
print(f'Diameter of above Graph G is : {diameter}')
```

```
Diameter of above Graph G is : 8
```

B.2 Radius

Radius of a graph is a measure of its "centeredness" or how close its vertices are to each other. It represents minimum eccentricity among all vertices in the graph.

In [97]:
```
radius = nx.radius(G)
print(f'Radius of above Graph G is : {radius}')
```

```
Radius of above Graph G is : 4
```

B.3 Graph Centrality

Centrality measures in graph theory quantify importance or influence of nodes within a graph. There are several types of centrality measures commonly used, each capturing different aspects of node centrality. Here are a few popular centrality measures:

B.3.1 Degree Centrality

It measures number of edges connected to a node. Nodes with a higher degree centrality are considered more central in terms of their connectivity within the graph.

In [98]:
```
# Calculate degree centrality
degree_centrality = nx.degree_centrality(G)
```

In [99]:
```
# Print centrality measures
degree_centrality_sorted = sorted(degree_centrality.items(), key=lambda X: X[1], reverse=True)
for node, centrality in degree_centrality_sorted:
    print(f"Degree Centrality of Node {node}: {centrality}")
```

```
Degree Centrality of Node 131: 0.07586206896551724
Degree Centrality of Node 5: 0.06206896551724138
Degree Centrality of Node 37: 0.06206896551724138
Degree Centrality of Node 100: 0.06206896551724138
Degree Centrality of Node 69: 0.05517241379310345
Degree Centrality of Node 0: 0.04827586206896552
Degree Centrality of Node 8: 0.04827586206896552
Degree Centrality of Node 16: 0.04827586206896552
Degree Centrality of Node 51: 0.04827586206896552
Degree Centrality of Node 68: 0.04827586206896552
Degree Centrality of Node 93: 0.04827586206896552
Degree Centrality of Node 113: 0.04827586206896552
Degree Centrality of Node 129: 0.04827586206896552
Degree Centrality of Node 134: 0.04827586206896552
Degree Centrality of Node 7: 0.041379310344827586
Degree Centrality of Node 15: 0.041379310344827586
Degree Centrality of Node 18: 0.041379310344827586
Degree Centrality of Node 43: 0.041379310344827586
Degree Centrality of Node 47: 0.041379310344827586
Degree Centrality of Node 48: 0.041379310344827586
Degree Centrality of Node 56: 0.041379310344827586
Degree Centrality of Node 66: 0.041379310344827586
Degree Centrality of Node 90: 0.041379310344827586
Degree Centrality of Node 91: 0.041379310344827586
Degree Centrality of Node 92: 0.041379310344827586
Degree Centrality of Node 94: 0.041379310344827586
Degree Centrality of Node 95: 0.041379310344827586
Degree Centrality of Node 109: 0.041379310344827586
Degree Centrality of Node 117: 0.041379310344827586
Degree Centrality of Node 119: 0.041379310344827586
Degree Centrality of Node 123: 0.041379310344827586
Degree Centrality of Node 128: 0.041379310344827586
Degree Centrality of Node 133: 0.041379310344827586
Degree Centrality of Node 137: 0.041379310344827586
Degree Centrality of Node 145: 0.041379310344827586
Degree Centrality of Node 2: 0.034482758620689655
Degree Centrality of Node 10: 0.034482758620689655
Degree Centrality of Node 27: 0.034482758620689655
Degree Centrality of Node 29: 0.034482758620689655
Degree Centrality of Node 31: 0.034482758620689655
Degree Centrality of Node 32: 0.034482758620689655
Degree Centrality of Node 33: 0.034482758620689655
Degree Centrality of Node 38: 0.034482758620689655
Degree Centrality of Node 42: 0.034482758620689655
Degree Centrality of Node 50: 0.034482758620689655
Degree Centrality of Node 60: 0.034482758620689655
Degree Centrality of Node 64: 0.034482758620689655
Degree Centrality of Node 65: 0.034482758620689655
Degree Centrality of Node 70: 0.034482758620689655
Degree Centrality of Node 77: 0.034482758620689655
Degree Centrality of Node 79: 0.034482758620689655
Degree Centrality of Node 84: 0.034482758620689655
Degree Centrality of Node 89: 0.034482758620689655
Degree Centrality of Node 107: 0.034482758620689655
Degree Centrality of Node 114: 0.034482758620689655
Degree Centrality of Node 126: 0.034482758620689655
Degree Centrality of Node 130: 0.034482758620689655
Degree Centrality of Node 143: 0.034482758620689655
```

```
Degree Centrality of Node 149: 0.034482758620689655
Degree Centrality of Node 6: 0.027586206896551724
Degree Centrality of Node 9: 0.027586206896551724
Degree Centrality of Node 11: 0.027586206896551724
Degree Centrality of Node 13: 0.027586206896551724
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Degree Centrality of Node 34: 0.027586206896551724
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Degree Centrality of Node 75: 0.027586206896551724
Degree Centrality of Node 82: 0.027586206896551724
Degree Centrality of Node 86: 0.027586206896551724
Degree Centrality of Node 88: 0.027586206896551724
Degree Centrality of Node 101: 0.027586206896551724
Degree Centrality of Node 102: 0.027586206896551724
Degree Centrality of Node 104: 0.027586206896551724
Degree Centrality of Node 116: 0.027586206896551724
Degree Centrality of Node 118: 0.027586206896551724
Degree Centrality of Node 121: 0.027586206896551724
Degree Centrality of Node 135: 0.027586206896551724
Degree Centrality of Node 138: 0.027586206896551724
Degree Centrality of Node 139: 0.027586206896551724
Degree Centrality of Node 142: 0.027586206896551724
Degree Centrality of Node 144: 0.027586206896551724
Degree Centrality of Node 148: 0.027586206896551724
Degree Centrality of Node 1: 0.020689655172413793
Degree Centrality of Node 12: 0.020689655172413793
Degree Centrality of Node 20: 0.020689655172413793
Degree Centrality of Node 22: 0.020689655172413793
Degree Centrality of Node 41: 0.020689655172413793
Degree Centrality of Node 44: 0.020689655172413793
Degree Centrality of Node 45: 0.020689655172413793
Degree Centrality of Node 46: 0.020689655172413793
Degree Centrality of Node 53: 0.020689655172413793
Degree Centrality of Node 54: 0.020689655172413793
Degree Centrality of Node 57: 0.020689655172413793
Degree Centrality of Node 59: 0.020689655172413793
Degree Centrality of Node 62: 0.020689655172413793
Degree Centrality of Node 63: 0.020689655172413793
Degree Centrality of Node 72: 0.020689655172413793
Degree Centrality of Node 78: 0.020689655172413793
Degree Centrality of Node 80: 0.020689655172413793
Degree Centrality of Node 83: 0.020689655172413793
Degree Centrality of Node 96: 0.020689655172413793
Degree Centrality of Node 97: 0.020689655172413793
Degree Centrality of Node 98: 0.020689655172413793
Degree Centrality of Node 110: 0.020689655172413793
Degree Centrality of Node 111: 0.020689655172413793
Degree Centrality of Node 115: 0.020689655172413793
Degree Centrality of Node 120: 0.020689655172413793
Degree Centrality of Node 127: 0.020689655172413793
Degree Centrality of Node 140: 0.020689655172413793
Degree Centrality of Node 146: 0.020689655172413793
Degree Centrality of Node 3: 0.013793103448275862
Degree Centrality of Node 17: 0.013793103448275862
Degree Centrality of Node 21: 0.013793103448275862
Degree Centrality of Node 24: 0.013793103448275862
Degree Centrality of Node 26: 0.013793103448275862
Degree Centrality of Node 30: 0.013793103448275862
Degree Centrality of Node 36: 0.013793103448275862
Degree Centrality of Node 49: 0.013793103448275862
Degree Centrality of Node 58: 0.013793103448275862
Degree Centrality of Node 73: 0.013793103448275862
Degree Centrality of Node 74: 0.013793103448275862
Degree Centrality of Node 76: 0.013793103448275862
Degree Centrality of Node 81: 0.013793103448275862
Degree Centrality of Node 103: 0.013793103448275862
Degree Centrality of Node 105: 0.013793103448275862
Degree Centrality of Node 106: 0.013793103448275862
Degree Centrality of Node 108: 0.013793103448275862
Degree Centrality of Node 112: 0.013793103448275862
Degree Centrality of Node 132: 0.013793103448275862
Degree Centrality of Node 136: 0.013793103448275862
Degree Centrality of Node 147: 0.013793103448275862
Degree Centrality of Node 4: 0.006896551724137931
Degree Centrality of Node 14: 0.006896551724137931
Degree Centrality of Node 19: 0.006896551724137931
Degree Centrality of Node 23: 0.006896551724137931
Degree Centrality of Node 35: 0.006896551724137931
Degree Centrality of Node 52: 0.006896551724137931
Degree Centrality of Node 61: 0.006896551724137931
Degree Centrality of Node 85: 0.006896551724137931
Degree Centrality of Node 87: 0.006896551724137931
Degree Centrality of Node 122: 0.006896551724137931
Degree Centrality of Node 124: 0.006896551724137931
```

B.3.2 EigenVector Centrality

It measures influence of a node based on centrality of its neighboring nodes. Nodes with a higher eigenvector centrality are connected to other highly central nodes.

In [100…
```
# Calculate eigenvector centrality
eigenvector_centrality = nx.eigenvector_centrality(G)
```

In [101…
```
eigenvector_centrality_sorted = sorted(eigenvector_centrality.items(), key=lambda X: X[1], reverse=True)
for node, centrality in eigenvector_centrality_sorted:
    print(f"Eigenvector Centrality of Node {node}: {centrality}")
```

```
Eigenvector Centrality of Node 131: 0.22351683119813806
Eigenvector Centrality of Node 0: 0.19931608570199902
Eigenvector Centrality of Node 5: 0.19125702317305673
Eigenvector Centrality of Node 37: 0.18127003308612236
Eigenvector Centrality of Node 100: 0.1810159102758829
Eigenvector Centrality of Node 16: 0.17609186722069964
Eigenvector Centrality of Node 8: 0.17322622749476962
Eigenvector Centrality of Node 93: 0.16832831149106395
Eigenvector Centrality of Node 69: 0.15613131186209248
Eigenvector Centrality of Node 129: 0.1474420528865173
Eigenvector Centrality of Node 51: 0.14455798704055883
Eigenvector Centrality of Node 18: 0.1425637016065165
Eigenvector Centrality of Node 2: 0.14039896059937437
Eigenvector Centrality of Node 133: 0.13373557813611667
Eigenvector Centrality of Node 91: 0.12952608783177302
Eigenvector Centrality of Node 95: 0.12773994783858494
Eigenvector Centrality of Node 47: 0.1270059850574479
Eigenvector Centrality of Node 113: 0.12363251838110356
Eigenvector Centrality of Node 134: 0.12155566217412318
Eigenvector Centrality of Node 48: 0.11832599861636686
Eigenvector Centrality of Node 145: 0.11715783689701445
Eigenvector Centrality of Node 10: 0.11135421327630216
Eigenvector Centrality of Node 43: 0.110827495103258
Eigenvector Centrality of Node 7: 0.10885273937820052
Eigenvector Centrality of Node 31: 0.10662122011780455
Eigenvector Centrality of Node 117: 0.10186923192718728
Eigenvector Centrality of Node 143: 0.1011886651816464
Eigenvector Centrality of Node 137: 0.10116457585153253
Eigenvector Centrality of Node 109: 0.09933992283836686
Eigenvector Centrality of Node 33: 0.09915657940406164
Eigenvector Centrality of Node 94: 0.0989445962267903
Eigenvector Centrality of Node 28: 0.09748555149359148
Eigenvector Centrality of Node 128: 0.09743418612044637
Eigenvector Centrality of Node 68: 0.09652864256905844
Eigenvector Centrality of Node 130: 0.09608578497970378
Eigenvector Centrality of Node 32: 0.09478345360759333
Eigenvector Centrality of Node 107: 0.09308851877652634
Eigenvector Centrality of Node 127: 0.09063125082751212
Eigenvector Centrality of Node 92: 0.09049667636636444
Eigenvector Centrality of Node 29: 0.08899496907810739
Eigenvector Centrality of Node 135: 0.08725141276352764
Eigenvector Centrality of Node 70: 0.08354794037136017
Eigenvector Centrality of Node 67: 0.08248618685109163
Eigenvector Centrality of Node 101: 0.08131963635639028
Eigenvector Centrality of Node 50: 0.0794304345768383
Eigenvector Centrality of Node 96: 0.07931445295816561
Eigenvector Centrality of Node 64: 0.07864460967327565
Eigenvector Centrality of Node 119: 0.07708208204320506
Eigenvector Centrality of Node 56: 0.07678371167512
Eigenvector Centrality of Node 144: 0.07648949368761009
Eigenvector Centrality of Node 86: 0.0763458522037465
Eigenvector Centrality of Node 1: 0.07634508126689102
Eigenvector Centrality of Node 27: 0.07536200659981054
Eigenvector Centrality of Node 38: 0.07520791136176991
Eigenvector Centrality of Node 90: 0.07478357262659843
Eigenvector Centrality of Node 123: 0.07444819268930994
Eigenvector Centrality of Node 72: 0.07421099663695488
Eigenvector Centrality of Node 15: 0.07397724913421504
Eigenvector Centrality of Node 75: 0.07258174985228077
Eigenvector Centrality of Node 60: 0.07215652884773902
Eigenvector Centrality of Node 77: 0.07121836048719066
Eigenvector Centrality of Node 82: 0.07000668425480372
Eigenvector Centrality of Node 11: 0.06962304206702286
Eigenvector Centrality of Node 79: 0.06949188357620101
Eigenvector Centrality of Node 78: 0.06875324303237808
Eigenvector Centrality of Node 65: 0.06870021255887261
Eigenvector Centrality of Node 138: 0.06855783207722518
Eigenvector Centrality of Node 126: 0.06762825154101357
Eigenvector Centrality of Node 104: 0.06753691470733313
Eigenvector Centrality of Node 66: 0.06750918586276411
Eigenvector Centrality of Node 84: 0.06669503520789308
Eigenvector Centrality of Node 25: 0.06601293872584914
Eigenvector Centrality of Node 30: 0.06357506133105167
Eigenvector Centrality of Node 40: 0.06332306820384978
Eigenvector Centrality of Node 54: 0.06019747931224508
```

```
Eigenvector Centrality of Node 89: 0.05935420757216223
Eigenvector Centrality of Node 34: 0.05834871035907327
Eigenvector Centrality of Node 73: 0.057738001323146396
Eigenvector Centrality of Node 116: 0.055667268987470236
Eigenvector Centrality of Node 9: 0.05563997345645524
Eigenvector Centrality of Node 110: 0.05531250063288572
Eigenvector Centrality of Node 39: 0.05524257782618834
Eigenvector Centrality of Node 106: 0.054752050406232475
Eigenvector Centrality of Node 42: 0.054430483540064946
Eigenvector Centrality of Node 57: 0.05420452263943734
Eigenvector Centrality of Node 139: 0.05417580193969082
Eigenvector Centrality of Node 149: 0.05346927331855938
Eigenvector Centrality of Node 114: 0.05257347250261394
Eigenvector Centrality of Node 120: 0.052325309644724025
Eigenvector Centrality of Node 142: 0.05230552654705601
Eigenvector Centrality of Node 59: 0.05178329437081156
Eigenvector Centrality of Node 88: 0.049363890779341495
Eigenvector Centrality of Node 111: 0.04898379466034093
Eigenvector Centrality of Node 115: 0.04882116322945999
Eigenvector Centrality of Node 12: 0.04845195007347955
Eigenvector Centrality of Node 6: 0.047412996711430545
Eigenvector Centrality of Node 80: 0.047209396115095274
Eigenvector Centrality of Node 20: 0.04676269727864179
Eigenvector Centrality of Node 45: 0.04652308676315709
Eigenvector Centrality of Node 41: 0.04484409405311827
Eigenvector Centrality of Node 71: 0.04471166074530931
Eigenvector Centrality of Node 146: 0.04344921400526611
Eigenvector Centrality of Node 140: 0.04310001199773796
Eigenvector Centrality of Node 49: 0.043078429032192826
Eigenvector Centrality of Node 53: 0.04294844812123778
Eigenvector Centrality of Node 118: 0.04154433017068659
Eigenvector Centrality of Node 121: 0.04080949064595568
Eigenvector Centrality of Node 24: 0.03991441471676344
Eigenvector Centrality of Node 97: 0.039534020336304695
Eigenvector Centrality of Node 148: 0.038943631723012906
Eigenvector Centrality of Node 26: 0.03851568148956669
Eigenvector Centrality of Node 102: 0.038234764100828274
Eigenvector Centrality of Node 36: 0.037574691575981686
Eigenvector Centrality of Node 122: 0.037018675376563406
Eigenvector Centrality of Node 62: 0.035136048190011086
Eigenvector Centrality of Node 83: 0.03428856716272151
Eigenvector Centrality of Node 98: 0.03403945518687919
Eigenvector Centrality of Node 58: 0.03344628166846647
Eigenvector Centrality of Node 44: 0.032818184347545756
Eigenvector Centrality of Node 13: 0.03273436686744964
Eigenvector Centrality of Node 63: 0.03131385948243369
Eigenvector Centrality of Node 103: 0.029390034719129186
Eigenvector Centrality of Node 52: 0.027593850374717174
Eigenvector Centrality of Node 46: 0.02742611130188212
Eigenvector Centrality of Node 132: 0.026325552524267427
Eigenvector Centrality of Node 22: 0.025818257966245414
Eigenvector Centrality of Node 17: 0.0255279490298598
Eigenvector Centrality of Node 81: 0.025456338351524575
Eigenvector Centrality of Node 21: 0.025053795188017886
Eigenvector Centrality of Node 112: 0.024950894342643713
Eigenvector Centrality of Node 105: 0.024556310205490536
Eigenvector Centrality of Node 108: 0.02427883736421661
Eigenvector Centrality of Node 136: 0.023912212180931605
Eigenvector Centrality of Node 74: 0.023588069671385208
Eigenvector Centrality of Node 23: 0.022902611871360924
Eigenvector Centrality of Node 147: 0.02092348344958692
Eigenvector Centrality of Node 19: 0.01958589739323841
Eigenvector Centrality of Node 14: 0.019228353300086237
Eigenvector Centrality of Node 3: 0.0164054789275133
Eigenvector Centrality of Node 87: 0.014474939071585537
Eigenvector Centrality of Node 61: 0.014318728606616538
Eigenvector Centrality of Node 124: 0.01345030394617033
Eigenvector Centrality of Node 76: 0.008270711958446341
Eigenvector Centrality of Node 35: 0.0074004273250888744
Eigenvector Centrality of Node 85: 0.006335888964902555
Eigenvector Centrality of Node 4: 0.004997263894881991
```

In [ ]:

B.3.3 Katz Centrality

Katz Centrality measures centrality of a node by considering both its direct connections and the indirect influence it receives from neighboring nodes. It assigns higher centrality scores to nodes that have more connections and are connected to other highly central nodes. Centrality of a node in Katz Centrality is determined by sum of centralities of its neighbors, with an attenuation factor applied to account for influence of distant nodes.

In [102…

```
# Calculation of Katz centrality
alpha = 0.1  # Damping factor for Katz centrality
katz_centrality = nx.katz_centrality(G, alpha=alpha)
```

In [103…

```
katz_centrality_sorted = sorted(katz_centrality.items(), key=lambda X: X[1], reverse=True)
```

```python
for node, centrality in katz_centrality_sorted:
    print(f"Katz Centrality of Node {node}: {centrality}")
```

```
Katz Centrality of Node 131: 0.1431225071170397
Katz Centrality of Node 100: 0.12684879987155892
Katz Centrality of Node 5: 0.12617323037246306
Katz Centrality of Node 37: 0.12527228032139537
Katz Centrality of Node 0: 0.12199621796310796
Katz Centrality of Node 69: 0.11665850979024373
Katz Centrality of Node 16: 0.11587867771741321
Katz Centrality of Node 8: 0.11428820151098387
Katz Centrality of Node 93: 0.1124713623057736
Katz Centrality of Node 134: 0.11013239598823153
Katz Centrality of Node 129: 0.10819857141266105
Katz Centrality of Node 51: 0.10818318531809037
Katz Centrality of Node 113: 0.10712037924669554
Katz Centrality of Node 47: 0.10376922039827026
Katz Centrality of Node 133: 0.10361205547664157
Katz Centrality of Node 18: 0.10352702860949202
Katz Centrality of Node 68: 0.10295756503265065
Katz Centrality of Node 95: 0.10093300326523151
Katz Centrality of Node 91: 0.10031749803776517
Katz Centrality of Node 145: 0.10003208251803247
Katz Centrality of Node 48: 0.09997527886763562
Katz Centrality of Node 94: 0.09987964637322255
Katz Centrality of Node 43: 0.09961923035352362
Katz Centrality of Node 7: 0.09920643688077534
Katz Centrality of Node 2: 0.09836542465175581
Katz Centrality of Node 137: 0.09830603884570237
Katz Centrality of Node 128: 0.09764713535315422
Katz Centrality of Node 117: 0.09713211634391422
Katz Centrality of Node 109: 0.09673789124014312
Katz Centrality of Node 123: 0.09505346651449159
Katz Centrality of Node 119: 0.09498657857162786
Katz Centrality of Node 92: 0.09394134759611389
Katz Centrality of Node 56: 0.0933393007609933
Katz Centrality of Node 10: 0.09292342523574224
Katz Centrality of Node 90: 0.09275808045023726
Katz Centrality of Node 31: 0.09179474335481277
Katz Centrality of Node 66: 0.09166168949288149
Katz Centrality of Node 143: 0.09084241762605866
Katz Centrality of Node 15: 0.09081020658688263
Katz Centrality of Node 32: 0.09050614876999798
Katz Centrality of Node 130: 0.0902219233871258
Katz Centrality of Node 33: 0.08971966488529737
Katz Centrality of Node 107: 0.08957661117059433
Katz Centrality of Node 70: 0.08892128700770607
Katz Centrality of Node 29: 0.08861493688577222
Katz Centrality of Node 50: 0.08801575967135865
Katz Centrality of Node 65: 0.0874372326017721
Katz Centrality of Node 60: 0.08696425170251146
Katz Centrality of Node 38: 0.08677753871132521
Katz Centrality of Node 126: 0.08645382882117995
Katz Centrality of Node 77: 0.08634231445893785
Katz Centrality of Node 64: 0.08618518162525475
Katz Centrality of Node 79: 0.0860032634330114
Katz Centrality of Node 84: 0.08561502433056496
Katz Centrality of Node 114: 0.08525877685506697
Katz Centrality of Node 27: 0.08521755167175574
Katz Centrality of Node 28: 0.08431244338181818
Katz Centrality of Node 89: 0.08411611978600414
Katz Centrality of Node 135: 0.08379179675530882
Katz Centrality of Node 42: 0.08329091368903645
Katz Centrality of Node 101: 0.08272081013200941
Katz Centrality of Node 67: 0.08228202614965903
Katz Centrality of Node 149: 0.082113474234884
Katz Centrality of Node 86: 0.08151426632792544
Katz Centrality of Node 144: 0.08114574306975063
Katz Centrality of Node 11: 0.08069350268725185
Katz Centrality of Node 82: 0.08056329824158086
Katz Centrality of Node 75: 0.08028061910536838
Katz Centrality of Node 40: 0.08027170065217608
Katz Centrality of Node 138: 0.08008289474282698
Katz Centrality of Node 25: 0.08006075193690683
Katz Centrality of Node 127: 0.07933284261771356
Katz Centrality of Node 9: 0.07878997280511975
Katz Centrality of Node 104: 0.07874652585584031
Katz Centrality of Node 142: 0.07831053438561693
Katz Centrality of Node 139: 0.07824109523029892
Katz Centrality of Node 88: 0.0780559511211938
Katz Centrality of Node 116: 0.07793437423954472
Katz Centrality of Node 121: 0.07666909975004173
Katz Centrality of Node 34: 0.07662150705950452
Katz Centrality of Node 96: 0.0760147027810406
Katz Centrality of Node 39: 0.07592425218575412
Katz Centrality of Node 6: 0.07509312247401731
Katz Centrality of Node 72: 0.075086387212147
Katz Centrality of Node 148: 0.07485896295682687
Katz Centrality of Node 1: 0.07478624901185696
```

```
Katz Centrality of Node 118: 0.07465299482414599
Katz Centrality of Node 71: 0.07457281932922294
Katz Centrality of Node 78: 0.07399493510004271
Katz Centrality of Node 102: 0.073640994128975
Katz Centrality of Node 57: 0.07232699658114035
Katz Centrality of Node 13: 0.0721219707489111
Katz Centrality of Node 54: 0.0720844750471984
Katz Centrality of Node 59: 0.07187656544132617
Katz Centrality of Node 110: 0.07156296325259097
Katz Centrality of Node 80: 0.07146866249884595
Katz Centrality of Node 115: 0.07078939750314167
Katz Centrality of Node 12: 0.07077561020021034
Katz Centrality of Node 120: 0.07071320900340164
Katz Centrality of Node 111: 0.07061474606752093
Katz Centrality of Node 20: 0.07057135466596148
Katz Centrality of Node 140: 0.07023964090696115
Katz Centrality of Node 53: 0.0699262671991423
Katz Centrality of Node 45: 0.0698632295325319
Katz Centrality of Node 146: 0.06956220309307487
Katz Centrality of Node 97: 0.06922332081150612
Katz Centrality of Node 83: 0.06920116065594303
Katz Centrality of Node 62: 0.06869643311368814
Katz Centrality of Node 41: 0.06819960117368166
Katz Centrality of Node 44: 0.06812622563917159
Katz Centrality of Node 98: 0.06804352528183676
Katz Centrality of Node 73: 0.067779987525076
Katz Centrality of Node 30: 0.06769666459766117
Katz Centrality of Node 63: 0.06766128261018843
Katz Centrality of Node 46: 0.06757950516049194
Katz Centrality of Node 106: 0.06691579212256461
Katz Centrality of Node 22: 0.06497294822646499
Katz Centrality of Node 49: 0.06434211150038291
Katz Centrality of Node 26: 0.0633393429461725
Katz Centrality of Node 36: 0.06291633725739208
Katz Centrality of Node 24: 0.06265101388410554
Katz Centrality of Node 58: 0.06247840287705878
Katz Centrality of Node 81: 0.06201968517695139
Katz Centrality of Node 105: 0.0617697170804879
Katz Centrality of Node 103: 0.06164398790997909
Katz Centrality of Node 74: 0.06120659526708298
Katz Centrality of Node 21: 0.0610719671004487
Katz Centrality of Node 17: 0.06037609950214206
Katz Centrality of Node 147: 0.060291995300326265
Katz Centrality of Node 136: 0.05989748864788969
Katz Centrality of Node 132: 0.05988228860189096
Katz Centrality of Node 108: 0.05941276555246562
Katz Centrality of Node 112: 0.05931853114756011
Katz Centrality of Node 3: 0.057903564790292524
Katz Centrality of Node 122: 0.05680925641643762
Katz Centrality of Node 76: 0.05597052511911448
Katz Centrality of Node 52: 0.05454463834214176
Katz Centrality of Node 23: 0.054189464412174634
Katz Centrality of Node 14: 0.05386572646424404
Katz Centrality of Node 87: 0.05346774644303077
Katz Centrality of Node 19: 0.053276179025030214
Katz Centrality of Node 61: 0.053272959091885695
Katz Centrality of Node 124: 0.05279226497165967
Katz Centrality of Node 35: 0.05155603938648049
Katz Centrality of Node 85: 0.051404137285568655
Katz Centrality of Node 4: 0.05068923533106567
```

In [ ]:

B.3.4 Page Rank

PageRank is an algorithm used by search engines to rank web pages based on their importance. It measures Centrality of a web page by considering number and quality of incoming links to that page. In the context of graph theory, PageRank assigns higher centrality scores to nodes that have more inbound links from other highly central nodes. Centrality of a node in PageRank is determined by random walk probability of reaching that node through a random traversal of the graph.

In [104…

```
# Calculation of PageRank
# pagerank = nx.pagerank(G)
pagerank = nx.pagerank_numpy(G, alpha=0.9)
```

In [105…

```
pagerank_sorted = sorted(pagerank.items(), key=lambda X: X[1], reverse=True)
for node, centrality in pagerank_sorted:
    print(f"PageRank of Node {node}: {centrality}")
```

```
PageRank of Node 131: 0.01716492316142752
PageRank of Node 37: 0.014161109171969758
PageRank of Node 5: 0.014119668765262565
PageRank of Node 100: 0.01408978156793933
PageRank of Node 69: 0.012463114246771287
PageRank of Node 68: 0.011199121089336357
PageRank of Node 51: 0.011042773228582424
PageRank of Node 113: 0.011034329761050406
```

PageRank of Node 129: 0.011033222857267705
PageRank of Node 134: 0.010857863410575928
PageRank of Node 93: 0.010707429380563044
PageRank of Node 8: 0.010698661230720904
PageRank of Node 0: 0.01068450638171585
PageRank of Node 16: 0.010638336812448333
PageRank of Node 90: 0.010313981465013007
PageRank of Node 15: 0.010218205469813509
PageRank of Node 109: 0.010184960590589997
PageRank of Node 48: 0.009913162588214496
PageRank of Node 56: 0.009851077847780401
PageRank of Node 18: 0.009790202697457255
PageRank of Node 92: 0.009775449866895766
PageRank of Node 145: 0.009756405336000227
PageRank of Node 95: 0.009748086012049685
PageRank of Node 66: 0.009722782127988147
PageRank of Node 91: 0.009586368193947795
PageRank of Node 119: 0.0095818763203666
PageRank of Node 128: 0.009576785232445598
PageRank of Node 123: 0.00955640698256046
PageRank of Node 117: 0.009542156680484243
PageRank of Node 133: 0.009451682893811458
PageRank of Node 43: 0.009437624222289354
PageRank of Node 7: 0.009421081463314829
PageRank of Node 94: 0.009367798961521082
PageRank of Node 137: 0.009365454406445152
PageRank of Node 47: 0.009297420785919368
PageRank of Node 79: 0.00873289122556799
PageRank of Node 143: 0.008495412944280523
PageRank of Node 65: 0.008429686185950162
PageRank of Node 77: 0.008376576341309672
PageRank of Node 42: 0.008325688134609013
PageRank of Node 27: 0.008324152500048827
PageRank of Node 89: 0.008301673293571059
PageRank of Node 70: 0.00827950498423042
PageRank of Node 29: 0.008243275681596786
PageRank of Node 149: 0.008238204172851966
PageRank of Node 130: 0.00821606389914321
PageRank of Node 33: 0.008189636891813174
PageRank of Node 60: 0.00817835848343964
PageRank of Node 32: 0.008155371371620953
PageRank of Node 84: 0.008115504111536529
PageRank of Node 64: 0.008111037061659753
PageRank of Node 50: 0.008081549911809836
PageRank of Node 114: 0.00807500224458019
PageRank of Node 38: 0.008074589174033002
PageRank of Node 126: 0.008043523285830807
PageRank of Node 10: 0.007972173600597744
PageRank of Node 107: 0.007954794980523008
PageRank of Node 31: 0.007826610568638322
PageRank of Node 2: 0.00781819257857989
PageRank of Node 13: 0.007631826593137252
PageRank of Node 102: 0.007475169163639276
PageRank of Node 148: 0.0070136090061509076
PageRank of Node 118: 0.006886428104451124
PageRank of Node 144: 0.006865832783193858
PageRank of Node 6: 0.006830708228112264
PageRank of Node 138: 0.006770516100746787
PageRank of Node 67: 0.006712514798203221
PageRank of Node 116: 0.006672305650182891
PageRank of Node 104: 0.006657671034214642
PageRank of Node 39: 0.006656405855695705
PageRank of Node 34: 0.006645582825405141
PageRank of Node 71: 0.006631958140123511
PageRank of Node 121: 0.006627764348993012
PageRank of Node 142: 0.006614557957611284
PageRank of Node 82: 0.006600063848816959
PageRank of Node 86: 0.006589038377743908
PageRank of Node 139: 0.006569891077303849
PageRank of Node 40: 0.006542781078122901 5
PageRank of Node 88: 0.00653847803680446
PageRank of Node 25: 0.006498973414459085
PageRank of Node 9: 0.0064958722835812615
PageRank of Node 11: 0.006473231766536689
PageRank of Node 135: 0.006461227533750793
PageRank of Node 101: 0.006446848792090393
PageRank of Node 75: 0.006438548973506161
PageRank of Node 28: 0.006321164772791543
PageRank of Node 22: 0.006077467499506899
PageRank of Node 41: 0.005482901714882883
PageRank of Node 98: 0.0053951823940154384
PageRank of Node 63: 0.005372886104216009
PageRank of Node 53: 0.005345922739223224
PageRank of Node 110: 0.00525829530690684
PageRank of Node 120: 0.005228626589640916
PageRank of Node 62: 0.005203629185315413
PageRank of Node 146: 0.005199372233542694
PageRank of Node 46: 0.005195964587811357
PageRank of Node 45: 0.005147637061238802

```
PageRank of Node 20: 0.005147114867942914
PageRank of Node 97: 0.005145219173400815
PageRank of Node 111: 0.0051446828734914235
PageRank of Node 44: 0.005142198989938124
PageRank of Node 80: 0.005138658791481484
PageRank of Node 140: 0.005134551399943854
PageRank of Node 1: 0.005122582430297834
PageRank of Node 12: 0.005088521801753017
PageRank of Node 115: 0.005075464394285599
PageRank of Node 83: 0.005063015520480696
PageRank of Node 59: 0.005040013181215452
PageRank of Node 54: 0.005010408784926794
PageRank of Node 72: 0.005007646189409201
PageRank of Node 57: 0.005006140526054103
PageRank of Node 96: 0.004999494472553923
PageRank of Node 127: 0.00498417793860572
PageRank of Node 78: 0.0049744293415075035
PageRank of Node 76: 0.004461397038866274
PageRank of Node 3: 0.004237372550557758
PageRank of Node 132: 0.004154773076146582
PageRank of Node 112: 0.0039049407151819007
PageRank of Node 17: 0.0038762271308315755
PageRank of Node 24: 0.0038582657458781492
PageRank of Node 108: 0.0037990241582120015
PageRank of Node 147: 0.00377445901528118
PageRank of Node 136: 0.003761303225177327
PageRank of Node 21: 0.0037293110132676404
PageRank of Node 103: 0.0037023070961217596
PageRank of Node 36: 0.003680642442329596
PageRank of Node 74: 0.0036553019055586356
PageRank of Node 49: 0.0036433559871447458
PageRank of Node 105: 0.0036376500188903217
PageRank of Node 73: 0.00363643153071806
PageRank of Node 81: 0.003620836819133922
PageRank of Node 58: 0.003619796741724949
PageRank of Node 26: 0.003603340500468114
PageRank of Node 106: 0.0035836355038088895
PageRank of Node 30: 0.0035124668881490934
PageRank of Node 4: 0.0025081717567013834
PageRank of Node 85: 0.0024020924903051955
PageRank of Node 35: 0.002366844568668153
PageRank of Node 124: 0.0022568519274515507
PageRank of Node 87: 0.0022320287266012658
PageRank of Node 61: 0.0022176623273213454
PageRank of Node 19: 0.002214105836819808
PageRank of Node 14: 0.0022126755954378135
PageRank of Node 23: 0.002171905895081488
PageRank of Node 52: 0.002153461911467892
PageRank of Node 122: 0.00209689838337557
```

In [ ]:

B.4 Exploratory Analysis of Centralities

Perform exploratory analysis of various centralities calculated in step-3 and explain the variation in centrality behavior

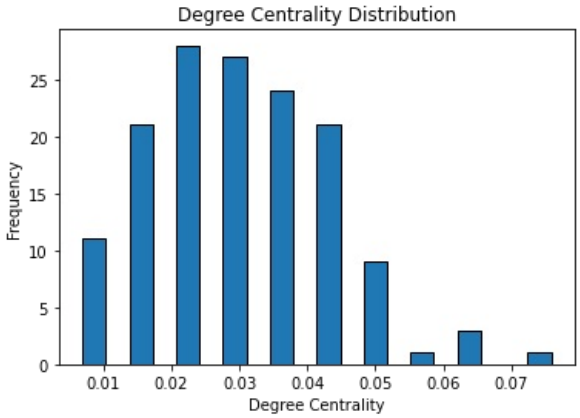
Exploratory Analysis of various Centralities

In below code, I performed exploratory analysis by plotting histograms of different centrality measures' distributions. This helps to visualize frequency distribution of centrality values across nodes in the graph.

By observing the histograms, I can analyze the variation in centrality behavior:

In [106…

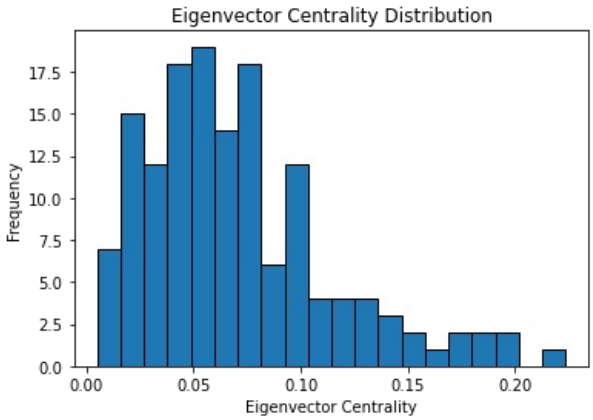
```python
# Degree Centrality
degree_values = list(degree_centrality.values())
plt.hist(degree_values, bins=20, edgecolor='black')
plt.xlabel('Degree Centrality')
plt.ylabel('Frequency')
plt.title('Degree Centrality Distribution')
plt.show()
```



Degree Centrality: Histogram of degree centrality shows the frequency distribution of nodes with different degrees. It is observed that most common degree centrality values and the spread of degrees in the graph. If there are nodes with significantly higher degrees, it indicates the presence of hubs or highly connected nodes.

In [ ]:

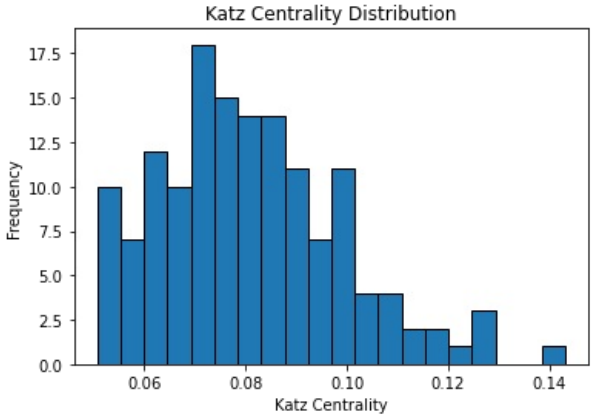
In [107…
```
# Eigenvector Centrality
eigenvector_values = list(eigenvector_centrality.values())
plt.hist(eigenvector_values, bins=20, edgecolor='black')
plt.xlabel('Eigenvector Centrality')
plt.ylabel('Frequency')
plt.title('Eigenvector Centrality Distribution')
plt.show()
```



Eigenvector Centrality: The histogram of eigenvector centrality displays the frequency distribution of nodes with different eigenvector centrality values. Nodes with higher eigenvector centrality are connected to other influential nodes. If there is a long tail in the distribution, it suggests the presence of highly influential nodes.

In [ ]:

In [108…
```
# Katz Centrality
katz_values = list(katz_centrality.values())
plt.hist(katz_values, bins=20, edgecolor='black')
plt.xlabel('Katz Centrality')
plt.ylabel('Frequency')
plt.title('Katz Centrality Distribution')
plt.show()
```

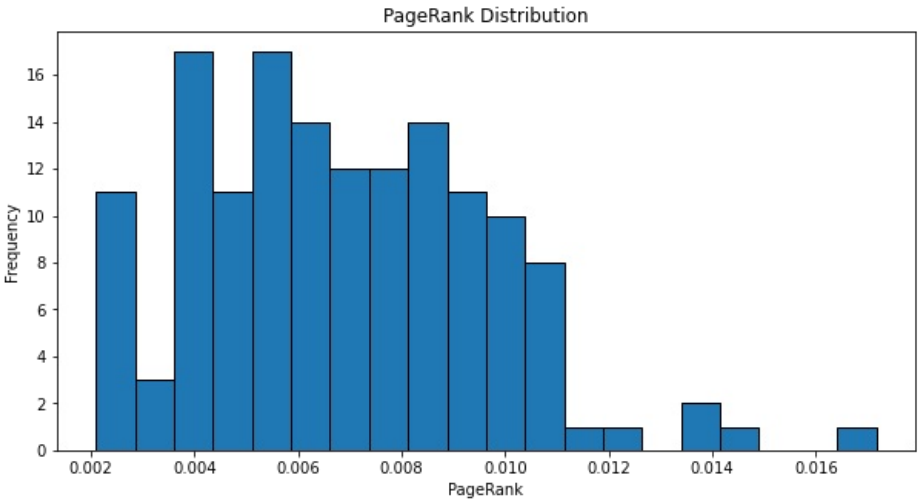


Katz Centrality: The histogram of Katz centrality shows the frequency distribution of nodes with different Katz centrality values. Varying the damping factor (alpha) can influence the centrality rankings. Observing the distribution helps identify nodes with high Katz centrality,

indicating their importance in terms of direct and indirect connections.

In [ ]:

In [109…
```
# PageRank
plt.figure(figsize=(10,5))
pagerank_values = list(pagerank.values())
plt.hist(pagerank_values, bins=20, edgecolor='black')
plt.xlabel('PageRank')
plt.ylabel('Frequency')
plt.title('PageRank Distribution')
plt.show()
```



PageRank: The histogram of PageRank displays the frequency distribution of nodes with different PageRank values. PageRank measures the importance of nodes based on the probability of reaching them through random walks. The distribution can indicate highly important nodes in the graph.

In [ ]:

Explanation of Variation in Centrality Behavior

By examining these histograms, we can gain insights into variation in centrality behavior and identify nodes that play crucial roles in network. Additionally, we can further analyze relationship between different centrality measures or explore other graph properties to deepen understanding of graph's structure and importance.

The variation in centrality behavior arises due to the different perspectives and measures of importance or influence that each centrality metric focuses on. Each measure considers different aspects of the network structure and topology, leading to variations in the centrality rankings and behaviors of nodes.

e.g.-->, nodes with high degree centrality may not necessarily have high closeness or betweenness centrality. Similarly, nodes with high betweenness centrality may not have high degree centrality. Centrality measures take into account different characteristics of network, such as connectivity, distance, or flow of information, resulting in variations in centrality scores and rankings across different metrics.

Understanding these variations helps in gaining insights into different aspects of node importance and influence within a network and provides a more comprehensive understanding of network's structure and dynamics.

In [ ]:

B.5 Betweenness and Closeness Centrality

Calculate betweenness and closeness centrality and explain the physical significance.

B.5.1 Betweenness Centrality

In [110…
```
# Calculation of betweenness centrality
betweenness_centrality = nx.betweenness_centrality(G)
```

In [111…
```
# Printing of  betweenness centrality
betweenness_centrality_sorted = sorted(betweenness_centrality.items(), key=lambda X: X[1], reverse=True)
for node, centrality in betweenness_centrality_sorted:
    print(f"Betweenness Centrality of Node {node}: {centrality}")
```

```
Betweenness Centrality of Node 131: 0.09194443290593483
Betweenness Centrality of Node 100: 0.0814881418014017
Betweenness Centrality of Node 37: 0.06733202707403654
Betweenness Centrality of Node 0: 0.06431041949845406
```

Betweenness Centrality of Node 5: 0.061669804199296054
Betweenness Centrality of Node 69: 0.05481054908455182
Betweenness Centrality of Node 134: 0.05063056344172524
Betweenness Centrality of Node 133: 0.04487210432132321
Betweenness Centrality of Node 51: 0.04278410387839323
Betweenness Centrality of Node 16: 0.04270992438199568
Betweenness Centrality of Node 113: 0.04172656879578638
Betweenness Centrality of Node 95: 0.041226877546322
Betweenness Centrality of Node 48: 0.04096916224399083
Betweenness Centrality of Node 94: 0.04077416082402559
Betweenness Centrality of Node 90: 0.039294510206443964
Betweenness Centrality of Node 18: 0.03866918539811263
Betweenness Centrality of Node 145: 0.038439770456180036
Betweenness Centrality of Node 15: 0.037860685316736 71
Betweenness Centrality of Node 8: 0.037108813152192395
Betweenness Centrality of Node 129: 0.03651801582836066
Betweenness Centrality of Node 109: 0.03622357588508705
Betweenness Centrality of Node 65: 0.03619457197761798
Betweenness Centrality of Node 7: 0.03520130376409958
Betweenness Centrality of Node 93: 0.03487135566423225
Betweenness Centrality of Node 68: 0.03454966400847628
Betweenness Centrality of Node 47: 0.03405791471290327
Betweenness Centrality of Node 128: 0.033493939620968034
Betweenness Centrality of Node 70: 0.03342237120858582
Betweenness Centrality of Node 56: 0.03277733760492381
Betweenness Centrality of Node 119: 0.03211383319057422
Betweenness Centrality of Node 92: 0.030797307736962917
Betweenness Centrality of Node 66: 0.030436583690894053
Betweenness Centrality of Node 117: 0.029197670568106692
Betweenness Centrality of Node 33: 0.028768389294727328
Betweenness Centrality of Node 79: 0.027570786837183045
Betweenness Centrality of Node 43: 0.027307736681468936
Betweenness Centrality of Node 91: 0.027012421281212128
Betweenness Centrality of Node 137: 0.02659367646873281
Betweenness Centrality of Node 123: 0.026586768200330298
Betweenness Centrality of Node 143: 0.025796678576850997
Betweenness Centrality of Node 77: 0.025586450179925502
Betweenness Centrality of Node 32: 0.025543926979552045
Betweenness Centrality of Node 29: 0.024424511737730133
Betweenness Centrality of Node 126: 0.02304620435804232
Betweenness Centrality of Node 50: 0.022977794514728256
Betweenness Centrality of Node 130: 0.0229223132433205
Betweenness Centrality of Node 2: 0.022593597842721535
Betweenness Centrality of Node 84: 0.021234789926473496
Betweenness Centrality of Node 60: 0.020924979926416707
Betweenness Centrality of Node 10: 0.020752326377326373
Betweenness Centrality of Node 144: 0.02042888704526637
Betweenness Centrality of Node 13: 0.020336082872002413
Betweenness Centrality of Node 102: 0.020102060561830667
Betweenness Centrality of Node 42: 0.01930692452878051
Betweenness Centrality of Node 82: 0.019097108989350367
Betweenness Centrality of Node 107: 0.01907324366840932
Betweenness Centrality of Node 149: 0.01858613608613608
Betweenness Centrality of Node 31: 0.018469690962507057
Betweenness Centrality of Node 38: 0.018333449568236584
Betweenness Centrality of Node 25: 0.01818079606830452
Betweenness Centrality of Node 64: 0.01775698731876893
Betweenness Centrality of Node 114: 0.017361083634184822
Betweenness Centrality of Node 67: 0.016797086830189156
Betweenness Centrality of Node 148: 0.016697586761396765
Betweenness Centrality of Node 40: 0.016573124259483273
Betweenness Centrality of Node 138: 0.015707038013072498
Betweenness Centrality of Node 22: 0.015545904446766508
Betweenness Centrality of Node 27: 0.014828187191692942
Betweenness Centrality of Node 89: 0.014430417390187512
Betweenness Centrality of Node 6: 0.014068349956463366
Betweenness Centrality of Node 118: 0.01350925787707397
Betweenness Centrality of Node 86: 0.013481625335073608
Betweenness Centrality of Node 135: 0.01321880652340423
Betweenness Centrality of Node 101: 0.013065814461042099
Betweenness Centrality of Node 88: 0.01271240121096443
Betweenness Centrality of Node 127: 0.01265575402561186
Betweenness Centrality of Node 121: 0.012619774329544444
Betweenness Centrality of Node 104: 0.012198605105693231
Betweenness Centrality of Node 116: 0.012026390572972548
Betweenness Centrality of Node 9: 0.011987465805924226
Betweenness Centrality of Node 11: 0.011874822176546316
Betweenness Centrality of Node 72: 0.0103719710472584
Betweenness Centrality of Node 39: 0.010077072596355718
Betweenness Centrality of Node 132: 0.009985404123335158
Betweenness Centrality of Node 1: 0.009959173520123307
Betweenness Centrality of Node 75: 0.009296843801154142
Betweenness Centrality of Node 53: 0.008961977424198521
Betweenness Centrality of Node 111: 0.008928291270245291
Betweenness Centrality of Node 139: 0.00882855232215575
Betweenness Centrality of Node 41: 0.008771959286932062
Betweenness Centrality of Node 140: 0.008716215936043525
Betweenness Centrality of Node 110: 0.008618818920543057
Betweenness Centrality of Node 73: 0.008361852334553487

```
Betweenness Centrality of Node 34: 0.008298182938564953
Betweenness Centrality of Node 80: 0.008033247084971223
Betweenness Centrality of Node 12: 0.007912155958132966
Betweenness Centrality of Node 28: 0.007868399427307476
Betweenness Centrality of Node 63: 0.007629203225467594
Betweenness Centrality of Node 98: 0.007568998689688347
Betweenness Centrality of Node 59: 0.006831098073914166
Betweenness Centrality of Node 20: 0.006783012645081609
Betweenness Centrality of Node 142: 0.006685558835941977
Betweenness Centrality of Node 45: 0.006657526700630151
Betweenness Centrality of Node 120: 0.006394446743500159
Betweenness Centrality of Node 97: 0.006165024311576037
Betweenness Centrality of Node 62: 0.006157141336739037
Betweenness Centrality of Node 57: 0.00613306676482809
Betweenness Centrality of Node 83: 0.006018418310084978
Betweenness Centrality of Node 115: 0.005915925815351104
Betweenness Centrality of Node 71: 0.005799241467344915
Betweenness Centrality of Node 44: 0.005785811145006547
Betweenness Centrality of Node 17: 0.005114144316730525
Betweenness Centrality of Node 78: 0.004917699328107321
Betweenness Centrality of Node 3: 0.004820554339232499
Betweenness Centrality of Node 46: 0.004669816666943105
Betweenness Centrality of Node 54: 0.004561191149338962
Betweenness Centrality of Node 96: 0.004431489912811751
Betweenness Centrality of Node 146: 0.004226321783793049
Betweenness Centrality of Node 106: 0.004215243568691845
Betweenness Centrality of Node 49: 0.004153031408778534
Betweenness Centrality of Node 24: 0.004022222456130502
Betweenness Centrality of Node 26: 0.003813270141479654
Betweenness Centrality of Node 147: 0.0034473739861670895
Betweenness Centrality of Node 30: 0.002724411603721949
Betweenness Centrality of Node 21: 0.0026228209848899505
Betweenness Centrality of Node 103: 0.0023620175056956673
Betweenness Centrality of Node 36: 0.0020887842718471526
Betweenness Centrality of Node 105: 0.0019308748403575988
Betweenness Centrality of Node 81: 0.0017502128565346953
Betweenness Centrality of Node 58: 0.0017411008000088463
Betweenness Centrality of Node 74: 0.0016685470484490092
Betweenness Centrality of Node 112: 0.0016678771420150734
Betweenness Centrality of Node 108: 0.001574872286079183
Betweenness Centrality of Node 76: 0.001204425895517849
Betweenness Centrality of Node 136: 0.0007320744389709907
Betweenness Centrality of Node 4: 0.0
Betweenness Centrality of Node 14: 0.0
Betweenness Centrality of Node 19: 0.0
Betweenness Centrality of Node 23: 0.0
Betweenness Centrality of Node 35: 0.0
Betweenness Centrality of Node 52: 0.0
Betweenness Centrality of Node 61: 0.0
Betweenness Centrality of Node 85: 0.0
Betweenness Centrality of Node 87: 0.0
Betweenness Centrality of Node 122: 0.0
Betweenness Centrality of Node 124: 0.0
```

Betweenness Centrality:

Betweenness centrality measures the extent to which a node lies on the shortest paths between other nodes in the graph. It quantifies the influence or control that a node has over the flow of information or resources in the network. Nodes with high betweenness centrality act as bridges or bottlenecks, connecting different parts of the graph. They play a critical role in information dissemination, as they can control the flow between communities or act as gatekeepers in the network.

In [ ]:

B.5.2 Closeness Centrality

In [112…

```
# Calculation of  Closeness Centrality
closeness_centrality = nx.closeness_centrality(G)
```

In [113…

```
# Printing of Closeness Centrality
closeness_centrality_sorted = sorted(closeness_centrality.items(), key=lambda X: X[1], reverse=True)
for node, centrality in closeness_centrality_sorted:
    print(f"Closeness Centrality of Node {node}: {centrality}")
```

```
Closeness Centrality of Node 0: 0.3589108910891089
Closeness Centrality of Node 100: 0.3493975903614458
Closeness Centrality of Node 131: 0.3419811320754717
Closeness Centrality of Node 16: 0.33642691415313225
Closeness Centrality of Node 37: 0.33642691415313225
Closeness Centrality of Node 5: 0.33564814814814814
Closeness Centrality of Node 8: 0.33256880733944955
Closeness Centrality of Node 18: 0.327313769751693
Closeness Centrality of Node 133: 0.327313769751693
Closeness Centrality of Node 93: 0.3251121076233184
Closeness Centrality of Node 47: 0.3243847874720358
Closeness Centrality of Node 2: 0.3215077605321508
Closeness Centrality of Node 51: 0.32079646017699115
```

Closeness Centrality of Node 69: 0.32079646017699115
Closeness Centrality of Node 134: 0.3200883002207506
Closeness Centrality of Node 94: 0.3172866520787746
Closeness Centrality of Node 48: 0.3159041394335512
Closeness Centrality of Node 113: 0.3159041394335512
Closeness Centrality of Node 129: 0.3159041394335512
Closeness Centrality of Node 7: 0.31453362255965295
Closeness Centrality of Node 31: 0.31317494600431967
Closeness Centrality of Node 95: 0.31049250535331907
Closeness Centrality of Node 137: 0.3091684434968017
Closeness Centrality of Node 145: 0.3078556263269639
Closeness Centrality of Node 43: 0.3072033898305085
Closeness Centrality of Node 128: 0.30655391120507397
Closeness Centrality of Node 92: 0.3059071729957806
Closeness Centrality of Node 109: 0.30526315789473685
Closeness Centrality of Node 91: 0.3039832285115304
Closeness Centrality of Node 10: 0.302713987473904
Closeness Centrality of Node 32: 0.302713987473904
Closeness Centrality of Node 117: 0.302713987473904
Closeness Centrality of Node 90: 0.30145530145530147
Closeness Centrality of Node 143: 0.30145530145530147
Closeness Centrality of Node 107: 0.3008298755186722
Closeness Centrality of Node 15: 0.3002070393374741
Closeness Centrality of Node 50: 0.29958677685950413
Closeness Centrality of Node 127: 0.29958677685950413
Closeness Centrality of Node 33: 0.29896907216494845
Closeness Centrality of Node 119: 0.29896907216494845
Closeness Centrality of Node 68: 0.29835390946502055
Closeness Centrality of Node 29: 0.29774127310061604
Closeness Centrality of Node 65: 0.29774127310061604
Closeness Centrality of Node 70: 0.29774127310061604
Closeness Centrality of Node 130: 0.29774127310061604
Closeness Centrality of Node 135: 0.29774127310061604
Closeness Centrality of Node 66: 0.29591836734693877
Closeness Centrality of Node 56: 0.2953156822810591
Closeness Centrality of Node 60: 0.2923387096774194
Closeness Centrality of Node 40: 0.2917505030181087
Closeness Centrality of Node 123: 0.2917505030181087
Closeness Centrality of Node 67: 0.29116465863453816
Closeness Centrality of Node 82: 0.29116465863453816
Closeness Centrality of Node 86: 0.29116465863453816
Closeness Centrality of Node 101: 0.29116465863453816
Closeness Centrality of Node 11: 0.2894211576846307
Closeness Centrality of Node 126: 0.2894211576846307
Closeness Centrality of Node 25: 0.28884462151394424
Closeness Centrality of Node 28: 0.28884462151394424
Closeness Centrality of Node 77: 0.28884462151394424
Closeness Centrality of Node 84: 0.2882703777335984
Closeness Centrality of Node 64: 0.2871287128712871
Closeness Centrality of Node 27: 0.2859960552268245
Closeness Centrality of Node 72: 0.2854330708661417
Closeness Centrality of Node 75: 0.2854330708661417
Closeness Centrality of Node 104: 0.283203125
Closeness Centrality of Node 149: 0.283203125
Closeness Centrality of Node 73: 0.2826510721247563
Closeness Centrality of Node 79: 0.2826510721247563
Closeness Centrality of Node 96: 0.2826510721247563
Closeness Centrality of Node 1: 0.2815533980582524
Closeness Centrality of Node 38: 0.2815533980582524
Closeness Centrality of Node 42: 0.2815533980582524
Closeness Centrality of Node 78: 0.2810077519379845
Closeness Centrality of Node 138: 0.2804642166344294
Closeness Centrality of Node 30: 0.2799227799227799
Closeness Centrality of Node 110: 0.27884615384615385
Closeness Centrality of Node 116: 0.27884615384615385
Closeness Centrality of Node 12: 0.2783109404990403
Closeness Centrality of Node 39: 0.2783109404990403
Closeness Centrality of Node 54: 0.2777777777777778
Closeness Centrality of Node 114: 0.2777777777777778
Closeness Centrality of Node 9: 0.2767175572519084
Closeness Centrality of Node 89: 0.2767175572519084
Closeness Centrality of Node 88: 0.2761904761904762
Closeness Centrality of Node 57: 0.27514231499051234
Closeness Centrality of Node 118: 0.27514231499051234
Closeness Centrality of Node 144: 0.27514231499051234
Closeness Centrality of Node 34: 0.2741020793950851
Closeness Centrality of Node 49: 0.2741020793950851
Closeness Centrality of Node 80: 0.2730696798493409
Closeness Centrality of Node 111: 0.2725563909774436
Closeness Centrality of Node 121: 0.2725563909774436
Closeness Centrality of Node 140: 0.2725563909774436
Closeness Centrality of Node 6: 0.27153558052434457
Closeness Centrality of Node 59: 0.27001862197392923
Closeness Centrality of Node 20: 0.2695167286245353
Closeness Centrality of Node 106: 0.2695167286245353
Closeness Centrality of Node 139: 0.2695167286245353
Closeness Centrality of Node 45: 0.26851851851851855
Closeness Centrality of Node 115: 0.26851851851851855
Closeness Centrality of Node 53: 0.2680221811460259

```
Closeness Centrality of Node 148: 0.26703499079189685
Closeness Centrality of Node 142: 0.26508226691042047
Closeness Centrality of Node 26: 0.2636363636363636
Closeness Centrality of Node 120: 0.2631578947368421
Closeness Centrality of Node 71: 0.26220614828209765
Closeness Centrality of Node 146: 0.26126126126126126
Closeness Centrality of Node 63: 0.2607913669064748
Closeness Centrality of Node 36: 0.25985663082437277
Closeness Centrality of Node 97: 0.25985663082437277
Closeness Centrality of Node 44: 0.25892857142857145
Closeness Centrality of Node 62: 0.25892857142857145
Closeness Centrality of Node 102: 0.25892857142857145
Closeness Centrality of Node 83: 0.25846702317290554
Closeness Centrality of Node 13: 0.2570921985815603
Closeness Centrality of Node 98: 0.2570921985815603
Closeness Centrality of Node 24: 0.25618374558303886
Closeness Centrality of Node 41: 0.25573192239858905
Closeness Centrality of Node 58: 0.25528169014084506
Closeness Centrality of Node 122: 0.2517361111111111
Closeness Centrality of Node 46: 0.2512998266897747
Closeness Centrality of Node 103: 0.2508650519031142
Closeness Centrality of Node 81: 0.25
Closeness Centrality of Node 147: 0.2495697074010327
Closeness Centrality of Node 21: 0.2482876712328767
Closeness Centrality of Node 52: 0.24701873935264054
Closeness Centrality of Node 105: 0.2465986394557823
Closeness Centrality of Node 17: 0.2461799660441426
Closeness Centrality of Node 112: 0.24328859060402686
Closeness Centrality of Node 74: 0.24247491638795987
Closeness Centrality of Node 22: 0.24207011686143573
Closeness Centrality of Node 108: 0.24207011686143573
Closeness Centrality of Node 23: 0.24046434494195687
Closeness Centrality of Node 132: 0.23887973640856672
Closeness Centrality of Node 136: 0.23462783171521034
Closeness Centrality of Node 14: 0.23424878836833601
Closeness Centrality of Node 19: 0.232
Closeness Centrality of Node 87: 0.232
Closeness Centrality of Node 61: 0.23125996810207336
Closeness Centrality of Node 124: 0.2207001522070015
Closeness Centrality of Node 3: 0.21739130434782608
Closeness Centrality of Node 35: 0.2059659090909091
Closeness Centrality of Node 85: 0.20480225988700565
Closeness Centrality of Node 76: 0.20279720279720279
Closeness Centrality of Node 4: 0.19515477792732167
```

Closeness Centrality:

Closeness centrality measures how close a node is to all other nodes in terms of the shortest path distances. It quantifies the ease of reaching a node from any other node in the graph. Nodes with high closeness centrality are easily accessible and can efficiently spread information or influence throughout the network. They are important for efficient communication and are often located at the center or core of the network.

In [ ]:

B.6 Drawing of Ego-graph

Draw the Ego-graph of various nodes found in above analysis

In [114…

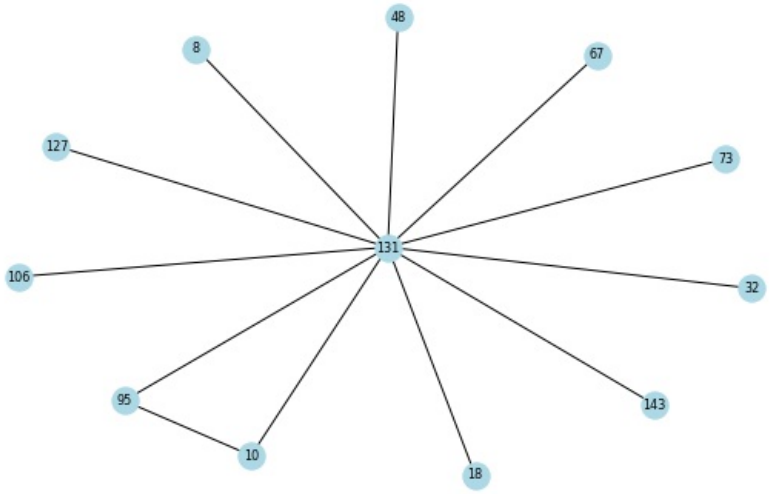
```python
# Draw ego-graphs for selected nodes

def graph_ego(nodes_ego, G):
    for node in nodes_ego:
        ego_graph = nx.ego_graph(G, node)

        # Plot the ego-graph
        plt.figure(figsize=(8, 5))
        pos = nx.spring_layout(ego_graph)
        nx.draw(ego_graph, pos, with_labels=True, node_color='lightblue', node_size=300, font_size=8)
        plt.title(f"Ego-graph of Node {node}")
        plt.show()
```

Ego-Graph Ploting of highest 5 Nodes based on Degree Centrality

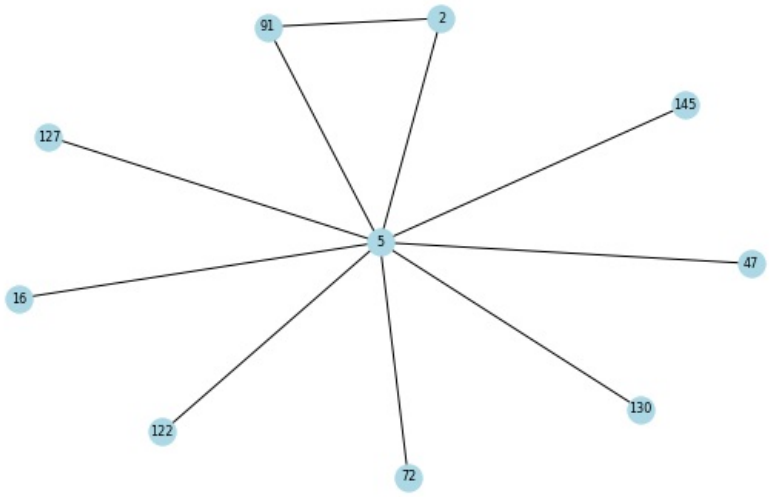
In [115…

```python
nodes_ego_degree_centrality = []
nodes_ego_degree_centrality = [row[0] for i, row in enumerate(degree_centrality_sorted) if i < 5]
graph_ego(nodes_ego_degree_centrality, G)
```

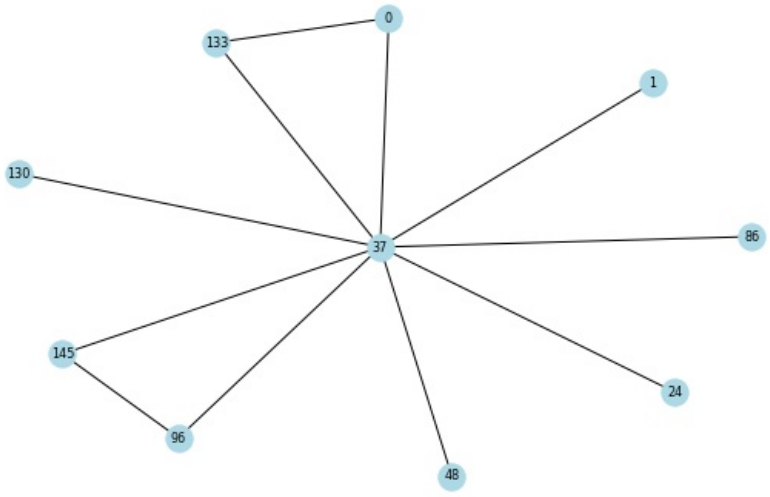
Ego-graph of Node 131

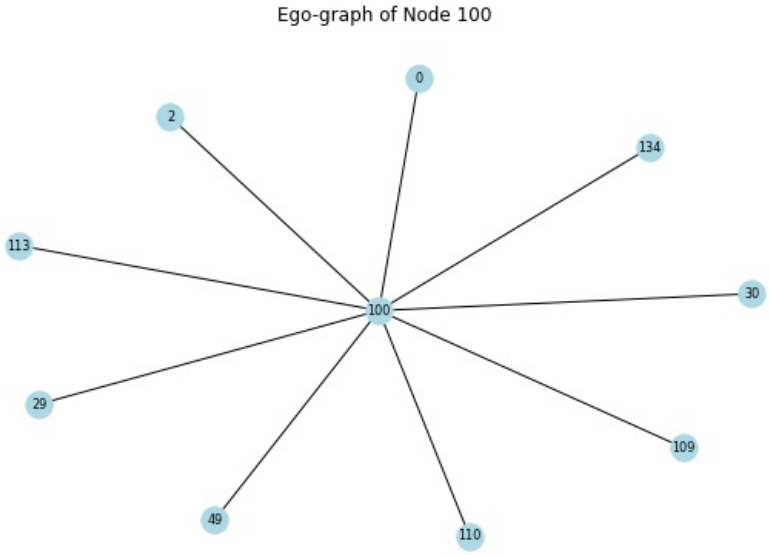


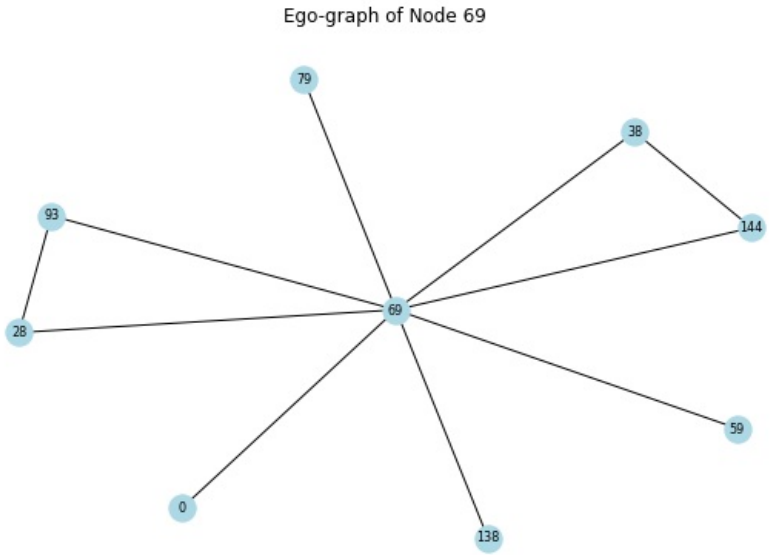
Ego-graph of Node 5



Ego-graph of Node 37





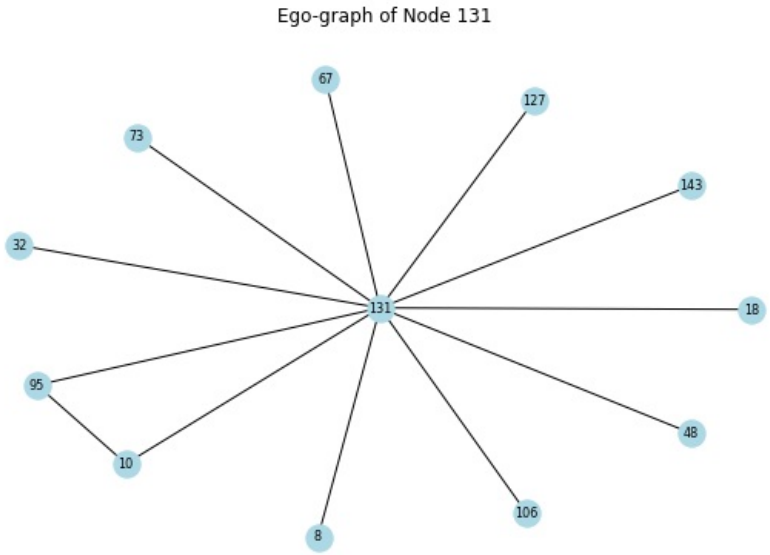


In [ ]:

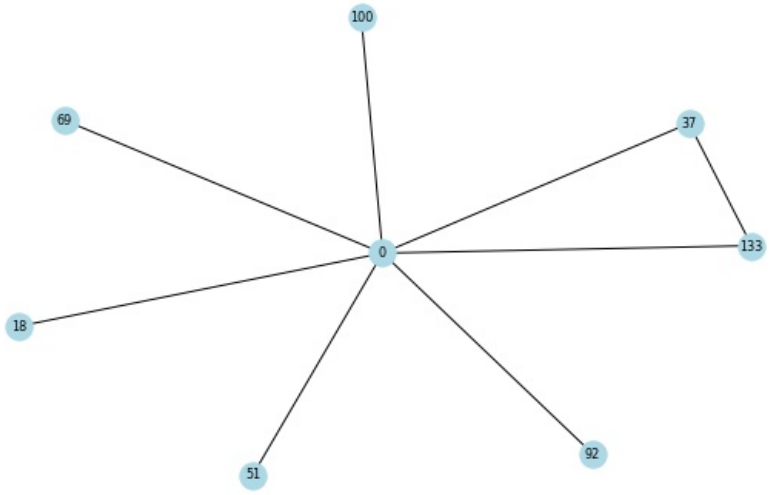
Ego-Graph Ploting of highest 5 Nodes based on Eigen-Vector Centrality

In [116…

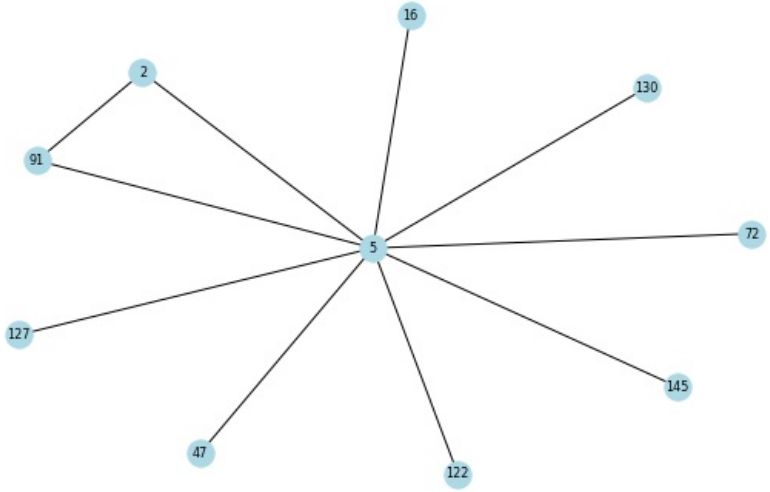
```
nodes_ego_eigenvector_centrality = []
nodes_ego_eigenvector_centrality = [row[0] for i, row in enumerate(eigenvector_centrality_sorted) if i < 5]
graph_ego(nodes_ego_eigenvector_centrality, G)
```



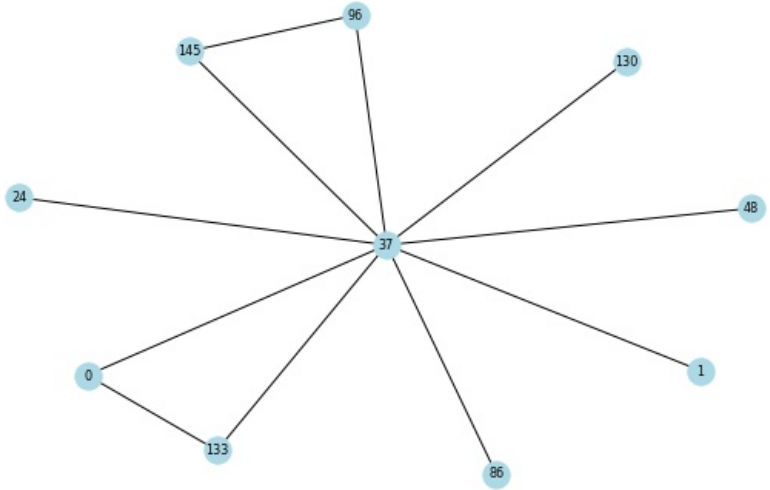
Ego-graph of Node 0

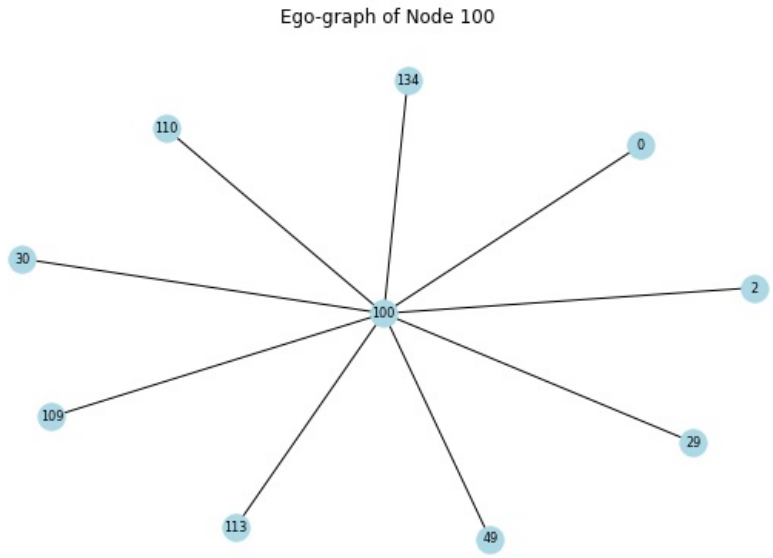


Ego-graph of Node 5



Ego-graph of Node 37

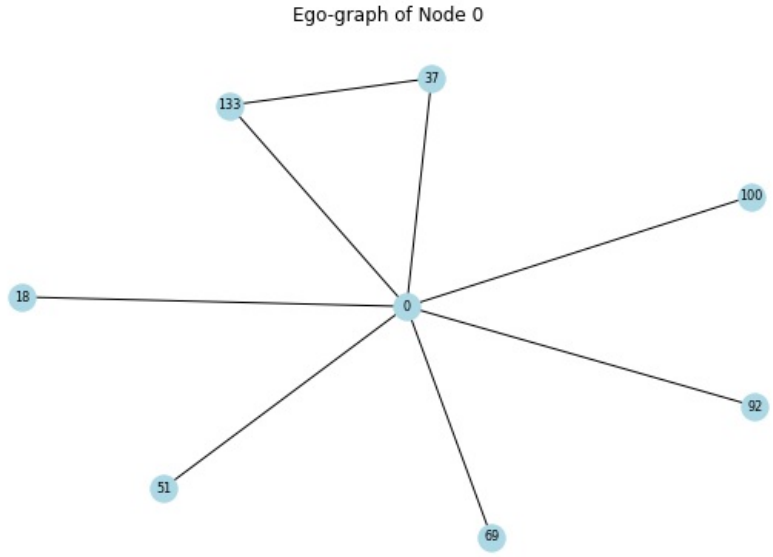


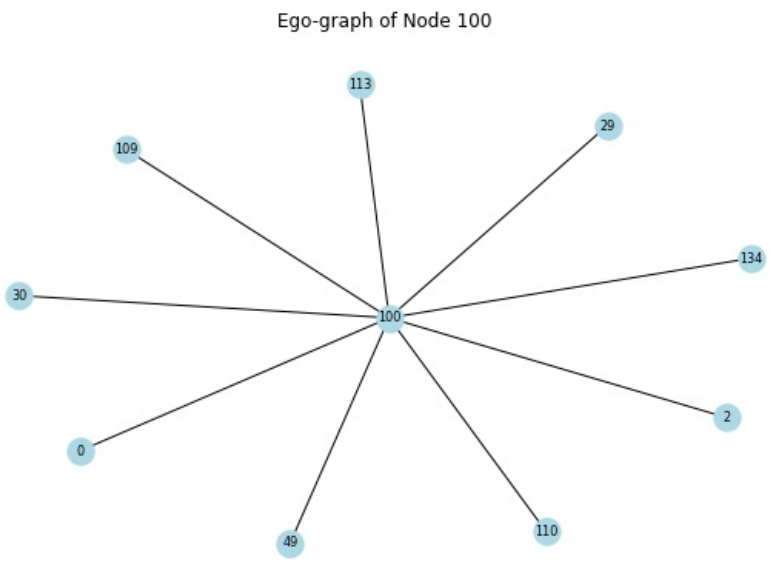


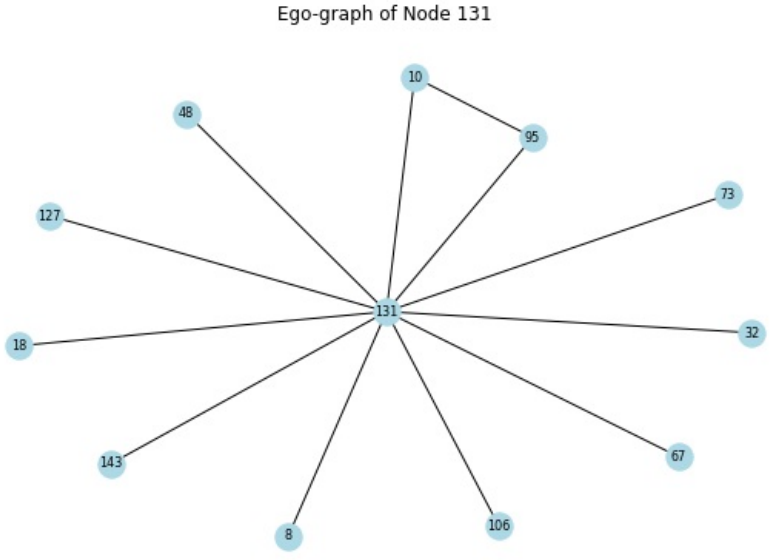
Ego-Graph Ploting of highest 5 Nodes based on Closeness Centrality

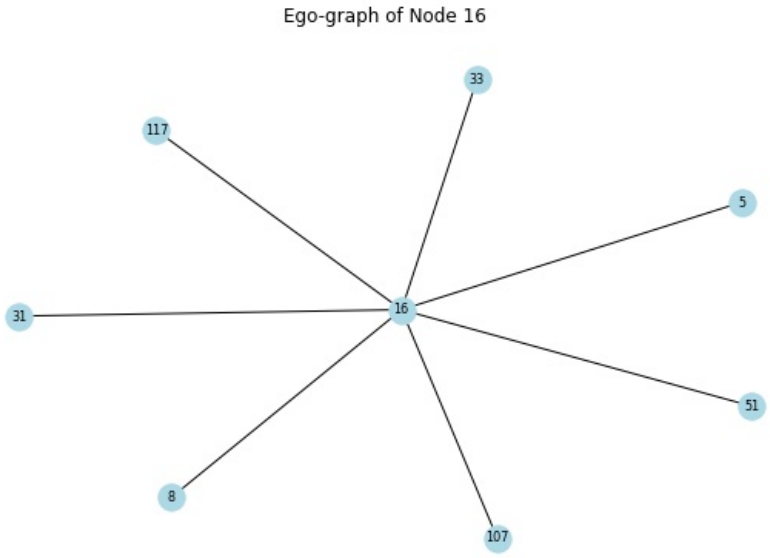
In [117…

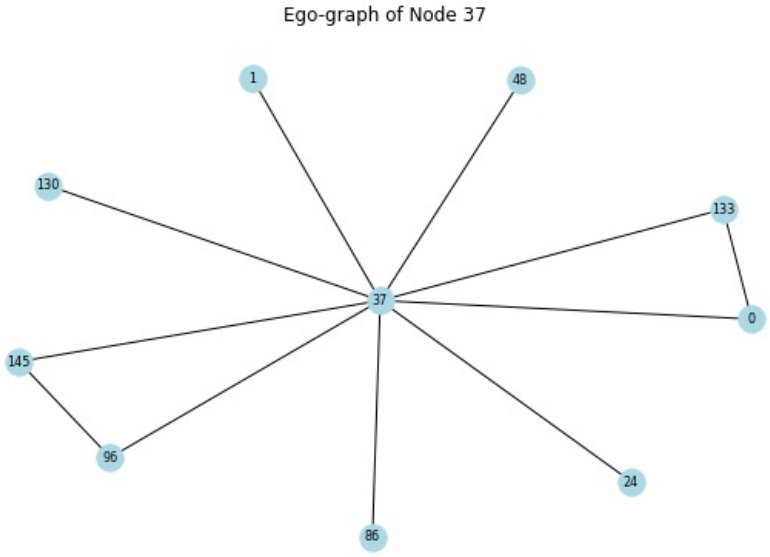
```
nodes_ego_closeness_centrality = []
nodes_ego_closeness_centrality = [row[0] for i, row in enumerate(closeness_centrality_sorted) if i < 5]
graph_ego(nodes_ego_closeness_centrality, G)
```




Ego-graph of Node 100
113
29
109
134
30
100
2
0
49
110


Ego-graph of Node 131
10
48
95
73
127
131
32
18
67
143
106
8





In [ ]:

B.7 Global Clustering Coefficient

Calculate the Global clustering coefficient of random graph

The global clustering coefficient measures the overall density of triangles (closed loops of three connected nodes) in the graph, providing insights into the level of clustering or local connectivity.

In [118…
```
# Calculate the global clustering coefficient
clustering_coefficient = nx.average_clustering(G)
```

In [119…
```
# Print the global clustering coefficient
print(f"Global Clustering Coefficient: {clustering_coefficient}")
```

```
Global Clustering Coefficient: 0.013806855245211408
```

In [ ]:

B.8 Local Clustering Coefficient

Calculate the Local clustering coefficient of nodes of Random graph

The local clustering coefficient measures the density of connections among a node's neighbors, providing insights into the level of clustering or local connectivity around each node.

In [120…
```
# Calculate the local clustering coefficient for each node
local_clustering = nx.clustering(G)
```

In [121…
```
# Print the local clustering coefficient for each node
local_clustering_sorted = sorted(local_clustering.items(), key=lambda X: X[1], reverse=True)
for node, coefficient in local_clustering_sorted:
    print(f"Local Clustering Coefficient of Node {node}: {coefficient}")
```

```
Local Clustering Coefficient of Node 96: 0.3333333333333333
Local Clustering Coefficient of Node 28: 0.16666666666666666
Local Clustering Coefficient of Node 142: 0.16666666666666666
Local Clustering Coefficient of Node 144: 0.16666666666666666
Local Clustering Coefficient of Node 2: 0.1
Local Clustering Coefficient of Node 10: 0.1
Local Clustering Coefficient of Node 38: 0.1
Local Clustering Coefficient of Node 89: 0.1
Local Clustering Coefficient of Node 69: 0.07142857142857142
Local Clustering Coefficient of Node 47: 0.06666666666666667
Local Clustering Coefficient of Node 91: 0.06666666666666667
Local Clustering Coefficient of Node 94: 0.06666666666666667
Local Clustering Coefficient of Node 95: 0.06666666666666667
Local Clustering Coefficient of Node 133: 0.06666666666666667
Local Clustering Coefficient of Node 137: 0.06666666666666667
Local Clustering Coefficient of Node 145: 0.06666666666666667
Local Clustering Coefficient of Node 37: 0.05555555555555555
Local Clustering Coefficient of Node 0: 0.047619047619047616
Local Clustering Coefficient of Node 93: 0.047619047619047616
Local Clustering Coefficient of Node 134: 0.047619047619047616
Local Clustering Coefficient of Node 5: 0.027777777777777776
Local Clustering Coefficient of Node 131: 0.01818181818181818
Local Clustering Coefficient of Node 1: 0
Local Clustering Coefficient of Node 3: 0
Local Clustering Coefficient of Node 4: 0
Local Clustering Coefficient of Node 6: 0
Local Clustering Coefficient of Node 7: 0
Local Clustering Coefficient of Node 8: 0
Local Clustering Coefficient of Node 9: 0
Local Clustering Coefficient of Node 11: 0
Local Clustering Coefficient of Node 12: 0
Local Clustering Coefficient of Node 13: 0
Local Clustering Coefficient of Node 14: 0
Local Clustering Coefficient of Node 15: 0
Local Clustering Coefficient of Node 16: 0
Local Clustering Coefficient of Node 17: 0
Local Clustering Coefficient of Node 18: 0
Local Clustering Coefficient of Node 19: 0
Local Clustering Coefficient of Node 20: 0
Local Clustering Coefficient of Node 21: 0
Local Clustering Coefficient of Node 22: 0
Local Clustering Coefficient of Node 23: 0
Local Clustering Coefficient of Node 24: 0
Local Clustering Coefficient of Node 25: 0
Local Clustering Coefficient of Node 26: 0
Local Clustering Coefficient of Node 27: 0
Local Clustering Coefficient of Node 29: 0
Local Clustering Coefficient of Node 30: 0
Local Clustering Coefficient of Node 31: 0
Local Clustering Coefficient of Node 32: 0
Local Clustering Coefficient of Node 33: 0
Local Clustering Coefficient of Node 34: 0
Local Clustering Coefficient of Node 35: 0
Local Clustering Coefficient of Node 36: 0
Local Clustering Coefficient of Node 39: 0
Local Clustering Coefficient of Node 40: 0
Local Clustering Coefficient of Node 41: 0
Local Clustering Coefficient of Node 42: 0
Local Clustering Coefficient of Node 43: 0
Local Clustering Coefficient of Node 44: 0
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Local Clustering Coefficient of Node 46: 0
Local Clustering Coefficient of Node 48: 0
Local Clustering Coefficient of Node 49: 0
Local Clustering Coefficient of Node 50: 0
Local Clustering Coefficient of Node 51: 0
Local Clustering Coefficient of Node 52: 0
Local Clustering Coefficient of Node 53: 0
Local Clustering Coefficient of Node 54: 0
Local Clustering Coefficient of Node 56: 0
Local Clustering Coefficient of Node 57: 0
```

```
Local Clustering Coefficient of Node 58: 0
Local Clustering Coefficient of Node 59: 0
Local Clustering Coefficient of Node 60: 0
Local Clustering Coefficient of Node 61: 0
Local Clustering Coefficient of Node 62: 0
Local Clustering Coefficient of Node 63: 0
Local Clustering Coefficient of Node 64: 0
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Local Clustering Coefficient of Node 66: 0
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Local Clustering Coefficient of Node 68: 0
Local Clustering Coefficient of Node 70: 0
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Local Clustering Coefficient of Node 90: 0
Local Clustering Coefficient of Node 92: 0
Local Clustering Coefficient of Node 97: 0
Local Clustering Coefficient of Node 98: 0
Local Clustering Coefficient of Node 100: 0
Local Clustering Coefficient of Node 101: 0
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Local Clustering Coefficient of Node 116: 0
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Local Clustering Coefficient of Node 119: 0
Local Clustering Coefficient of Node 120: 0
Local Clustering Coefficient of Node 121: 0
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Local Clustering Coefficient of Node 130: 0
Local Clustering Coefficient of Node 132: 0
Local Clustering Coefficient of Node 135: 0
Local Clustering Coefficient of Node 136: 0
Local Clustering Coefficient of Node 138: 0
Local Clustering Coefficient of Node 139: 0
Local Clustering Coefficient of Node 140: 0
Local Clustering Coefficient of Node 143: 0
Local Clustering Coefficient of Node 146: 0
Local Clustering Coefficient of Node 147: 0
Local Clustering Coefficient of Node 148: 0
Local Clustering Coefficient of Node 149: 0
```

In [ ]:

B.9 Highest Local Clustering Coefficients

Identify the highest local clustering coefficient and their significance in terms of structural behavior.

In [122…

```
# Calculate local clustering coefficient for each node
local_clustering = nx.clustering(G)
```

In [123…

```
# Find node with highest local clustering coefficient
```

```
highest_clustering_node = max(local_clustering, key=local_clustering.get)
highest_clustering_coefficient = local_clustering[highest_clustering_node]
```

In [124…
```
# Print the node with highest local clustering coefficient
print(f"Node {highest_clustering_node} has the highest local clustering coefficient of {highest_clustering_coef
```

```
Node 96 has the highest local clustering coefficient of 0.3333333333333333.
```

In [125…
```
# Analyze significance of node with highest local clustering coefficient
neighbors = list(G.neighbors(highest_clustering_node))
neighbor_count = len(neighbors)

print(f"Node {highest_clustering_node} has {neighbor_count} neighbors.")
```

```
Node 96 has 3 neighbors.
```

In [126…
```
# Calculate average degree of the neighbors
# average_degree = sum(G.degree(neighbors).values()) / neighbor_count
average_degree = nx.average_neighbor_degree(G, nodes=[highest_clustering_node])

print(f"Average degree of neighbors of node {highest_clustering_node} is {average_degree[highest_clustering_nod
```

```
Average degree of neighbors of node 96 is 6.666666666666667.
```

In [ ]:

Significance of Node with Highest Local Clustering Coefficient depends on context and characteristics of graph as below:

- **Hubs or influential node**: Nodes with high local clustering coefficients may act as hubs or central points in the network, connecting multiple clusters or communities. They can facilitate the flow of information or resources between different parts of the graph.
- **Structural importance**: Nodes with high local clustering coefficients often play a crucial role in maintaining the structural integrity of the graph. They contribute to the overall connectedness and resilience of the network by forming densely connected subgraphs.
- **Community leaders**: Nodes with high local clustering coefficients may represent influential individuals or leaders within specific communities or clusters. They can have a significant impact on the dynamics and behavior of their respective communities.
- **Specialized roles**: Depending on the domain or application, nodes with high local clustering coefficients can represent specialized entities with unique functions or roles within the network. For example, in social networks, they could be opinion leaders, topic experts, or information sources.