SNA Programming Assignment 4

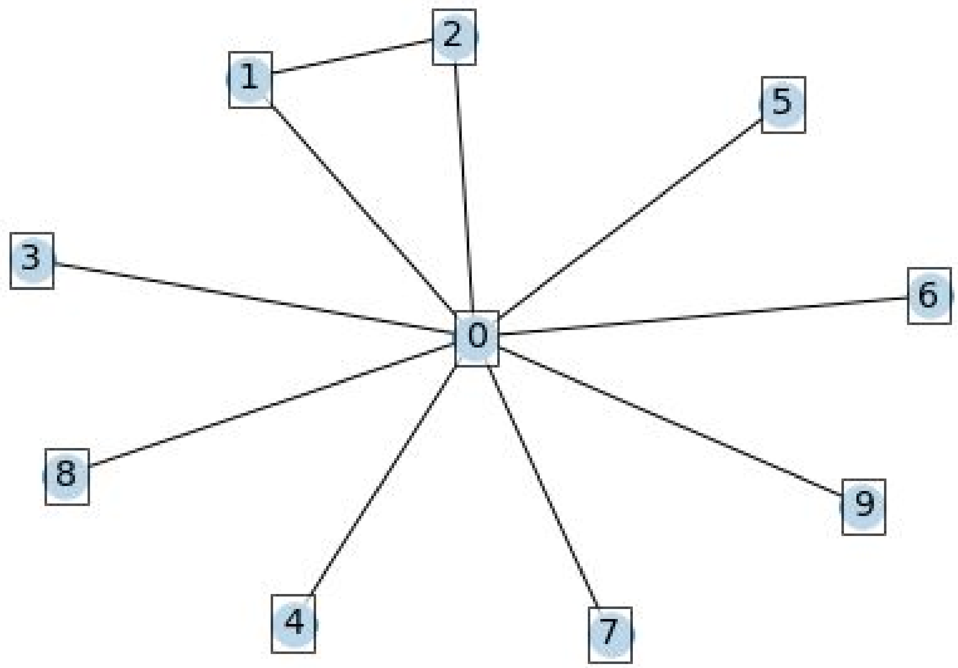
Q: 1. Write functions to Generate Random Graph with (i) N nodes and L edges and (ii) N and p parameter. (Do not use lib function)

The algorithm that was used for this question takes advantage of batch streaming of edge information while generating the graph. If all the edges are stored in the memory at the same time while adding them to the graph, it leads to memory overflow even on platforms like Google Colab.

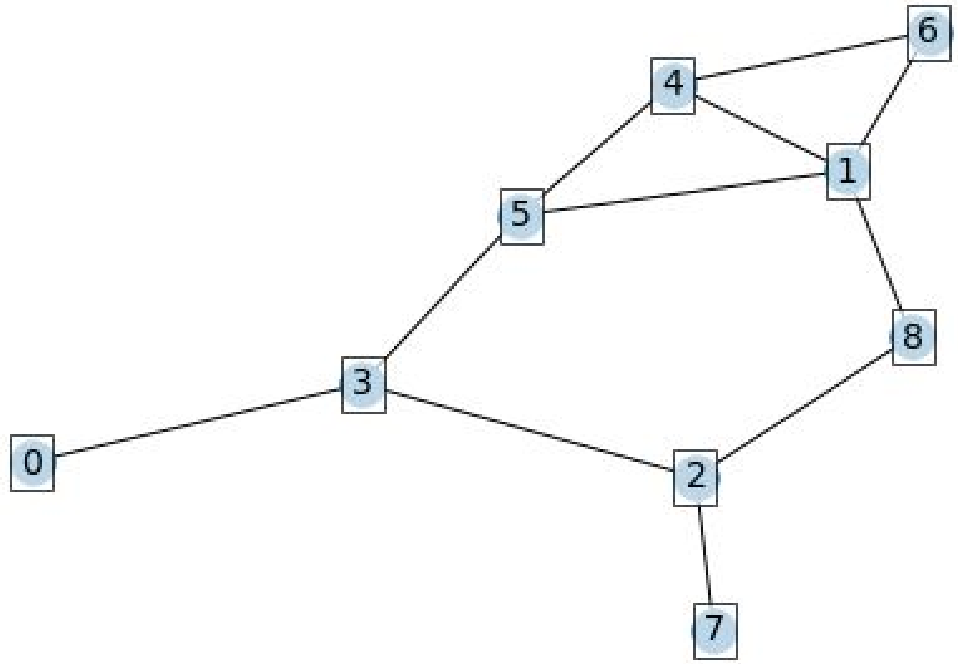
The following are the random graphs generated for different values of N from both functions.

N = 10:

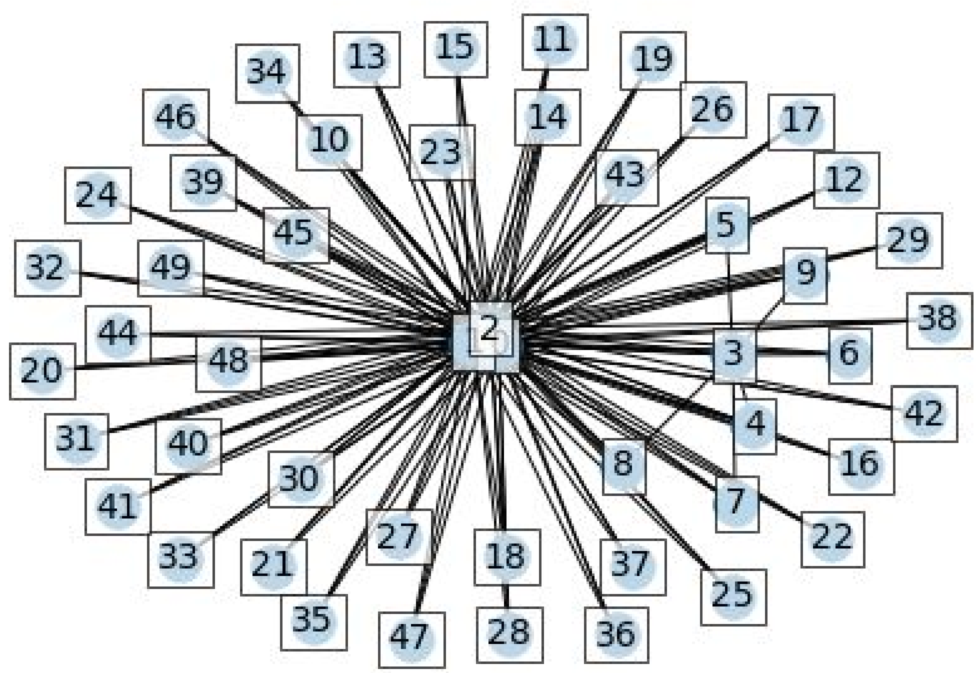
Random Gnm Graph with 10 nodes and 10 edges



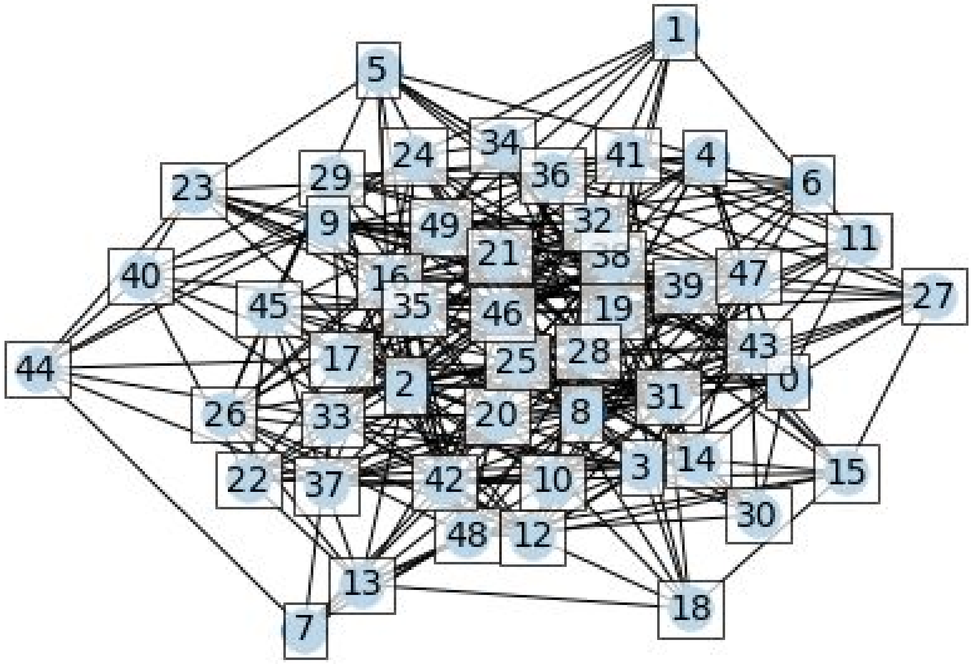
Random Gnp Graph with 9 nodes and 11 edges



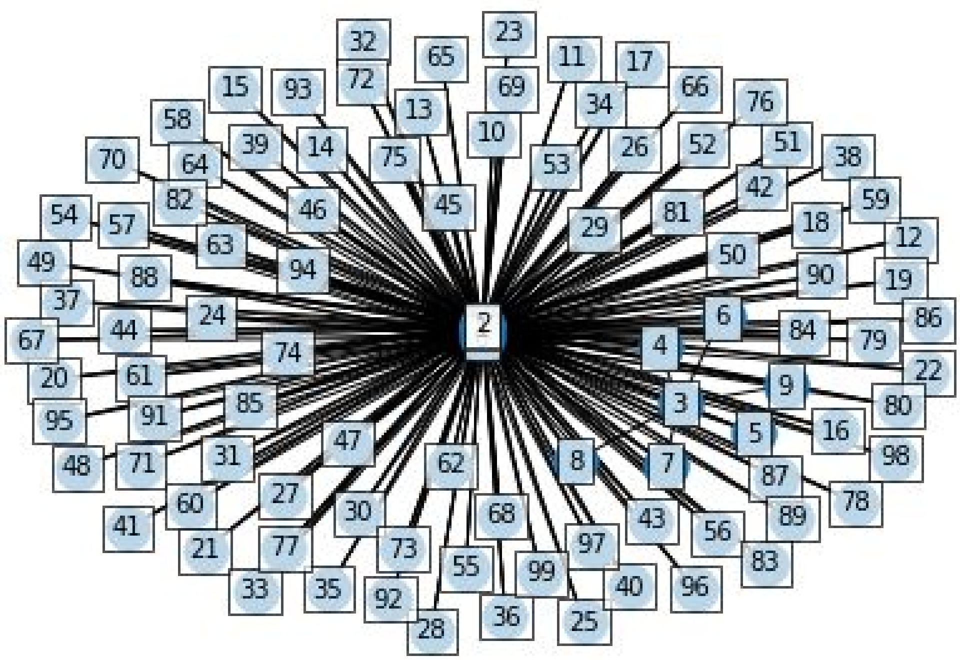
N = 50:
Random Gnm Graph with 50 nodes and 150 edges



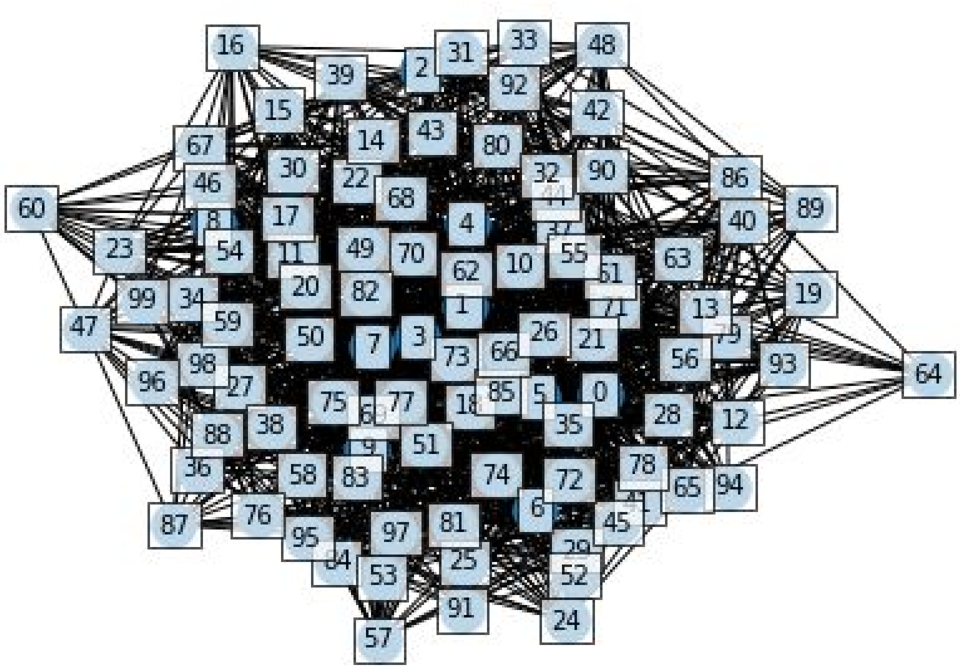
Random Gnp Graph with 50 nodes and 297 edges



N=100:
Random Gnm Graph with 100 nodes and 300 edges



Random Gnp Graph with 100 nodes and 1231 edges



Details:
The algorithm uses a common function to with an option to keep p static (for G_{np}) or keep increasing p to meet L (for G_{nl}).
The maths behind the second case is as follows:
The total edges covered ratio:

$$T=1-\frac{covered}{\frac{N*(N-1)}{2}}$$

The edges considered to be added to the graph ratio:

$$E=1-\frac{edge_{c}ount}{L}$$

Dynamically incrementing p:

$$p=1-(T-E)\geq 0$$

i.e. if T - E = 0, then add every edge.

These equations ensure that the algorithm quickly optimizes adding edges over the batch iterations for G_{nl}. The starting probability is 0.5.

Evaluation

Networkx algorithms for random graph generation were used as benchmarks. The `dense_gnm_random_graph` was used for dense graphs and `gnm_random_graph` was used for sparse graphs. The implemented algo `generate_gnl_random` can be used in both cases.

S. No.	N	L	batch-size-divisor	nx-algo	generate_gnl_random
1	100	100	1	0.000600	0.001100
2	100	100	10	0.000600	0.001400
3	100	100	100	0.000800	0.000900
4	100	1000	1	0.012500	0.009400
5	100	1000	10	0.012500	0.007900
6	100	1000	100	0.012600	0.010600
8	1000	1000	1	0.007300	0.010500
9	1000	1000	10	0.006800	0.009100
10	1000	1000	100	0.007600	0.009800
12	1000	10000	1	0.129100	0.101300
13	1000	10000	10	0.069400	0.077000
14	1000	10000	100	0.063900	0.132400
15	1000	100000	1	1.530700	1.086100
16	1000	100000	10	1.451700	0.944500
17	1000	100000	100	1.482300	0.879800
18	10000	10000	1	0.094700	0.108200
19	10000	10000	10	0.095000	0.088200
20	10000	10000	100	0.106500	0.101000
23	10000	100000	1	0.907000	1.183700
24	10000	100000	10	0.878800	0.892800
25	10000	100000	100	0.902400	0.832500
26	100000	100000	1	1.361500	1.506800
27	100000	100000	10	1.405000	1.227300
28	100000	100000	100	0.995700	0.781100

Here batch-size-divisor is the integer used to get batch size.

$$batch_size = \frac{L}{batch-size-divisor}$$

Out of the experimented results for the same values for the set of N, L and batch-size-divisor, the minimum value was chosen.

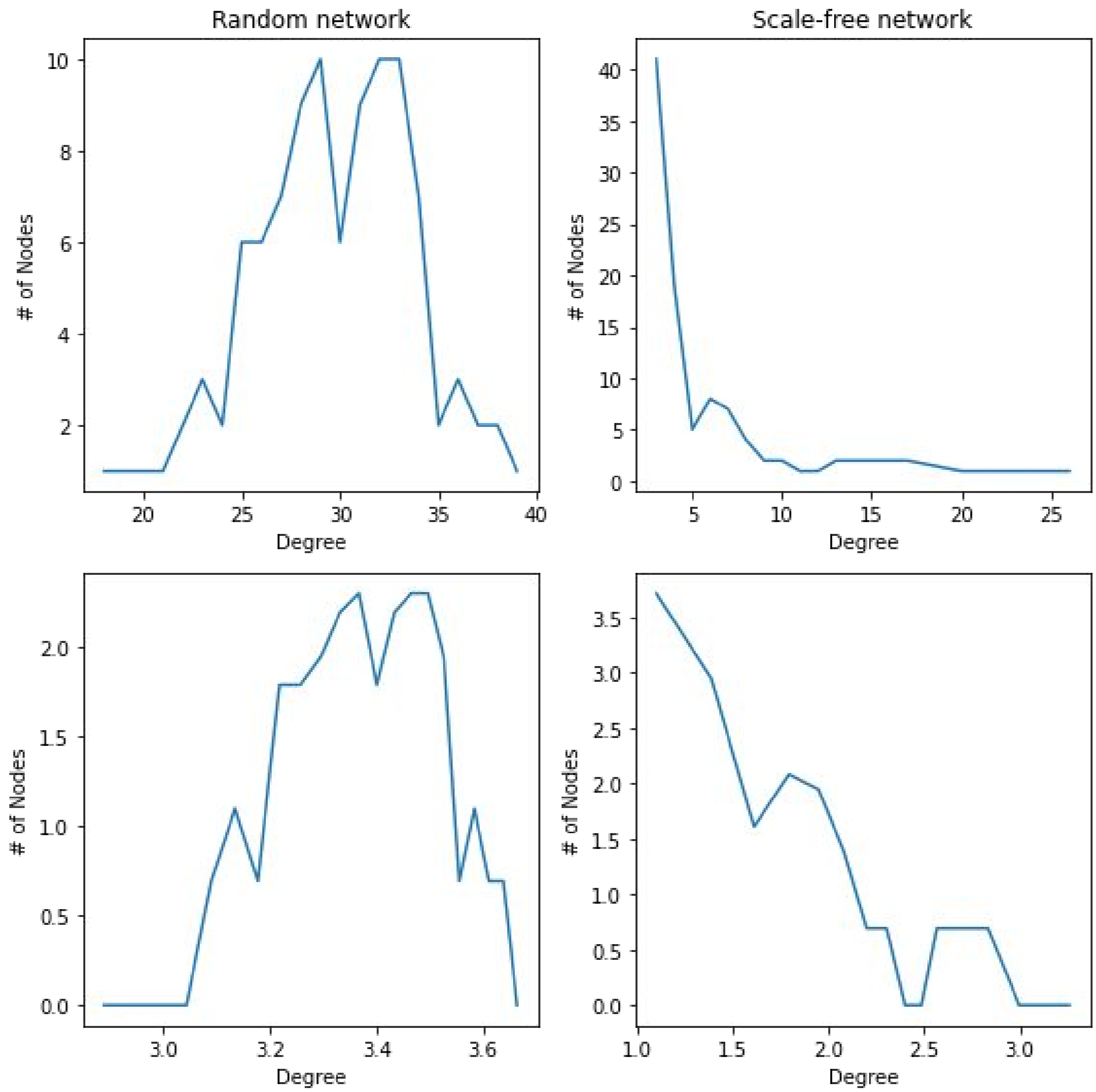
Similar evaluation was performed for `generate_gnp_random` with benchmark algorithms taken as `gnp_random_graph` and `fast_gnp_random_graph`.
The following results were obtained.

	N	p	nx-algo	generate_gnp_random
0	100	0.000100	0.0001	0.000001
1	100	0.001000	0.0002	0.000001
2	100	0.010000	0.0003	0.000001
3	100	0.100000	0.0014	0.051814
4	1000	0.000100	0.0019	0.000001
5	1000	0.001000	0.0034	4.600649
6	1000	0.010000	0.0197	1.481913
7	1000	0.100000	0.1129	0.811151

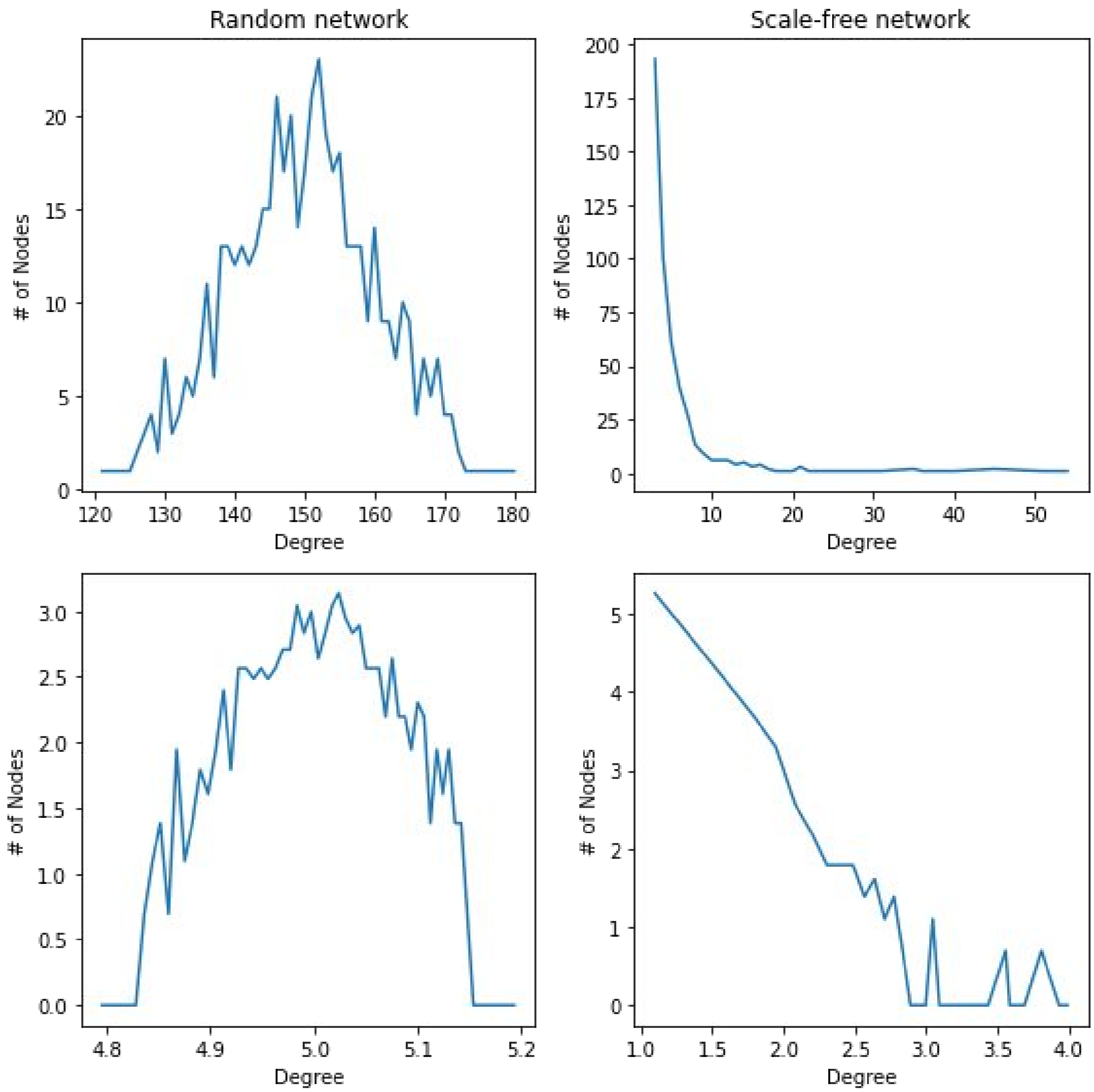
For the green values for this algorithm, the `generate_gnp_random` function skips those pairs of N and p that have no edges.

Q: 2. Generate Random Graph (Using any algorithm) and Scale-Free Graph (using Barabasi-Albert model) of different sizes ranging from N=100 to $10^{5/10}$6 (based on your machine). Plot their degree distributions, both in usual scale and log-log scale.

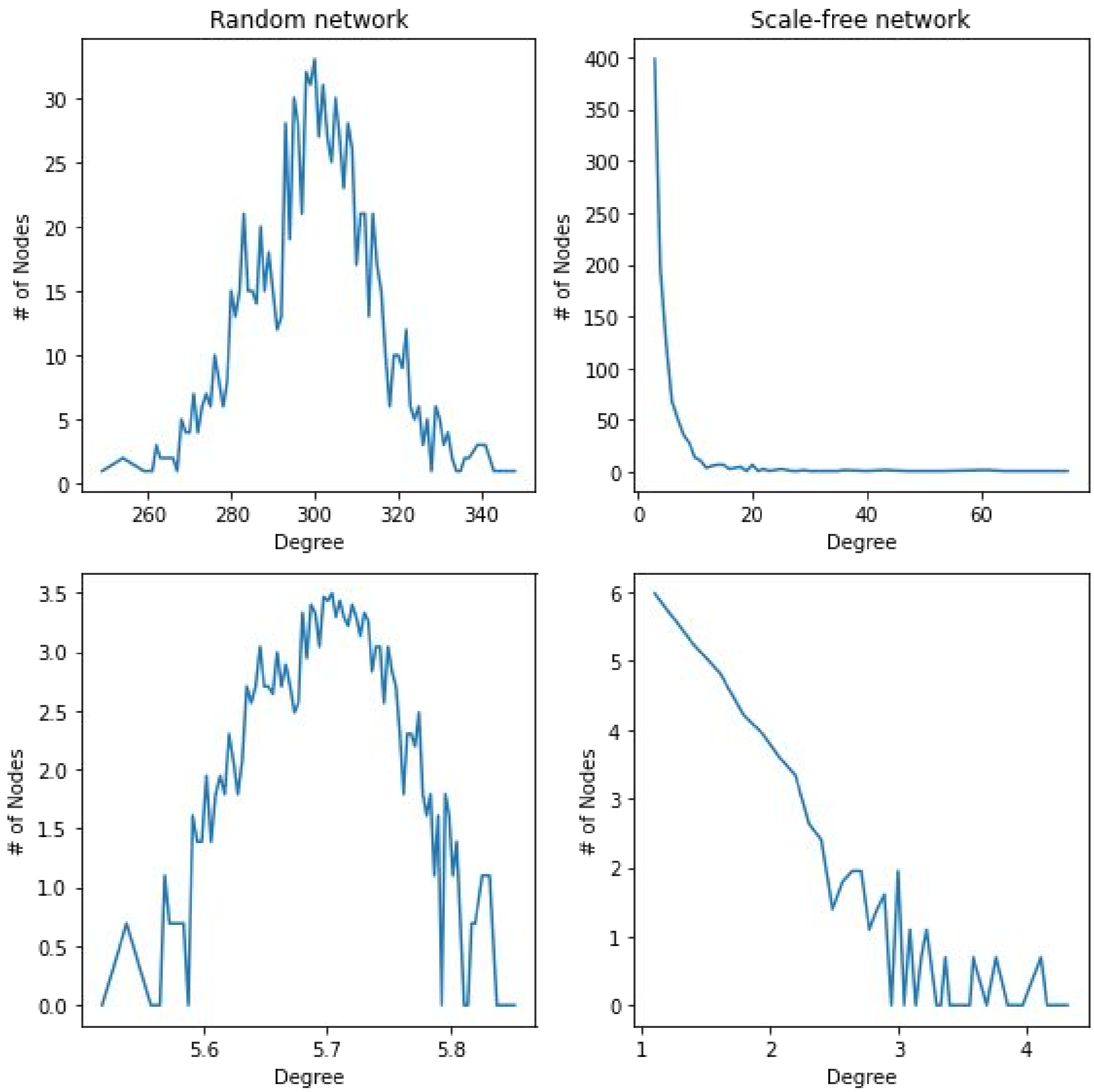
N=100:



N=500:

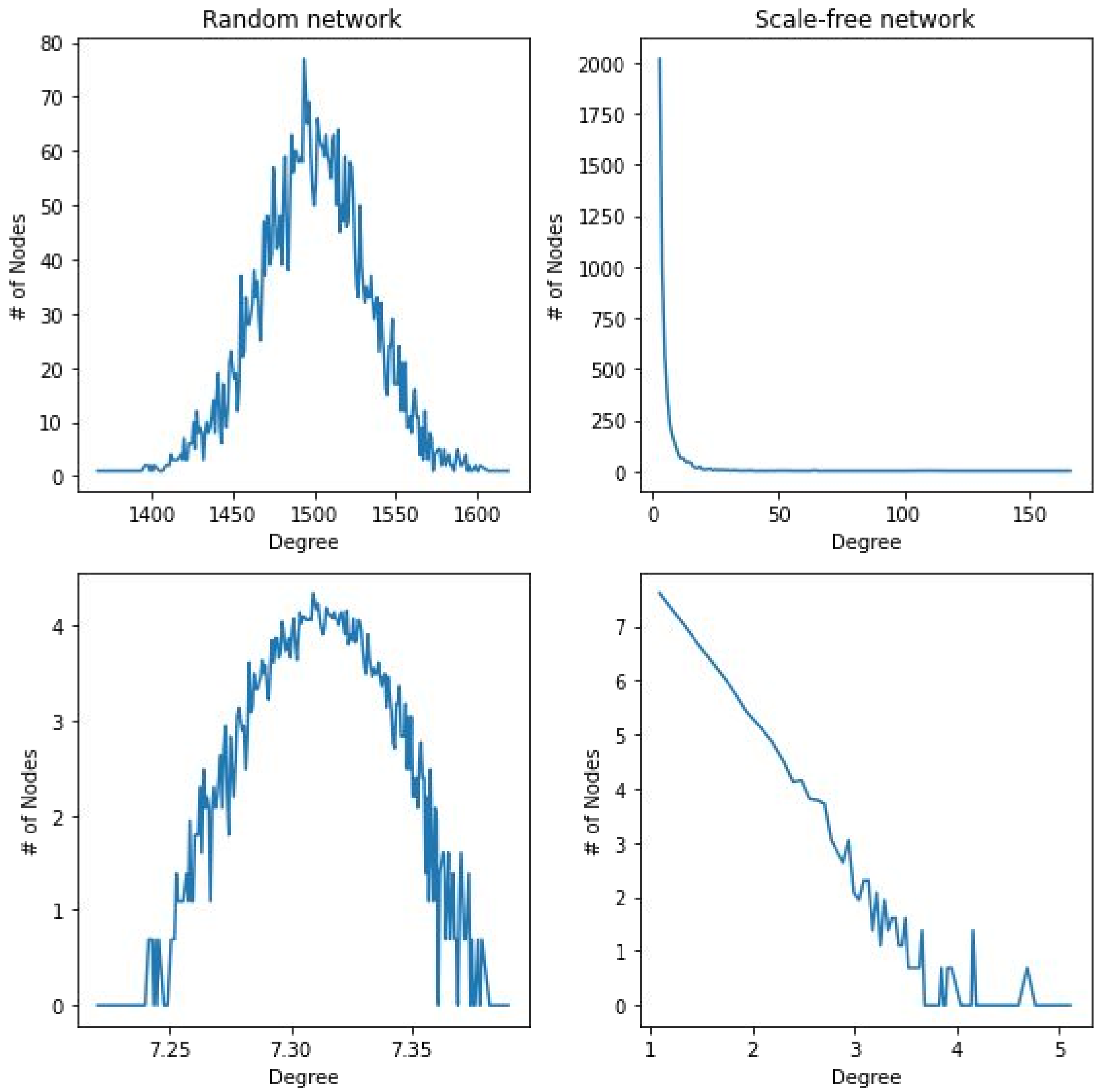

Random network
Scale-free network
# of Nodes
Degree
0
5
10
15
20
120
130
140
150
160
170
180
0
25
50
75
100
125
150
175
200
10
20
30
40
50
0.0
0.5
1.0
1.5
2.0
2.5
3.0
4.8
4.9
5.0
5.1
5.2
0
1
2
3
4
5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

N=1000:



Random network
Scale-free network
# of Nodes
Degree

N=5000:

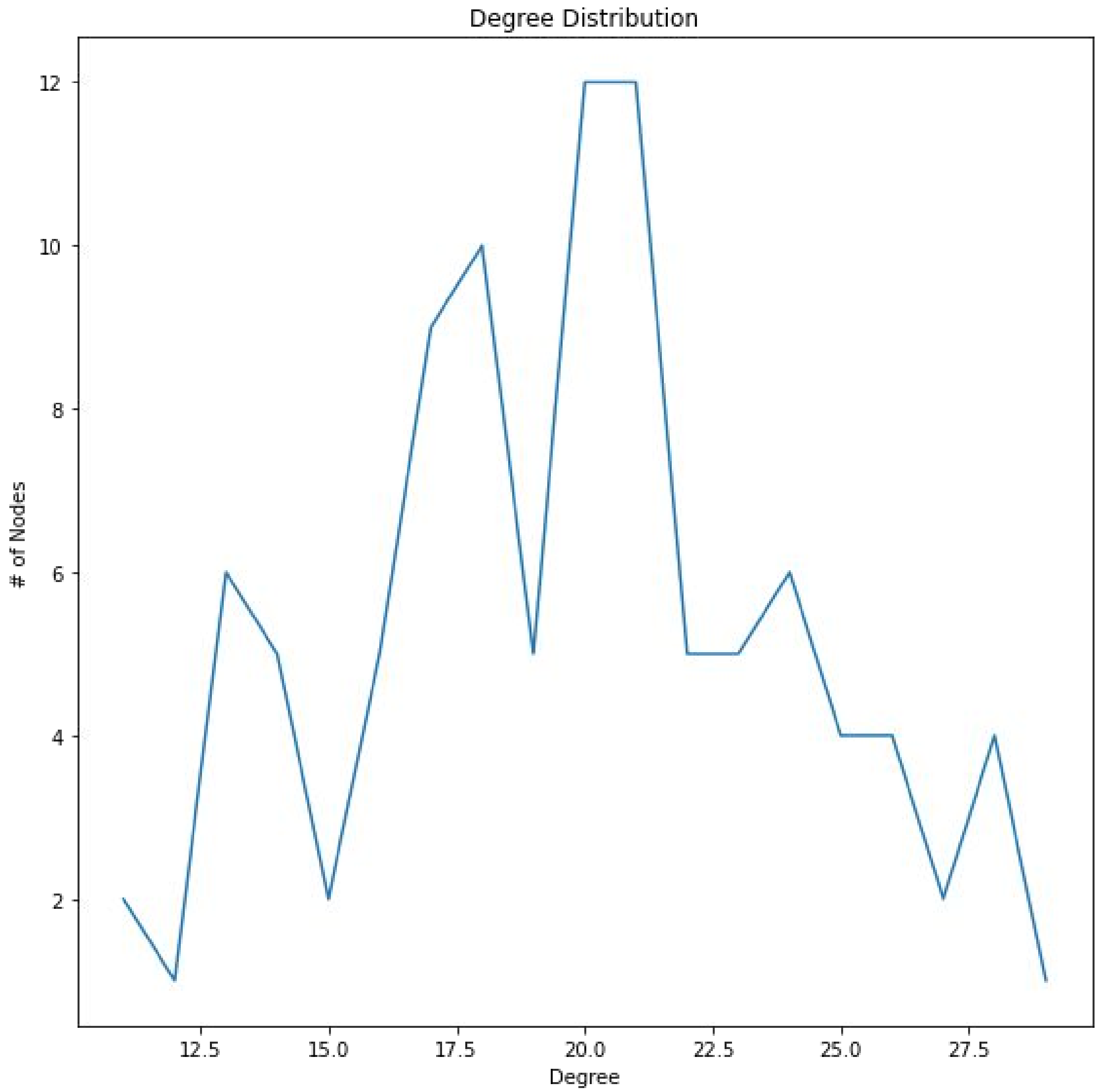


Q: 3. Do a structural analysis of a Random Graph and a Scale-Free Graph of moderate size.

The structural analysis for random graph of 1000 nodes is as follows:

```
============================== Node Count, Edge Count, Average Degree
==============================
Graph with 100 nodes and 990 edges
Average Degree: 2e+01
```

================================== Degree Distribution ==================================



============================== Triangles ==============================

The number of triangles at nodes:

```
 0 :          38 1 :          48 2 :          14 3 :          57 4 :
45
 5 :          57 6 :          27 7 :          32 8 :          40 9 :
23
10 :          4611 :          3612 :          4013 :          3114 :
50
15 :          1516 :          6817 :          1418 :          2519 :
38
```

The total number of triangles in the graph is 1315.0

============================== Diameter ==============================

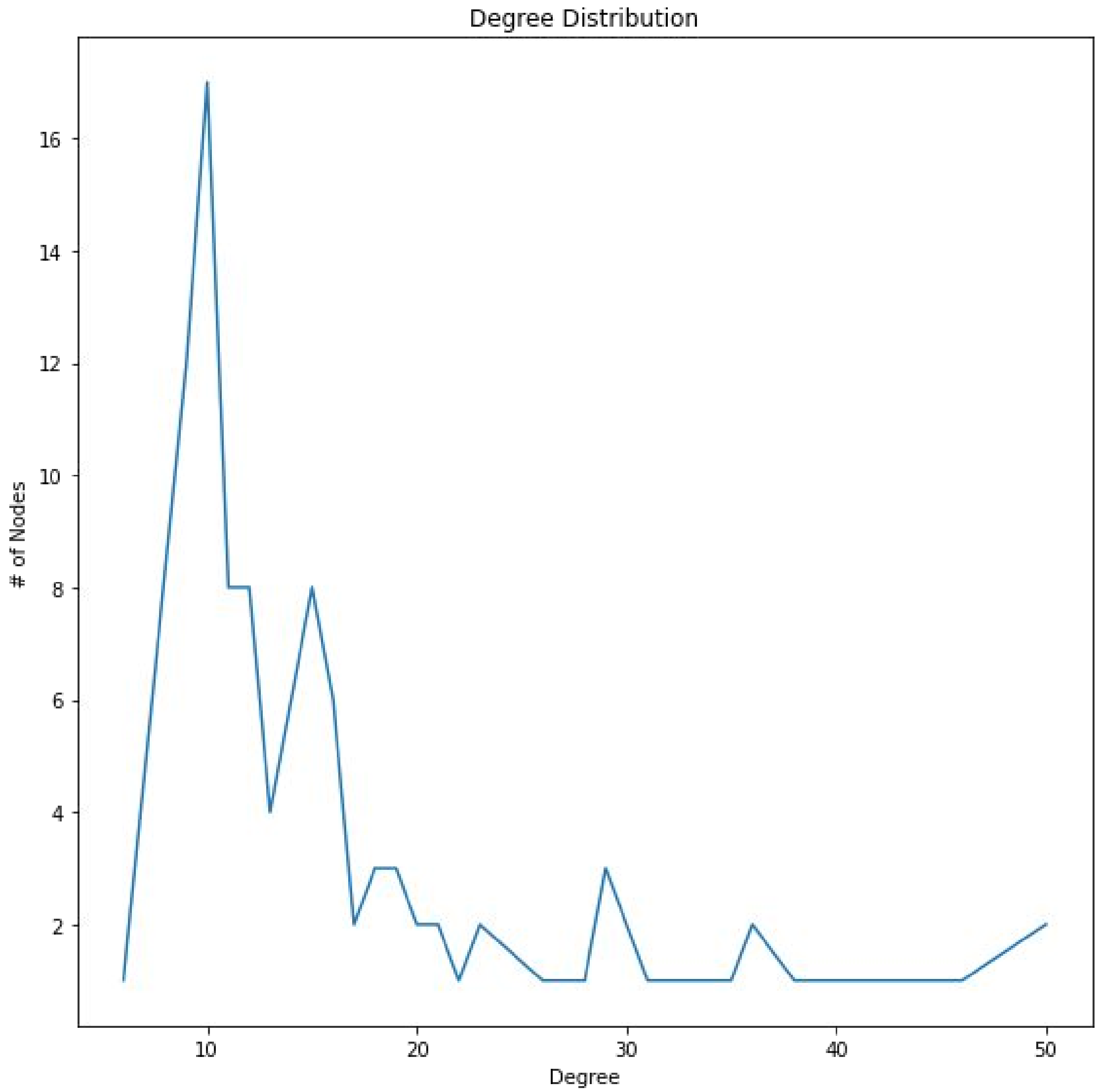
```
The diameter of the graph is 3
============================== Connected Components
==============================
Component 1      Length : 100
Total connected components in the graph: 1
Size of largest connected component:  100
============================== Clustering Coefficient
==============================
The clustering coefficient of node:
 0 : 0.20      1 : 0.17      2 : 0.15      3 : 0.19      4 : 0.21

 5 : 0.21      6 : 0.18      7 : 0.24      8 : 0.19      9 : 0.19

10 : 0.22     11 : 0.17     12 : 0.17     13 : 0.23     14 : 0.20

15 : 0.19     16 : 0.18     17 : 0.18     18 : 0.16     19 : 0.20

The average clustering coefficient of the graph is 0.20
============================== Degree Centrality
==============================
 0 : 0.20      1 : 0.24      2 : 0.14      3 : 0.25      4 : 0.21

 5 : 0.24      6 : 0.18      7 : 0.17      8 : 0.21      9 : 0.16

10 : 0.21     11 : 0.21     12 : 0.22     13 : 0.17     14 : 0.23

15 : 0.13     16 : 0.28     17 : 0.13     18 : 0.18     19 : 0.20

============================== Closeness Centrality
==============================
 0 : 0.55      1 : 0.57      2 : 0.53      3 : 0.57      4 : 0.56

 5 : 0.57      6 : 0.55      7 : 0.54      8 : 0.56      9 : 0.54

10 : 0.55     11 : 0.56     12 : 0.56     13 : 0.54     14 : 0.56

15 : 0.53     16 : 0.58     17 : 0.52     18 : 0.55     19 : 0.56

============================== Betweenness Centrality
==============================
 0 : 0.02      1 : 0.01      2 : 0.00      3 : 0.01      4 : 0.01

 5 : 0.01      6 : 0.00      7 : 0.00      8 : 0.00      9 : 0.00

10 : 0.01     11 : 0.01     12 : 0.01     13 : 0.00     14 : 0.01

15 : 0.00     16 : 0.01     17 : 0.00     18 : 0.00     19 : 0.01

============================== Eigenvector Centrality
```

```
==============================
 0 : 0.10       1 : 0.12       2 : 0.06       3 : 0.12       4 : 0.10

 5 : 0.12       6 : 0.09       7 : 0.08       8 : 0.10       9 : 0.08

10 : 0.10      11 : 0.10      12 : 0.11      13 : 0.09      14 : 0.11

15 : 0.07      16 : 0.14      17 : 0.06      18 : 0.08      19 : 0.10
```

Structural analysis for scale-free network:

```
============================== Node Count, Edge Count, Average Degree
==============================
Graph with 100 nodes and 819 edges
Average Degree: 1.6e+01
```

================================== Degree Distribution ==================================




```
============================== Triangles
==============================
The number of triangles at nodes:
 0 :        291 1 :         80 2 :         34 3 :        129 4 :
46
 5 :         24 6 :         55 7 :          6 8 :         67 9 :
56
10 :        25911 :        20512 :        15413 :        16014 :
159
15 :        14016 :        13217 :         8918 :        11119 :
100
The total number of triangles in the graph is  1385.0
============================== Diameter ==============================
```

```
The diameter of the graph is 3
============================== Connected Components
==============================
Component 1      Length : 100
Total connected components in the graph: 1
Size of largest connected component:  100
============================== Clustering Coefficient
==============================
The clustering coefficient of node:
 0 : 0.24       1 : 0.23       2 : 0.32       3 : 0.28       4 : 0.34

 5 : 0.36       6 : 0.36       7 : 0.40       8 : 0.35       9 : 0.27

10 : 0.21      11 : 0.20      12 : 0.24      13 : 0.27      14 : 0.25

15 : 0.20      16 : 0.25      17 : 0.27      18 : 0.27      19 : 0.25

The average clustering coefficient of the graph is 0.26
============================== Degree Centrality
==============================
 0 : 0.51       1 : 0.27       2 : 0.15       3 : 0.31       4 : 0.17

 5 : 0.12       6 : 0.18       7 : 0.06       8 : 0.20       9 : 0.21

10 : 0.51      11 : 0.46      12 : 0.36      13 : 0.35      14 : 0.36

15 : 0.38      16 : 0.33      17 : 0.26      18 : 0.29      19 : 0.29

============================== Closeness Centrality
==============================
 0 : 0.67       1 : 0.58       2 : 0.52       3 : 0.59       4 : 0.54

 5 : 0.52       6 : 0.55       7 : 0.47       8 : 0.56       9 : 0.55

10 : 0.67      11 : 0.65      12 : 0.61      13 : 0.61      14 : 0.61

15 : 0.62      16 : 0.60      17 : 0.57      18 : 0.59      19 : 0.59

============================== Betweenness Centrality
==============================
 0 : 0.05       1 : 0.03       2 : 0.01       3 : 0.01       4 : 0.00

 5 : 0.01       6 : 0.00       7 : 0.00       8 : 0.00       9 : 0.03

10 : 0.08      11 : 0.10      12 : 0.02      13 : 0.04      14 : 0.03

15 : 0.06      16 : 0.03      17 : 0.01      18 : 0.01      19 : 0.03

============================== Eigenvector Centrality
```

==============================

0 : 0.26	1 : 0.14	2 : 0.09	3 : 0.17	4 : 0.11
5 : 0.07	6 : 0.11	7 : 0.04	8 : 0.13	9 : 0.12
10 : 0.25	11 : 0.22	12 : 0.19	13 : 0.19	14 : 0.19
15 : 0.18	16 : 0.18	17 : 0.14	18 : 0.16	19 : 0.15