Complex Networks

Assignment 1: Structural Descriptors of Complex Networks

MESIIA 2024-2025

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Net1.net

Network Statistics:

1. Nodes: 5000

2. Edges: 25000

3. **Min Degree: 6**

4. **Max Degree: 16**

5. **Avg Degree: 10.00**

6. **Avg Clustering: 0.4141**

7. Assortativity: -0.0097

8. Avg Path Length: 5.12

9. Diameter: 8

Top Central Nodes:

1. By Degree:
   1. Node 1693: 0.0032
   2. Node 1579: 0.003
   3. Node 651: 0.003
   4. Node 4891: 0.003
   5. Node 41: 0.0028

2. By Betweenness:
   1. Node 4747: 0.0041
   2. Node 2645: 0.004
   3. Node 230: 0.0038
   4. Node 4360: 0.0038
   5. Node 1579: 0.0037

3. By Eigenvector:
   1. Node 651: 0.0286
   2. Node 1937: 0.0265
   3. Node 4526: 0.0256
   4. Node 4398: 0.0253
   5. Node 1939: 0.0252

CDDF

Degree Distribution (CCDF in log-log scale)
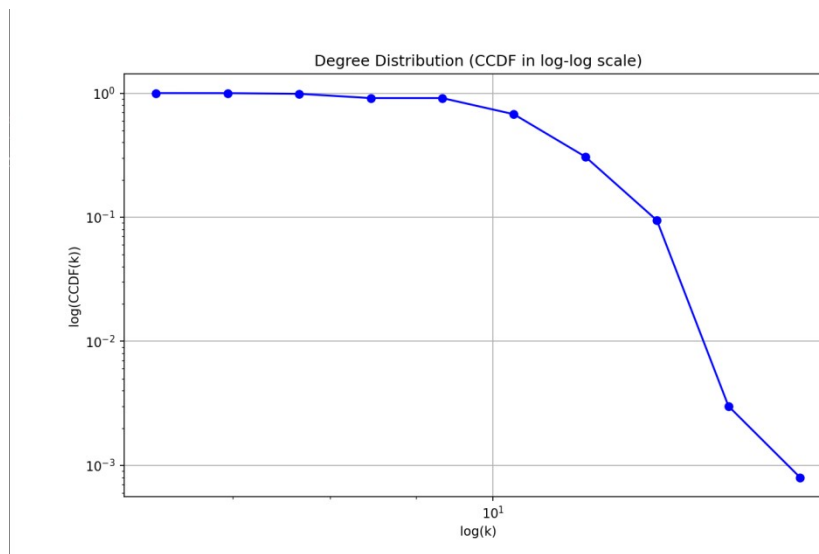
Conclusion

We think **Net1** is built on a **Watts-Strogatz** model.

CDDF is not a power-law → excludes BA and our variant of CM.

CDDF has a hard drop → suggests Poisson distribution in non-log scale

Clustering 0.4141 – super high compared to other variants → excludes BA, ER and our CM variant.

Narrow degree distribution → may be ER but excludes BA and CM.

Centralities suggest no hubs → excludes BA and CM.

Net2.net
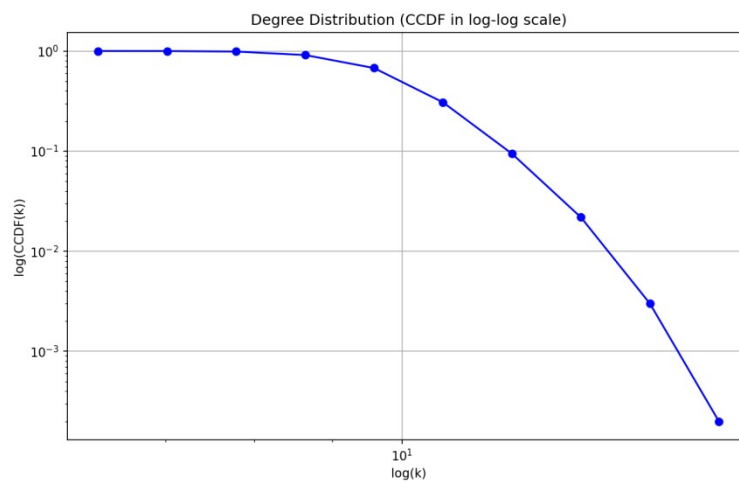
Network Statistics:

1. Nodes: 5000
2. Edges: 24873
3. Min Degree: 1

4. **Max Degree: 24**

5. **Avg Degree: 9.95**

6. **Avg Clustering: 0.0021**

7. Assortativity: -0.0057

8. Avg Path Length: 3.96

9. Diameter: 7

Top Central Nodes:

1. Degree:

   1. Node 1581: 0.0048

   2. Node 787: 0.0046

   3. Node 52: 0.0042

   4. Node 1990: 0.0042

   5. Node 4917: 0.0042

2. Betweenness:

   1. Node 1581: 0.0033

   2. Node 787: 0.0026

   3. Node 4382: 0.0025

   4. Node 52: 0.0023

   5. Node 2375: 0.0023

3. Eigenvector:

   1. Node 1581: 0.0412

   2. Node 3233: 0.0343

   3. Node 787: 0.0341

   4. Node 2375: 0.0337

   5. Node 131: 0.0335

CDDF

Degree Distribution (CCDF in log-log scale)

Conclusion

We think **Net2** is built on an **ER** model.

CDDF plot is not a power-law – excludes BA and our variant of CM

Degrees range is very narrow.

Clustering is extremely low – excludes WS and BA

Top 5 centralities are almost evenly spread, which means no hubs.

Net3

Network Statistics:

1. Nodes: 5000
2. Edges: 23508
3. Min Degree: 3
4. **Max Degree: 732**
5. Avg Degree: 9.40
6. **Avg Clustering: 0.0862**
7. Assortativity: -0.1339
8. Avg Path Length: 3.01
9. Diameter: 5

Top Central Nodes:

1. Degree:
   1. Node 5: 0.1464
   2. Node 7: 0.1382
   3. Node 2: 0.1252
   4. Node 0: 0.124
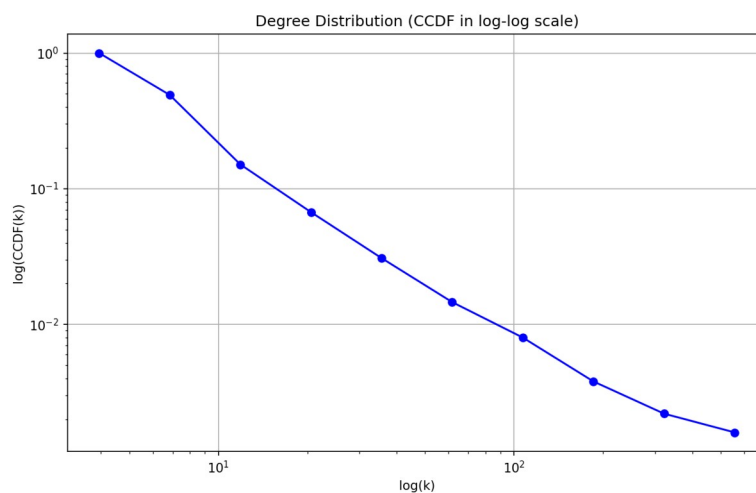   5. Node 6: 0.111

2. Betweenness:
   1. Node 5: 0.1378
   2. Node 7: 0.1277
   3. Node 0: 0.1113
   4. Node 2: 0.1093
   5. Node 6: 0.0943

3. Eigenvector:
   1. Node 5: 0.2592
   2. Node 7: 0.2417
   3. Node 2: 0.2254
   4. Node 0: 0.2254
   5. Node 3: 0.207

CDDF

Degree Distribution (CCDF in log-log scale)

Conclusion

We think **Net3** is built on **Barabási-Albert** model.

CDDF log-log plot is almost flat → power-law, scale-free network – matches BA and CM.

Clustering 0.0862 → too large for ER and CM, too small for WS.

Assortativity -0.1339 → hub-dominated network → BA and CM.

Super high max degree 732 → we have enormous hubs → too much for CM with $\gamma < 2.5$
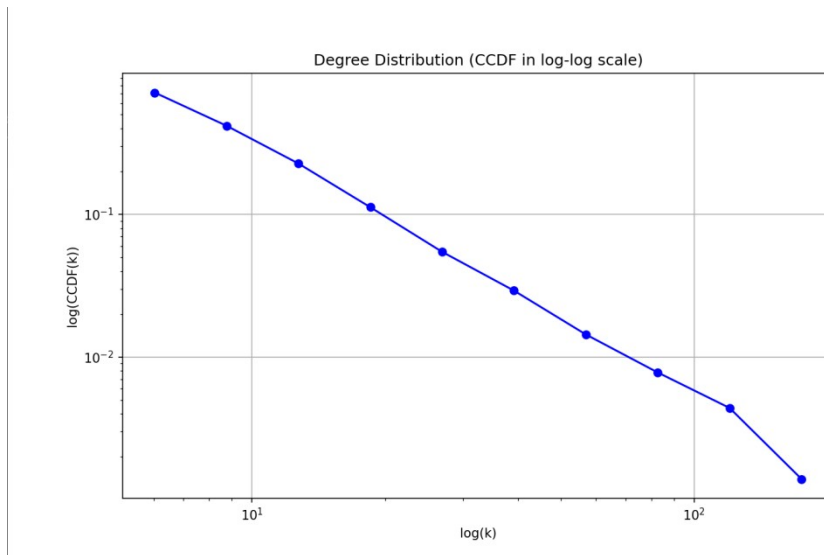
Net4

Network Statistics:

1. Nodes: 5000
2. Edges: 24975
3. Min Degree: 5
4. **Max Degree: 210**
5. Avg Degree: 9.99
6. **Avg Clustering: 0.0107**
7. **Assortativity: -0.0325**
8. Avg Path Length: 3.49
9. Diameter: 5

Top Central Nodes:

1. Degree:
   1. Node 6: 0.042
   2. Node 0: 0.0412
   3. Node 9: 0.0408
   4. Node 10: 0.0326
   5. Node 8: 0.0324
2. Betweenness:
   1. Node 0: 0.0605
   2. Node 6: 0.0576
   3. Node 9: 0.0553
   4. Node 8: 0.0391
   5. Node 3: 0.0379
3. Eigenvector:

1. Node 6: 0.2239

2. Node 0: 0.2234

3. Node 9: 0.2062

4. Node 8: 0.1741

5. Node 3: 0.1686

CDDF

Conclusion

We think that **Net4** is built by a **Configuration model**.

It was specified in the task that CM had $\gamma < 2.5$.

CDDF plot is a flat slope $\rightarrow$ a power-law distribution and a scale-free network. So it's not an ER model and likely not a WS.

Clustering coefficient 0.01 too low for WS with moderate rewiring and for BA. (compare with Net3)

Nodes 6, 0 and 9 have all centralities clearly dominating any other nodes.

An intermediary note on conclusions

In all four networks the diameter and the average shortest path length are not very informative because essentially all of them was a lot smaller than the network size, and the difference between their values is not representative enough to differentiate these models. However, these metrics surely would differentiate these four networks from *other* possible network construction models.

Net5

Network Statistics:

1. Nodes: 200

2. Edges: 465

3. Min Degree: 1

4. Max Degree: 10

5. Avg Degree: 4.65

6. Avg Clustering: 0.6107

7. Assortativity: 0.5502

8. Avg Path Length: 13.13

9. Diameter: 35

Top Central Nodes:
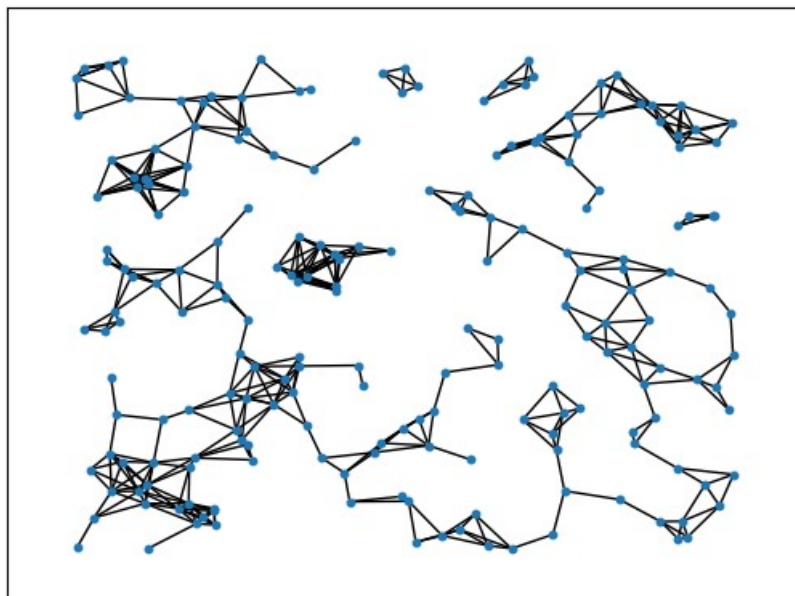
1. Degree:

    1. Node 18: 0.0503

    2. Node 33: 0.0503

    3. Node 37: 0.0503

    4. Node 170: 0.0503

    5. Node 126: 0.0503

2. Betweenness:

    1. Node 177: 0.1955

    2. Node 129: 0.1933

    3. Node 78: 0.1926

    4. Node 84: 0.1926

    5. Node 104: 0.1923

There is no eigenvector centrality because the network is disjointed.

CDDF

Degree Distribution (CCDF in log-log scale)
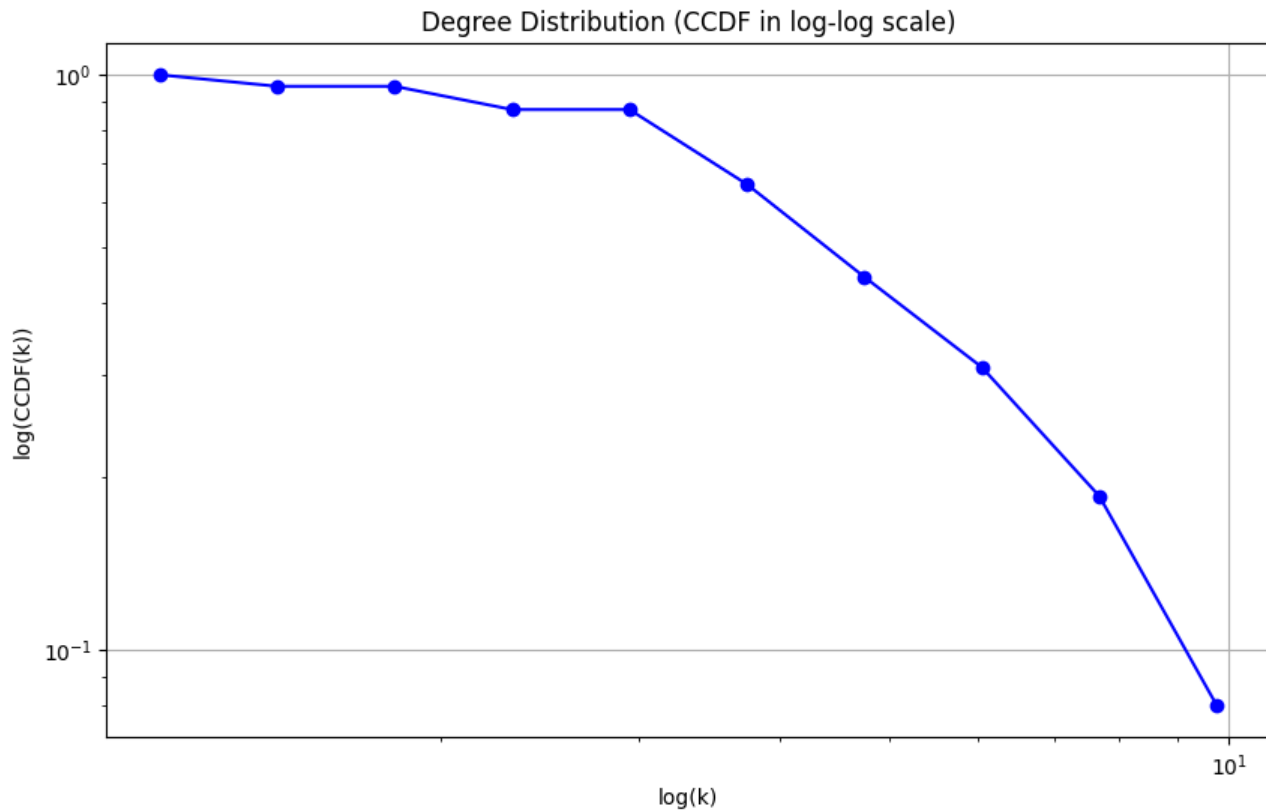
Network rendering

We clearly see that this network has:

1. Disconnected components

2. Sparse regions

3. Dense cliques

In the purely numerical features we can clearly see:

1. Super large diameter compared to network size

2. High clustering *and* average path length at the same time

3. Super high assortativity compared to previous four networks

Is it scale-free? No. It is clearly seen on the CDDF plot.

Is the largest connected component a small-world network? It's tempting to say "yes" because it's a connection of small-world cliques, but as a whole, the largest connected component is **not** a small-world. This is a segment where the smallest shortest path is 1 and the longest is a network diameter – 30.

Out of the blue the first idea which comes to mind is that this network was generated by something like multiple random walkers.