Python scripting for network analysis — II

Lab session on February 27th

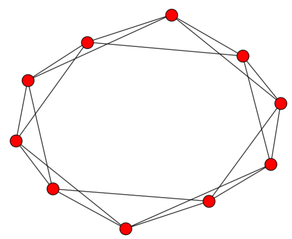
Homework review

General aspects

1. for jupyter notebooks, submit .ipynb format
2. "Kernel → Restart and run all" before submission
3. submit all code, not just plots / numerical results
4. correctness vs. stylistic comments

Ring network

Write a script to create a network of a ring of N nodes, with first and second neighbors connected. An example:



Checking correctness

- run for different values of N
- check the results: draw the network
- check some quantity: number of nodes, number of edges

An elegant solution:

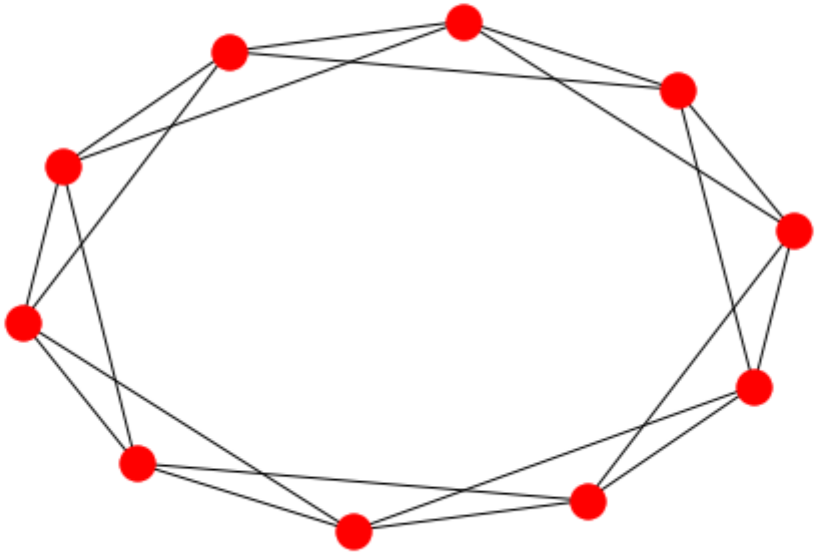
In [2]:

```
import networkx
import matplotlib.pyplot as plt

def ring_network(N):
    g = networkx.Graph()
    for i in range(N):
        g.add_edge(i, (i+1)%N)
        g.add_edge(i, (i+2)%N)
    return g
```

In [3]:
```
networkx.draw(ring_network(10))
g = ring_network(10)
print(g.number_of_nodes(), g.number_of_edges())
```

```
10 20
```



In- and out-strength

Calculate, plot and describe the in- and out-strength (weighted degree) distribution of the word association dataset

Calculating the in- and out-strengths

In [4]:
```
graph = networkx.read_edgelist('../lab_03/word_association_graph_DSF.txt',
                               create_using=networkx.DiGraph(),
                               nodetype=str, data=[('weight', float),])
```

In [5]:
```
in_degrees = {}
for node in graph.nodes():
    in_degrees[node] = 0
for source, target, attrs in graph.edges(data=True):
    in_degrees[target] += 1
```

In [6]:
```
out_degrees = {}
for node in graph.nodes():
    out_degrees[node] = 0
for source, target, attrs in graph.edges(data=True):
    out_degrees[source] += 1
```

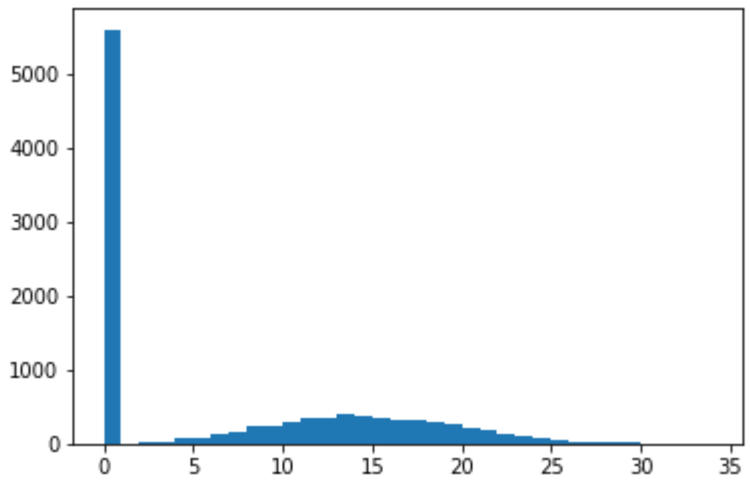
In [7]:
```
in_strengths = {}
for node in graph.nodes():
    in_strengths[node] = 0
for source, target, attrs in graph.edges(data=True):
    in_strengths[target] += attrs['weight']
```

In [8]:
```
out_strengths = {}
for node in graph.nodes():
    out_strengths[node] = 0
for source, target, attrs in graph.edges(data=True):
    out_strengths[source] += attrs['weight']
```

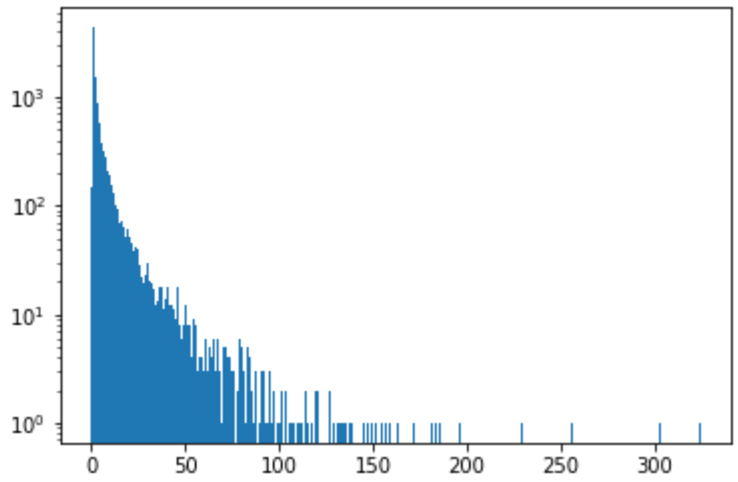
In [9]:
```
len(out_strengths.keys()), graph.number_of_nodes()
```
Out[9]:
```
(10616, 10616)
```

Plotting the histograms

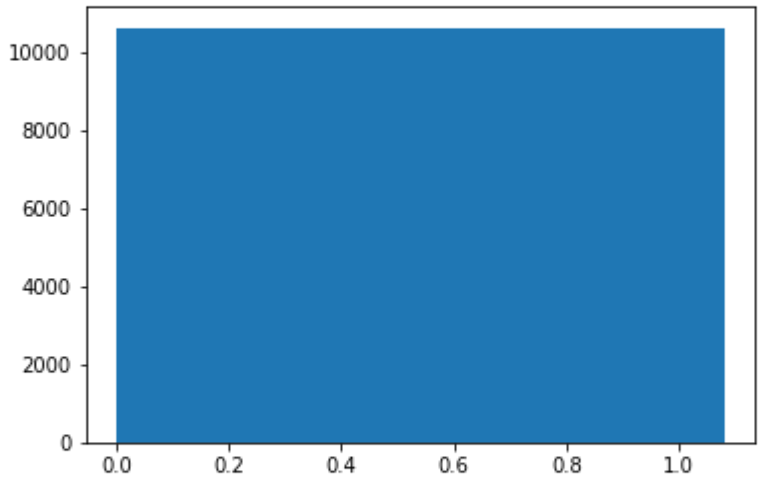
In [10]:
```
_ = plt.hist(out_degrees.values(), bins=max(out_degrees.values()))
```



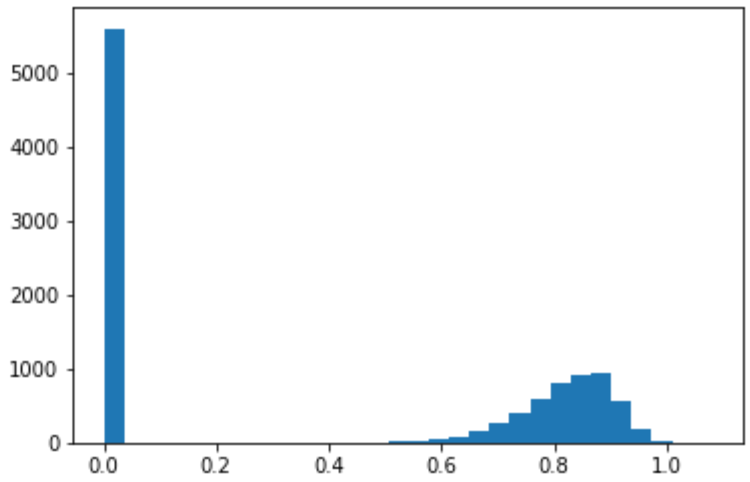
In [11]:
```
_ = plt.hist(in_degrees.values(), bins=max(in_degrees.values()), log=True)
```



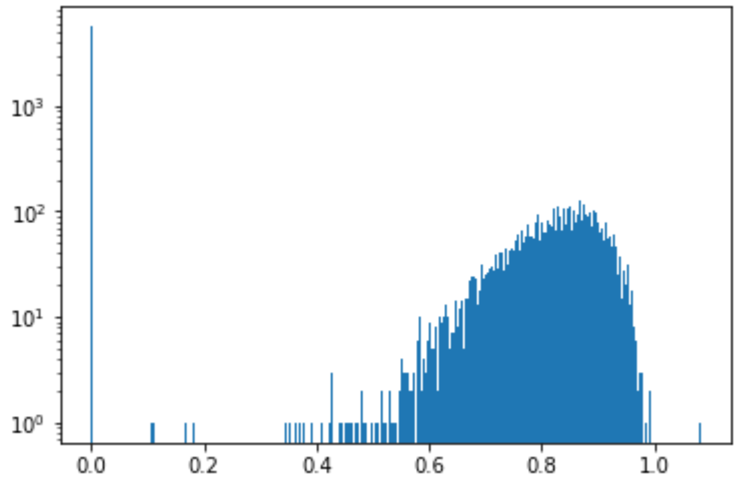
In [12]:
```
_ = plt.hist(out_strengths.values(), bins=int(max(out_strengths.values())))
```



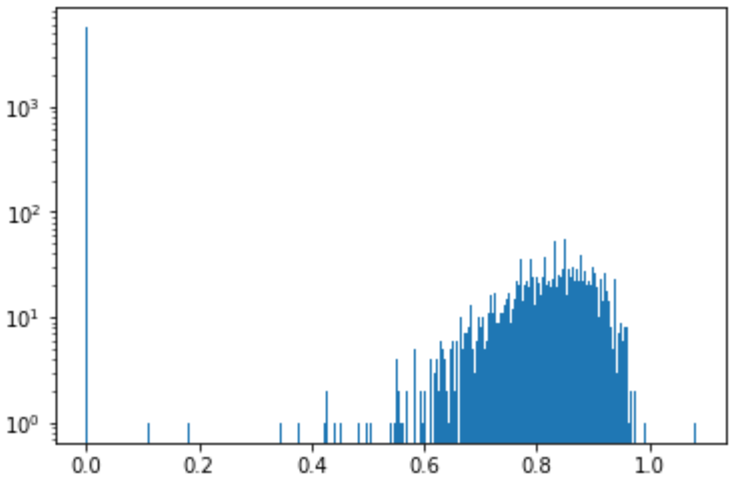
In [13]:
```python
_ = plt.hist(out_strengths.values(), bins=30)
```



In [14]:
```python
_ = plt.hist(out_strengths.values(), bins=300, log=True)
```



In [15]:
```
_ = plt.hist(out_strengths.values(), bins=900, log=True)
```



In [16]:
```
len([v for v in in_degrees.values() if v == 0])
```

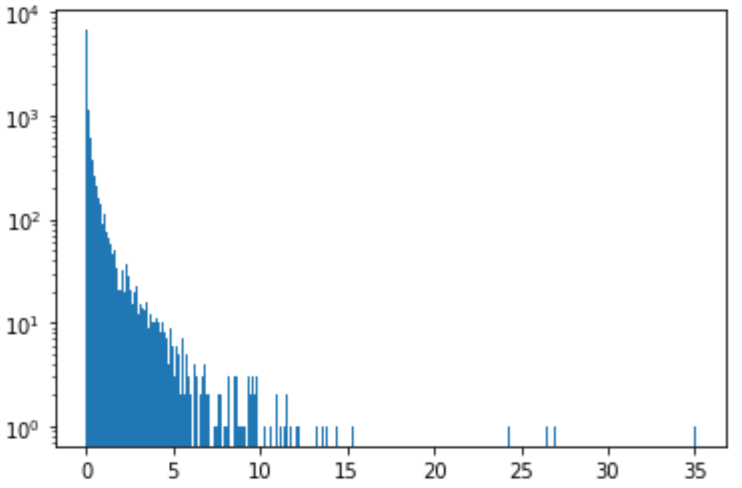
Out[16]:
```
149
```

In [17]:
```
_ = plt.hist(in_strengths.values(), bins=300, log=True)
```

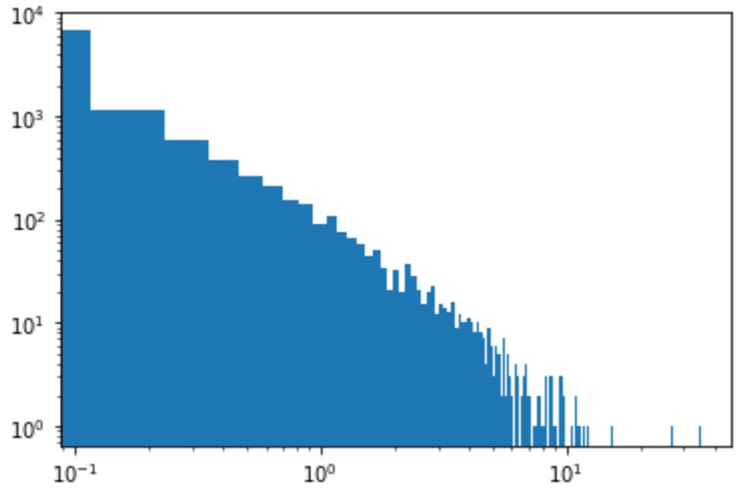
Best way to plot

- number of bins
- scaling of axes

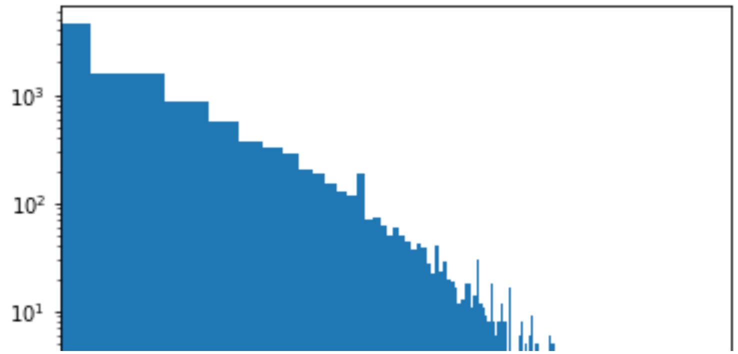
In [18]:
```
_ = plt.hist(in_strengths.values(), bins=300, log=True)
```



In [19]:
```
plt.xscale('log')
_ = plt.hist(in_strengths.values(), bins=300, log=True)
```



In [20]:
```
plt.xscale('log')
_ = plt.hist(in_degrees.values(), bins=300, log=True)
```



Describing the histograms

- is spike at zero due to zero degree nodes? (check data, histogram might be misleading)
- compare to degree histograms -- which parts are the same, which are different?
- are datapoints at the right-hand edge outliers?

Out-degrees and out-strengths: which function?

- already called it "self-similar" last week: zooming to leave out initial spike doesn't change it
- powerlaws discussed by Prof. Palla during the last lecture

powerlaw?

What else can it be?

How do we check?

A. Clauset, C.R. Shalizi, and M.E.J. Newman, "Power-law distributions in empirical data" SIAM Review 51(4), 661-703 (2009) https://arxiv.org/abs/0706.1062 (https://arxiv.org/abs/0706.1062)

In python: "powerlaw" library — "! pip install powerlaw"

In [21]:
```
import powerlaw
fit = powerlaw.Fit(list(in_degrees.values()))
```

```
Values less than or equal to 0 in data. Throwing out 0 or negative values
Calculating best minimal value for power law fit
/home/demo/anaconda3/lib/python3.7/site-packages/powerlaw.py:700: RuntimeWarning:
invalid value encountered in true_divide
  (Theoretical_CDF * (1 - Theoretical_CDF))
```

In [22]:
```
fit.power_law.alpha
```

Out[22]:
```
2.9852246312570587
```

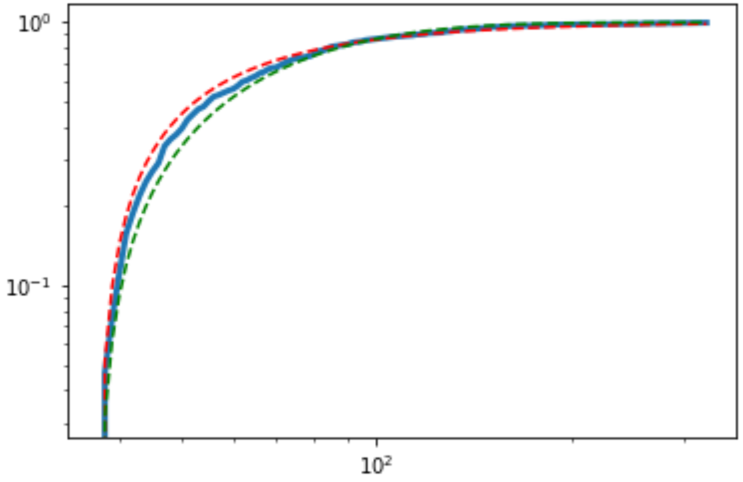
In [23]:
```
R, p = fit.distribution_compare('power_law', 'exponential', normalized_ratio=True)
```

In [24]:
```
R,p
```

Out[24]:
```
(0.773738003221026, 0.43908574152893753)
```

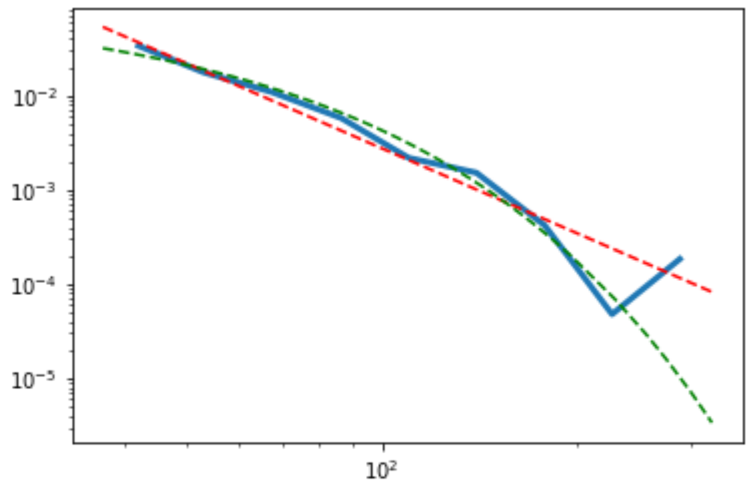
In [25]:
```python
fig = fit.plot_cdf(linewidth=3)
fit.power_law.plot_cdf(ax=fig, color='r', linestyle='--')
fit.exponential.plot_cdf(ax=fig, color='g', linestyle='--')
```

Out[25]: <matplotlib.axes._subplots.AxesSubplot at 0x7f9322efd860>



In [26]:
```
fig = fit.plot_pdf(linewidth=3)
fit.power_law.plot_pdf(ax=fig, color='r', linestyle='--')
fit.exponential.plot_pdf(ax=fig, color='g', linestyle='--')
```

Out[26]: <matplotlib.axes._subplots.AxesSubplot at 0x7f9322c51390>

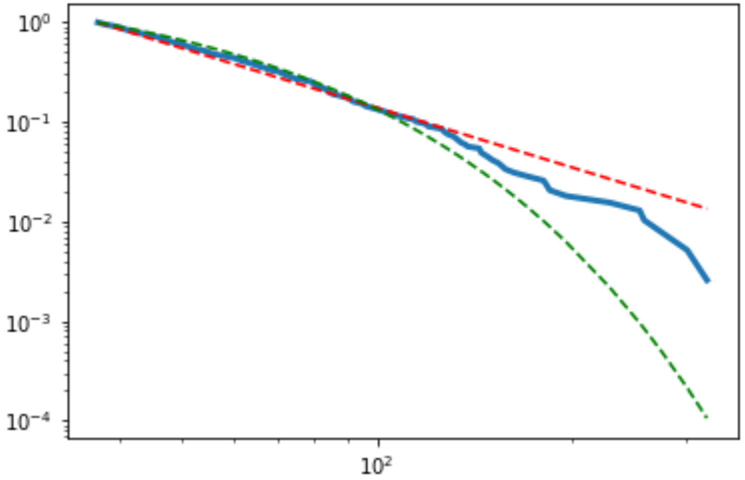


In [27]:

```
fig = fit.plot_ccdf(linewidth=3)
fit.power_law.plot_ccdf(ax=fig, color='r', linestyle='--')
fit.exponential.plot_ccdf(ax=fig, color='g', linestyle='--')
```

Out[27]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7f9323ad1160>
```



In [28]:

```
R, p = fit.distribution_compare('power_law', 'truncated_power_law', normalized_rat
io=True)
```

```
Assuming nested distributions
```

Various ways of plotting:

1. PDF: probability density function
2. CDF: cumulative density function
3. CCDF: complementary cumulative density function

Note

Newer paper of same main author: A. D. Broido and A. Clauset: "Scale-free networks are rare" Nature Communications 10, 1017 (2019) https://arxiv.org/abs/1801.03400 (https://arxiv.org/abs/1801.03400)

Their claim: scale-free property is much more rare

Barabási Albert-László's counter-argument (https://www.barabasilab.com/post/love-is-all-you-need (https://www.barabasilab.com/post/love-is-all-you-need)): using their method, not even scale-free model is considered scale-free

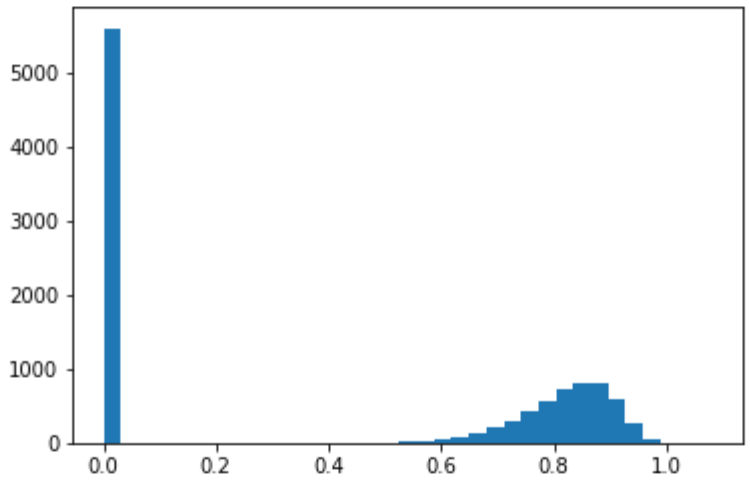
Does it matter?

powerlaw vs. fat-tailed

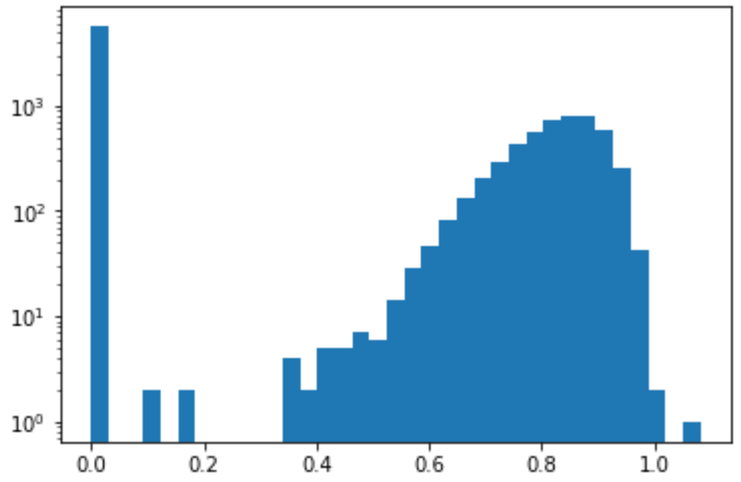
Explaining the histograms

- what the histograms look like (describing)
- why they look like that (explaining)

In [31]:
```
_ = plt.hist(out_strengths.values(), bins=35)
```



In [32]:
```
_ = plt.hist(out_strengths.values(), bins=35, log=True)
```



Ring & shortcuts network

We construct the following network:

1. ring of N nodes with first and second neighbor connections
2. add $N/2$ shortcuts (additional edges) at random

Question: what is the average clustering coefficient of this network as $N \to \infty$?

Homework assignment

Calculate a computational estimate: write a script to generate such networks and measure the average clustering coefficient; give an estimate for $N \to \infty$

Useful tools

- random module ("import random") -- especially random.choice and random.shuffle
- networkx.average_clustering