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SMA Lab 9: Cascading behavior in networks

In [1]:

```
import networkx as nx
import pandas as pd
import matplotlib.pyplot as plt
import matplotlib as mpl
import numpy as np
import warnings
warnings.filterwarnings('ignore')
from collections import Counter
import sys
import os
from __future__ import division
plt.rcParams["figure.figsize"] = (20,10)
from itertools import chain
import tqdm as tqdm
from colorthief import ColorThief
warnings.filterwarnings('ignore')
from IPython.core.display import display, HTML
display(HTML("<style>.container { width:80% !important; }</style>"))
```

In [8]:

```
votes_data = pd.read_excel('ESC2018_GF.xlsx',sheet_name='Combined result')
print(votes_data.shape)
votes_data.head(5)
```

```
(26, 47)
```

Out[8]:

	Rank	Running order	Country	Total	Albania	Austria	Belarus	Belgium	Croatia	Cyprus	...
0	1	22	Israel	529	6	19	8	16	16	10	...
1	2	25	Cyprus	436	20	1	15	11	8	0	...
2	3	5	Austria	342	2	0	10	15	0	2	...
3	4	11	Germany	340	14	16	0	7	3	3	...
4	5	26	Italy	308	24	10	4	6	10	15	...

5 rows × 47 columns

In [9]:

```
votes_data.tail(5)
```

Out[9]:

	Rank	Running order	Country	Total	Albania	Austria	Belarus	Belgium	Croatia	Cyprus	...
21	22	3	Slovenia	64	0	5	4	0	7	0	...
22	23	2	Spain	61	0	0	0	1	0	7	...
23	24	9	United Kingdom	48	3	0	0	0	2	0	...
24	25	17	Finland	46	0	0	0	0	0	0	...
25	26	8	Portugal	39	0	0	0	0	0	0	...

5 rows × 47 columns

Step2:Build the network out of the dataset

In [10]:

```
votes_melted = votes_data.melt(
 ['Rank','Running order','Country','Total'],
 var_name = 'Source Country',value_name='points')
votes_melted.head()
```

Out[10]:

	Rank	Running order	Country	Total	Source Country	points
0	1	22	Israel	529	Albania	6
1	2	25	Cyprus	436	Albania	20
2	3	5	Austria	342	Albania	2
3	4	11	Germany	340	Albania	14
4	5	26	Italy	308	Albania	24

In [11]:

```
votes_melted = votes_data.melt(
 ['Rank','Running order','Country','Total'],
 var_name = 'Source Country',value_name='points')
votes_melted.head()
```

Out[11]:

	Rank	Running order	Country	Total	Source Country	points
0	1	22	Israel	529	Albania	6
1	2	25	Cyprus	436	Albania	20
2	3	5	Austria	342	Albania	2
3	4	11	Germany	340	Albania	14
4	5	26	Italy	308	Albania	24

In [12]:

```
G = nx.from_pandas_edgelist(votes_melted,
 source='Source Country',
target='Country',
edge_attr='points',
create_using=nx.DiGraph())
```

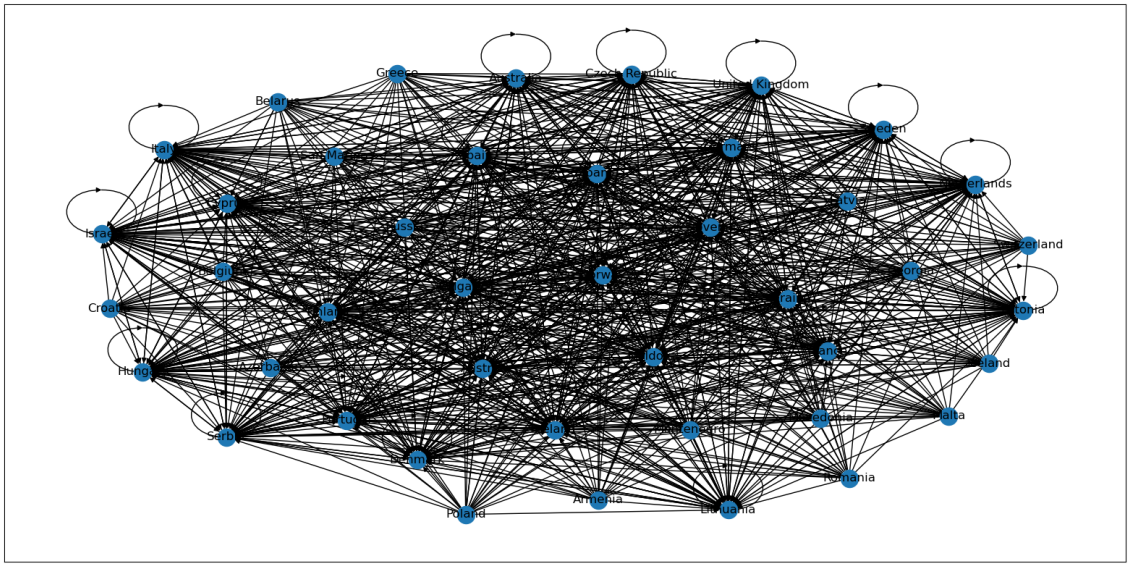
In [13]:

```
print(nx.info(G))
```

```
DiGraph with 43 nodes and 1118 edges
```

In [14]:

```
nx.draw_networkx(G)
```



Step3:Understand the concept of information diffusion

In [15]:

```
dataframe1 = pd.read_csv("countries.csv", encoding="ISO-8859-1")
```

In [16]:

```
import chardet

with open("countries.csv", "rb") as f:
    result = chardet.detect(f.read())
    encoding = result["encoding"]

dataframe1 = pd.read_csv("countries.csv", encoding=encoding)
```

In [17]:

```
countries = pd.read_csv('countries.csv', index_col='Country', encoding='ISO-8859-1')
```

In [18]:

```
with open("countries.csv", "rb") as f:
    content = f.read().decode("ISO-8859-1")  # Use the appropriate encoding here

# Process the content to remove or replace problematic characters
# Then create a StringIO object to read using pandas
from io import StringIO
countries = pd.read_csv(StringIO(content), index_col='Country')
```

In [19]:

```
countries.head()
```

Out[19]:

Country	cc2	cc3	numeric	latitude	longitude
Afghanistan	AF	AFG	4	33.0000	65.0
Albania	AL	ALB	8	41.0000	20.0
Algeria	DZ	DZA	12	28.0000	3.0
American Samoa	AS	ASM	16	-14.3333	-170.0
Andorra	AD	AND	20	42.5000	1.6

In [20]:

```
pos_geo = { node:
 ( max(-10,min(countries.loc[node]['longitude'],55)), # fixing scale
 max(countries.loc[node]['latitude'],25)) #fixing scale
 for node in G.nodes() }
```

In [21]:

```
pos_geo = {}
for node in G.nodes():pos_geo[node] = (
 max(-10,min(countries.loc[node]['longitude'],55)), # fixing scale
 max(countries.loc[node]['latitude'],25) #fixing scale
 )
```

In [22]:

```
flags = {}
flag_color = {}
for node in tqdm.tqdm_notebook(G.nodes()):
    flags[node] = 'flags/'+(countries.loc[node]['cc3']).lower().replace(' ','')+'.png'
    flag_color[node] = ColorThief(flags[node]).get_color(quality=1)
```

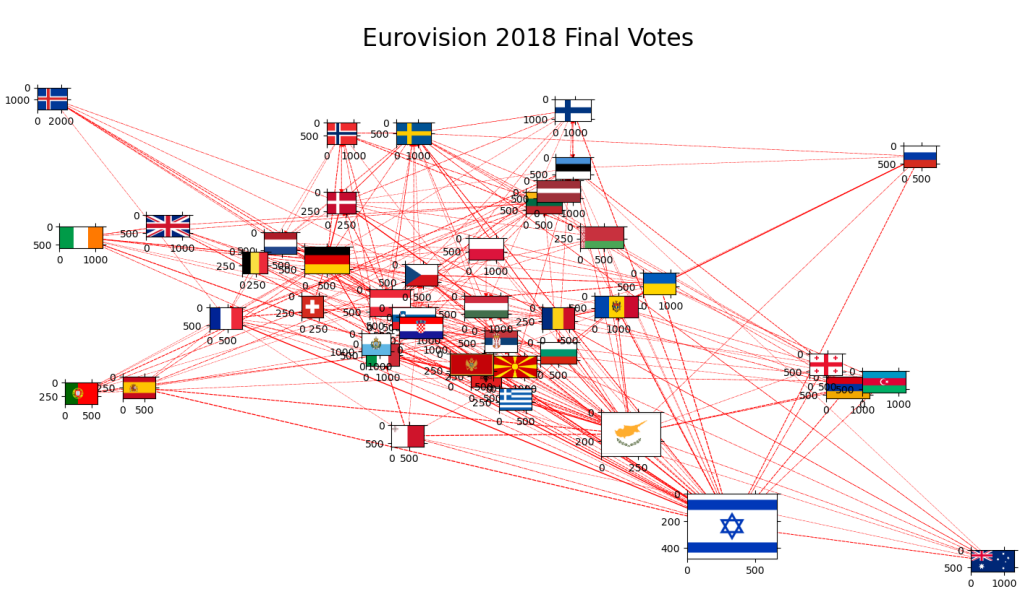
```
  0%|          | 0/43 [00:00<?, ?it/s]
```

In [23]:

```
def RGB(red,green,blue):
    return '#%02x%02x%02x' % (red,green,blue)
```

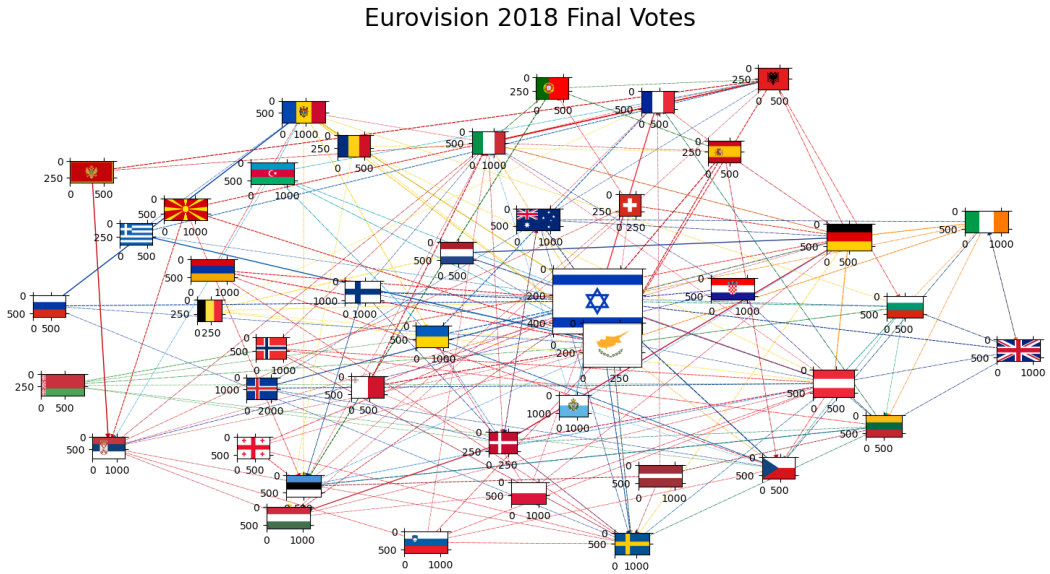
In [24]:

```
ax=plt.gca()
fig=plt.gcf()
plt.axis('off')
plt.title('Eurovision 2018 Final Votes',fontsize = 24)
trans = ax.transData.transform
trans2 = fig.transFigure.inverted().transform
tick_params = {'top':'off', 'bottom':'off', 'left':'off', 'right':'off','labelleft':'off
styles = ['dotted','dashdot','dashed','solid'] # line styles
pos = pos_geo

# draw edges
for e in G.edges(data=True):
    width = e[2]['points']/24 #normalize by max points
    style=styles[int(width*3)]
    if width>0.3: #filter small votes

        RG = 'red'  # Replace 'red' with the actual color you want to use


        nx.draw_networkx_edges(G,pos,edgelist=[e],width=width, style=style, edge_color =

 # in networkx versions >2.1 arrowheads can be adjusted
#draw nodes
for node in G.nodes():

    imsize = max((0.3*G.in_degree(node,weight='points')

                  /max(dict(G.in_degree(weight='points')).values()))**2,0.03)

 # size is proportional to the votes
    flag = mpl.image.imread(flags[node])
    (x,y) = pos[node]
    xx,yy = trans((x,y)) # figure coordinates
    xa,ya = trans2((xx,yy)) # axes coordinates
    country = plt.axes([xa-imsize/2.0,ya-imsize/2.0, imsize, imsize ])
    country.imshow(flag)
    country.set_aspect('equal')
    country.tick_params(**tick_params)
    fig.savefig('images/eurovision2018_map.png')
```


Eurovision 2018 Final Votes

In [30]:

```
ax=plt.gca()
fig=plt.gcf()
plt.axis('off')
plt.title('Eurovision 2018 Final Votes',fontsize = 24)
pos = nx.layout.fruchterman_reingold_layout(G,k=1,weight = 'points',iterations=1000,scal
trans = ax.transData.transform
trans2 = fig.transFigure.inverted().transform
tick_params = {'top':'off', 'bottom':'off', 'left':'off', 'right':'off','labelleft':'off
styles = ['dotted','dashdot','dashed','solid'] # line styles
# draw edges
for e in G.edges(data=True):
    width = e[2]['points']/24
    style=styles[int(width*3)]
    if width>0.4:
        nx.draw_networkx_edges(G,pos,edgelist=[e],width=width,
        style=style, edge_color = RGB(*flag_color[e[0]]) )
for node in G.nodes():
    imsize = max((0.3 * G.in_degree(node, weight='points') / max(dict(G.in_degree(weight
    flag = mpl.image.imread(flags[node])
    (x,y) = pos[node]
    xx,yy = trans((x,y)) # figure coordinates
    xa,ya = trans2((xx,yy)) # axes coordinates
    country = plt.axes([xa-imsize/2.0,ya-imsize/2.0, imsize, imsize ])
    country.imshow(flag)
    country.set_aspect('equal')
    country.tick_params(**tick_params)
fig.savefig('images/eurovision2018_spring.png')
```



Step4:Build an indepent cascade model for the above network to illustrate the rumor spread dynamics

In [35]:

```
books = []
for i in range(5):
    books.append(pd.read_csv('asoiaf-book1-edges.csv'.format(i+1)))
all_books = pd.concat(books)
all_books.head()
```

Out[35]:

	Source	Target	Type	weight	book
0	Addam-Marbrand	Jaime-Lannister	Undirected	3	1
1	Addam-Marbrand	Tywin-Lannister	Undirected	6	1
2	Aegon-I-Targaryen	Daenerys-Targaryen	Undirected	5	1
3	Aegon-I-Targaryen	Eddard-Stark	Undirected	4	1
4	Aemon-Targaryen-(Maester-Aemon)	Alliser-Thorne	Undirected	4	1

In [36]:

```
edges = all_books.groupby(['Source','Target']).agg({'weight':'sum'}).reset_index()
edges.sort_values('weight',ascending=False).head()
```

Out[36]:

	Source	Target	weight
329	Eddard-Stark	Robert-Baratheon	1455
134	Bran-Stark	Robb-Stark	560
62	Arya-Stark	Sansa-Stark	520
249	Daenerys-Targaryen	Drogo	505
479	Joffrey-Baratheon	Sansa-Stark	435

In [37]:

```
edges = all_books.groupby(['Source','Target']).agg({'weight':'sum'}).reset_index()
edges.sort_values('weight',ascending=False).head()
```

Out[37]:

	Source	Target	weight
329	Eddard-Stark	Robert-Baratheon	1455
134	Bran-Stark	Robb-Stark	560
62	Arya-Stark	Sansa-Stark	520
249	Daenerys-Targaryen	Drogo	505
479	Joffrey-Baratheon	Sansa-Stark	435

In [39]:

```
GOT = nx.from_pandas_edgelist(edges,
 source='Source',
target='Target',
edge_attr='weight' )
```

In [40]:

```
print(nx.info(GOT))
```

```
Graph with 187 nodes and 684 edges
```

In [41]:

```
weighted_degrees = dict(nx.degree(GOT,weight='weight'))
max_degree = max(weighted_degrees.values())
```

In [42]:

```
subG = GOT.subgraph([n for n in weighted_degrees if weighted_degrees[n]>200])
print(nx.info(subG))
```

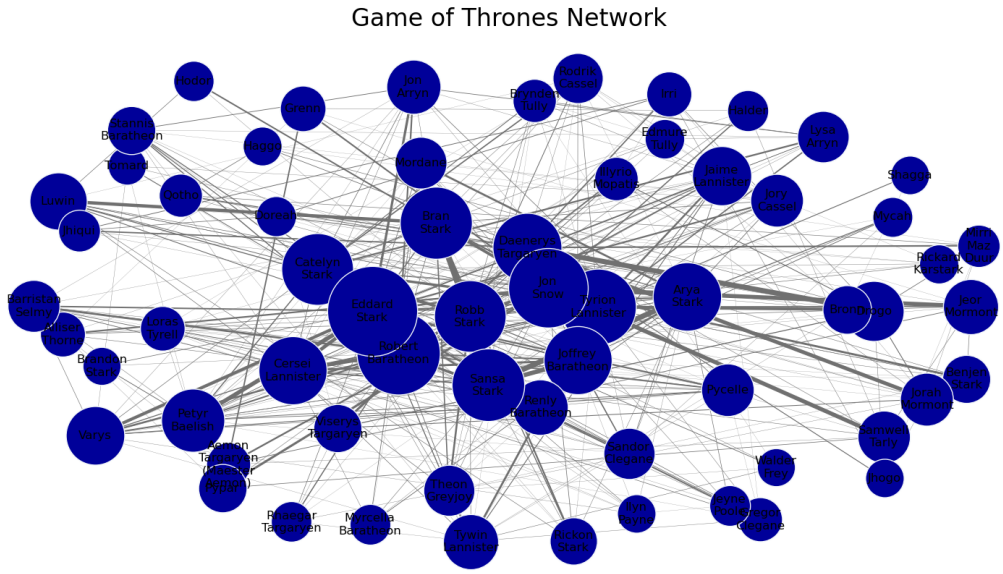
```
Graph with 64 nodes and 395 edges
```

In [43]:

```
pos = nx.spring_layout(subG,weight='weight',iterations=20, k = 4)
```

In [60]:

```
plt.axis('off')
plt.title('Game of Thrones Network',fontsize = 24)
threshold = 10
for node in subG.nodes():
    size = 100*weighted_degrees[node]**0.5
    ns = nx.draw_networkx_nodes(subG, pos, nodelist=[node], node_size=size, node_color='
    ns.set_edgecolor('#f2f6fa')
nx.draw_networkx_labels(subG, pos, {n: n.replace('-', '\n') for n in subG.nodes() if wei
for e in subG.edges(data=True):
    if e[2]['weight']>10:
        nx.draw_networkx_edges(subG,pos,[e],width=e[2]['weight']/100,edge_color='#707070
```



In [61]:

```
infection_times = {}
```

In [62]:

```
def independent_cascade(G,t,infection_times):
    max_weight = max([e[2]['weight'] for e in G.edges(data=True)])
    current_infectious = [n for n in infection_times if infection_times[n]==t]
    for n in current_infectious:
        for v in G.neighbors(n):
            if v not in infection_times:
                if G.get_edge_data(n,v)['weight'] >= np.random.random()*max_weight:
                    infection_times[v] = t+1
    return infection_times
```

In [73]:

```
def plot_G(G,pos,infection_times,t):
    current_infectious = [n for n in infection_times if infection_times[n]==t]
    plt.figure()
    plt.axis('off')
    plt.title('Game of Thrones Network, t={}'.format(t),fontsize = 24)
    for node in G.nodes():
        size = 100*weighted_degrees[node]**0.5
        if node in current_infectious:
            ns = nx.draw_networkx_nodes(G, pos, nodelist=[node], node_size=size, node_cc

        elif infection_times.get(node,9999999)<t:

            ns = nx.draw_networkx_nodes(G, pos, nodelist=[node], node_size=size, node_cc

        else:
            ns = nx.draw_networkx_nodes(G, pos, nodelist=[node], node_size=size, node_cc

        ns.set_edgecolor('#f2f6fa')
    nx.draw_networkx_labels(subG, pos, {n: n.replace('-', '\n') for n in subG.nodes() if
    for e in G.edges(data=True):
        if e[2]['weight']>10:
            nx.draw_networkx_edges(G,pos,[e],width=e[2]['weight']/100,edge_color='#70707
```

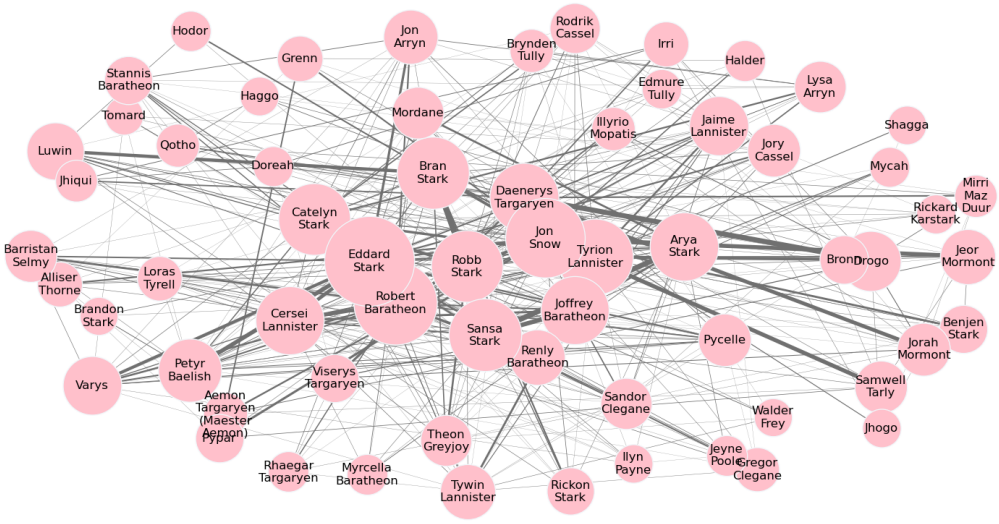
In [74]:

```
infection_times = {'Bran-Stark':-1,'Samwell-Tarly':-1,'Jon-Snow':0}
```

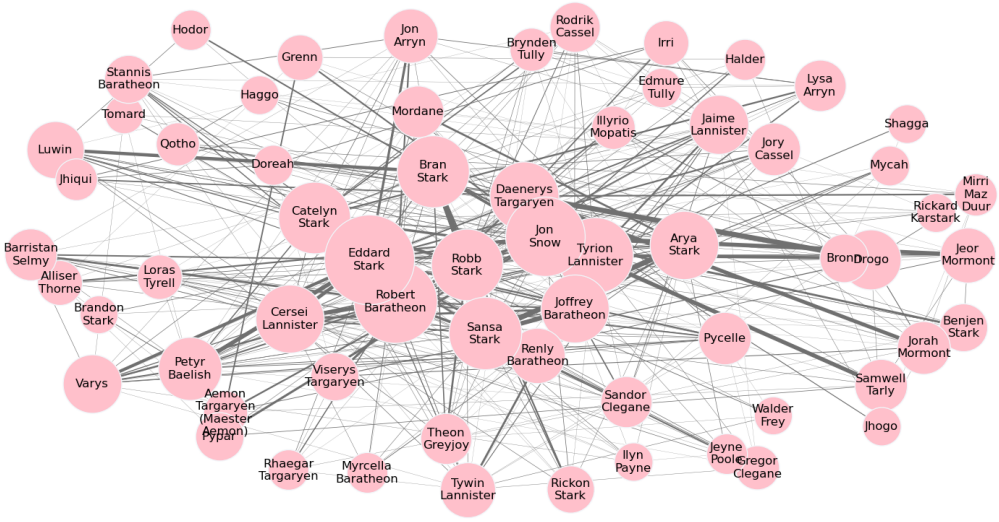
In [75]:

```
for t in range(10):
    plot_G(subG,pos,infection_times,t)
    infection_times = independent_cascade(subG,t,infection_times)
```

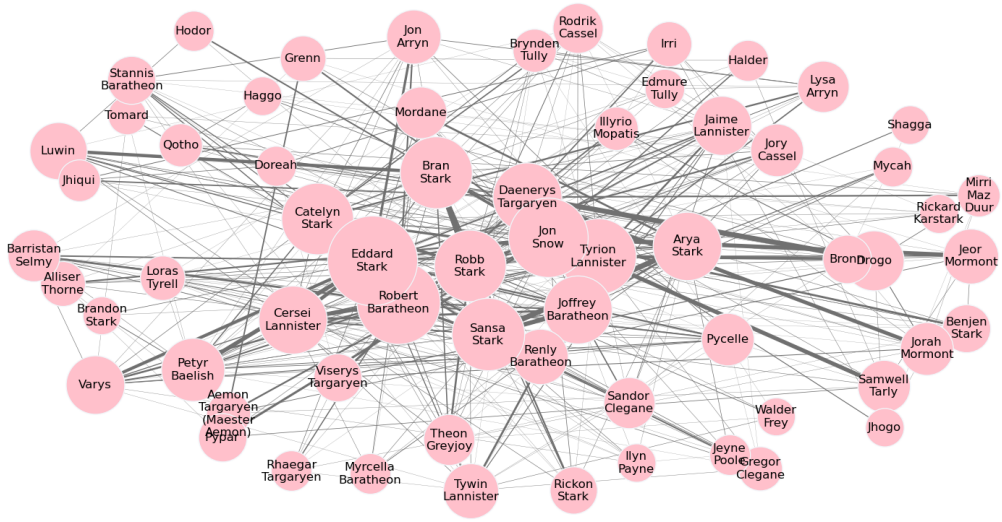
Game of Thrones Network, t=0



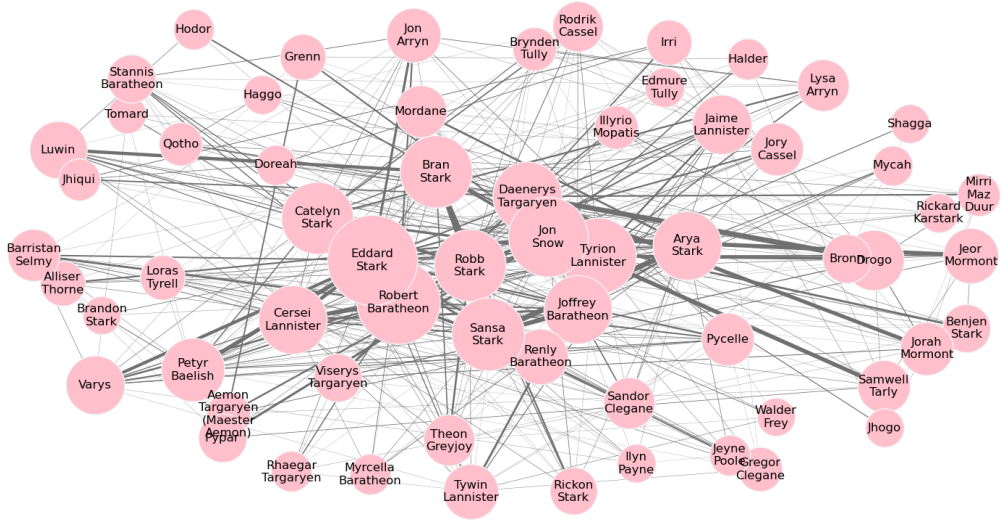
Game of Thrones Network, t=1



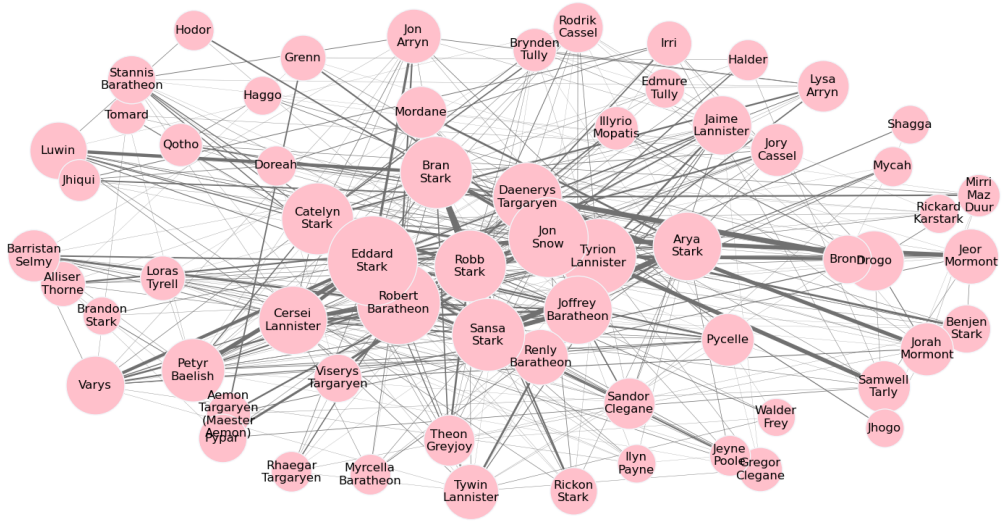
Game of Thrones Network, t=2



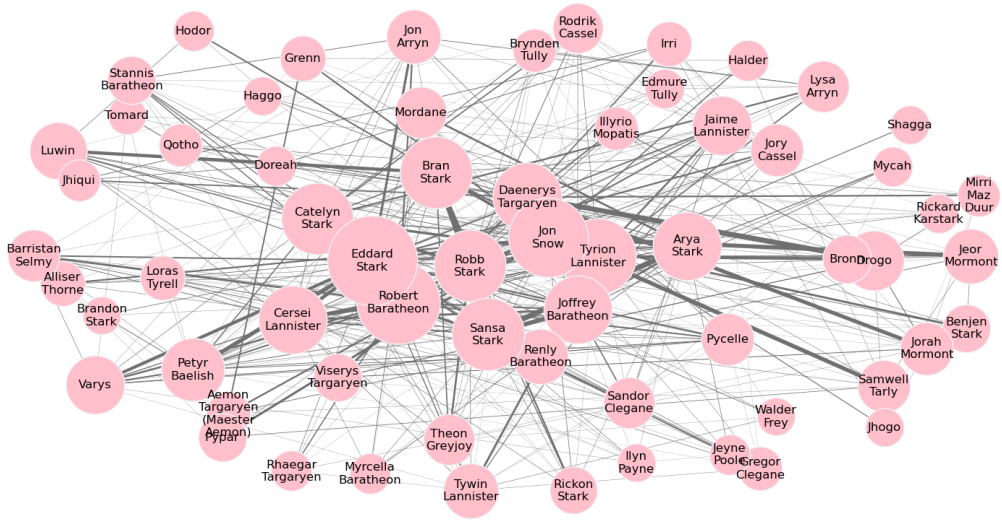
Game of Thrones Network, t=3



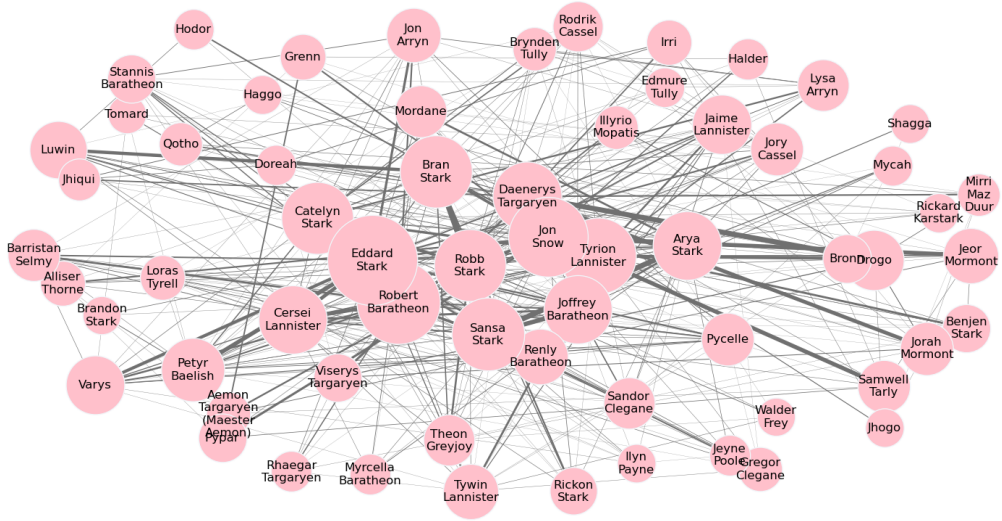
Game of Thrones Network, t=4



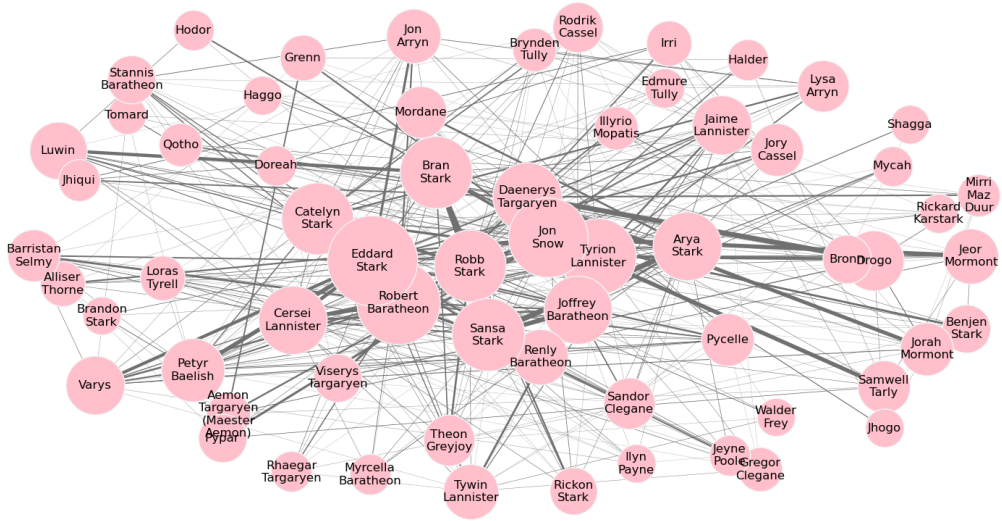
Game of Thrones Network, t=5



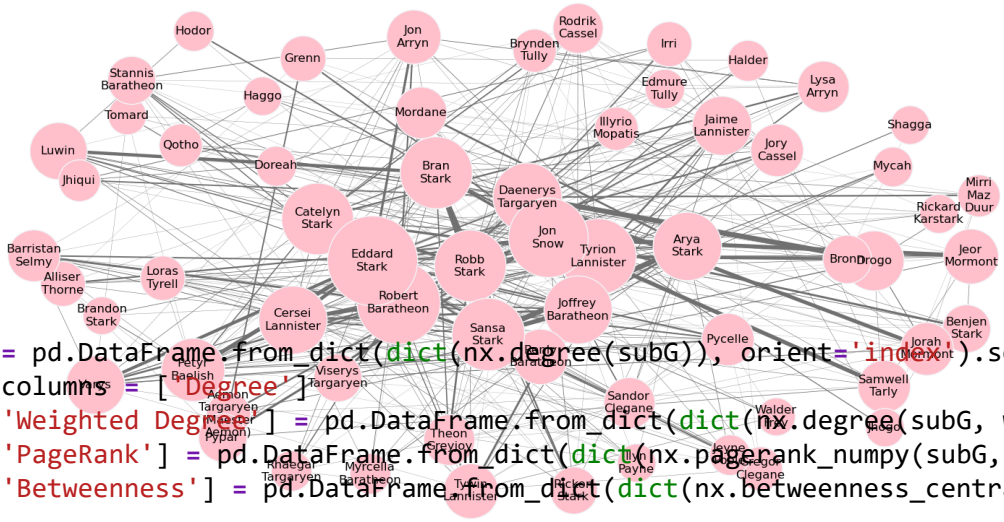
Game of Thrones Network, t=6



Game of Thrones Network, t=7

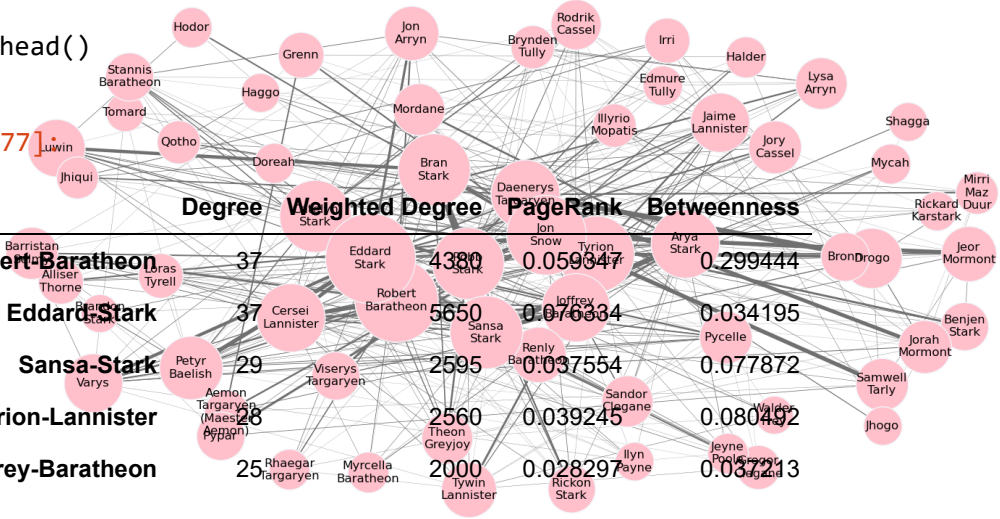


Game of Thrones Network, t=8




```
top = pd.DataFrame.from_dict(dict(nx.degree(subG)), orient='index').sort_values(0, ascer
top.columns = [ 'Degree' ]
top['Weighted Degree'] = pd.DataFrame.from_dict(dict(nx.degree(subG, weight='weight')),
top['PageRank'] = pd.DataFrame.from_dict(dict(nx.pagerank_numpy(subG, weight='weight')),
top['Betweenness'] = pd.DataFrame.from_dict(dict(nx.betweenness_centrality(subG, weight=
```

Game of Thrones Network, t=9




```
top.head()
```

Out[77]:

	Degree	Weighted Degree	PageRank	Betweenness
Robert-Baratheon	37	4380	0.059347	0.299444
Eddard-Stark	37	5650	0.076334	0.034195
Sansa-Stark	29	2595	0.037554	0.077872
Tyrion-Lannister	28	2560	0.039245	0.080452
Joffrey-Baratheon	25	2000	0.028297	0.037213

In [78]:

```
methods = top.columns
```

In [80]:

```
max_budget = len(subG.nodes())
trials = 50
all_results = []
for budget in tqdm.tqdm_notebook(range(max_budget)):
    results = {'budget':budget}
    for method in methods:
        infections = []
        for i in range(trials):
            infected = 0
            t= 0
            infection_times = {n:0 for n in top.sort_values(method,ascending=False).inde
            while len(infection_times)>infected:
                infected = len(infection_times)
                infection_times = independent_cascade(subG,t,infection_times)
                t+=1
            infections.append(infected)
        results[method] = np.round(np.mean(infections)/len(subG.nodes()),2)
    all_results.append(results)
```

```
  0%|          | 0/64 [00:00<?, ?it/s]
```

In [81]:

```
res_df = pd.concat([pd.DataFrame.from_dict(r,orient='index').T
for r in all_results]).set_index('budget')
```

In [82]:

```
res_df.index = res_df.index/len(subG.nodes())
res_df.head()
```

Out[82]:

budget	Degree	Weighted Degree	PageRank	Betweenness
0.000000	0.00	0.00	0.00	0.00
0.015625	0.19	0.19	0.18	0.18
0.031250	0.17	0.19	0.17	0.24
0.046875	0.22	0.22	0.22	0.26
0.062500	0.26	0.25	0.28	0.26

In [83]:

```
res_df.plot()
plt.legend(fontsize = 18)
plt.ylabel('Virality rate (out of total graph size)',fontsize = 18)
plt.xlabel('Seeding Budget (out of graph size)', fontsize = 18)
```

Out[83]:

```
Text(0.5, 0, 'Seeding Budget (out of graph size)')
```