report

April 20, 2016

In [1]:
```
import pandas as pd
import numpy as np
import pylab as pl
import networkx as nx
import urllib
import json
import time
import random
import pickle
import igraph as ig
from sklearn.preprocessing import LabelEncoder

%matplotlib inline
pd.__version__, np.__version__, nx.__version__, ig.__version__
```

Out[1]:
```
('0.17.1', '1.10.4', '1.11', '0.7.1')
```

In [2]:
```
def get_url_friends(uid):
    return 'https://api.vk.com/method/friends.get?user_id=%d' % uid

def get_url_users(uid):
    return 'https://api.vk.com/method/users.get?user_id=%d&fields=city,country,sex,bdate' % uid
```

In [3]:
```
def get_friends(uid):
    with urllib.request.urlopen(get_url_friends(uid)) as response:
        data = json.loads(response.read().decode('utf-8')).get('response')
        if data is None:
            print('No friends for', uid, end=', ')
            return []
        return data

def get_users(uid):
    with urllib.request.urlopen(get_url_users(uid)) as response:
        data = json.loads(response.read().decode('utf-8')).get('response')
        if data is None:
            print('No info for', uid, end=', ')
            return []
        return data
```

In [4]:
```
my_uid = 12867893
first_run = False
```

In [5]:
```
if first_run:
    graph = nx.Graph()
```

```
            my_friends = get_friends(my_uid)
            print('adding friends-to-friends relationships from:')
            for friend_uid in my_friends:
                graph.add_edge(my_uid, friend_uid)
                print(friend_uid, end=', ')
                time.sleep(1)
                for deep_friend_uid in get_friends(friend_uid):
                    if deep_friend_uid in set(my_friends):
                        graph.add_edge(friend_uid, deep_friend_uid)
            nx.write_gpickle(graph, 'graph.pickle')
            print('\ngraph.pickle created')
```

```
In [6]: if first_run:
            users_info = {k:'' for k in graph.nodes()}
            print('Adding info about:')
            for node in users_info.keys():
                print(node, end=', ')
                users_info[node] = get_users(node)
            with open('users_info.pickle', 'wb') as file:
                pickle.dump(users_info, file)
```

```
In [7]: with open('users_info.pickle', 'rb') as file:
            users_info = pickle.load(file)
        names = {k: (v[0]['first_name'] + ' ' + v[0]['last_name']) for k,v in users_info.items()}
        cities = {k: v[0].get('city', -1) for k,v in users_info.items()}
        countries = {k: v[0].get('country', -1) for k,v in users_info.items()}
        genders = {k: v[0].get('sex') for k,v in users_info.items()}
        bdates = {k: v[0].get('bdate', 'unknown') for k,v in users_info.items()}
```

```
In [8]: if first_run:
            nx.set_node_attributes(graph, 'gender', genders)
            nx.set_node_attributes(graph, 'city', cities)
            nx.set_node_attributes(graph, 'country', countries)
            nx.set_node_attributes(graph, 'bdate', bdates)
            nx.write_gpickle(graph, 'graph.pickle')
```

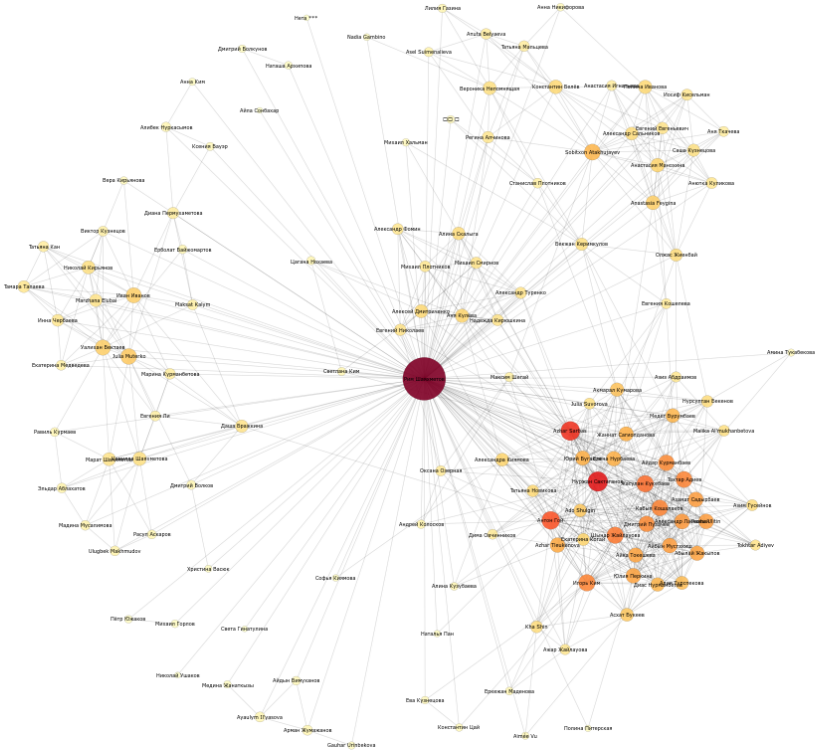
```
In [9]: graph = nx.read_gpickle('graph.pickle')
        graph.number_of_nodes(), graph.number_of_edges()
```

```
Out[9]: (131, 760)
```

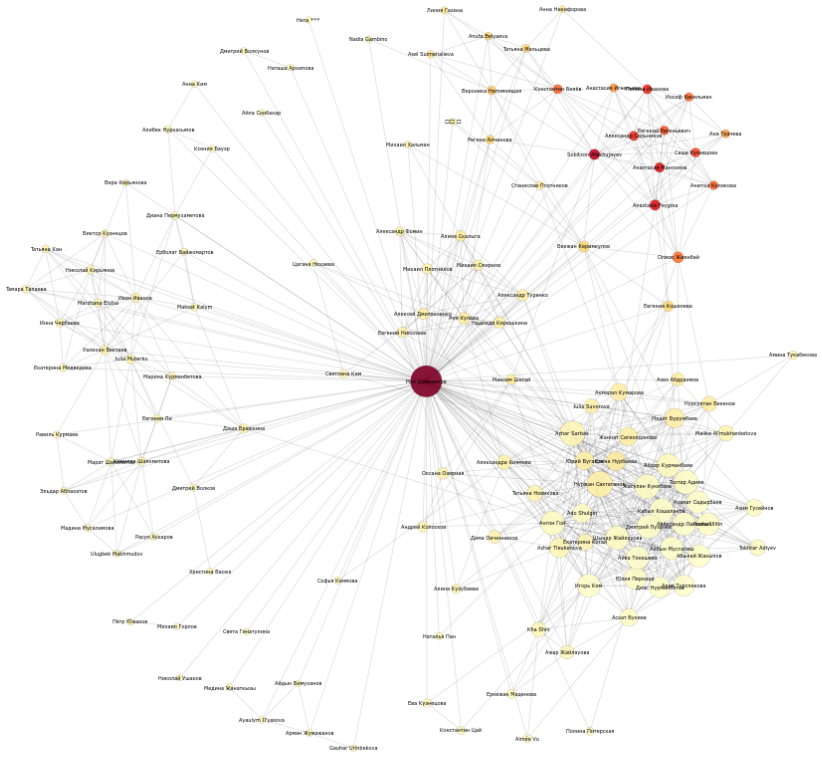
```
In [10]: # with open('edgelist.csv', 'w') as file:
         #     for a, b, c in nx.to_edgelist(graph):
         #         file.write('%s;%s\n' % (a,b))
```

```
In [11]: if first_run:
             pos=nx.spring_layout(graph, k=1.2/np.sqrt(len(nodes)), iterations=1000)
             with open('pos.pickle', 'wb') as file:
                 pickle.dump(pos, file)
         with open('pos.pickle', 'rb') as file:
             pos = pickle.load(file)
         edge_width = 0.6
         edge_alpha = 0.15
         font_size = 5
         linewidths = 0.1
         node_alpha = 0.9
```

In [12]:
```
f = pl.figure(figsize=(15, 15))
nodes = graph.nodes()
degree_centrality = nx.degree_centrality(graph)
betweenness_centrality = nx.betweenness_centrality(graph)
eigenvector_centrality = nx.eigenvector_centrality(graph)
katz_centrality = nx.katz_centrality_numpy(graph)
closeness_centrality = nx.closeness_centrality(graph)
page_ranks = nx.pagerank(graph)

# pl.title('size ~ PAGE RANK centrality \n color ~ DEGREE centrality', fontsize=13)
node_size = [page_ranks[l]*10**4*2 for l in nodes]
node_color = [0.4 if l == my_uid else degree_centrality[l] for l in nodes]
nx.draw(graph, labels=names, pos=pos, font_family='Verdana', nodelist=nodes,
        cmap='YlOrRd', font_color='black', node_color=node_color, font_size=font_size,
        width=0, node_size=node_size, alpha=node_alpha, linewidths=linewidths)
nx.draw_networkx_edges(graph, pos=pos, alpha=edge_alpha, width=edge_width)
pl.savefig('graph.pdf')
# One of my friends has chinees name and matplotlib doesn't show his name properly
```

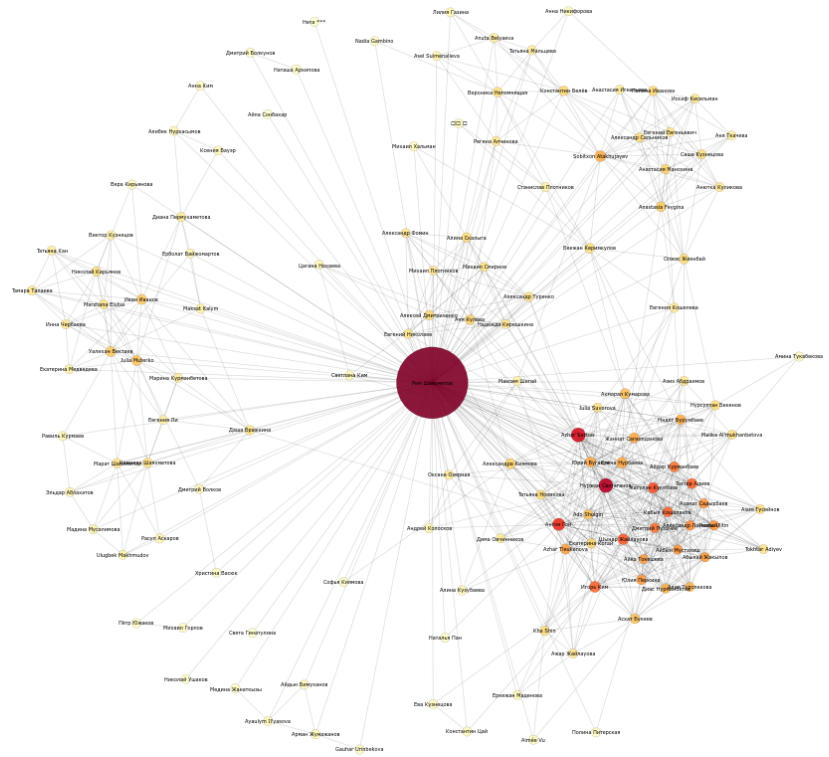


In [13]:
```
f = pl.figure(figsize=(15, 15))
# pl.title('size ~ EIGENVECTOR CENTRALITY, color ~ KATZ CENTRALITY')
node_size = [eigenvector_centrality[l]*10**3*3 for l in nodes]
node_color = [katz_centrality[l] for l in nodes]

nx.draw(graph, labels=names, pos=pos, font_family='Verdana', nodelist=nodes,
        cmap='YlOrRd', font_color='black', node_color=node_color, font_size=font_size,
        width=0, node_size=node_size, alpha=node_alpha, linewidths=linewidths)
nx.draw_networkx_edges(graph, pos=pos, alpha=edge_alpha, width=edge_width)
pl.savefig('graph_eigen_katz.pdf')
```



In [14]:
```
f = pl.figure(figsize=(15, 15))
# pl.title('size ~ BETWEENESS CENTRALITY, color ~ CLOSENESS CENTRALITY')
```

```
        node_size = [np.log10(1.01 + betweenness_centrality[l])*10**4*2 for l in nodes]
        node_color = [0.6 if l == my_uid else closeness_centrality[l] for l in nodes]
        nx.draw(graph, labels=names, pos=pos, font_family='Verdana', nodelist=nodes,
                cmap='YlOrRd', font_color='black', node_color=node_color, font_size=font_size,
                width=0, node_size=node_size, alpha=node_alpha, linewidths=linewidths)
        nx.draw_networkx_edges(graph, pos=pos, alpha=edge_alpha, width=edge_width)
        pl.savefig('graph_closeness_betweeness.pdf')
```



```
In [15]: print('average clustering coefficient =', nx.average_clustering(graph))
         print('diameter =', nx.diameter(graph))
         print('average shortest path length =', nx.average_shortest_path_length(graph))
         print('transitivity coefficient =', nx.transitivity(graph))
```

```
average clustering coefficient = 0.7181817564520412
diameter = 2
average shortest path length = 1.9107457428068115
transitivity coefficient = 0.3805104408352668
```

```
In [16]: print('assortativity by gender', nx.attribute_assortativity_coefficient(graph, 'gender'))
         print('assortativity by city', nx.attribute_assortativity_coefficient(graph, 'city'))
         print('assortativity by country', nx.attribute_assortativity_coefficient(graph, 'country'))
         print('degree assortativity', nx.degree_assortativity_coefficient(graph))
```

```
assortativity by gender 0.01052809368314346
assortativity by city 0.03913596454796606
assortativity by country 0.054281167424358893
degree assortativity -0.174124312168
```

```
In [17]: def degree_pdf(graph):
             degrees = pd.Series(list(graph.degree().values()))
             return (degrees.value_counts()/degrees.count()).sort_index()

         def degree_cdf(graph):
             return degree_pdf(graph).cumsum()

         def degree_ccdf(graph):
             return 1 - degree_cdf(graph)
```

```
In [18]: def plot_pdf_cdf(graph):
             pl.figure(figsize=(15,5))
             pl.semilogx(degree_pdf(graph), 's--')
             pl.xlabel('degree')
             pl.ylabel('probability')
             pl.title('PDF')
             pl.savefig('pdf.pdf')
             pl.figure()
             degree_ccdf(graph).plot(style='-*', loglog=True, figsize=(15,5))
             pl.title('cCDF')
             pl.xlabel('degree')
             pl.ylabel('cCDF')
             pl.savefig('cCDF.pdf')
```

```
In [19]: def estimate_alpha_sigma(observations, x_min=1):
             ''' MLE of alpha and sigma
             '''
             observations = np.asarray(observations)
             observations = observations[observations >= x_min]
             n = observations.shape[0]
             alpha = 1 + n/np.log(observations/x_min).sum()
             sigma = (alpha - 1)/np.sqrt(n)
             return alpha, sigma
```

```
In [20]: def actual_cdf(observations, x_min=1):
             ''' calculate discrete CDF
             '''
             observations = np.asarray(observations)
             observations = observations[observations >= x_min]
             x = pd.Series(observations).value_counts().sort_index()/observations.shape[0]
             return x.cumsum()
```

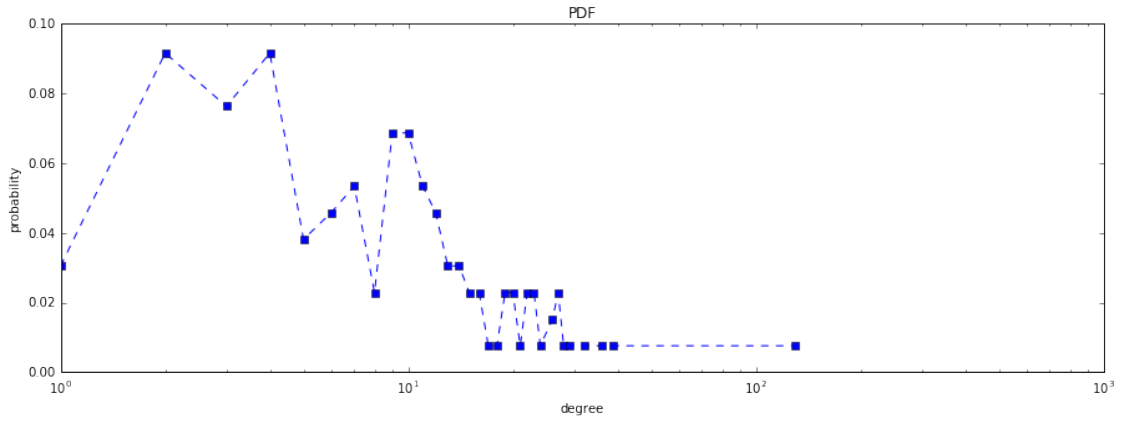
```
In [21]: def hypothesis_cdf(observations, x_min=1, x_max=None):
             ''' for X_min computes hypothesis Power Law CDF and estimates alpha and sigma
             '''
```

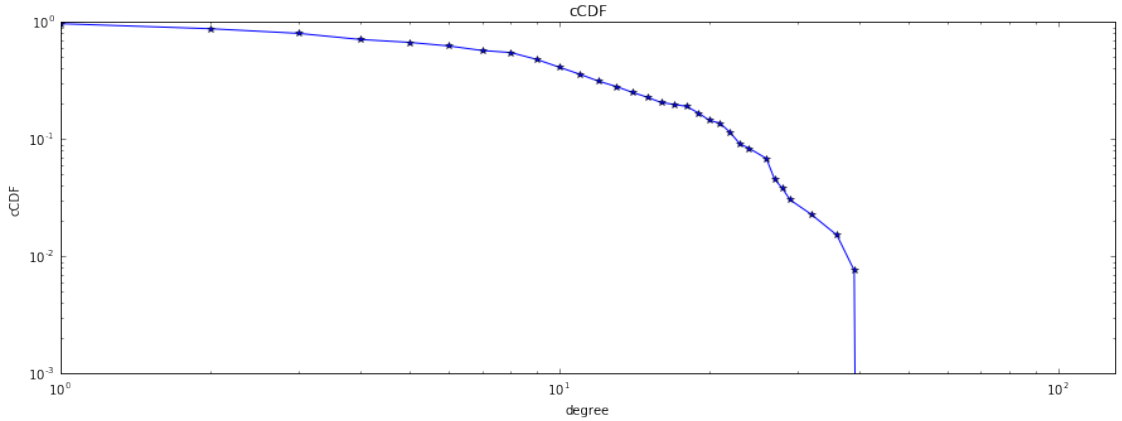
```
        observations = np.asarray(observations)
        observations = observations[observations >= x_min]
        alpha, sigma = estimate_alpha_sigma(observations, x_min=x_min)
        x = np.unique(observations)
        series = pd.Series(1 - (x/x_min)**(-alpha + 1), index=x)
        return series
```

In [22]:
```
def plot_data_hypothesis_diff(observations, x_min=1, x_max=None):
    ''' draws the difference between hypothesis and the real data
    '''
    observations = np.asarray(observations)
    observations = observations[observations >= x_min]
    if x_max is not None:
        observations = observations[observations <= x_max]
    pl.figure(figsize=(15,5))
    pl.title('CDF')
    pl.xlabel('degree')
    pl.ylabel('CDF')
    label = 'x_min=' + str(x_min)
    if x_max is not None:
        label += (', x_max=' + str(x_max))
    pl.semilogx(actual_cdf(observations), '--*', label='data from ' + label)
    pl.semilogx(hypothesis_cdf(observations, x_min=x_min), '-',
                label='hypothesis with ' + label, linewidth=2)
    pl.legend()
```

In [23]:
```
def kolmogorov_smirnov_test(observations):
    pl.figure(figsize=(10, 5))
    x_mins = np.arange(1, observations.max())
    D = [np.max(np.abs(hypothesis_cdf(observations, x_min=x_min) - actual_cdf(observations, x_
    pl.semilogx(x_mins, D, '-', color='red')
    pl.xlabel('x_min')
    pl.ylabel('D')
    pl.title('Kolmogorov-Smirnov test')
    minimun = x_mins[np.argmin(D)]
    print('MIN x_min =', minimun)
    pl.axvline(x_mins[np.argmin(D)], color='blue')
    return minimun

def plot_text(graph, observations, minimum, x_max=None):
    if x_max is not None:
        observations = observations[observations <= x_max]
    alpha, sigma = estimate_alpha_sigma(observations, x_min=minimum)
    print('alpha is', alpha)
    print('sigma is', '%.7f' % sigma)
    print('sigma**2 is', '%.7f' % sigma**2)
    if x_max is not None:
        print('Ending at x_max =', x_max-1, 'and', end=' ')
    print('Starting from x_min =', minimum,
          'the degrees (x) are distributed by the Power Law with alpha ==', alpha)
    print('PDF(x) = (', (alpha-1), '/', minimum, ') *', '(x /', minimum, ') ^', -alpha)
    print('CDF(x) = 1 - (x /', minimum, ') ^', -alpha+1)
```

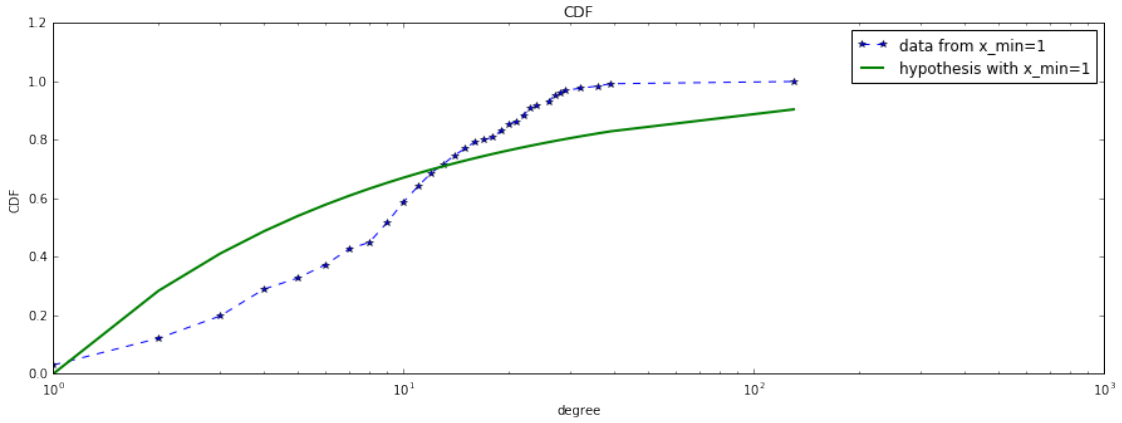
In [24]:
```
plot_pdf_cdf(graph)
```



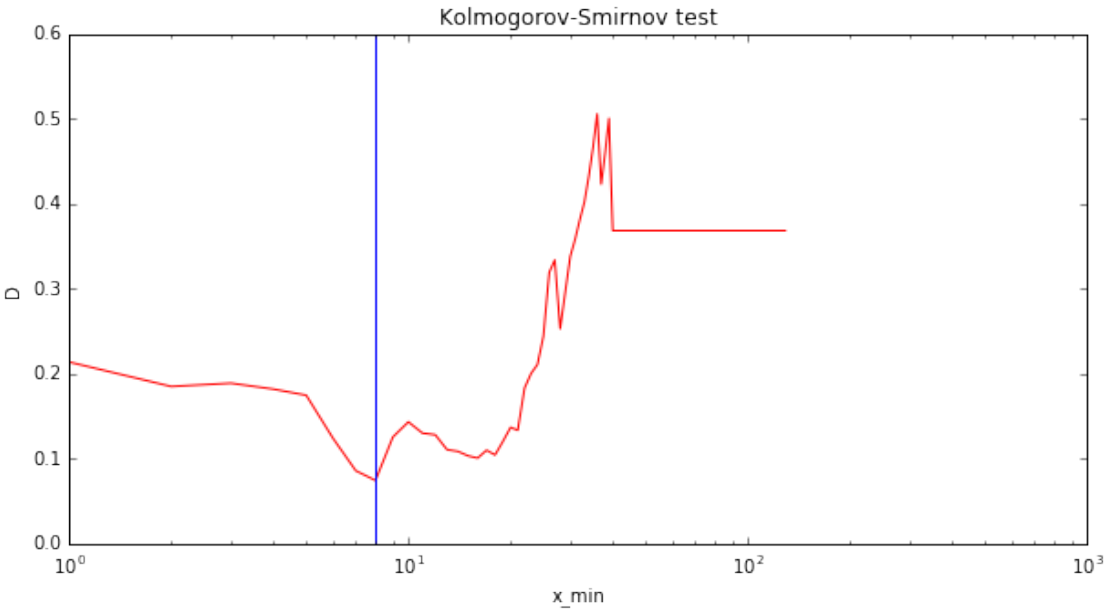


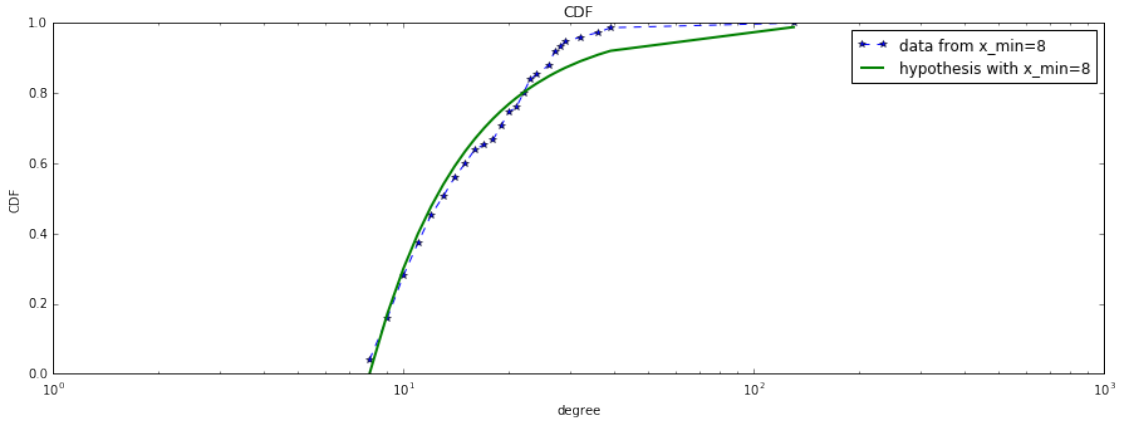
0.0.1 trying to fit Power Law, but it's not so good. Let's divide CDF on two regions, where different Power Law may take place

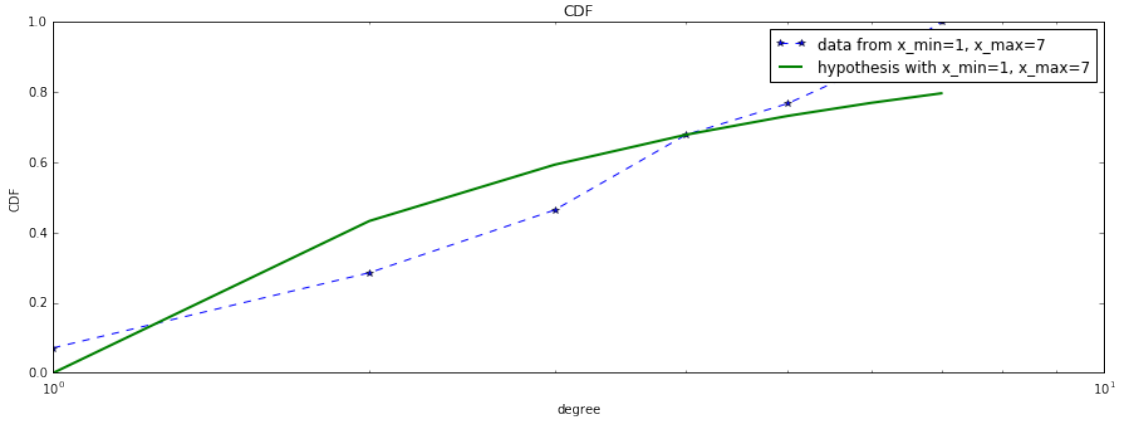
In [25]:
```
observations = np.asarray(list(graph.degree().values()))
plot_data_hypothesis_diff(observations)
```



```
In [26]: minimum = kolmogorov_smirnov_test(observations)
         pl.savefig('kolmogorov.pdf')
         plot_data_hypothesis_diff(observations, x_min=minimum)
         pl.savefig('right.pdf')
         plot_data_hypothesis_diff(observations, x_max=minimum-1)
         pl.savefig('left.pdf')
         print('LEFT SIDE OF THE DISTRIBUTION:', end='\n\n')
         plot_text(graph, observations, minimum=1, x_max=minimum)
         print('\nRIGHT SIDE OF THE DISTRIBUTION:', end='\n\n')
         plot_text(graph, observations, minimum)
         pl.savefig('cdf_split.pdf')

MIN x_min = 8
LEFT SIDE OF THE DISTRIBUTION:

alpha is 1.79091797275
sigma is 0.1029687
sigma**2 is 0.0106026
Ending at x_max = 7 and Starting from x_min = 1 the degrees (x) are distributed by the Power Law with a
PDF(x) = ( 0.790917972753 / 1 ) * (x / 1 ) ^ -1.79091797275
CDF(x) = 1 - (x / 1 ) ^ -0.790917972753

RIGHT SIDE OF THE DISTRIBUTION:

alpha is 2.60047847233
sigma is 0.1848073
sigma**2 is 0.0341538
Starting from x_min = 8 the degrees (x) are distributed by the Power Law with alpha == 2.60047847233
PDF(x) = ( 1.60047847233 / 8 ) * (x / 8 ) ^ -2.60047847233
CDF(x) = 1 - (x / 8 ) ^ -1.60047847233
```





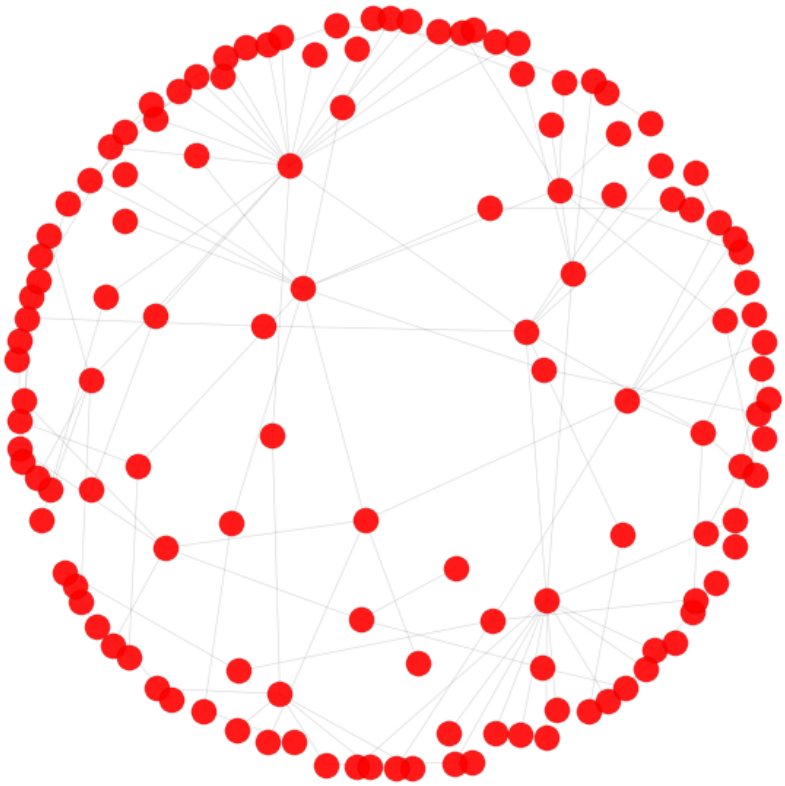


0.1 That's not bad and the hypothesis, which states that CDF can be represented by two regions of different Power Law, seems reasonable

0.1.1 Barbasi-Albert Random Graph model is not ideal, but according to the properties of the network is the closest

In [46]:
```
temp_graph = nx.barabasi_albert_graph(131, 1, seed=10023)

f = pl.figure(figsize=(10, 10))
temp_pos = nx.spring_layout(temp_graph, k=1.2/np.sqrt(131))
nx.draw(temp_graph, pos=temp_pos, font_color='black',
        width=0, alpha=node_alpha, linewidths=linewidths)
nx.draw_networkx_edges(temp_graph, pos=temp_pos, alpha=edge_alpha, width=edge_width)
```

Out[46]:
```
<matplotlib.collections.LineCollection at 0x7efe27d04cf8>
```



```
In [29]: def cosine_similarity(graph):
             result = []
             nodes = graph.nodes()
             degrees = graph.degree()
             matrix = nx.adjacency_matrix(graph)
             for i in range(matrix.shape[0]):
                 for j in range(i+1, matrix.shape[0]):
                     result.append([nodes[i], nodes[j], (
                                 matrix[i, :].multiply(matrix[j, :]).sum()/(np.sqrt(matrix[i, :].sum()*
             return result

In [30]: def get_similarities(similarities):
             names_df = pd.DataFrame(list(names.items()), columns=['uid', 'name'])
             similarities = pd.DataFrame(similarities,
                                         columns=['user1', 'user2', 'sim'])
```

```
    similarities = similarities.merge(names_df, left_on='user1', right_on='uid')
    similarities['user1'] = similarities.name
    del similarities['uid'], similarities['name']

    similarities = similarities.merge(names_df, left_on='user2', right_on='uid')
    similarities['user2'] = similarities.name
    del similarities['uid'], similarities['name']

    return similarities.sort_values(by='sim', ascending=False)
```

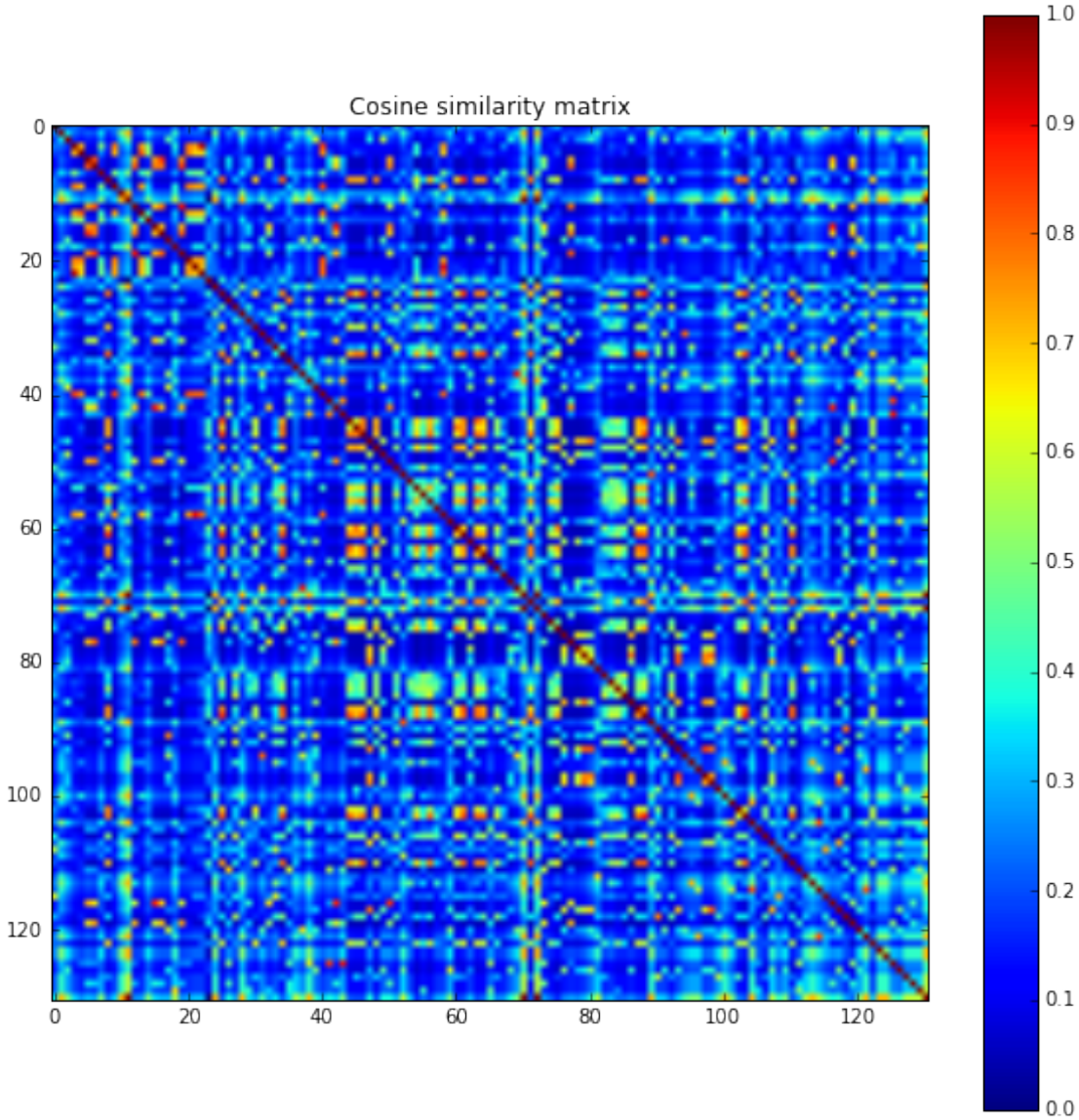
In [31]:
```
def construct_sim_matrix(similarities):
    users_encoder = LabelEncoder()
    users_encoder.fit(nodes)
    sim_matrix = np.eye(users_encoder.classes_.shape[0])
    for u, v, s in similarities:
        i, j =  users_encoder.transform(u), users_encoder.transform(v)
        sim_matrix[i, j] = s
        sim_matrix[j, i] = s
    return sim_matrix
```

In [32]:
```
print('COSINE SIMILARITY')
similarities = cosine_similarity(graph)
pl.figure(figsize=(10, 10))
pl.title('Cosine similarity matrix')
pl.imshow(construct_sim_matrix(similarities))
pl.colorbar()
pl.savefig('cosine.pdf')
get_similarities(similarities).head(15)
```

```
COSINE SIMILARITY
```

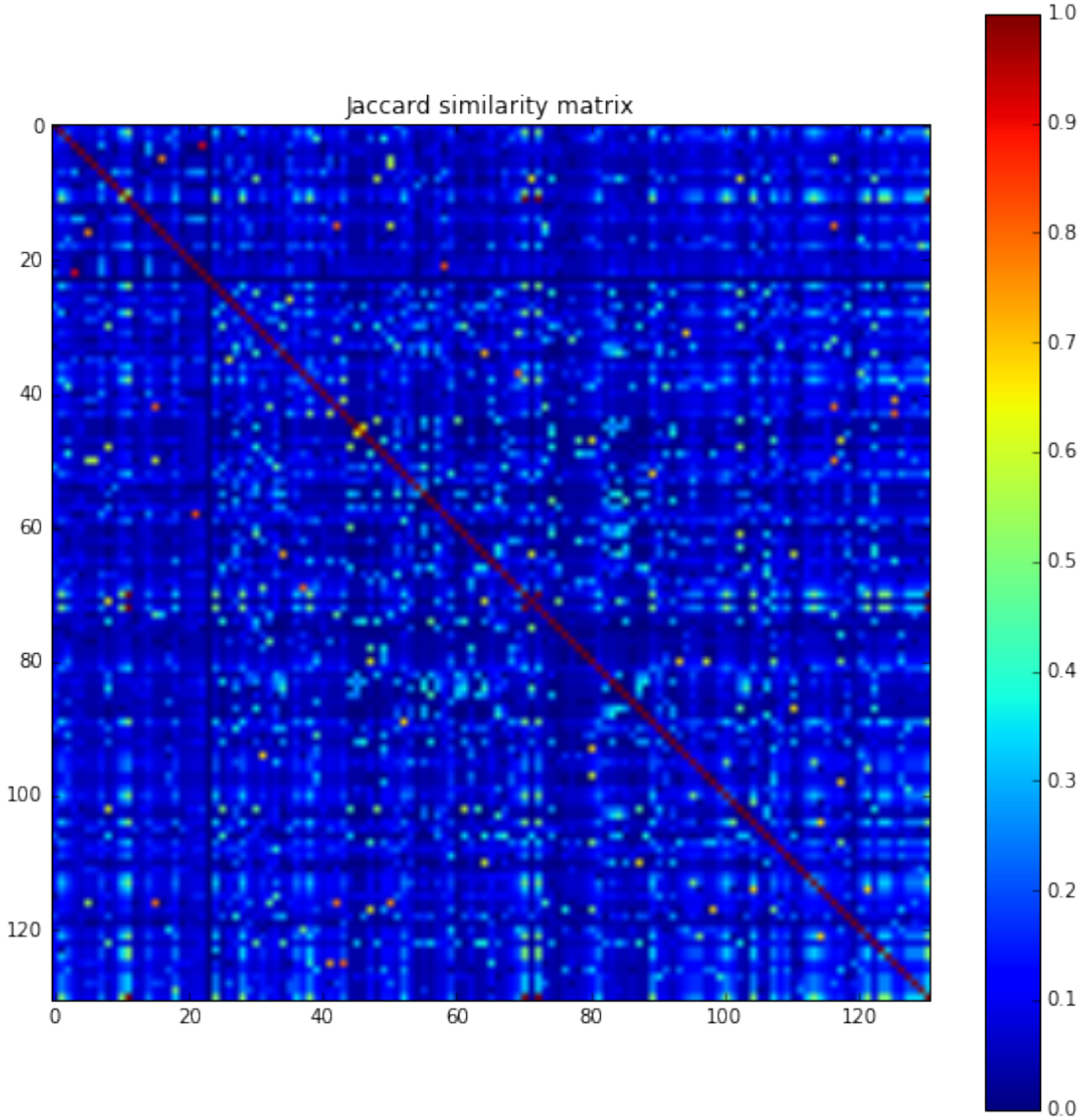
Out[32]:

	user1	user2	sim
2190	Николай Ушаков	Айла Сонбахар	1.000000
2344	Айла Сонбахар	Света Гинатулина	1.000000
2256	Николай Ушаков	Нета ***	1.000000
2345	Нета ***	Света Гинатулина	1.000000
2323	Николай Ушаков	Света Гинатулина	1.000000
2277	Айла Сонбахар	Нета ***	1.000000
7637	Надежда Кирюшкина	Михаил Плотников	0.948683
4425	Евгений Николаев	Александр Туренко	0.900000
132	Anastasia Feygina	Анастасия Манохина	0.897085
2766	Мадина Мусалимова	Расул Аскаров	0.894427
1215	Asel Suimenalieva	Лилия Газина	0.894427
402	Иосиф Кисельман	Анютка Куликова	0.888889
2799	Иосиф Кисельман	Анастасия Игнатьева	0.881917
2803	Анютка Куликова	Анастасия Игнатьева	0.881917
8367	Дмитрий Пузачев	Александр Ласковый	0.880705




```
In [33]: print('JACCARD SIMILARITY')
         similarities = list(nx.jaccard_coefficient(graph))
         pl.figure(figsize=(10, 10))
         pl.title('Jaccard similarity matrix')
         pl.imshow(construct_sim_matrix(similarities))
         pl.colorbar()
         pl.savefig('jaccard.pdf')
         get_similarities(similarities).head(15)

JACCARD SIMILARITY

Out[33]:                    user1              user2       sim
         474       Николай Ушаков          Нета ***  1.000000
         5629           Нета ***      Айла Сонбахар  1.000000
```

5620	Николай Ушаков	Айла Сонбахар	1.000000
5730	Николай Ушаков	Света Гинатулина	1.000000
5739	Нета ***	Света Гинатулина	1.000000
5817	Айла Сонбахар	Света Гинатулина	1.000000
2040	Надежда Кирюшкина	Михаил Плотников	0.900000
4786	Александр Туренко	Евгений Николаев	0.818182
5527	Расул Аскаров	Мадина Мусалимова	0.800000
3124	Иосиф Кисельман	Анютка Куликова	0.800000
5982	Asel Suimenalieva	Лилия Газина	0.800000
2860	Анастасия Игнатьева	Иосиф Кисельман	0.777778
3085	Анастасия Игнатьева	Анютка Куликова	0.777778
2514	Анастасия Игнатьева	Аня Ткачева	0.750000
7572	Евгений Евгеньевич	Саша Кузнецова	0.750000



Friends which have a few (only me) connections, have highest similarity between them. Also friends from one university/school or relatives tend to have high value of similarity.

```
In [34]: cliques = list(nx.find_cliques(graph))
         sizes = pd.Series([len(l) for l in cliques])
         pl.title('Sizes of maximal cliques')
         pl.xlabel('size')
         pl.ylabel('count')
         sizes.value_counts().sort_index().plot()
         pl.savefig('maximal_cliques_sizes.pdf')
         print('Maximal Maximum cliques:')
         for clique in cliques:
             if len(clique) == sizes.max():
                 print(clique)
```

```
Maximal Maximum cliques:
[12867893, 86579341, 56910820, 33644597, 31661689, 50059488, 40476645, 67725137, 132667107, 14805738, 18
[12867893, 86579341, 56910820, 33644597, 31661689, 50059488, 40476645, 67725137, 132667107, 14805738, 18
[12867893, 86579341, 56910820, 33644597, 31661689, 50059488, 40476645, 67725137, 132667107, 14805738, 18
[12867893, 86579341, 56910820, 33644597, 30821204, 50059488, 40476645, 67725137, 132667107, 14805738, 18
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[12867893, 86579341, 56910820, 33644597, 30821204, 50059488, 40476645, 67725137, 132667107, 14805738, 18
[12867893, 86579341, 56910820, 6275805, 50059488, 132667107, 40476645, 14805738, 67725137, 182080254, 59
[12867893, 86579341, 56910820, 6275805, 50059488, 132667107, 40476645, 14805738, 67725137, 182080254, 59
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[12867893, 86579341, 56910820, 6275805, 50059488, 132667107, 40476645, 14805738, 67725137, 182080254, 59
[12867893, 86579341, 56910820, 6275805, 50059488, 132667107, 40476645, 14805738, 67725137, 182080254, 59
[12867893, 86579341, 29476586, 14805738, 132667107, 50059488, 40476645, 67725137, 31661689, 6275805, 18
[12867893, 86579341, 29476586, 14805738, 132667107, 50059488, 40476645, 67725137, 31661689, 6275805, 18
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[12867893, 86579341, 29476586, 14805738, 132667107, 50059488, 40476645, 67725137, 30821204, 6275805, 18
[12867893, 86579341, 29476586, 14805738, 132667107, 50059488, 40476645, 67725137, 30821204, 6275805, 18
[12867893, 86579341, 29476586, 14805738, 132667107, 50059488, 40476645, 67725137, 30821204, 6275805, 18
[12867893, 84875410, 67725137, 50059488, 40476645, 132667107, 19017125, 14805738, 182080254, 59911167, 5
[12867893, 84875410, 67725137, 50059488, 40476645, 132667107, 19017125, 14805738, 182080254, 59911167, 5
[12867893, 84875410, 67725137, 50059488, 40476645, 132667107, 19017125, 14805738, 182080254, 59911167, 5
[12867893, 84875410, 67725137, 50059488, 40476645, 132667107, 19017125, 14805738, 182080254, 59911167, 5
```
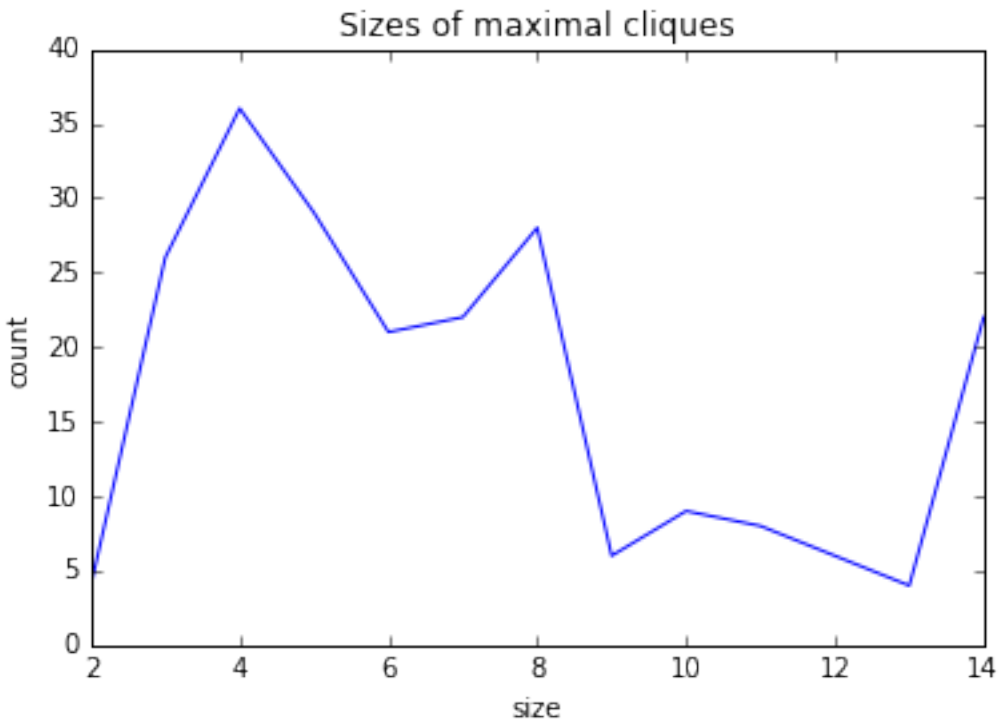
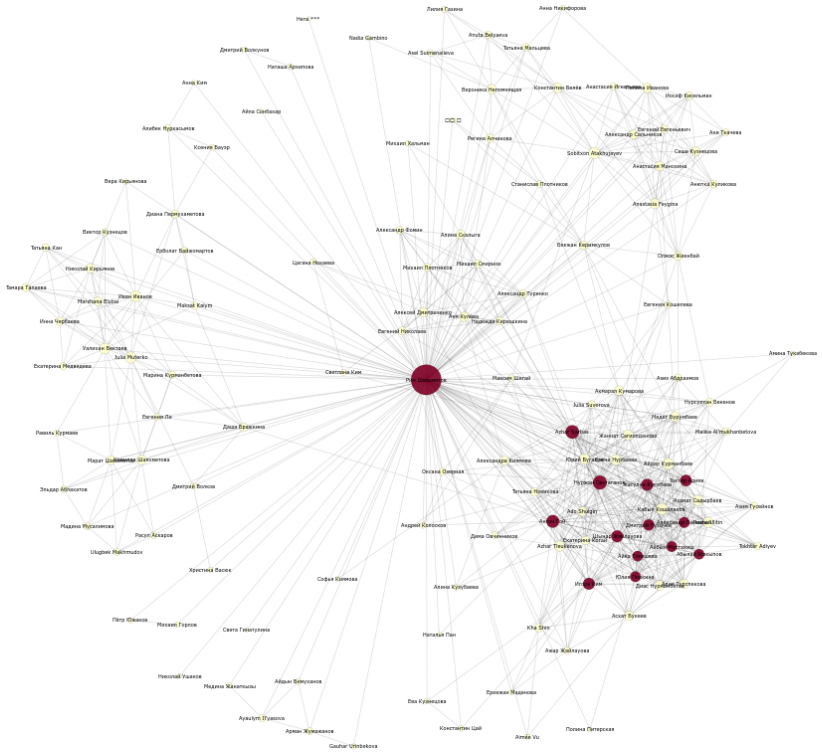
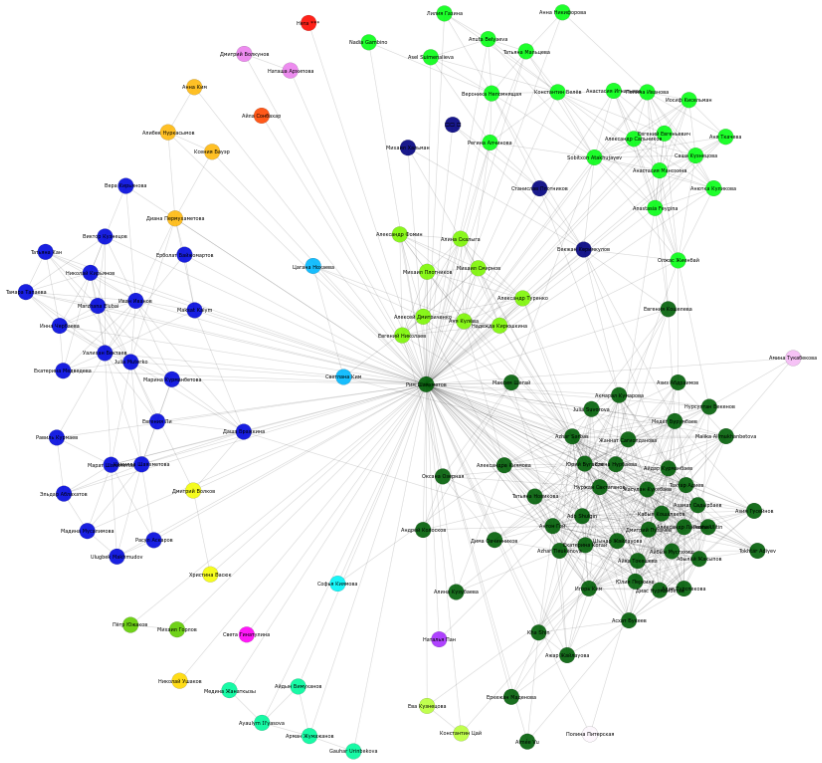




```
In [35]: clique = cliques[sizes[sizes == sizes.max()].index[5]]
         f = pl.figure(figsize=(15, 15))
         # pl.title('Some Maximum Maximal Clique (colored). Node size ~ PageRank')
         node_color = [1 if l in clique else 0 for l in nodes]
         node_size = [page_ranks[l]*10**4 for l in nodes]

         nx.draw(graph, labels=names, pos=pos, font_family='Verdana', nodelist=nodes,
                 cmap='YlOrRd', font_color='black', node_color=node_color, font_size=font_size,
                 width=0, node_size=node_size, alpha=node_alpha, linewidths=linewidths)
         nx.draw_networkx_edges(graph, pos=pos, alpha=edge_alpha, width=edge_width)
         pl.savefig('graph_clique.pdf')
```



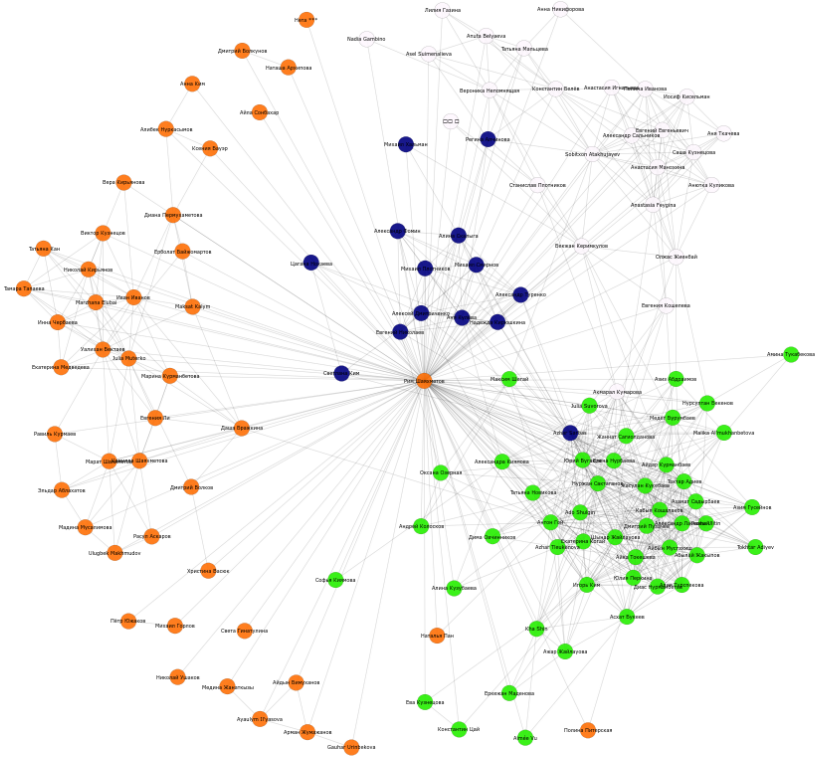
```
In [36]: nx.write_gml(graph, 'graph.gml')
         G = ig.read('graph.gml')

In [37]: dend_edge_betweenness = G.community_edge_betweenness(directed=False)
         dend_fast_greedy = G.community_fastgreedy()
         dend_walktrap = G.community_walktrap(steps=5)
         dend_infomap = G.community_infomap(trials=50)
         dend_label_propagation = G.community_label_propagation()
         dend_leading_eigenvector = G.community_leading_eigenvector()
         dend_spinglass = G.community_spinglass()

In [38]: f = pl.figure(figsize=(15, 15))
         # pl.title('COMMUNITIES by edge betweeness')
         node_size = 250
         nodes = G.vs.get_attribute_values('label')
         membership = dend_edge_betweenness.as_clustering().membership
```

```
node_color = [c/max(membership) for c in membership]

nx.draw(graph, labels=names, pos=pos, font_family='Verdana', nodelist=nodes,
        cmap='gist_ncar', font_color='black', node_color=node_color, font_size=font_size,
        width=0, node_size=node_size, alpha=node_alpha, linewidths=linewidths)
nx.draw_networkx_edges(graph, pos=pos, alpha=edge_alpha, width=edge_width)
pl.savefig('edge_betweenness_com.pdf')
```

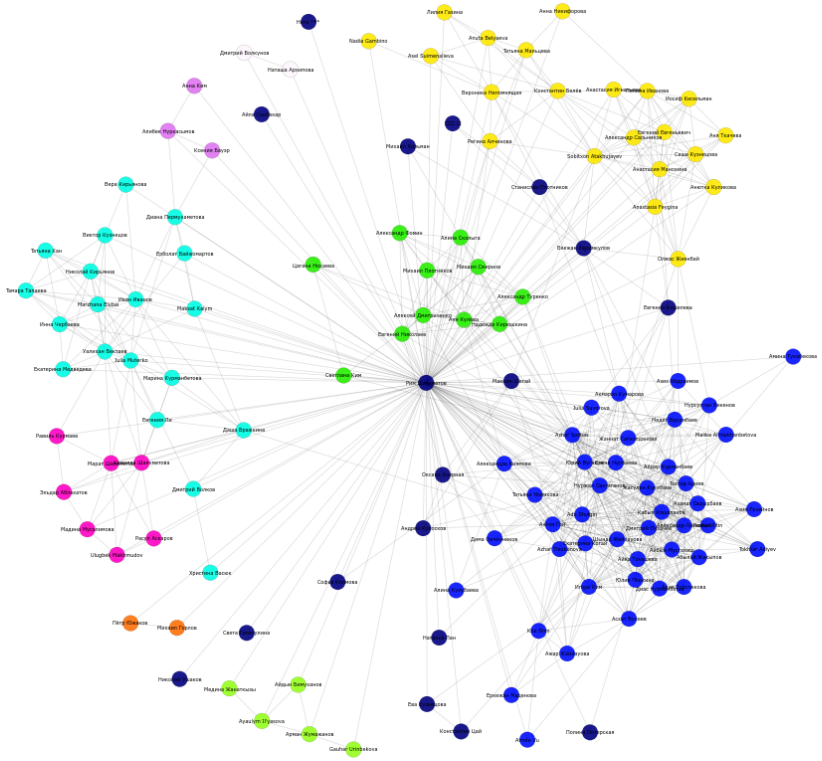


In [39]:
```
f = pl.figure(figsize=(15, 15))
# pl.title('COMMUNITIES by fast greedy')
node_size = 250
nodes = G.vs.get_attribute_values('label')
membership = dend_fast_greedy.as_clustering().membership
node_color = [c/max(membership) for c in membership]
nx.draw(graph, labels=names, pos=pos, font_family='Verdana', nodelist=nodes,
        cmap='gist_ncar', font_color='black', node_color=node_color, font_size=font_size,
```

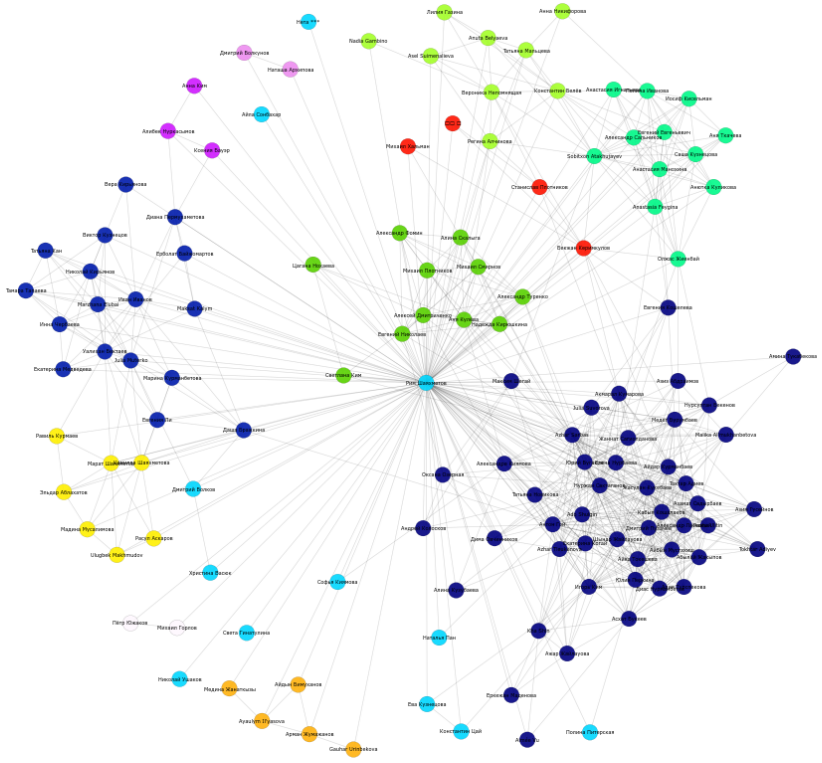
```
        width=0, node_size=node_size, alpha=node_alpha, linewidths=linewidths)
nx.draw_networkx_edges(graph, pos=pos, alpha=edge_alpha, width=edge_width)
pl.savefig('fast_greedy_com.pdf')
```



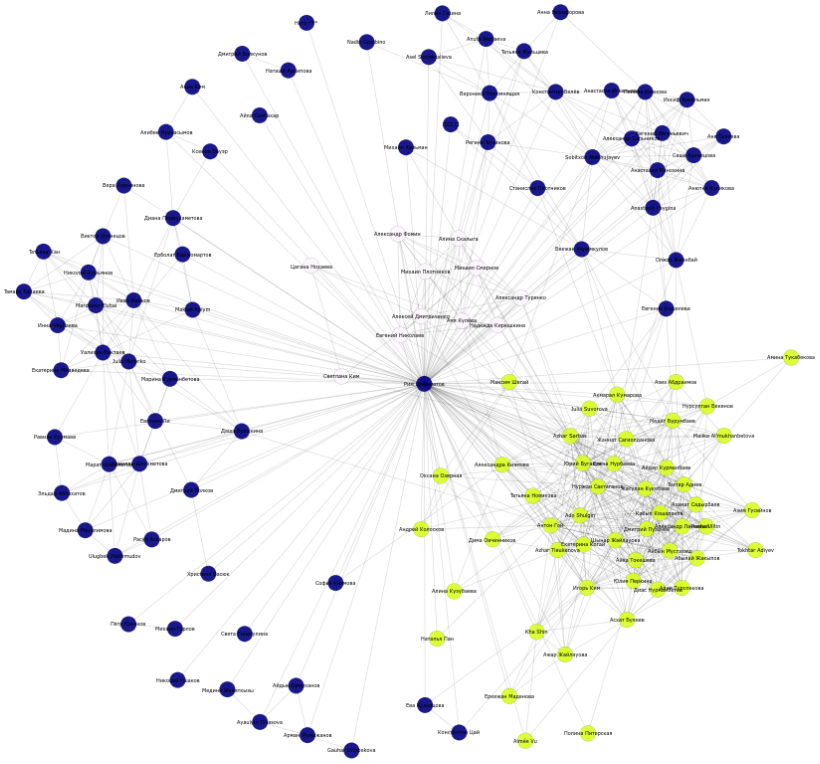
In [40]:
```
f = pl.figure(figsize=(15, 15))
# pl.title('COMMUNITIES by walktrap')
node_size = 250
nodes = G.vs.get_attribute_values('label')
membership = dend_walktrap.as_clustering().membership
node_color = [c/max(membership) for c in membership]
nx.draw(graph, labels=names, pos=pos, font_family='Verdana', nodelist=nodes,
        cmap='gist_ncar', font_color='black', node_color=node_color, font_size=font_size,
        width=0, node_size=node_size, alpha=node_alpha, linewidths=linewidths)
nx.draw_networkx_edges(graph, pos=pos, alpha=edge_alpha, width=edge_width)
pl.savefig('walktrap_com.pdf')
```



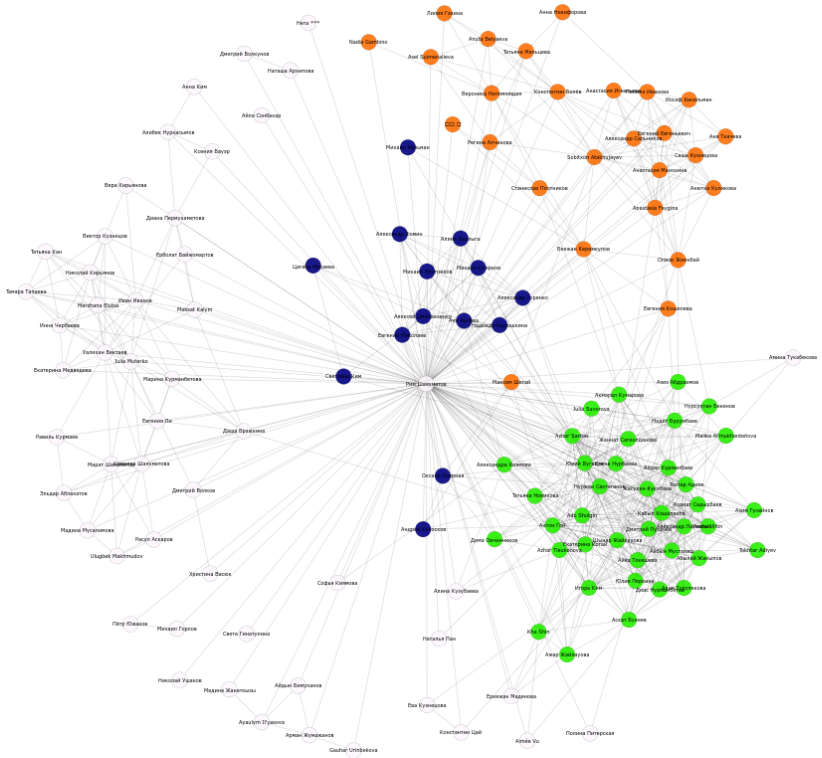
```
In [41]: f = pl.figure(figsize=(15, 15))
         # pl.title('COMMUNITIES by infomap')
         node_size = 250
         nodes = G.vs.get_attribute_values('label')
         membership = [c[0] for c in dend_infomap.as_cover().membership]
         node_color = [c/max(membership) for c in membership]
         nx.draw(graph, labels=names, pos=pos, font_family='Verdana', nodelist=nodes,
                 cmap='gist_ncar', font_color='black', node_color=node_color, font_size=font_size,
                 width=0, node_size=node_size, alpha=node_alpha, linewidths=linewidths)
         nx.draw_networkx_edges(graph, pos=pos, alpha=edge_alpha, width=edge_width)
         pl.savefig('infomap_com.pdf')
```



```
In [42]: f = pl.figure(figsize=(15, 15))
         # pl.title('COMMUNITIES by label propagation')
         node_size = 250
         nodes = G.vs.get_attribute_values('label')
         membership = [c[0] for c in dend_label_propagation.as_cover().membership]
         node_color = [c/max(membership) for c in membership]
         nx.draw(graph, labels=names, pos=pos, font_family='Verdana', nodelist=nodes,
                 cmap='gist_ncar', font_color='black', node_color=node_color, font_size=font_size,
                 width=0, node_size=node_size, alpha=node_alpha, linewidths=linewidths)
         nx.draw_networkx_edges(graph, pos=pos, alpha=edge_alpha, width=edge_width)
         pl.savefig('label_propagation_com.pdf')
```



```
In [43]: f = pl.figure(figsize=(15, 15))
         # pl.title('COMMUNITIES by leading eigenvector')
         node_size = 250
         nodes = G.vs.get_attribute_values('label')
         membership = [c[0] for c in dend_leading_eigenvector.as_cover().membership]
         node_color = [c/max(membership) for c in membership]
         nx.draw(graph, labels=names, pos=pos, font_family='Verdana', nodelist=nodes,
                 cmap='gist_ncar', font_color='black', node_color=node_color, font_size=font_size,
                 width=0, node_size=node_size, alpha=node_alpha, linewidths=linewidths)
         nx.draw_networkx_edges(graph, pos=pos, alpha=edge_alpha, width=edge_width)
         pl.savefig('leading_eigenvector_com.pdf')
```



```
In [44]: f = pl.figure(figsize=(15, 15))
         # pl.title('COMMUNITIES by springlass')
         node_size = 250
         nodes = G.vs.get_attribute_values('label')
         membership = [c[0] for c in dend_spinglass.as_cover().membership]
         node_color = [c/max(membership) for c in membership]
         nx.draw(graph, labels=names, pos=pos, font_family='Verdana', nodelist=nodes,
                 cmap='gist_ncar', font_color='black', node_color=node_color, font_size=font_size,
                 width=0, node_size=node_size, alpha=node_alpha, linewidths=linewidths)
         nx.draw_networkx_edges(graph, pos=pos, alpha=edge_alpha, width=edge_width)
         pl.savefig('springlass_com.pdf')
```