DNA Analysis Enron Monthly 01

July 24, 2016

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2 Introduction

Here using the Enron Email datawith timestamps from John Hopkins, I will attempt to recreatea dynamic network at monthly level of granularity. Previously I conducted this analysis at the yearly level.

For this analysis we use some typical attributes in addition to novel ones.

2.1 The traditional attributes used are:

- Degree Centrality
- Closenss Centrality
- Betweenness Centrality
- Eigenvector Centrality
- Katz Centrality

- Load Centrality
- Density
- Clustering Coefficient

2.2 Novel attributes introduced in this analysis:

- Instantaneous Phase
- Instantaneous Amplitude
- Instantatneous Frequency
- Gaussian Curvature
- Energy Envelope
- First Derivative of Energy Envelope
- Second Derivative of Energy Envelope

2.3 Attributes implemented from other authors:

- Persistence & Emergence (ref: CMU)
- Resistance Distance (ref: Klein 93)

2.4 Novel Visualisation suggested in this analysis:

- Frequency vs Wavenumber Plots
- Radon Domain plots

3 Import Libraries

In [386]:
```
import pandas as pd
import numpy as np
import networkx as nx
import seaborn as sns
import matplotlib.pyplot as plt
import scipy as sc
%matplotlib inline
sns.set(style="whitegrid", color_codes=True, context='paper')
import random
random.seed(1111111111111)
plt.rc('axes', grid=False, titlesize='large', labelsize='medium',labelwei
plt.rc('lines', linewidth=4)
plt.rc('font',family='serif',size=12, serif='Georgia')
plt.rc('figure', figsize = (15,6),titlesize='large',titleweight='heavy')
plt.rc('grid',linewidth=3)
sns.set_palette('cubehelix')
from scipy.signal import *
from numpy.linalg import *
```

4 Helper Functions

```
In [408]: def get_val(val):
              return sorted(set(val.values()))
```

```
In [409]: def avg_cent(cent):
              avg = sum(set(cent.values()))/len(cent)
              return avg
```

```
In [410]: def get_cent(net):
              degC = nx.degree_centrality(net)
              cloC = nx.closeness_centrality(net)
              betC = nx.betweenness_centrality(net)
              eigC = nx.eigenvector_centrality_numpy(net)
              commCC = nx.communicability_centrality(net)
              katzC = nx.katz_centrality_numpy(net)
              loadC = nx.load_centrality(net)

              return [degC,cloC,betC,eigC,commCC,katzC, loadC]
```

```
In [411]: def stationarity_ratio(G):
              #stationarity ratio with laplian
              L = nx.laplacian_matrix(G).todense()
              U = nx.laplacian_spectrum(G)
              C =np.cov(L)
              CF = np.dot(L,np.dot(np.dot(U.T,C),U))
              r = np.linalg.norm(np.diag(CF))/np.linalg.norm(CF)

              return [r]
```

```
In [412]: #cite:`klein1993resistance`
          def resistance_distance(net):
              M = nx.laplacian_matrix(net).todense()
              pseudo = pinv(M)
              N = M.shape[0]
              d = np.diag(pseudo)
              rd  = np.kron(d,np.ones((N,1))).T+np.kron(d,np.ones((N,1))).T - pseuc

              return [rd, rd.mean()]
```

```
In [413]: def calc_seisatt(net):
              M = nx.laplacian_matrix(net).todense()
              Ht = hilbert(M)
              IA = np.real(np.nan_to_num(np.sqrt(np.dot(M,M)+np.dot(Ht,Ht))))
              IP = np.real(np.nan_to_num(np.arctan(Ht/M)))
              IF,_ = np.real(np.nan_to_num(np.asarray(np.gradient(IP))))
              E = np.real(np.sqrt(np.dot(M,M)+np.dot(Ht,Ht)))
              dE, _ = np.nan_to_num(np.asarray(np.gradient(E)))
              dEe, _ = np.nan_to_num(np.asarray(np.gradient(dE)))
```

```
att_globalval = pd.DataFrame([IA.mean(),IP.mean(),IF.mean(),\
                              E.mean(),dE.mean(),dEe.mean()]).T
att_globalval.columns =['InstAmp','InstPhase','InstFreq.','EnergyEnv'

return [IA,IP,IF,E, dE, dEe, att_globalval]
```

```
In [414]: def curvature(net):
              from skimage.feature import hessian_matrix, hessian_matrix_det, hessi
              M = nx.laplacian_matrix(net).todense()
              M = np.float64(M)
              fx, fy = np.gradient(M)
              Hxx, Hxy, Hyy = hessian_matrix(M)
              K = np.divide((np.dot(Hxx,Hxy)-np.dot(Hxy,Hxy)),\
                            (1+np.dot(fx,fx)+np.dot(fy,fy)))

              He1,He2 = hessian_matrix_eigvals(Hxx,Hxy,Hyy)
              mean_curv = np.trace(He1)
              s, a = np.linalg.slogdet(He1)
              conc = s * np.exp(a)
              Pmax = np.max(He1)
              Pmin = np.min(He1)

              return [K,mean_curv,conc]
```

```
In [708]: def cal_avgstat(net):
              #calculate all attributes from previously defined functions here
              degC,cloC,betC,eigC,_C,katzC, loadC = get_cent(net)
              _,meanK,_ = curvature(net)
              IA,IP,IF,E, dE, dEe, att_globalval = calc_seisatt(net)
              _,norm_rd = resistance_distance(net)
              r = stationarity_ratio(net)
              den = nx.density(net)
              clustcof = nx.clustering(net)

              #create attribute volume here
              stat_df = pd.DataFrame([avg_cent(degC),avg_cent(cloC), avg_cent(betC)
                      avg_cent(katzC), avg_cent(loadC), meanK, den, avg_cent(clustc
              stat_df.columns= ['AvgDeg','AvgCloseness','AvgBet','AvgEig','AvgKatz'
              stat_df = stat_df.join(att_globalval)
              stat_df['MeanResistanceDist']= norm_rd
              stat_df['StatRat']=r


              return stat_df
```

```
In [709]: def std_klpca_ratio(net):
              from sklearn.decomposition import KernelPCA
```

```
    M = nx.laplacian_matrix(net)
    kpca =KernelPCA(n_components=3,kernel='rbf')
    eigv = kpca.fit_transform(M)
    pc1_std = eigv[:,0] - eigv[:,0].mean() /eigv[:,0].std()
    pc2_std = eigv[:,1] - eigv[:,1].mean() /eigv[:,1].std()
    pc3_std = eigv[:,2] - eigv[:,2].mean() /eigv[:,2].std()
    klpca_ratio_std = pc1_std - pc3_std/pc1_std - pc2_std

    return klpca_ratio_std
```

5 Data Analysis Monthly Aggregation

5.1 Load Preprocessed Data

```
In [710]: data = pd.read_excel("../Data/data 03.2.xlsx")

In [711]: data.head()

Out[711]:              timestamp  to  from  year  month
          0 1979-12-31 21:00:00  24   153  1979     12
          1 1979-12-31 21:00:00  24   153  1979     12
          2 1979-12-31 21:00:00  29    29  1979     12
          3 1979-12-31 21:00:00  29    29  1979     12
          4 1979-12-31 21:00:00  29    29  1979     12
```

5.2 Check Year Labels

```
In [712]: set(data.year)

Out[712]: {1979, 1998, 1999, 2000, 2001, 2002}

In [713]: data[data.year==1979].count()

Out[713]: timestamp    174
          to           174
          from         174
          year         174
          month        174
          dtype: int64

In [714]: data.shape

Out[714]: (125409, 5)

In [715]: #total % of mislabelled 1979 entries
          (data[data.year==1979].count()/data.shape[0]) * 100

Out[715]: timestamp    0.138746
          to           0.138746
          from         0.138746
          year         0.138746
          month        0.138746
          dtype: float64
```

5.3 Split data into yearly slices

The entries labelled 1979 are mislabelled hence they will be excluded from analysis. As we see that they are a tiny fraction of the dataset anyway

```
In [716]: data = data[data.year!= 1979]

In [717]: years = sorted(set(data.year))

In [718]: years

Out[718]: [1998, 1999, 2000, 2001, 2002]

In [719]: df_98 = data[data.year==years[0]]
          df_99 = data[data.year==years[1]]
          df_2k = data[data.year==years[2]]
          df_2k1 = data[data.year==years[3]]
          df_2k2 = data[data.year==years[4]]

In [720]: df_98.head()

Out[720]:               timestamp  to   from  year  month
          174 1998-11-13 09:07:00  114   169  1998     11
          175 1998-11-13 09:07:00  114   169  1998     11
          176 1998-11-19 12:19:00  114   123  1998     11
          177 1998-11-19 12:19:00  114   123  1998     11
          178 1998-11-19 13:24:00  114   123  1998     11

In [721]: df_98.describe()

Out[721]:               to        from    year      month
          count   82.000000   82.000000    82.0  82.000000
          mean   114.292683  119.000000  1998.0  11.634146
          std      2.051725   48.393449     0.0   0.484633
          min    112.000000   11.000000  1998.0  11.000000
          25%    114.000000  110.000000  1998.0  11.000000
          50%    114.000000  123.000000  1998.0  12.000000
          75%    114.000000  169.000000  1998.0  12.000000
          max    123.000000  169.000000  1998.0  12.000000

In [722]: df_99.head()

Out[722]:               timestamp  to   from  year  month
          256 1999-01-04 07:21:00  114    65  1999      1
          257 1999-01-04 07:21:00  114    65  1999      1
          258 1999-01-04 09:11:00  114   169  1999      1
          259 1999-01-04 09:11:00  114   169  1999      1
          260 1999-01-07 13:42:00  114   112  1999      1

In [723]: df_2k.head()
```

```
Out[723]:                timestamp  to  from  year  month
          3971 2000-01-03 06:47:00  82    51  2000      1
          3972 2000-01-03 06:47:00  82    51  2000      1
          3973 2000-01-03 06:47:00  82    51  2000      1
          3974 2000-01-03 06:47:00  82    51  2000      1
          3975 2000-01-03 06:47:00  82    51  2000      1
```

```
In [724]: df_99.describe()
```

```
Out[724]:                to         from    year        month
          count  3715.000000  3715.000000  3715.0  3715.000000
          mean    116.191386   115.949933  1999.0     9.725707
          std      56.692443    43.626945     0.0     2.648675
          min      11.000000     2.000000  1999.0     1.000000
          25%      65.000000    88.000000  1999.0     8.000000
          50%     145.000000   114.000000  1999.0    10.000000
          75%     169.000000   156.000000  1999.0    12.000000
          max     178.000000   178.000000  1999.0    12.000000
```

```
In [725]: df_2k1.head()
```

```
Out[725]:                 timestamp  to  from  year  month
          48030 2001-01-01 13:36:00  78    82  2001      1
          48031 2001-01-01 13:36:00  78    82  2001      1
          48032 2001-01-01 13:36:00  78    82  2001      1
          48033 2001-01-01 13:55:00  78   127  2001      1
          48034 2001-01-01 13:55:00  78   127  2001      1
```

```
In [726]: df_2k2.head()
```

```
Out[726]:                  timestamp  to  from  year  month
          116918 2002-01-01 17:27:27   0     9  2002      1
          116919 2002-01-01 17:27:27   0    48  2002      1
          116920 2002-01-01 20:12:31   0    20  2002      1
          116921 2002-01-01 21:27:27   0     9  2002      1
          116922 2002-01-01 21:27:27   0    48  2002      1
```

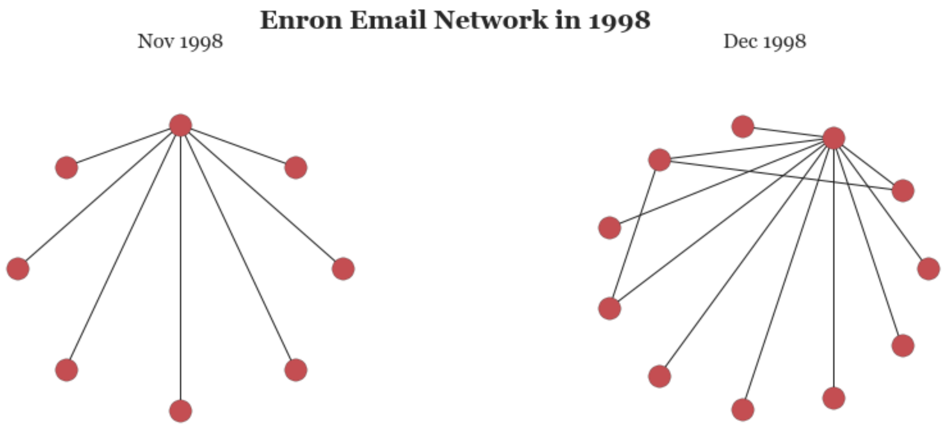
6 Network Year 1998

```
In [727]: nov_98 = df_98[df_98.month==11]
          dec_98= df_98[df_98.month==12]
```

```
In [728]: def create_graph(df):
              tmp = df.values[:,1:3]
              G= nx.Graph()
              G = nx.from_edgelist(tmp)

              return G
```

```
In [729]: G_nov98 = create_graph(nov_98)
          G_dec98 = create_graph(dec_98)
```

```
In [730]: plt.figure()
          plt.suptitle("Enron Email Network in 1998", fontsize=20)
          plt.subplot(121)
          plt.title("Nov 1998", fontsize=16)
          nx.draw_circular(G_nov98)
          plt.subplot(122)
          plt.title("Dec 1998", fontsize=16)
          nx.draw_circular(G_dec98)
```




```
In [731]: stat_nov98 = cal_avgstat(G_nov98)
          stat_dec98 = cal_avgstat(G_dec98)
```

```
In [732]: stat_nov98
```

```
Out[732]:      AvgDeg  AvgCloseness   AvgBet    AvgEig   AvgKatz  AvgLoad  MeanKurv
          0  0.142857      0.192308    0.125  0.255427  0.185435    0.125 -0.186746

             Density  AvgClustCoef   InstAmp  InstPhase  InstFreq.  EnergyEnv  \
          0     0.25           0.0  1.673053   0.402325   0.148795   1.673053

             dEnergyEnv  d2EnergyEnv  MeanResistanceDist   StatRat
          0    0.005621     0.018756             1.53125  0.894427
```

```
In [733]: stat_dec98
```

```
Out[733]:      AvgDeg  AvgCloseness    AvgBet    AvgEig    AvgKatz    AvgLoad  MeanKur
          0  0.145455      0.242737  0.086869  0.25114  0.175111  0.086869 -0.2119
```

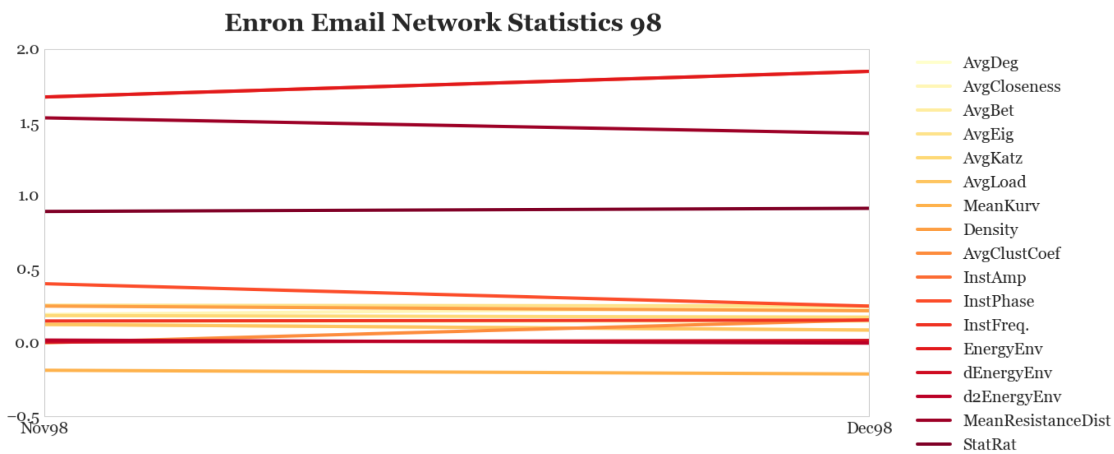
```
     Density  AvgClustCoef  InstAmp  InstPhase  InstFreq.  EnergyEnv  \
0  0.218182      0.155556  1.84759   0.249824   0.154485    1.84759

   dEnergyEnv  d2EnergyEnv  MeanResistanceDist   StatRat
0    0.016204    -0.001828             1.42562  0.915335
```

In [734]:
```
stat98= stat_nov98.append(stat_dec98).T
```

In [735]:
```
stat98.columns = ['Nov98','Dec98']
```

In [798]:
```
stat98.T.plot(fontsize=20, figsize=(18,8),cmap='YlOrRd')
plt.suptitle("Enron Email Network Statistics 98", fontsize=30)
plt.legend(fontsize=20, bbox_to_anchor=(1.05, 1), loc=2, borderaxespad=0.
```

Out[798]:
```
<matplotlib.legend.Legend at 0x1488cd48978>
```



7 Network Year 1999

In [737]:
```
df_99.describe()
```

Out[737]:

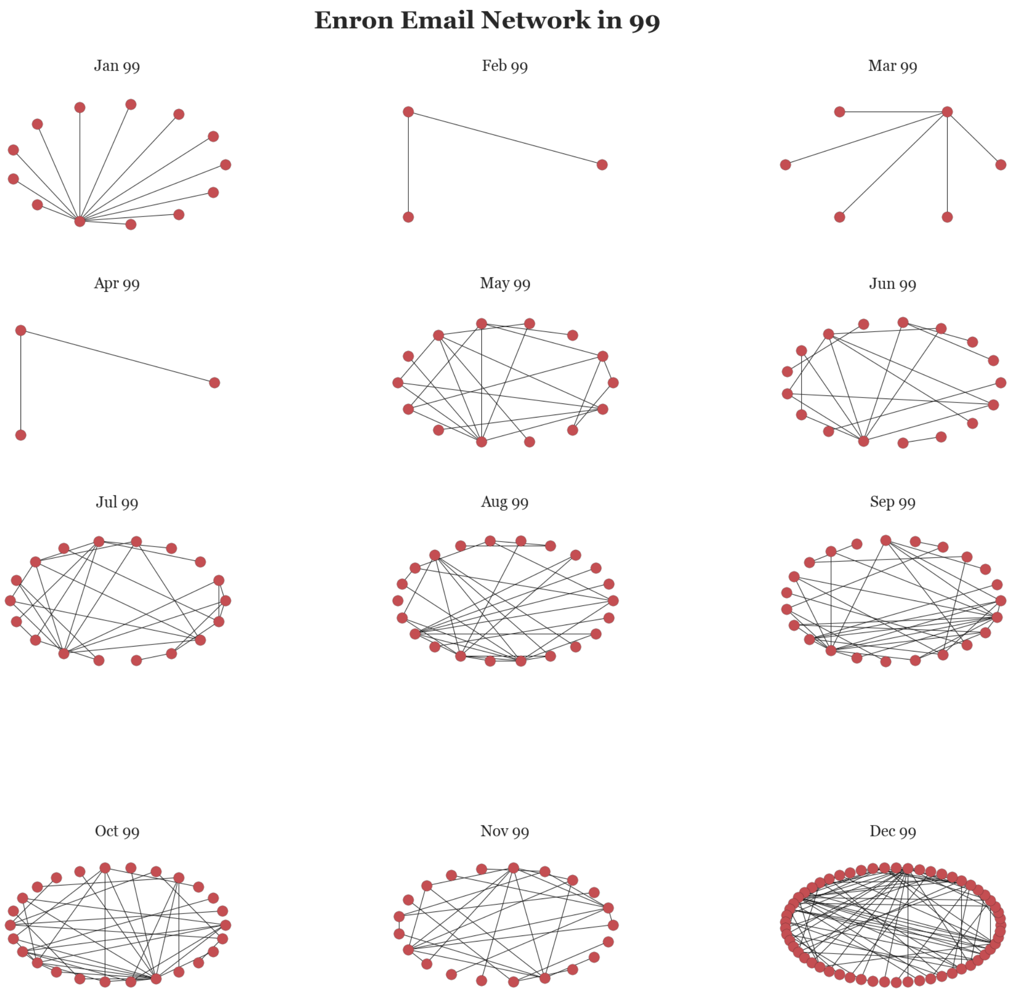
	to	from	year	month
count	3715.000000	3715.000000	3715.0	3715.000000
mean	116.191386	115.949933	1999.0	9.725707
std	56.692443	43.626945	0.0	2.648675
min	11.000000	2.000000	1999.0	1.000000
25%	65.000000	88.000000	1999.0	8.000000
50%	145.000000	114.000000	1999.0	10.000000
75%	169.000000	156.000000	1999.0	12.000000
max	178.000000	178.000000	1999.0	12.000000

In [738]:
```
jan_99=df_99[df_99.month==1]
feb_99=df_99[df_99.month==2]
```

```
mar_99=df_99[df_99.month==3]
apr_99=df_99[df_99.month==4]
may_99=df_99[df_99.month==5]
jun_99=df_99[df_99.month==6]
jul_99=df_99[df_99.month==7]
aug_99=df_99[df_99.month==8]
sep_99=df_99[df_99.month==9]
oct_99=df_99[df_99.month==10]
nov_99=df_99[df_99.month==11]
dec_99=df_99[df_99.month==12]


G_jan_99=create_graph(jan_99)
G_feb_99=create_graph(feb_99)
G_mar_99=create_graph(mar_99)
G_apr_99=create_graph(apr_99)
G_may_99=create_graph(may_99)
G_jun_99=create_graph(jun_99)
G_jul_99=create_graph(jul_99)
G_aug_99=create_graph(aug_99)
G_sep_99=create_graph(sep_99)
G_oct_99=create_graph(oct_99)
G_nov_99=create_graph(nov_99)
G_dec_99=create_graph(dec_99)
```

In [739]:
```
plt.figure(figsize=(32,18))
plt.suptitle("Enron Email Network in 99", fontsize=40)

plt.subplot(331)
plt.title("Jan 99", fontsize=25)
nx.draw_circular(G_jan_99)

plt.subplot(332)
plt.title("Feb 99", fontsize=25)
nx.draw_circular(G_feb_99)

plt.subplot(333)
plt.title("Mar 99", fontsize=25)
nx.draw_circular(G_mar_99)

plt.subplot(334)
plt.title("Apr 99", fontsize=25)
nx.draw_circular(G_apr_99)

plt.subplot(335)
plt.title("May 99", fontsize=25)
nx.draw_circular(G_may_99)
```

```python
plt.subplot(336)
plt.title("Jun 99", fontsize=25)
nx.draw_circular(G_jun_99)

plt.subplot(337)
plt.title("Jul 99", fontsize=25)
nx.draw_circular(G_jul_99)

plt.subplot(338)
plt.title("Aug 99", fontsize=25)
nx.draw_circular(G_aug_99)

plt.subplot(339)
plt.title("Sep 99", fontsize=25)
nx.draw_circular(G_sep_99)

plt.figure(figsize=(32,5))
#plt.suptitle("Enron Email Network in 99", fontsize=40)

plt.subplot(131)
plt.title("Oct 99", fontsize=25)
nx.draw_circular(G_oct_99)

plt.subplot(132)
plt.title("Nov 99", fontsize=25)
nx.draw_circular(G_nov_99)

plt.subplot(133)
plt.title("Dec 99", fontsize=25)
nx.draw_circular(G_dec_99)
```

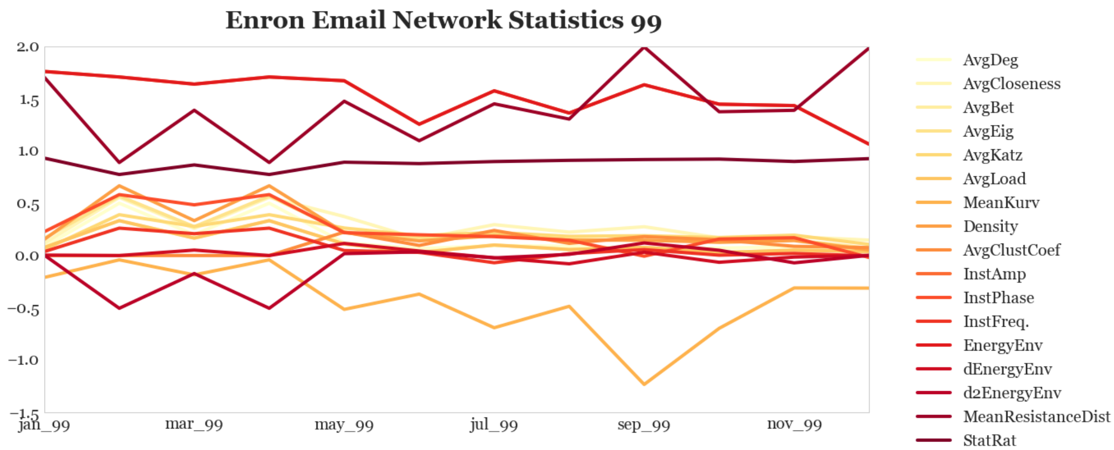


In [740]:
```
stat_jan_99=cal_avgstat(G_jan_99)
stat_feb_99=cal_avgstat(G_feb_99)
stat_mar_99=cal_avgstat(G_mar_99)
stat_apr_99=cal_avgstat(G_apr_99)
stat_may_99=cal_avgstat(G_may_99)
stat_jun_99=cal_avgstat(G_jun_99)
stat_jul_99=cal_avgstat(G_jul_99)
stat_aug_99=cal_avgstat(G_aug_99)
stat_sep_99=cal_avgstat(G_sep_99)
stat_oct_99=cal_avgstat(G_oct_99)
stat_nov_99=cal_avgstat(G_nov_99)
stat_dec_99=cal_avgstat(G_dec_99)
```

In [741]:
```
stat_99 = stat_jan_99.append(stat_feb_99).append(stat_mar_99).append(stat
stat_99 = stat_99.append(stat_jun_99).append(stat_jul_99).append(stat_aug
stat_99 = stat_99.append(stat_oct_99).append(stat_nov_99).append(stat_dec
stat_99.columns = ['jan_99','feb_99','mar_99','apr_99','may_99','jun_99',
```

```
In [795]: stat_99.T.plot(fontsize=20, figsize=(18,8), cmap='YlOrRd')
          plt.suptitle("Enron Email Network Statistics 99", fontsize=30)
          plt.legend(fontsize=20, bbox_to_anchor=(1.05, 1), loc=2, borderaxespad=0.
```

```
Out[795]: <matplotlib.legend.Legend at 0x14882a87f60>
```



8 Network Year 2000

```
In [742]: df_2k.month.describe()
```

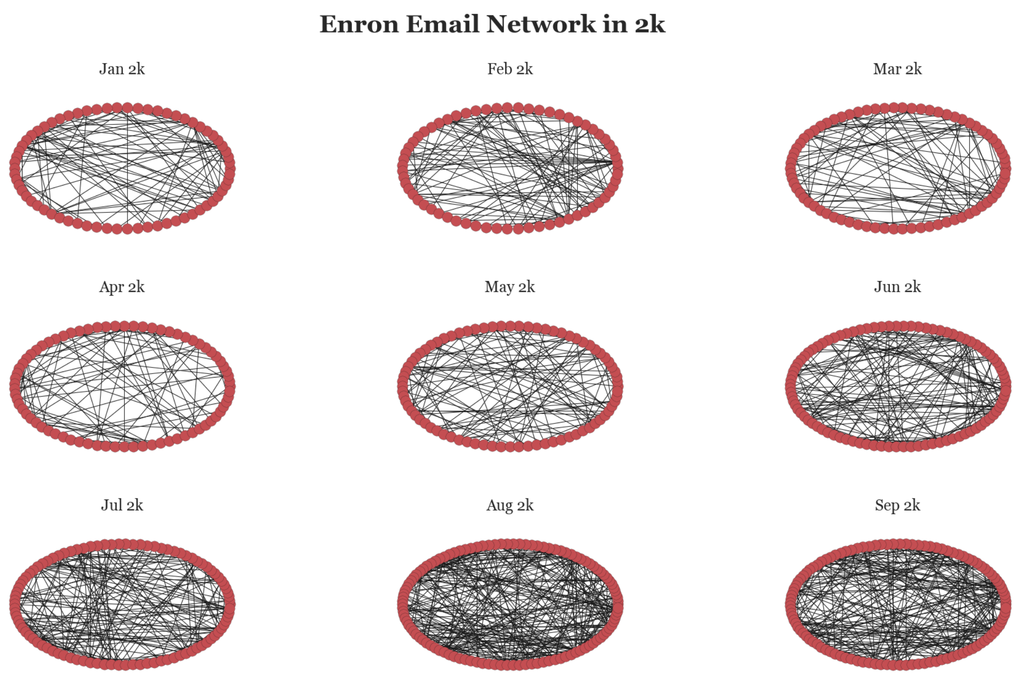
```
Out[742]: count    44059.000000
          mean         8.183163
          std          3.169912
          min          1.000000
          25%          6.000000
          50%          9.000000
          75%         11.000000
          max         12.000000
          Name: month, dtype: float64
```

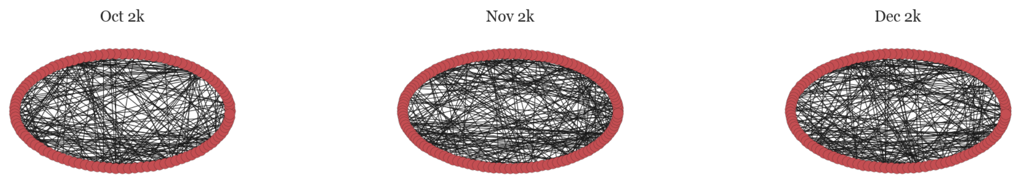
```
In [743]: jan_2k=df_2k[df_2k.month==1]
          feb_2k=df_2k[df_2k.month==2]
          mar_2k=df_2k[df_2k.month==3]
          apr_2k=df_2k[df_2k.month==4]
          may_2k=df_2k[df_2k.month==5]
          jun_2k=df_2k[df_2k.month==6]
          jul_2k=df_2k[df_2k.month==7]
          aug_2k=df_2k[df_2k.month==8]
          sep_2k=df_2k[df_2k.month==9]
          oct_2k=df_2k[df_2k.month==10]
          nov_2k=df_2k[df_2k.month==11]
```

```
dec_2k=df_2k[df_2k.month==12]


G_jan_2k=create_graph(jan_2k)
G_feb_2k=create_graph(feb_2k)
G_mar_2k=create_graph(mar_2k)
G_apr_2k=create_graph(apr_2k)
G_may_2k=create_graph(may_2k)
G_jun_2k=create_graph(jun_2k)
G_jul_2k=create_graph(jul_2k)
G_aug_2k=create_graph(aug_2k)
G_sep_2k=create_graph(sep_2k)
G_oct_2k=create_graph(oct_2k)
G_nov_2k=create_graph(nov_2k)
G_dec_2k=create_graph(dec_2k)
```

In [744]:
```
plt.figure(figsize=(32,18))
plt.suptitle("Enron Email Network in 2k", fontsize=40)

plt.subplot(331)
plt.title("Jan 2k", fontsize=25)
nx.draw_circular(G_jan_2k)

plt.subplot(332)
plt.title("Feb 2k", fontsize=25)
nx.draw_circular(G_feb_2k)

plt.subplot(333)
plt.title("Mar 2k", fontsize=25)
nx.draw_circular(G_mar_2k)

plt.subplot(334)
plt.title("Apr 2k", fontsize=25)
nx.draw_circular(G_apr_2k)

plt.subplot(335)
plt.title("May 2k", fontsize=25)
nx.draw_circular(G_may_2k)

plt.subplot(336)
plt.title("Jun 2k", fontsize=25)
nx.draw_circular(G_jun_2k)

plt.subplot(337)
plt.title("Jul 2k", fontsize=25)
nx.draw_circular(G_jul_2k)

plt.subplot(338)
```

```python
plt.title("Aug 2k", fontsize=25)
nx.draw_circular(G_aug_2k)

plt.subplot(339)
plt.title("Sep 2k", fontsize=25)
nx.draw_circular(G_sep_2k)

plt.figure(figsize=(32,5))
#plt.suptitle("Enron Email Network in 2k", fontsize=40)

plt.subplot(131)
plt.title("Oct 2k", fontsize=25)
nx.draw_circular(G_oct_2k)

plt.subplot(132)
plt.title("Nov 2k", fontsize=25)
nx.draw_circular(G_nov_2k)

plt.subplot(133)
plt.title("Dec 2k", fontsize=25)
nx.draw_circular(G_dec_2k)
```





In [746]:
```
stat_jan_2k=cal_avgstat(G_jan_2k)
stat_feb_2k=cal_avgstat(G_feb_2k)
stat_mar_2k=cal_avgstat(G_mar_2k)
stat_apr_2k=cal_avgstat(G_apr_2k)
stat_may_2k=cal_avgstat(G_may_2k)
stat_jun_2k=cal_avgstat(G_jun_2k)
stat_jul_2k=cal_avgstat(G_jul_2k)
stat_aug_2k=cal_avgstat(G_aug_2k)
stat_sep_2k=cal_avgstat(G_sep_2k)
stat_oct_2k=cal_avgstat(G_oct_2k)
stat_nov_2k=cal_avgstat(G_nov_2k)
stat_dec_2k=cal_avgstat(G_dec_2k)
```

In [747]:
```
stat_2k = stat_jan_2k.append(stat_feb_2k).append(stat_mar_2k).append(stat
stat_2k = stat_2k.append(stat_jun_2k).append(stat_jul_2k).append(stat_aug
stat_2k = stat_2k.append(stat_oct_2k).append(stat_nov_2k).append(stat_dec
stat_2k.columns = ['jan_2k','feb_2k','mar_2k','apr_2k','may_2k','jun_2k',
```

In [748]:
```
stat_2k.head()
```

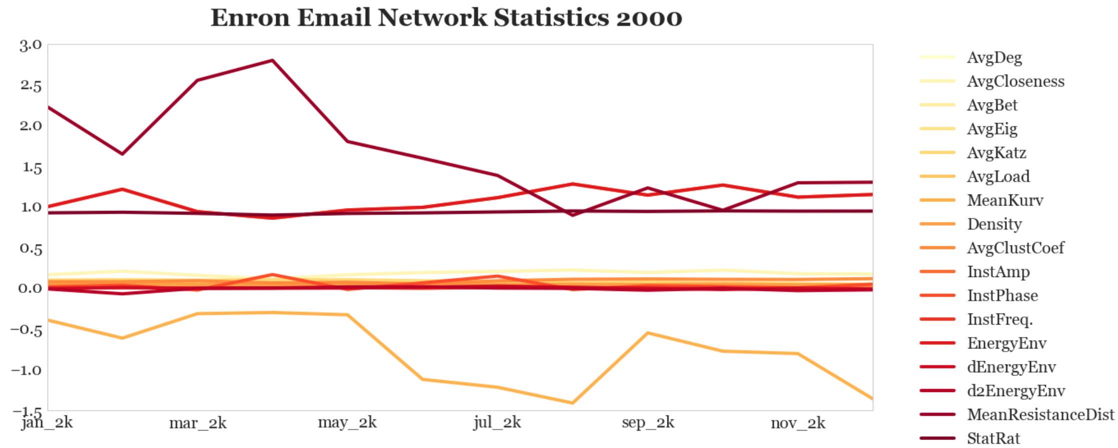
Out[748]:

	jan_2k	feb_2k	mar_2k	apr_2k	may_2k	jun_2k
AvgDeg	0.022378	0.026626	0.014809	0.010464	0.014035	0.010867
AvgCloseness	0.165628	0.208593	0.157985	0.113773	0.164460	0.192022
AvgBet	0.034948	0.035326	0.046531	0.042264	0.033091	0.027877
AvgEig	0.069247	0.084514	0.065003	0.053698	0.072435	0.068502
AvgKatz	0.099556	0.104652	0.097354	0.103359	0.104188	0.091210

	jul_2k	aug_2k	sep_2k	oct_2k	nov_2k	dec_2k
AvgDeg	0.012697	0.016514	0.012147	0.018086	0.010884	0.013887
AvgCloseness	0.206035	0.223131	0.192691	0.222388	0.177589	0.174585
AvgBet	0.026787	0.017815	0.019417	0.019777	0.017789	0.019199
AvgEig	0.068311	0.062979	0.062015	0.062333	0.054194	0.051451
AvgKatz	0.086094	0.068437	0.073747	0.064164	0.058620	0.038943

In [800]:
```
stat_2k.T.plot(fontsize=20, figsize=(18,8), cmap='YlOrRd')
plt.suptitle("Enron Email Network Statistics 2000", fontsize=30)
plt.legend(fontsize=20, bbox_to_anchor=(1.05, 1), loc=2, borderaxespad=0.
```

Out[800]: <matplotlib.legend.Legend at 0x1488c068780>



9 Network Year 2k1

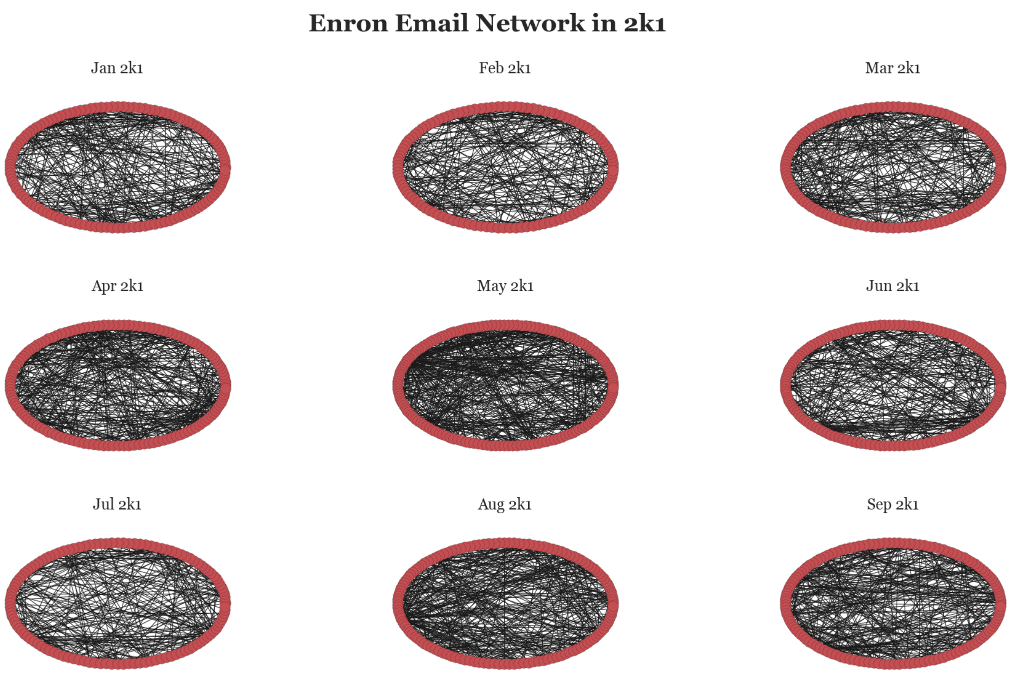
In [749]:
```
df_2k1.month.describe()
```

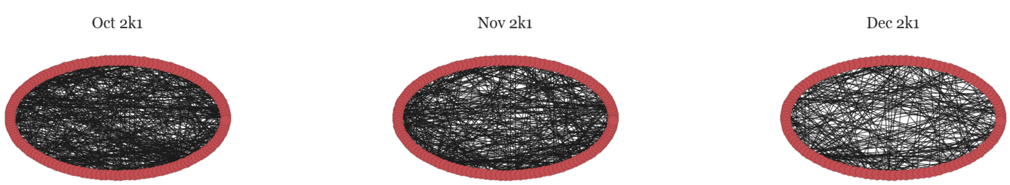
Out[749]:
```
count    68888.000000
mean         6.125073
std          3.537309
min          1.000000
25%          3.000000
50%          5.000000
75%         10.000000
max         12.000000
Name: month, dtype: float64
```

In [750]:
```
jan_2k1=df_2k1[df_2k1.month==1]
feb_2k1=df_2k1[df_2k1.month==2]
mar_2k1=df_2k1[df_2k1.month==3]
apr_2k1=df_2k1[df_2k1.month==4]
may_2k1=df_2k1[df_2k1.month==5]
jun_2k1=df_2k1[df_2k1.month==6]
jul_2k1=df_2k1[df_2k1.month==7]
aug_2k1=df_2k1[df_2k1.month==8]
sep_2k1=df_2k1[df_2k1.month==9]
oct_2k1=df_2k1[df_2k1.month==10]
nov_2k1=df_2k1[df_2k1.month==11]
dec_2k1=df_2k1[df_2k1.month==12]


G_jan_2k1=create_graph(jan_2k1)
G_feb_2k1=create_graph(feb_2k1)
G_mar_2k1=create_graph(mar_2k1)
```

```
G_apr_2k1=create_graph(apr_2k1)
G_may_2k1=create_graph(may_2k1)
G_jun_2k1=create_graph(jun_2k1)
G_jul_2k1=create_graph(jul_2k1)
G_aug_2k1=create_graph(aug_2k1)
G_sep_2k1=create_graph(sep_2k1)
G_oct_2k1=create_graph(oct_2k1)
G_nov_2k1=create_graph(nov_2k1)
G_dec_2k1=create_graph(dec_2k1)

plt.figure(figsize=(32,18))
plt.suptitle("Enron Email Network in 2k1", fontsize=40)

plt.subplot(331)
plt.title("Jan 2k1", fontsize=25)
nx.draw_circular(G_jan_2k1)

plt.subplot(332)
plt.title("Feb 2k1", fontsize=25)
nx.draw_circular(G_feb_2k1)

plt.subplot(333)
plt.title("Mar 2k1", fontsize=25)
nx.draw_circular(G_mar_2k1)

plt.subplot(334)
plt.title("Apr 2k1", fontsize=25)
nx.draw_circular(G_apr_2k1)

plt.subplot(335)
plt.title("May 2k1", fontsize=25)
nx.draw_circular(G_may_2k1)

plt.subplot(336)
plt.title("Jun 2k1", fontsize=25)
nx.draw_circular(G_jun_2k1)

plt.subplot(337)
plt.title("Jul 2k1", fontsize=25)
nx.draw_circular(G_jul_2k1)

plt.subplot(338)
plt.title("Aug 2k1", fontsize=25)
nx.draw_circular(G_aug_2k1)

plt.subplot(339)
plt.title("Sep 2k1", fontsize=25)
nx.draw_circular(G_sep_2k1)
```

```
plt.figure(figsize=(32,5))
#plt.suptitle("Enron Email Network in 2k1", fontsize=40)

plt.subplot(131)
plt.title("Oct 2k1", fontsize=25)
nx.draw_circular(G_oct_2k1)

plt.subplot(132)
plt.title("Nov 2k1", fontsize=25)
nx.draw_circular(G_nov_2k1)

plt.subplot(133)
plt.title("Dec 2k1", fontsize=25)
nx.draw_circular(G_dec_2k1)
```





In [751]:
```
stat_jan_2k1=cal_avgstat(G_jan_2k1)
stat_feb_2k1=cal_avgstat(G_feb_2k1)
stat_mar_2k1=cal_avgstat(G_mar_2k1)
stat_apr_2k1=cal_avgstat(G_apr_2k1)
stat_may_2k1=cal_avgstat(G_may_2k1)
stat_jun_2k1=cal_avgstat(G_jun_2k1)
stat_jul_2k1=cal_avgstat(G_jul_2k1)
stat_aug_2k1=cal_avgstat(G_aug_2k1)
stat_sep_2k1=cal_avgstat(G_sep_2k1)
stat_oct_2k1=cal_avgstat(G_oct_2k1)
stat_nov_2k1=cal_avgstat(G_nov_2k1)
stat_dec_2k1=cal_avgstat(G_dec_2k1)

stat_2k1 = stat_jan_2k1.append(stat_feb_2k1).append(stat_mar_2k1).append
stat_2k1 = stat_2k1.append(stat_jun_2k1).append(stat_jul_2k1).append(stat
stat_2k1 = stat_2k1.append(stat_oct_2k1).append(stat_nov_2k1).append(stat
stat_2k1.columns = ['jan_2k1','feb_2k1','mar_2k1','apr_2k1','may_2k1','ju
```

In [752]:
```
stat_2k1.head()
```

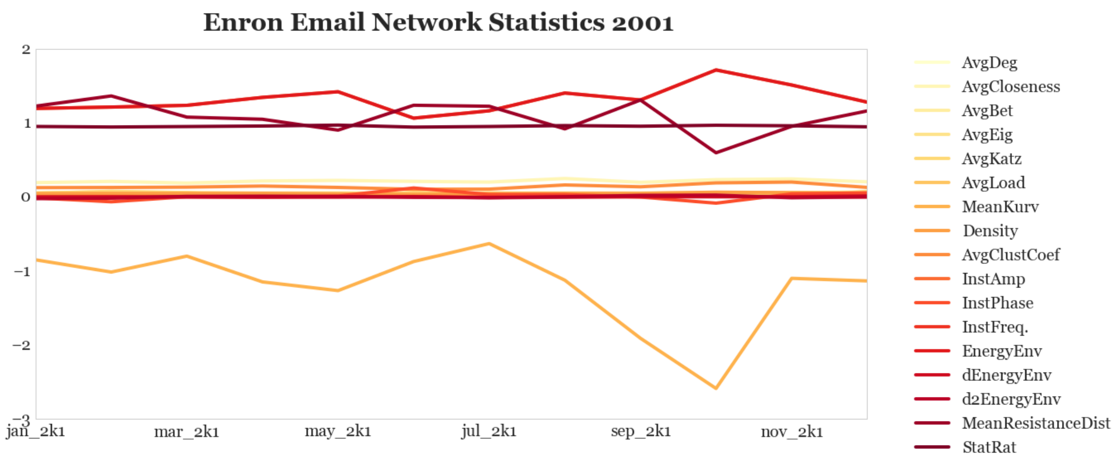
Out[752]:

	jan_2k1	feb_2k1	mar_2k1	apr_2k1	may_2k1	jun_2k1
AvgDeg	0.013179	0.012052	0.012982	0.015607	0.012401	0.008815
AvgCloseness	0.191559	0.208446	0.186307	0.214056	0.221824	0.209019
AvgBet	0.017710	0.021867	0.017525	0.017928	0.011548	0.019936
AvgEig	0.055170	0.064597	0.058794	0.051706	0.053974	0.048988
AvgKatz	0.048244	0.074620	0.057339	0.002995	0.022108	0.059015

	jul_2k1	aug_2k1	sep_2k1	oct_2k1	nov_2k1	dec_2k1
AvgDeg	0.016036	0.016639	0.012930	0.019379	0.016612	0.011789
AvgCloseness	0.199306	0.247621	0.195912	0.232163	0.241737	0.202481
AvgBet	0.020539	0.015186	0.021407	0.012743	0.017048	0.022688
AvgEig	0.053507	0.051803	0.051587	0.058752	0.056969	0.065293
AvgKatz	0.046579	0.000057	0.021531	0.003949	0.002392	0.074214

In [801]:
```
stat_2k1.T.plot(fontsize=20, figsize=(18,8), cmap='YlOrRd')
plt.suptitle("Enron Email Network Statistics 2001", fontsize=30)
plt.legend(fontsize=20, bbox_to_anchor=(1.05, 1), loc=2, borderaxespad=0.
```

Out[801]: <matplotlib.legend.Legend at 0x1488c8ba400>



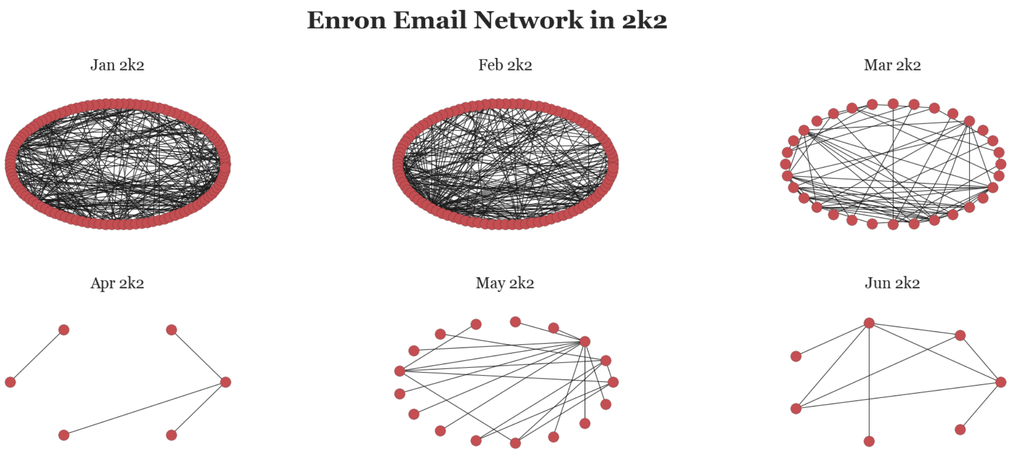
10 Network Year 2k2

In [753]:
```
df_2k2.month.describe()
```

Out[753]:
```
count    8491.000000
mean        1.758921
std         0.807467
min         1.000000
25%         1.000000
50%         2.000000
75%         2.000000
max         6.000000
Name: month, dtype: float64
```

In [754]:
```
jan_2k2=df_2k2[df_2k2.month==1]
feb_2k2=df_2k2[df_2k2.month==2]
mar_2k2=df_2k2[df_2k2.month==3]
apr_2k2=df_2k2[df_2k2.month==4]
may_2k2=df_2k2[df_2k2.month==5]
jun_2k2=df_2k2[df_2k2.month==6]
jul_2k2=df_2k2[df_2k2.month==7]
aug_2k2=df_2k2[df_2k2.month==8]
sep_2k2=df_2k2[df_2k2.month==9]
oct_2k2=df_2k2[df_2k2.month==10]
nov_2k2=df_2k2[df_2k2.month==11]
dec_2k2=df_2k2[df_2k2.month==12]


G_jan_2k2=create_graph(jan_2k2)
G_feb_2k2=create_graph(feb_2k2)
G_mar_2k2=create_graph(mar_2k2)
```

```
G_apr_2k2=create_graph(apr_2k2)
G_may_2k2=create_graph(may_2k2)
G_jun_2k2=create_graph(jun_2k2)
G_jul_2k2=create_graph(jul_2k2)
G_aug_2k2=create_graph(aug_2k2)
G_sep_2k2=create_graph(sep_2k2)
G_oct_2k2=create_graph(oct_2k2)
G_nov_2k2=create_graph(nov_2k2)
G_dec_2k2=create_graph(dec_2k2)

plt.figure(figsize=(32,18))
plt.suptitle("Enron Email Network in 2k2", fontsize=40)

plt.subplot(331)
plt.title("Jan 2k2", fontsize=25)
nx.draw_circular(G_jan_2k2)

plt.subplot(332)
plt.title("Feb 2k2", fontsize=25)
nx.draw_circular(G_feb_2k2)

plt.subplot(333)
plt.title("Mar 2k2", fontsize=25)
nx.draw_circular(G_mar_2k2)

plt.subplot(334)
plt.title("Apr 2k2", fontsize=25)
nx.draw_circular(G_apr_2k2)

plt.subplot(335)
plt.title("May 2k2", fontsize=25)
nx.draw_circular(G_may_2k2)

plt.subplot(336)
plt.title("Jun 2k2", fontsize=25)
nx.draw_circular(G_jun_2k2)
```

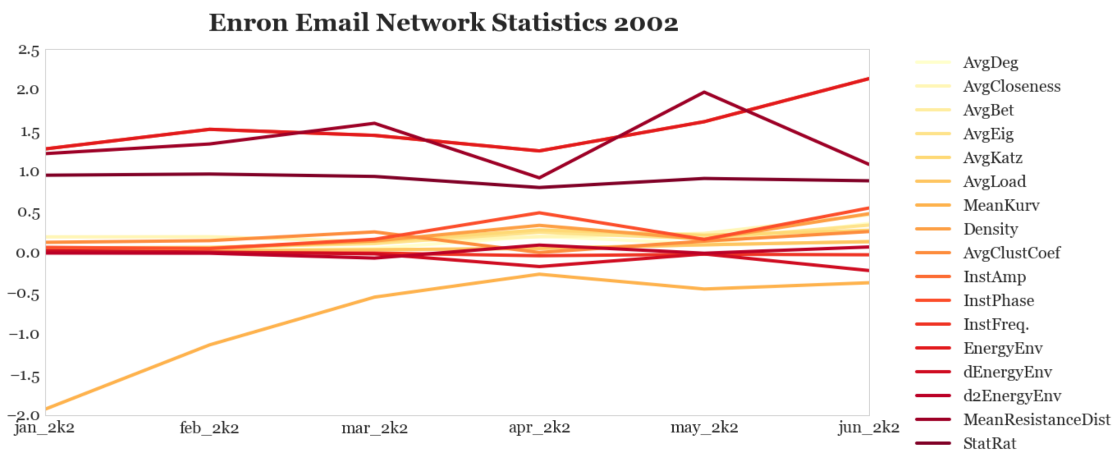



```
In [755]: stat_jan_2k2=cal_avgstat(G_jan_2k2)
          stat_feb_2k2=cal_avgstat(G_feb_2k2)
          stat_mar_2k2=cal_avgstat(G_mar_2k2)
          stat_apr_2k2=cal_avgstat(G_apr_2k2)
          stat_may_2k2=cal_avgstat(G_may_2k2)
          stat_jun_2k2=cal_avgstat(G_jun_2k2)

          stat_2k2 = stat_jan_2k2.append(stat_feb_2k2).append(stat_mar_2k2).append(
          stat_2k2.columns = ['jan_2k2','feb_2k2','mar_2k2','apr_2k2','may_2k2','ju

In [756]: stat_2k2.head()
```

Out[756]:

	jan_2k2	feb_2k2	mar_2k2	apr_2k2	may_2k2	jun_2k2
AvgDeg	0.018018	0.021818	0.049395	0.200000	0.106618	0.357143
AvgCloseness	0.191514	0.193146	0.133727	0.193333	0.234243	0.462193
AvgBet	0.022664	0.022488	0.033737	0.050000	0.094118	0.133333
AvgEig	0.055595	0.065003	0.108396	0.248878	0.168015	0.336275
AvgKatz	0.042359	0.046586	0.131887	0.277666	0.212198	0.273203

```
In [802]: stat_2k2.T.plot(fontsize=20, figsize=(18,8), cmap='YlOrRd')
          plt.suptitle("Enron Email Network Statistics 2002", fontsize=30)
          plt.legend(fontsize=20, bbox_to_anchor=(1.05, 1), loc=2, borderaxespad=0.

Out[802]: <matplotlib.legend.Legend at 0x1488c1a7e48>
```

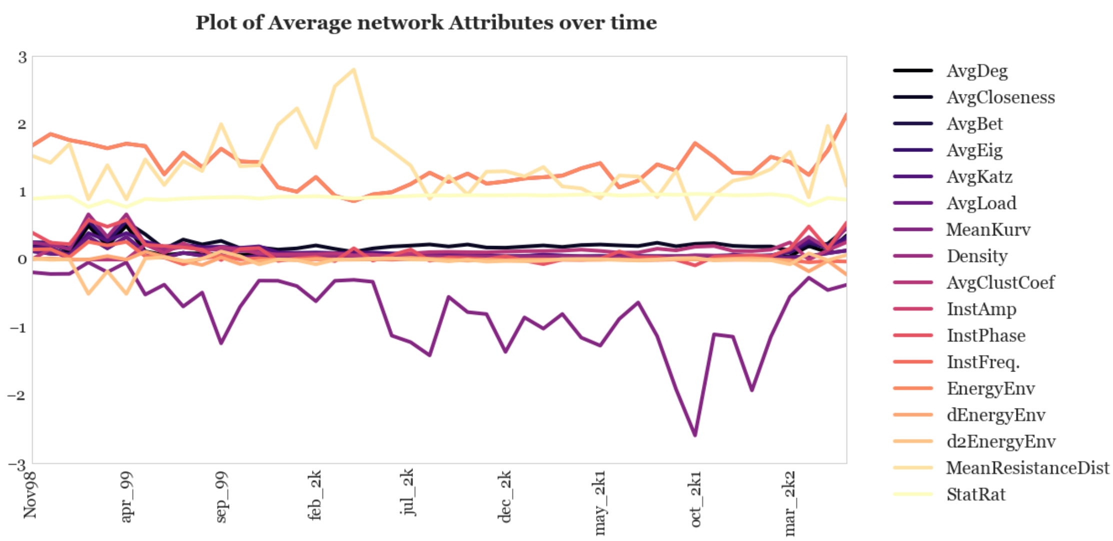


Network Attributes over full time range

```
In [757]: stat_all = stat98.join(stat_99).join(stat_2k).join(stat_2k1).join(stat_2k
```

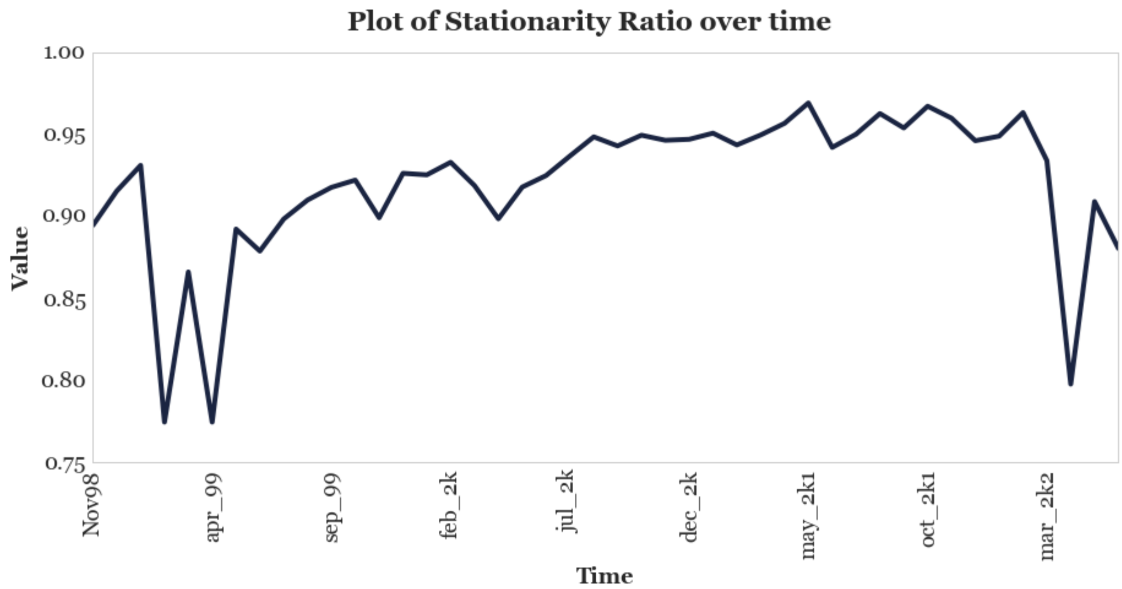
```
In [940]: stat_all.plot(figsize=(16,8), fontsize=18, rot=90,cmap='magma')
          plt.suptitle("Plot of Average network Attributes over time", fontsize=22)
          plt.legend(fontsize=20, bbox_to_anchor=(1.05, 1), loc=2, borderaxespad=0.
```

```
Out[940]: <matplotlib.legend.Legend at 0x148a4791da0>
```



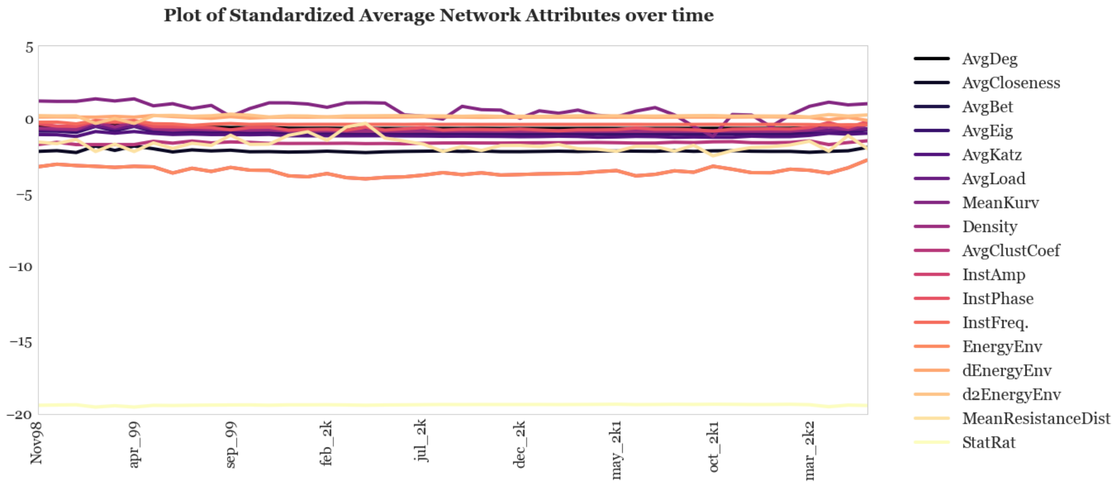

```
In [759]: stat_all.StatRat.plot(fontsize=18, rot=90)
          plt.suptitle('Plot of Stationarity Ratio over time', fontsize=22)
          plt.xlabel("Time", fontsize=18)
          plt.ylabel("Value", fontsize=18)
```

```
Out[759]: <matplotlib.text.Text at 0x1488c264278>
```




```
In [760]: stat_all_std = stat_all - stat_all.mean()/ stat_all.std()

In [761]: stat_all_std.head()

Out[761]:           AvgDeg  AvgCloseness    AvgBet    AvgEig   AvgKatz   AvgLoad  \
          Nov98  -0.501559     -2.190459 -0.683674 -0.811947 -1.049629 -0.683703
          Dec98  -0.498961     -2.140030 -0.721805 -0.816233 -1.059953 -0.721834
          jan_99 -0.561083     -2.265710 -0.731751 -0.903068 -1.177372 -0.731780
          feb_99 -0.144416     -1.827211 -0.475340 -0.498338 -0.844841 -0.475370
          mar_99 -0.444416     -2.123508 -0.642007 -0.791408 -0.957380 -0.642036

                 MeanKurv   Density  AvgClustCoef   InstAmp  InstPhase  InstFreq.
          Nov98  1.223986 -0.614423     -1.728109 -3.234486  -0.322693  -0.213067
          Dec98  1.198805 -0.646242     -1.572554 -3.059949  -0.475194  -0.207377
          jan_99 1.201116 -0.710577     -1.728109 -3.148094  -0.497733  -0.324490
          feb_99 1.369452 -0.197757     -1.728109 -3.200872  -0.142786  -0.100063
          mar_99 1.225887 -0.531090     -1.728109 -3.269003  -0.240465  -0.152871

                 EnergyEnv  dEnergyEnv  d2EnergyEnv  MeanResistanceDist    StatRat
          Nov98  -3.234486    0.136924     0.231110           -1.554605 -19.38749
          Dec98  -3.059949    0.147507     0.210526           -1.660235 -19.36658
          jan_99 -3.148094    0.135652     0.216238           -1.381713 -19.35096
          feb_99 -3.200872    0.131303    -0.291969           -2.196966 -19.50732
          mar_99 -3.269003    0.183316     0.040216           -1.696966 -19.41589

In [942]: stat_all_std.plot(figsize=(18,8), cmap='magma',fontsize=18, rot=90)
          plt.suptitle("Plot of Standardized Average Network Attributes over time",
          plt.legend(fontsize=20, bbox_to_anchor=(1.05, 1), loc=2, borderaxespad=0.
```

```
Out[942]: <matplotlib.legend.Legend at 0x148a49ef438>
```

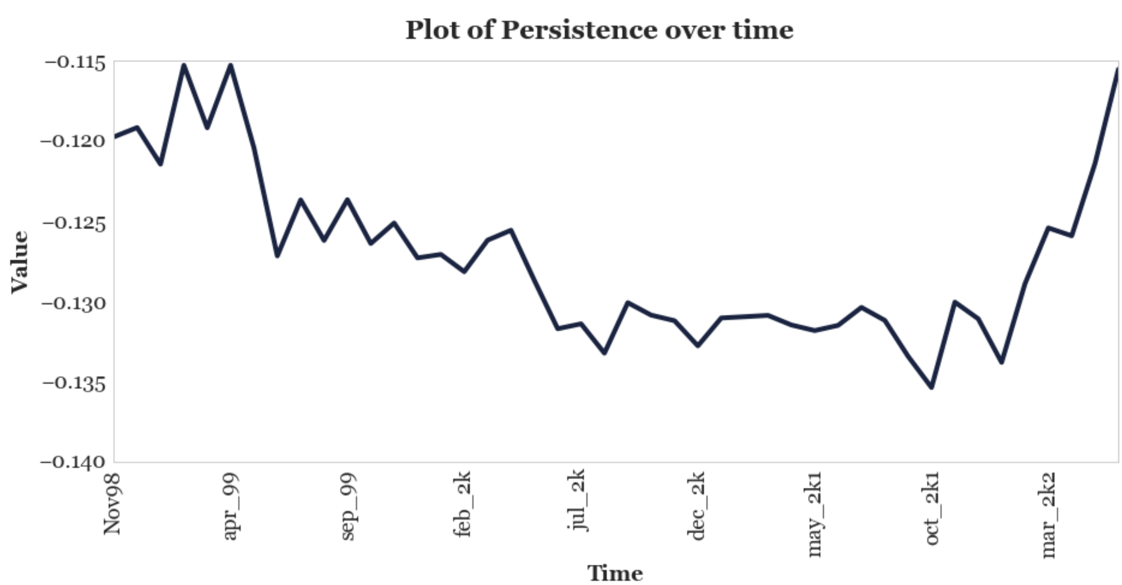


11 Persistence and Emergence

```
In [763]: persistence = stat_all_std.T.mean()/stat_all_std.T.shape[0]
```

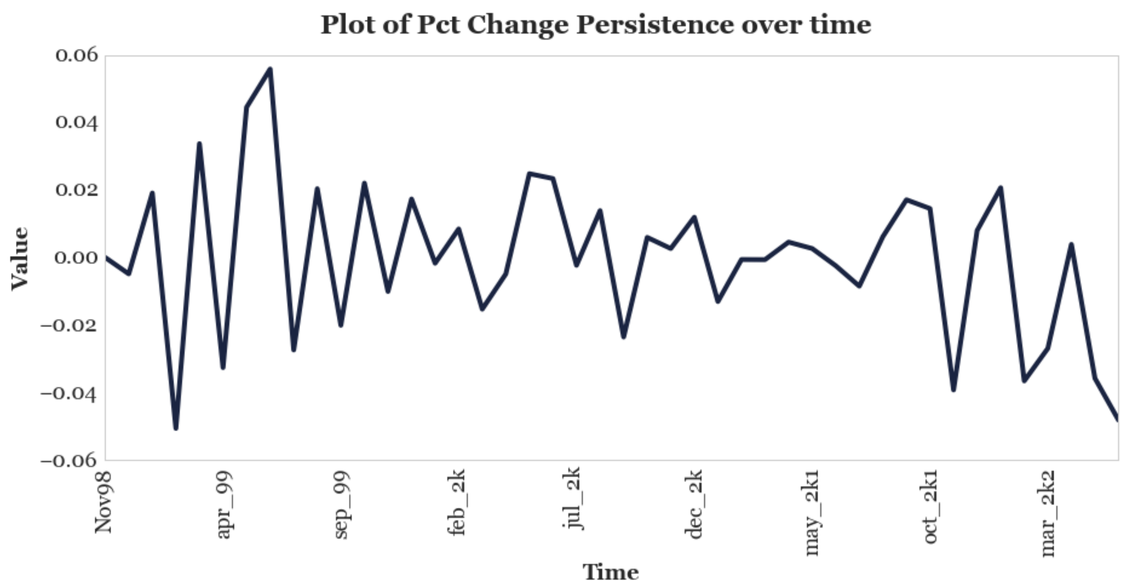
```
In [764]: persistence.plot(fontsize=18, rot=90)
          plt.suptitle("Plot of Persistence over time", fontsize=22)
          plt.xlabel("Time", fontsize=18)
          plt.ylabel("Value", fontsize=18)
```

```
Out[764]: <matplotlib.text.Text at 0x1488d9fc518>
```



In [765]:
```
persistence.pct_change().fillna(0).plot(fontsize=18, rot=90)
plt.suptitle("Plot of Pct Change Persistence over time", fontsize=22)
plt.xlabel("Time", fontsize=18)
plt.ylabel("Value", fontsize=18)
```

Out[765]: <matplotlib.text.Text at 0x1488d1b6dd8>



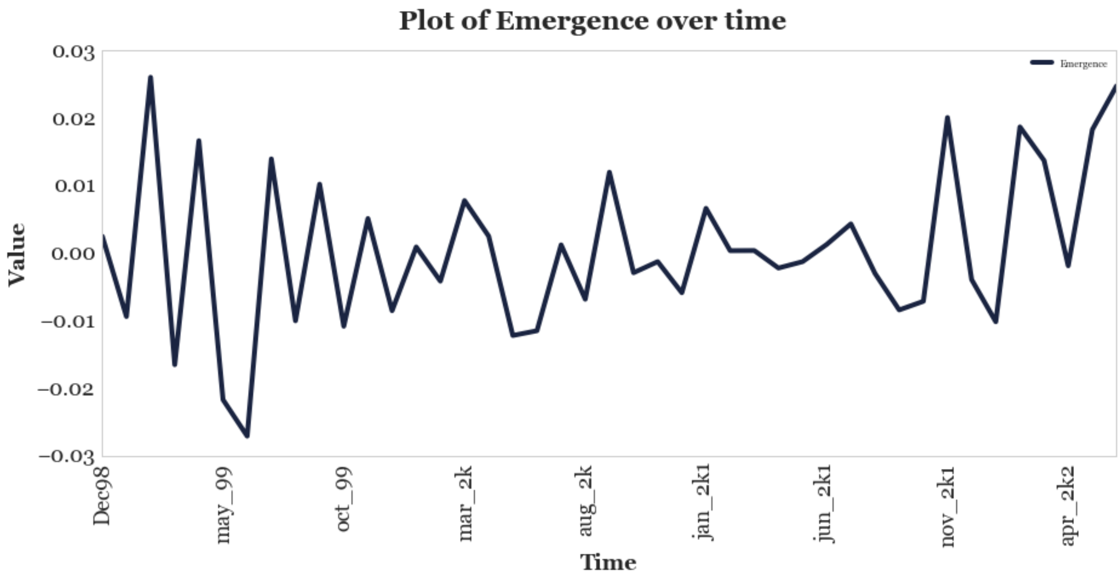
In [766]:
```
def emergence(a,b):
    e = (a-b)/ (np.linalg.norm(a)+np.linalg.norm(b))
    return e
```

In [767]:
```
emerg = []
for i in range(0,persistence.shape[0]-1):
    x = int(i)
    y = x +1
    emerg.append(emergence(persistence.values[y],persistence.values[x]))
```

In [768]:
```
emerg_df = pd.DataFrame(emerg).T
emerg_df.columns = list(stat_all.T.columns)[1:]
emerg_df = emerg_df.T
emerg_df.columns = ['Emergence']
```

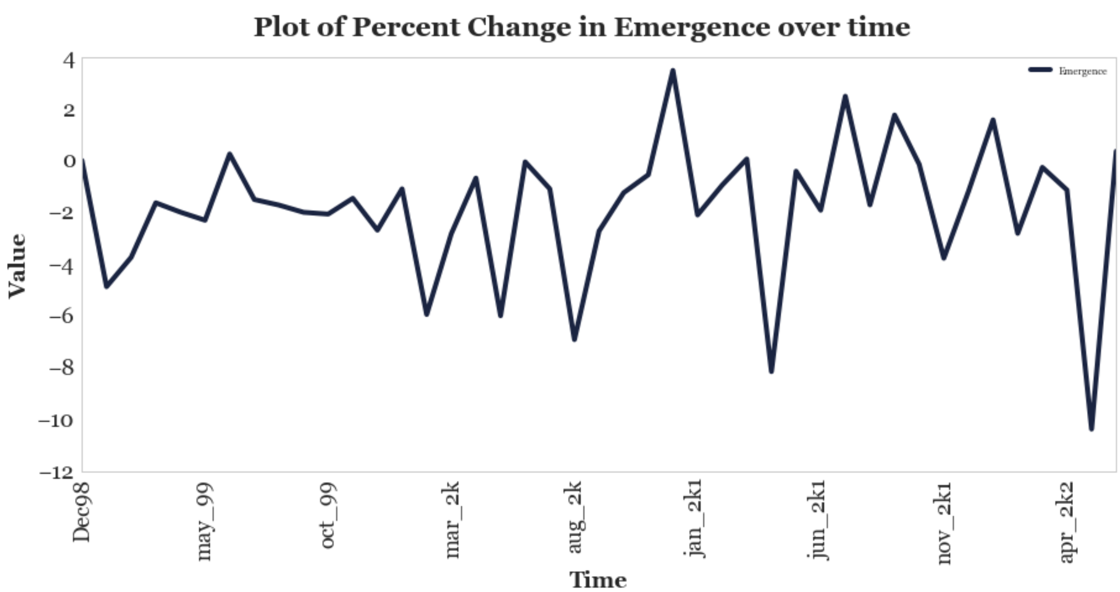
In [769]:
```
emerg_df.plot(fontsize=18, rot=90)
plt.suptitle("Plot of Emergence over time", fontsize=22)
plt.xlabel("Time", fontsize=18)
plt.ylabel("Value", fontsize=18)
```

Out[769]: <matplotlib.text.Text at 0x14882b09cc0>




```
In [770]: emerg_df.pct_change().fillna(0).plot(fontsize=18, rot=90)
          plt.suptitle("Plot of Percent Change in Emergence over time", fontsize=22
          plt.xlabel("Time", fontsize=18)
          plt.ylabel("Value", fontsize=18)
```

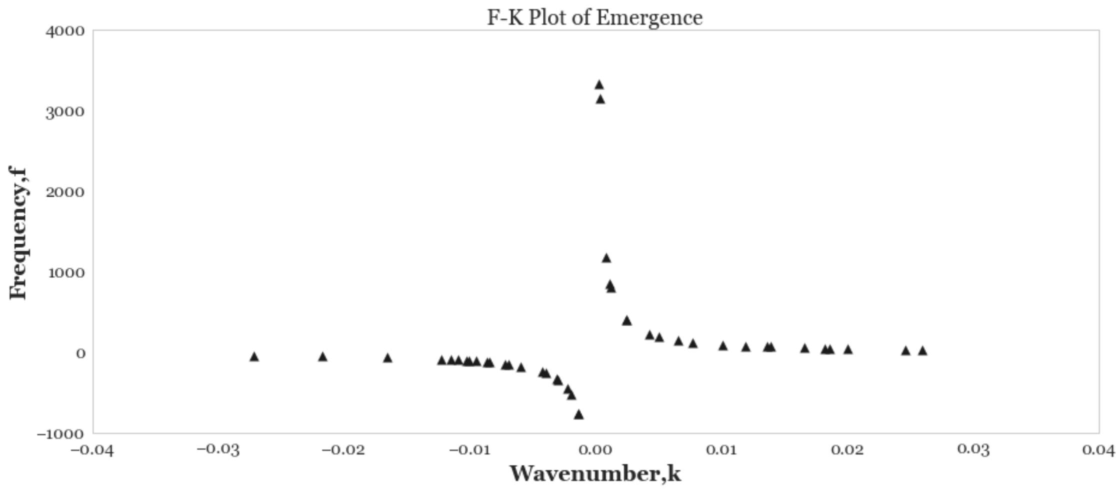
Out[770]: <matplotlib.text.Text at 0x1488d05b710>



In [771]:
```
freq = sc.fft(emerg_df)
wavnumber = 1/freq

plt.scatter(freq, wavnumber, s=60, marker='^', c='k')
plt.title("F-K Plot of Emergence", fontsize=18)
plt.xticks(fontsize=14)
plt.yticks(fontsize=14)
plt.xlabel("Wavenumber,k", fontsize=18)
plt.ylabel("Frequency,f", fontsize=18)
```

```
C:\Users\arsha_000\Anaconda3\lib\site-packages\numpy\core\numeric.py:533: ComplexWa
  return array(a, dtype, copy=False, order=order, subok=True)
```

Out[771]: <matplotlib.text.Text at 0x1488e0f9208>



In [772]:
```
print("Maximum Frequency :\n", emerg_df.iloc[np.argmax(freq)])
print("-----------------\n")
print("Minimum Frequency :\n", emerg_df.iloc[np.argmin(freq)])
```

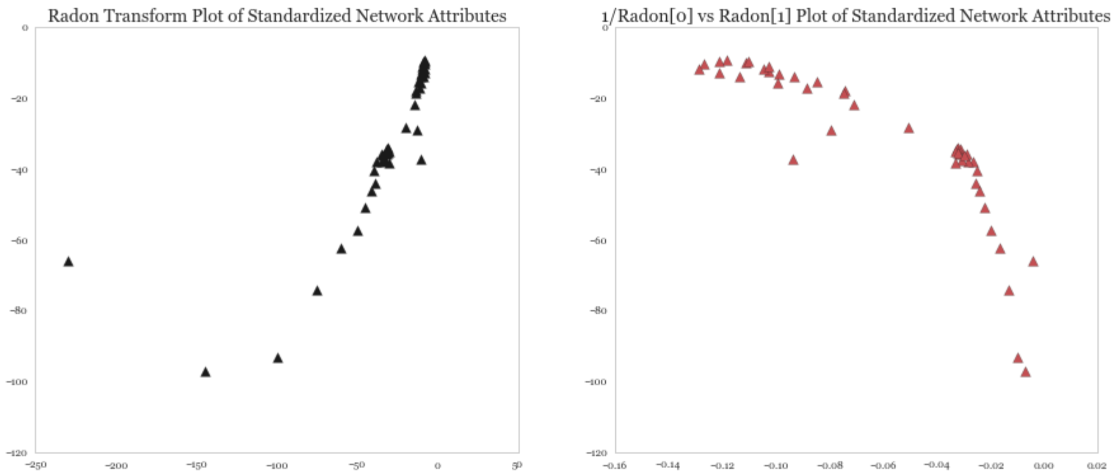
```
Maximum Frequency :
 Emergence    0.025951
Name: feb_99, dtype: float64
-----------------

Minimum Frequency :
 Emergence   -0.027137
Name: jun_99, dtype: float64
```

In [773]:
```
def plot_radon(m, name):
    from skimage.transform import radon
```

```
        theta = np.linspace(0., 180., max(m.shape), endpoint=False)
        sinogram = radon(m, theta=theta, circle=True)

        fig, ax = plt.subplots(1,2)

        ax[0].scatter(sinogram[0], sinogram[1], s=60, marker='^', c='k')
        ax[0].set_title("Radon Transform Plot of "+str(name), fontsize=14)


        ax[1].scatter(1/sinogram[0], sinogram[1], s=60, marker='^', c='r')
        ax[1].set_title("1/Radon[0] vs Radon[1] Plot of "+str(name), fontsize


        plt.show()
```

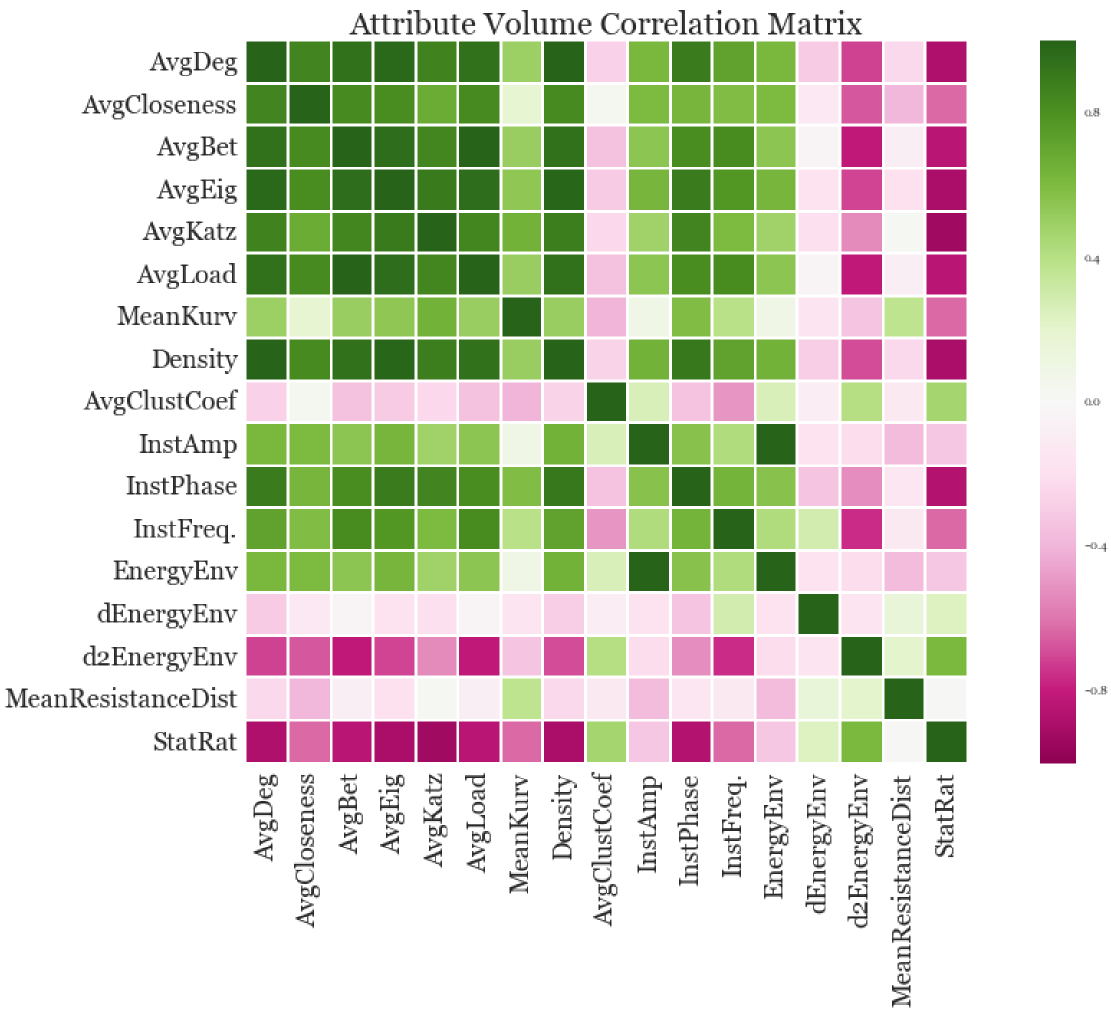
```
In [774]: plot_radon(stat_all_std.values,'Standardized Network Attributes')
```

```
C:\Users\arsha_000\Anaconda3\lib\site-packages\skimage\transform\radon_transform.py
  warn('Radon transform: image must be zero outside the '
```




```
In [908]: plt.figure(figsize=(18,9))
          sns.heatmap(stat_all_std.corr(), cmap='PiYG',robust=True, fmt='d', linewi
          plt.title("Attribute Volume Correlation Matrix", fontsize=22)
          plt.xticks(fontsize=18)
          plt.yticks(fontsize=18)
```

```
Out[908]: (array([  0.5,   1.5,   2.5,   3.5,   4.5,   5.5,   6.5,   7.5,   8.5,
                   9.5,  10.5,  11.5,  12.5,  13.5,  14.5,  15.5,  16.5]),
           <a list of 17 Text yticklabel objects>)
```



12 Subgraph Stationarity

```
In [815]: def pad_shape(x,ref,offset=0):
              result = np.zeros_like(ref)
              result[0:x.shape[0]+0,0:x.shape[1]+0] = x

              return result
```

```
In [838]: all_graphs = tuple([G_nov98,G_dec98,G_jan_99,G_feb_99,G_mar_99,G_apr_99,G
                  G_nov_99,G_dec_99,G_jan_2k,G_feb_2k,G_mar_2k,G_apr_2k,G_may
                  G_oct_2k,G_nov_2k,G_dec_2k,G_jan_2k1,G_feb_2k1,G_mar_2k1,G_
                  G_aug_2k1,G_sep_2k1,G_oct_2k1,G_nov_2k1,G_dec_2k1,G_jan_2k2
```

```
In [909]: all_graphs[:5]
```

```
Out[909]: (<networkx.classes.graph.Graph at 0x1489f391ba8>,
           <networkx.classes.graph.Graph at 0x1489f386f28>,
```

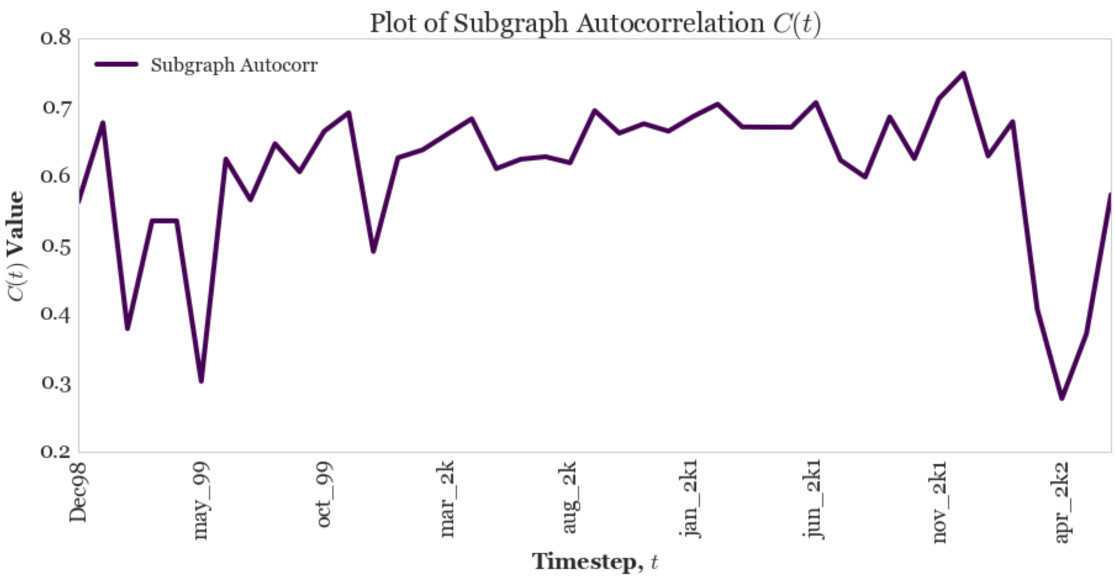
```
 <networkx.classes.graph.Graph at 0x148965122b0>,
 <networkx.classes.graph.Graph at 0x1489f4ef4e0>,
 <networkx.classes.graph.Graph at 0x148f102b0b8>)
```

```
In [913]: def subgraph_stat(net1,net2):
              net1_int_net2 = net1.copy()
              net1_int_net2.remove_nodes_from(n for n in net1 if n not in net2)
              net1_u_net2 = nx.disjoint_union(net1, net2)
              int_adjmat = nx.adjacency_matrix(net1_int_net2).todense()
              uni_adjmat = nx.adjacency_matrix(net1_u_net2).todense()
              int_adjmat_pad = pad_shape(int_adjmat,uni_adjmat)

              Ct = np.divide(norm(int_adjmat_pad),norm(uni_adjmat))

              return Ct
```

```
In [923]: Ct = []
          for i in range(0,len(all_graphs)-1):
              x = int(i)
              y = x +1
              Ct.append(subgraph_stat(all_graphs[x],all_graphs[y]))
```

```
In [972]: Ct_df = pd.DataFrame(Ct, columns=['Subgraph Autocorr']).T
          Ct_df.columns = list(stat_all.T.columns)[1:]
          Ct_df = Ct_df.T

          Ct_df.plot(fontsize=18, cmap='viridis', rot = 90)
          plt.title("Plot of Subgraph Autocorrelation $C(t)$", fontsize=22)
          plt.xlabel("Timestep, $t$", fontsize=18)
          plt.ylabel("$C(t)$ Value", fontsize=18)
          plt.legend(fontsize=16, loc=2)
          plt.xticks(fontsize=18)
          plt.yticks(fontsize=18)
```

```
Out[972]: (array([ 0.2,  0.3,  0.4,  0.5,  0.6,  0.7,  0.8]),
           <a list of 7 Text yticklabel objects>)
```

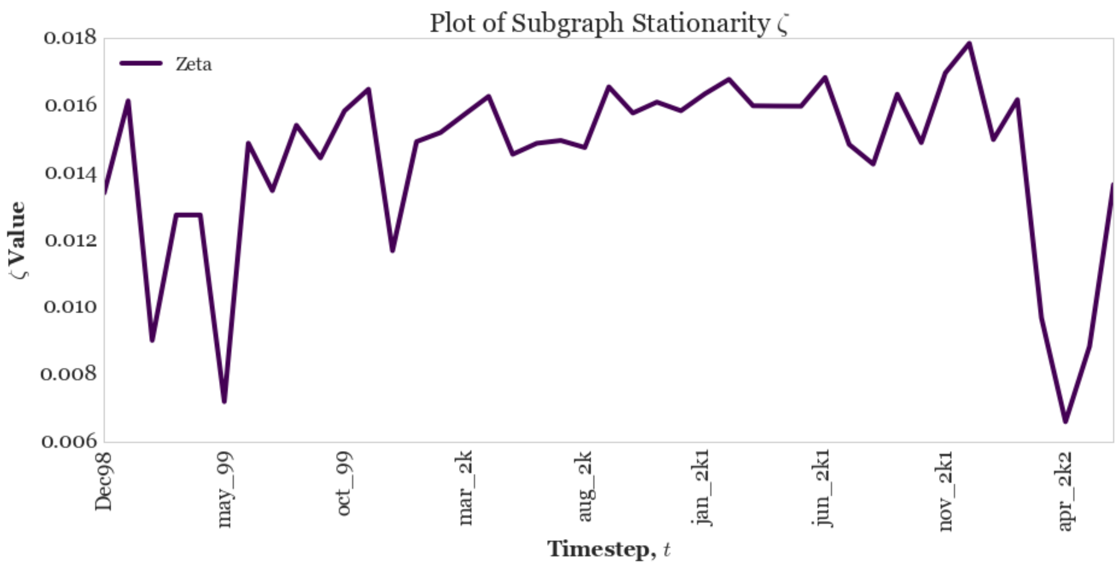



```
In [968]: zeta = Ct_df.cumsum(axis=1)/(Ct_df.shape[0]-1)
          zeta =  zeta.T
          zeta.columns = list(stat_all.T.columns)[1:]
          zeta = zeta.T
          zeta.columns = ['Zeta']
          zeta.head()
```

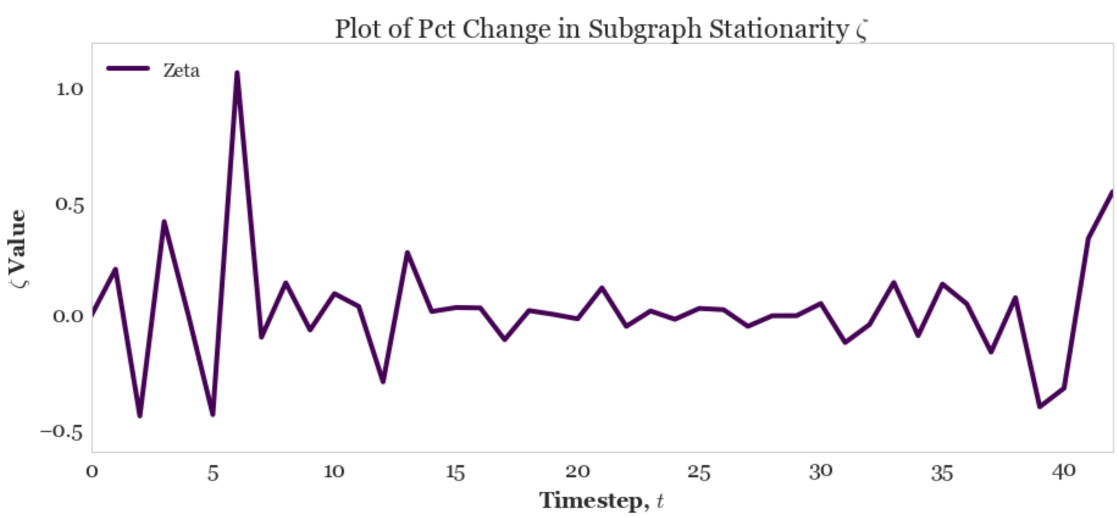
```
Out[968]:              Zeta
          Dec98   0.013380
          jan_99  0.016119
          feb_99  0.008999
          mar_99  0.012727
          apr_99  0.012727
```

```
In [970]: zeta.plot(fontsize=18, cmap='viridis', rot =90)
          plt.title("Plot of Subgraph Stationarity $\zeta$", fontsize=22)
          plt.xlabel("Timestep, $t$", fontsize=18)
          plt.ylabel("$\zeta$ Value", fontsize=18)
          plt.legend(fontsize=16, loc=2)
          plt.xticks(fontsize=18)
          plt.yticks(fontsize=18)
```

```
Out[970]: (array([ 0.006,  0.008,  0.01 ,  0.012,  0.014,  0.016,  0.018,  0.02 ]),
           <a list of 8 Text yticklabel objects>)
```

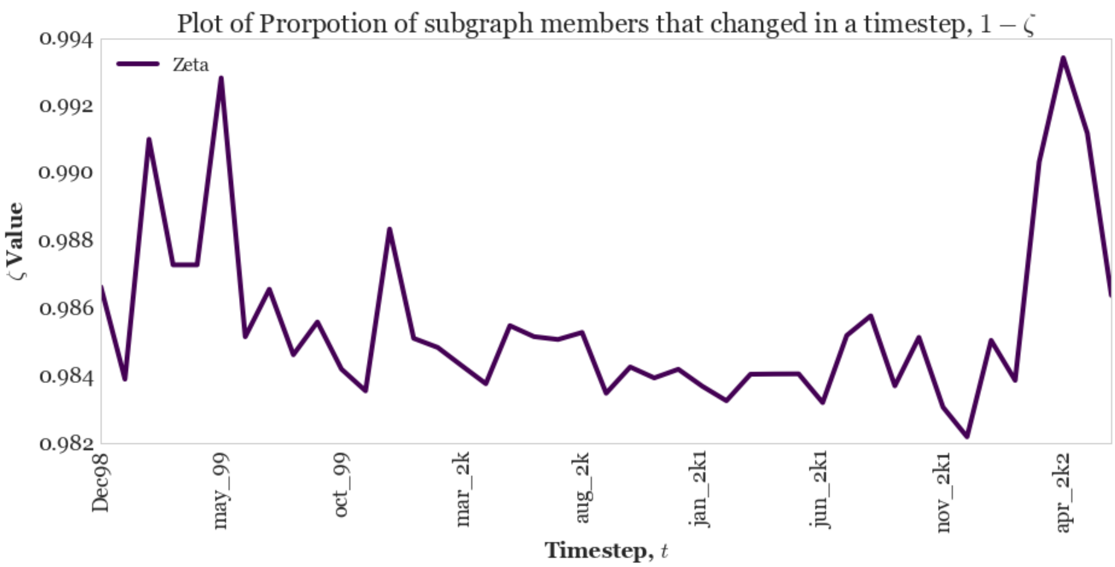



```
In [962]: zeta.pct_change().fillna(0).plot(fontsize=18, cmap='viridis')
          plt.title("Plot of Pct Change in Subgraph Stationarity $\zeta$", fontsize
          plt.xlabel("Timestep, $t$", fontsize=18)
          plt.ylabel("$\zeta$ Value", fontsize=18)
          plt.legend(fontsize=16, loc=2)
          plt.xticks(fontsize=18)
          plt.yticks(fontsize=18)

Out[962]: (array([-1. , -0.5,  0. ,  0.5,  1. ,  1.5]),
           <a list of 6 Text yticklabel objects>)
```



```
In [978]: (1-zeta).plot(fontsize=18, cmap='viridis', rot =90)
          plt.title("Plot of Prorpotion of subgraph members that changed in a times
          plt.xlabel("Timestep, $t$", fontsize=18)
          plt.ylabel("$\zeta$ Value", fontsize=18)
          plt.legend(fontsize=16, loc=2)
          plt.xticks(fontsize=18)
          plt.yticks(fontsize=18)
```

```
Out[978]: (array([ 0.98 ,  0.982,  0.984,  0.986,  0.988,  0.99 ,  0.992,  0.994]),
           <a list of 8 Text yticklabel objects>)
```




```
In [988]: np.mean(np.correlate(std_klpca_ratio(G_nov98),std_klpca_ratio(G_dec98)))
```

```
Out[988]: -0.7282589594178992
```

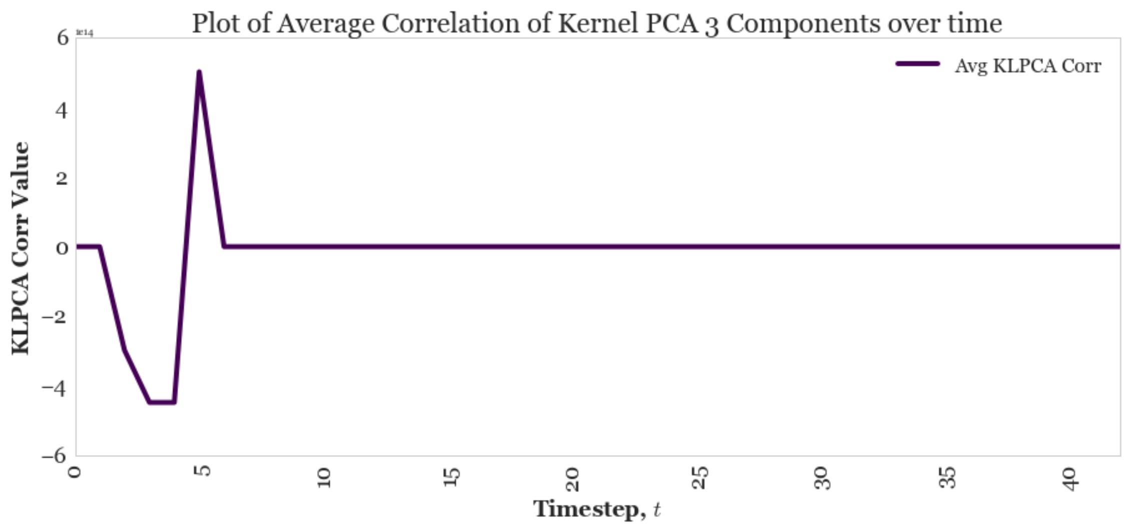
```
In [990]: def avg_klpca_corr(net1,net2):
              avg = np.mean(np.correlate(std_klpca_ratio(net1),std_klpca_ratio(net2
              return avg
```

```
In [991]: avg_klpca_corr(G_nov98,G_dec98)
```

```
Out[991]: -0.7282589594178992
```

```
In [992]: avg_klpca3_corr = []
          for i in range(0,len(all_graphs)-1):
              x = int(i)
              y = x +1
              avg_klpca3_corr.append(avg_klpca_corr(all_graphs[x],all_graphs[y]))
```

```
In [995]: klpca = pd.DataFrame(avg_klpca3_corr,columns=['Avg KLPCA Corr'])

In [998]: klpca.plot(fontsize=18, cmap='viridis', rot =90)
          plt.title("Plot of Average Correlation of Kernel PCA 3 Components over ti
          plt.xlabel("Timestep, $t$", fontsize=18)
          plt.ylabel("KLPCA Corr Value", fontsize=18)
          plt.legend(fontsize=16, loc=1)
          plt.xticks(fontsize=18)
          plt.yticks(fontsize=18)

Out[998]: (array([ -6.00000000e+14,  -4.00000000e+14,  -2.00000000e+14,
                    0.00000000e+00,   2.00000000e+14,   4.00000000e+14,
                    6.00000000e+14]), <a list of 7 Text yticklabel objects>)
```




```
In [1000]: klpca=klpca.T
           klpca.columns = list(stat_all.T.columns)[1:]
           klpca=klpca.T
           klpca.head()

Out[1000]:         Avg KLPCA Corr
           Dec98    -7.282590e-01
           jan_99    2.600181e+00
           feb_99   -2.979981e+14
           mar_99   -4.476561e+14
           apr_99   -4.476561e+14

In [1004]: (klpca - klpca.mean())/klpca.std()

Out[1004]:          Avg KLPCA Corr
           Dec98          0.121836
```

```
jan_99        0.121836
feb_99       -2.137343
mar_99       -3.271929
apr_99       -3.271929
may_99        3.929607
jun_99        0.121836
jul_99        0.121836
aug_99        0.121836
sep_99        0.121836
oct_99        0.121836
nov_99        0.121836
dec_99        0.121836
jan_2k        0.121836
feb_2k        0.121836
mar_2k        0.121836
apr_2k        0.121836
may_2k        0.121836
jun_2k        0.121836
jul_2k        0.121836
aug_2k        0.121836
sep_2k        0.121836
oct_2k        0.121836
nov_2k        0.121836
dec_2k        0.121836
jan_2k1       0.121836
feb_2k1       0.121836
mar_2k1       0.121836
apr_2k1       0.121836
may_2k1       0.121836
jun_2k1       0.121836
jul_2k1       0.121836
aug_2k1       0.121836
sep_2k1       0.121836
oct_2k1       0.121836
nov_2k1       0.121836
dec_2k1       0.121836
jan_2k2       0.121836
feb_2k2       0.121836
mar_2k2       0.121836
apr_2k2       0.121836
may_2k2       0.121836
jun_2k2       0.121836
```

```
In [ ]:
```