

Data Set 2 - Texas road network

Dataset Description :

This is a road network of Texas. Intersections and endpoints are represented by nodes, and the roads connecting these intersections or endpoints are represented by edges.

Finding Random Sample

In the original network, there are 1379917 nodes and 1921660 edges. Since it is a very huge network , we used a random sample in order to get the inferences.

In [1]:

```
#finding random sample
import os
import random

filename = 'wiki-Talk.txt'

result = []
f = open("data.txt", "a")

with open(filename) as fh:
    data = fh.readlines()
    for line in data:
        if line:
            words = line.split()
            result.append(words)

sample = random.sample(result, 1000)

for item in sample:
    f.write(item[0] + "    " + item[1] + "\n")
```

Now using the above random sample , we will read the graph G from the list of edges ('data.txt') and find the general information about the graph.

In [27]:

```
import networkx as nx

#reading graph from list of edges
G=nx.read_edgelist('data.txt',nodetype=int,create_using=nx.DiGraph())

#general information about the graph
print (nx.info(G))
```

```
Name:
Type: DiGraph
Number of nodes: 1746
Number of edges: 3623
Average in degree: 2.0750
Average out degree: 2.0750
```

Basic Information about graph:

From here , we can see that the graph generated has 1746 nodes and 3623 edges. It is a directed graph and average in degree & out degree are 2.0750 (fraction) .

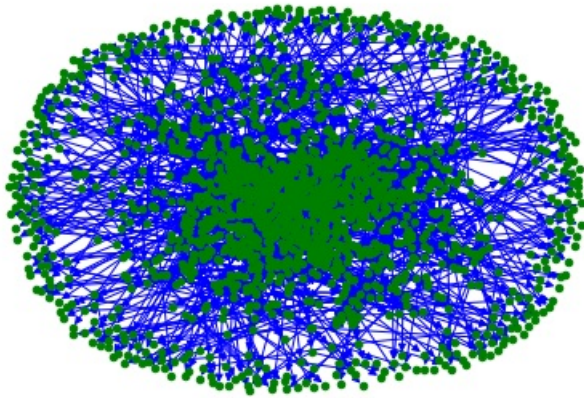
Graph Representation

In [28]:

```
In [28]:
```

```
import matplotlib.pyplot as plt

# drawing graph
nx.draw(G, pos=None, node_color='g', edge_color='b', node_size=20)
plt.show()
```



In the graph , nodes are represented by green colour and directed edges are represented by blue colour.

Degree Distribution

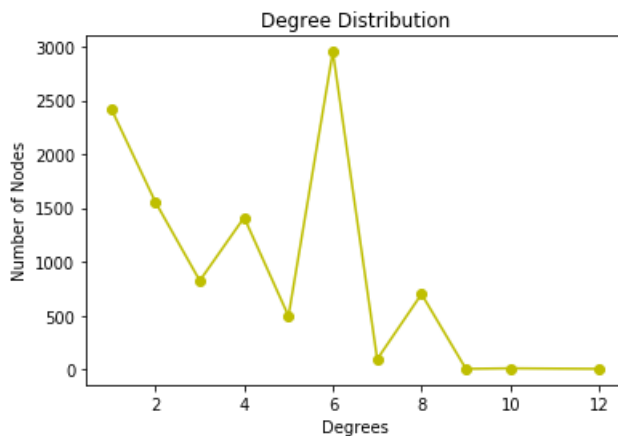
We will now try to find how

```
In [81]:
```

```
#d=dict()
for x,y in nx.degree(G):
    if y not in d:
        d[y]=1
    else:
        d[y]+=1
#for x in d:
    #print(x,d[x])
plt.plot(d.keys(),d.values(),'yo-')
plt.xlabel("Degrees")
plt.ylabel("Number of Nodes")
plt.title("Degree Distribution")
```

```
Out[81]:
```

```
Text(0.5,1,'Degree Distribution')
```



It can be observed that most of the nodes have degree '6' . This means that 6 roads passes through most of the roads.

Density Calculation

A graph is more dense if the number of edges is close to the number of maximal edges possible. Density is calculated as the ratio of edges in network to maximal edges possible.

In [67]:

```
#calculating density
print (nx.density(G))
```

```
0.00118912815867
```

The density is 0.001189 . Thus , it is a sparse graph

Local Clustering Coefficient

It measures the immediate neighbour connectivity of a node.

In [78]:

```
#getting average local clustering coefficient
print "Average Local Clustering Coefficient is:"
print nx.average_clustering(G)

#printing local clustering coefficient of all nodes
w=1
#for i in (nx.clustering(G).items()):
print "Some of the nodes with their clustering coefficient are:"
print("Node      Local Clustering Coefficient")
for p,r in nx.clustering(G).items():
    if(p==88):
        w=w+1
        print (str(p)+"\t"+str(r))
    elif(w>=2 and w<7):
        w=w+1
        print (str(p)+"\t"+str(r))
    elif(w>7):
        break
```

```
Average Local Clustering Coefficient is:
0.0318649464955
Some of the nodes with their clustering coefficient are:
Node      Local Clustering Coefficient
88 0
89 0
90 0.1666666666667
91 0.3333333333333
92 0
93 0.1666666666667
```

In the dictionary , first element gives node number and 2nd element gives We get average local clustering as 0.03186. This means that if node A has roads to a group of nodes, then no 2 nodes are connected by a road most of the time.

Global Clustering Coefficient

It measures the fraction of all possible triangles present in G.

In [69]:

```
#printing global clustering coefficient of nodes
print "The Golbal Clustering Coefficient is:"
print(nx.transitivity(G))
```

```
The Golbal Clustering Coefficient is:
0.0464488252768
```

The Global Transitivity is 0.0464. It means that some triangles are present in Graph G. That means, if node A is connected to node B

by a road and node B is directly connected to node C by a road , then it happens sometimes that node A has a road to node C.

Reciprocity

The reciprocity of a directed graph is defined as the ratio of the number of edges pointing in both directions to the total number of edges in the graph.

In [70]:

```
print nx.reciprocity(G)
```

```
0.874965498206
```

The reciprocity is 0.8749. This means that most of the roads are bidirectional.

Centrality Measures

Centrality measures indicate how important a node is in a graph. Following are the different Centrality Measures:

1. Degree Cenrality

It computes degree of all nodes in graph.

We observe that the highest in-degree is "6". This means that this node acts as a junction with maximum connectivity.

In [76]:

```
dict1=G.degree()
print "The nodes with maximum degree is :"
i= max(nx.out_degree_centrality(G),key=(nx.out_degree_centrality(G)).get)

val=dict1[i]
print("Node    Degree")
for p,r in dict1:
    if (r==val):
        print (str(p)+"\t"+str(r))

print (" ")
print "List of some nodes with their degree:"
w=1
for p,r in dict1:
    if (w<=5):
        print(str(p)+"\t"+str(r))
        w=w+1
```

The nodes with maximum degree is :

```
Node    Degree
219 12
```

List of some nodes with their degree:

```
0 6
1 6
2 6
3 6
4 6
```

The maximum degree is "12" which is associated with node 216. This means this node acts as a junction and has maximum connectivity.

Eigen Vector Centrality :

Eigenvector centrality computes the centrality for a node based on the centrality of its neighbors. The eigenvector centrality for node i is $Ax=\lambda x$ where A is the adjacency matrix of the graph G with eigenvalue λ .

Since "influential" node is irrelevant to this network, we won't calculate it.

Betweenness Centrality:

Betweenness centrality of a node v is the sum of the fraction of all-pairs shortest paths that pass through v .

In [60]:

```
dict = nx.betweenness_centrality(G)
i= max(nx.betweenness_centrality(G),key=(nx.betweenness_centrality(G)).get)
#print i,dict[i]
print("Node    Betweenness Centrality")

dict_sorted_keys = sorted(dict, key=dict.get, reverse=True)
w=1
for r in dict_sorted_keys:
    if(w<=5):
        w=w+1
        print (str(r)+"\t"+str(dict[r]))
```

```
Node    Closeness Centrality
436 0.0792040523436
476 0.0782095053678
565 0.0767475903726
564 0.0767265604312
563 0.0767009870419
```

Node 436 has highest Between Centrality measure. It means that most of the shortest paths pass through this node (considering weight of all edges as 1).

Closeness Centrality

Closeness centrality of a node u is the reciprocal of the average shortest path distance to u over all $n-1$ reachable nodes.

Since path is irrelevant in context of this data, this centrality measure is not apt for our analysis.

In [77]:

```
dict= nx.closeness_centrality(G, u=None, distance=None, wf_improved=True, reverse=False)
i= max(nx.closeness_centrality(G, u=None, distance=None, wf_improved=True, reverse=False),key=(nx.closeness_centrality(G, u=None, distance=None, wf_improved=True, reverse=False)).get)
#print i,dict[i]
print("Node    Closeness Centrality")

dict_sorted_keys = sorted(dict, key=dict.get, reverse=True)
w=1
for r in dict_sorted_keys:
    if(w<=5):
        w=w+1
        print (str(r)+"\t"+str(dict[r]))
```

```
Node    Closeness Centrality
476 0.0186759310163
565 0.0186402047016
564 0.018609690759
566 0.0185957385645
436 0.0185843386839
```

Node 476 has the highest Closeness Centrality measure. It means that from this node, we can reach other nodes very quickly.

Conclusion

1. In the original network, there are 1379917 nodes and 1921660 edges. Since it is a very huge network, we used a random sample in order to get the inferences.
2. Intersections and endpoints are represented by nodes, and the roads connecting these intersections or endpoints are represented by edges.
3. It can be observed that if node A has roads to a group of nodes, then no 2 nodes are connected by a road most of the time.
4. Most of the roads are bidirectional.
5. Most of the shortest paths pass through the node having highest betweenness centrality measure (considering weight of all

of most of the shortest paths passes through the nodes having highest betweenness centrality measure (considering weight of all edges as 1).

Round 2

We will generate graphs using $G(n,p)$ model where n (no. of nodes) = 500. We will vary $\langle k \rangle$ from 0 to 5 with increment of 0.1. For each value of $\langle k \rangle$, we will find the ratio N_g/N where N is the number of nodes in the graph. Later, we will plot this ratio with respect to $\langle k \rangle$ taking $\langle k \rangle$ as x-axis and ratio N_g/N as y-axis.

In [9]:

```
import networkx as nx

a=[]
n=500

for k in range (51):
    #calculating probability
    p= (1.0)*(k)/(10.0*(n-1))
    #generating graph based on G(n,p) model
    G1=nx.gnp_random_graph(n, p, seed=None, directed=False))
    #finding the giant component Ng
    giant = max(nx.connected_component_subgraphs(G1), key=len)
    #calculating Ng/N ratio
    a.append(1.0*(giant.number_of_nodes())/(1.0*n))

#List containing all the ratios Ng/N for each average degree <k>
print ("Ratios Ng/N :")
print a
```

Ratios Ng/N :

```
[0.002, 0.006, 0.008, 0.008, 0.018, 0.01, 0.014, 0.084, 0.03, 0.186, 0.132, 0.312, 0.216, 0.158, 0.456, 0.644, 0.662, 0.71, 0.666, 0.792, 0.8, 0.806, 0.83, 0.87, 0.886, 0.89, 0.882, 0.948, 0.942, 0.936, 0.944, 0.948, 0.962, 0.96, 0.958, 0.97, 0.942, 0.984, 0.964, 0.976, 0.972, 0.976, 0.988, 0.984, 0.974, 0.986, 0.986, 0.976, 0.99, 0.994, 0.99]
```

Here, we have calculated ratio N_g/N for each of the above mentioned degree.

In [8]:

```
import matplotlib.pyplot as plt
b=[]

#storing all the average degrees <k> in list b
for i in range(0,51):
    b.append(i/10.0)

print ("Average degrees :")
print b
```

Average degrees :

```
[0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3.0, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 4.0, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5.0]
```

Here, we have made a list of all the required average degree values

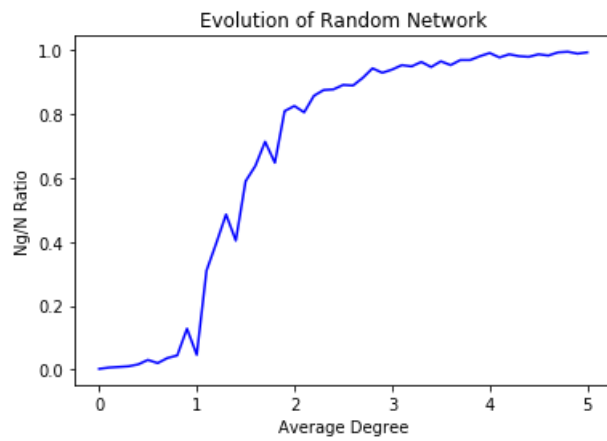
In [5]:

```
#Plotting graph between <k> and ratio Ng/N
plt.plot(b,a,'-b')

#X-axis label
plt.xlabel("Average Degree")
#Y-axis label
plt.ylabel("Ng/N Ratio")
#Plot title
plt.title("Evolution of Random Network")
```

Out[5]:

```
Text(0.5,1,'Evolution of Random Network')
```



The plot obtained is almost exponential in nature. N_g/N remains zero for small $\langle k \rangle$, indicating the lack of a large cluster. Once $\langle k \rangle$ exceeds a critical value ($k=1$), N_g/N increases, signaling the rapid emergence of a large cluster that we call the giant component.