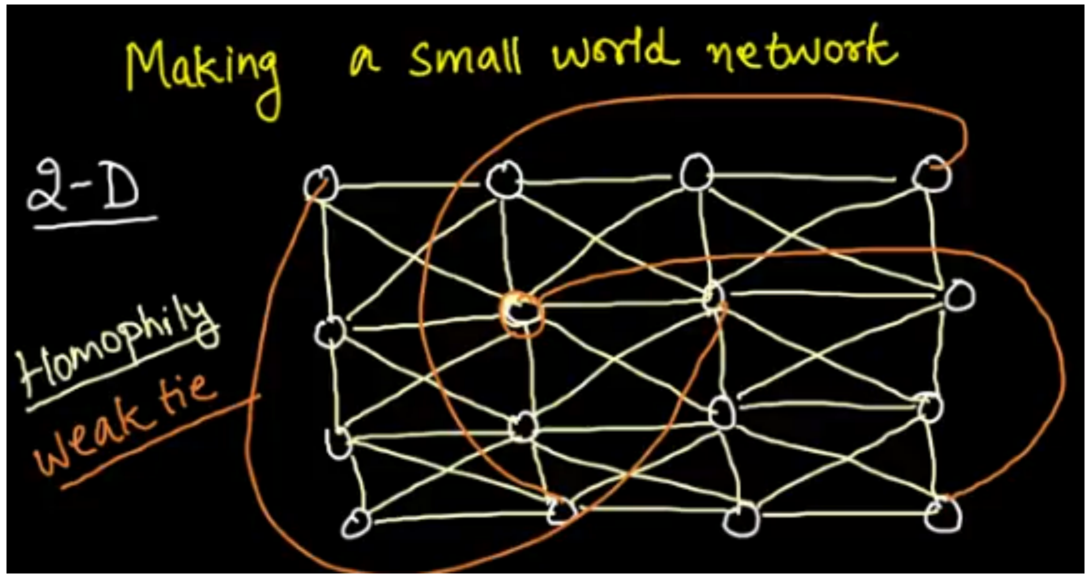
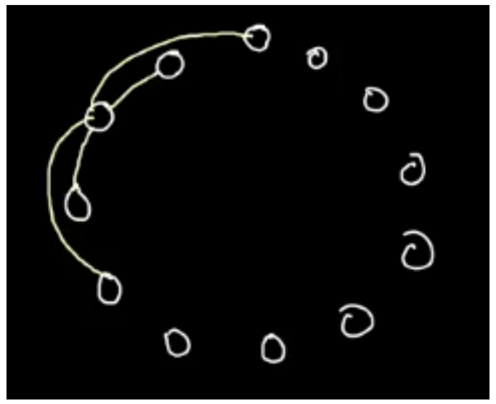
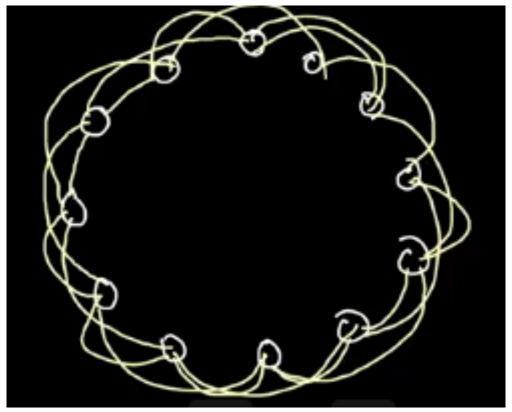
Week-12: **How to go Viral on Web**

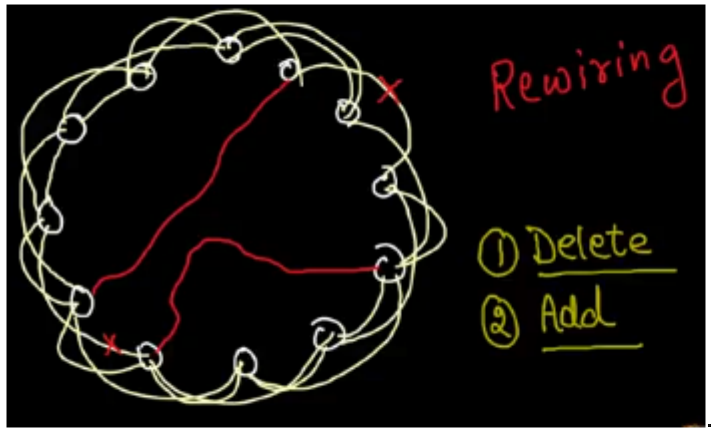
Module-1: Programming illustration - Small world networks

Covers...

- How to make a small world network? How to model i """/
- How a Myopic Search works?

How do we make a small world network?

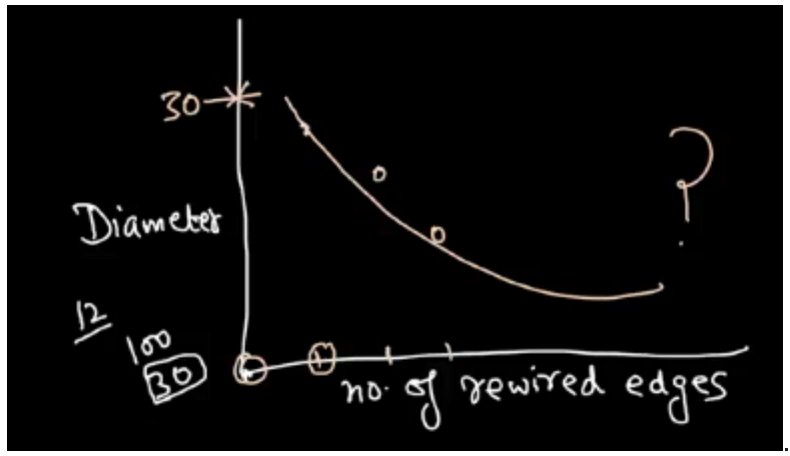
> - In 2D space.. with a set of nodes, the connection decided on
>   - **Homophily**: The nodes which are graphically closer (all the square blocks) -- comes edges and diagonals
>   - **Weak ties**: (what makes th network smaller).. random longer connections
>
>   
>
>
> - In 1D, nodes are circularly arranged.
>   - Because of **homophily**, connected like  -- repeat the process for each node. 

> - For **Weak ties** -- did **Re-Wiring**, remove an edge randomly and place the edge randomly. Like 
>
> . But instead of deleting and adding, just adding a few edges, as for a large network, that doesn't matter much.

What's the Diameter of the network *(as per the above ring network..)*

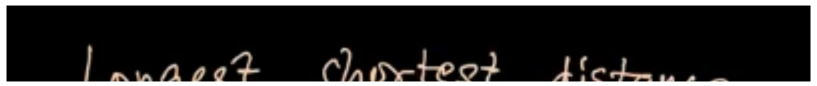
> - No. of nodes = 12, Radius = 6 **With how many hops can you reach from start of semi-circle to end of semi-circle..??**
>
> > 3 The additin of ***Random long edges*** reduces the diameter --- as we count the hops... right. Hence the more the wiring the less the diameter.

Looking it graphically..



.. Think in-terms of big numbers. If had 1Million nodes, addition of 2-3 edges, doesn't make much difference.

How do you define the Diameter..??\

> **Longest Shortest distance** -- i.e., *Shortest*, refer -- still some cloudy... get clarified
>
> 

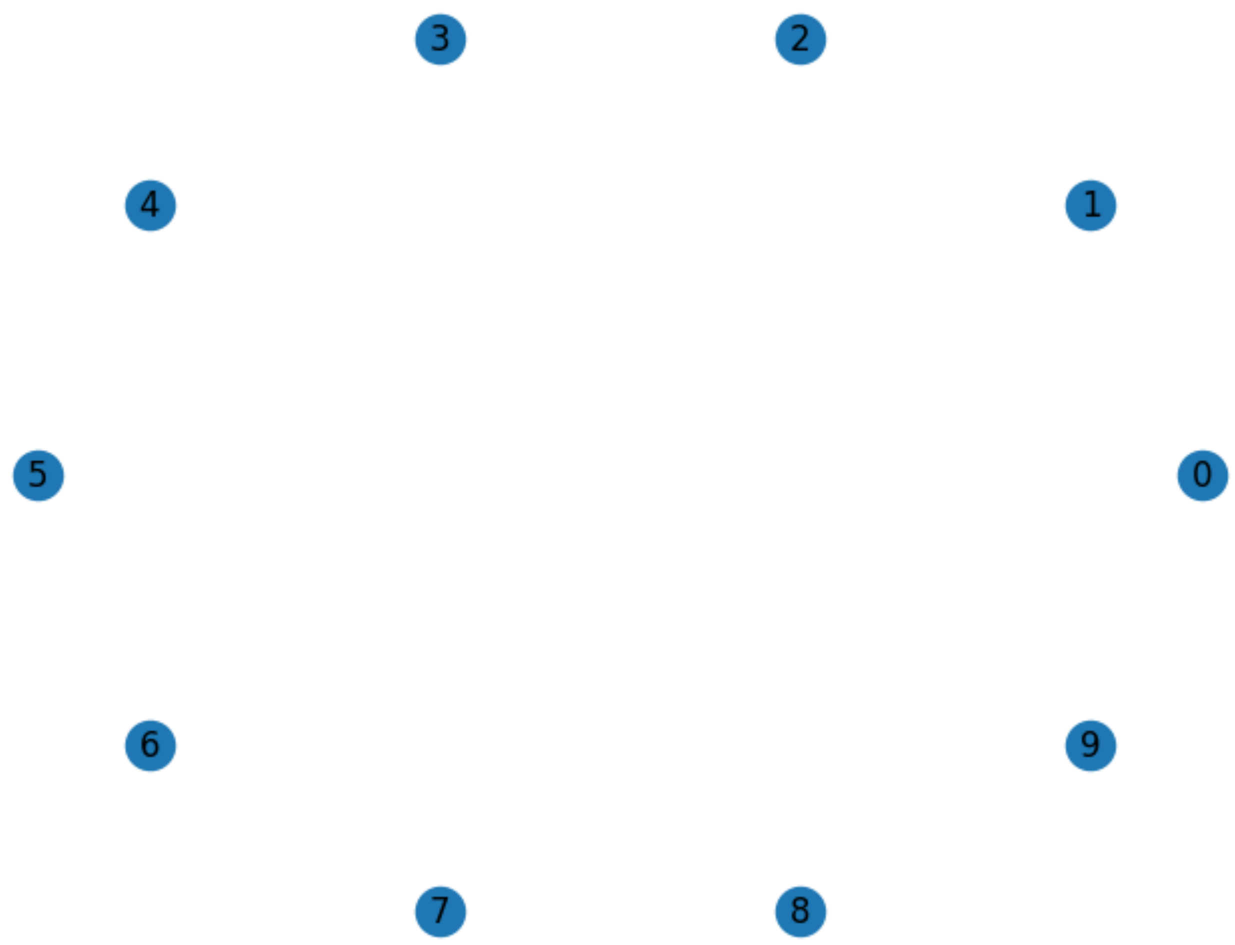
https://youtu.be/jHgNv8_qhcs*** Our task is going to be...

- We're given a network, and should make it small world network, by adding some edges.
- Take a plot on, as the diameter gets varied as we increase the rewired-edges(weak-ties).

In [1]:

```
## Module-2: **Base Code**
```

In [2]:
```
# Import the required libraries..
import networkx as nx            # for working with the graphs
import matplotlib.pyplot as plt  # For visualizing the graph..

# Create a graph..
G = nx.Graph()
# Add some nodes to it..
G.add_nodes_from(range(0, 10))
# Look at the graph..
nx.draw(G, nx.circular_layout(G), with_labels=True, )
plt.show()
```

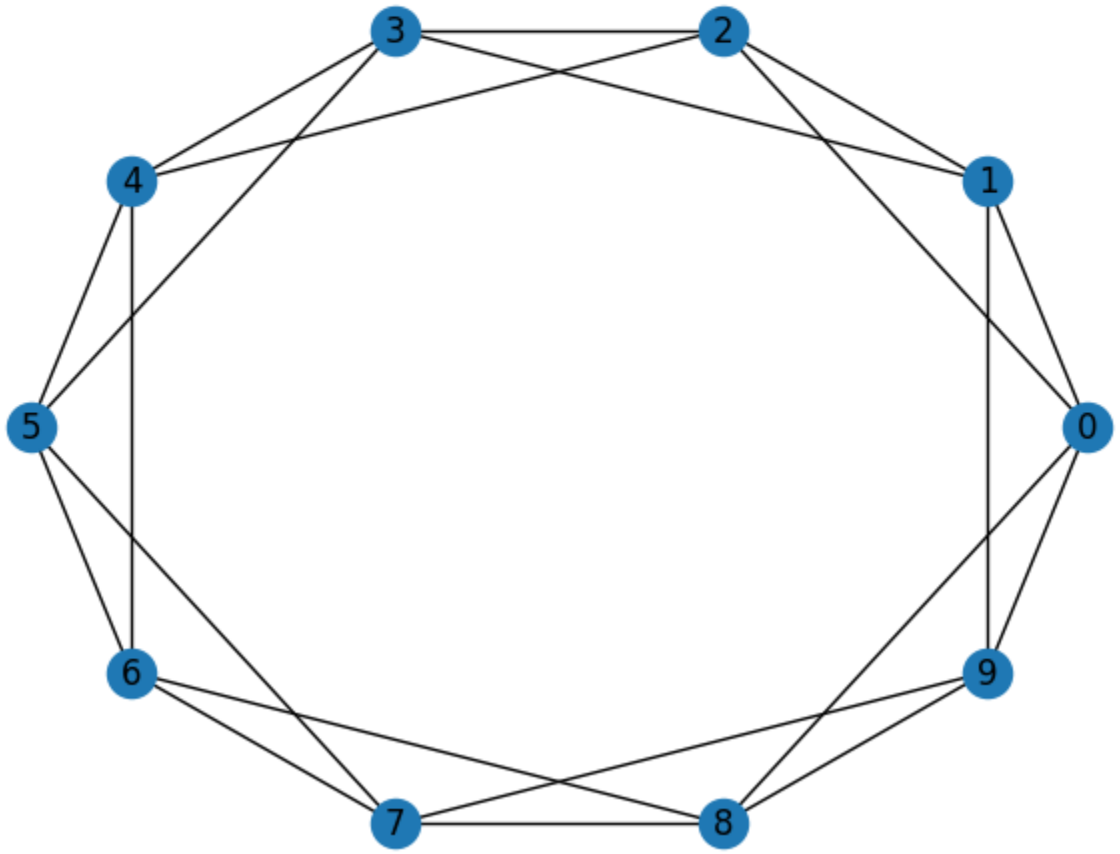


Module-3: **Making homophily based edges**

For each node, connect to two nodes left and two nodes to right

In [3]:
```
# logic adopted from "Abhishek Mohite" --- commmented on the lecture's video

def add_homophily_nodes(G):
    n = len(G.nodes())
    for idx in range(len(G.nodes())):
        G.add_edge(idx%n, (idx+1)%n);   #print(idx%n, (idx+1)%n, end=", ")
        G.add_edge(idx%n, (idx+2)%n);   #print((idx+2)%n)
    return G
```

In [4]:
```
# -----------HOMOPHILY------------------
G = add_homophily_nodes(G)
nx.draw(G, nx.circular_layout(G), with_labels=True)
plt.show()
```



In [5]:
```
G.edges()
```

Out[5]:
```
EdgeView([(0, 1), (0, 2), (0, 8), (0, 9), (1, 2), (1, 3), (1, 9), (2, 3), (2, 4), (3, 4), (3, 5), (4, 5), (4, 6), (5, 6), (5, 7), (6, 7), (6, 8), (7, 8), (7, 9), (8, 9)])
```

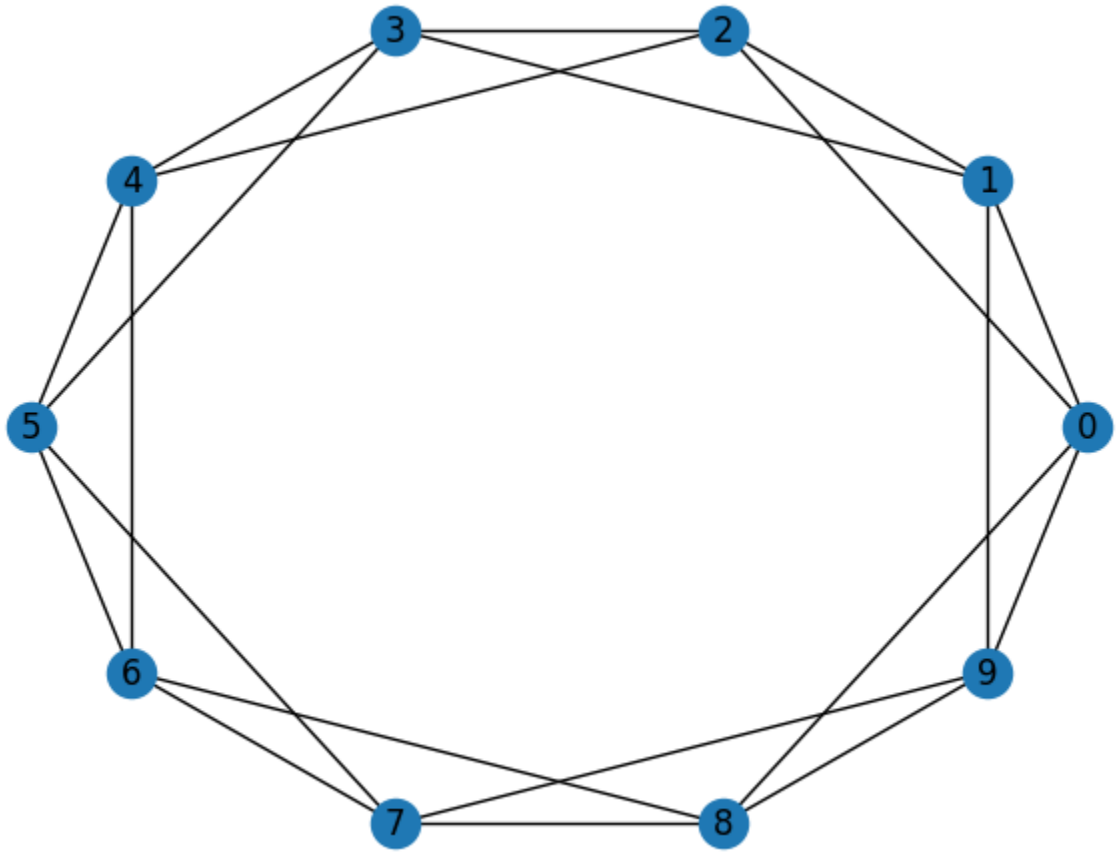
Module-4: **Adding weak ties**

In [65]:
```
import random
def add_weak_ties(G, num_iterations):
    for i in range(num_iterations):
        v1 = random.choice(list(G.nodes()))
        v2 = random.choice(list(G.nodes()))
        while v1 == v2:                              # Go, as long as you gethttps://youtu.be/jHgNv8_qhcs the same nodes
            v1 = random.choice(list(G.nodes()))
            v2 = random.choice(list(G.nodes()))
            G.add_edge(v1, v2)                       # If already exists an edge b/w, v1 and v2, this doesn't seems to be affected
    return G
```

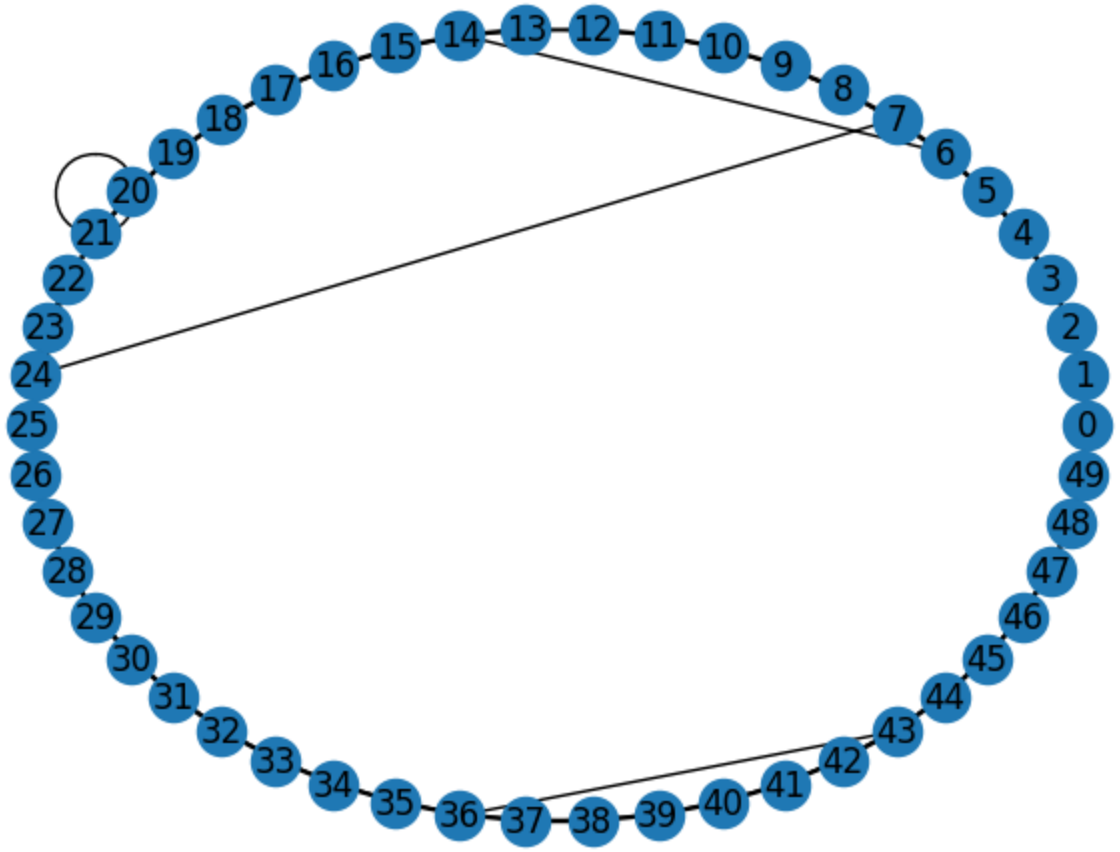
In [7]:
```
import random
random.choice(list(G.nodes()))
```

Out[7]: 1

In [8]:
```
G = add_weak_ties(G, num_iterations=15)
nx.draw(G, nx.circular_layout(G), with_labels=True)
plt.show()
```



In [66]:
```
# Import the required libraries..
import networkx as nx           # for working with the graphs
import matplotlib.pyplot as plt  # For visualizing the graph..

# Create a graph..
G = nx.Graph()
# Add some nodes to it..
G.add_nodes_from(range(50))

# ----------HOMOPHILY------------------
add_homophily_nodes(G)

# -------------Weak ties ----------------
G = add_weak_ties(G, 100)

# Look at the graph..
nx.draw(G, nx.circular_layout(G), with_labels=True, )
plt.show()
```



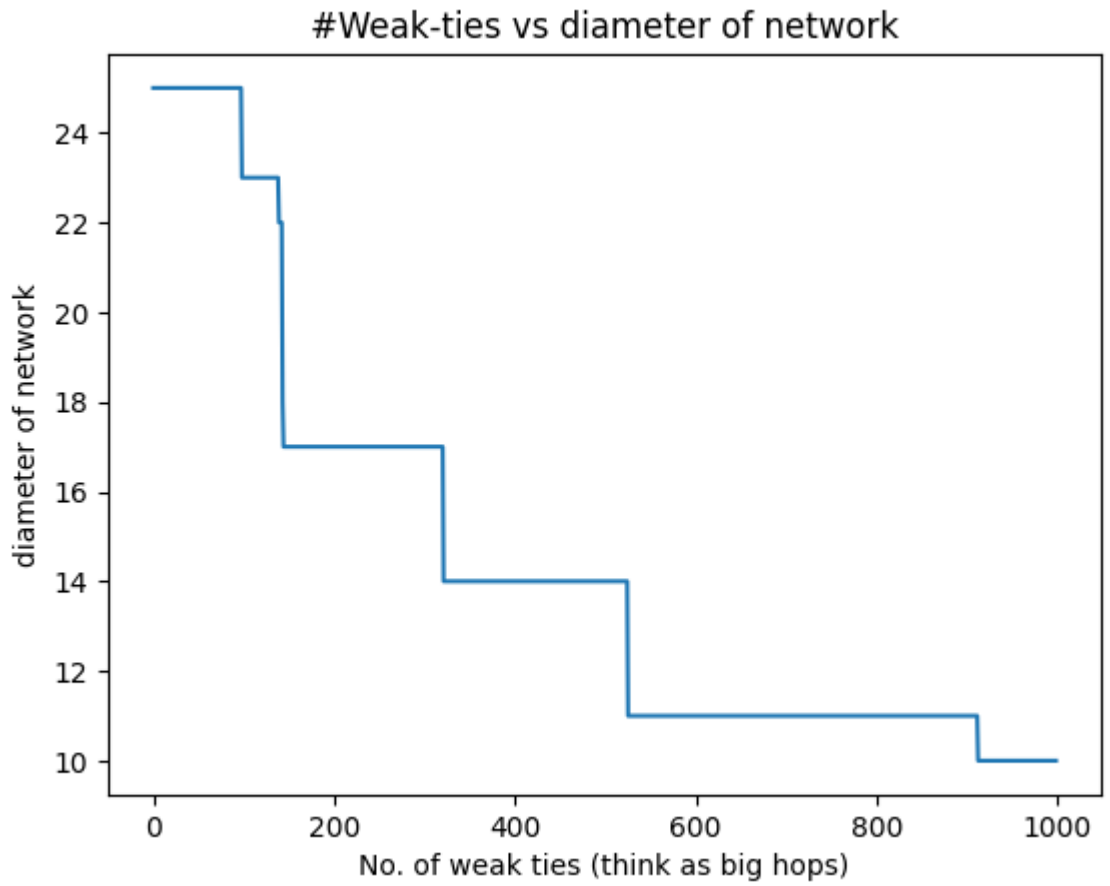
Module-5: **Plotting change in diameter**

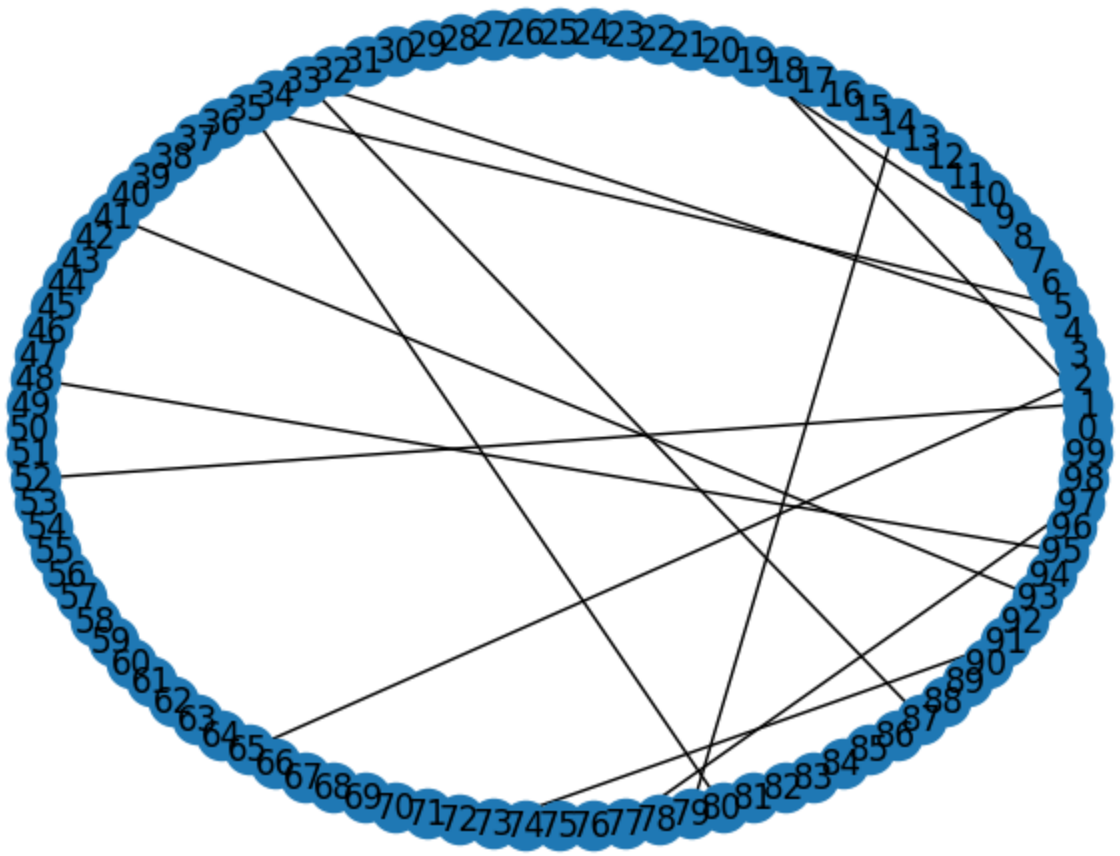
In [10]:
```
nx.diameter(G)
```

Out[10]:
```
13
```

In [11]:

```
# Import the required libraries..
import networkx as nx           # for working with the graphs
import matplotlib.pyplot as plt  # For visualizing the graph..

# Create a graph..
G = nx.Graph()
# Add some nodes to it..
G.add_nodes_from(range(100))

# -----------HOMOPHILY------------------
add_homophily_nodes(G)

# Lists for tracking...
x = [0]
y = [nx.diameter(G)]

for i in range(999):#9999
    x.append(i)
    G = add_weak_ties(G, 2)
    y.append(nx.diameter(G))

plt.plot(x, y)
plt.xlabel("No. of weak ties (think as big hops)")
plt.ylabel("diameter of network")
plt.title("#Weak-ties vs diameter of network")
plt.show()

# Look at the graph..
nx.draw(G, nx.circular_layout(G), with_labels=True, )
plt.show()
```



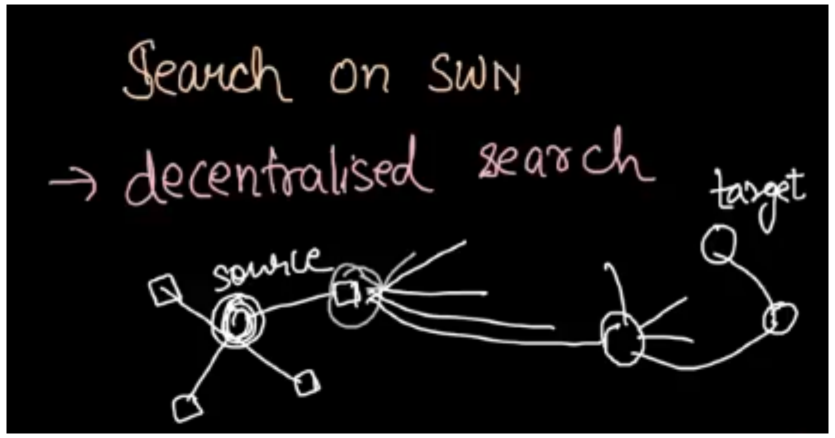


Module-6: **Programming illustration- Myopic Search : Introduction**

Seen the Small World Network (SWN)

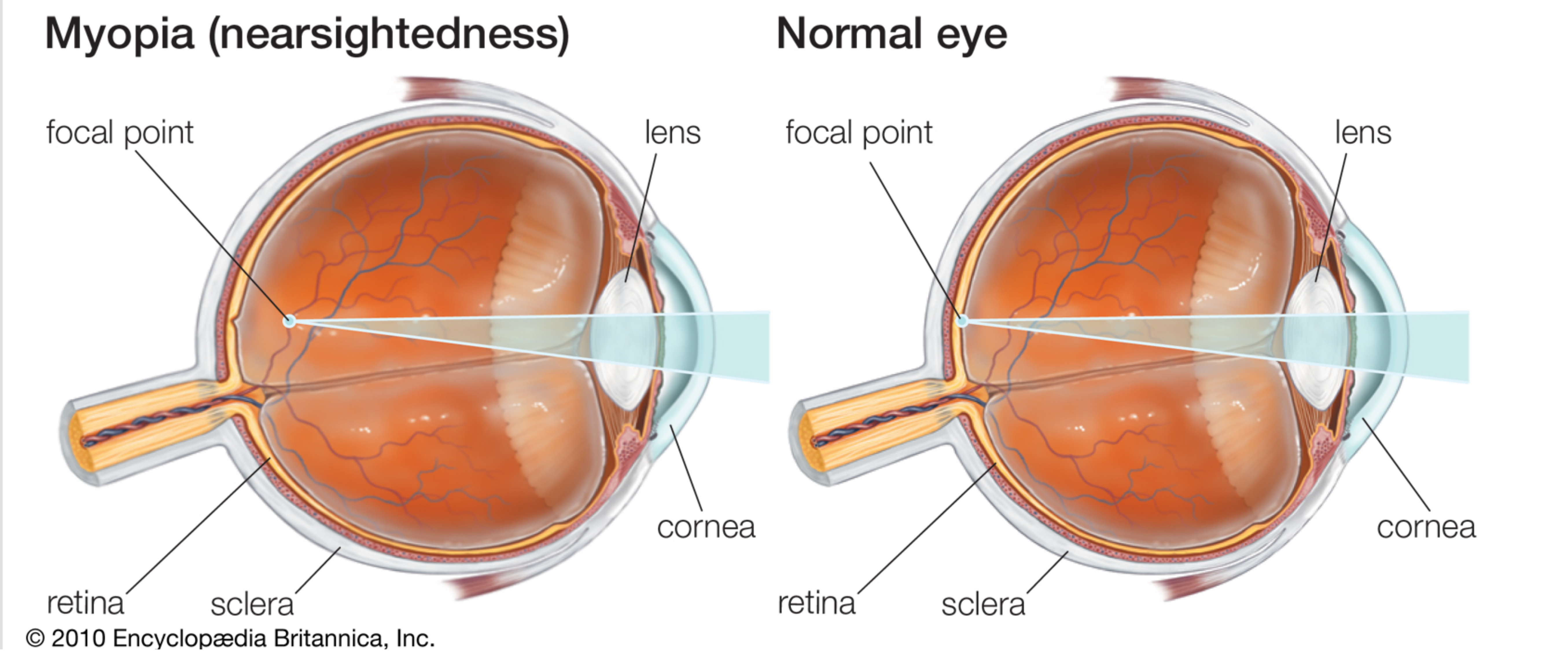
Now, the **De-Centralized Search** -- i.e., no centralized control

How it happens..??

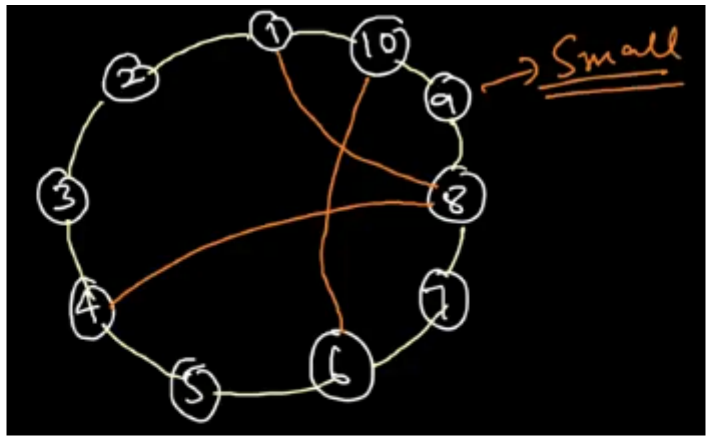
> Let's start from the **source** (towards the **target** node).
>
> - The source, finds the distance to all the nodes which are neighbours to it
> - It picks the one having **smallest distance**, and it takes over.., again same story .... till the target.
>
> 
>

Why named Myopia..

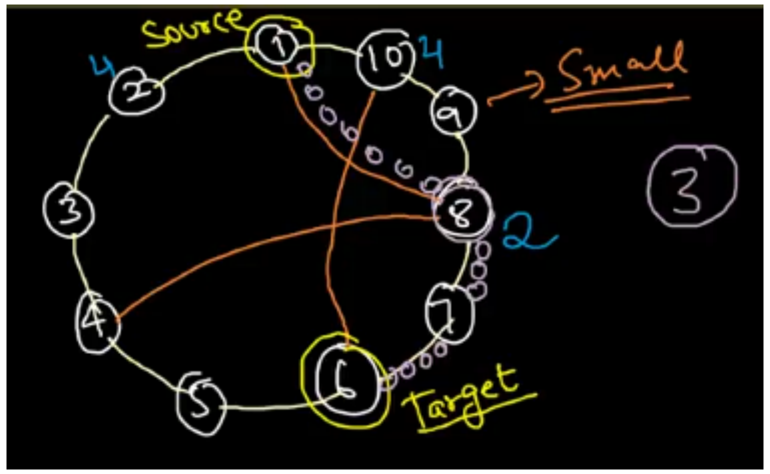
> Recollect what's meant by Myopia, from the Physics 9th Std. Recollect.....



Consider the basic networkk...



Yellow colored: Homophily, and Red: Weak ties -- which made this network, small World network.

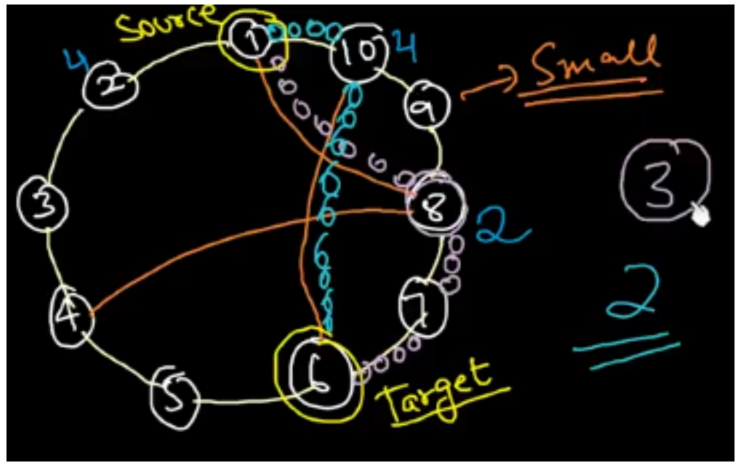
Consider **start** as 1, and **target** to be 6. 

How the distance was calculated..??

> - Neighbours of 1: `{2, 10, 8}`.
> - Subtract the **target** from all those. It gives.. `{4, 4, 2}`.
> - Pick the node, which gave smallest **distance**. It's `8` here. So transmitted to `8`.
> - This story repeats till reaching target `6`.

No. of hops taken are: 3

Is this search optimal..?? No right, still we have the path of length `2` via, `1 -> 10- > 6`.

> 
>
> -- but this **need the global knowledge of the network**.

What's going to be a see in the screen cast is..

> Ring graphs(networks) having 100, 200, 300,.. 1D small world networks, and going to apply the Decentralized search and going to look at the average plot of it.

Module-7: **Myopic Search**

In [88]:

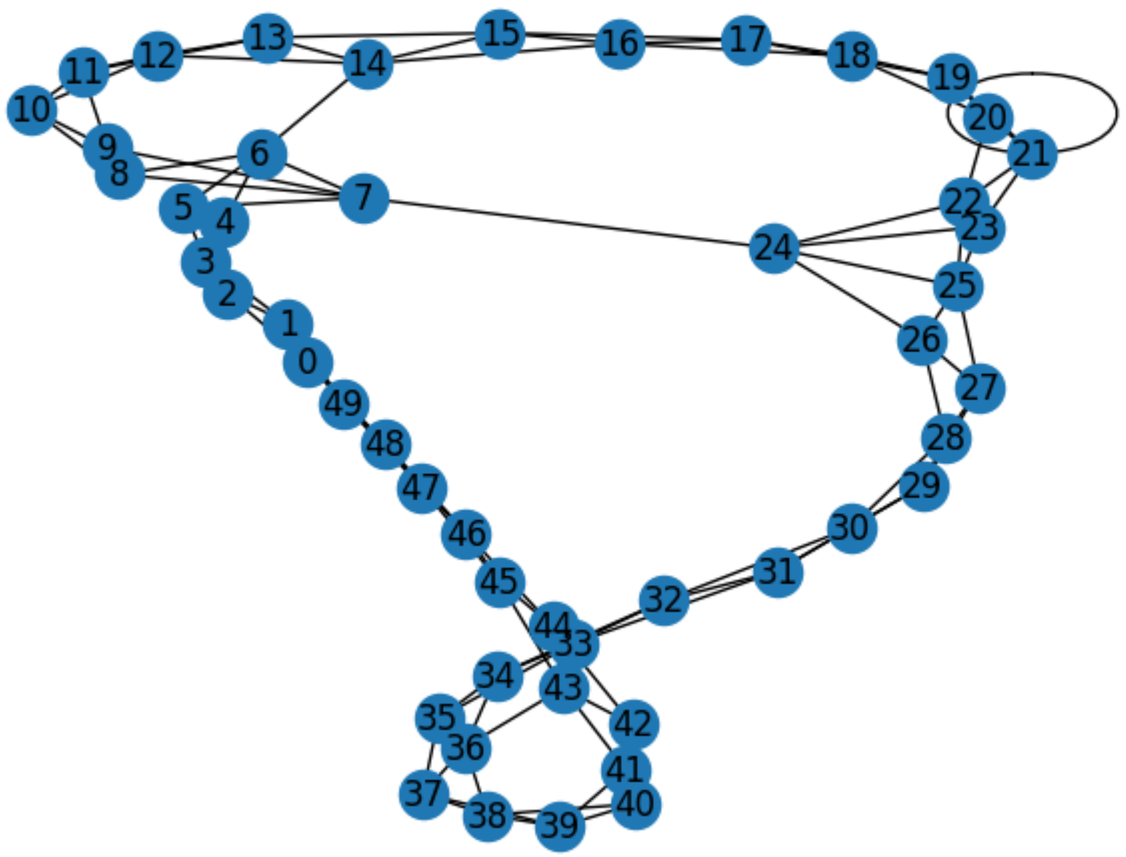
```
def find_nearest_neighbor(G, src, dstn):
    shortest_distance = G.number_of_nodes()    # As atleast distance, in the worst-case...
    nearest_node = 0;                          # To keep track of, which neighbor had the shortest proximity..
    for neighbor in G.neighbors(src):
        calc_shortDistance = len(nx.shortest_path(G, neighbor, dstn))  # Find the shortest path(an array) b/w the src's neighbor and dstn.
        if calc_shortDistance < shortest_distance:           # A filter to get only the shortEST-distance.. out of all short distances
            shortest_distance = calc_shortDistance
            nearest_node = neighbor
    return nearest_node                        # Return the node having, nearest distance to the source...
```

In [89]:

```
def myopic_search(G, src, dstn):
    path = [src]
    current = src
    while(current != dstn):             # Loop, as lon current reaches the target...
        nearest_neighbor = find_nearest_neighbor(G, current, dstn)
        current = nearest_neighbor
        path.append(nearest_neighbor)
    return path
```

In [93]:

```
nx.draw(G, with_labels=True)
plt.show()
```



In [1...

```
temp = 40
```

In [1...

```
nx.shortest_path(G, 1, temp)
```

Out[1...

```
[1, 49, 47, 45, 43, 41, 40]
```

In [1...

```
myopic_search(G, 1, temp)
```

Out[1...

```
[1, 0, 48, 46, 44, 42, 40]
```

In [72]:

```
def set_path_colors(G, path1, path2):
    colors = []
    for node in G.nodes():
        if node == path1[0]:
            colors.append('red')
        if node == path1[len(path1)-1]:
            colors.append('red')
        if node in path1 and node in path2 and node !=path1[0] and node != path2[len(path2)-1]:
            colors.append('green')
        if node in path1 and node not in path2:
            colors.append('yellow')
        if node not in path1 and node in path2:
            colors.append('yellow')
        if node not in path1 and node not in path2:
            colors.append('black')
    return colors
```

In [1...

```
# Import the required libraries..
import networkx as nx           # for working with the graphs
import matplotlib.pyplot as plt  # For visualizing the graph..

def main():
    # Create a graph..
    G = nx.Graph()
    # Add some nodes to it..
    num_nodes = int(input("no of nodes = "))
    G.add_nodes_from(range(num_nodes))

    # -----------HOMOPHILY------------------
    add_homophily_nodes(G)

    # ----------Weak ties--------------
    x = [0]
    y = [nx.diameter(G)]
    for i in range(10):
        x.append(i)
        G = add_weak_ties(G, 100)
        y.append(nx.diameter(G))

    # --------Search------------
    src = int(input("source node = "))
    dstn = int(input(" destination node = "))
    myopic_path = myopic_search(G, src, dstn)
    optimal_path = nx.shortest_path(G, source=src, target=dstn)
    colors = set_path_colors(G, myopic_path, optimal_path)
    #nx.draw(G,  nx.spectral_layout(G), node_color=colors, with_labels=True)
    nx.draw_networkx(G, nx.spring_layout(G), arrows=True, node_color=colors, node_shape='o', font_family='c059', alpha=0.7, node_size=800, font_color="white")
    plt.show()

    compare_paths(G, num_nodes)
main()
```

```
---------------------------------------------------------------------------
ModuleNotFoundError                       Traceback (most recent call last)
<ipython-input-106-33354d808b6b> in <module>
     32
     33     compare_paths(G, num_nodes)
---> 34 main()

<ipython-input-106-33354d808b6b> in main()
     28     colors = set_path_colors(G, myopic_path, optimal_path)
     29     #nx.draw(G,  nx.spectral_layout(G), node_color=colors, with_labels=True)
---> 30     nx.draw_networkx(G, nx.spring_layout(G), arrows=True, node_color=colors, node_shape='o', font_family='c059', alpha=0.7, node_size=800, font_color="white")
     31     plt.show()
     32

~/anaconda3/envs/Python-R/lib/python3.8/site-packages/networkx/utils/decorators.py in argmap_spring_layout_1(G, k, pos, fixed, iterations, threshold, weight, scale, center, di
m, seed)
      2 from os.path import splitext
      3 from contextlib import contextmanager
----> 4 from pathlib import Path
      5 import warnings
      6

~/anaconda3/envs/Python-R/lib/python3.8/site-packages/networkx/drawing/layout.py in spring_layout(G, k, pos, fixed, iterations, threshold, weight, scale, center, dim, seed)
    474         if len(G) < 500:  # sparse solver for large graphs
    475             raise ValueError
```

```
--> 476         A = nx.to_scipy_sparse_matrix(G, weight=weight, dtype="f")
    477         if k is None and fixed is not None:
    478             # We must adjust k by domain size for layouts not near 1x1

~/anaconda3/envs/Python-R/lib/python3.8/site-packages/networkx/convert_matrix.py in to_scipy_sparse_matrix(G, nodelist, dtype, weight, format)
    849        https://docs.scipy.org/doc/scipy/reference/sparse.html
    850     """
--> 851     import scipy as sp
    852     import scipy.sparse  # call as sp.sparse
    853
```

In [19]:

```
nx.draw_networkx(G, nx.spring_layout(G), arrows=True, node_color=colors, node_shape='o', font_family='c059', alpha=0.6, node_size=800, font_color="white")
```

```
---------------------------------------------------------------------------
NameError                                 Traceback (most recent call last)
<ipython-input-19-91ad9b603594> in <module>
----> 1 nx.draw_networkx(G, nx.spring_layout(G), arrows=True, node_color=colors, node_shape='o', font_family='c059', alpha=0.6, node_size=800, font_color="white")

NameError: name 'colors' is not defined
```

In [ ]:

```
# Create a graph..
G = nx.Graph()
# Add some nodes to it..
num_nodes = int(input("no of nodes = "))
G.add_nodes_from(range(num_nodes))

# -----------HOMOPHILY-------------------
add_homophily_nodes(G)

# ----------Weak ties--------------
x = [0]
y = [nx.diameter(G)]
for i in range(10):
    x.append(i)
    G = add_weak_ties(G, 2)
    y.append(nx.diameter(G))
```

In [ ]:

```
nx.draw_networkx(G, arrows=True, node_color='red', node_shape='o', font_family='c059', alpha=0.6, node_size=800)
plt.show()
```

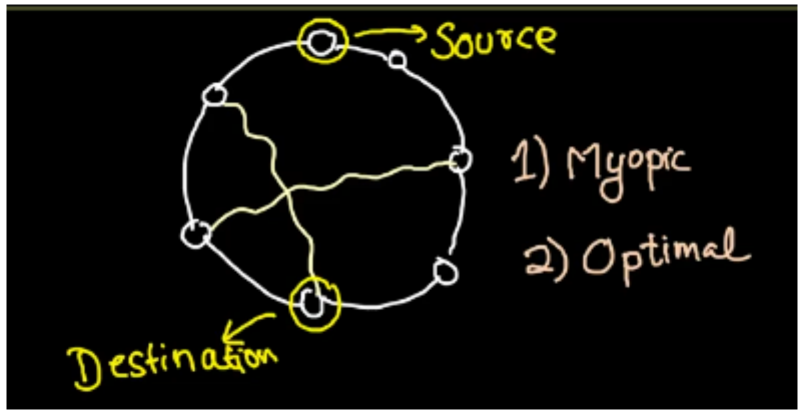
In [ ]:

```
import networkx as nx
nx.draw_networkx?
```

Module-8: **Myopic Search comparision to optimal search**

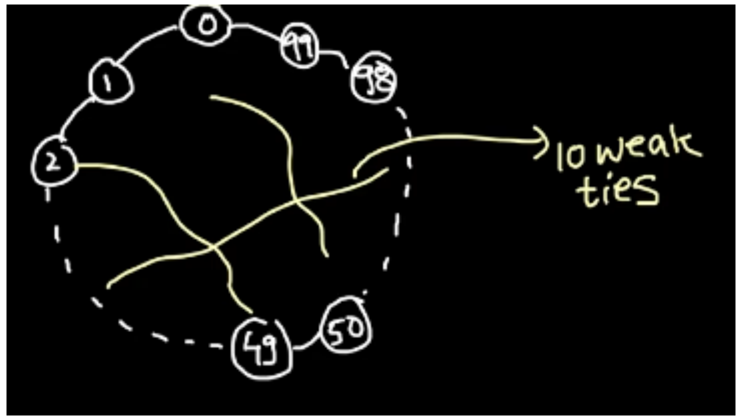
In [ ]:

```
asw
```



-- on this 1D network.

Now, in this lecture... going to take a small world network on 100nodes and put some weak ties(10).

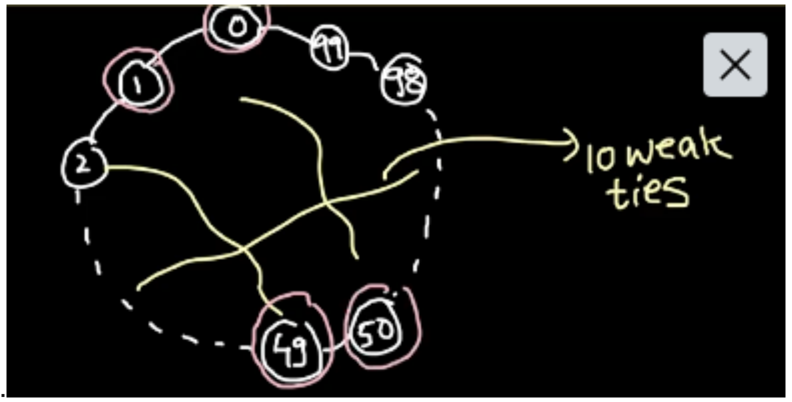


Now our aim is going to be...

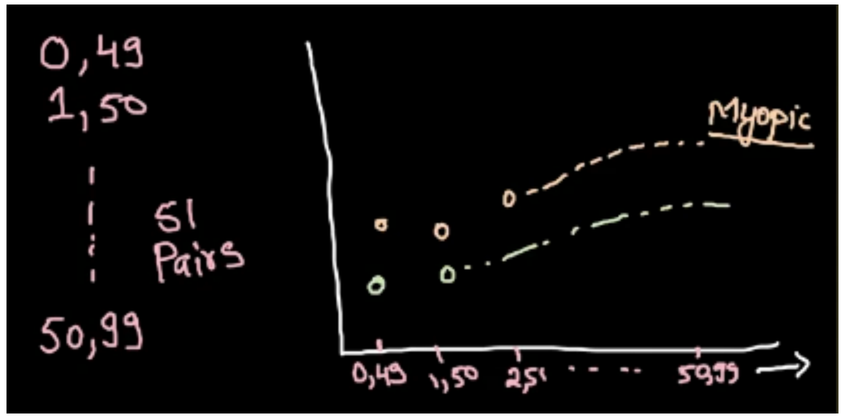
- **Compare Myopic search with optimal Search *for various different pairs*.**
- But which pairs do we choose..?? We want many pairs of src and destination.. . **How the comparison is going to be..**

> **Difference between the path** taken by myopic search and optimal for each pair.

but, **What would be the best pairs..?**

> The pairs which are diametrically opposite (i.e., along the ring they had the highest distance)
>
> **Ex:** $0 \& 49$, $1 \& 50$ ....
>
> 
>

How we are going to do..??



In [79]:

```
def compare_paths(G, num_nodes):
    x = []                  # To store all the tuples of pairs (0, 50), (1, 50)..
    myopic_lengths = []     # To store al the lengths taken by myopic search, for each corresponding pair..
    optimal_lengths = []    # ................................optimal.......................................

    # Calculate the path-lengths..
    #for (u, v) in zip(range(0, 49+1), range(50, 99+1)):
    v=0
    for u in range(0,num_nodes//2-1):
        v = u+num_nodes//2
        #print("u: ", u)
        #print("v: ", v)
        myopic_lengths.append(len(myopic_search(G, u, v)))
        optimal_lengths.append(len(nx.shortest_path(G, source=u, target=v)))
        x.append(str((u, v)))

    print(myopic_lengths)
    print(optimal_lengths)

    # Plot it..
    plt.plot(x, myopic_lengths, 'ro-')
    plt.plot(x, optimal_lengths, 'b^-')
    plt.xticks(rotation=90)
    plt.title("Comparing Myopic search and Optimal in-terms of path-lengths")
    plt.xlabel("Pairs as (src, destination)")
    plt.ylabel("Path-lengths for corresponding pair chosen")
    plt.legend(["Myopic search", "Optimal Search"])
    plt.show()
```

In [84]:

```
def create_network(num_nodes):
    # Create a graph..
    G = nx.Graph()
    # Add some nodes to it..
    #num_nodes = int(input("no of nodes = "))
    G.add_nodes_from(range(num_nodes))

    # -----------HOMOPHILY-------------------
    add_homophily_nodes(G)

    # ----------Weak ties--------------
    x = [0]
    y = [nx.diameter(G)]
    for i in range(50):        # 50 tells, the no. of weak ties (ofcourse, the picks happen randomly)
        x.append(i)
        G = add_weak_ties(G, 2)
        y.append(nx.diameter(G))

    return G
```

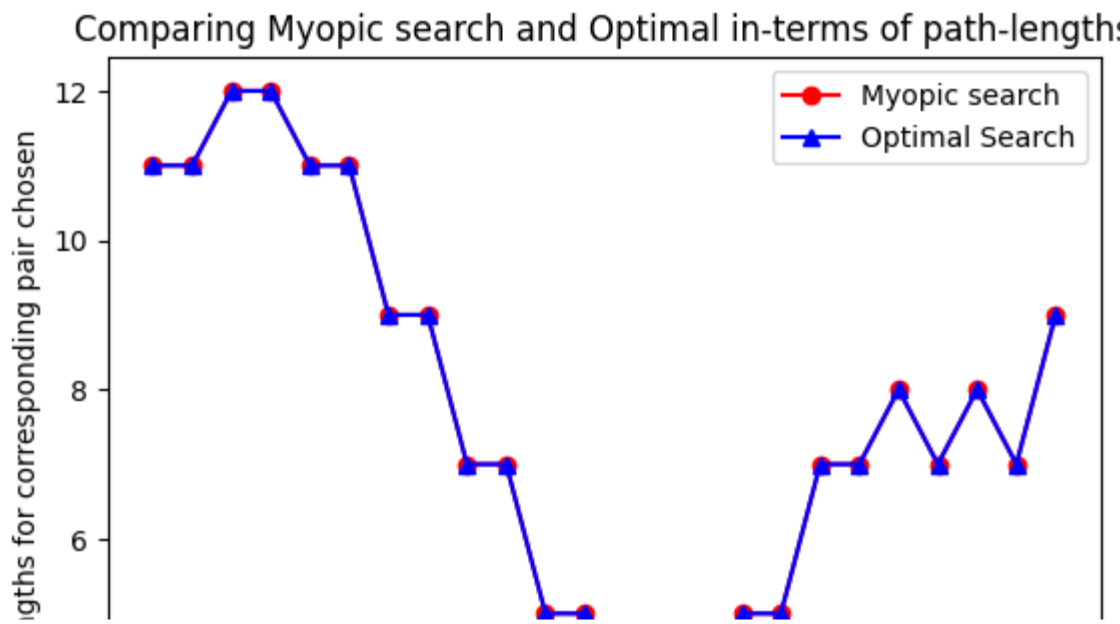
In [43]:

```
def search_in_network(do_plot=False):
    # --------Search------------
    src = int(input("source node = "))
    dstn = int(input(" destination node = "))
    myopic_path = myopic_search(G, src, dstn)
    optimal_path = nx.shortest_path(G, source=src, target=dstn)
    colors = set_path_colors(G, myopic_path, optimal_path)
    if do_plot:
        #nx.draw(G,  nx.spectral_layout(G), node_color=colors, with_labels=True)
        nx.draw_networkx(G, nx.spring_layout(G), arrows=True, node_color=colors, node_shape='o', font_family='c059', alpha=0.7, node_size=800, font_color="white")
        plt.show()
```

In [86]:

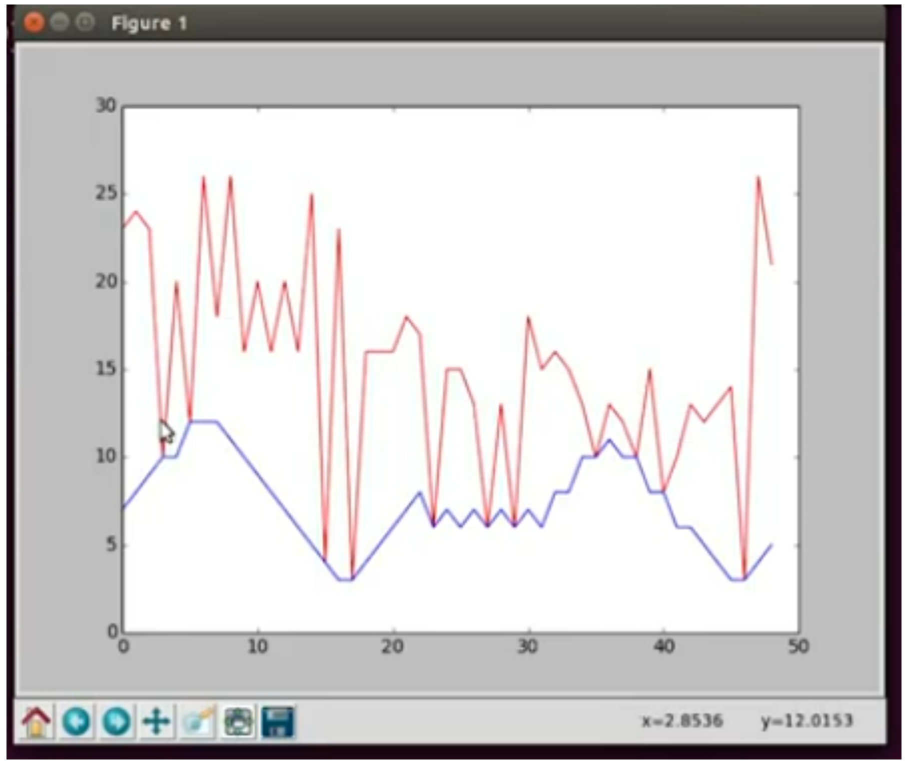
```
# Import the required libraries..
import networkx as nx           # for working with the graphs
import matplotlib.pyplot as plt  # For visualizing the graph..

def main():
    num_nodes = int(input("no of nodes = "))
    G = create_network(num_nodes)
    #search_in_network();

    compare_paths(G, num_nodes)

main()
```

```
[11, 11, 12, 12, 11, 11, 9, 9, 7, 7, 5, 5, 3, 4, 3, 5, 5, 7, 7, 8, 7, 8, 7, 9]
[11, 11, 12, 12, 11, 11, 9, 9, 7, 7, 5, 5, 3, 4, 3, 5, 5, 7, 7, 8, 7, 8, 7, 9]
```



How the optimal and myopic giving the same path lengths..??

But the actual plot should look like..



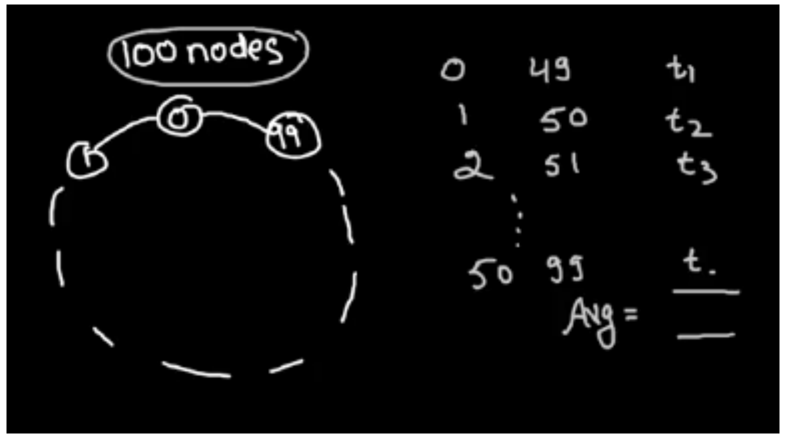
In [38]:
```
for each in [(1, 2), (3, 4)]:
    print(str(each))
```

```
(1, 2)
(3, 4)
```

Module-9: **Time Taken by Myopic Search**

Now, will be looking at the ... **How much does Myopic search takes** for different set sizes of the networks.

Say, for 100 nodes, for points taken for **diametrically opposite points**..



Next for 200 nodes..


A care....

- Earlier its only 10 weak ties for that network.... (note that for 100 nodes its 10%).
- Now, we should maintain the 10% of weak ties for the given network size..

What we'll be doing..

In [ ]:

```

```

In [1...

```python
# logic adopted from "Abhishek Mohite" --- commmented on the lecture's video

def add_homophily_nodes_v1(G):
    n = len(G.nodes())
    for idx in range(len(G.nodes())):
        G.add_edge(idx%n, (idx+1)%n);   #print(idx%n, (idx+1)%n, end=", ")
        G.add_edge(idx%n, (idx+2)%n);   #print((idx+2)%n)
    return G
```

In [1...

```python
import random
def add_weak_ties_v1(G, num_iterations):
    for i in range(num_iterations):
        v1 = random.choice(list(G.nodes()))
        v2 = random.choice(list(G.nodes()))
        while v1 == v2 and (v1, v2) not in G.edges() or (v2, v1) not in G.edges():                              # Go, as long as you gethttps://youtu.be/jHgNv8_qhcs the same no
            v1 = random.choice(list(G.nodes()))
            v2 = random.choice(list(G.nodes()))
            G.add_edge(v1, v2)                       # If already exists an edge b/w, v1 and v2, this doesn't seems to be affected
    return G
```

In [1...

```
def create_network_v1(num_nodes):
    # Create a graph..
    G = nx.Graph()
    # Add some nodes to it..
    G.add_nodes_from(range(num_nodes))

    # -----------HOMOPHILY------------------
    add_homophily_nodes(G)

    # ----------Weak ties--------------
    x = [0]
    y = [nx.diameter(G)]
    for i in range(G.number_of_nodes()//10):        # Adding 10% of weak ties..
        x.append(i)
        G = add_weak_ties(G, 2)
        y.append(nx.diameter(G))

    return G
```

In [1...

```
def myopic_timeFinding(G, num_nodes):
    x = []                  # To store all the tuples of pairs (0, 50), (1, 50)..
    myopic_lengths = []     # To store al the lengths taken by myopic search, for each corresponding pair..
    optimal_lengths = []    # ..................................optimal.......................................

    # Calculate the path-lengths..
    #for (u, v) in zip(range(0, 49+1), range(50, 99+1)):
    v=0
    for u in range(0,num_nodes//2-1):
        v = u+num_nodes//2
        myopic_lengths.append(len(myopic_search(G, u, v)))
        #optimal_lengths.append(len(nx.shortest_path(G, source=u, target=v)))
        #x.append(str((u, v)))
        x.append(u)

    #print(myopic_lengths)
    #print(optimal_lengths)

    return G.number_of_nodes(), np.average(myopic_paths)
```

In [1...

```
import networkx as nx
import matplotlib.pyplot as plt
import random
import numpy as np

def build_diff_sized_SWNs():  # Build diff sized SmallWorldNetworks
    xaxis, yaxis = [], []

    tempx, tempy = 0, 0      # temporary variables..
    for size in range(100, 1000+1, 100):
        # Create network..
        create_network_v1(size);

        # Get values for different sized search paths..
        tempx, tempy = myopic_timeFinding(G, size)
        xaxis.append(tempx);
        yaxis.append(tempy)

        print(tempx, tempy)

    # Plot it..
    plt.plot(xaxis, yaxis, 'ro-')
    #plt.plot(x, optimal_lengths, 'b^-')
    plt.xticks(rotation=90)
    plt.title("Comparing Myopic search and Optimal in-terms of path-lengths")
    plt.xlabel("Pairs as (src, destination)")
    plt.ylabel("Path-lengths for corresponding pair chosen")
    plt.legend(["Myopic search", "Optimal Search"])
    plt.show()
```

In [1...

```
build_diff_sized_SWNs()
```

```
---------------------------------------------------------------------------
NodeNotFound                              Traceback (most recent call last)
<ipython-input-127-a3e2b69a8701> in <module>
----> 1 build_diff_sized_SWNs()

<ipython-input-124-a604b8d10a83> in build_diff_sized_SWNs()
     13
     14         # Get values for different sized search paths..
---> 15         tempx, tempy = myopic_timeFinding(G, size)
     16         xaxis.append(tempx);
     17         yaxis.append(tempy)

<ipython-input-118-a4d29c325356> in myopic_timeFinding(G, num_nodes)
      9     for u in range(0,num_nodes//2-1):
     10         v = u+num_nodes//2
---> 11         myopic_lengths.append(len(myopic_search(G, u, v)))
     12         #optimal_lengths.append(len(nx.shortest_path(G, source=u, target=v)))
     13         #x.append(str((u, v)))

<ipython-input-89-f18dd215d71e> in myopic_search(G, src, dstn)
      3     current = src
      4     while(current != dstn):             # Loop, as lon current reaches the target...
----> 5         nearest_neighbor = find_nearest_neighbor(G, current, dstn)
      6         current = nearest_neighbor
      7         path.append(nearest_neighbor)

<ipython-input-88-d2fdeb3773fe> in find_nearest_neighbor(G, src, dstn)
      3     nearest_node = 0;                          # To keep track of, which neighbor had the shortest proximity..
```

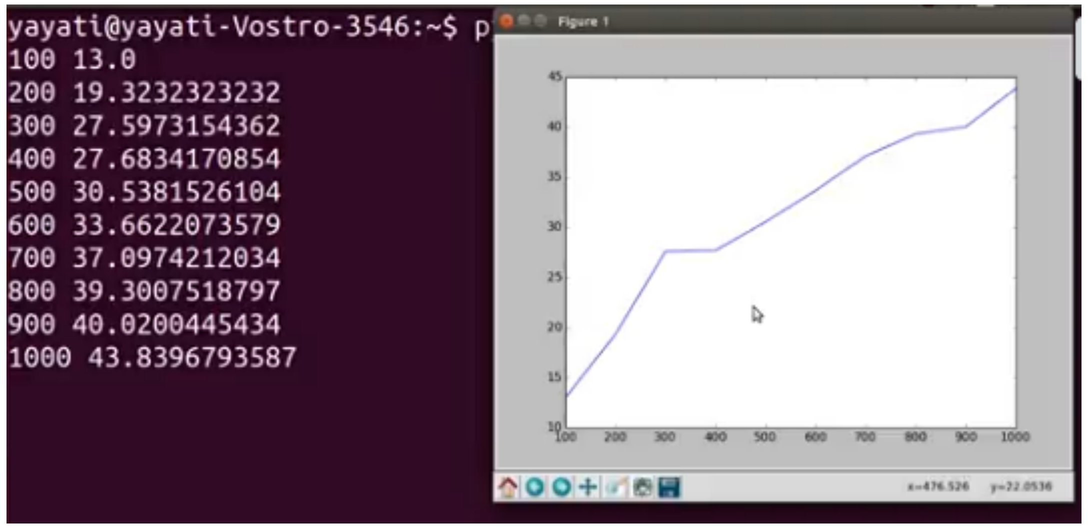
```
      4     for neighbor in G.neighbors(src):
----> 5         calc_shortDistance = len(nx.shortest_path(G, neighbor, dstn))  # Find the shortest path(an array) b/w the src's neighbor and dstn.
      6         if calc_shortDistance < shortest_distance:           # A filter to get only the shortEST-distance.. out of all short distances
      7             shortest_distance = calc_shortDistance

~/anaconda3/envs/Python-R/lib/python3.8/site-packages/networkx/algorithms/shortest_paths/generic.py in shortest_path(G, source, target, weight, method)
    158             # Find shortest source-target path.
    159             if method == "unweighted":
--> 160                 paths = nx.bidirectional_shortest_path(G, source, target)
    161             elif method == "dijkstra":
    162                 _, paths = nx.bidirectional_dijkstra(G, source, target, weight)

~/anaconda3/envs/Python-R/lib/python3.8/site-packages/networkx/algorithms/shortest_paths/unweighted.py in bidirectional_shortest_path(G, source, target)
    219     if source not in G or target not in G:
    220         msg = f"Either source {source} or target {target} is not in G"
--> 221         raise nx.NodeNotFound(msg)
    222
    223     # call helper to do the real work

NodeNotFound: Either source 1 or target 50 is not in G
```

In [1...

```
G.edges()
```

Out[1...

```
EdgeView([(0, 1), (0, 2), (0, 48), (0, 49), (1, 2), (1, 3), (1, 49), (2, 3), (2, 4), (3, 4), (3, 5), (4, 5), (4, 6), (5, 6), (5, 7), (6, 7), (6, 8), (6, 14), (7, 8), (7, 9), (7, 24), (8, 9), (8, 10), (9, 10), (9, 11), (10, 11), (10, 12), (11, 12), (11, 13), (12, 13), (12, 14), (13, 14), (13, 15), (14, 15), (14, 16), (15, 16), (15, 17), (16, 17), (16, 18), (17, 18), (17, 19), (18, 19), (18, 20), (19, 20), (19, 21), (20, 21), (20, 22), (21, 22), (21, 23), (21, 21), (22, 23), (22, 24), (22, 25), (23, 24), (23, 25), (24, 25), (24, 26), (25, 26), (25, 27), (26, 27), (26, 28), (27, 28), (27, 29), (28, 29), (28, 30), (29, 30), (29, 31), (30, 31), (30, 32), (31, 32), (31, 33), (32, 33), (32, 34), (33, 34), (33, 35), (34, 35), (34, 36), (35, 36), (35, 37), (36, 37), (36, 38), (36, 43), (37, 38), (37, 39), (38, 39), (38, 40), (39, 40), (39, 41), (40, 41), (40, 42), (41, 42), (41, 43), (42, 43), (42, 44), (43, 44), (43, 45), (44, 45), (44, 46), (45, 46), (45, 47), (46, 47), (46, 48), (47, 48), (47, 49), (48, 49)])
```

Should get like.. 

Inference:

- Its linear with a +ve relationship

Module-10: **Pseudocores: Introduction**

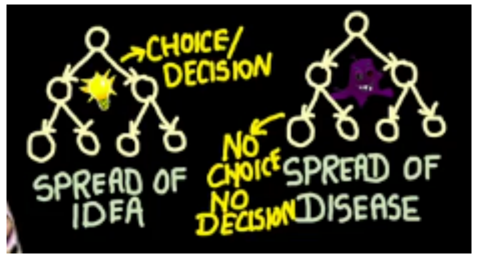
Have a quick glimpse...

- Cascades
  - How people follow..?? -------------- interms of behaviour, idea and product..

- Epidemics

< --How they spread from person to person, and modellings like SIS and SIR.

- Subtle difference between **Spread of an Idea** and **Spread of Disease** -- i.e., spread of idea had chance to take or reject, for contagion not.



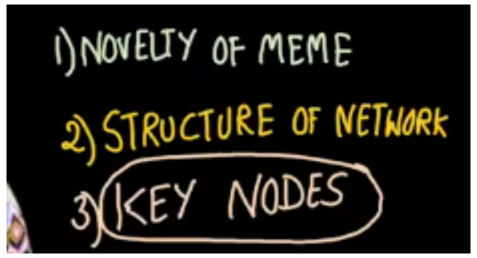
Spreading of idea had a special interest. In internet world, becoming famous is vrey easy compared to earlier time.
It can be like a photo, video, meme, riot... -- called **Internet meme**.

Justin Beiber...

> In his childhood, he used to sing songs and his parents used to record and post in YouTube. Slowly they gained popularity. Once a producer seen that and invited to singing industry.
>
> 
>

Module-11: **How to be Viral**

Then how do we make it popular..??

> 
>
>
> **1. Novelty of meme**: quality, background music..
>
> **2. Structure**: how the network is structured... some make popular fast and some not.
>
> **3. Key Nodes**: i.d., Some famous helping out in becoming famous

Novelty of meme: quality, background music..

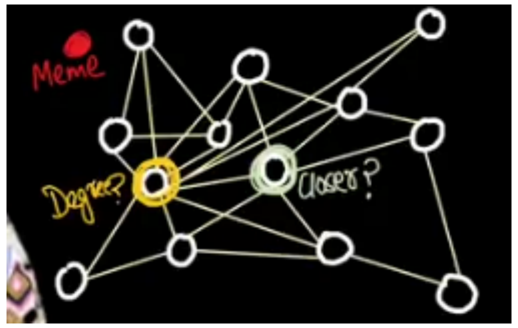
Module-12: **Who are the right key nodes?**

Key nodes show some impact, but who are those key nodes..??

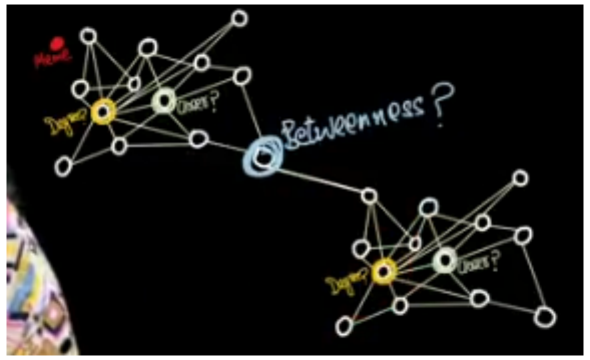
Ok, given a network like this, How do you tell, this is the key node...??

And there are many many possiblities.. like

- Node having maximum number of friends..?? (or highest degree)
- or a Node which is structurally closer to all the nodes --- (technically called **closness centrality**)

- or having high in-betweenness -- how good are you in connecting the networks

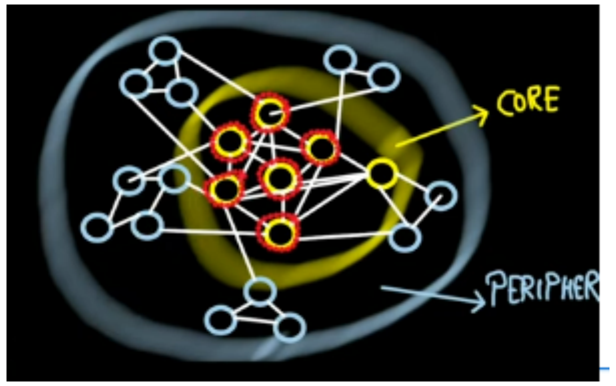
  

How.. How..?? a node should be chosen, such that, if chosen that node, and infected with an idea, it becomes viral.

Module-13: **finding the right key nodes (the core)**

Here goes the answer for the question...

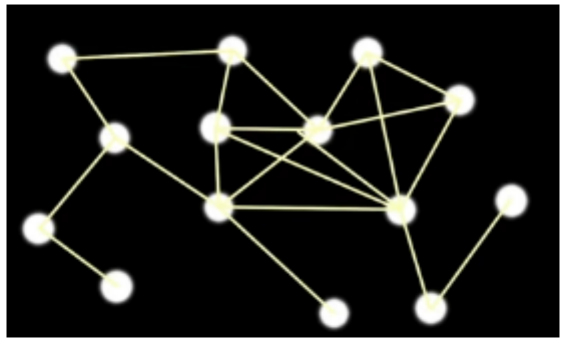
Core-Periphery structure.



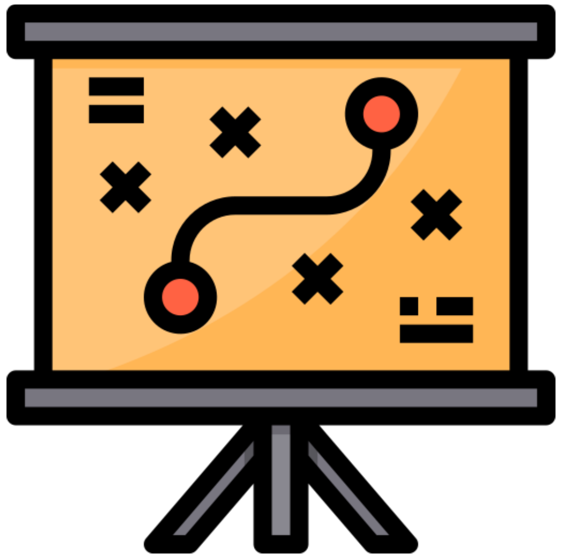
Idea is: When the idea is informed to any one of the core node, (as it is dense and connected to more nodes) it soon spreads to all the network.

Ok, that's fine. If given a core and periphery in a network.

But, what if given some network and asked to distinct the core and periphery..?



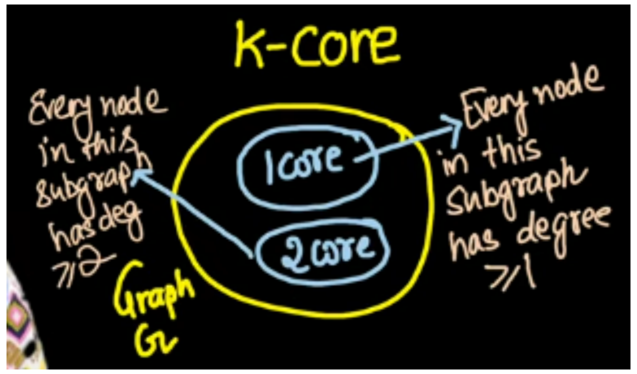
An approach..



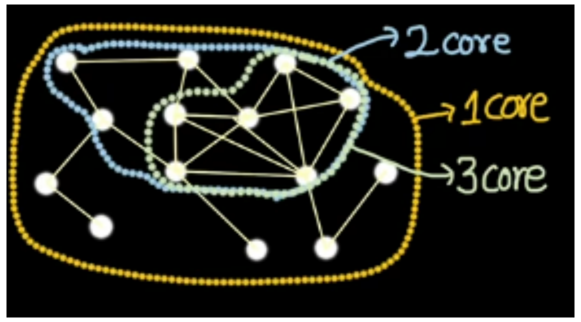
A help of a simple math definition..

K-Core:

> A sub-graph of a graph, having `>=k` degree for every node. Ex: if had `>=2` as degree for every node in a sub-graph its the 2-core.

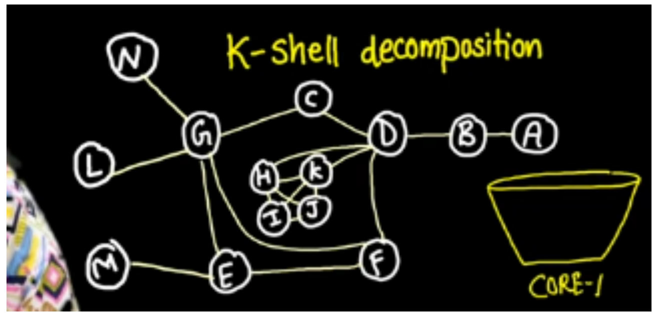


Answer..

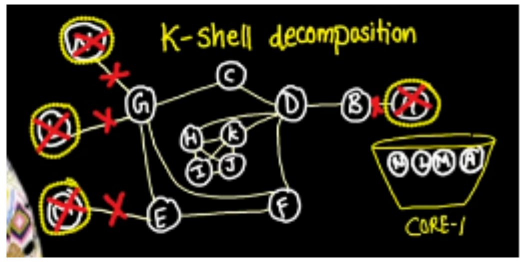


-- its fine, for a small network

K-Shell Decomposition algorithm

Consider the below network... For sometime, consider them as Balls. 

-- the bucket is used to hold all the balls having `1-degree` -- ONLY 1 friend. (Pendent nodes) and place them in the bucket..

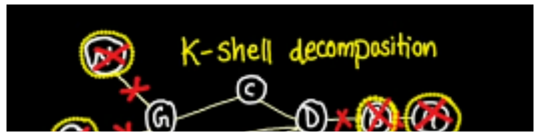


NOTE: When removed a node, all the edges attached to it are also removed.

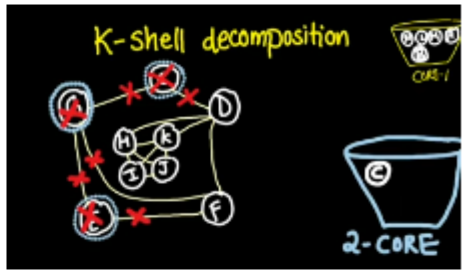
Have you noticed something..??

> When removed an node with degree-1, another node having degree-2, will now become degree-2, right....???
> So, if removed some balls, new balls emerge out of that or less degree.

As per example, now **B** becomes degree-1 after removal of **G**, so place even that in the bucket.

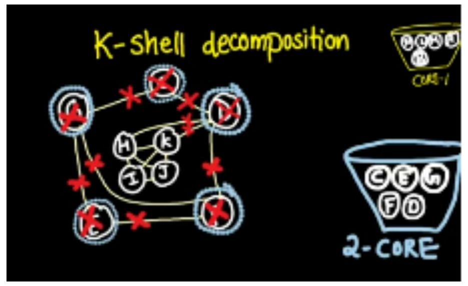


Now, get the fresh bucket, and label as degree-2_Core.



, first removed **C** and **E**, which made **G**, of degree-2, so even made ready to remove.

Now,.. have you noticed one thing, now we also got a ball of degree-1.. Look at **F**.
What should one do about it..?? -- in core-1 bucket or core-2 bucket..??

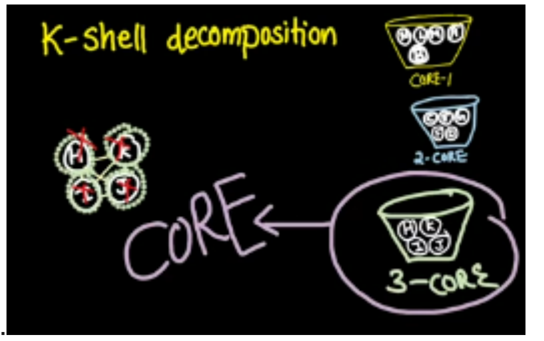
> in the bucket of core-2. i.e., all the balls of degree <=2, should go to its bucket only. So, it looks like: 

For degree-3..

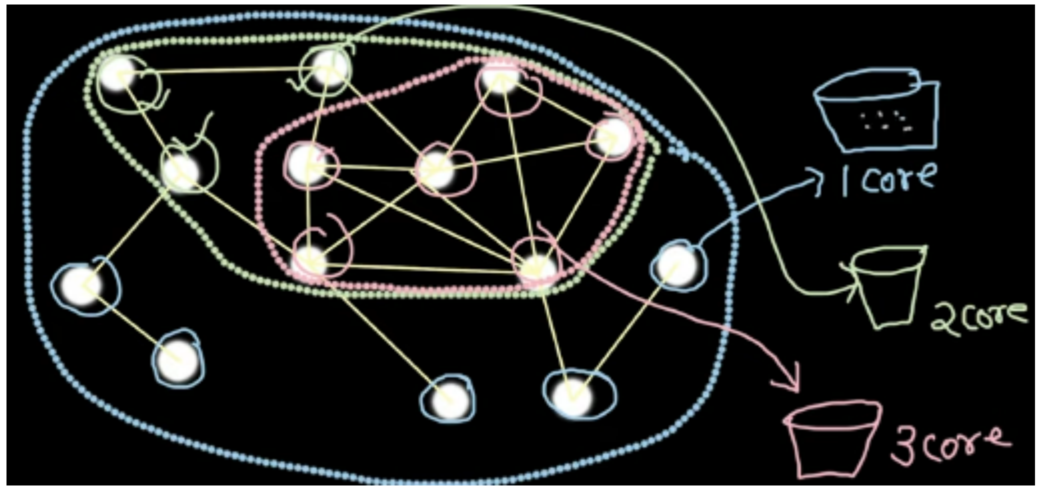
...

Repeat the process, until no node is left in the network.

but, how can this algorithm give the **Core of the network..??**

> The last bucket which got filled, is the core. Here its 3rd...
> 
>

Now, looking at the earlier example....with the **k-shell decomposition**...



Recollect the definition of the **K-core**.

> the nodes which are having `>=` k belongs to **K-core**.
>
> ---
>
> Hence, for the K-shell decomposition algorithm..

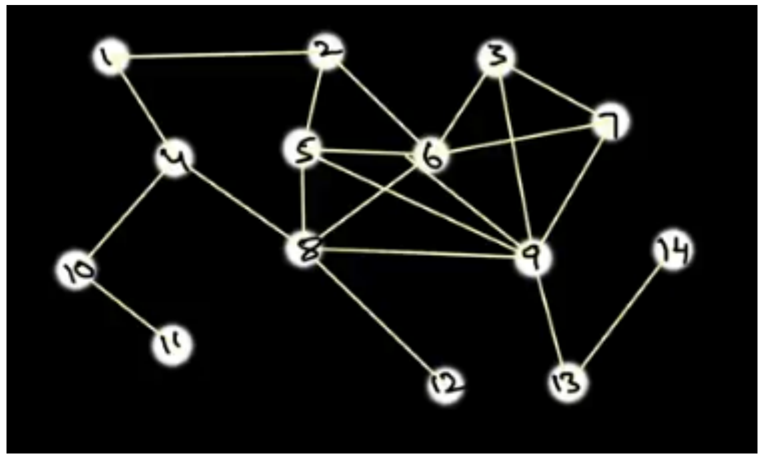
> 
>

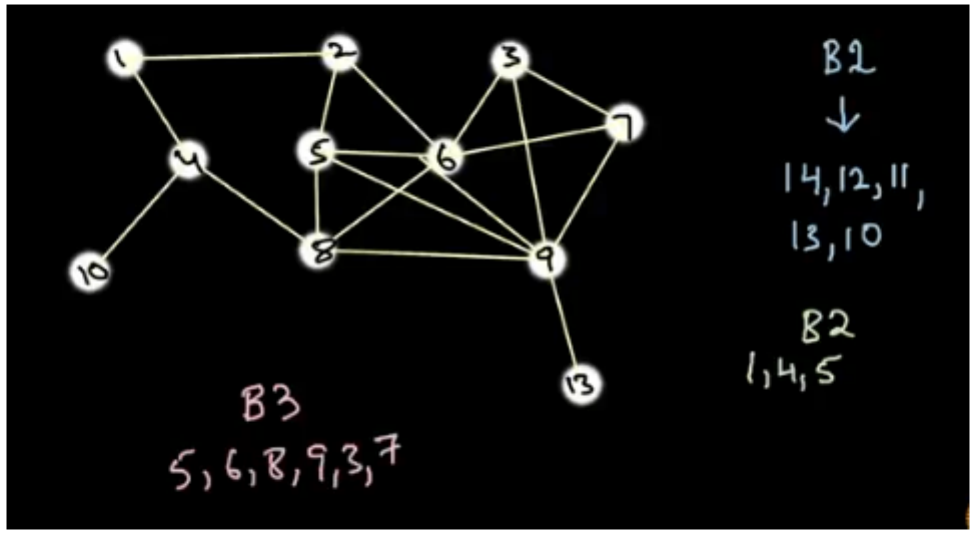
i..e, if need 1 core, we can't take it simply that bucket, need to take all the higher buckets.


Have you observed,..??

> To get any one of the core, one needs to calculate all the cores.
>
> ---
>
> How..??
>
> - Say if needed the lowest degree one (say, 1), then for that need to calculate all the higher ones right..
> - If of any node's degree >=1 or the highest one for the case, need to calculate the below ones to arrive at there right..??.

Module-13: **Coding K-Shell Decomposition**

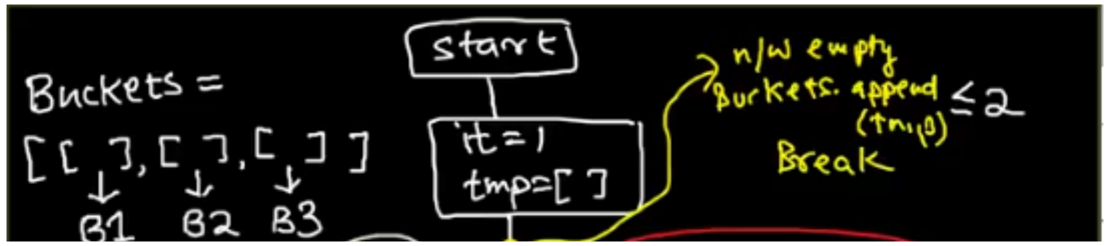
Look at the example, and try solving it...


Solution: 

How do we write code for it... before getting into it, lets look at the structure..

- **buckets**: list of lists, each corresponding to a bucket of spefific degree.
- **it**: at any instant of the code, it holds, which degree nodes are being removed.
- **temp**:it holds one bucket at one time (temporarily)
  - It is filled as long as there are some elements with that degree, and when the point reached, where there are no more nodes of degree `<=k` and appended to the **`Buckets`**

Flowchart of the algorithm..



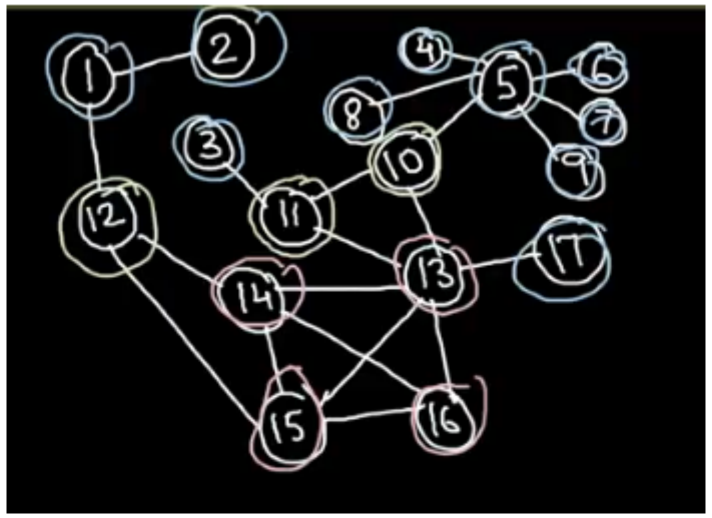
In [10]:

```python
def check_degree_existence(G, degree):
    group = []
    for node in G.nodes():
        if G.degree(node) <= degree:
            group.append(node)              # When  found a node with matching criteria, send that node..
    return group if len(group) != 0 else False                                  # Send false, when couldn't able to find a node having degree<= passed_degree
```

In [11]:

```python
def find_max_degree(G):
    max_degree=0
    for node in G.nodes():
        if max_degree < G.degree(node):
            max_degree = G.degree(node)

    return max_degree
```

In [16]:
```
def k_shell_decomposition(G):
    buckets    = []
    tmp_bucket = []  # temp
    curr_degree= 1   # it
    max_degree = find_max_degree(G)
    tmp_node   = -1

    while(G.number_of_nodes() >= 1):      # Run, as long as there are some nodes in the graph..
        #if curr_degree <= max_degree:        -- this condition doesn't matter
        group = check_degree_existence (G, curr_degree)
        if group != False:   # If found a node meeting <= degree..
            for node in group:
                G.remove_node(node)       # Prune the node
                tmp_bucket.append(node)   # Add it to working bucket..

        else:                              # When no such nodes found matching the crteria.. by now the working bucket would have got filled...
            buckets.append(tmp_bucket)        # Store the filled bucket
            tmp_bucket = []                   # Set it back to empty, as to hold new nodes
            curr_degree += 1                  # As done with the a degree, its time to go for next degree.
    else:                                      # When control comes here, tmp_bucket still holds some nodes which are to be stored..
        buckets.append(tmp_bucket)                # Store it

    return buckets
```

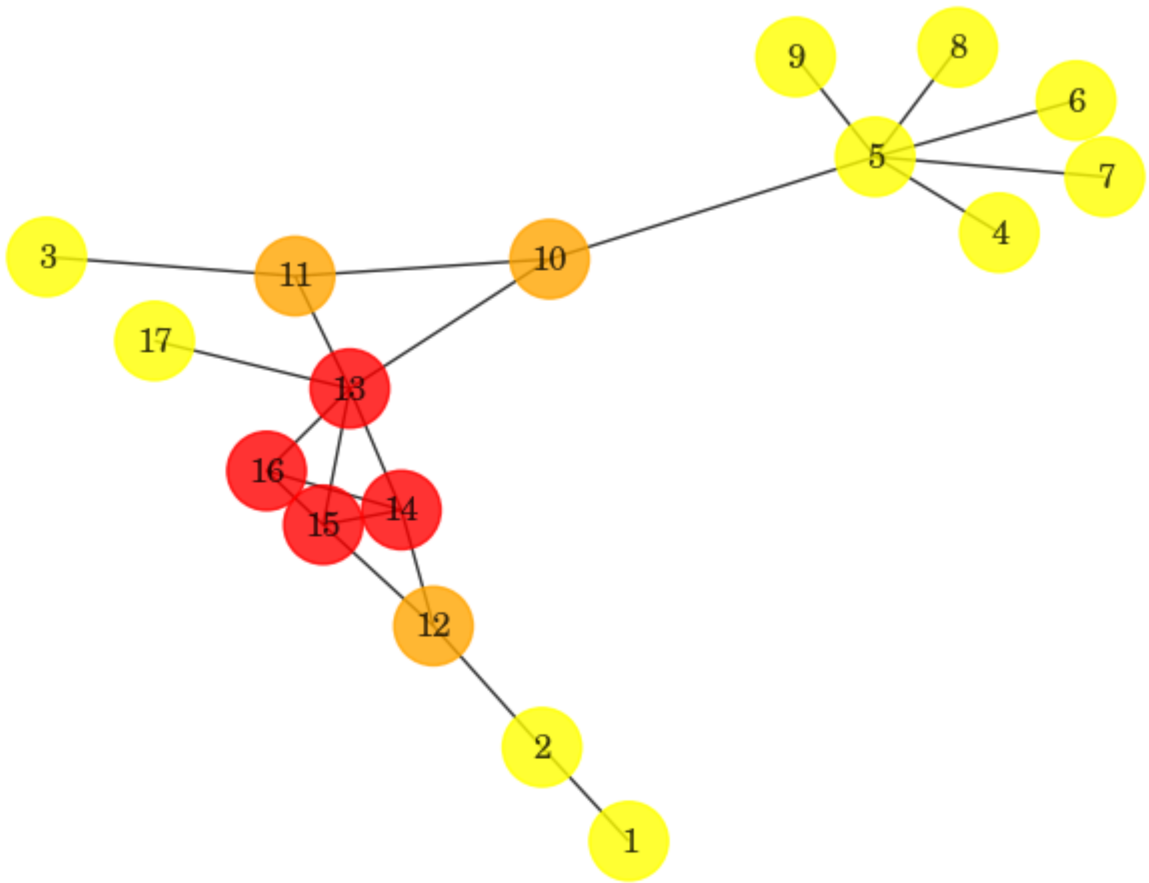


A Modal network..

In [28]:

```
import networkx as nx
import matplotlib.pyplot as plt

G = nx.Graph()   # Create a graph..
G.add_edges_from([(1, 2), (2, 12), (3, 11), (4, 5), (5, 6), (5, 7), (5, 8), (5, 9), (5, 10), (10, 11), (10, 13), (11, 13), (12, 14), (12, 15), (13, 14), (13, 15), (13, 16), (13

H = G.copy()
shells = k_shell_decomposition(G)
print(shells)
colors = []

for node in H.nodes():
    if node in shells[0]:
        colors.append('yellow')
    elif node in shells[1]:
        colors.append('orange')
    else:
        colors.append('red')

nx.draw(H, with_labels=True, node_color=colors, node_size=800, alpha=0.8, font_family="c059")
plt.show()
#print(k_shell_decomposition(G))
```

```
[[1, 3, 4, 6, 7, 8, 9, 17, 2, 5], [12, 11, 10], [13, 14, 15, 16]]
```

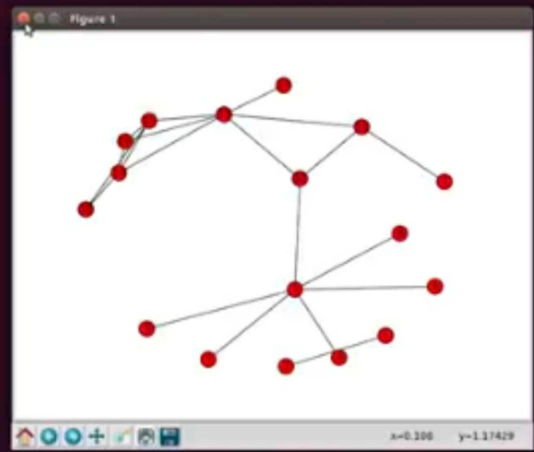


```
import networkx as nx
import matplotlib.pyplot as plt

def check_existence(H,d):
        f=0     #there is no node of deg <=d
        for each in G.nodes():
                if H.degree(each)<=d:
                        f=1
                        break
        return f

def find(H,it):
        set1=[]
        for each in H.nodes():
                if H.degree(each)<=it:
                        set1.append(each)
        return set1
```

```
                if H.degree(each)<=it:
                        set1.append(each)
        return set1

G=nx.Graph()
G.add_edges_from([(1,2),(3,11),(4,5),(5,6),(5,7),(5,8),(5,9),
(5,10),(10,11),(10,13),(11,13),(12,14),(12,15),(13,14),(13,15),
(13,16),(13,17),(14,15),(14,16),(15,16)])

H=G.copy()
it=1
tmp=[] #for the bucket being filled currently
buckets=[]#list of lists(buckets)
while(1):
        flag=check_existence(H,it)
        if flag==0:
                it = it +1
```

```
while(1):
        flag=check_existence(H,it)
        if flag==0:
                it = it +1
                buckets.append(tmp)
                tmp=[]  #start with a fresh bucket
        if flag==1:
                node_set=find(H,it)
                for each in node_set:
                        H.remove_node(each)
                        tmp.append(each)
        if H.number_of_nodes()==0:
                buckets.append(tmp)
                break
print buckets
nx.draw(G)
```

```
yayati@yayati-Vostro-3546:~$ python kshell.py
[[1, 2, 3, 4, 6, 7, 8, 9, 17, 5], [10, 11, 12], [13, 14, 15, 16]]
```



Module-14: **Coding cascading Model**

Our next aim: **finding the influential pair of nodes** https://youtu.be/jHgNv8_qhcshttps://youtu.be/jHgNv8_qhcshttps://youtu.be/jHgNv8_qhcshttps://youtu.be/jHgNv8_qhcshttps://youtu.be/jHgNv8_qhcs

If it was of:

- with more technical terms and critical concepts --- go verbatim way
- For simple conceptual based, just take-down the key-ideas and catching examples.