Introduction

Network Science (I606)

Course description

Networks pervade all aspects of our lives: networks of friends, communication, computers, the Web, and transportation are examples we experience, while our brain cells and the proteins in our body form networks that determine our survival and intelligence.

The network is a general yet powerful way to represent and study simple and complex relationships. This course explores the study of networks and how they help us understand the complex patterns of connections and relationships that shape our lives.

Through examples from popular social and information networks, students learn about key aspects of networks and basic tools to analyze and visualize them.

Course objectives

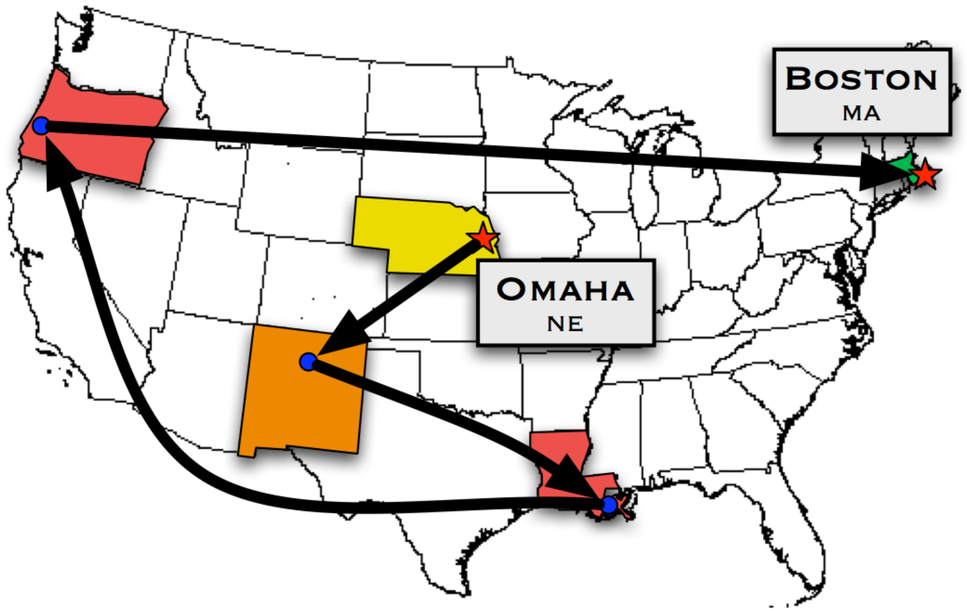
- Learn essential concepts and core ideas of network literacy
- Acquire skills to load, manipulate, export, visualize and analyze networks using tools and programming languages such as Python/NetworkX and Gephi
- Recognize and describe a network's structural components and properties (nodes, links, degree, connectivity, sparsity, paths, etc.)
- Measure various centrality measures and their distributions, and apply them to detect important nodes and characterize their roles in the network
- Quantify network homophily and clustering and explain how they arise in different systems
- Describe dynamic processes on networks, such as the spread of diseases, information, opinions, rumors
- Learn basic models of network formation
- Learn and apply algorithms for detecting communities in networks
- Demonstrate the networks algorithms used by search engines to crawl and rank Web pages
- Appreciate the broad relevance of network science to domains and applications such as biology, business, AI, search, recommendation, social media

Network phenomena: Epidemic spreading

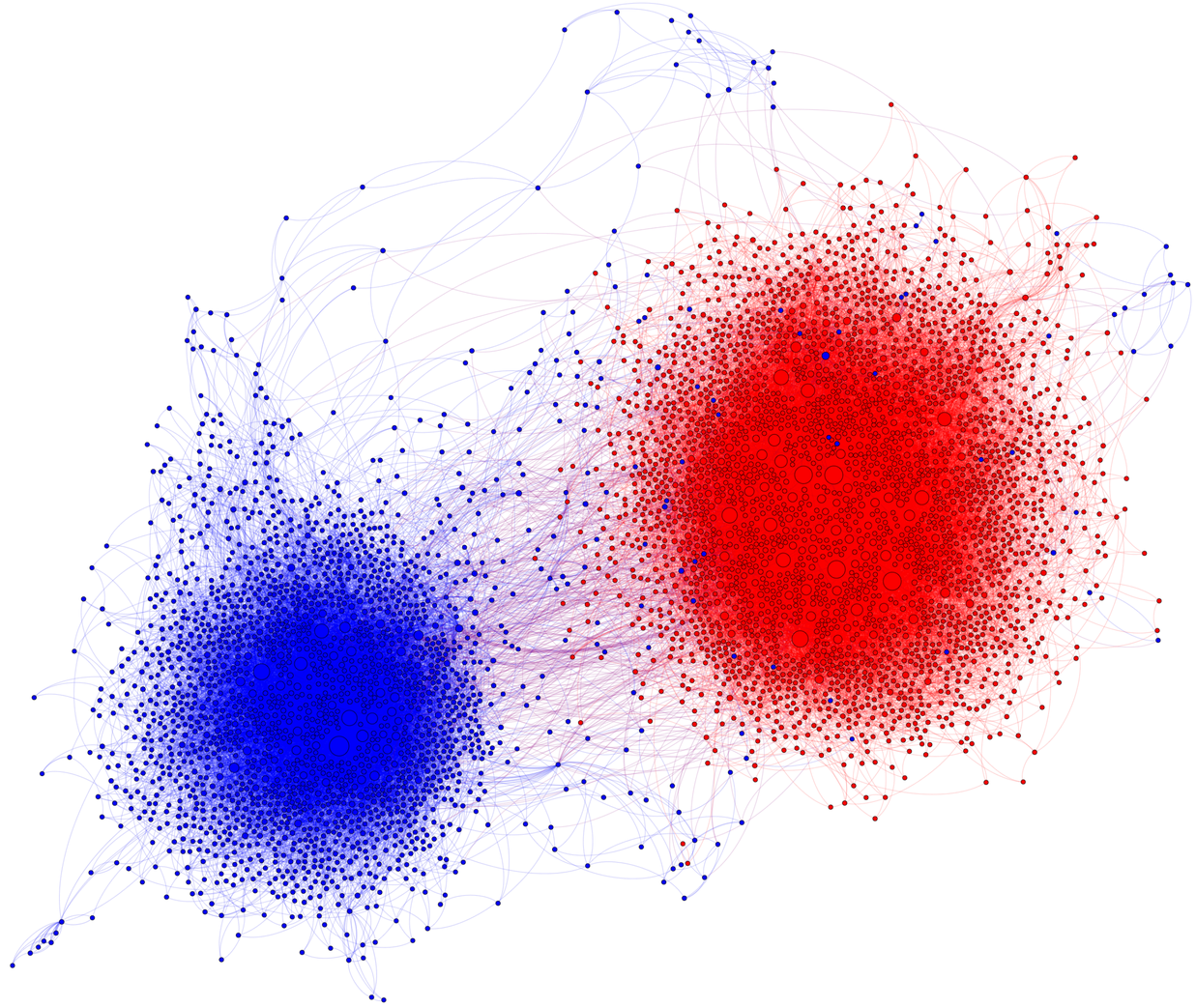
Network phenomena: Google

Google Search I'm Feeling Lucky

Network phenomena:
Six degrees of separation



Network phenomena: Echo chambers



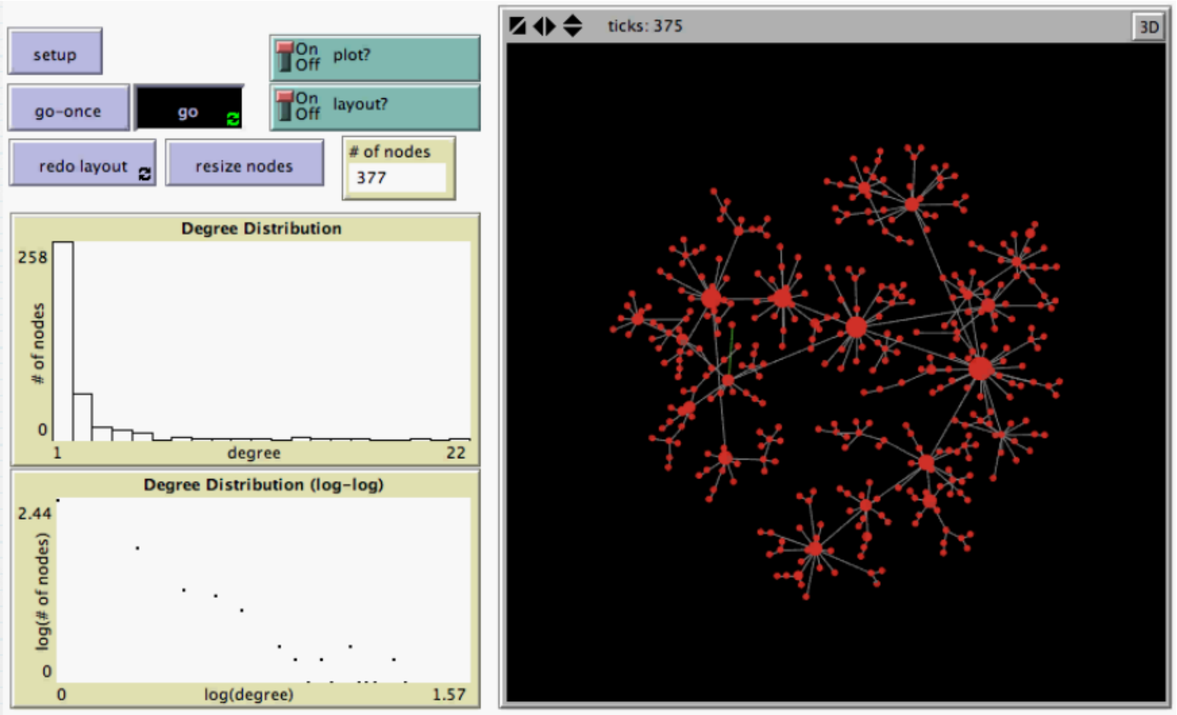
Software

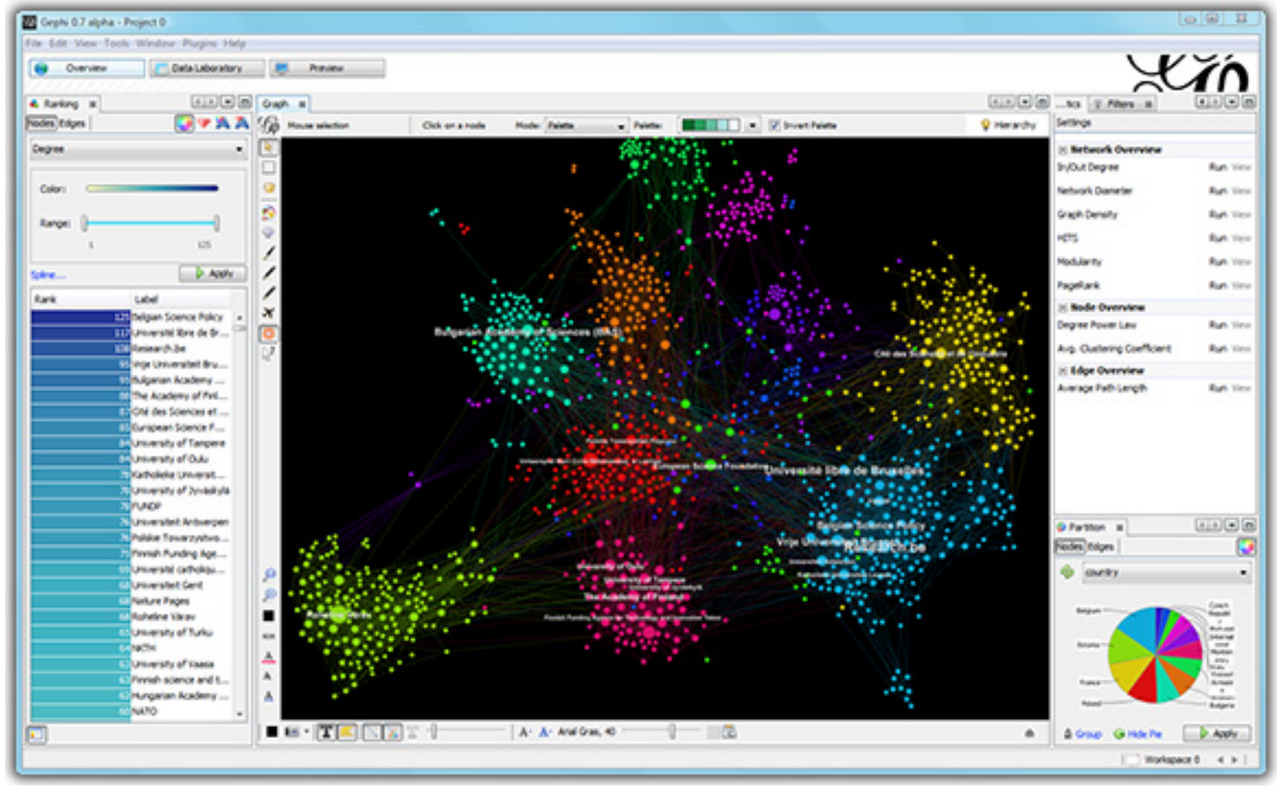
We will be using Python and the NetworkX (networkx.readthedocs.org) module. You can follow one or both of two approaches:

1. There are currently several free services to run Jupyter notebooks in the cloud, including:
   - Google Colab (colab.research.google.com)
   - Binder (mybinder.org)
   - Kaggle Kernels (www.kaggle.com/kernels)
   - Azure Notebooks (notebooks.azure.com)
   - Datalore (datalore.io)
   - Gryd (gryd.us)
2. If you wish to run Python locally on your laptop, and don't have Jupyter/IPython installed on your machine, we recommend installing the Anaconda Python 3 distribution (www.anaconda.com/distribution). We do not recommend other distributions. This option requires that you are comfortable with managing software packages (i.e., using `pip` or `conda`).

Be warned: each cloud-based notebook service has pros and cons and we cannot test them all extensively, so your mileage may vary. You may have to try more than one solution, read documentation, and/or seek support from the providers to install packages. Local Python installations can present issues, especially on Windows machines. Packages are system dependent. Instructors may be unable to provide support.

Other software

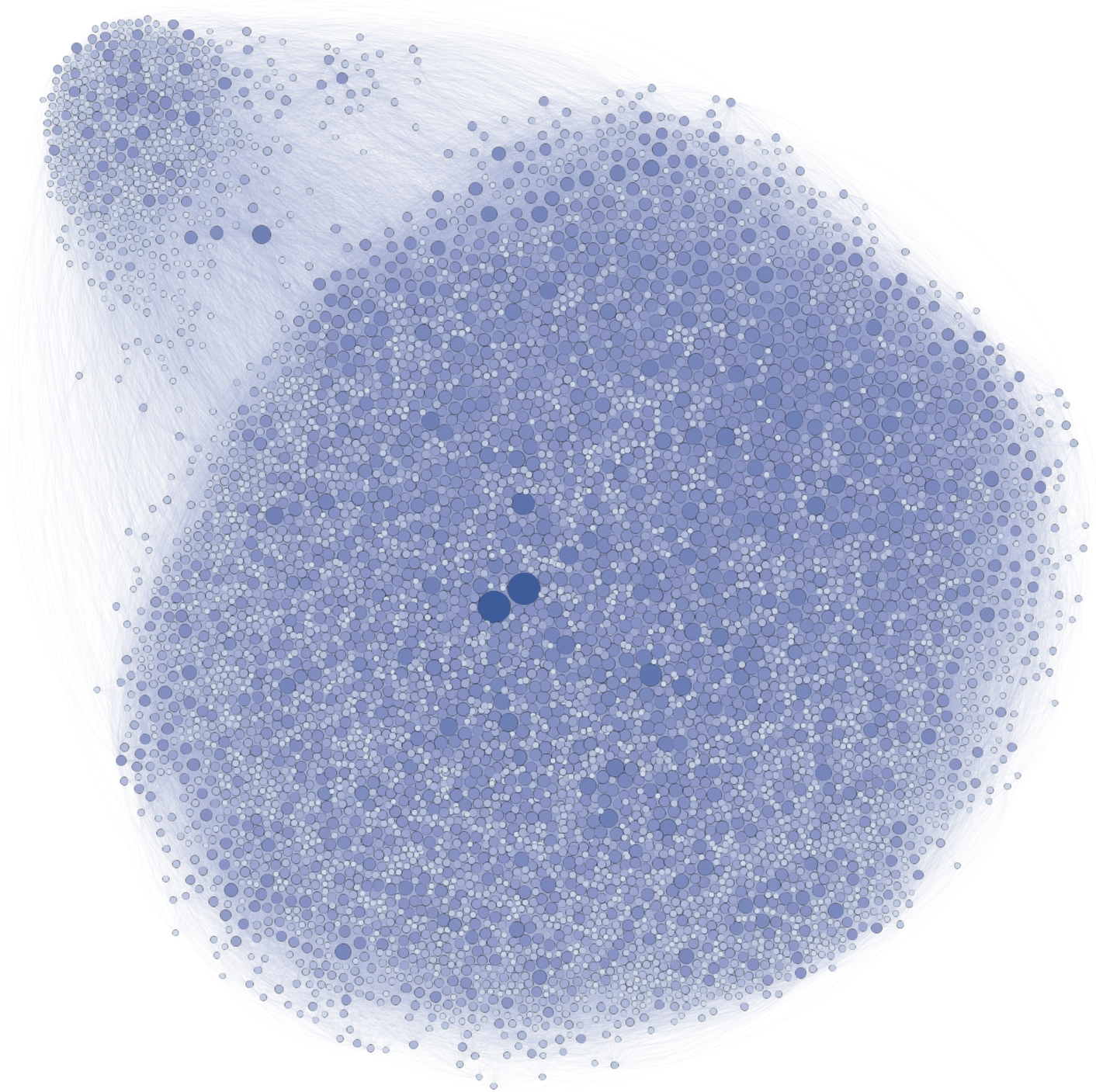


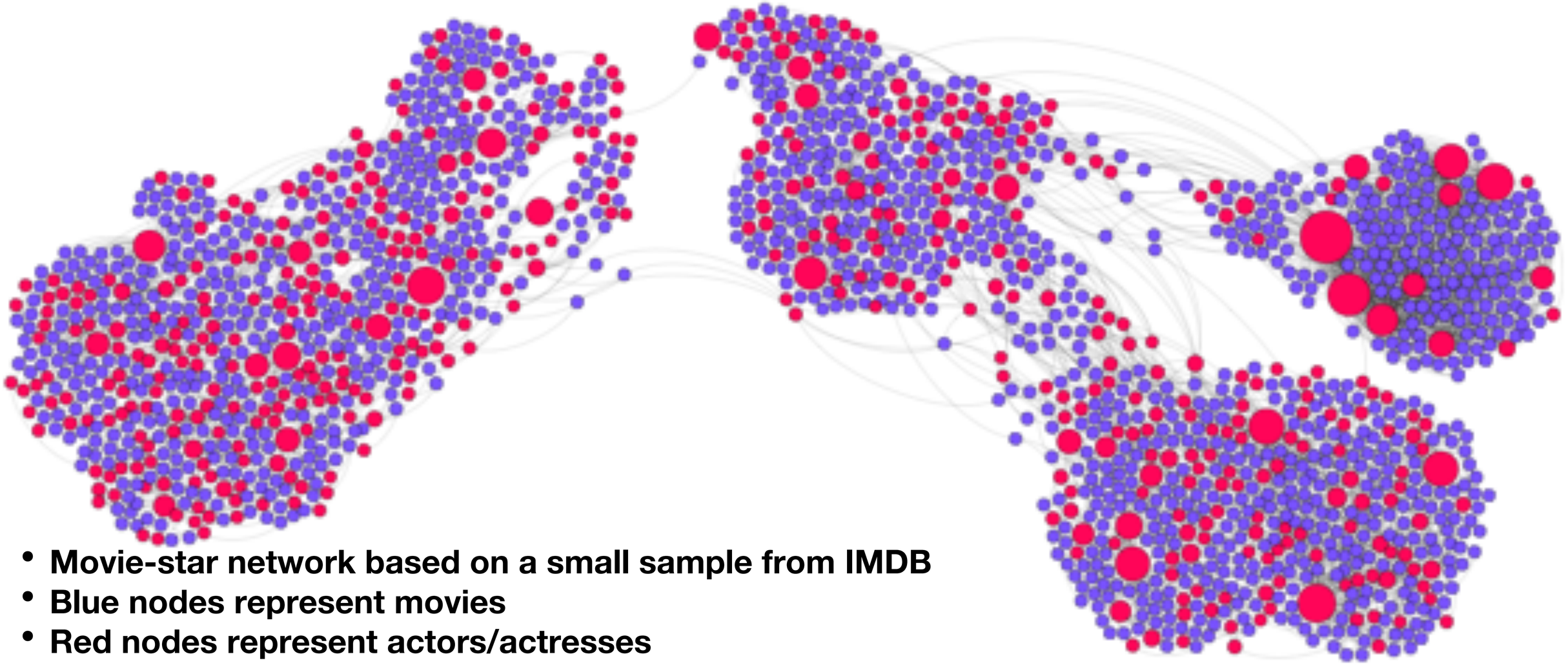


- Gephi (gephi.org)
- NetLogo (ccl.northwestern.edu/netlogo)

Network gallery

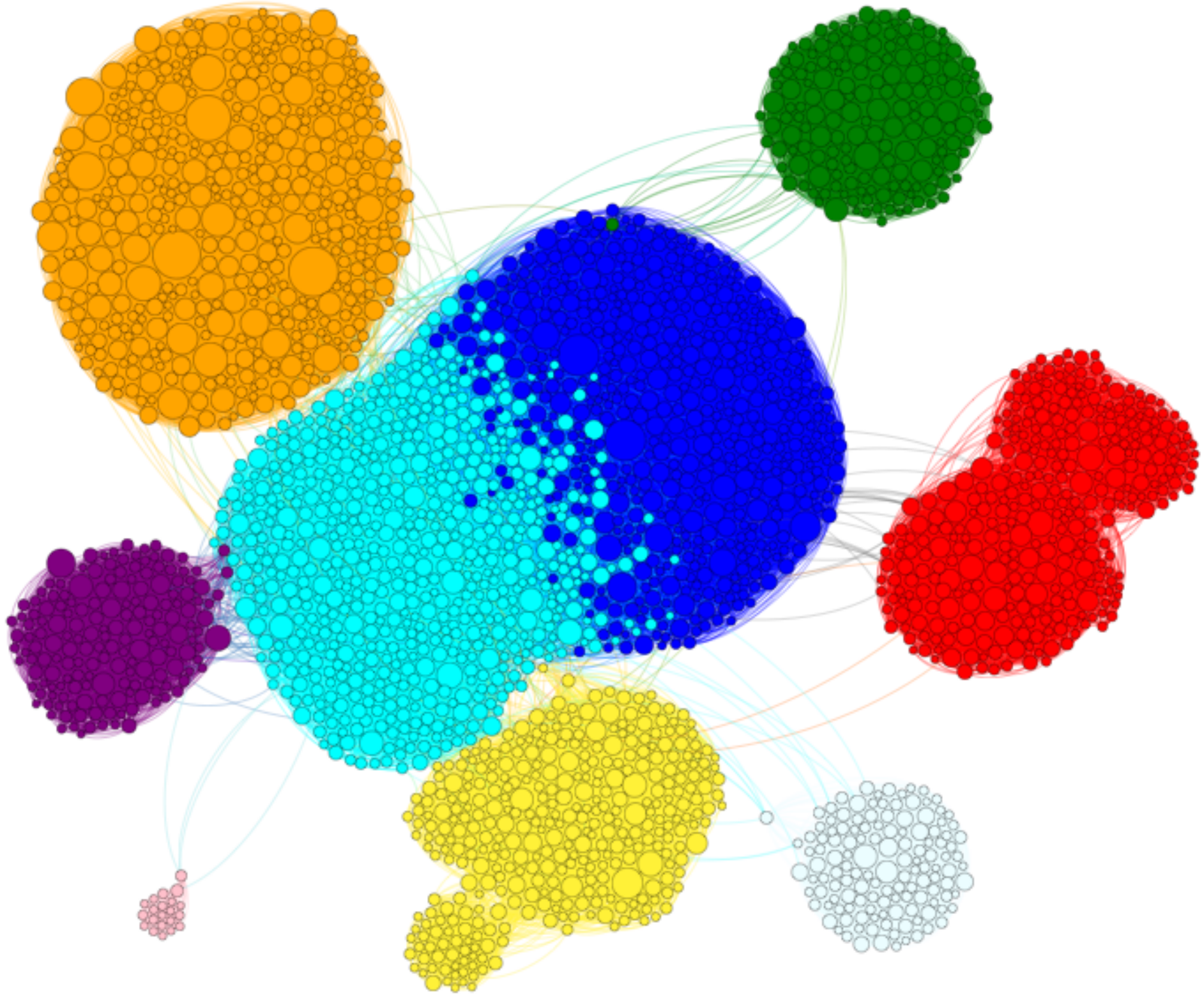
- Facebook users at Northwestern University
- What do nodes represent?
- What do links represent?
- Do links have direction?
- Do links have weights?
- Larger, darker nodes have more connections; what does that represent?
- What do the two clusters tell us?



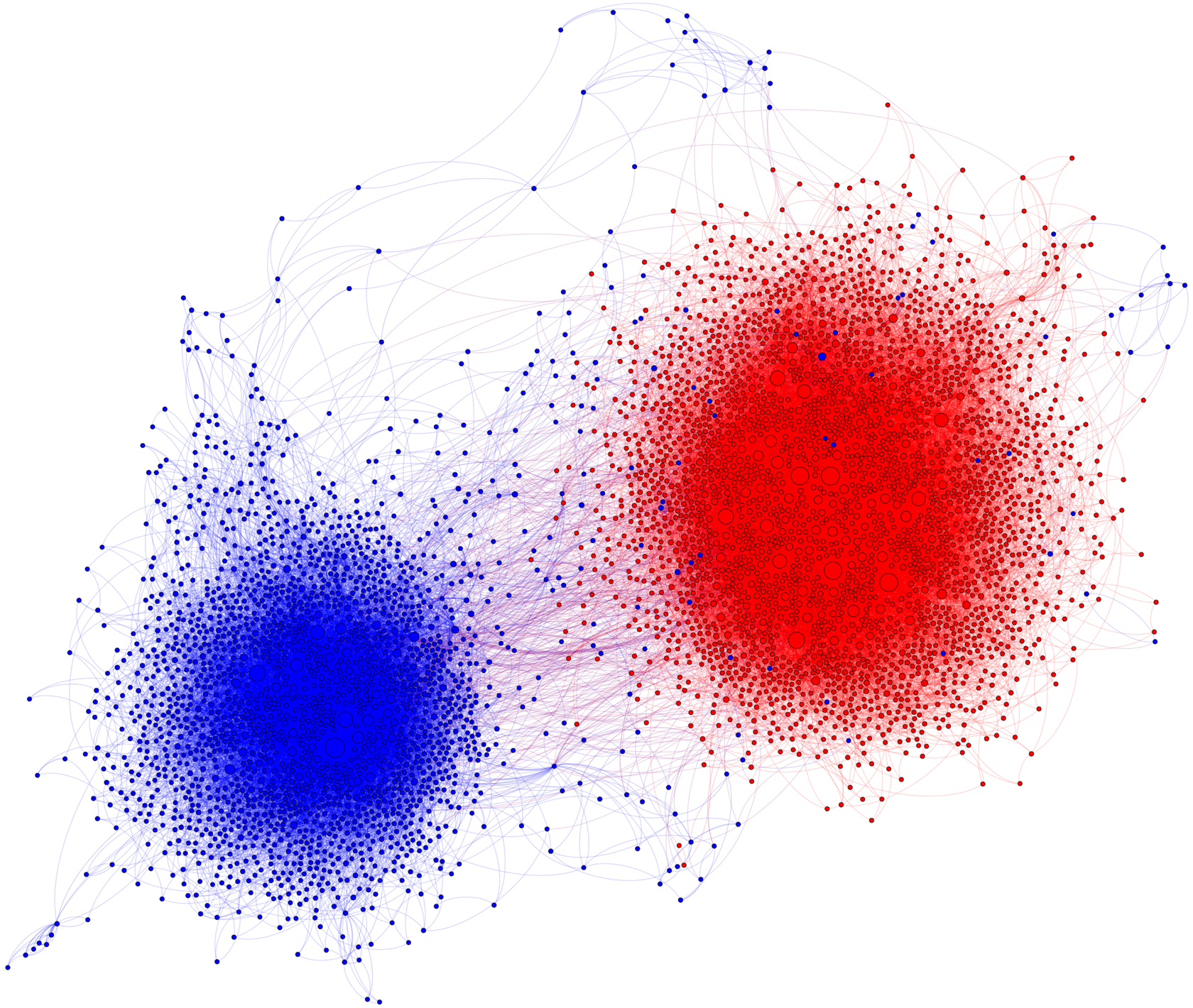


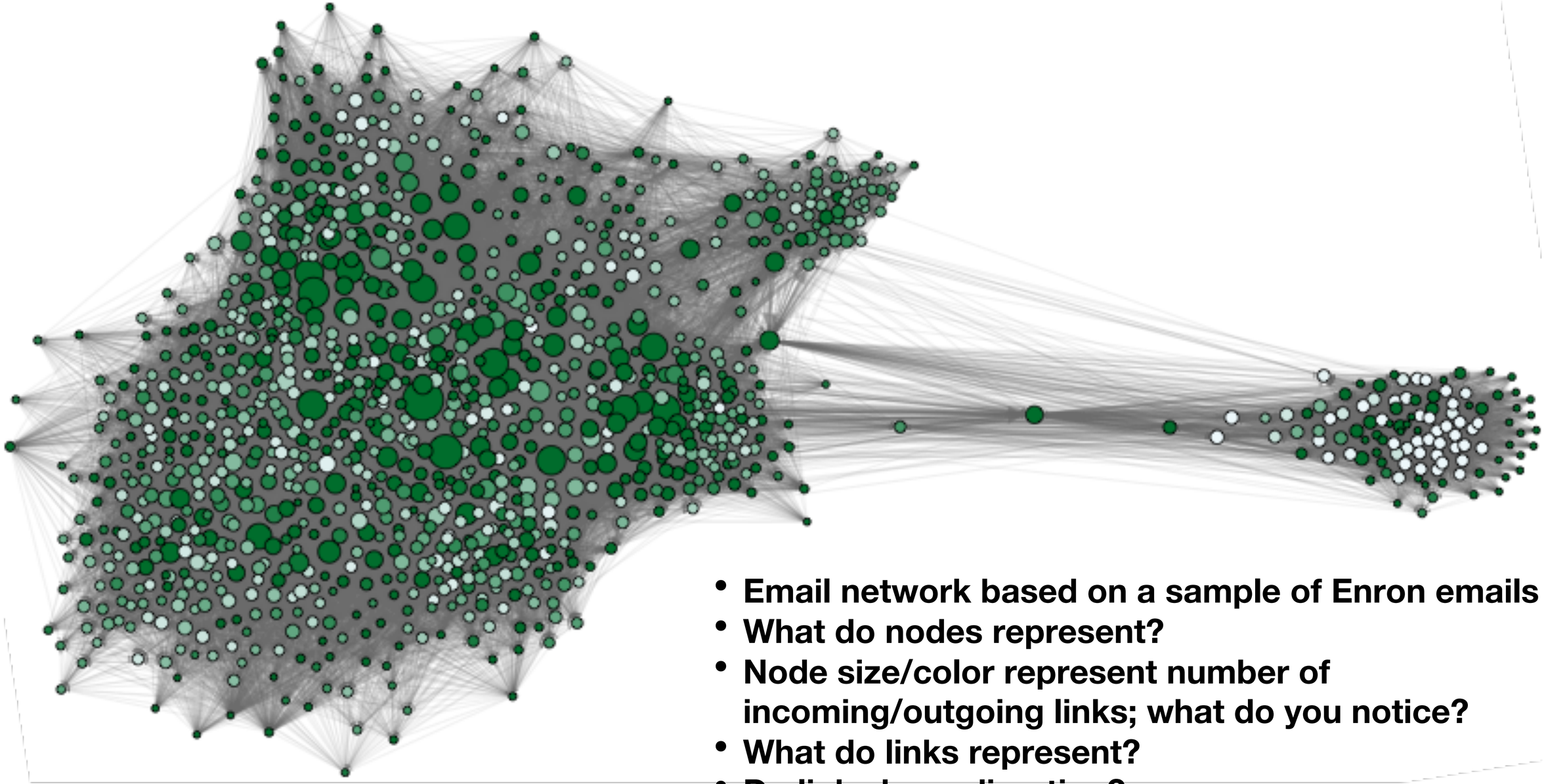
- Movie-star network based on a small sample from IMDB
- Blue nodes represent movies
- Red nodes represent actors/actresses
- What do links represent?
- Do links have direction?
- Do links have weights?
- Larger nodes have more connections; what does that mean?
- What do the clusters represent?

- Movie co-star network based on a small sample from IMDB
- What do nodes represent?
- What do links represent?
- Do links have direction?
- Do links have weights?
- Larger nodes have more connections; what does that mean?
- What do the clusters represent?

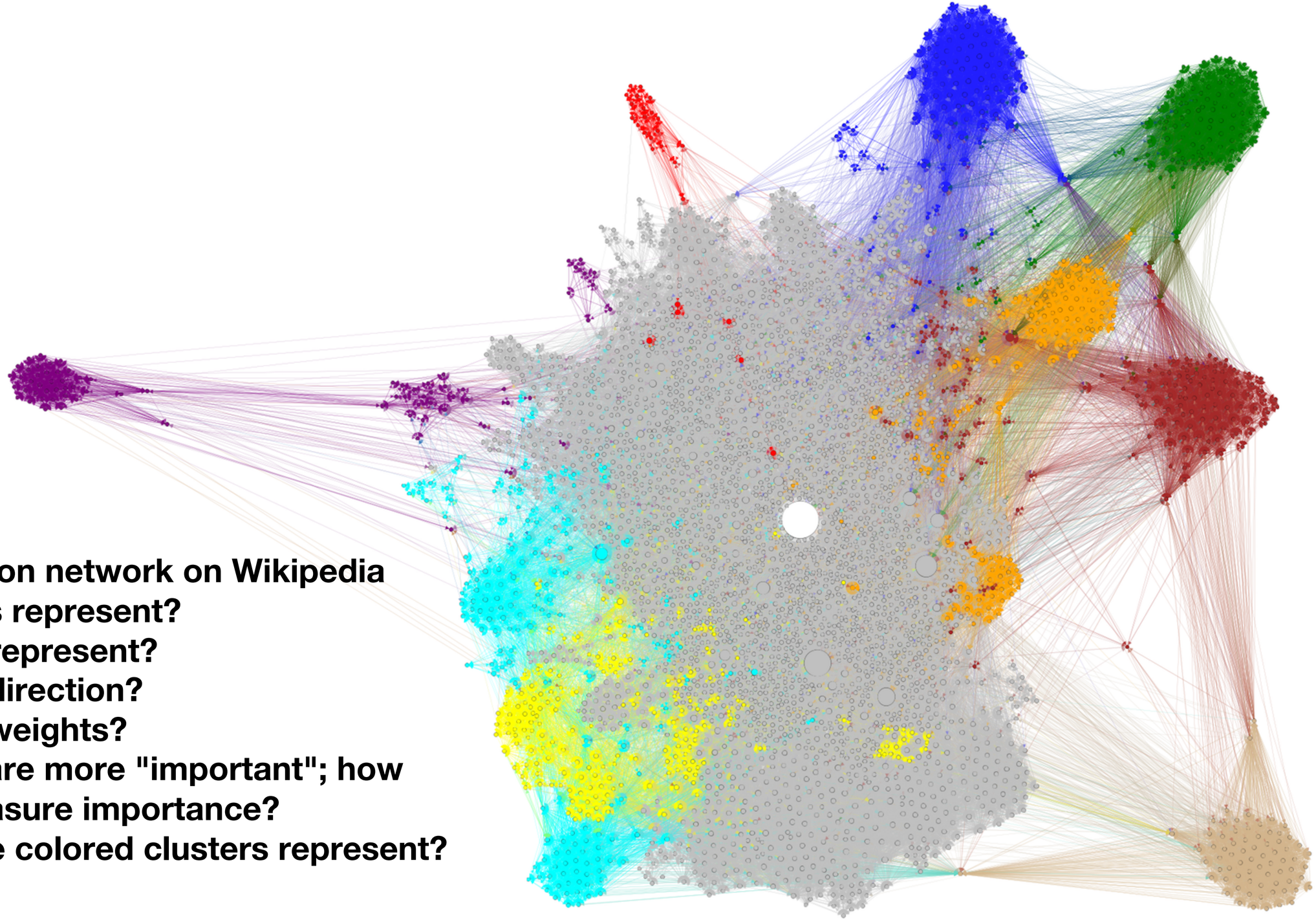


- Retweet network on Twitter, based on political posts during 2010 US election
- What do nodes represent?
- What do links represent?
- Do links have direction?
- Do links have weights?
- Larger nodes have more connections; what does that mean?
- What do the clusters and colors represent?



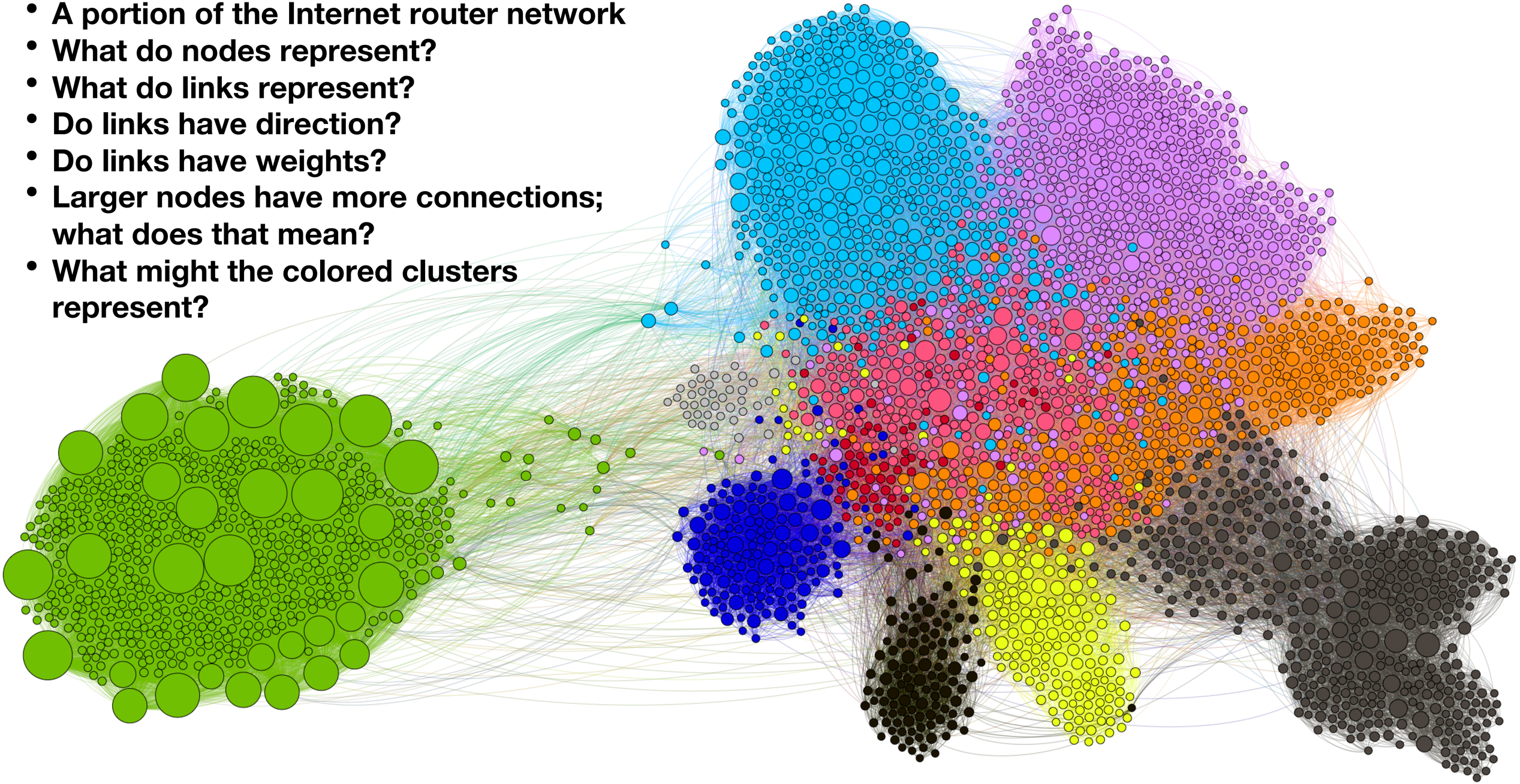


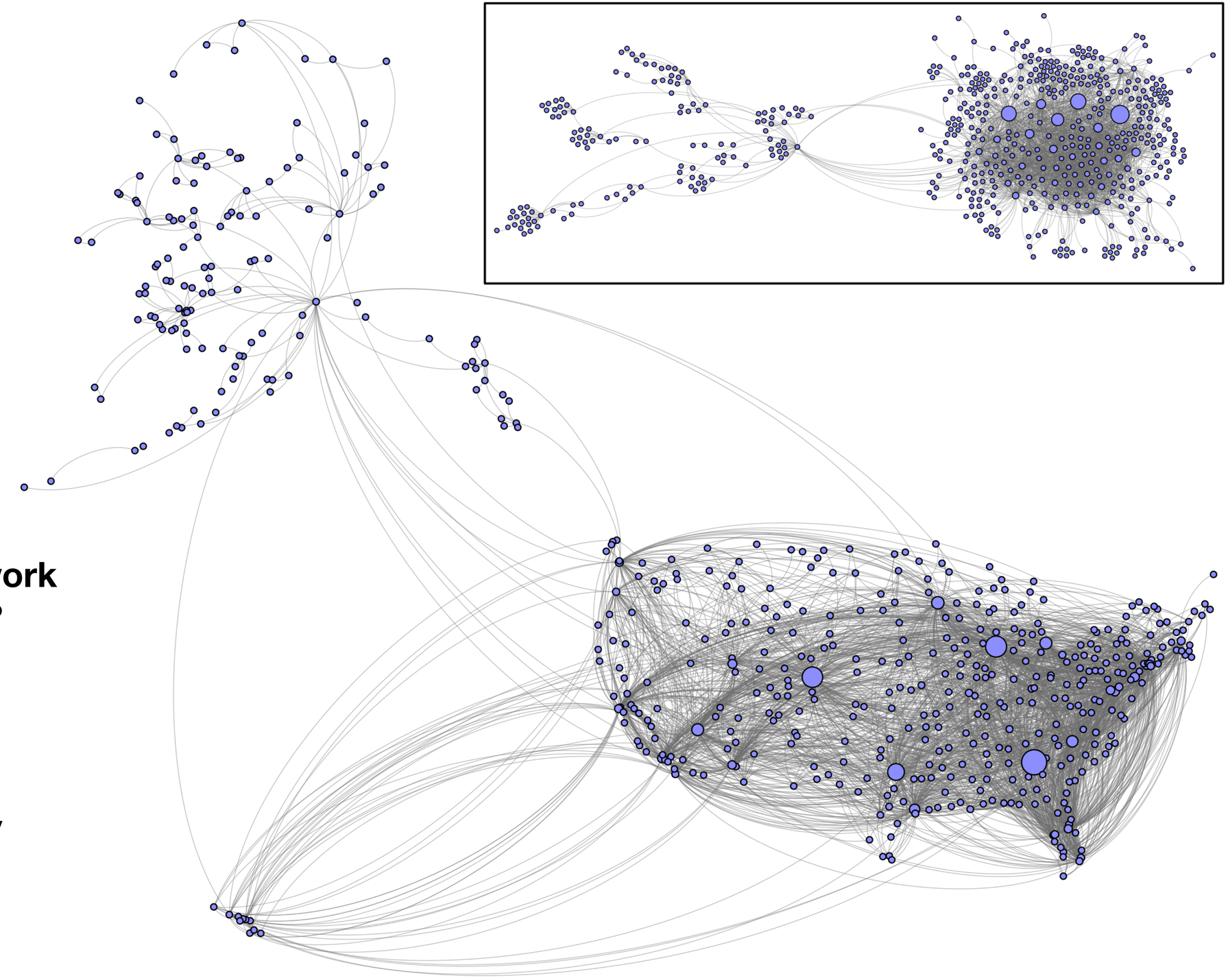
- Email network based on a sample of Enron emails
- What do nodes represent?
- Node size/color represent number of incoming/outgoing links; what do you notice?
- What do links represent?
- Do links have direction?
- Do links have weights?
- What do the clusters represent?



- Math information network on Wikipedia
- What do nodes represent?
- What do links represent?
- Do links have direction?
- Do links have weights?
- Larger nodes are more "important"; how would you measure importance?
- What might the colored clusters represent?

- A portion of the Internet router network
- What do nodes represent?
- What do links represent?
- Do links have direction?
- Do links have weights?
- Larger nodes have more connections; what does that mean?
- What might the colored clusters represent?

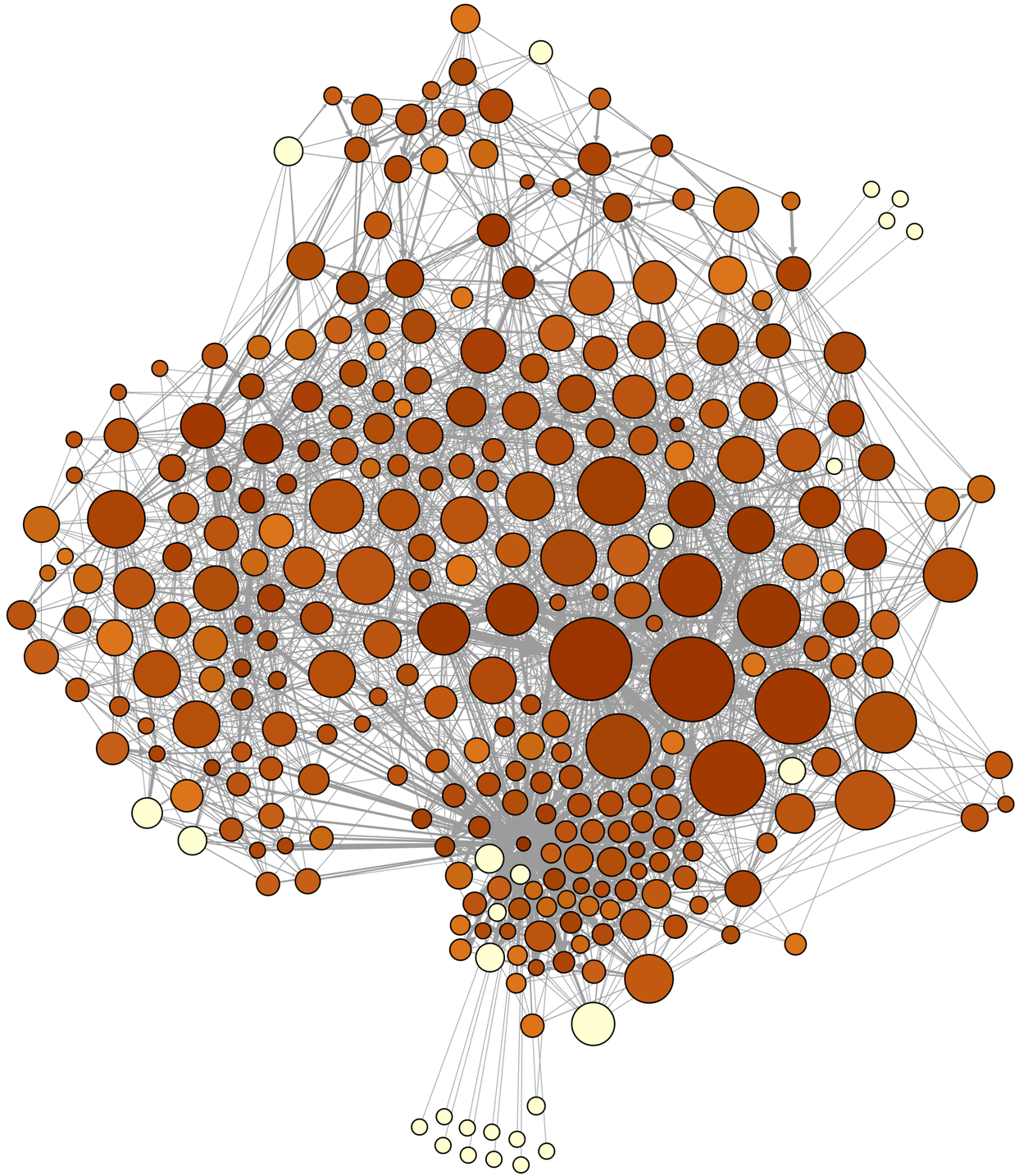


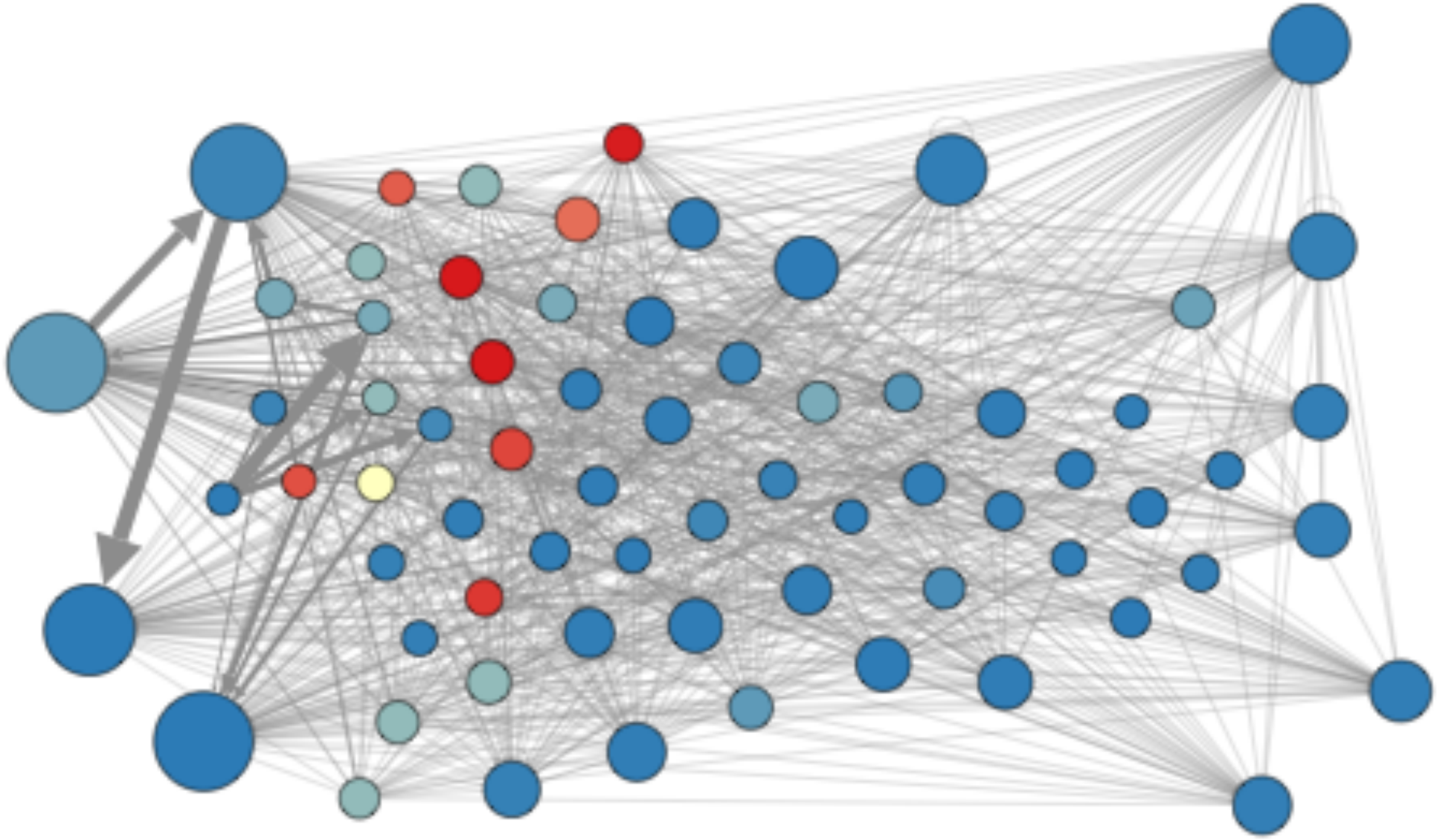


- US air transportation network
- What do nodes represent?
- What do links represent?
- Do links have direction?
- Do links have weights?
- Larger nodes have more connections; what do they represent?

- Protein interaction network of yeast
- What do nodes represent?
- What do links represent?
- Do links have direction?
- Do links have weights?
- Larger nodes have more connections; what does that mean?
- What do the clusters represent?

- Neural network of the roundworm c. elegans
- What do nodes represent?
- What do links represent?
- Do links have direction?
- Do links have weights?
- Larger/darker nodes have more outgoing/incoming connections; what does that mean?





- Food web of species in the Florida Everglades
- What do nodes represent?
- What do links represent?
- Do links have direction? What does it represent?
- Do links have weights? What do they represent?
- Larger nodes have more incoming links; what are they?
- Red nodes have more outgoing links; what are they?