Networked societies

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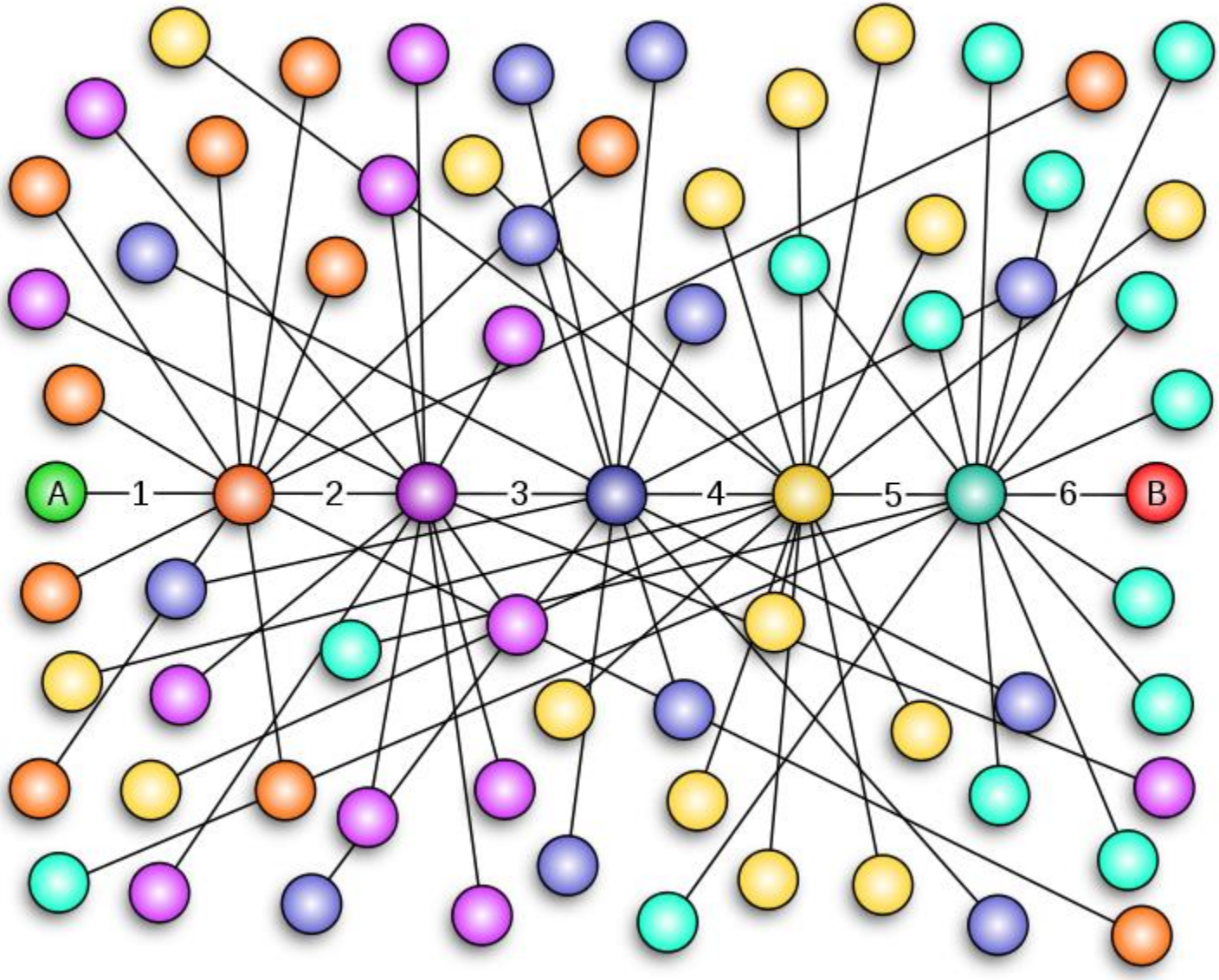


Source: https://en.wikipedia.org/wiki/Six_degrees_of_separation 2018/1/14

What is a network?

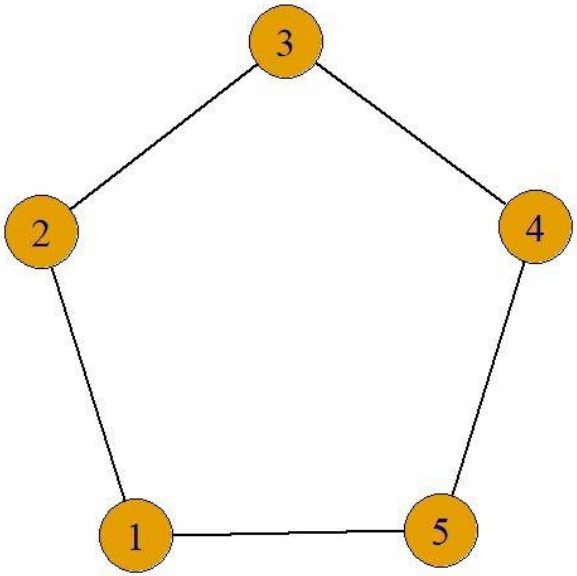
- A network is a collection of elements (usually referred to as nodes or vertices), that are connected by some type of relationship (called links or edges).
- Network Analysis allows for visualizing data and retrieving information from it that is not possible through other tools.
  - Which variables are having an indirect effect on others (such as in the case of externalities or influences).
  - Social learning and diffusion processes (diseases, goods, education effects, etc.)

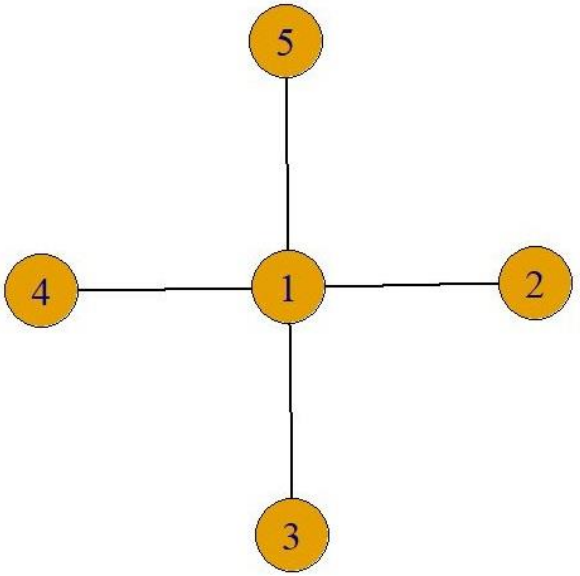
- Network structures appear in a great variety of contexts such as technology infrastructure, social phenomena and biological systems.
- Many relationships are “networked” and understanding network structures can help us recognize behaviors of the systems that networks represent.

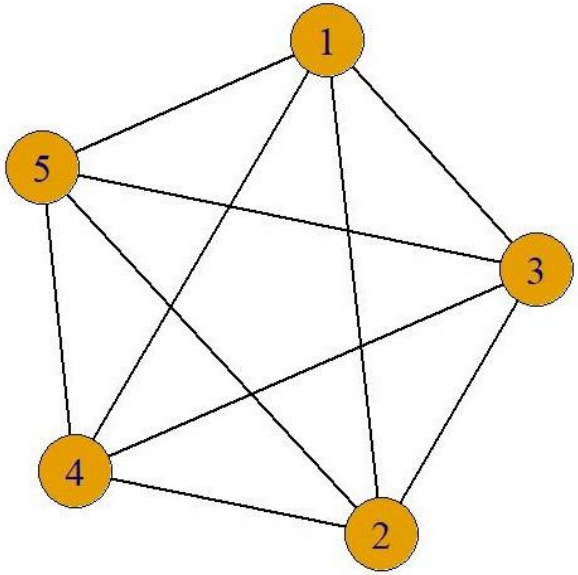
Network theory is an interdisciplinary field that takes tools from and is used in different areas of study such as:

- Sociology
- Physics
- Computer Science
- Economics
- Math (Graph theory)
- Biology

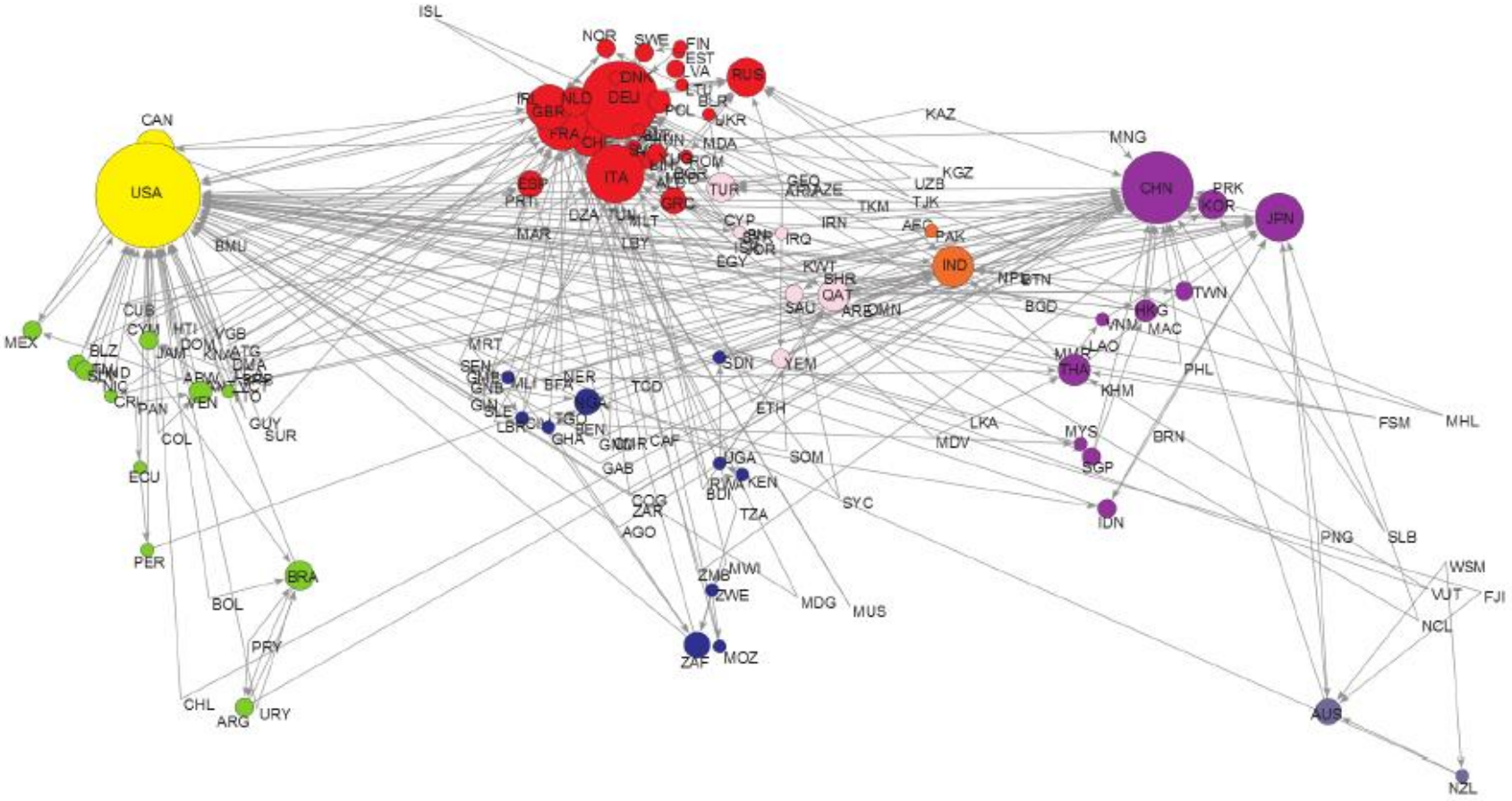
Examples of graphs







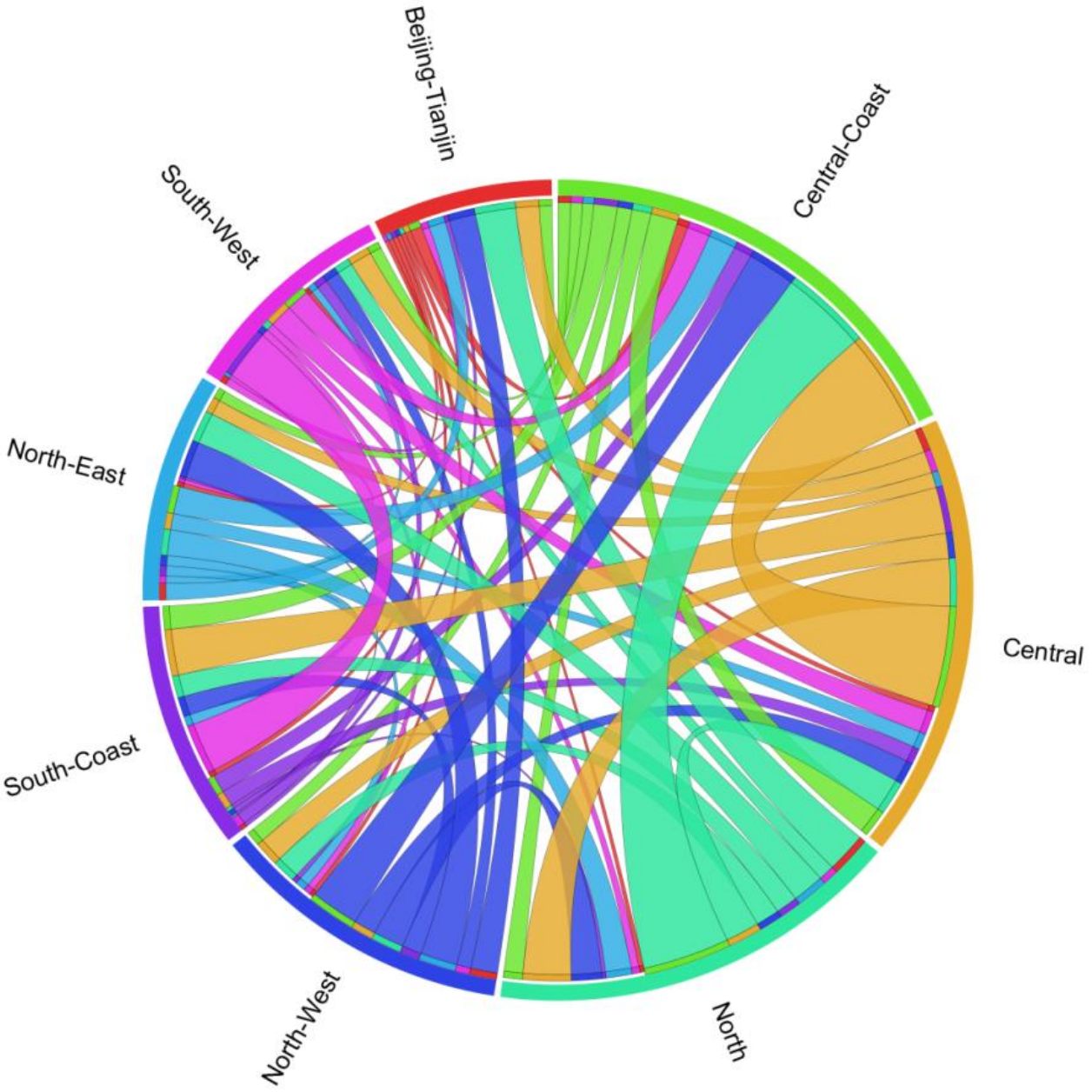
Map of World Trade in Goods as a Geographical Network (major two export partners,) 2007.



Source: De Benedictis et. al. (2011)

https://www.researchgate.net/figure/Map-of-World-Trade-in-Goods-as-a-Geographical-Network-major-two-export-partners-2007_fig2_272298945 2018/1/14

Trade between different regions in China



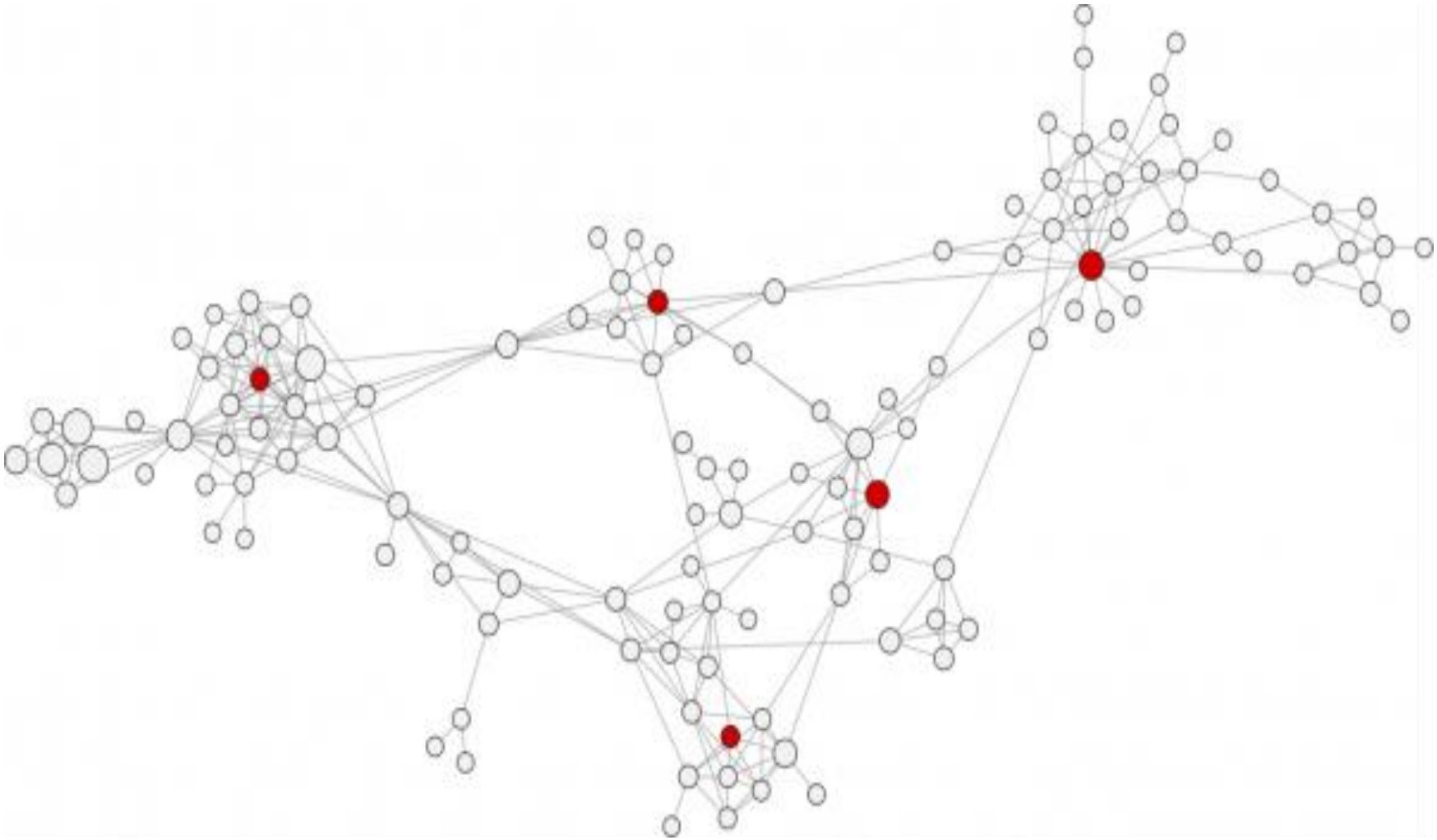
Centralities or “what node has an important position?”

- One of the basic questions that network theory raises is that of what node is the “most important” or central in a given network.
- What does “central” mean? This depends on the definition we use:
  - **Degree** – How connected a node is . The degree centrality is thus given by the number of links connected to a given node.
  - **Closeness** – How easily a node can reach other nodes.
  - **Betweenness** – How important a node is in terms of connecting other nodes (intermediary, connector, etc).
  - **Eigenvector-related centrality** – How important, central or influential a node’s neighbors are (not what you know, but who you know).

Why do we use different centralities?

- Depending on the structure of the network, a type of centrality might be a good measure of how “important” a given node is or not.

Closeness centrality

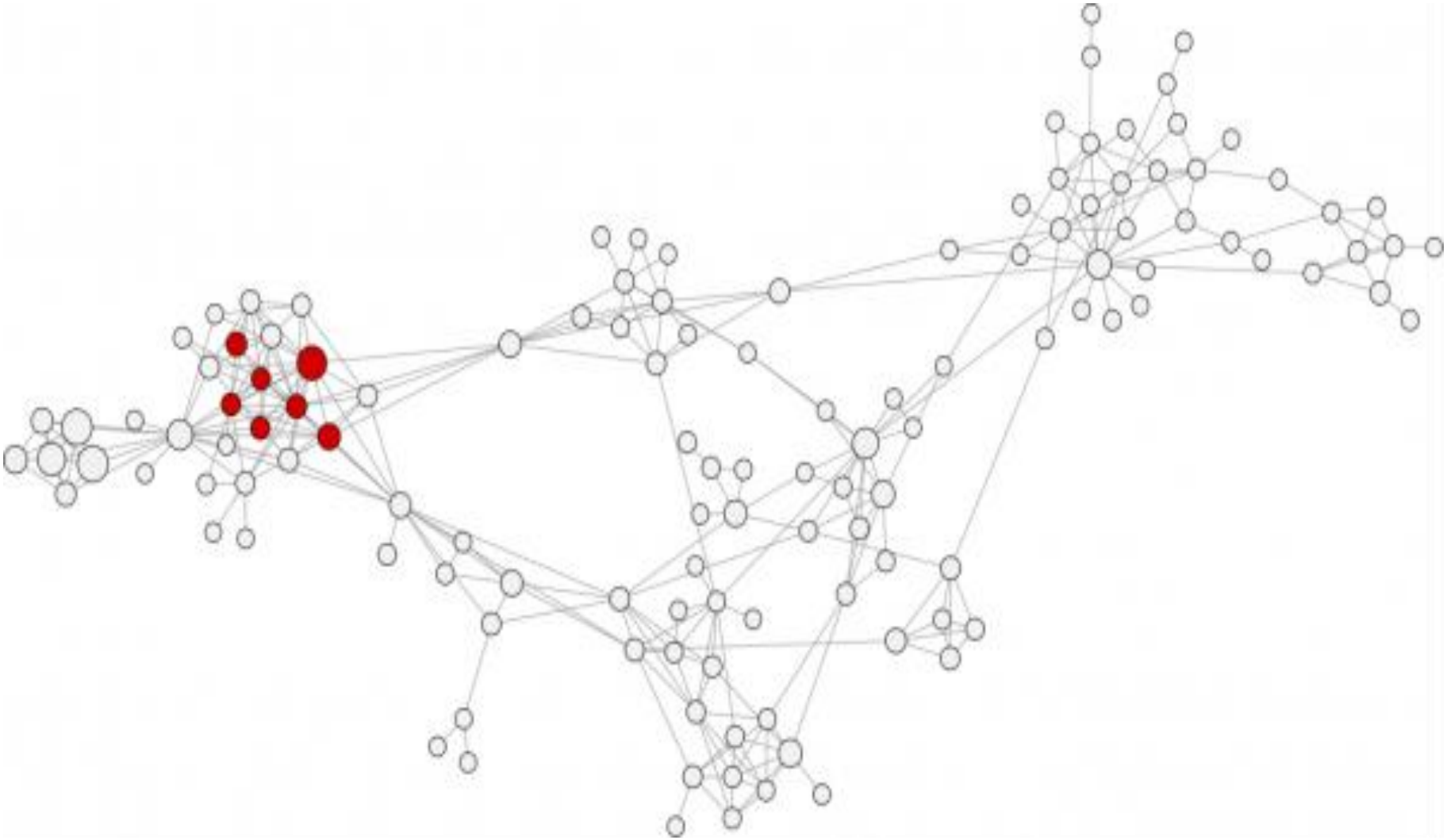


https://cs.hse.ru/data/2015/05/14/1098547089/4._Centrality_Metrics.pdf 2019/1/14

Betweenness Centrality

https://cs.hse.ru/data/2015/05/14/1098547089/4._Centrality_Metrics.pdf 2019/1/14

Eigenvector Centrality



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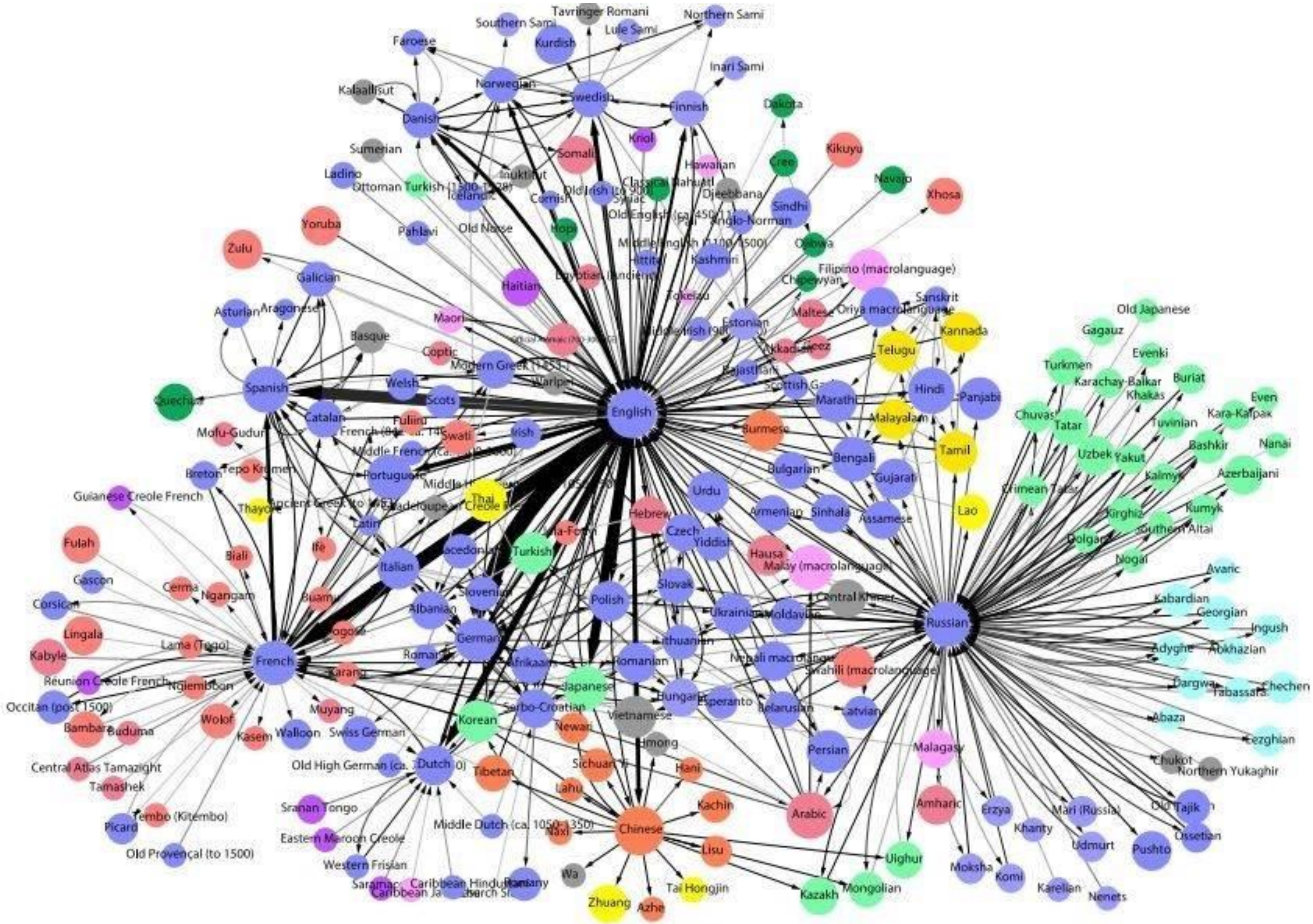
Centralities have been used to find and study different things such as:

- Who is the most important agent in a crime network.
- Key infrastructure nodes in a computer network.
- Super-spreaders of viruses
- Etc.

A famous application of the idea of centrality is that of Google's Pagerank:

- Developed by Sergei Bryn and Larry Page when they were students at Stanford.
- It was the first algorithm used by Google as the basis of its search engine.

Application: Influence of languages



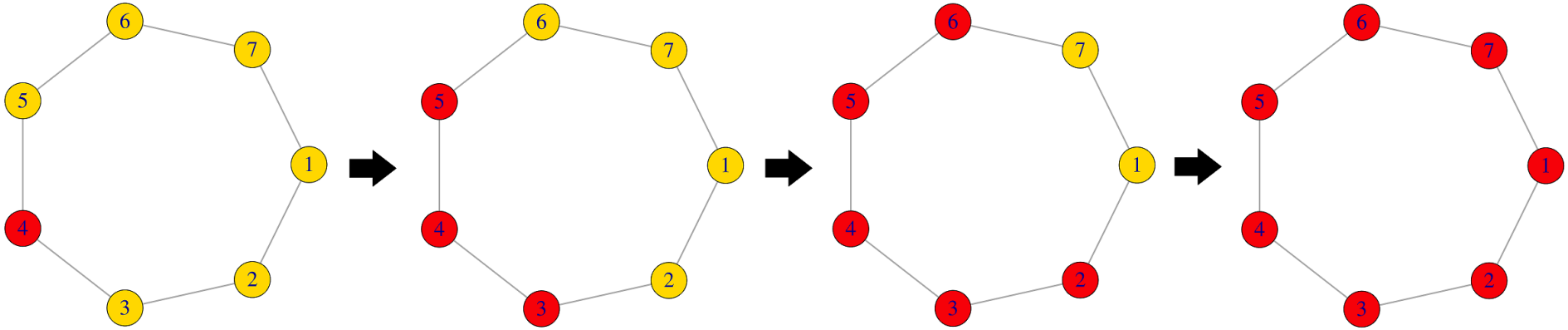
Source: Ronen et al. (2014)

Diffusion processes

- Networks can help us understand how diffusion processes occur:

- Through these tools we can analyze the diffusion of:
  - Diseases in a population.
  - Information in a society.
  - Opinions between a group of people.
  - Innovations and technology adoption in a region/area.
  - Financial or economic crises across countries.
  - Etc.

- Structure and connectivity matters!! These affect the speed and "how far" the spread goes.
  - Behavior of agents (infected or those that interact with them) can accelerate, slow down, or even stop a diffusion process.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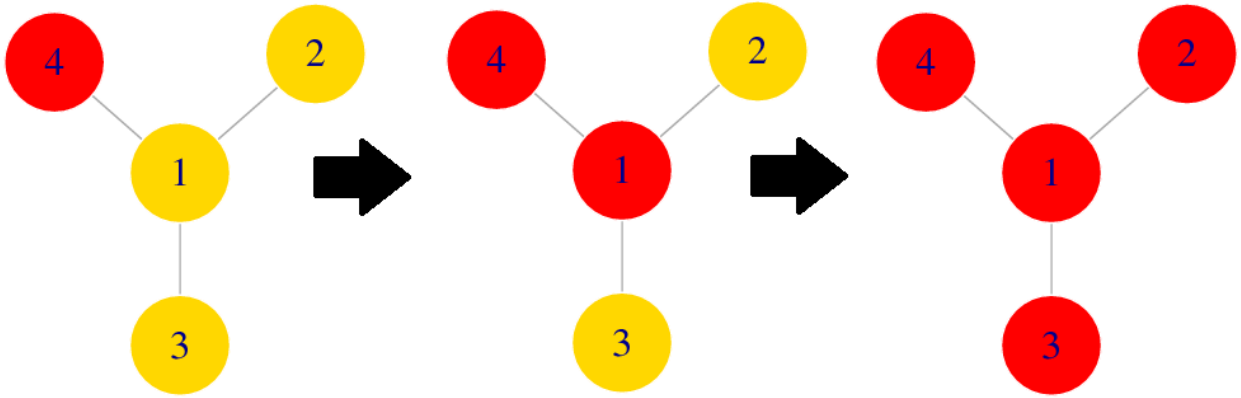
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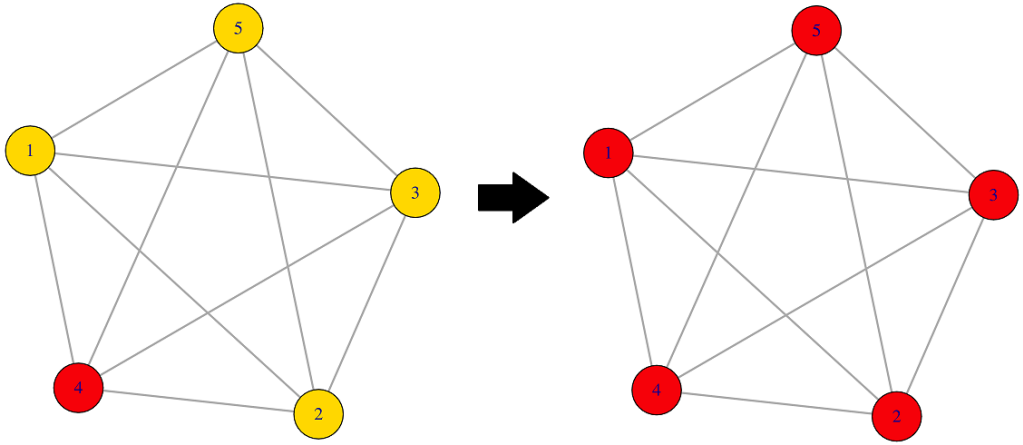
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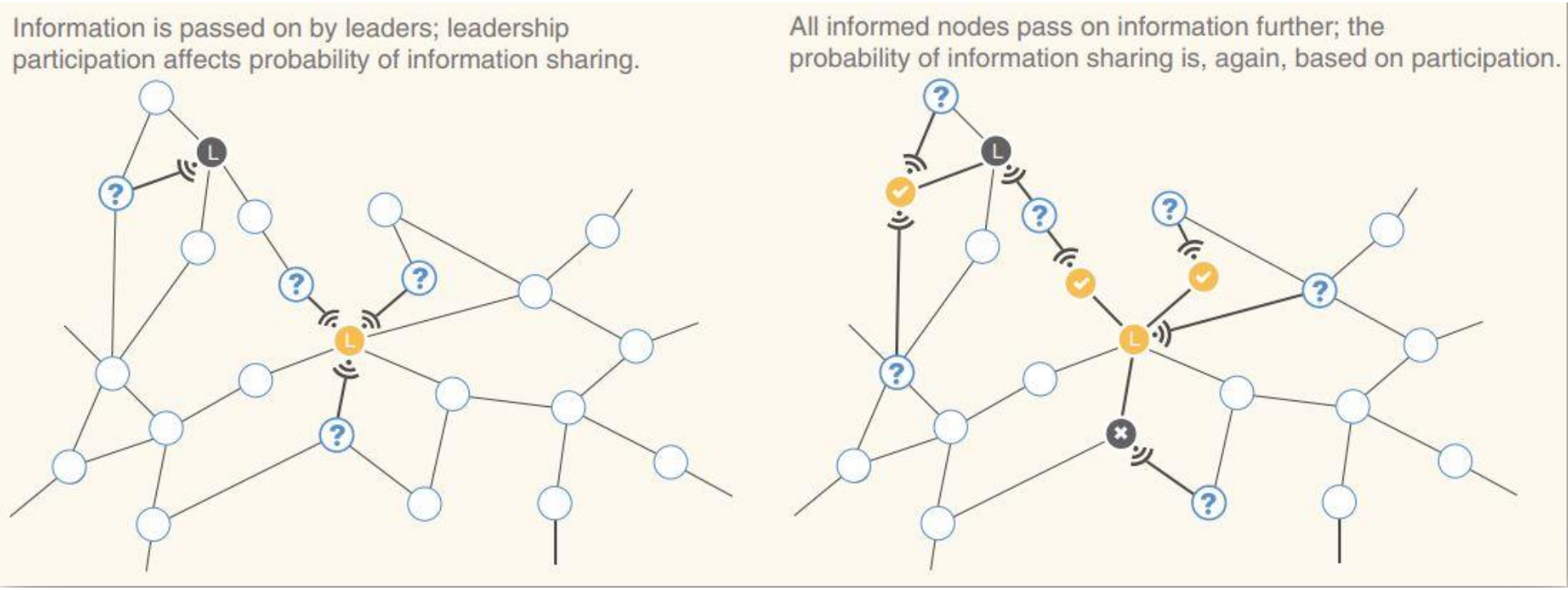
- In present times, our interconnectivity allows for so called “cascading effects” to take place.
  - Domino effect or chain reactions.
  - Can be partial or complete.

- Some examples of cascade effects are:
  - The spread of certain behavior of beliefs in a population.
  - A series of extinction of species triggered by the extinction of primary key specie in an ecosystem.
  - Information cascades which happen when mass media or social network platforms spread information (real or fake).

Application: Diffusion of microfinance in an Indian Village

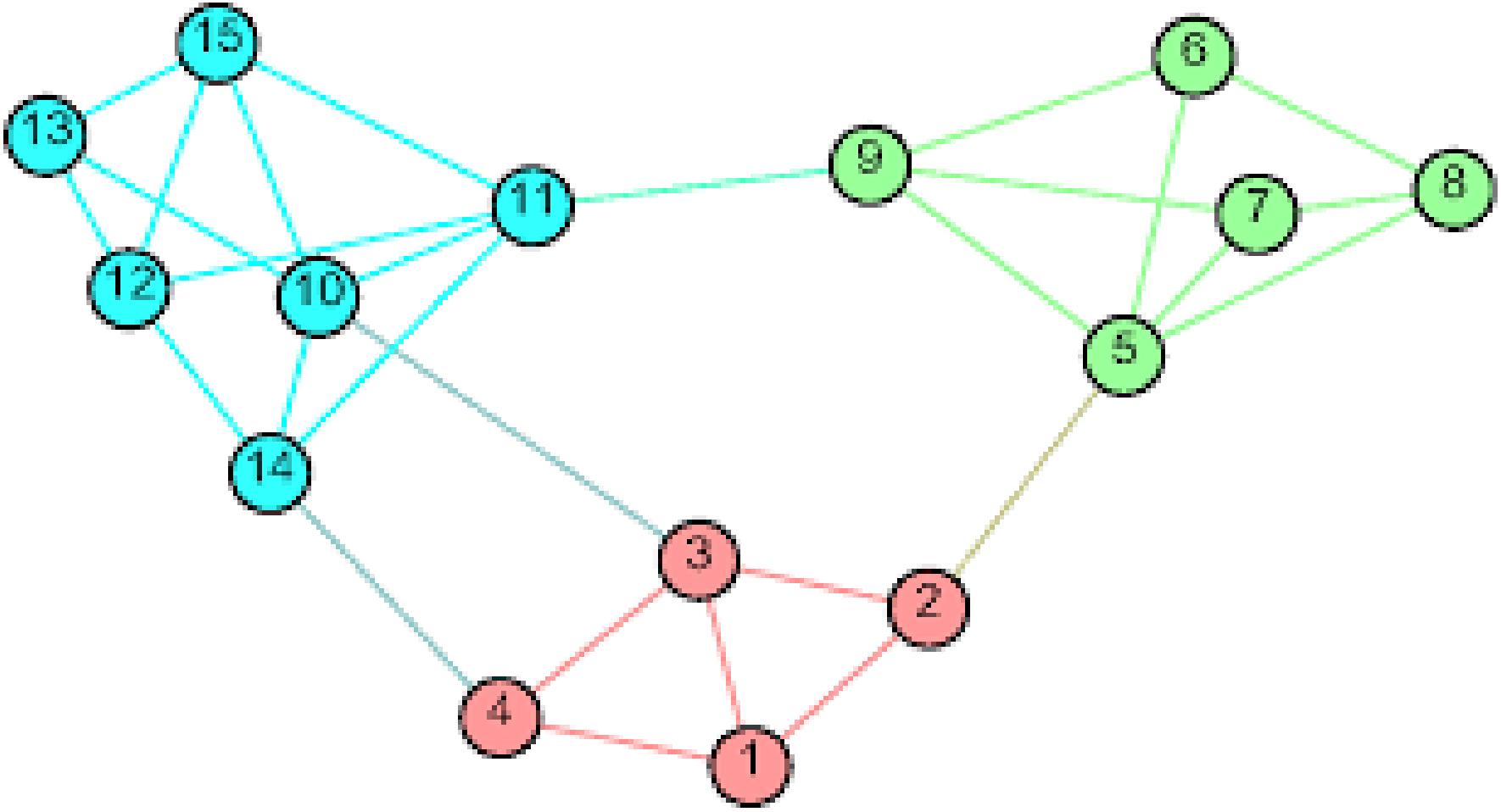


Source: Banarjee et al. (2013)

http://science.sciencemag.org/content/341/6144/1236498 2019/3/18

Community detection

- No universal definition of "community", but basic idea is that $k_i^{\text{int}} > k_i^{ext}$



https://www.semanticscholar.org/paper/LabelRank%3A-A-stabilized-label-propagation-algorithm-Xie-Szymanski/68edf1d4c57163116c33aec817cc4838d3fcf88a/figure/0 2019/3/29

Relevance of community detection

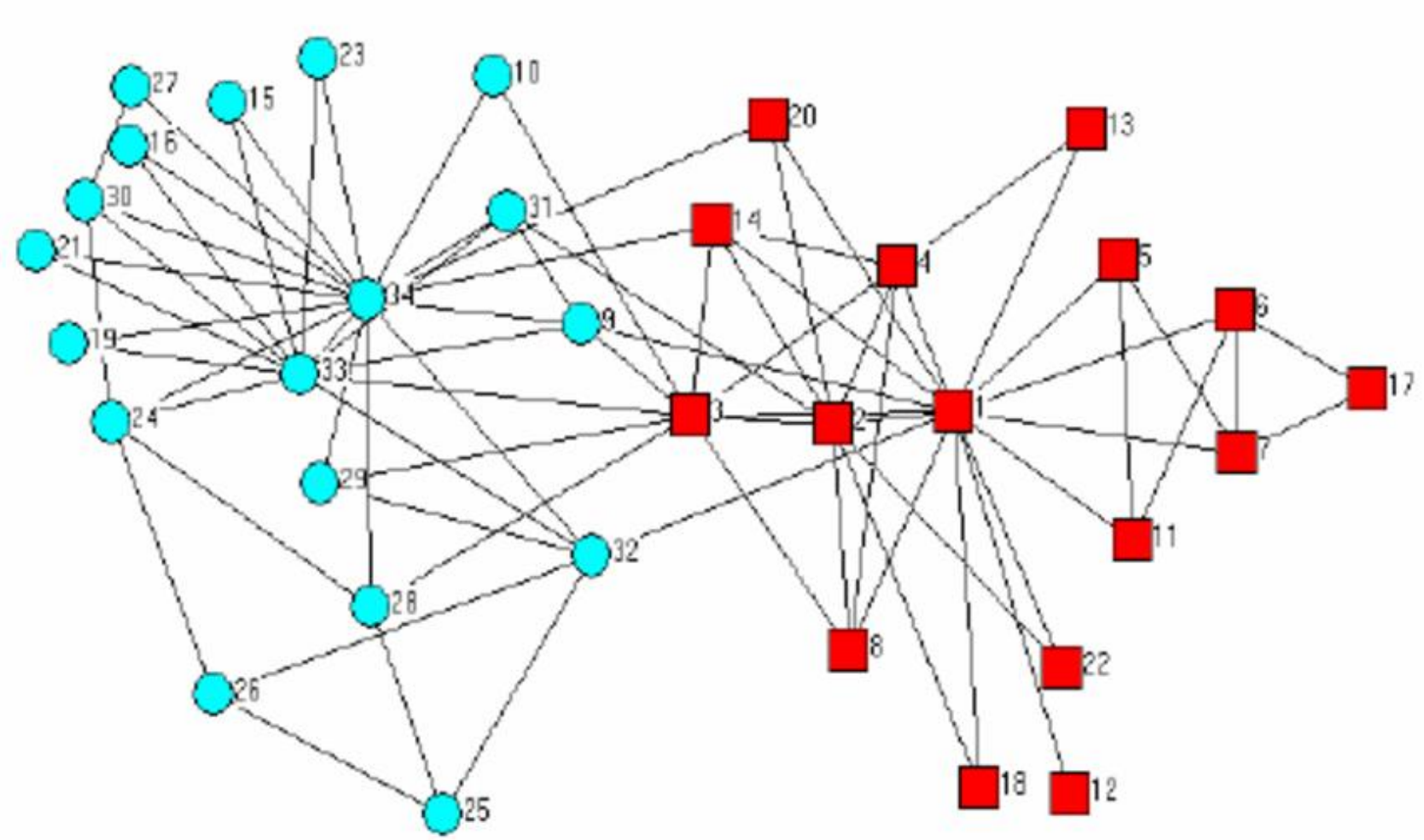
- By understanding community structure, we can have insights into why a given network's architecture has the shape it does:
  - Reasons such as homophily plays a role.
  - Different communities have different shapes in a large network.
- Communities usually have distinct properties relative to the entire network.
  - Understanding their structure is important to predict spreading of events.
- Membership of communities gives information regarding group positioning.
  - Relationship with centralities.

How can we detect communities in Networks?

- Various fields are working in developing methods:
  - Algorithms.
  - Statistical methods.

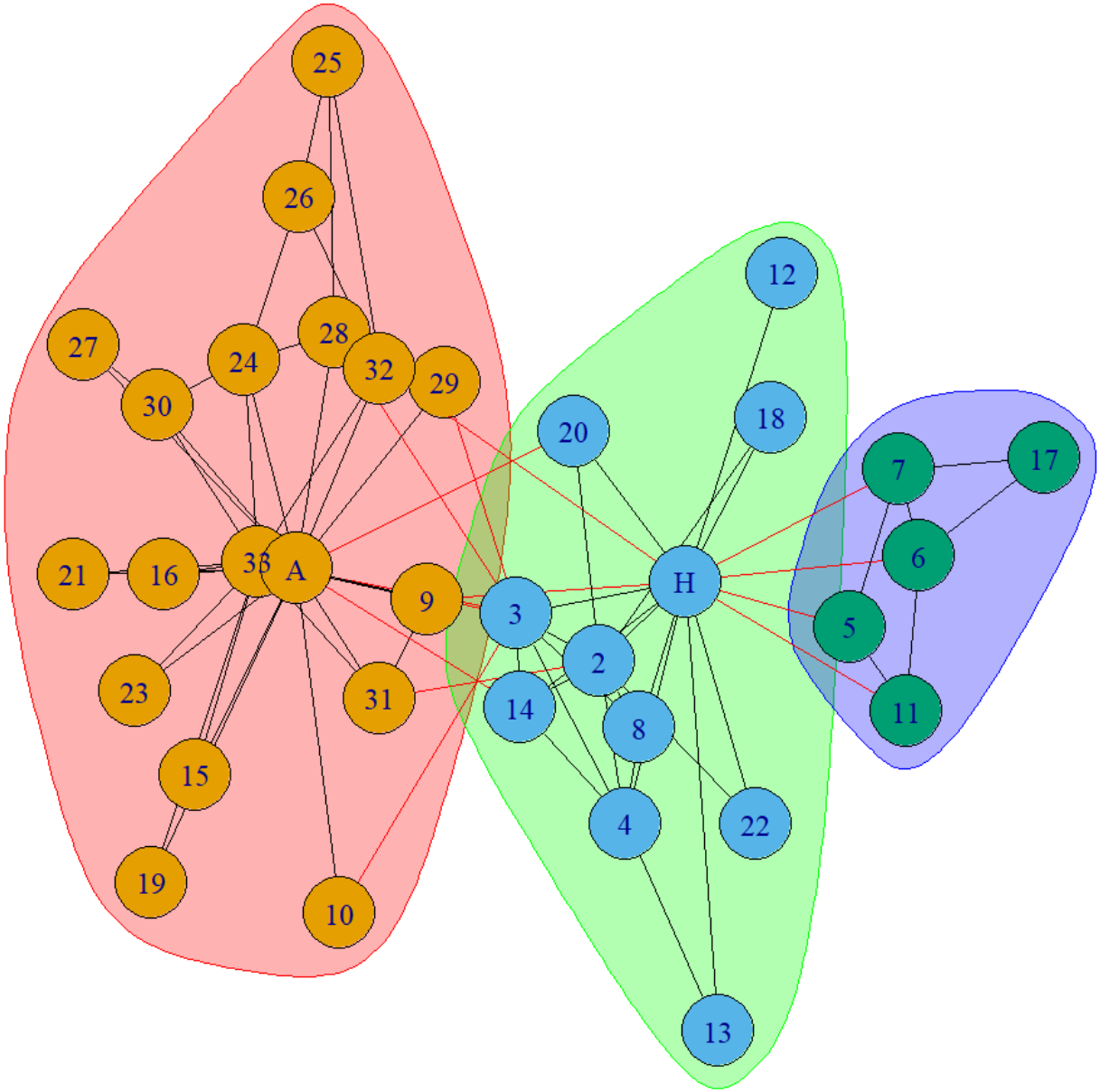
- Researchers need to test these methods in many different types of networks:
  - Randomly generated networks.
  - Real and well-known communities.

Zachary's Karate Club



https://www.researchgate.net/figure/The-Zachary-Karate-Club-Network-We-apply-our-bibliometric-algorithm-to-the-karate-club_fig1_220995476 2019/3/29

Detecting communities through algorithms

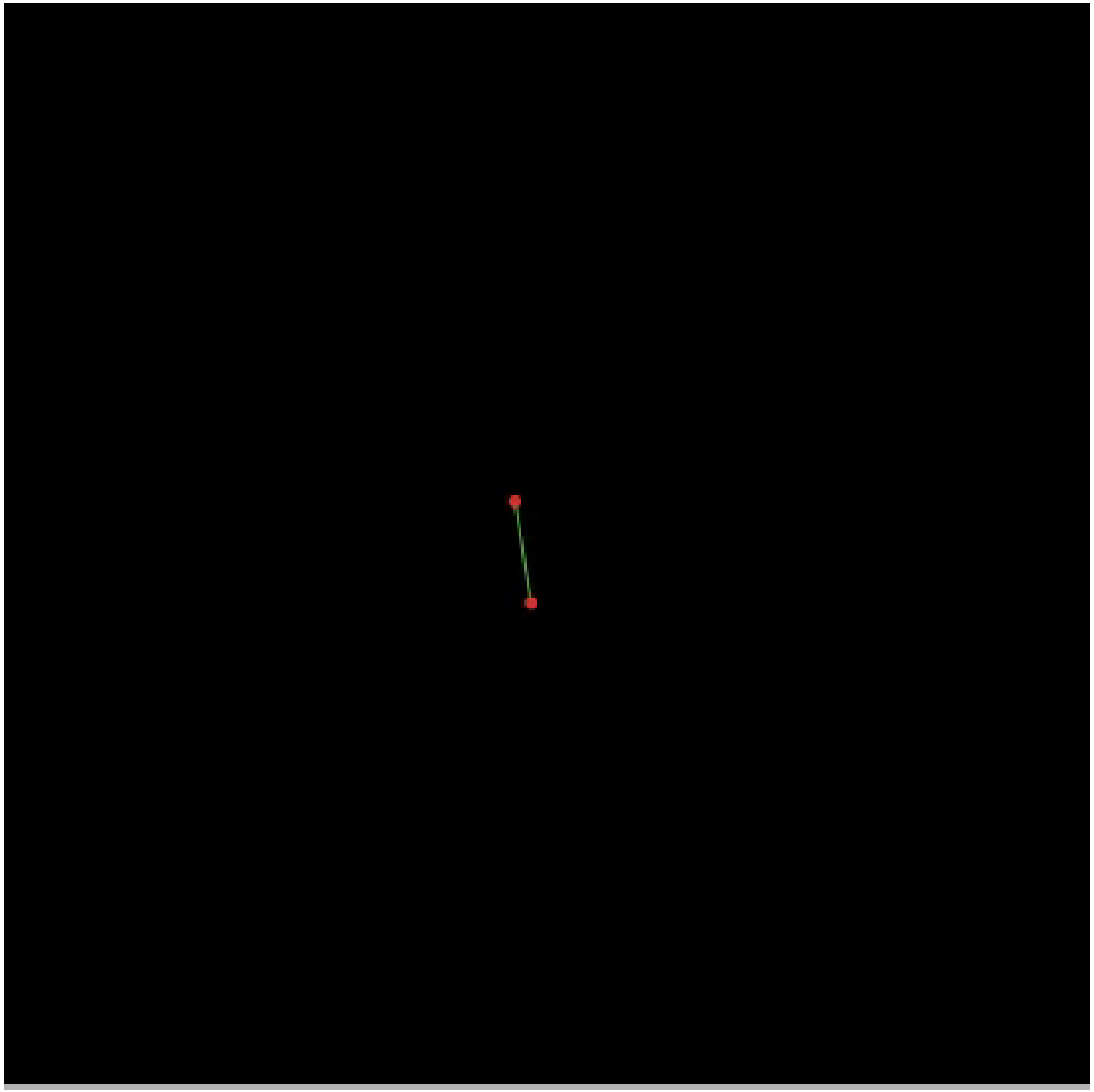


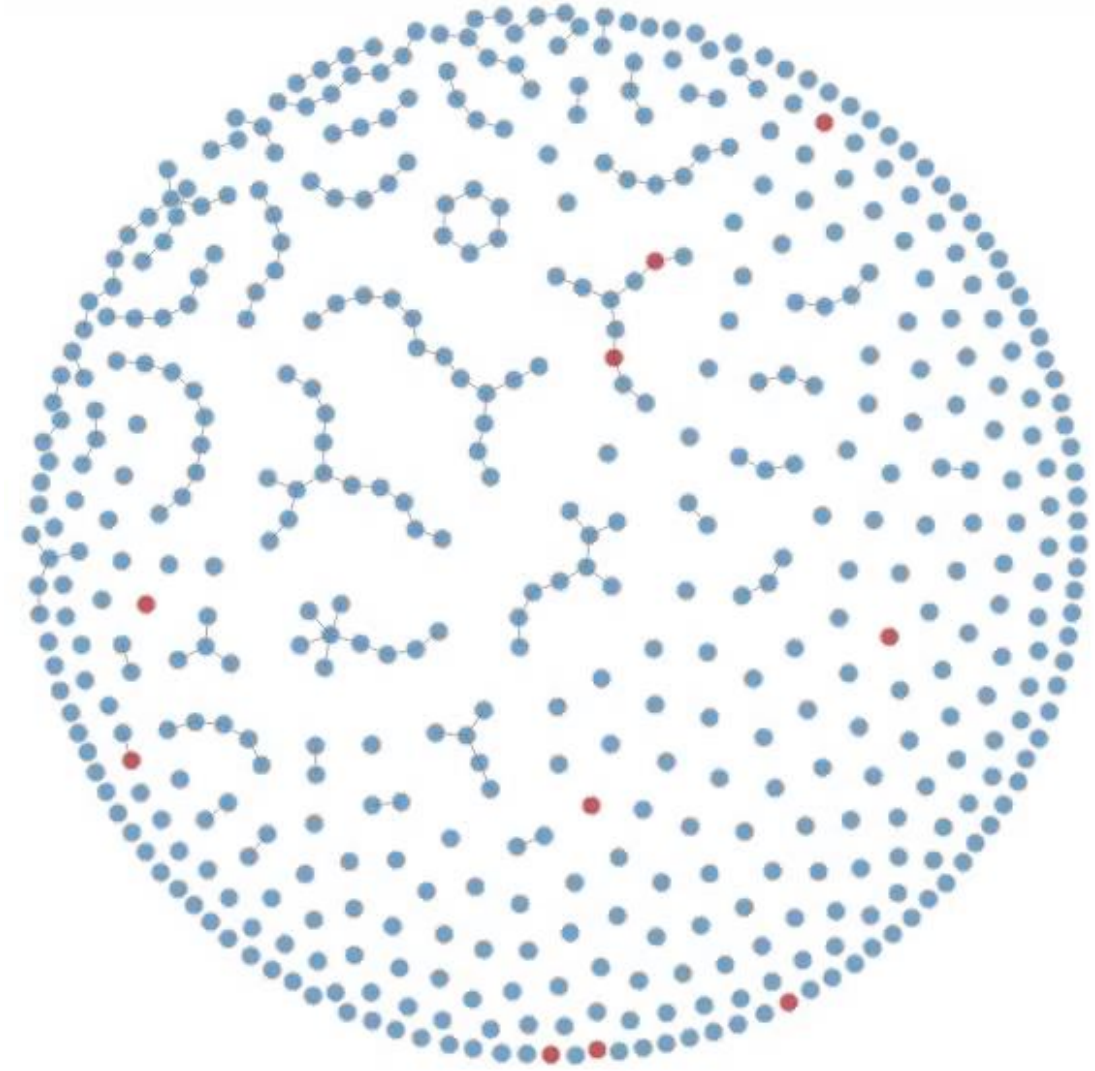
Network formation

- An area of network science that is very relevant is the study of how and why networks form and how they evolve.

- Different models and explanations exist for this:
  - Random models.
  - Agent-based or strategic models.

- The first type of model helps us understand the “how” of network formation while the latter explains better the “why”.





Conclusions

- Networks are everywhere: Society, friendships, natural and economic systems, etc.

- Through their analysis we can understand how and why they form and ways we can improve or alter them.
  - How these modify an agent's or system's behavior and the results that this generates.

- Different tools from network science allow us to analyze patterns such as diffusion processes, influence and formation of communities.
  - These help us have a better grasp of societies and their functioning.

Thank you!!