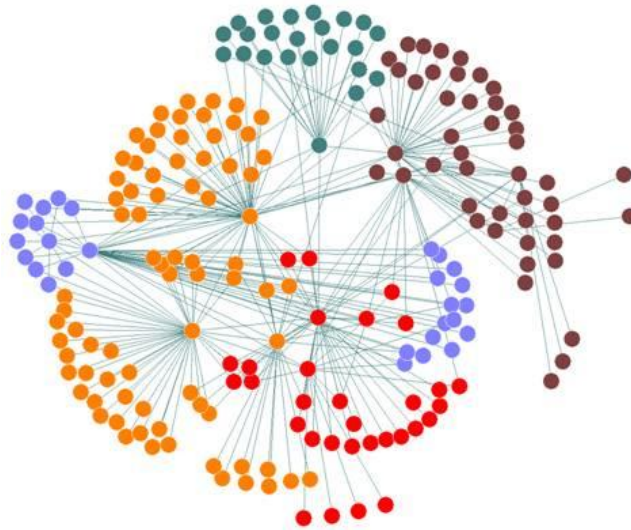# Algorithms and Applications in Social Networks

2023/2024, Semester A

Slava Novgorodov
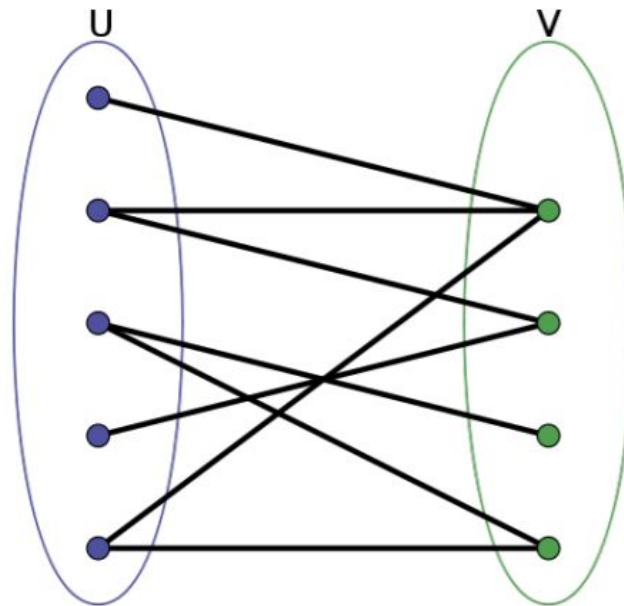
1

Lesson #3

- Bipartite graph (recap)
- Networks with Signed Edges
  - Single edge
  - Theory of Balance
  - Examples
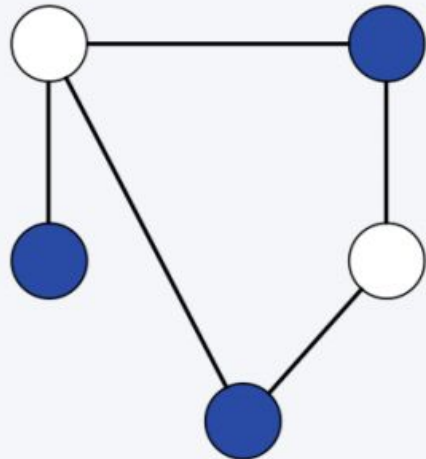
Bipartite Graph

Bipartite Graph

- A graph whose vertices can be divided into two disjoint sets U and V such that every edge connects a vertex in U to one in V
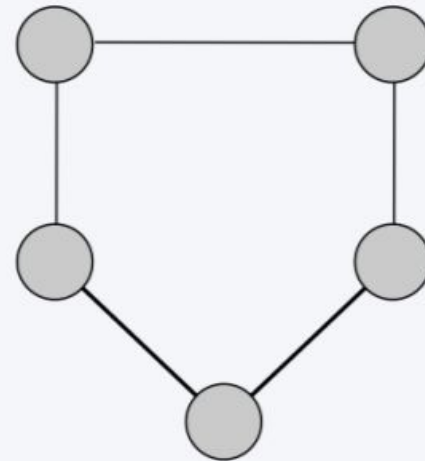

- A bipartite graph does not contain any odd-length cycles
- A bipartite graph can be vertex colored wtih 2 colors

Testing Bipartiteness

- Triangle – not bipatite
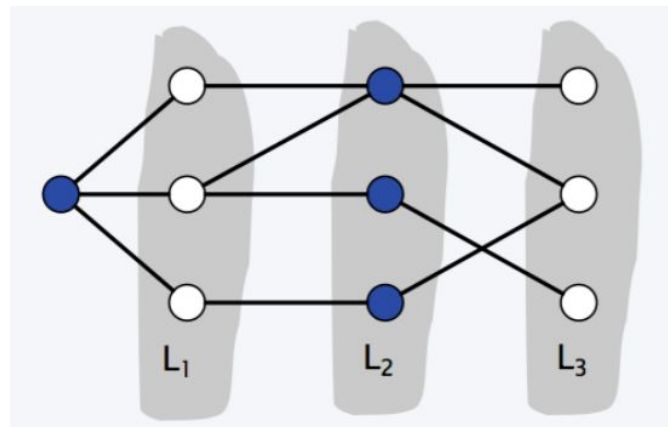- Graph contains an odd cycle – not bipartite


bipartite
(2-colorable)

not bipartite
(not 2-colorable)

Testing Bipartiteness

- Is given graph bipartite?
- Algorithm:
    - Select and node and perform BFS, color each layer alternate colors
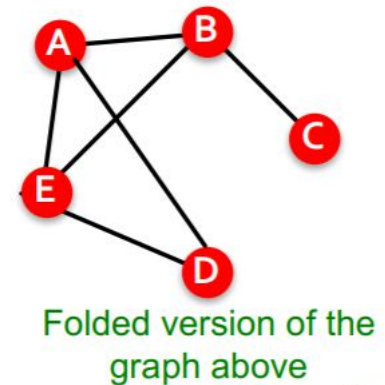   - Scan all the edges, see if any edge has nodes with the same color (one layer nodes)
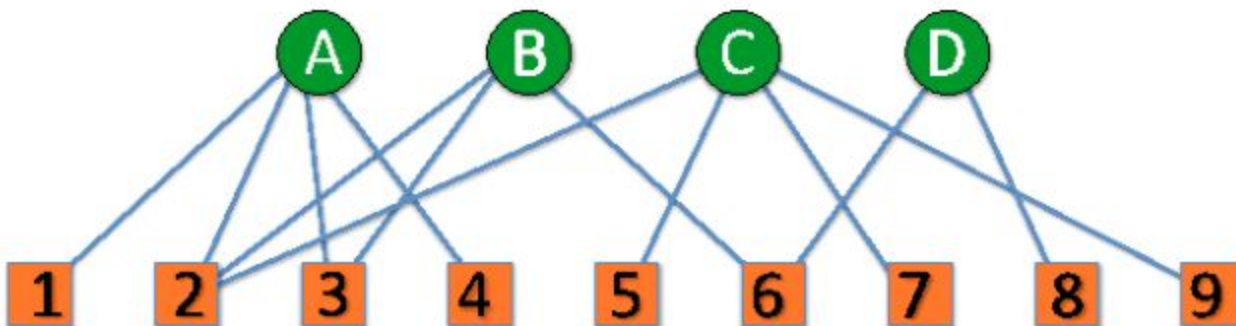
Usage of Bipartite Graph

- Different types of nodes:
  - Users/Items ranking
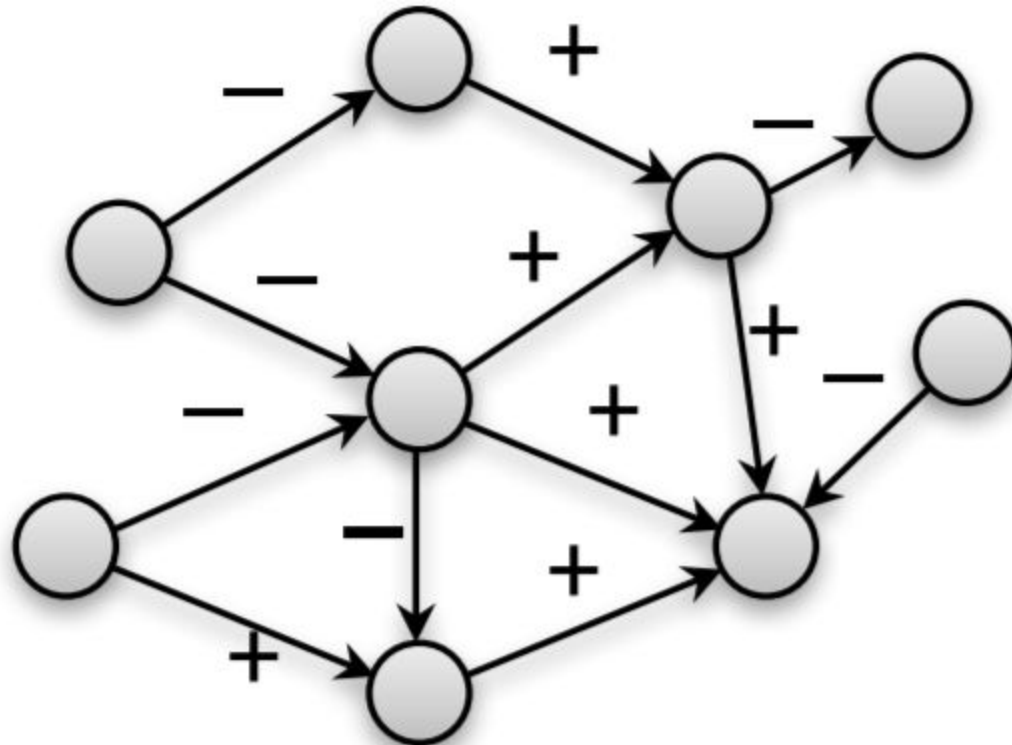 - Papers/Authors
  - Courses/Students

U V

Folded network:

Folded version of the graph above
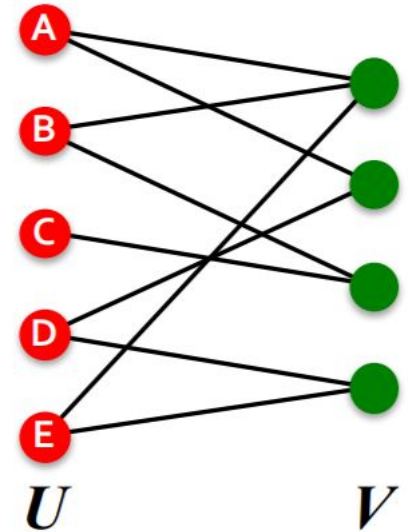
Networks with Signed Edges

Networks with Signed Edges

- Sometimes just "Signed Network"
- Can be directed or undirected

Motivation

- Trying to model behavior of people in (online) social networks

- Relationships between people in the network can be positive or negative

- People express opinion that can be positive or negative

Opinions of People in the Network

People can express opinion:

- By action:
  - Pressing "Like"/"Dislike" button
  - Giving rating to a product/person
- By writing text:
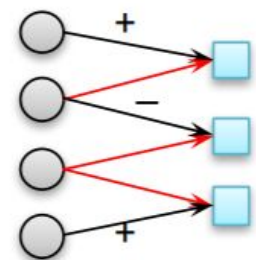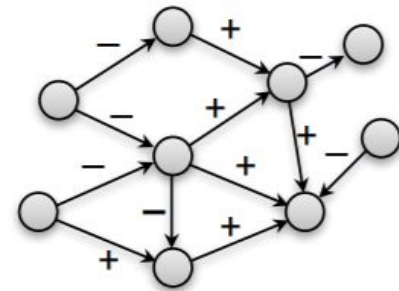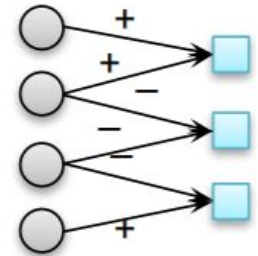 - Comments, review, etc

Applications:

- Recommendation systems
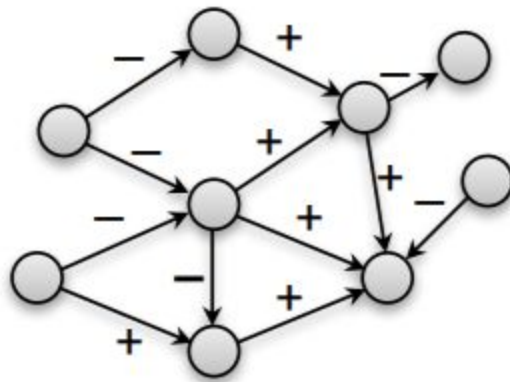- Crowdsourcing

Types of Opinions

People can express opinion about:

- Items:
  - Movies, hotels, purchases rating/reviews

- Other people:
  - GetTaxi drivers, AirBnB, Wikipedia

- Content generated by other people:
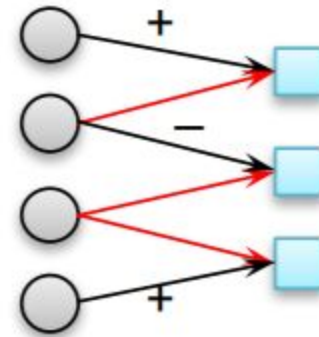 - StackOverflow, Facebook

Evaluation

- Factors:
  - What drives people to give particular evaluation?

- Types: Direct/Indirect

Direct

Indirect

Datasets

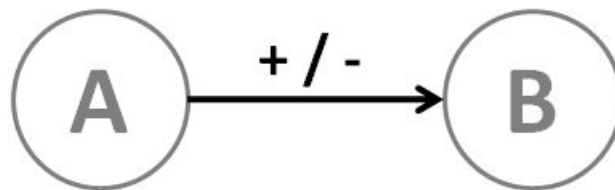Where it exists on the Web?

- Wikipedia moderators elections
  - Positive/Neagtive vote (120K votes in English)

- StackOverflow Community
  - Upvotes/Downvotes (7.5M votes)

- Epinions product review
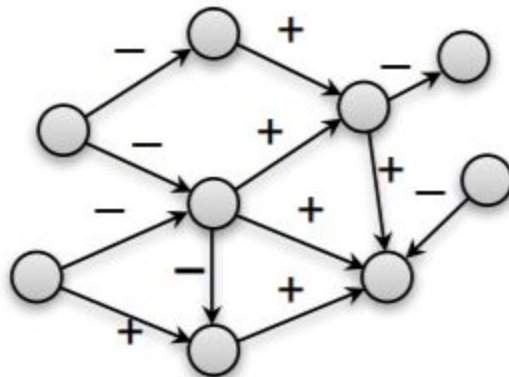 - Ratings of product review (13M ratings)
  - 5 – positive, 1-4 – negative

Evaluation – two ways to analyze

Two ways to look on it:
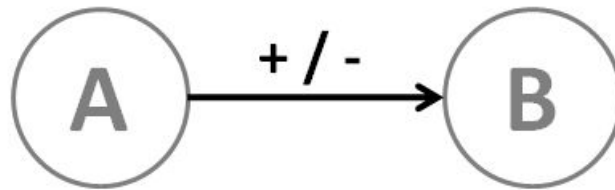
- Single evaluation (without network context)
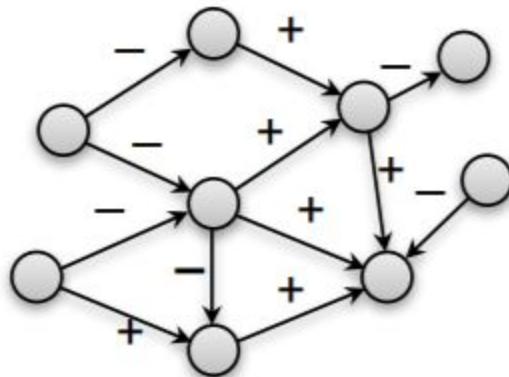

- Evaluations in the context of the network

From: <u>Effects of User Similarity in Social Media</u>. A. Anderson, D. Huttenlocher, J. Kleinberg, J. Leskovec (WSDM 2012)

Evaluation – without context

Two ways to look on it:

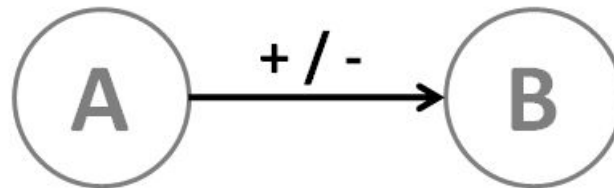- Single evaluation (without network context)

- Evaluations in the context of the network

Human Evaluation

- What drives human evaluation?

- Which (and whose) properties are important?
  - Properties of A?
  - Properties of B?
  - Which properties?

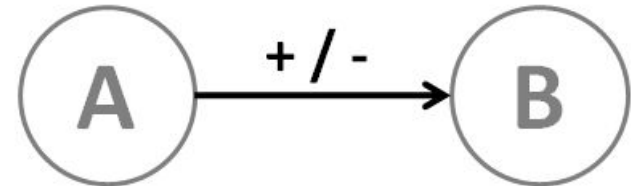# Important Properties

- **Status:**
  - Level of recognition, achievements, reputation in the community
    - Wikipedia: # of edits, # of new articles written
    - StackOverflow: # of answers
- **Similarity:**
  - Overlapping interests between A and B
    - Wikipedia: similarity of edited articles
    - StackOverflow: similarity of users evaluated

Relative vs. Absolute evaluation

Two hypothesis:

- B receives a positive evaluation depends primarily on the characteristics of B
  - There is some objective criteria for user B to receive a positive evaluation
- B receives a positive evaluation depends on relationship between the characteristics of A and B
  - A compares herself to B

Effect of Status

- How does status of B affects A's evaluation?
- Status $\Delta = S_A - S_B$

- Observations:
  - P(+) doesn't depends on B's status
  - Different Δ implies different behavior

(Wikipedia dataset)
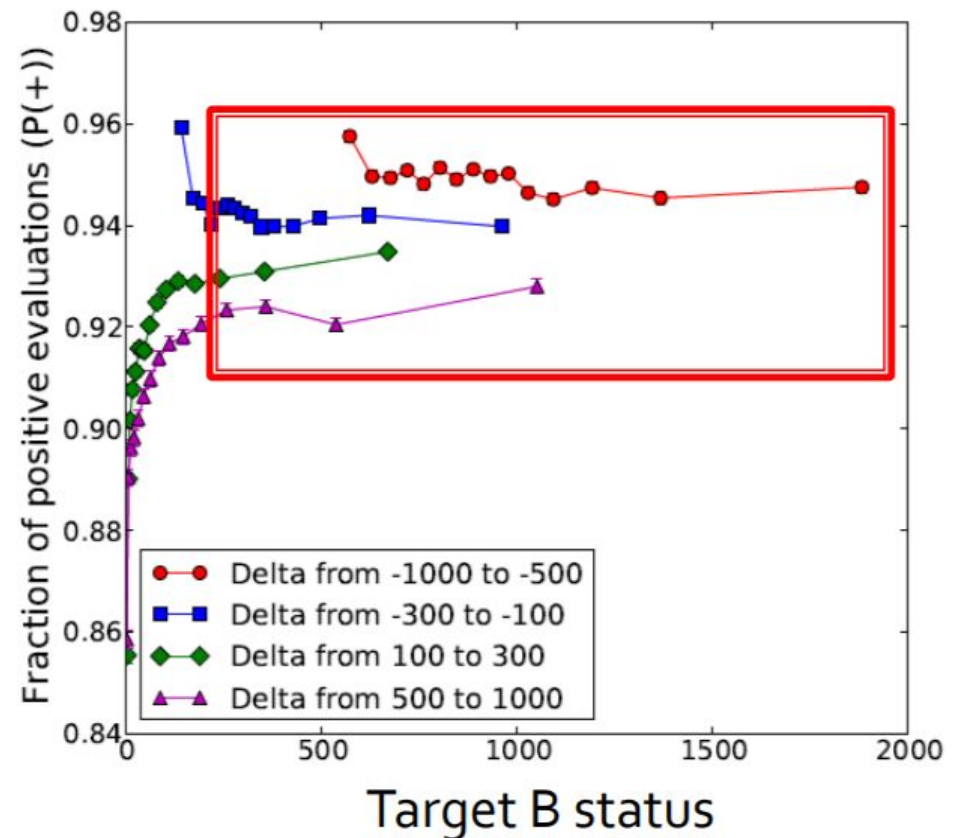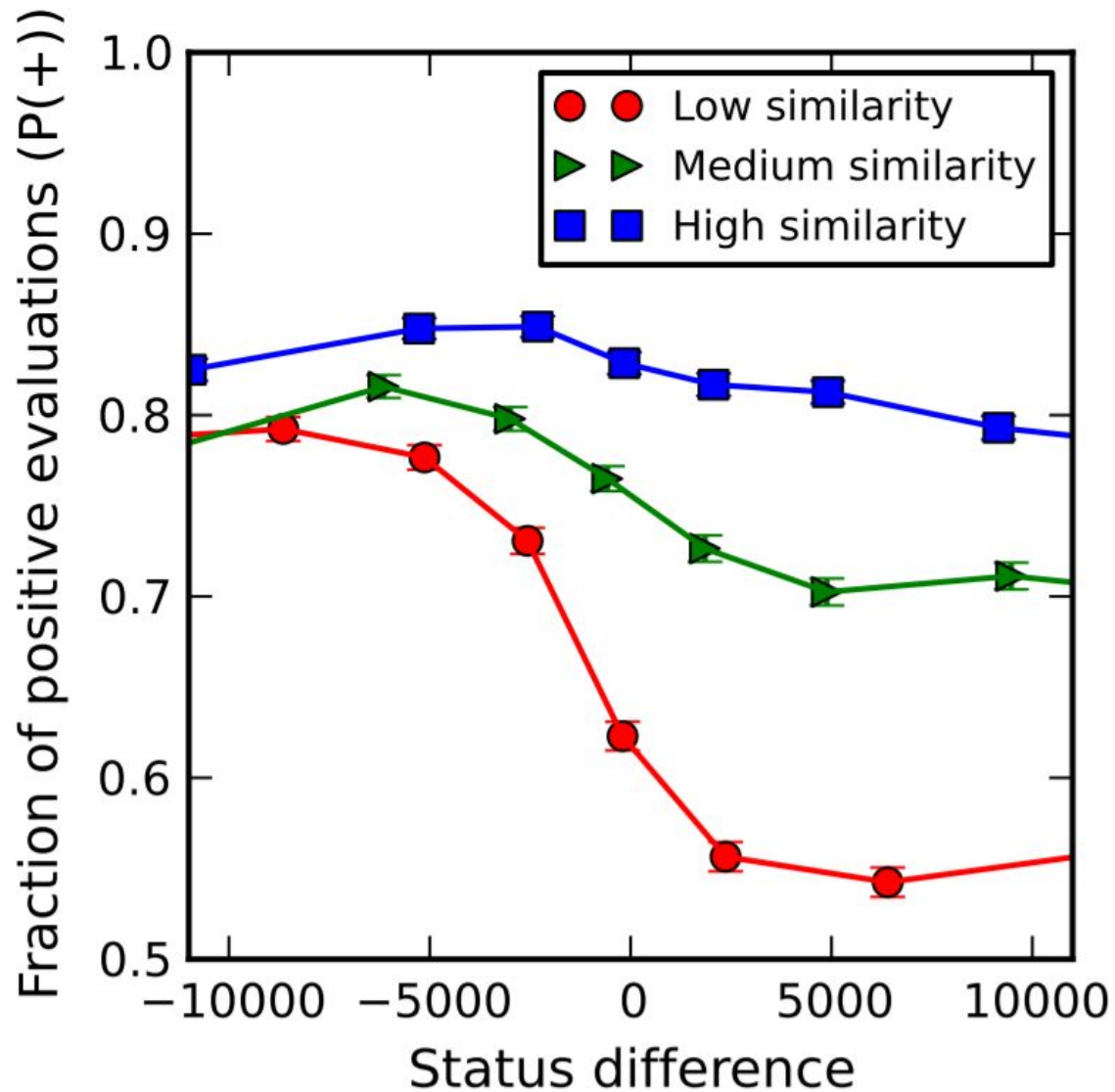
Effect of Similarity

Two hypothesis:

- People are more supportive to other people in their domain of knowledge/area
  - "The more similar you are, the more I like you"

- People know the domain, hence know the weak point and are more harsh
  - "The more similar you are, the better I can understand your weaknesses"

Effect of Similarity
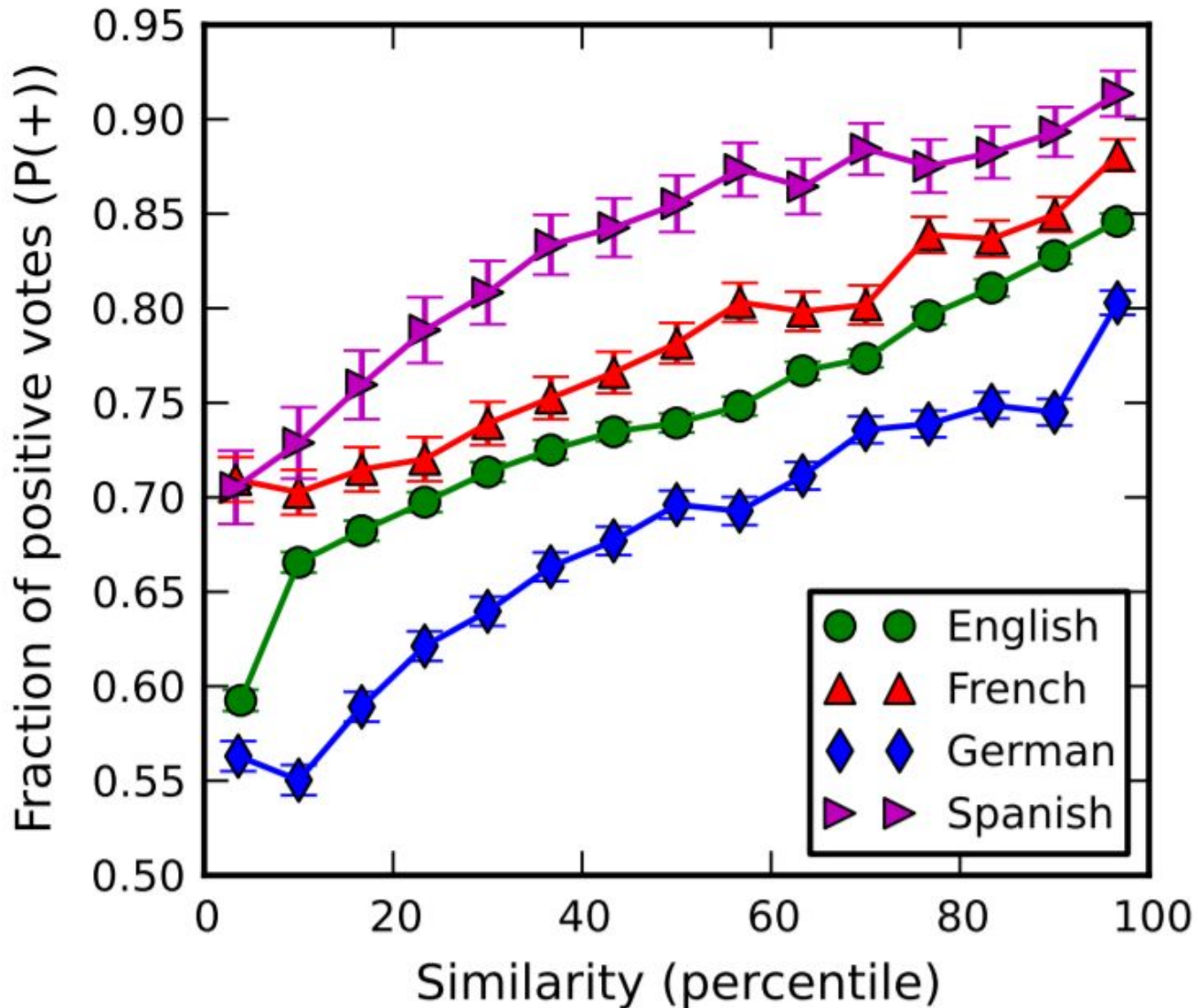
Similarity and Status

Summary so far

- Online Social Networks and Social Media websites support (sometimes implicitly) user evaluations (e.g. Wikipedia has transparent mechanism of elections)

- Two important characteristics:
  - Status: importance of relative assessments
  - Similarity: importance of prior interactions

More info: https://cs.stanford.edu/people/jure/talks/evals-recsys-sep12.pdf

Evaluation – with context

Two ways to look on it:

- Single evaluation (without network context)
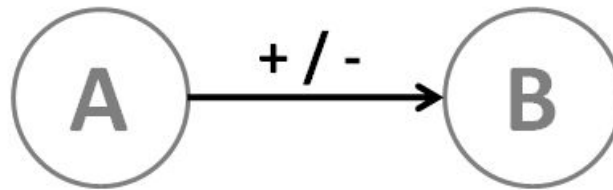
- Evaluations in the context of the network
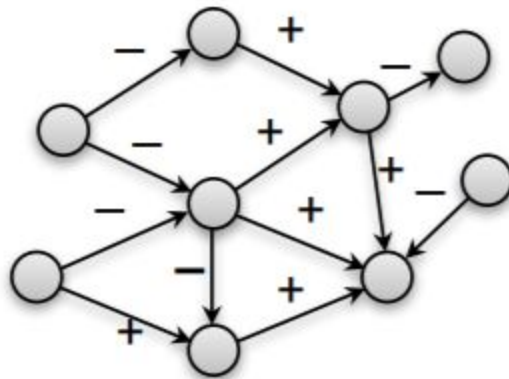
Networks with Signed Edges

- Also called: "Signed Network"

- Basic unit of investigation: **Signed triangles**

- Can be undirected or directed:
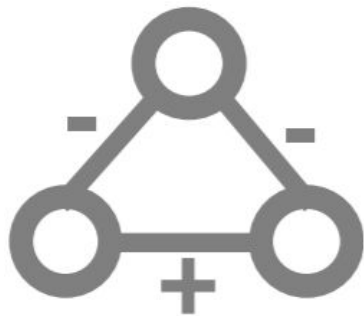
Signed Networks

- Network with **positive** or **negative** relationships

- Consider a complete signed undirected graph
  - **Positive** edges:
    - Friendship, positive sentiment, …
  - **Negative** edges:
    - Enemy, negative sentiment

- Let's focus on three connected nodes A, B, C

Theory of Structural Balance

- Intuition (theory by Fritz Heider 1946):
  - **Friend** of a **friend** is a **friend**
  - **Enemy** of an **enemy** is a **friend**
  - **Enemy** of a **friend** is an **enemy**

- Let's have a look on a triangle in a graph

Balanced/Unbalanced Triangles
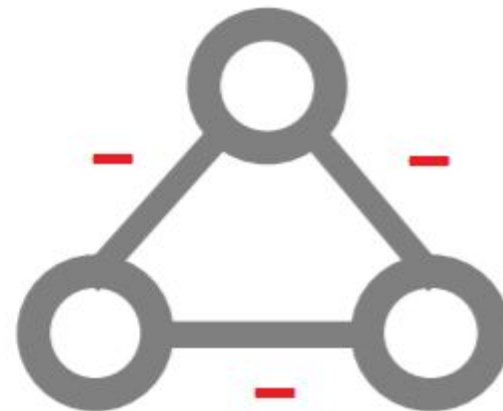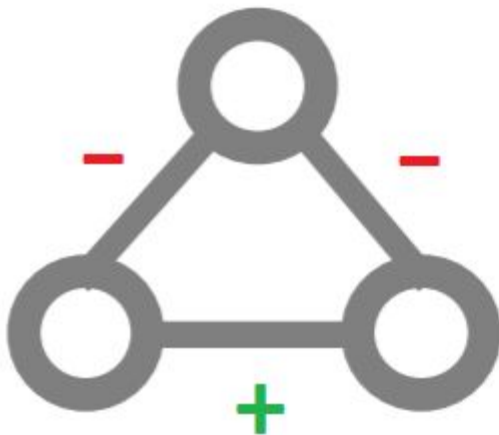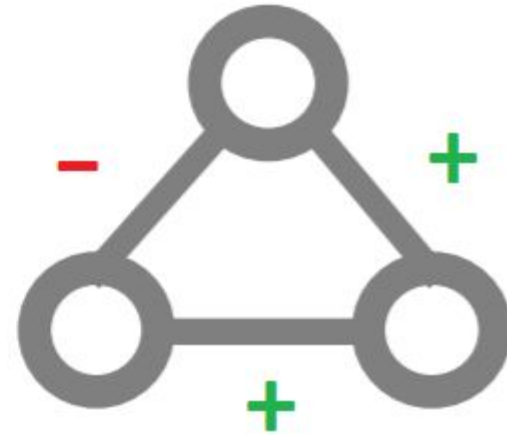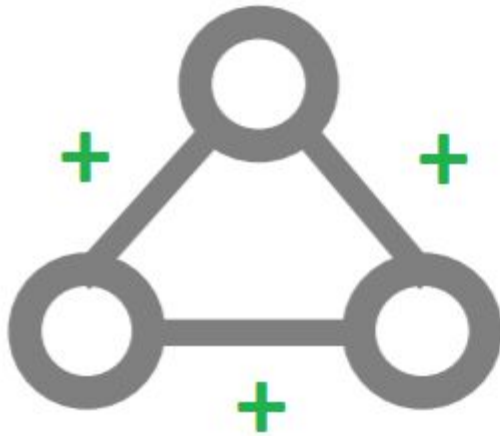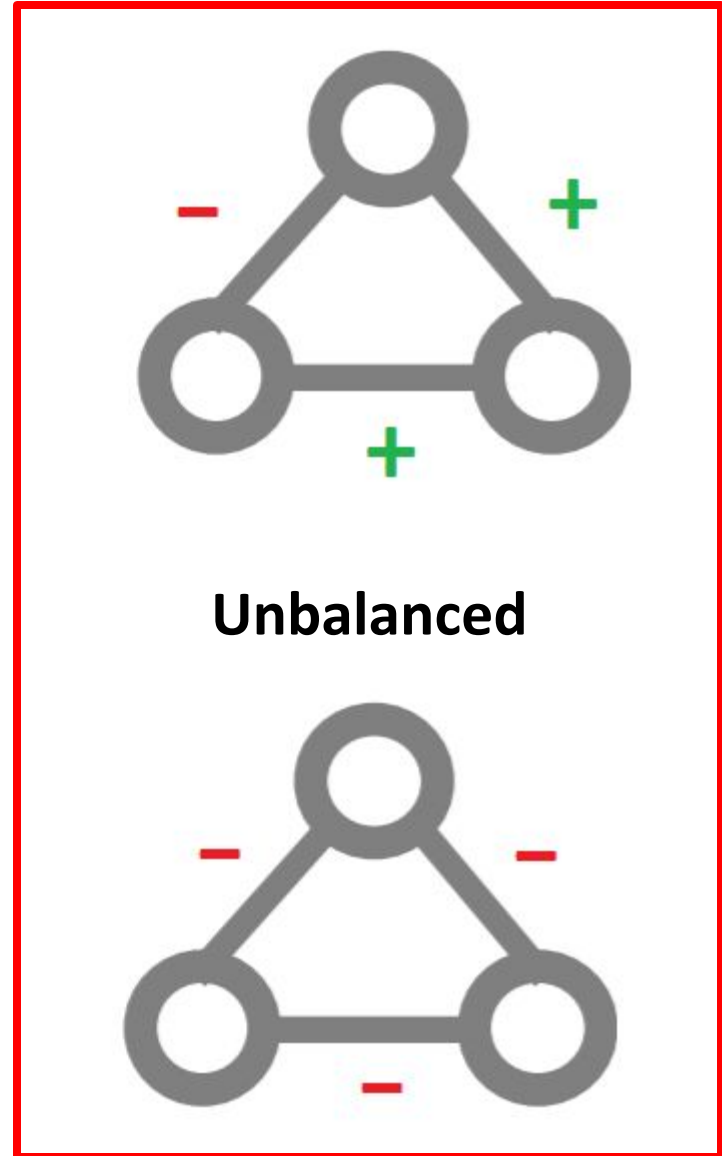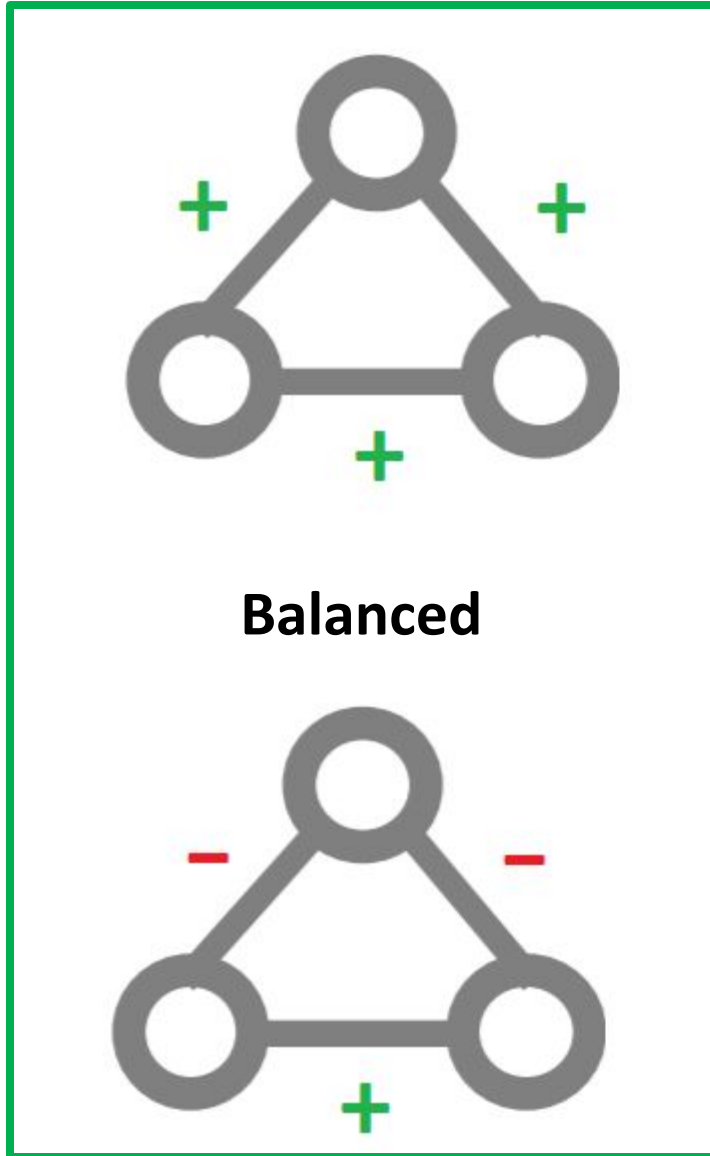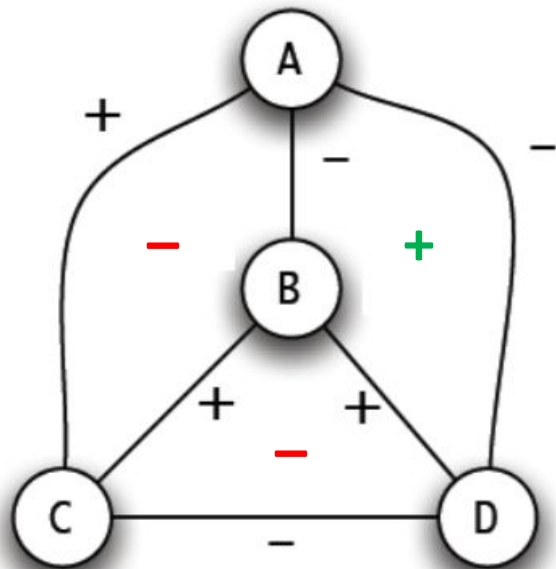
Balanced/Unbalanced Triangles

Balanced

Unbalanced

Balanced/Unbalanced Network

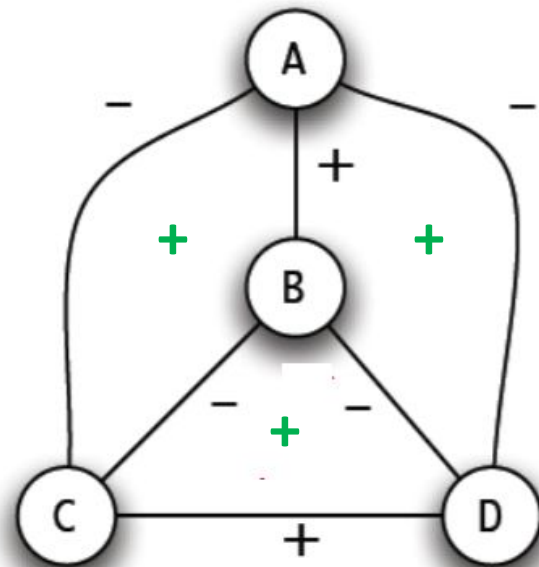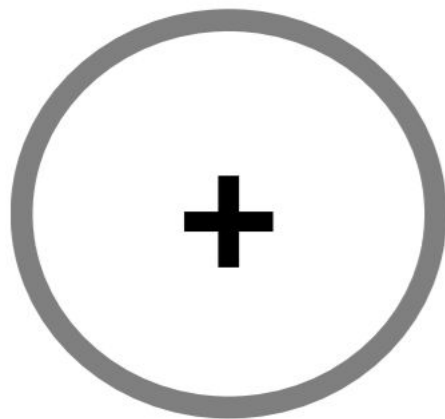- Network is balanced if every triangle in the network is balanced.
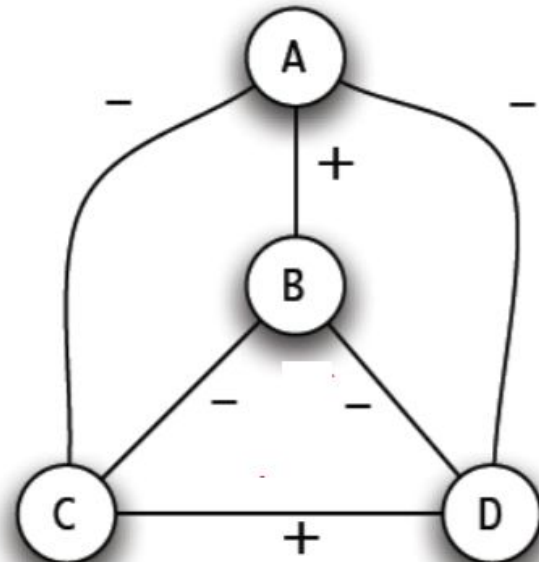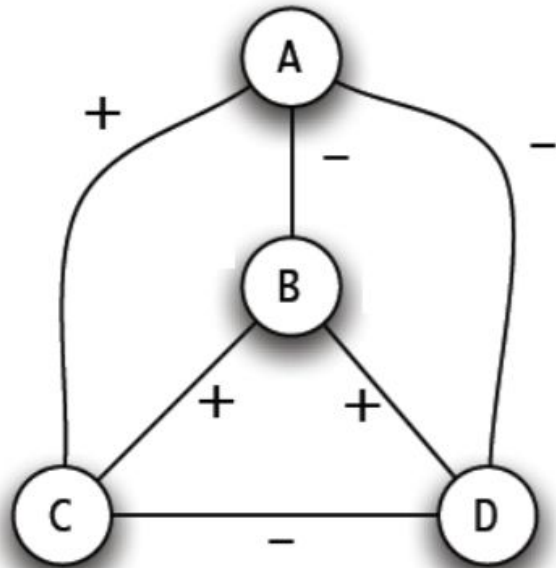
- Balanced triangle – 1 or 3 "+" edges

Balanced/Unbalanced Network

- Network is balanced if every triangle in the network is balanced.
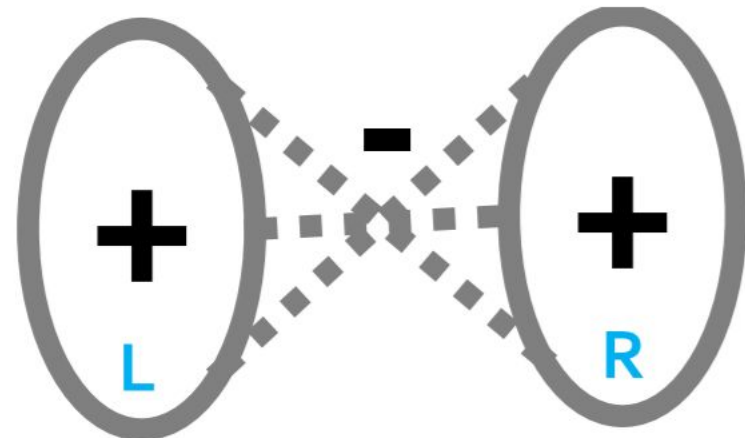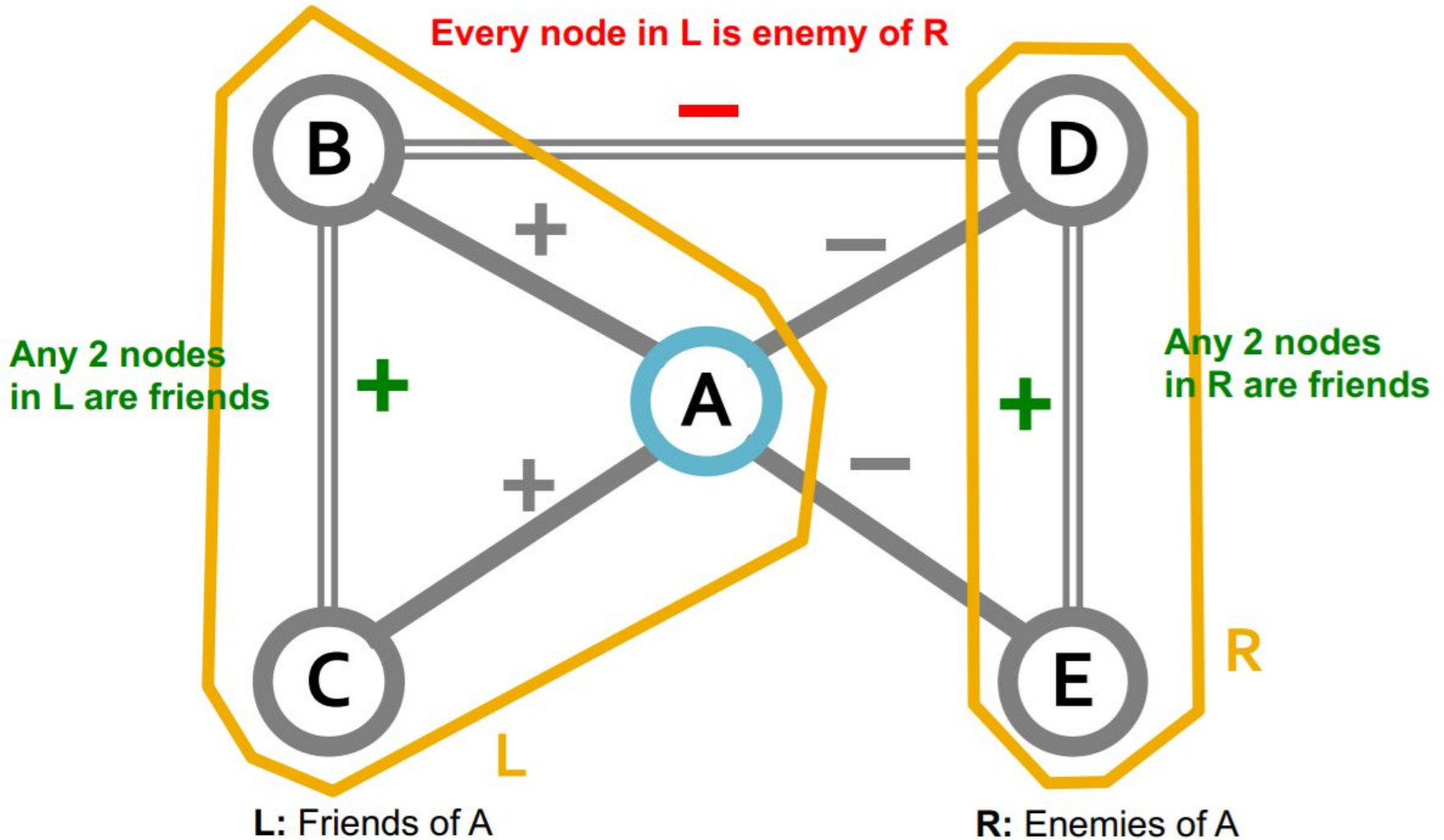

Unbalanced **Balanced**

Balance and Coalitions

- If the network is balanced, then either:
  - All edges are positive, or
  - We can split the network into two parts (L and R),
    - All edges inside R are **positive**
    - All edges inside L are **positive**
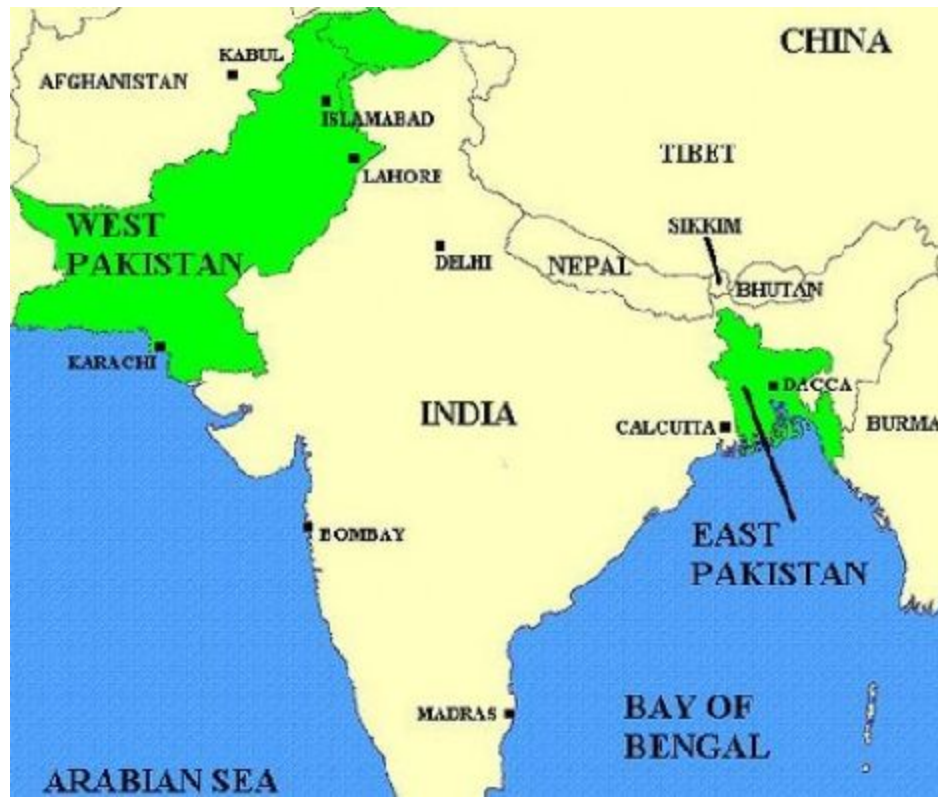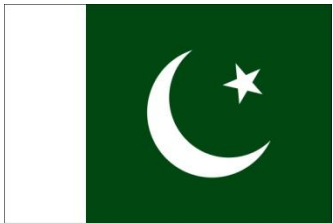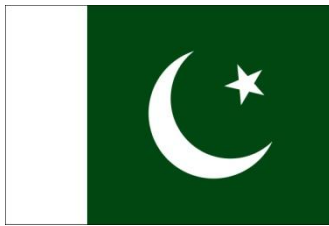   - All edges between R and L are **negative**

Analysis of Balance: Coalitions

Every node in L is enemy of R

−

B   +   −   D

Any 2 nodes
in L are friends   +   A   +   Any 2 nodes
in R are friends

+   −

C   E

L: Friends of A

R: Enemies of A
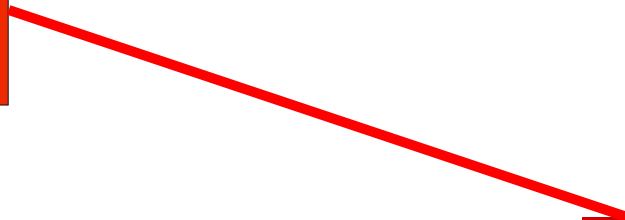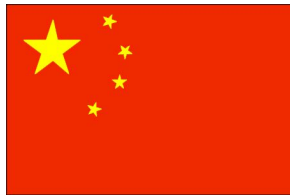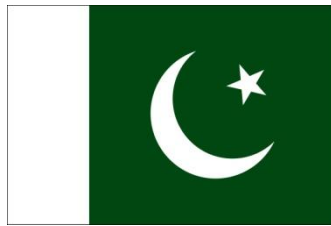
Example: International relations

Independence of Bangladesh from Pakistan in 1971
USA supported Pakistan. Why?
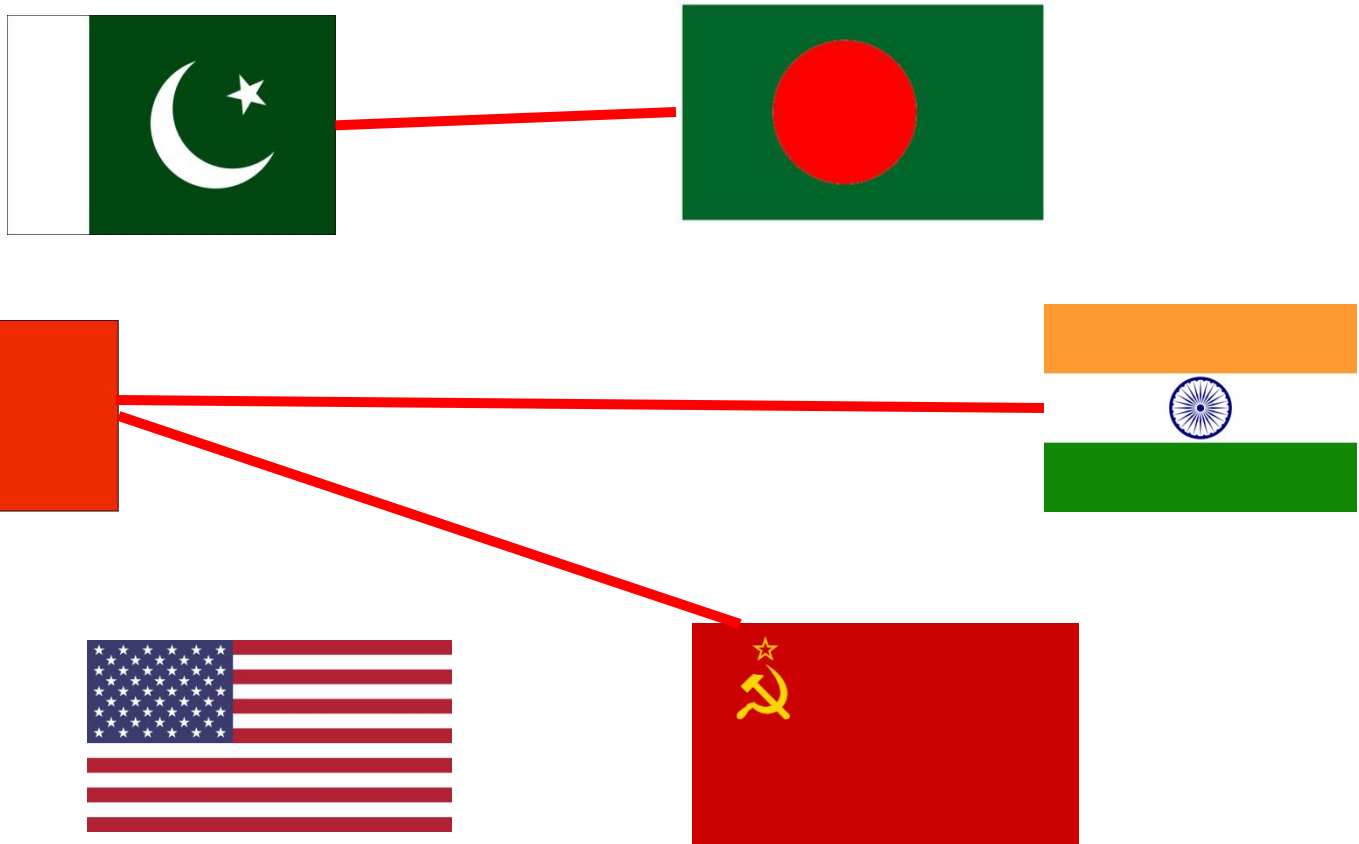
Example: International relations

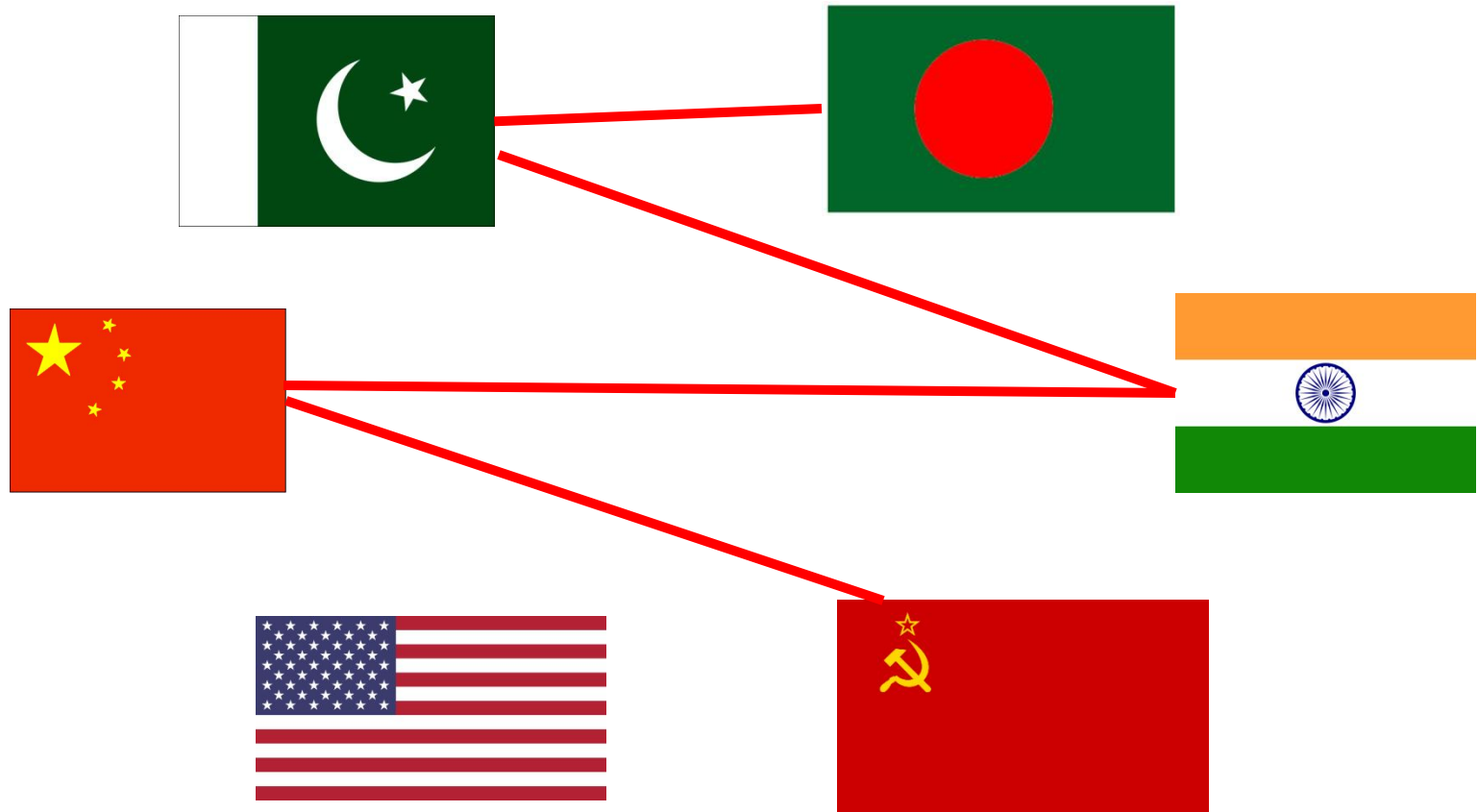# Example: International relations

USSR is an **enemy** of China

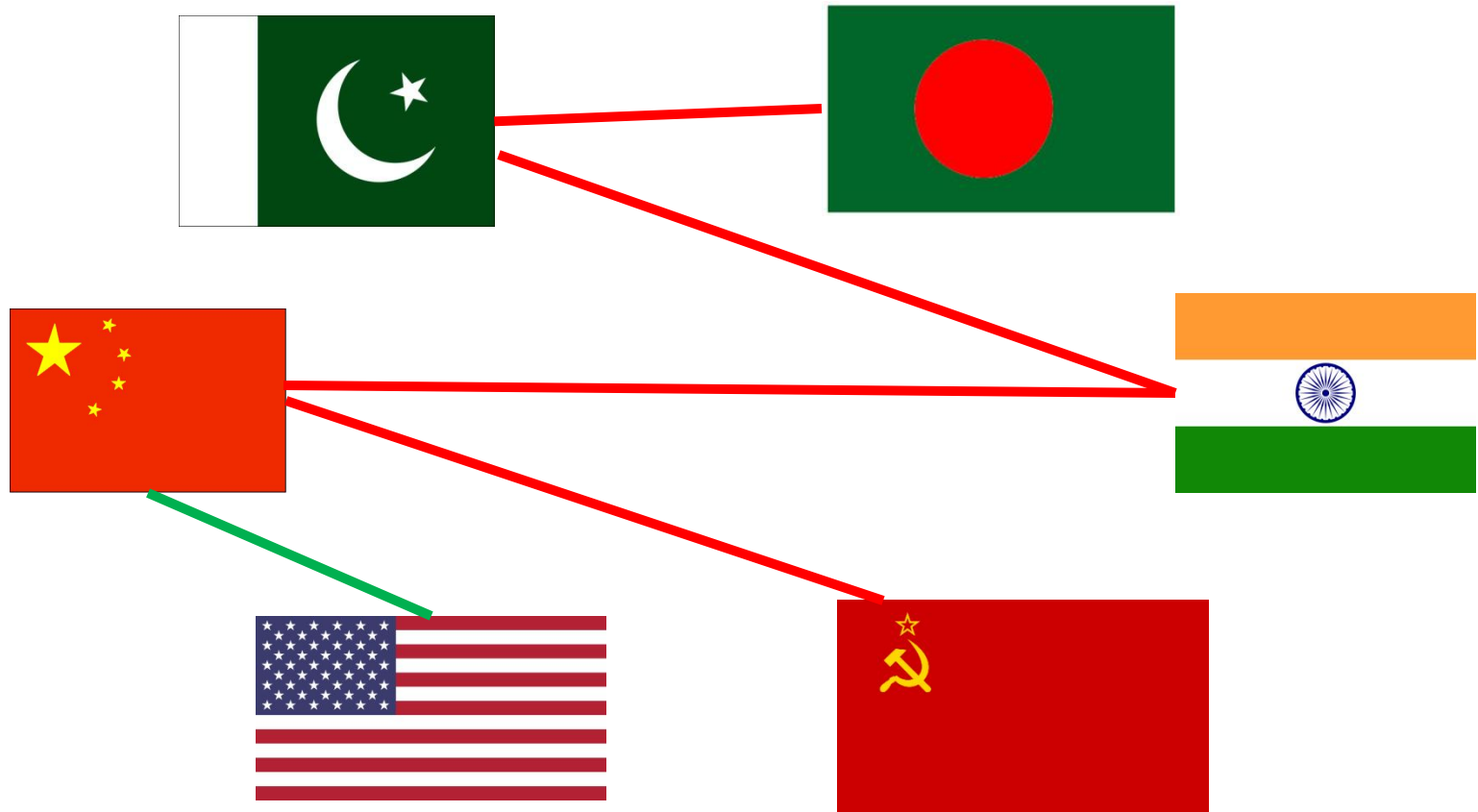# Example: International relations

China is an **enemy** of India

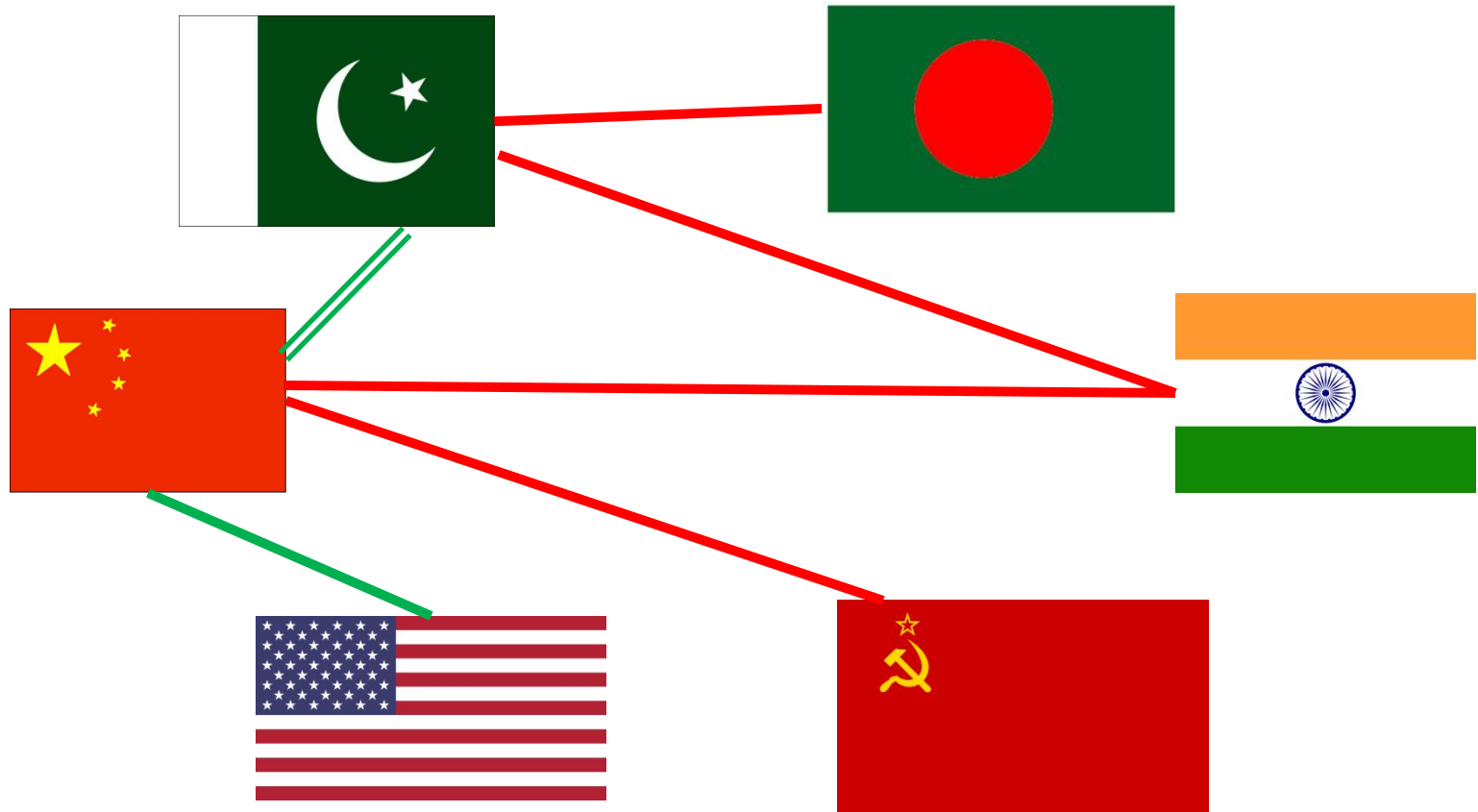# Example: International relations

India is an **enemy** of Pakistan
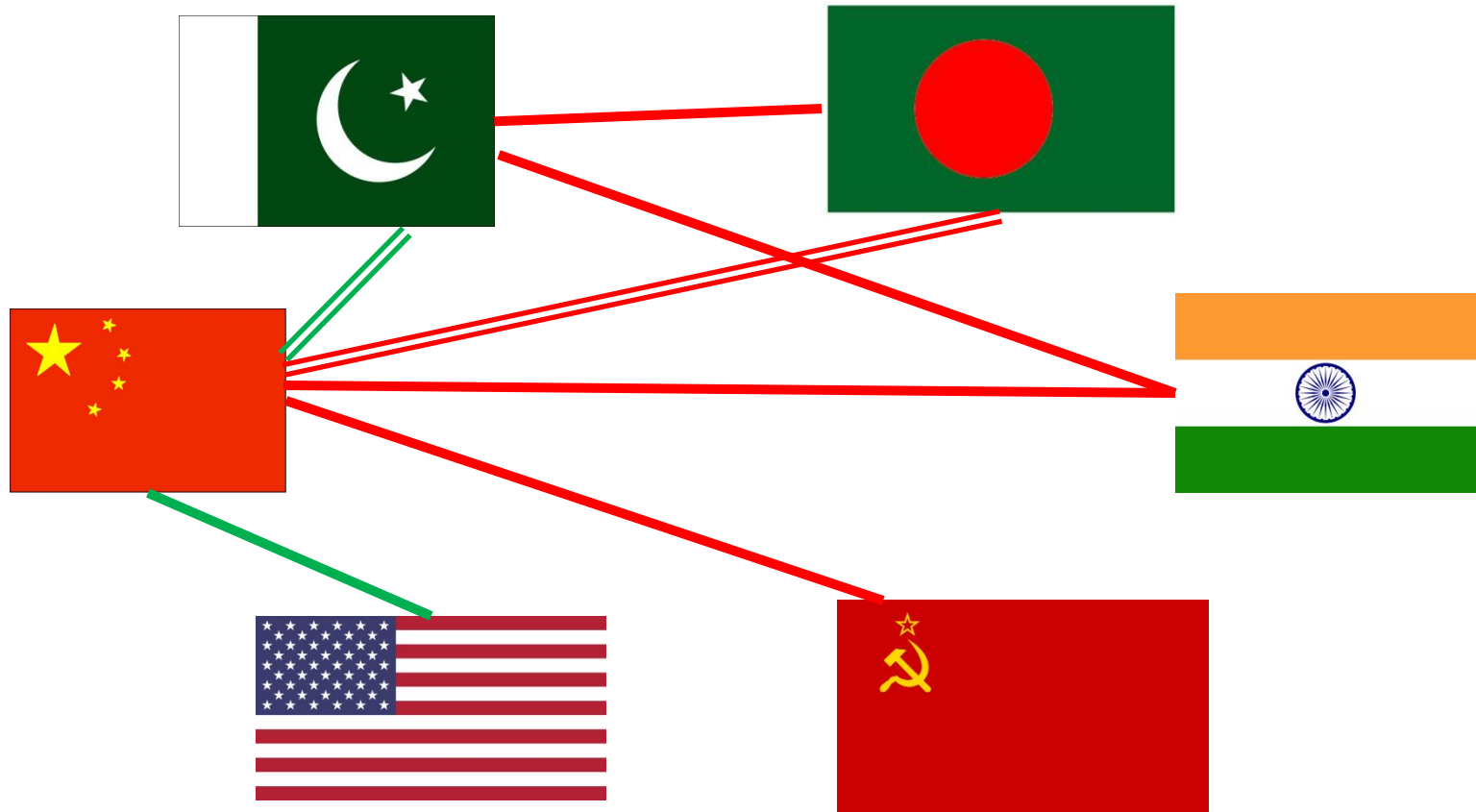
Example: International relations

USA is a **friend** of China

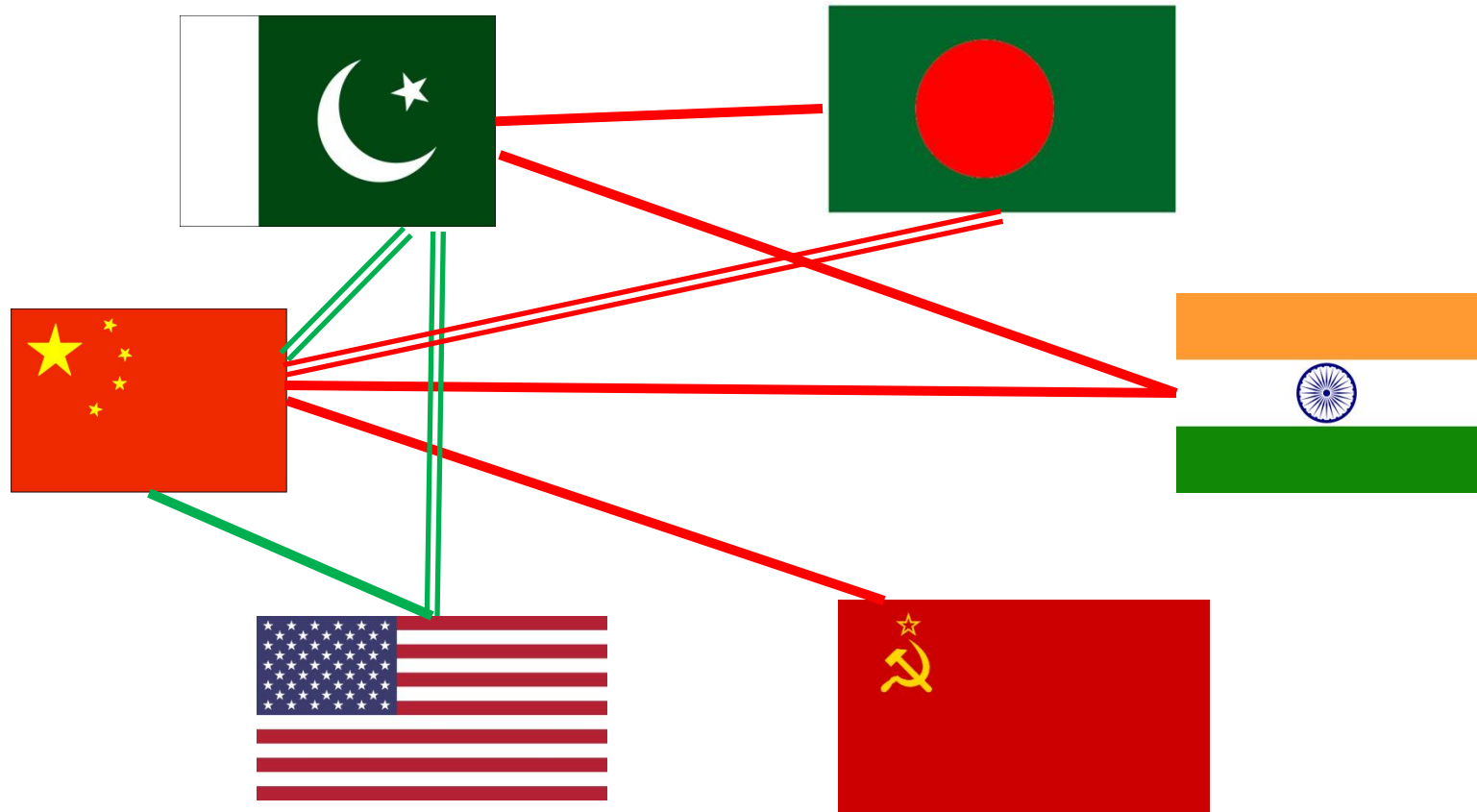# Example: International relations

Derived: China is a **friend** of Pakistan

Example: International relations

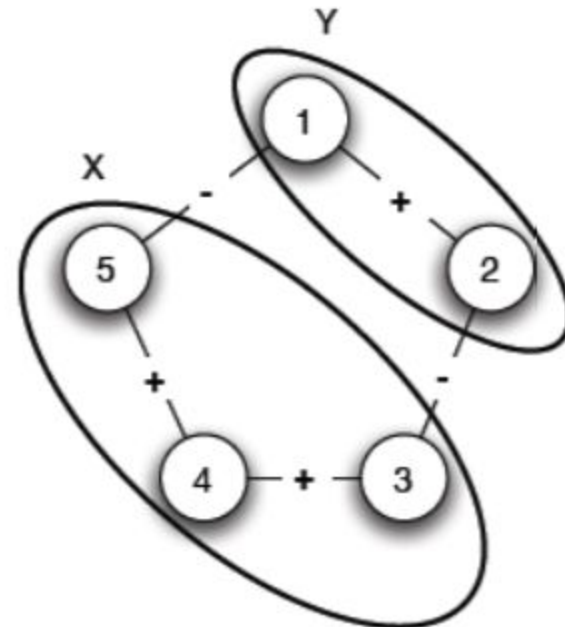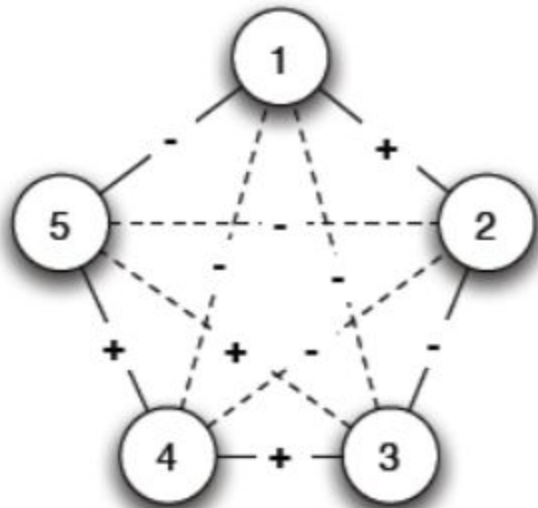Derived: China is **vetoed** of Bangaladesh

Example: International relations

Derived: USA **supported** Pakistan

Balance in General Network

- The (general) network is balanced if:
  - We can fill all missing edges to achieve balance
 - We can divide the network into two coalitions

Check if Network is Balanced

- Graph is balanced if and only if it contains no cycle with an odd number of negative edges

- Find connected components on +edges
  - If we find a component of nodes on +edges that contains a –edge
    - □ Unbalanced

- For each component create a super-node

- Connect components A and B if there is a negative edge between the members

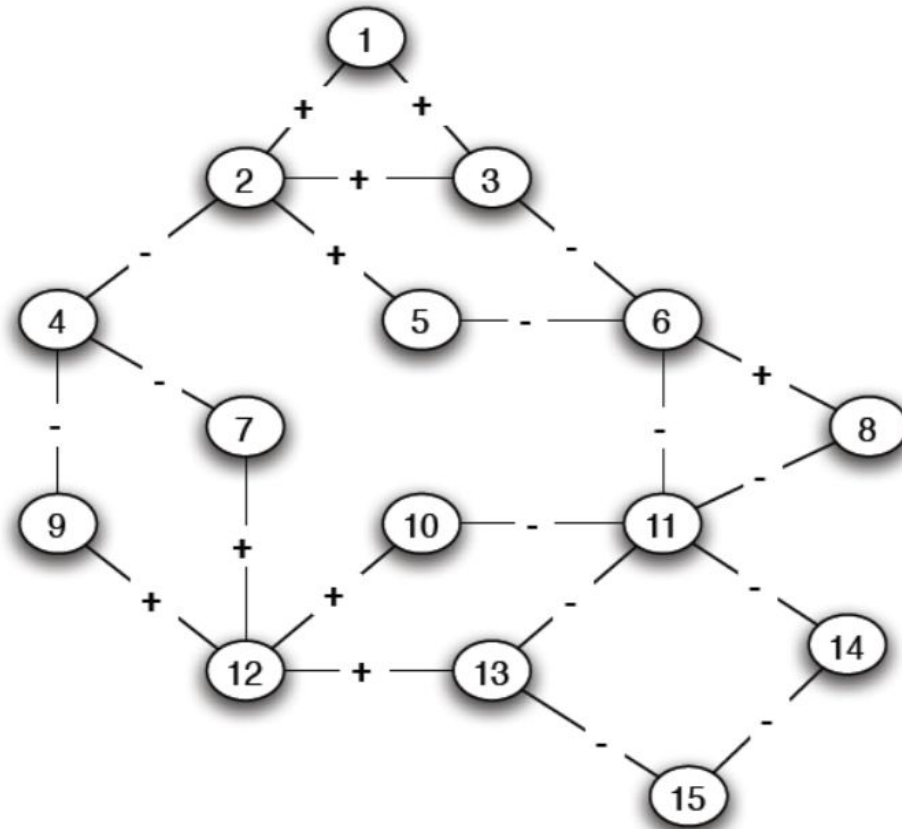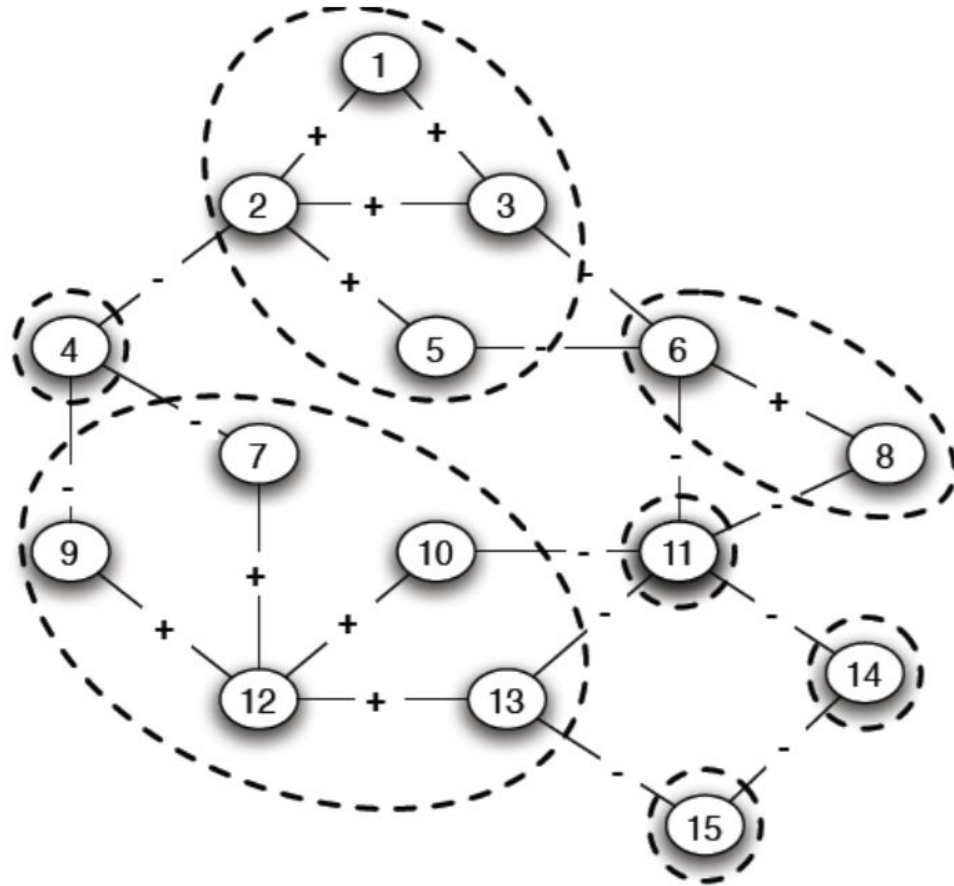- Assign super-nodes to sides using BFS
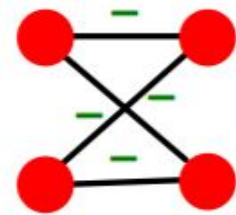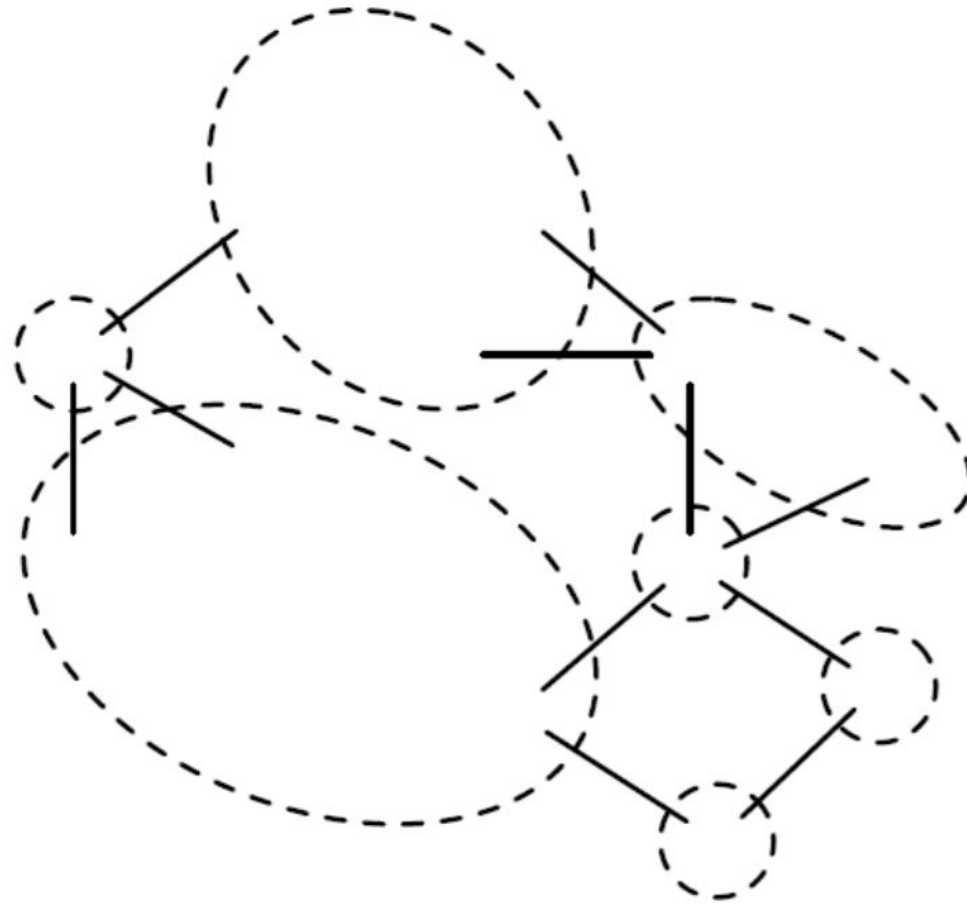
Even length cycle
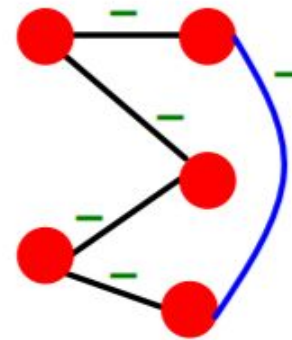
Odd length cycle

Check if Network is Balanced
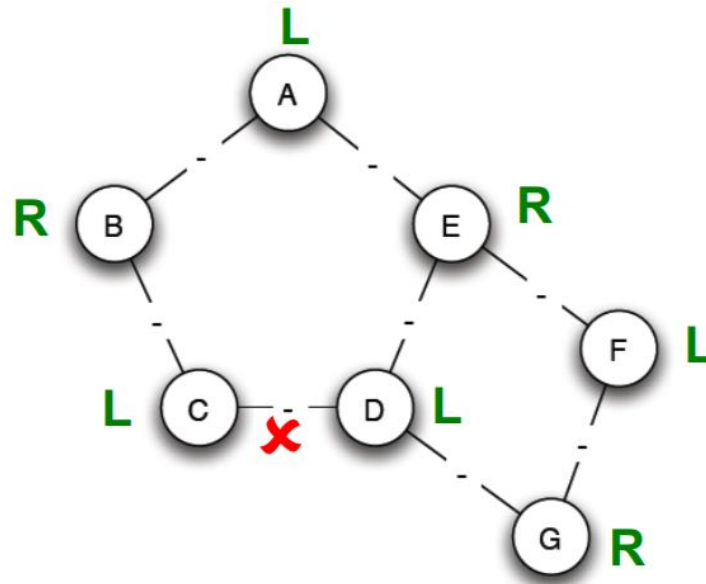
Check if Network is Balanced

Check if Network is Balanced

Check if Network is Balanced

- Using BFS – assign each node to a side
- Graph is **unbalanced** if any two connected super-nodes are assigned the same side

Thank you!
Questions?