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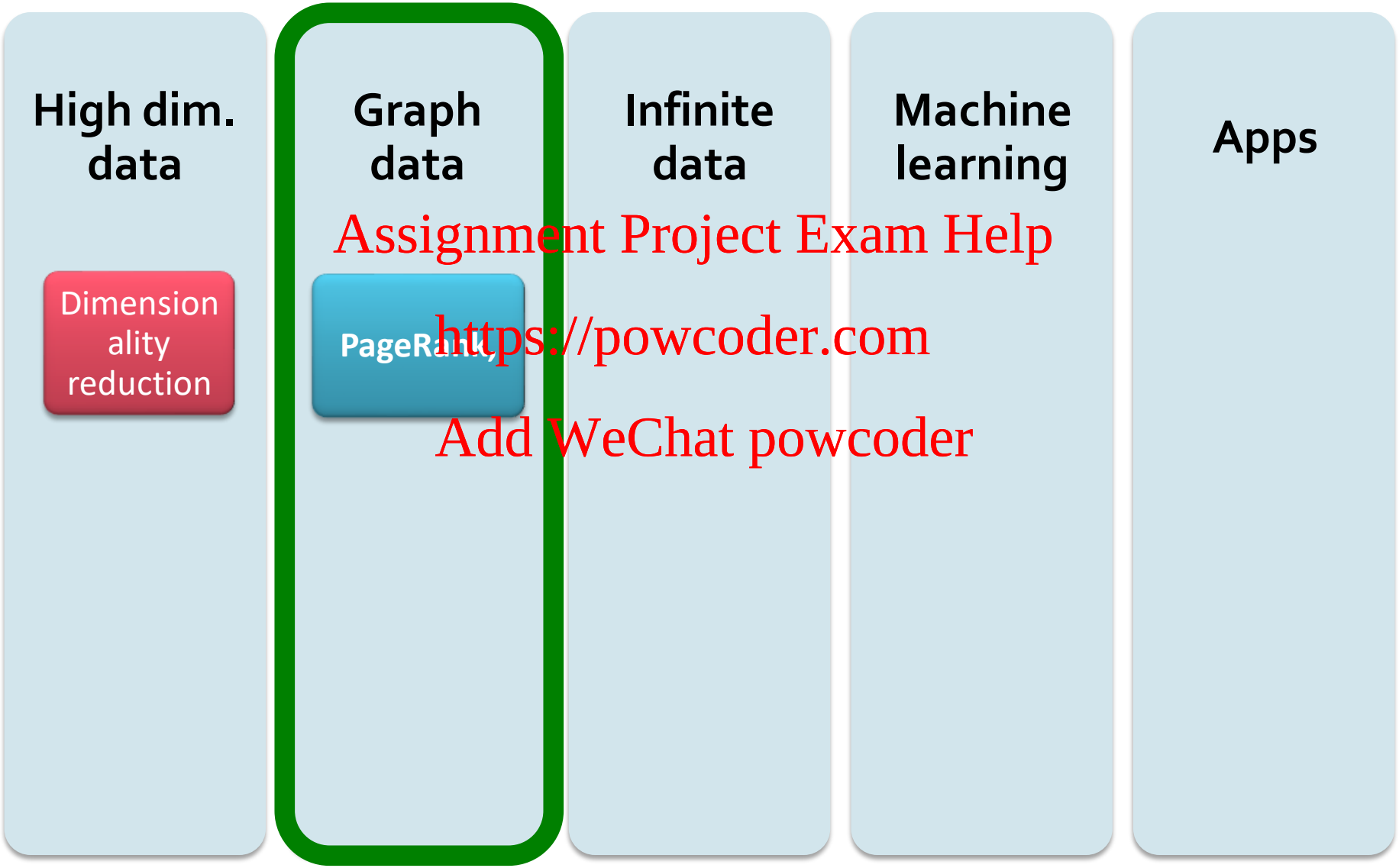
Analysis of Large Graphs: Link Analysis, PageRank

New Topic: Graph Data!



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Graph Data: Social Networks

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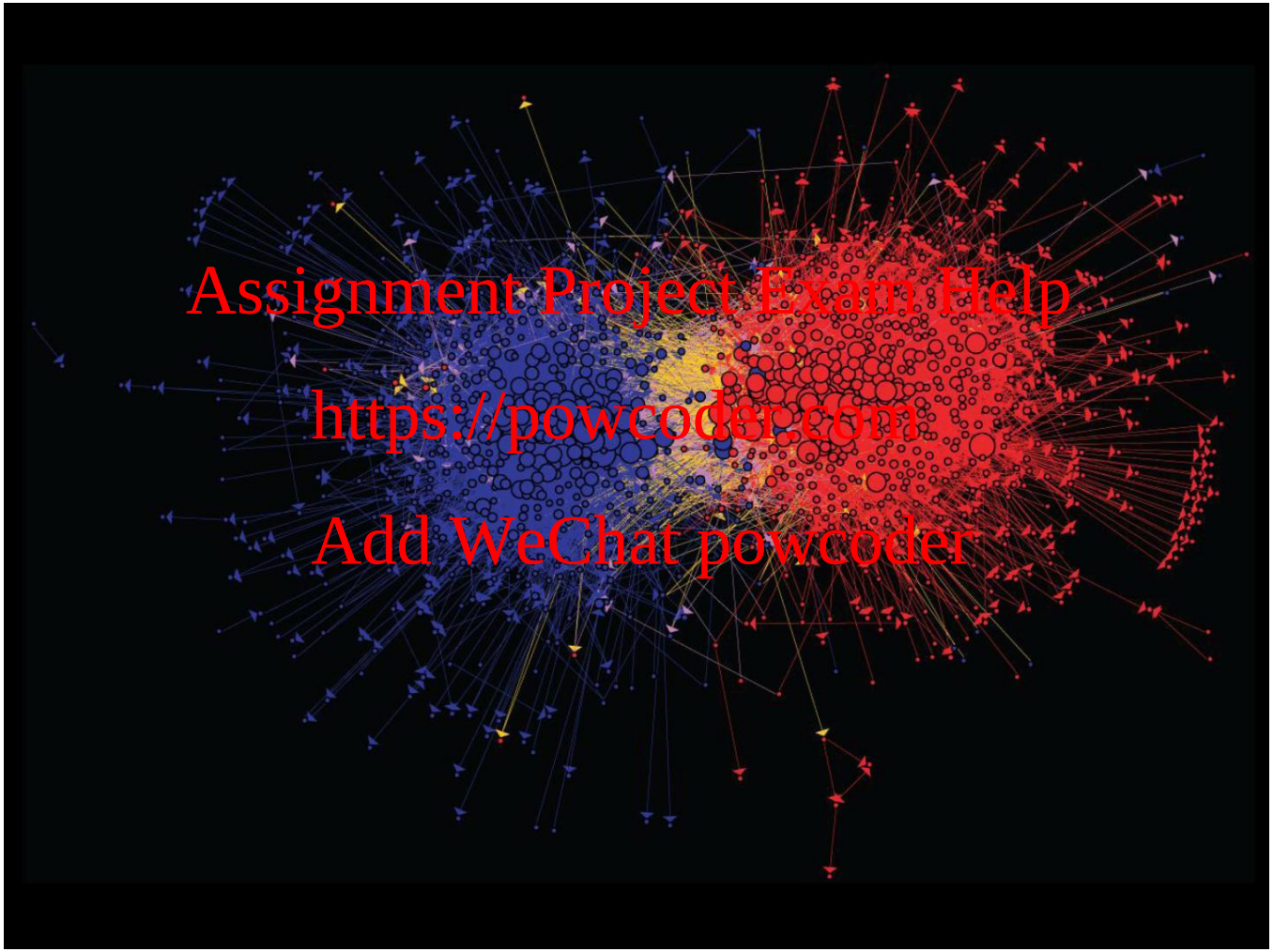
Facebook social graph

4-degrees of separation [Backstrom-Boldi-Rosa-Ugander-Vigna, 2011]

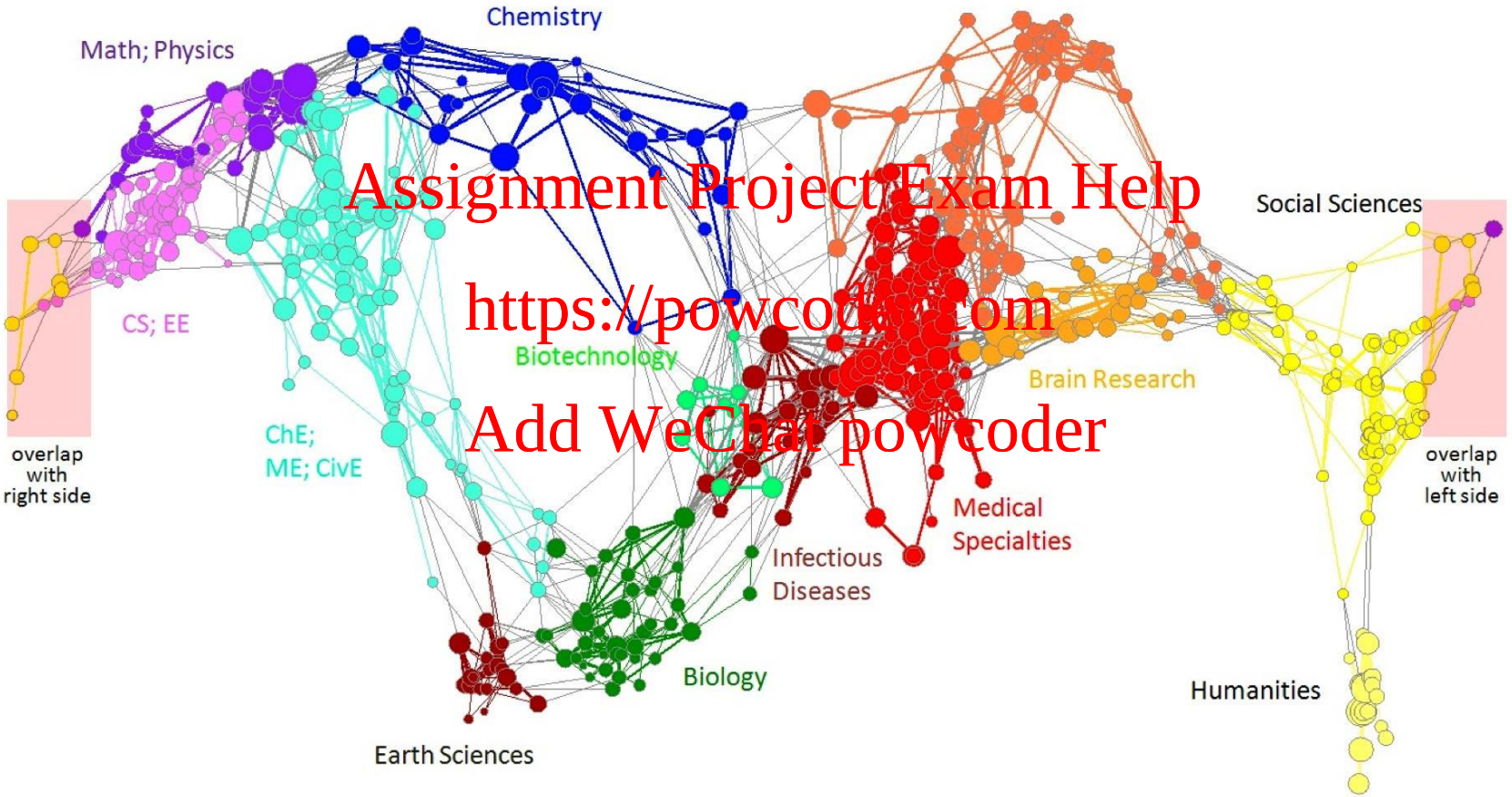
Graph Data: Media Networks



Connections between political blogs

Polarization of the network [Adamic-Glance, 2005]

Graph Data: Information Nets



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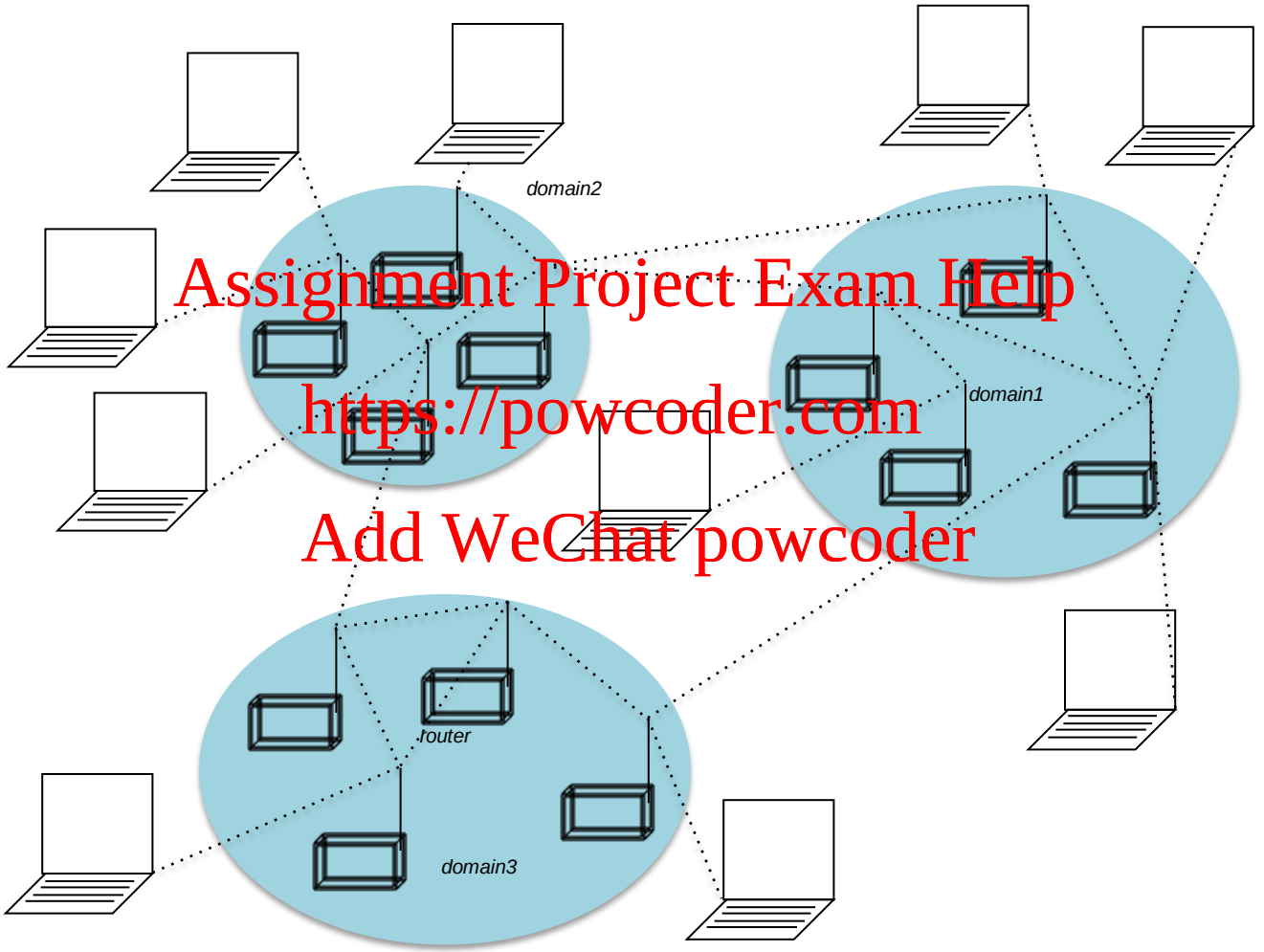
Citation networks and Maps of science

[Börner et al., 2012]

Graph Data: Communication Nets



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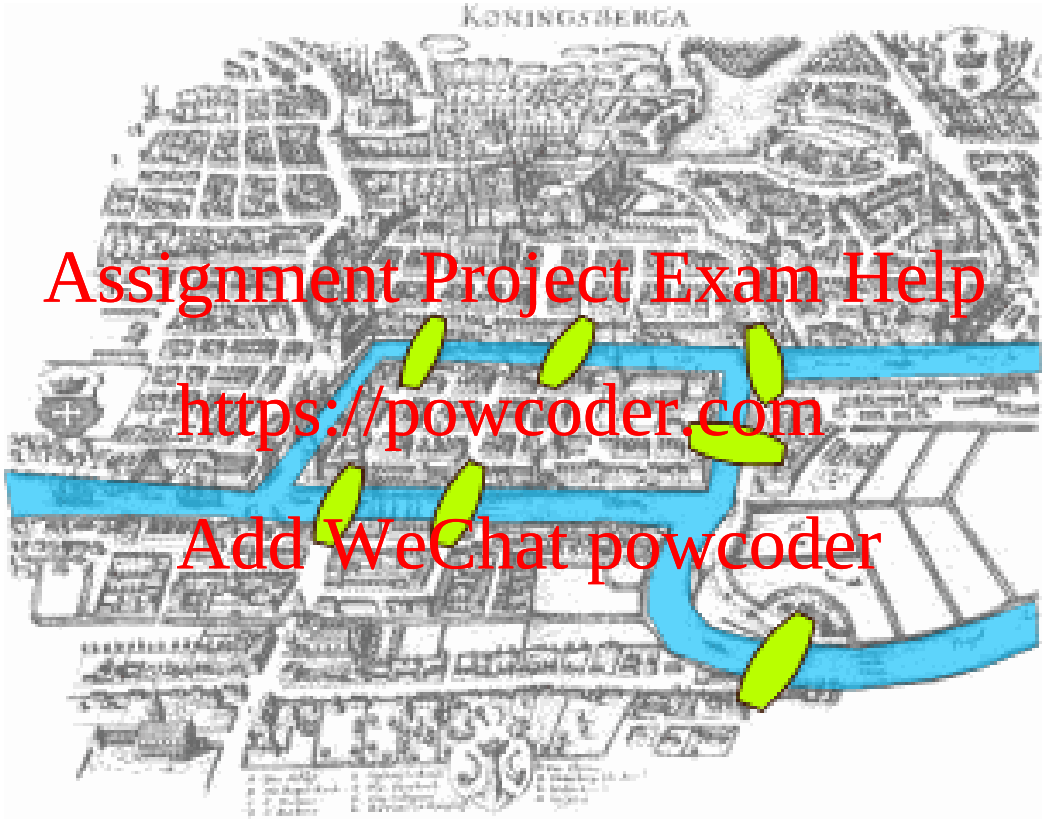
Graph Data: Technological Networks



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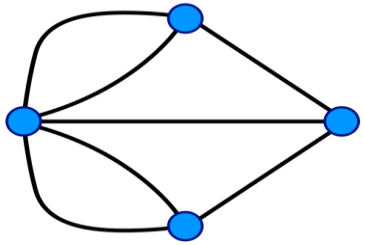
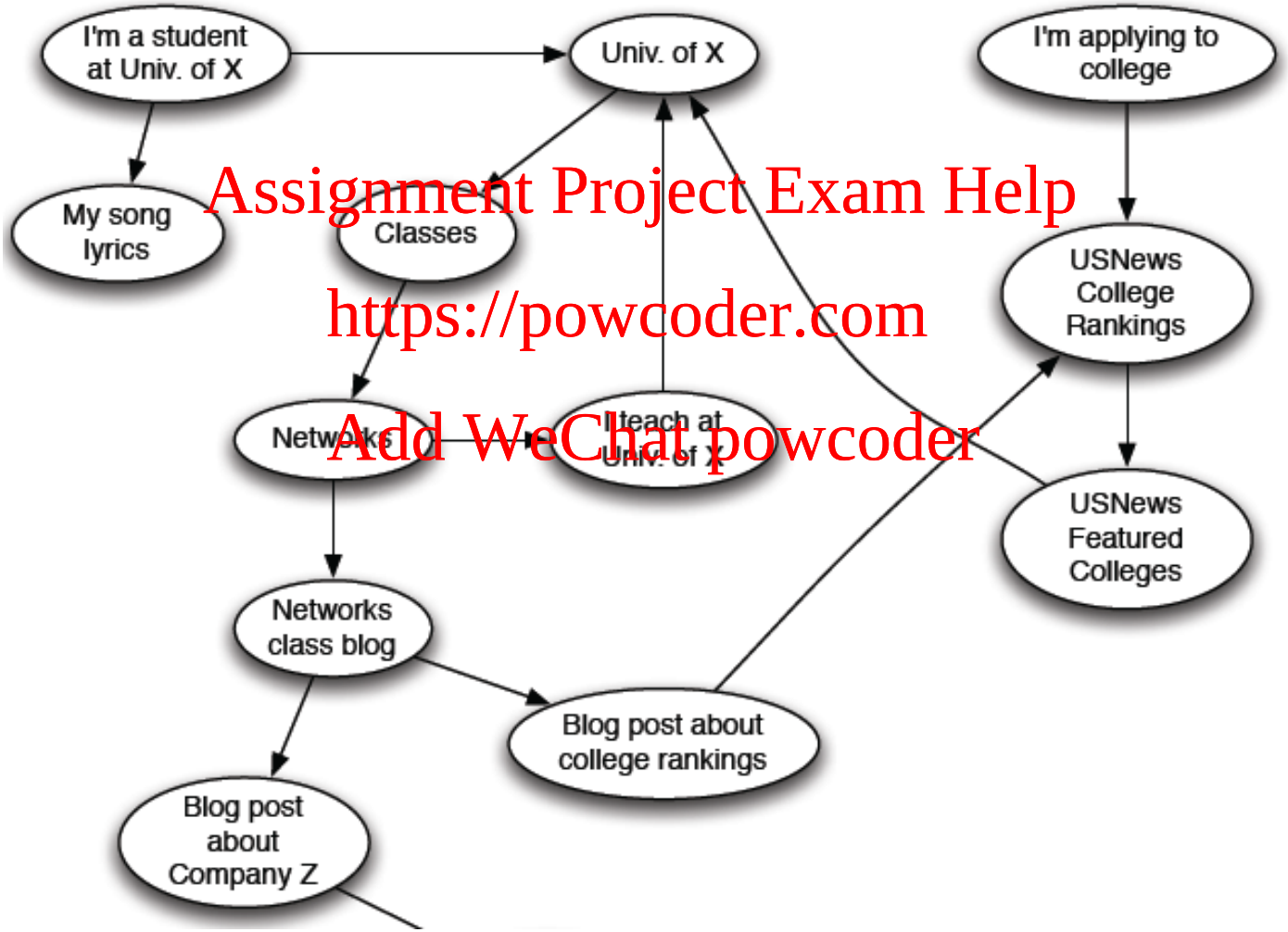
Seven Bridges of Königsberg

[Euler, 1735]

Return to the starting point by traveling each link of the graph once and only once.



Web as a Directed Graph



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Broad Question

- **How to organize the Web?**
- **First try:** Human curated **Web directories**
  - Yahoo, DMOZ, LookSmart
- **Second try:** **Web Search**
  - **Information Retrieval** investigates: Find relevant docs in a small and trusted set
    - Newspaper articles, Patents, etc.
  - **But:** Web is **huge**, full of untrusted documents, random things, web spam, etc.

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Web Search: 2 Challenges

2 challenges of web search:

- **(1) Web contains many sources of information Who to "trust"?**
  - **Trick:** Trustworthy pages may point to each other!
- **(2) What is the "best" answer to query "newspaper"?**
  - No single right answer
  - **Trick:** Pages that actually know about newspapers might all be pointing to many newspapers

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Ranking Nodes on the Graph

- **All web pages are not equally "important"**

- There is large diversity in the web-graph node connectivity.
  Let's rank the pages by the link structure!

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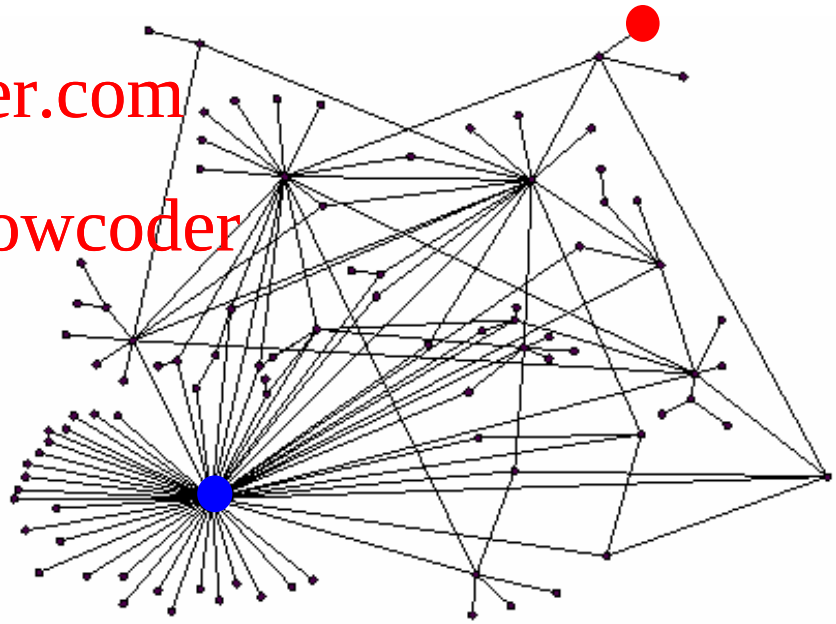

Link Analysis Algorithms

- We will cover the following **Link Analysis approaches** for computing **importances** of nodes in a graph:
  - Page Rank
  - Topic-Specific (Personalized) Page Rank
  - Web Spam Detection Algorithms

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Links as Votes

- **Idea: Links as votes**
  - **Page is more important if it has more links**
    - In-coming links? Out-going links?
- **Think of in-links as votes:**
- **Are all in-links are equal?**
  - **Links from important pages count more**

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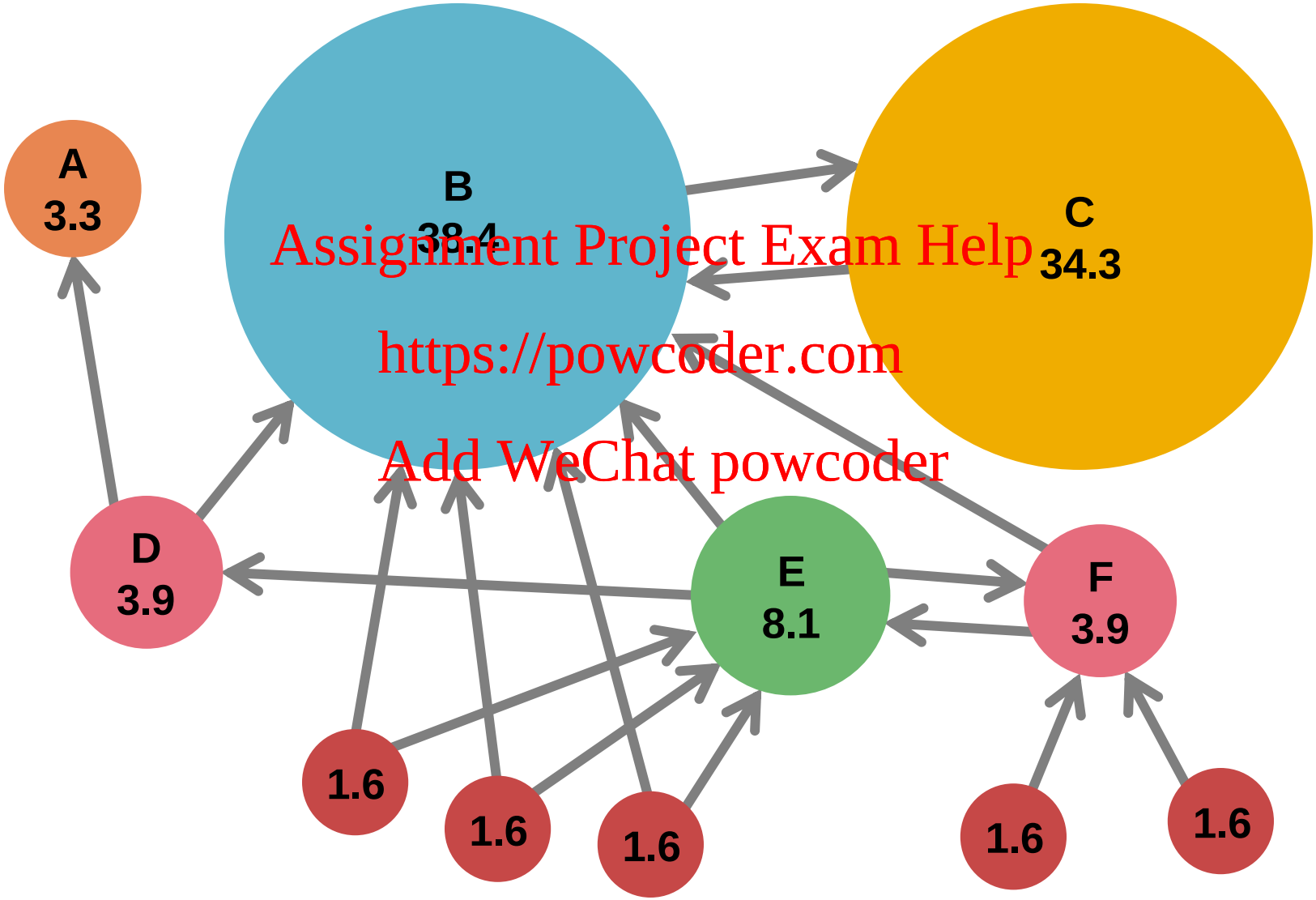
Example: PageRank Scores



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Simple Recursive Formulation

- Each link's vote is proportional to the **importance** of its source page
- If page ***j*** with importance r_j has ***n*** out-links, each link gets r_j / n votes
- Page ***j***'s own importance is the sum of the votes on its in-links

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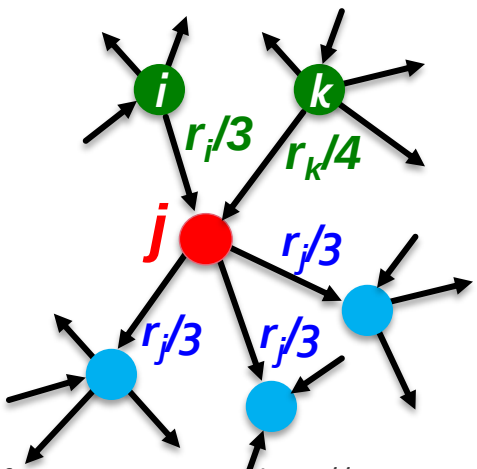
$r_j = r_i/3 + r_k/4$



Page Rank

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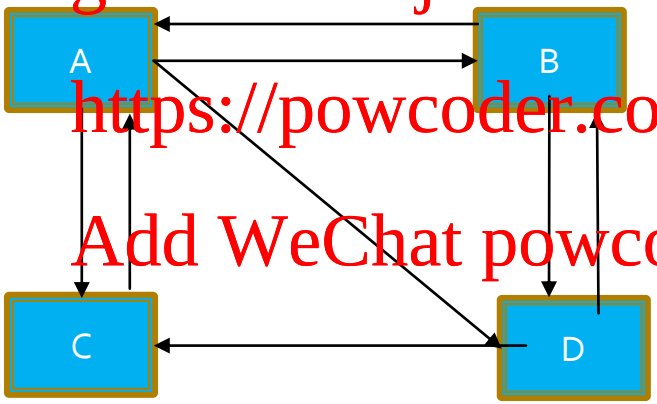

Link Matrix

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	A	B	C	D
A	0	1	1	0
B	1	0	0	1
C	1	0	0	1
D	1	1	0	0

Transition Matrix

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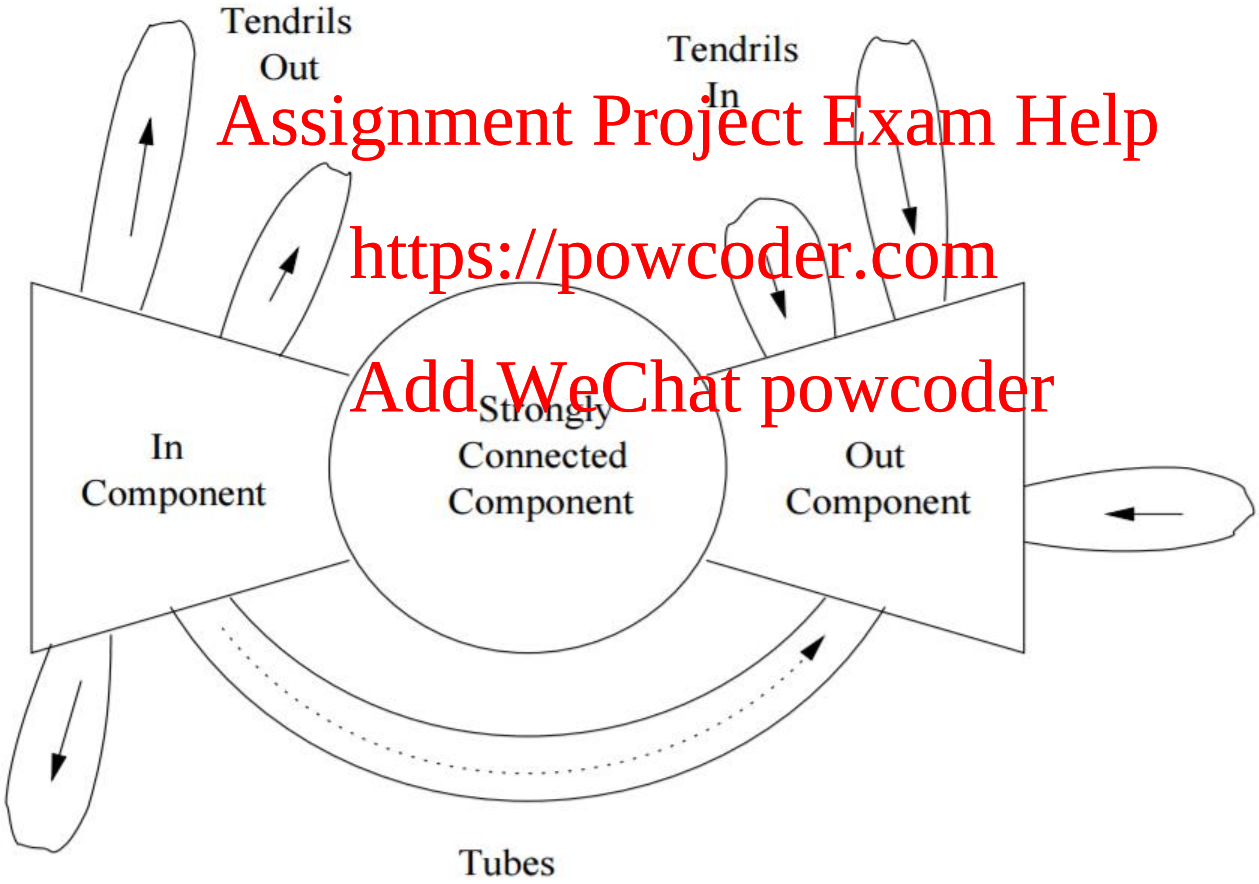
	A	B	C	D
A	0	1/2	1/1	0
B	1/3	0	0	1/2
C	1/3	0	0	1/2
D	1/3	1/2	0	0

A	0.25
B	0.25
C	0.25
D	0.25

Web structure

/~ullman/mmds/book.pdf



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