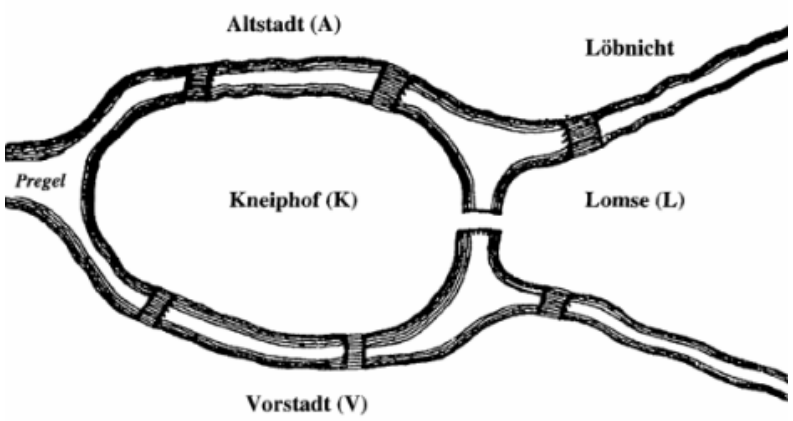
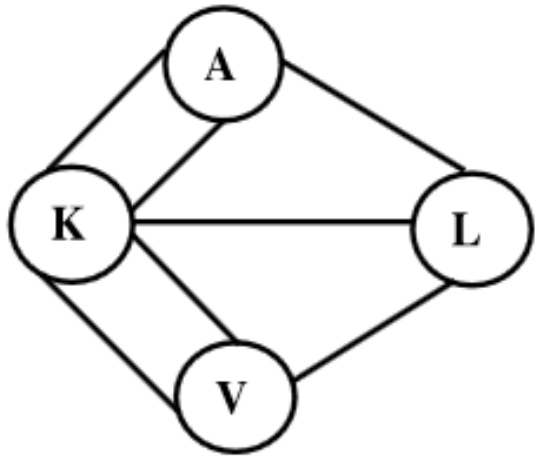

Keep
CALM
because
THE MATRIX
has you

What is a Graph?





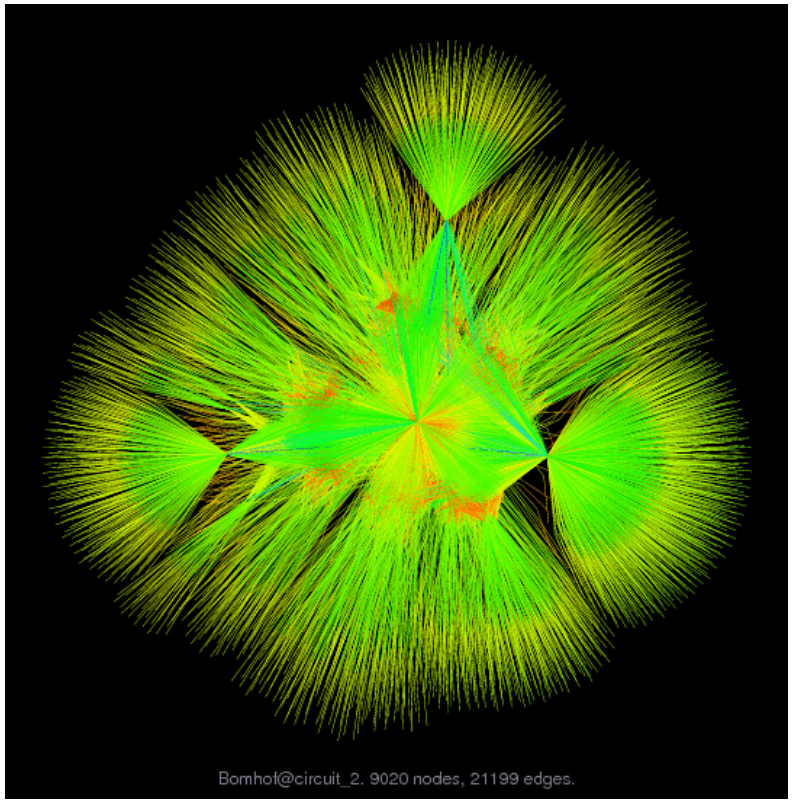
Seven Bridges of Königsberg

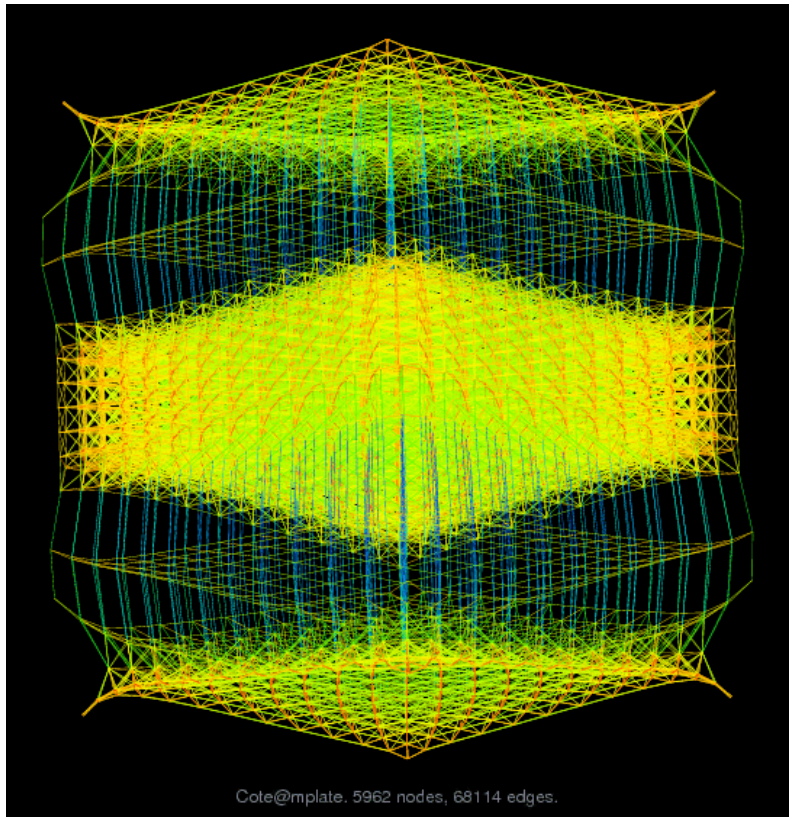
Find a walk through the city that would cross each bridge once and only once.
Negative resolution by Leonhard Euler (1735).

Let define a graph $G = (V, E)$ where:

- V is the vertices set
- $E = \{(u, v) | u, v \in V\}$ is the edges set

Big Graphs





Examples

- Social network Graphs, Online communities
- Road networks, Communication networks
- Brain Connectome, Protein structures

Distributed graph processing

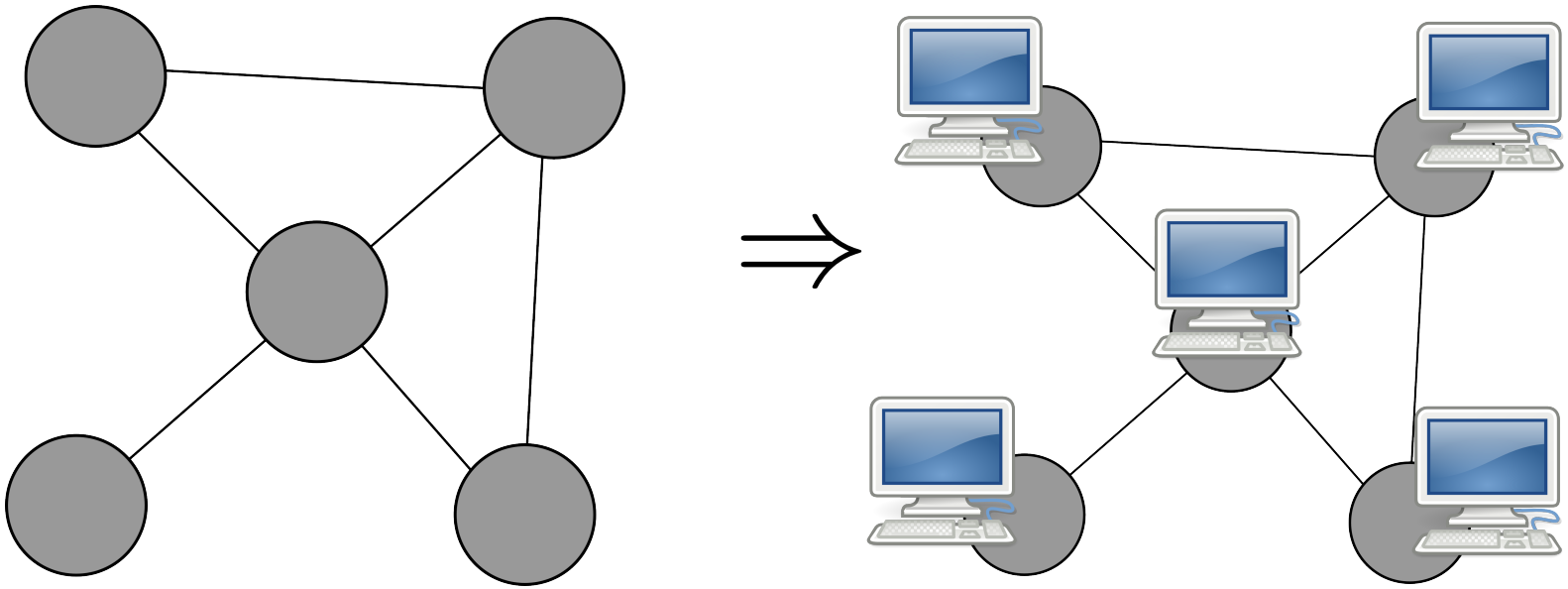
Figure: Yahoo! Cluster @ OSCON 2007

Bulk Synchronous Parallel

Parallel execution over several machines synchronized by a communication barrier.
Actual inspired frameworks:

- MapReduce
- Pregel

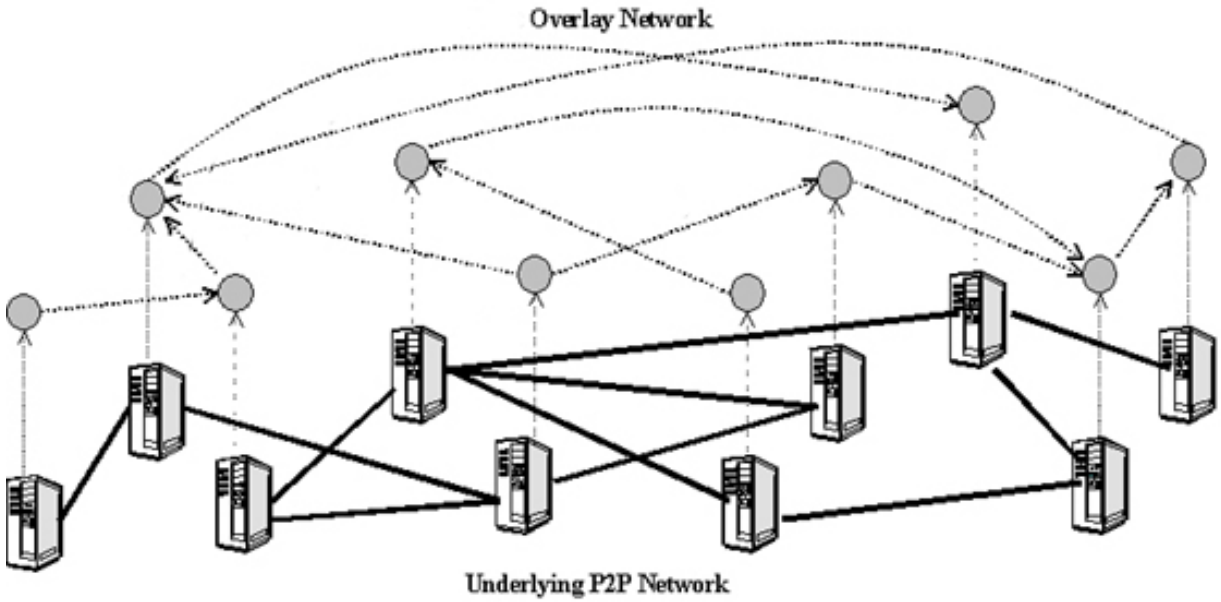
Graph as a Network



..Think as a Vertex..

function vertexLogic:
$(Vertex, Set <Messages>) \Rightarrow (Vertex, Set <Messages>)$

Peer-to-Peer & Gossip



P2P

- completely distributed environment
- fixed physical network
- churn phenomenon
- overlays

Gossip

- simple
- epidemic process
- information percolation
- approximate process

Framework motivations

Outlining

- lack of tools
- algorithms re-usability encouraging communities interactions
- distributed data processing resources are becoming a P2P environment
- topology overlay exploitation
- adopting a P2P-like approach into the graph processing subject

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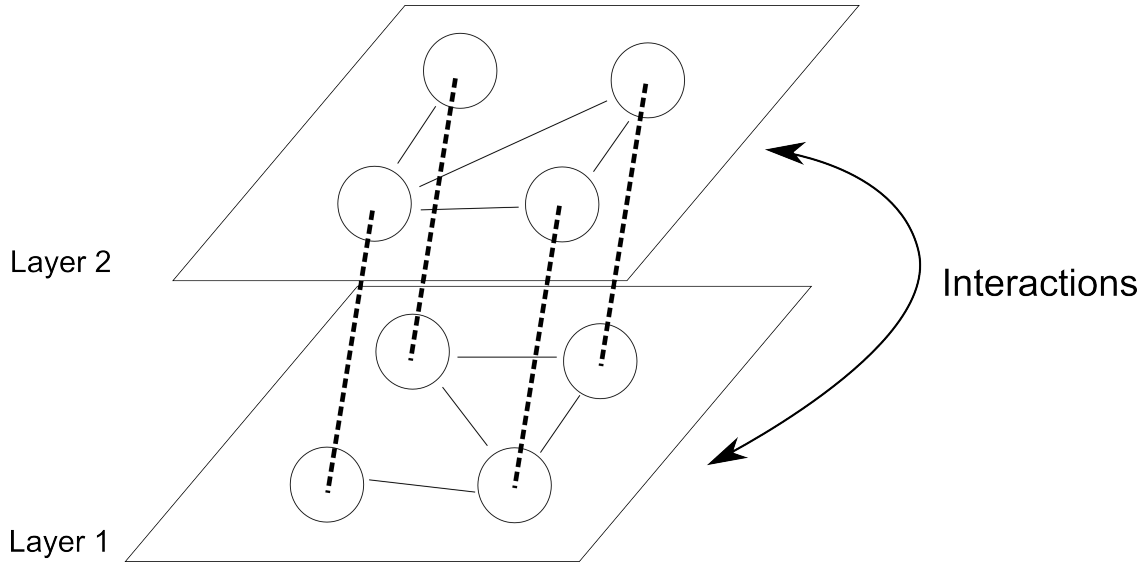

Overlays Not Just A Graph

A parallel multi-layered graph abstraction

- Each Protocol can exchange information with other Protocols in order to orchestrate a complex but convenient computation
- Development of a Peer-to-Peer (P2P) protocol stack emphasizing the topology overlays which could be exploited

Facts

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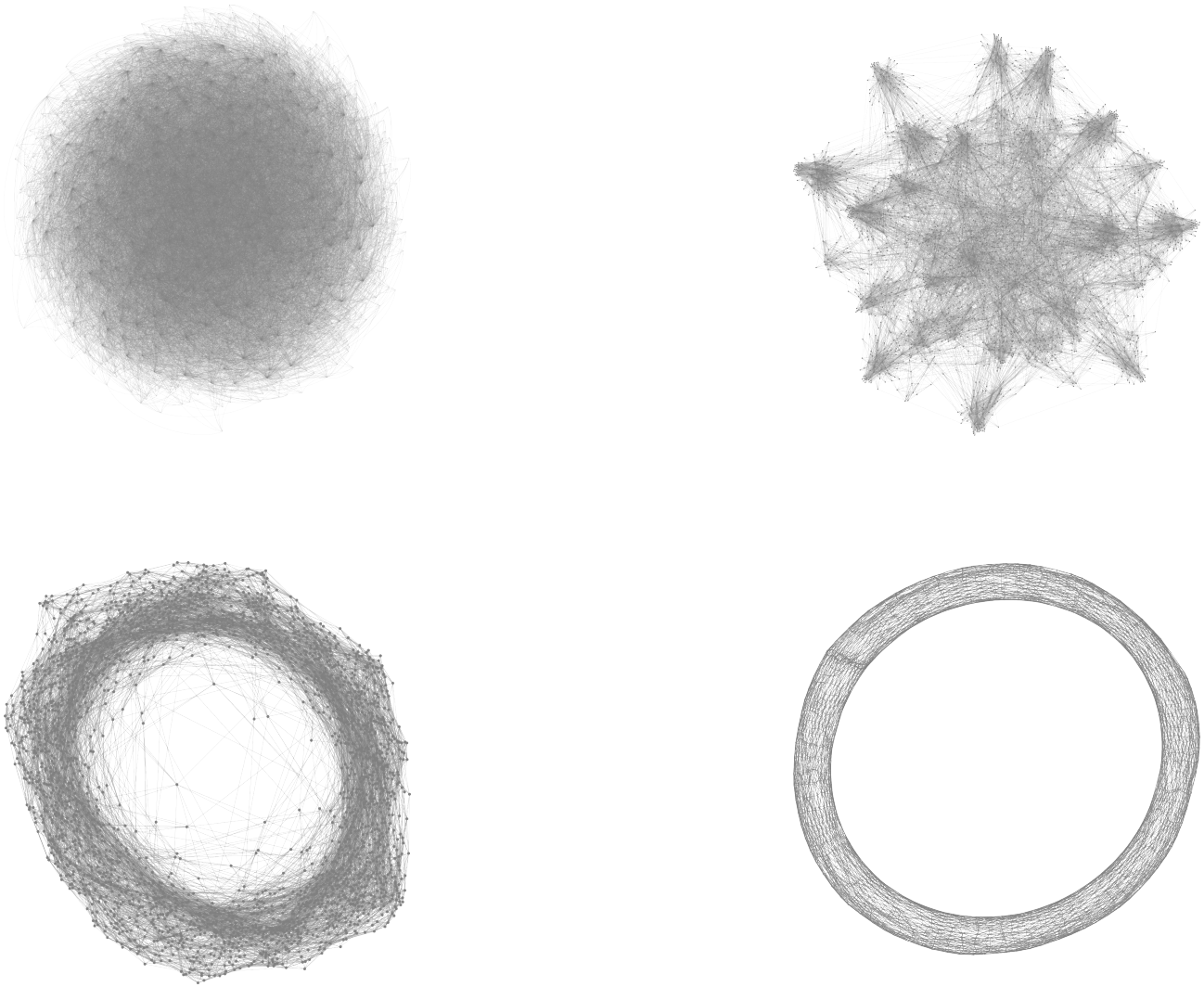
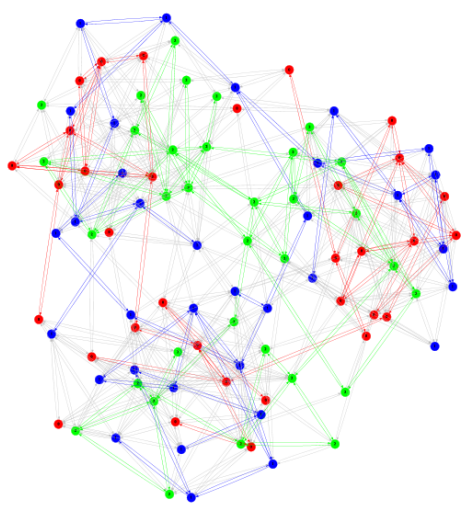
- Scala language (JVM based)
- around 7000 lines of code
- Spark *Lightning-Fast Cluster Computing*
- Protocols Toolbox:
  - Distributed k-core decomposition
  - Random Peer Sampling
  - T-MAN, topology overlay manager
  - JA-BE-JA, balanced minimum k-cut

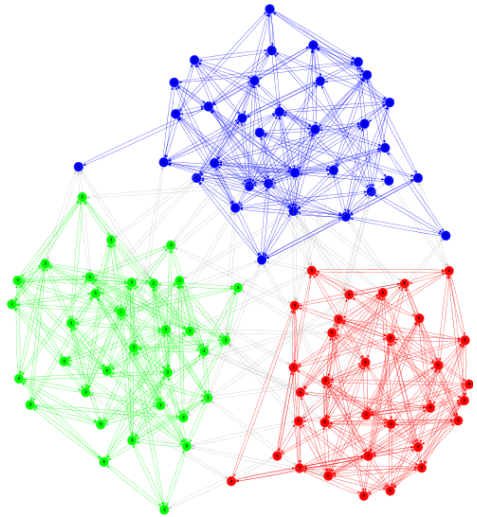
Torus overlay by T-MAN



Jelasity M. and Babaoglu O.. *"T-Man: Gossip-based Overlay Topology Management"*. ESOA'05, 2006.

Balanced k-way partitioning





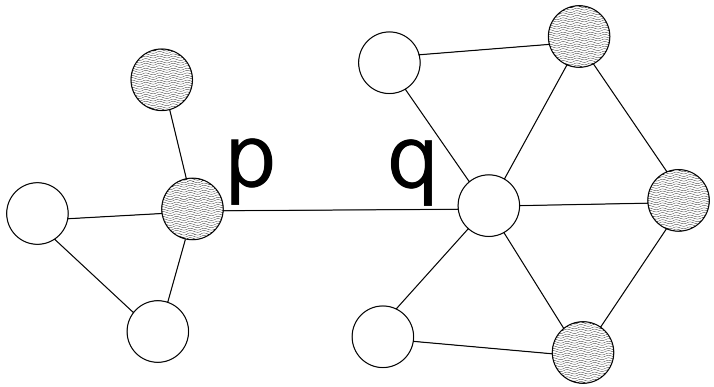
Balanced minimum k-way cut

Given an undirected graph $G = (V, E)$
partition into $k \in [2, \cdots, |V|]$
disjoint sets $S = \{P_1, P_2, \cdots, P_k\}$ minimizing:

$$\sum_{i=1}^{k-1} \sum_{j=i+1}^{k} \sum_{v_i \in P_i, v_j \in P_j} w(v_i, v_j)$$

where $w(a, b) = |\{(a, b)\} \cap E|$

JA-BE-JA



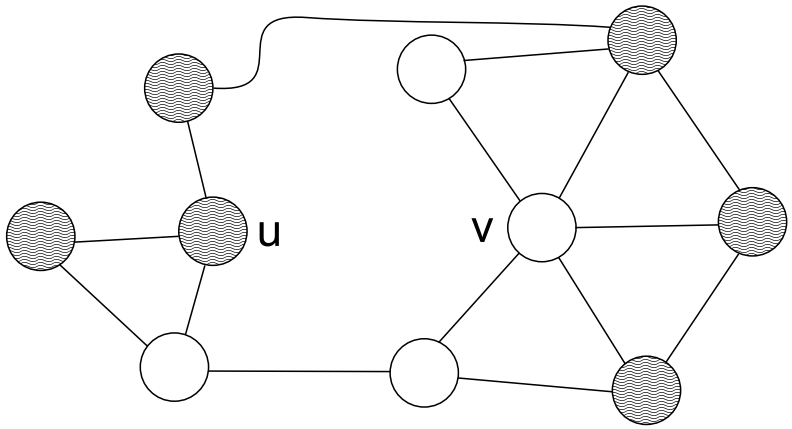
Local search optimization

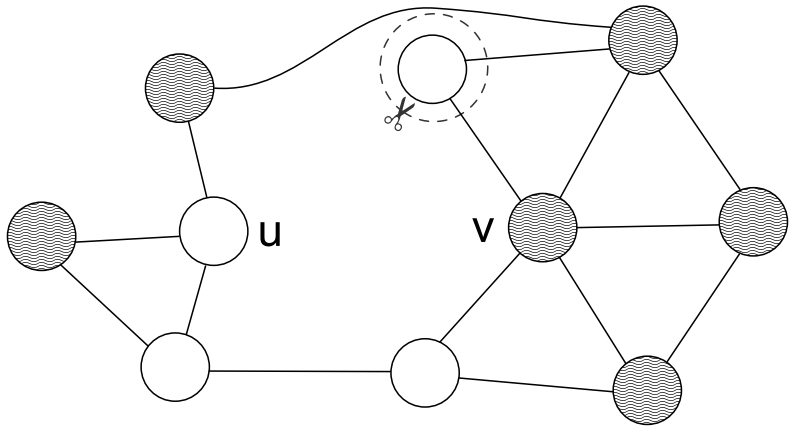
- heuristic, simple and asynchronous algorithm
- aims with extremely large distributed graphs
- Simulated Annealing against local minima
- update decision criterion:

$$(d_p(\pi_q)^\alpha + d_q(\pi_p)^\alpha) \times T > d_p(\pi_p)^\alpha + d_q(\pi_q)^\alpha$$

Rahimian F. and Payberah A. H. and Girdzijauskas S. and Jelasity M. and Haridi S.. *"JA-BE-JA: A Distributed Algorithm for Balanced Graph Partitioning"*. SASO, IEEE. 2013.

Issues

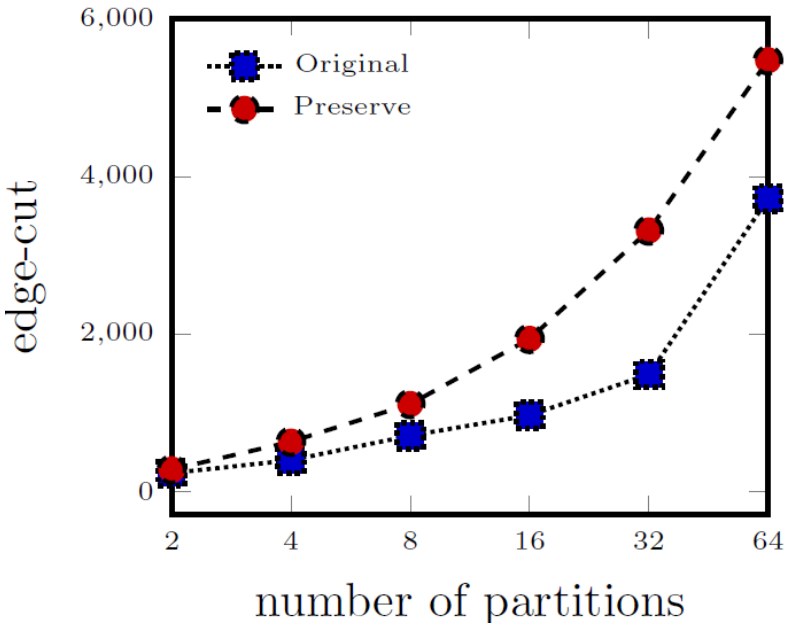




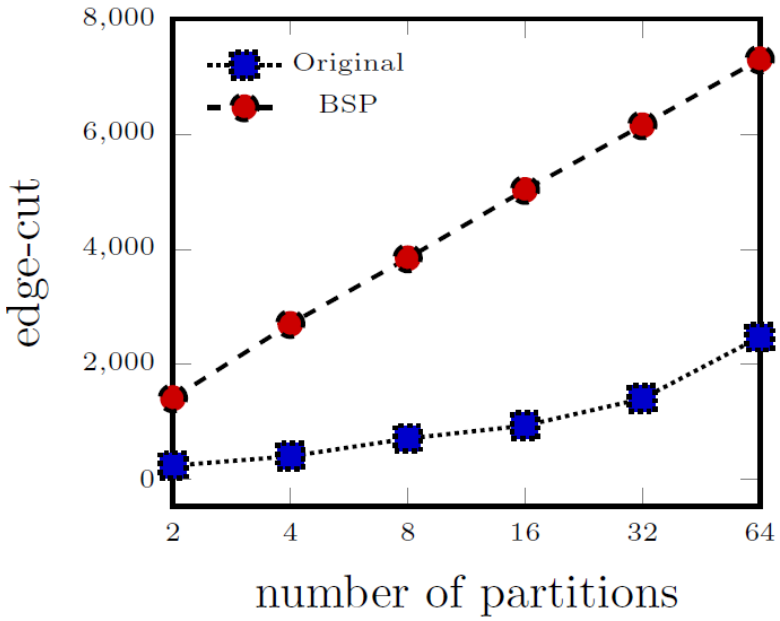
JA-BE-JA:

- does NOT preserve the *connected components* property
  $\Rightarrow$ NO proper mincut!
- requires neighbours' color and their neighbourhood colors
  $\Rightarrow$ NO Pregel-like frameworks friendly

Solutions & Experiments

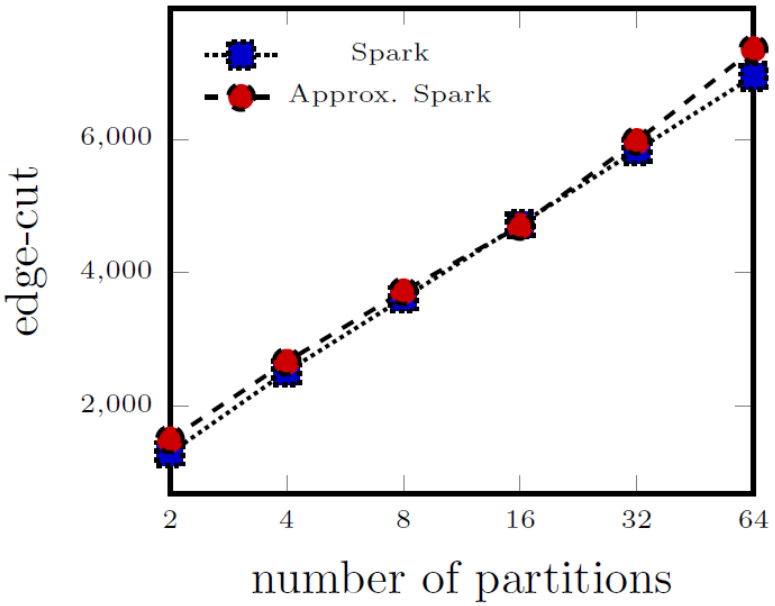


P2P

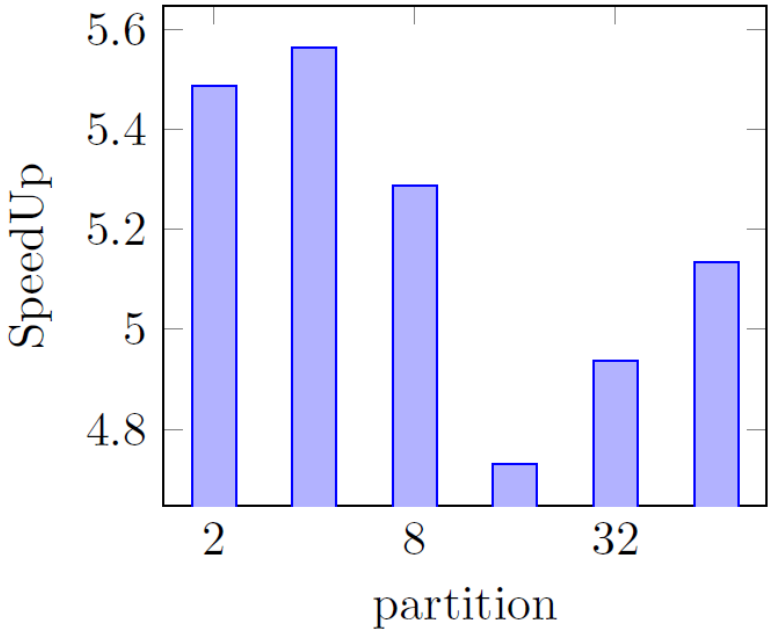


Spark

Solutions & Experiments



Approximate JA-BE-JA



Speed Up

New k-cut partitioning measure

$$Nassocc(A, B)$$

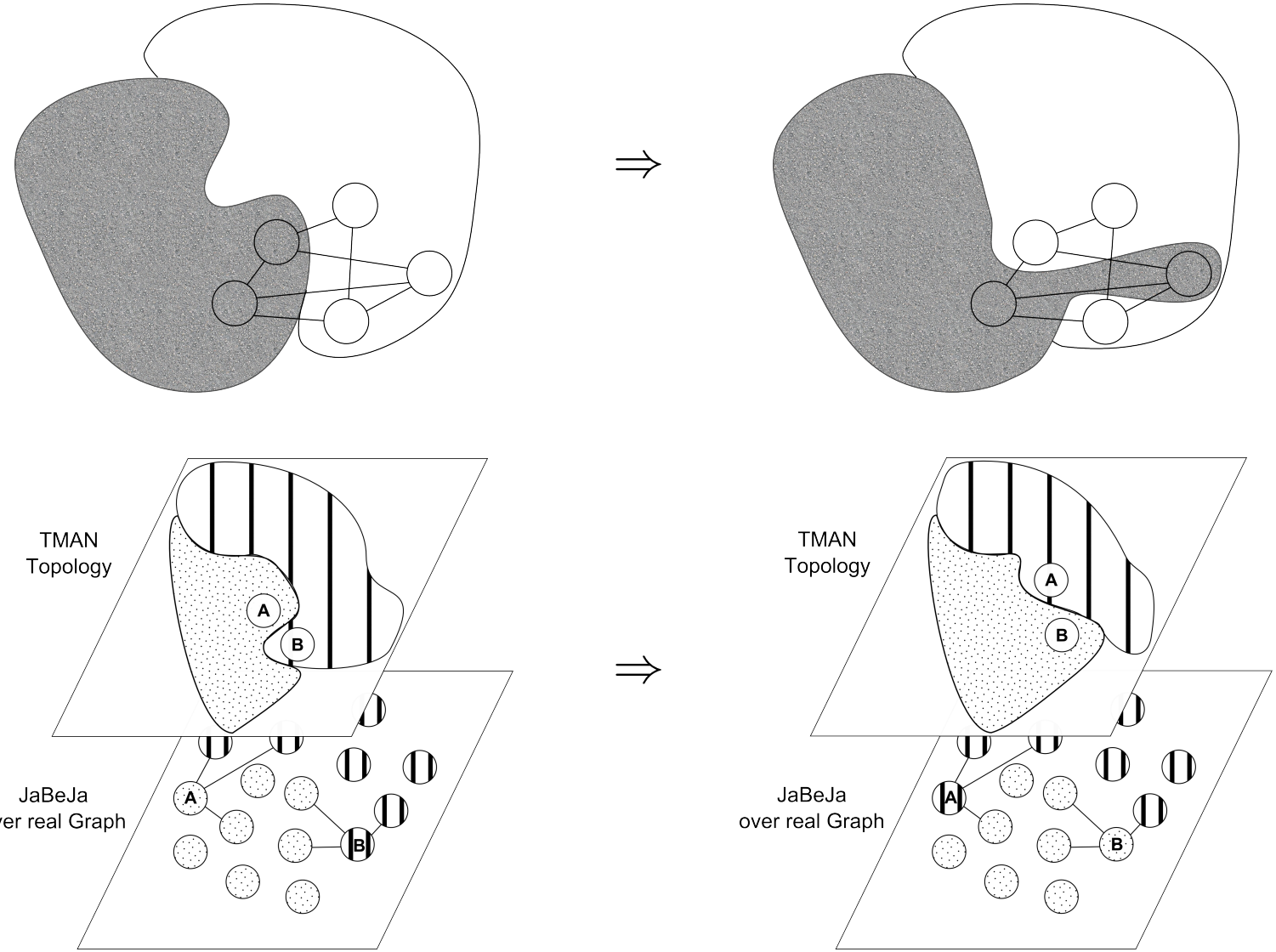
$$Ncut(A, B) = 2 - Nassocc(A, B)$$

Normalized Quasi cut (NQcut)

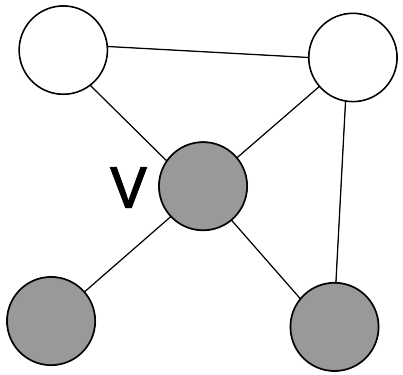
- derived from the *Normalized cut* by Shi-Malik (extended to k partitions)
- defined a custom *Nassocc*, *Ncut* is derived subsequently
- $f(X_i)$ function that measures the fragmentation quality of a partition X_i

Shi J. and Malik J.. *"Normalized Cuts and Image Segmentation"*. IEEE Trans. Pattern Anal. Mach. Intell. 2000.

Stain metaphor



Overlays Exploitation



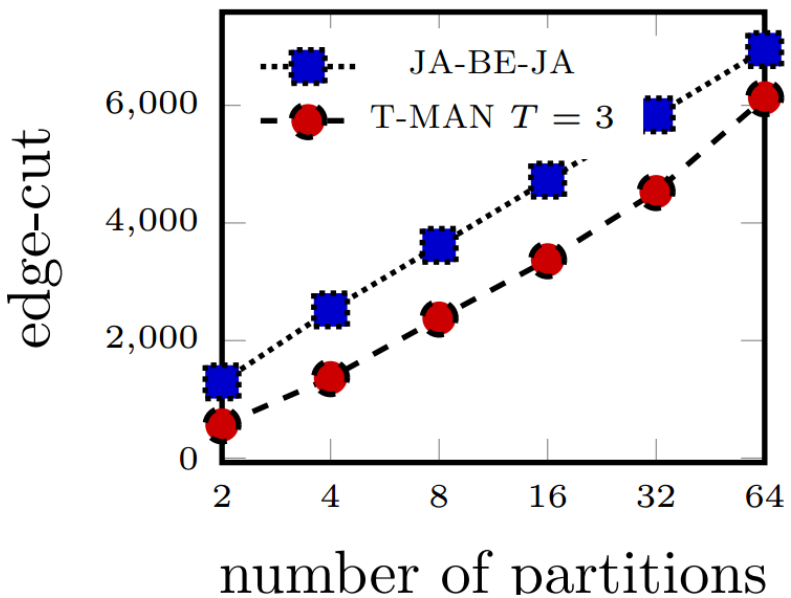
T-MAN add-on

- decisional equation evaluated over a T-MAN overlay
- swaps occur over the JA-BE-JA overlay
- JA-BE-JA damages T-MAN taking advantages
- T-MAN's *ranking function* describing the "borderness"

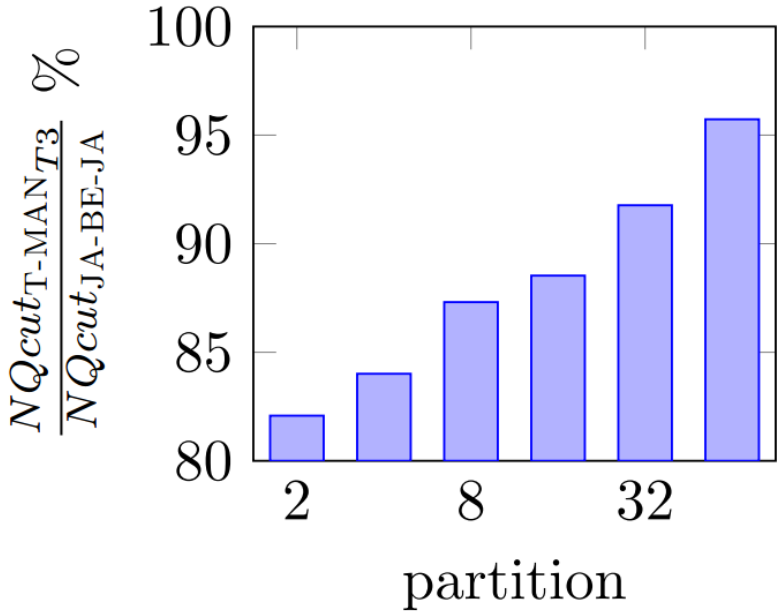
$$rankFunction(peerA, peerB) = \begin{cases} +\infty, & \text{if peerA.color} == \text{peerB.color} \\ |H_A - H_B|, & \text{otherwise} \end{cases}$$

$$\text{where } H_P = \frac{d_p(\pi_p)}{|N_p|}$$

Experiments

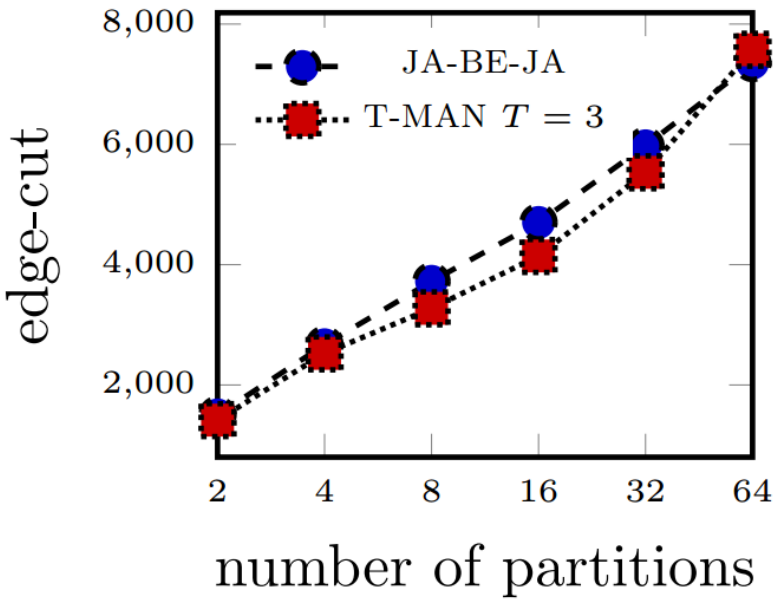


Plain run

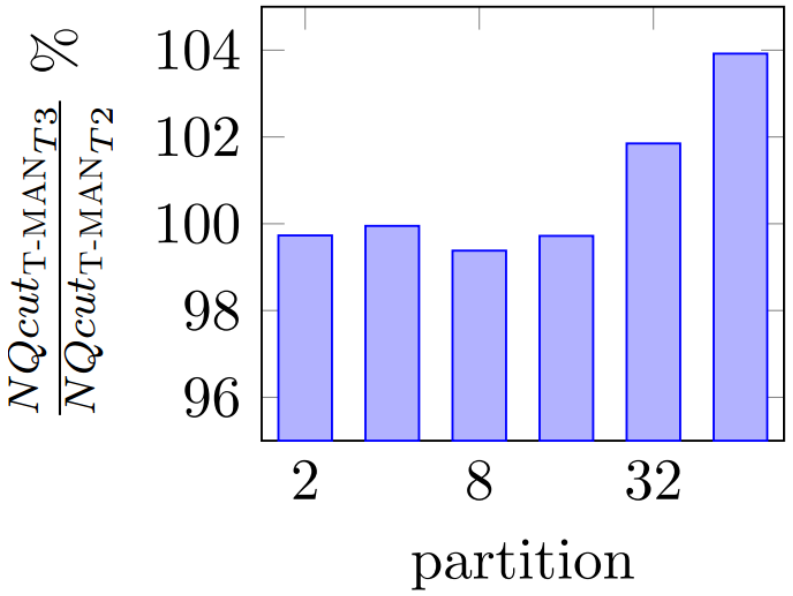


NQcut proportional to original JA-BE-JA

Experiments



Approximate run



NQcut proportional to T-MAN plain run

Summary

- graph $\Rightarrow$ **big** graph
- distributed graph processing $\Rightarrow$ *graph as a network*
- P2P and Gossip $\Rightarrow$ Overlays

- *Overlays Not Just a Graph* abstraction
- Balanced k-way partitioning problem (JA-BE-JA)
- T-MAN add-on as Proof-of-concept of the Overlay exploitation

 Carlini E., Dazzi P., Esposito A., Lulli A. and Ricci L.. *"Balanced Graph Partitioning with Apache Spark"*. BigDataClouds, Euro-Par. 2014.

ONJAG, network overlays supporting distributed graph processing

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Q&A