Systèmes pair à pair de partage de données

And some other things I do

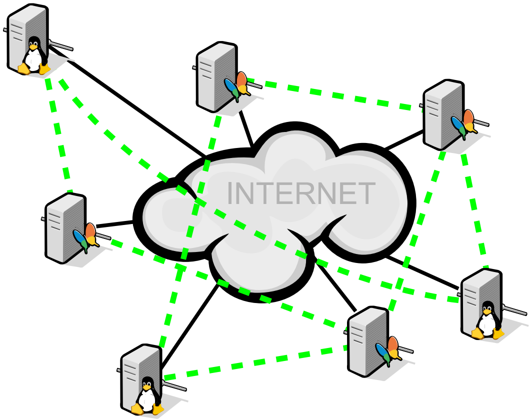
Remigiusz Modrzejewski

May 11, 2012
MASCOTTE Project

I3S(CNRS/UNS)–INRIA, PACA

Outline

Intuition of P2P



Peer to peer networks — end systems creating a virtual overlay

Peer-to-peer storage

With: Frédéric Giroire, Sandeep Kumar Gupta, Julian Monteiro, Stéphane Perennes

Related works:

- Analysis of Failure Correlation Impact on Peer-to-Peer Storage Systems by Dalle et al. looks into whole disk failures, but assumes exponential reconstruction time; 2009
- Simulation analysis of download and recovery processes in P2P storage systems by Dandoush et al. find download/recovery time hypo-exponential, but looks only at single fragment level; 2009
- Availability in Globally Distributed Storage Systems by Ford et al. bases on a large body of data tracing Google storage systems; 2010

Peer-to-peer storage

Considered system:

- Indefinite backup
  - negligible read rate
  - high reliability: 10^{-5} loss probability/100GB $\rightsquigarrow$ 10^{-12} loss probability/5MB
- Cheap and scalable
  - highly distributed
  - unreliable hardware
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Our work: find a better model of the system, thoroughly validate

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Redundancy

- Blocks divided into s fragments
- Additional r fragments of redundancy
- Using **erasure codes**
  - Reed-Solomon
  - Regenerating codes

All data can be **reconstructed** as long as $\geq s$ fragments are available

a b c

a + b + 2c a + 2b + c

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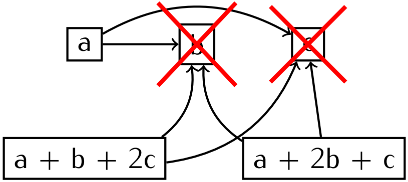
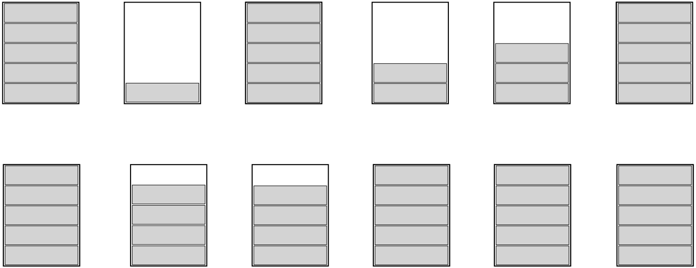


System mechanics



Data redundancy maintained in continuous repair process

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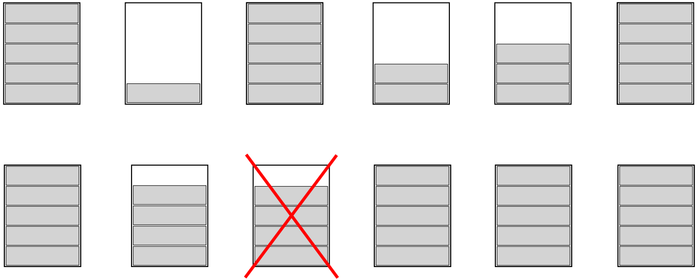

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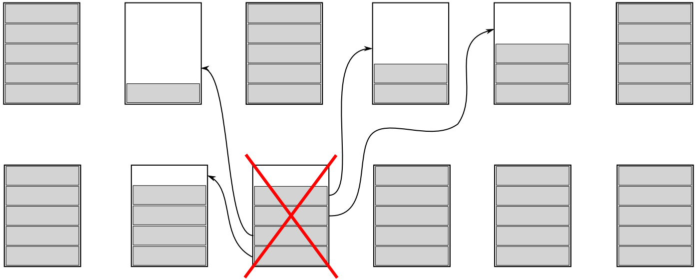

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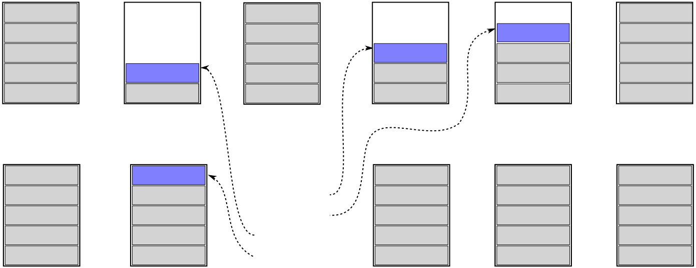

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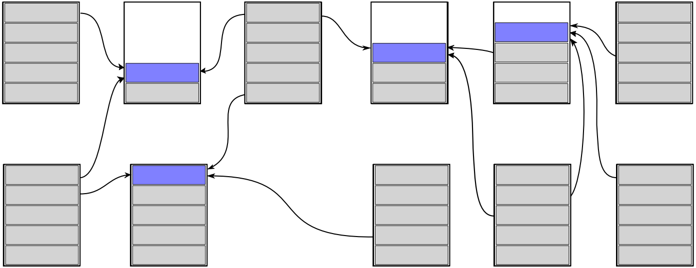

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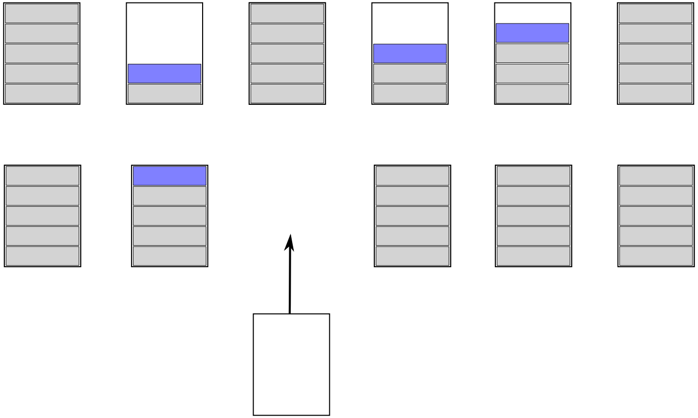

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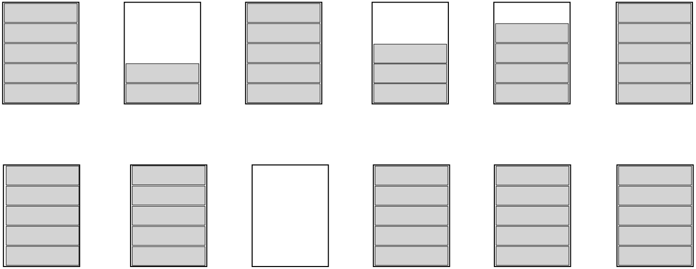

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Factor of efficiency

Workload proportional to stored data $\wedge$ new disks have little data $\wedge$ nearly all repairs need a full disk $\Rightarrow$ wasted bandwidth

Let:

- x be the disk **overcapacity** — average capacity / average usage
- ρ be the **factor of efficiency** — total throughput / total bandwidth

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$$\rho \approx \frac{1}{x}$$

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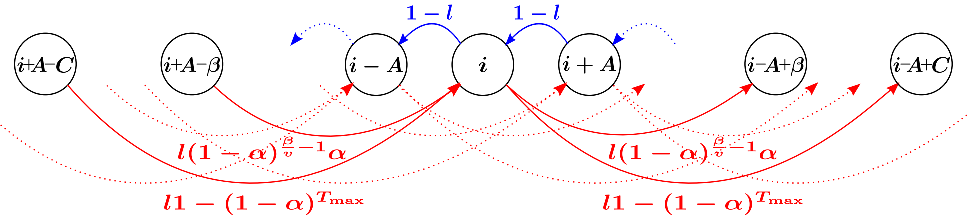
Markovian queuing model



- **Global** $M^{\beta}/D/1$ queue of all blocks needing repair
- States — number of fragments in queue
- Transitions — reconstructions or failings

Case study

Scenario:

- Users have 1Mbps connections, but allocate 128kbps to repairs
- Users allocate 300GB disk space, insert 100GB data
- Expected lifetime = 1 year, neighbourhood size = 100 peers

Simple intuition:

- Repair time of 1 disk = **17 hours** ($= 100 \cdot 8 \cdot 10^6$kb$/(100 \cdot 128$kbps$)$)
- Probability of data loss per year **(PDLPY) of 10^{-8}**

Our model (more realistic assumptions, validated by simulation and experiments):

- Repair time = **9 days**
- **PDLPY = 0.2**

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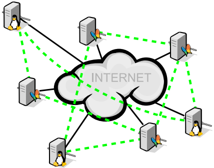
Peer-to-peer streaming

With: Frédéric Giroire, Stéphane Perennes

Related works:

- **Epidemic live streaming: optimal performance trade-offs**, by Bonald, Massoulié, Mathieu, Perino, and Twigg; simple random schemes
- **Prime: Peer-to-peer receiver-driven mesh-based streaming**, by Magharei and Rejaie; an unstructured algorithm which yields temporarily structured flows
- **SplitStream: high-bandwidth multicast in cooperative environments**, by Castro, Druschel, Kermarrec, Nandi, Rowstron and Singh; the best known structured network

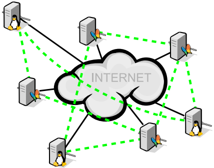
Video distribution



File sharing

Live streaming

Video distribution



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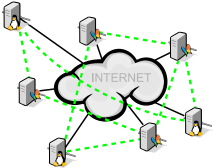

File sharing

Live streaming

Problem definition

- Disseminate a stream of data
- Single source
- Multiple recipients
- Recipients contribute to further disseminate
- Finite dissemination deadline
- High bandwidth utilization
- Participants are autonomous – **distributed algorithms**
- Local, delayed view

Churn

- **Node dynamics** shown to be biggest problem of live systems
- When $n \approx 20000$, almost 1000 peers join and leave per minute
- Often overlooked in literature

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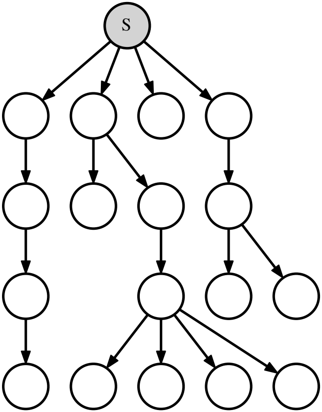
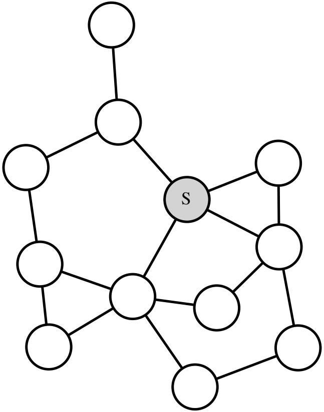
Types of overlays

Structured:



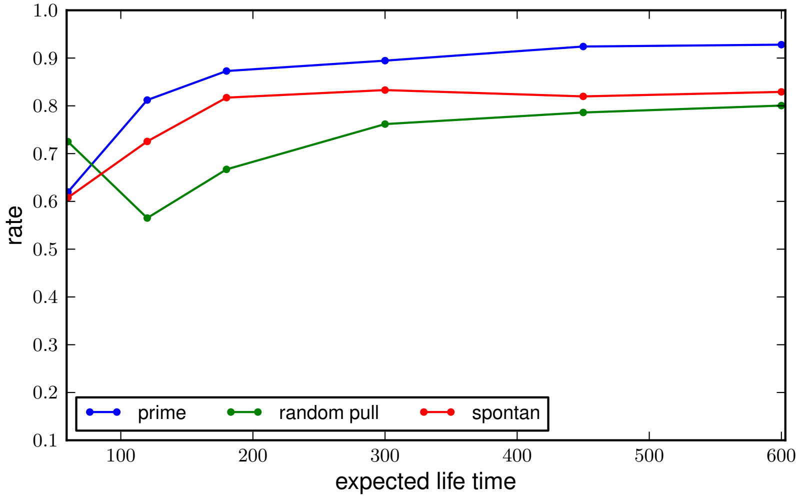
Random:



Simulator

- Test overlays under bandwidth constraints and churn
- Custom discrete event simulator
- Implemented 6 overlay algorithms
- Total 9889 lines of Python code
- 572 automated tests

Simulation results for varying churn



Dynamic online tree balancing

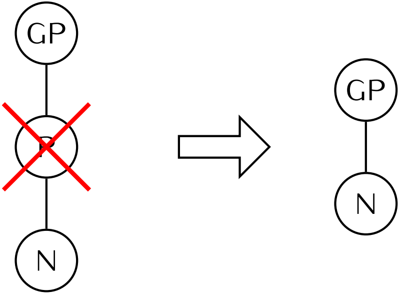
- k-ary tree (simple case: binary)
- Preserve a balanced state
- Random node arrivals and departures
- Local, **distributed** algorithm

Subtree size

- Number of nodes in subtree rooted at a given node
- “Size of the node”
- **Periodically reported** by the node to its parent

The algorithm

1. Parent left $\rightsquigarrow$ **reattach** to grandparent
2. Overloaded $\rightsquigarrow$ **push** a child to become a grandchild
3. Underloaded $\rightsquigarrow$ **pull** a grandchild to become a child
4. Children imbalanced $\rightsquigarrow$ **balance** the children
   - Smallest underloaded $\rightsquigarrow$ move a child of the biggest to the smallest
   - Smallest saturated $\rightsquigarrow$ swap 2 children between smallest and biggest



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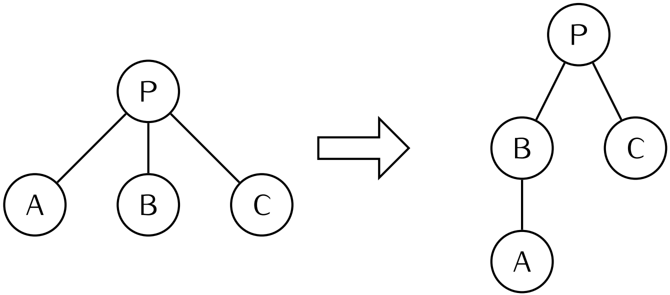

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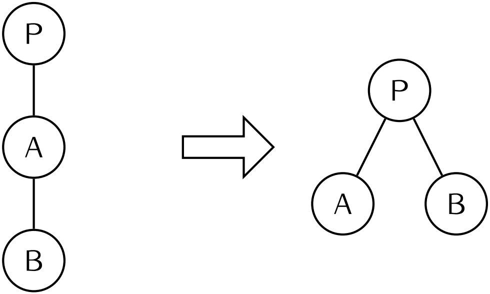

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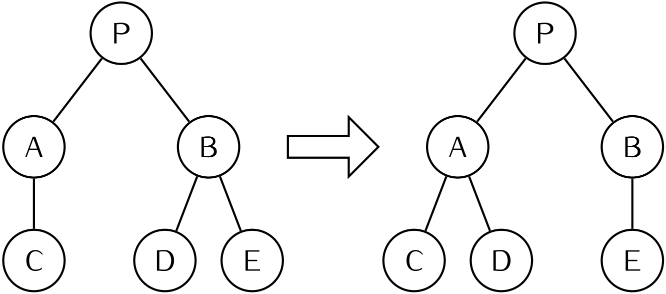

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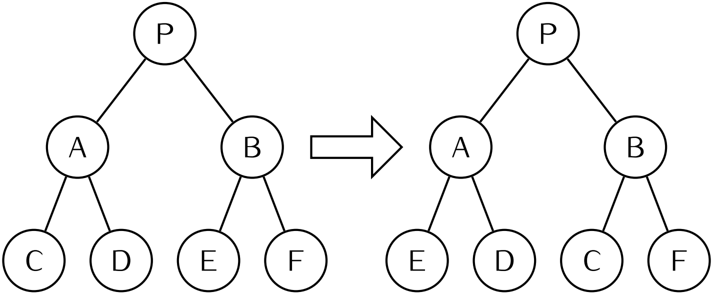


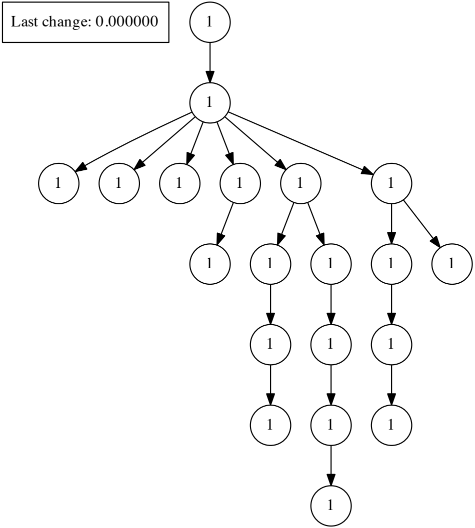
Model

1. Each node performs operations according to a **Poisson process**

or

2. In each **round** each node performs one operation, random order

Example



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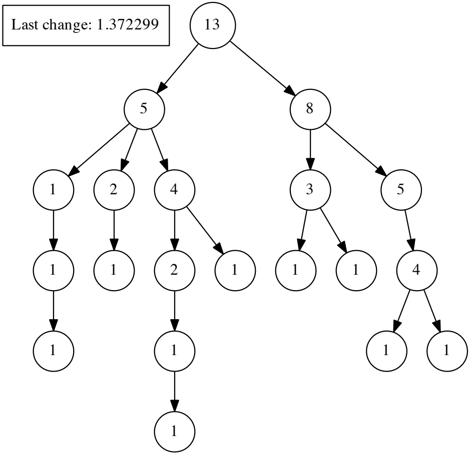

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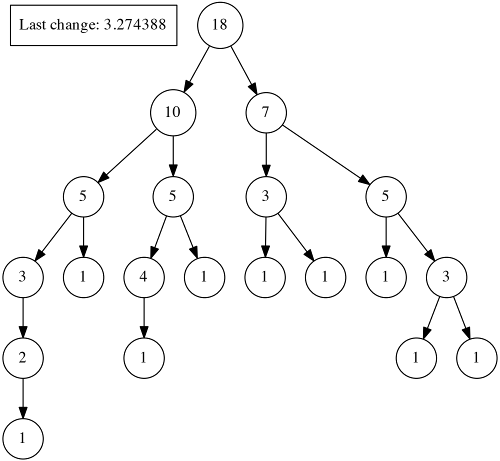

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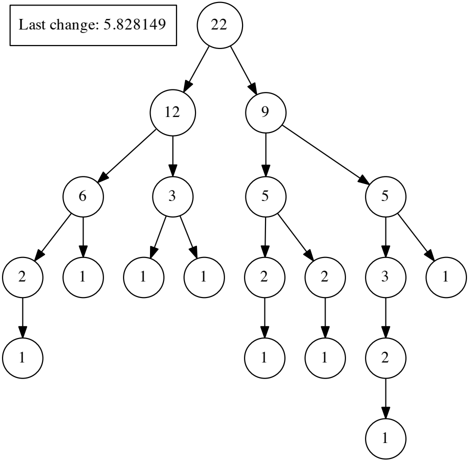

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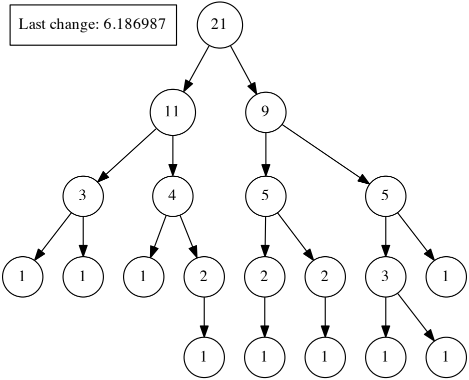

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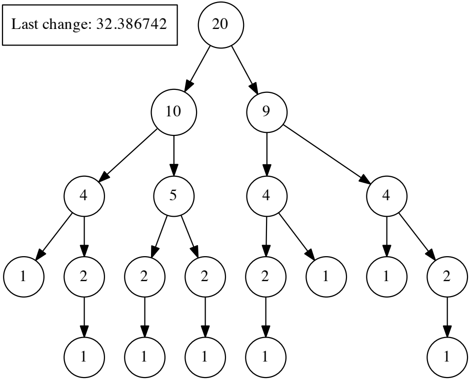

Work in progress

Already done:

- Guaranteed stop in tree of optimal height
- Expected time to fix tree after single failure $= k - 1 + \log_k \log_k n$
- Convergent in $O(n^3)$ rounds

Still working on:

- Proof of convergence in $O(n^2)$ rounds or $O(n^2)$ operations
- Worst cases: convergent in $O(n)$ rounds or $O(n \log n)$ operations

More practical model:

- Extend to heterogenous out-degree
- Extend to multi-trees

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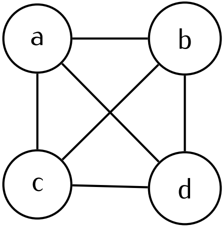
Energy Efficient Content Distribution

With: Julio Araujo, Frédéric Giroire, Yaning Liu, Joanna Moulierac

Related works:

- **Minimizing Routing Energy Consumption: from Theoretical to Practical Results** by Giroire, Mazauric, Moulierac and Onfroy; turning off links with traditional demands
- **Energy-Aware Network Management and Content Distribution** by Chiaraviglio and Matta; turning off links and servers in CDN

Energy Efficient Content Distribution



- We want to shut down links in a network
- Traditional demands
- Overlay demands
  - Demands can be served by any one of replicated servers
  - Servers have limited capacity
- Content caches
  - Caches located at routers
  - Can be on/off, consume energy
  - Can be selective in what to cache
- Routing is **fractional**, links are undirected

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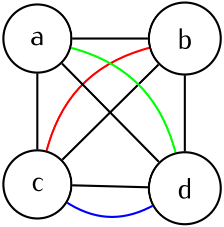

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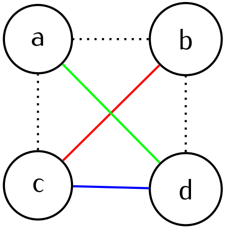

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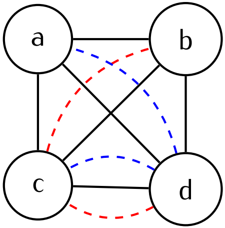

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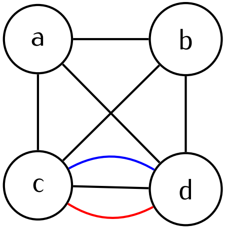

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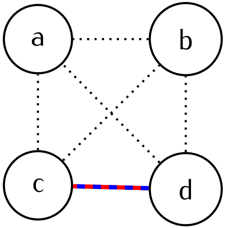

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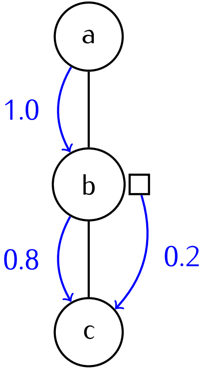

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- ILP formulations and 5 heuristics (without caches)

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Weighted Improper Colouring

With: Julio Araujo, Jean-Claude Bermond, Frédéric Giroire, Frédéric Havet, Dorian Mazauric

Related works:

- **Models and solution techniques for frequency assignment problems** by Aardal, van Hoesel, Koster, Mannino and Sassano; survey on FAP
- **An enumerative algorithm for the frequency assignment problem** by Mannino and Sassano; similar model, different results
- **Frequency assignment in mobile radio systems using branch-and-cut techniques** by Fischetti, Lepschy, Minerva, Romanin-Jacur and Toto; similar model, different results

Weighted Improper Colouring

- We assign colours to nodes of a graph
- Nodes of the same colour interfere with each other
  - Interference is function of distance
  - In general case $f(a, b) \rightarrow \mathbb{R}_+$
- A certain amount of interference can be tolerated at each node

Simple distance function

We consider a simple interference function:

$$f(d) = \begin{cases} 1, & \text{if } d = 1 \\ \frac{1}{2}, & \text{if } d = 2 \\ 0, & \text{otherwise} \end{cases}$$

In other words: given a graph $G = (V, E)$ and its square $G^2 = (V, E^2)$, we study *from now on* the function $w : E \to \{1, 0.5\}$ such that $w(e) = 0.5$ if, and only if, $e \in E^2 \setminus E$.

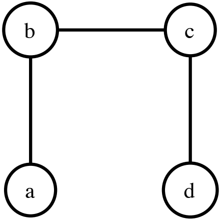
Simple distance function

We consider a simple interference function:

$$f(d) = \begin{cases} 1, & \text{if } d = 1 \\ \frac{1}{2}, & \text{if } d = 2 \\ 0, & \text{otherwise} \end{cases}$$

In other words: given a graph $G = (V, E)$ and its square $G^2 = (V, E^2)$, we study *from now on* the function $w : E \to \{1, 0.5\}$ such that $w(e) = 0.5$ if, and only if, $e \in E^2 \setminus E$.

Simple distance function



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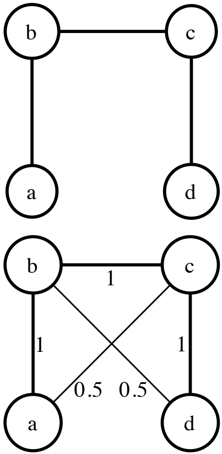


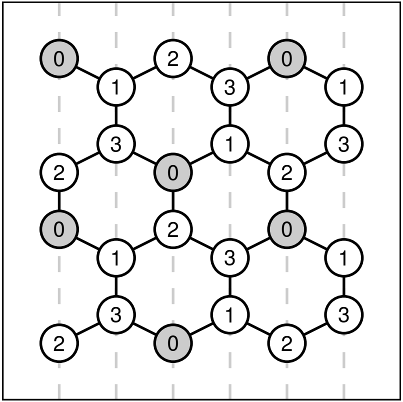
Results

- NP-Complete, APX-hard
- General bounds (e.g. $\chi_t(G, w) \leq \left\lceil \frac{\Delta(G,w)+\text{gcd}(w)}{t+\text{gcd}(w)} \right\rceil$)
- Optimal solutions for infinite grids
- IP, greedy heuristic and branch-and-bound algorithm

Hexagonal grid

If G is an infinite hexagonal grid, then

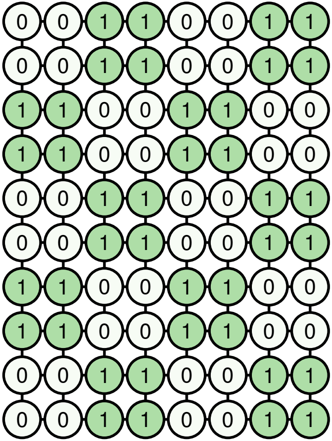
$$\chi_t^w(G^2) = \begin{cases} 4, & \text{if } 0 \leq t < 1; \\ 3, & \text{if } 1 \leq t < 2; \\ 2, & \text{if } 2 \leq t < 6; \\ 1, & \text{if } 6 \leq t. \end{cases}$$



Square grid

If G is an infinite square grid, then

$$\chi_t^w(G^2) = \begin{cases} 5, & \text{if } 0 \leq t < 0.5; \\ 4, & \text{if } 0.5 \leq t < 1; \\ 3, & \text{if } 1 \leq t < 3; \\ 2, & \text{if } 3 \leq t < 8; \\ 1, & \text{if } 8 \leq t. \end{cases}$$



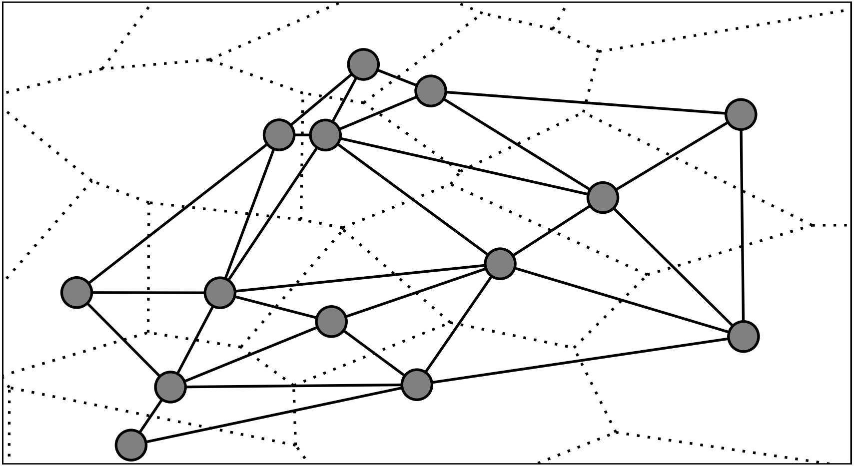
6-regular grid

Theorem

If G is an infinite triangular grid, then

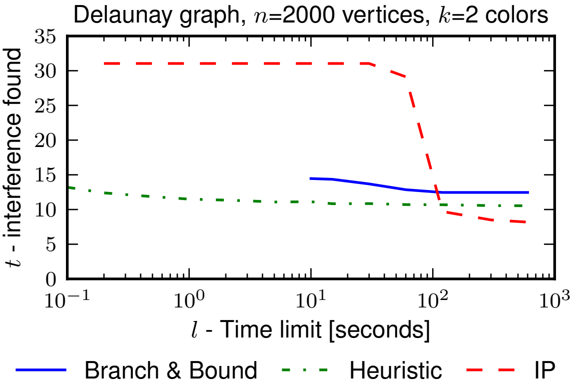
$$\chi_t^w(G^2) = \begin{cases} \leq 7, & \text{if } t = 0; \\ \leq 6, & \text{if } t = 0.5; \\ \leq 5, & \text{if } t = 1; \\ \leq 4, & \text{if } 1.5 \leq t < 3; \\ \leq 3, & \text{if } 3 \leq t < 5; \\ \leq 2, & \text{if } 5 \leq t < 12; \\ 1, & \text{if } 12 \leq t. \end{cases}$$

Delaunay graph



Effect of Delaunay tesselation for a set of random points.
Dual of Voronoi diagram.

Algorithms performance



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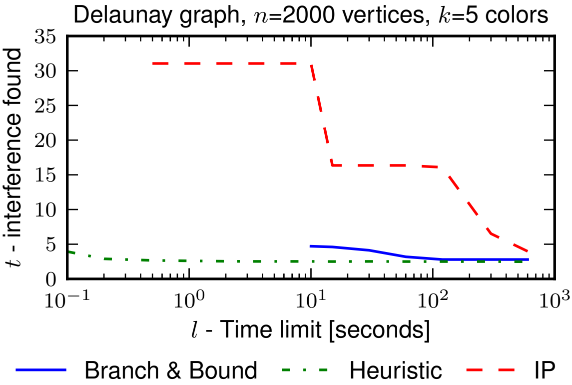

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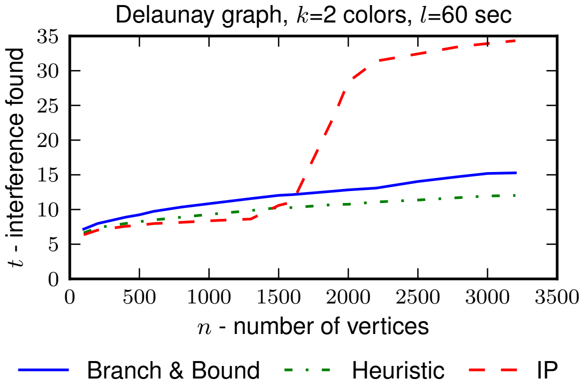

Questions