On a Parameterized Problem in Access Control

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Joint work with: Jason Crampton and Gregory Gutin

Séminaire COATI - Sophia Antipolis
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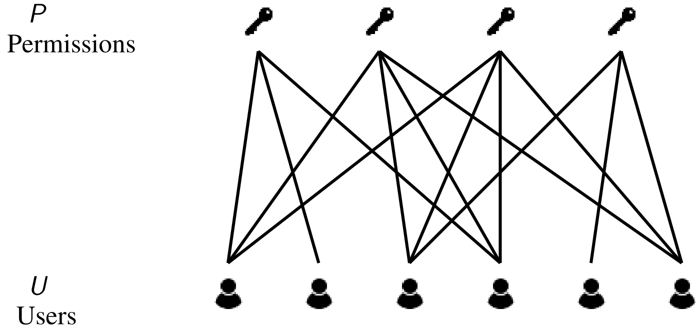
1. Definition of the problem
2. Appetizer: easy observations
3. FPT algorithms
4. Efficient algorithms and implementation
5. Conclusion

Resiliency Checking Problem (RCP)

Input: an authorization policy: $UP \subseteq U \times P$

$s, d, t \in \mathbb{N}$



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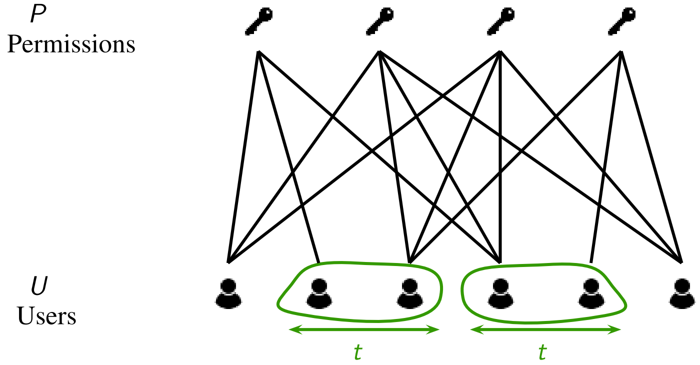

Set of teams: d mutually disjoint sets of t users having collectively all permissions.

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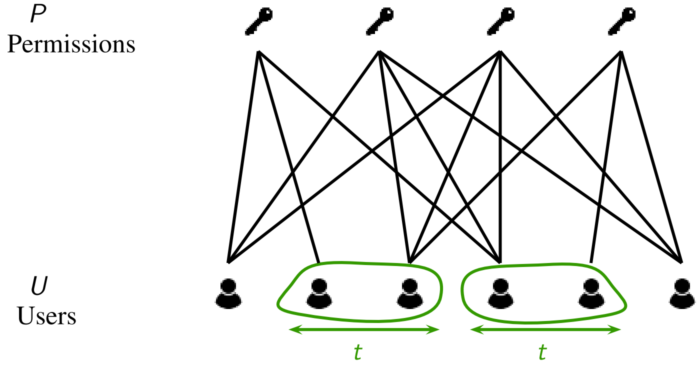

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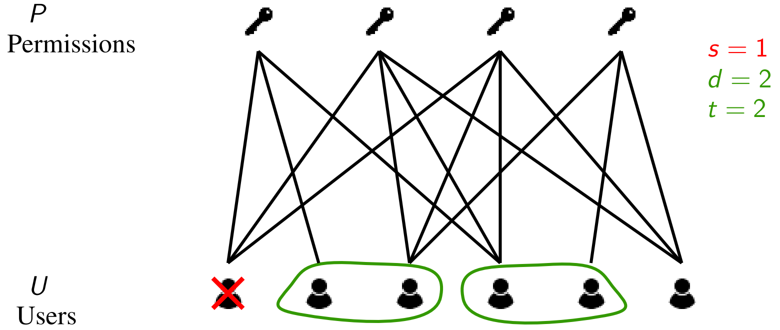

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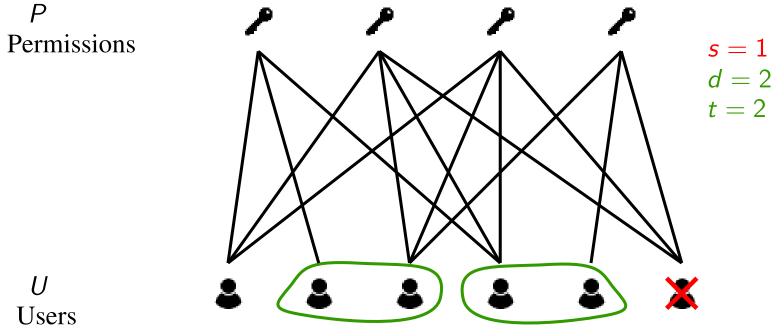

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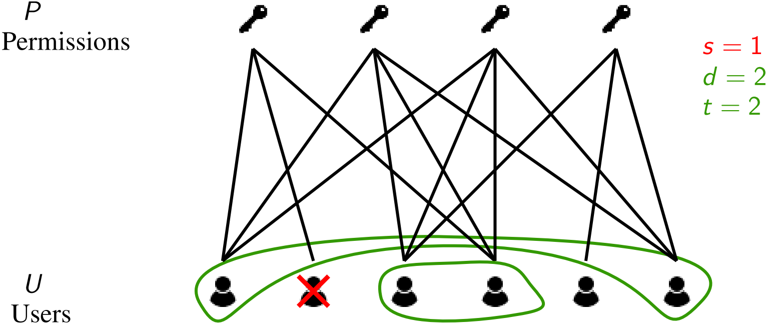

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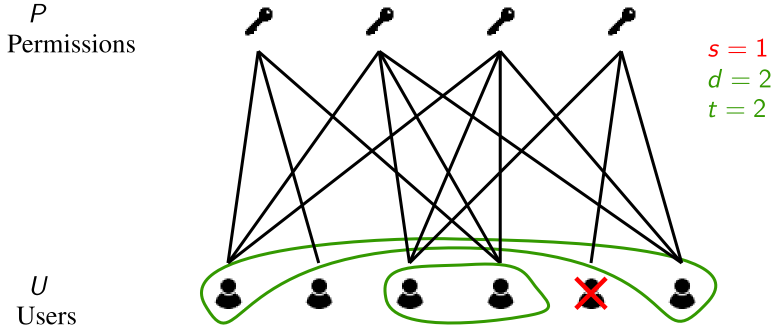

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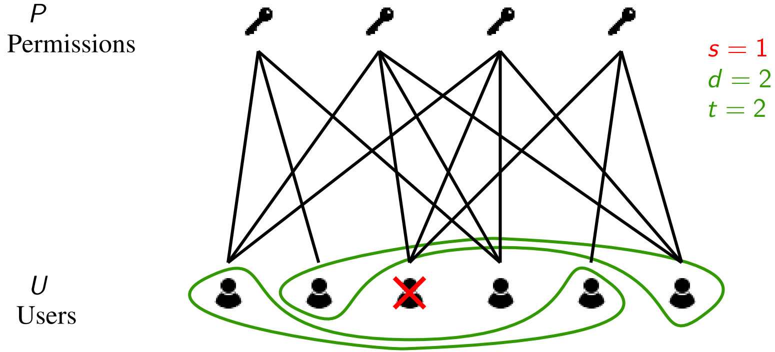

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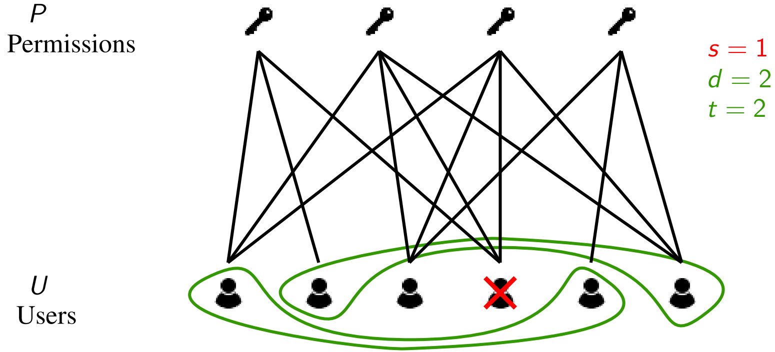

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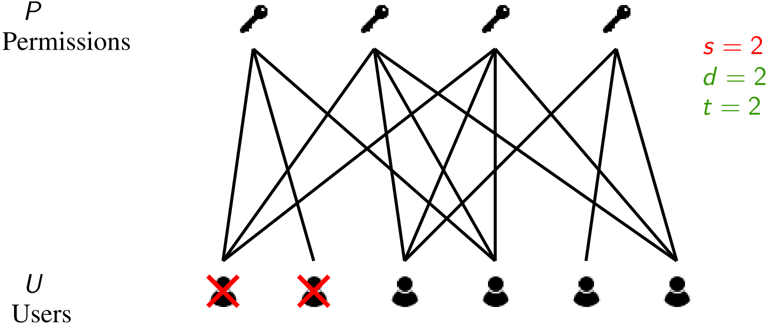

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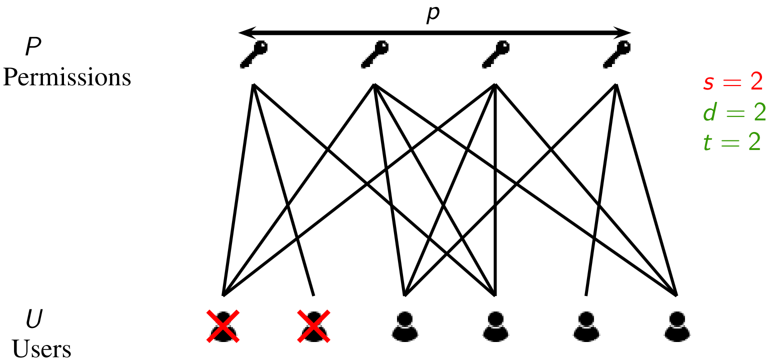

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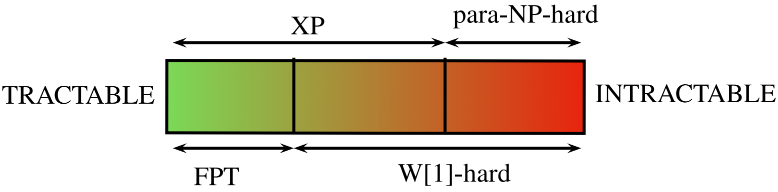

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Li, Tripunitara, Wang, 2009

- RCP$<>$, RCP$<d = 1>$ and RCP$<t = \infty>$ are NP-hard and in $coNP^{NP}$.
- RCP$<s = 0,\ d = 1>$ and RCP$<s = 0,\ t = \infty>$ are NP-hard.
- RCP$<d = 1,\ t = \infty>$ is linear-time solvable.

And they present an implementation of an algorithm relying on a SAT formulation.

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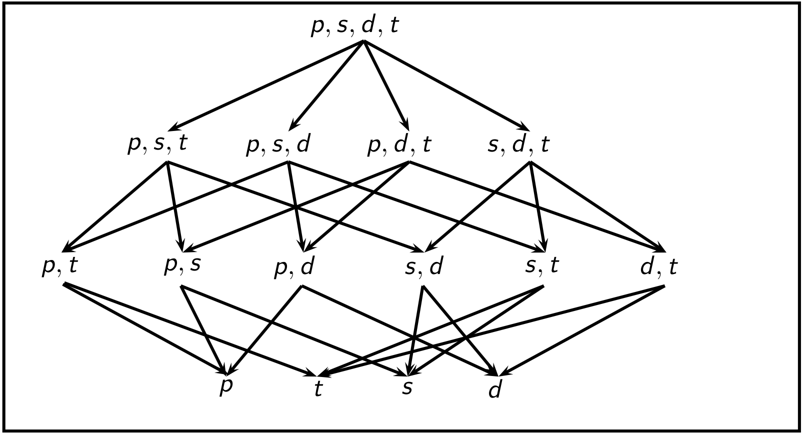

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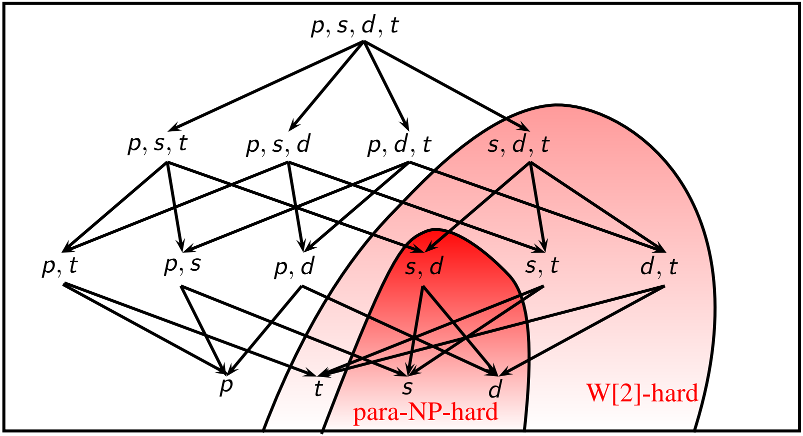
RCP<$s = 0,\ d = 1$> is equivalent to the Hitting Set problem



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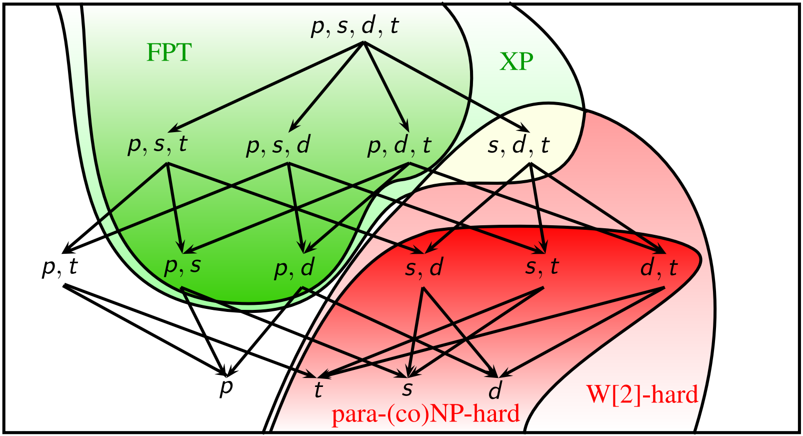

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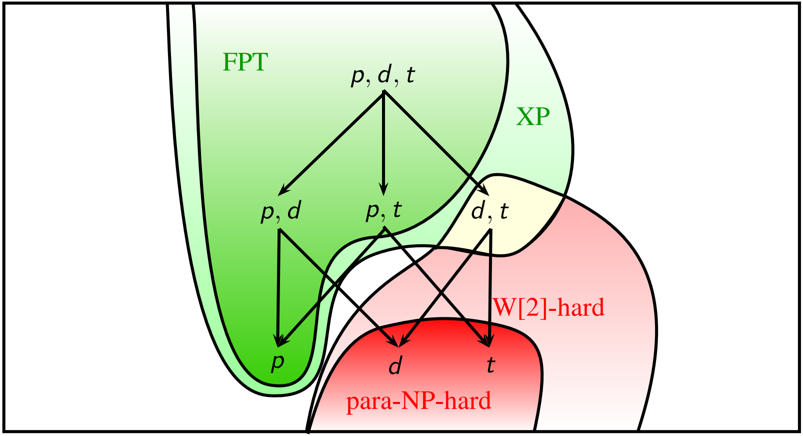

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- first: let us show that RCP<$s = 0$> is FPT parameterized by p only

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Theorem [Lenstra, 1983]+[Kannan, 1987]+[Frank and Tardos, 1987]

Whether a given ILP has a non-empty solution set can be decided in $O^*(n^{2.5n+o(n)})$ time and polynomial space, where n is the number of variables.

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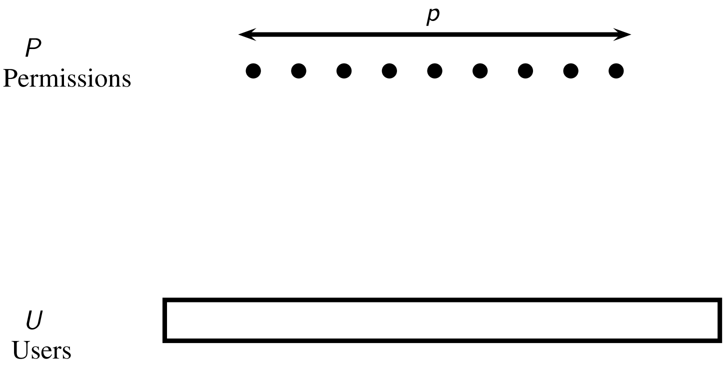

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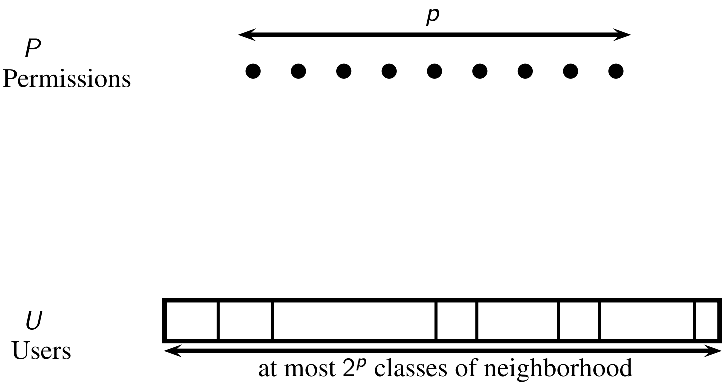

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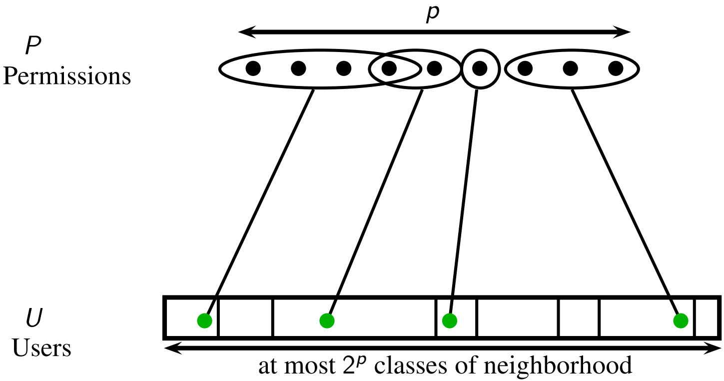

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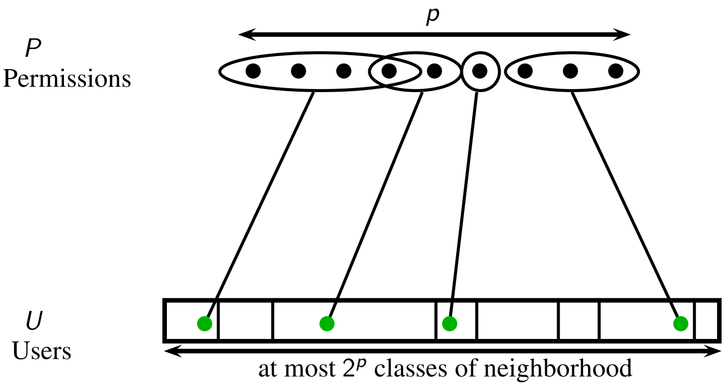

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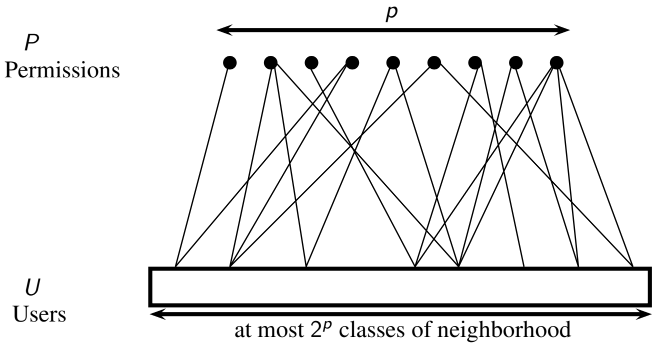
- Second constraint:

$$\sum_{c \in \mathcal{C}[N]} x_c \leq |U[N]| \quad \forall N \subseteq P$$

  where:
  - $\mathcal{C}[N]$ are the configurations involving N
  - $U[N]$ users having neighborhood N

RCP<> is FPT parameterized by $(p, min\{s, d\})$



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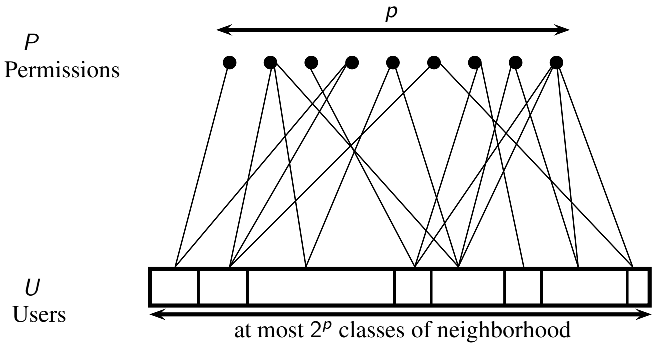

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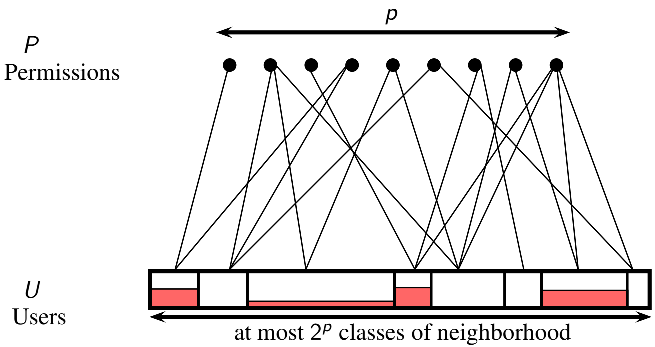

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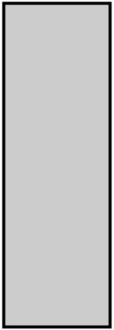

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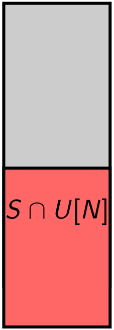

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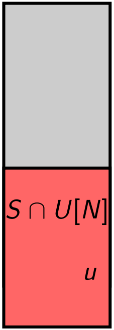

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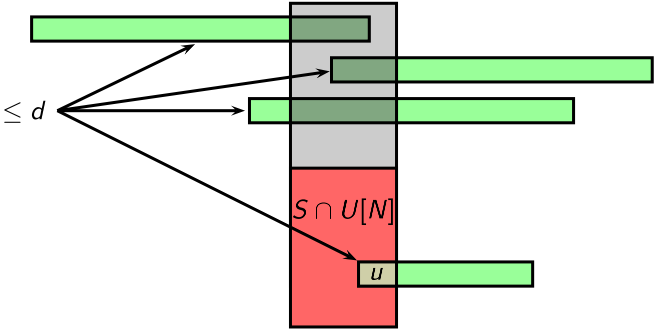

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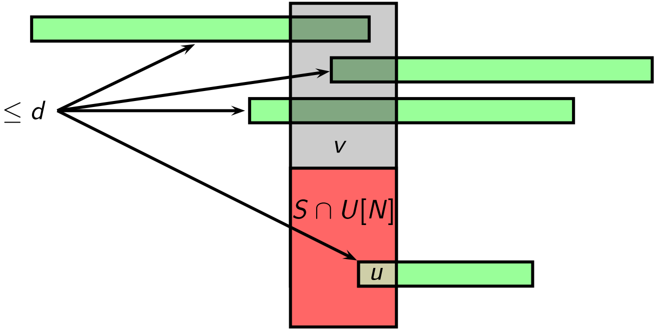

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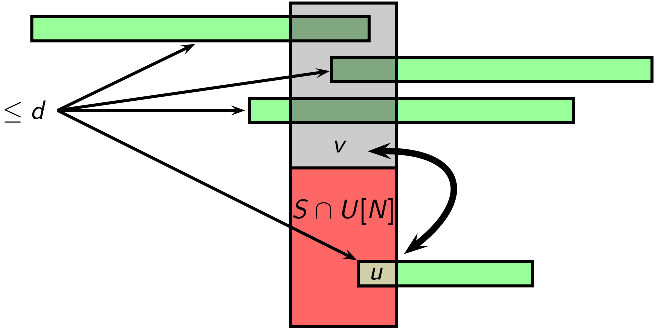
- Replacing u by v creates another set of teams which does not intersect S: impossible!



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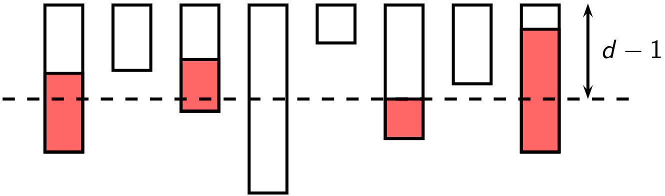

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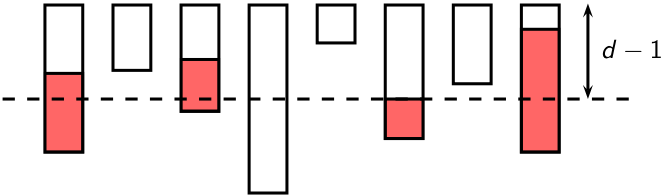

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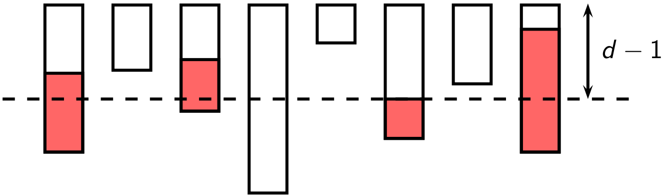

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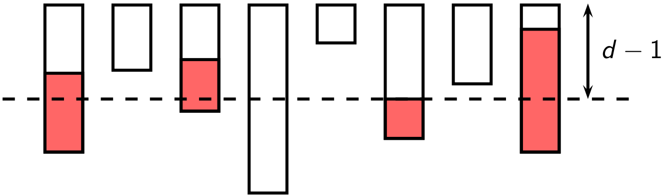

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Open questions:

- what about parameterized by p only ?
- better running time ? (combinatorial algorithm for RCP<$s = 0$>)

Contents

1. Definitions

2. Appetizer: easy observations

3. FPT algorithms

4. Efficient algorithms and implementation

5. Conclusion

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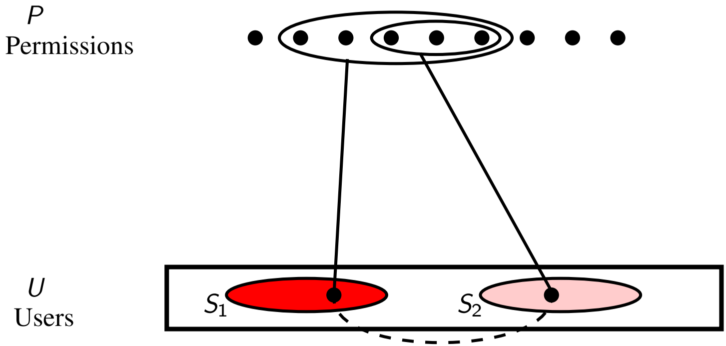

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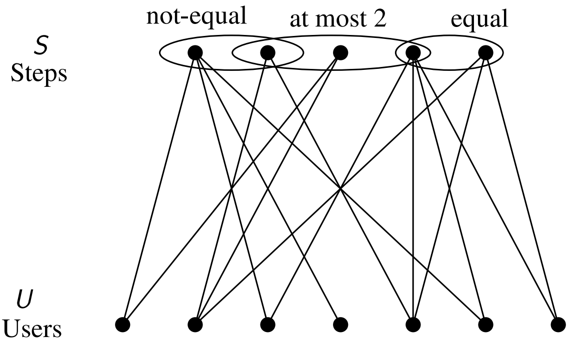
- the bottleneck comes from the SAT solver
  $\implies$ what about a fast algorithm for RCP$<s = 0>$?
- better not to use:
  - Lenstra's algorithm/ILP (FPT param. by p only)
  - dynamic programming ($O^*(2^{dp})$ time and space)

Efficient algorithms?

Workflow Satisfaction Problem (WSP)

Input: a set of steps S, a set of users U
authorization policy $A \subseteq U \times S$, a set of constraints
Output: a plan $\pi : S \to U$ such that:

- $(\pi(s), s) \in A$ for all $s \in S$
- π does not violate any constraint



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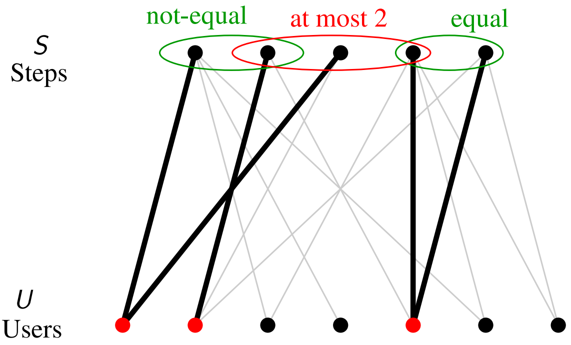

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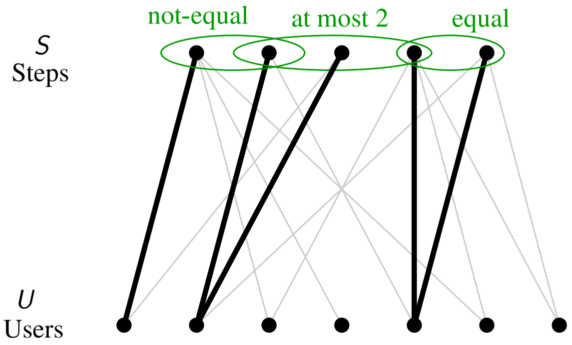

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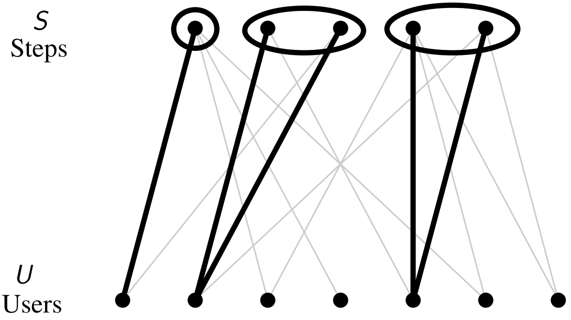

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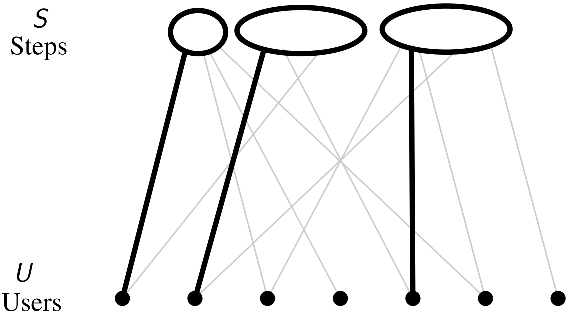

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Theorem [Karapetyan, Gagarin, Gutin, 2015]

WSP can be solved in $O^*(2^{k \log k})$, where k is the number of steps.

More importantly: an efficient implementation of the algorithm can solve instances with up to 60 steps !

Efficient algorithms ?

Theorem [Crampton, Gutin, W.]

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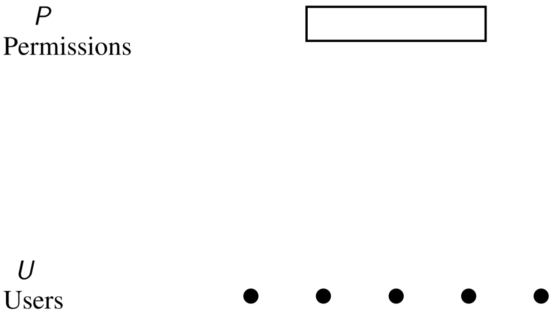

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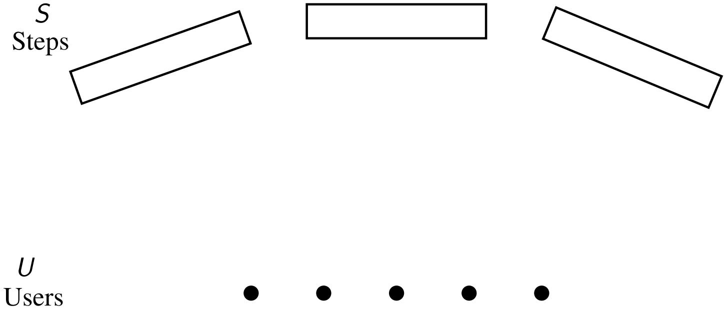

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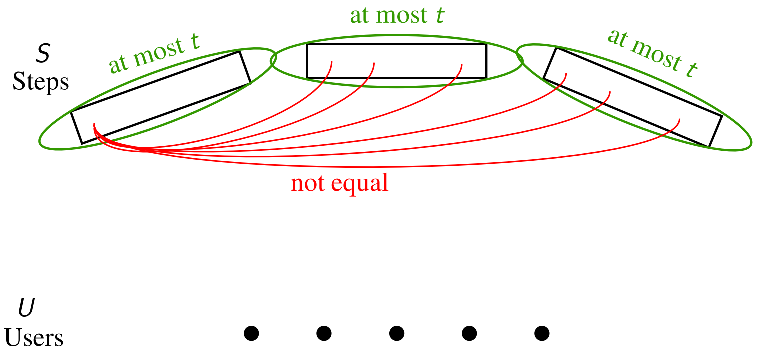

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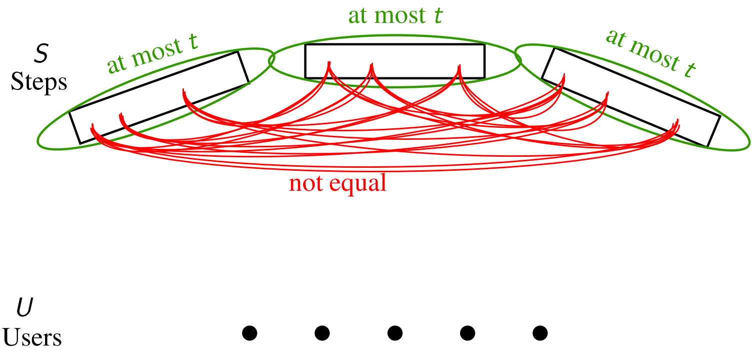

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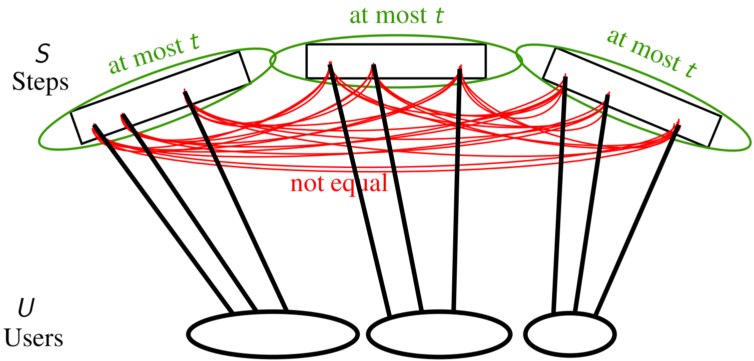

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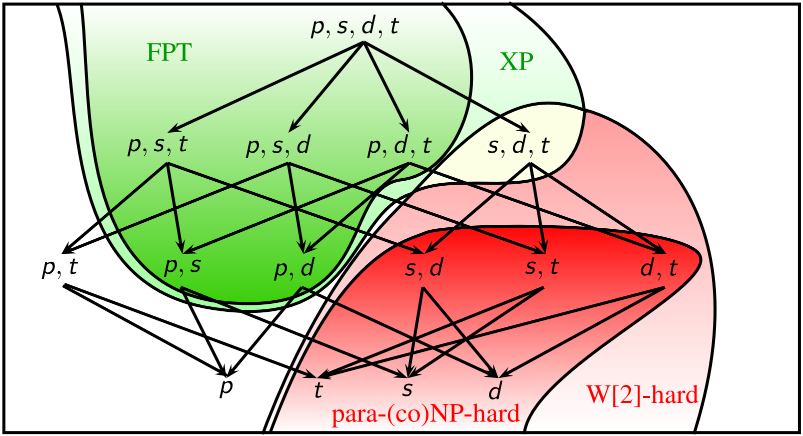

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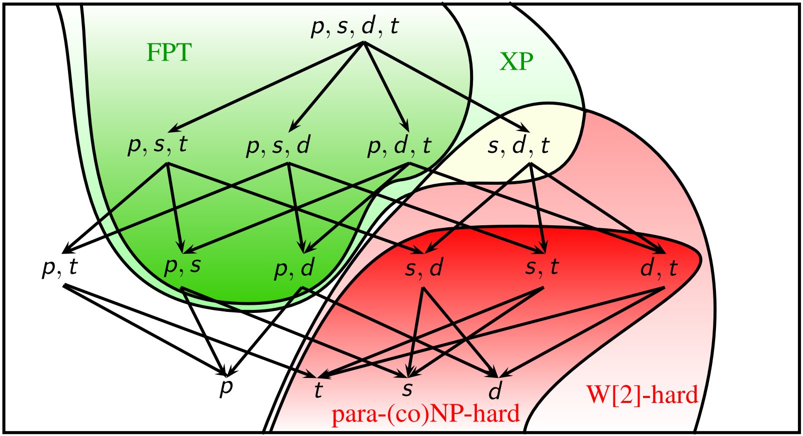
Conclusion



- RCP<> parameterized by p only ?
- resiliency w.r.t. other problems ?

Merci !