Reconfiguration dans les réseaux optiques

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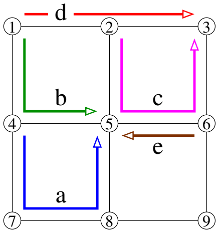
4- KAM, Faculty of Math. and Physics, Charles Univ., Prague, Czech Republic

Example: maintenance operation

- Symmetric links, capacity 1
- Maintenance on link 5-8



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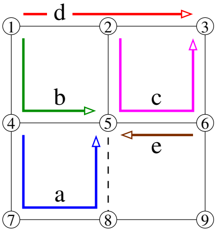

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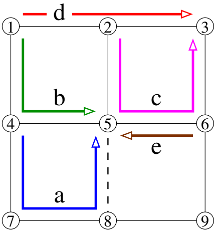
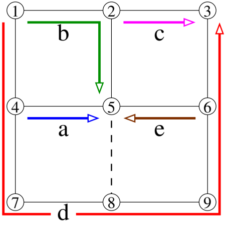




Context

Circuit-switched networks

- Telephone: call repacking (70's)
- ATM
- WDM, MPLS

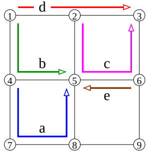
Motivation

- Optimize usage of resources (reduce blocking probability)
- Fault tolerance
- Maintenance operations

Related problems

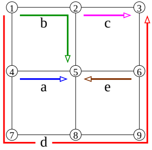
Compute new “*optimal*“ routing

- Minimizing number of changes
- NP-hard
- ILP, heuristics
- ? How to switch from current to new routing



Sequence of rerouting to converge to a valid routing

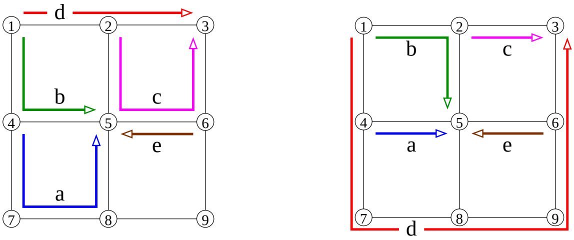
- ? Convergence time
- ? Existence



Compute new routing + sequence of rerouting

- Very hard problems
- ? Existence

Our problem



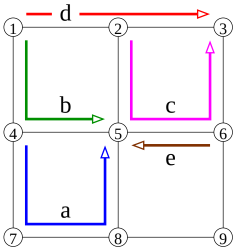
Inputs: Set of connection requests
+ current **and** new routing

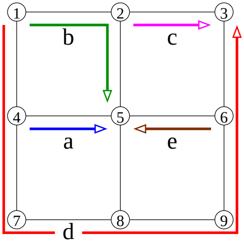
Output: Scheduling for rerouting connection requests from current to new routes

Objective: Minimizing the number of simultaneous interrupted requests

Constraint: Reroute requests one by one

Dependency digraph





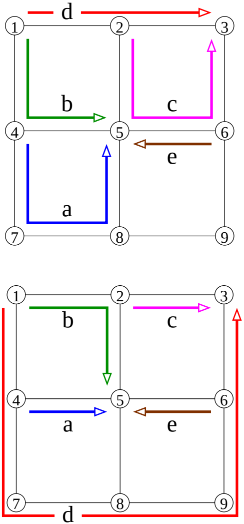
b before *a*

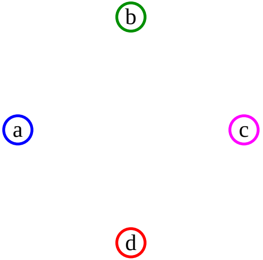
c and *d* before *b*

d before *c*

a, *b*, *c* before *d*

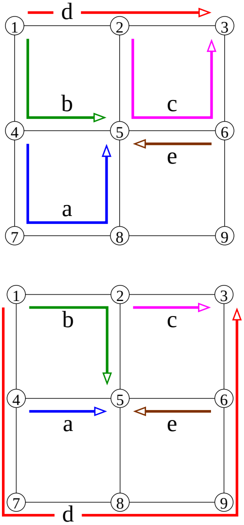
Dependency digraph

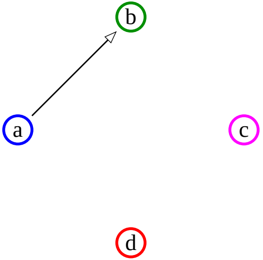




b before a
c and d before b
d before c
a, b, c before d

Dependency digraph





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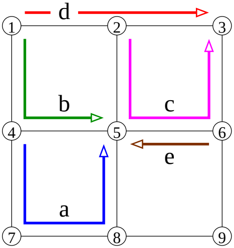

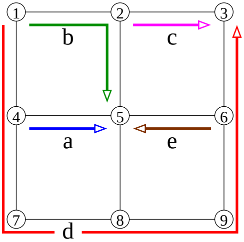

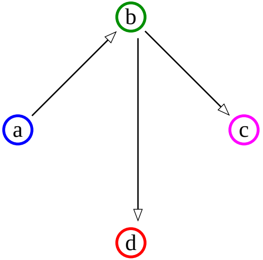

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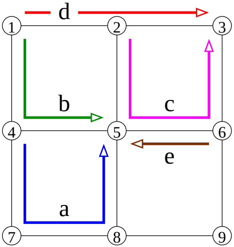

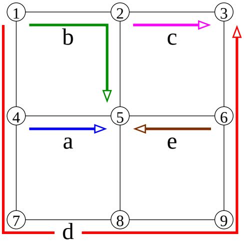

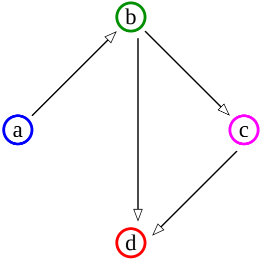

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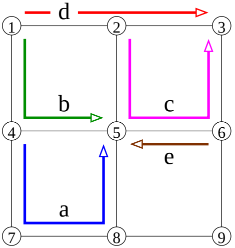

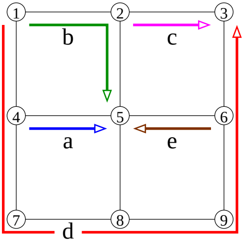

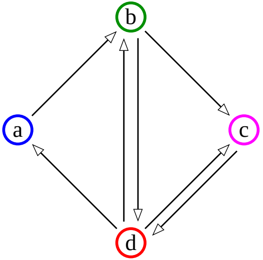

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Process number, *pn*

Modeling in terms of cops-and-robber game
[Coudert & Pérennes & Pham & Sereni, AlgoTel, 2005]

- Fugitive in a graph: invisible, infinite speed
- Agents: with teleportation
- The goal is to capture the fugitive surely with the minimum number of agents
- **Captured** = caught or surrounded

Process number, *pn*

Rules

R_1 Put an agent on a vertex

$=$ break/interrupt/route on temporary resources a connection

R_2 Process a vertex if all its out-neighbors are either processed or occupied by an agent

$=$ (Re)route a connection when final resources are available

R_3 An agent can be re-used after the processing of the vertex

p-process strategy $=$ strategy to process a (di)graph using at most p agents

Process number $=$ smallest p s.t. G can be p-processed, $pn(G)$

Example: DAG

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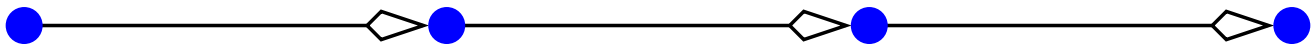
Direct path



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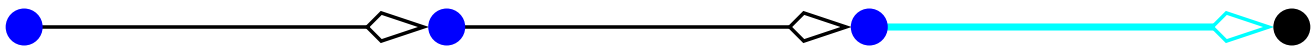

Th: If D is a DAG, then $pn(D) = 0$

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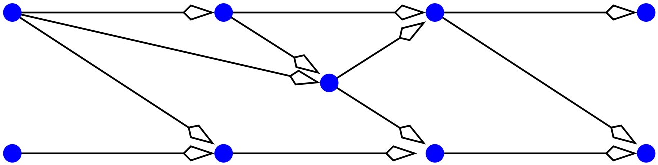

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Digraphs with process number 1

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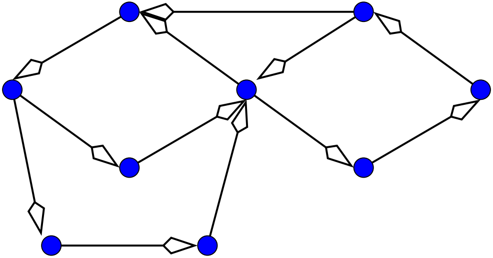

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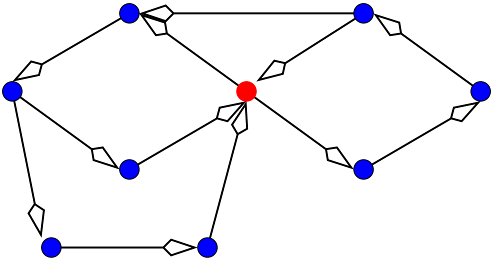

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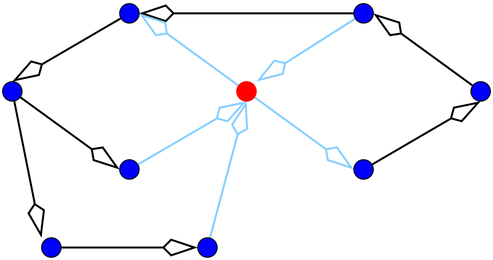

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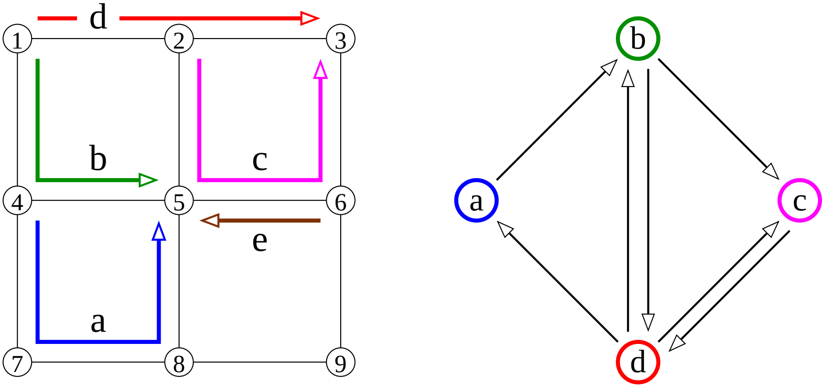

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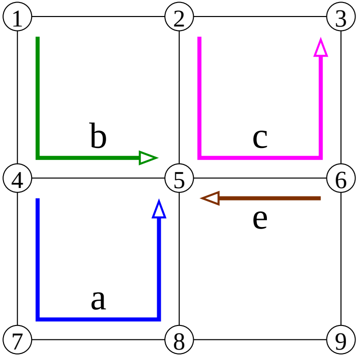
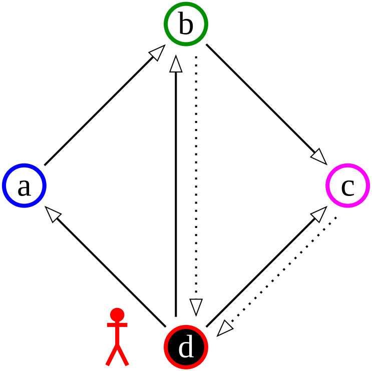
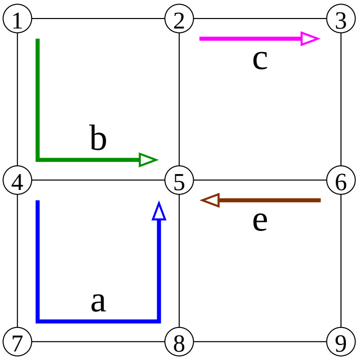


break request *d*

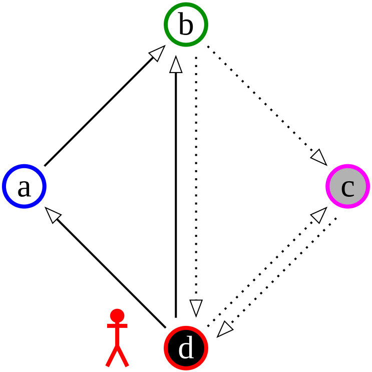


put an agent on node *d*

Example

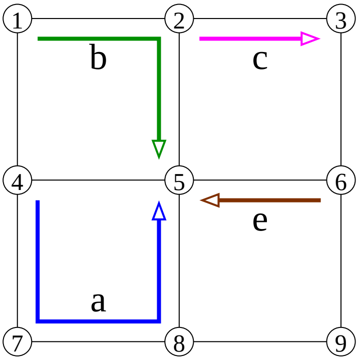


reroute request c

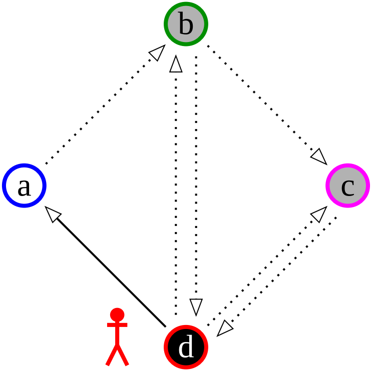


process node c

Example

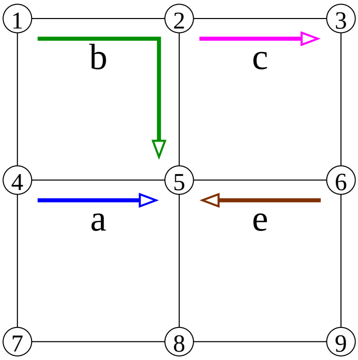


reroute request *b*

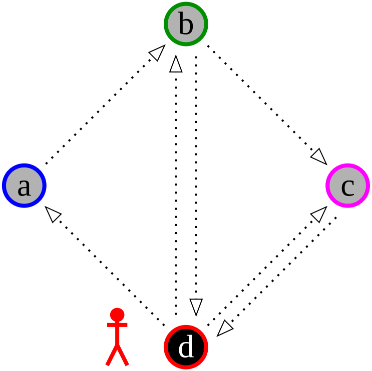


process node *b*

Example

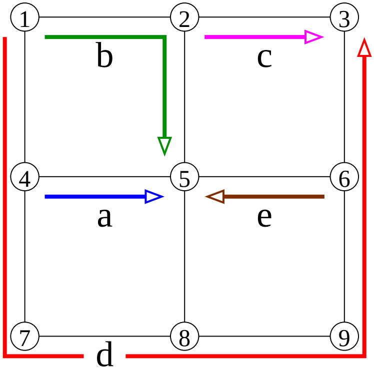


reroute request *a*

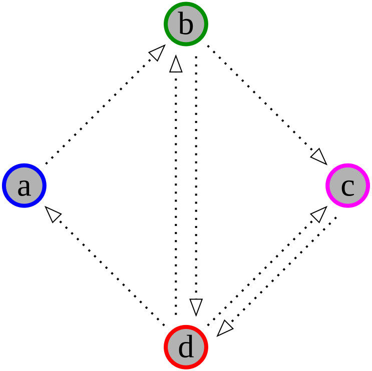


process node *a*

Example



route request *d*



process node *d*
and remove agent

Process number: what is known

Related parameters

- Pathwidth, *pw* [Robertson & Seymour, JCTB, 1983]
- Node search number, *ns* [Kirousis & Papadimitriou, TCS, 1986]
- Vertex separation, *vs* [Kinnersley, IPL, 1992]

Relations

- $pw(G) = vs(G) = ns(G) - 1$
- $vs(D) \leq pn(D) \leq vs(D) + 1$ [Coudert & Sereni, 2007]

Complexity

- NP-Complete
- Not APX
  - = No polynomial time constant factor approximation algorithm
- Characterization of digraphs with process number 0, 1, 2
- Heuristic algorithms (MFVS) [Jose & Somani, DRCN, 2003]

Previous heuristic [Jose & Somani, DRCN, 2003]

1 Compute all directed cycles using Johnson's algorithm
2 Choose u^* that belongs to the maximum number of cycles
3 Remove u^* and update set of cycles
4 Repeat 2-3 until remaining digraph is a DAG
5 Process DAG
6 Process removed vertices

- Heuristic for MFVS
- Complexity in $O((n+m)(c+1))$
- Exponential number of cycles $c \Rightarrow$ only for small digraphs

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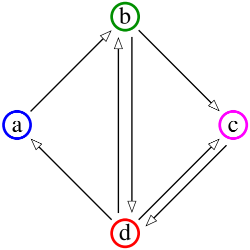
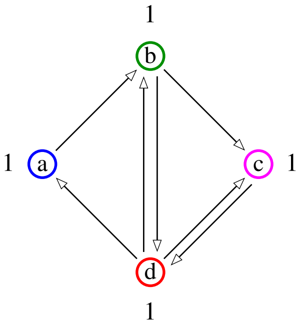
Heuristic algorithms

Flow circulation method



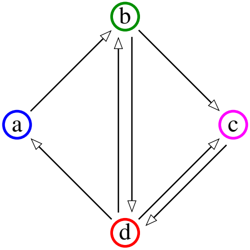
Dependency Digraph



$t = 0$

Heuristic algorithms

Flow circulation method



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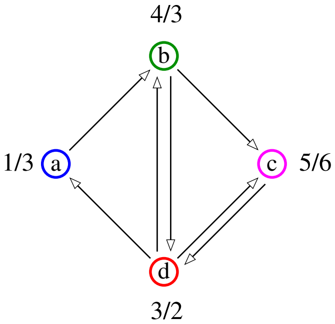

$t = 1$

Heuristic algorithms

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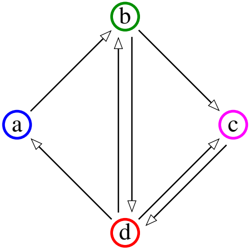

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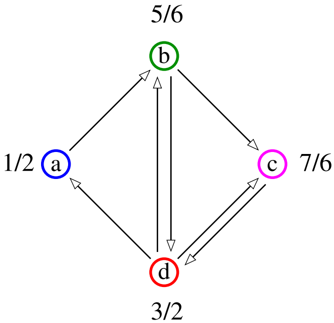
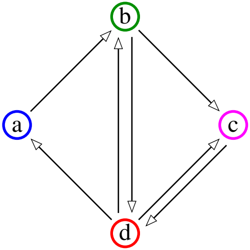


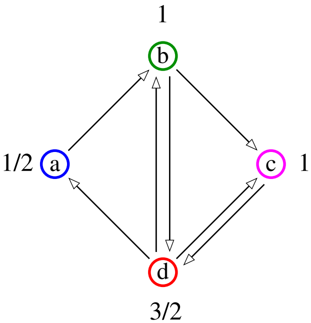
$t = 2$

Heuristic algorithms

Flow circulation method



Dependency Digraph



$t = k$

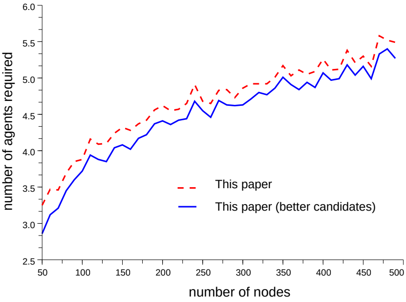
Heuristic algorithms

Given a strongly connected digraph D:

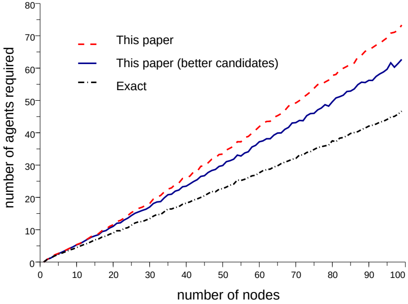
1 Apply flow circulation method
2 Let u^* be one the nodes of maximum weight
3 Place an agent on u^*
4 Process all the nodes whose can be processed
5 Decompose remaining digraph into *SCCs*
6 Apply sequentially the heuristic on each *SCC*

- Heuristic for the process number
- Complexity in $O(n^2(n+m)) \Rightarrow$ large digraphs

Simulation results



2-digraphs



Circular arc graphs

Two classes of services

Priority connections

- Refuse *by contract* (SLA) any interruption

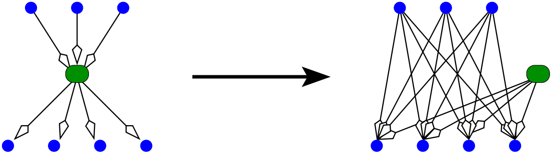
Impossibility

- Direct cycle of priority connections in the dependency digraph

$\Rightarrow$ *Small* number of such connections

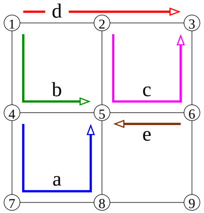
- Partition into strongly connected components, $O(N + M)$

Transformation

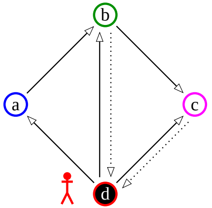


$\Rightarrow$ Same problem to solve

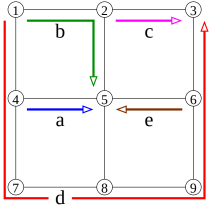
Example with priority connection d



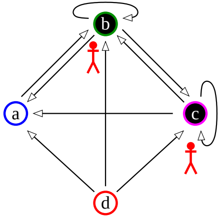
Routing 1



Dependency digraph, $pn = 1$



Routing 2



Without d, $pn = 2$

Conclusion and future works

- Conclusion:
  - Heuristic algorithms
  - Two classes of services
- Future works:
  - Compromise simultaneous interruptions / duration of interruption
    - Multiple classes of services
    - Time dependent penalities
  - Allow to reroute more than once

Merci