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IMITATOR II

A Tool for Solving the Good Parameters Problem in Timed Automata

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The Good Parameters Problem

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  - Use of timing parameters (unknown constants)
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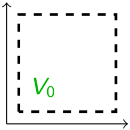

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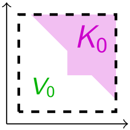

Classical approaches

- Verification of the property on a set of discrete points
  - Drawback: would need an infinite number of verifications to obtain a dense set of points
- Computation of all the reachable states of a PTA, and intersection with the set of bad states [Alur et al., 1995]
  - Drawback: too costly in practice
- Approach based on CEGAR [Clarke et al., 2000, Frehse et al., 2008]
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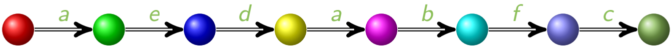
- New approach implemented in IMITATOR II
  - Method of behavioral cartography

Good and Bad Traces

- Trace over a PTA: finite alternating sequence of locations and actions (time-abstract run)

- A trace is said to be good if it verifies a given property
  - Example of property ϕ: "b always occurs before c"
  - Example of good trace w.r.t. ϕ



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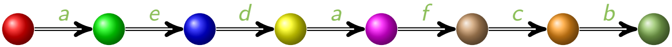

Outline

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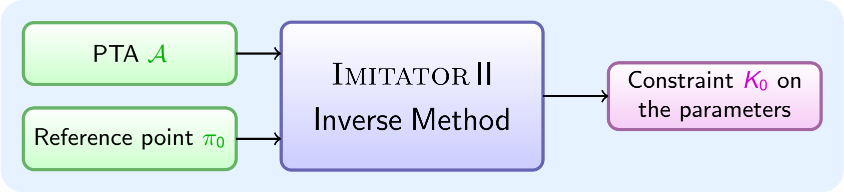
The Inverse Method (1/2)



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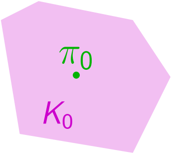
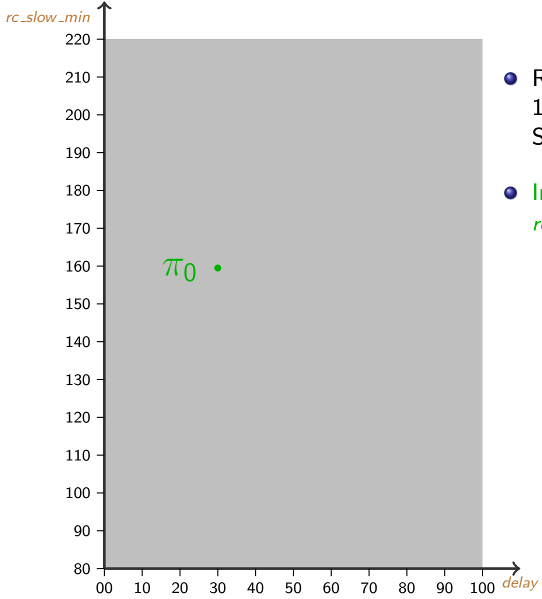
- Output: tile K_0
  - Convex constraint on the parameters such that
    - $\pi_0 \models K_0$
    - For all point $\pi \models K_0$, $\mathcal{A}$ under π has the same trace set as for π_0 [André et al., 2009]



Application to the Root Contention Protocol



- Root contention protocol of the IEEE 1394 ("FireWire") High Performance Serial Bus [Hune et al., 2002]
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$$rc\_slow\_min = 159ns$$
$$delay = 30ns$$

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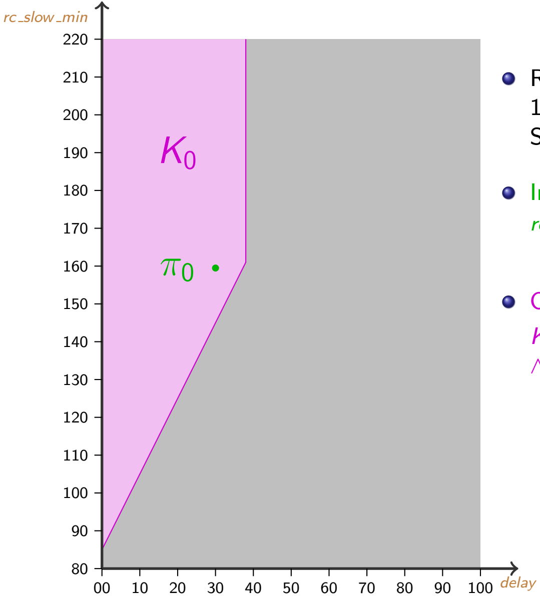

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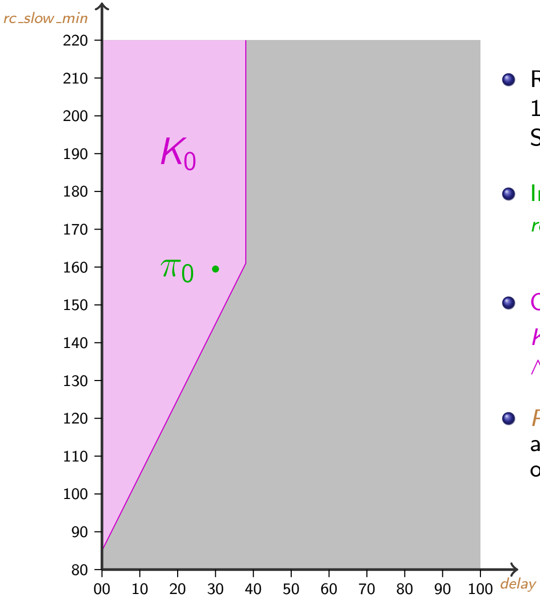

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- Output:
  $K_0 : 2delay < 76$
  $\wedge \ 2delay + 85 < rc\_slow\_min$
- $Prop_3$: The minimum probability that a leader is elected after three rounds or less is greater or equal to 0.75
  - For all $\pi \models K_0$, $Prop_3$ is satisfied

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The Behavioral Cartography Algorithm

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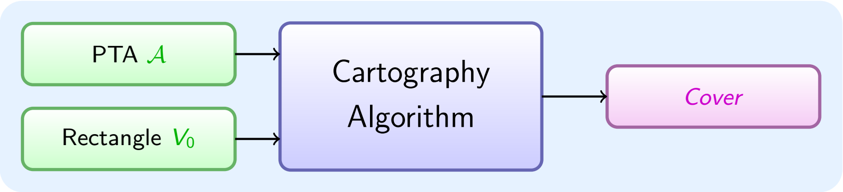
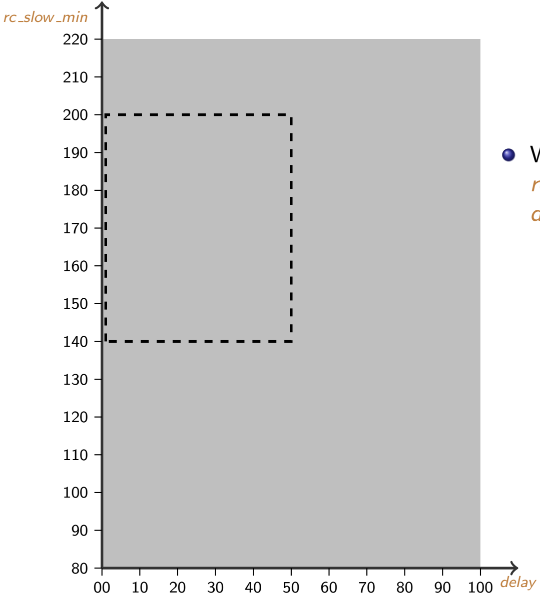
- Method: Iterate the inverse method for all the integer points of a given rectangle V_0
- Output: set of tiles for all the integer points of V_0
  - $\rightsquigarrow$ behavioral cartography of the parameter space [André and Fribourg, 2010]



The Root Contention Protocol: Cartography



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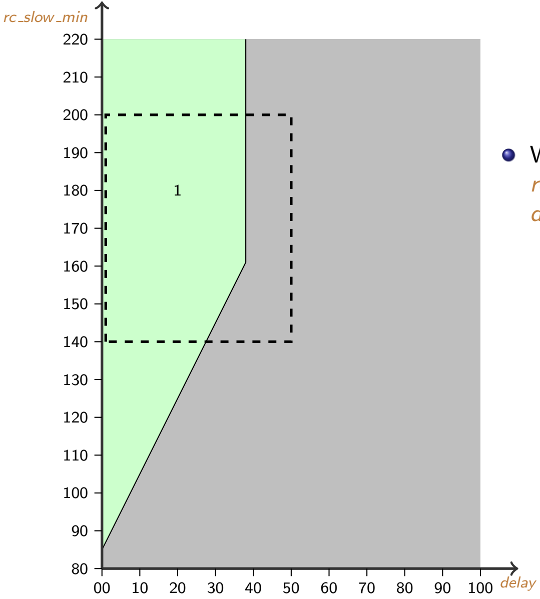

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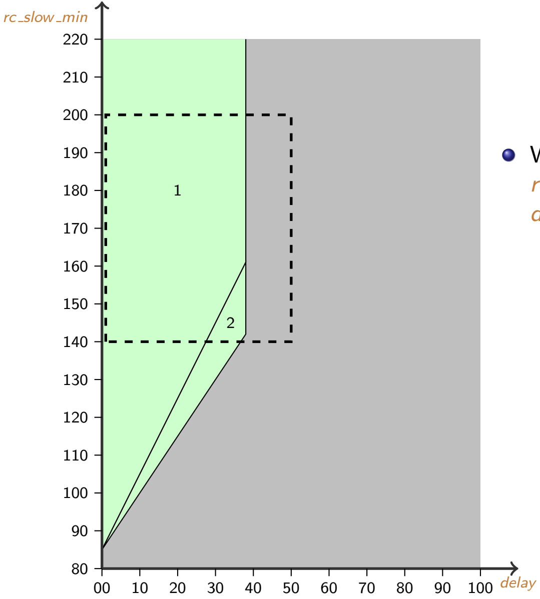

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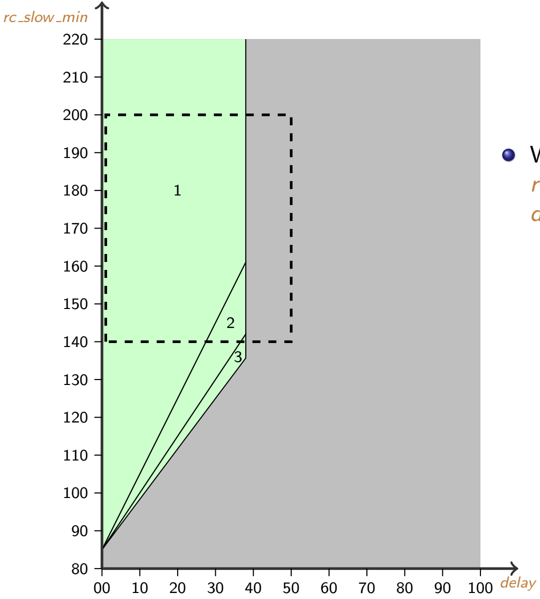

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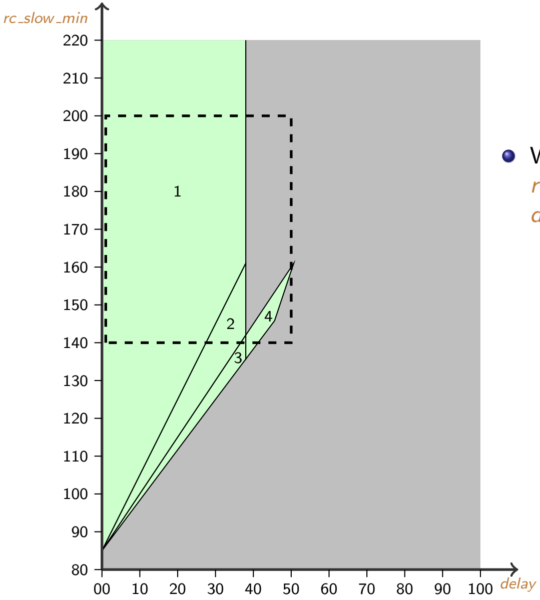

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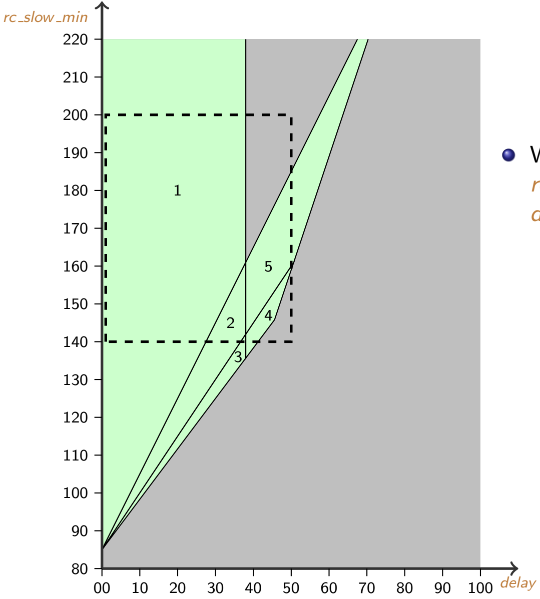

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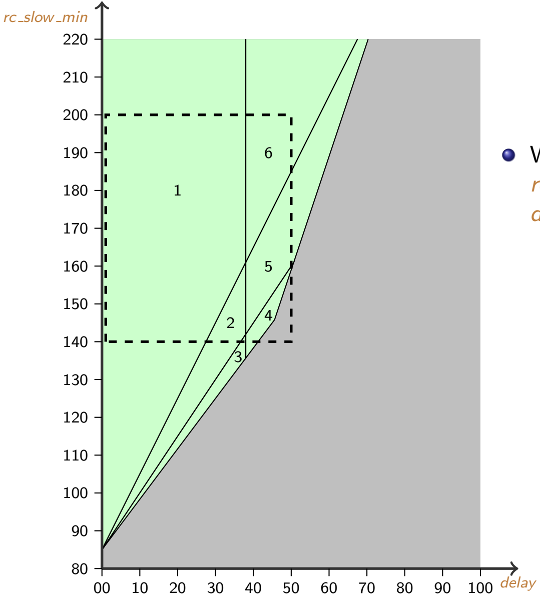

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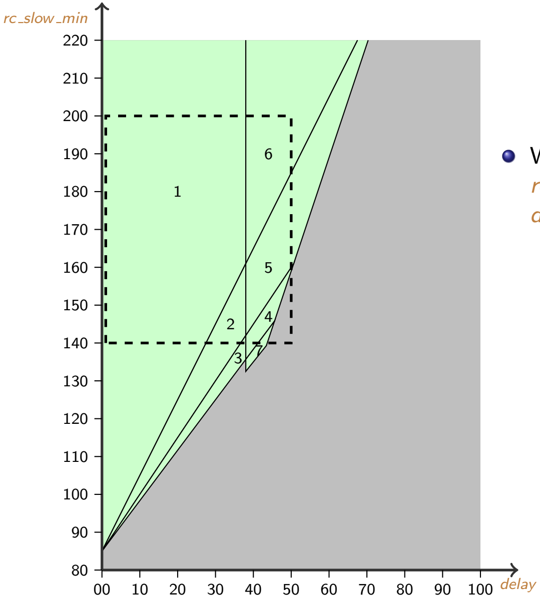

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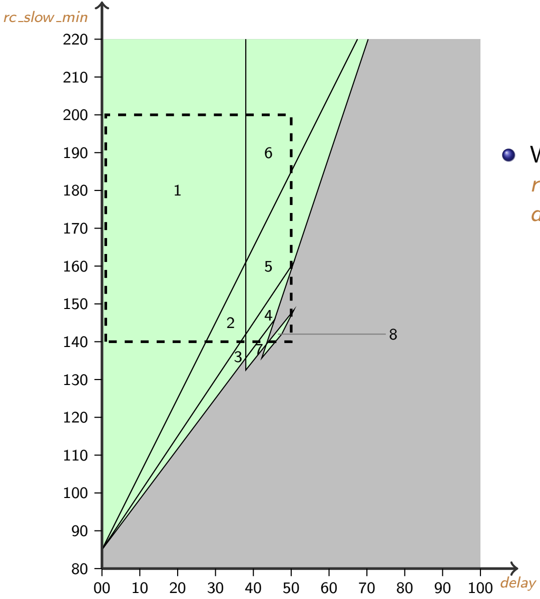

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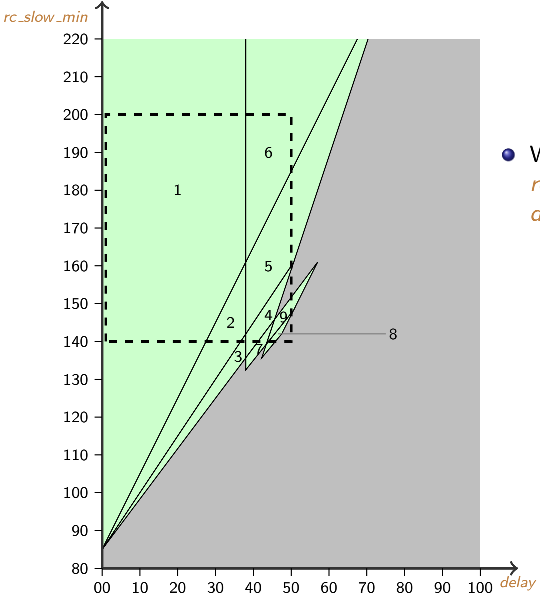

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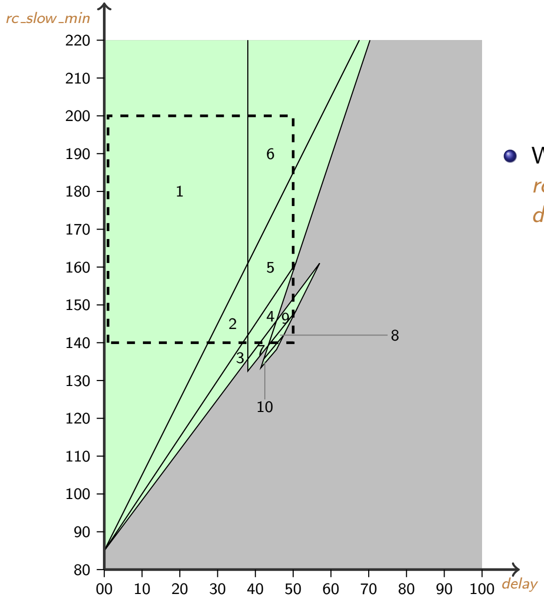

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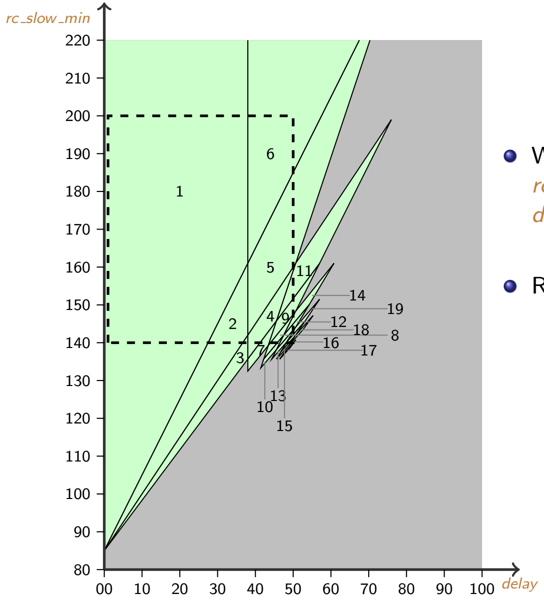
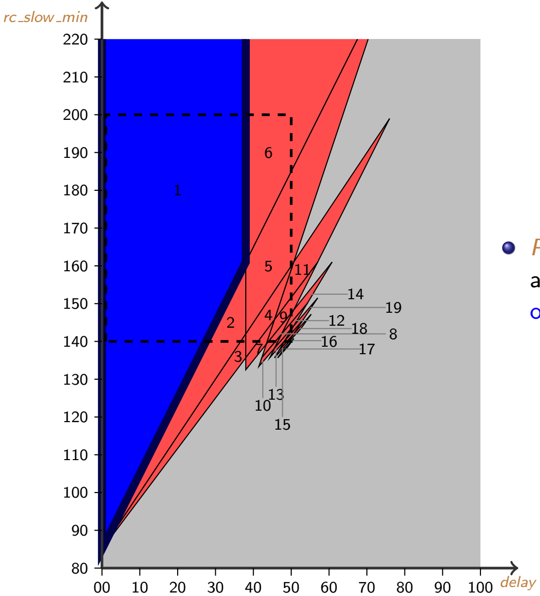


- We consider the following V_0 : *rc_slow_min* $\in [140; 200]$ and *delay* $\in [1; 50]$
- Remarks
  - Tiles 1 and 6 are infinite towards one dimension
  - The cartography does not cover the whole real-valued space within V_0 (holes in the lower right corner of V_0)

Partition into Good and Bad Tiles

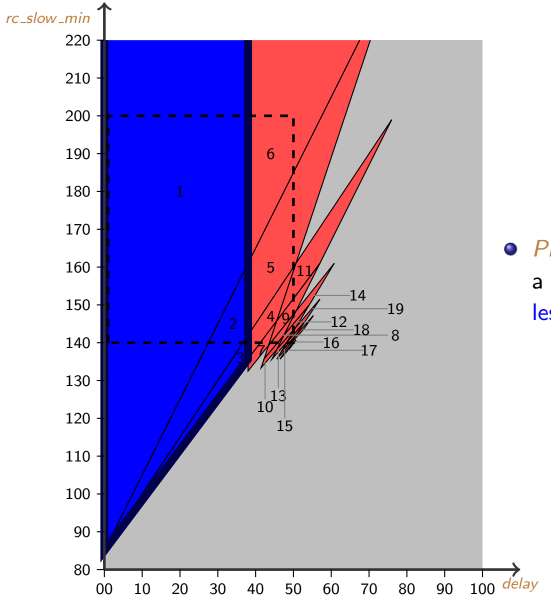
- A tile is said to be good if all its corresponding traces are good
- According to the nature of the trace sets, we can partition the tiles into good and bad ones

The Root Contention Protocol: Partition (1/2)



- *Prop*$_3$: "The minimum probability that a leader is elected after three rounds or less is greater or equal to 0.75"
  - Good tile: 1
  - Bad tiles: 2 to 19

The Root Contention Protocol: Partition (2/2)



- *$Prop_5$*: "The minimum probability that a leader is elected after five rounds or less is greater or equal to 0.75"
  - Good tiles: 1, 2, 3
  - Bad tiles: 4 to 19

Outline

Implementation

- In short
  - IMITATOR II: new improved version of IMITATOR
  - "Inverse Method for Inferring Time AbstracT BehaviOR"
  - 8000 lines of code
  - Program written in OCaml
  - Makes use of the PPL library for handling polyhedra [Bagnara et al., 2008]
- Some features
  - List of tiles with their corresponding trace set under a graphical form
  - Cartography under a graphical form (for 2 parameter dimensions)
- IMITATOR II is available on its Web page
  - `http://www.lsv.ens-cachan.fr/~andre/IMITATOR2`

Case Studies

- Application to various case studies
  - Asynchronous circuits
  - Communication protocols
- Computation time for the cartography algorithm
  - Experiments conducted on an Intel Core2 Duo 2.4 GHz with 2 Gb

Example	PTAs	loc./PTA	$\|X\|$	$\|P\|$	$\|V_0\|$	tiles	states	trans.	Time (s)
SR-latch	3	$[3, 8]$	3	3	1331	6	5	4	0.3
Flip-flop	5	$[4, 16]$	5	2	644	8	15	14	3
Latch circuit	7	$[2, 5]$	8	4	73062	5	21	20	96.3
And–Or	3	$[4, 8]$	4	6	75600	4	64	72	118
CSMA/CD	3	$[3, 8]$	3	3	2000	140	349	545	269
SPSMALL	10	$[3, 8]$	10	2	3149	259	60	61	1194
RCP	5	$[6, 11]$	6	3	186050	19	5688	9312	7018

Outline

Summary

- Implementation of the Inverse Method
  - Modeling of a system with parametric timed automata
  - Starting with a valuation π_0 of the system, we synthesize a constraint K_0 with the same trace set as π_0
  - Gives a criterion of robustness by guaranteeing the same behavior around π_0
- Implementation of the Behavioral cartography
  - Solves the good parameters problem: synthesizes the largest set of points within a rectangle V_0 corresponding to a given good behavior
  - Independent from the property: only the partition does

Future Work

- Automatize the partition into good and bad tiles
  - Make use of the UPPAAL model checker [Larsen et al., 1997]
- Extend the behavioral cartography to hybrid automata
  - Allow to consider different clock rates
- Consider a dynamic cartography
  - Refine the scale in order to fill the whole real-valued V_0
- Consider a weaker property than equality of trace sets
  - Reference trace with partial orders

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