Computing DBF/RBF for Timed/Task Automata

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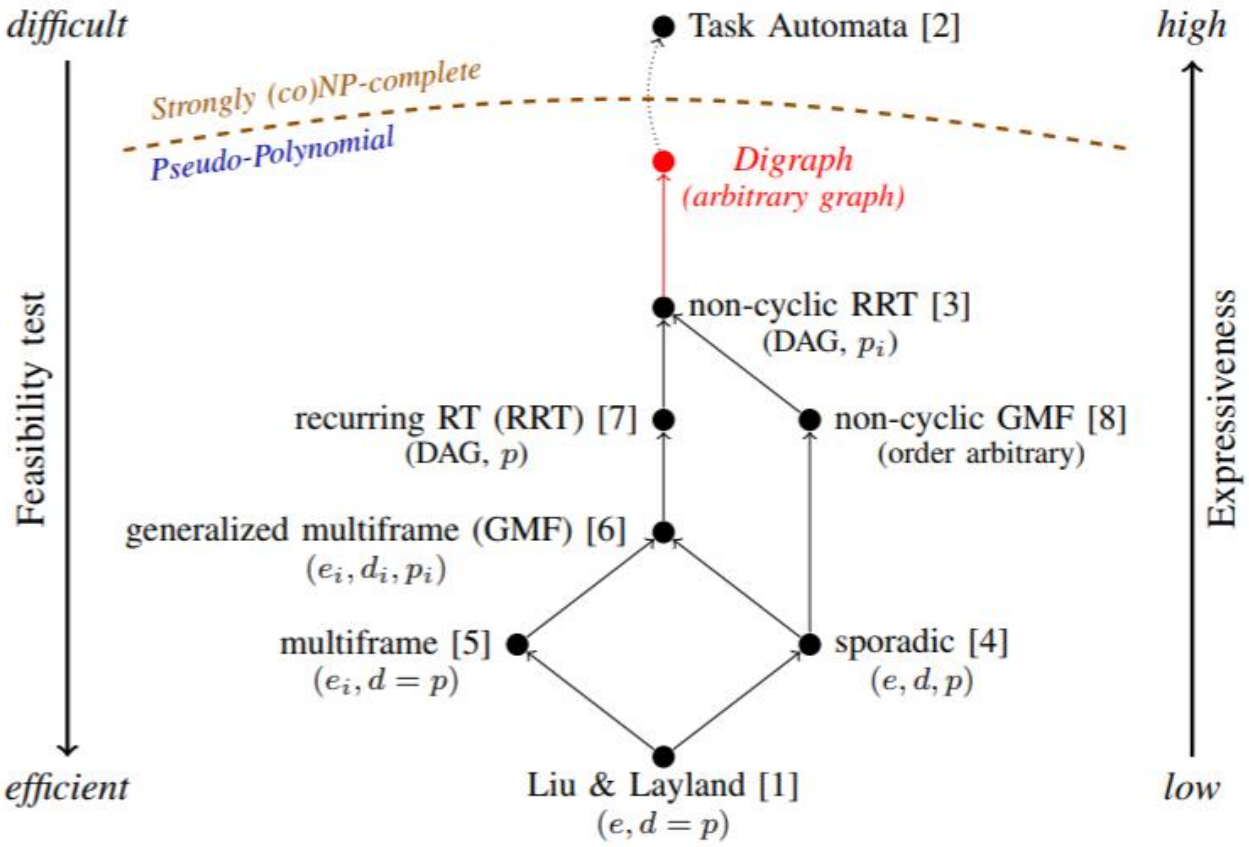
@RTSOPS, 2019 July, Paris

Outline

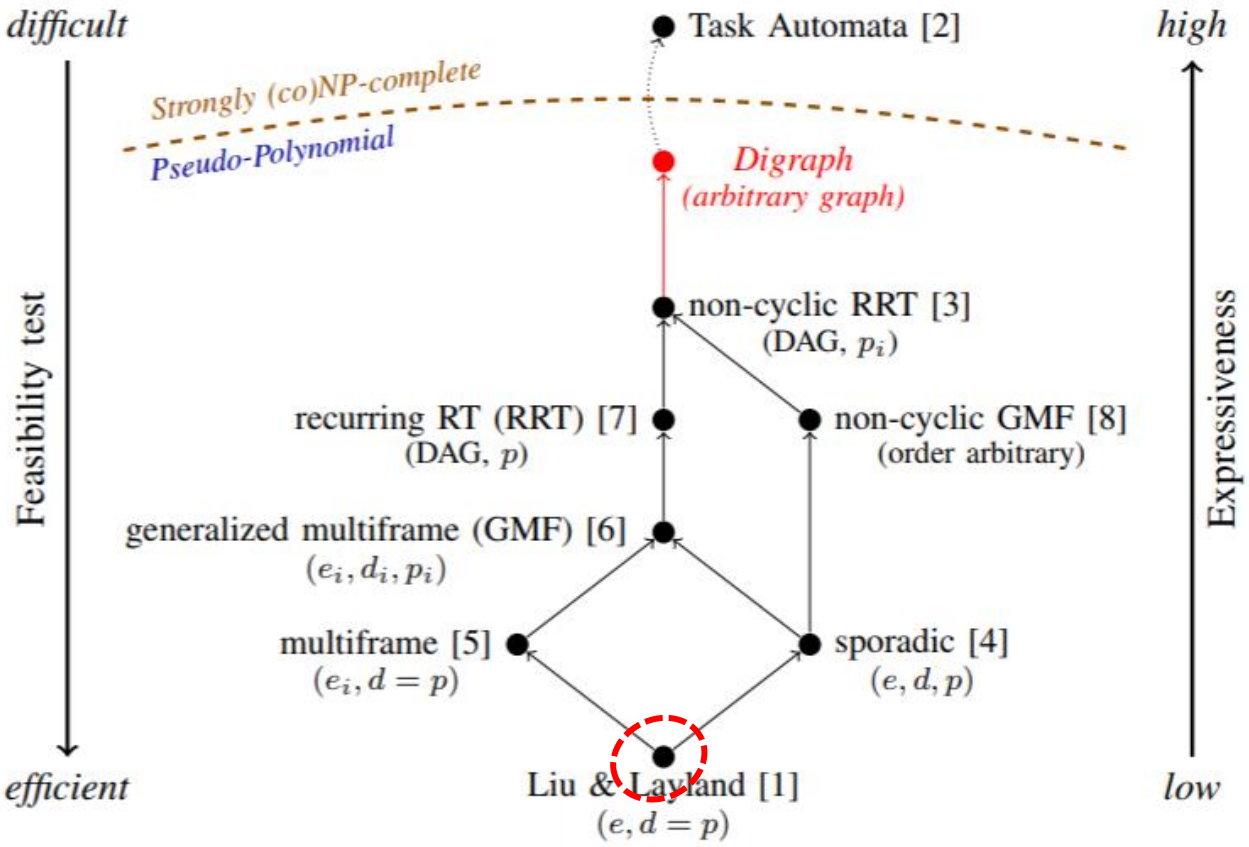
- Problem
  - What are Timed/Task Automata?
  - Why compute their DBF/RBF?

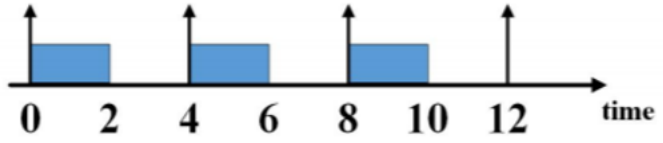
- A Starting Point

Real-Time Task Models

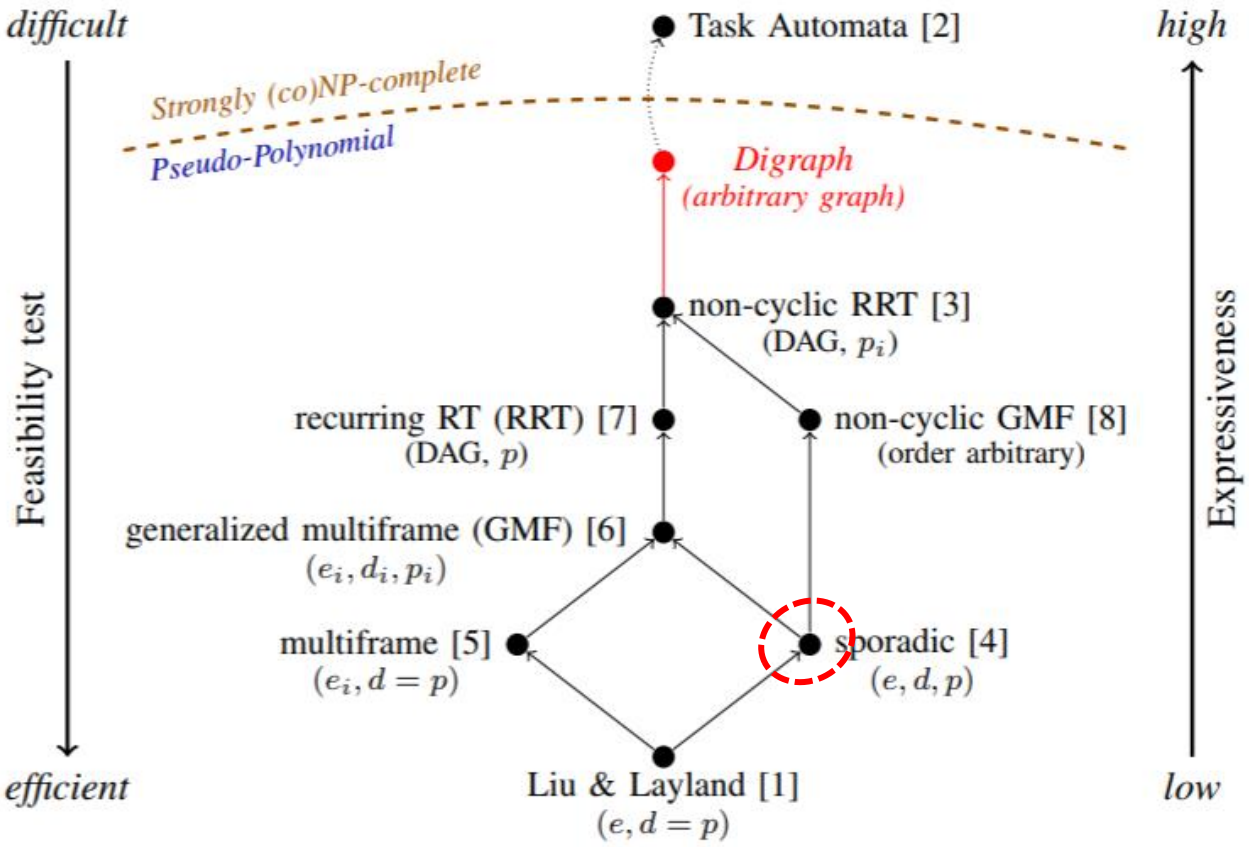


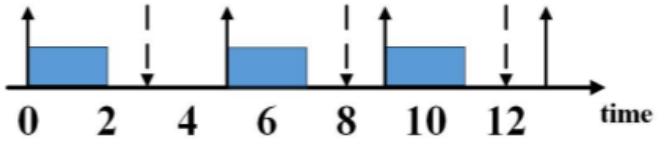
Real-Time Task Models





Real-Time Task Models





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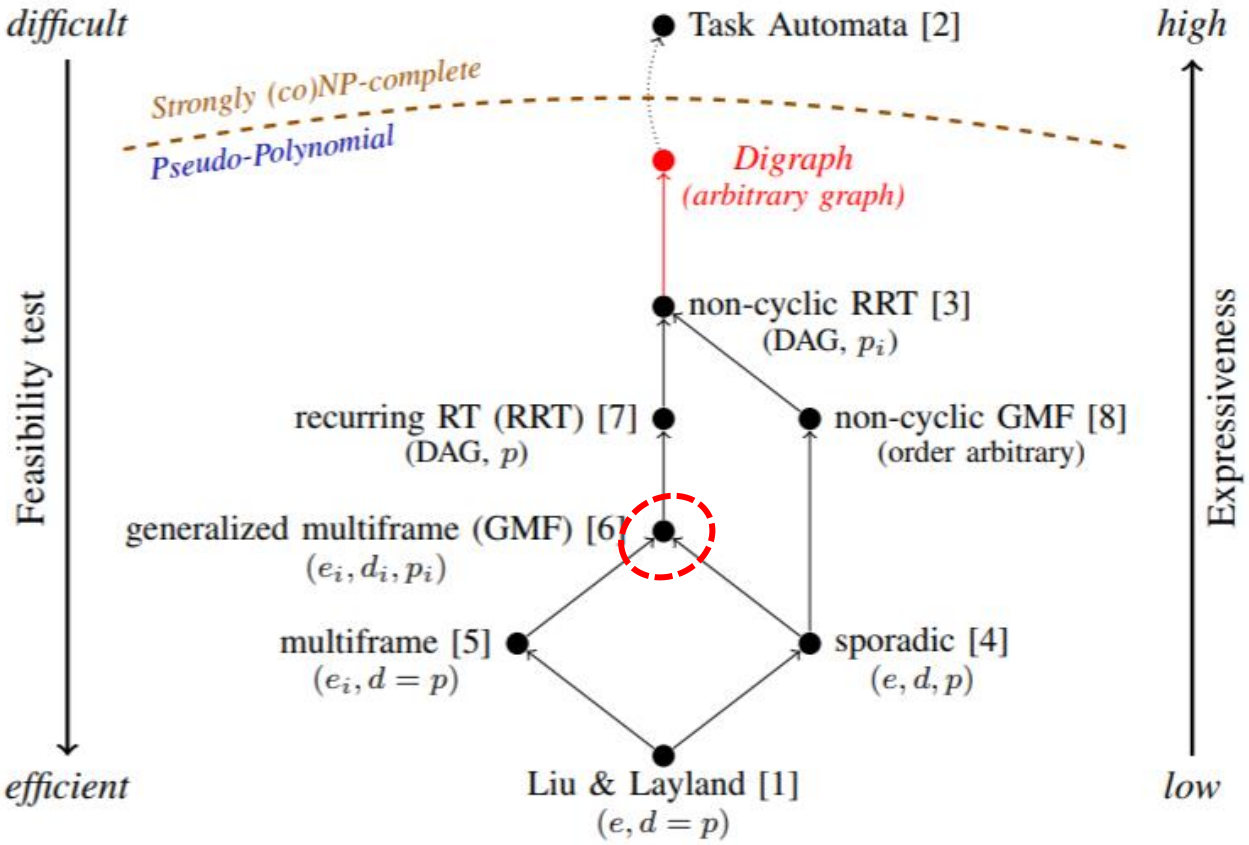

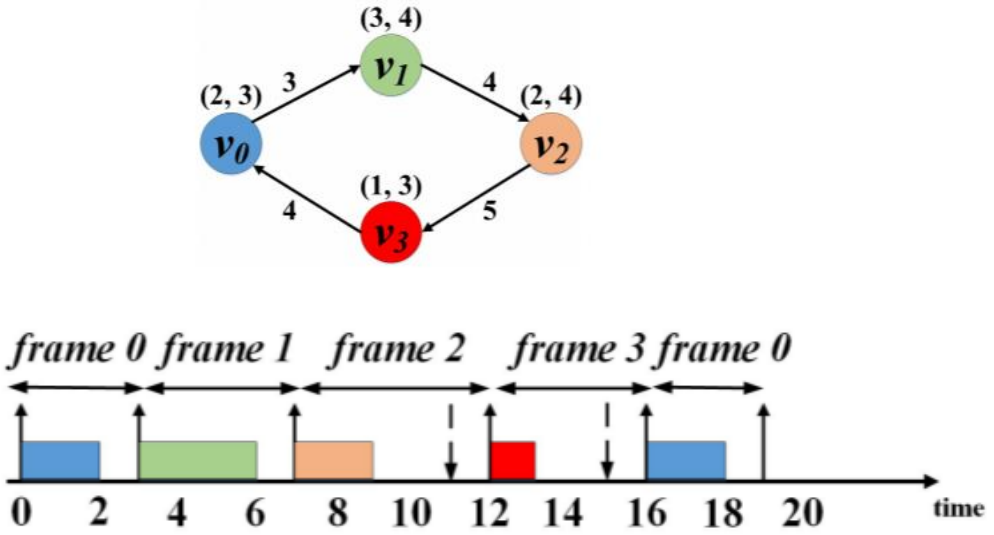

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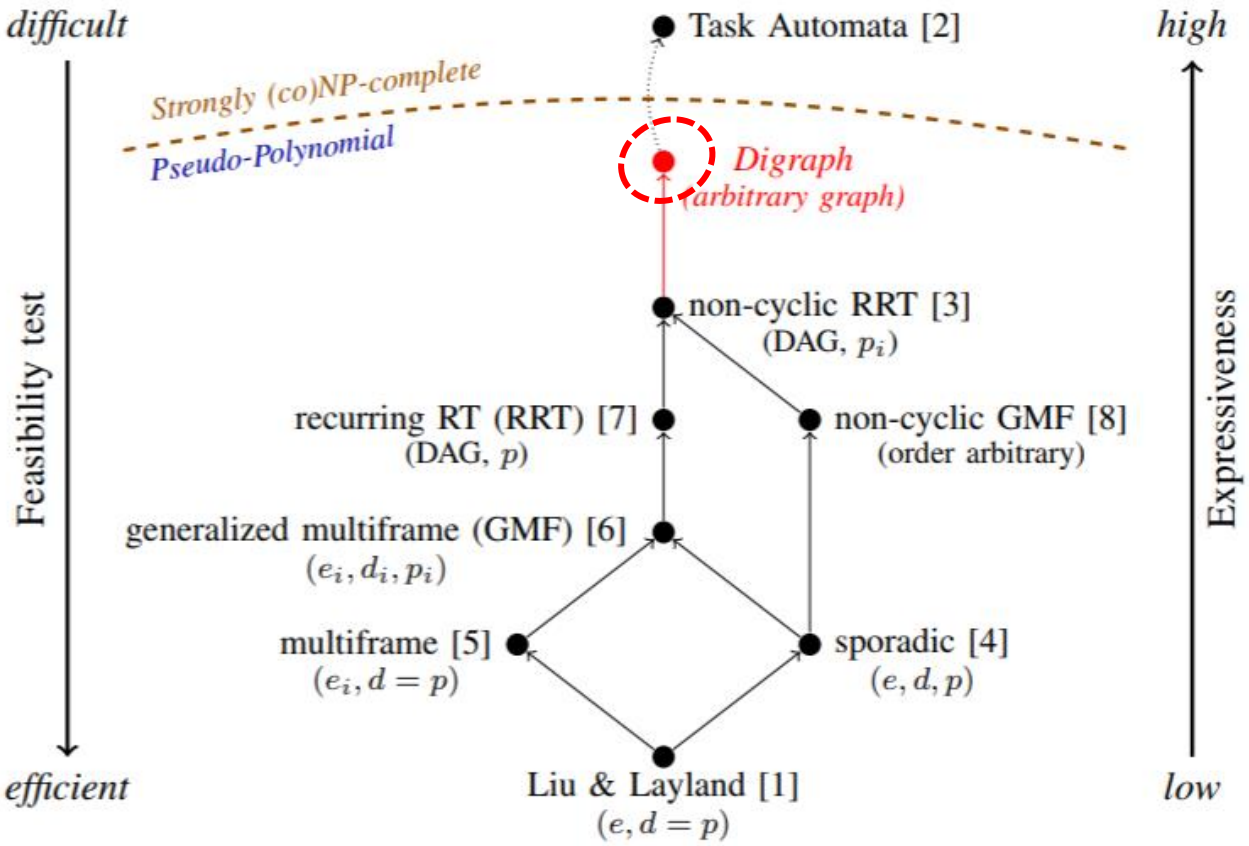

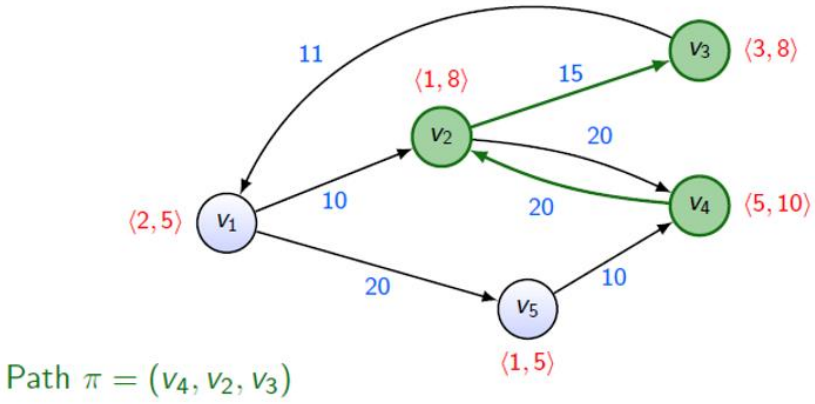

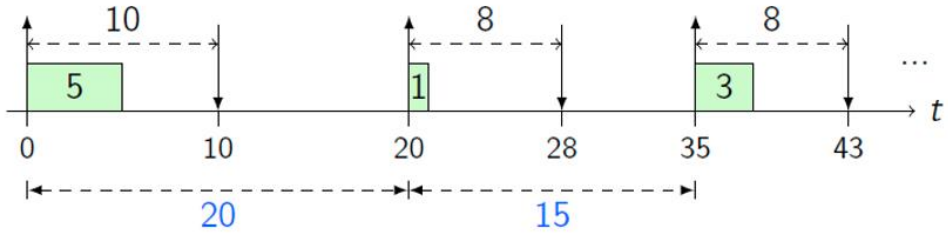

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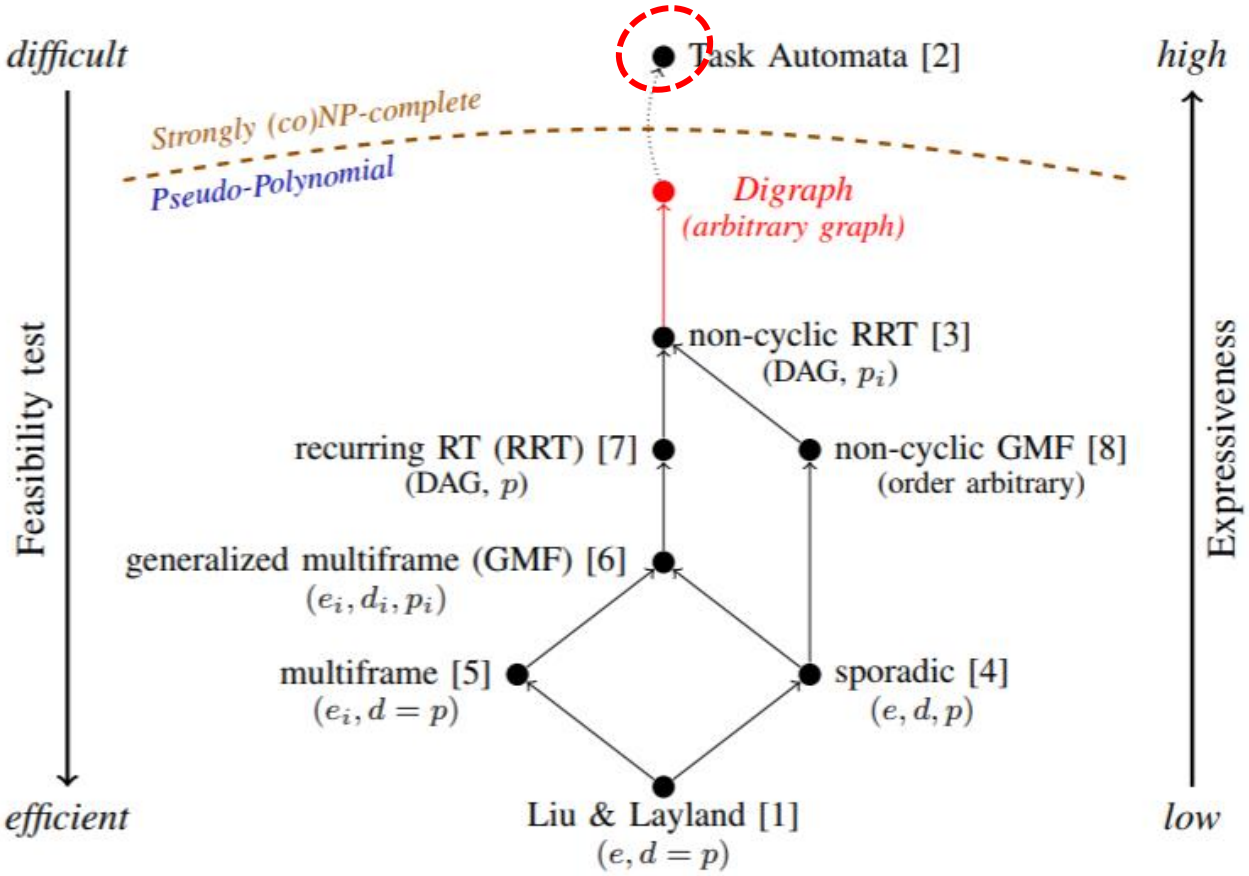
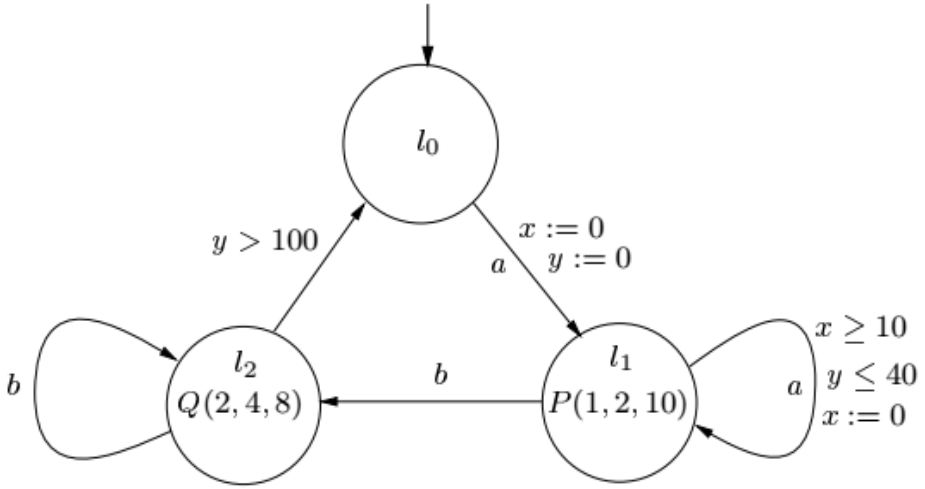
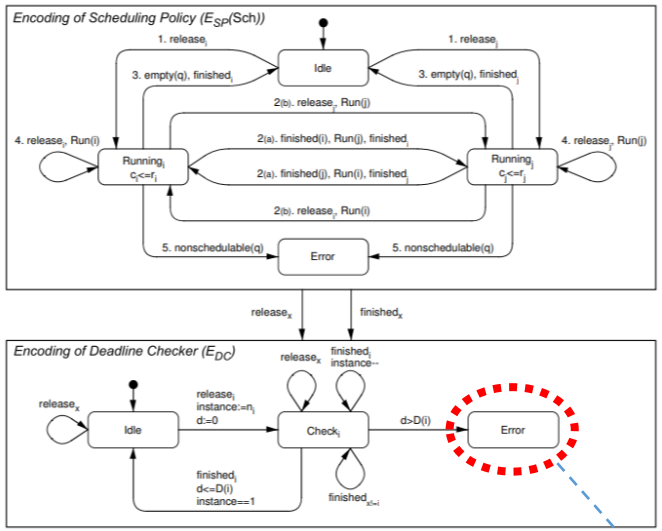




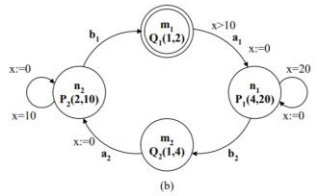
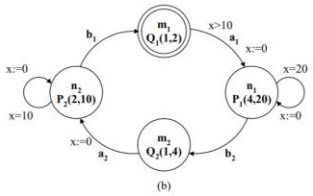
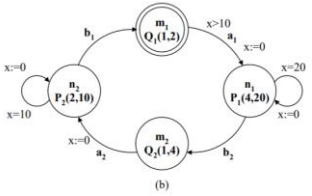
Timed Automata = FSM + clocks
Task Automata = Timed Automata + Task Release

Real-Time Task Models

Scheduability as Reachability of TA -- Model Checking



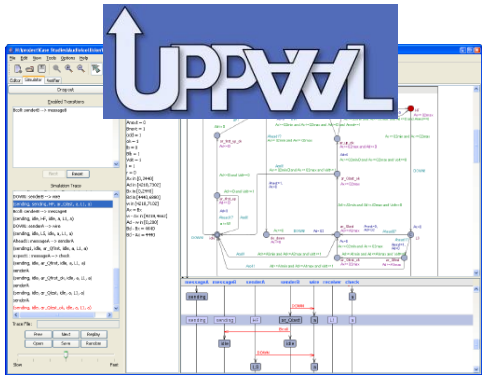
TA for scheduler and deadline checking

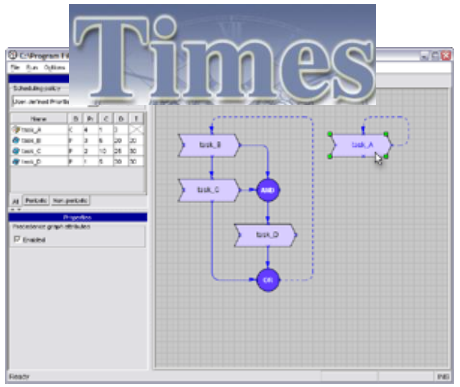
X  X  X … … X 

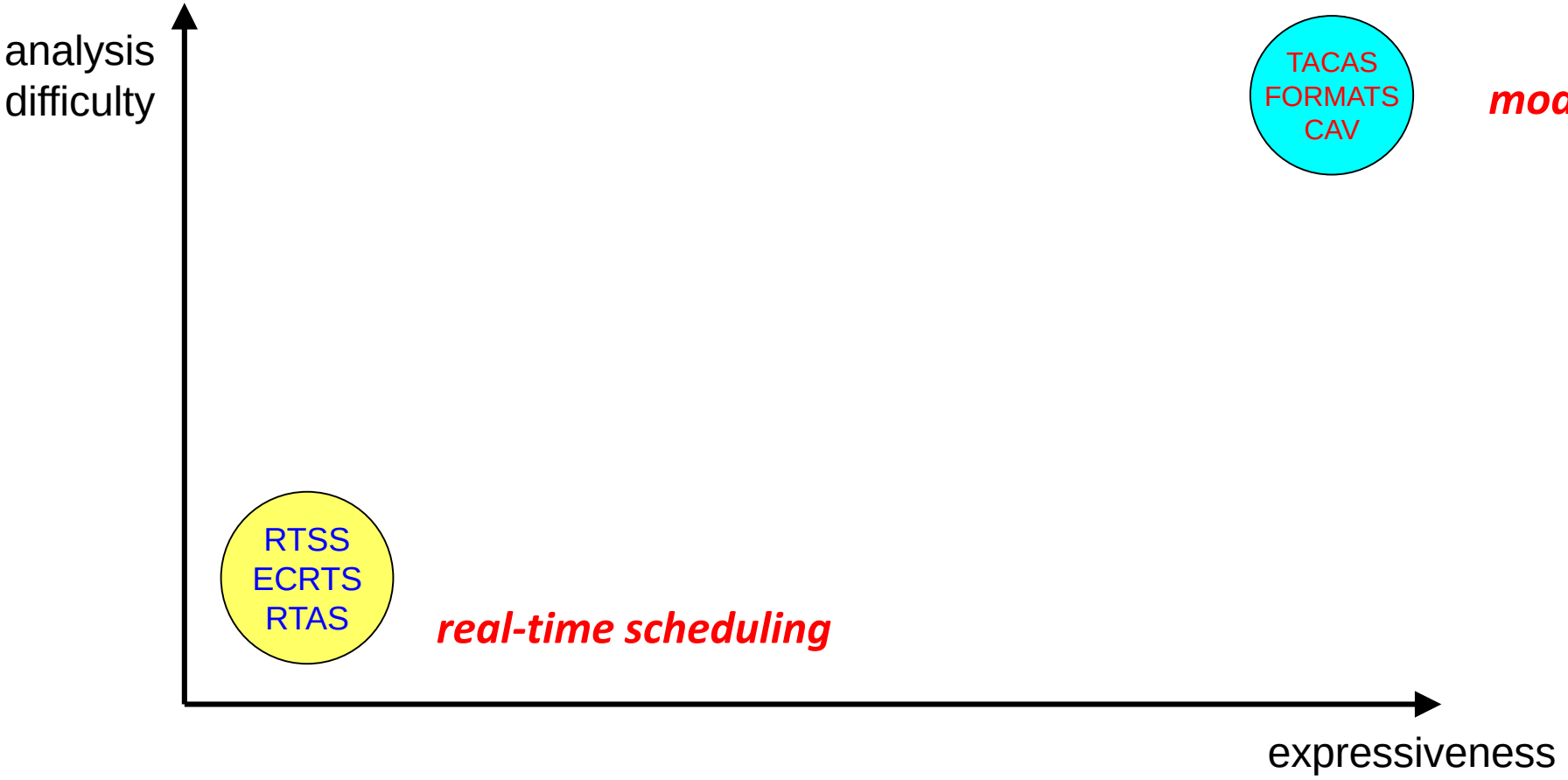
TA for task 1 TA for task 2 TA for task 2

Search the composed state transition graph, to check whether the state representing deadline miss is reachable.

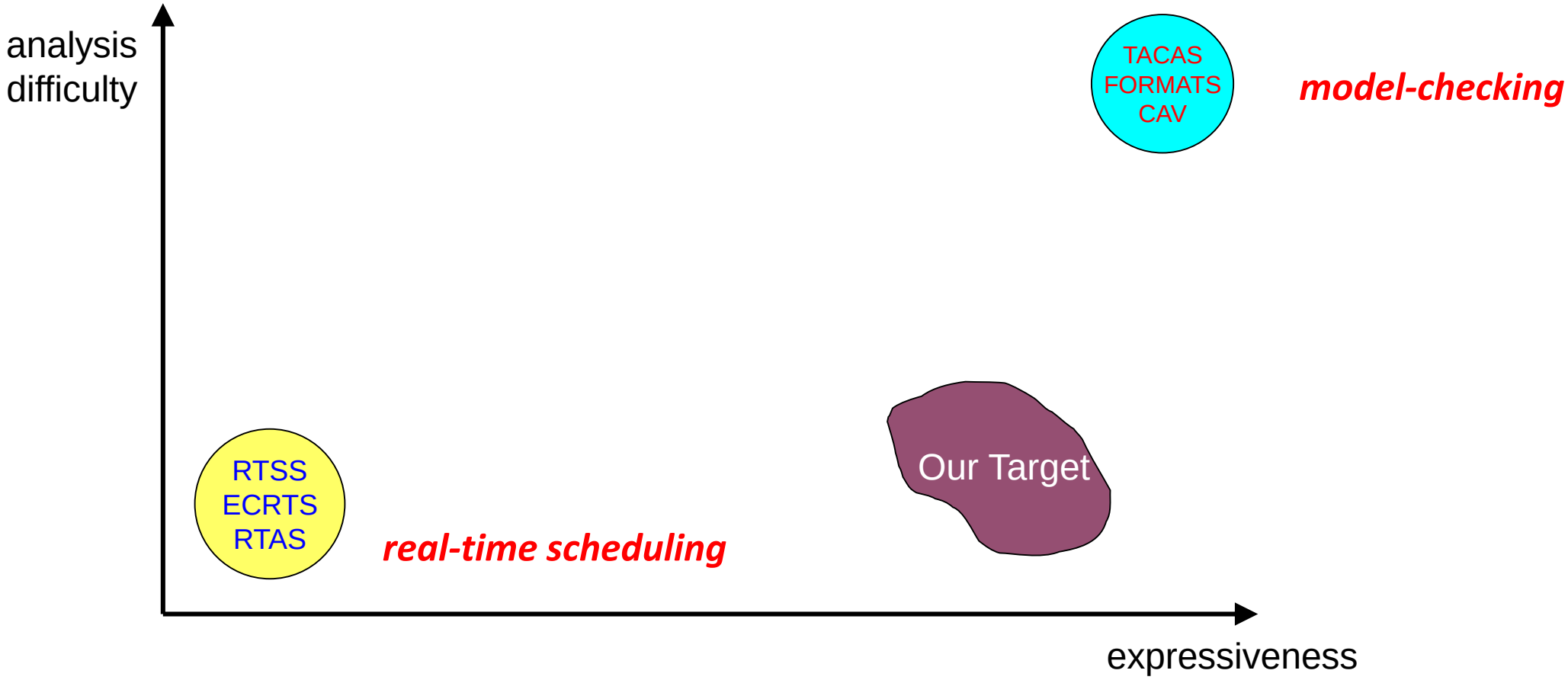
Real-Time Task Models







Real-Time Task Models



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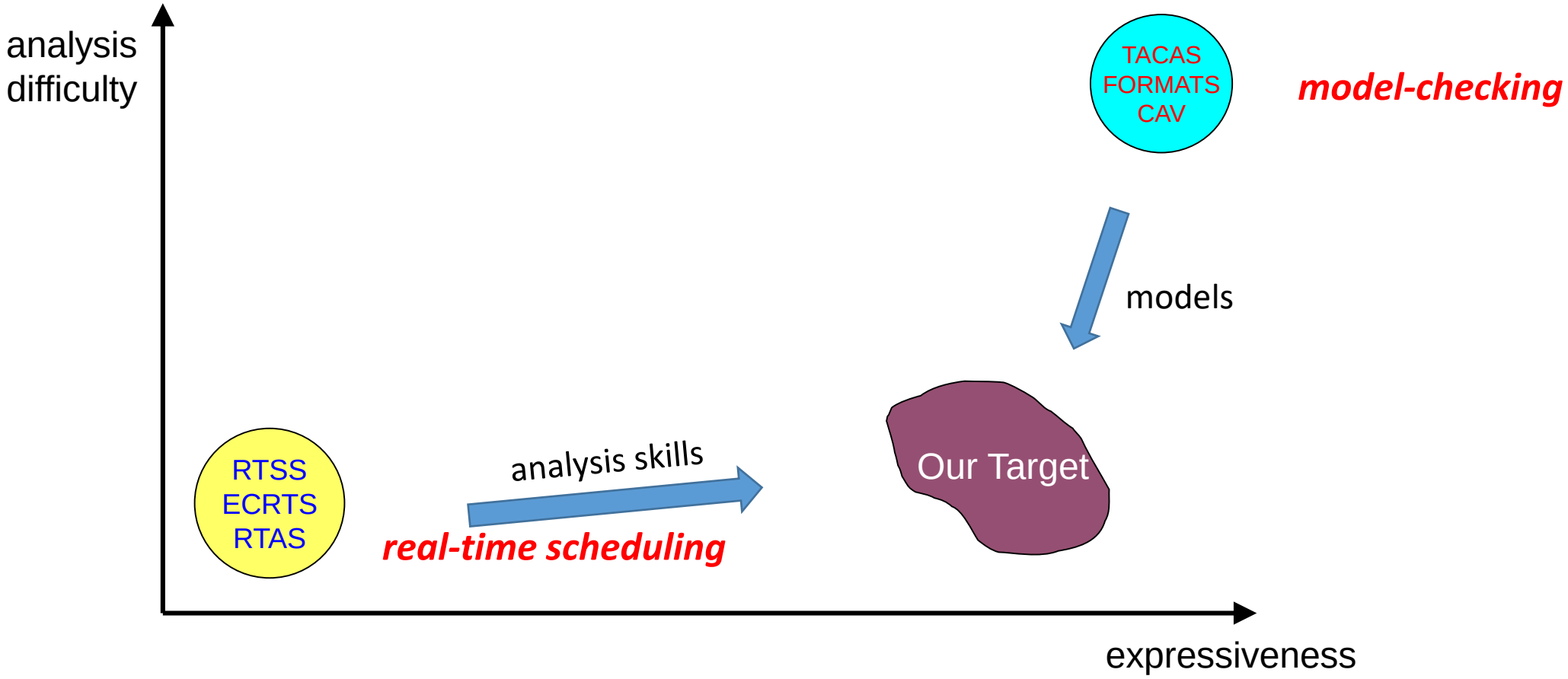

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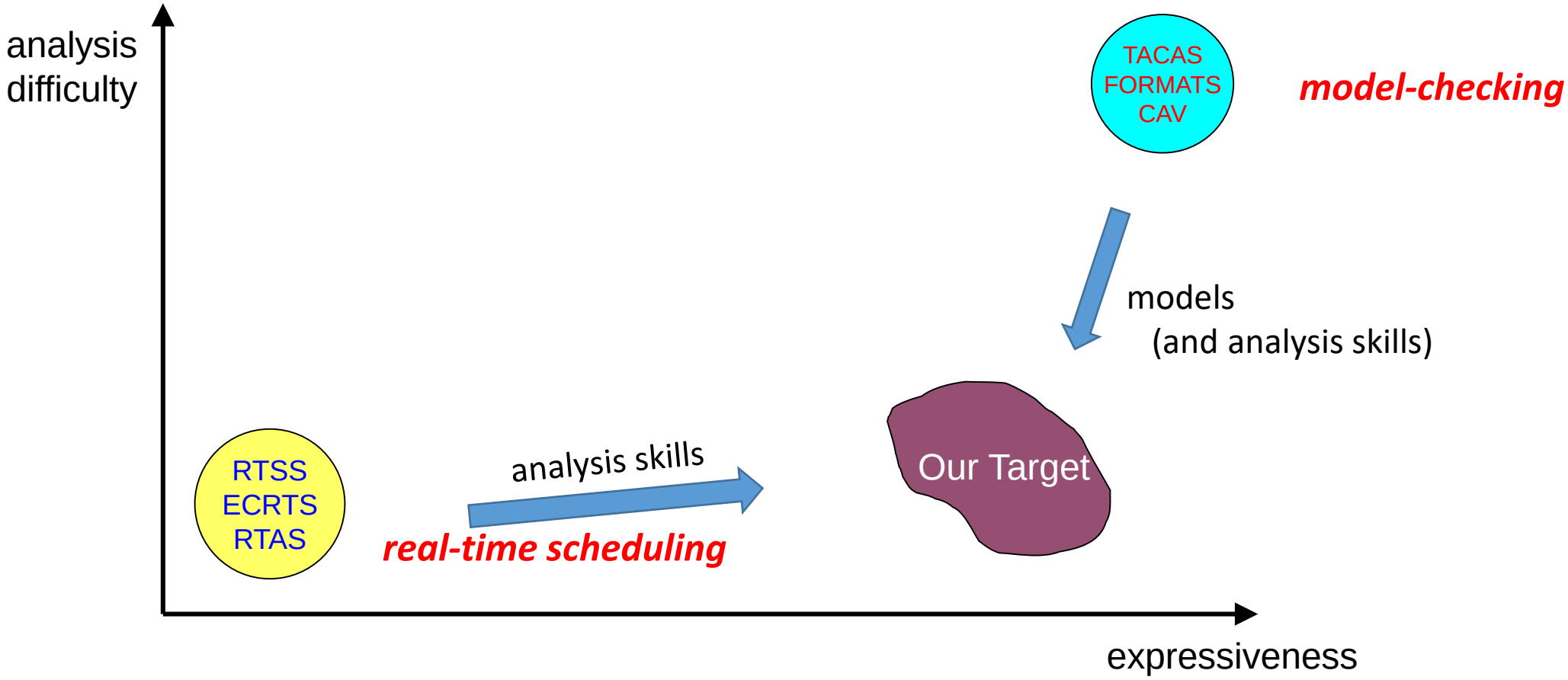
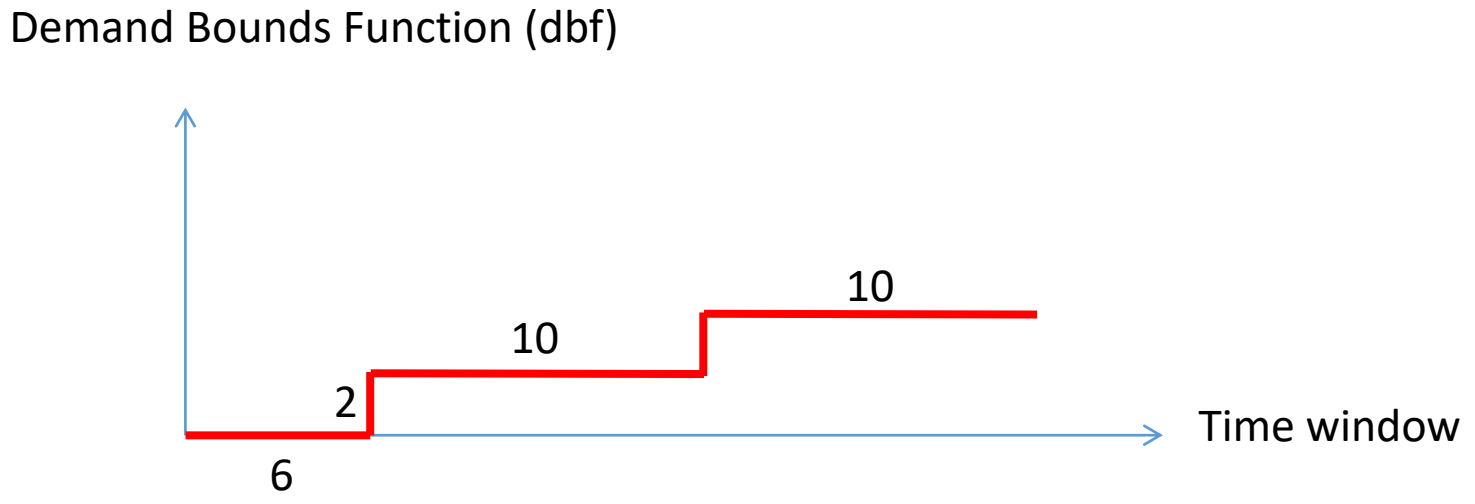


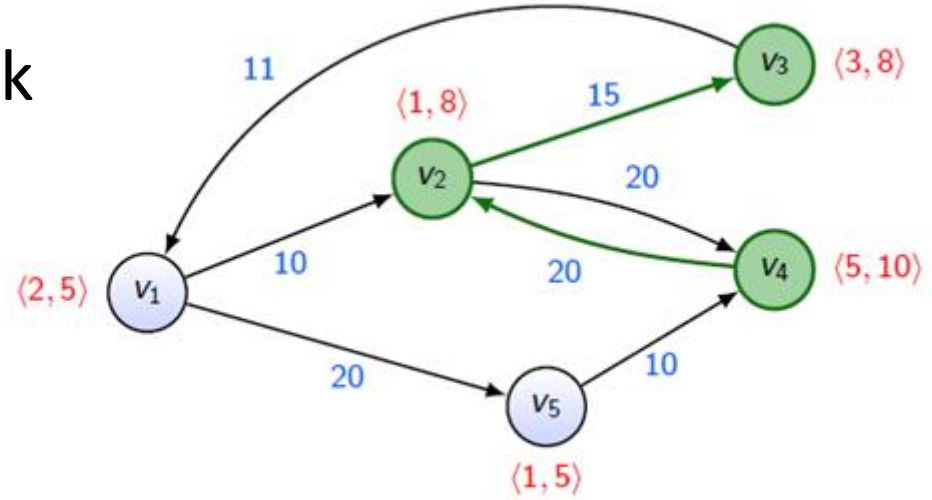
Demand Bound Function (DBF)

- DBF of a ***sporadic*** task
  - Period = 10
  - WCET = 2
  - Deadline = 6

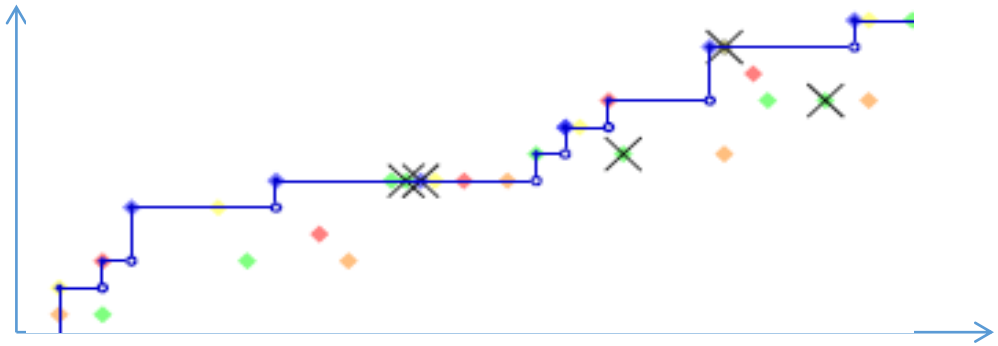


Demand Bound Function (DBF)

- DBF of a ***Digraph*** task

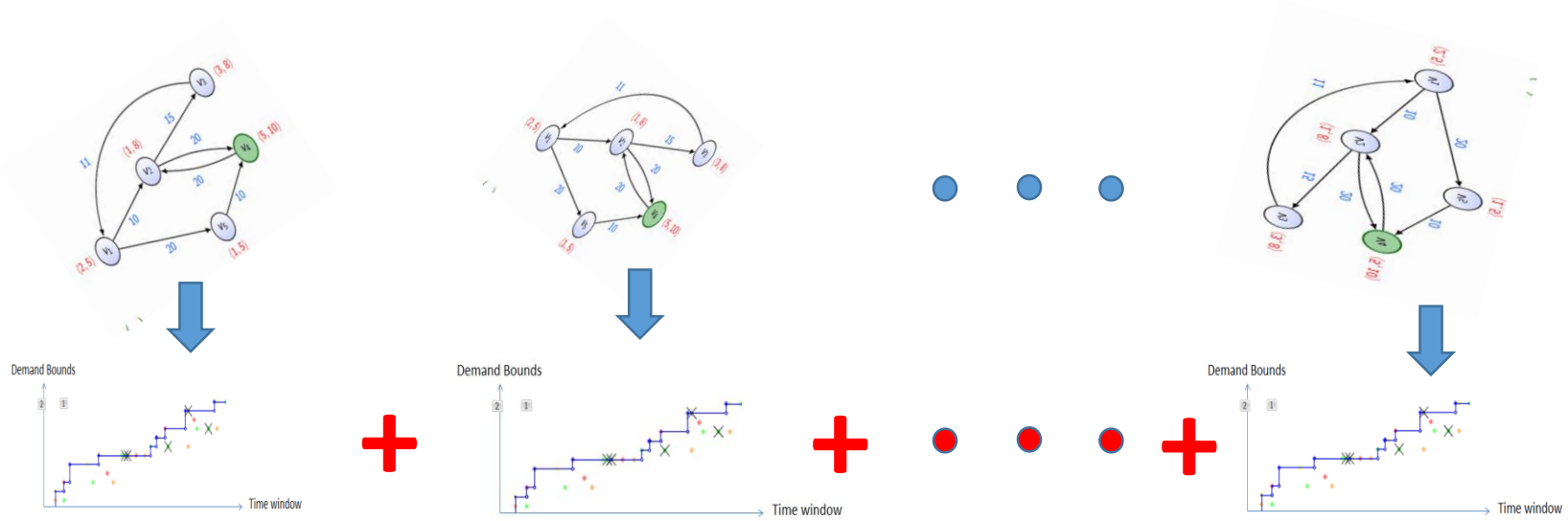


Demand Bounds Function (dbf)

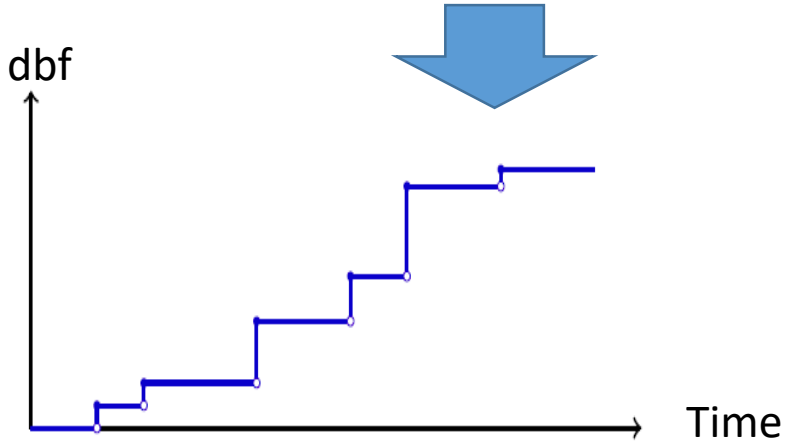


Time window

Demand Bound Function (DBF)



The system workload:



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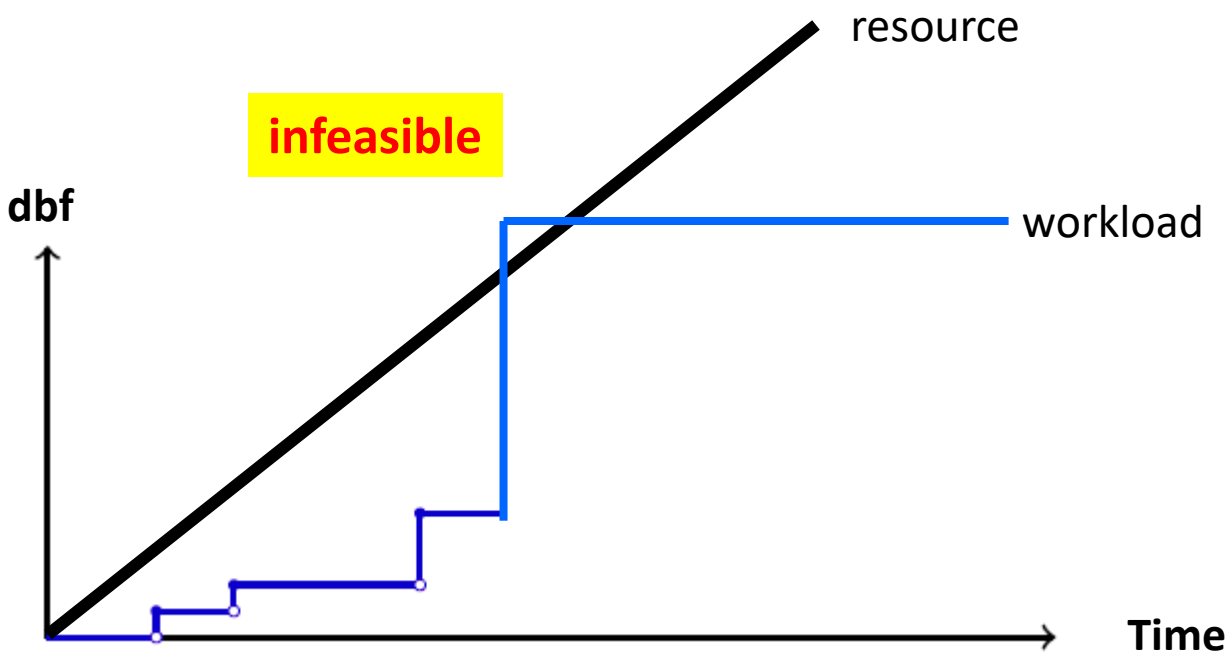

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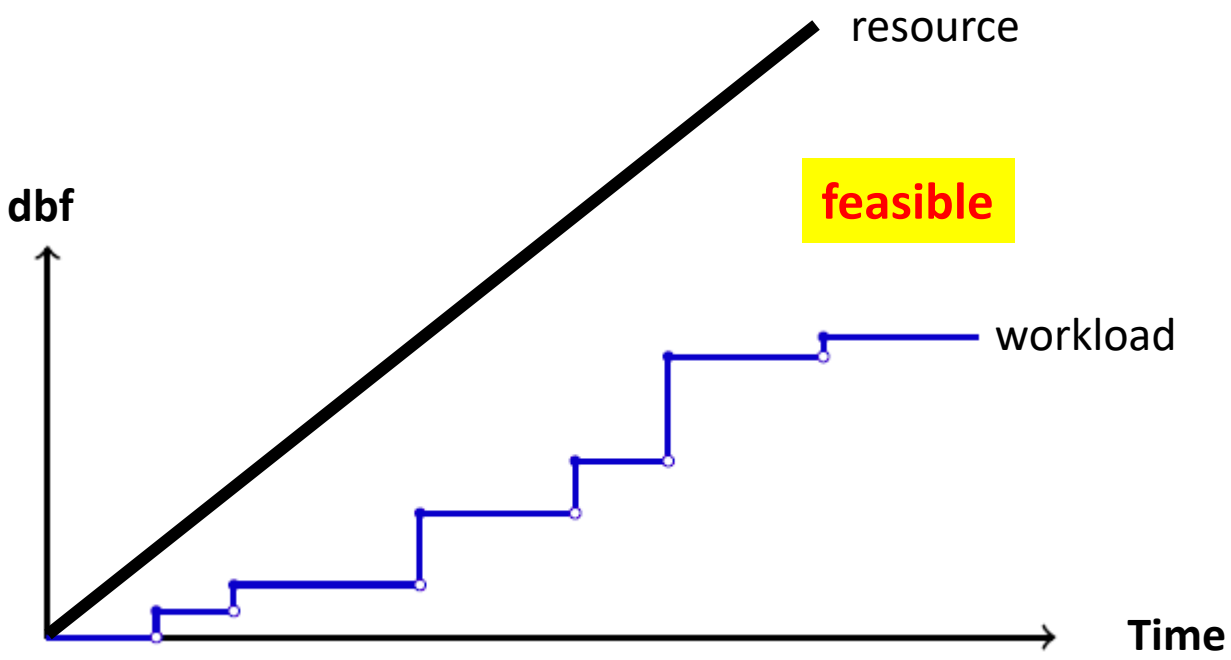

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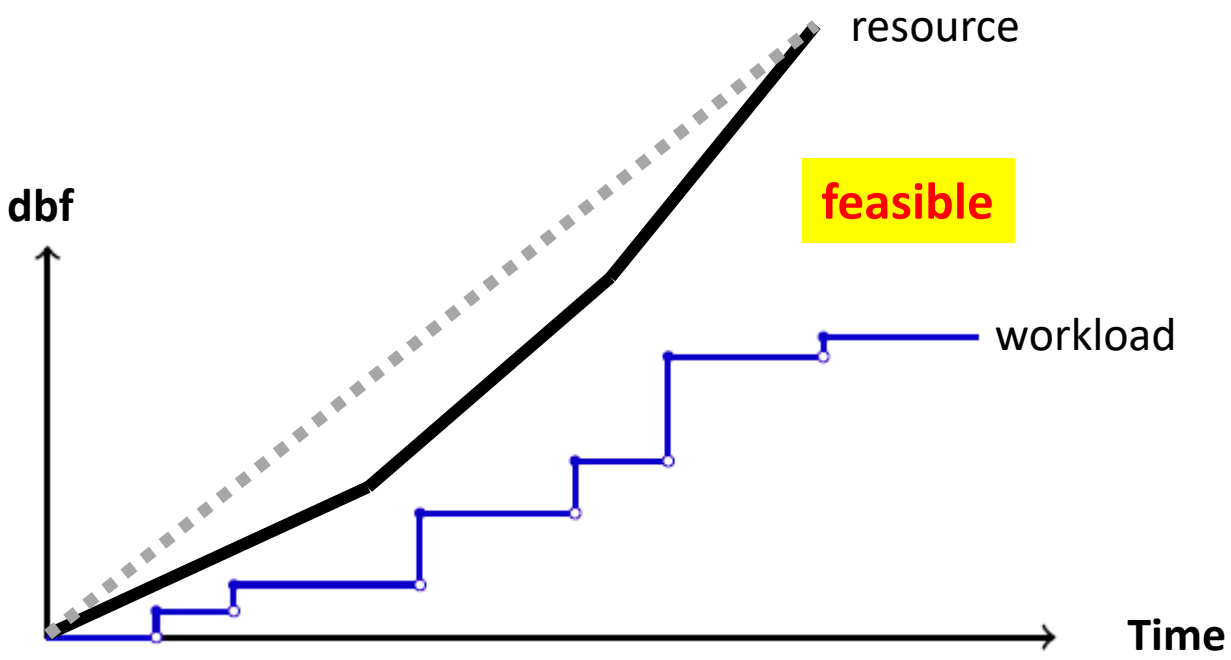
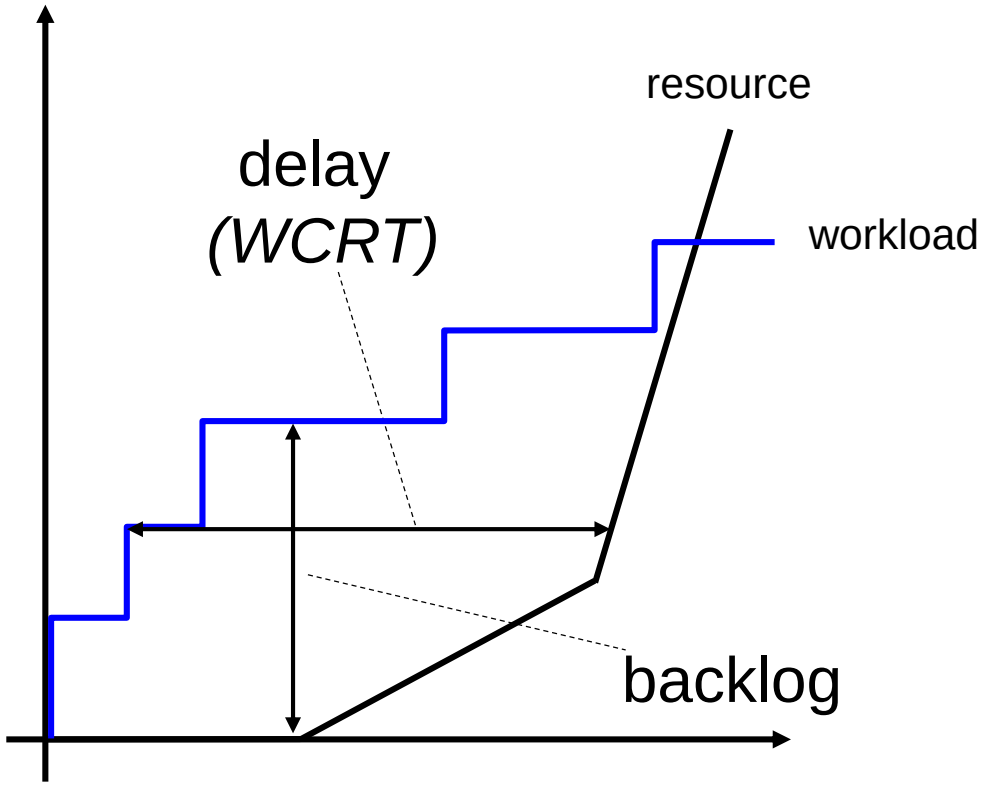
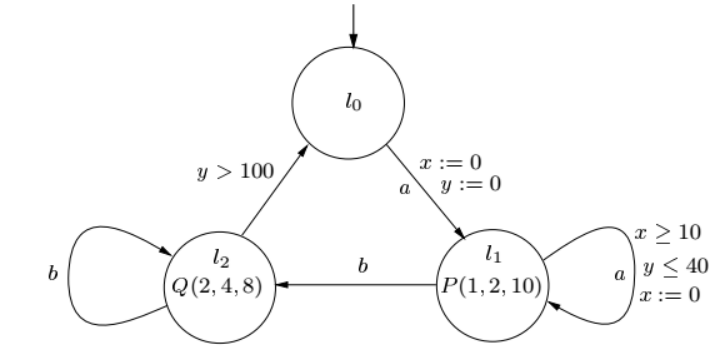
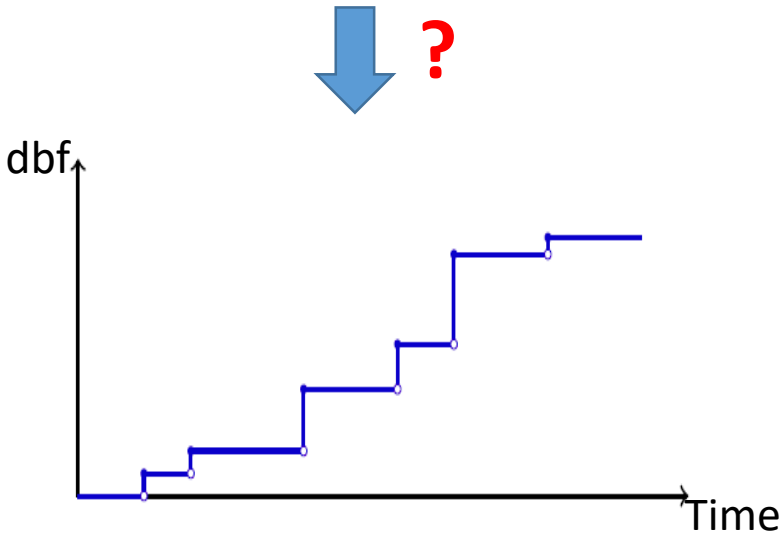


Request Bound Function (RBF) / Arrival Curve



Problem: Compute DBF/RBF of a TA (Efficiently)





- If solved
  - The first step towards scalable schedulability analysis of general Task Automata models
  - Can efficiently check schedulability of a system composed of **independent** tasks each modeled as a Task Automaton

Outline

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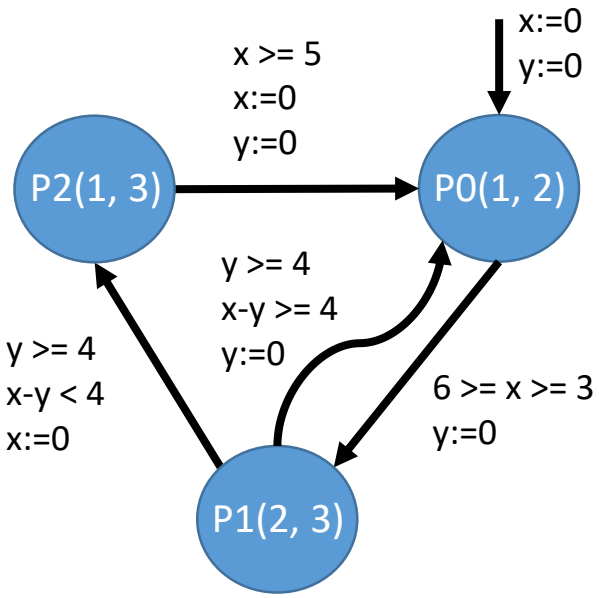
  - Why compute their DBF/RBF?

- A Starting Point

Semantics of Task Automata



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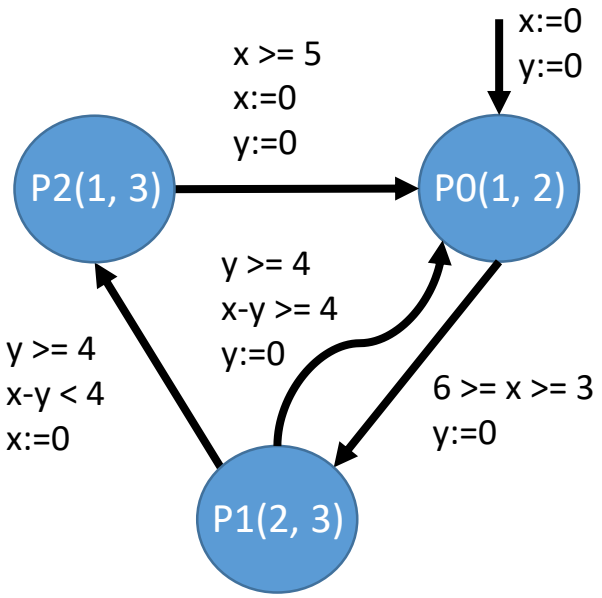
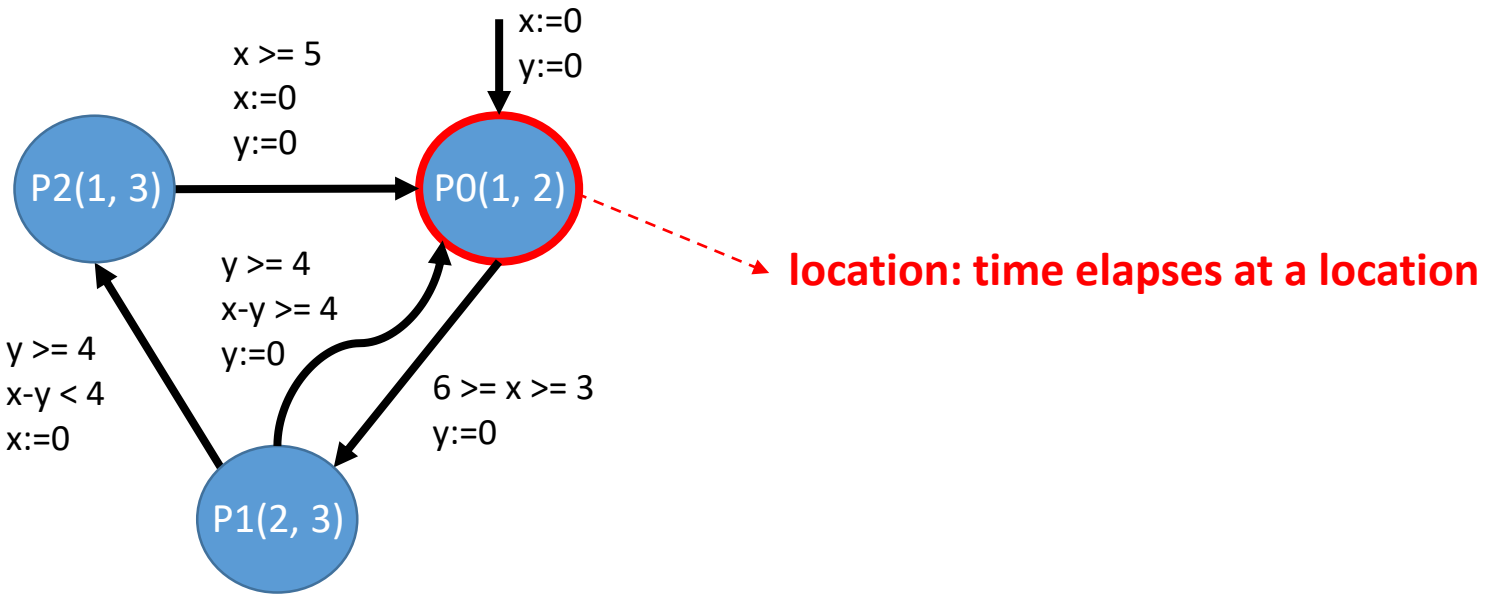
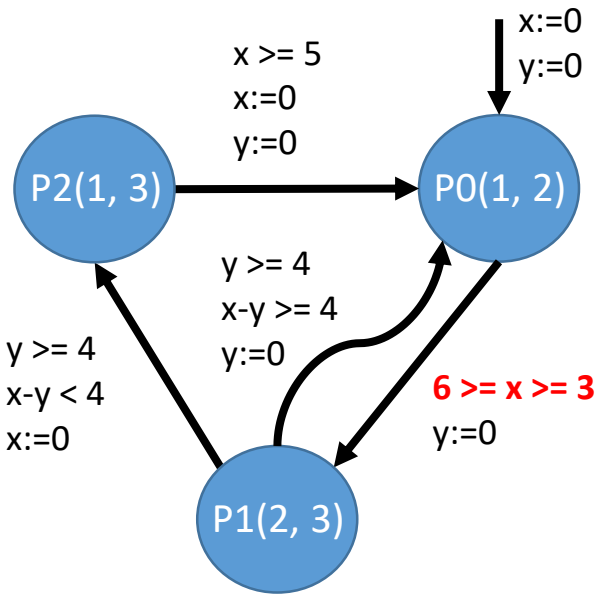


x, y: clocks

Semantics of Task Automata

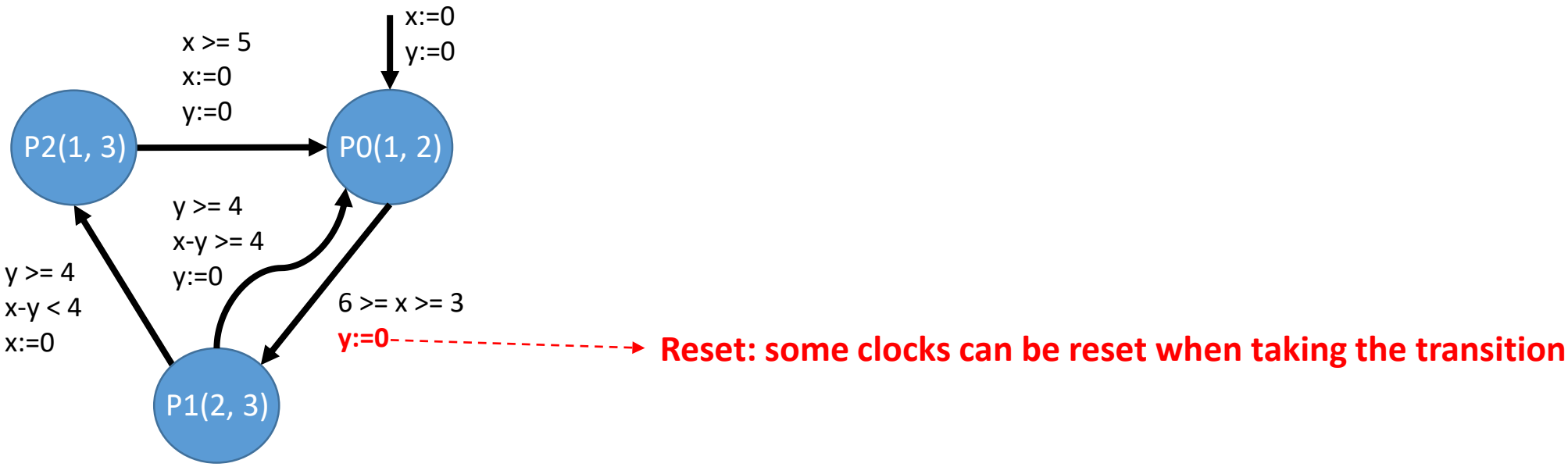


Semantics of Task Automata



Guard: conditions on clock values to take the transition

Semantics of Task Automata



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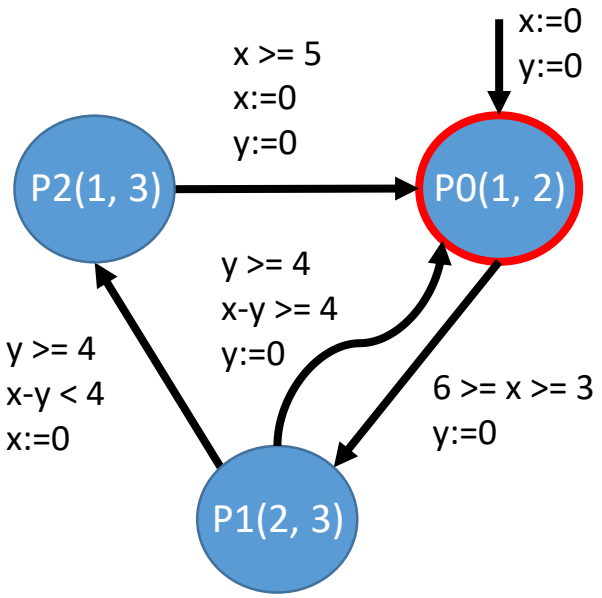


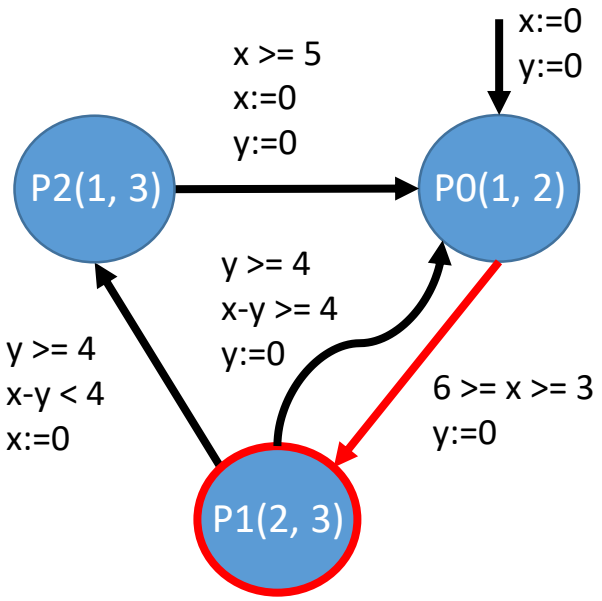
before

after

x=0
y=0

A possible run:

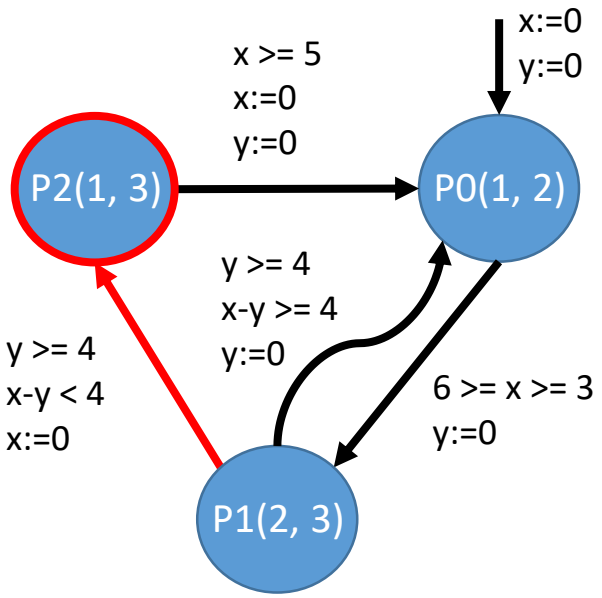
Semantics of Task Automata



A possible run:

before		x=4.5 y=4.5
after	x=0 y=0	x=4.5 y=0

Semantics of Task Automata



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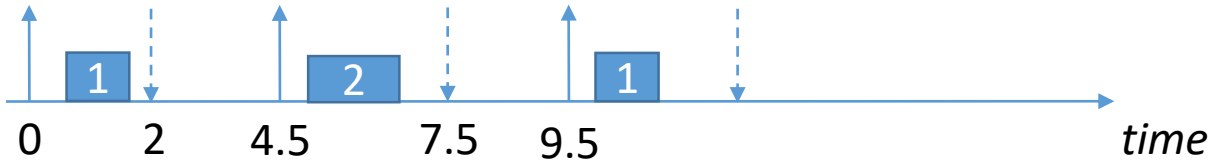
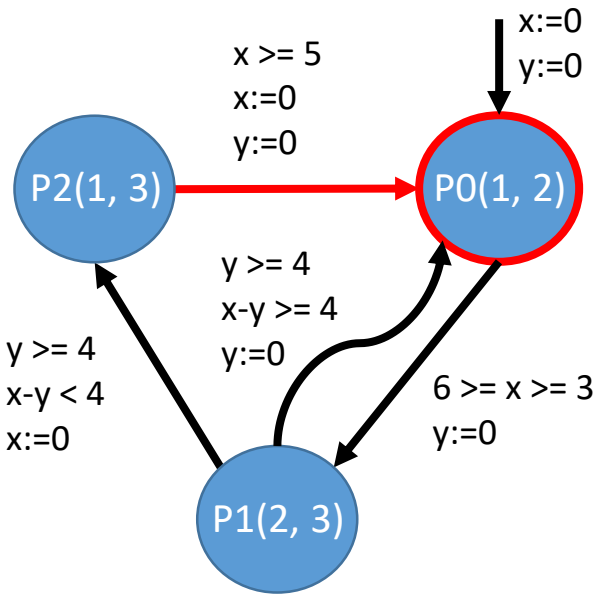


before		x=4.5 y=4.5	x=9.5 y=5
after	x=0 y=0	x=4.5 y=0	x=0 y=5

Semantics of Task Automata



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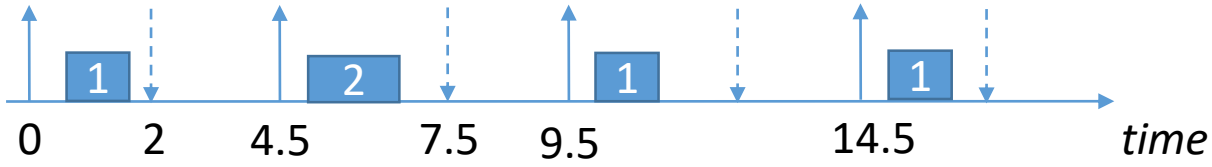
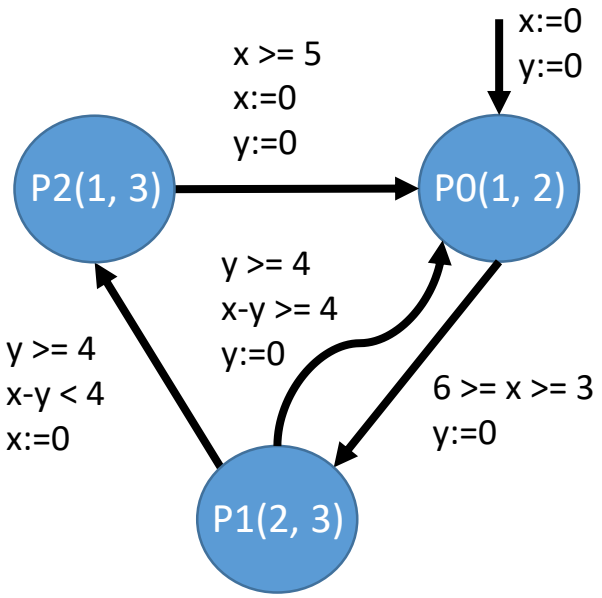


before		x=4.5 y=4.5	x=9.5 y=5	x=5 y=10
after	x=0 y=0	x=4.5 y=0	x=0 y=5	x=0 y=0

Semantics of Task Automata



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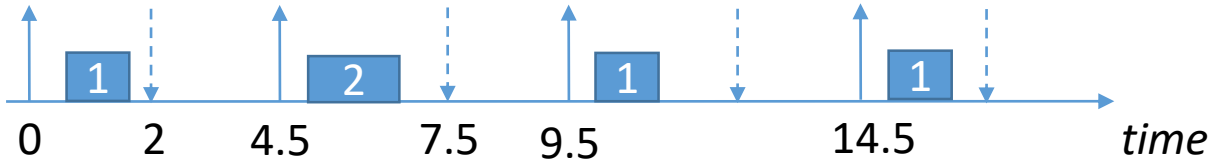
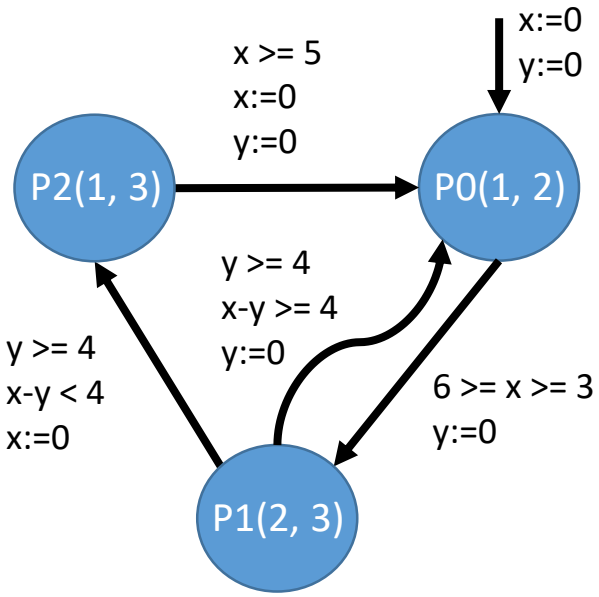


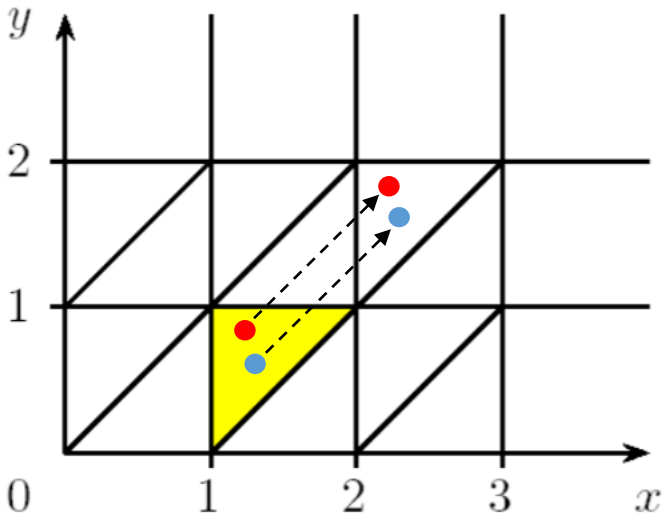
before		x=4.5 y=4.5	x=9.5 y=5	x=5 y=10
after	x=0 y=0	x=4.5 y=0	x=0 y=5	x=0 y=0

Problem: Infinitely many possible runs

Region

From Infinite to Finite State Space

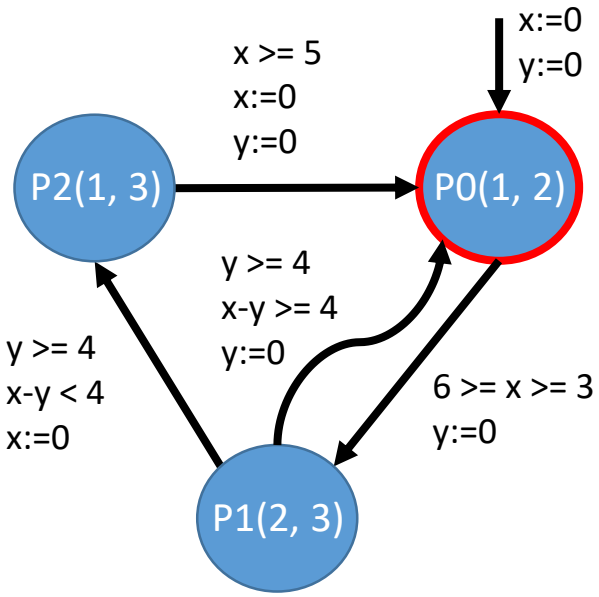


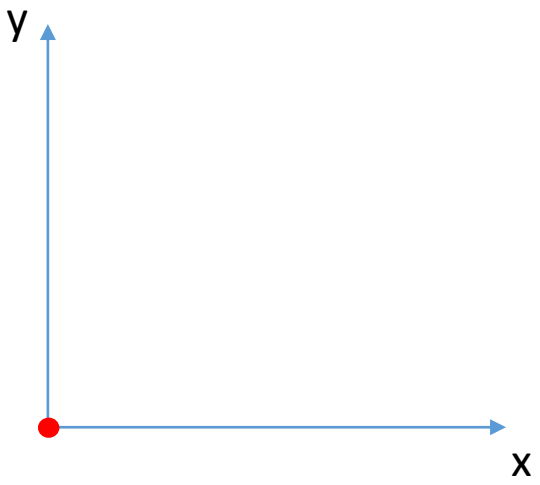


Region preserves reachability

Zone

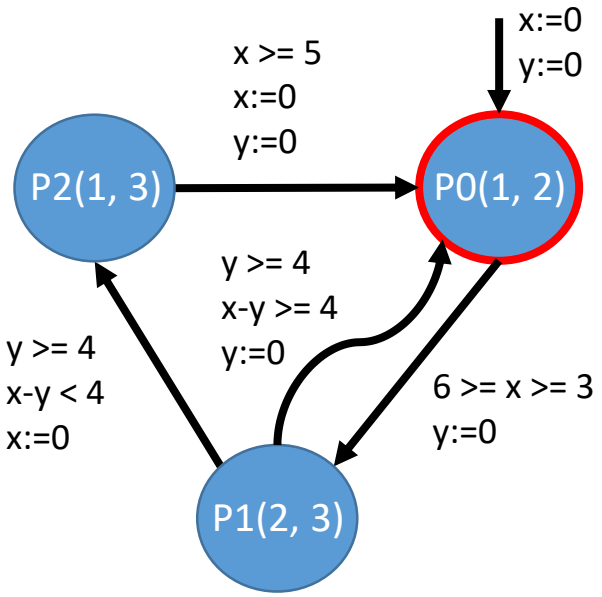
More compact state space representation

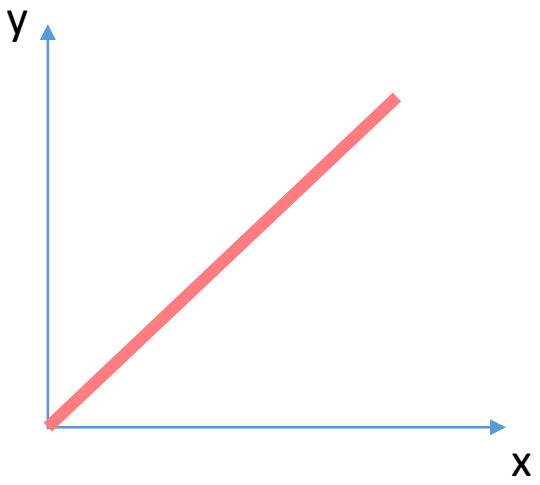




Zone

More compact state space representation





Zone

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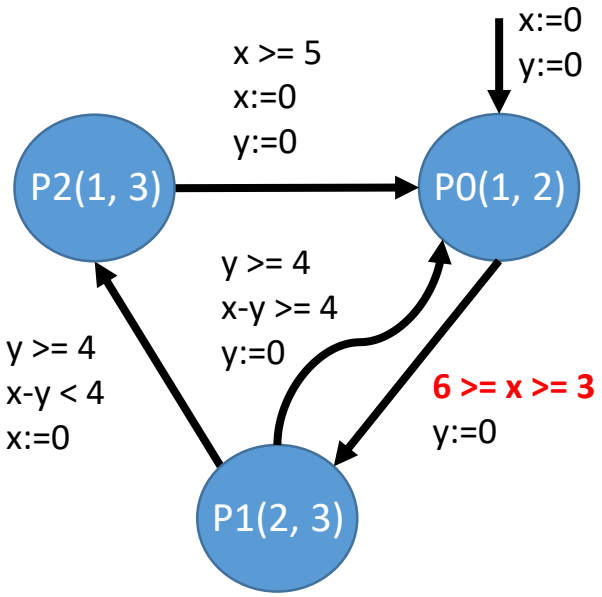

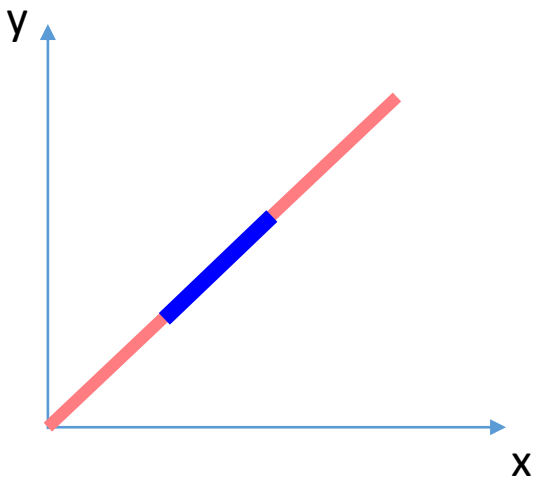

Zone

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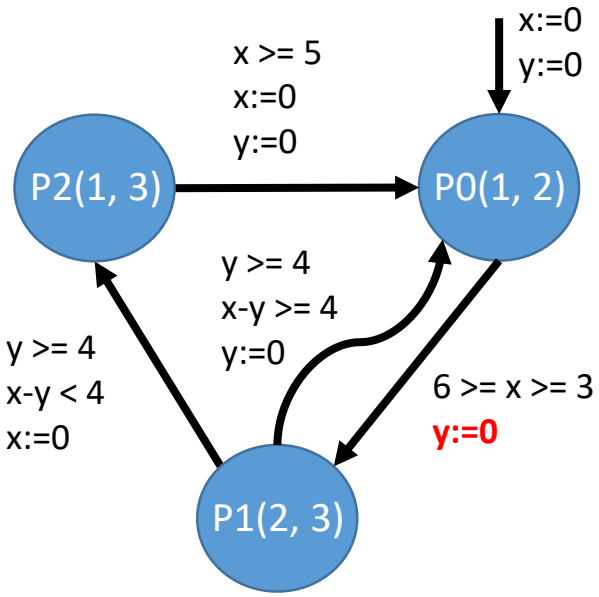
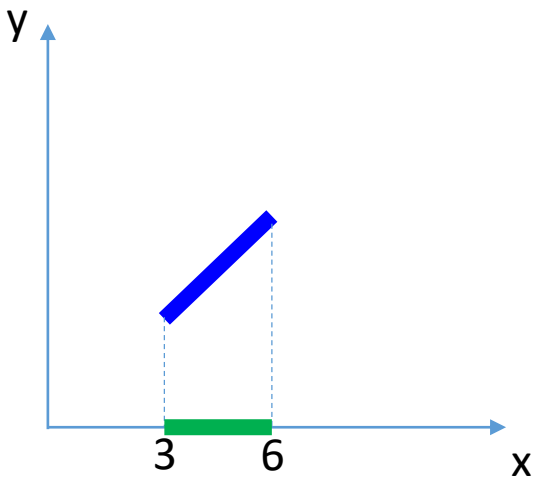
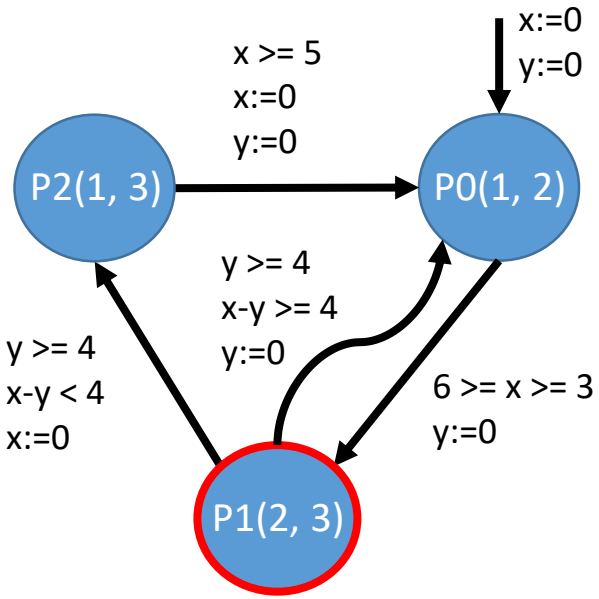
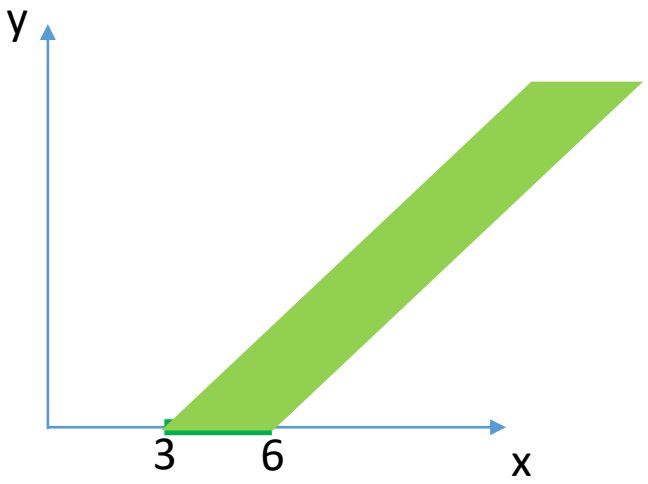




Zone

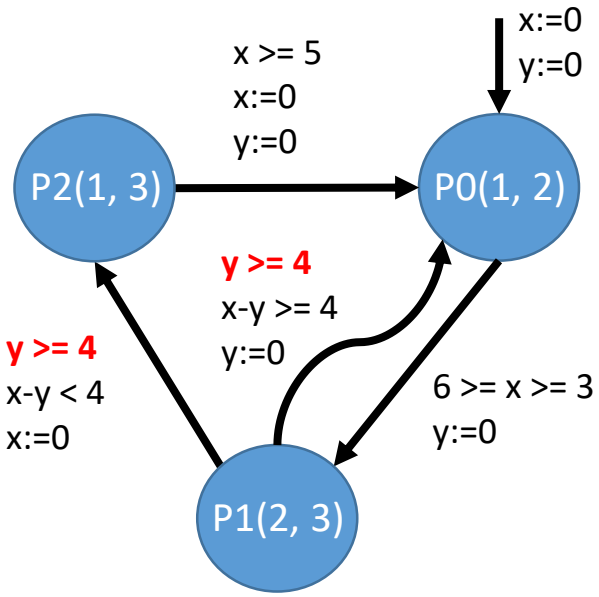
More compact state space representation

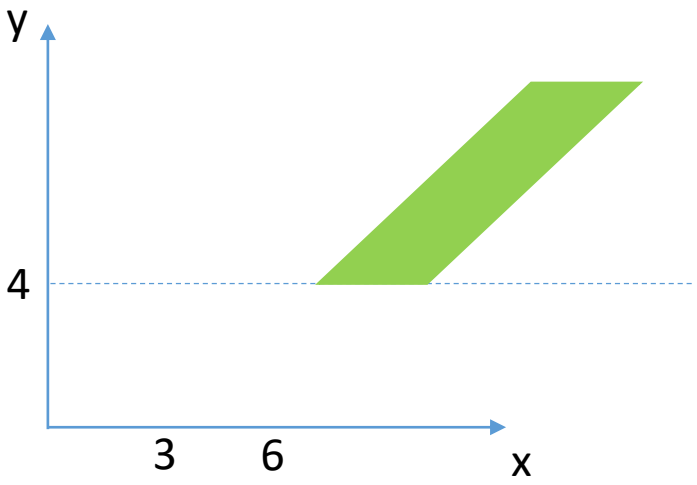




Zone

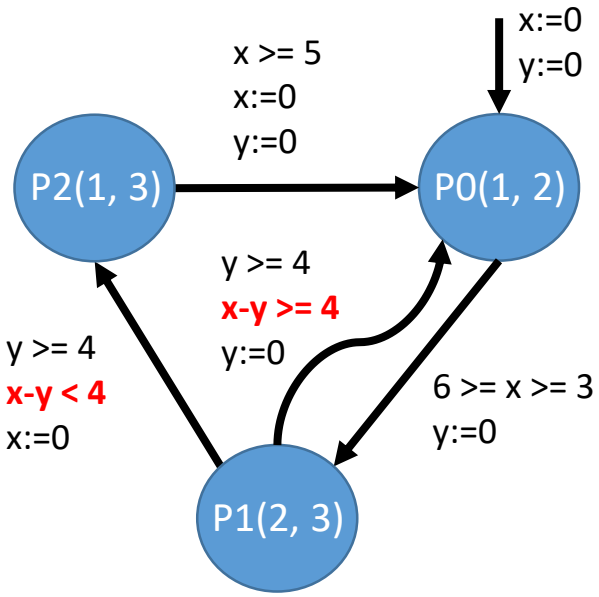
More compact state space representation

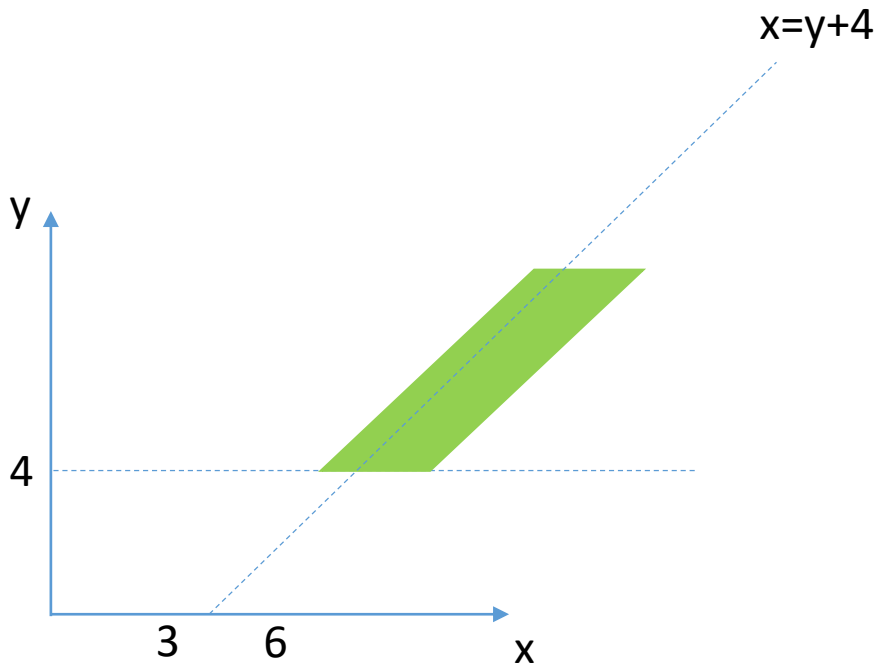




Zone

More compact state space representation





Zone

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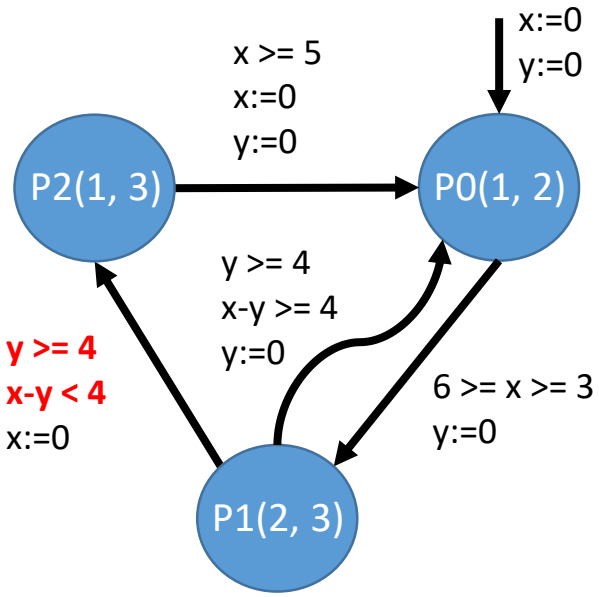

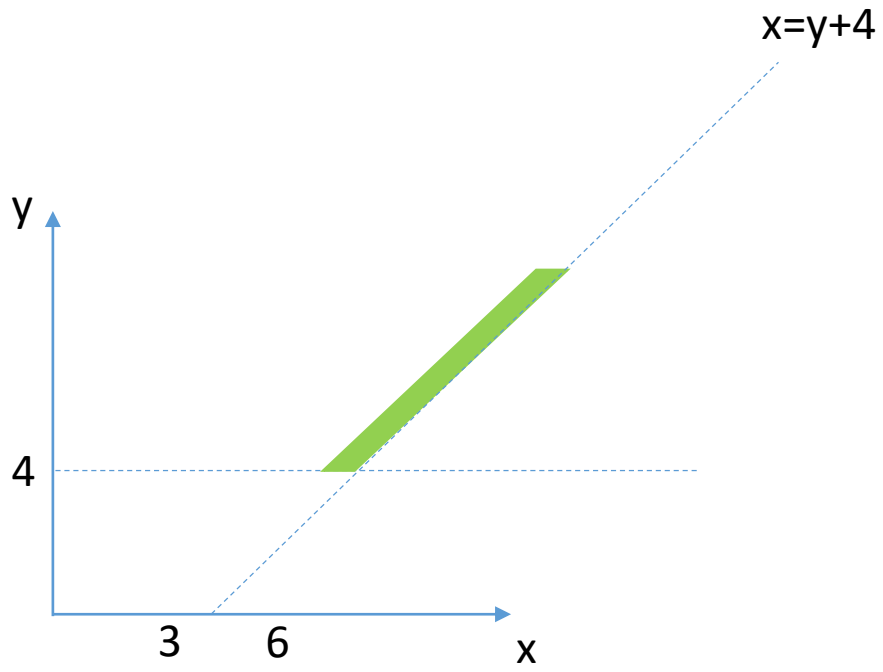

Zone

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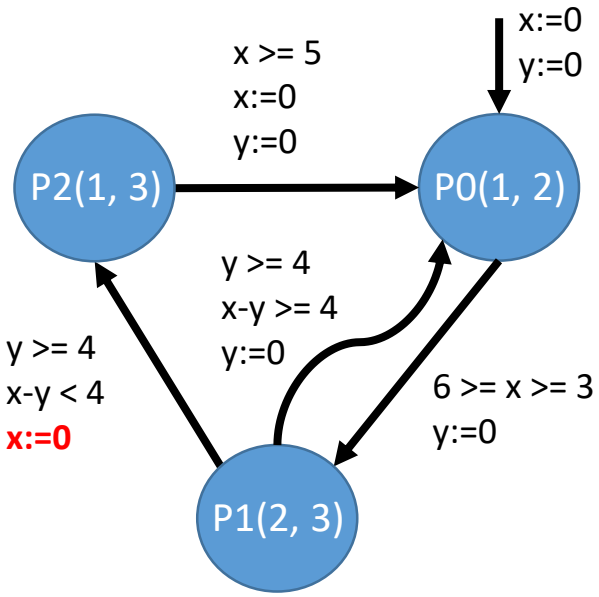
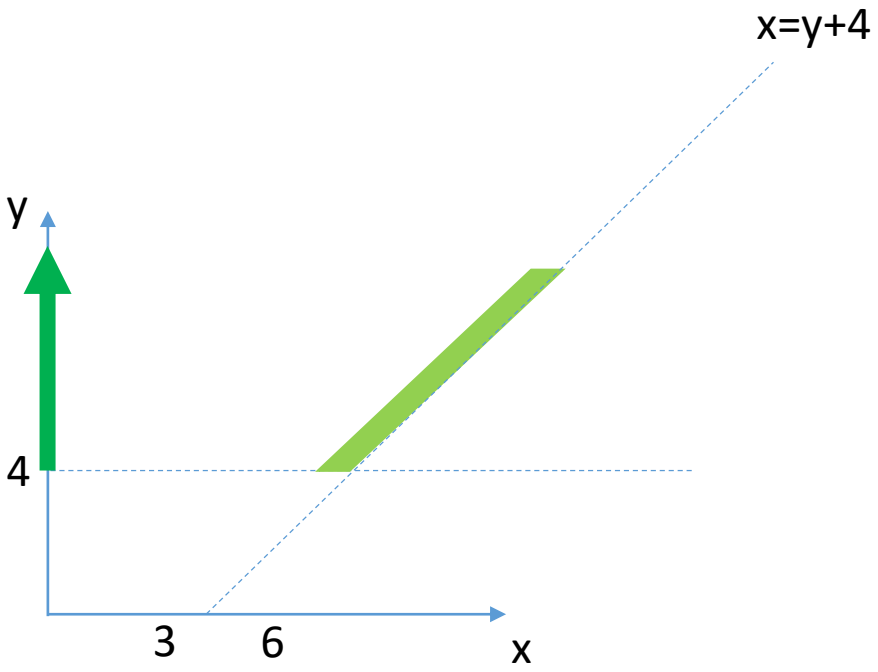
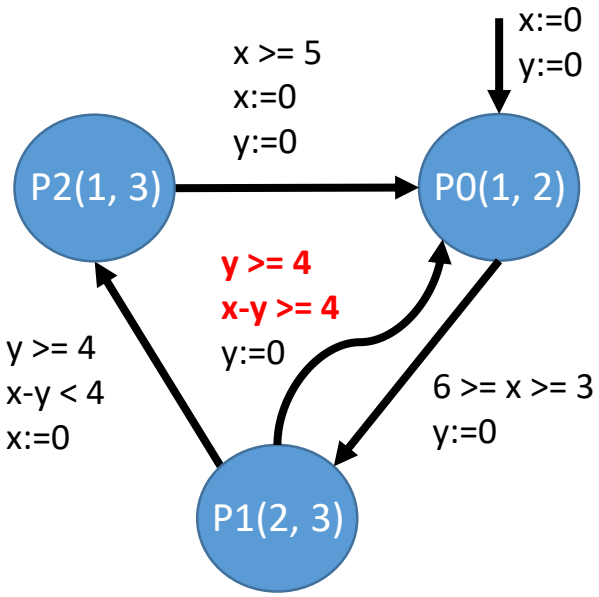
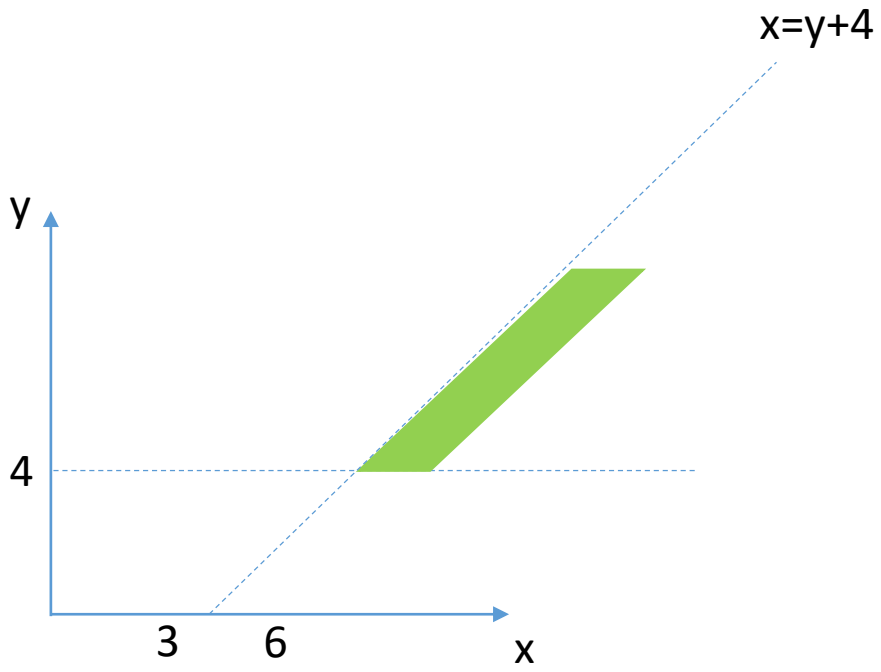




Zone

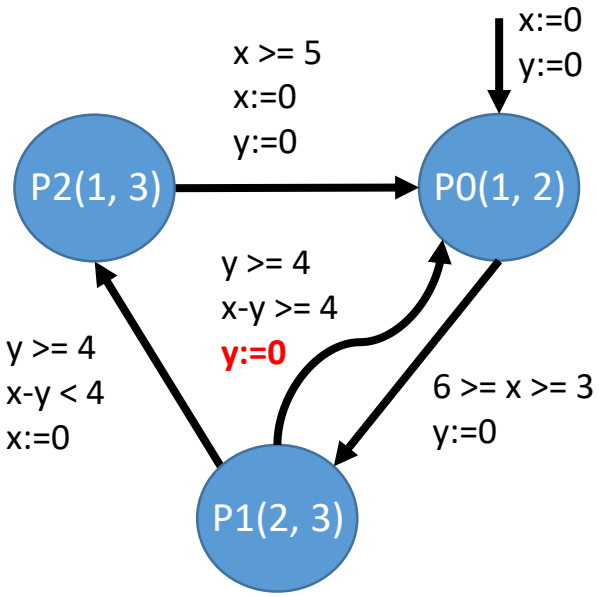
More compact state space representation

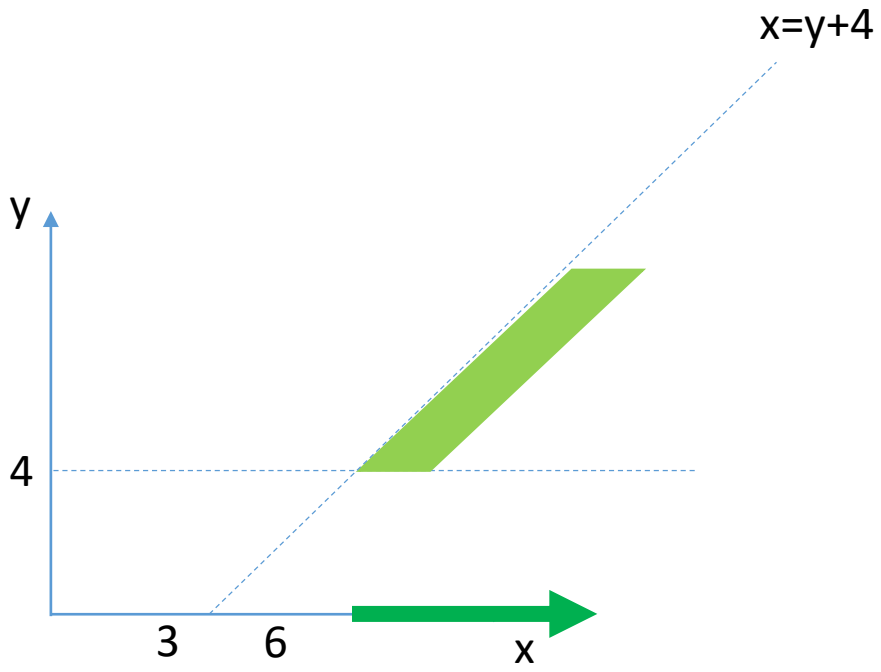




Zone

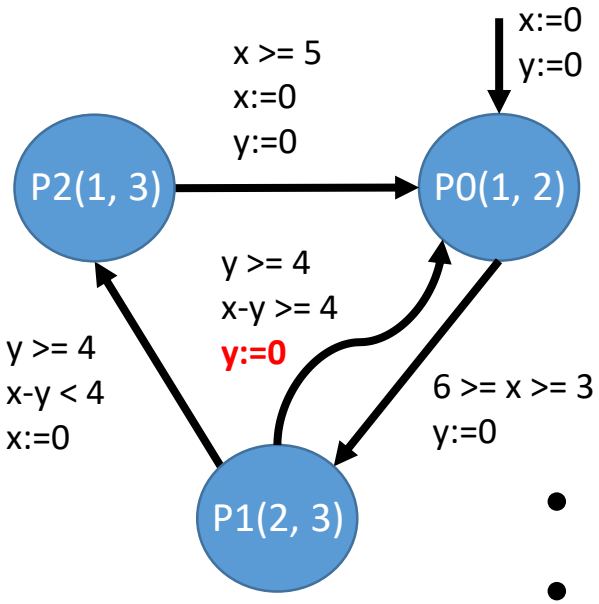
More compact state space representation

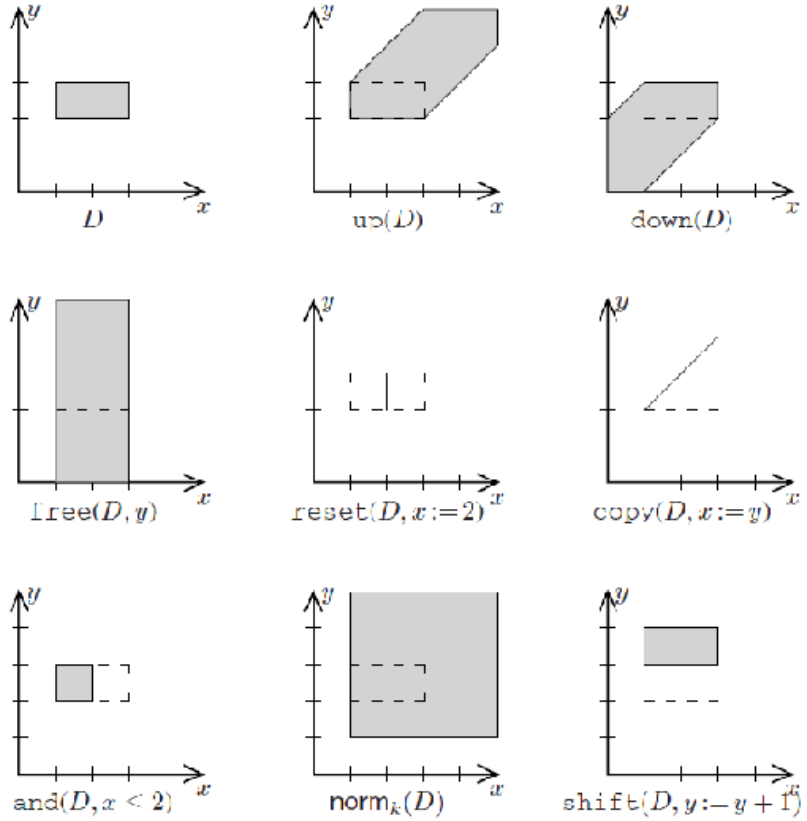




Zone

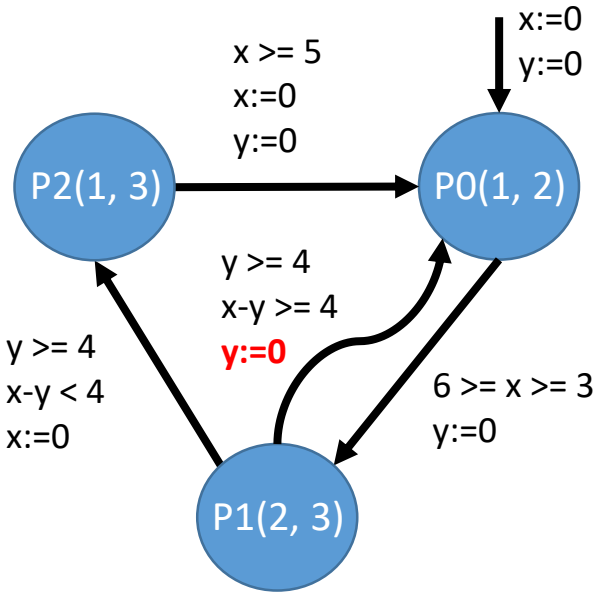
More compact state space representation



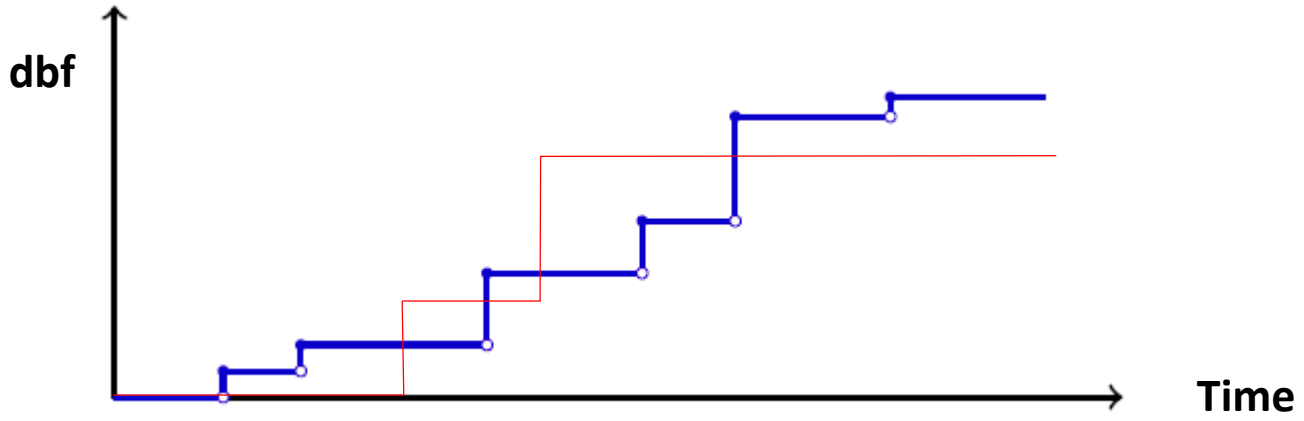


- Zone also preserves reachability
- A Zone is the solution set of a clock constraint
  - maximal set of clock assignments satisfying the constraint
  - Such sets can be efficiently represented and stored in memory as DBMs (Difference Bound Matrices)

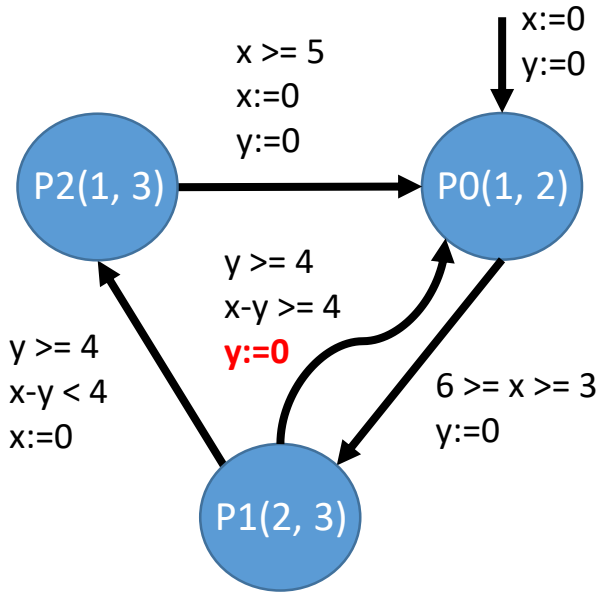
Computing DBF based on Zone



- Traverse the graph with Zone
- Split a Zone upon “branches”
- Each traversal trace generates a “demand trace”
  - the “worst case” must be on the border of Zones
- DBF = Maximization of all “demand functions”



Computing DBF based on Zone



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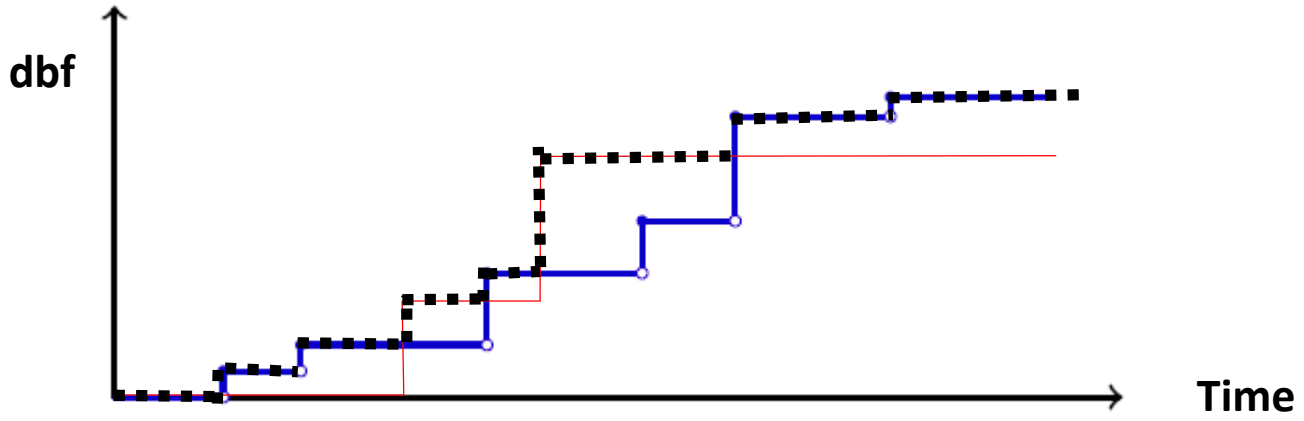
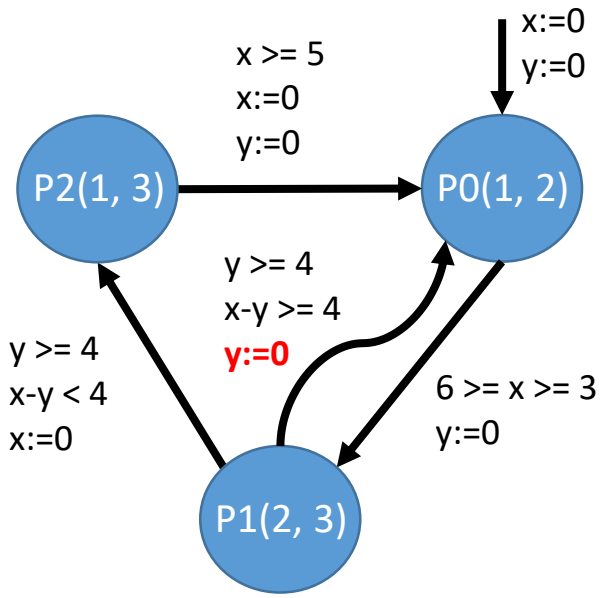


Computing DBF based on Zone

Exponential



- Traverse the graph with Zone
- Split a Zone upon “branches”
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  - the “worst case” must be on the border of Zones
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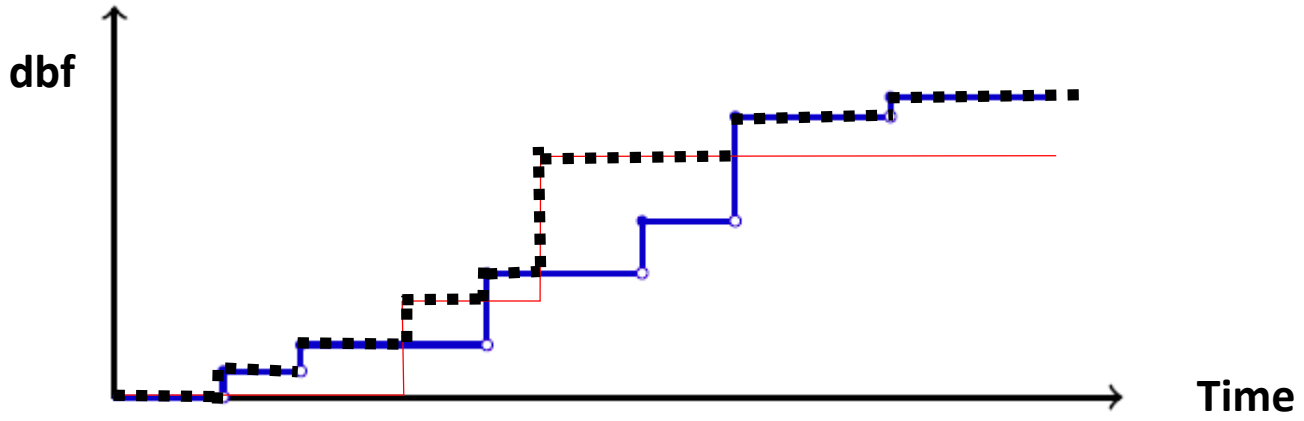

Summary

- Ultimate goal
  - Utilizing efficient abstraction and analysis techniques in scheduling theory to analyze the TA systems
- As the first step
  - Computing the DBF/RBF of an individual TA
- Starting point
  - Zone is a good starting point as state-space representation
    - Efficient storage and operations are known