Radboud Universiteit Nijmegen

TU/e Technische Universiteit Eindhoven University of Technology

Embedded Systems INSTITUTE

océ Printing for Professionals

Formal Modeling and Scheduling of Data Paths of Digital Document Printers

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Outline

- Introduction
  - The Octopus Project
  - Océ System Architecture
- Modelling and Analysis Approaches
  - Timed Automata
- Comparison
- Conclusions and Future Work

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- **Introduction**
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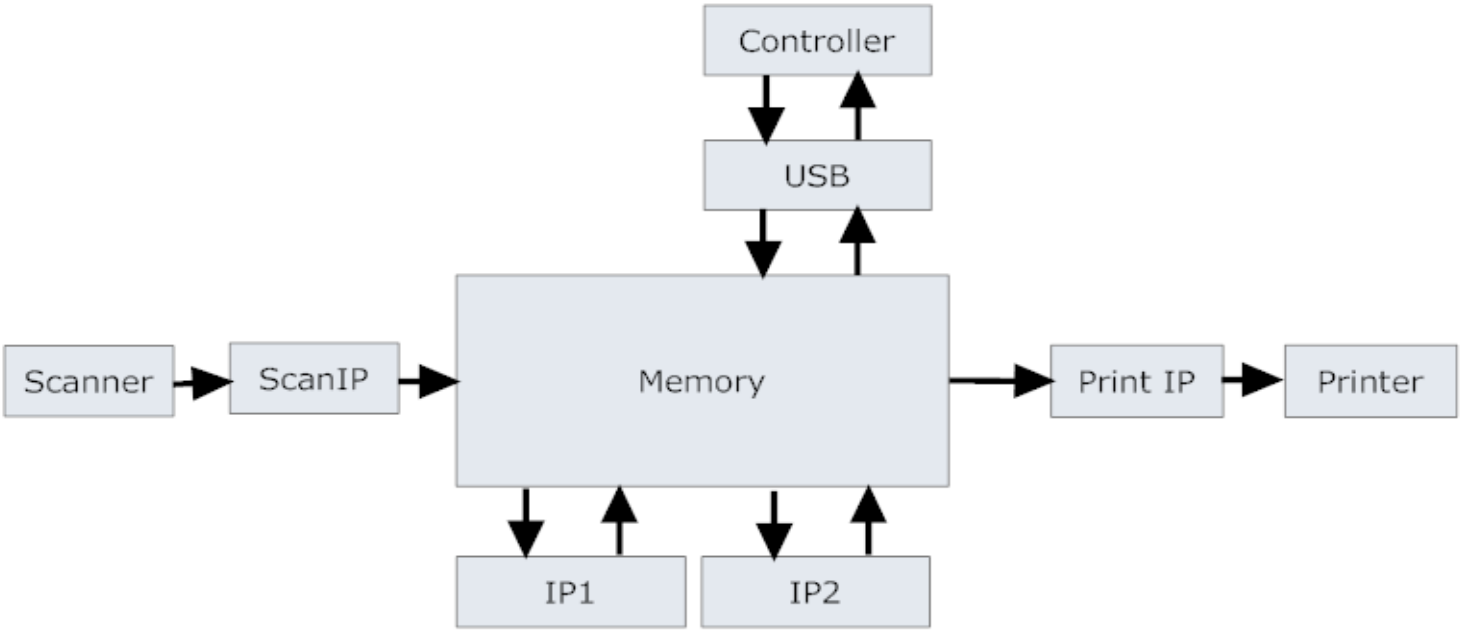
The Octopus Project

- **Aim**
  - new methods for designing adaptive datapaths of printers/copiers
- **Academic Partners**
  - *Radboud University of Nijmegen*
    - **Timed Automata**
  - *Technical University of Eindhoven*
    - **Colored Petri Nets**
  - *Technical University of Eindhoven*
    - **Synchronous Dataflow Graphs**

Océ System Architecture(1)



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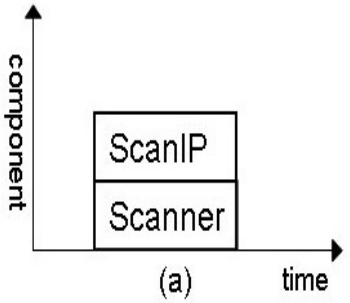
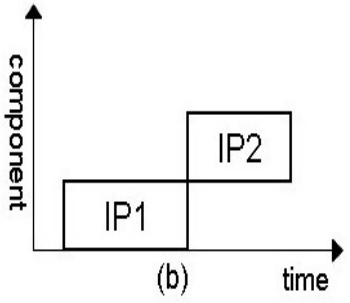
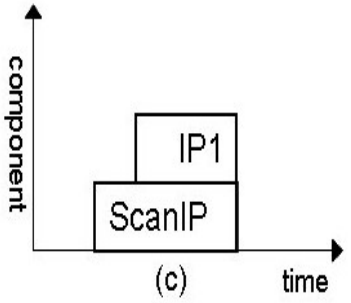
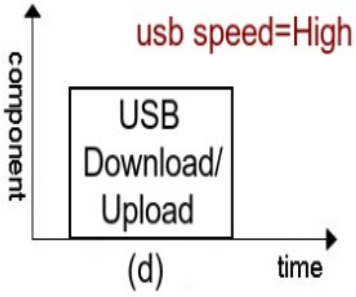
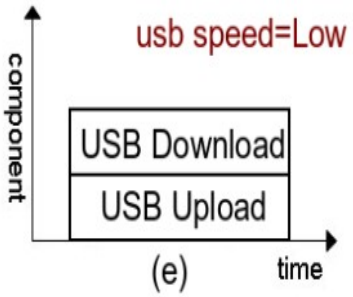


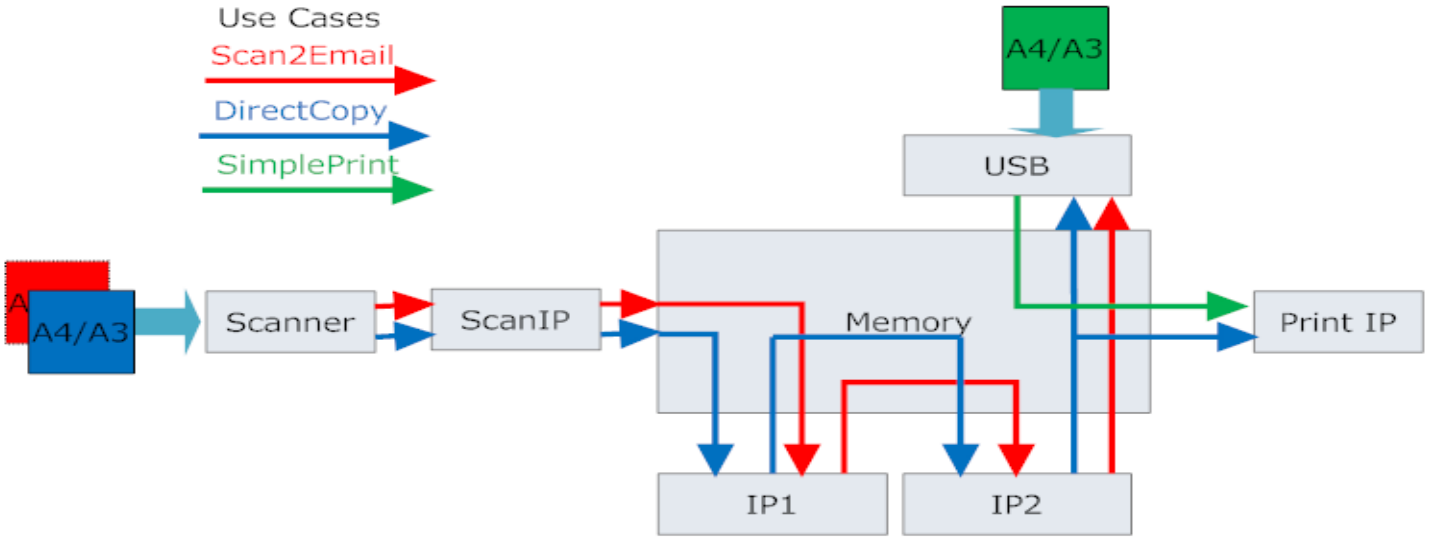


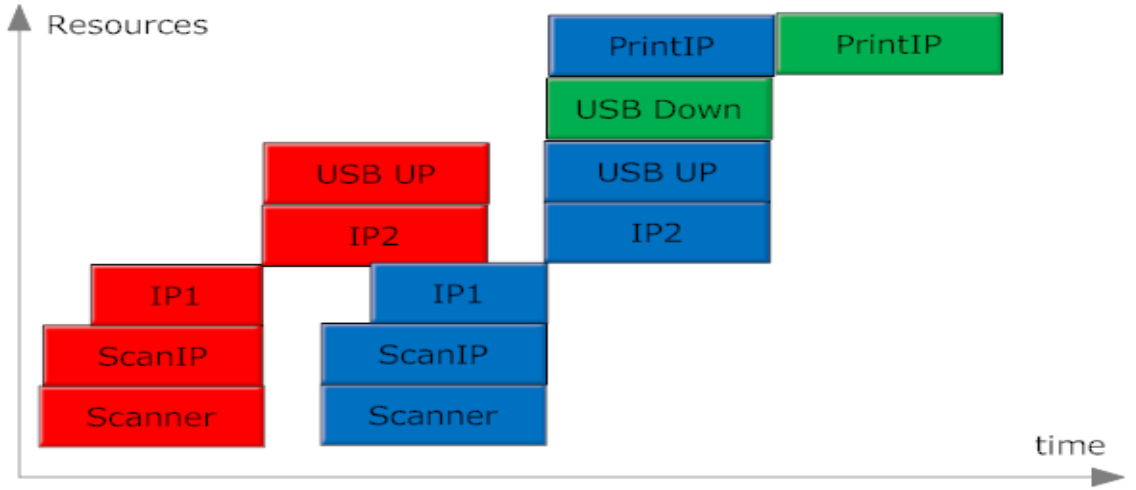






Océ System Architecture(2)





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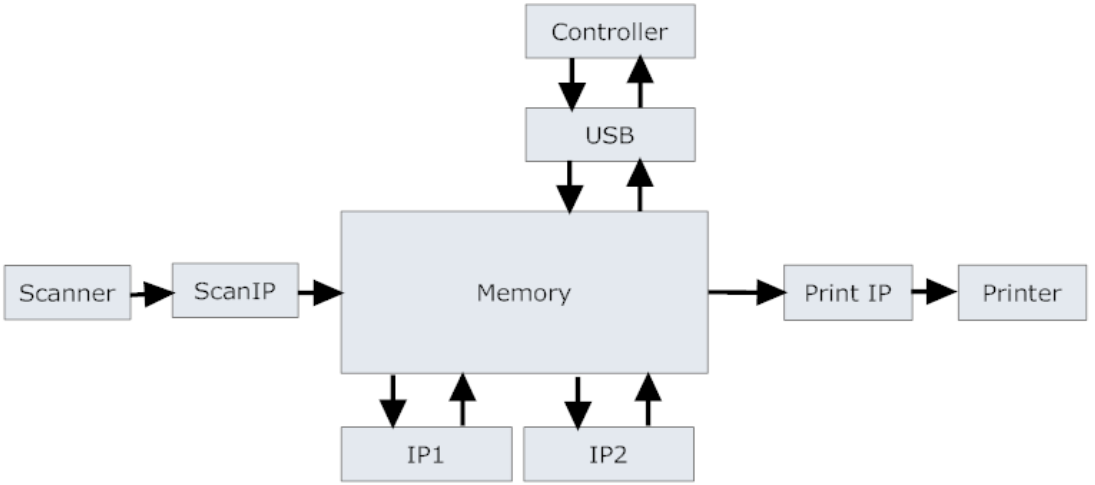
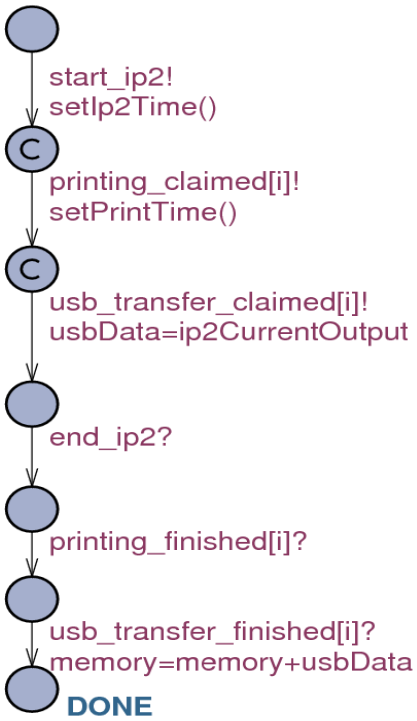
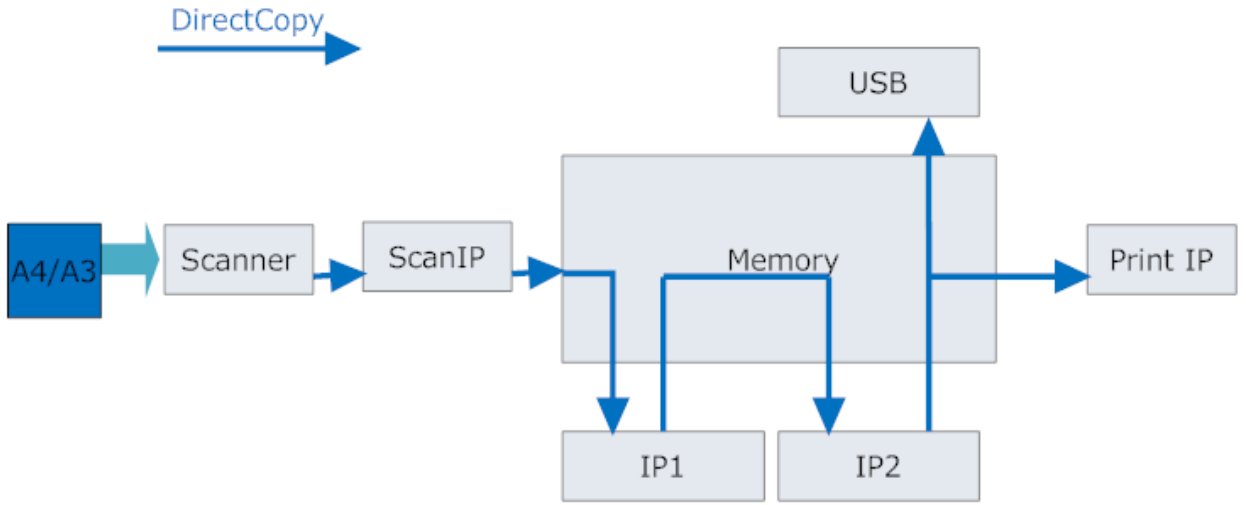
Timed Automata Model – General View

- Model
  - Automata:
    - Components: Scanner, ScanIP, IP1, IP2, and PrintIP
    - Use Case
    - USB model
  - Shared variables:
    - Memory
- Analysis
  - Uppaal model checker

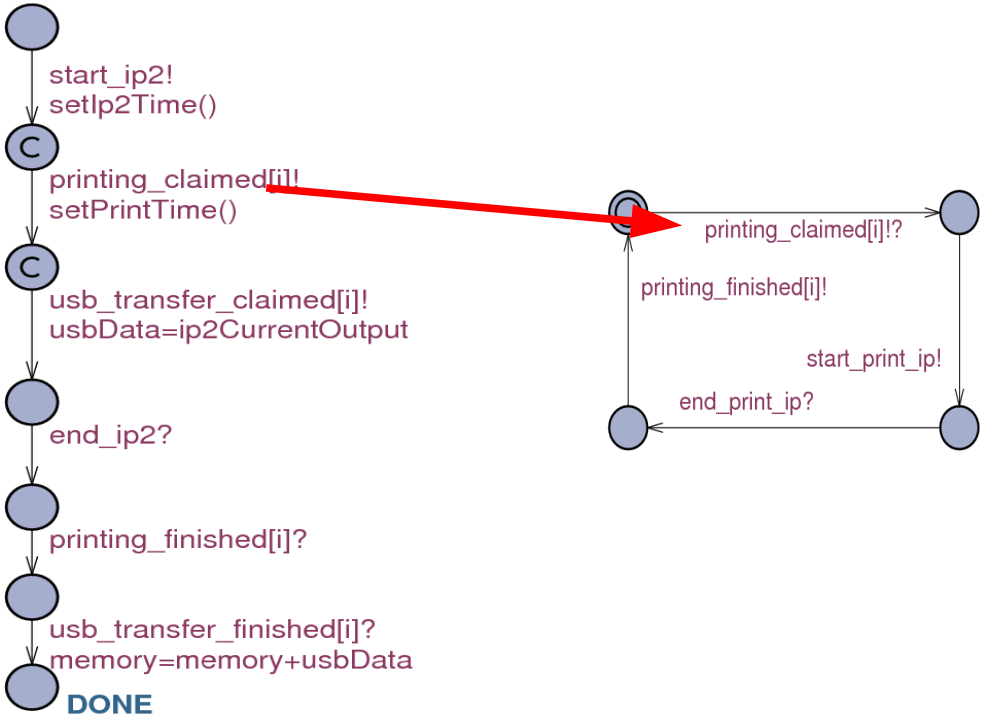


TA Model – Modelling Job's Parallel Activities(1)

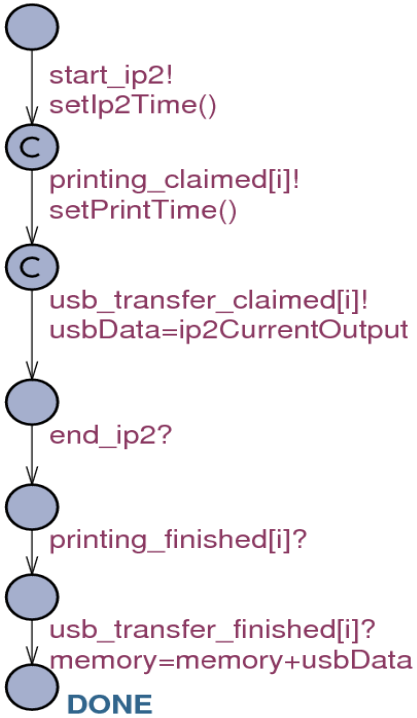


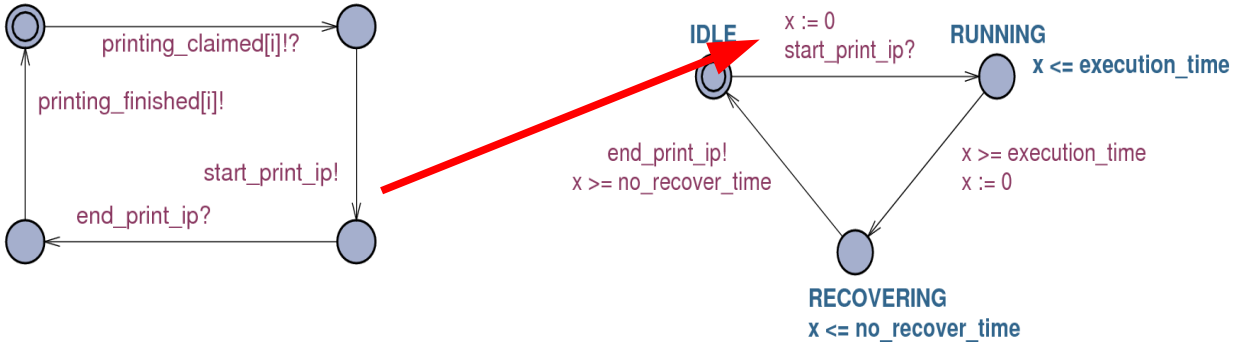


TA Model – Modelling Job's Parallel Activities(2)

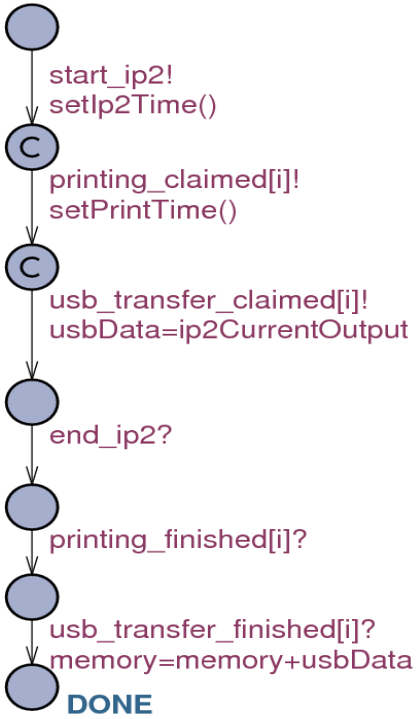


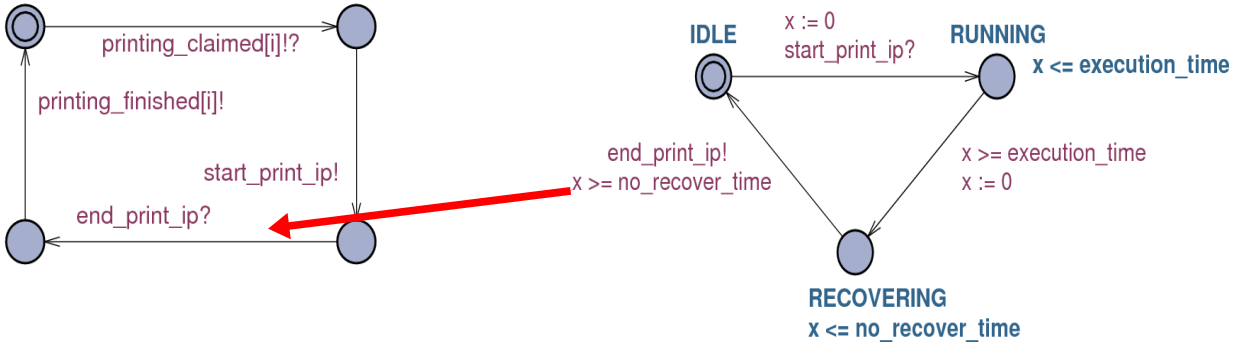
TA Model – Modelling Job's Parallel Activities(3)



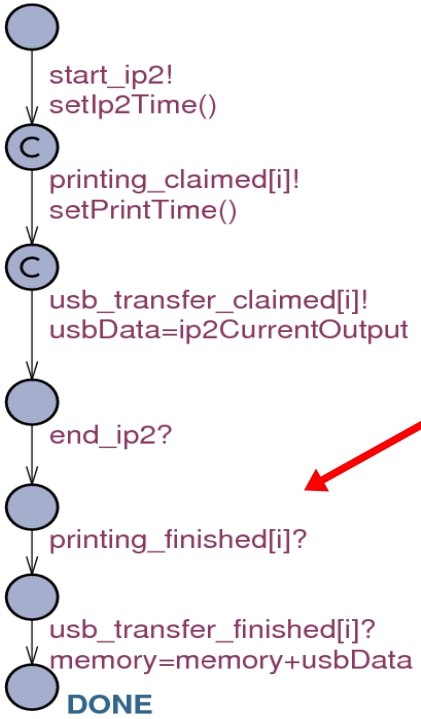


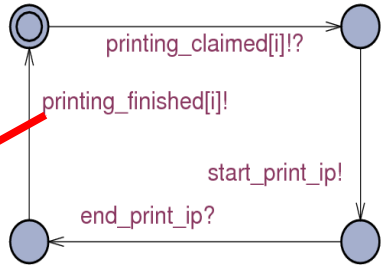
TA Model – Modelling Job's Parallel Activities(4)

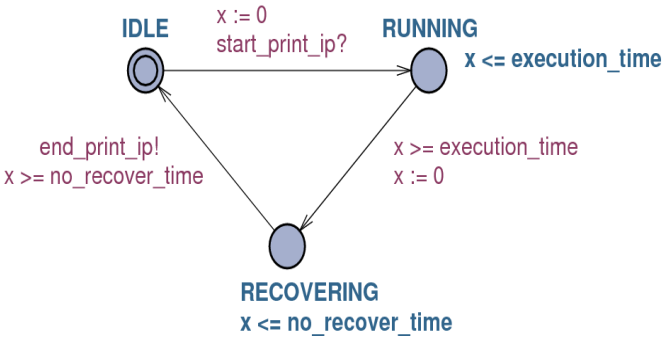




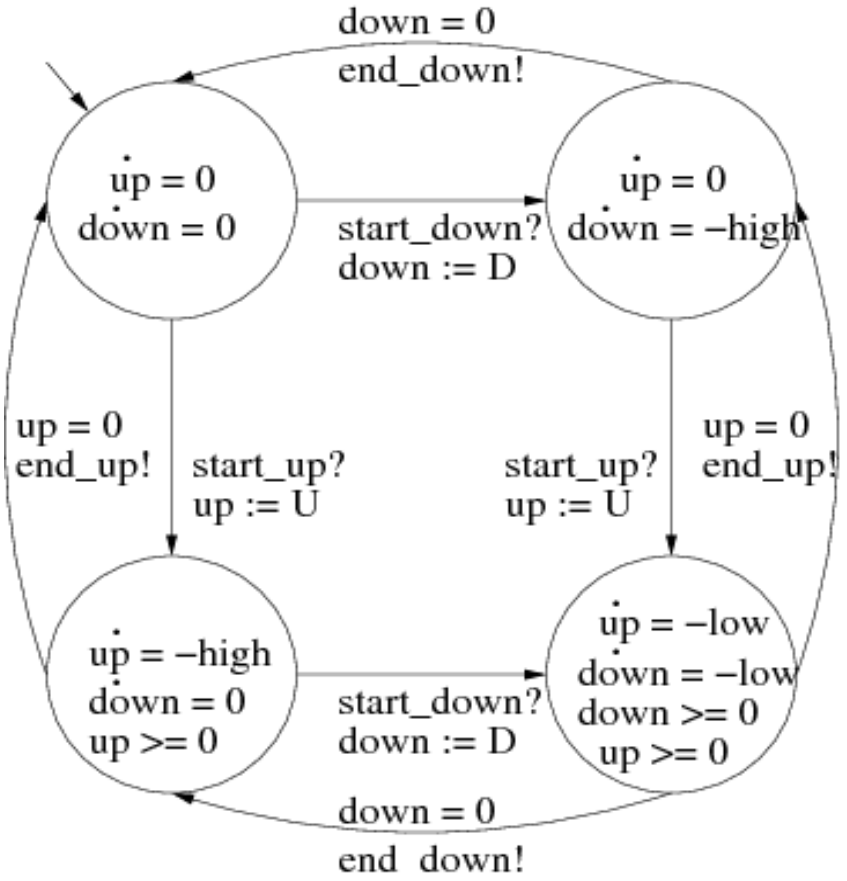
TA Model – Modelling Job's Parallel Activities(5)



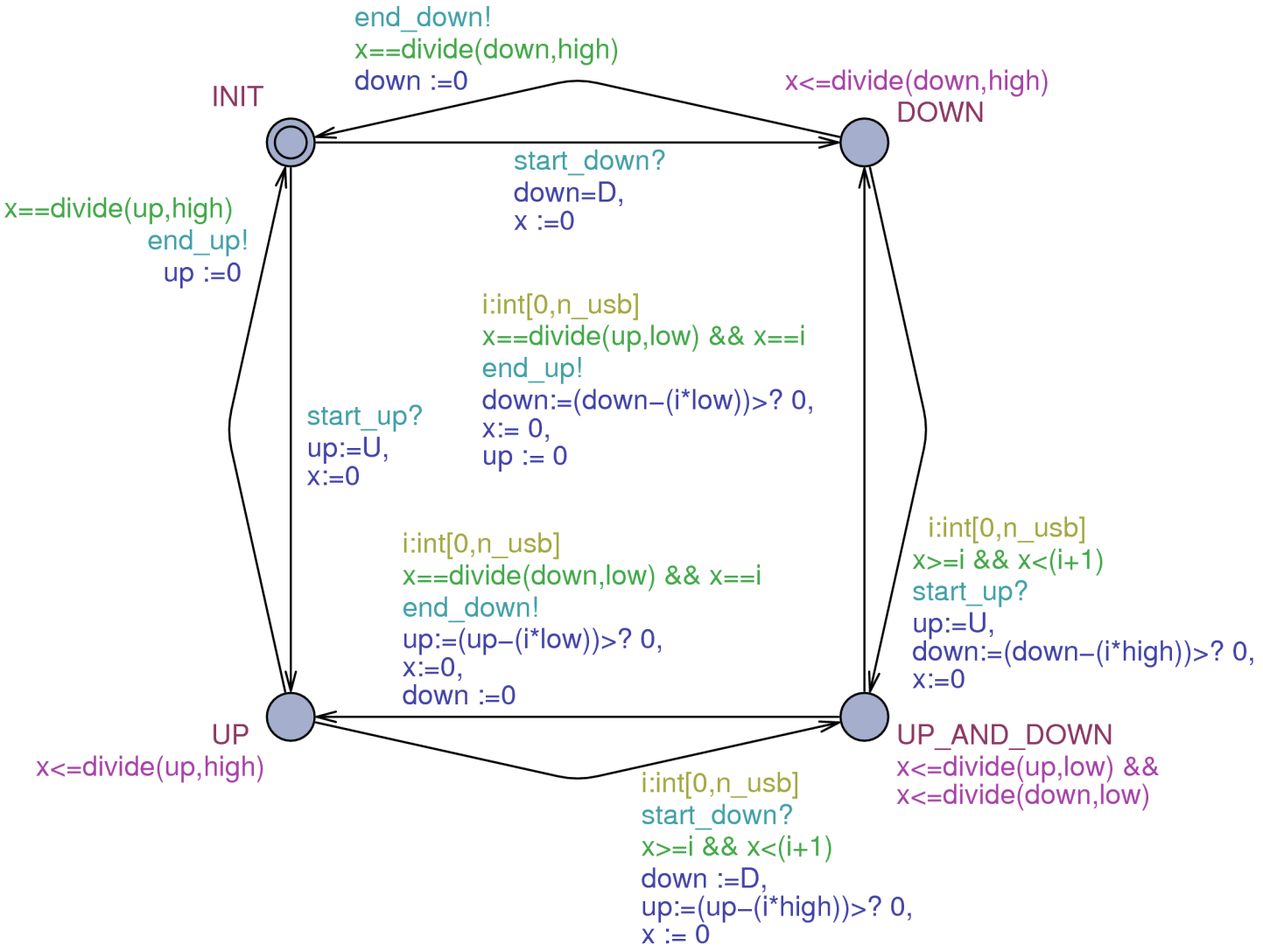




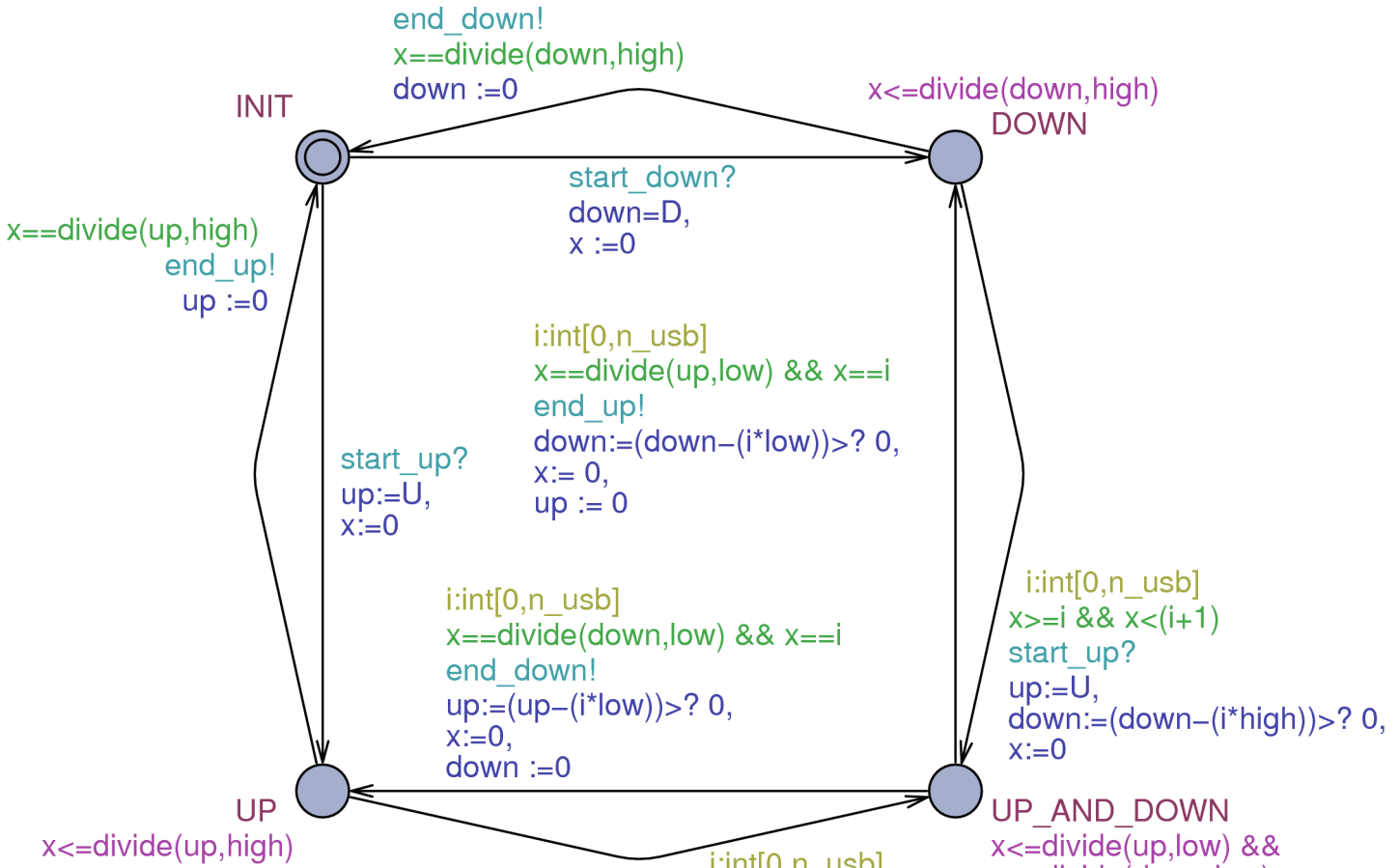
TA model – USB Linear Hybrid Automaton(1)



TA model - USB Automaton(1)



TA model - USB Automaton(2)



approximate the value of a clock to the closest integer

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Comparison

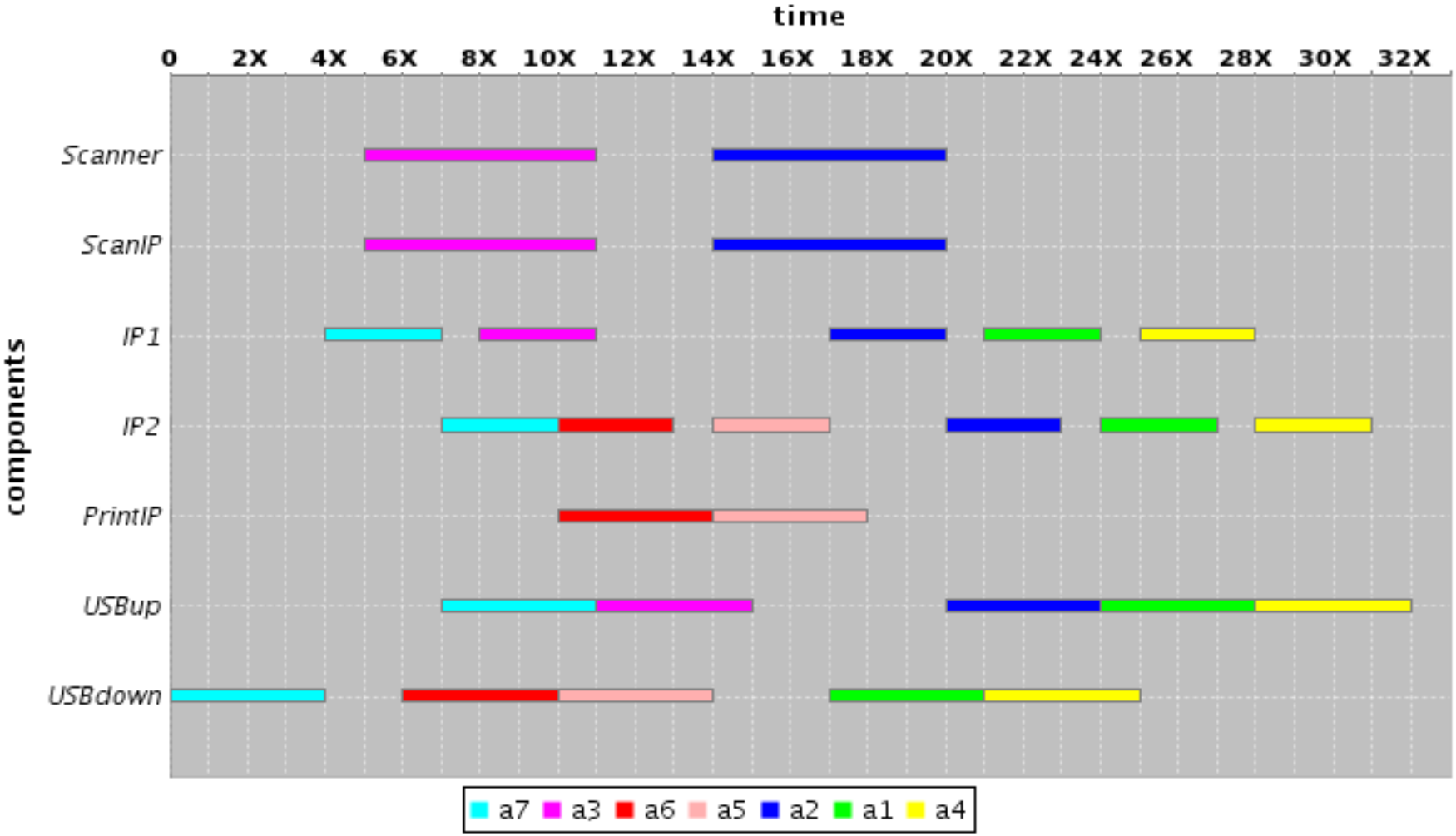
JobID	Use Case	Arrival time	Memory required
a1	ProcessFromStore	2X	24Y
a2	Scan2Email	1X	48Y
a3	Scan2Store	1X	36Y
a4	ProcessFromStore	3X	24Y
a5	PrintWithProcessing	1X	12Y
a6	PrintWithProcessing	0	12Y
a7	ProcessFromStore	0	24Y

X = 1s, 0.1s, 0.01s, ...
Y = 1MB, 32MB, 64MB, ...

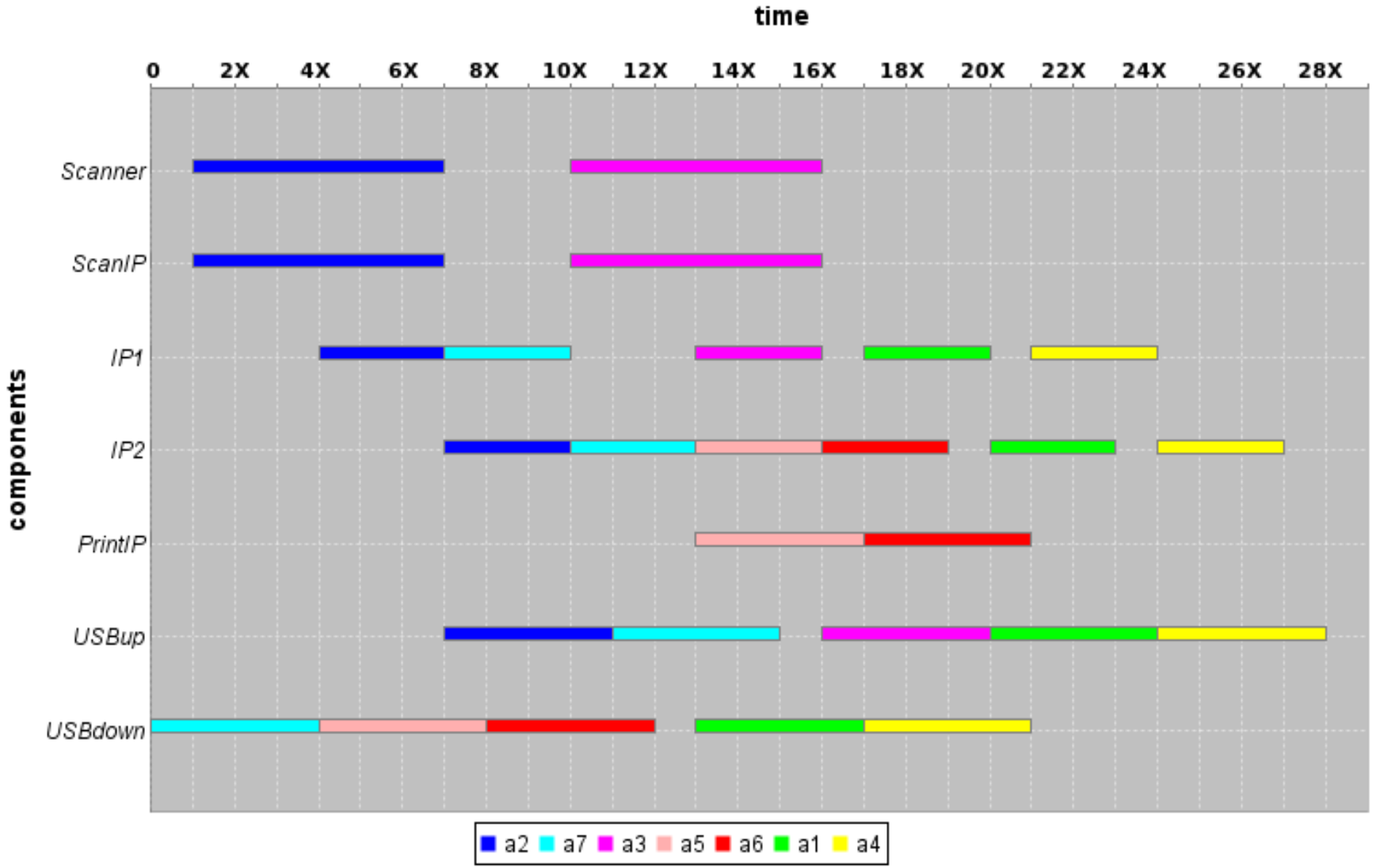
Completion time	**Static USB Model**	**Dynamic USB Model**
TA	27X	25X
CPN	28X	25.5X
SDF	32X	-

Static USB Model: USB speed=Low
Dynamic USB Model: USB speed=High/Low

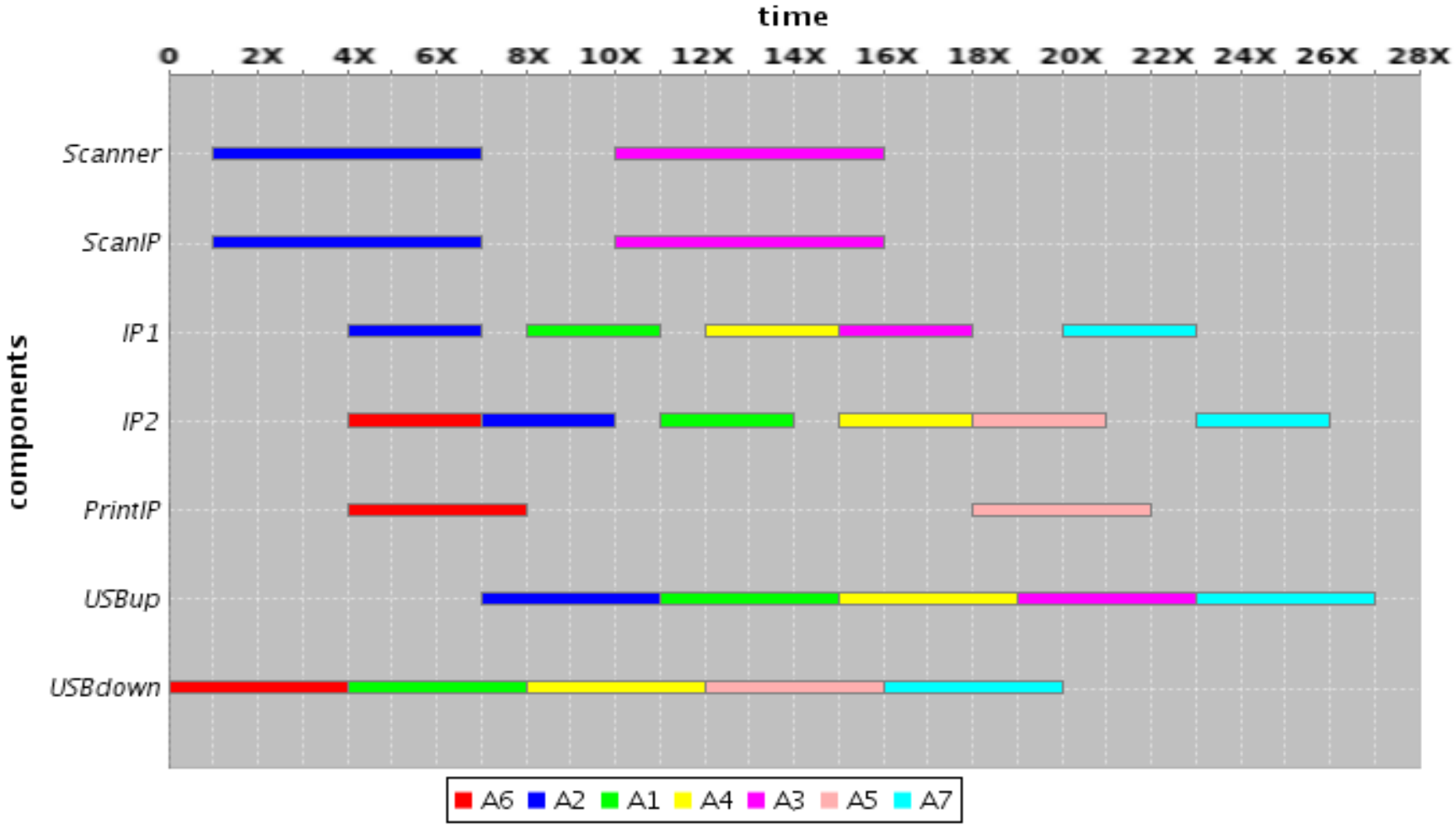
Static USB Model - SDF Results



Static USB Model - CPN Results



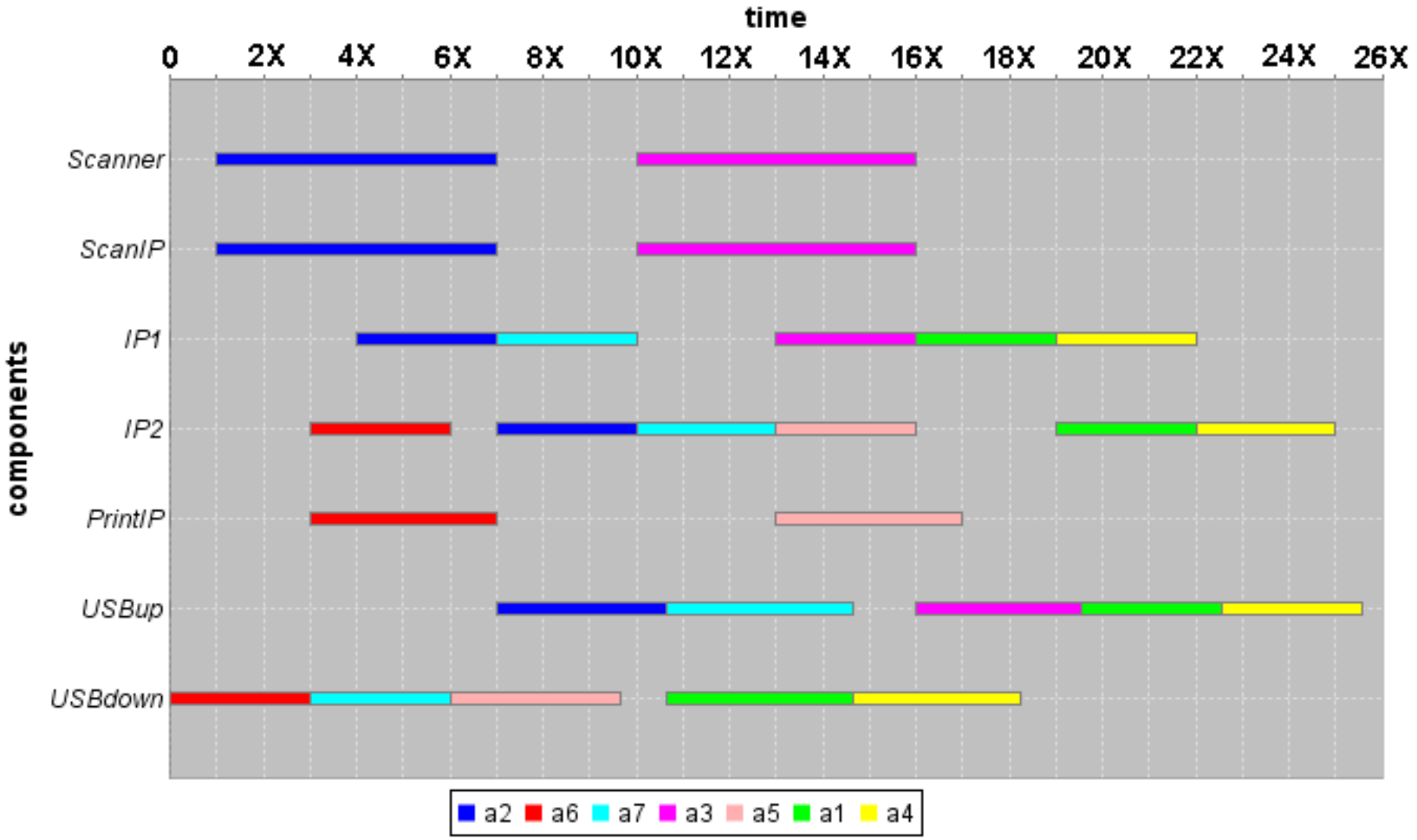
Static USB Model - TA Results



Conclusions and Future Work

- Model construction for the Océ system using three different models: TA, CPN, and SDF
- Comparison between models
  - TA gives the optimal schedules but close to state space explosion
  - CPN is the most expressive model
  - SDF can analyse a bigger number of input jobs
- *Current Status*
  - add another level of refinement: multipage jobs, real data for execution times of the components
  - comparison between results obtained with models and obtained using real printers
- *Next steps:*
  - model the memory bus
  - memory fragmentation

Dynamic USB Model – CPN Results



Dynamic USB Model – TA Results