Modeling and Analysis of Data Flow Graphs using the Digraph Real-Time Task Model

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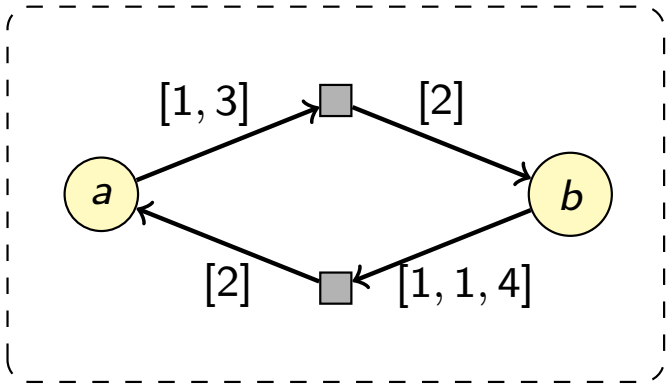
Uppsala University

Ada-Europe 2016

Introduction

Data Flow Graphs:

- Signal processing
- Stream processing
- Data dependency



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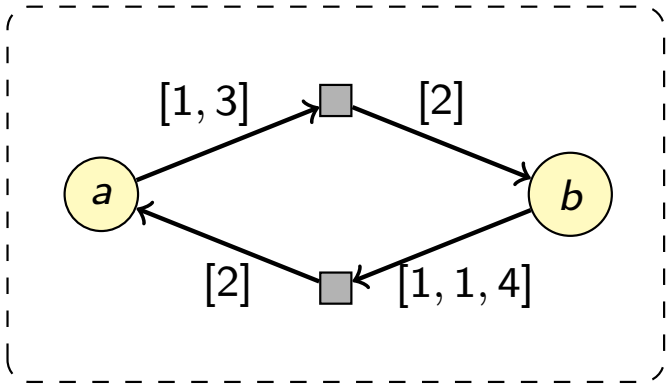


Design Objectives

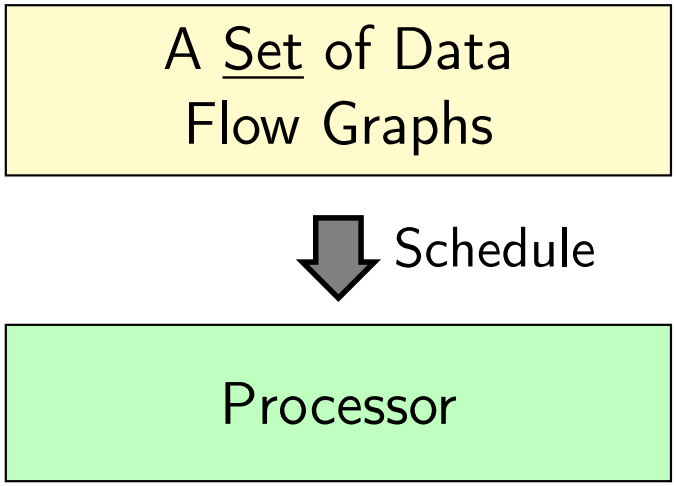
Throughput maximization

Design Constraints

- Buffer overflow/underflow avoidance
- Schedulability

An Overview

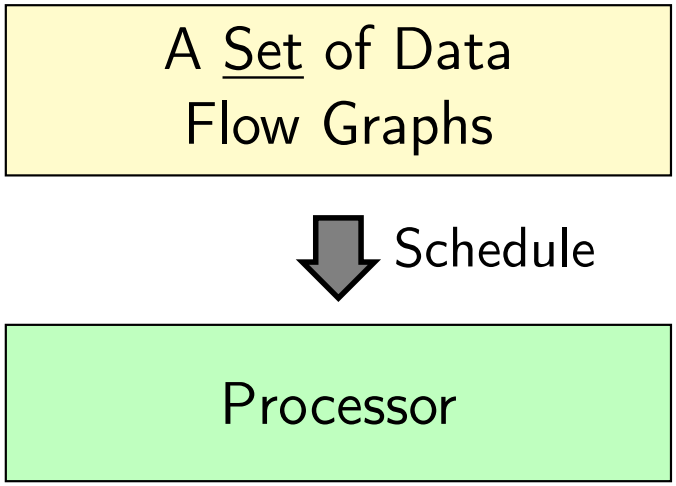
- The Problem:



- Our Approach:

An Overview

- The Problem:



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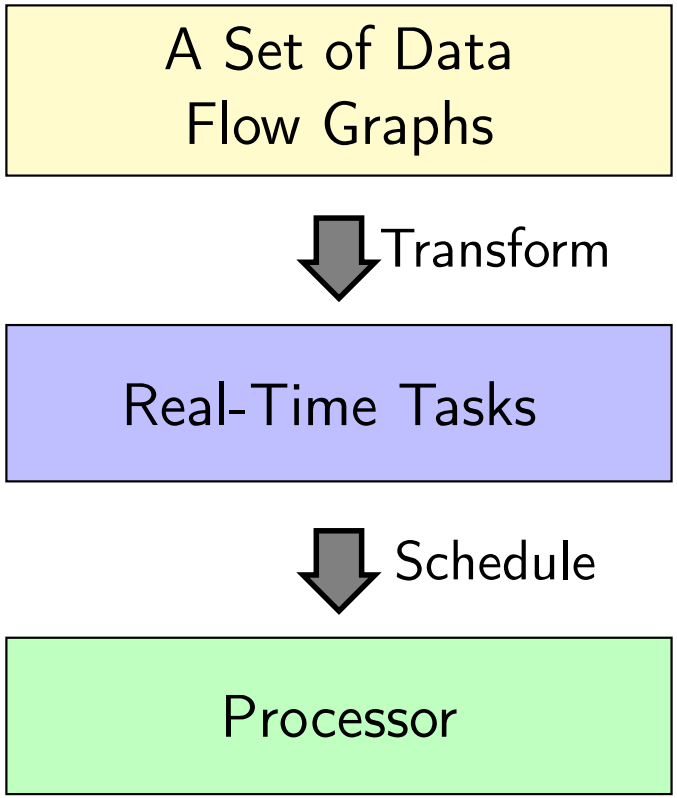

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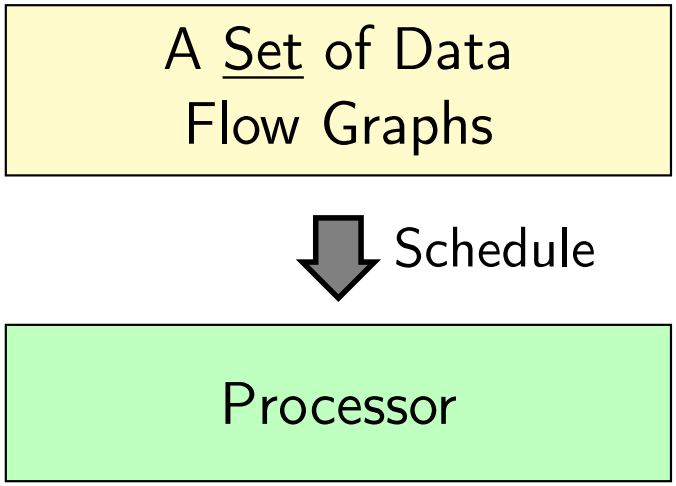

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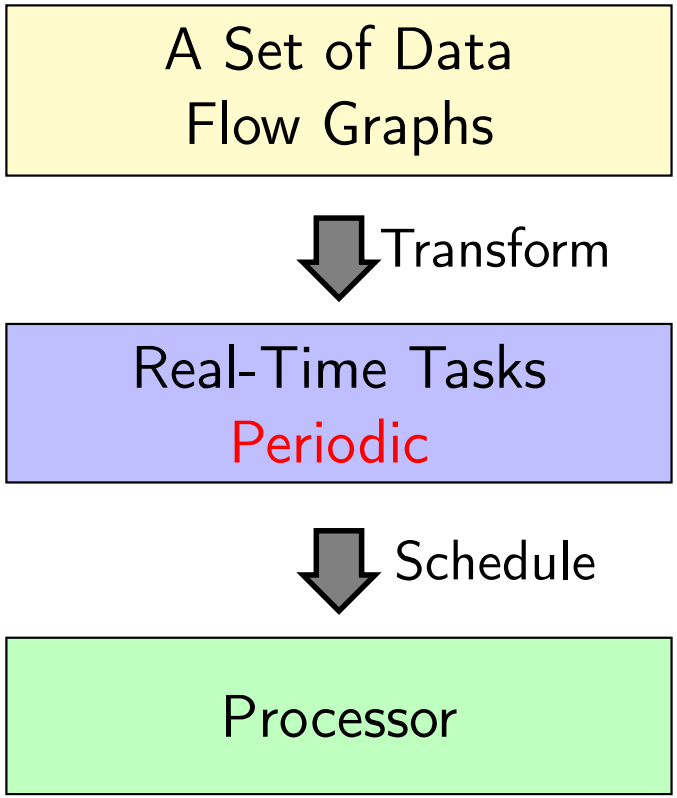

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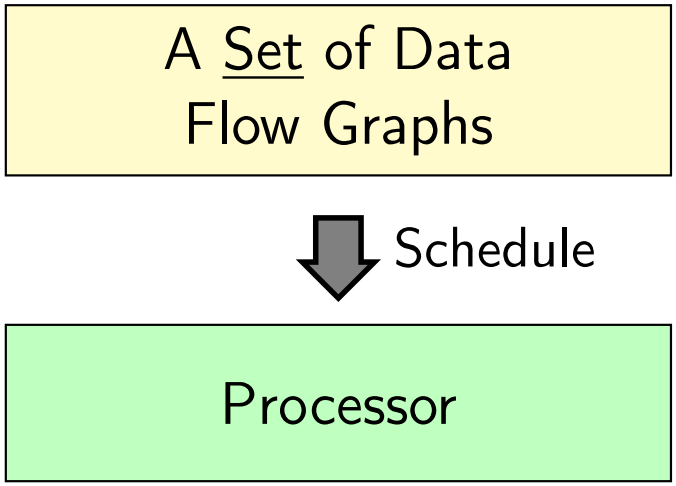

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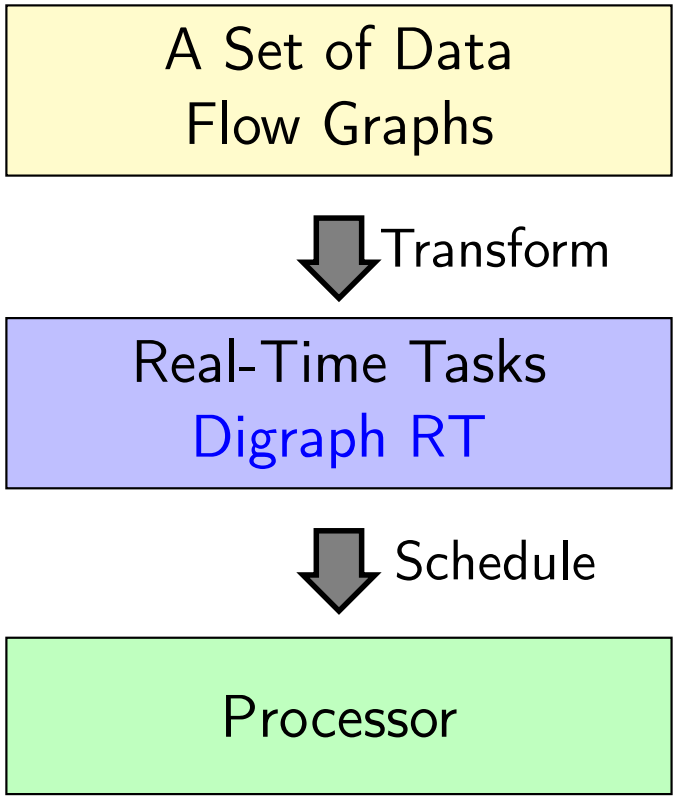
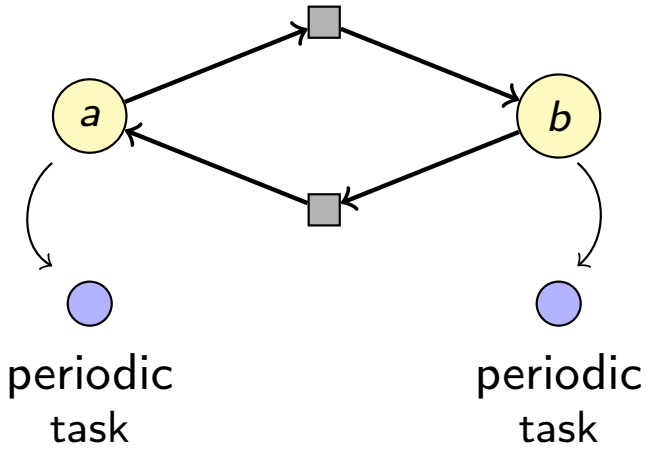


Previous Work



Our work

Strictly Period Schedule [Bouakaz 2014]

Digraph Real-Time (DRT) task model [Stigge et al 2013]

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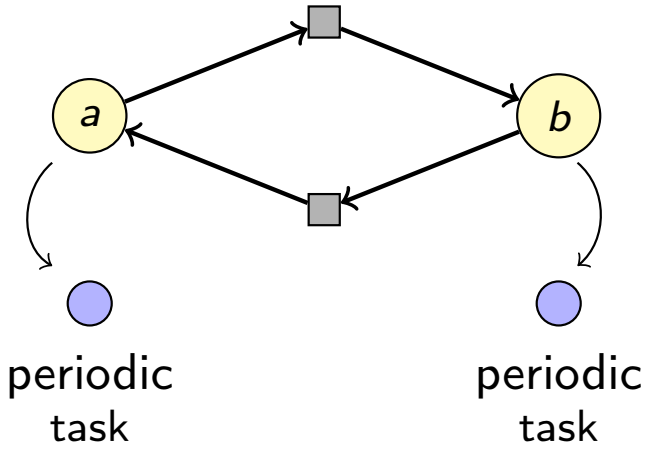

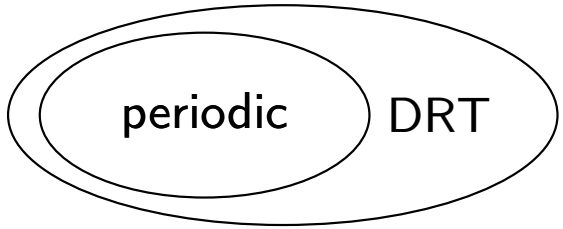

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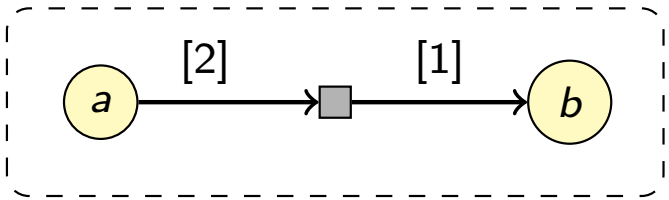
Outline

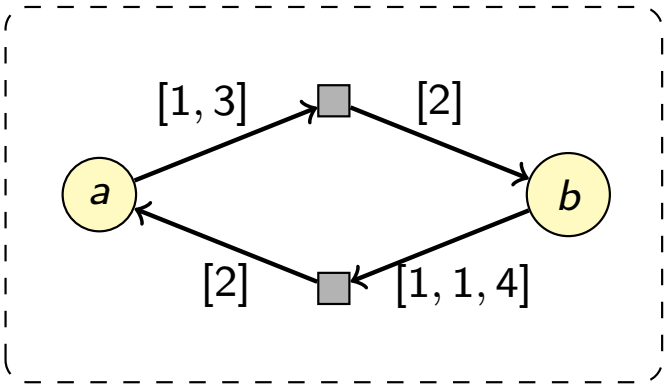
(Static) Data Flow Graphs

Synchronous Data Flow



- Fixed token production (consumption) rate
- Fixed execution time

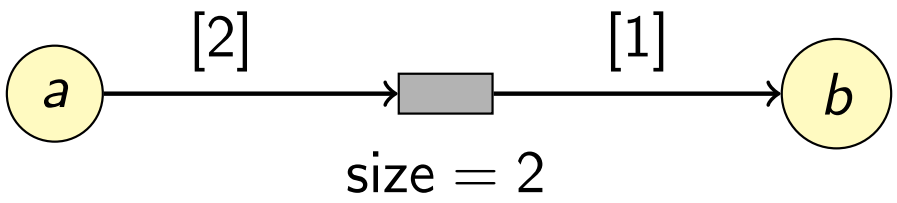
Cyclo-Static Data Flow



- Variable token production (consumption) rate
- Variable execution time

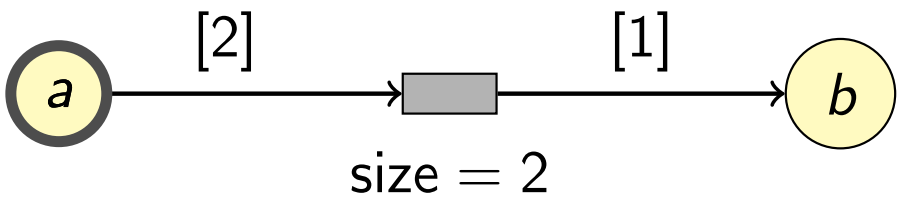
Semantics

- Empty buffer



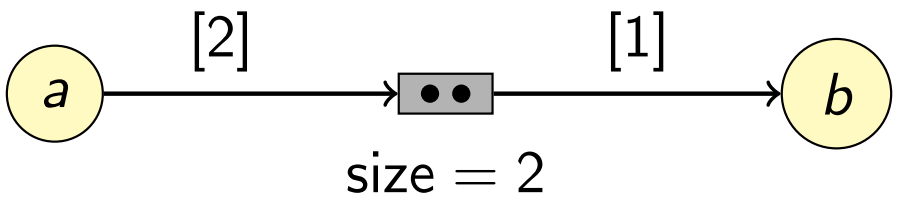
Semantics

- Empty buffer
- 'a' can be fired



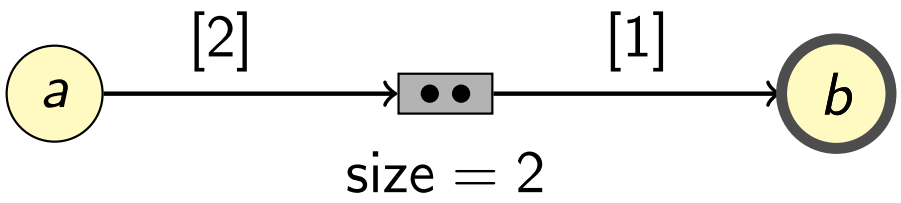
Semantics

- Full buffer



Semantics

- Full buffer
- 'a' **cannot** be fired
- 'b' **can** be fired



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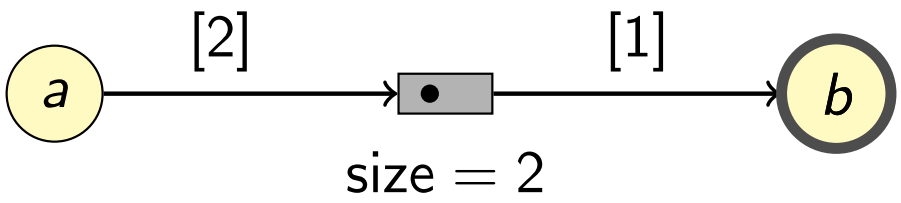

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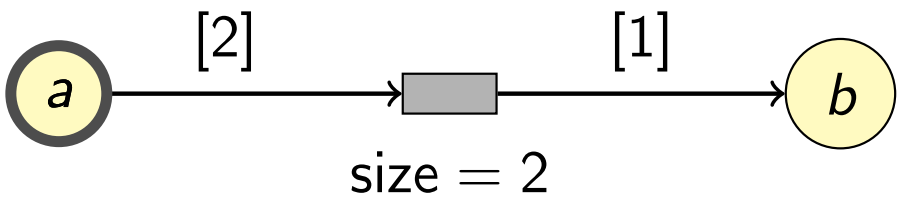


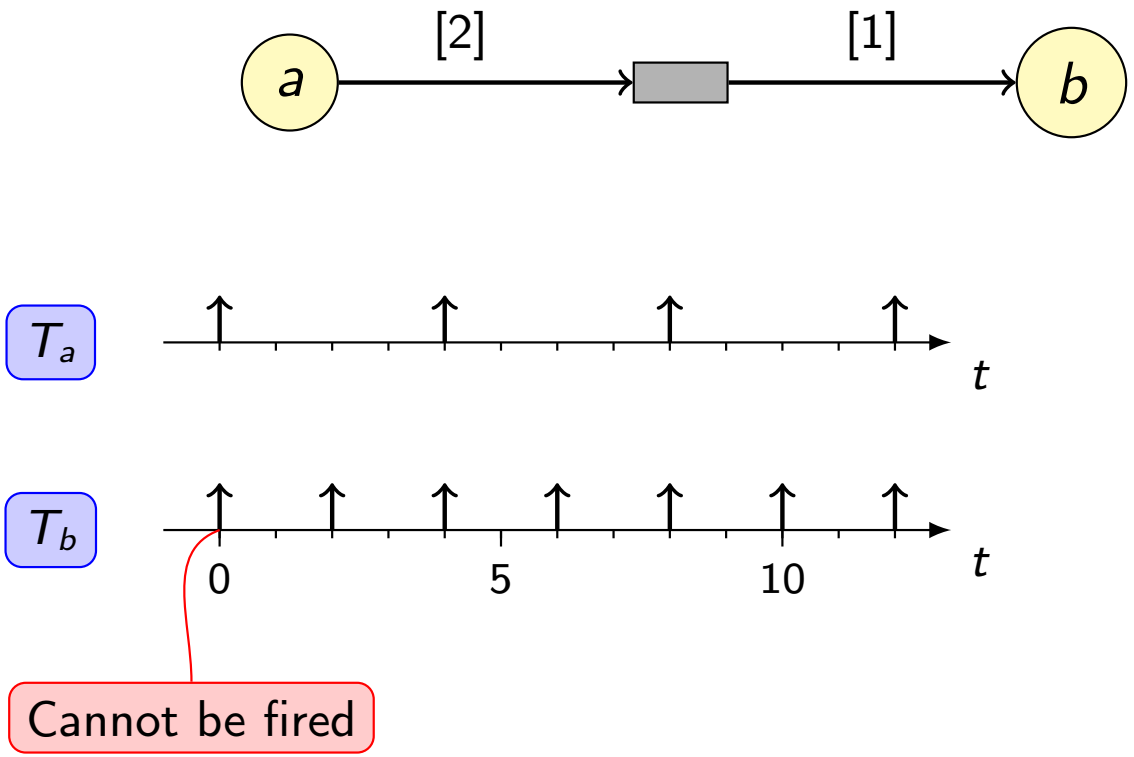
Constraints

Design Constraints

- Underflow/overflow avoidance
- Schedulability

Underflow and Overflow

- **Underflow** avoidance



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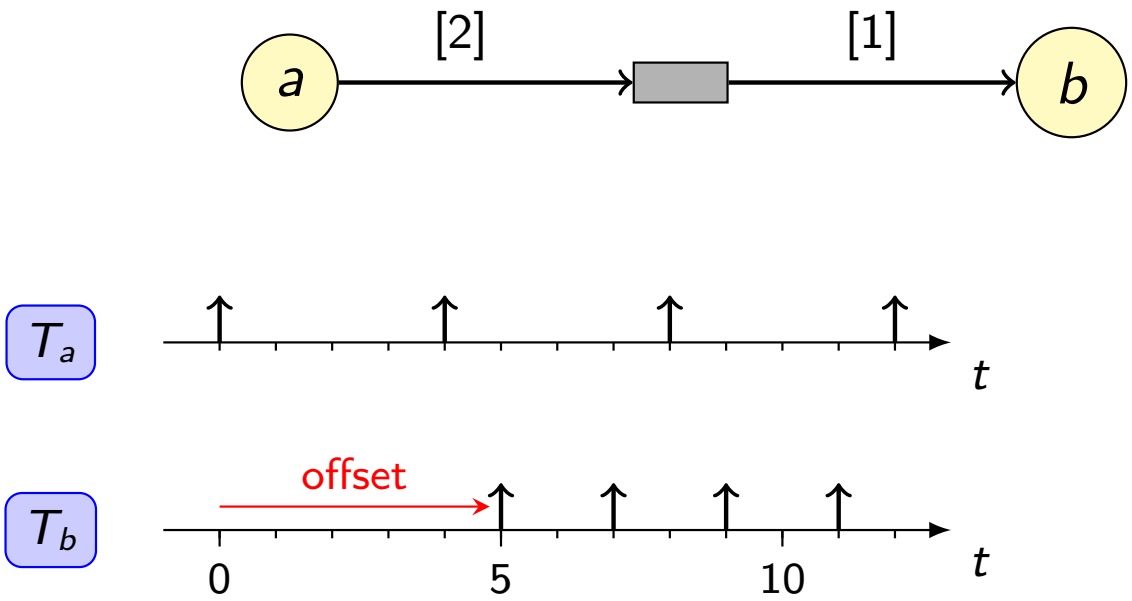
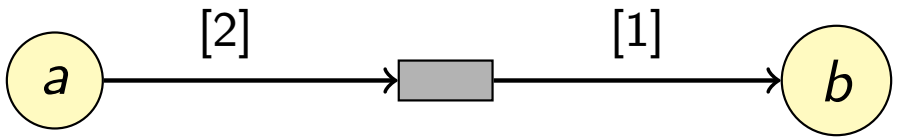
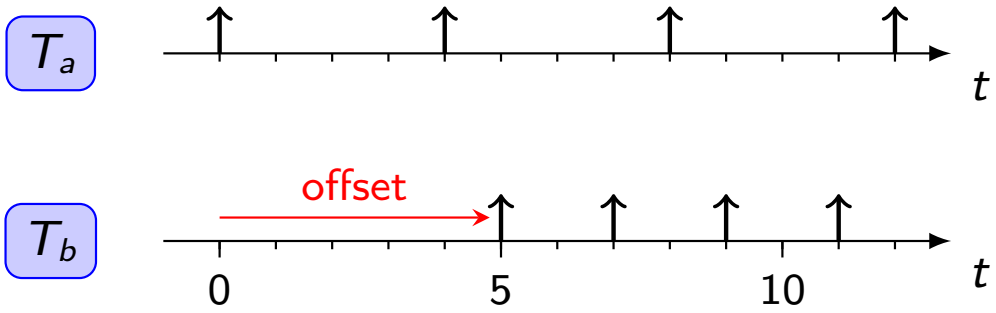
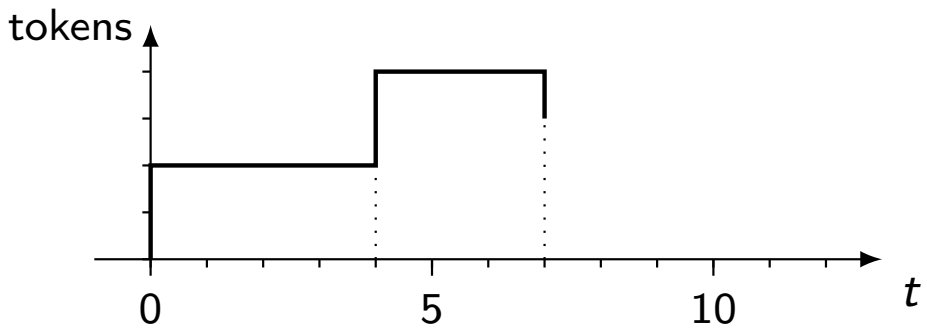


Underflow and Overflow

- Produce token as **soon** as possible
- Consume token as **late** as possible







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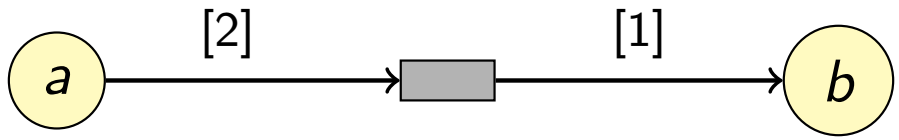

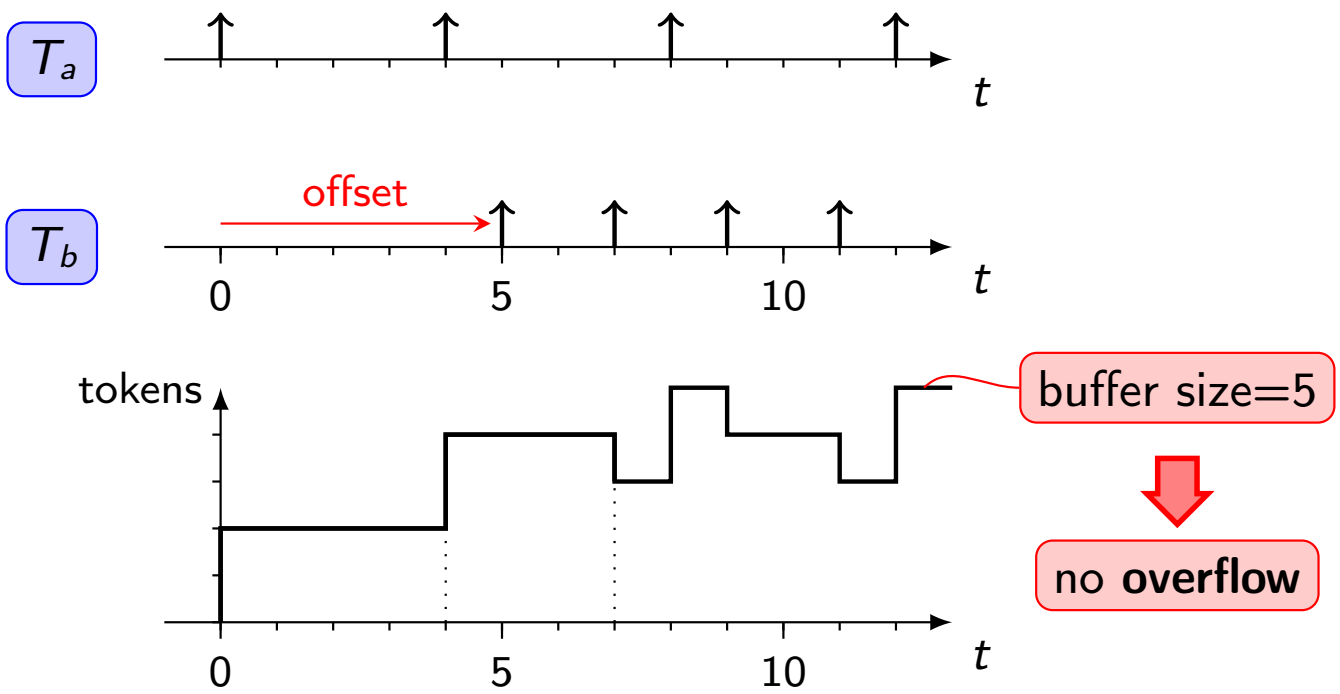

Constraints

Design Constraints

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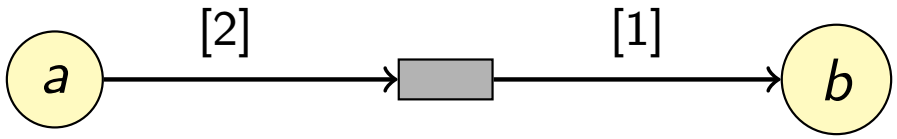

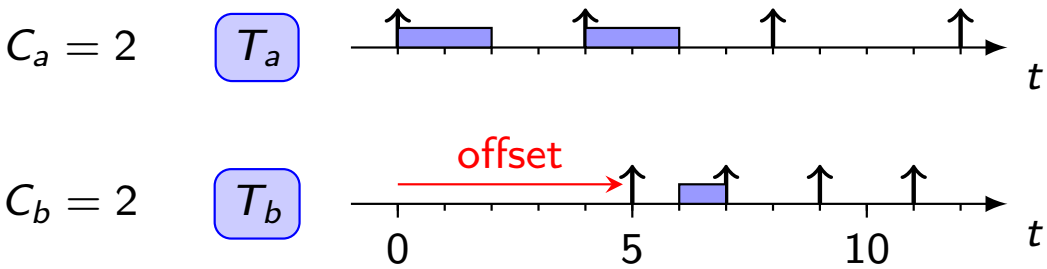

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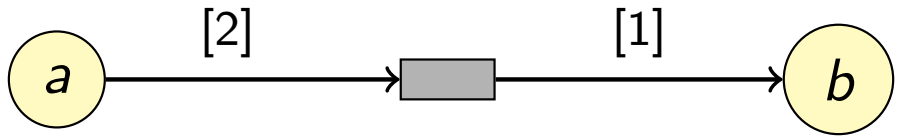

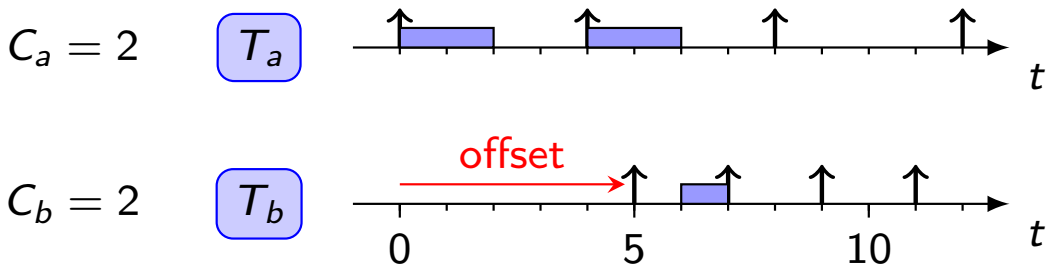

Unschedulable!

Constraints

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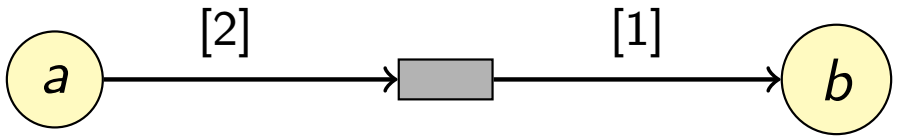
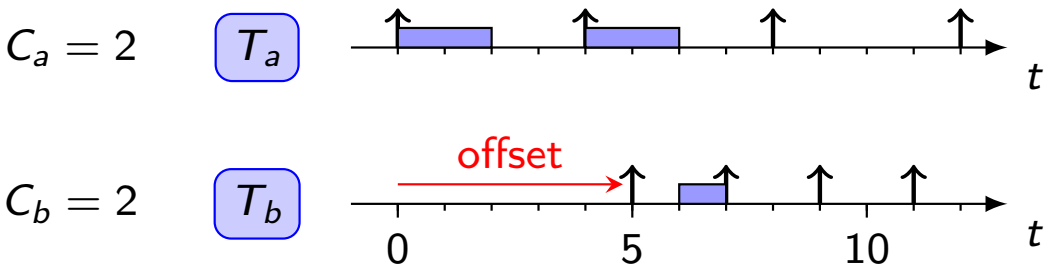




Larger Periods ⇒ Lower **Throughput**

The Problem

Design Parameters

- Periods
- Offsets

Constraints

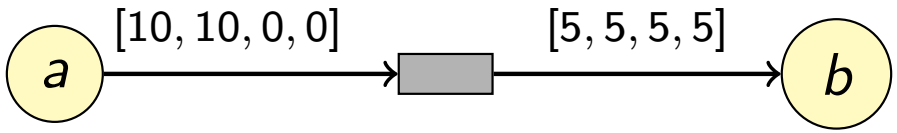
- No underflow
- No overflow
- Schedulability

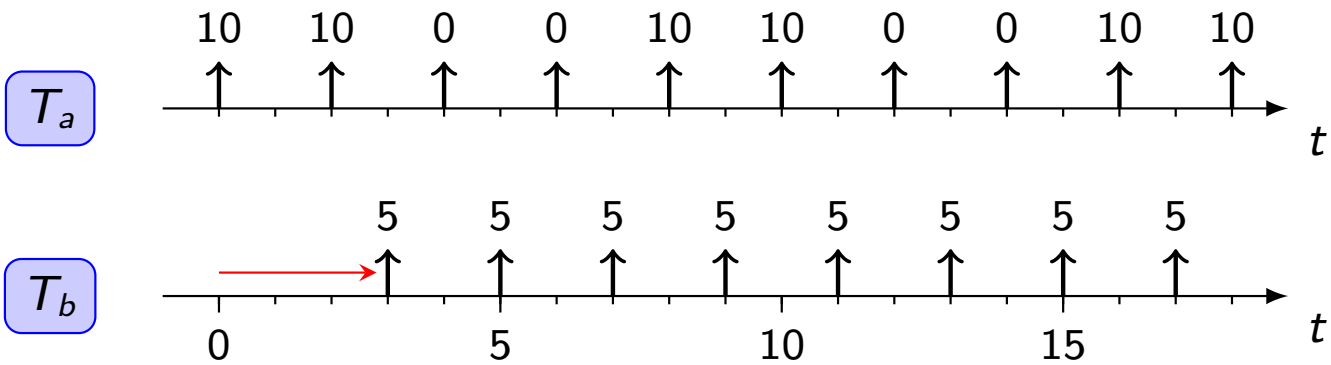
Objective

Throughput maximization

Cyclo-Static Data Flow Graphs

- Repeating **pattern**





Cyclo-Static Data Flow Graphs

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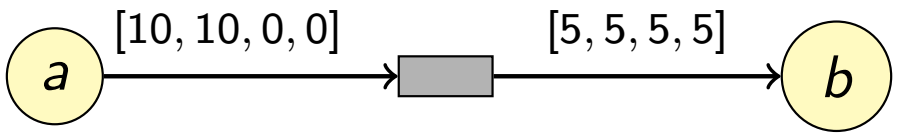

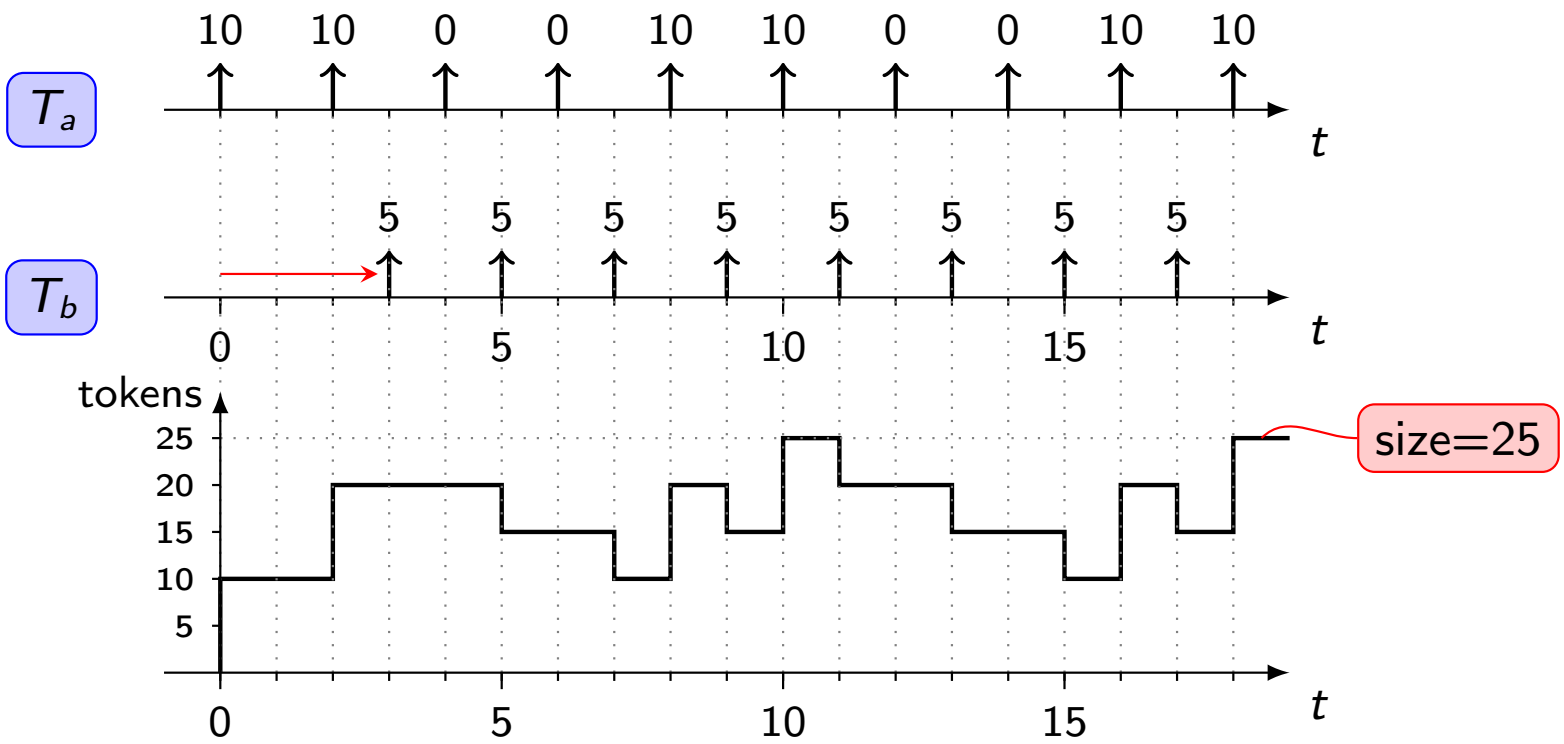

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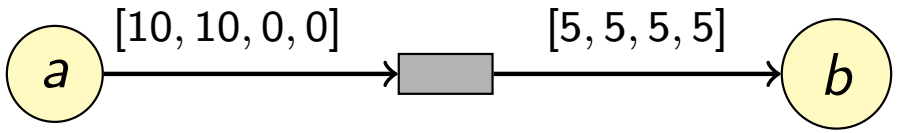

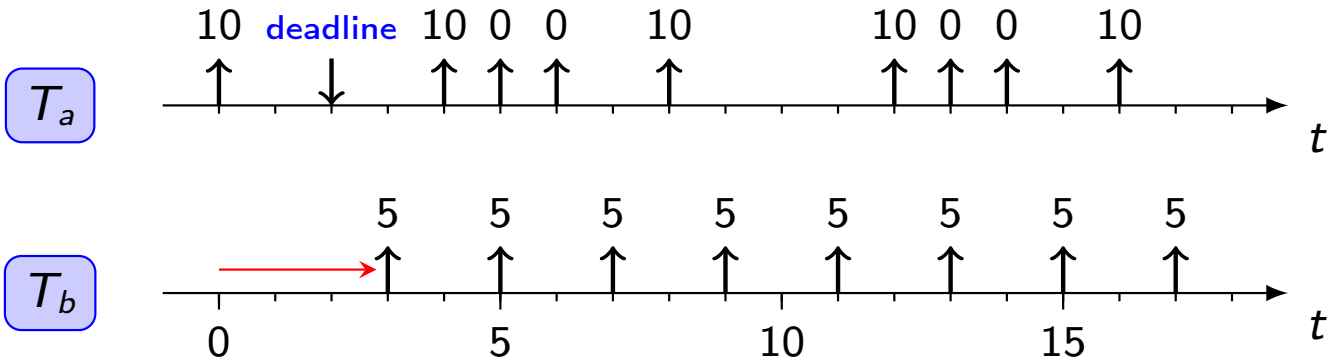

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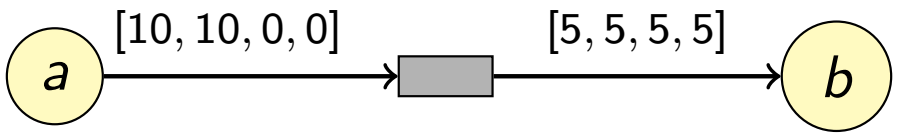
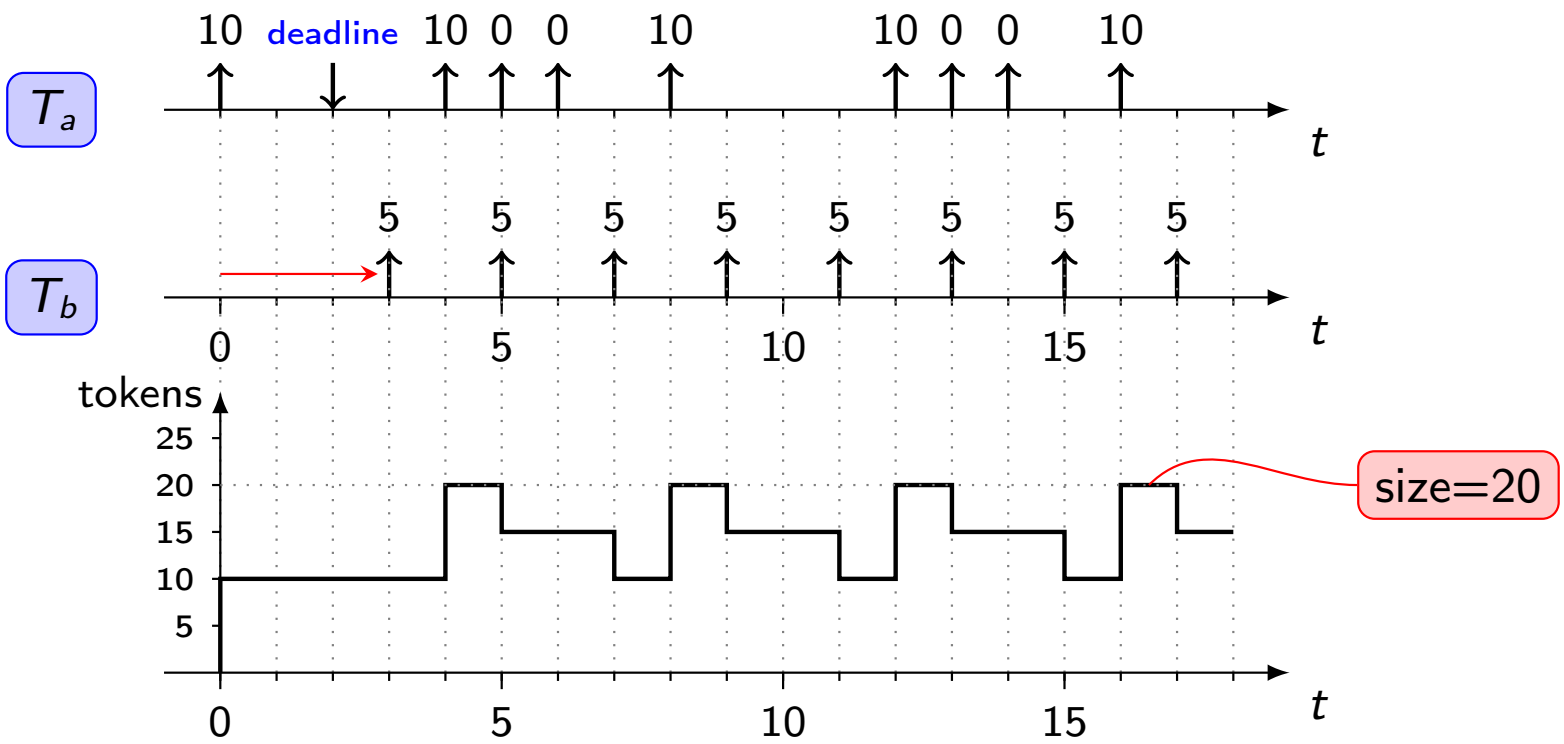


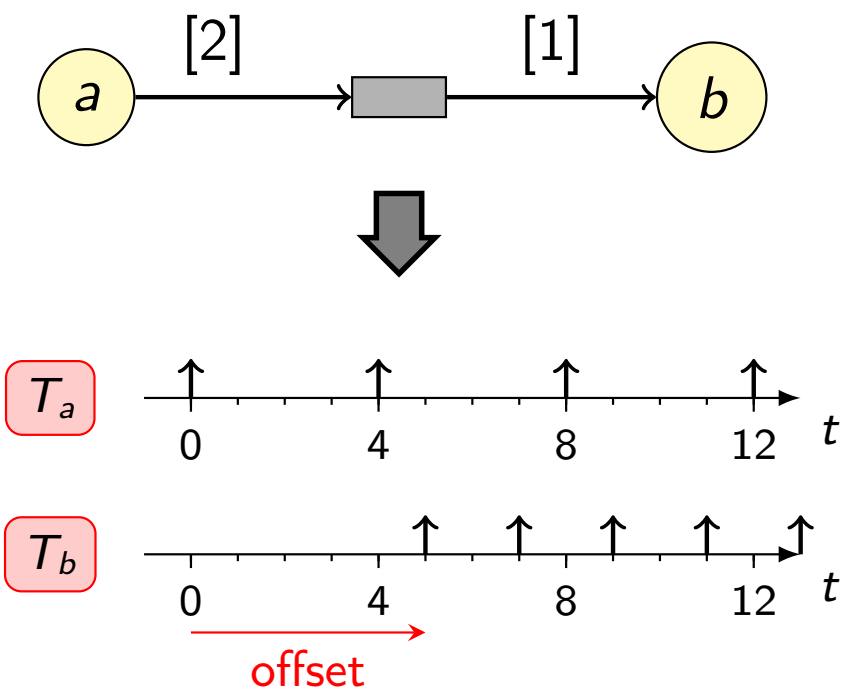


We need a non-periodic task model

Scheduling Data Flow Graphs

Synchronous Data Flow

- Fixed behavior
- Periodically repeating



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- Fixed behavior
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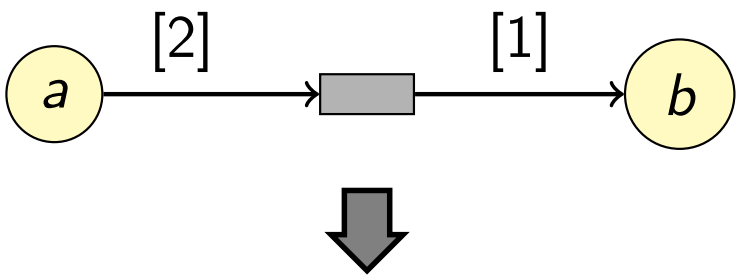
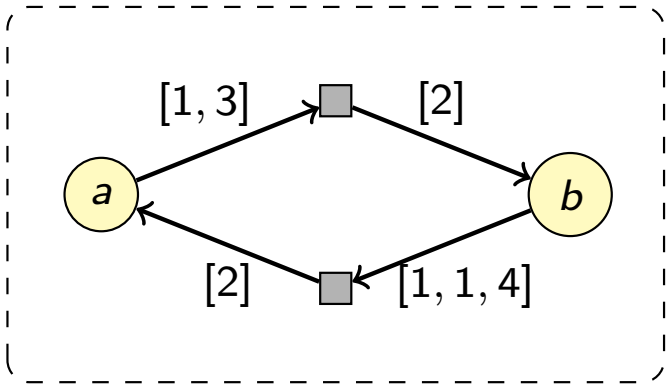
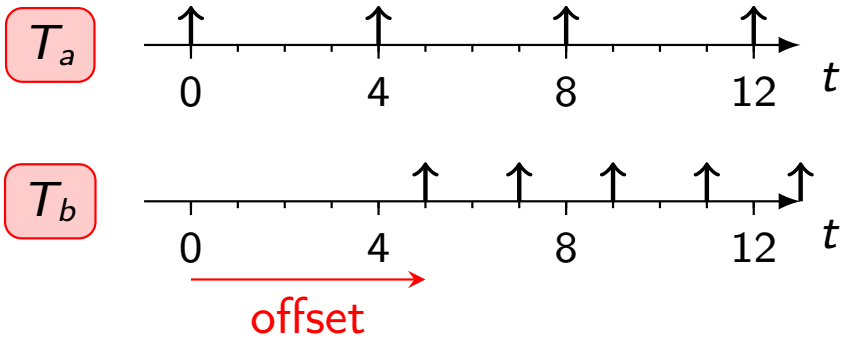
Cyclo-Static Data Flow

- Changing behavior
- Repeating **pattern**







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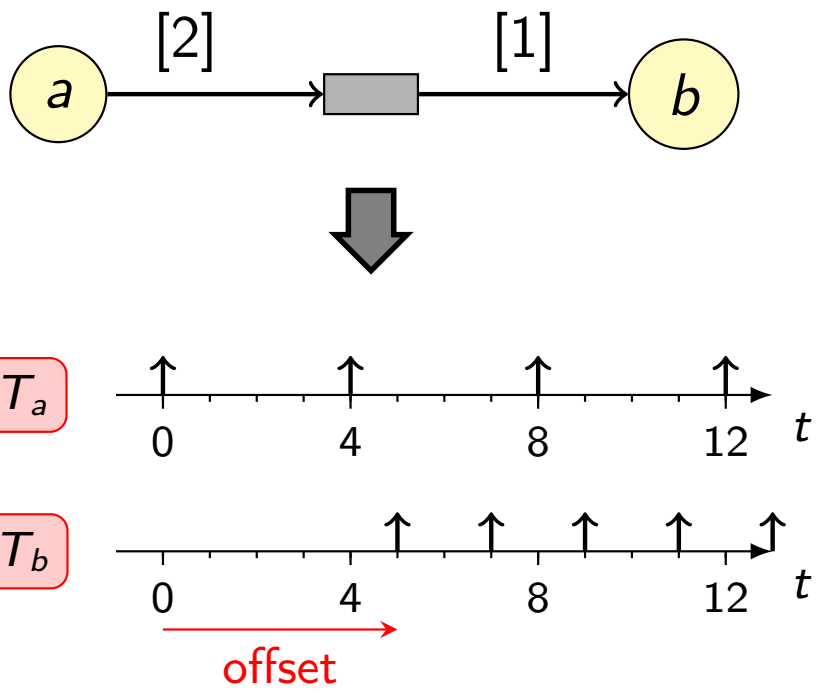
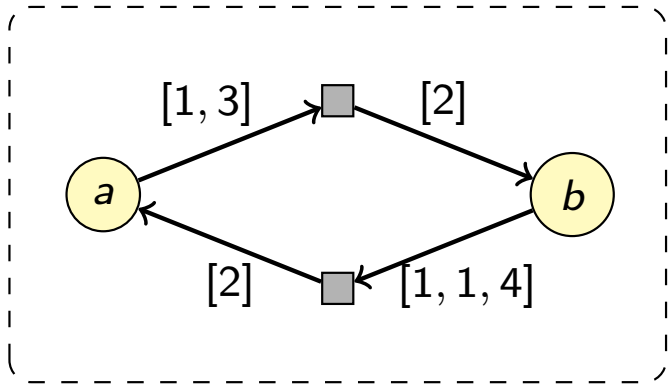
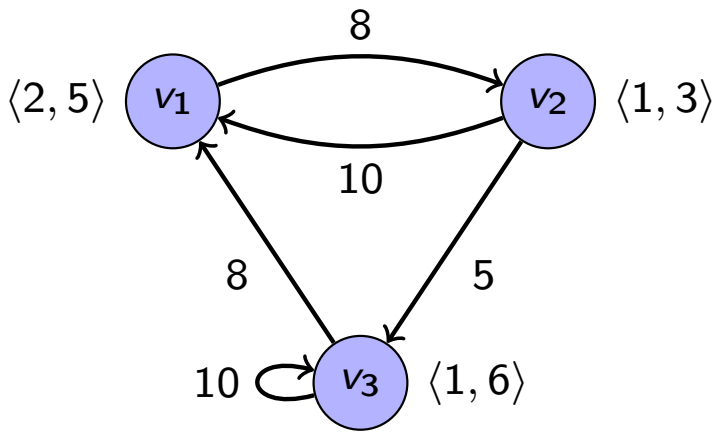




The Digraph Real-Time task model.

The Digraph Real-Time (DRT) Task Model

- A graph-based representation
- Different job types



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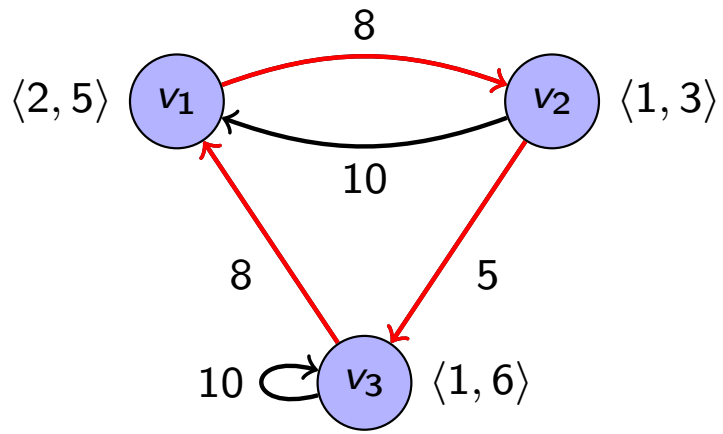
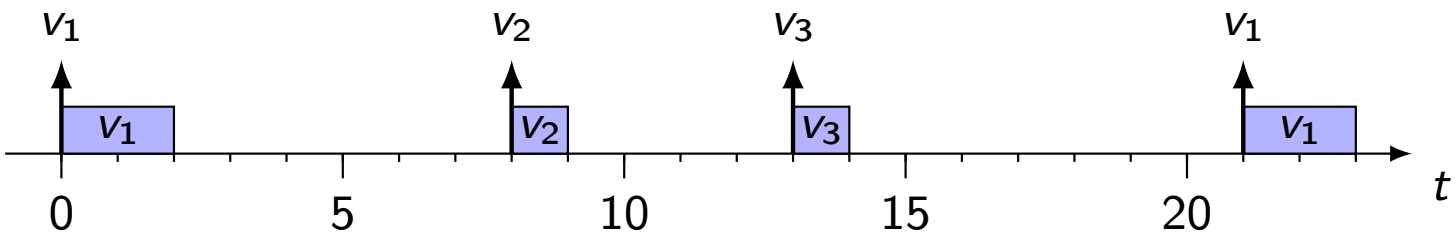
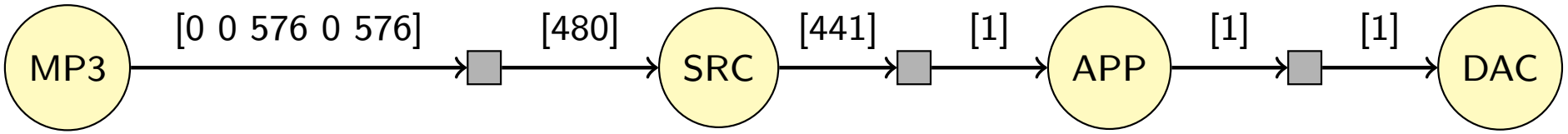




Example

- MP3 playback application

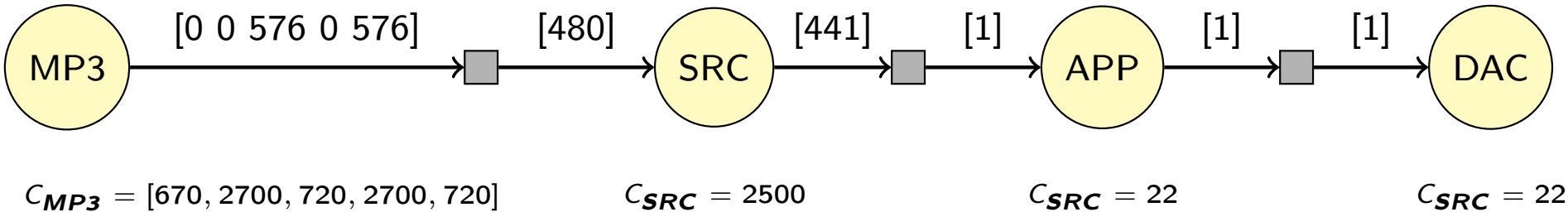


$C_{MP3} = [670, 2700, 720, 2700, 720]$ $C_{SRC} = 2500$ $C_{SRC} = 22$ $C_{SRC} = 22$

- DRT task for the actor MP3

Example

- MP3 playback application



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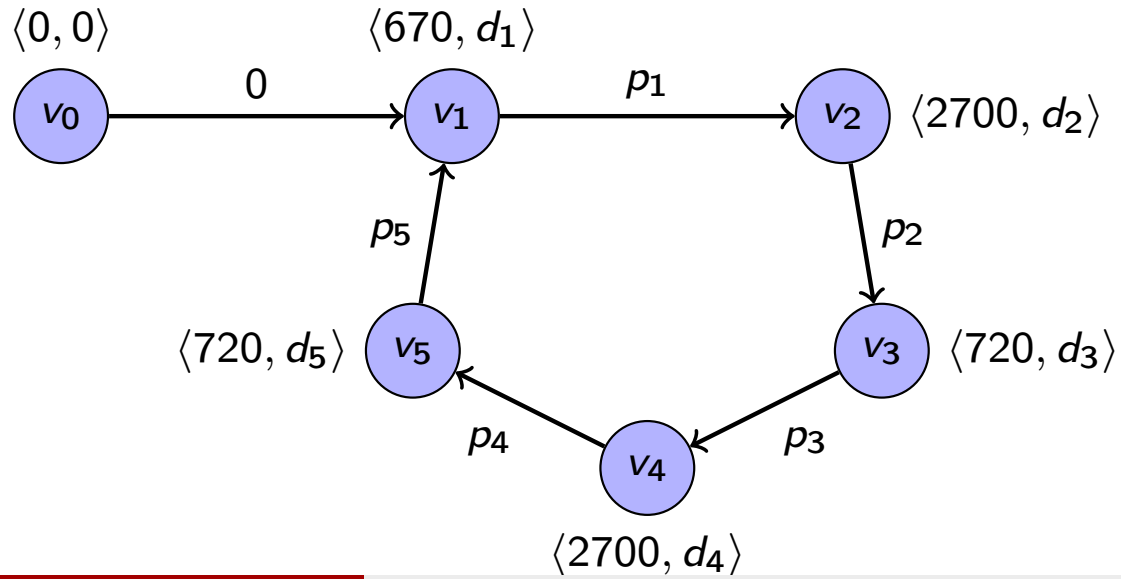

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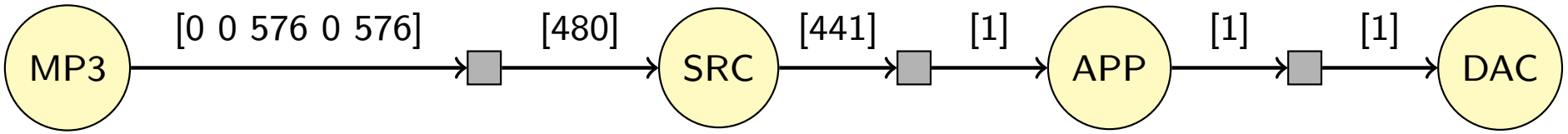

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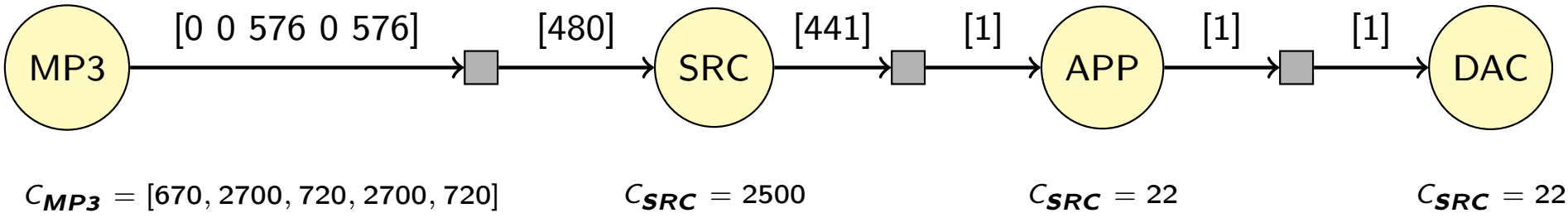
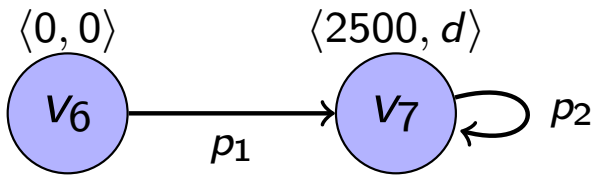
Example

- MP3 playback application



- DRT task for the actor SRC



Obtained DRT tasks

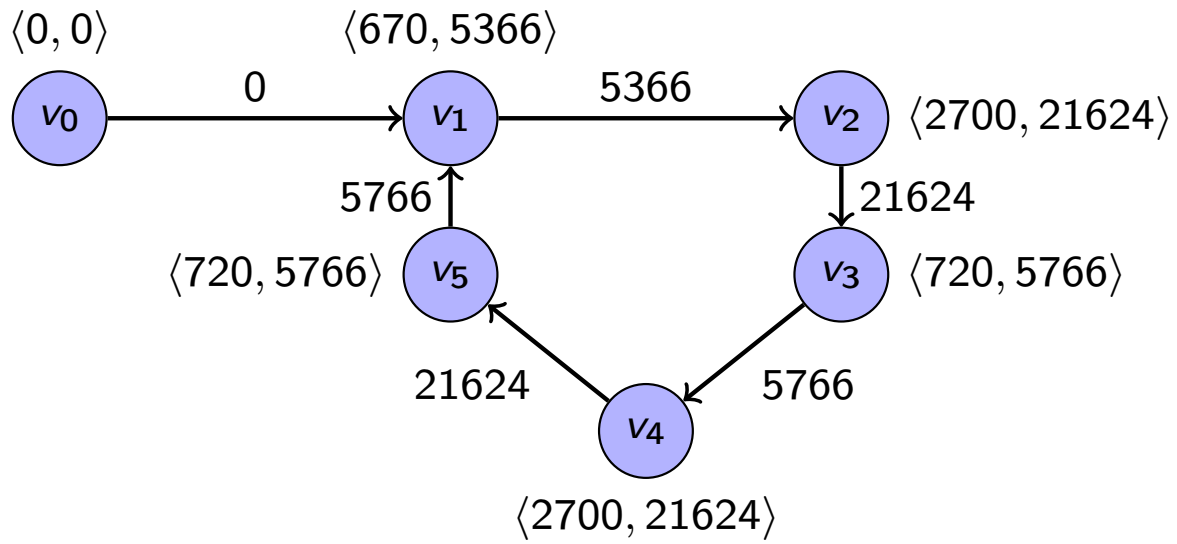


Table: Task set parameters for the DRT tasks (μs)

	Period	Offset
SRC	25061.809	60649.578
APP	56.829	110801.612
DAC	56.829	110943.686

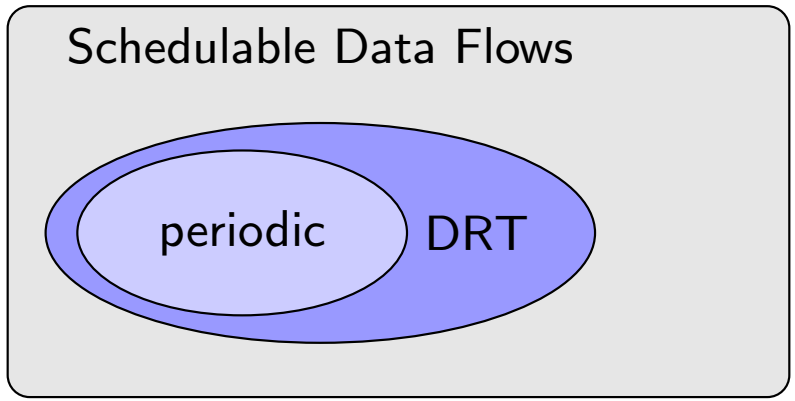
Evaluation Results

Table: Total buffer requirement and throughput for each method

	Buffer Requirement	Throughput (s^{-1})
Periodic Task Set	2273	16013
DRT Task Set	2155	17596
Improvement	5%	9.8%

Conclusion

- Using a more general task model
  - More flexibility
  - Larger state-space



- Linear approximation

Modeling and Analysis of Data Flow Graphs using the Digraph Real-Time Task Model

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Ada-Europe 2016

Thanks!