Removing Implicit Places Using Regions for Process Discovery

Seminar - Selected Topics in Process Mining

Faizan Zafar

Chair of Process and Data Science

RWTH Aachen University

faizan.zafar@rwth-aachen.de

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Outline

- Literature
- Introduction
- Motivation
- Removing Implicit Places
- Evaluation
- Related Work
- Conclusion
- Future Work

Literature

- [L. Mannel, R. Bergenthum, W. Aalst+ 20] Removing Implicit Places Using Regions for Process Discovery. 41st International Conference on Application and Theory of Petri Nets and Concurrency, 2020
- Process discovery aims to discover simple Petri nets
- Petri nets may contain *implicit* places which have adverse outcomes
- A novel technique to identify and remove implicit places
- Integrating the approach with the eST-Miner algorithm

Introduction: Process Discovery

Input: Event Log

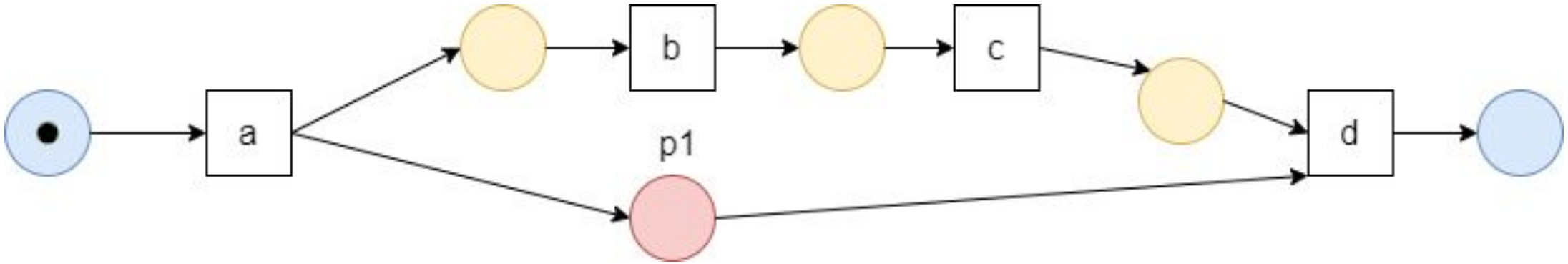
Output: Process model

Introduction: Preliminaries

- Activity -> Trace -> Event Log
- A marked Petri net (N,m_0) is a process model composed of places P, transitions T and a multiset of arcs F -> $\mathbb{N}_0$
- Language L of a Petri net N
- Implicit Place p
- Token Count Function x_p

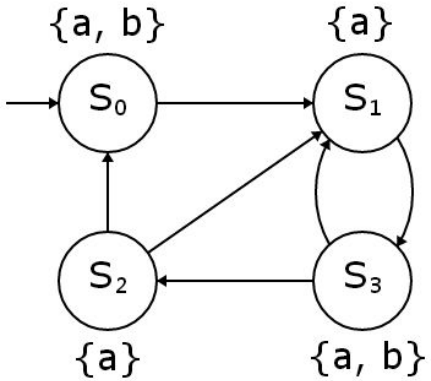
Introduction: Preliminaries

$$L = [\epsilon, \langle a, b, c \rangle^4]$$



Introduction: Region Theory

Transition System



Prefix-closed Language

$\langle a \rangle$
$\langle a, b \rangle$
$\langle a, b, c \rangle$
$\langle a, b, c, d \rangle$

Introduction: Region Theory

- Identifying *regions* in the event log
- A region is a mathematical structure satisfying certain conditions
- State-based region theory makes use of a transition system
- Language-based region theory makes use of a prefix-closed language
- Each region corresponds to a feasible place in the resulting Petri net
- Different approaches exist for finding the subset of regions

Motivation

- Minimal regions method avoids adding implicit places to a model
- *r'* is a sub-region of *r* if *r'* is a subset of *r*. *r* is a minimal region if and only if there is no other region *r'* which is a sub-region of *r*. For each minimal region *r*, a place *p* is produced.
- Transitioning directly from the event log to the resulting model
- The goal is to remove implicit places from a discovered set of places

Removing Implicit Places: Main Idea

➢ **Given an Event Log and the corresponding Petri net N:**

- $p_1, p_2 \in P$ **are two individual places in** N
- **Comparing** p_1 **and** p_2**, we verify the conditions:**

$$\forall \sigma \in L(N) : x_{p_1}(\sigma) \geq x_{p_2}(\sigma) \qquad (1)$$

$$\exists \sigma \in L(N) : x_{p_1}(\sigma) > x_{p_2}(\sigma) \qquad (2)$$

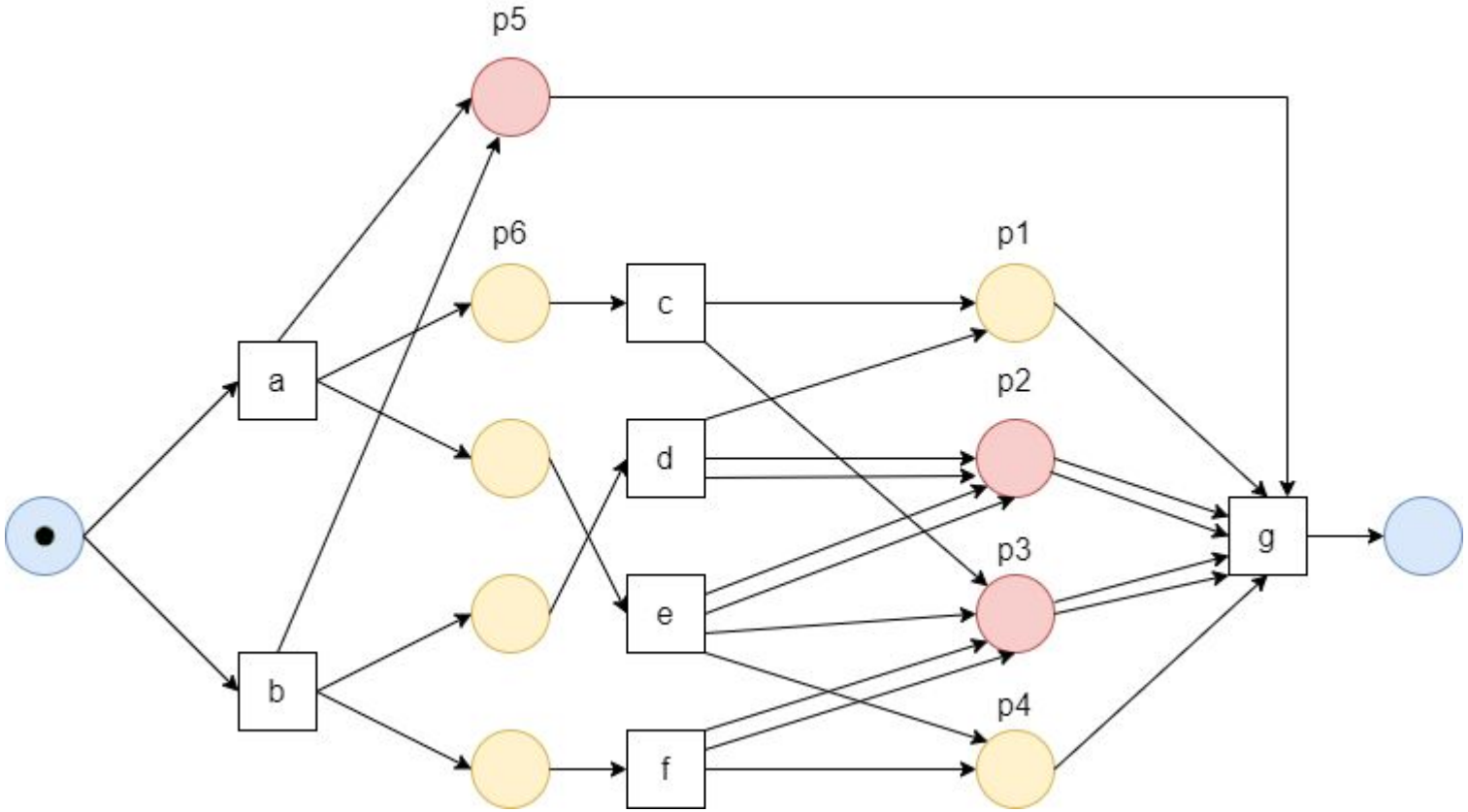
- **If** $x_{p1} > x_{p2}$ **for the prefix-closed language of** N**, then**

$$x_{p_3} = x_{p_1} - x_{p_2} \qquad (3)$$

is a region and p_1 **can be regarded as *implicit***

Removing Implicit Places: Fundamental Case

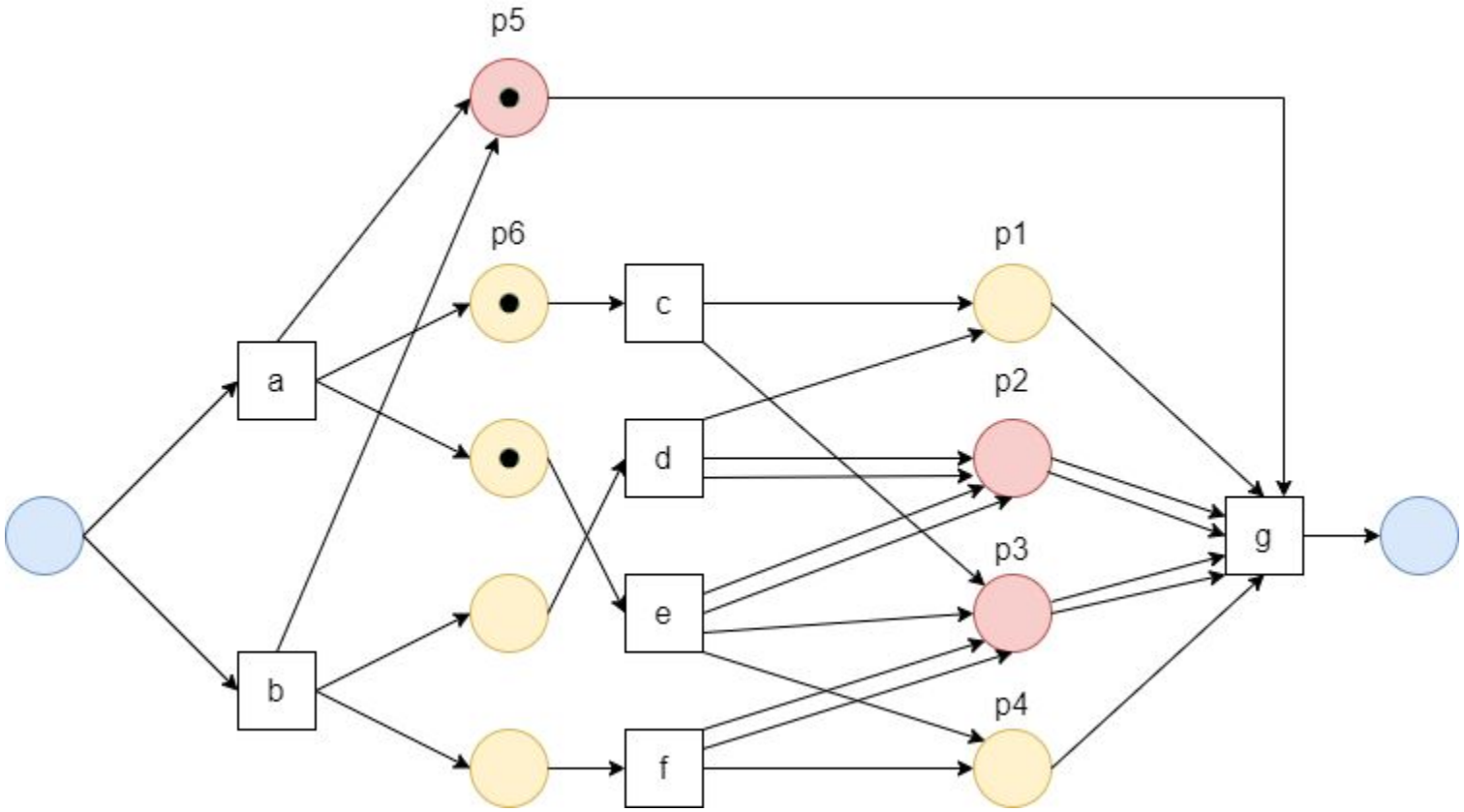
$$L = [\epsilon, \langle a, c, e, g\rangle^2, \langle a, e, c, g\rangle^3, \langle b, d, f, g\rangle^2, \langle b, f, d, g\rangle^4]$$



	ε	a	c	e	g
p_5	0				
p_6	0				
p_7					

Removing Implicit Places: Fundamental Case

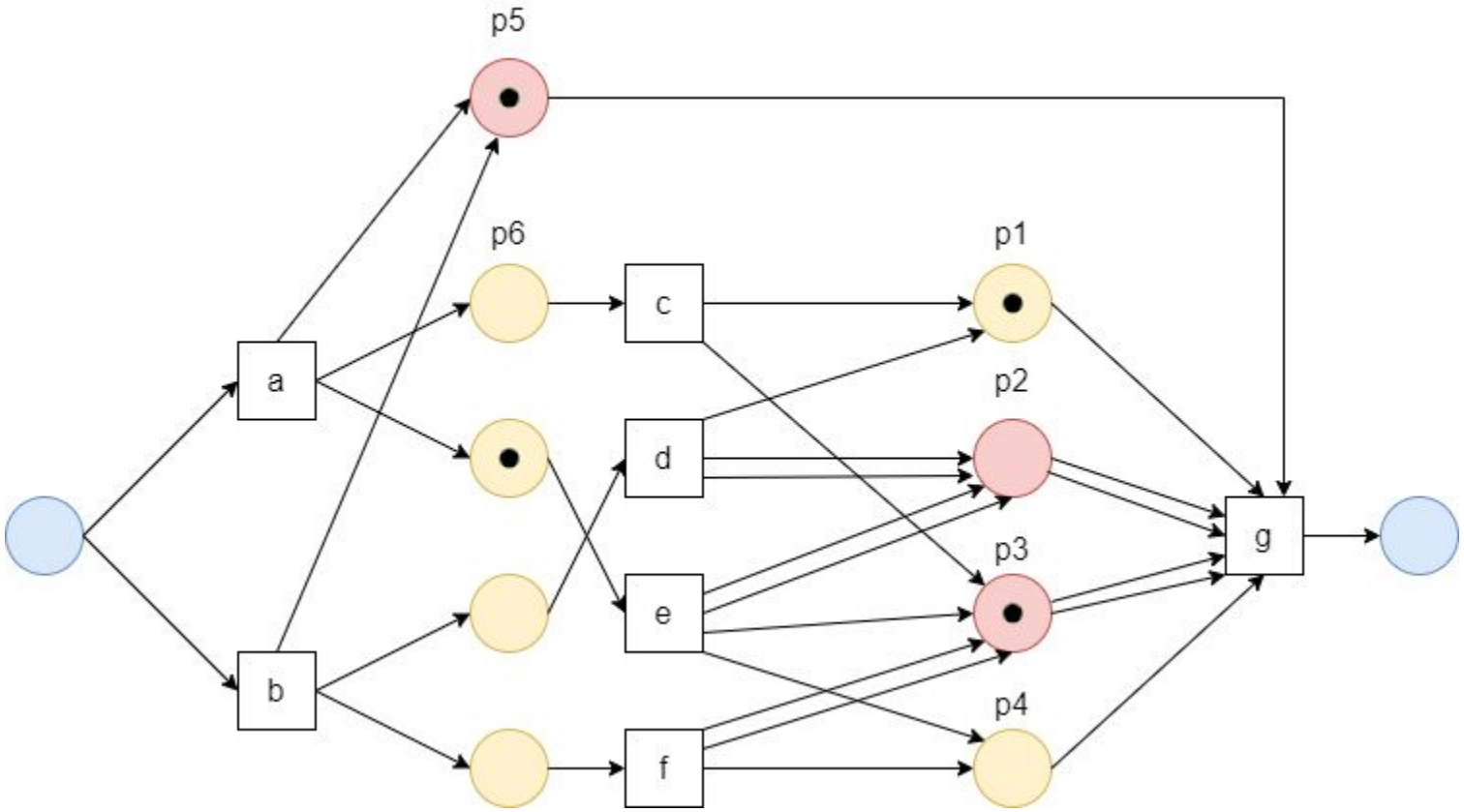
$$L = [\epsilon, \langle a, c, e, g\rangle^2, \langle a, e, c, g\rangle^3, \langle b, d, f, g\rangle^2, \langle b, f, d, g\rangle^4]$$



	ϵ	a	c	e	g
p_5	0	1			
p_6	0	1			
p_7					

Removing Implicit Places: Fundamental Case

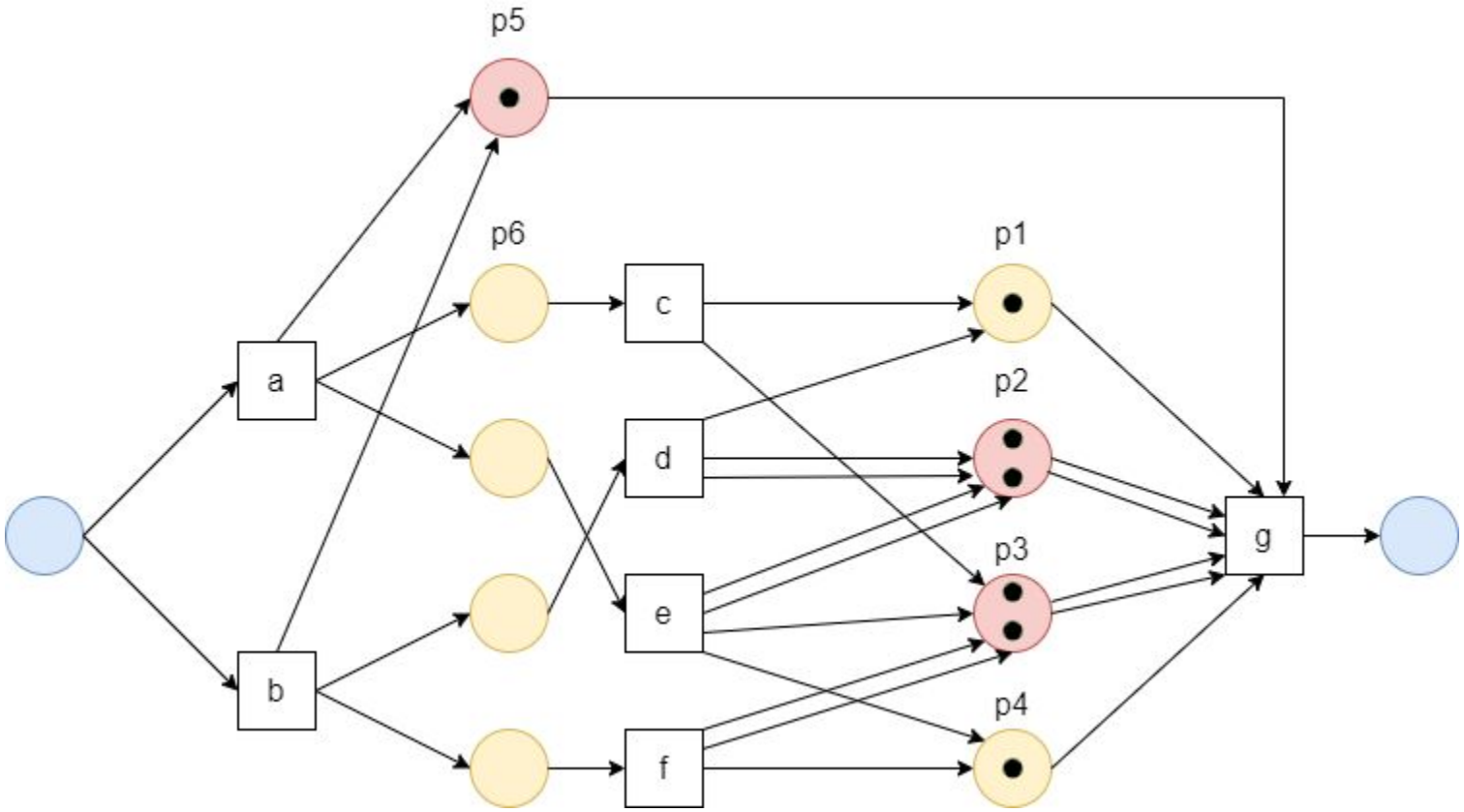
$$L = [\epsilon, \langle a, c, e, g\rangle^2, \langle a, e, c, g\rangle^3, \langle b, d, f, g\rangle^2, \langle b, f, d, g\rangle^4]$$



	ε	a	c	e	g
p_5	0	1	1		
p_6	0	1	0		
p_7					

Removing Implicit Places: Fundamental Case

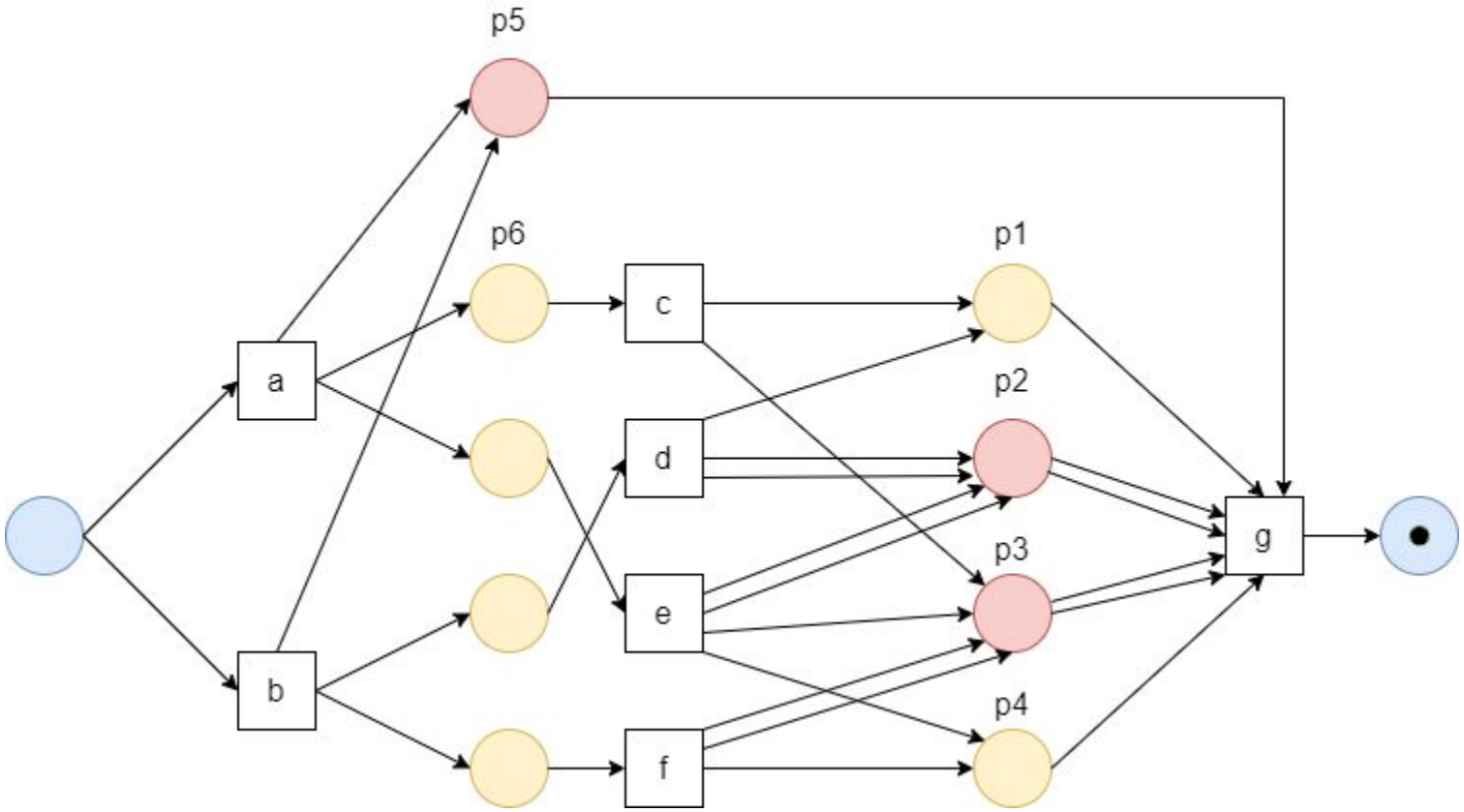
$$L = [\epsilon, \langle a, c, e, g\rangle^2, \langle a, e, c, g\rangle^3, \langle b, d, f, g\rangle^2, \langle b, f, d, g\rangle^4]$$



	ε	a	c	e	g
p_5	0	1	1	1	
p_6	0	1	0	0	
p_7					

Removing Implicit Places: Fundamental Case

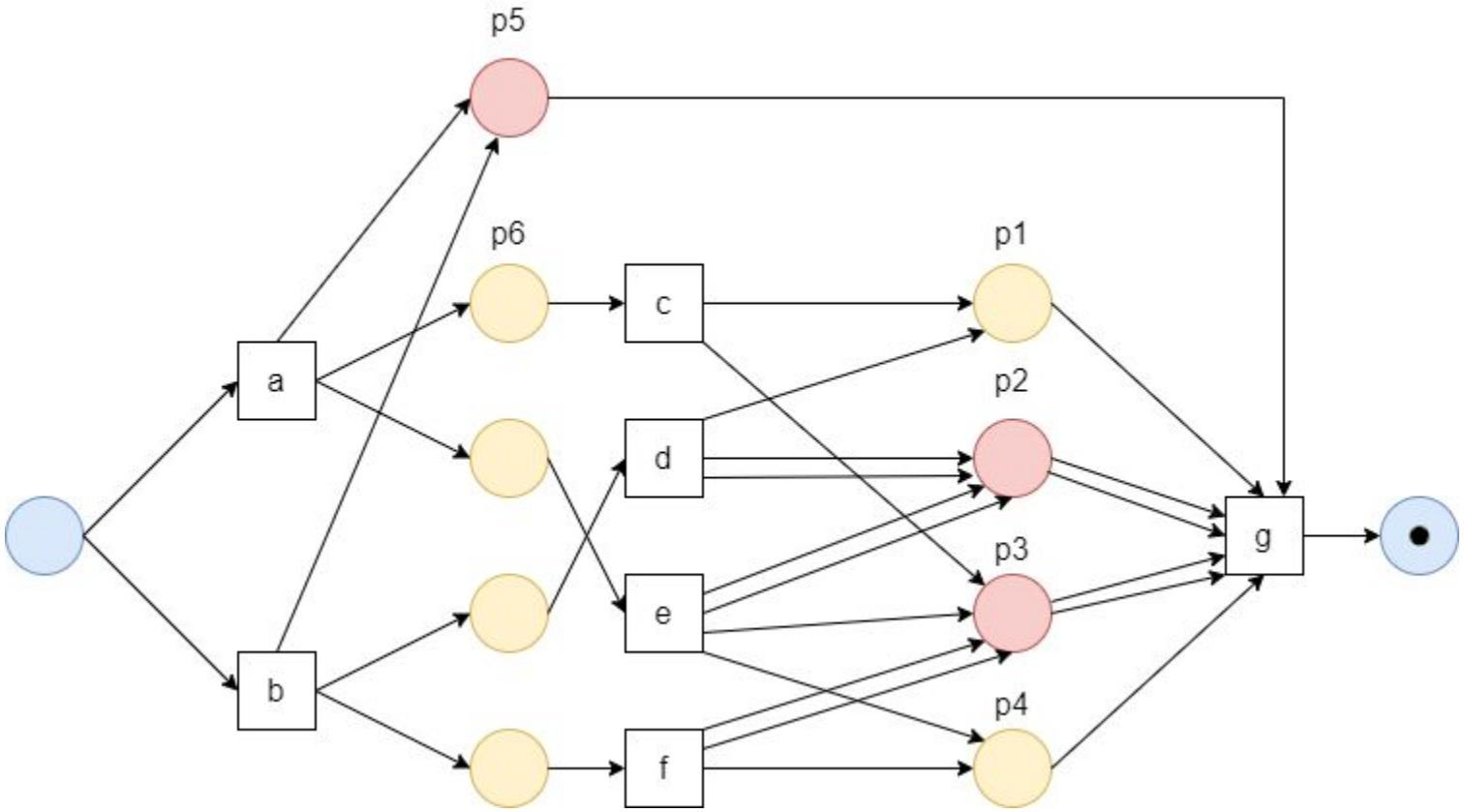
$$L = [\epsilon, \langle a, c, e, g\rangle^2, \langle a, e, c, g\rangle^3, \langle b, d, f, g\rangle^2, \langle b, f, d, g\rangle^4]$$



	ε	a	c	e	g
p_5	0	1	1	1	0
p_6	0	1	0	0	0
p_7					

Removing Implicit Places: Fundamental Case

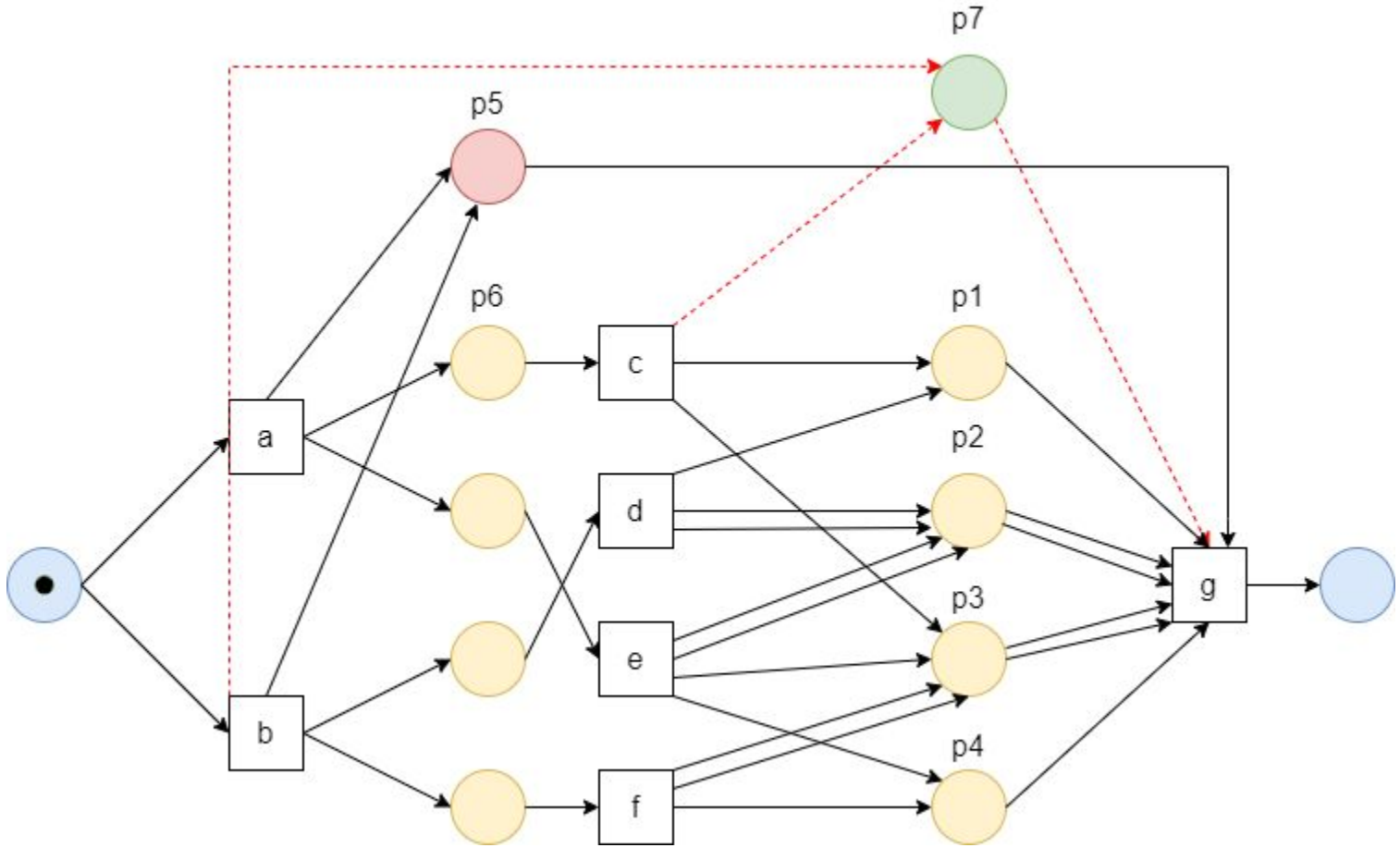
$$L = [\epsilon, \langle a, c, e, g\rangle^2, \langle a, e, c, g\rangle^3, \langle b, d, f, g\rangle^2, \langle b, f, d, g\rangle^4]$$



	ε	a	c	e	g
p_5	0	1	1	1	0
p_6	0	1	0	0	0
p_7	0	0	1	1	0

Removing Implicit Places: Fundamental Case

$$L = [\epsilon, \langle a, c, e, g\rangle^2, \langle a, e, c, g\rangle^3, \langle b, d, f, g\rangle^2, \langle b, f, d, g\rangle^4]$$



	ε	a	c	e	g
p_5	0	1	1	1	0
p_6	0	1	0	0	0
p_7	0	0	1	1	0

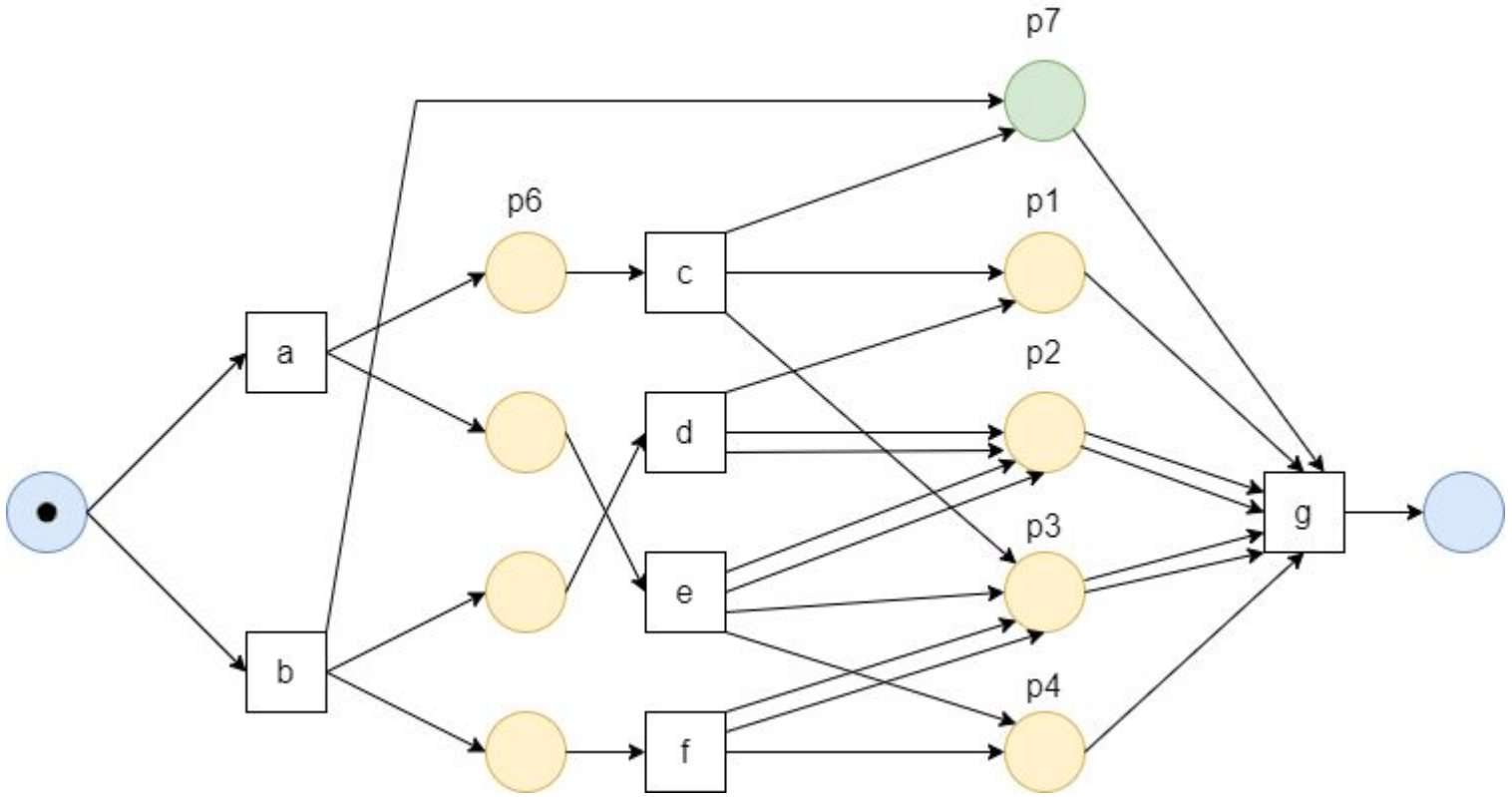
	ε	a	e	c	g
p_5	0	1	1	1	0
p_6	0	1	1	0	0
p_7	0	0	0	1	0

	ε	b	d	f	g
p_5	0	1	1	1	0
p_6	0	0	0	0	0
p_7	0	1	1	1	0

	ε	b	f	d	g
p_5	0	1	1	1	0
p_6	0	0	0	0	0
p_7	0	1	1	1	0

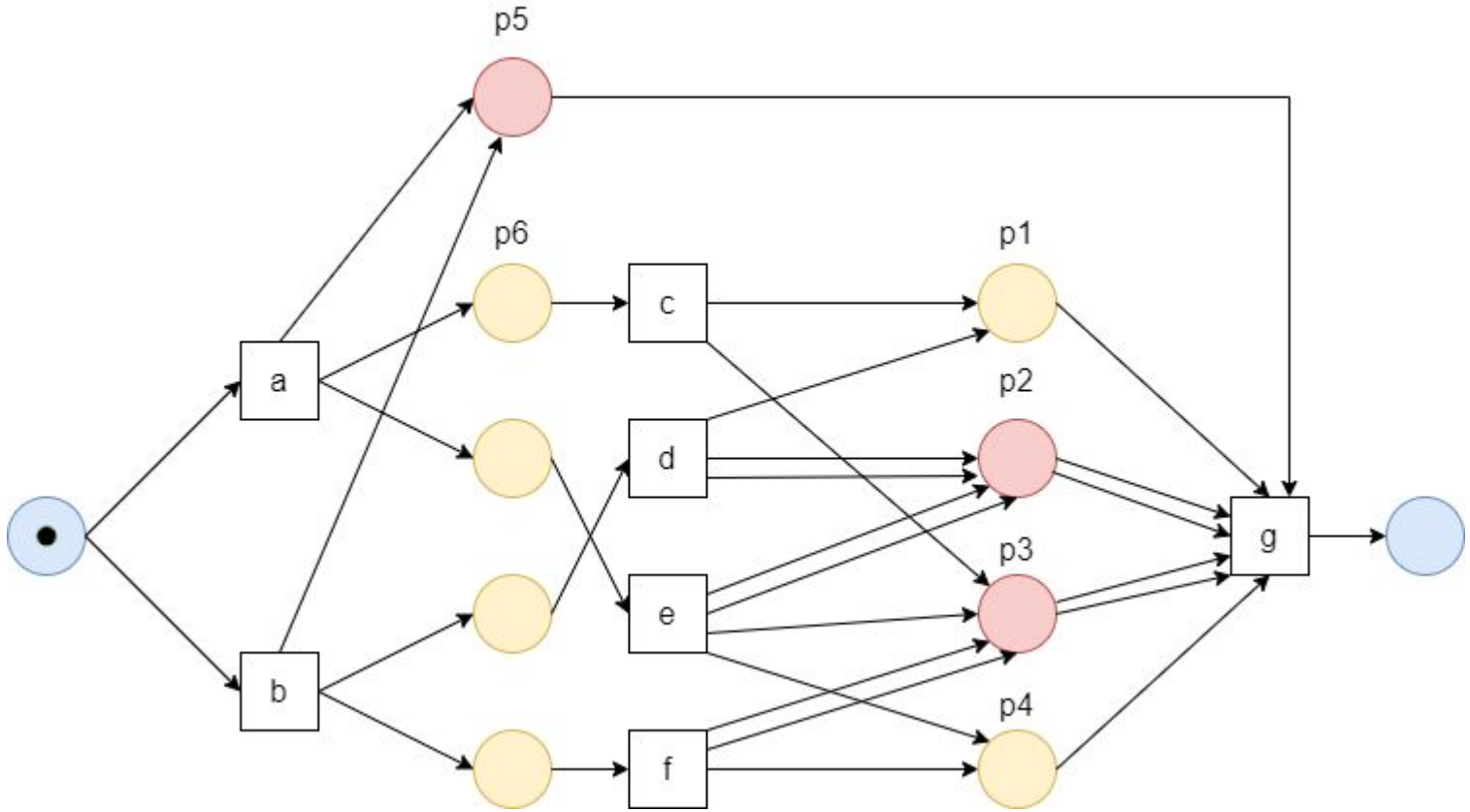
Removing Implicit Places: Fundamental Case

$$L = [\epsilon, \langle a, c, e, g\rangle^2, \langle a, e, c, g\rangle^3, \langle b, d, f, g\rangle^2, \langle b, f, d, g\rangle^4]$$



Removing Implicit Places: Extended Case

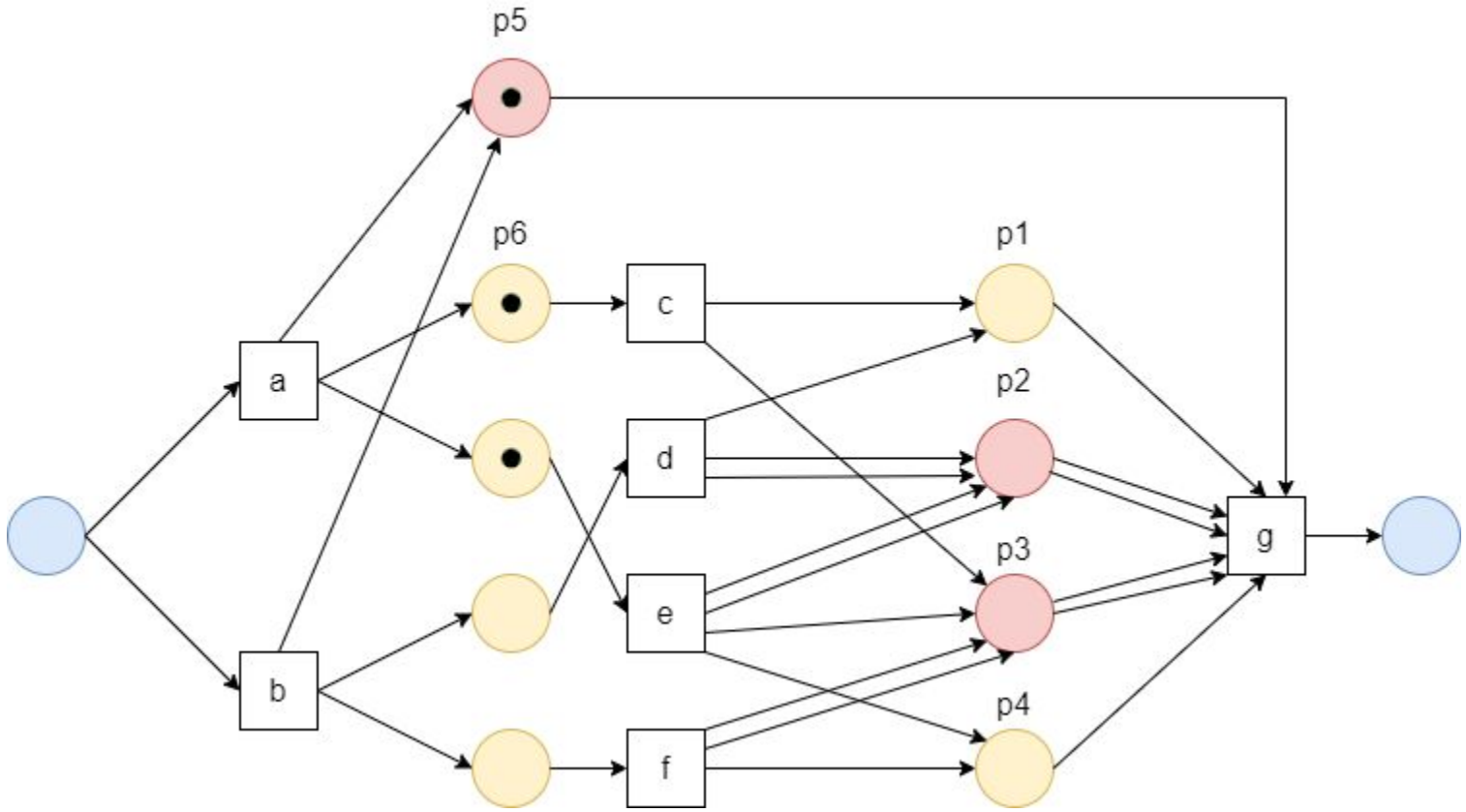
$$L = [\epsilon, \langle a, c, e, g \rangle^2, \langle a, e, c, g \rangle^3, \langle b, d, f, g \rangle^2, \langle b, f, d, g \rangle^4]$$



	ϵ	a	c	e	g
p_3	0				
p_4	0				
p_8					

Removing Implicit Places: Extended Case

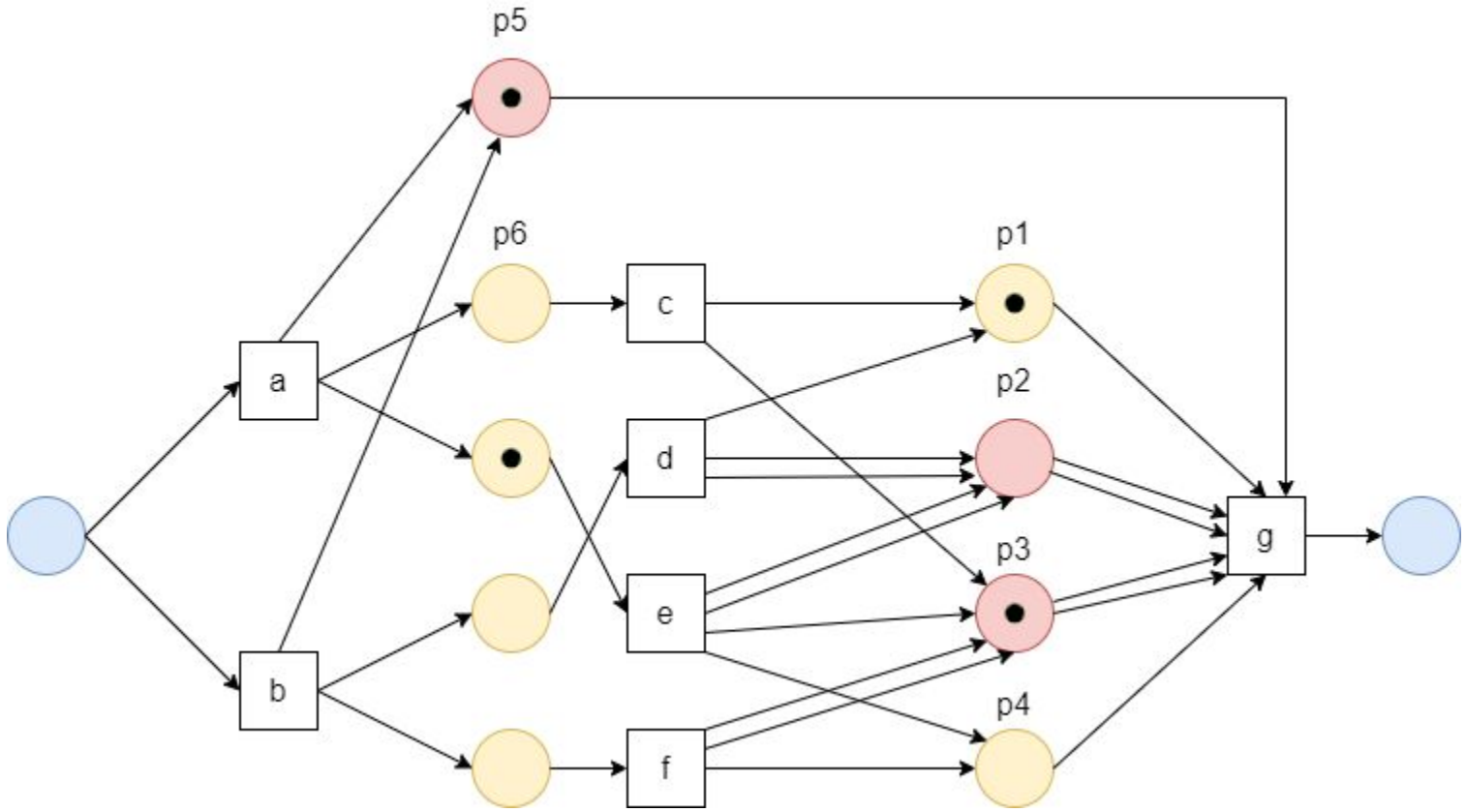
$$L = [\epsilon, \langle a, c, e, g\rangle^2, \langle a, e, c, g\rangle^3, \langle b, d, f, g\rangle^2, \langle b, f, d, g\rangle^4]$$



	ϵ	a	c	e	g
p_3	0	0			
p_4	0	0			
p_8					

Removing Implicit Places: Extended Case

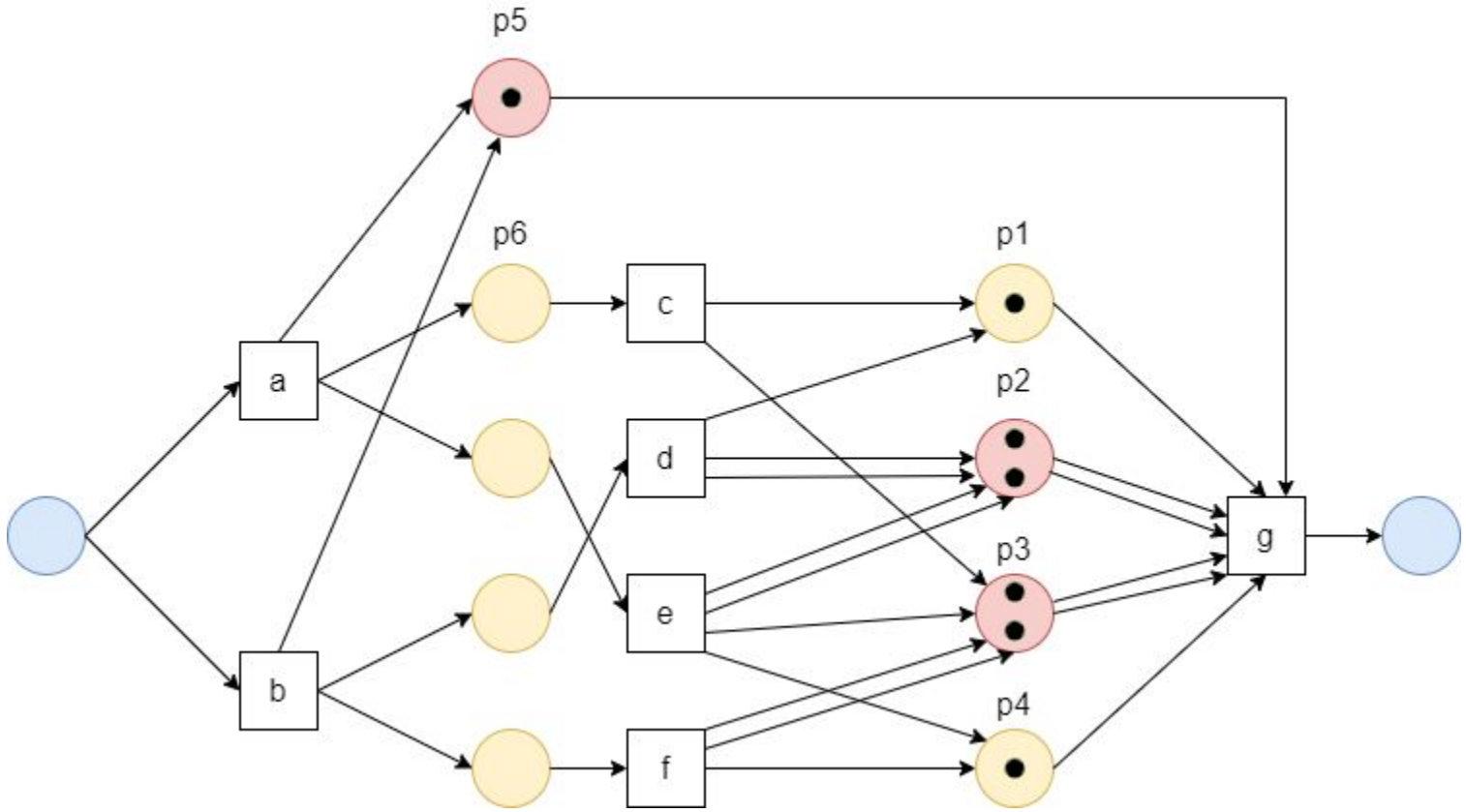
$$L = [\epsilon, \langle a, c, e, g\rangle^2, \langle a, e, c, g\rangle^3, \langle b, d, f, g\rangle^2, \langle b, f, d, g\rangle^4]$$



	ϵ	a	c	e	g
p_3	0	0	1		
p_4	0	0	0		
p_8					

Removing Implicit Places: Extended Case

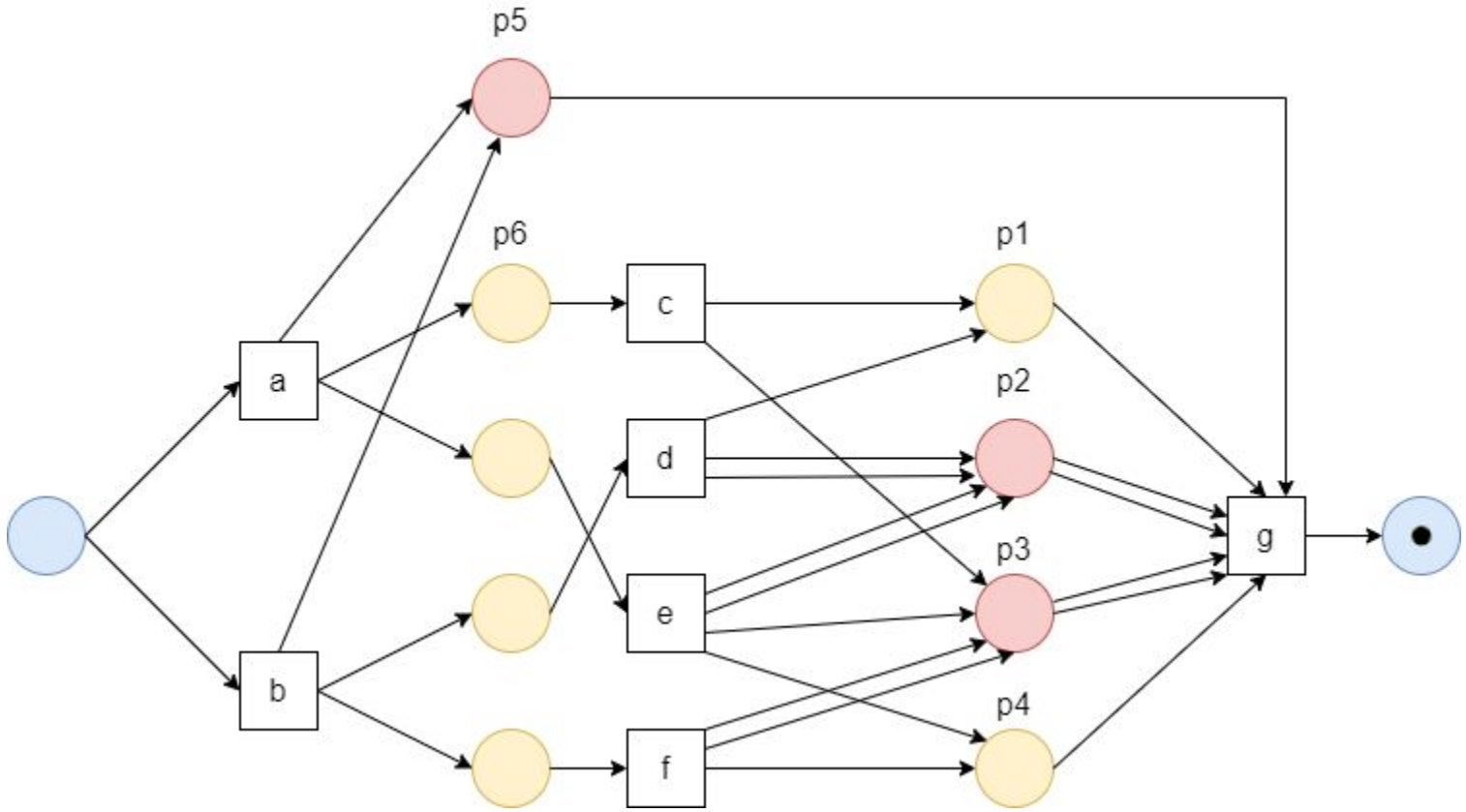
$$L = [\epsilon, \langle a, c, e, g\rangle^2, \langle a, e, c, g\rangle^3, \langle b, d, f, g\rangle^2, \langle b, f, d, g\rangle^4]$$



	ϵ	a	c	e	g
p_3	0	0	1	2	
p_4	0	0	0	1	
p_8					

Removing Implicit Places: Extended Case

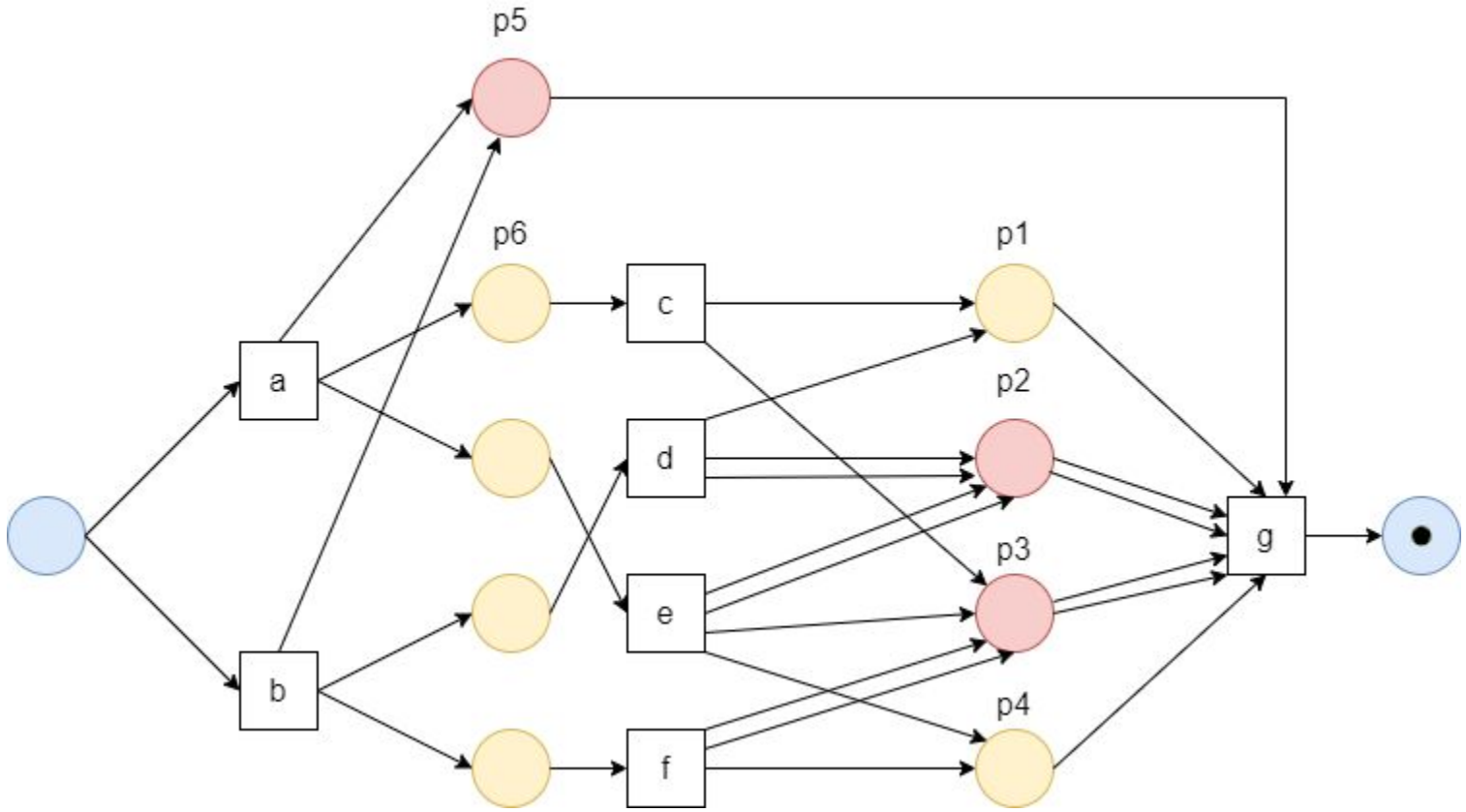
$$L = [\epsilon, \langle a, c, e, g\rangle^2, \langle a, e, c, g\rangle^3, \langle b, d, f, g\rangle^2, \langle b, f, d, g\rangle^4]$$



	ϵ	a	c	e	g
p_3	0	0	1	2	0
p_4	0	0	0	1	0
p_8					

Removing Implicit Places: Extended Case

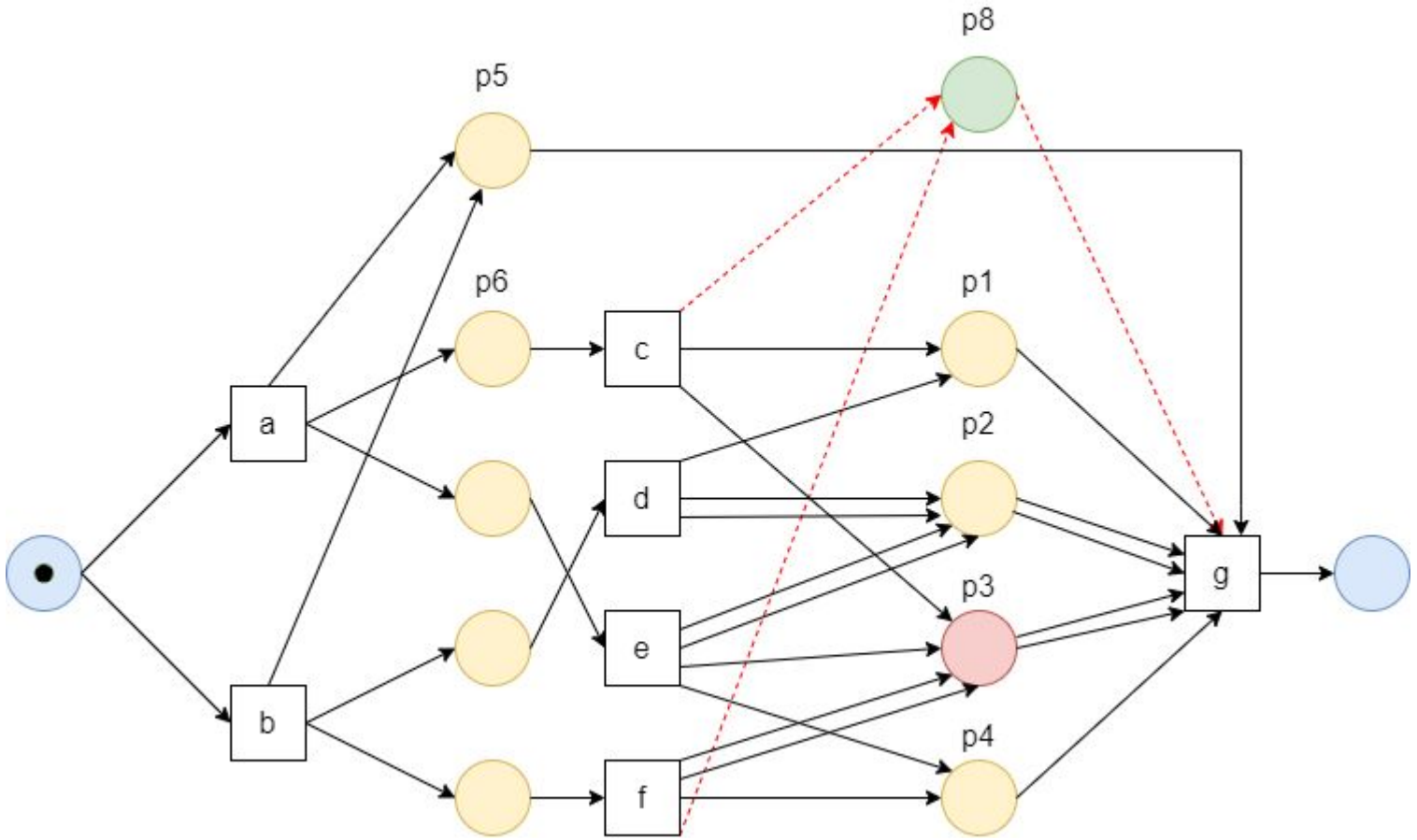
$$L = [\epsilon, \langle a, c, e, g\rangle^2, \langle a, e, c, g\rangle^3, \langle b, d, f, g\rangle^2, \langle b, f, d, g\rangle^4]$$



	ε	a	c	e	g
p_3	0	0	1	2	0
p_4	0	0	0	1	0
p_8	0	0	1	1	0

Removing Implicit Places: Extended Case

$$L = [\epsilon, \langle a, c, e, g\rangle^2, \langle a, e, c, g\rangle^3, \langle b, d, f, g\rangle^2, \langle b, f, d, g\rangle^4]$$



	ε	a	c	e	g
p_3	0	0	1	2	0
p_4	0	0	0	1	0
p_8	0	0	1	1	0

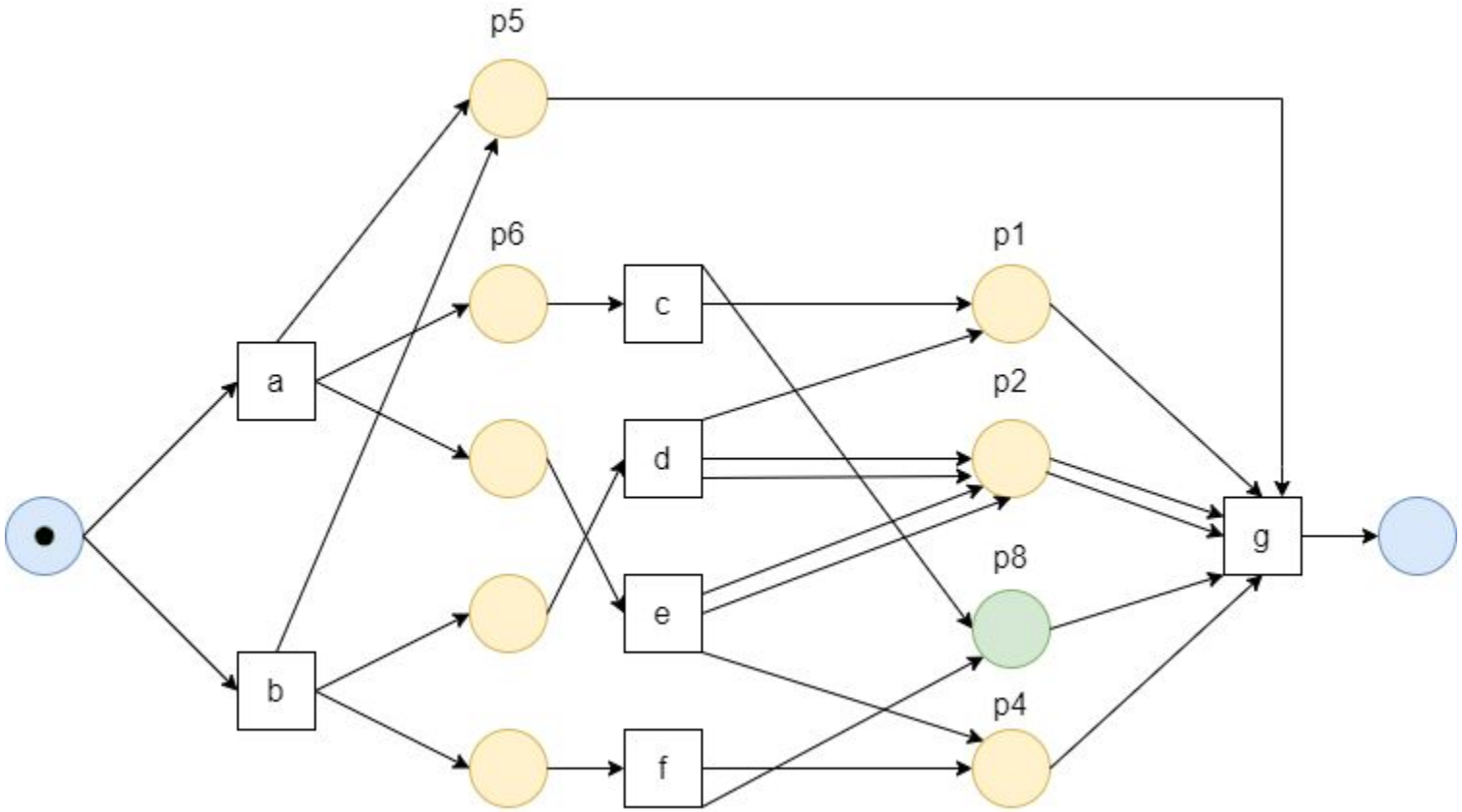
	ε	a	e	c	g
p_3	0	0	1	2	0
p_4	0	0	1	1	0
p_8	0	0	0	1	0

	ε	b	d	f	g
p_3	0	0	0	2	0
p_4	0	0	0	1	0
p_8	0	0	0	1	0

	ε	b	f	d	g
p_3	0	0	2	2	0
p_4	0	0	1	1	0
p_8	0	0	1	1	0

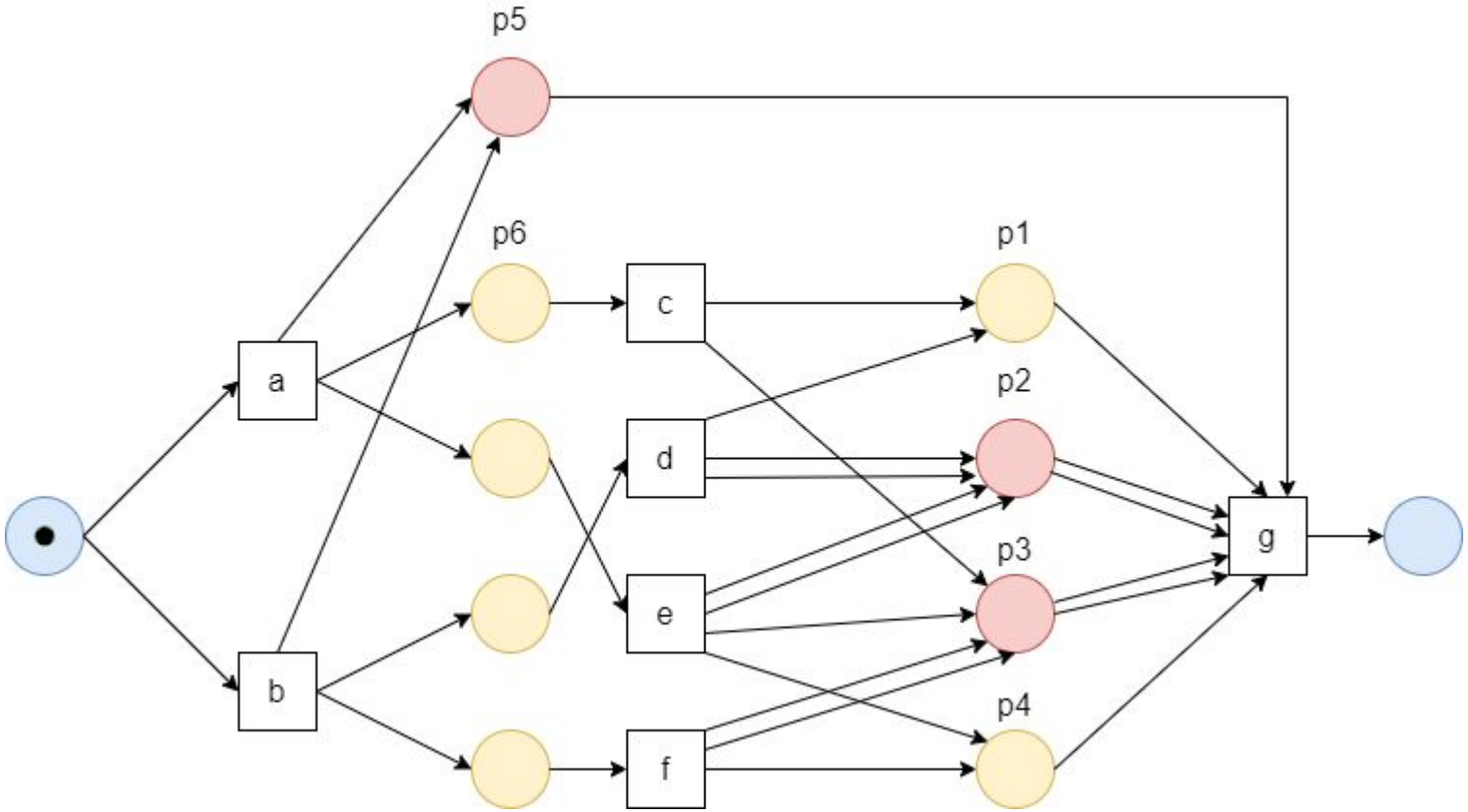
Removing Implicit Places: Extended Case

$$L = [\epsilon, \langle a, c, e, g \rangle^2, \langle a, e, c, g \rangle^3, \langle b, d, f, g \rangle^2, \langle b, f, d, g \rangle^4]$$



Removing Implicit Places: Undiscoverable implicit place

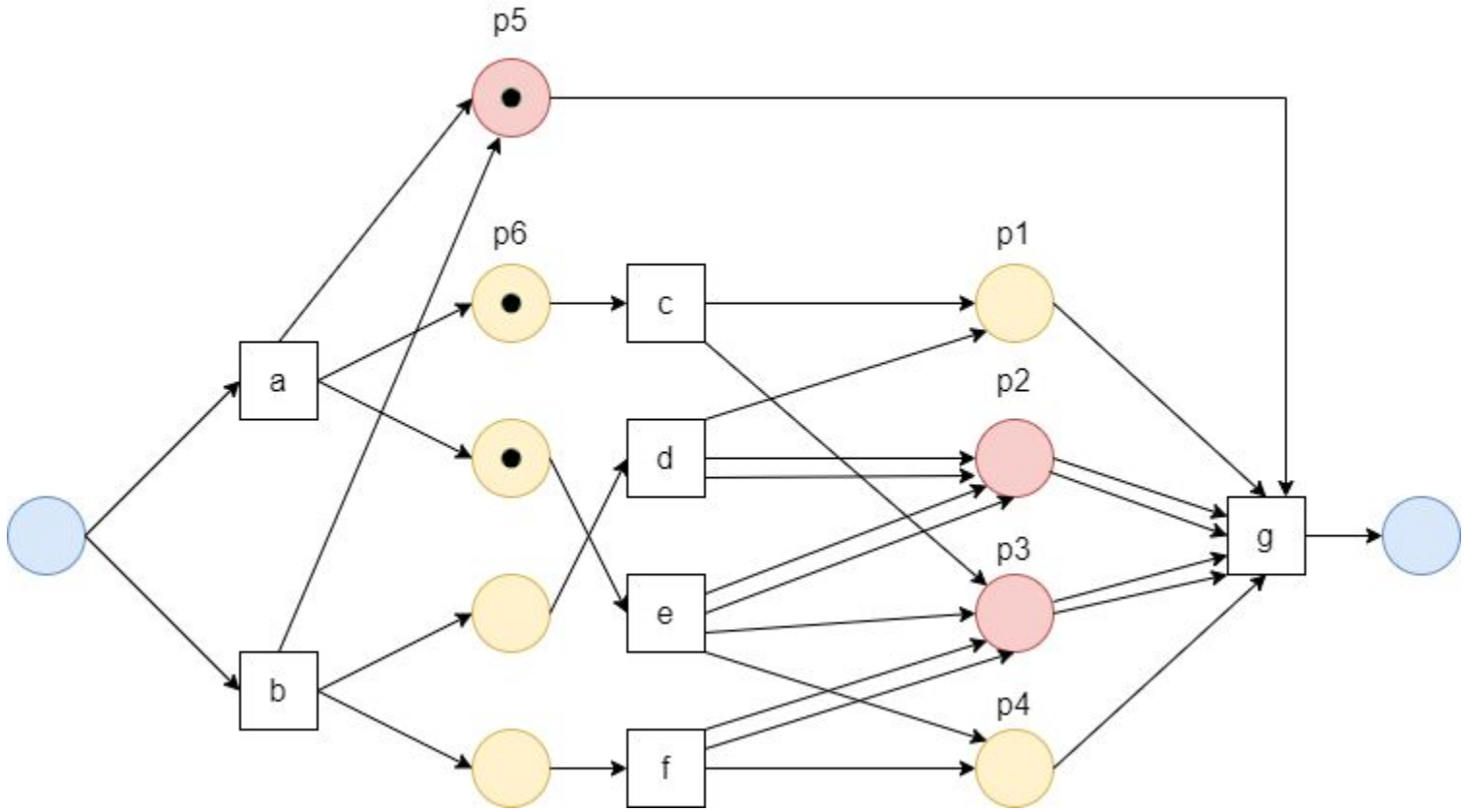
$$L = [\epsilon, \langle a, c, e, g\rangle^2, \langle a, e, c, g\rangle^3, \langle b, d, f, g\rangle^2, \langle b, f, d, g\rangle^4]$$



	ε	a	c	e	g
p_2	0				
p_1	0				
p_9					

Removing Implicit Places: Undiscoverable implicit place

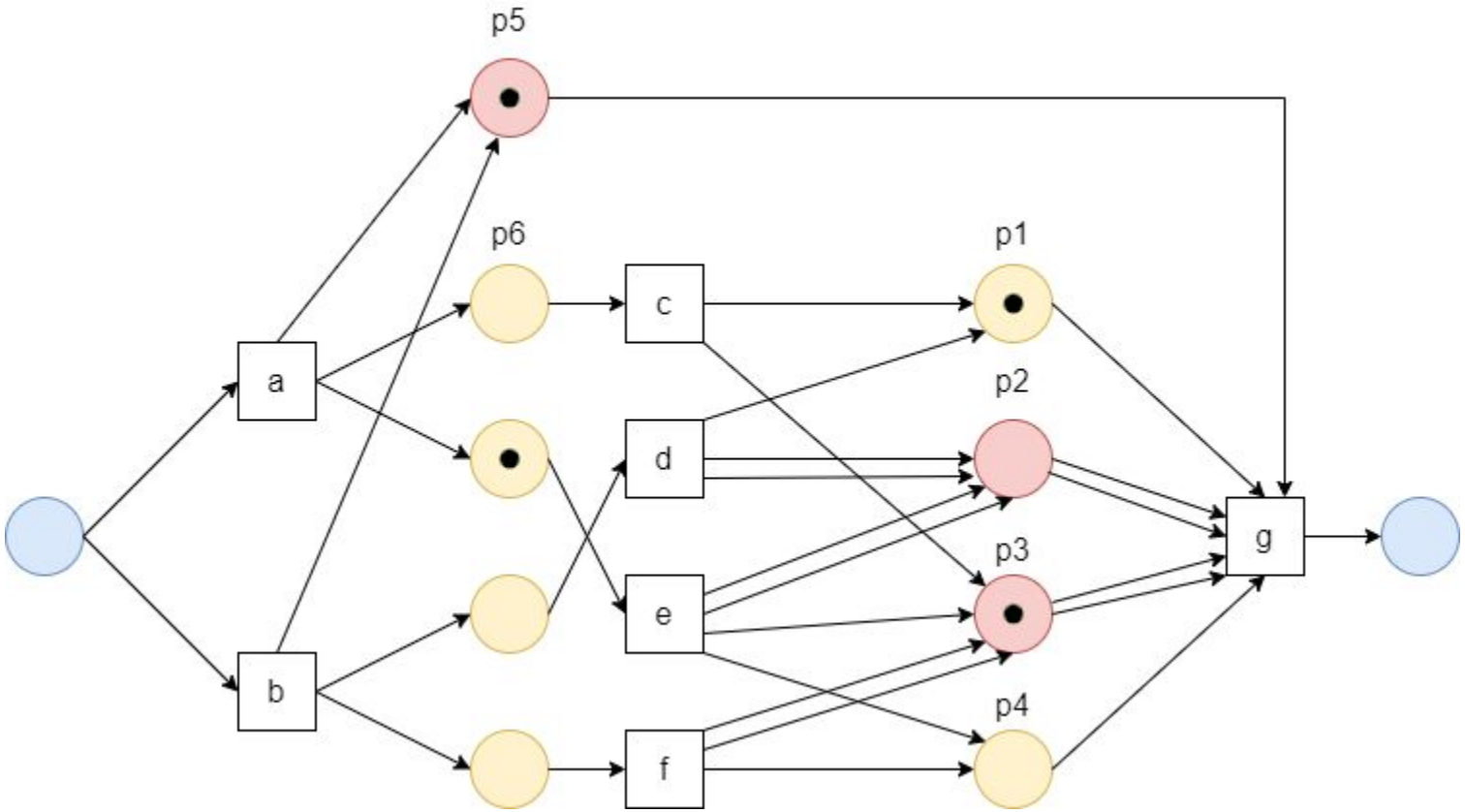
$$L = [\epsilon, \langle a, c, e, g\rangle^2, \langle a, e, c, g\rangle^3, \langle b, d, f, g\rangle^2, \langle b, f, d, g\rangle^4]$$



	ε	a	c	e	g
p_2	0	0			
p_1	0	0			
p_9					

Removing Implicit Places: Undiscoverable implicit place

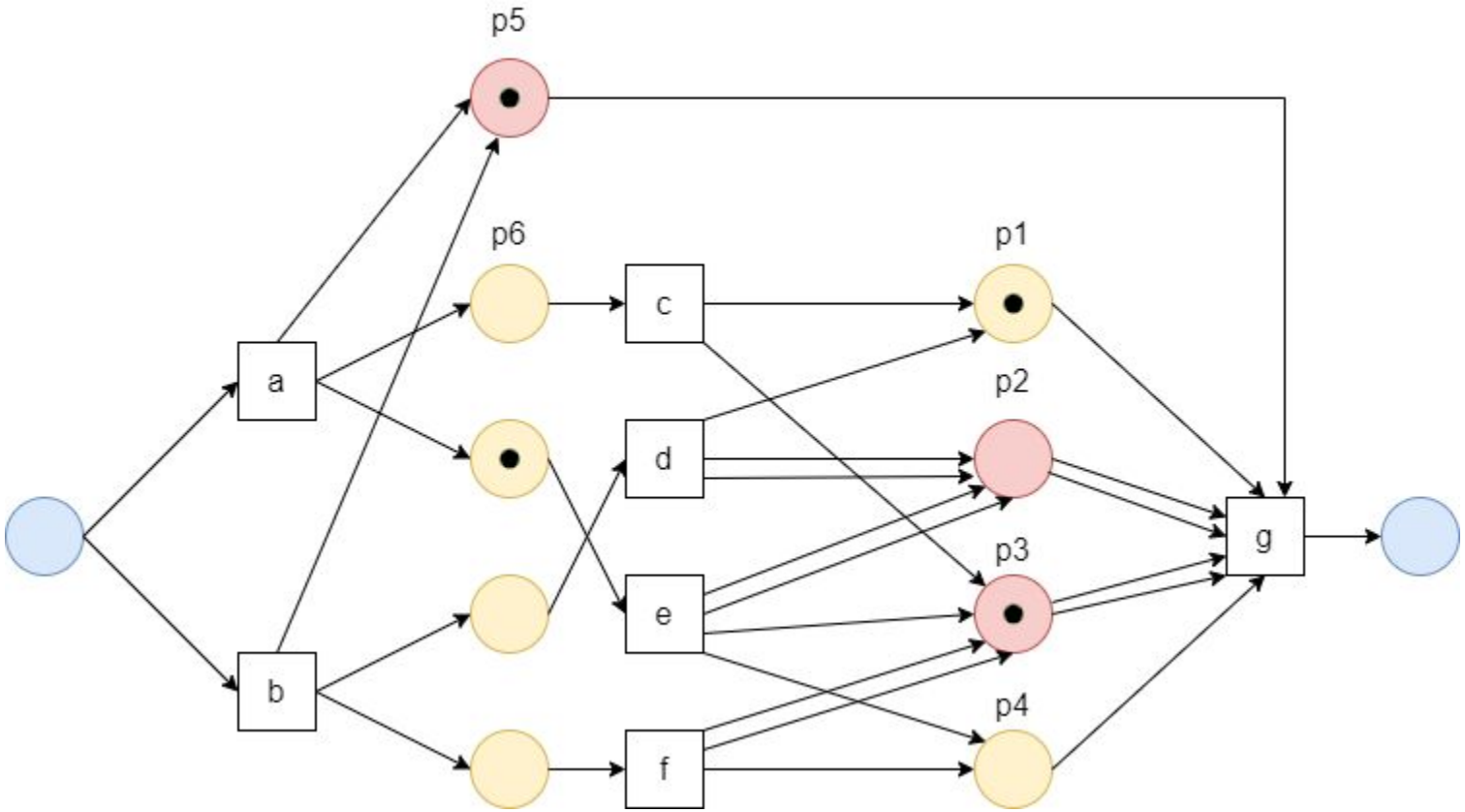
$$L = [\epsilon, \langle a, c, e, g\rangle^2, \langle a, e, c, g\rangle^3, \langle b, d, f, g\rangle^2, \langle b, f, d, g\rangle^4]$$



	ε	a	c	e	g
p_2	0	0	0		
p_1	0	0	1		
p_9	0	0	-1		

Removing Implicit Places: Undiscoverable implicit place

$$L = [\epsilon, \langle a, c, e, g\rangle^2, \langle a, e, c, g\rangle^3, \langle b, d, f, g\rangle^2, \langle b, f, d, g\rangle^4]$$



	ε	a	c	e	g
p_2	0	0	0		
p_1	0	0	1		
p_9	0	0	-1		

$x_{p2} > x_{p1}$ **does not hold!**

Application to the eST-Miner

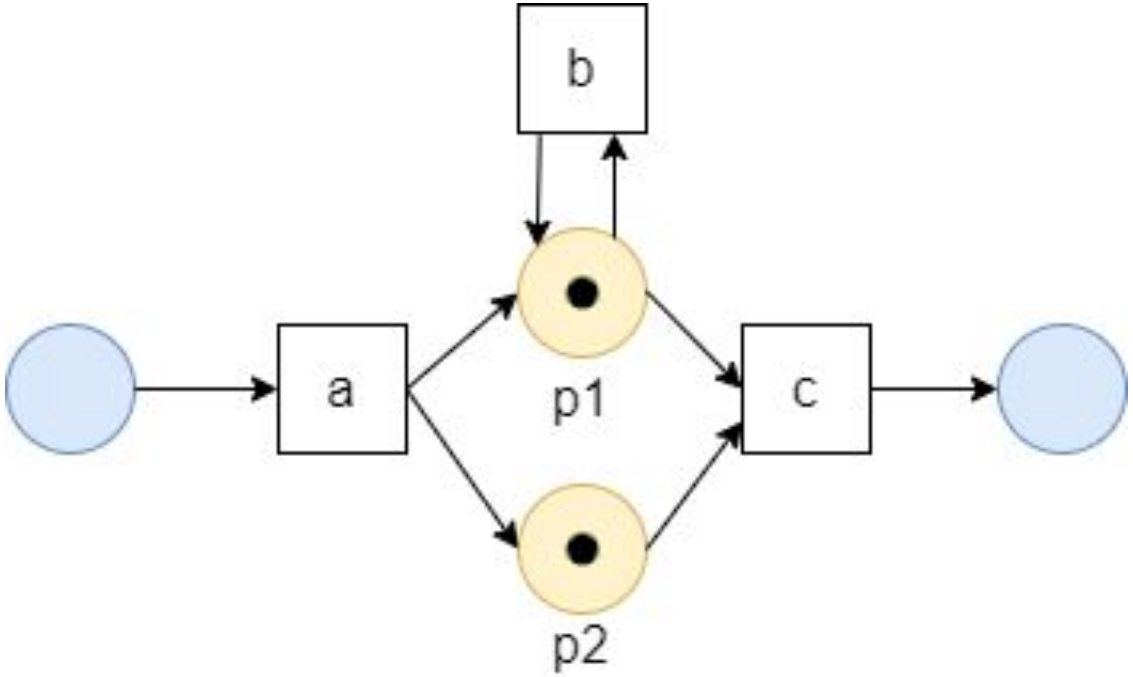
- Using the eST-Miner as a process discovery algorithm
- Candidate places are traversed and evaluated using token replay
- The discovery of a set of all *fitting* places is guaranteed
- A significant number of implicit places are also discovered
- Motivation for applying the implicit place removal technique

Application to the eST-Miner

- Benefitting from the eST-Miner as a space efficient algorithm
- Checking for the existence of places is not necessary
- Place comparisons occur very infrequently
- Final Place Removal (FPR)
- Concurrent Place Removal (CPR)

Challenges

eST-Miner allows for Petri nets with self-loops

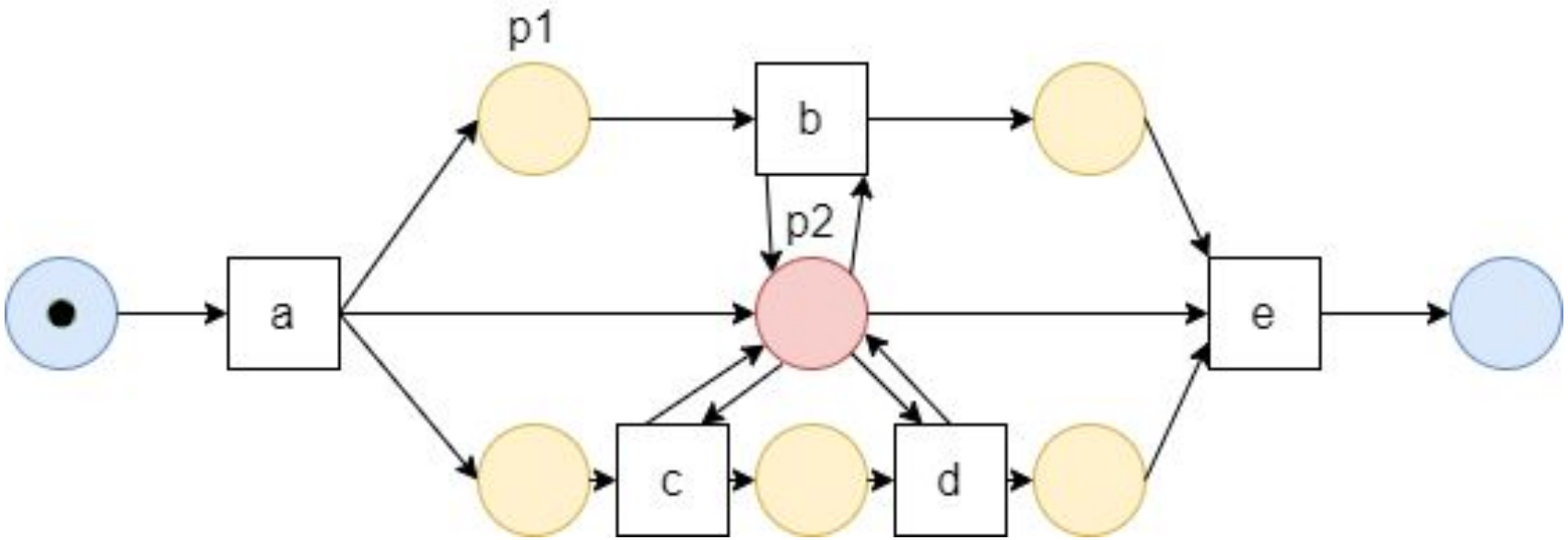


		b
p_1	1	1
p_2	1	1

		b
p_1	1	0/1
p_2	1	1/1

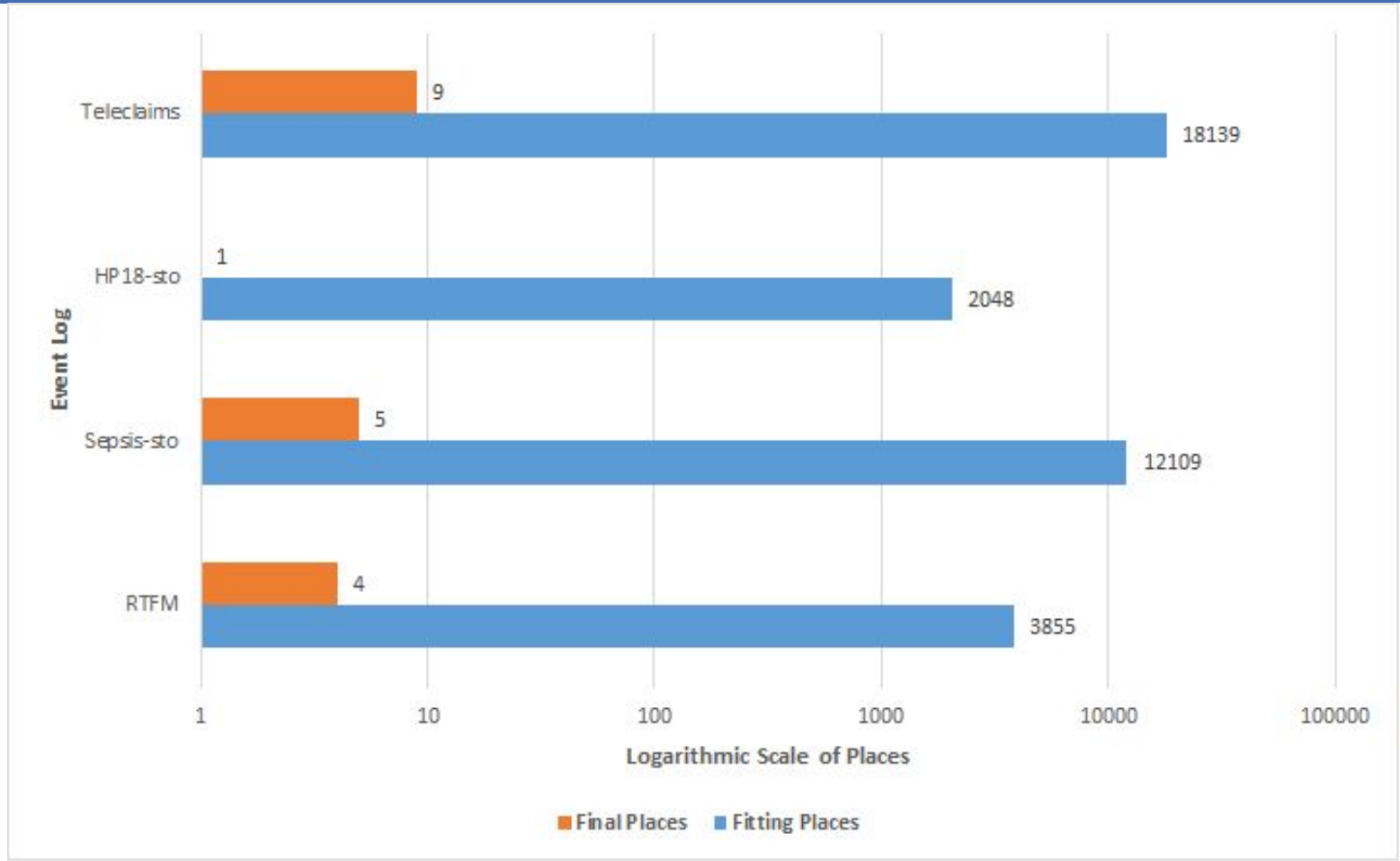
Challenges

Special case of places with self-loops in parallel constructs



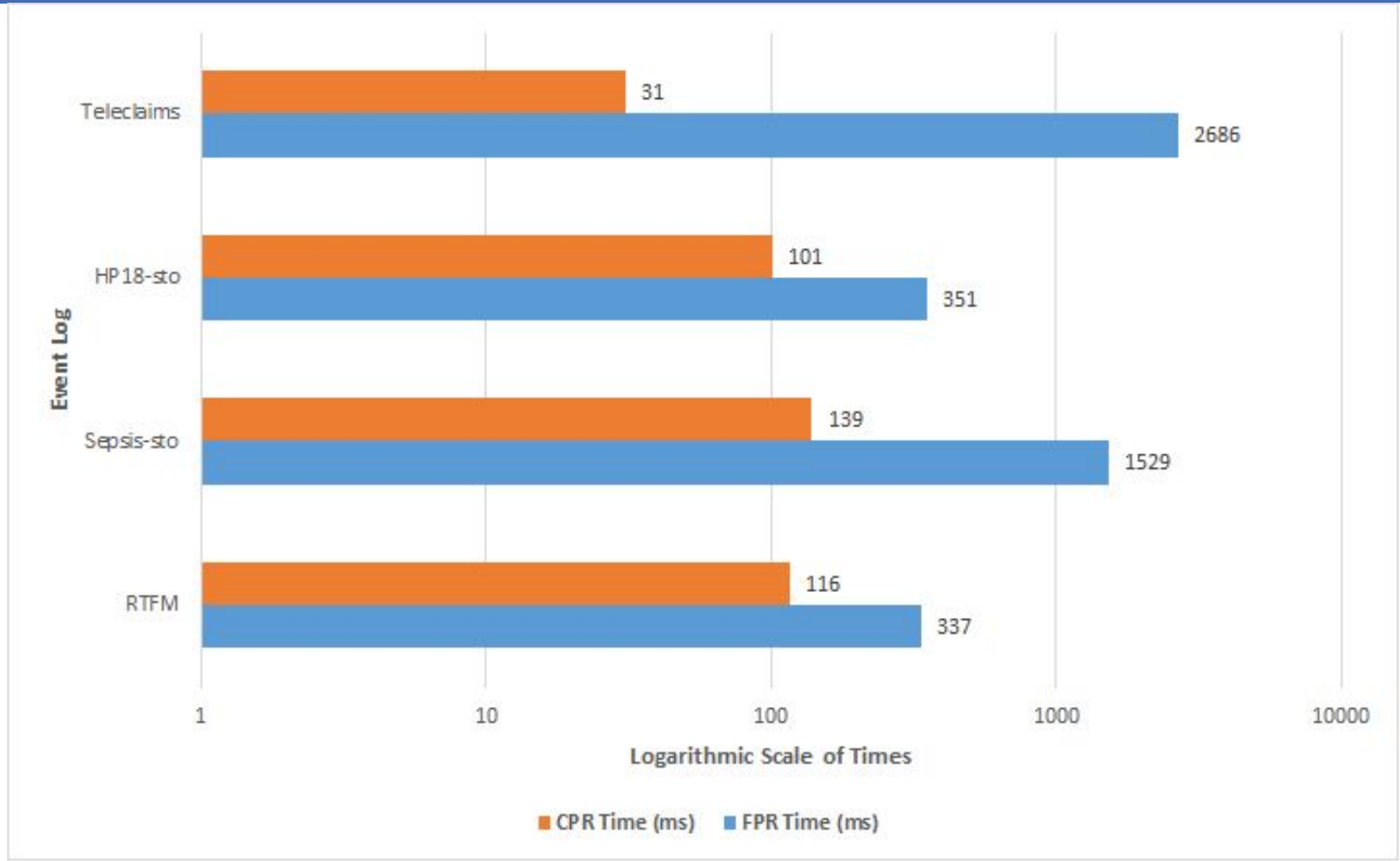
Evaluation: Space Efficiency

Remaining final places are significantly less than total fitting places



Evaluation: Time Efficiency

CPR is always significantly faster than FPR



Related Work

- [B. Berthomieu, D. Botlan, and S. Dal Zilio+ 20] Counting petri net markings from reduction equations. International Journal on Software Tools for Technology Transfer, 2020
- Complex Integer Linear Programming problem
- Developing a reduced Petri net architecture
- Highlighting the state space of a Petri net
- Post-processing step of the eST-Miner

Conclusion

- An approach to identify and remove implicit places from Petri nets
- Sequential and concurrent application schemes
- Combination with the eST-Miner process discovery algorithm
- Robust time and space efficiency of the CPR variant

Future Work

- Further investigations with the eST-Miner
  - Increasing the efficiency of the candidate traversal step
  - Returning results after a certain running time
- Choosing the order of place comparisons
- Solving the problem of self-loop places in parallel constructs
- Application to the Inductive-Miner process discovery algorithm

Thank you!

Questions?

References

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