Towards Ideal Semantics for Analyzing Stream Reasoning

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FAKULTÄT FÜR !NFORMATIK
Faculty of Informatics

What & Why

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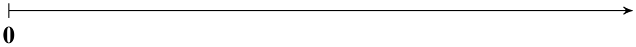
- Ideal
  - Idealization: Abstract from practical (operational) issues
  - Generalization: Uniform representation

Example: Trams and buses

Arrival times at different stations p_i



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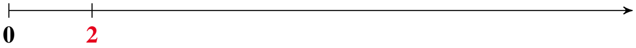

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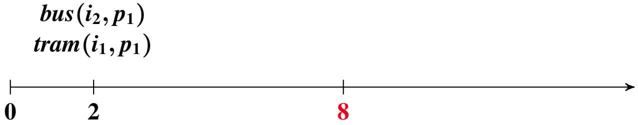

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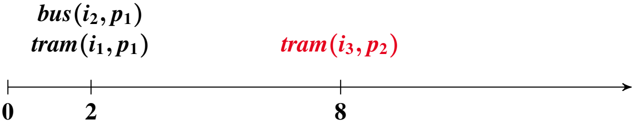

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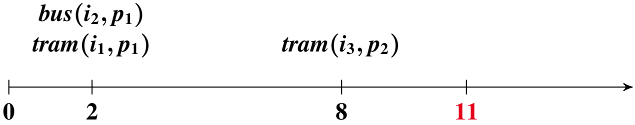

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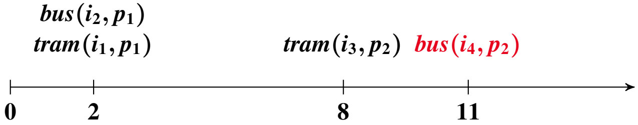

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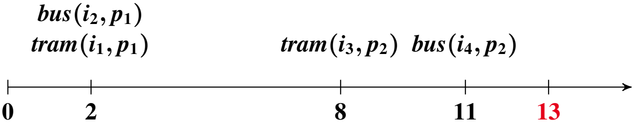

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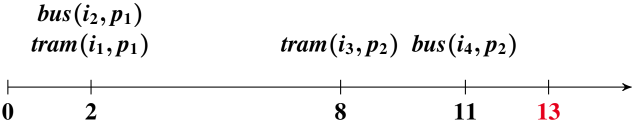

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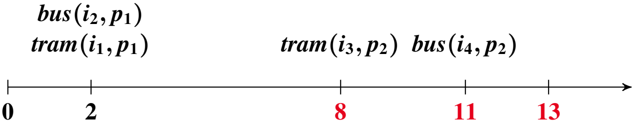

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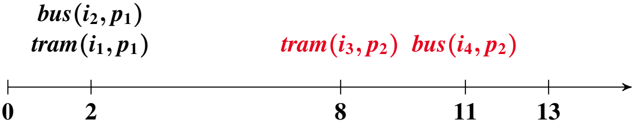

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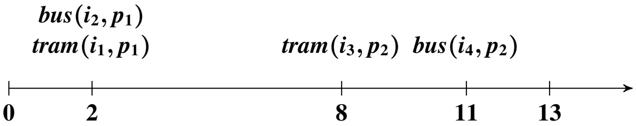

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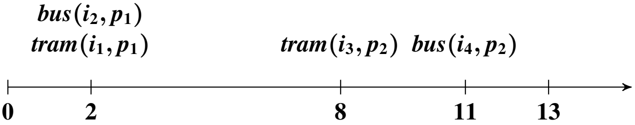

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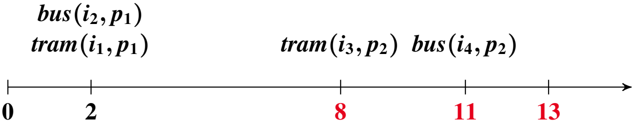

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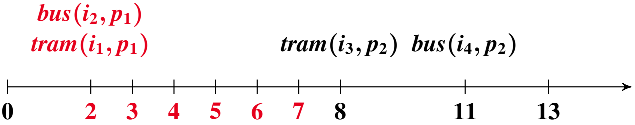

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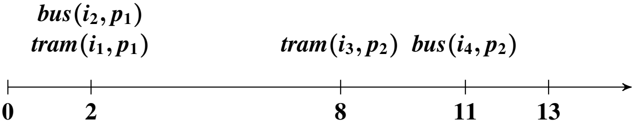

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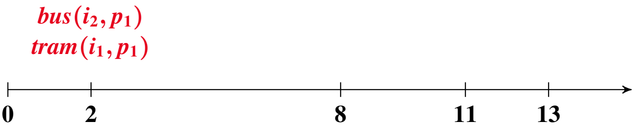

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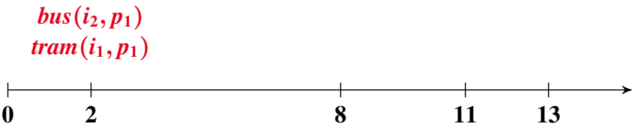

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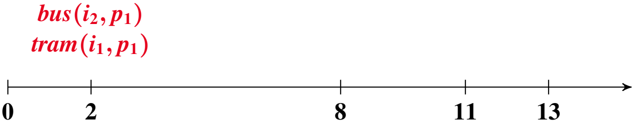

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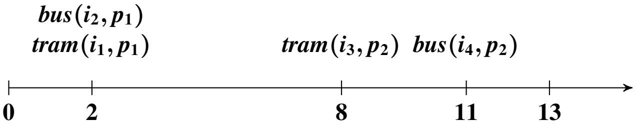

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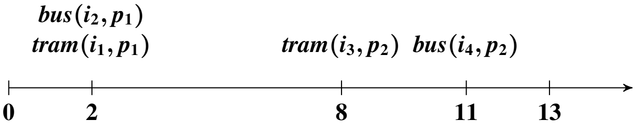

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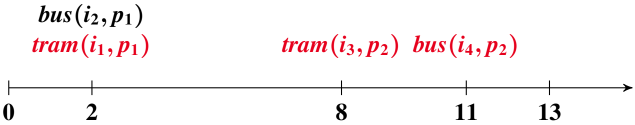

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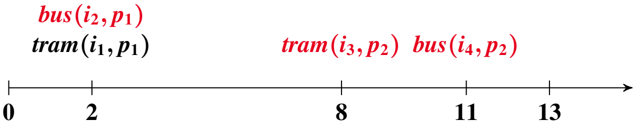

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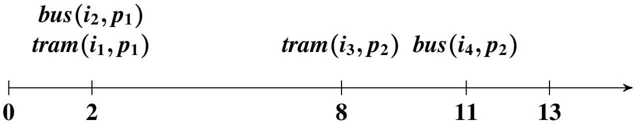

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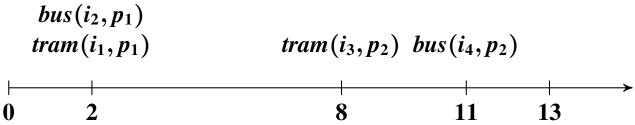

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- Partition-based
  - Apply tuple-based window on substreams

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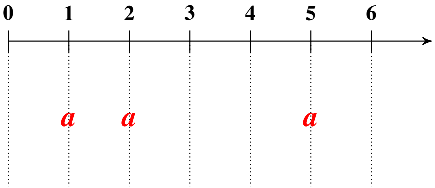
  - $w(S,t) \mapsto S'$
  - Stream S, time point $t \in \mathbb{N}$, new stream S'

Ideas for Time Reference

- Atoms a appearing in the stream at time points $1, 2, 5$



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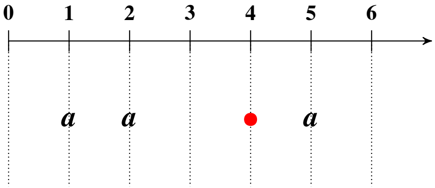

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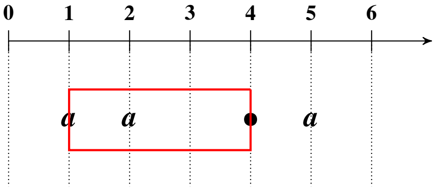

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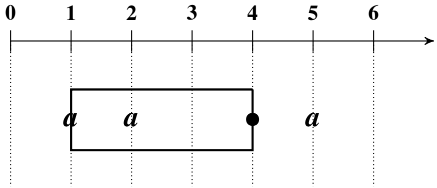

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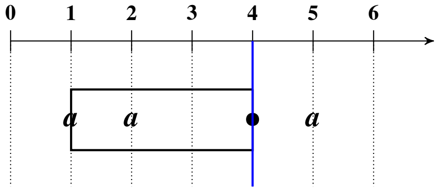

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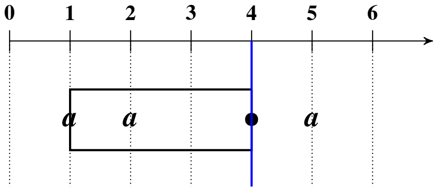

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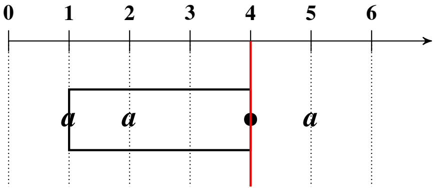

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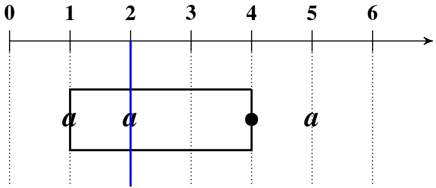

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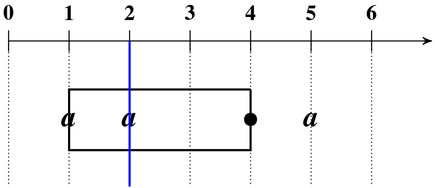

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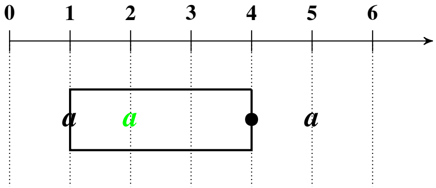

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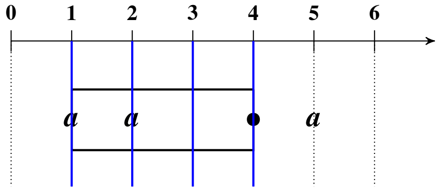

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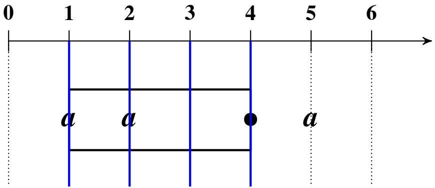

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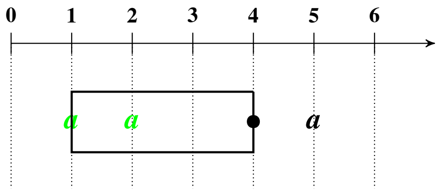

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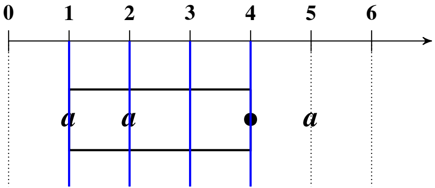

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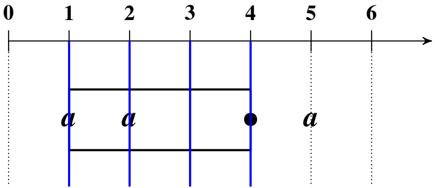

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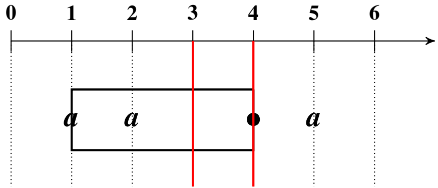

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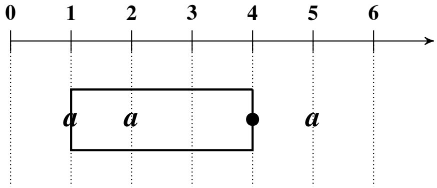

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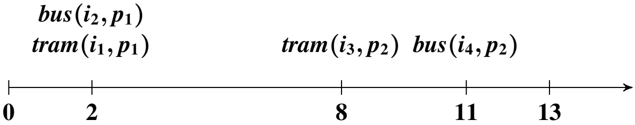
Streams



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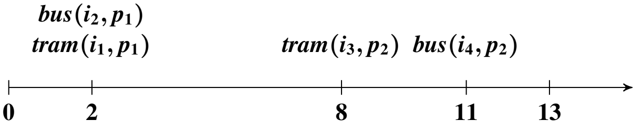

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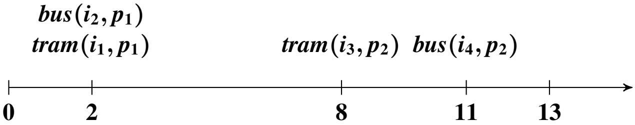

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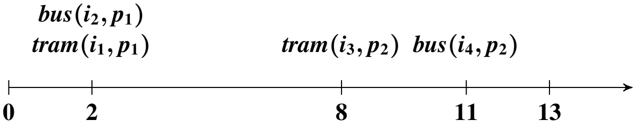

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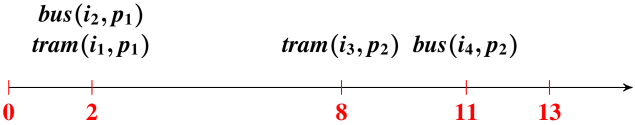

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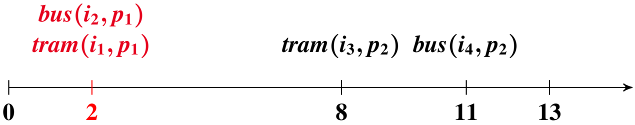

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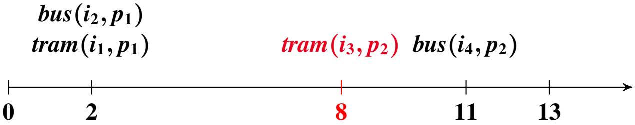

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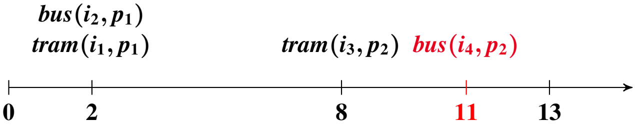

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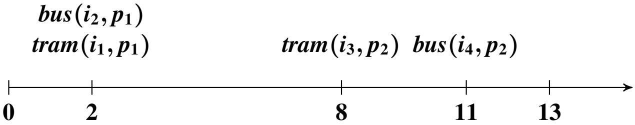

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Nested Windows and Stream Choice

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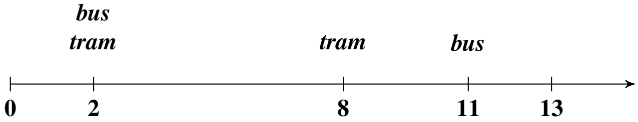

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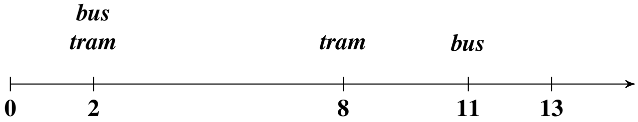

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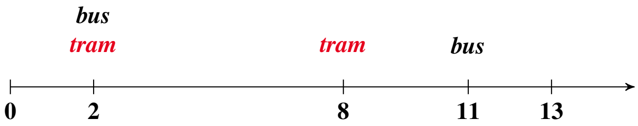

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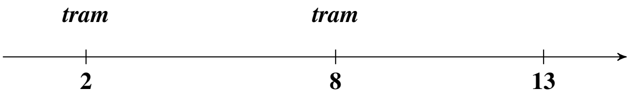

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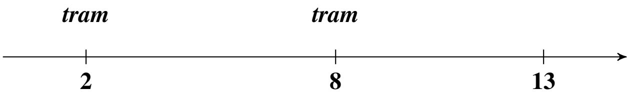

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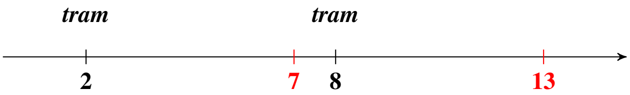

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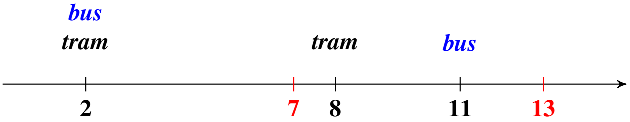

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$M, S, t \Vdash \alpha \wedge \beta$	iff	$M, S, t \Vdash \alpha$ and $M, S, t \Vdash \beta$,
$M, S, t \Vdash \alpha \vee \beta$	iff	$M, S, t \Vdash \alpha$ or $M, S, t \Vdash \beta$,
$M, S, t \Vdash \alpha \rightarrow \beta$	iff	$M, S, t \nVdash \alpha$ or $M, S, t \Vdash \beta$,
$M, S, t \Vdash \Diamond\alpha$	iff	$M, S, t' \Vdash \alpha$ for some $t' \in T_S$,
$M, S, t \Vdash \Box\alpha$	iff	$M, S, t' \Vdash \alpha$ for all $t' \in T_S$,
$M, S, t \Vdash @_{t'}\alpha$	iff	$M, S, t' \Vdash \alpha$ and $t' \in T_S$,
$M, S, t \Vdash \boxplus_i\alpha$	iff	$M, S', t \Vdash \alpha$ where $S' = \hat{w}_i(S_M, S, t)$.

Queries

- Query $\alpha[t]$: "$M, S_M, t \Vdash \alpha$"?

Queries

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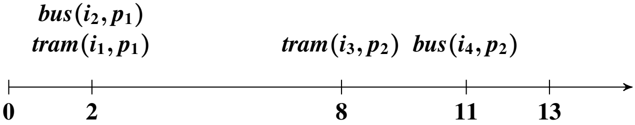

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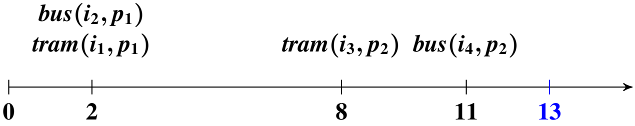

$$M, S_M, 13 \Vdash bus(i_2, p_1)?$$

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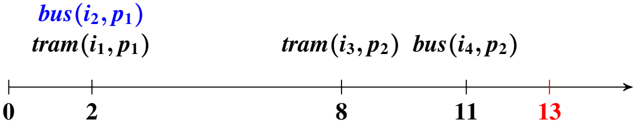

$$M, S_M, \mathbf{13} \nVdash bus(i_2, p_1), \text{ since } bus(i_2, p_1) \notin \upsilon(\mathbf{13})$$

Queries

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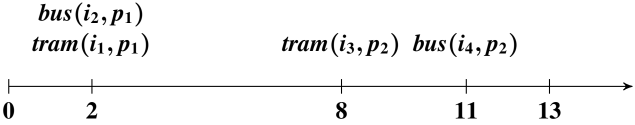

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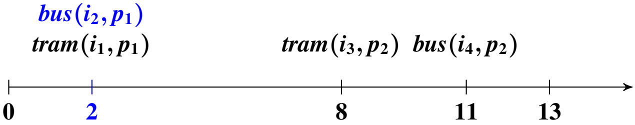
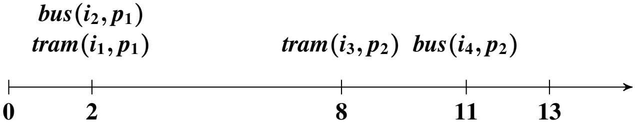


$$M, S_M, 13 \Vdash \Diamond bus(i_2, p_1), \text{ since } \exists t' \in T_{S_M} \text{ s.t. } bus(i_2, p_1) \in \upsilon(t')$$

Queries

- Query $\alpha[t]$: "$M, S_M, t \Vdash \alpha$"? $\boxplus_1$: last 5 min



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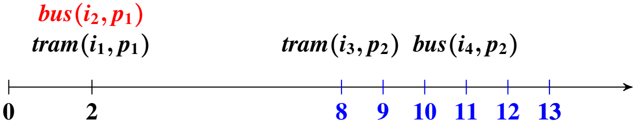

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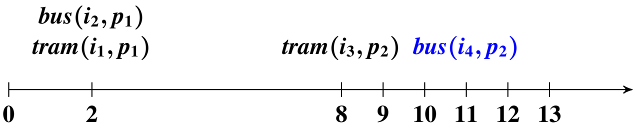

$$M, S_M, 13 \Vdash \boxplus_1 \Diamond\, bus(i_4, p_2)$$

Non-ground Queries

- Non-ground query: Assignments s.t. substitution hold

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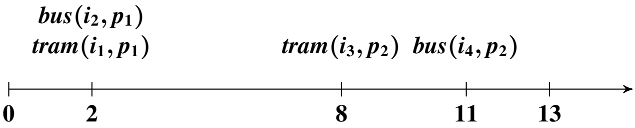

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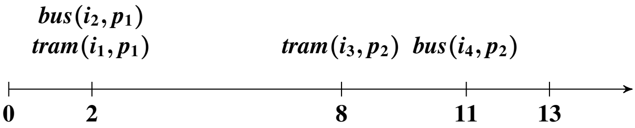

$$M, S_M, 13 \Vdash \boxplus_1 \Diamond bus(X, P)?$$

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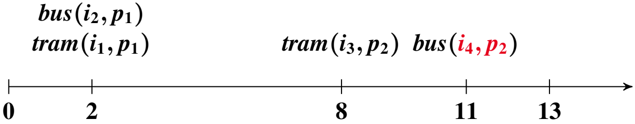

$$M, S_M, 13 \Vdash \boxplus_1 \Diamond bus(X, P)?$$

$$X \mapsto i_4,\ P \mapsto p_2$$

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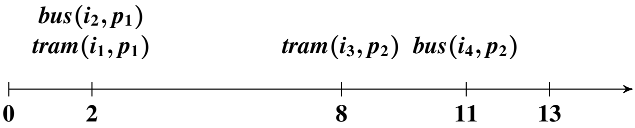

$$M, S, U \Vdash \boxplus_1 \Diamond bus(i_2, p_1)?$$

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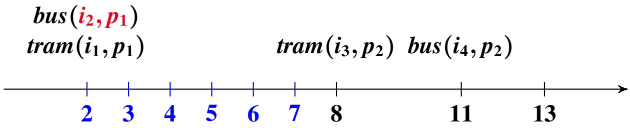

$$M, S, U \Vdash \boxplus_1 \Diamond bus(i_2, p_1)?$$

$$U \mapsto 2, \ldots, 7$$

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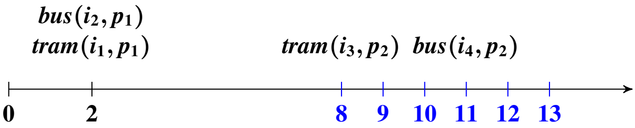

$$M, S_M, 13 \Vdash \boxplus_1(\Diamond tram(X,P) \wedge \Diamond bus(Y,P))?$$

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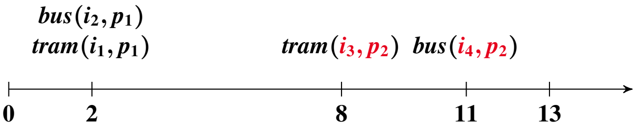

$$M, S_M, 13 \Vdash \boxplus_1(\Diamond tram(X, P) \land \Diamond bus(Y, P))?$$

$$X \mapsto i_3,\ P \mapsto p_2,\ Y \mapsto i_4$$

Non-ground Queries

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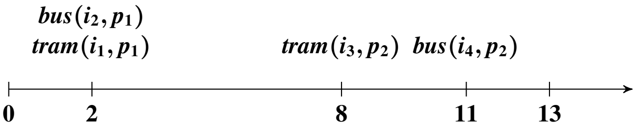

$$M, S_M, U \Vdash \boxplus_1 \Diamond (tram(X,P) \ \wedge \ bus(Y,P))?$$

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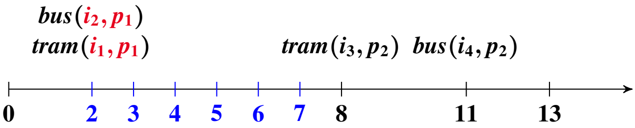

$$M, S_M, U \Vdash \boxplus_1 \Diamond(tram(X, P) \wedge bus(Y, P))?$$

$$U \mapsto 2, \ldots, 7 \quad \times \quad X \mapsto i_1, P \mapsto p_1, Y \mapsto i_2$$

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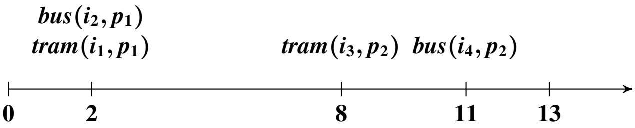

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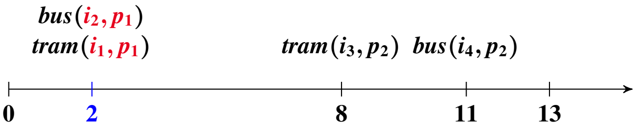
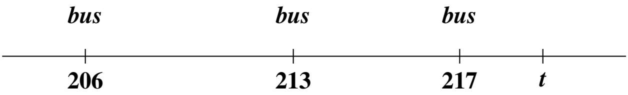


$$M, S_M, 13 \Vdash @_U(tram(X, P)) \land bus(Y, P))?$$

$$U \mapsto 2, \quad X \mapsto i_1, P \mapsto p_1, Y \mapsto i_2$$

Example: Nested Window

- “In the last hour, did a bus always appear in the last 5 minutes?”



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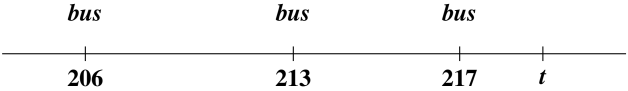

- $\boxplus_i$: time-based window for last i minutes

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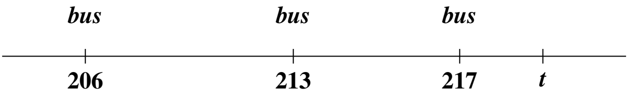

- $\boxplus_i$: time-based window for last i minutes
- Query: $\boxplus_{60}$

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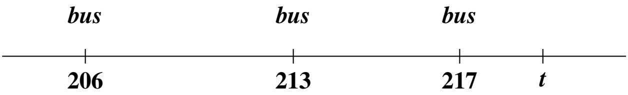

- $\boxplus_i$: time-based window for last i minutes
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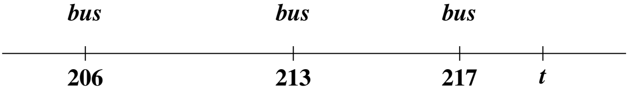

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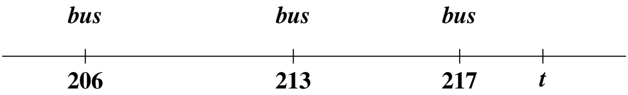

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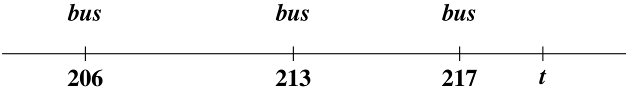

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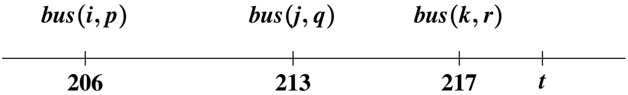

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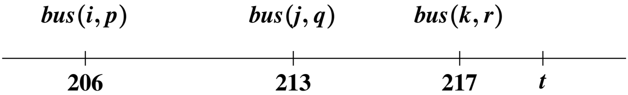

- $\boxplus_i$: time-based window for last i minutes
- Query: $\boxplus_{60} \Box \boxplus_5 \Diamond\, bus$
- Limitation: $\boxplus_{60} \Box \boxplus_5 \Diamond\, bus(X, P)$
  - Result: List of fixed combinations X, P
  - Need a rule: $some\_bus \leftarrow bus(X, P)$
  - Then: $\boxplus_{60} \Box \boxplus_5 \Diamond some\_bus$

Conclusion Stream

- Past

Conclusion Stream

- Past: Lack of theoretical underpinning for stream reasoning

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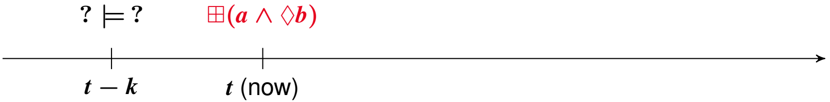
- Now

Conclusion Stream



- Past: Lack of theoretical underpinning for stream reasoning
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  - time reference / time abstraction

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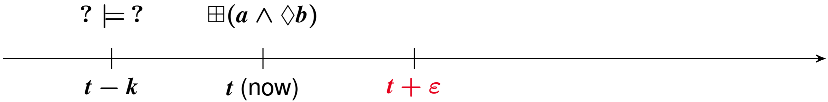

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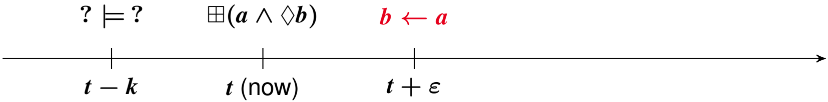

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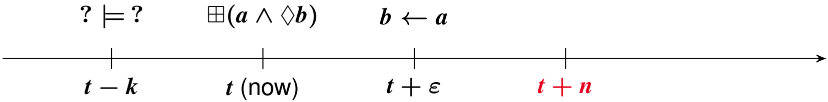

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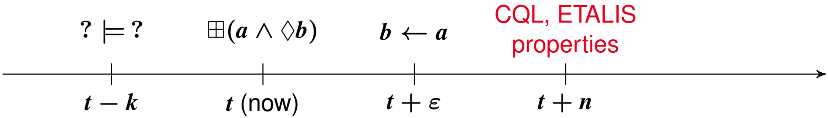

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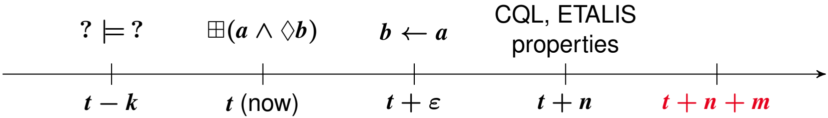

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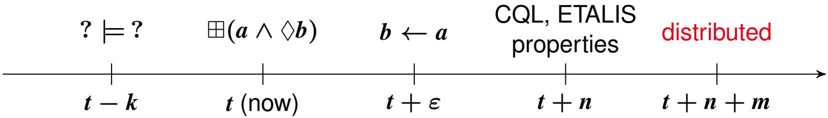

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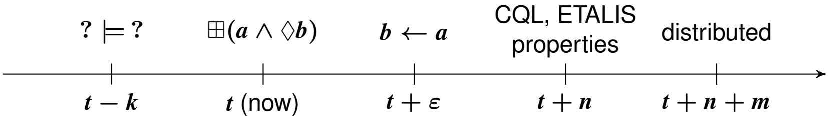
Conclusion Stream



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To je ono.

(That's it.)

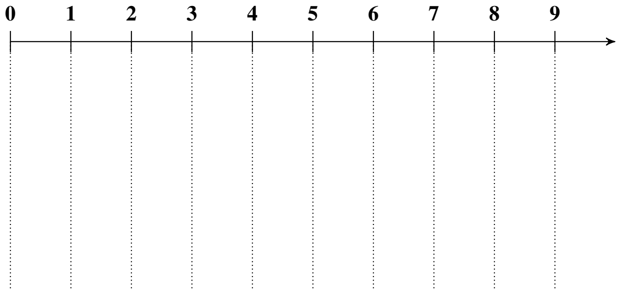
Time-based window

- Example

  ℓ 2 time points into the past

  u 1 time points into the future

  d 3 step size (slide parameter)



●: query times t ×: pivot points t'

Time-based window

- Example: Query time $t = 4$
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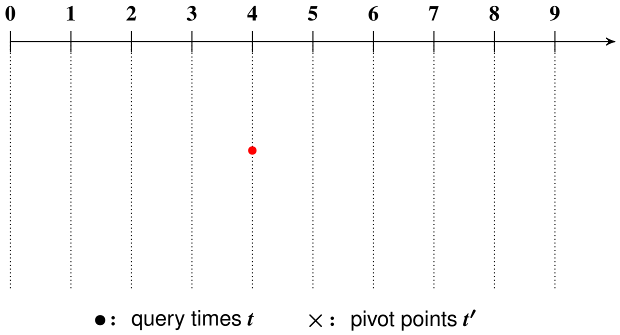

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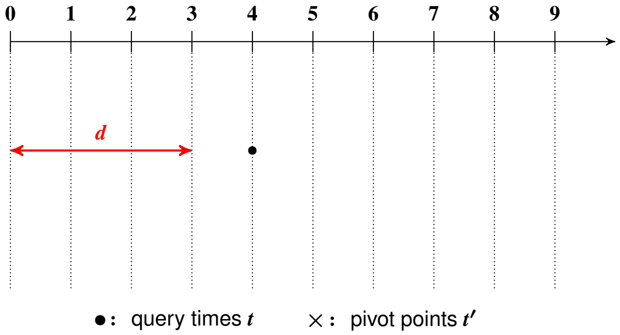

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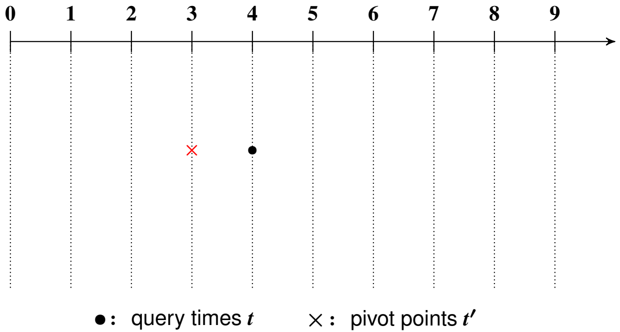

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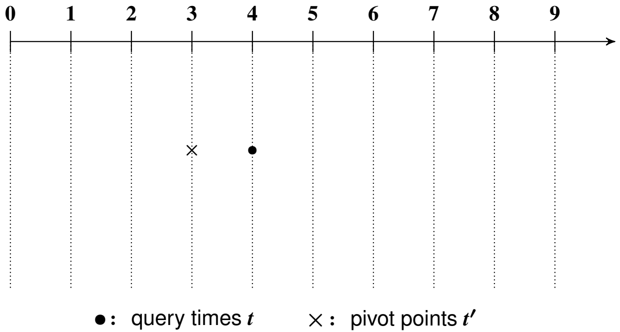

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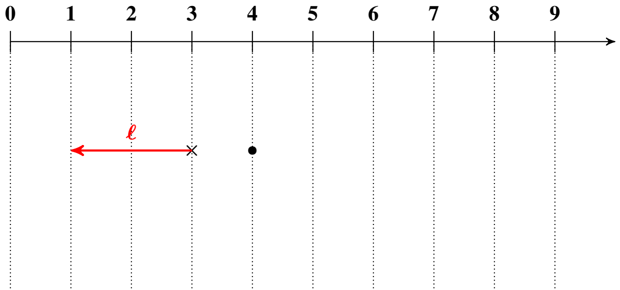

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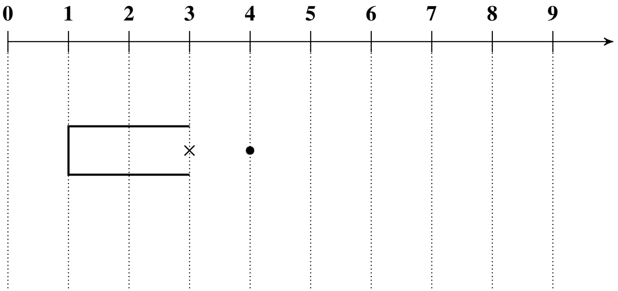

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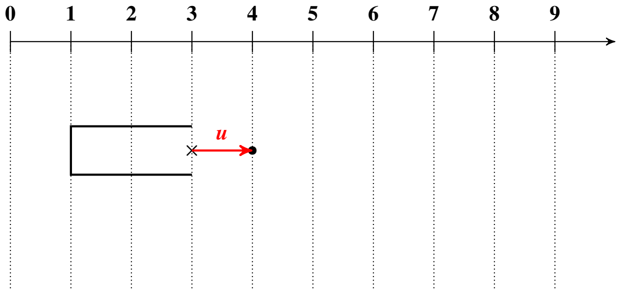

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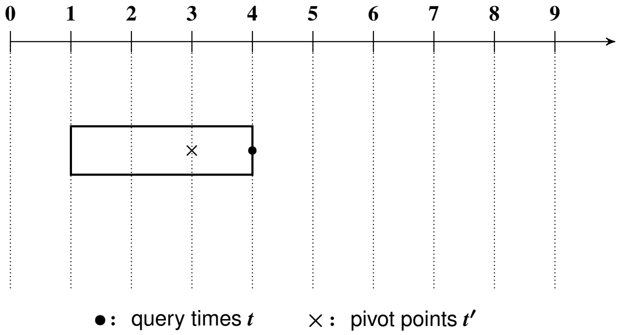
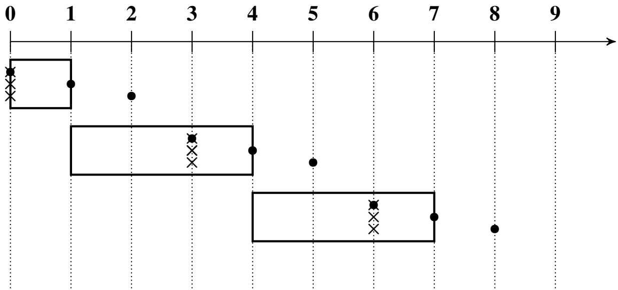
  - d 3 step size (slide parameter)



Time-based window

- Example
  - ℓ 2 time points into the past
  - u 1 time points into the future
  - d 3 step size (slide parameter)



●: query times t ×: pivot points t'