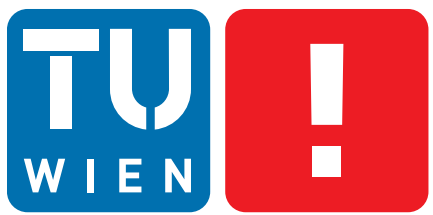
Answer Update for Rule-based Stream Reasoning

Harald Beck Minh Dao-Tran Thomas Eiter

International Joint Conference on Artificial Intelligence

July 30, 2015



FAKULTÄT
FÜR !NFORMATIK

Faculty of Informatics

Overview

LARS: **L**ogic-based Framework for **A**nalyzing **R**easoning over **S**tream.

Overview

LARS: **L**ogic-based Framework for **A**nalyzing **R**easoning over **S**tream.

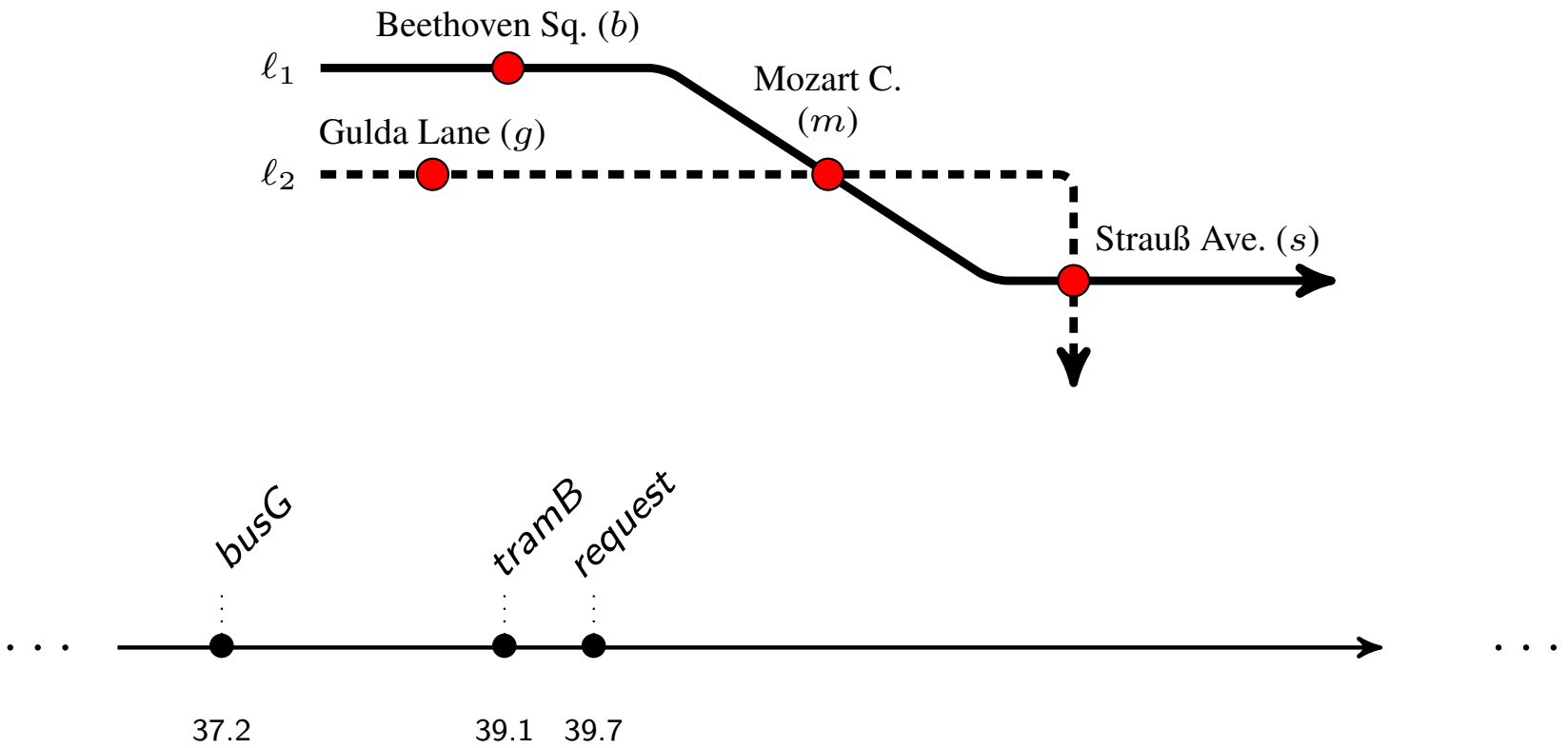
$\Rightarrow$ **Incremental algorithm** for computing answer streams of **stream-stratified** LARS programs.

Overview

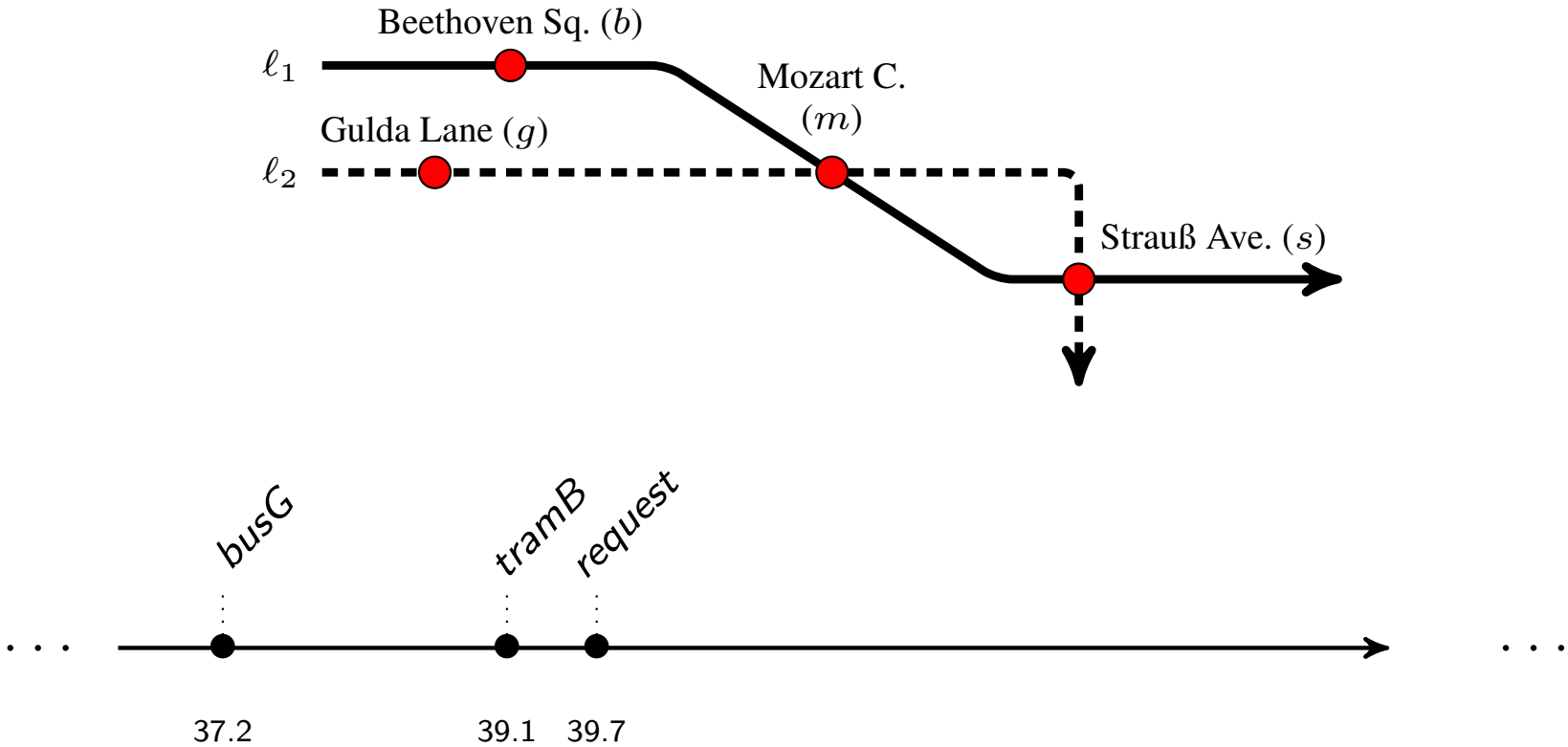
LARS: **L**ogic-based Framework for **A**nalyzing **R**easoning over **S**tream.

$\Rightarrow$ **Incremental algorithm** for computing answer streams of **stream-stratified** LARS programs.

LARS in a Nutshell

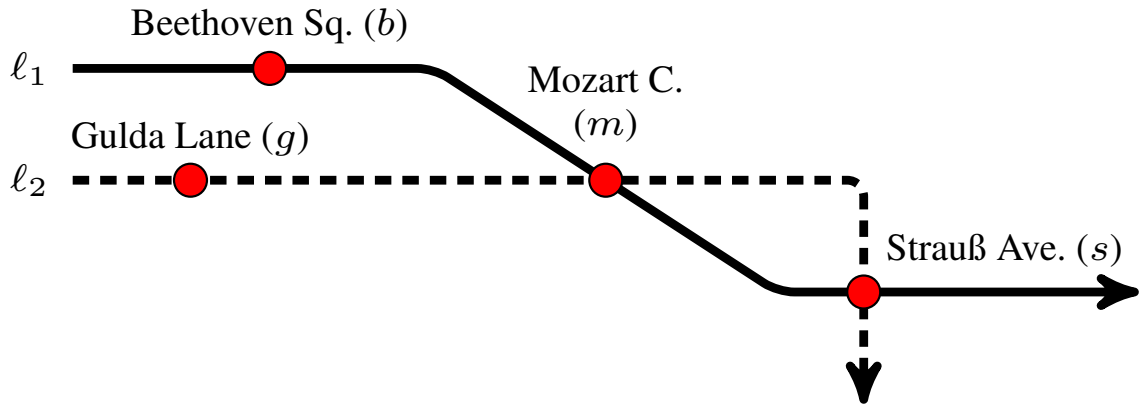


LARS in a Nutshell



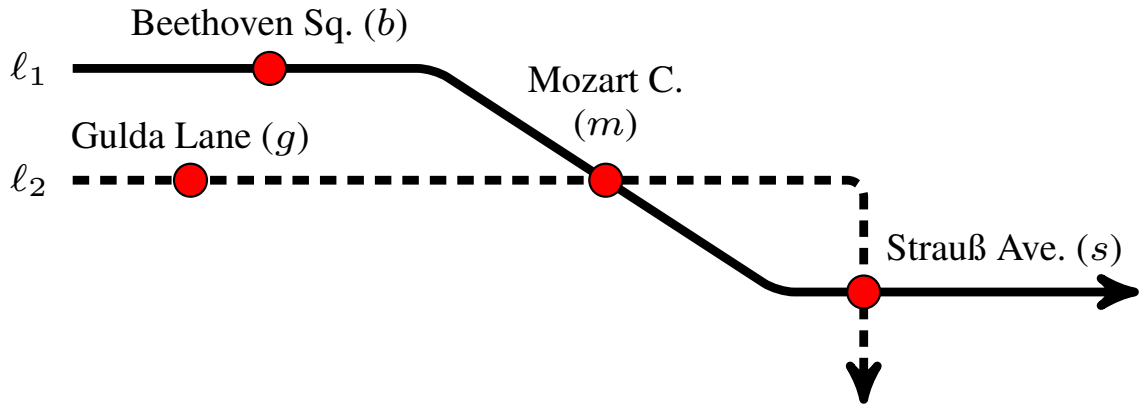
$@_{37.2m}busG$

LARS in a Nutshell



$\boxplus^{3m}@_{37.2m}busG$

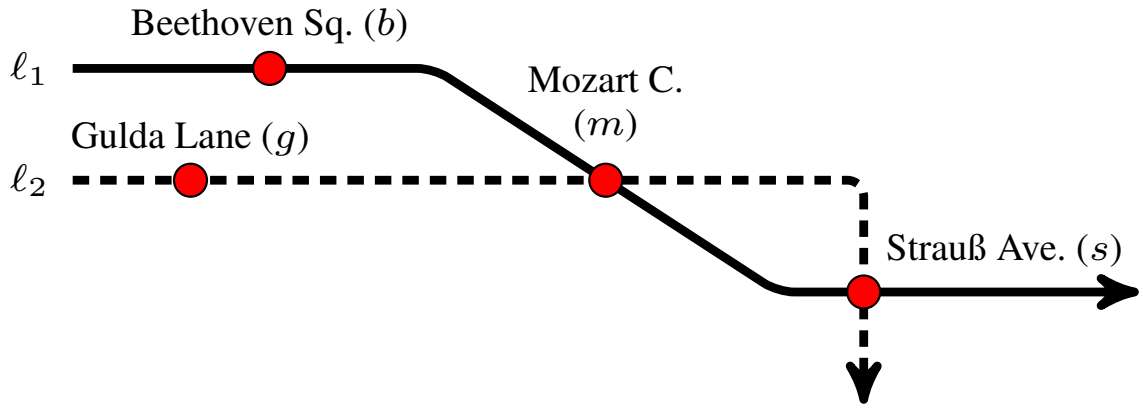
LARS in a Nutshell

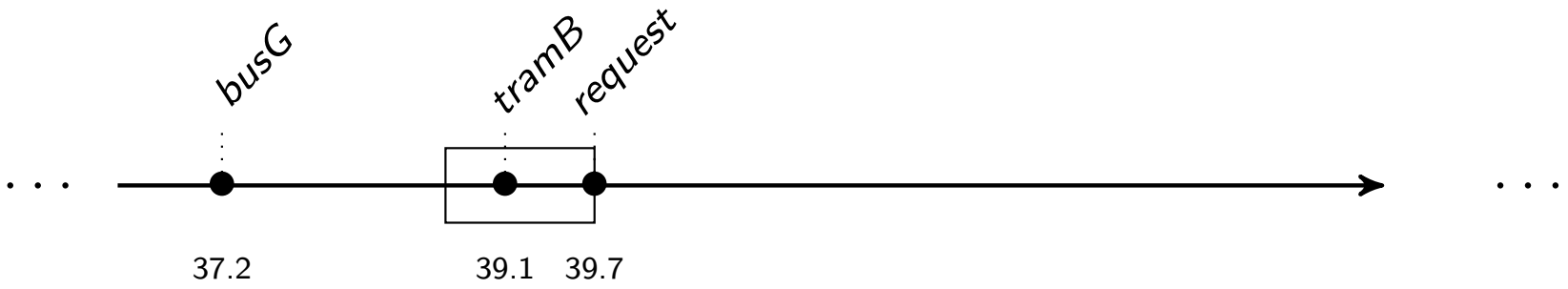


$\boxplus^{3m} @_T busG$

$\boxplus^{5m} @_T tramB$

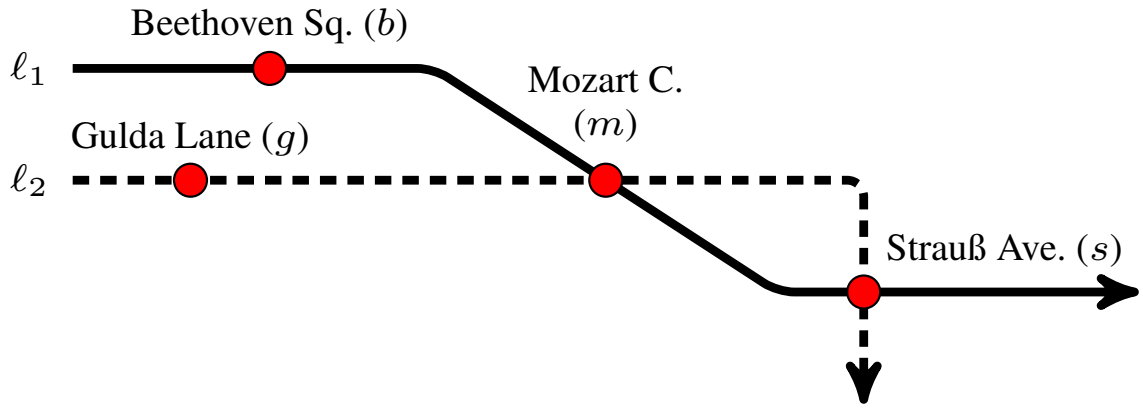
LARS in a Nutshell

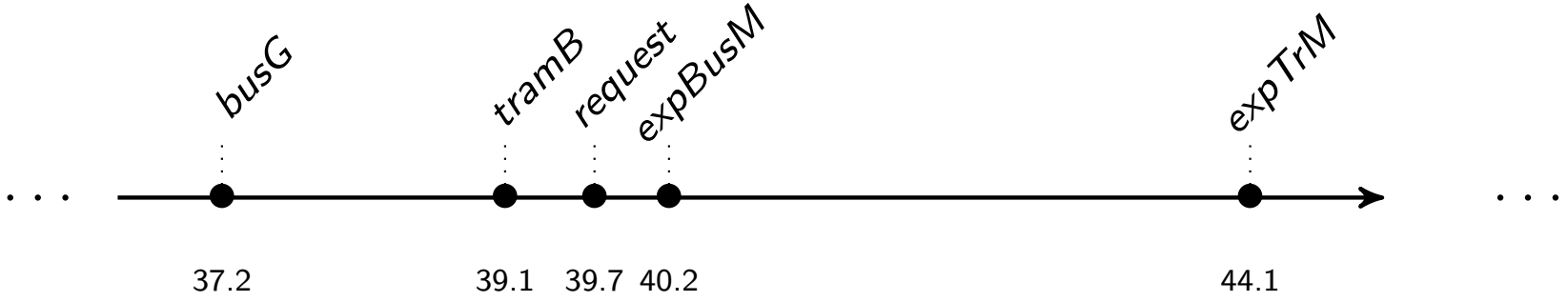




$\boxplus^{1m} \Diamond request.$

LARS in a Nutshell





$@_{T+3m}\mathit{expBusM} \leftarrow \boxplus^{3m} @_T\mathit{busG}, \text{not } \boxplus^{3m}\Diamond\mathit{jam}, \mathit{on}.$

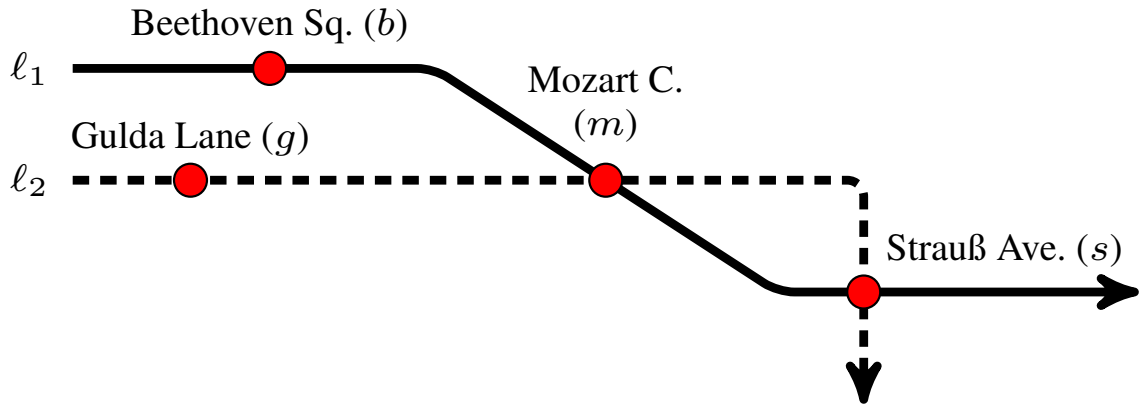
$@_{T+5m}\mathit{expTrM} \leftarrow \boxplus^{5m} @_T\mathit{tramB}, \mathit{on}.$

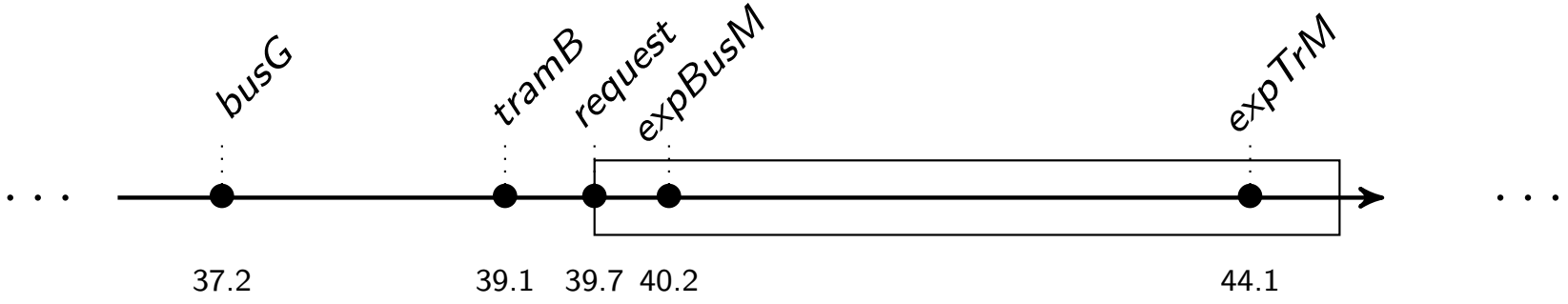
$\mathit{on} \leftarrow \boxplus^{1m} \Diamond\mathit{request}.$

$\mathit{takeBusM} \leftarrow \boxplus^{+5m} \Diamond\mathit{expBusM}, \text{not } \mathit{takeTrM}.$

$\mathit{takeTrM} \leftarrow \boxplus^{+5m} \Diamond\mathit{expTrM}, \text{not } \mathit{takeBusM}.$

LARS in a Nutshell

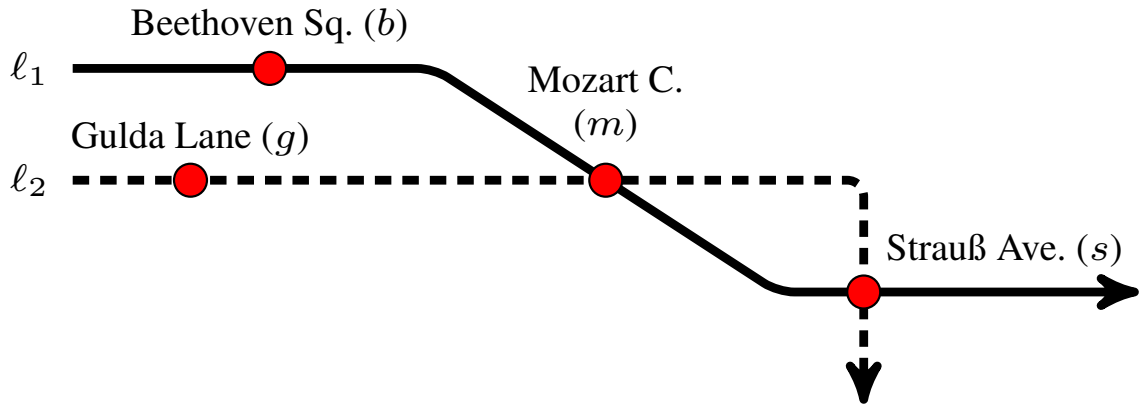


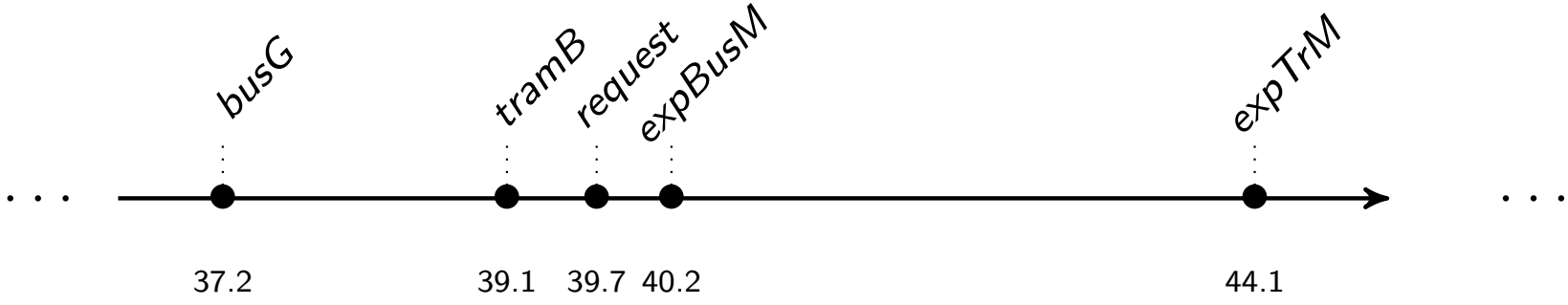


$\boxplus^{+5m}\ \Diamond expBusM$

$\boxplus^{+5m}\ \Diamond expTrM$

LARS in a Nutshell

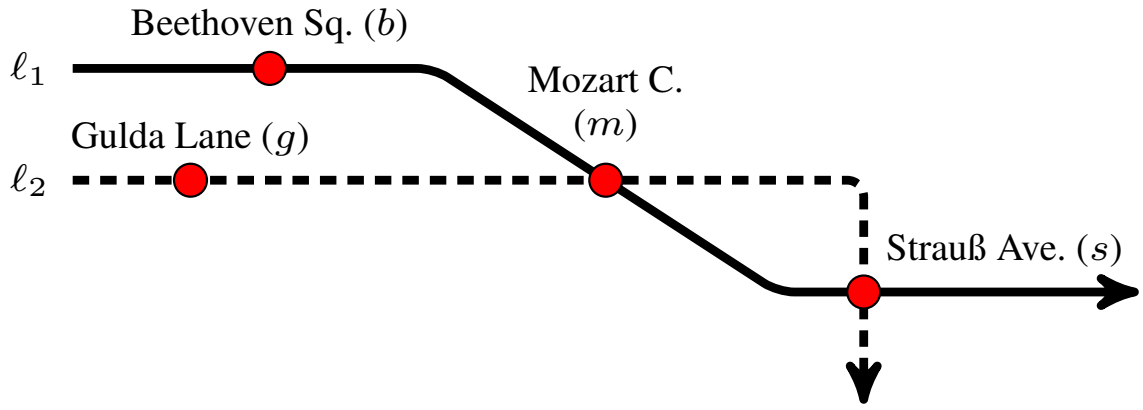


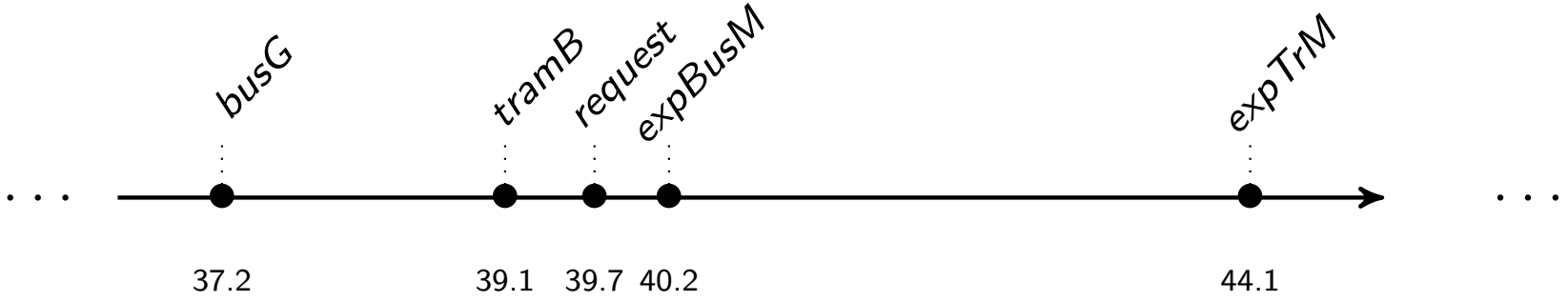


$takeBusM \leftarrow \boxplus^{+5m} \Diamond expBusM$, not $takeTrM$.

$takeTrM \leftarrow \boxplus^{+5m} \Diamond expTrM$, not $takeBusM$.

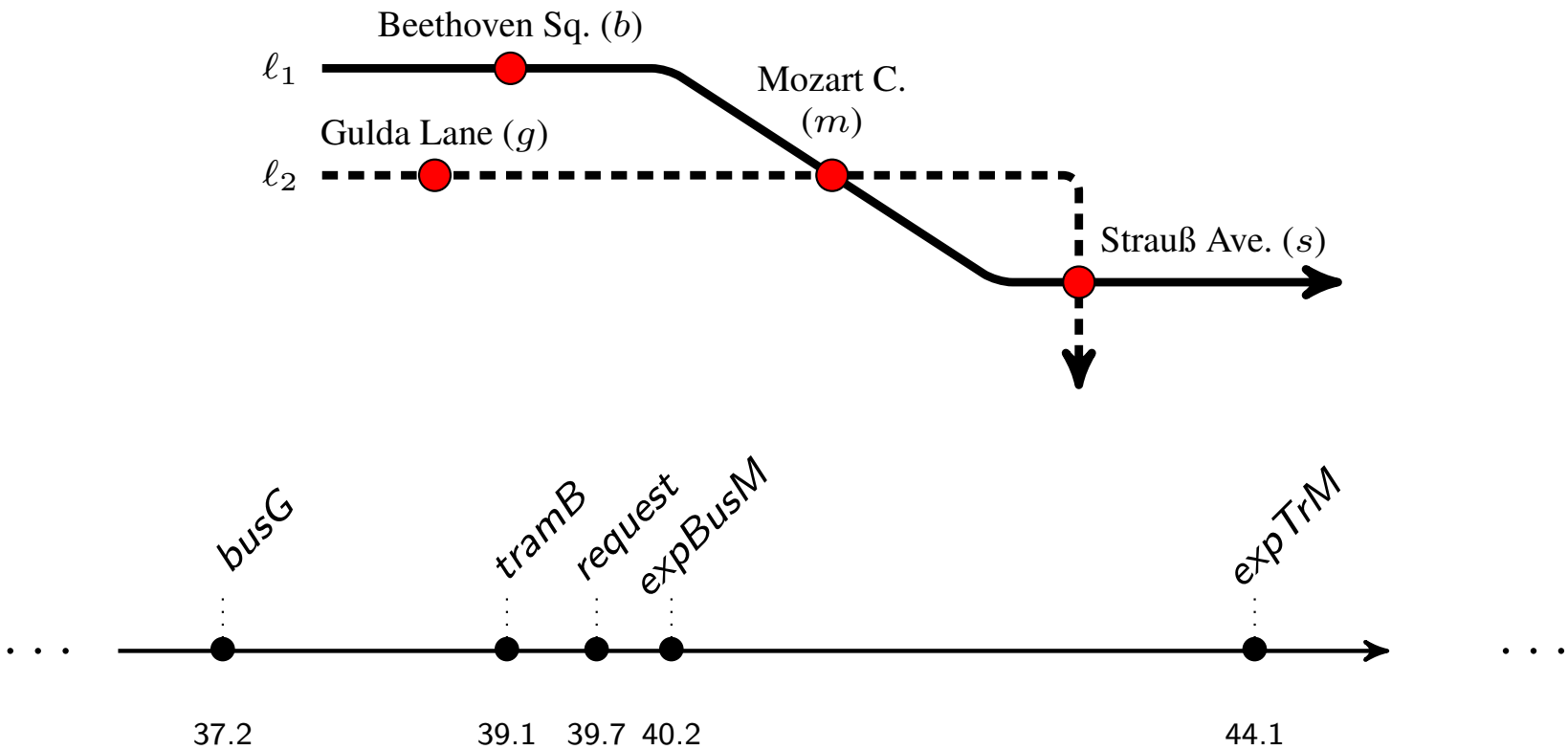
LARS in a Nutshell





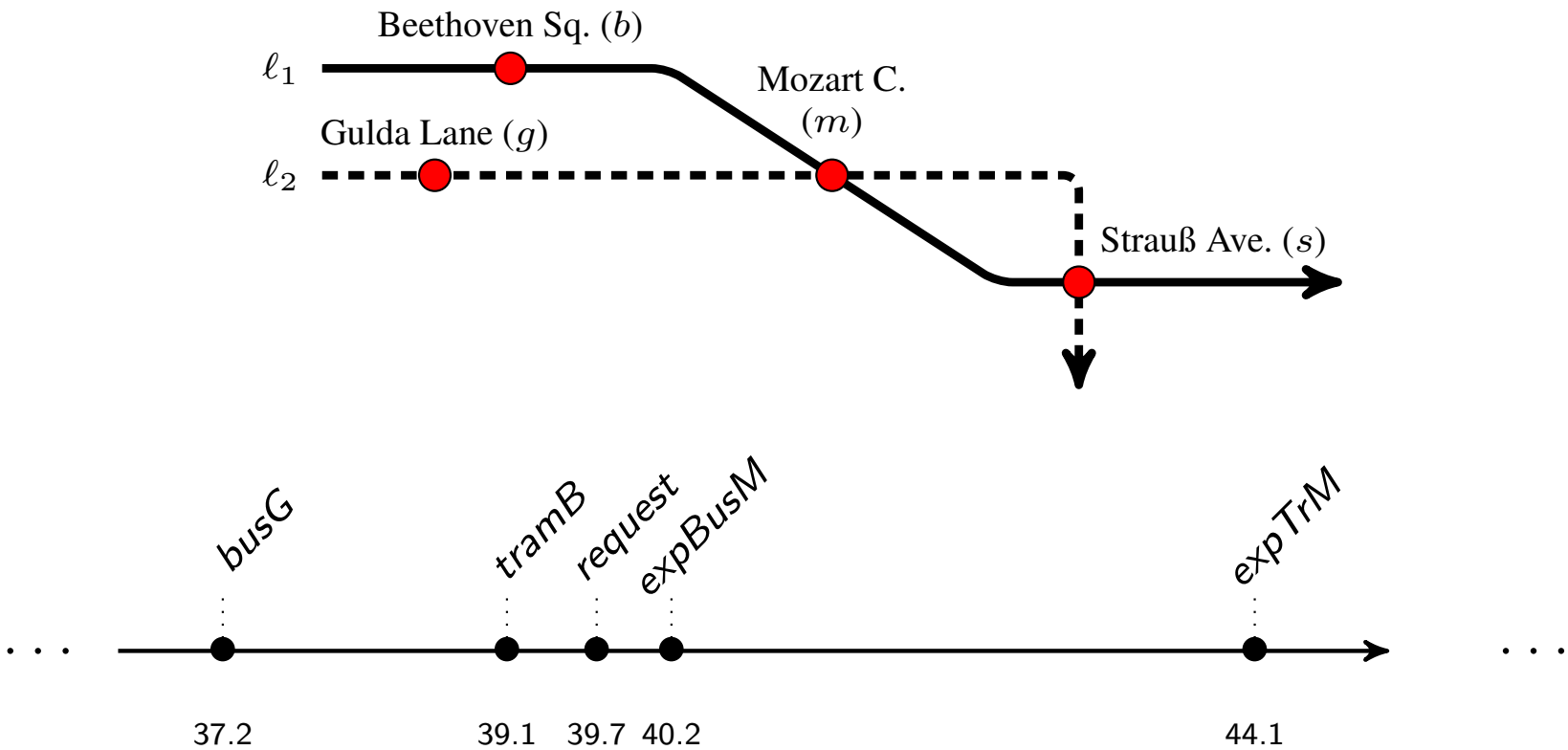
$$@_{T+3m}\mathit{expBusM} \leftarrow \boxplus^{3m} @_T\mathit{busG}, \text{not } \boxplus^{3m}\Diamond\mathit{jam}, \mathit{on}.$$
$$@_{T+5m}\mathit{expTrM} \leftarrow \boxplus^{5m} @_T\mathit{tramB}, \mathit{on}.$$
$$\mathit{on} \leftarrow \boxplus^{1m} \Diamond\mathit{request}.$$
$$\mathit{takeBusM} \leftarrow \boxplus^{+5m} \Diamond\mathit{expBusM}, \text{not } \mathit{takeTrM}.$$
$$\mathit{takeTrM} \leftarrow \boxplus^{+5m} \Diamond\mathit{expTrM}, \text{not } \mathit{takeBusM}.$$

LARS in a Nutshell



$$I_1 = \left\{ \begin{array}{l} 37.2 \mapsto \{busG\}, 39.1 \mapsto \{tramB\}, \\ 39.7 \mapsto \{request, on, takeBusM\}, \\ 40.2 \mapsto \{expBusM\}, 44.1 \mapsto \{expTrM\} \end{array} \right\}$$

LARS in a Nutshell



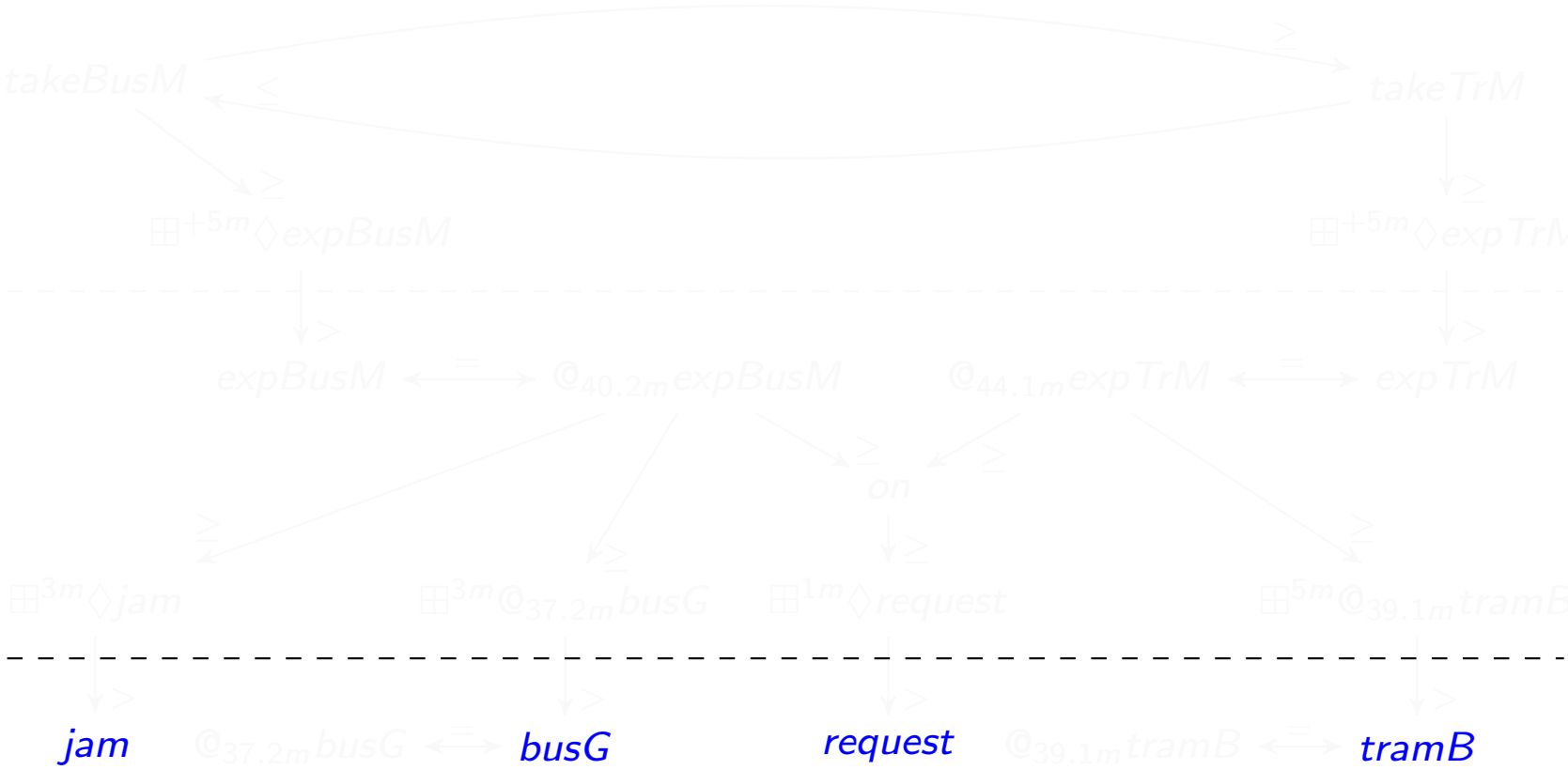
$$l_2 = \left\{ \begin{array}{l} 37.2 \mapsto \{busG\}, 39.1 \mapsto \{tramB\}, \\ 39.7 \mapsto \{request, on, takeTrM\}, \\ 40.2 \mapsto \{expBusM\}, 44.1 \mapsto \{expTrM\} \end{array} \right\}$$

Stream-stratified LARS Programs

Stream-stratified LARS Programs

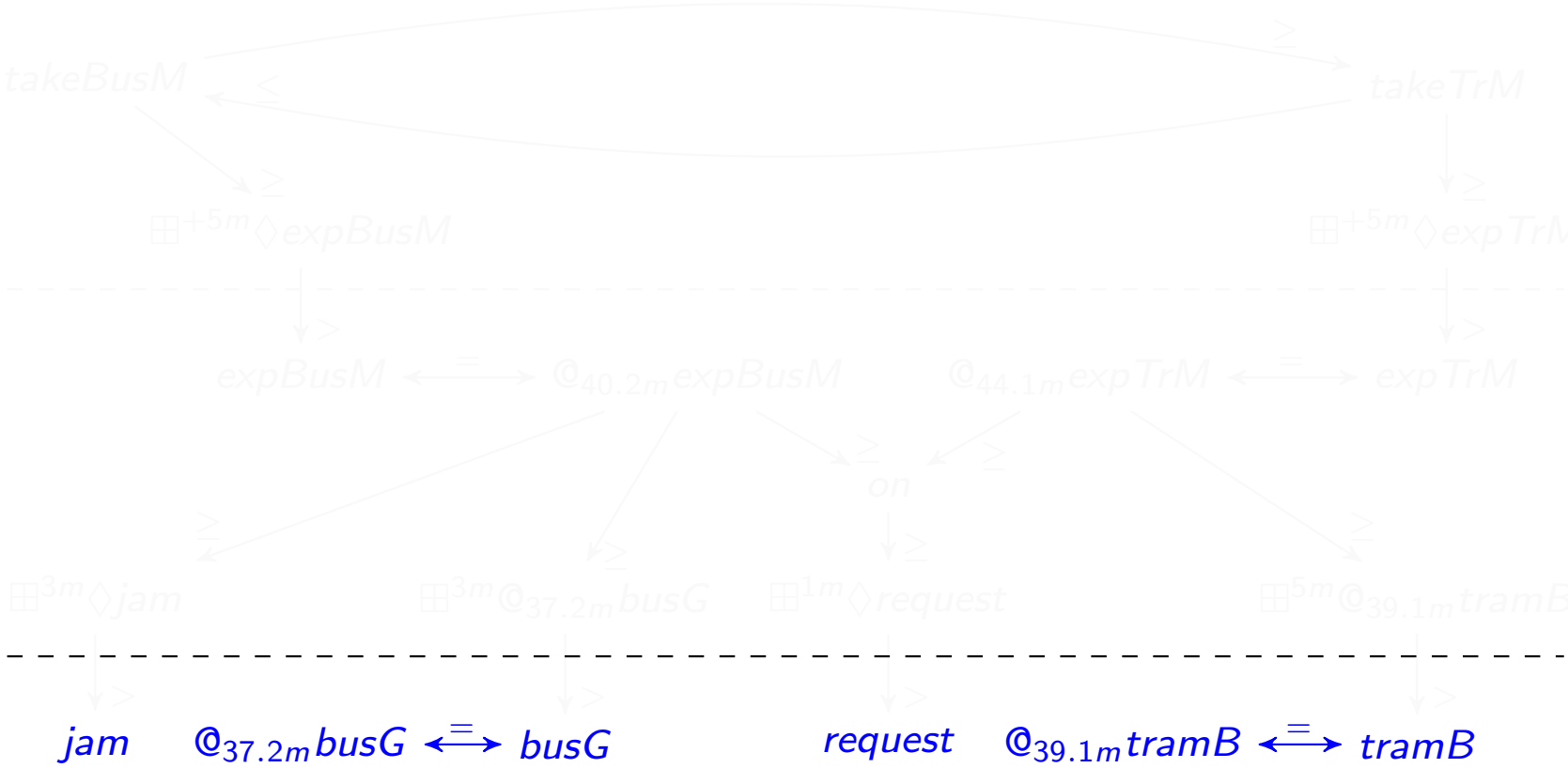
$$@_{40.2m}expBusM \leftarrow \boxplus^{3m}@_{37.2m}busG, \text{not } \boxplus^{3m}\Diamond jam, on.$$
$$@_{44.1m}expTrM \leftarrow \boxplus^{5m}@_{39.1m}tramB, on.$$
$$on \leftarrow \boxplus^{1m}\Diamond request.$$
$$takeBusM \leftarrow \boxplus^{+5m}\Diamond expBusM, \text{not } takeTrM.$$
$$takeTrM \leftarrow \boxplus^{+5m}\Diamond expTrM, \text{not } takeBusM.$$

Stream-stratified LARS Programs



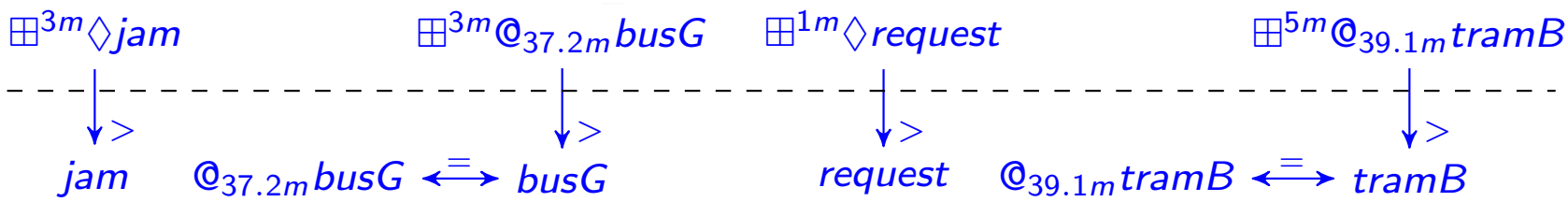
$$busG, \quad \text{not } \boxplus^{3m}\Diamond jam, \quad tramB, \quad request.$$

Stream-stratified LARS Programs



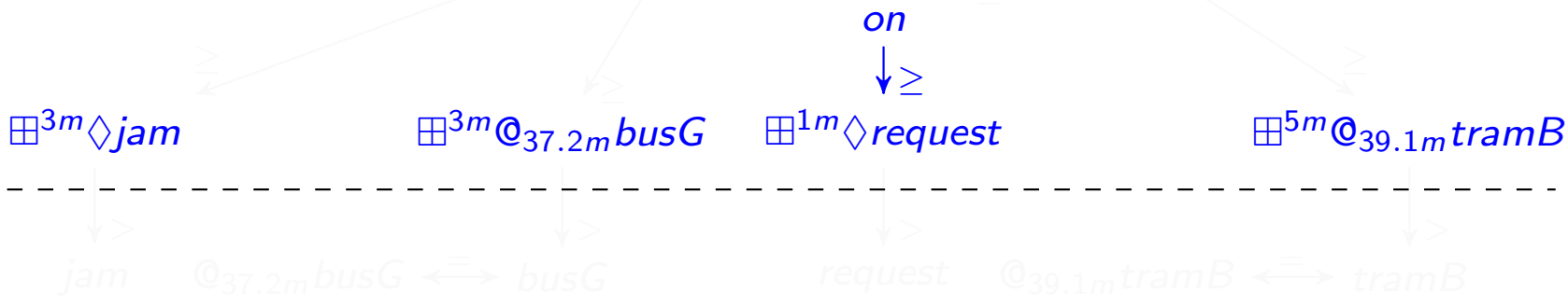
$$@_{37.2m}busG,\quad \text{not } \boxplus^{3m}\Diamond jam,$$
$$@_{39.1m}tramB,$$
$$request.$$

Stream-stratified LARS Programs



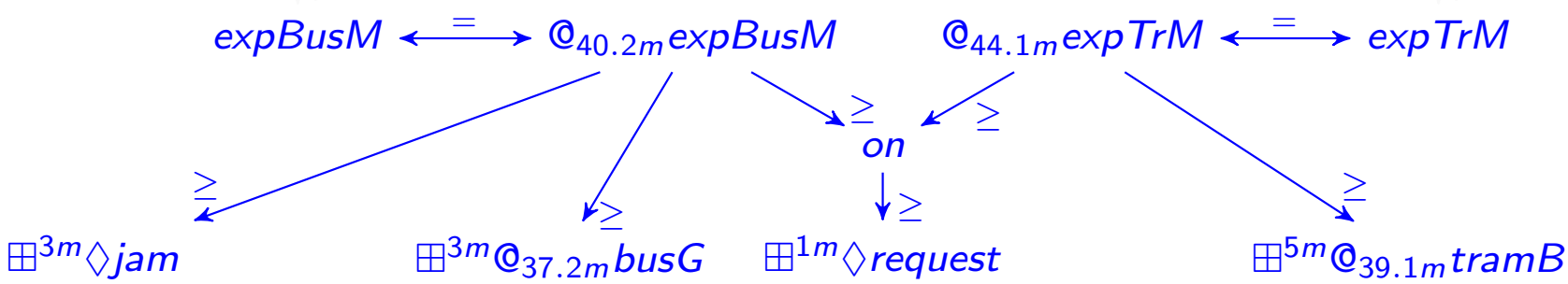
$\boxplus^{3m}@_{37.2m}busG$, not $\boxplus^{3m}\Diamond jam$,
$\boxplus^{5m}@_{39.1m}tramB$,
$\boxplus^{1m}\Diamond request$.

Stream-stratified LARS Programs



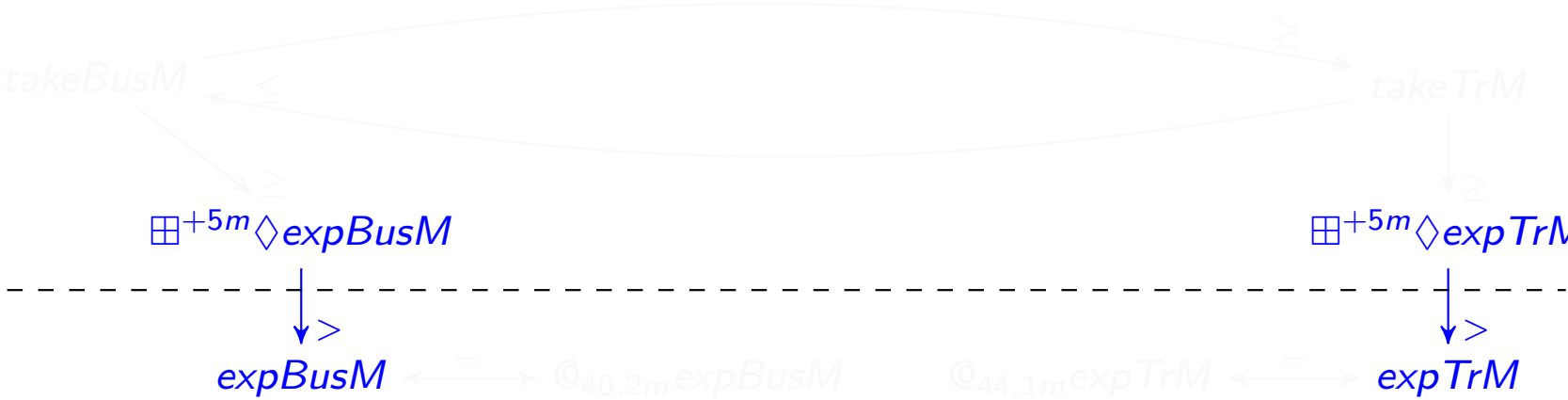
$$on \leftarrow \boxplus^{1m} \Diamond request.$$

Stream-stratified LARS Programs



$$@_{40.2m}\,expBusM \leftarrow \boxplus^{3m} @_{37.2m}\,busG, \text{not } \boxplus^{3m} \Diamond jam, on.$$
$$@_{44.1m}\,expTrM \leftarrow \boxplus^{5m} @_{39.1m}\,tramB, on.$$
$$on \leftarrow \boxplus^{1m} \Diamond request.$$

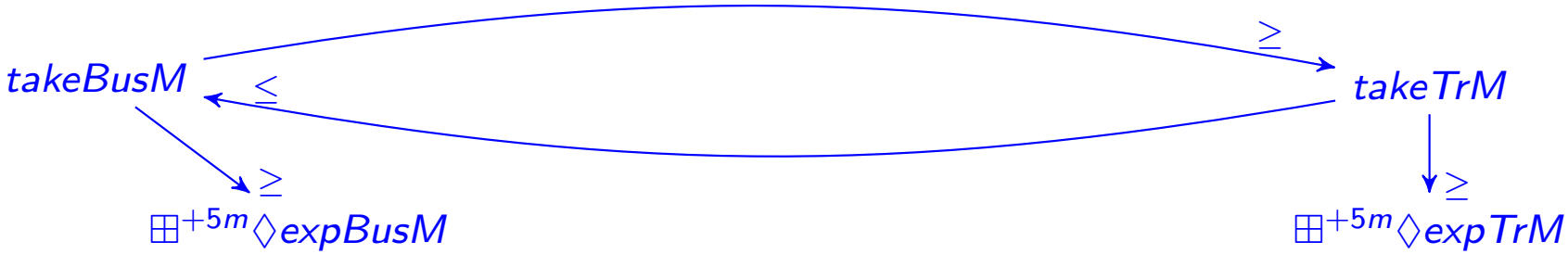
Stream-stratified LARS Programs



$@_{40.2m}expBusM$
$@_{44.1m}expTrM$

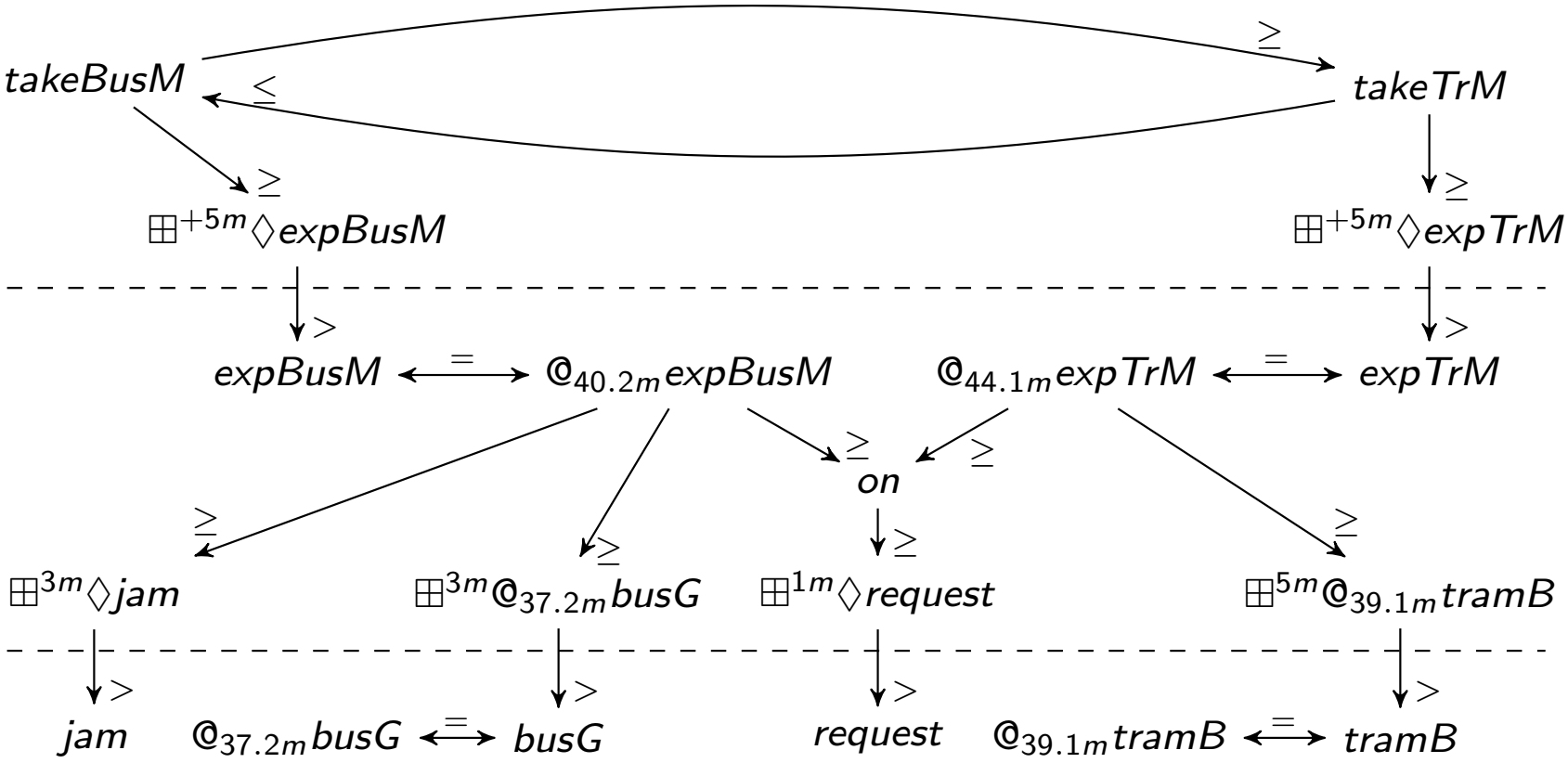
$\leftarrow \boxplus^{+5m}\Diamond expBusM, \text{not } takeTrM.$
$\leftarrow \boxplus^{+5m}\Diamond expTrM, \text{not } takeBusM.$

Stream-stratified LARS Programs



$$takeBusM \leftarrow \boxplus^{+5m} \Diamond expBusM, \text{not } takeTrM.$$
$$takeTrM \leftarrow \boxplus^{+5m} \Diamond expTrM, \text{not } takeBusM.$$

Stream-stratified LARS Programs



$$@_{40.2m}expBusM \leftarrow \boxplus^{3m}@_{37.2m}busG, \text{not } \boxplus^{3m}\Diamond jam, on.$$
$$@_{44.1m}expTrM \leftarrow \boxplus^{5m}@_{39.1m}tramB, on.$$
$$on \leftarrow \boxplus^{1m}\Diamond request.$$
$$takeBusM \leftarrow \boxplus^{+5m}\Diamond expBusM, \text{not } takeTrM.$$
$$takeTrM \leftarrow \boxplus^{+5m}\Diamond expTrM, \text{not } takeBusM.$$

Answer Update Algorithm

Answer Update Algorithm

Goal: given an answer stream I' at $t' < t$ and the input change from t' to t, compute I at t!

Answer Update Algorithm

Goal: given an answer stream I' at $t' < t$ and the input change from t' to t, compute I at t!

Idea: "Truth Maintanance Systems" + Temporal Aspect

- $I \Leftrightarrow$ TMS-like structure $\mathcal{M}$
- Label: $(in/out/unknown, \{[t_1, t_2], \ldots, [t_{n-1}, t_n]\})$

Answer Update Algorithm

Goal: given an answer stream I' at $t' < t$ and the input change from t' to t, compute I at t!

Idea: "Truth Maintanance Systems" + Temporal Aspect

- $I \Leftrightarrow$ TMS-like structure $\mathcal{M}$
- Label: $(in/out/unknown, \{[t_1, t_2], \ldots, [t_{n-1}, t_n]\})$

Algorithm AnswerUpdate$(t, D, \mathcal{M})$

- Update time labels of atoms with unchanged status
- Only re-evaluate the status of atoms affected by change in the input

Answer Update Algorithm: Main Building Blocks

Initialization

- all labels(out, $[0, 0]$) $\Rightarrow \mathcal{M}$
- call AnswerUpdate(0, empty stream, $\mathcal{M}$)

Answer Update Algorithm: Main Building Blocks

Initialization

- all labels(out, $[0, 0]$) $\Rightarrow \mathcal{M}$
- call AnswerUpdate(0, empty stream, $\mathcal{M}$)

Expire/Fire Input

- $\mathit{Expired}(\ell, t', t)$
- $\mathit{Fired}(\ell, t', t)$

$\Rightarrow$ Collect affected window atoms

Answer Update Algorithm: Main Building Blocks

Time adjustment

- Body window atoms with unchanged status and updated time labels $\Rightarrow$ update head's time labels

Answer Update Algorithm: Main Building Blocks

Time adjustment

- Body window atoms with unchanged status and updated time labels $\Rightarrow$ update head's time labels

Status adjustment

- Set *unknown* atoms
- Founded (in)valid rules $\Rightarrow$ set head's status
- Unfounded (in)valid rules $\Rightarrow$ assign head & *unknown* body's status

Answer Update Algorithm: Main Building Blocks

Time adjustment

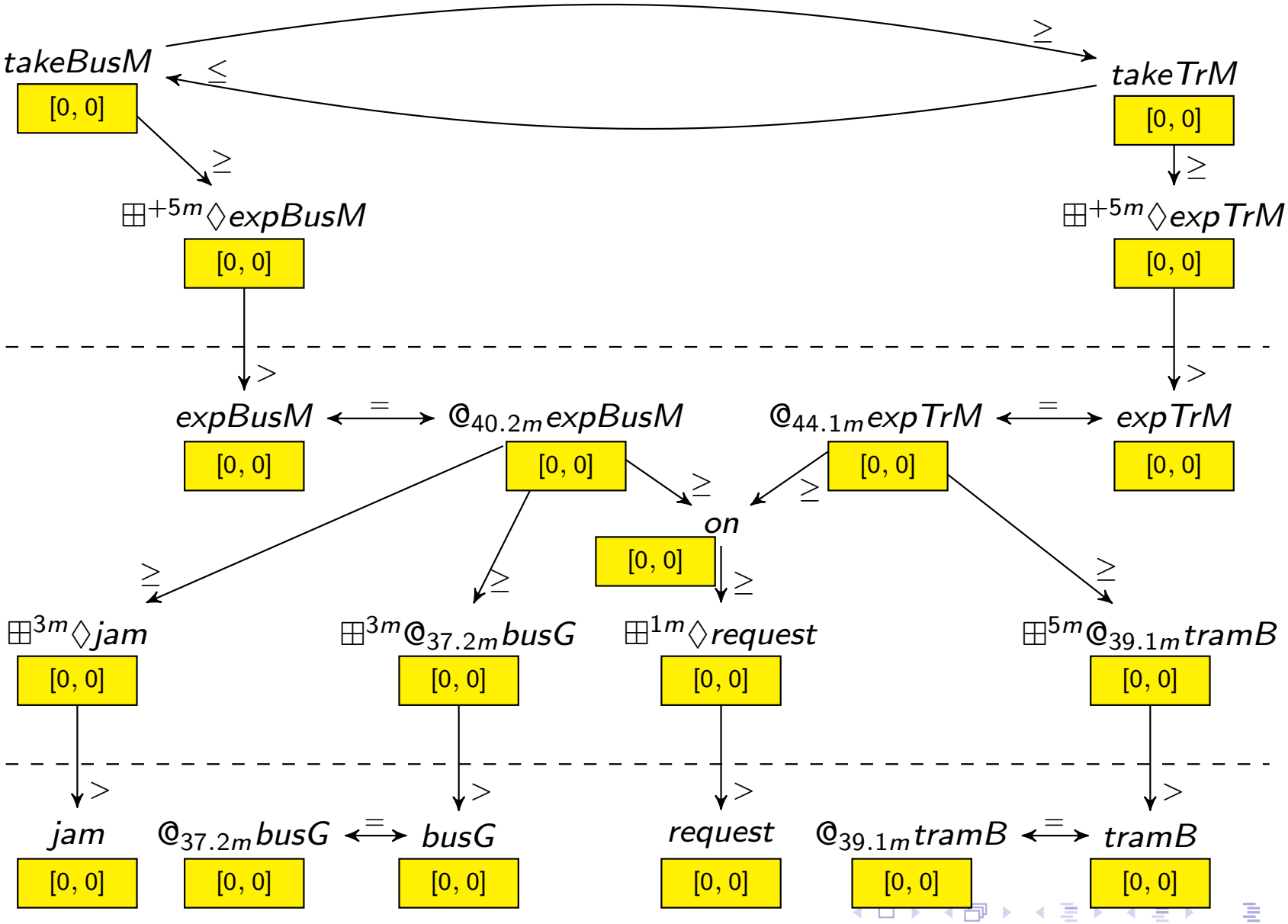
- Body window atoms with unchanged status and updated time labels $\Rightarrow$ update head's time labels

Status adjustment

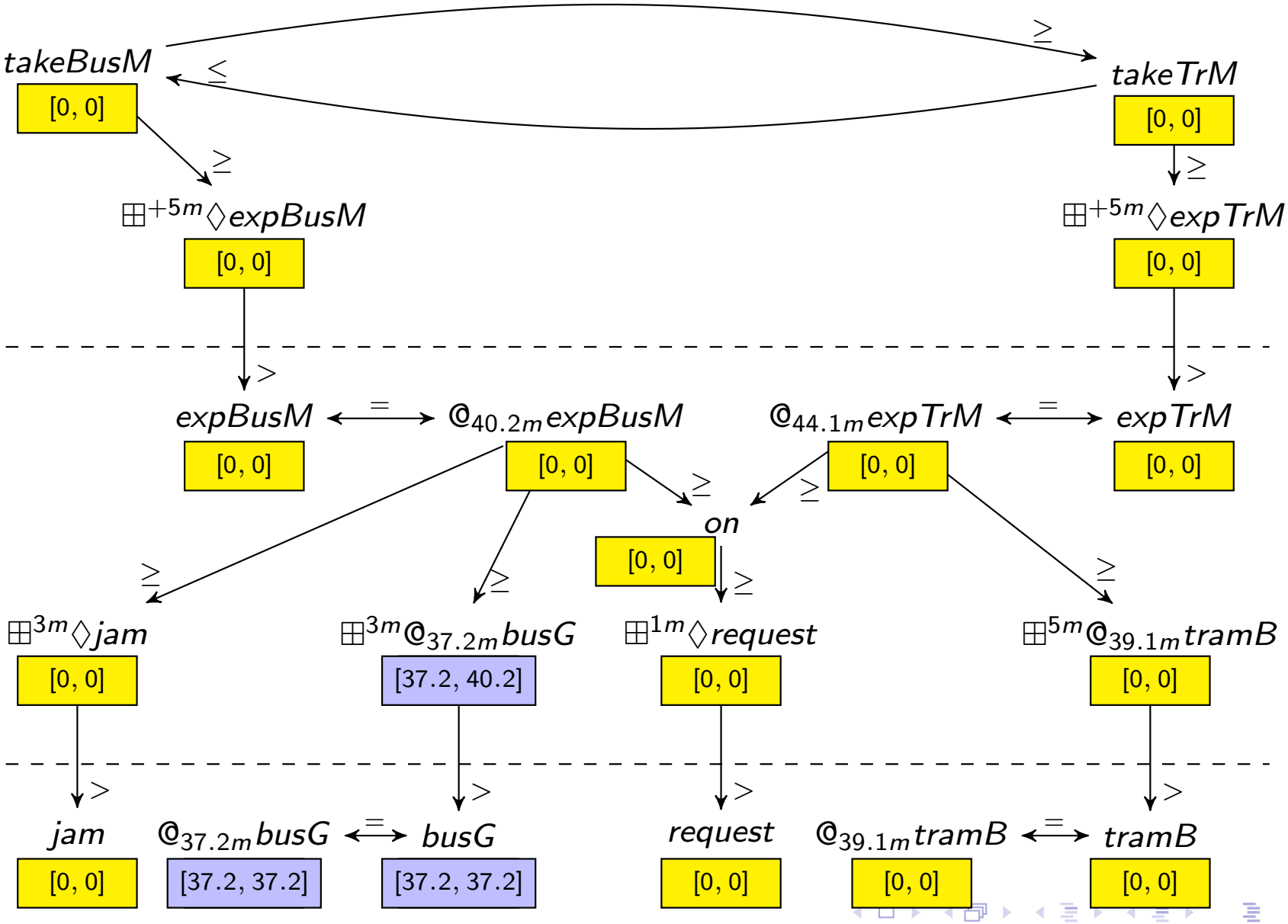
- Set *unknown* atoms
- Founded (in)valid rules $\Rightarrow$ set head's status
- Unfounded (in)valid rules $\Rightarrow$ assign head & *unknown* body's status

Loop through strata

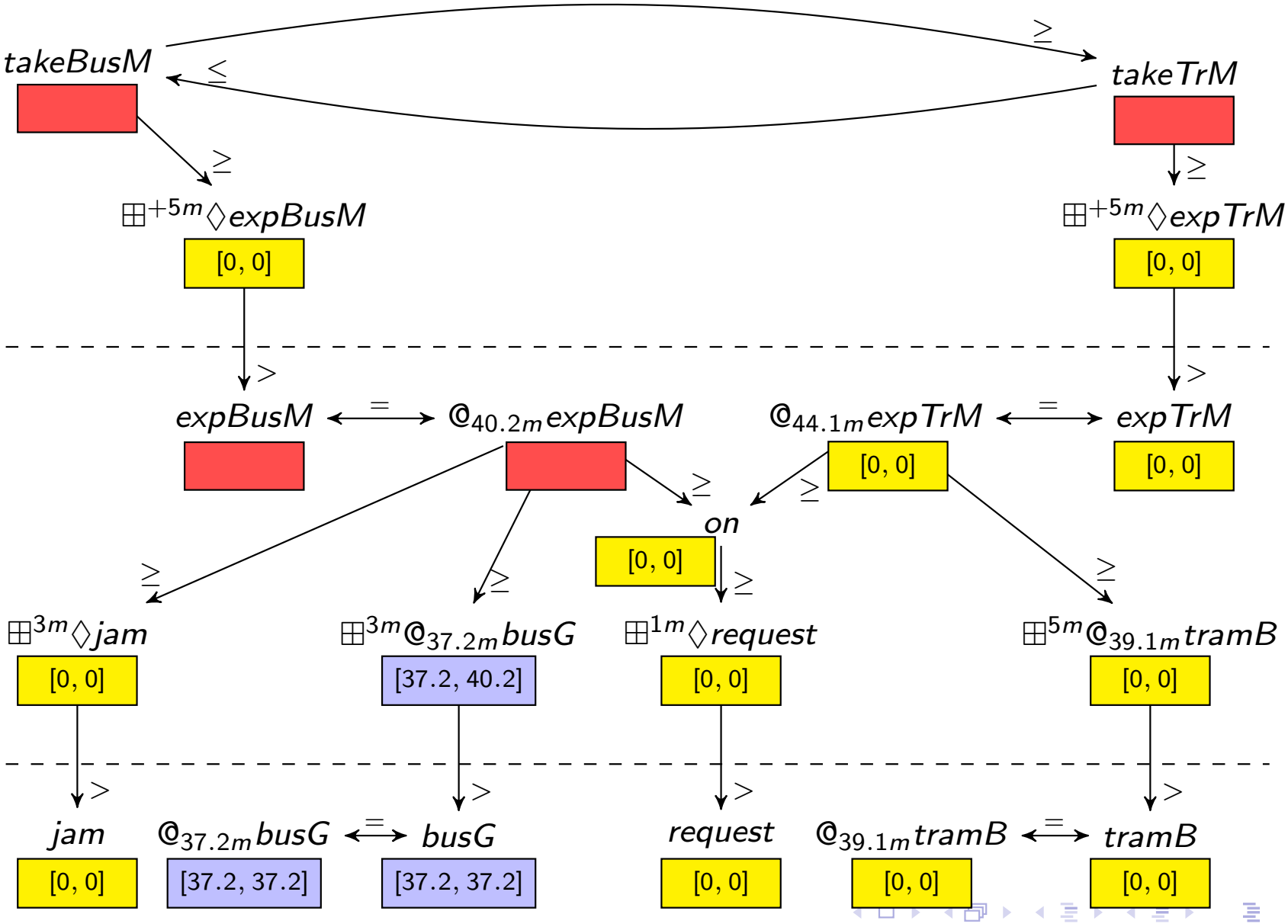
Answer Update Algorithm



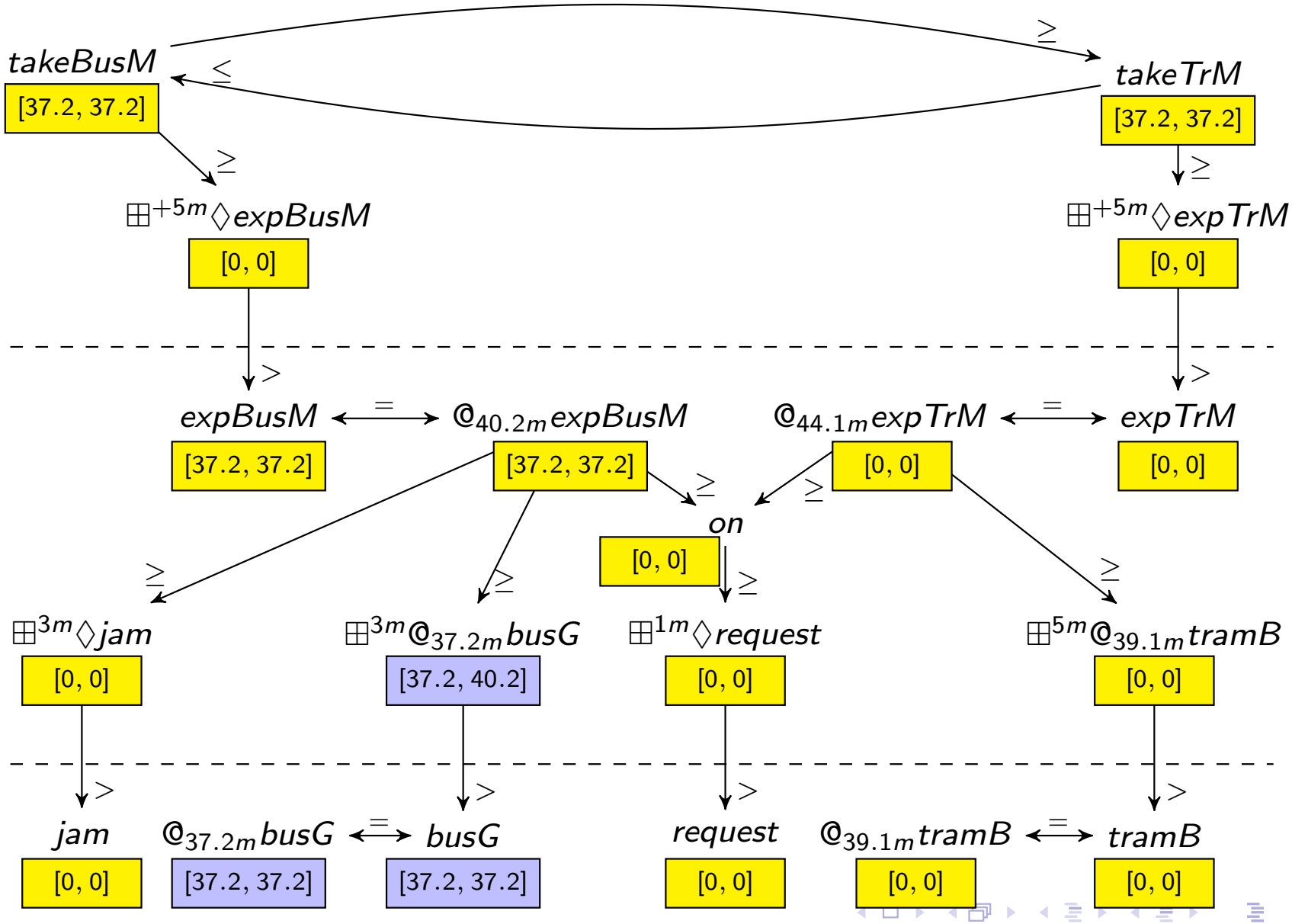
Answer Update Algorithm



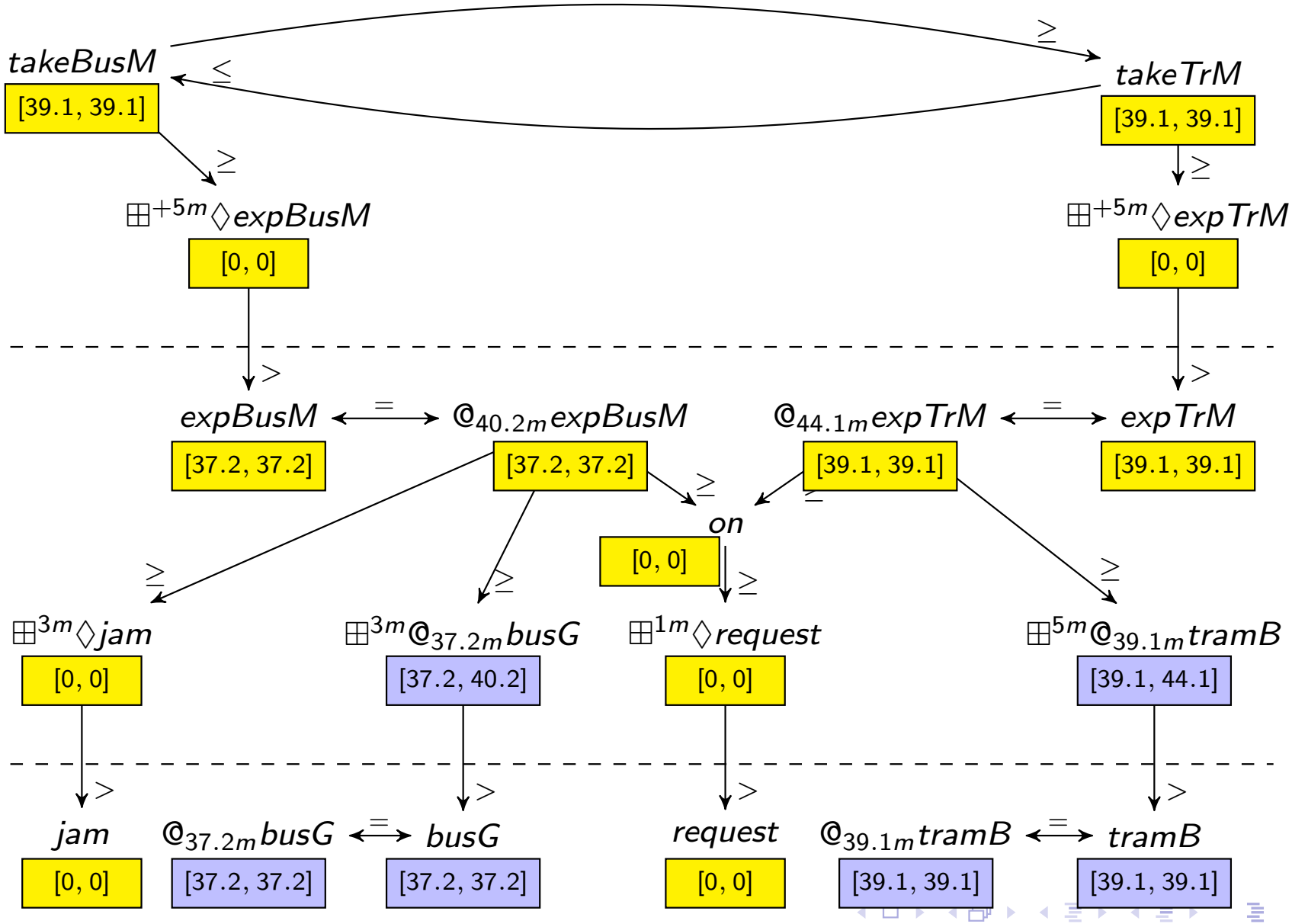
Answer Update Algorithm



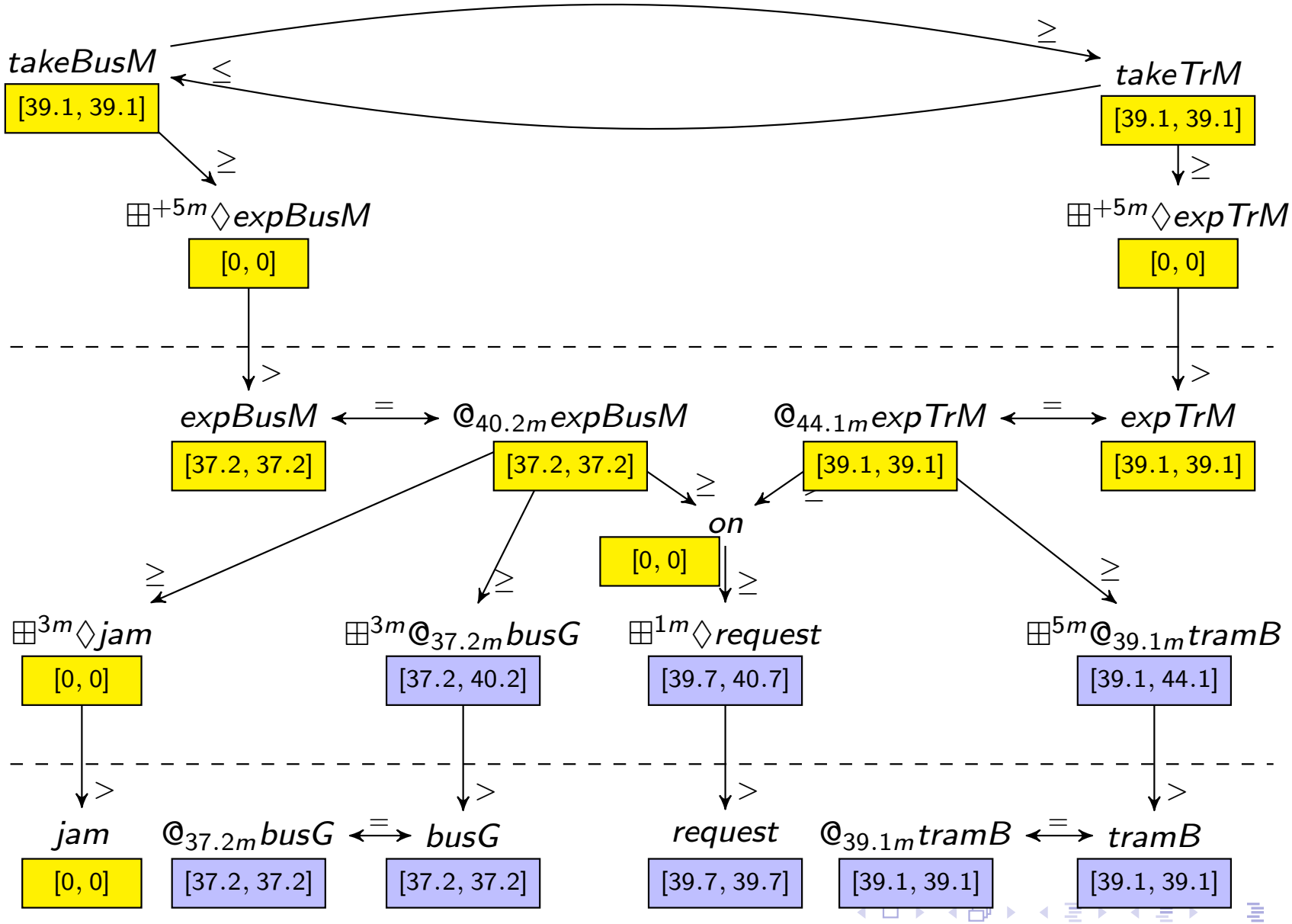
Answer Update Algorithm



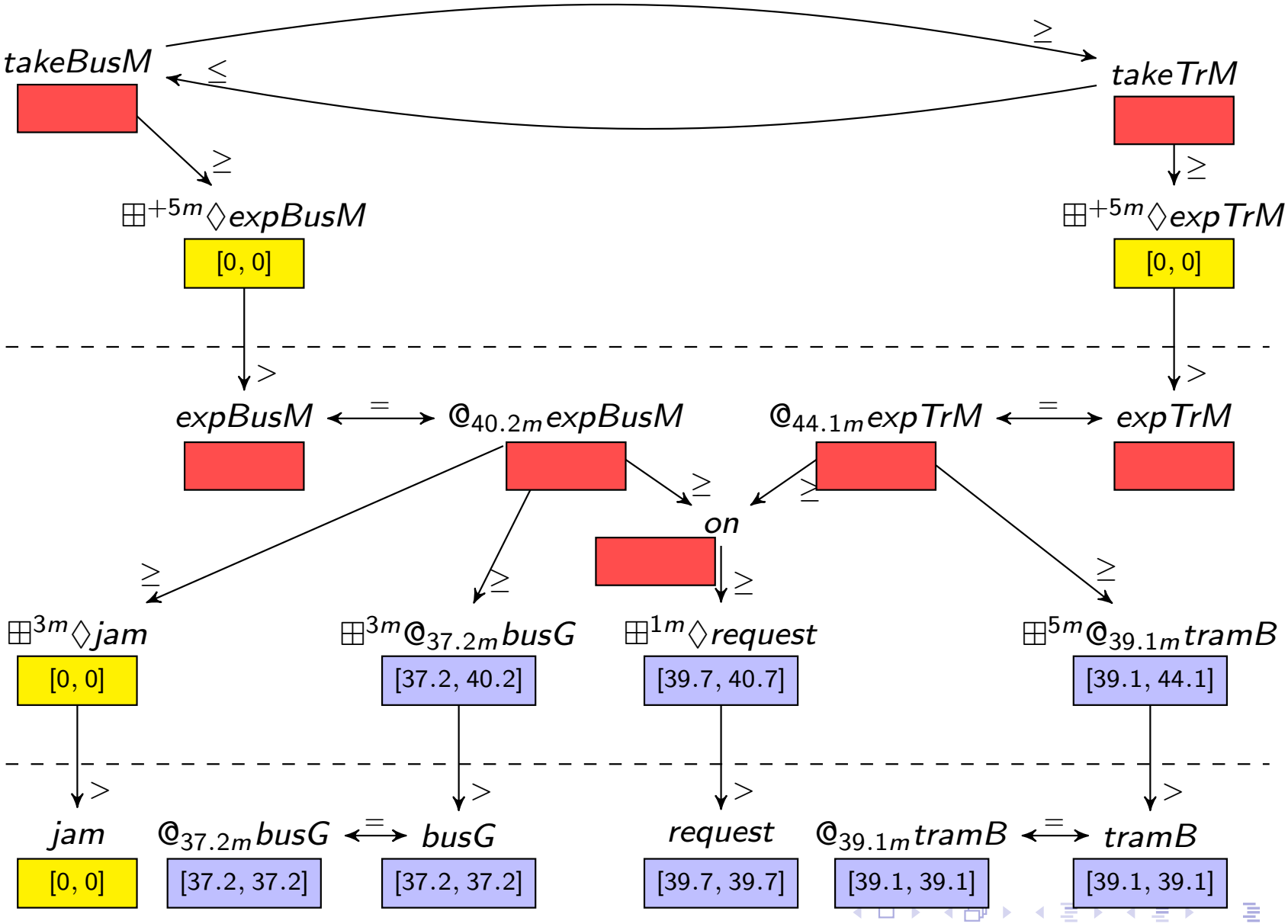
Answer Update Algorithm



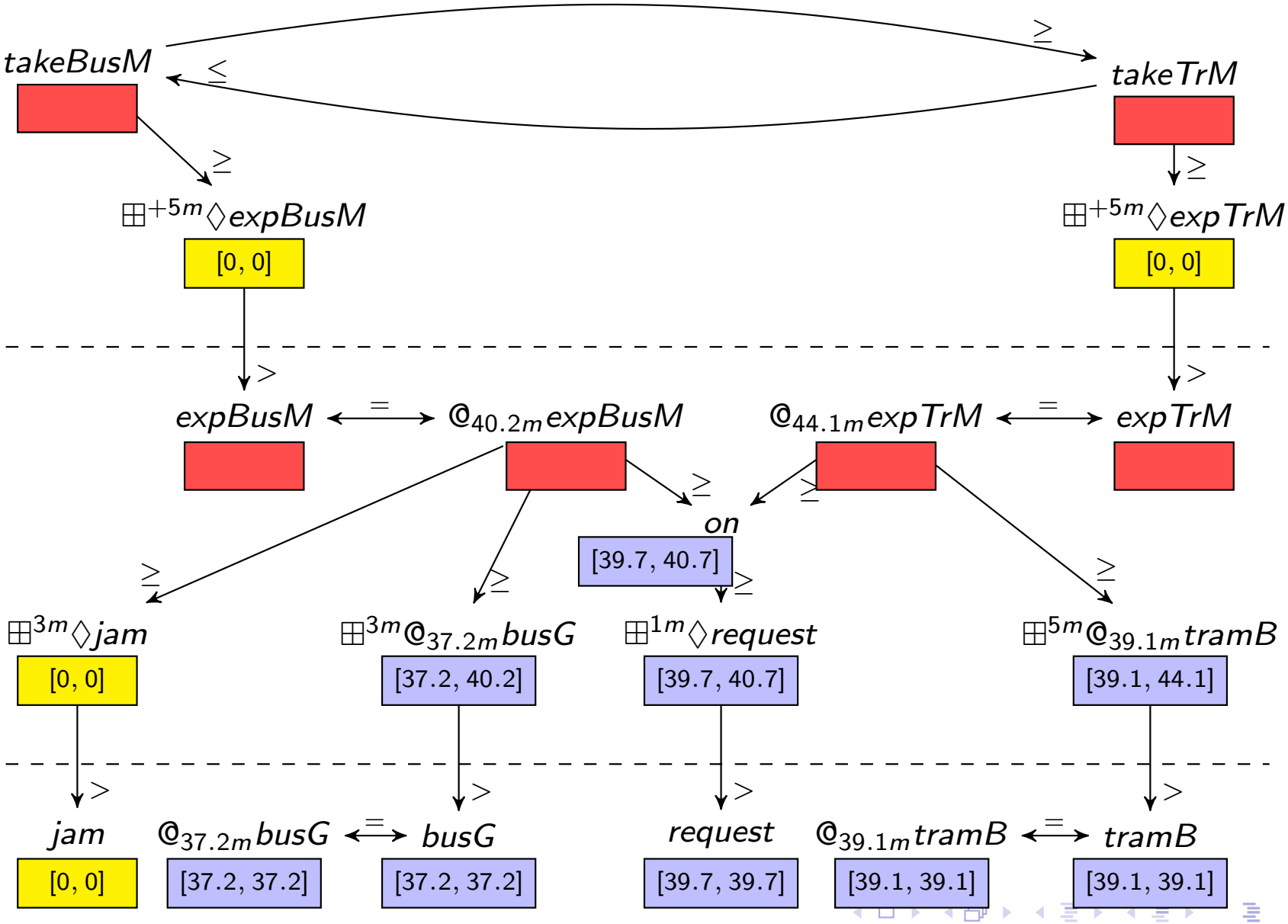
Answer Update Algorithm



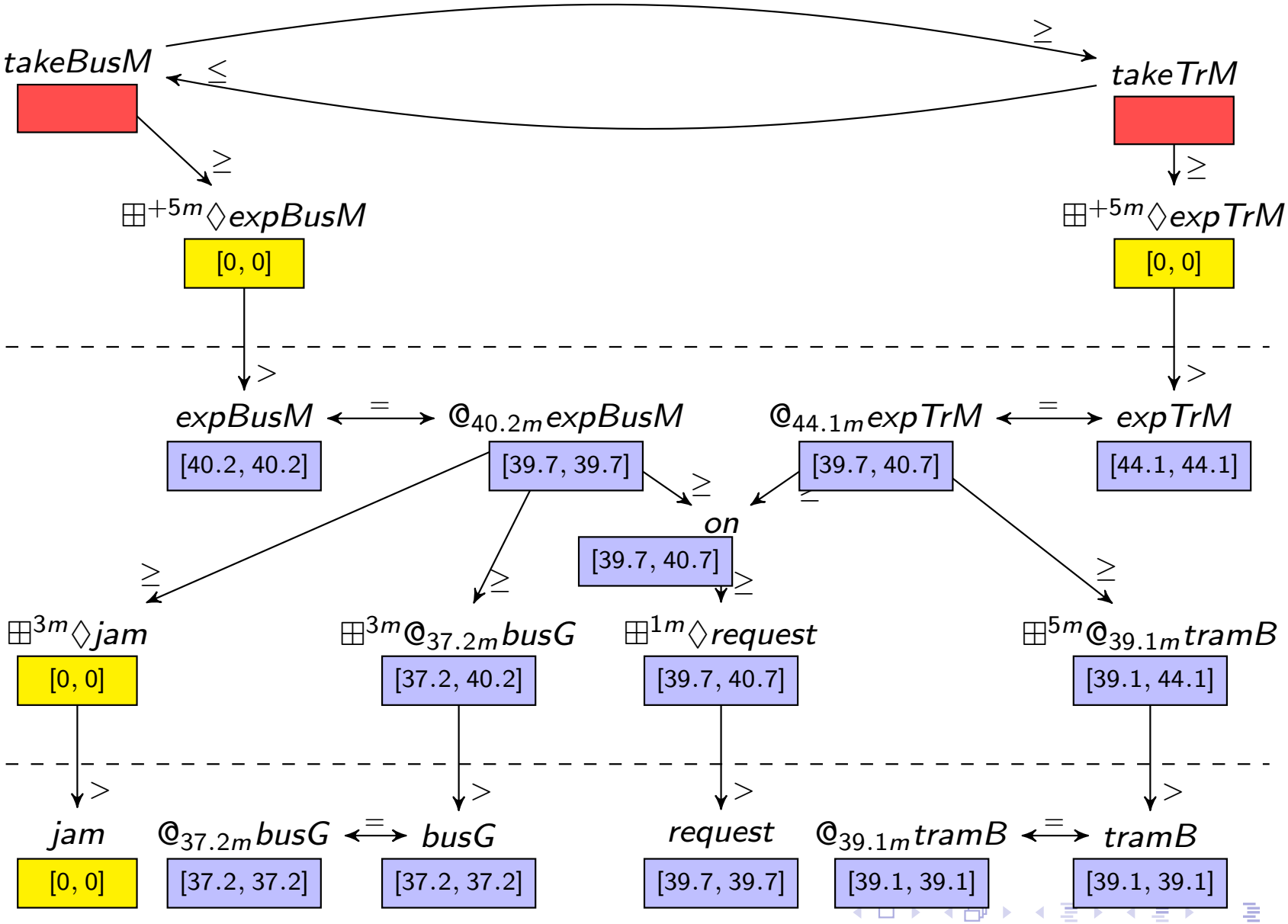
Answer Update Algorithm



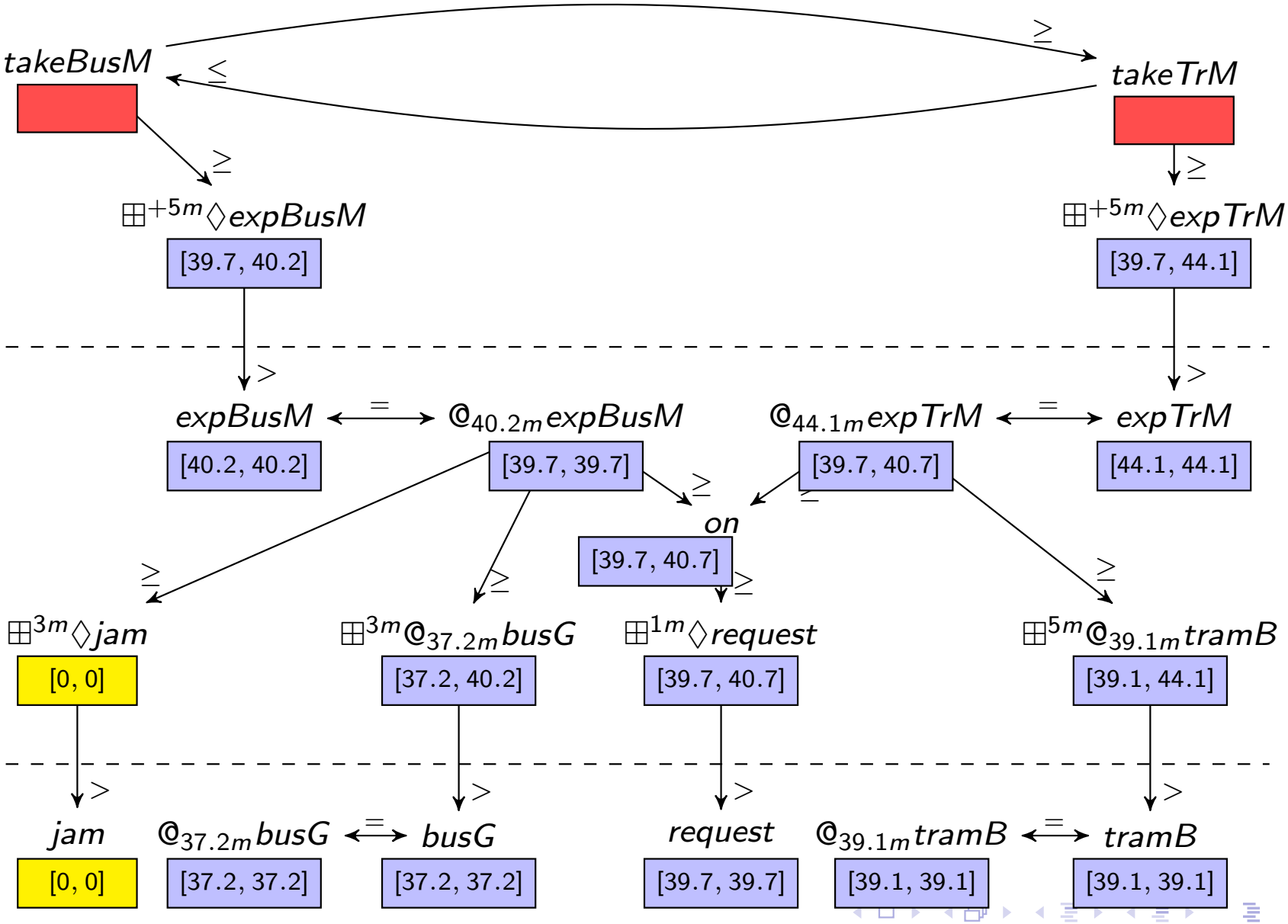
Answer Update Algorithm



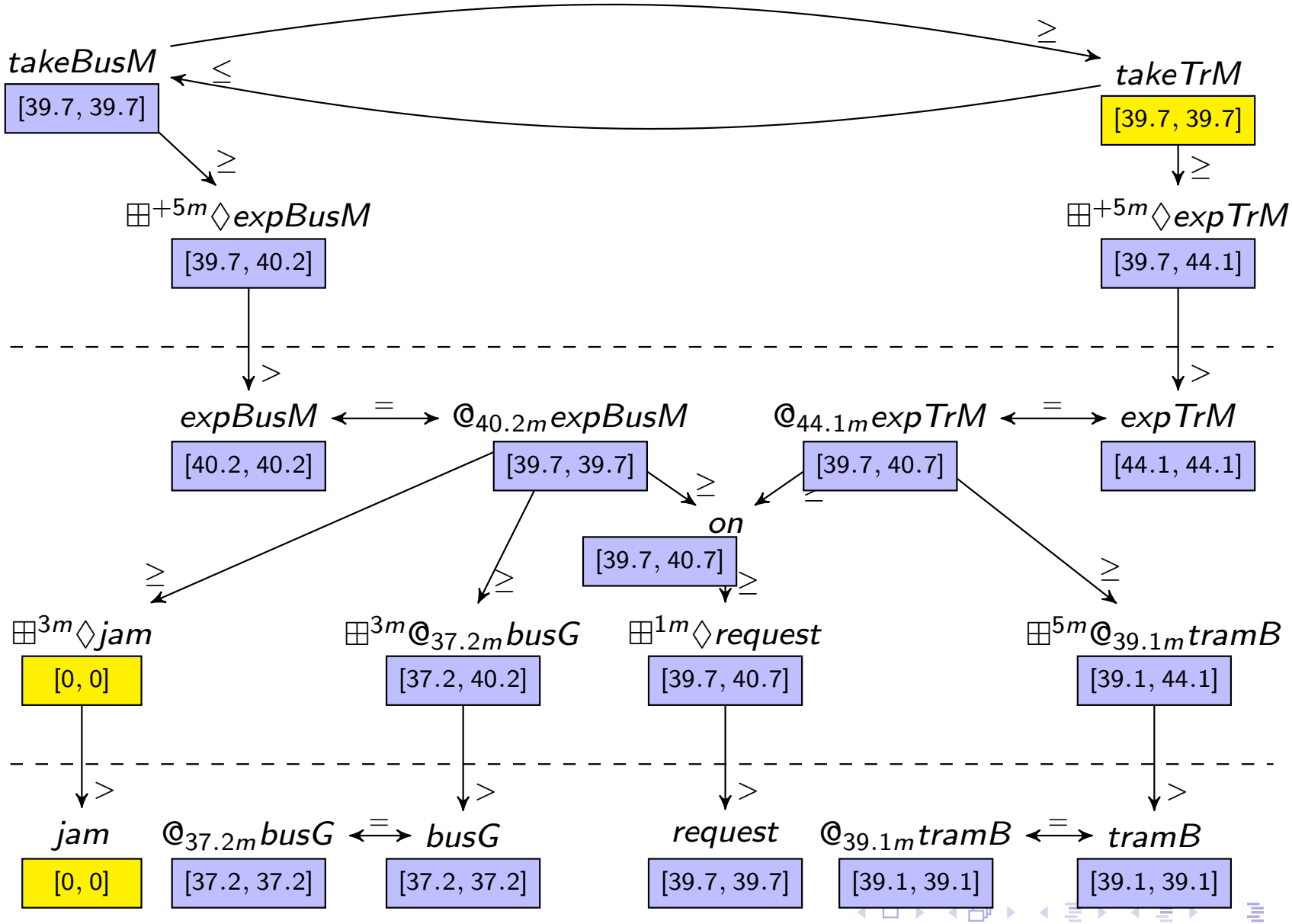
Answer Update Algorithm



Answer Update Algorithm



Answer Update Algorithm



Ongoing Implementation

- Simple evaluation for general LARS formulas
- Stream stratification recognition
- Initial comparison between generic evaluation and stratified evaluation
- More to come ...

Conclusions