Parametrized verification of networks with many identical probabilistic processes

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Thierry Jeron

Team : Vertecs, INRIA

Parameterized Verification

Problems

- Models with an unknown parameter (*e.g.* size, probability)
- Standard verification for each instances of the parameter impossible

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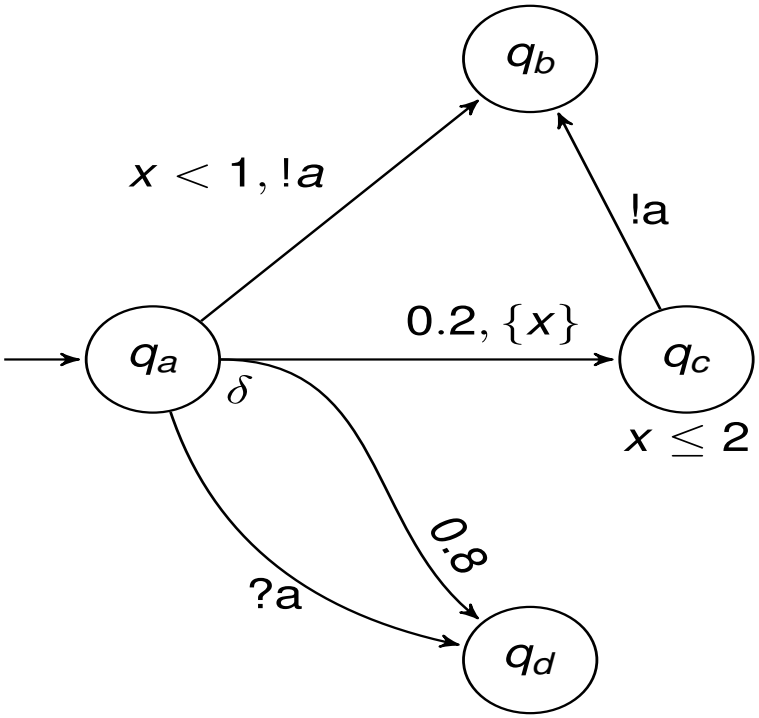
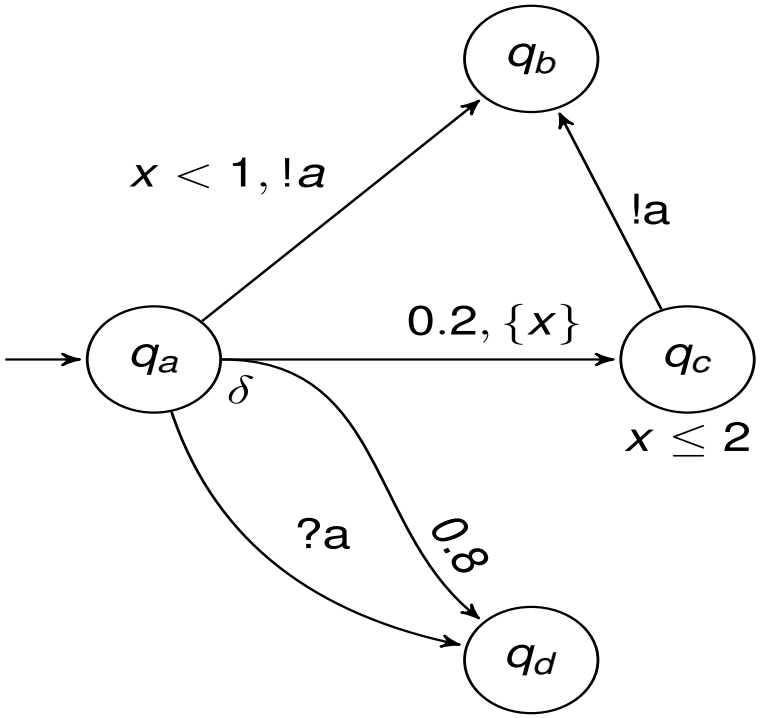
Our work

- Model: Probabilistic Timed Protocol
- Parameter: Number of processes
- Applications: Wireless sensor networks, Peer to peer, ...

The model: Probabilistic timed protocol

N identical processes in a **clique**.





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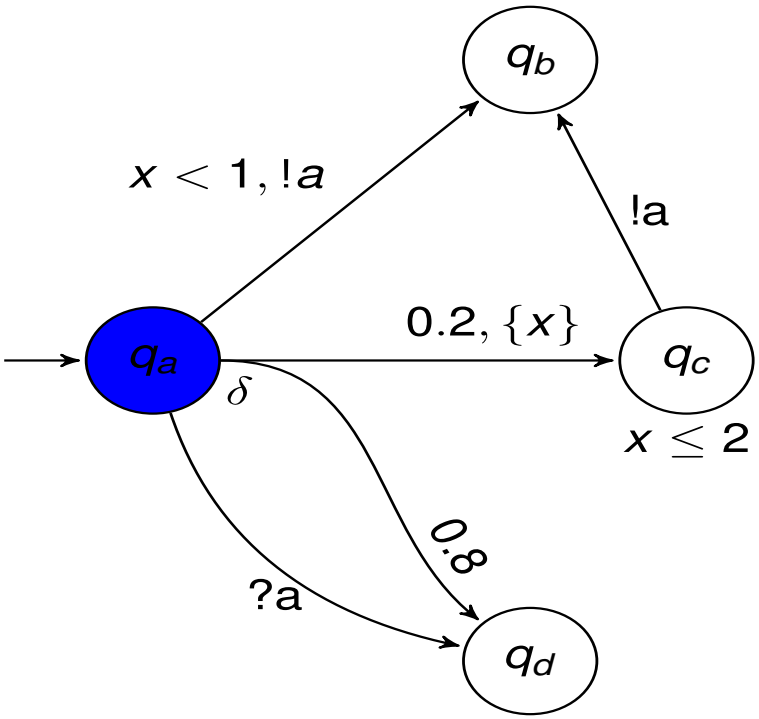

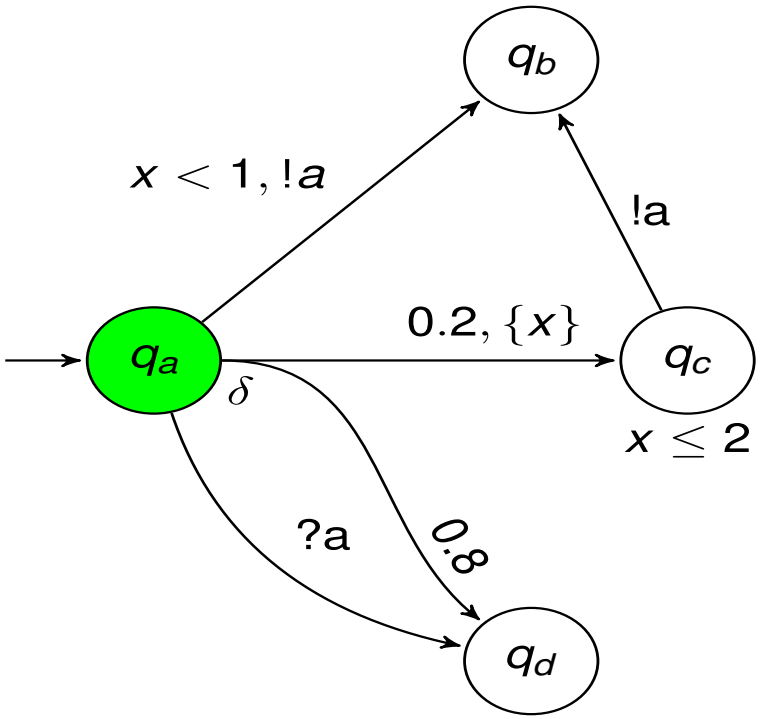

q_a 0

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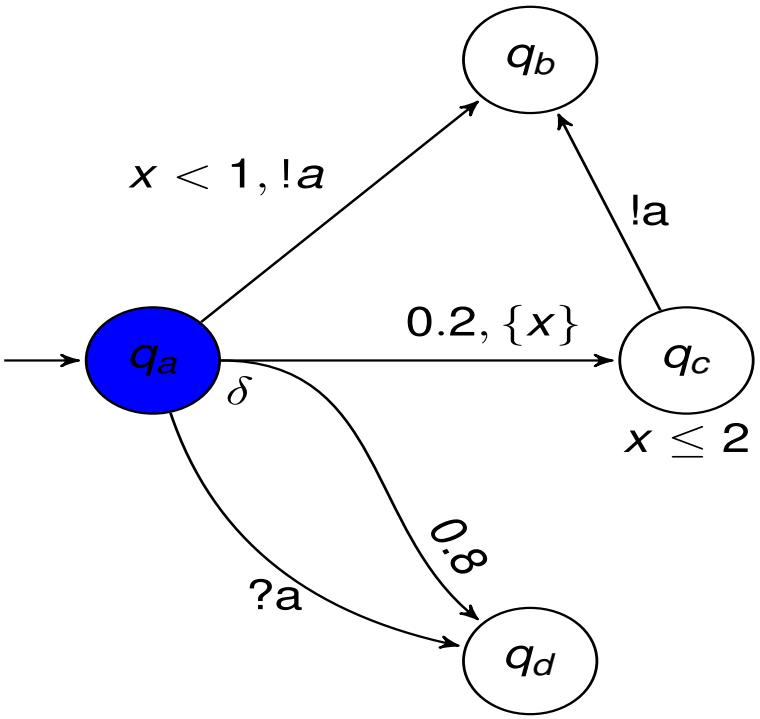

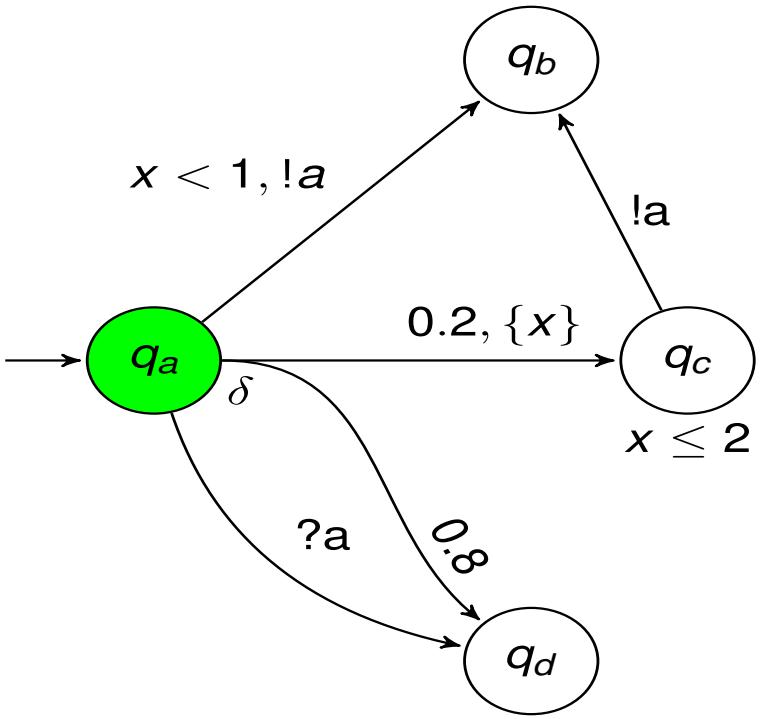

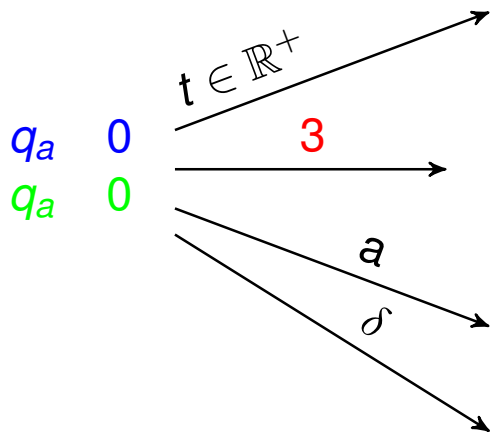

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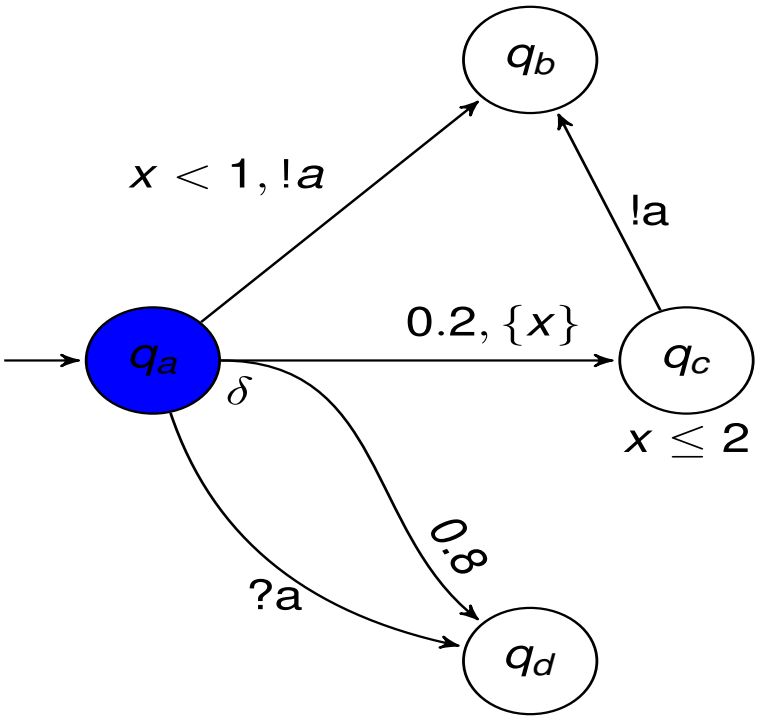

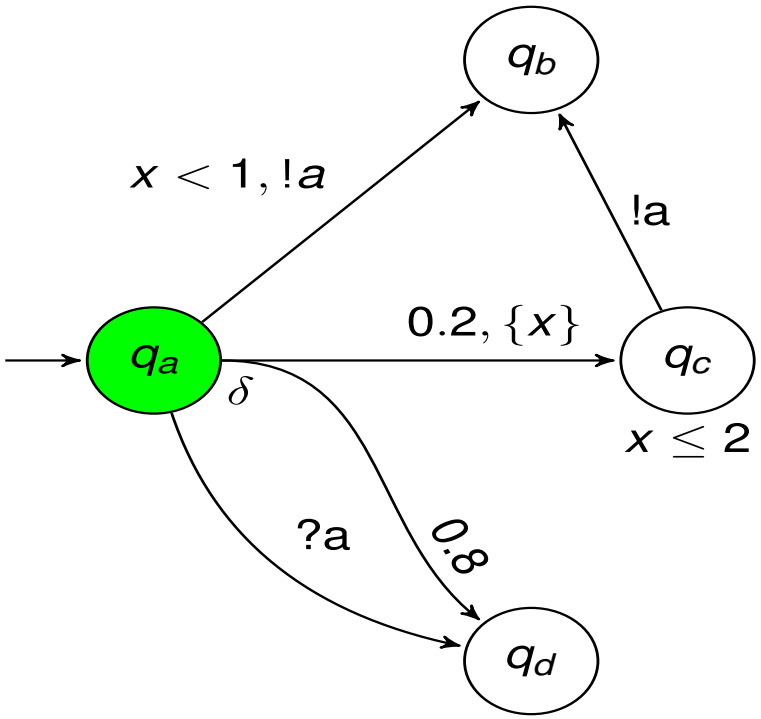

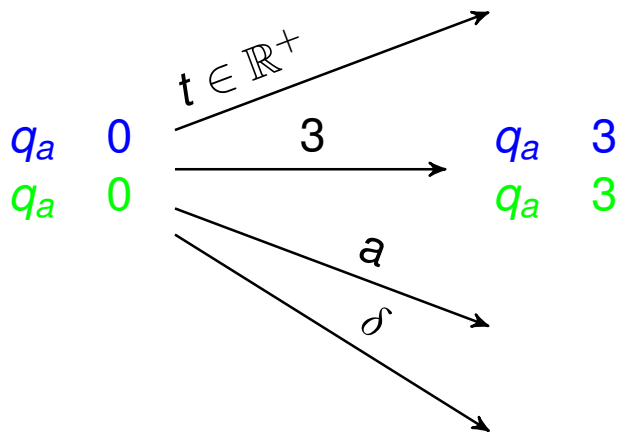

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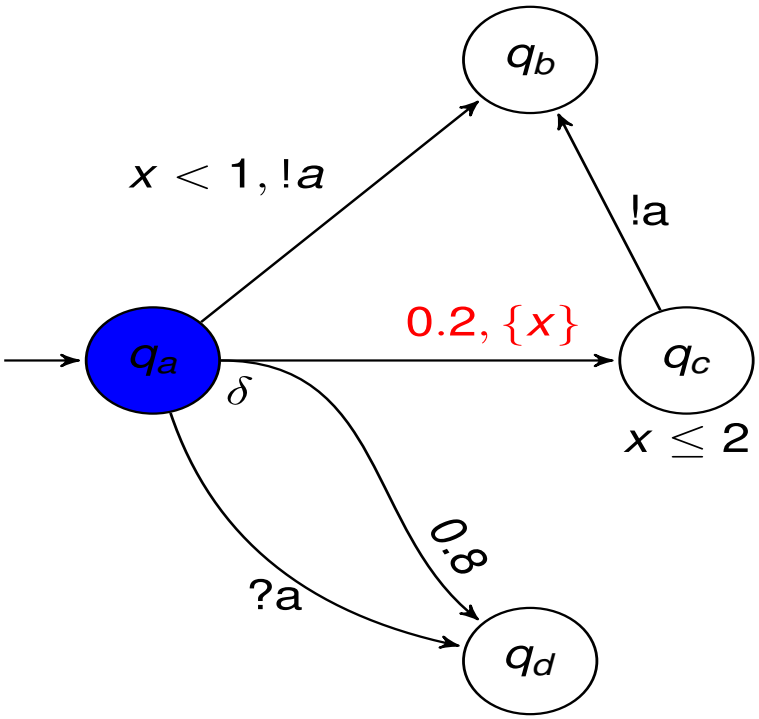

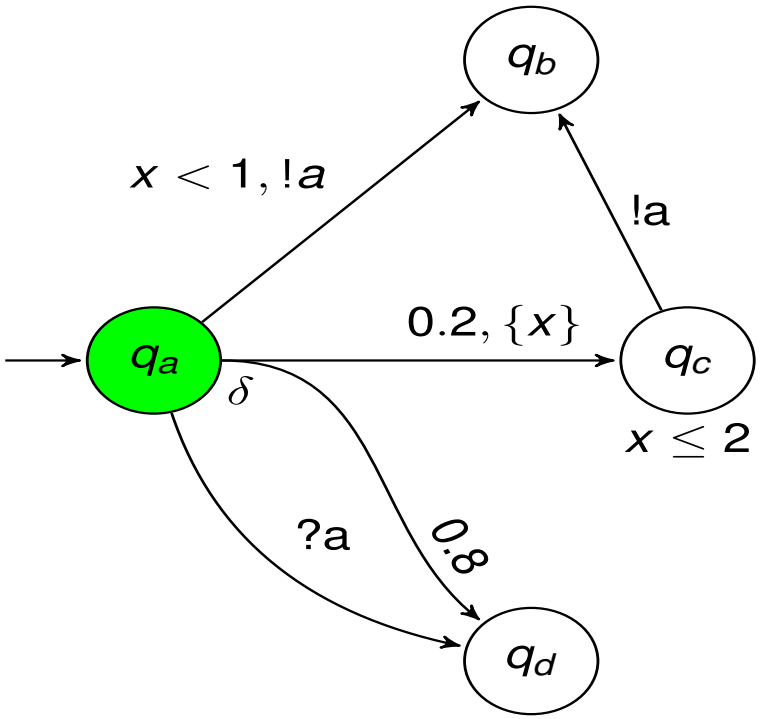

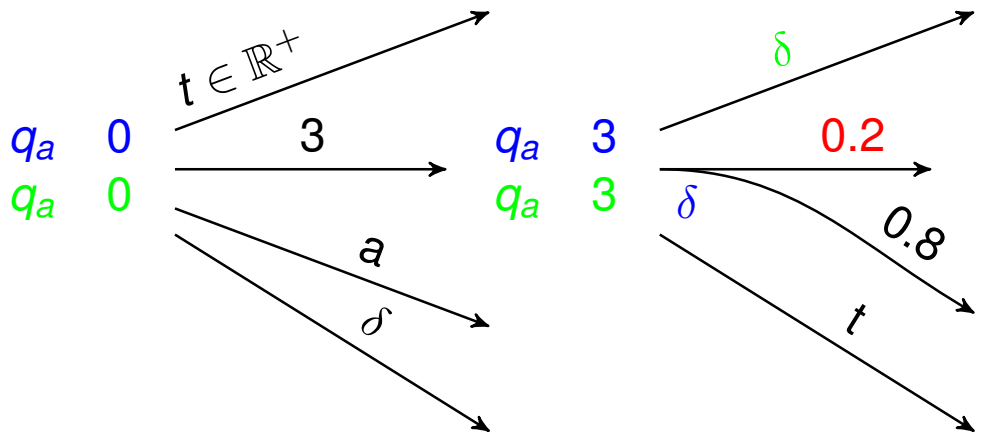

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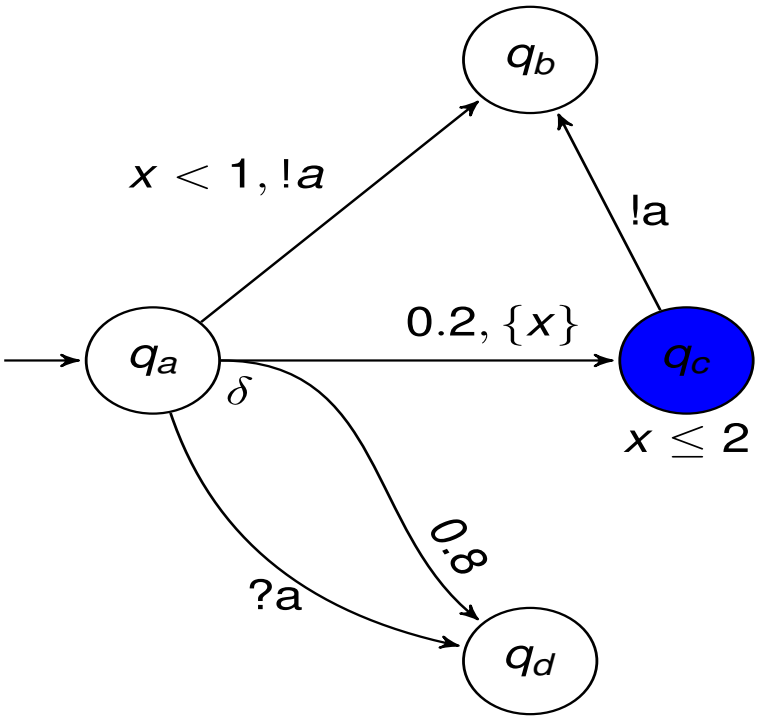

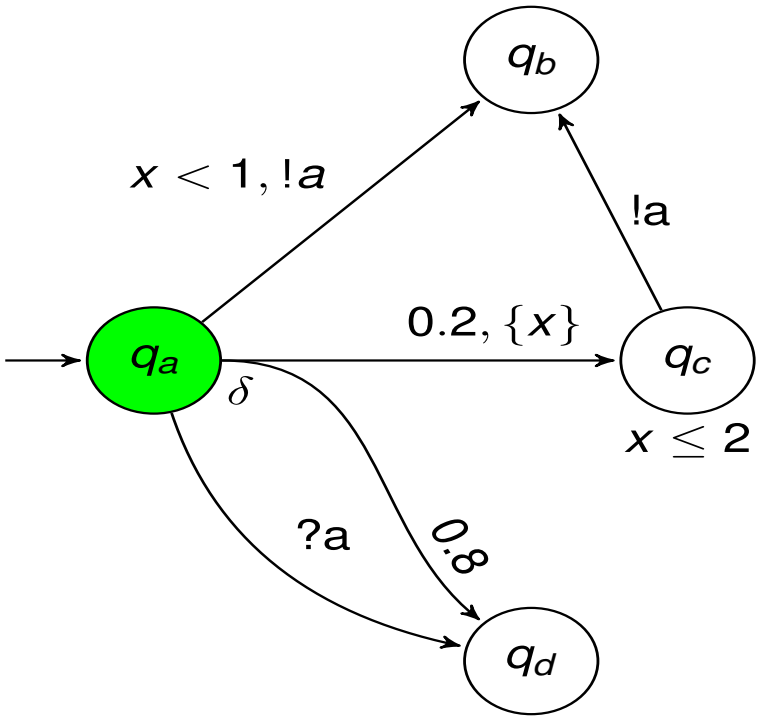

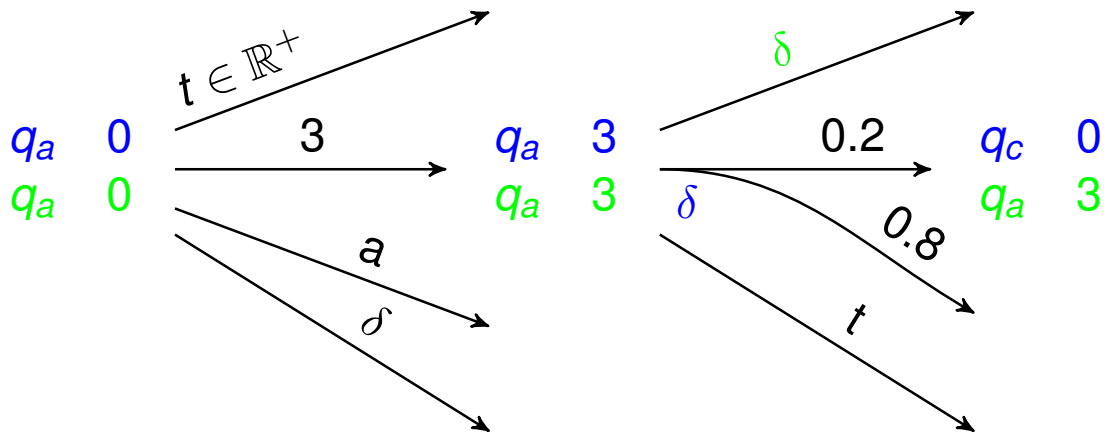

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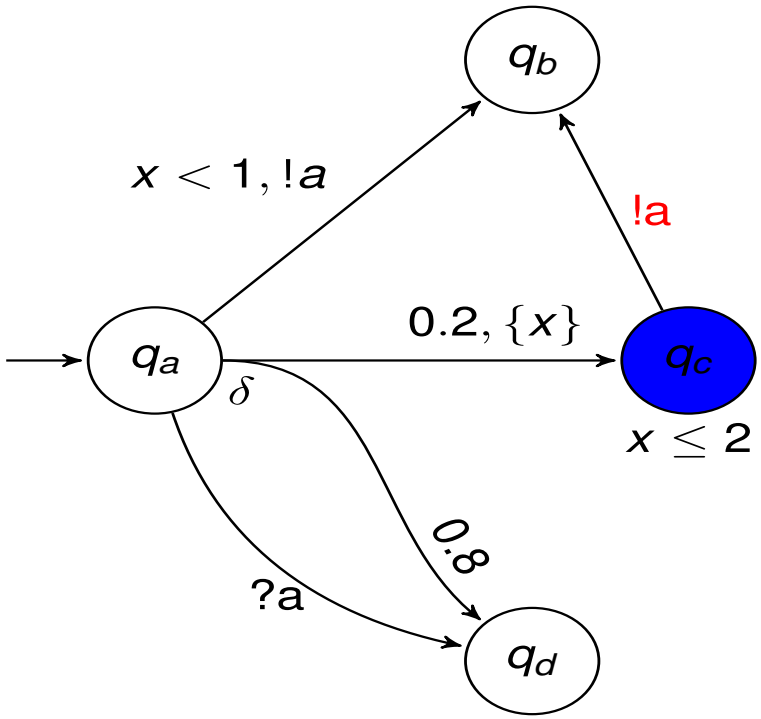

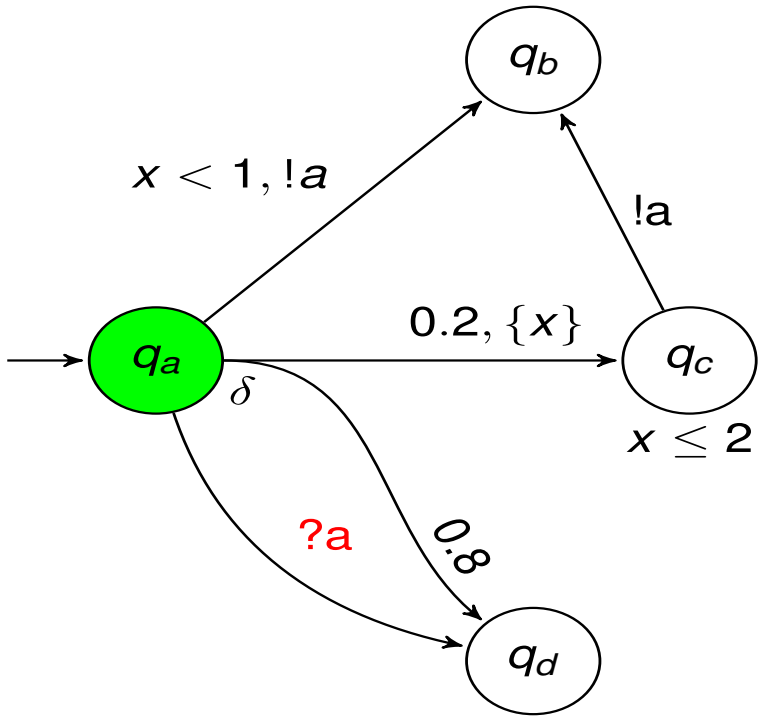

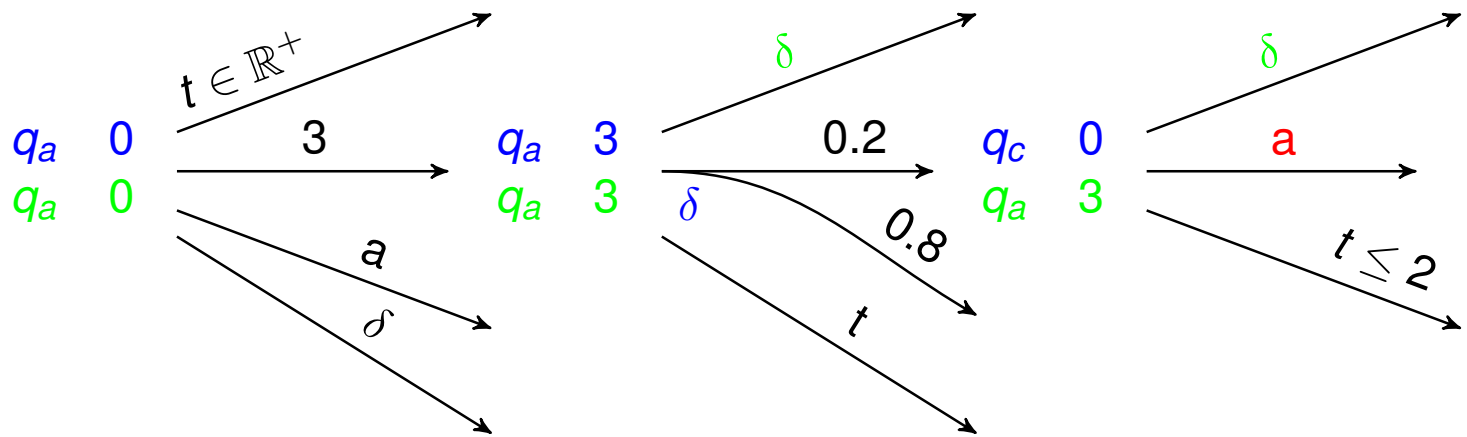

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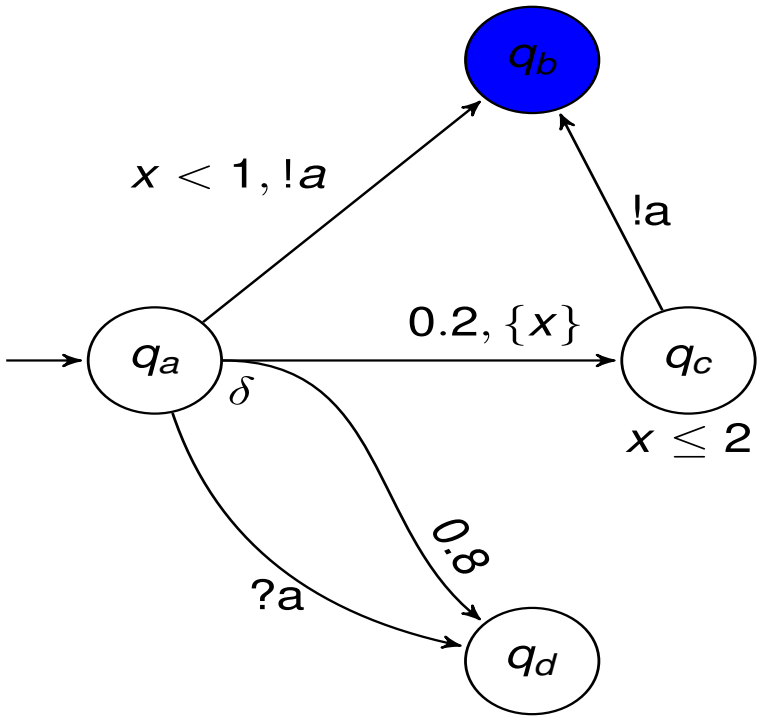

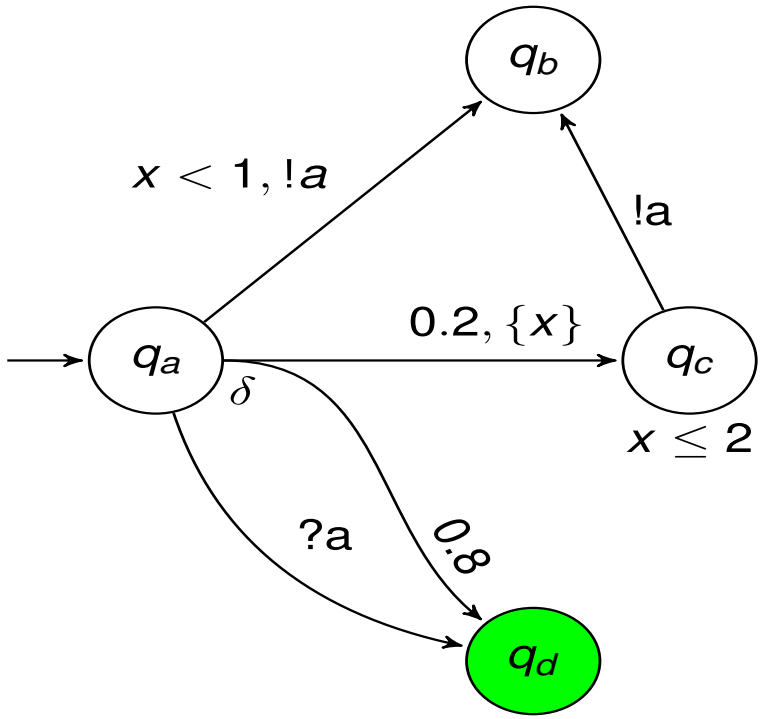

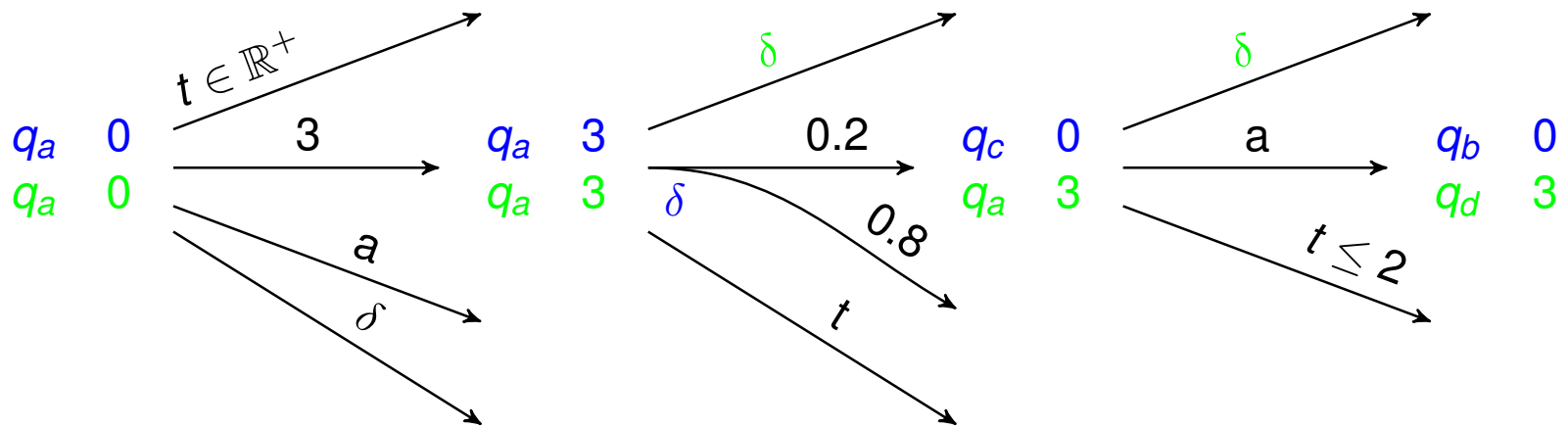

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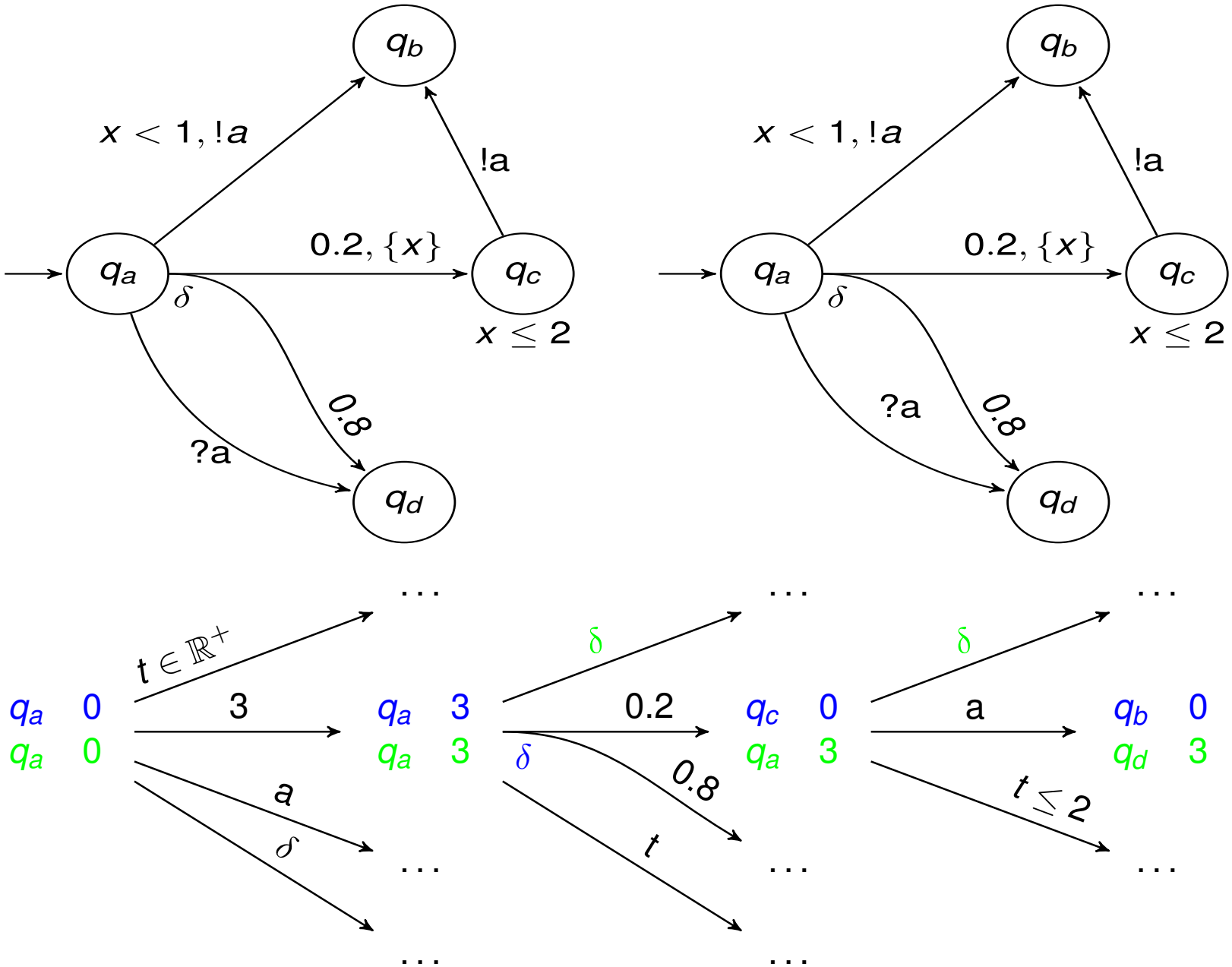

Problems studied: $\text{REACH}_{opt}^{\sim b}$

Input: A probabilistic protocol $\mathcal{P}$, and a control state $q_f \in Q$.
Question: Does there exists $N \in \mathbb{N}_{>0}$ with

$$\mathbb{P}_{opt}(\mathcal{P}^N \models \diamond q_f) \sim b?$$

$opt \in \{\min, \max\}$, $b \in \{0, 1\}$ and $\sim \in \{<, =, >\}$

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Notes

- $\text{REACH}^{=1}_{max}$: reach good state with friendly adversary
- $\text{REACH}^{=1}_{min}$: reach for all adversary
- $\text{REACH}^{>0}_{max}$: negative answer: avoid for all adversary

---

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Undecidability with fix topology

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Reduction of existence of bounded path in 2 counter machine (Undecidable [Minsky 67])

Two counter machine instructions

- i : $x++$ goto i'
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- Infinite (false) zero tests
- $P_{min}(\Diamond error) = 1 \Leftrightarrow$ existence of bounded path

Mobil topology: Decidability

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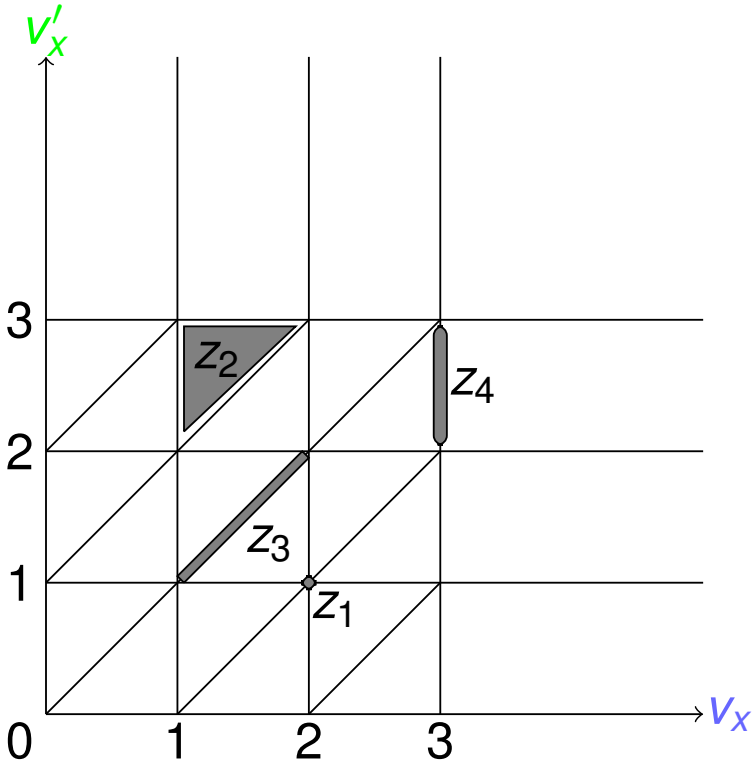
Clique of probabilistic timed protocol with:

Deletion rate λ:
Each process have probability λ to be lost after each action and each time unit.
Models: crash, out of range, out of power, ...

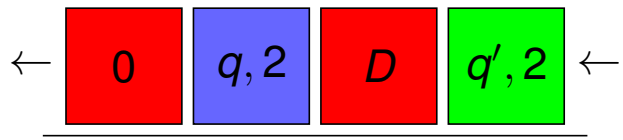
Creation rate μ:
Creation of *n* processes with probability $\mu^n(1-\mu)$.
Models: maintenance, new comer, ...

Reduction of regions to channel contents

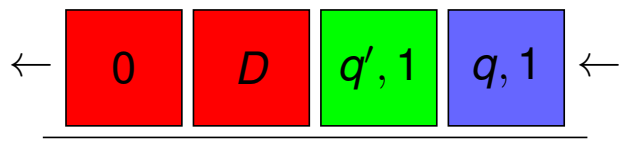
$\mathcal{P} : (q, x)$ and $\mathcal{P} : (q', x)$



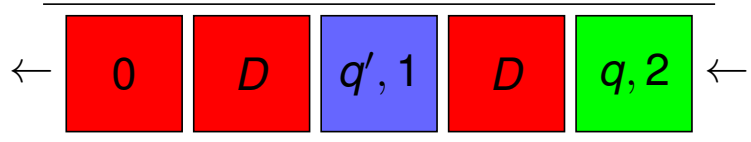
z_4: $v_x = 2 < v'_x < 3$



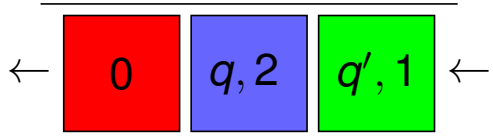
z_3: $1 < v_x = v'_x < 2$



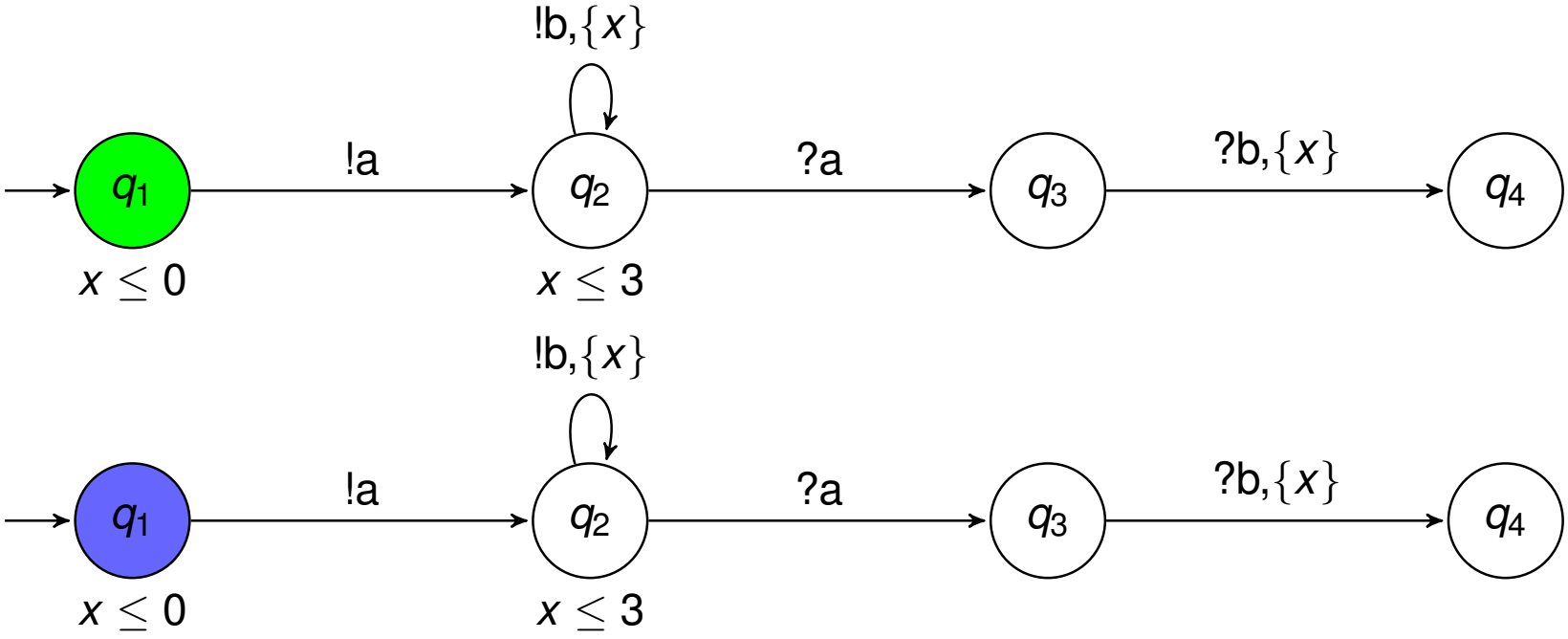
z_2: $1 < v_x < 2 < v'_x < 3, \{v_x\} < \{v'_x\}$

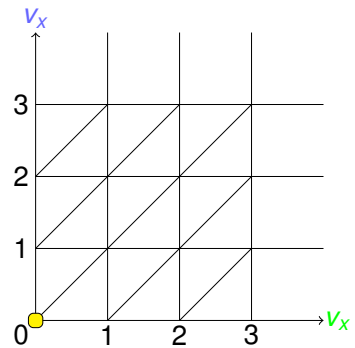


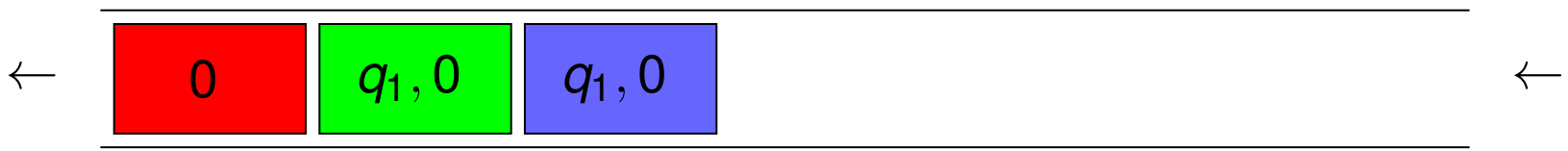
z_1: $v_x = 2, v'_x = 1$



Simulation

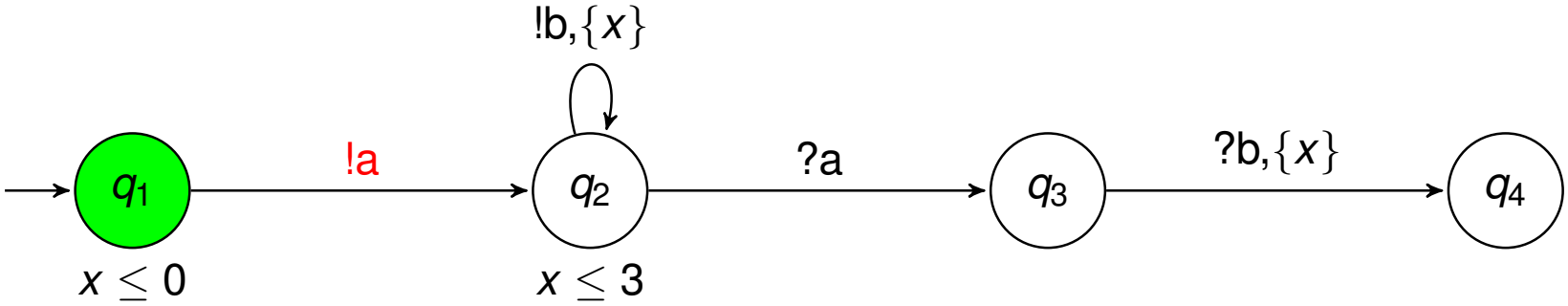


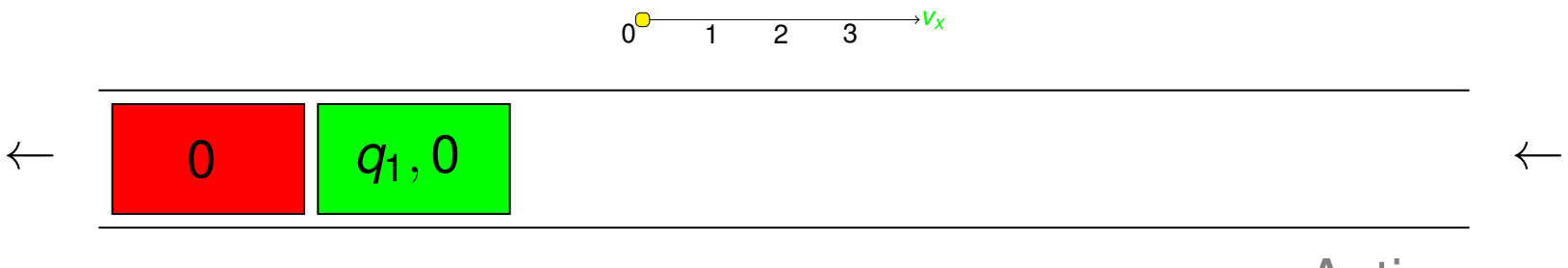




Loss

Simulation





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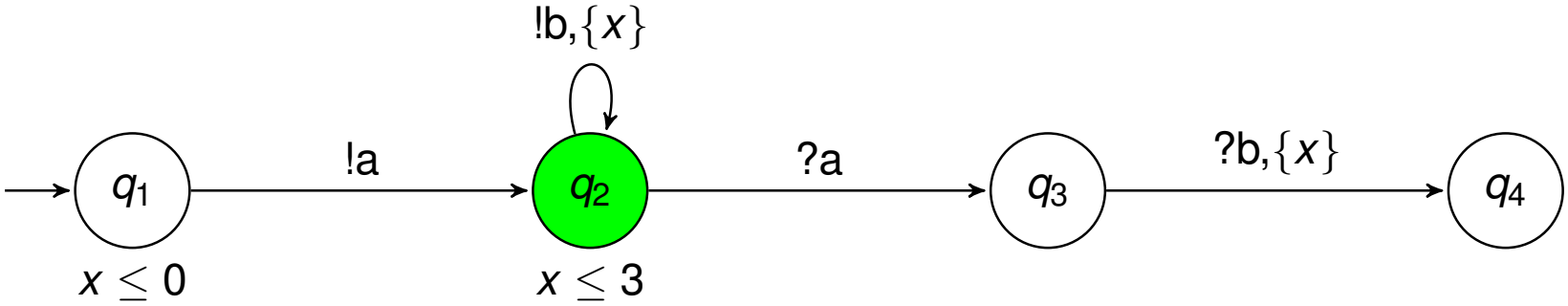
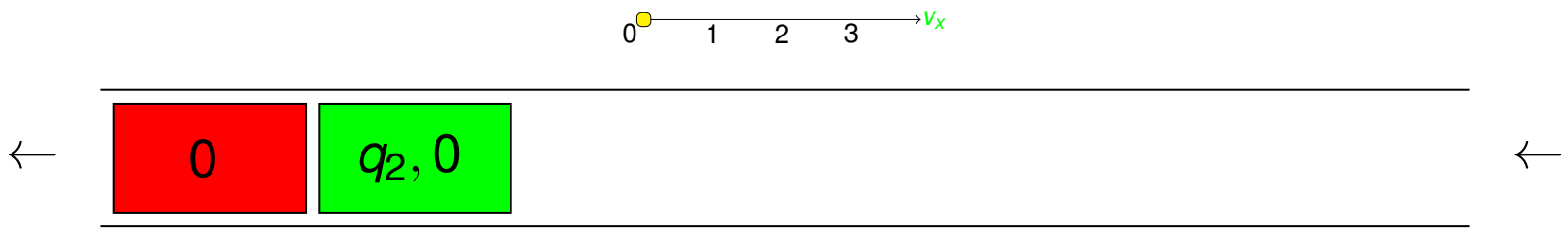
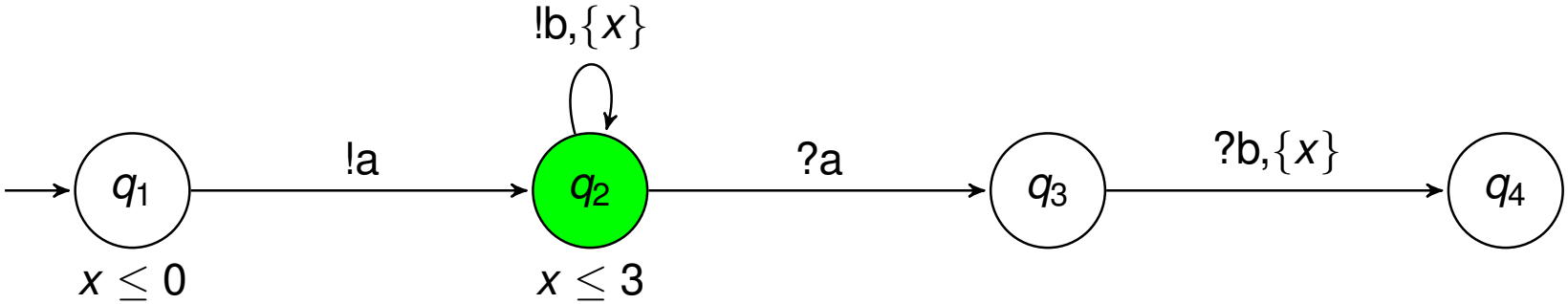


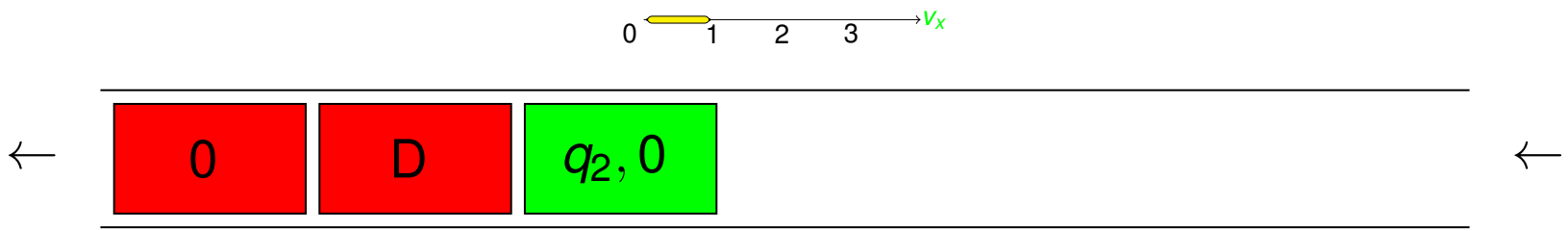


Action a

Time elapsing

Simulation

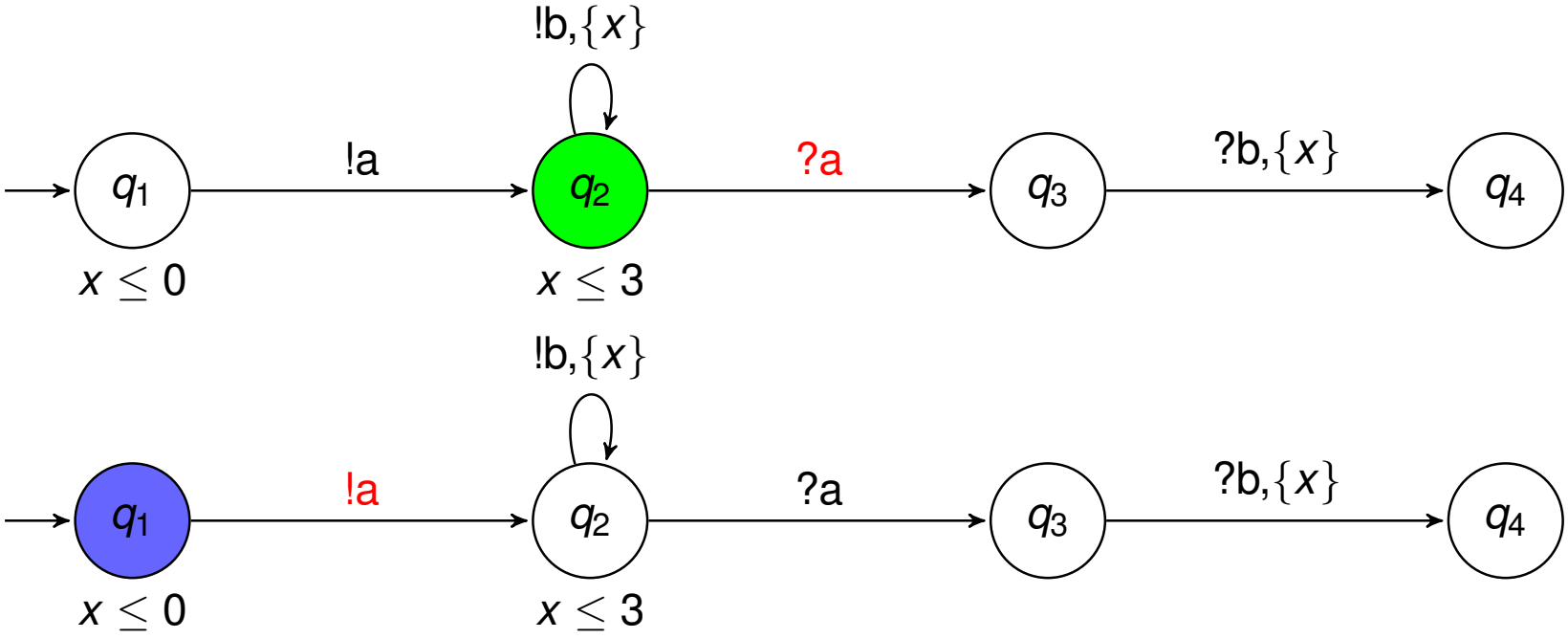


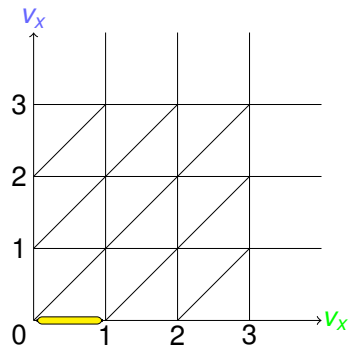


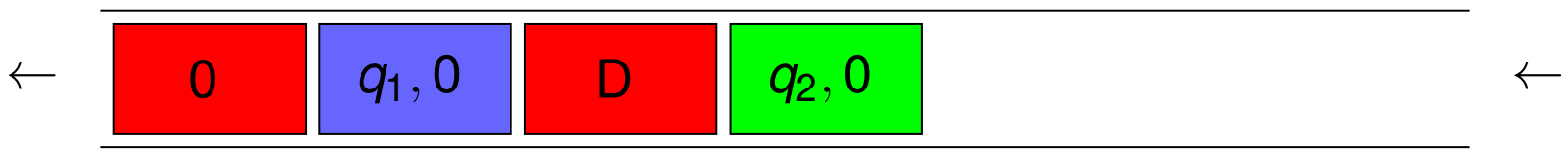
Time elapsing

Maintenance/creation

Simulation







Maintenance/creation

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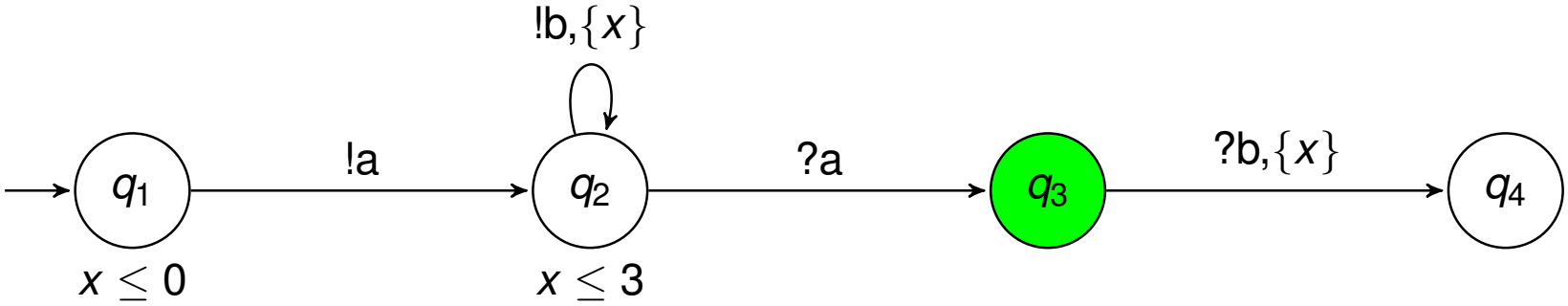

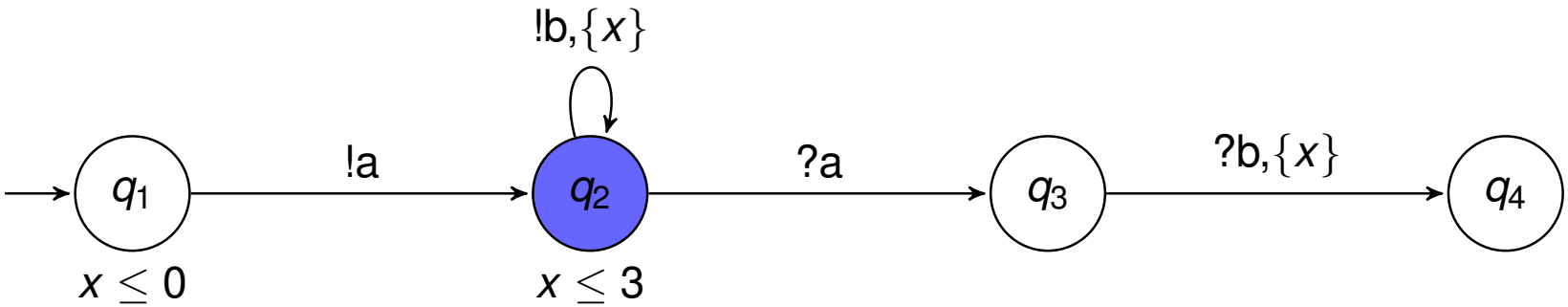

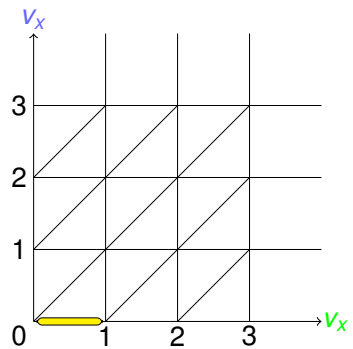

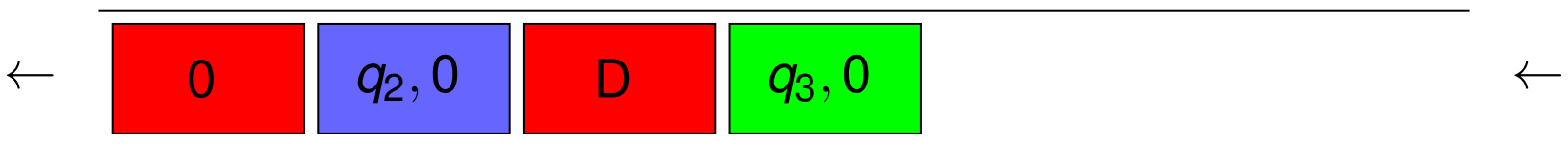

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Time elapsing

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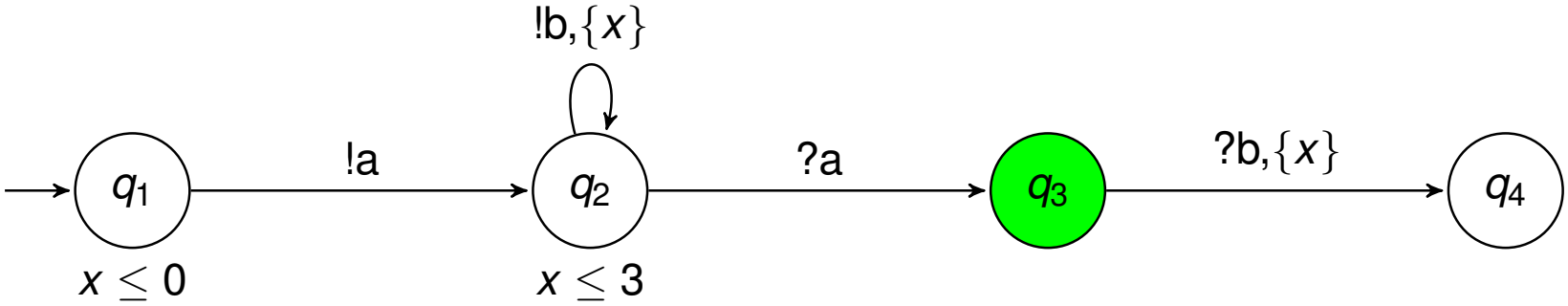

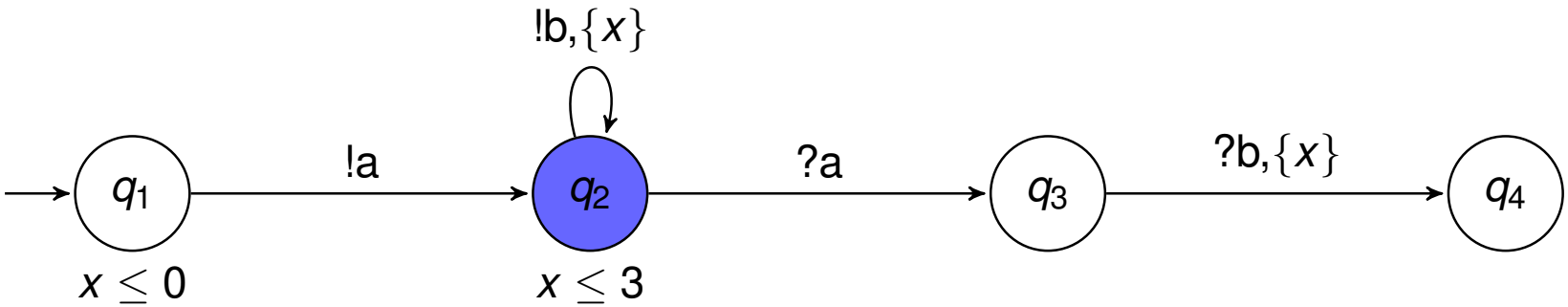

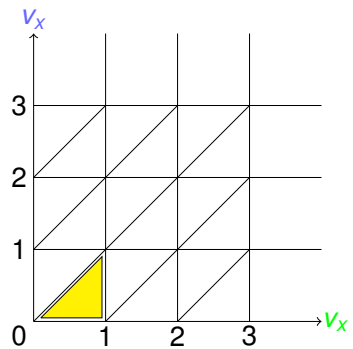

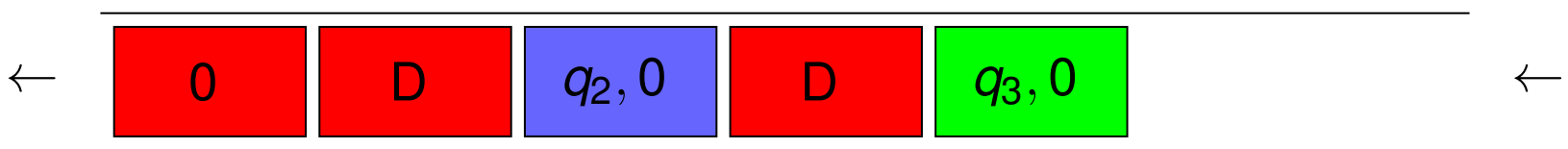

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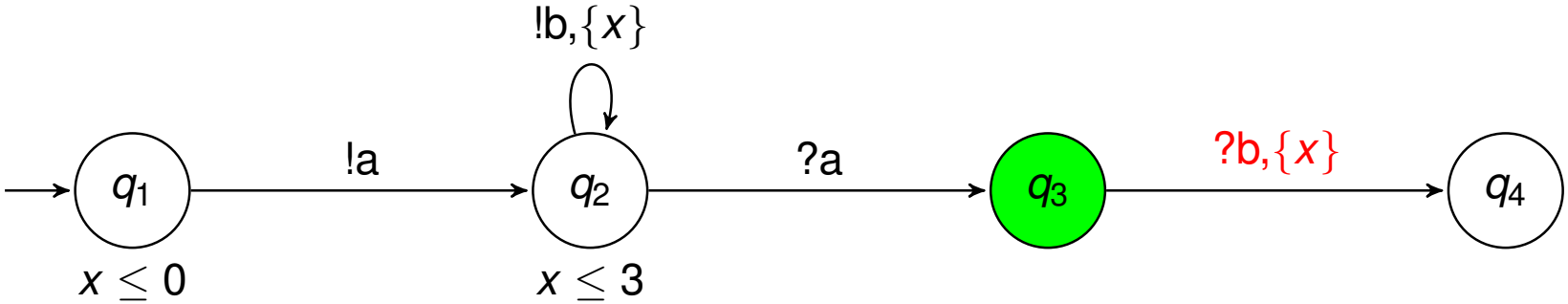
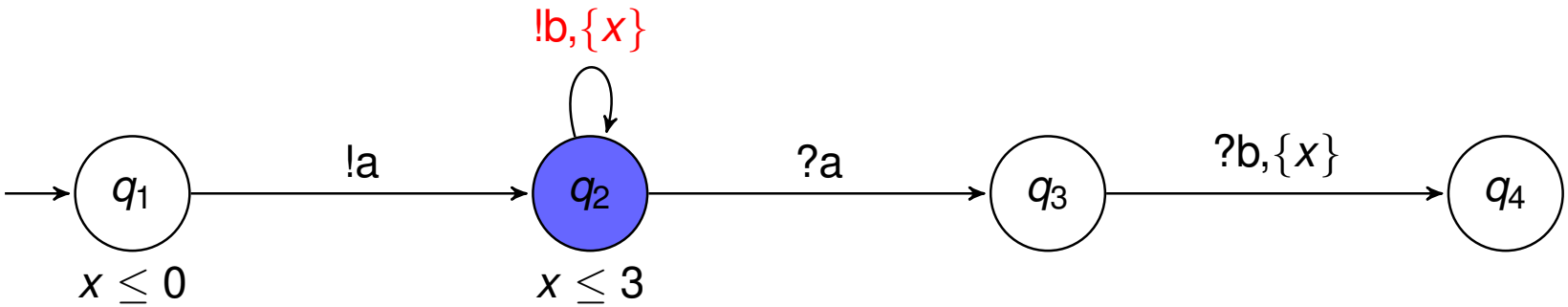
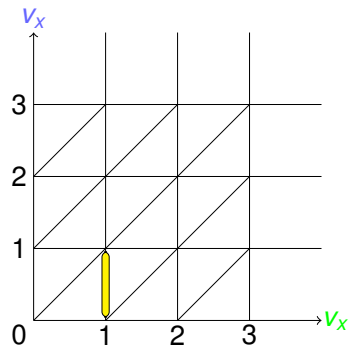
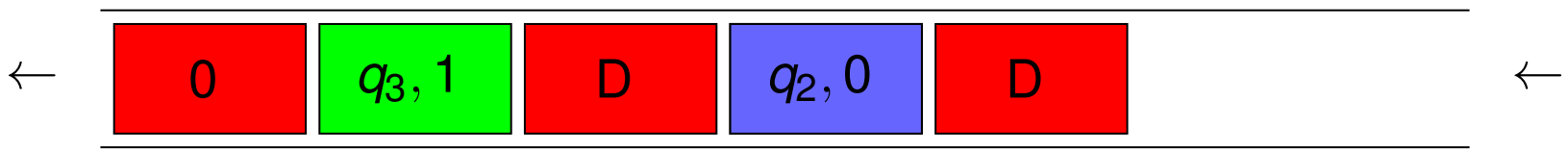
Simulation





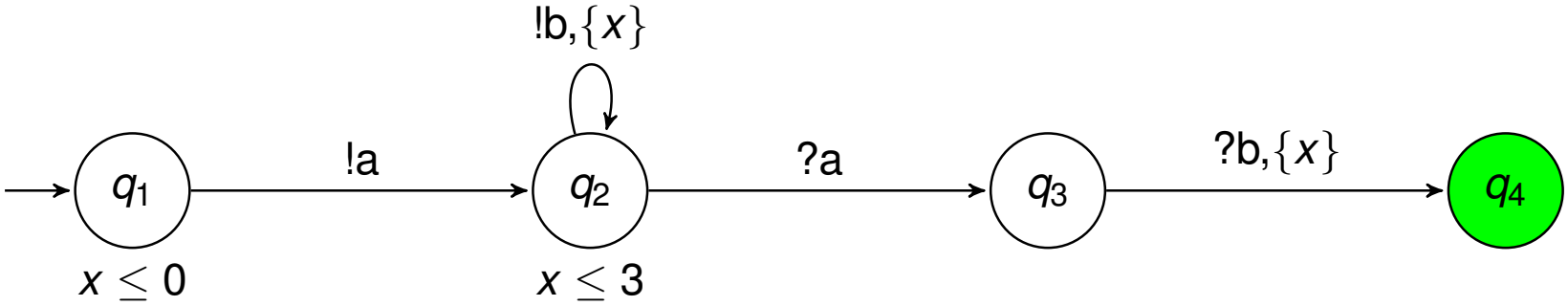


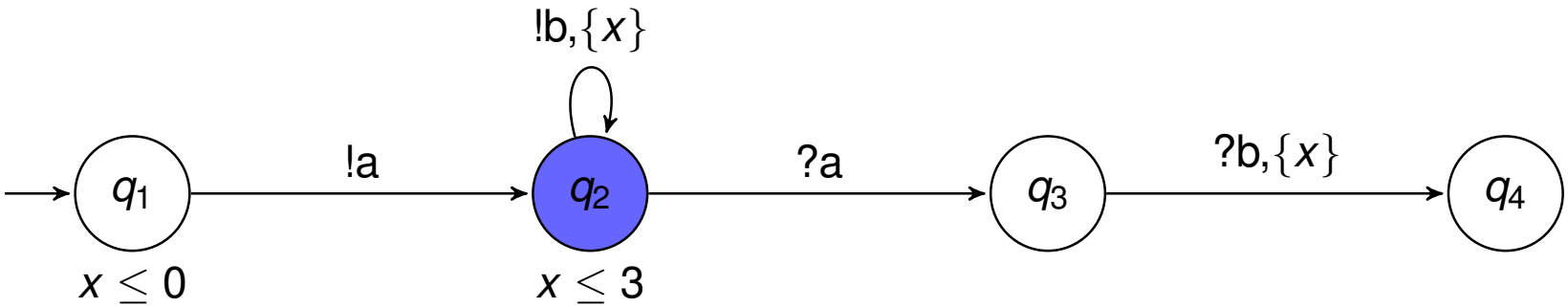


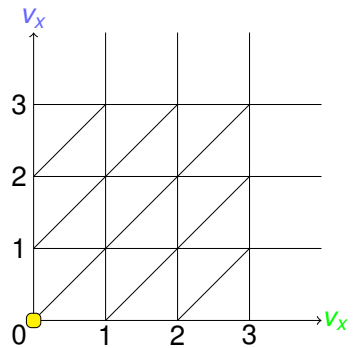
Time elapsing

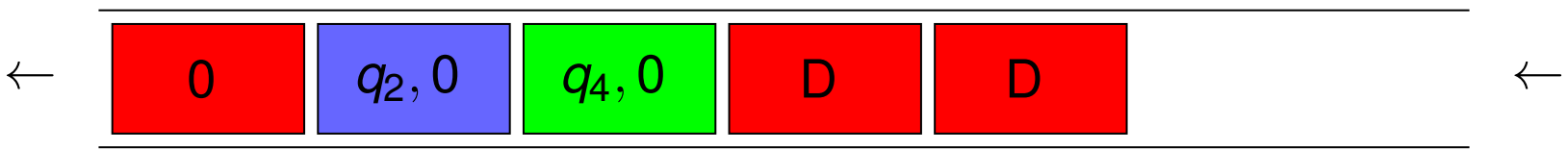
Action b

Simulation





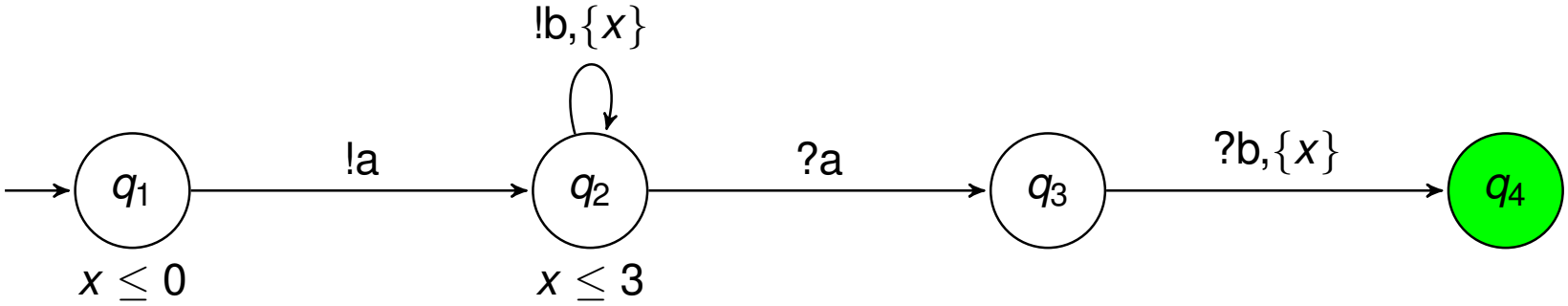


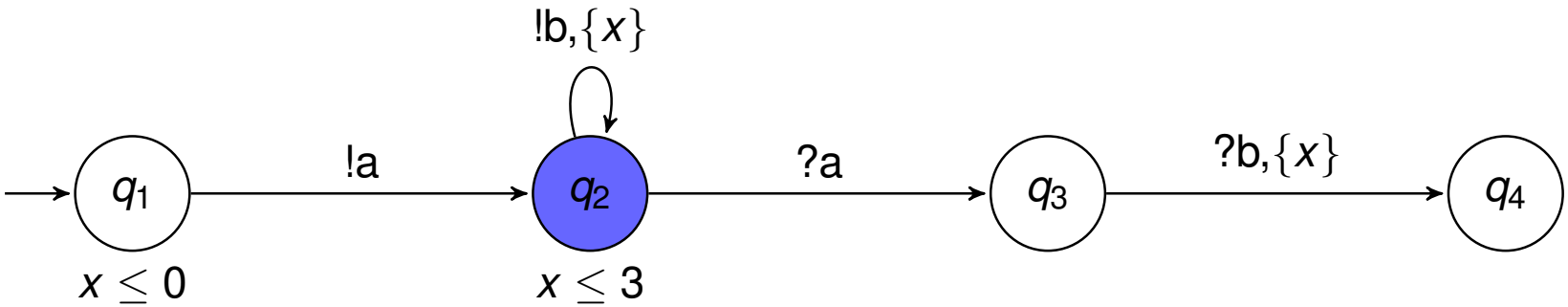


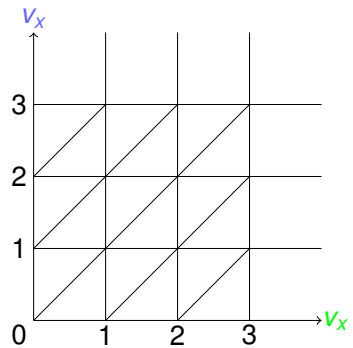
Action b

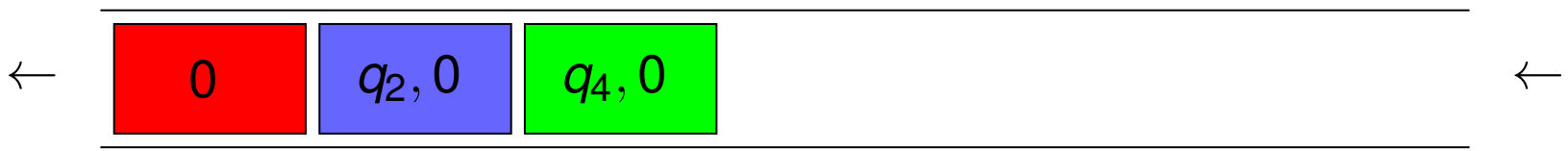
Remove useless messages

Simulation









Remove useless messages

Conclusion

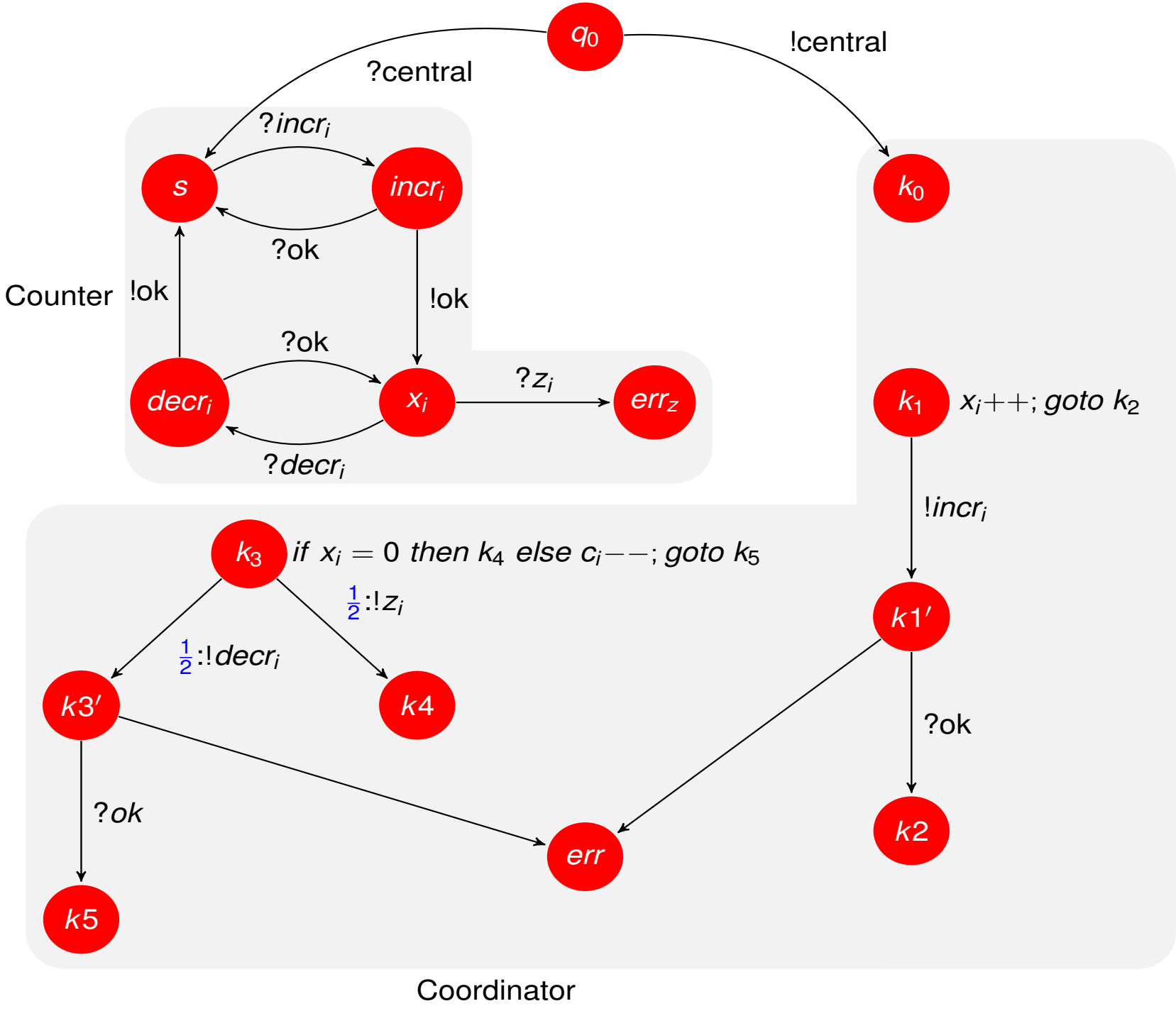
Parametric verification is :

- Verifying for all parameter at once
- Undecidable for fix topology
- Decidable for Mobile topology

			$\text{REACH}^{>0}_{max}$	$\text{REACH}^{=1}_{max}$	$\text{REACH}^{=1}_{min}$	$\text{REACH}^{<1}_{min}$
Static			[ADRST11]	U	U	U
mobil	timed	1	D	D	D	D
		≥ 2	[ADM04]	U	U	U

Future works

- Quantitative properties
- $P_{min}(\phi) = f(N) \pm \epsilon$
- Topologies properties
- Synthesis of parameter


q_0
?central
!central
?$incr_i$
s
$incr_i$
?ok
Counter
!ok
!ok
?ok
$decr_i$
x_i
?z_i
err_z
?$decr_i$
k_0
k_1
$x_i{+}{+}$; goto k_2
!$incr_i$
k_3
if $x_i = 0$ then k_4 else $c_i{-}{-}$; goto k_5
$\frac{1}{2}$:!z_i
$\frac{1}{2}$:!$decr_i$
$k3'$
$k4$
$k1'$
?ok
?ok
err
$k2$
$k5$
Coordinator

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