Background

Parameterized Systems

Petri Nets

Lossy Channel Systems

Timed Petri Nets

Lossy Channel Systems

Lossy Channel Systems

Model

Configurations

Transitions

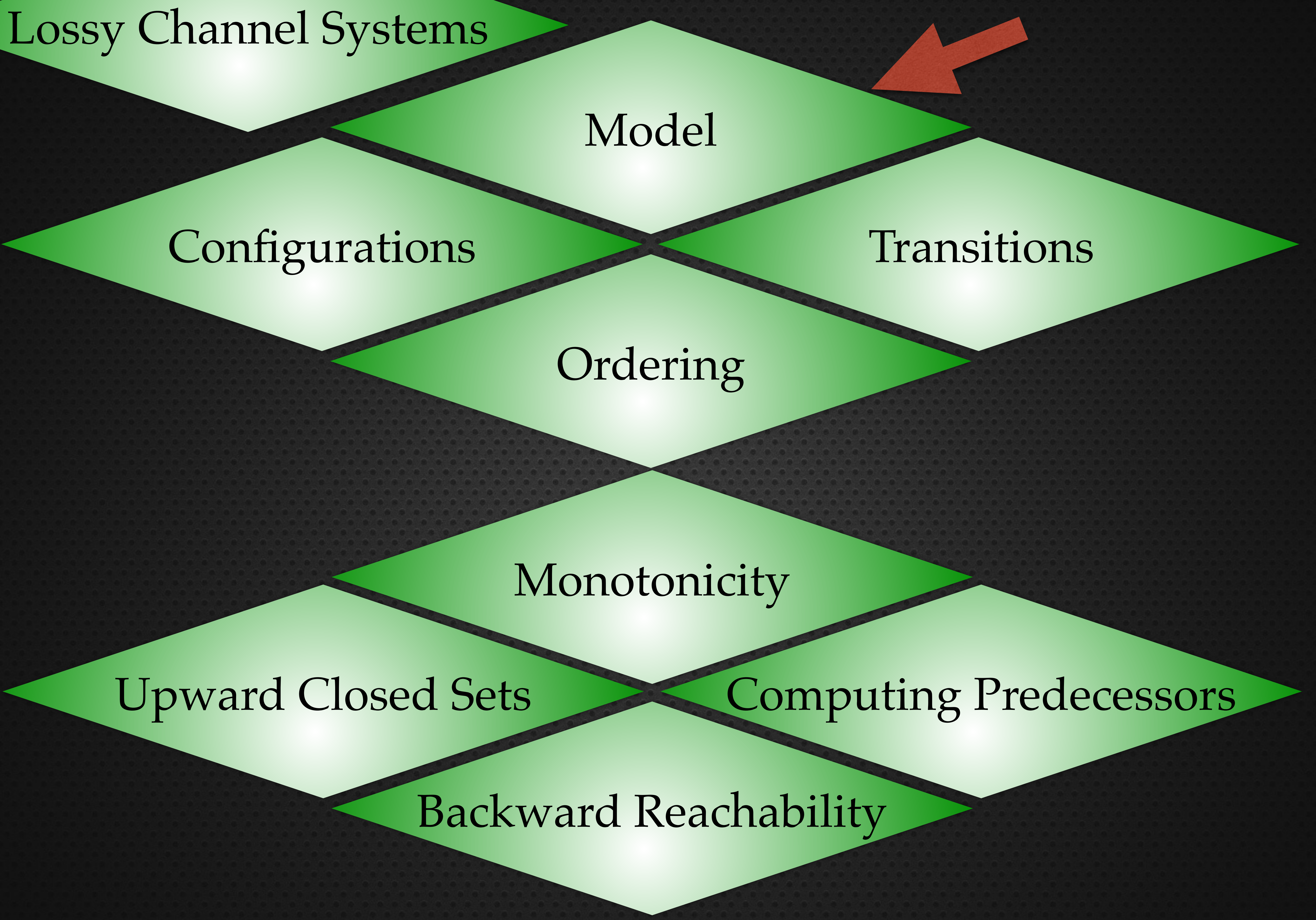
Ordering

Monotonicity

Upward Closed Sets

Computing Predecessors

Backward Reachability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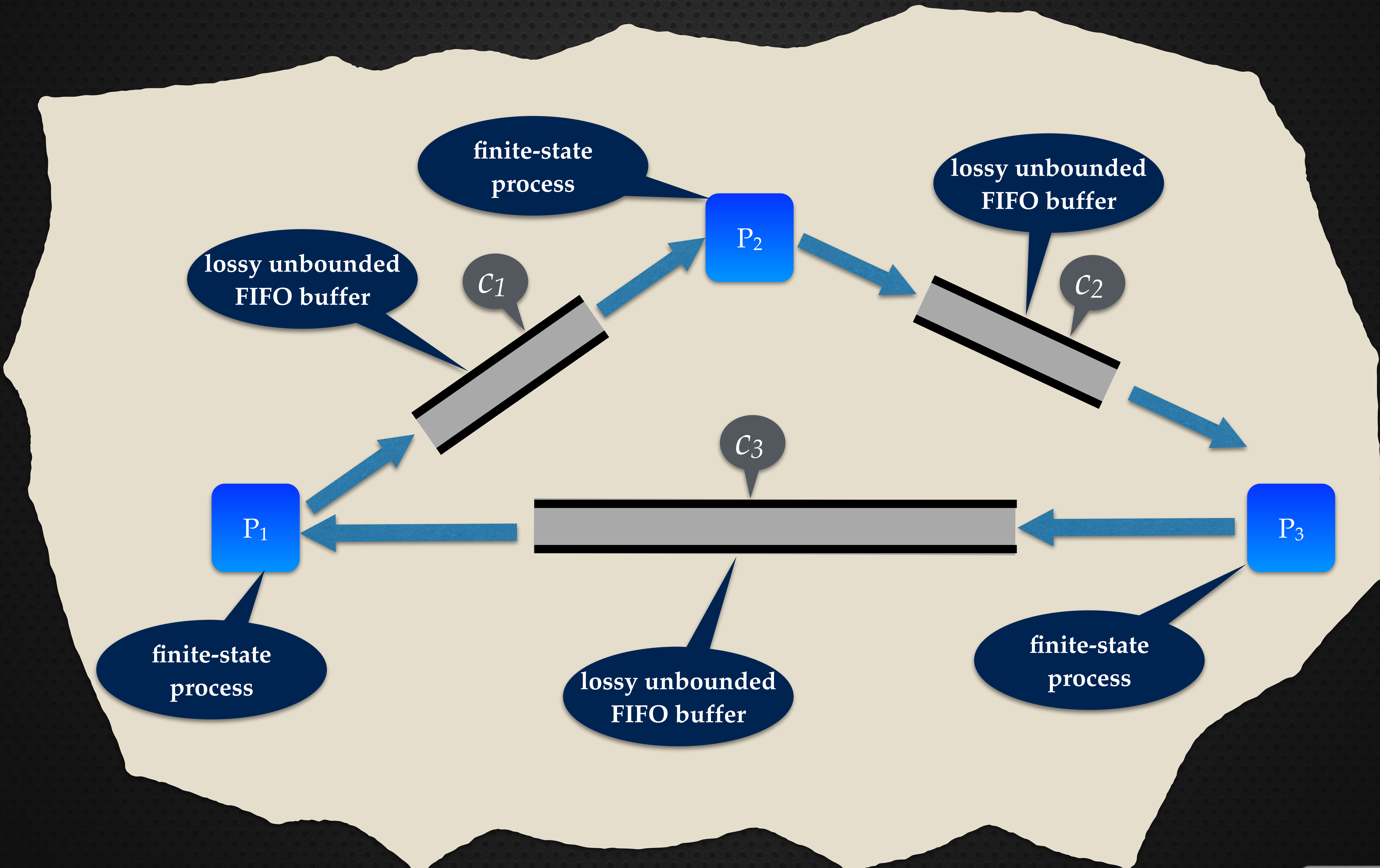
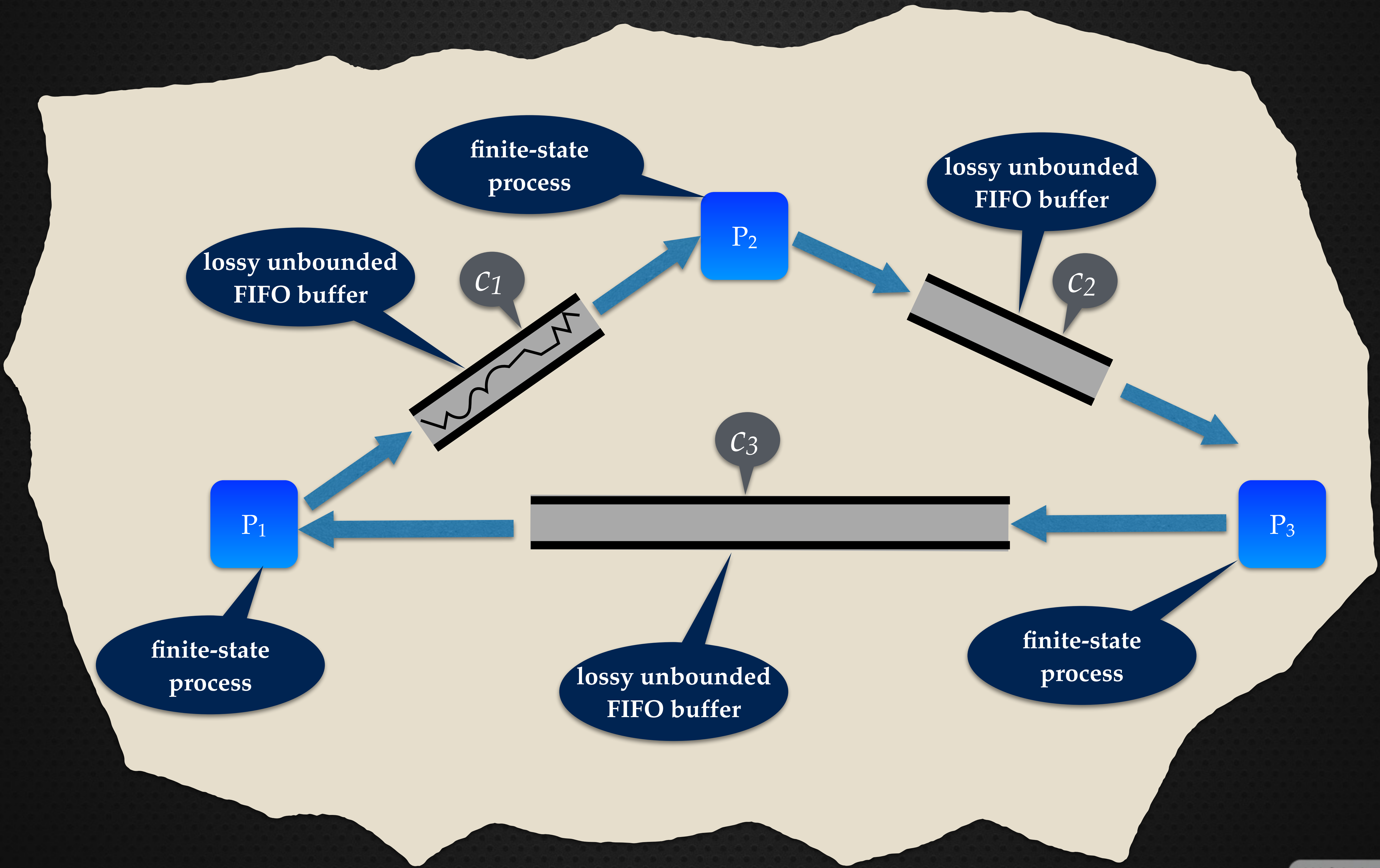
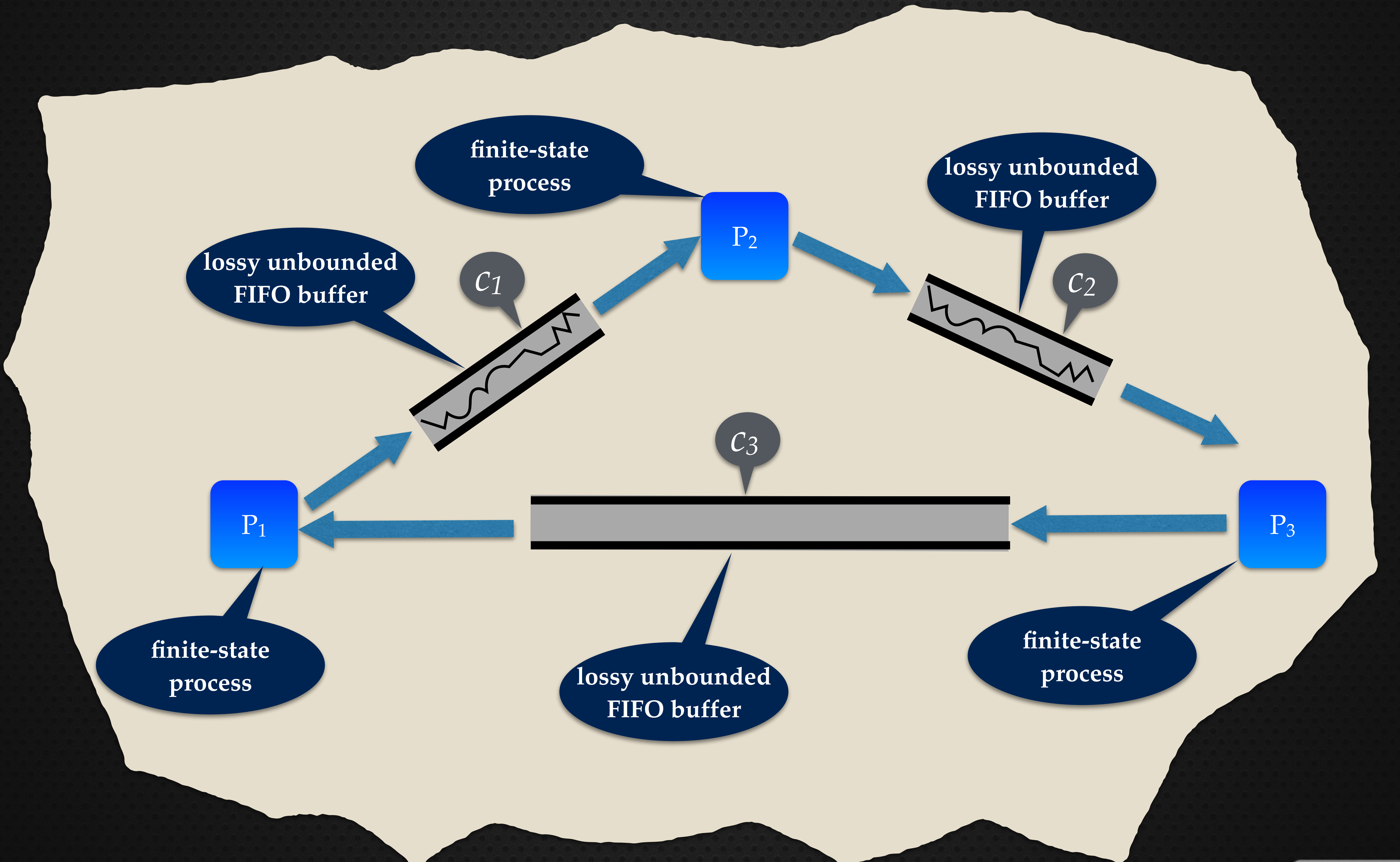
Lossy C Model



Lossy Channel Model



Lossy C Model



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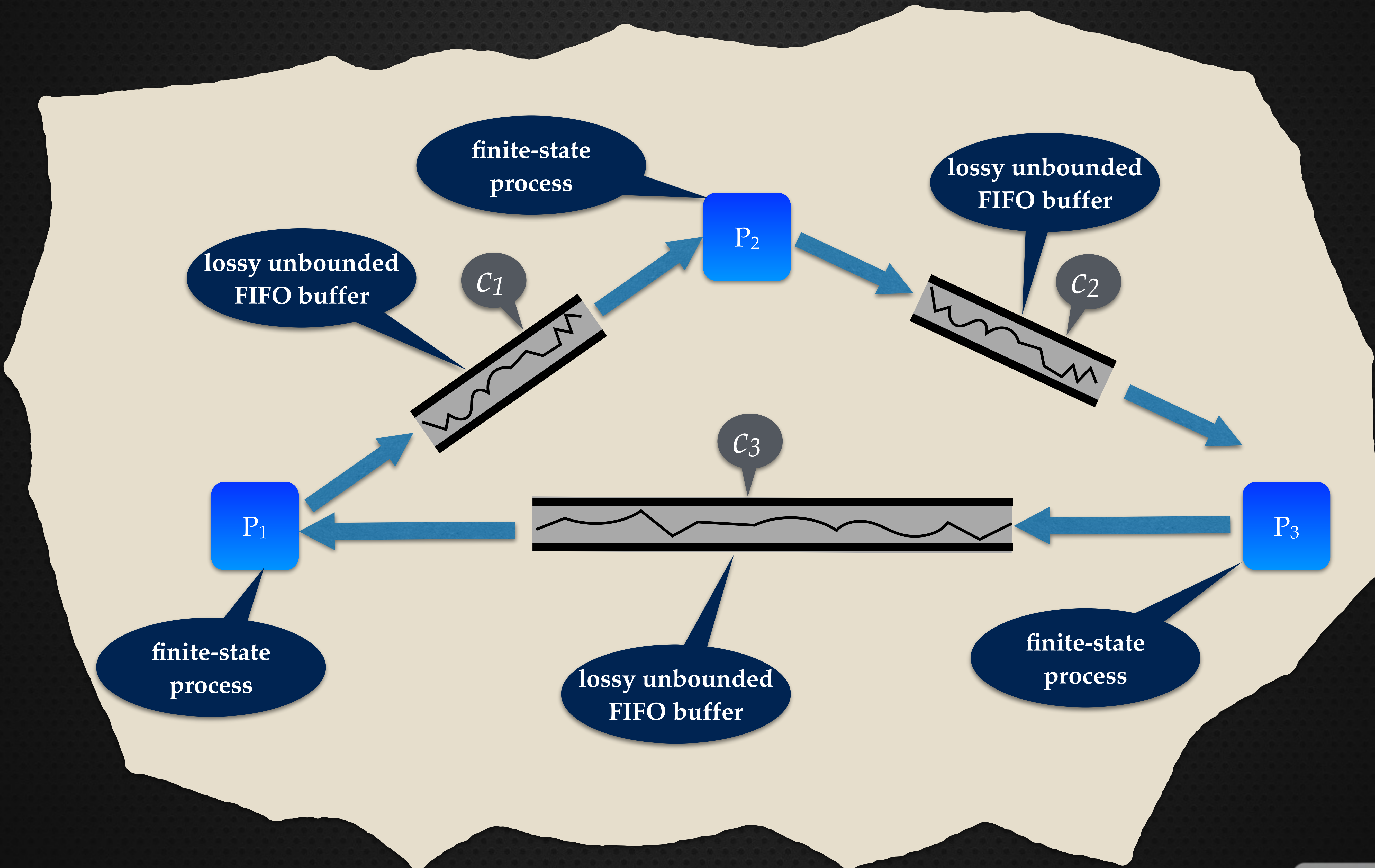
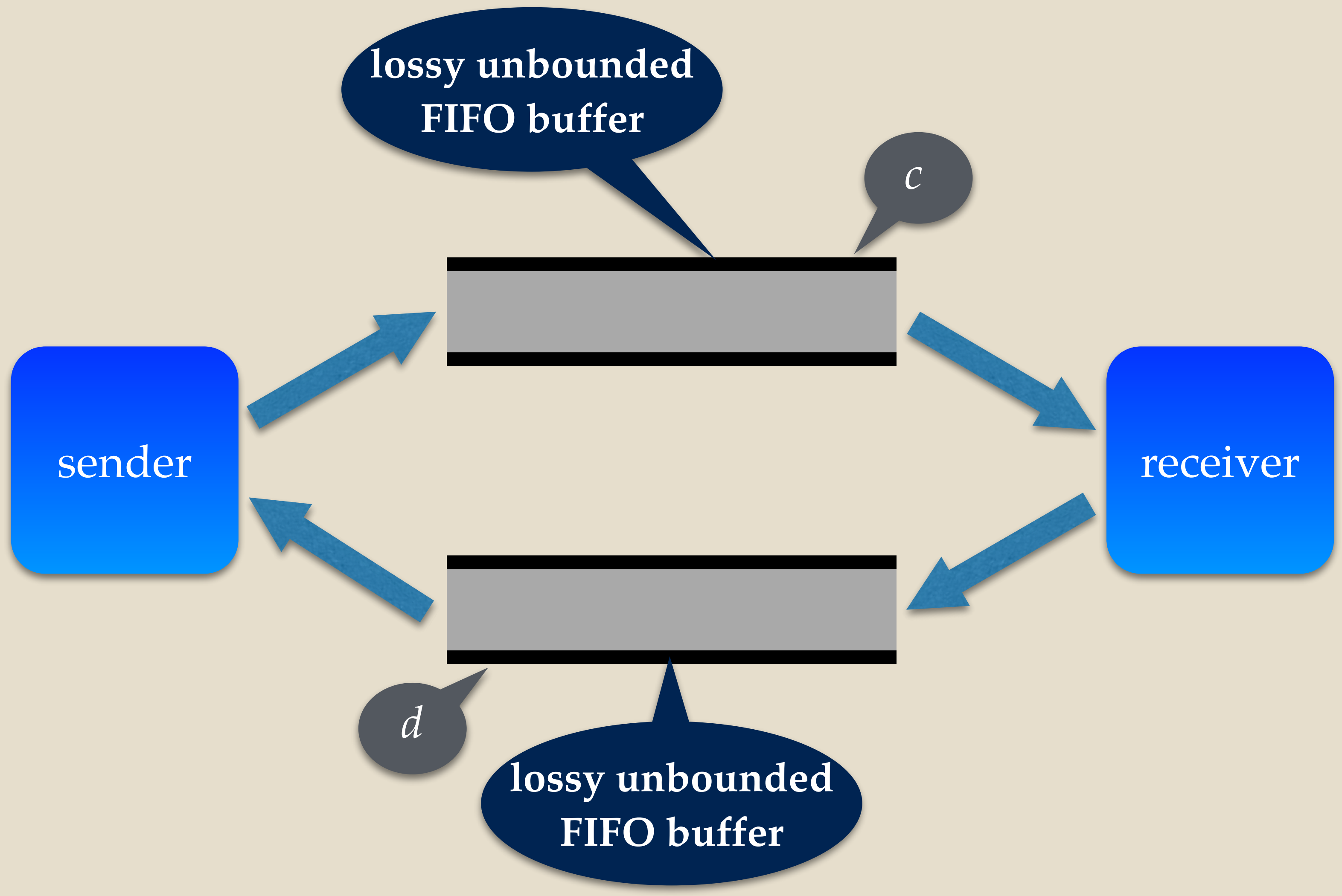


Telecommunication Protocols



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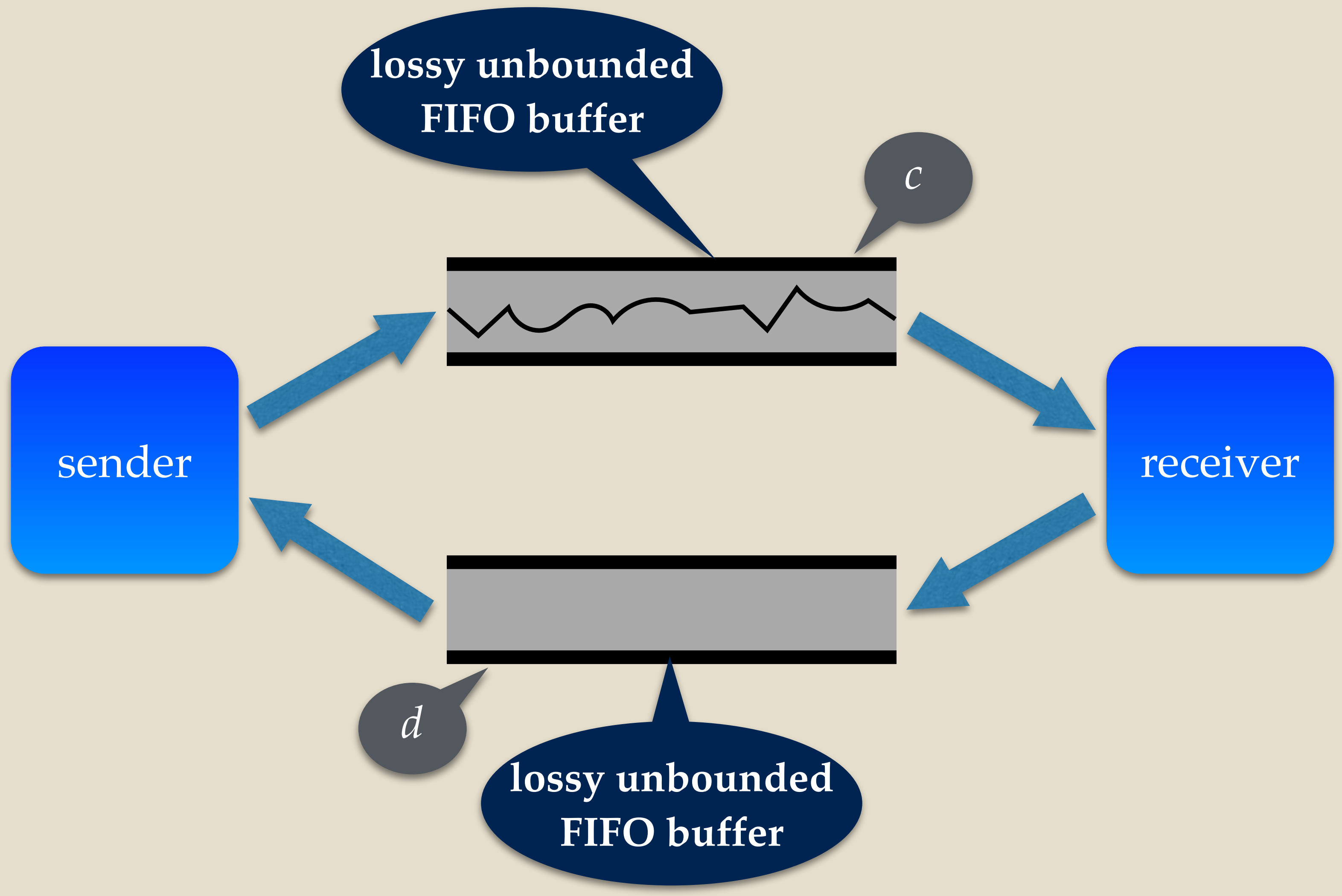
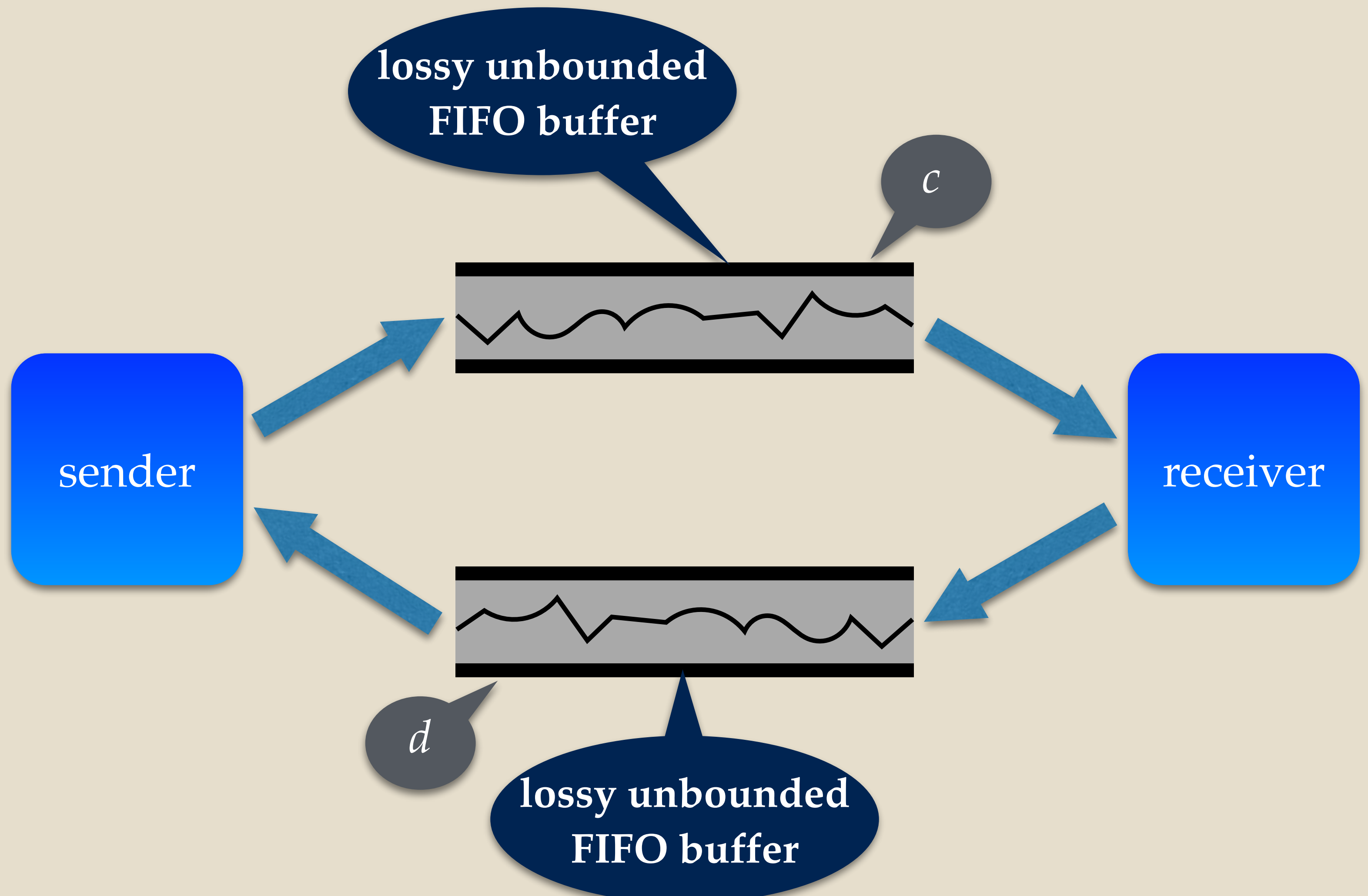
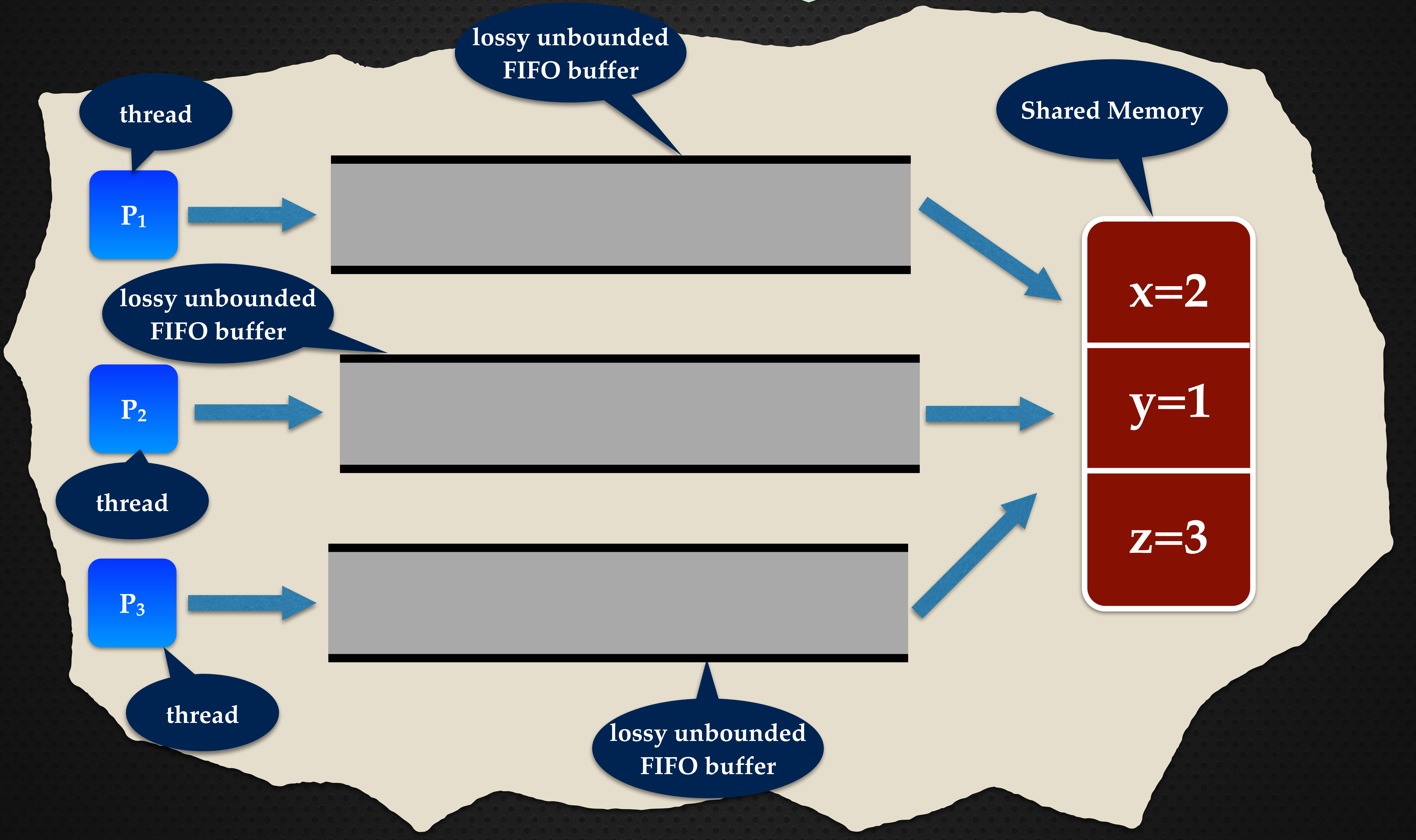


Lossy C… M…

Telecommunication Protocols



Weak Memory Models



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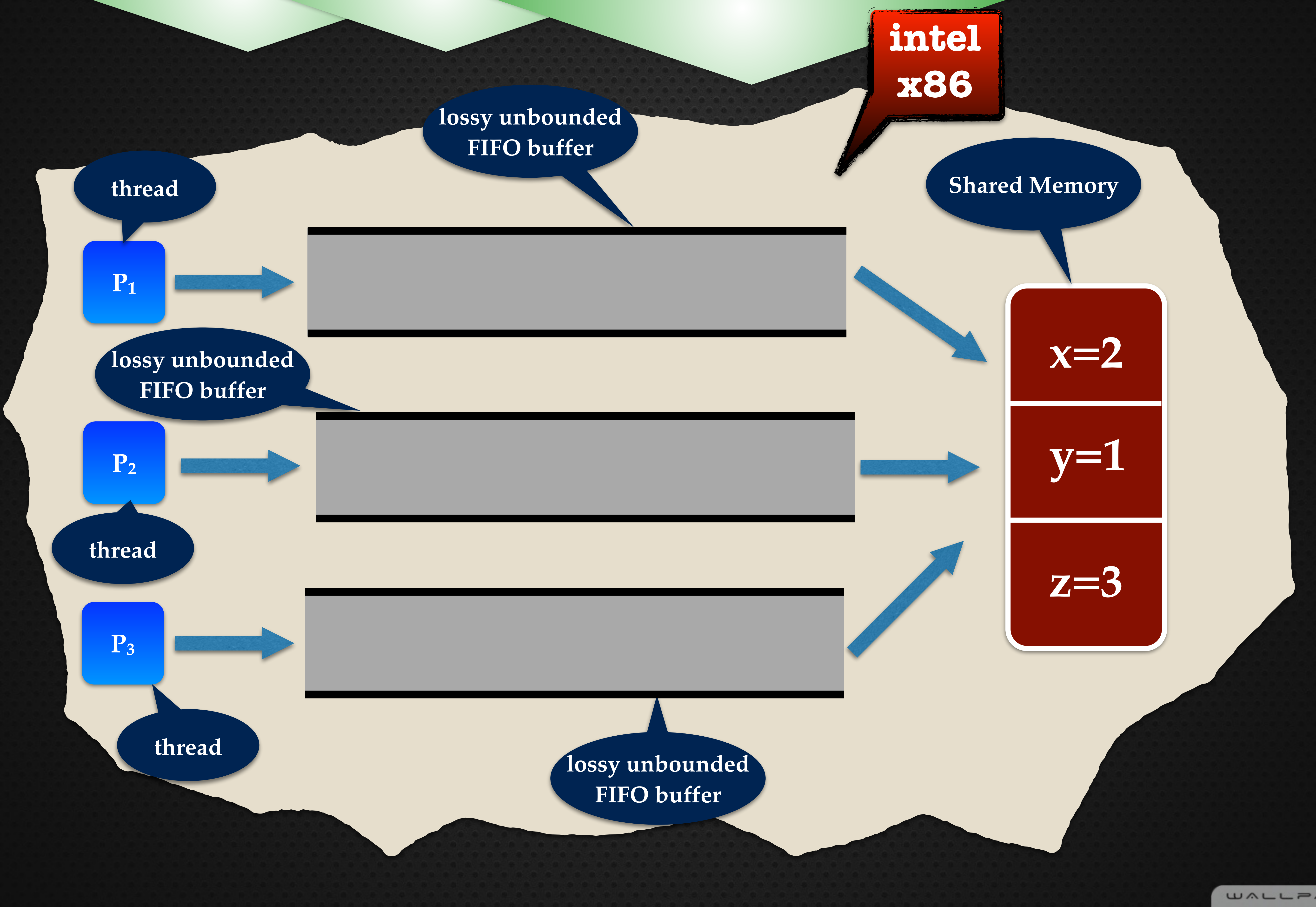

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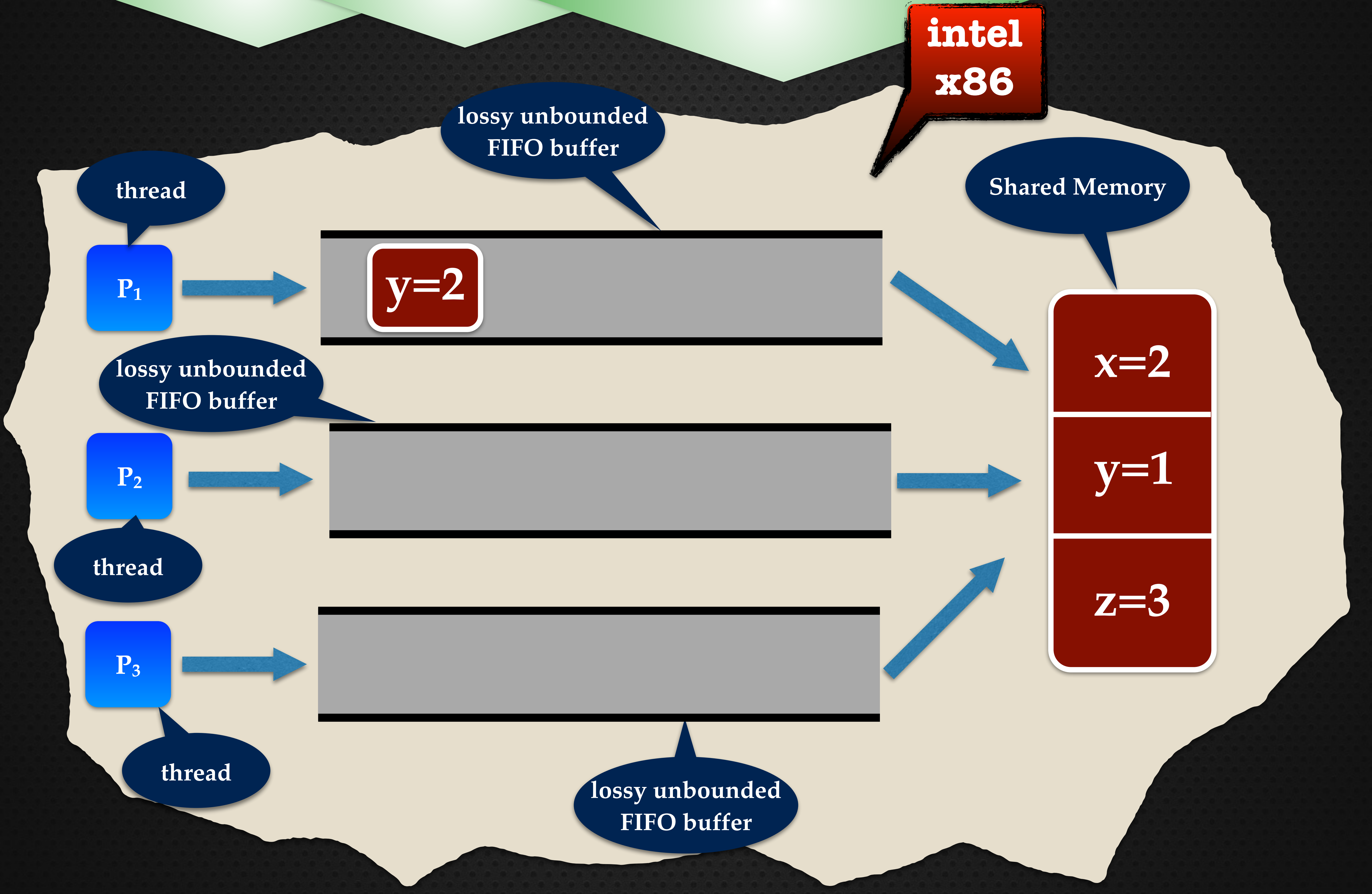

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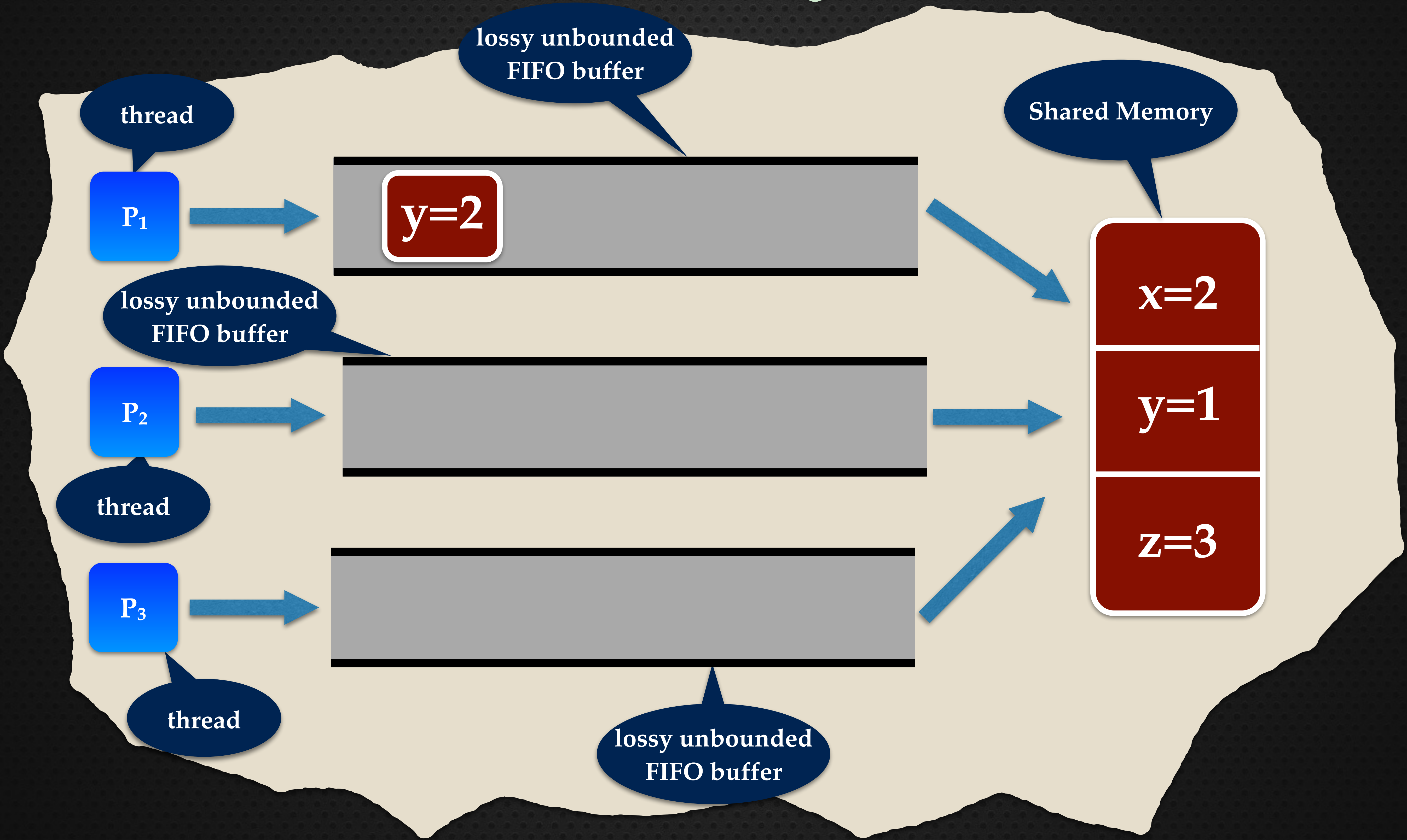

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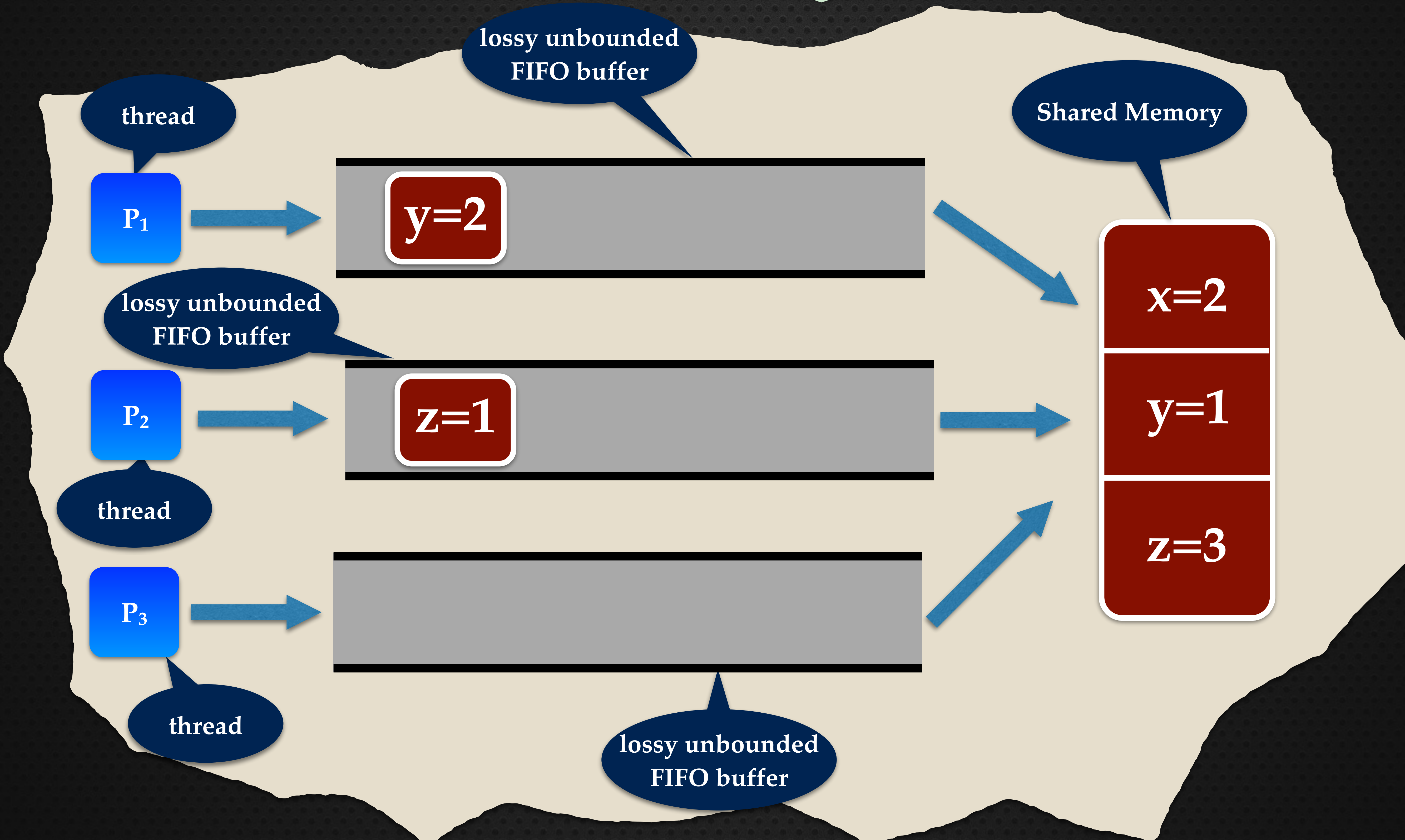

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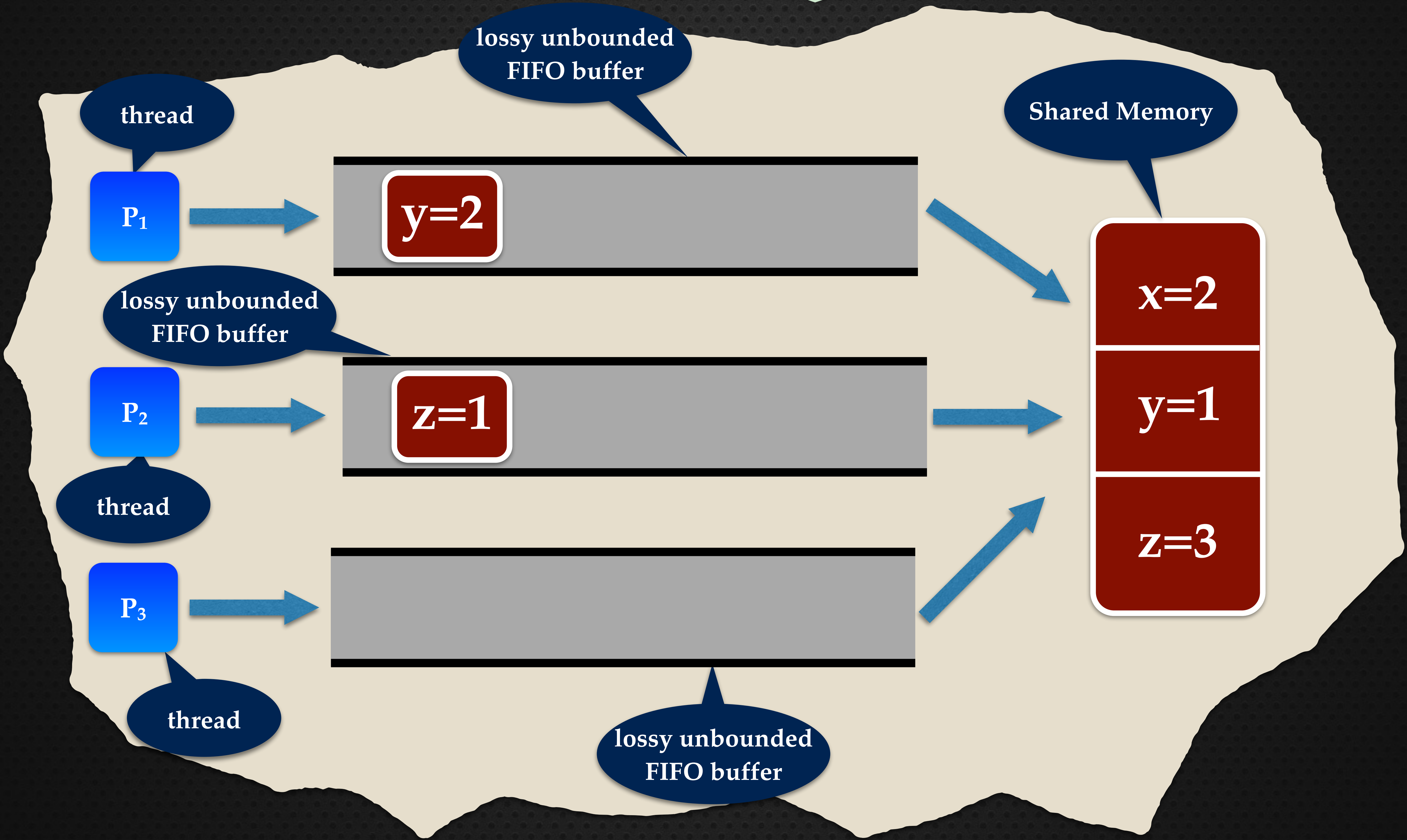

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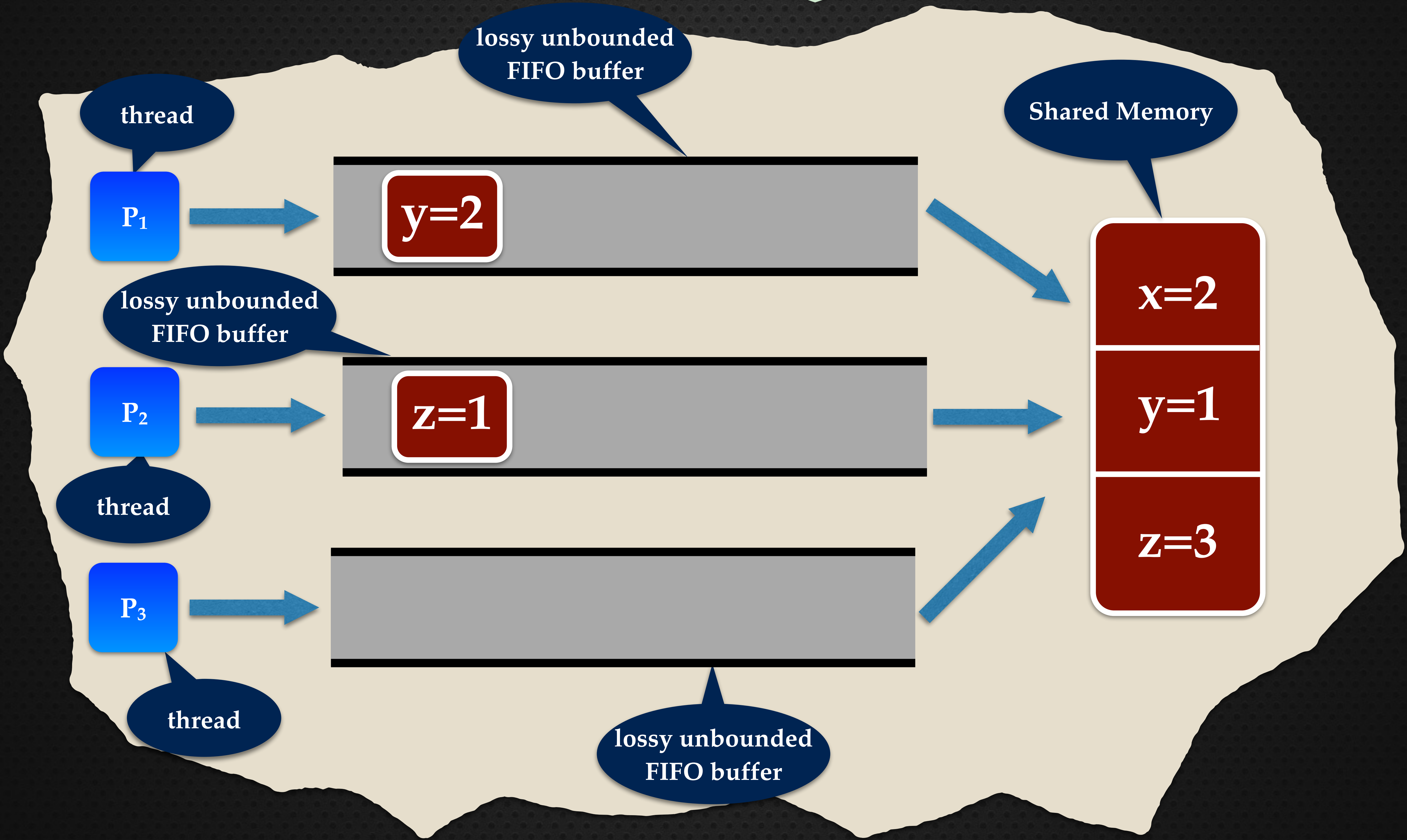

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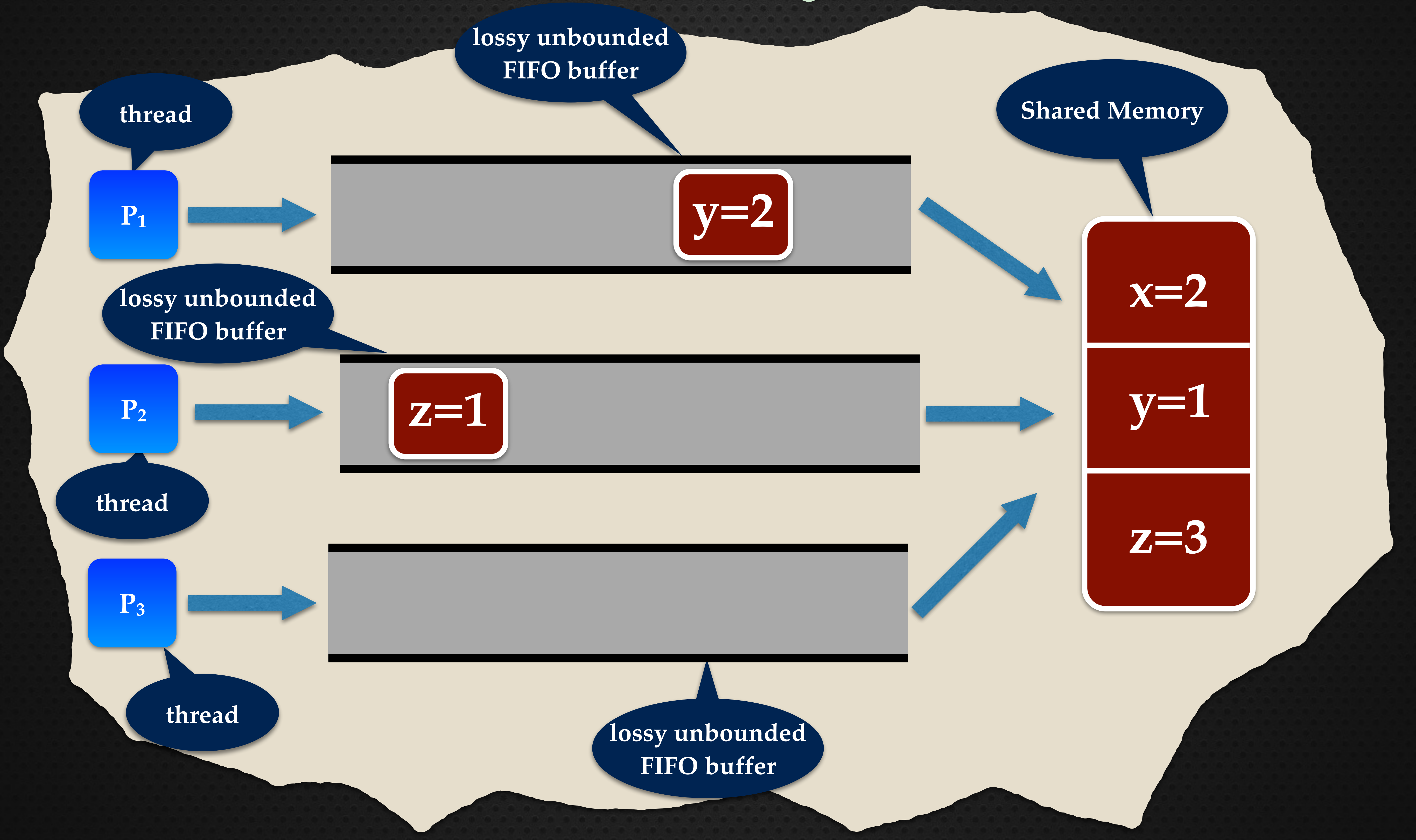

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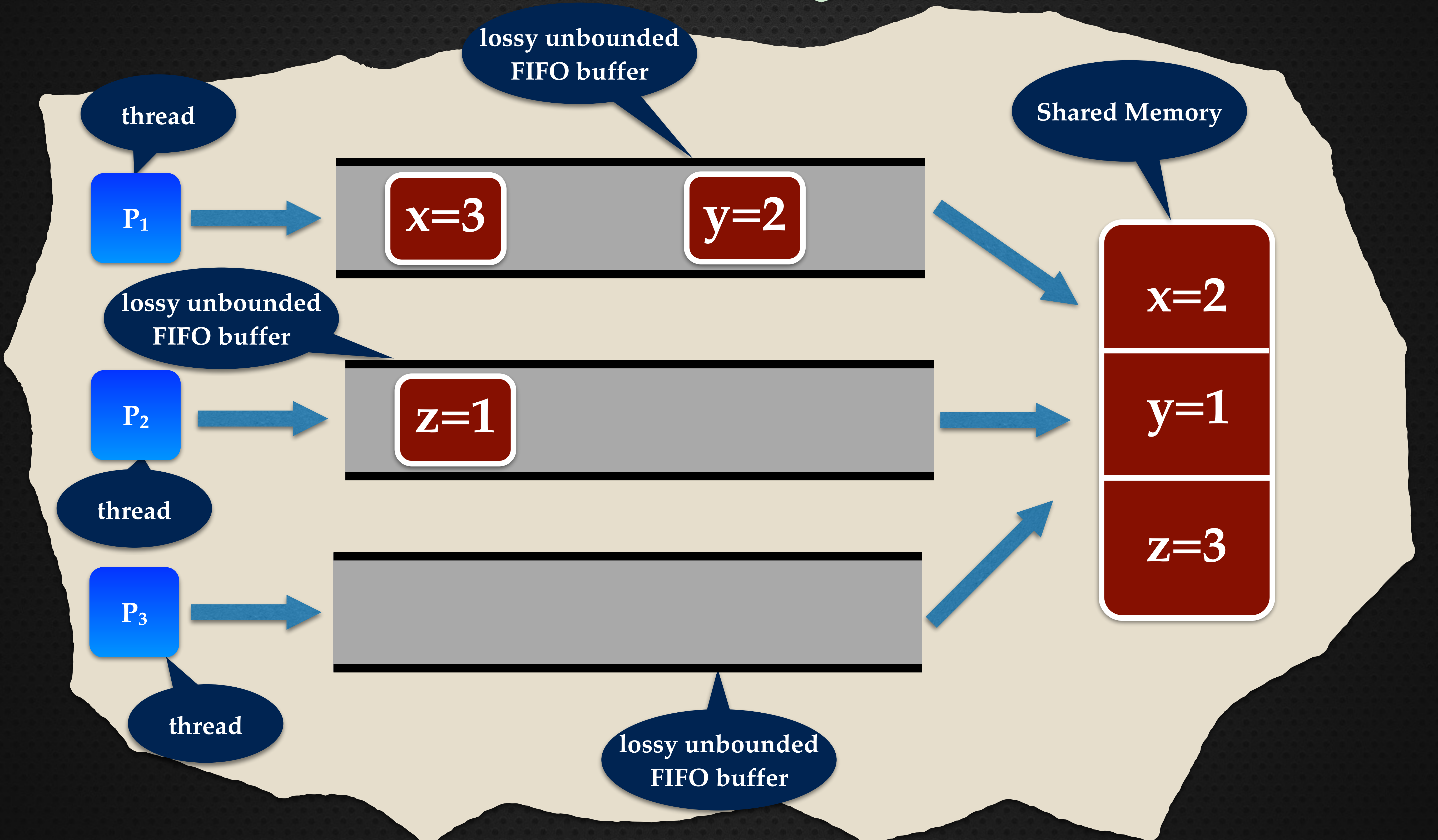

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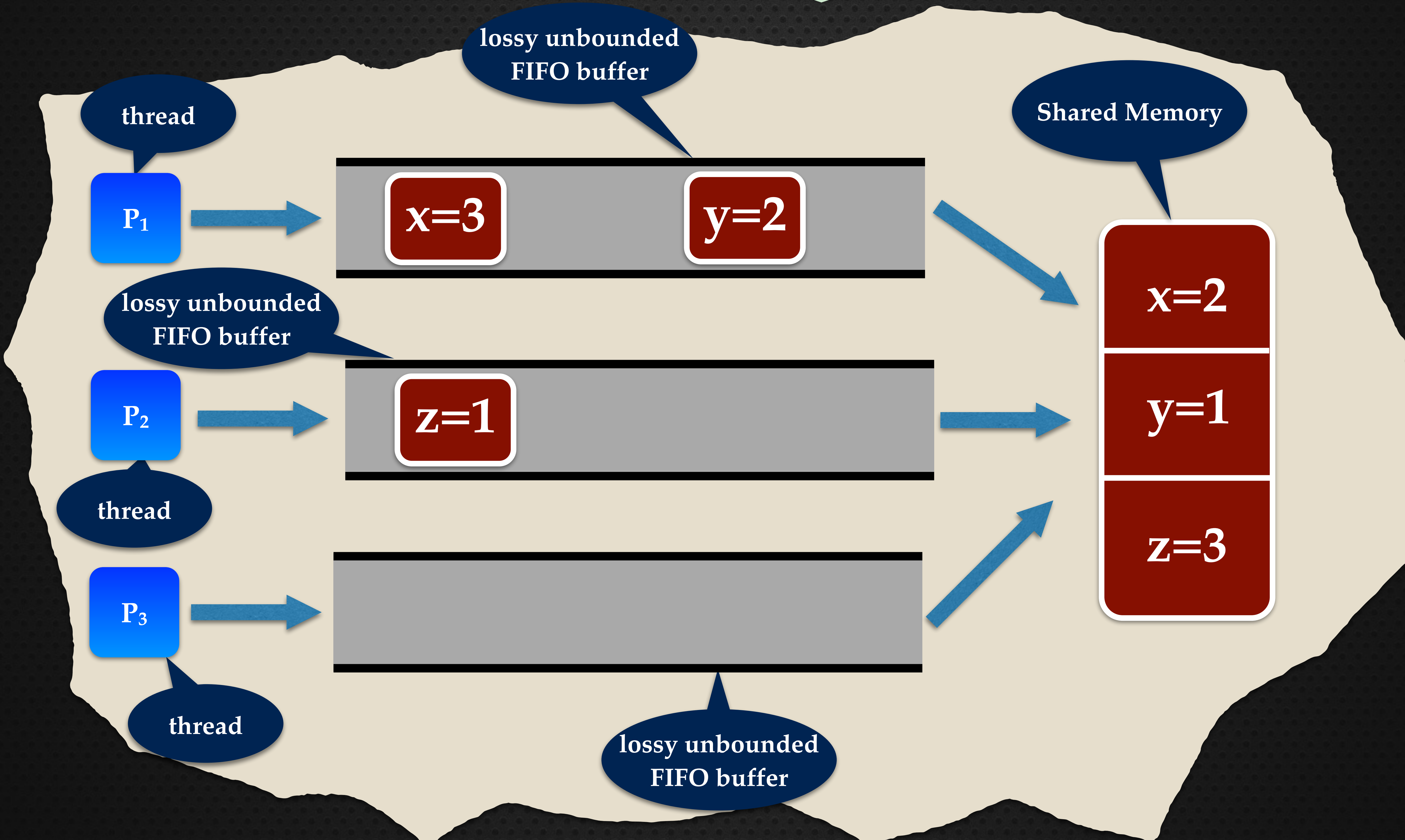

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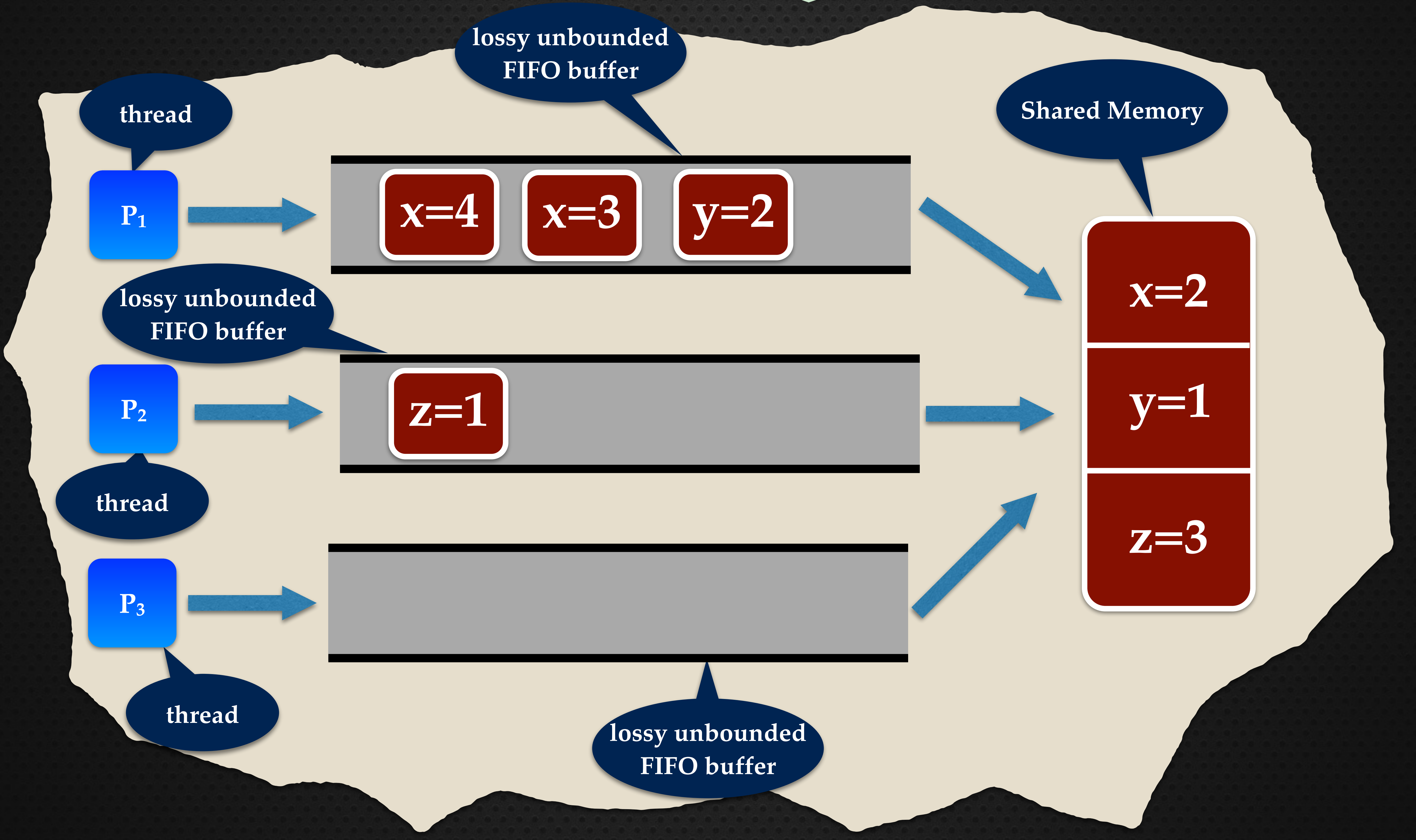

Lossy C M

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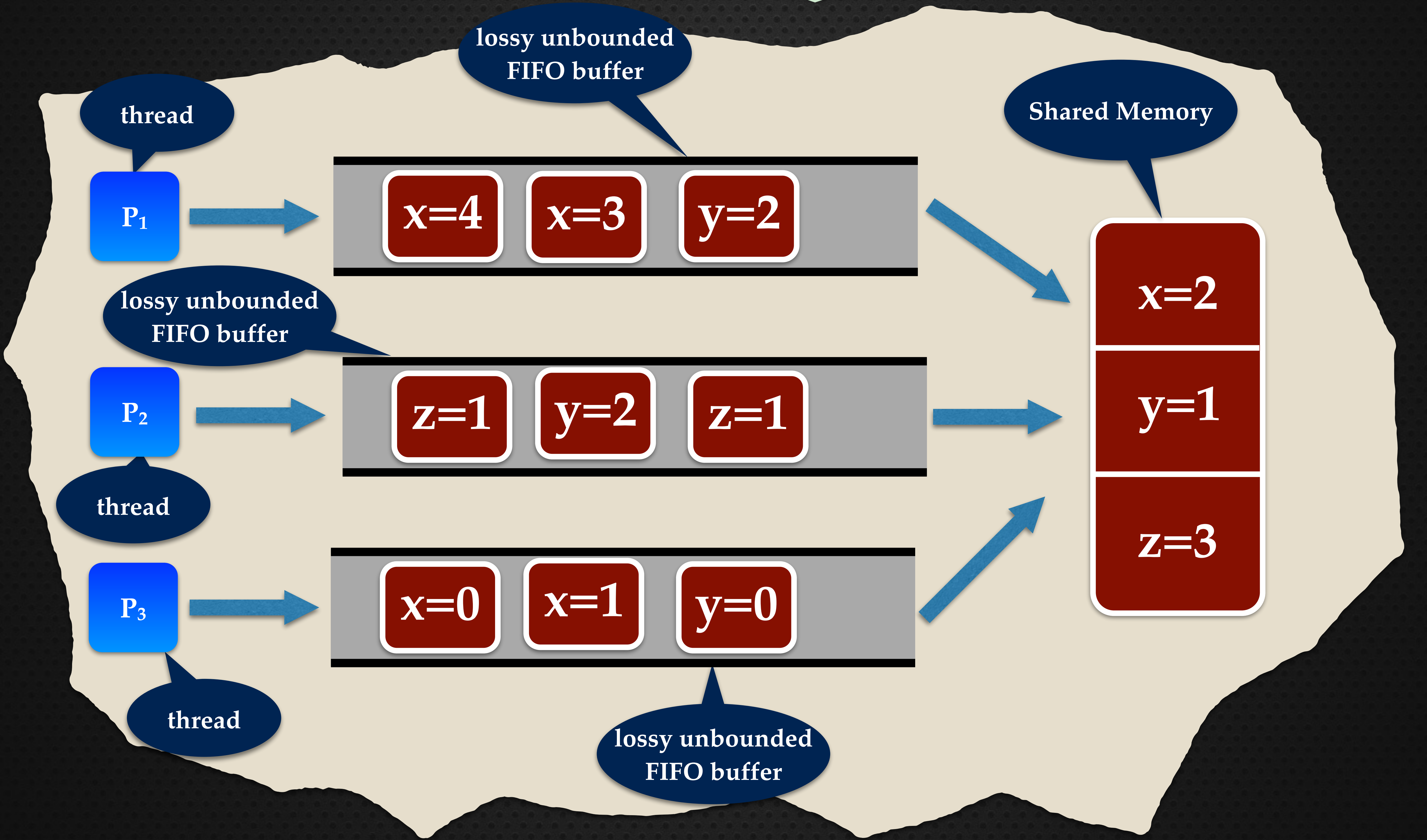

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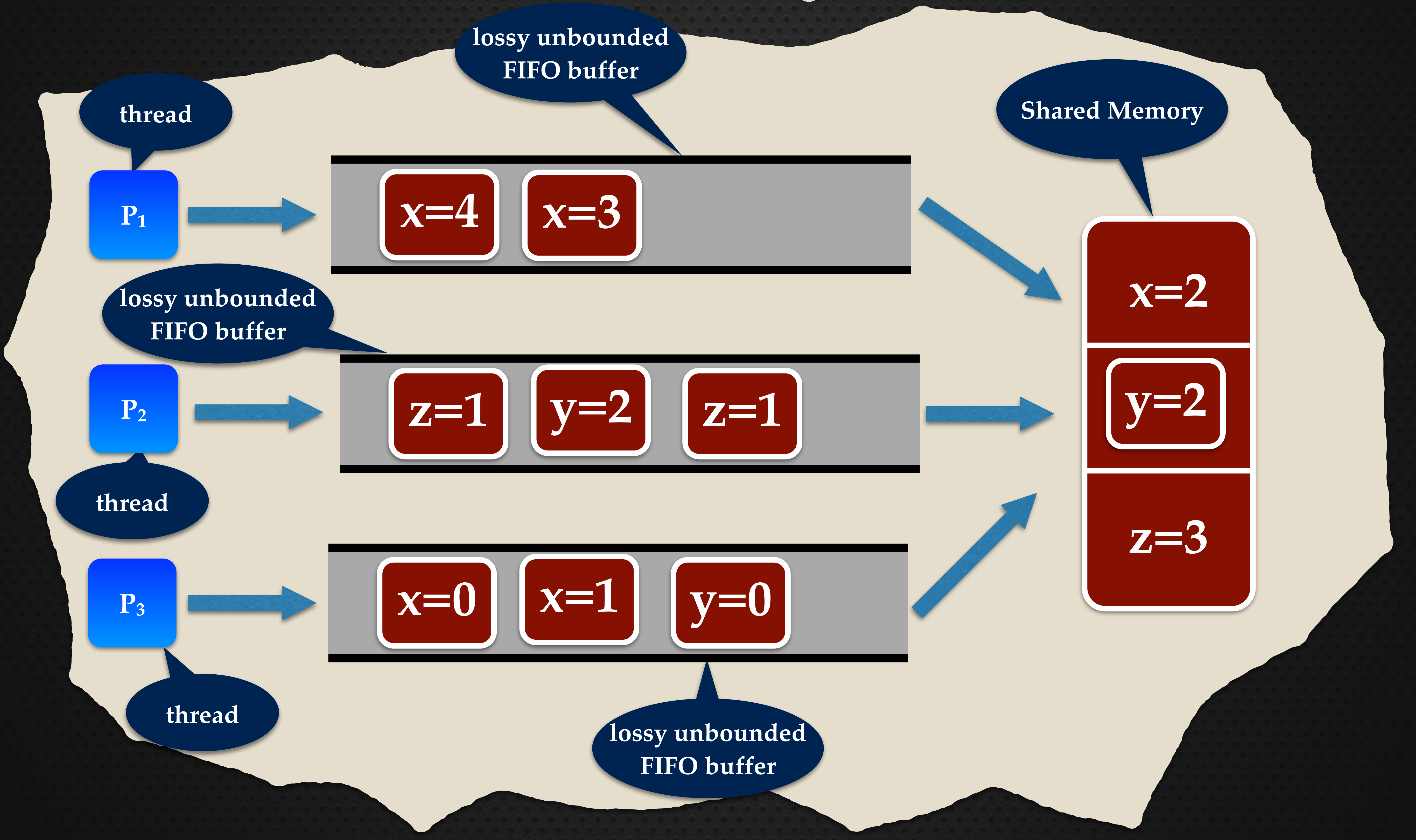

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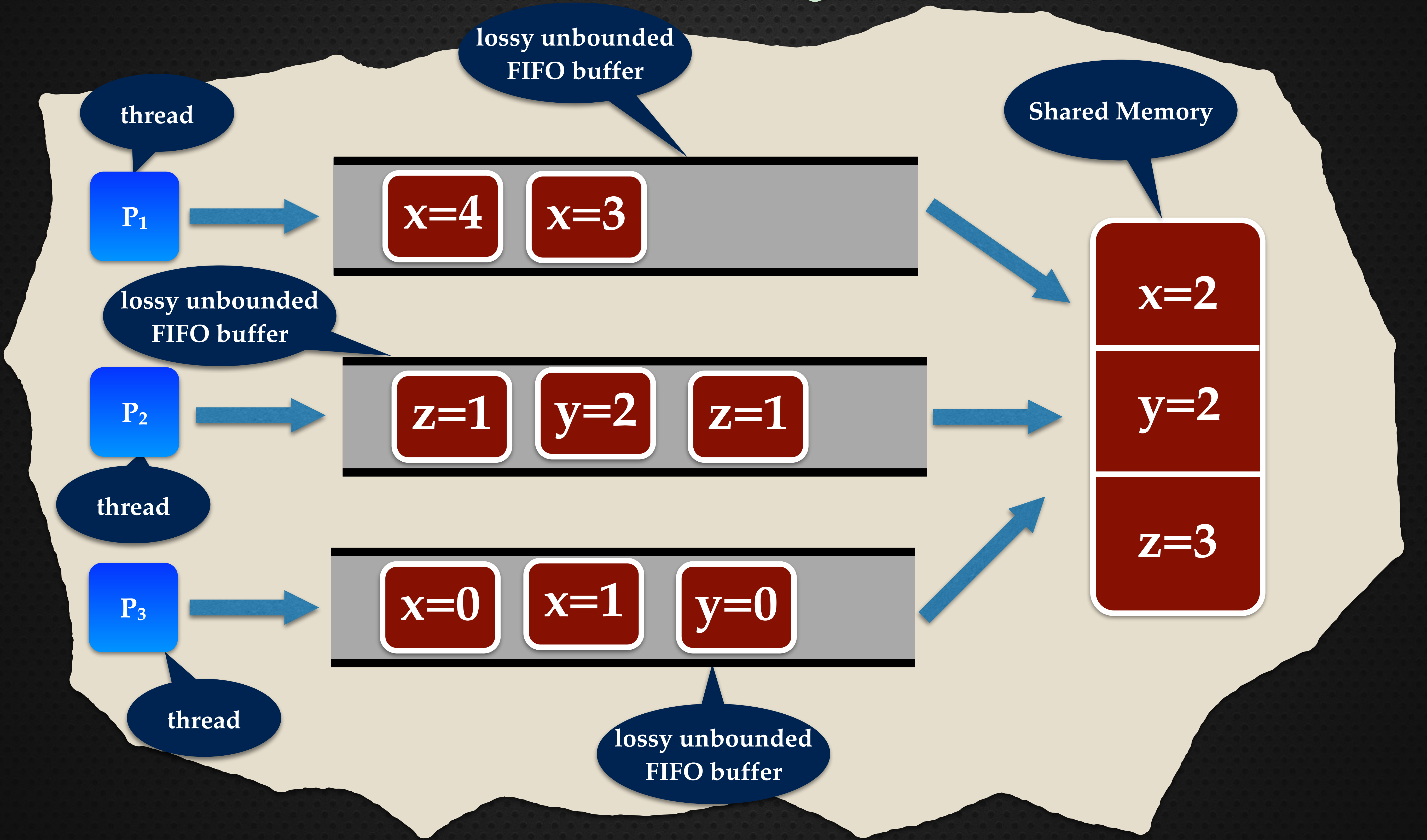

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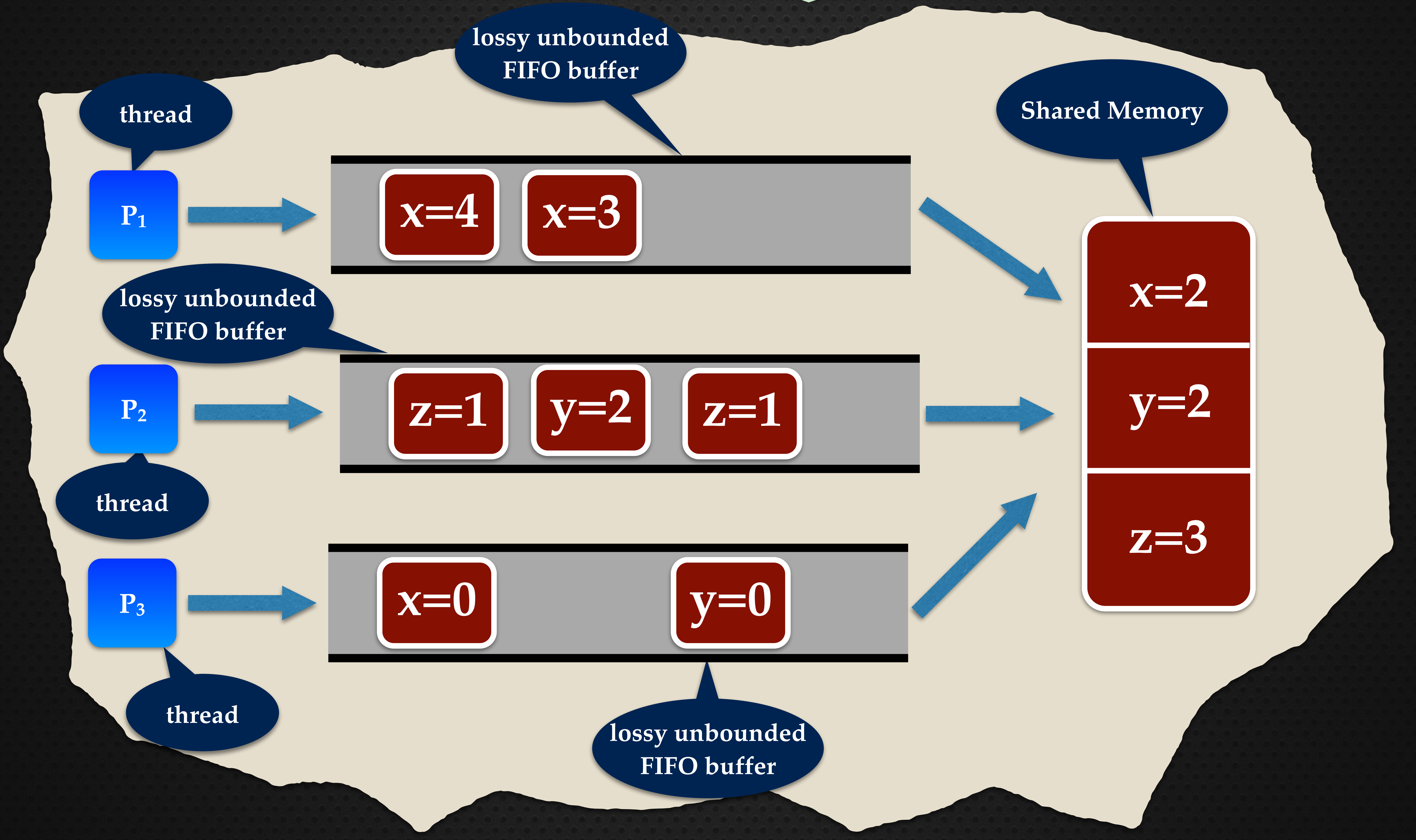
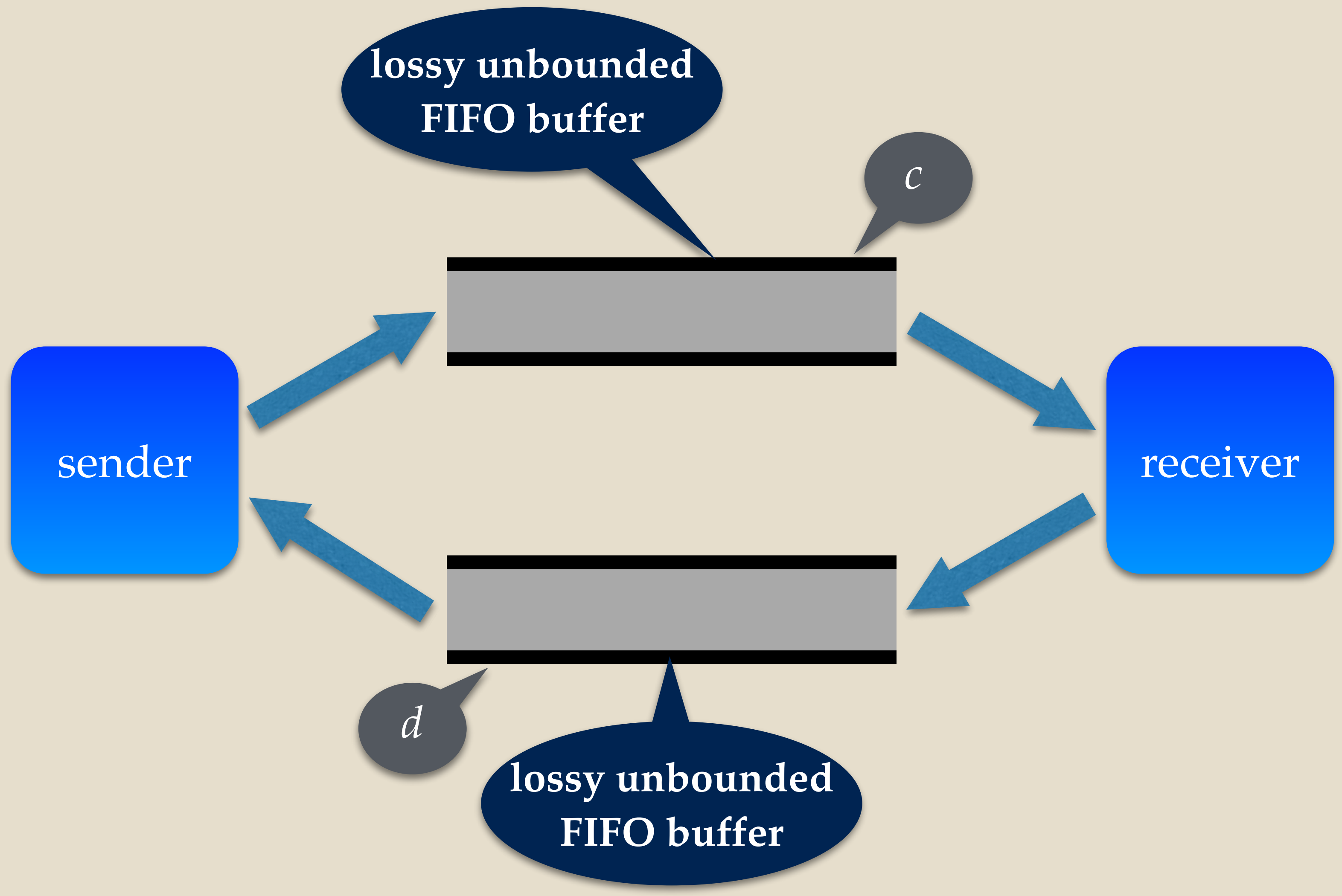


Telecommunication Protocol



Lossy

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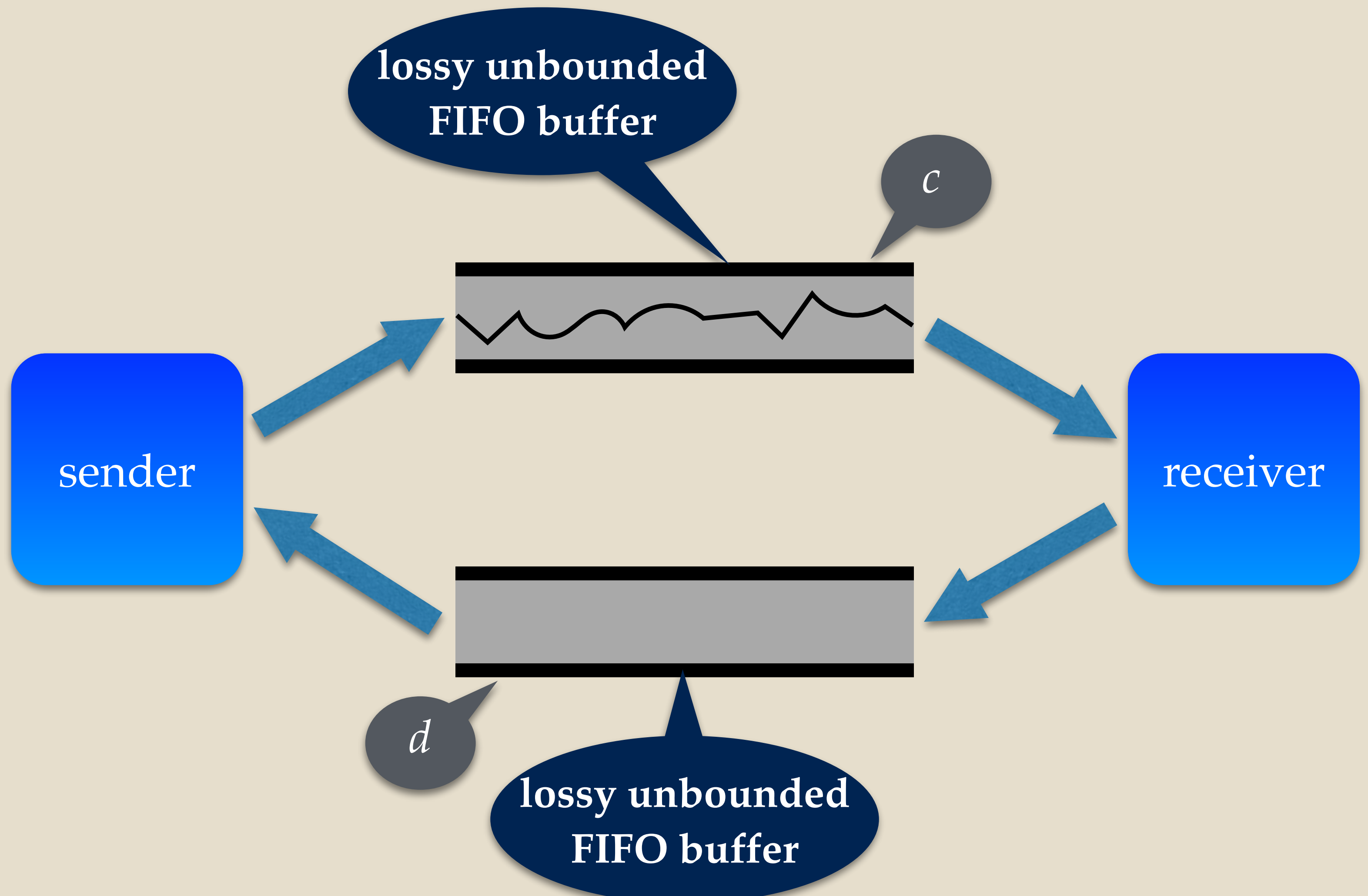

Lossy C M

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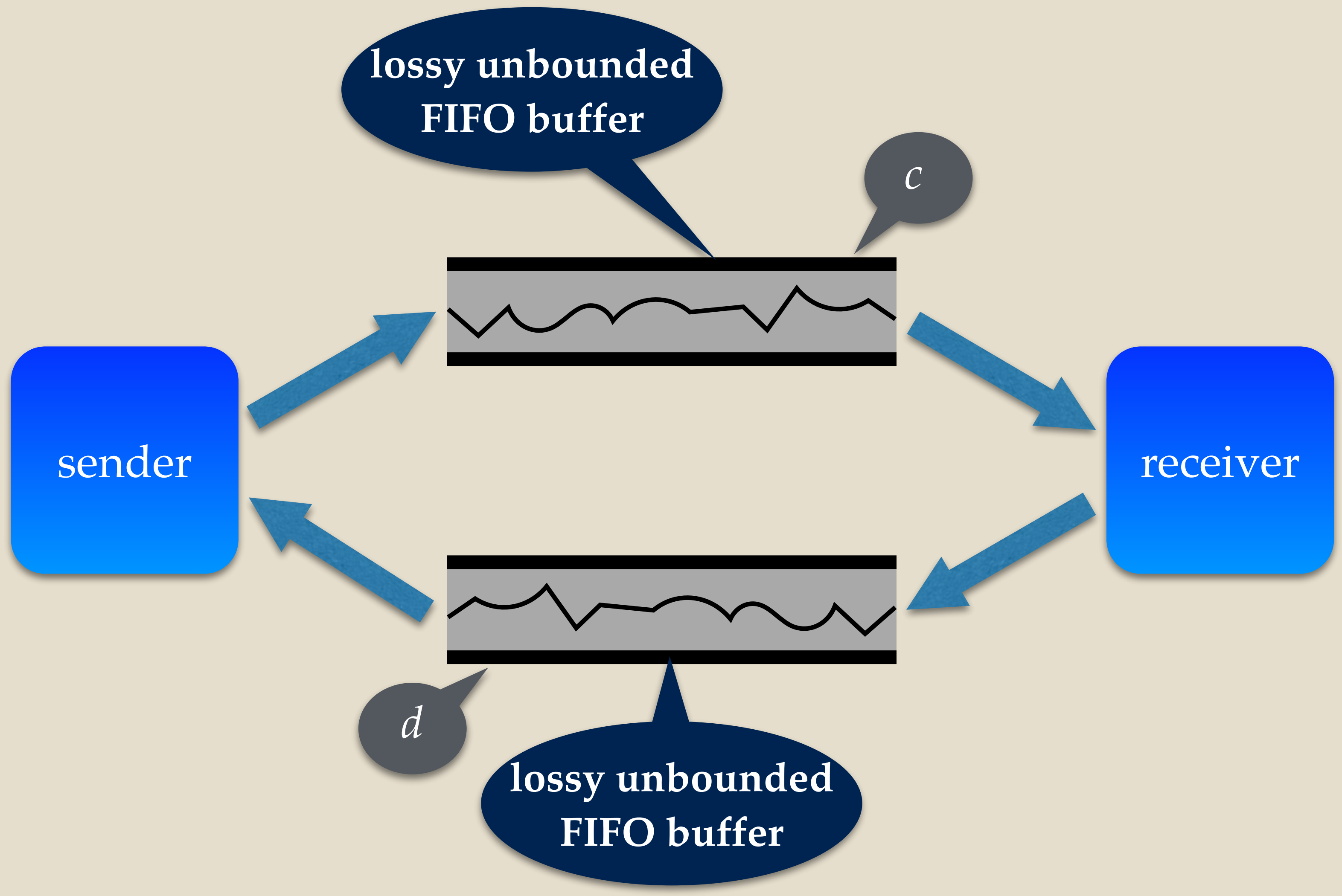
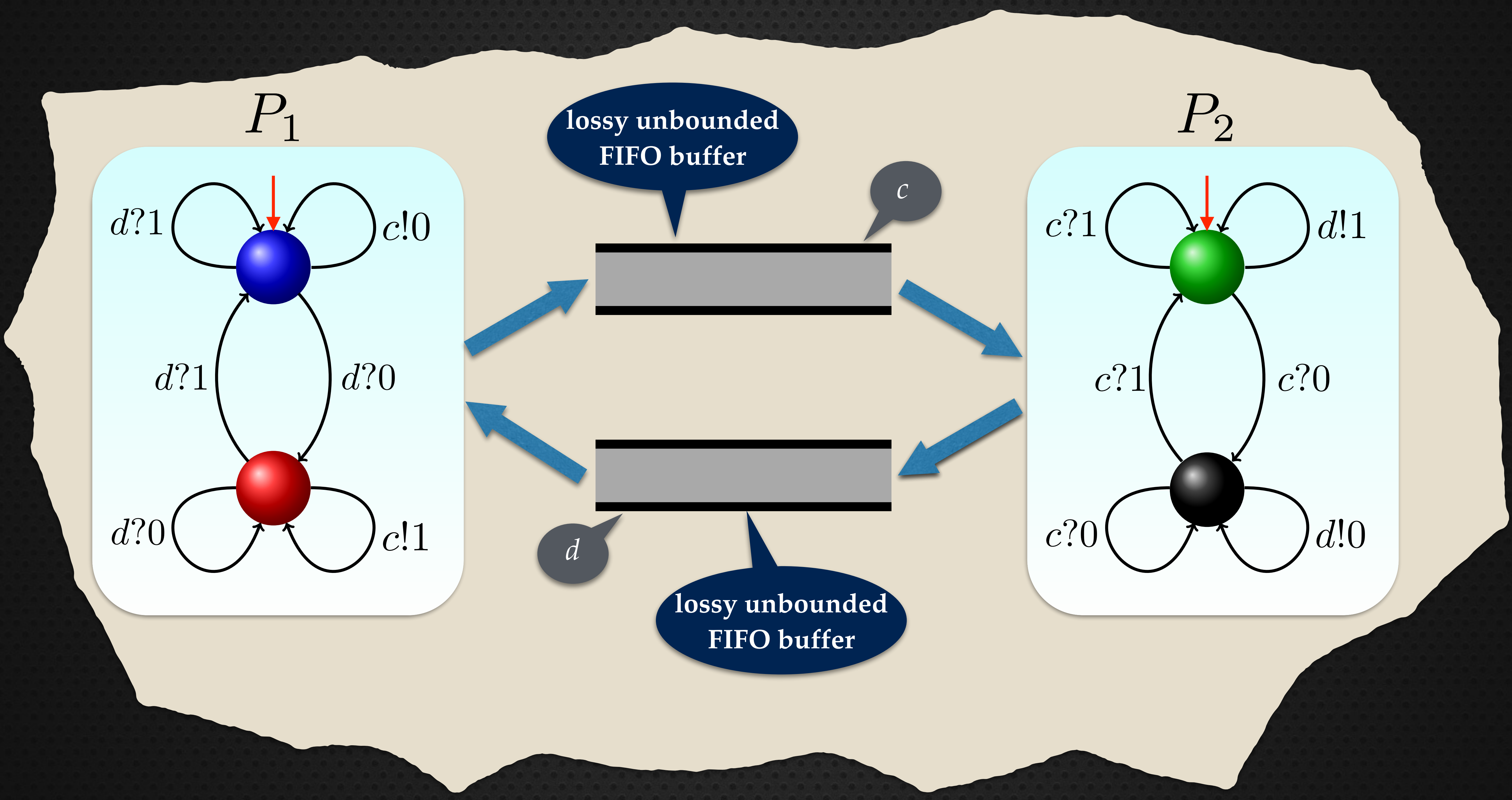


Lossy Channel Systems



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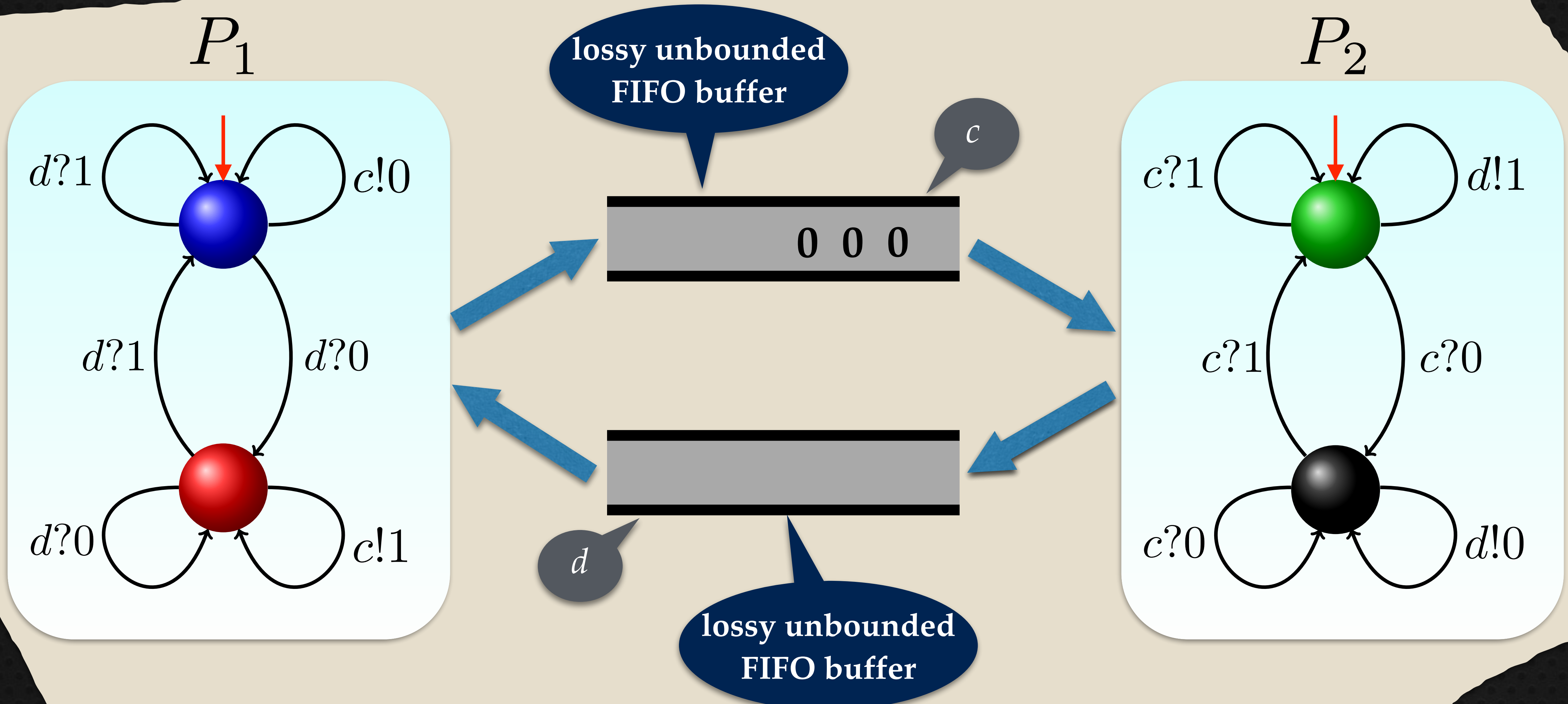

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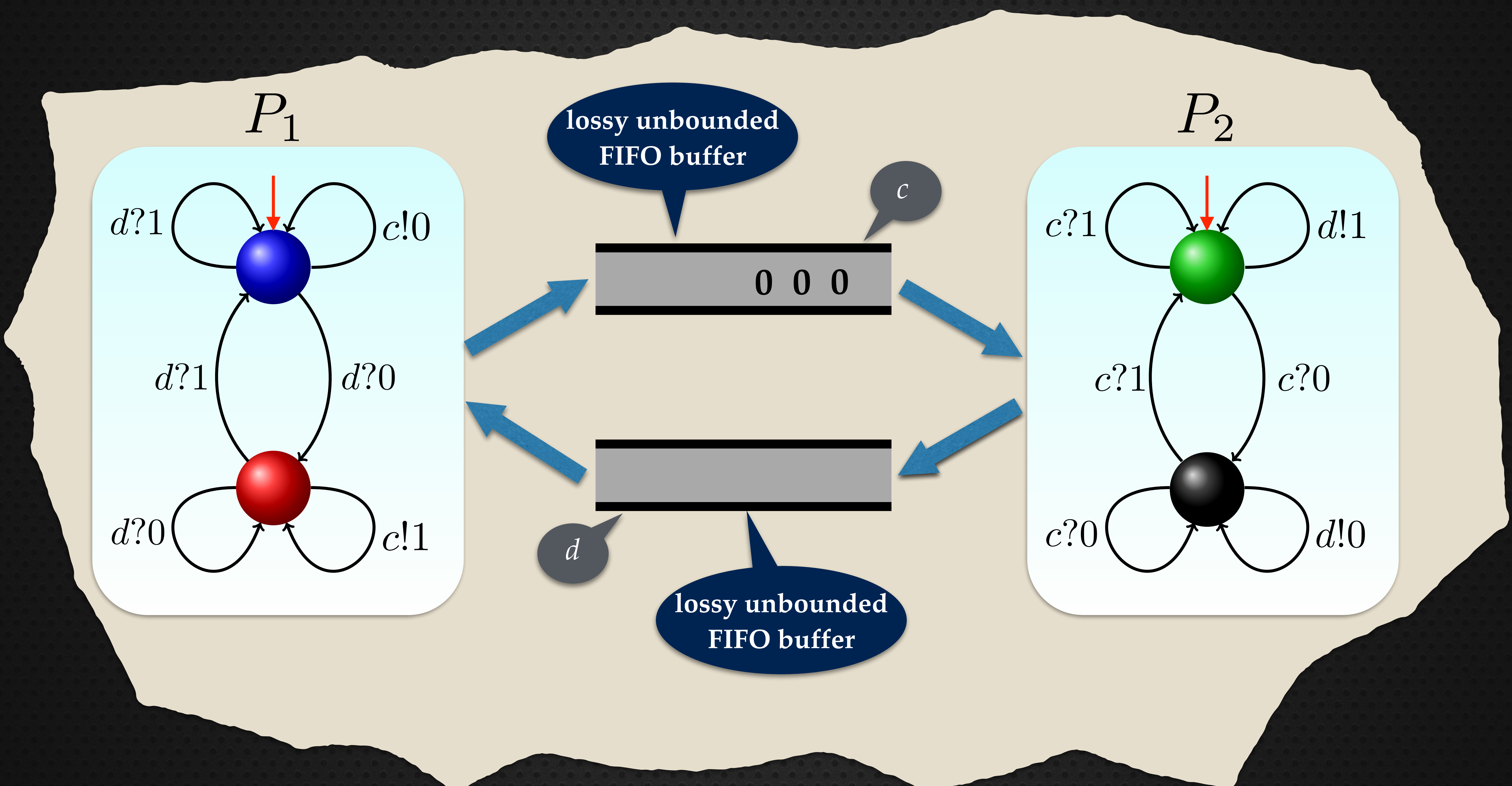

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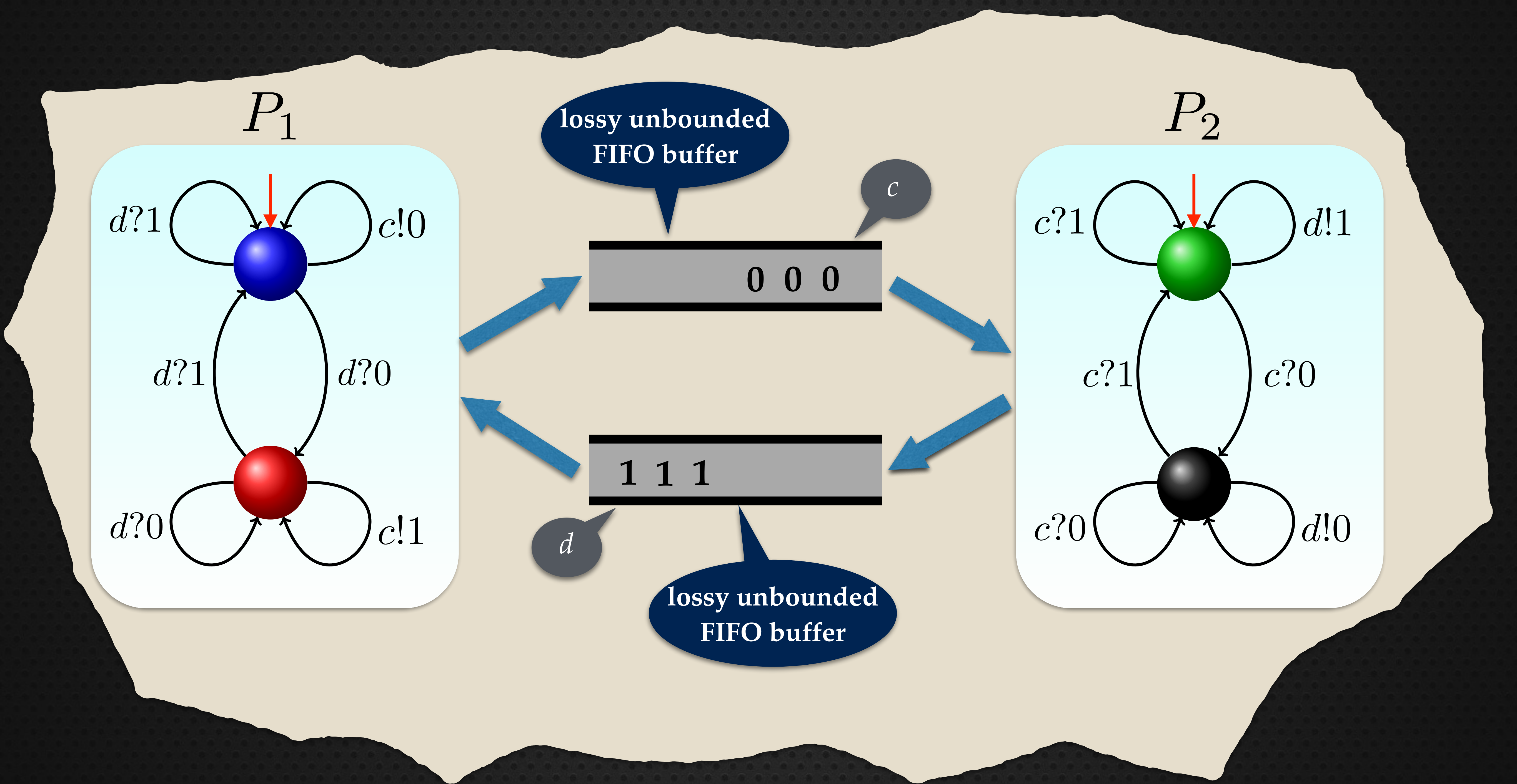

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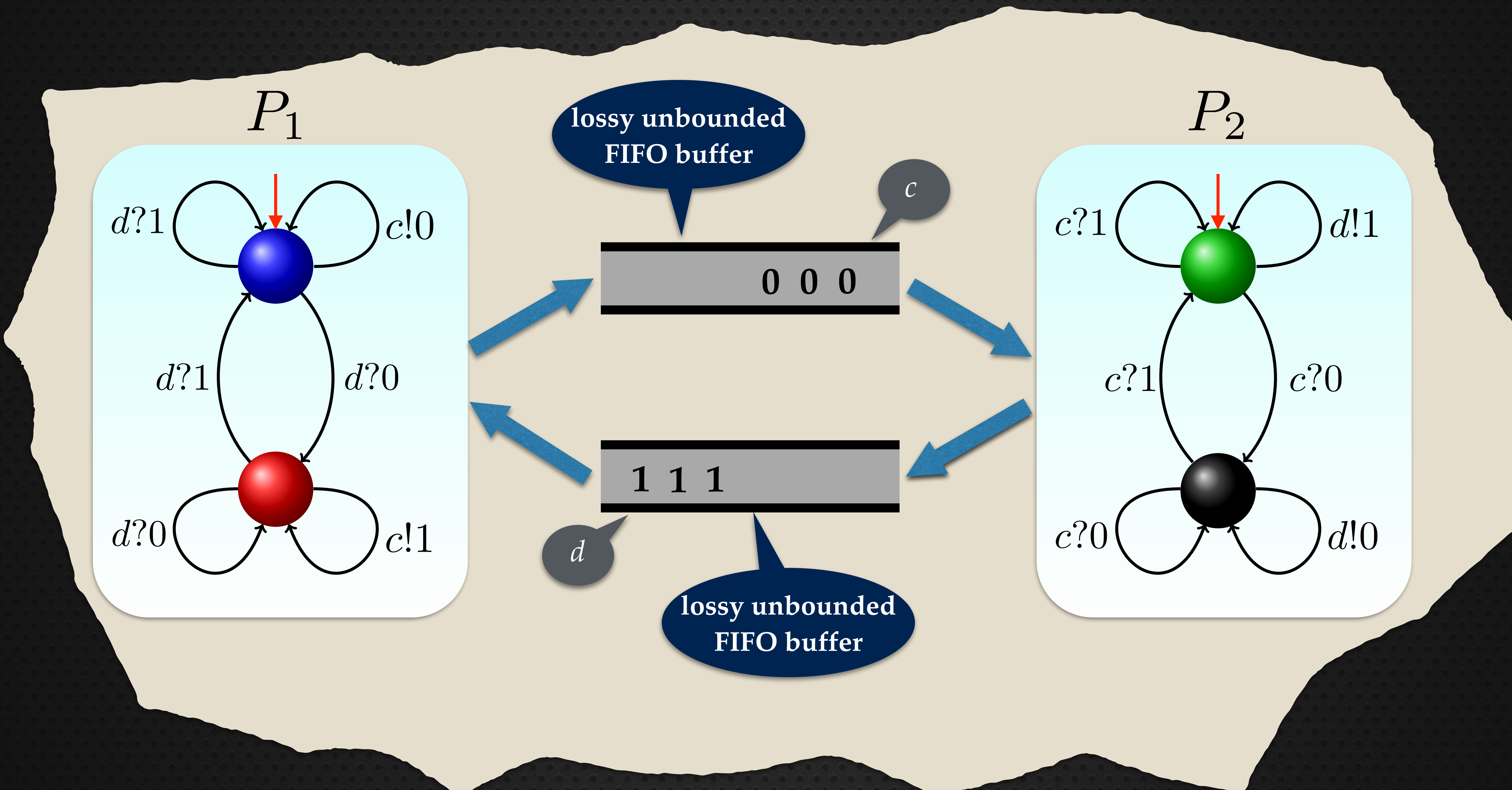

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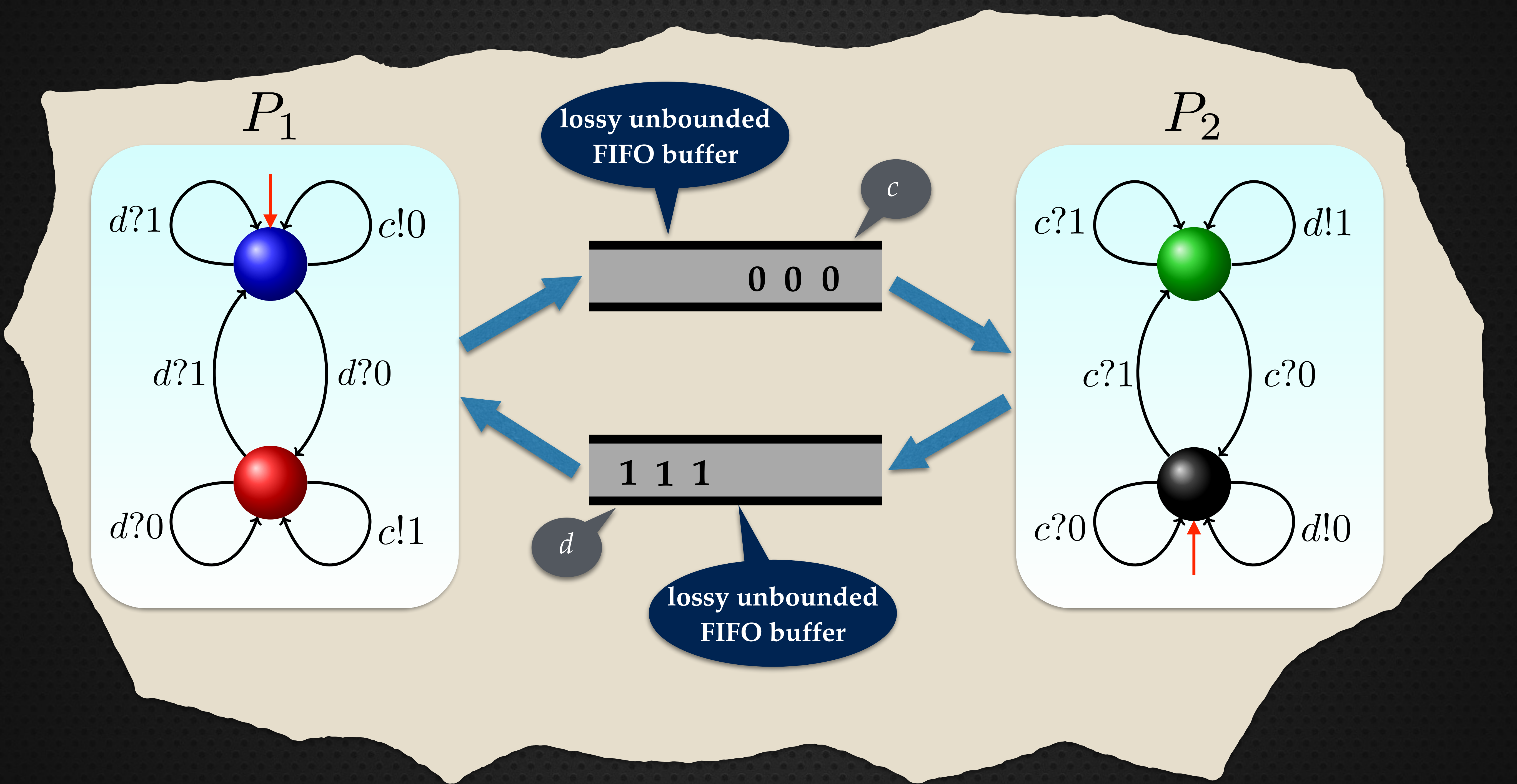

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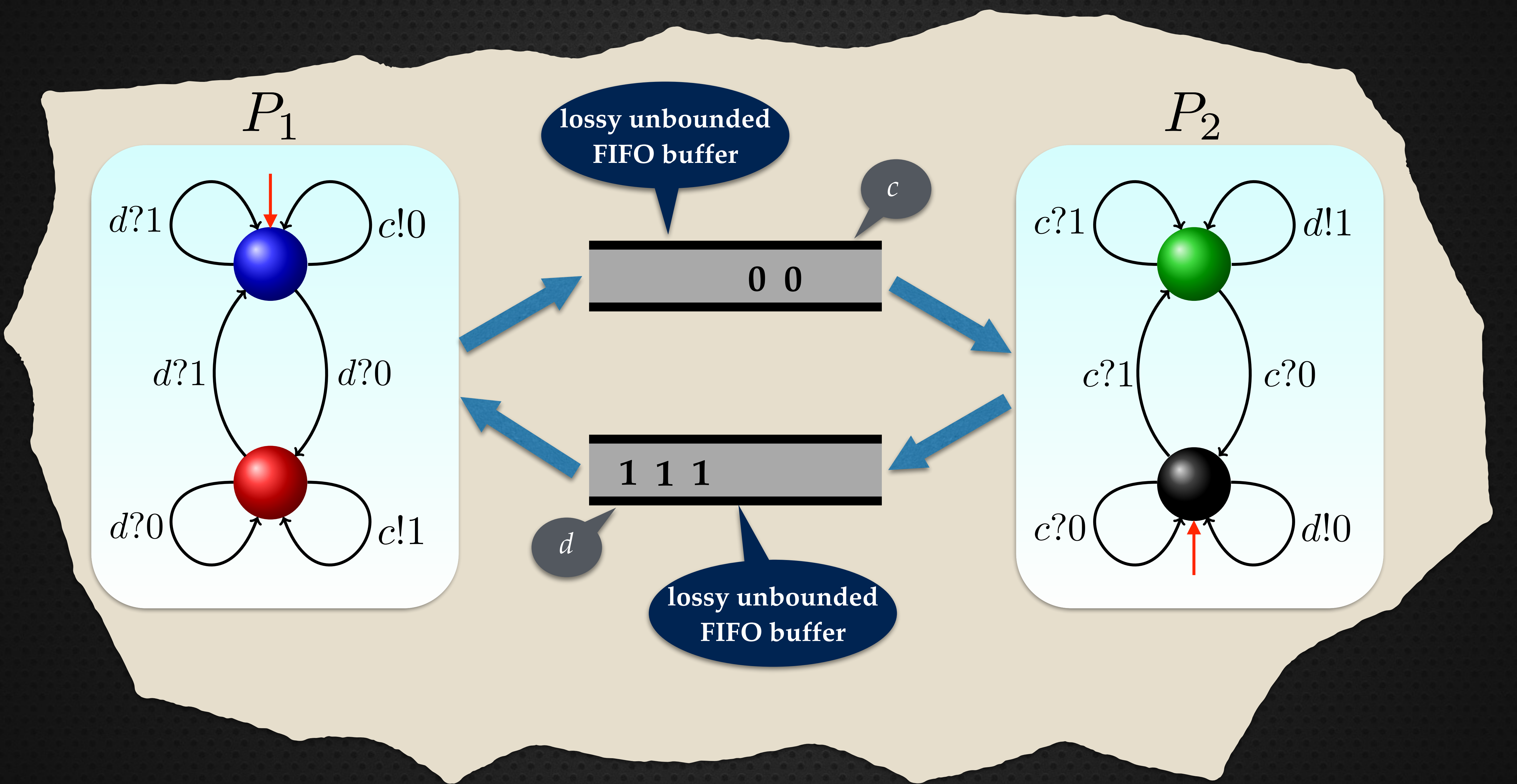

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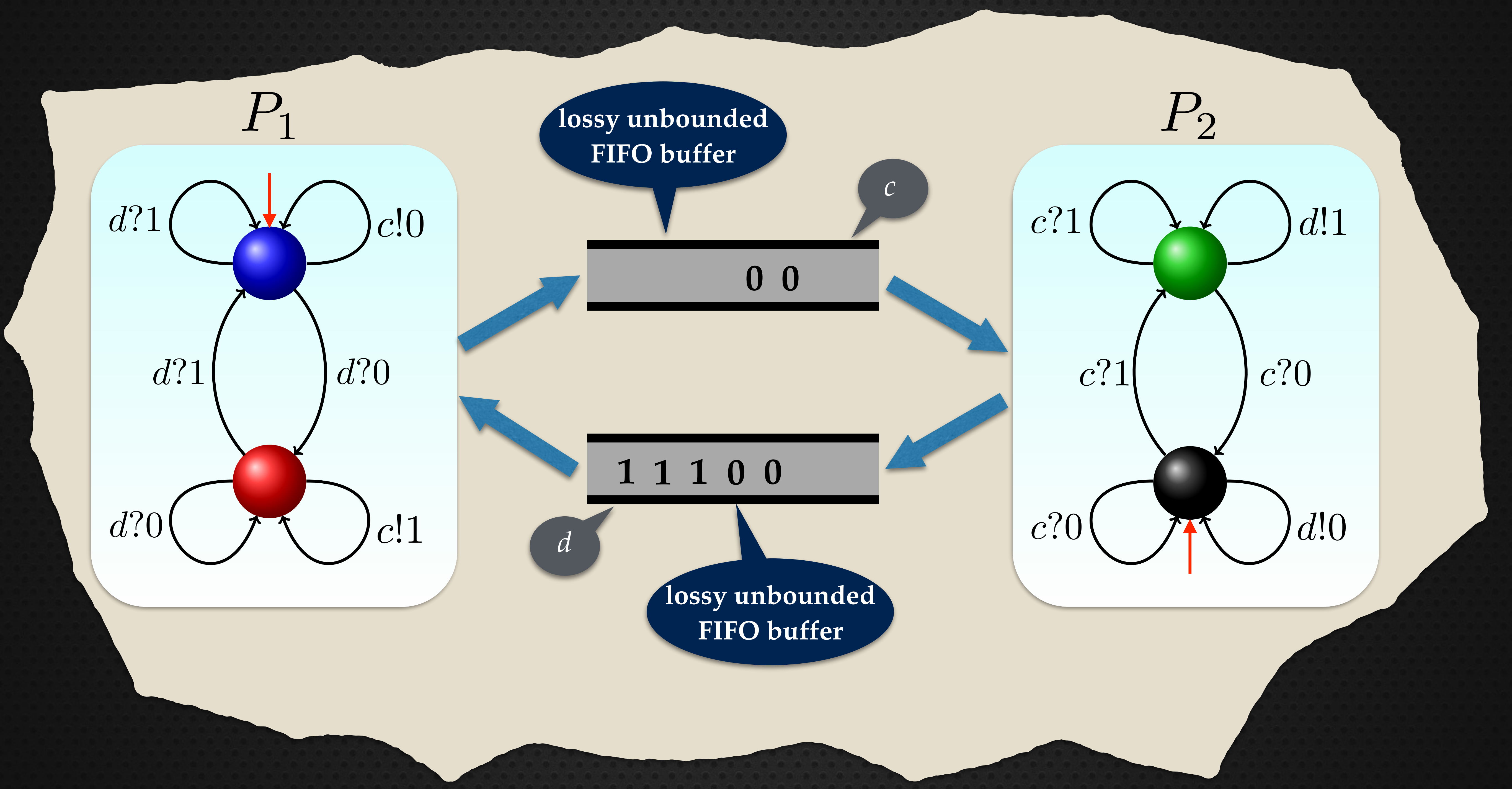

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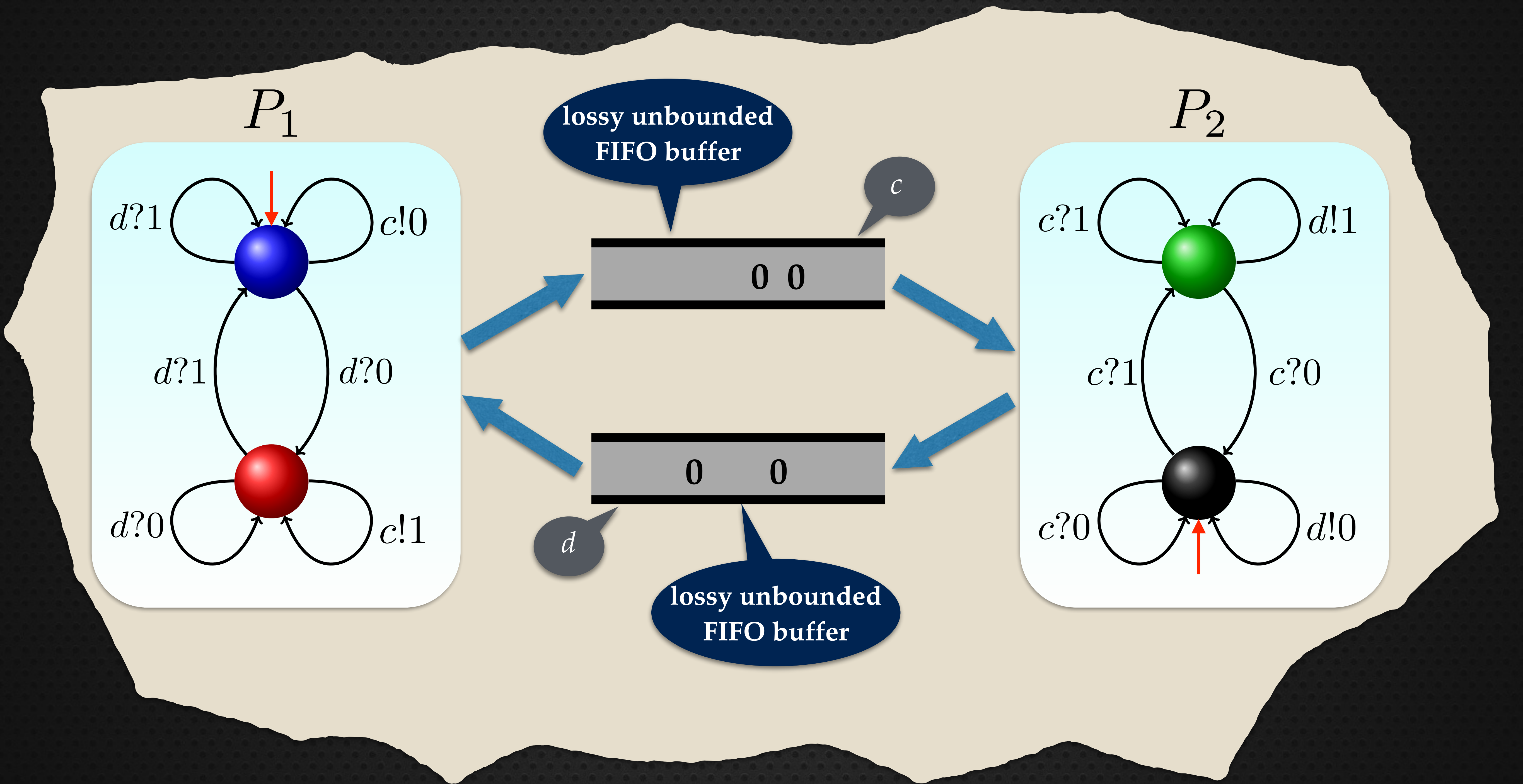

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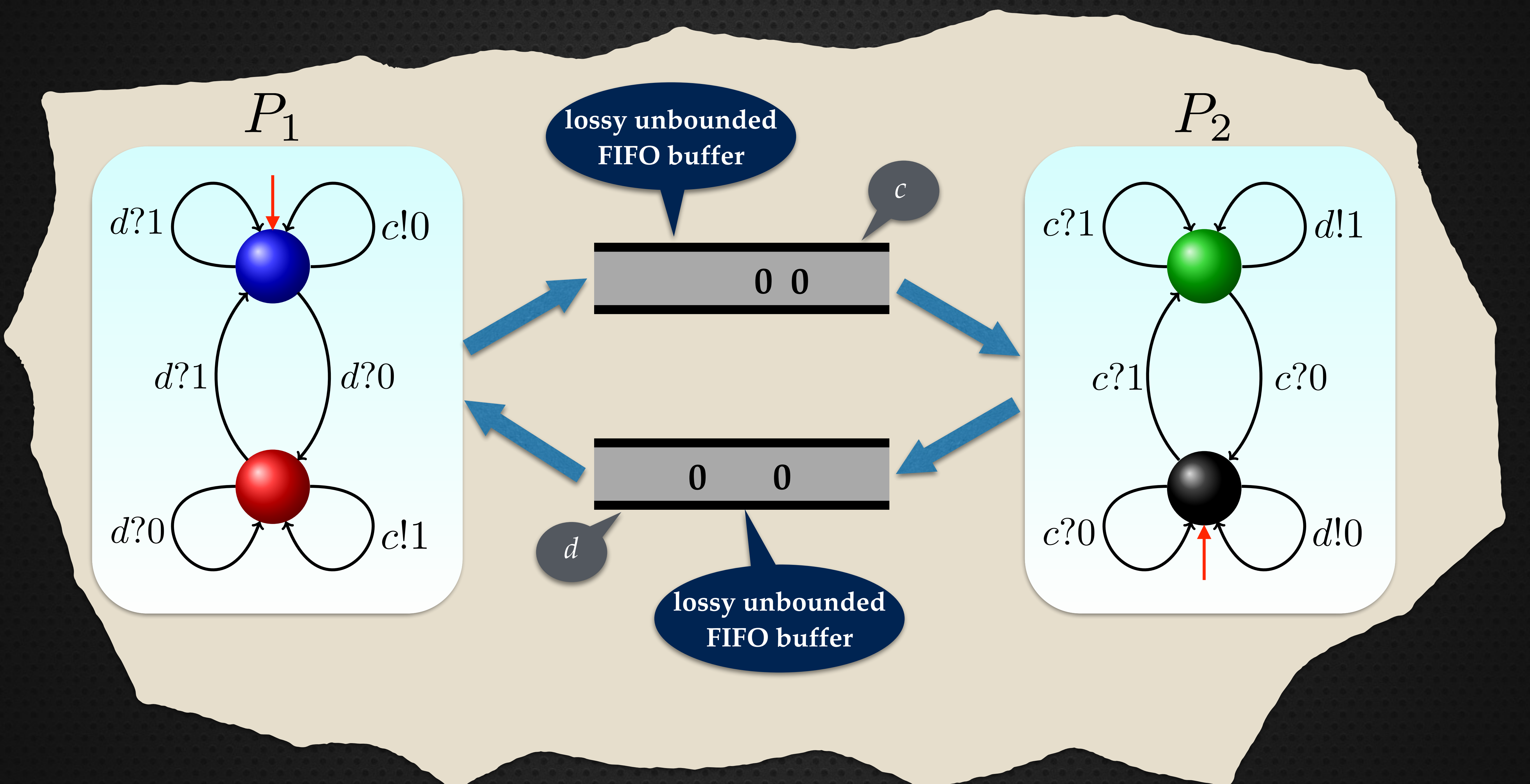

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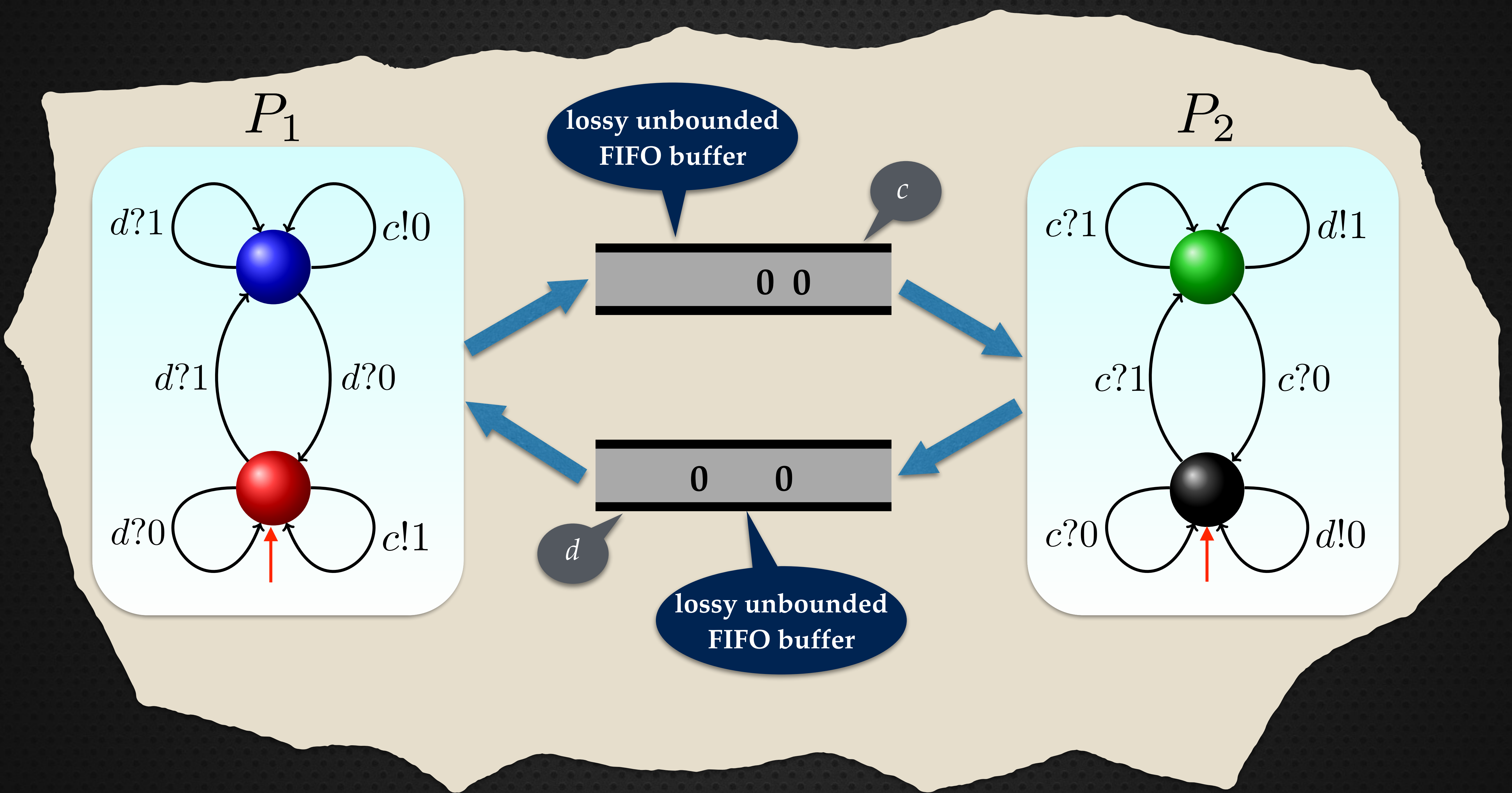

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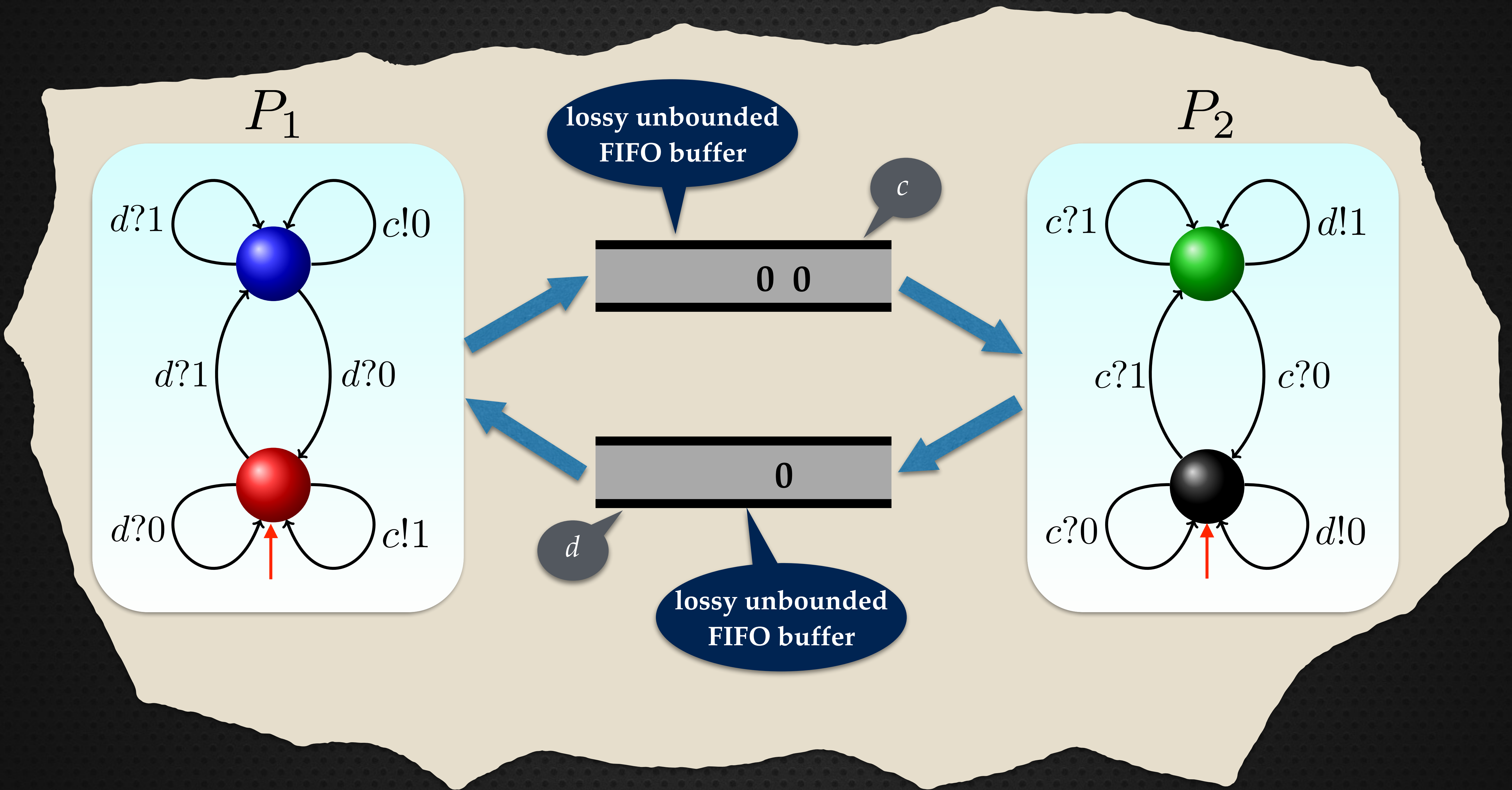

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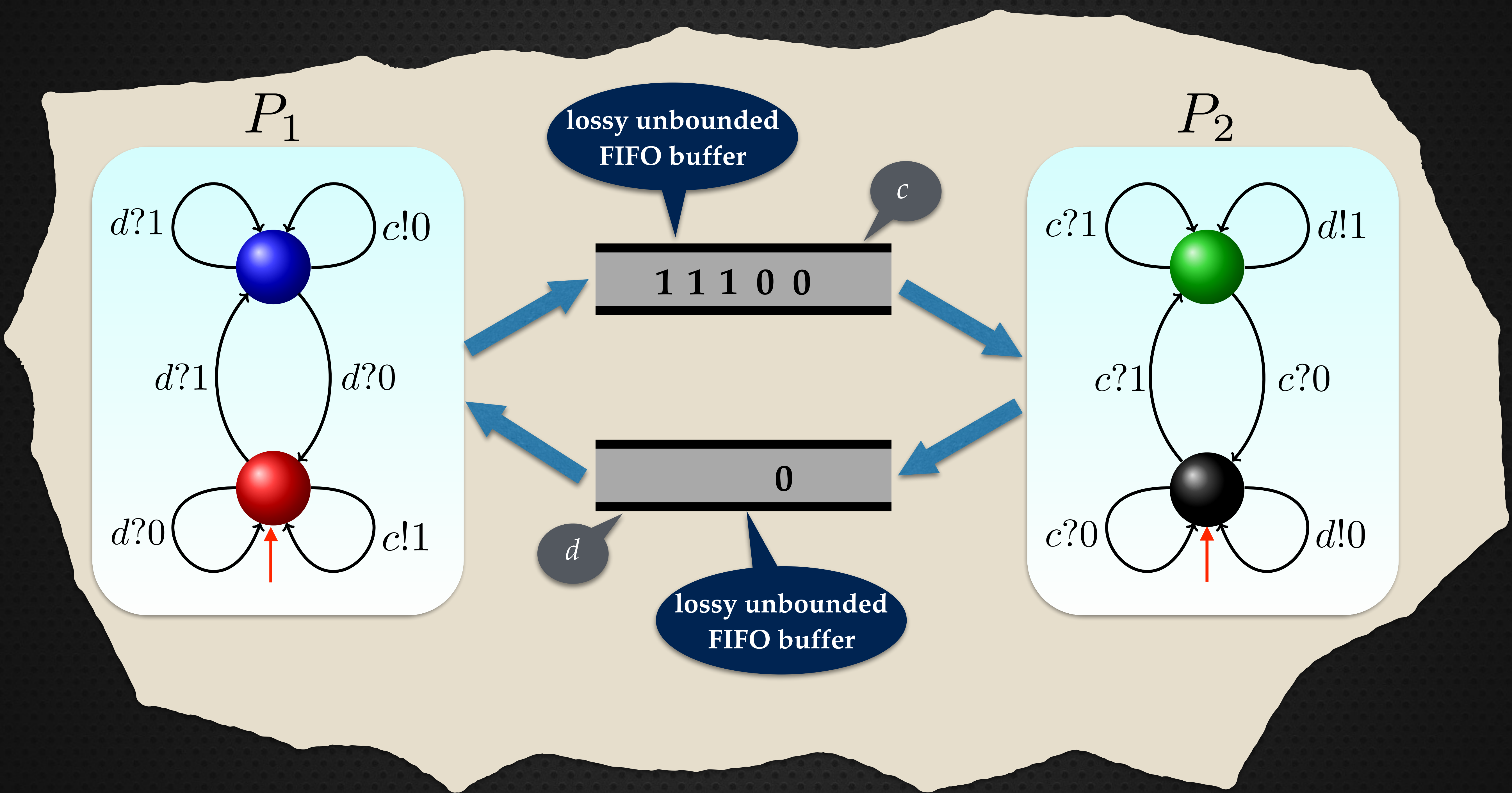

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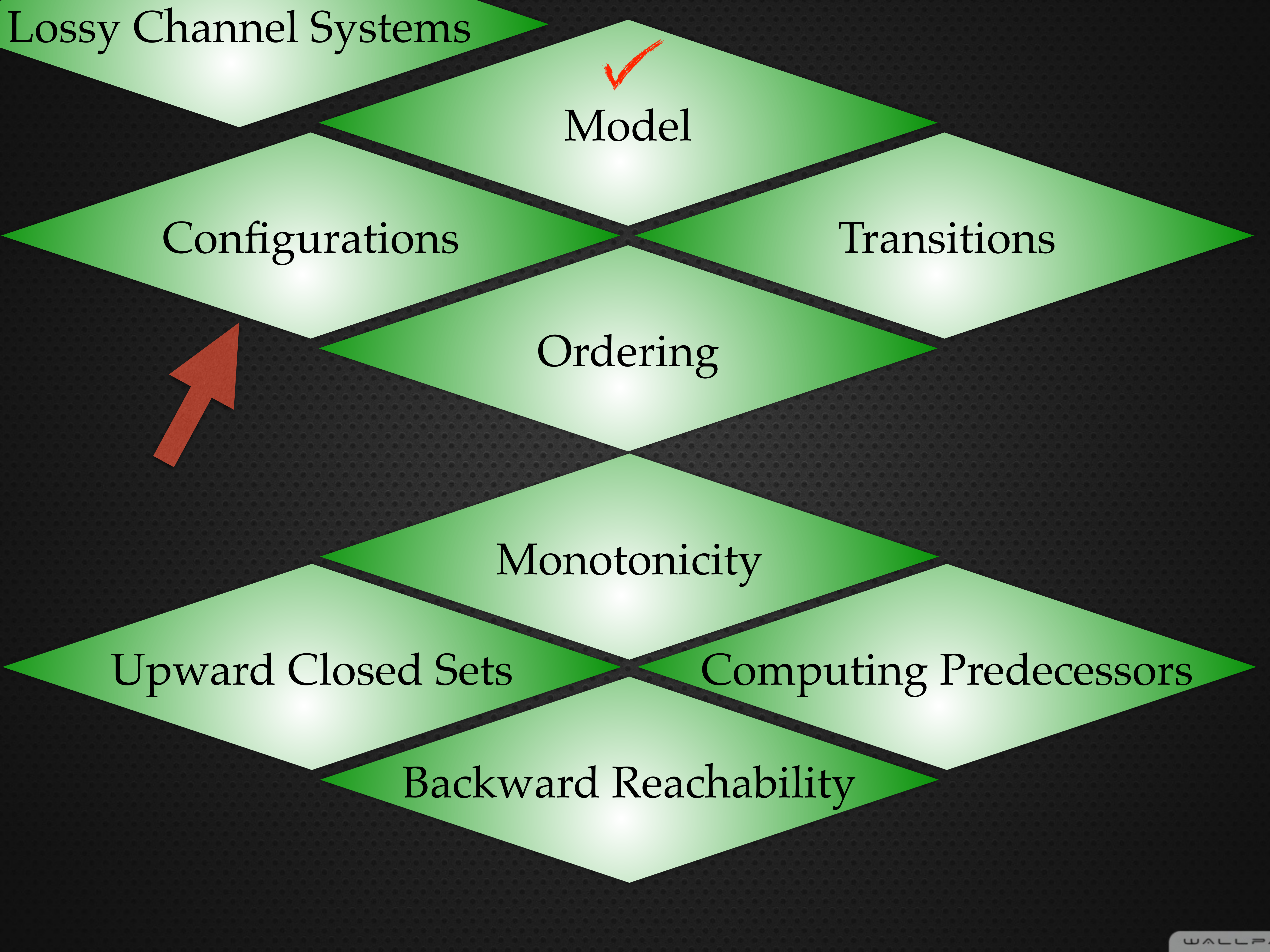
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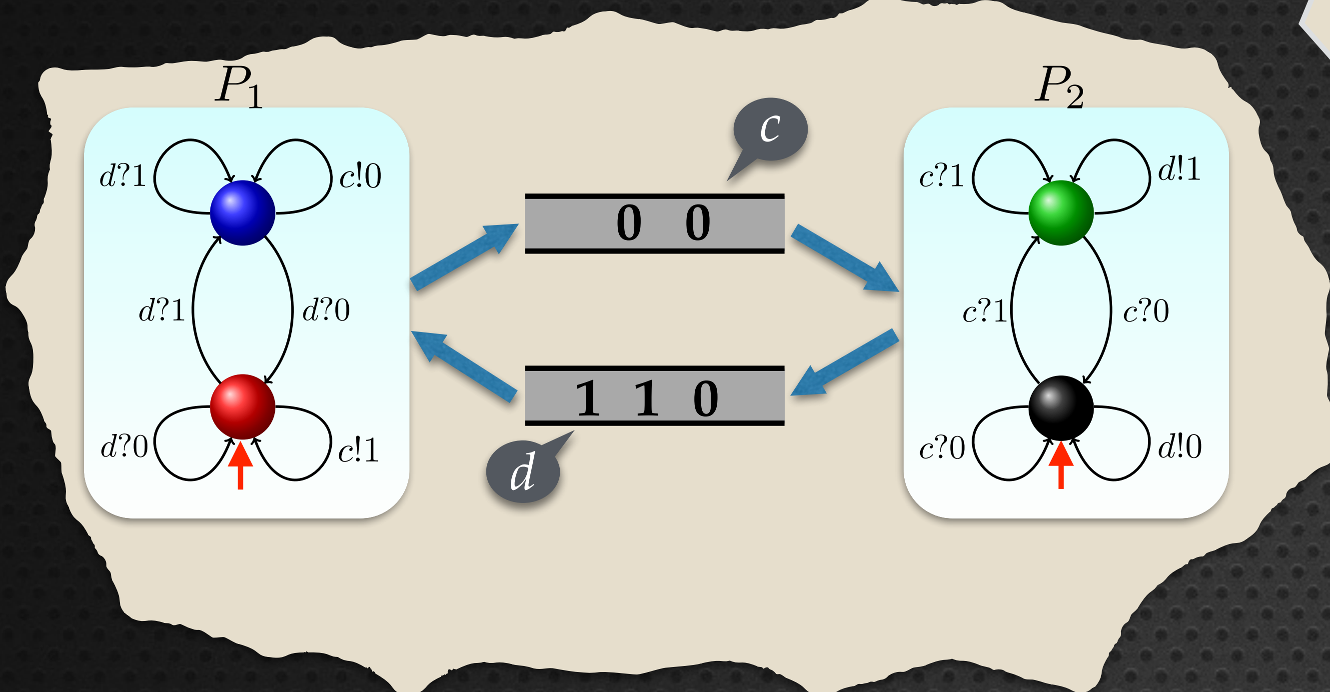

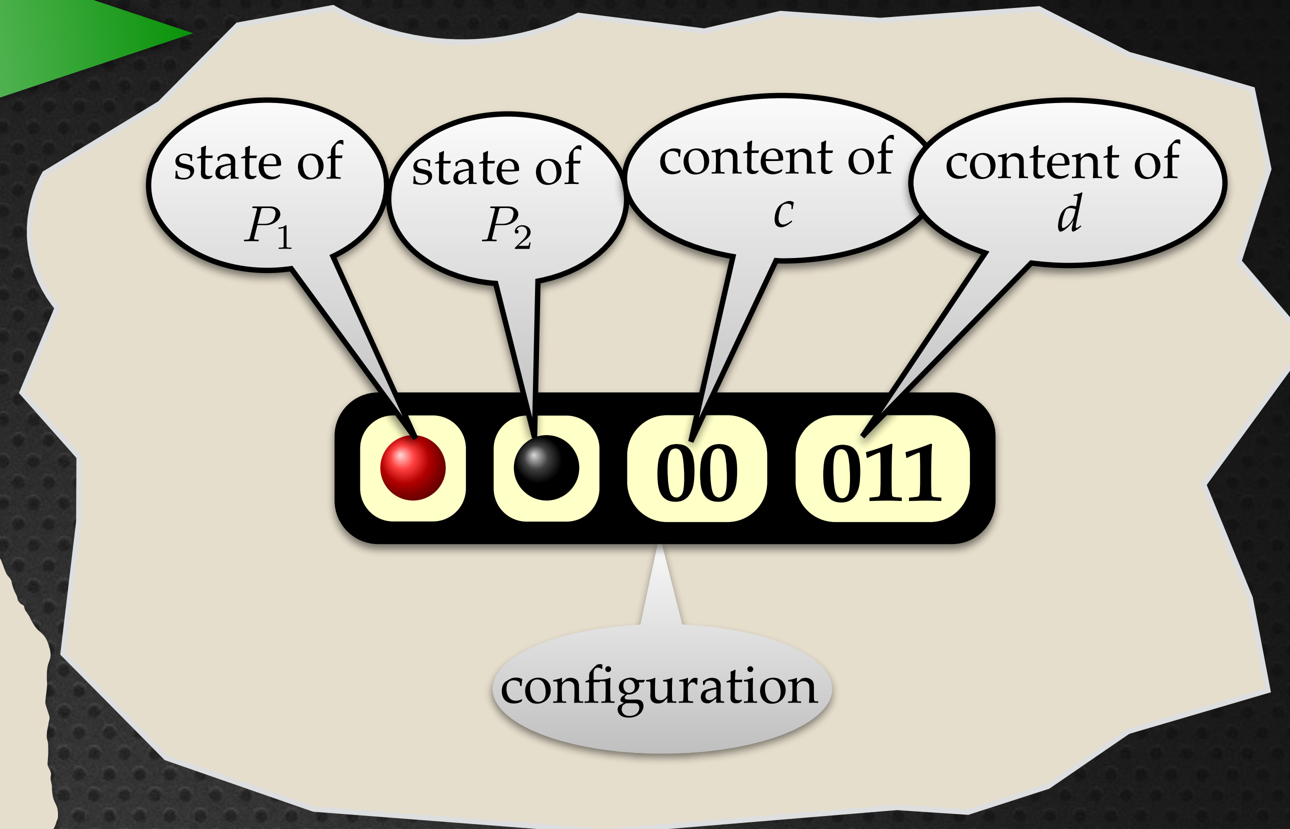

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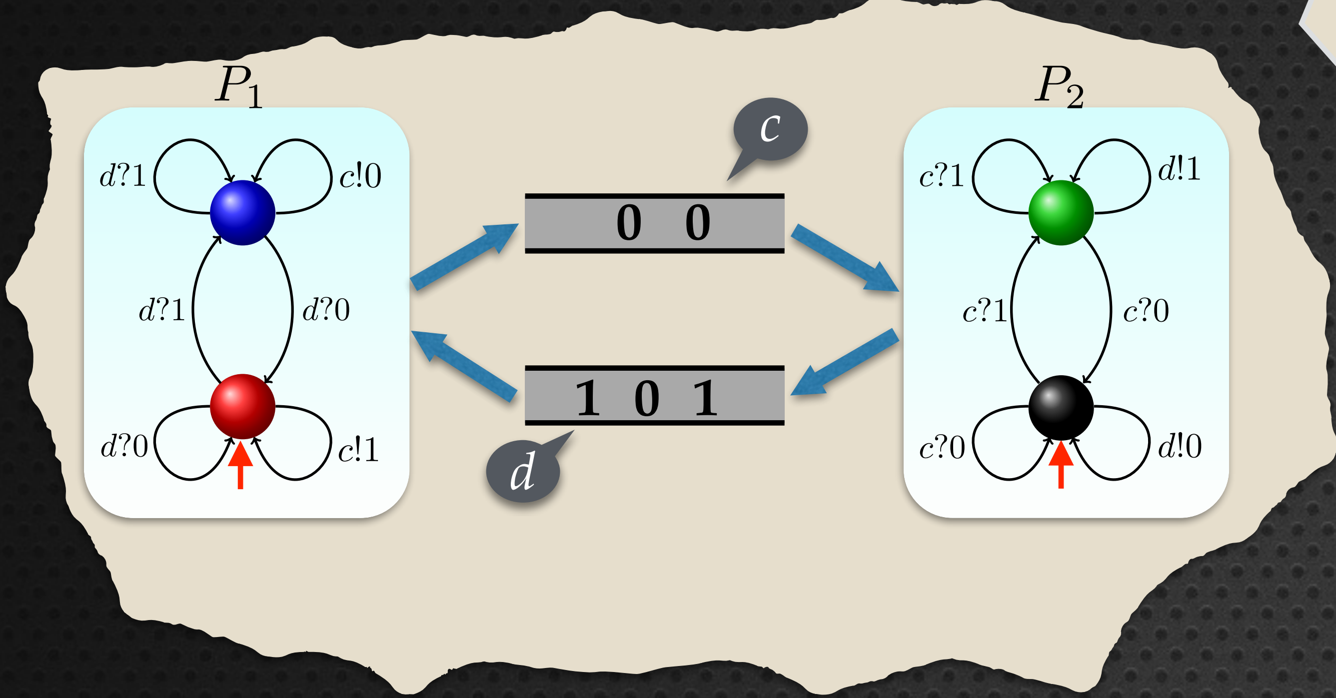

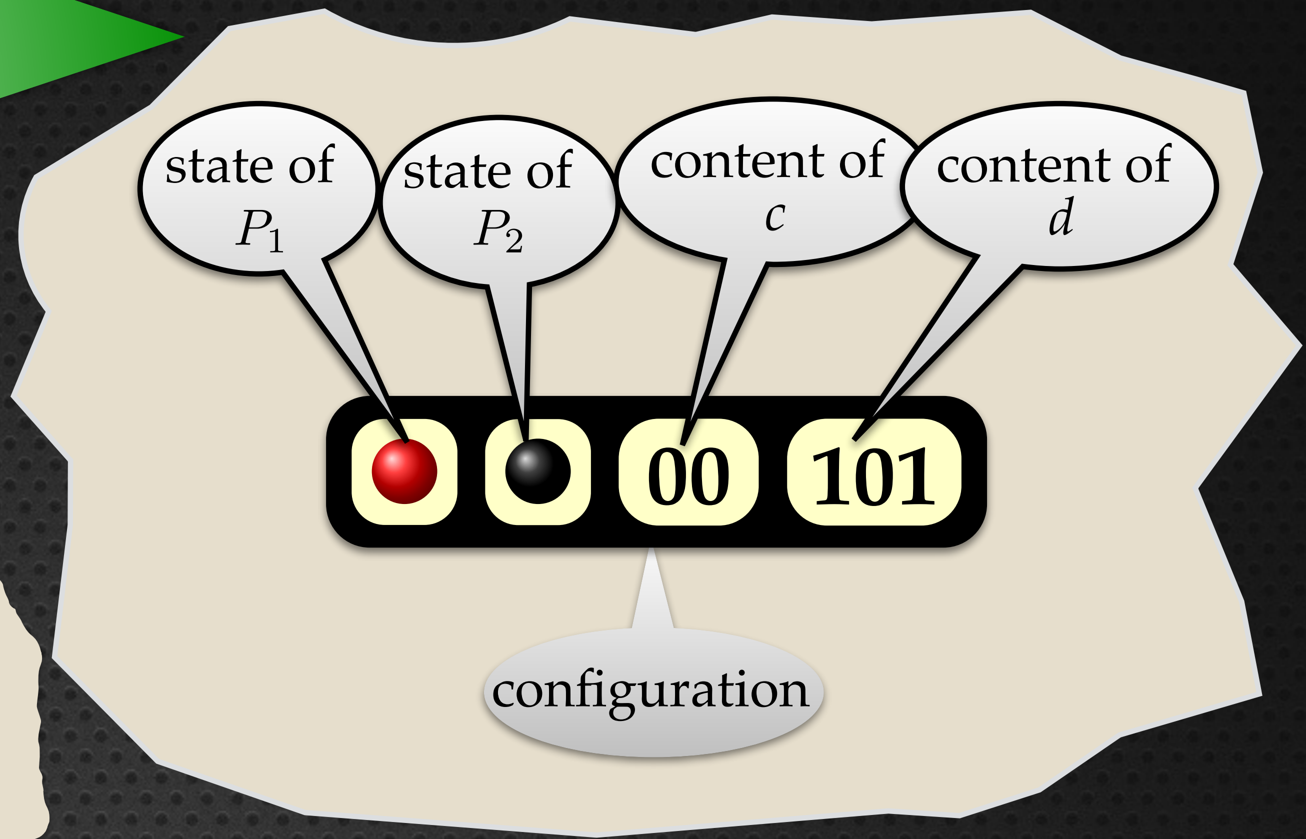

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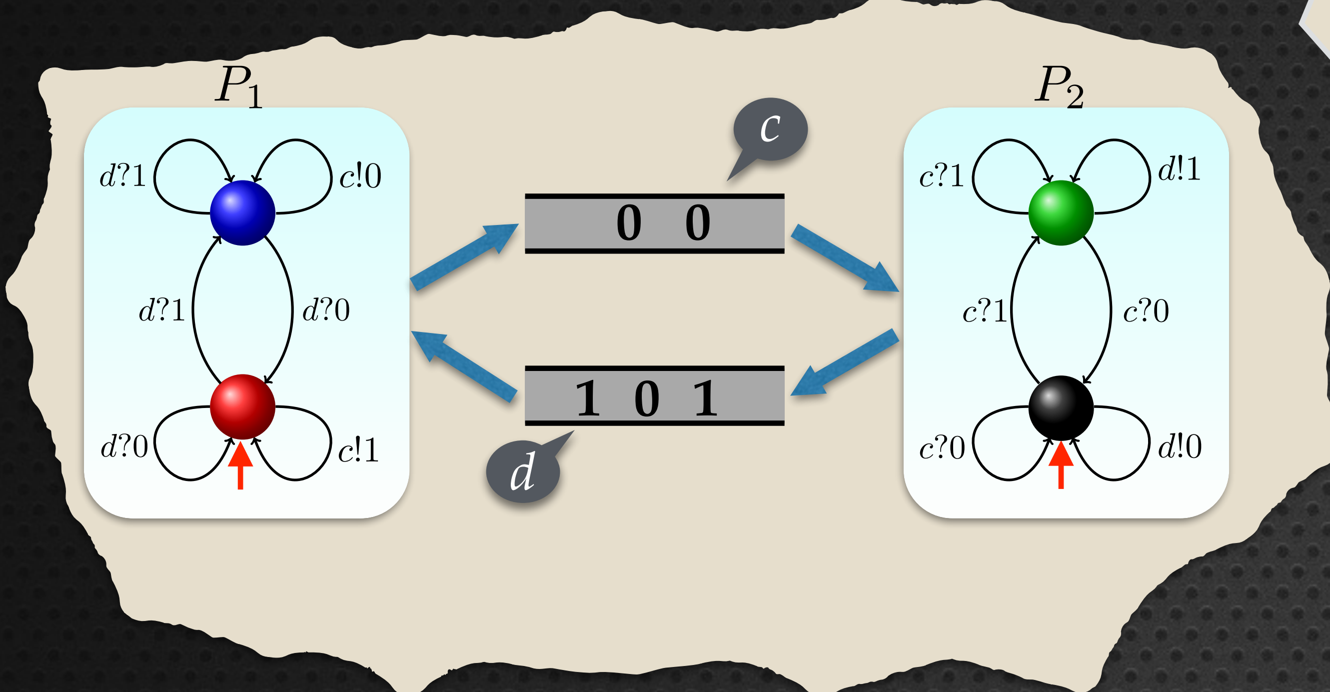

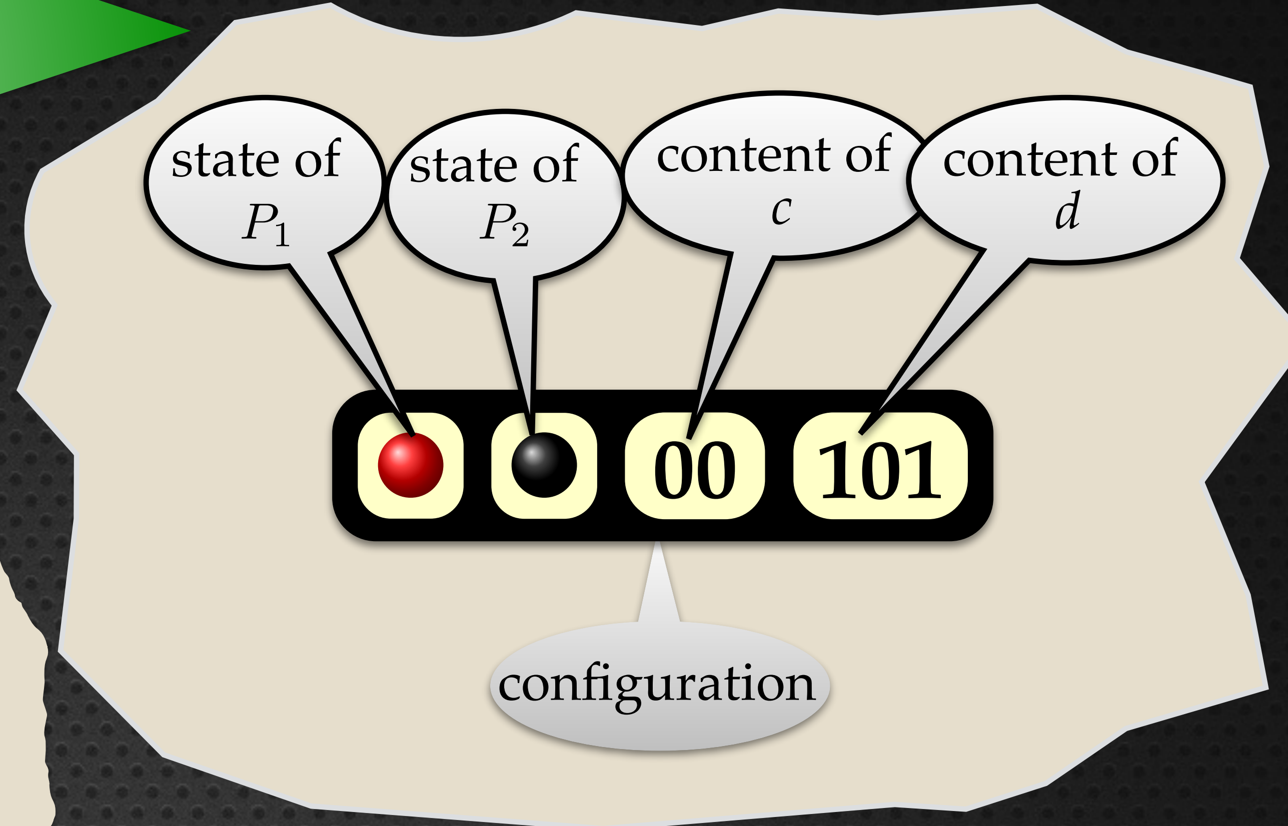

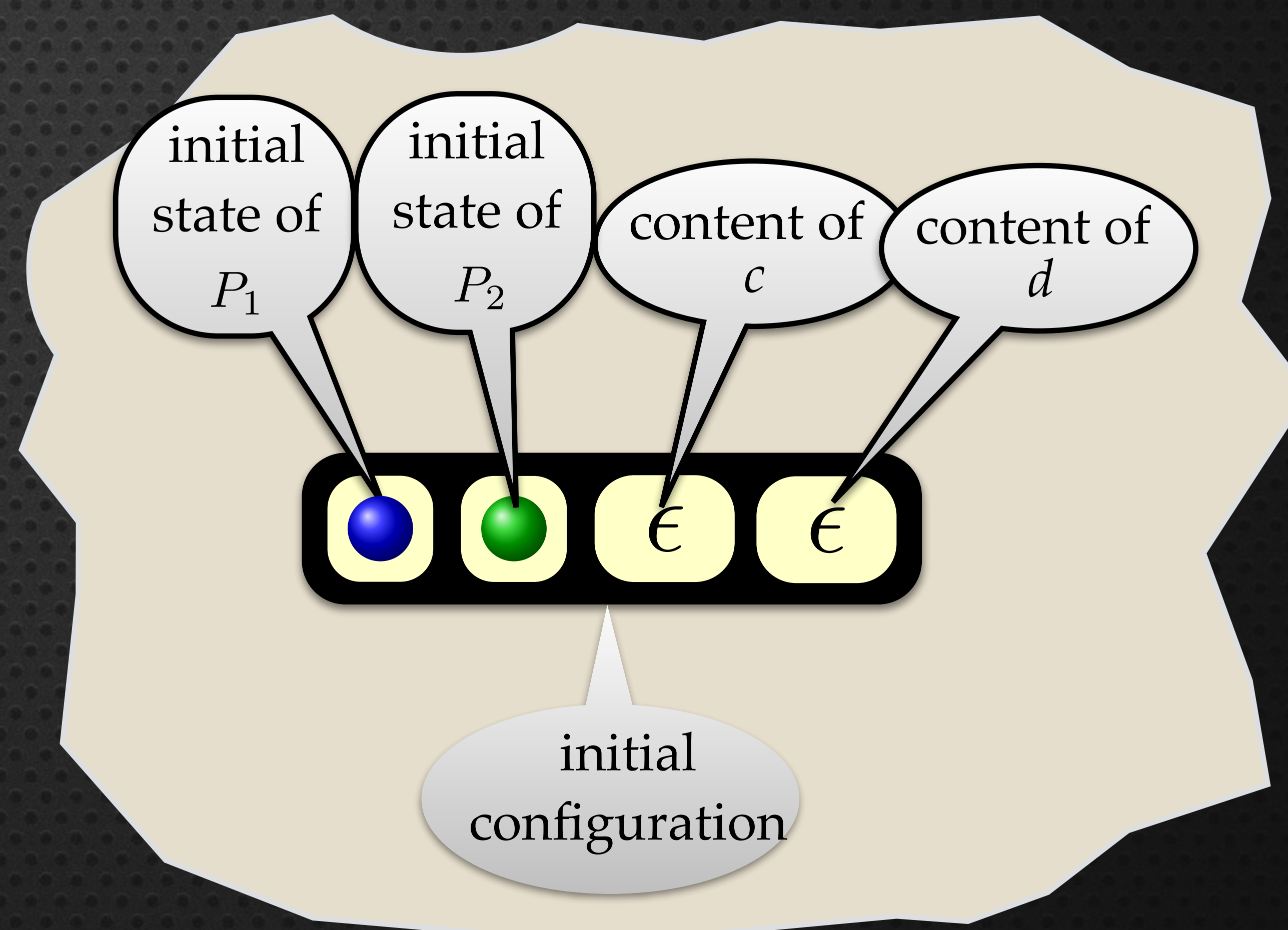

Lossy Channel Systems

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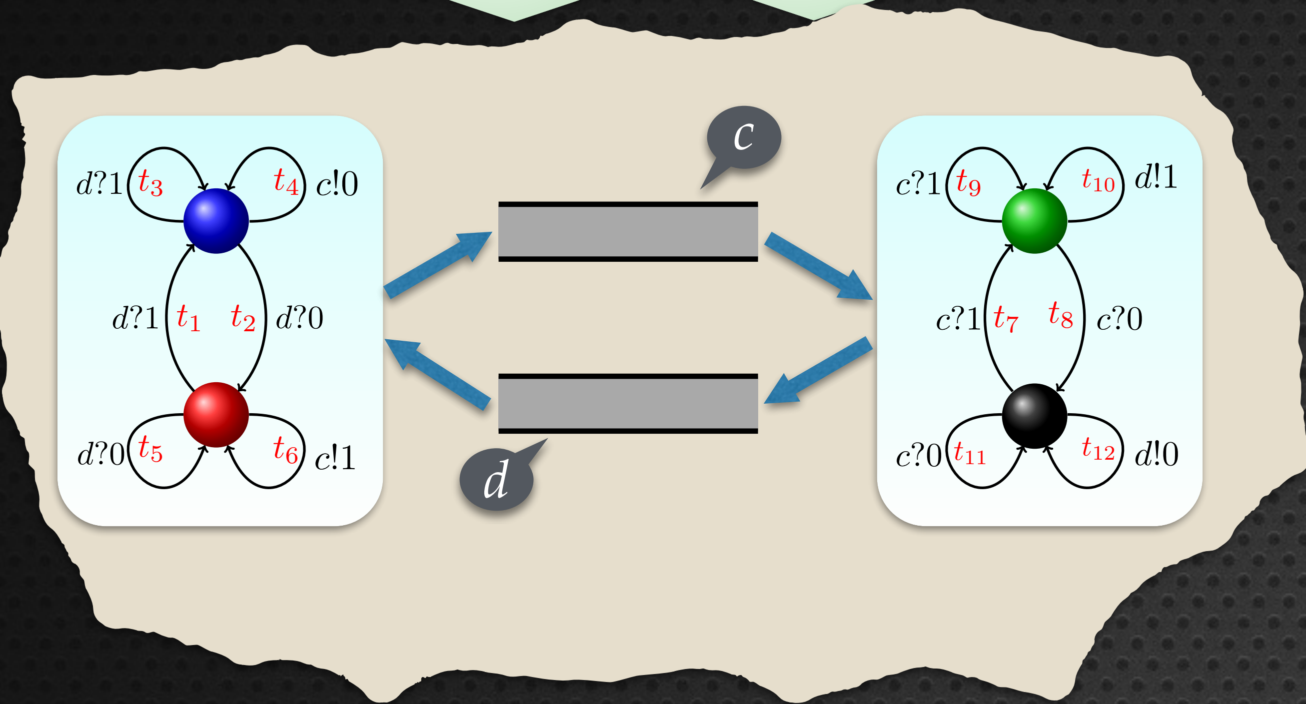

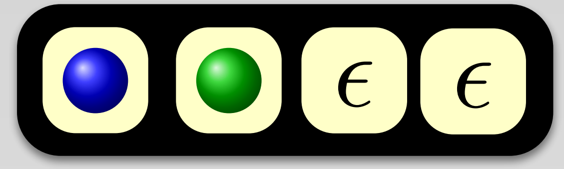

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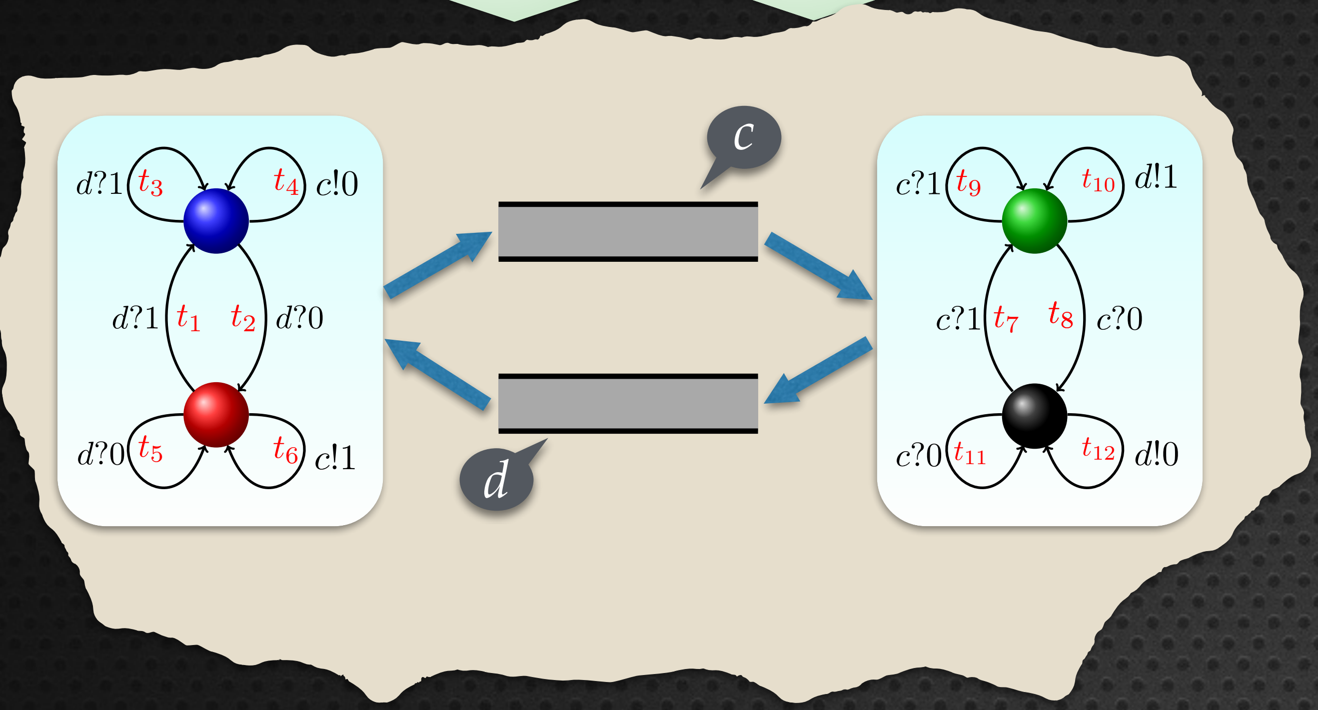

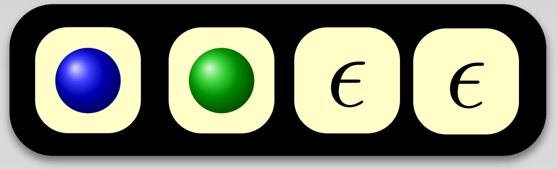

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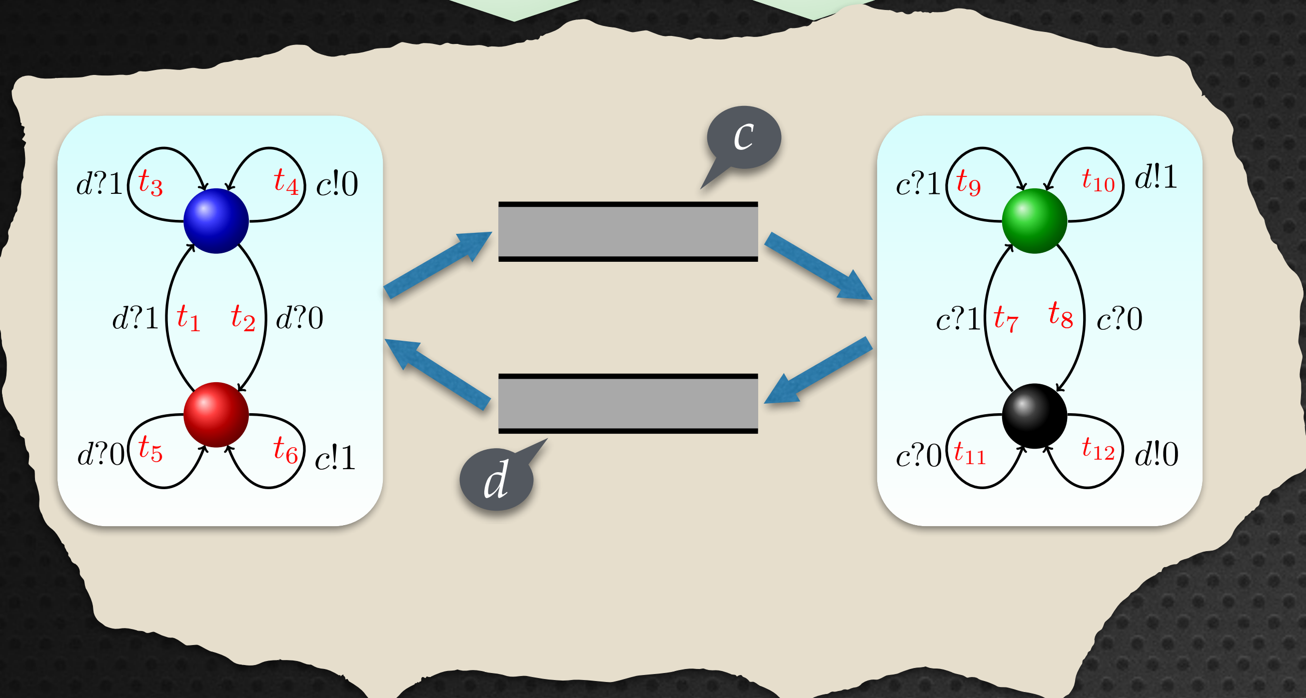

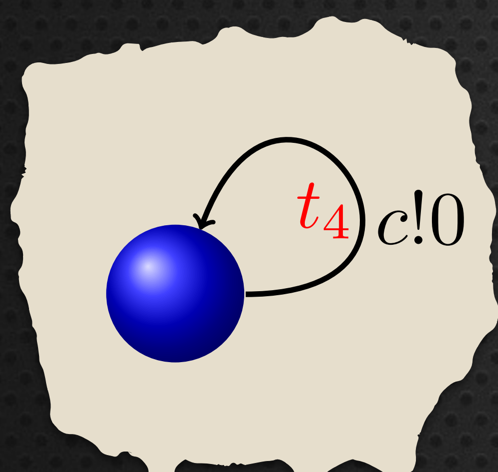

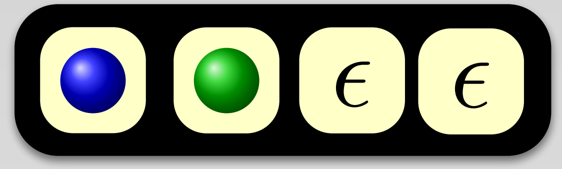

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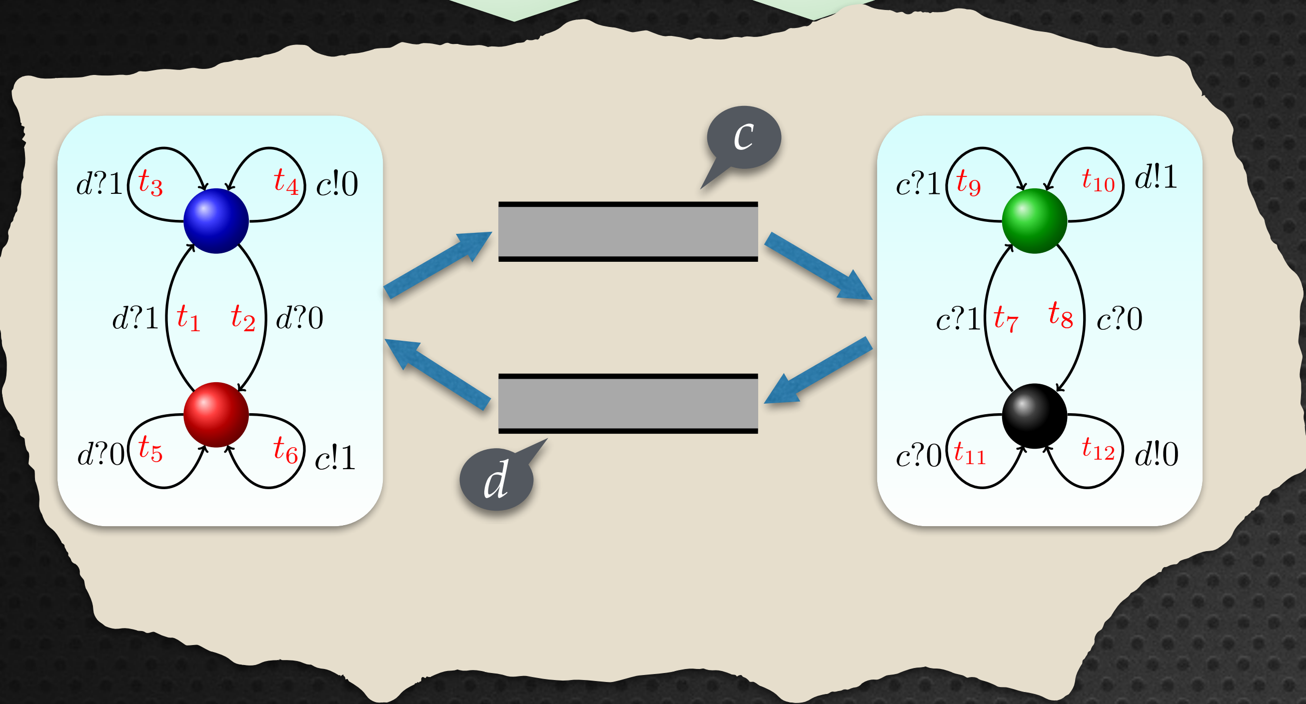

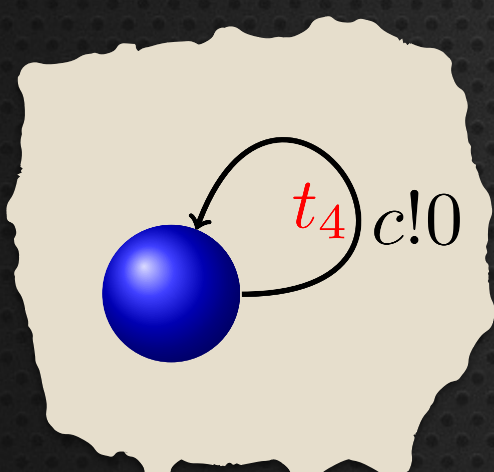

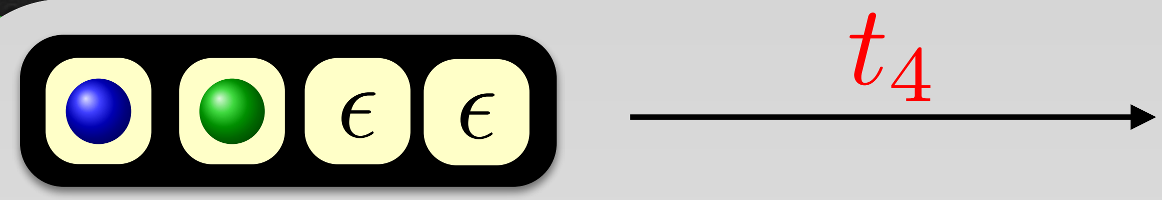

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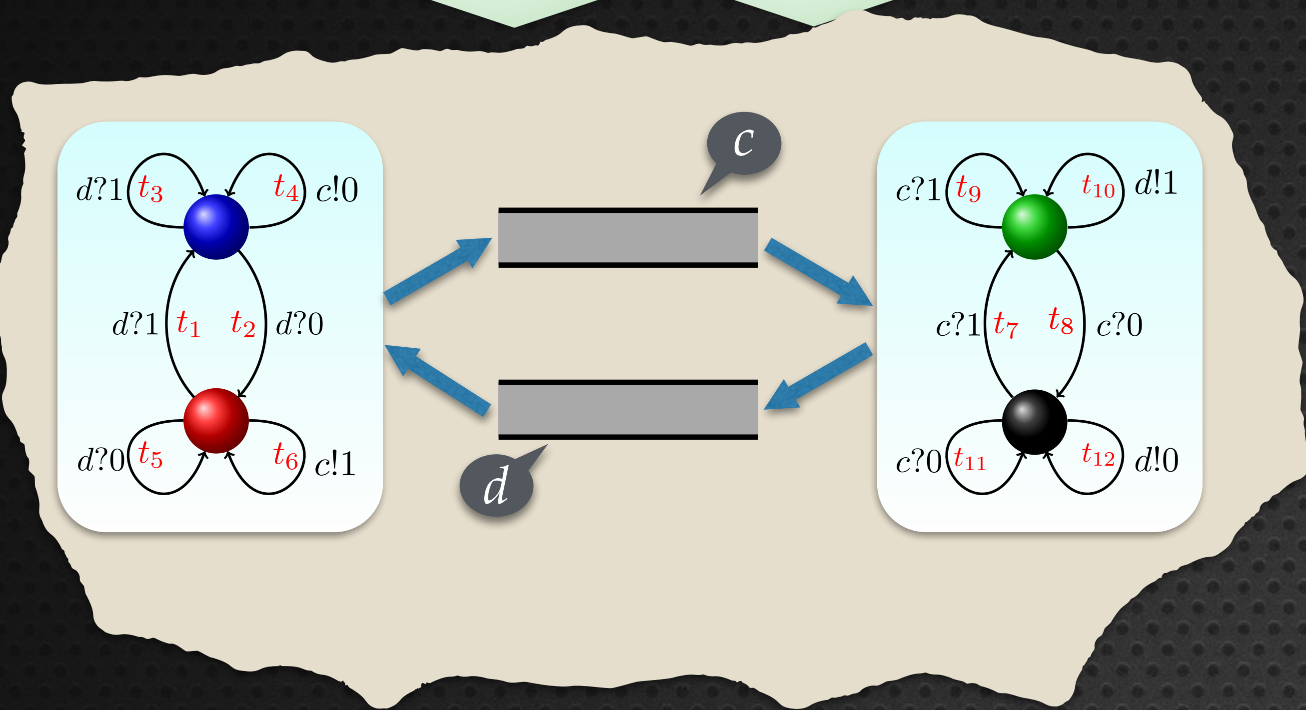

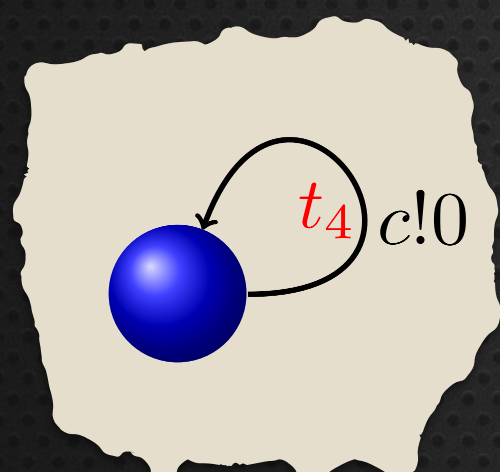

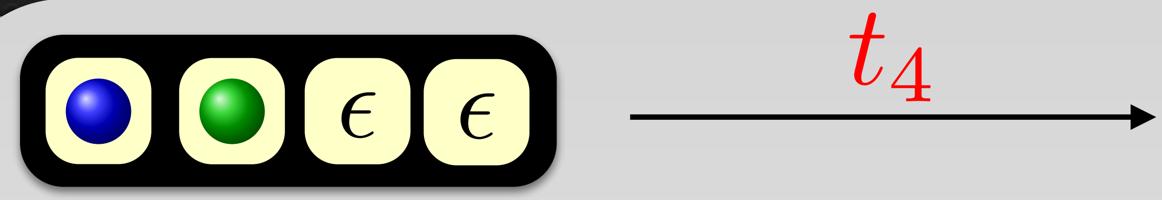

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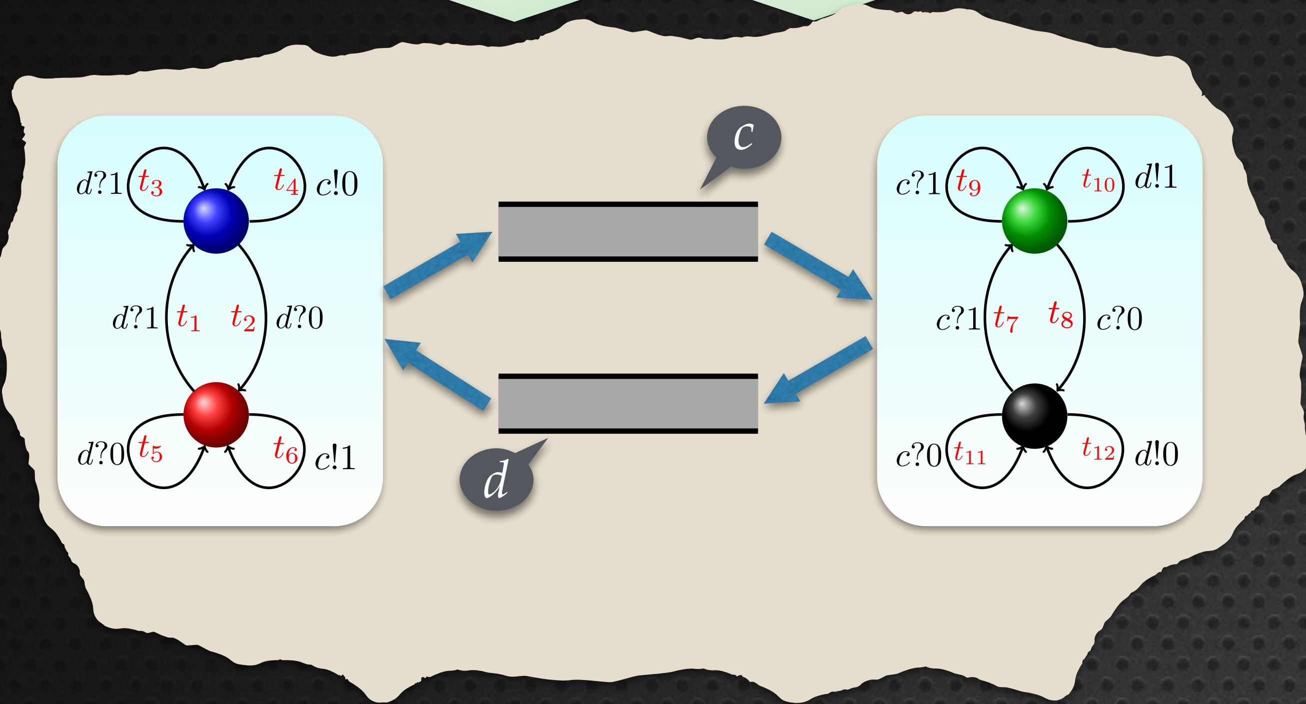

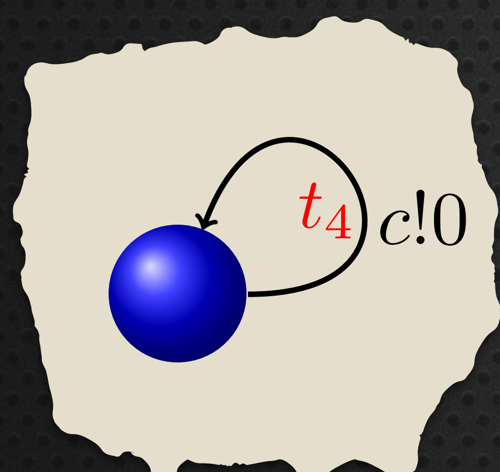

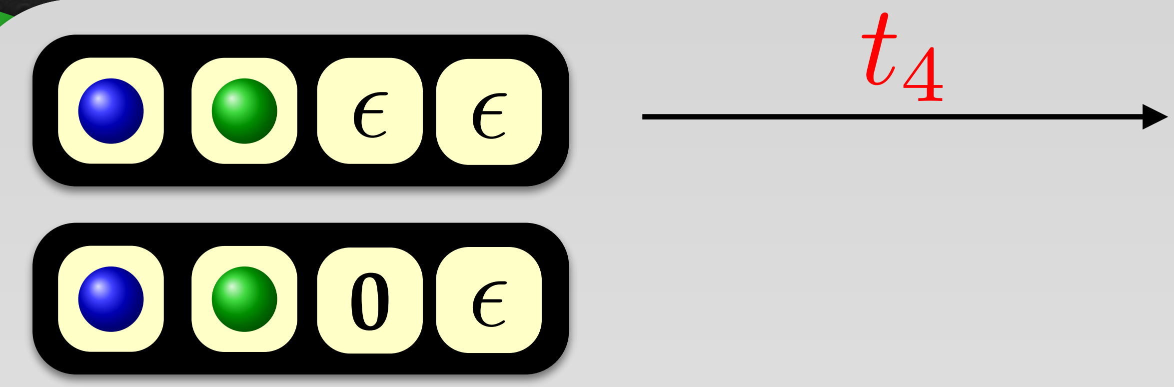

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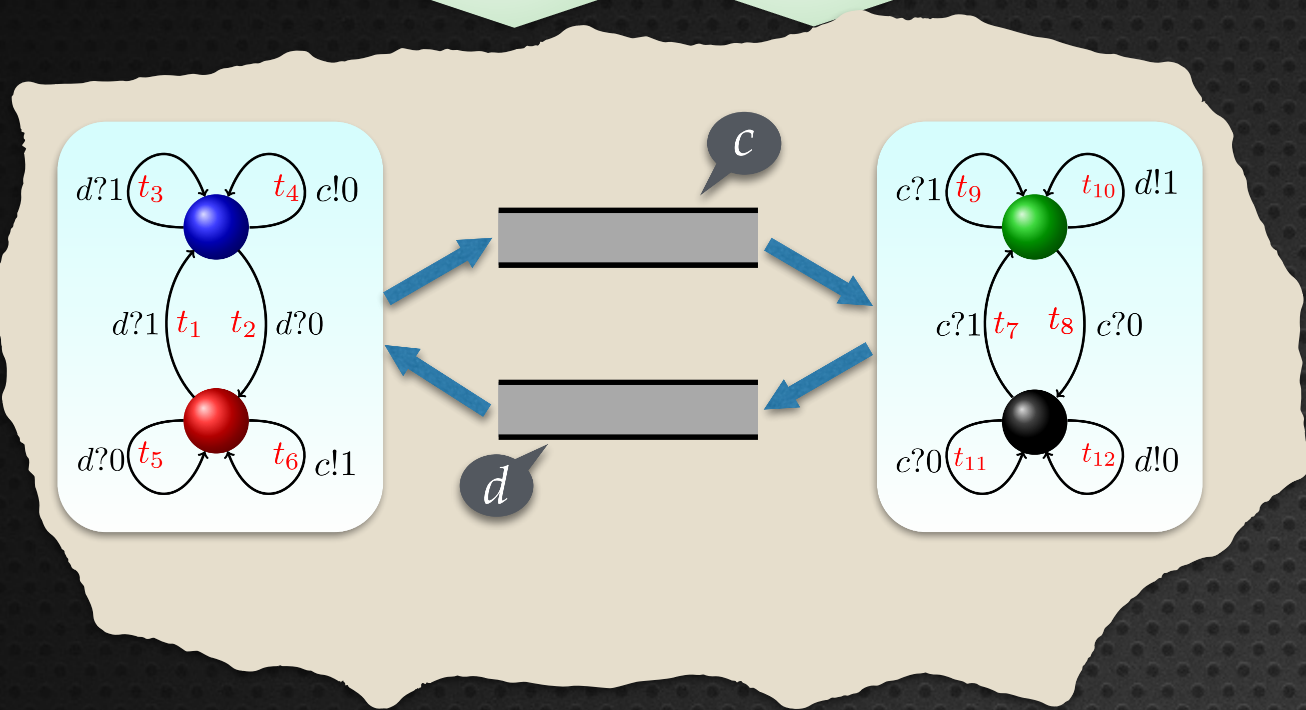

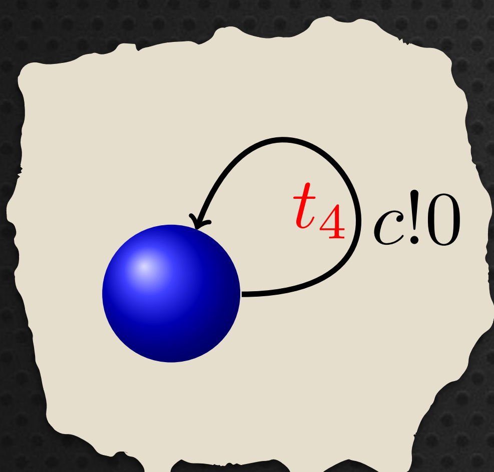

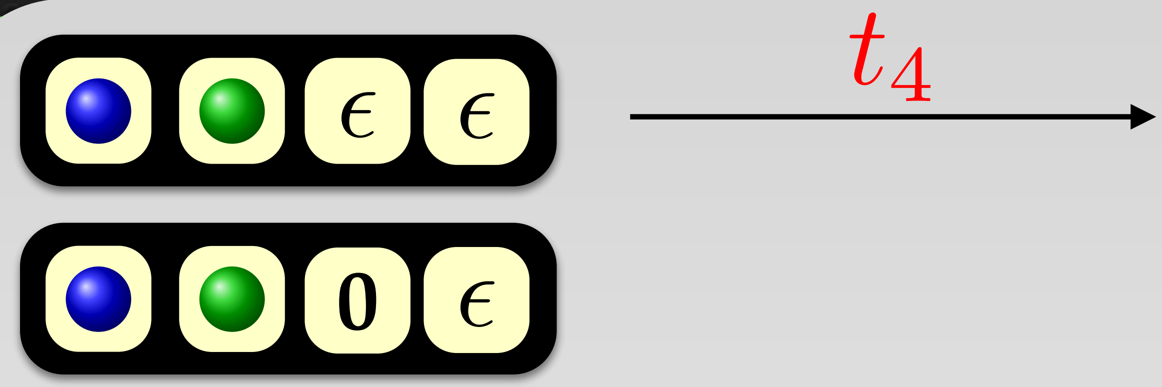

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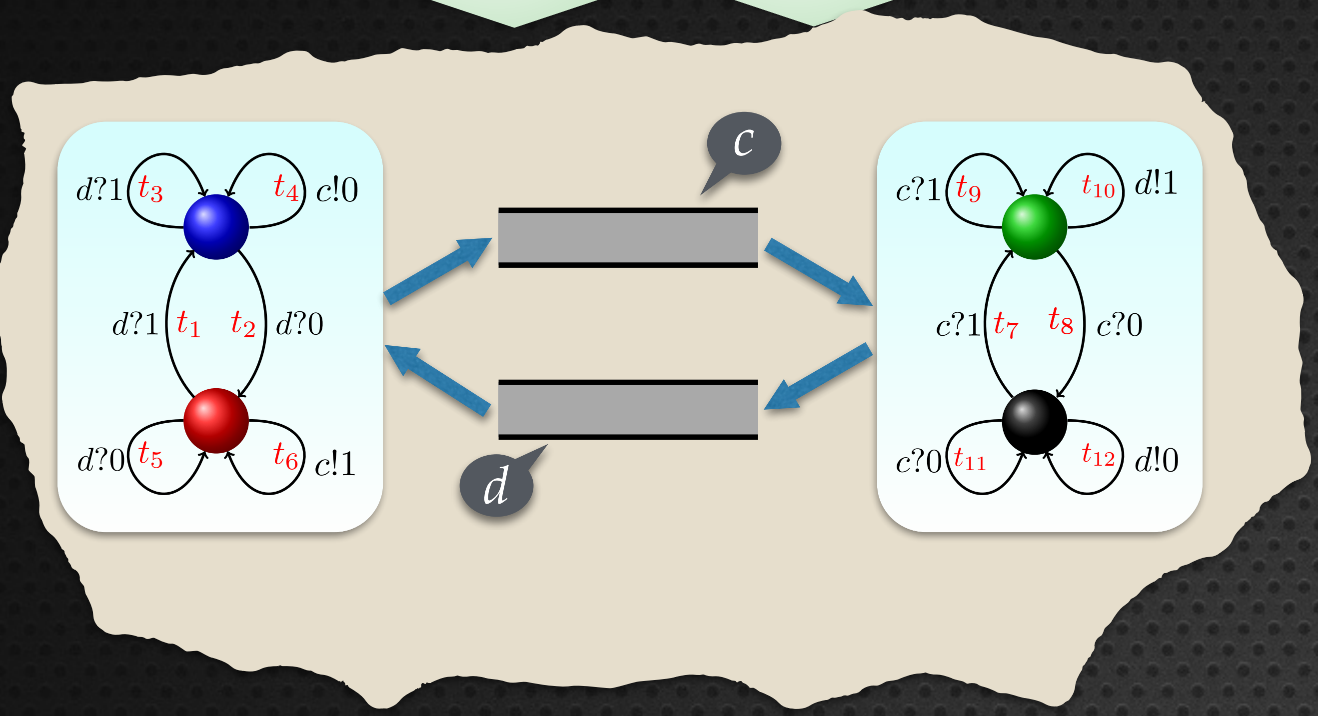

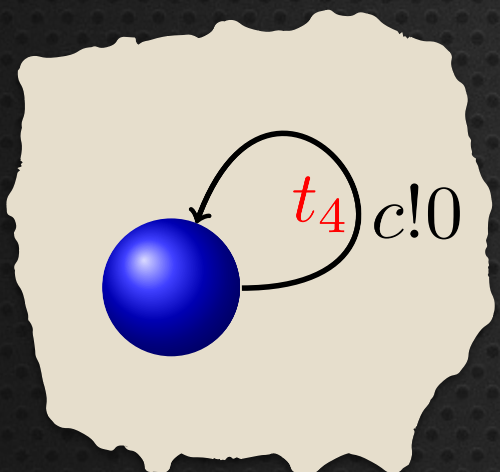

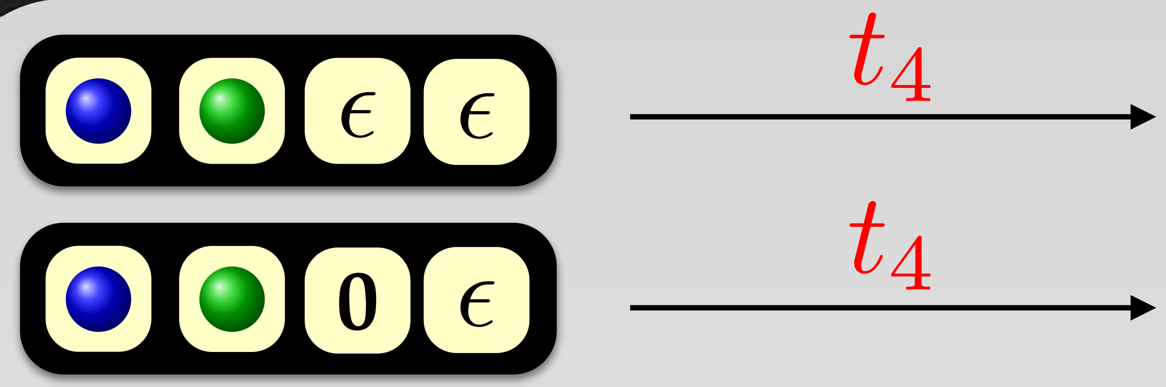

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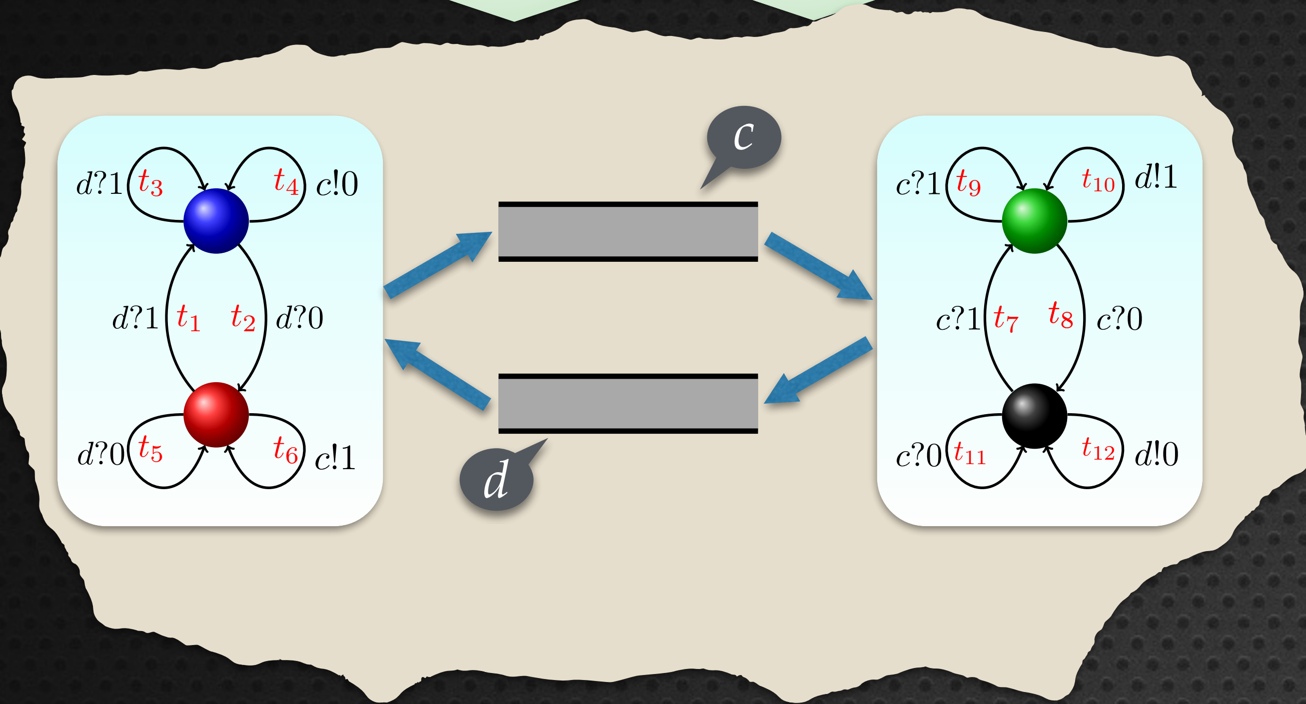

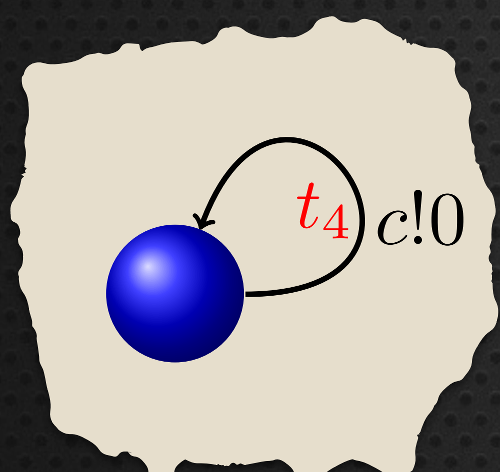

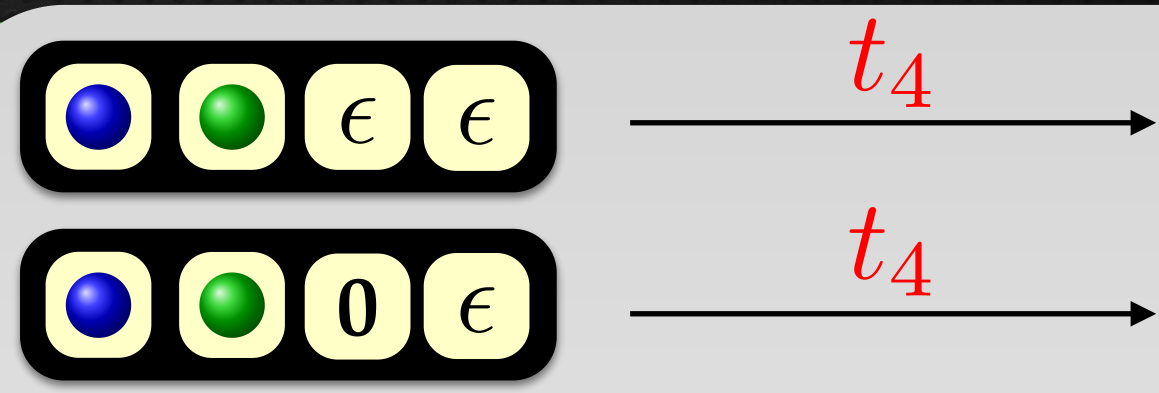

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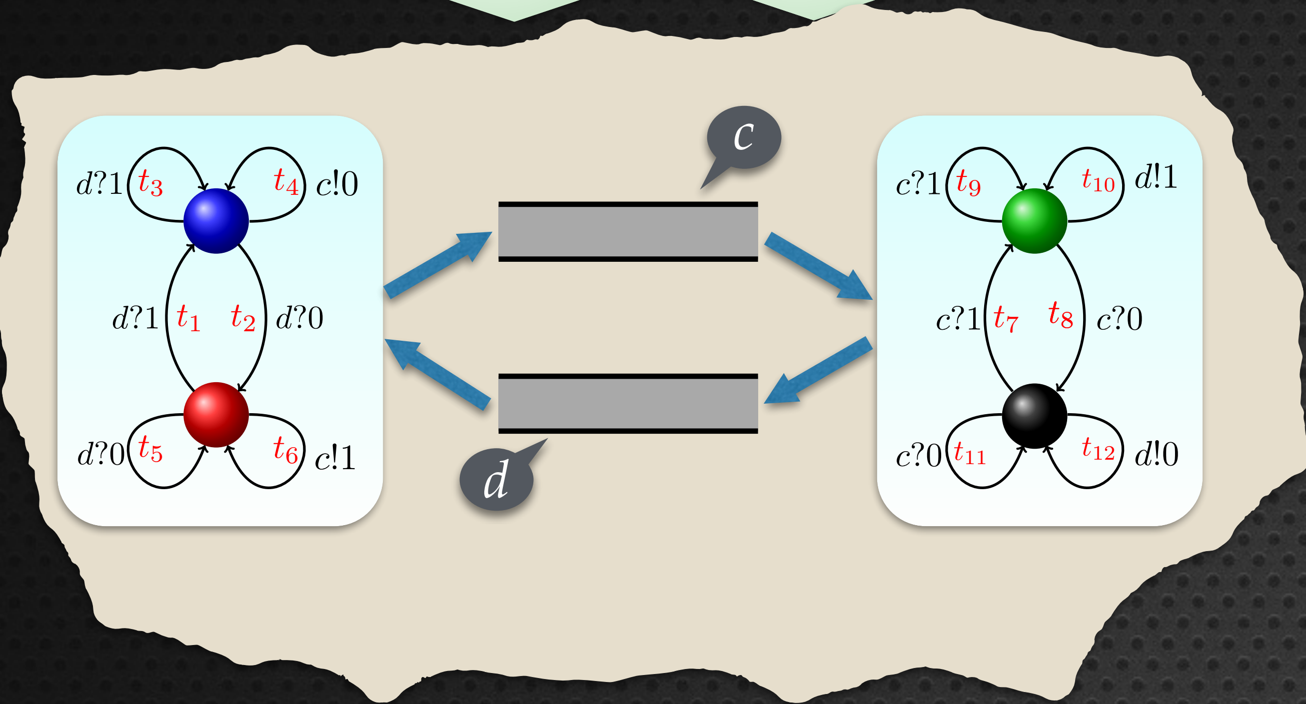

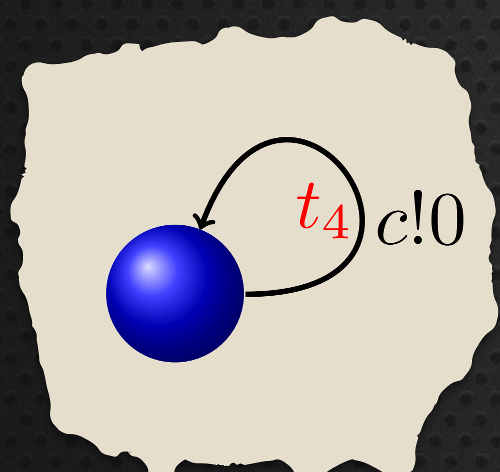

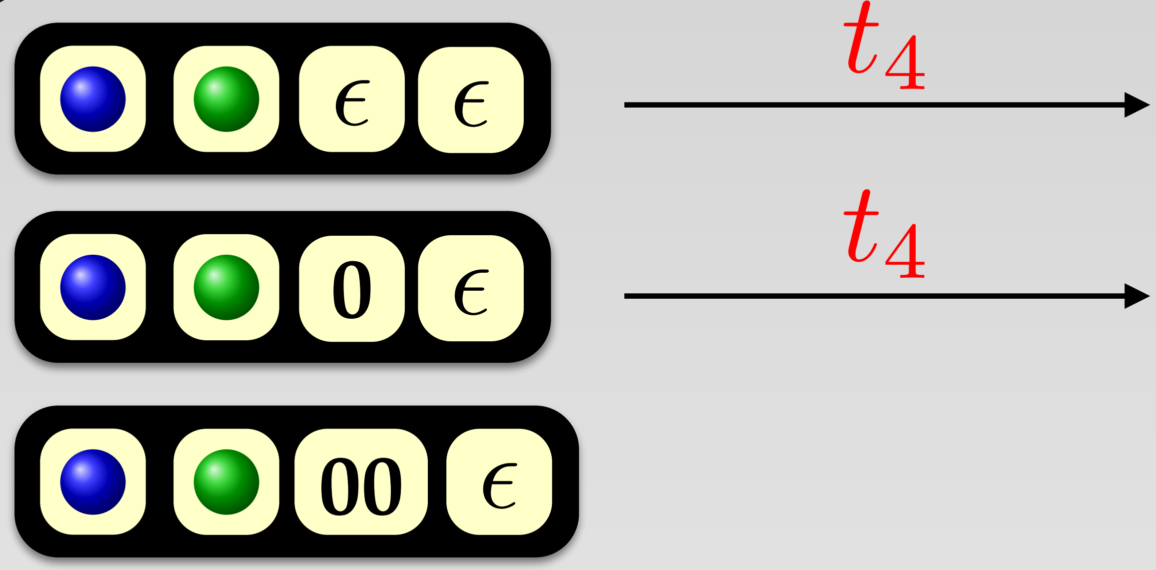

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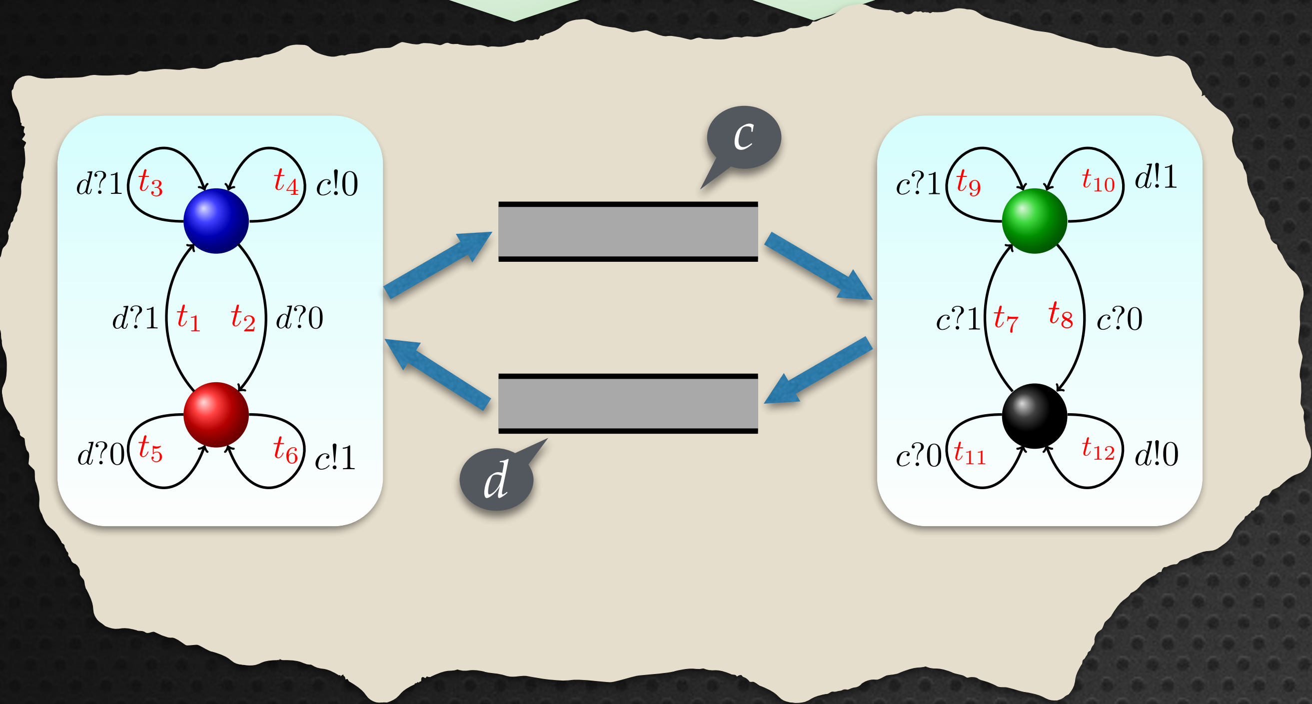

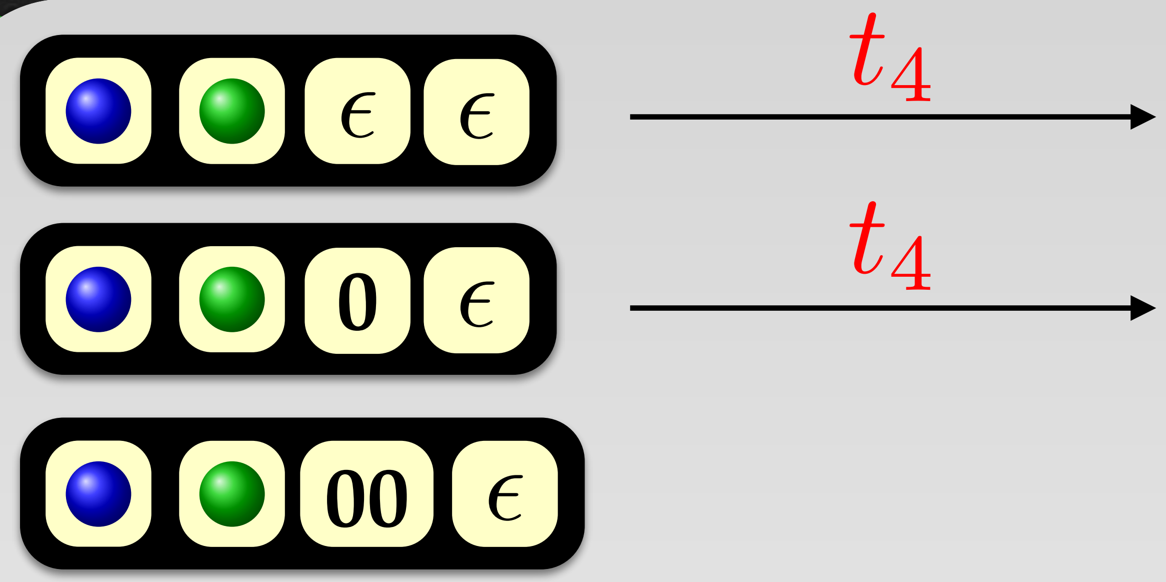

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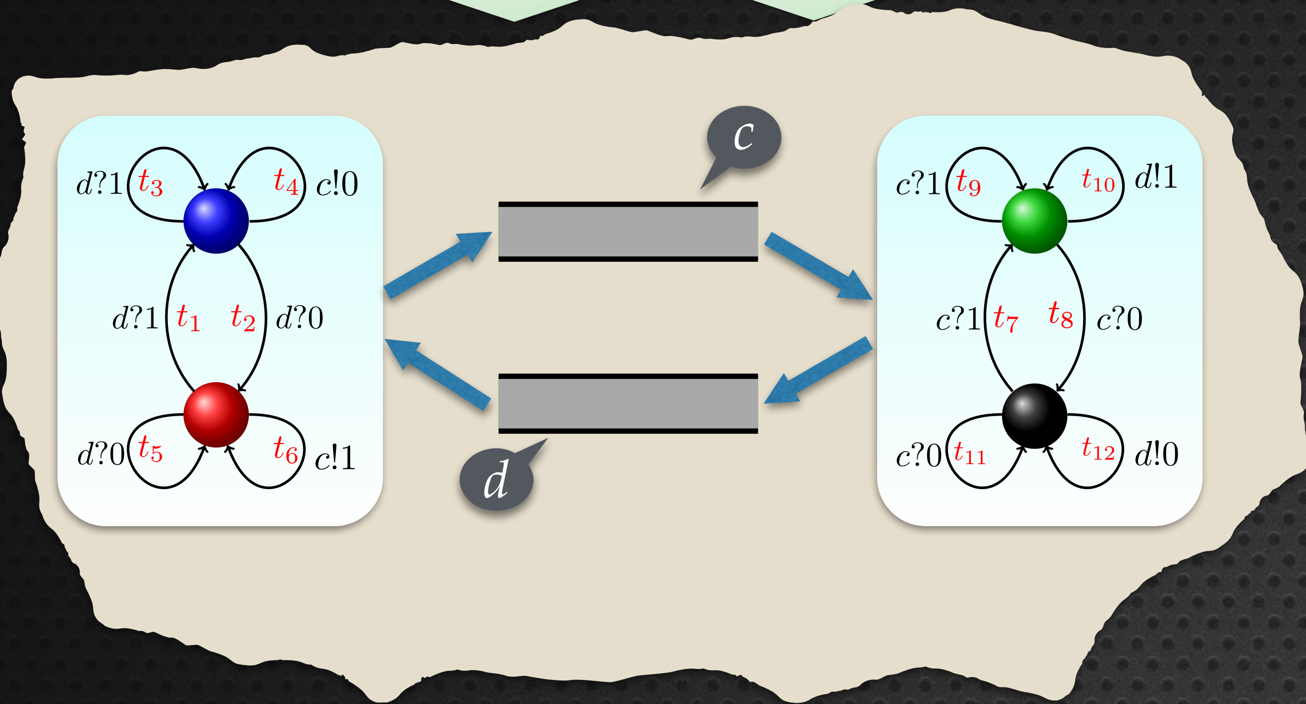

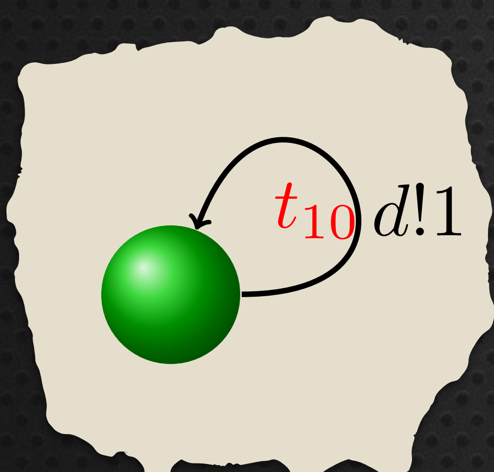

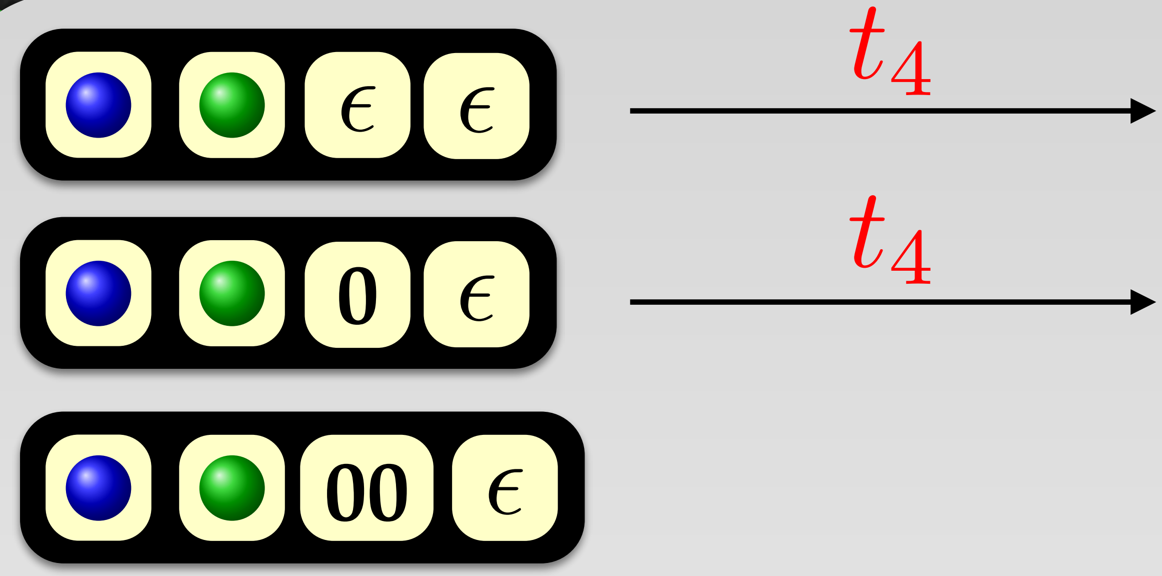

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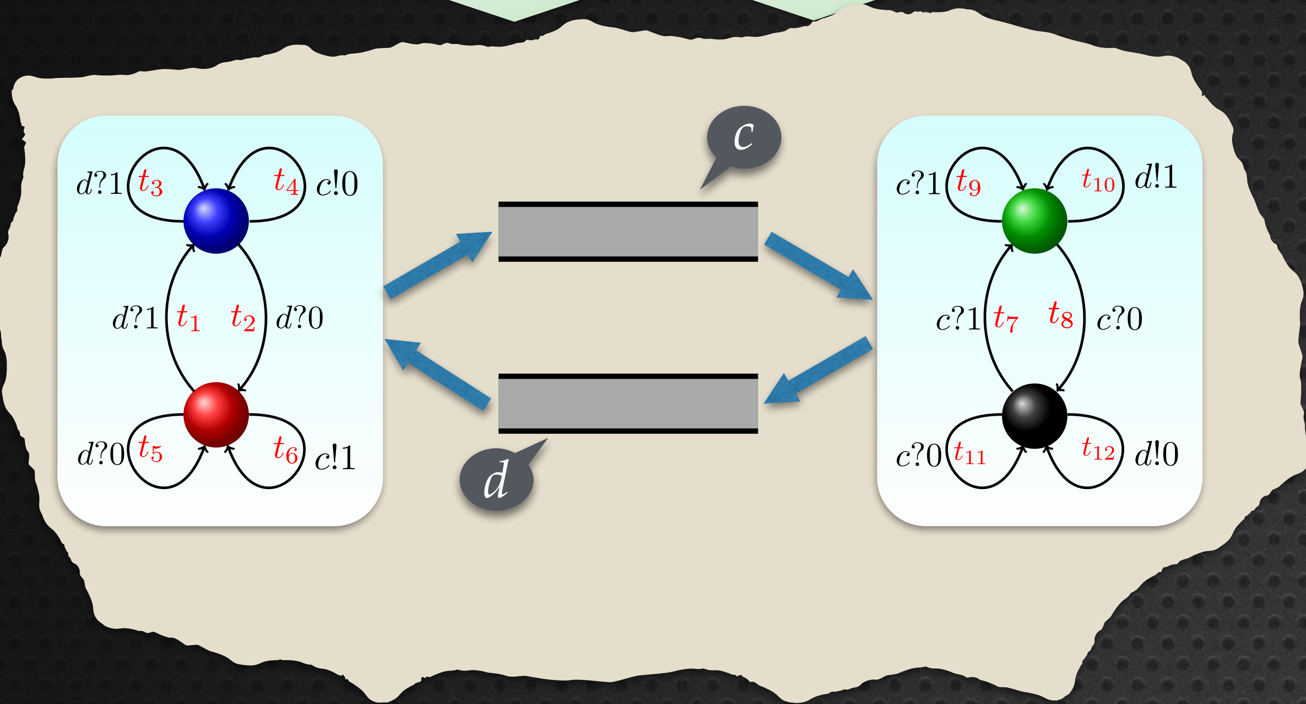

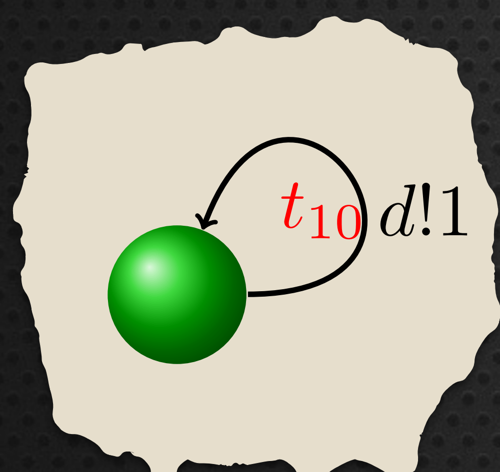

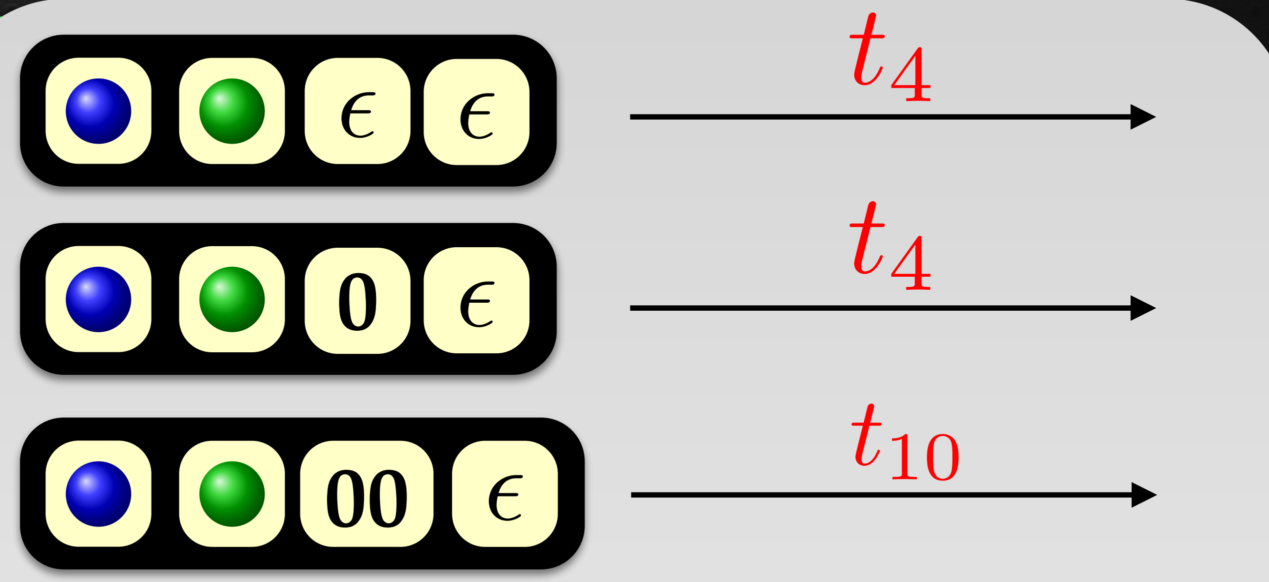

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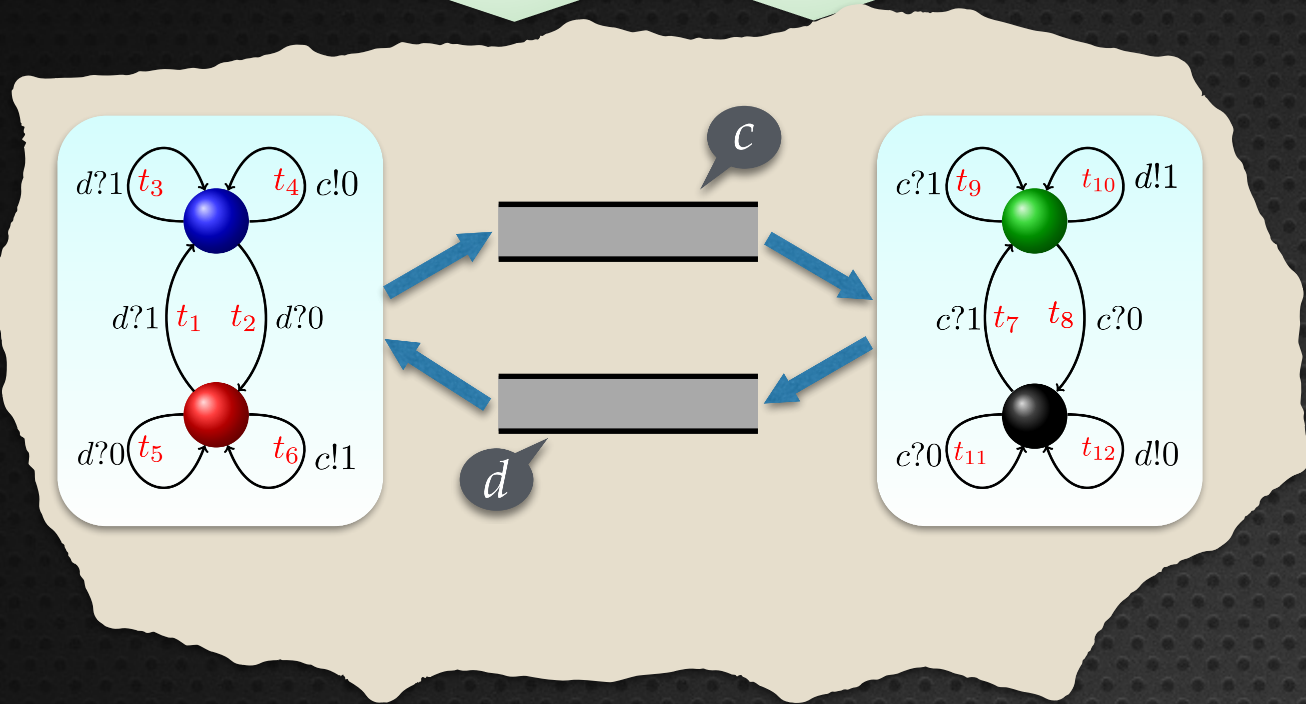

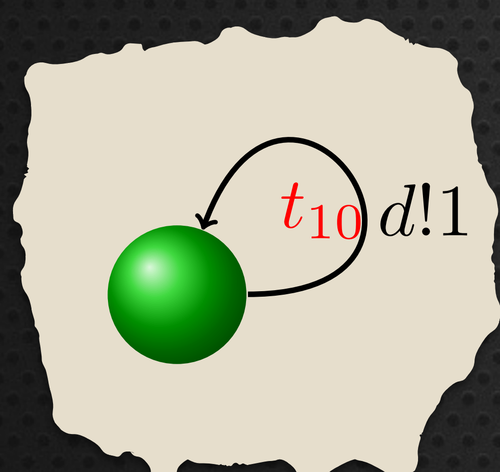

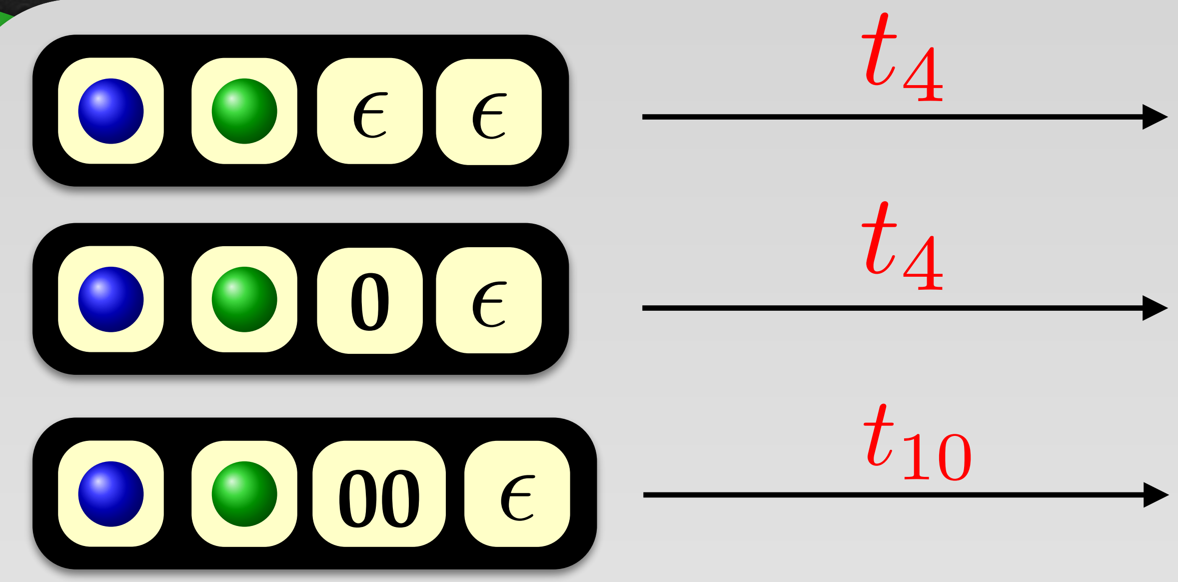

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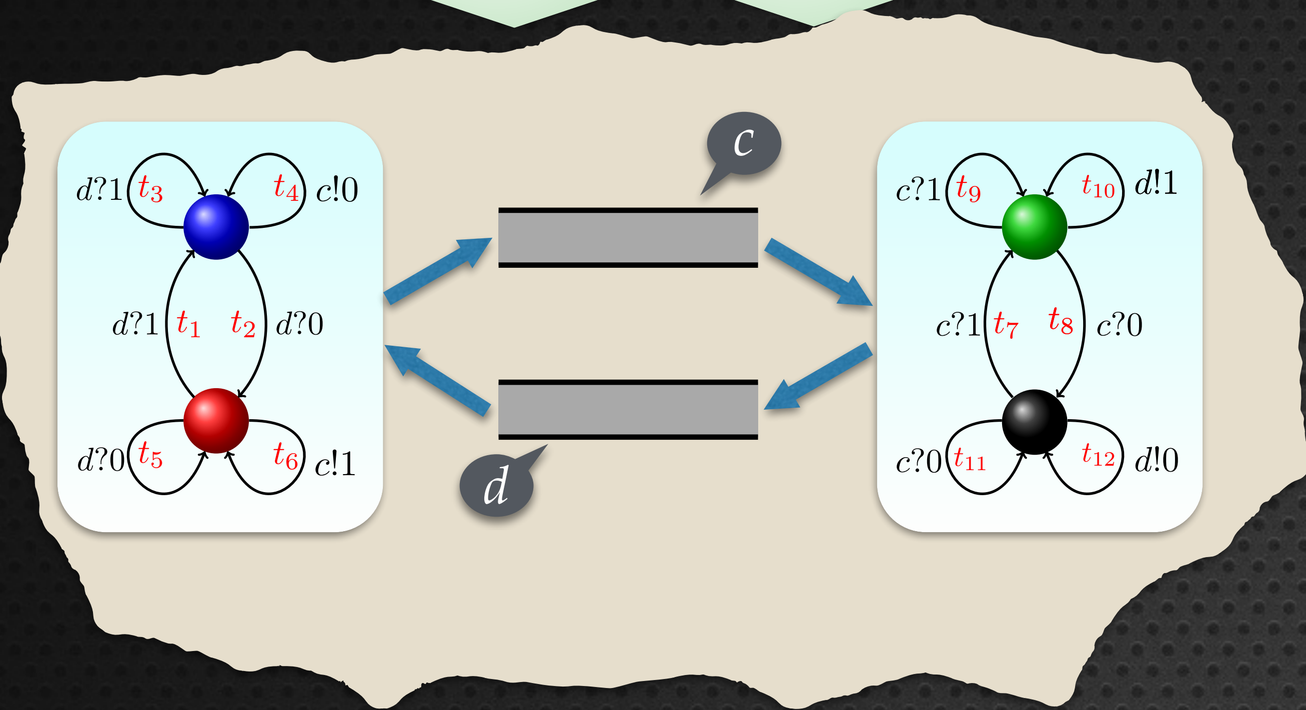

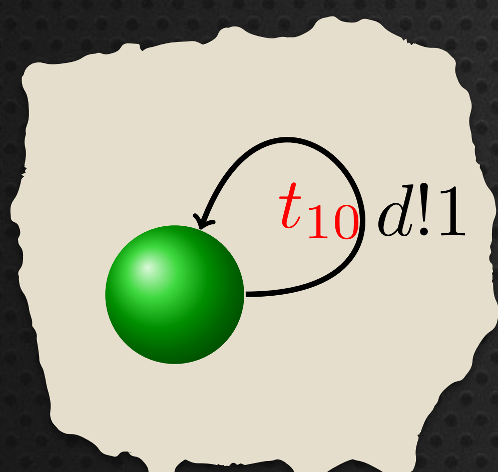

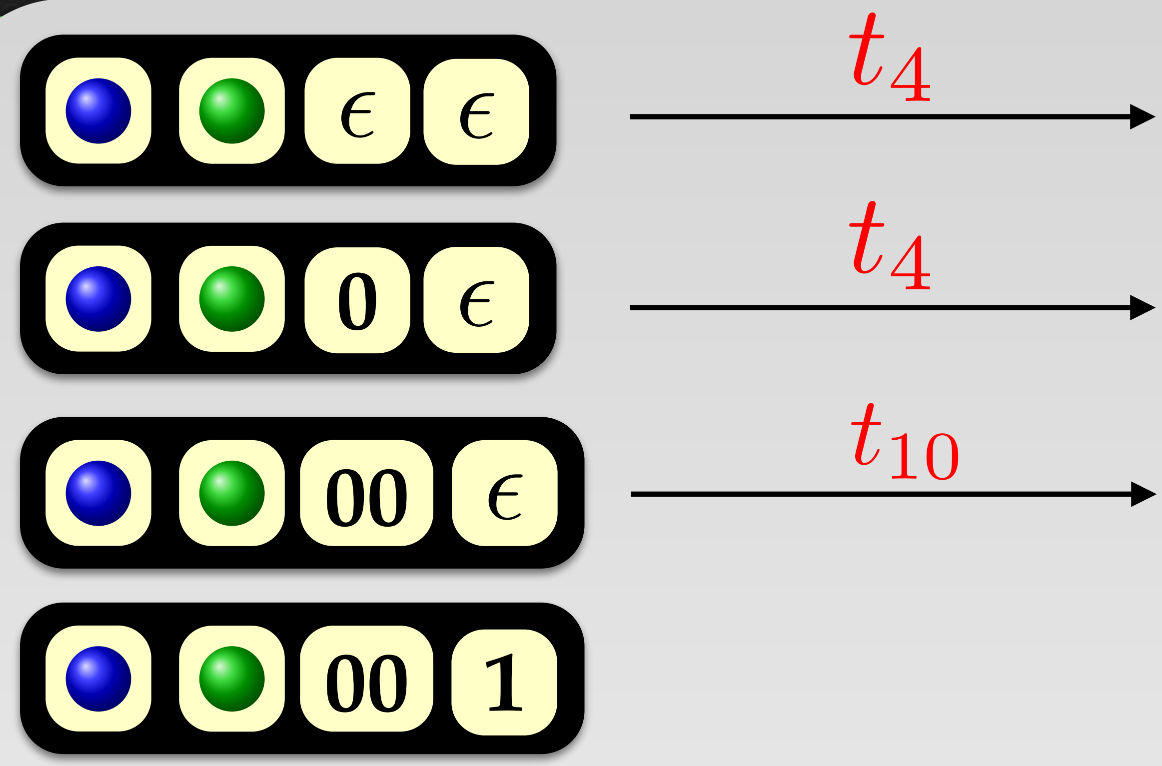

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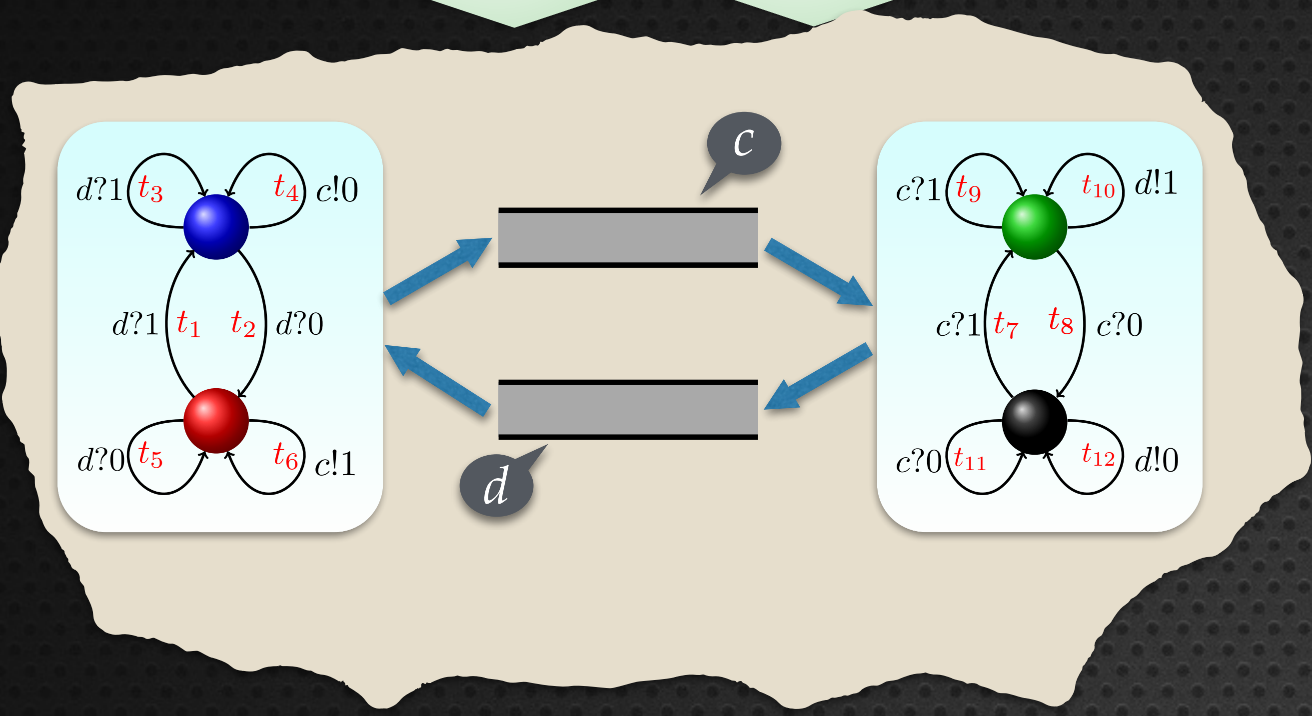

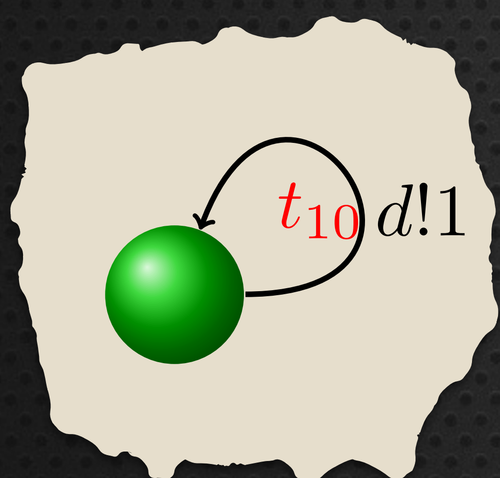

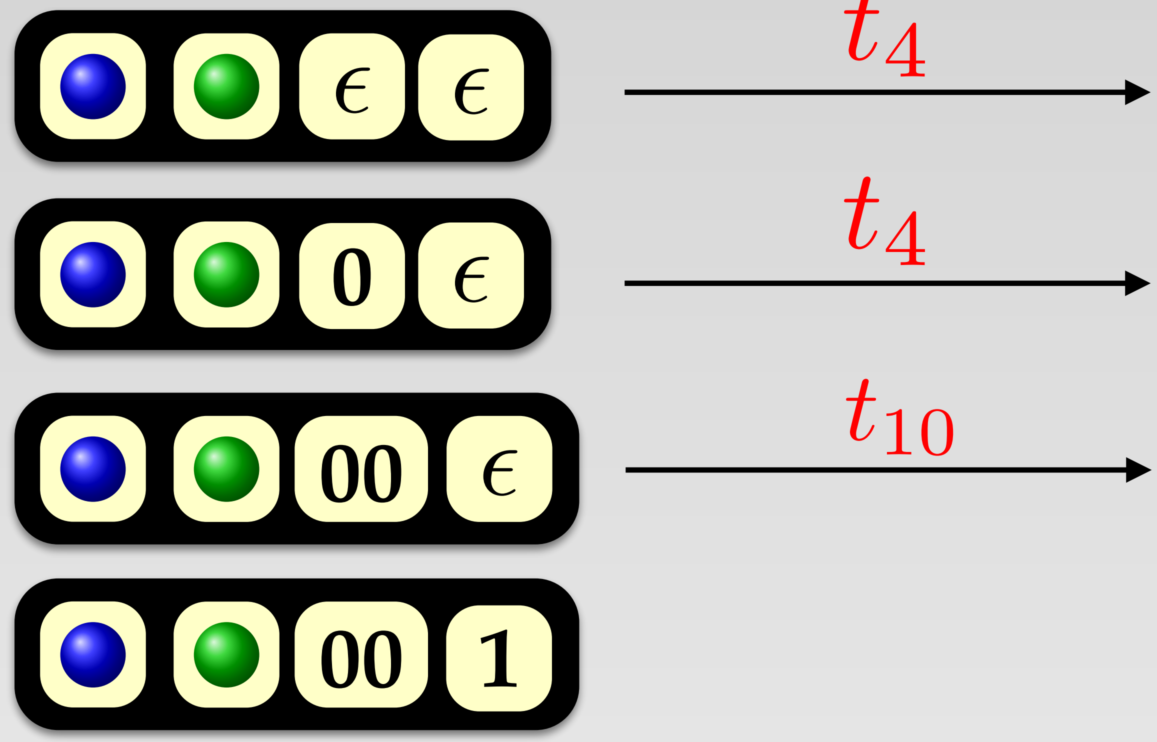

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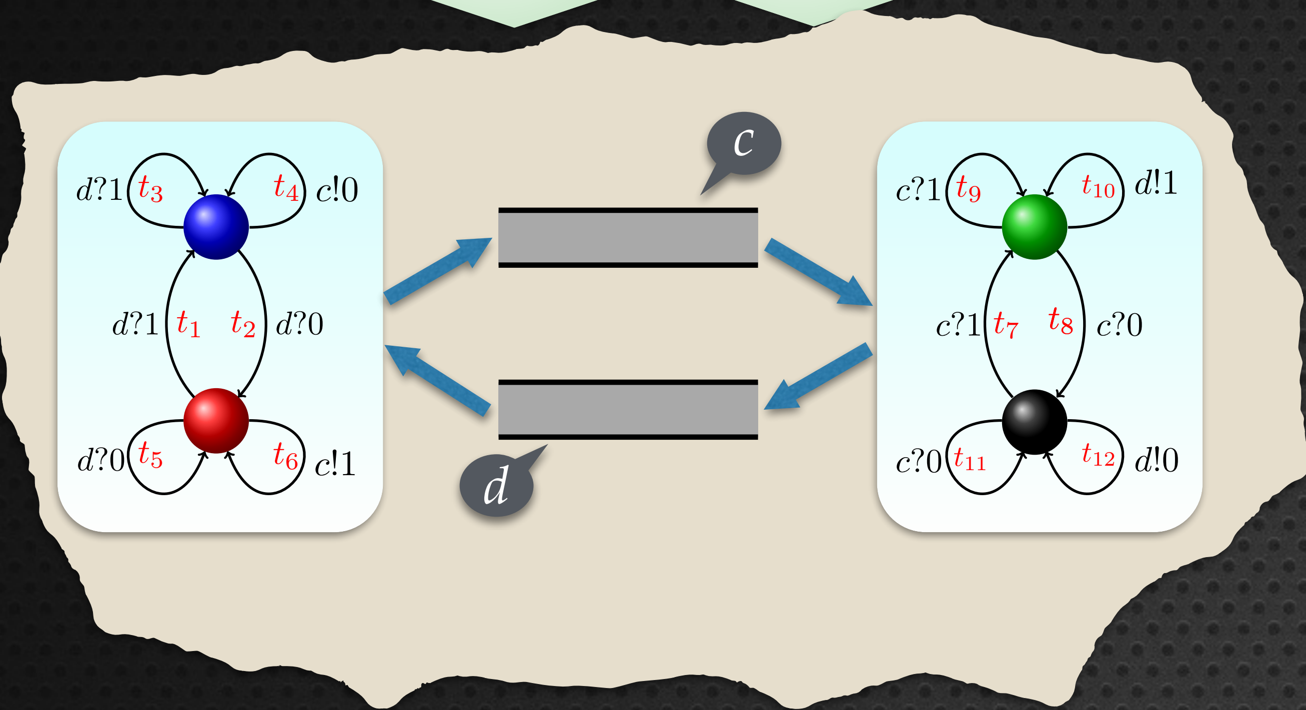

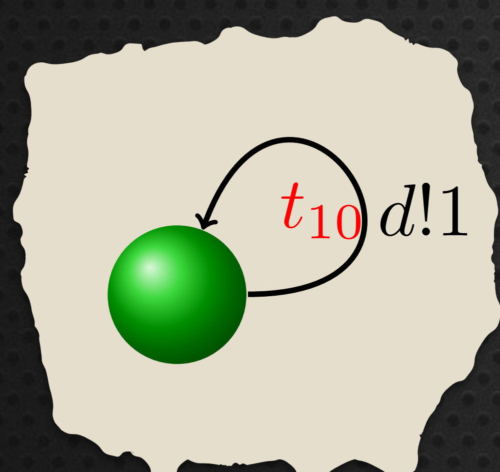

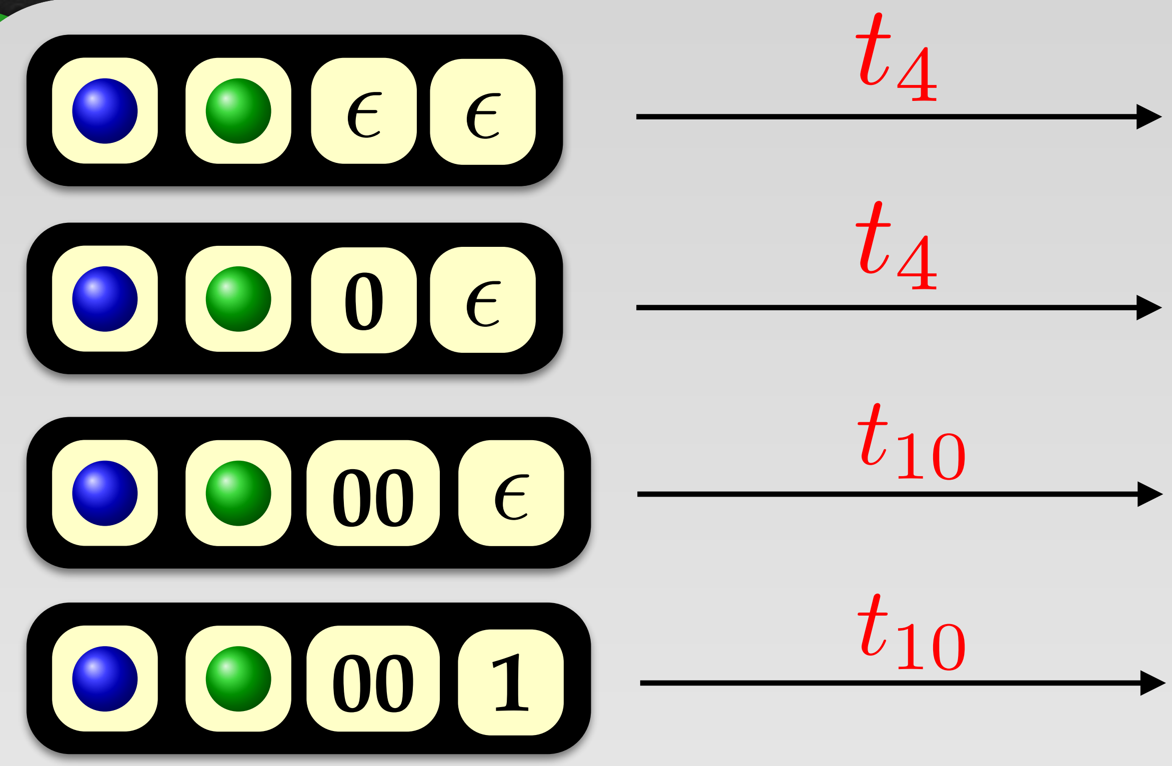

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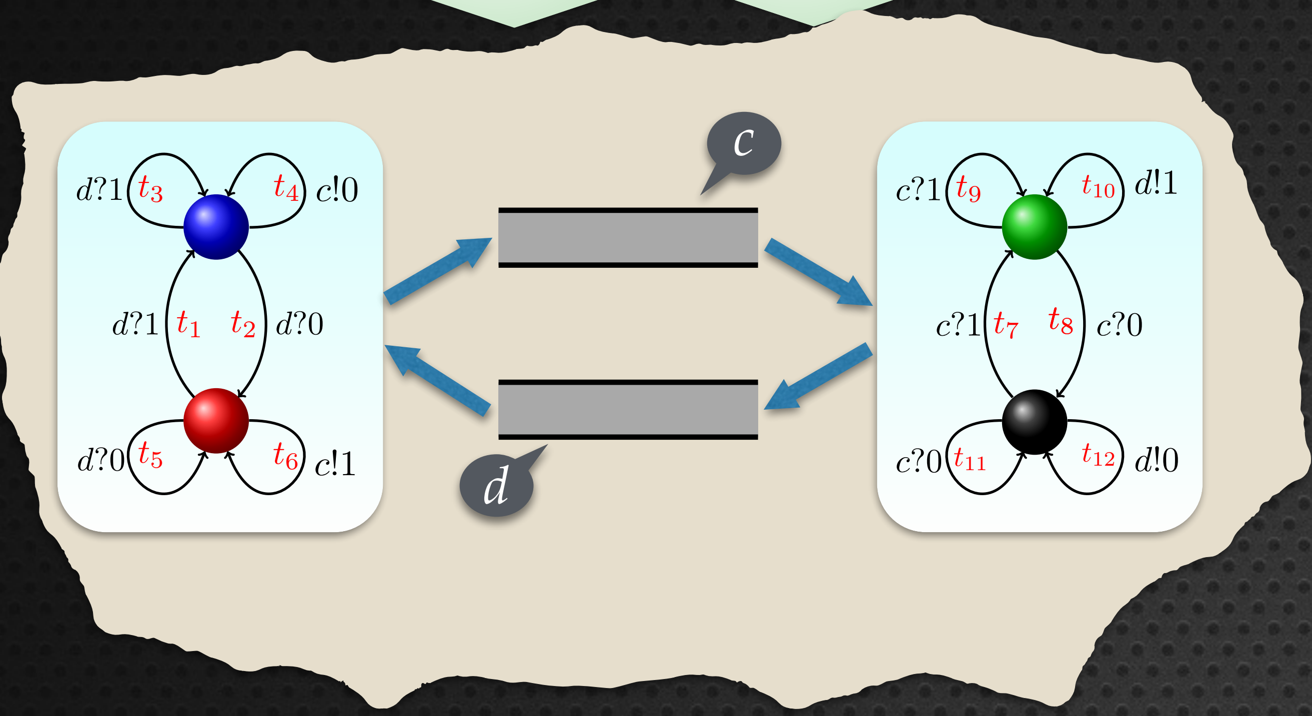

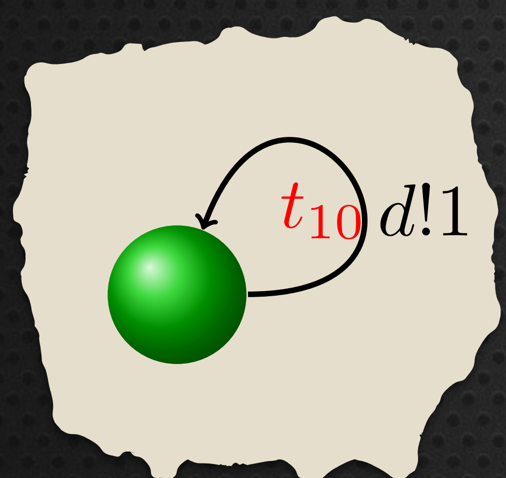

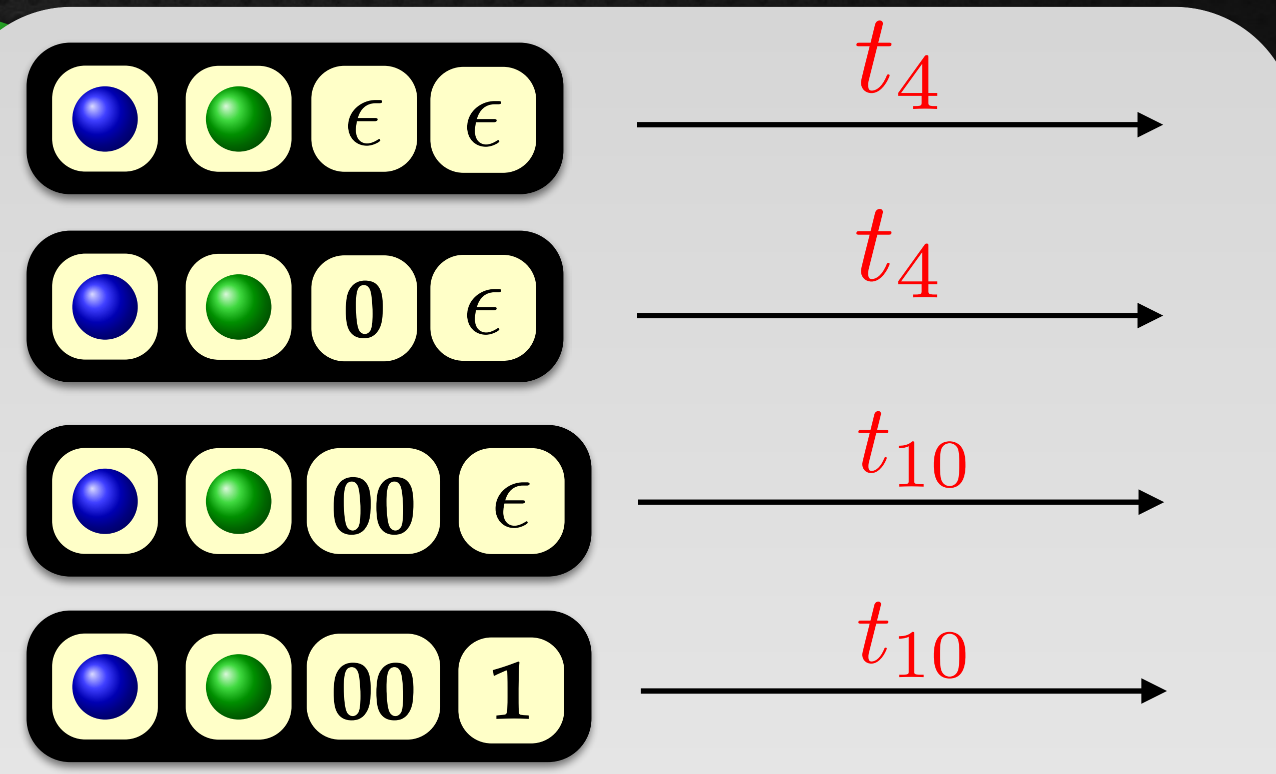

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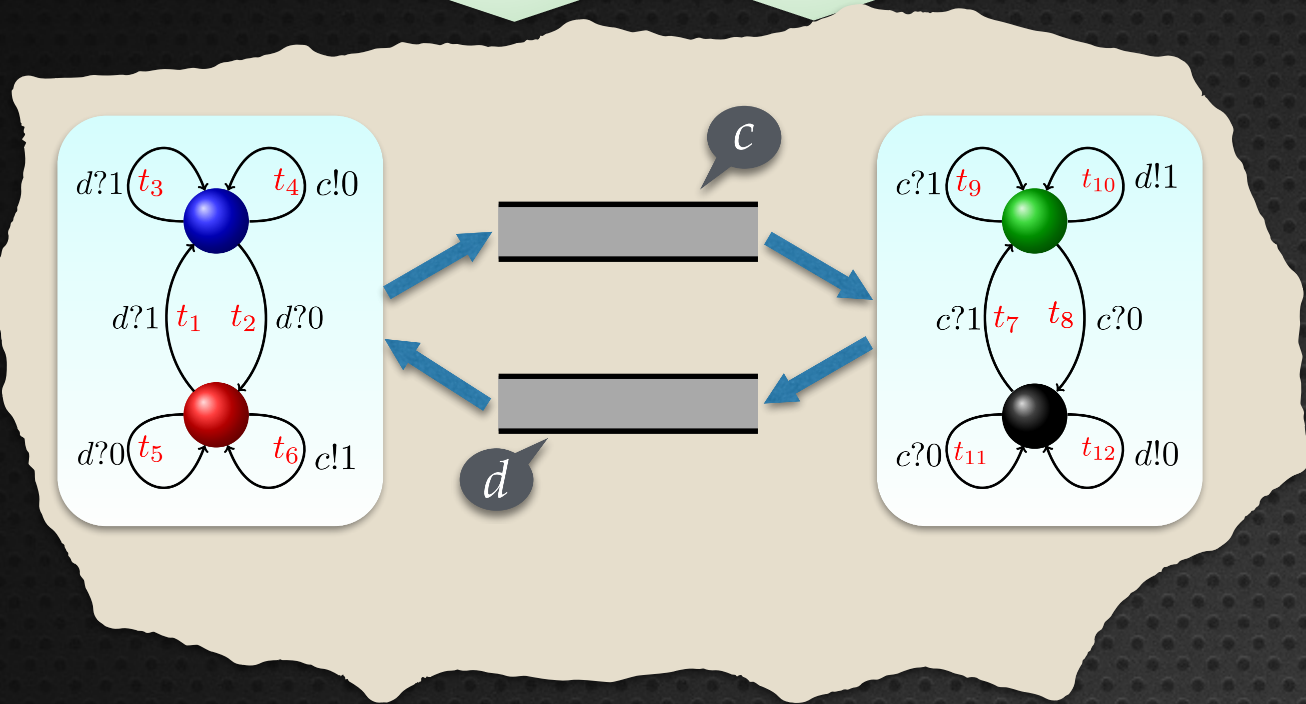

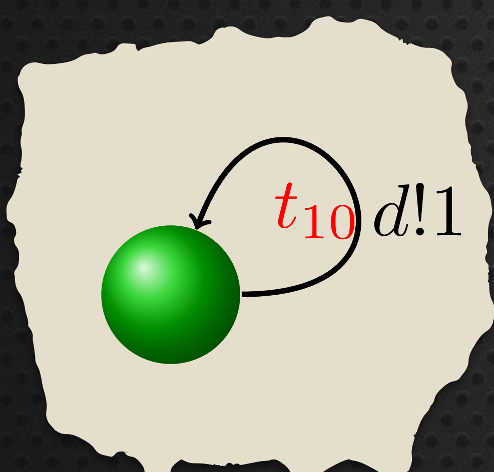

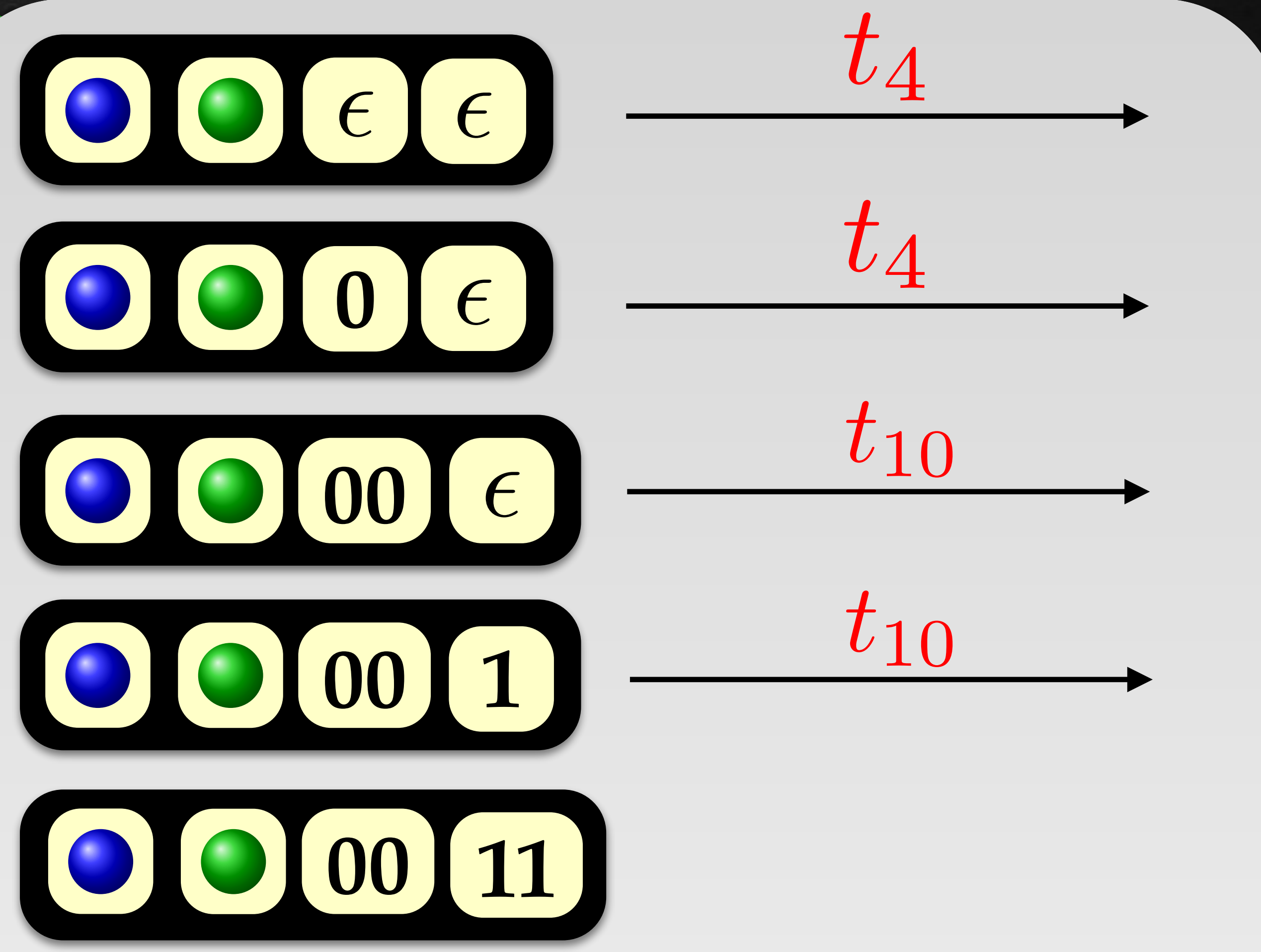

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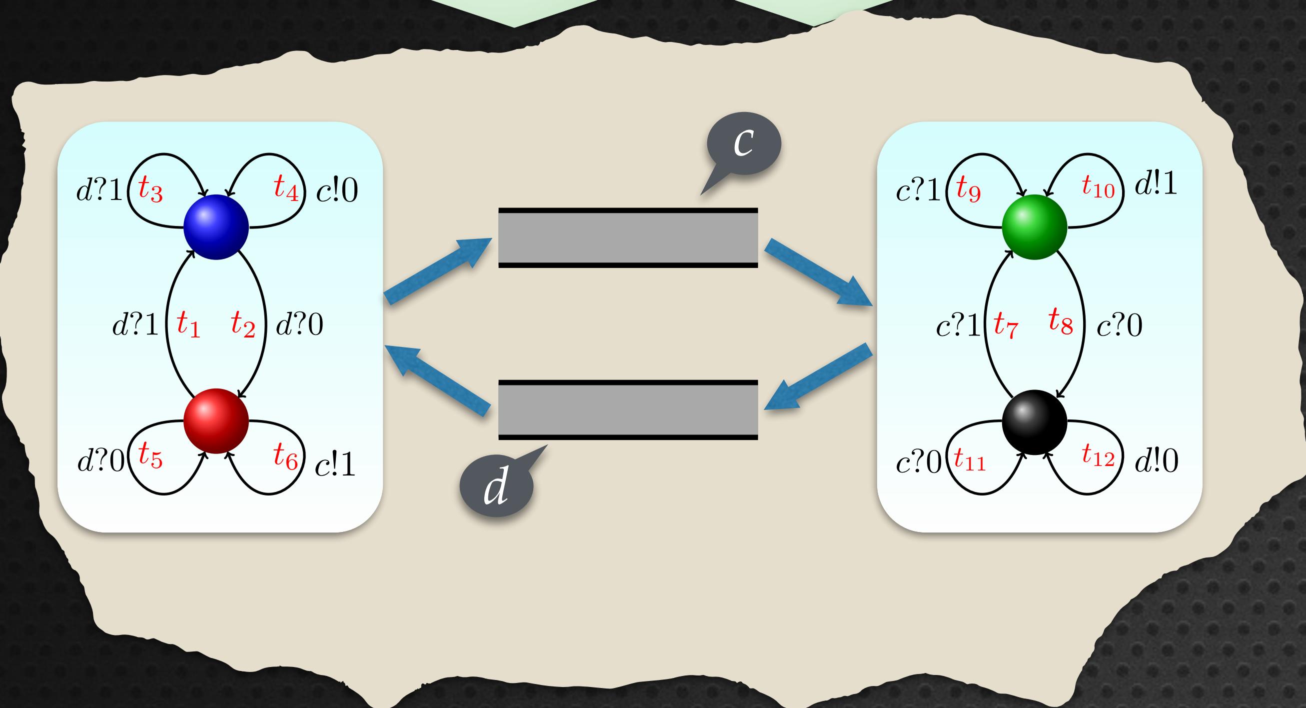

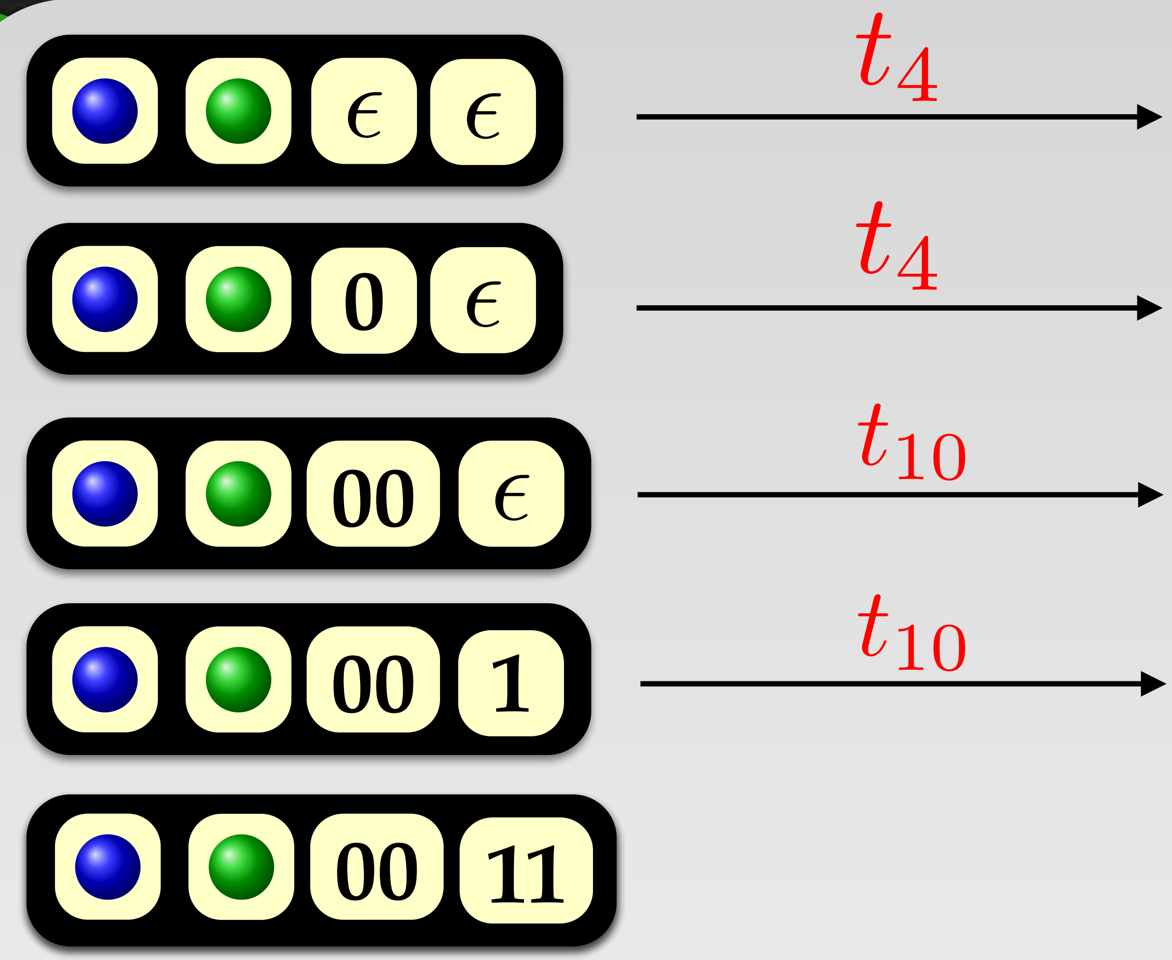

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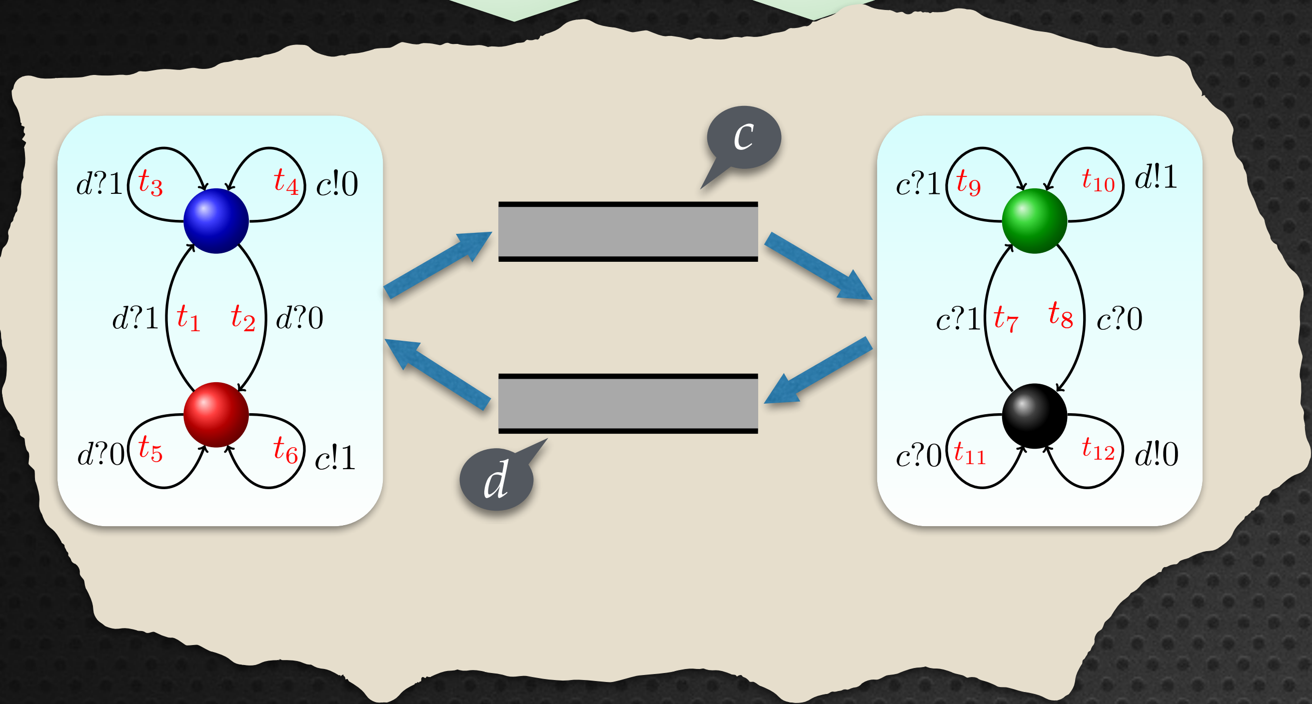

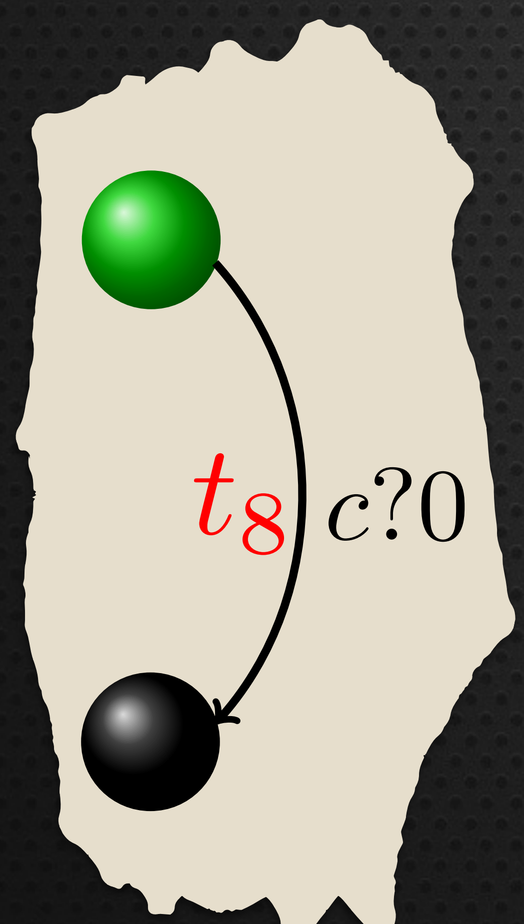

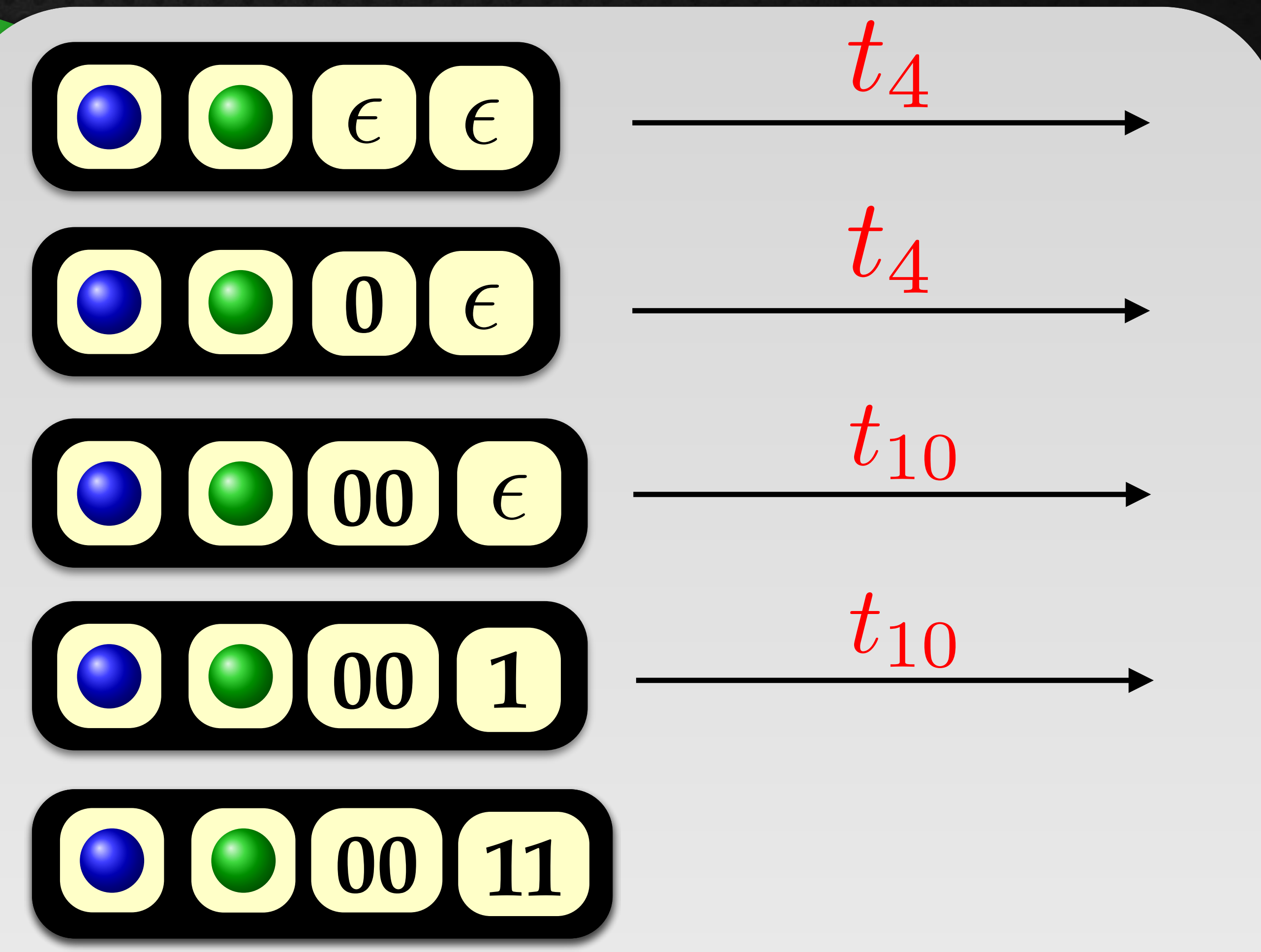

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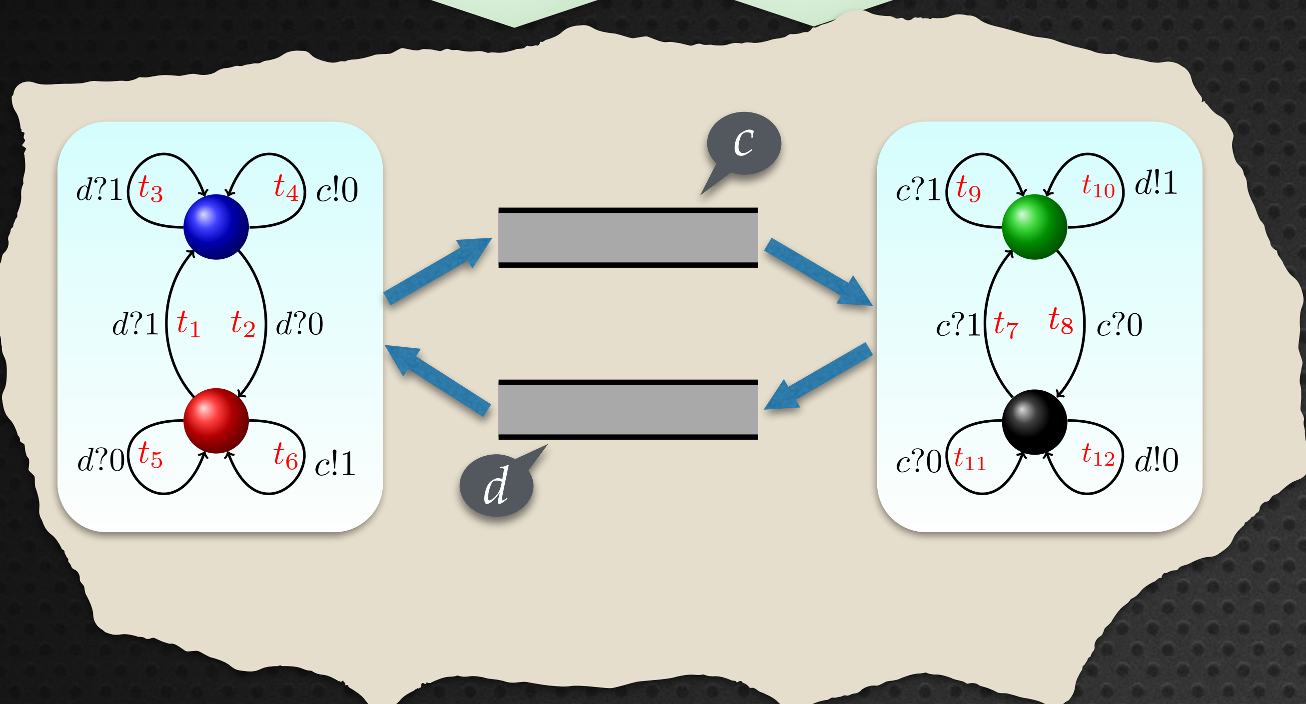

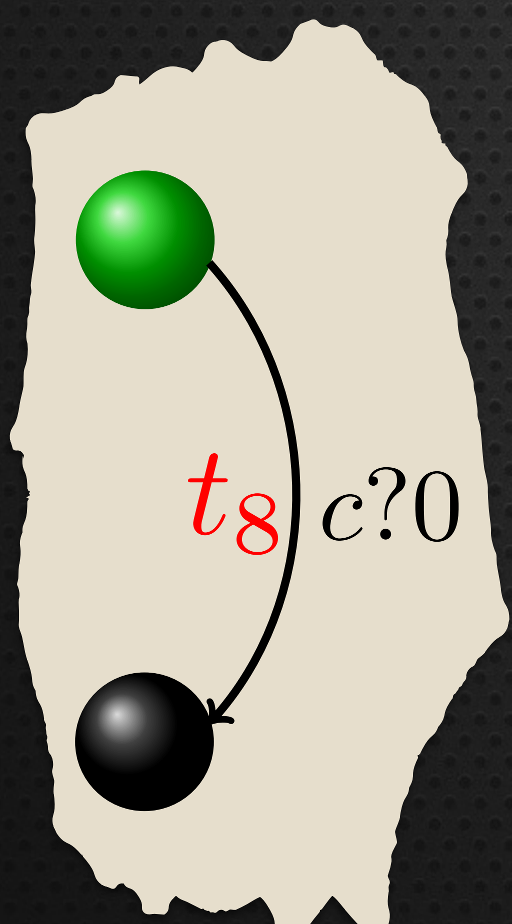

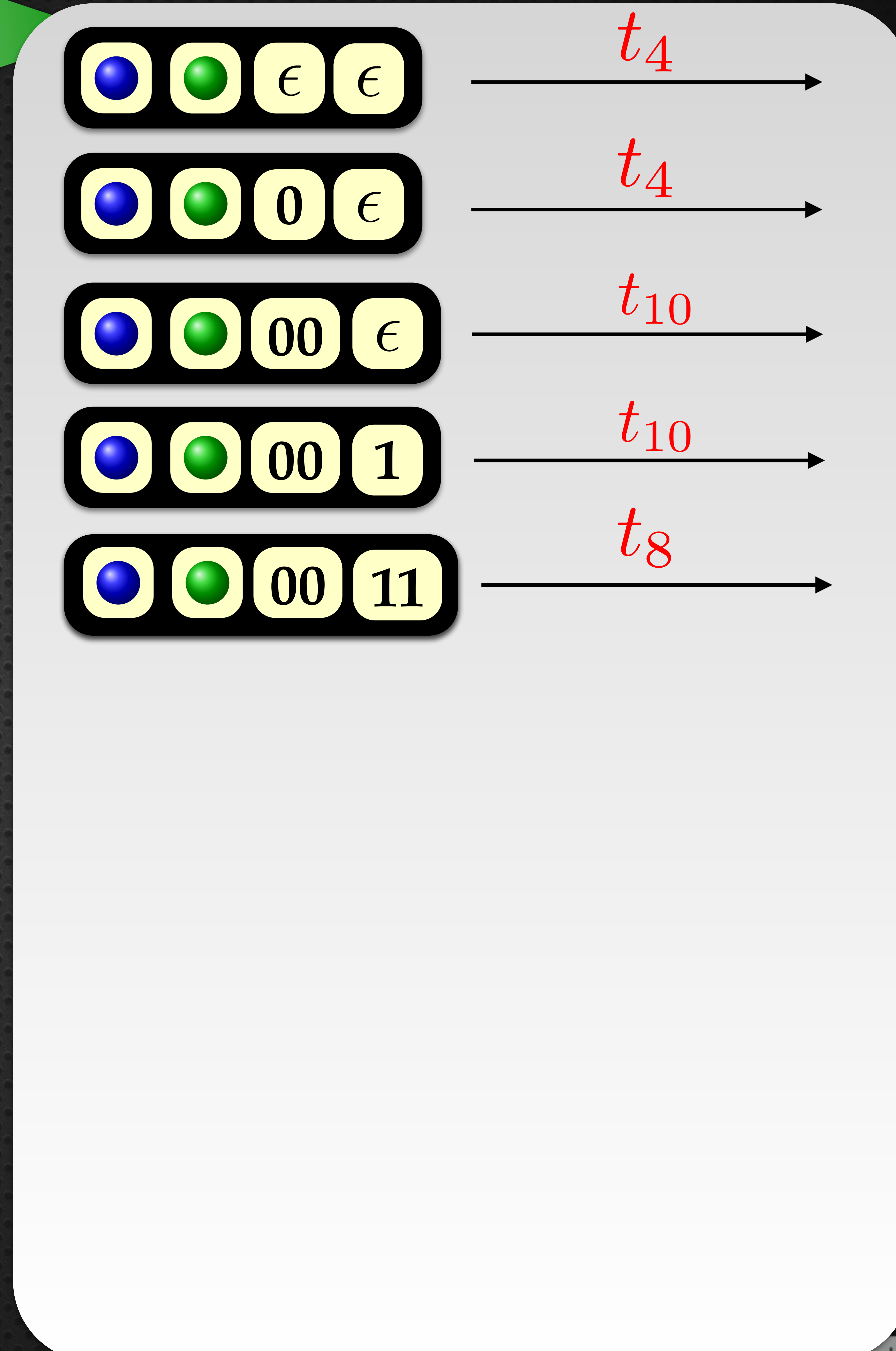

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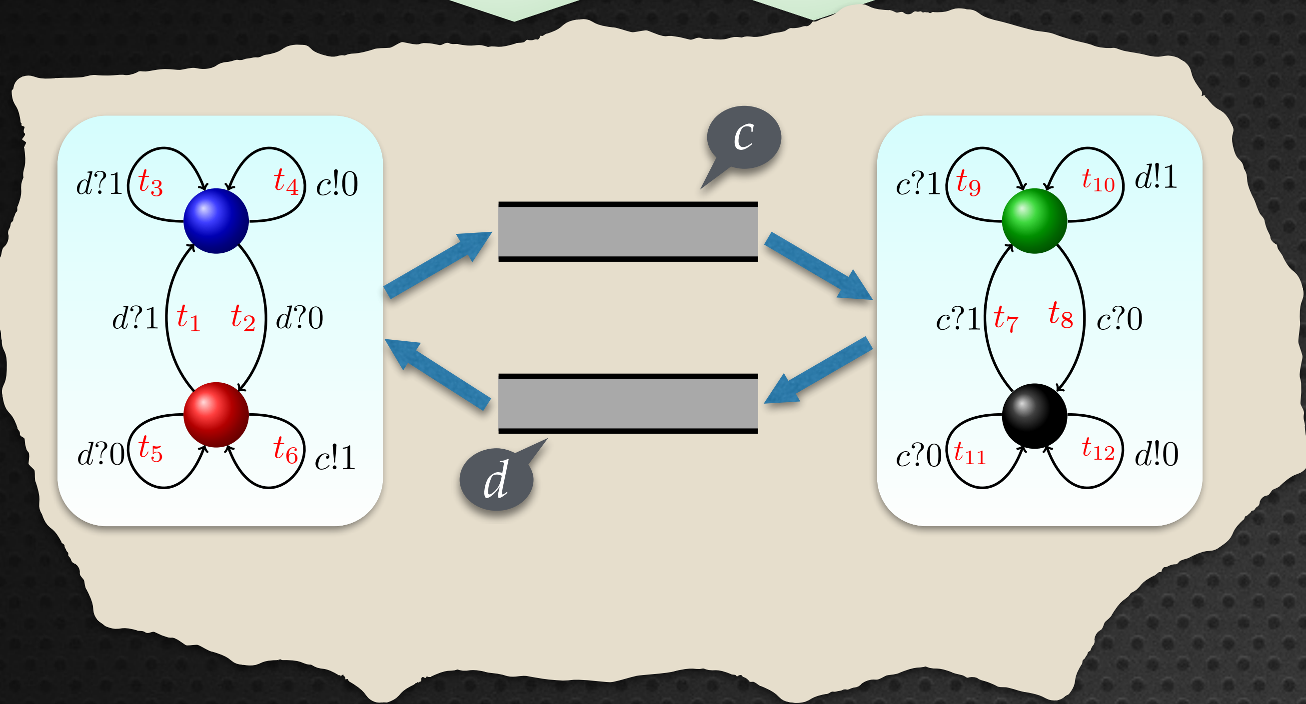

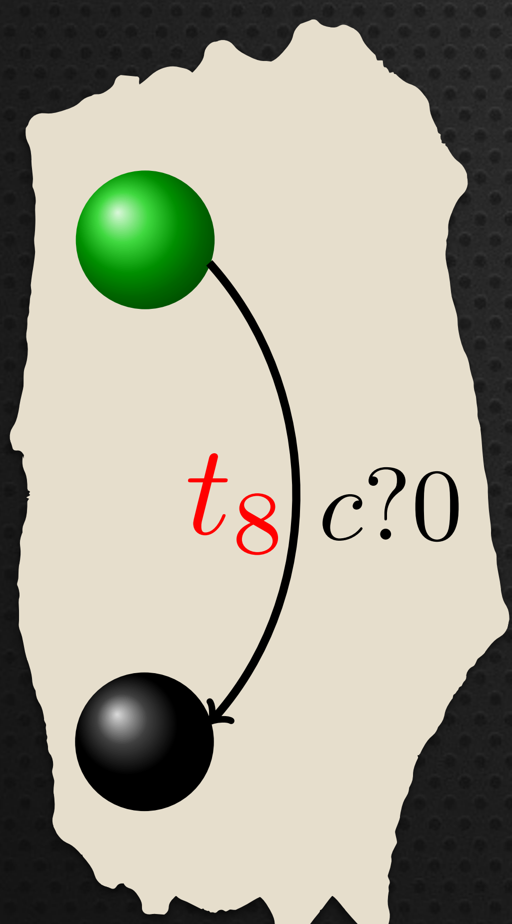

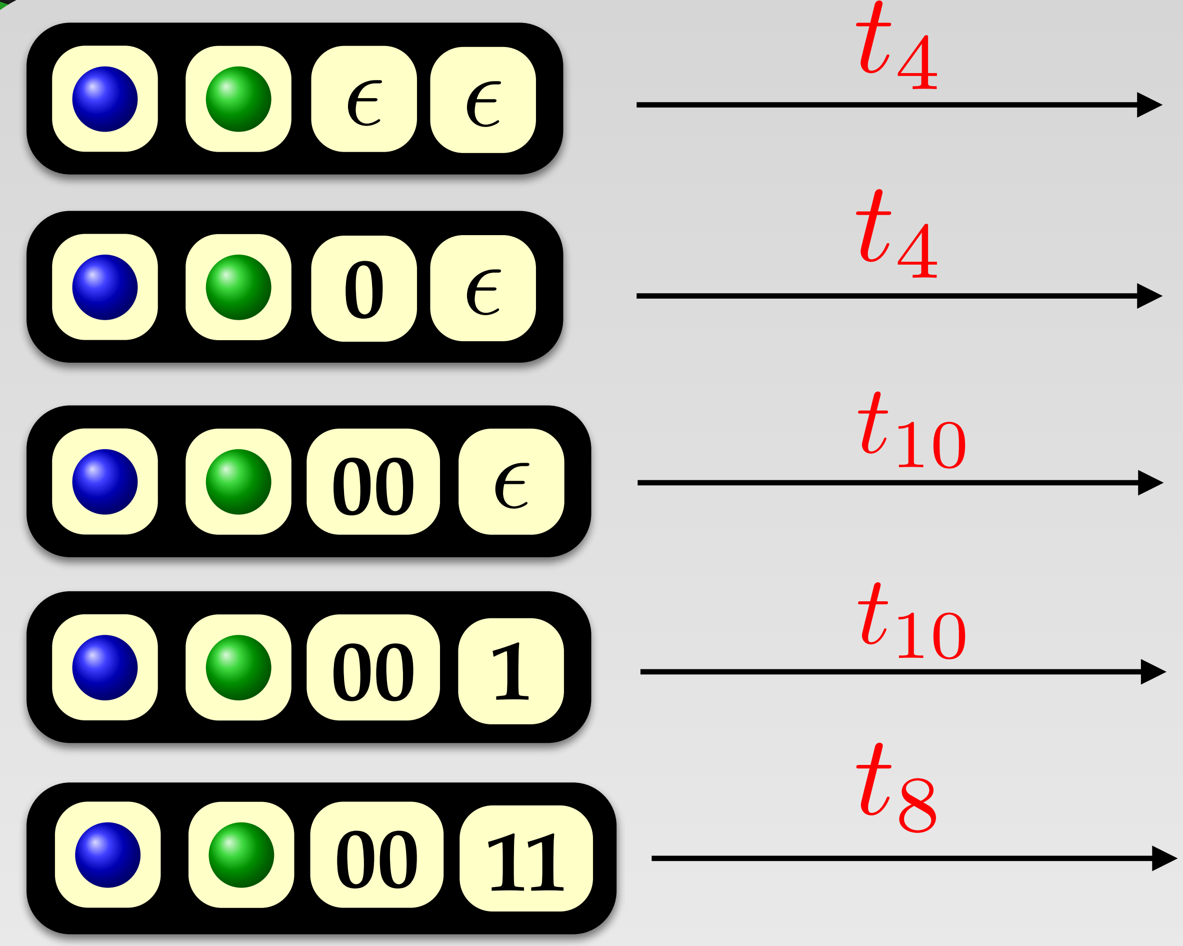

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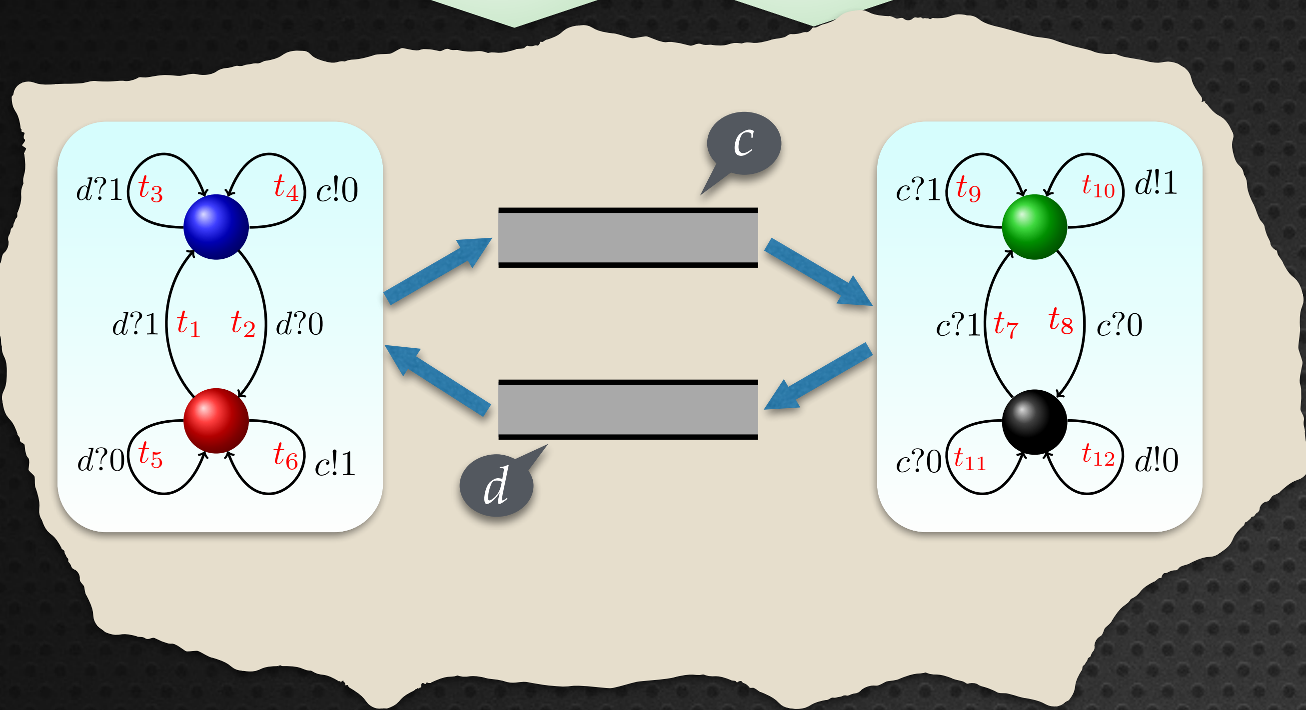

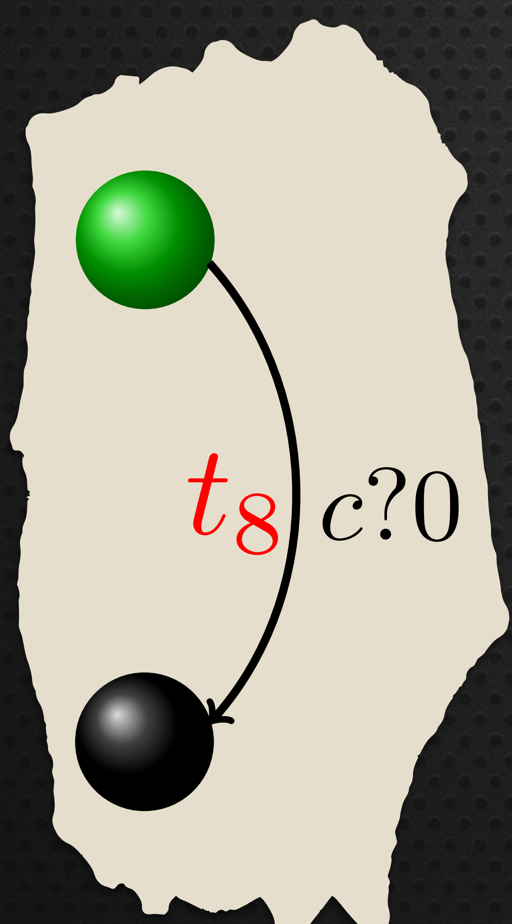

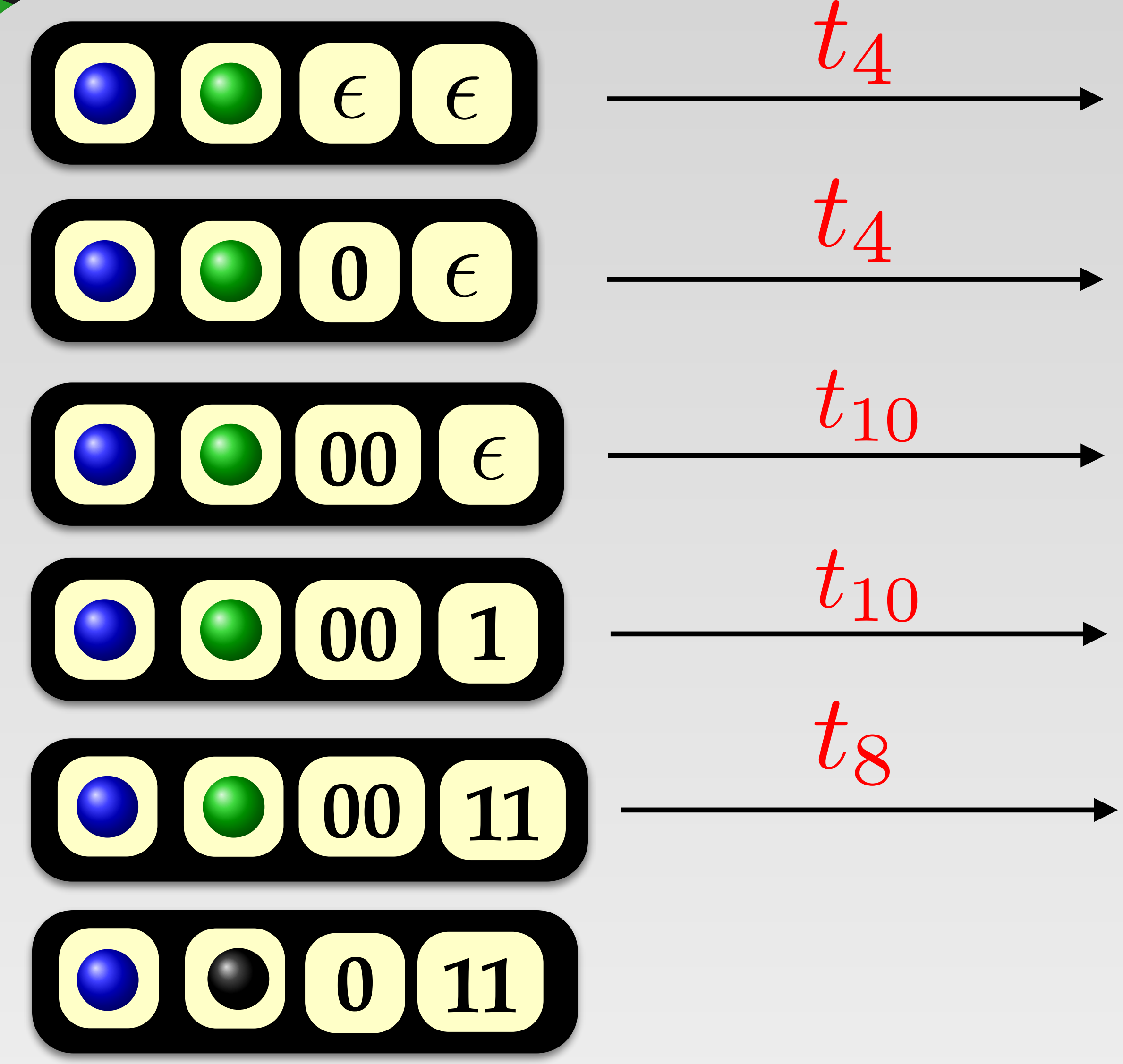

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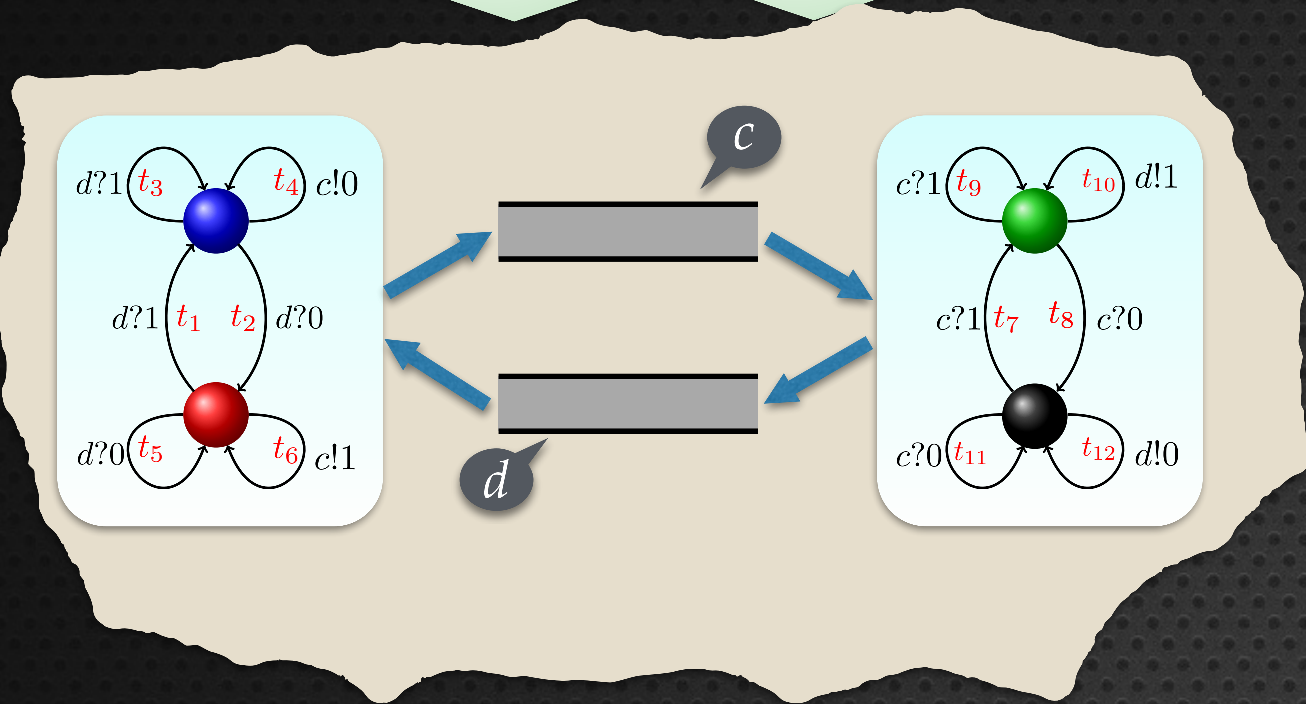

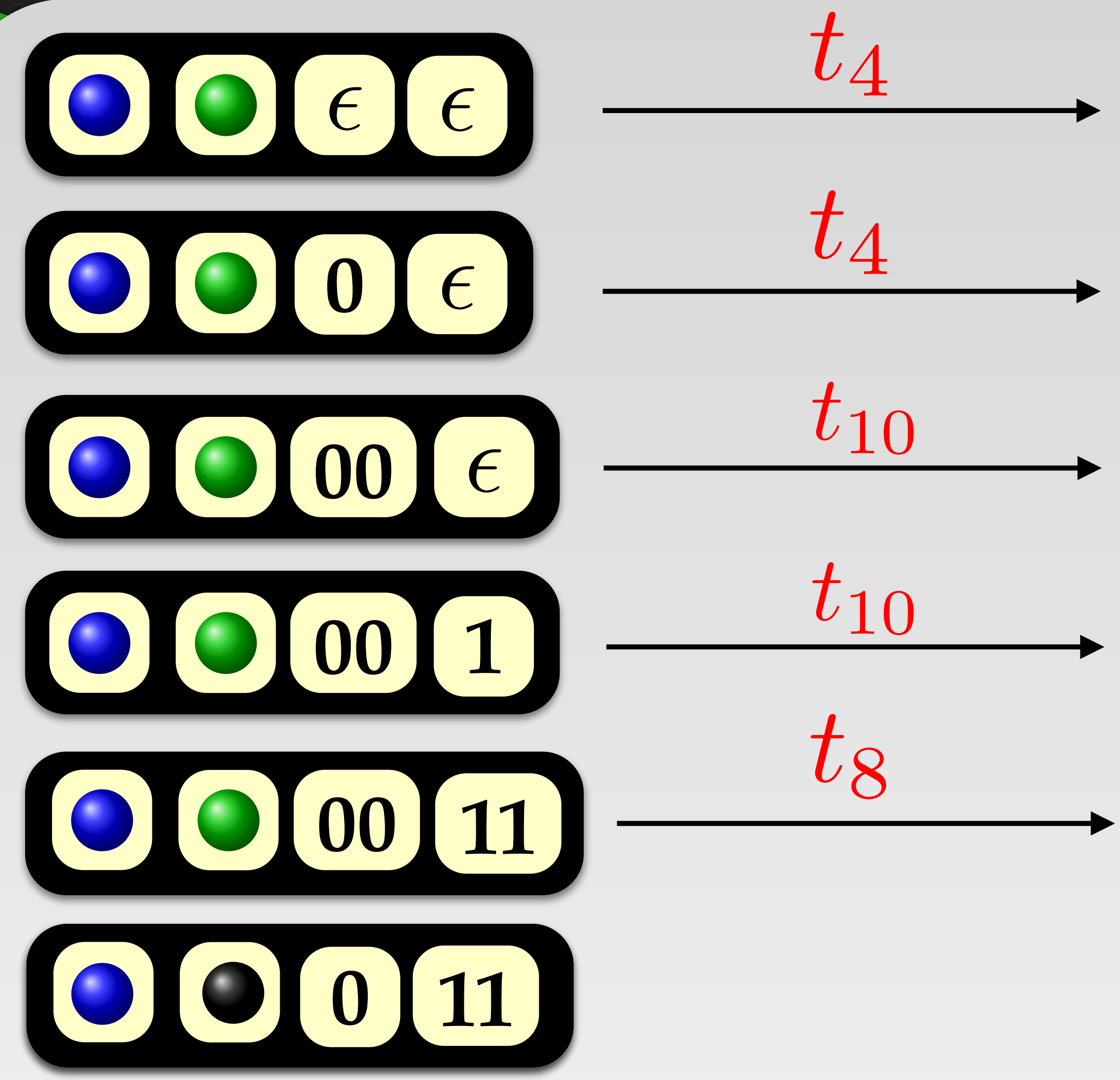

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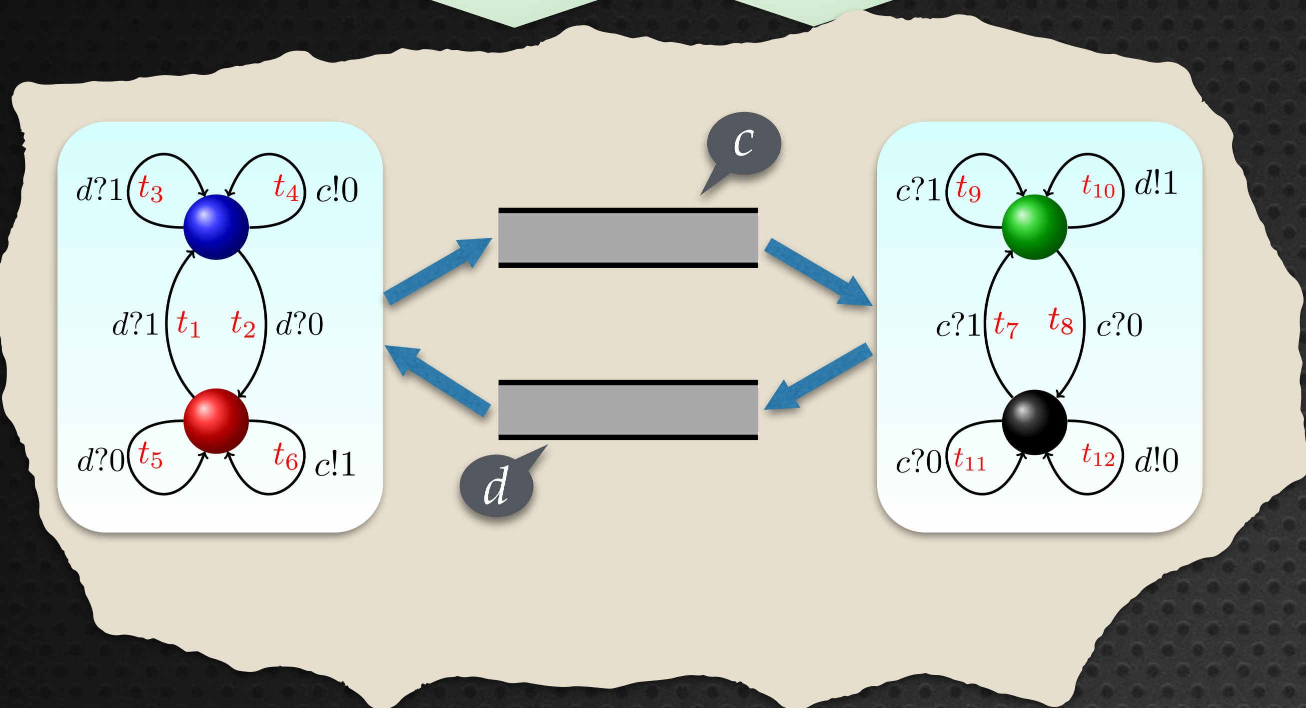

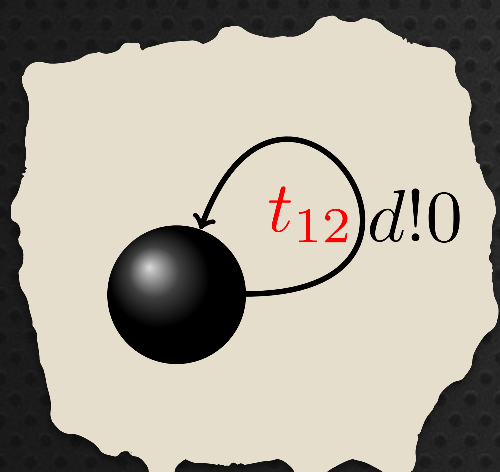

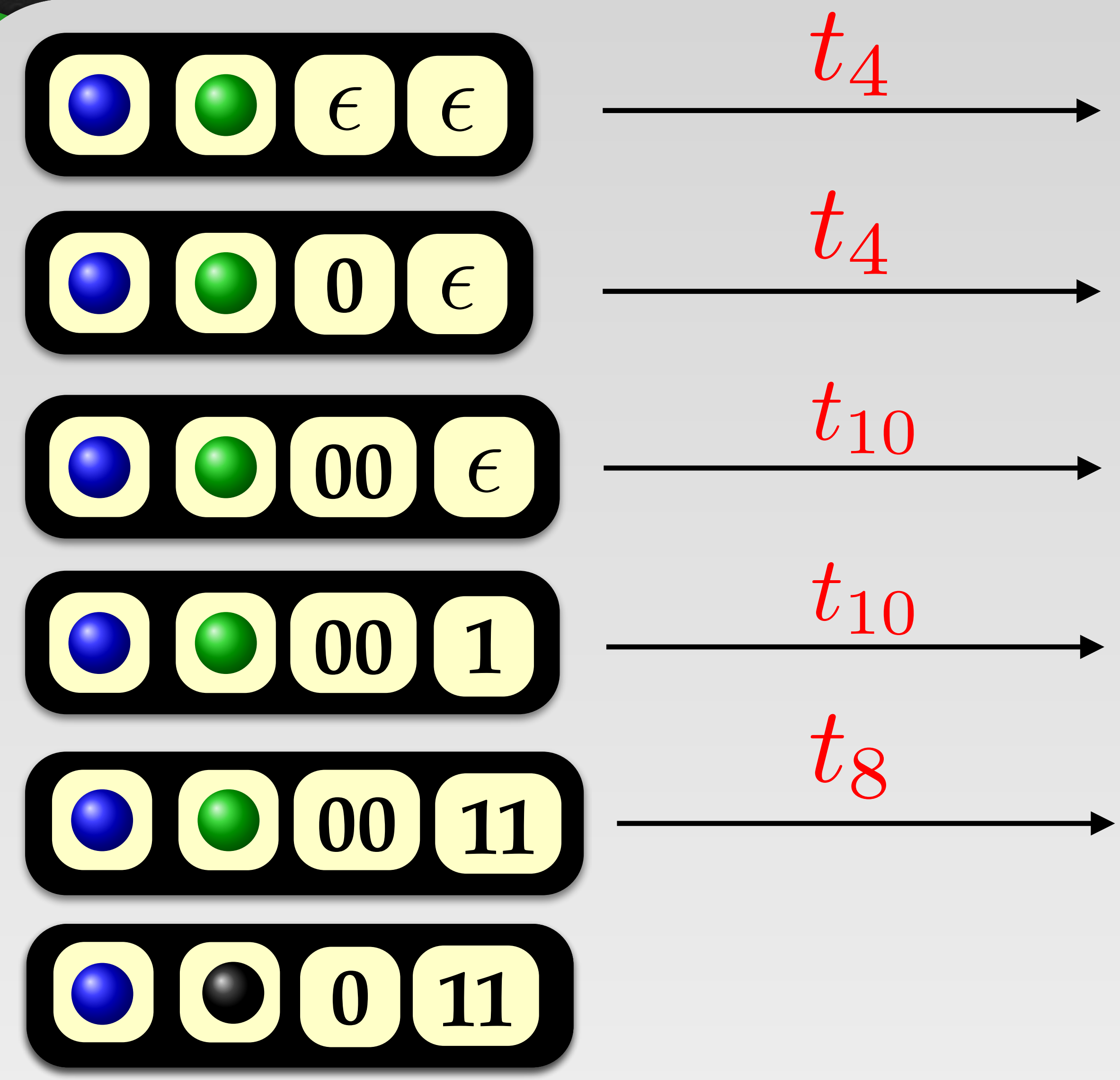

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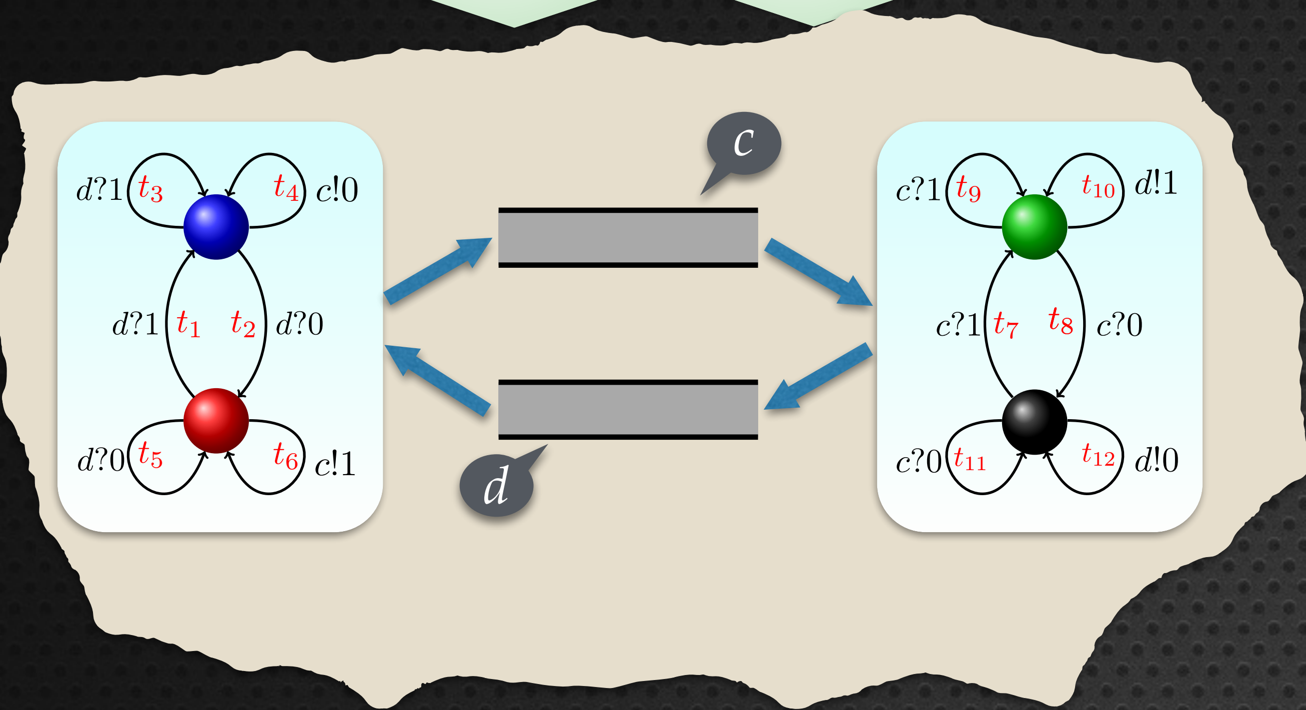

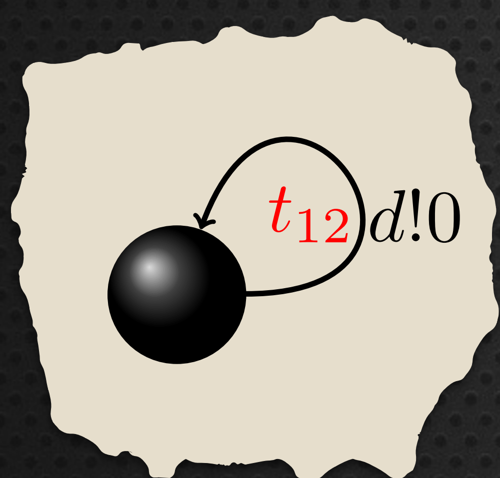

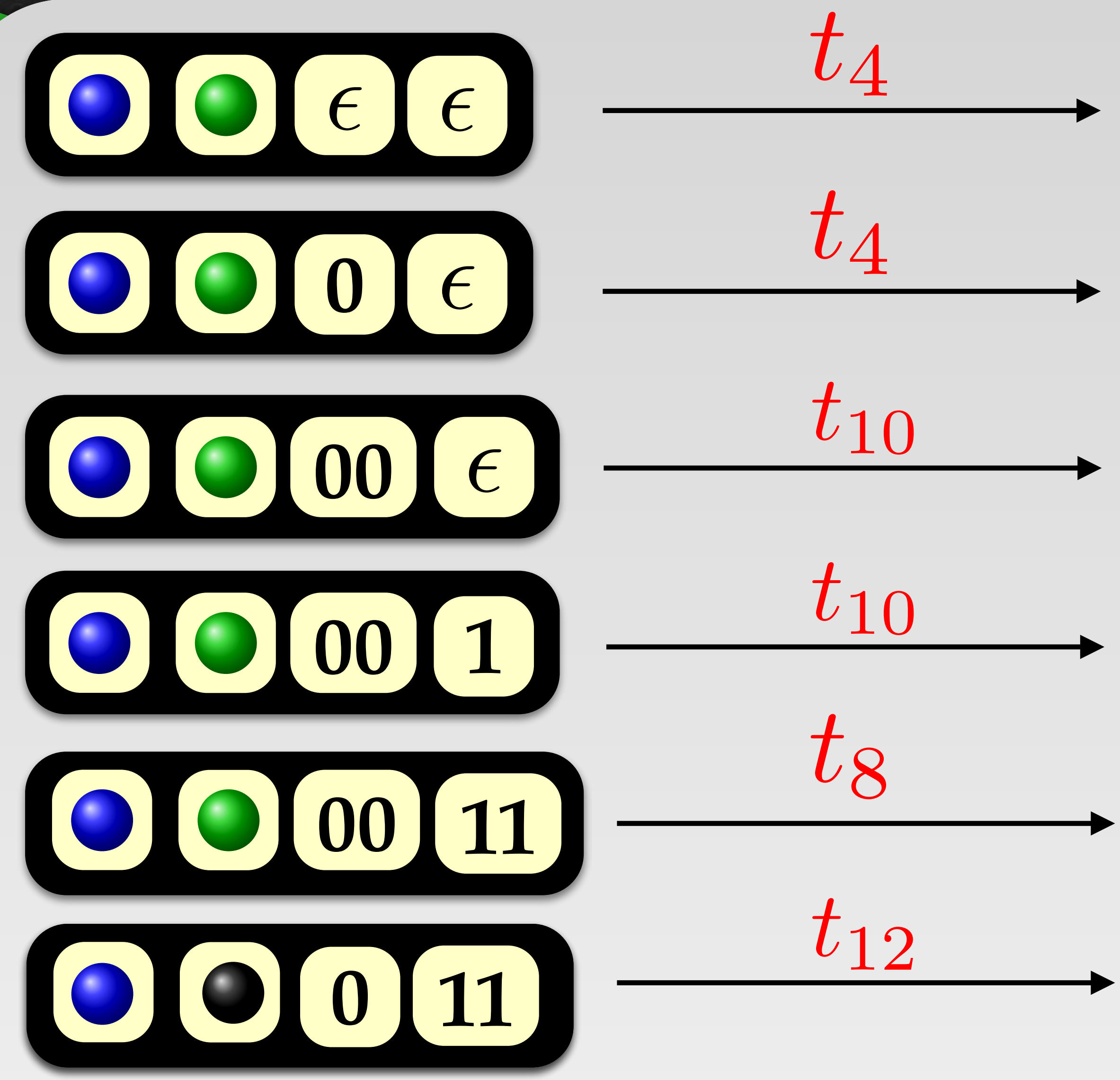

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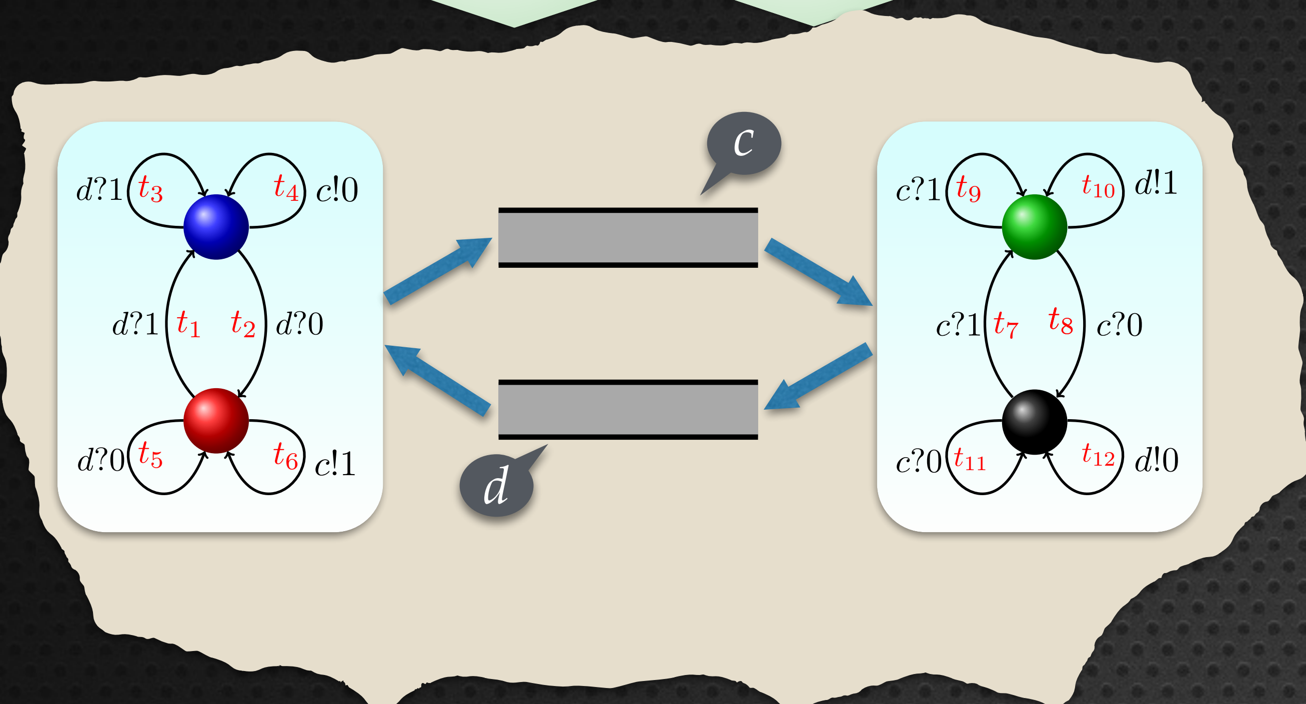

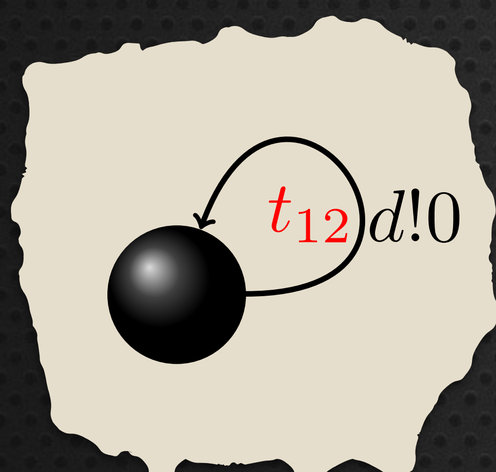

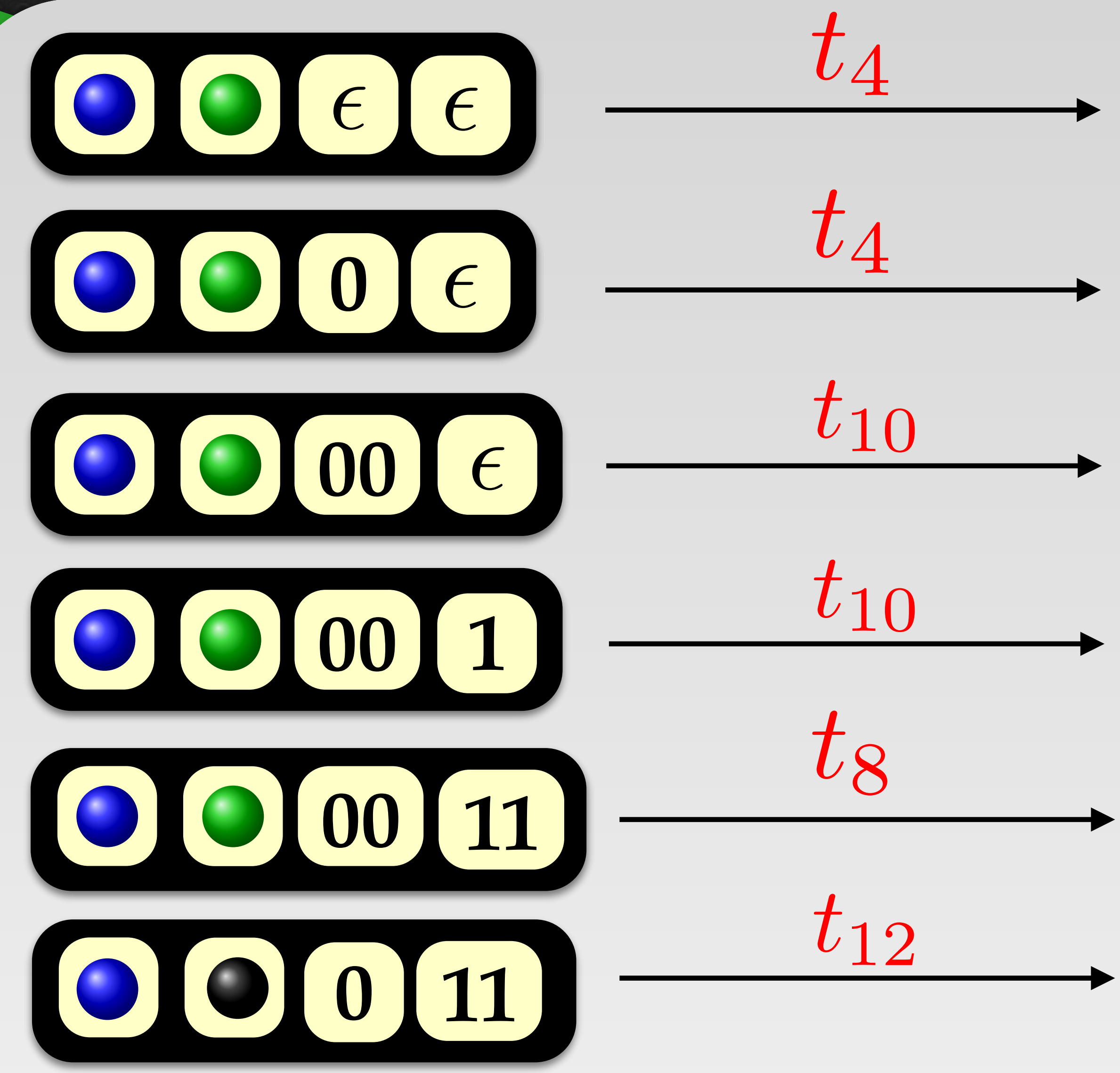

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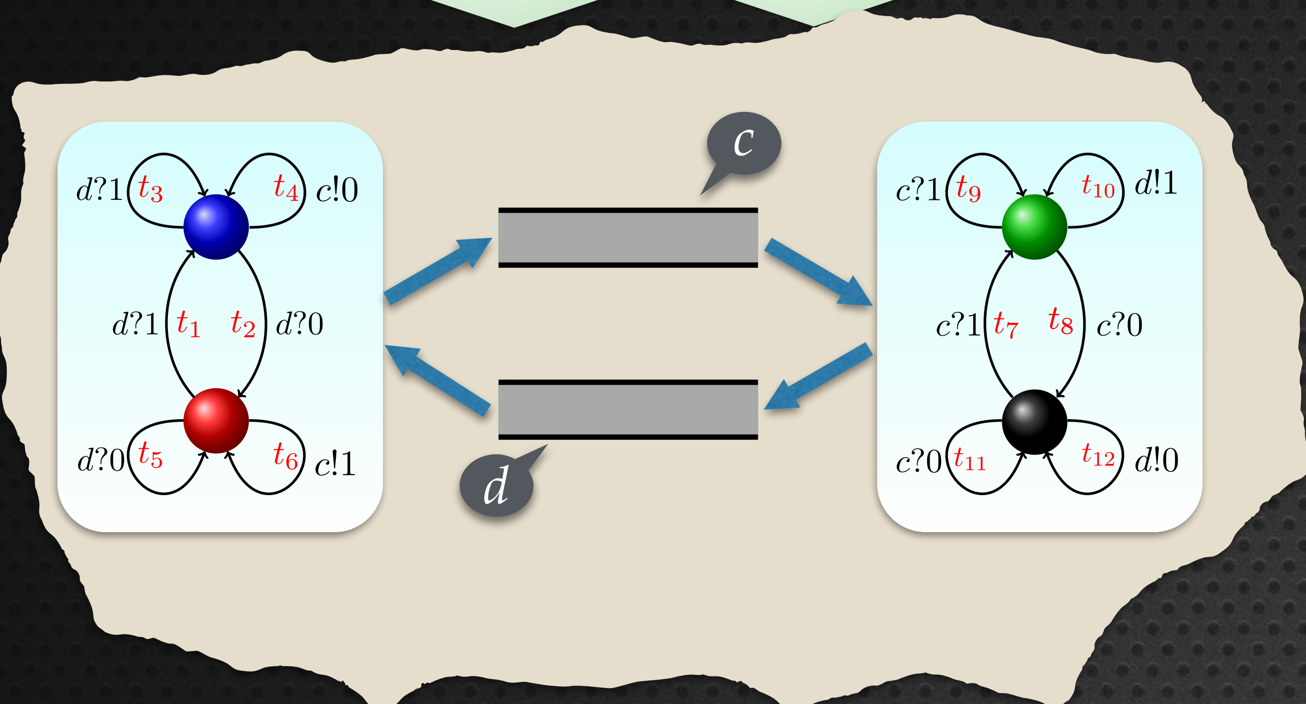

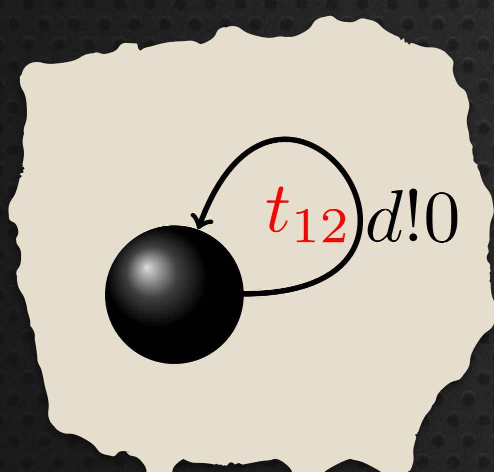

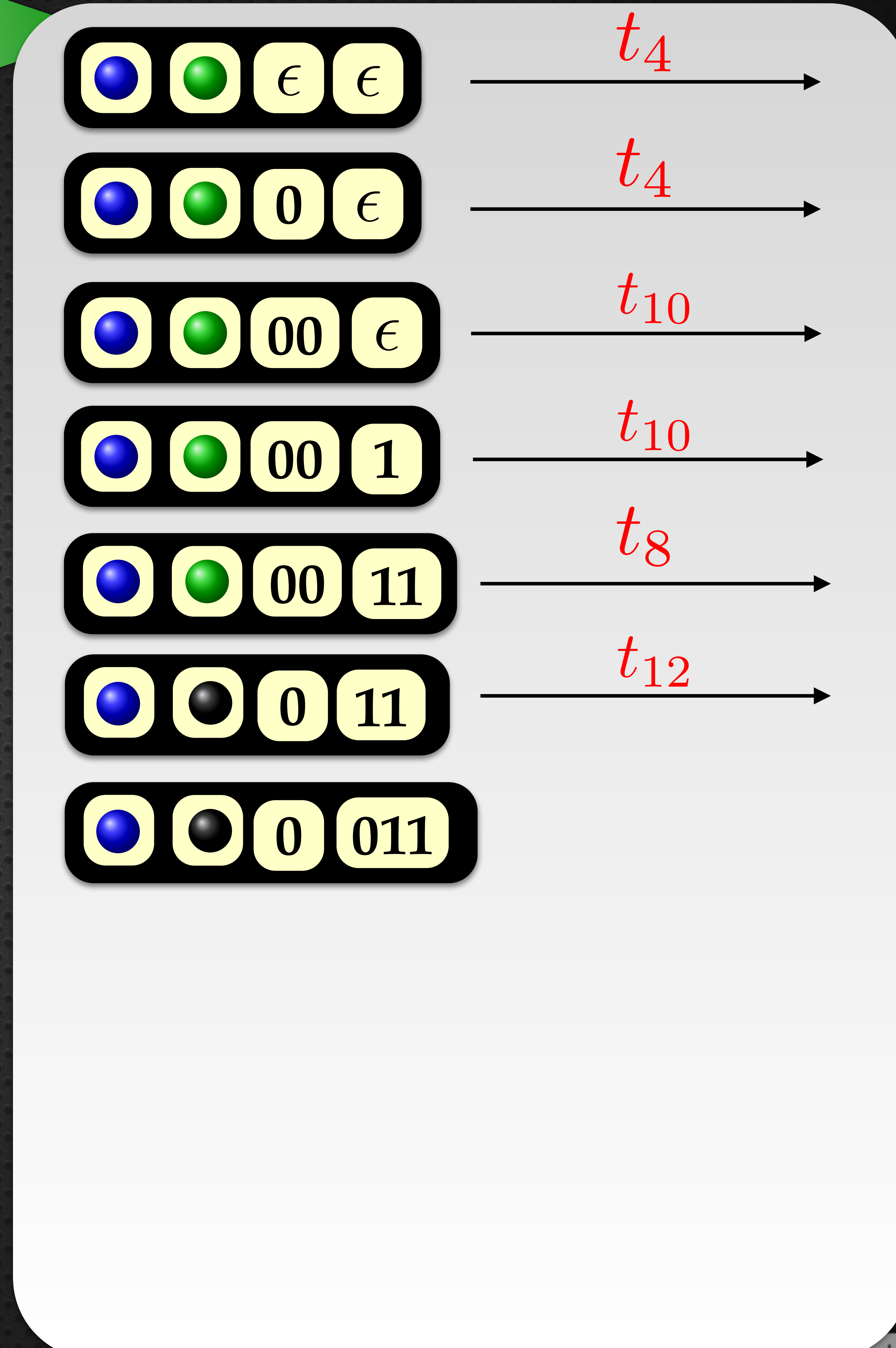

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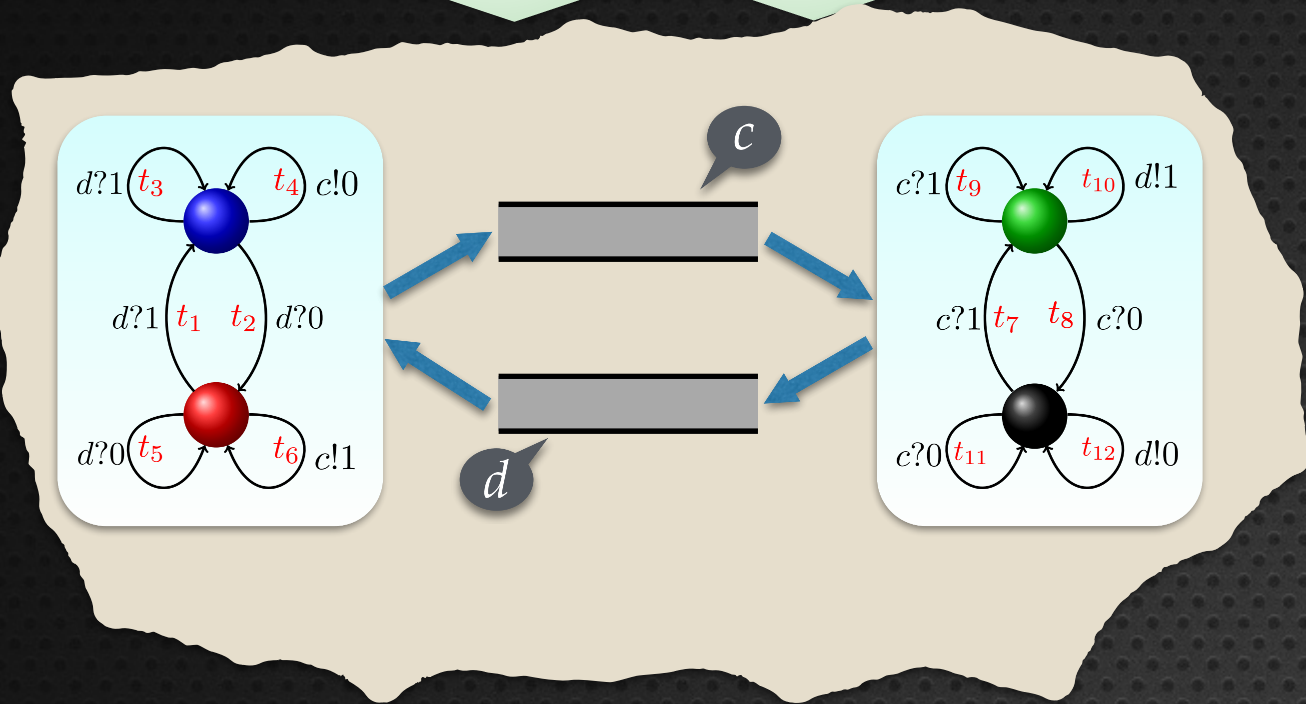

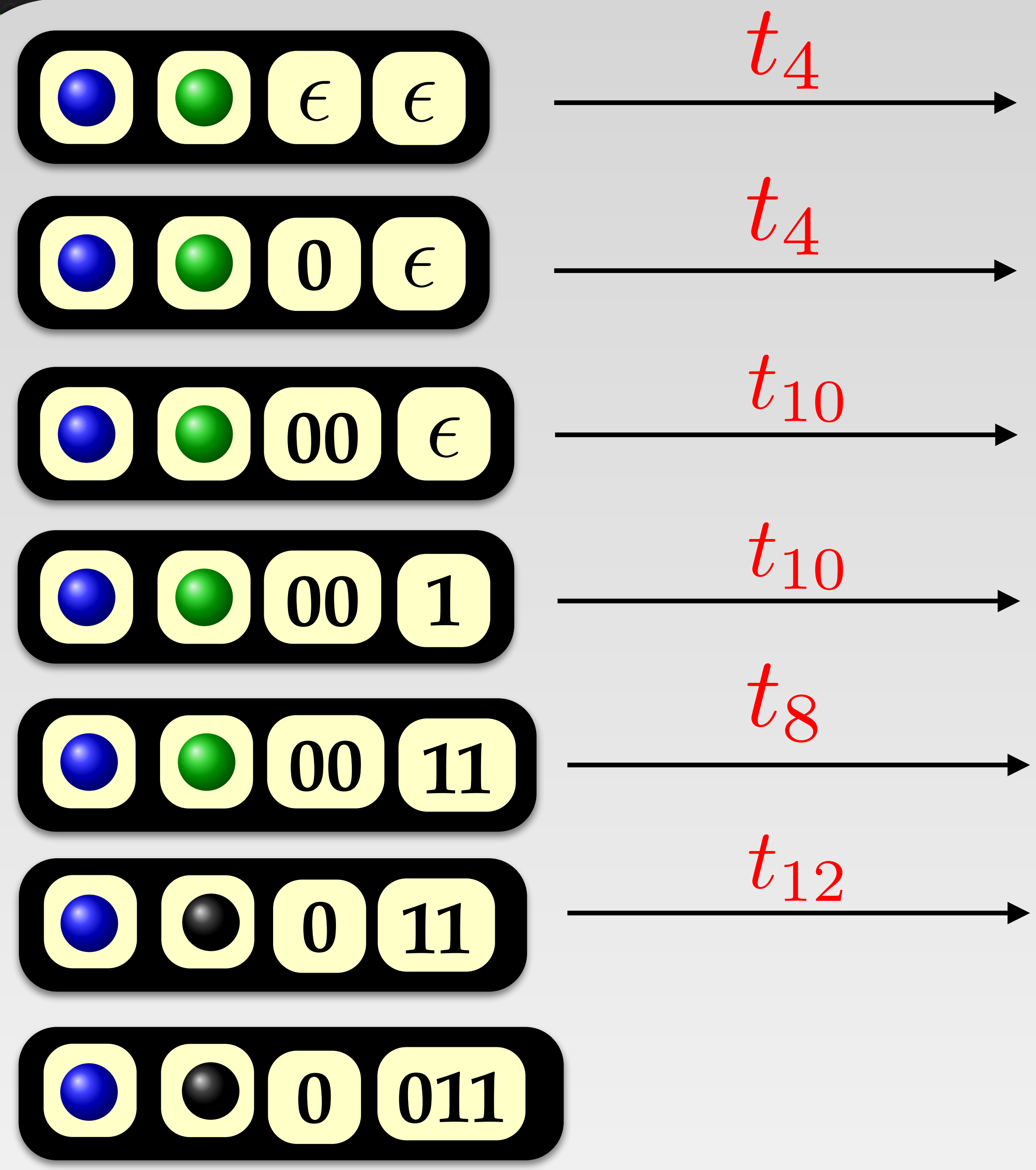

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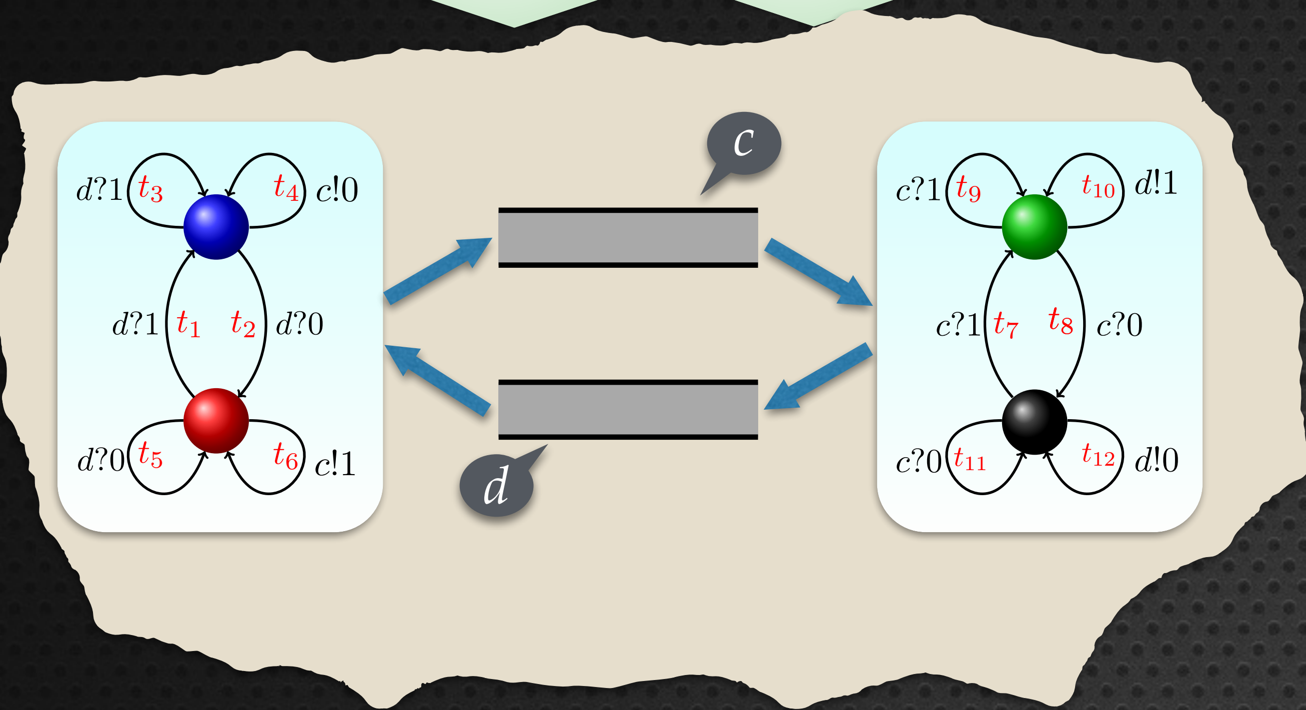

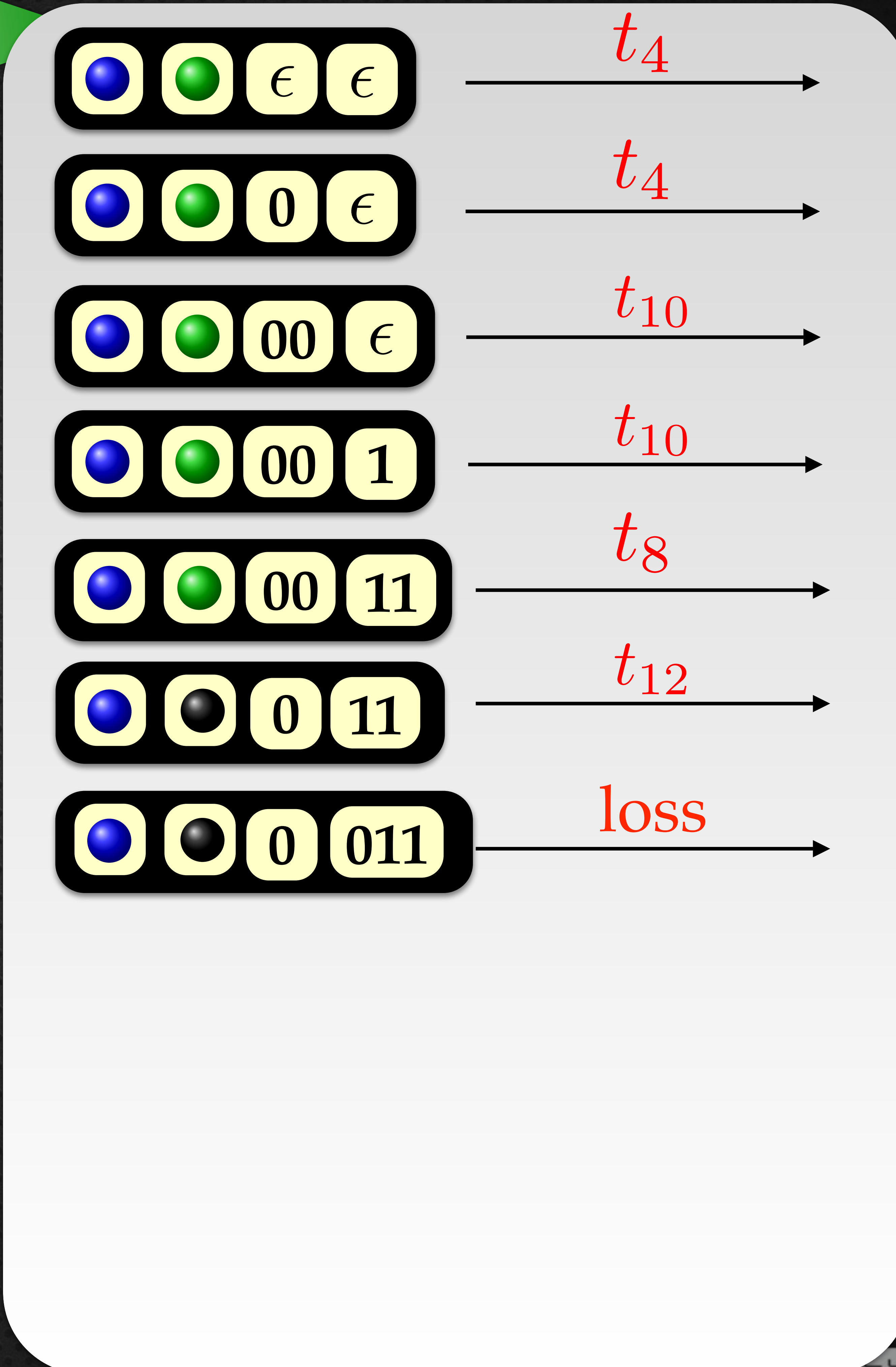

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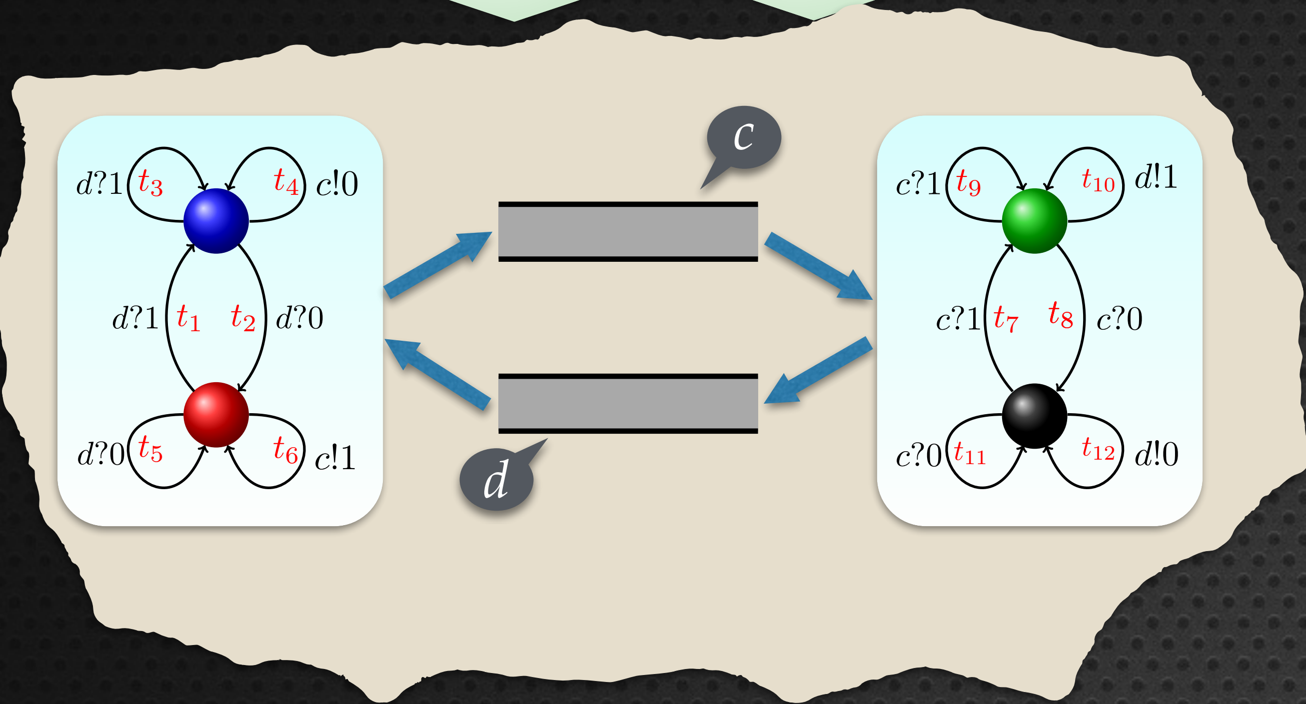

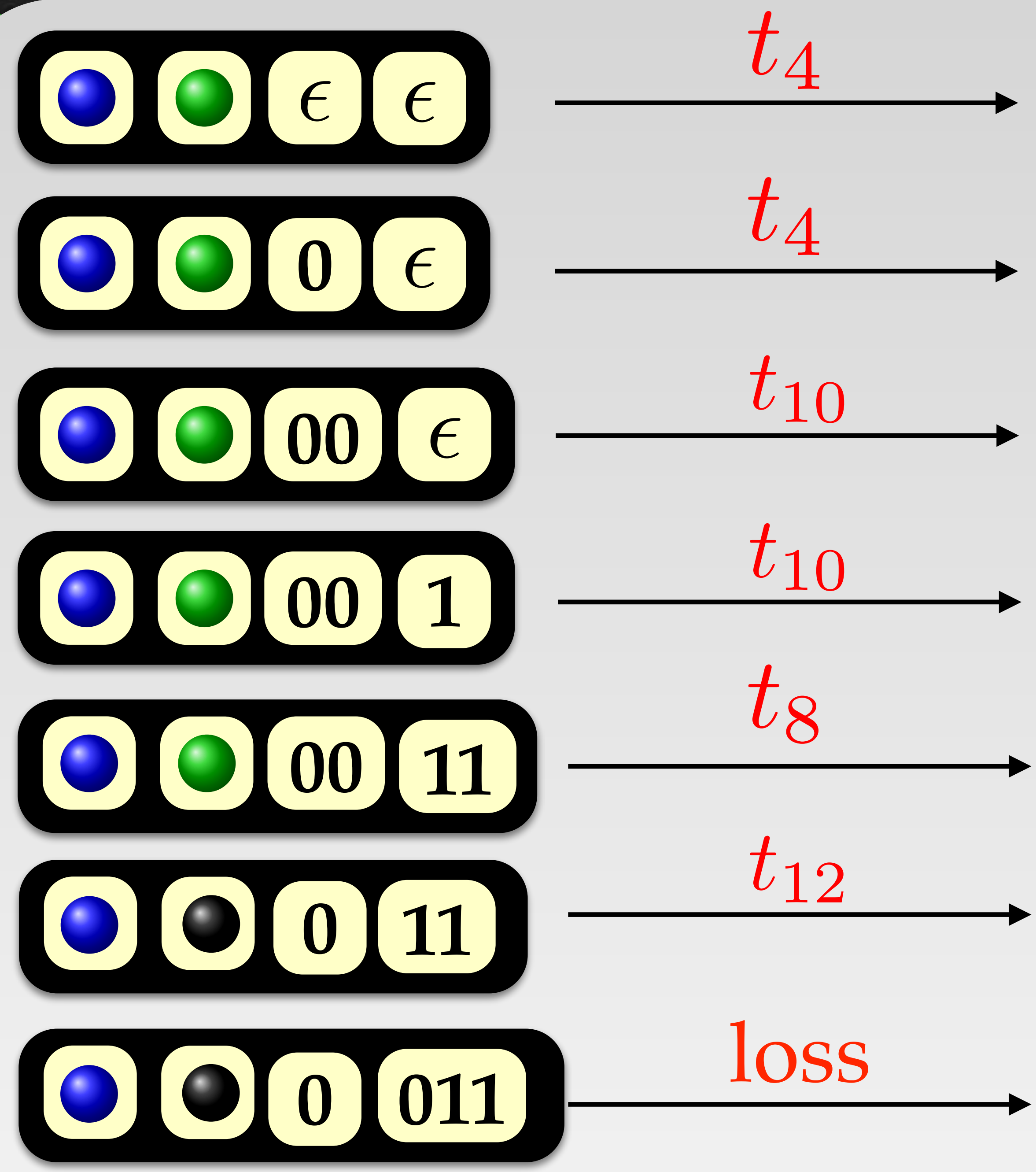

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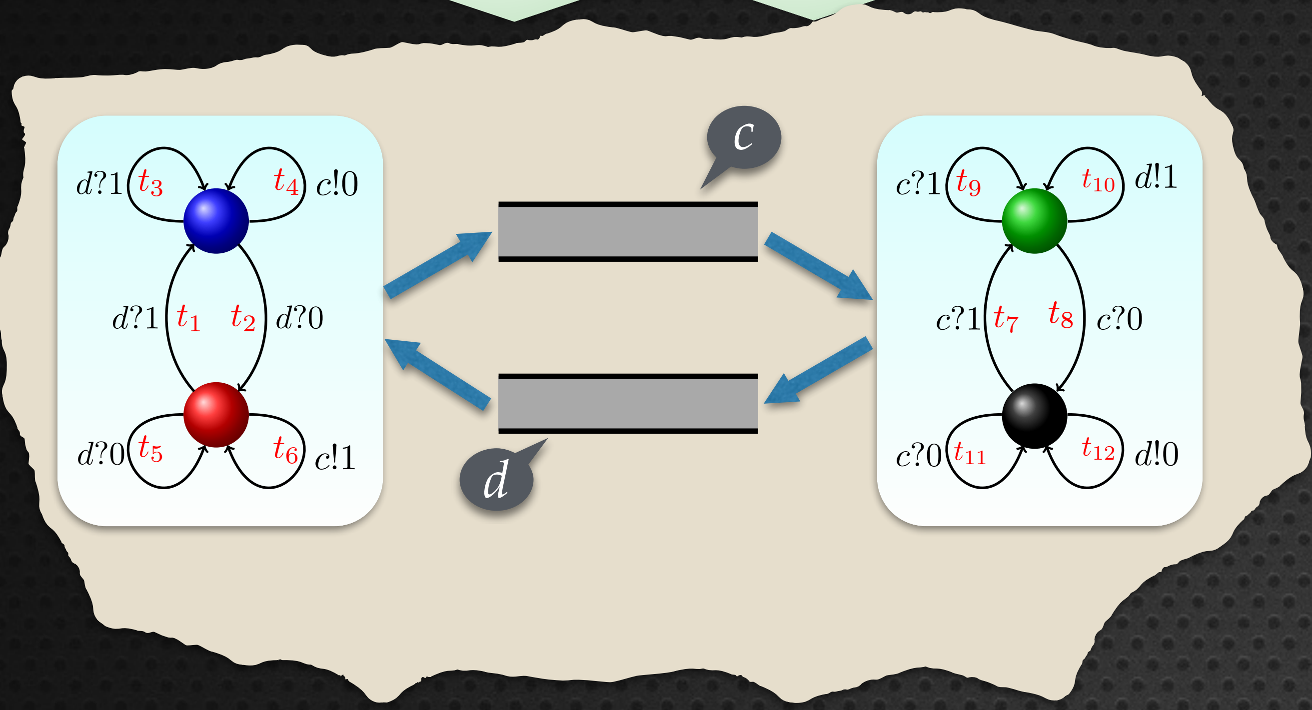

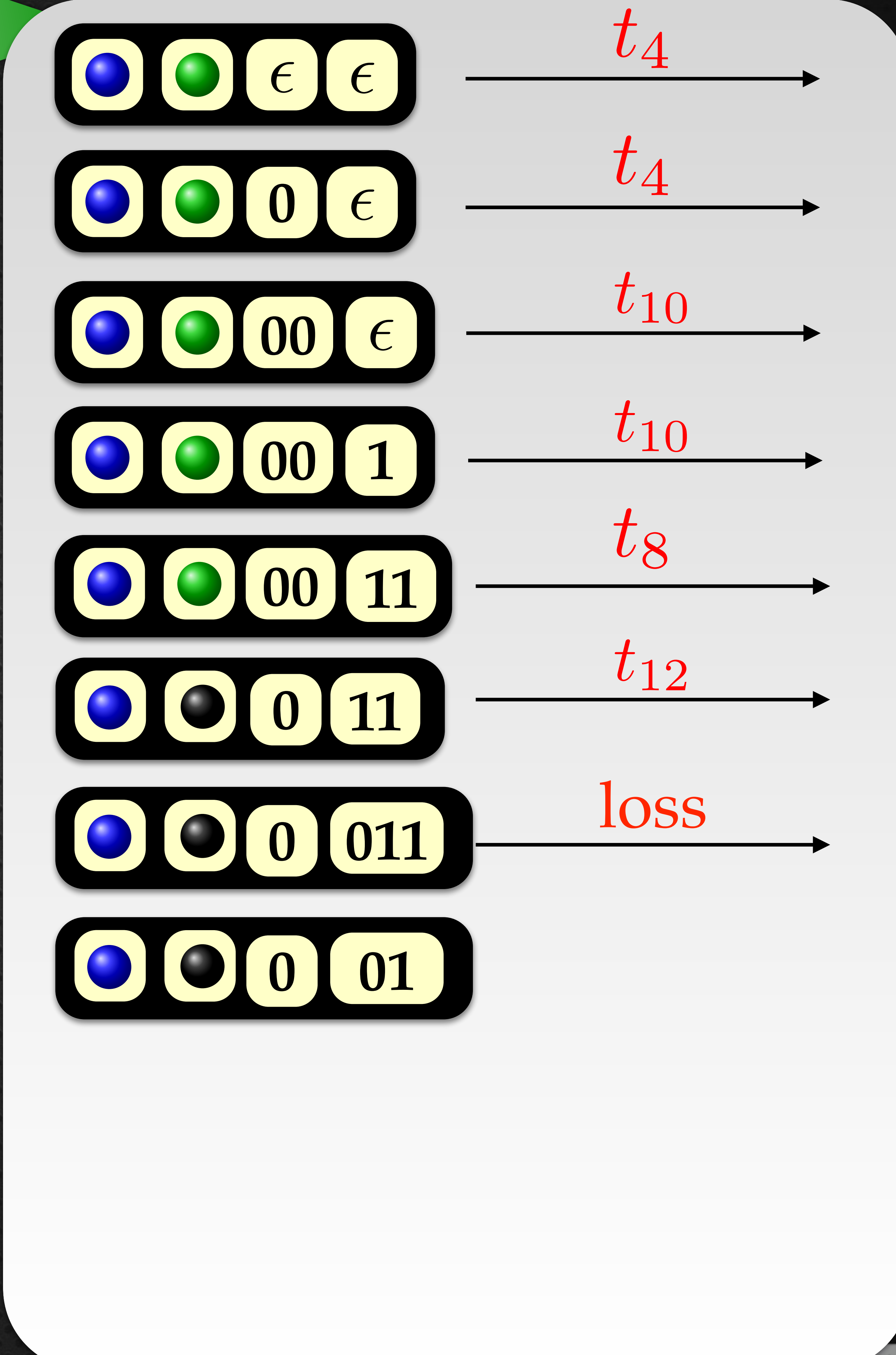

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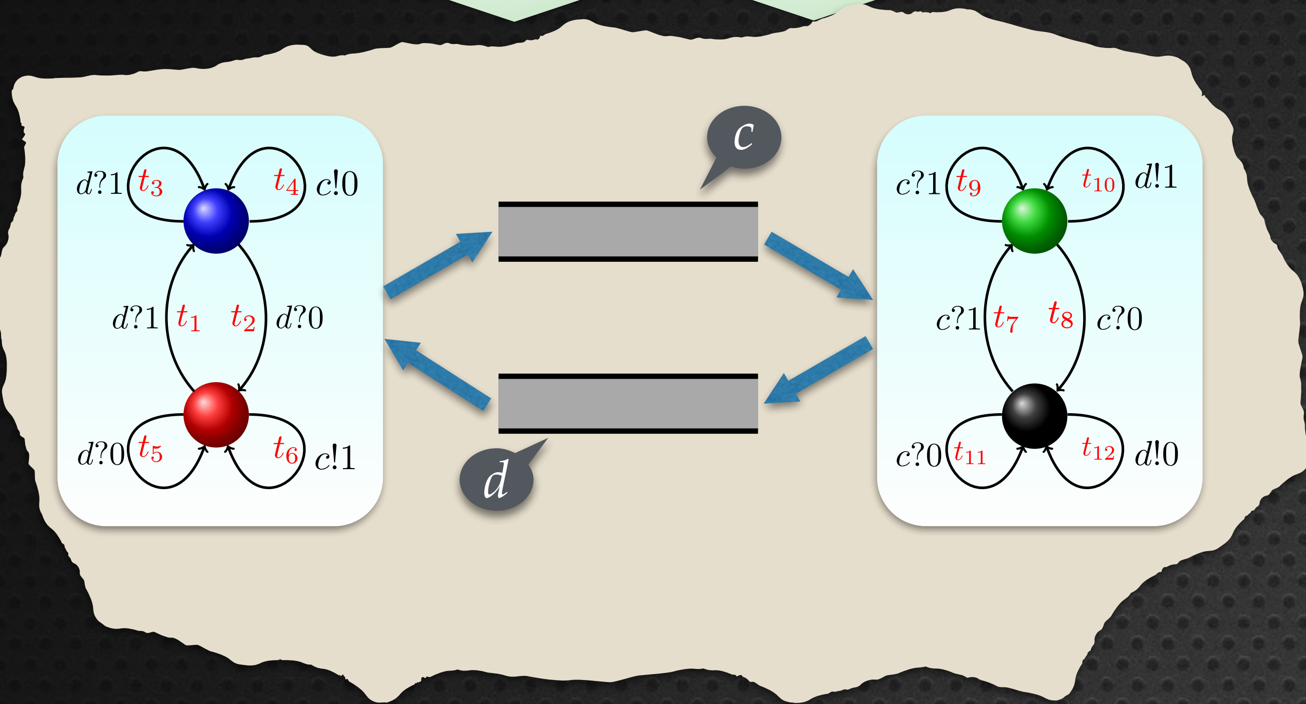

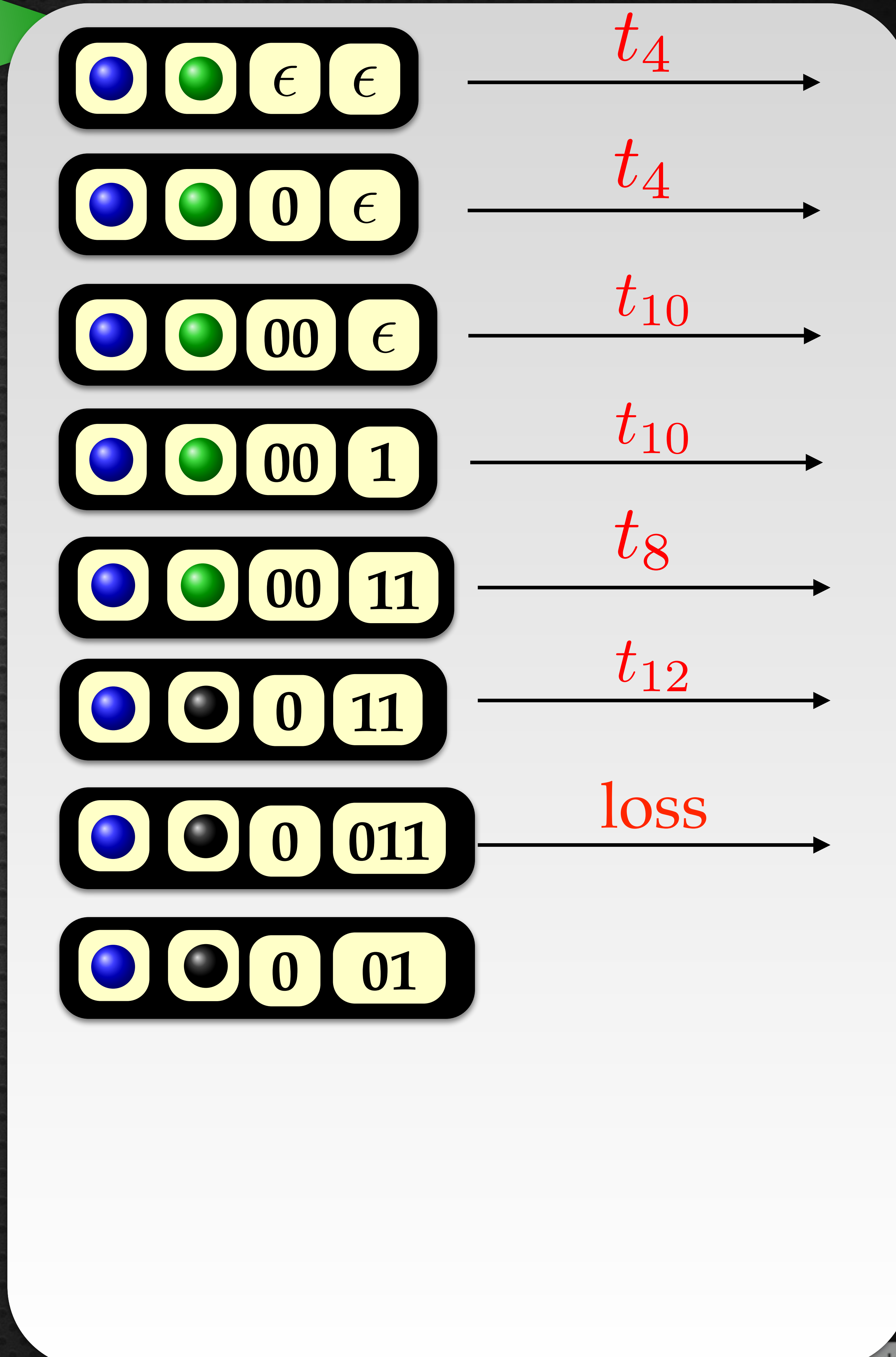

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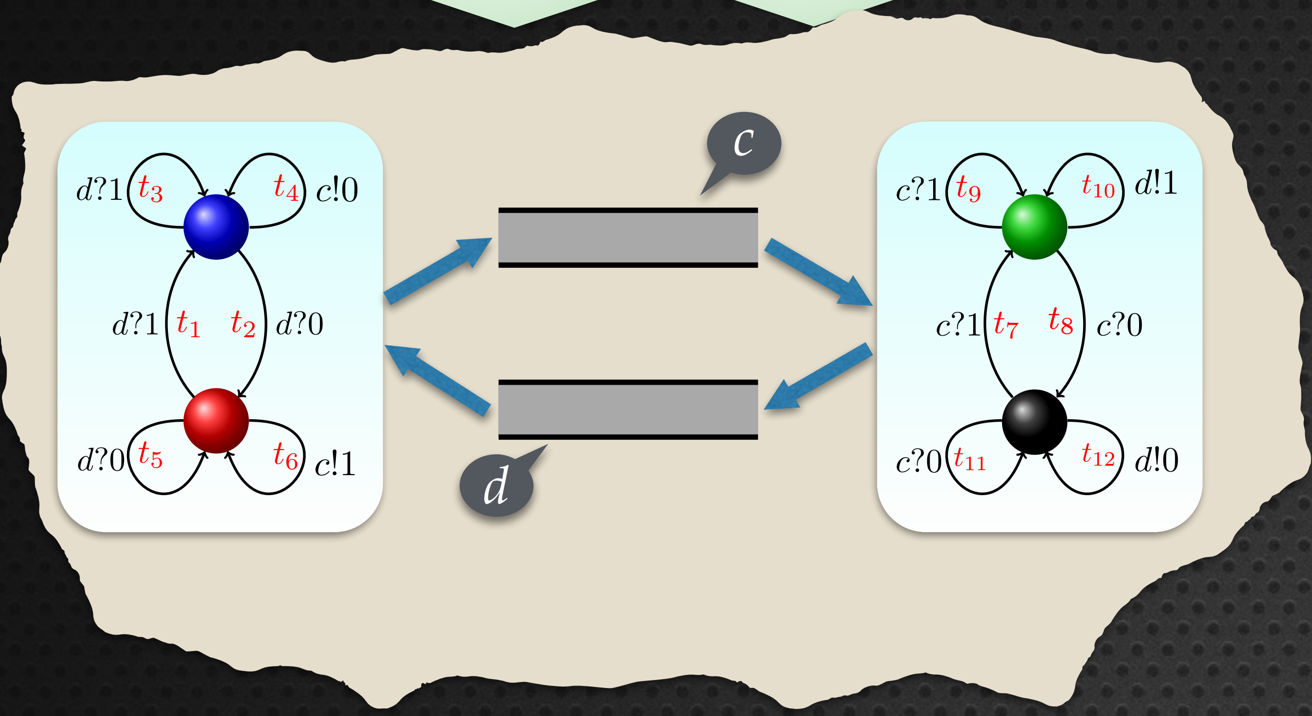

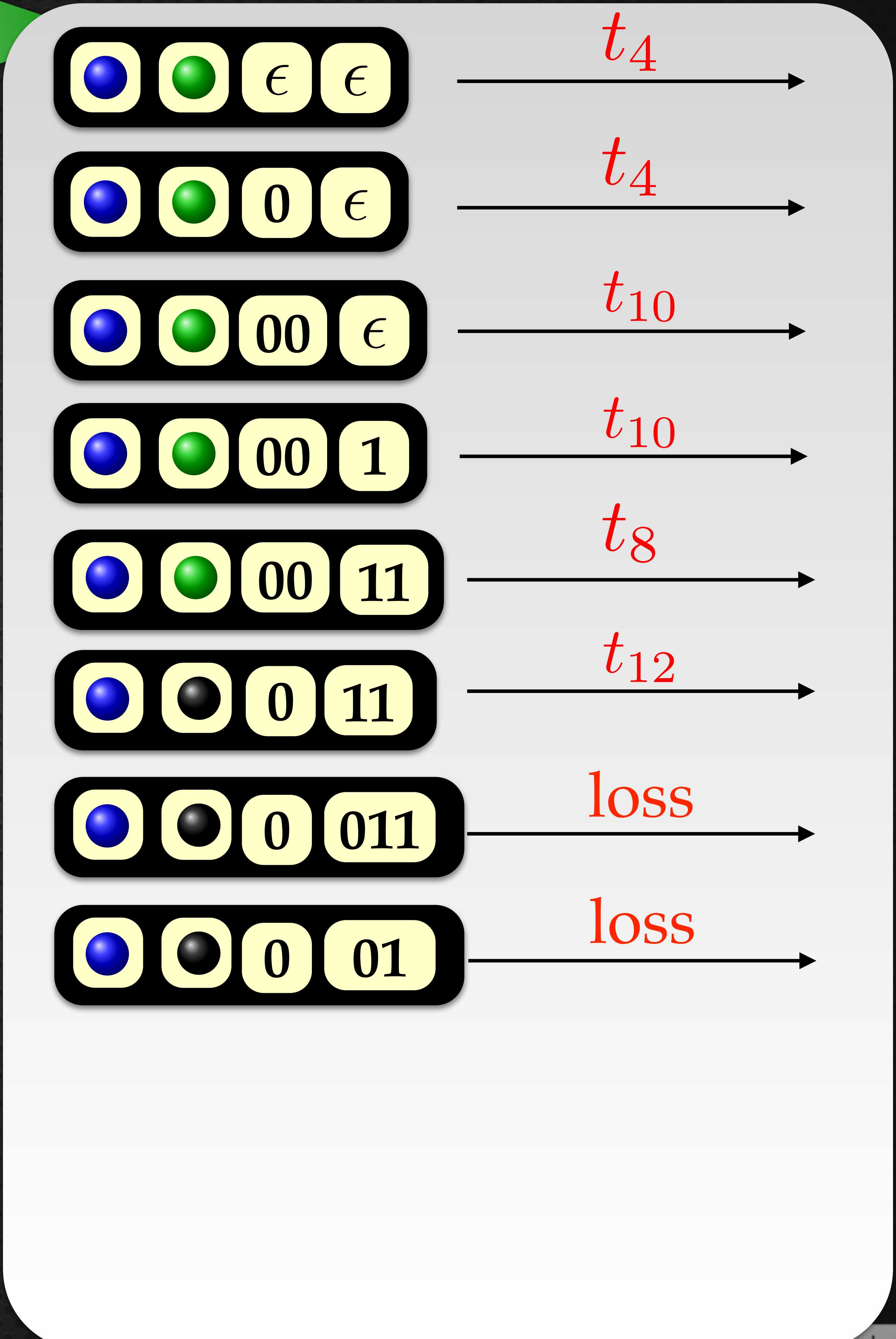

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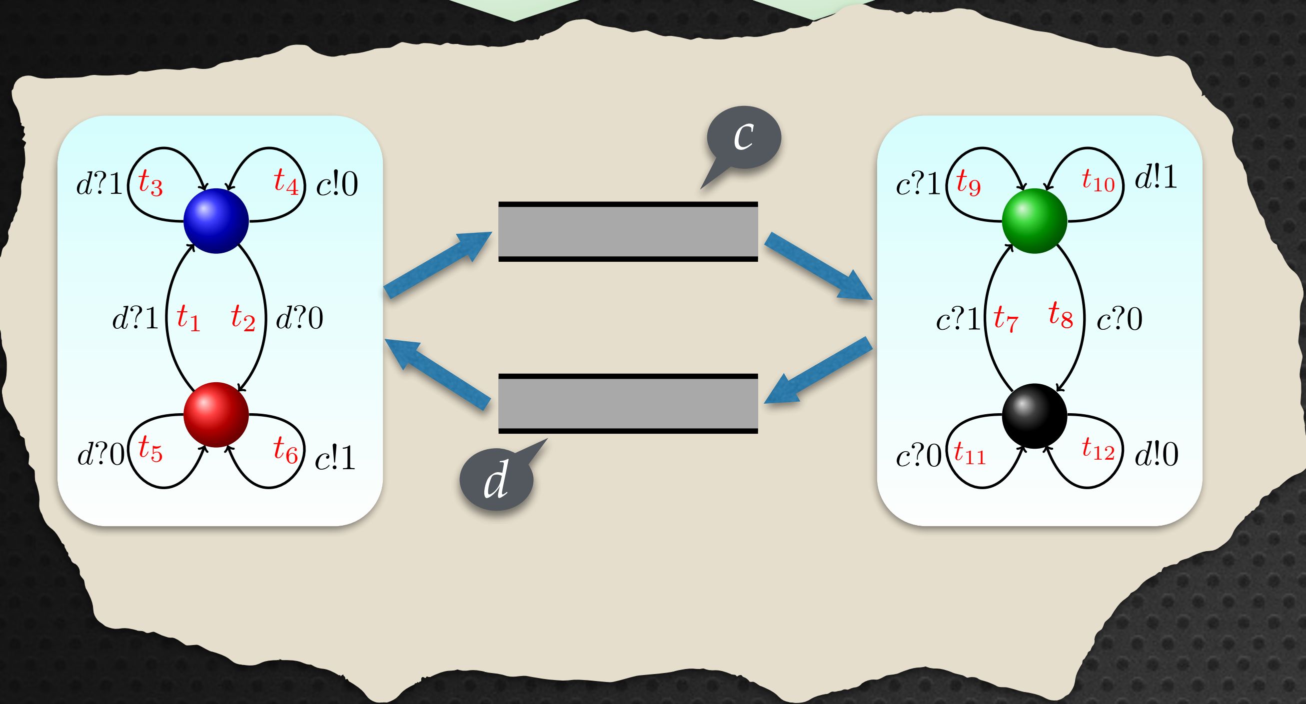

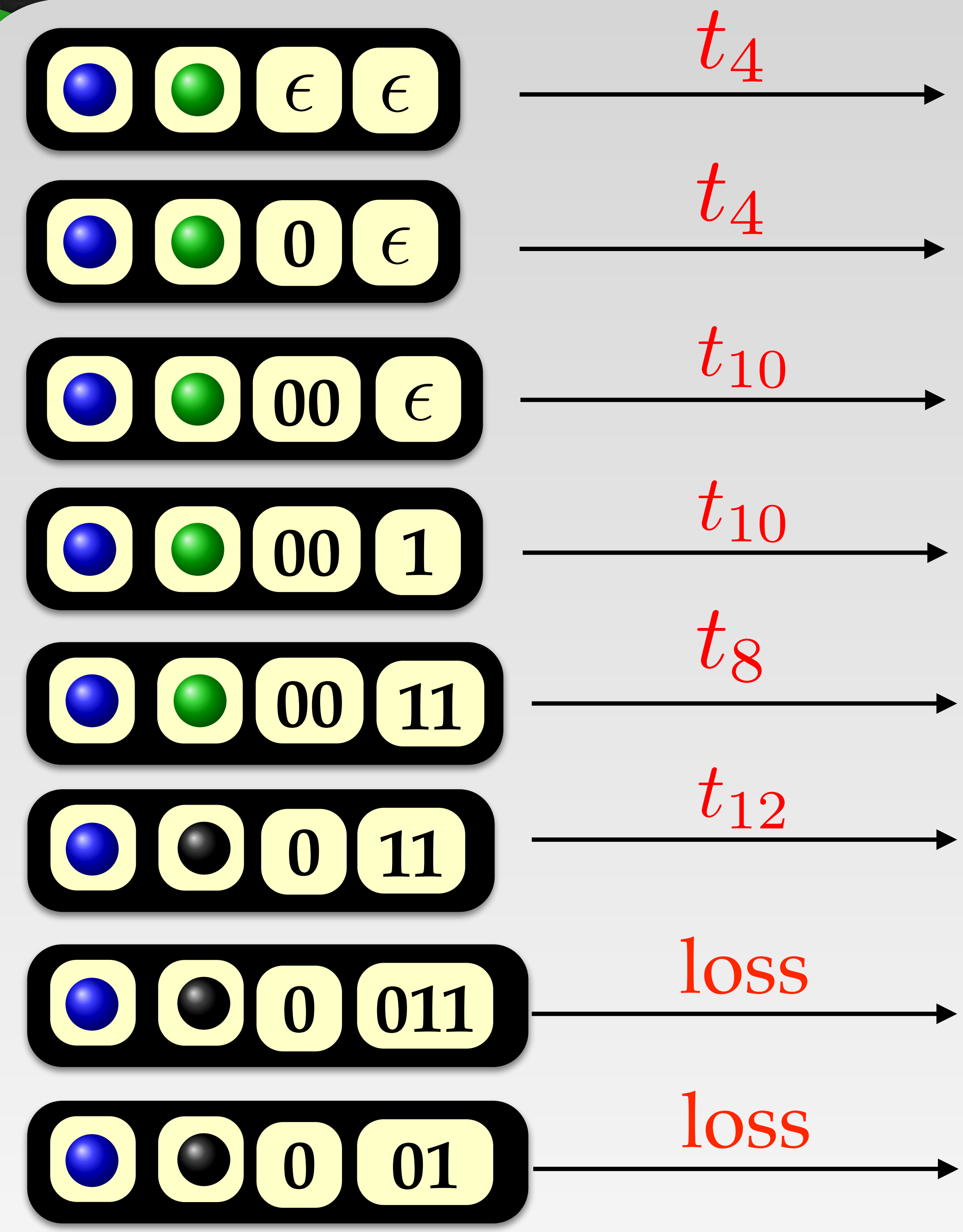

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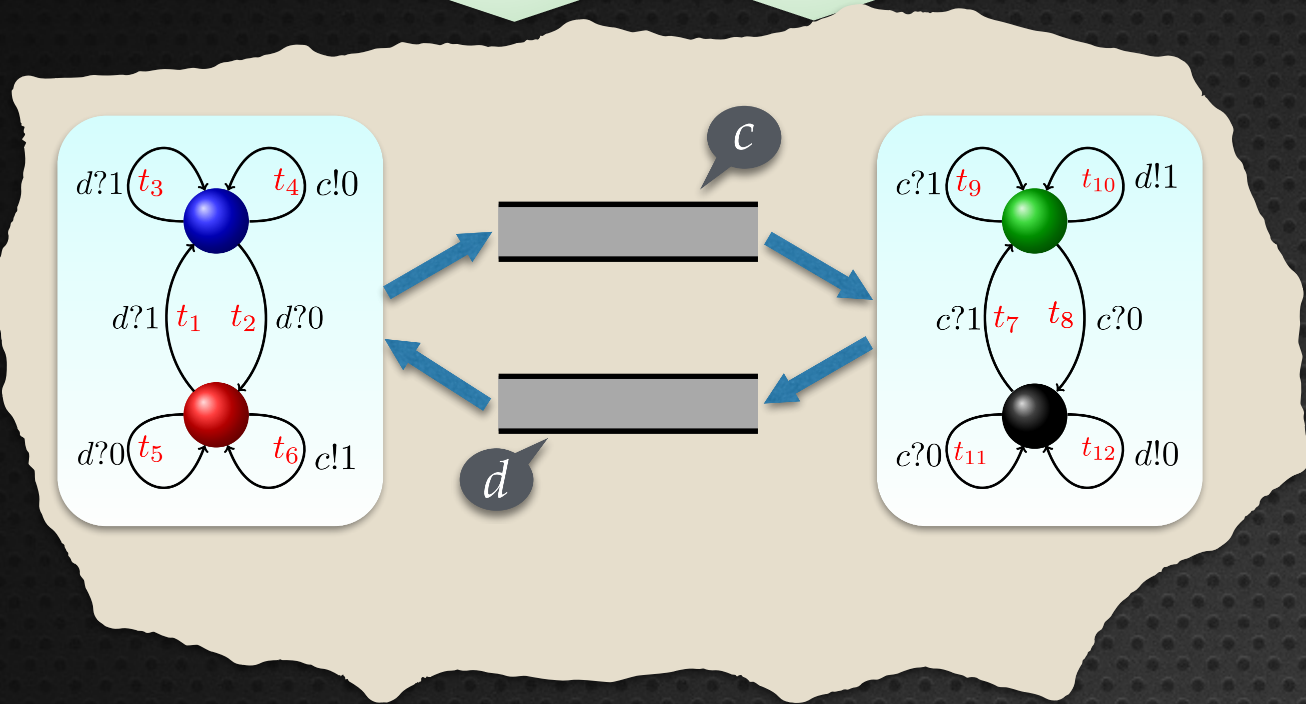

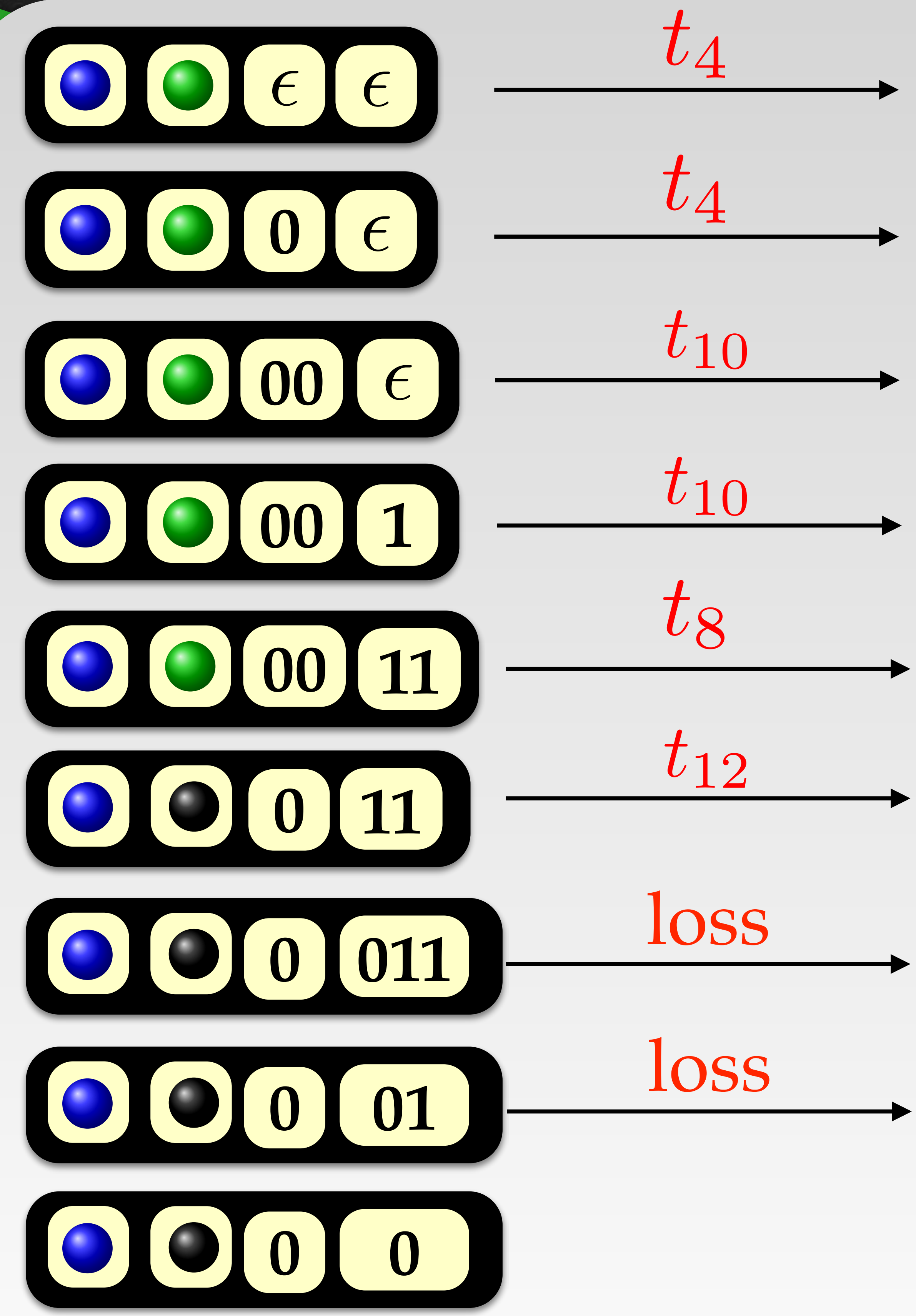

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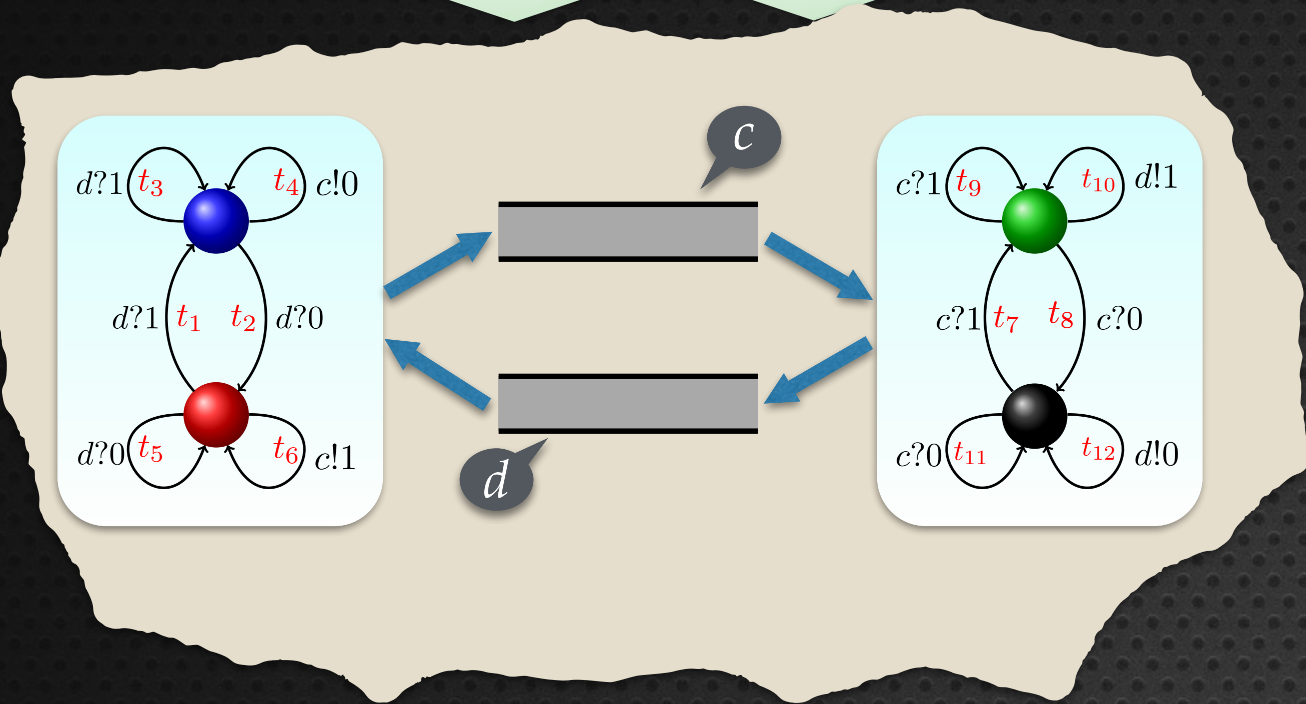

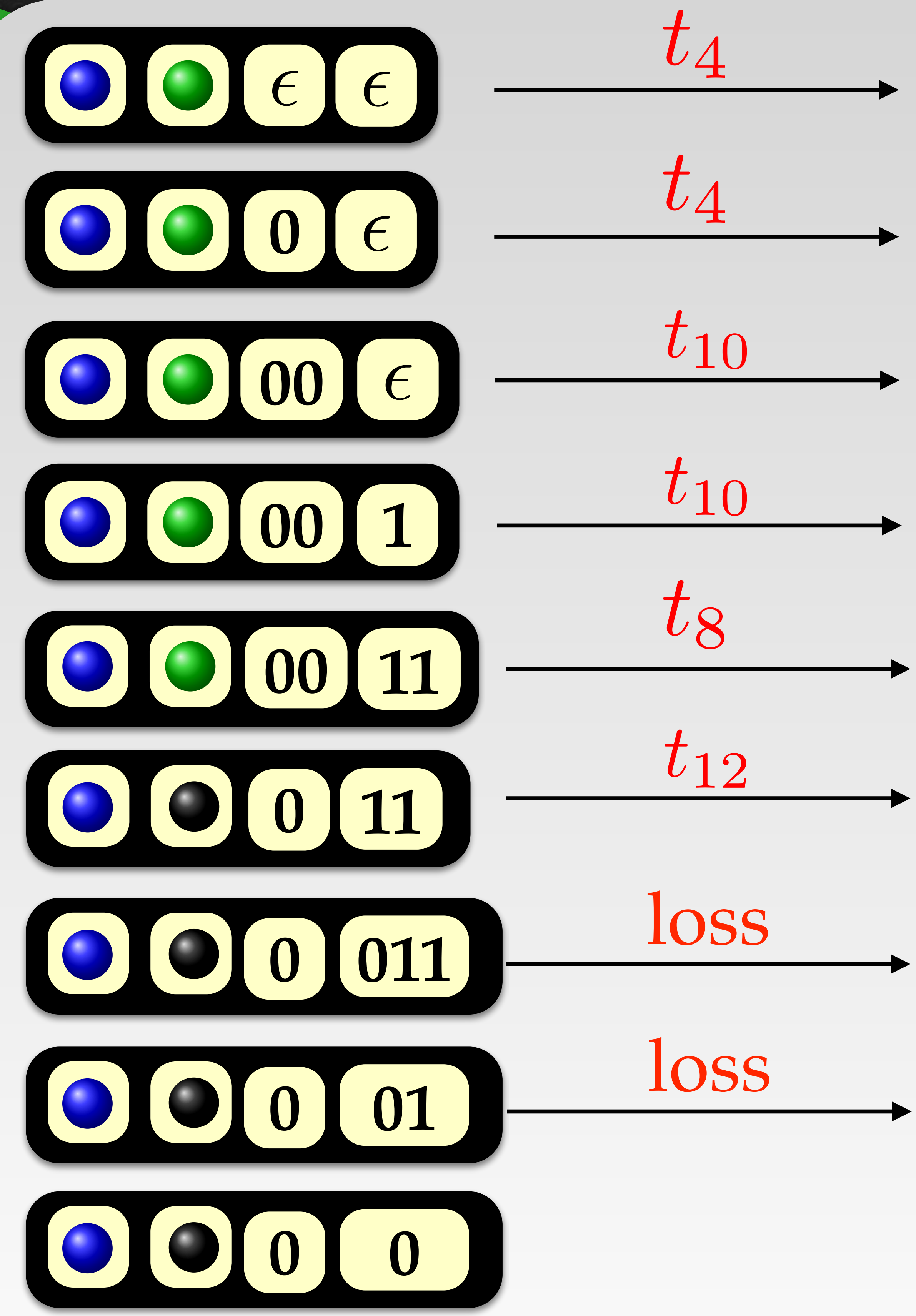

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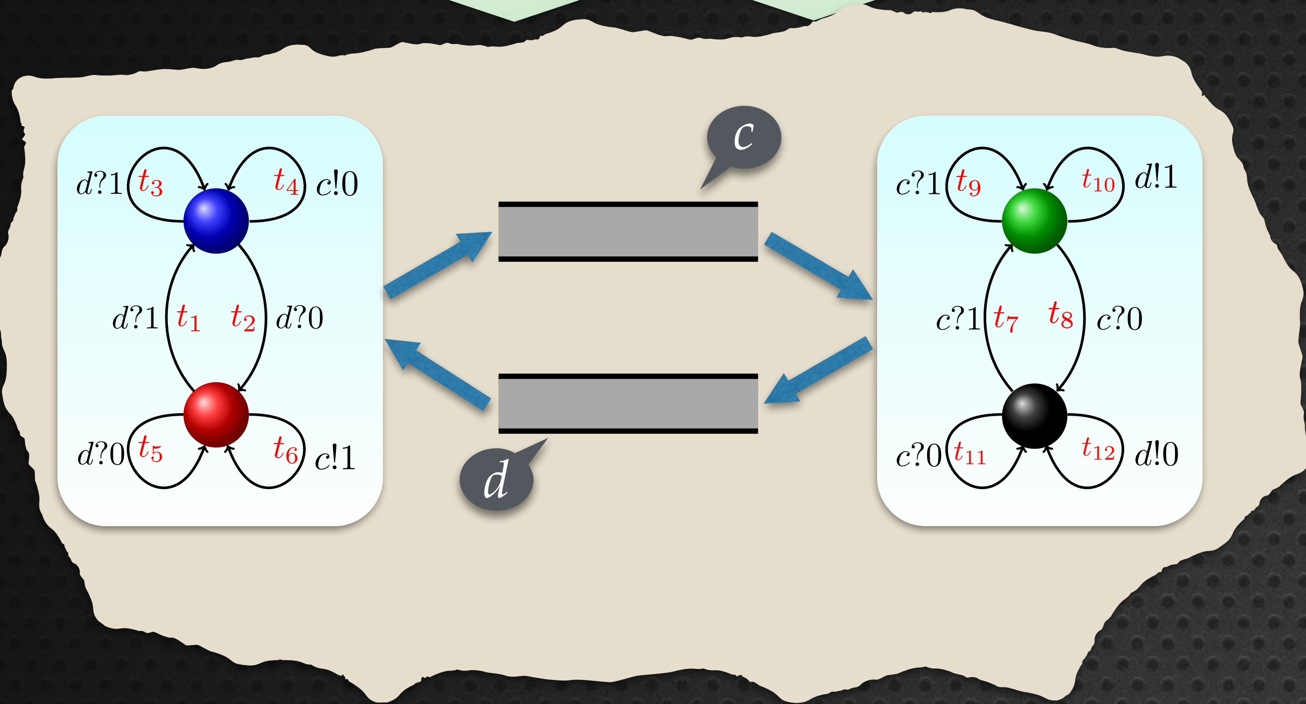
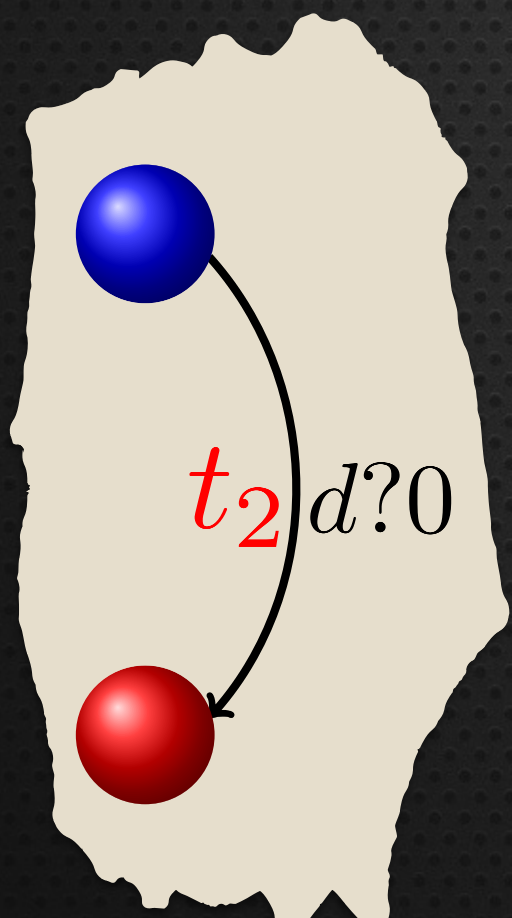
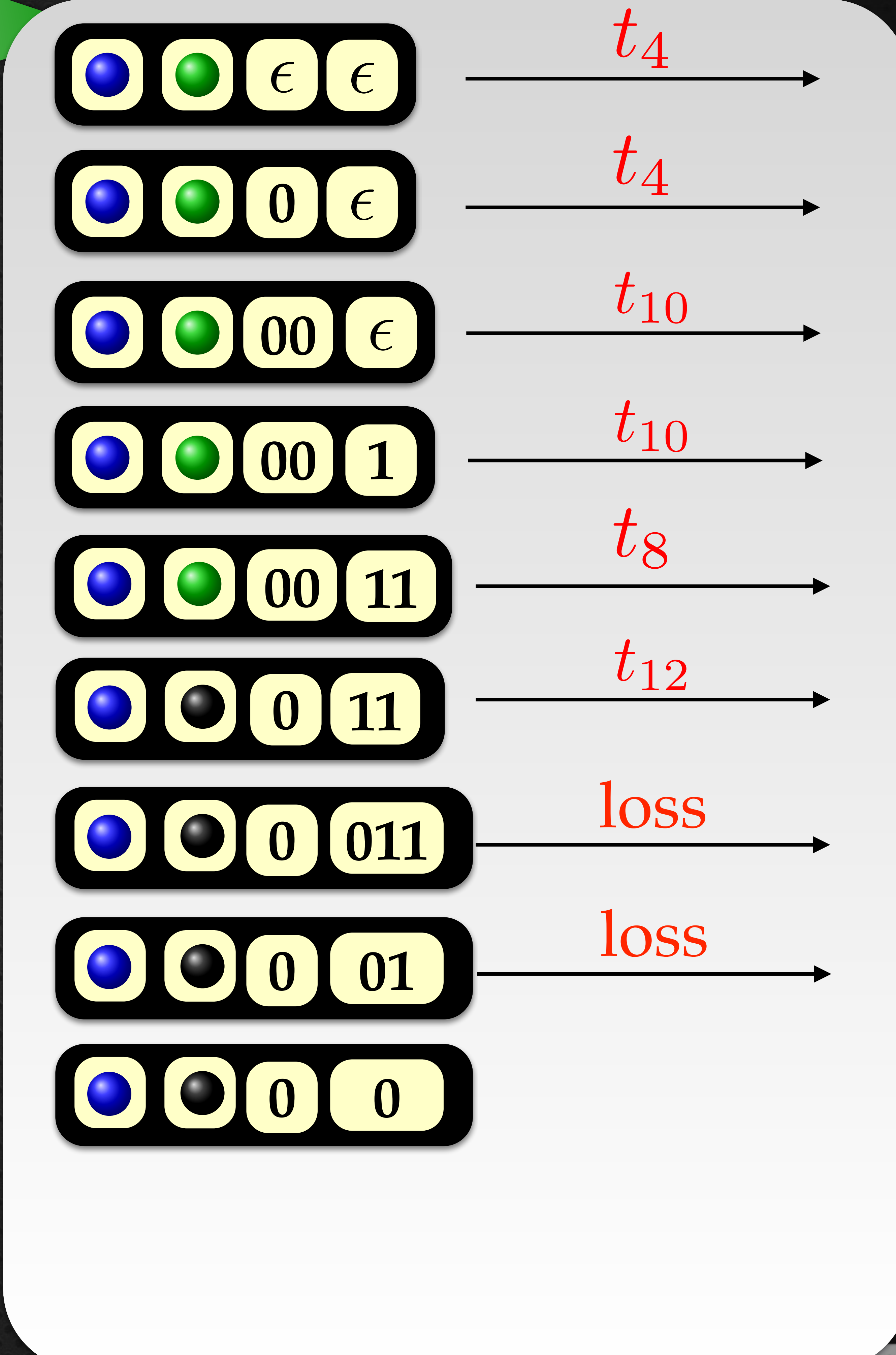
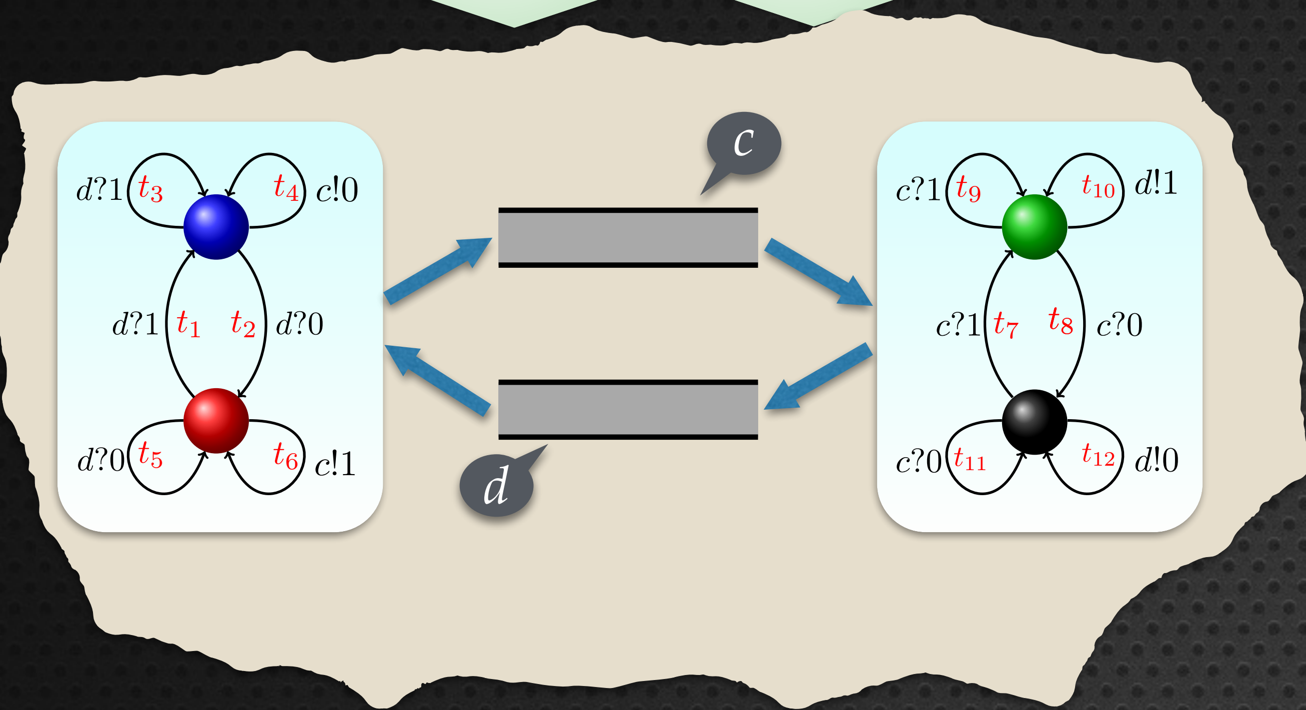
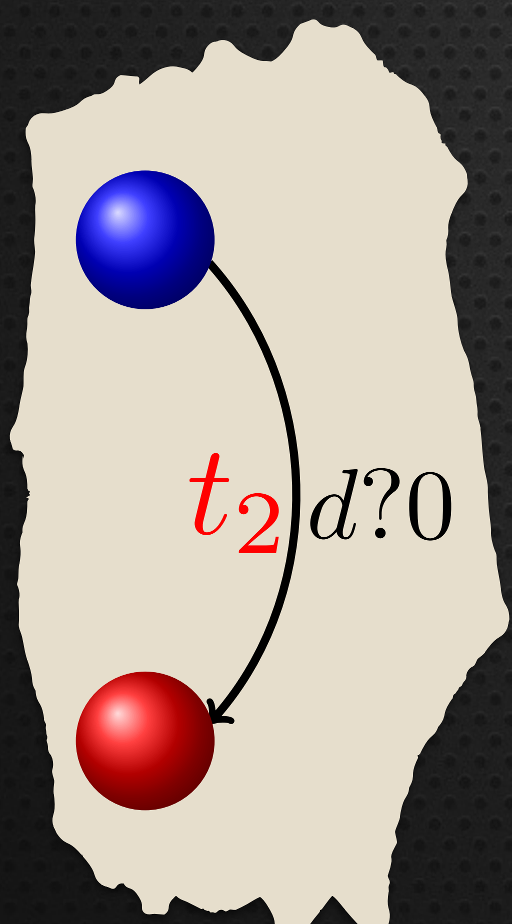


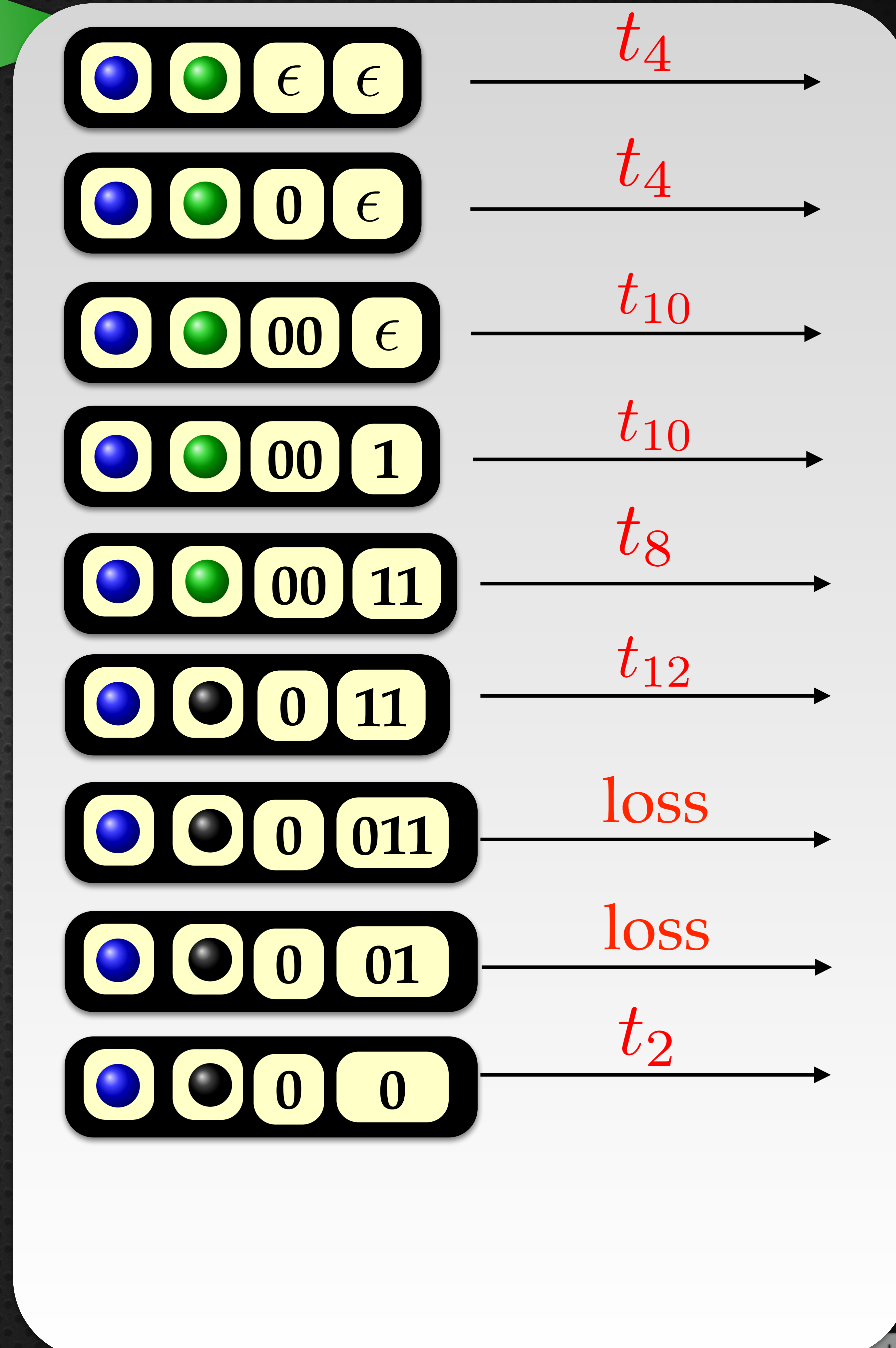




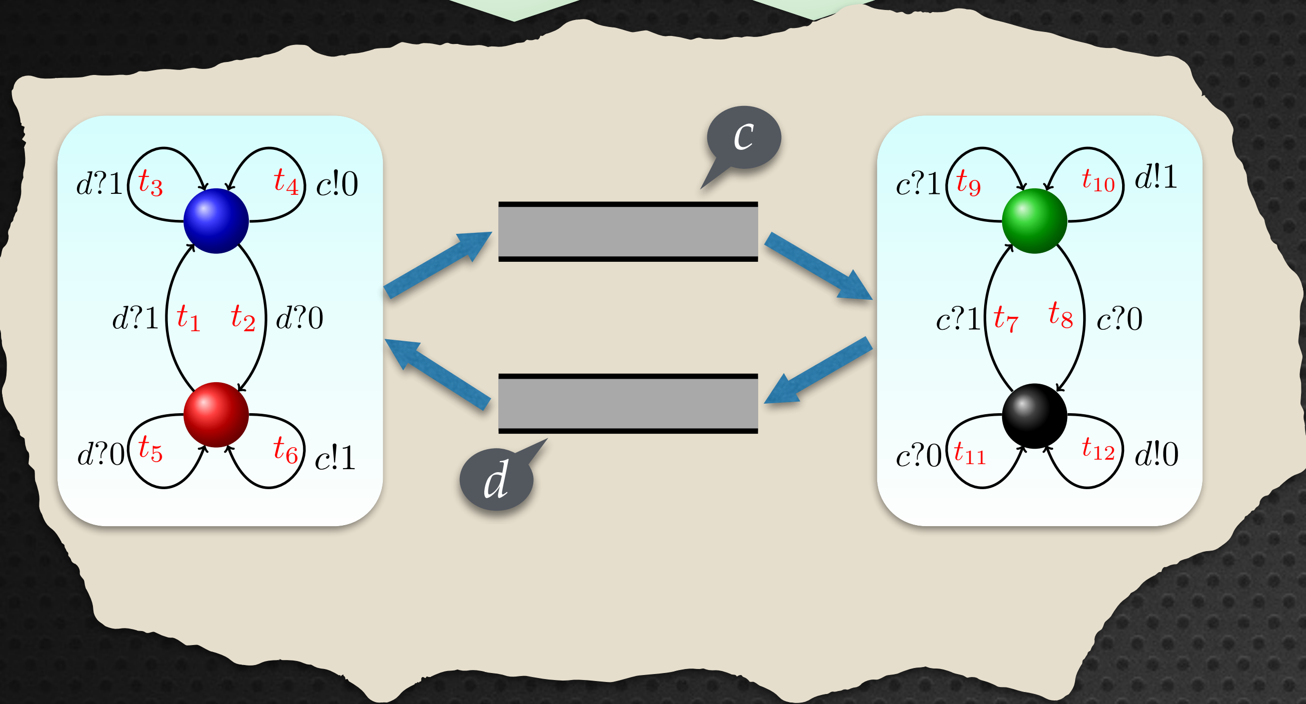
Lossy Transitions

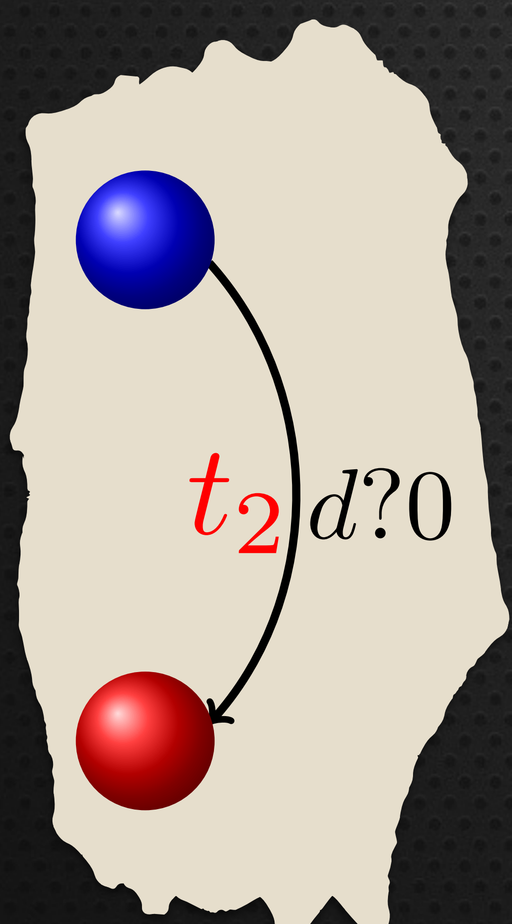


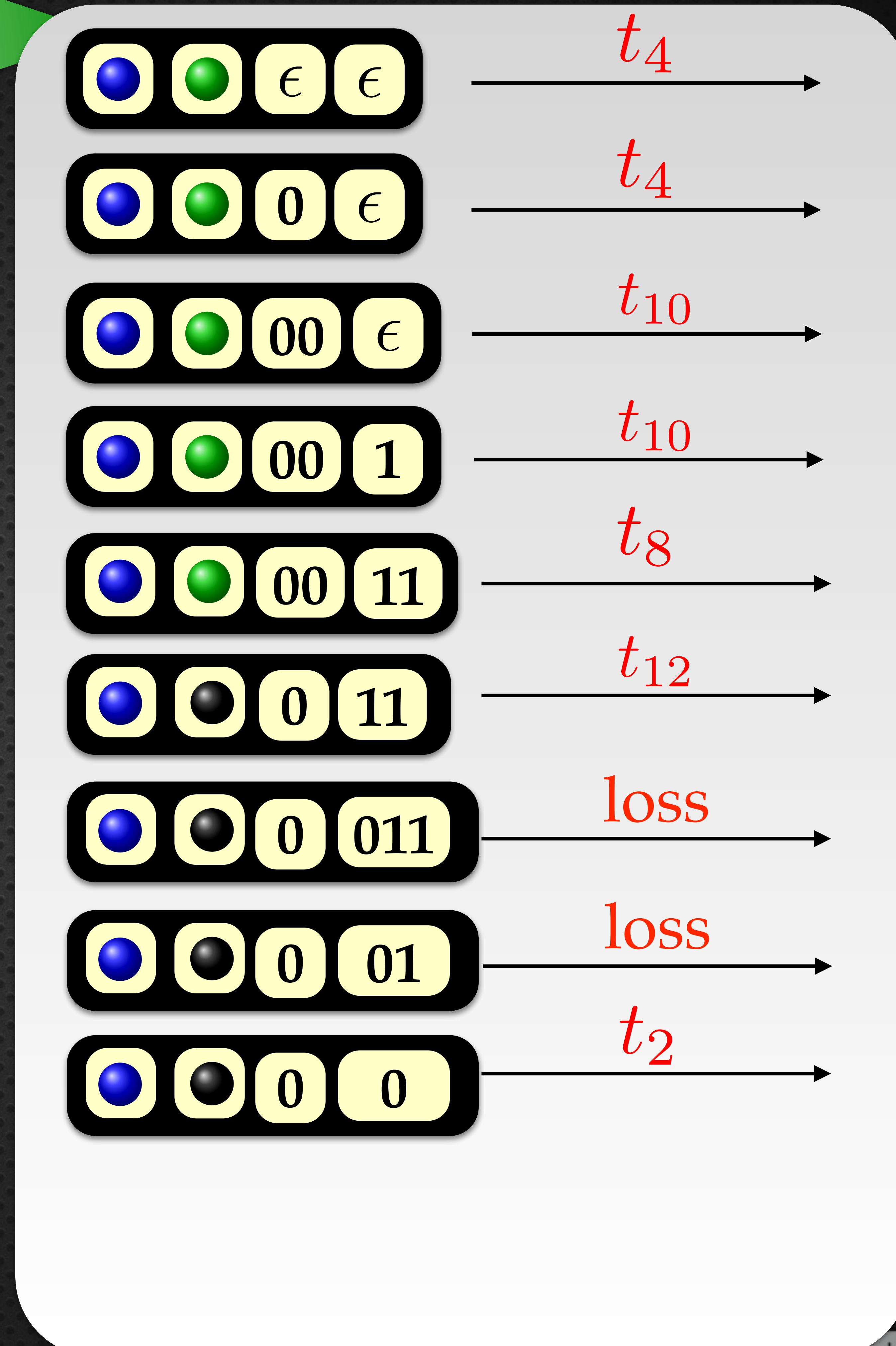




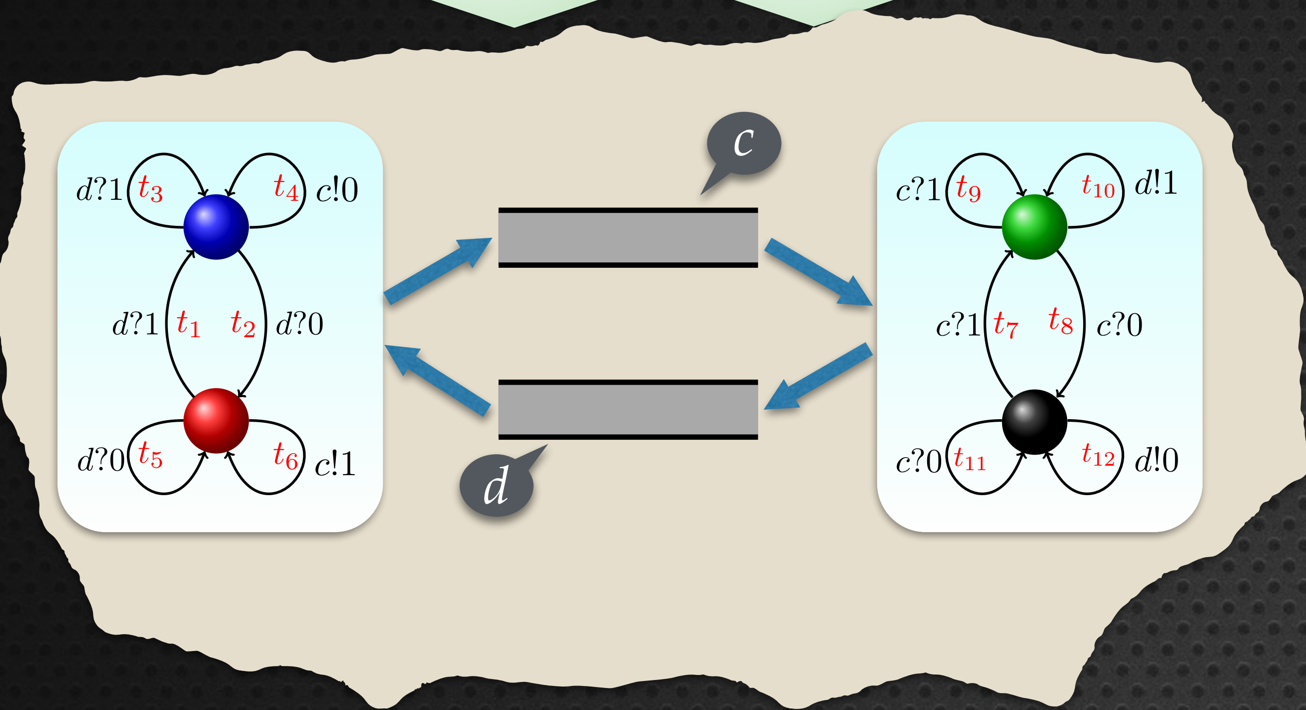
Lossy Transitions

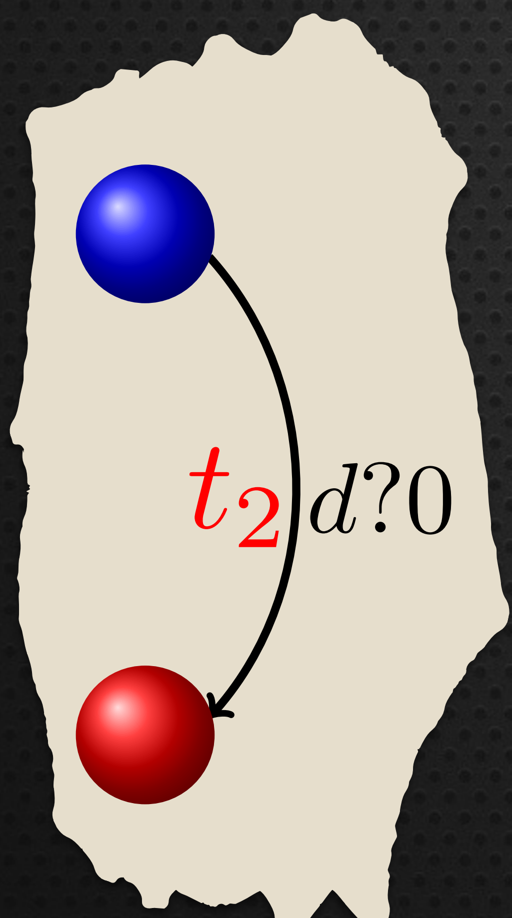


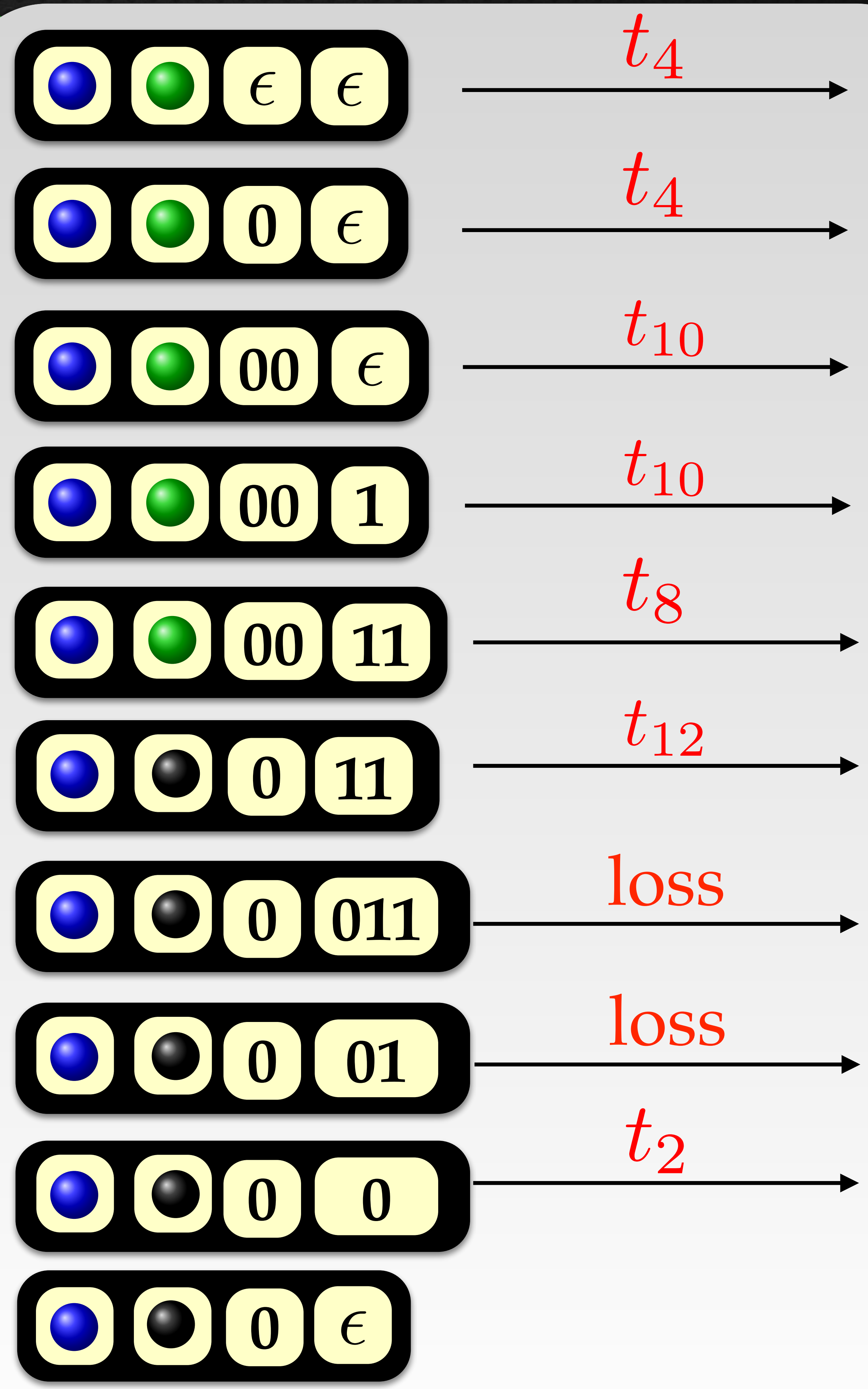




Lossy Transitions







Lossy Channel Systems

Model

Configurations

Transitions

Ordering

Monotonicity

Upward Closed Sets

Computing Predecessors

Backward Reachability

Lossy Channel Systems

Model

Configurations

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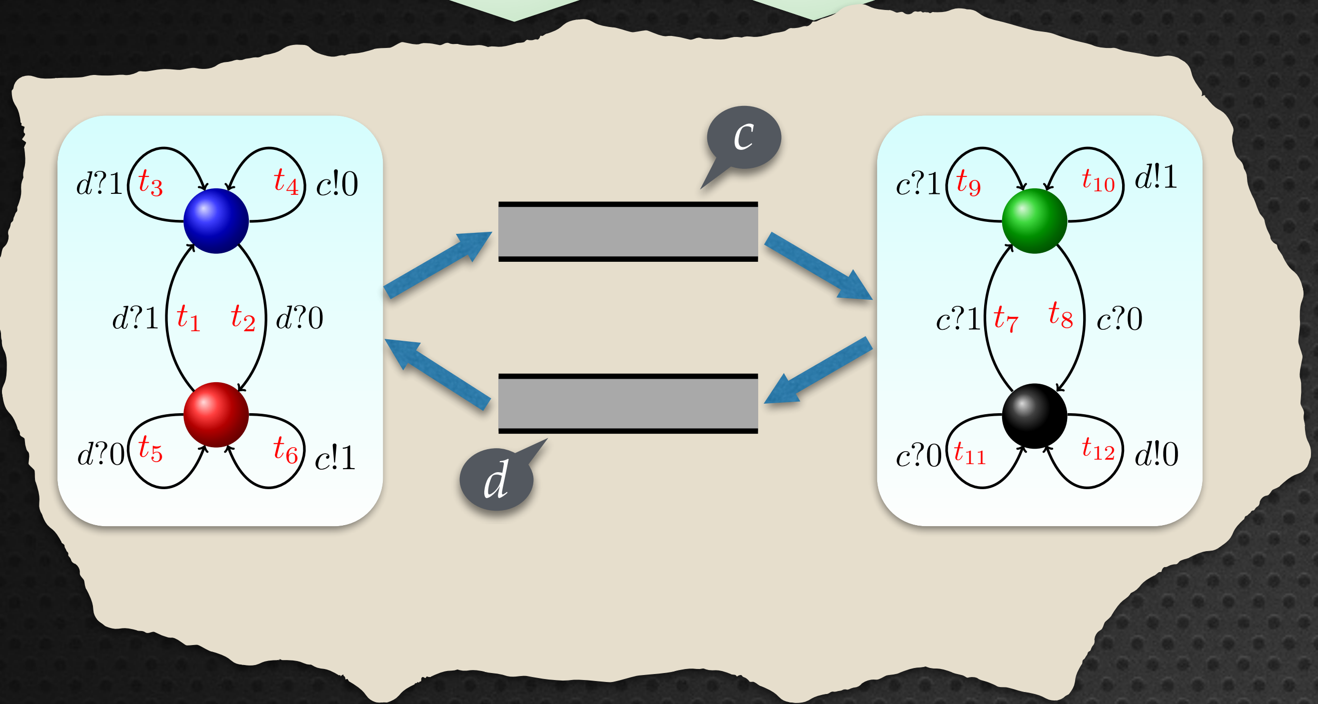
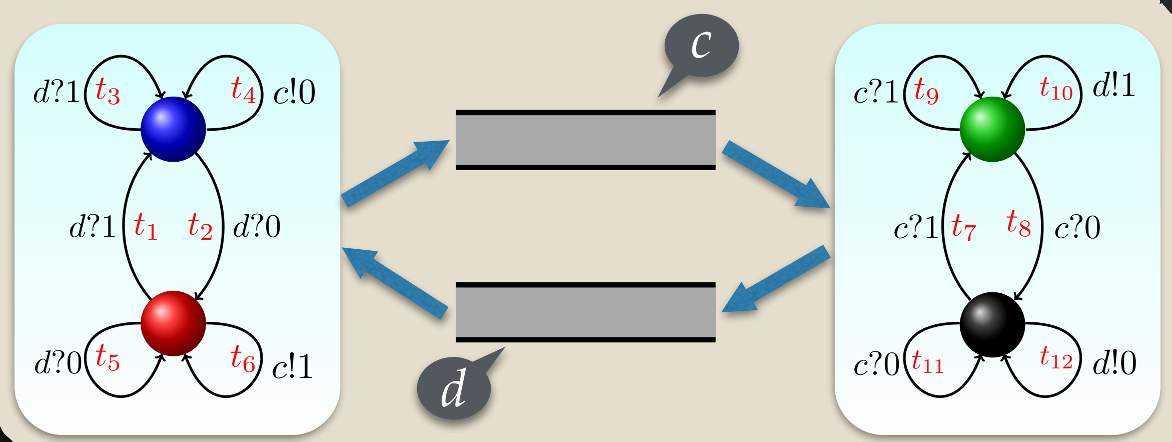
Ordering



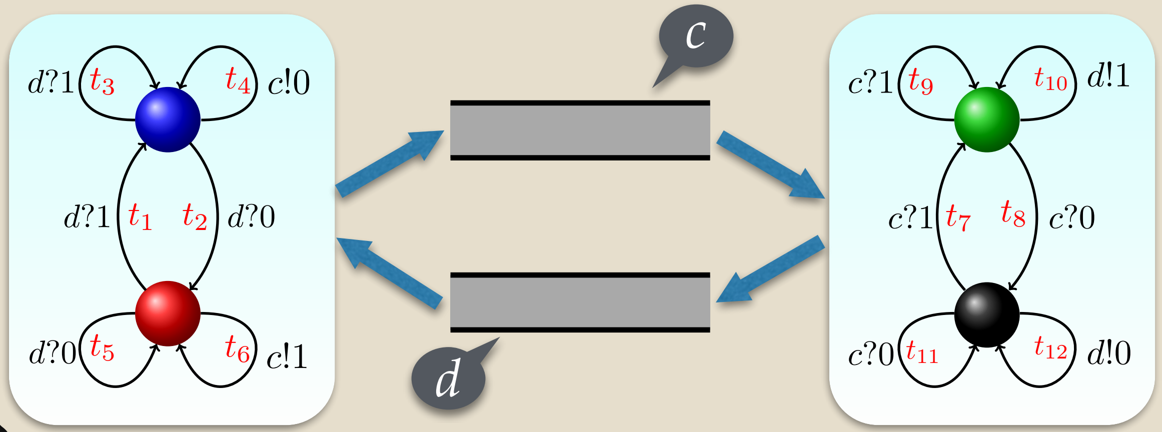
Lossy Ordering



Subword Relation

ab $\sqsubseteq$ xaybz

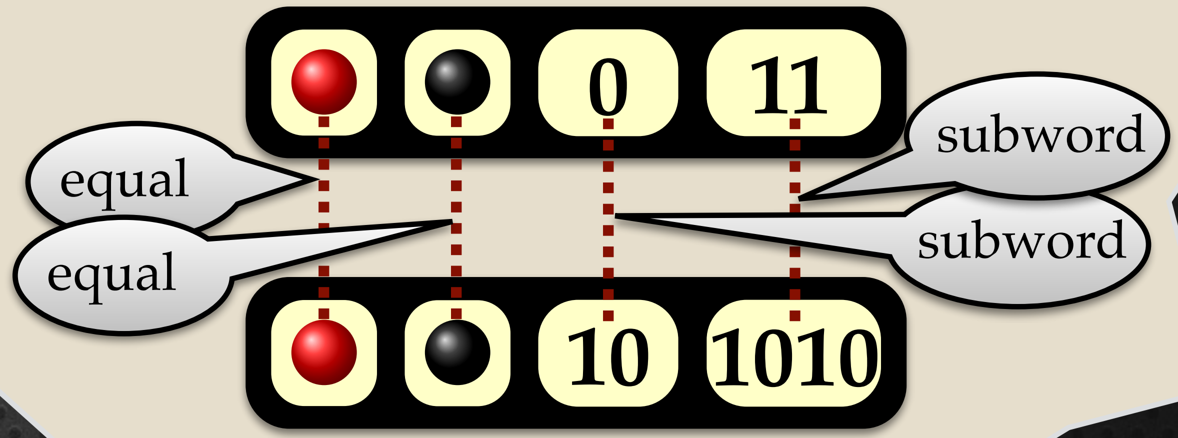
Lossy Ordering



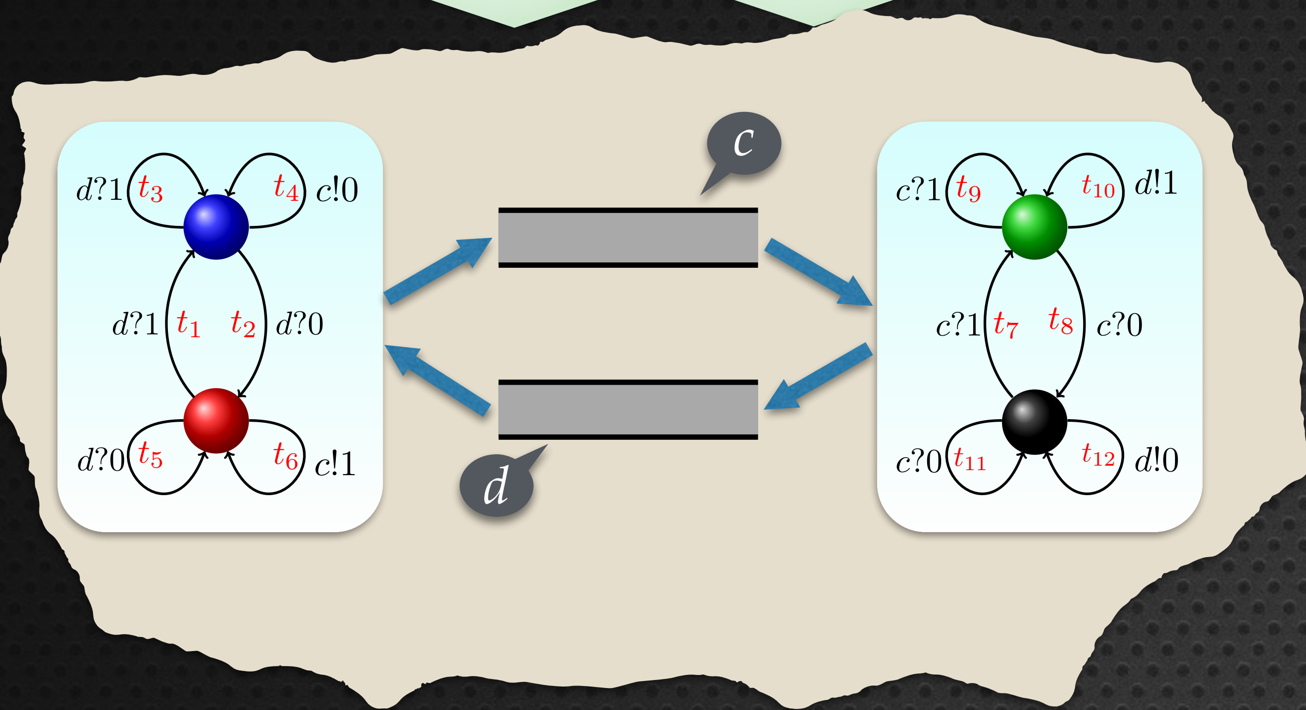
Subword Relation

ab $\sqsubseteq$ xaybz

Ordering



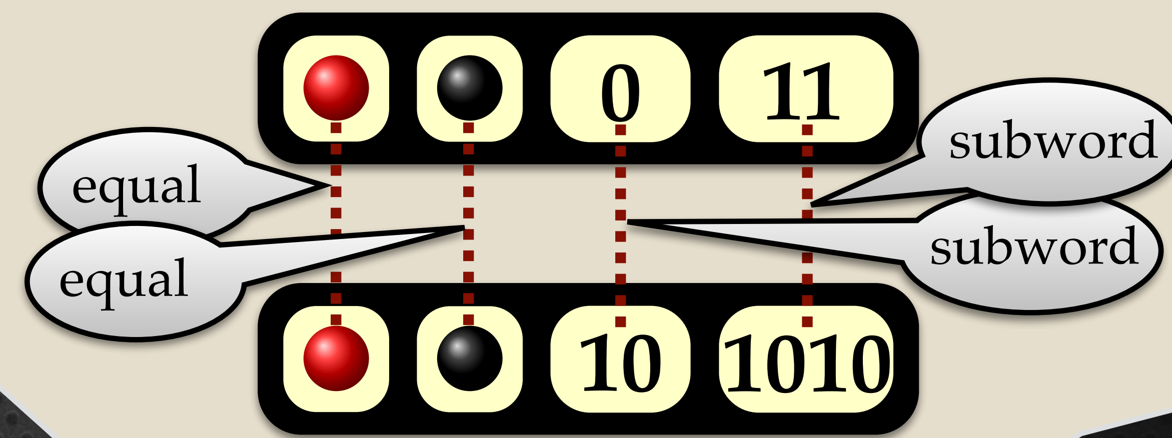
Lossy Ordering

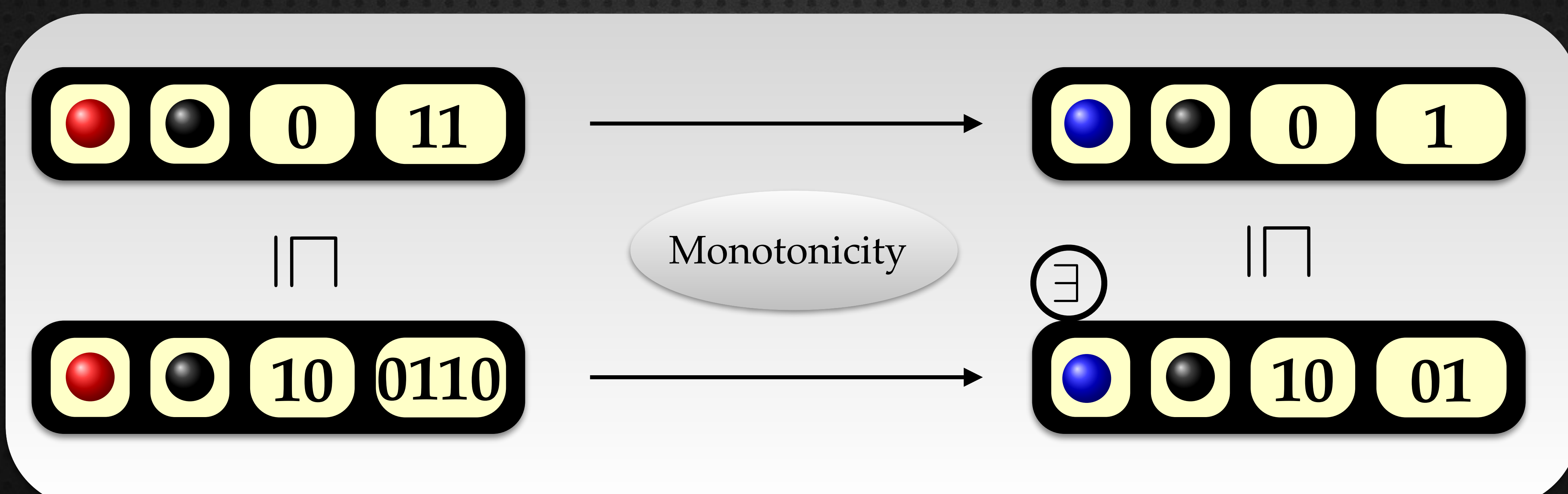


Subword Relation

$$\text{ab} \sqsubseteq \text{xaybz}$$

Ordering





Lossy Channel Systems

- Model
- Configurations
- Transitions
- Ordering
- Monotonicity
- Upward Closed Sets
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Lossy Channel Systems

Model ✓

Configurations ✓

Transitions ✓

Ordering ✓

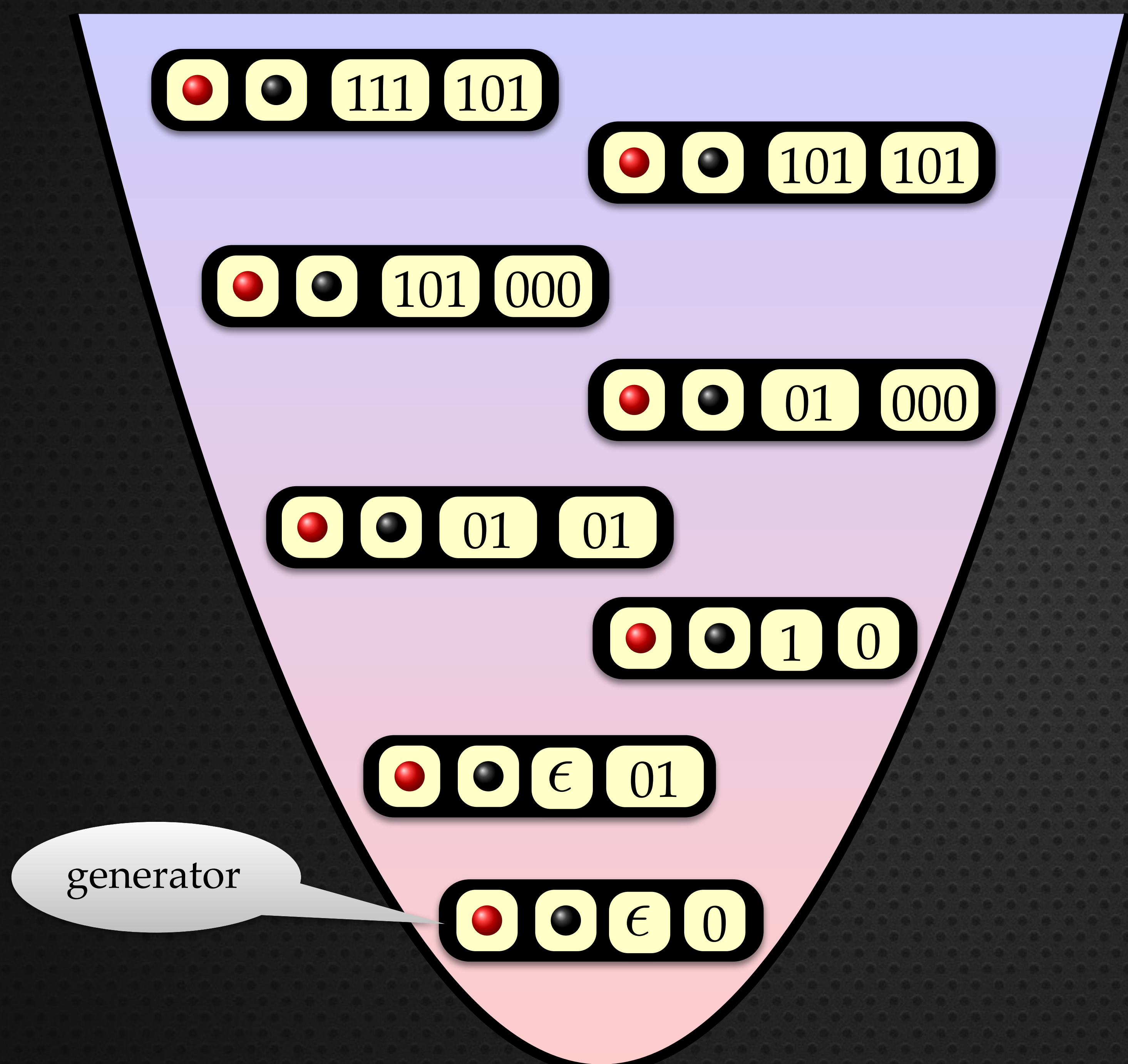
Monotonicity ✓

Upward Closed Sets

Computing Predecessors

Backward Reachability

Loss Upward-Closed Sets



Lossy Channel Systems

Model ✓

Configurations ✓

Transitions ✓

Ordering ✓

Monotonicity ✓

Upward Closed Sets ✓

Computing Predecessors

Backward Reachability

Lossy Channel Systems

Model ✓

Configurations ✓

Transitions ✓

Ordering ✓

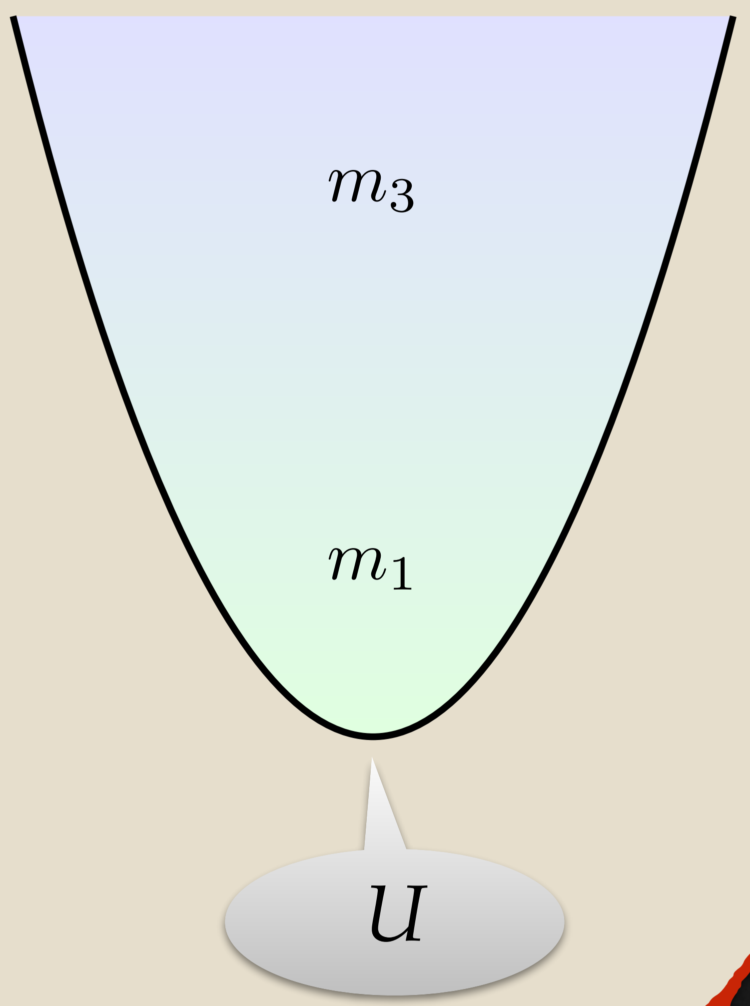
Monotonicity ✓

Upward Closed Sets ✓

Computing Predecessors

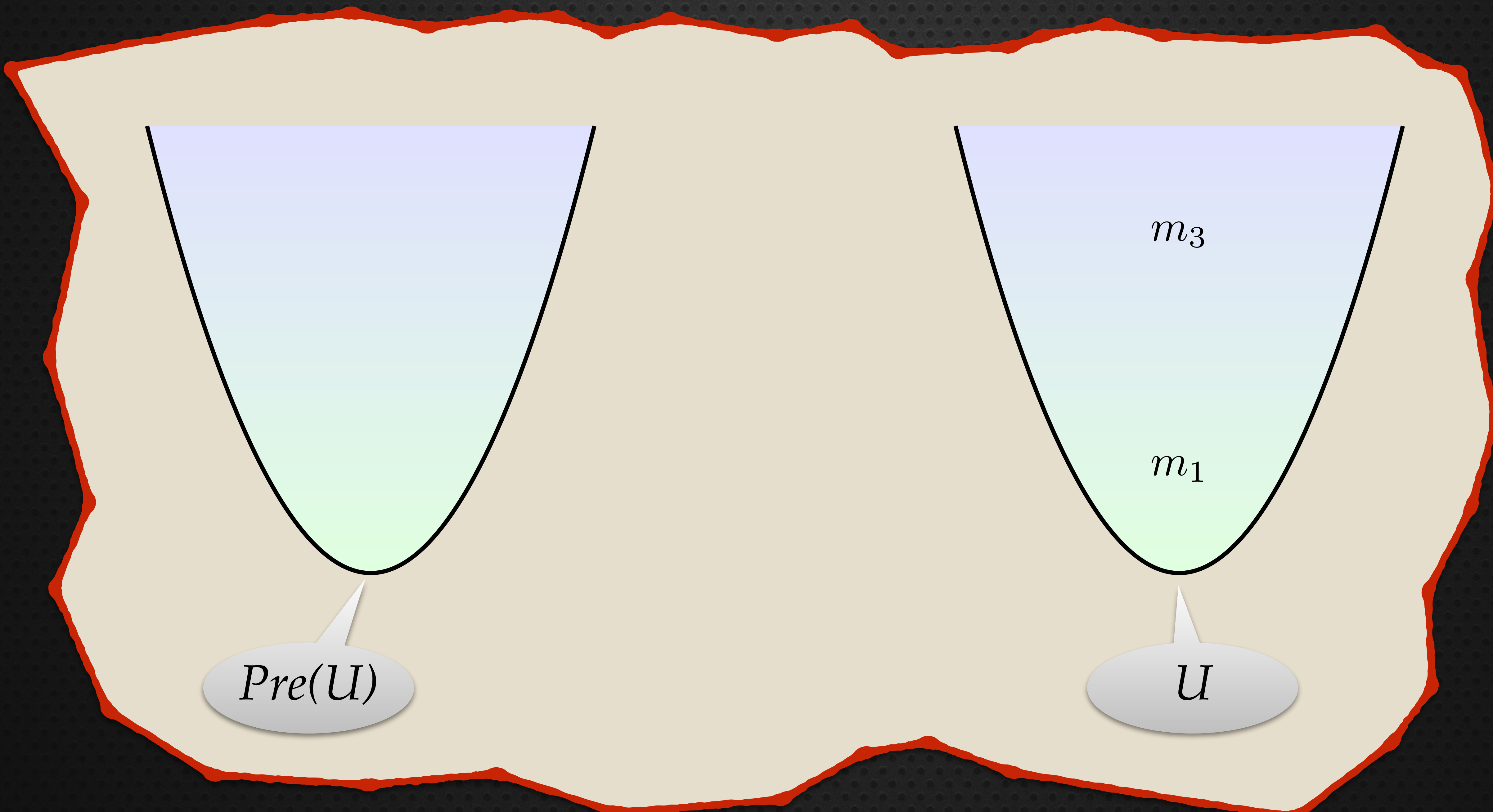
Backward Reachability

Lossy Predecessors

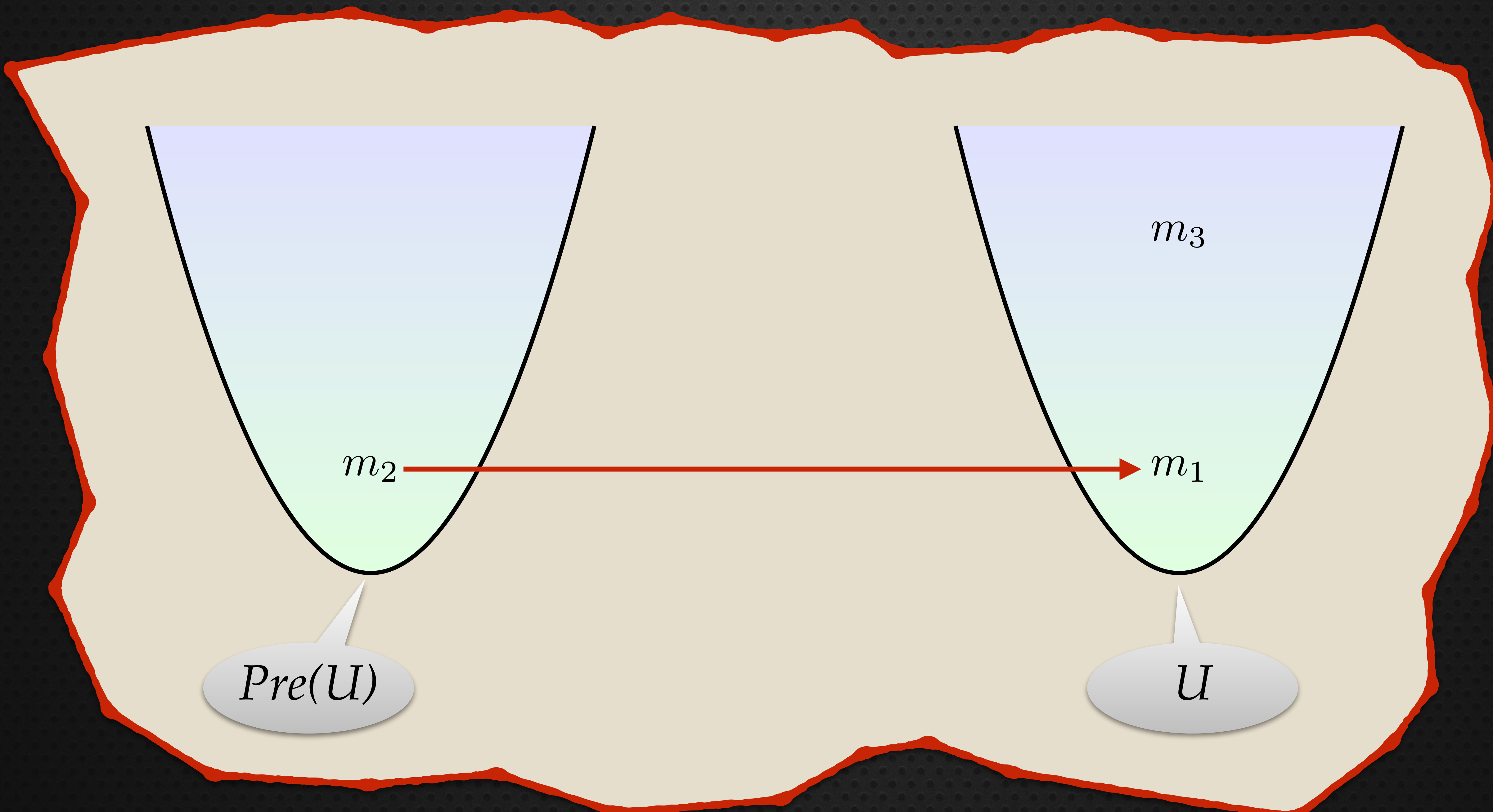


Lossy

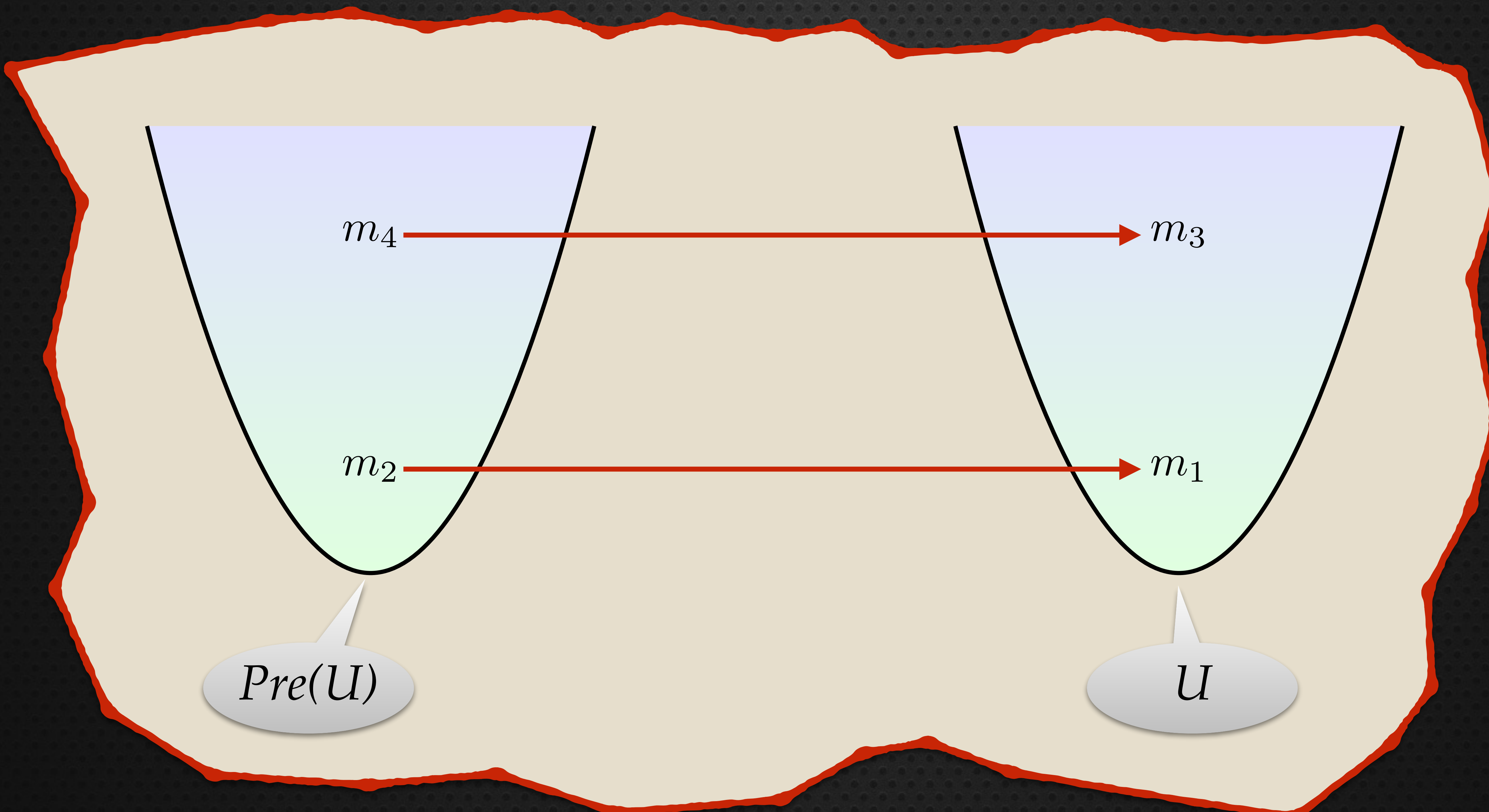
Predecessors



Lossy Predecessors



Predecessors



Lossy Predecessors

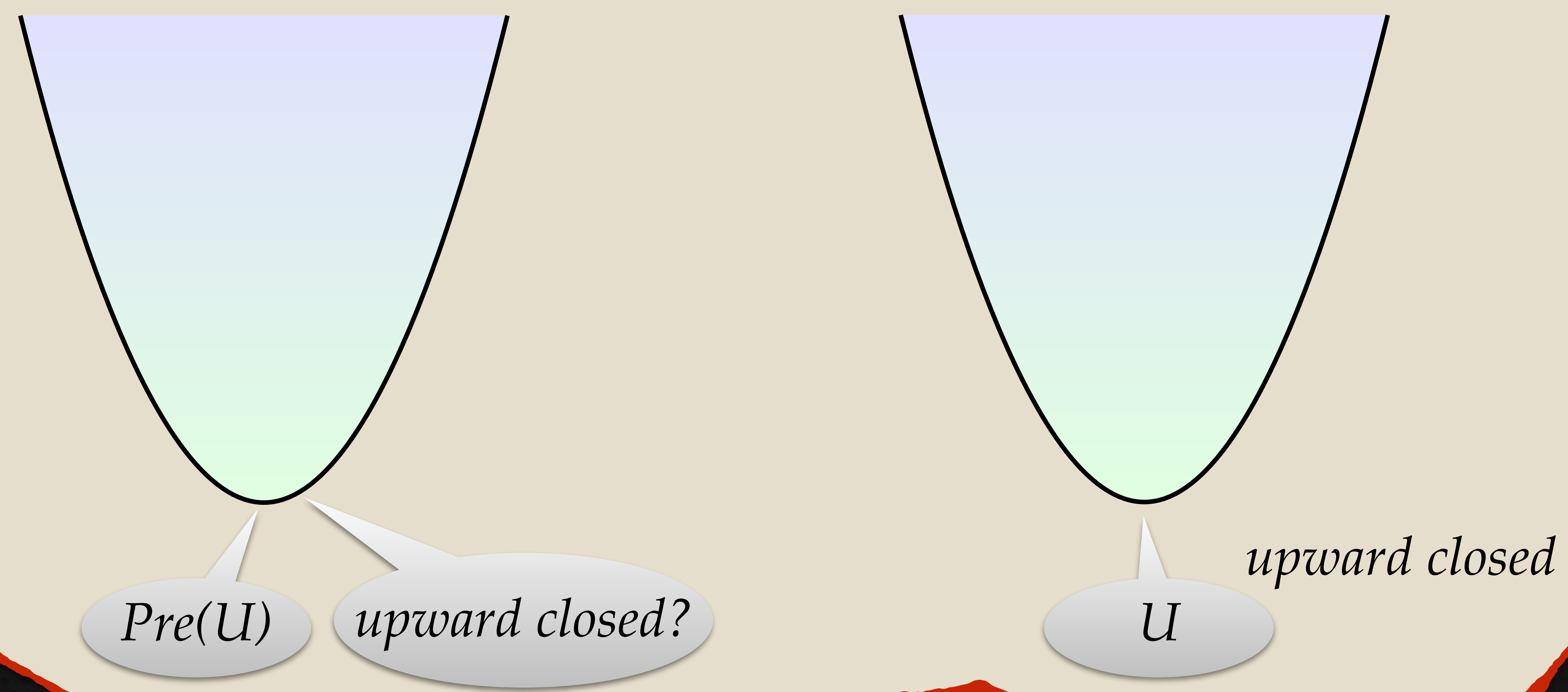
$$
\begin{tikzcd}
m_1 \arrow[r] \arrow[d, phantom, "\rotatebox{-90}{$\sqsubseteq$}"] & m_2 \arrow[d, phantom, "\rotatebox{-90}{$\sqsubseteq$}"] \\
m_3 \arrow[r, "\exists"] & m_4
\end{tikzcd}
$$

Monotonicity: UC persevered by *Pre*

Lossy Predecessors

Monotonicity: UC persevered by *Pre*

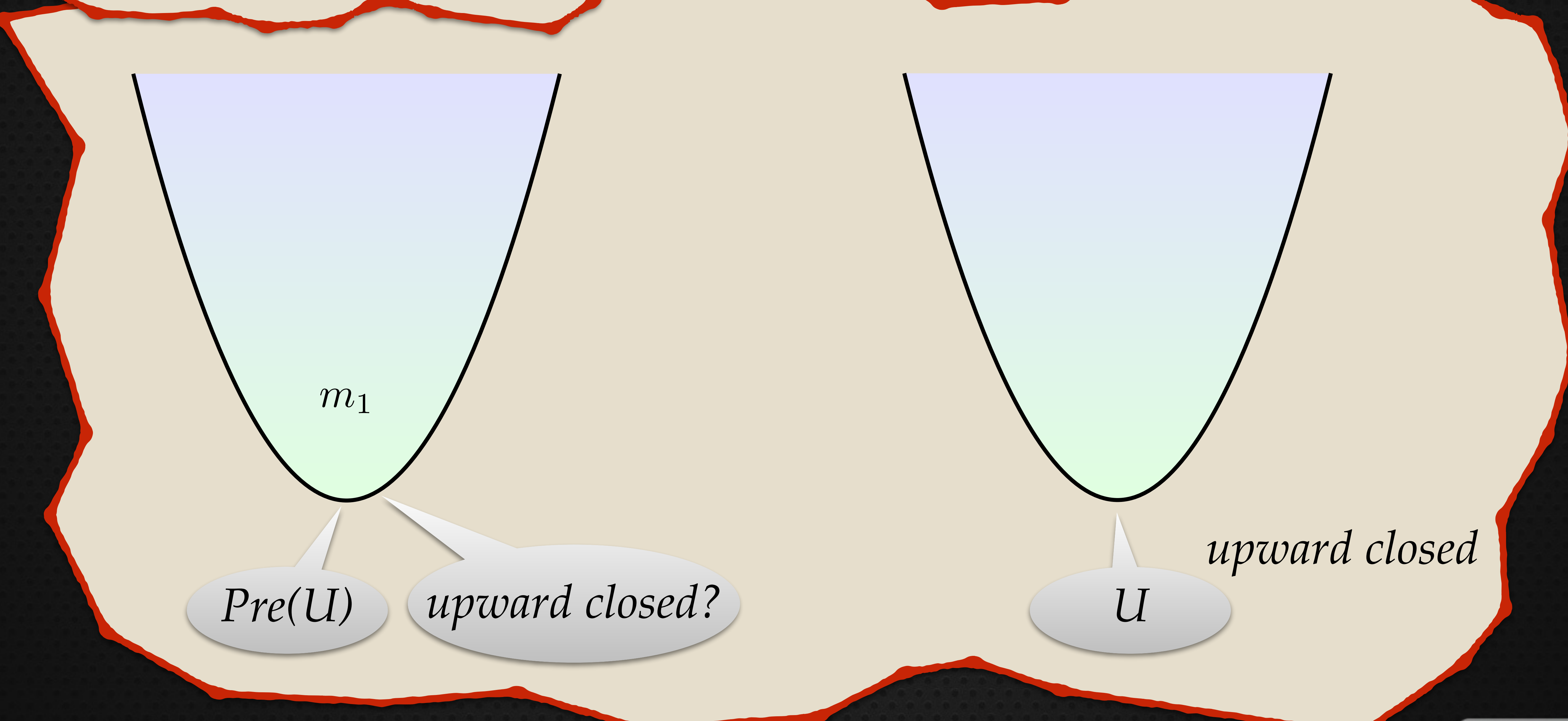
$$\begin{array}{ccc} m_1 & \longrightarrow & m_2 \\ \rotatebox{-90}{$\sqsubseteq$} & & \rotatebox{-90}{$\sqsubseteq$} \\ m_3 & \longrightarrow & \exists\, m_4 \end{array}$$



Lossy Predecessors

Monotonicity: UC persevered by *Pre*

$$\begin{tikzcd}
m_1 \arrow[r] \arrow[d, phantom, sloped, "\sqsubseteq"] & m_2 \arrow[d, phantom, sloped, "\sqsubseteq"] \\
m_3 \arrow[r] & \exists\, m_4
\end{tikzcd}$$



Lossy Predecessors

$$
\begin{tikzcd}
m_1 \arrow[r] \arrow[d, phantom, sloped, "\sqsubseteq"] & m_2 \arrow[d, phantom, sloped, "\sqsubseteq"] \\
m_3 \arrow[r] & \exists\, m_4
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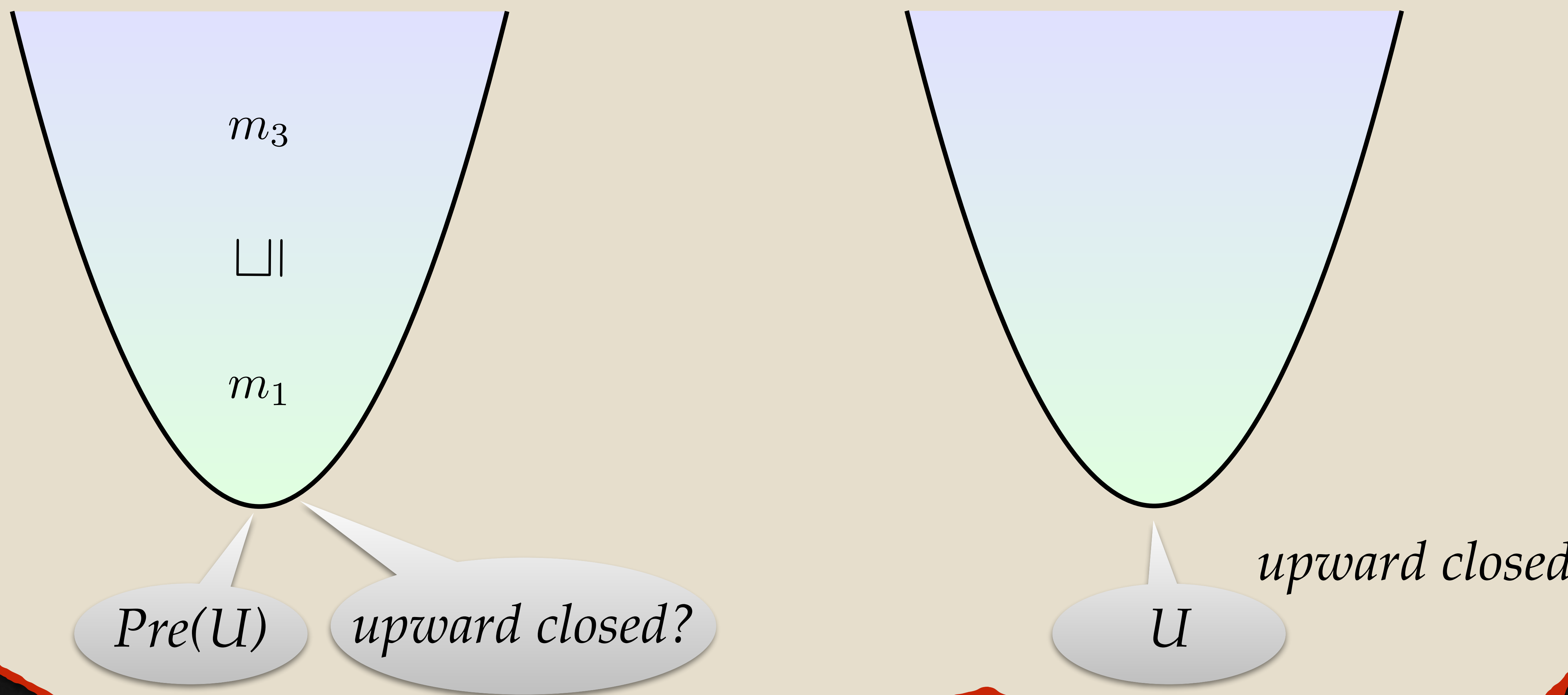
Monotonicity: UC persevered by *Pre*



Lossy Predecessors

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$$\begin{tikzcd}
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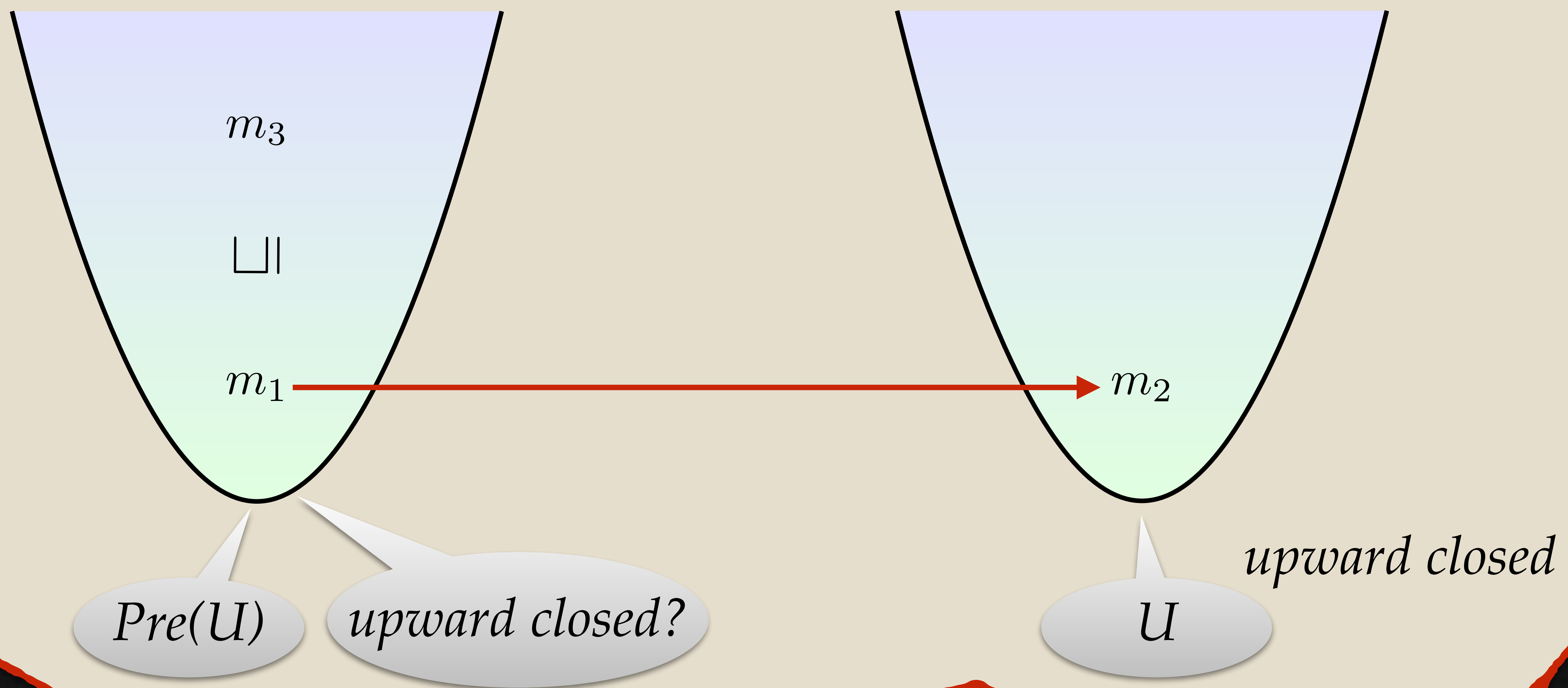

Lossy Predecessors

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m_1 \arrow[r] \arrow[d, phantom, "\rotatebox{90}{$\sqsubseteq$}"] & m_2 \arrow[d, phantom, "\rotatebox{90}{$\sqsubseteq$}"] \\
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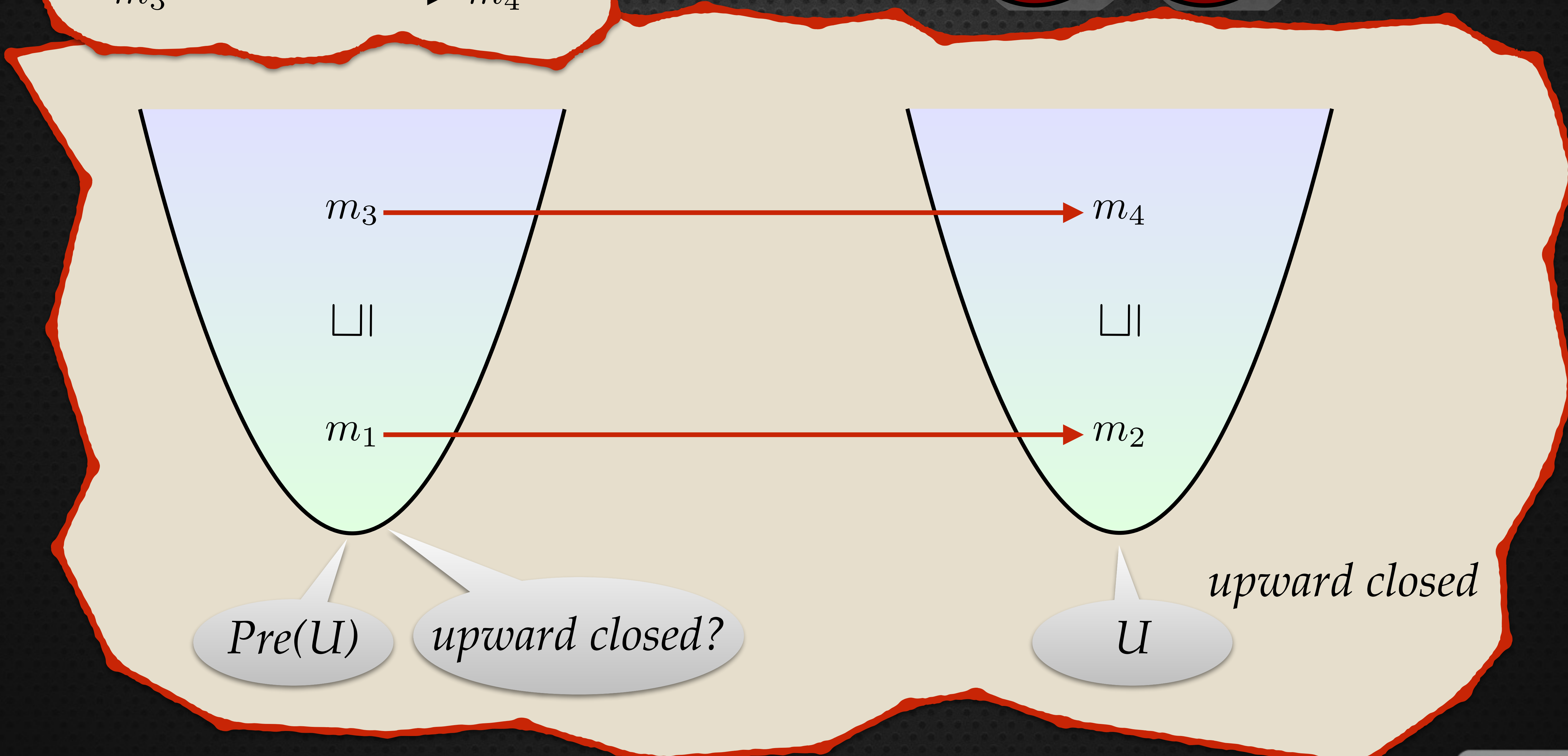
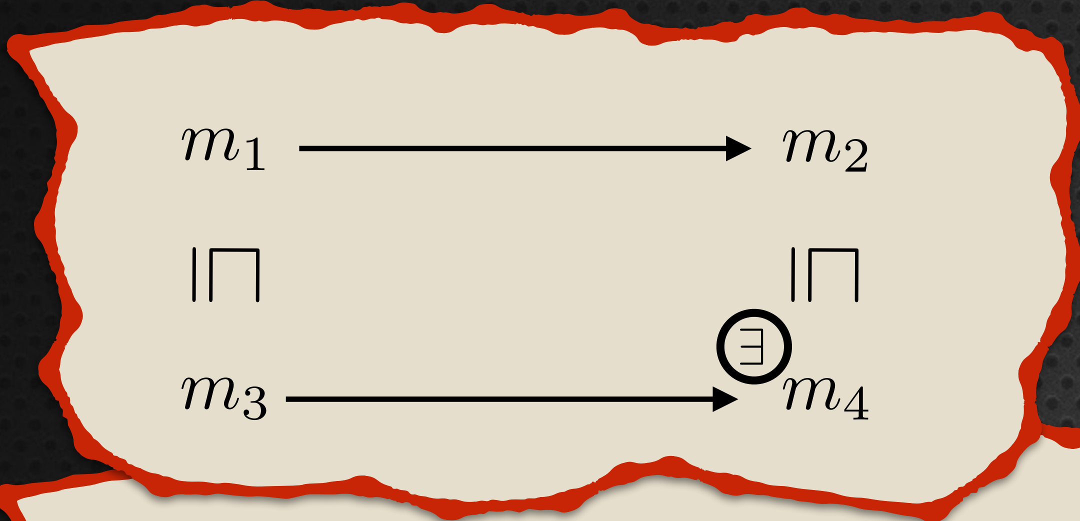
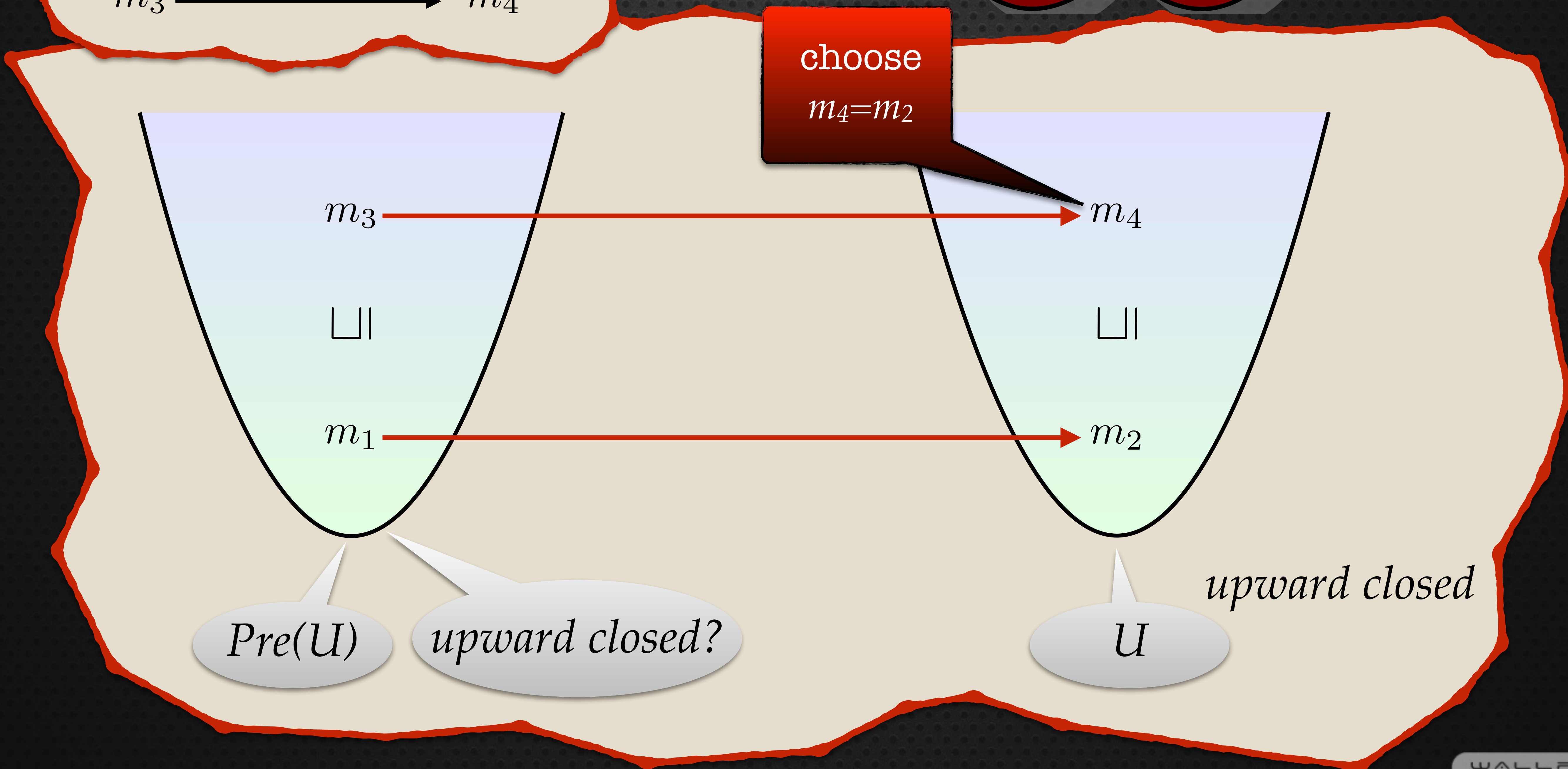
Monotonicity: UC persevered by *Pre*



Lossy Predecessors

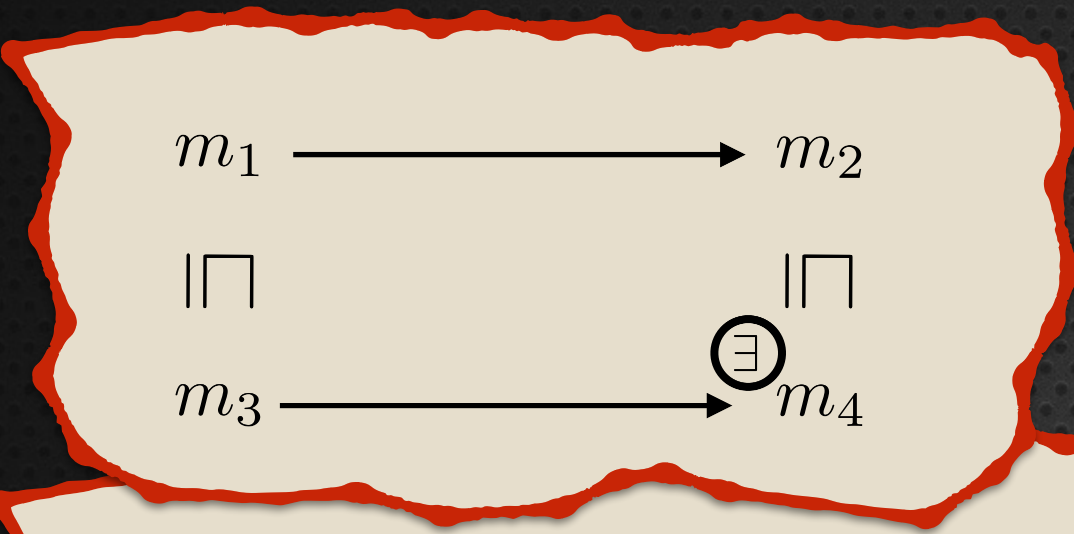
Monotonicity: UC persevered by *Pre*

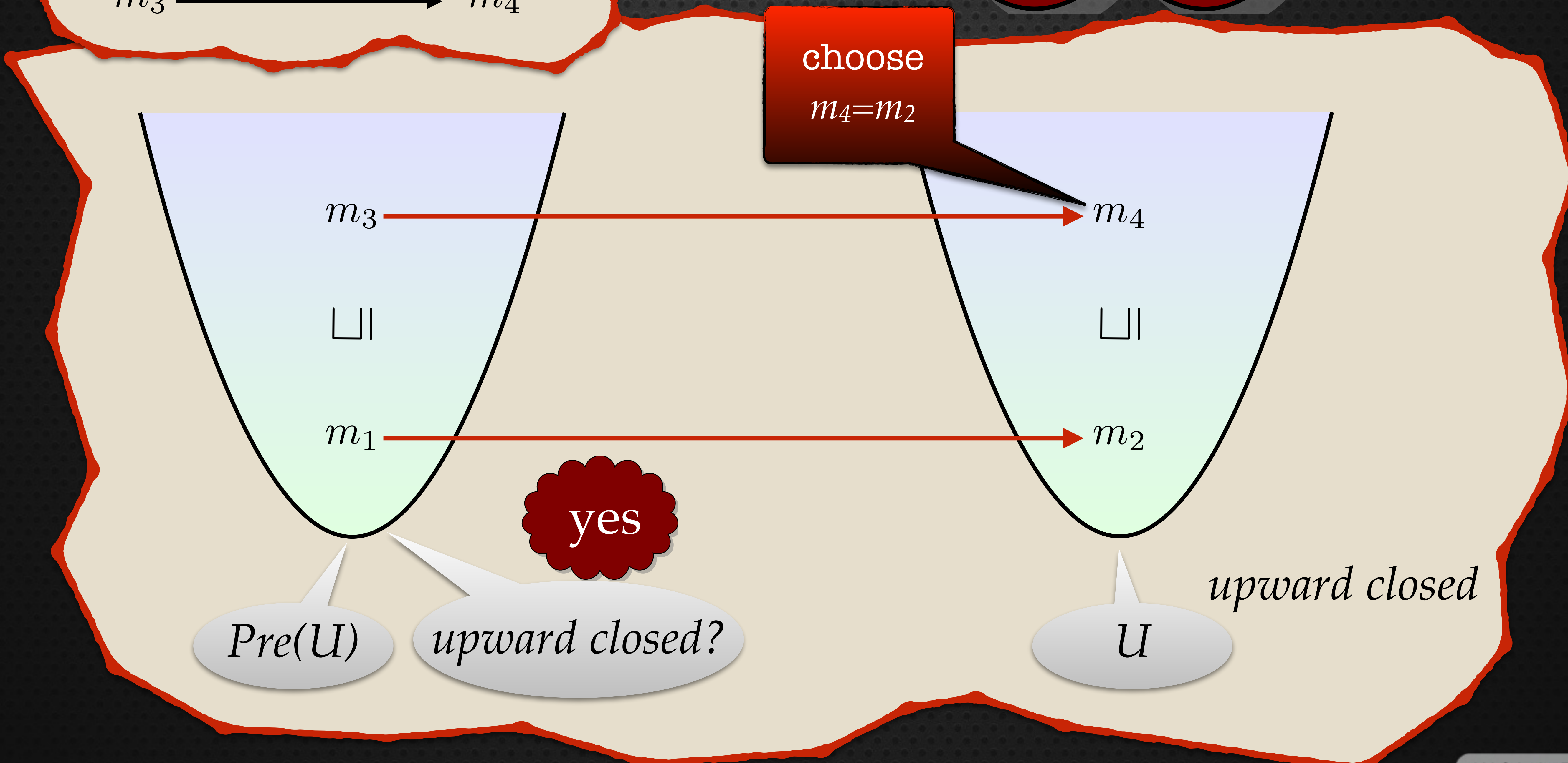




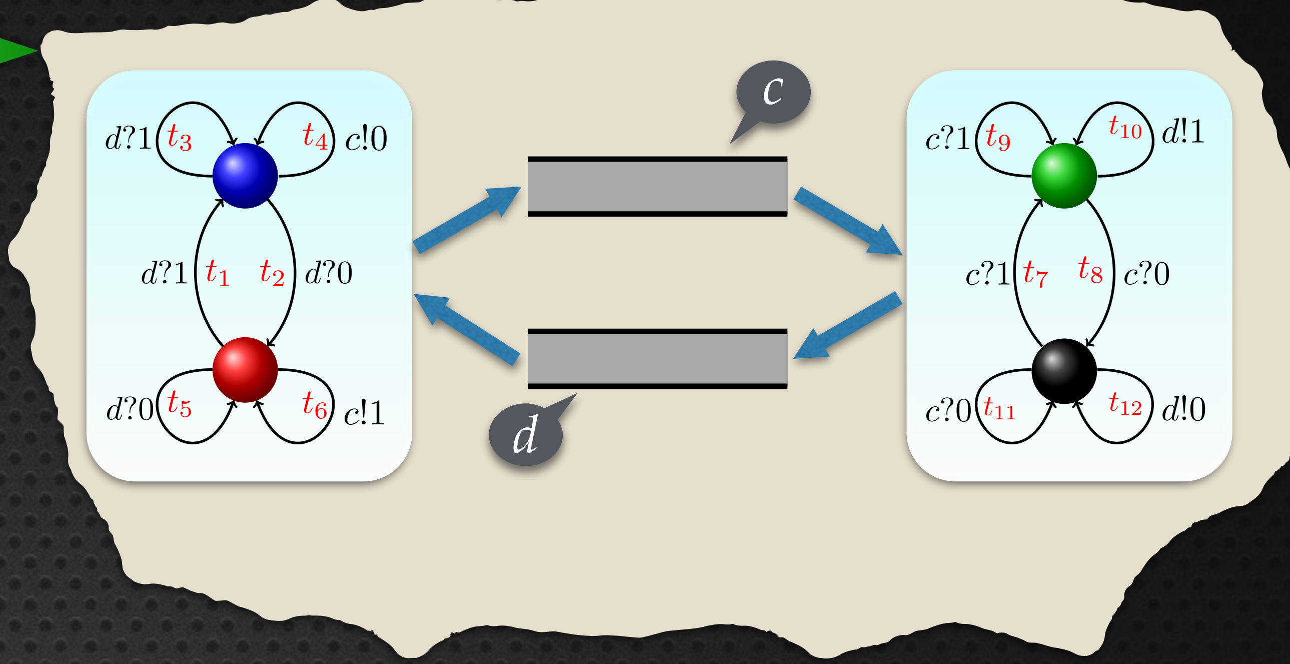
Lossy Predecessors

Monotonicity: UC persevered by *Pre*

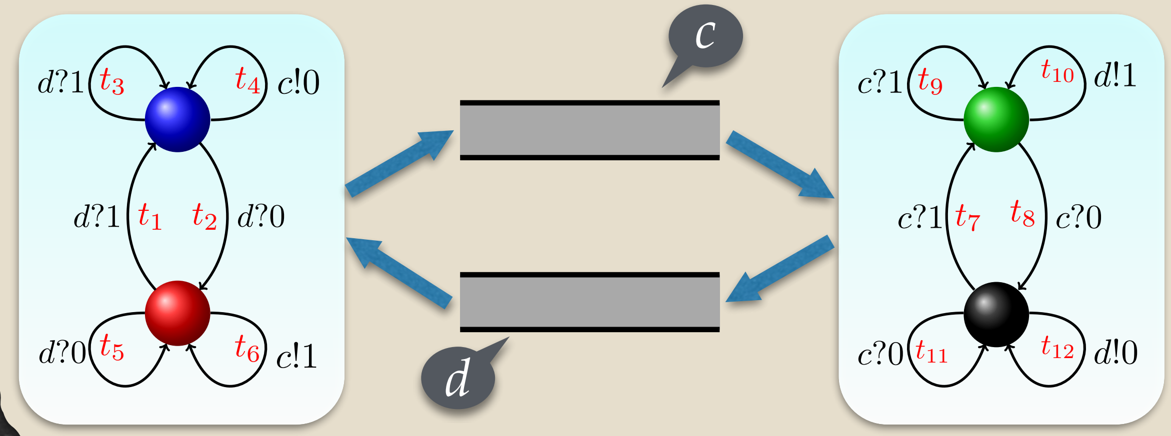




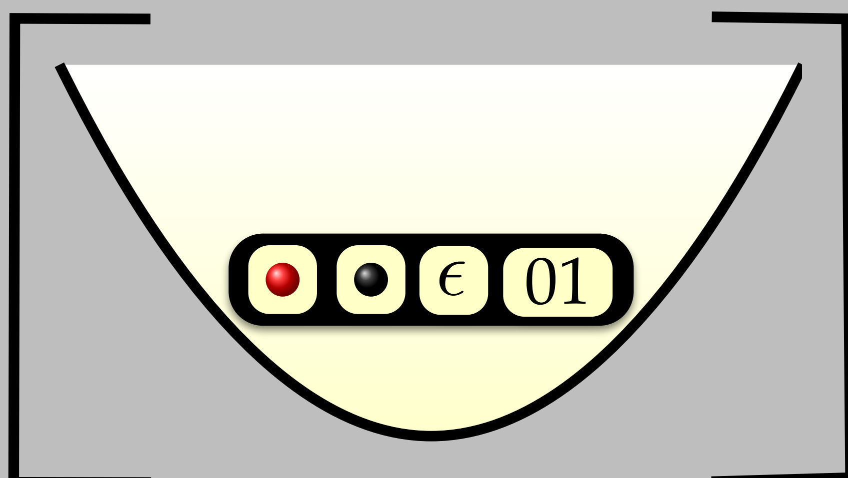
Lossy Computing Predecessors



Lossy Computing Predecessors



Pre_{t_2}



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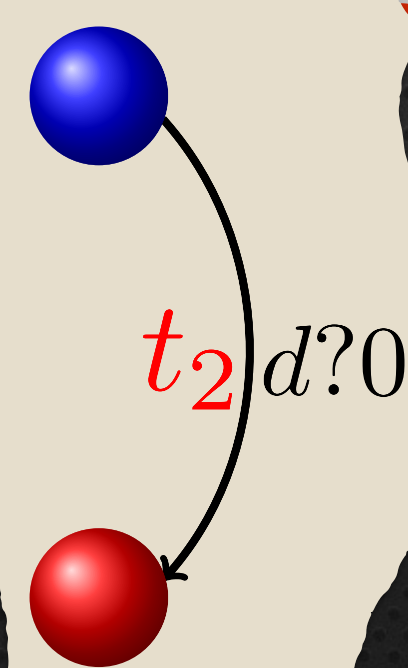
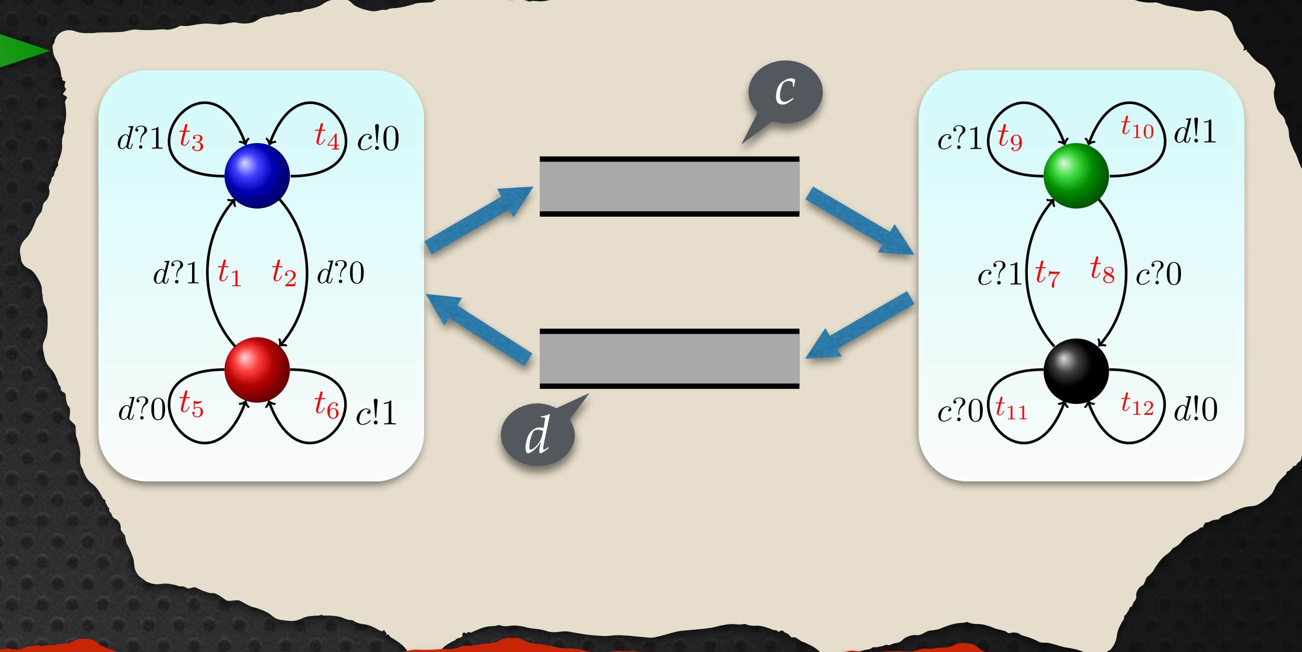
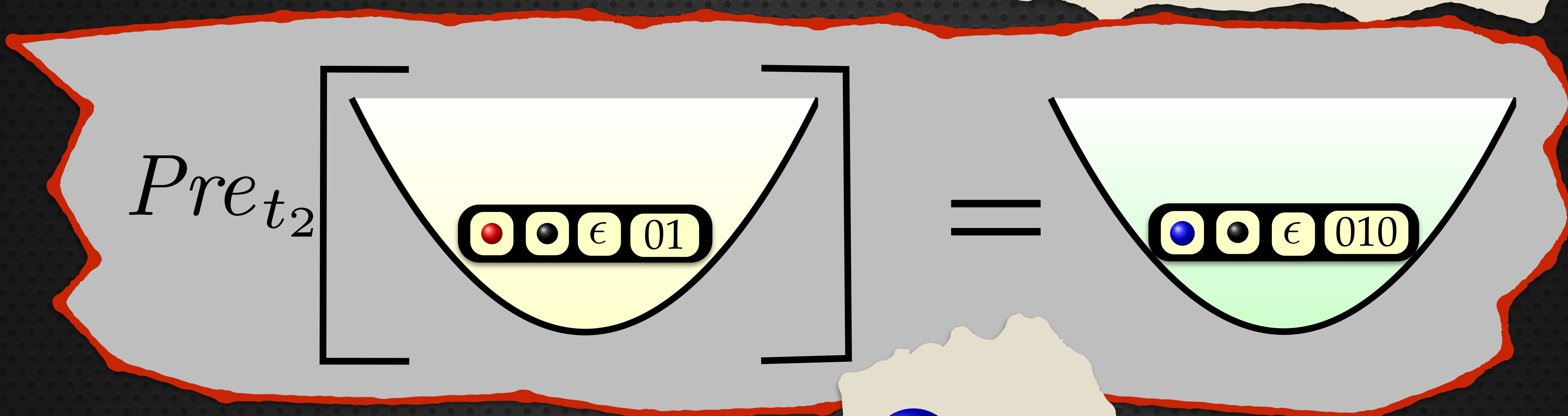
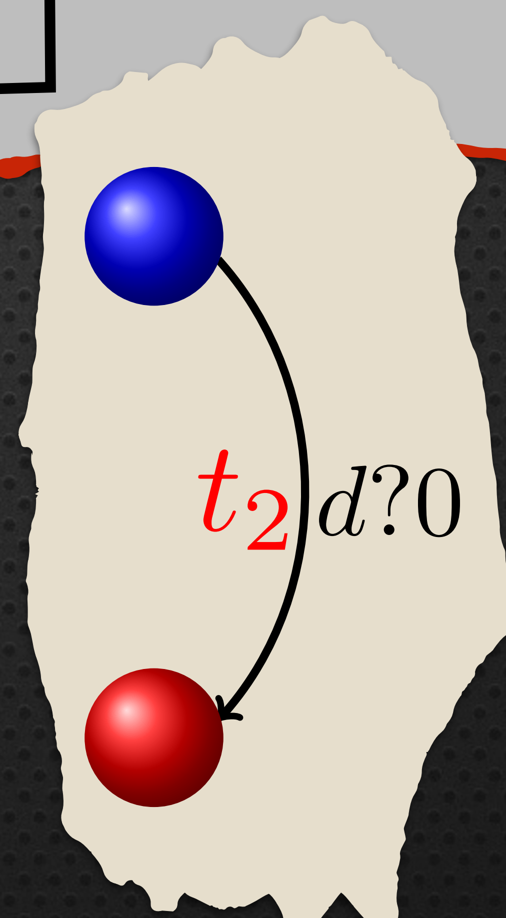


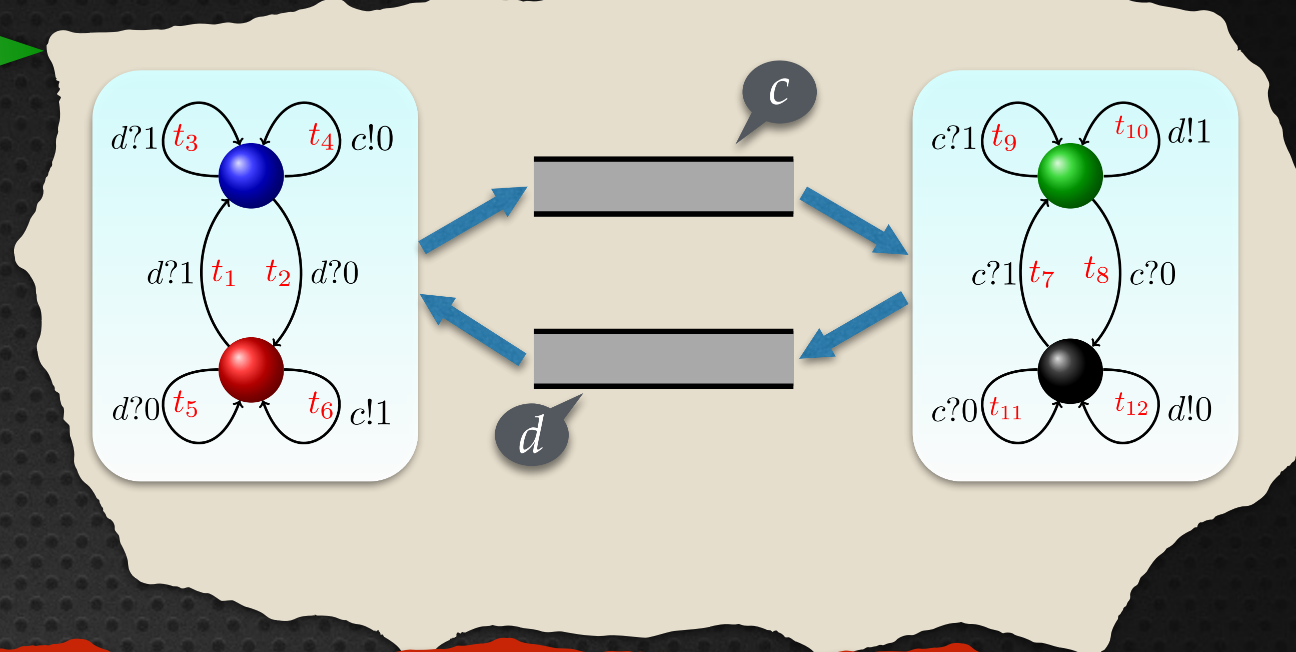
Lossy Computing Predecessors

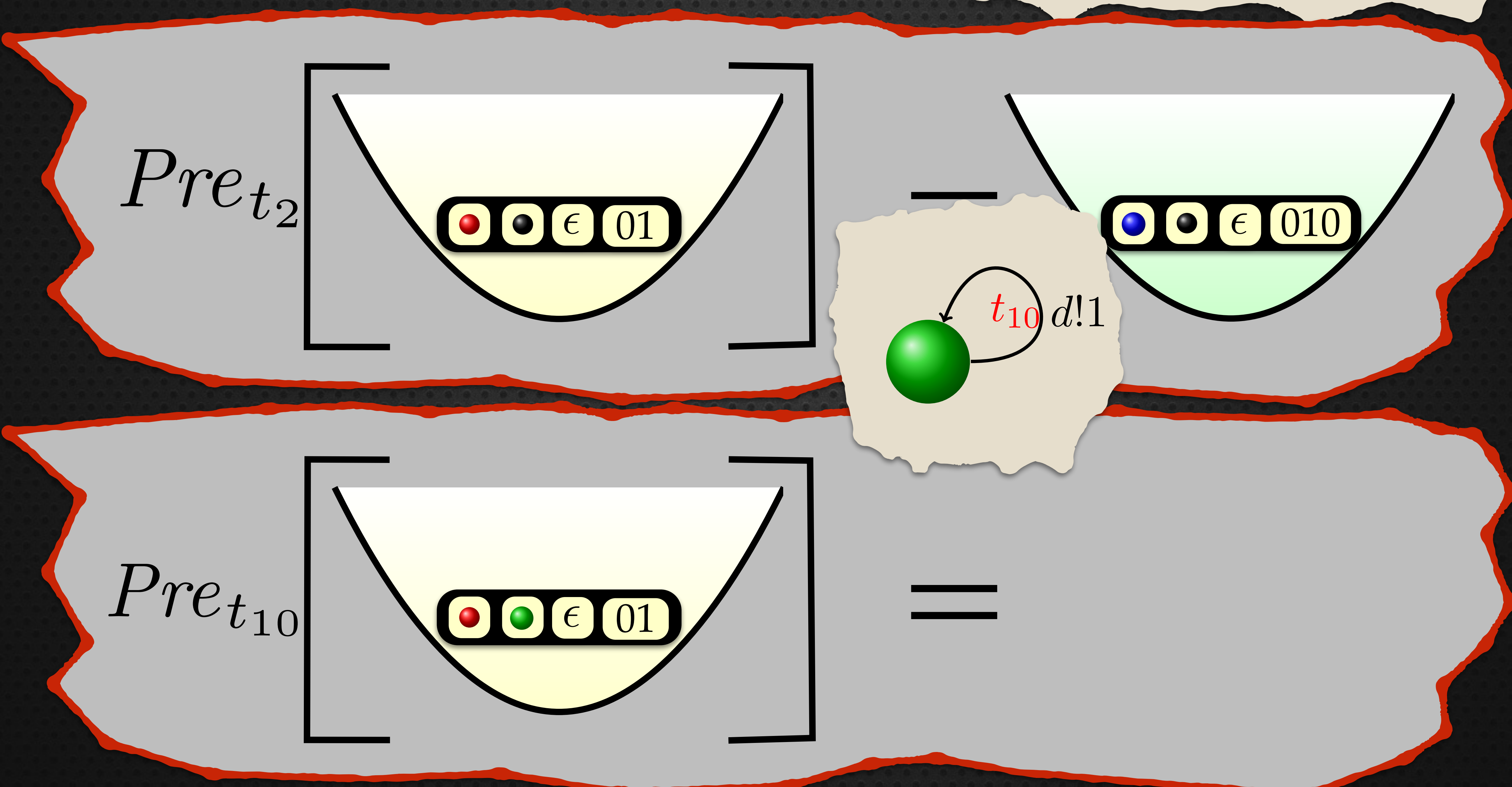




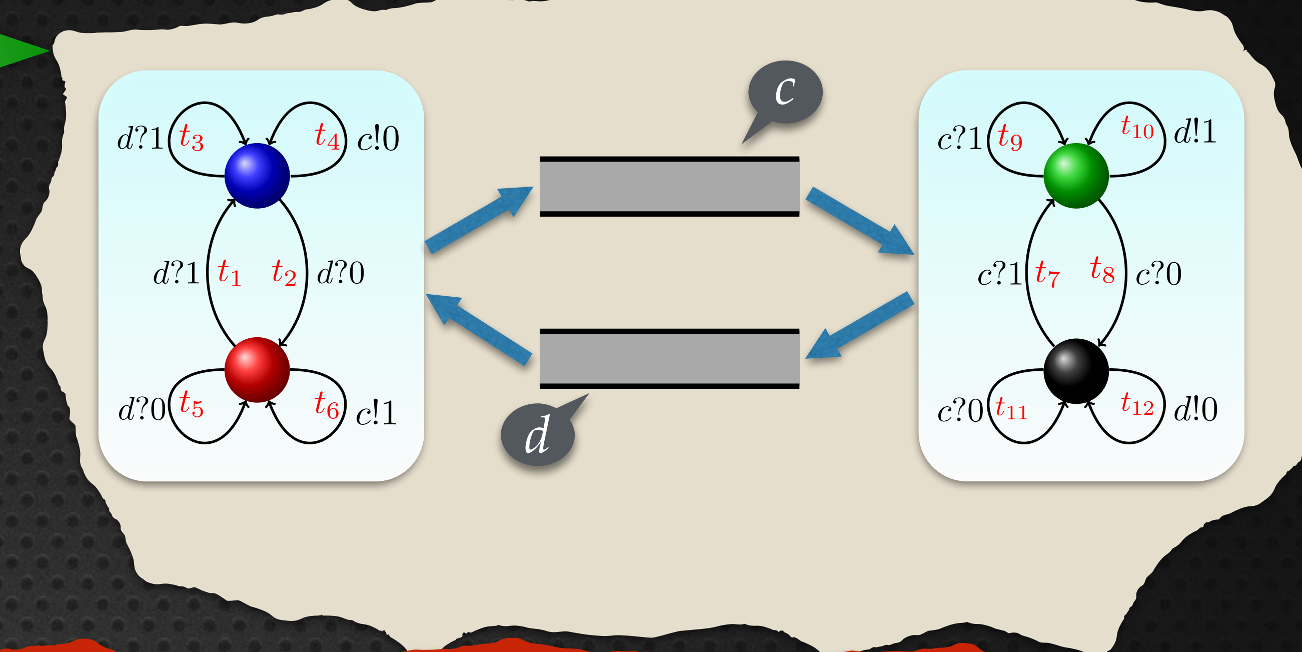


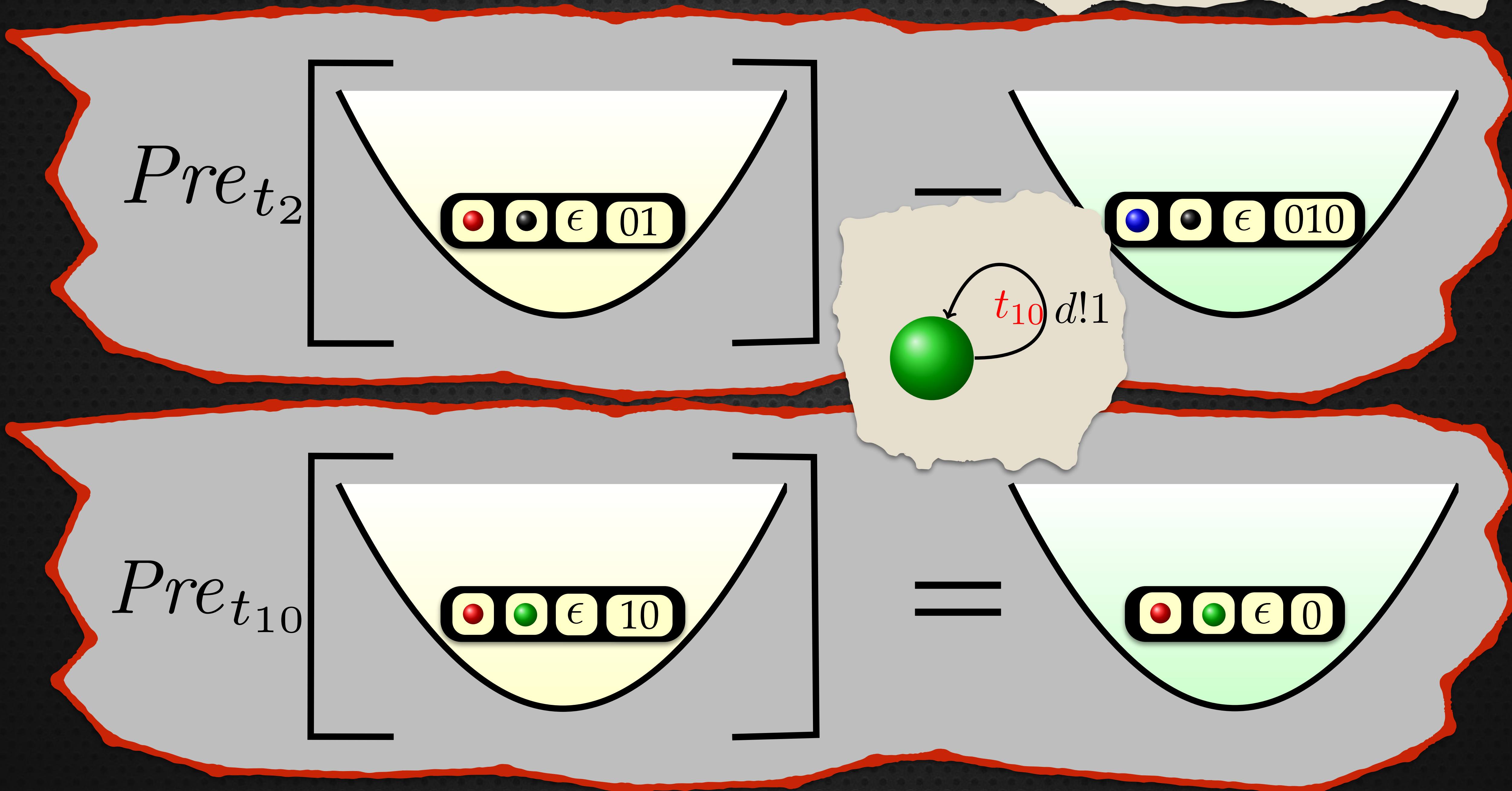
Lossy Computing Predecessors



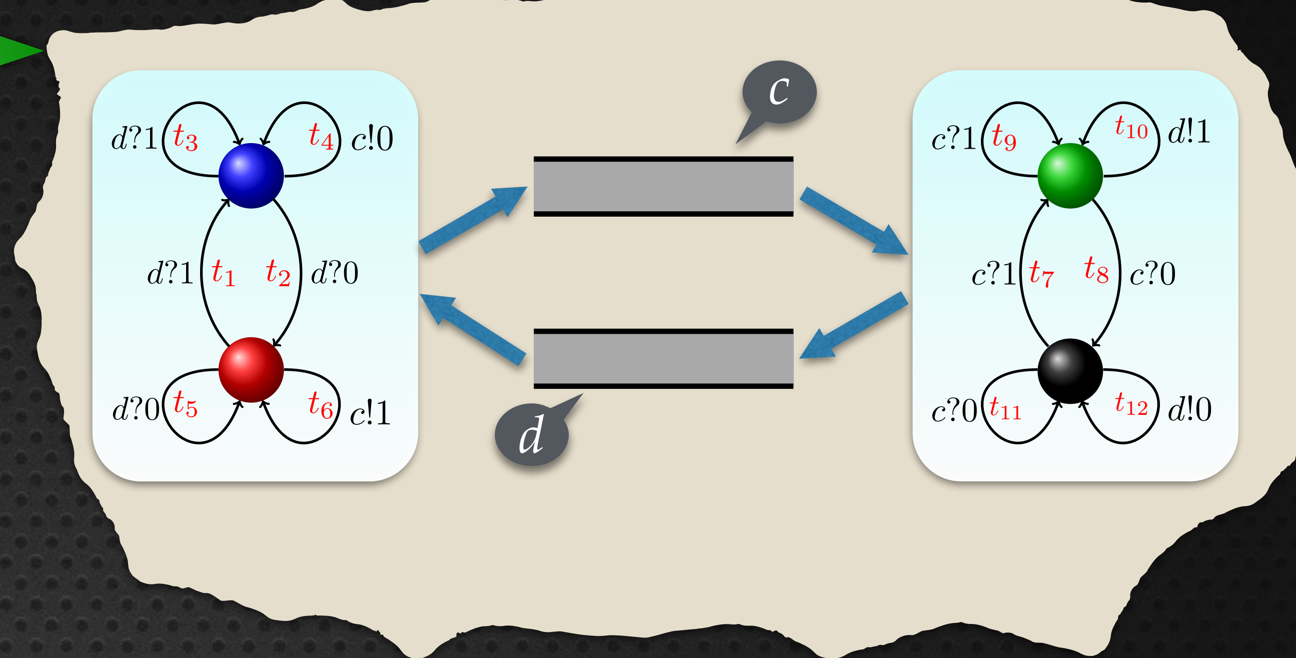


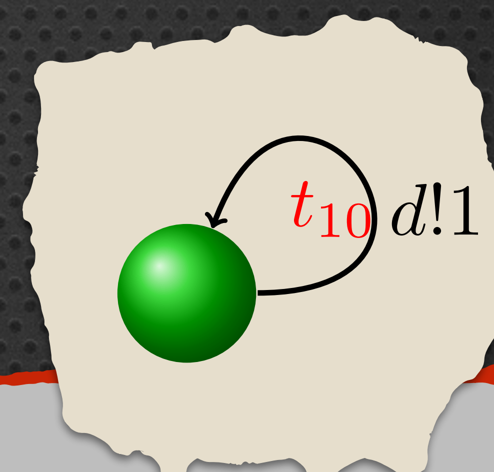
Lossy Computing Predecessors



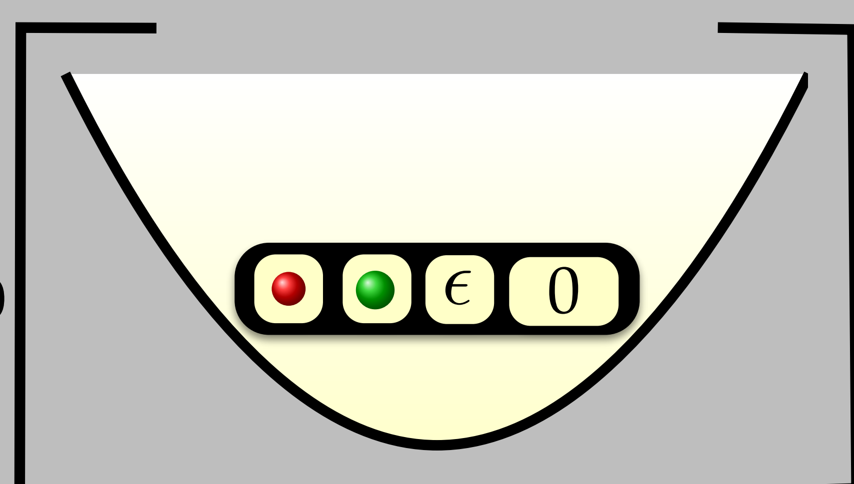


Lossy Computing Predecessors





$Pre_{t_{10}}$



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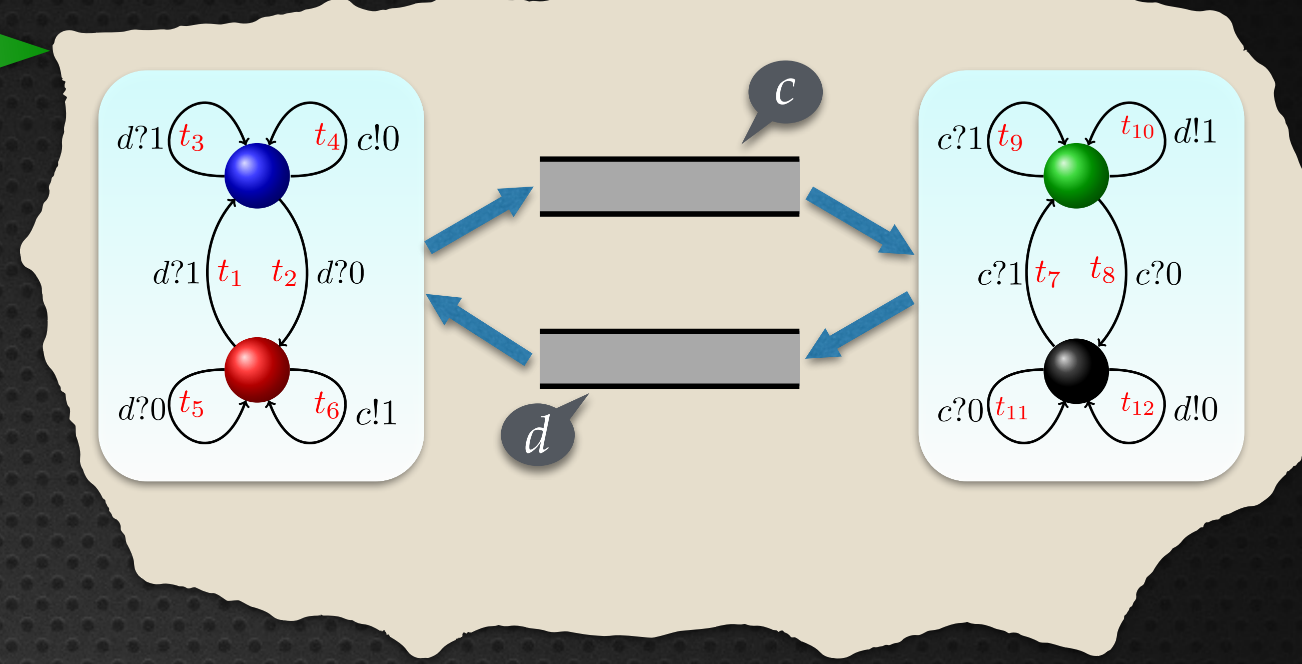
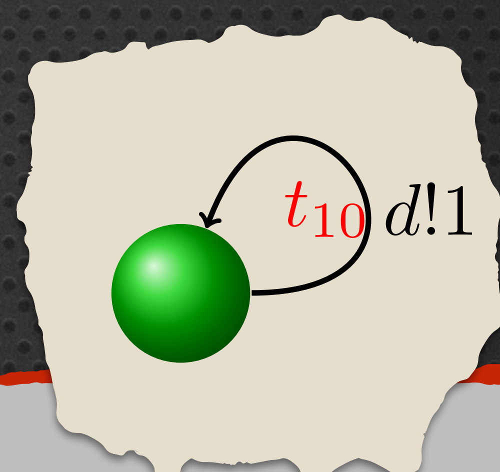
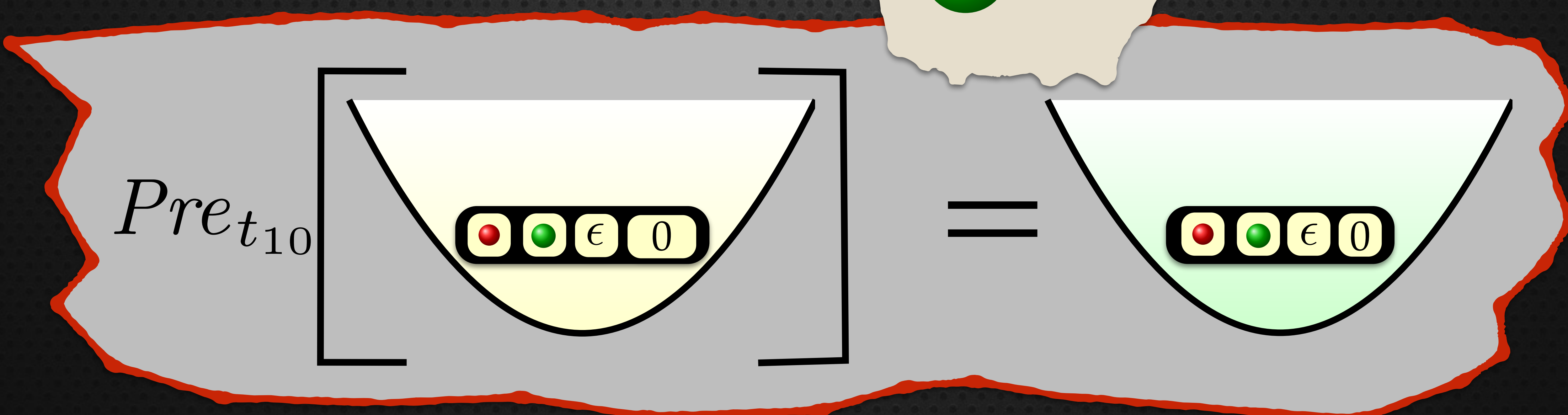
Lossy Computing Predecessors







Lossy Channel Systems

- Model ✓
- Configurations ✓
- Transitions ✓
- Ordering ✓
- Monotonicity ✓
- Upward Closed Sets ✓
- Computing Predecessors ✓
- Backward Reachability

Lossy Channel Systems

✓ Model

✓ Configurations

✓ Transitions

✓ Ordering

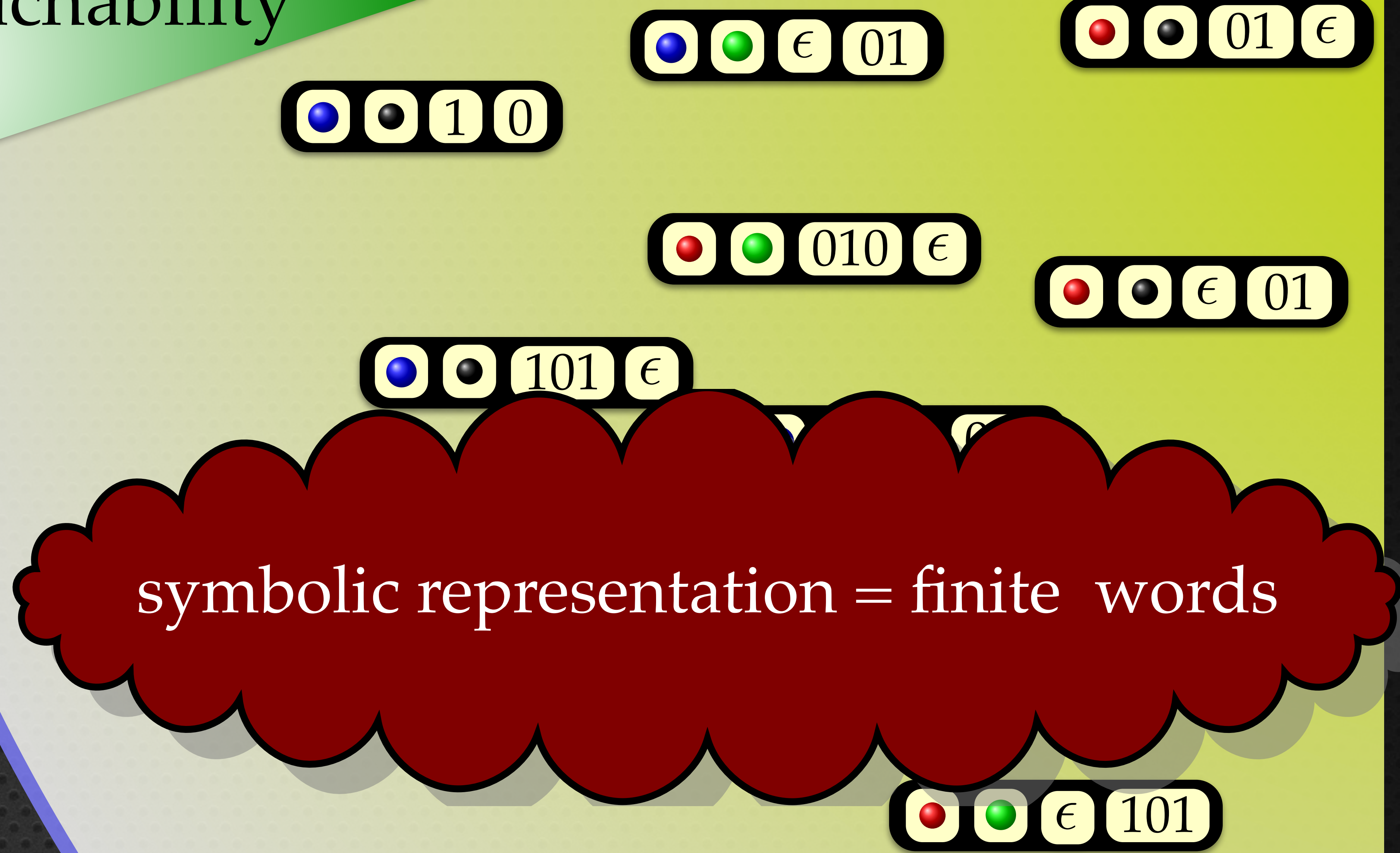
✓ Monotonicity

✓ Upward Closed Sets

✓ Computing Predecessors

Backward Reachability

Lossy Backward Reachability



Lossy Backward Reachability

symbolic representation = finite words

Termination: words well quasi-ordered

Lossy Channel Systems

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Lossy Channel Systems

- Model ✓
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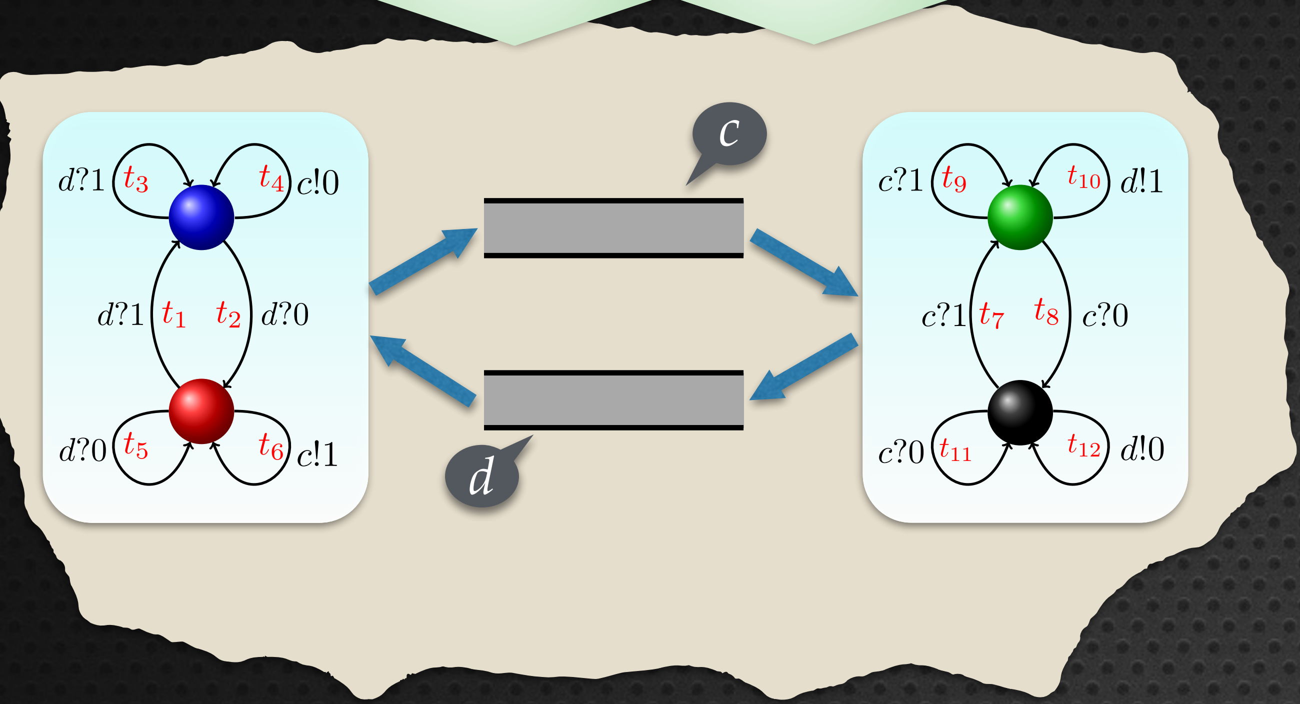
- Monotoncity ✓
- Upward Closed Sets ✓
- Computing Predecessors ✓
- Backward Reachability

Lossy Channel Systems

- ✓ Model
- ✓ Configurations
- ✓ Transitions
- ✓ Ordering
- ✓ Monotoncity
- ✓ Upward Closed Sets
- ✓ Computing Predecessors
- Backward Reachability

a more systematic algorithm

Lossy Backward Reachability



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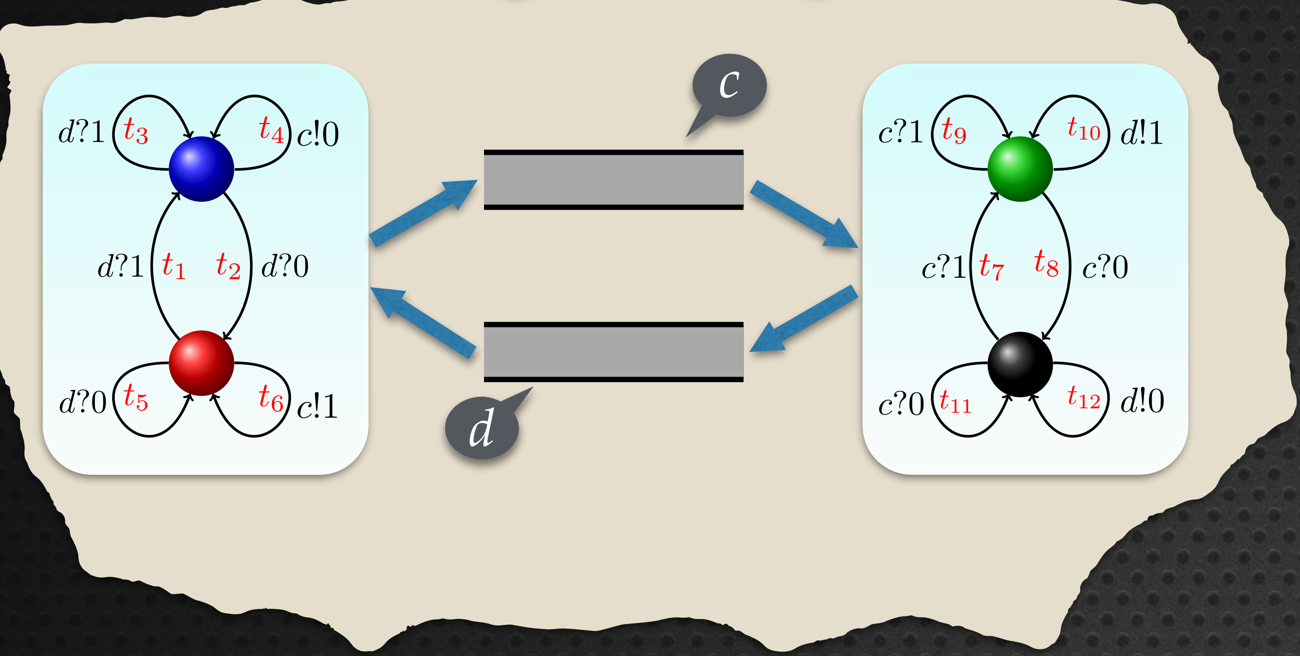
Lossy Backward Reachability



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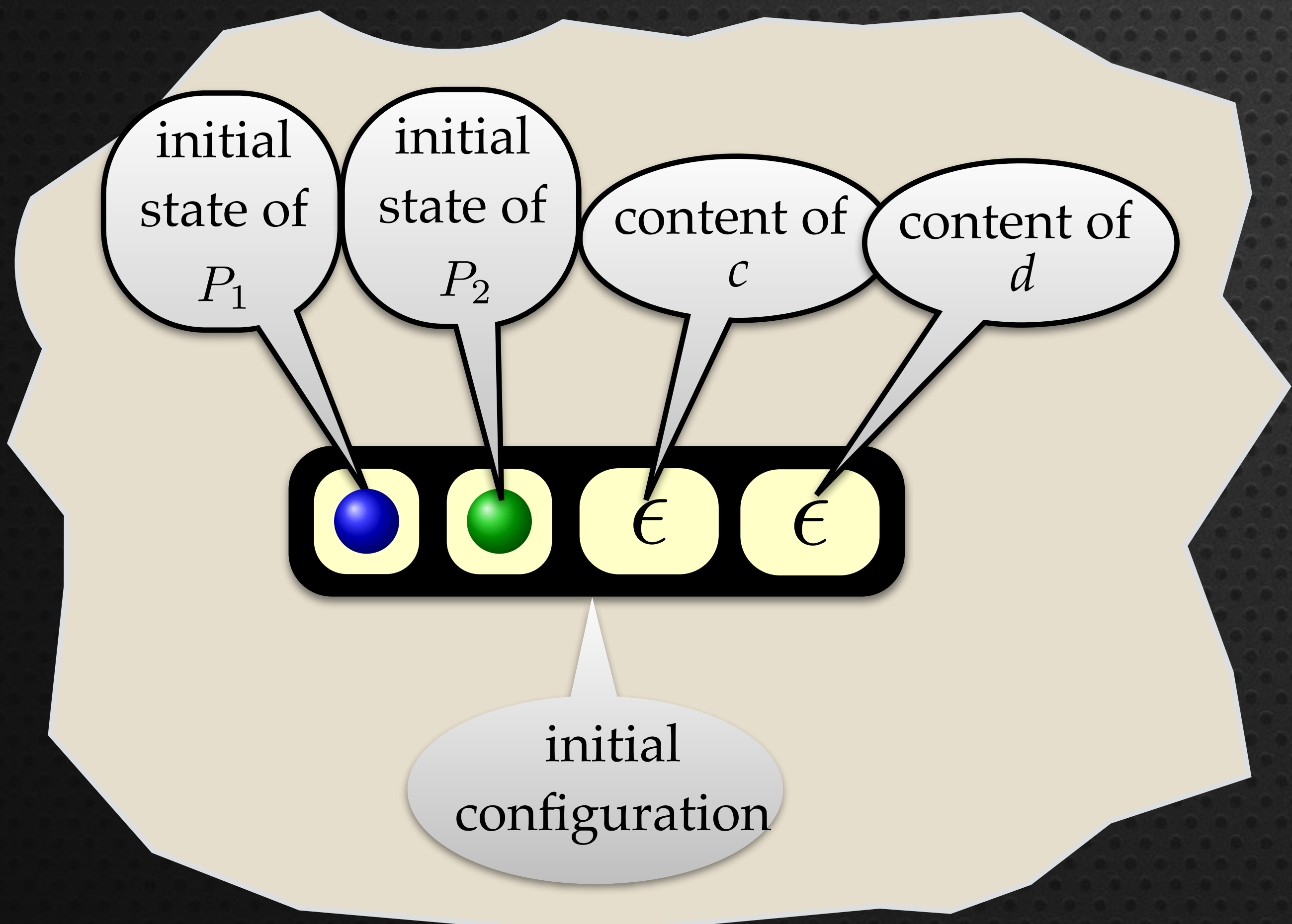
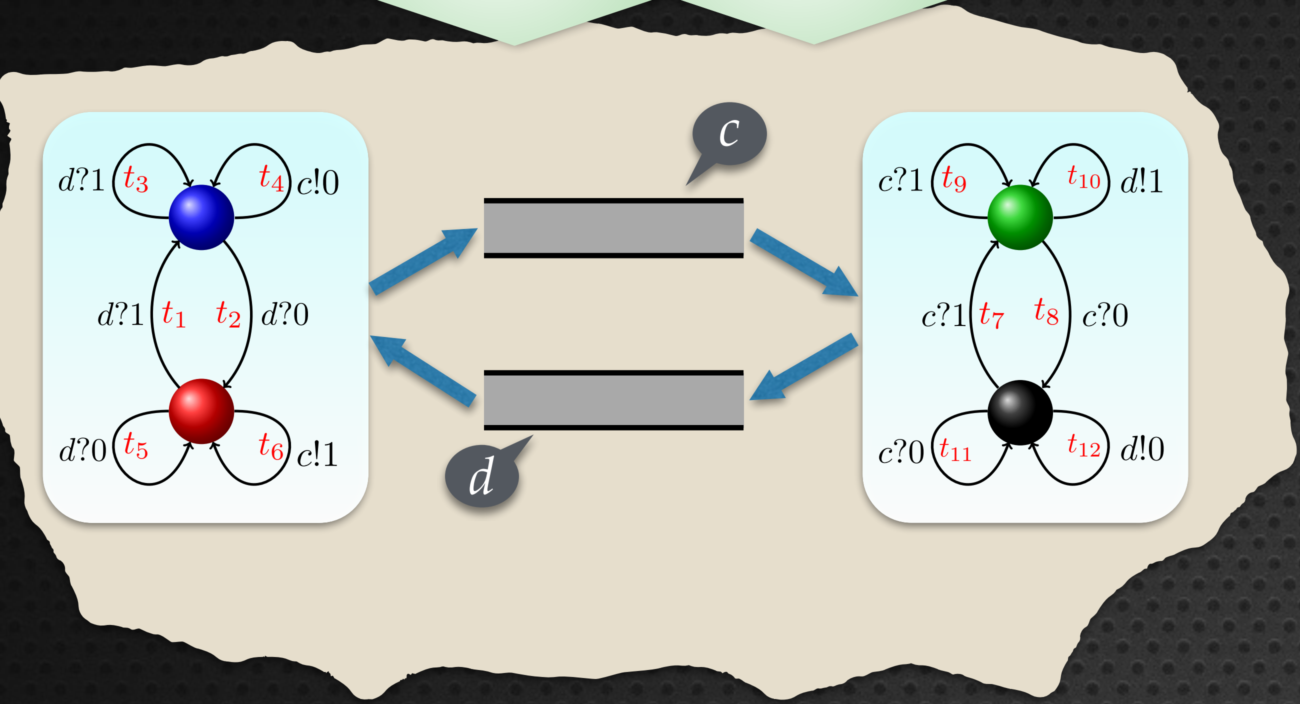
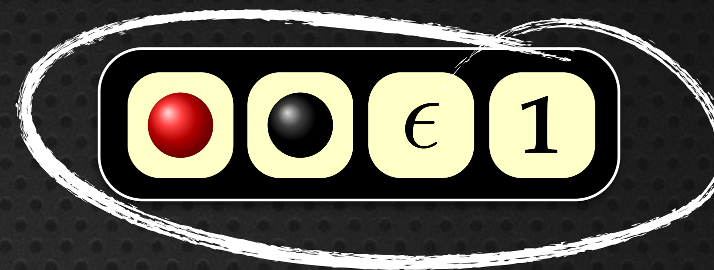
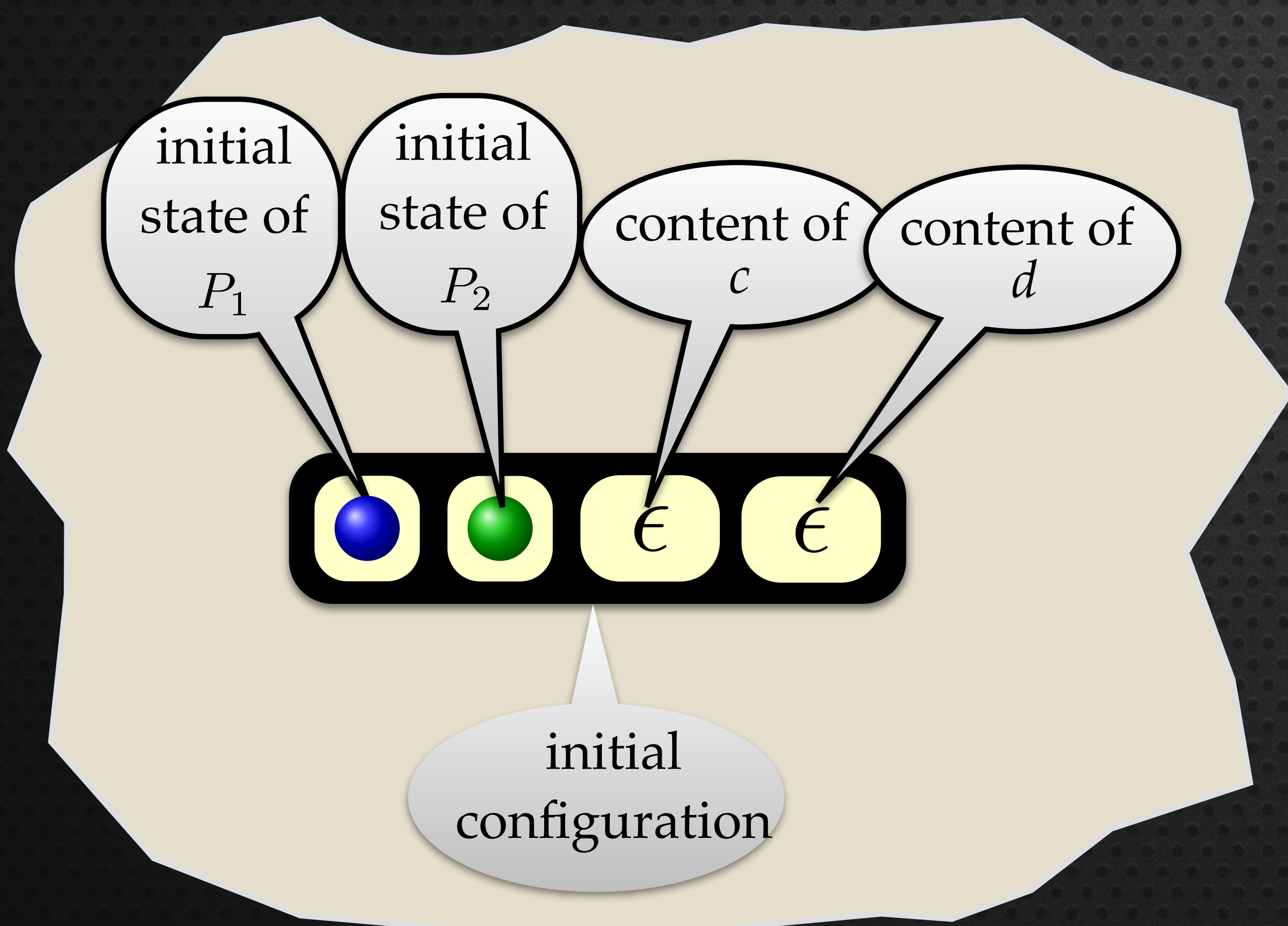


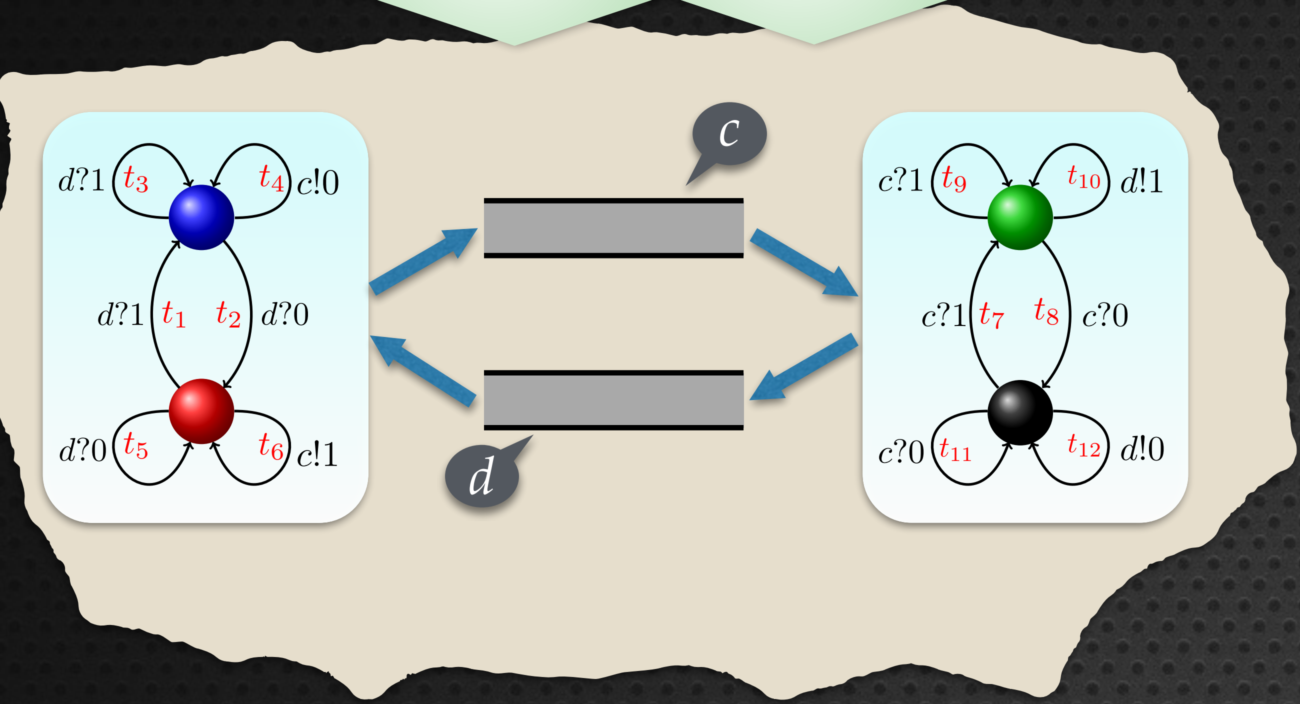
Lossy Backward Reachability

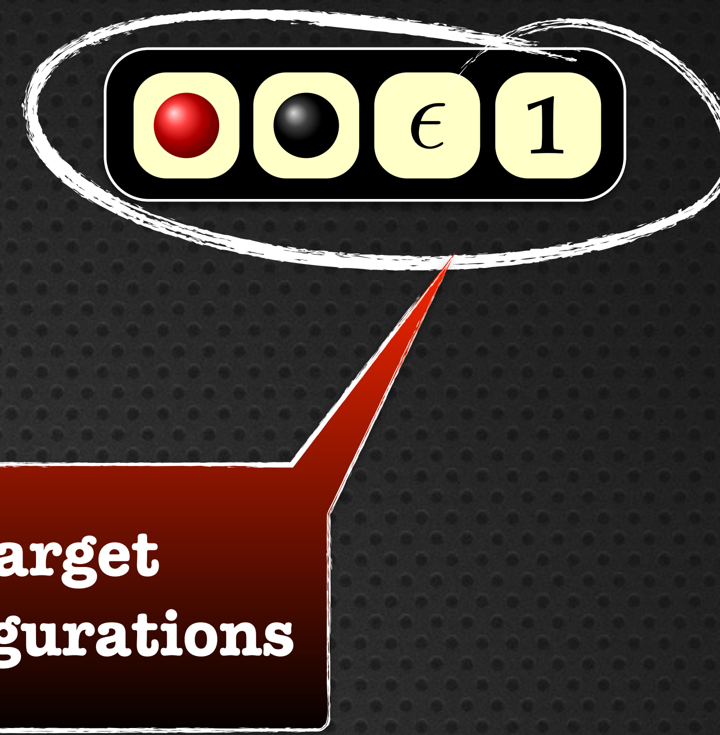


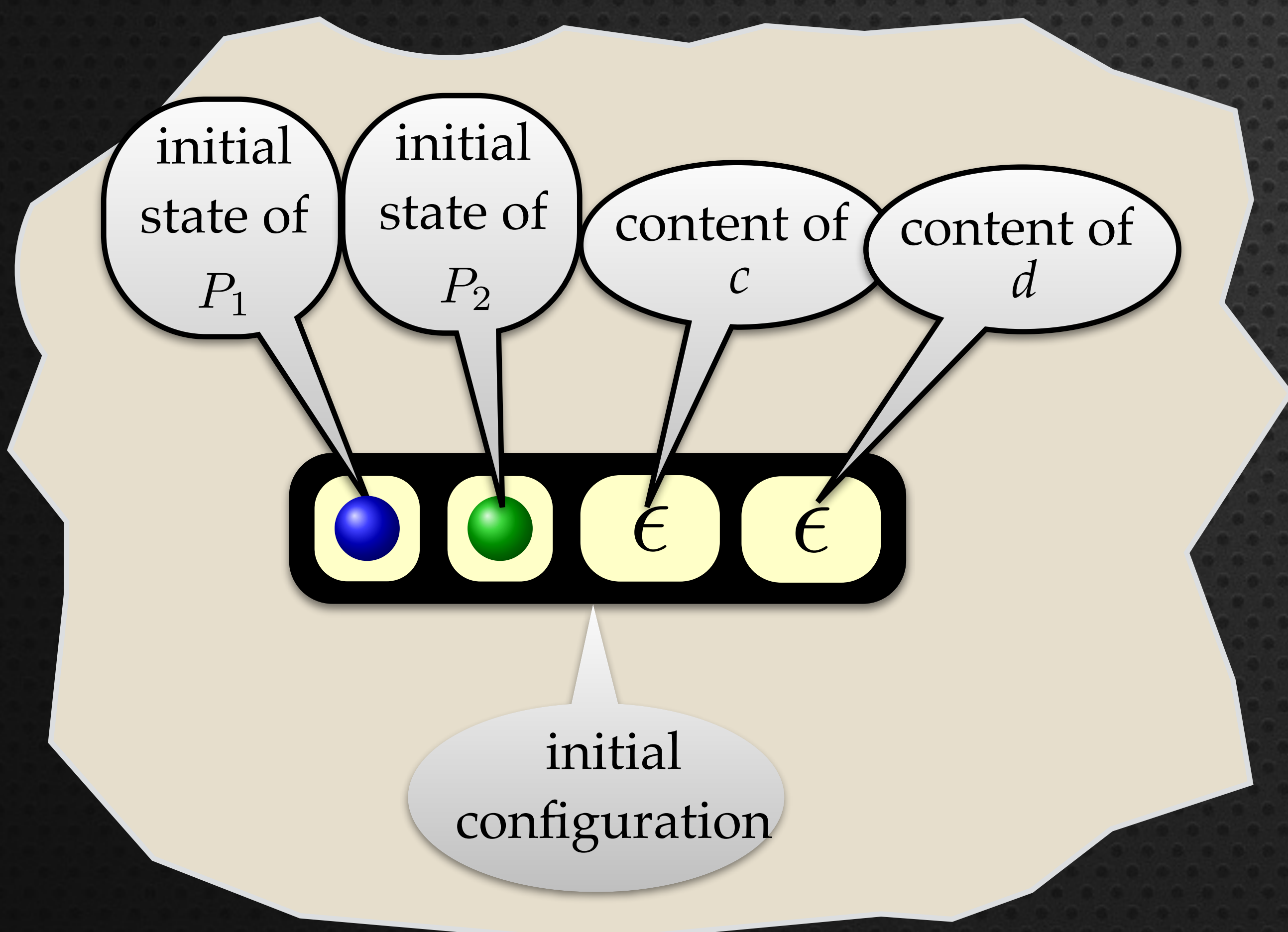




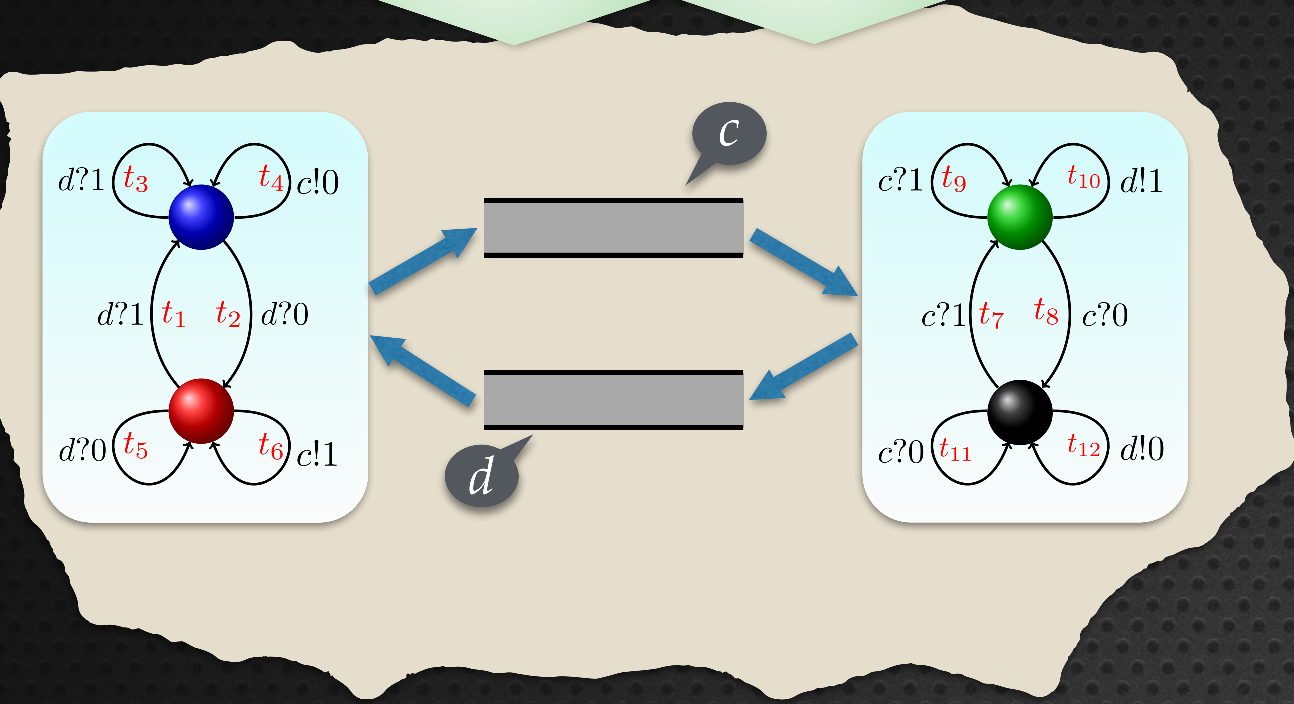
Lossy Backward Reachability

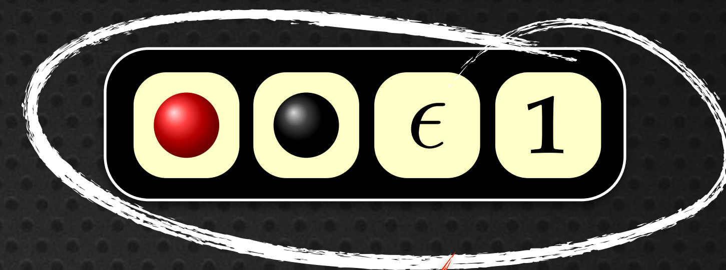






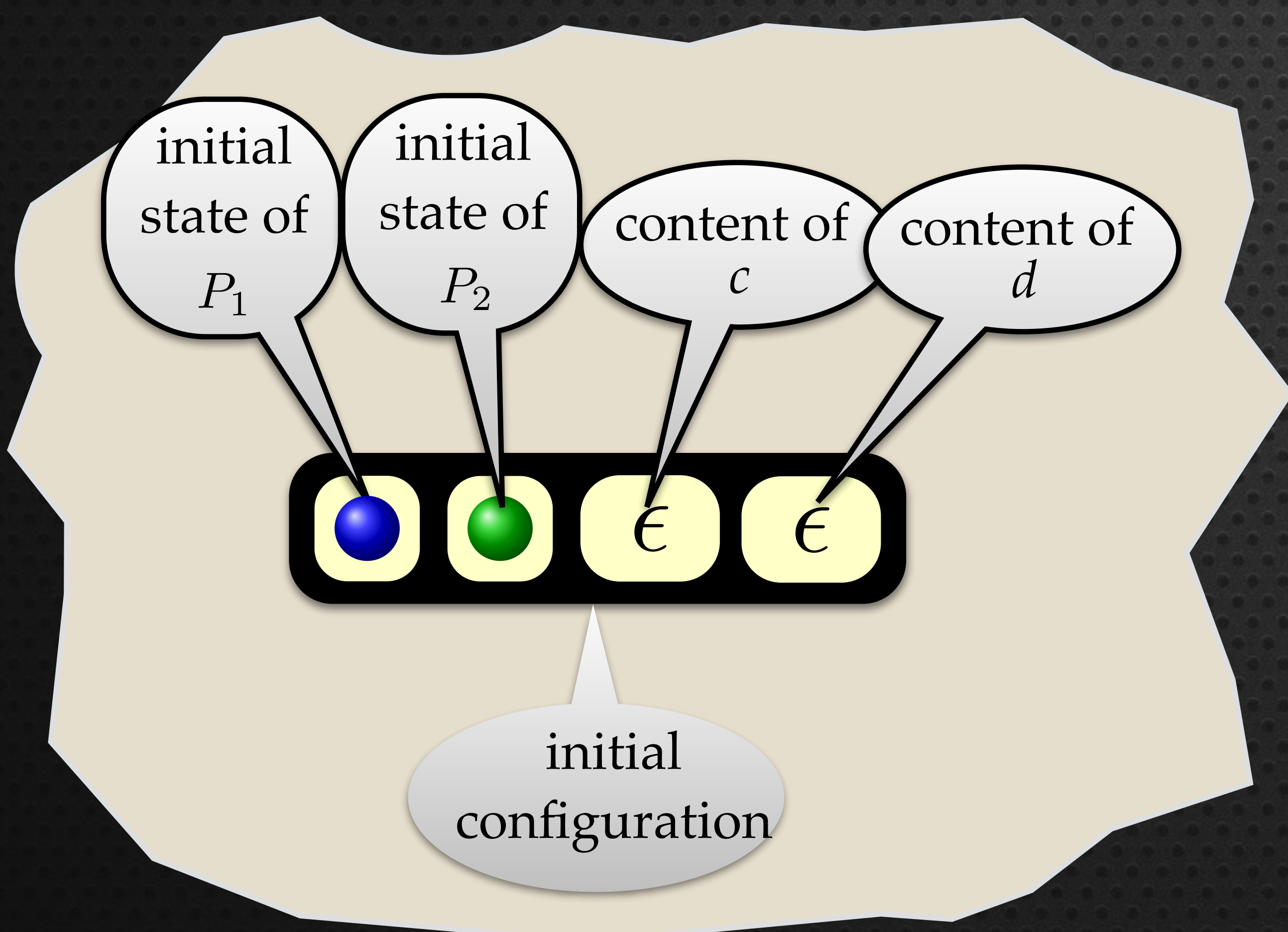
Lossy Backward Reachability



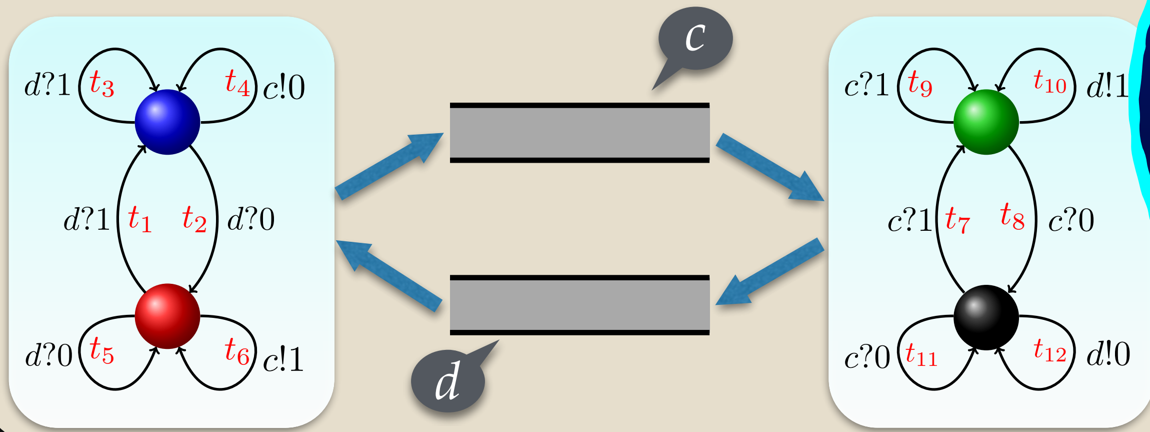


target configurations

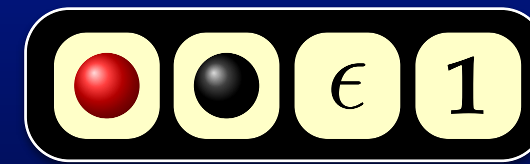
- **processes :**
  - **red and black states**
- **channel c :**
  - **any content**
- **channel d :**
  - **at least a “1”**



Lossy Backward R…bility

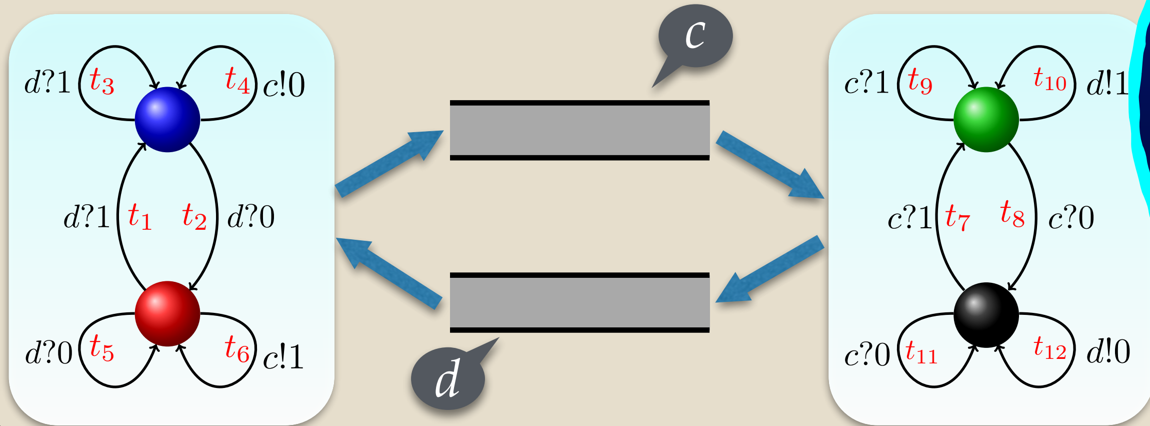


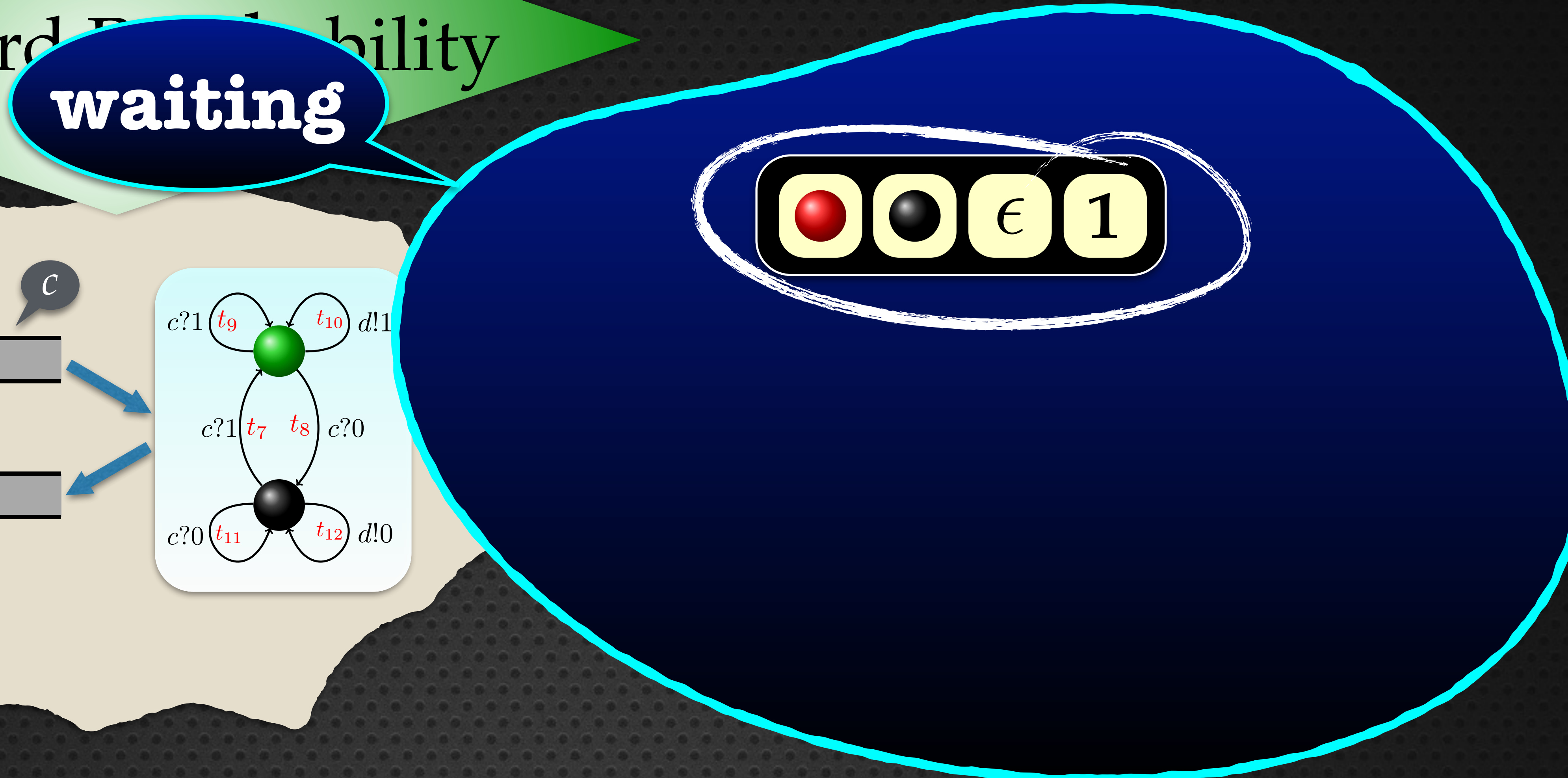
waiting



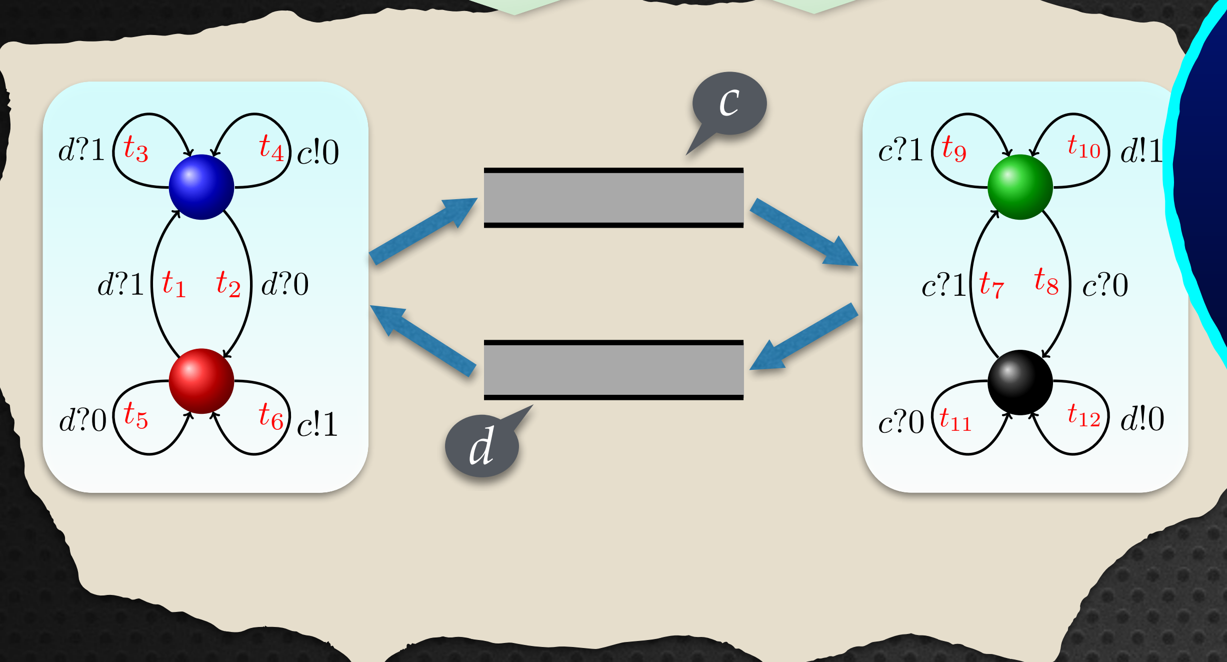
visited

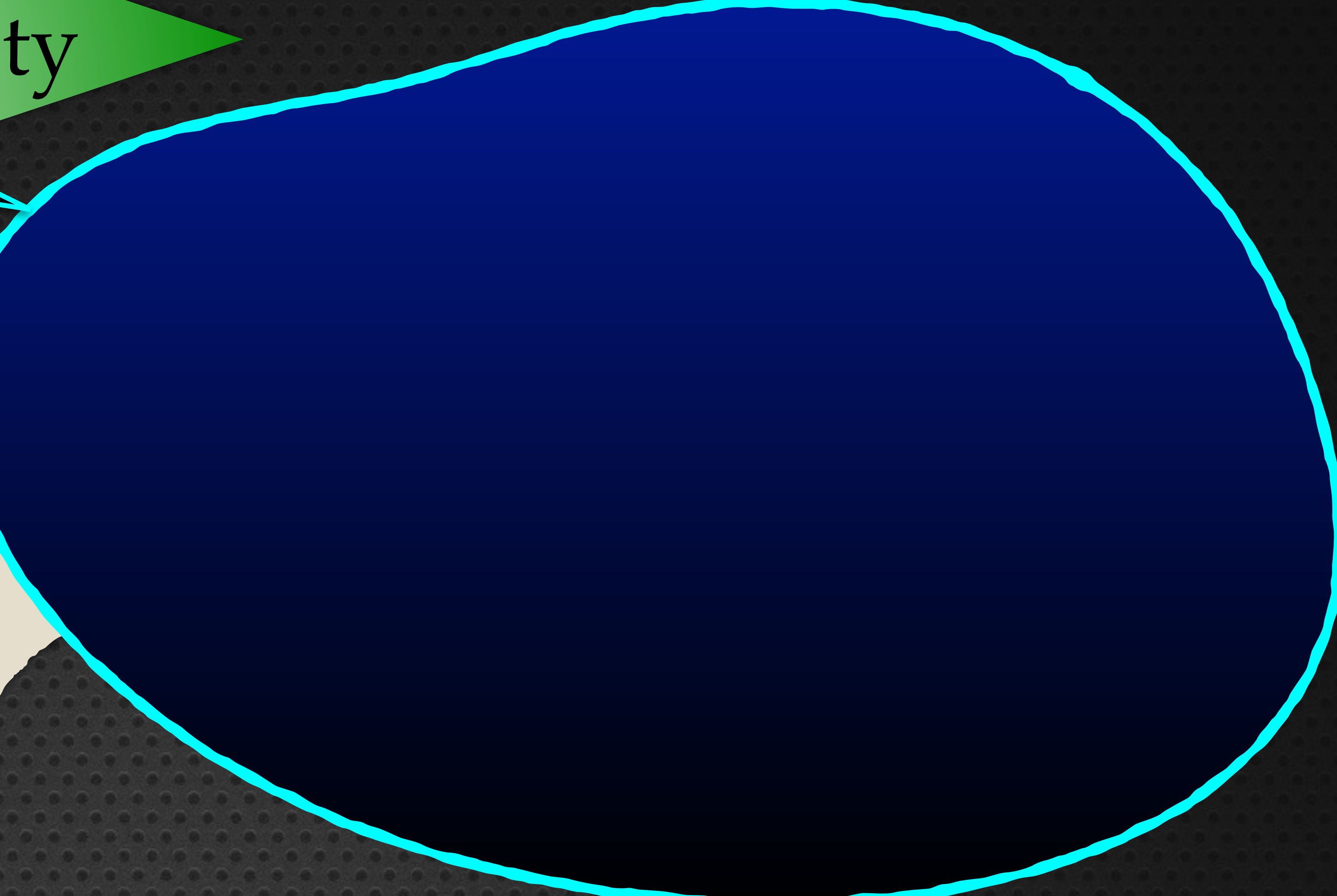
Lossy Backward R bility

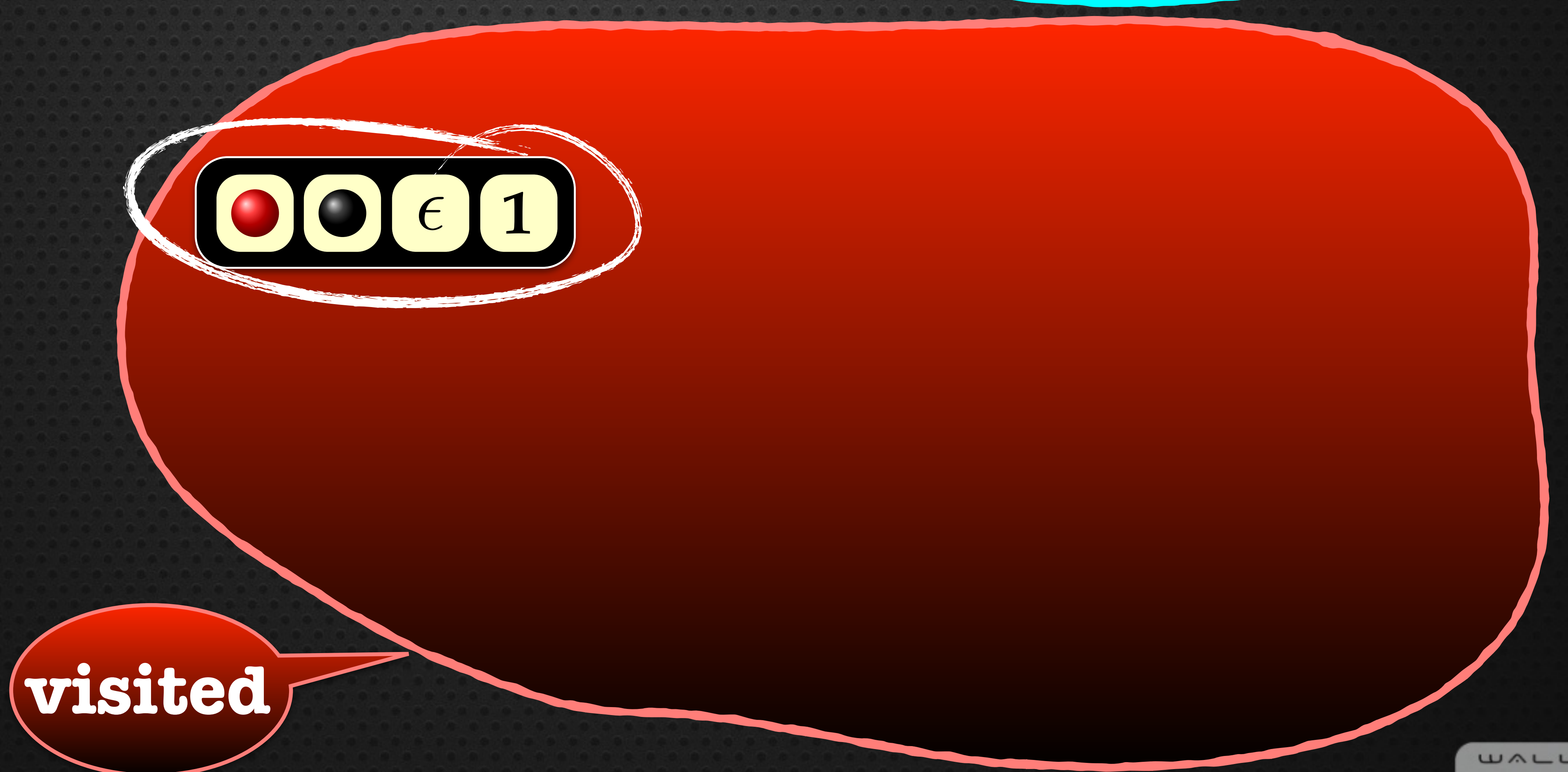




Lossy Backward Reachability

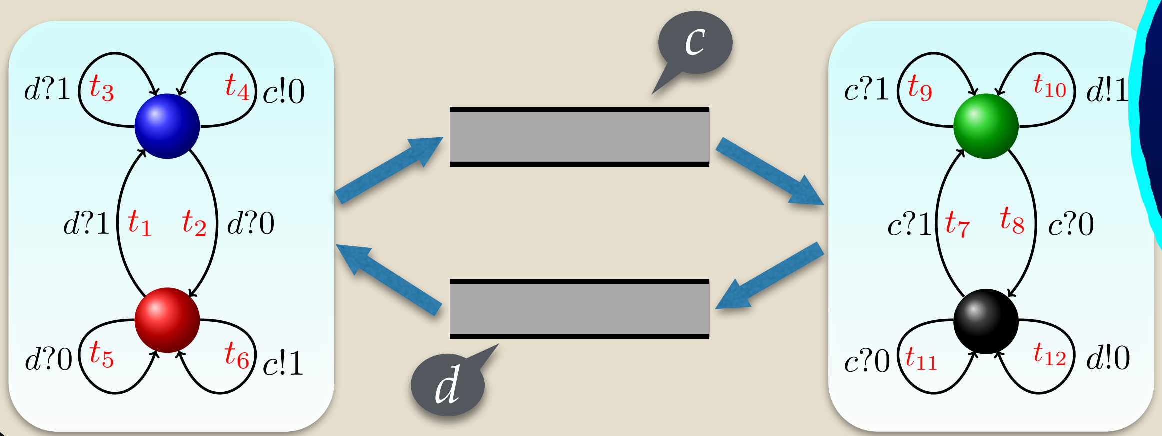


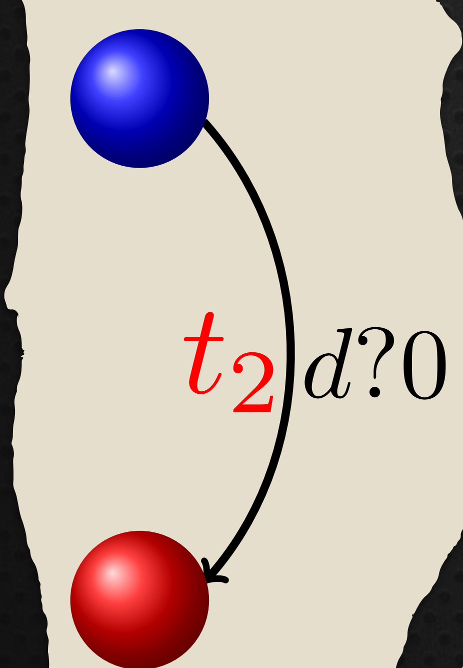




Lossy Backward ... bility

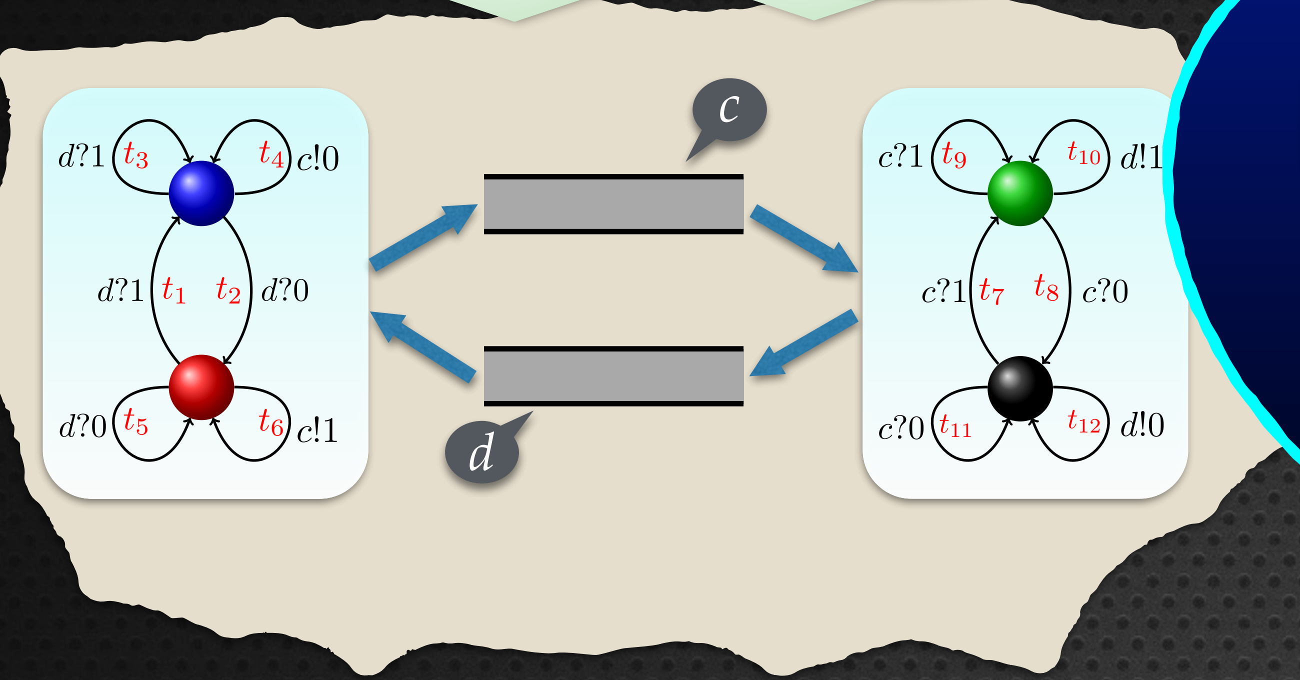
waiting

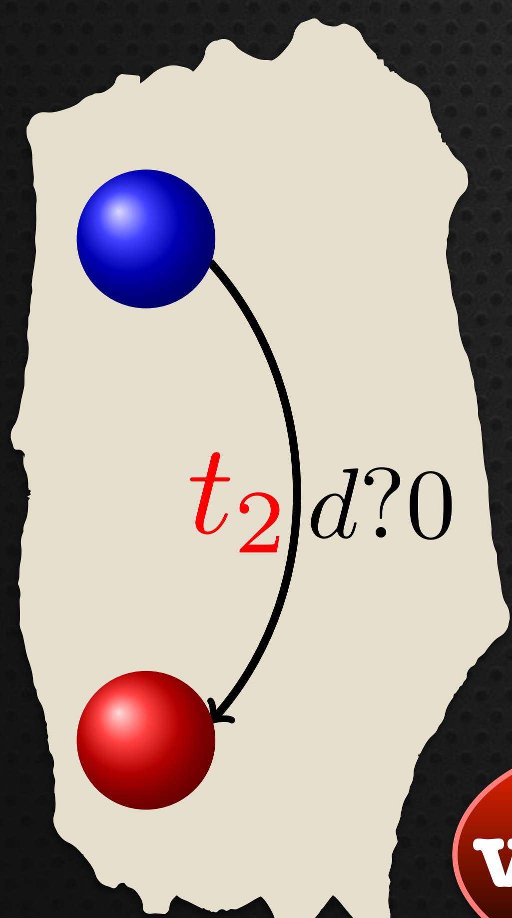


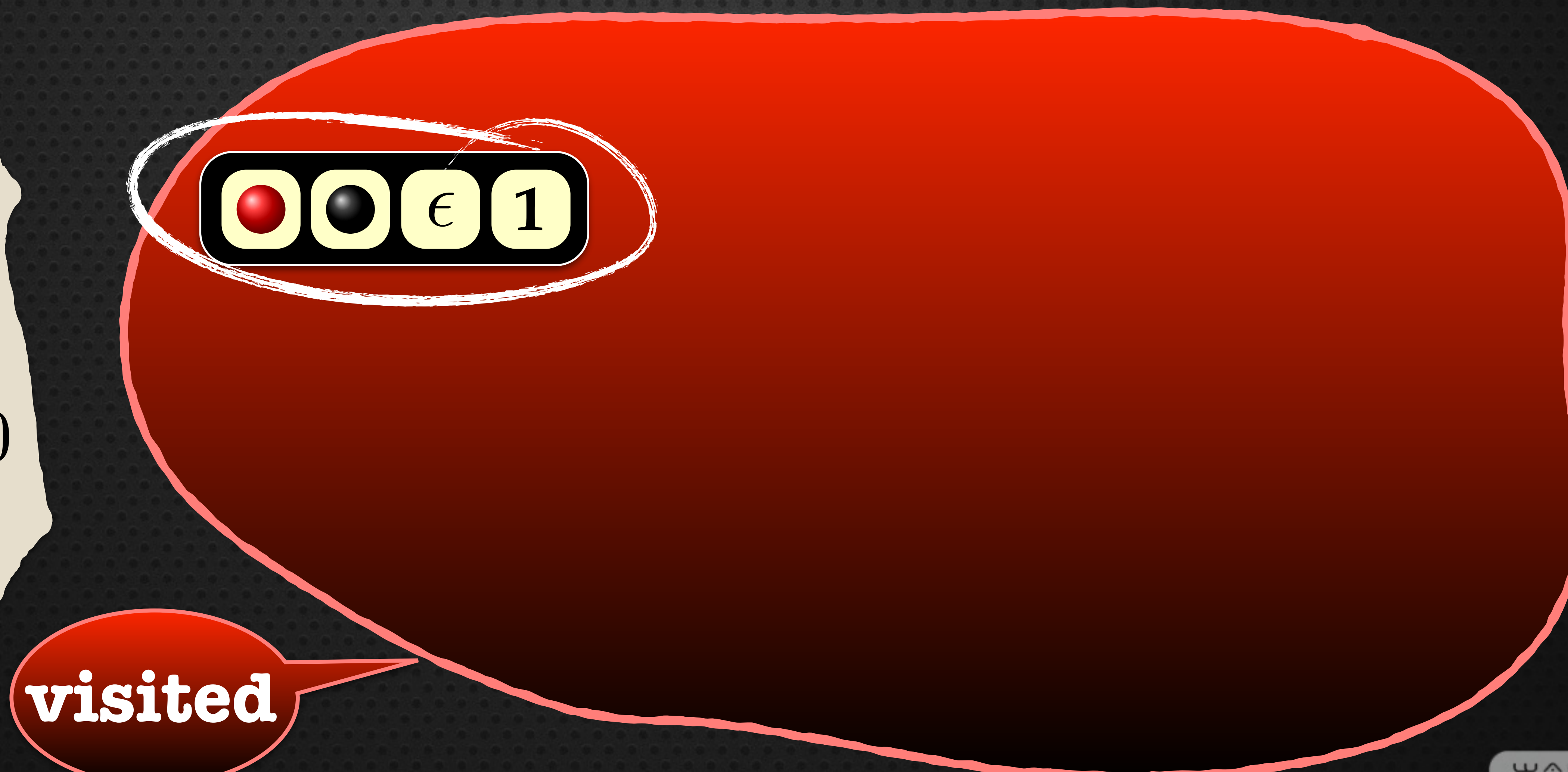


visited

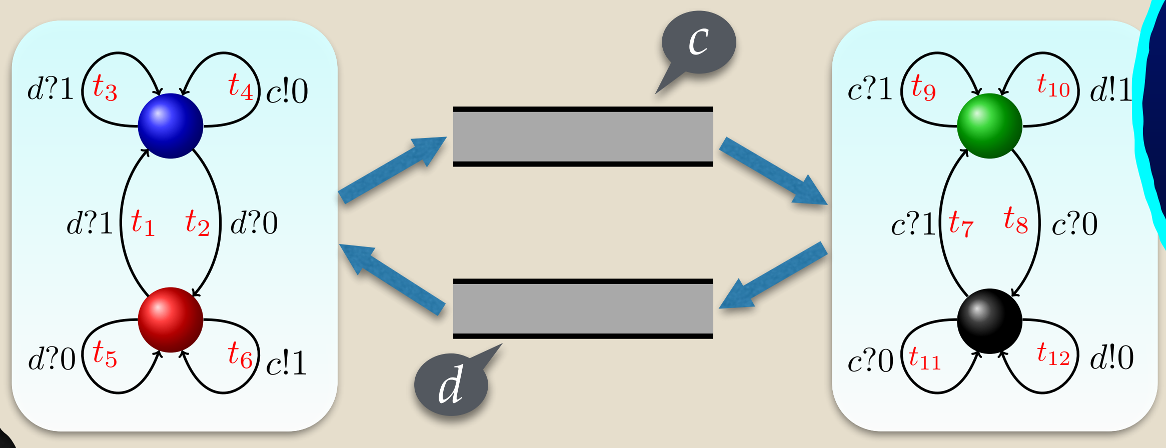
Lossy Backward Reachability

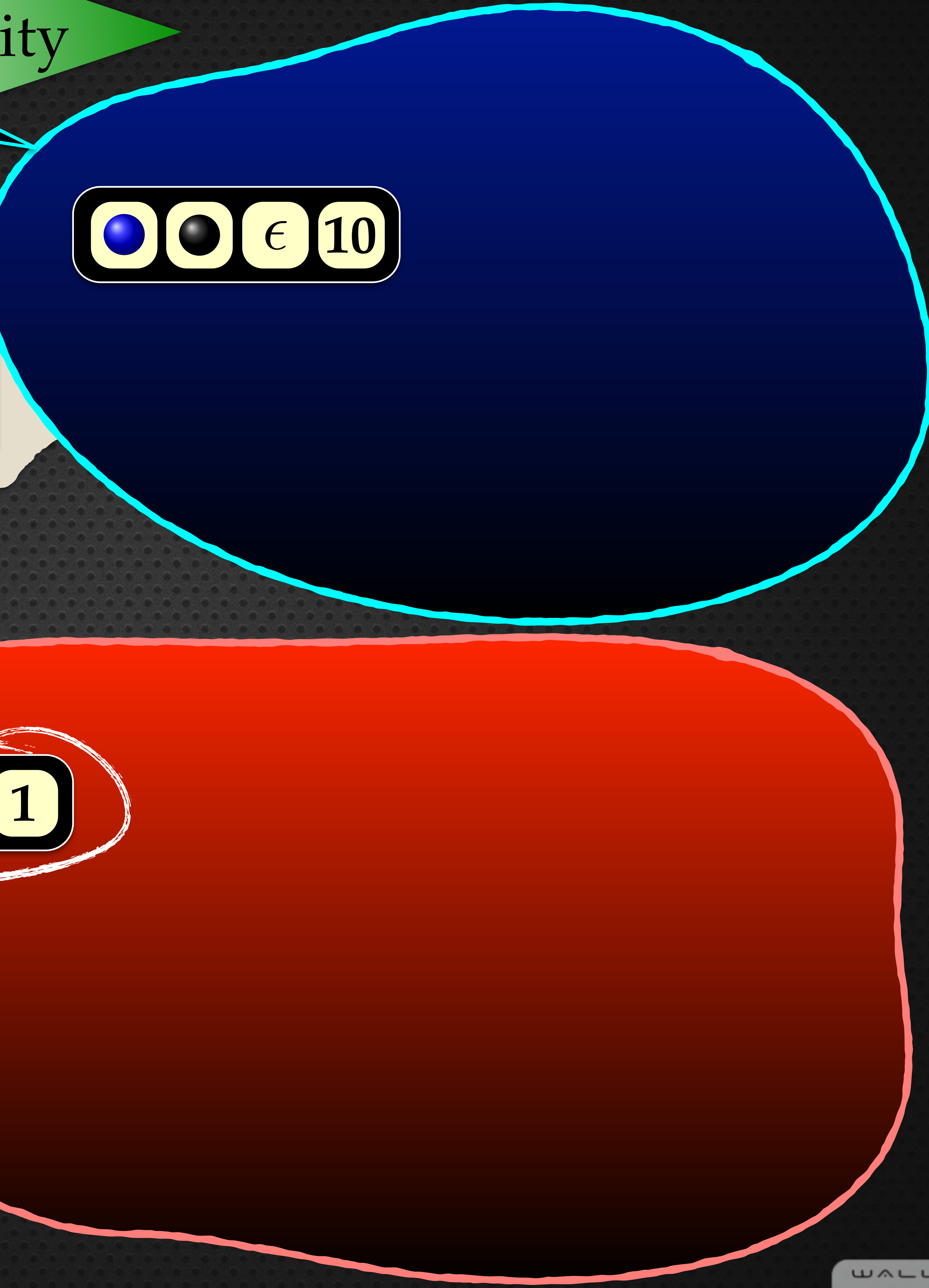


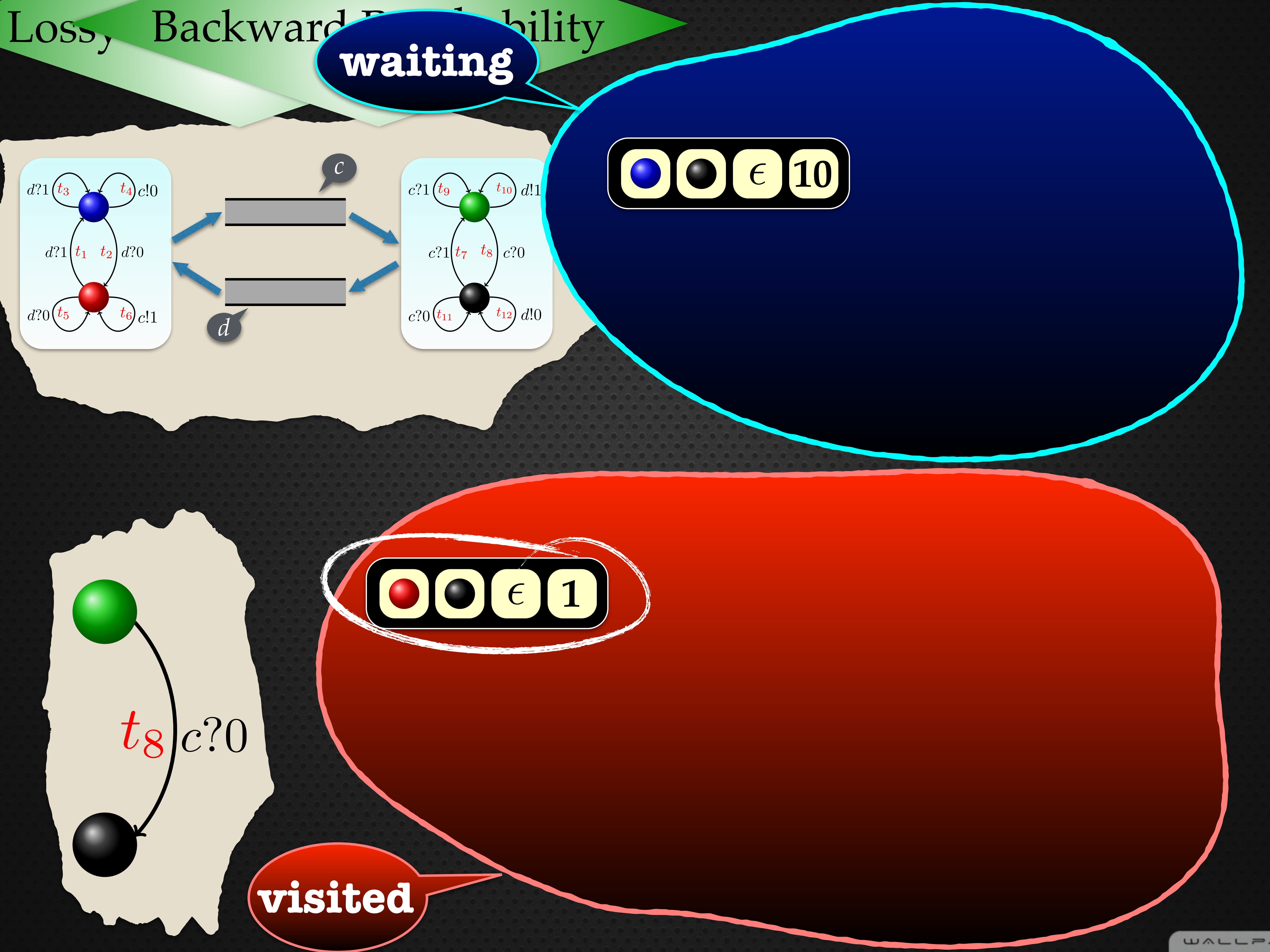




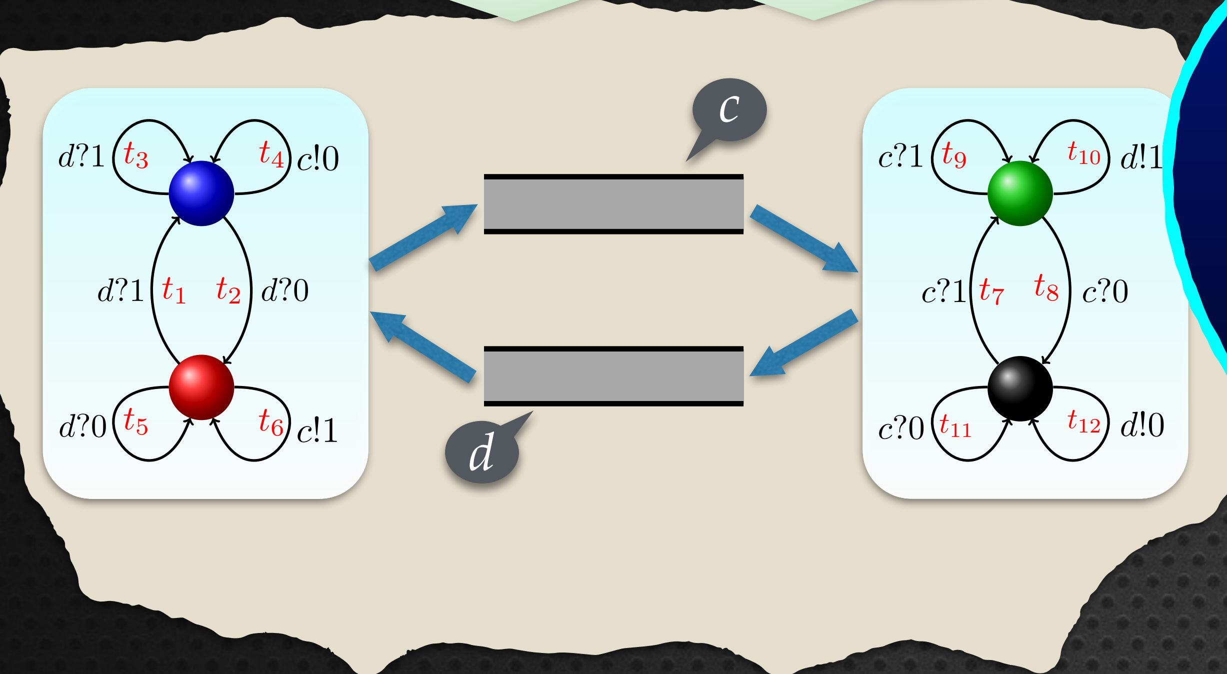
Lossy Backward R… bility

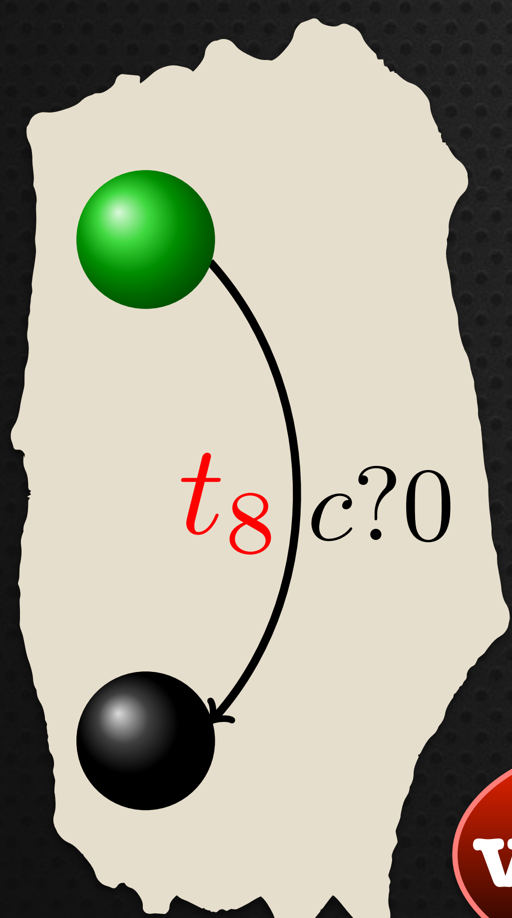


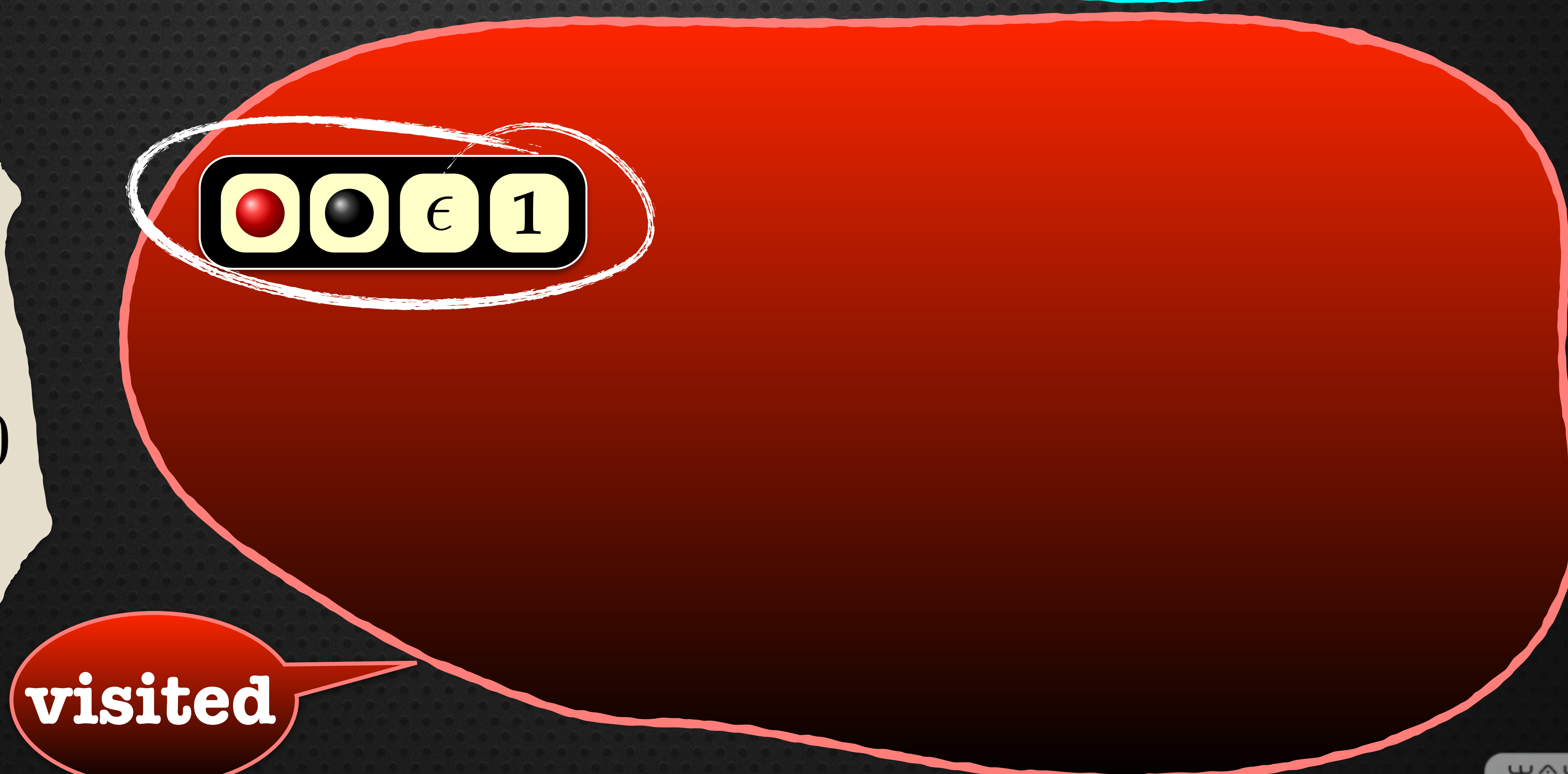



Lossy Backward
bility
waiting
$d?1$ t_3
t_4 $c!0$
$d?1$ t_1
t_2 $d?0$
$d?0$ t_5
t_6 $c!1$
c
d
$c?1$ t_9
t_{10} $d!1$
$c?1$ t_7
t_8 $c?0$
$c?0$ t_{11}
t_{12} $d!0$
ϵ 10
ϵ 1
t_8 $c?0$
visited

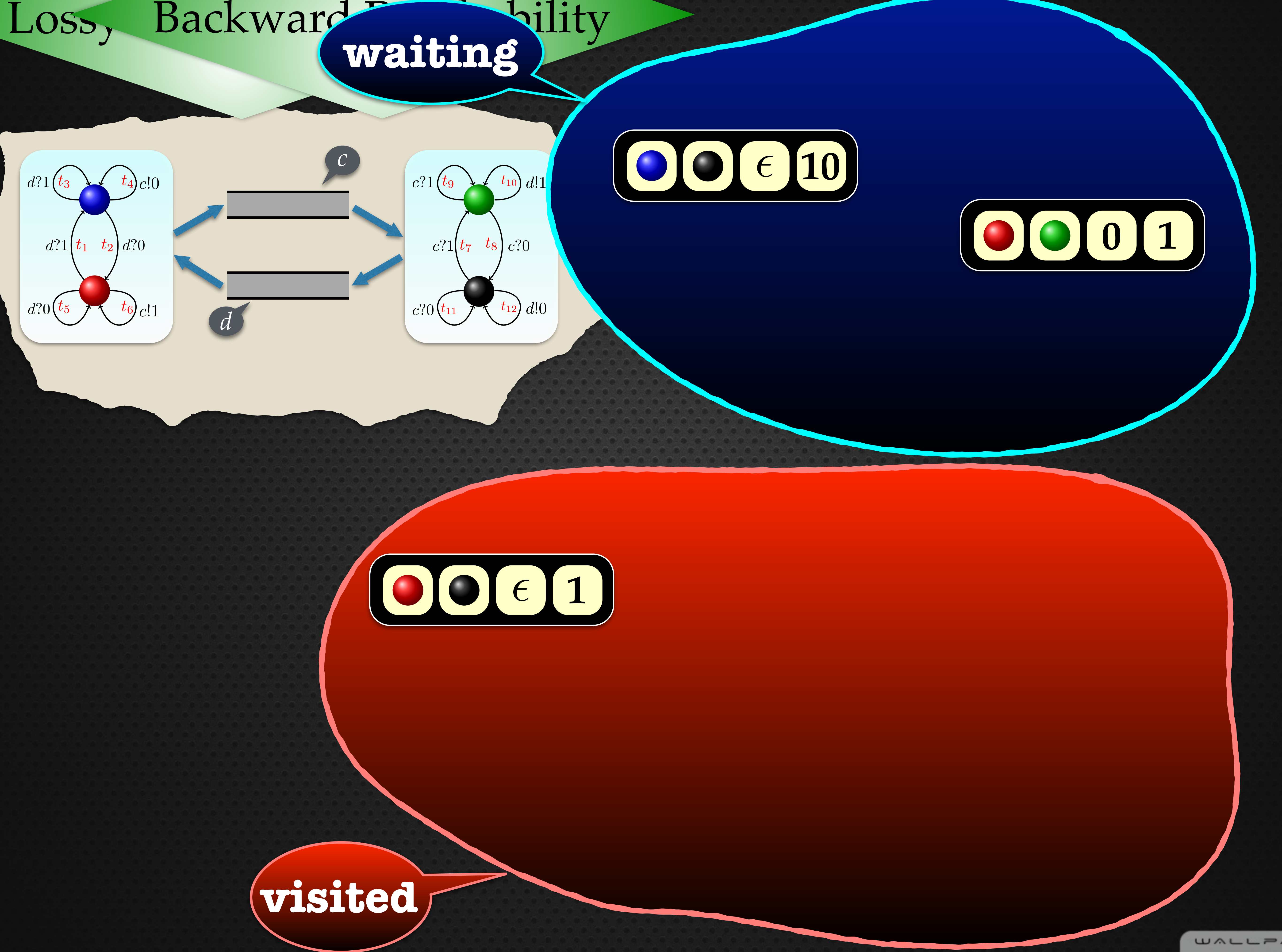
Lossy Backward … bility



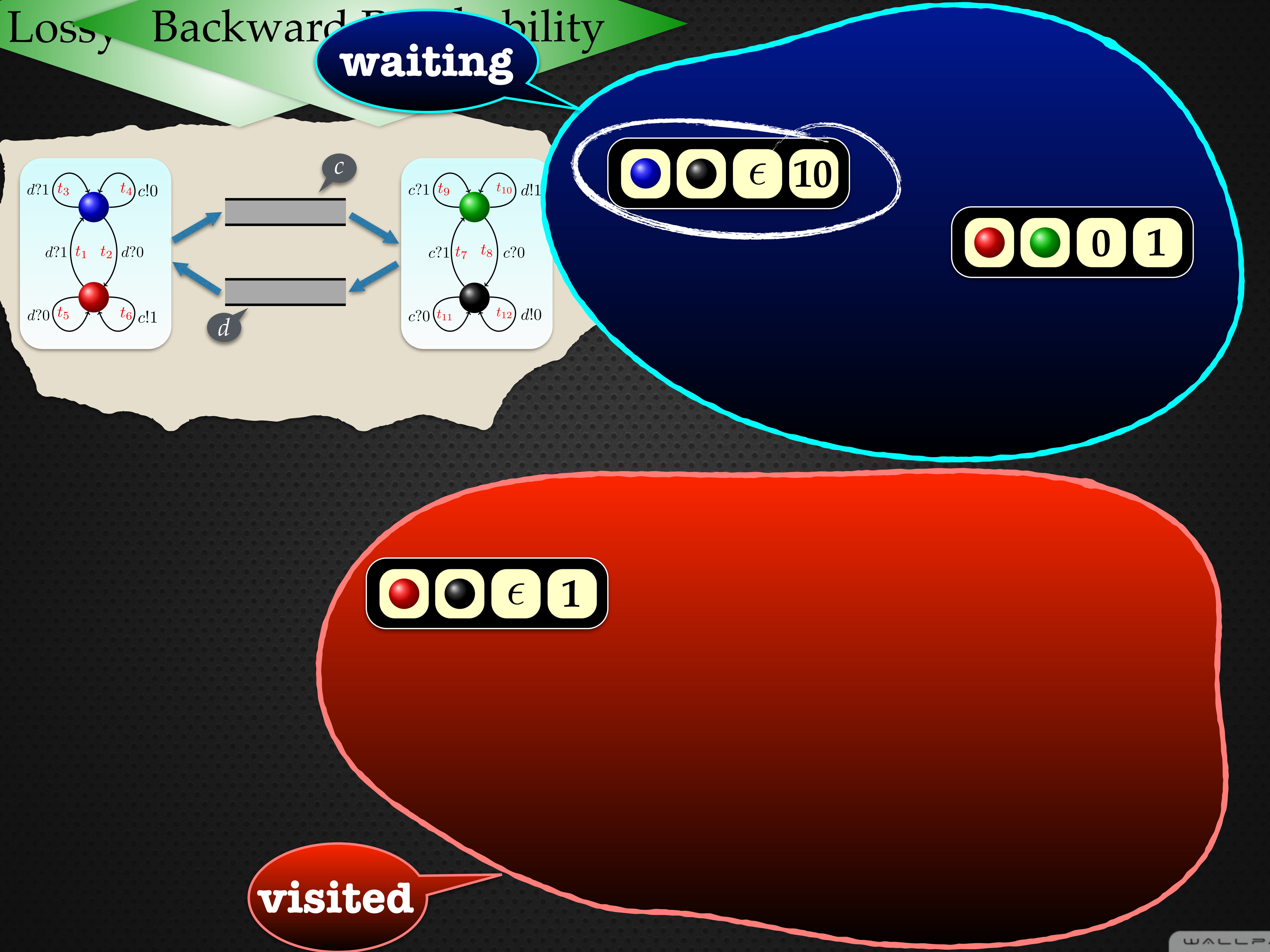


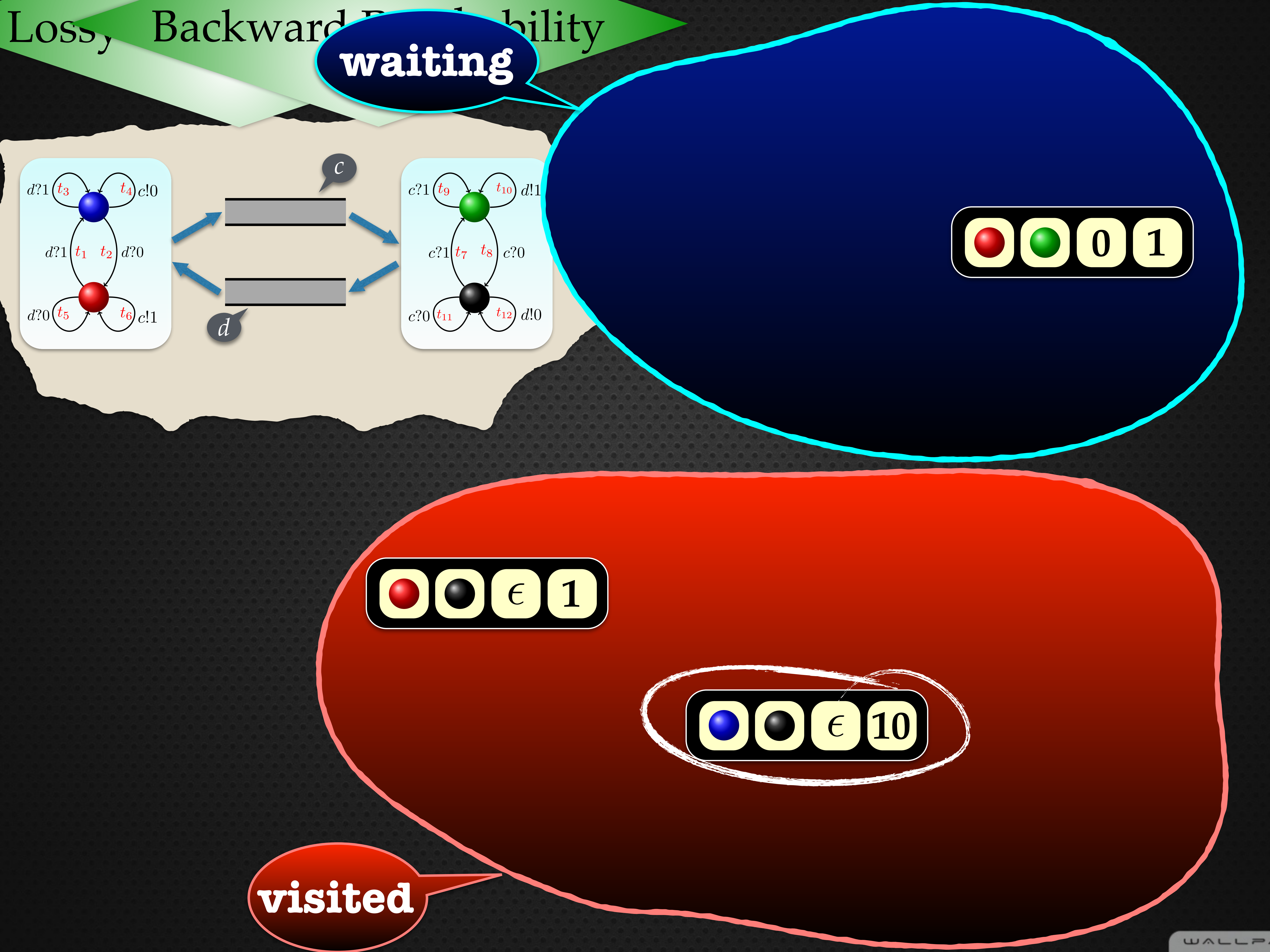


Lossy Backward Reachability



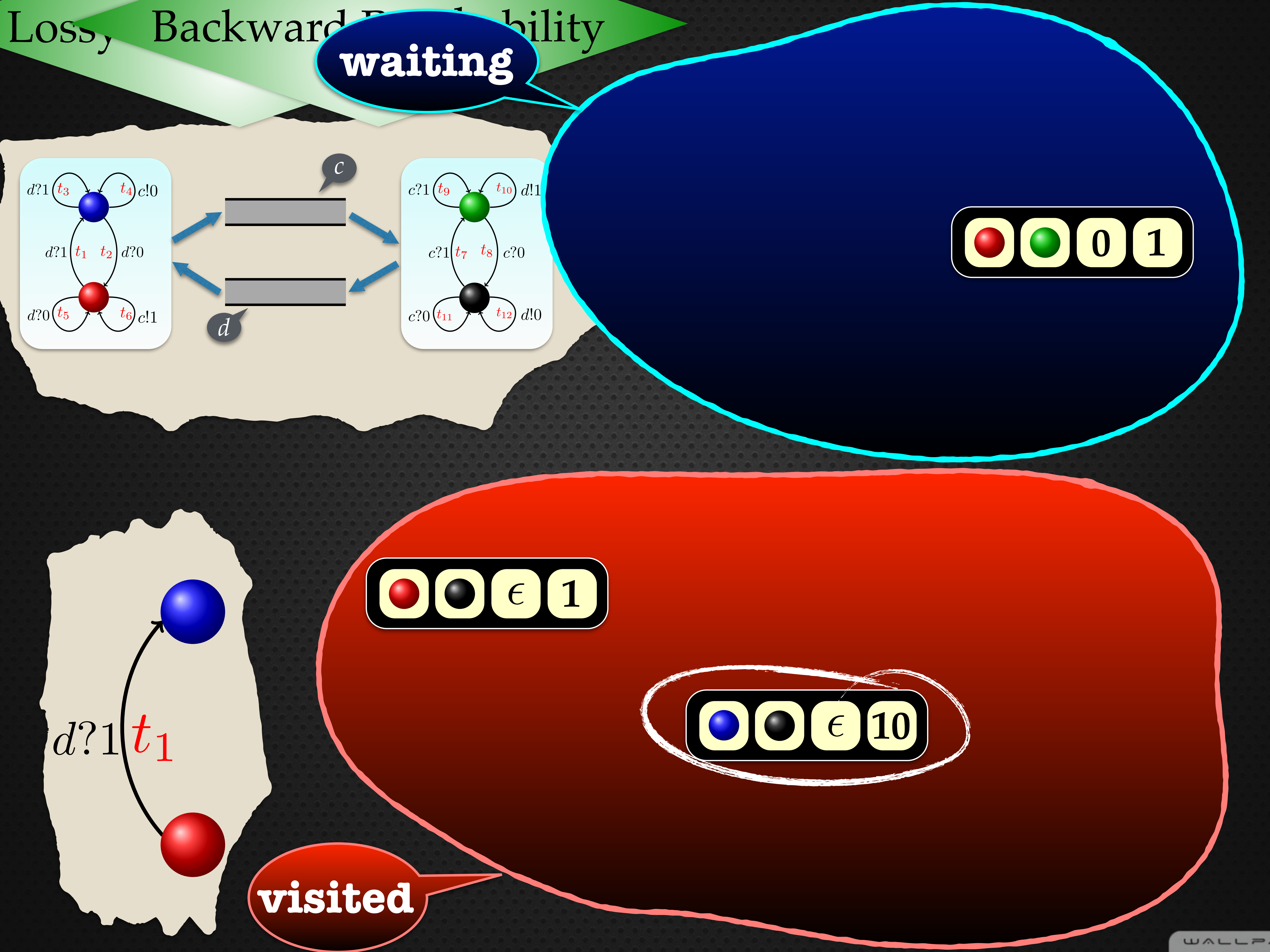
Lossy Backward Reachability



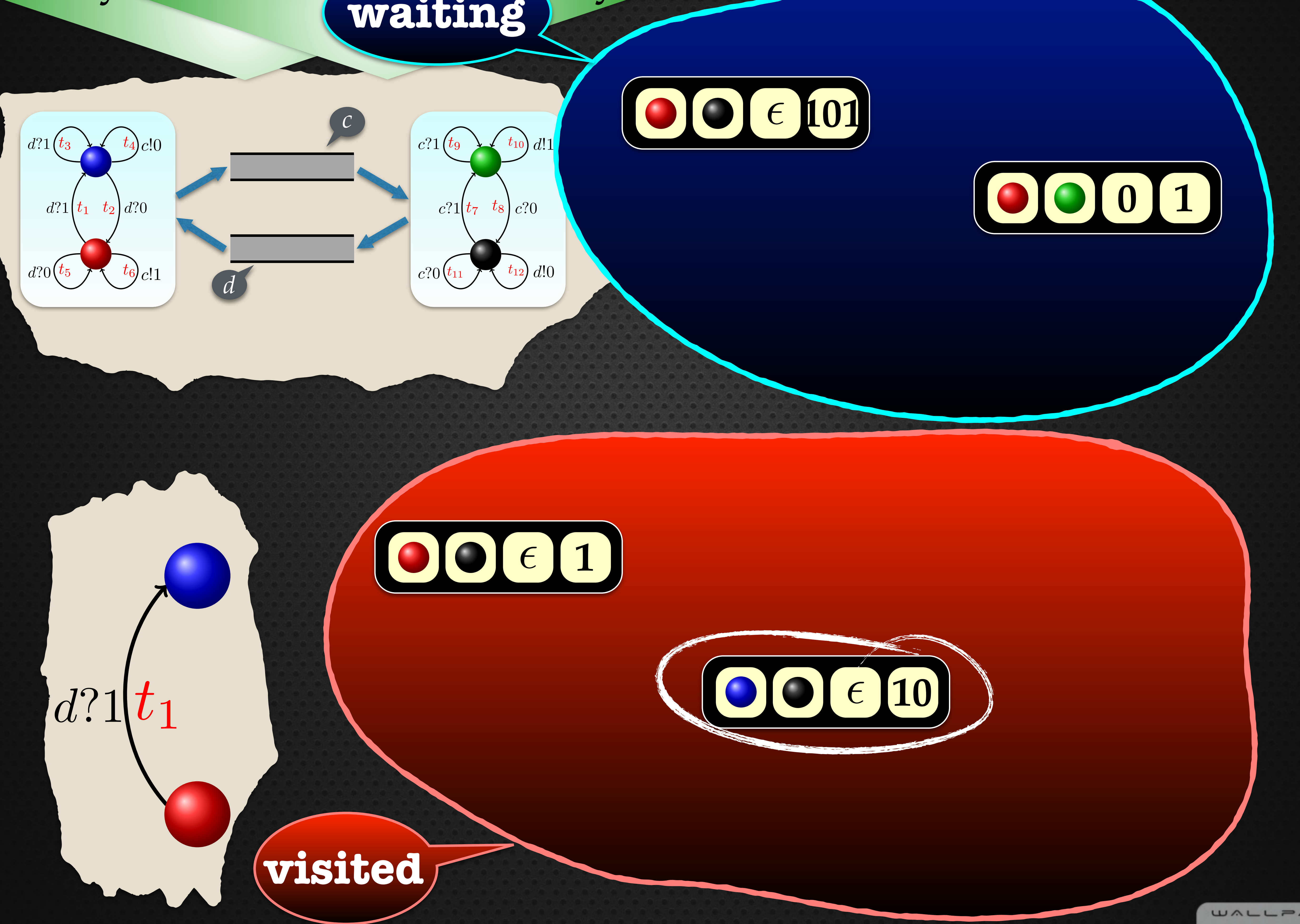


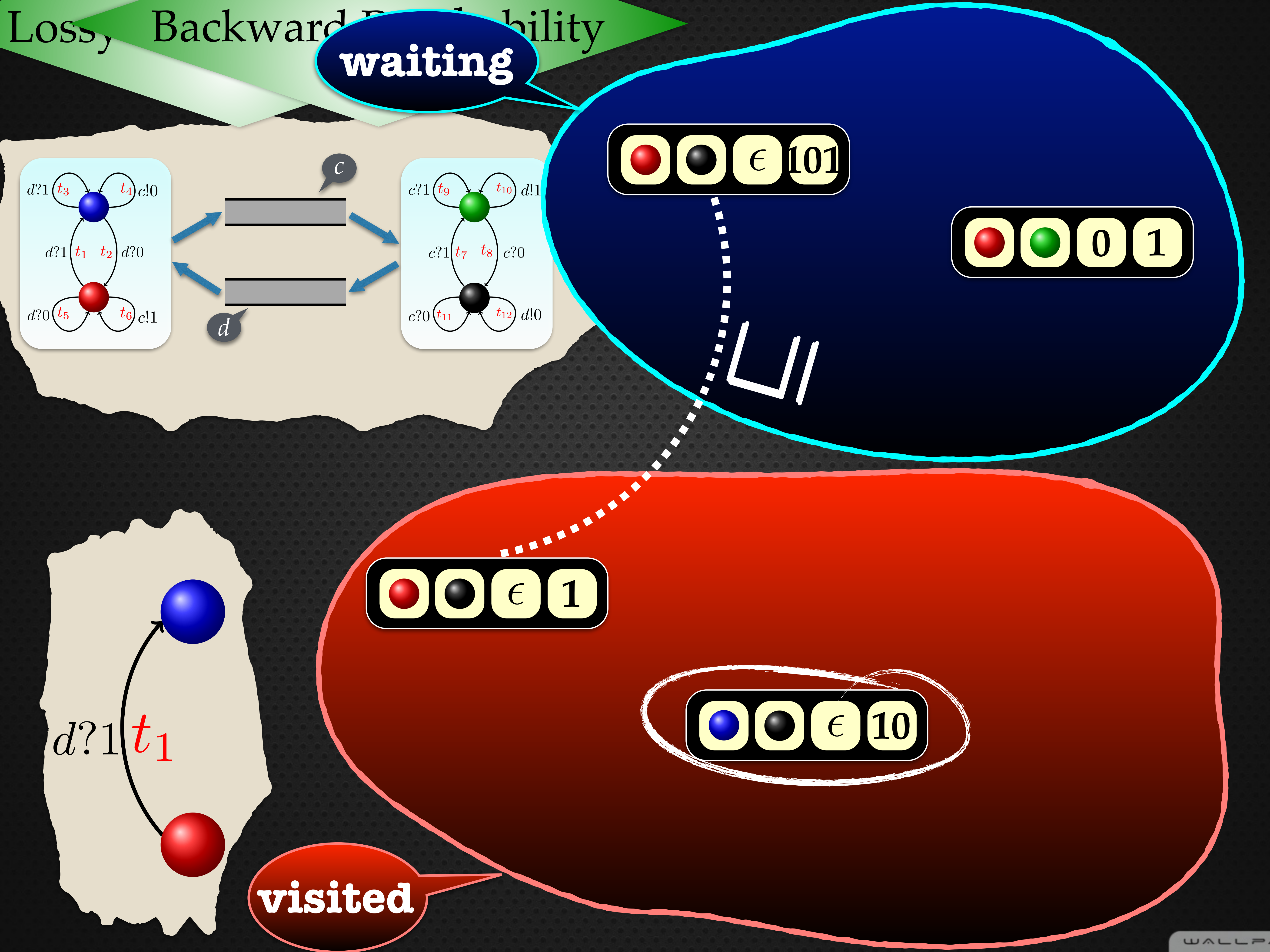
Loss
Backward R
bility
waiting
c
d
d?1 t3
t4 c!0
d?1 t1
t2 d?0
d?0 t5
t6 c!1
c?1 t9
t10 d!1
c?1 t7
t8 c?0
c?0 t11
t12 d!0
0 1
ϵ 1
ϵ 10
visited

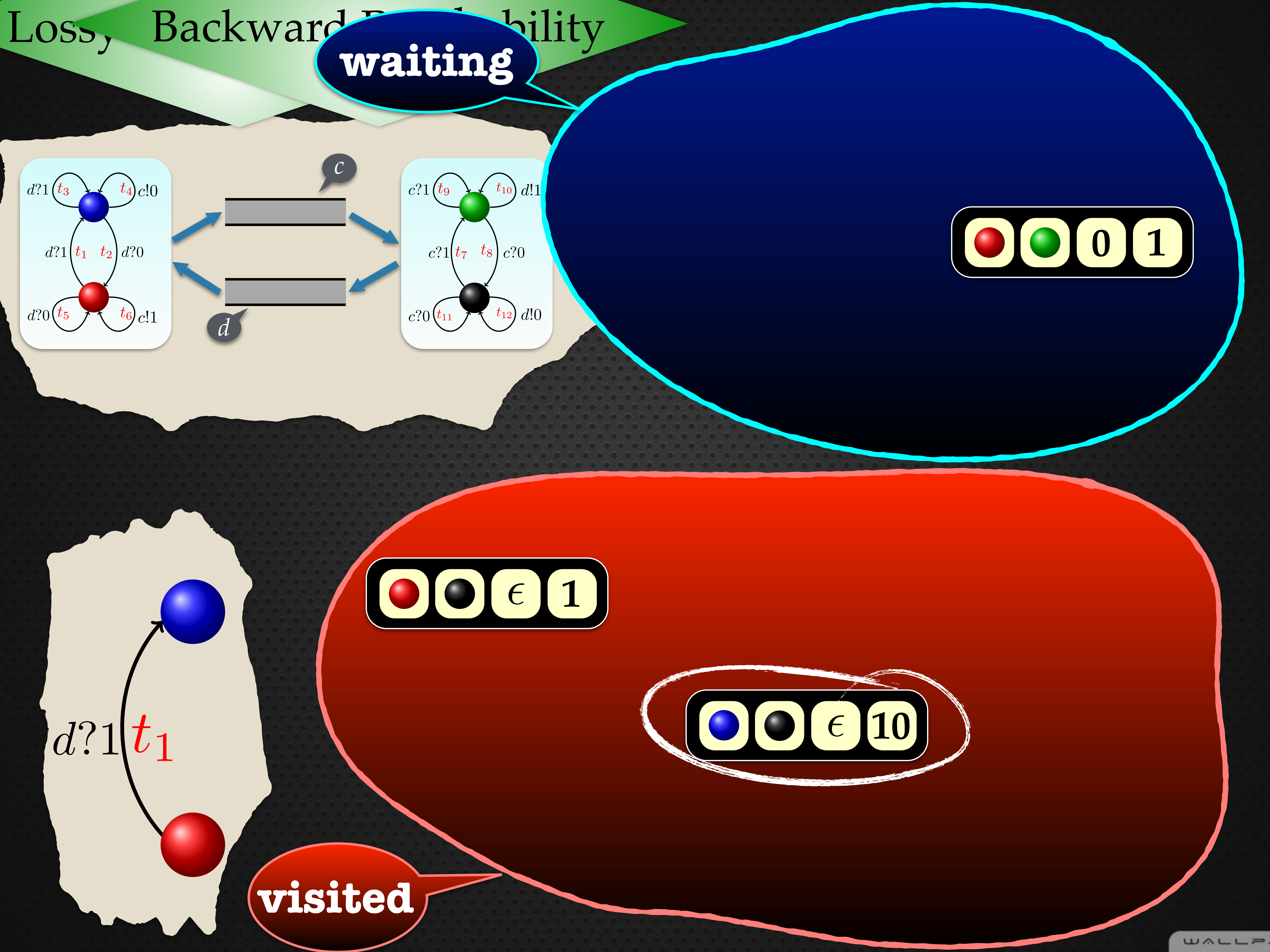
Loss Backward bility



Lossy Backward Reachability

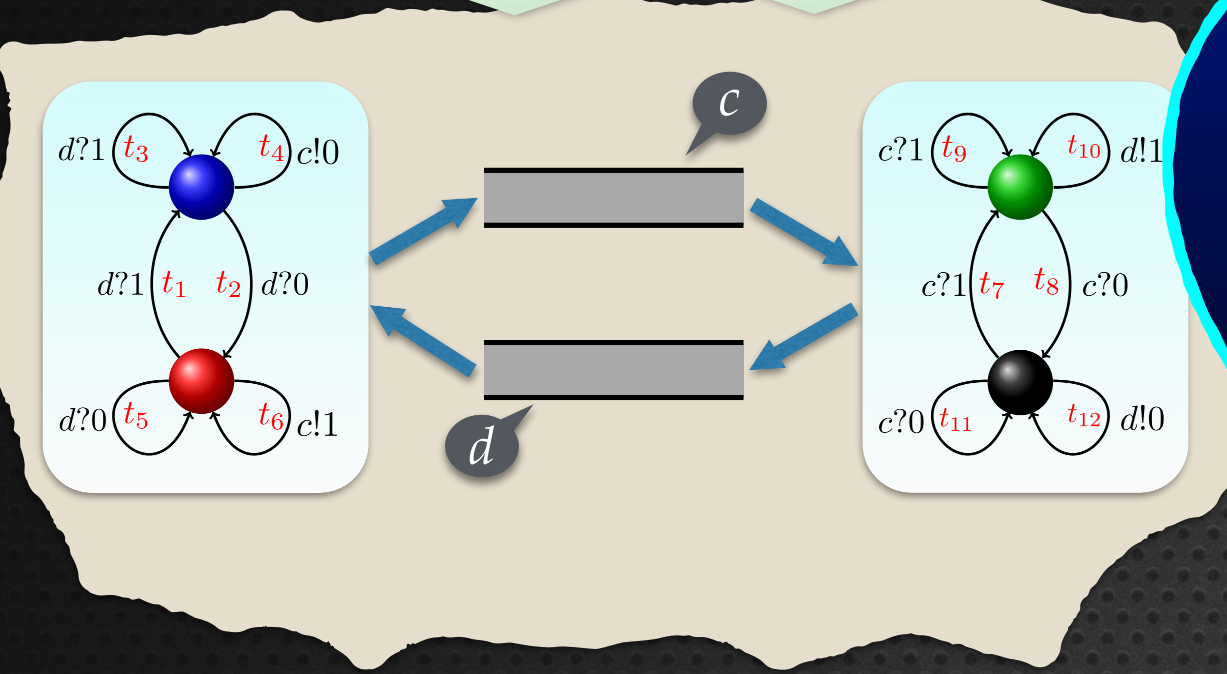


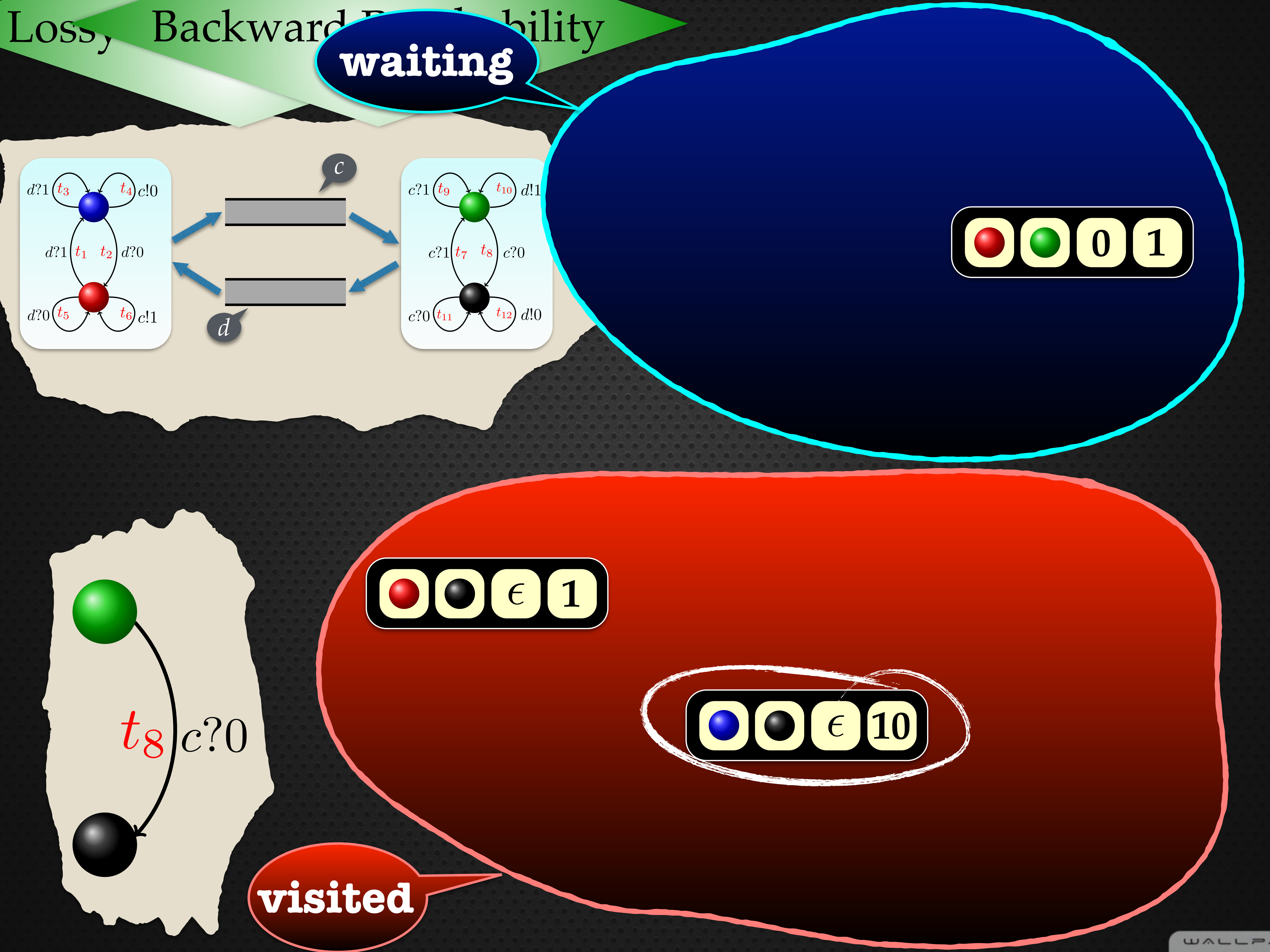

Lossy Backward R...bility
waiting
ϵ 101
0 1
$\sqsubseteq$
$d?1$ t_3
t_4 $c!0$
$d?1$ t_1
t_2 $d?0$
$d?0$ t_5
t_6 $c!1$
c
d
$c?1$ t_9
t_{10} $d!1$
$c?1$ t_7
t_8 $c?0$
$c?0$ t_{11}
t_{12} $d!0$
ϵ 1
ϵ 10
$d?1$ t_1
visited



Lossy Backward
waiting
c
d
d?1 t_3
t_4 c!0
d?1 t_1
t_2 d?0
d?0 t_5
t_6 c!1
c?1 t_9
t_{10} d!1
c?1 t_7
t_8 c?0
c?0 t_{11}
t_{12} d!0
0 1
ϵ 1
ϵ 10
d?1 t_1
visited

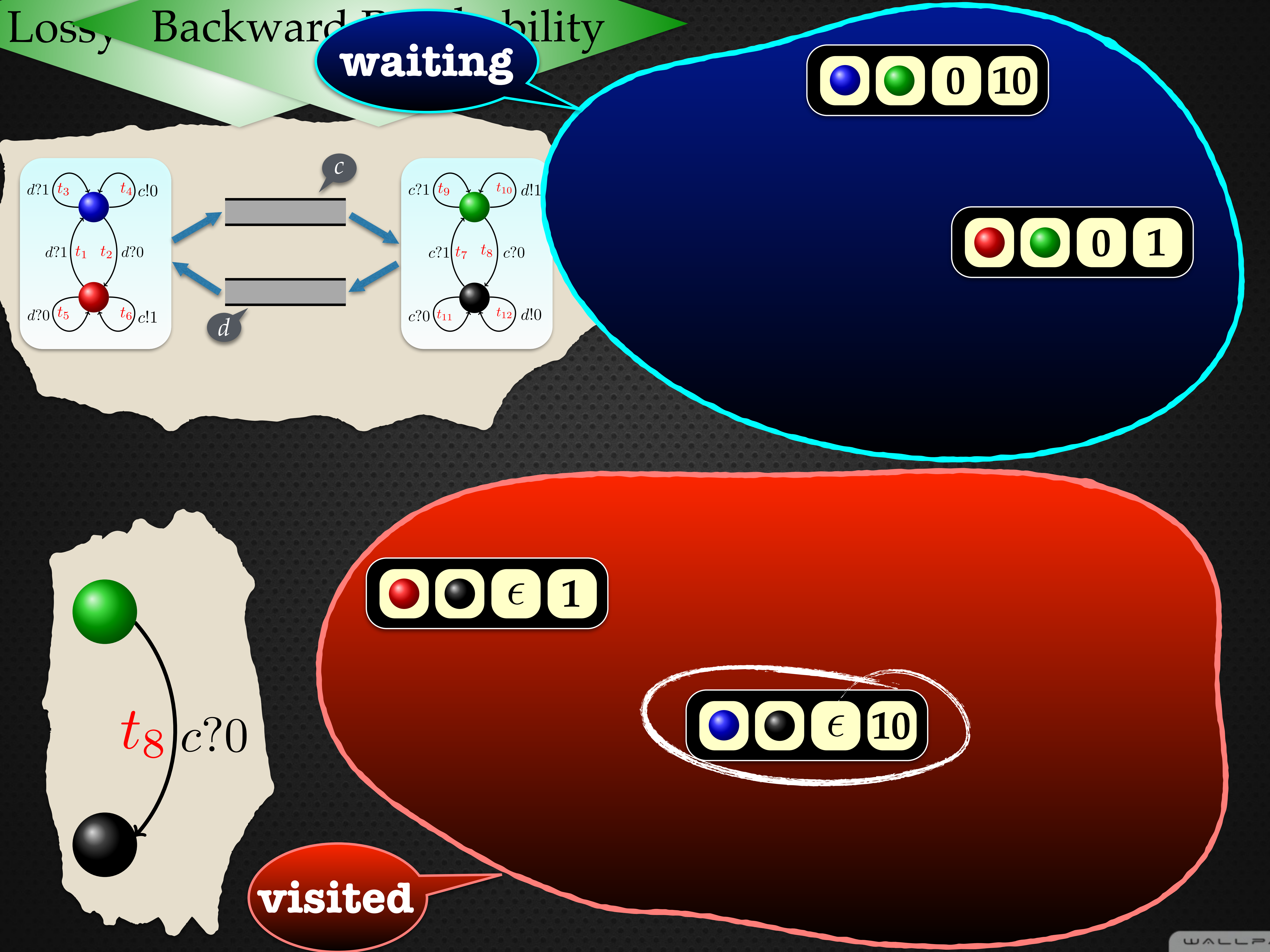
Lossy Backward Reachability

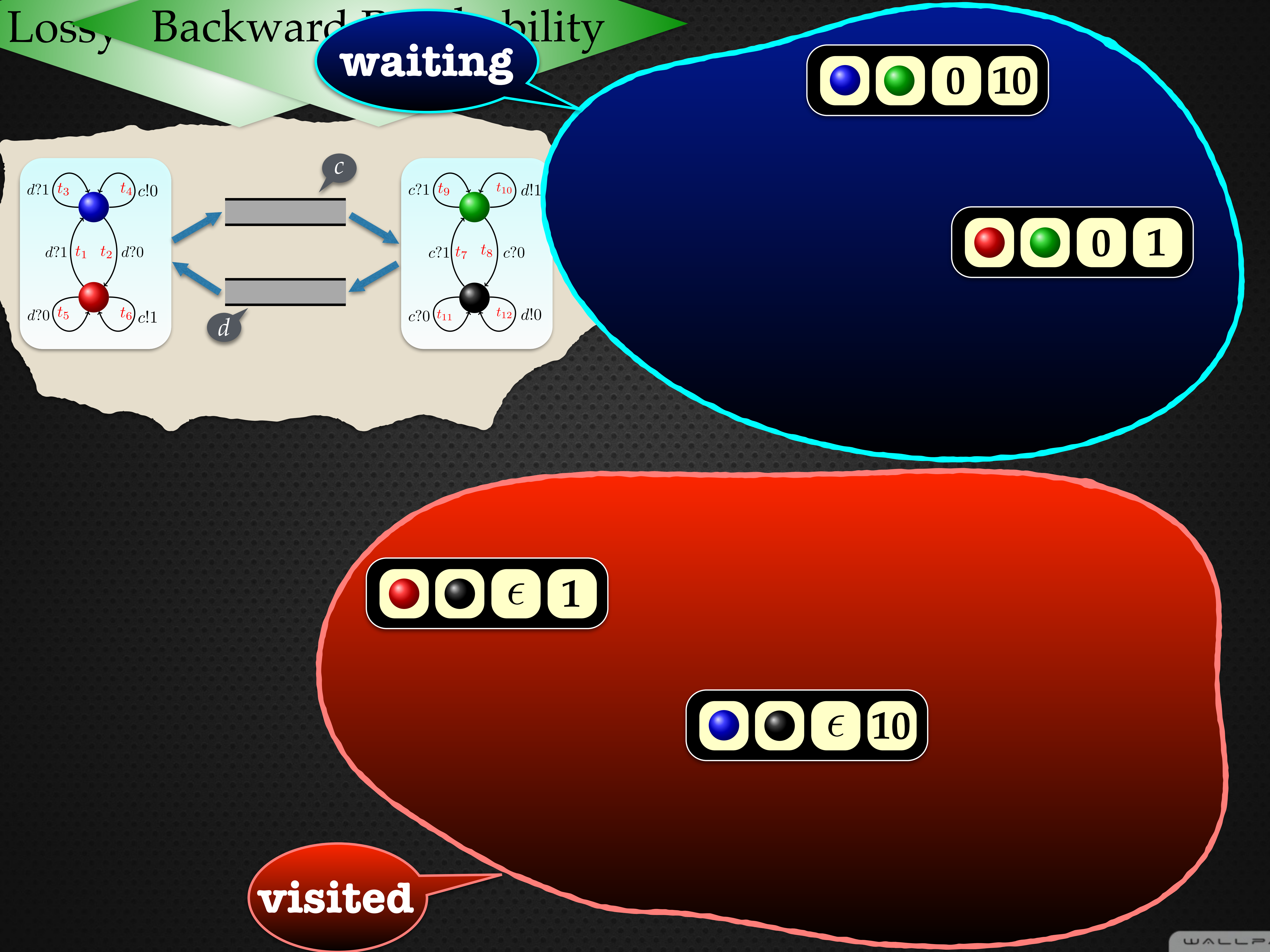


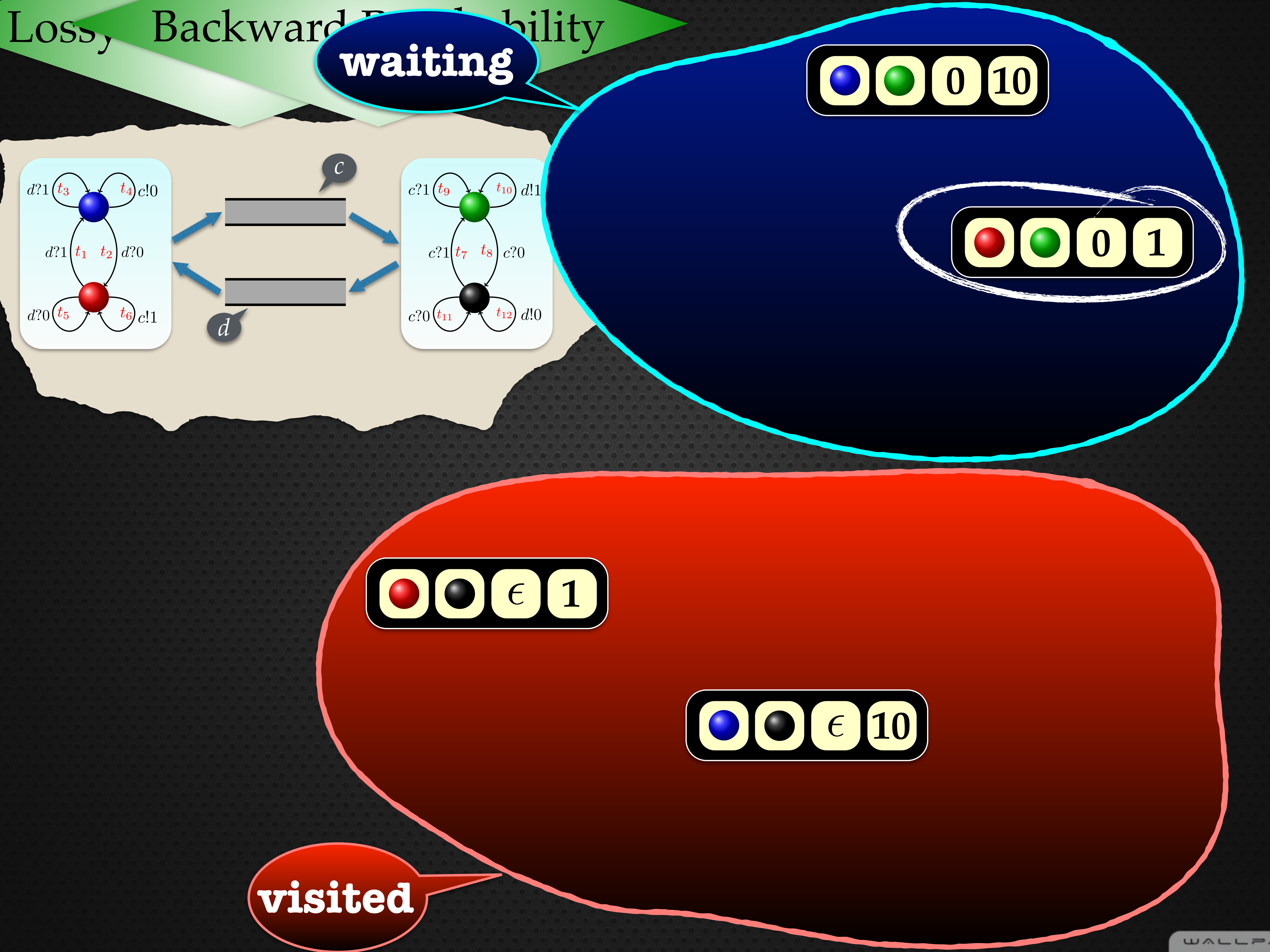


Lossy Backward
bility
waiting
c
d
d?1 t1
t2 d?0
d?1 t3
t4 c!0
d?0 t5
t6 c!1
c?1 t7
t8 c?0
c?1 t9
t10 d!1
c?0 t11
t12 d!0
0 1
ϵ 1
ϵ 10
t8 c?0
visited

Lossy Backward R… bility

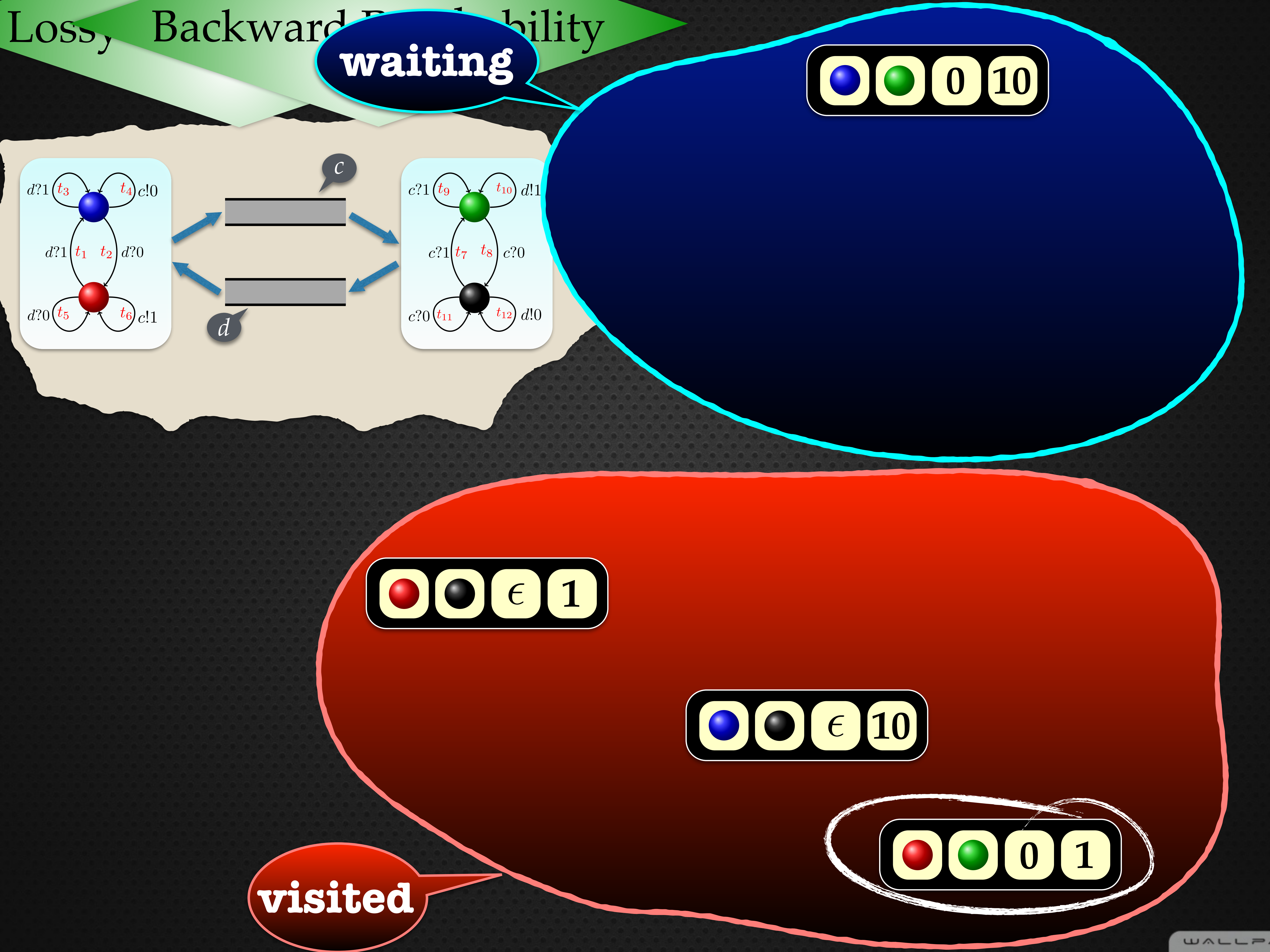


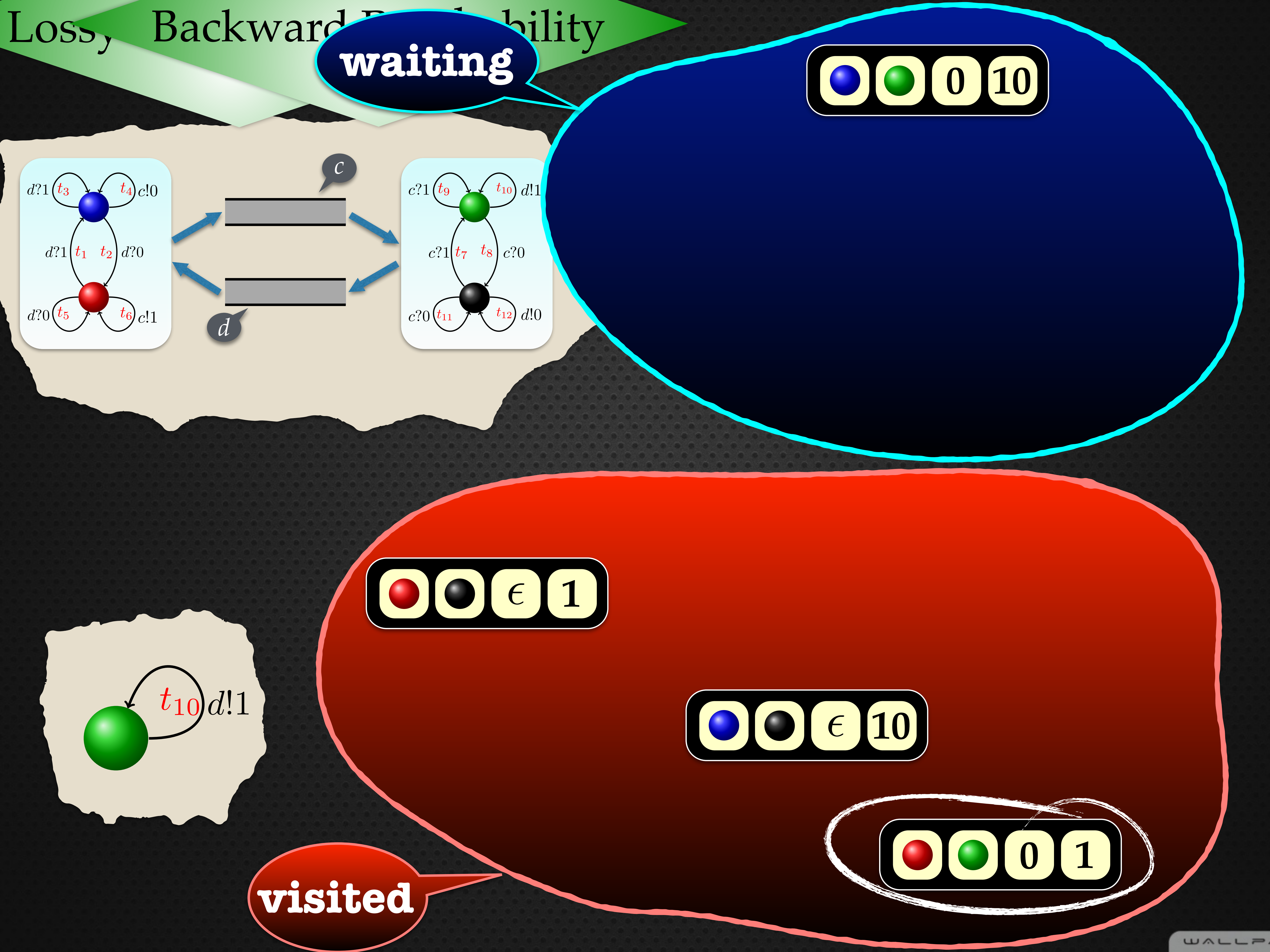

Lossy Backward R...bility
waiting
0 10
0 1
visited
ϵ 1
ϵ 10
c
d
d?1 t3
t4 c!0
d?1 t1
t2 d?0
d?0 t5
t6 c!1
c?1 t9
t10 d!1
c?1 t7
t8 c?0
c?0 t11
t12 d!0



Backward
waiting
visited
c
d
d?1 t3 t4 c!0
d?1 t1 t2 d?0
d?0 t5 t6 c!1
c?1 t9 t10 d!1
c?1 t7 t8 c?0
c?0 t11 t12 d!0
0 10
0 1
ϵ 1
ϵ 10

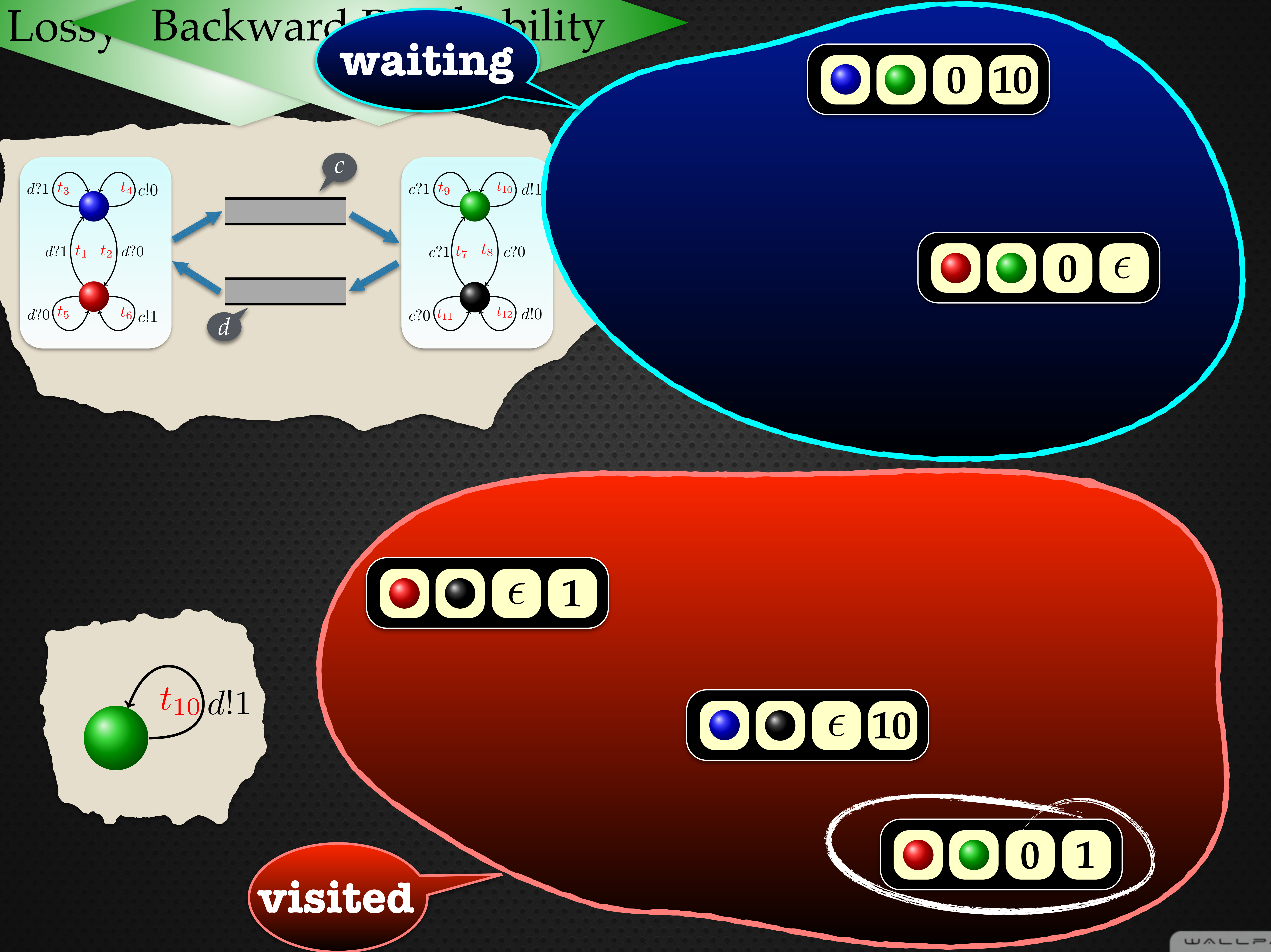
Lossy Backward Reachability

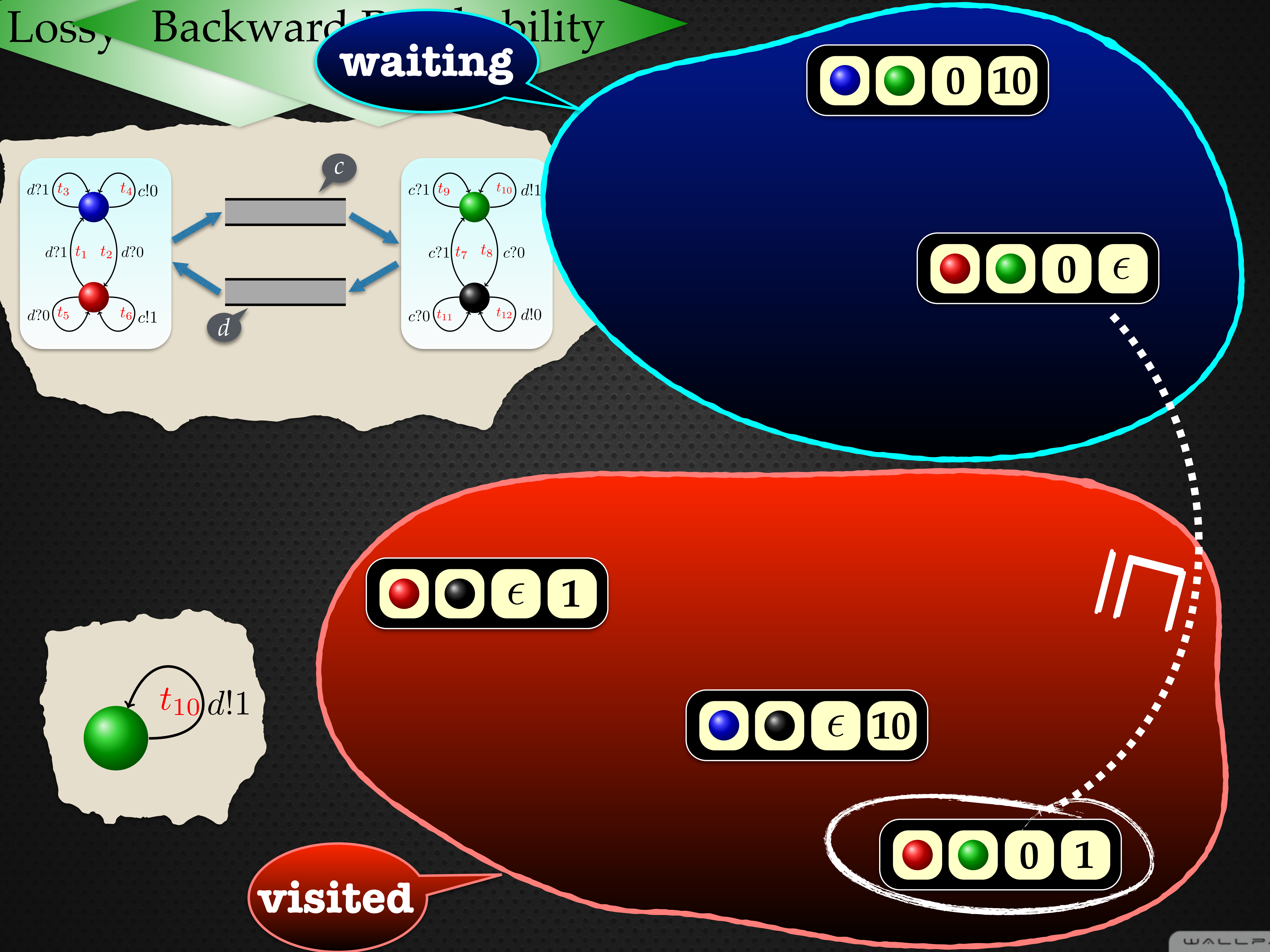




Lossy Backward
bility
waiting
0 10
c
d?1 t3 t4 c!0
d?1 t1 t2 d?0
d?0 t5 t6 c!1
d
c?1 t9 t10 d!1
c?1 t7 t8 c?0
c?0 t11 t12 d!0
t10 d!1
ϵ 1
ϵ 10
0 1
visited

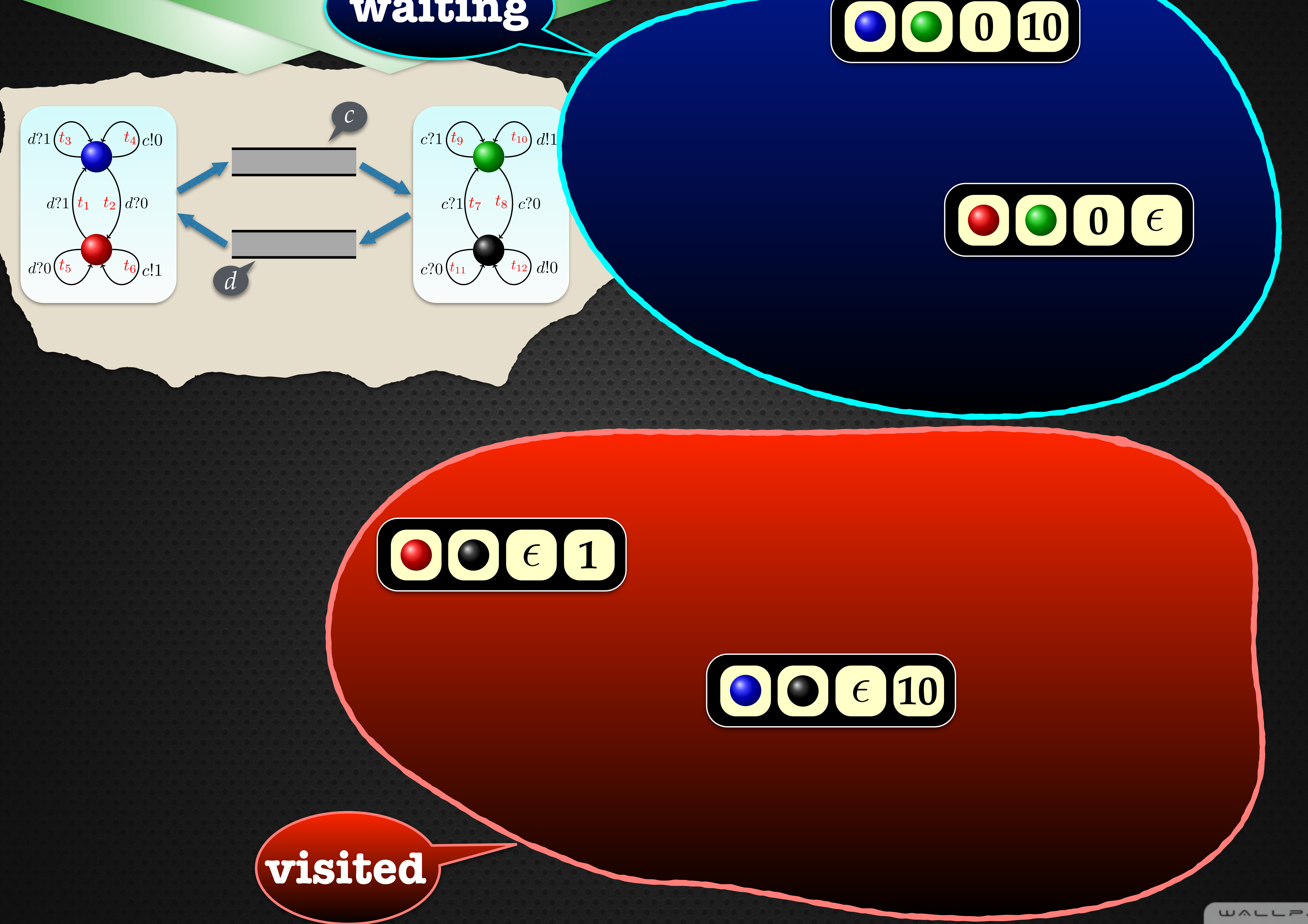
Lossy Backward R… bility



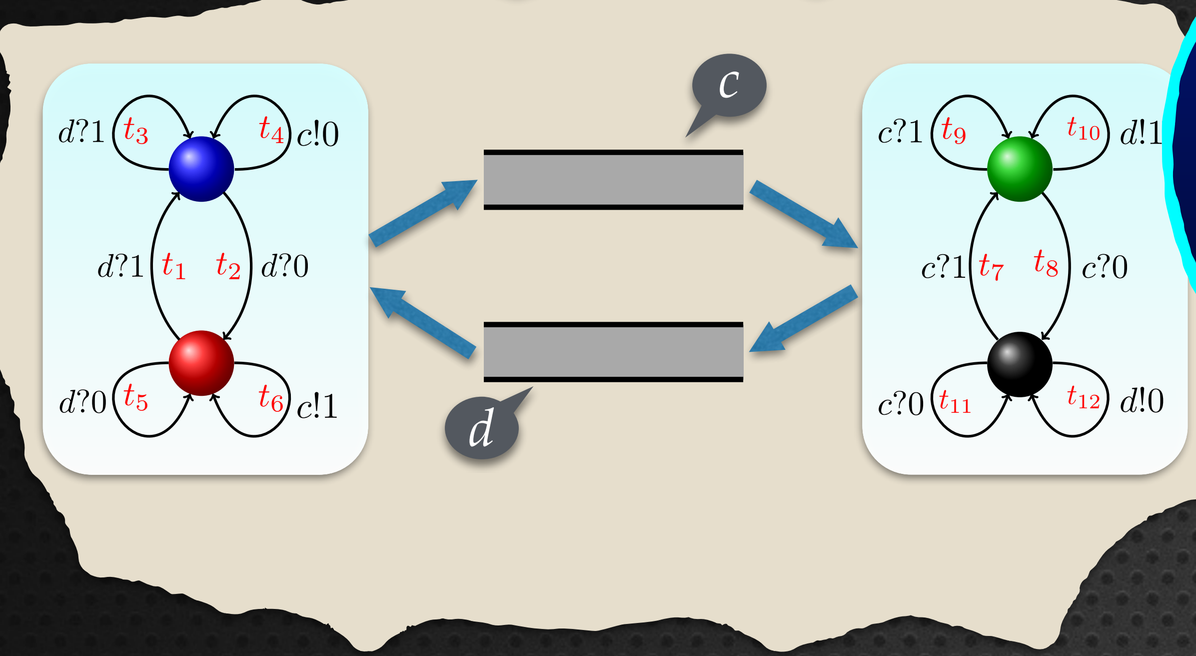


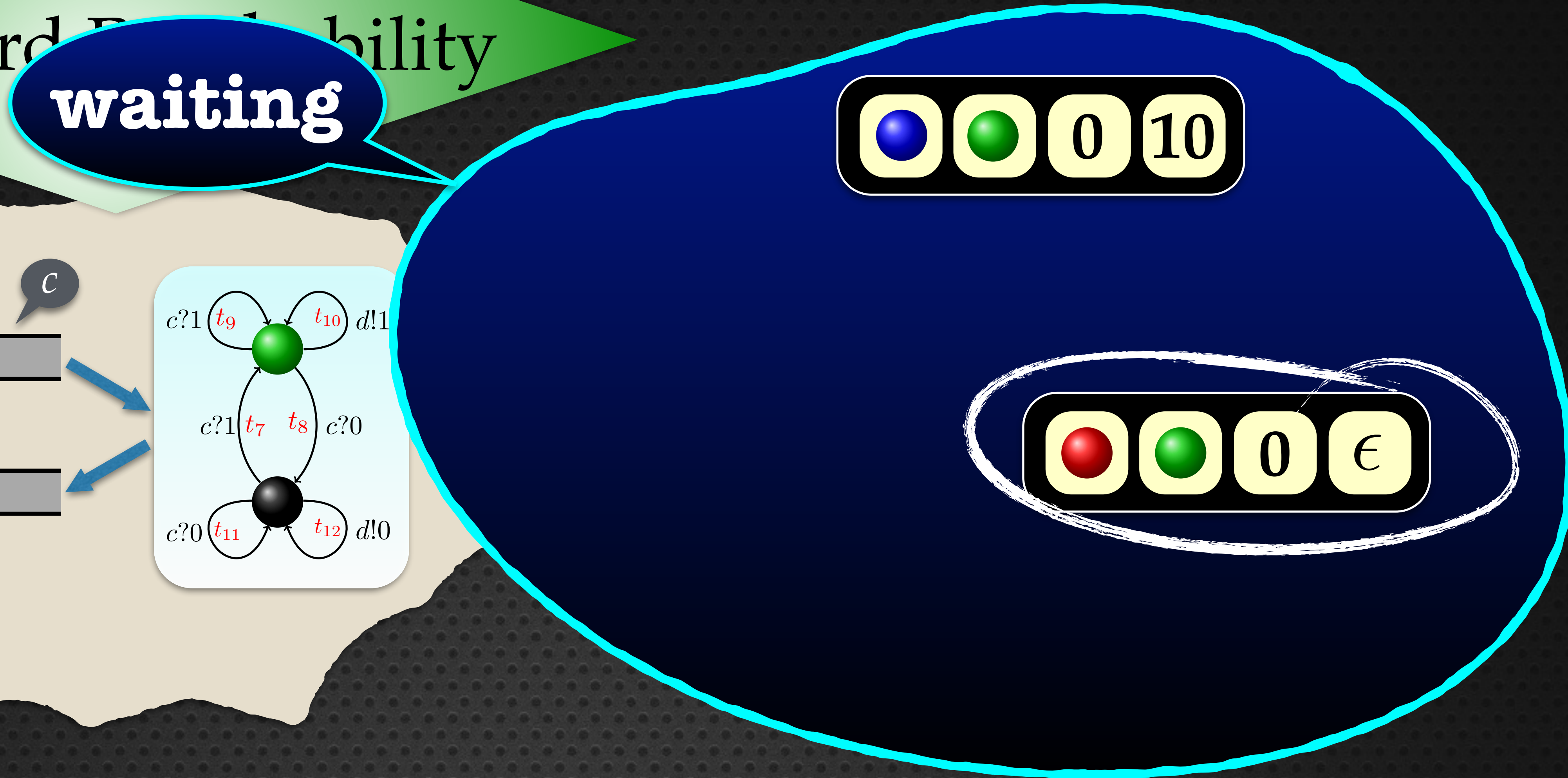
Lossy Backward
bility
waiting
$d?1$ t_3
t_4 $c!0$
$d?1$ t_1
t_2 $d?0$
$d?0$ t_5
t_6 $c!1$
c
d
$c?1$ t_9
t_{10} $d!1$
$c?1$ t_7
t_8 $c?0$
$c?0$ t_{11}
t_{12} $d!0$
0 10
0 ϵ
ϵ 1
ϵ 10
0 1
t_{10} $d!1$
visited

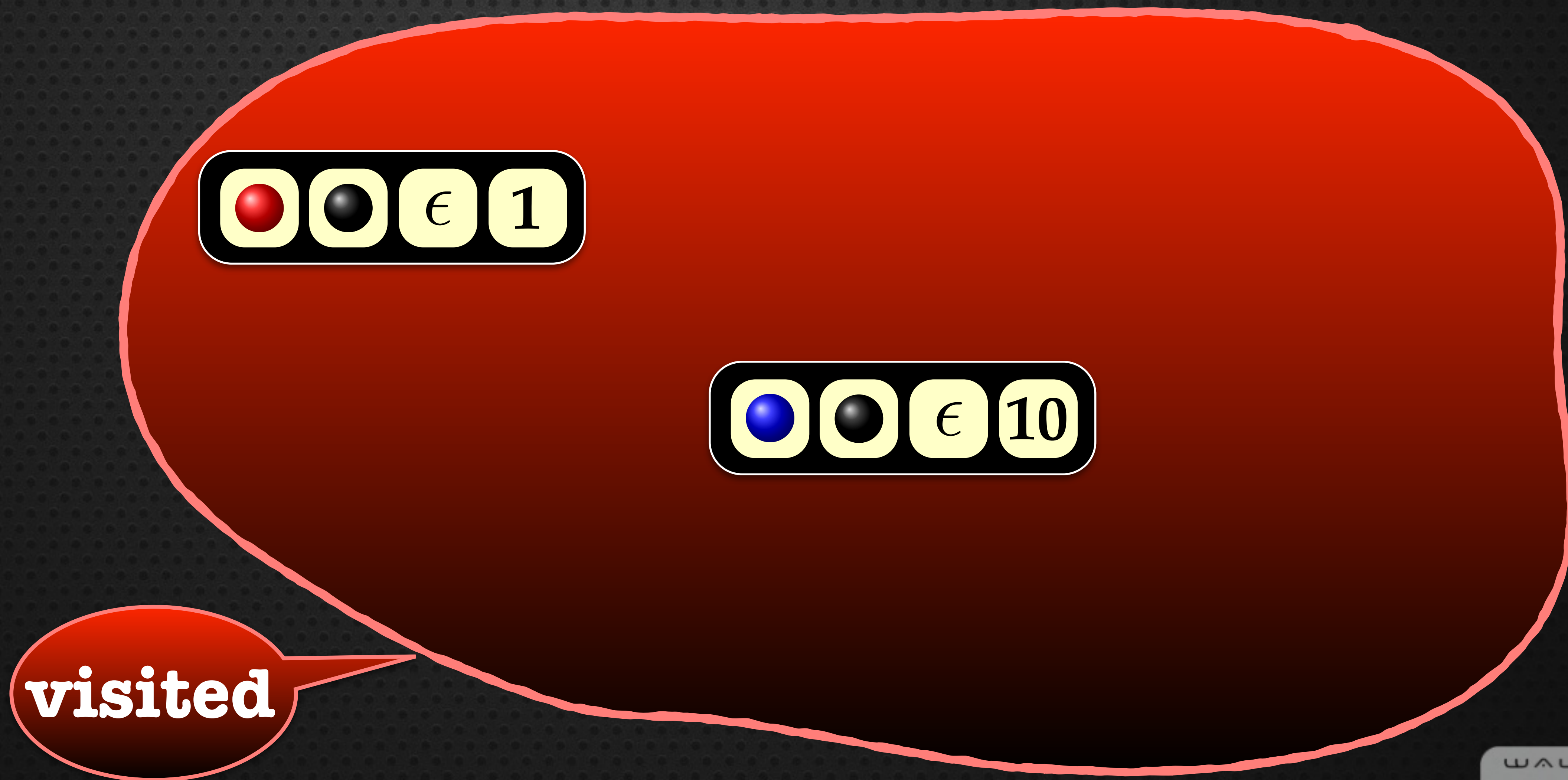
Lossy Backward Reachability

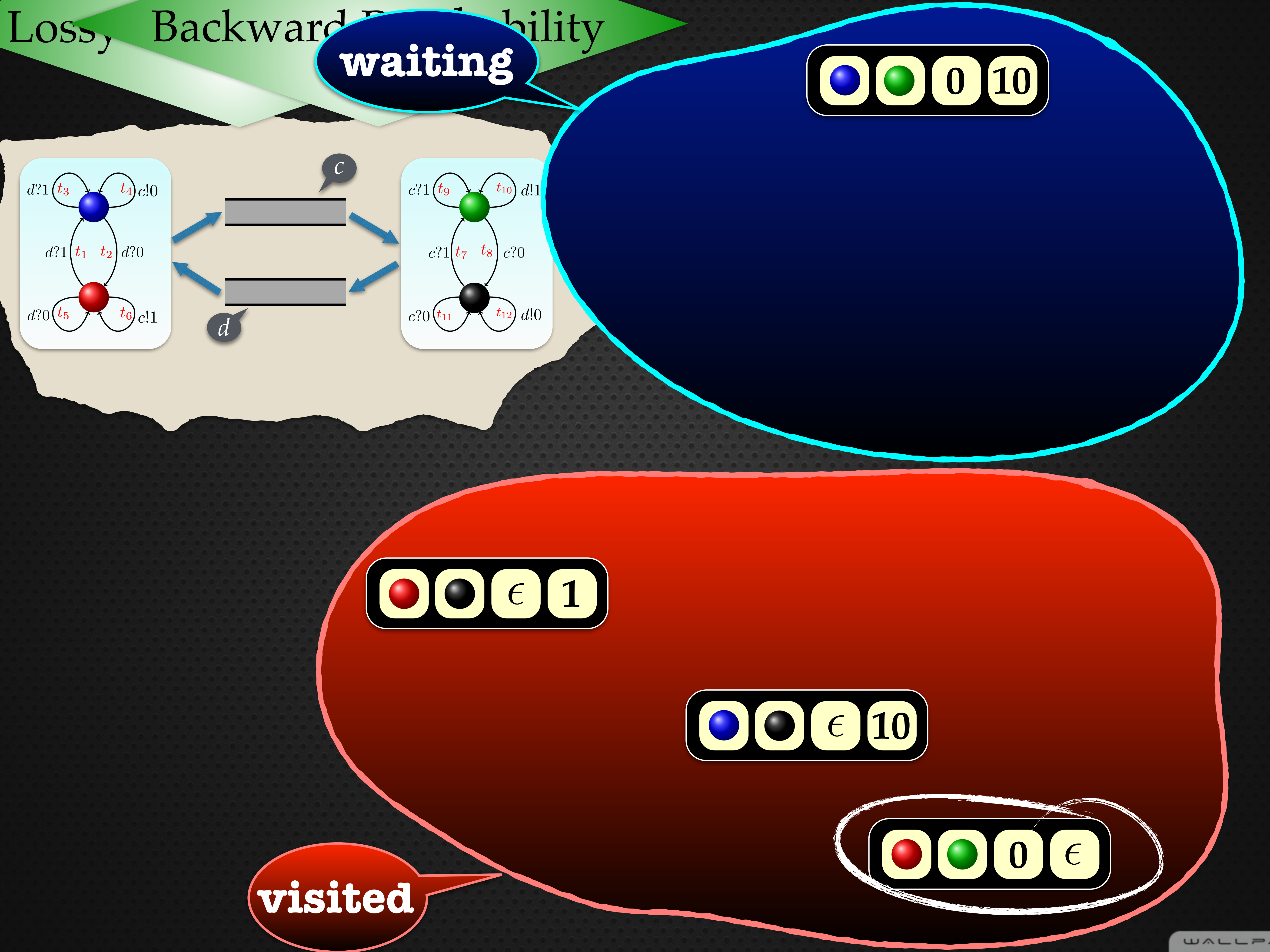


Lossy Backward Reachability









Lossy Backward R bility
waiting
0
10
c
d
$d?1$ t_3 t_4 $c!0$
$d?1$ t_1 t_2 $d?0$
$d?0$ t_5 t_6 $c!1$
$c?1$ t_9 t_{10} $d!1$
$c?1$ t_7 t_8 $c?0$
$c?0$ t_{11} t_{12} $d!0$
ϵ
1
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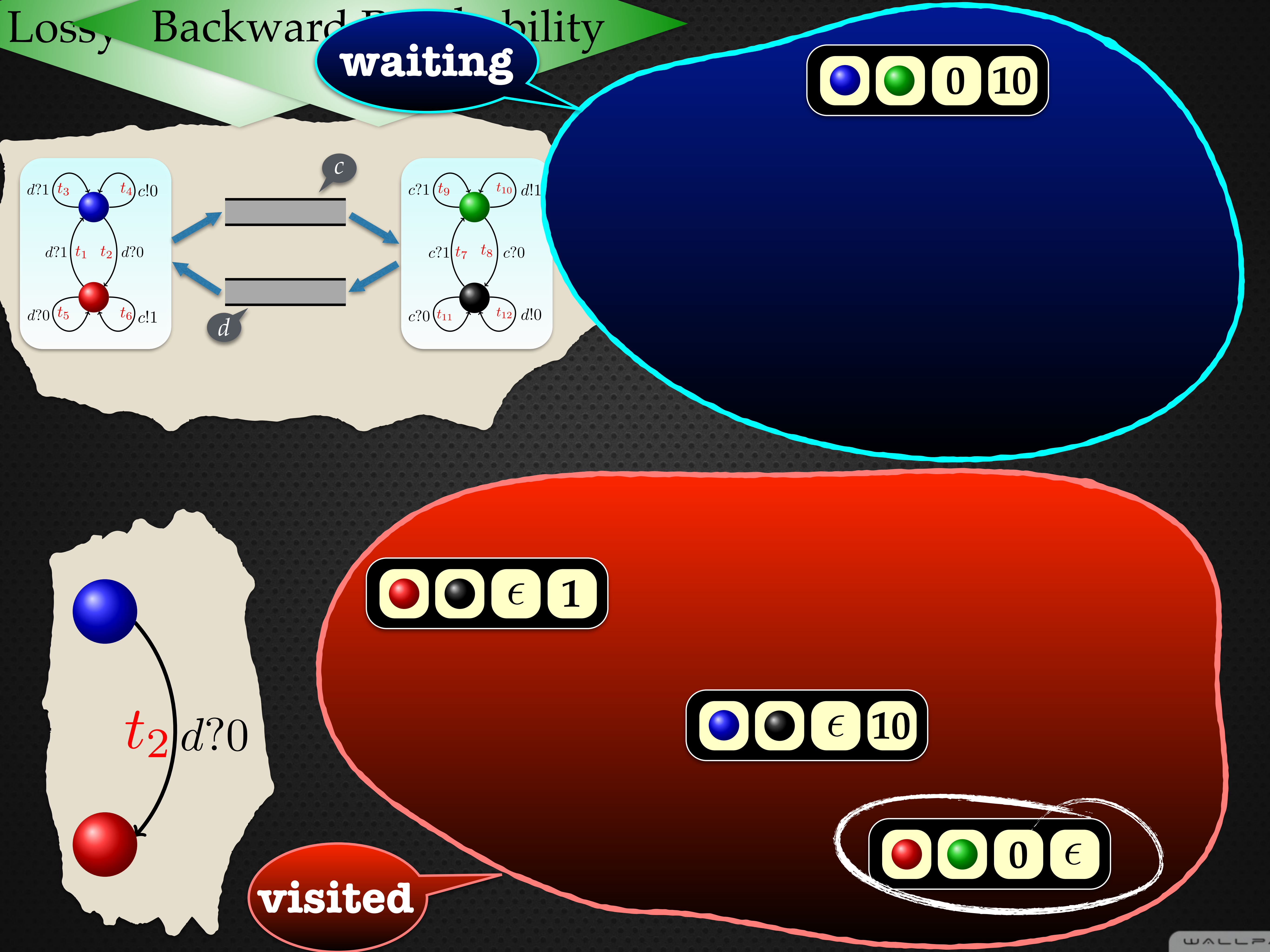
visited


Loss
Backward
bility
waiting
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10
$d?1$ t_3
t_4 $c!0$
$d?1$ t_1
t_2 $d?0$
$d?0$ t_5
t_6 $c!1$
c
d
$c?1$ t_9
t_{10} $d!1$
$c?1$ t_7
t_8 $c?0$
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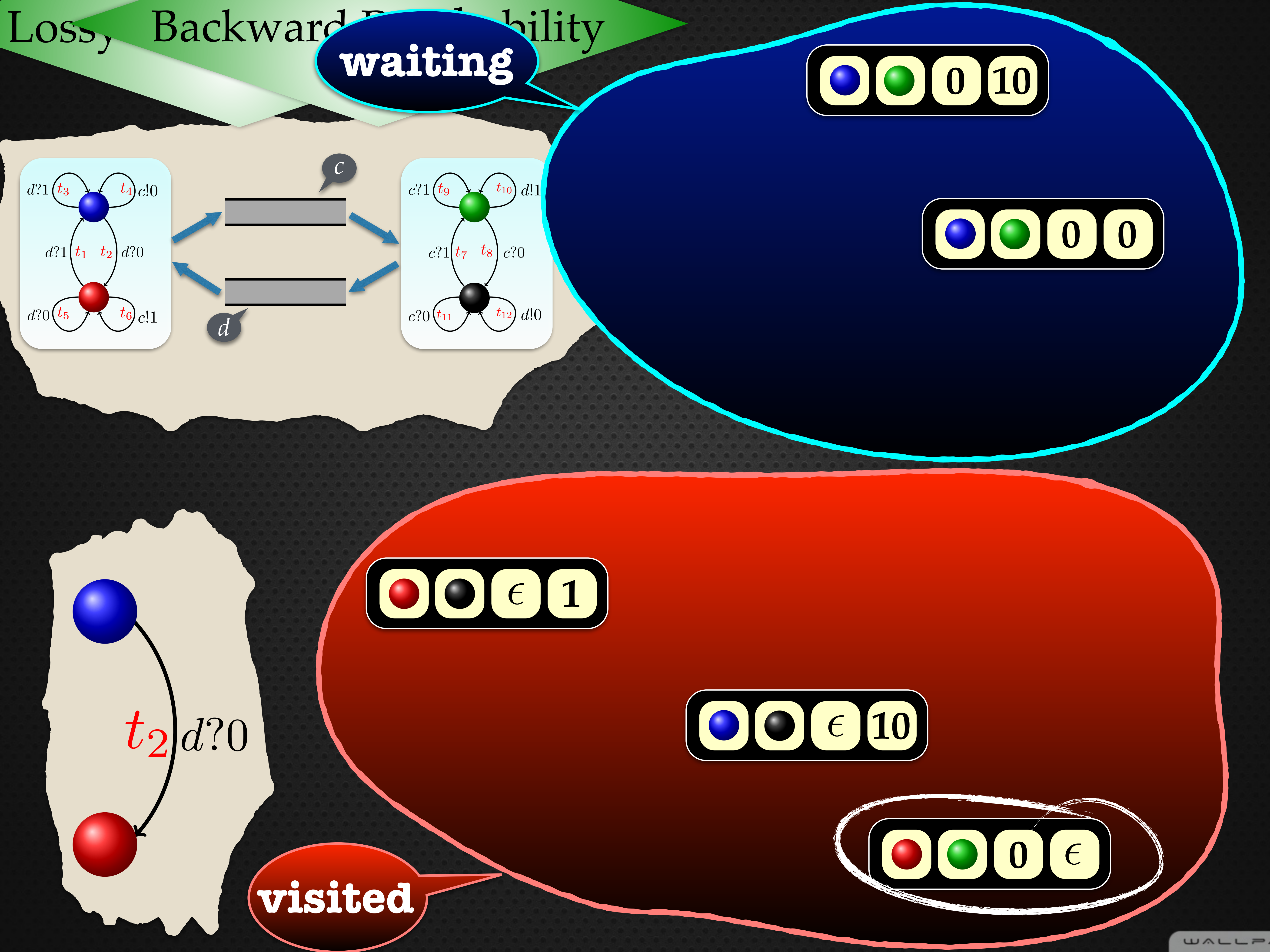
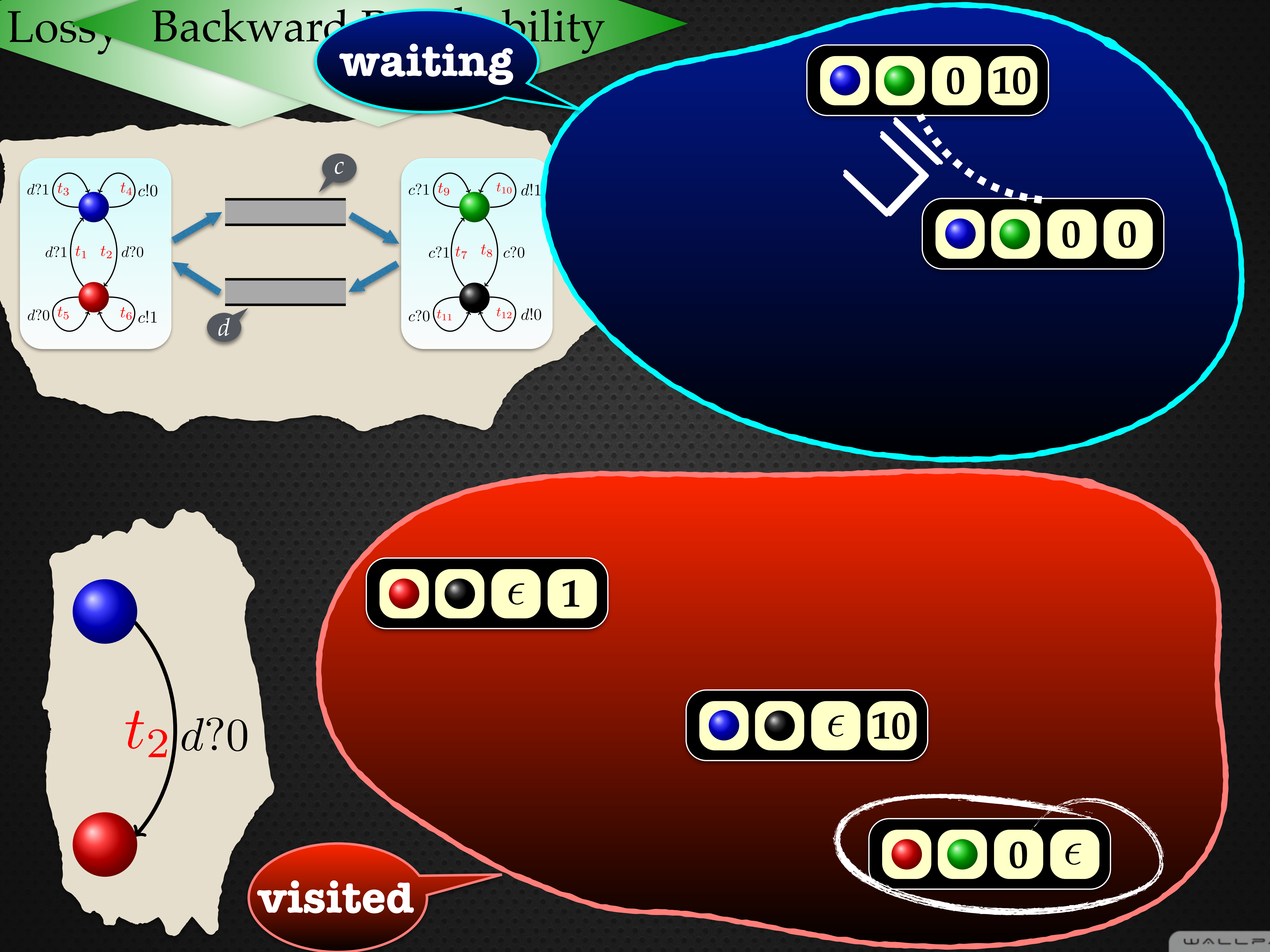
t_2 $d?0$
visited



Lossy
Backward
bility
waiting
0 10
0 0
c
d
d?1 t3
t4 c!0
d?1 t1
t2 d?0
d?0 t5
t6 c!1
c?1 t9
t10 d!1
c?1 t7
t8 c?0
c?0 t11
t12 d!0
t2 d?0
visited
ϵ 1
ϵ 10
0 ϵ



Loss Backward bility
waiting
visited
c
d
$d?1$ t_3 t_4 $c!0$
$d?1$ t_1 t_2 $d?0$
$d?0$ t_5 t_6 $c!1$
$c?1$ t_9 t_{10} $d!1$
$c?1$ t_7 t_8 $c?0$
$c?0$ t_{11} t_{12} $d!0$
0 10
0 0
ϵ 1
ϵ 10
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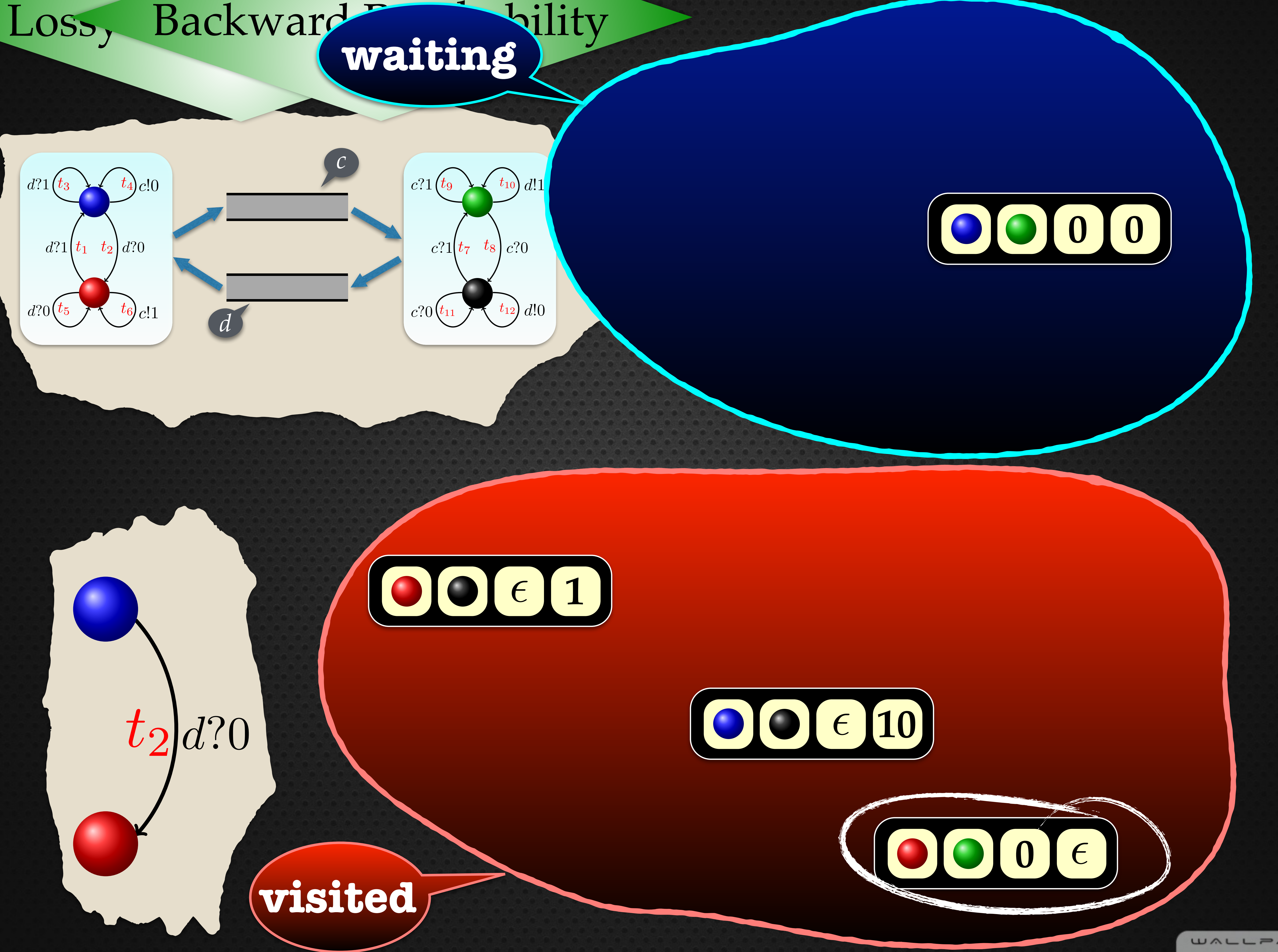
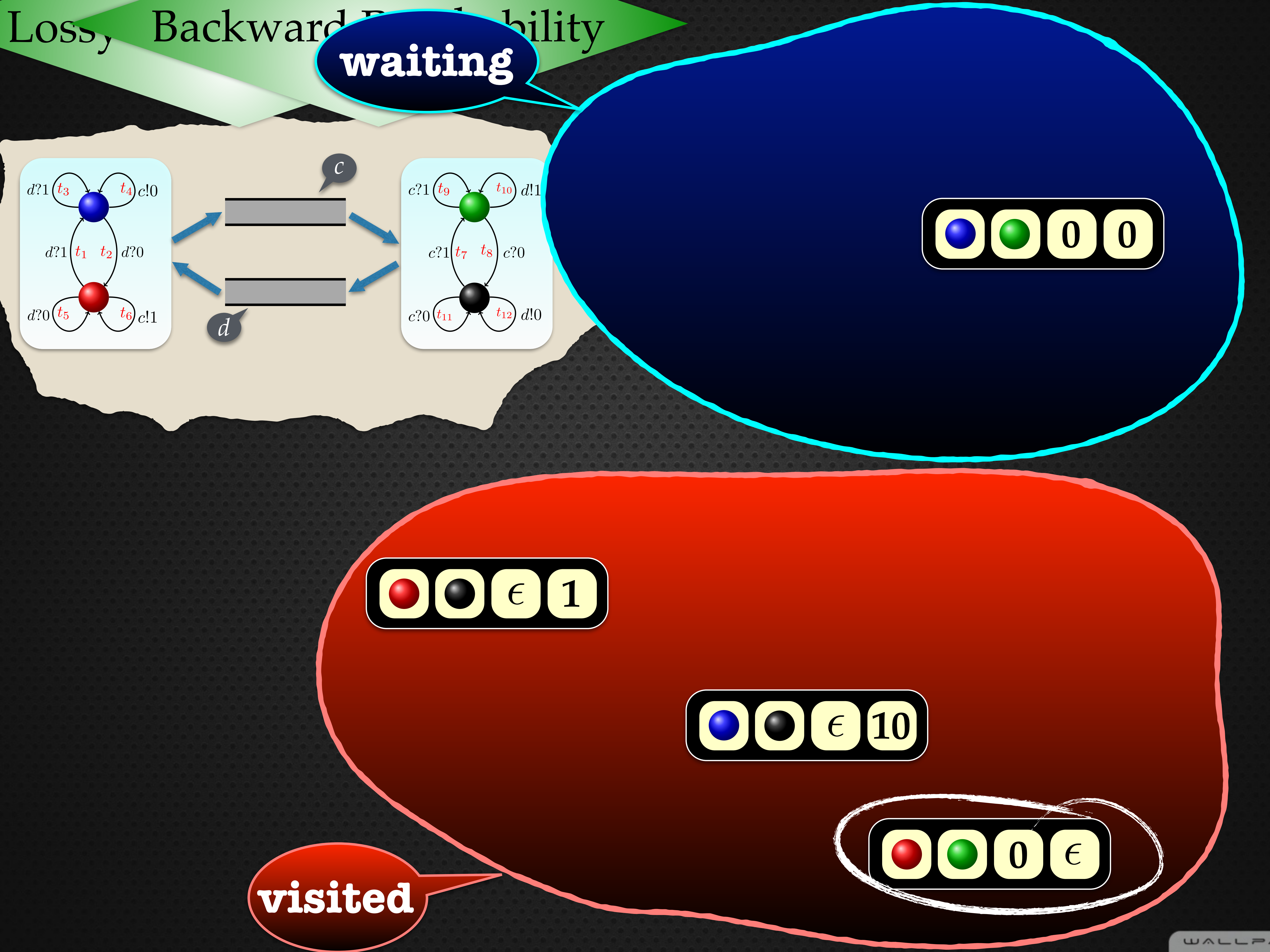
t_2 $d?0$

Lossy Backward R bility




Loss
Backward
bility
waiting
$d?1$ t_3
t_4 $c!0$
$d?1$ t_1
t_2 $d?0$
$d?0$ t_5
t_6 $c!1$
c
d
$c?1$ t_9
t_{10} $d!1$
$c?1$ t_7
t_8 $c?0$
$c?0$ t_{11}
t_{12} $d!0$
0 0
ϵ 1
ϵ 10
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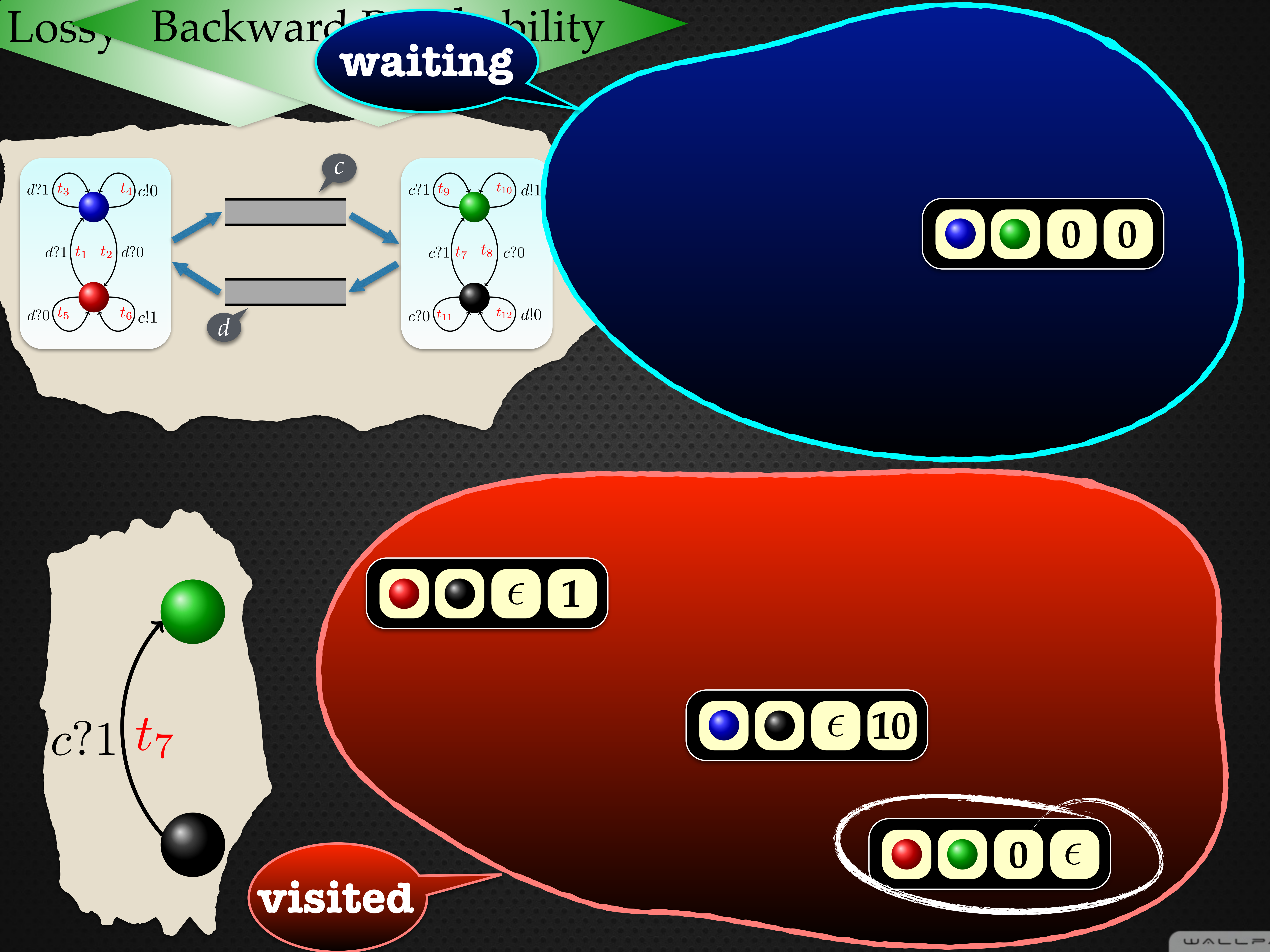
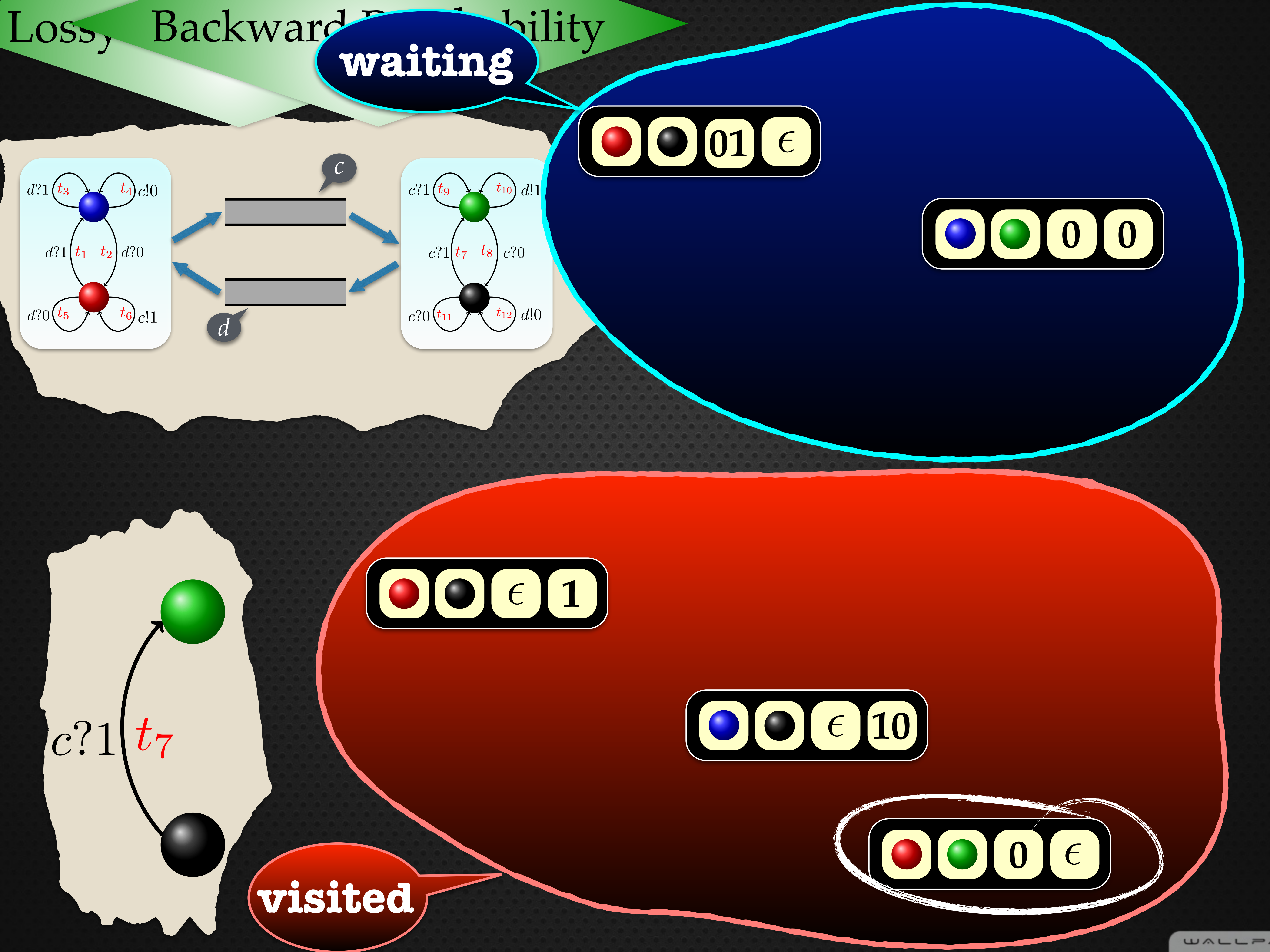
visited


Lossy Backward Reachability
waiting
c
d
d?1 t3
t4 c!0
d?1 t1
t2 d?0
d?0 t5
t6 c!1
c?1 t9
t10 d!1
c?1 t7
t8 c?0
c?0 t11
t12 d!0
0 0
ϵ 1
ϵ 10
0 ϵ
c?1 t7
visited


Lossy Backward Reachability
waiting
01 ϵ
0 0
c
d
d?1 t3
t4 c!0
d?1 t1
t2 d?0
d?0 t5
t6 c!1
c?1 t9
t10 d!1
c?1 t7
t8 c?0
c?0 t11
t12 d!0
ϵ 1
ϵ 10
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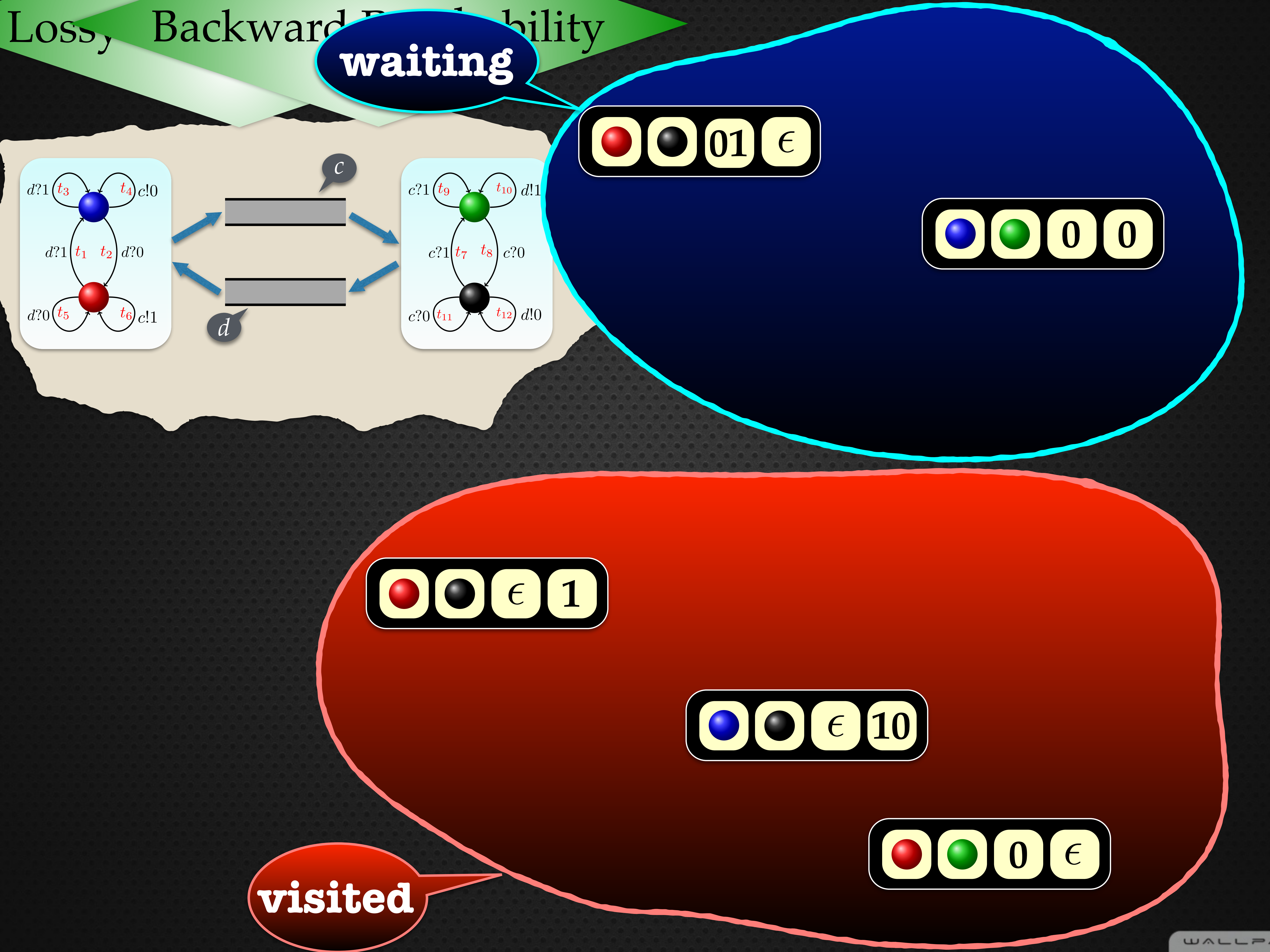
c?1 t7
visited



waiting
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ϵ 1
ϵ 10
0 ϵ
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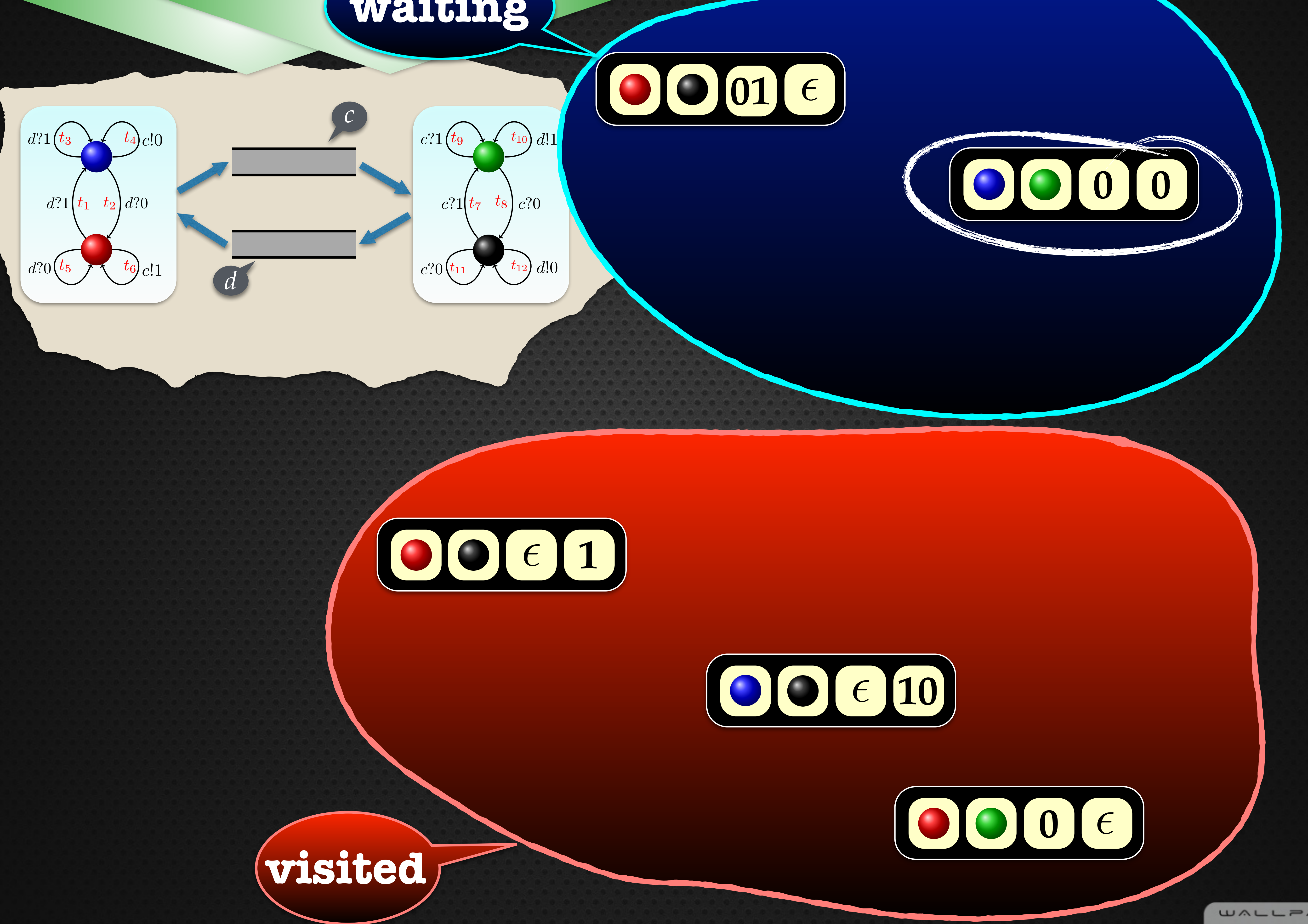
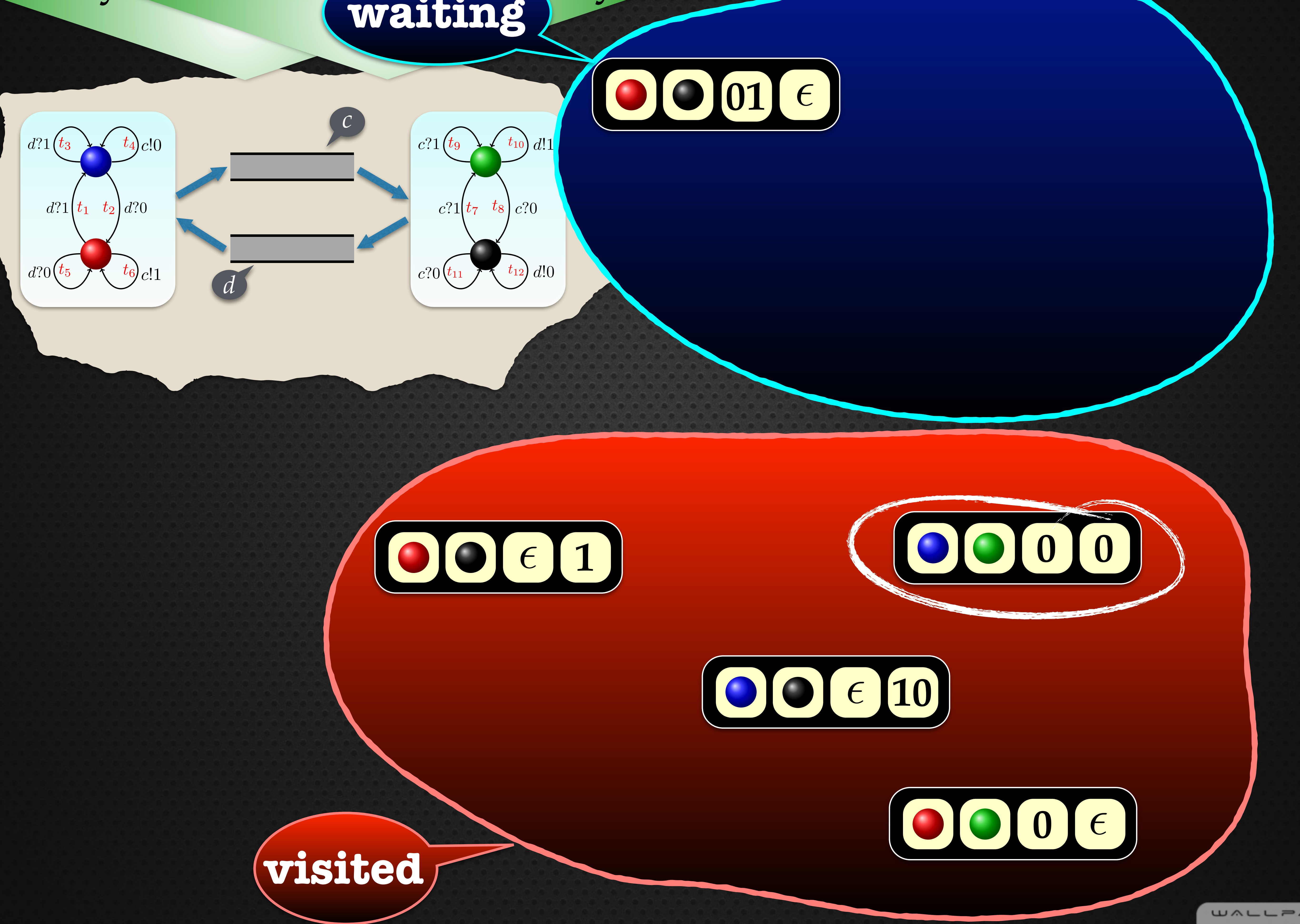
d
$d?1$ t_3 t_4 $c!0$
$d?1$ t_1 t_2 $d?0$
$d?0$ t_5 t_6 $c!1$
$c?1$ t_9 t_{10} $d!1$
$c?1$ t_7 t_8 $c?0$
$c?0$ t_{11} t_{12} $d!0$

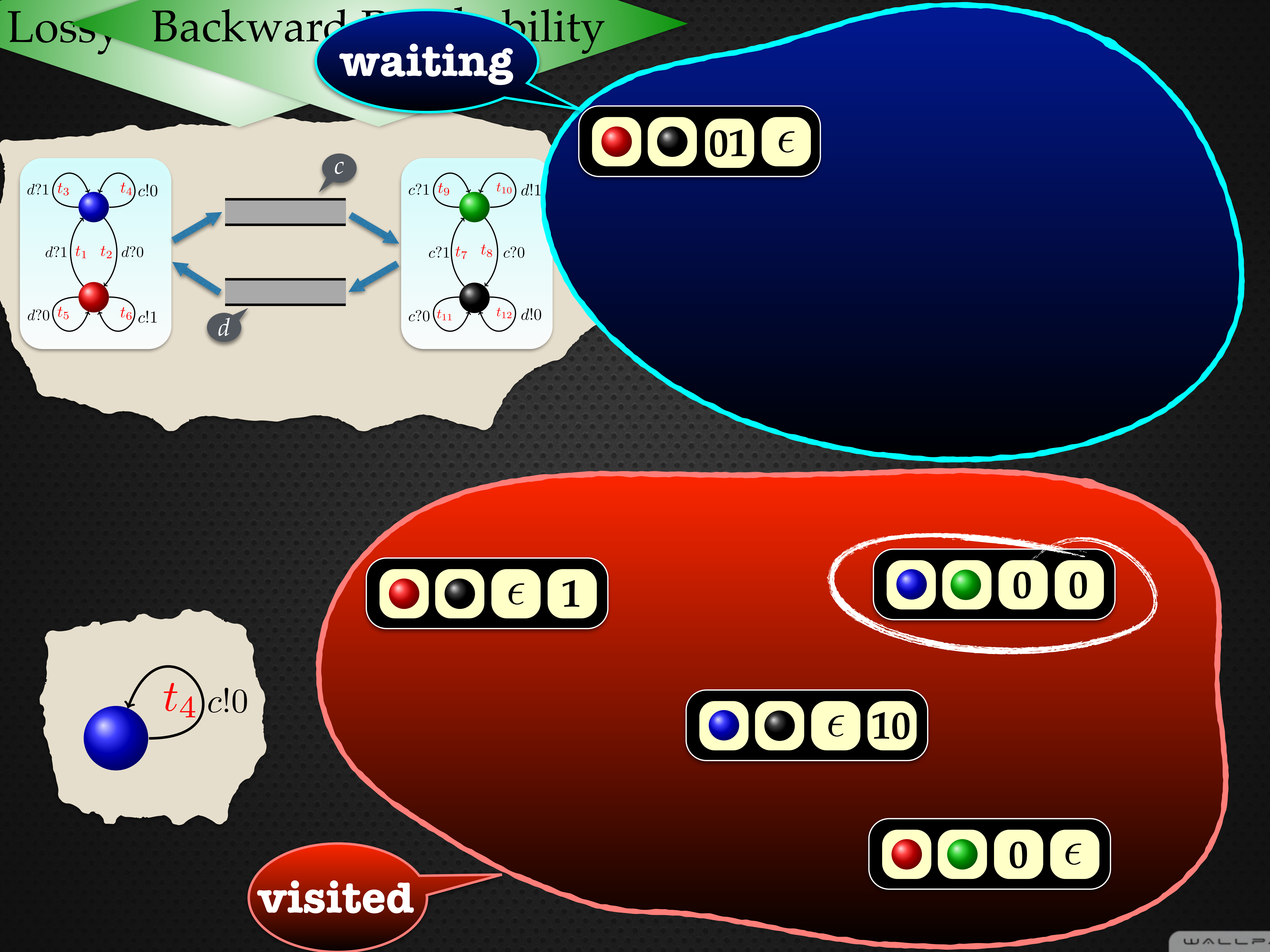
Lossy Backward Reachability

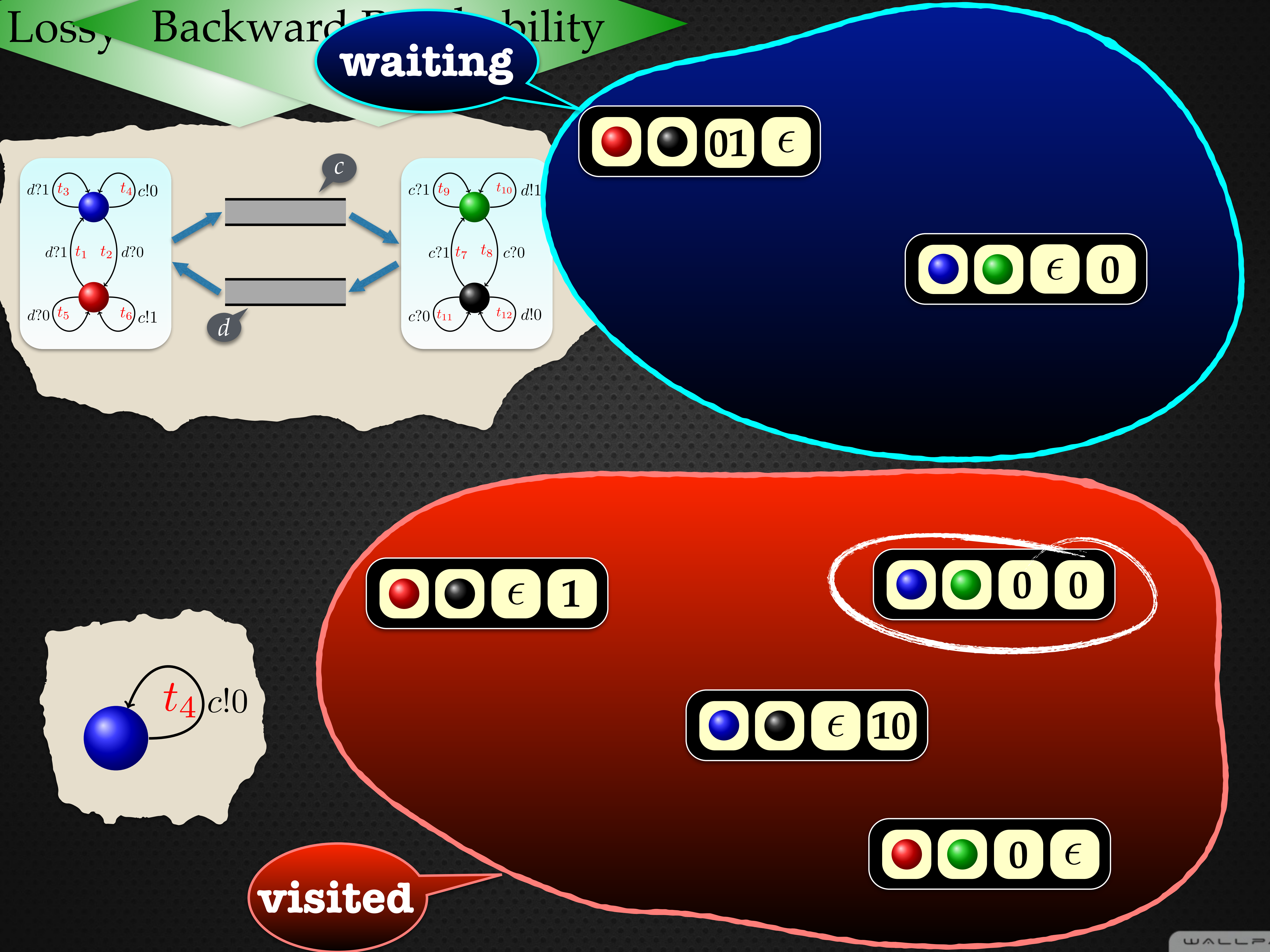


Lossy Backward Reachability



Lossy Backward R…bility




Lossy Backward R bility
waiting
visited
c
d
d?1 t3 t4 c!0
d?1 t1 t2 d?0
d?0 t5 t6 c!1
c?1 t9 t10 d!1
c?1 t7 t8 c?0
c?0 t11 t12 d!0
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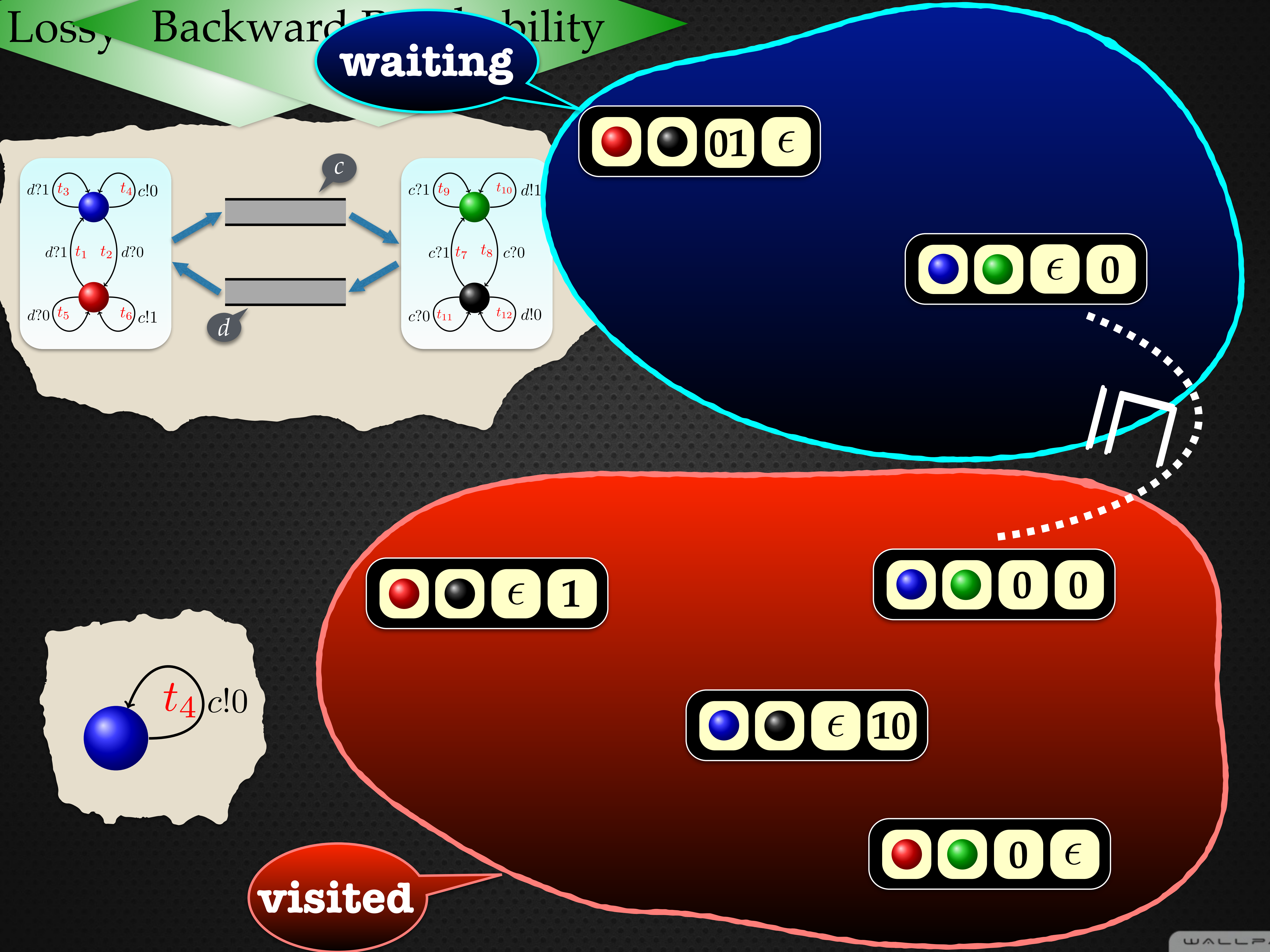
t4 c!0



Lossy
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c!0
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t2
d?0
d?0
t5
t6
c!1
c?1
t9
t10
d!1
c?1
t7
t8
c?0
c?0
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t12
d!0
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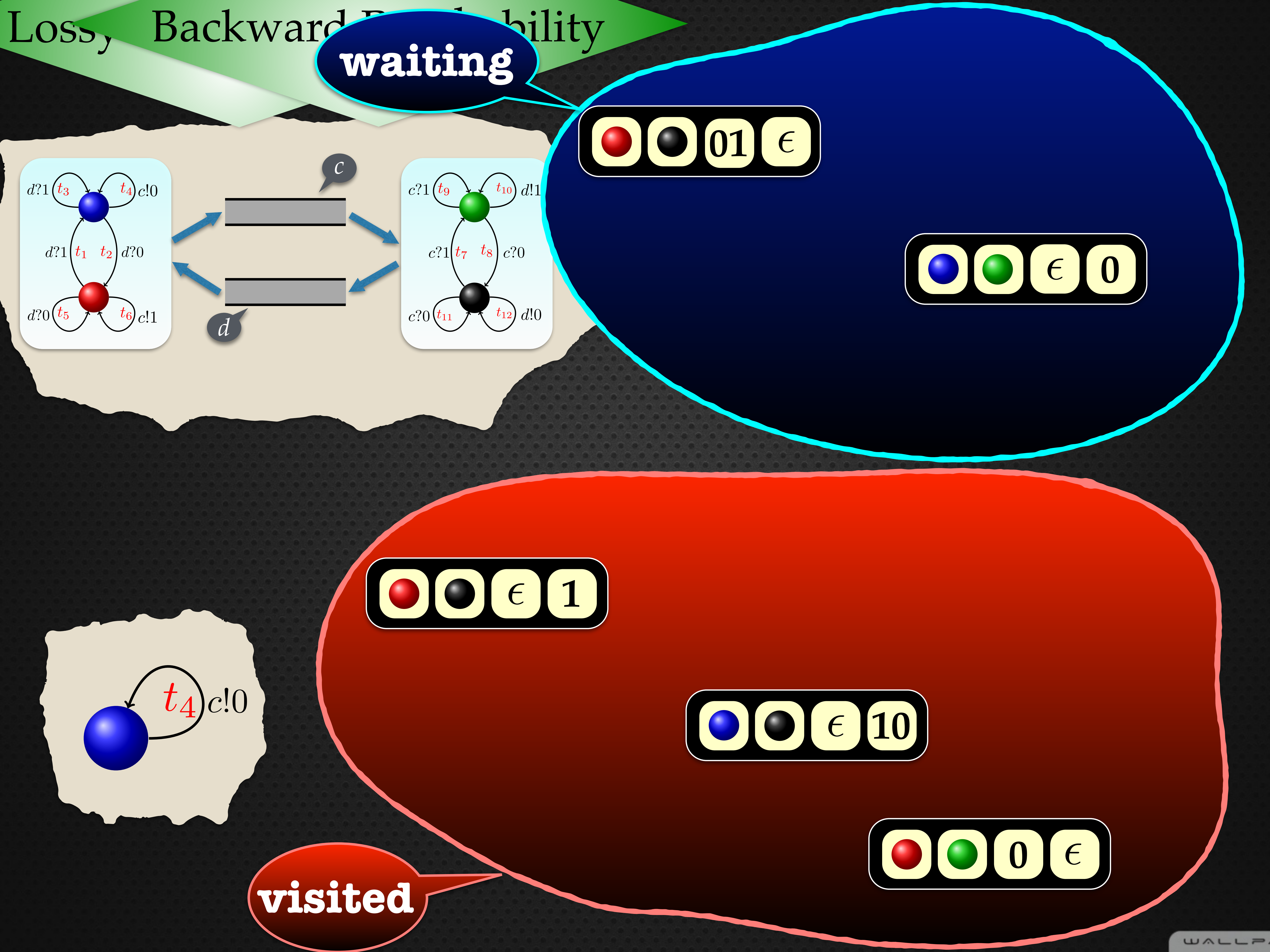
t4
c!0
visited



Loss
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waiting
01 ϵ
ϵ 0
d?1 t3
t4 c!0
d?1 t1
t2 d?0
d?0 t5
t6 c!1
c
d
c?1 t9
t10 d!1
c?1 t7
t8 c?0
c?0 t11
t12 d!0
ϵ 1
ϵ 10
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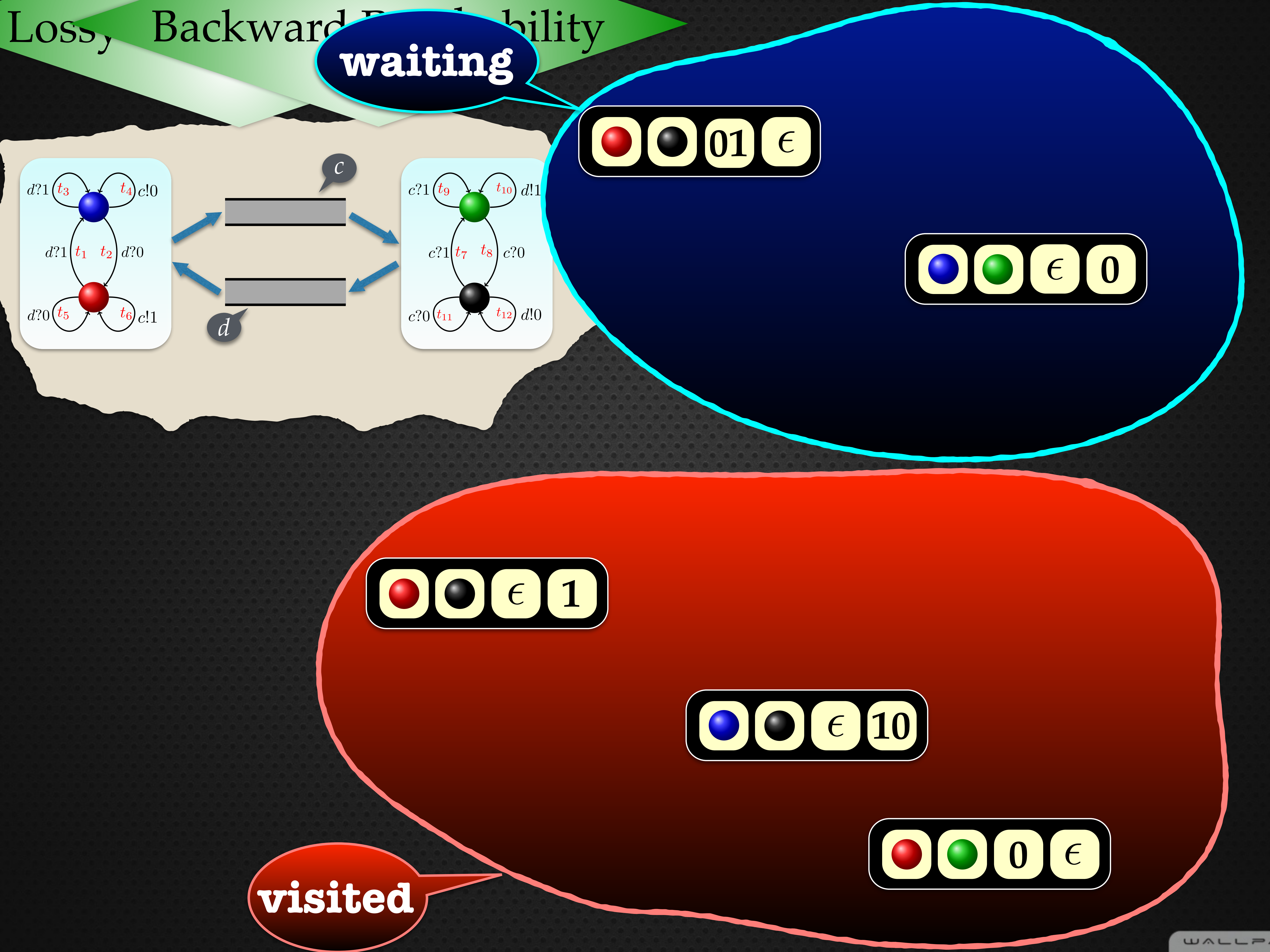
t4 c!0
visited



Lossy Backward
waiting
d?1 t3 t4 c!0
d?1 t1 t2 d?0
d?0 t5 t6 c!1
c
d
c?1 t9 t10 d!1
c?1 t7 t8 c?0
c?0 t11 t12 d!0
01 ϵ
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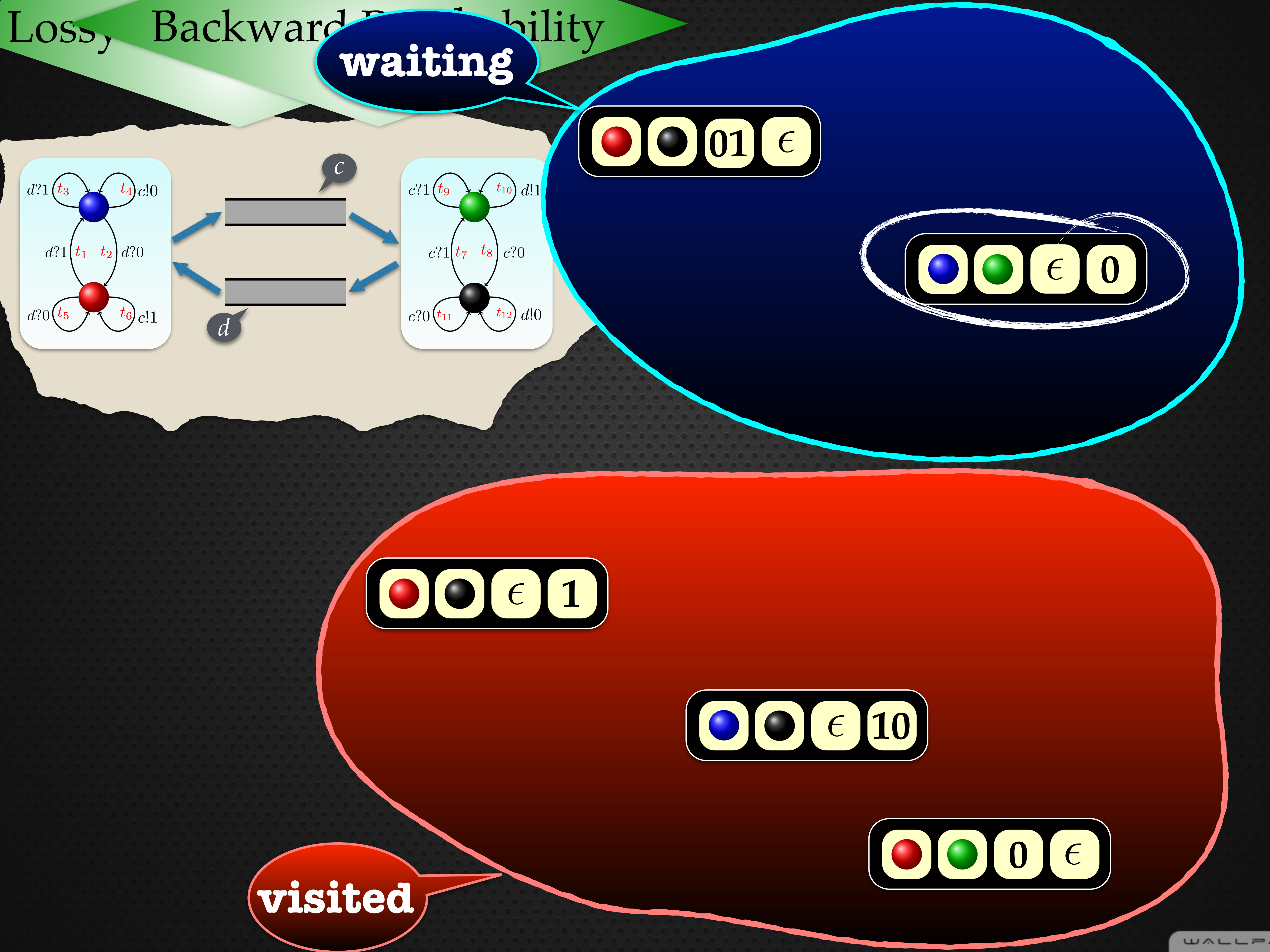
visited


Loss Backward R bility
waiting
$d?1$ t_3 t_4 $c!0$
$d?1$ t_1 t_2 $d?0$
$d?0$ t_5 t_6 $c!1$
c
d
$c?1$ t_9 t_{10} $d!1$
$c?1$ t_7 t_8 $c?0$
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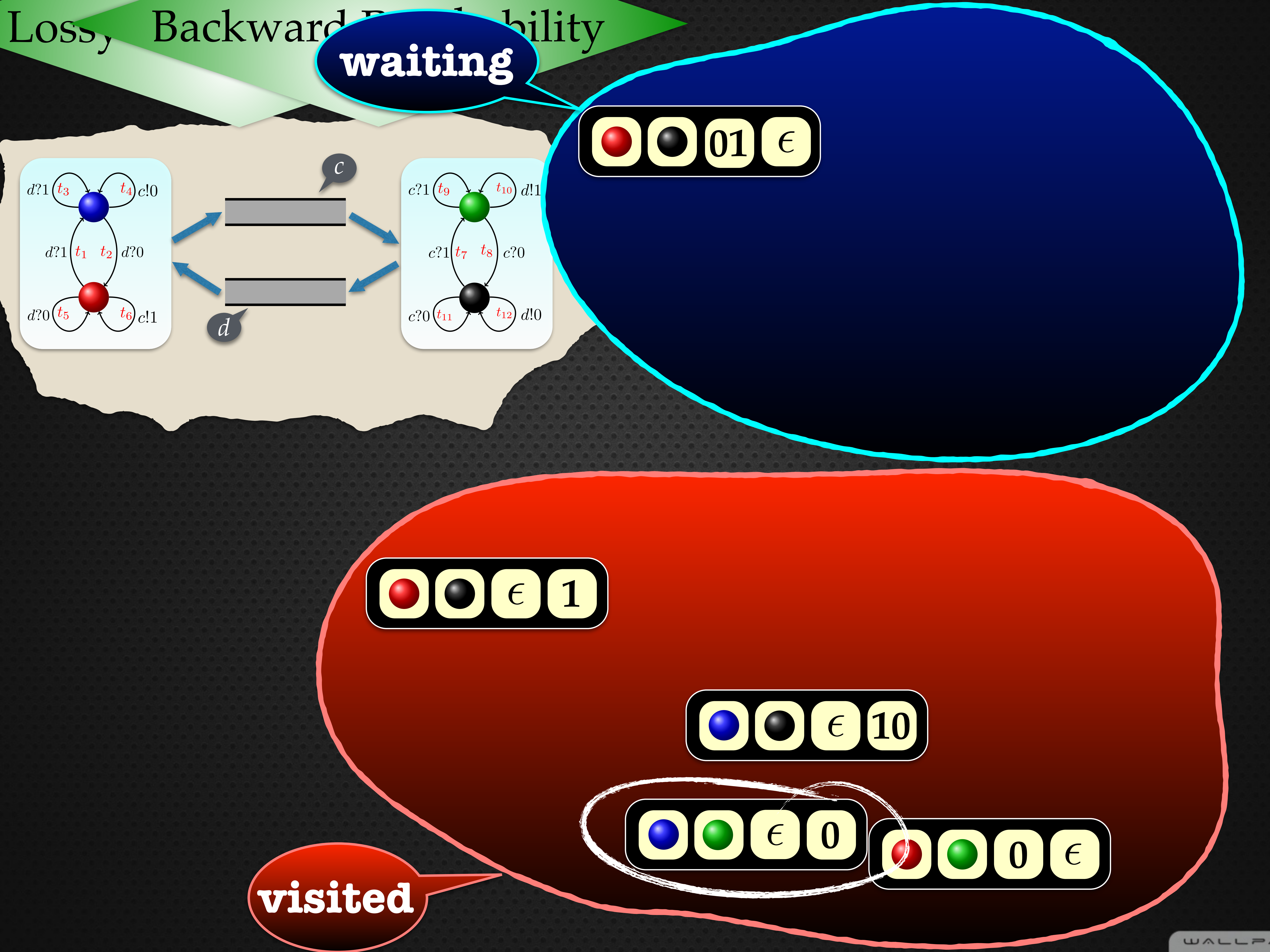
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$c?1$ t_7
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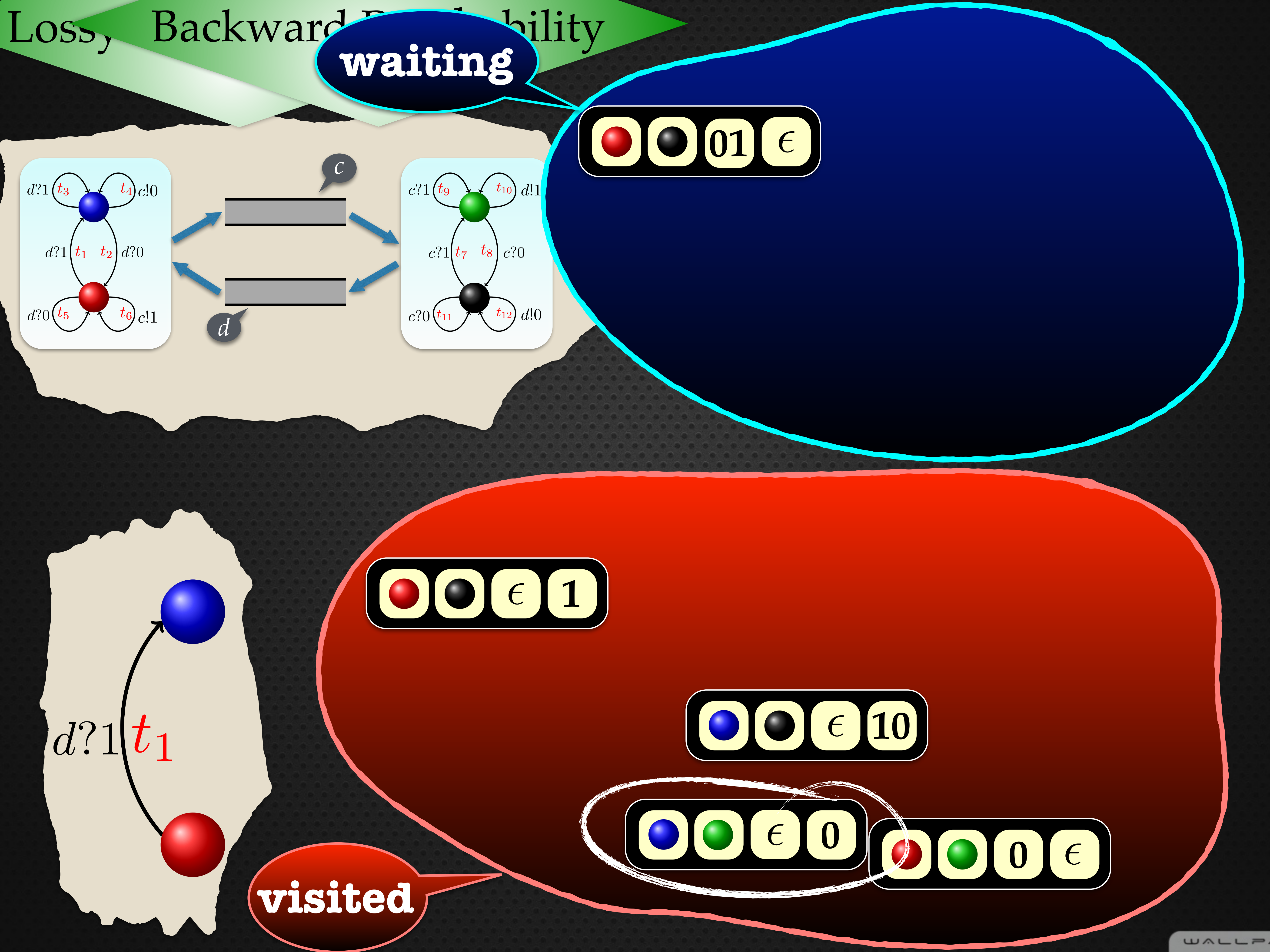
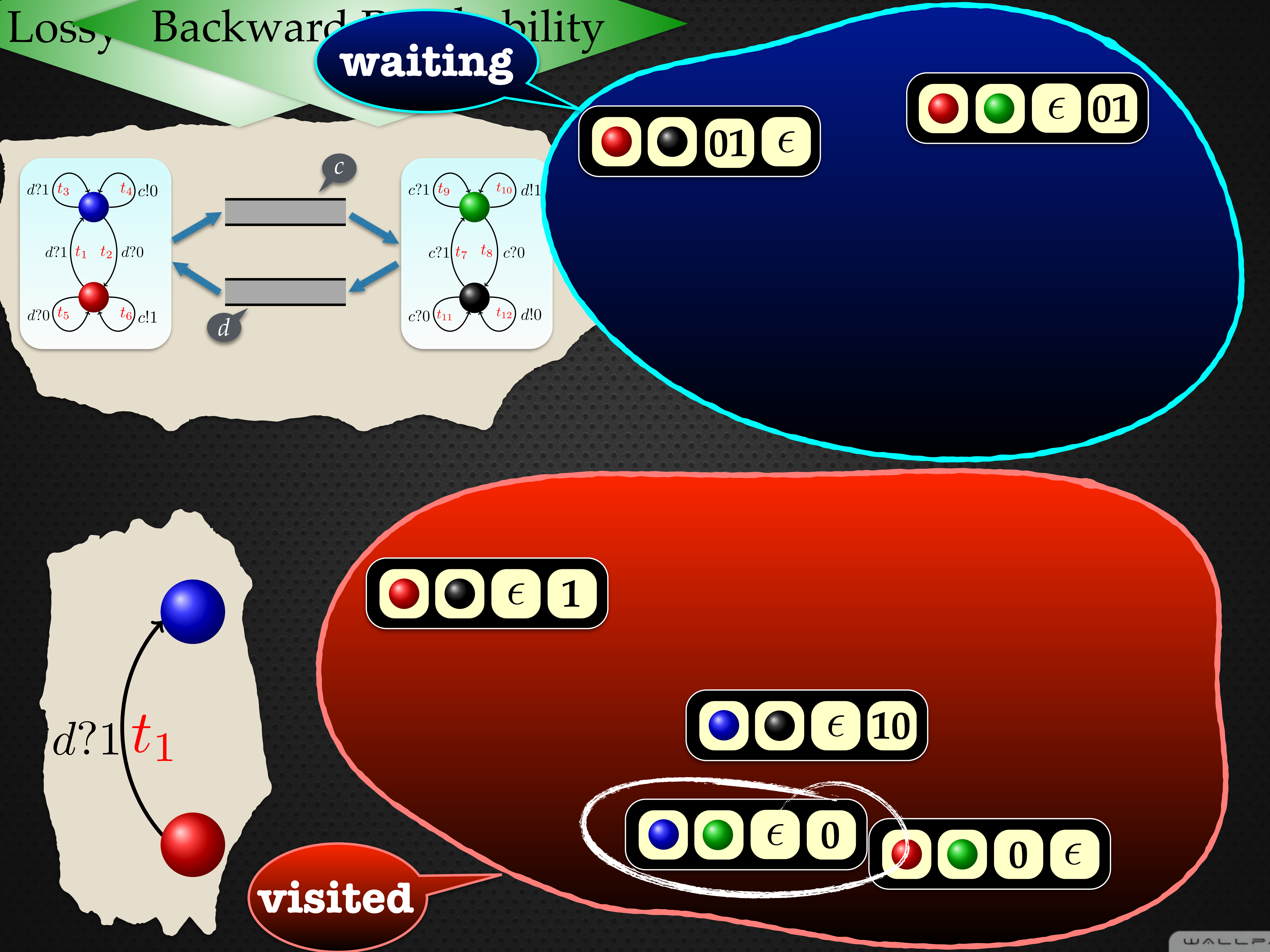
visited

Lossy Backward Reachability





Loss
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t4 c!0
d?1 t1
t2 d?0
d?0 t5
t6 c!1
c?1 t9
t10 d!1
c?1 t7
t8 c?0
c?0 t11
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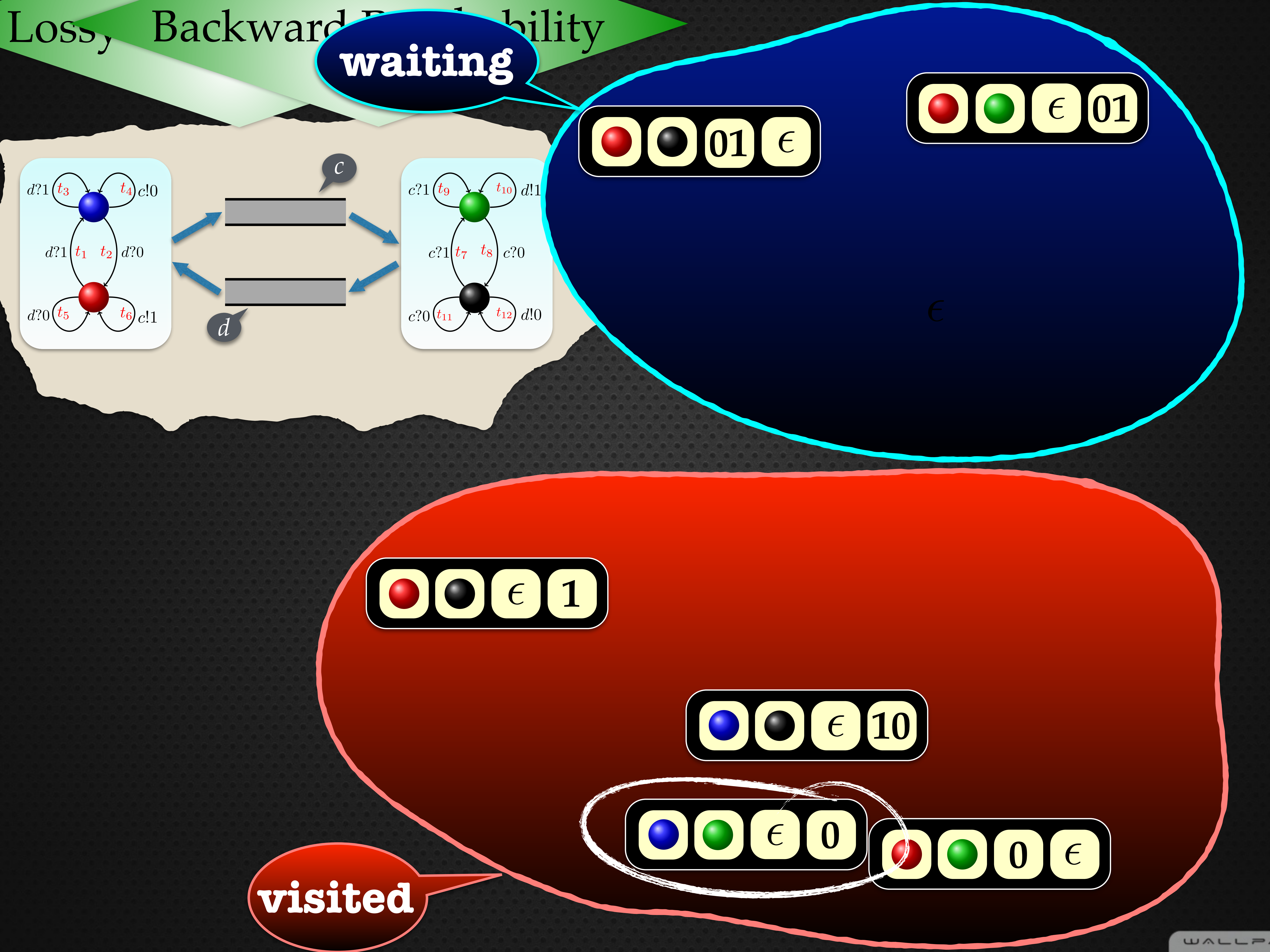
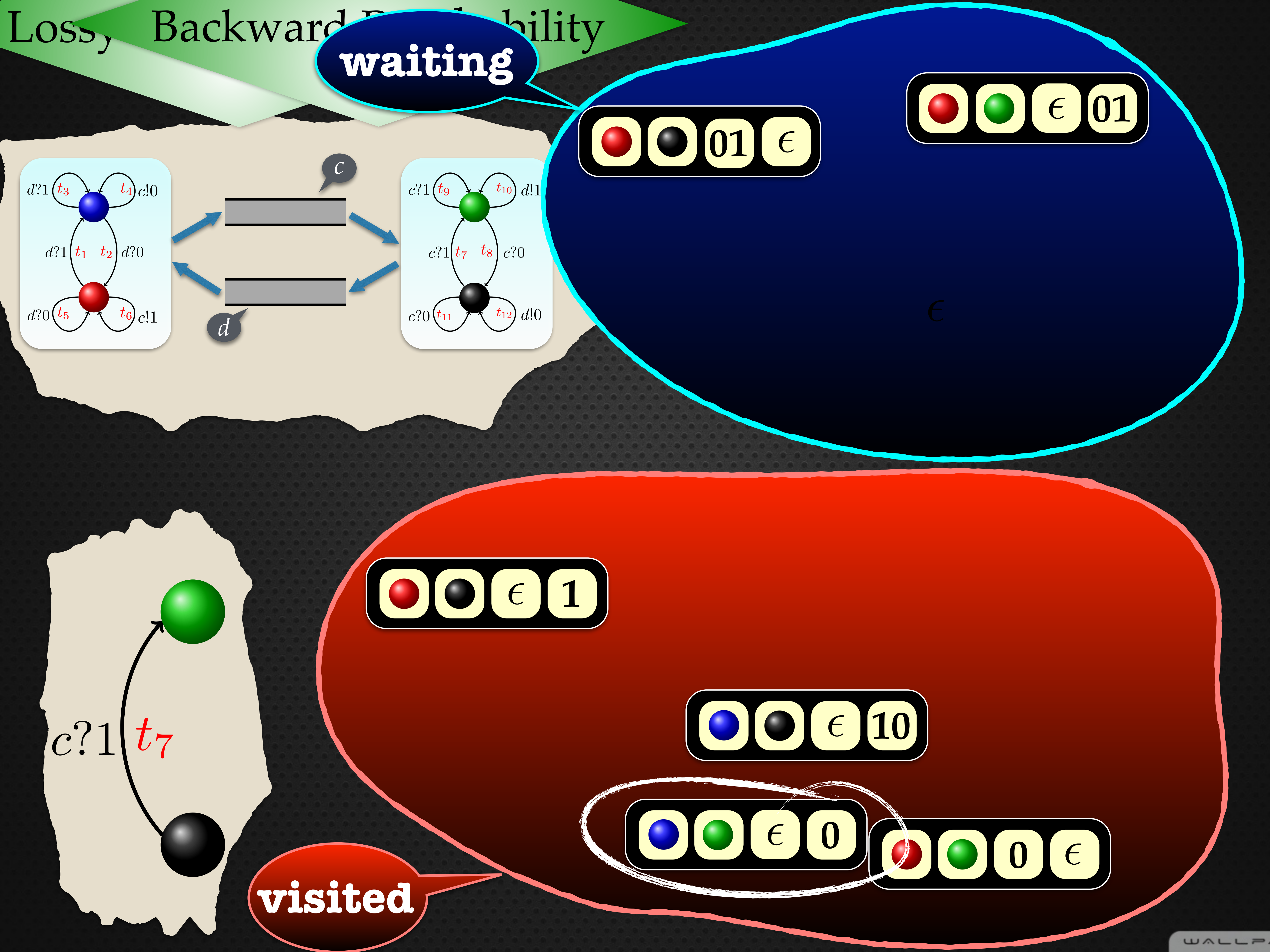
Lossy Backward Reachability




waiting
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d?1 t1
t2 d?0
d?0 t5
t6 c!1
c?1 t9
t10 d!1
c?1 t7
t8 c?0
c?0 t11
t12 d!0
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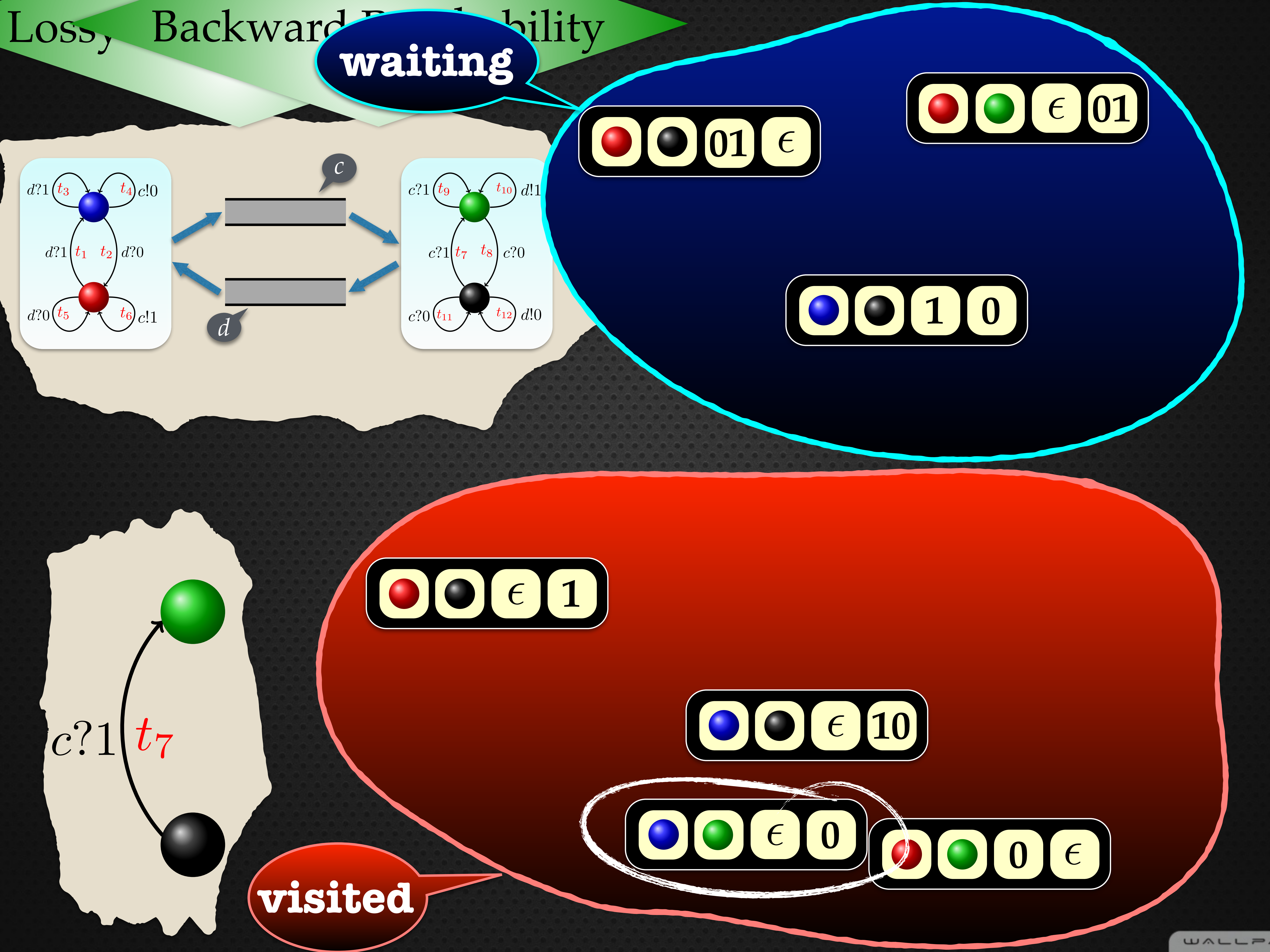
visited



Lossy Backward ... bility
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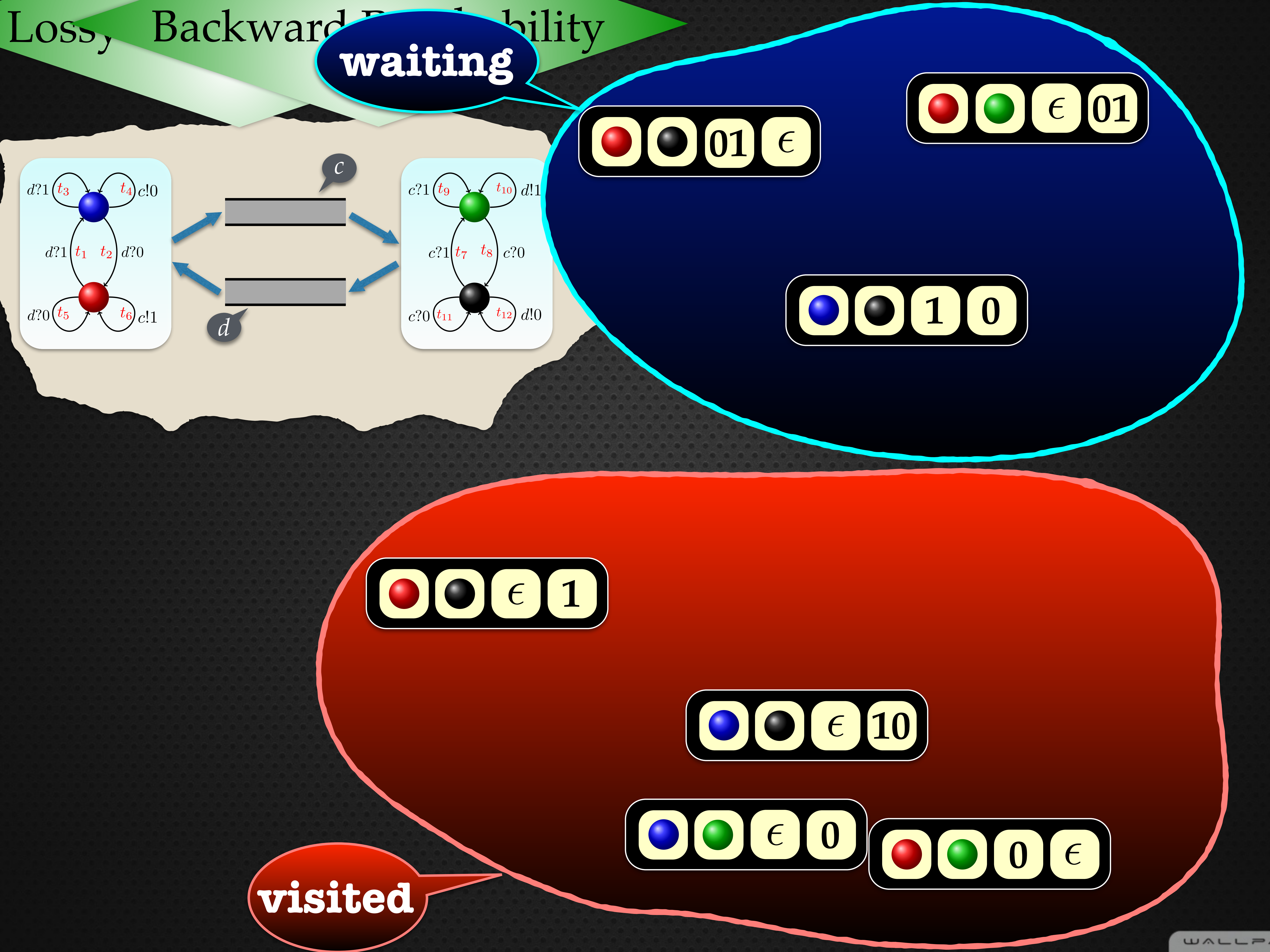
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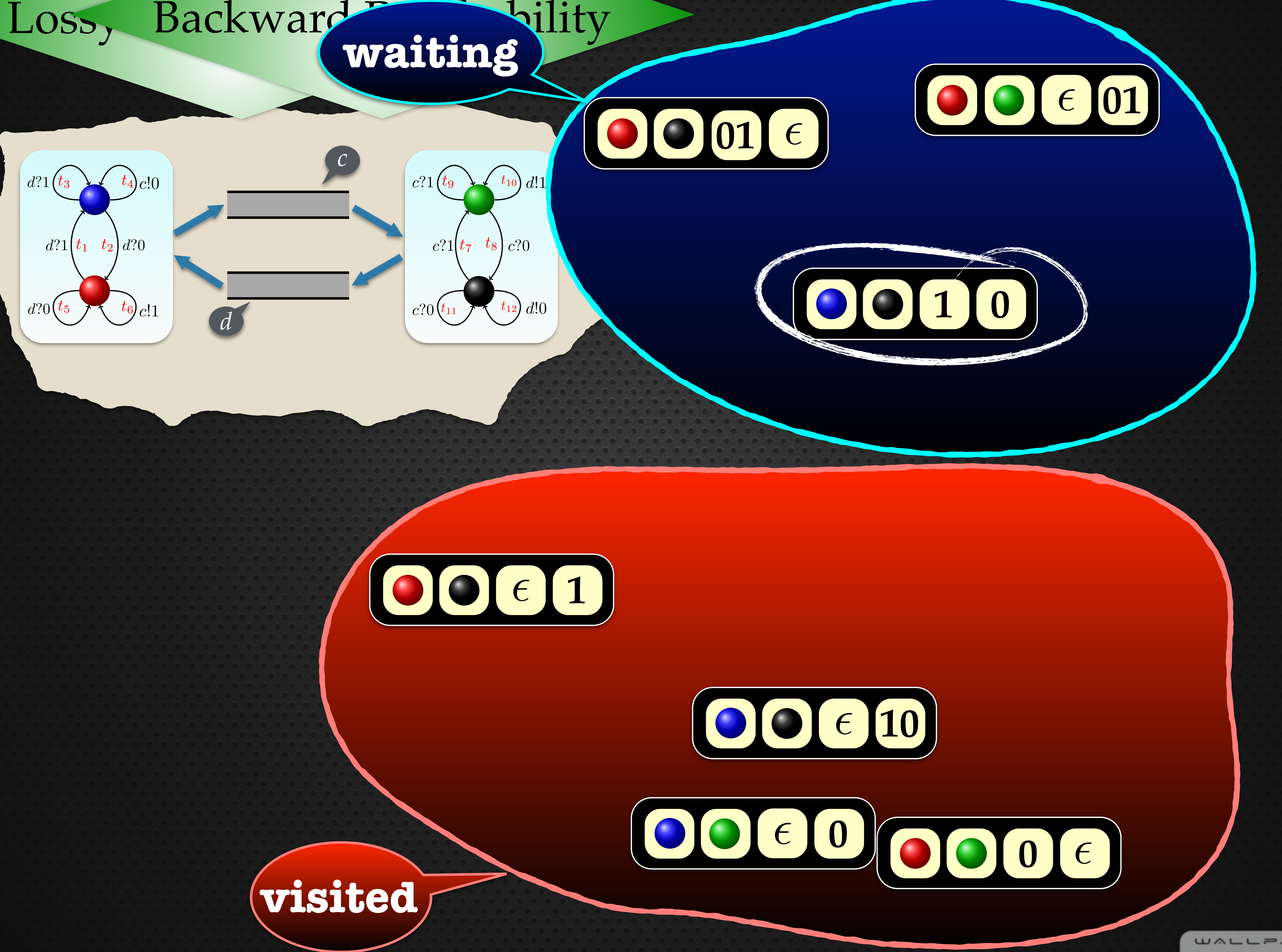
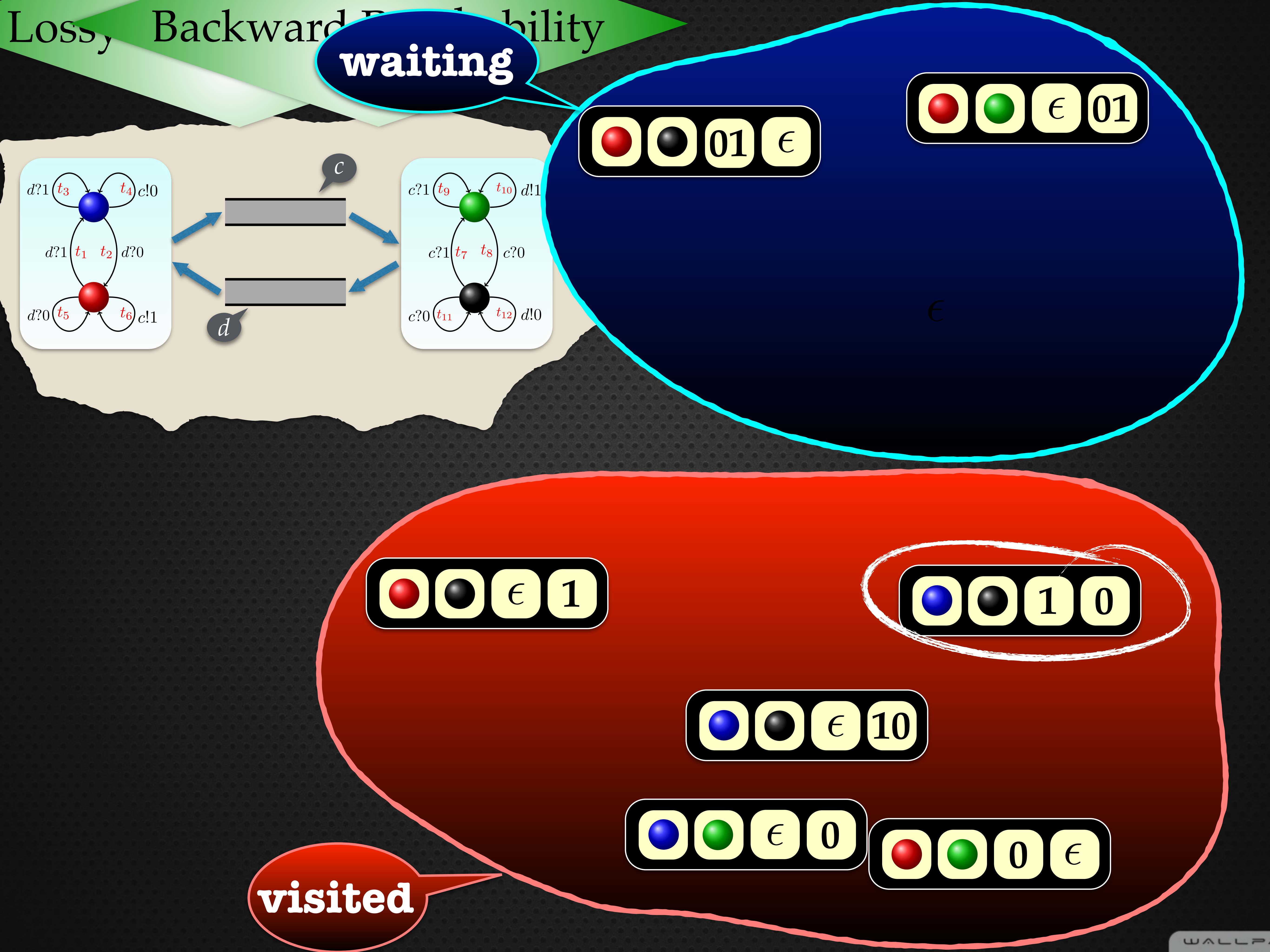
Lossy Backward R…bility





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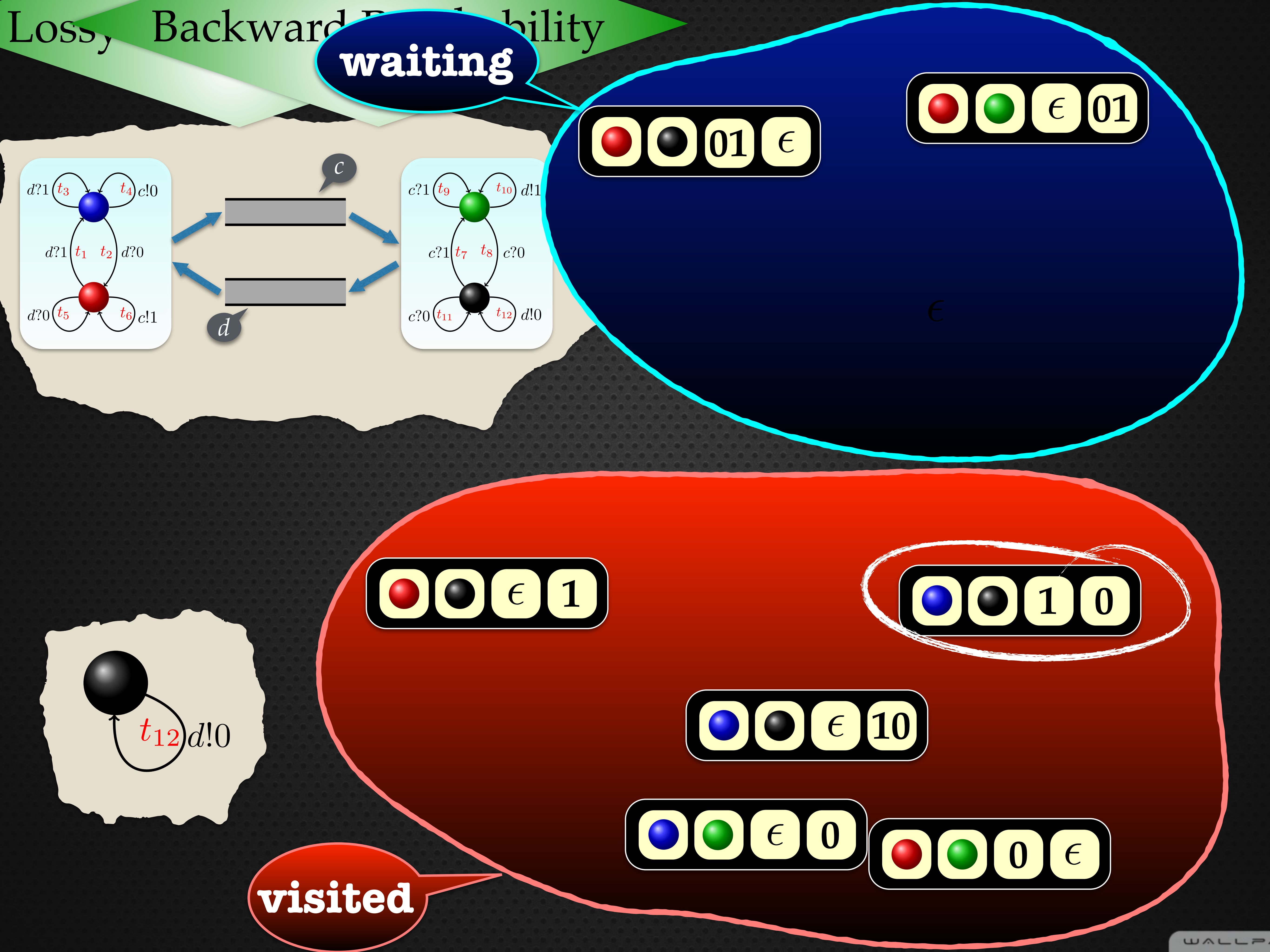

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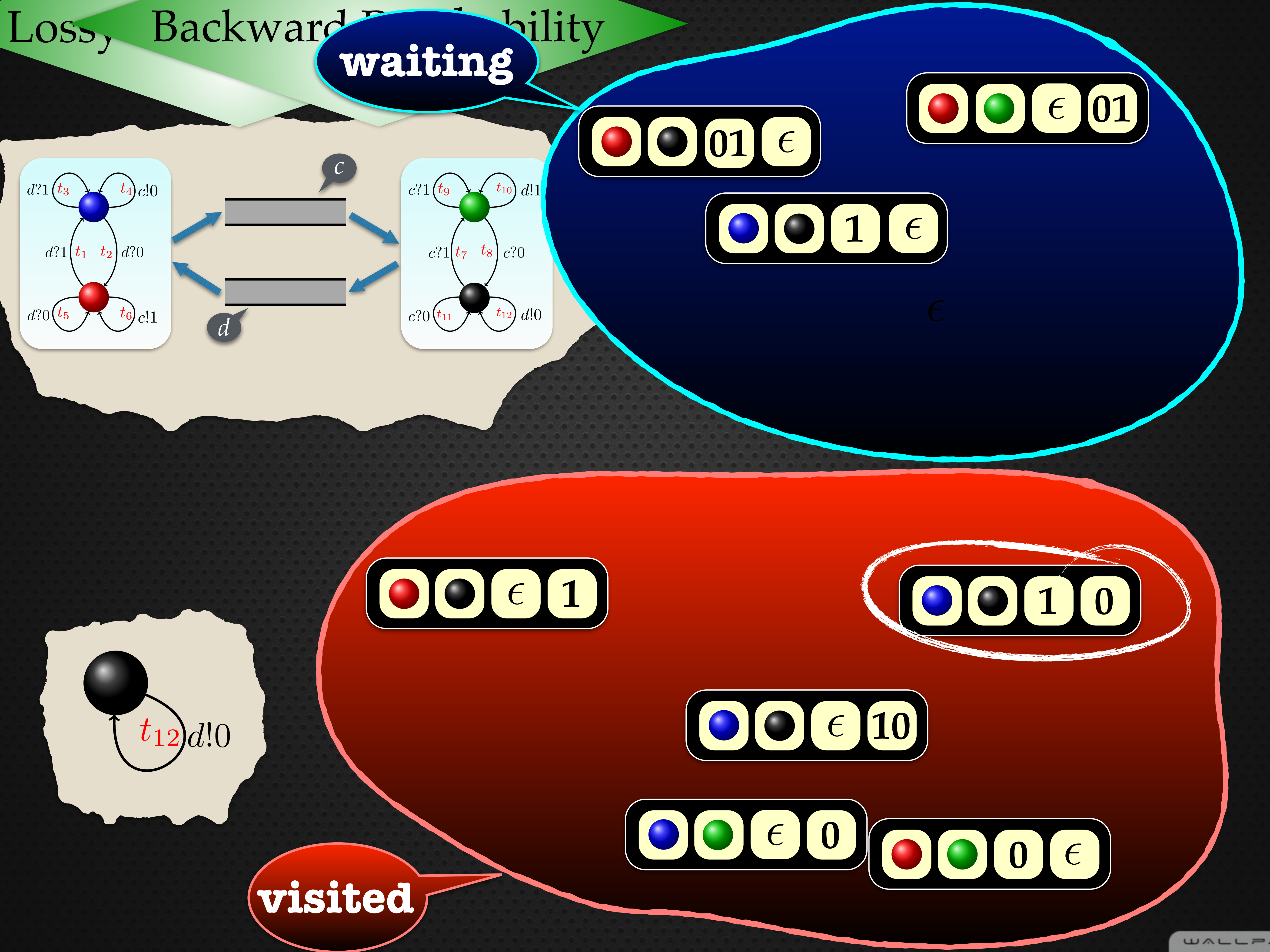
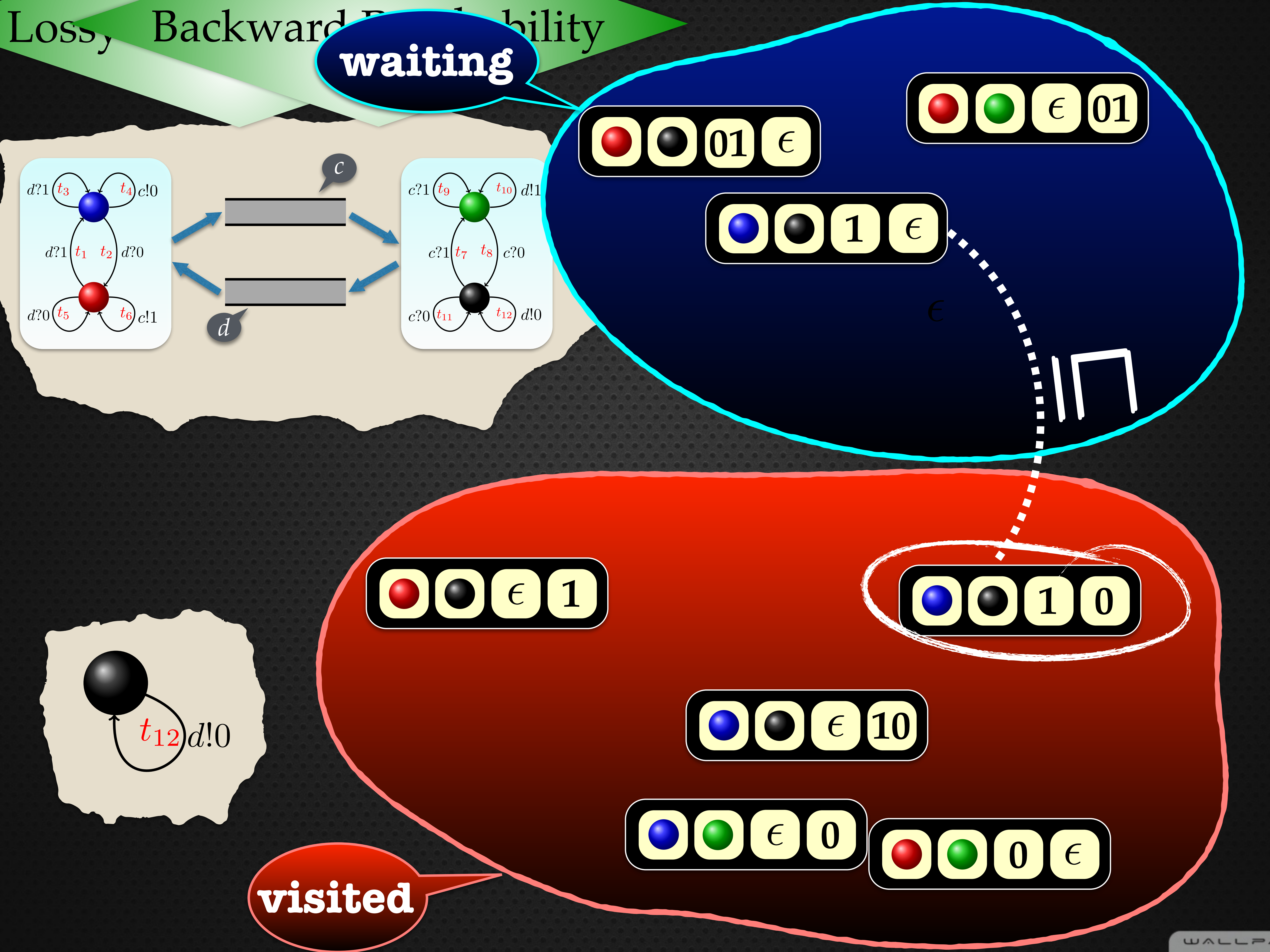
Lossy Backward R… bility

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$d?1$ t_3 t_4 $c!0$
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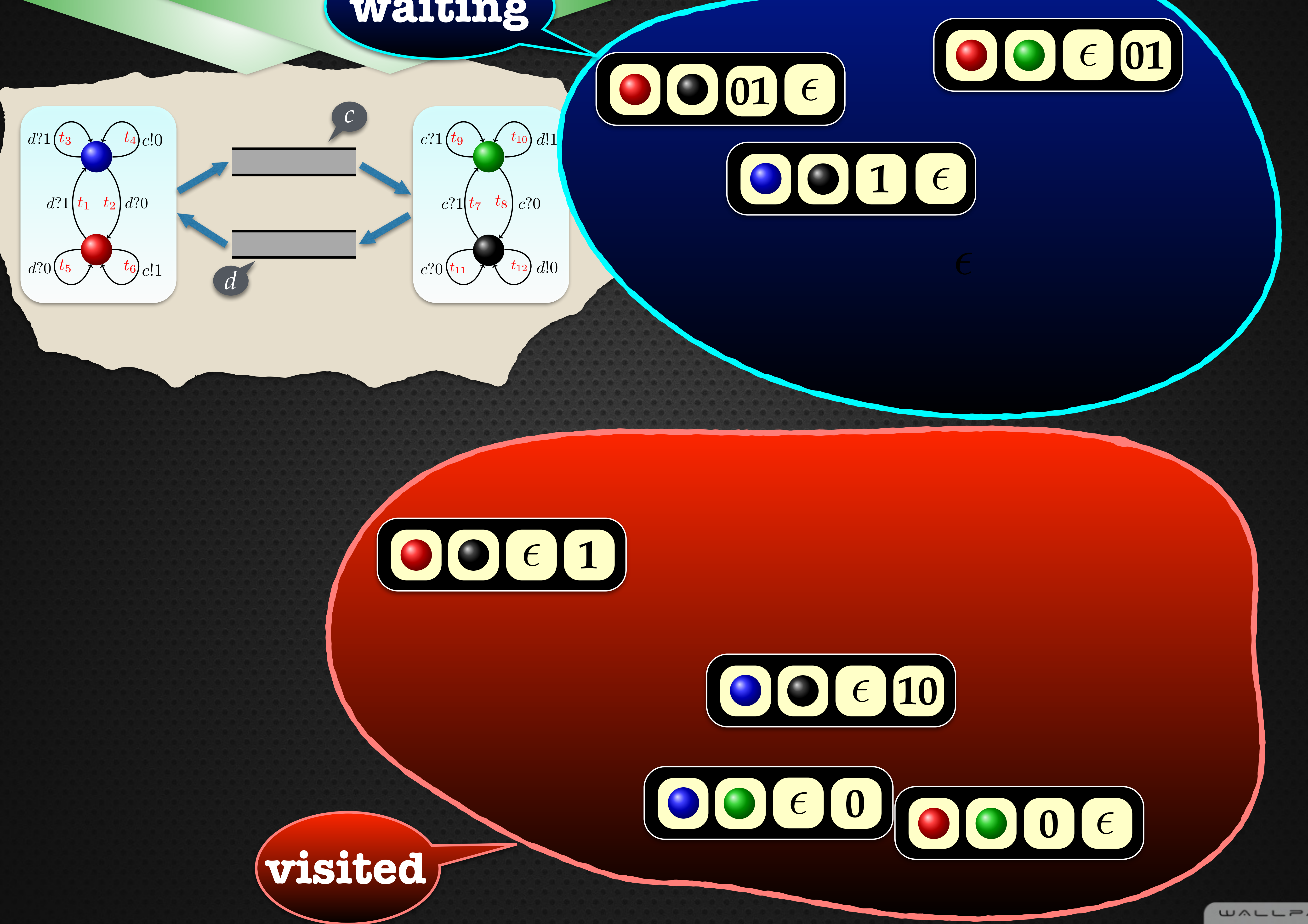
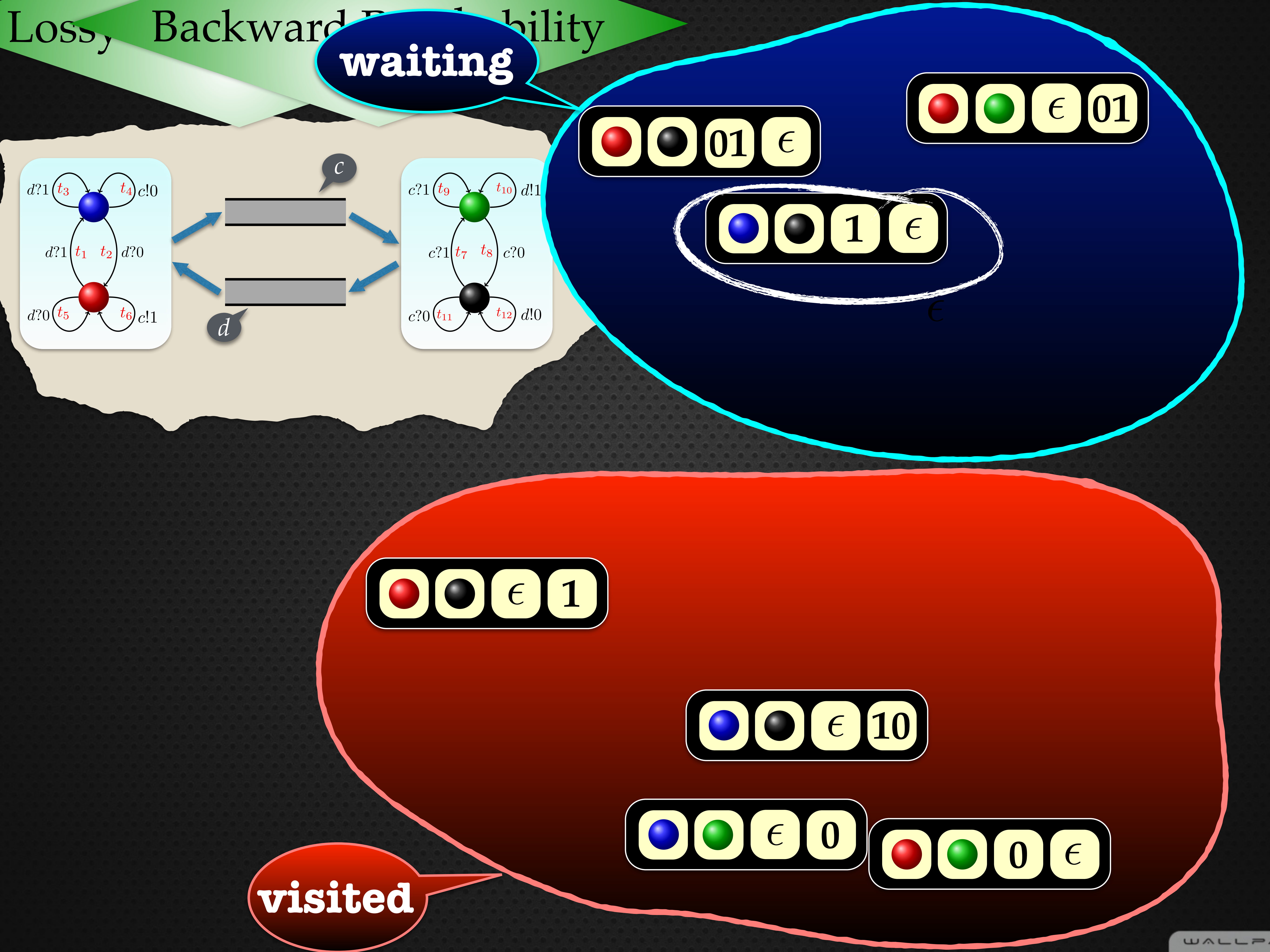
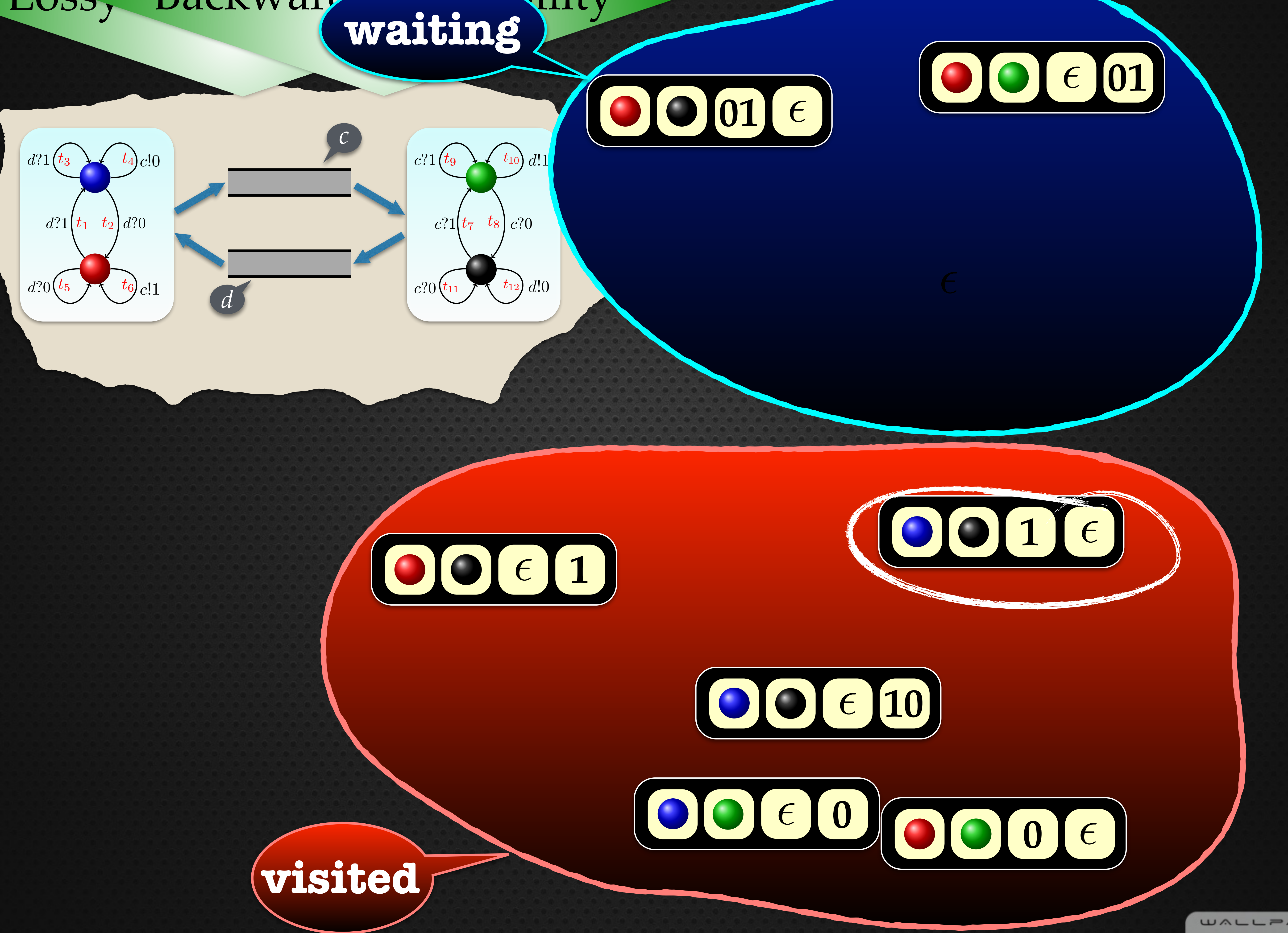
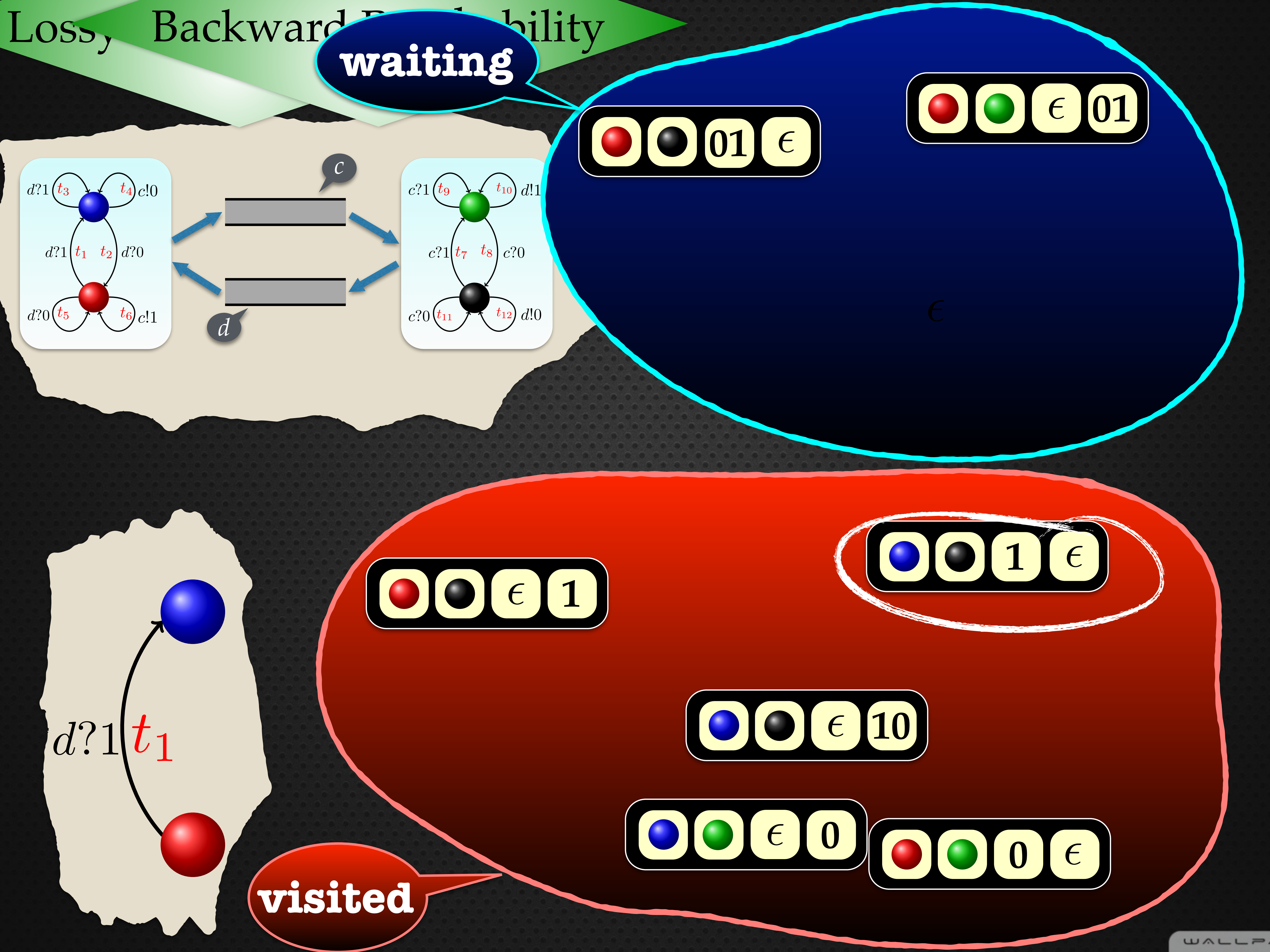


Loss y Backward R bility



Lossy Backward Reachability





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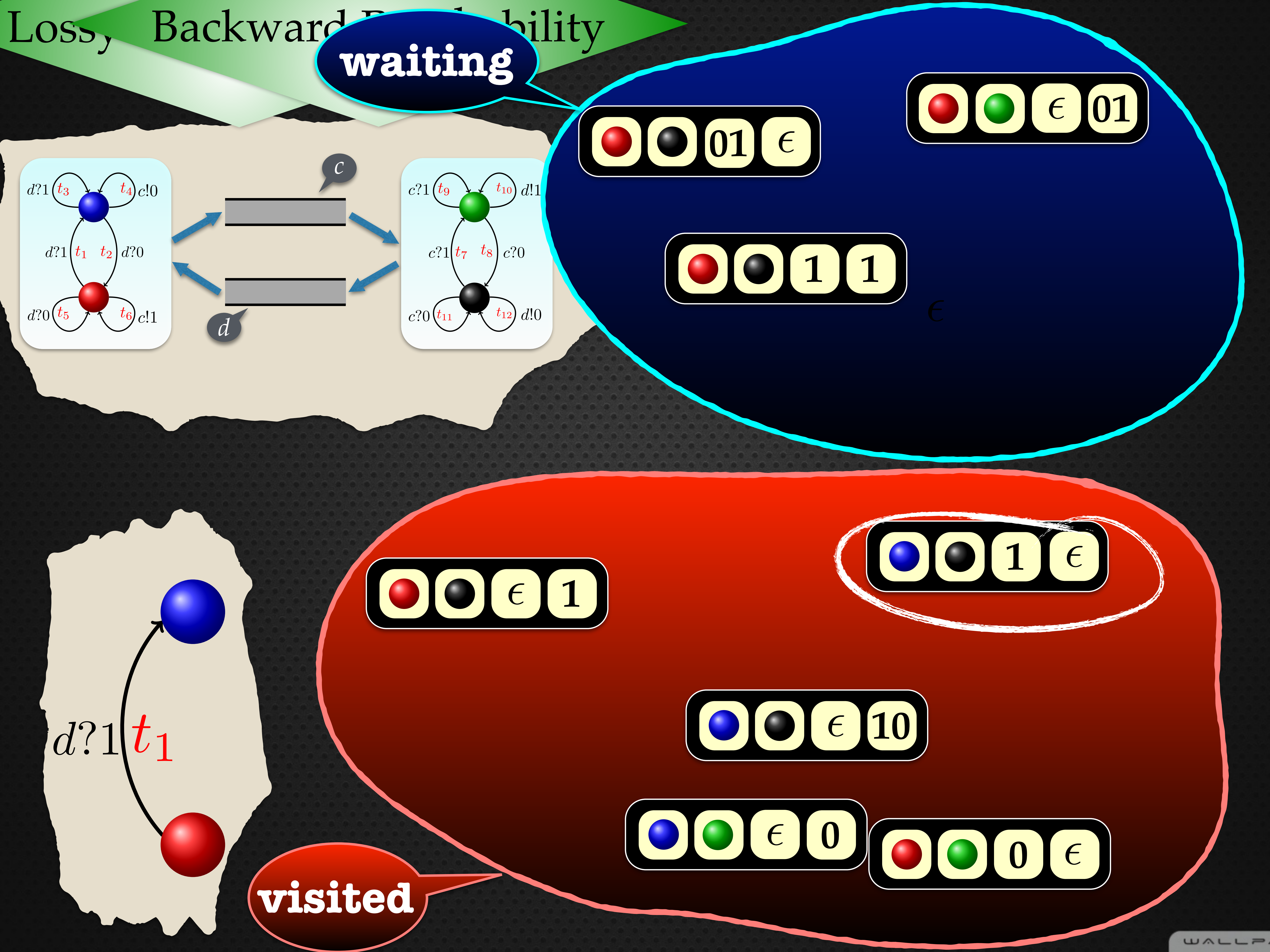
d?1 t3
t4 c!0
d?0 t5
t6 c!1
c?1 t7
t8 c?0
c?1 t9
t10 d!1
c?0 t11
t12 d!0



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t6 c!1
c?1 t9
t10 d!1
c?1 t7
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c?0 t11
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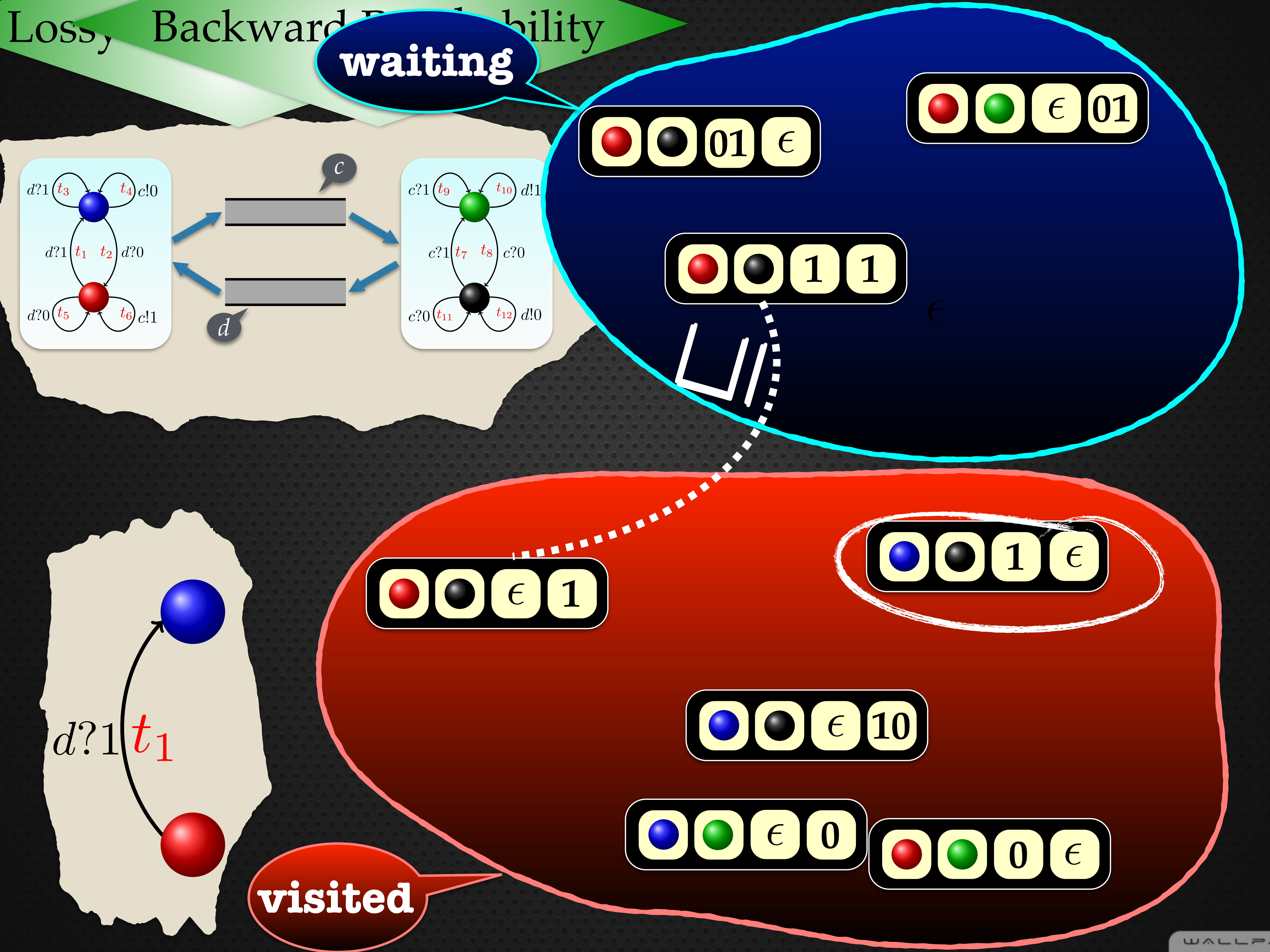
visited



Lossy
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$d?1$ t_1
t_2 $d?0$
$d?0$ t_5
t_6 $c!1$
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d
$c?1$ t_9
t_{10} $d!1$
$c?1$ t_7
t_8 $c?0$
$c?0$ t_{11}
t_{12} $d!0$
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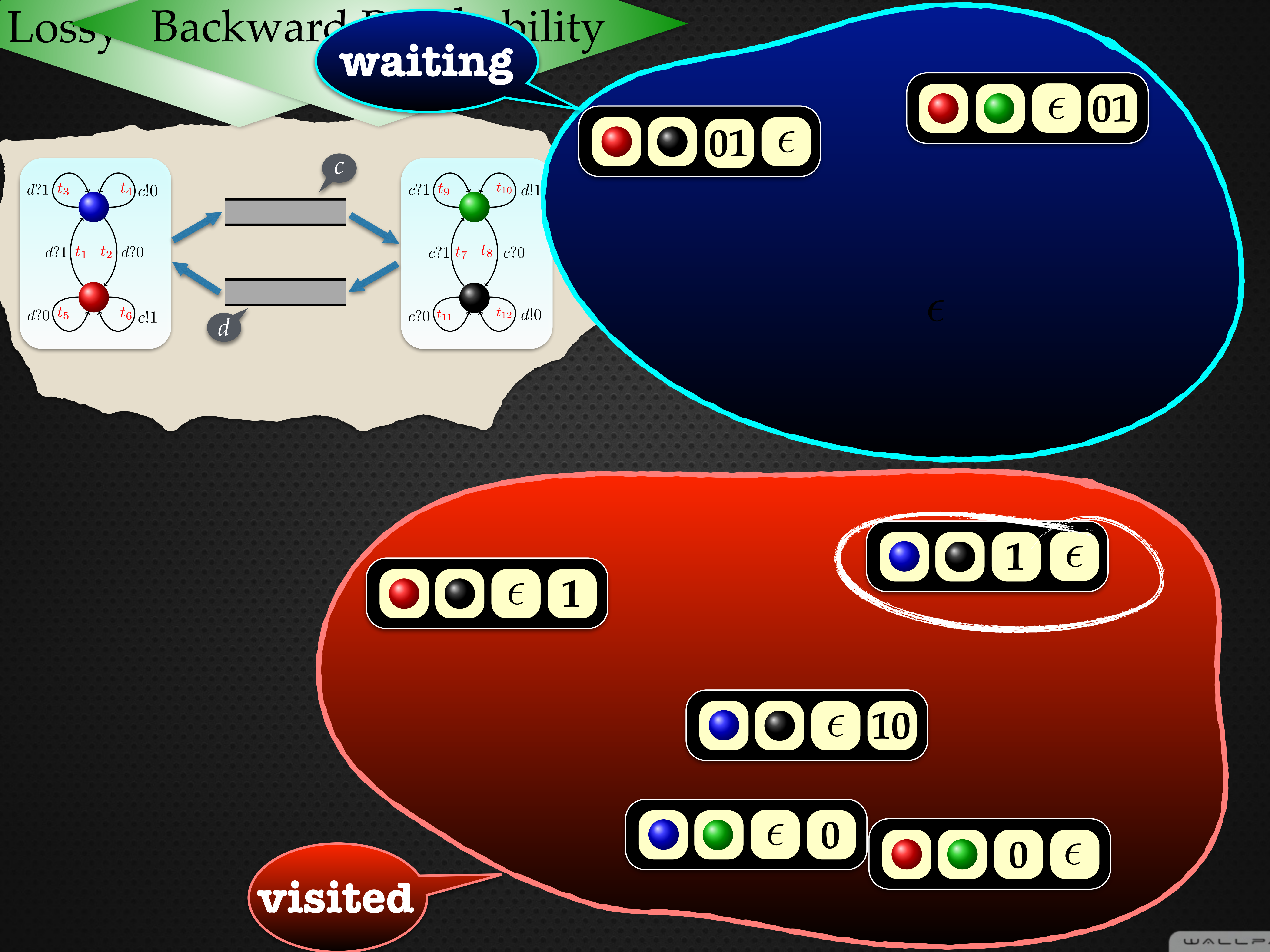
$d?1$ t_1
visited



Lossy Backward … bility
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c
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d?1 t_3
t_4 c!0
d?1 t_1
t_2 d?0
d?0 t_5
t_6 c!1
c?1 t_9
t_{10} d!1
c?1 t_7
t_8 c?0
c?0 t_{11}
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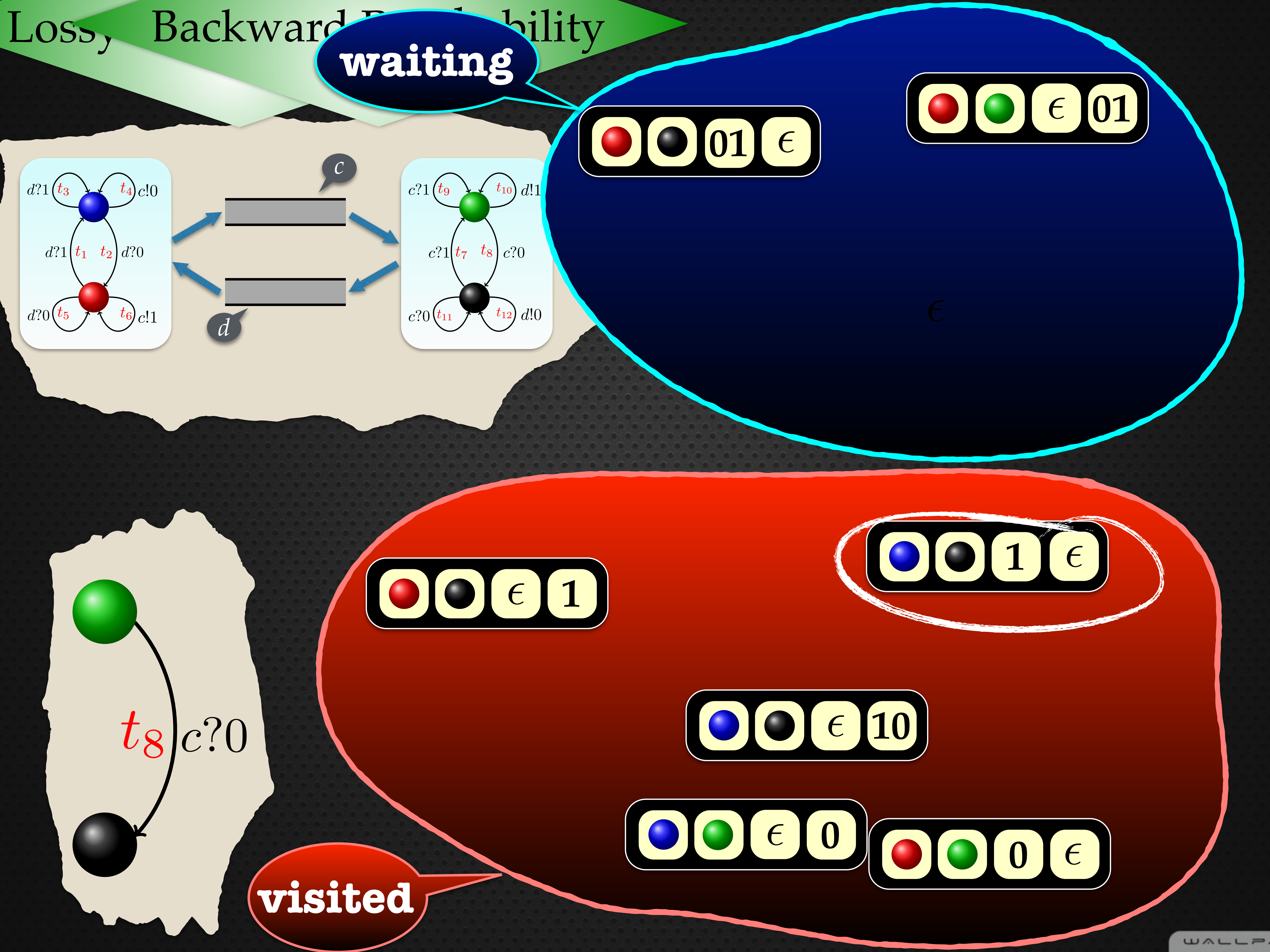
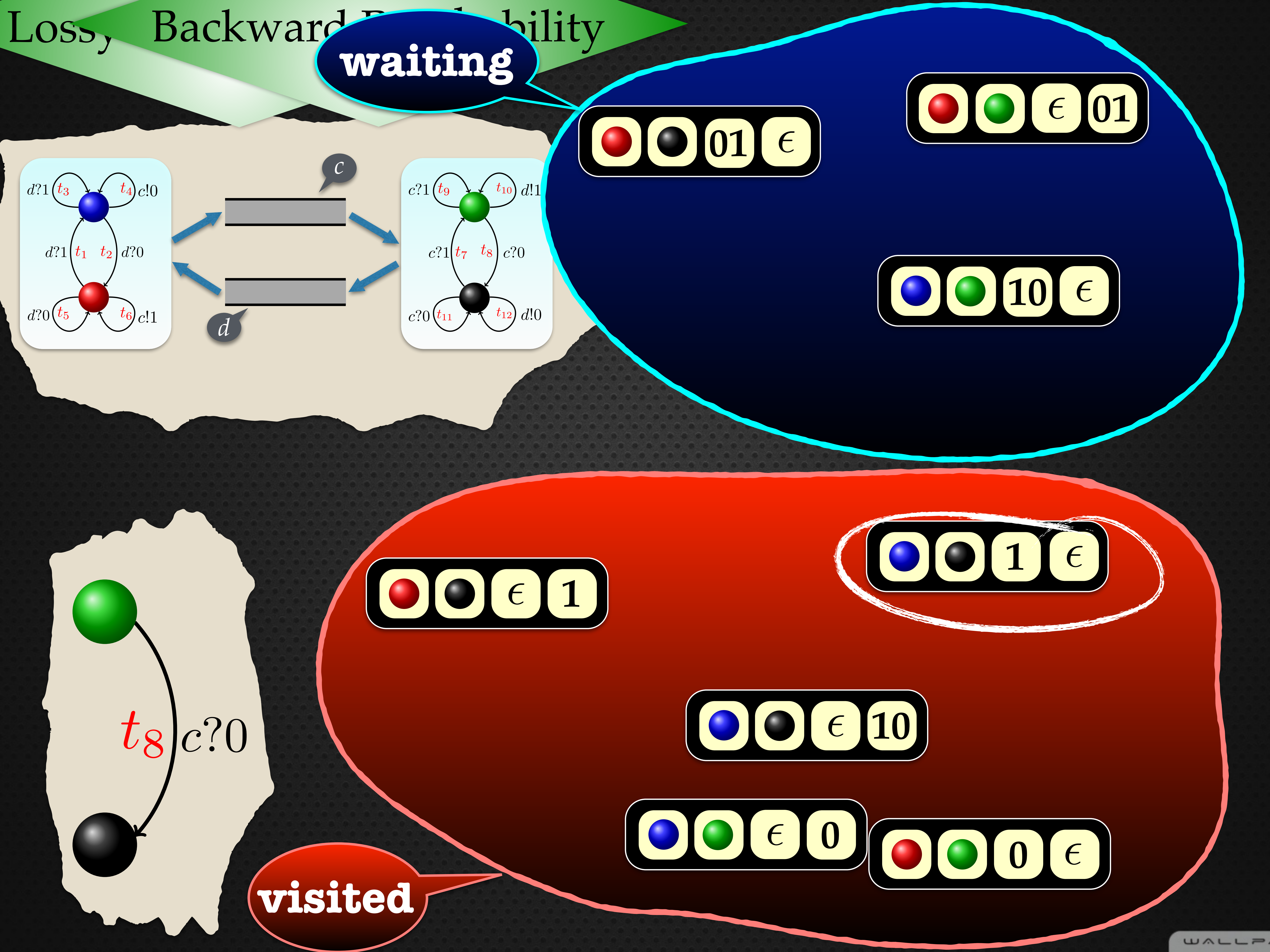
Lossy Backward Reachability





Loss
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$d?1$ t_3 t_4 $c!0$
$d?1$ t_1 t_2 $d?0$
$d?0$ t_5 t_6 $c!1$
$c?1$ t_9 t_{10} $d!1$
$c?1$ t_7 t_8 $c?0$
$c?0$ t_{11} t_{12} $d!0$
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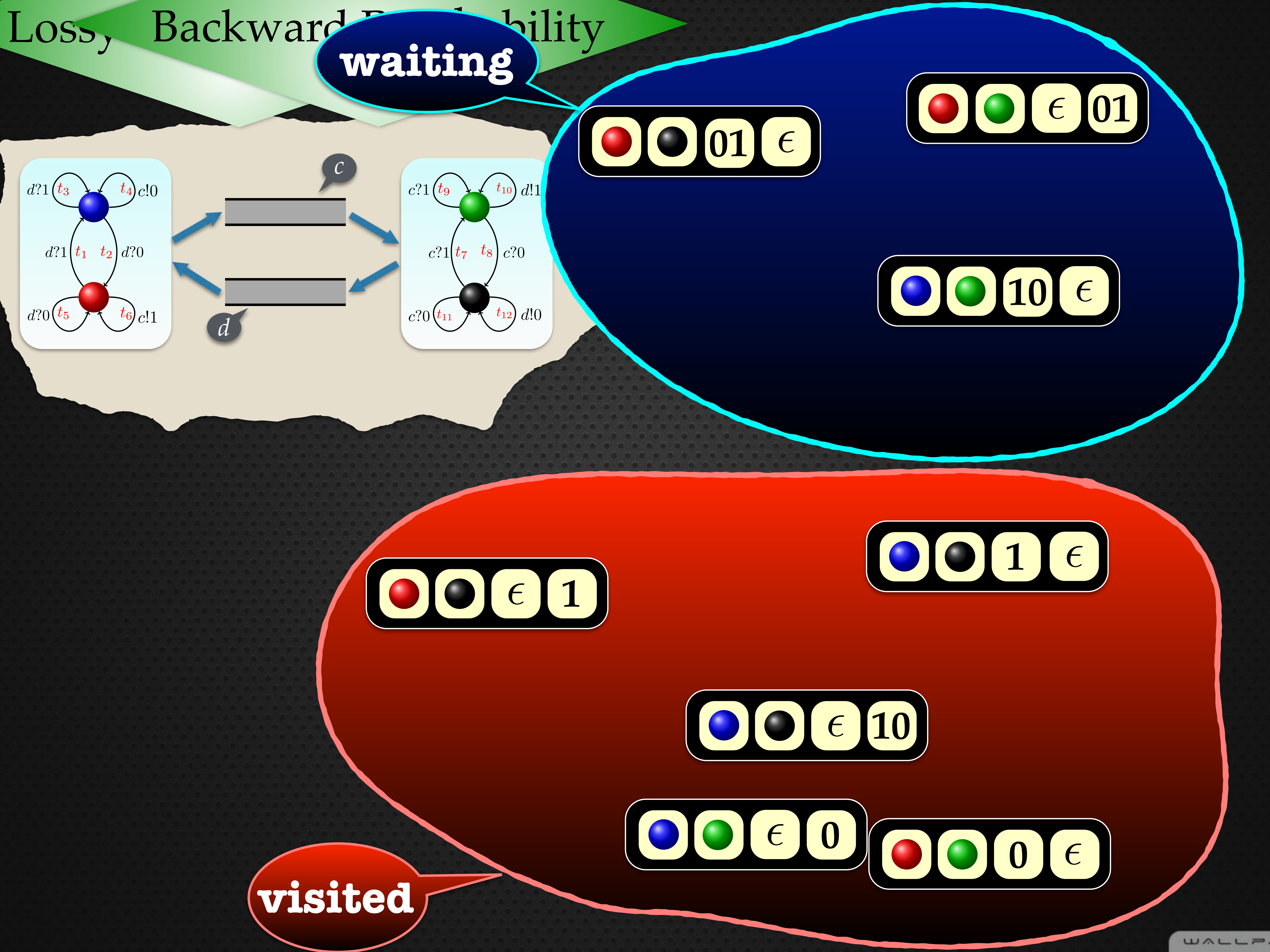
visited


Lossy Backward
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t_6 $c!1$
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t_{10} $d!1$
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t_8 $c?0$
$c?0$ t_{11}
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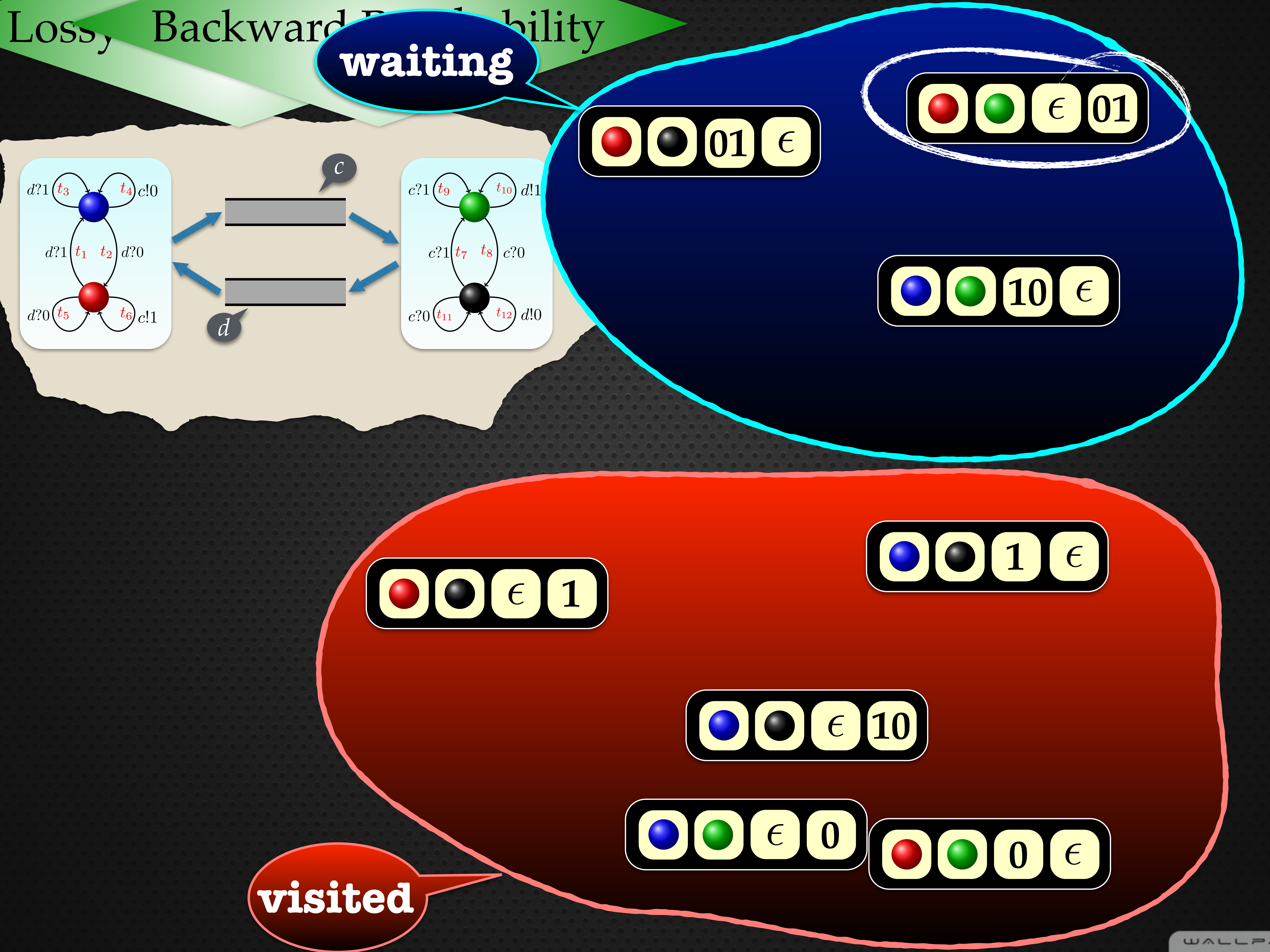

Lossy Backward
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$c?1$ t_9 t_{10} $d!1$
$c?1$ t_7 t_8 $c?0$
$c?0$ t_{11} t_{12} $d!0$
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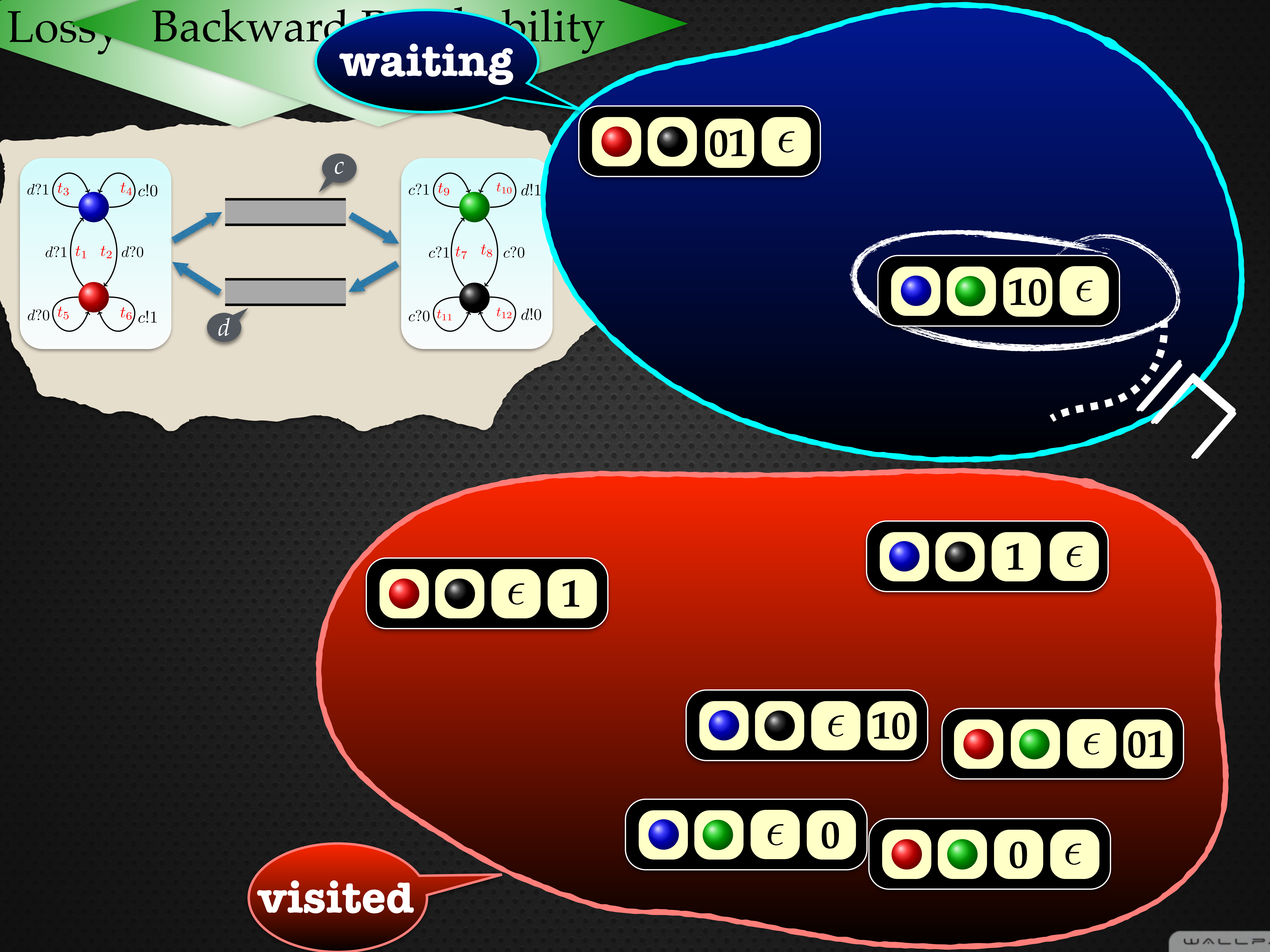
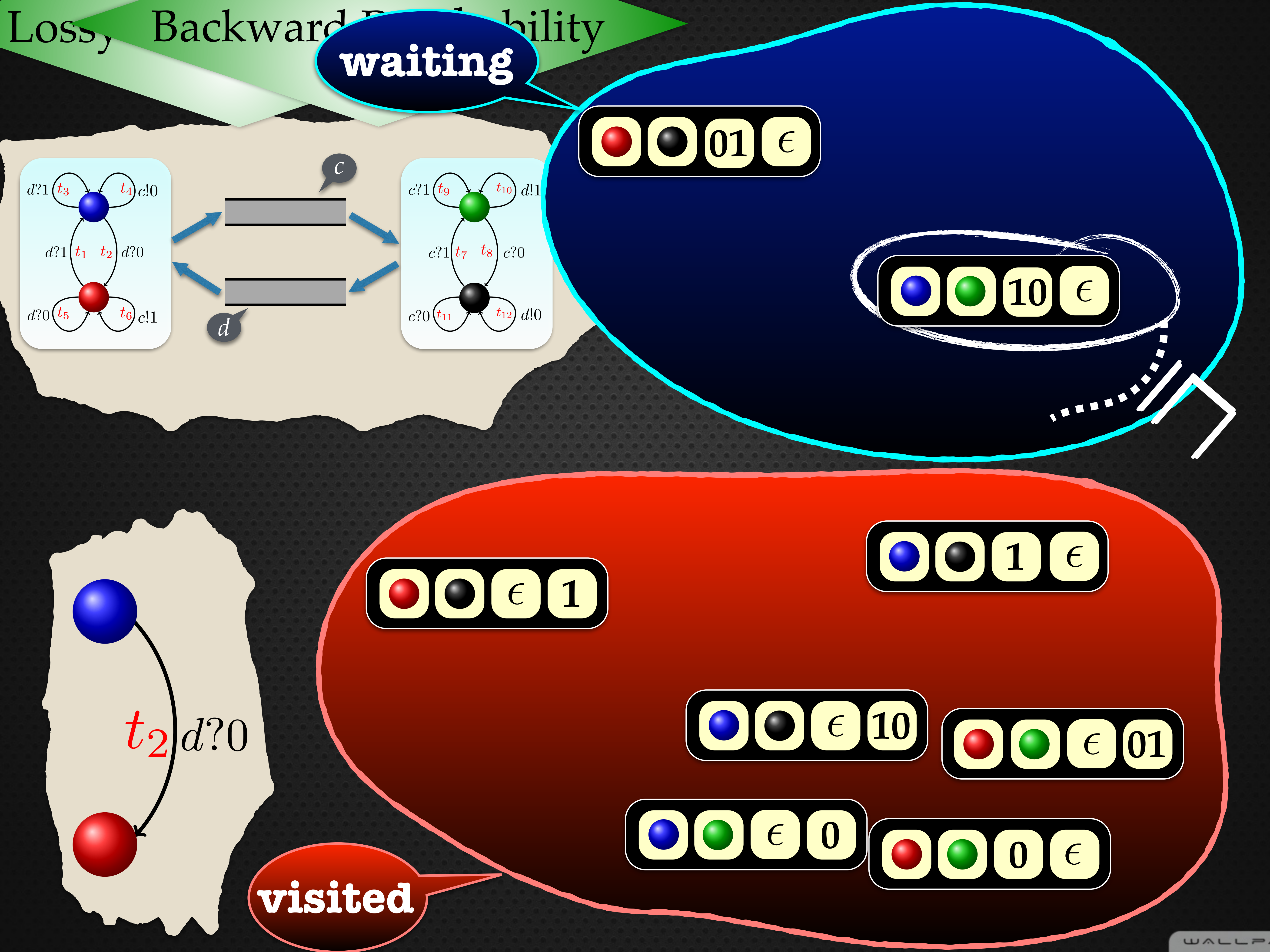
Lossy Backward Reachability





Lossy
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$d?1$ t_3
t_4 $c!0$
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t_2 $d?0$
$d?0$ t_5
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$c?1$ t_9
t_{10} $d!1$
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$c?0$ t_{11}
t_{12} $d!0$
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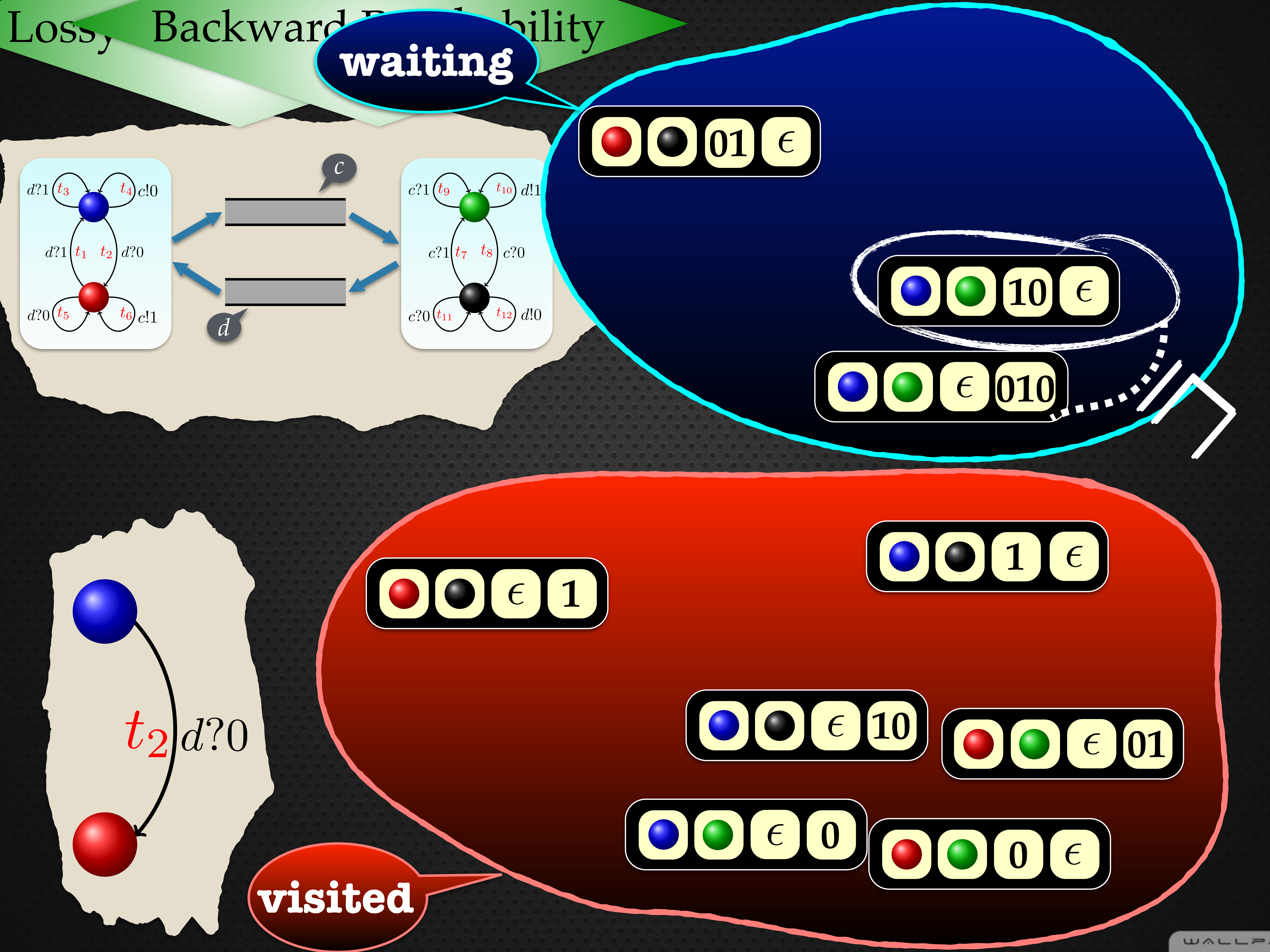
visited



Loss
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$d?1$ t_3
t_4 $c!0$
$d?1$ t_1
t_2 $d?0$
$d?0$ t_5
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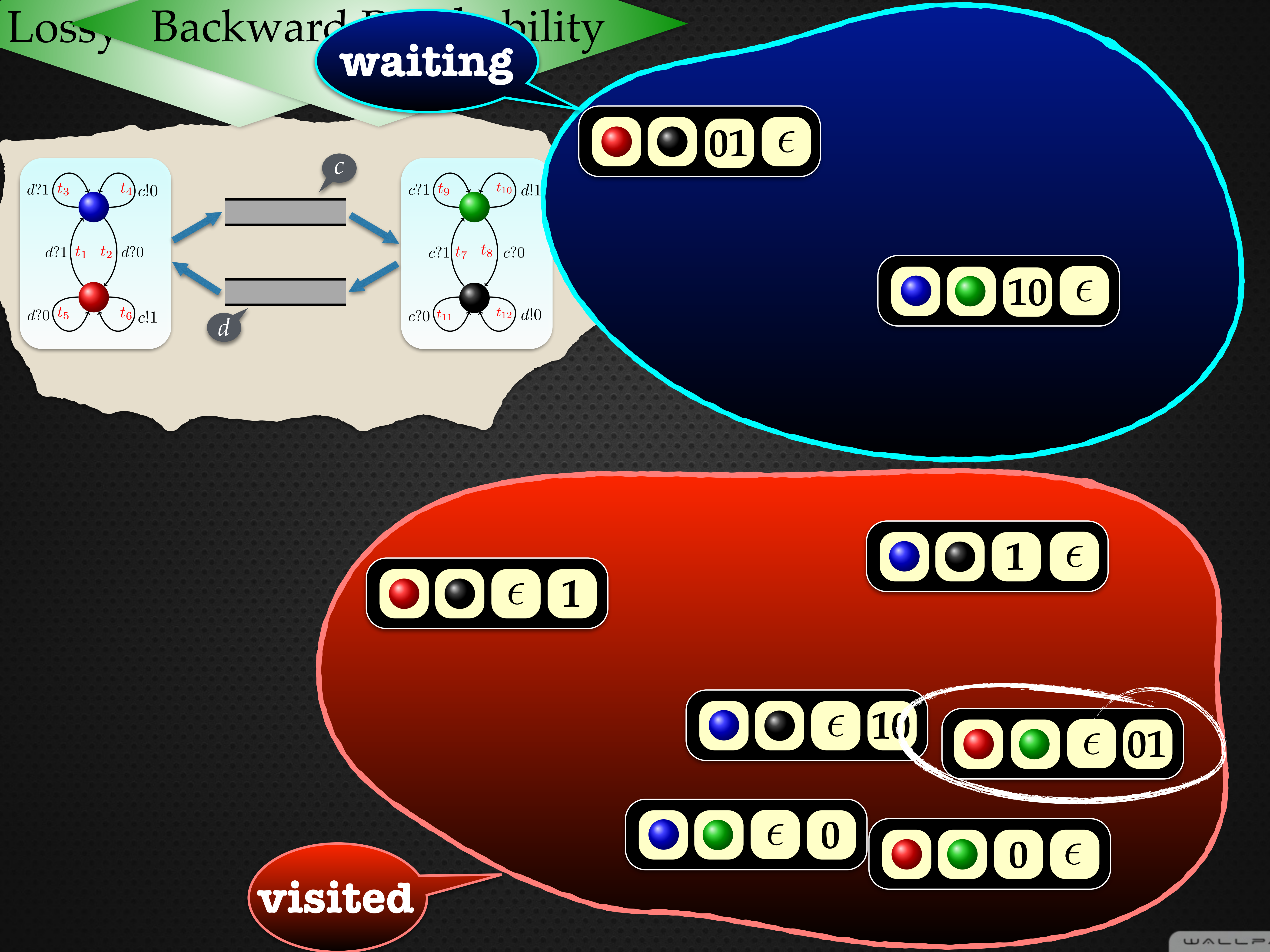
visited



Lossy Backward
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t6 c!1
c?1 t9
t10 d!1
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t8 c?0
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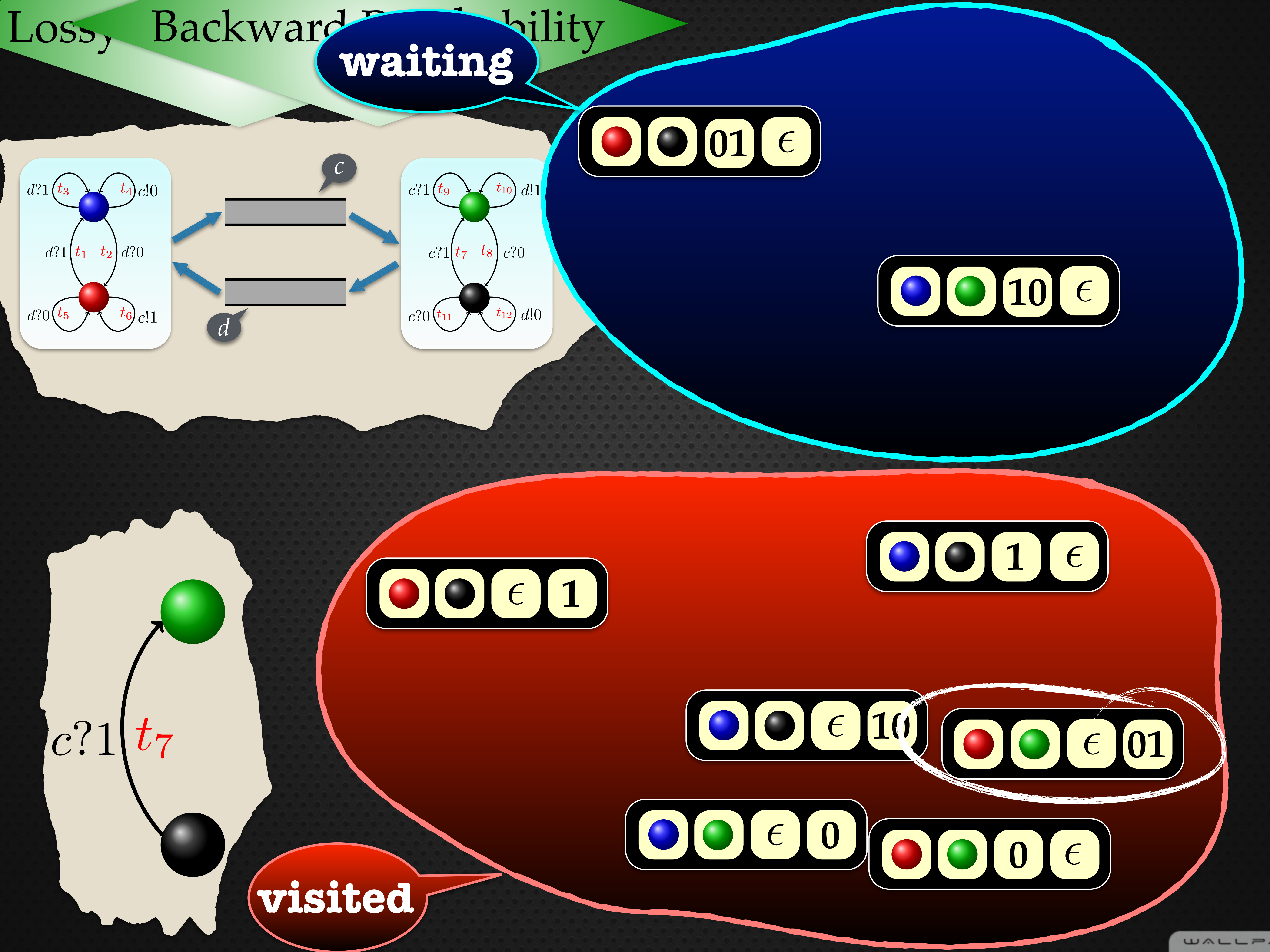

Loss
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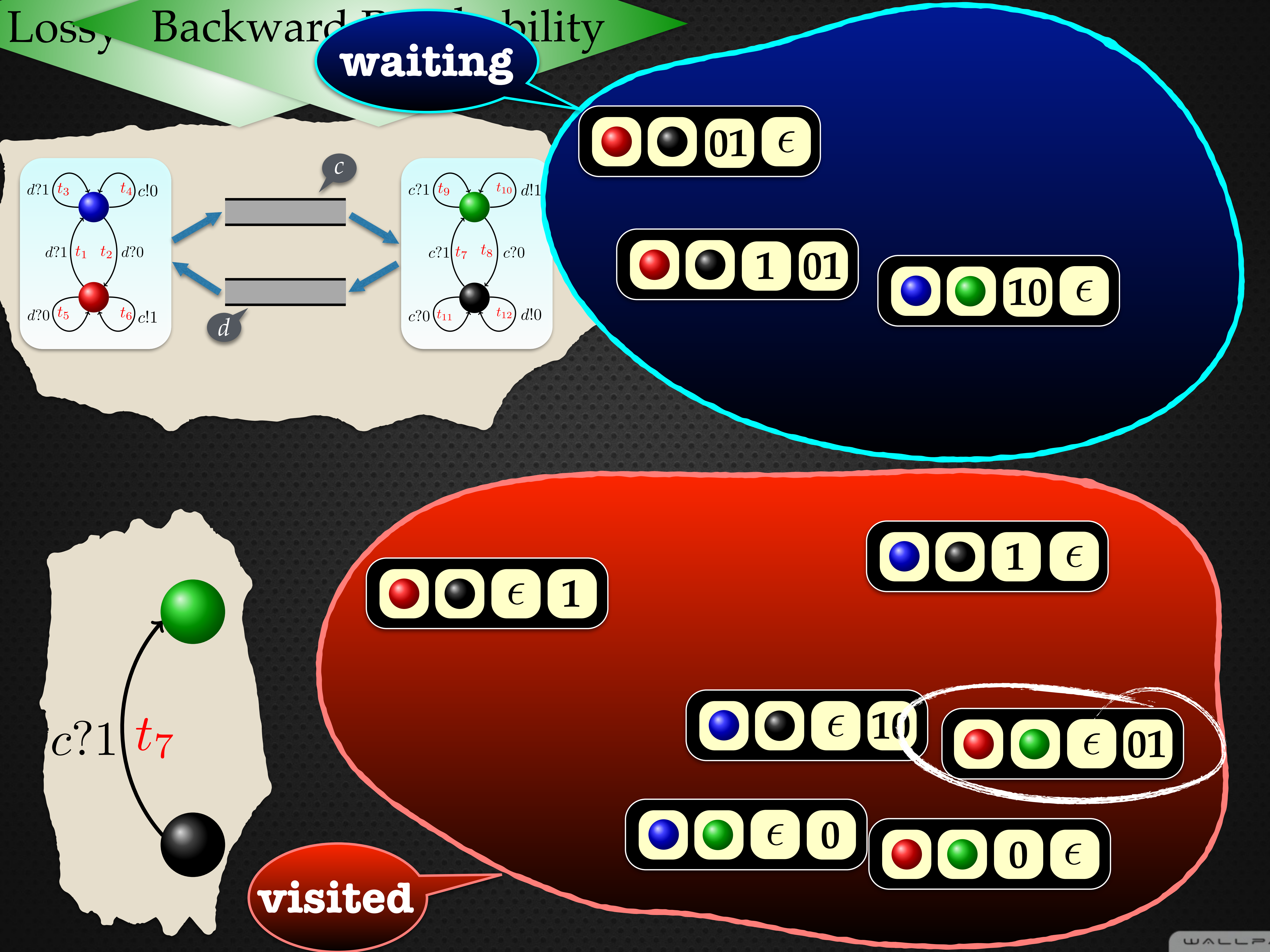
visited



Lossy Backward bility
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t2 d?0
d?0 t5
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t10 d!1
c?1 t7
t8 c?0
c?0 t11
t12 d!0
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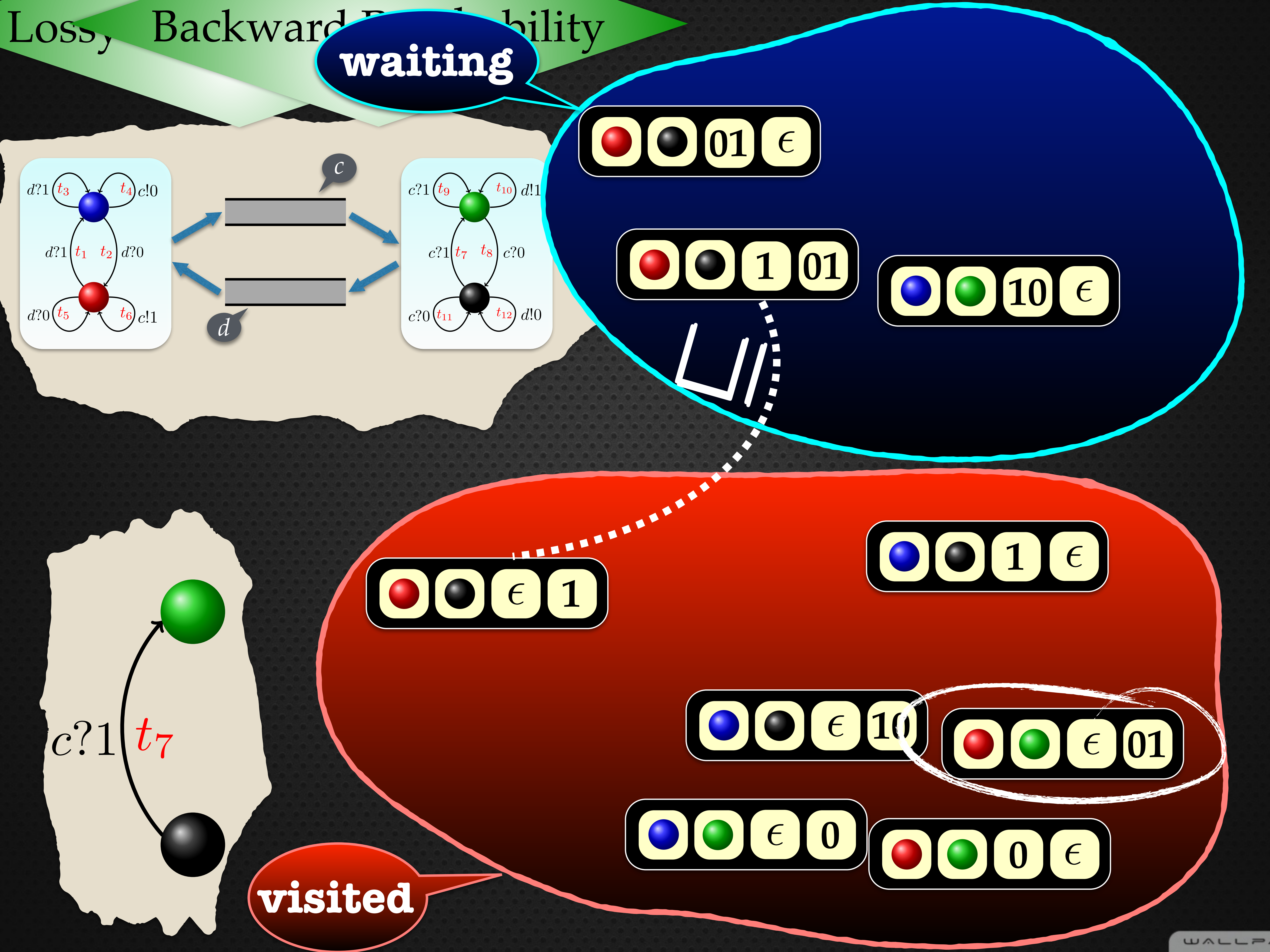
c?1 t7



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t10 d!1
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t8 c?0
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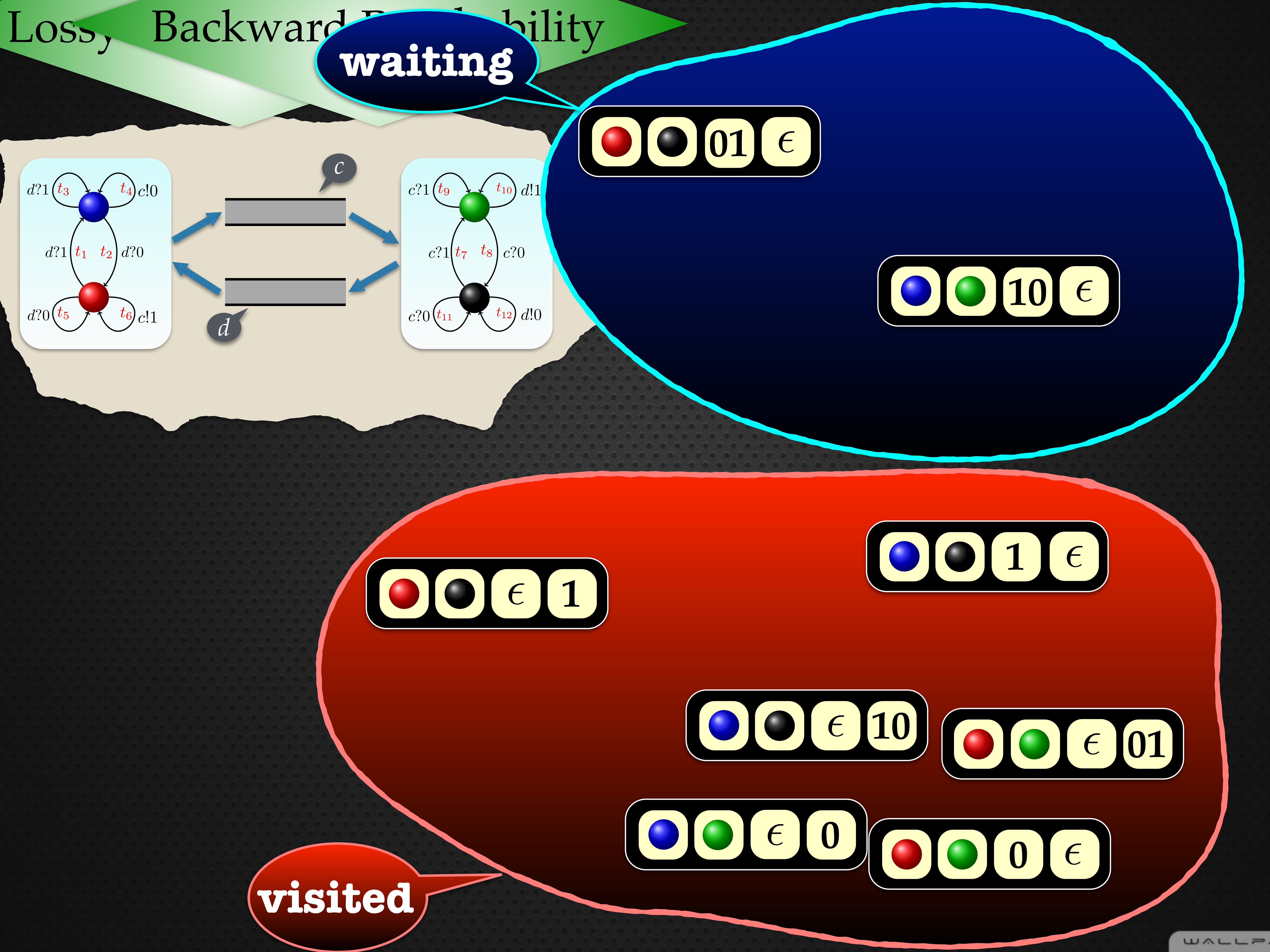
visited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d?1 t3 t4 c!0
d?1 t1 t2 d?0
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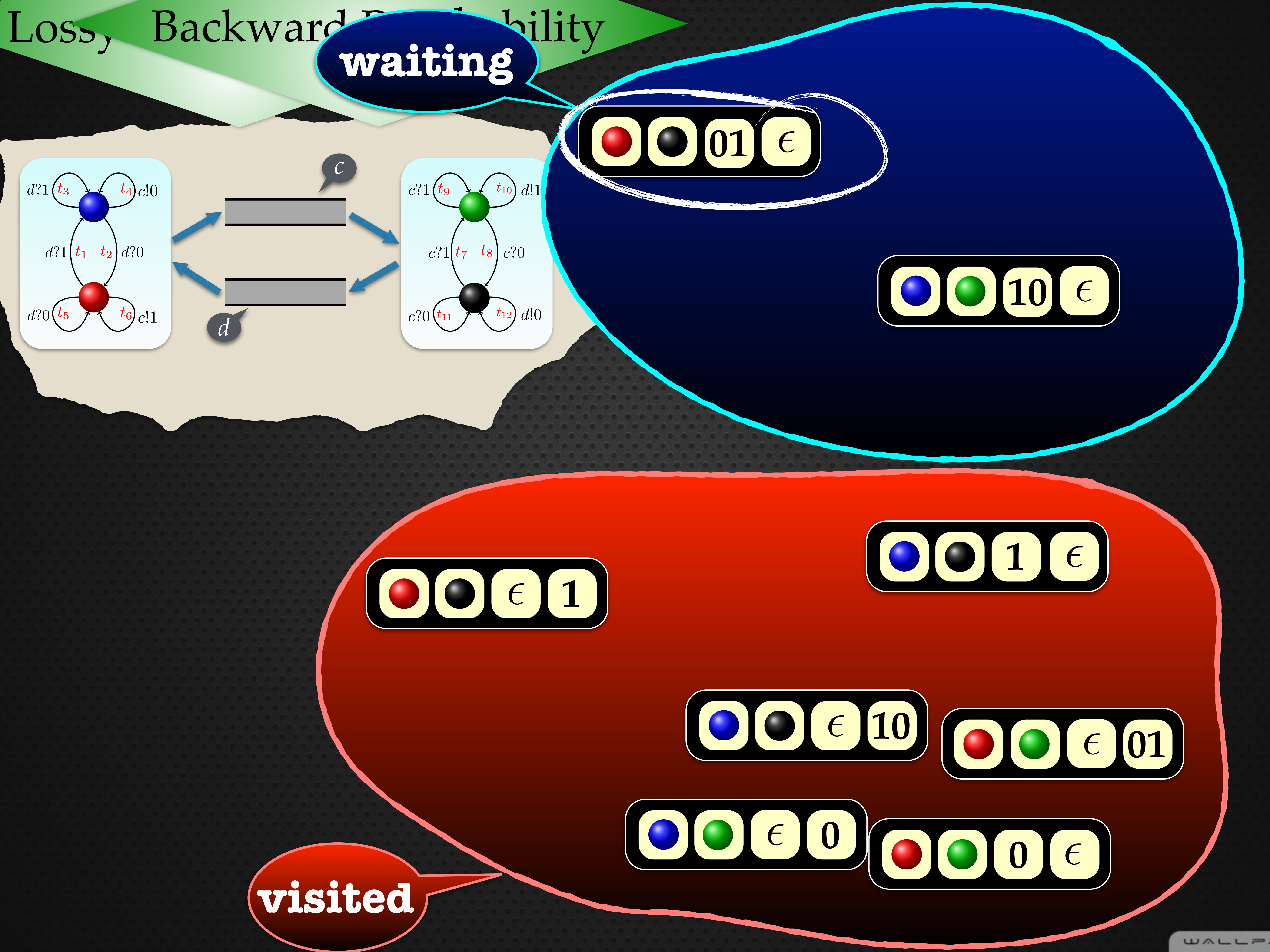
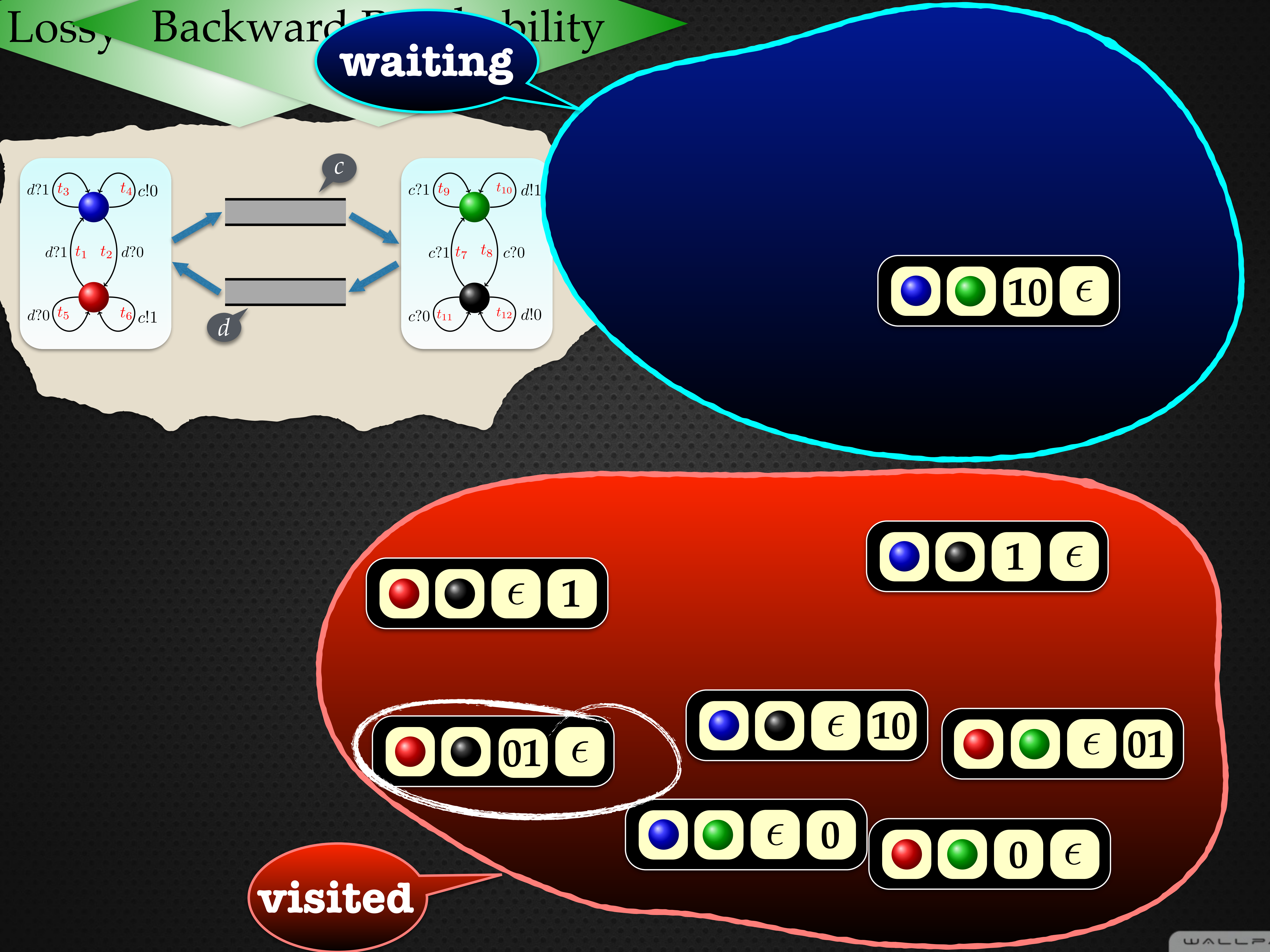
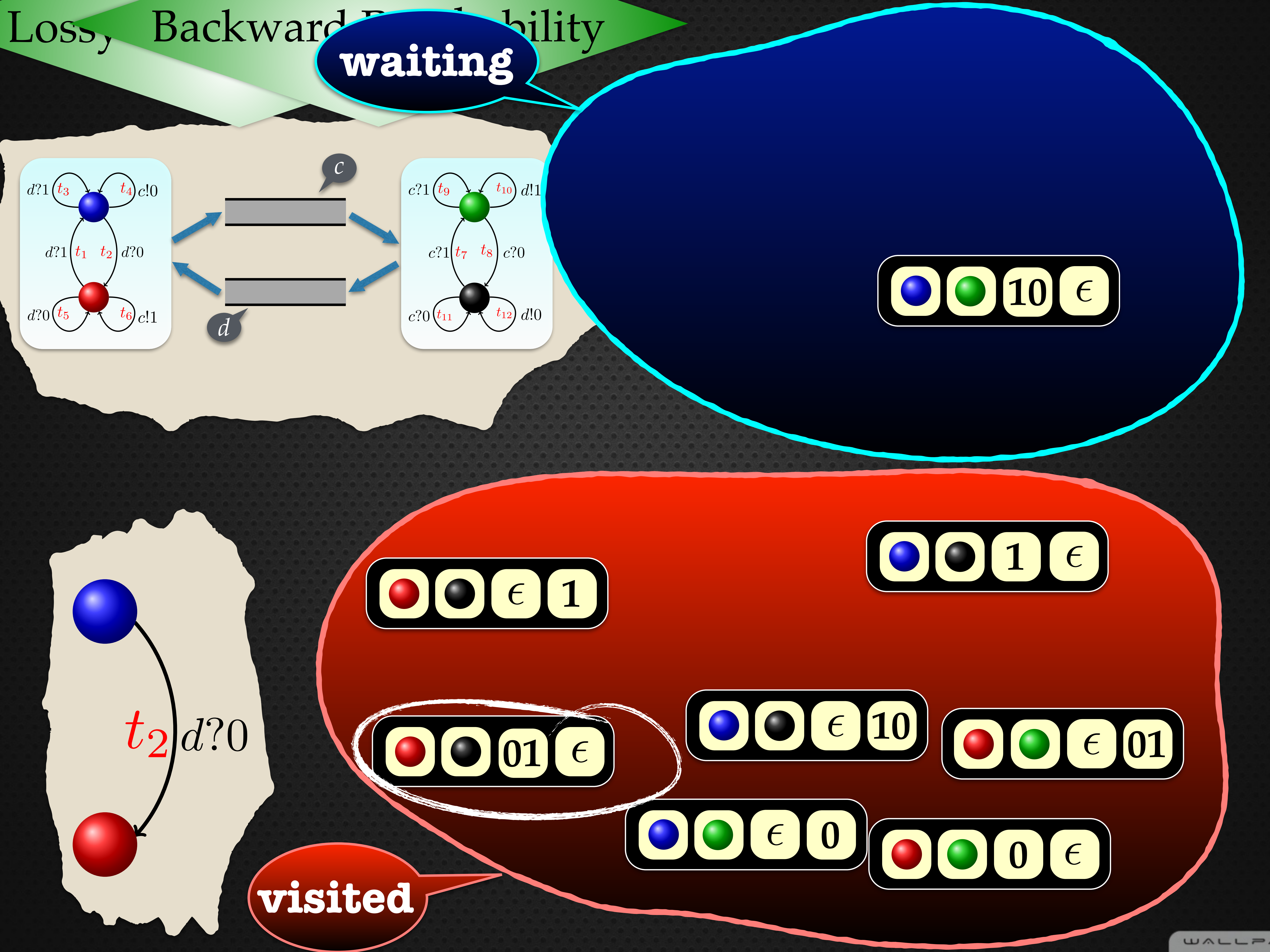
c
d
c?1 t9 t10 d!1
c?1 t7 t8 c?0
c?0 t11 t12 d!0
01 ϵ
10 ϵ
1 ϵ
ϵ 1
ϵ 10
ϵ 01
ϵ 0
0 ϵ
visited



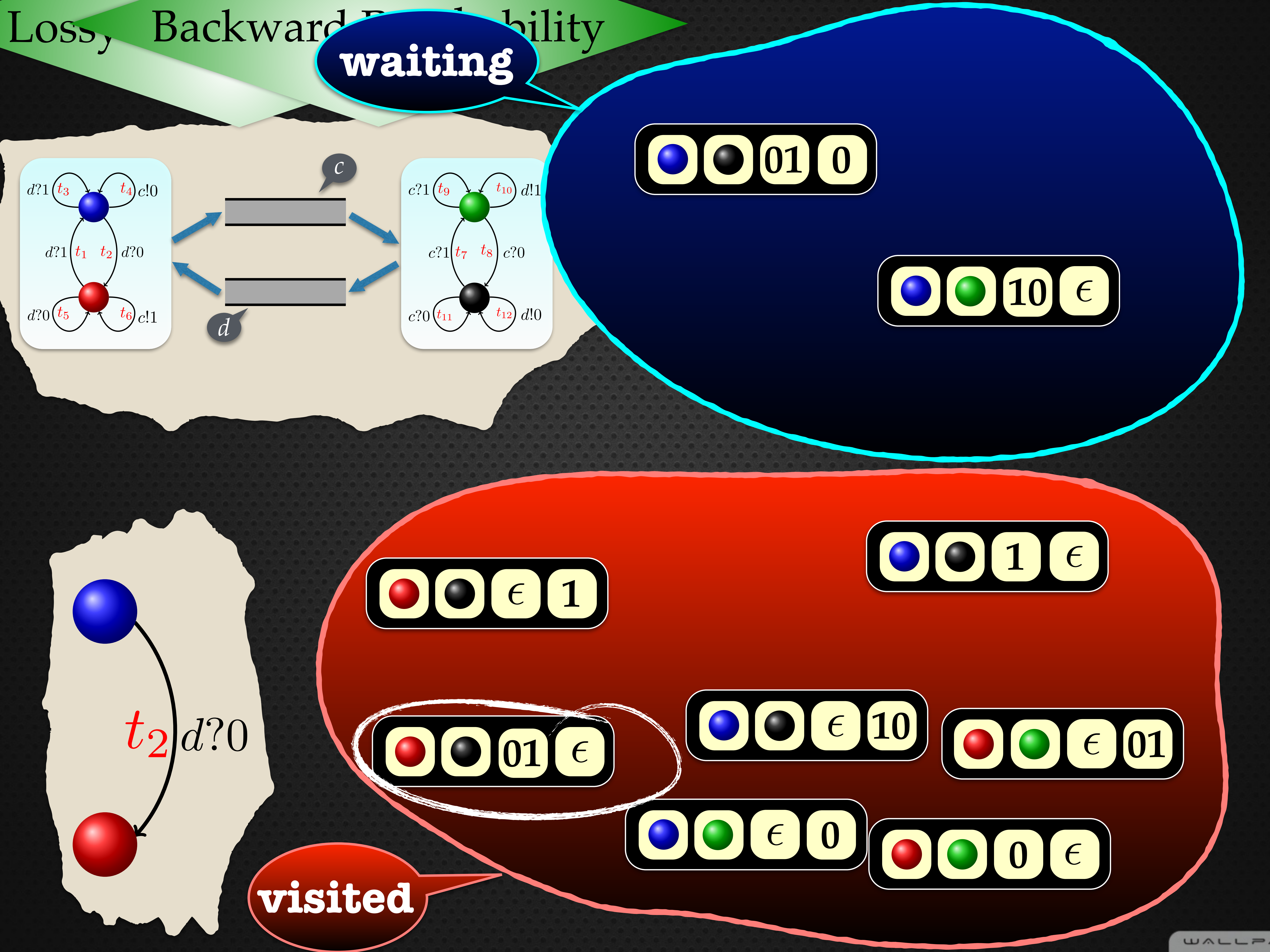
waiting
visited
c
d
d?1
t3
t4
c!0
d?1
t1
t2
d?0
d?0
t5
t6
c!1
c?1
t9
t10
d!1
c?1
t7
t8
c?0
c?0
t11
t12
d!0
01 ϵ
10 ϵ
ϵ 1
1 ϵ
ϵ 10
ϵ 01
ϵ 0
0 ϵ



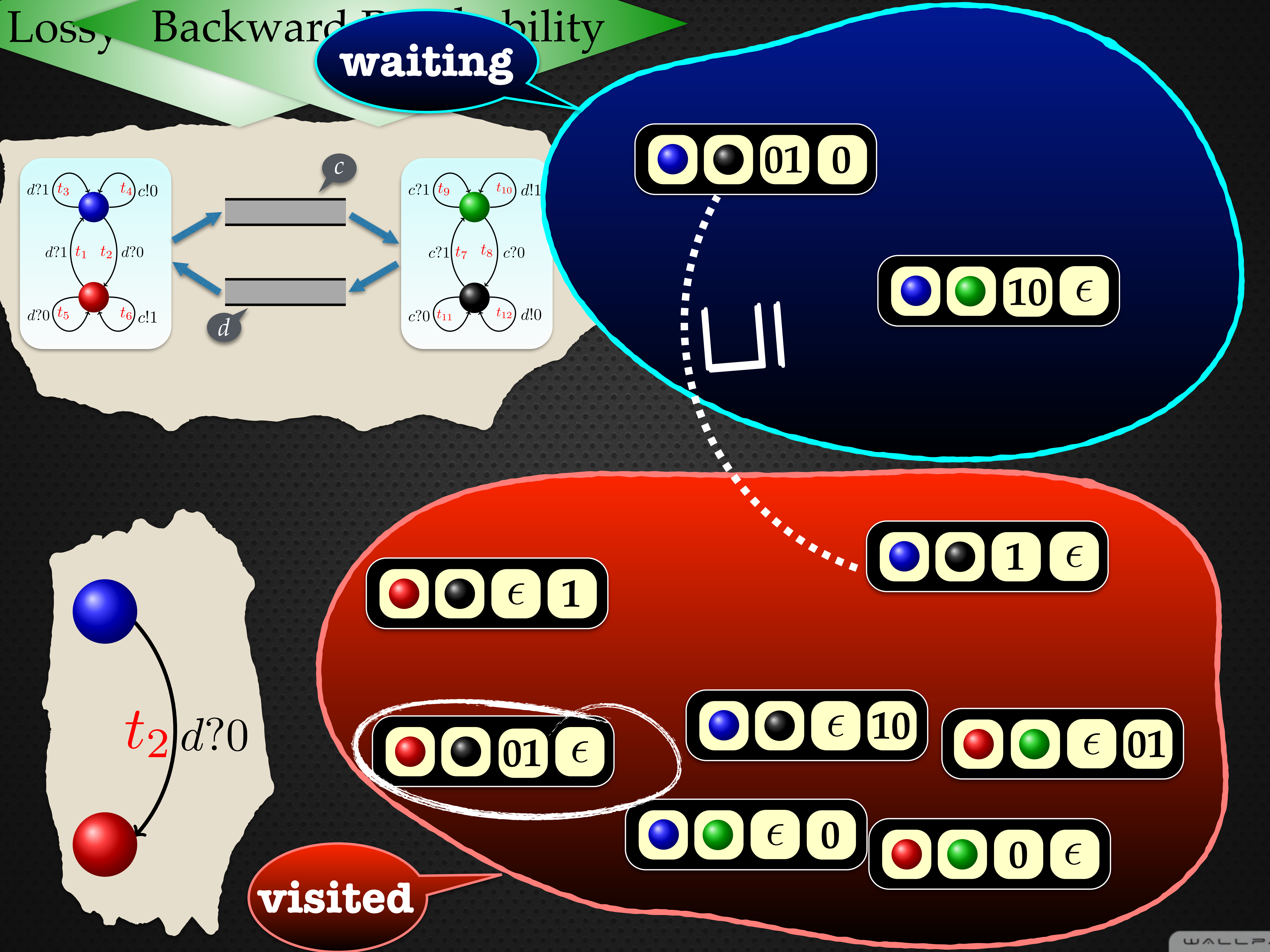
Backward
bility
waiting
d?1 t3
t4 c!0
d?1 t1
t2 d?0
d?0 t5
t6 c!1
c
d
c?1 t9
t10 d!1
c?1 t7
t8 c?0
c?0 t11
t12 d!0
10 ϵ
ϵ 1
1 ϵ
01 ϵ
ϵ 10
ϵ 01
ϵ 0
0 ϵ
visited



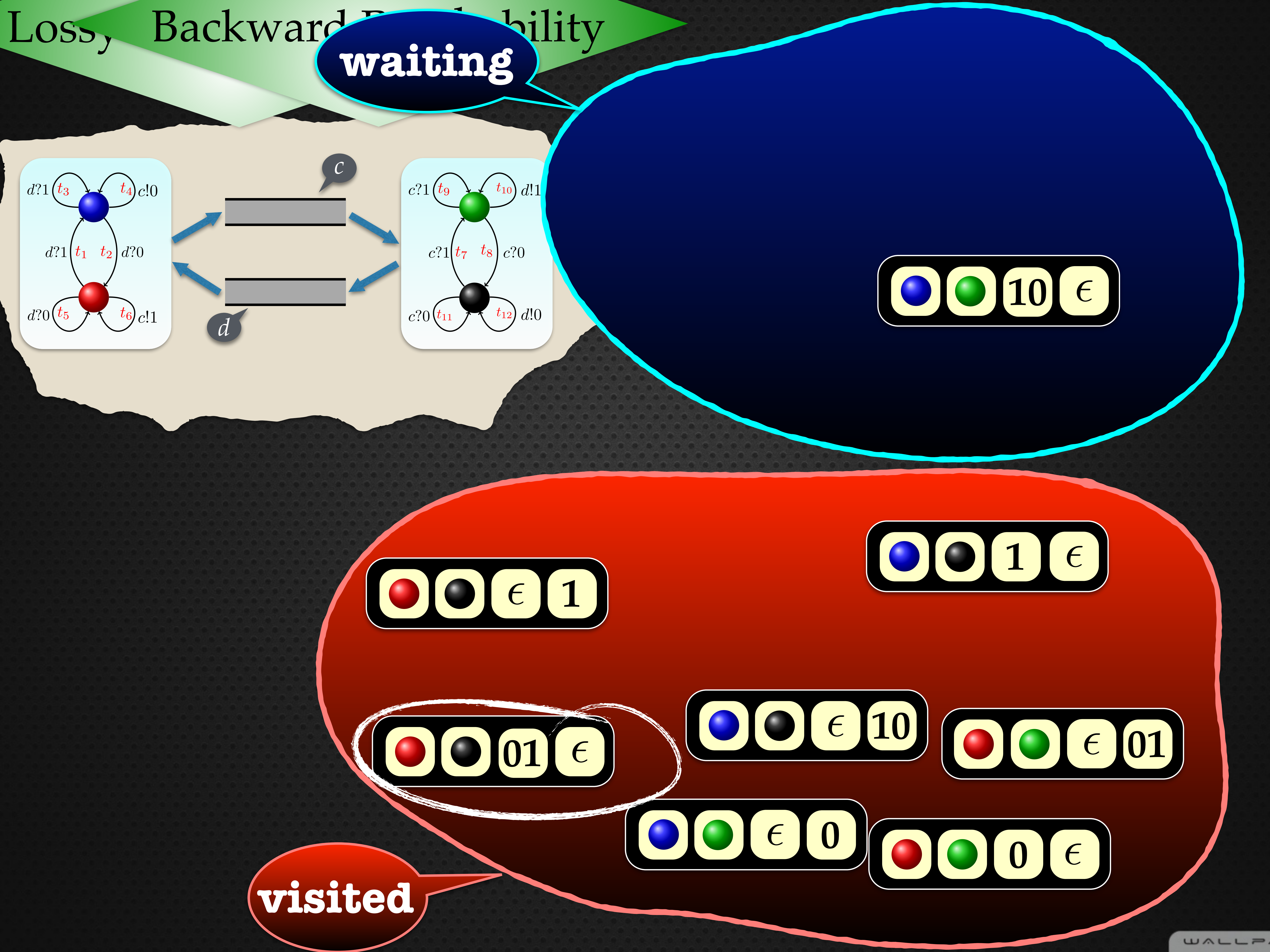
Loss
Backward
bility
waiting
visited
c
d
d?1 t3
t4 c!0
d?1 t1
t2 d?0
d?0 t5
t6 c!1
c?1 t9
t10 d!1
c?1 t7
t8 c?0
c?0 t11
t12 d!0
10 ϵ
ϵ 1
1 ϵ
01 ϵ
ϵ 10
ϵ 01
ϵ 0
0 ϵ
t2 d?0

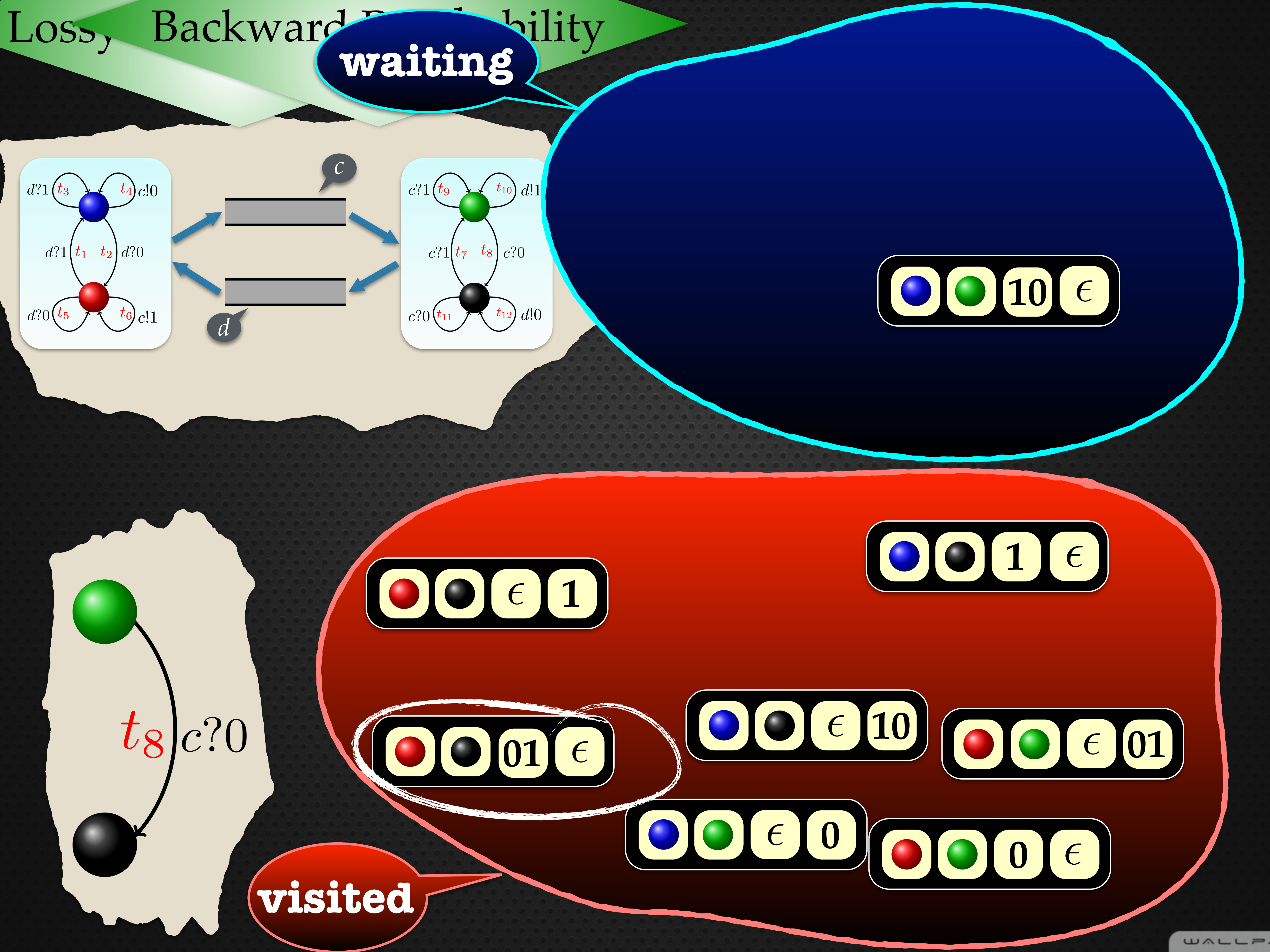


Lossy Backward
bility
waiting
visited
c
d
d?1 t3
t4 c!0
d?1 t1
t2 d?0
d?0 t5
t6 c!1
c?1 t9
t10 d!1
c?1 t7
t8 c?0
c?0 t11
t12 d!0
01 0
10 ϵ
1 ϵ
ϵ 1
01 ϵ
ϵ 10
ϵ 01
ϵ 0
0 ϵ
t2 d?0

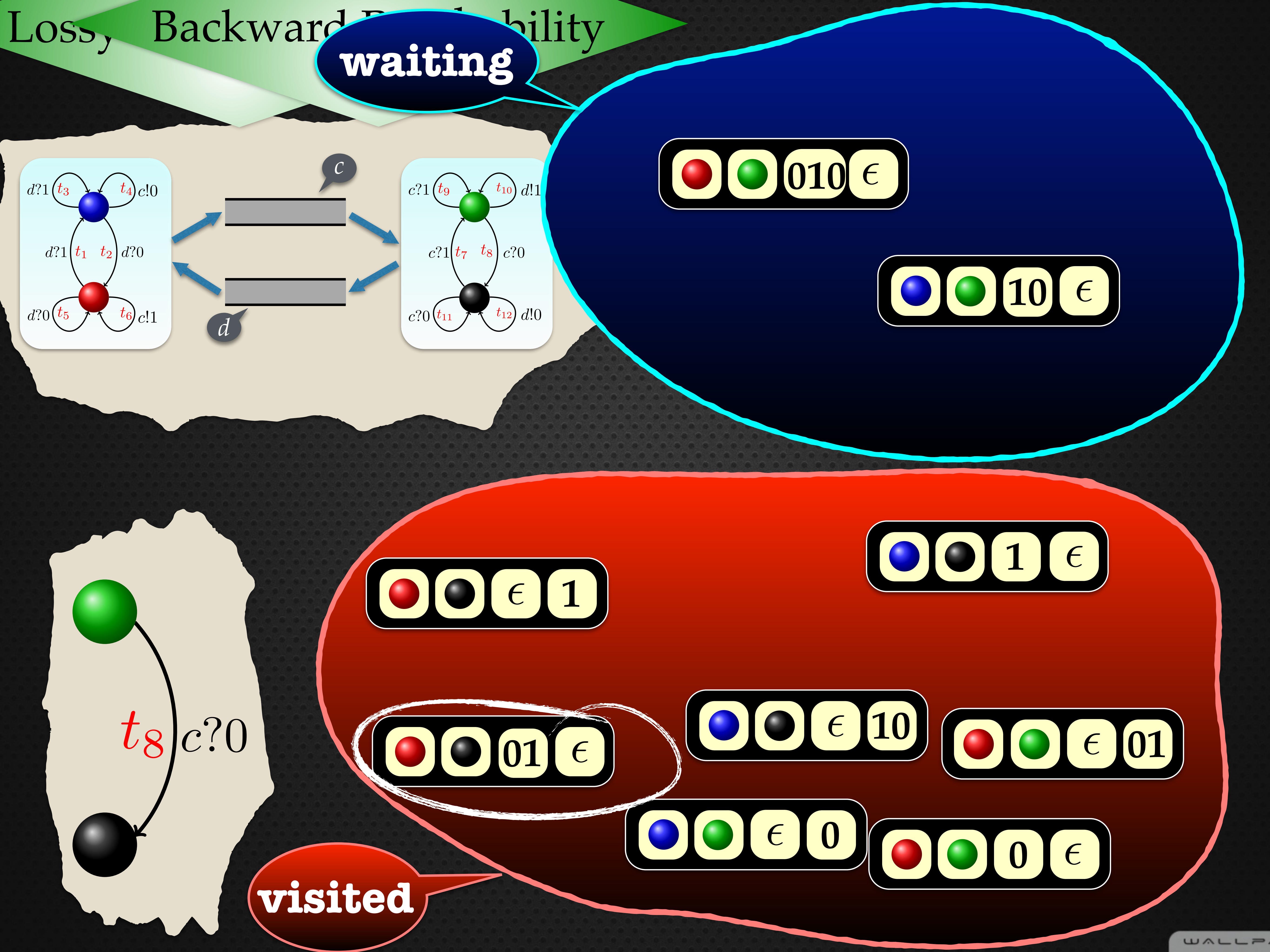


Lossy Backward
waiting
c
d
d?1 t3
t4 c!0
d?1 t1
t2 d?0
d?0 t5
t6 c!1
c?1 t9
t10 d!1
c?1 t7
t8 c?0
c?0 t11
t12 d!0
01 0
10 ϵ
⊑
1 ϵ
ϵ 1
01 ϵ
ϵ 10
ϵ 01
ϵ 0
0 ϵ
t2 d?0
visited

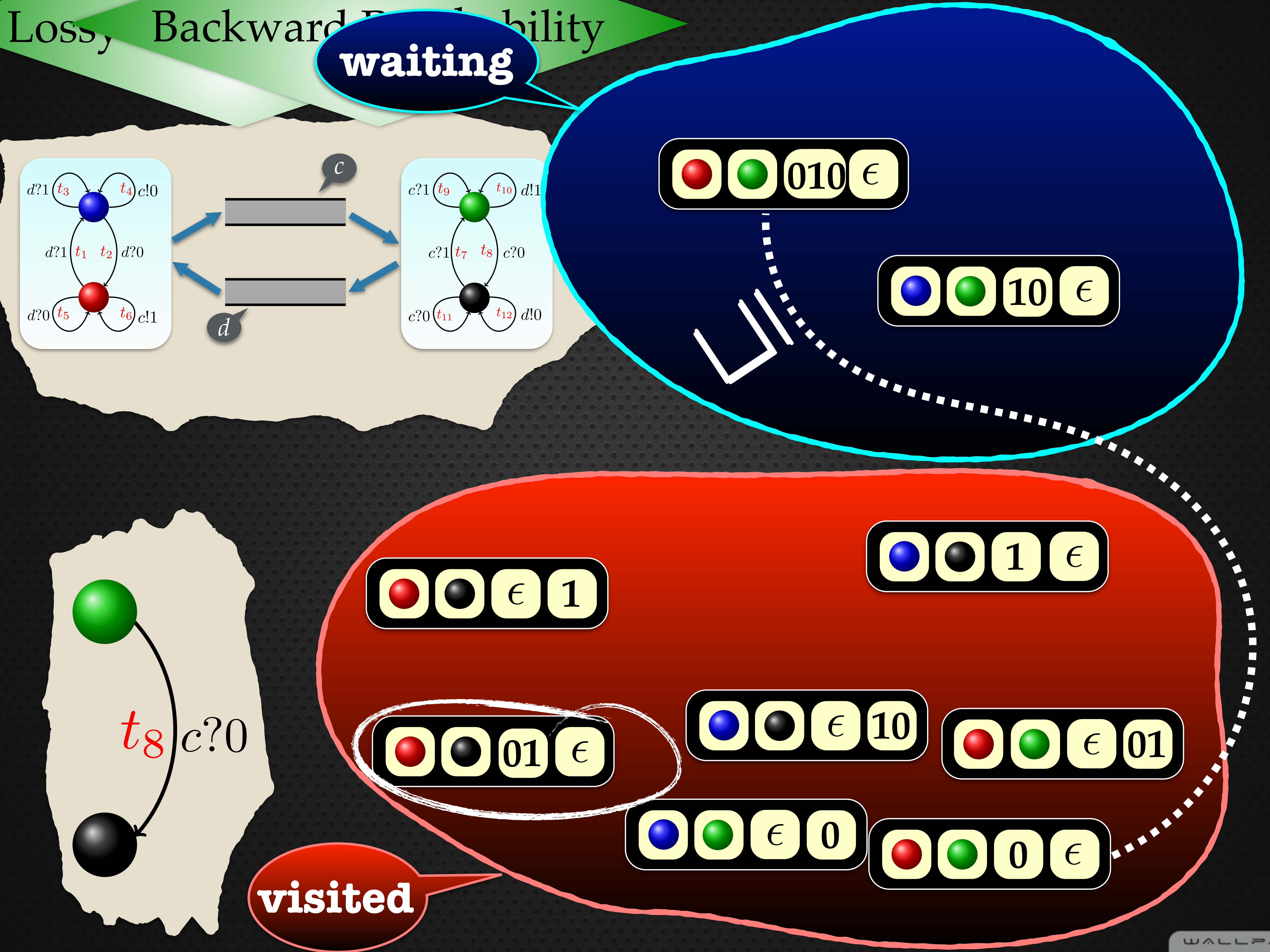

Lossy Backward R bility
waiting
c
d
$d?1$ t_3
t_4 $c!0$
$d?1$ t_1
t_2 $d?0$
$d?0$ t_5
t_6 $c!1$
$c?1$ t_9
t_{10} $d!1$
$c?1$ t_7
t_8 $c?0$
$c?0$ t_{11}
t_{12} $d!0$
10 ϵ
ϵ 1
1 ϵ
01 ϵ
ϵ 10
ϵ 01
ϵ 0
0 ϵ
visited



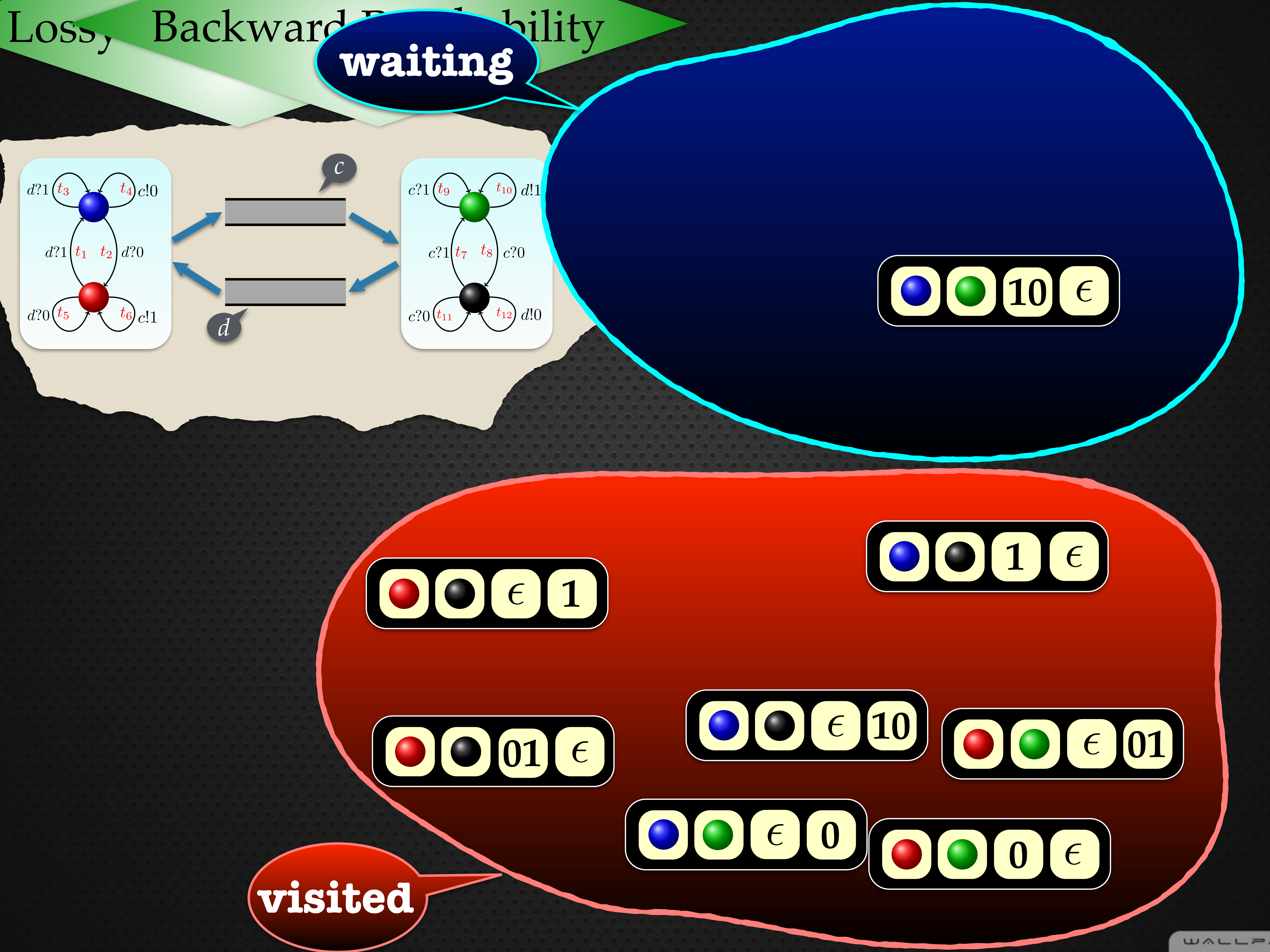
Lossy Backward
bility
waiting
c
d
$d?1$ t_3
t_4 $c!0$
$d?1$ t_1
t_2 $d?0$
$d?0$ t_5
t_6 $c!1$
$c?1$ t_9
t_{10} $d!1$
$c?1$ t_7
t_8 $c?0$
$c?0$ t_{11}
t_{12} $d!0$
10 ϵ
ϵ 1
1 ϵ
01 ϵ
ϵ 10
ϵ 01
ϵ 0
0 ϵ
t_8 $c?0$
visited



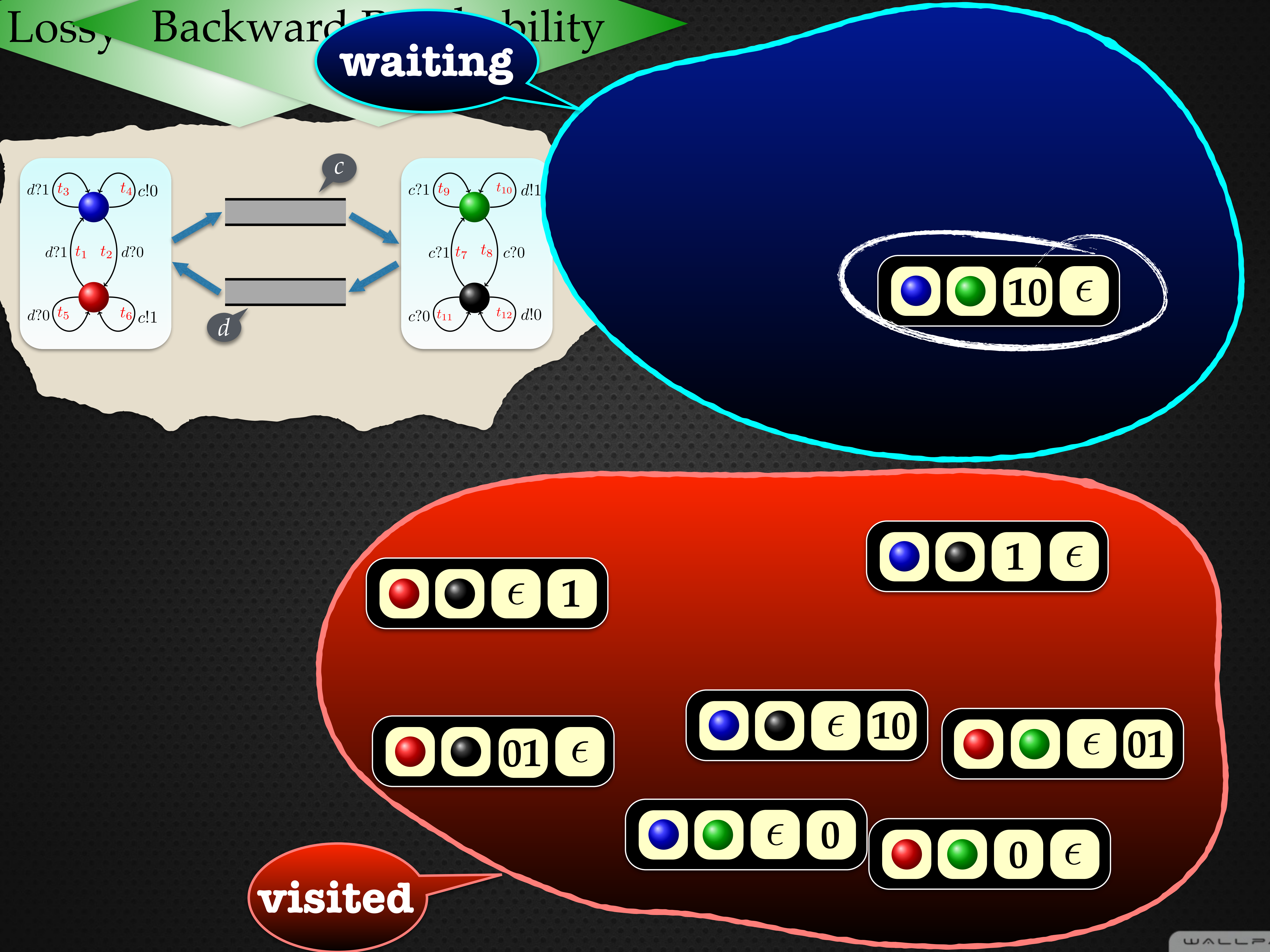
Lossy Backward
bility
waiting
d?1 t3 t4 c!0
d?1 t1 t2 d?0
d?0 t5 t6 c!1
c
d
c?1 t9 t10 d!1
c?1 t7 t8 c?0
c?0 t11 t12 d!0
010 ϵ
10 ϵ
ϵ 1
1 ϵ
01 ϵ
ϵ 10
ϵ 01
ϵ 0
0 ϵ
t8 c?0
visited



Lossy Backward Reachability
waiting
visited
d?1 t3 t4 c!0
d?1 t1 t2 d?0
d?0 t5 t6 c!1
c
d
c?1 t9 t10 d!1
c?1 t7 t8 c?0
c?0 t11 t12 d!0
010 ϵ
10 ϵ
ϵ 1
1 ϵ
01 ϵ
ϵ 10
ϵ 01
ϵ 0
0 ϵ
t8 c?0

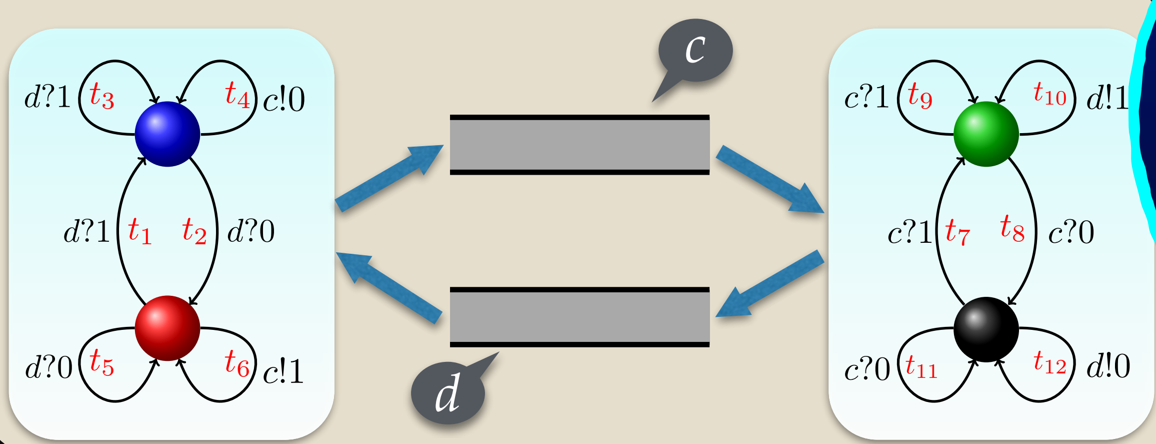


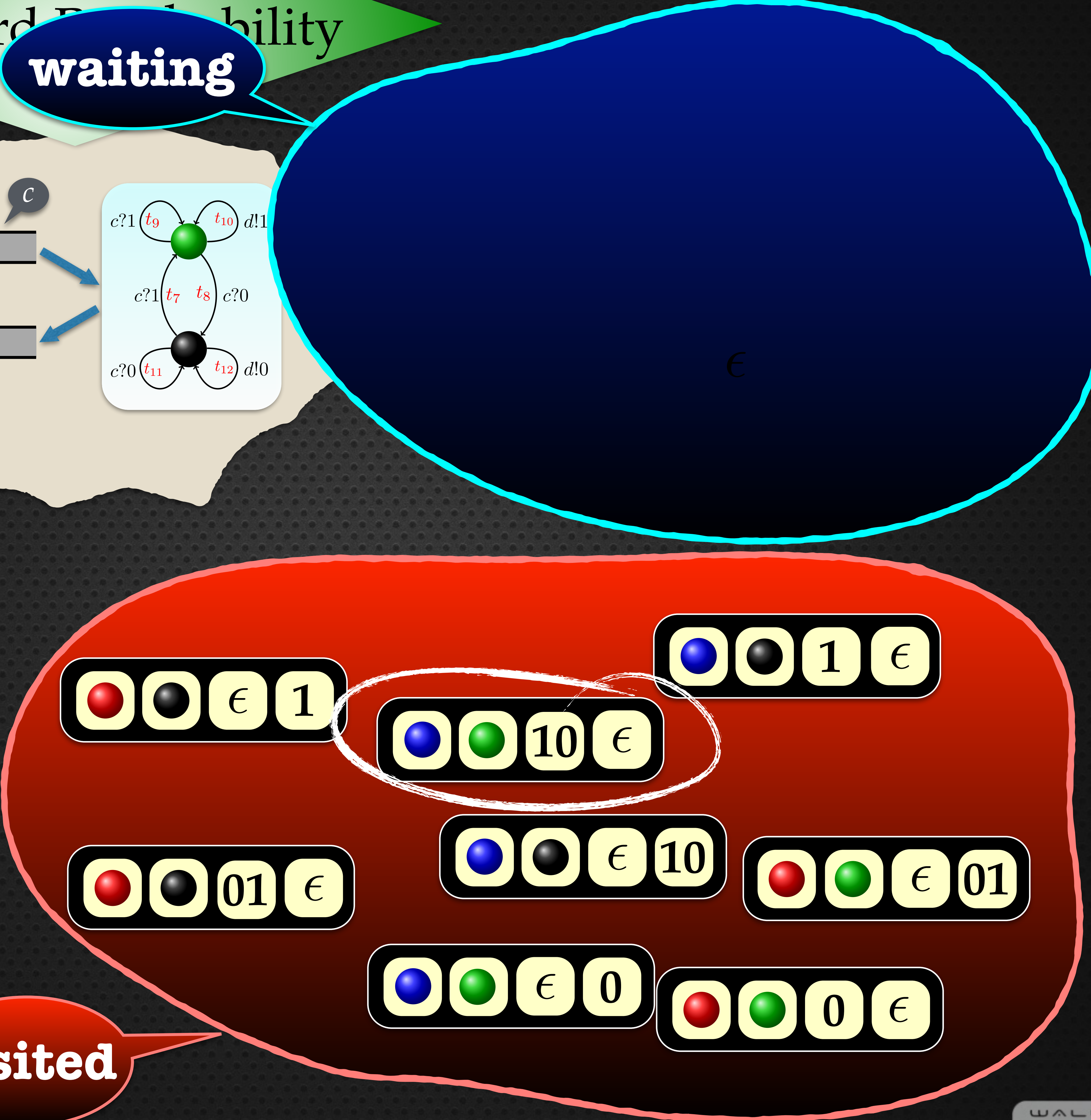
Backward
bility
waiting
$d?1$ t_3
t_4 $c!0$
$d?1$ t_1
t_2 $d?0$
$d?0$ t_5
t_6 $c!1$
c
d
$c?1$ t_9
t_{10} $d!1$
$c?1$ t_7
t_8 $c?0$
$c?0$ t_{11}
t_{12} $d!0$
10 ϵ
1 ϵ
ϵ 1
ϵ 10
01 ϵ
ϵ 01
ϵ 0
0 ϵ
visited



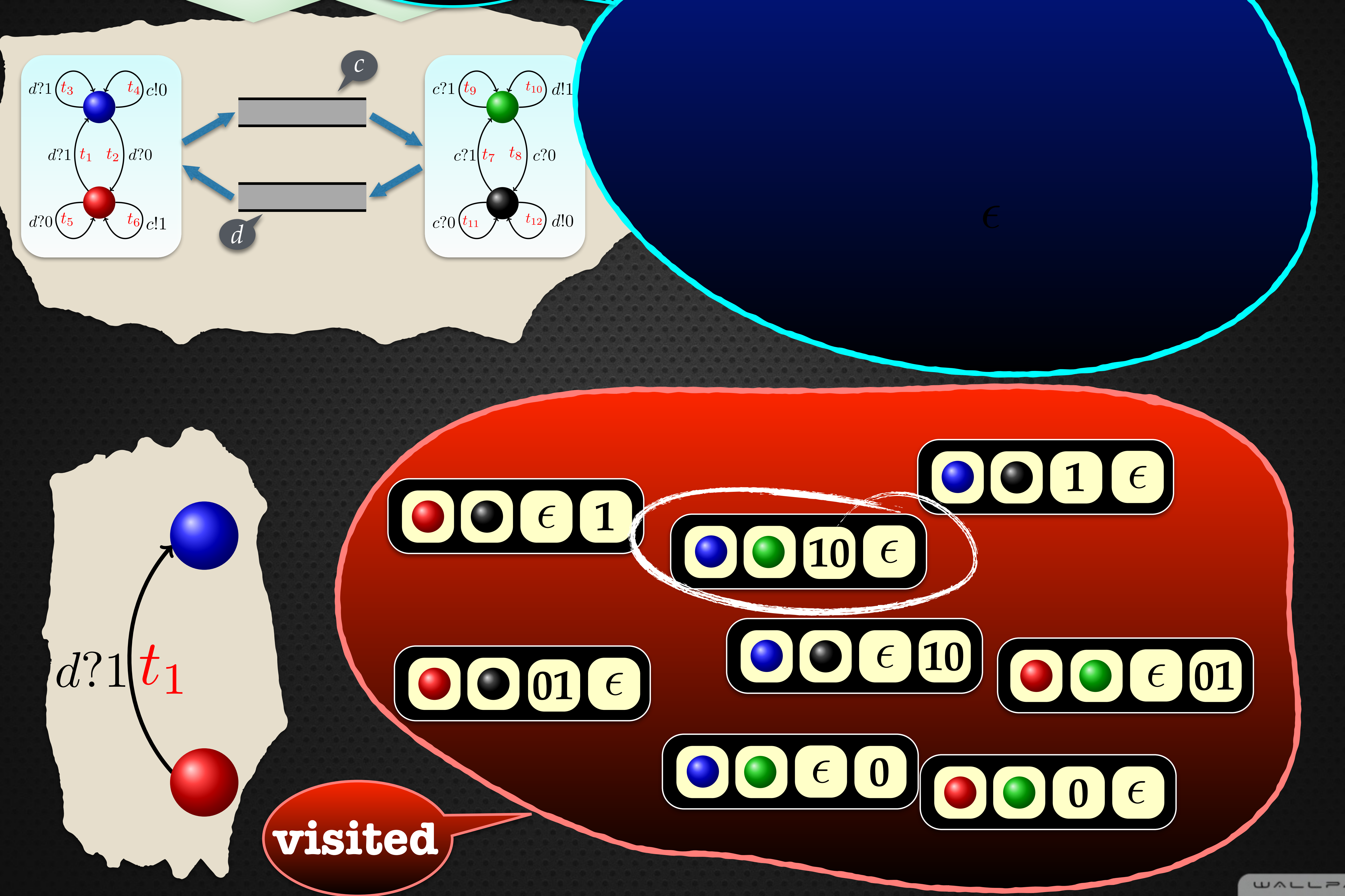
Lossy Backward R…bility
waiting
visited
c
d
d?1 t3
t4 c!0
d?1 t1
t2 d?0
d?0 t5
t6 c!1
c?1 t9
t10 d!1
c?1 t7
t8 c?0
c?0 t11
t12 d!0
10 ϵ
ϵ 1
1 ϵ
01 ϵ
ϵ 10
ϵ 01
ϵ 0
0 ϵ

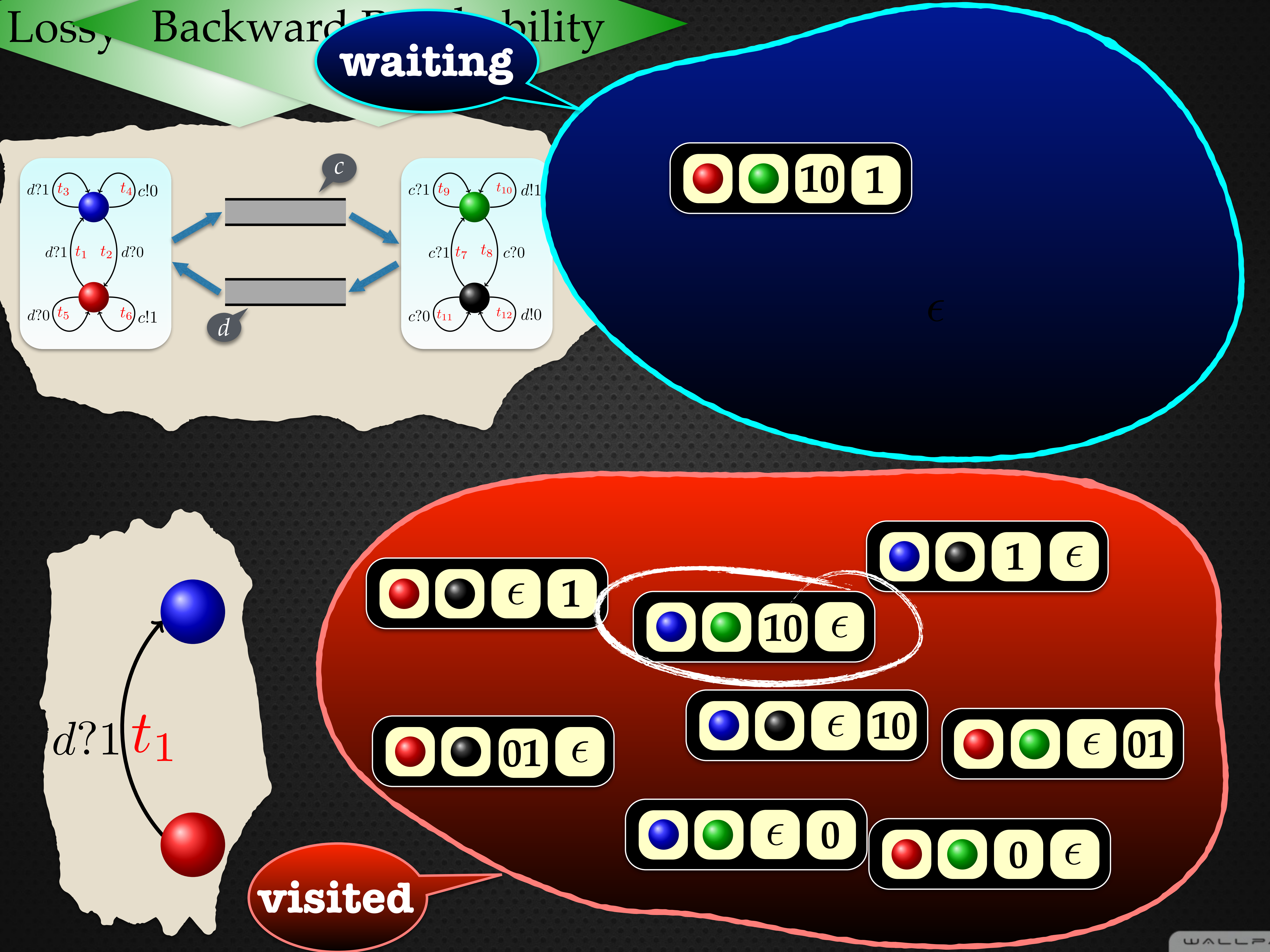
Lossy Backward Reachability

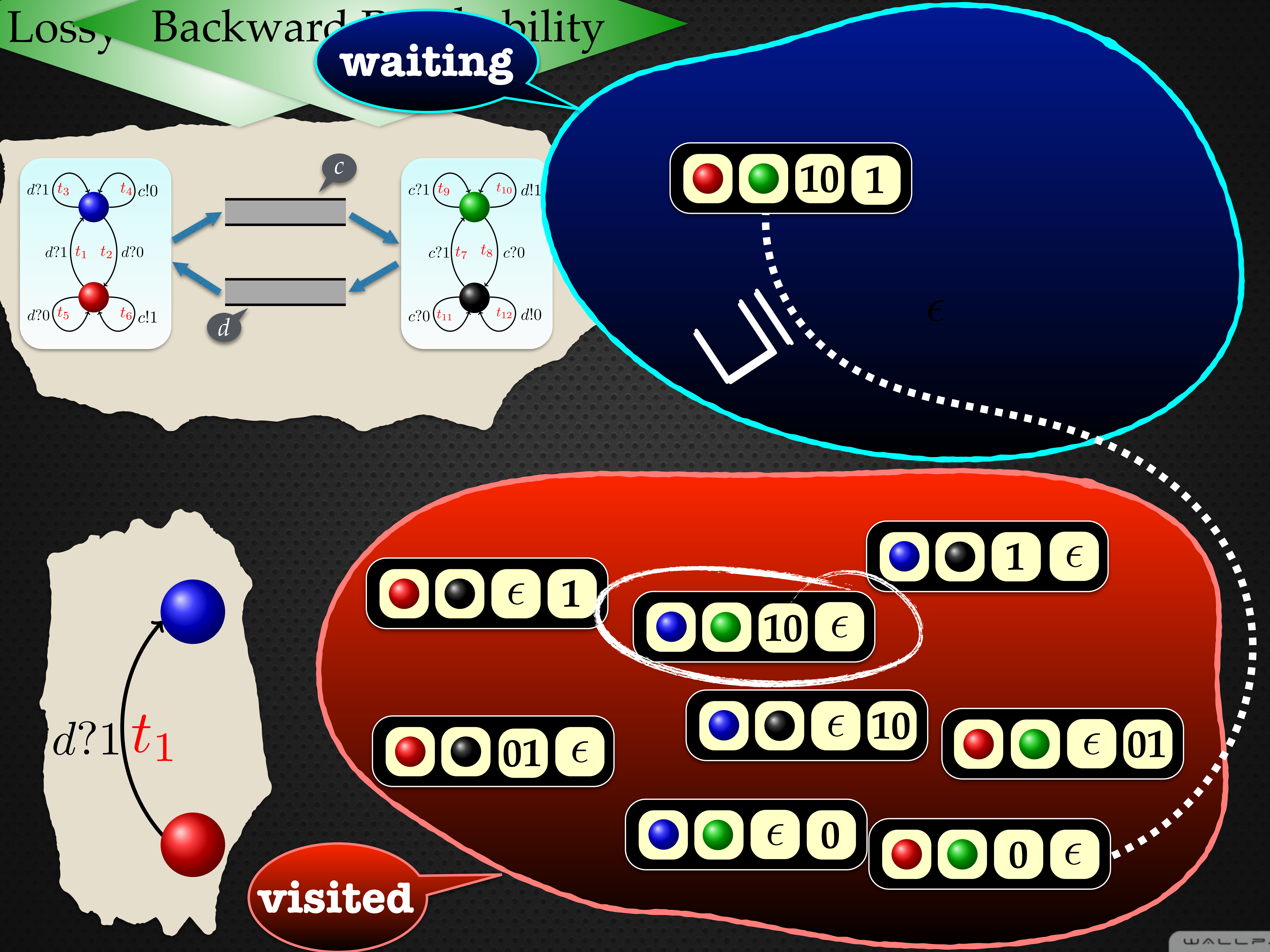




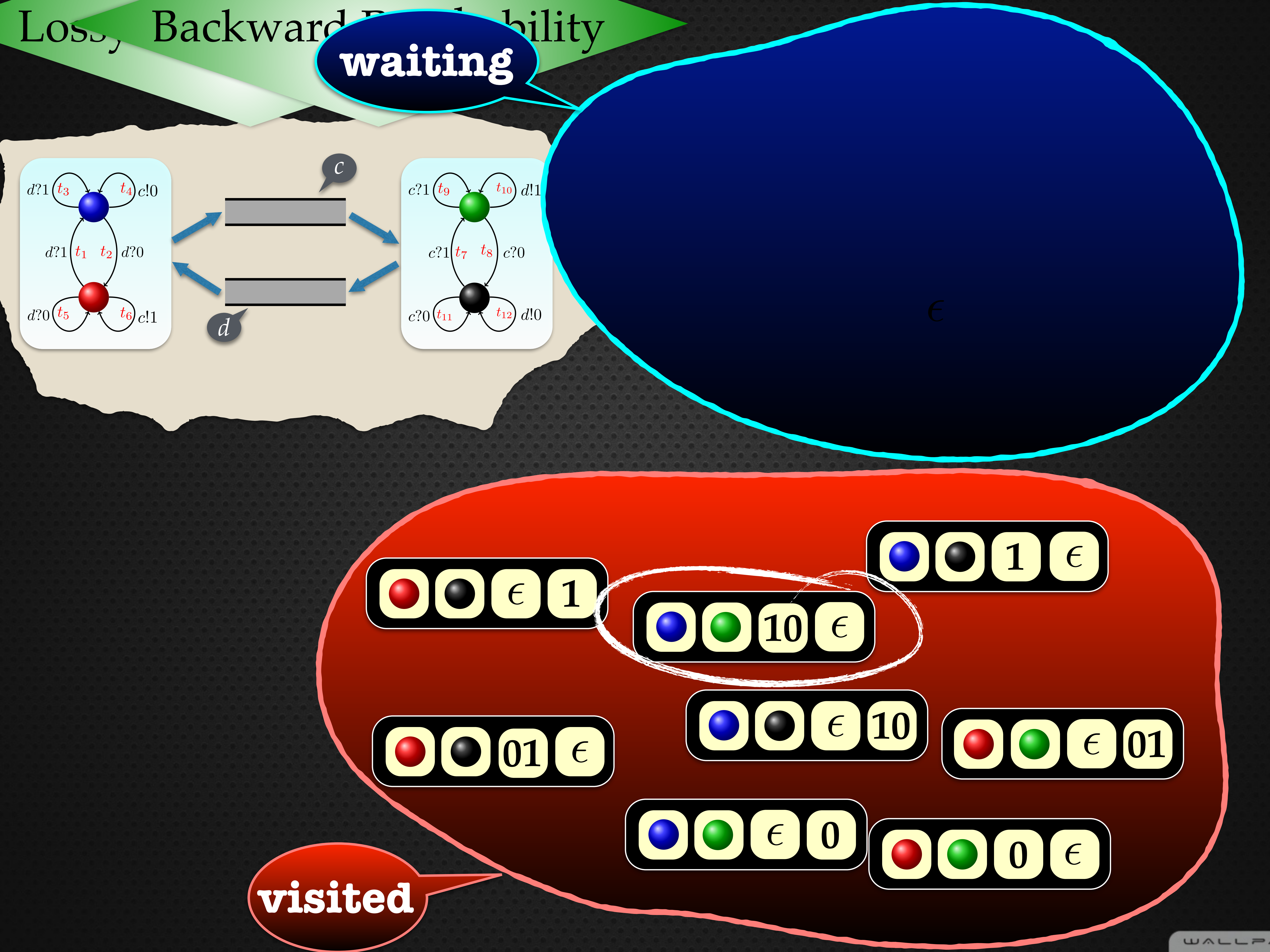
Lossy Backward R bility

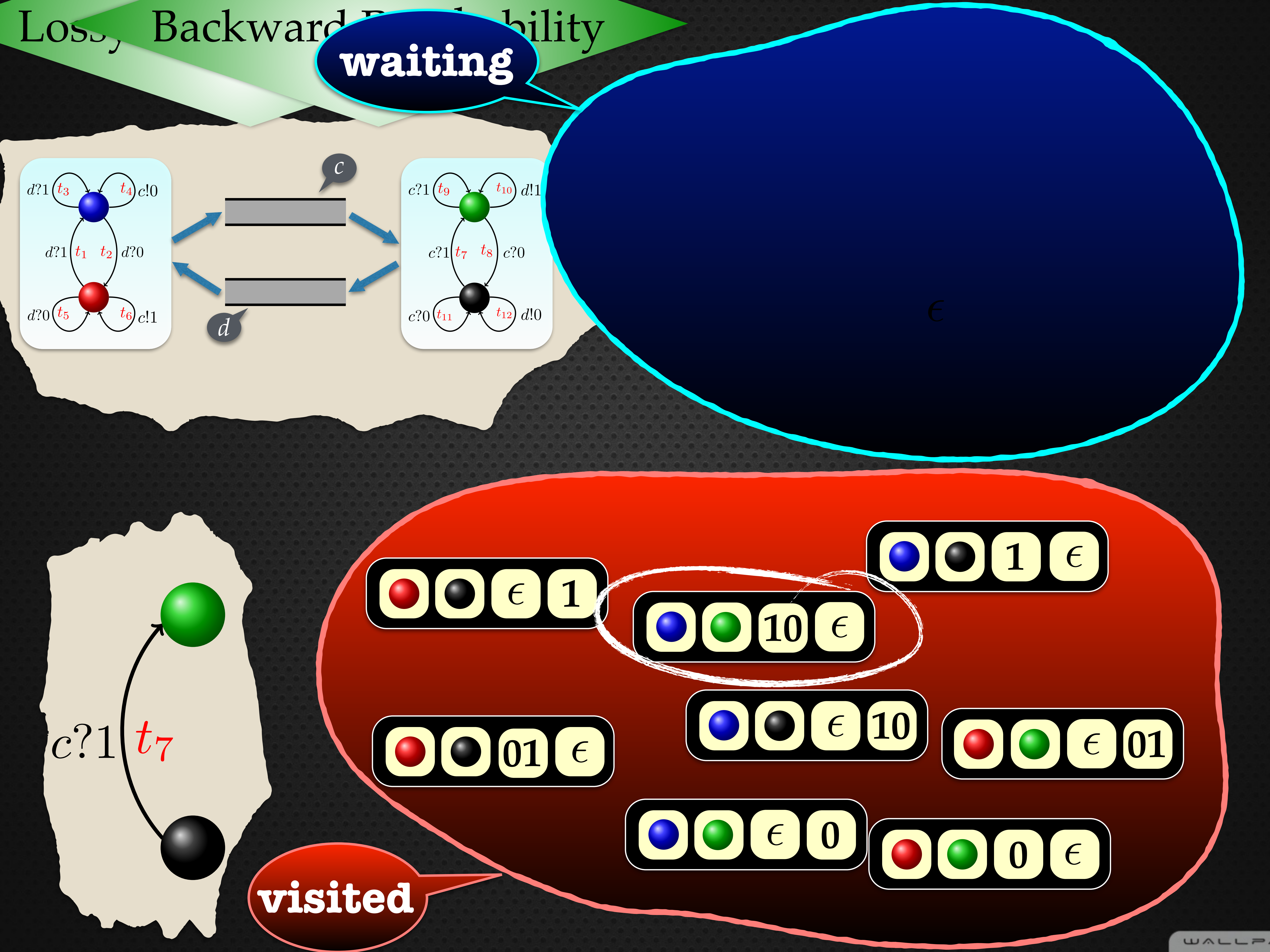



Loss Backward bility
waiting
visited
d?1 t_3
t_4 c!0
d?1 t_1
t_2 d?0
d?0 t_5
t_6 c!1
c
d
c?1 t_9
t_{10} d!1
c?1 t_7
t_8 c?0
c?0 t_{11}
t_{12} d!0
10 1
ϵ
ϵ 1
1 ϵ
10 ϵ
01 ϵ
ϵ 10
ϵ 01
ϵ 0
0 ϵ
d?1 t_1

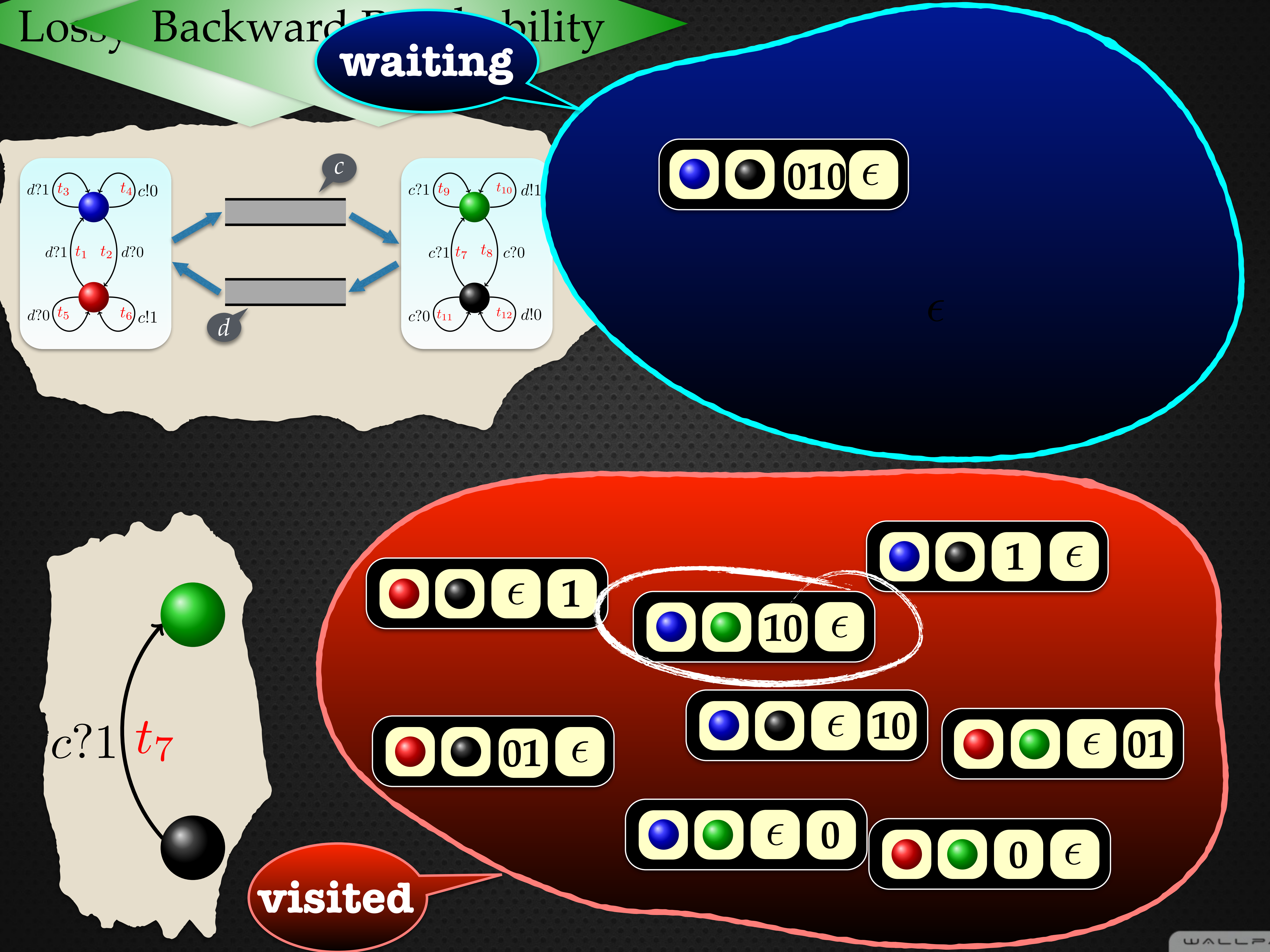


Lossy Backward R…bility
waiting
10
1
c
d
d?1 t3
t4 c!0
d?1 t1
t2 d?0
d?0 t5
t6 c!1
c?1 t9
t10 d!1
c?1 t7
t8 c?0
c?0 t11
t12 d!0
⊑
ϵ
d?1 t1
1 ϵ
ϵ 1
10 ϵ
01 ϵ
ϵ 10
ϵ 01
ϵ 0
0 ϵ
visited

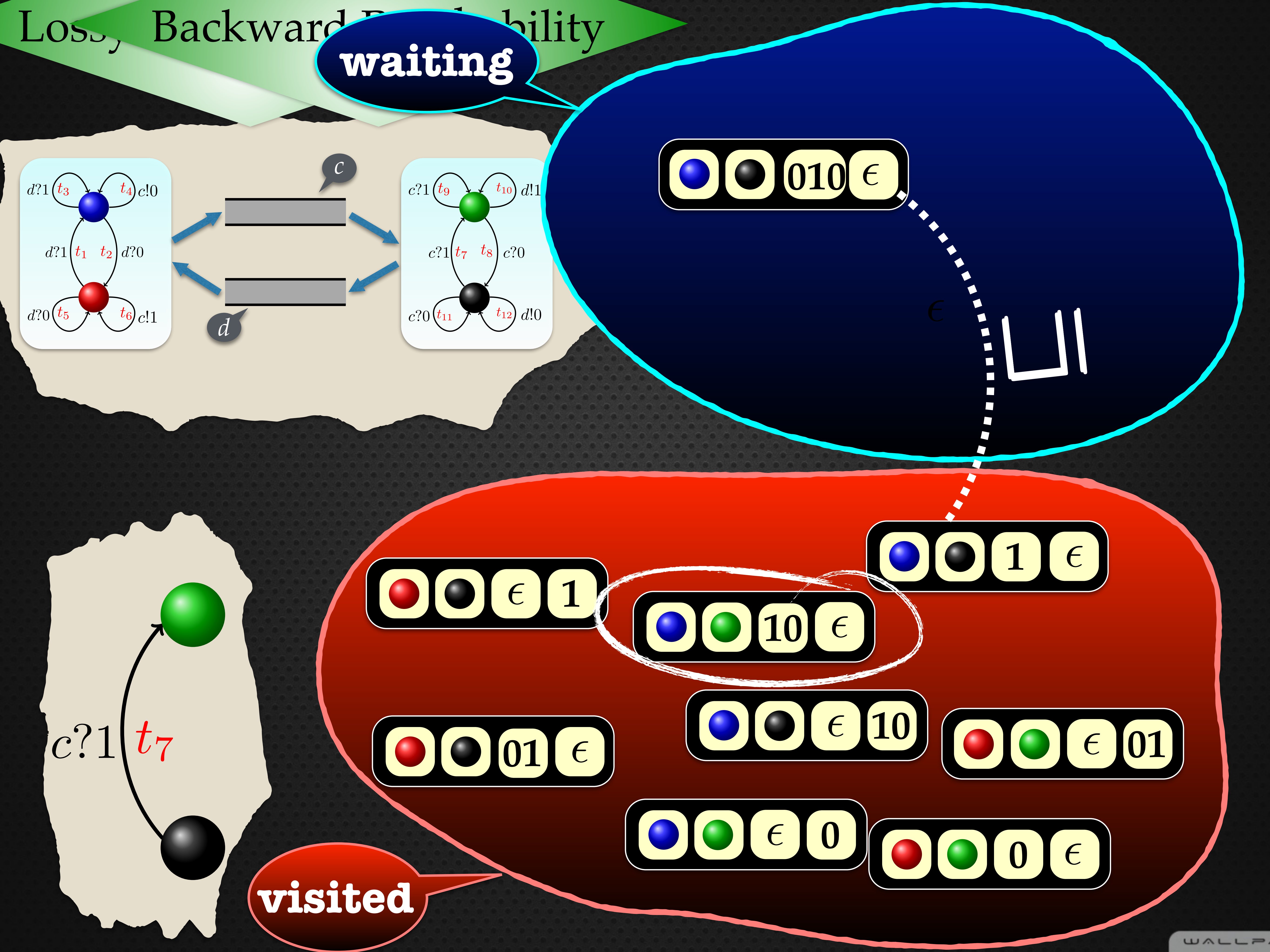

Backward
waiting
visited
c
d
d?1 t3
t4 c!0
d?1 t1
t2 d?0
d?0 t5
t6 c!1
c?1 t9
t10 d!1
c?1 t7
t8 c?0
c?0 t11
t12 d!0
ϵ
1 ϵ
ϵ 1
10 ϵ
ϵ 10
01 ϵ
ϵ 01
ϵ 0
0 ϵ



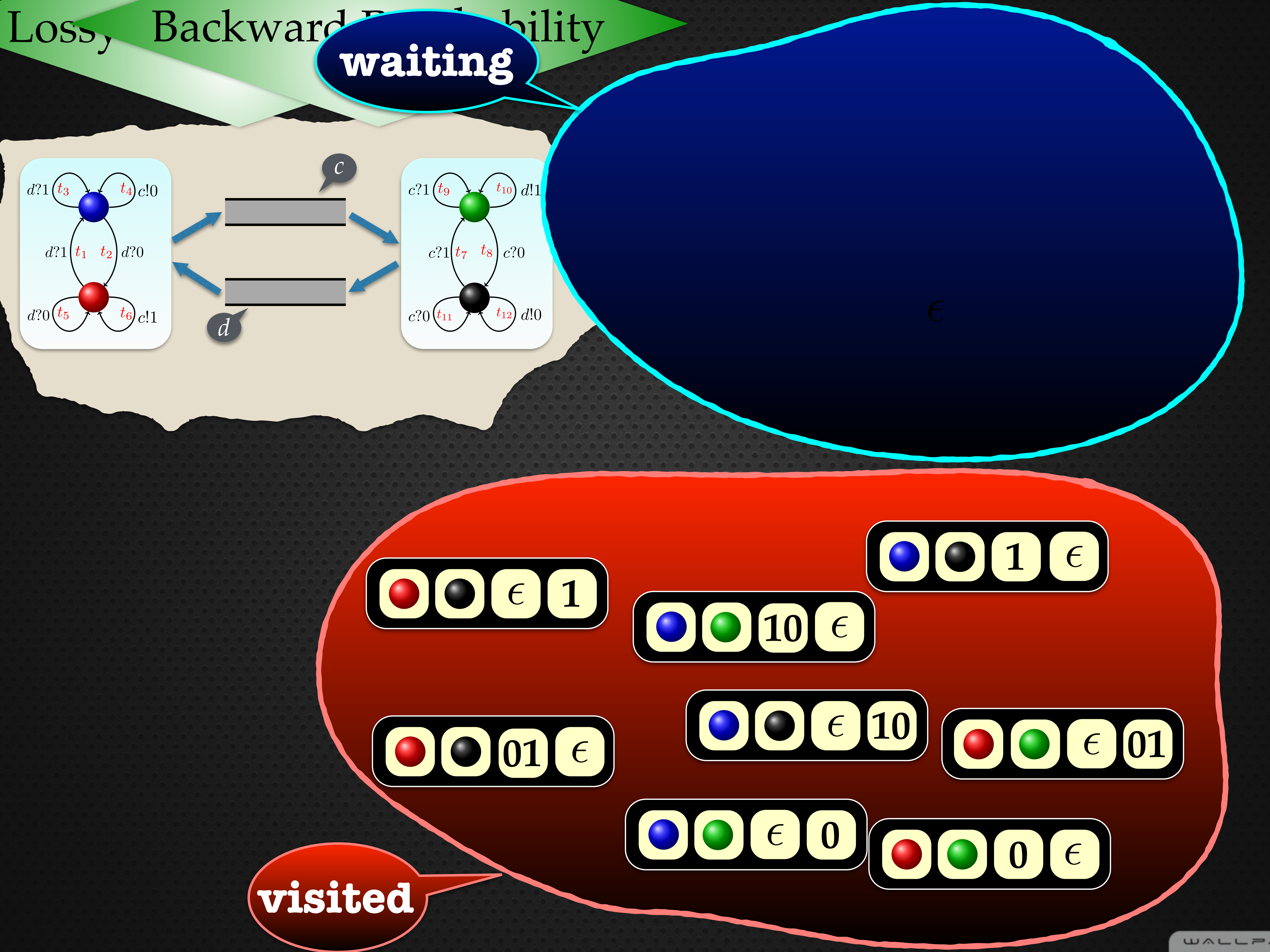
Los
y
Backward
bility
waiting
ϵ
c
d
d?1 t3
t4 c!0
d?1 t1
t2 d?0
d?0 t5
t6 c!1
c?1 t9
t10 d!1
c?1 t7
t8 c?0
c?0 t11
t12 d!0
c?1 t7
ϵ 1
1 ϵ
10 ϵ
01 ϵ
ϵ 10
ϵ 01
ϵ 0
0 ϵ
visited



Loss
Backward R
bility
waiting
visited
c
d
d?1 t3
t4 c!0
d?1 t1
t2 d?0
d?0 t5
t6 c!1
c?1 t9
t10 d!1
c?1 t7
t8 c?0
c?0 t11
t12 d!0
010 ϵ
ϵ
ϵ 1
1 ϵ
10 ϵ
01 ϵ
ϵ 10
ϵ 01
ϵ 0
0 ϵ
c?1 t7



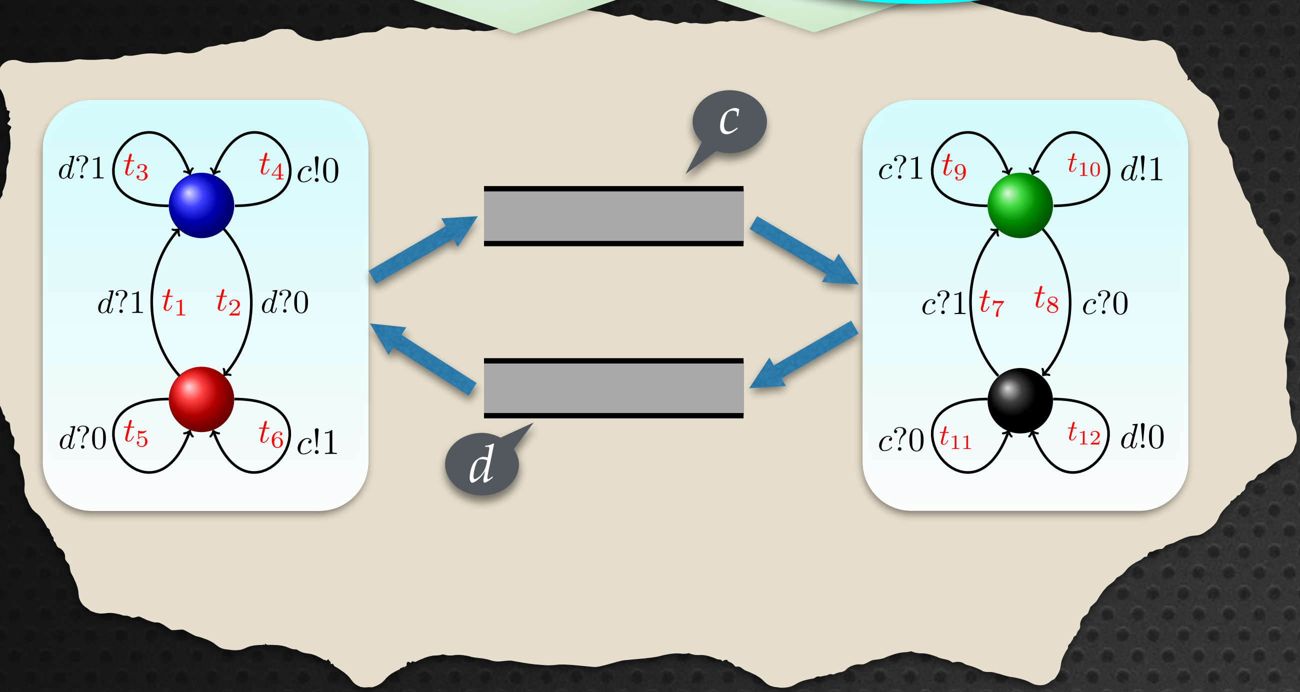
Loss
Backward
bility
waiting
010 ϵ
ϵ
⊑
c
d
d?1 t3
t4 c!0
d?1 t1
t2 d?0
d?0 t5
t6 c!1
c?1 t9
t10 d!1
c?1 t7
t8 c?0
c?0 t11
t12 d!0
ϵ 1
1 ϵ
10 ϵ
ϵ 10
01 ϵ
ϵ 01
ϵ 0
0 ϵ
c?1 t7
visited

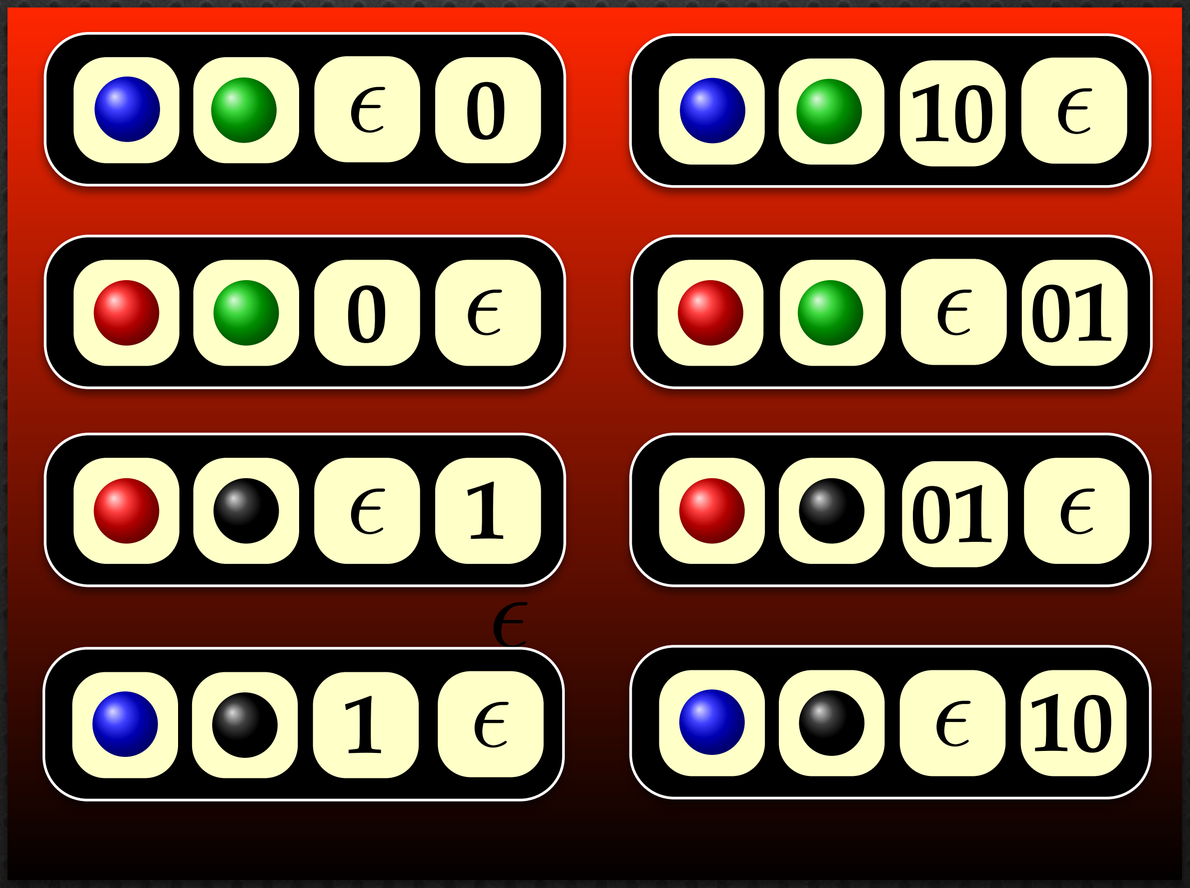


Loss
Backward
bility
waiting
$d?1$ t_3
t_4 $c!0$
$d?1$ t_1
t_2 $d?0$
$d?0$ t_5
t_6 $c!1$
c
d
$c?1$ t_9
t_{10} $d!1$
$c?1$ t_7
t_8 $c?0$
$c?0$ t_{11}
t_{12} $d!0$
ϵ
ϵ 1
1 ϵ
10 ϵ
ϵ 10
01 ϵ
ϵ 01
ϵ 0
0 ϵ
visited

Lossy Backward Reachability

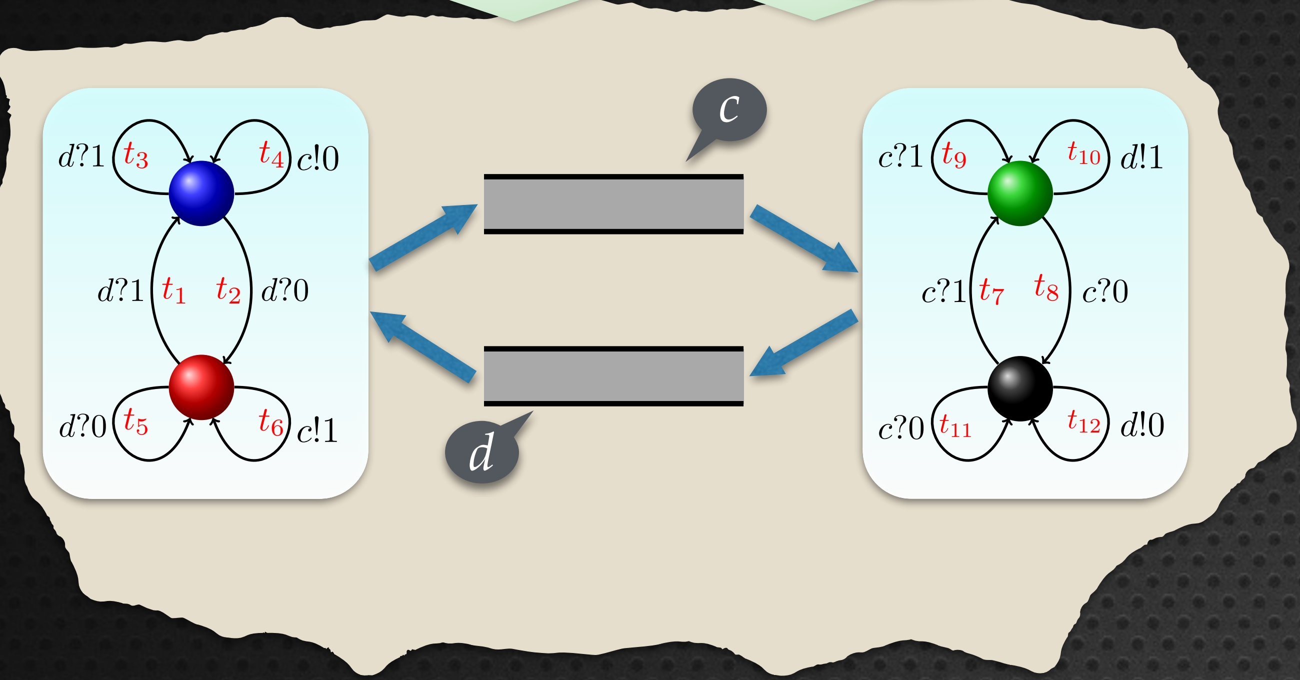
waiting

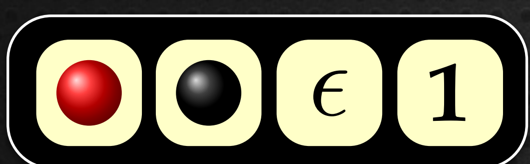




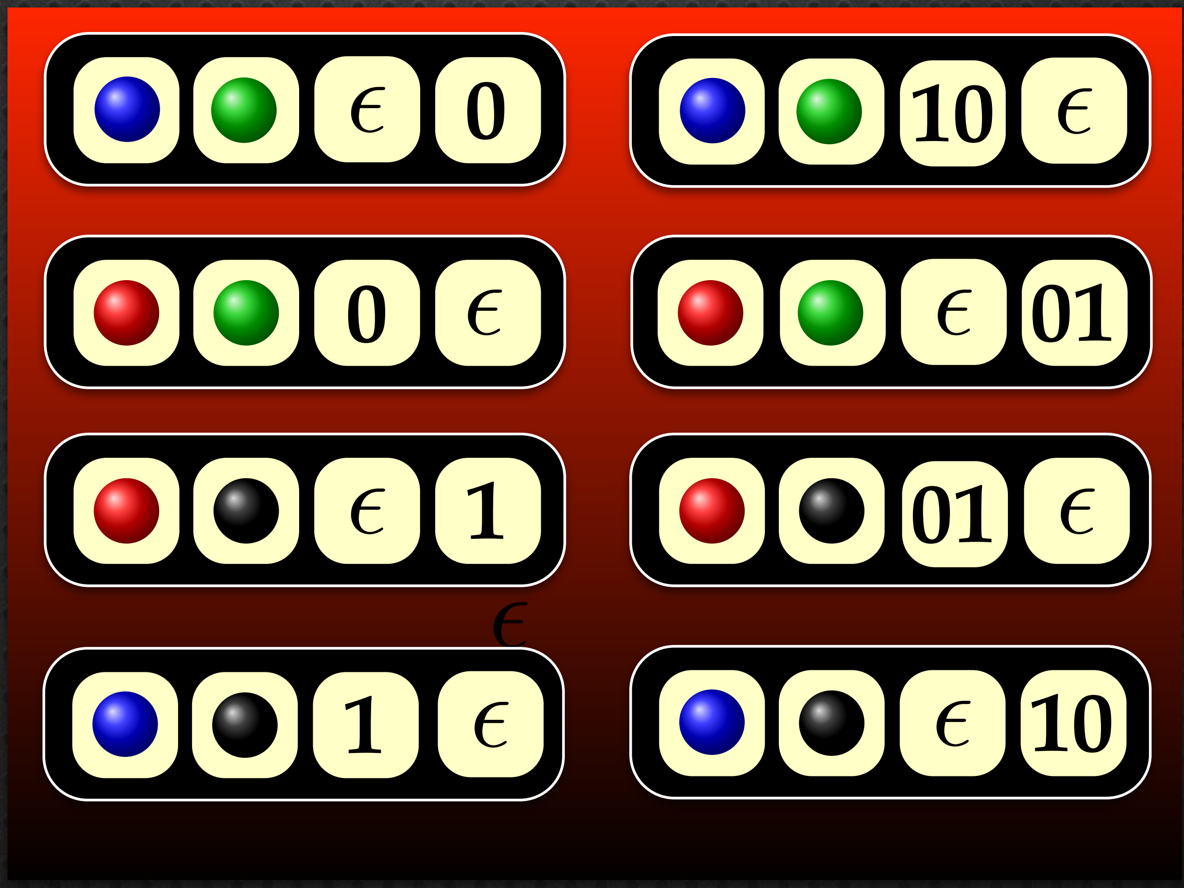
Loss… Backward … bility

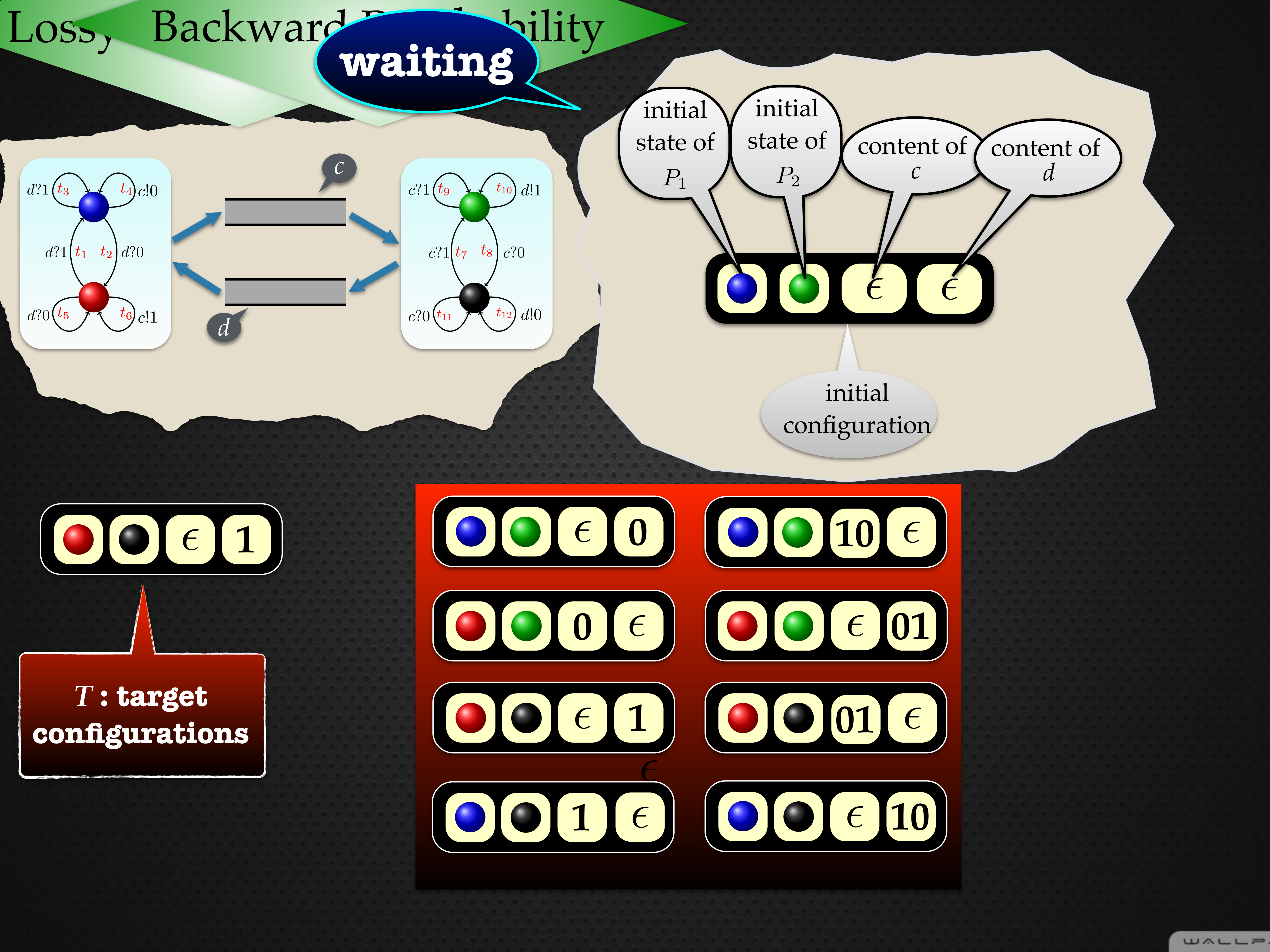
waiting



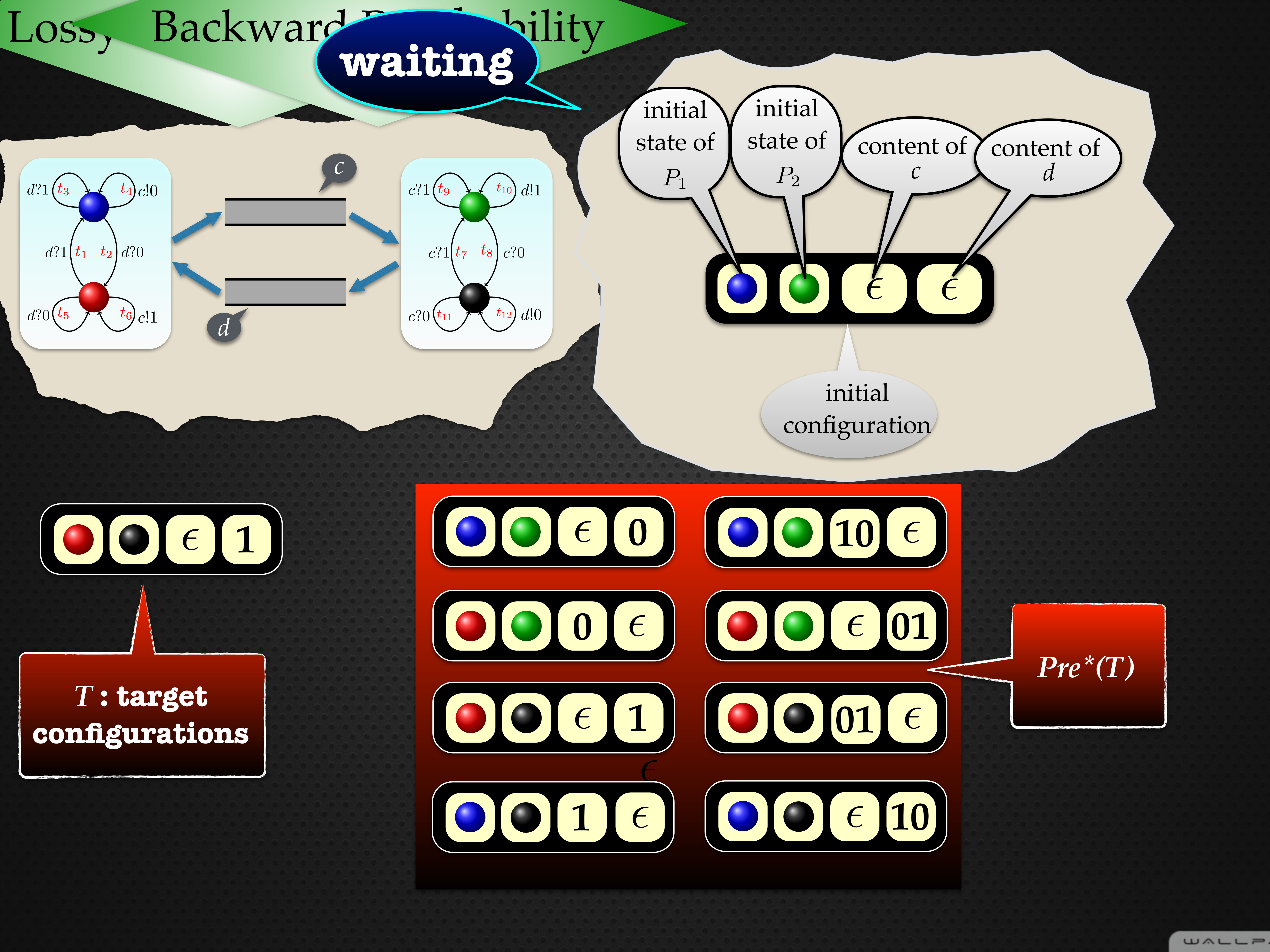


T : **target configurations**

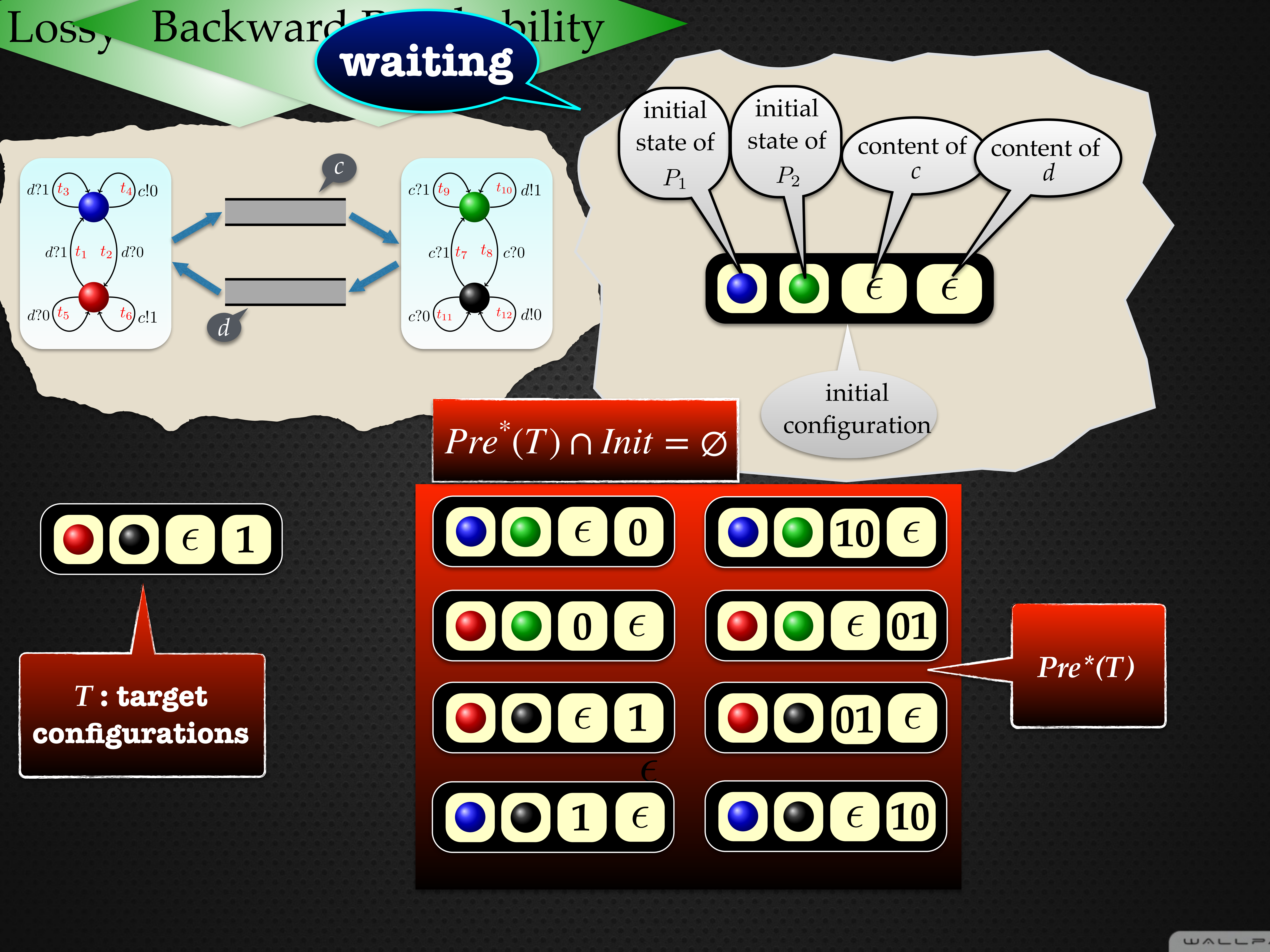




waiting
c
d
d?1 t3
t4 c!0
d?1 t1
t2 d?0
d?0 t5
t6 c!1
c?1 t9
t10 d!1
c?1 t7
t8 c?0
c?0 t11
t12 d!0
initial state of P1
initial state of P2
content of c
content of d
ϵ ϵ
initial configuration
ϵ 1
T : target configurations
ϵ 0
10 ϵ
0 ϵ
ϵ 01
ϵ 1
01 ϵ
ϵ
1 ϵ
ϵ 10



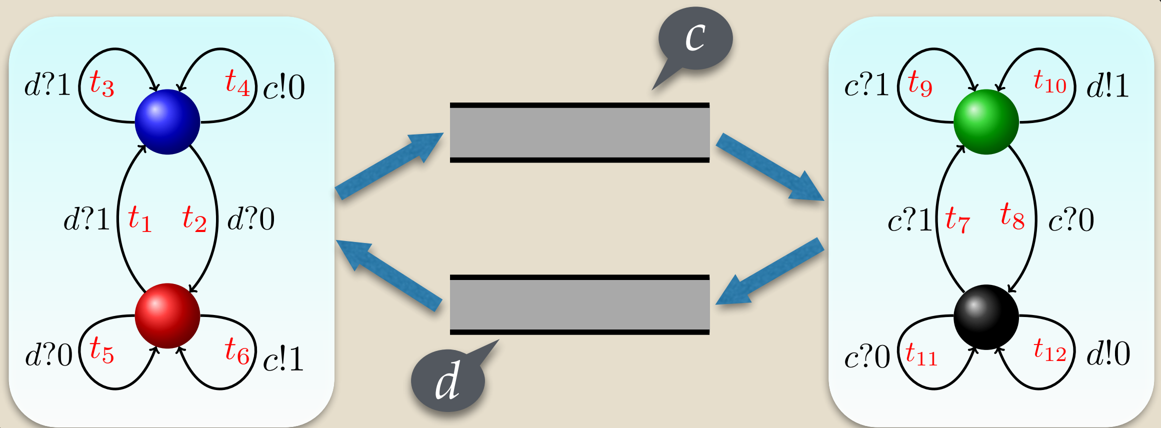
Lossy Backward
bility
waiting
c
d
d?1 t3 t4 c!0
d?1 t1 t2 d?0
d?0 t5 t6 c!1
c?1 t9 t10 d!1
c?1 t7 t8 c?0
c?0 t11 t12 d!0
initial state of P1
initial state of P2
content of c
content of d
ϵ ϵ
initial configuration
ϵ 1
T : target configurations
ϵ 0
10 ϵ
0 ϵ
ϵ 01
ϵ 1
01 ϵ
ϵ
1 ϵ
ϵ 10
Pre*(T)



Lossy Backward
bility
waiting
$d?1$ t_3 t_4 $c!0$
$d?1$ t_1 t_2 $d?0$
$d?0$ t_5 t_6 $c!1$
c
d
$c?1$ t_9 t_{10} $d!1$
$c?1$ t_7 t_8 $c?0$
$c?0$ t_{11} t_{12} $d!0$
initial state of P_1
initial state of P_2
content of c
content of d
ϵ ϵ
initial configuration
$Pre^*(T) \cap Init = \emptyset$
ϵ 1
T : target configurations
ϵ 0
10 ϵ
0 ϵ
ϵ 01
ϵ 1
01 ϵ
ϵ
1 ϵ
ϵ 10
$Pre^*(T)$

Lossy Backward Reachability

waiting



initial state of P_1

initial state of P_2

content of c

content of d

ϵ ϵ

"target configurations not reachable from initial configuration"

$$Pre^*(T) \cap Init = \varnothing$$

ϵ 1

T : target configurations

ϵ 0 — 10 ϵ

0 ϵ — ϵ 01

ϵ 1 — 01 ϵ

ϵ

1 ϵ — ϵ 10

$Pre^*(T)$

Well Quasi-Ordering

Well Quasi-Ordering

infinite sequence of words

$$w_0, w_1, w_2, \ldots, w_i, \ldots, w_j, \ldots$$

$$\exists i < j : w_i \sqsubseteq w_j$$

Well Quasi-Ordering

Well Quasi-Ordering

infinite sequence of words

$$w_0, w_1, w_2, \ldots, w_i, \ldots, w_j, \ldots$$

$$\sqsubseteq$$

$$\exists i < j : w_i \sqsubseteq w_j$$

Well Quasi-Ordering

Well Quasi-Ordering

infinite sequence of words

$$w_0, w_1, w_2, \ldots, w_i, \ldots, w_j, \ldots$$

$$\sqsubseteq$$

$$\exists i < j : w_i \sqsubseteq w_j$$

Well Quasi-Ordering

infinite sequence of configurations

$$c_0, c_1, c_2, \ldots, c_i, \ldots, c_j, \ldots$$

$$\exists i < j : c_i \sqsubseteq c_j$$

Well Quasi-Ordering

Well Quasi-Ordering

infinite sequence of words

$$w_0, w_1, w_2, \ldots, w_i, \ldots, w_j, \ldots$$

$$\sqsubseteq$$

$$\exists i < j : w_i \sqsubseteq w_j$$

Well Quasi-Ordering

infinite sequence of configurations

$$c_0, c_1, c_2, \ldots, c_i, \ldots, c_j, \ldots$$

$$\sqsubseteq$$

$$\exists i < j : c_i \sqsubseteq c_j$$

Lossy Channel Systems

Lossy Channel Systems

Ordering:

- monotonicity
- computing predecessors
- well quasi-ordering