Business Processes Modelling

MPB (6 cfu, 295AA)

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22 - Diagnosis for WF nets

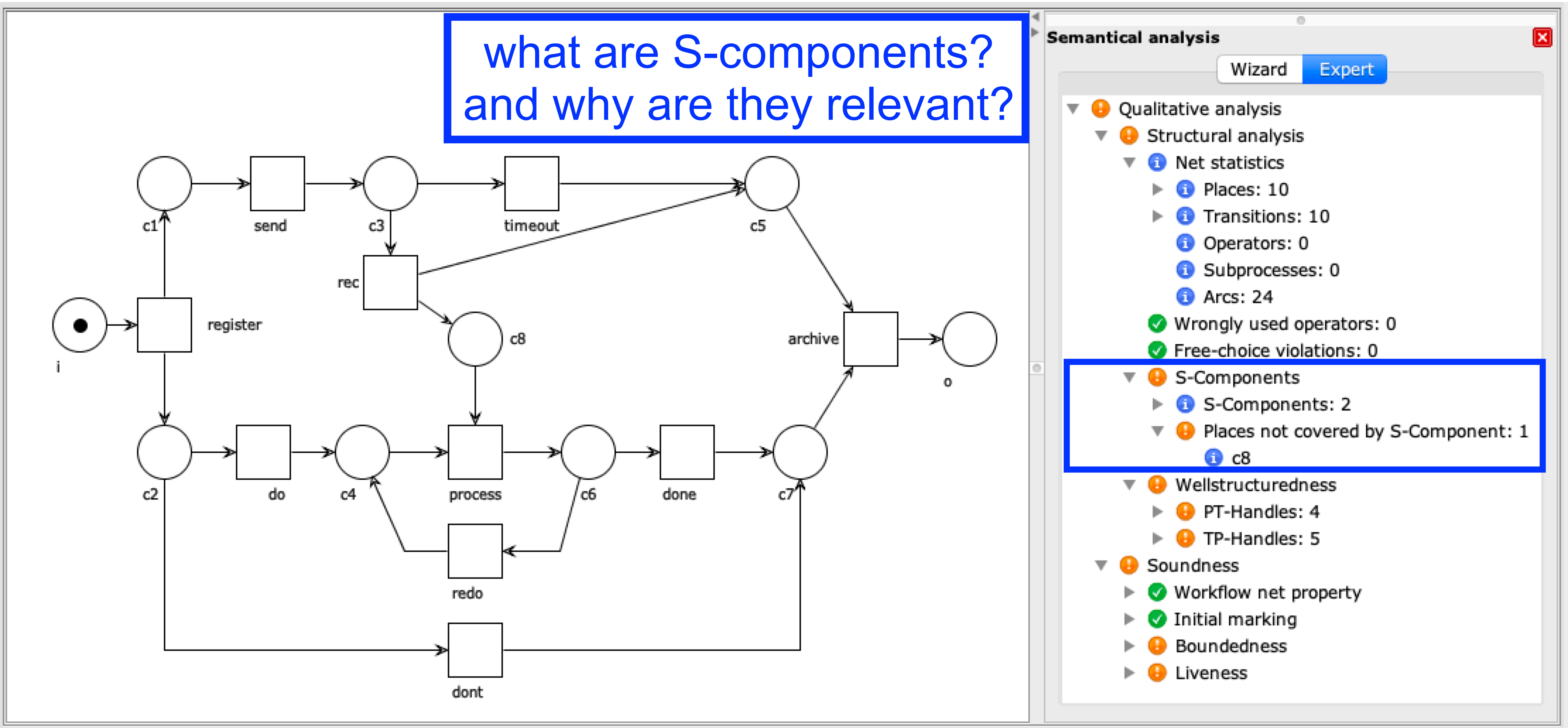
Object

We study suitable diagnosis techniques
for unsound Workflow nets

Diagnosing workflow processes using Woflan (article, optional reading)
http://wwwis.win.tue.nl/~wvdaalst/publications/p135.pdf

S-Coverability

Woped



what are S-components?
and why are they relevant?
c1
send
c3
timeout
c5
rec
register
c8
archive
i
o
c2
do
c4
process
c6
done
c7
redo
dont
Semantical analysis
Wizard
Expert
Qualitative analysis
Structural analysis
Net statistics
Places: 10
Transitions: 10
Operators: 0
Subprocesses: 0
Arcs: 24
Wrongly used operators: 0
Free-choice violations: 0
S-Components
S-Components: 2
Places not covered by S-Component: 1
c8
Wellstructuredness
PT-Handles: 4
TP-Handles: 5
Soundness
Workflow net property
Initial marking
Boundedness
Liveness

Rank Theorem (main result, proof omitted)

Theorem:

A free-choice system (P,T,F,M_0) is live and bounded

iff

1. it has at least one place and one transition
2. it is connected
3. M_0 marks every proper siphon
4. it has a positive S-invariant
5. it has a positive T-invariant
6. $rank(N) = |C_N| - 1$

(where C_N is the set of clusters)

A technique to find a positive S-invariant

A case is often composed by parallel threads of control
(each thread imposing some order over its tasks)

Decompose the net N in suitable S-nets
so that any place of N belongs to some S-net
(the same place can appear in more S-nets)

Each S-net induces a uniform S-invariant

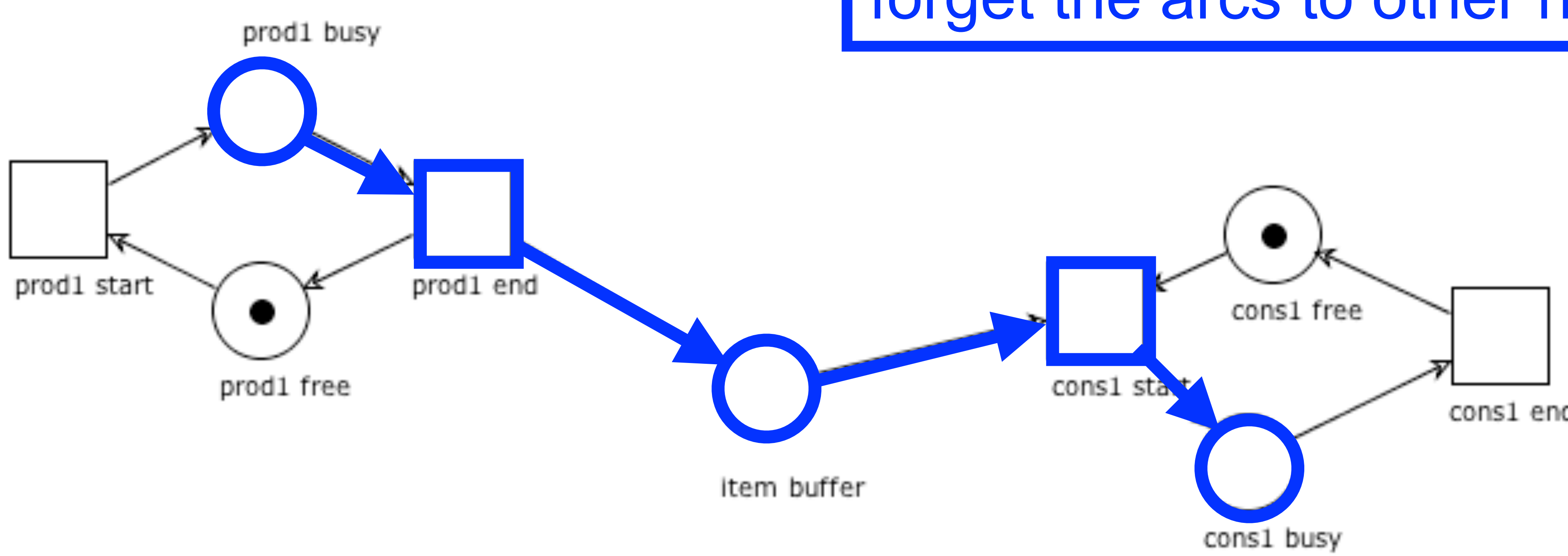
A positive S-invariant is obtained
as the sum of the S-invariants of each subnet

Subnet

take a set of nodes

Definition: Let $N = (P, T, F)$ and $\emptyset \subset X \subseteq P \cup T$
Let $N' = (P \cap X, T \cap X, F \cap (X \times X))$ be a subnet of N.

forget the arcs to other nodes



S-component

take a set of nodes

Definition: Let $N = (P, T, F)$ and $\emptyset \subset X \subseteq P \cup T$
Let $N' = (P \cap X, T \cap X, F \cap (X \times X))$ be a subnet of N.
N' is an **S-component** if

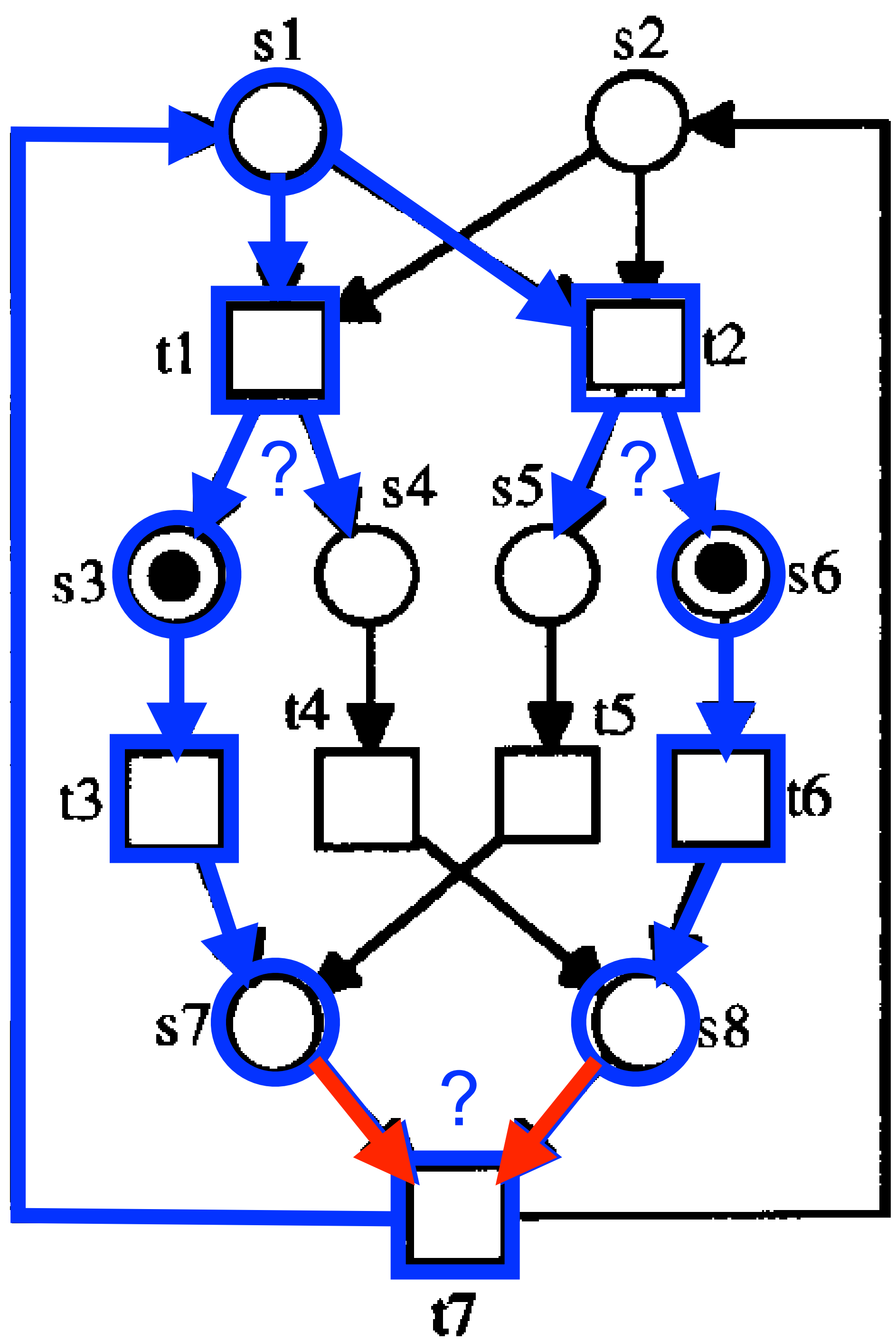
forget the arcs to other nodes

1. it is a strongly connected S-net
2. for every place $p \in X \cap P$, we have $\bullet p \cup p \bullet \subseteq X$

if a place p is taken
then all transitions attached to p must be selected

if a place p is taken
then all transitions attached to p must be selected

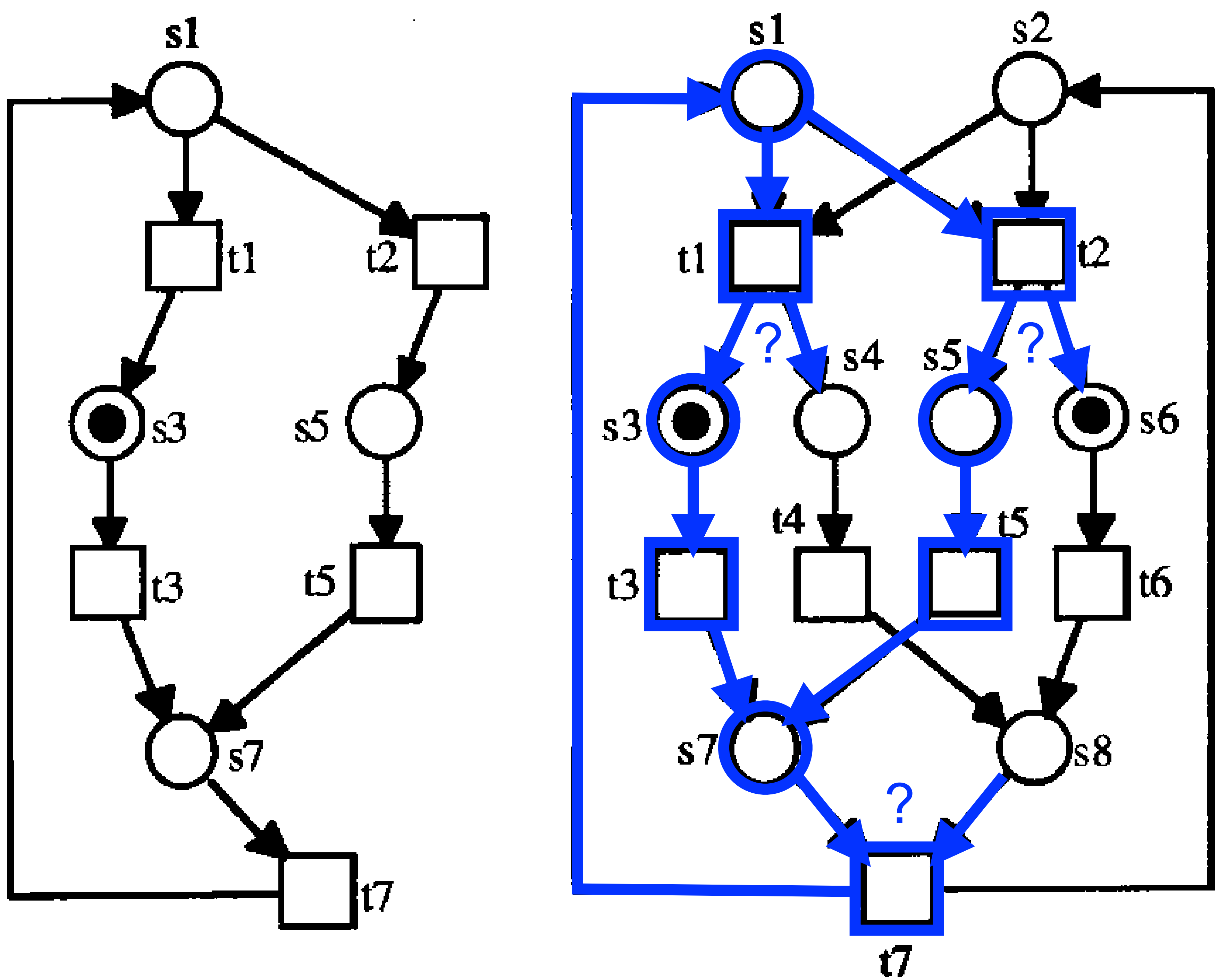
S-component: example



not an S-net

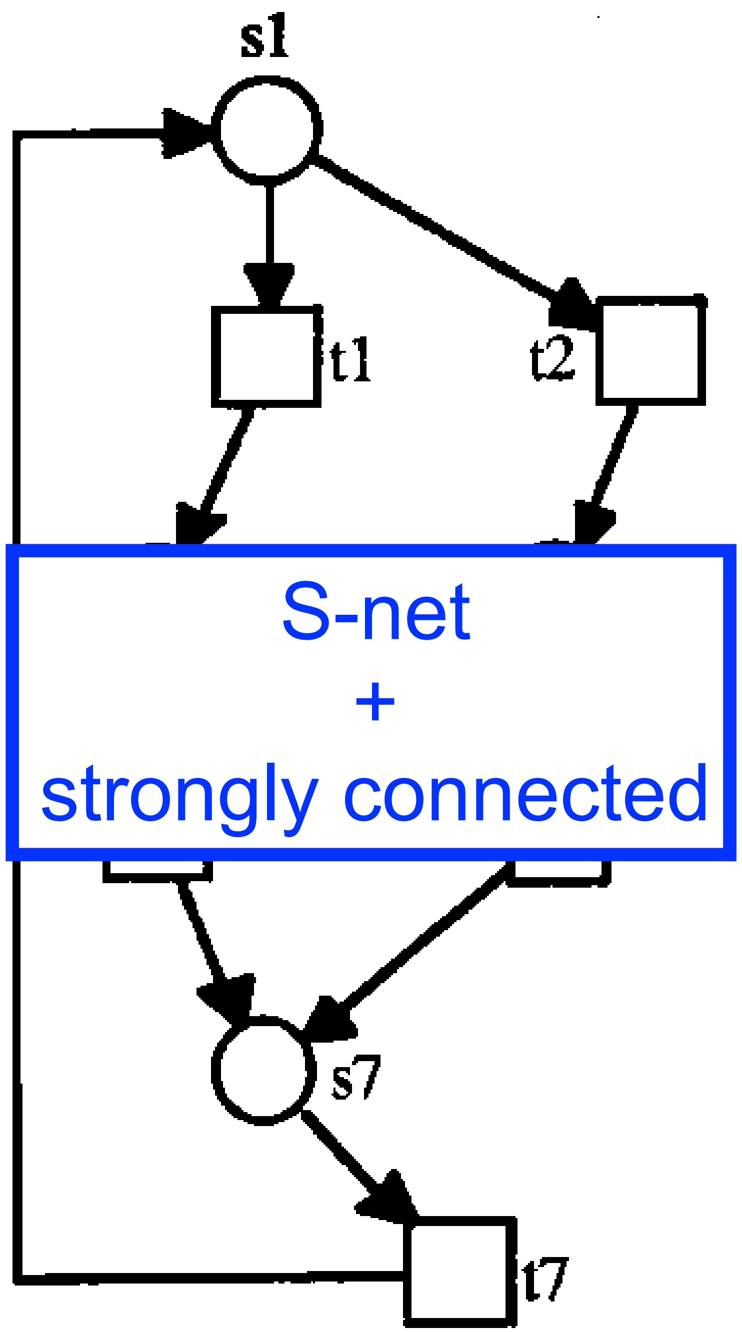
if a place p is taken
then all transitions attached to p must be selected

S-component: example

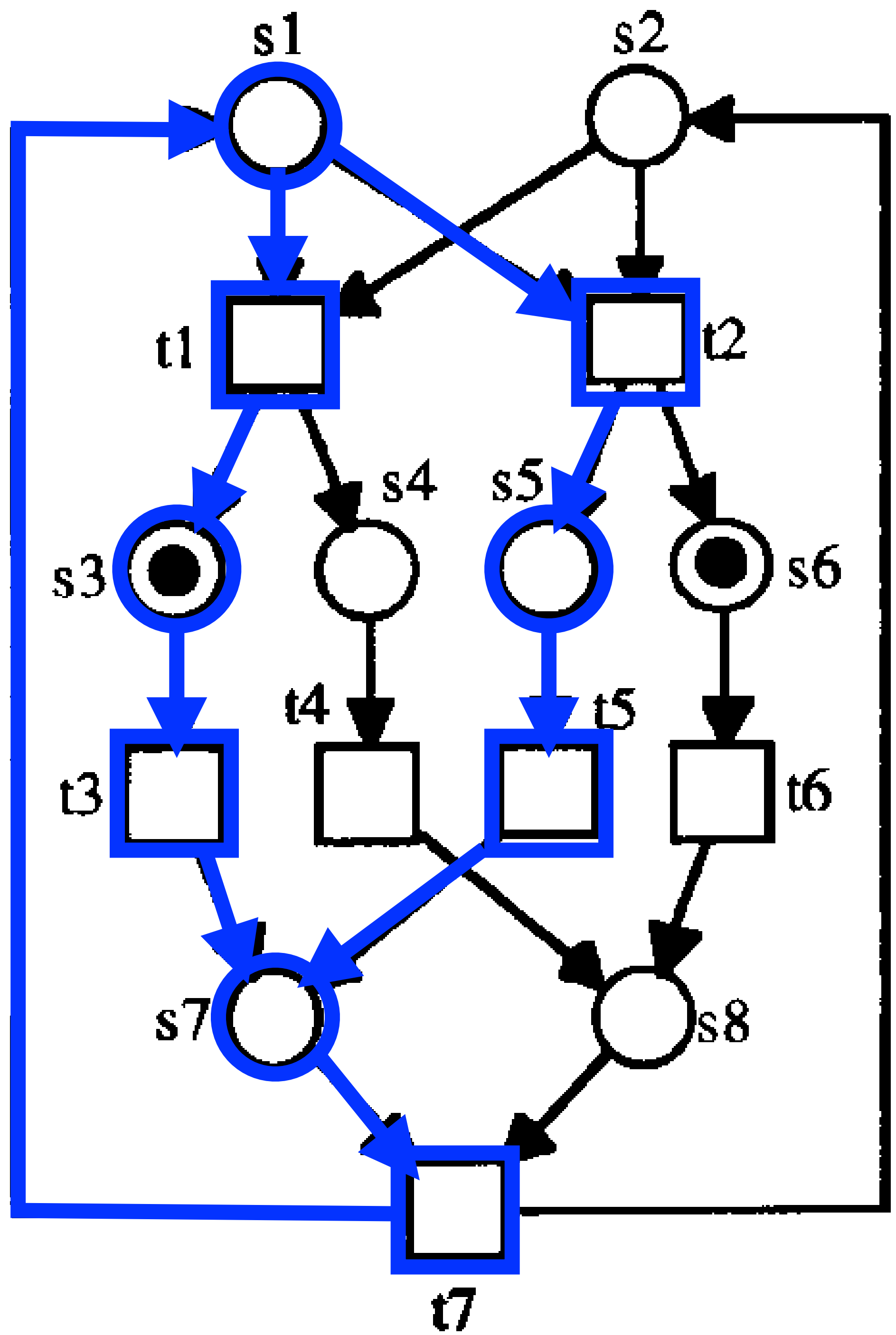


if a place p is taken
then all transitions attached to p must be selected

S-component: example



S-component



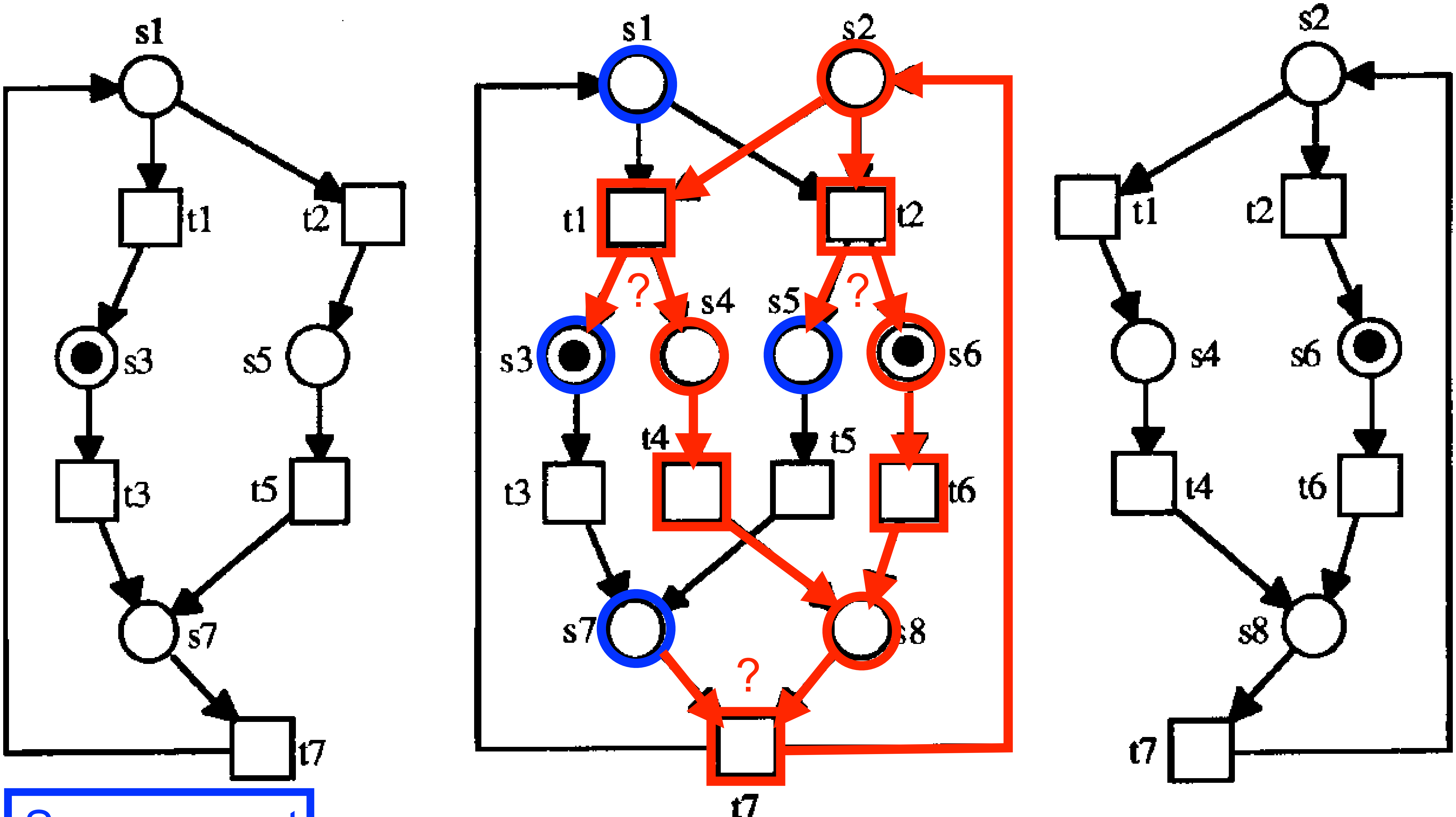
S-cover

Definition: an **S-cover** of a net N
is a set **C** of S-components of N such that
every place p of N belongs to one or more S-components in **C**

N is **S-coverable** if it has an S-cover

if a place p is taken
then all transitions attached to p must be selected

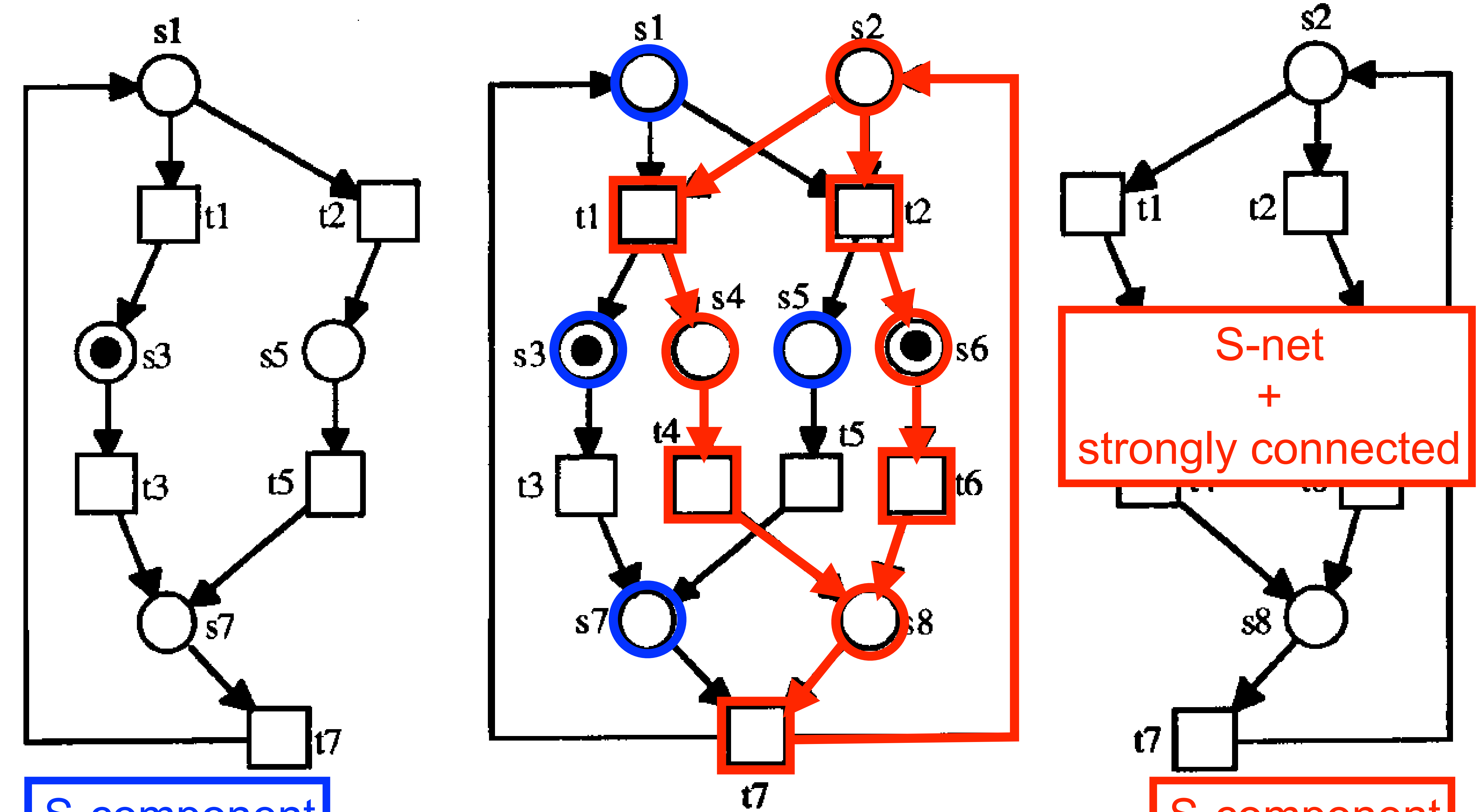
S-cover: example



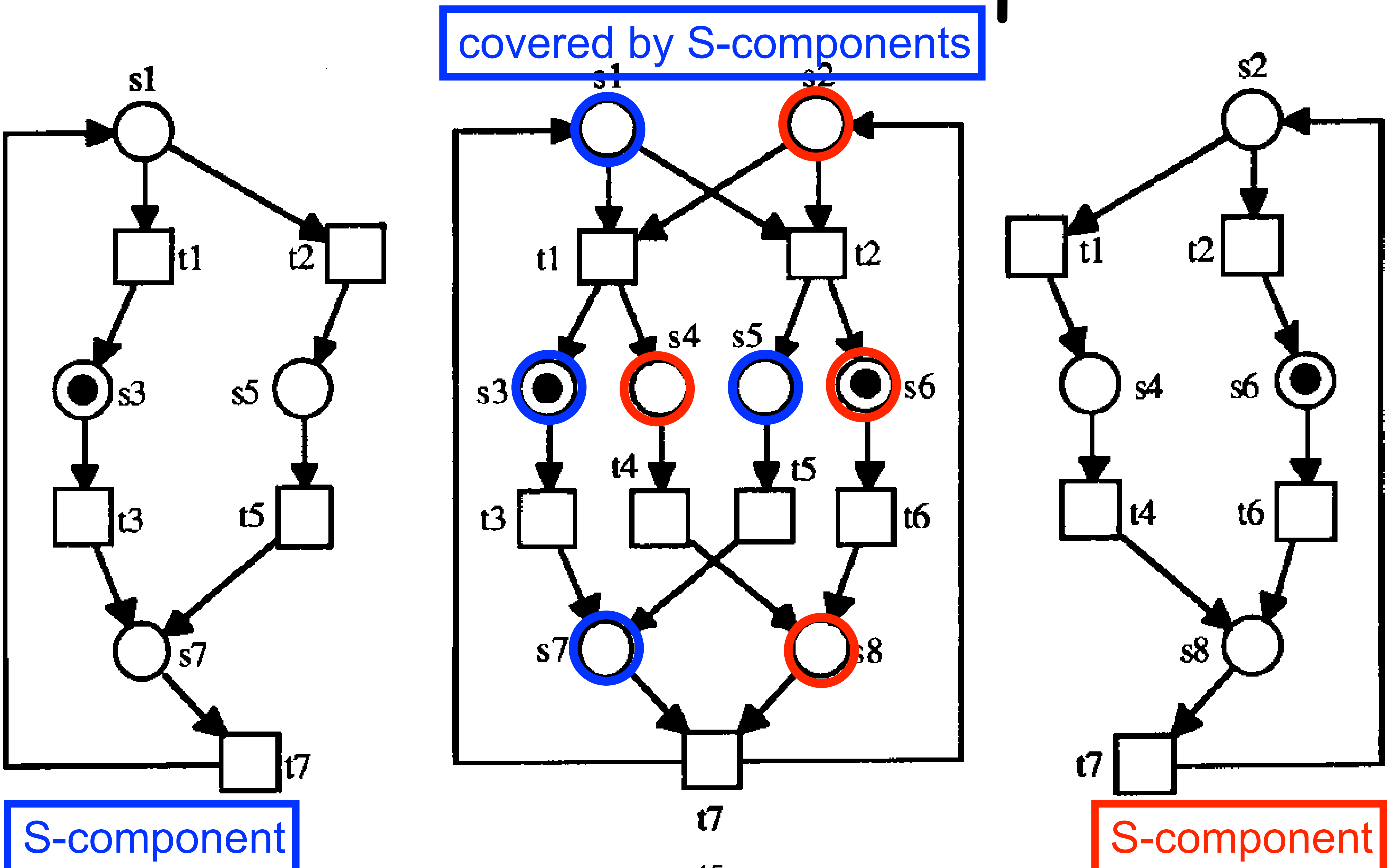
S-component

if a place p is taken
then all transitions attached to p must be selected

S-cover: example

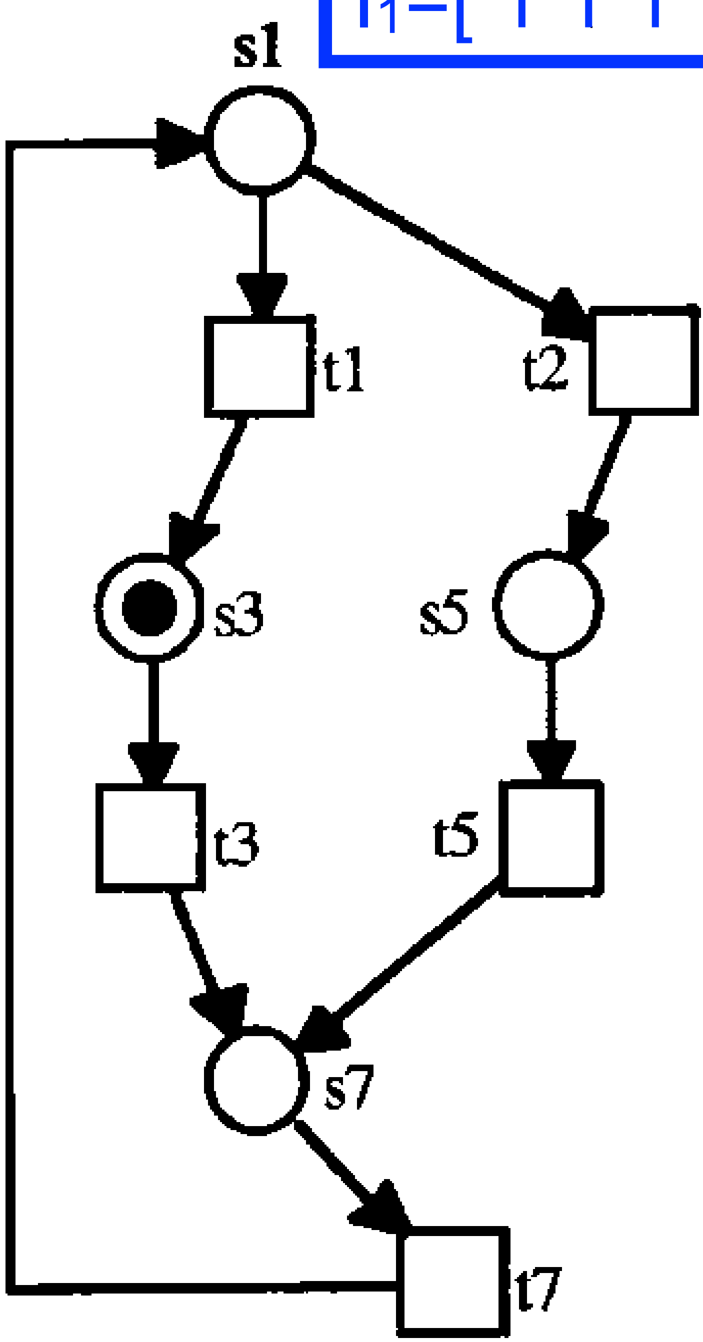


S-cover: example



S-cover: example

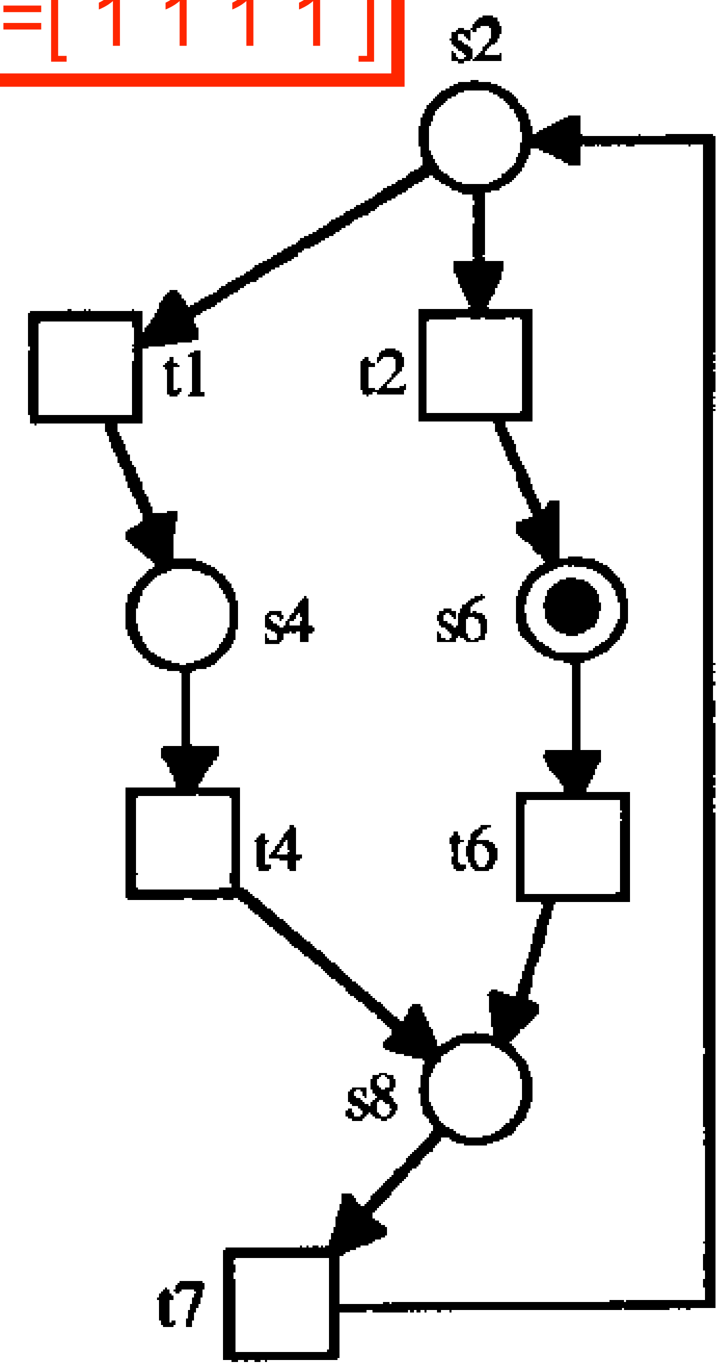
I_1=[1 1 1 1]



S-component

S-cover

I_2=[1 1 1 1]



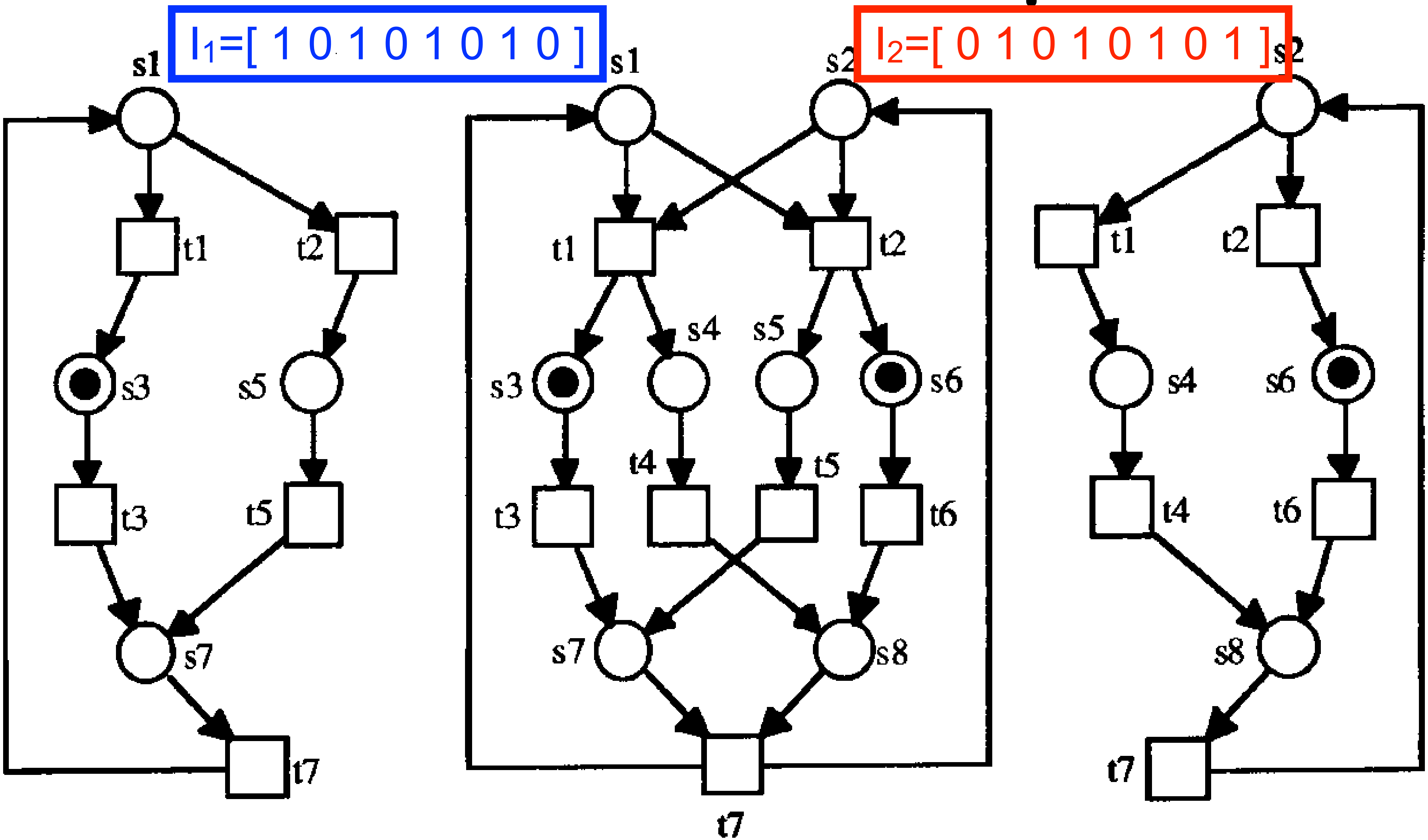
S-component

S-invariants

Any S-invariant of an S-component
induces an S-invariant for the whole net

(it is enough to assign weight 0 to
all places not covered by the S-component)

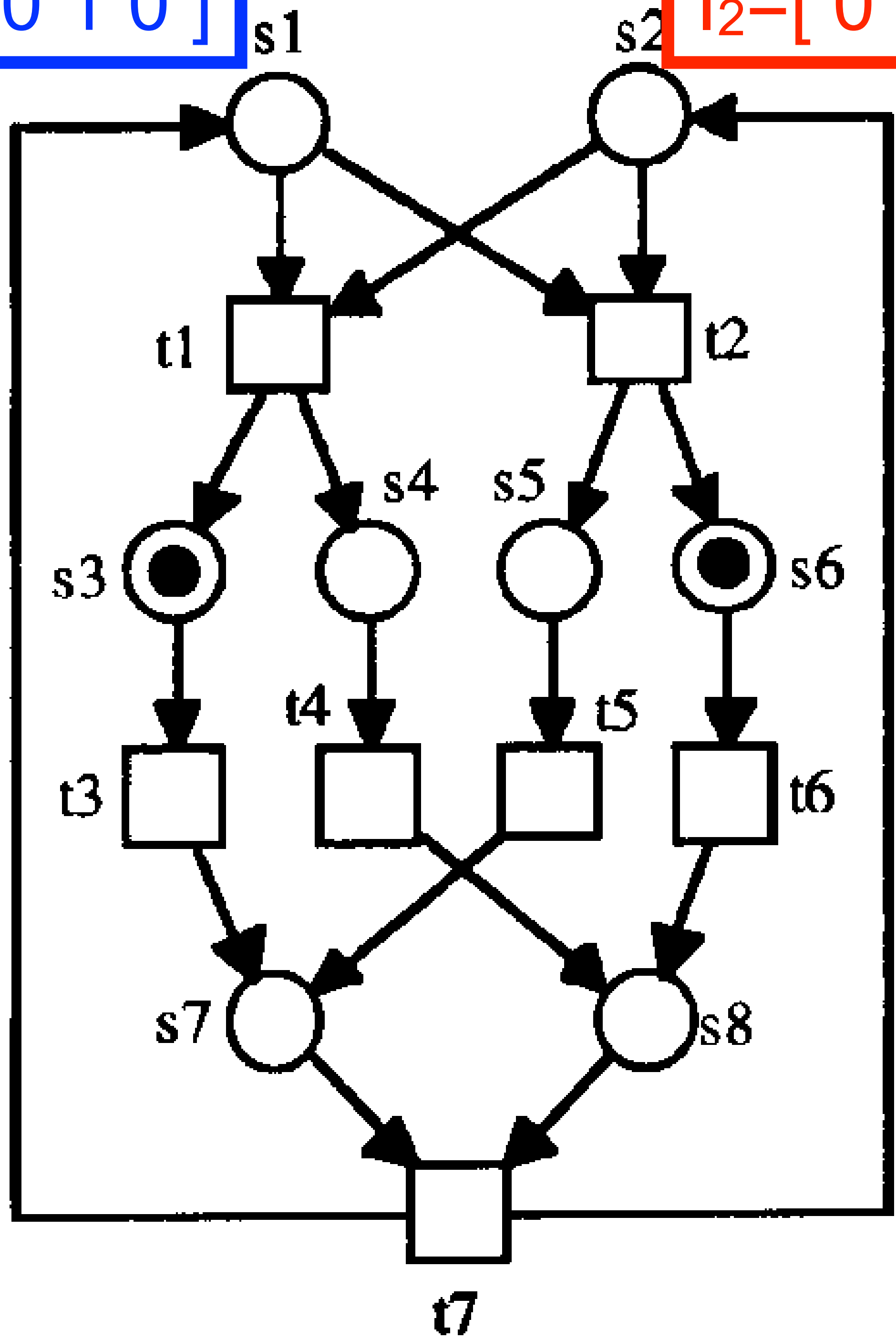
S-cover: example



S-cover: example

I_1=[1 0 1 0 1 0 1 0]

I_2=[0 1 0 1 0 1 0 1]



I_1+I_2=[1 1 1 1 1 1 1 1]

positive S-invariant

S-coverability theorem

Theorem: If a free-choice system is live and bounded then it is S-coverable

(proof omitted)

Consequence:
free-choice + not S-coverable => not (live and bounded)

S-Coverability diagnosis

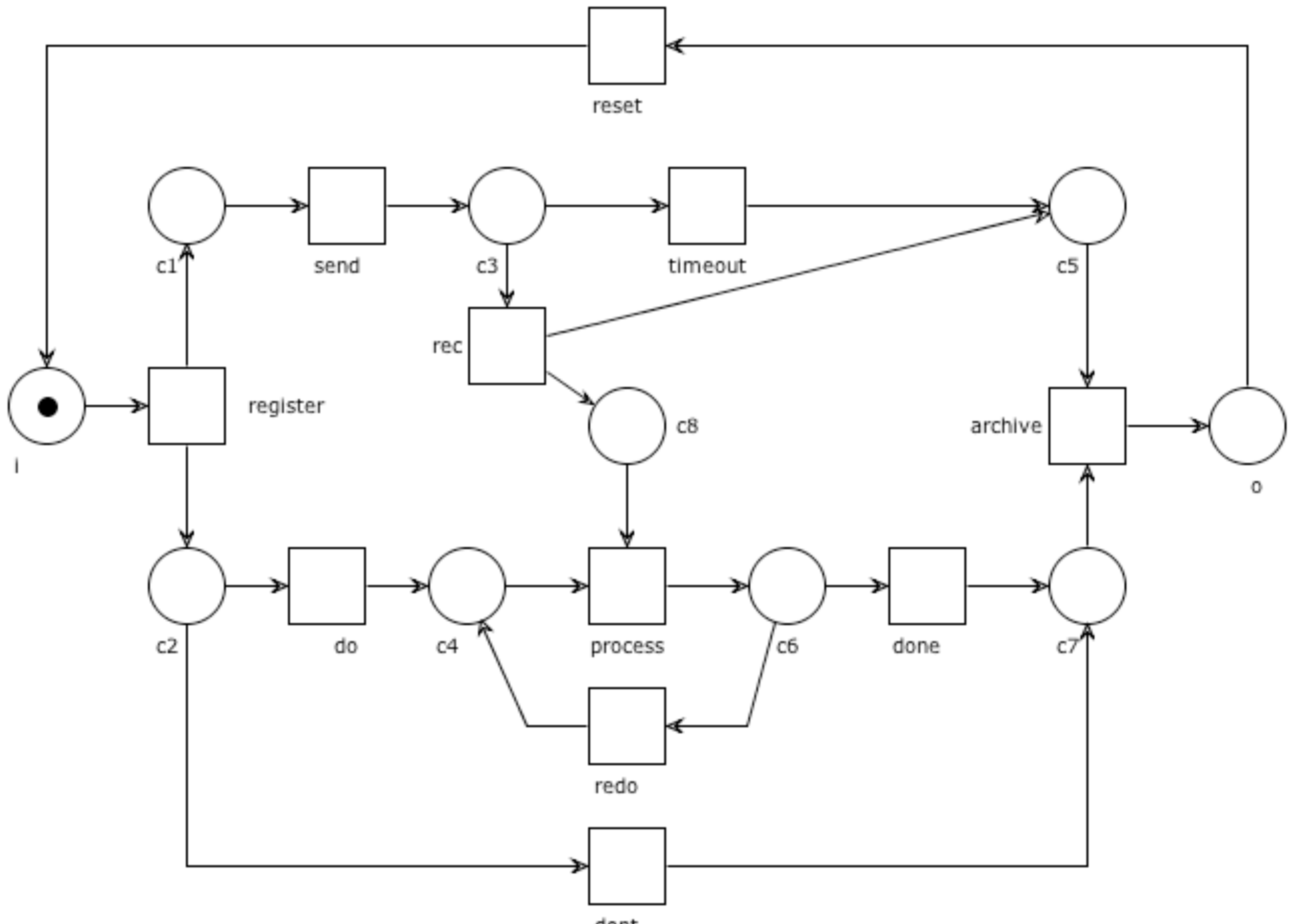
N is sound iff N* is live and bounded (Main Theorem)
N is free-choice iff N* is free-choice

If N* is free-choice, live and bounded
it must be S-coverable (S-coverability theorem)

Corollary: If N is sound and free-choice,
then N* must be S-coverable

N free-choice + N* not S-coverable => N not sound

S-cover for N* ?



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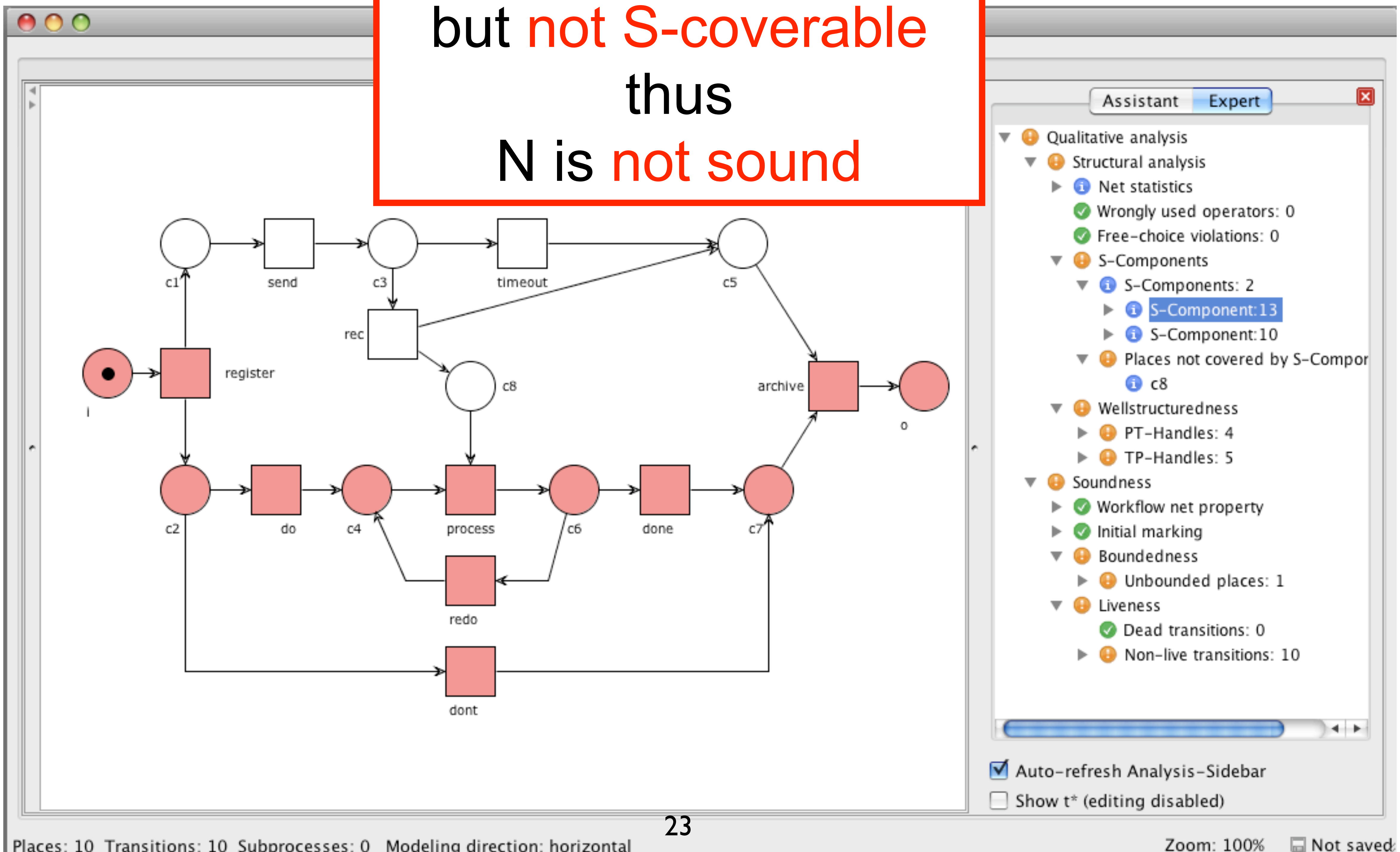
WoPeD Diagnosis

N* is free-choice
but not S-coverable
thus
N is not sound



Be careful

reset transition is implicit in WoPeD

WoPeD shows S-components for N*
(not for N)

Compositionality of sound free-choice nets

Lemma:
If a free-choice workflow net N is sound
then it is safe

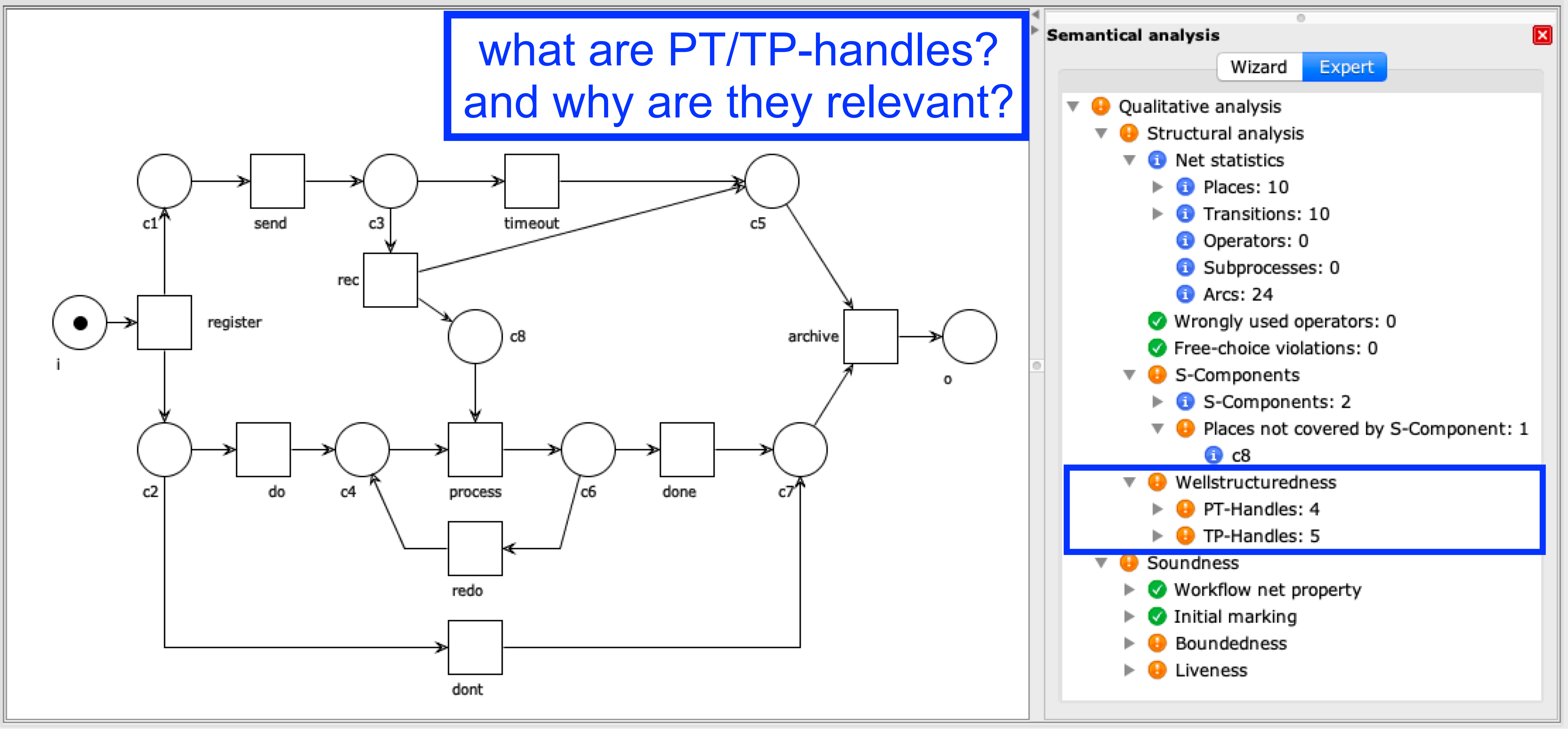
(because N* is S-coverable and M_0=i has just one token)

Proposition:
If N and N’ are sound free-choice workflow nets
then N[N’/t] is a sound free-choice workflow net

(N, N’ are safe; we just need to show that N[N’/t] is free-choice)

Well-structuredness (PT/TP-handles)

Woped



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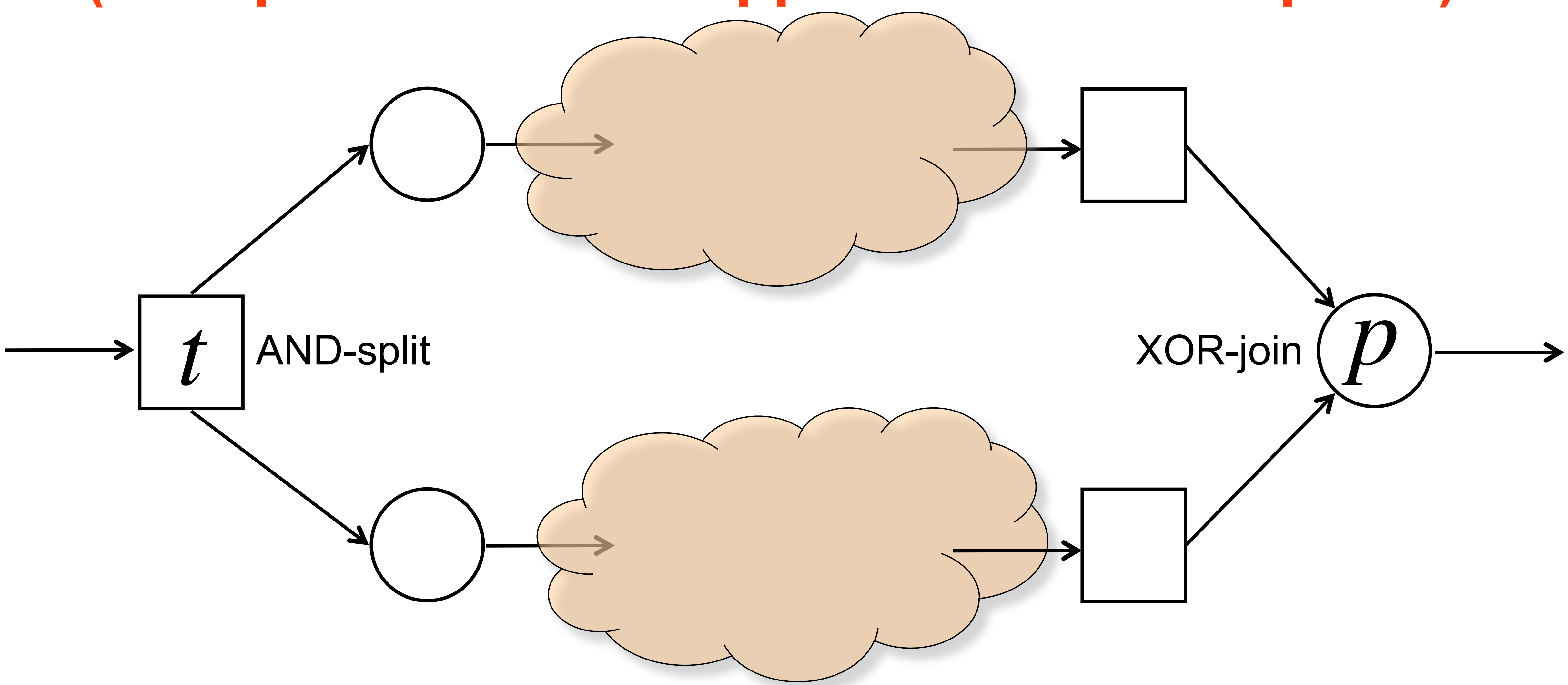
Boundedness
Liveness

TP-handles

Two parallel flows initiated by an AND-split
should not be joined by a XOR-join
(multiple tokens can appear in the same place)

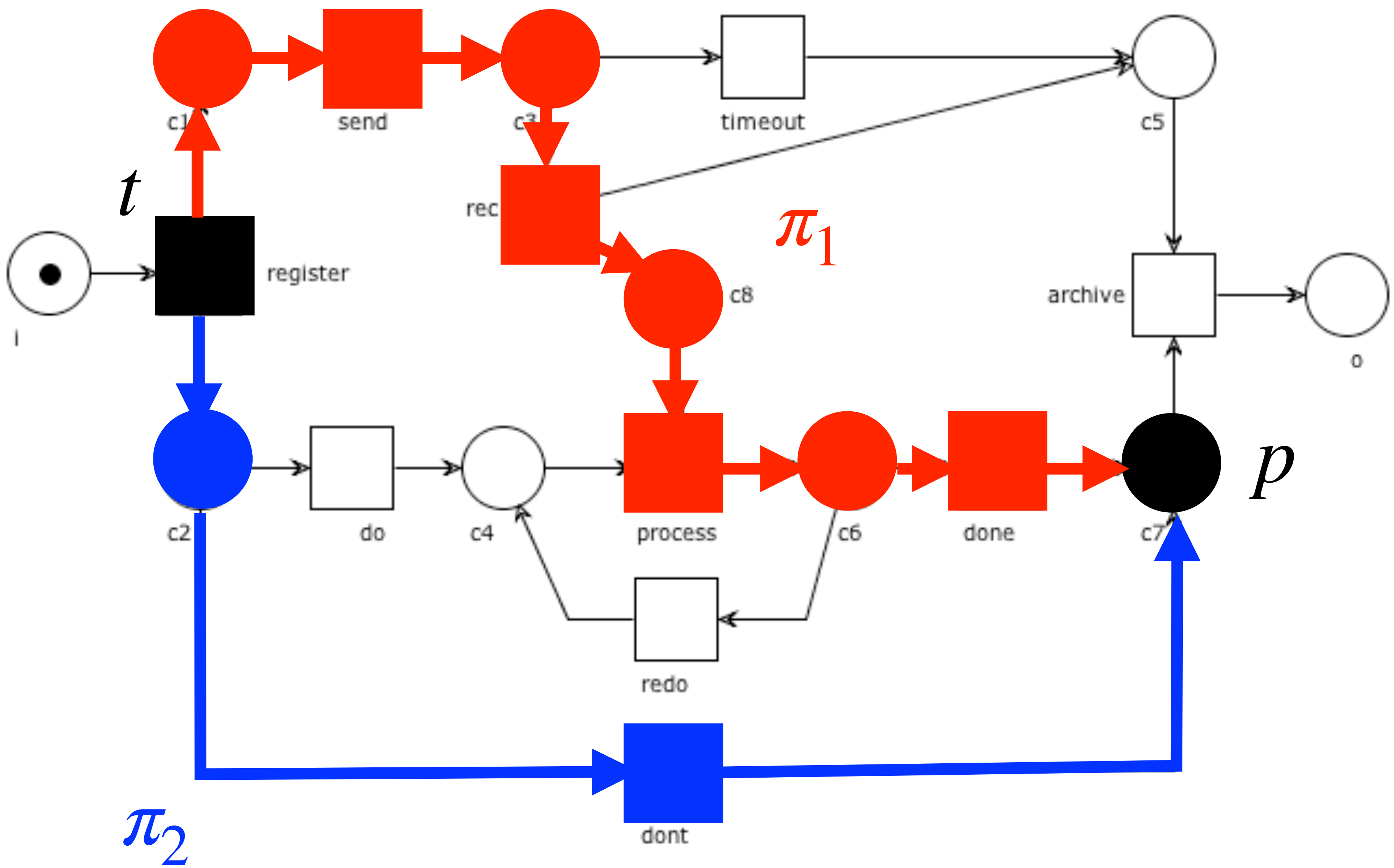


TP-handles

Definition:

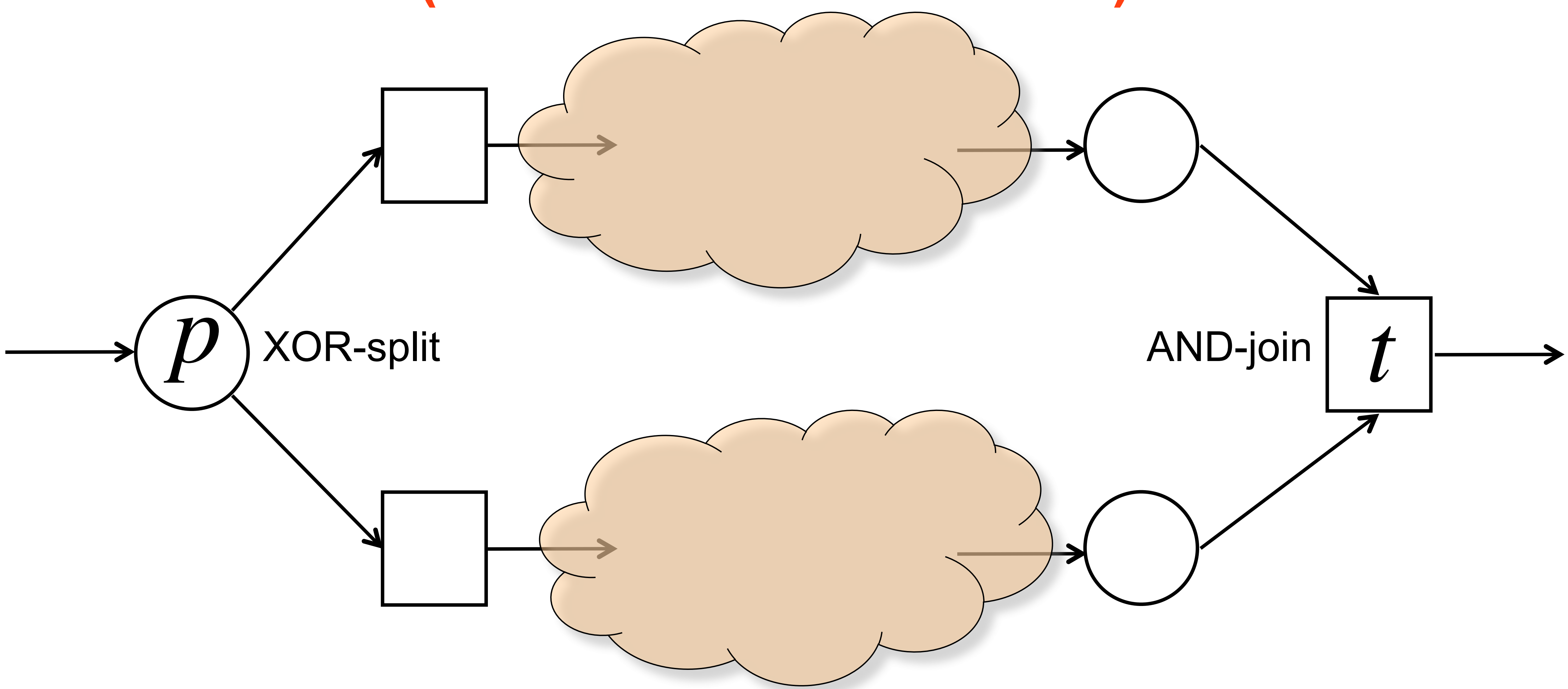
A transition t and a place p form a **TP-handle**
if there are
two distinct elementary paths π_1 and π_2 from t to p
such that the only nodes they have in common are t, p

Example: TP-handle



PT-handles

Two alternative flows created via a XOR-split should not be synchronized by an AND-join
(the net could deadlock)

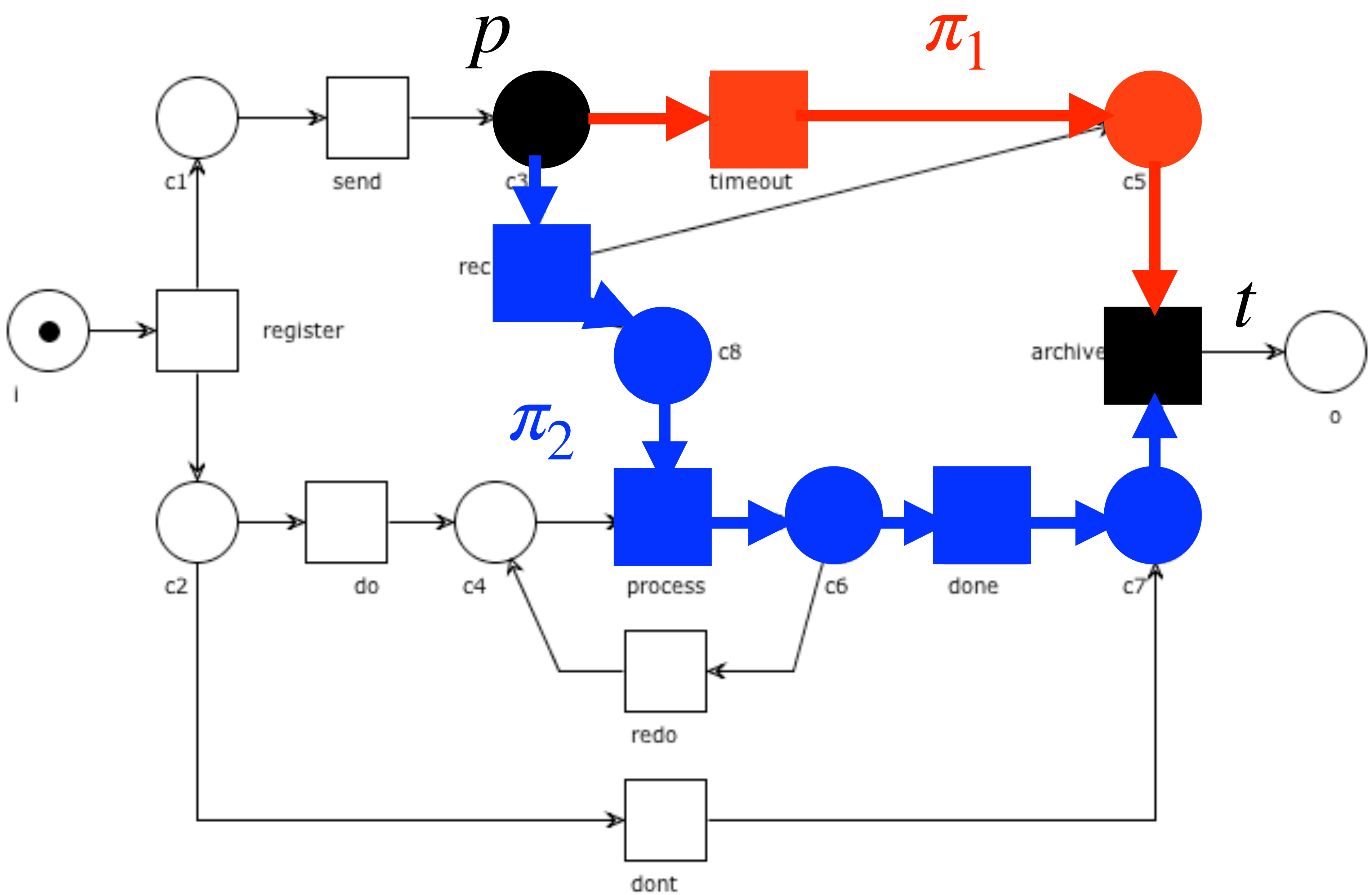


PT-handles

Definition:

A place p and a transition t form a **PT-handle**
if there are
two distinct elementary paths π_1 and π_2 from p to t
such that the only nodes they have in common are p, t

Example: PT-handle



Well-Structured Nets

Definition: A net is **well-handled** if it has neither TP-handles nor PT-handles

Definition: A workflow net N is **well-structured** if N* is well-handled

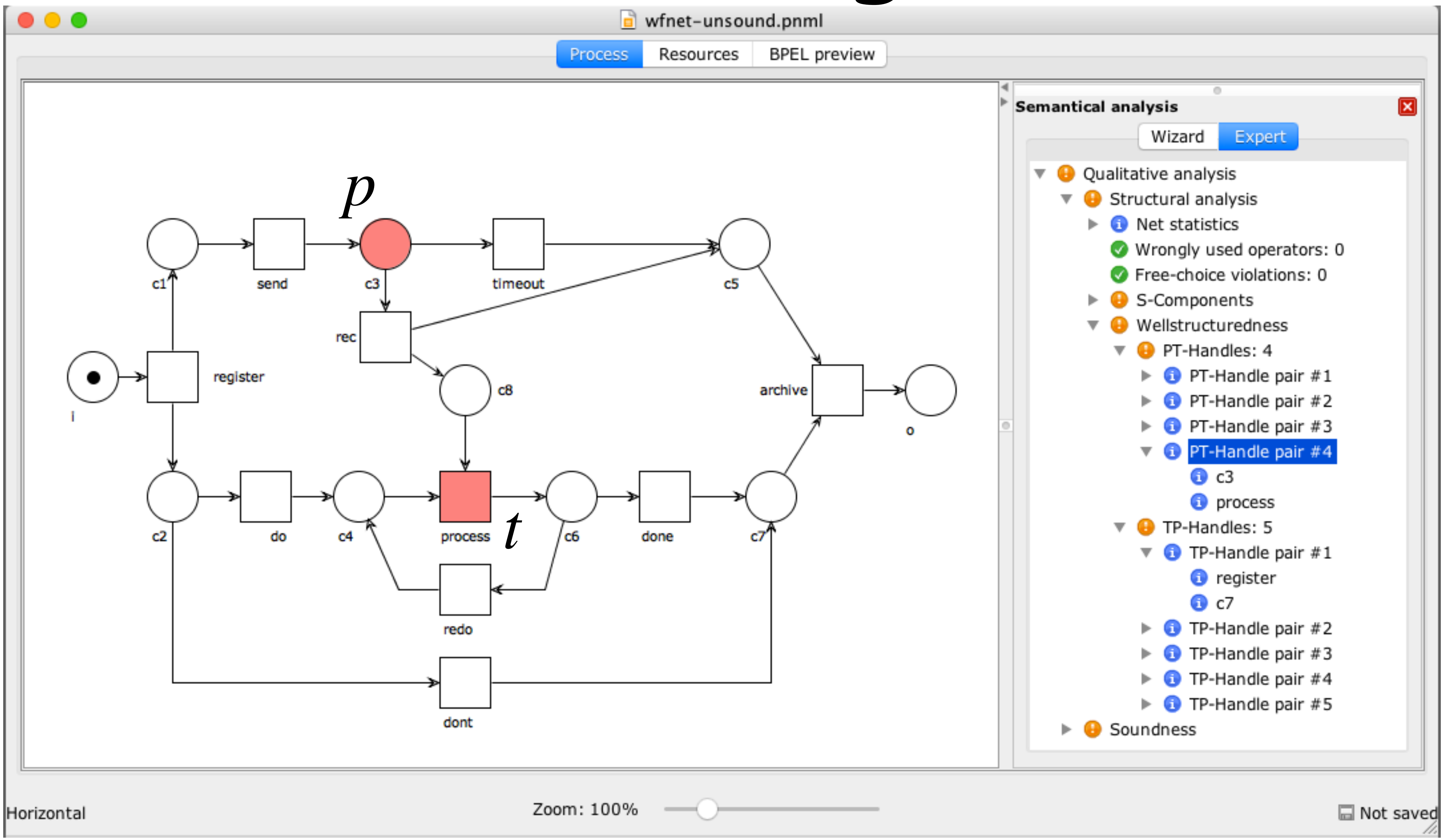
Be careful

N well-structured = N* well-handled

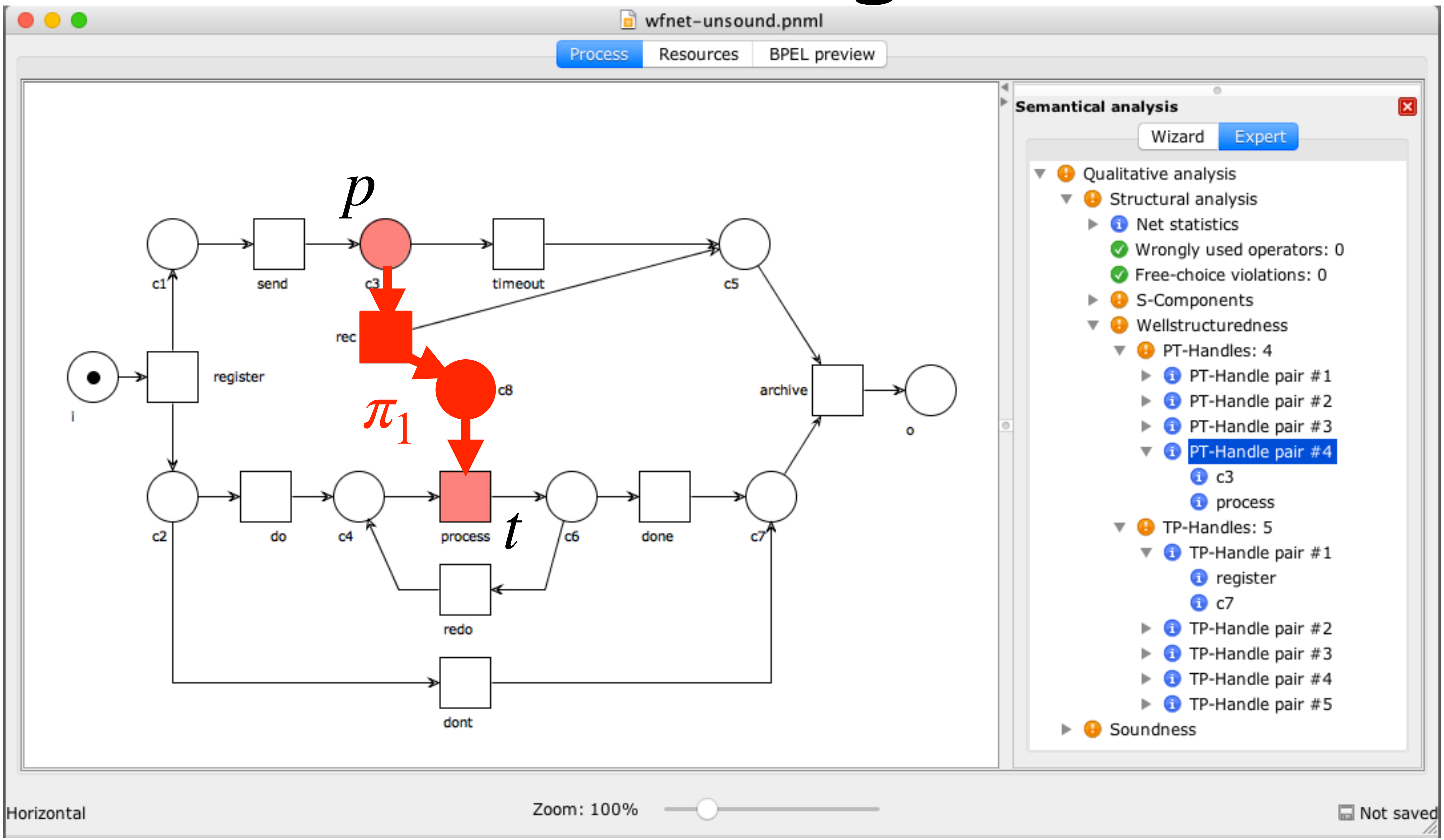
reset transition is implicit in WoPeD

WoPeD marks PT/TP-handles over N*
(not over N)

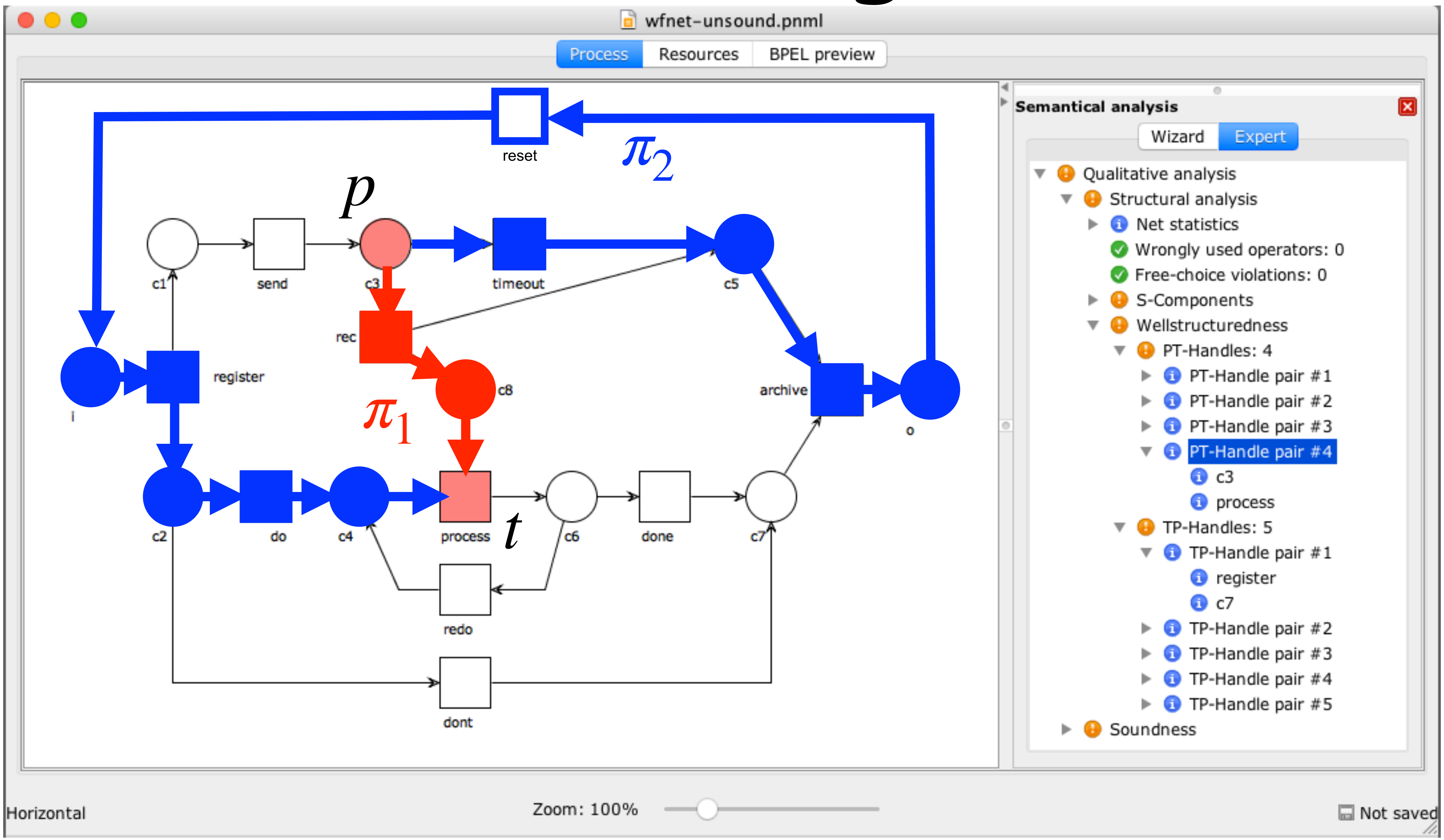
WoPeD Diagnosis



WoPeD Diagnosis



WoPeD Diagnosis



Well-structuredness, S-coverability and Soundness

Theorem: If N is sound and well-structured,
then N* is S-coverable
(proof omitted)

Consequence:
N well-structured + N* not S-coverable => N not sound

Error sequences

Woflan

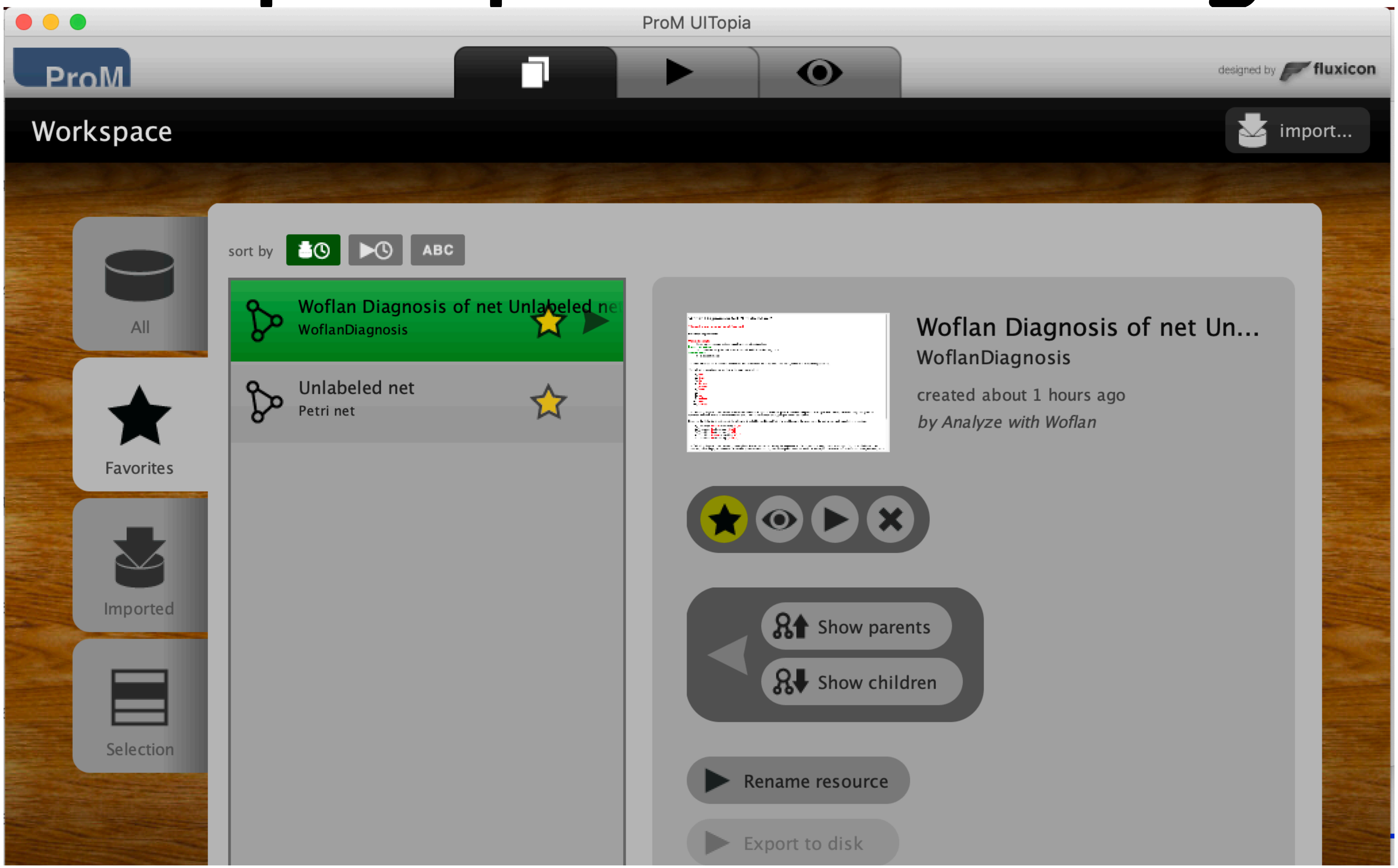
http://www.win.tue.nl/woflan/

WOrkFLow ANalyzer
(Microsoft Windows only)

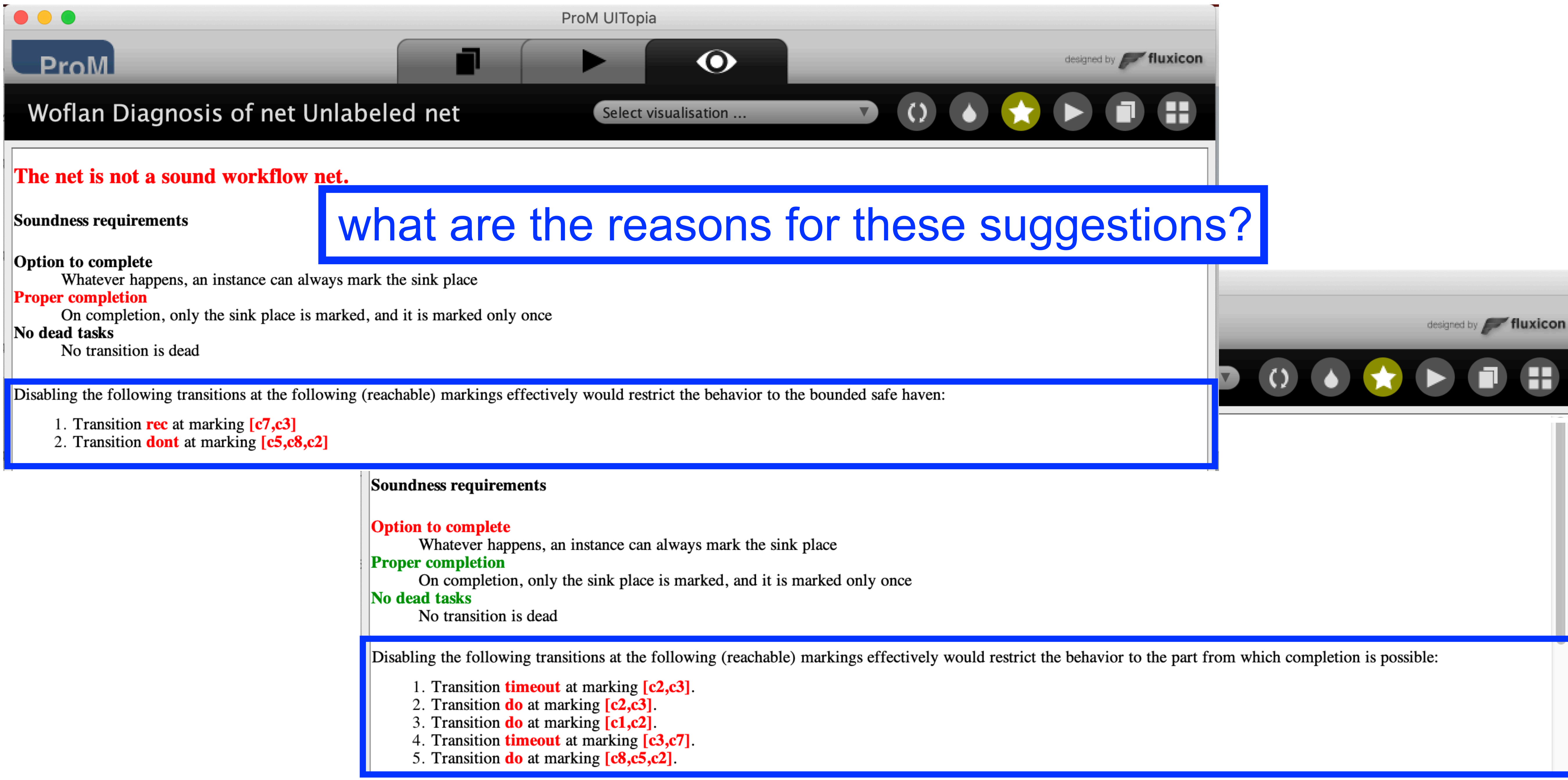
Woflan tells us if N is a sound workflow net
(Is N a workflow net? Is N* bounded? Is N* live?)
if not, provides some diagnostic information

Woflan now a ProM plugin

http://promtools.org/



Woflan (in ProM)



what are the reasons for these suggestions?

Diagnostic information

The sets of:
unbounded places of N*
dead transitions of N*
non-live transitions of N*

may provide useful information for
the diagnosis of behavioural errors

Unfortunately, this information is not always sufficient
to determine the exact cause of the error

Behavioural error sequences help us to locate problems

Error sequences

Rationale:
We want to find firing sequences such that:

1. every continuation of such sequences will lead to an error

2. they are as short as possible
(none of their prefixes satisfies the above property)

Informally:
error sequences are scenarios that capture
the essence of errors made in the workflow design
(violate “option to complete” or “proper completion”)

Error sequences:
Non-live sequences

Non-Live sequences: informally

A **non-live sequence** is a
firing sequence as short as possible
such that **completion of the case is no longer possible**

i.e. a witness for transition reset being non-live in N*

Non-Live sequences: fundamental property

Let N be such that:
N* is bounded
N (or equivalently N*) has no dead task

Then, N* is live
iff
N has no non-live sequences

Non-Live sequences: graphically

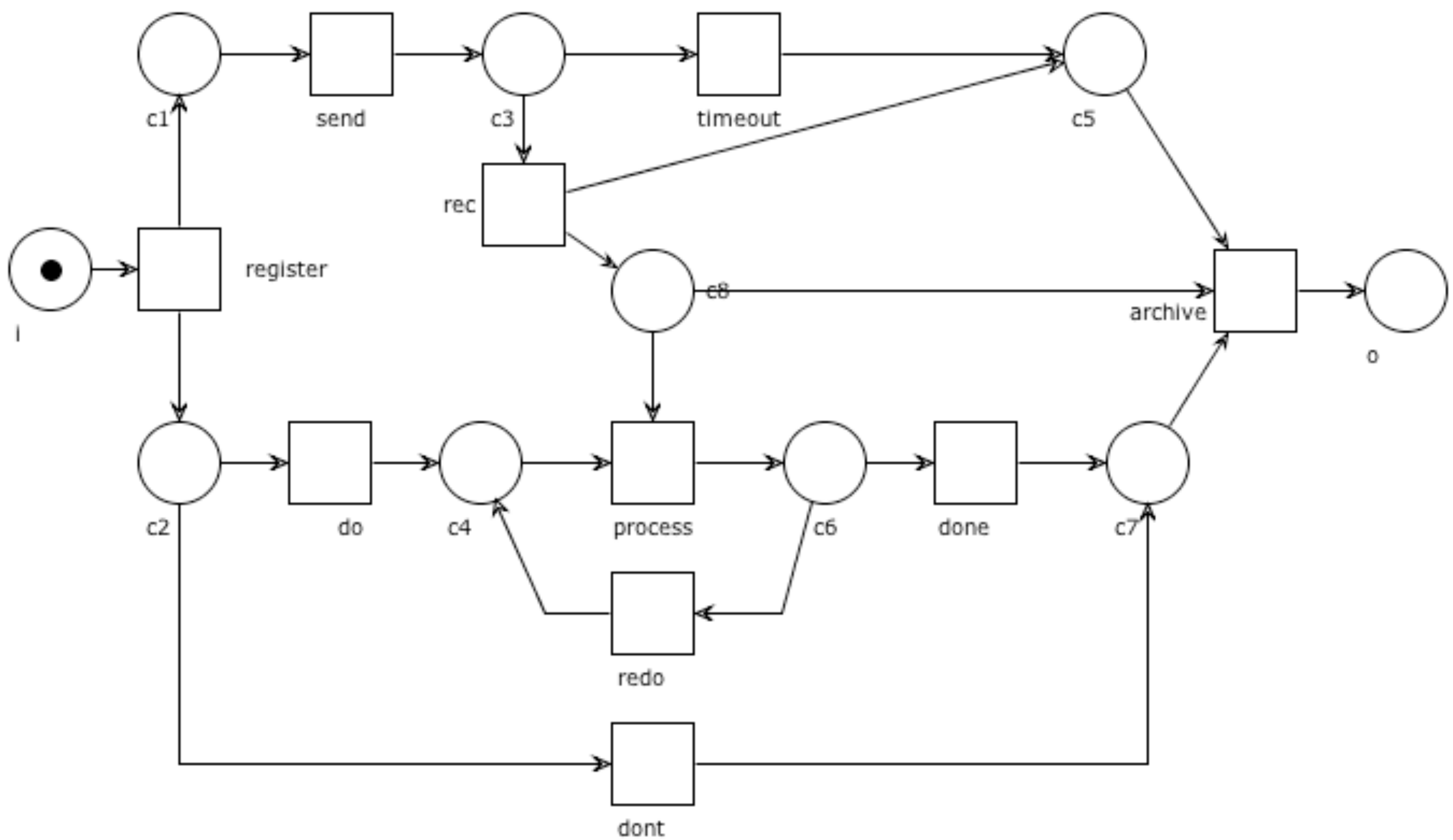
The analysis is possible in bounded systems only

Compute the RG of N*
Color in **red** all nodes from which there is **no path** to o

Color in **green** all nodes from which **all paths** lead to o

Color in yellow all remaining nodes
(some but not all paths lead to o)

Example: N


c1
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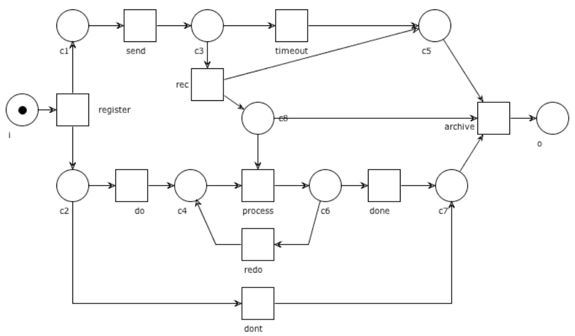
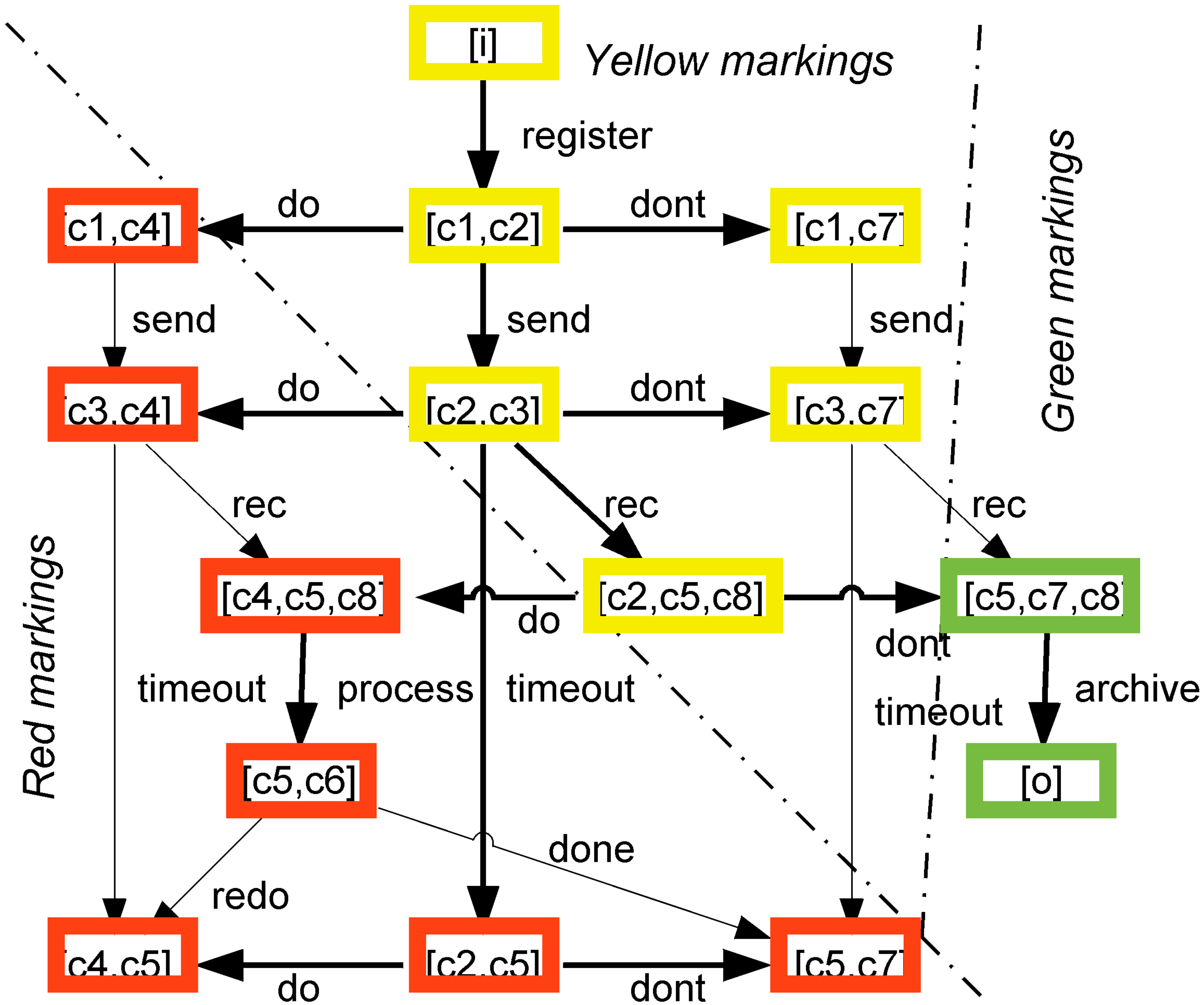


Example: RG (N)



Non-live sequences:

register, do

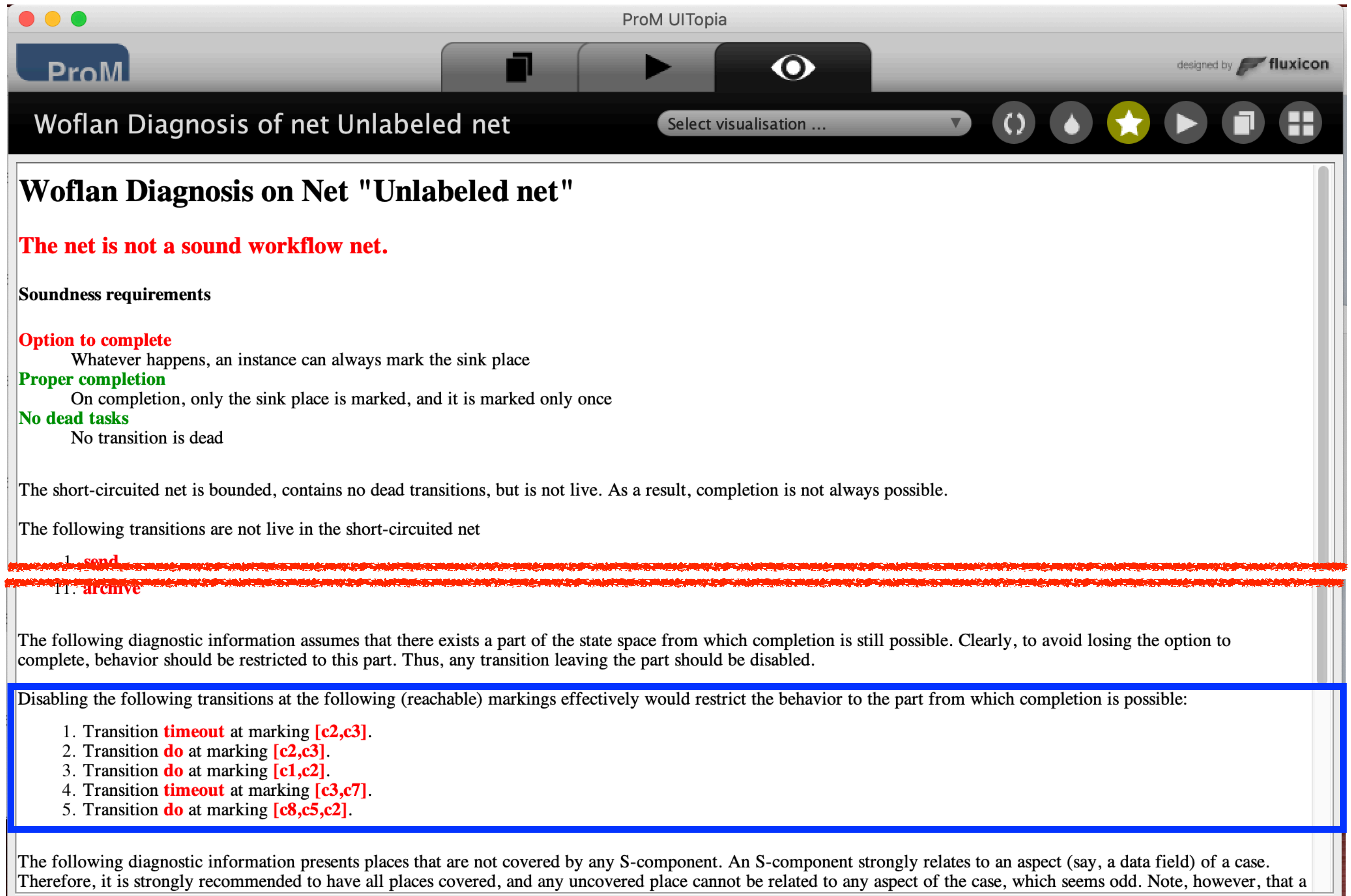
register, send, do

register, send, timeout

register, send, rec, do

register, send, dont, timeout
register, dont, send, timeout

Woflan (in ProM)



Error sequences: Unbounded sequences

Unbounded sequences: informally

An **unbounded sequence** is a
firing sequence of **minimal length** such that
every continuation **invalidates proper completion**

i.e. a witness for unboundedness

Unbounded sequences: fundamental property

N* is bounded
iff
N has no unbounded sequences

Undesired markings:
infinite-weighted markings or markings greater than o

Unbounded sequences: graphically

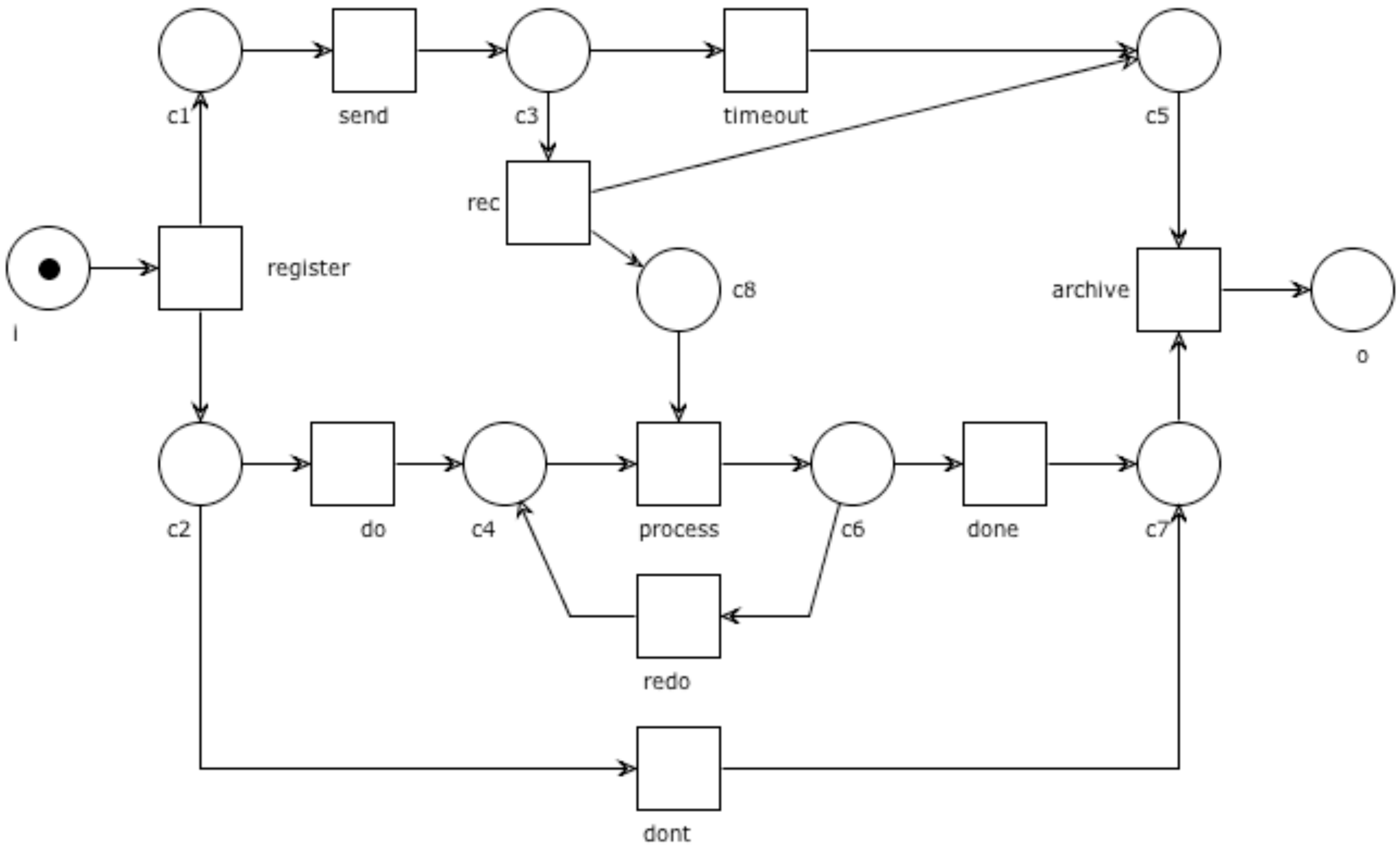
Compute the CG of N*

Color in **green** all nodes from which
undesired markings are not reachable

Color in **red** all nodes from which
no green marking is reachable
(undesired markings are unavoidable)

Color in yellow all remaining nodes
(undesired markings are reachable but avoidable)

Example: N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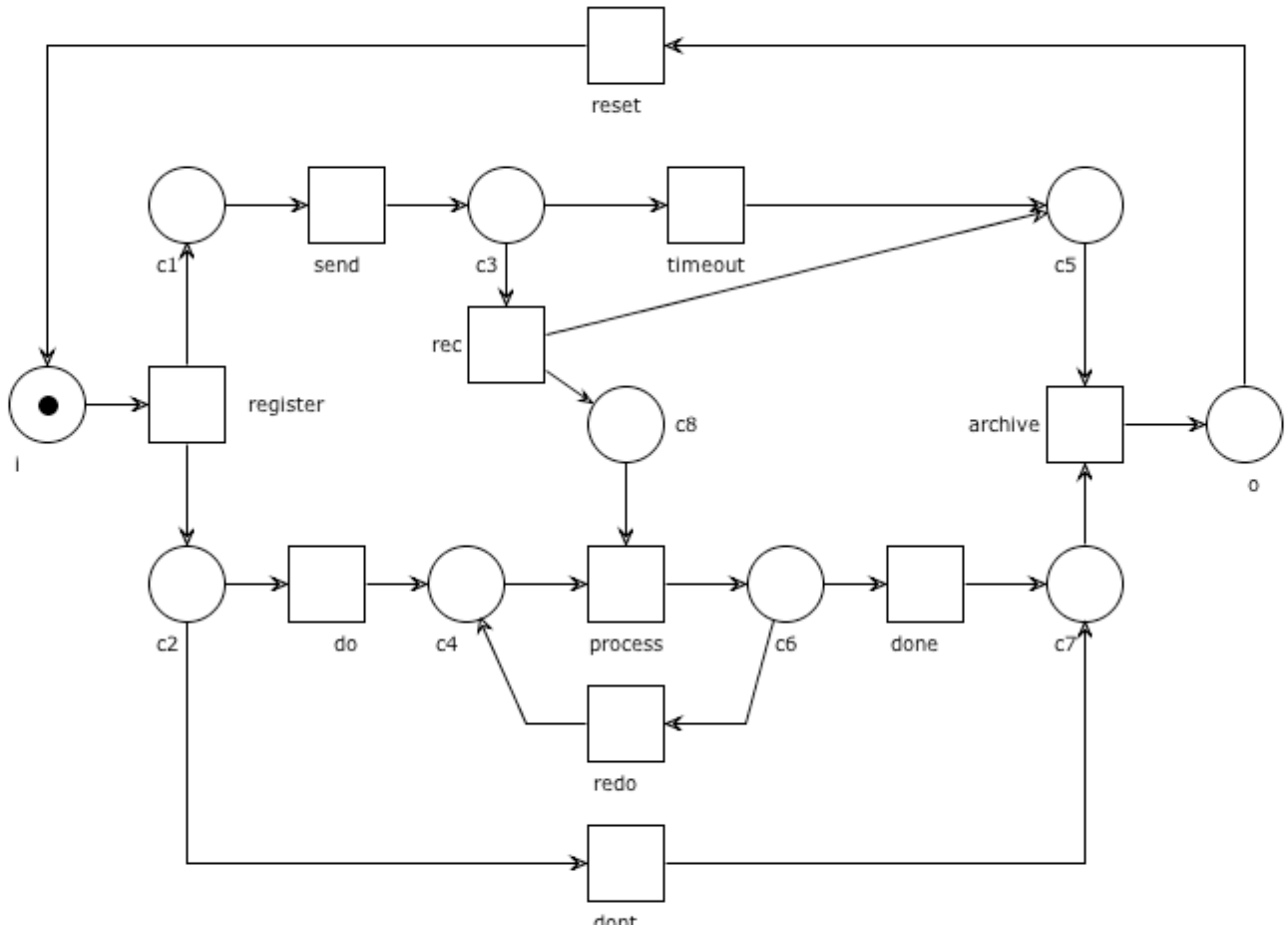
Example: N*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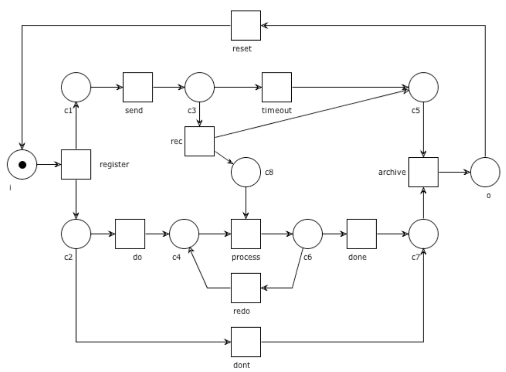
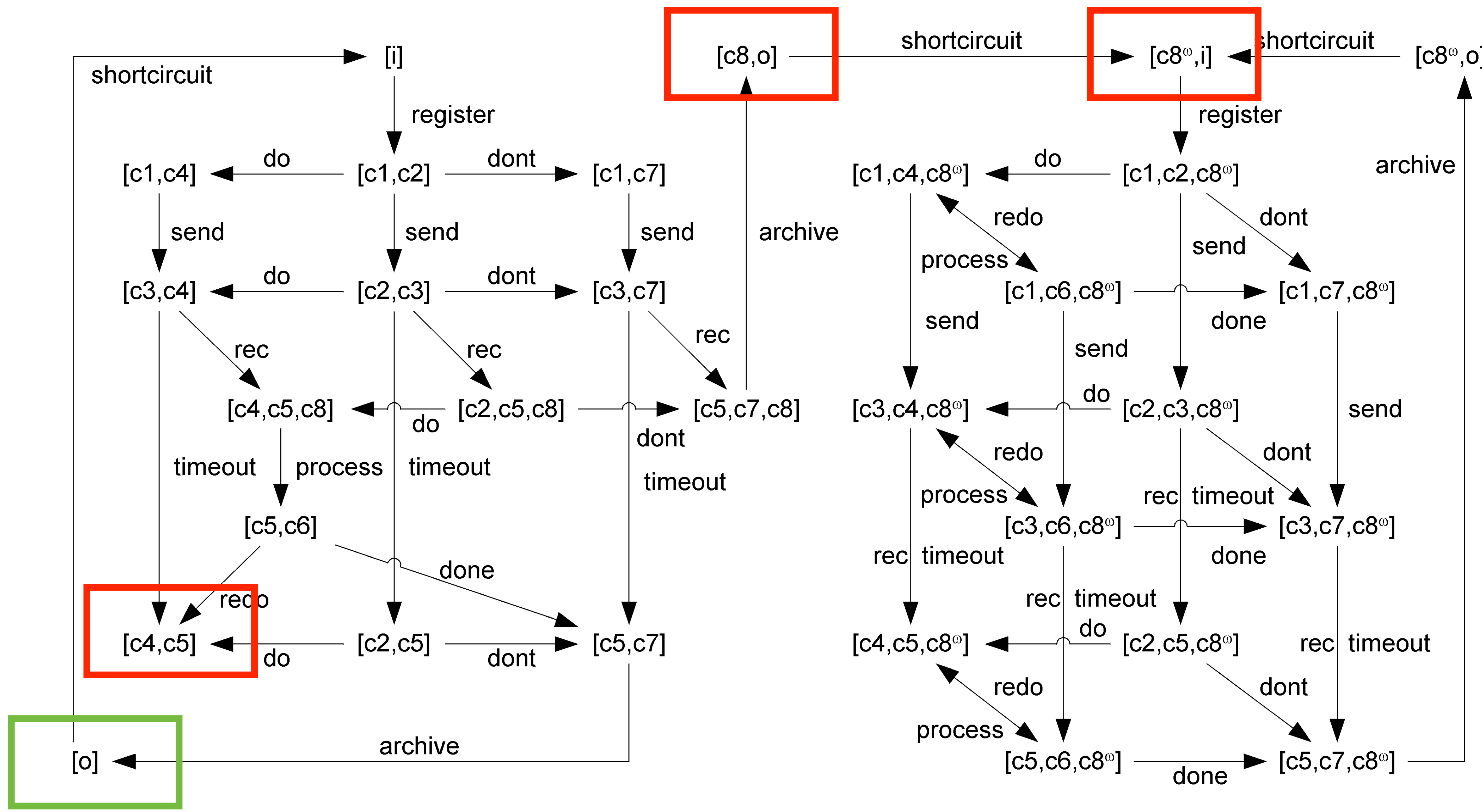


Example: CG (N*)


[i]
shortcircuit
register
[c1,c4]
do
[c1,c2]
dont
[c1,c7]
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send
send
[c3,c4]
do
[c2,c3]
dont
[c3,c7]
rec
rec
rec
[c4,c5,c8]
do
[c2,c5,c8]
[c5,c7,c8]
dont
timeout
process
timeout
timeout
[c5,c6]
done
redo
[c4,c5]
do
[c2,c5]
dont
[c5,c7]
[o]
archive
[c8,o]
archive
shortcircuit
[c8ω,i]
shortcircuit
[c8ω,o]
register
[c1,c4,c8ω]
do
[c1,c2,c8ω]
archive
redo
dont
process
send
[c1,c6,c8ω]
[c1,c7,c8ω]
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[c3,c7,c8ω]
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do
[c4,c5,c8ω]
[c2,c5,c8ω]
rec
timeout
redo
dont
process
[c5,c6,c8ω]
done
[c5,c7,c8ω]

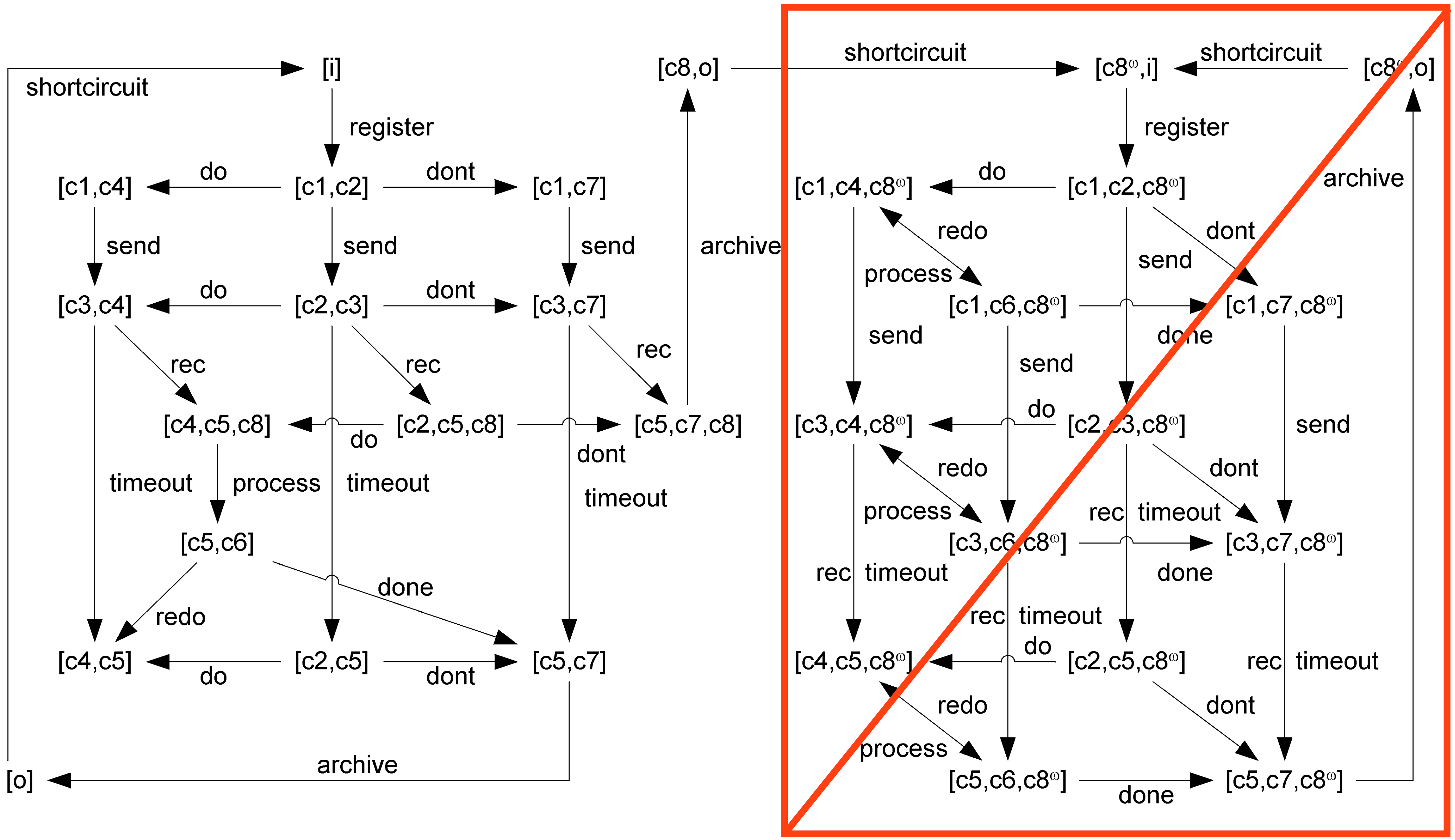
Restricted coverability graph (RCG)

CG can become very large

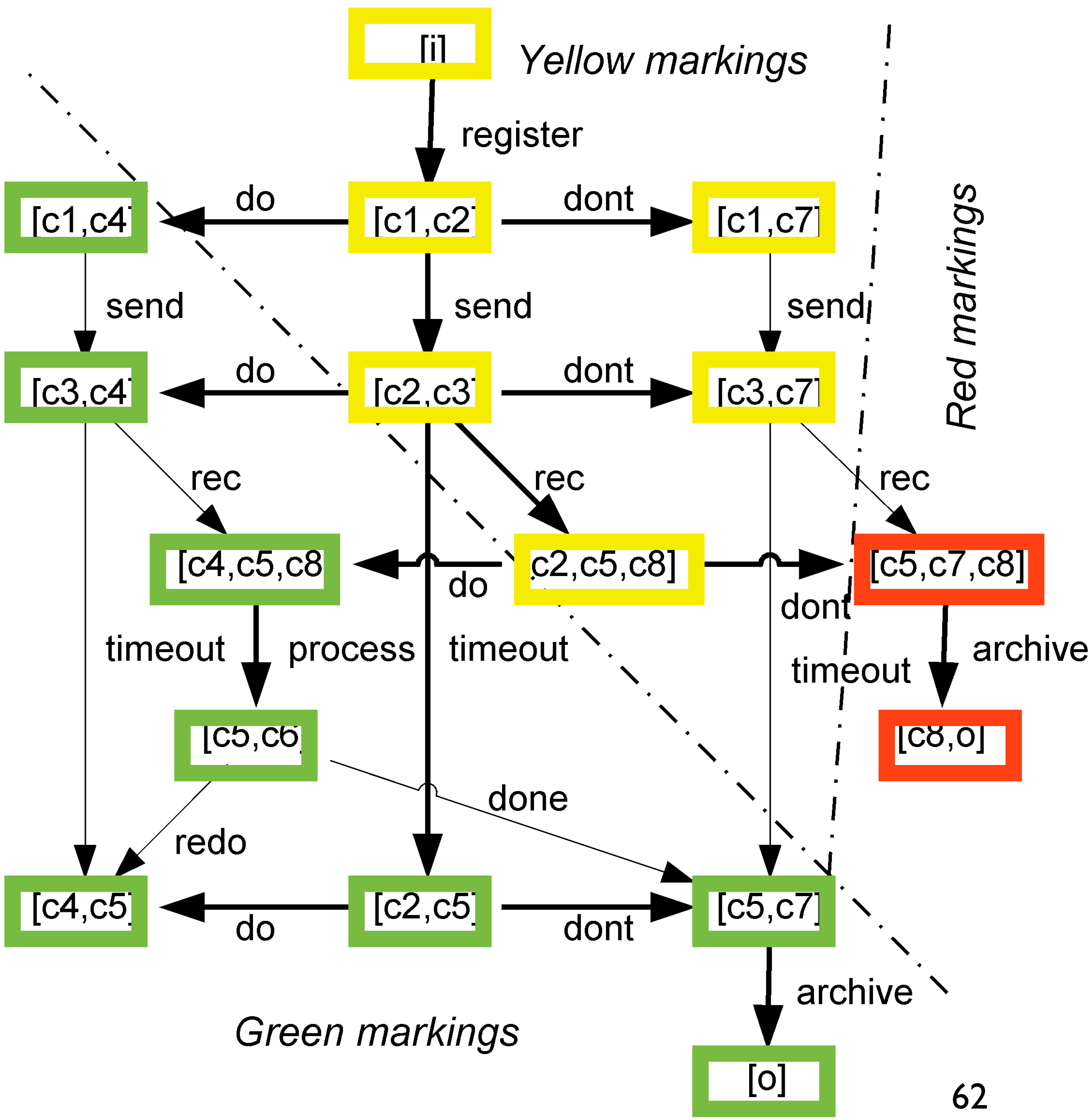
Basic observation:
infinite-weighted markings leads to infinite-weighted markings
and they will be all red

We can just avoid computing them!

Example: Restricted CG vs CG



Example: RCG (N*)

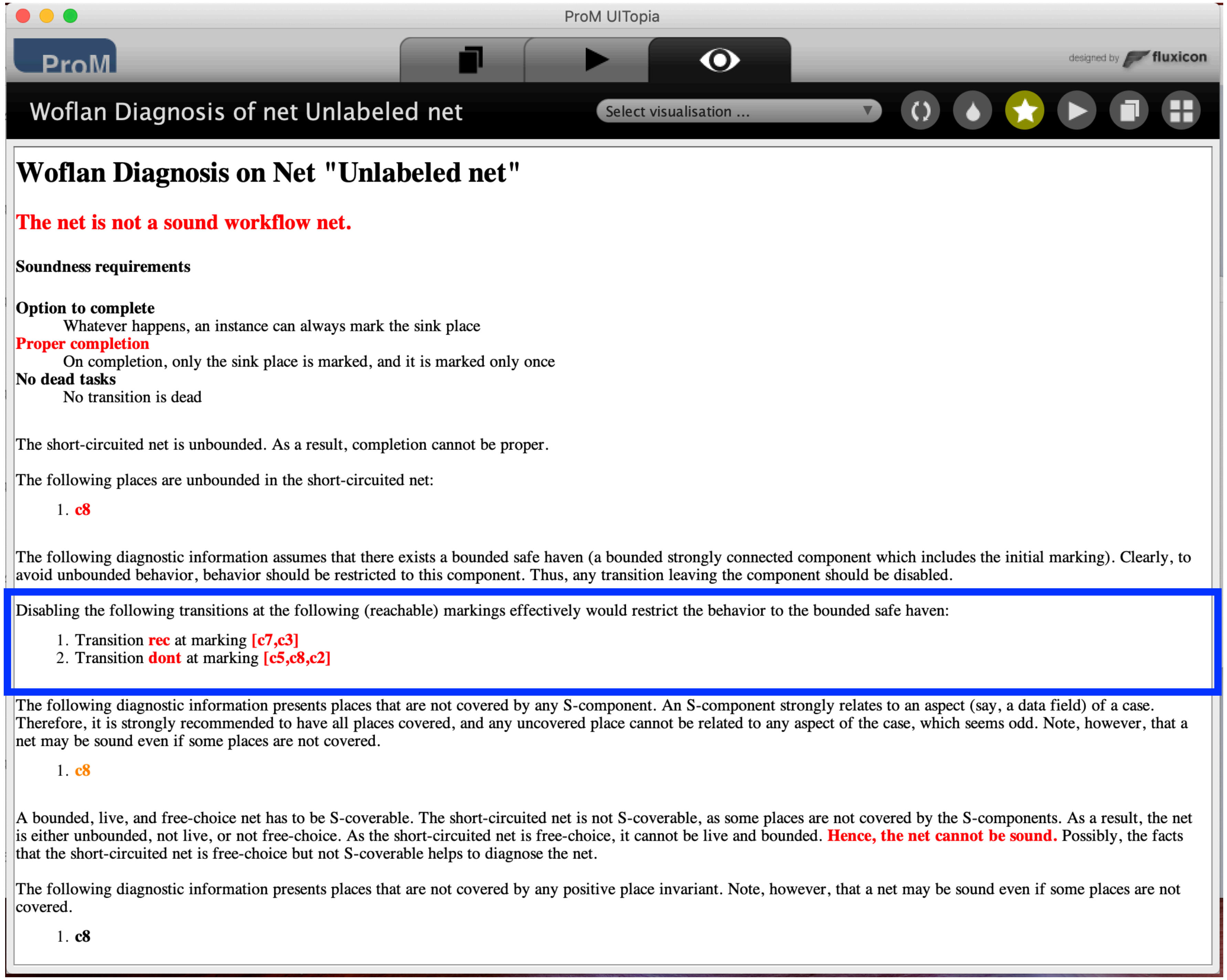


Unbounded sequences:

register, dont, send, rec
register, send, dont, rec

register, send, rec, dont

Woflan (in ProM)



ProM UITopia

ProM

designed by fluxicon

Woflan Diagnosis of net Unlabeled net

Select visualisation ...

Woflan Diagnosis on Net "Unlabeled net"

The net is not a sound workflow net.

Soundness requirements

Option to complete
Whatever happens, an instance can always mark the sink place
Proper completion
On completion, only the sink place is marked, and it is marked only once
No dead tasks
No transition is dead

The short-circuited net is unbounded. As a result, completion cannot be proper.

The following places are unbounded in the short-circuited net:

1. **c8**

The following diagnostic information assumes that there exists a bounded safe haven (a bounded strongly connected component which includes the initial marking). Clearly, to avoid unbounded behavior, behavior should be restricted to this component. Thus, any transition leaving the component should be disabled.

Disabling the following transitions at the following (reachable) markings effectively would restrict the behavior to the bounded safe haven:

1. Transition **rec** at marking **[c7,c3]**
2. Transition **dont** at marking **[c5,c8,c2]**

The following diagnostic information presents places that are not covered by any S-component. An S-component strongly relates to an aspect (say, a data field) of a case. Therefore, it is strongly recommended to have all places covered, and any uncovered place cannot be related to any aspect of the case, which seems odd. Note, however, that a net may be sound even if some places are not covered.

1. **c8**

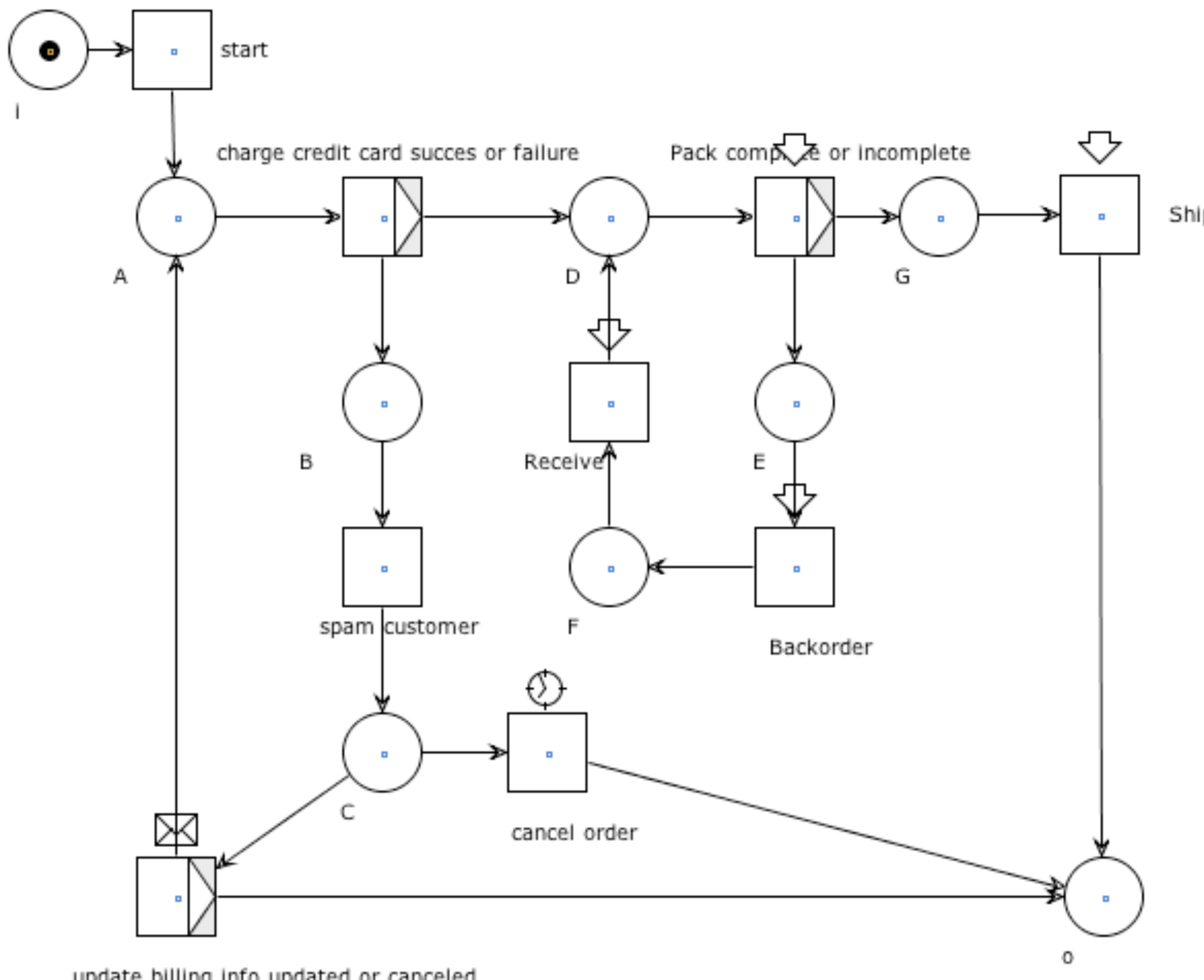
A bounded, live, and free-choice net has to be S-coverable. The short-circuited net is not S-coverable, as some places are not covered by the S-components. As a result, the net is either unbounded, not live, or not free-choice. As the short-circuited net is free-choice, it cannot be live and bounded. **Hence, the net cannot be sound.** Possibly, the facts that the short-circuited net is free-choice but not S-coverable helps to diagnose the net.

The following diagnostic information presents places that are not covered by any positive place invariant. Note, however, that a net may be sound even if some places are not covered.

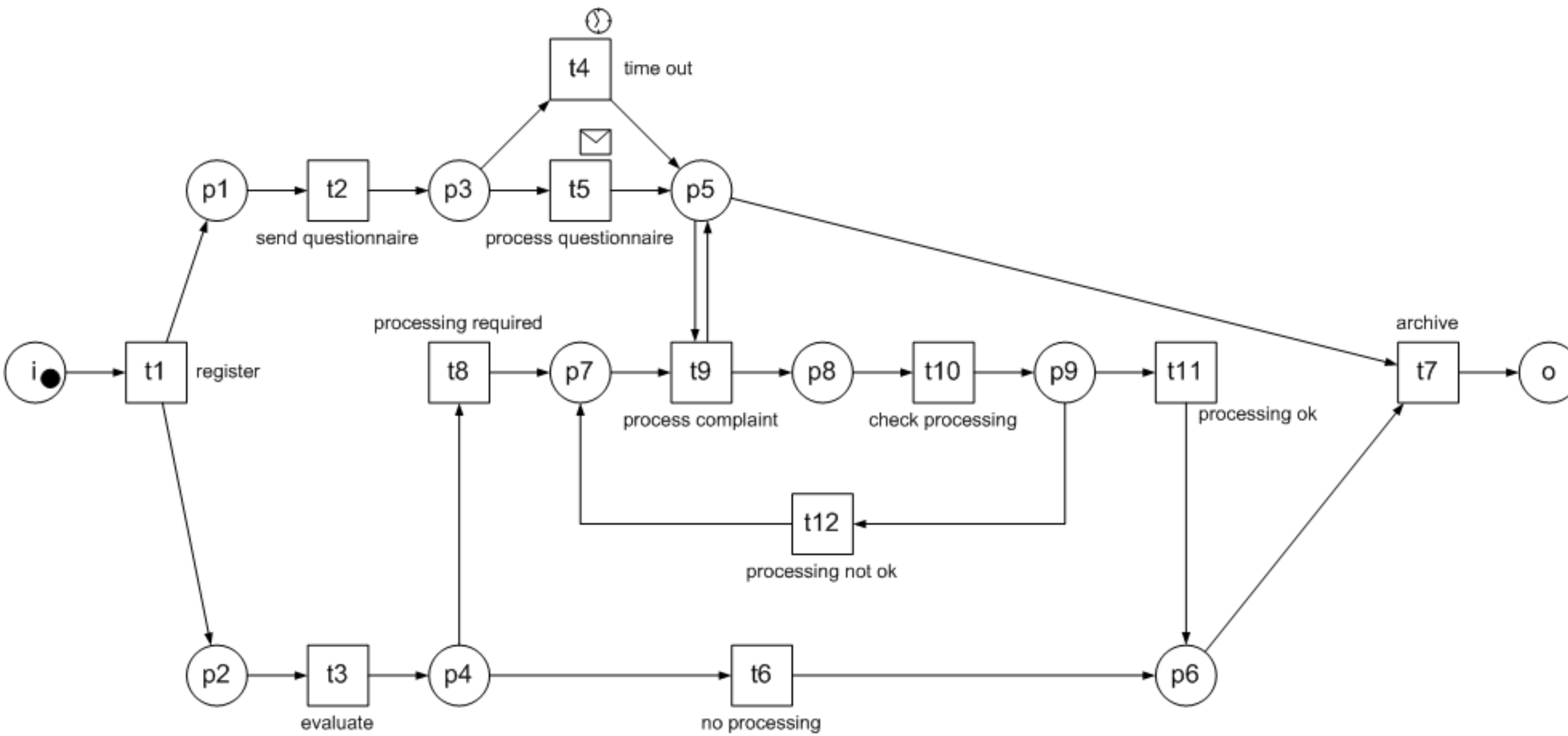
1. **c8**

Practice with WoPeD (and Woflan)

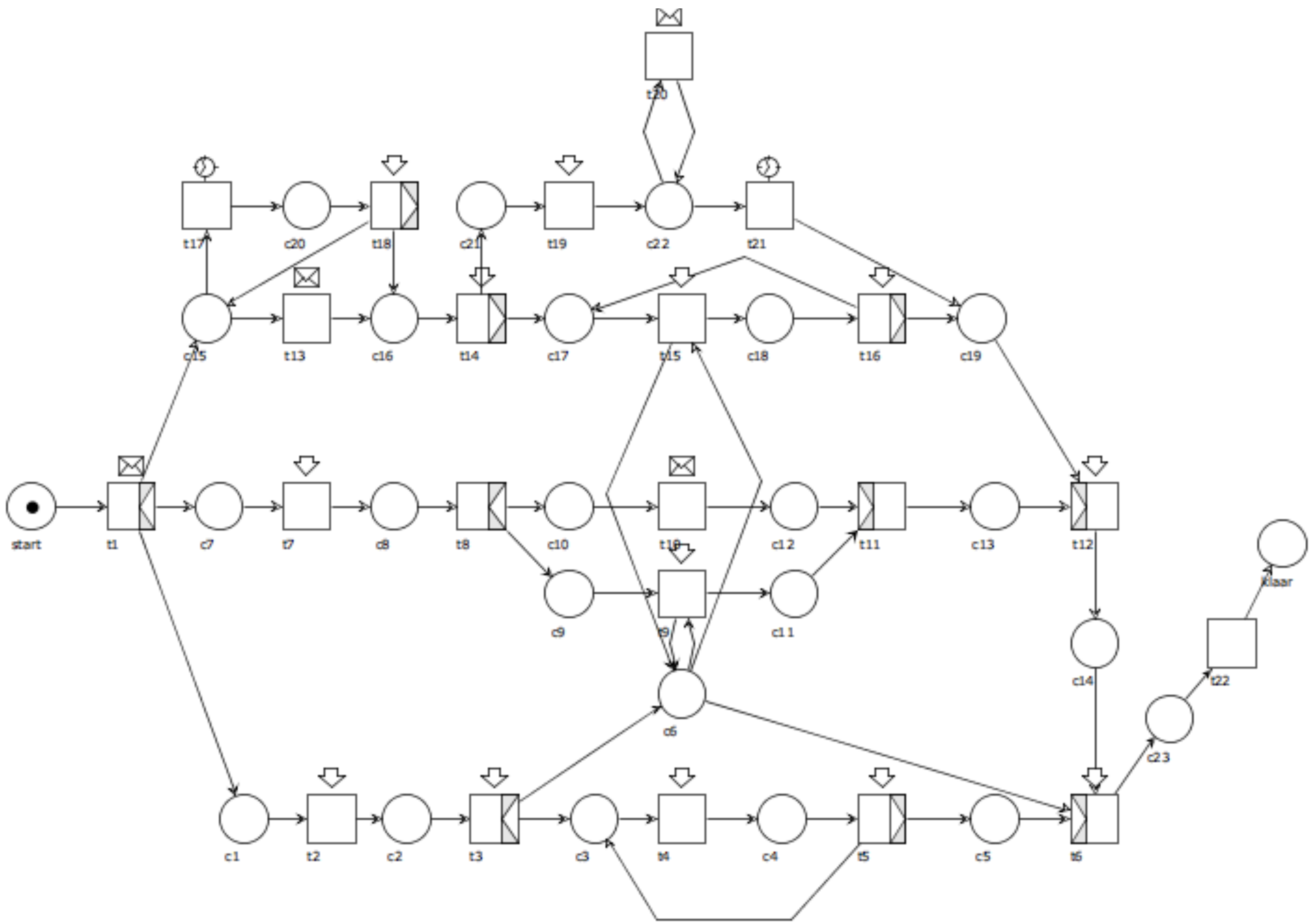
Analyse this net



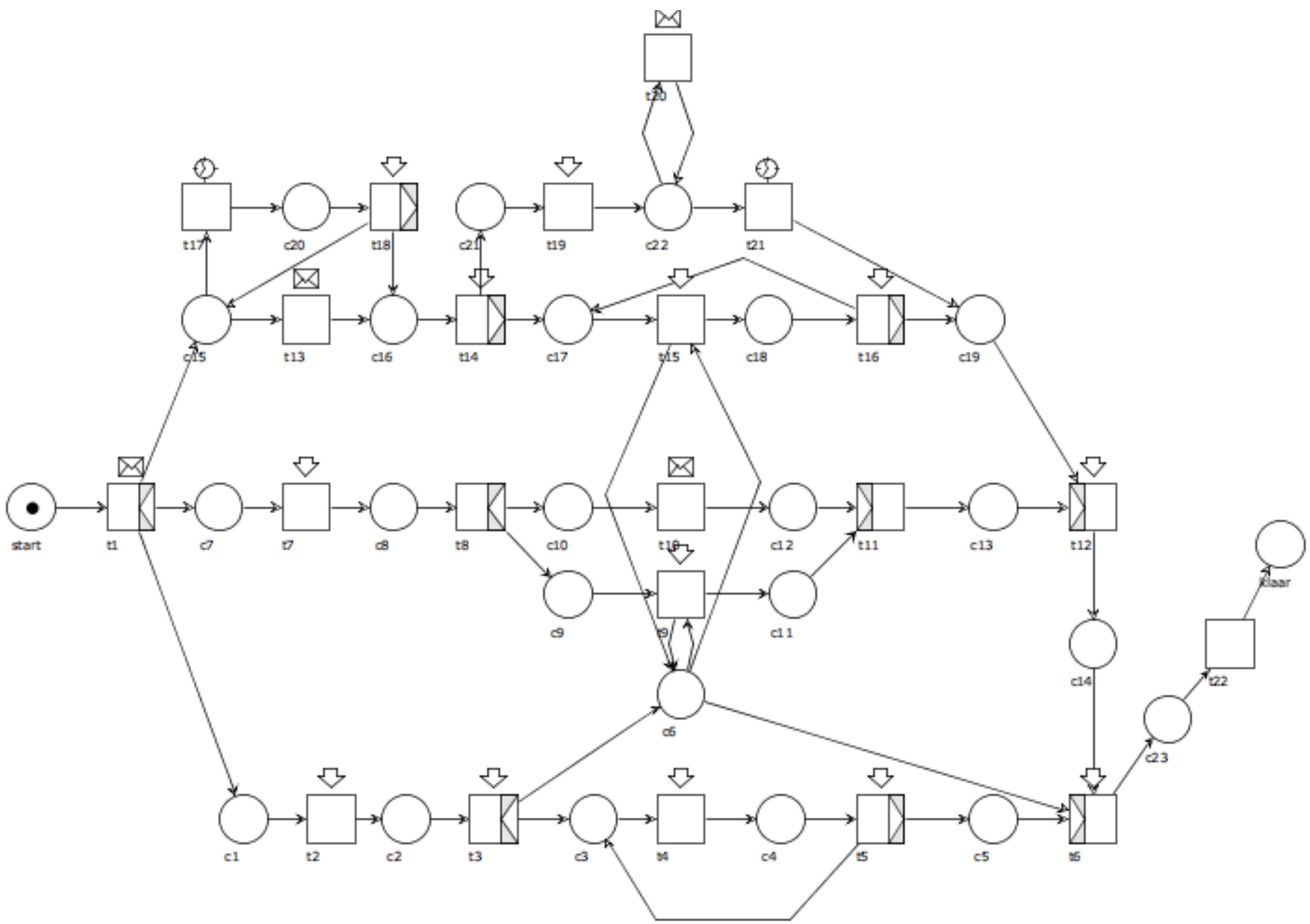
Analyse this net



Is this net free-choice?



Is this net S-coverable?



Is this net sound?