

Towards a Translation from Nested Petri Nets into Colored Petri Nets

Towards a
Translation from
Nested Petri Nets
into Colored Petri
Nets



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Definition of Coloured
Petri Net (CP-net)

Definition of Nested
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Conclusions

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Translation motivation

Coloured Petri Nets (CPNs, CP-nets) —

from K. Jensen “Coloured Petri Nets”, 2009

- is a class of high level Petri nets which are characterized by the combination of Petri Nets and programming languages
- the widely used formalism for modelling and analysis of concurrent systems
- has the formal execution semantics
- is Turing powerful with infinite types
- **has the reference implementation - CPNtools:**
 - **is a tool for the editing, simulation, state space analysis, and performance analysis**
 - **is used by more than 8000 users in 140 different countries**
 - **AccessCPN 2.0 — access to the internal structure of CP-net from Java**
 - **ASK-CTL — CTL model checker**
 - **State-space tool — deadlocks, liveness, SCC**
 - **integration with PROM (a lot of other analysis plugins - performance analysis, process mining, etc)**

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Nested Petri Nets (NP-nets) —

- is an extension of high-level Petri nets for modelling active objects, mobility and dynamics in distributed systems
- is high level Petri nets with PT nets as tokens (“nets-within-nets” approach)
- has the formal execution semantics
- less expressive than Turing machines, but more expressive than P/T nets
- **has no instrumental support**

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Coloured Petri Net —

- colours are values of defined types “coloured sets”
- places are typed — a place holds tokens only of the place’s colour set
- marking of a place is the multiset over its colour set
- arcs are labelled with expressions, which evaluate to multisets over the coloured sets of their incident places
- firing of the transition t is defined by the marking equation:

$$\forall p \in P : M'(p) = M(p) - \theta(p, t) + \theta(t, p)$$

where addition and subtraction over multisets are defined as usual

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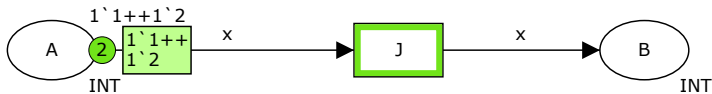
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CP-net. Firing of the transition.



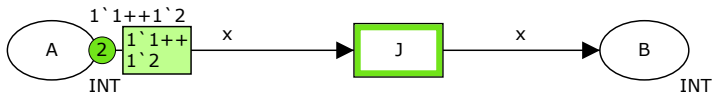
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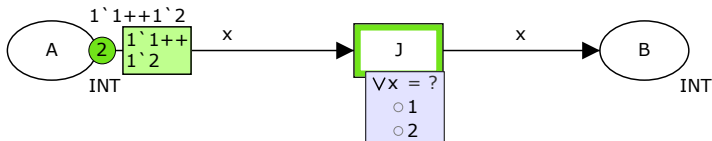
CP-net. Firing of the transition.



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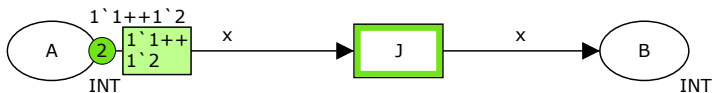
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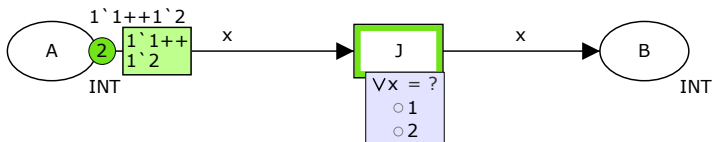
CP-net. Firing of the transition.



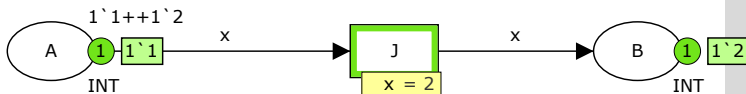
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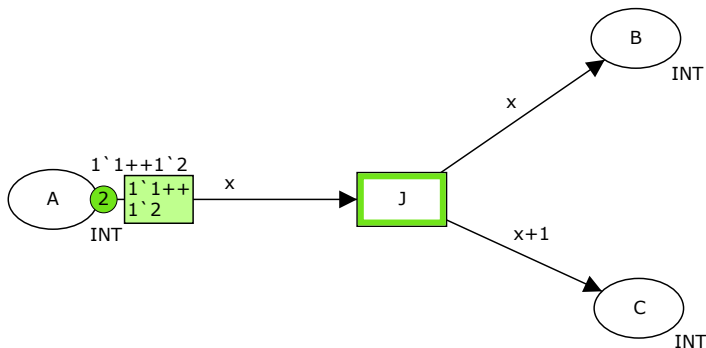
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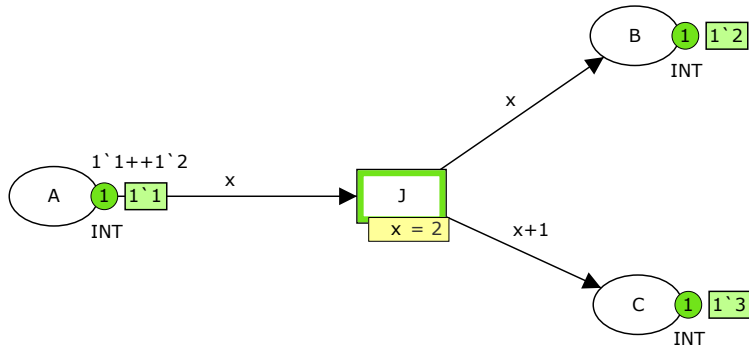
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CP-net. Firing of the transition.



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CP-net. Firing of the transition.



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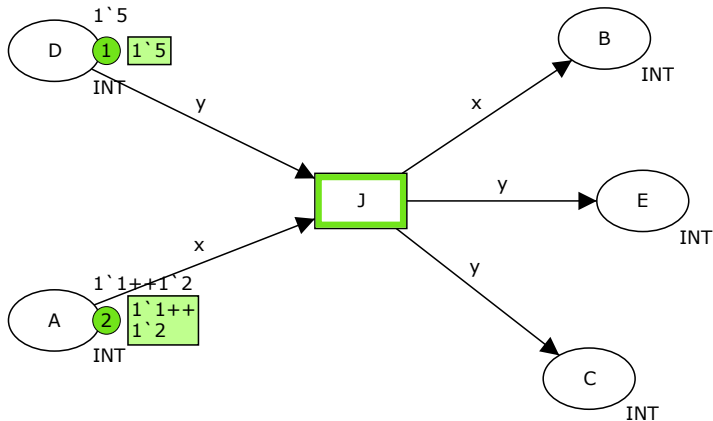
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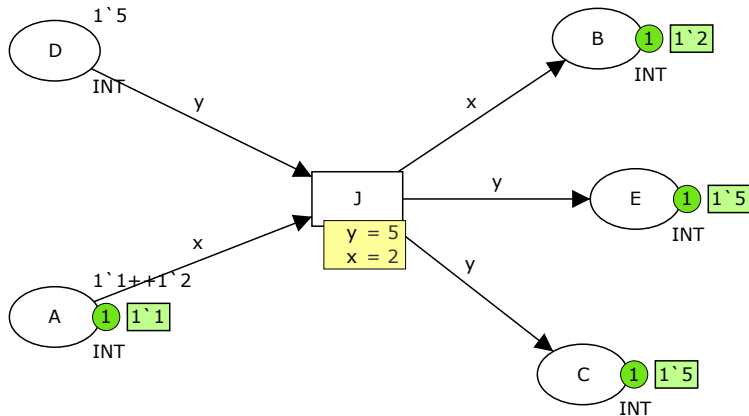
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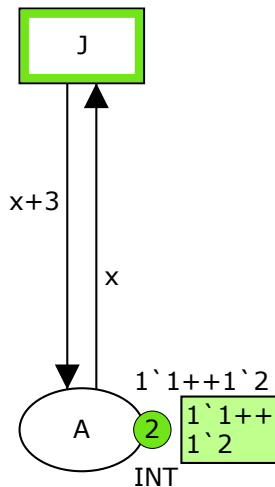
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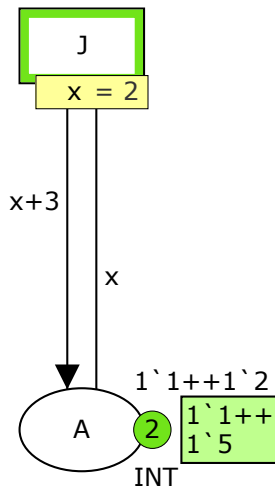
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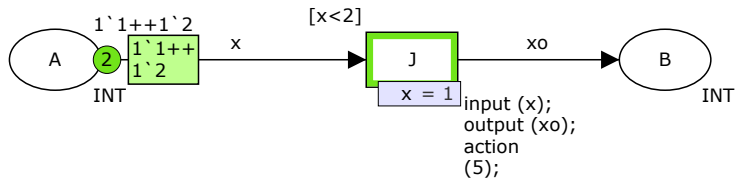
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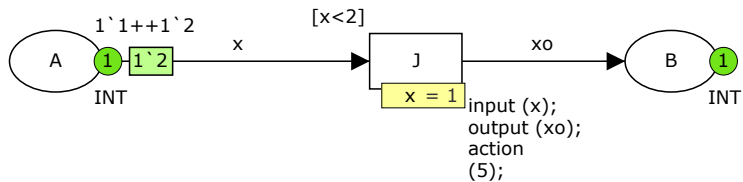
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CP-net. Firing of the transition.



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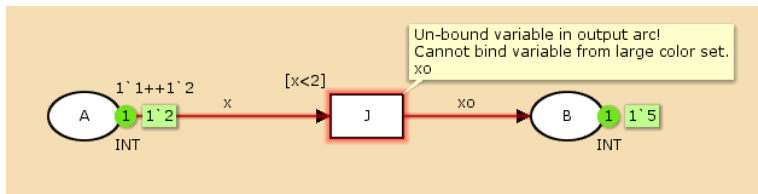
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Definition

Two-level NP-net is a tuple

$NP = \langle Lab, SN, \mathbb{E} \rangle$ where

- Lab — set of labels for synchronization of transitions;
- SN — system net of the NP-net;
- \mathbb{E} — finite set of element nets.

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Definition

System net is a tuple

$SN = \langle N, \mathcal{L}, \mathcal{U}, W, m_0 \rangle$ where

- $N = \langle P_{SN}, T_{SN}, F_{SN} \rangle$ — high-level PN of System net;
- P_{SN} — set of typed places;
- $\mathcal{L} = Expr$ — arc expression language (sums of constants and variables);
- $\mathcal{U} = \langle A, \mathcal{I} \rangle$ — model of \mathcal{L} with domain $A = A_{net} \cup A_{atom}$;
- A_{net} — set of marked element nets (net tokens);
- A_{atom} — set of plain colored tokens;
- $\mathcal{I} : Con \rightarrow A$ — interpretation function;
- $W : F_{SN} \rightarrow \mathcal{L}$ — arc expression function;
- $\Lambda : T_{SN} \rightarrow Lab$ — transition labeling function.

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System consists of

- Seeds — sources of datum
- Peers — consumers of datum
- Tracking server — which is a coordinator of seeds' and peers' interaction

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A **seed** is a source of data. In the initial state it waits for a request from a peer to upload the data to the peer. Then it clears its upload buffer and returns to the initial state.

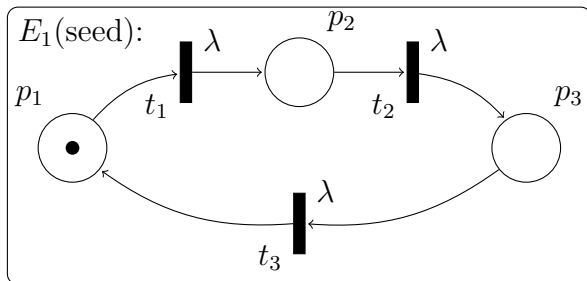


Figure: Seed net.



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A **peer** is just a consumer of data. In the initial state it waits for a seed with a piece of datum. Then it downloads the data and returns to the initial state.

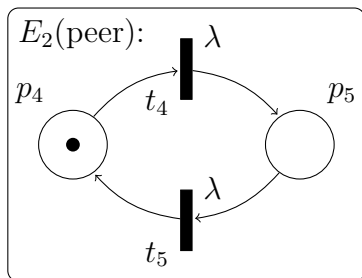


Figure: Peer net.

Tracking server

A **tracking server** is a coordinator of the seeds and peers interaction. It has the pools for ready-to-transmit peers and seeds and the pool for reinitializing seeds.

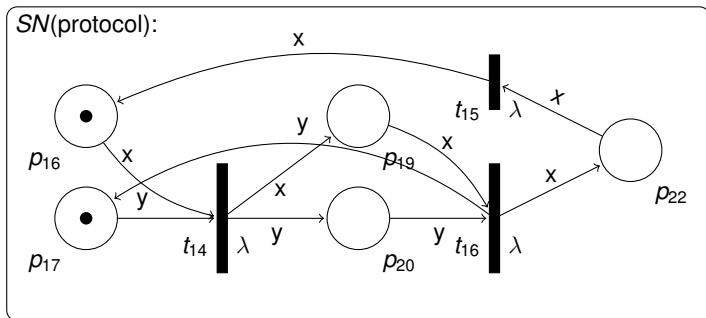


Figure: Tracking server.





Pipe

Tracking server coordinates such interactions by introducing a new entity — **pipe**. In the initial state a pipe waits for a seed and a peer, then it coordinates their interaction. Then the pipe reinitializes its internal buffers and returns to the initial state. A pipe can handle such aspects of a transmission as security, reliability, anonymity etc.

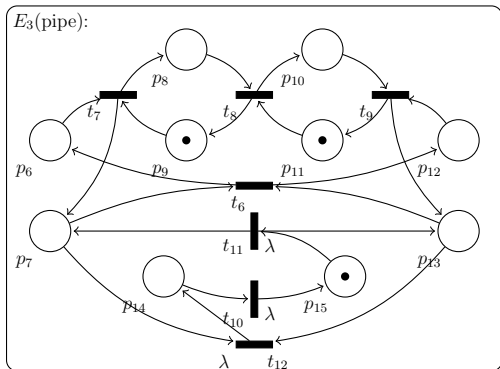


Figure: Pipe net.



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Returning to our tracking server. There are no pipes.

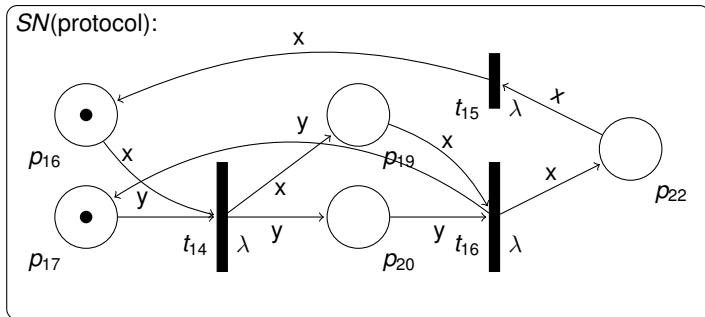


Figure: Tracking server.

Tracking server

But we can add them.

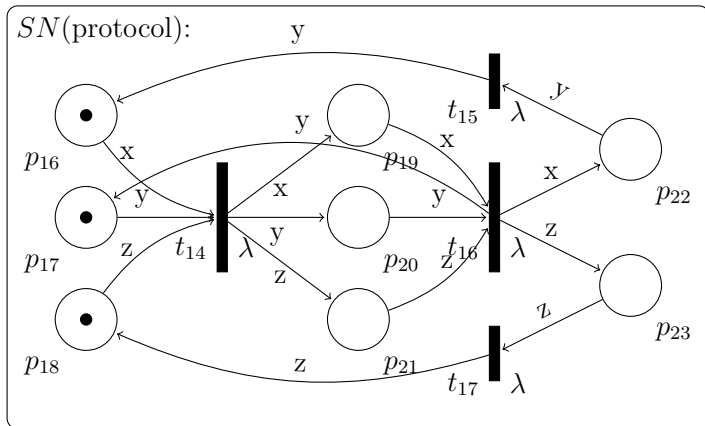
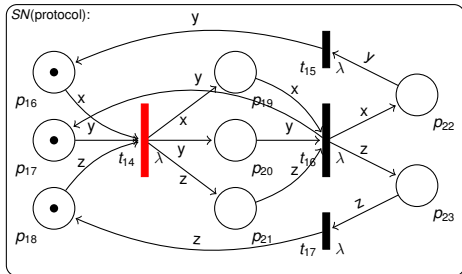
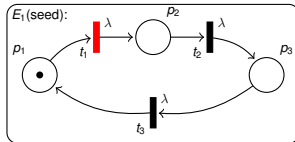
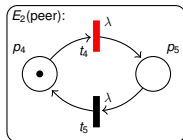
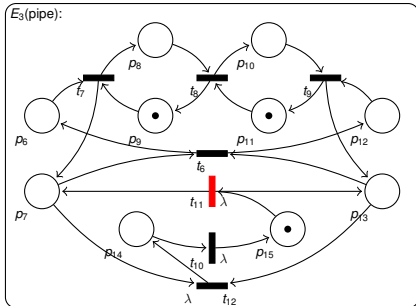


Figure: Tracking server.



The whole picture



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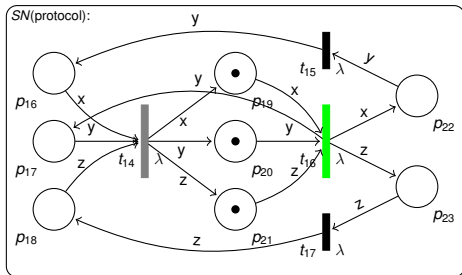
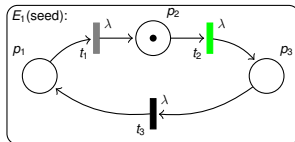
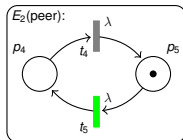
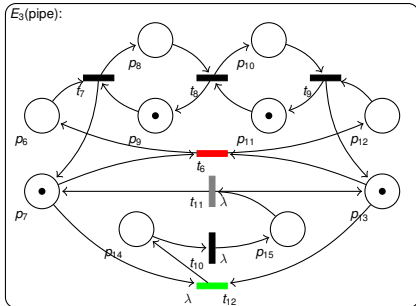
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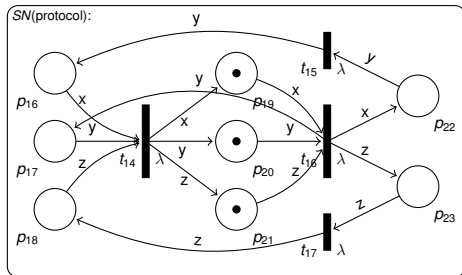
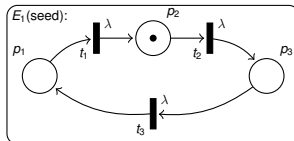
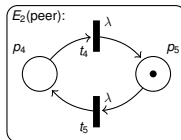
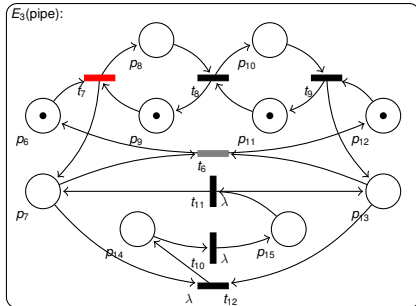
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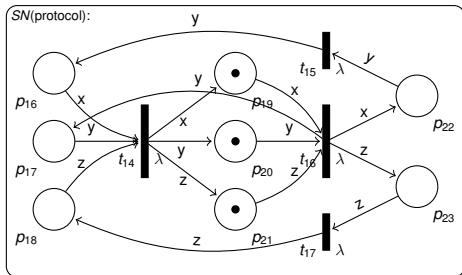
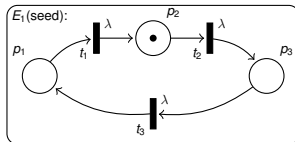
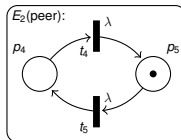
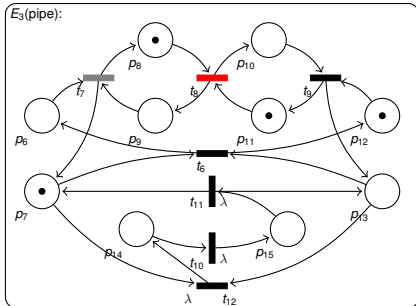
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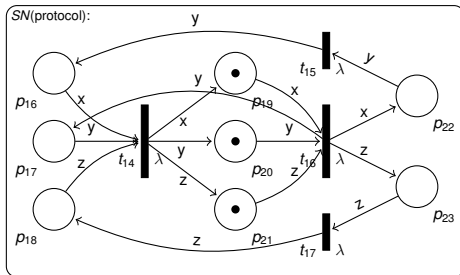
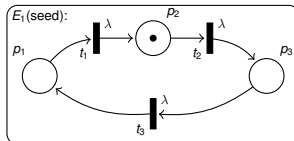
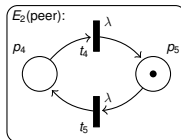
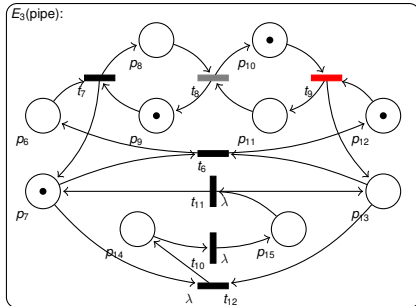
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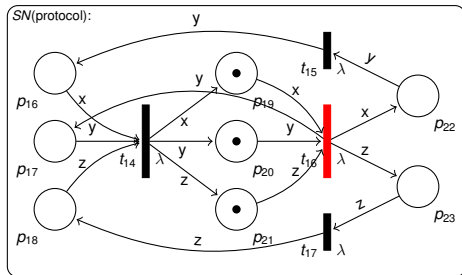
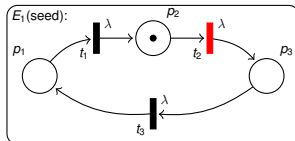
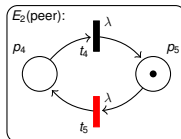
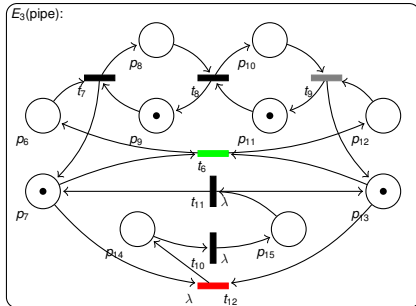
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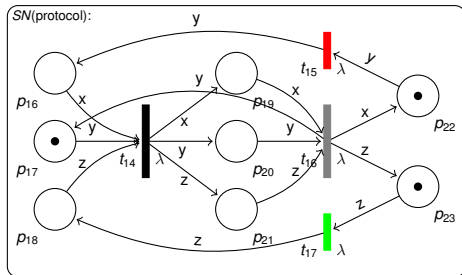
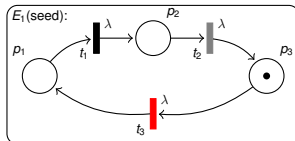
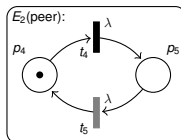
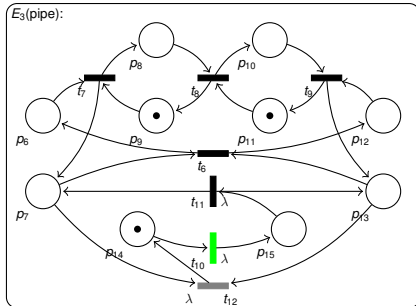
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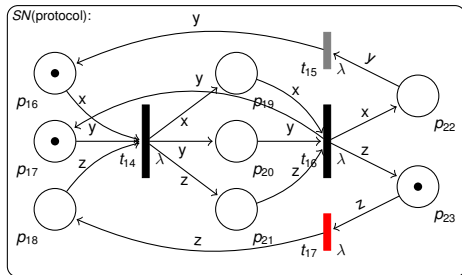
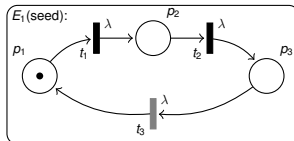
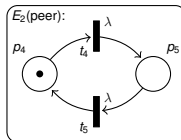
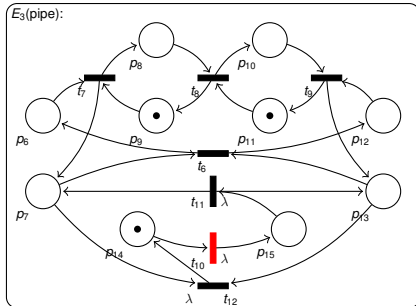
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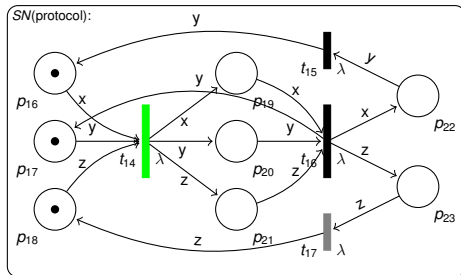
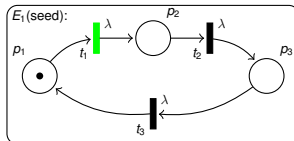
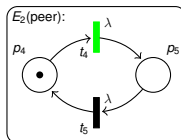
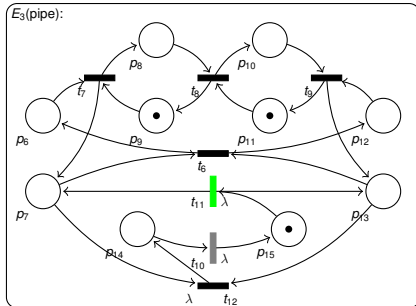
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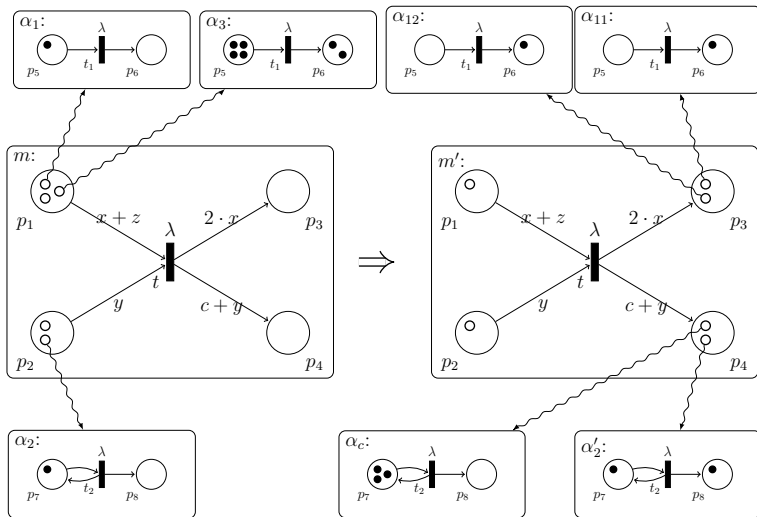
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Nuances of vertical synchronization firing.



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Translation requirements:

- 1 preservation of behavioral properties (boundedness, liveness);
- 2 existence of a similarity relation between runs of NP-nets and runs of corresponding CP-nets (important for simulation);
- 3 compatibility of target CP-nets with CPNtools analysis engine.

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Translation NP-net \Rightarrow CP-net.

- place structure of a system net is preserved — for each place of the system net we create a place in result CP-net
- the translation is defined by translation rules for each kind of transition — element-autonomous transition, system-autonomous transition, and vertical synchronization transition
- marked net-tokens are represented by lists of integer (usual vector representation of Petri net markings)



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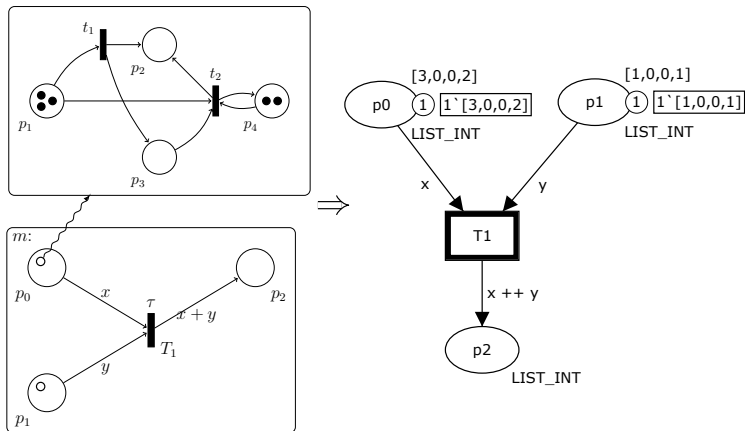
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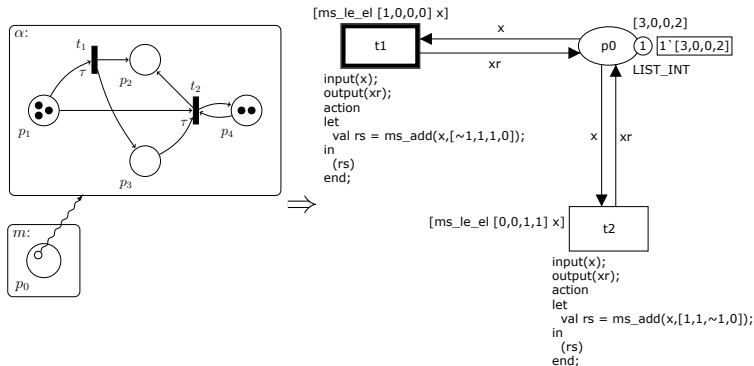
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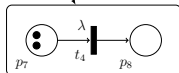
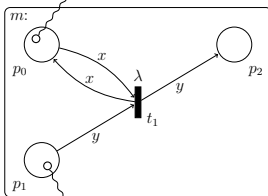
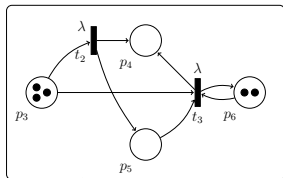
Translation of System-Autonomous step.



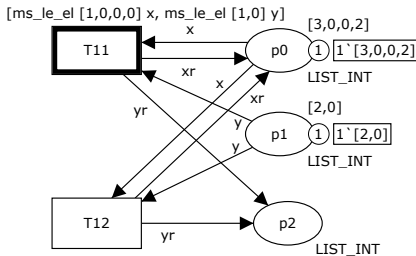
Translation of Element-Autonomous step.



Translation of Vertical Synchronization step.



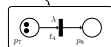
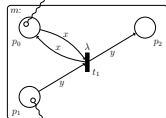
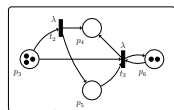
```
input(x,y);
output(xr,yr);
action
let
  val rs1 = ms_add(x,[~1,1,1,0]);
  val rs2 = ms_add(y,[~1,1]);
in
  (rs1,rs2)
end;
```



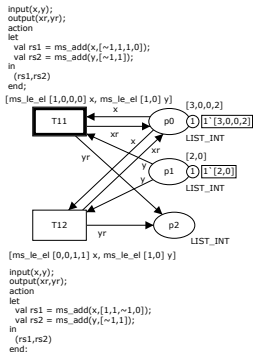
```
[ms_le_el [0,0,1,1] x, ms_le_el [1,0] y]
```

```
input(x,y);
output(xr,yr);
action
let
  val rs1 = ms_add(x,[1,1,~1,0]);
  val rs2 = ms_add(y,[~1,1]);
in
  (rs1,rs2)
end;
```

Translation of Vertical Synchronization step.



⇒



An alternative to the combinatorial unfolding is a selection procedure which is injected into a transition action section, but it breaks requirement 3 (wrong occurrence graph is constructed by CPNtools)

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Translation multi-level and recursive NP-nets.



The translation

- 1 could be extended to multi-level NP-nets
- 2 translation of recursive NP-nets is an open question

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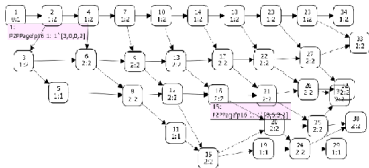
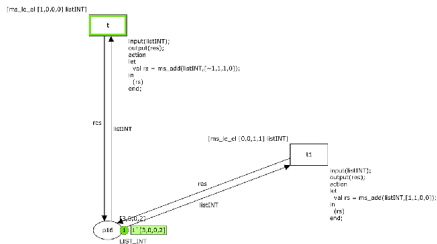
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Technical results

- The translation has been implemented (Java) and tested
- A few toy NP-nets were analysed by CPNtools



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Conclusions

- The translation is obtained and implemented;
- A few simple NP-nets were analysed by CPN tools;
- Further directions:
 - support of analysis results interpretation on source NP-nets (counterexamples from ASK-CTL, the state-space tool)
 - simulation support (via Access/CPN 2.0)