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This form is a summary description of the model entitled "Token Ring" proposed for the Model Checking Contest @ Petri Nets. Models can be given in several instances parameterized by scaling parameters. Colored nets can be accompanied by one or many equivalent, unfolded P/T nets. Models are given together with property files (possibly, one per model instance) giving a set of properties to be checked on the model.

Description

We consider a system where a set of machines are places in a ring, numbered 0 to N. Each machine i only knows its own state and the state of its left neighbor, i.e., machine $(i-1)\%(N+1)$. Machine number 0 plays a special role, and it is called "the bottom machine". The state of each machine is an integer number in $[0, N]$. We will note $S(i)$ the state of machine i.

Each machine may determine if it has a so-called "*privilege*" based on its state and the one of its left neighbor. A privilege is in this context the right to perform an operation. After performing its operation, the machine updates its own state, and may loose its privilege.

The objective of the protocol is to reach a stable state for the system. In a stable state:

- there is a unique machine with a privilege,
- any subsequent state is also a stable state.

Furthermore, the protocol ensures non-starvation: at any time, any machine is sure to have a privilege after a finite number of steps.

The detail of the protocol is different for the bottom machine, and the other machines:

- The bottom machine has the privilege if its left neighbor state is equal to its own state. In this case, the bottom machine updates its status by incrementing it: if $S(N) = S(0)$ then $S(0) := (S(0)+1)\%N$
- Any other machine $i > 0$ has the privilege if its left neighbor state is different from its own state. In this case, machine i updates its status by setting it to the value of the left machine: if $S(i-1)! = S(i)$ then $S(i) := S(i-1)$.

In March 2020, Pierre Bouvier and Hubert Garavel provided a decomposition of five instances of this model into networks of communicating automata. Each network is expressed as a Nested-Unit Petri Net (NUPN) that can be found, for each instance, in the "toolspecific" section of the corresponding PNML file. In April 2021, Pierre Bouvier decomposed all the remaining instances of this model.

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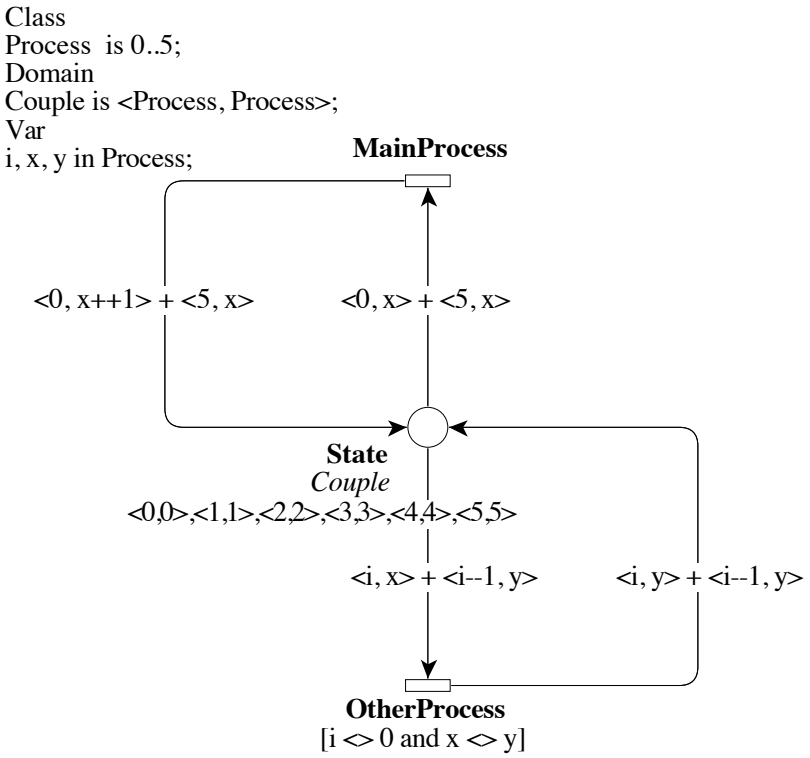

Graphical representation for $N = 5$

References

http://www.cs.utexas.edu/~EWD/ewd04xx/EWD426.PDF

Scaling parameter

Parameter name	Parameter description	Chosen parameter values
N	Number of processes. It has an impact on the initial marking of the place *State*, as well as most of the colored functions.	5, 10, 15, 20, 30, 40, 50

Size of the colored net model

number of places:	1
number of transitions:	2
number of arcs:	4

Size of the derived P/T model instances

Parameter	Number of places	Number of transitions	Number of arcs	Number of units	HWB code
$N = 5$	36	156	624	7	1–6–18
$N = 10$	121	1111	4444	12	1–11–44
$N = 15$	256	3616	14464	17	1–16–64
$N = 20$	441	8421	33684	22	1–21–105
$N = 30$	961	27931	111724	32	1–31–155
$N = 40$	1681	65641	262564	42	1–41–246
$N = 50$	2601	127551	510204	52	1–51–306

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Structural properties

ordinary — *all arcs have multiplicity one* ..... ✔
simple free choice — *all transitions sharing a common input place have no other input place* ..... ✗ (a)
extended free choice — *all transitions sharing a common input place have the same input places* ..... ✗ (b)
state machine — *every transition has exactly one input place and exactly one output place* ..... ✗ (c)
marked graph — *every place has exactly one input transition and exactly one output transition* ..... ✗ (d)
connected — *there is an undirected path between every two nodes (places or transitions)* ..... ✔ (e)
strongly connected — *there is a directed path between every two nodes (places or transitions)* ..... ✔ (f)
source place(s) — *one or more places have no input transitions* ..... ✗ (g)
sink place(s) — *one or more places have no output transitions* ..... ✗ (h)
source transition(s) — *one or more transitions have no input places* ..... ✗ (i)
sink transitions(s) — *one or more transitions have no output places* ..... ✗ (j)
loop-free — *no transition has an input place that is also an output place* ..... ✗ (k)
conservative — *for each transition, the number of input arcs equals the number of output arcs* ..... ✔ (l)
subconservative — *for each transition, the number of input arcs equals or exceeds the number of output arcs* ..... ✔ (m)
nested units — *places are structured into hierarchically nested sequential units* (n) ..... ✔

Behavioural properties

safe — *in every reachable marking, there is no more than one token on a place* ..... ✔ (o)
dead place(s) — *one or more places have no token in any reachable marking* ..... ? (p)
dead transition(s) — *one or more transitions cannot fire from any reachable marking* ..... ✗ (q)
deadlock — *there exists a reachable marking from which no transition can be fired* ..... ✗ (r)
reversible — *from every reachable marking, there is a transition path going back to the initial marking* ..... ✗
live — *for every transition t, from every reachable marking, one can reach a marking in which t can fire* ..... ✔ (s)

(a) stated by CÆSAR.BDD version 1.7 on all 7 instances (5, 10, 15, 20, 30, 40, and 50).
(b) stated by CÆSAR.BDD version 2.6 on all 7 instances (5, 10, 15, 20, 30, 40, and 50).
(c) stated by CÆSAR.BDD version 1.7 on all 7 instances (5, 10, 15, 20, 30, 40, and 50).
(d) stated by CÆSAR.BDD version 1.7 on all 7 instances (5, 10, 15, 20, 30, 40, and 50).
(e) stated by CÆSAR.BDD version 1.7 on all 7 instances (5, 10, 15, 20, 30, 40, and 50).
(f) stated by CÆSAR.BDD version 1.7 on all 7 instances (5, 10, 15, 20, 30, 40, and 50).
(g) stated by CÆSAR.BDD version 1.7 on all 7 instances (5, 10, 15, 20, 30, 40, and 50).
(h) stated by CÆSAR.BDD version 1.7 on all 7 instances (5, 10, 15, 20, 30, 40, and 50).
(i) stated by CÆSAR.BDD version 1.7 on all 7 instances (5, 10, 15, 20, 30, 40, and 50).
(j) stated by CÆSAR.BDD version 1.7 on all 7 instances (5, 10, 15, 20, 30, 40, and 50).
(k) stated by CÆSAR.BDD version 1.7 on all 7 instances (5, 10, 15, 20, 30, 40, and 50).
(l) stated by CÆSAR.BDD version 1.7 on all 7 instances (5, 10, 15, 20, 30, 40, and 50).
(m) stated by CÆSAR.BDD version 1.7 on all 7 instances (5, 10, 15, 20, 30, 40, and 50).
(n) the definition of Nested-Unit Petri Nets (NUPN) is available from http://mcc.lip6.fr/nupn.php
(o) stated by CÆSAR.BDD version 3.5 on all 7 instances (5, 10, 15, 20, 30, 40, and 50).
(p) stated by CÆSAR.BDD version 3.3 to be false on 5 instance(s) out of 7, and unknown on the remaining 2 instance(s).
(q) true in the colored version, false in the P/T unfolding — the latter was confirmed by CÆSAR.BDD on 3 instance(s) out of 7, and unknown on the remaining 4 instance(s).
(r) stated by CÆSAR.BDD version 2.0 to be false on 3 instance(s) out of 7, and unknown on the remaining 4 instance(s); confirmed at MCC'2014 by Helena on 3 colored instances ($N = 5$, $N = 10$, $N = 15$), and by Lola and Tapaal on 2 P/T instances ($N = 5$ and $N = 10$).
(s) true in the colored version, false in the P/T unfolding — the latter was confirmed by CÆSAR.BDD version 3.3 on 3 instance(s) out of 7.

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Size of the marking graphs

Parameter	Number of reachable markings	Number of transition firings	Max. number of tokens per place	Max. number of tokens per marking
$N = 5$	166 [(t)]	365 [(u)]	1 [(v)]	6 [(w)]
$N = 10$	58,905 [(x)]	294 050 [(y)]	1 [(z)]	11 [(aa)]
$N = 15$	3.5358E+7 [(ab)]	2.6518E+8 [(ac)]	1 [(ad)]	16 [(ae)]
$N = 20$	2.44663E+10 [(af)]	?	1 [(ag)]	21 [(ah)]
$N = 30$	$\geq$ 6.01279e+15 [(ai)]	?	1 [(aj)]	31 [(ak)]
$N = 40$	$\geq$ 4.43419e+11 [(al)]	?	1 [(am)]	41 [(an)]
$N = 50$	?	?	1 [(ao)]	51 [(ap)]

(t) computed at MCC'2013 by GreatSPN, ITS-Tools, Marcie, Neco, and PNXDD; confirmed by CÆSAR.BDD version 1.8; confirmed by Helena, GreatSPN, Marcie, PNMC, PNXDD, Stratagem, and Tapaal at MCC'2014.
(u) computed by Helena and Marcie at MCC'2014.
(v) computed by GreatSPN, PNMC, Marcie, and Tapaal at MCC'2014.
(w) number of initial tokens, because the net is conservative.
(x) computed at MCC'2013 by GreatSPN, ITS-Tools, Marcie, Neco, and PNXDD; confirmed by CÆSAR.BDD version 1.8; confirmed by Helena, Marcie, PNMC, PNXDD, Stratagem, and Tapaal at MCC'2014.
(y) computed by Helena and Marcie at MCC'2014.
(z) computed by Marcie, PNMC, and Tapaal at MCC'2014.
(aa) number of initial tokens, because the net is conservative.
(ab) computed at MCC'2014 by Helena, Marcie, PNMC, and PNXDD; exact value: 35,357,924.
(ac) computed by Helena and Marcie at MCC'2014; exact value: 265,182,780.
(ad) computed by Marcie and PNMC at MCC'2014.
(ae) number of initial tokens, because the net is conservative.
(af) computed by PNXDD at MCC'2013; confirmed by PNMC and PNXDD at MCC'2014; exact value: 24,466,267,459.
(ag) computed by PNMC at MCC'2014.
(ah) number of initial tokens, because the net is conservative.
(ai) stated by CÆSAR.BDD version 3.3.
(aj) stated by CÆSAR.BDD version 3.3.
(ak) number of initial tokens, because the net is conservative.
(al) stated by CÆSAR.BDD version 3.5.
(am) the P/T instance is safe.
(an) number of initial tokens, because the net is conservative.
(ao) the P/T instance is safe.
(ap) number of initial tokens, because the net is conservative.