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This form is a summary description of the model entitled "NoC3x3" 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

These models describe a fault-tolerant wormhole routing algorithm for an asynchronous Network on Chip. Data transmission between two arbitrary nodes of the network is achieved by packets flowing from the their sources to destinations in the network. Each routing node is also connected to a local computing node, which is responsible for injecting and absorbing packets to and from its routing node. A routing node accepts a packet from its neighbors and/or its computing node, determines the forwarding routing direction based on the packet's source and destination, and then transmits it accordingly. Each routing node has a router and an arbiter for its computing node and for each of its neighbors. Routers accept packets and transfer them to an appropriate arbiter. Links can fail transmitting packets. To make the routing algorithm fault-tolerant, each packet is in general issued with two routing choices, providing an alternative if the first choice fails. Therefore, a router is connected to all arbiters that are in the same node, and if one arbiter is not available, the router can still try to communicate with another arbiter.

We considered a set of eight different models, which vary in the implementation of the algorithm and the size of the network. The smallest model corresponds to a three-by-two network with four corner routing nodes and two edge routing nodes. All the other models feature a three-by-three two-dimensional mesh having four corner routing nodes (with two neighbor nodes), four edge routing nodes (with three neighbor nodes), and one middle node (with four neighbor nodes).

These models have been specified in LNT (*LOTOS New Technology*), which combines functional languages (to describe data types and user-defined functions operating on typed values) and process calculi (to describe concurrent components that synchronize using rendezvous and communicate via message passing). We used the LNT versions dated February 28, 2019, which are between 1200- and 2700-line long.

Each LNT model was translated to LOTOS, and then to an interpreted Petri net using the CADP toolbox. Finally, the P/T nets were obtained by stripping out all dataflow-related information (variables, types, assignments, guards, etc.) from the interpreted Petri nets, leading to a NUPN (*Nested-Unit Petri Net*) model translated to PNML using the CÆSAR.BDD tool.

Each instance of this model is designated by its number N, between 1 and 8. Each instance is also parameterized by its version V, which specifies how the NUPN has been produced from the LOTOS specification. V is either equal to "a" if the NUPN has been generated *after* applying all the structural and data-flow optimizations of the CÆSAR compiler for LOTOS, or to "b" if the NUPN has been generated *before* these optimizations.

References

Zhen Zhang, Wendelin Serwe, Jian Wu, Tomohiro Yoneda, Hao Zheng, and Chris Myers. *An Improved Fault-Tolerant Routing Algorithm for a Network-on-Chip Derived with Formal Analysis.* Science of Computer Programming, Elsevier, Volume 118, March 2016, 35 pages. http://cadp.inria.fr/publications/Zhang-Serwe-Wu-et-al-16.html

Scaling parameter

Parameter name	Parameter description	Chosen parameter values
(N, V)	N is the index of the model and V is the version defined above	$\{1,2,3,4,5,6,7,8\} \times \{a,b\}$

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Size of the model

Parameter	Number of places	Number of transitions	Number of arcs	Number of units	HWB code
$N = 1, V = a$	165	355	1069	41	2–40–90
$N = 1, V = b$	1416	1640	3639	79	40–40–234
$N = 2, V = a$	361	428	1697	67	2–66–184
$N = 2, V = b$	2003	2292	5835	131	66–66–382
$N = 3, V = a$	370	450	1773	67	2–66–189
$N = 3, V = b$	2117	2435	6177	131	66–66–389
$N = 4, V = a$	293	608	1905	67	2–66–157
$N = 4, V = b$	2328	2701	6091	131	66–66–392
$N = 5, V = a$	417	933	3585	67	2–66–201
$N = 5, V = b$	1571	2173	6109	131	66–66–376
$N = 6, V = a$	512	1117	4279	67	2–66–210
$N = 6, V = b$	1544	2229	6663	131	66–66–374
$N = 7, V = a$	801	1544	4519	67	2–66–256
$N = 7, V = b$	7014	8833	19619	131	66–66–458
$N = 8, V = a$	317	4293	9691	67	2–66–181
$N = 8, V = b$	9140	14577	30726	197	66–99–623

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) .... ✔

(a) stated by CÆSAR.BDD version 2.8 on all 16 instances (8 values of N × 2 values of V).
(b) stated by CÆSAR.BDD version 2.8 on all 16 instances (8 values of N × 2 values of V).
(c) stated by CÆSAR.BDD version 2.8 on all 16 instances (8 values of N × 2 values of V).
(d) stated by CÆSAR.BDD version 2.8 on all 16 instances (8 values of N × 2 values of V).
(e) stated by CÆSAR.BDD version 2.8 on all 16 instances (8 values of N × 2 values of V).
(f) from place 1 one cannot reach place 0.
(g) place 0 is a source place.
(h) stated by CÆSAR.BDD version 2.8 to be true on 1 instance(s) out of 16, and false on the remaining 15 instance(s).
(i) stated by CÆSAR.BDD version 2.8 on all 16 instances (8 values of N × 2 values of V).
(j) stated by CÆSAR.BDD version 2.8 on all 16 instances (8 values of N × 2 values of V).
(k) stated by CÆSAR.BDD version 2.8 to be true on 8 instance(s) out of 16, and false on the remaining 8 instance(s).
(l) stated by CÆSAR.BDD version 2.8 on all 16 instances (8 values of N × 2 values of V).
(m) stated by CÆSAR.BDD version 2.8 on all 16 instances (8 values of N × 2 values of V).
(n) the definition of Nested-Unit Petri Nets (NUPN) is available from `http://mcc.lip6.fr/nupn.php`

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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* .... ?
dead transition(s) — *one or more transitions cannot fire from any reachable marking* .... ?
deadlock — *there exists a reachable marking from which no transition can be fired* .... ?
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* .... ?

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
$N = 1, V = a$	$\geq$ 2.98125e+13 [p]	?	1 [q]	40
$N = 1, V = b$	$\geq$ 7.13429e+39 [r]	?	1 [s]	40
$N = 2, V = a$	$\geq$ 2.2033e+15 [t]	?	1 [u]	66
$N = 2, V = b$	$\geq$ 6.87988e+25 [v]	?	1 [w]	66
$N = 3, V = a$	$\geq$ 5.27407e+15 [x]	?	1 [y]	66
$N = 3, V = b$	$\geq$ 1.81904e+26 [z]	?	1 [aa]	66
$N = 4, V = a$	$\geq$ 1.93845e+13 [ab]	?	1 [ac]	66
$N = 4, V = b$	$\geq$ 2.96817e+58 [ad]	?	1 [ae]	66
$N = 5, V = a$	$\geq$ 5.58784e+12 [af]	?	1 [ag]	66
$N = 5, V = b$	$\geq$ 3.91672e+20 [ah]	?	1 [ai]	66
$N = 6, V = a$	$\geq$ 1.03441e+17 [aj]	?	1 [ak]	66
$N = 6, V = b$	$\geq$ 1.23365e+13 [al]	?	1 [am]	66
$N = 7, V = a$	$\geq$ 1.08282e+07 [an]	?	1 [ao]	66
$N = 7, V = b$	$\geq$ 6.2244e+59 [ap]	?	1 [aq]	66
$N = 8, V = a$	$\geq$ 1.45588e+20 [ar]	?	1 [as]	66
$N = 8, V = b$	$\geq$ 6.16355e+44 [at]	?	1 [au]	99

[o] safe by construction – stated by the CÆSAR compiler.
[p] stated by CÆSAR.BDD version 2.8.
[q] stated by the CÆSAR compiler.
[r] stated by CÆSAR.BDD version 2.8.
[s] stated by the CÆSAR compiler.
[t] stated by CÆSAR.BDD version 2.8.
[u] stated by the CÆSAR compiler.
[v] stated by CÆSAR.BDD version 2.8.
[w] stated by the CÆSAR compiler.
[x] stated by CÆSAR.BDD version 2.8.
[y] stated by the CÆSAR compiler.
[z] stated by CÆSAR.BDD version 2.8.
[aa] stated by the CÆSAR compiler.
[ab] stated by CÆSAR.BDD version 2.8.
[ac] stated by the CÆSAR compiler.
[ad] stated by CÆSAR.BDD version 2.8.
[ae] stated by the CÆSAR compiler.
[af] stated by CÆSAR.BDD version 2.8.
[ag] stated by the CÆSAR compiler.
[ah] stated by CÆSAR.BDD version 3.3.
[ai] stated by the CÆSAR compiler.
[aj] stated by CÆSAR.BDD version 2.8.
[ak] stated by the CÆSAR compiler.
[al] stated by CÆSAR.BDD version 2.8.
[am] stated by the CÆSAR compiler.
[an] stated by CÆSAR.BDD version 2.8.
[ao] stated by the CÆSAR compiler.
[ap] stated by CÆSAR.BDD version 2.8.
[aq] stated by the CÆSAR compiler.
[ar] stated by CÆSAR.BDD version 2.8.

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(as) stated by the CÆSAR compiler.
(at) stated by CÆSAR.BDD version 2.8.
(au) stated by the CÆSAR compiler.