Model: Hexagonal Communication Grid
Type: P/T Net
Origin: Academic

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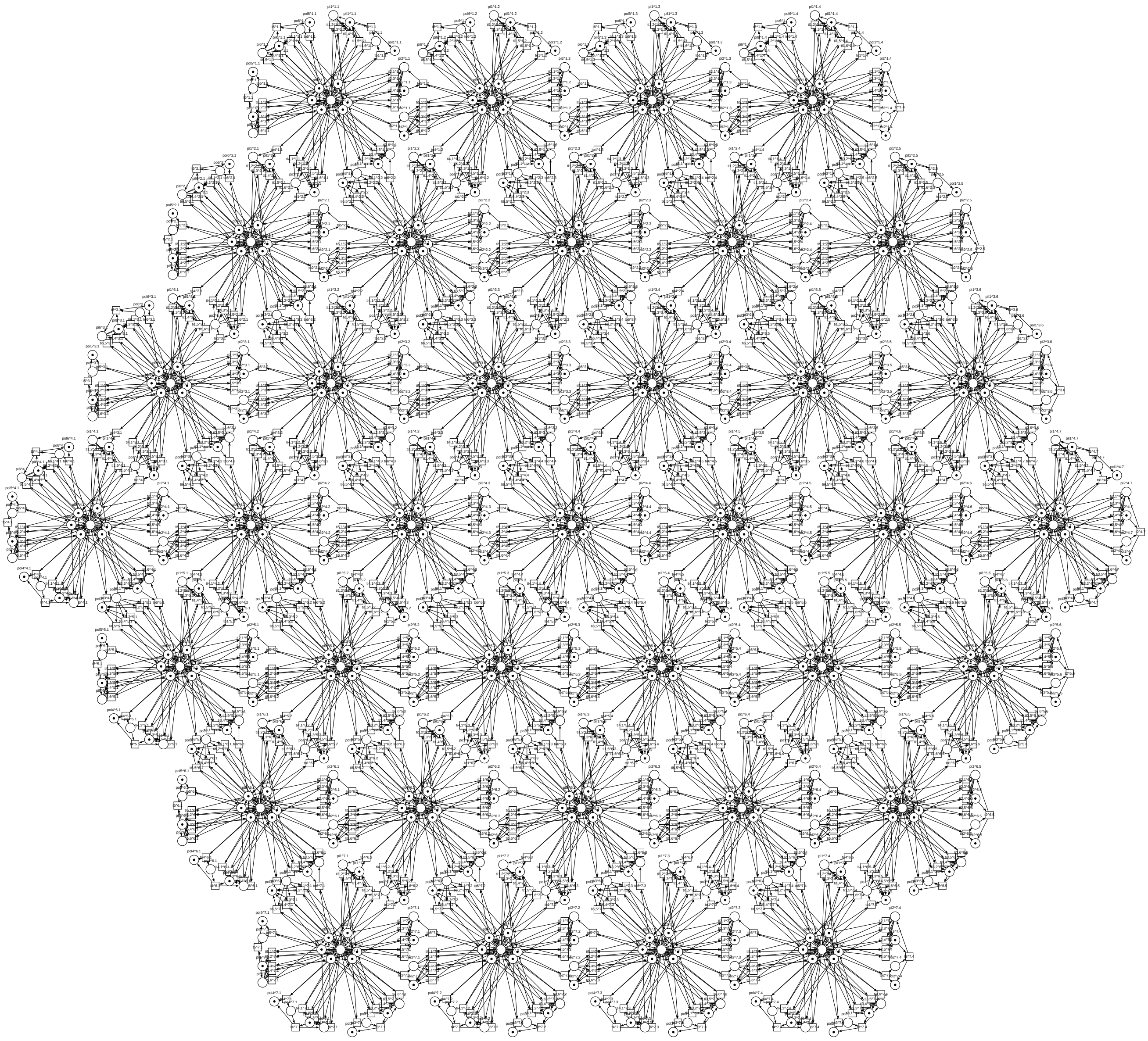
This form is a summary description of the model entitled "Hexagonal Communication Grid" proposed for the Model Checking Contest @ Petri Nets. Models can be given in several instances parameterized by scaling parameters. Colored nets can be accompanied by one or many equivalent, unfolded P/T nets. Models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

Description

A composition of hexagonal grid is presented. The model is composed of packet switching devices whose ports are situated on sides of a unit-size equilateral hexagon. Each device works in full-duplex mode based on store-and-forward principle. Hexagons are connected via merging contact places situated on common sides. On the edges of hexagons, plug devices are attached. Hexagonal grids are widely applied in mobile networks.



Graphical representation for $k = 4$, $p = 1$ and $b = 0$

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References

[1] Zaitsev D.A., Zaitsev I.D., Shmeleva T.R. Infinite Petri Nets as Models of Grids (pp.187-204). Chapter 19 in Mehdi Khosrow-Pour (Ed.) Encyclopedia of Information Science and Technology, Third Edition (10 Volumes). IGI-Global: USA, 2014.

[2] Shmeleva T.R. Parametric specification of open hexagonal grid. 71 ONAT Conference, December 6-8, 2016, Odessa, p.65-68.

Scaling parameter

Parameter name	Parameter description	Chosen parameter values
k, p, b	k – size of hexagonal grid, p – number of packets in each buffer section, b – available buffer size	(1,1,0), (1,2,6), (2,2,6), (3,1,6), (4,1,0), (5,1,6), (8,1,6)

Size of the model

Parameter	Number of places	Number of transitions	Number of arcs
k, p, b, with N_c denoting the number of cells in the grid ($N_c = 3k^2 - 3k + 1$)	$19N_c + 24k - 12$	$36N_c + 12k - 6$	$144N_c + 48k - 24$
$k = 1, p = 1, b = 0$	31	42	168
$k = 1, p = 2, b = 6$	31	42	168
$k = 2, p = 2, b = 6$	169	270	1080
$k = 3, p = 1, b = 6$	421	714	2856
$k = 4, p = 1, b = 0$	787	1374	5496
$k = 5, p = 1, b = 6$	1267	2250	9000
$k = 8, p = 1, b = 6$	3391	6174	24696

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)]

[(a)] confirmed by CÆSAR.BDD version 2.7 on all 7 instances (namely: (1,1,0), (1,2,6), (2,2,6), (3,1,6), (4,1,0), (5,1,6), and (8,1,6)).
[(b)] transitions “ti1_2_1_1” and “ti2_1_1_1” share a common input place “pbl_1_1”, but only the former transition has input place “pi1_1_1”.
[(c)] confirmed by CÆSAR.BDD version 2.7 on all 7 instances (namely: (1,1,0), (1,2,6), (2,2,6), (3,1,6), (4,1,0), (5,1,6), and (8,1,6)).
[(d)] confirmed by CÆSAR.BDD version 2.7 on all 7 instances (namely: (1,1,0), (1,2,6), (2,2,6), (3,1,6), (4,1,0), (5,1,6), and (8,1,6)).
[(e)] confirmed by CÆSAR.BDD version 2.7 on all 7 instances (namely: (1,1,0), (1,2,6), (2,2,6), (3,1,6), (4,1,0), (5,1,6), and (8,1,6)).
[(f)] confirmed by CÆSAR.BDD version 2.7 on all 7 instances (namely: (1,1,0), (1,2,6), (2,2,6), (3,1,6), (4,1,0), (5,1,6), and (8,1,6)).
[(g)] confirmed by CÆSAR.BDD version 2.7 on all 7 instances (namely: (1,1,0), (1,2,6), (2,2,6), (3,1,6), (4,1,0), (5,1,6), and (8,1,6)).
[(h)] confirmed by CÆSAR.BDD version 2.7 on all 7 instances (namely: (1,1,0), (1,2,6), (2,2,6), (3,1,6), (4,1,0), (5,1,6), and (8,1,6)).
[(i)] confirmed by CÆSAR.BDD version 2.7 on all 7 instances (namely: (1,1,0), (1,2,6), (2,2,6), (3,1,6), (4,1,0), (5,1,6), and (8,1,6)).
[(j)] confirmed by CÆSAR.BDD version 2.7 on all 7 instances (namely: (1,1,0), (1,2,6), (2,2,6), (3,1,6), (4,1,0), (5,1,6), and (8,1,6)).
[(k)] confirmed by CÆSAR.BDD version 2.7 on all 7 instances (namely: (1,1,0), (1,2,6), (2,2,6), (3,1,6), (4,1,0), (5,1,6), and (8,1,6)).
[(l)] confirmed by CÆSAR.BDD version 2.7 on all 7 instances (namely: (1,1,0), (1,2,6), (2,2,6), (3,1,6), (4,1,0), (5,1,6), and (8,1,6)).

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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* .... ✔
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
$k = 1, p = 1, b = 0$	40193	430884	6	18 [r]
$k = 1, p = 2, b = 6$	2664192	39907584	18	30 [s]
$k = 2, p = 2, b = 6$	?	?	18	186 [t]
$k = 3, p = 1, b = 6$	?	?	12	372 [u]
$k = 4, p = 1, b = 0$	?	?	6	486 [v]
$k = 5, p = 1, b = 6$	?	?	12	1152 [w]
$k = 8, p = 1, b = 6$	?	?	12	3132 [x]

Other properties

1. To observe a deadlock, the number of packets for blocking a few devices should be provided with parameter p.
2. Models were analysed using the Tina `http://www.laas.fr/tina` system.

[m] confirmed by CÆSAR.BDD version 2.7 on all 7 instances (namely: (1,1,0), (1,2,6), (2,2,6), (3,1,6), (4,1,0), (5,1,6), and (8,1,6)).
[n] the definition of Nested-Unit Petri Nets (NUPN) is available from `http://mcc.lip6.fr/nupn.php`
[o] confirmed by CÆSAR.BDD version 2.7 on all 7 instances (namely: (1,1,0), (1,2,6), (2,2,6), (3,1,6), (4,1,0), (5,1,6), and (8,1,6)).
[p] stated by CÆSAR.BDD version 3.3 to be false on 4 instance(s) out of 7, and unknown on the remaining 3 instance(s).
[q] confirmed by CÆSAR.BDD version 2.7 to be false on 2 instance(s) out of 7, and unknown on the remaining 5 instance(s).
[r] number of initial tokens, because the net is conservative.
[s] number of initial tokens, because the net is conservative.
[t] number of initial tokens, because the net is conservative.
[u] number of initial tokens, because the net is conservative.
[v] number of initial tokens, because the net is conservative.
[w] number of initial tokens, because the net is conservative.
[x] number of initial tokens, because the net is conservative.