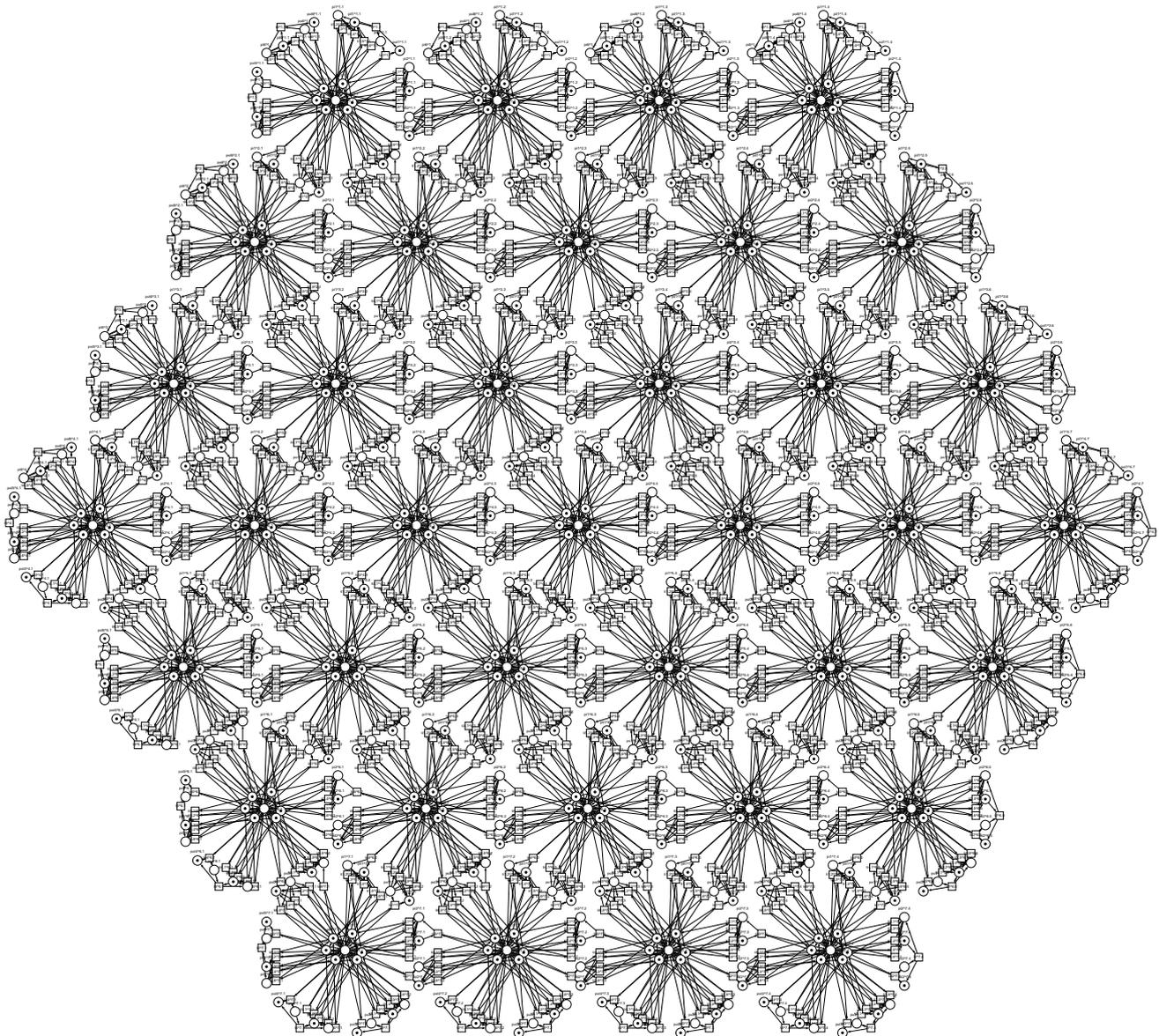


*This form is a summary description of the model entitled “Hexagonal Communication Grid” proposed for the Model Checking Contest @ Petri Nets. Models can be given in several instances parameterized by scaling parameters. Colored nets can be accompanied by one or many equivalent, unfolded P/T nets. Models 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  $b = 0$*

## 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 ..... yes
- simple free choice** — all transitions sharing a common input place have no other input place ..... no <sup>(a)</sup>
- extended free choice** — all transitions sharing a common input place have the same input places ..... no <sup>(b)</sup>
- state machine** — every transition has exactly one input place and exactly one output place ..... no <sup>(c)</sup>
- marked graph** — every place has exactly one input transition and exactly one output transition ..... no <sup>(d)</sup>
- connected** — there is an undirected path between every two nodes (places or transitions) ..... yes <sup>(e)</sup>
- strongly connected** — there is a directed path between every two nodes (places or transitions) ..... yes <sup>(f)</sup>
- source place(s)** — one or more places have no input transitions ..... no <sup>(g)</sup>
- sink place(s)** — one or more places have no output transitions ..... no <sup>(h)</sup>
- source transition(s)** — one or more transitions have no input places ..... no <sup>(i)</sup>
- sink transitions(s)** — one or more transitions have no output places ..... no <sup>(j)</sup>
- loop-free** — no transition has an input place that is also an output place ..... yes <sup>(k)</sup>
- conservative** — for each transition, the number of input arcs equals the number of output arcs ..... yes <sup>(l)</sup>

<sup>(a)</sup> 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)).

<sup>(b)</sup> 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”.

<sup>(c)</sup> 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)).

<sup>(d)</sup> 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)).

<sup>(e)</sup> 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)).

<sup>(f)</sup> 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)).

<sup>(g)</sup> 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)).

<sup>(h)</sup> 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)).

<sup>(i)</sup> 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)).

<sup>(j)</sup> 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)).

<sup>(k)</sup> 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)).

<sup>(l)</sup> 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)).

**subconservative** — for each transition, the number of input arcs equals or exceeds the number of output arcs ..... yes <sup>(m)</sup>  
**nested units** — places are structured into hierarchically nested sequential units <sup>(n)</sup> ..... no

## Behavioural properties

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

## 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 <sup>(r)</sup>
$k = 1, p = 2, b = 6$	2664192	39907584	18	30 <sup>(s)</sup>
$k = 2, p = 2, b = 6$	?	?	18	186 <sup>(t)</sup>
$k = 3, p = 1, b = 6$	?	?	12	372 <sup>(u)</sup>
$k = 4, p = 1, b = 0$	?	?	6	486 <sup>(v)</sup>
$k = 5, p = 1, b = 6$	?	?	12	1152 <sup>(w)</sup>
$k = 8, p = 1, b = 6$	?	?	12	3132 <sup>(x)</sup>

## 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.

<sup>(m)</sup> 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)).

<sup>(n)</sup> the definition of Nested-Unit Petri Nets (NUPN) is available from <http://mcc.lip6.fr/nupn.php>

<sup>(o)</sup> 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)).

<sup>(p)</sup> 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).

<sup>(q)</sup> 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).

<sup>(r)</sup> number of initial tokens, because the net is conservative.

<sup>(s)</sup> number of initial tokens, because the net is conservative.

<sup>(t)</sup> number of initial tokens, because the net is conservative.

<sup>(u)</sup> number of initial tokens, because the net is conservative.

<sup>(v)</sup> number of initial tokens, because the net is conservative.

<sup>(w)</sup> number of initial tokens, because the net is conservative.

<sup>(x)</sup> number of initial tokens, because the net is conservative.