*This form is a summary description of the model entitled "Reader/Writer Mutual Exclusion" 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.*
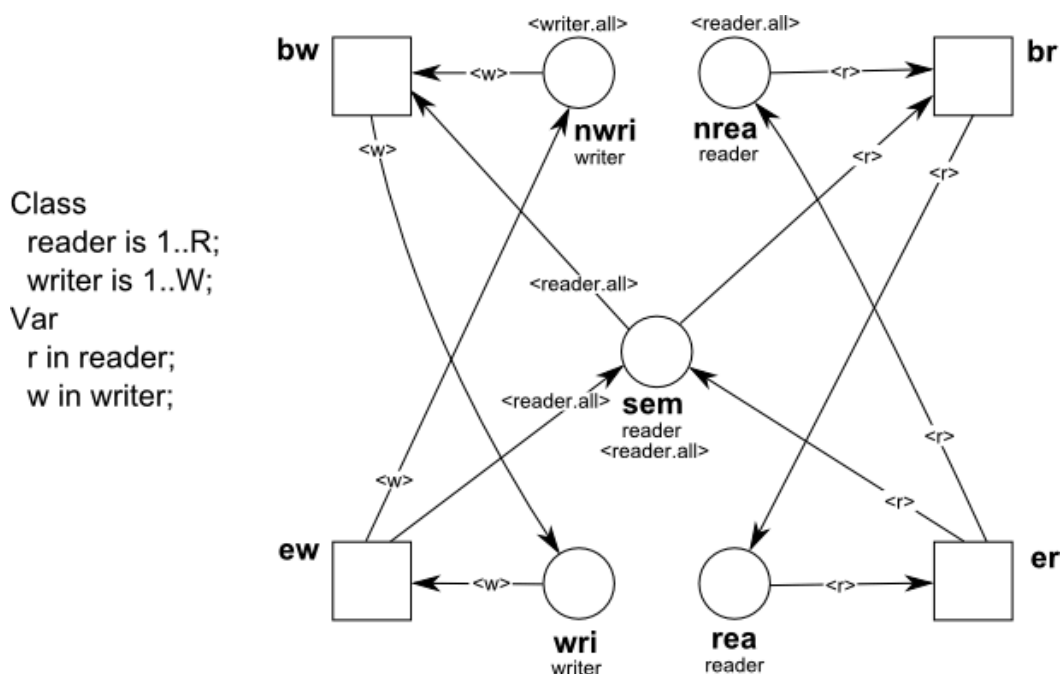
## Description

The net models a system with readers and writers. Reading can be conducted concurrently whereas writing has to be done exclusively. This is modeled by a number of semaphores (one for each reader) that need to be collected by a writer prior to writing.

**Net formalism:** This submission contains unfolded versions of the net for a variety of scaling parameters. These nets are given in LoLA low-level format and PNML. The original net has been modeled as an algebraic Petri net in LoLA high-level format, see http://service-technology.org/files/lola/lola.pdf.

The model is sketched in the figure. The two sorts $R$ and $W$ model the number of readers and writers, respectively.

*In March 2020, Pierre Bouvier and Hubert Garavel provided a decomposition of eight 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.*



## References

Wolfgang Reisig. *Elements of Distributed Algorithms. Modeling and Analysis with Petri Nets.*, Springer, 1998.

## Scaling parameter

| Parameter name | Parameter description | Chosen parameter values |
|---|---|---|
| (readers $r$, writers $w$) | see description | (10,10), (10,20), (10,50), (10,100), (10,500), (10,1000), (10,2000), (20,10), (100,10), (500,10), (1000,10), (2000,10) |

*generated on January 2, 2024*

Model: Reader/Writer Mutual Exclusion
Type: P/T Net
Origin: Academic

since
**MCC 2012**

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## Size of the model

| Parameter | Number of places | Number of transitions | Number of arcs | Number of units | HWB code |
|---|---|---|---|---|---|
| $(r,w) = (10,10)$ | 50 | 40 | 300 | 31 | 1–30–36 |
| $(r,w) = (10,20)$ | 70 | 60 | 540 | 41 | 1–40–48 |
| $(r,w) = (10,50)$ | 130 | 120 | 1260 | 71 | 1–70–82 |
| $(r,w) = (10,100)$ | 230 | 220 | 2460 | 121 | 1–120–127 |
| $(r,w) = (10,500)$ | 1030 | 1020 | 12060 | 521 | 1–520–533 |
| $(r,w) = (10,1000)$ | 2030 | 2020 | 24060 | 1021 | 1–1020–1030 |
| $(r,w) = (10,2000)$ | 4030 | 4020 | 48060 | 2021 | 1–2020–2033 |
| $(r,w) = (20,10)$ | 80 | 60 | 560 | 51 | 1–50–68 |
| $(r,w) = (100,10)$ | 320 | 220 | 2640 | 211 | 1–210–229 |
| $(r,w) = (500,10)$ | 1520 | 1020 | 13040 | 1011 | 1–1010–1369 |
| $(r,w) = (1000,10)$ | 3020 | 2020 | 26040 | 2011 | 1–2010–2660 |
| $(r,w) = (2000,10)$ | 6020 | 4020 | 52040 | 4011 | 1–4010–4628 |

## 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]

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[a] stated by CÆSAR.BDD version 1.7 on all 12 instances (see all aforementioned parameter values).
[b] stated by CÆSAR.BDD version 2.6 on all 12 instances (see all aforementioned parameter values).
[c] stated by CÆSAR.BDD version 1.7 on all 12 instances (see all aforementioned parameter values).
[d] stated by CÆSAR.BDD version 1.7 on all 12 instances (see all aforementioned parameter values).
[e] stated by CÆSAR.BDD version 1.7 on all 12 instances (see all aforementioned parameter values).
[f] stated by CÆSAR.BDD version 1.7 on all 12 instances (see all aforementioned parameter values).
[g] stated by CÆSAR.BDD version 1.7 on all 12 instances (see all aforementioned parameter values).
[h] stated by CÆSAR.BDD version 1.7 on all 12 instances (see all aforementioned parameter values).
[i] stated by CÆSAR.BDD version 1.7 on all 12 instances (see all aforementioned parameter values).
[j] stated by CÆSAR.BDD version 1.7 on all 12 instances (see all aforementioned parameter values).
[k] stated by CÆSAR.BDD version 1.7 on all 12 instances (see all aforementioned parameter values).
[l] stated by CÆSAR.BDD version 1.7 on all 12 instances (see all aforementioned parameter values).
[m] stated by CÆSAR.BDD version 1.7 on all 12 instances (see all aforementioned parameter values).
[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 12 instances (see all aforementioned parameter values); confirmed by Tina's Struct version 3.5.0 in April 2018 on all 12 instances.
[p] stated by CÆSAR.BDD version 3.3 to be false on 9 instance(s) out of 12, and unknown on the remaining 3 instance(s).

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**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* ................?

## 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 |
|---|---|---|---|---|
| $(r, w) = (10, 10)$ | 1034 [s] | 10 260 [t] | 1 [u] | 30 [v] |
| $(r, w) = (10, 20)$ | 1044 [w] | 10 280 [x] | 1 [y] | 40 [z] |
| $(r, w) = (10, 50)$ | 1074 [aa] | 10 340 [ab] | 1 [ac] | 70 [ad] |
| $(r, w) = (10, 100)$ | 1124 [ae] | 10 440 [af] | 1 [ag] | 120 [ah] |
| $(r, w) = (10, 500)$ | 1524 [ai] | 11 240 [aj] | 1 [ak] | 520 [al] |
| $(r, w) = (10, 1000)$ | 2024 [am] | 12 240 [an] | 1 [ao] | 1020 [ap] |
| $(r, w) = (10, 2000)$ | 3024 [aq] | ? | 1 [ar] | 2020 [as] |
| $(r, w) = (20, 10)$ | 1.0486E+6 [at] | 2.0972E+7 [au] | 1 [av] | 50 [aw] |
| $(r, w) = (100, 10)$ | 1.2677E+30 [ax] | ? | 1 [ay] | $\in [210, 320]$ |
| $(r, w) = (500, 10)$ | 3.2734E+150 [az] | ? | 1 [ba] | $\geq 1010$ |
| $(r, w) = (1000, 10)$ | 1.0715E+301 [bb] | ? | 1 [bc] | $\geq 2010$ |
| $(r, w) = (2000, 10)$ | ? | ? | 1 [bd] | 4010 |

[q] stated by CÆSAR.BDD version 3.5 to be false on 9 instance(s) out of 12, and unknown on the remaining 3 instance(s).

[r] stated by CÆSAR.BDD version 3.5 to be false on 9 instance(s) out of 12, and unknown on the remaining 3 instance(s); confirmed at MCC'2014 by Cunf, Lola, and Tapaal on all 12 instances, and by GreatSPN on fewer instances.

[s] computed at MCC'2013 by Alpina, ITS-Tools, Marcie, Neco, and PNXDD; confirmed by CÆSAR.BDD version 1.8; confirmed at MCC'2014 by GreatSPN, Marcie, PNMC, PNXDD, Stratagem, and Tapaal.

[t] computed at MCC'2014 by Marcie.

[u] computed at MCC'2014 by GreatSPN, Marcie, PNMC, and Tapaal.

[v] computed at MCC'2014 by Marcie, PNMC, and Tapaal.

[w] computed at MCC'2013 by Alpina, ITS-Tools, Marcie, Neco, and PNXDD; confirmed by CÆSAR.BDD version 1.8; confirmed at MCC'2014 by GreatSPN, Marcie, PNMC, PNXDD, Stratagem, and Tapaal.

[x] computed at MCC'2014 by Marcie.

[y] computed at MCC'2014 by GreatSPN, Marcie, PNMC, and Tapaal.

[z] computed at MCC'2014 by Marcie, PNMC, and Tapaal.

[aa] computed at MCC'2013 by Alpina, ITS-Tools, Marcie, Neco, and PNXDD; confirmed by CÆSAR.BDD version 1.8; confirmed at MCC'2014 by GreatSPN, Marcie, PNMC, PNXDD, Stratagem, and Tapaal.

[ab] computed at MCC'2014 by Marcie.

[ac] computed at MCC'2014 by GreatSPN, Marcie, PNMC, and Tapaal.

[ad] computed at MCC'2014 by Marcie, PNMC, and Tapaal.

[ae] computed at MCC'2013 by Alpina, ITS-Tools, Marcie, Neco, and PNXDD; confirmed by CÆSAR.BDD version 1.8; confirmed at MCC'2014 by GreatSPN, Marcie, PNMC, PNXDD, Stratagem, and Tapaal.

[af] computed at MCC'2014 by Marcie.

[ag] computed at MCC'2014 by GreatSPN, Marcie, PNMC, and Tapaal.

[ah] computed at MCC'2014 by Marcie, PNMC, and Tapaal.

[ai] computed at MCC'2013 by ITS-Tools, Marcie, Neco, and PNXDD; confirmed at MCC'2014 by GreatSPN, Marcie, PNMC, PNXDD, and Tapaal.

[aj] computed at MCC'2014 by Marcie.

[ak] computed at MCC'2014 by GreatSPN, Marcie, PNMC, and Tapaal.

[al] computed at MCC'2014 by Marcie, PNMC, and Tapaal.

[am] computed at MCC'2013 by ITS-Tools, Marcie, Neco, and PNXDD; confirmed at MCC'2014 by GreatSPN, Marcie, PNMC, PNXDD, and Tapaal.

[an] computed at MCC'2014 by Marcie.

[ao] computed at MCC'2014 by GreatSPN, Marcie, PNMC, and Tapaal.

[ap] computed at MCC'2014 by GreatSPN, Marcie, PNMC, and Tapaal.

[aq] computed at MCC'2013 by ITS-Tools; confirmed at MCC'2014 by PNMC, PNXDD, and Tapaal.

[ar] computed at MCC'2014 by PNMC and Tapaal.

[as] computed at MCC'2014 by PNMC and Tapaal.

[at] computed at MCC'2013 by Marcie, Neco, and PNXDD; confirmed by CÆSAR.BDD version 1.8; exact value: 1 048 586; confirmed at MCC'2014 by GreatSPN, Marcie, PNMC, PNXDD, and Tapaal.

[au] computed at MCC'2014 by Marcie.

[av] computed at MCC'2014 by GreatSPN, Marcie, PNMC, and PNXDD.

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## Other properties

A mutual exclusion violation (two concurrent writers) can be checked using a CTL formula like

$$\forall i \neq j: \mathbf{EF} \ (\mathrm{wri}.i \wedge \mathrm{wri}.j)$$

This formula is given for the unfolded low-level models.

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[aw] computed at MCC'2014 by GreatSPN, Marcie, PNMC, and PNXDD.

[ax] computed by CÆSAR.BDD version 1.8.

[ay] computed at MCC'2014 by GreatSPN.

[az] computed at MCC'2014 by GreatSPN.

[ba] computed at MCC'2014 by GreatSPN.

[bb] computed at MCC'2014 by GreatSPN.

[bc] computed at MCC'2014 by GreatSPN.

[bd] the net is safe.