PGM protocol: Experiments with LASH
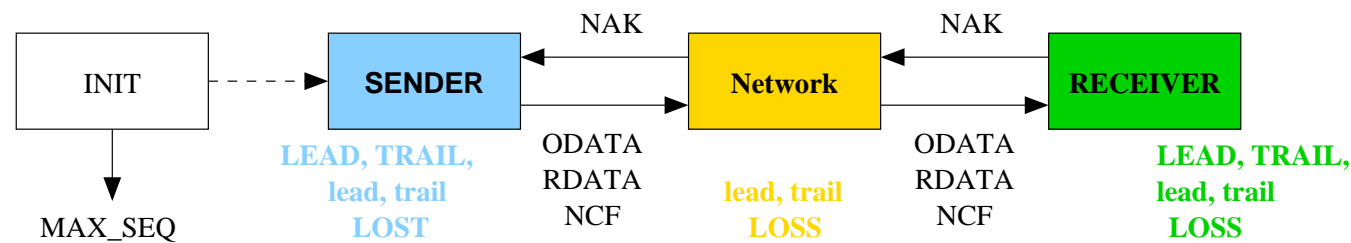
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1. LASH toolkit

Front−ends

Visualization Tool	Arithmetic Solver	Simple−PROMELA Compiler	Simple−IF Compiler

Libraries

Symbolic State−Space Exploration

NDD	RVA	QDD

Finite−state Automata

2. Protocol Model

```
                        NAK                         NAK
  ┌─────────┐       ┌──────────┐      ┌─────────┐      ┌──────────┐
  │  INIT   │- - - >│  SENDER  │<─────│ Network │<─────│ RECEIVER │
  └─────────┘       └──────────┘──────└─────────┘──────└──────────┘
       │                                 ODATA              ODATA
       │            LEAD, TRAIL,         RDATA              RDATA        LEAD, TRAIL,
       ▼             lead, trail          NCF    lead, trail  NCF         lead, trail
   MAX_SEQ              LOST                         LOSS                    LOSS
```
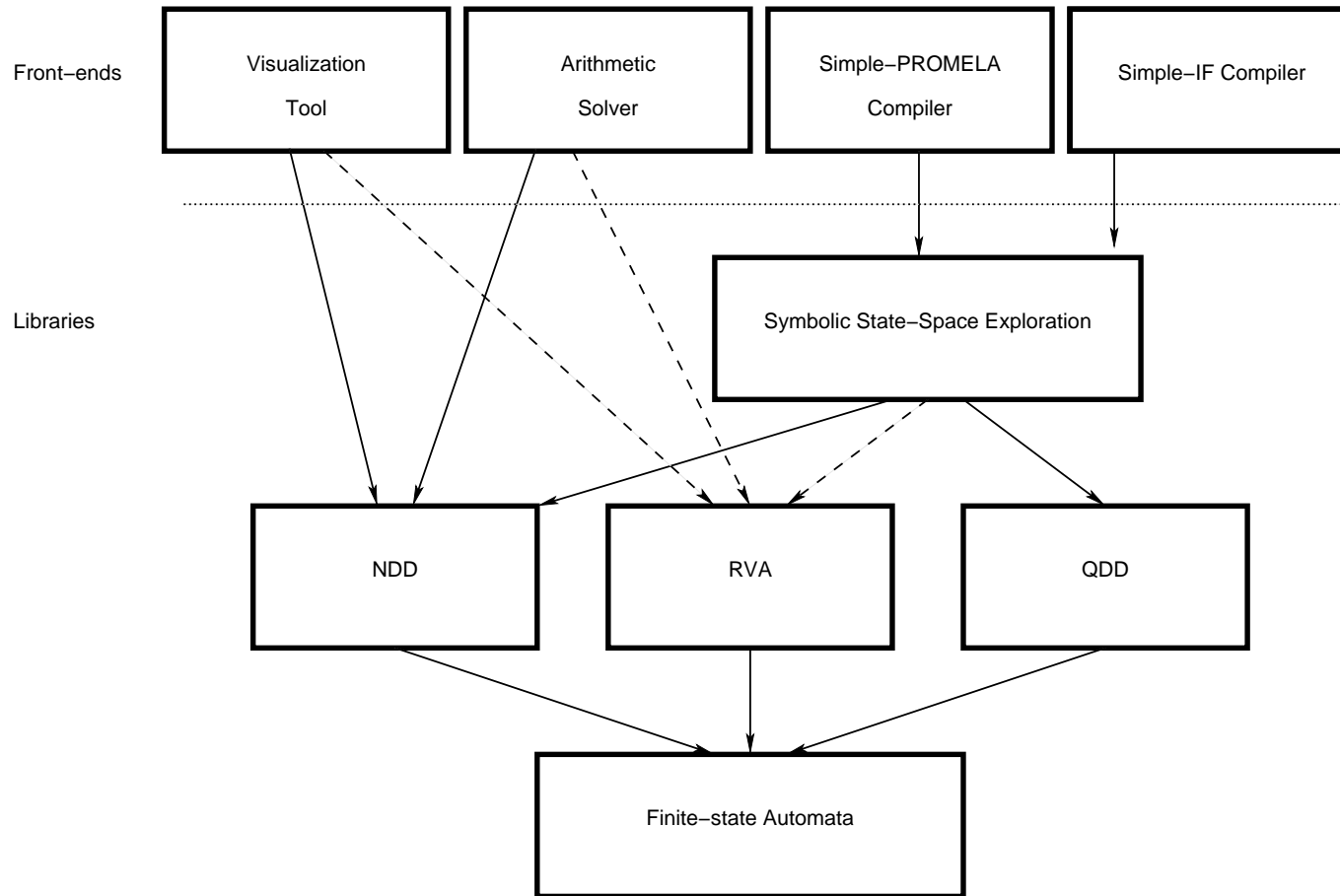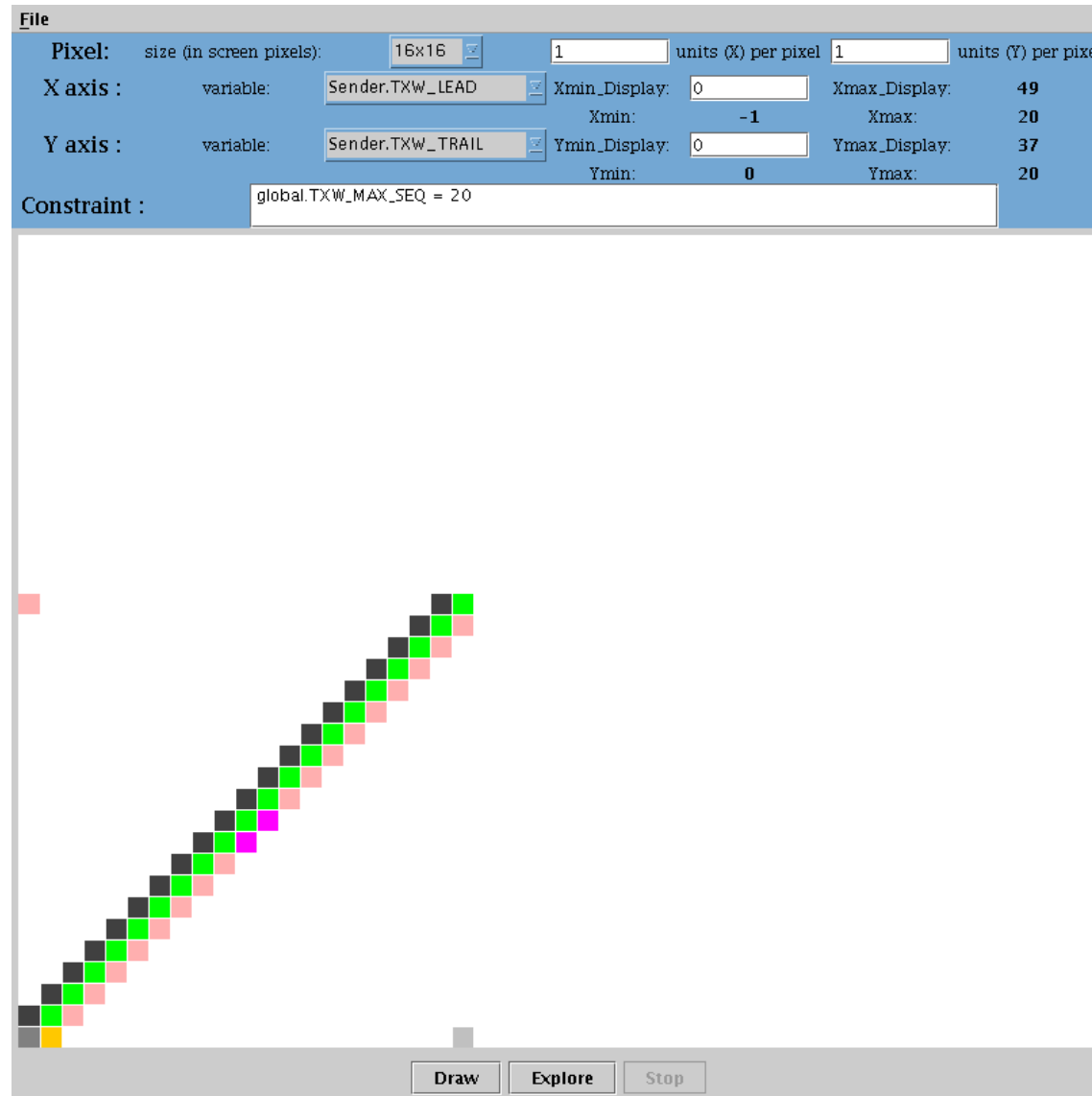
- Messages transfered through SYNCHRONIZATION

- 1 LOSS (at a given sequence number)

- NO SPMs

- NO signal, NO clock

- <u>Sender</u> Window size: variable but bounded, non-deterministic advance (TRAIL and LEAD)

- <u>Receiver</u> Window size: variable and unbounded, non-deterministic advance (TRAIL only)
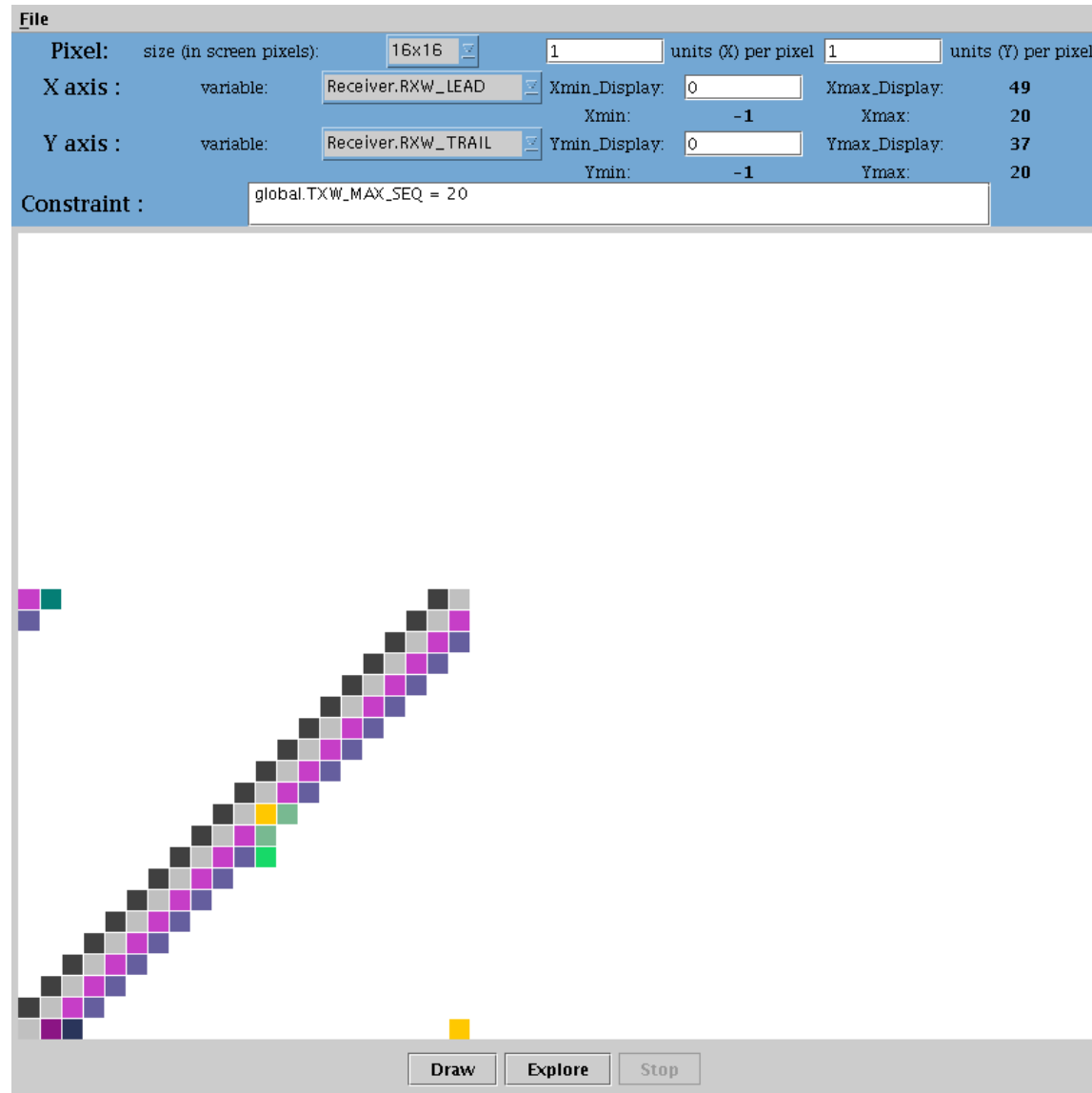
- + Meta-transitions.

3. Verification Task

- Debugging the model

  – Impact of meta-transitions

  – Values of auxiliary variables

- Analysis Goals :

  – Relationships between variables

  – Is there a bound (mod NO_MAX_SEQ) on LEAD - TRAIL ?

4.a Analysis: SENDER (TRAIL vs LEAD) (**MAX_SEQ = 20)**

4.c Analysis: SENDER (TRAIL vs LEAD) (**MAX_SEQ = 20)**

4.d Analysis: Trace (manual)

ACTION	(**Sender**) (LEAD, TRAIL)	Network (**lead, trail**)	(**Receiver**) (LEAD, TRAIL)
init	(7,8)	-	-
send	(7,8)	(8,8)	-
receive (a-b)	(7,8)	-	(8,8)
Sender.LEAD++	(8,8)	-	(8,8)
send	(8,8)	(9,8)	(8,8)
receive (a-b)	(8,8)	-	(9,8)
Sender.LEAD++	(9,8)	-	(9,8)
Sender.TRAIL++	(9,10)	-	(9,8)
loss	(9,10)	-	(9,8)
Sender.LEAD++	(10,10)	-	(9,8)
Sender.TRAIL++	(10,11)	-	(9,8)
send	(10,11)	(11,11)	(9,8)
receive (a)	(10,11)	-	(11,8)
Sender.LEAD++	(11,11)	-	(11,8)
Sender.TRAIL++	(11, 12)	-	(11,8)
send	(11, 12)	(12, 12)	(11,8)
Sender.LEAD++	(12, 12)	(12, 12)	(11,8)
Sender.TRAIL++	(12, 13)	(12, 12)	(11,8)
receive (b)	(12, 13)	(12, 12)	(11,11)

4.e Analysis: SENDER (TRAIL vs LEAD) (**MAX_SEQ = free)**
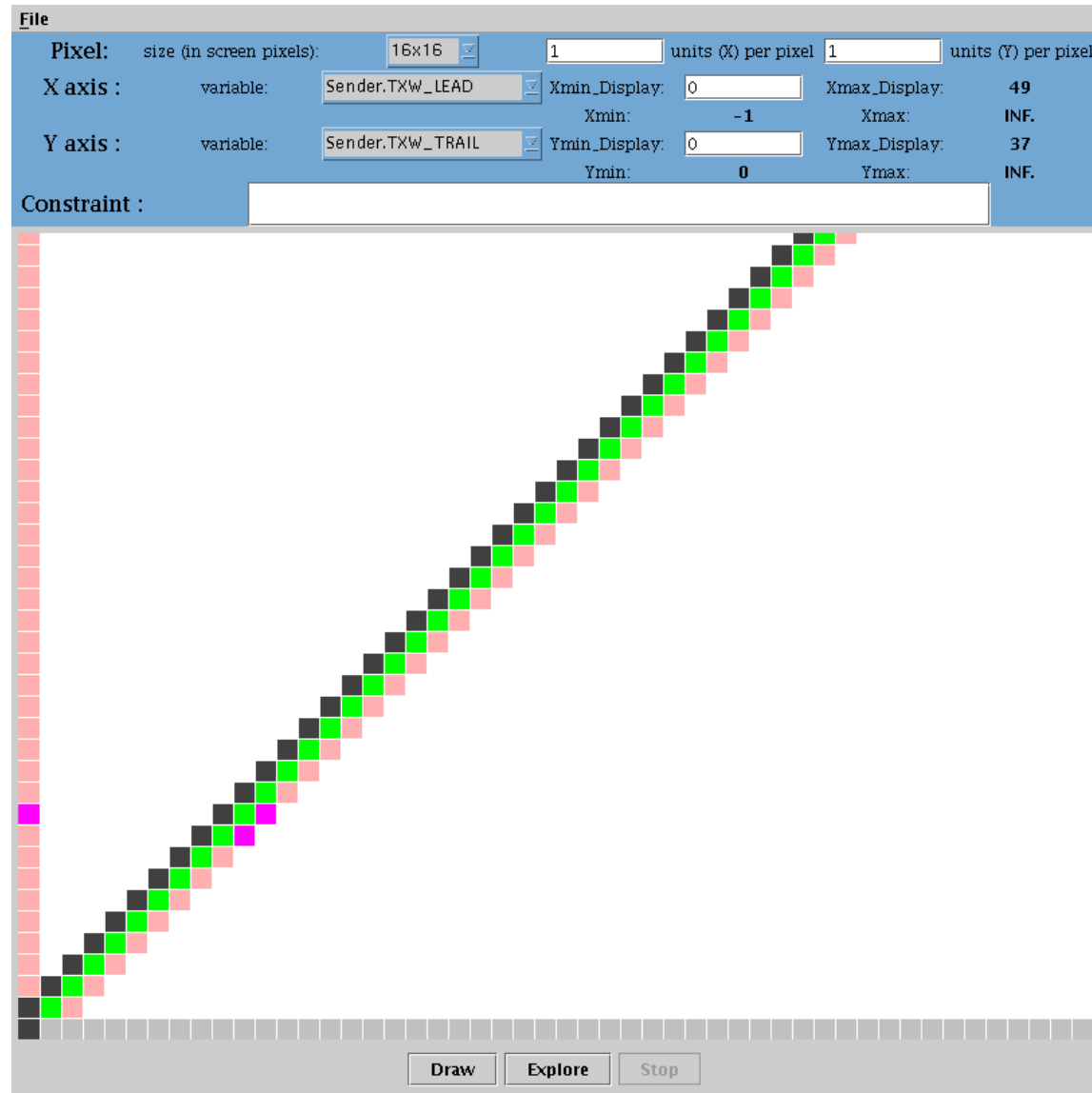
4.g Analysis: RECEIVER (TRAIL vs LEAD) (**MAX_SEQ = 10)**
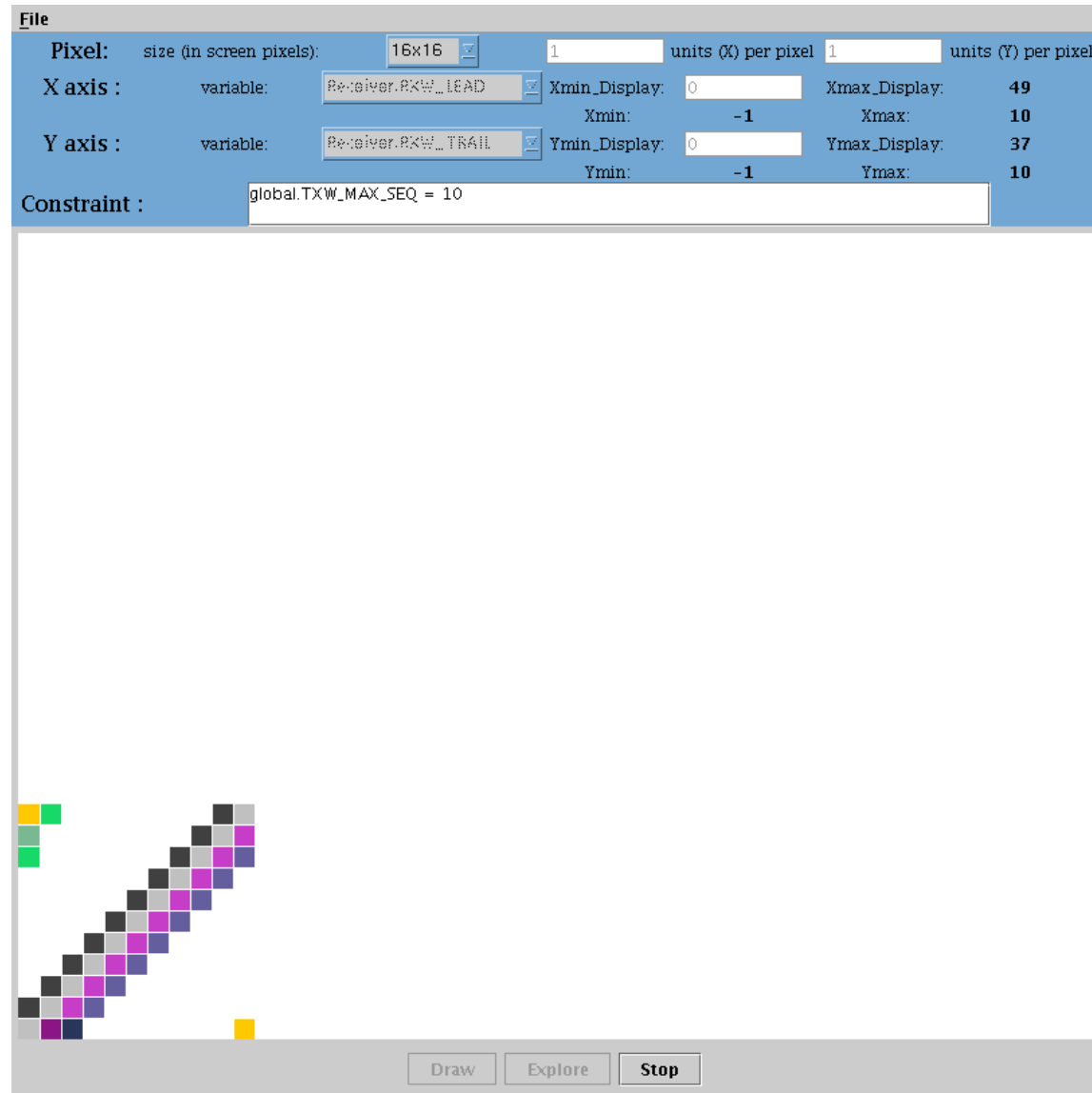
5. Experimental Results (Window size = 2)

MAX_SEQ	Nb_steps	Max. Mem.	Nb. NDD States	Nb. States	Time
20	62	125 Mb	100 K	26 K	7h42
200	62	283 Mb	160 K	249 K	10h19
2000	62	467 Mb	219 K	2,479 K	17h09
20000	62	719 Mb	294 K	24,781 K	35h59
ND	76	279 Mb	225 K	INF.	23h52

6. Property

```
not (
 (Sender.LOST = 0 and
    ( ( Receiver.loop_LEAD = 0 and Receiver.loop_TRAIL = 0 and
        Receiver.RXW_LEAD - Receiver.RXW_TRAIL <= 2 and
        Receiver.RXW_LEAD - Receiver.RXW_TRAIL >= -1)
      or
      ( Receiver.loop_LEAD = 1 and
        Receiver.RXW_LEAD + global.TXW_MAX_SEQ - Receiver.RXW_TRAIL <= 2 and
        Receiver.RXW_LEAD + global.TXW_MAX_SEQ - Receiver.RXW_TRAIL >= -1)
      or
      ( Receiver.loop_TRAIL = 1 and
        Receiver.RXW_LEAD - global.TXW_MAX_SEQ - Receiver.RXW_TRAIL <= 2 and
        Receiver.RXW_LEAD - global.TXW_MAX_SEQ - Receiver.RXW_TRAIL >= -1)))
  or
  (Sender.LOST = 1 and
    ( ( Receiver.loop_LEAD = 0 and Receiver.loop_TRAIL = 0 and
        Receiver.RXW_LEAD - Receiver.RXW_TRAIL <= 3 and
        Receiver.RXW_LEAD - Receiver.RXW_TRAIL >= -1)
      or
      ( Receiver.loop_LEAD = 1 and
        Receiver.RXW_LEAD + global.TXW_MAX_SEQ - Receiver.RXW_TRAIL <= 3 and
        Receiver.RXW_LEAD + global.TXW_MAX_SEQ - Receiver.RXW_TRAIL >= -1)
      or
      ( Receiver.loop_TRAIL = 1 and
        Receiver.RXW_LEAD - global.TXW_MAX_SEQ - Receiver.RXW_TRAIL <= 3 and
        Receiver.RXW_LEAD - global.TXW_MAX_SEQ - Receiver.RXW_TRAIL >= -1))))
```

7. Conclusion

- **Exact reachability analysis of a PGM model with a parametric value of MAX_SEQ.**

- Visualization tool gives essential feedback on the model behavior.

- Slow . . . but once !

8. Future Work

- Incorporate Reals.

- Increase efficiency (better representation, better algorithm, heuristics).

- Add tracing features.