A step towards reconciling GALS industrial design with formal verification

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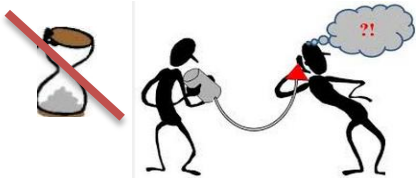
GALS: Globally Asynchronous, Locally Synchronous

- Synchrony
  - Several components governed by a single clock
  - Instantaneous computations and communications
  - Deterministic behaviour

1s, 2s, 3s, …

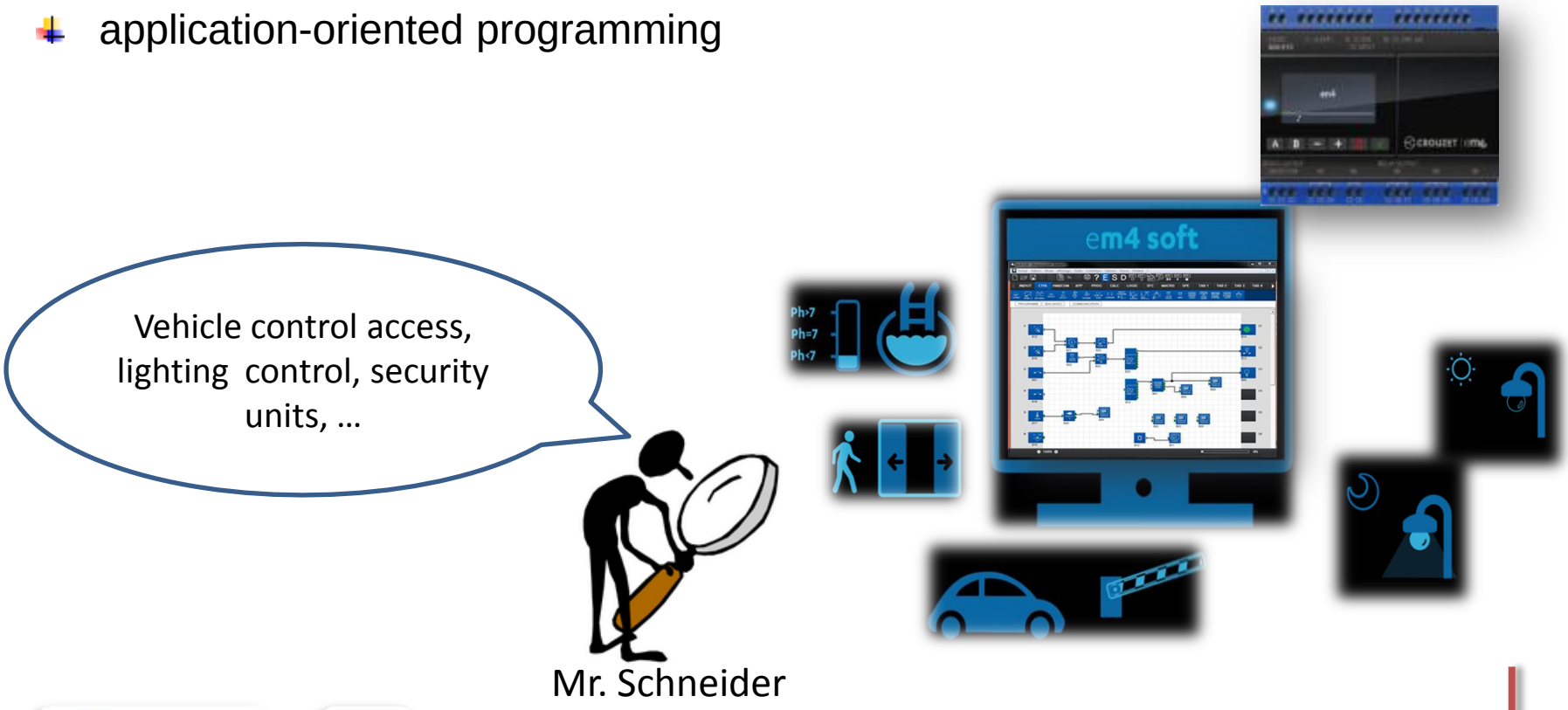
- Asynchrony
  - Several subsystems executing at different speeds and interacting asynchronously
  - Communications take arbitrary delays
  - Nondeterministic behaviour

rendezvous

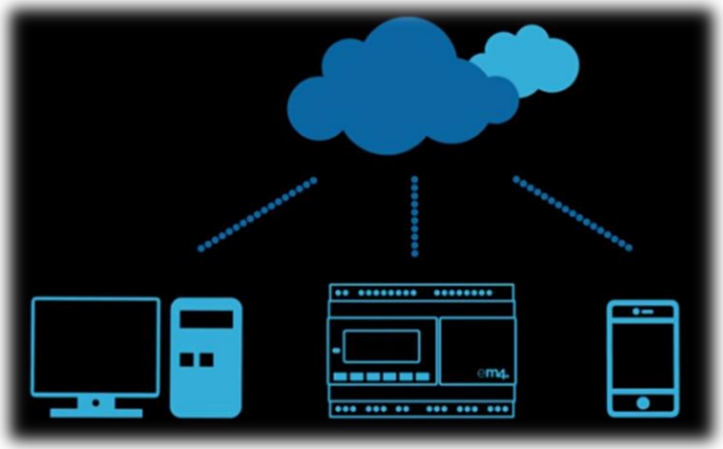


Em4: smart generation of PLCs (Programmable Logic Controllers)

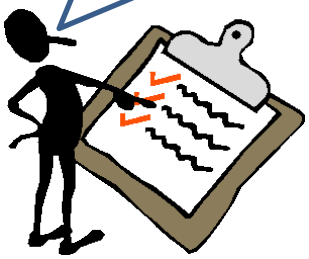
- Software-based and multi-platform systems
- easy-to-use programming tool (block diagram model)
- application-oriented programming



Em4: smart generation of PLCs (Programmable Logic Controllers)

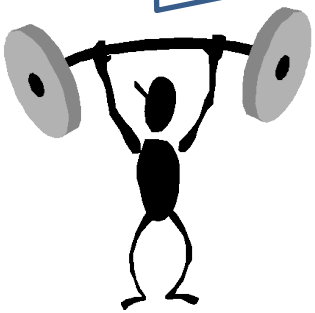


Want my em4 be smarter:
- let distributed programs communicate with each other
- program and validate applications in the cloud from different mobile platforms

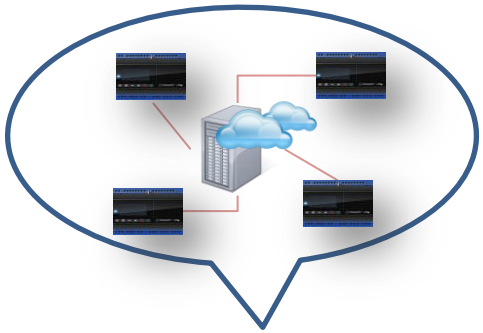


Mr. Schneider

Seems to be innovative.
But, how can I validate em4 networks?



Verification of Em4 applications



Several platforms?!

Mr. Synch

Mr. Schneider

Mr. Asynch

Synchronous features?!

- Powerful automatic tools
- Correct systems

But, expertise required:
Concurrency, formal methods

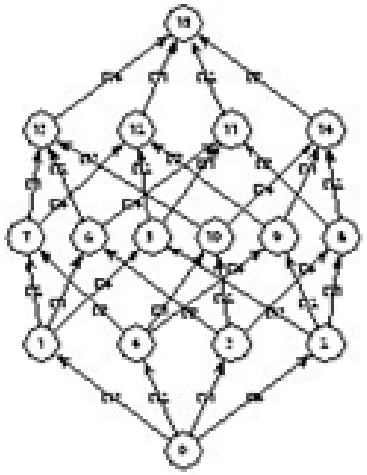
How to bridge the gap between industrial design software and formal verification tools?

CADP Construction and Analysis of Distributed Processes

- Modular toolbox based on formal methods (nearly 50 tools up to now)

- Explicit-state verification
  - Model checking (μ-calculus, MCL)
  - Equivalence checking (bisimulations)
  - Visual checking

- Different techniques
  - Exhaustive
  - Partial
  - On the fly
  - Compositional
  - Distributed

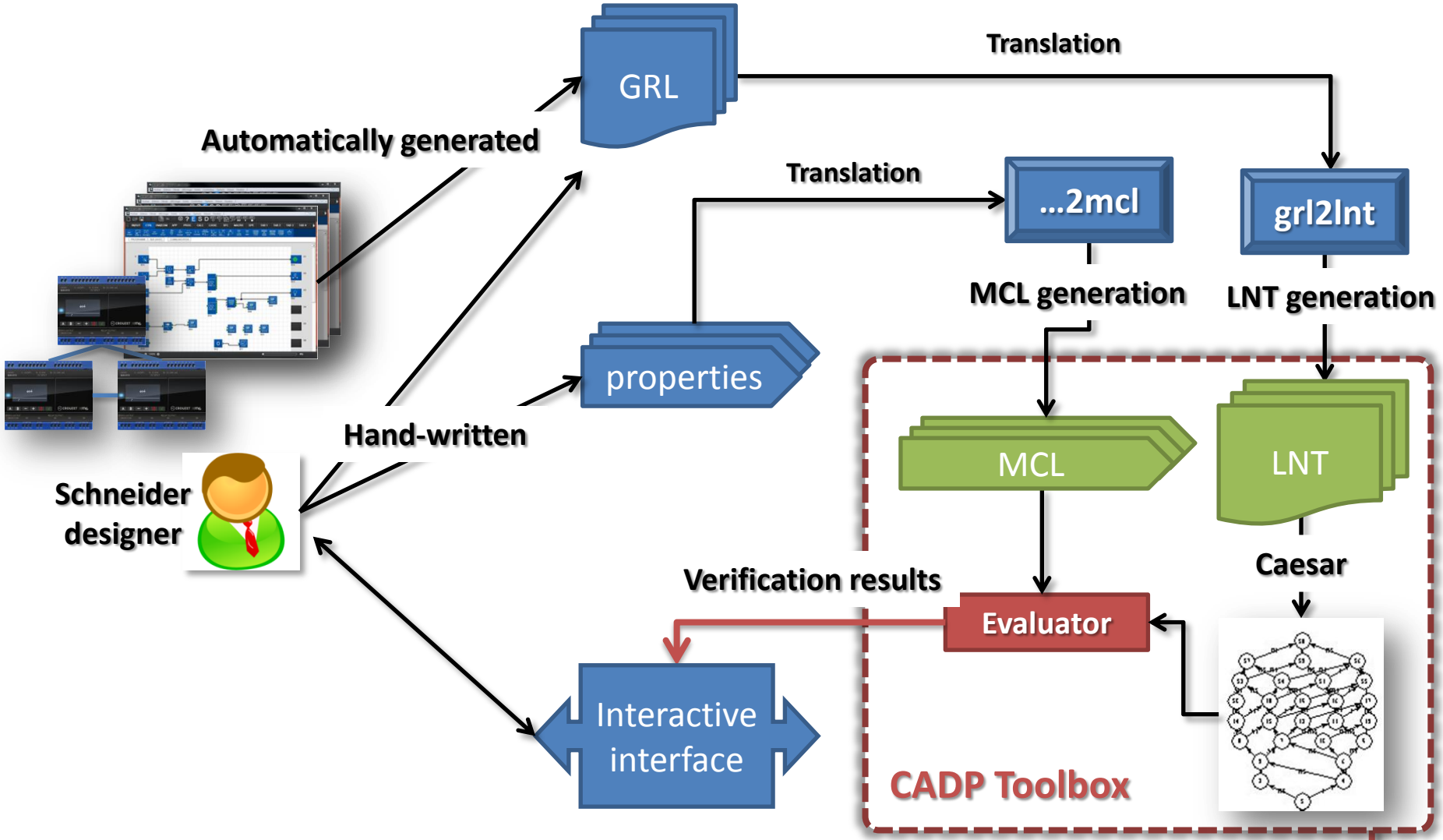


http://cadp.inria.fr

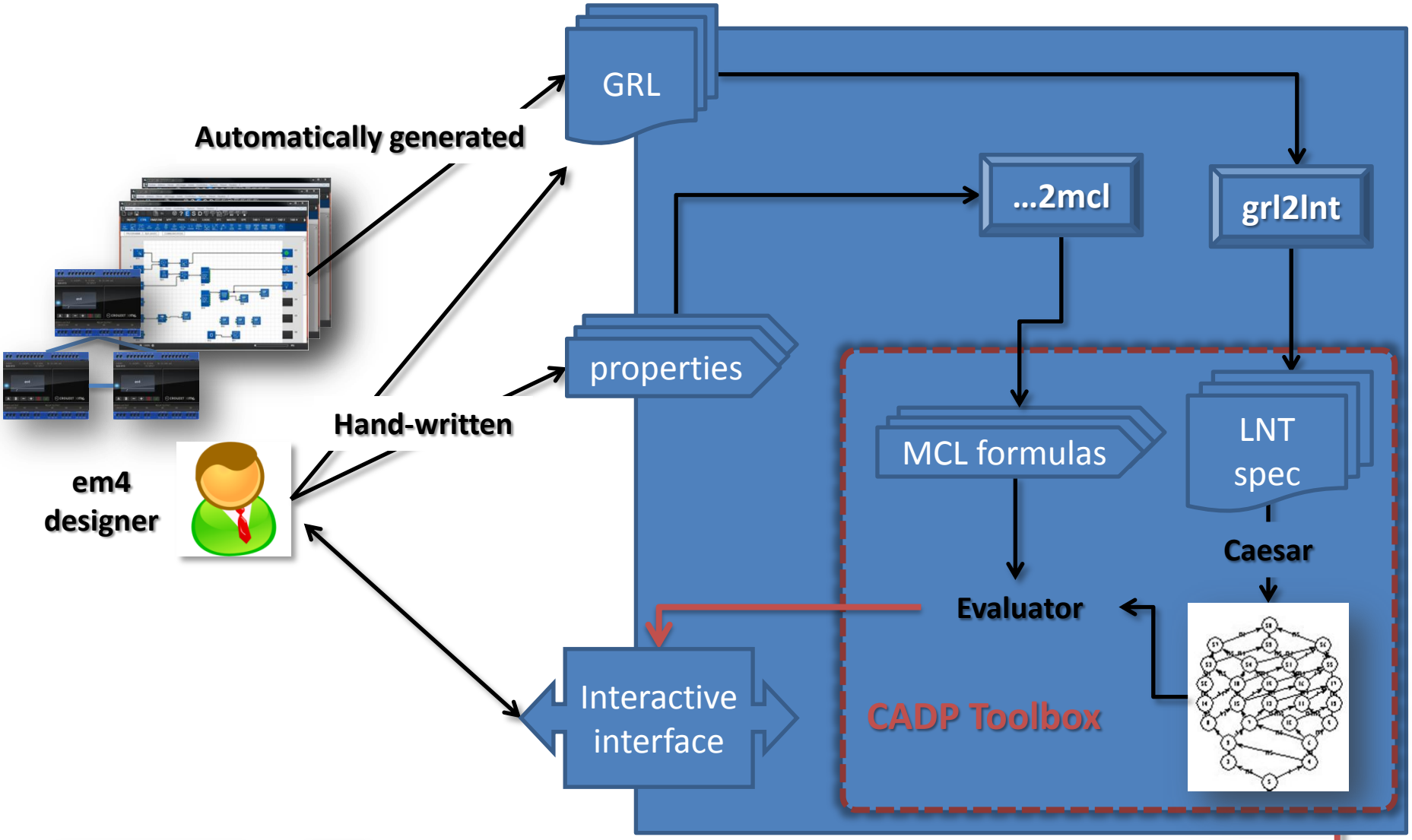
The challenge

- Scalability of Model-checking (state space explosion)
- Expertise required to ensure correct and efficient specifications, write properties
- Automatic modeling and verification is recommended
  - Ability to handle industrial-size applications
  - Designer-friendly interfaces

Towards industrial-friendly formal verification



Towards industrial-friendly formal verification



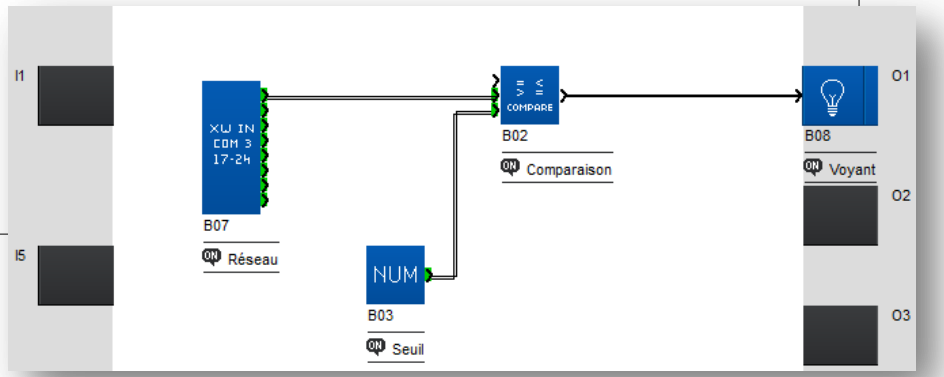
Blocks: synchronous programs

```
block Controller1(out Light : bool)
                 {receive Temperature : nat} is

   allocate Block_Comparator [Superior] as B02_Comparator,
            Block_Numeric_Constant [Threshold2] as B03_Numeric_Constant,
            Block_Xw_In as B07_Xw_In

   perm c0 : nat
   temp c1 : nat, c2 : nat
   B07_Xw_In (Temperature, ?c1);
   B03_Numeric_Constant (?c2);
   B02_Comparator (_; c1, c2; ?Light)

end block
```



Blocks as reactive systems

- Permanently interaction with the environment
- Constraints on one block
- Constraints on several blocks

Blocks as reactive systems

```
environment Env_Sensor (out Sensor : nat) is

   on ?Sensor -> Sensor := any nat
                           where ((Sensor <= 3)
                                  and (Sensor >= 1))

end environment
```

```
environment Env_Sensor (out Sensor : nat) is

   on ?Sensor -> Sensor := select
                              Sensor = 1
                              []
                              Sensor = 2
                              []
                              Sensor = 3
                           end select

end environment
```

Blocks as asynchronously communicating systems

- Accurate design of
  - complex network topologies (bus, ring, star, etc.)
  - connection modes (point-to-point, **multi-point,** etc.)
  - communication protocol

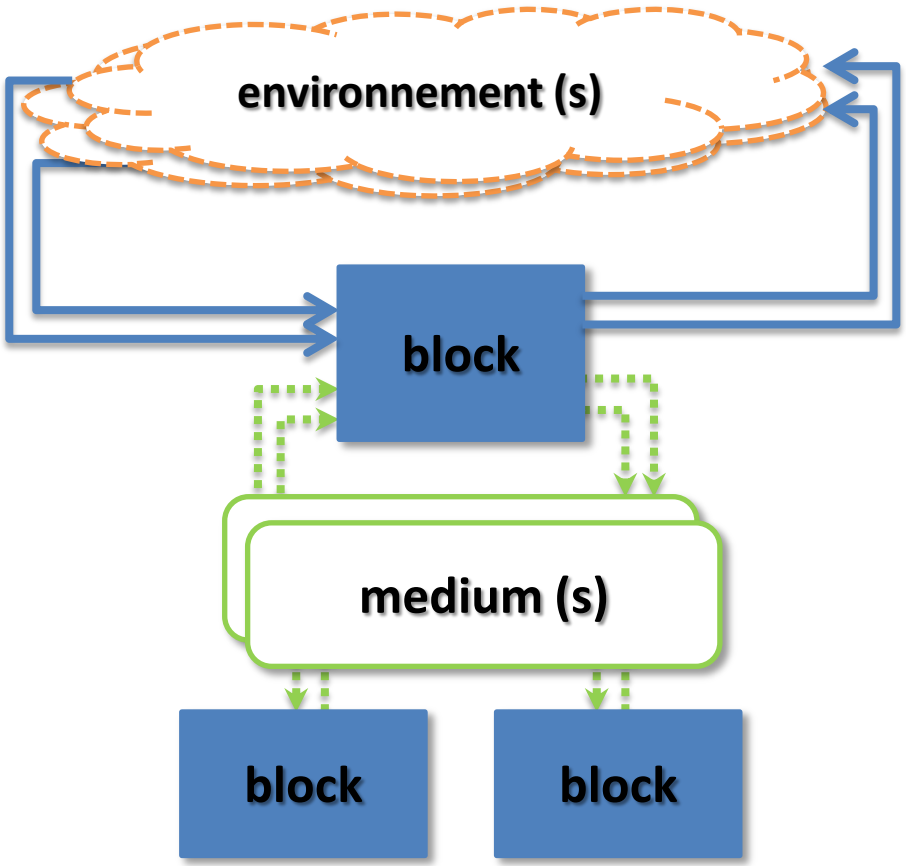
- Existing languages
  - rigid topologies
  - point-to-point communications between separate synchronous systems

Blocks as asynchronously communicating systems

```
medium Med {receive Input : nat | send Output : nat} is
   perm Buffer : nat := 0
   select
     on Input -> if (Buffer == 0)then
                     Buffer := Input
                 else
                    null
                 end if
   []
      on ?Output -> if (Buffer == 0) then
                       Output := 0
                    else
                       Output := Buffer;
                       Buffer := 0
                    end if
   end select
end medium
```

Asynchronous composition and communication

- Define the system actors: blocks, environments, mediums
- Specify interactions between actors (message-passing synchronizations)
- Blocks execute arbitrarily and cyclically (active behaviour), triggering the activation of connected environments and mediums (passive behaviour)



Asynchronous composition and communication

```
system Main (in  Switch : bool; in  Sensor : nat;
             out Is_On  : bool; out Light  : bool) is

   allocate Diagram1 as Controller1, Diagram2 as Controller2,
            Med as Medium1,
            Env_Sensor as Env1

   temp Send_Temperature : nat, Receive_Temperature : nat

   network
      Controller1 (Switch; Sensor; ?Is_On1) {?Send_Temperature},
      Controller2 (?Light) {Receive_Temperature}
   constrainedby
      Env1 (?Sensor)
   connectedby
      Medium1 {Send_Temperature | ?Receive_Temperature}

end system
```

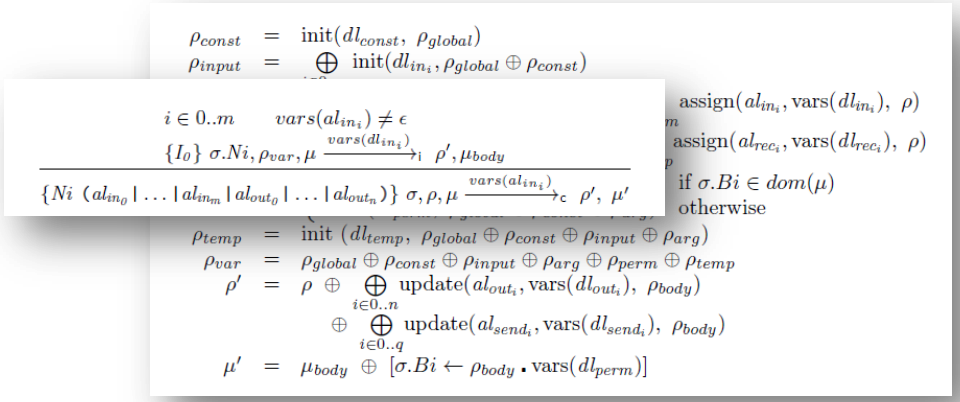
This is just the tip of the iceberg…

First results

- F. Jebali, F. Lang, and R. Mateescu. GRL: A Specification Language for Globally Asynchronous Locally Synchronous Systems (Syntax and formal semantics). Research Report 8527, 82 pages, Inria, April 2014.

- F. Jebali, F. Lang, and R. Mateescu. GRL: A Specification Language for Globally Asynchronous Locally Synchronous Systems. In Proc. of ICFEM, October 2014.

- Automatic translator **grl2lnt** already designed and implemented, paper to be submitted (ETAPS 2015)



Ongoing work

- Automatic generation of GRL code from em4 software applications (large-scale industrial case studies)
- Industrial-friendly property language

Future work

- Automatic C code generation from GRL
- Connect GRL to other industrial frameworks to handle more instances of GALS systems
- Connect GRL to other verification tools

Thank you