Verifying Large SDL-Specifications using Model Checking

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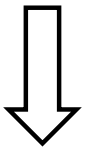
Outline

- *Motivation*
- *Mascara protocol*
- *Model-checking environment*
- *Verification methodology*
- *Verification results*
- *Conclusions*

Model Checking in Practice

Model checking problem:
Does system S satisfy property f?

Method: *state-space exploration*



Pros: *a "push-button technology"*
and
Cons: *applicability to relatively small finite state systems only*

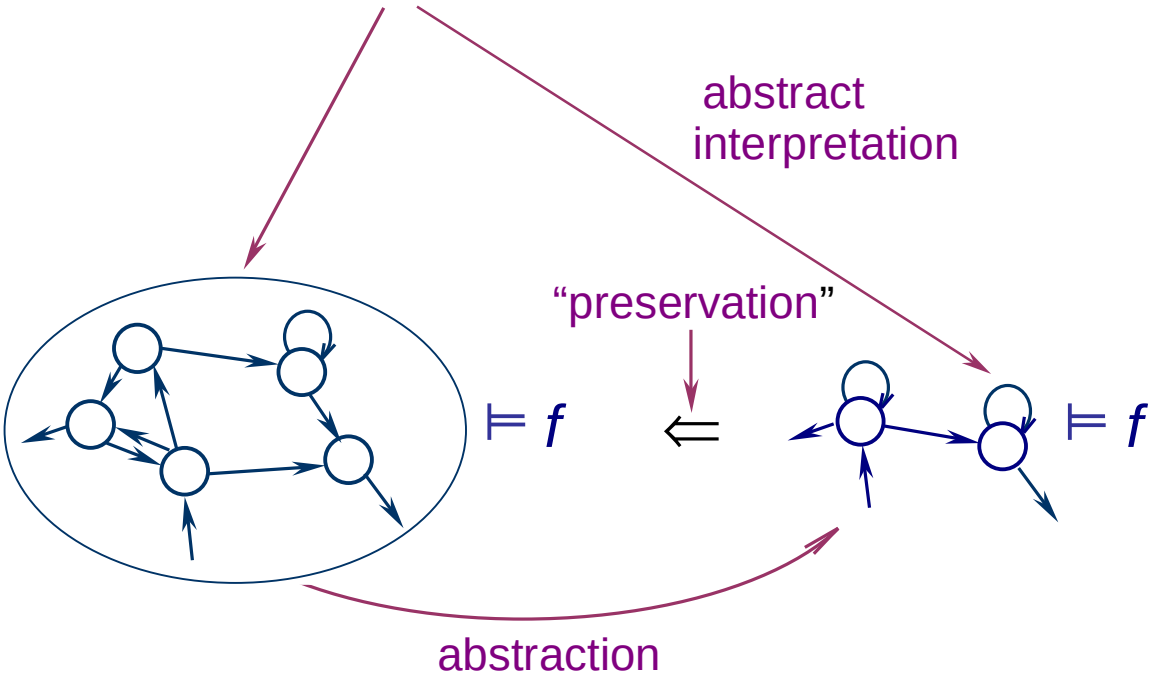
Task: *to verify (model-check) the control layer of the wireless ATM communication protocol Mascara*

?????

Abstraction and Compositional Techniques

Abstraction:

Does system S satisfy property f ?



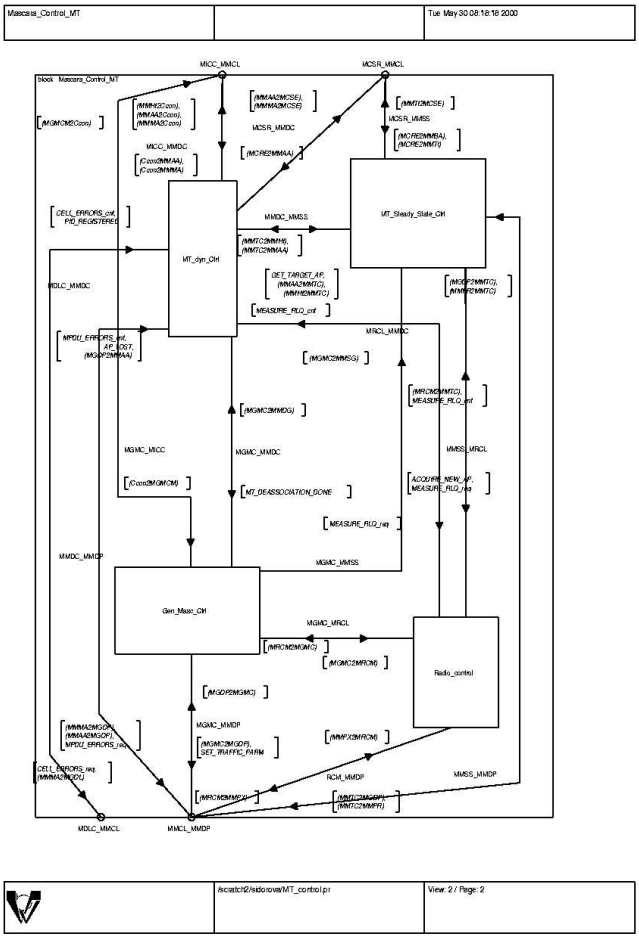
Safe abstractions:

Every property checked to be true on the abstract model holds for the concrete one as well.

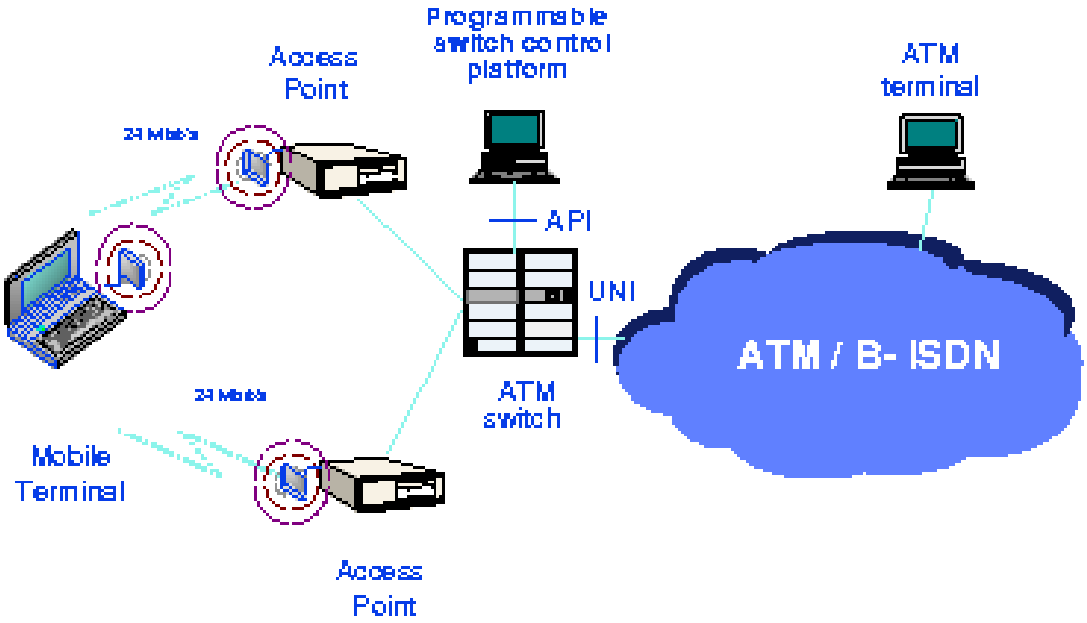
Abstraction and Compositional Techniques

Compositional approach:

Divide et impera!



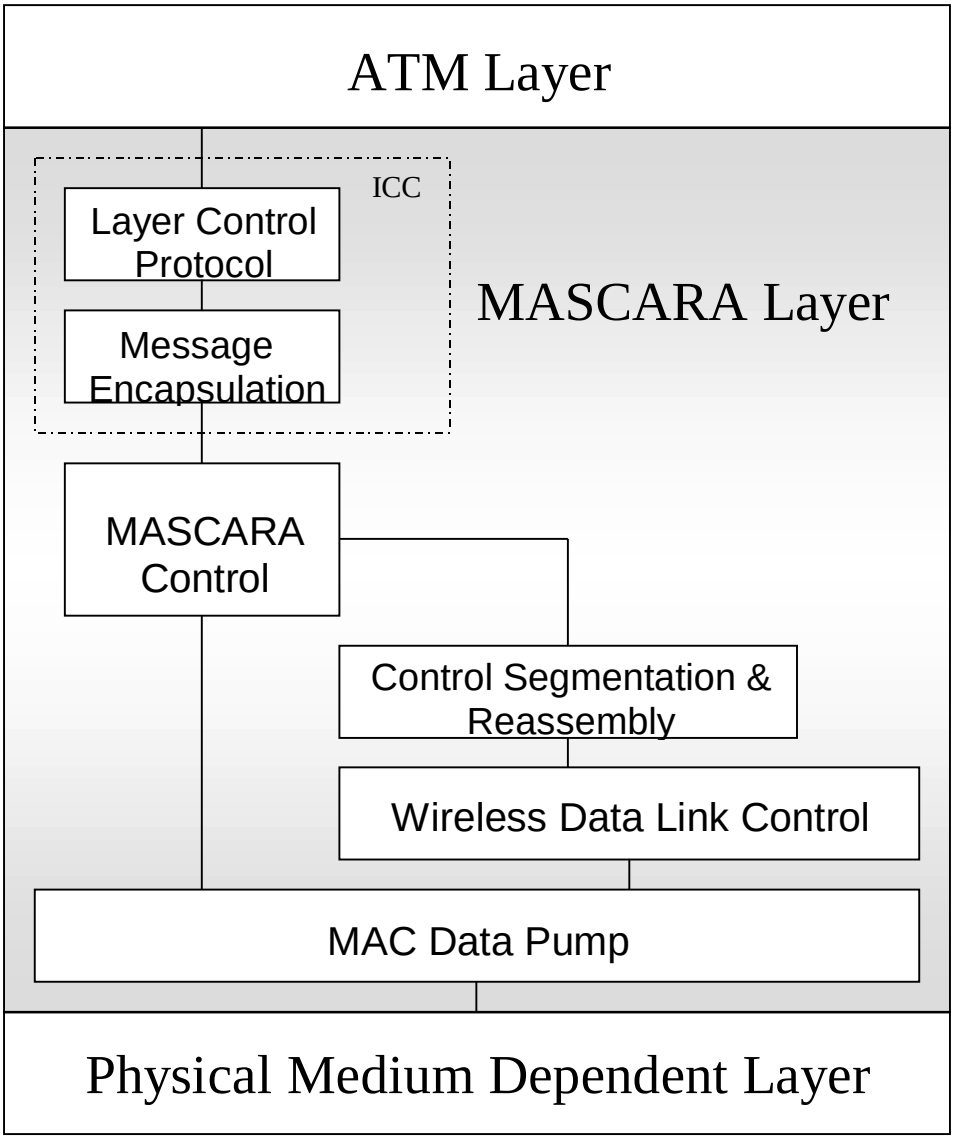
Mascara Protocol



A medium-access layer for wireless ATM communication in local area networks, developed within the WAND project (Intracom)

- *Cell-delineation*
- *Transmission frame adaptation*
- *Header error control*
- *Cell-rate decoupling*
- *Operating over radio links*
- *Mobility features*

Mascara Protocol (continued)



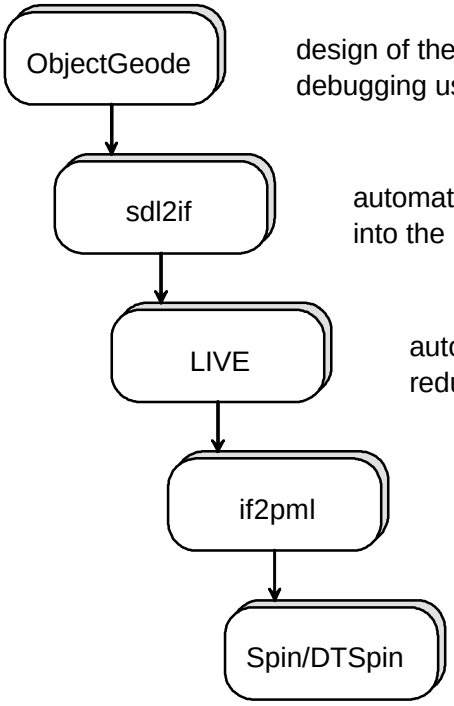
Mascara Control

Function: *to maintain and to manage associations and connections*

Sub-entities:

- *Dynamic Control*
  sets up and tears down associations and connections, performs address management and resource allocation
- *Steady-State Control*
  monitors current associations and the quality of radio environment, initiates in time handovers (change of associations)
- *Radio Control*
  upon a request instructs the radio modem to tune into a specific radio frequency and reports back whether it succeeded or not
- *Generic Mascara Control*
  brings into operation and terminates the entire MAC layer.

Model-checking Environment



design of the SDL-specification, syntax checking, debugging using the ObjectGeode simulator facilities

automatic translation of the SDL-specification into the Intermediate format (IF)

automatic transformation of the IF specification reducing the state space of the model

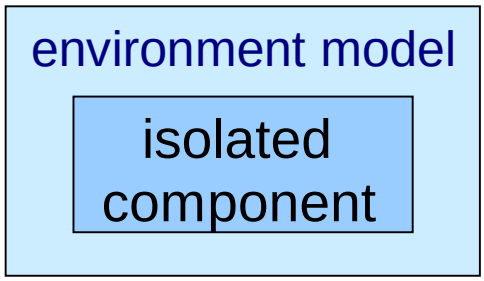
automatic translation of the obtained IF-specification into DT Promela/Promela

model checking the model

Bottom-up Verification

- *How to break-up complex program into smaller entities?*
- *How to close the smaller components in order to feed them into the model-checking environment?*
- *How to simplify and abstract these components to withstand the state-space explosion?*
- *How to proceed from the verification of small components to the verification of blocks constructed out of these components?*

Modelling Environment
(control abstractions)

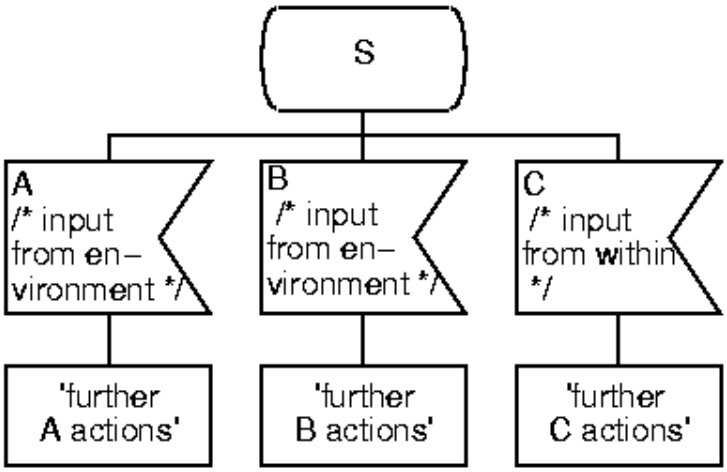


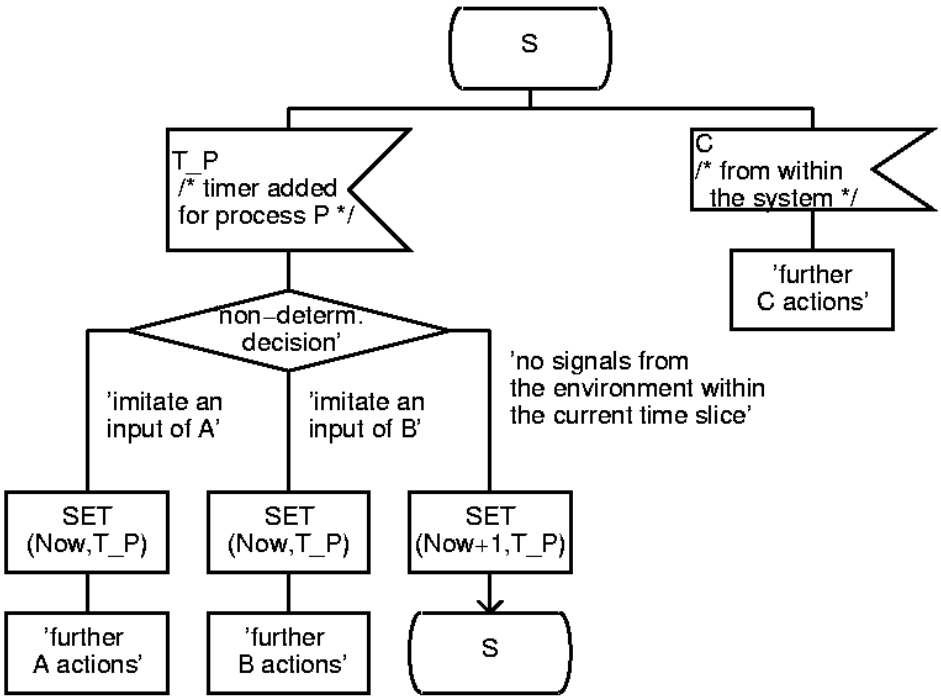
Chaotic environment

- *all traces are allowed ⇒ abstraction is safe;*
- *can be constructed fast and routinely*
- *the structure of the entity under investigation is left untouched*
- *it can cause "false-negatives"*
- *redundant behaviour can increase the state space*

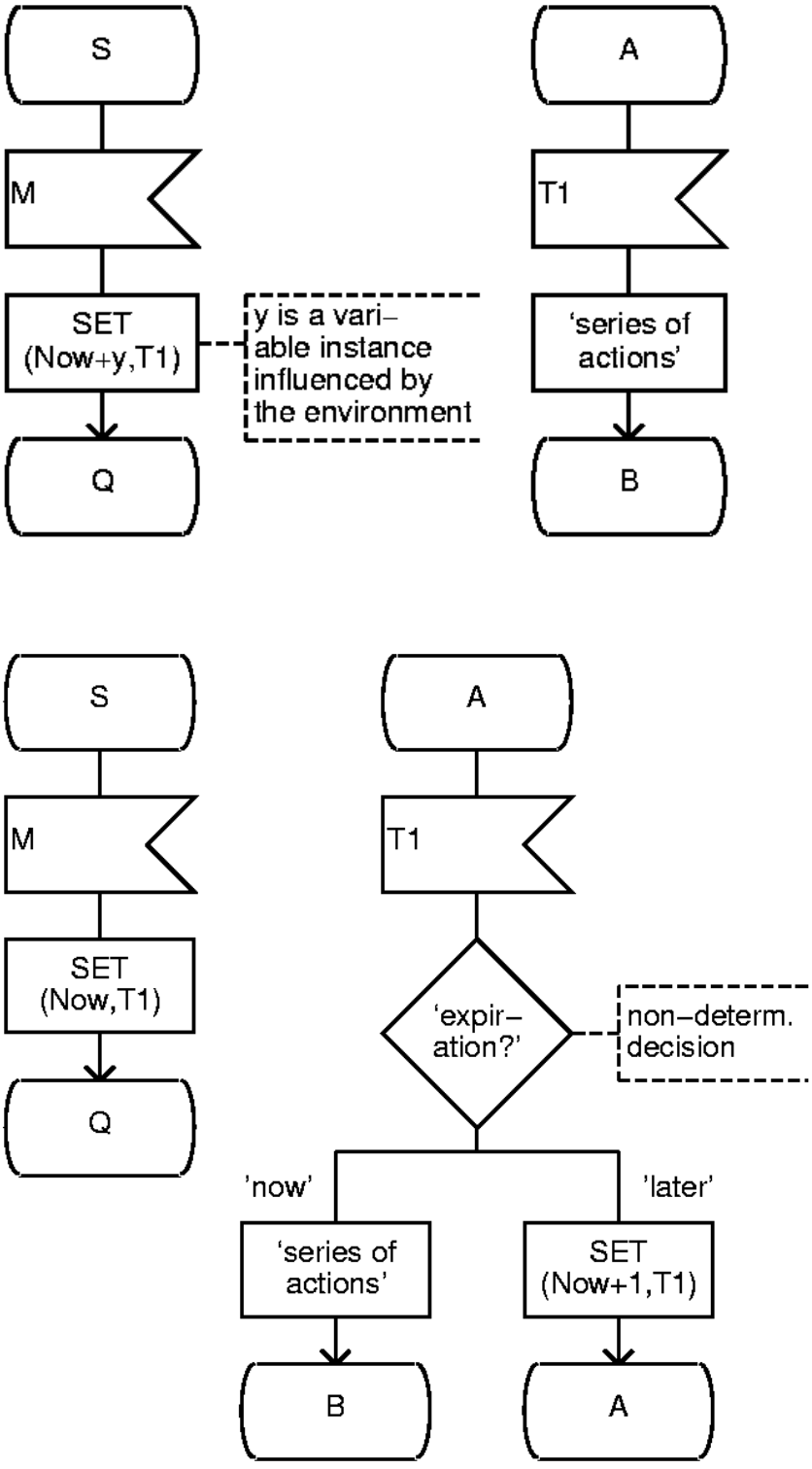
Solution: embedded chaotic environment

Inputs from the Environment

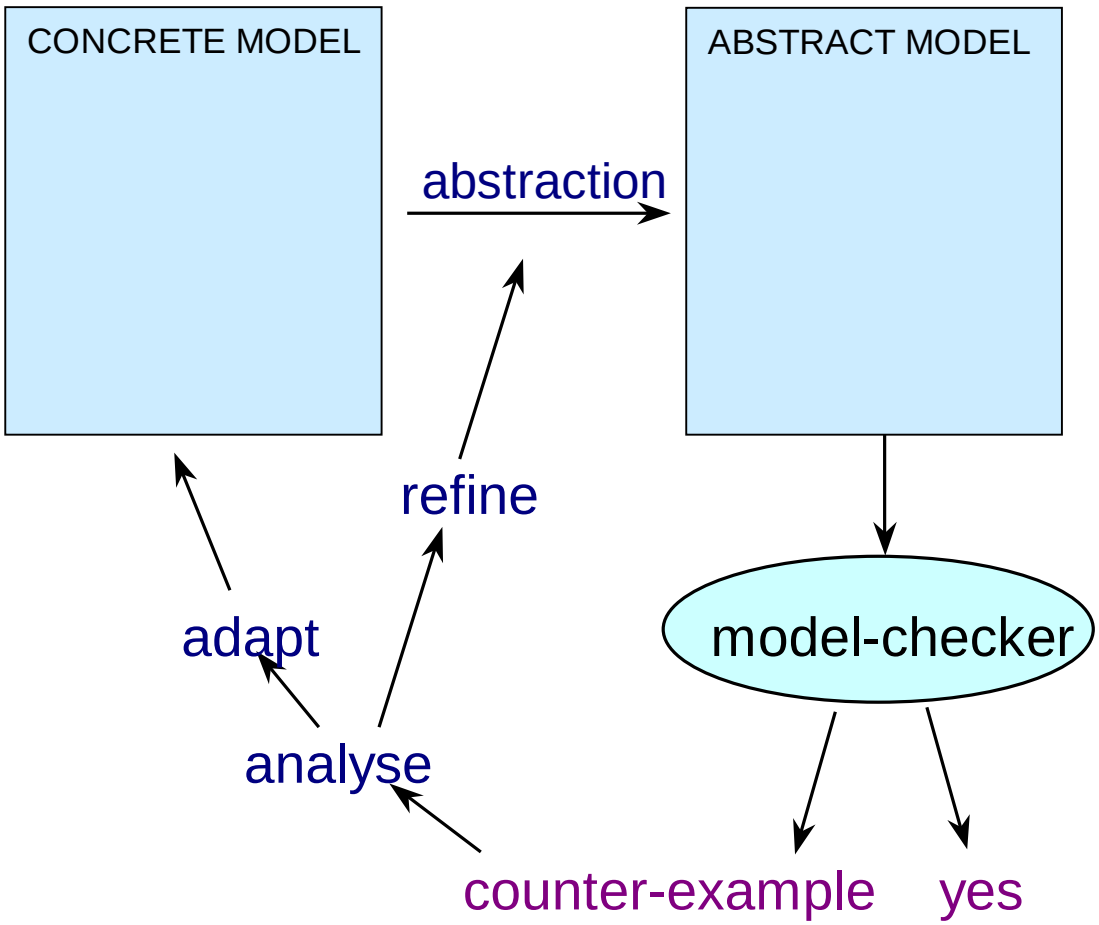


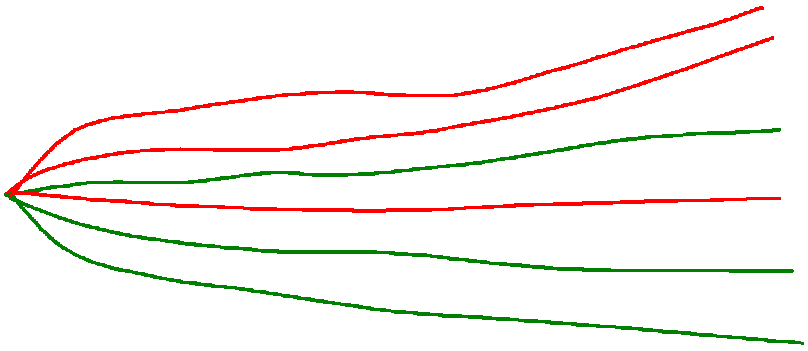


Transformation of timers



Applying Safe Abstractions

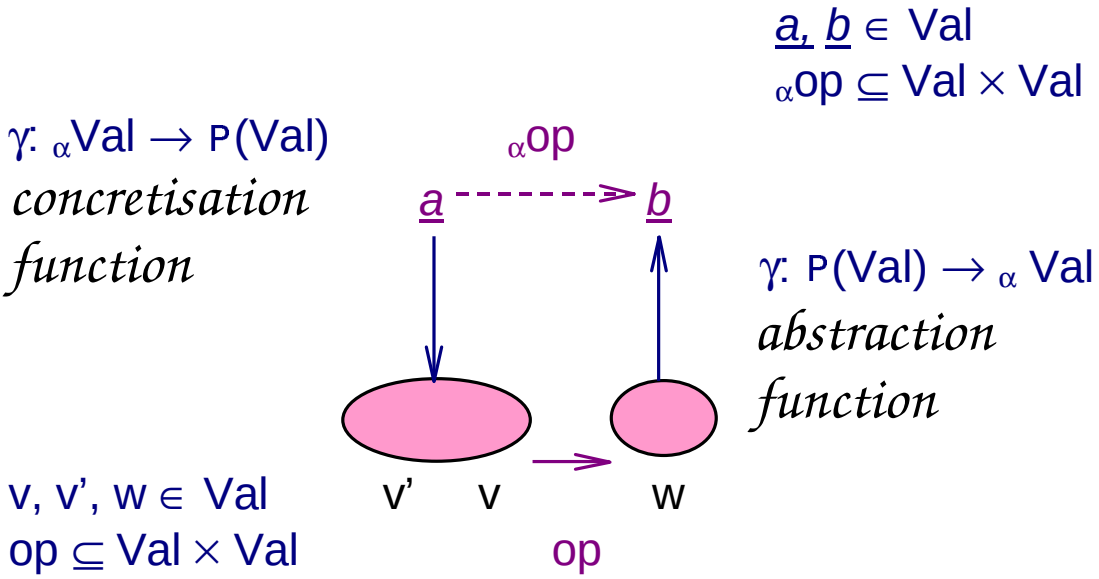




Data Abstractions

Idea:

Replace data values by descriptions (abstract values) and "mimic" operations. Then every universal property checked to be true on the abstract system holds for the concrete system as well.



(α, γ) Galois Insertion

[Cousot & Cousot 77
Clarke, Grumberg & Long 92
Graf & Loiseaux 92
Dams, Gerth & Grumberg 94]

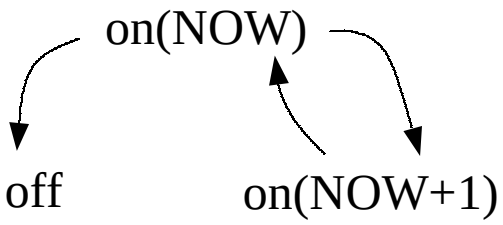
Time abstraction

3-values abstraction:

off → *off*

0, 1, 2, … → *0*

1, 2, 3, … → *1*



Spin ? DT Spin

Time-dependant property ⇒ *verification of the concrete model in DT Spin*

Property that should hold for all timer settings ⇒ *verification of abstract model in Spin*

No clear dependence on time ⇒ *???*

Time abstraction (continued)

No clear dependence on time ⇒
Do you really think the property holds?

If yes, try to verify the abstract model first;
if the property is proved then stop,
otherwise switch to the concrete model

Reason:

An abstraction adds some behaviour ;

if the property is disproved, it should be checked whether the erroneous trace given by Spin is a real error or a false error caused by adding behaviour.

DT Spin guarantees that timers expire in the correct order ⇒ less "false-negatives"

An Example:
Abstracting Radio Control

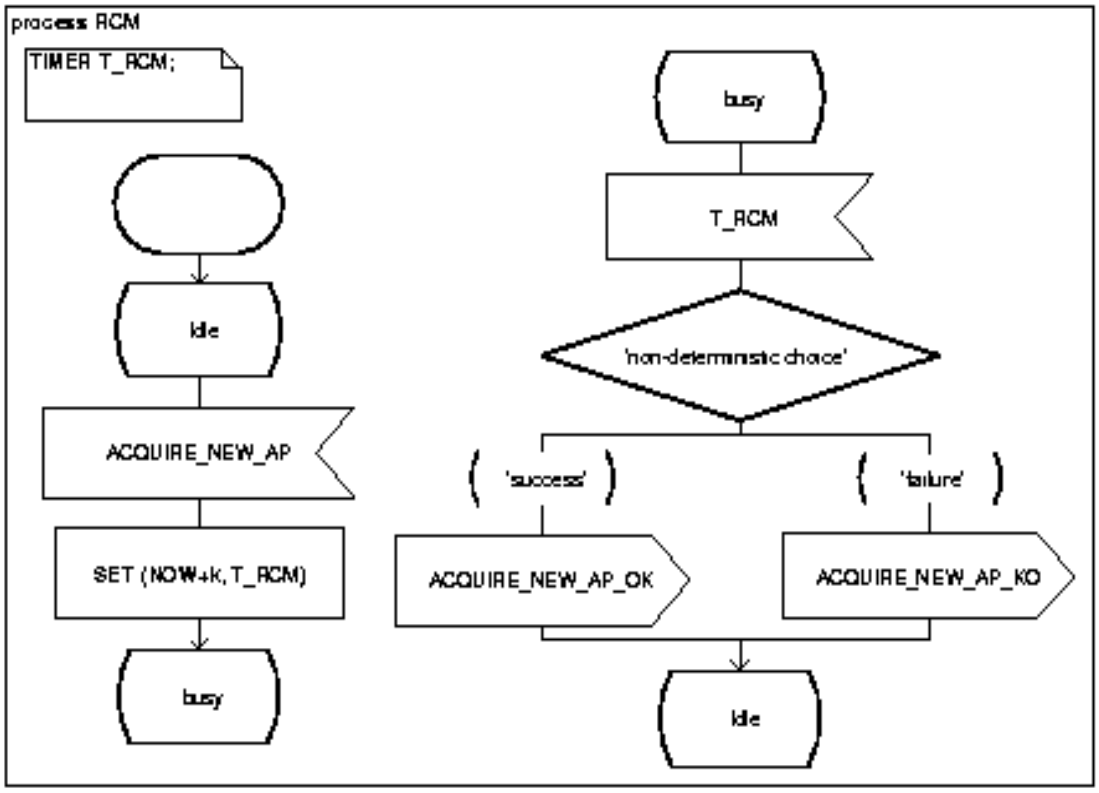
Property (formalized in LTL)

" Whenever, after initialisation,
the radio control manager receives a request *AcquireNewAP(newchannel)*,
the RCM-process responds either positively or negatively (*AcquireNewAPok* or *AcquireNewAPko*).

Moreover, the answer is sent in a given amount of time after getting the request."

was proved for the component closed in a chaotic environment with the only restriction on the number of signals that can be send per time unit.

An Example: Abstracting Radio Control
(continued)



Abstract Radio Control Manager

Verifying Mascara

- Reachability checks: *"A distinguished state will be eventually reached".*
  - Analysis of the unreachable code detected by Spin
  - Assertion violations
- Safety properties:
  "Nothing bad may happen".
  - Variables are not out of range
- Liveness properties:
  "Something good has to happen".
- Response properties: *"Every request is eventually confirmed" and "Every acknowledgment is caused by a previous request.*
  - Bounded response properties:
    The confirmation comes within some defined amount of time.

Errors found

- programming errors
  - Forgotten branches in case distinctions
  - Mal-considered limit cases in loops
  - ...
- race conditions
- ambiguous receiver
- unspecified reception
- variables out of range
- components waiting for a reception confirmation that does not come

A Time-Dependent Safety Property

Safety requirement:

"never the access point relinquishes an association before the mobile terminal does"

In *LTL:* $\Box(\varphi_{\text{mt-lost}} \rightarrow \varphi_{\text{ap-lost}})$

$\varphi_{\text{mt-lost}}$ – the *access point* gives up the association sending the signal *MT_Lost*.

$\varphi_{\text{ap-lost}}$ – the *mobile terminal* gives up the association.

The property holds if $min(\tau_{AP}) > max(\tau_{MT})$

$$\tau_{AP} \geq (Max\_Time\_periods + 1) * T_{iaa\_poll} + (IAA\_Max - 1) * T_{frame\_start}$$

$$\tau_{MT} \leq (Max\_Cellerrors) * T_{GDP\_period} + (Max\_AP\_Index + 1) * T_{RCM}$$

Conclusions

- Model-checking is an effective way of *debugging*.
- Reports of a model-checker about *unreachable code* are a cheap and easy way for the following debugging.
- *Shortest trail* option greatly simplifies the analysis of the cause of the error.
- Verifying simple properties is very fruitful for finding errors.
- *Tools supporting abstractions* are needed! Just with applying the *Live* tool, the state space is in average reduced by one order of magnitude.