Specification of Distributed and Embedded Sytems

MDE, Distributed Components & Specification Environments

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Schéma du cours

1. **Introduction: concurrence/parallelisme, synchrone/asynchrone, embarqué/distribué** RS
2. **MDE: machines d'états, diagrammes d'activité, composants** EM
3. **Calculs de processus et SOS** LH
4. **Composants asynchrones et fondements de ProActive** LH
5. **Sémantique synchrone (Esterel)** RS
6. **Logique temporelle** EM
7. **Model Checking** RS
8. **EXPOSES**

Flash back & keywords…

- Formal methods in the design flow of distributed/embedded systems
- Provide mathematical semantics to models so that their relation to implemented product can be asserted and proved :
  - model checking, equivalence checking
  - test generation
- Communication and control (control-flow): interactions, protocols
- Modeling languages:
  - UML and variants (StateCharts, SysML,…)
  - Dedicated IDLs and ADLs for system decomposition (…)

Systems: structure and behavior

In general, a system is:

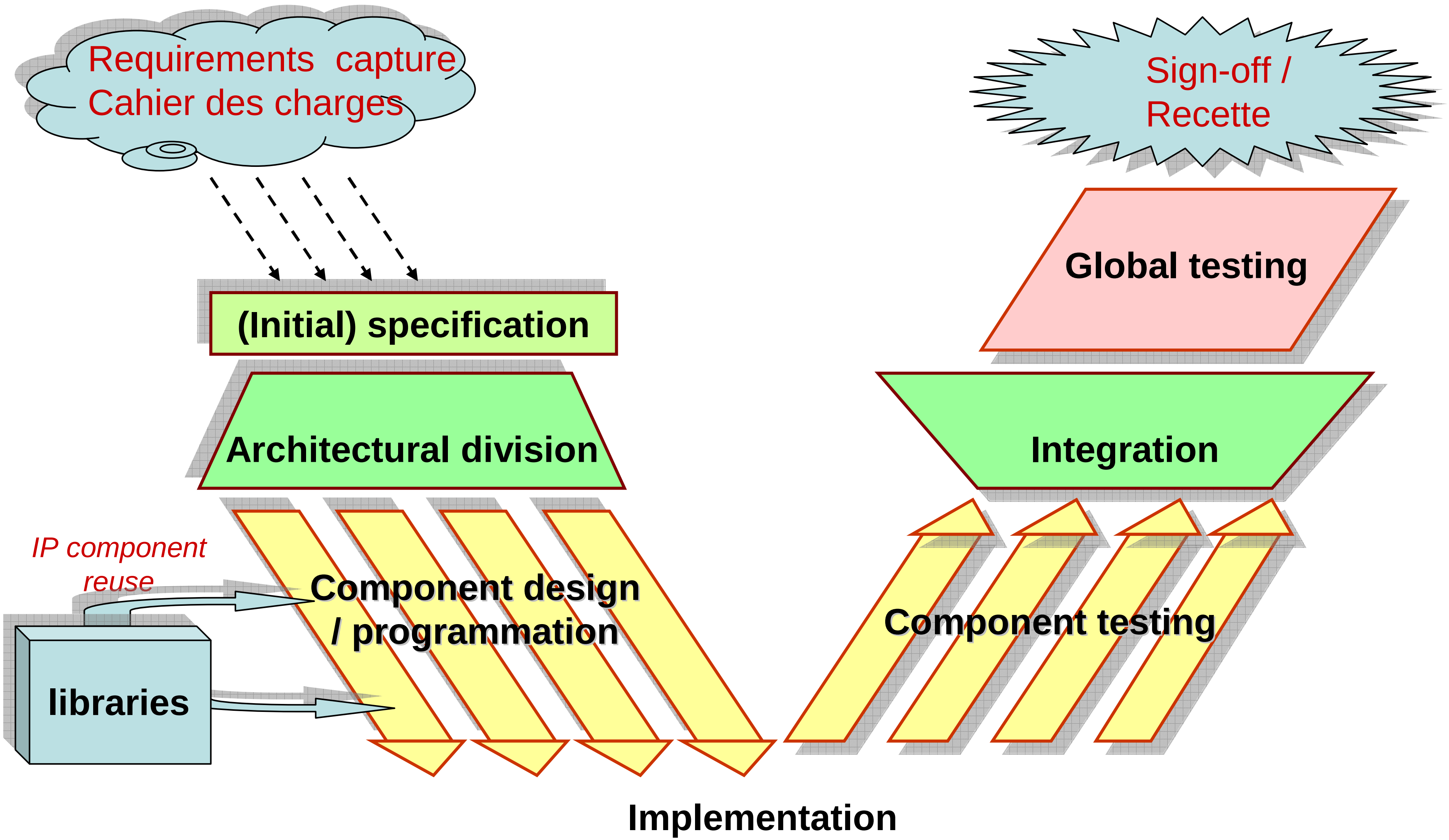
- constituted of components, interacting in a collaborative or hierarchical fashion (structure)
- evolving, as a result of the composed functional of its components (behavior)

a system changes state through time; time is counted in number of actions/operations

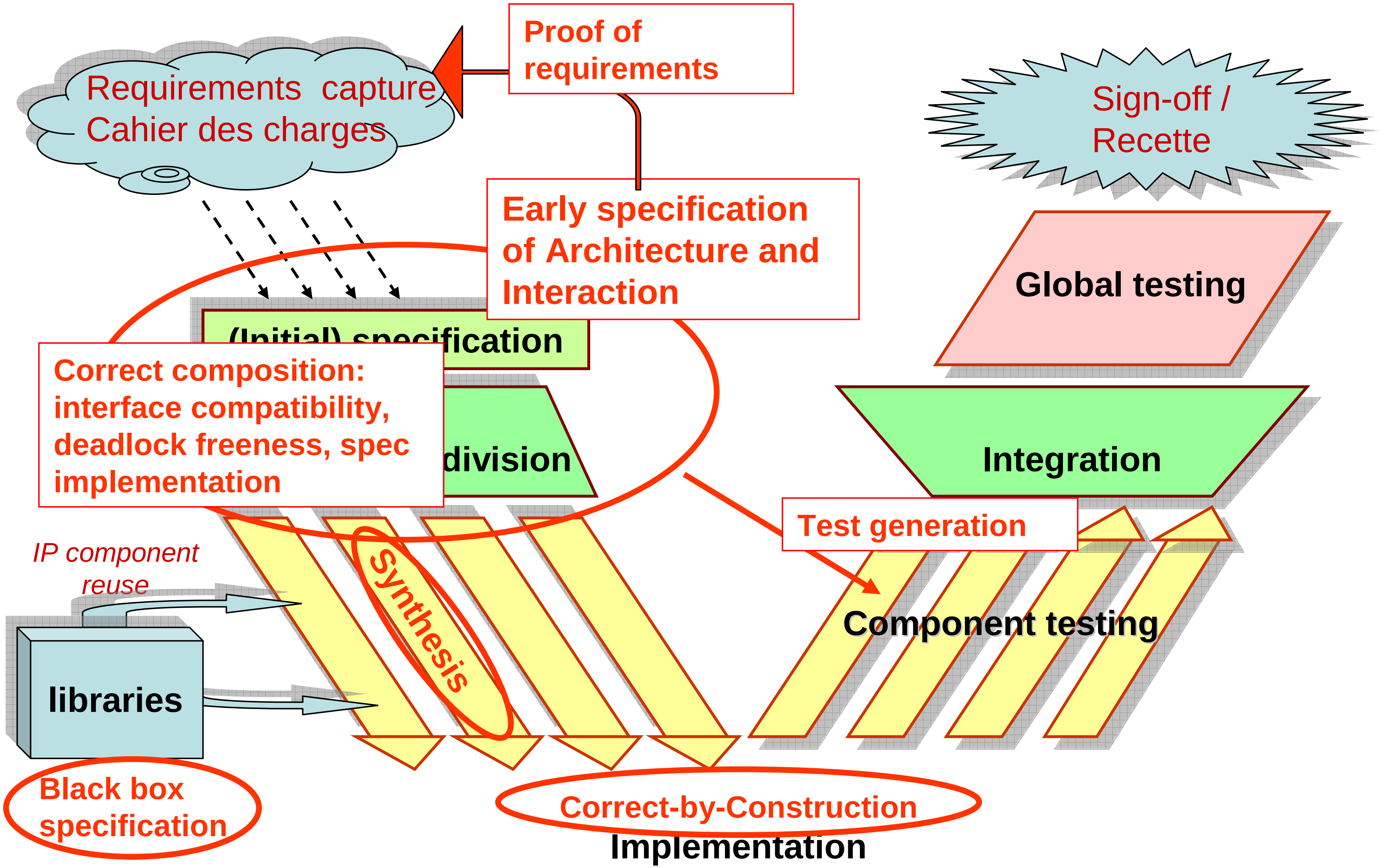
- In highly dynamic systems the division is blurred, as structure is transformed by behaviors; e.g. in large scale software services (= business grids, SOA, …)
- rarely the case in embedded systems

See UML and elsewhere, models divided between structural and behavioral ones

Cycle de developpement/ design cycle



Cycle de développement/ design cycle



Agenda

- Graphical Modeling Languages :
  - » A zoo of UML diagrams
- Components models :
  - » Fractal, GCM
- Tools
  - » Build development platforms ?
- Hands-on exercices

UML -- MDE -- Visual models
Single (unified)

Too many different languages, platforms, formalisms….

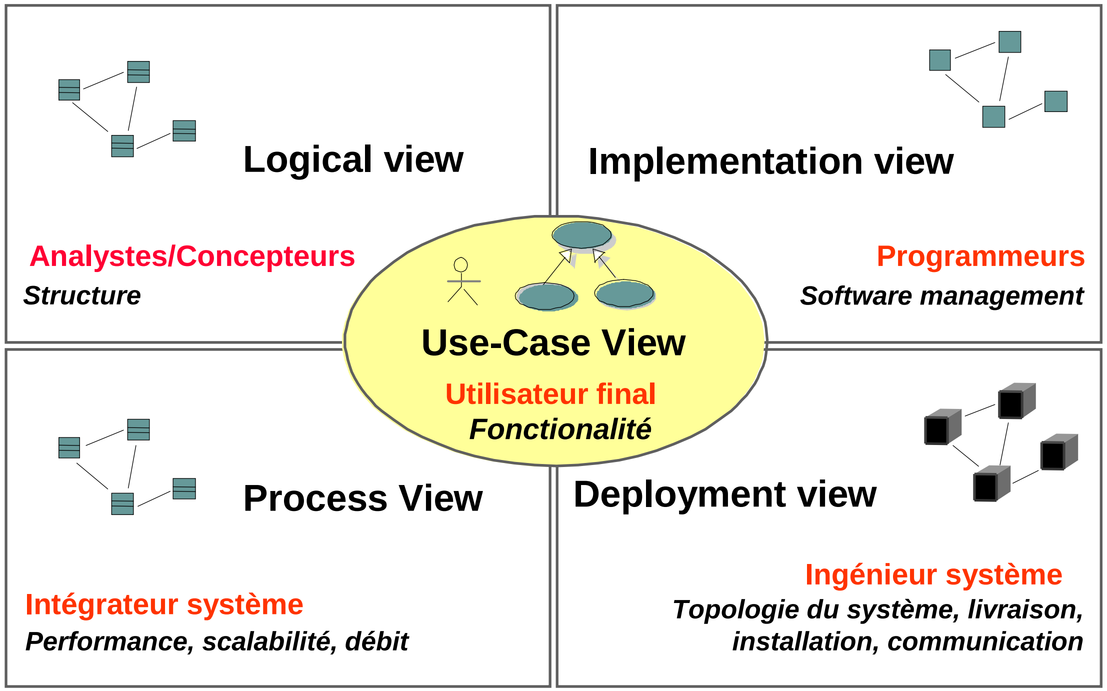
- Unified visual Language
  - Everybody must speak the same language
- Language for specification / code generation
  - Supposedly precise and non-ambiguous

One single view is not enough:

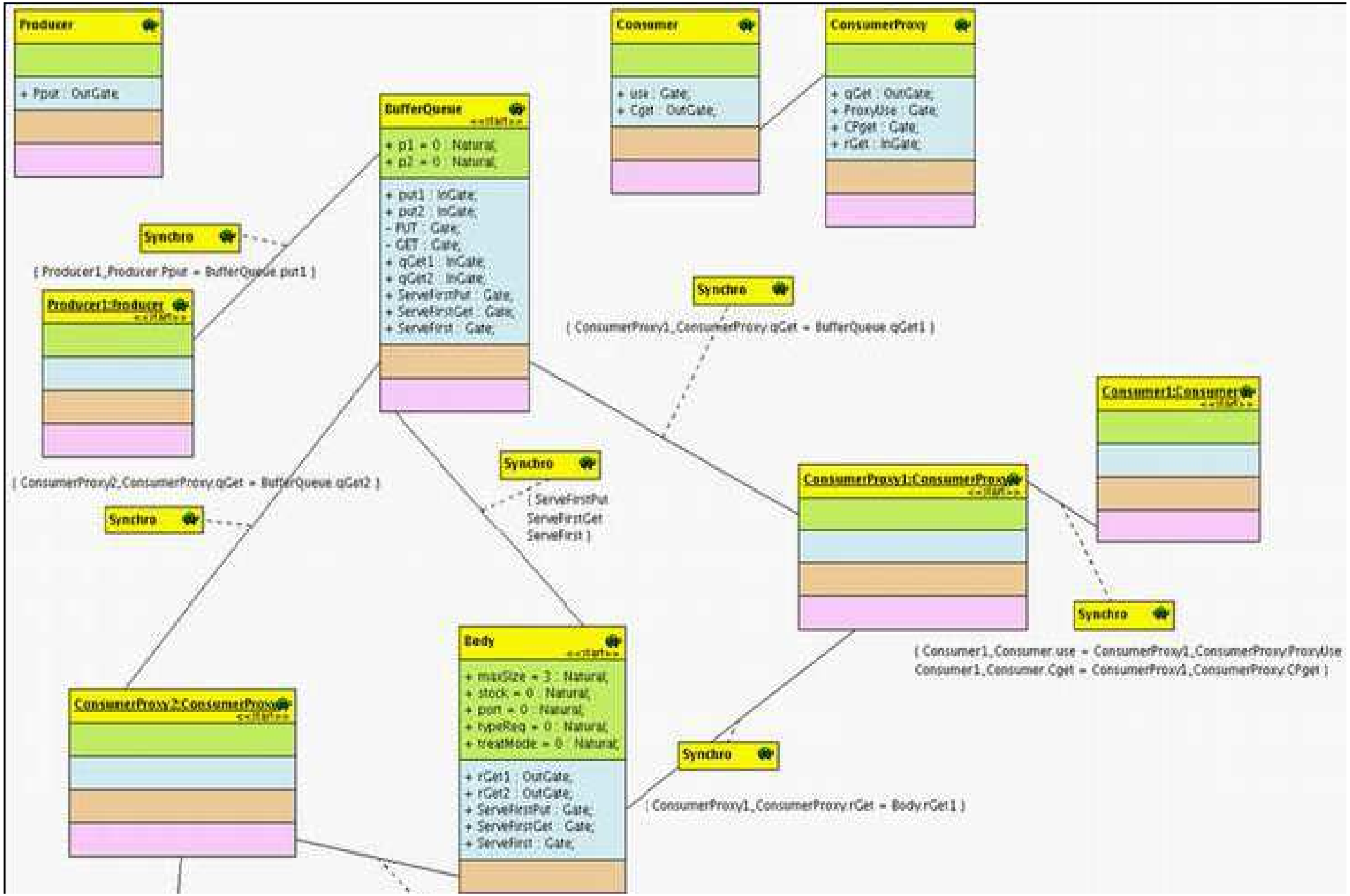
- Class diagrams
- Sequence diagrams
- Activity diagrams
- State machines
- Composite structure diagrams
- Deployment diagrams
- Marte profile

A single model is not enough!

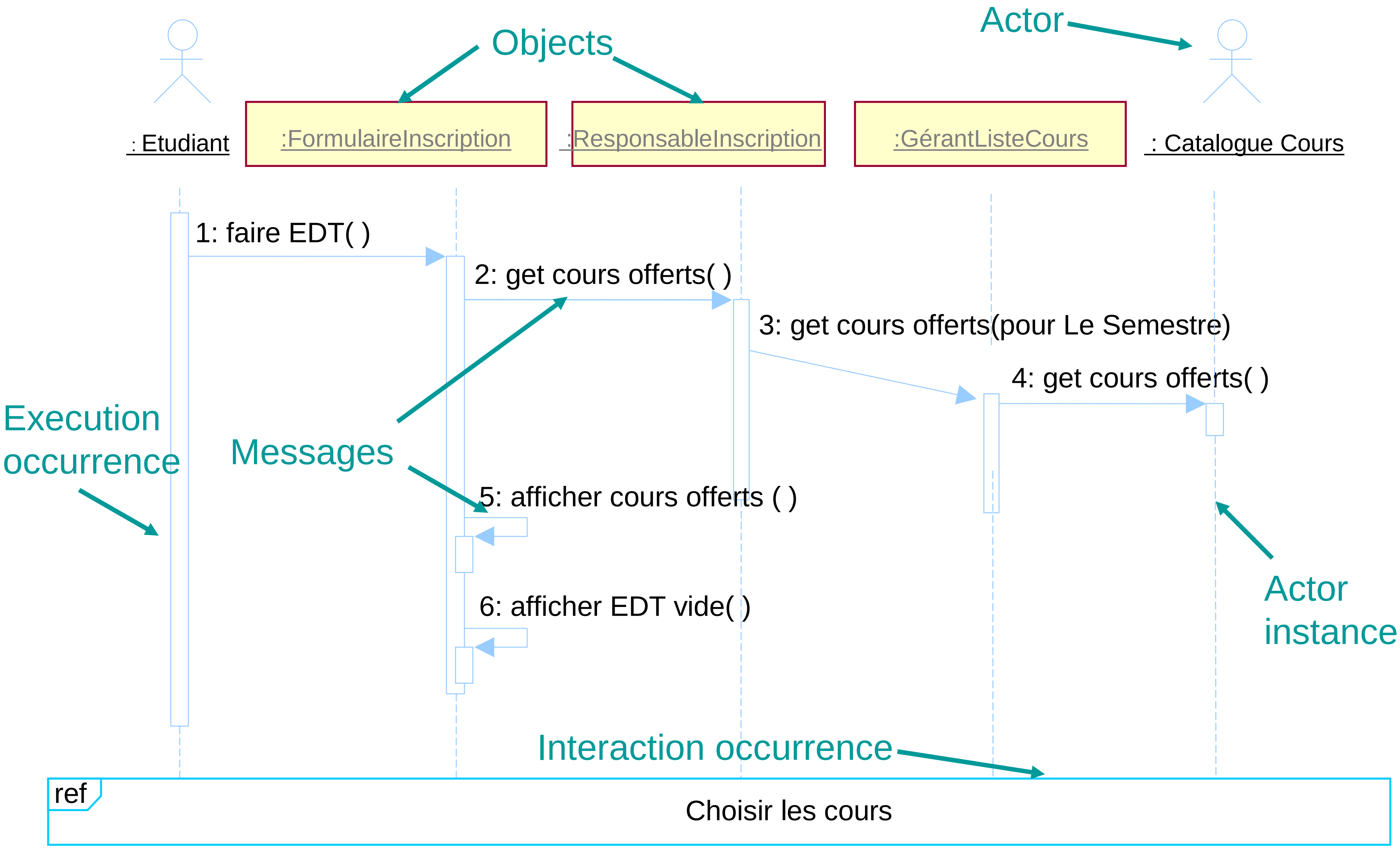
- Create several independent models but with common points and relations.



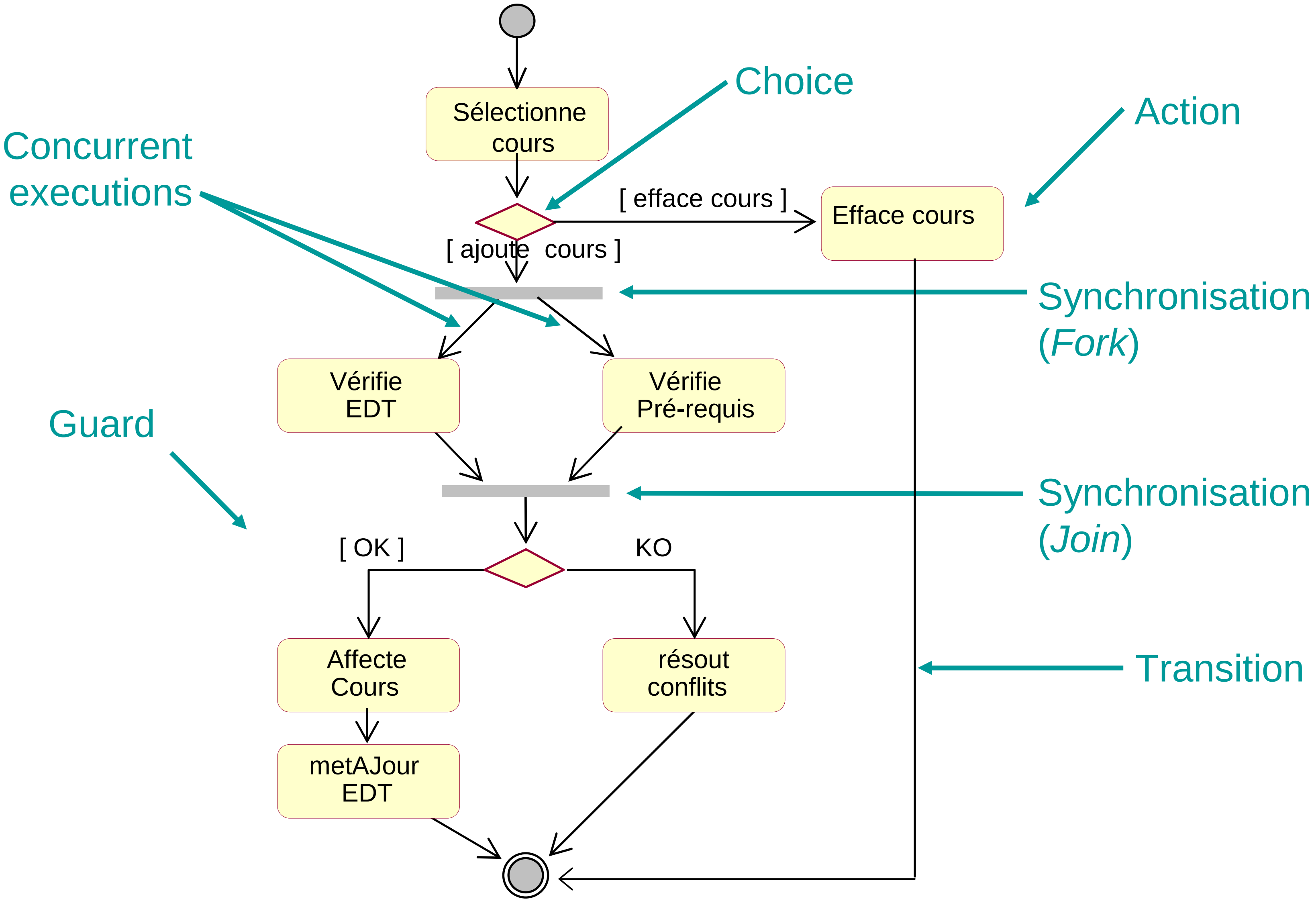
Class diagrams



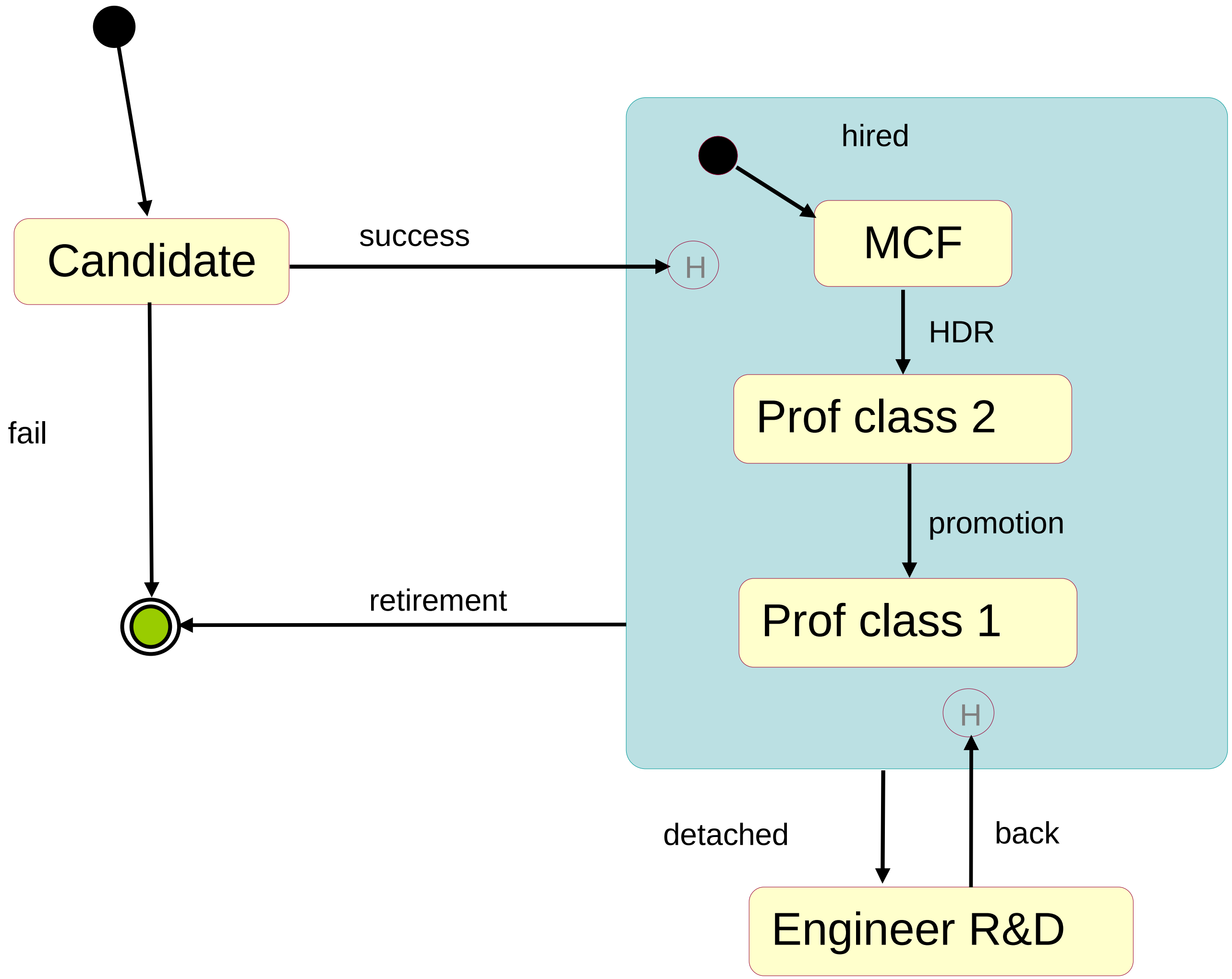
Sequence diagram



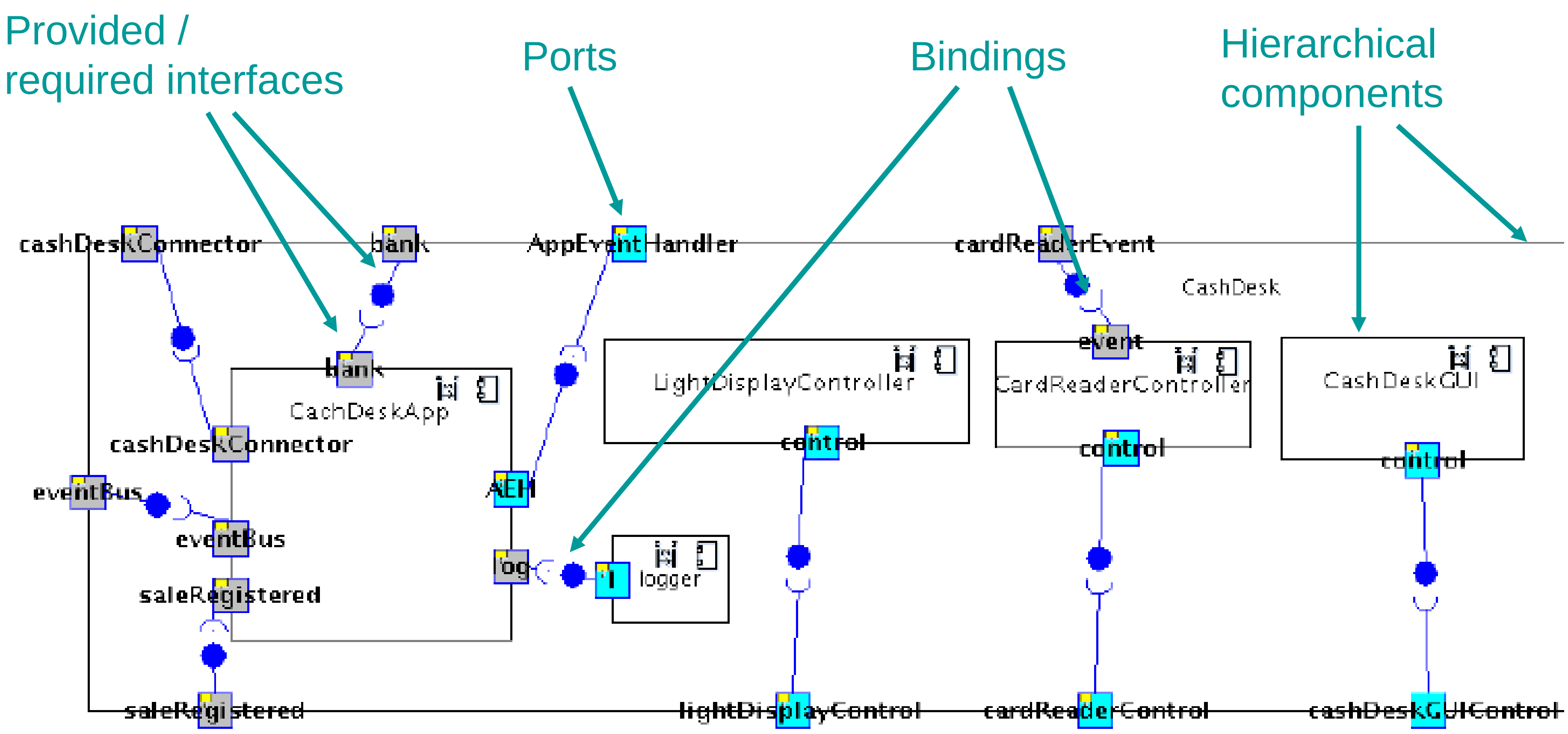
Activity diagram



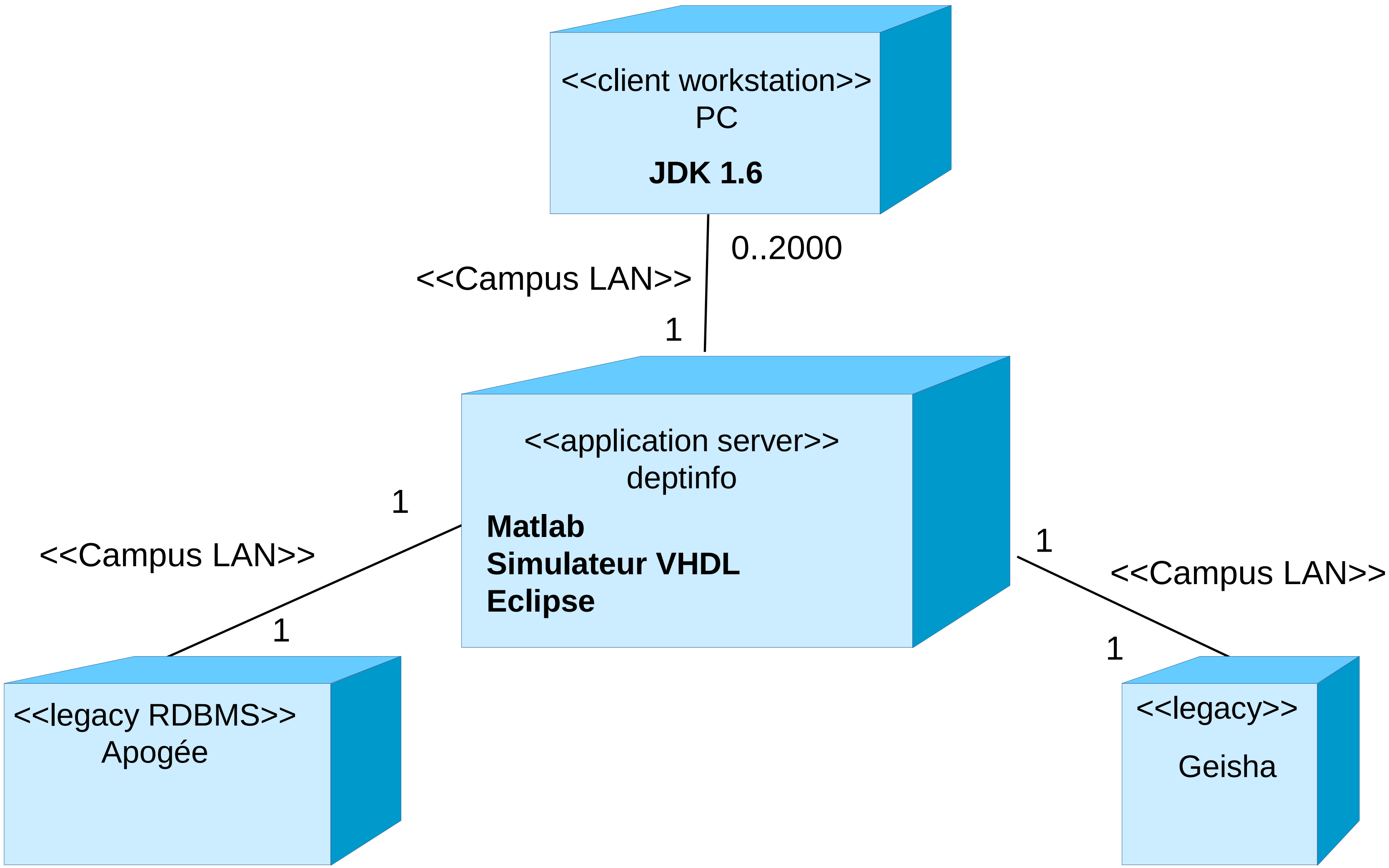
State machine diagram



Component and Composite structure diagrams

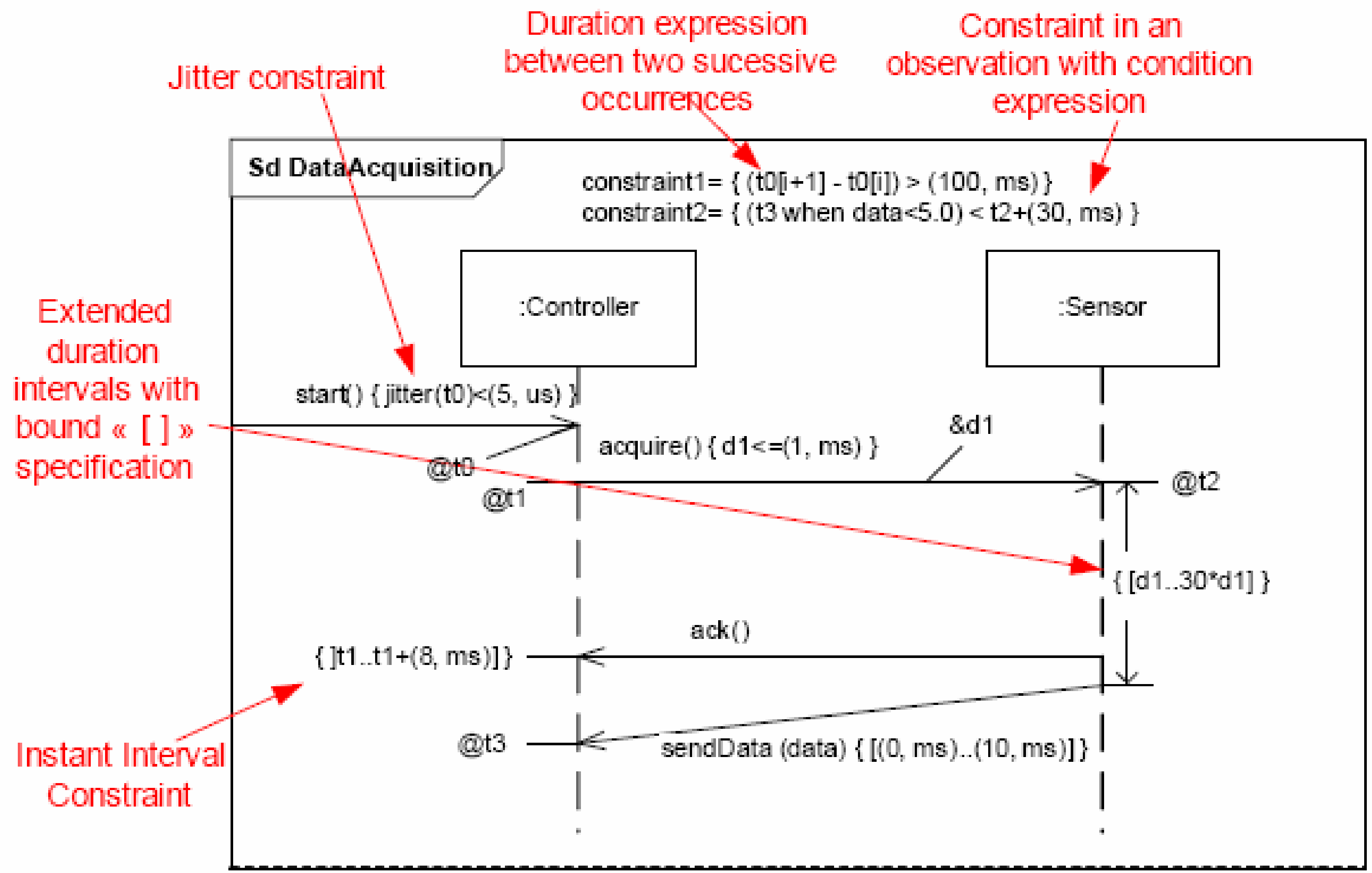


Deployment diagram



MARTE: UML Profile for

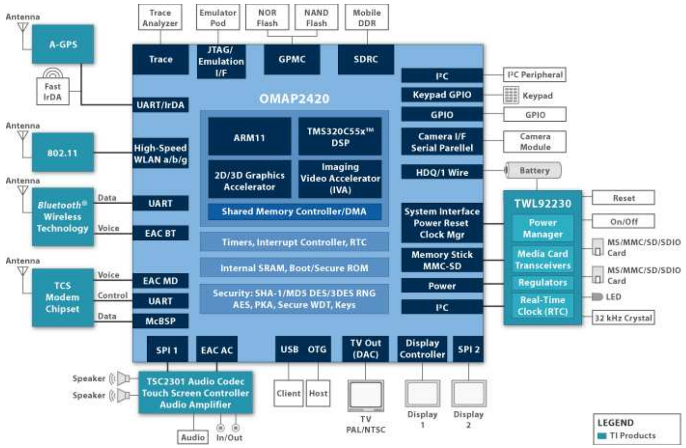
Modeling and Analysis of Real-Time and Embedded Systems

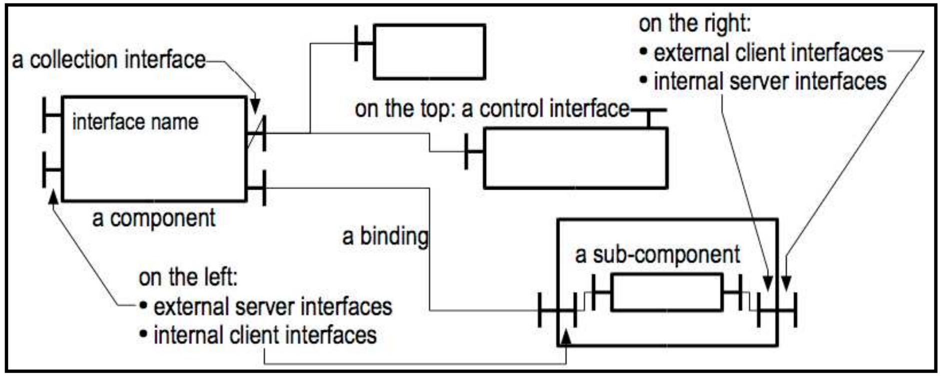


Slide courtesy of Sebastien Gerard, CEA-LETI

Components

- Hardware / software





- Synchronous / Asynchronous
- Flat / Hierarchical

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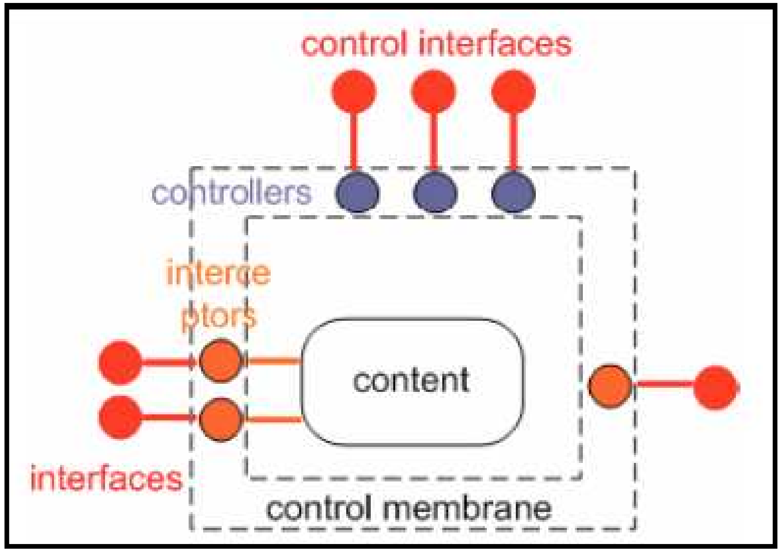
The Fractal component model

- Systems and middleware engineering
  - Generic enough to be applied to any other domain
  - Fine grain (wrt EJB or CCM), close to a class model
  - Lightweight (low overhead on top of objects)
  - Independent from programming languages
  - Homogeneous vision of all layers (OS, middleware, services, applications)

Fractal

- Open and adaptable/extensible
- Usable as a component framework to build applications
  - with “standard” Fractal components
- Usable as a component framework framework
  - building different kinds of components
  - with minimum introspection and simple aggregation (à la COM)
  - with binding and lifecycle controllers (à la OSGi)
  - with a two-level hierarchy and bindings (à la SCA)
  - with persistence and transaction controllers (à la EJB)
  - with attribute controllers (à la MBean)

Fractal : controllers



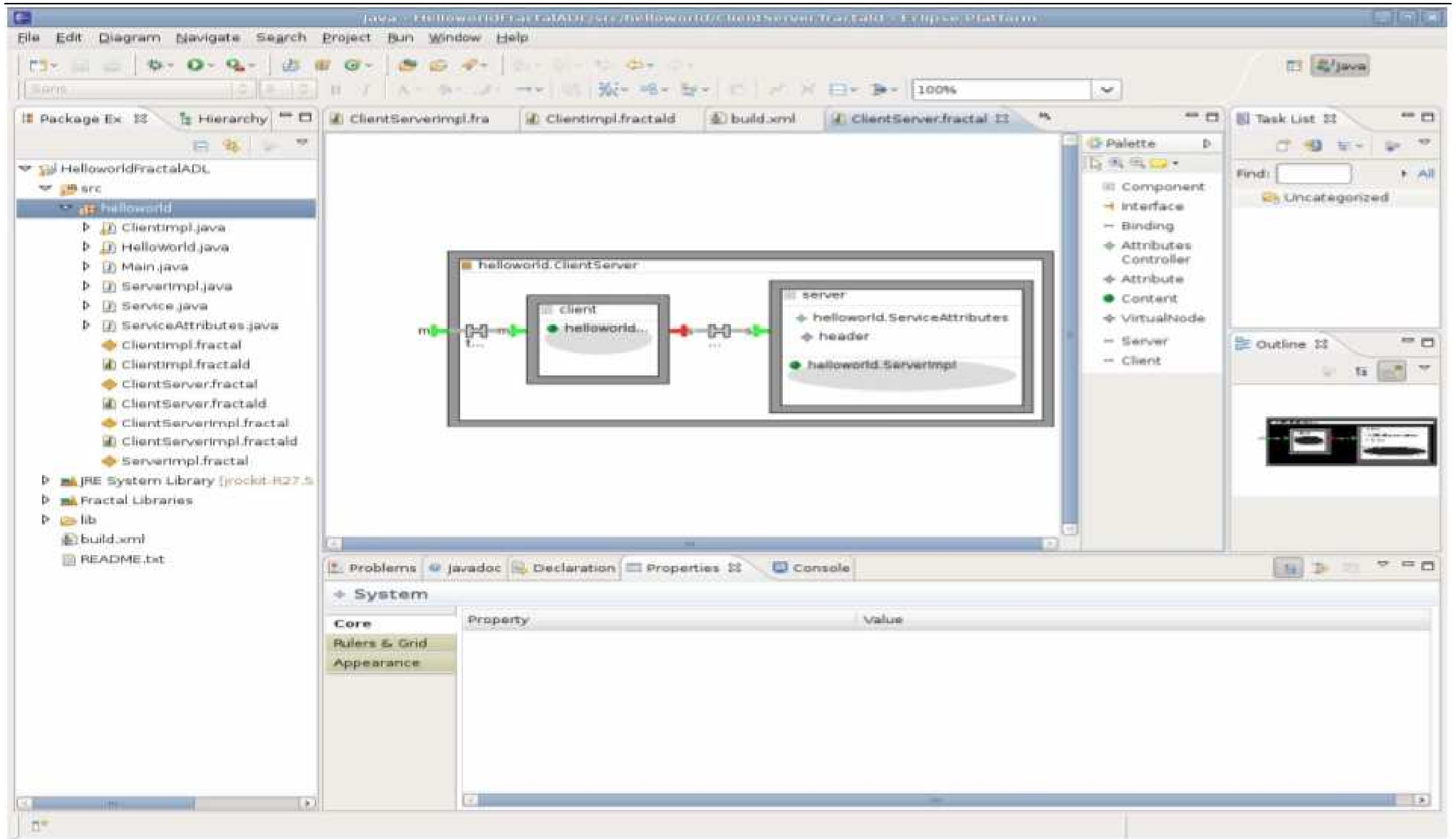
- Control
  - Non functional (tech'al) properties
  - Implemented in the membrane
  - Made of a set of controllers
  - E.g. security, transaction, persistence, start/stop, naming
  - Controllers accessible through a control interface
  - Controllers and membranes are open

Fractal tools

- Fraclet
  - programming model based on annotations (within Java programs)
- Fractal ADL
  - XML-based architecture description language (ADL)
- Fractal API
  - set of Java interfaces for
    - introspection
    - reconfiguration
    - dynamic creation/modification
  - of Fractal components and component assemblies

Fractal : development tools

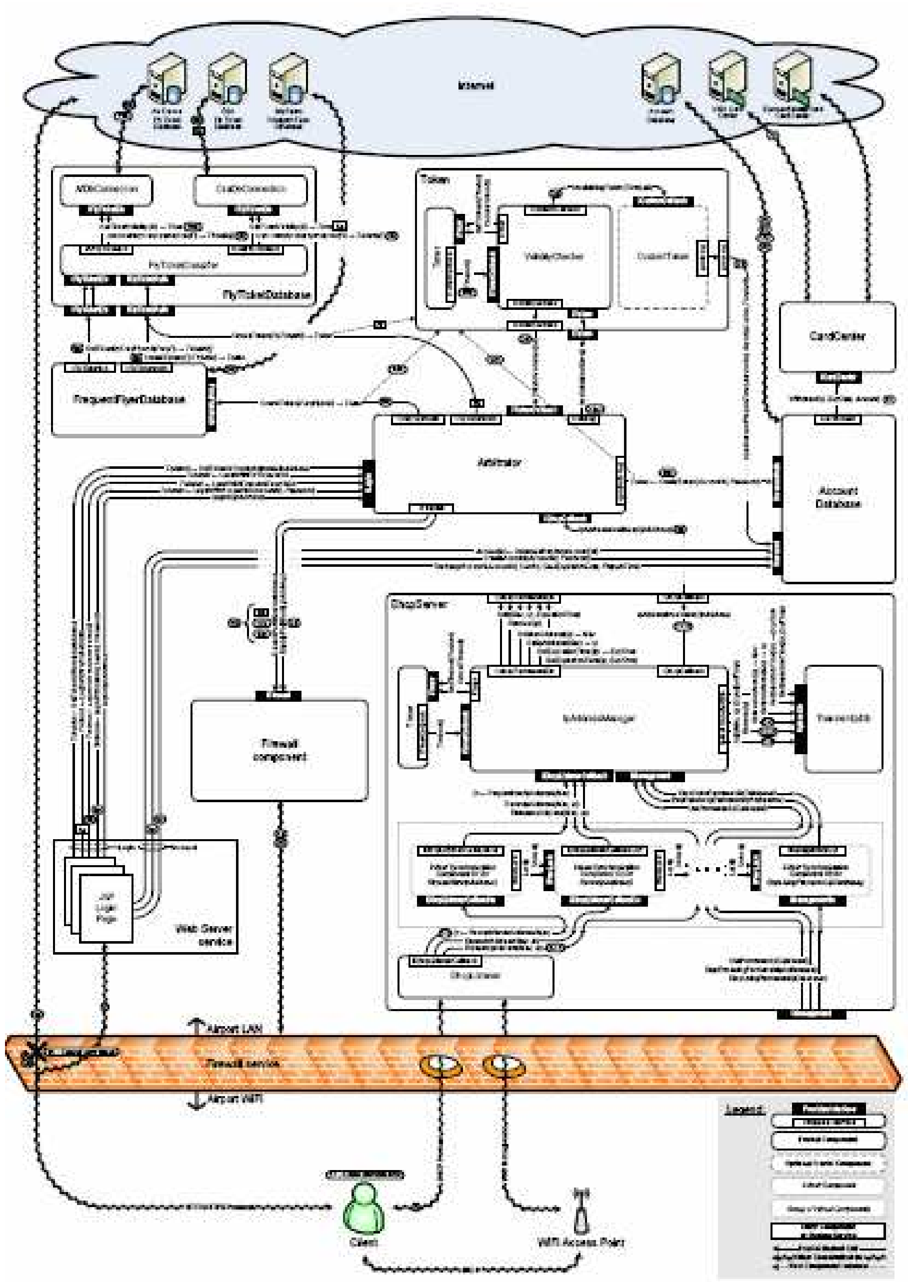
F4E: Eclipse development environment for Fractal applications



Case Study

- Source: France Telecom / Charles Un. Prague
- Specification of an Airport Wifi Network
- Hierarchical, real-size

  - Fractal specification
    +
    Sofa “behavior protocols”
    +
    Model-checking



GCM

Grid Component Model

A Fractal Extension

Scopes and Objectives:

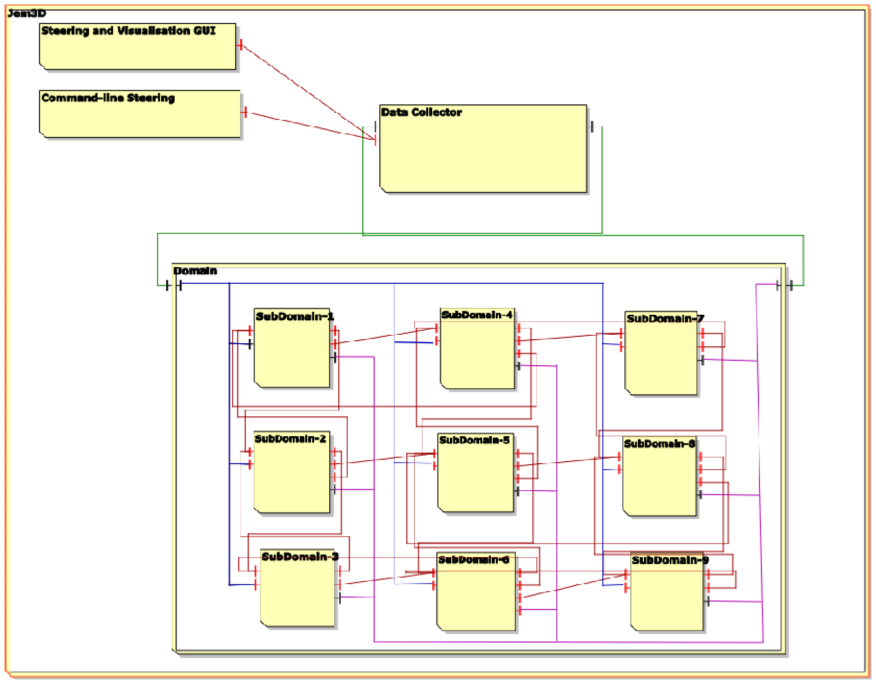
- Grid Codes that Compose and Deploy
- No programming, No Scripting, …

Innovations:

- Abstract Deployment
- Multicast and GatherCast
- Controller (NF) Components

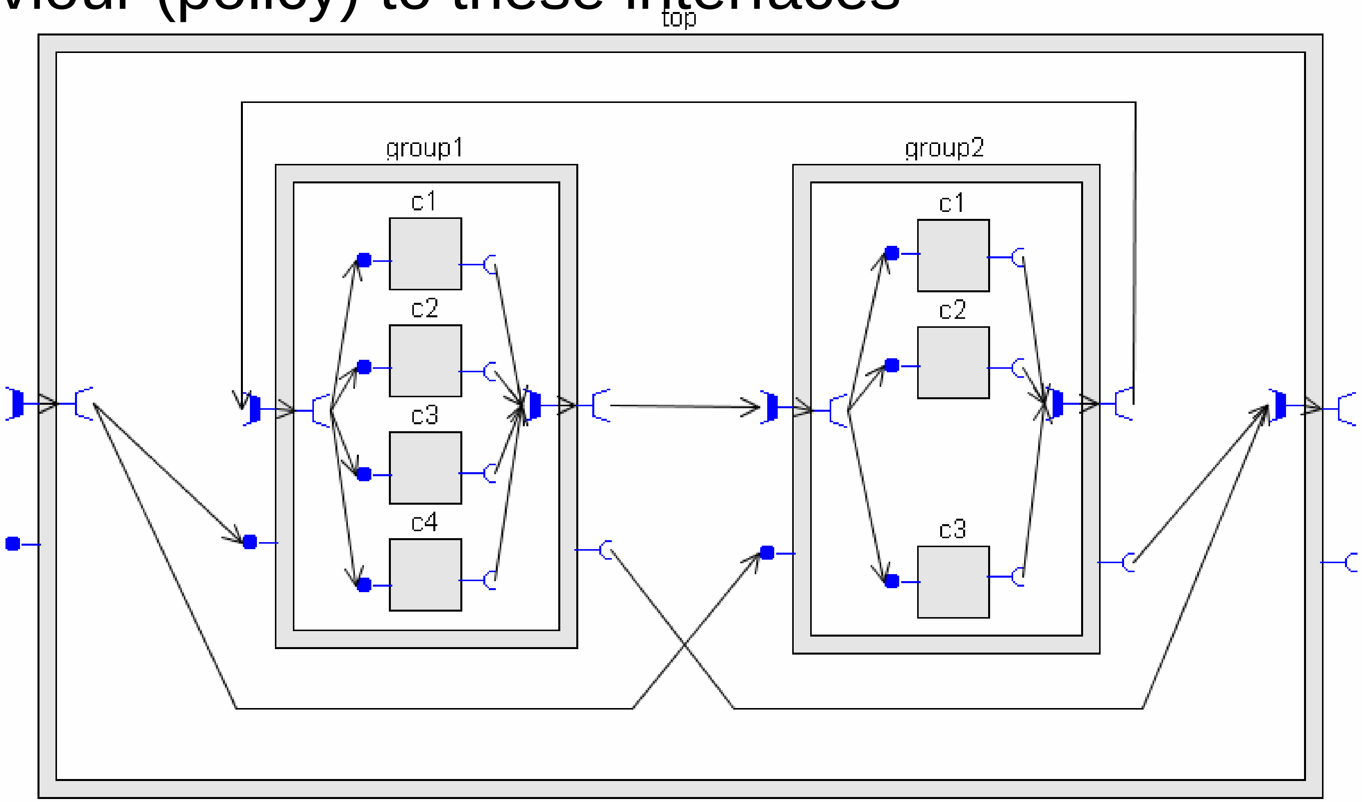
Standardization

- By the ETSI TC-GRID

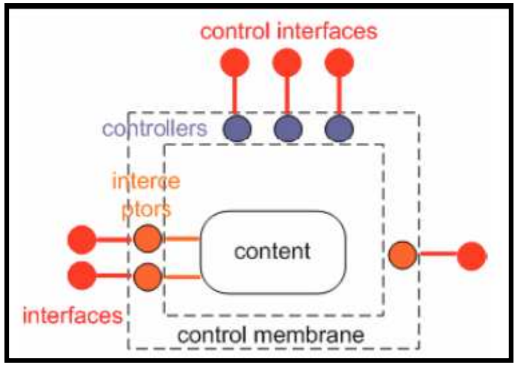


GCM: NxM communication

- 1 to N = multicast / broadcast / scatter
- N to 1 bindings = gathercast
- Attach a behaviour (policy) to these interfaces

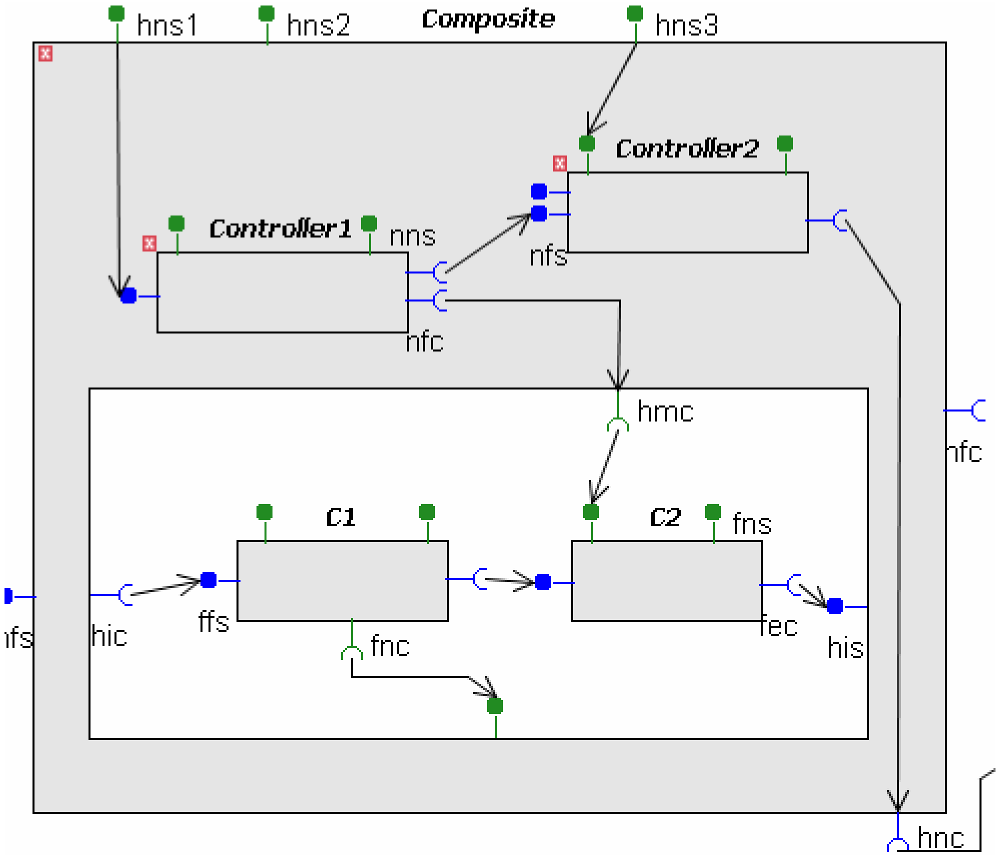


GCM: components for controllers

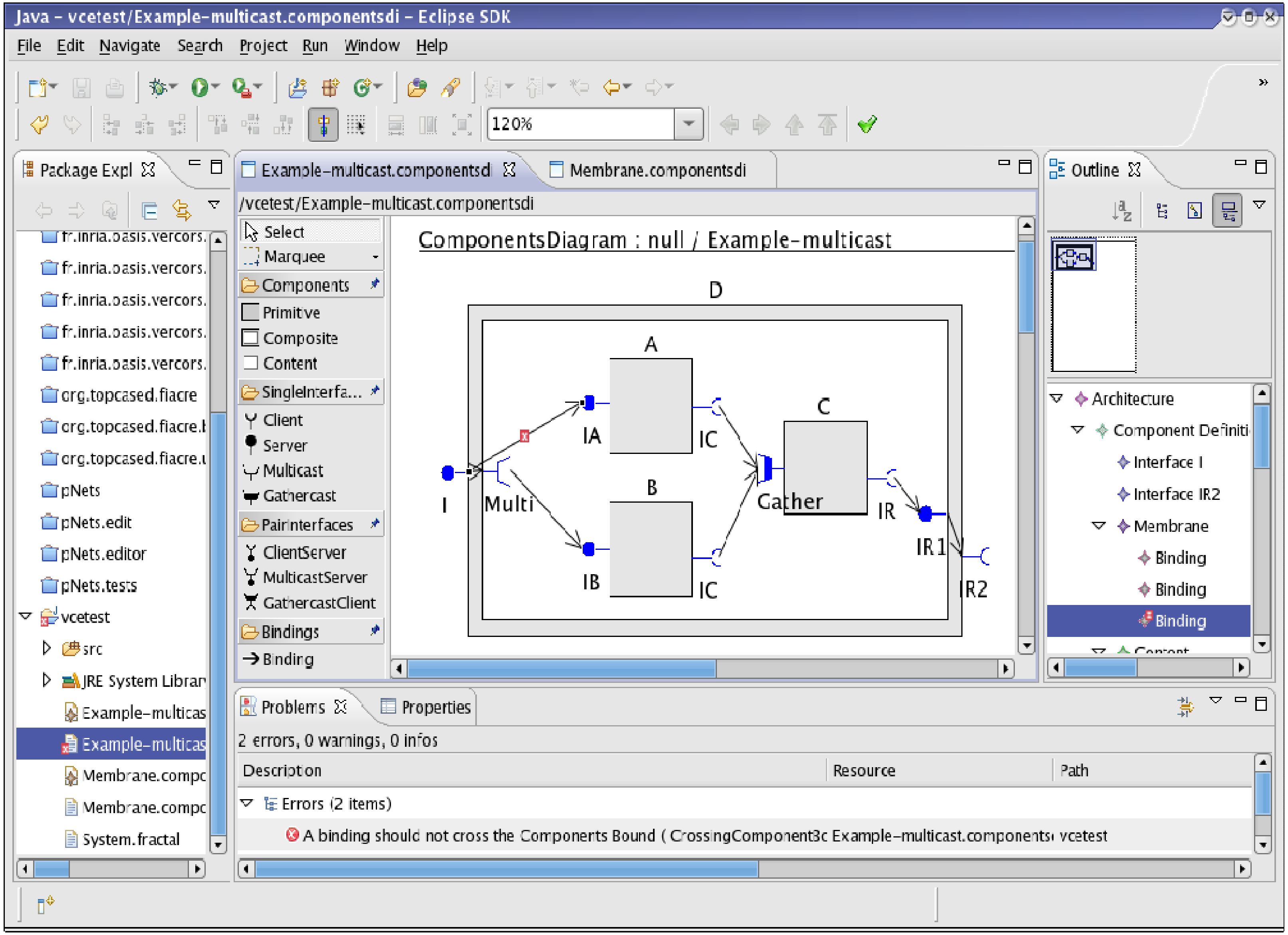


“Componentize” the membrane:

- Build controllers in a structured way
- Reuse of controller components
- Applications: control components for self-optimization, self-healing, self-configuring, interceptors for encryption, authentication, …



GCM architecture specifications: VCE tool



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VCE
VerCors Component Editor

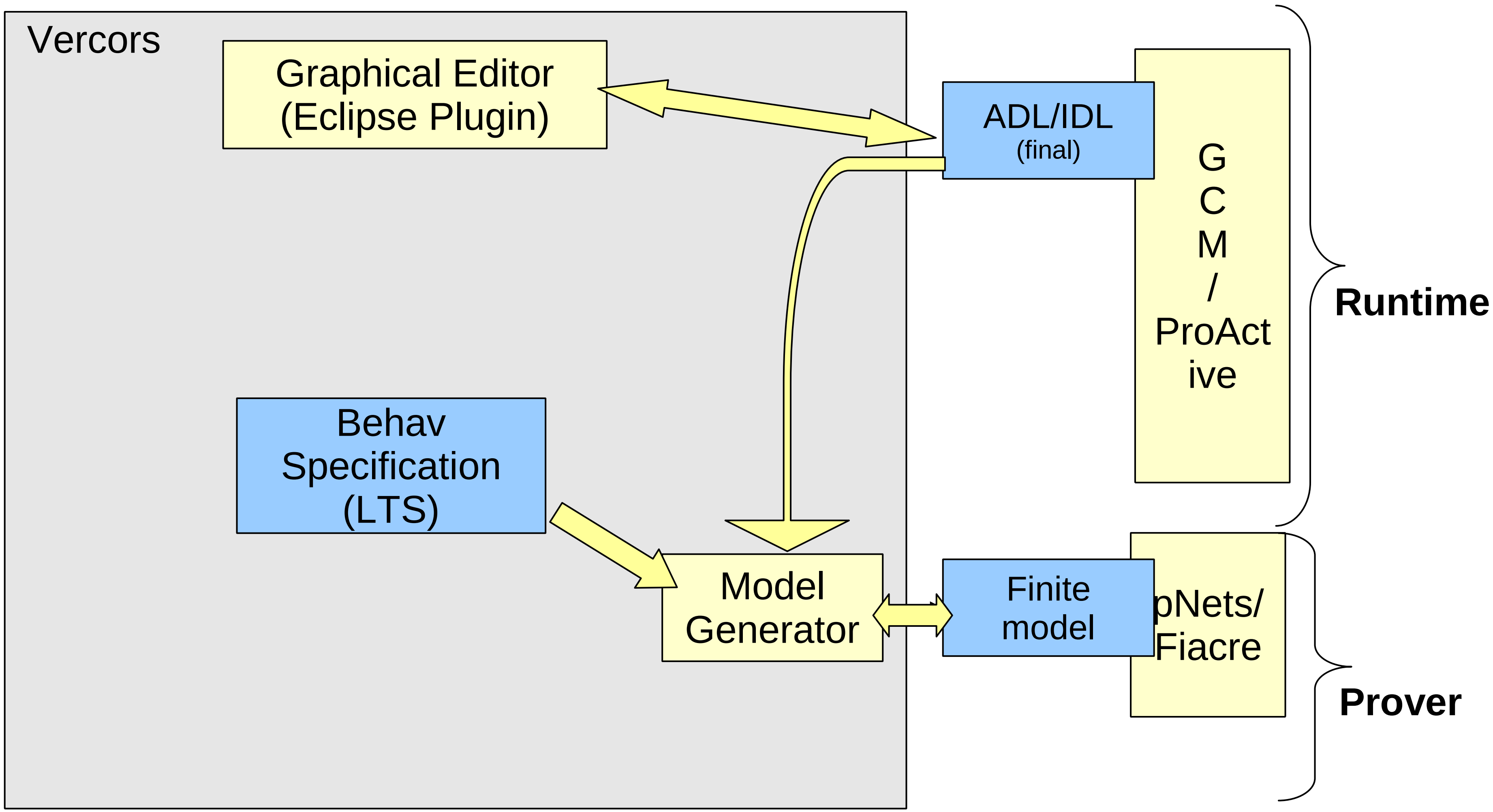
A “Domain Specific Language” for Fractal/GCM

- Component architecture diagrams
- Behaviour diagrams
- Model generation for verification tools
- Code generation

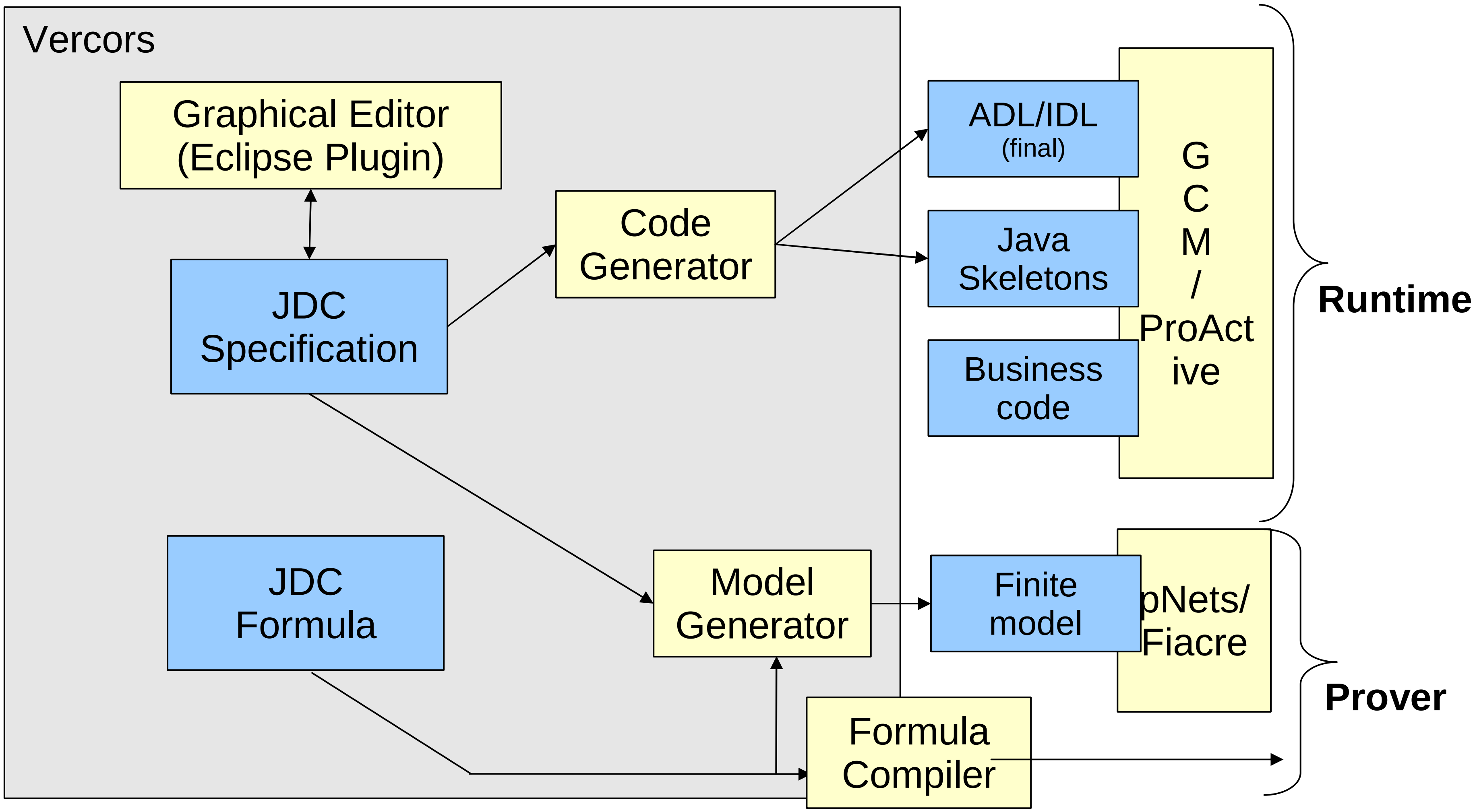
Agenda:

- Tool architecture
- Validation rules
- “hands-on” exercices

VCE
Architecture



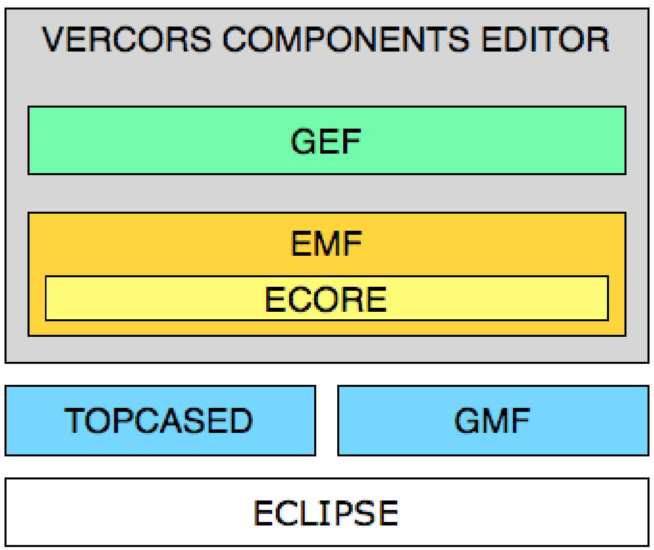
VCE Architecture (middle term)

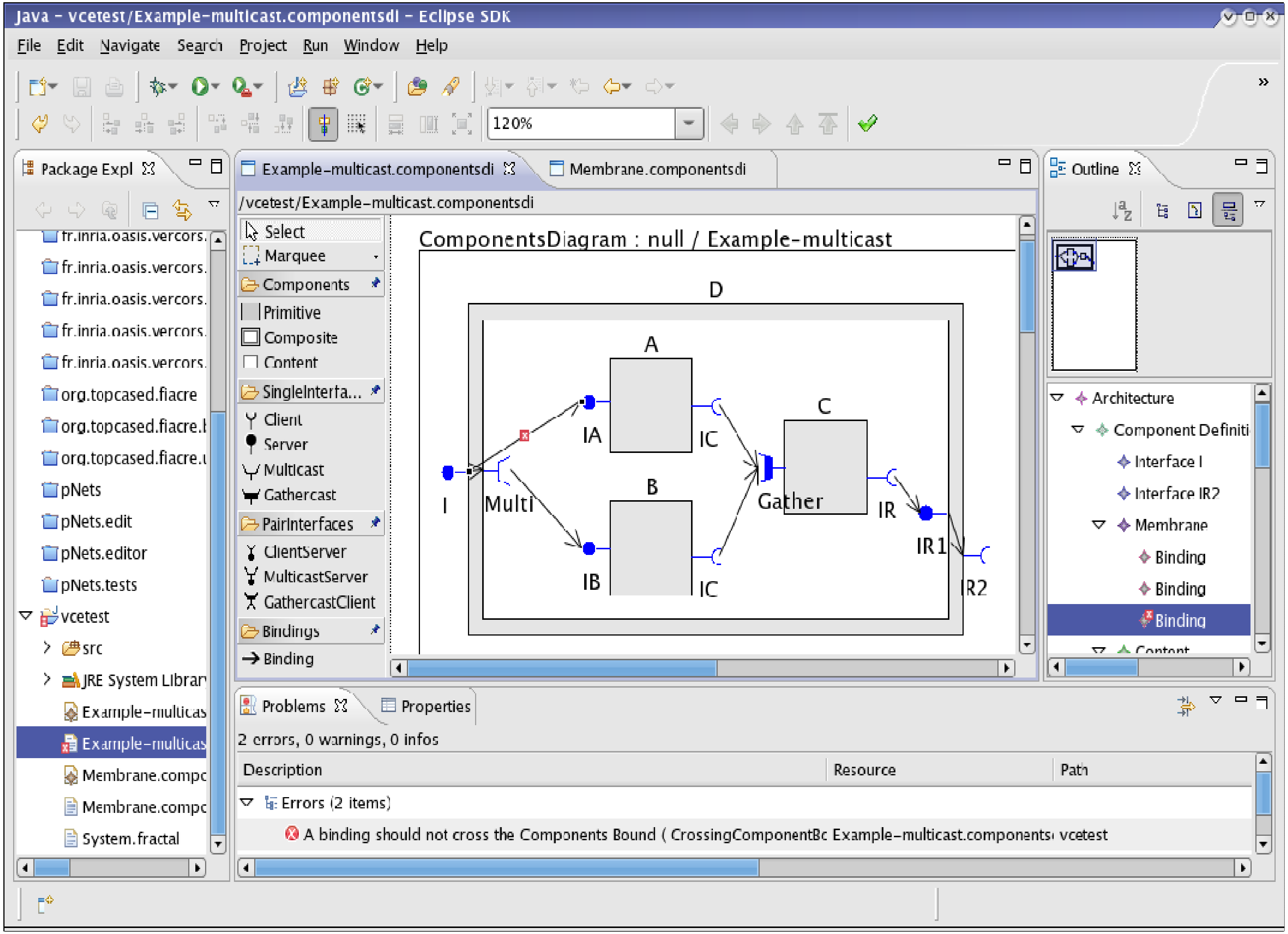


VCE
Eclipse and MDE Tools

Eclipse Modelling Tools:

- EMF (Eclipse Modeling Framework): XMI model definition and Java code generation
- GEF (Graphical Editing Framework)
- GMF (Graphical Modeling Framework) for developing graphical editors
- Model Development Tools
- Atlas Transformation Language (ATL)
- ….

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IR2
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pNets.editor
pNets.tests
vcetest
src
System.fractal
Architecture
Interface I
Interface IR2
Membrane
Binding
Problems
Properties
2 errors, 0 warnings, 0 infos
Description
Resource
Path
Errors (2 items)
A binding should not cross the Components Bound (CrossingComponentBc Example-multicast.components vcetest

VCE
Validation, OCL

Several notions of correctness in the diagram editors:

- Structural correctness, by construction: the graphical tools maintain a number of constraints, like bindings attached to interfaces, interfaces on the box borders, etc.
- But some rules are related to the model structure, not to the graphical objects. E.g. bindings should not cross component levels, or sibling objects should have distinct names…
- There is a “Validation” function (and button), that must be checked only on “finished” diagrams, before model/code generation. It is defined using OCL rules.

VCE : Validation, OCL

OCL example :

- In Content, Bindings must go from Client to Server.

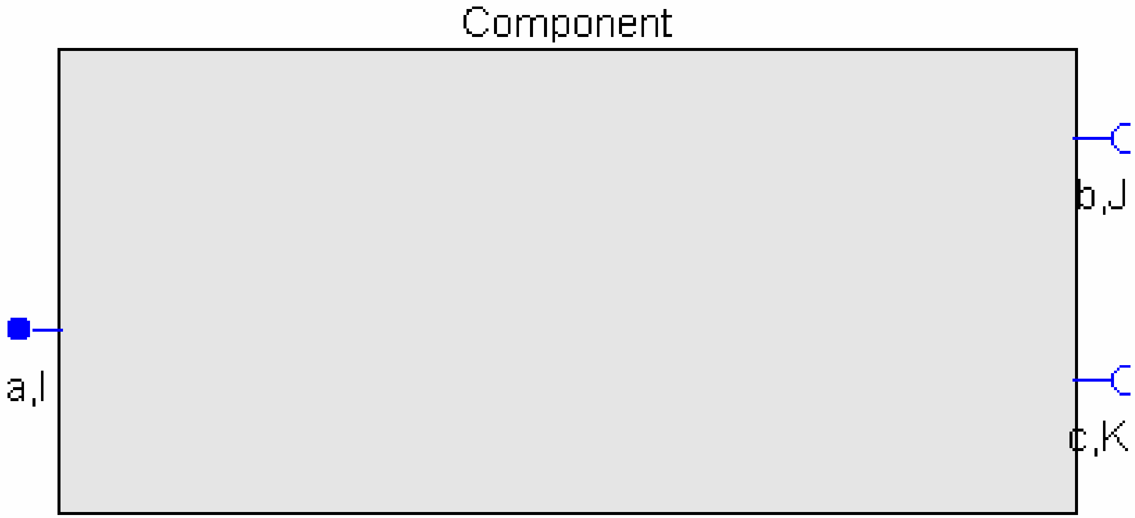
$$B =< Itf_1, Itf_2 > \ \in \ Ct_C \ \Rightarrow Itf_1.\rho = client \ \wedge \ Itf_2.\rho = server$$

```
context Binding inv FromClientToServer_InContent_ROLES:
    ( Content.allInstances()->exists(c : Content | c.bindings->includes(self))
      and
      Content.allInstances()->any(bindings->includes(self)).subcomponents
              ->exists(sc : Component | sc.oclAsType(ComponentDefinition).externalInterfaces
              ->includes(self.sourceInterface))
      and
      Content.allInstances()->any(bindings->includes(self)).subcomponents
               ->exists(sc : Component | sc.oclAsType(ComponentDefinition).externalInterfaces
               ->includes(self.targetInterface))
    )
    implies self.sourceInterface.role = InterfaceRole::client
            and   self.targetInterface.role = InterfaceRole::server
```

VCE
Examples for the SSDE course

1. Component: external view
2. Component: internal architecture
3. Multicast: example, workflow style
4. Multicast: build a matrix application
5. Master/slave, RPC style
6. Matrix: parameterized style

1. External view



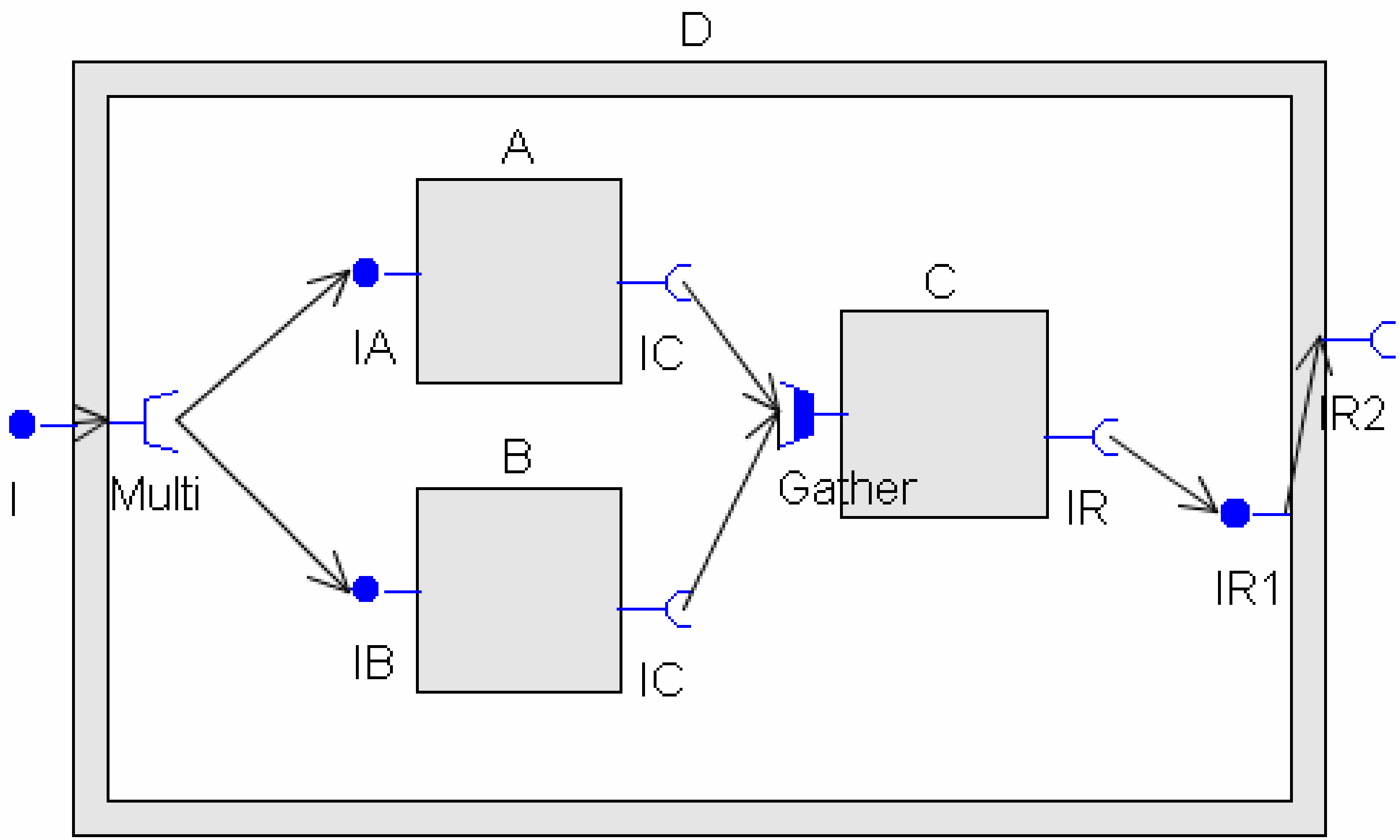
2. Internal architecture

Build a composite component, with :

- Outside:
  - 1 serveur interface SI
  - 2 client interface CI1, CI2
  - A number of control (NF) interfaces
- Inside:
  - 2 subcomponents
  - One connected to SI
  - Each connected to one client interface
  - One binding between them

Check its validity and produce the ADL

3. Multicast and gathercast, workflow style

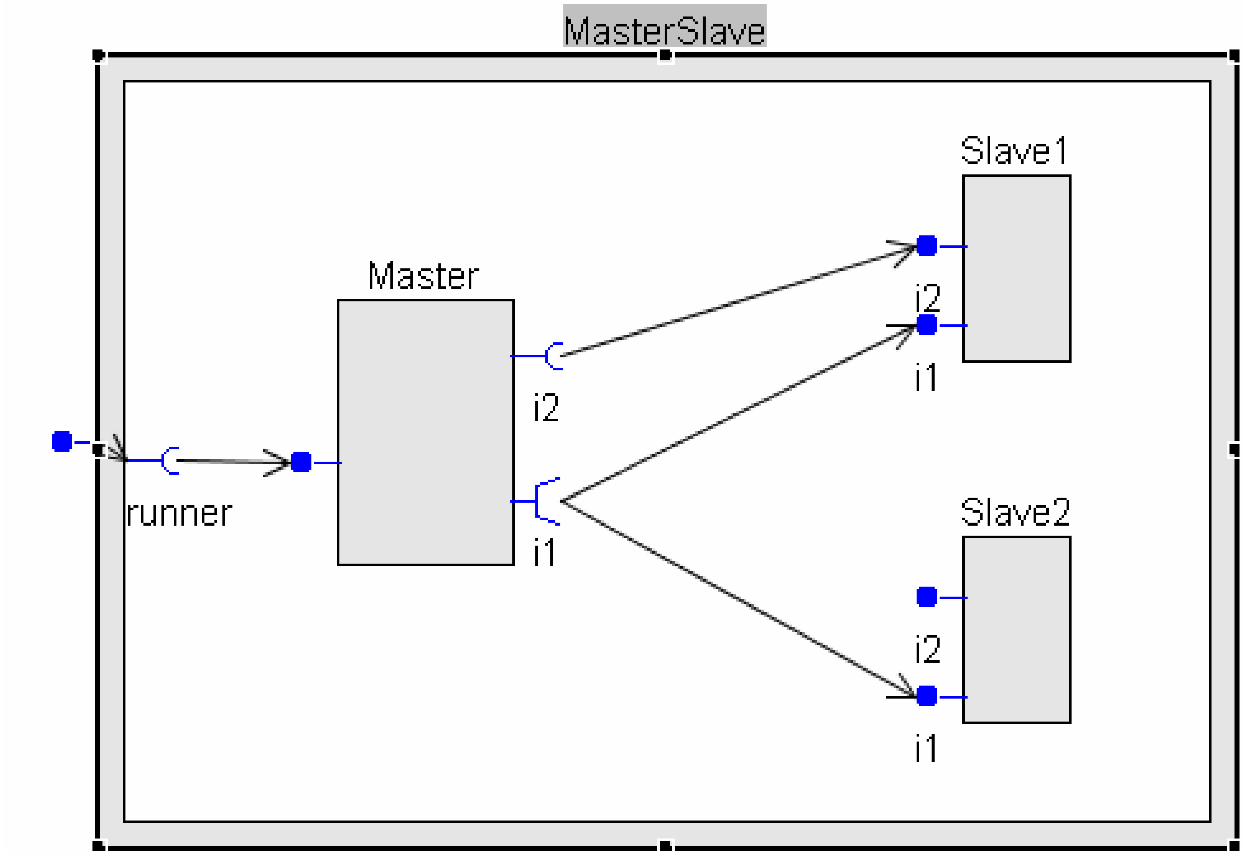


4. Composite, multicast, matrix

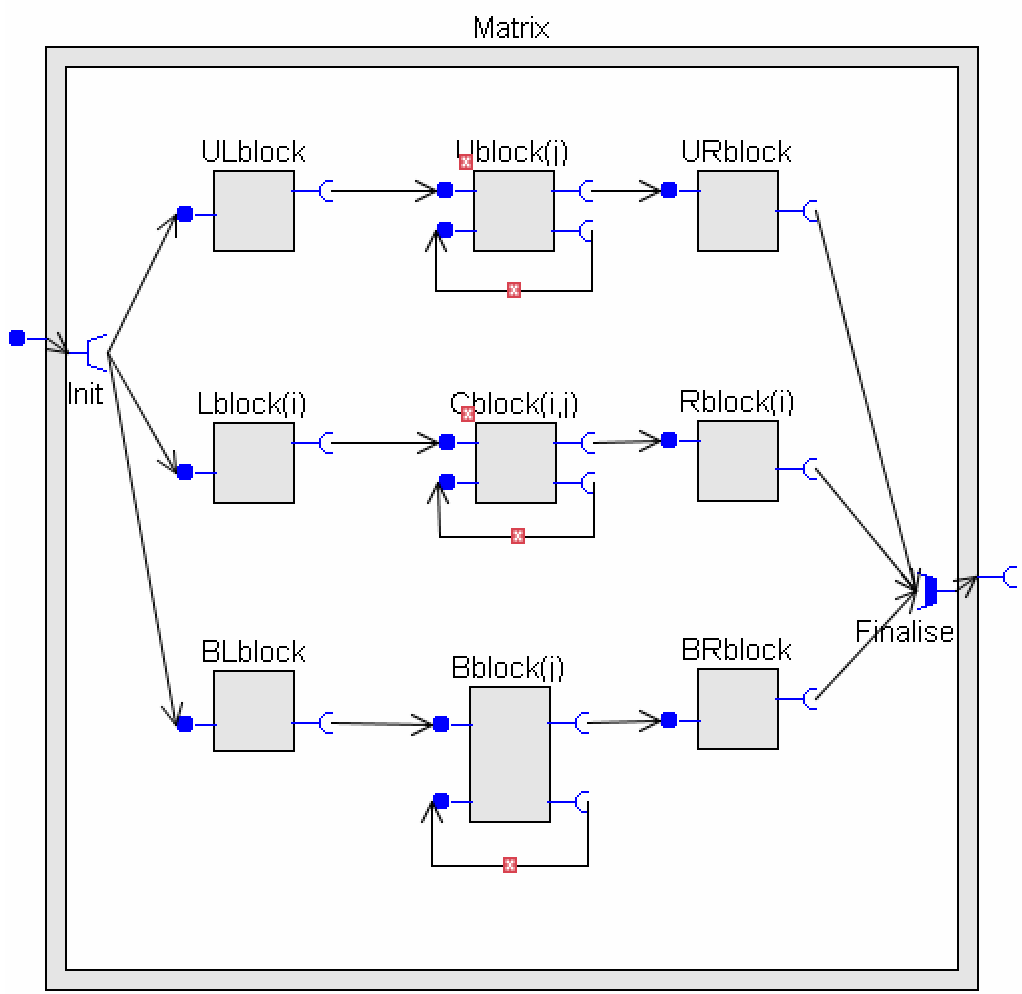
Build a composite component, with:

- One server interface, with an internal multicast interface
- 2 x 3 subcomponents representing matrix blocks, each linked to its left neighbour

5. Master/slave, RPC style

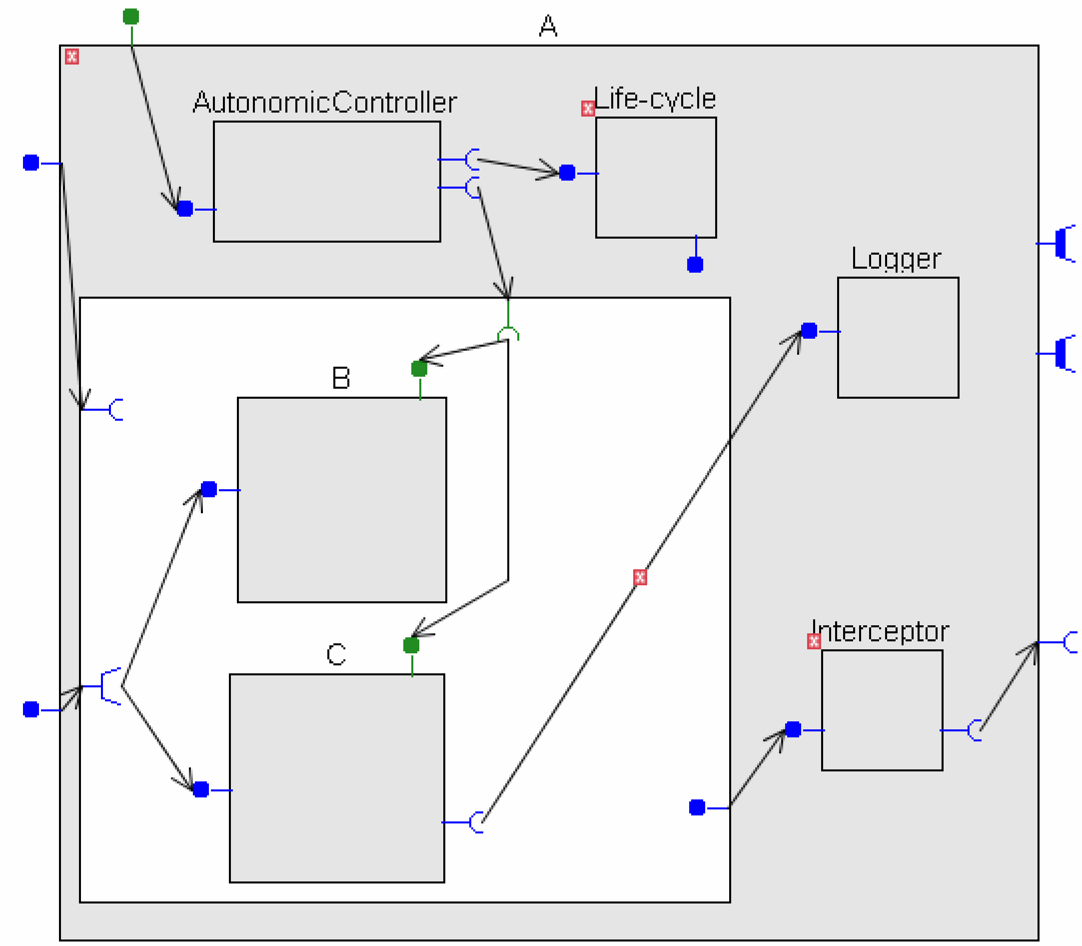


6. Matrix, parameterized style



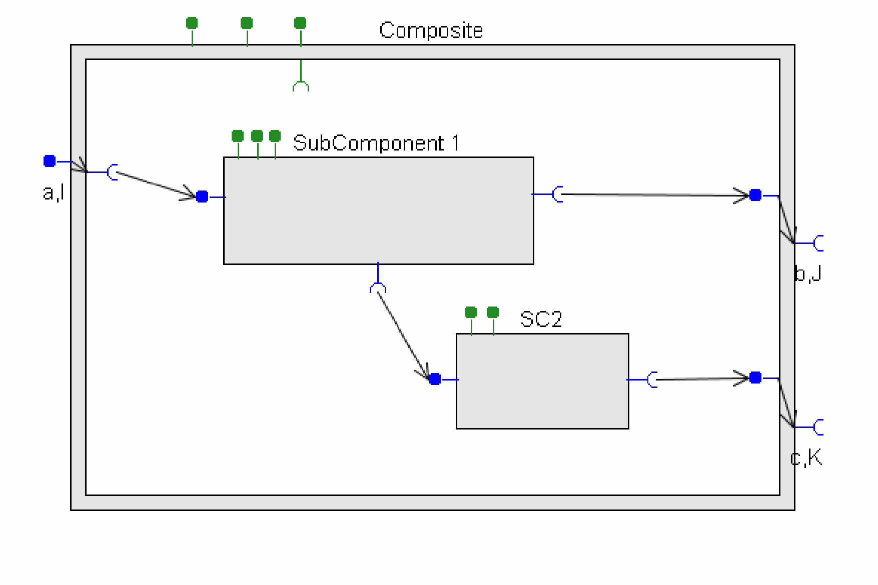
7. Exercice

- Analyze this diagram (semantics, errors, …)

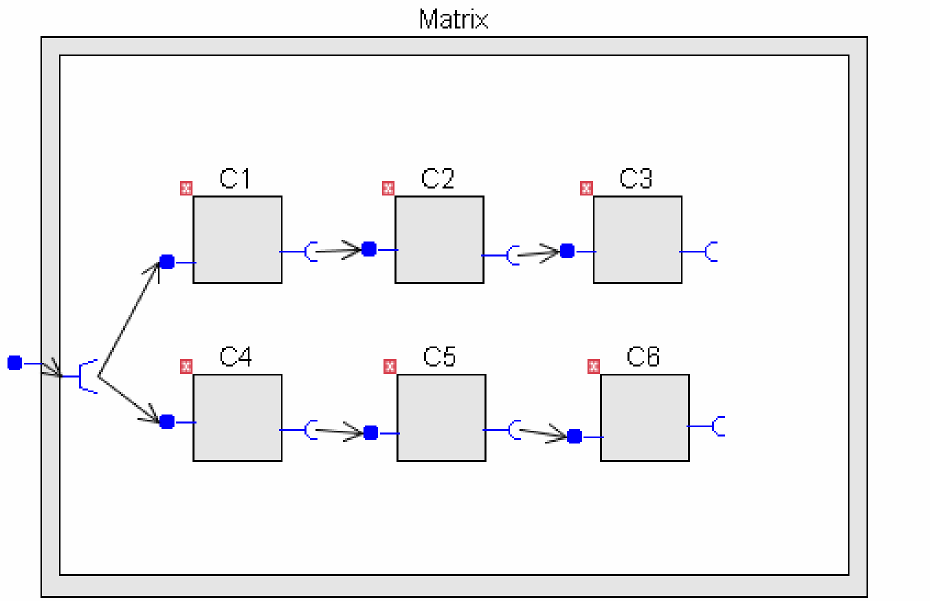


Corrigés

Exercice 2



Exercice 4



Exercice 7:

- 1 true error: Bindings crossing component bounds
- 1 false error (bug in a validation rule): more than one component in membrane

Interesting features :

- 1 provided service is not connected (thus not implemented…); is this a problem?
- 2 client interfaces are not used; is this a problem ?
- The logger component has no visible interface; is this a problem ?
- The life-cycle controller does not control anything; this may be a problem…