Specifying and Generating Safe GCM Components

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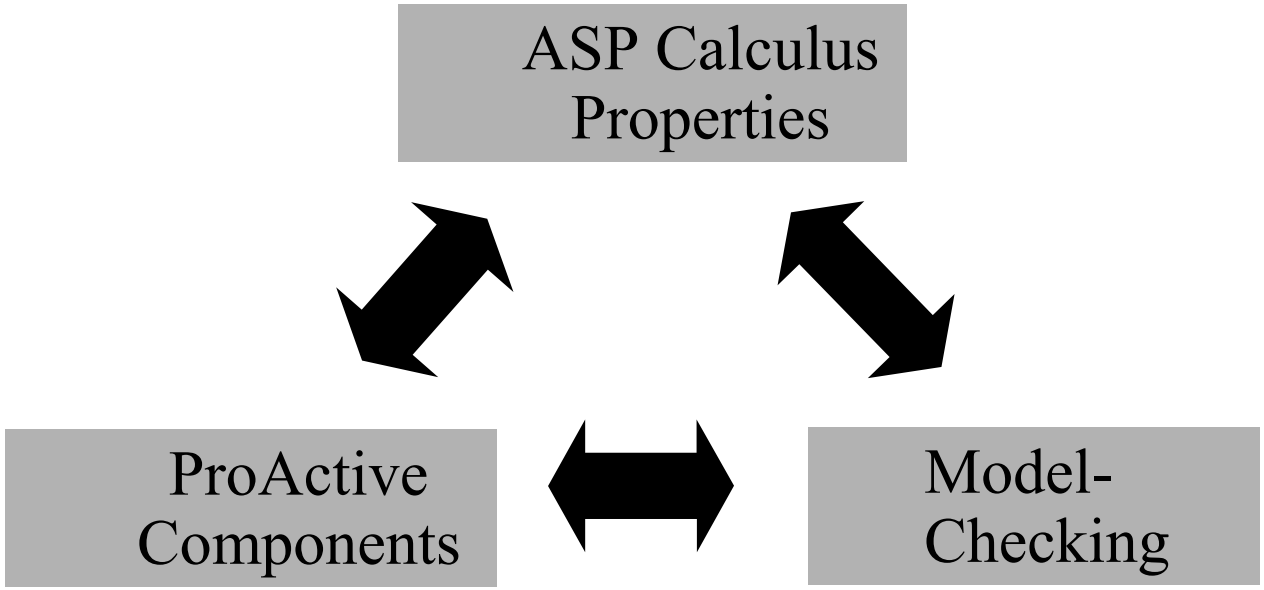
Agenda

- Motivation
- VCE Prototype (Vercors Component Environment)
- Specification of GCM components
- Generation of safe components

The OASIS Team
A Threefold Approach



- Proposes fundamental principles, techniques and tools for the design, development, analysis, and verification of **reliable distributed systems**
- Target, application areas: Distributed, Parallel, Concurrent applications, GRID Computing

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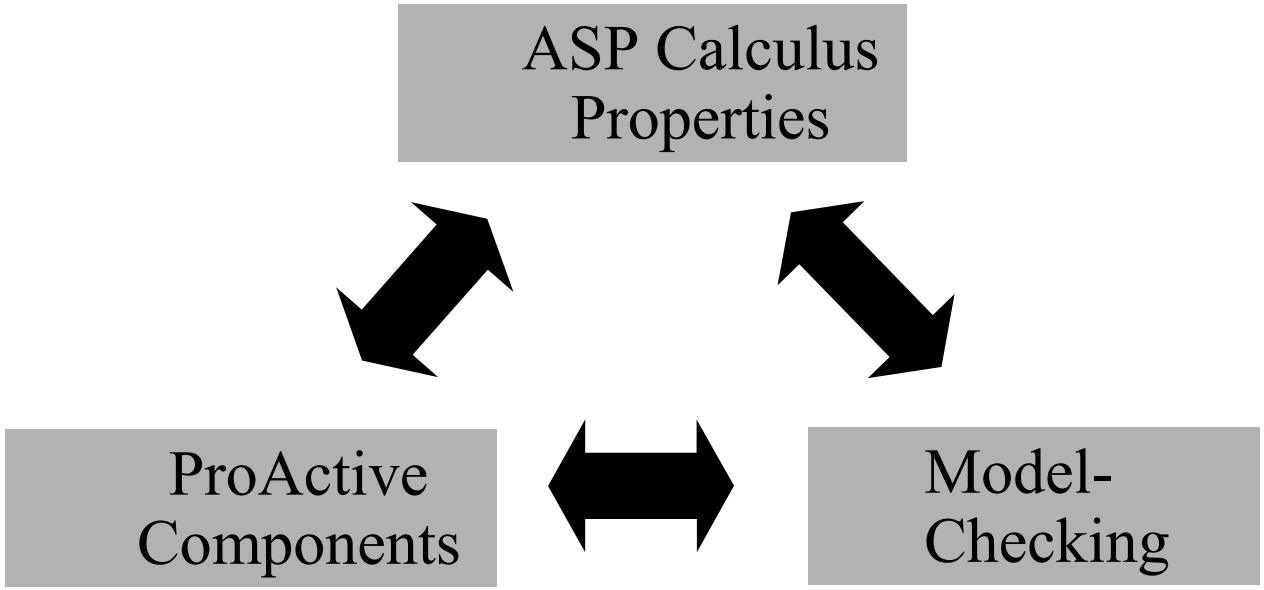
A Threefold Approach

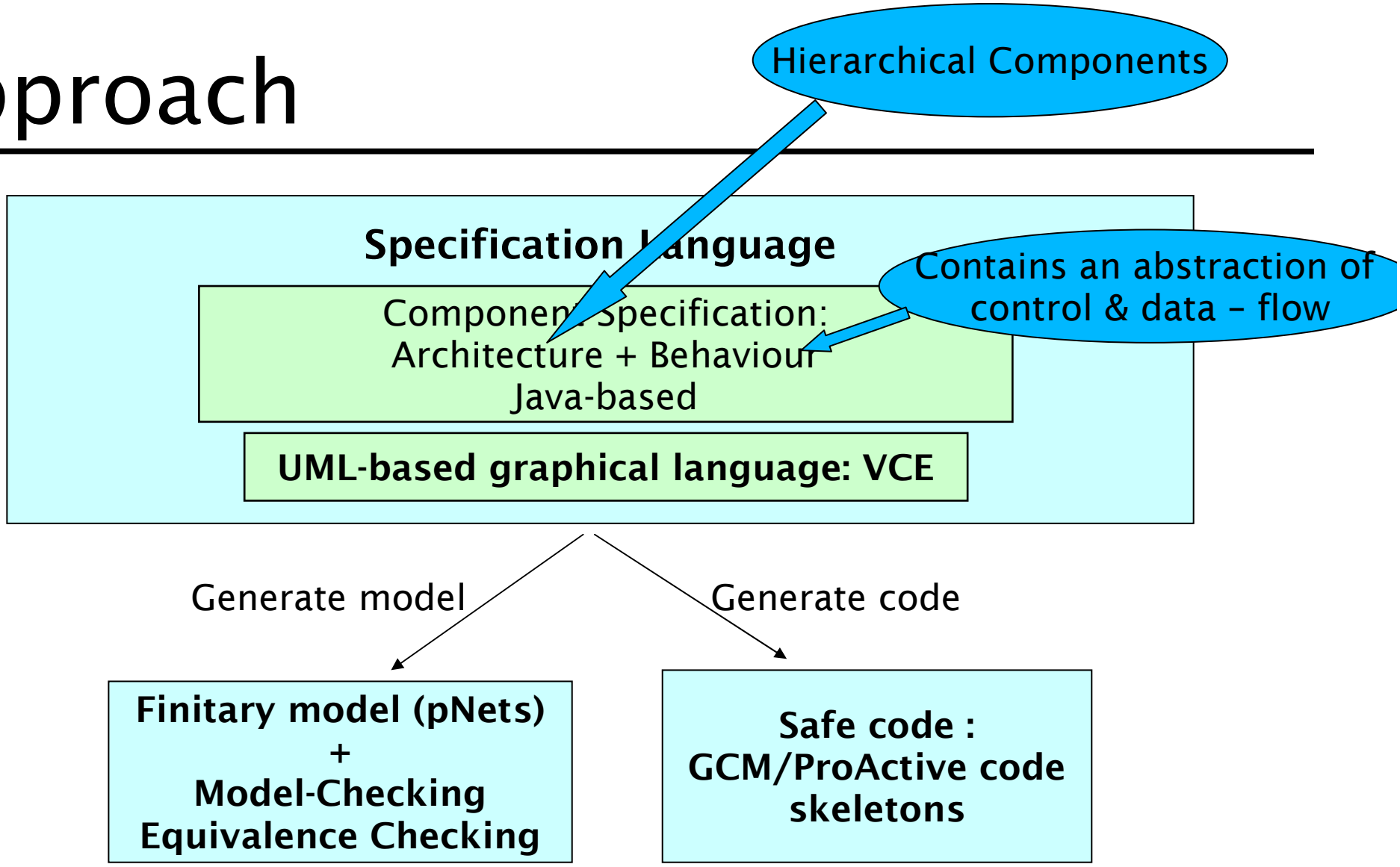


- SLOGAN /DREAM:
  - Bring the formal methods, tools, guarantees,
  - in the Development Environment => to non-expert programmers.

Build safe component-based systems

- Need :
  - Safe assembly of components
    - Static typing of bound interfaces is not sufficient
    - Compatibility of dynamic behaviour
      - Formal specification of Components
- Specification Language :
  - Integrate ADL and BDL (architecture and behaviour)

Approach


Hierarchical Components
Specification language
Component Specification:
Architecture + Behaviour
Java-based
Contains an abstraction of control & data – flow
UML-based graphical language: VCE
Generate model
Generate code
Finitary model (pNets)
+
Model-Checking
Equivalence Checking
Safe code :
GCM/ProActive code
skeletons

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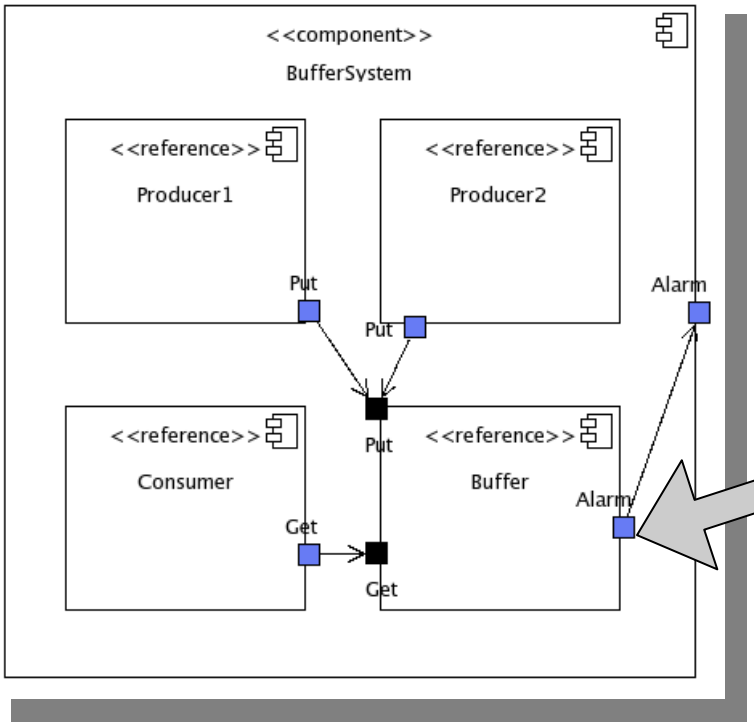
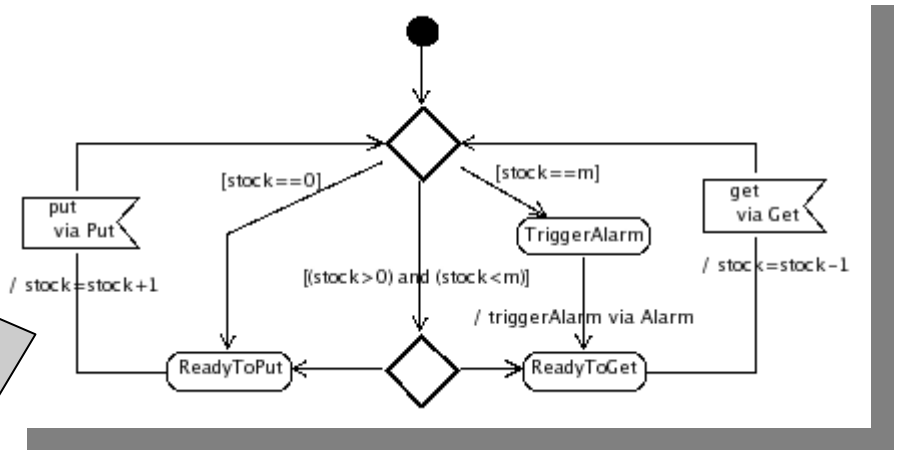
UML2 Prototype: Vercors Component Environment

- Component Diagram
- State Machine Diagram



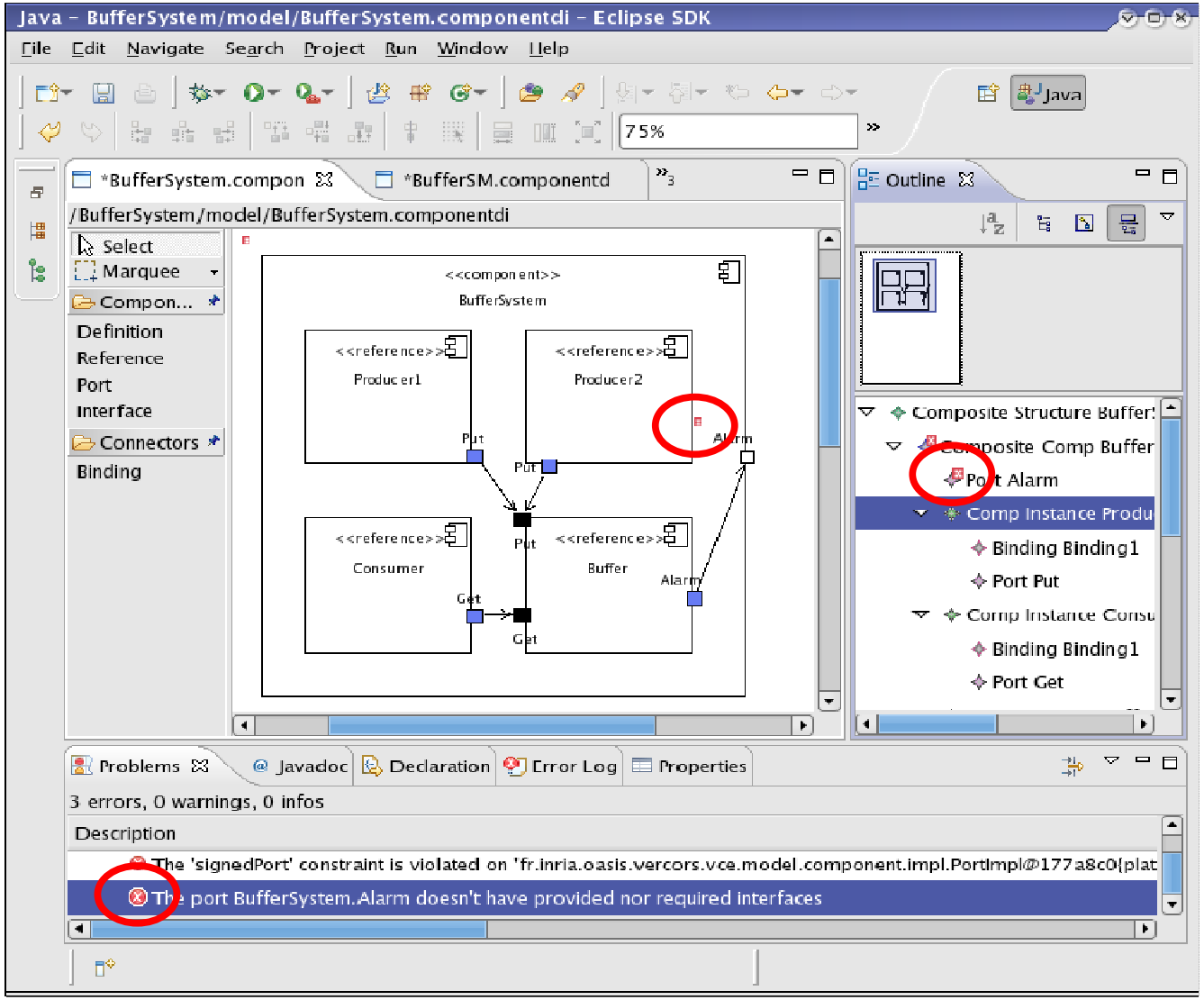


Need only the Data influencing the control-flow and the topology
In practice: use Java interfaces, + ad-hoc abstraction

VCE Prototype

- Functional behaviour of components
  - Specification given as a State Machine
  - Implementation given as a composition of subcomponents
- Integrated into Eclipse as plugins
- Generation of behavioural model for Verification

VCE: Snapshot



VCE: Validate and Verify

- Use of sound semantic model - pNets
  - Hierarchical, Parameterized Networks of Labelled Transition Systems
  - Simple predefined datatypes
- Generate Behavioural Models based on pNets
  - Functional and Non-Functional concerns
- Model-check the behavioural model
  - Deadlocks, Reachability, Safety, Liveness
  - Properties specified as automata
  - Functional verification + safety of reconfiguration

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- Specification of GCM components :

  (Grid Component Model)
- Generation of safe components

GCM / ProActive Components

- Hierarchical components
- Strong encapsulation of functional activity
- Interfaces expose all communication between components
  - Sorts given by: method calls, arguments, and return types
- State-full
  - Persistent variables (in primitive components)
  - Request queues (in primitives and composites)

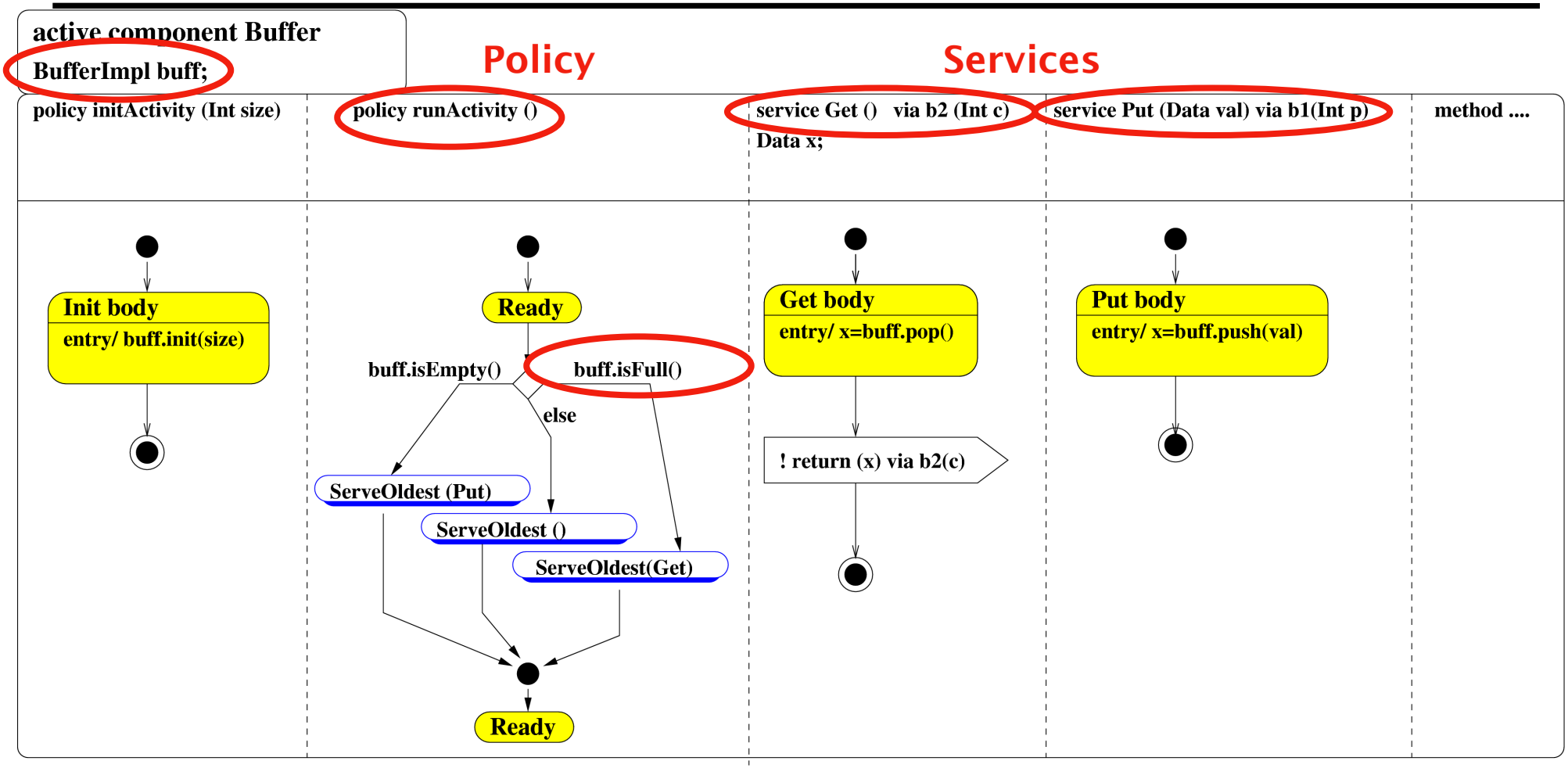
Specify the Behaviour of GCM / ProActive Components

- Service policy
  - How to serve requests from the request-queue
    - Calls on service methods (and local methods)
    - Depends on local component state
    - Most used: serveOldest(*filter*)
- A policy can be concurrent (for composite parallel components)

Behaviour of GCM / ProActive Components

- Service methods
  - Contain an abstraction of the business code
    - Using *real* Java user classes
  - Are unaware of the request-queue
  - Are not allowed to call (local) service methods
    - the only allowed interference is through shared variables
  - Triggers events
    - calls on client interfaces

Behaviour of GCM / ProActive components



- ✓ Generate skeletons for GCM components

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Guidelines for Generating ProActive Code

- Goal
  - Same behaviour as the specification
- Generated Java/ProActive code
  - Full and final:
    - GCM ADL
    - Code of Fractal controllers
    - Service policy: `runActivity()`
  - Skeletons for:
    - service methods (methods defined in server interfaces)
    - With hooks to fill-in final implementation (User-defined Business code)

Black-Box View of Components

- Externally, components are seen as:
  - **Sequential** component
    - These may implemented as GCM primitives or composites
    - Our choice: generate a primitive GCM component
  - **Concurrent** component
    - These must be implemented as GCM composites to deal with concurrency
    - Our choice: explore the architecture for finding sequential parts which will become primitives, and concurrent ones that become composites

Generate a GCM Primitive

- Can be generated in an isolated manner
  - All provided and required interfaces are known
  - No need to know its environment / architecture
- Body: `runActivity()` + service methods
  - Simulate a State-Machine with Java/ProActive code
    - **Non-determinism is an issue**
  - Calls on client interfaces create futures: all communication is handled by ProActive
- Control code shouldn't be modified
  - Ensure the same behaviour as the specification

Generate a GCM Composite

- Architecture definition: ADL
  - XML with static information about the architecture of the component
- Service Policy and Sequential behaviour are treated by primitives

Data within Components

- In the specification, there are user datatypes
  - Used to generate directly Java interfaces of types

- Need to specify an abstraction to be used within the state machines

From the Architecture Definition

GCM ADL

```
<component name="CashDesk">
   <interface signature="LightDisplayControlIf" role="server"
name="lightDisplayControlIf"/>
          ...
   <component name="CashDeskApplication">
      <interface signature="ApplicationEventHandlerIf" role="server"
name="applicationEventHandlerIf"/>
             ...
      <content class="CashDeskApplication"/>
      <controller desc="primitive"/>
   </component>
...
   <binding client="this.lightDisplayControlIf"
server="LightDisplayController.lightDisplayControlIf"/>
   <controller desc="composite "/>
</component>
```


From the Architecture Definition

Fractal Controllers

```
public String[] listFc() {
   return new String[]{ CASHBOXEVENTIF_BINDING };
}

public Object lookupFc (String clientItfName) {
   if (CASHBOXEVENTIF_BINDING.equals(clientItfName))
      return cashBoxEventIf;
   return null;
}

public void bindFc (String clientItfName, Object serverItf) {
   if (CASHBOXEVENTIF_BINDING.equals(clientItfName))
      cashBoxEventIf = (CashBoxEventIf)serverItf;
}

public void unbindFc (String clientItfName) {
   if (CASHBOXEVENTIF_BINDING.equals(clientItfName))
      cashBoxEventIf = null;
}
```


Generate GCM / ProActive code

Service Policy: runActivity()

```
public void runActivity(Body body) {
        Service service = new Service(body);
        while (body.isActive()) {
                switch(state){
                case ENABLE: // states of the automata
                        if (service.hasRequestToServe()) {
                                Request request = service.getOldest();
                                if
(request.getMethodName().equals("scanCreditCard")) {
                                        service.serveOldest();
                                } else if (request.getMethodName()

        .equals("expressModeDisabled")) {
                                        service.serveOldest();
                                }
                                else {
                                        service.serveOldest();
                                        state = State.DISABLE;
                                }
                        }
                        break;
                 case DISABLE
                        … // other states
```


Service Method

- Control structure
  - Control-flow and data-flow
- Method calls performed on client interfaces
  - Creation of futures
  - Flow of futures
- Data-usage
  - First use of a future is meaningful
    - wait-by-necessity – synchronisation points
  - Programmers may use these data within the computation

Generate GCM / ProActive code

Service Method

```
public void pinEntered(PIN pin) {
   if (creditInfo != null) {
      Transaction transId = bankIf.validateCard(creditInfo, pin);
          // call on client interface
          // arguments may be futures
      if (ProActive.getFutureValue(transId) != null) {
         Info info = bankIf.debitCard(transId, runningTotal);
         if (ProActive.getFutureValue(info) != null){
            Sale sale = new SaleImpl(
               new PaymentModeImpl(PaymentModeImpl.CREDIT),
               products, runningTotal);
            saleRegisteredIf.bookSale(sale);
            info.getInfo(); // wait-by-necessity
            init();
      ...
}
```


Correctness of the Generated Code

- Our modelisation preserves safety formulas
  - Including abstraction of value-passing data
- Semantics of communication is sound
  - ProActive library is based on ASP-calculus (and its properties)
  - Semantics are simulated by the behavioural model (pNets) which closely fits in ProActive's MOP
- Reliability of code is highly dependent on the set of formulas and the abstraction used in them

Some Open Questions

- How to manage hooks for filling in the final implementation?
  - Don't limit the programmer
  - Don't interfere with the control code
- Implementation issues
  - Use of Java annotations?
- Where is the right place to put abstractions (which depend on the set of formulas to prove) ?

- Which is the best way to have human-readable code? *[Code based on State-machines]*

Conclusions and Perspectives

- Short-term
  - Graphical tool for GCM Specification (VCE)
    - Asynchronous distributed components
  - Generation of Safe code (A. Cansado PhD)
    - Java code generated
- Long-term
  - Advanced GCM-specific features
    - Multicast, gathercast interfaces
    - Autonomicity : behaviour of the membranes of composites
  - Formalisation and proofs
  - Language for expressing reconfiguration of components (related to M. Rivera PhD)

References

- http://www-sop.inria.fr/oasis/Vercors
- Behavioural Models

  Model checking distributed components: The Vercors platform.
  T. Barros, A. Cansado, E. Madelaine, and M. Rivera
  In 3rd workshop on Formal Aspects of Component Systems
  Prague, Czech Republic, Sep 2006. ENTCS

- Case-study: CoCoME

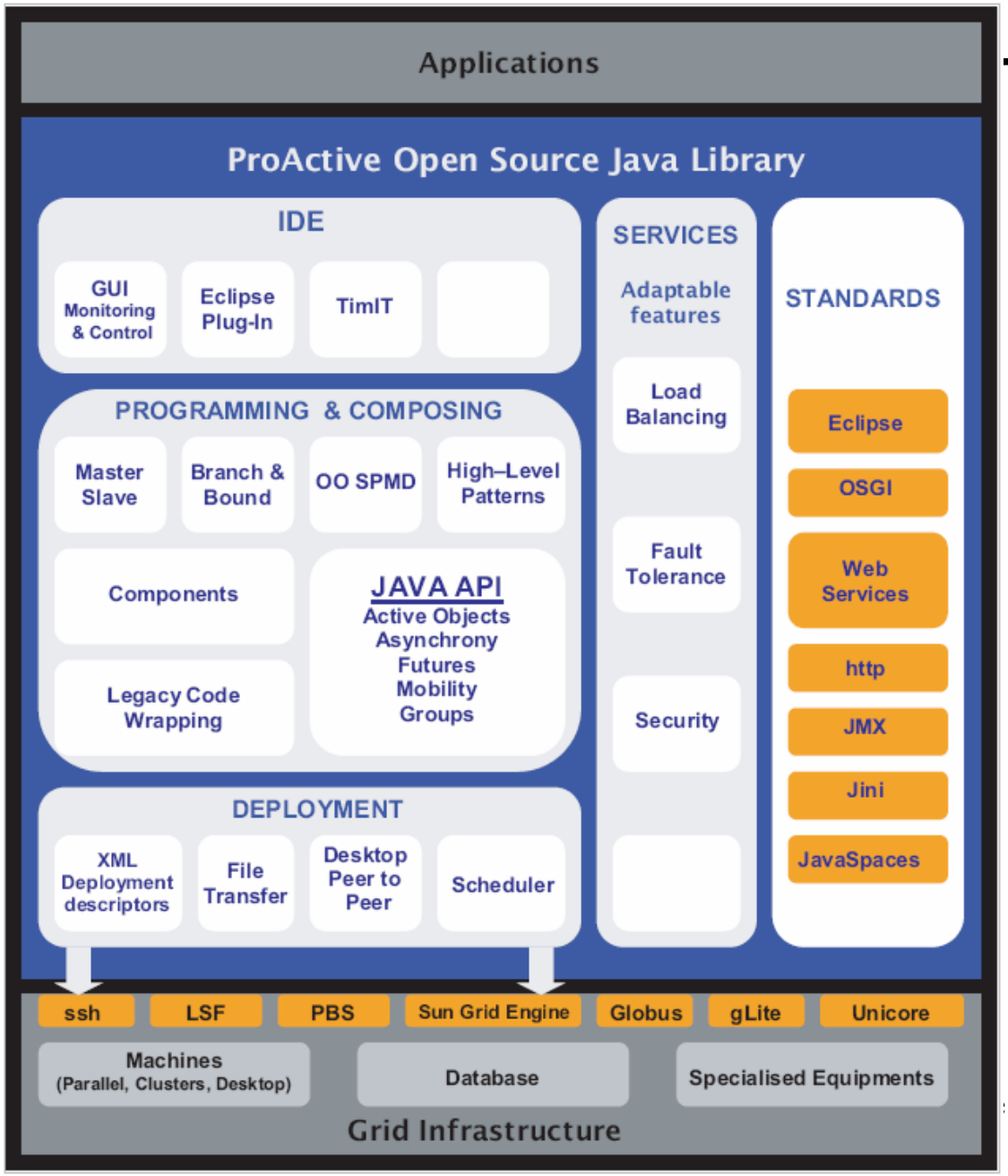
  A Specification Language for Distributed Components implemented in GCM/ProActive
  A. Cansado, D. Caromel, L. Henrio, E. Madelaine, M. Rivera, and E. Salageanu
  Lecture Notes in Computer Science. Springer, (to be published 2007)

- Diagrams for GCM components

  Specifying Fractal and GCM Components With UML
  S. Ahumada, L. Apvrille, T. Barros, A. Cansado, E. Madelaine, and E. Salageanu.
  In XXVI Inter.Conf. of the Chilean Computer Science Society, Chile, Nov. 2007. IEEE

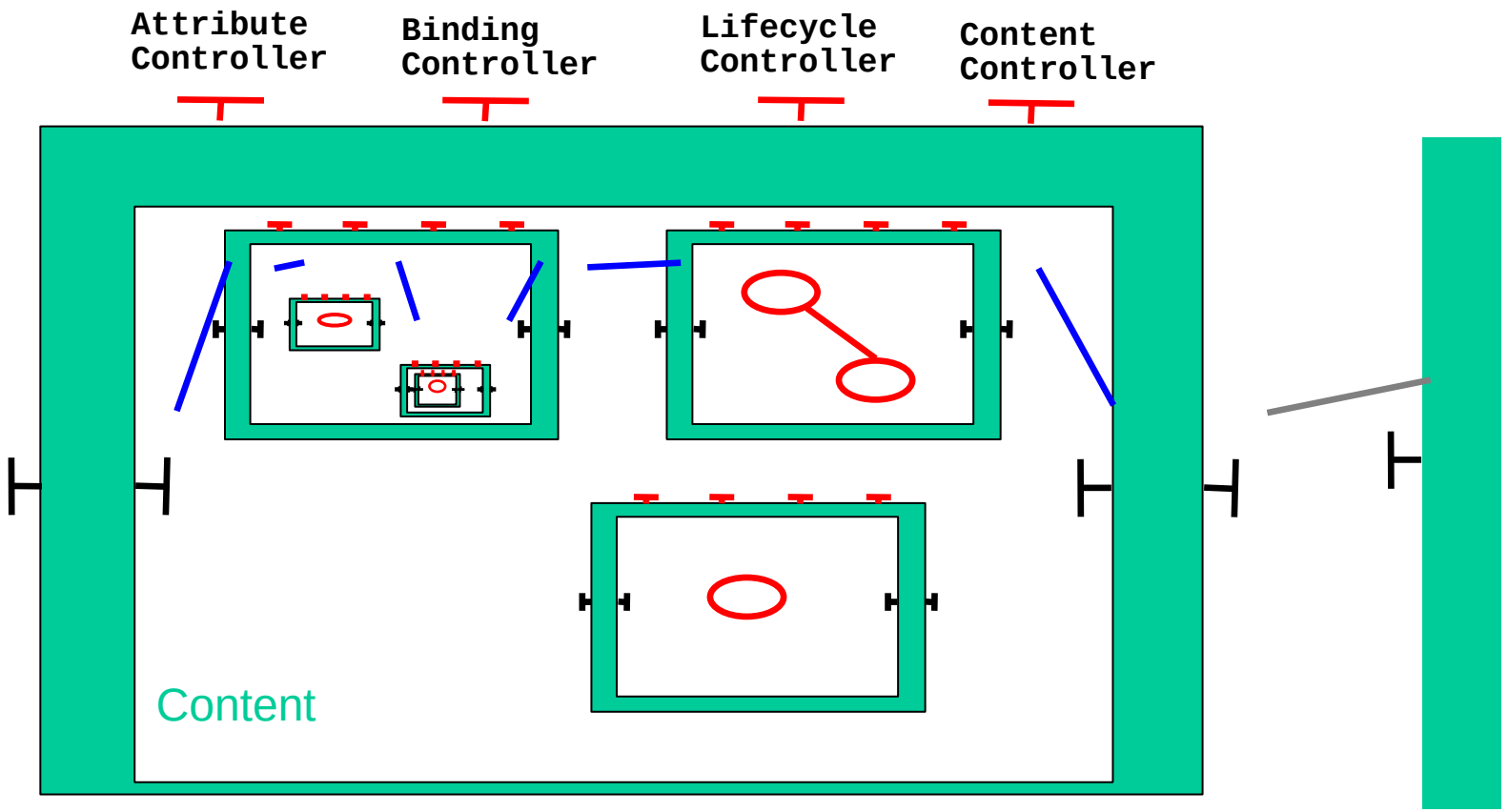
Annexes

ProActive Architecture



Fractal hierarchical model :

composites encapsulate primitives, which enca
code



now the basis for the GCM

Architectural View