Component based Middleware for real-time embedded systems

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CEA-List

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Agenda

- Introduction – Demands of RT & Embedded Applications
- Towards a common component model for this domain
  - Convergence of models
  - Extensions for Embedded & RealTime applications
  - Complementary activities – validation, model of computation
  - Specific usage: fault tolerance mechanisms
- Model Driven Development
  - From Models to executable middleware code
  - eC3M UML Models (within Papyrus UML)
  - Code generation

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Demands of RT & Embedded applications

- Real-time: timing constraints (soft or hard deadlines)
- Resource constraints (small memory, RAM/ROM)
- OS constraints (fixed number of threads, Semaphores, message sizes, ...)

⇨ software tailored to specific target, costly to port and to adapt

- Quote from ITEA-Merced project, same spirit behind IST-Compare

move from **performance-centric**
to **complexity-centric**...
..without loosing
performance and time support!

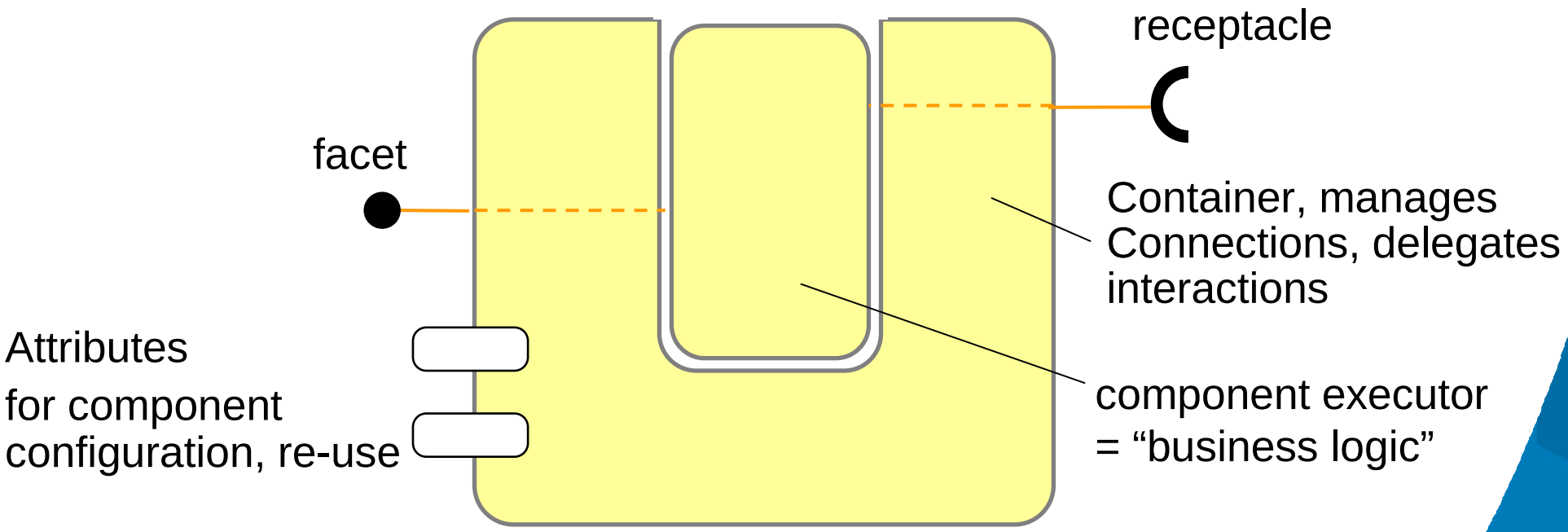
Component Approach

- CORBA Component model as good base candidate
  - OMG Standard
  - Separation of component & container enabling better portability
  - Lightweight variant exists
- But … only pre-defined container with fixed services
- But …only supports small set of *interaction patterns* … with specific and *fixed* implementations
  - Synchronous method calls (via CORBA)
  - Event based communications
  - Streaming (recently added)

⇨ Not enough for embedded systems

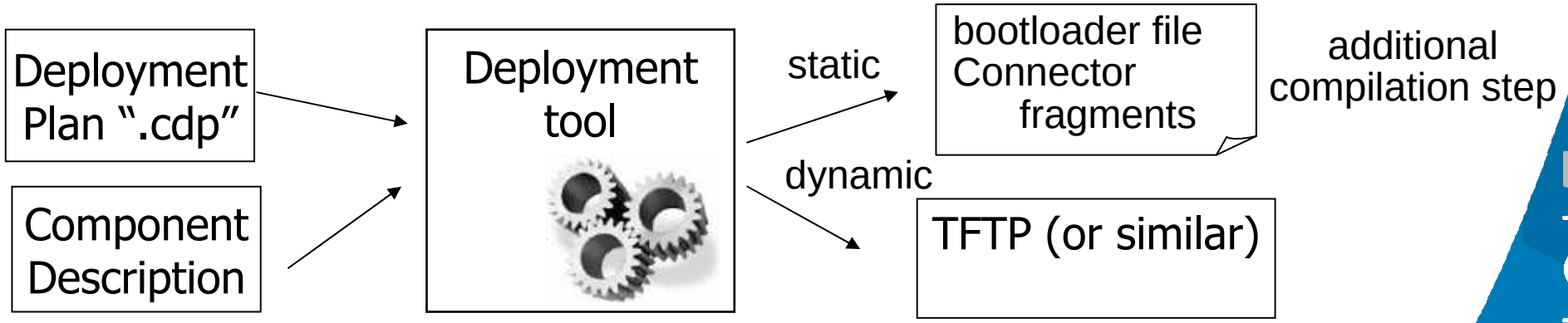
Excursion: CORBA Component Model

- Component has provided and required ports (interfaces, events)
- Lightweight CCM = CCM w/o introspection, simple container type (no security/persistence/transaction)



Packaging and Deployment

- "Classic" CORBA: No standard means of ...
  - Instantiation& Configuration, Deployment on nodes
- Deployment & Configuration (OMG standard)
  - Components are packaged into a self-descriptive package
  - Packages can be assembled
  - Assemblies can be deployed
- Deployment tools are based on XML descriptors



Towards an enhanced component model

- Better container support
  - New “simple” container with interception plug-ins
  - OMG Standard QoS for CCM
- Connector support allows to specify
  - Interaction pattern during component development time
  - Interaction implementation during deployment time
- Basic principles: Connectors are …
  - … like components: can be configured, have implementations
  - … like connections: ports don’t have fixed interface types, need to be *generated,* are split into connector ends (fragments)

Towards an enhanced component model

- Configuration of services/connectors in *declarative* way
- Advantage: keep platform specific programming (Mutex, Conditions, ...) out of business logic within component

⇨ *eC3M*
embedded Component-Container-Connector Middleware
(www.ist-compare.org)

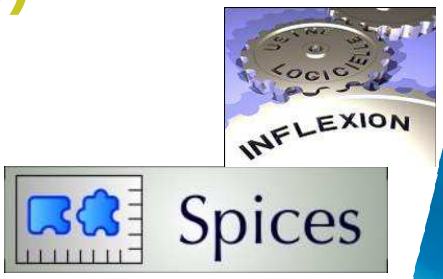
- Ongoing convergence actions among: CCM, Fractal, Autosar, IMA…
  - **Ongoing project** 

focus on CCM & Fractal
  - **Take Model Driven Development in Account**
  - 

for declarative NFPs http://www.omgmarte.org

Connector/Container Service Examples

- **Connector Examples**
  - Synchronous Calls via CORBA, OSEK messages
  - FIFO – in shared memory or distributed via CORBA
  - Events (making pre-defined event ports obsolete)
  - Connectors supporting Fault Tolerance, Communication avec FPGA (current projects)
- **Container Service Examples**
  - Access protection via n-readers, 1 writer
  - Logging/Tracing of requests
  - Execution time measurement
- **Limits: focus on structural info + declarative NFP**
  - *execution model managed implicitly*



How to define port semantics?

Component implementation assumes a certain semantics associated with call on port (and being called on a port)

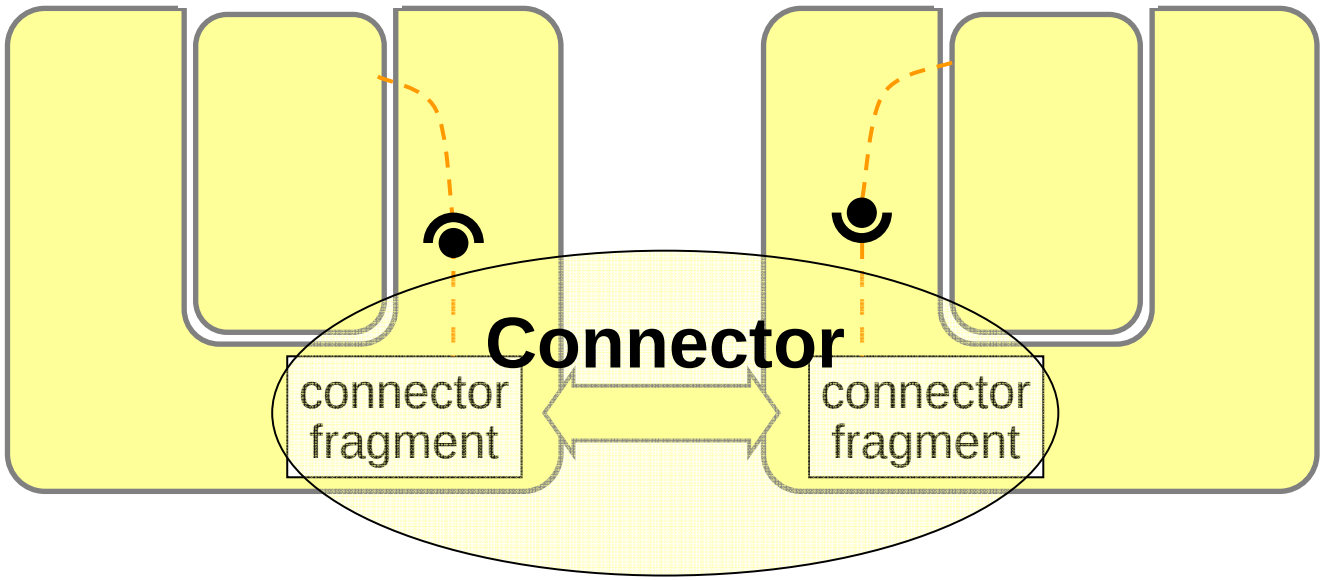
⇨ Connector maybe incompatible with a component, even if port interfaces are matching

Options

- Specify required connector type at component design time
  - A bit restrictive with respect to component reuse
- Via *port type* definitions
  - Port type captures certain semantics
  - Better component reuse of component implementations
  - Support complex-ports (single port can provide & require)

More insight on connectors for CCM (runtime)

- connectors realizations are fragmented
  - fragments are co-localized with components
    - Implement interface between component and connector
  - communication between fragments is connector specific



Complementary activities: computation models

- Formal technique: compute execution paths from finite state machine
  - Rules to trigger transitions, consume events, chain actions
    → are parameters
  - Symbolic execution engine
  - Applied to test generation, property verification…
  - Reuse free tools for formal techniques
    - reduce symbolic expressions, optimize trees, solve constraints…
    - Integrated to MDE technologies (Eclipse, EMF, ATL, Papyrus)

→ Manage heterogeneity by dynamically changing execution rules
  - Global view of system architecture: components (// state machines)

✓ **Limits: rules are defined case by case**

Heterogeneity of computation and communication models

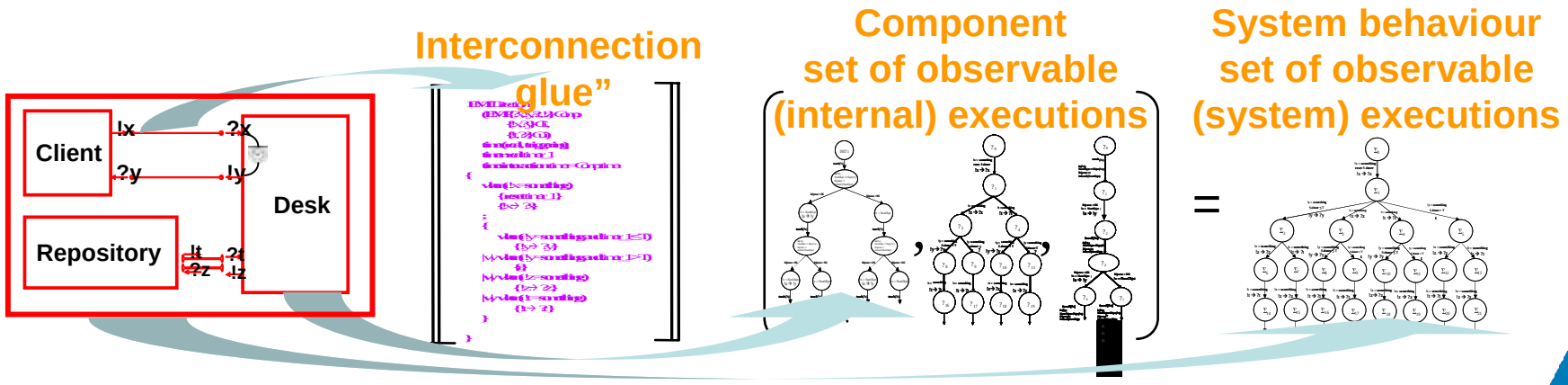
THeSys (**T**ackling **He**terogeneous **Sys**tems)

www.thesys.eu.org

Christophe Gaston

- Mathematical foundation (denotational):
  LEM (Language for expressing Execution Models)
  - integrate hierarchy, component, interconnection and (unrestricted) time
  - values and times of exchanged data are synchronised

  → *formal description of* Model of Computation and Communication (MoCC)



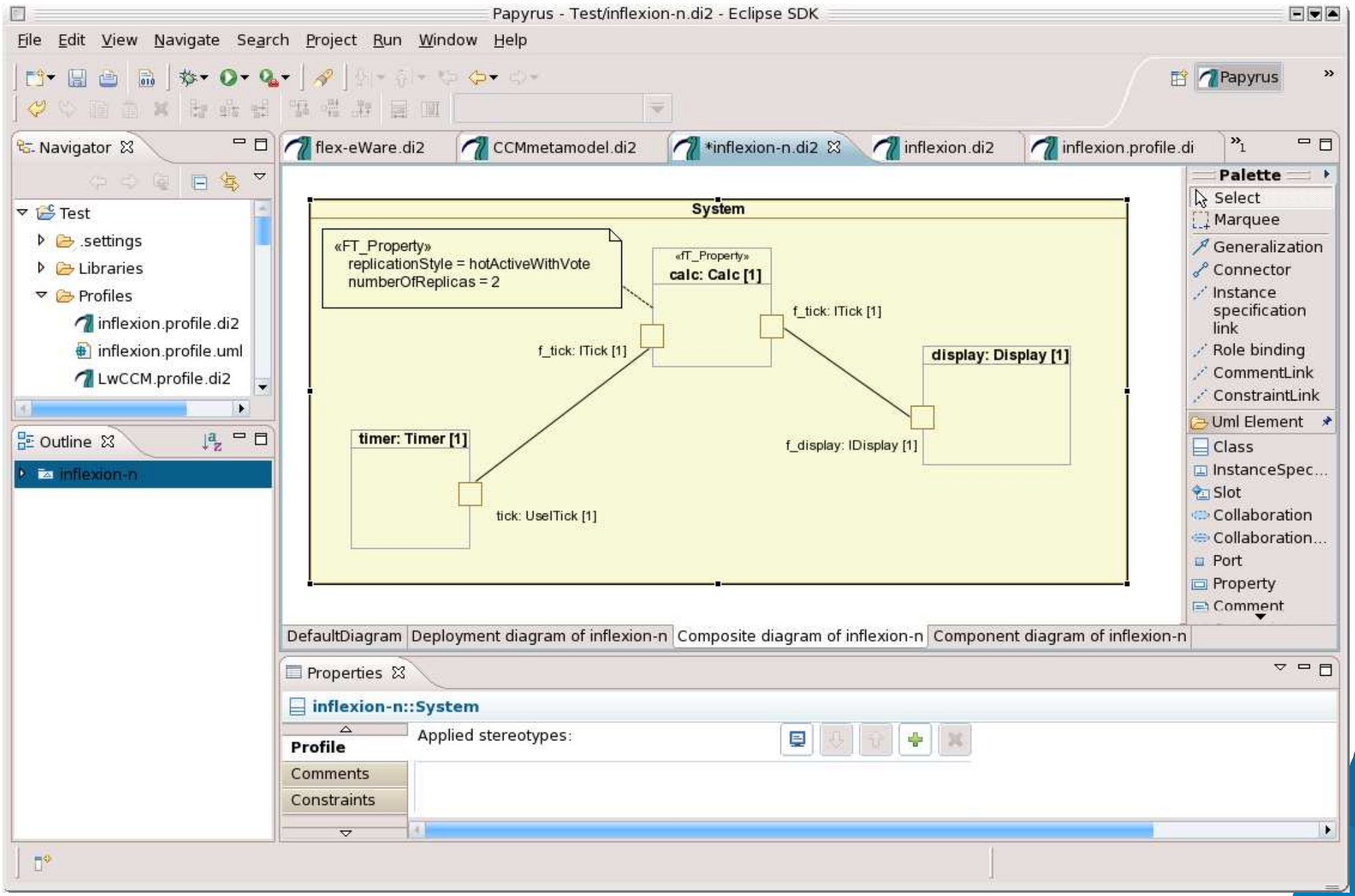
Related work (THeSys)

- Ptolemy II: not formal, heterogeneous (hierarchical), no language for expressing models of computation
- CommUnity (Univ. Leicester, Lisbon):
  formal, no time but causality (pre/post).
- BIP: formal, powerful interaction language, more limited to interactions
- Time treated externally, not meta model oriented
- Kermeta: not formal, meta programming language

Model Driven Development

- Meta-Model of component approach eC3M ⇨ UML Profile
- UML + 

Profile (for NFPs) + eC3M Profile
- Use of Papyrus (www.papyrus-uml.org) UML modeler
  - Strong Profile Support
  - “Invented here”
- Build model, apply stereotypes/values
- Generate eC3M descriptor files from model
  - IDL, Component Descriptor (CCD), Deployment plan (CDP)
- Generate container, bootloader (glue) via MicroCCM (joint implementation from Thales and CEA-List, hopefully released soon as OpenSource)


Papyrus - Test/inflexion-n.di2 - Eclipse SDK
File Edit View Navigate Search Project Run Window Help
Papyrus
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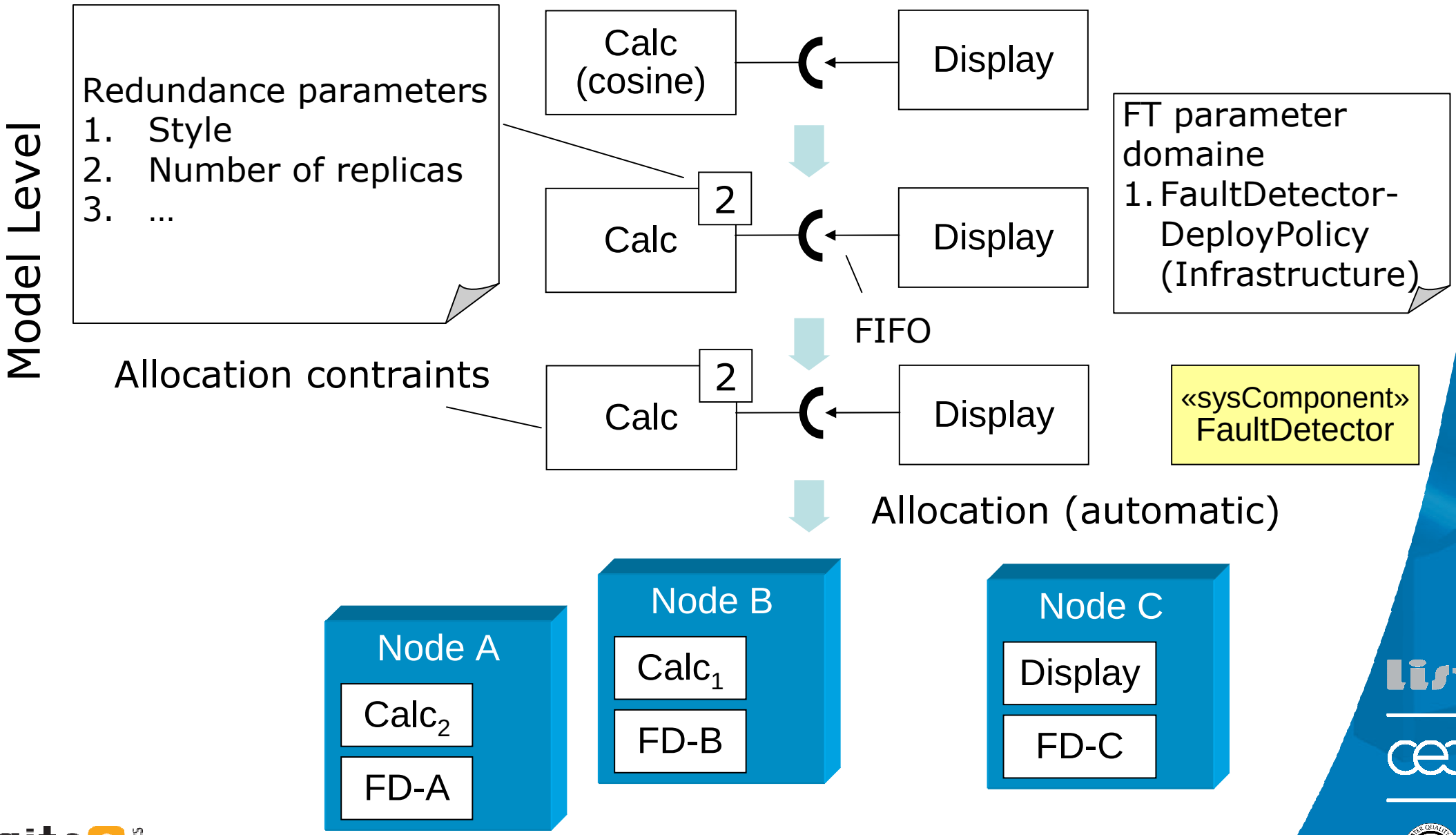
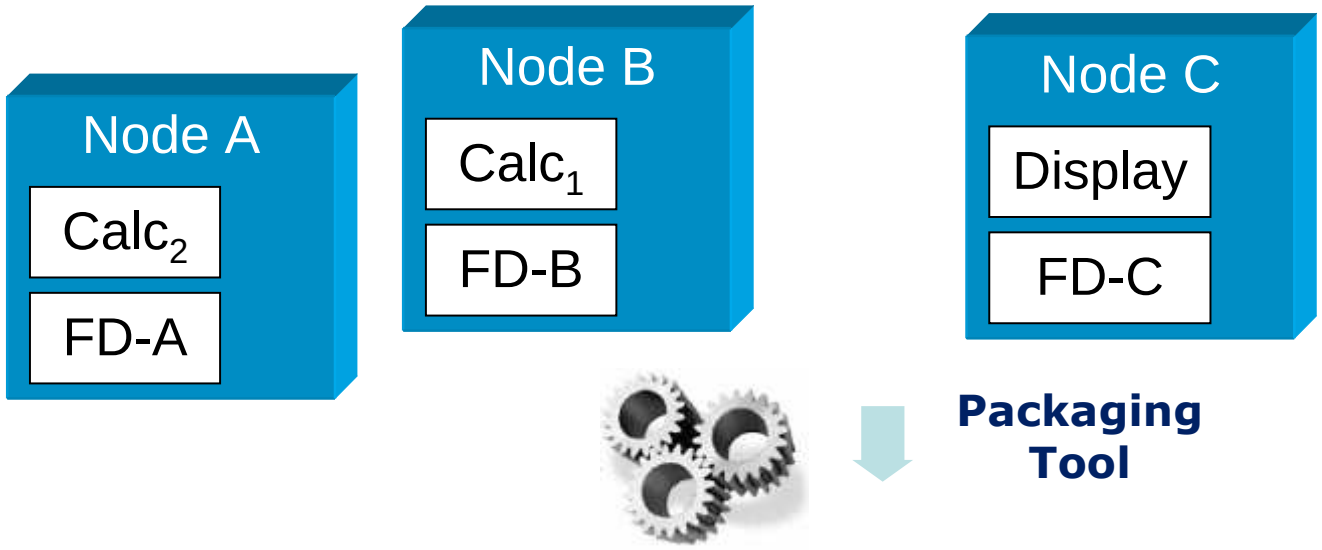
Test
.settings
Libraries
Profiles
inflexion.profile.di2
inflexion.profile.uml
LwCCM.profile.di2
Outline
inflexion-n
flex-eWare.di2
CCMmetamodel.di2
*inflexion-n.di2
inflexion.di2
inflexion.profile.di
System
«FT_Property»
replicationStyle = hotActiveWithVote
numberOfReplicas = 2
«fT_Property»
calc: Calc [1]
f_tick: ITick [1]
f_tick: ITick [1]
display: Display [1]
timer: Timer [1]
f_display: IDisplay [1]
tick: UseITick [1]
Palette
Select
Marquee
Generalization
Connector
Instance specification link
Role binding
CommentLink
ConstraintLink
Uml Element
Class
InstanceSpec...
Slot
Collaboration
Collaboration...
Port
Property
Comment
DefaultDiagram
Deployment diagram of inflexion-n
Composite diagram of inflexion-n
Component diagram of inflexion-n
Properties
inflexion-n::System
Profile
Applied stereotypes:
Comments
Constraints

Refinement steps



Deployment of a component (replica) on multiple nodes

Model Level



XML D&C

```
<!-- Instance of Calc -->
   <instance id="instance1">
   <name>Calc_inst</name>
   <node>nodeA, nodeB</node>
   <implementation ref="implCalc"/>
    <configProperty>…
</instance>
```

```
<connection id="connexion3">
        <name>Calc_Display</name>
   <implementation
      ref="implFT-FIFO"/>
   …
```

Fragment code (example)

```
void FTFIFO_IDisplay_f_conn::display (CORBA::Float value)
{
    if (m_voter != NULL) {
        // calculate hash of request (used to simplify comparisons).
        Hash hash;
        hash.add (m_voter->getRequestNr ());
        hash.add (value);
        m_voter->acknowledgeRequest (hash.get ());
    }
    for (int i = 0; i<MAX_NR_OF_NODES; i++) {
        if (m_set.isOnNode (i)) m_set.getObj (i)->display (value);
    }
}
```

Communication between replicas

Multiplier: Communication with other instance (maybe replicated)

Conclusions

- Specific support for embedded requirements through
  - Container services
  - Connectors (configurable)
  - ⇨Towards adaptive executions & communication platforms (heterogeneity at several levels)
  - ⇨Declarative specification of non-funtional properties
- Complete MDD tool chain
  - Model, Analysis (not shown Thesis H. Espinoza), deployment, execution & operation
- Future work
  - Convergence of component models based on standards
  - Overcome “two worlds” separation:
    - ⇨integrate formal approaches

Questions?