A Component Framework for HPC Applications

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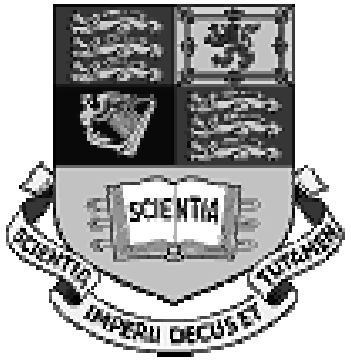


Outline

- Components for Grid Computing
- An Extensible Component Framework
- Separation of Abstraction & Implementation
- Static & Dynamic information
- Example: Linear Solver
- Further developments

Motivation & Background

- Grid developments typically low-level services
- Lack of penetration into user base
- High barrier to utilisation
- Goal:

  from explicit “hands on” grid use

  to automatic, transparent use

Requirements of Grid Computing

- Mobile
  - Dynamic, unreliable resource context
    - "Complex Resources"
- High Performance
  - Raison d'être of grid computing
    - "Complex Applications"
- Accessible
  - e-science portals, etc
    - "Transparent Mapping"

Information!

- User:
  - Who, what, when, where
- Resources:
  - Availability, character, policy
- Application:
  - Composition, behaviour, performance

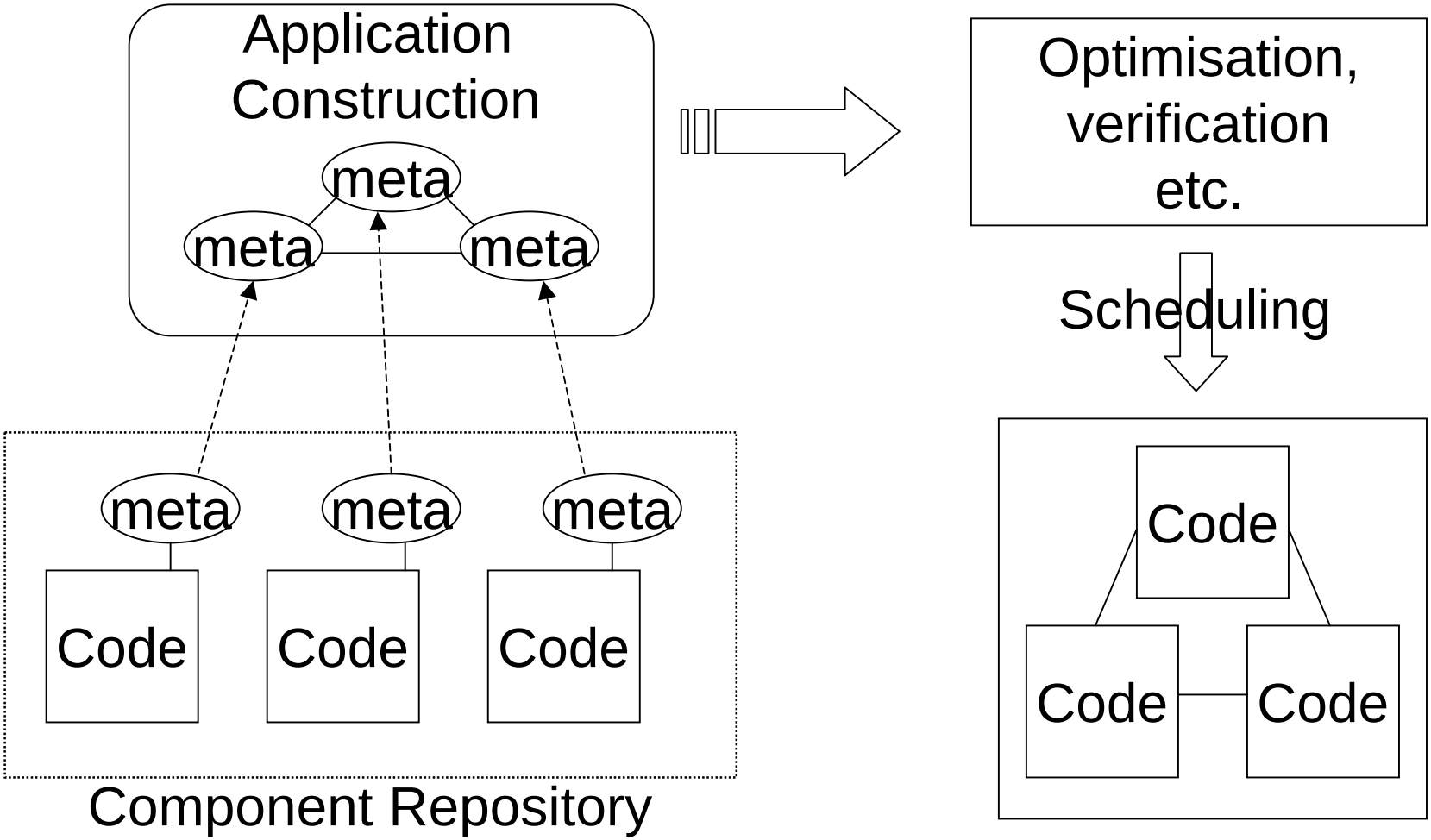
Software Abstraction: Components

- Separation between implementation and abstraction
- Expressability suitable for end-user programming
- Encapsulation of meta-data to enable dynamic optimisation

High Performance Software Components

- Express an application as a composition of components (high-level abstract data types)
- Separation of implementation & abstraction allows very late binding of low-level libraries
- Use component meta-information to inform all stages of application construction and execution
- Minimise execution time while maximising throughput over the available resources

Separating Meta-Information from Implementation

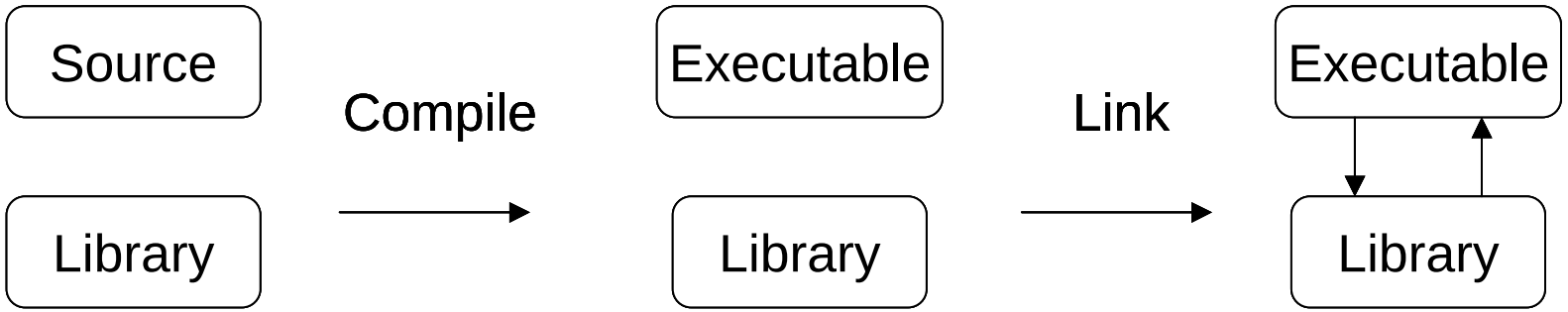


Augmented Component Lifecycle

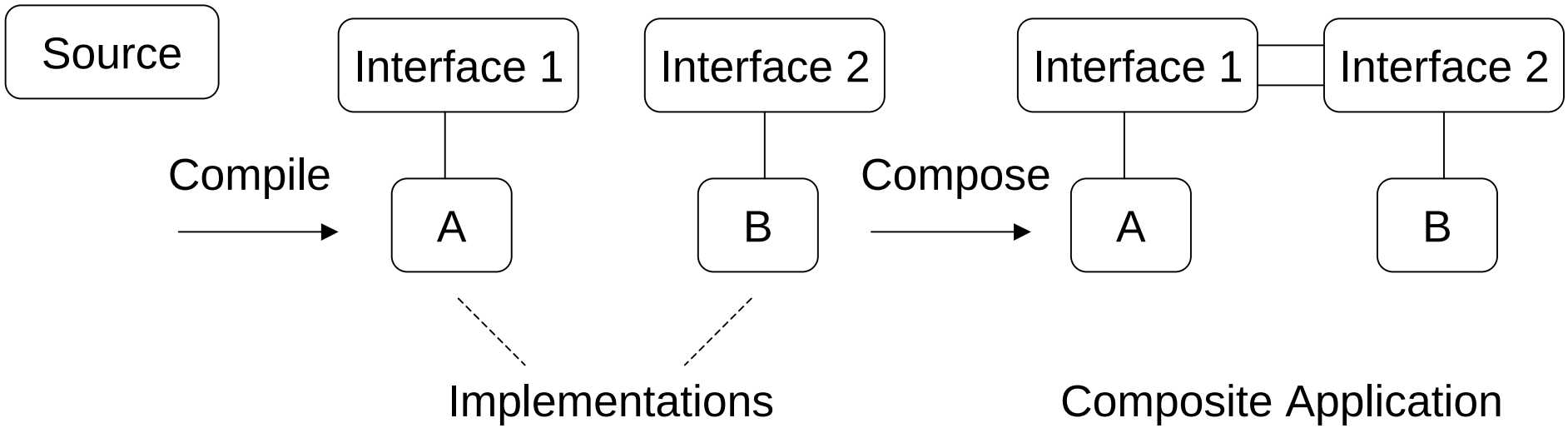
1. Compose Application
2. Cross Component Optimisation
3. Dynamic Implementation Selection
4. Deployment

Requires Resource Information

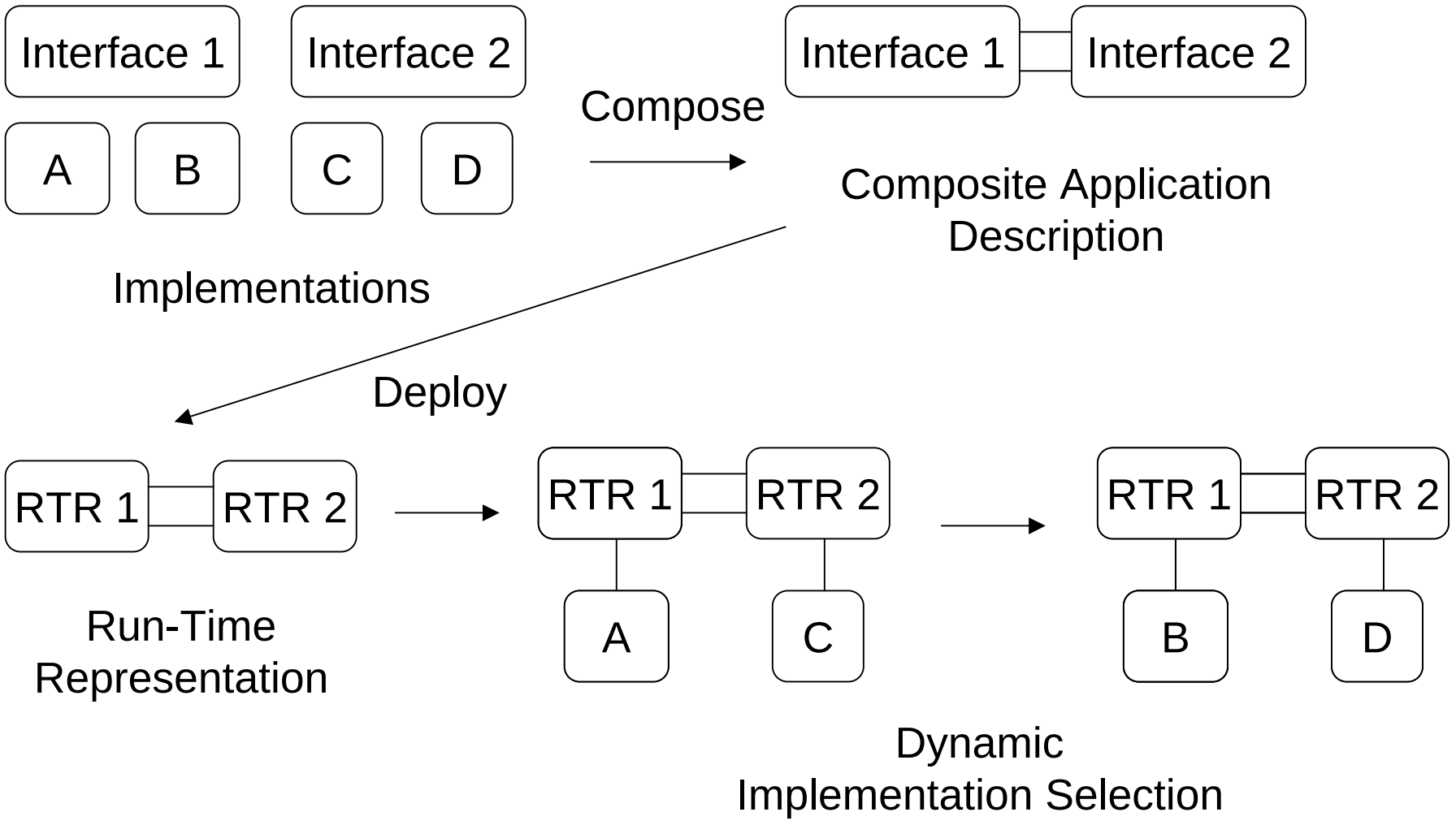
Conventional Software Lifecycle



Component Software Lifecycle



An Augmented Component Lifecycle



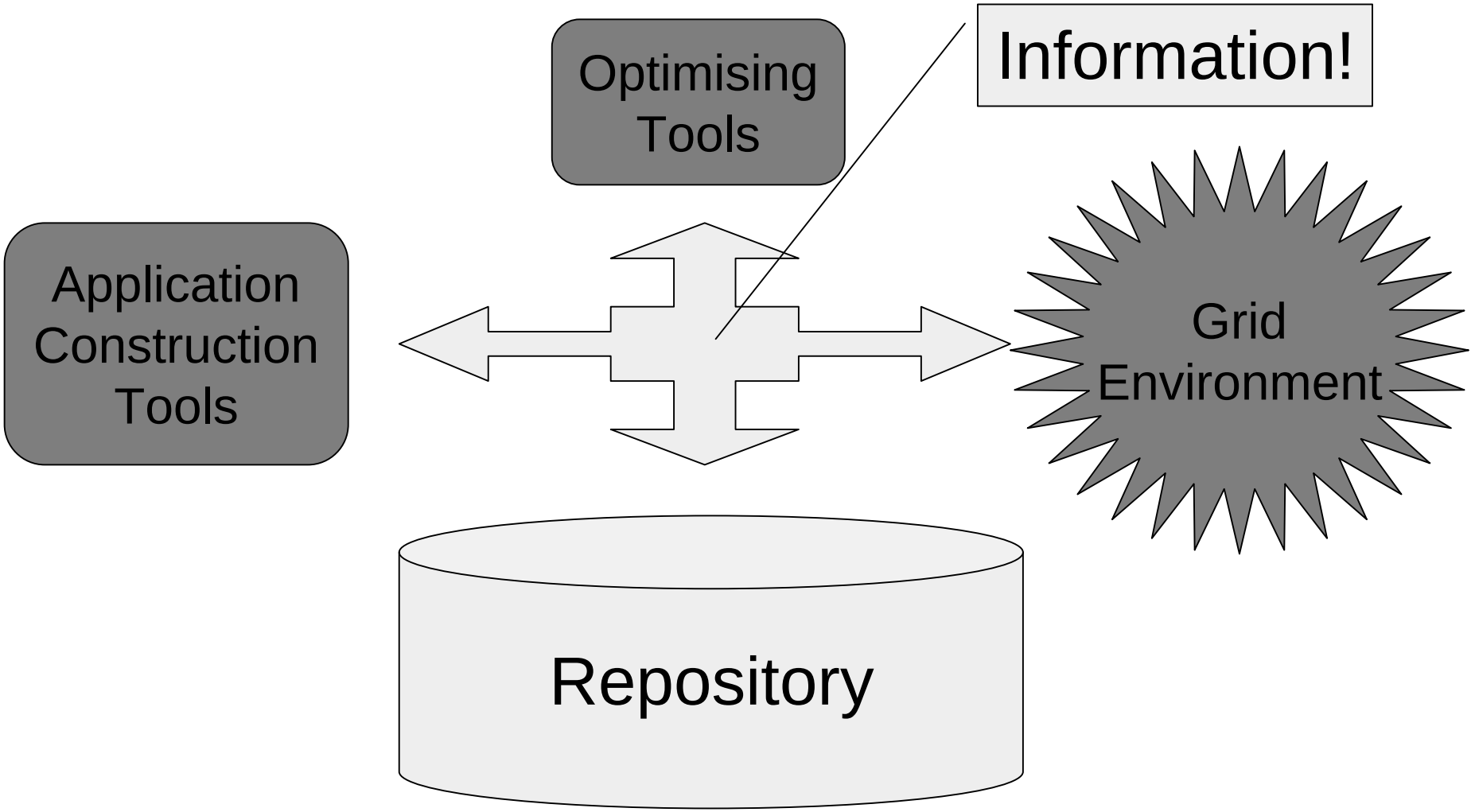
Very late binding

- Mobility of the high-level representation
- Performance of low-level implementation
- Dynamic Implementation Selection
- Cross-component optimisation

User Roles : Levels of Abstraction

- End-User
    5. Customise component instances
    6. Assemble composite application
- Scientist
    1. Design new component interfaces
    2. Specify component meta-information
- Developer
    3. Develop new implementations
    4. Specify implementation meta-data

An Extensible Component Framework



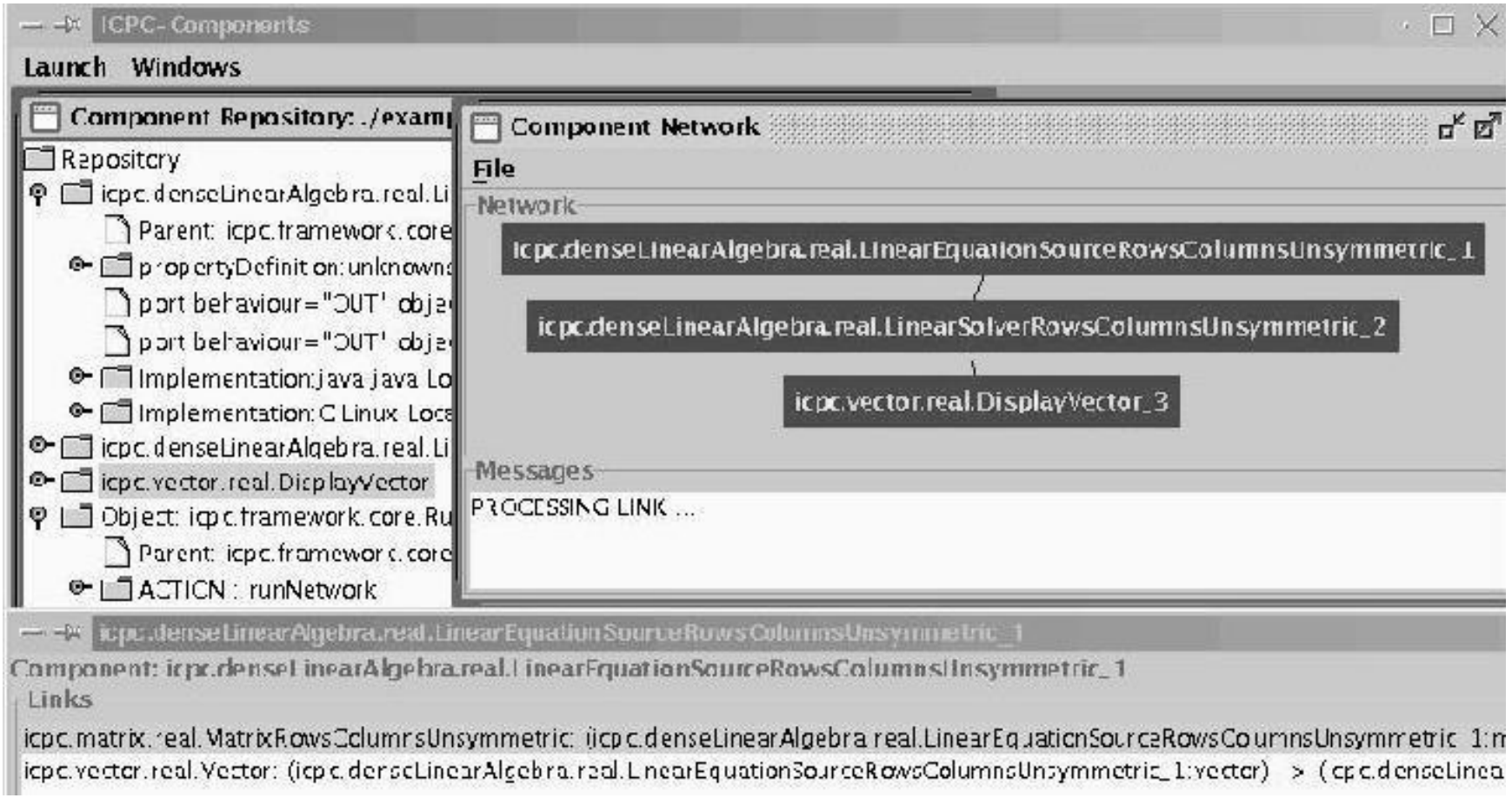
Framework: Repository

- Component Abstractions
  - Interface
  - Other meta-data (behaviour)
- Implementation Codes
- Implementation Meta-Data
  - Resource Requirements
  - Performance Characteristics

Framework: Application Construction

- Connection – oriented programming
  - Customisable component instances
  - Connections between inports & outports
- Extensibility: Visual or textual programming

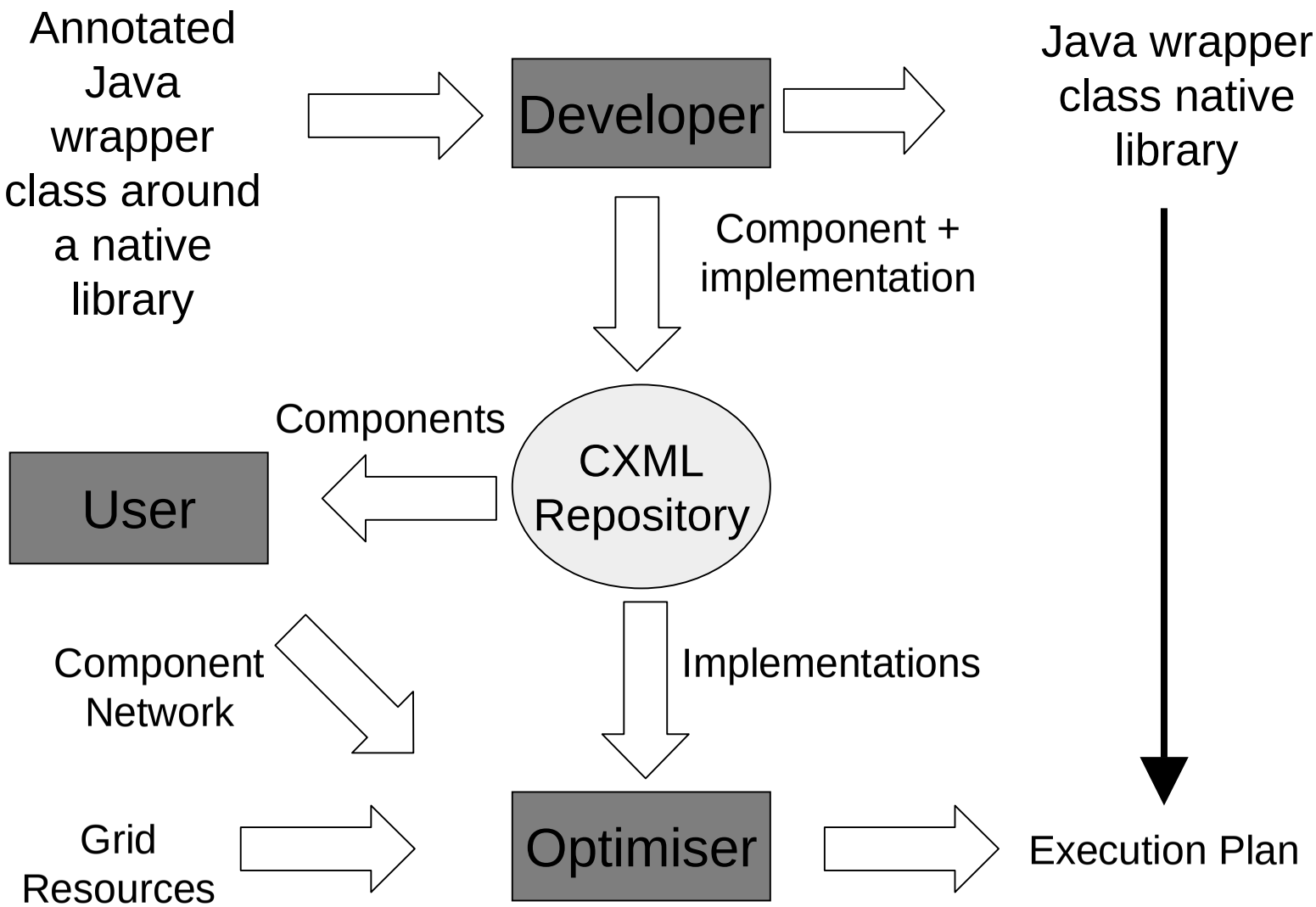
Visual Application Construction Tool



Static Application Information

- Component XML (CXML):
  - Application as network of components: Application Description Document
  - Component interfaces
  - Implementation Performance Characteristics
- Stored in Repository
- Produced by Application Construction

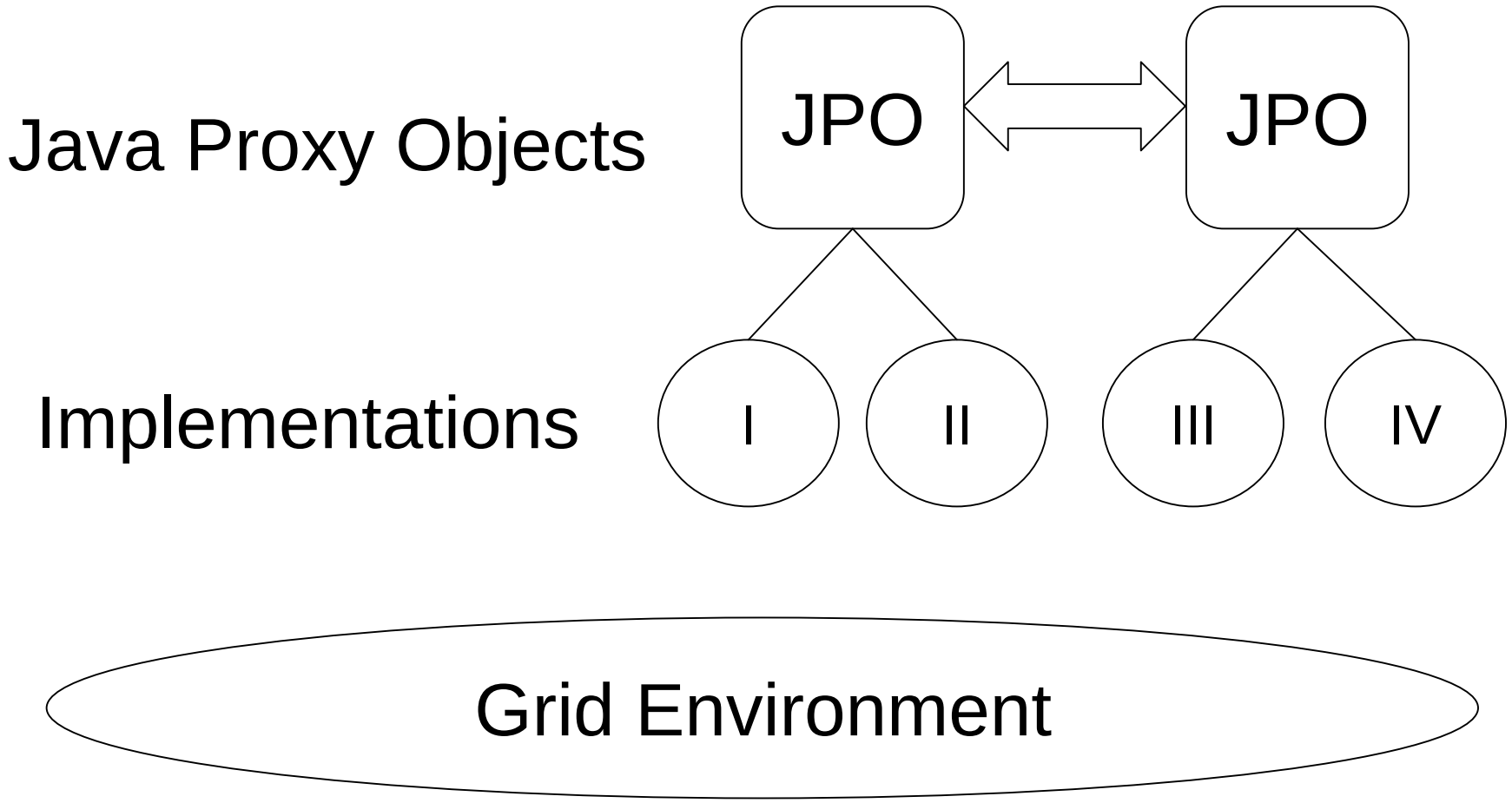
CXML as an Intermediate Language



Dynamic Information

- Run-Time Representation
  - Network of Java Proxy Objects
  - JPO corresponding to each component instance
  - Platform Independent
- Native Implementations
  - Platform Dependent
  - Wrapped & controlled by the JPOs
- Deployed on Grid

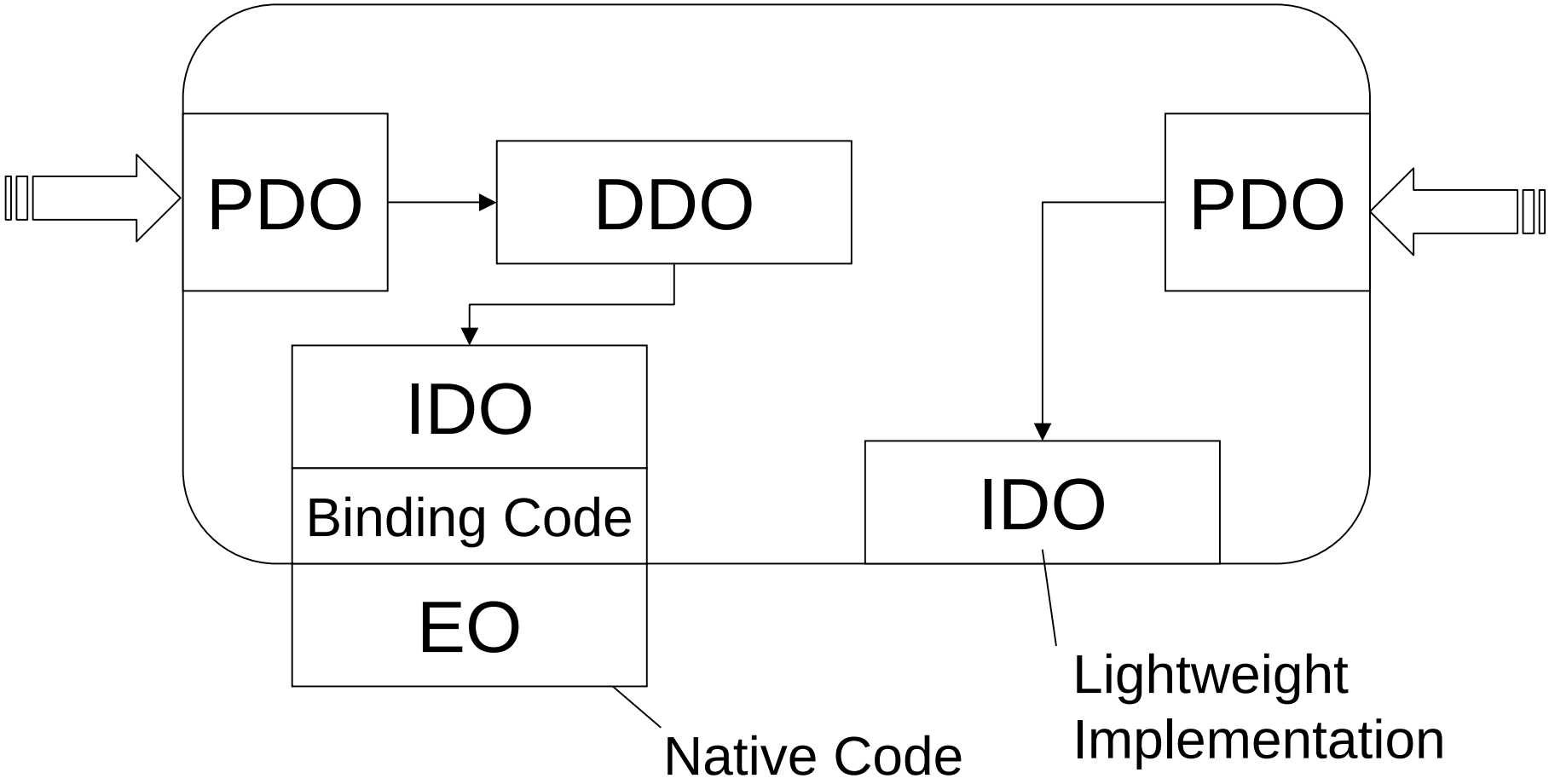
Dynamic Implementation Selection



Run Time Representation Architecture

- Port Definition Object
  - Outports trap method calls & data access calls
  - Inports make calls from other JPOs (pull model)
- Data Definition Object
  - Implementation independant data provides mobility
- Implementation Definition Object
  - Implementation Performance Characteristics
  - Binding Code
- Execution Object
  - Wrapping for native implementations

Java Proxy Object Architecture



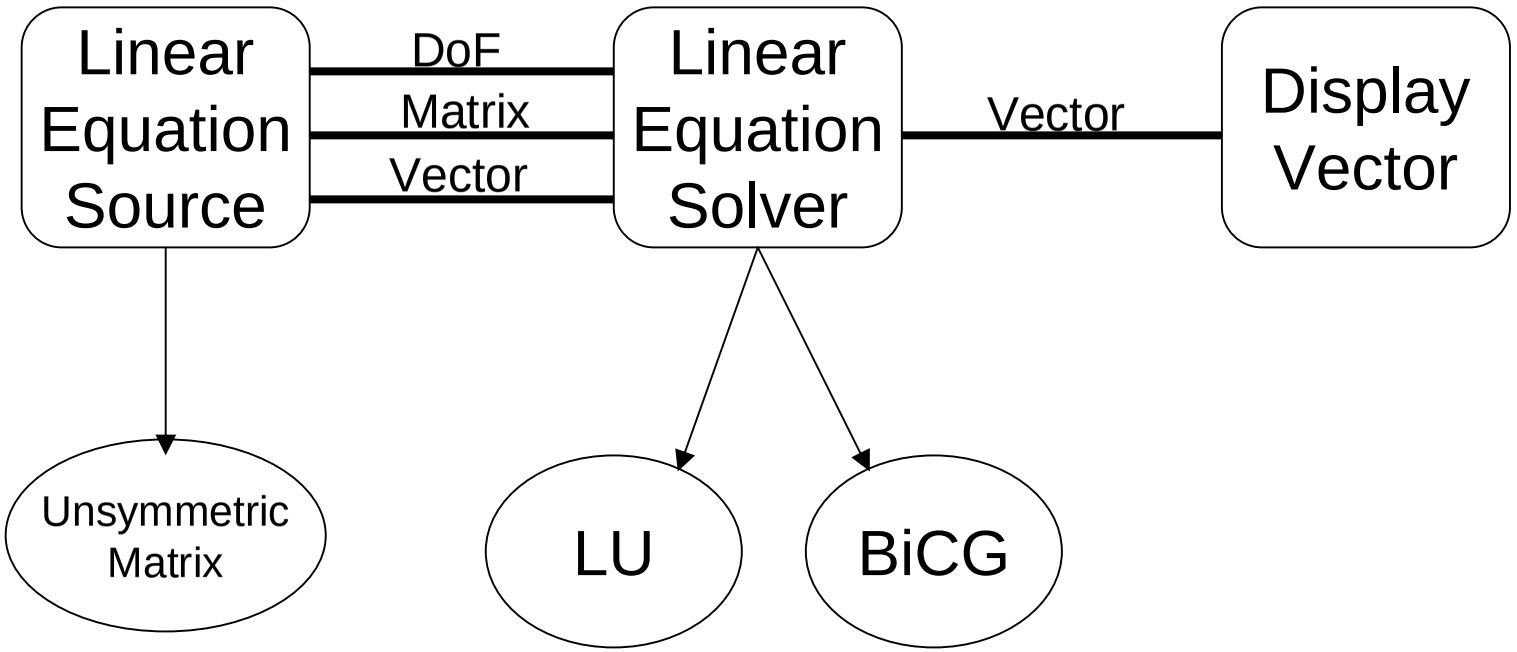
Performance Guided Implementation Selection

- Selection Policy
  - From Component Framework
- Resource Information
  - From Grid Infrastructure
- Implementation Performance Models
  - From Run-Time Representation
- Application Composition
  - From Run-Time Representation

Composite Performance Modelling

- Models derived empirically
- Composed according to component *behaviour* – encapsulated in CXML.

Example: Linear Solver



Linear Solver: Repository CXML

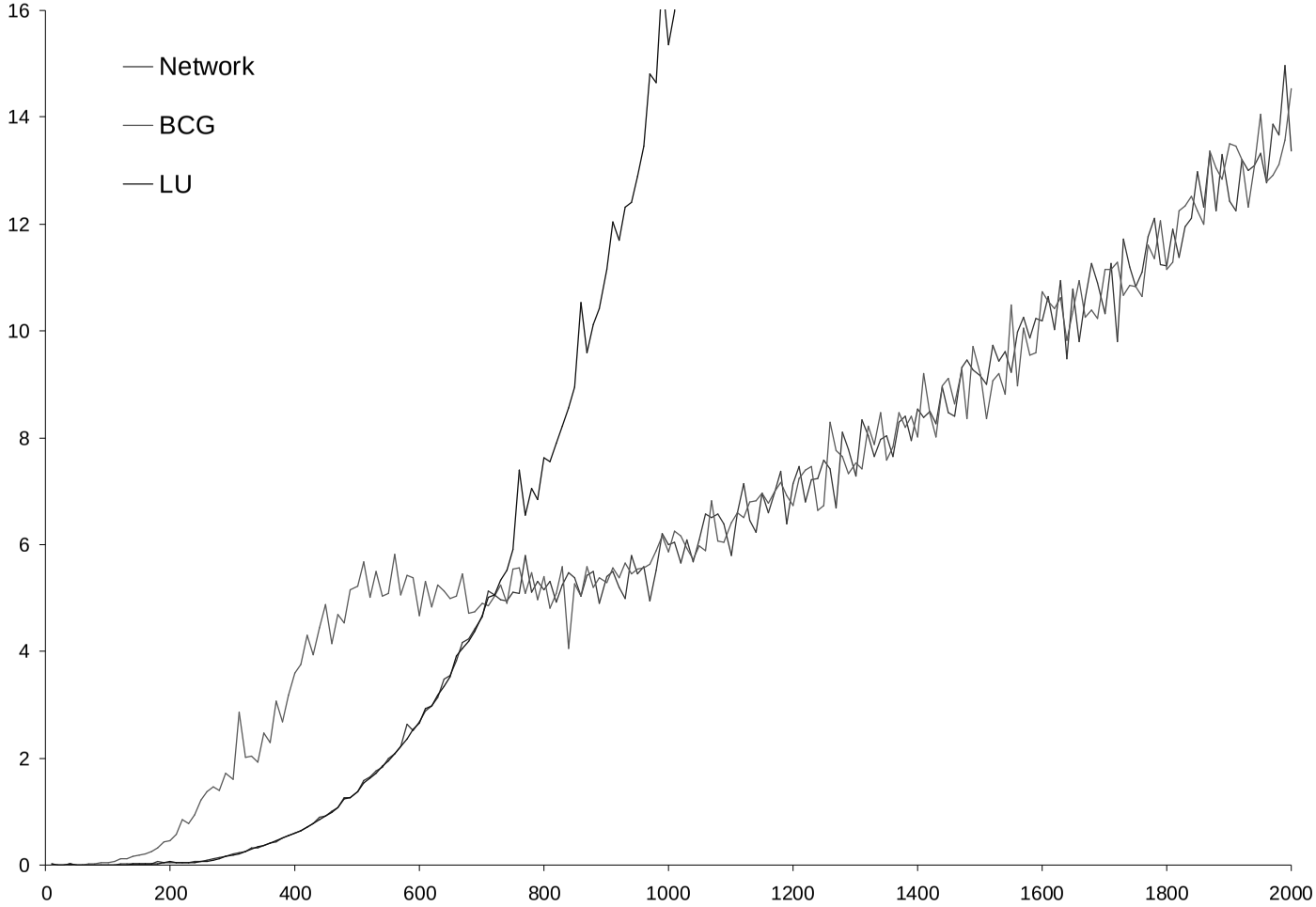
```
<repository>
     <component package="icpc.denseLinearAlgebra.real"
          name="LinearEquationSourceRowsColumnsUnsymmetric" version="1">
       <propertyDefinition type="external" name="degrees of freedom" value="1000"/>
       <port behaviour="OUT" objectPackage="icpc.matrix.real"
           objectName="MatrixRowsColumnsUnsymmetric" portName="matrix"/>
       <port behaviour="OUT" objectPackage="icpc.vector.real"
           objectName="Vector" portName="vector"/>
       <implementation language="java" platform="java" url="file:.">
           <action portName="matrix">
             <binding method="getMatrix"> ... </binding>
             <classPerformanceModel type="initial" url="http:" />
           </action>
       <implementation language="C" platform="Linux" url="file:."> ...
   </implementation>
     </component>
     <object package="icpc.matrix.real“ name="MatrixRowsColumnsUnsymmetric"
   version="1">
         ...
       <method name="getMatrix" type="action">
         <argument mode="out" typeName="MatrixRowsColumnsUnsymmetric"
            typePackage="icpc.matrix.real" />
       </method>
     </object>
   </repository>
```

Linear Solver: Application CXML

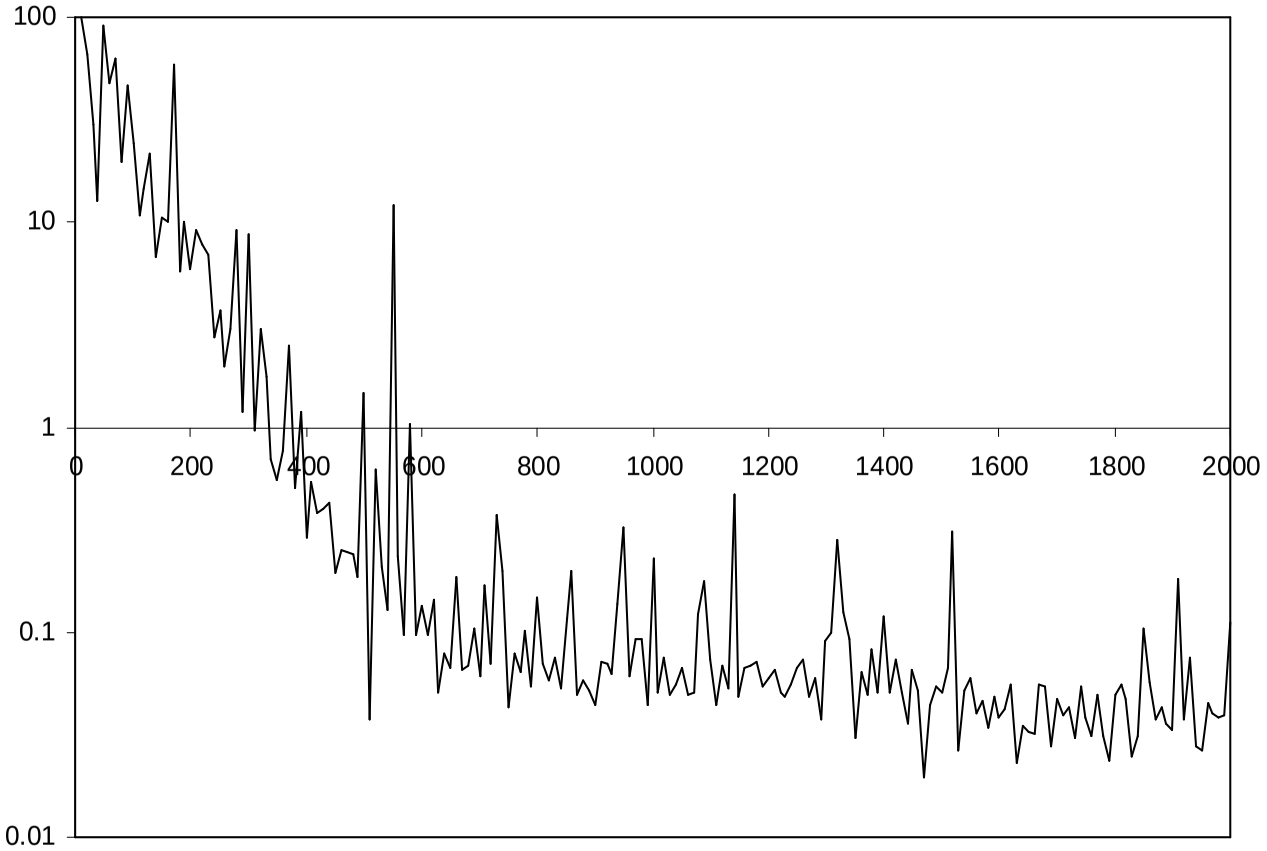
```
<application>
  <network>
    <instance componentName="LinearEquationSourceRowsColumnsUnsymmetric"
              componentPackage="icpc.denseLinearAlgebra.real" id="1">
              <property name="degrees of freedom" value="100"/>
    </instance>
    <instance componentName="LinearSolverRowsColumnsUnsymmetric"
              componentPackage="icpc.denseLinearAlgebra.real" id="2"/>
    <instance componentName="DisplayVector"
              componentPackage="icpc.vector.real" id="3"/>

    <dataflow sinkComponent="2" sinkPort="matrix"
              sourceComponent="1" sourcePort="matrix"/>
    <dataflow sinkComponent="2" sinkPort="vector"
              sourceComponent="1" sourcePort="vector"/>
    <dataflow sinkComponent="3" sinkPort="vector"
              sourceComponent="2" sourcePort="solution"/>
  </network>
</application>
```

Solution Time v Matrix Size



System Overhead v Matrix Size



Open Extensible Technologies

- XML used to define:
  - application, component, implementation meta-data
  - the computational, storage and software resources
  - the resource usage policy
- Java used to construct the framework, run-time representation and interfaces to the assembled components
- Framework part of complete Grid services package – utilises Jini & Java

Further Work via Extensible Framework

- Multiple Cost Models:
  - Data transfer costs
- Parallel Implementations
- Distributed Applications
- Further use of run-time information:
  - Verification / optimisation at application level, eg numerical stability of FEM code

Summary

- Components for Grid computation
- Separation of abstraction & implementation
- Extensible architecture based on CXML
- Implementation selection through run-time representation

Acknowledgements

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- Further Information:
  - http://www-icpc.doc.ic.ac.uk/components
  - email:icpc-sw@doc.ic.ac.uk