Tool-Support for the Development of (Self-)Adaptive Applications

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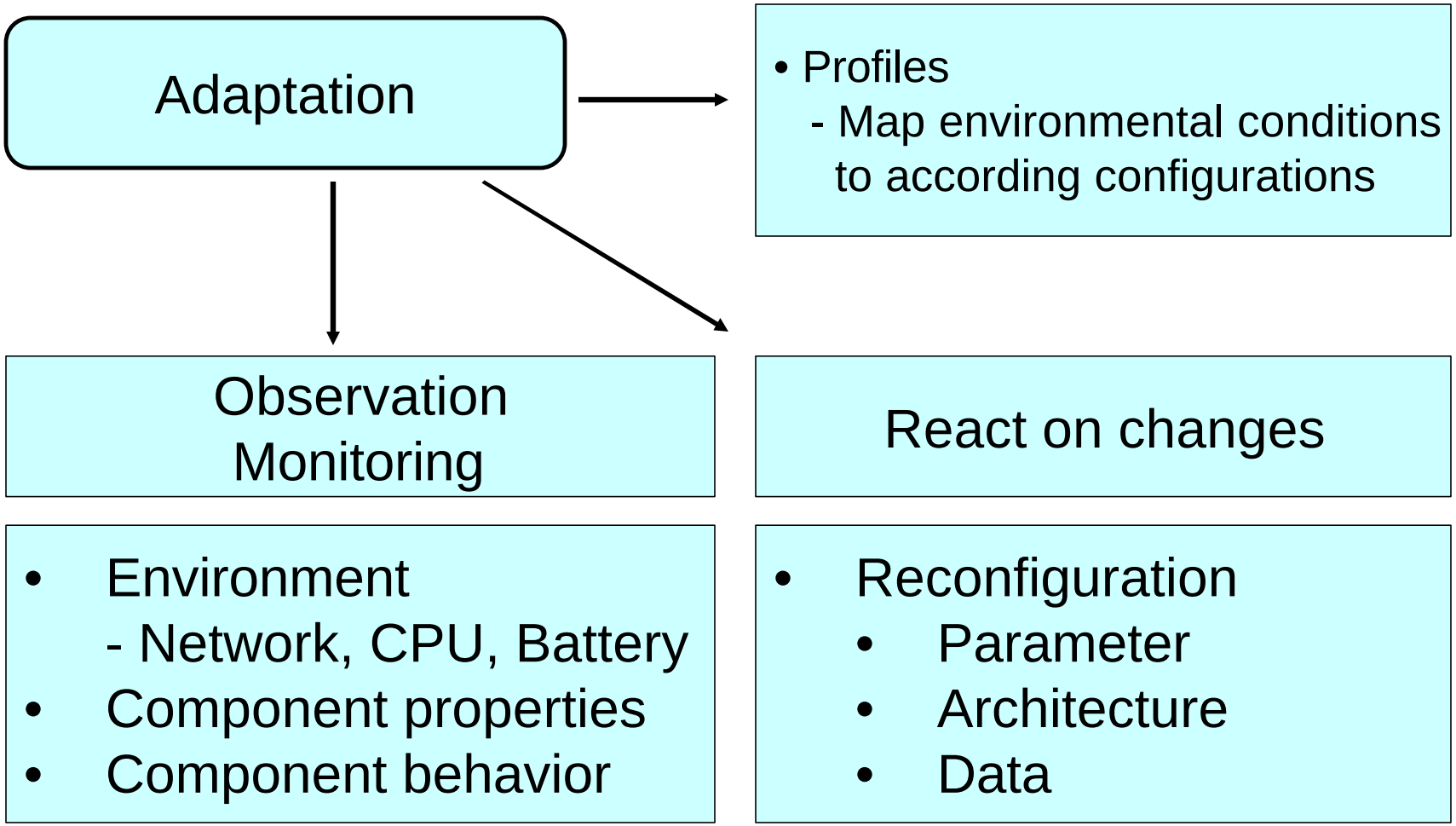
Outline

- Motivation
- Adaptive Application with the Adapt.Net Framework
  - Dynamic reconfiguration of component-based applications
  - Synchronization patterns
  - Creating configurable components
  - Runtime Infrastructure
- Building alternative configurations:
  - Integrating architectural patterns
- Concluding remarks

New Patterns for Developing Adaptive Applications

- Dynamic environments of modern software demand adaptation of software
- Self-configuration: change must be programmed
- State-of-the-art development realize adaptation application-specific
- Improving development of adaptive software by:
  - Identification of architectural patterns
  - Tool-support for automatic integration of adaptation-specific concerns
  - Support for developing alternative configurations

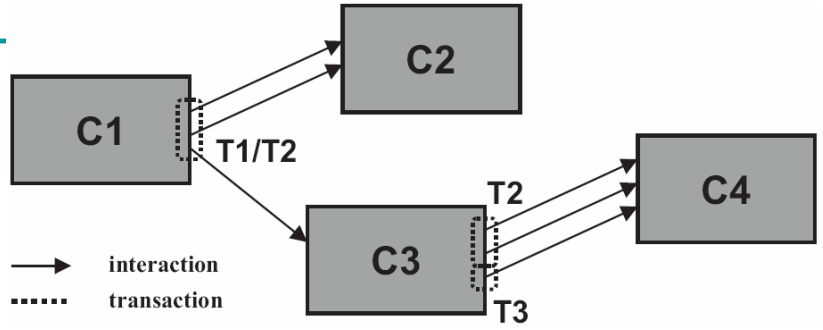
Adaptation: Building Blocks



The Adapt.Net Framework

- Selection among alternative application configurations enables adaptive behavior
- Dynamic reconfiguration / runtime deployment
- Tool-support for creating reconfigurable applications
- Building alternative configurations: architectural patterns
- Runtime updates and migration
- Monitoring infrastructure: environmental properties, component parameter, component state
- Choosing configurations: Adaptation Profiles

Application Model



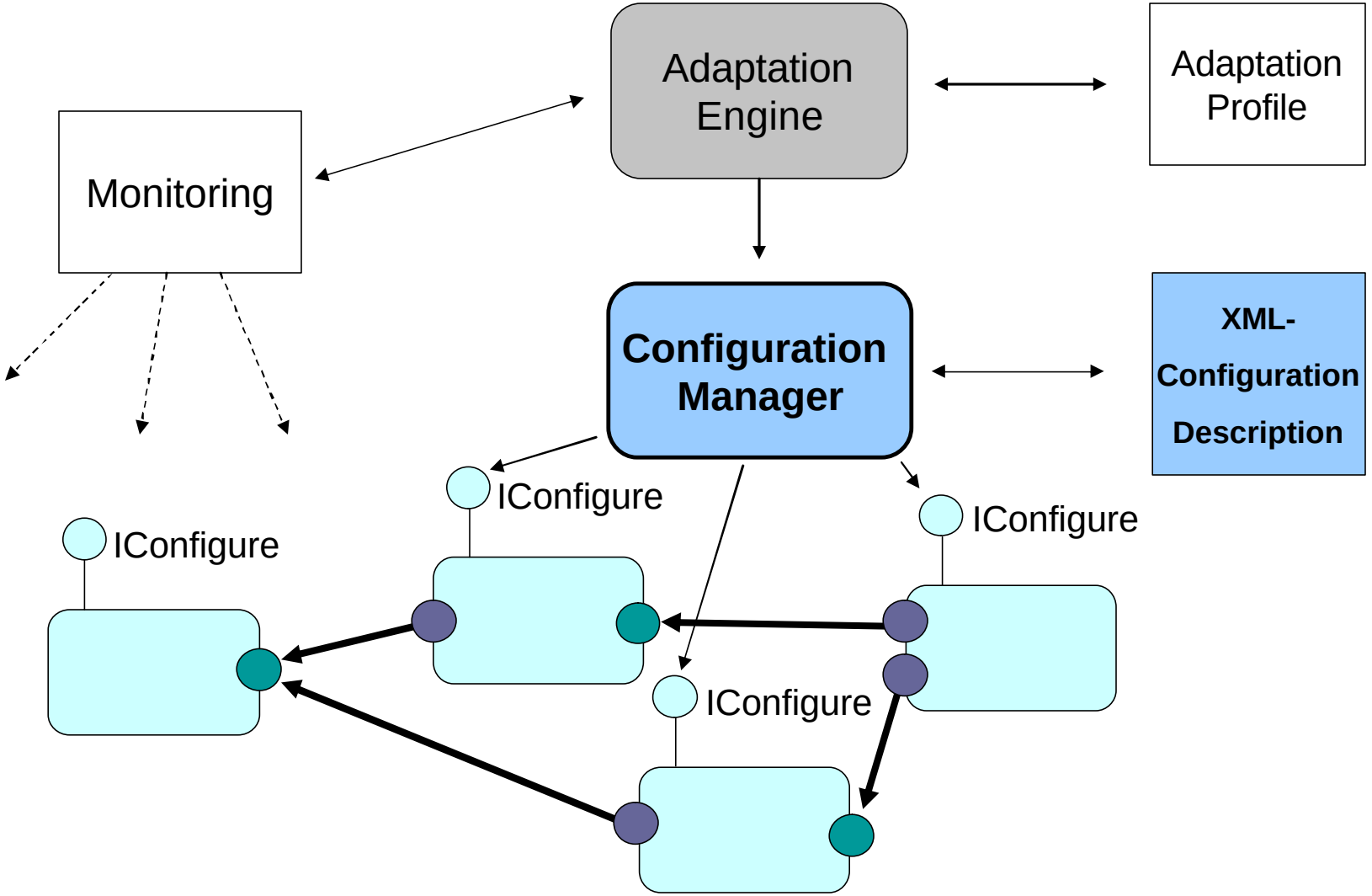
- Based on a work of J. Magee, J. Kramer, M. Wermelinger
- Components: Interconnected computational entities
  - Provide interfaces : in-ports
  - Require other components: out-ports
- Components connected by connectors
- No cycles in application topology graph
- A **transaction** virtually combines a number of bidirectional interactions between components
  - completes in bounded time
  - Initiator is informed about completion
- A transaction T1 is dependent on a subsequent transaction T2 (T1/T2) if its completion depends on the completion of this transaction

XML-Based Configuration Description

- "A **Configuration** of a component-based application denotes the set of its parameterized components and the connections among them."
- Configuration description:
  - List of components
  - Component attributes
  - Component ports
  - Connectors

```
<configuration configurationname="c1">
    <component name="Viewer" args="" loadtype="OBJECT" assembly="MessageView
          .dll" assemblyVersion="..." access="" type="AdaptNet.
          ConfiguredObjectProxy.MessageView" location="localhost">
        <port name="m_source" type="OUT" vartype="sample.proxys.
              IMessageSource" />
        <port name="default" type="IN" vartype="System.Object" />
    </component>
    <component name="Source" args="" loadtype="CorbaComponent" assembly="
          MessageView.dll" assemblyVersion="..." access="" type="sample.
          proxys.IMessageSource" location="localhost">
        <port name="default" type="IN" vartype="System.Object" />
        <property name="encoding" value="UTF-8" type="System.String" />
    </component>
    <connector sourcecomponent="Viewer" sourceport="m_source" sinkcomponent=
          "Source" sinkport="default" type="IIOP" />
</configuration>
```

Configuration Infrastructure

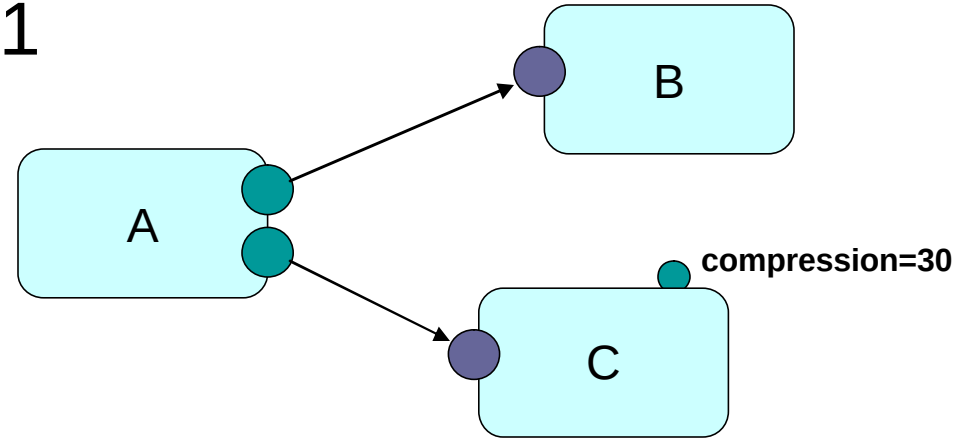


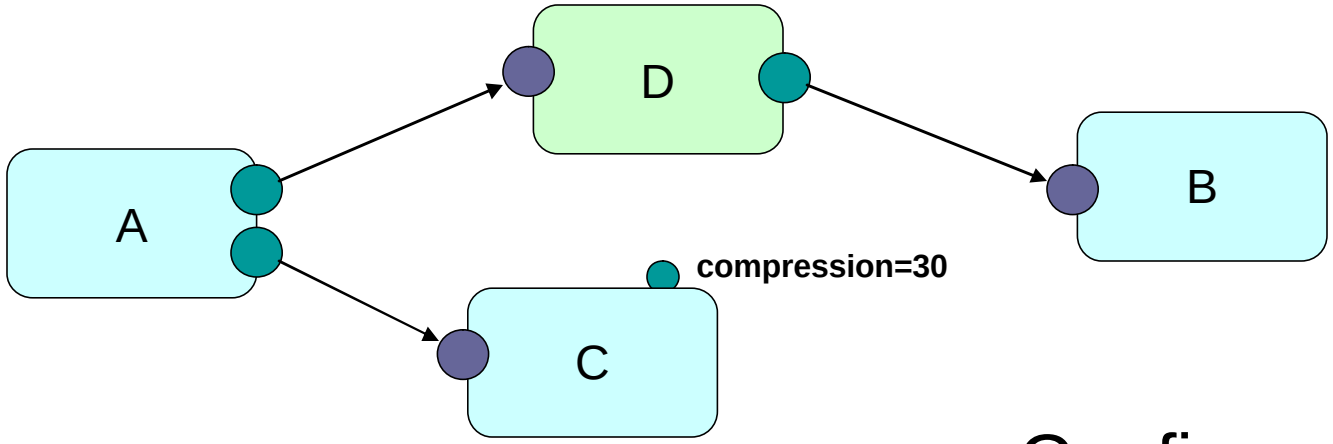
Reconfiguration Algorithm

1. Loading of new components
2. Bringing application into reconfigurable state
   - Application consistency must be preserved during reconfiguration
   - Blocking all connections: Wait for all on-going transactions to complete; don't allow initialization of new ones
   - Blocking must be ordered due to dependent transactions
3. Transferring state of migrated/updated components
4. Setting changed component parameters
5. Reconnecting components (create connectors)
6. Restarting component processing
7. Removing old components

Dynamic Reconfiguration

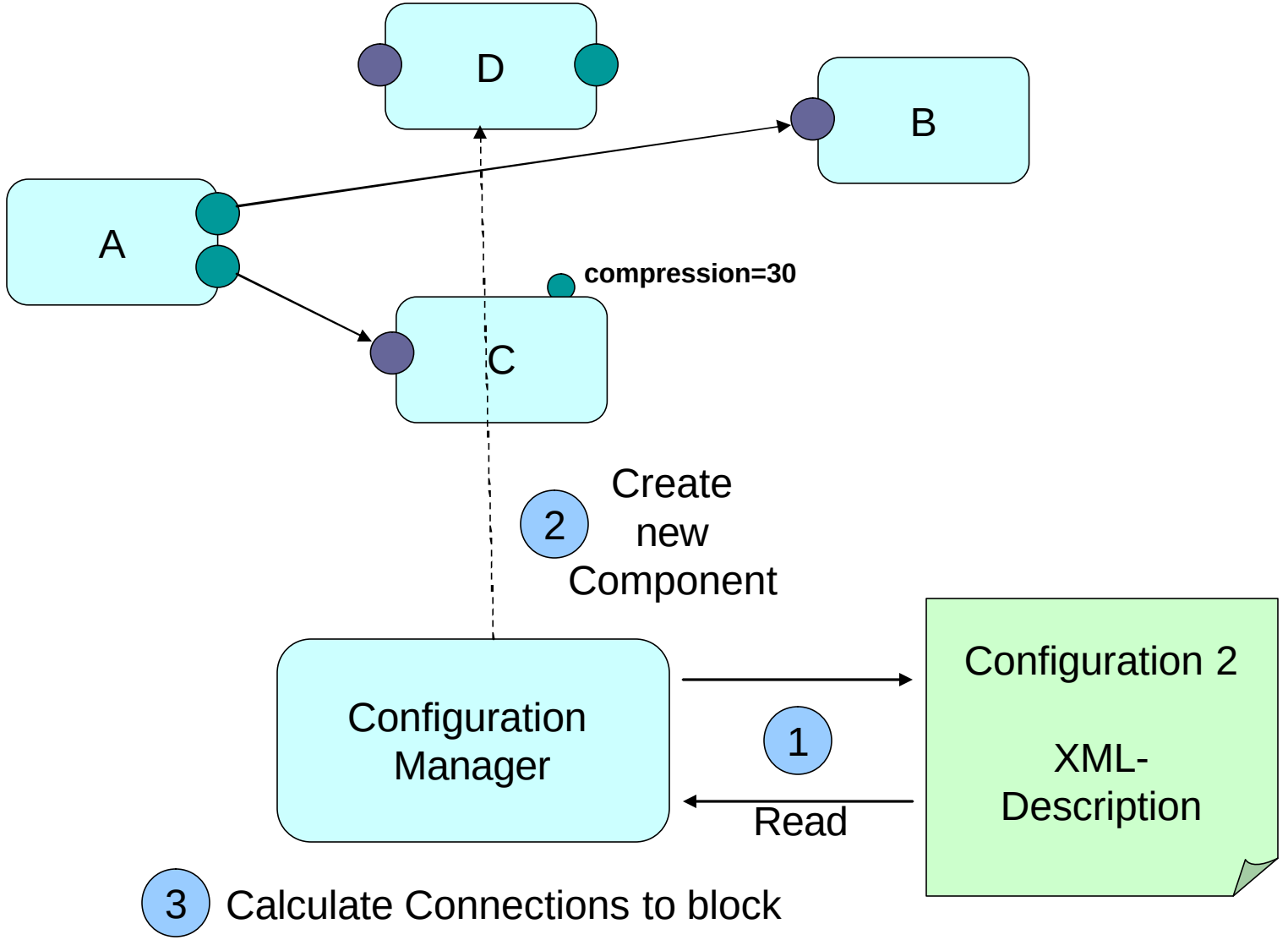
Configuration 1



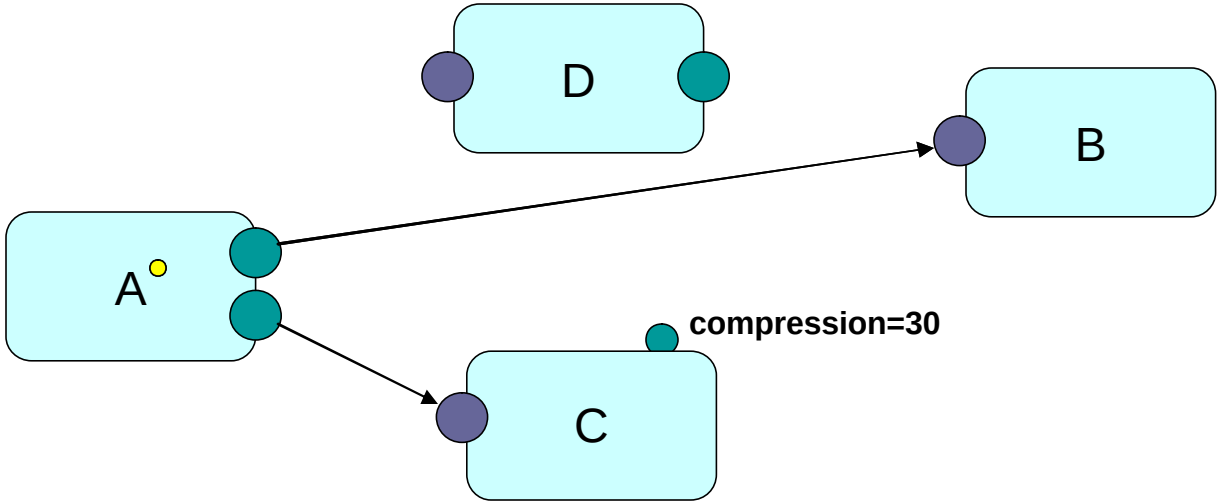


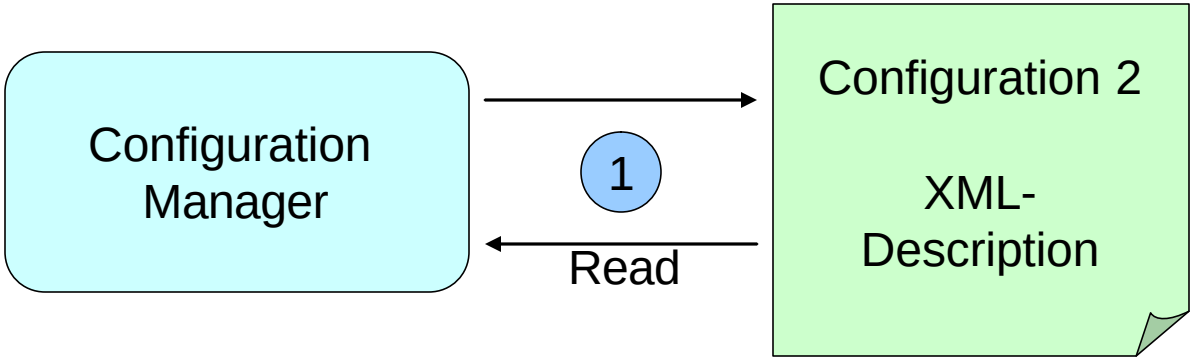
Configuration 2

Dynamic Reconfiguration

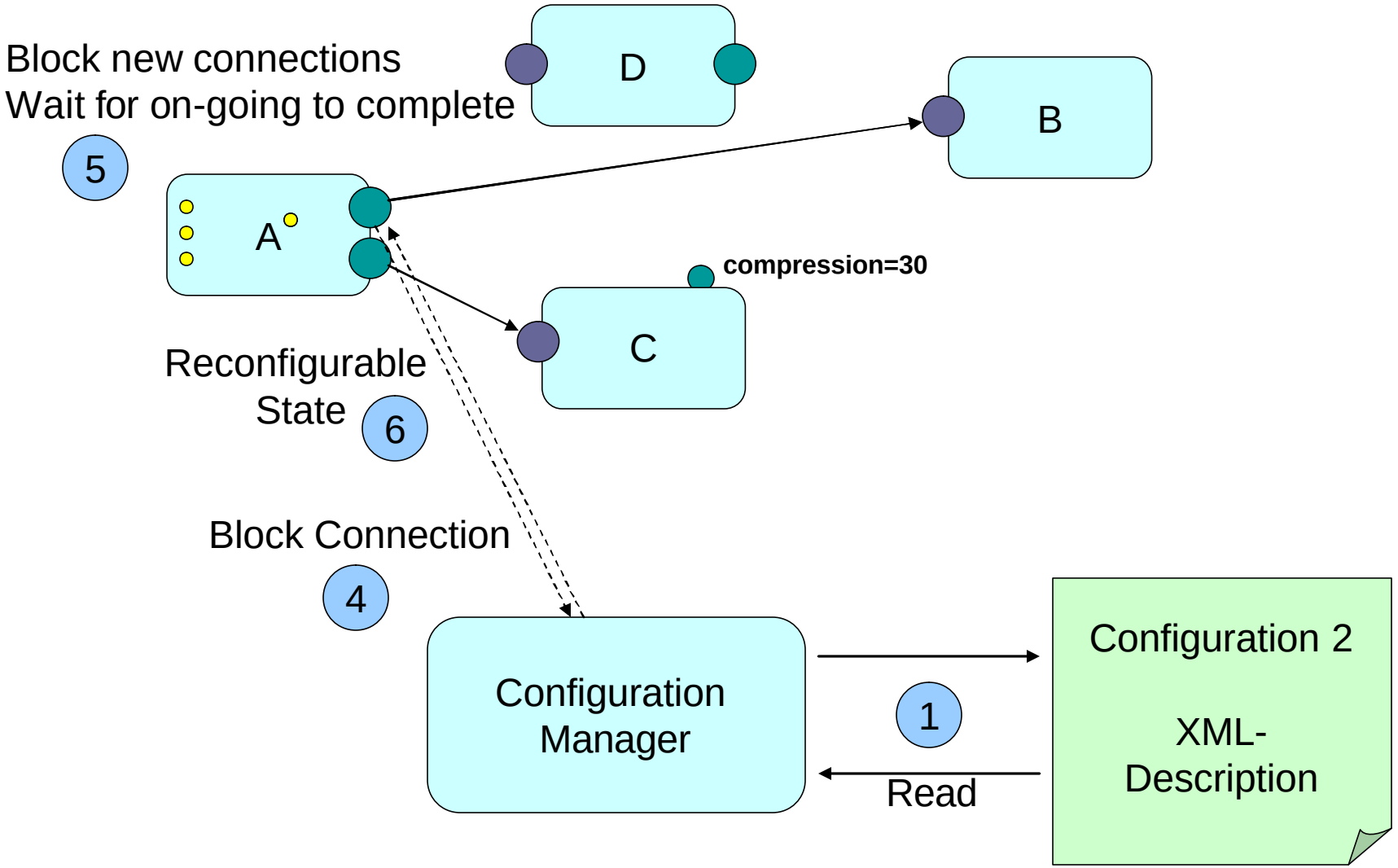


Dynamic Reconfiguration

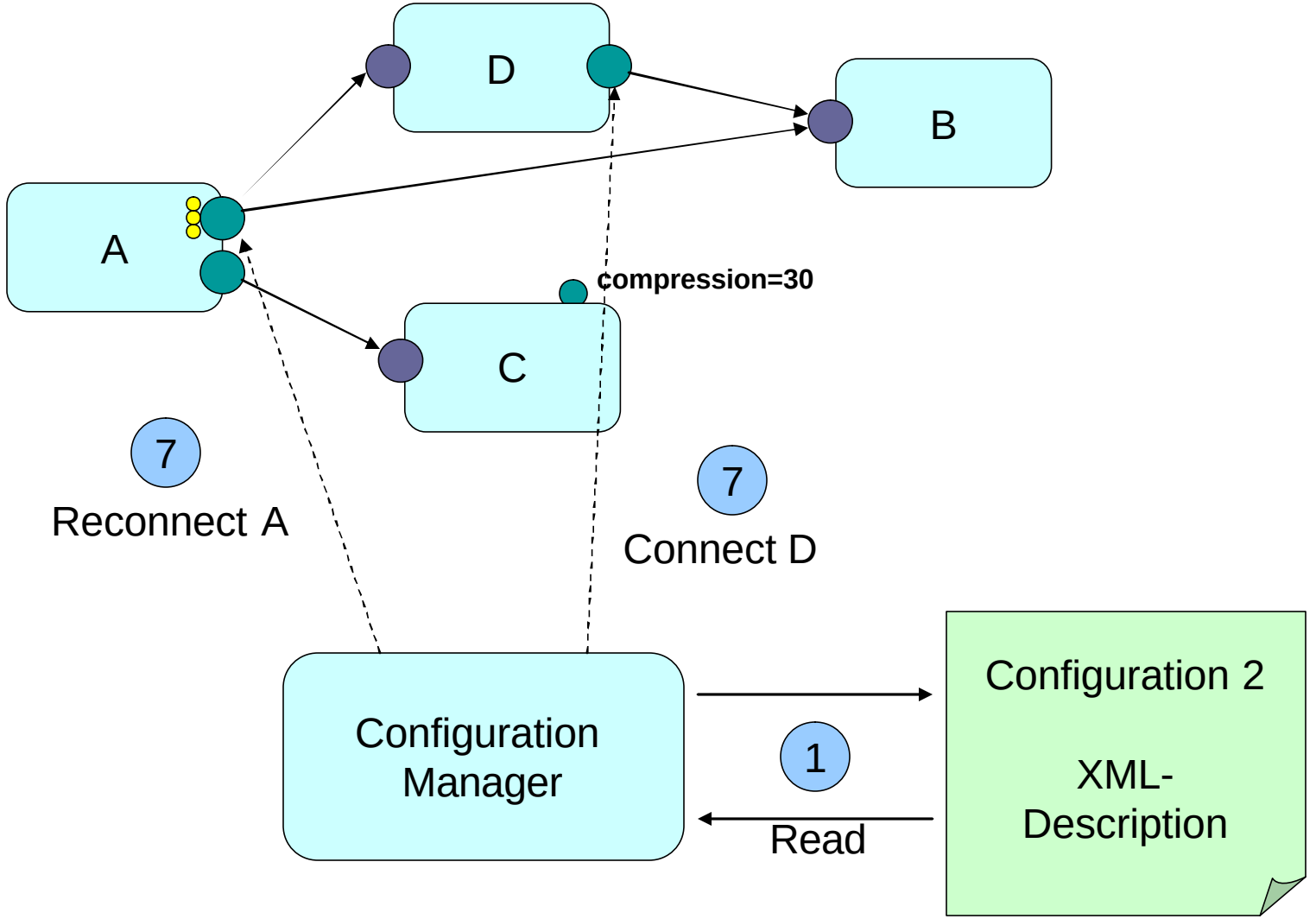




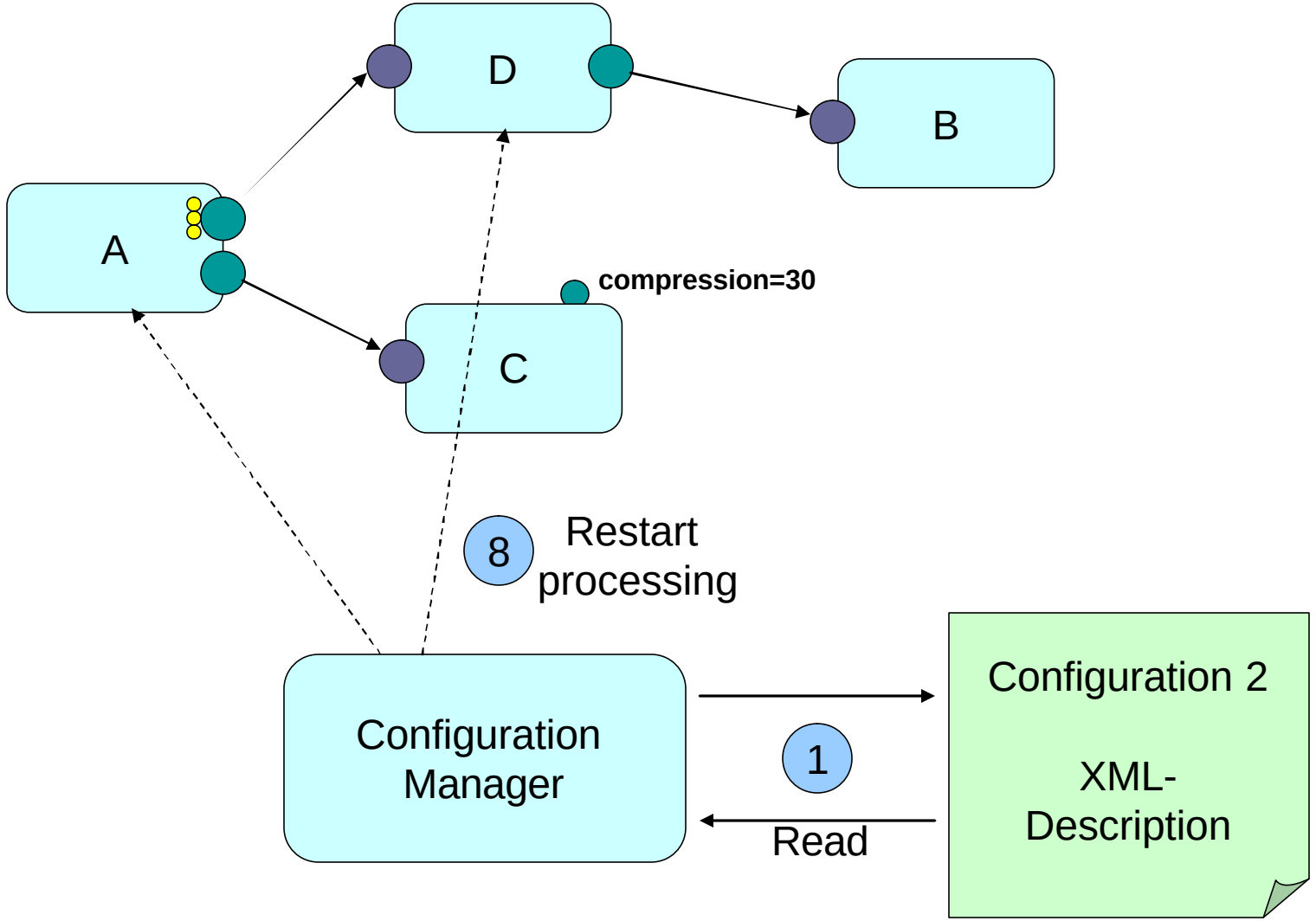
Dynamic Reconfiguration



Dynamic Reconfiguration



Dynamic Reconfiguration



Blocking a Connection

- Component Code calls
  - **TransactionBegin:**
    If(blocked) Wait(block_semaphore);
    processing=true;
    Wait(proc_semaphore);
  - **TransactionEnd:**
    processing=false;
    Release(proc_semaphore)

- Configuration interface
  - **BlockConnection**
    blocked=true;
    Wait(block_semaphore)
    if(processing) Wait(proc_semaphore)
    Release(proc_semaphore)
  - **Start** of Configuration interface
    blocked=false;
    Release(block_semaphore);

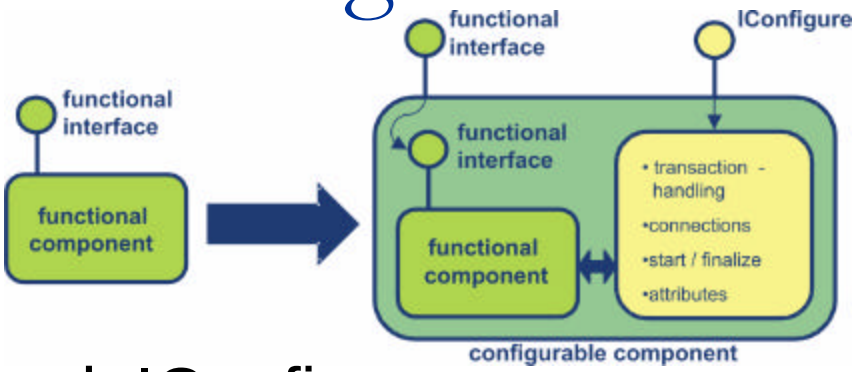
```
int a = 3;
int b = 5;
    Transaction.Begin();
        b = calc.Add(1,b);
        a = calc.Sub(a,b);
    Transaction.End();
```

Multithreading ?
Recursive Function ?

Reader-Writer Lock for Synchronization

- Synchronizes multiple read and concurrent write requests
- On write request: wait for all acquired read locks to complete
- New read requests are queued
- No synchronization needed for a read request if there is no write request
- Here we synchronize methods calls (reads) and reconfiguration requests (writes)
- Recursive read locks: threads already owning a read lock can acquire new read locks (for on-going method calls) despite pending write request

Configuration : A crosscutting concern



- Each component has to implement a configuration hook IConfigure:
  - Start component processing
  - Block connections
  - Set properties
  - Connect/disconnect out-going ports
  - Initialization / Finalization
- Implementation for IConfigure can be generated
  - Integrated into graphical development tool of Adapt.Net
  - Usage of Aspect-Oriented Development (AOP) tools

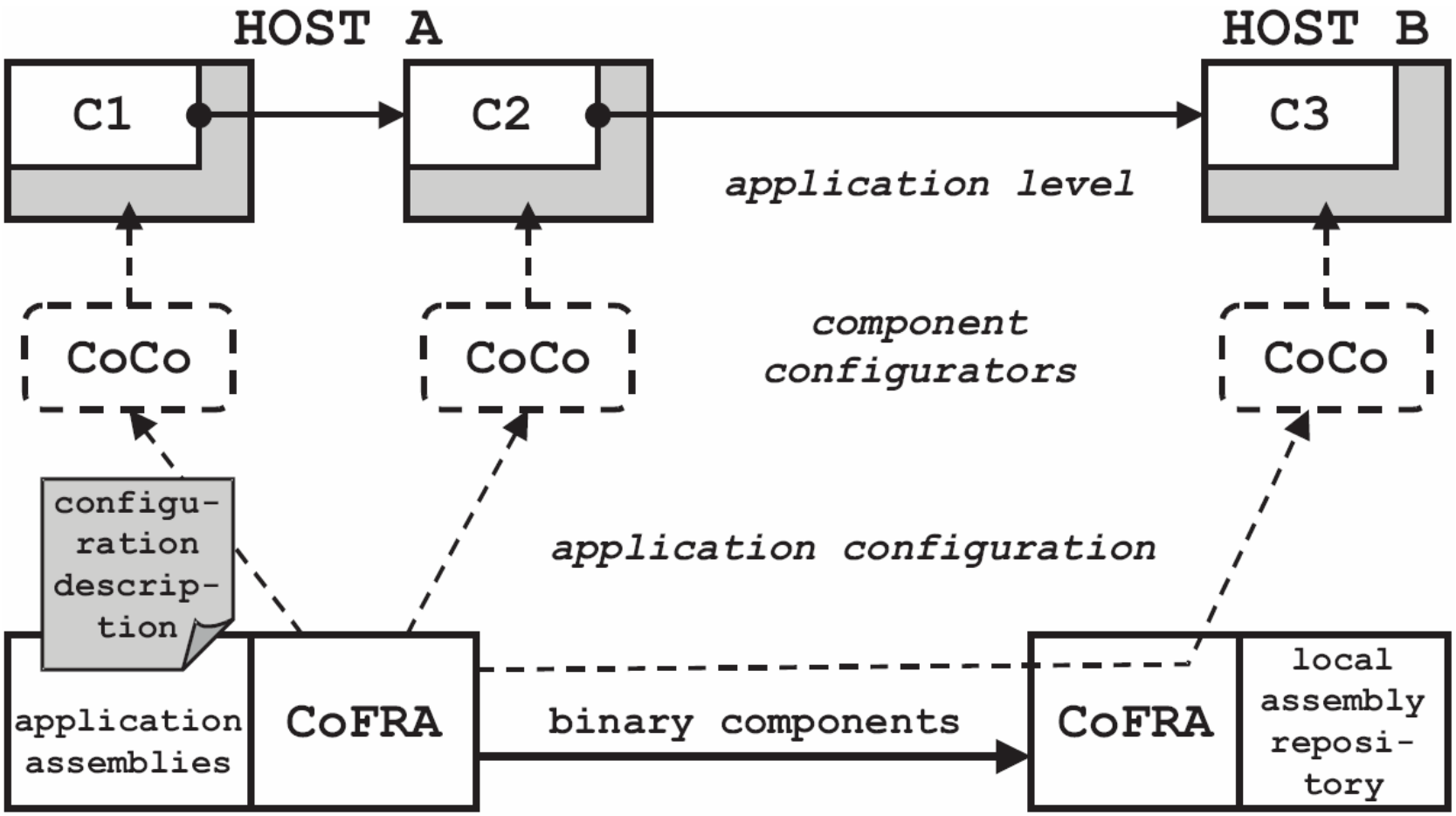
Configurable Components

```
public class ConfiguredFilter:Filter,IConfigure
{
    void SetProperty(string name, string val){
        cval = Convert(val);
        this.GetField(name).SetValue(cval)
    }
    void Connect(string port, obj target){
        this.GetField(port).SetValue(obj);
    }
    void BlockConnection(string conn){
         mutex.Aquire();
    }
    void StartProcessing(){
         mutex.Release();
    }
}
```

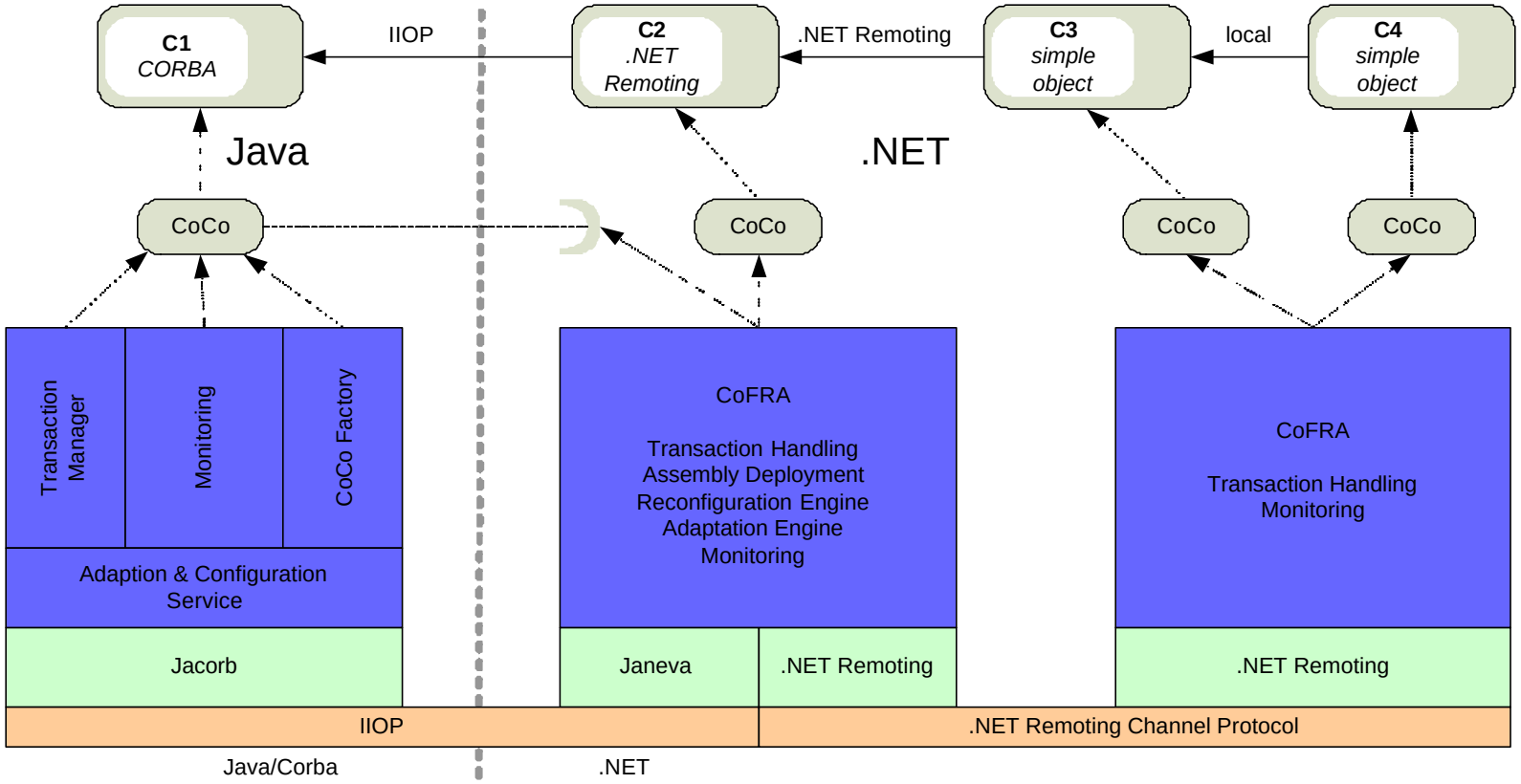
```
public class Filter{
    [AdaptNet.Property]
    int compression;
    [AdaptNet.Connection]
    IViewer viewer;

    public void Send(byte[] data)
    {
        Transaction.Begin(viewer);
        viewer.Send(data);
        Transaction.End(viewer);
    }
}
```

CoFRA Infrastructure / Deployment



The Component Configurator - abstracting away CORBA, Java, and .NET



Component Type Loaders

- **Component Configurators** hide implementation details of component instances during runtime
- Available **Component Type Loaders** manage components life cycle : loading, initialization, deletion, finalization
- Existing Component Type Loaders and component start
  - **Simple Object**
    - Created using **new** language construct
  - **.NET Remoting Object**
    - Registration of Remote Service
  - **Process Component Type**
    - CreateProcess and Registration of Management Service Interface
  - **Java-based CORBA Object**
    - Initialization of CORBA runtime, object creation and registration

Connector Architecture

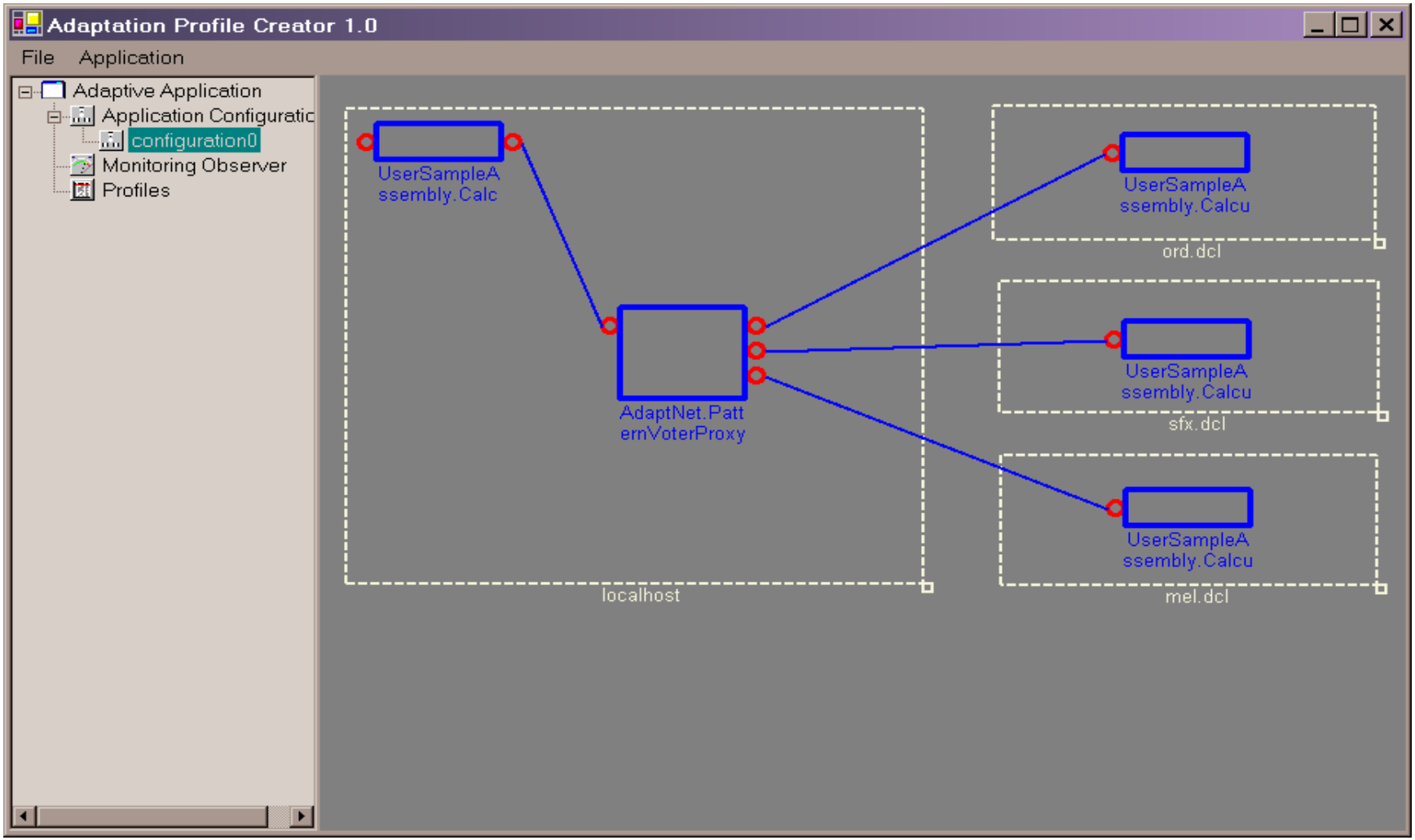
- Connector between components exchangeable during runtime
- Connector establishment implemented in IConfigure.Connect method
- .NET Remoting Connector
  - .NET-.NET
- Local Call Connector
  - Between simple Objects
- IIOP Connector
  - CORBA -.NET and CORBA-CORBA
- Planned connector patterns:
  - Tupelspace connector for online/offline configurations
  - Webservice connector to integrate available functionality
  - Gridservice connector to exploit available computing grids

```
public bool Connect(string portname, string conntype, object options)
{
  ...
  if(conntype == "LOCAL")
  {
    FieldInfo conn = this.GetFieldofThis(portname);
    conn.SetValue(this,options);
    return true;
  }
  if(conntype == "REMOTING")
  {
    object[] params = (object[]) options;
    FieldInfo conn = this.GetFieldofThis(portname);
    string connStr = "tcp://"+params[1]+"/"+params[0];
    conn.SetValue(this,Activator.GetObject(conn.FieldType,connStr));
    return true;
  }
  if(conntype == "IIOP")
  {
    FieldInfo conn = this.GetFieldofThis(portname);
    object corbaRef = Narrow(options);
    conn.SetValue(this,corbaRef);
    return true;
  }
  ...
}
```

Architectural Patterns for Alternative Configurations

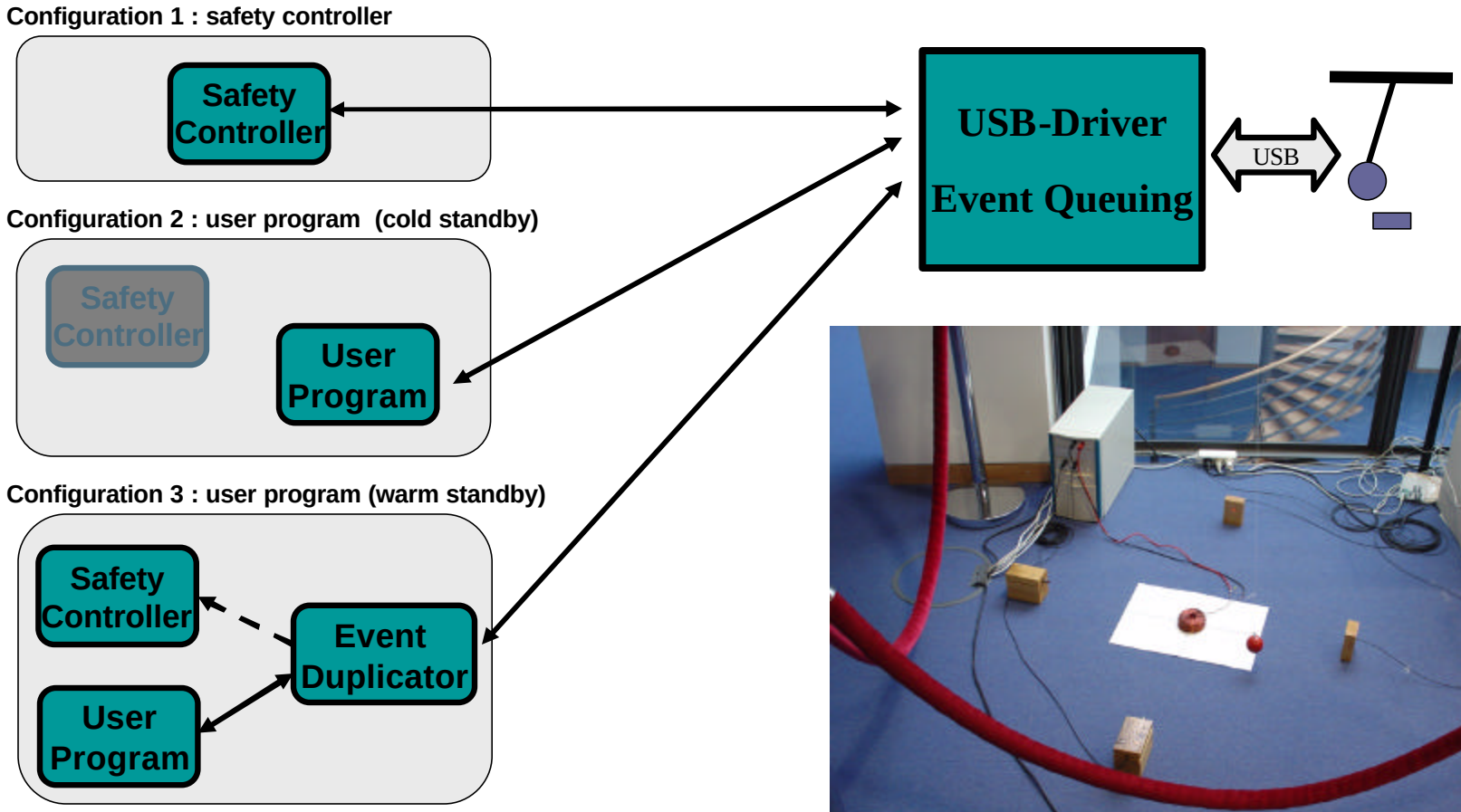
- Smart Connector pattern
- Voter Pattern
  - Compare output of 3 objects supporting the same interface
- Safe update pattern
  - Update a running object to a new version
- Load balancer pattern
- Migration pattern
  - Migrate an object from one host to another
- Filter, Compression, Encryption Pattern
- Simplex Pattern
  - Used in Foucault's Pendulum

Grafical Support for Pattern Integration

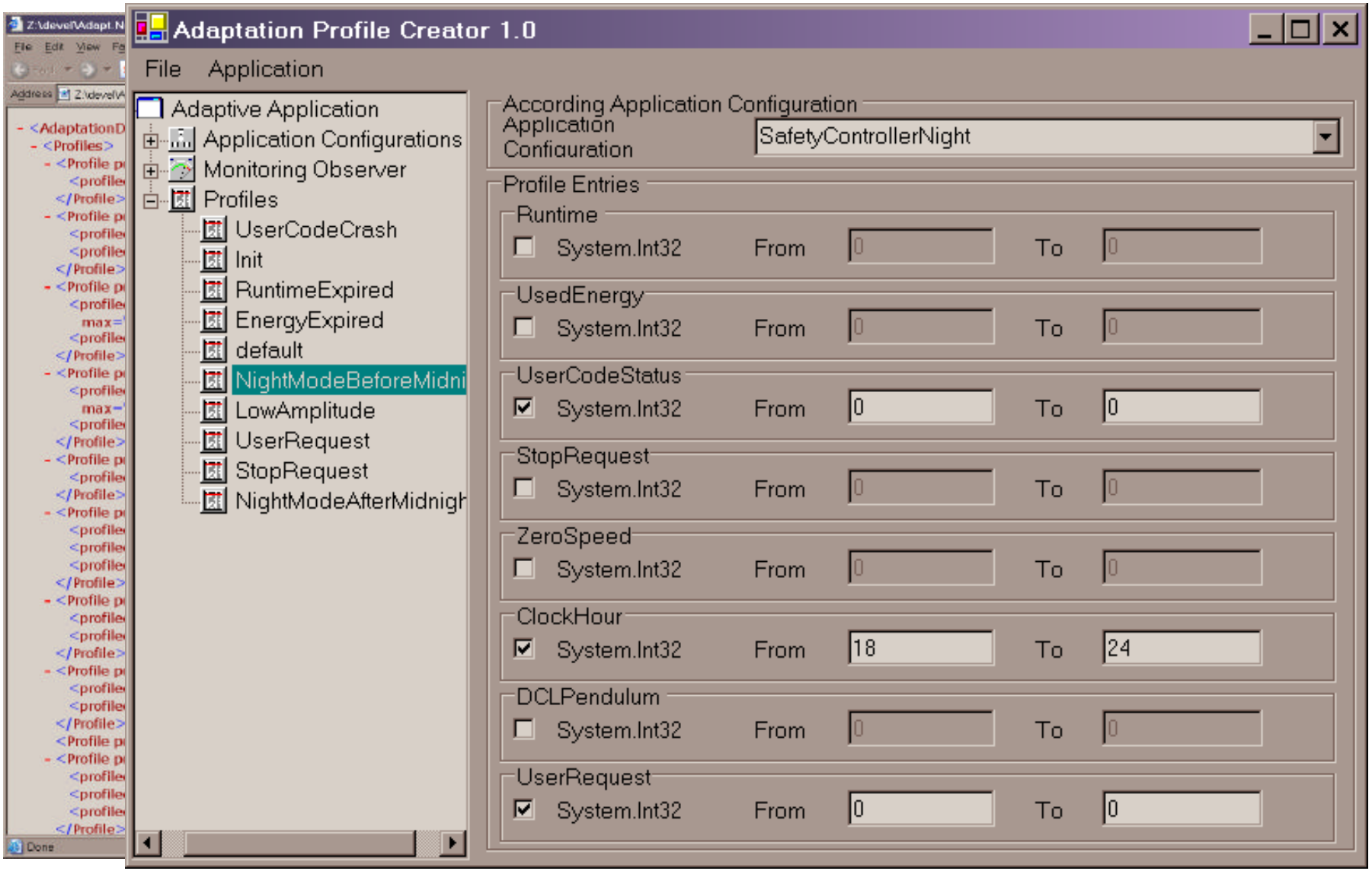


The Simplex Pattern Applied

Foucault's Pendulum in the Distributed Control Lab



Adaptation Profiles



Dynamic Reconfiguration & State

- Realizing component updates
- Component migration for mobility

Component Updates: An Algorithm

- Bring components into reconfigurable state
- Traversal of whole object graph
- Member-wise investigation of nodes using Reflection
- Investigation of each node for update
- Update specified via assembly mapping:
  - Specification of updated assemblies
- State transfer via member-wise close

Component Update State Transfer II

- Cycle recognition – visited nodes:

```
bool firstTime;
long id = idGenerator.GetId(node,out firstTime);
if(!firstTime)
        return visitedNodes[id];
```

- Save updated nodes in visited nodes list
- Investigation of all arrays
  - Traverse all reference type members
  - Create new version in case of base-type update
  - Copy content of updated arrays

Component Update: Delegates

```
public abstract class Delegate
{
    private System.Type target_type;
    private object m_target;
    private string method_name;
    private int method_ptr;
}
```

- Funtion pointers in .NET
- Traverse all targets of delegates
- Multicast delegates contain multiple delegates
- Updating multicast delegates:
  - Extract all delegates from multicast delegate
  - Create new versions: `Delegate.CreateDelegate`
  - Combine to new multicast delegate

Ongoing Work

- Dynamic reconfiguration / adaptation in real-time systems
- Service Integration in ad-hoc networks
  - Finding best service available
- Beyond adaptation profiles : Closed looped control of application parameter
- Resource manager for handling concurrent applications
- Integrated solution of the configuration problem
  - Creation of a optimal configuration out of a set of given software components
- Dynamic Aspect Activation

Conclusions

- Development of adaptive applications can be improved by:
  - Tool-support for building alternative application configurations
  - Reusable Runtime Infrastructures
  - Tool-based generation of configuration-specific code
  - Identification of patterns for dynamic reconfiguration, migration, monitoring, deployment improves development productivity