Cost-effective development of flexible self-* applications

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Outline

- Motivation
- Generic self-* framework
- Self-* application development

Motivation

word processing

spreadsheets

email

✗ cost-effective

✗ flexible

no general-purpose architecture & generic development approaches for self-* applications

✓ cost-effective

✓ flexible

Framework objectives

Significant reduction in development effort/expertise/cost

- component reuse
- off-the-shelf technologies & tools

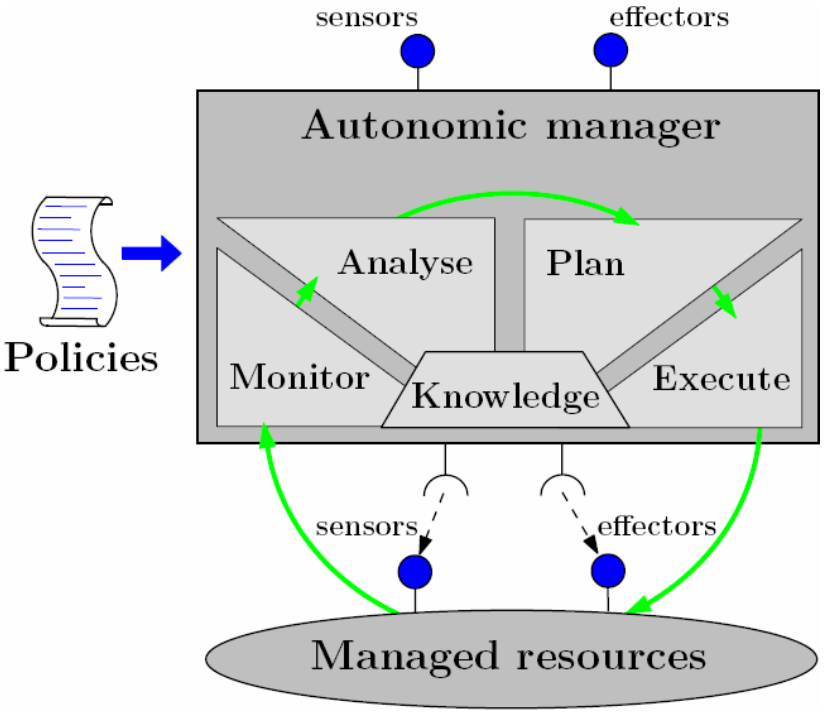
Major improvement in application flexibility/robustness

- model-based development
- automated code generation

New powerful capabilities

- new classes of policies
- support for system-of-systems development

Typical drawbacks of self-* architectures



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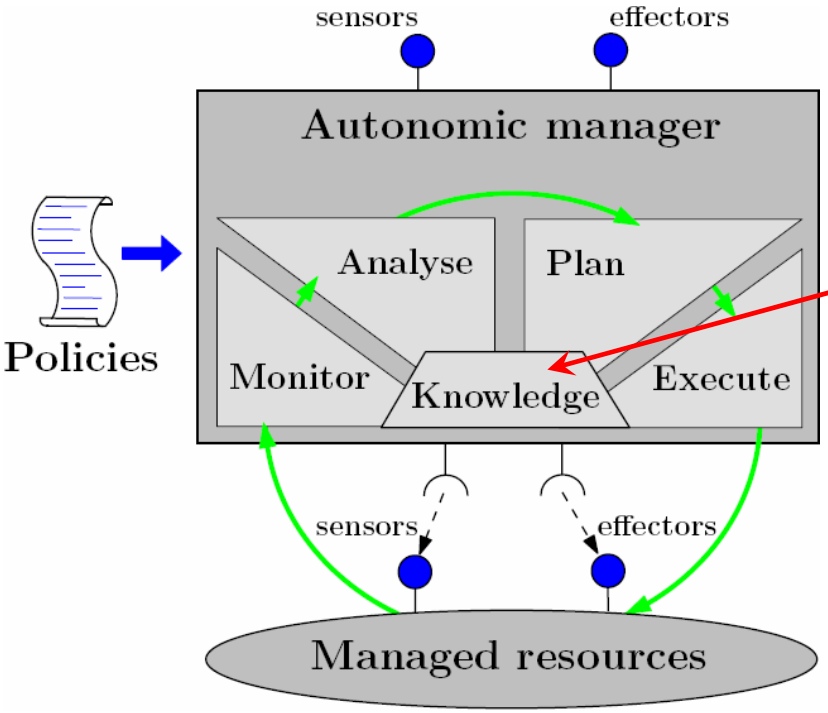
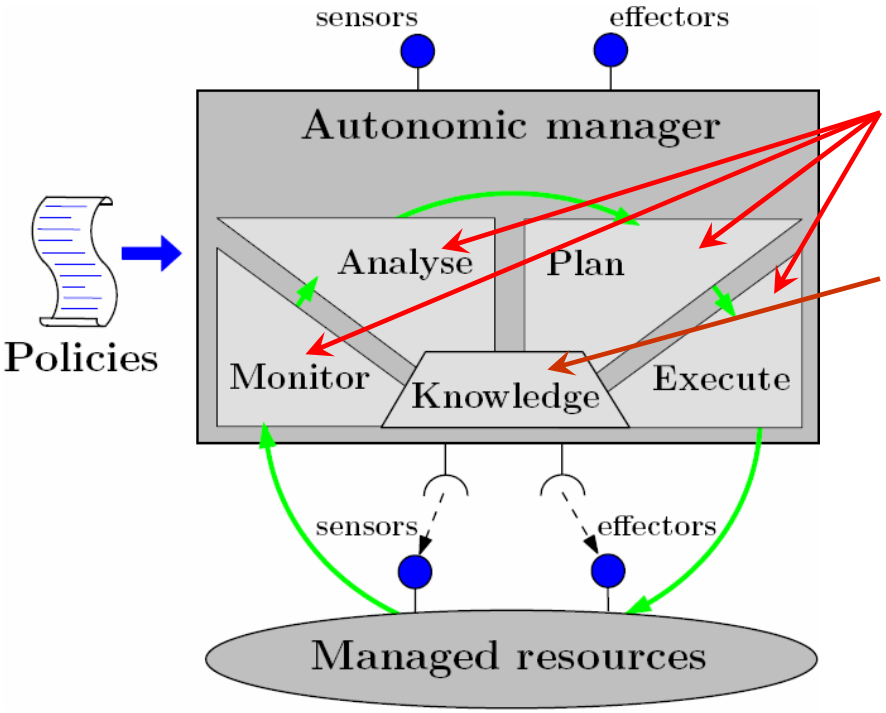


application-specific metadata hard-coded within the autonomic manager

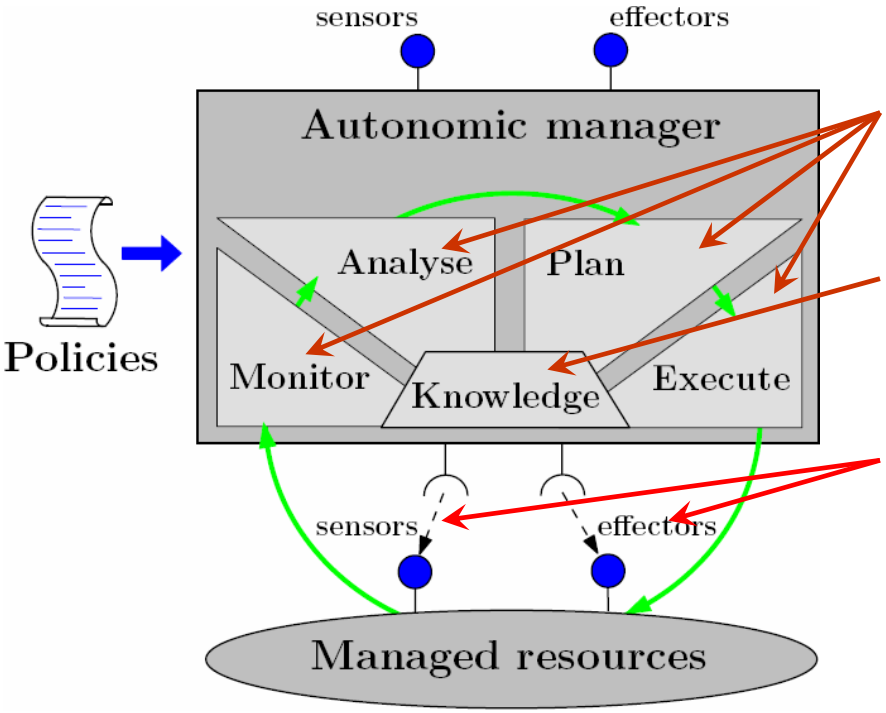
Typical drawbacks of self-* architectures



resource-specific code

application-specific metadata hard-coded within the autonomic manager

Typical drawbacks of self-* architectures



resource-specific code

application-specific metadata hard-coded within the autonomic manager

manually-implemented interfaces

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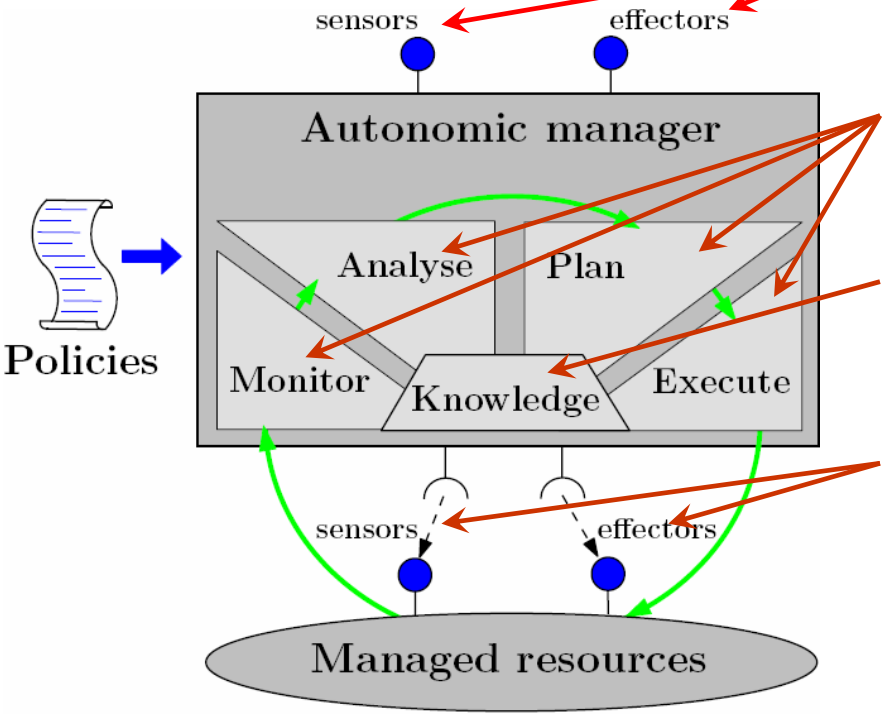


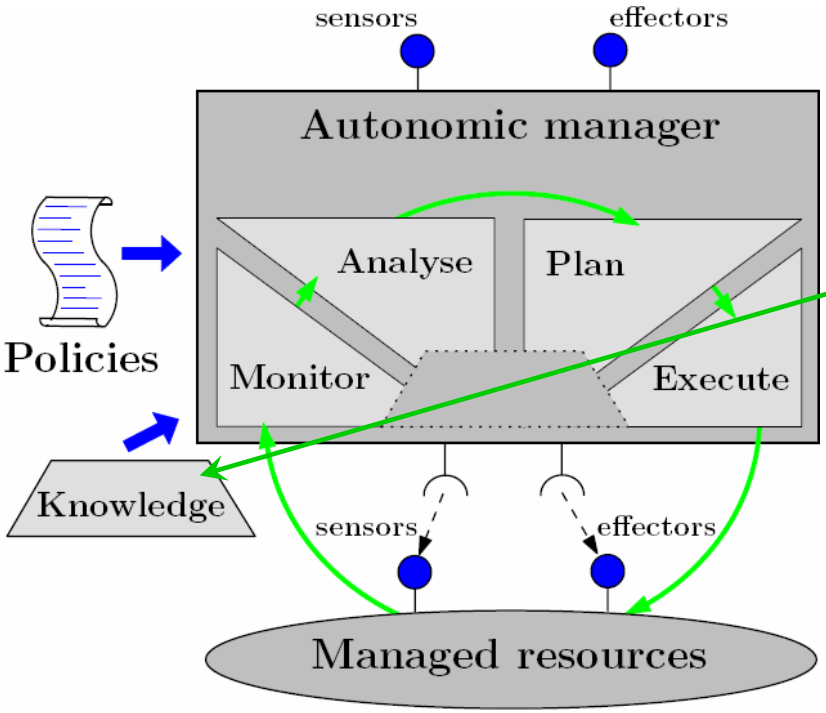
statically-defined high-level interfaces

resource-specific code

application-specific metadata hard-coded within the autonomic manager

manually-implemented interfaces

Generic self-* architecture



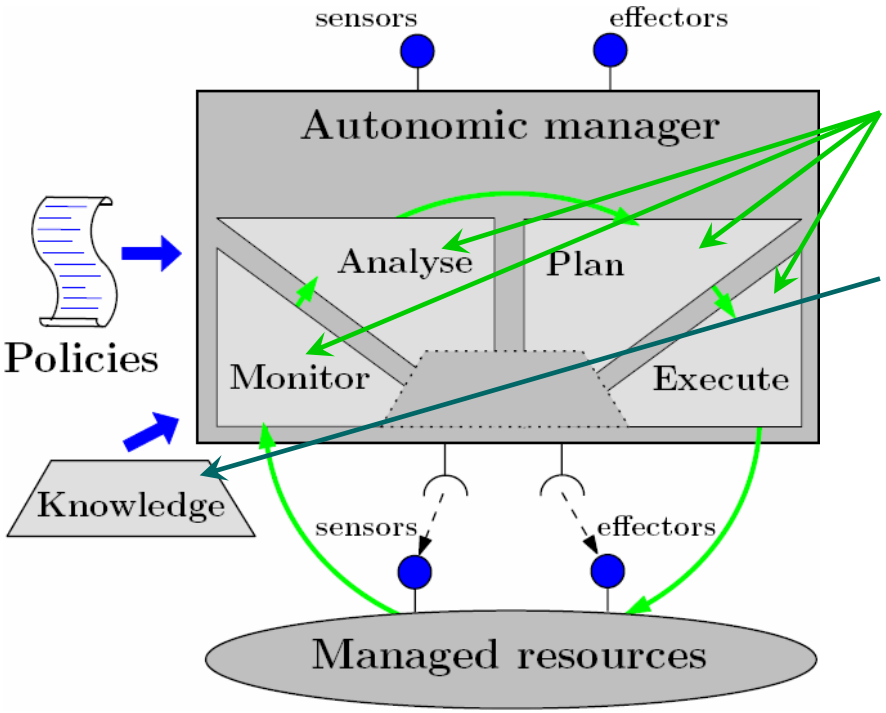
statically-defined high-level interfaces

resource-specific code

supply the “knowledge” at runtime to application-oblivious autonomic manager

manually-implemented interfaces

Generic self-* architecture



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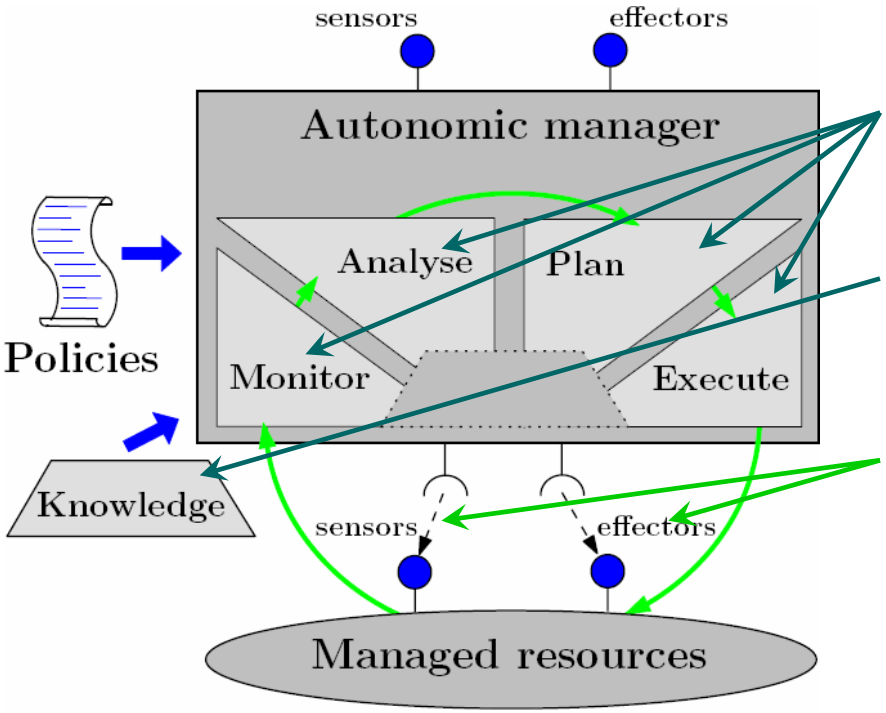


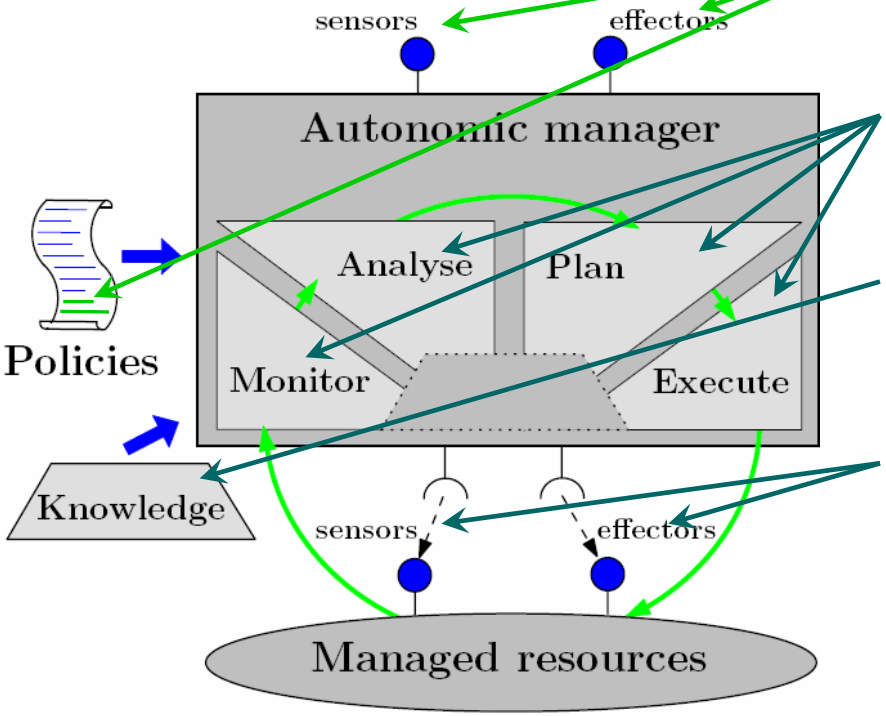
statically-defined high-level interfaces

resource-oblivious code

supply the “knowledge” at runtime to application-oblivious autonomic manager

automatic generation of autonomic manager interfaces & computer-aided development of resource interfaces

Generic self-* architecture



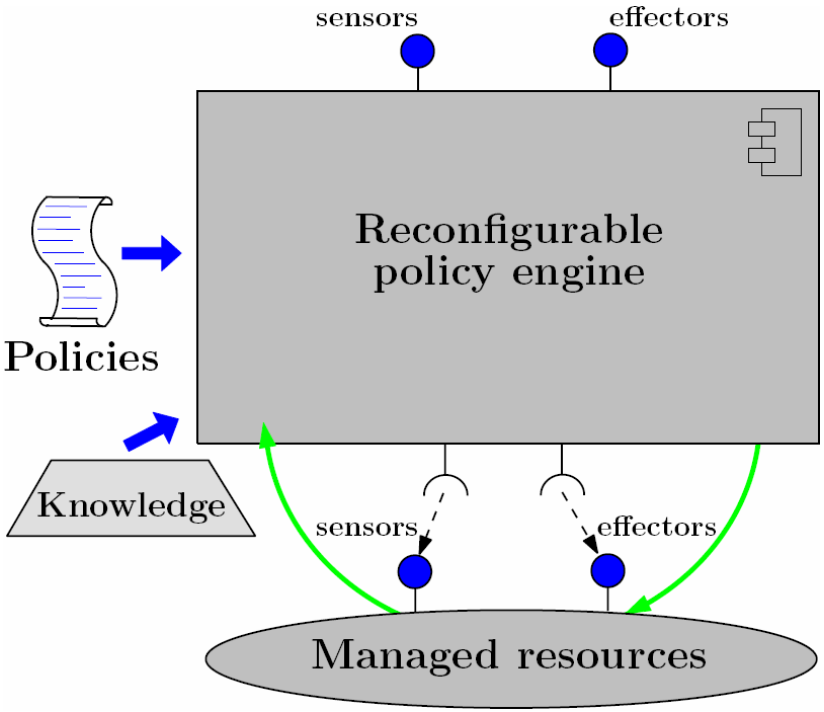
policy-driven, runtime generation of high-level interfaces

resource-oblivious code

supply the “knowledge” at runtime to application-oblivious autonomic manager

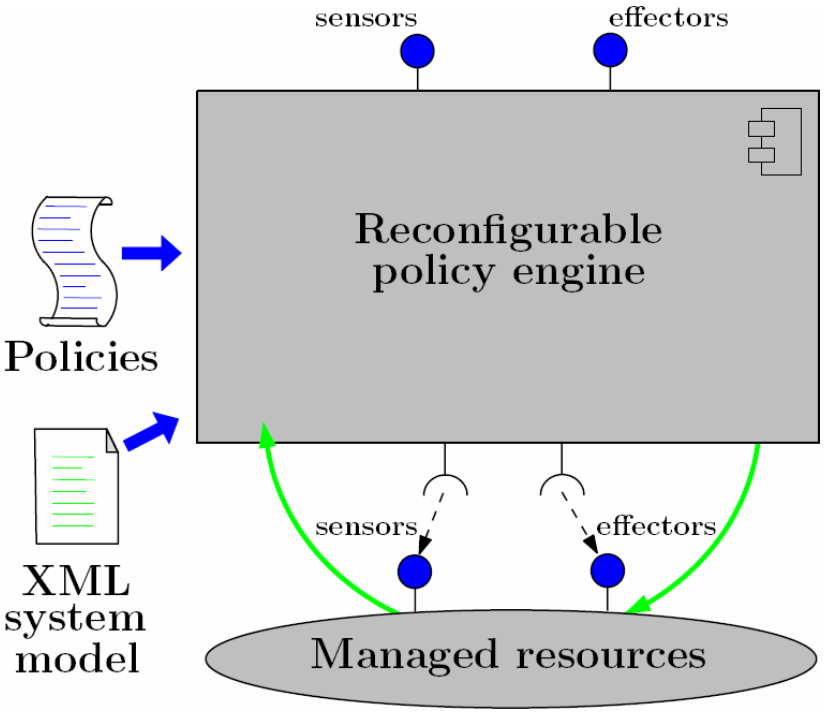
automatic generation of autonomic manager interfaces & computer-aided development of resource interfaces

Implementation



Policy engine = (.NET/C#) web service
- platform independence
- standards-based support for security
- loose coupling

Implementation

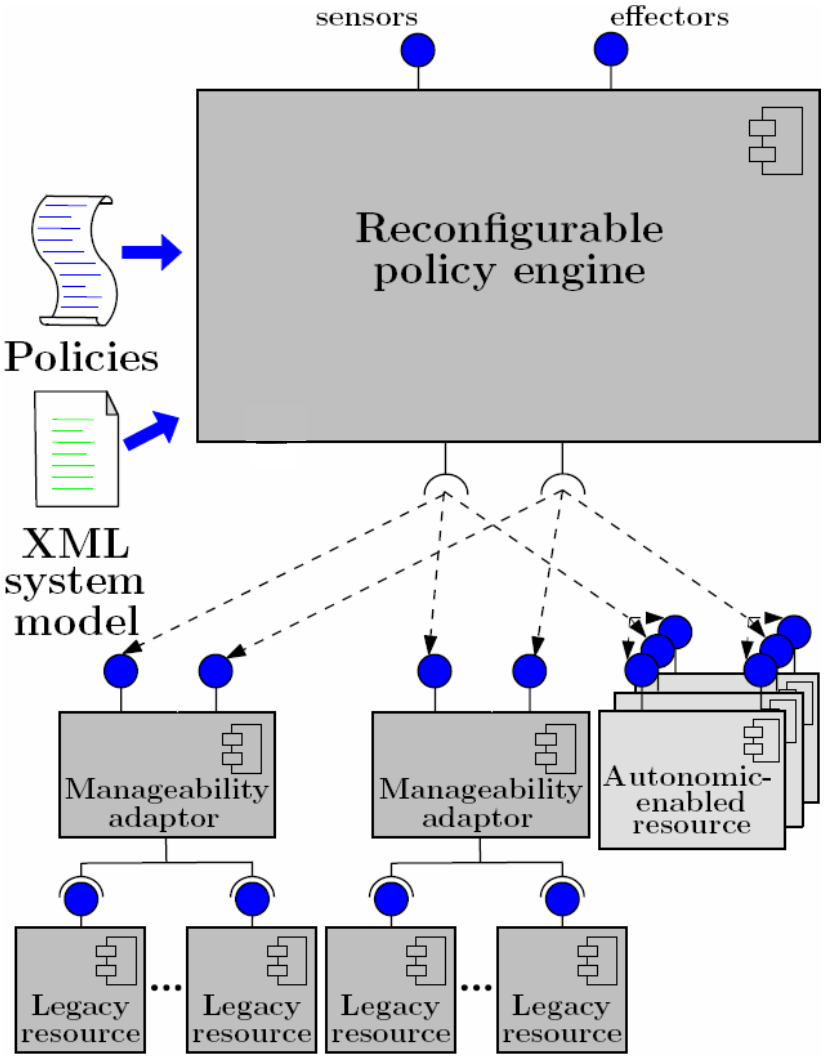


Policy engine = (.NET/C#) web service

Knowledge = XML-encoded model of resource parameters & behaviour

- off-the-shelf tools to process model (XSLT engines, XSD code generators)

Implementation



Policy engine = (.NET/C#) web service

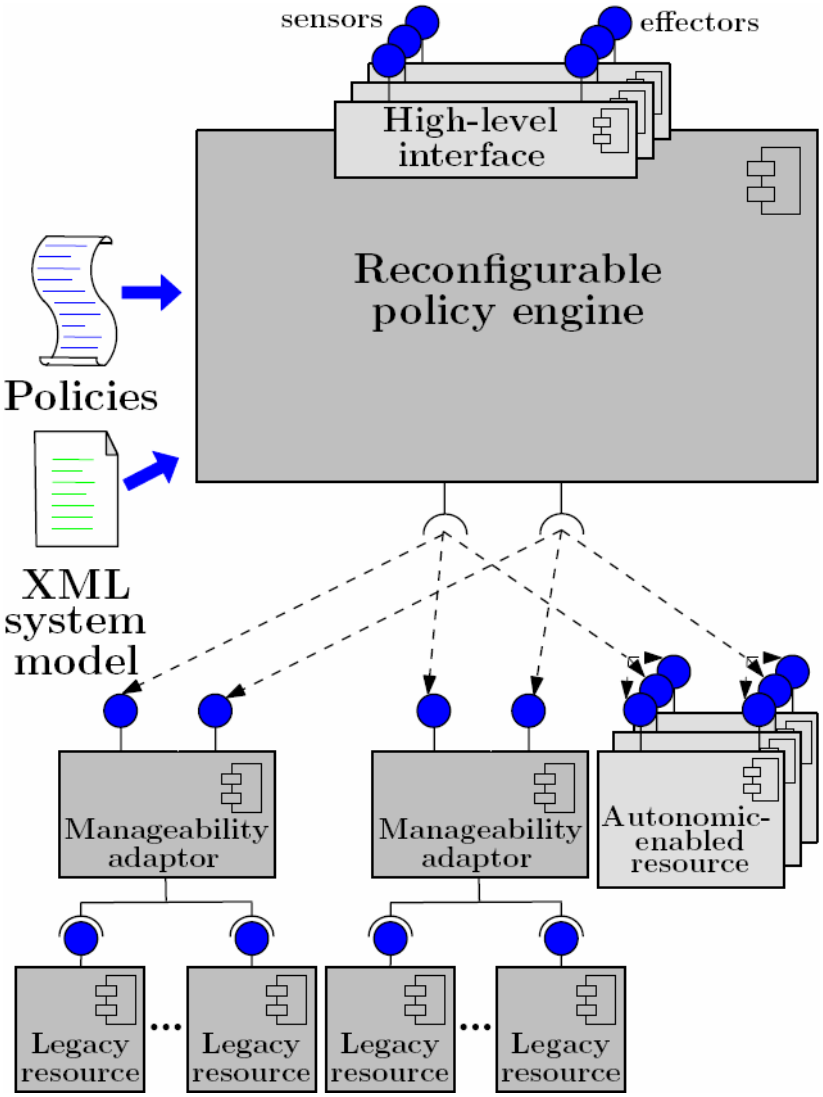
Knowledge = XML-encoded model of resource parameters & behaviour

Manageability adaptors = web services that subclass abstract *Adaptor* class

- *Adaptor* class implements the bulk of the functionality
- several other components generated automatically from the system model

Policy engine interface = generated online from model using OO *reflection*

Implementation



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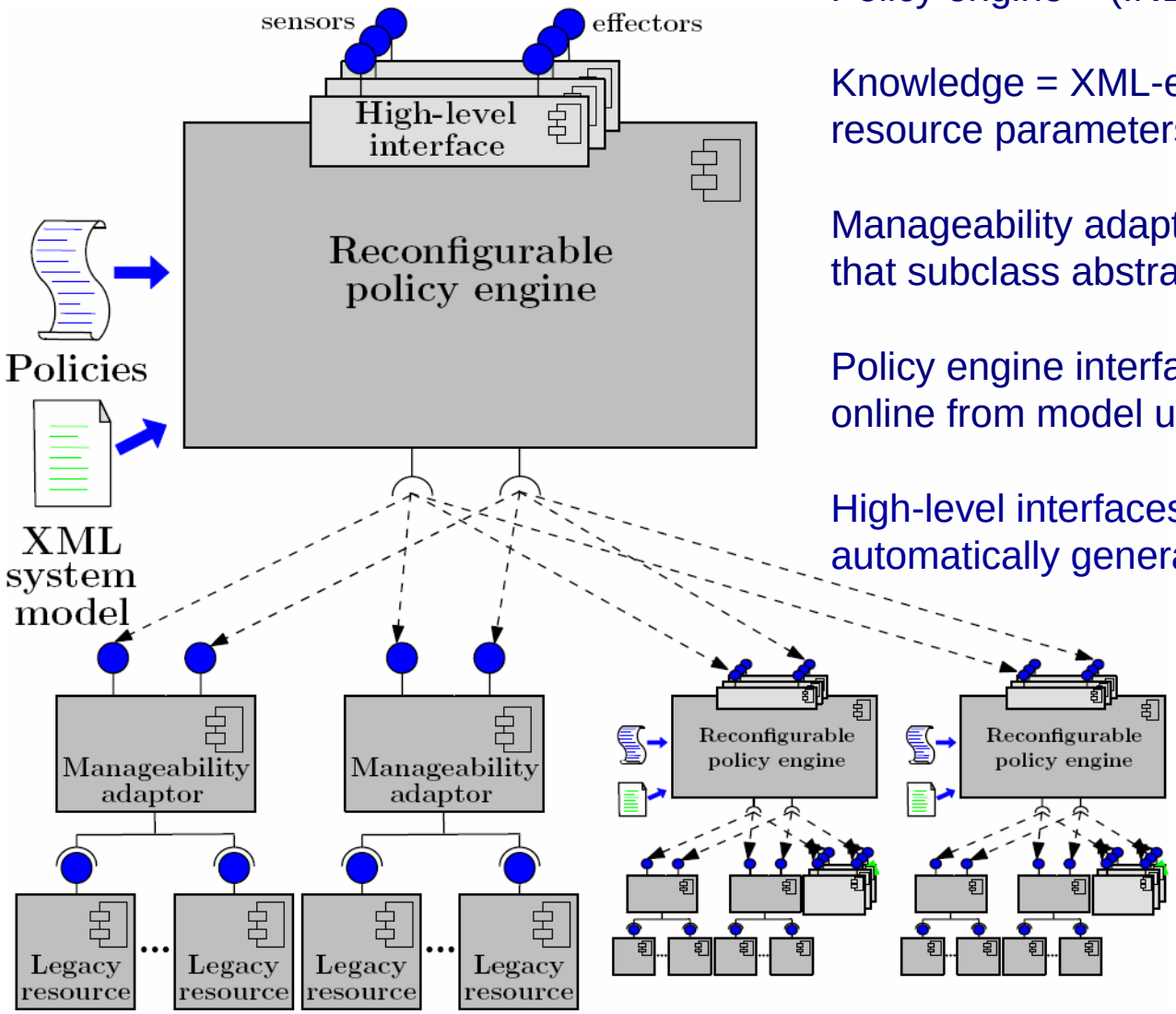
Policy engine interface = generated online from model using OO *reflection*

High-level interfaces = policy-driven, automatically generated web services

- expose system to its environment
- specified by “resource definition” policies
- enable system integration into self-* systems of systems

Implementation – hierarchical system of systems



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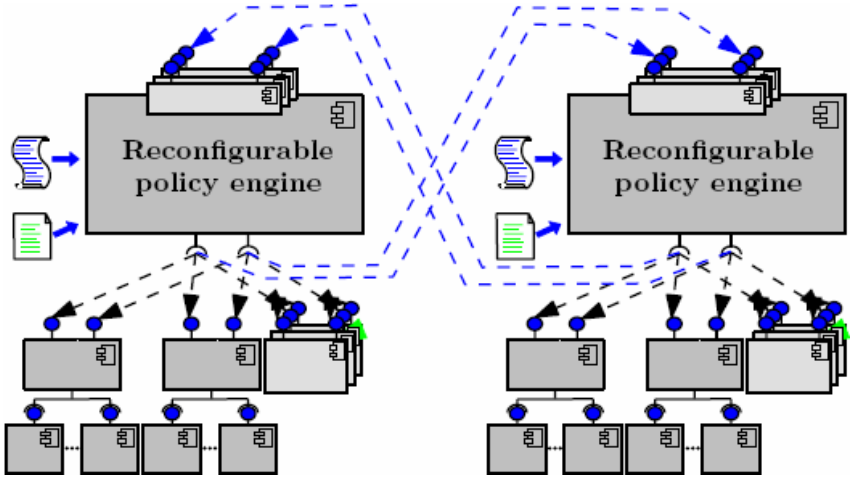
Implementation – system-of-systems federation



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Application development

Generation	Deployment	Exploitation
generate/implement application-specific components	configure policy engine & deploy new components	specify/select self-* policies
(*system developer*)	(*system administrator*)	(*system user*)

Application development

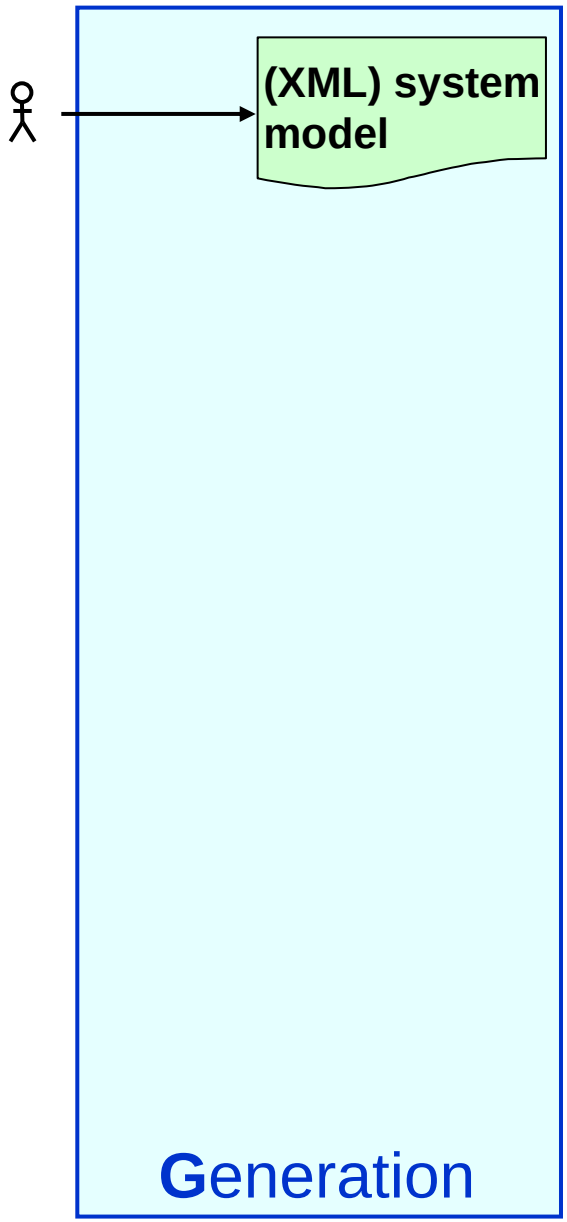
Sample self-* application

Allocate data-centre servers to clusters of different priorities & variable workloads such that they achieve user-defined levels of availability in the presence of cluster component failures.

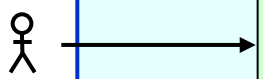
Generation

Deployment

Exploitation



- Build XML model describing the system resources, their parameters and behaviour
- Instance of pre-defined XML schema (*meta-model*)



(XML) system model

Generation

File Edit Find Project Perspective Options Tools Document

External Tools LIBXML

XPath 2.0

Outline Project

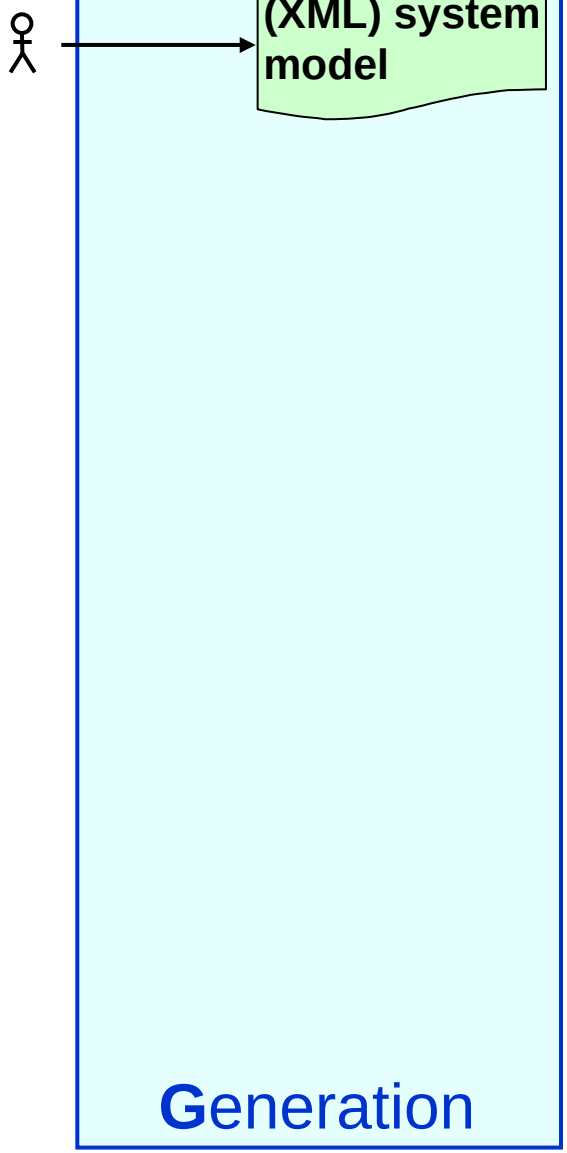
datacentre.xml

```
1   <?xml version="1.0" encoding="UTF-8"?>
2   <system xmlns="http://www.rcc.com/system"
3       <name>datacentre</name>
4
5       <!-- Cluster of workstations -->
6       <resource>
7           <ID>cluster</ID>
8
9           <!-- Unique cluster ID -->
10          <property> [12 lines]
23
24          <!-- Priority of this cluster -->
25          <property> [14 lines]
40
41          <!-- Number of operational servers
42          <property> [14 lines]
57
58          <!-- Number of servers allocated f
59          <property> [14 lines]
74
75          <!-- CTMC model -->
76          <property> [12 lines]
89
90          <!-- Expected availability (as the
91          <property> [12 lines]
104
105     </resource>
106
107     <!-- Pool of servers to be organised i
108     <resource>
109         <ID>serverPool</ID>
110
111         <!-- Unique server pool ID -->
```

Text Grid Author

Stylesheet Templates

XSLT/XQuery input



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datacentre.xml

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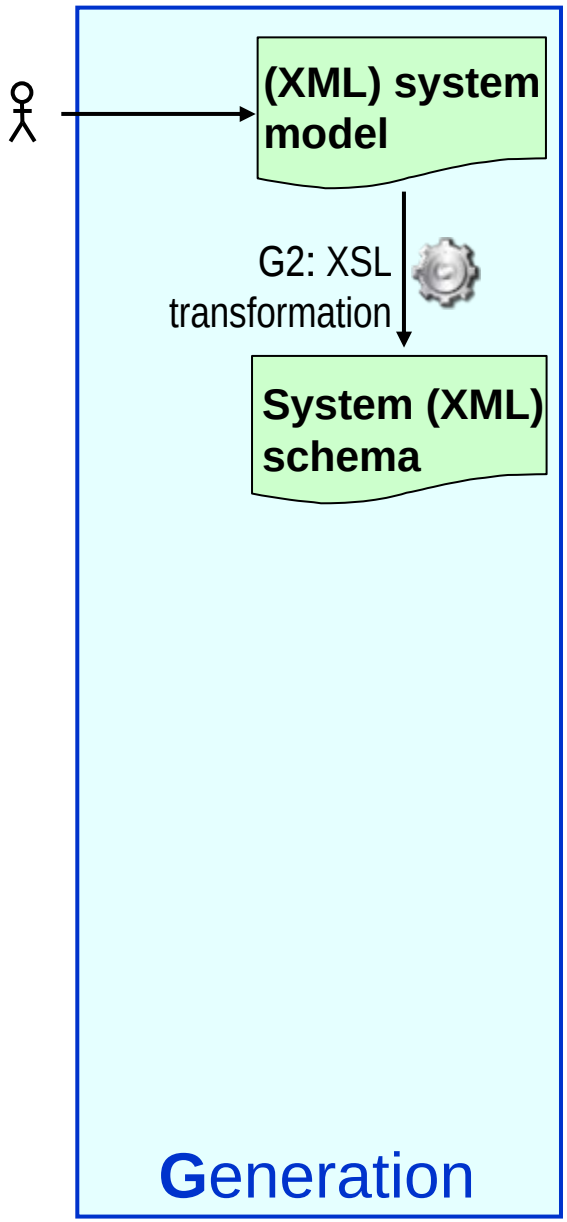
42    <property> [14 lines]
57
58    <!-- Number of servers allocated for the clust
59    <property>
60      <ID>allocatedServers</ID>
61      <propertyDataType>
62        <xs:element name="allocatedServers" type="
63        <xs:simpleType name="clusterAllocatedServe
64          <xs:restriction base="xs:int">
65            <xs:minExclusive value="0"/>
66          </xs:restriction>
67        </xs:simpleType>
68      </propertyDataType>
69      <mutability>mutable</mutability>
70      <modifiability>read-write</modifiability>
71      <subscribeability>false</subscribeability>
72      <primaryKey>false</primaryKey>
73    </property>
74
75    <!-- CTMC model -->
76    <property> [12 lines]
```

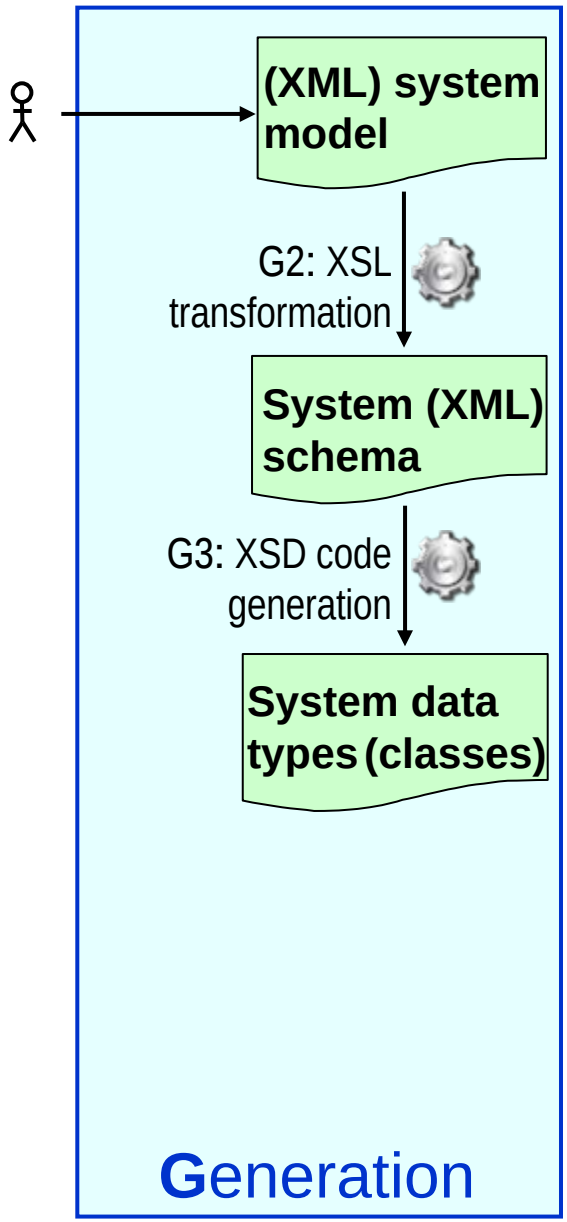
W [Xerces] schema_reference.4: Failed to read schema document 'file:../Metamodels/mar



Project

Full Model View | Logical Model View

```
1  <?xml version="1.0" encoding="UTF-8"?>
2  <xs:schema xmlns="http://www.rcc.com/system" xmlns:xs="
3
4    <xs:element name="cluster" type="cluster"/>
5    <xs:complexType name="cluster">
6      <xs:sequence>
7        <xs:element name="id" type="clusterId" nillable="
8        <xs:element name="priority" type="clusterPriority
9        <xs:element name="requiredServers" type="clusterR
10       <xs:element name="allocatedServers" type="cluster
11       <xs:element name="behaviouralModel" type="cluster
12       <xs:element name="availability" type="clusterAvai
13       <xs:element name="availabilityDefinition" type="x
14     </xs:sequence>
15   </xs:complexType>
16
17   <xs:element name="serverPool" type="serverPool"/>
18   <xs:complexType name="serverPool">
19     <xs:sequence>
20       <xs:element name="id" type="serverPoolId" nillabl
21       <xs:element name="nservers" type="serverPoolNserv
22     </xs:sequence>
23   </xs:complexType>
24
25   <xs:simpleType name="clusterId">
26     <xs:restriction base="xs:string"/>
27   </xs:simpleType>
```



DataCentreManageabilityAdaptor (3) - Microsoft Visual Studio

File Edit View Refactor Website Build Debug Tools Window Community H

Debug .NET

App_Code/datacentre.cs

cluster idField

```
//------------------------------------------------------------------------------
// <auto-generated>
//     This code was generated by a tool.
//     Runtime Version:2.0.50727.1433
//
//     Changes to this file may cause incorrect behavior and
//     the code is regenerated.
// </auto-generated>
//------------------------------------------------------------------------------

using System.Xml.Serialization;

// ...
[System.CodeDom.Compiler.GeneratedCodeAttribute("xsd", "2.0
[System.SerializableAttribute()]
[System.Diagnostics.DebuggerStepThroughAttribute()]
[System.ComponentModel.DesignerCategoryAttribute("code")]
[System.Xml.Serialization.XmlTypeAttribute(Namespace="http:/
[System.Xml.Serialization.XmlRootAttribute(Namespace="http:/
public partial class cluster {

    private string idField;

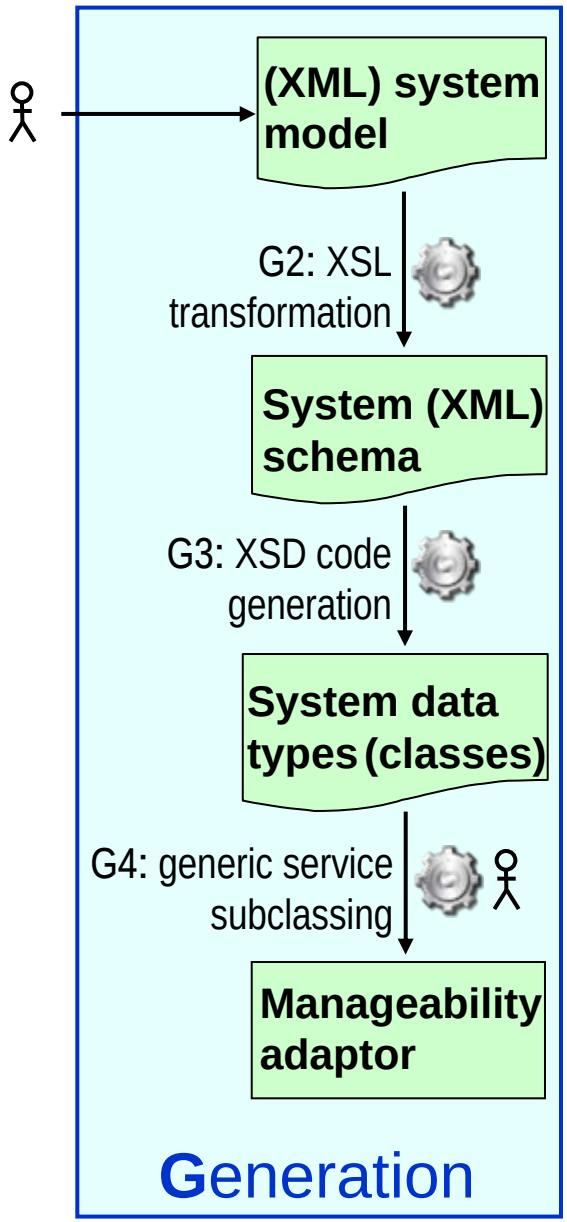
    private System.Nullable<int> priorityField;

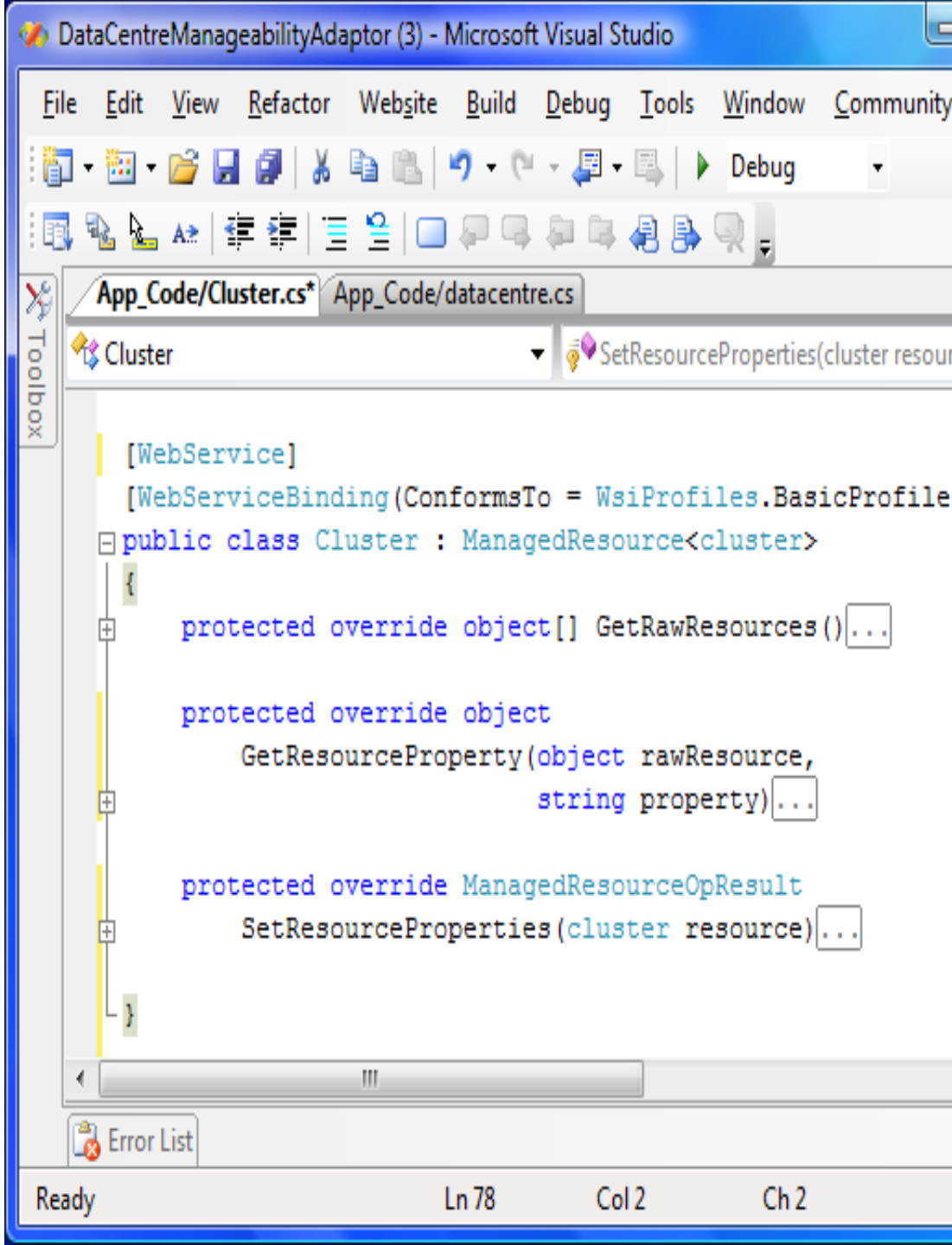
    private System.Nullable<int> requiredServersField;

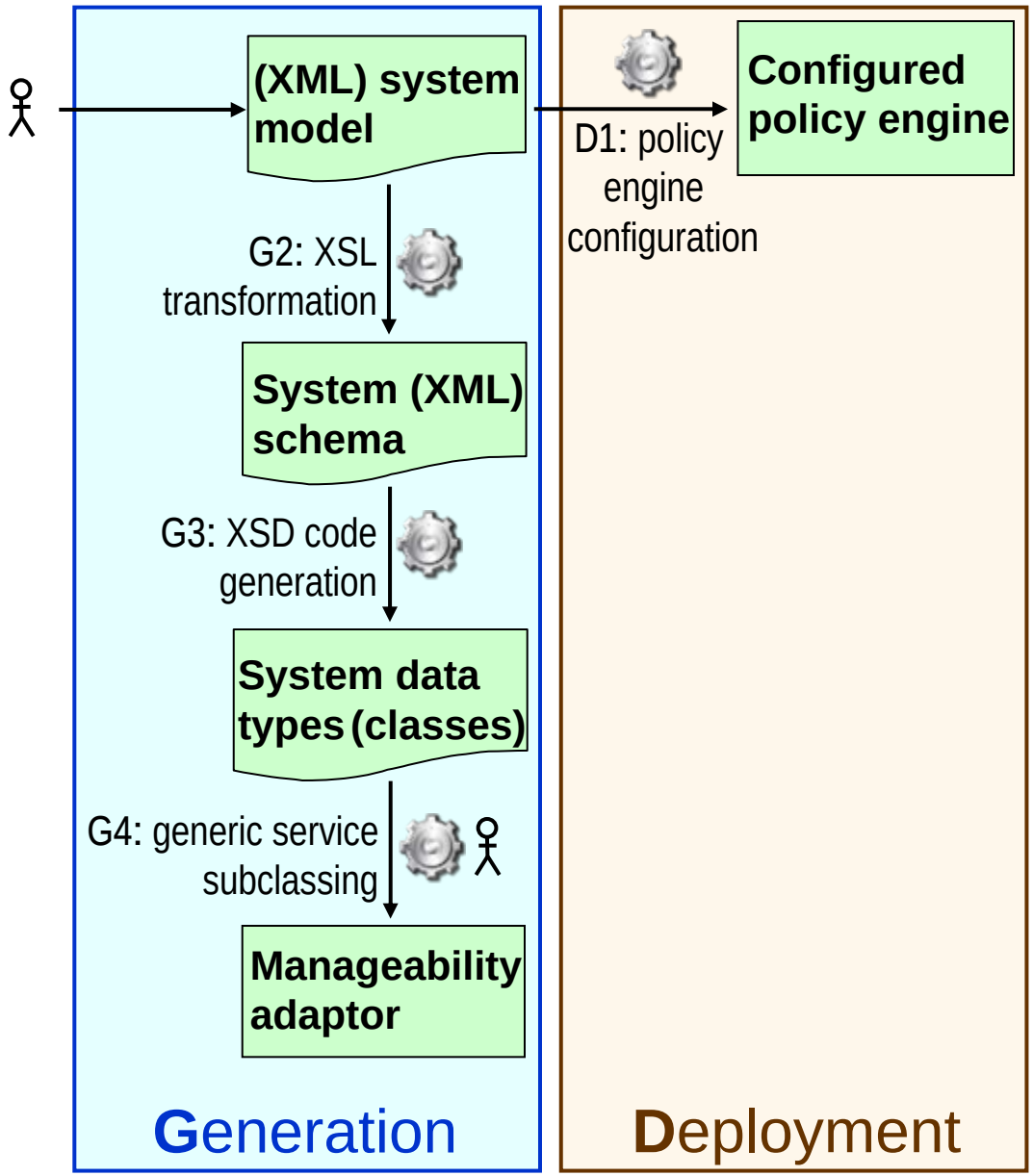
    private System.Nullable<int> allocatedServersField;

    private string behaviouralModelField;

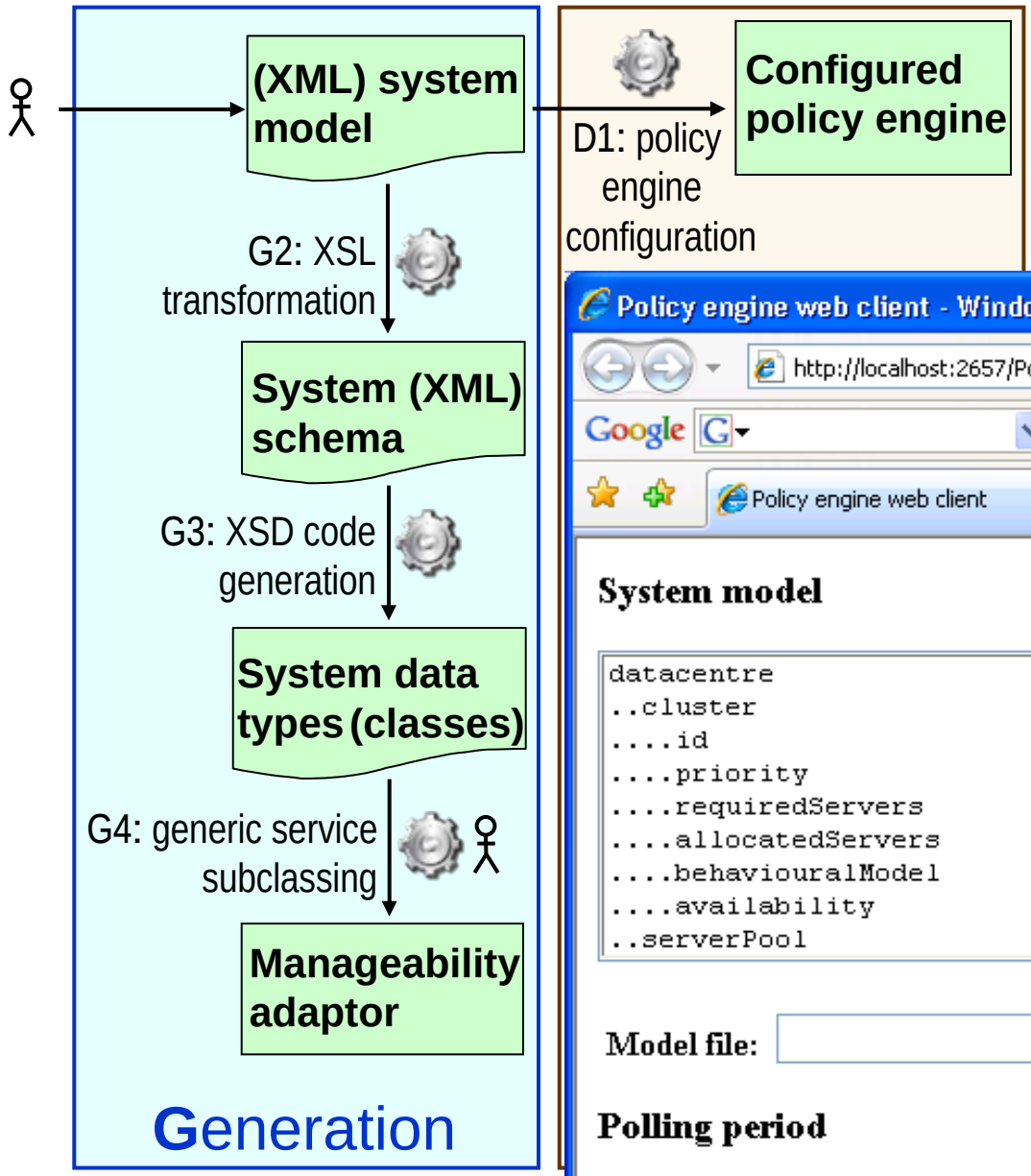
    private System.Nullable<double> availabilityField;
```


(XML) system model
G2: XSL transformation
System (XML) schema
G3: XSD code generation
System data types (classes)
G4: generic service subclassing
Manageability adaptor
Generation


DataCentreManageabilityAdaptor (3) - Microsoft Visual Studio
File Edit View Refactor Website Build Debug Tools Window Community
Debug
App_Code/Cluster.cs*
App_Code/datacentre.cs
Toolbox
Cluster
SetResourceProperties(cluster resour
[WebService]
[WebServiceBinding(ConformsTo = WsiProfiles.BasicProfile
public class Cluster : ManagedResource<cluster>
{
protected override object[] GetRawResources()...
protected override object
GetResourceProperty(object rawResource,
string property)...
protected override ManagedResourceOpResult
SetResourceProperties(cluster resource)...
}
Error List
Ready
Ln 78
Col 2
Ch 2



- Use web client to supply model to the policy engine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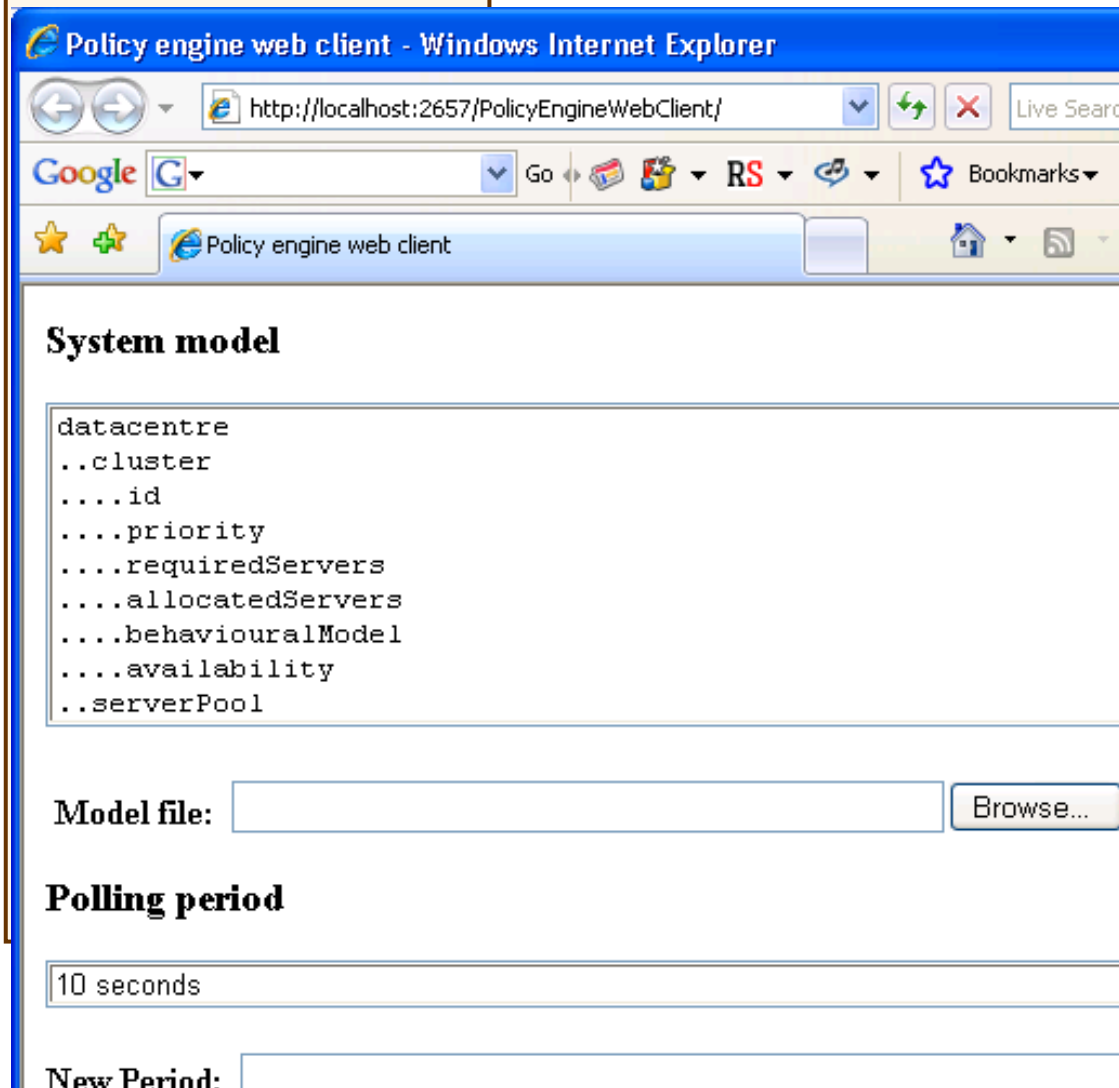
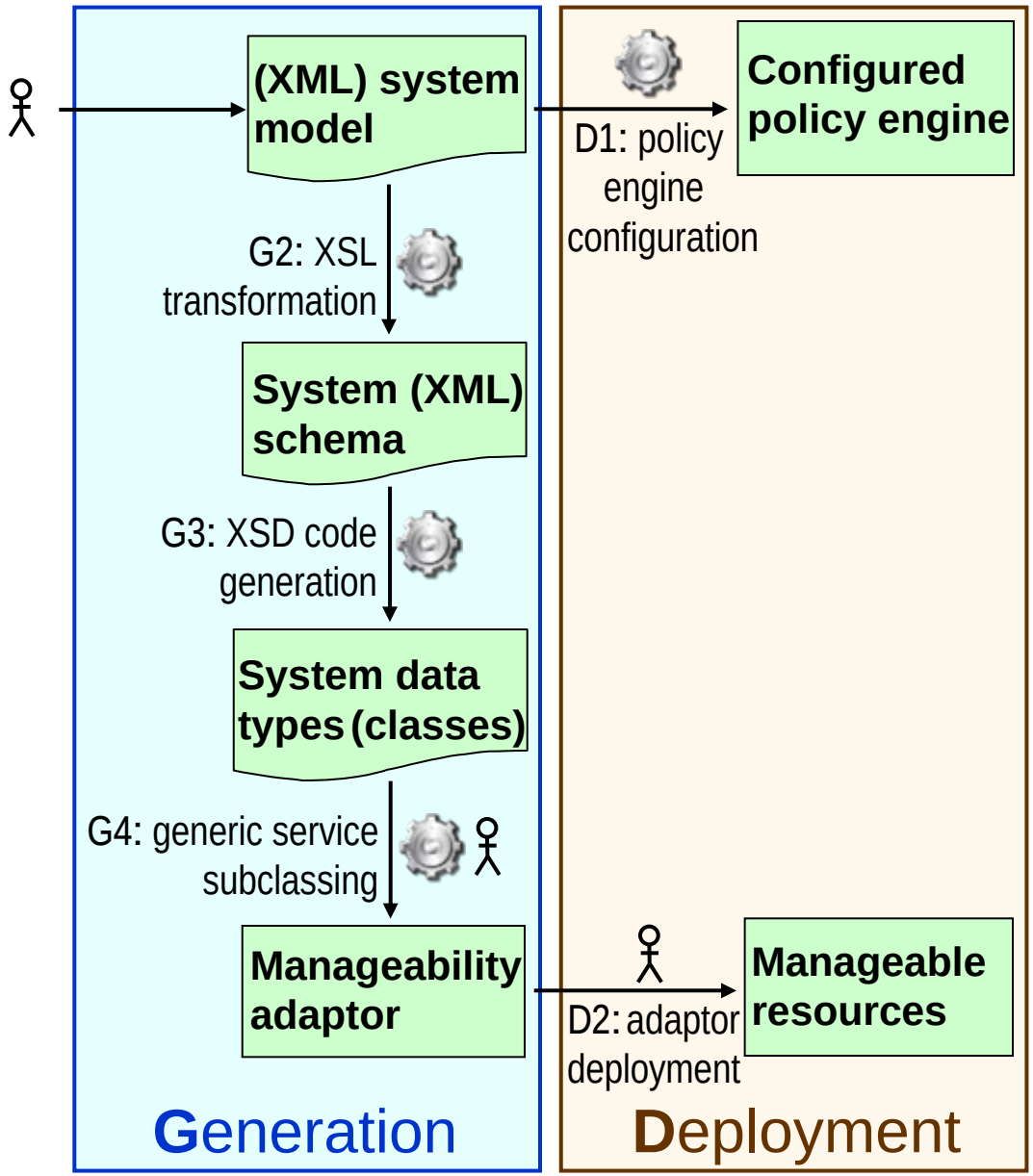
Configured policy engine


Policy engine web client - Windows Internet Explorer
http://localhost:2657/PolicyEngineWebClient/
Policy engine web client
System model
datacentre
..cluster
....id
....priority
....requiredServers
....allocatedServers
....behaviouralModel
....availability
..serverPool
Model file:
Browse...
Polling period
10 seconds
New Period: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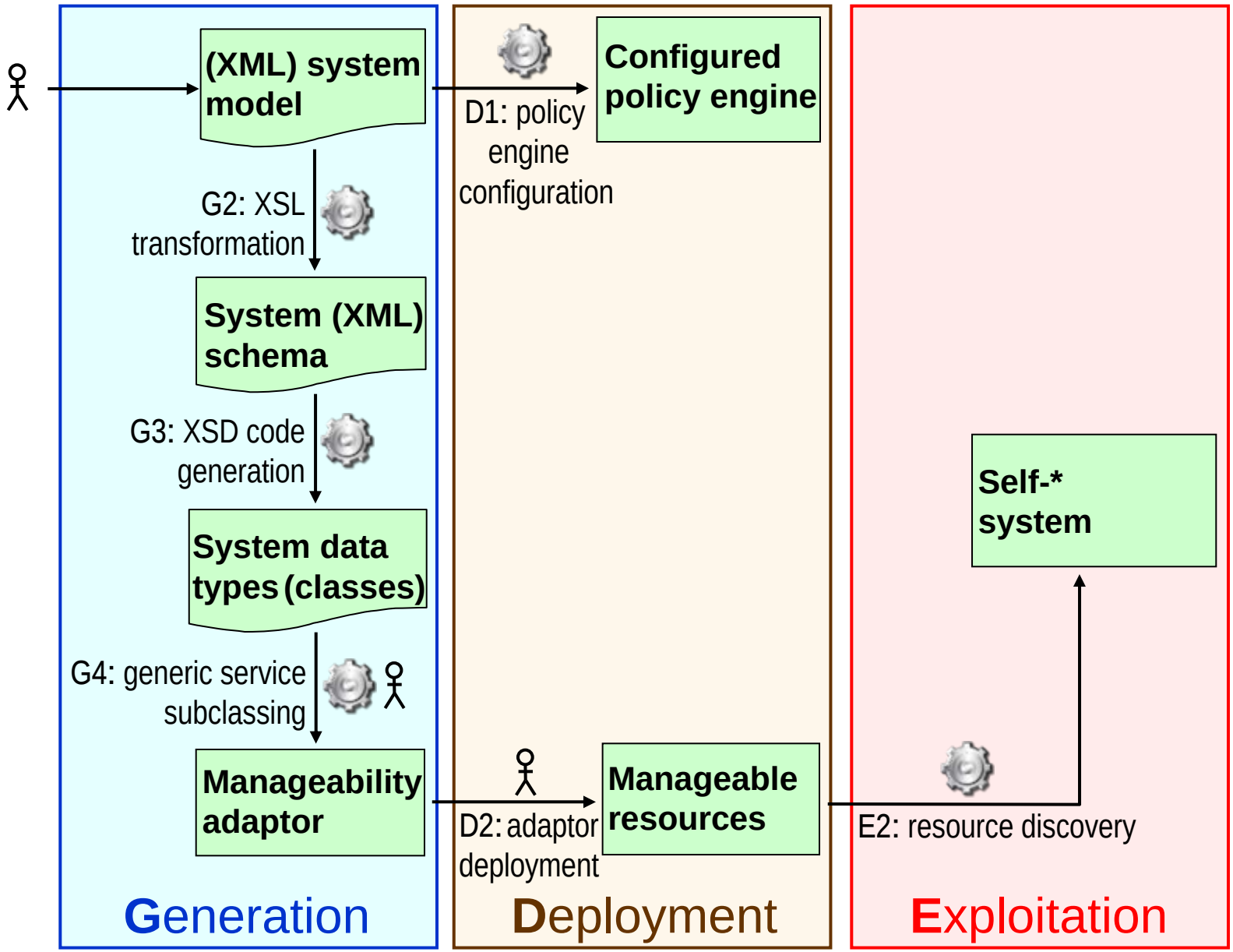
Deployment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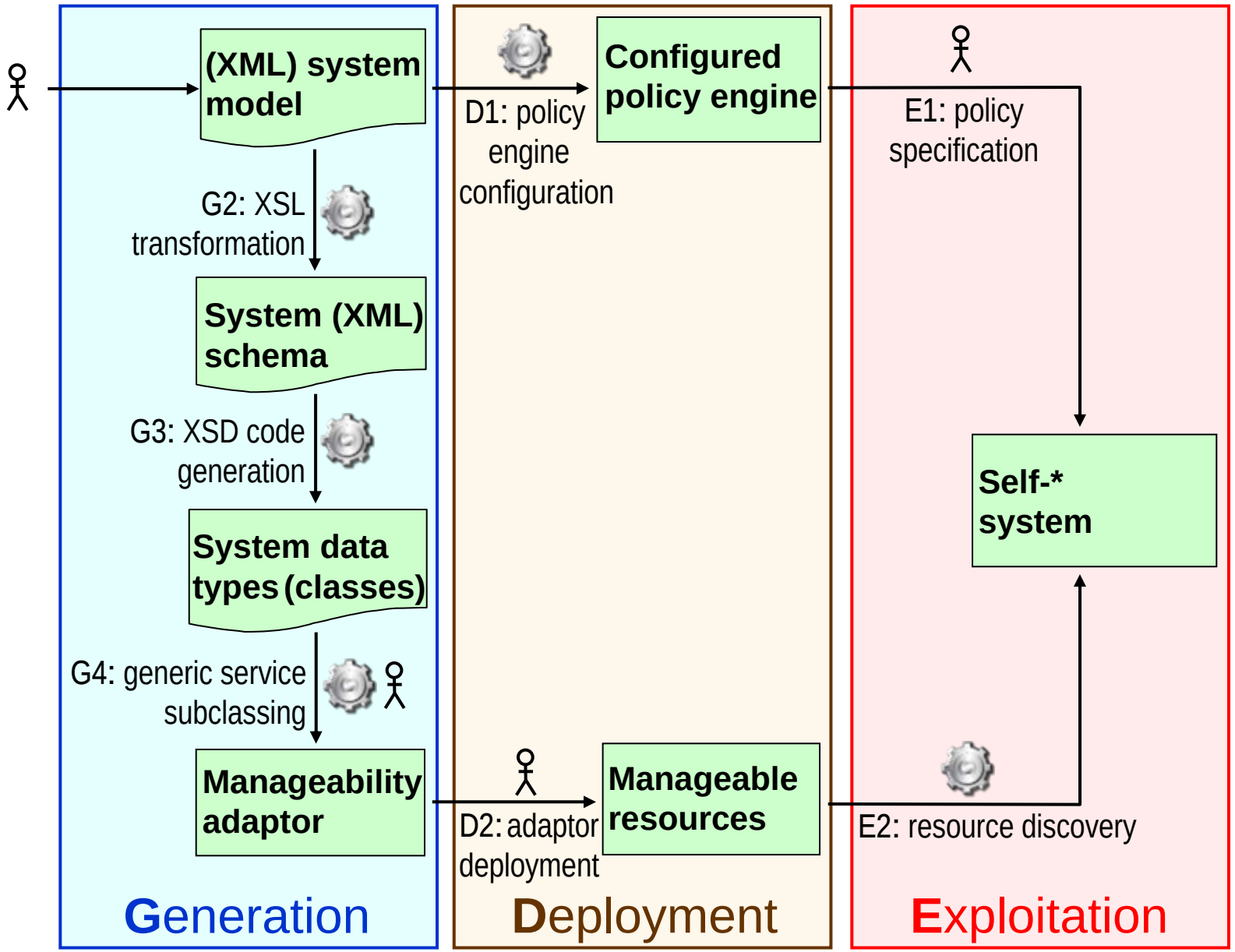
E2: resource discovery
Exploitation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Self-* system
E2: resource discovery
Exploitation

Utility-function policy

$$\textbf{MAXIMIZE}\left(\sum_{i=1}^{N} priority_i \textbf{GOAL}(availability_i \geq targetAvailability_i) - \epsilon \sum_{i=1}^{N} allocatedServers_i\right)$$

Utility-function policy

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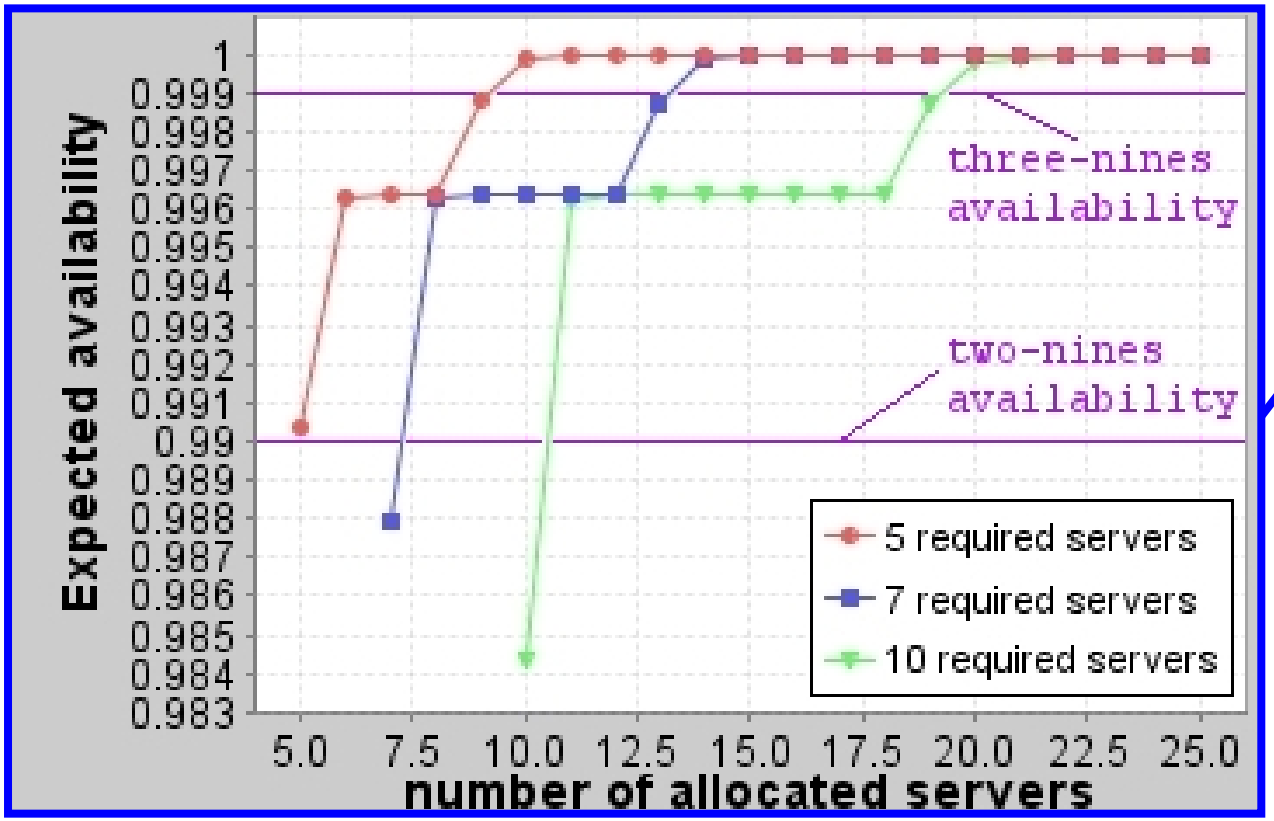
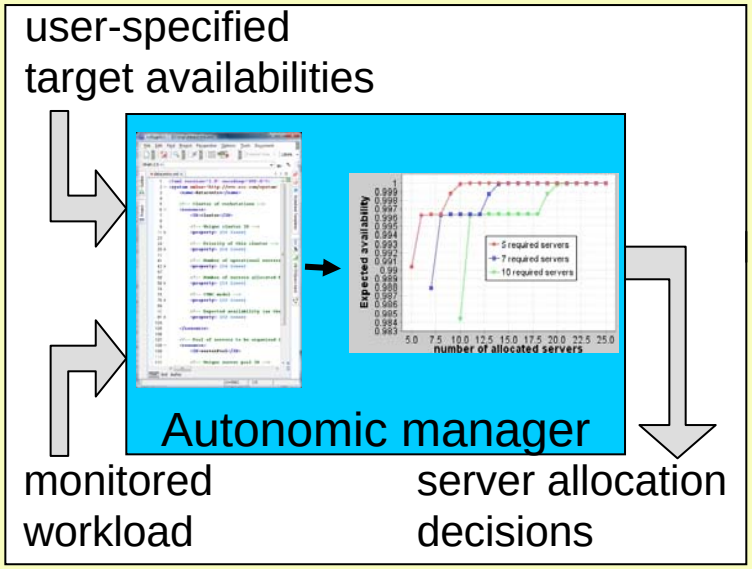


Online quantitative analysis in self-* systems

Sample self-* application: summary



The allocation of data-centre servers to clusters is managed automatically, based on high-level system objectives specified by data-centre administrators.

Case study summary

	Resource type					self-* areas & policy type					application domain
	software	hardware	data	legacy	autonomic-enabled	main self-* functional areas	action	goal	utility-function	resource-definition	
Allocation of CPU capacity	√			√		self-monitoring self-optimisation			√		CPU capacity allocation
Goal-driven CPU sched.	√			√		self-monitoring self-optimisation		√			CPU capacity allocation
Disk drive DPM		√		√		self-monitoring self-adaptation			√		dynamic power management
Ctrl. of cluster availability		√		√		self-configuration self-protection			√		availability management
Dynamic gen. of web content		√	√	√	√	self-monitoring self-generation	√		√	√	online report generation