Toward Self-Optimization of Autonomic Systems

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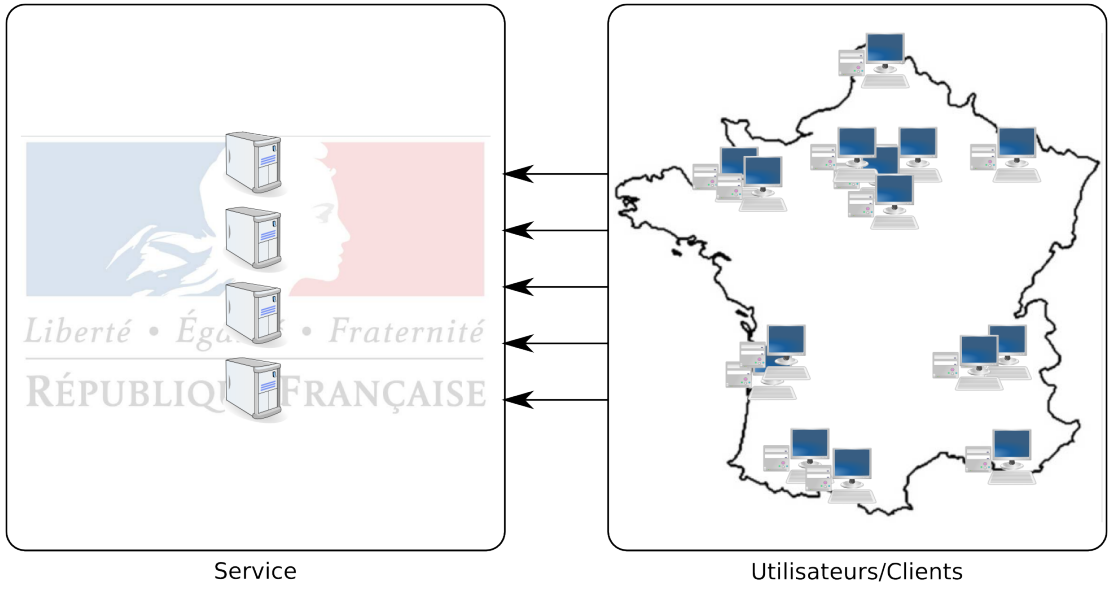
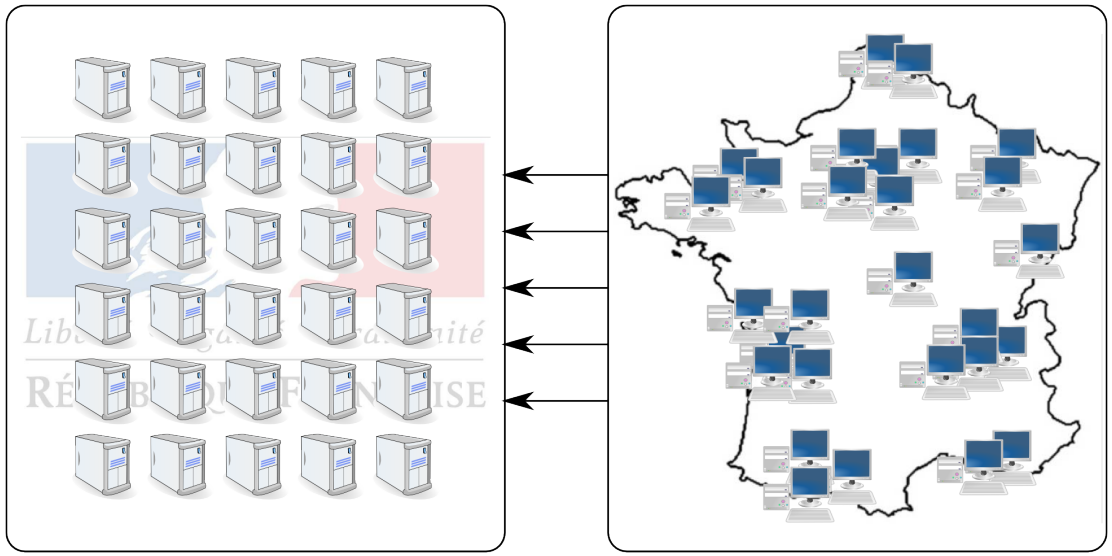
Introduction
French online income declaration service (2005)



- System capacity: 1,5 million users
- Actual load: 3,7 million users

Bad capacity planning:
System overloaded!

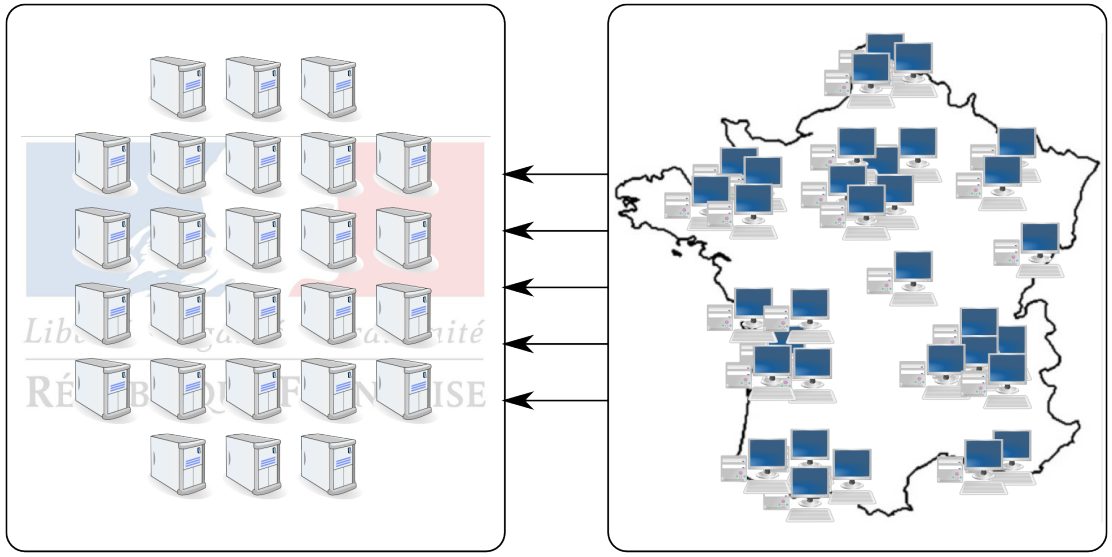
Introduction
French online income declaration service (2006)



- System capacity: 10 million users
- Actual load: 5,7 million users

Sub-optimal capacity planning:
almost 50% resources wasted!

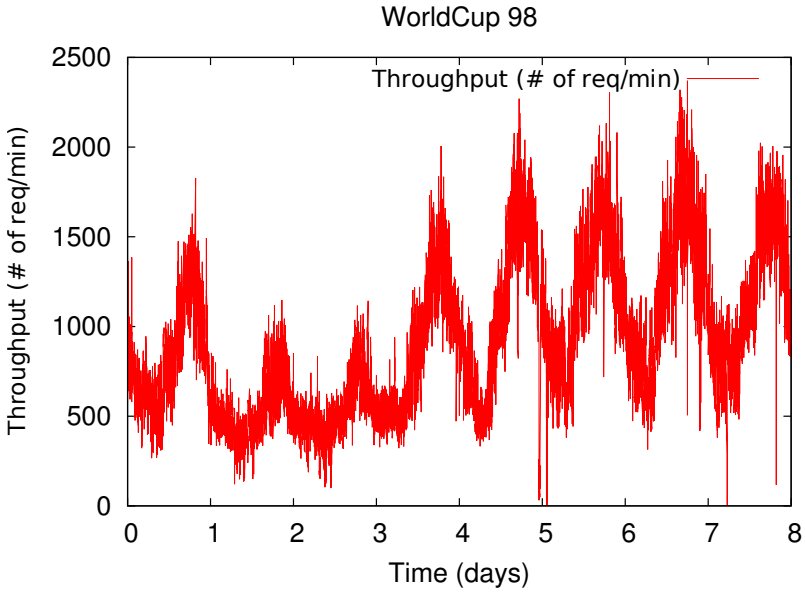
Introduction
French online income declaration service (2007)

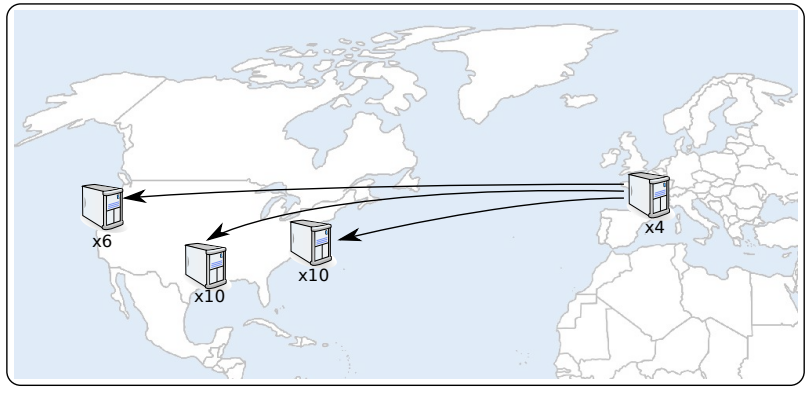


- System capacity: 8 million users
- Actual load: 7.4 million users

Optimal capacity planning!

Introduction
WorldCup'98 Web site





WorldCup 98 Internet Service Architecture

- Dynamic workload: min/max load ratio = $\times 4$
- Fixed system size: 30 servers
  - France Télécom, Hewlett Packard

Challenges
Building self-optimized autonomic systems

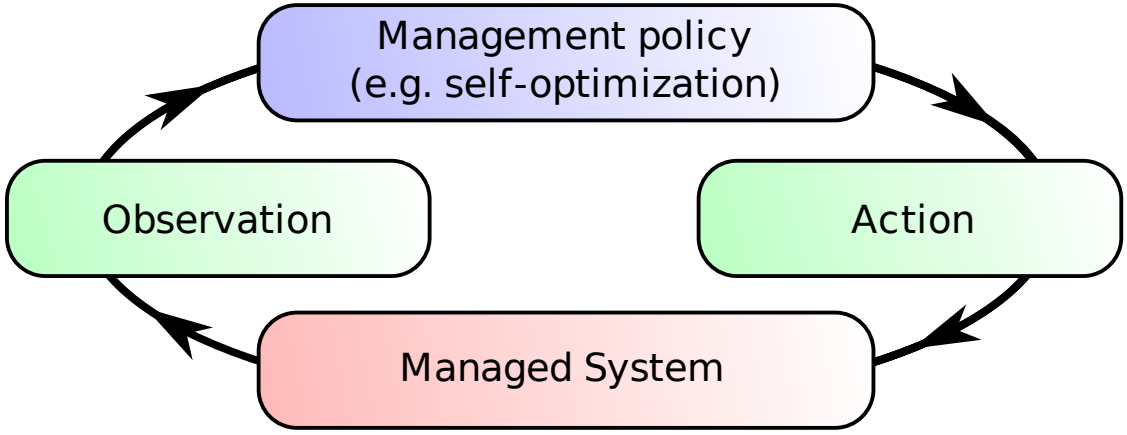
System capacity planning

- Performance and availability guarantees
- Load variation
- Oscillations
- Legacy systems

Dynamic software architecture

- Distributed systems
- Synchronized deployments
- Dynamic architectures

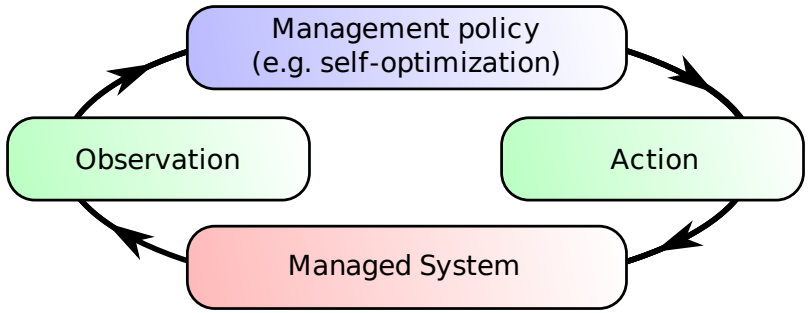
Self-Optimization of Dynamic Software Architecture



Feedback control-loop

Overview

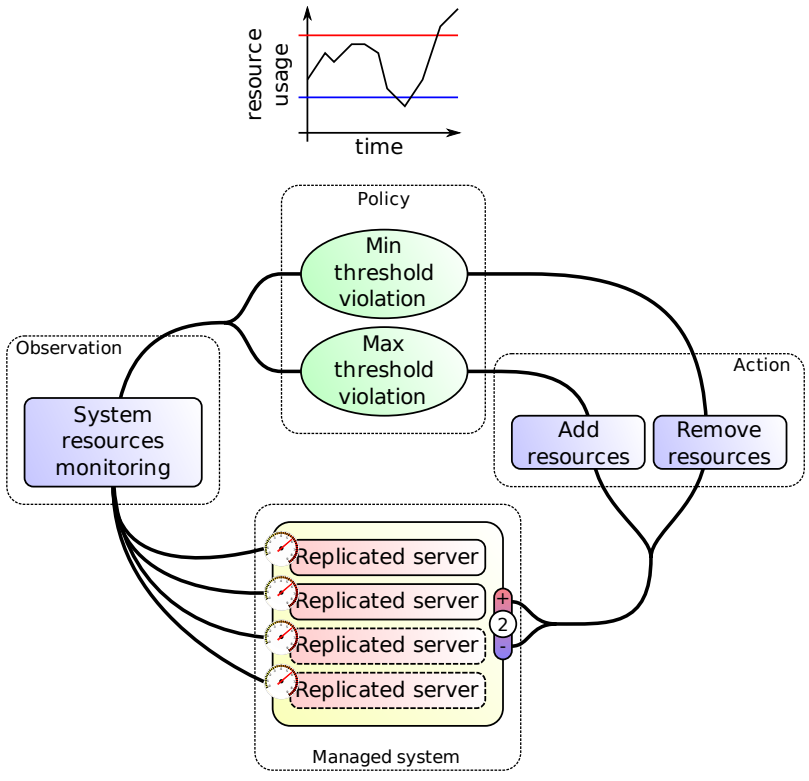
- Contributions
  - Self-optimization policy
  - Actions
  - Observations
- Conclusions & Perspectives



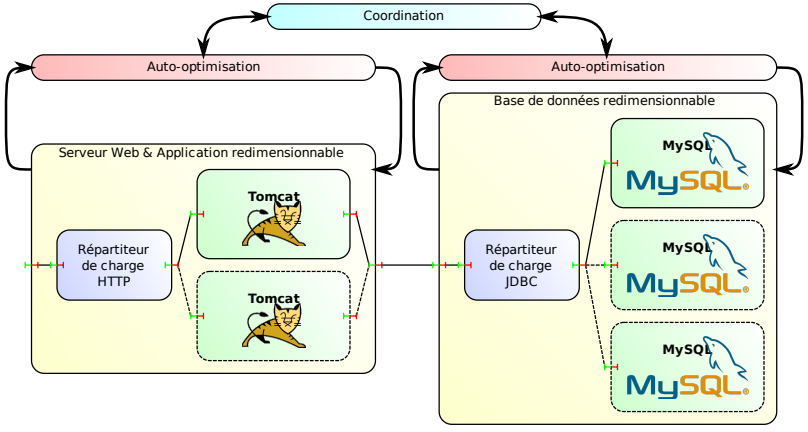
Contributions

Self-optimization policy
Overview

- Feedback control-loop
- Threshold based policy
- Resource usage thresholds
- $\pm n$ resources

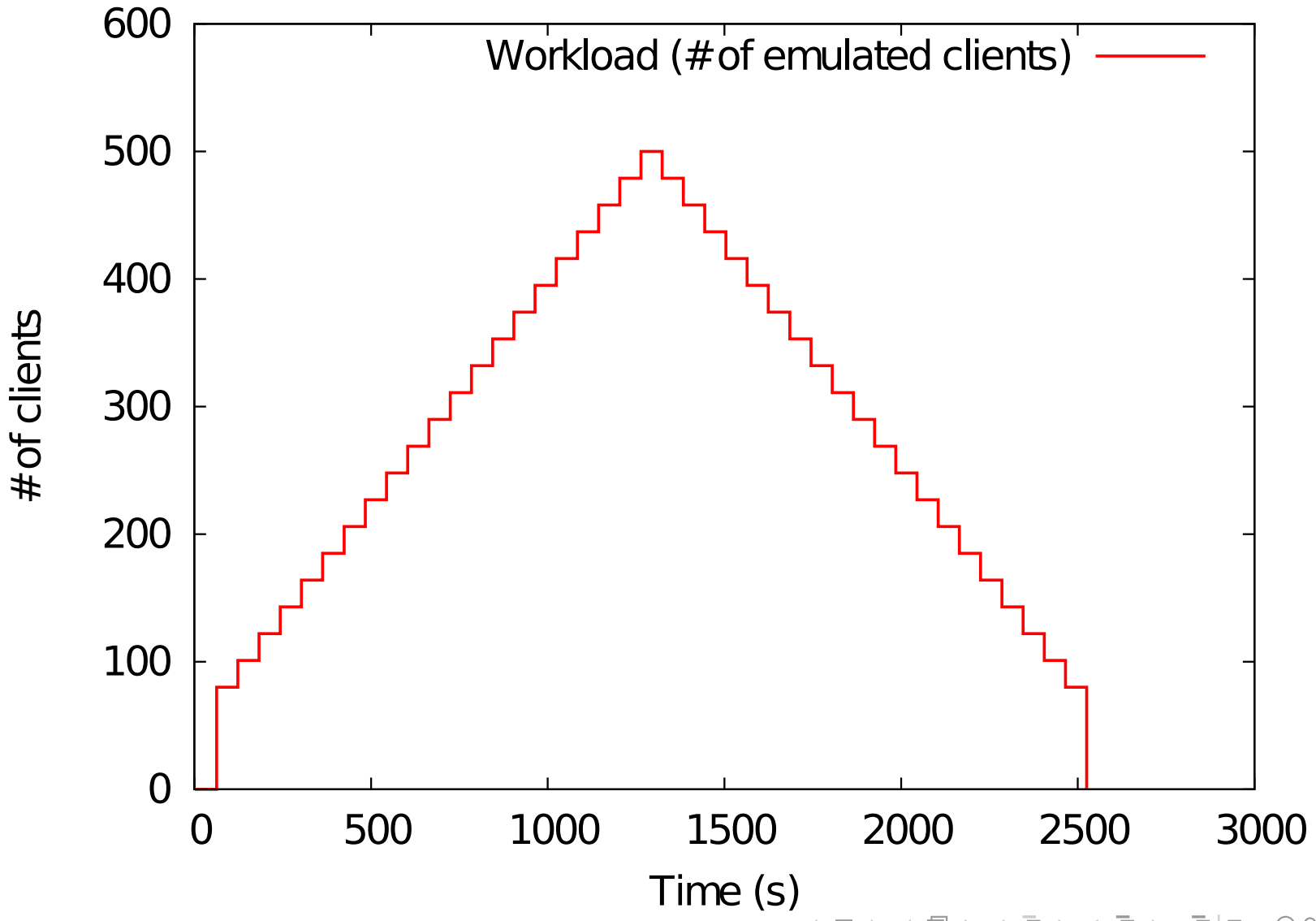


Multi-tier Service Dynamic provisioning

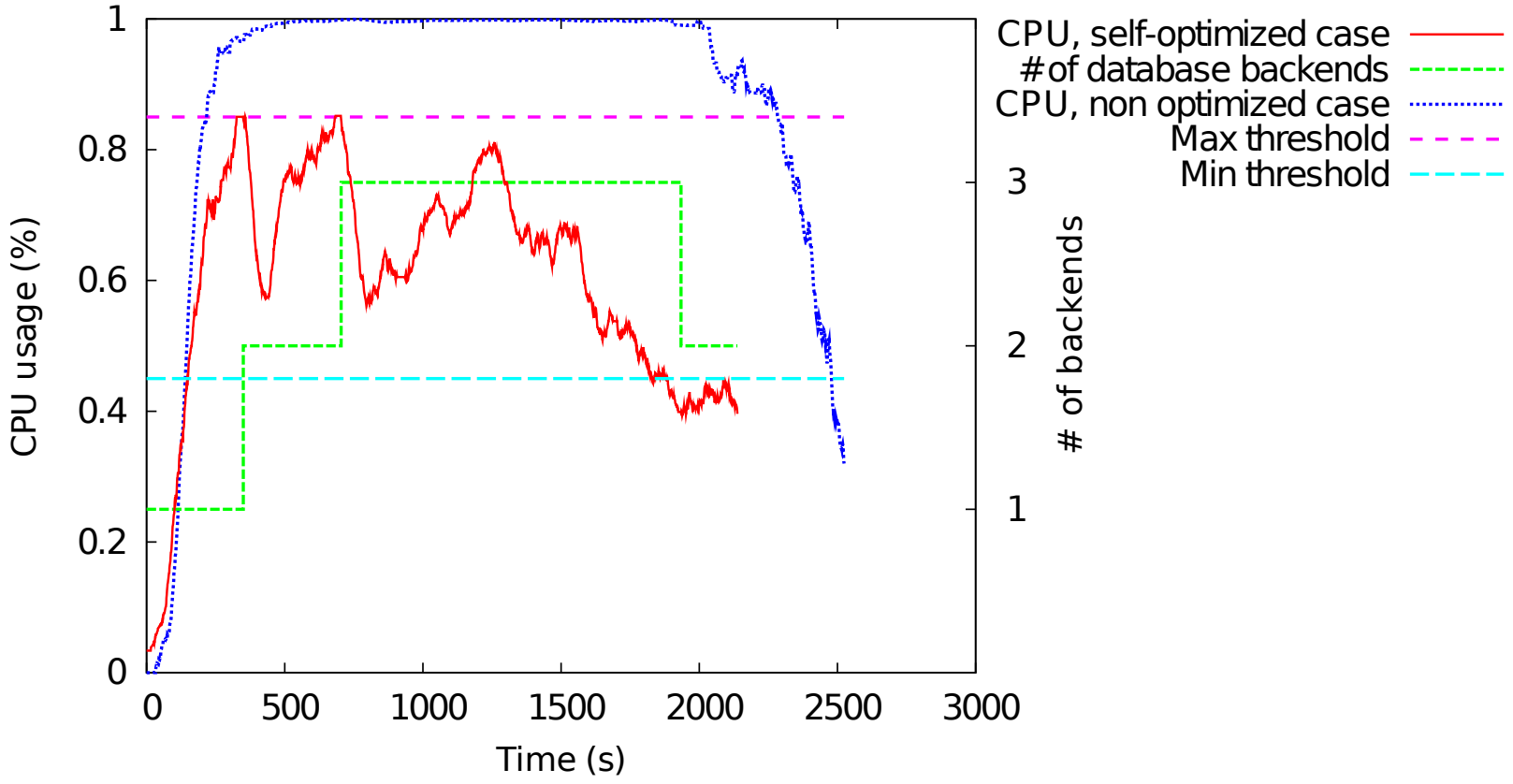


- J2EE System
  - Web & Application: Apache Tomcat v5 (1 or 2 instances)
  - Database: MySQL v5 & Sequoia (from 1 to 3 instances)
- Benchmark: RUBiS (eBay)
  - Gradual load variations

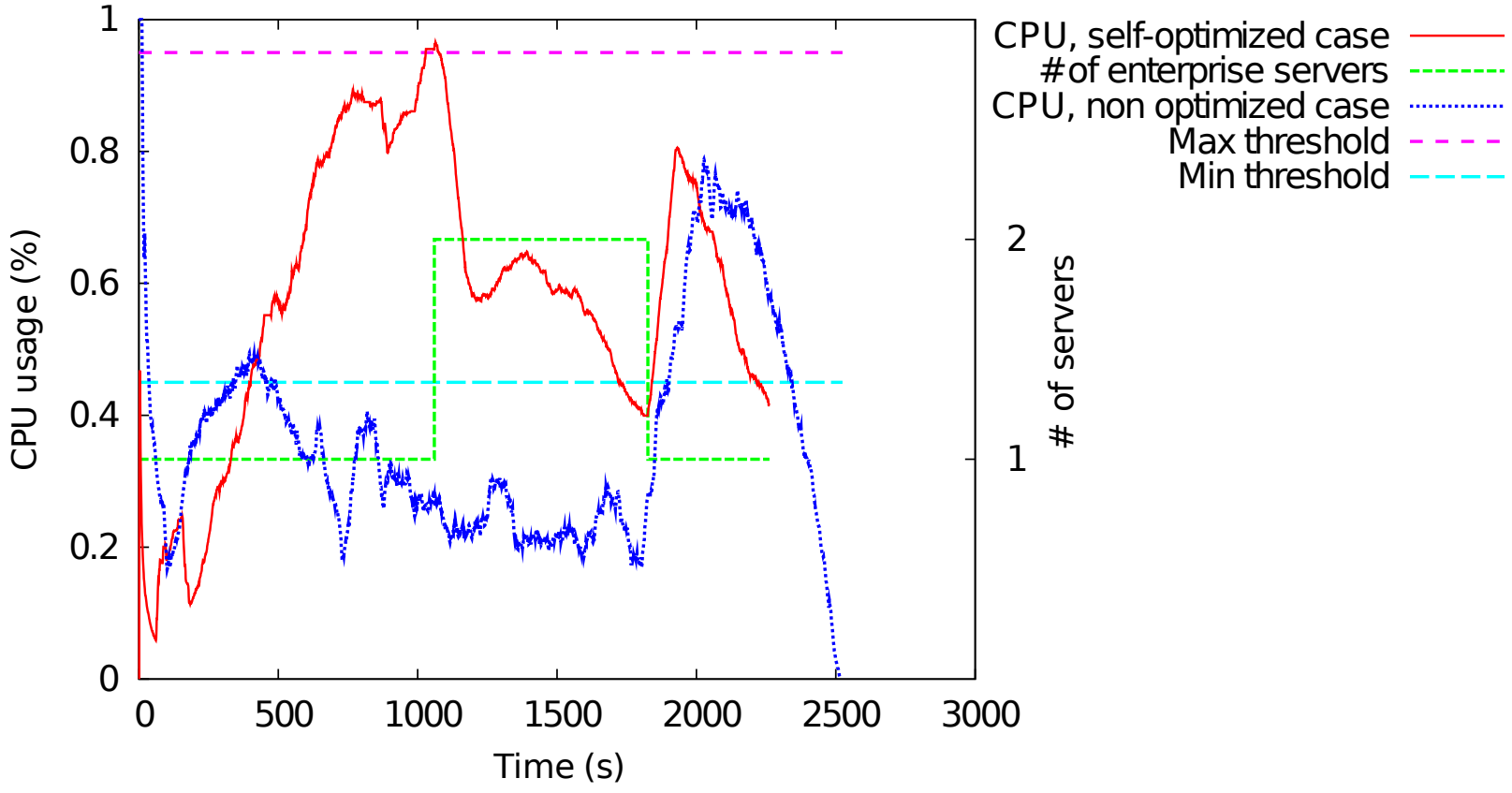
Gradual load variations



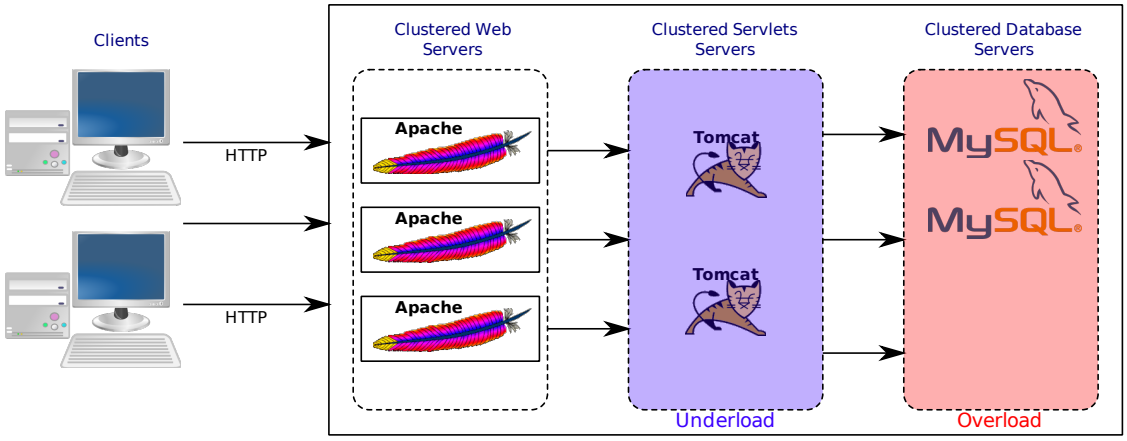
System behaviour
Database servers



System behaviour
Web & Application servers

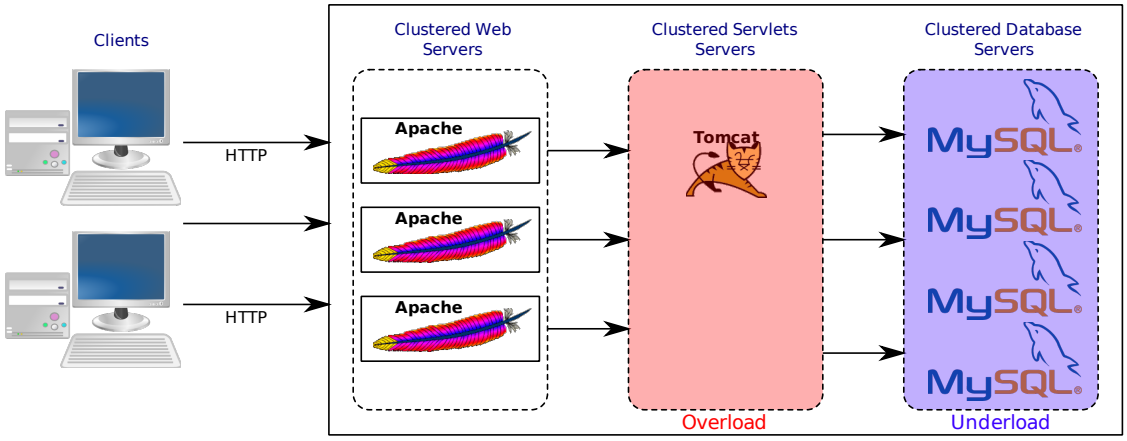


Oscillations
Example (1)



- Sub-system dependencies
  - X directly linked to Y
  - X overload may induce Y underload
- Harmful uncorrelated separate reactions
  - Over/Under-load: add/remove resources

Oscillations
Example (2)



- Sub-system dependencies
  - X directly linked to Y
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Oscillation prevention
Related work

- Global inhibition delay (Cluster-on-Demand) [Moore et al., 2002]
  - Freeze of the whole system
- Fake resource removal (Chameleon) [Soundararajan et al., 2006]
  - Database specific approach
- Control theory approaches [Hellerstein et al., 2004]
  - Accurate system modeling

Approach toward oscillation prevention

Design principles

- Architecture knowledge
- Sub-system dependencies identification
- Allow coordination
- Reconfiguration inhibition for systems with direct dependencies

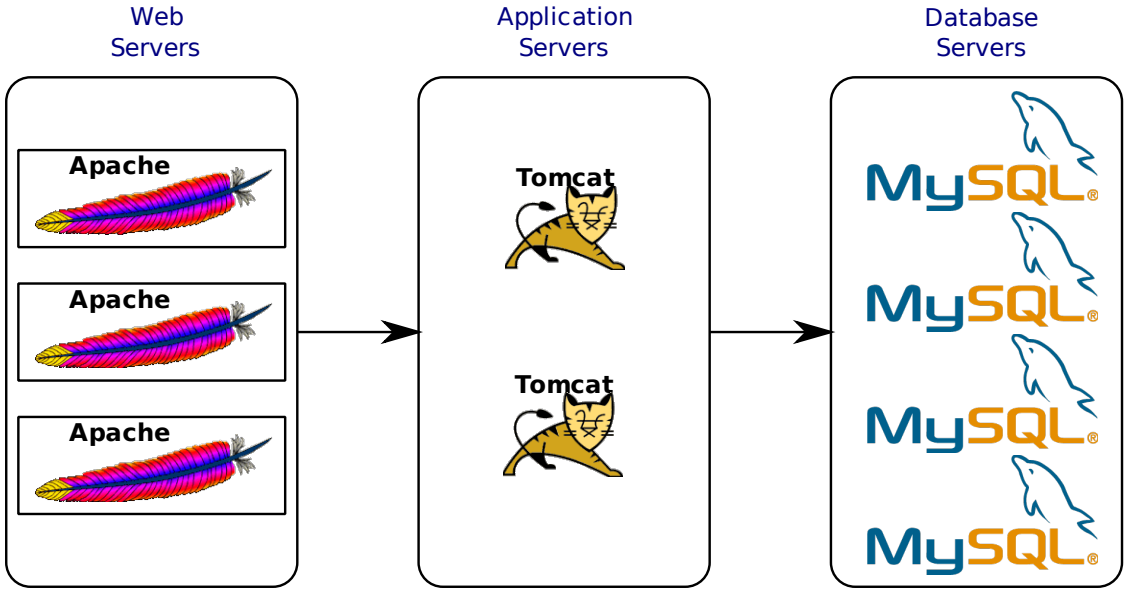
Implementation

- Jade autonomic management platform
- Fractal software components
- Self-optimization manager with oscillation prevention

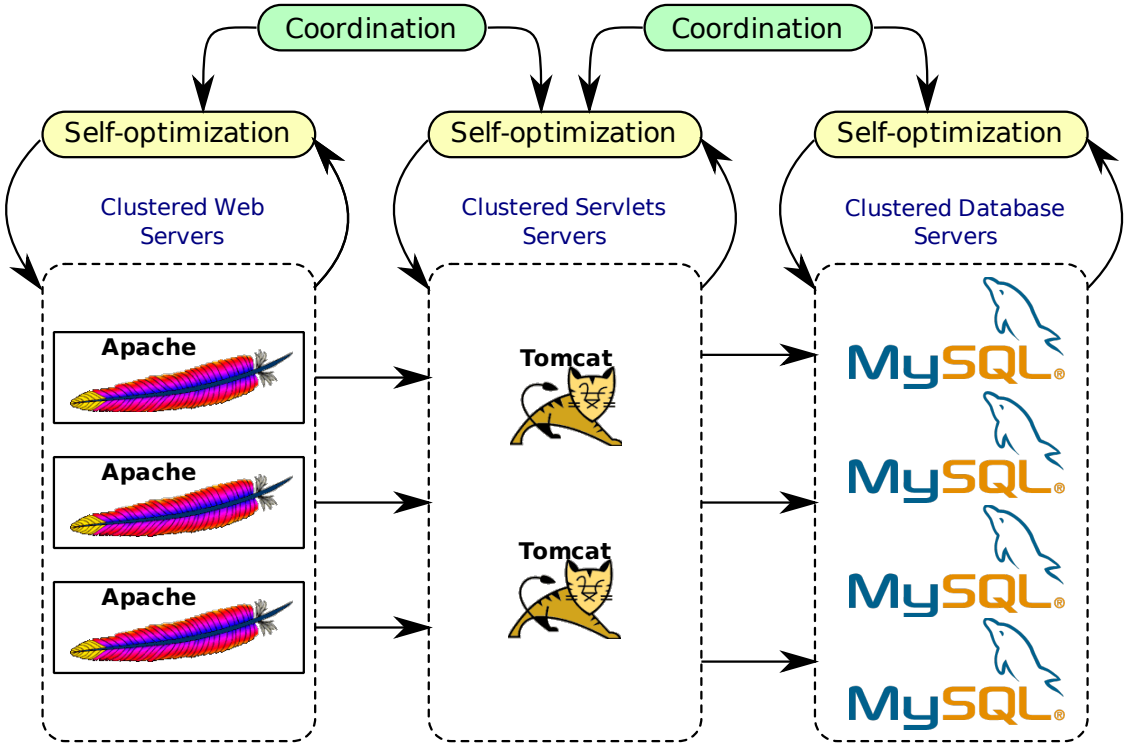
Implementation

Principles

- Components represent sub-systems
- Bindings symbolize dependencies



Implementation
Self-optimized J2EE Internet Service



Dynamic provisioning inhibition rule

Resizing on Database servers
inhibits
Resizing on Application and Database servers

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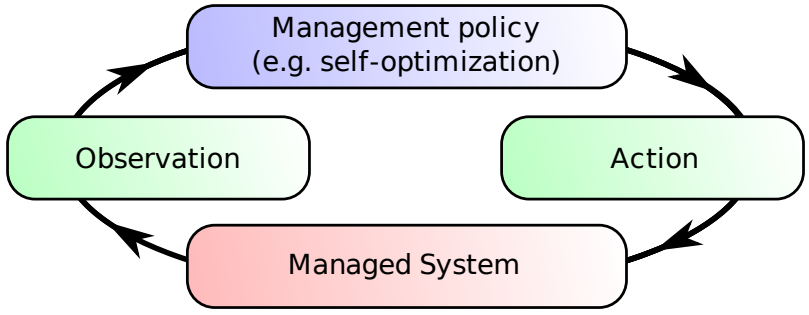


Architecture Description Language (ADL)

Architecture Description Language

- System elements: Components

```
<component name="my-component" ...> ... </component>
```

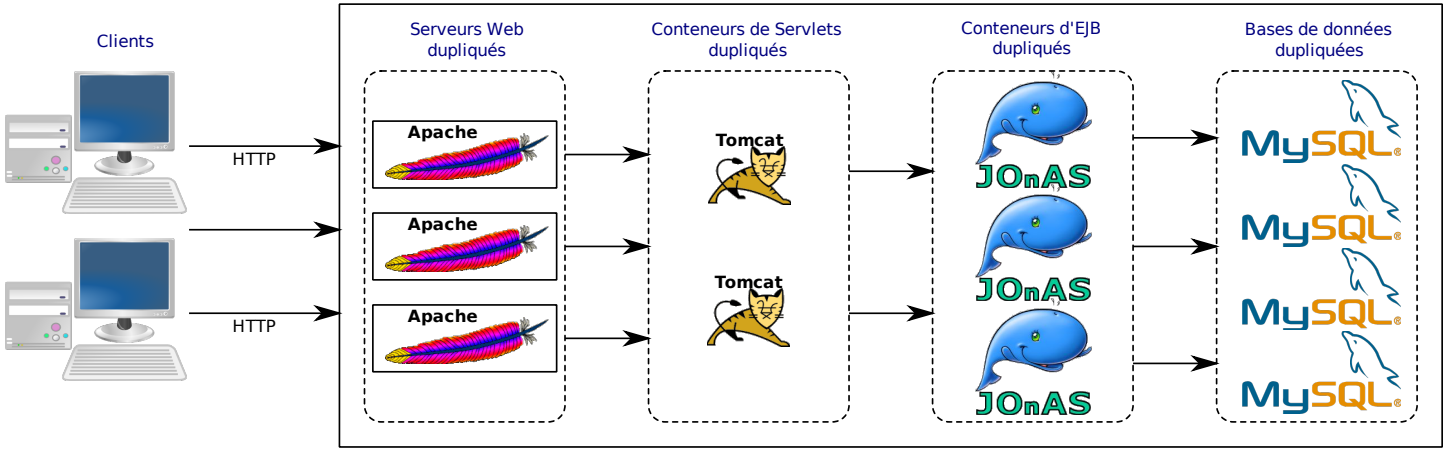
- Sub-system relationships: Interfaces and Bindings

```
<binding name="my-binding"
        client="my-client-itf" server="my-server-itf" .../>
```

Deployment

ADL instantiation process

Distributed deployment synchronization
Example



Distributed deployment of a complex architecture (Multi-tier J2EE)

- What if we parallelize all deployments?
- Invariant: backends started before frontends
- Dependencies through architecture

Related work
Distributed deployment coordination

- Deployment synchronization encoded in factories (Fractal ADL/Julia Factories) [Bruneton et al., 2006]
- Factory parameter (Prism) [Mikic-Rakic et al., 2005]
- Simple ADL parameter (ProActive) [Caromel et al., 2007]
  - Does not allow arbitrary synchronizations
- Generated deployment procedure (IA Planning or Constraints solving) [Arshad, 2006]
  - No control on synchronization
- Workflow languages (SmartFrog, BPEL) [Goldsack, 2003] [Keller et al., 2004]
  - Not applicable to architecture deployments

Approach
Distributed deployment synchronization

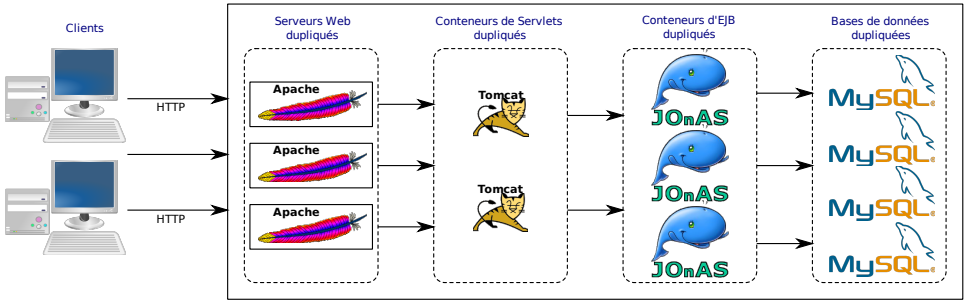
Design principles

- Package
  - Description, deployment and architectural unit
  - 1^{st}-class programming language entity
  - Deployment procedure
- Distributed deployment
  - Coordination and synchronization of local package deployments

Implementation

- Mozart/Oz distributed platform
  - Using Oz synchronization abilities
- FructOz framework
  - Fractal component model

Implementation
Synchronized distributed deployment




```
proc {DeployJ2EE NWebs NServlets NEJBs NDBs}
    {Barrier {MakeList NDBs DeployDB}}
    % Require all DB servers up

    {PartialBarrier {MakeList NEJBs DeployEJB} (NEJBs/2)}
    % Ok when 1/2 EJB servers are up

    {Barrier {MakeList NServlets DeployServlet}}
    % Require all Servlet servers up

    {PartialBarrier {MakeList NWebs DeployWeb} 1}
    % Ready as soon as one Web server instance is up
end
```

Distributed deployment

Database deployment procedure

```
% Set of DB servers initially empty
DBTier = {SNew}

% Deployment procedure for a single DB server
proc {DeployDB}
    Host = {AllocateHost Cluster}
    DB = {RemoteDeploy Host DBPkg}
in
    {DBTier add(DB)}
end
```

Synchronization barrier

Partial synchronization barrier

```
proc {PartialBarrier LDeploys N}
   Continue % Synchronization signal (undefined yet)
   Counter = {NewCell N} % Counter initialized to N
in
   for Deploy in LDeploys do
      thread % Start all deployment procedures in separate threads
         {Deploy}
         local % Thread−safe counter decrement
            NewCount PreviousCount = {Exchange Counter NewCount}
         in
            if (PreviousCount > 0) then
               NewCount = PreviousCount − 1
               if (NewCount == 0) then
                  Continue = true % Synchronization signal when counter reaches 0
               end
            end
         end
      end
   end
   {Wait Continue} % Wait until synchronization signal is defined
end
```

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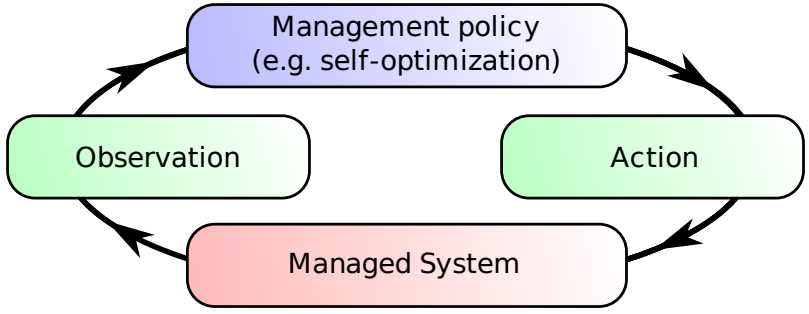


Dynamic architecture instrumentation
Overview

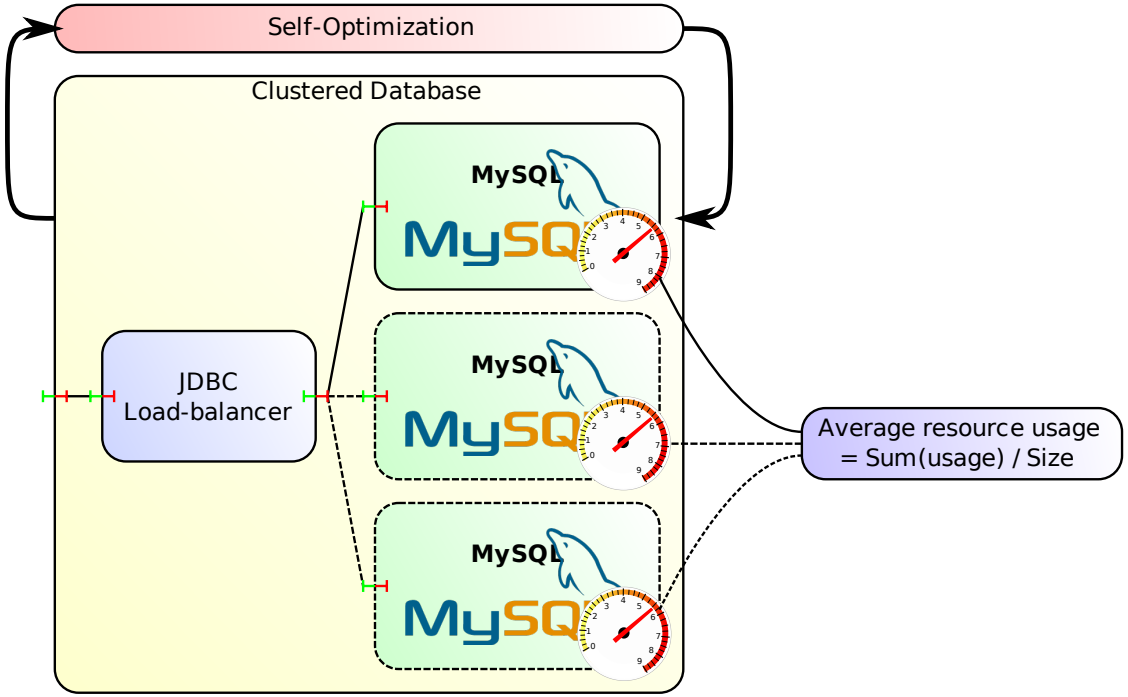
Design principles

- Dynamic architecture as a 1^{st} class citizen
- Dynamic computation model

Implementation

- Integration with FructOz
  - Fractal components
  - Architectural constructions
- LactOz library of navigation primitives

Clustered service monitoring
Example



Challenge

- Dynamic set of nodes to monitor
- Monitoring system adaptations

Dynamic architecture instrumentation
Related work

- Navigation and scripting DSL: Fractal FPath/FScript/ECA (Safran) [David, 2005]
  - Reactions only
- Active database: Triggers, Views, ECA rules
  - Not distributed & Database specific

Dynamic components as 1^{st} class citizen
Dynamic monitoring instrumentation


```
%% Dynamic monitoring architecture
fun {MonitoringPkg SComponents}
   %% Set of nodes hosting the components
   SHosts = {SMap SComponents CGetHost}
in
   functor $
   export Membrane
   define
      C = {CNew nil}

      %% Deploy the monitoring information aggregator
      Aggregator = {Deploy AggregatorPkg}
      {CAddSubComponent C Aggregator}

      %% Deploy a dynamic set of sensors on every host
      SSensors = {ClusteredDeploy SHosts SensorPkg}

      %% Bind all sensors to the aggregator
      SAggregators = {SSingleton Aggregator}
      {ApplyBindingScheme FullInterconnect SSensors SAggregator}

      Membrane = C
   end
end
```

Deployment on a dynamic set of hosts
Dynamic monitoring instrumentation


```
%% Deploy the given component (Package) on each host in the given set of hosts
%% Each component instance is made sub−component of the given Parent component
fun {ClusteredDeploy SHosts Package}
   %% Class for an implicit component set mapped over SHosts
   class ComponentSet from ImplicitSet
      ...
      %% Adding some hosts
      meth addHosts(SElements)
         {FSet.forAll SElements % for every new host
            proc {$ Host}
               % remotely deploy a component instance
               SubComp = {RemoteDeploy Host Package}
               % add the component to the implicit set
               Set,add(SubComp)
            end}
      end
      ...
   end
in
   %% Instantiate the implicit set
   {New ComponentSet init}
end
```

Conclusion

Summary of the problems

Problem

Self-Optimization of Autonomic Systems

- System provisioning optimization and coordination
- Distributed deployment of architectures
- Dynamic architecture instrumentation

Summary of the contributions

Jade self-optimization manager

- Simple threshold-based policy
- Architecture-based coordination

FructOz framework

- Higher Order ADL (Package)
- Synchronization of distributed architecture deployments

LactOz library

- Distributed dynamic computation model
- Dynamic architectures

Perspectives

Self-optimization policies

- Toward self-stabilizing control-loop parameters
- Modeling

FructOz & LactOz

- Transactional architecture manipulation
- (Self-)Optimization of dynamic computations
- Architecture checking (typing)
- Syntactic sugar (package, architectural entities, dynamic variables)

Main results

Code

Jade prototype:	Java code	23 kloc in 150 classes
	Fractal ADL	250 loc in 70 files
	Experimentations	20 nodes cluster
FructOz/LactOz:	Oz code	10 kloc in 90 files
	Experimentations	16 nodes cluster

Publications

- Bouchenak et al., Int. Conf. on Cluster Computing, 2006
- Taton et al., Int. Conf on Dist. Objects and Applications, 2007
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Appendix

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