Automatic Configuration of Component-Based Distributed Systems

Ph.D. Thesis Defense

Fabio Kon

Advisor: Prof. Roy H. Campbell

May 17, 2000

Introduction

- Modern Society requires software developers to
  - produce large quantities of programs
  - write large, complex programs
  - support different OSes
  - support different machine architectures
- Partial solution:
  - Component Technologies
    - Enterprise Java Beans, ActiveX Controls, CORBA Component Model

Problems in Existing Component Technologies

- Lack support for representing dependencies among components
- Difficult to support
  - Automatic Configuration
  - Dynamic Reconfiguration
  - Fault-tolerance
  - Adaptation, etc...

Lack of Proper Dependence Management in Existing Operating Systems

1. Administration / Configuration
   - Junk libraries left on Windows after uninstall
2. System Architecture
   - Different (static) instances of same OS
   - Configuration of Microkernels
3. Fault-tolerance
   - Module failure not handled by others

Our Solution

- Infrastructure for Dependence Management supporting
  - Automatic Configuration
  - Dynamic Reconfiguration
  - Code Distribution
- Help developers to support
  - Fault-Tolerance
  - Consistent Reconfiguration
  - Adaptation

Presentation Overview

1 Introduction

2 Overall Architecture

- 2.1 Automatic Configuration Service
- 2.2 Component Configurators
- 2.3 Reconfiguration Agents

3 Applications

4 Experimental Results

5 Related Work

6 Future Directions and Conclusions

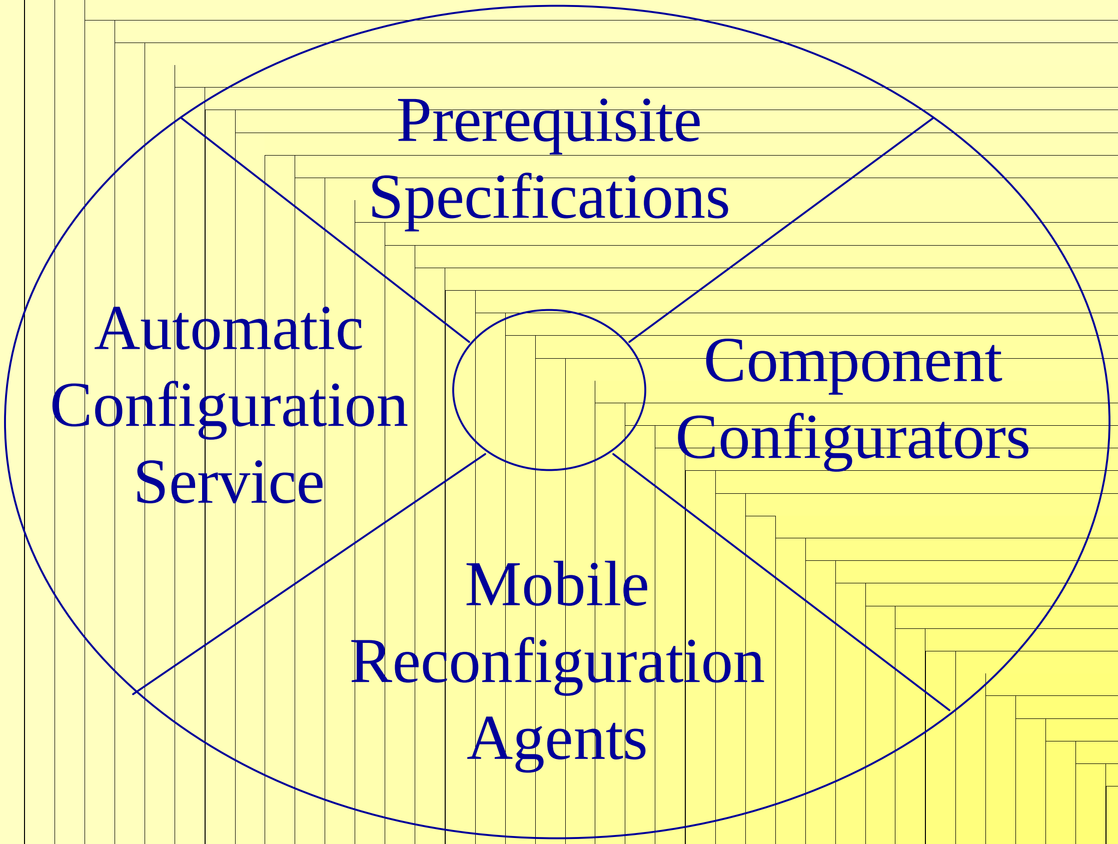
Architecture

Manages two kinds of dependencies:

1. ***Prerequisites*** - requirements for loading a component into the system runtime.

2. ***Dynamic Dependencies*** among running components.

Overall Architecture



Prerequisite Specifications

Automatic Configuration Service

Component Configurators

Mobile Reconfiguration Agents

CORBA services

QoS-Aware Resource Management

1. Automatic Configuration Service

1. Fetches component code and prerequisites from a *Component Repository*.

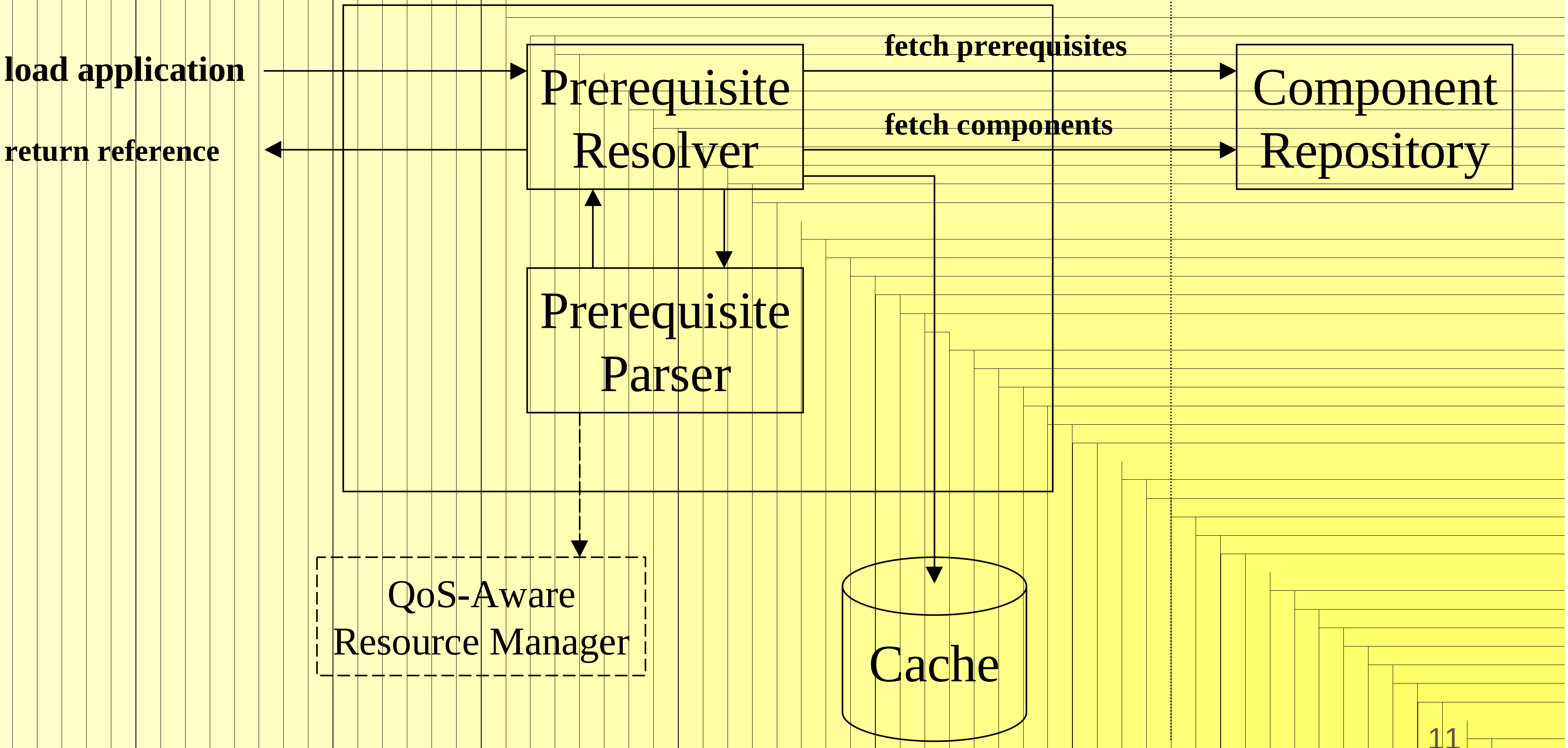
2. Dynamically link component code into the application address-space.

3. Based on the prerequisites, repeats the process for other components.

Prerequisites

- What a component needs to run:
  - nature of hardware resources
  - share of the hardware resources
  - software services (i.e., components) it requires
- Video Client example:
  - PC with Sound card
  - 50% of 300MHz CPU
  - software component with MPEG decoder
  - CORBA Video Service

Automatic Configuration Architectural Framework

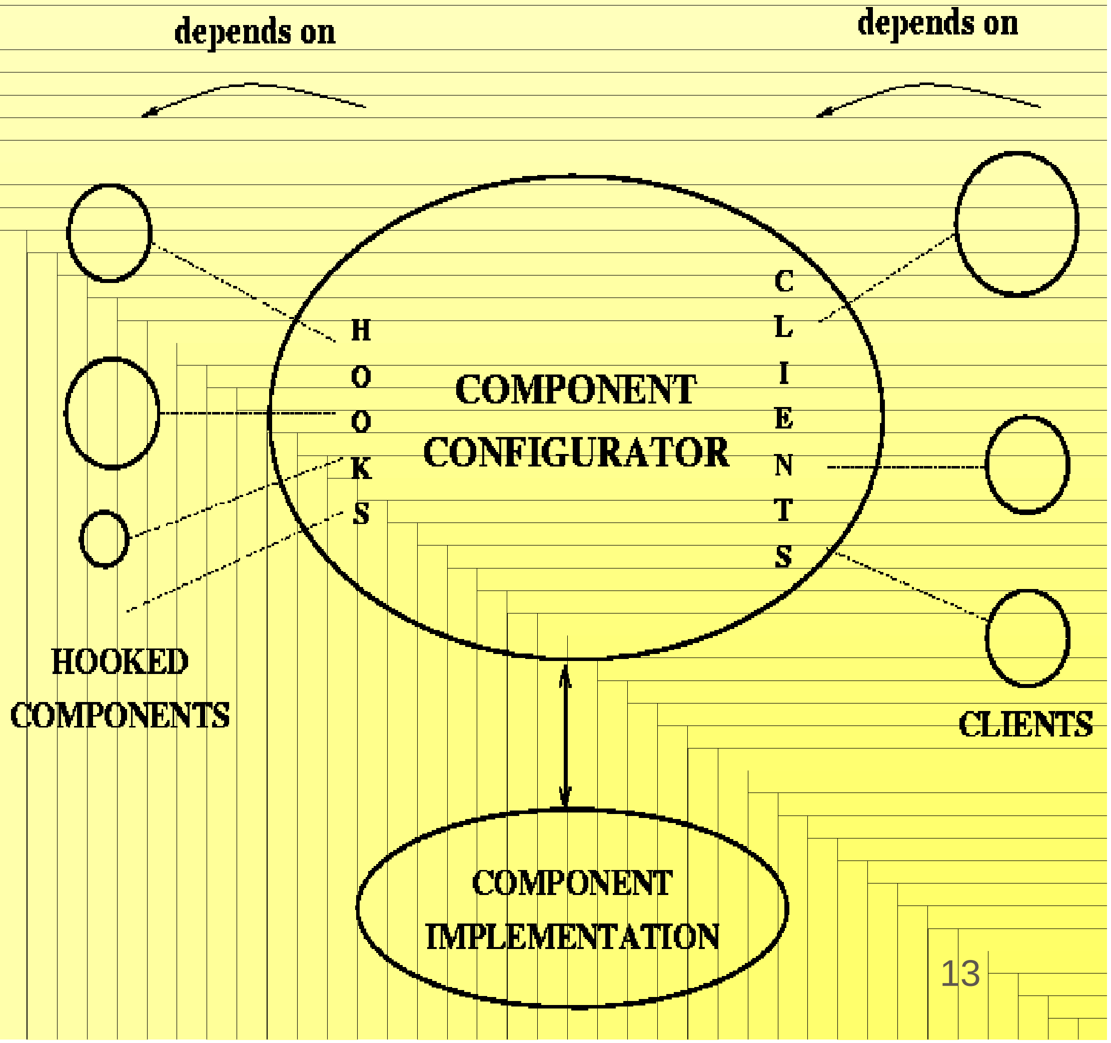


2. Component Configurators

- Reify dynamic inter-component dependencies.
- Created on-the-fly by the Prerequisite Resolver.
- System and application software can inspect and reconfigure the Dependence Graph.

ComponentConfigurator Framework

- Allows browsing, inspection, and reconfiguration
- Can be customized through inheritance
- Clear separation of concerns



ComponentConfigurator Implementation

- Single-process applications: Java and C++
- Distributed applications: CORBA

```
interface ComponentConfigurator {
 void addHook          (in string hookName);
 void deleteHook       (in string hookName);
 void hook             (in string hookName, in ComponentConfigurator cc);
 void unhook           (in string hookName);

 void registerClient          (in ComponentConfigurator client,
                               in string hookNameInClient);
 void unregisterClient        (in ComponentConfigurator client,
                               in string hookNameInClient);
 void eventFromHookedComponent(in ComponentConfigurator hookedComponent,
                               in Event e, in unsigned short timeToLive);
 void eventFromClient         (in ComponentConfigurator client,
                               in Event e, in unsigned short timeToLive);
(...) }
```

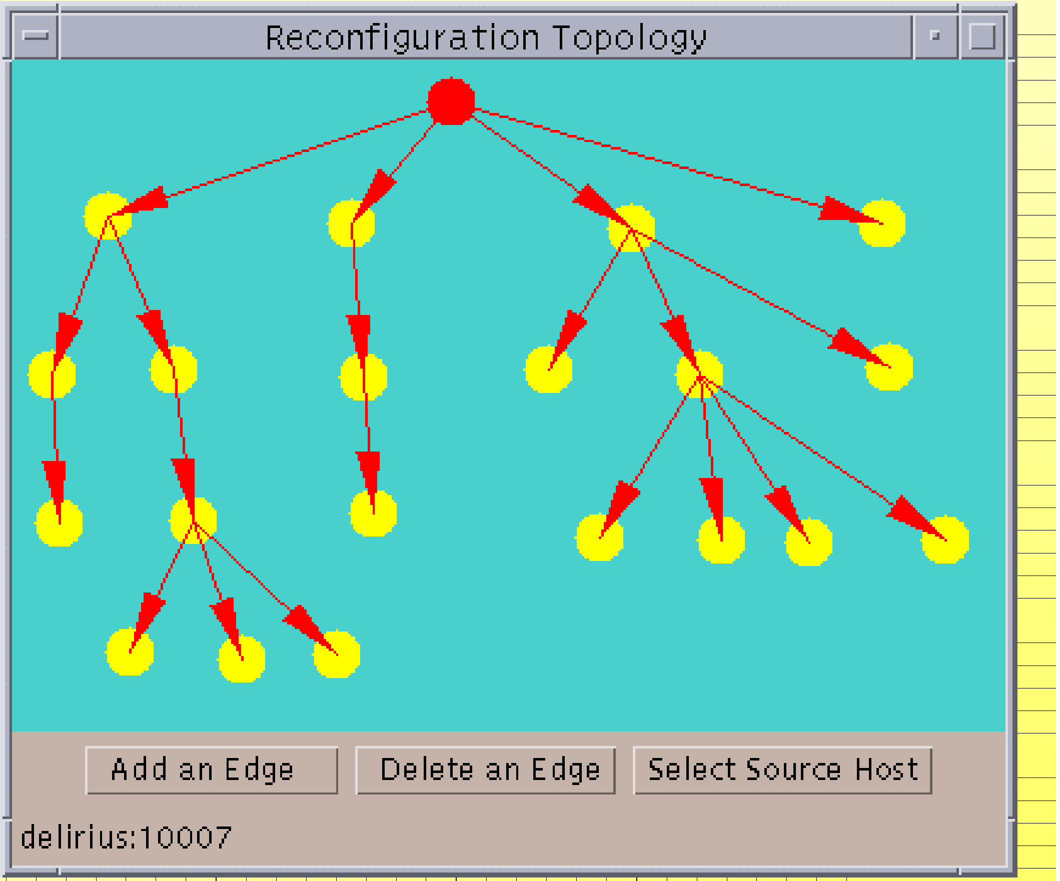
Customizing Component Configurators

- Synchronization: **`LockingConfigurator`**
- Attributes: **`ComponentConfiguratorAttrib`**

- Application-specific customization to support:
  - fault-tolerance
  - consistent reconfiguration
  - adaptation

3. Reconfiguration and Inspection with Mobile Agents

- Suitable for Large-Scale Systems
- Agents may carry
  - graph
  - reconfiguration script
  - state
  - results



Presentation Overview

1 Introduction

2 Overall Architecture

    2.1 Automatic Configuration Service

    2.2 Component Configurators

    2.3 Reconfiguration Agents

3 Applications

4 Experimental Results

5 Related Work

6 Future Directions and Conclusions

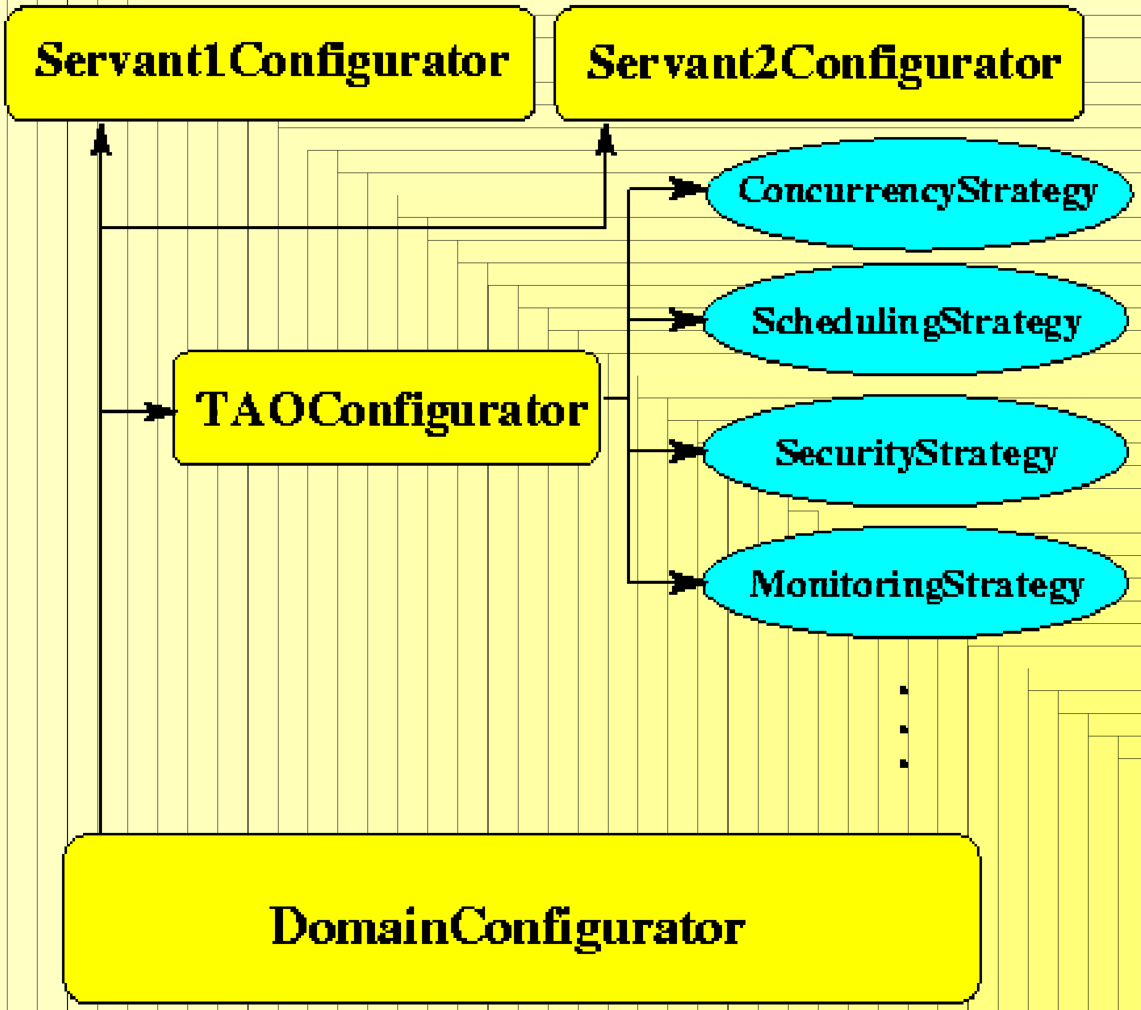
Applications of the Architecture

- *dynamicTAO*
- Multimedia Distribution System
- Developed by other researchers:
  - *LegORB*
  - *$2K^Q$* and QoS-aware VoD service
  - SIDAM: road traffic information system
  - CORBA Persistent Object Service
  - Distributed Chess Game
  - *Gaia OS* for Active Spaces
  - *2KFS*

Application: *dynamicTAO*

- CORBA-compliant Reflective ORB
- Extension of TAO (Washington University)
- Uses Component Configurators to support
  - inspection
  - reconfiguration
- Interaction with the reflective interface can be done
  - using a point-to-point connection
  - using mobile agents

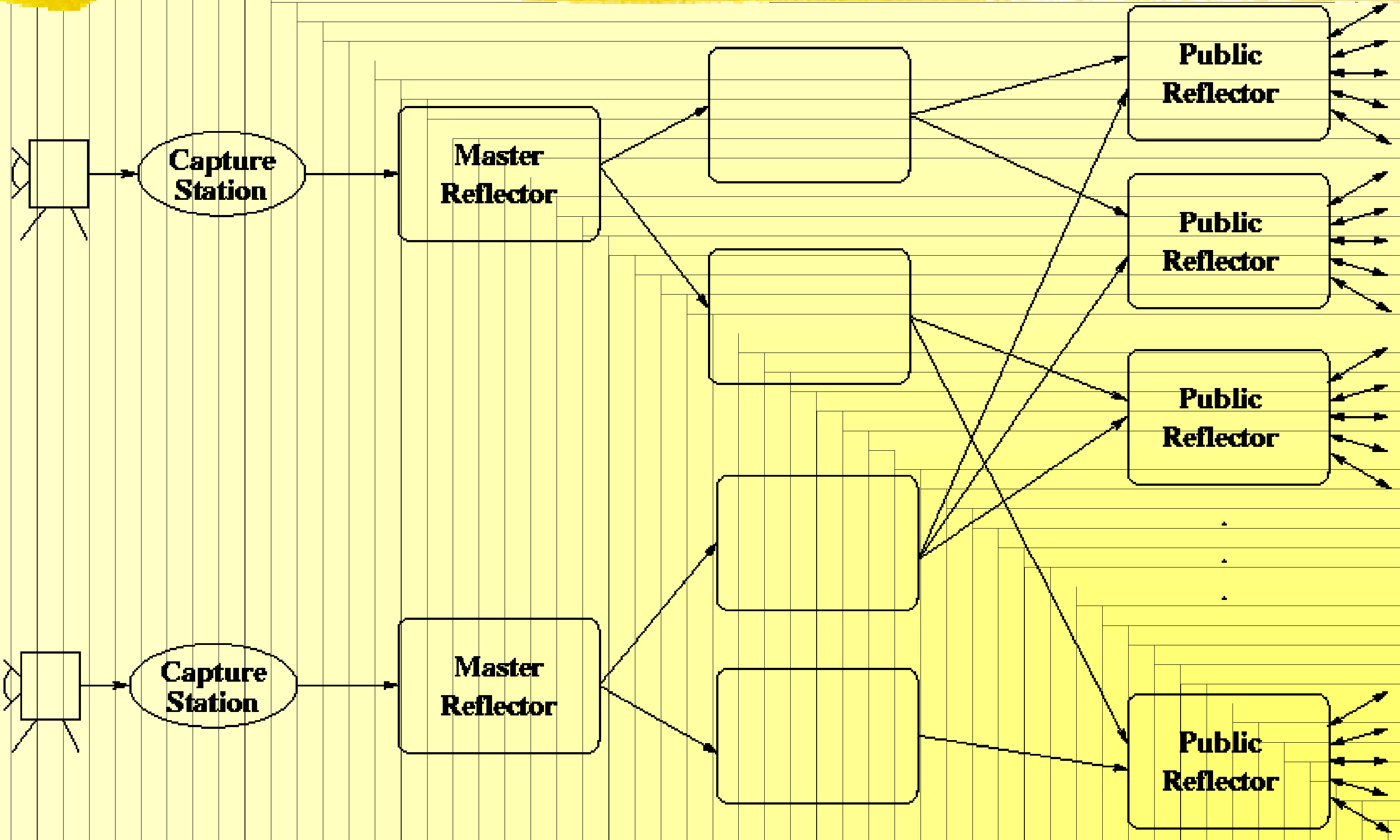
dynamicTAO Structure



Application: Scalable Multimedia Distribution

- **Goal**: stream multimedia to millions of users over the Internet.
- The system can be used with
  - Live Multimedia Streaming
  - Stored Content Streaming
  - Audio/Videoconference
- **Approach**: use a wide-area network of *Reflectors*

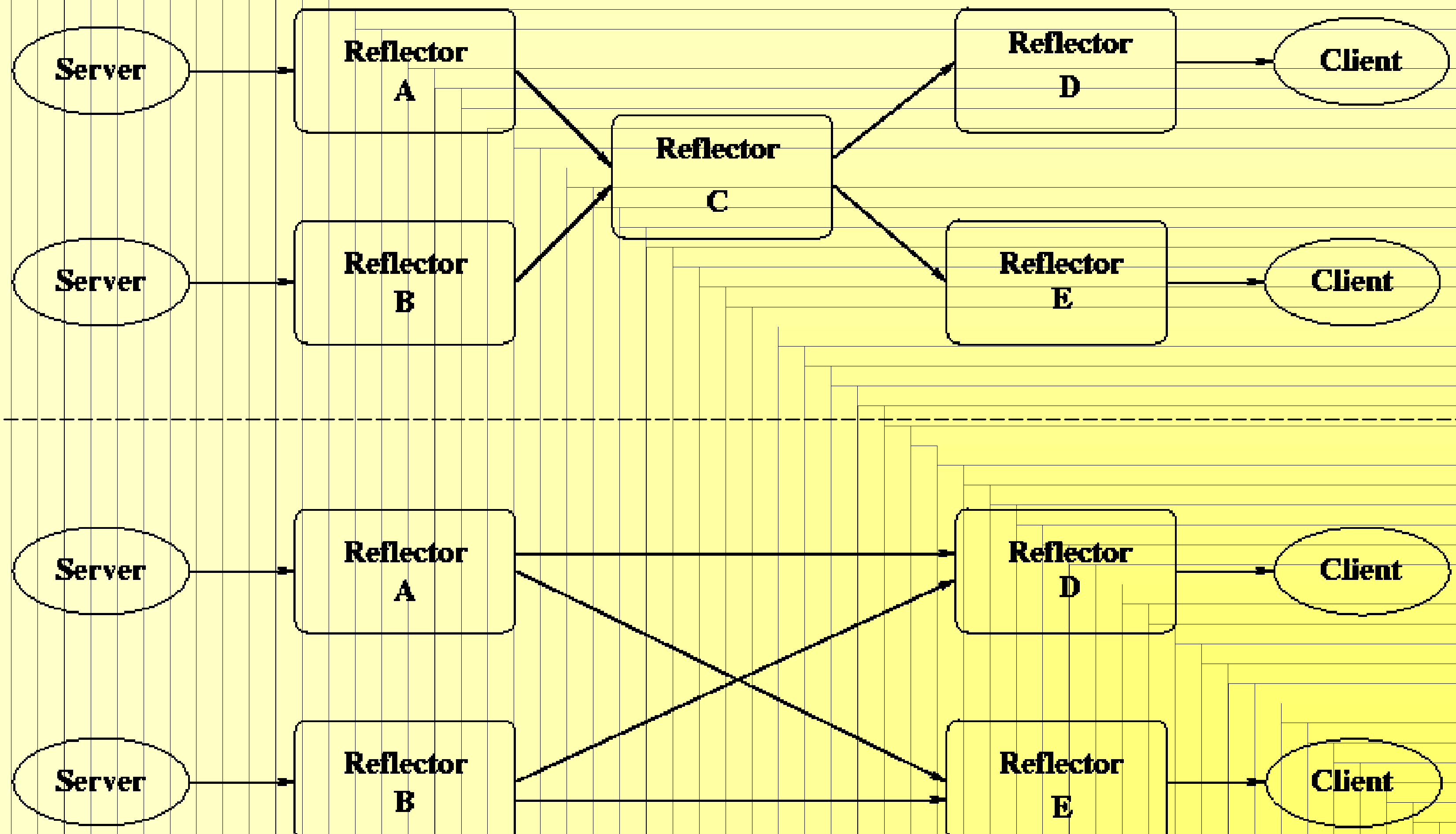
A Reflector Network



Applying the Architecture

- Prerequisites and AutoConfig Service
  - Used to customize the components of each Reflector
  - Reserving memory, CPU, bandwidth (not implemented)
- Component Configurators
  - represent intra- and inter-Reflector dependencies
  - support fault-tolerance

Dynamic Reconfiguration for Fault-Tolerance



Presentation Overview

1 Introduction

2 Overall Architecture

2.1 Automatic Configuration Service

2.2 Component Configurators

2.3 Reconfiguration Agents

3 Applications

4 Experimental Results

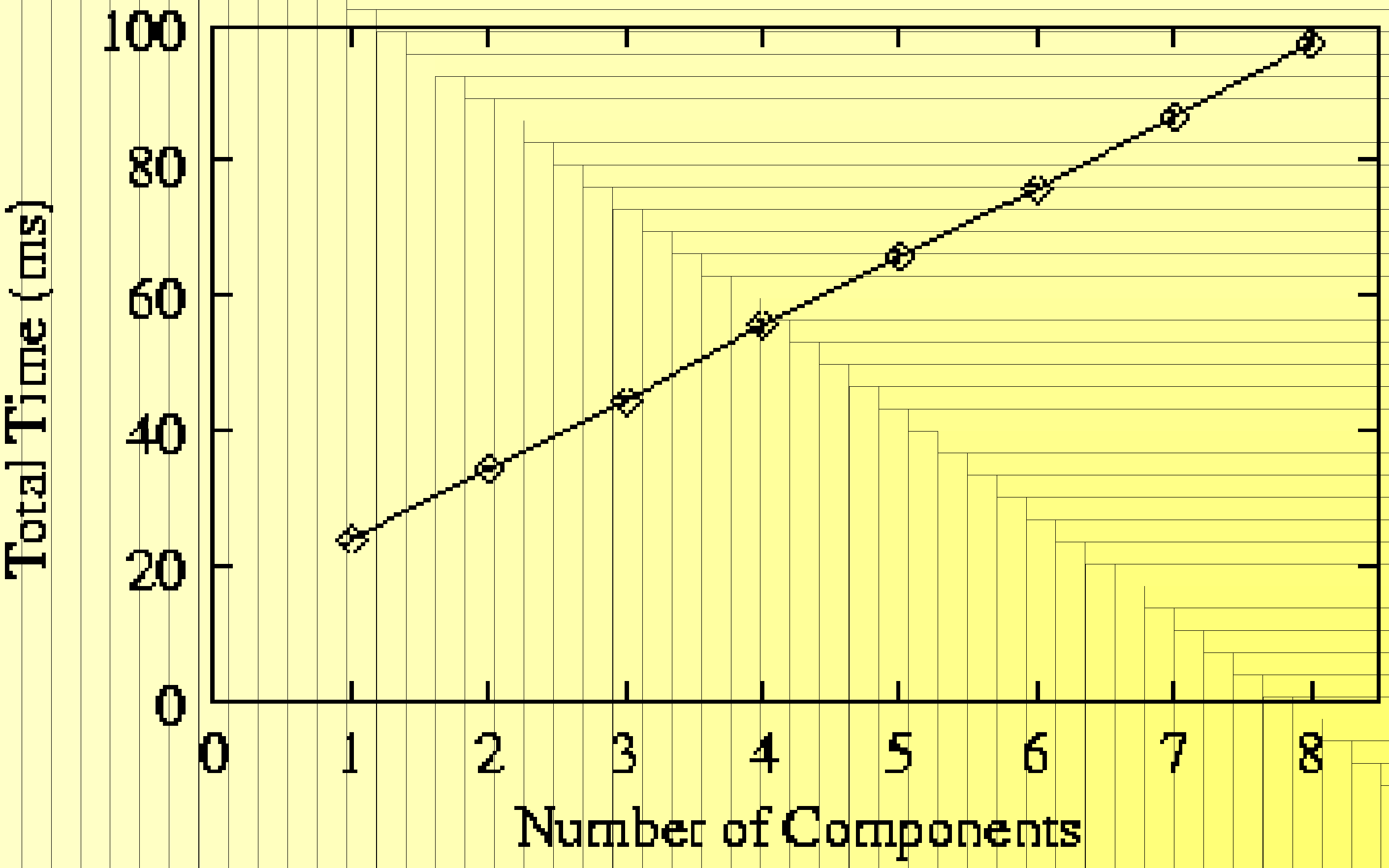
5 Related Work

6 Future Directions and Conclusions

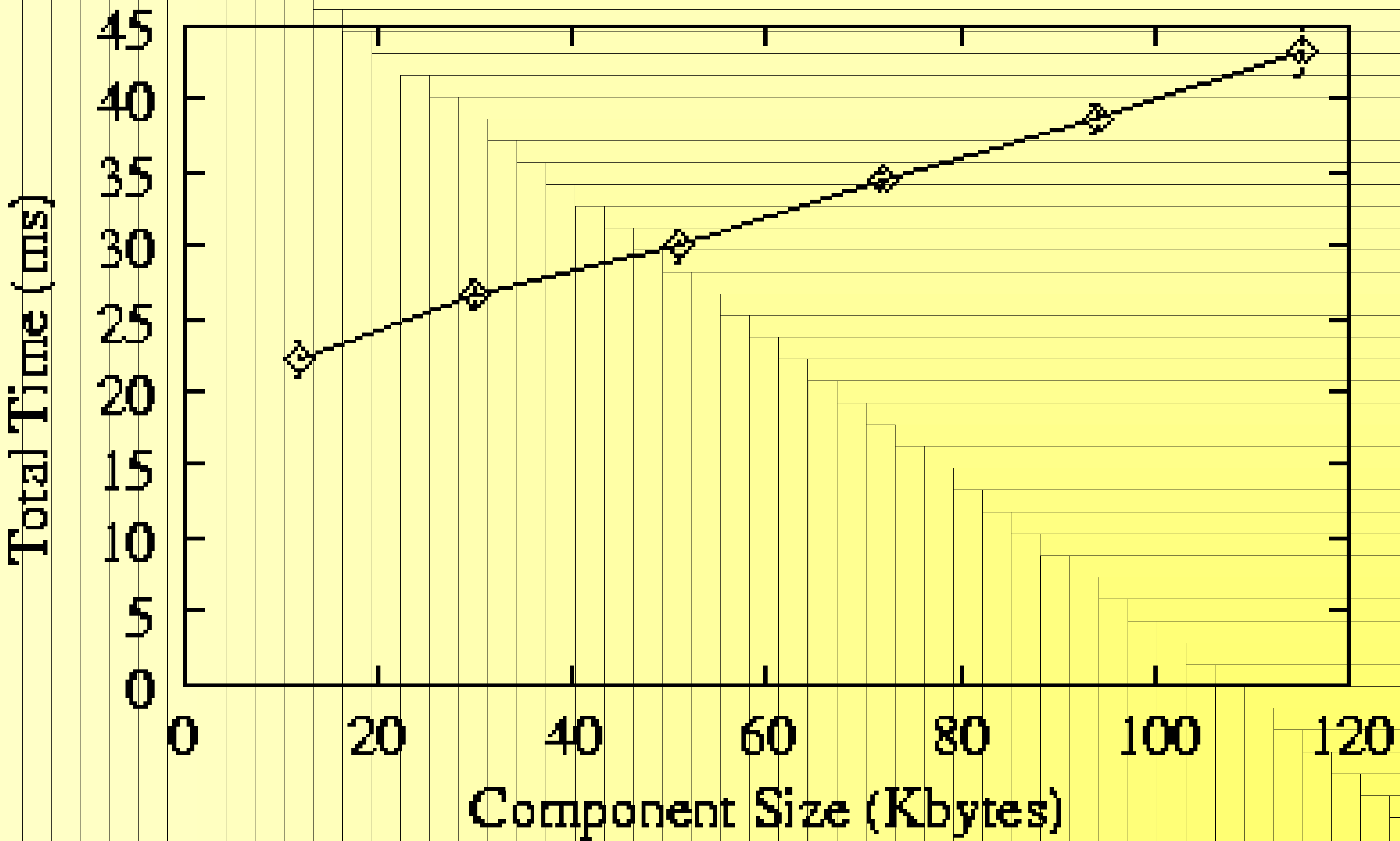
Experimental Results

- Experiments with the three elements of the architecture
- Testbed:
  - 2 Sun Sparc Ultra-60, two 360MHz CPUs
  - 5 Sun Sparc Ultra-5, 333MHz CPU
  - Solaris 7 OS
  - 100Mbps Fast Ethernet
  - third experiment: Internet

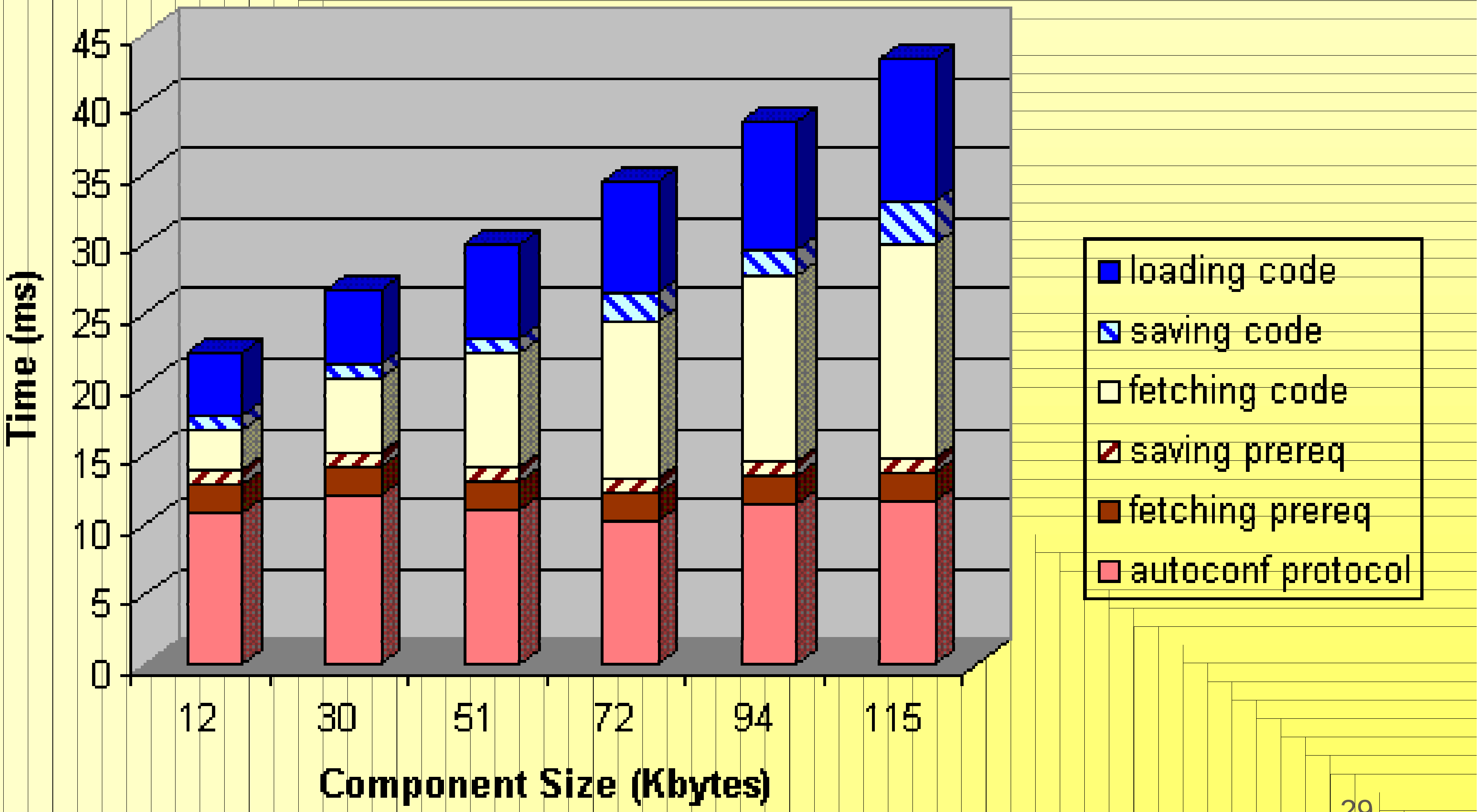
1. AutoConfig Service Loading Several Components



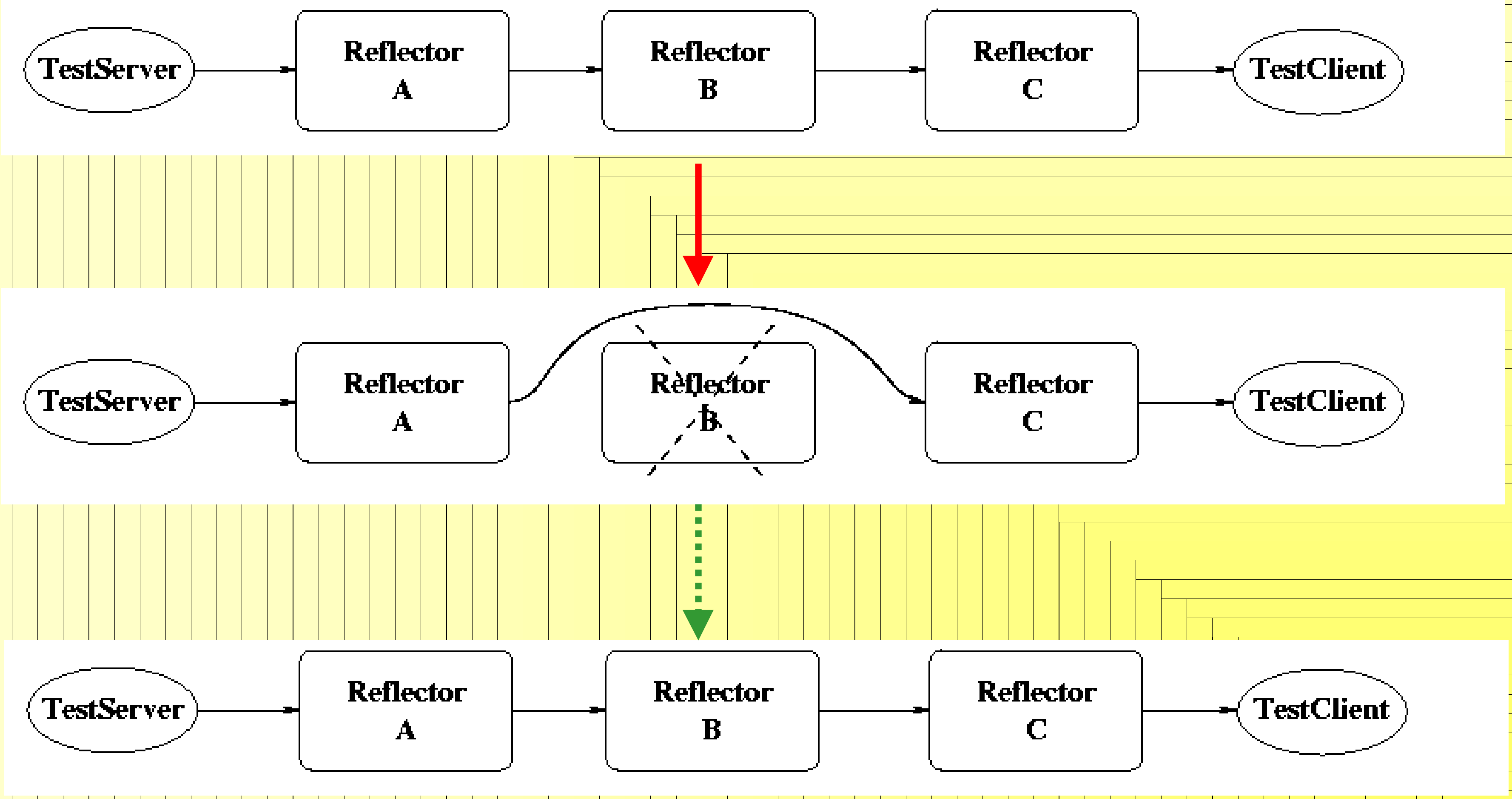
AutoConfig Service
Loading Components of Different Sizes



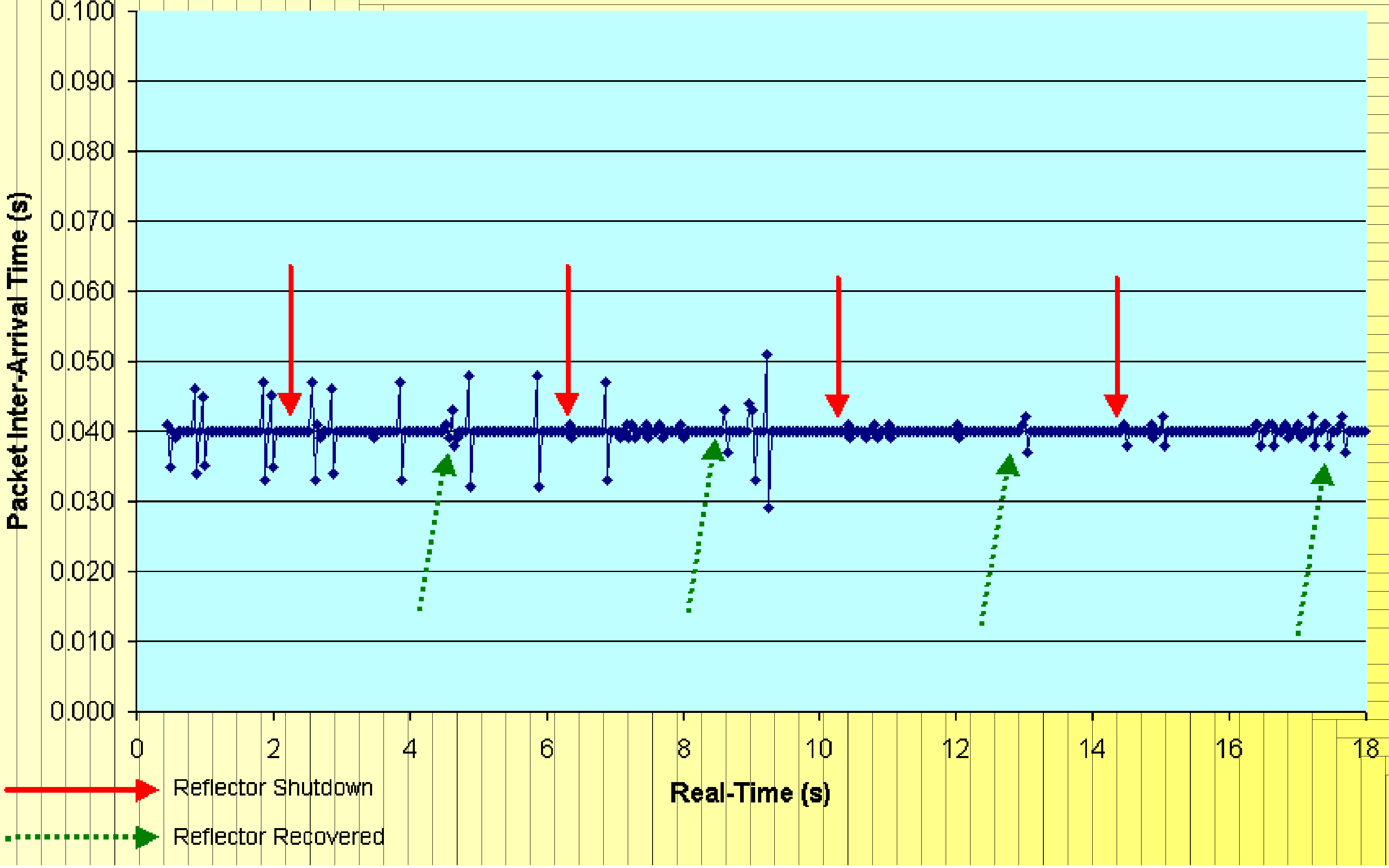
AutoConfig Service
Loading Components of Different Sizes



2. Dynamic Reconfiguration Using Component Configurators



Impact of Dynamic Reconfiguration on QoS

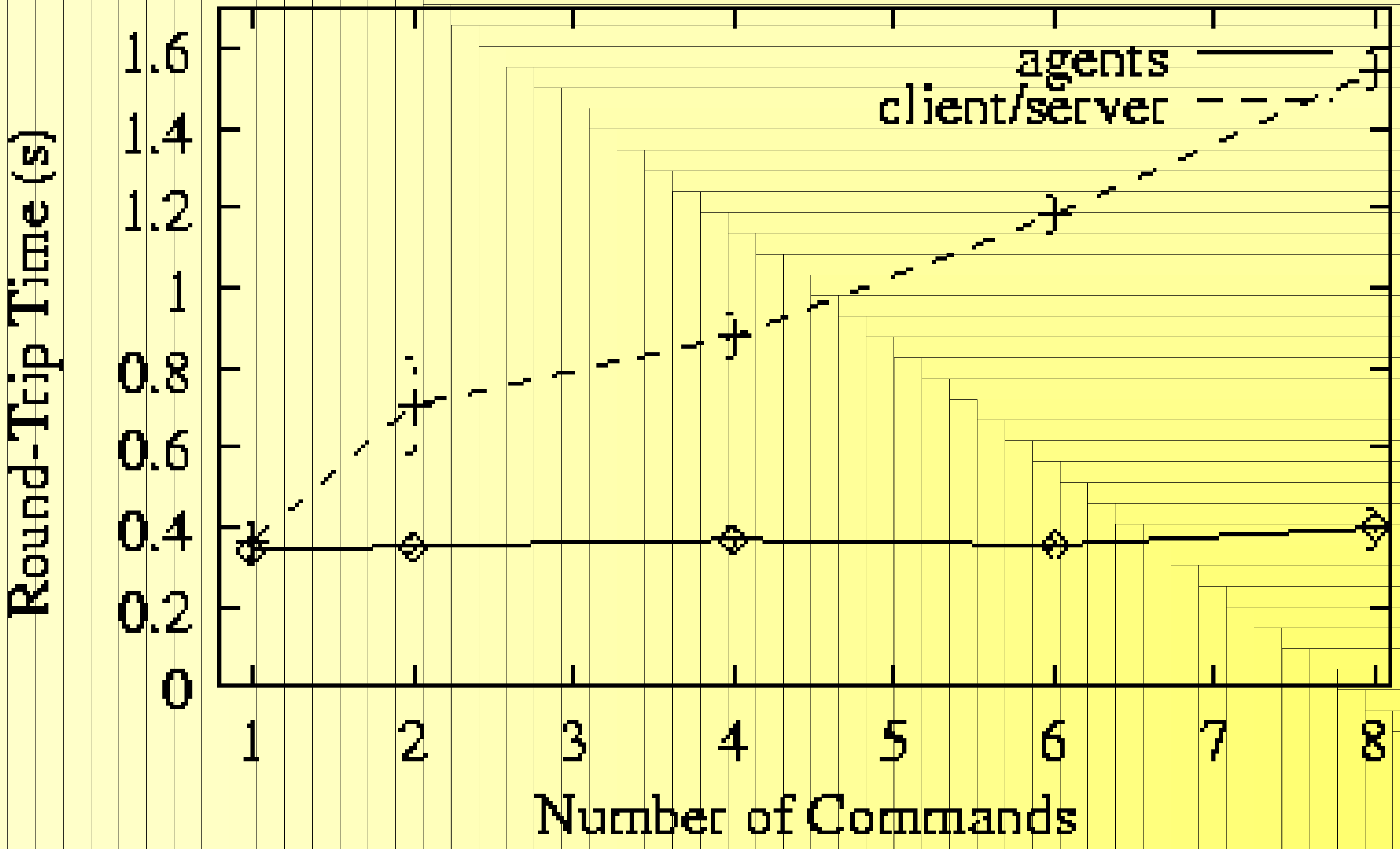


3. Mobile Agents for Reconfiguration and Inspection

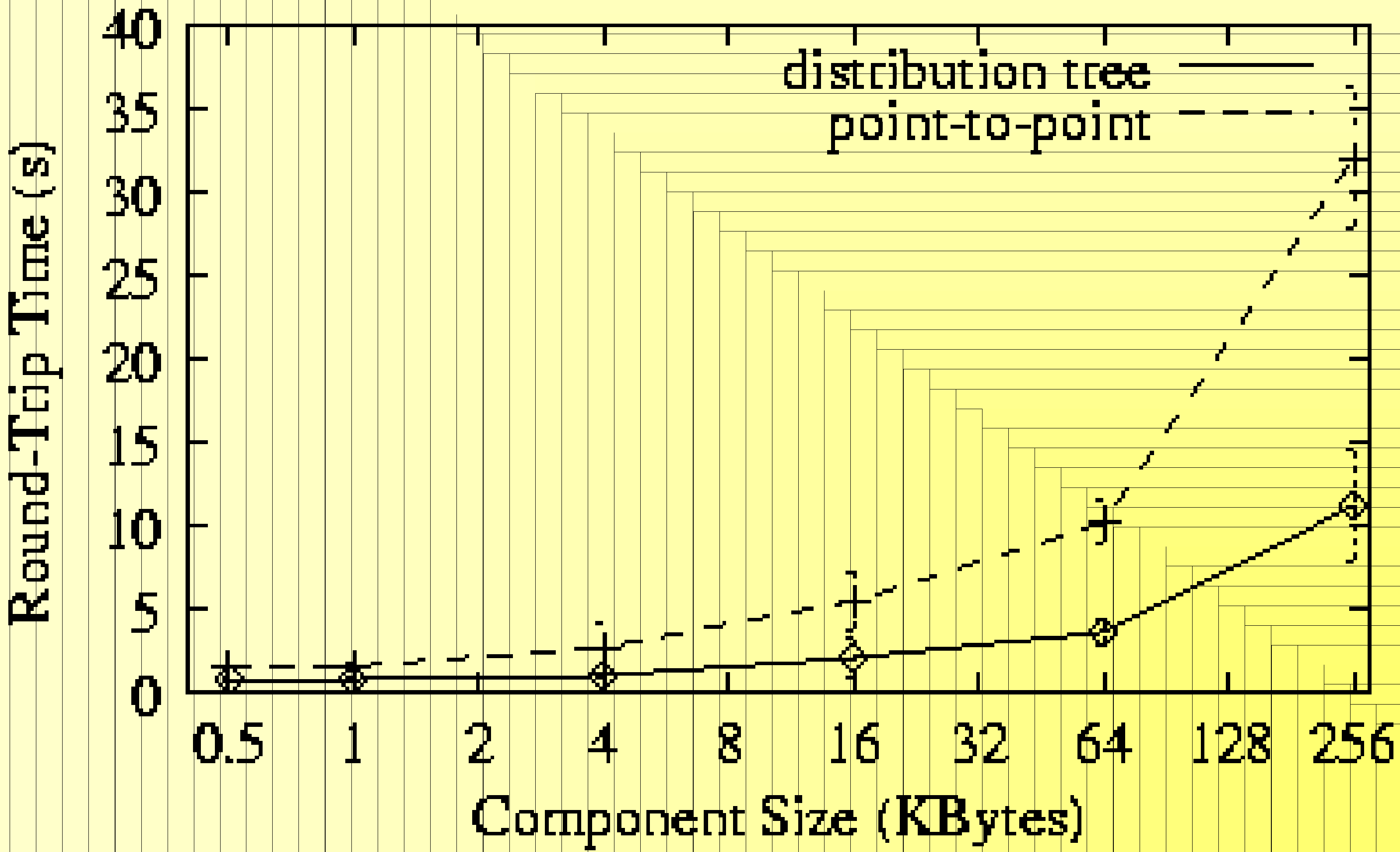
- Testbed:
  - Three Sparc Ultras, Solaris 7 @cs.uiuc.edu
  - Three 333MHz PCs, Linux RH6.1 @escet.urjc.es
  - Three 300MHz PCs, Linux RH6.1 @ic.unicamp.br

  - 100Mbps Fast Ethernet (intra-domain)
  - Public Internet (inter-domain)

Mobile Agents vs. Conventional Client/Server



Uploading a New Component to 9 Nodes



Conclusion of the Experiments

- The three elements of our architecture
  - can be implemented efficiently
  - can improve the performance of existing systems

Related Work

- Prerequisites:
  - Job Control Languages [IBM 65]
  - SOS operating system [Shapiro 94]
  - QoS description languages [Frølund 99]

- Automatic Configuration:
  - Customizable Operating Systems
  - Jini

Related Work

- Component Configurators
  - Reflection
  - Software Architectures (ADLs)
- Dynamic Reconfiguration based on
  - Software Buses [Hofmeister 93]
  - Connectors [Taylor 98]
  - Workflow applications [Wheater 98]

Original Contributions

1. Dependence Management using Component Configurators [USENIX COOTS'99, IEEE Concurrency, 2000]

2. Automatic Configuration Service [IEEE HPDC'2000]

3. Mobile Reconfiguration Agents [IEEE ASAMA'2000]

4. *dynamicTAO* [IFIP/ACM Middleware'2000]

5. Multimedia Distribution System [ICAST'98]

Future Work

- Libraries of Component Configurators
- Dynamic Adaptability
- Integration with ADLs

- Security
- Reconfiguration as atomic transactions
- Automating Prerequisite generation and verification

Summary

- This thesis has
  1. presented an architectural framework for dependence management in component-based distributed systems,
  2. described a concrete implementation of the architecture,
  3. presented two applications that utilize the architecture, and
  4. described experiments and analyzed the performance of the implementation.

Conclusions

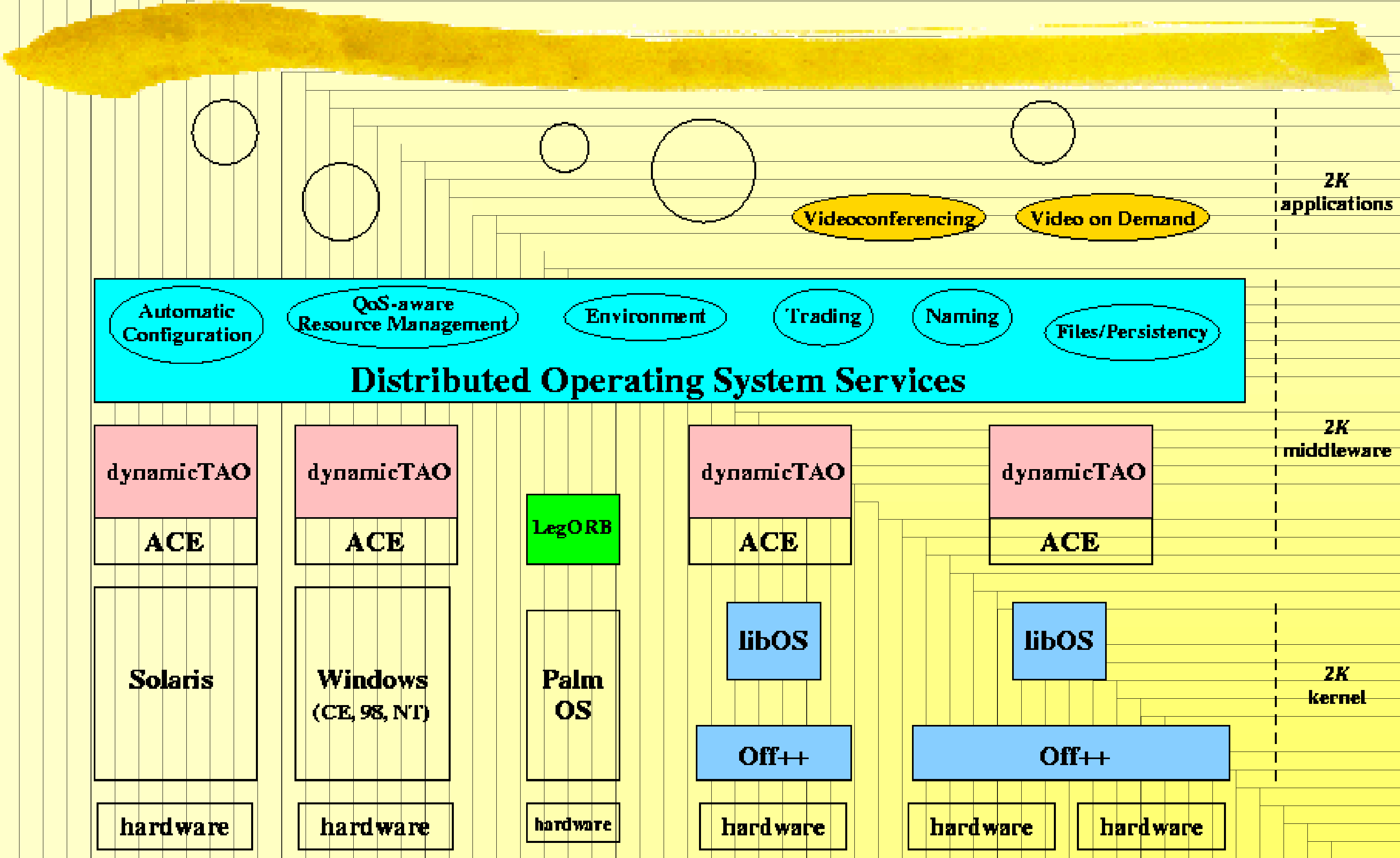
- As computing devices become pervasive in our society, we will encounter
  - highly dynamic environments
  - complex dependencies
  - potentially difficult management

- This thesis presented an integrated architecture that addresses these problems in a clean and efficient way.

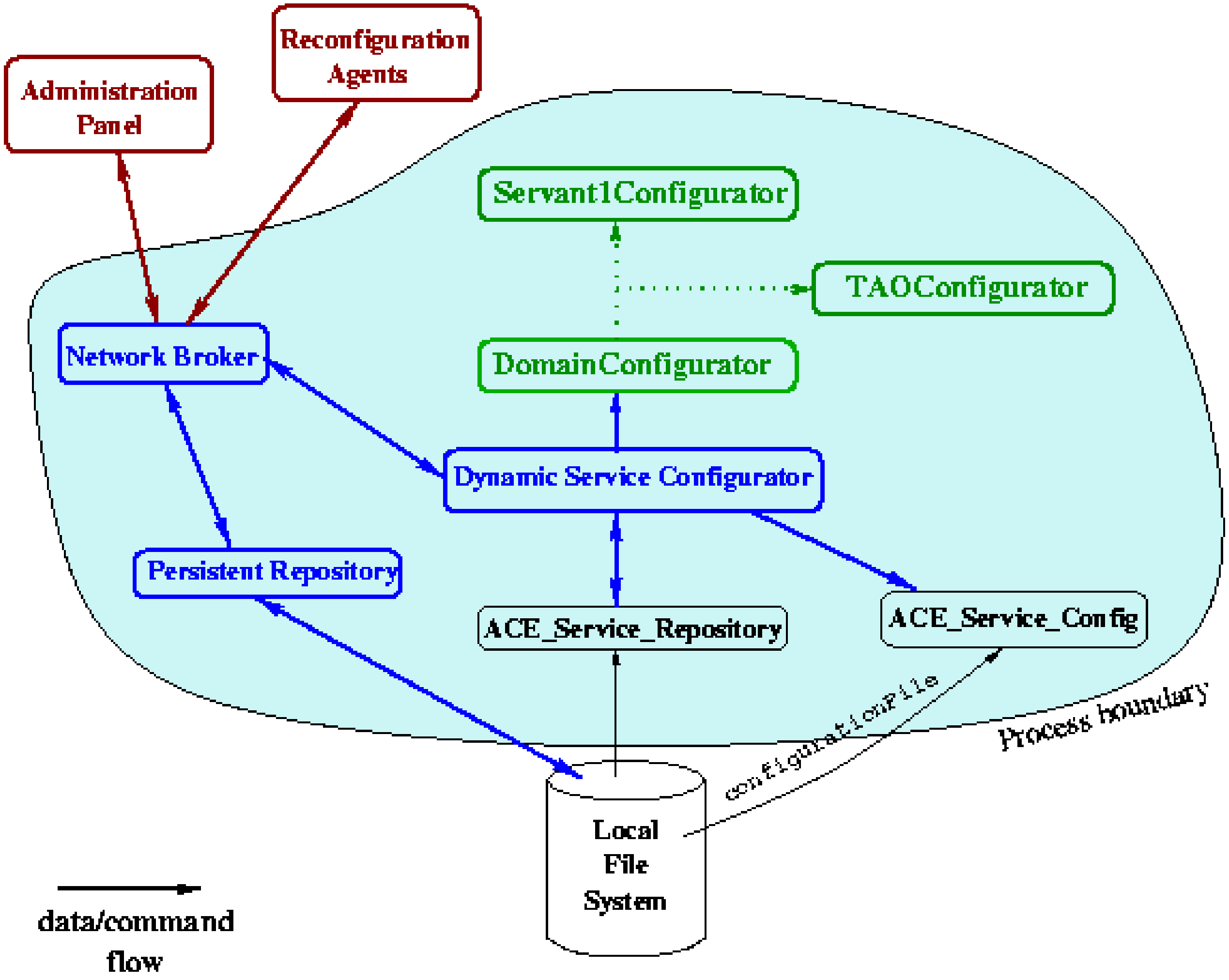
Updating the JVM

```
int WebBrowserConfigurator::eventOnHookedComponent
                (ComponentConfigurator *cc, Event e)
{
 if (cc == JVMConfigurator)
  {
   if (e == REPLACED)
    try {
     FrozenObjs fo = currentJVM->freezeAllObjs ();
     currentJVM = JVMConfigurator->implementation ();
     currentJVM->meltObjects (fo);
    }
    catch (Exception exp)
      throw new ReconfigurationFailed(exp);
  }
 else ...
}
```

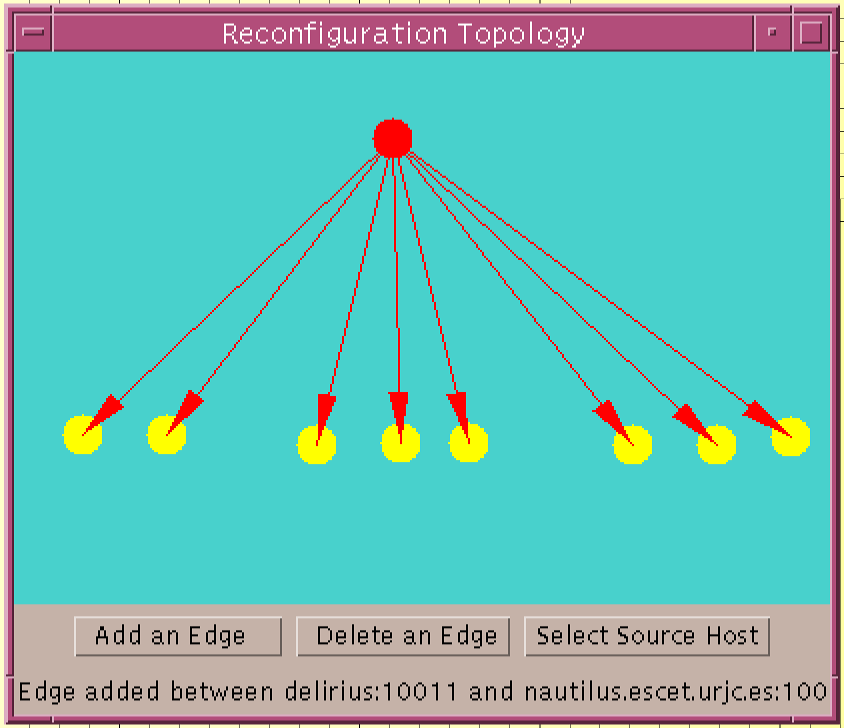
The *2K* Architecture



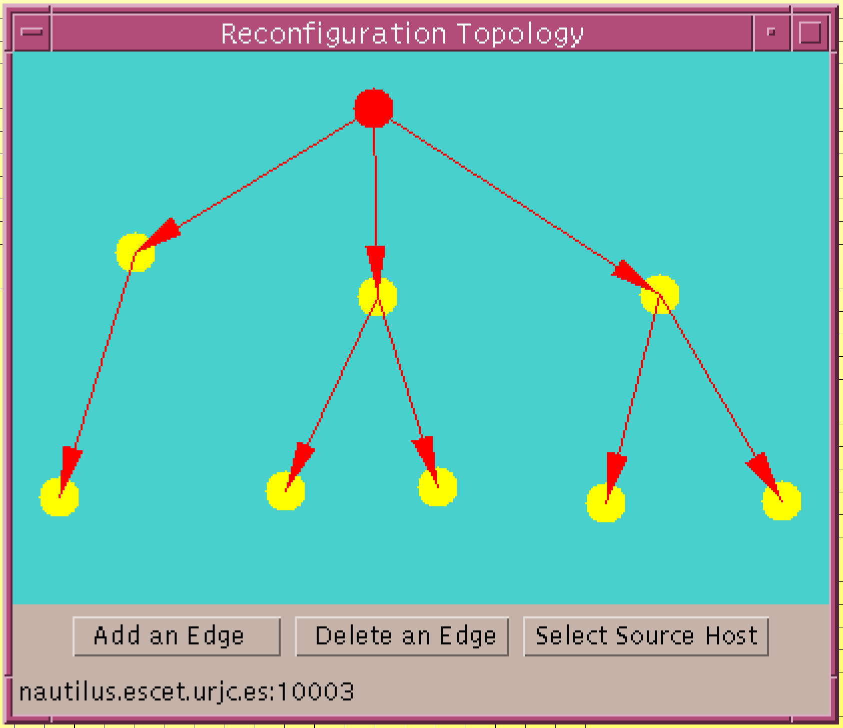
dynamicTAO Architecture



Distribution Tree vs. Point-to-Point

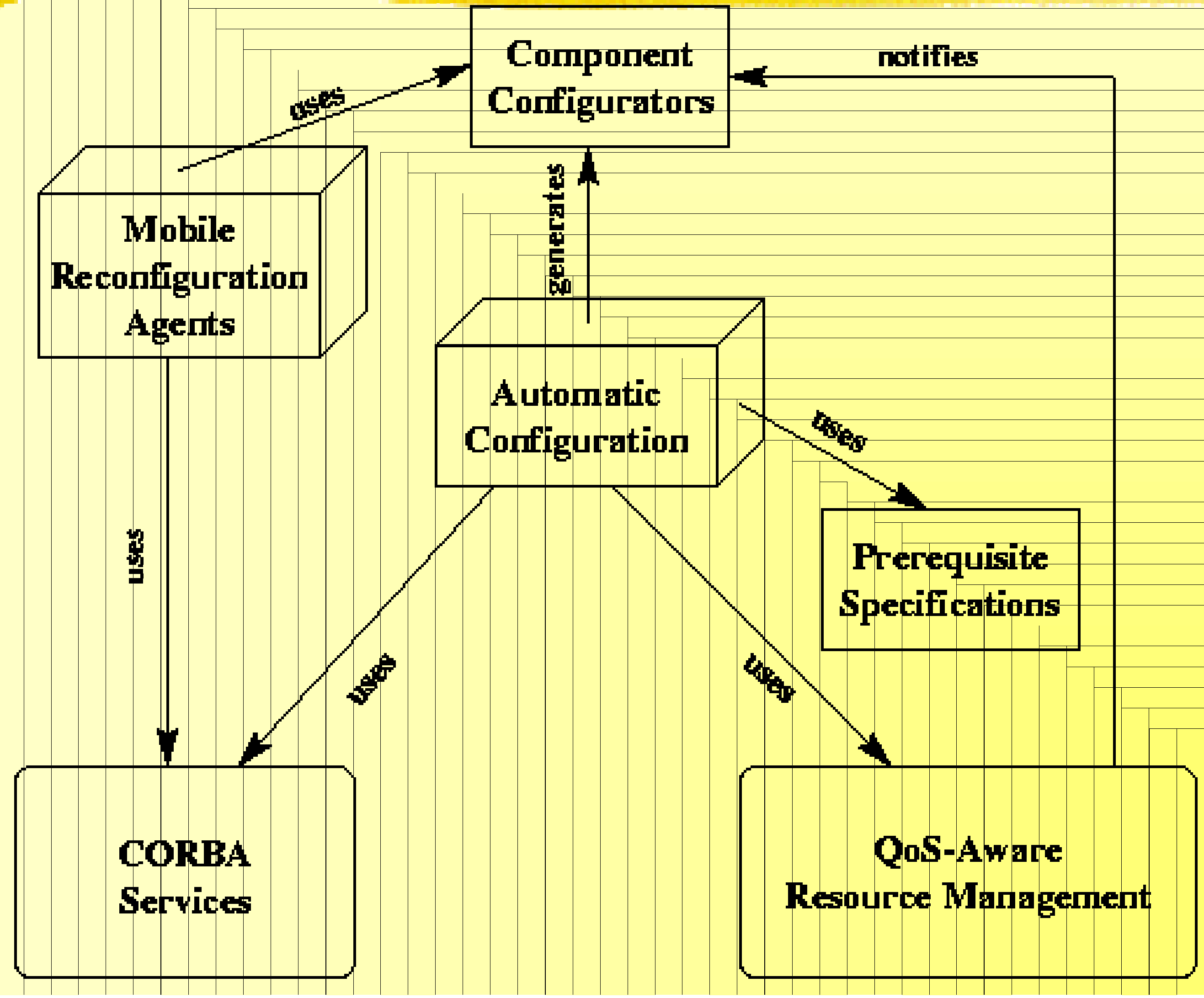


Edge added between delirius:10011 and nautilus.escet.urjc.es:100



nautilus.escet.urjc.es:10003

Overall Architecture (relationships)

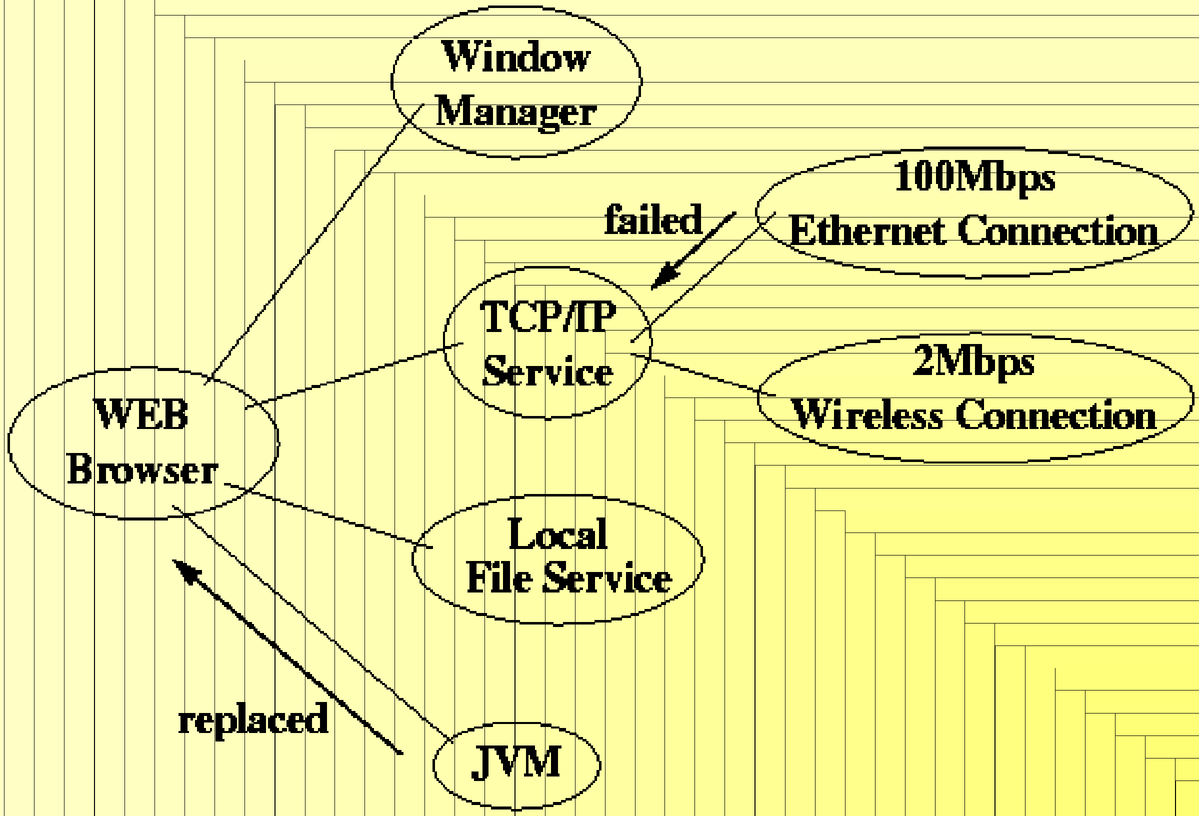


Simple Prerequisite Description Format (SPDF)

```
# Web Browser application
:hardware requirements
 machine_type    SPARC
 os_name         Solaris
 os_version      2.7
 min_ram         5MB
 optimal_ram     40MB
 cpu_speed       >300MHz
 cpu_share       10%

 :software requirements
 FileSystem      CR:/sys/storage/DFS1.0 (optional)
 TCPNetworking   CR:/sys/networking/BSD-sockets
 WindowManager   CR:/sys/WinManagers/simpleWin
 JVM             CR:/interp/Java/jvm1.2 (optional)
```

Application-Specific Customization: Web Browser Example



A WEB Browser ComponentConfigurator and its relations to system ComponentConfigurators

2. Dynamic Reconfiguration Using Component Configurators

- Events triggering reconfiguration:
  1. Reflector shutdown, kill, or **`Ctrl-C`**
  2. Errors leading to Seg. Fault or Bus Error
  3. Reconfiguration message sent by sysadmin
  4. Sudden machine crash or network disconnection
- 1, 2, and 3 can use the dependency info
- Our experiments use the **`Ctrl-C`** option