Object-Oriented Middleware for Distributed Systems

Distributed Systems
Sistemi Distribuiti

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Outline

1. Middleware Overview

2. Object-Oriented Middleware

3. CORBA & OSGi

These Slides. . .

. . . are derived from a Presentation by Giovanni Rimassa, which we warmly thank

Slides were made kindly available by the author

- Every problem or mistake contained in these slides, however, should be attributed to the sole responsibility of the teacher of this course

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2. Object-Oriented Middleware
3. CORBA & OSGi

What is Middleware?

Traditional definition

- What is middleware?
  - The word suggests something belonging to the middle
  - But middle between what?
- The traditional middleware definition
  - The middleware lies in the middle between the Operating System and the applications
- The traditional definition stresses *vertical* layers
  - Applications on top of middleware on top of the OS
  - Middleware-to-application interfaces (top interfaces)
  - Middleware-to-OS interfaces (bottom interfaces)

Why Middleware?

Behind middleware

- Problems of today
  - Software development is *hard*
  - Experienced designers are *rare* (and *costly*)
  - Applications become more and more complex
- What can middleware help with?
  - Middleware is developed once for many applications
  - Higher quality designers can be afforded
  - Middleware can provide *services* to applications
  - Middleware abstracts away from the specific OS

Middleware and Models I

Middlewares

- A key feature of middleware is *interoperability*
  - Applications using the same middleware can interoperate
  - This is true of any common platform (e.g. OS file system)
- But, many incompatible middleware systems exist
  - Applications on middleware *A* can work together
  - Applications on middleware *B* can work together, too
  - But, *A*-applications and *B*-applications cannot!
- The *Enterprise Application Integration* (EAI) task
  - Emphasis on *horizontal* communication
  - *Application-to-application* and *middleware-to-middleware*

Middleware and Models II

Conceptual integrity

- Software development does not happen *in vacuum*
  - Almost any software project must cope with past systems
  - There is never time nor resources to start *from scratch*
  - Legacy systems were built with their own approaches
- System integration is the only way out
  - Take what is already there and add features to it
  - Try to add without modifying existing subsystem
- First casualty: Conceptual Integrity
  - The property of a system of being understandable and explainable through a coherent, limited set of concepts

Middleware and Models III

Models from middleware to applications

- Real systems are heterogeneous
  - Piecemeal growth is a *very troublesome* path for software evolution
  - Still, it is very popular – being asymptotically the most cost effective when development time goes to zero
- Middleware technology is an *integration* technology
  - Adopting a given middleware should ease *both* new application development *and* legacy integration
  - To achieve integration while limiting conceptual drift, middleware tries to cast a model on heterogeneous applications.

Middleware and Models IV

Integration middleware

- Before: you have a total mess
  - A lot of systems, using different technologies
  - Ad-hoc interactions, irregular structure
  - Each piece must be described in its own reference frame
- Then: the Integration Middleware (IM) comes
  - A new, shiny model is supported by the IM
  - Existing systems are re-cast under the Model
  - New model-compliant software is developed
- After: you have the same total mess
  - But, no, now they are CORBA objects, or TuCSoN agents

Middleware Technologies

Abstract vs. concrete middleware

- Abstract middleware: a common *model*
- Concrete middleware: a common *infrastructure*
- Example: Distributed Objects
  - Abstractly, any middleware modeling distributed systems as a collection of network reachable objects has the same model: OMG CORBA, Java RMI, MS DCOM, OSGI Architecture. . .
    - Actually, even at the abstract level there are differences. . .
  - Concrete implementations, instead, aim at actual interoperability, so they must handle much finer details
    - Until CORBA 2.0, two CORBA implementations from different vendors were not interoperable
    - OSGI easily provides you with specifications—technology not so easy to find

Middleware Standards

The role of standards

- Dealing with infrastructure, a key-issue is the so-called *network effect*
  - The value of a technology grows with the number of its adopters
- Standardisation efforts become critical to build momentum around an infrastructure technology
  - Large standard consortia are built, which gather several industries together (OMG, W3C, FIPA, OSGi)
  - Big industry players try to push their technology as de facto standards, or set up more open processes for them (Microsoft, IBM, Sun)

Middleware Discussion Template

How to (re)present a middleware

- Presentation and analysis of the model underlying the middleware
  - What do they want your software to look like?
- Presentation and analysis of the infrastructure created by widespread use of the middleware
  - If they conquer the world, what kind of world will it be?
- Discussion of implementation issues at the platform and application level
  - What kind of code must I write to use this platform?
  - What kind of code must I write to build my own platform?

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Distributed Objects

From OO to Distributed OO

- Distributed systems need quality software, and they are a difficult system domain
- OOP is a current software best practice
- Questions are
  - Can we apply OOP to Distributed Systems programming?
  - What changes and what stays the same?
- Distributed Objects apply the OO paradigm to Distributed Systems
  - Examples: CORBA, DCOM, Java RMI, JINI, EJB, OSGi

Core of OOP I

What is the fundamental concept of OOP?

- From the very name of object-oriented programming, could it be

  The **Object**

  ?
- Definitely not—and *you should know this*!
- The fundamental concept of object-oriented programming is

  The **Class**

  !

Core of OOP II

Class: A definition

- A class is an abstract data type, with an associated module that implements it
- Writing this as a conceptual equation *à la* Wirth,

$$\text{Type} + \text{Module} = \text{Class}$$

Modules *vs.* Types

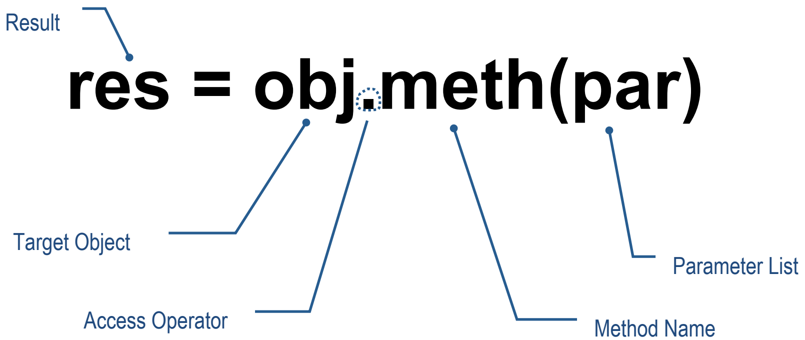
Modules & Types

- Modules and types look very different
    - Modules give structure to the implementation
    - Types specifies how each part can be used
- But they share the interface concept
    - In modules, the interface selects the *public* part
    - In types, the interface describes the allowed *operations* as well as their *properties*
- As a result, the interface is at the very core of the notion of class

OOP Mechanism

Method Call

The fundamental OOP computation mechanism



Result

```
res = obj.meth(par)
```

Target Object

Access Operator

Method Name

Parameter List

OOP Extensibility

Subclassing

Subclassing is the main OOP extension mechanism, and it is affected by the dual nature of classes

- Type + Module = Class
- Subtyping + Inheritance = Subclassing

Subtyping — a partial order on types

- A valid operation on a type is also valid on a subtype
- Liskov Substitutability Principle: If S is a subtype of T, then replacing objects of type T with objects of type S does not alter the properties of a program

Inheritance — a partial order on modules

- A module grants special access to its sub-modules
- Open/Closed Principle: An OO language must allow the creation of modules *closed* for use but *open* for extension

Distributing the Objects

How to?

Q How can we extend OOP to a distributed system, preserving all its desirable properties?

A Just pretend the system is not distributed, and then do business as usual!

- This is called *transparency*
  - As crazy as it may seem, it works!
  - Well, up to a point at least, but generally enough for a lot of applications
- Problems arise from failure management
  - In reliable and fast networks, things run smooth. . .
  - Whenever a failure comes from what we abstracted away – e.g., a network failure –, we are just plain dead

Core of Distributed OOP

What is the fundamental concept of Distributed OOP?

- Could it be

  The Object

  or, again,

  The Class

  ?
- Clearly not
- The fundamental concept of distributed OOP is

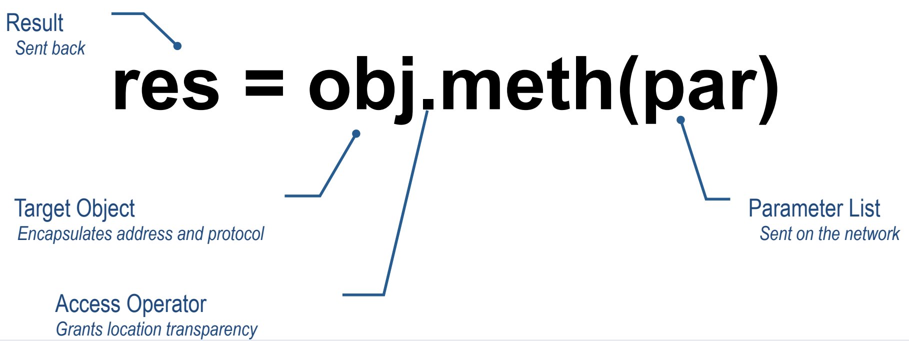
  The Remote Interface

  !

Distributed OOP Mechanism

Remote Method Call

The fundamental Distributed OOP computation mechanism



Result
Sent back

res = obj.meth(par)

Target Object
Encapsulates address and protocol

Parameter List
Sent on the network

Access Operator
Grants location transparency

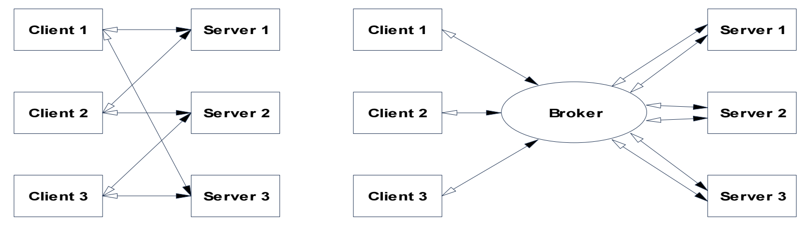
Distributed OOP: Communication Model

The Distributed Objects communication model. . .

- . . . is *implicit*
  - Transmission is implicit, everything happens through stubs
  - The stub turns an ordinary call into an Inter-Process Communication (IPC) mechanism
  - As a result, both local and remote calls are handled homogeneously—*location transparency*
- . . . is *object-oriented*
  - Only *objects* exist, invoking operations on each other
  - Interaction is client/server with respect to the individual call—micro C/S, not necessarily macro C/S
  - Each call is attached to a specific target object: the result can depend on the target object state
  - Callers refer to objects through an object reference

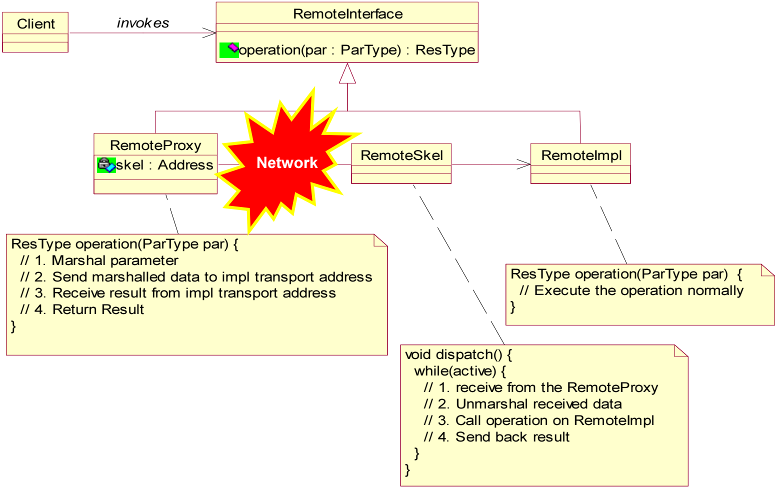
Broker Architecture

Broker architectural pattern [Buschmann et al., 1996]



- Stock market metaphor
- Publish/subscribe scheme
- Extensibility, portability, interoperability
- A broker reduces communication channels from $N_c x N_s$ to $N_c + N_s$

Proxy and Impl, Stub and Skeleton



```
ResType operation(ParType par) {
  // 1. Marshal parameter
  // 2. Send marshalled data to impl transport address
  // 3. Receive result from impl transport address
  // 4. Return Result
}
```

```
ResType operation(ParType par)  {
  // Execute the operation normally
}
```

```
void dispatch() {
  while(active) {
    // 1. receive from the RemoteProxy
    // 2. Unmarshal received data
    // 3. Call operation on RemoteImpl
    // 4. Send back result
  }
}
```

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CORBA

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. . . to Giovanni Rimassa for his slides

OSGi

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Summing Up

Object-oriented Middleware. . .

- . . . provides a coherent framework for Distributed OOP, both conceptually and technologically
- . . . extends OOP to Distributed Systems
- . . . hides the complexity of programming DS
- . . . is supported by open standards—such as OMG CORBA and OSGi
- . . . promotes integration across OSs, networks and languages
- . . . counts on a lot of free implementations available

Does it solve everything?

- Of course not.
- That is why why have a course on Multi-agent Systems, then!

References I

Buschmann, F., Meunier, R., Rohnert, H., Sommerlad, P., and Stal, M. (1996).
Pattern-Oriented Software Architecture: A System of Patterns, volume 1.
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