Object-Oriented Middleware for Distributed Systems

Distributed Systems
Sistemi Distribuiti

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Ingegneria Due
Alma Mater Studiorum—Università di Bologna a Cesena

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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.
Outline

1. Middleware Overview
2. Object-Oriented Middleware
3. CORBA & OSGi
What is Middleware?

- **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
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*
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
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.
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
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
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).
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!
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 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

The fundamental OOP computation mechanism is:

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

**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
Remote Method Call

The fundamental Distributed OOP computation mechanism

\[ \text{res} = \text{obj.meth(par)} \]

- **Result**
  - Sent back
- **Target Object**
  - Encapsulates address and protocol
- **Parameter List**
  - Sent on the network
- **Access Operator**
  - Grants location transparency
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 \(N_c \times N_s\) 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
}

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

*Pattern-Oriented Software Architecture: A System of Patterns*, volume 1.

John Wiley & Sons, New York, NY.
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