Software Engineering

Lecture 07: Physical Design — Components and Middleware

Peter Thiemann

University of Freiburg, Germany

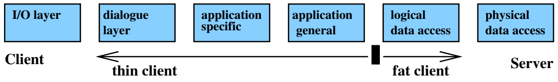
SS 2013

Distributed Applications

Basic choices

- Architecture
  - Client/Server architecture
  - Web-Architecture
- Middleware
  - Communication between program components
  - Requirements
    - Language independence
    - Platform independence
    - Location independence
- Security

Client/Server Architecture



- Application divided in client-part and server-part
- → Five possible divisions of standard (six) layer architecture (thin client → fat client)
- Characteristics fixed in the requirements (# of users, operating systems, database systems, ...)

advantages: traceability of user session, special protocols, design influenced by # users

disadvantages: scalability, distribution of client software, portability

Web Architecture

- Client: only I/O layer; Server: everything else
- Client requirements: Web browser (user interface)
- Server requirements:
  - Web server (distribution of documents, communication with application)
  - Application server (application-specific and application-general objects)
  - Database server (persistent data)

advantages: scalability (very high number of users, in particular with replicated servers), maintainability (standard components), no software distribution required

disadvantages: restriction to HTTP, stateless and connectionless protocol requires implementation of session management, different Web browsers need to be supported (Internet Programming)

Current technology addresses some of the disadvantages: Servlets, ASP, ...

Refinement: N-tier Architecture

- Physical deployment follows the logical division into layers (tiers)
- Why?
  - Separation of concerns (avoids *e.g.* mixing of presentation logic and business logic)
  - Scalability
  - Standardized frameworks (*e.g.*, Java Platform, Enterprise Edition, Java EE 6) handle issues like security and multithreading automatically
- Example (Java EE):
  - Presentation: Web browser
  - Presentation logic: Web Tier (JSP/servlets, JavaServer Faces, JavaBeans)
  - Business logic: Business Tier (Enterprise JavaBeans, Web Services)
  - Data access: Enterprise Information System Tier (Java Persistence API, JDBC, Java Transaction API)
  - Backend integration (legacy systems, DBMS, distributed objects)

Enterprise JavaBeans (EJB): Goals

- Part of Java Platform, Enterprise Edition (Java EE 6)
- A SPECIFICATION! but implementations are available
- Server-side component architecture for enterprise applications in Java [1]
- Defines interaction of components with their container [2]
- Development, deployment, and use of web services
- Abstraction from low-level APIs
- Deployment on multiple platforms without recompilation
- Interoperability
- Components developed by different vendors
- Compatible with other Java APIs

---

[1] → main target: business logic, between UI and DBMS

[2] directory services, transaction management, security, resource pooling, fault tolerance

EJB Component Types

Session Beans

- Interfaces to server-side operations
- Typically business methods
- Three kinds
  - Stateless Session Bean: no state carried over between method invocations; one Bean instance can be shared between multiple clients
  - Stateful Session Bean: maintains state between method invocations; one Bean instance per client
  - Singleton Bean: one instance for all

EJB Component Types /2

Message-Driven Beans

- Event Listeners
- Asynchronous Messaging

Entity Bean

- Object View of RDBMS; object-relational mapping
- Persistence defined separately with JPA (Java Persistence API)

EJB Component Types /3

- All components implemented as POJOs (plain old Java objects)
- No subclassing or implementing of particular interfaces required
- Special roles imposed by annotations

All invocations through interfaces

- Local interface: for method invocations inside the same VM
- Remote interface: for method invocations with unknown location (less efficient)
- Implementing one bean means implementing several interfaces and classes consistently

EJB Example: Remote Interface

A plain Java interface

```
public interface CalculatorCommonBusiness {
  /**
  * Adds all arguments
  * @return The sum of all arguments */
  int add(int... arguments);
}

public interface CalculatorRemoteBusiness
         extends CalculatorCommonBusiness{}
```

EJB Example: Bean Implementation Class

A plain Java class

```
public class CalculatorBeanBase implements CalculatorCommonBusiness {
  /**
  * {@link CalculatorCommonBusiness#add(int...)}
  */
  @Override
  public int add(final int... arguments) {
    // Initialize
    int result = 0;
    // Add all arguments
    for (final int arg : arguments) {
      result += arg;
    }
    // Return
    return result;
  }
}
```

EJB Example: Bean Class

A plain Java class with annotations

```
import javax.ejb.LocalBean;
import javax.ejb.Stateless;
@Stateless (name = CalculatorEJB)
@Local (CalculatorRemoteBusiness.class)
public class SimpleCalculatorBean extends CalculatorBeanBase {
  /*
  * Implementation supplied by common base class
  */
}
```

Lower Level Services

Lower Level Services

Connection of resources in Client/Server architecture

1. Sockets (TCP/IP, ...)
2. RPC
3. RMI
4. SOAP (Simple Object Access Protocol)/Web Services

Sockets

- Software terminal of a network connection (a data structure)
- Two modes of communication to host
  - Reliable, bidirectional communication stream or
  - Unreliable, unidirectional one-shot message
- Local variant: inter-process communication (IPC)
- Low level:
  - Manipulation of octet-streams required
  - Custom protocols

Sockets in Java

Server: Read two numbers and output their sum

```
ServerSocket serverSocket = new ServerSocket(1234);
while ( true ) {
    Socket client = serverSocket.accept();
    InputStream input = client.getInputStream();
    OutputStream output = client.getOutputStream();
    int value1 = input.read();
    int value2 = input.read();
    output.write(value1 + value2);
    input.close();
    output.close();
}
```

Sockets in Java

Client: Send two numbers and obtain their sum

```
Socket server = new Socket("localhost", 1234);
InputStream input = server.getInputStream();
OutputStream output = server.getOutputStream();
output.write(1);
output.write(2);
int result = input.read();
input.close();
output.close();
```

Sockets in Java

Client: Send two numbers and obtain their sum

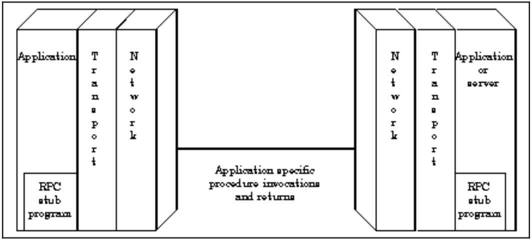
```
Socket server = new Socket("localhost", 1234);
InputStream input = server.getInputStream();
OutputStream output = server.getOutputStream();
output.write(1);
output.write(2);
int result = input.read();
input.close();
output.close();
```

Aside

- How do we ensure that client and server fit together?
- We'll consider an approach later on. . .

Remote Procedure Call (RPC)

- Procedure call across process and system boundaries (heterogeneous)
- Transparent to client code, but some specialities
  - Error handling: failures of the remote server or network
  - No global variables or side-effects
  - Performance: RPC usually one or more orders of magnitude slower
  - Authentication: may be necessary for RPC



Anatomy of RPC

- Define interface in terms of XDR (e**X**ternal **D**ata **R**epresentation)
  - XDR is a data representation format
  - XDR is independent of a particular host language and host architecture (network format)
- **Marshalling**: data conversion from internal representation (host language data) to standardized external representation
  Synonyms: Serialization, pickling
- Stub functions for each remotely callable procedure
  client code is written in terms of calls to client stubs
  server code is called from server stubs
- Stub functions generated by RPC compiler from **interface definition**

Timeline of an RPC

time	client stub		server stub
$\downarrow$	marshall parameters to XDR		
	connect to server	$\rightarrow$	invoked by incoming connection
	transmit parameters	$\rightarrow$	receive parameters
	wait for server response		unmarshall parameters
			call actual implementation
			marshall results
	receive results	$\leftarrow$	transmit results
	unmarshall results from XDR		exit

Remote Method Invocation (RMI)

- Object-oriented RPC
- Specific to Java
- Implements method calls
  - Dynamic dispatch
  - Access to object identity (`this`)
- Object serialization (marshalling)
- Access via interfaces
- Easy to use
- Latest variant: asynchronous method invocation
- "*Experience has shown that the use of RMI can require significant programmer effort and the writing of extra source code*"
  Douglas Lyon: "Asynchronous RMI for CentiJ", in Journal of Object Technology, vol. 3, no. 3, March-April 2004, pp. 49-64. `http://www.jot.fm/issues/issue_2004_03/column5`

Simple Object Access Protocol (SOAP)

- Transport protocol specification for method invocations
- Based on HTTP plus extensions[3]
- Encodes information using XML / XML Schema[4]

```
POST /StockQuote HTTP/1.1
Host: www.stockquoteserver.com
Content-Type: text/xml; charset="utf-8"
Content-Length: nnnn
SOAPAction: "Some-URI"

<SOAP-ENV:Envelope ...>
   <SOAP-ENV:Body>
       <m:GetLastTradePrice xmlns:m="Some-URI">
           <symbol>DIS</symbol>
       </m:GetLastTradePrice>
   </SOAP-ENV:Body>
</SOAP-ENV:Envelope>
```

[3] reason: internet security, firewalls

[4] reason: standard, extensibility, can be validated

Web Services and WSDL

- Web Service Description Language
- XML-based
- Describes location and protocol of the service
- Main elements:

portType	Operations of service (cf. RPC program)
message	Spezification of parameters
types	Data types (XML Schema)
binding	Message format and protocol

WSDL 2.0 Example (excerpt)

```
<types>
  <xs:element name="getTermRequest" type="xs:string">
  </xs:element>

  <xs:element name="getTermResponse" type="xs:string">
  </xs:element>
</types>

<interface name="glossaryTerms">
  <operation name="getTerm">
    <input  messageLabel="In"  element="tns:getTermRequest"/>
    <output messageLabel="Out" element="tns:getTermResponse"/>
  </operation>
</interface
```

- xs is the namespace for XML Schema definitions
  `xmlns:xs="http://www.w3.org/2001/XMLSchema"`
- tns is the targetnamespace for the type definitions

WSDL Example: One-Way Operation

```
<types>
  <xs:element name="newTermValues">
    <xs:attribute name="term"  type="xs:string" use="required"/>
    <xs:attribute name="value" type="xs:string" use="required"/>
  </xs:element>
</types>

<interface name="glossaryTerms">
  <operation name="setGlossaryTerm">
    <input messageLabel="In" element="tns:newTermValues"/>
  </operation>
</interface>
```

- No return value $\Rightarrow$ no answer message

Further Kinds of Operation

- output-only (no `<input>` params), Example:

```
<types>
  <xs:element name="whatTimeValue"/>
  <xs:element name="theTimeValue" type="xs:date"/>
</types>

<interface name="Date">
  <operation name="currentTime">
    <input  messageLabel="In"  element="tns:whatTimeValue"/>
    <output messageLabel="Out" element="tns:theTimeValue"/>
  </operation>
</interface>
```

- “Notification”: output with empty request

Automatic generation of WSDL code

- Translation from WDSL to a client API is tedious
- Parsing XML
- Verifying XML Schema
- Choice of data types
- Binding to HTTP and SOAP possible

⇒ Tools: WSDL2Java

Glimpse on Two Further Component Models

Distributed Component Object Model (DCOM)

- Proprietary format for communication between objects
- Binary standard (not language specific) for “components”
- COM object implements one or more interfaces
  - Described by IDL (**I**nterface **D**efinition **L**anguage);
    stubs etc. directly generated by tools
  - Immutable and persistent
  - May be queried dynamically
- COM services
  - Uniform data transfer `IDataObject`
    (clipboards, drag-n-drop, files, streams, etc)
  - Dispatch interfaces `IDispatch` combine all methods of a regular interface into one method (RTTI)
  - Outgoing interfaces (required interfaces, female connector)

Common Object Request Broker Architecture (CORBA)

- Open distributed object computing infrastructure
- Specified by OMG (Object Management Group)
- Manages common network programming tasks
  - Cross-Language: Normalizes the method-call semantics
  - Parameter marshalling and demarshalling
  - Object registration, location, and activation
  - Request demultiplexing
  - Framing and error-handling
- Extra services
  Component model reminiscent of EJB

Summary

- Distributed Systems Architecture
  - client/server
  - web
  - n-tier (Java EE 6)
- Middleware building blocks