Software Engineering

Lecture 11: Physical Design — Components and Middleware

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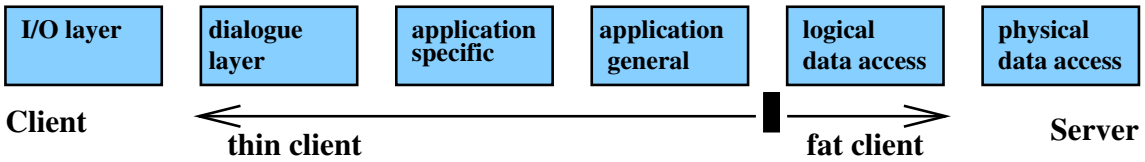
Distributed Applications

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
- $\rightarrow$ Five possible divisions of standard (six) layer architecture (thin client $\rightarrow$ 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

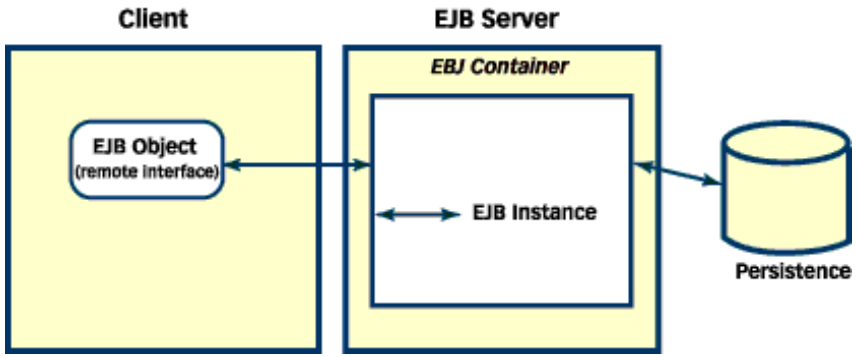
disadvantages: restriction to HTTP, stateless and connectionless protocol requires implementation of session management, different Web browsers need to be supported (Internet Programming)

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
- 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, etc.

EJB Component Types

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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

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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

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```
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
  */
}
```

EJB Example: Bean Class

Client Code

```
import javax.naming.InitialContext;

public class Client
{
   public static void main(String[] args) throws Exception
   {
      InitialContext ctx = new InitialContext();
      CalculatorCommonBusiness calculator =
      (CalculatorCommonBusiness) ctx.lookup("CalculatorEJB/remote")

      System.out.println("1 + 1 = " + calculator.add(1, 1));
   }
}
```

Lower Level Services

Lower Level Services

Connection of resources in Client/Server architecture

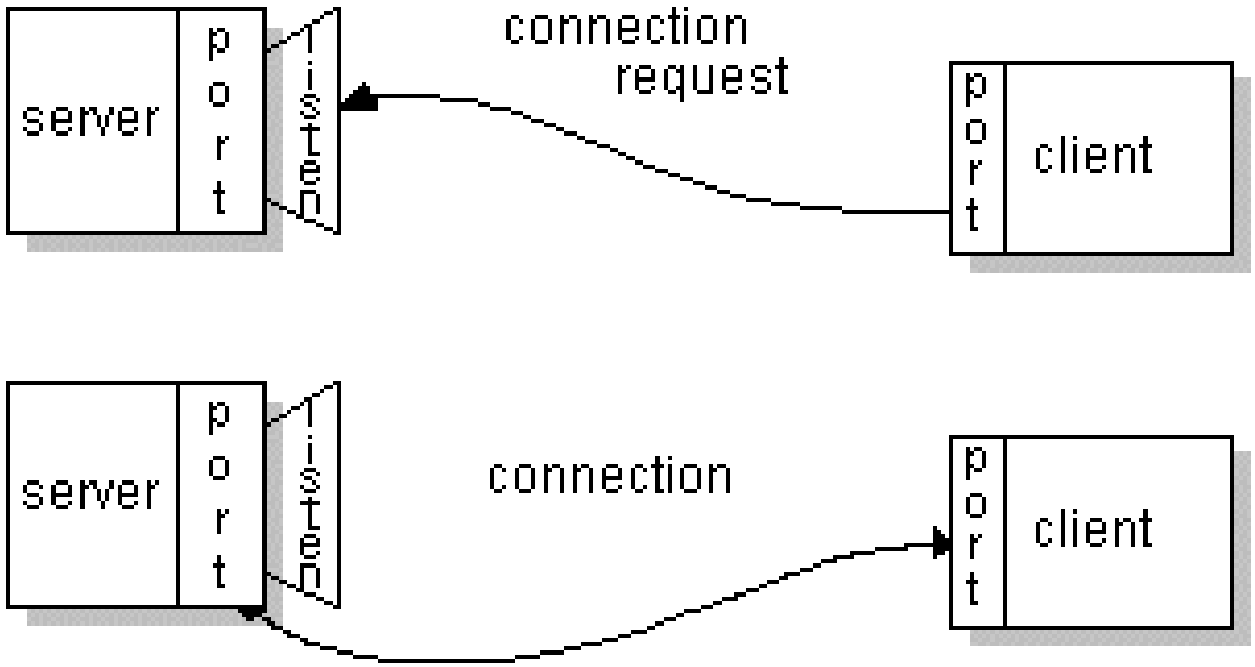
1. Sockets (TCP/IP, . . .)
2. RPC
3. RMI
4. SOAP (Simple Object Access Protocol)/Web Services

Sockets

A means for inter-process communication (IPC), both local and over a computer network.

- Software terminal of a network connection (a data structure)
- Two modes of communication
  - Reliable, bidirectional communication *stream* or
  - Unreliable, unidirectional one-shot message (*datagram*)
- Low level:
  - Manipulation of octet-streams required
  - Custom protocols

Sockets


server
port
listen
connection
request
port
client
server
port
listen
connection
port
client

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

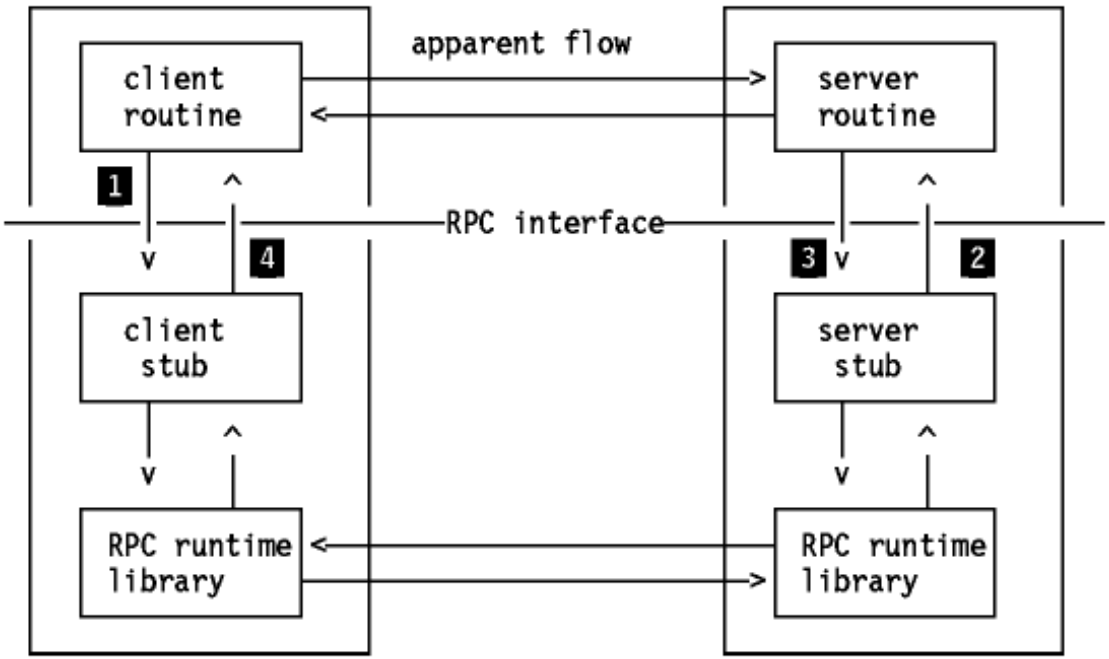
```
Socket server = new Socket("localhost", 1234);
InputStream input = server.getInputStream();
OutputStream output = server.getOutputStream();
output.write(1);
output.write(2);
int result = input.read();
input.close();
output.close();
```

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
  - Authentication: may be necessary for RPC
  - Performance: RPC usually one or more orders of magnitude slower



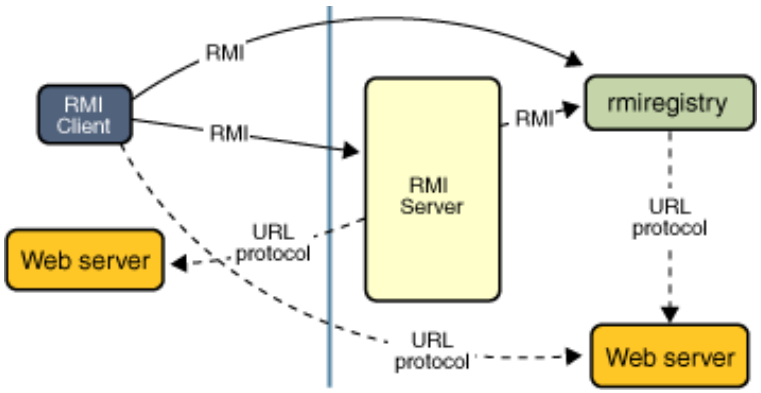
Anatomy of RPC

- 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
↓	marshall parameters to XDR		
	connect to server	→	invoked by incoming connection
	transmit parameters	→	receive parameters
	wait for server response		unmarshall parameters
			call actual implementation
			marshall results
	receive results	←	transmit results
	unmarshall results from XDR		exit

Remote Method Invocation (RMI)



- EJB is built on top of RMI
- Object-oriented RPC, specific to Java
- Implements method calls
  - Dynamic dispatch
  - Access to object identity (`this`)
- Object serialization (marshalling)
- Easy to use, access via interfaces
- Latest variant: asynchronous method invocation

Simple Object Access Protocol (SOAP)

- Transport protocol specification for data exchange and method invocations between heterogeneous systems.
- Base for the implementation of *web services*.
- Usually based on HTTP plus extensions.[3] May use any other transport protocol.
- Encodes information using XML / XML Schema[4]

[3] reason: internet security, firewalls

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

Simple Object Access Protocol (SOAP)

Sample request:

```
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>
```

Simple Object Access Protocol (SOAP)

Sample response:

```
HTTP/1.1 200 OK
Content-Type: text/xml;
charset="utf-8"
Content-Length: nnnn
<?xml version="1.0"?>
<SOAP-ENV:Envelope
  xmlns:SOAP-ENV="http://schemas.xmlsoap.org/soap/envelope/"
  SOAP-ENV:encodingStyle="http://schemas.xmlsoap.org/soap/enco
  <SOAP-ENV:Body>
    <m:GetLastTradePriceResponse xmlns:m="Some-URI">
      <Price>34.5</Price>
    </m:GetLastTradePriceResponse>
  </SOAP-ENV:Body>
</SOAP-ENV:Envelope>
```

Web Services and WSDL

Web Services Description Language

- XML-based
- Describes location and protocol of the service
- Often used in combination with SOAP and XML Schema to provide web services over the Internet
- Main elements (WSDL 1.1):

port	Address or connection point (URL)
portType	Operations of service (cf. RPC program)
message	Specification 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:

1. Parsing XML
2. Verifying XML Schema
3. Choice of data types
4. Binding to HTTP and SOAP possible

$\Rightarrow$ Tools: WSDL2Java

Glimpse on Two Further Component Models

Distributed Component Object Model (DCOM)

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- Proprietary (Microsoft) 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)

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