Softwaretechnik

Middleware

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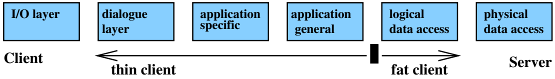
Distributed Applications

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
- → 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)

Recent 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 2 Enterprise Edition, J2EE) handle issues like security and multithreading automatically
- Example (J2EE):
  - Presentation: Web browser
  - Presentation logic: Web server (JSP/servlets or XML/XSLT)
  - Business logic: Session EJBs (Enterprise Java Beans)
  - Data access: Entity EJBs
  - Backend integration (legacy systems, dbms, distributed objects)

Enterprise JavaBeans (EJB): Goals

- A SPECIFICATION! but implementations are available
- standard component architecture for business 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
- part of Java 2 Platform, Enterprise Edition (J2EE)
- compatible with other Java APIs
- compatible with CORBA protocols

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

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

Middleware / Components / Communication infrastructure

Connection of resources in Client/Server architecture

1. Sockets (TCP/IP, . . .)
2. RPC
3. RMI
4. SOAP (Simple Object Access Protocol)/Web Services
5. .NET
6. COM, COM+ (Distributed Component Object Model)
7. CORBA (Common Object Request Broker Architecture)

Items 6 and 7 are software component models

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

```
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();
}
```

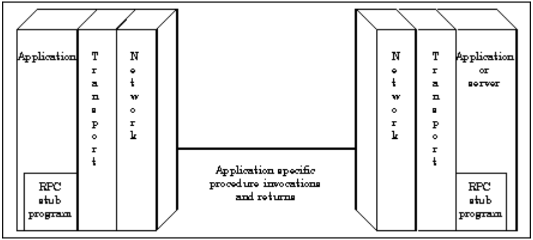
Sockets in Java

Client

```
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();
```

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 the interface in terms of XDR
  XDR is a language for describing e**X**ternal **D**ata **R**epresentation
  XDR is independent of a particular host language (network format)
  host language data has to be marshalled[3] to and from XDR
- 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

[3] data marshalling = transferring data to a network buffer and conversion to external representation; synonyms: serialization, pickling

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)

- object-oriented RPC
- specific to Java
- implements method calls
  - dynamic dispatch
  - access to object identity (`self`, `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)

- protocol specification for invoking methods
- based on HTTP plus extensions [4]
- encodes information using XML / XML Schema [5]

```
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>
```

[4] reason: internet security, firewalls

[5] reason: standard, extensibility

SOAP example: travel agent ⇒ tour operator

```
<?xml version=’1.0’ ?>
<env:Envelope xmlns:env="http://www.w3.org/2003/05/soap-envelope">
  <env:Header>
    <m:reservation xmlns:m="http://travelcompany.example.org/reservation"
                   env:role="http://www.w3.org/2003/05/soap-envelope/role/next"
                   env:mustUnderstand="true">
      <m:reference>uuid:093a2da1-q345-739r-ba5d-pqff98fe8j7d</m:reference>
      <m:dateAndTime>2003-11-29T13:20:00.000-05:00</m:dateAndTime>
    </m:reservation>
    <n:passenger xmlns:n="http://mycompany.example.com/employees"
                 env:role="http://www.w3.org/2003/05/soap-envelope/role/next"
                 env:mustUnderstand="true">
      <n:name>Marilyn Manson</n:name>
    </n:passenger>
  </env:Header>
  <env:Body>
    <p:itinerary xmlns:p="http://travelcompany.example.org/reservation/travel">
      <p:departure>
        <p:departing>New York</p:departing>
        <p:arriving>Los Angeles</p:arriving>
        <p:departureDate>2003-12-14</p:departureDate>
        <p:departureTime>late afternoon</p:departureTime>
        <p:seatPreference>aisle</p:seatPreference>
      </p:departure>
      <p:return>
        <p:departing>Los Angeles</p:departing>
        <p:arriving>New York</p:arriving>
        <p:departureDate>2003-12-20</p:departureDate>
        <p:departureTime>mid-morning</p:departureTime>
        <p:seatPreference/>
      </p:return>
    </p:itinerary>
    <q:lodging xmlns:q="http://travelcompany.example.org/reservation/hotels">
      <q:preference>none</q:preference>
    </q:lodging>
  </env:Body>
</env:Envelope>
```

WSDL

- Web Service Description Language
- XML based
- describes location and protocol of the service
- main elements (XML):

portType	operations of service (cf. RPC program)
message	spezification of parameters
types	data types (XML Schema)
binding	message format and protocol

WSDL Example

```
<message name="getTermRequest">
  <part name="term" type="xs:string"/>
</message>

<message name="getTermResponse">
  <part name="value" type="xs:string"/>
</message>

<portType name="glossaryTerms">
  <operation name="getTerm">
    <input message="getTermRequest"/>
    <output message="getTermResponse"/>
  </operation>
</portType>
```

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

WSDL example: one-way-operation

```
<message name="newTermValues">
  <part name="term" type="xs:string"/>
  <part name="value" type="xs:string"/>
</message>

<portType name="glossaryTerms">
  <operation name="setTerm">
    <input name="newTerm" message="newTermValues"/>
  </operation>
</portType>
```

- no return value ⇒ no answer message

Further Kinds of Operation

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

```
<message name="whatTimeValue"/>
<message name="theTimeValue">
  <part name="time" type="xs:date"/>
</message>
<portType name="Date">
  <operation name="currentTime">
    <input  name="whatTime" message="whatTimeValue"/>
    <output name="theTime" message="theTimeValue"/>
  </operation>
</portType>
```

- "Notification": output without request

SOAP Binding

```
<portType name="glossaryTerms">
  <operation name="getTerm">

...

<binding type="glossaryTerms" name="b0">
  <soap:binding style="document"
                transport="http://schemas.xmlsoap.org/soap/http" />
  <operation>
    <soap:operation soapAction="http://example.com/getTerm"/>
    <input>
      <soap:body use="literal"/>
    </input>
    <output>
      <soap:body use="literal"/>
    </output>
  </operation>
</binding>
```

- soap is SOAP's namespace
- style ∈ rpc, document
- transport defines base protocol (HTTP)

Automatic generation of WSDL code

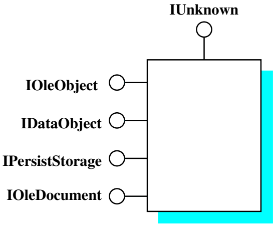
- translation from WDSL to a client API is tedious
- parsing XML
- verifying XML Schema
- choice of data types
- correct SOAP messages

⇒ tools: WSDL2Java

Distributed Component Object Model (DCOM)

- proprietary format for communication between objects
- binary standard (not language specific) for “components”
- COM object implements interfaces (at least one)
  - described by IDL (interface definition language); 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
  - outgoing interfaces (required interfaces, female connector)

Example: COM



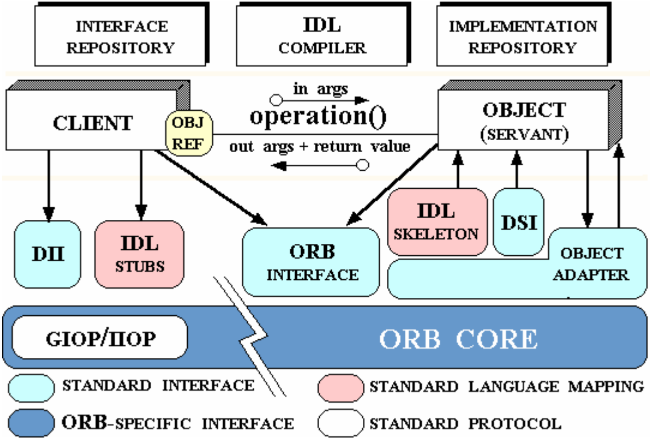
```
[ uuid(00000000-0000-0000-C000-000000000046) ]
interface IUnknown {
  HRESULT QueryInterface ([in] const IID requestedIID,
                          [out, iid_is(requestedIID)] void **ppvObject);
  ULONG AddRef ( );
  ULONG Release ( );
}
```

Common Object Request Broker Architecture (CORBA)

- emerging open distributed object computing infrastructure
- specified by OMG (Object Management Group)
- manages common network programming tasks
  - object registration, location, and activation;
  - request demultiplexing;
  - framing and error-handling;
  - parameter marshalling and demarshalling; and
  - operation dispatching
- extra services

  component model reminiscent of EJB

CORBA ORB Architecture



Summary

- Distributed Systems Architecture
  - client/server
  - web
  - n-tier (J2EE)
- Middleware
  - communication infrastructure
  - component frameworks