Script **generated by TTT**

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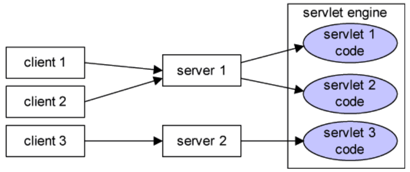
Servlets

Servlets (Java Servlets) are programs invoked by a client and executed on the server host:

used to extend the functionality of the server.



Servlet Properties

Servlet Lifecycle

HttpServlet Interface

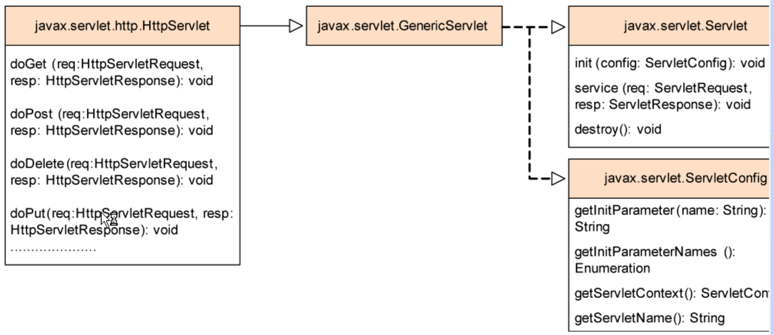
Structure of a Servlet

HttpServlet Interface

HttpServlet inherits abstract class GenericServlet which implements interfaces Servlet and ServletConfig.

GenericServlet defines a generic protocol-independent servlet

HttpServlet defines a servlet for the HTTP protocol



doGet is invoked to respond to a GET request

doPost is invoked to respond to a POST request

doDelete is invoked to respond to a DELETE request; normally used to delete a file on the server

Structure of a Servlet

```
import javax.servlet.*;
import javax.servlet.http.*
import java.io.*;

public class MyServlet extends HttpServlet {
    /** called by the servlet engine to initialize servlet */
    public void init() throws ServletException { .... }
    /** process the HTTP Get request */
    public void doGet(HttpServletRequest request, HttpServletResponse
    response) throws ServletException, IOException { .... }
    /** process the HTTP Post request */
    public void doPost(HttpServletRequest request, HttpServletResponse
    response) throws ServletException, IOException { .... }
    /** called by the servlet engine to release the resource */
    public void destroy () { .... }
    // other methods
}
```

Example - CurrentTime

Example - Registration of Students

```
import javax.servlet.*;
import javax.servlet.http.*
import java.io.*;

public class GetParameters extends HttpServlet {
    /** process the HTTP Get request */
    public void doGet(HttpServletRequest request, HttpServletResponse
    response) throws ServletException, IOException {
       response.setContentType('text/html');
       //obtain parameters from the client
       String lastName = request.getParameter("lastName");
       String firstName = request.getParameter("firstName");
       String gender = request.getParameter("gender");
       String major = request.getParameter("major");
       String[] minors = request.getParameterValues("minor");
       String tennis = request.getParameter("tennis");
       String soccer = request.getParameter("soccer");
       String golf = request.getParameter("golf");
       String remarks = request.getParameter("remarks");
       out.println("Last Name: <b>" + lastName + "</b> First Name: <b>"
          + firstName + "</b><br>");
       out.println("Gender: <b>" + gender + "</b><br>");
```



```
response.setContentType('text/html');
//obtain parameters from the client
String lastName = request.getParameter("lastName");
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String[] minors = request.getParameterValues("minor");
String tennis = request.getParameter("tennis");
String soccer = request.getParameter("soccer");
String golf = request.getParameter("golf");
String remarks = request.getParameter("remarks");
out.println("Last Name: <b>" + lastName + "</b> First Name: <b>"
   + firstName + "</b><br>");
out.println("Gender: <b>" + gender + "</b><br>");
out.println("Major: <b>" + major + "</b> Minor: <b>");
if (minors != null)
   for (int i = 0; i < minors.length; i++)
      out.println(minors[i] + " ");
out.println("</b><br> Tennis: <b>" + tennis + "</b> Soccer: <b>"
   + soccer + "</b> Golf: <b>" + golf + "</b><br>");
out.println("Remarks: <b>" + remarks + "</b>");
```

get value

to obtain parameters

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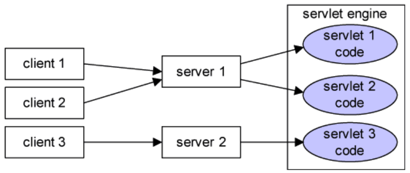


Issues

The following section discusses several important basic issues of distributed applications.

- Data representation in heterogeneous environments.
- Discussion of an execution model for distributed applications.
- What is the appropriate error handling?
- What are the characteristics of distributed transactions?
- What are the basic aspects of group communication (e.g. algorithms used by ISIS) ?
- How are messages propagated and delivered within a process group in order to maintain a consistent state?

External data representation

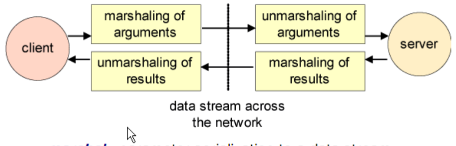
Heterogeneous environment means different data representations

⇒ requirement to enable data transformation.

independence from hardware characteristics while exchanging messages means: use of external data representation.

[Marshalling and unmarshalling]
[Centralized transformation]
[Decentralized transformation]
[Common external data representation]
[XML as common data representation]

Marshalling and unmarshalling



marshal : parameter serialization to a data stream.

unmarshal : data stream extraction and reassembly of arguments.

software for argument transformation either provided by RPC system or as plugin by the application programmer.

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Representation of numbers

For the representation of numbers in main memory, one of the following methods are generally used.

- "little endian" representation: the lower part of a number is stored in the lower memory area
- "big endian" representation: the higher part of a number is stored in the lower memory area, e.g. the Sun-Sparc architecture
- Example representation of the number 1347

Memory Address	1000	1001	1002	1003
Big Endian	00000000	00000000	00000101	01000011
Little Endian	01000011	00000101	00000000	00000000

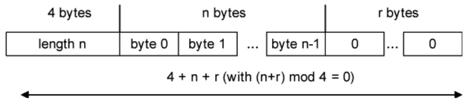
- Convention: for network transfer, numbers which encompass several bytes are structured according to a well-defined representation, such as "big endian".

External representation of strings

There are different internal representations for strings:

C: "abc" →	a	b	c	\0
Pascal: "abc" →	3	a	b	c

Standardized external representation:



Common external data representation

Two aspects of a common external data representation are of importance:

- a machine-independent format for data representation, and
- a language for description of complex data structures.

Examples: XDR ("eXternal Data Representation") by Sun and ASN.1 (Abstract Syntax Notation). Other formats are

- Corba's common data representation: structured and primitive types can be passed as arguments and results.
- Java's object serialization: flattening of single objects or tree of objects.

Example: primitive datatypes

Request for the invocation of the Java method

```
echoString("cat")
```

SOAP body of request that sends a string.

```
<soap:Body>
   <n:echoString
   xmlns:n='http://tempuri.org/mapping.server.Primitive'>
   <value xsi:type='xsd:string'>cat</value>
   </n:echoString>
</soap:Body>
```

XML as common data representation

Complex data types can be mapped to XML for transmission across the network.

- primitive datatypes → XSD equivalent
  - boolean, byte, unsignedShort (used for char), int, long, float, string, ...

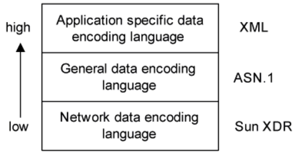
Example: primitive datatypes

SOAP provides built-in support for encoding arrays.

Example: array datatype

complex data types are mapped to XML schema types;

- SOAP platforms provide API for creating custom mapping.
- e.g. writeSchema to specify an XML schema definition



Level of Abstraction

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Example: array datatype

Request for Java method invocation

```
echoInts([1, 2, 3])
```

SOAP body of request that sends an array.

```
<soap:Body>
   <n:echoInts
   xmlns:n='http://tempuri.org/mapping.server.Array'>
   <ints href='#id0'>
   </n:echoInts>
   <id0 id='id0'
      soapenc:root='0'
      xsi:type='soapenc:Array'
      soapenc:ArrayType='xsd:int[3]'>
      <i xsi:type='xsd:int'>1</i>
      <i xsi:type='xsd:int'>2</i>
      <i xsi:type='xsd:int'>3</i>
   </id0>
</soap:Body>
```

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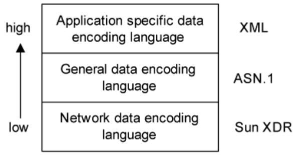

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Marshalling and unmarshalling

Centralized transformation

Decentralized transformation

Common external data representation

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Time

Time is an important and interesting issue in distributed systems

- We need to measure time accurately:
  - to know the time an event occurred at a computer
  - to do this we need to synchronize its clock with an authoritative external clock
- Algorithms for clock synchronization useful for
  - concurrency control based on timestamp ordering
  - authenticity of requests e.g. in Kerberos

Three notions of time:

- time seen by an external observer ⇒ global clock of perfect accuracy.
  - However, there is ***no global clock in a distributed system***
- time seen on clocks of individual processes.
- logical notion of time: event a occurs before event b.

Introduction

Synchronizing physical clocks

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Introduction

Each computer in a distributed system (DS) has its own internal clock

- used by local processes to obtain the value of the current time
- processes on different computers can timestamp their events
- but clocks on different computers may give different times
- computer clocks drift from perfect time and their drift rates differ from one another.
- clock drift rate: the relative amount that a computer clock differs from a perfect clock

⇒ Even if clocks on all computers in a DS are set to the same time, their clocks will eventually vary quite significantly unless corrections are applied.

Timestamp

Skew between clocks

Coordinated Universal Time (UTC)

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Timestamp

To timestamp events, we use the computer's clock

1. At real time t, the operating system reads the time on the computer's hardware clock $H_i(t)$
2. It calculates the time on its software clock
   - $C_i(t) = a\,H_i(t) + b$
   - e.g. a 64 bit number giving nanoseconds since some "base time"
   - in general, the clock is not completely accurate,
   - but if C_i behaves well enough, it can be used to timestamp events at p_i

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[Introduction](#)

[Synchronizing physical clocks](#)

External - internal synchronization

External synchronization

- A computer's clock C_i is synchronized with an external authoritative time source S, so that:
  - $|S(t) - C_i(t)| < D$ for $i = 1, 2, \ldots N$ over an interval I of real time t.
  - The clocks C_i are accurate to within the bound D.

Internal synchronization

- The clocks of a pair of computers are synchronized with one another so that:
  - $| C_i(t) - C_j(t)| < D$ for $i, j = 1, 2, \ldots N$ over an interval I of real time t.
  - The clocks C_i and C_j agree within the bound D.

Internally synchronized clocks are not necessarily externally synchronized, as they may drift collectively.

if the set of processes P is synchronized externally within a bound D, it is also internally synchronized within bound 2D.

Synchronizing physical clocks

physical clocks are used to compute the current time in order to timestamp events, such as

- modification date of a file
- time of an e-commerce transaction for auditing purposes

[External - internal synchronization](#)

[Clock correctness](#)

[Synchronization in a synchronous system](#)

[Cristian's method for an asynchronous system](#)

[Network Time Protocol (NTP)](#)

[Precision Time Protocol (PTP)](#)