Middleware Programming

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More complex C/S Systems

- Internet mail and browser applications are simple examples. In more complex cases:
  - The client may need to search for a server which offers the required functionality.

    Need a lookup service in the network.
  - Client and server may need to exchange arbitrary data in a more efficient way than by using messages in ASCII text.

    Need an efficient platform-independent manner of representing arbitrary data.
  - The client may need to authenticate itself to the server.

    Need suitable authentication and key distribution mechanisms.
- Such common facilities are often introduced by using a **middleware** layer between T- and A-layers.

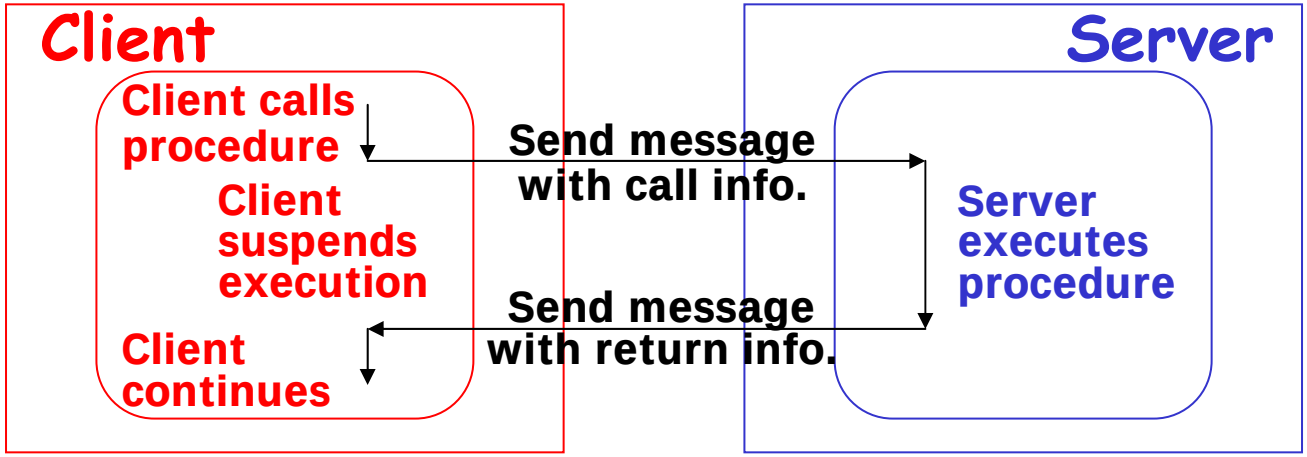
Middleware

- Offers common facilities for supporting applications.
- Allows the applications to be implemented in a manner which is independent of the underlying platform.
- Examples of types of middleware:
  - **Remote Procedure Call (RPC).** Replaces explicit exchange of messages by procedure-call-like construction (e.g. SunRPC).
  - **Remote Object Invocation (ROI).** Activates methods on objects located on remote systems, as in RMI, DCE.
  - **Message-oriented Middleware (MOM).** Exchange of synchronous messages, as in MPI, MQSeries.
  - **Stream-oriented Communication.** Intended to support exchange of continuous media (audio, video,...).

RPC, ROI and CORBA

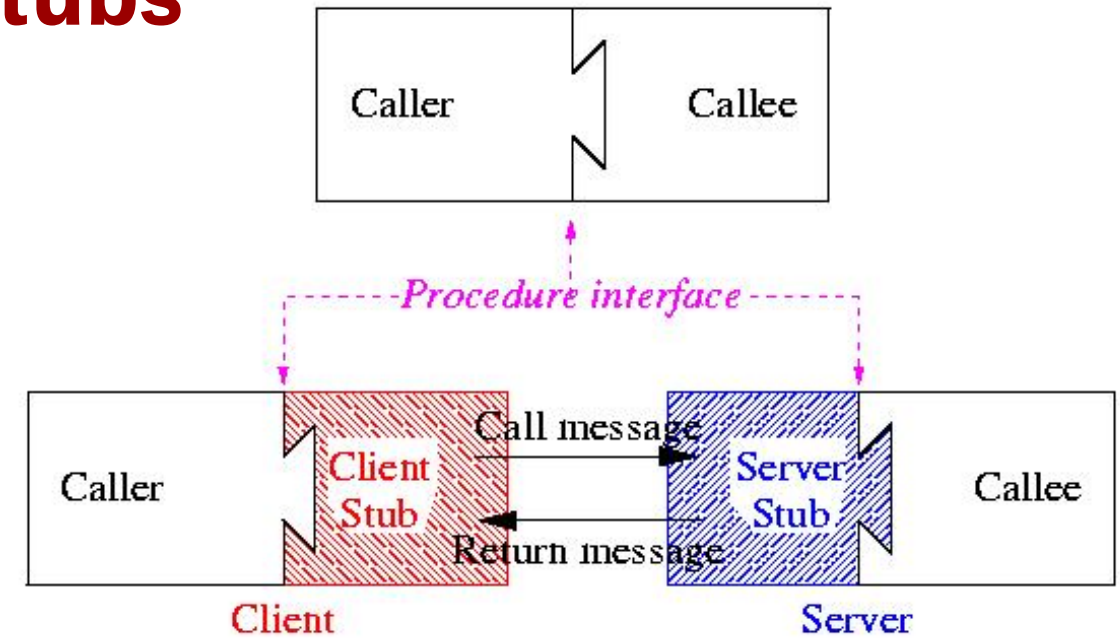
Remote Procedure Call (RPC)

- A simple program interface for client/server interaction.
- Looks to the client application like a procedure call.



- Stubs on client and server sides deal transparently with exchange of messages when procedure is called.

RPC stubs



- Stubs offer both calling and called procedure the same view of the interface as for a local procedure.
- Stubs are compiled from description of the interface in a suitable **Interface Definition Language (IDL)**.
- Description specifies types and directions of flow for the parameters of the procedure.

RPC stubs (2)

- Compiled stub code in the client or server:
  - **Marshals** data for transfer to other party: Values are put into a serial (linear) representation in a buffer.

    Not all types of parameter can be used:
    - The type must be serialisable.
    - Pointer types may need special care (hand coding?)
  - **Unmarshals** data received from other party: Data structures are built up again from linear transfer representation.
  - (Possibly) exchanges security info. **authenticating** client to server and *vice versa*.
- Usually one stub procedure for each procedure in the interface. A despatcher on server side parses incoming messages and passes them to appropriate stub procedure.

RPC Semantics

- Not quite true that RPC offers same behaviour as a local procedure call: *Messages can get lost in transfer or at either end.*
- RPC systems offer different guarantees for execution:
  - **Exactly-once:** As for local procedure call. Called procedure is executed exactly once for each call.

    Difficult to guarantee in a distributed system!
  - **At-most-once:** Called proc. executed once or not at all.
  - **At-least-once:** Called proc. executed one or more times.
  - **Maybe:** No guarantees.
- Note that:
  - **Maybe**, **At-least-once** may give repeated execution.
  - **Maybe**, **At-most-once** may mean proc. is not executed.

Binding

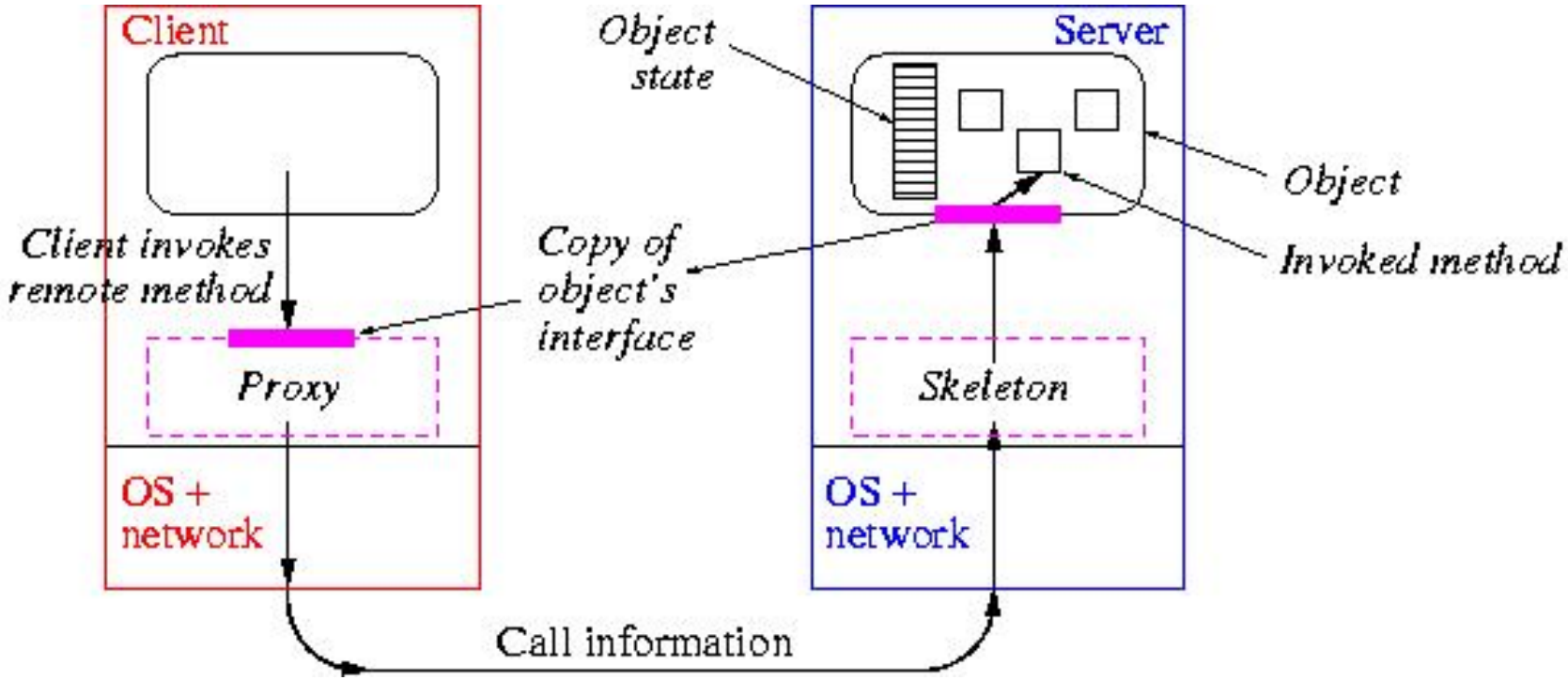
- In an RPC/ROI system, **server** must be associated with an identifier used for lookup by **client**.
- Mapping (*id→server)* is stored in a **registry**.
- Typical operations/methods needed:
  - **bind**: Register service interface and associate it with network name or URI.
  - **rebind**: Associate new service with an already registered name or URI.
  - **unbind**: Remove info. about a service interface with a given name or URI.
  - **lookup**: Obtain reference to service interface with a given name or URI. (Often includes **client binding**: import client stub code, authenticate client and server to one another)

Remote Object Invocation (ROI)

- The OO analogue of RPC, but more tricky because of need to pass references to remote objects.
- On binding to a remote object, the **client** imports an object proxy from the **server**.
- Remote references specify server name and path to the object (or to the proxy code).
- Proxy offers same interface to client as the remote object would, and contains code for marshalling, checking security, etc.
- As with RPC, not all object types can be marshalled; they must be *serialisable*.

ROI (2)

- Typical ROI system architecture:



Java RMI

- Example of an ROI middleware system.
- User program (as **client**) can invoke methods of a remote object (as **server**).
- Remote object implements a Java **remote interface** (which extends the `Remote` interface).
- Remote object is identified by a URL specifying server host name and path to object code.
- Bytecode for object proxy is imported to **client** when client binding takes place.

Java remote interface definition

Example:

```
public interface RemoteTarget extends Remote
{ public void start(int n)
        throws java.rmi.RemoteException;

  public int  add(int i)
        throws java.rmi.RemoteException;

  public void stop()
        throws java.rmi.RemoteException;
}
```

- Must extend `Remote` interface.
- All methods must be declared as raising `java.rmi.RemoteException`.

Java remote object

- Must implement the given **remote interface**.
- Must extend a suitable **RemoteObject** subclass.
- Constructor must throw **RemoteException**.

```
public class Target extends    UnicastRemoteObject
                    implements RemoteTarget
private int bcount;
private boolean active;

public Target() throws RemoteException
{ super(); }

public void start(int n) ...
public int  add  (int i) ...
public void stop ()      ...
```

Implementations of methods of the remote interface

Java remote object (2)

- Main method of remote object class must:
  - Create an object of the class.
  - Register object with RMI registry, so clients can find it.

```
public static void main(String args[])
{ try
  { Target t    = new Target();
    String url = "//localhost/Target";
    Naming.rebind(url, t);
    System.out.println( "Bound server at "
                        + url + " to registry" );
  }
  catch(Exception e){ e.printStackTrace(); }
}
```

Java client for remote object

- Looks up object in registry to get reference to **remote interface**.
- Calls remote methods using reference.
- May need suitable security manager + permissions.

```
public static void main(String args[])
{ String server = sss;
  try
  { if (System.getSecurityManager() == null)
    { System.setSecurityManager( ... );
    };
    String url = "//" + server + "/Target";
    RemoteTarget rTarget =
          (RemoteTarget) Naming.lookup( url );
    rTarget.start(20); ...
  }
  catch (SecurityException e) { ... }
  catch (Exception e)         { ... }
}
```

An RMI application: Summary

- Compile remote interface def.: `javac RemoteTarget.java`
- Compile remote object impl.: `javac Target.java`
- Compile client implementation: `javac Blipper.java`
- Compile code for stubs: `rmic Target`

  (If remote object is a package, use full qualified package name)

  This produces `Target_Stub.class` for client stub and `Target_Skel.class` for server stub, both on server system.

  Java 1.4 or earlier
- Start RMI registry: `rmiregistry &`
- Start remote object: `java Target &`

  May need to specify codebase and/or security policy file.
- Start client(s): `java Blipper &`

  If remote object is correctly registered and permissions given, client will be able to activate methods of the remote object.

CORBA

A software architecture and environment for developing and implementing distributed applications.

Developed by **Object Management Group (OMG)**.

CORBA = **C**ommon **ORB** **A**rchitecture

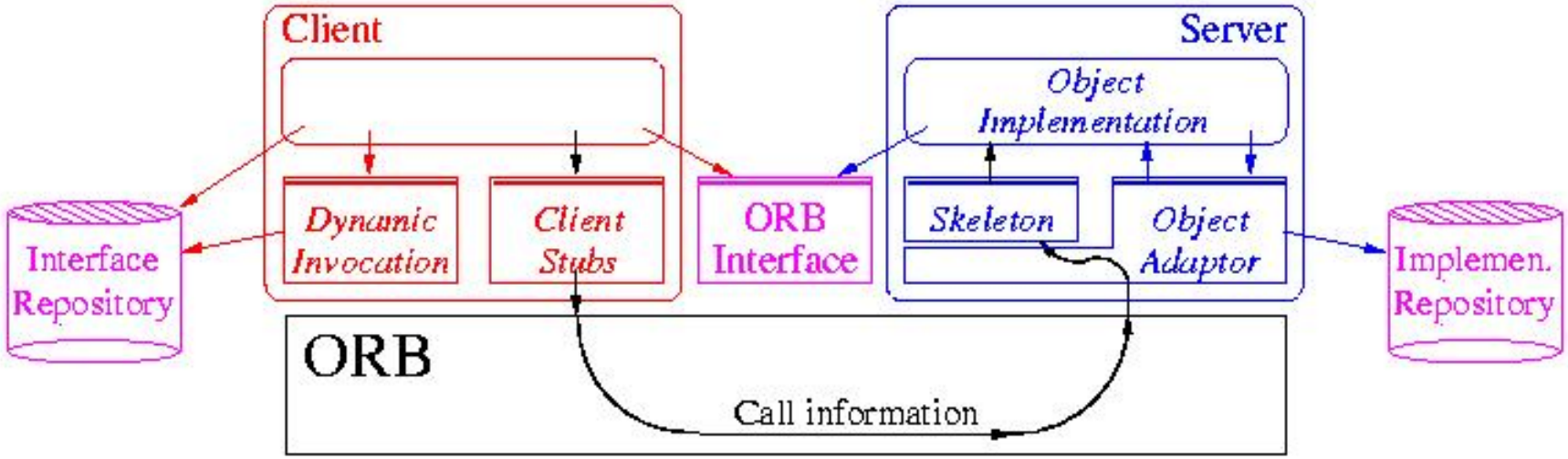
ORB = **O**bject **R**equest **B**roker: "software bus" which can connect different types of software component, possibly developed in different languages (C, Java,...)

ORB defined in terms of its interface -- many different implementations, sometimes giving rise to differences visible at application level.

We focus on Java ORB, using conventions to make implementations portable to other ORBs.

CORBA (2)

- System architecture:



- Familiar features: Client stub, server stub (skeleton).
- New features:
  - Object adaptor
  - Interface and implementation repositories
  - Dynamic invocation interface.

Common Object Services

A characteristic feature of CORBA, including:

- **Naming Service:** for registration of bindings between names and object references.
- **Event Service:** allows components on the ORB to register and de-register their interest in receiving particular *asynchronous* events.
- **Security Service:** provides security facilities, such as authentication, non-repudiation and audit trails.
- **Concurrency Service:** provides a lock manager.
- **Time Service:** provides clock synchronisation over multiple computers.

CORBA IDL

- Used to describe client/server interface, for example:

```
module BlipTarget
{ interface Blip
  { void start(in long n);
    long add  (in long i);
    void stop ();
    oneway void shutdown();
  };
};
```

- "C++" types (IDL `long` <-> Java `int`, etc.)
- Direction of information flow indicated by "in", "out", "in out".
- Compiled to desired target language by appropriate IDL compiler.

A CORBA application: Summary

- Compile remote interface def.: `idlj Blip.idl`
- Compile server implem.: `javac BlipTarget.java`
- Compile client implementation: `javac BlipClient.java`
- Compile code derived from IDL: `javac BlipApp/*.java`

  This produces class files for client & server stubs and helper classes.
- Start ORB Name Service dæmon:

```
orbd -ORBInitialPort 1050 &
```

- Start server:

```
java BlipTarget -ORBInitialPort 1050
                -ORBInitialHost localhost &
```

- Start client(s):

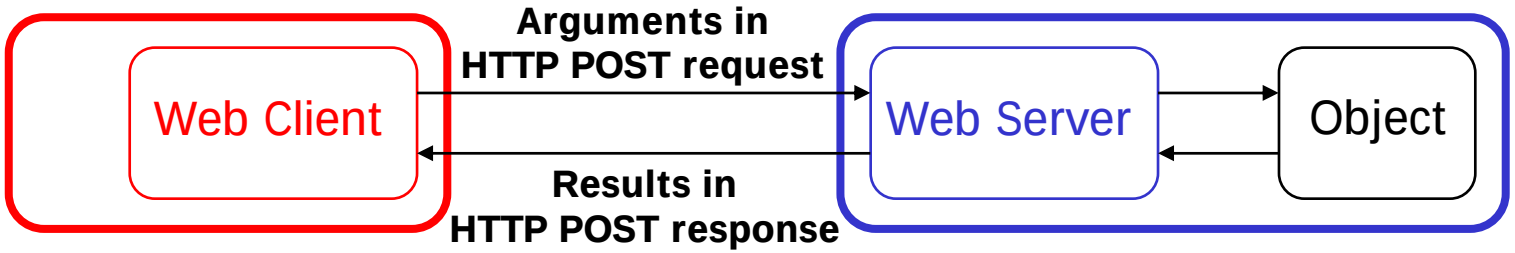
```
java BlipClient -ORBInitialPort 1050
                -ORBInitialHost localhost &
```

- Don't forget to stop ORB name server dæmon when finished!

Web services and SOAP

Another approach: SOAP

- SOAP: Simple Object Access Protocol
- Offers a way to pass arguments to an application and return results from the application via an existing Application Layer protocol (typically HTTP).
- System structure (using HTTP):

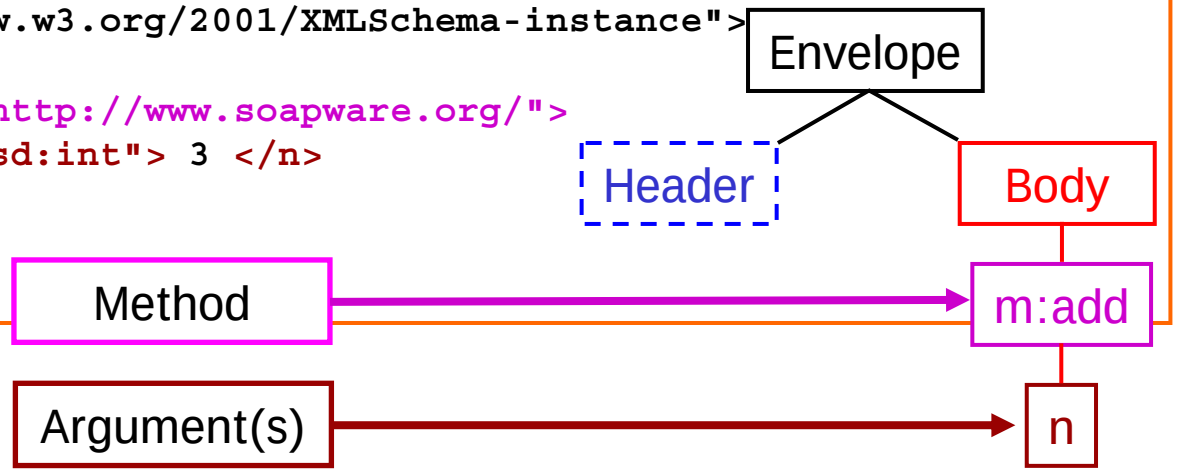


- Arguments and results are embedded in **SOAP messages** encoded in **XML**.

SOAP messages in XML

- SOAP messages are syntactically **XML documents** with a hierarchical structure:
- E.g. for method invocation:

```
<?xml version="1.0"?>
<SOAP-ENV:Envelope
  xmlns:SOAP-ENC:encodingStyle="http://schemas.xmlsoap.org/soap/encoding/"
  xmlns:SOAP-ENV:encodingStyle="http://schemas.xmlsoap.org/soap/envelope/"
  xmlns:xsd="http://www.w3.org/2001/XMLSchema"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
    <SOAP-ENV:Body>
      <m:add xmlns:m="http://www.soapware.org/">
        <n xsi:type="xsd:int"> 3 </n>
      </m:add>
    </SOAP-ENV:Body>
</SOAP-ENV:Envelope>
```



SOAP messages in XML (2)

- Results from invoked method are embedded in a similar manner:

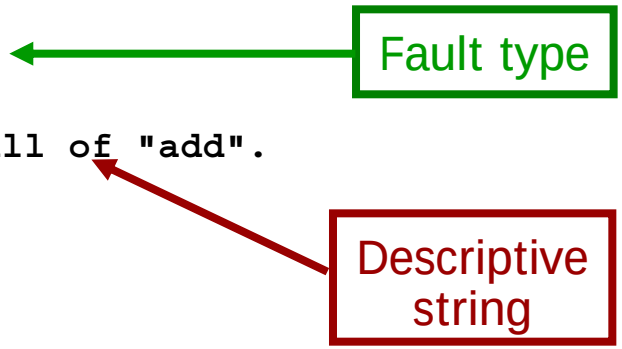
```
<?xml version="1.0"?>
<SOAP-ENV:Envelope
 xmlns:SOAP-ENC:encodingStyle="http://schemas.xmlsoap.org/soap/encoding/"
 xmlns:SOAP-ENV:encodingStyle="http://schemas.xmlsoap.org/soap/envelope/"
 xmlns:xsd="http://www.w3.org/2001/XMLSchema"
 xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
    <SOAP-ENV:Body>
      <m:addResponse xmlns:m="http://www.soapware.org/">
        <addresult xsi:type="xsd:int"> 27 </addresult>
      </m:addResponse>
    </SOAP-ENV:Body>
</SOAP-ENV:Envelope>
```

... at least if the invocation terminated correctly.

SOAP messages in XML (3)

- If errors occur, a Fault Response message is returned:

```
<?xml version="1.0"?>
<SOAP-ENV:Envelope
 xmlns:SOAP-ENC:encodingStyle="http://schemas.xmlsoap.org/soap/encoding/"
 xmlns:SOAP-ENV:encodingStyle="http://schemas.xmlsoap.org/soap/envelope/"
 xmlns:xsd="http://www.w3.org/2001/XMLSchema"
 xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
    <SOAP-ENV:Body>
      <SOAP-ENV:Fault>
        <faultcode>SOAP-ENV:Client</faultcode>
        <faultstring>Client error.
                     Too many parameters in call of "add".
        </faultstring>
      </SOAP-ENV:Fault>
    </SOAP-ENV:Body>
</SOAP-ENV:Envelope>
```



SOAP Types

- A subset of **XML datatypes**.
- As in most programming languages, fall into:
  - **Simple types**: scalar values, no internal structure.
  - **Compound types**: structured values.
- Some simple types in SOAP 1.1:

Set of values in type	Type name	Value Example
Decimal fractions	`xsd:decimal`	12.345
Signed floating point numbers	`xsd:float`	-12.345E3
Signed double precision numbers	`xsd:double`	-12.34567890E3
Boolean values	`xsd:boolean`	true
Strings of characters	`xsd:string`	good morning
Date/times	`xsd:dateTime`	2001-10-01T04:05:06
Base64 encoded binary	`SOAP-ENC:base64`	GWalP2A=
32-bit signed integers	`xsd:int`	-1234567
16-bit signed integers	`xsd:short`	-1234
Negative integers	`xsd:negativeInteger`	-32768

SOAP Types (2)

- New types can be **derived** from already defined ones by definition of subtypes:
  - **Enumerations**: Selected explicitly from a simple base type.
  - **Subsets** selected by **restriction** rules. E.g. `int`, `short`, `negativeInteger` etc. are all subsets of `decimal`.
- **Compound** SOAP types can be:
  - **Struct**s: *sets* of named elements, of any types, whose order is unimportant.
  - **Array**s: ordered *sequences* of elements, of same or different types. (Names, if any, are unimportant.)

Note: SOAP compound types and derived types are (currently) only a subset of those available in XML.

SOAP struct types

- Members of **struct** types are *sets* of named elements, whose order is not significant.
- Example: A **struct** of type **Bibentry**.

```
<e:Bibentry>
  <author>Alfons Aaberg</author>
  <title>My life as a latchkey child</title>
  <pubyear>2015</pubyear>
</e:Bibentry>
```

  Three elements: two strings and an integer.

  Reference to elements by name (author, title,...).

- Type definition given in **schema**, e.g.:

```
<element name="Bibentry">
  <complexType>
    <element name="author" type="xsd:string"/>
    <element name="title" type="xsd:string"/>
    <element name="pubyear" type="xsd:int"/>
  </complexType>
</element>
```

SOAP array types

- Members of **array** types are *ordered sequences* of elements, of same or different types. Element names are not significant.
- Example: An array of type **int[5]** (5 **int** elements)

```
<Primes SOAP-ENC:arrayType="xsd:int[5]">
  <item xsi:type="xsd:int">2</item>
  <item xsi:type="xsd:int">3</item>
  <item xsi:type="xsd:int">5</item>
  <item xsi:type="xsd:int">7</item>
  <item xsi:type="xsd:int">11</item>
</Primes>
```

Or, alternatively, with implicit element types:

```
<Primes SOAP-ENC:arrayType="xsd:int[5]">
  <number>2</number>
  <number>3</number>
  <number>5</number>
  <number>7</number>
  <number>11</number>
</Primes>
```

Element type given by array type

Web Services with SOAP

- Simple idea: Implement programs which send and receive HTTP POST requests/responses containing SOAP messages.
- More advanced environments hide details (like RMI and CORBA).
- Examples:
  - Apache SOAP (Java-based)
  - SOAP::lite (Perl-based)
  - .NET (C#-based, but other languages also OK?)

Apache SOAP

A toolkit for producing Web services:

- Offers a Java environment for:
  - Defining interface to service (à la RMI).
  - Producing implementation on **server**.
  - Producing implementation of **client**.
- Offers facilities for **deploying** service:
  - Defining service offered to users.
  - Registering in **registry**.
  - Browsing in registry.

Apache SOAP server definitions

- Interface definition:

```
public interface IBlip
{ public void start(int n);
  public int  add(int i);
  public void stop();
}
```

- Server-side implementation:

```
public class WSBlip implements IBlip
{ private int bcount;
  private boolean active;

public void start(int n)
{ System.out.println(new Date() + ": Target activated.");
  bcount = n;
  active = true; }

public int add(int i) { ... }

public void stop()    { ... }
```

Compile as usual using `javac`.

Apache SOAP Client code

- Not quite as easy as Server-side code!
- Uses modified versions of methods, referring to remote service by URL.
- Each method needs to:
  - Set up Call object describing call of remote method.
  - Create vector with parameters and insert into Call object.
  - Invoke remote service.
  - Deal with (correct or faulty) SOAP response.
- Apache SOAP environment offers classes whose methods make this (relatively) easy.

Example: `add` method in client

```
public static int add(URL url, int n) throws Exception
{ // Create Call object and set SOAP encoding spec.
  Call call = new Call();
  call.setEncodingStyleURI( Constants.NS_URI_SOAP_ENC );
  // Set parameters for service locator
  call.setTargetObjectURI( "urn:xmethods-Blipper" );
  call.setMethodName( "add" );
  // Create vector with parameter(s) and insert into Call object
  Parameter param1 = new Parameter("n", int.class, n, null);
  Vector    params = new Vector();
  params.addElement( param1 );           call.setParams( params );

  // Invoke remote service and deal with response
  Response resp = call.invoke(url, "/Blipper");
  if( resp.generatedFault() )
  { Fault f = resp.getFault();
    System.err.println("Fault= "+f.getFaultCode()+", "+f.getFaultString());
    throw new Exception();
  } else
  { // The call was successful.  Retrieve return value.
    Parameter result = resp.getReturnValue();
    Int       addobj = (Int) result.getValue();
    return addobj.intValue();
  }
}
```

Apache SOAP Web Service deployment

- Offers facilities to inform Web server about:
  - Identity of Web service being offered, as URN.
  - Scope: Activation mode of service.
    E.g. **Request**: New instance of service for each new request.
  - Methods made available.
  - Provider type: Java class, Bean script, EJB,...
  - Provider Class: Name of the Java class offered.
  - Static?: True if methods are static on Java class.

  ... or whatever is appropriate for the implementation type.
- Offers facilities for **browsing** deployed services.
- Offers facilities for **undeploying** services which are no longer needed.

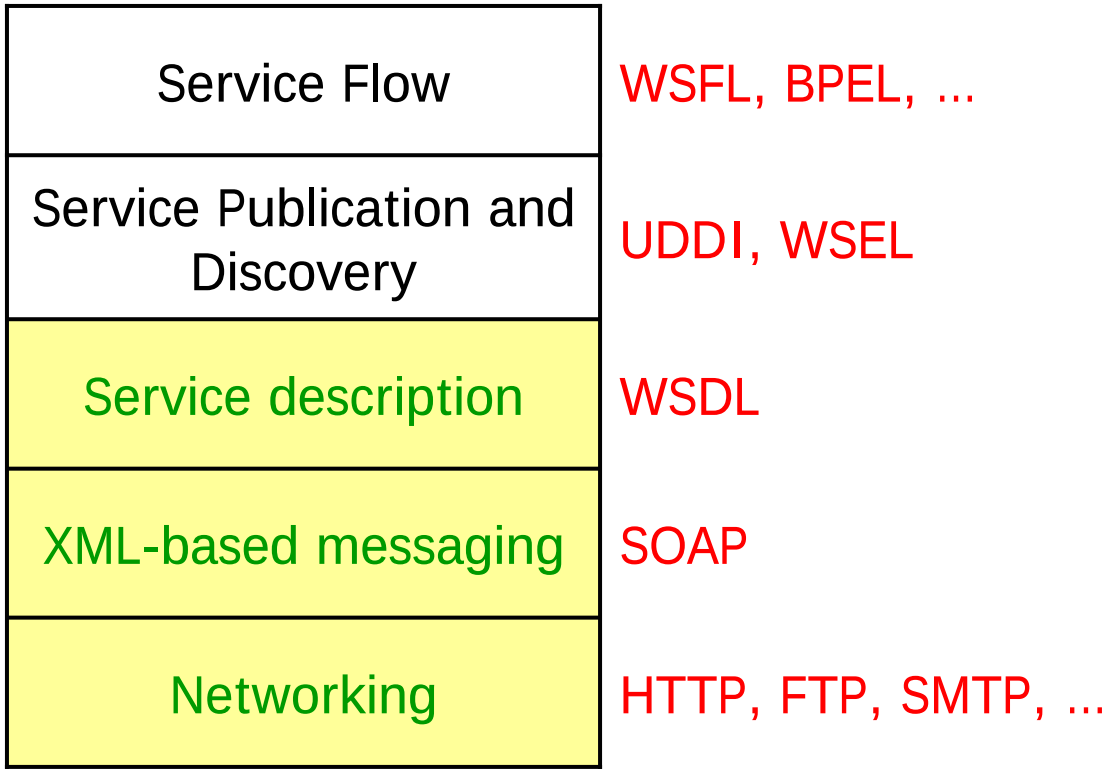
Deployment Descriptors

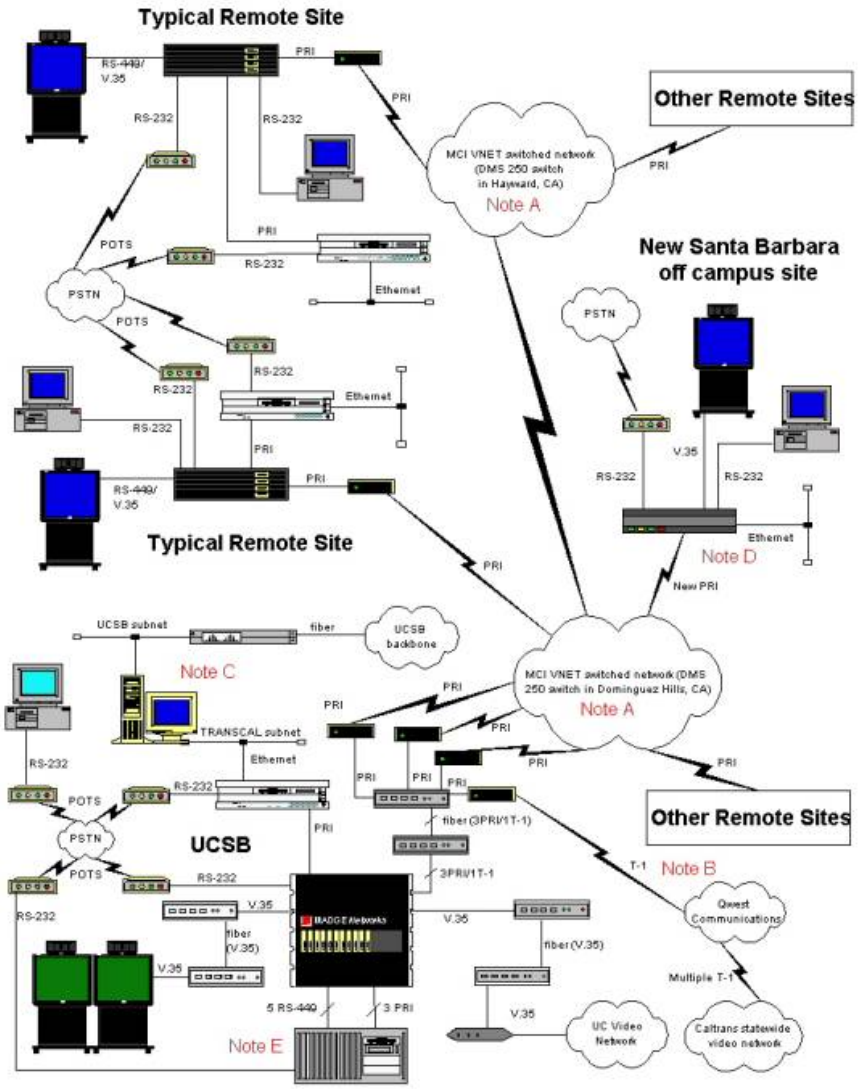
- XML documents which describe the deployed service. E.g. for Apache SOAP:

```
<isd:service xmlns:isd="http://xml.apache.org/xml-soap/deployment"
     id="urn:demo:wsblip"
     type="message"
     checkMustUnderstands="false">
  <isd:provider type="java"
     scope="Request"
     methods="start add stop">
     <isd:java class="WSBlip" static="true"/>
  </isd:provider>
  <isd:faultListener>
     org.apache.soap.server.DOMFaultListener
  </isd:faultListener>
</isd:service>
```

SOAP in context...

- SOAP is really just one protocol layer in the multi-layer Web Services Architecture:





Thank you for your attention