SOAP II: Data Encoding

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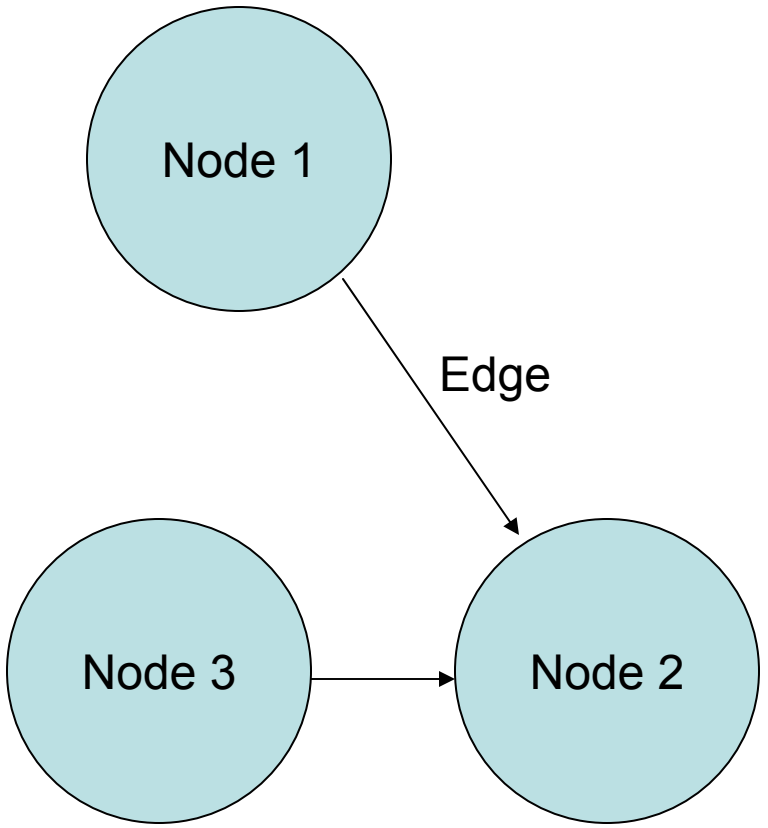
Review: SOAP Message Payloads

- SOAP has a very simple structure:
  - Envelopes wrap body and optional header elements.
- SOAP body elements may contain any sort of XML
  - Literally, use <any> wildcard to include other XML.
- SOAP does not provide specific encoding *restrictions*.
- Instead, provides *conventions* that you can follow for different message styles.
  - RPC is a common convention.
- Remember: SOAP designers were trying to design it to be general purpose.
  - SOAP encoding and data models are optional

SOAP Data Models

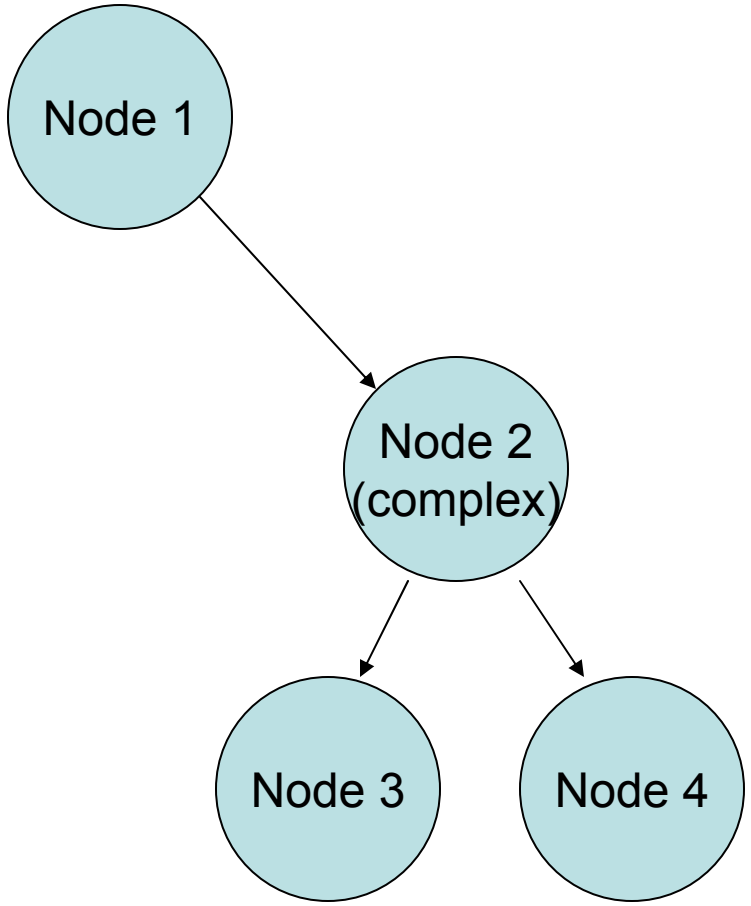
SOAP's Abstract Data Model

- SOAP data may be optional represented using Node-Edge Graphs.
- Edges connect nodes
  - Have a direction
  - An *edge* is labeled with an XML QName.
- A *node* may have 0 or more *inbound* and *outbound* edges.
- Implicitly, Node 2 describes Node 1.
- A few other notes:
  - Nodes may point to themselves.
  - Nodes may have inbound edges originating from more than one Node.



Nodes and Values

- Nodes have values.
  - Values may be either simple (lexical) or compound.
- A simple value may be (for example) a string.
  - It has no outgoing edges
- A complex value is a node with both inbound and outbound edges.
- For example, Node 1 has a value, Node 2, that is structured.
- Complex values may be either *structs* or *arrays.*



Complex Types: Structs and Arrays

- A compound value is a graph node with zero or more outbound edges.
- Outbound edges may be distinguished by either labels or by position.
- Nodes may be one of two sorts:
  - *Struct*: all outbound edges are distinguished solely by labels.
  - *Array:* all outbound edges are distinguished solely by position order.
- Obviously we are zeroing in on programming language data structures.

Abstract Data Models

- The SOAP Data Model is an abstract model
  - Directed, labeled graph
- It will be expressed in XML.
- The graph model implies *semantics* about data structures that are not in the XML itself.
  - XML describes only *syntax.*
- Implicitly, nodes in the graph model resemble nouns, while the edges represent predicates.
- We will revisit this in later lectures on the Semantic Web.

Graphs to XML

- SOAP nodes and edges are not readily apparent in simple XML encoding rules.
  - Normally, an XML element in the SOAP body acts as both the edge and the node of the abstract model.
- However, SOAP does have an internal referencing system.
  - Use it when pointing from one element to another.
  - Here, the XML-to-graph correspondence is more obvious.

SOAP Encoding

Intro: Encoding Conventions

- SOAP header and body tags can be used to contain arbitrary XML
  - Specifically, they can contain an arbitrary sequence of tags, replacing the <any> tag.
  - These tags from other schemas can contain child tags and be quite complex.
  - See body definition on the right.
- And that's all it specifies.
- SOAP thus does not impose a content model.
- Content models are defined by *convention* and are optional.

```
<xs:element name="Body"
    type="tns:Body" />
<xs:complexType name="Body">
    <xs:sequence>
      <xs:any
          namespace="##any"
           processContents="lax"
          minOccurs="0“
          maxOccurs="unbounded"
    />
      </xs:sequence>
      <xs:anyAttribute
          namespace="##other"
          processContents="lax" />
</xs:complexType>
```

Encoding Overview

- Data models such as the SOAP graph model are abstract.
  - Represented as graphs.
- For transfer between client and server in a SOAP message, we encode them in XML.
- We typically should provide encoding rules along with the message so that the recipient knows how to process.
- SOAP provides some encoding rule definitions:
  - http://schemas.xmlsoap.org/soap/encoding/
  - But these rules are not required and must be explicitly included.
  - Note this is NOT part of the SOAP message schema.
- Terminology:
  - Serialization: transforming a model instance into an XML instance.
  - Deserialization: transforming the XML back to the model.

Specifying Encoding

- Encoding is specified using the encodingStyle attribute.
  - This is optional
  - There may be no encoding style
- This attribute can appear in the envelope, body, or headers.
  - The example from previous lecture puts it in the body.
  - The value is the standard SOAP encoding rules.
- Thus, each part may use different encoding rules.
  - If present, the envelope has the default value for the message.
  - Headers and body elements may override this within their scope.

```
<soapenv:Body>
 <ns1:echo
   soapenv:encodingStyle="http://
   schemas.xmlsoap.org/soap/enc
   oding/"
    xmlns:ns1="…">
   <!--
   The rest of the payload
   -->
</soapenv:Body>
```

Encoding Simple Values

- Our echo service exchanges strings. The actual message is encoded like this:
  - **<in0 xsi:type="xsd:string">Hello World</in0>**
- xsi:type means that <in0> will take string values.
  - And string means explicitly xsd:string, or string from the XML schema itself.
- In general, all encoded elements should provide xsi:type elements to help the recipient decode the message.

Simple Type Encoding Examples

Java examples

- int a=3;
- float pi=3.14
- String s="Hello";

SOAP Encoding

- <a xsi:type="xsd:int">
  10

- <pi xsi:type="xsd:float">
  3.14
  </pi>
- <s xsi:type="xsd:string">
  Hello
  </s>

Explanation of Simple Type Encoding

- The XML snippets have two namespaces (would be specified in the SOAP envelope typically).
  - xsd: the XML schema. Provides definitions of common simple types like floats, ints, and strings.
  - xsi: the XML Schema Instance. Provides the definition of the type element and its possible values.
- Basic rule: each element must be given a type and a value.
  - Types come from XSI, values from XSD.
- In general, all SOAP encoded values must have a type.

XML Schema Instance

- A very simple supplemental XML schema that provides only four attribute definitions.
- *Type* is used when an element needs to explicitly define its type rather than implicitly, through a schema.
  - The value of xsi:type is a qualified name.
- This is needed when the schema may not be available (in case of SOAP).
  - May also be needed in schema inheritance
    - See earlier XML schema lectures on “Polymorphism”

Example for Encoding Arrays in SOAP 1.1

- Java Arrays
  - int[3] myArray={23,10,32};

- Possible SOAP 1.1 Encoding:

```
<myArray xsi:type="SOAP-ENC:Array
      SOAP-ENC:arrayType="xsd:int[3]">
            <v1>21</v1>
            <v2>10</v2>
            <v3>32</v3>
</myArray>
```

An Explanation

- We started out as before, mapping the Java array name to an element and defining an xsi:type.
- But there is no array in the XML schema data definitions.
  - XSD doesn't preclude it, but it is a complex type to be defined elsewhere.
  - The SOAP encoding schema defines it.
- We also made use of the SOAP encoding schema's arrayType attribute to specify the type of array (3 integers).
- We then provide the values.

Encoding a Java Class in SOAP

- Note first that a general Java class (like a Vector or BufferedReader) does not serialize in XML.
- But JavaBeans (or if you prefer, Java data objects) do serialize.
  - A bean is a class with accessor (get/set) methods associated with each of its data types.
  - Can be mapped to C structs.
- XML Beans and Castor are two popular Java-to-XML converters.

Example of Encoding a Java Bean

- Java class

```
class MyBean {
    String Name="Marlon";
    public String getName() {return Name;}
    public void setName(String n) {Name=n;}
}
```

- Possible SOAP Encoding of the data (as a struct)

```
<MyBean>
    <name xsi:type="xsd:string">Marlon</name>
</MyBean>
```

Structs

- Structs are defined in the SOAP Encoding schema as shown.
- Really, they just are used to hold yet more sequences of arbitrary XML.
- Struct elements are intended to be accessed by name
  - Rather than order, as Arrays.

```
<xs:element name="Struct"
    type="tns:Struct" />
<xs:group name="Struct">
  <xs:sequence>
    <xs:any namespace="##any"
        minOccurs="0"
        maxOccurs="unbounded"
        processContents="lax" />
  </xs:sequence>
</xs:group>

<xs:complexType name="Struct">
  <xs:group ref="tns:Struct"
    minOccurs="0" />
  <xs:attributeGroup
    ref="tns:commonAttributes" />
</xs:complexType>
```

SOAP 1.1 Arrays

- As stated several times, SOAP encoding includes rules for expressing arrays.
- These were significantly revised between SOAP 1.1 and SOAP 1.2.
- You will still see both styles, so I'll cover both.
- The basic array type (shown) was intended to hold 0 or 1 Array groups.

```
<xs:complexType
   name="Array">
  <xs:group ref="tns:Array"
        minOccurs="0" />
  <xs:attributeGroup
        ref="tns:arrayAttribut
        es" />
   <xs:attributeGroup
        ref="tns:commonAttri
        butes" />
</xs:complexType>
```

SOAP 1.1 Array Group

- Array elements contain zero or more array groups.
- The array group in turn is a sequence of <any> tags.
- So the array group can hold arbitrary XML.

```
<xs:group name="Array">
<xs:sequence>
  <xs:any
    namespace="##any"
    minOccurs="0"
    maxOccurs="unbounded"
    processContents="lax" />
  </xs:sequence>
</xs:group>
```

SOAP 1.1 Array Attributes

- The array group itself is just for holding arbitrary XML.
- The array attributes are used to further refine our definition.
- The array definition may provide an arrayType definition and an offset.
- Offsets can be used to send partial arrays.
- According to the SOAP Encoding schema itself, these are only required to be strings.

```
<xs:attributeGroup
    name="arrayAttributes">
  <xs:attribute ref="tns:arrayType" />
  <xs:attribute ref="tns:offset" />
  </xs:attributeGroup>
<xs:attribute name="offset"
    type="tns:arrayCoordinate" />

<xs:attribute name="arrayType"
    type="xs:string" />

<xs:simpleType
    name="arrayCoordinate">
    <xs:restriction base="xs:string" />
</xs:simpleType>
```

Specifying Array Sizes in SOAP 1.1

- The arrayType specifies only that the it takes a string value.
- The SOAP specification (part 2) does provide the rules.
- First, it should have the form *enc:arraySize.*
  - Encoding can be an XSD type, but not necessarily.
  - Ex: xsd:int[5], xsd:string[2,3], p:Person[5]
  - The last is an array of five persons, defined in *p.*
- Second, use the following notation:
  - [] is a 1D array.
  - [][] is a array of 1D arrays
  - [,] is a 2D array.
  - And so on.

Encoding Arrays in SOAP 1.2

- Array encodings have been revised and simplified in the latest SOAP specifications.
  - http://www.w3.org/2003/05/soap-encoding
- ArrayType elements are derived from a generic nodeType element.
- Now arrays have two attributes
  - itemType is the the type of the array (String, int, XML complex type).
  - arraySize

```
<xs:attribute name="arraySize"
        type="tns:arraySize" />
<xs:attribute name="itemType"
    type="xs:QName" />

<xs:attributeGroup
    name="arrayAttributes">
  <xs:attribute ref="tns:arraySize"
    />
  <xs:attribute ref="tns:itemType"
    />
</xs:attributeGroup>
```

SOAP 1.2 Array Sizes

- The arraySize attribute (shown below). The regular expression means
  - I can use a “*” for an unspecified size, OR
  - I can specify the size with a range of digits
  - I may include multiple groupings of digits for multi-dimensional arrays, with digit groups separated by white spaces.

```
<xs:simpleType name="arraySize">
 <xs:restriction base="tns:arraySizeBase">
        <xs:pattern value="(\*|(\d+))(\s+\d+)*" />
 </xs:restriction>
</xs:simpleType>
```

Comparison of 1.1 and 1.2 Arrays

```
<numbers
  enc:arrayType="xs:int[2]">
   <number>3
   </number> <number>4
   </number>
</numbers>
```

```
<numbers
   enc:itemType="xs:int"
   enc:arraySize="2">
   <number>3
   </number> <number>4
   </number>
</numbers>
```

SOAP 1.1 Encoding's Common Attributes

- As we have seen, both structs and arrays contain a group called commonAttributes.
- The definition is shown at the right.
- The ID and the HREF attributes are used to make internal references within the SOAP message payload.

```
<xs:attributeGroup
   name="commonAttributes">
  <xs:attribute name="id"
   type="xs:ID" />
  <xs:attribute name="href"
   type="xs:anyURI" />
  <xs:anyAttribute
   namespace="##other"
   processContents="lax" />
</xs:attributeGroup>
```

References and IDs

- As you know, XML provides a simple tree model for data.
- While you can convert many data models into trees, it will lead to redundancy.
- The problem is that data models are graphs, which may be more complicated than simple trees.
- Consider a typical manager/employee data model.
  - Managers are an extension of the more general employee class.
  - Assume in following example we have defined an appropriate schema.

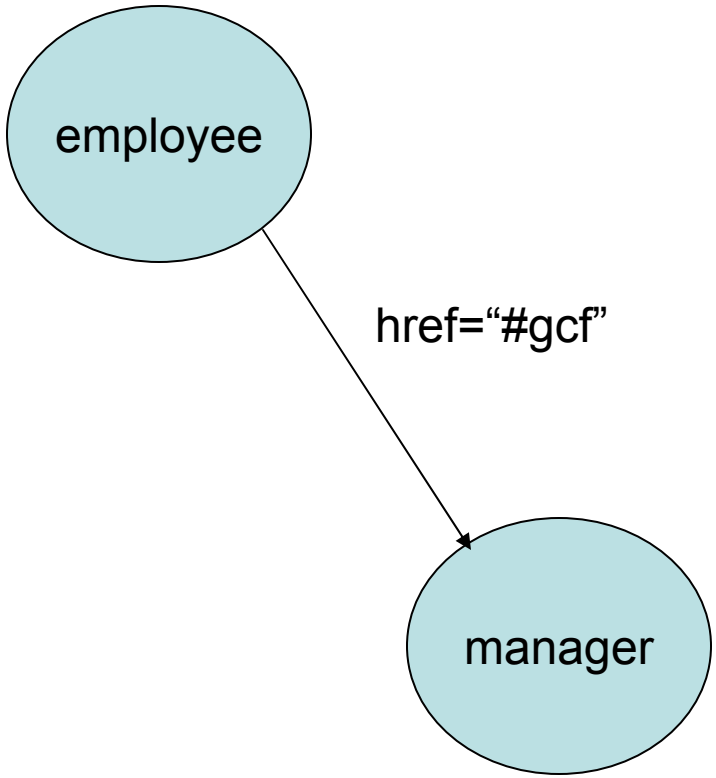
Before/After Referencing (SOAP 1.1 Encoding)

```
<manager>
   <fname>Geoffrey</>
   <lname>Fox</>
</manager>
<employee>
   <fname>Marlon</>
   <lname>Pierce</>
   <manager>
         <fname>Geoffrey</>
         <lname>Fox</>
   </manager>
</employee>
```

```
<manager id="GCF">
   <fname>Geoffrey</>
   <lname>Fox</>
</manager>
<employee>
   <fname>Marlon</>
   <lname>Pierce</>
   <manager href="#gcf">
</employee>
```

References, IDs and Graphs

- References serve two purposes.
  - They save space by avoiding duplication
    - A good thing in a message.
  - They lower the potential for errors.
- They also return us to the graph model.
  - Normal nodes and edges get mapped into one element information item.
  - Ref nodes actually split the edge and node.



References in SOAP 1.2

- SOAP 1.1 required all references to point to other top level elements.
- SOPA 1.2 changed this, so now refs can point to child elements in a graph as well as top level elements.
  - See next figure
- They also changed the tag names and values, so the encoding looks slightly different.

```
<manager id="GCF">
    <fname>Geoffrey</>
    <lname>Fox</>
</manager>
<employee>
    <fname>Marlon</>
    <lname>Pierce</>
    <manager ref="gcf">
</employee>
```

SOAP 1.1 and 1.2 Refs

```
<e:Books>
<e:Book>
<title>My Life and Work </title>
    <author href="#henryford" />
    </e:Book>
<e:Book>
<title>Today and
    Tomorrow</title>
<author href="#henryford" />
</e:Book>
</e:Books>

<author id="henryford">
    <name>Henry Ford</name>
</author>
```

```
<e:Books>
  <e:Book>
   <title>My Life and Work </title>
   <author id="henryford" >
     <name>Henry Ford</name>
    </author>
 </e:Book>
<e:Book>
    <title>Today and Tomorrow
    </title>
    <author ref="henryford" />
  </e:Book>
</e:Books>
```

Using SOAP for Remote Procedure Calls

The Story So Far…

- We have defined a general purpose abstract data model.
- We have looked at SOAP encoding.
  - SOAP does not provide standard encoding rules, but instead provides a pluggable encoding style attribute.
- We examined a specific set of encoding rules that may be optionally used.
- We are now ready to look at a special case of SOAP encodings suitable for remote procedure calls (RPC).

Requirements for RPC with SOAP

- RPC is just a way to invoke a remote operation and get some data back.
  - All of your Web Service examples use RPC
- How do we do this with SOAP? We encode carefully to avoid ambiguity.
- But it really is just common sense.

- Information needed for RPC:
  - Location of service
  - The method name
  - The method values
- The values must be associated with the method's argument names.

Location of the Service

- Obviously the SOAP message needs to get sent to the right place.
- The location (URL) of the service is not actually encoded in SOAP.
- Instead, it is part of the transport protocol used to carry the SOAP message.
- For SOAP over HTTP, this is part of the HTTP Header:

```
POST /axis/service/echo HTTP/1.0
Host: www.myservice.com
```

RPC Invocation

- Consider the remote invocation of the following Java method:
  - public String echoService(String toEcho);
- RPC invocation conventions are the following:
  - The invocation is represented by a single struct.
  - The struct is named after the operation (echoService).
  - The struct has an outbound edge for each transmitted parameter.
  - Each transmitted parameter is an outbound edge with a label corresponding to the parameter name.

SOAP Message by Hand

```
<env:Envelope xmlns:env="…" xmlns:xsd="…"
              xmlns:xsi="…"
              env:encodingStyle="…">
   <env:Body>
        <e:echoService xmlns:e="…">
            <e:toEcho xsi:type="xsd:string">Hello
            </e:toEcho>
        </e:echoService>
   </env:Body>
</env:Envelope>
```

Notes

- I have omitted the namespace URIs, but you should know that they are the SOAP, XML, and XSI schemas.
- I also omitted the encoding style URI, but it is the SOAP encoding schema.
  - Required by RPC convention.
- I assume there is a namespace (e:) that defines all of the operation and parameter elements.
- The body follows the simple rules:
  - One struct, named after the method.
  - One child element for each input parameter.

RPC Responses

- These follow similar rules as requests.
  - We need one (and only one) struct for the remote operation.
  - This time, the label of the struct is not important.
  - This struct has one child element (edge) for each argument.
  - The child elements are labeled to correspond to the operational parameters.
- The response may also distinguish the “return” value.

RPC Return Values

- Often in RPC we need to distinguish one of the output values as the “return value”.
  - Legacy of C and other programming languages.
- We do this by labeling the return type like this:

  <rpc:result>ex:myReturn</rpc:result>

  <ex:myReturn xsi:type=“xsd:int”>0</>
- The rpc namespace is
  - http://www.w3c.org/2003/05/soap-rpc

An RPC Response

```
<env:Envelope xmlns:env="…" xmlns:xsd="…"
              xmlns:xsi="…" env:encodingStyle="…">
   <env:Body>
        <e:echoResponse
                xmlns:rpc="…"
                xmlns:e="…">
           <rpc:result>e:echoReturn</rpc:result>
           <e:echoReturn xsi:type="xsd:string">
                Hello
           </e:echoReturn>
        </e:echoResponse>
   </env:Body>
</env:Envelope>
```

Going Beyond Simple Types

- Our simple example just communicates in single strings.
- But it is straightforward to write SOAP encodings for remote procedures that use
  - Single simple type arguments of other types (ints, floats, and so on).
  - Arrays
  - Data objects (structs)
  - Multiple arguments, both simple and compound.

Discovering the Descriptions for RPC

- The RPC encoding rules are based on some big assumptions:
  - You know the location of the service.
  - You know the names of the operations.
  - You know the parameter names and types of each operation.
- How you learn this is out of SOAP's scope.
- WSDL is one obvious way.

Relation to WSDL Bindings

- Recall from last WSDL lecture that the <binding> element binds WSDL portTypes to SOAP or other message formats.
- Binding to SOAP specified the following:
  - RPC or Document Style
  - HTTP for transport
  - SOAP encoding for the body elements

The WSDL Binding for Echo

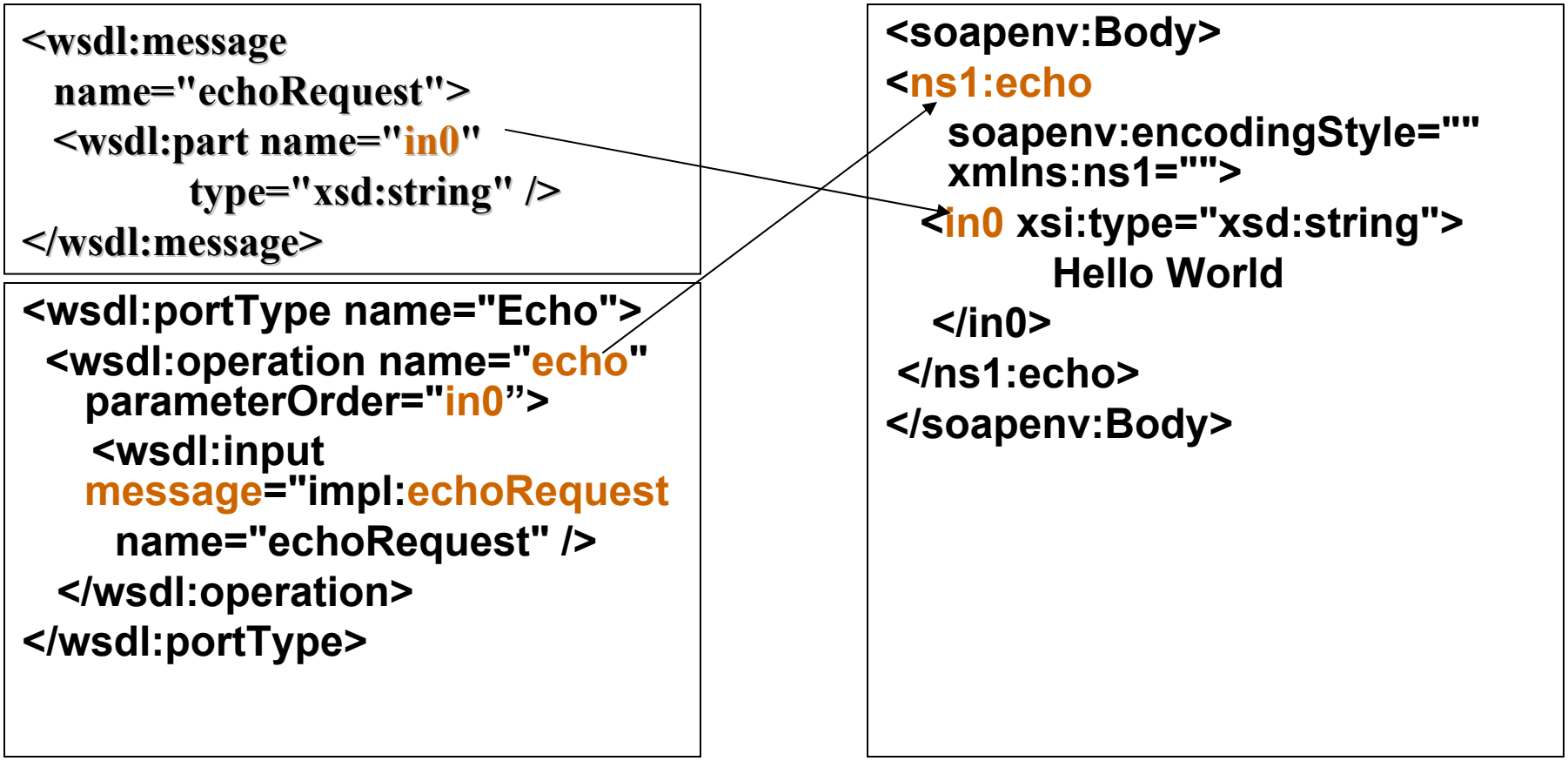
```
<wsdl:binding name="EchoSoapBinding" type="impl:Echo">
  <wsdlsoap:binding style="rpc"
    transport="http://schemas.xmlsoap.org/soap/http" />
  <wsdl:operation name="echo">
    <wsdlsoap:operation soapAction="" />
    <wsdl:input name="echoRequest">
      <wsdlsoap:body
          encodingStyle="http://schemas.xmlsoap.org/so     ap/encoding/"
                              namespace="…" use="encoded" />
    </wsdl:input>
    <wsdl:output name="echoResponse">
      <wsdlsoap:body
          encodingStyle="http://schemas.xmlsoap.org/soap/encoding/"
                              namespace="…" use="encoded" />
    </wsdl:output>
  </wsdl:operation>
</wsdl:binding>
```

RPC Style for Body Elements

- The body element just contains XML.
- Our WSDL specified RPC style encoding.
  - So we will structure our body element to look like the WSDL method.
- First, the body contains an element <echo> that corresponds to the remote comnand.
  - Using namespace ns1 to connect <echo> to its WSDL definition
- Then the tag contains the element <in0> which contains the payload.

```
<soapenv:Body>
<ns1:echo
    soapenv:encodingStyle=""
    xmlns:ns1="">
  <in0 xsi:type="xsd:string">
          Hello World
   </in0>
 </ns1:echo>
</soapenv:Body>
```

Connection of WSDL Definitions and SOAP Message for RPC



WSDL-RPC Mappings for Response

```
<wsdl:portType name="Echo">
  <wsdl:operation name="echo"
        parameterOrder="in0">
        …
    <wsdl:output
      message="echoResponse”
      name="echoResponse" />
  </wsdl:operation>
</wsdl:portType>

<wsdl:message
        name="echoResponse">
    <wsdl:part name="echoReturn"
        type="xsd:string" />
</wsdl:message>
```

```
<soapenv:Body>
 <ns1:echoResponse
    env:encodingStyle=“…”
    xmlns:ns1=“…">
    <echoReturn   xsi:type=“String“>
        Hello World
    </echoReturn>
 </ns1:echoResponse>
</soapenv:Body>
```

Alternative Encoding Schemes

Wrap Up

- As we have seen, SOAP itself does not provide encoding rules for message payloads.
  - Instead, it provides a pluggable encoding style attribute.
- SOAP encoding rules are optional, but likely to be commonly supported in software like Axis.
- SOAP encoding's three main parts for RPC:
  - Abstract Data Model
  - XML Encoding of model
  - Further conventions for RPC
- What about other encodings?

Alternative Encoding Schemes

- SOAP encoding uses graph models for data but, apart from references, does not explicitly map the parts of the graph to different XML elements.
- There are other XML data encoding schemes that make a much more explicit connection between the graph and the encoding.
- The Resource Description Framework is one such scheme.
- So we may choose to use RDF instead of SOAP encoding in a SOAP message.

RDF Encoding Example of Echo

```
<?xml version='1.0' ?>
<env:Envelope xmlns:env="…">
<env:Body
    env:encodingStyle="http://www.w3c.org/1999/02/22-rdf-syntax-ns#">
    <rdf:RDF>
        <rdf:Description about="echo service uri">
            <e:echoService>
              <e:in0>Hello</e:in0>
            </e:echoService>
        </rdf:Description>
    </rdf:RDF>
</env:Body>
</env:Envelope>
```

RDF Encoding Notes

- We will look at RDF in detail in next week's lectures.
- Basic idea is that <rdf:Description> tags are envelopes for xml tags from other schemas.
- The <Description>'s *about* attribute tells you what is being described.
- Note that standard Web Service engines do not support RDF or other encodings.
  - You would need to extend it yourself.
  - But it is possible.