Announcements

- Lab 3 due date extended to November 2nd (Sunday), 11:59pm
  - Additional helper code available from 
    D:\VSDev\Public\vijayk\Lab3-Helper.zip
  - Please see the TA’s if you continue to have difficulty
- Lab 4 out on October 30th (Thursday)
  - due back November 12th (Wednesday)

(Review) SOAP, WSDL, and UDDI

- SOAP: Simple Object Access Protocol
  - XML-RPC-like request/response protocol +
  - Support for asynchronous invocations
  - Encoding of additional information in the message
    - Security tokens for authentication/encryption,
    - Message route information, ...
- WSDL: Web Services Description Language
  - RPC, Distributed Objects-like common structs/interface +
  - Support for asynchronous invocations
  - Possibility of language-neutral (and automatic) interpretation
    - Web-services tools use WSDL description of a service to automatically generate a SOAP-capable proxy
- UDDI: Universal Description, Discovery, and Integration
  - Defines ways of mapping service “characteristics” to service providers
  - “characteristics” generalize “names”

Web Services in .NET using Visual Studio

[ Code walkthrough using Remote Desktop ]

Building and deploying a simple web service
- Setting up the service class and methods
  - [WebMethod] and [WebService] attributes
- Invoking its functionality
- Inspecting its description and discovery interfaces

Writing a web services client
- Adding a “web reference”
- Inspecting automatically generated code for proxy
- Instantiating and using the proxy

Understanding the implementation
- SOAP message exchange
- IIS mapping of service URL
SOAP

History
- SOAP 1.0 (1997): An XML-based protocol for accessing objects
- XML-RPC (1998): A subset of SOAP 1.0
- SOAP 1.1 (2000): Widely supported, de facto standard
  - Standard, will soon replace SOAP 1.1 implementations
- Originally an interoperable protocol for accessing “objects”
- Current versions focus on a generalized XML messaging framework

What is SOAP?

SOAP is a lightweight protocol intended for exchanging structured information in a decentralized environment. SOAP uses XML technologies to define an extensible messaging framework, which provides a message construct that can be exchanged over a variety of underlying protocols. The framework has been designed to be independent of any particular programming model and other implementation-specific semantics.

- SOAP is an XML-based messaging framework
  - Defines a way to move XML messages from point A to point B
  - It is extensible
  - It is usable over a variety of underlying networking protocols
  - It is independent of programming models

SOAP Features

- Extensibility
  - Allows addition of features as layered extensions
  - Basis for IBM/Microsoft Global XML Web Services Architecture (GXA)
    - WS-Security, WS-Router, WS-Referral, ....
    - More about this in a few weeks
  - Contrast with XML-RPC specification
- Usable over a variety of transport protocols
  - TCP, HTTP, SMTP, MSMQ (message queues)
  - Standard protocol bindings need to be defined that specify how a SOAP message is encoded in each protocol
- Support for a variety of programming models
  - RPC-like request-response
  - One-way messaging
  - Several other Message Exchange Protocols (MEPs)

Elements of the SOAP Specification

- Messaging framework
  - Defines a suite of XML elements for “packaging” arbitrary XML messages for transport between systems
  - i.e., what constitutes a “SOAP message”
- Processing model
  - Rules for processing a SOAP message as it travels from a SOAP sender to a SOAP receiver
  - Permits multiple intermediary nodes that can act upon message
- Protocol bindings (an explicit one for HTTP)
  - Defines transmission of SOAP messages using a given transport protocol
- RPC encoding
  - Standard way for mapping RPC calls to SOAP messages
SOAP Messaging Framework

- Core XML elements: Envelope, Header, Body, and Fault
  - Defined in a version-specific XML namespace
    - SOAP 1.1: http://schemas.xmlsoap.org/soap/envelope
    - SOAP 1.2: http://www.w3.org/2003/05/soap-envelope
- Structure of a SOAP message

```xml
<soap:Envelope
xmlns:soap="http://schemas.xmlsoap.org/soap/envelope/"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <soap:Header> <!--optional -->
    <!--header blocks go here … -->
  </soap:Header>
  <soap:Body>
    <!--payload or Fault element goes here … -->
  </soap:Body>
</soap:Envelope>
```

XML Schemas

- XML Schema specifies the structure of an XML element
  - What are its sub-elements?
  - What are their “types”, other restrictions (if any)?
- Example:

```xml
<schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"
  targetNamespace="http://netserver1.pdsg.cs.nyu.edu/vijayk"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <complexType name="Book">
    <element type="Title"></element>
    <element type="Author"></element>
    <element type="Copyright"></element>
  </complexType>
  <simpleTypename="Title" xsi:type="string"></simpleType>
  <simpleTypename="Author" xsi:type="string"></simpleType>
  <simpleTypename="Copyright" xsi:type="integer"></simpleType>
</schema>
```

XML Namespaces

- Denoted by the xmlns: tag
- Define a set of unique names within a given context
  - Context identified by a URI
    - Unlike a URL, need not have a physical resource associated with it
    - Performs same function as in C++, Java, C#, …
    - Permits reuse of names
- In the SOAP messaging framework, namespaces serve two functions
  - They help distinguish between different versions of SOAP
  - The associated schema defines the structure of the SOAP elements:
    Envelope, Header, Body, and Fault
    - This can then be checked by a parser/validator

```xml
<soap:Envelope
xmlns:soap="http://schemas.xmlsoap.org/soap/envelope/"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <soap:Header> <!--optional -->
    <!--header blocks go here … -->
  </soap:Header>
  <soap:Body>
    <!--payload or Fault element goes here … -->
  </soap:Body>
</soap:Envelope>
```

Examples of SOAP Messages

- Client-to-StringReverser:

```xml
<soap:Envelope
xmlns:soap="http://schemas.xmlsoap.org/soap/envelope/"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xmlns:xsd="http://www.w3.org/2001/XMLSchema">
  <soap:Body>
    <Reverse
      xmlns="http://netserver1.pdsg.cs.nyu.edu/vijayk">
      <arg>hi there</arg>
    </Reverse>
  </soap:Body>
</soap:Envelope>
```

- StringReverser-to-Client

```xml
<soap:Body>
  <ReverseResponse
    xmlns="http://netserver1.pdsg.cs.nyu.edu/vijayk">
    <ReverseResult>ereht ih</ReverseResult>
  </ReverseResponse>
</soap:Body>
```
SOAP Fault Element

- Like XML-RPC, faults communicated back to the receiver as part of the response message

```xml
<soap:Body>
  <soap:Fault>
    <faultcode>soap:Server</faultcode>
    <faultstring>Insufficient funds</faultstring>
    <detail>
      <x:TransferError xmlns:x="urn:examples-org:banking">
        <sourceAccount>22-342439</sourceAccount>
        <transferAmount>100.00</transferAmount>
        <currentBalance>89.23</currentBalance>
      </x:TransferError>
    </detail>
  </soap:Fault>
</soap:Body>
```

- Fault codes: VersionMismatch, MustUnderstand, Client, Server

SOAP Header Element

- Header element is optional
- Can contain one or more sub-elements (called header blocks)
  - Each header block can be an element from some namespace
    - `mustUnderstand="1"` indicates receiver must understand this header block (mandatory)
      - Else return a Fault element
  - Primary source for extensibility
    - Security tokens, routing information, processing instructions, ...

```xml
<soap:Header>
  <!-- security credentials -->
  <s:credentials xmlns:s="urn:examples-org:security" soap:mustUnderstand="1">
    <username>dave</username>
    <password>evad</password>
  </s:credentials>
</soap:Header>
```

SOAP Processing Model

- Three kinds of SOAP nodes
  - Initial sender, an intermediary, or ultimate receiver

- When processing a message, a SOAP node assumes one or more roles
  - Roles determine how headers are processed
    - Headers target specific roles using the global `actor` attribute (role in SOAP 1.2)
    - SOAP 1.1 defines only one role: `http://schemas.xmlsoap.org/soap/actor/next`
- A node first processes mandatory headers (mustUnderstand="1"), then others

```
HTTP

Initial SOAP Sender

Client

message

SOAP Node

intermediaries

SOAP Node

SOAP Node

SOAP Node

SOAP Receiver

Endpoint

TCP

MSMQ

SMTP
```

SOAP Processing Model (cont’d)

- Example

```xml
<soap:Envelope
  xmlns:soap="http://schemas.xmlsoap.org/soap/envelope/">
  <soap:Header>
  </soap:Header>
</soap:Envelope>
```

- Fault element generated if node does not understand header
- Successful processing of a header removes it from the message
  - Can reinsert the header, but now treated as relationship between the intermediary node and the downstream node
- Ultimate receiver also responsible for processing the Body element
SOAP Protocol Bindings (HTTP)

- SOAP request/response mapped to HTTP Post/Reply model

SOAP processor

Request

POST /path/bank.asmx HTTP/1.1
Content-Type: text/xml
SOAPAction: "urn:banking:transfer"
Content-Length: nnnn
<soap:Envelope...

Response

HTTP/1.1 200 OK
Content-Type: text/xml
Content-Length: nnnn
<soap:Envelope...

SOAP RPC Encoding

- Defines how to encapsulate RPC info within the SOAP body
  - Endpoint location (URI), method name, parameter names/values

- Method invocation modeled as a struct named after the method
  - Named fields for each in or in/out parameter

  ```xml
  <soap:Body>
  <Reverse
    xmlns="http://netserver1.pdsg.cs.nyu.edu/vijayk">
    <arg>hi there</arg>
  </Reverse>
  </soap:Body>
  ```

- Method response also modeled as a struct, named <Method>Response

  ```xml
  <soap:Body>
  <ReverseResponse
    xmlns="http://netserver1.pdsg.cs.nyu.edu/vijayk">
    <ReverseResult>ereht ih</ReverseResult>
  </ReverseResponse>
  </soap:Body>
  ```