Middleware and Web Services

Lecture 7: Service Concepts and Technologies

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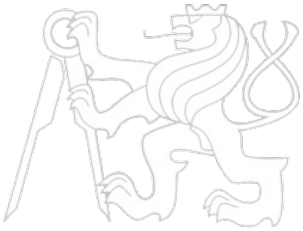

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Service Oriented Architecture

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- SOA supports two core business strategies
  - *Growing top-line revenue*
    - → *Enterprise reacts quickly to requirements from the market*
    - → *Business processes can be reconfigured rather than reimplemented*
  - *Improving bottom-line profit*
    - → *Saving development costs by resuing existing services*
- Pre-integrated solutions
  - *Out-of-the-box applications and integration solutions among them*

Overview

- Integrating Applications
- Web Service Architecture
- Web Service Technologies

Integration and Interoperability

- Integration
  - *A process of connecting applications so that they can exchange and share capabilities, that is — information and functionalities.*
  - *Includes methodological approaches as well as technologies*
- Interoperability
  - *Ability of two or more applications to understand each other*
  - *Interoperability levels*
    - → *Data – syntax/structure and semantics*
    - → *Functions/Processes – syntax and semantics*
    - → *Technical aspects – protocols, network addresses, etc.*

Integration Approaches Overview

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Data-oriented Integration

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- Third-party database access
  - *Application D accesses a database of application B directly by using SQL and a knowledge of database B structure and constraints*
  - *In the past: monolithic and two-tier client/server architectures*
  - *Today: ETL (Extract, Transform, Load) technologies*
- Problems
  - *App D must understand complex structures and constraints*
    - *→ Data – very complex, includes structure and integrity constraints*
    - *→ Functions/processes – hidden in integrity constraints*
    - *→ Technical – access mechanisms can vary*

Service-oriented Integration

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- Integration at the application layer
  - *Application exposes services that other applications consume*
  - *Services hide implementation details but only define interfaces for integration*
- Problems
  - *Can become unmanageable if not properly designed*
  - *Interoperability*
    - → *Data – limited to input and output messages only*
    - → *Functions/processes – limited to semantics of services*
    - → *Technical – access mechanisms can vary*

One-to-One Service Integration

- Direct integration of applications
  - *Multiple protocols problem, multiple vendor problem*
  - *Replication of integration functionalities such as interoperability solutions*

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Many-to-Many Service Integration

- Enterprise Service Bus – central integration technology
  - *Realizes so called Service Oriented Architecture (SOA)*
  - *Contains various integration components such as process server, mediators, messaging middleware, identity management, etc.*

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Integration and Types of Data

- Transactional data – Web services
  - *Service-oriented integration*
  - *online, realtime communication between a client and a service*
  - *Usually small amount of data and small amount of service invocation in a process*
- Bulk data – ETL
  - *Data-oriented integration*
  - *processing of large amount of data in batches*
- **ESB provides both Web service and ETL capabilities**

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Web Service Architecture

- Web Service Architecture
  - *Defined by W3C in Web Service Architecture Working Group Note*
  - *Defines **views***
    - *→ message-oriented view (WSDL and SOAP)*
    - *→ resource-oriented view (REST and HTTP)*
  - *Defines **architecture entities** and their **interactions***
    - *→ Abstraction over underlying technology*
    - *→ Basis for service usage processes and description languages*
- Service Oriented Architecture
  - *Collection of tools, methods and technologies*
  - *There is some implicit understanding of SOA in the community such as*
    - *→ SOA provides advances over Enterprise Application Integration*
    - *→ SOA is realized by using SOAP, WSDL, (and UDDI) technologies*
    - *→ SOA utilizes Enterprise Service Bus (ESB)*
  - *⇒ ~ a realization of Web Service Architecture message-oriented view*

Basic Entities

- Agent
  - *software or hardware that sends/receives messages*
  - *concrete implementation of a service*
- Service
  - *abstract set of functionality and behavior*
  - *two different agents may realize the same service*
- Provider
  - *owner (person or organization) that provides an agent realizing a service*
  - *also called a service provider*
- Requester
  - *a person or organization that wishes to make use of a provider's service*
  - *uses a requester's agent to exchange messages with provider's agent*

Interaction of Entities

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Service

- Difficult to agree on one definition
- Business definition
  - *A service realizes an effect that brings a business value to a service consumer*
    → *for example, to pay for and deliver a book*
- Conceptual definition
  - *service characteristics*
    → *encapsulation, reusability, loose coupling, contracting, abstraction, discoverability, composability*
- Logical definition
  - *service interface, description and implementation*
  - *service usage process*
    → *service use tasks, service types*
- Architectural definition
  - *business service (also application service)*
    → *external, exposed functionality of an application*
  - *infrastructure service*
    → *internal/technical, supports processing of requests*

Interface, Description and Implementation

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- Terminology clarification
  - *service ~ service interface + service implementation*
  - *WSDL service ~ service description in WSDL language*
  - *SOAP service ~ a service interface is possible to access through SOAP protocol; there is a WSDL description usually available too.*
  - *REST/RESTful service ~ service interface that conforms to REST architectural style and HTTP protocol*

Service Characteristics

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Overview

- Integrating Applications
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  - *SOAP*
  - *WSDL*
  - *WS-Addressing*
  - *REST*
  - *Comparision*

Web Service Architecture

- WSDL, SOAP and UDDI

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– *Realization of SOA*
– *Message-Oriented view*
  → *SOAP messaging (header, body)*
  → *types of messages – input, output, fault*

SOAP Protocol

- SOAP defines a messaging framework

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– *XML-based protocol*
– *a layer over transport protocols*
  → *binding to HTTP, SMTP, JMS, ...*
– *involves multiple nodes (message path)*
  → *sender, receiver, intermediary*

SOAP Message

- Envelope
  - *A container of a message*
- Header
  - *Metadata – describe a message, organized in header blocks*
    - → *routing information*
    - → *security measures implemented in the message*
    - → *reliability rules related to delivery of the message*
    - → *context and transaction management*
    - → *correlation information (request and response message relation)*
  - *WS extensions (WS-*) utilize the message header*
- Body (payload)
  - *Actual contents of the message, XML formatted*
  - *Contains also faults for exception handling*
- Attachment
  - *Data that cannot be serialized into XML such as binary data*

Endpoint

- SOAP service endpoint definition

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  - *Endpoint – a network address used for communication*
  - *Communication – request-response, SOAP messages over a communication (application) protocol*
  - *Synchronous communication – only service defines endpoint*
  - *Asynchronous communication – service and client define endpoints*

Service Invocation Example (1)

- Example service implementation
  - *A service that evaluates an expression*
  - *Uses SOAP over HTTP*
    - → *We can use standard HTTP tools to invoke the service*
- SOAP request message

`evaluate-input.xml`

```
<soap:Envelope xmlns:soap="http://schemas.xmlsoap.org/soap/envelope/">
        <soap:Body>
                <ns1:evaluateRequest
                xmlns:ns1="http://xmlns.oracle.com/mdw_examples/Evaluate/evalu
                        <ns1:x>12</ns1:x>
                        <ns1:y>18</ns1:y>
                </ns1:evaluateRequest>
        </soap:Body>
</soap:Envelope>
```

- Invoking the service using `curl`

```
curl -s -X POST --header "Content-Type: text/xml;charset=UTF-8" \
--header "SOAPAction: \"evaluate\"" --data @evaluate-input.xml \
http://mimdw.fit.cvut.cz/soa-infra/services/mdw-examples/Evaluate/evaluate_cli
```


Service Invocation Example (2)

- Invocation result

```
* About to connect() to mimdw.fit.cvut.cz port 80 (#0)
*   Trying 147.32.233.55... connected
* Connected to sb.vitvar.com (147.32.233.55) port 80 (#0)
> POST /soa-infra/services/mdw-examples/Evaluate/evaluate_client_ep HTTP/1.1
> User-Agent: curl/7.19.7 (x86_64-redhat-linux-gnu) libcurl/7.19.7 NSS/3.14.0.
> Host: mimdw.fit.cvut.cz
> Accept: */*
> Content-Type: text/xml;charset=UTF-8
> SOAPAction: "evaluate"
> Content-Length: 302
>
} [data not shown]
< HTTP/1.1 200 OK
< Date: Sun, 17 Nov 2013 11:24:59 GMT
< Server: Oracle-Application-Server-11g
< Content-Length: 569
< X-ORACLE-DMS-ECID: 004upqiWhdD0zkWVLybQ8A0005uX0004Y^
< SOAPAction: ""
< X-Powered-By: Servlet/2.5 JSP/2.1
< Content-Type: text/xml; charset=UTF-8
< Content-Language: en
```

Service Invocation Example (3)

- SOAP response message

```
<?xml version="1.0"?>
<env:Envelope xmlns:env="http://schemas.xmlsoap.org/soap/envelope/"
    xmlns:wsa="http://www.w3.org/2005/08/addressing">
  <env:Header>
    <wsa:MessageID>urn:E42018C04F7A11E3BFD5D1953058407C</wsa:MessageID>
  </env:Header>
  <env:Body>
    <evaluateResponse
        xmlns="http://xmlns.oracle.com/mdw_examples/Evaluate/evaluate">
      <result>30</result>
    </evaluateResponse>
  </env:Body>
</env:Envelope>
```


Client Implementation

- WSDL – Web Service Description Language
  - *definitions for the client to know how to communicate with the service*
    - → *which operations it can use*
    - → *data formats for input (request), output (response) and fault messages*
    - → *how to serialize the data as payloads of a communication protocol (binding)*
    - → *where the service is physically present on the network*
- Clients' environments
  - *Clients implemented in a language such as Java*
    - → *Tools to generate service API for the client, e.g. WSDL2Java*
    - → *Can be written manually too, e.g. our example in bash*
  - *Clients reside on the middleware, e.g. on an Enterprise Service Bus*
    - → *They provide added values in end-to-end communication, proxy services, SOAP intermediaries*

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  - *REST*
  - *Comparision*

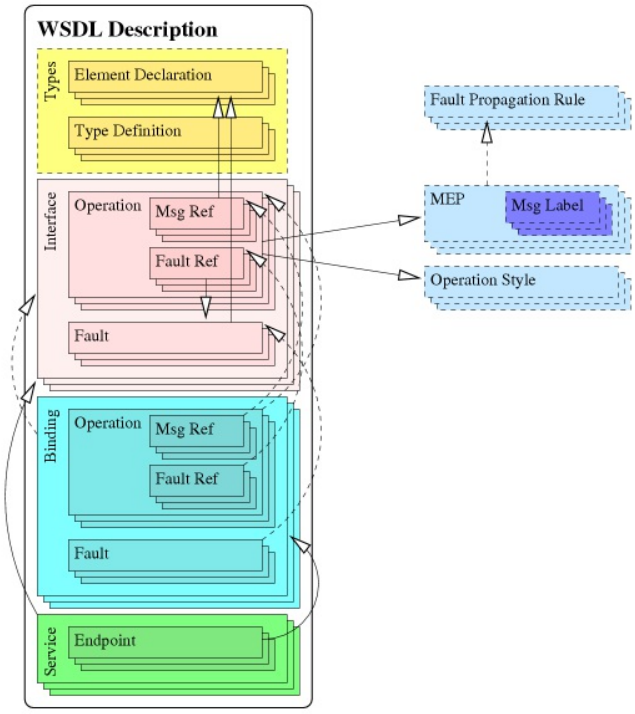
Specifications

- WSDL = Web Service Description Language
  - *A standard that allows to describe Web services explicitly (main aspects)*
  - *A contract between a requester and a provider*
- Specifications
  - *WSDL 1.1 – still widely used*
    - → *Web Service Description Language 1.1*
  - *WSDL 2.0 – An attempt to address several issues with WSDL 1.1*
    - → *SOAP vs. REST, naming, exrpessivity*
    - → *WSDL 2.0 Primer (part 0)*
    - → *WSDL 2.0 Core Language (part 1)*

WSDL Overview and WSDL 1.1 Syntax

- Components of WSDL
  - *Information model (`types`)*
    - → *Element types, message declarations (XML Schema)*
  - *Set of operations (`portType`)*
    - → *A set of operations is "interface" in the WSDL terminology*
    - → *operation name, input, output, fault*
  - *Binding (`binding`)*
    - → *How messages are transfered over the network using a concrete transport protocol*
    - → *Transport protocols: HTTP, SMTP, FTP, JMS, ...*
  - *Endpoint (`service`)*
    - → *Where the service is physically present on the network*
- Types of WSDL documents
  - ***Abstract WSDL*** *– only information model and a set of operations*
  - ***Concrete WSDL*** *– everything, a concrete service available in the environment*

WSDL Components and Dependencies



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Overview

- WS-Addressing
  - *W3C Recommendation, May 2006*
  - *A transport-independent mechanisms for web services to communicate addressing information*
  - *WSDL describes WS-Addressing as a policy attached to a WSDL binding*

```
1  <binding name="OrderProcessBinding" type="op:OrderProcess">
2      <soap:binding transport="http://schemas.xmlsoap.org/soap/http"/>
3      <PolicyReference xmlns:wsp="http://schemas.xmlsoap.org/ws/2004/09/polic
4          URI="#wsaddr_policy" wsdl:required="false"/>
```

- Two main purposes
  1. *Asynchronous communication*
     - *Client sends an endpoint where the server should send a response asynchronously*
  2. *Relating interactions to a conversation*
     - *Client and service communicate conversation ID*

Order Processing Example

- Asynchronous communication via callback, steps:
  - *Client submits an order request*
  - *Service starts processing of the order (CRM, OMS, back-office)*
  - *Client can retrieve the order status*
  - *Service responds asynchronously with an order response message*

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Interface Example (1)

- Order process complex conversation
  1. *The client invokes* `processOrder`.
  2. *The service responses back* ***synchronously*** *with order status.*
  3. *The client gets the status of order processing by invoking synchronous* `getStatus` *operation (this can be invoked serveral times).*
  4. *The service responses back* ***asynchronously*** *by invoking* `processOrderResponse` *– callback on client's interface*
- Interface implemented by the order process service
  - `getStatus` *operation must be executed in the same* ***conversation*** *as* `processOrder` *operation*

```
<portType name="OrderProcess">
    <operation name="processOrder">
        <input message="op:OrderProcessRequestMessage"/>
        <output message="op:OrderStatusResponseMessage"/>
    </operation>
    <operation name="getStatus">
        <input message="op:OrderStatusRequestMessage"/>
        <output message="op:OrderStatusResponseMessage"/>
    <operation>
<portType>
```

Interface Example (2)

- Interface implemented by the client

```xml
<portType name="OrderProcessCallback">
    <operation name="processOrderResponse">
        <input message="op:OrderProcessResponseMessage"/>
        <fault message="op:OrderProcessFaultMessage"/>
    <operation>
</portType>
```


ProcessOrder Request Message

- Client sends process order request – `processOrder`
  - *it sends addressing information where the client listens for the callback*
  - *it sends conversation ID (message ID) to start the conversation on the server*

```
> POST /soa-infra/services/mdw-examples/ProcessOrder/orderprocess_client_ep HTTP/1.1
> Host: mimdw.fit.cvut.cz
> Content-Type: text/xml;charset=UTF-8
> SOAPAction: "processOrder"
> Content-Length: 810

<soap:Envelope xmlns:soap="http://schemas.xmlsoap.org/soap/envelope/"
    xmlns:ord="http://mimdw.fit.cvut.cz/mdw-examples/cdm/order">
     <soap:Header xmlns:wsa='http://www.w3.org/2005/08/addressing'>
        <wsa:ReplyTo>
            <wsa:Address>http://192.168.94.110:2233/path/to/service</wsa:Address>
        </wsa:ReplyTo>
        <wsa:MessageID>urn:AXYYBA00531111E3BFACA780A7E5AF64</wsa:MessageID>
     </soap:Header>
     <soap:Body>
        <ord:Order>
            <ord:CustomerId>1</ord:CustomerId>
            <ord:LineItems>
                <ord:item>
                    <ord:label>Apple MacBook Pro</ord:label>
                    <ord:action>ADD</ord:action>
                </ord:item>
            </ord:LineItems>
        </ord:Order>
    </soap:Body>
</soap:Envelope>
```

GetStatus Request Message

- Client sends get status request – `getStatus`
  - *after it invokes* `processOrder` *with conversation ID (message ID)*
  - *it uses the same conversation ID for get status request too*
    → *the request will be procesessed by the running service instance*

```
1  > POST /soa-infra/services/mdw-examples/ProcessOrder/orderprocess_client_ep HTTP/1.1
2  > Host: mimdw.fit.cvut.cz
3  > Content-Type: text/xml;charset=UTF-8
4  > SOAPAction: "getStatus"
5  > Content-Length: 472
6
7  <soap:Envelope xmlns:soap="http://schemas.xmlsoap.org/soap/envelope/">
8      <soap:Header xmlns:wsa="http://www.w3.org/2005/08/addressing">
9          <wsa:RelatesTo>urn:AXYYBA00531111E3BFACA780A7E5AF64</wsa:RelatesTo>
10     </soap:Header>
11     <soap:Body>
12         <ns1:StatusRequest
13             xmlns:ns1="http://mimdw.fit.cvut.cz/mdw_examples/ProcessOrder/OrderProces
14             <ns1:process-id>18a9baec2d5ac0a2:64d155de:1425c4185f1:-7ff2</ns1:process-
15         </ns1:StatusRequest>
16     </soap:Body>
17 </soap:Envelope>
```


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REST

- REST
  - *Representational State Transfer*
- Architecture Style
  - *Roy Fielding – co-author of HTTP*
  - *He coined REST in his PhD thesis.*
    - → *The thesis abstracts from HTTP technical details*
    - → *HTTP is one of the REST implementation →* ***RESTful***
    - → *REST is a leading programming model for Web APIs*
- REST (RESTful) proper design
  - *people break principles often*
  - *See REST Anti-Patterns for some details.*
- REST and Web Service Architecture
  - *REST is a realization of WSA resource-oriented model*

REST Core Principles

- REST architectural style defines constraints
  - *if you follow them, they help you to achieve a good design, interoperability and scalability.*
- Constraints
  - *Client/Server*
  - *Statelessness*
  - *Cacheability*
  - *Layered system*
  - *Uniform interface*
- Guiding principles
  - *Identification of resources*
  - *Representations of resources and self-descriptive messages*
  - *Hypermedia as the engine of application state (HATEOAS)*

Resource

- A resource can be anything such as
  - *A real object: car, dog, Web page, printed document*
  - *An abstract thing such as address, name, etc. → RDF*
- A resource in REST
  - *A resource corresponds to one or more entities of a data model*
  - *A representation of a resource can be conveyed in a message electronically (information resource)*
  - *A resource has an identifier (URI) and a representation (XML, JSON, ...) and a client can apply an access to it (use HTTP methods)*

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Resources over Entities

- Application's data model
  - *Entities and properties that the app uses for its data*

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- URI identifies a resource within the app's data model
  - `path` – *a "view" on the data model*
    - → *data model is a graph*
    - → *URI identifies a resource using a path in a tree with some root*

Examples of Views

- View 1
  - *all customers:* `/customers`
  - *a particular customer:* `/customers/{customer-id}`
  - *All orders of a customer:* `/customers/{customer-id}/orders`
  - *A particular order:* `/customers/{customer-id}/orders/{order-id}`
- View 2
  - *all orders:* `/orders`
  - *All orders of a customer:* `/orders/{customer-id}`
  - *A particular order:* `/orders/{customer-id}/{order-id}`
- Various views represented by **URL path**

Uniform Interface

- Finite set of operations
  - *They are not dependent on the domain semantics*
  - *They only define how to manipulate with resources*
- RESTful service – HTTP methods
  - *GET – reads a resource (+ HEAD, OPTIONS)*
  - *PUT – updates or creates a resource (+ PATCH)*
  - *POST – creates a new resource*
  - *DELETE – deletes a resource*
- HTTP methods' properties
  - *a method is **safe***
    - → *It does not change the application state (it does not modify the data)*
    - → *GET, OPTIONS, HEAD*
    - → *Results can be cached by intermediaries (e.g. proxy servers)*
  - *a method is **idempotent***
    - → *Every method invocation will always have the same effect*
    - → *GET, PUT, DELETE*

Examples

- Operation `getCustomerOrder(customerId, OrderId)`
  - *Retrieves a representation of the order resource that belongs to a particular customer*

```
> GET /customers/{cutomerId}/orders/{orderId}
```

- Operation `openOrder(customerId)`
  - *Creates a new order for a customer*

```
> POST /customers/{cutomerId}/orders
< Location: /customers/{customerId}/orders/{orderId}

> GET /customers/{customerId}/orders/{orderId}
```

- Operation `addLineItem(customerId, orderId)`
  - *Adds a new item to the order*

```
> POST /customers/{customerId}/orders/{orderId}
< Location: /customers/{customerId}/orders/{orderId}/items/{itemId}

> GET /customers/{customerId}/orders/{orderId}/items/{itemId}
```

- Operation `closeOrder(customerId, orderId)`
  - *Closes the order (i.e., changes a state of the order resource)*

```
> PUT /customers/{customerId}/orders/{orderId}
> <status>CLOSED</status>
```


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Service Description

- Standards-driven
  - *Standards that define service description*
  - *They give a space for variability*
    - → *too much – big flexibility but increases complexity (~WSDL)*
    - → *limited – enforce agreement and interoperability (~REST)*
      (as long as parties correctly implement the standard)
- Languages to describe service interfaces
  - *formal – machine processable*
  - *textual – natural text description*
- Comparison of WSDL and REST models for service interfaces

Model	Standards-driven	Languages
WSDL	XML-based WSDL, XML Schema for input/output/fault messages; big space for variations (operations, exchange patterns, protocols)	WSDL+XML, textual description for rules of public processes
REST	Web Architecture, HTTP, XML Schema, JSON; little space for variations (uniform interface, statelessness, etc.)	HTML – mostly textual description, AtomPub, WADL

SOAP vs. REST

- SOAP uses input and output messages in operations
- REST uses resources and defines access on them
- SOAP can use more protocols
- REST uses HTTP
  - *Pratically, most of the SOAP implementations use SOAP over HTTP*
- Operations in SOAP are domain-specific
- HTTP operations are independent on domain semantics
  - *REST operations' semantics is defined by HTTP method + resource semantics*
- SOAP uses XML and XML Schema
- REST can use many representation formats
  - *For example, XML, JSON, YAML, etc.*
- SOAP is defined by WSDL
- REST is described in text or HTML
- Client libraries can be generated from WSDL
- REST vendor provides client libraries

SOAP vs. REST

- SOAP clients must hard-code service's public process
- REST clients can follow links in hypertext for application states
- SOAP services are used for inter/intra-enterprise integration
- REST services are used for Web APIs for integration on the Web