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SWE30003
Software Architectures and Design

Lecture 10
Service Oriented Architectures (SOA) and Web Services

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Logistical matters

- Weekly submissions – A & Q
  - Week 2: 214 and 202 out of 270;
  - Week 3: 222 and 215 out of 270;
  - Week 4: 202 and 199 out of 266;
  - Week 5: 217 and 210 out of 265;
  - Week 6: 213 and 211 out of 265;
  - Week 7: 194 and 186 out of 265;
  - Week 8: 196 and 190 out of 263;
  - Week 9: 192 and 191 out of 263;
  - Week 10: ..... ;
  - **No late submission, hurdle requirement**
- Assignment 3: released … Questions?

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Question to Answer – Week 9

Discuss the differences, advantages, and disadvantages of data-centred and data-flow architectures. Give examples where either of these two styles would be applicable.

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Required Readings - Week 10

Service Oriented Architectures (SOAP, REST, and Micro-Services)

- Michael N. Huhns, Munindar P. Singh: Service-Oriented Computing: Key Concepts and Principles. IEEE Internet Comput.9(1): 75-81 (2005) (Link to an external site)
- Stefan Tilkov: A Brief Introduction to REST. InfoQ (2007) (Link to an external site)
- Chris Richardson: Microservices: Decomposing Applications for Deployability and Scalability. InfoQ (2014) (Link to an external site)
- P Jamshidi, C Pahl, NC Mendonça, J Lewis, S Tilkov: Microservices: The journey so far and challenges ahead. IEEE Software (2018) (Link to an external site)

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Additional Resources/Readings

- Follow the links provided …
- Michael Papazoglou: *Web Services: Principles and Technology*, Pearson/Prentice Hall, 2008. Chapters 1 & 2 (and more)
- Leonard Richardson and Sam Ruby: *RESTful Web Services,* O'Reilly, 2007. Chapter 1 (and more)
- Webber, Parastatidis, Robinson: *REST in Practice*, O'Reilly, 2010 (Free download http://it-ebooks.info/book/393/)
- InfoQ (http://www.infoq.com): SOA, Web services, REST, Microservices, Enterprise Architecture, …

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Content

- **Software services & web services**
- Some concepts you need to understand
- Service oriented architecture (SOA)
- Web application architectural styles and middleware
- WS* (SOAP) approach
- REST approach
- Microservices

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The Web

- Initially, **documents** – for sharing between humans: documents on the web
  - Web Server: hosting documents
  - Web Client (Brower): reading/using documents
- Distributed
- Searchable/addressable
- Extensible/unbounded
- …

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Enterprise (Software) Systems

- Distributed
- Integration (vs greenfield decomposition)
- Business process
- Cross-organisation, cross-geography
- Large-scale
- Addressable
- Then, **software** – for sharing between machines (& between humans): software on the web
  - How? … make software a "**service**" deployable on the web

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Service / Software Service / Web Service

A (software) service – beyond component:

- Independently deployable,
- Self-contained,
- Self-describing,
- Discoverable (open),
- Composable,
- Software system (component).

Not necessarily on the Web …

web service = service + web: a service deployed on the web using web technology.

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Web Services in the Enterprise

Web Services: W3C Definition

- A Web service is a software system *identified* by a URL, whose public interfaces and bindings are *defined* and *described* ~~using XML.~~
- Its definition can be *discovered* by other software systems ?? Maybe if WADL is used
- These systems may then interact with the Web service using ~~XML based messages~~ conveyed by Internet protocols (~~not necessarily Web protocols!~~)

W3C definition does not apply to RESTful 'Web services'!

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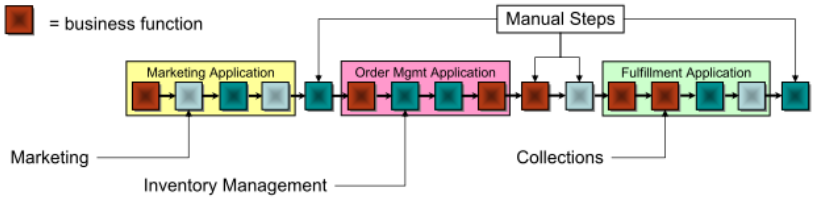
Web Services in the Enterprise – Example (business/sales process management)

Need to make an existing business process more flexible



- Business process is embedded in three or four separate applications
- Business functions are tightly coupled within applications
- Business functions have unique and proprietary interfaces, restricting re-use
- Manual steps introduce functional gaps in the process
- Process cannot be easily measured or managed
- Changes to the process are difficult to implement

Example from IBM Rational

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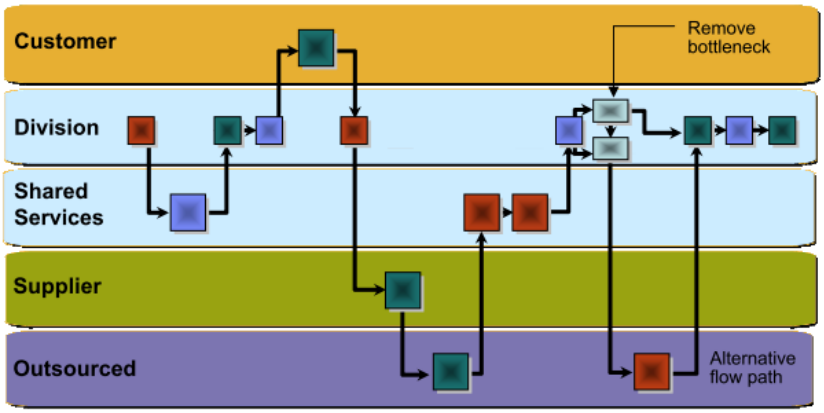
On demand flexibility: Improve the process



- Identify and remove bottlenecks in the process
- Customize the business rules and policies to better serve customers
- A more efficient business process costs less

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Web Services in the Enterprise

Advantages of Web Services for Business

- Within an enterprise (Enterprise Application Integration)
  - Accelerate and reduce the cost of integration
  - Save on infrastructure deployment & management costs
  - Reduce skill requirements
  - Improve reuse
  - Improve flexibility leads quicker response to market opportunities
- Between enterprises (e-Business integration)
  - Providing service to a company's customers
  - e.g., an Insurance company wishes to link its systems to the systems of a new institutional customer (IAG for RACV, NRMA etc)
  - Accessing services from a company's partners and suppliers
  - e.g., dynamically link to new partners and suppliers to offer their services to complement the value the company provides (Master Card from Coles)
- *Standards and common infrastructure reduce the barriers*
- *Simplicity and reuse accelerates deployment*
- *Dynamics opens new business opportunities*

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Some underlying concepts …

- Functional and non-functional properties
- Stateless and stateful services
- Granularity
- Synchronicity
- Separation of interfaces and implementation
- Loose coupling

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Some concepts …

Service Properties & State

- Functional & non-functional properties:
  - The *functional* service description details the operational characteristics that define the overall behavior of the service,
  - The *non-functional* description targets service quality attributes, e.g., service metering and cost, performance metrics (response time or accuracy), security, authorization, authentication, scalability, & availability, etc.
- Stateless or stateful services:
  - Services that can be invoked repeatedly without having to maintain context or state are called *stateless*.
    - Simple informational services are stateless.
  - Services that require their context to be preserved from one invocation to the next are called *stateful*.
    - Complex services (business processes) typically involve stateful interactions.

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Some concepts …

Granularity

- Service granularity:
  - Simple services are discrete in nature, exhibit normally a request/reply mode of operation & are of fine granularity, i.e., they are atomic in nature.
  - Complex services are coarse-grained, e.g., a PurchaseOrder. These involve interactions with other services and possibly end-users in a single or multiple sessions.
  - Coarse-grained communication implies larger and richer data structures, (viz. those supported by XML).

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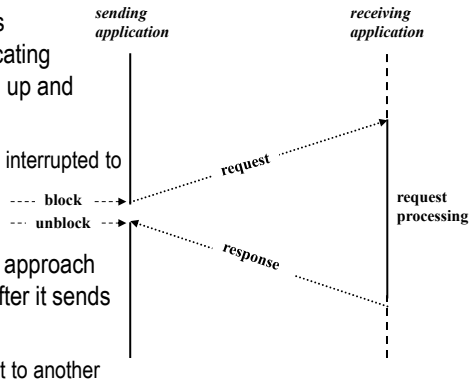
Some concepts …

Synchronous & asynchronous communication

- Synchronous communication which is synchronized between two communicating application systems, which must both up and running.
  - Execution flow at the client's side is interrupted to execute the call.
- Asynchronous communication where the caller employs a send and forget approach that allows it to continue to execute after it sends the message.
  - Here an application sends a request to another while it continues its own processing activities.



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Some concepts …

Service Interface (API) & Implementation

- The *service interface* defines service functionality visible to the external world and provides the means to access this functionality.
  - The service describes its own interface characteristics, i.e., the operations available, the parameters, data-typing and the access protocols, in a way that other software modules can determine what it does, how to invoke its functionality, & what result to expect in return.
- The *service implementation* realizes a specific service interface whose implementation details are hidden from its users.
  - Different service providers using any programming language of their choice may implement the same interface.

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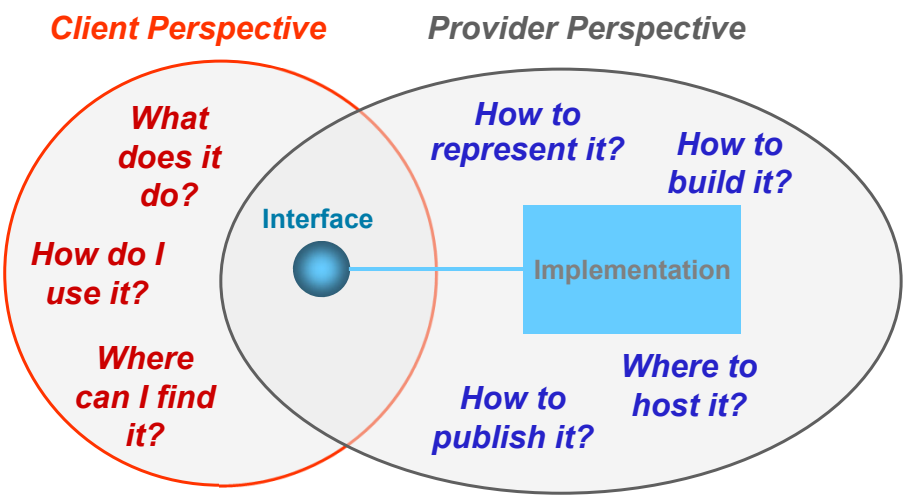
Perspectives on Web Services



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Some concepts …

Loose Coupling

Coupling indicates the degree of dependency any two systems have on each other. Some types relevant to enterprise computing include:

Type of Coupling	Problem Description	Reduced by
Functional	One module relies on the internal workings of others	Well defined interface/API describing inputs and outputs
Interface	Interfaces reflect the implementation details	Avoid detailed mandatory parameters; Use more general methods and message passing (do not get too fine-grained)
Data Structure	Data passed between modules reflects internal representations, or is over-constrained	Explicitly define formats, e.g XML in interface; Allow multiple representations e.g.mime-types; 'Vertical' standards that define semantics of messages
Temporal	Client blocked while waiting response Process over-constrained	Asynchronous messages; Explicitly define behaviour in interface e.g. abstract BPEL; Interaction via events / event-driven processes
Address/URI	Addresses change Providers change URI patterns change	Do not hard code references; Virtualise services; Use middleware directory services

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- Software services / web services
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- Web Application architectural styles and middleware
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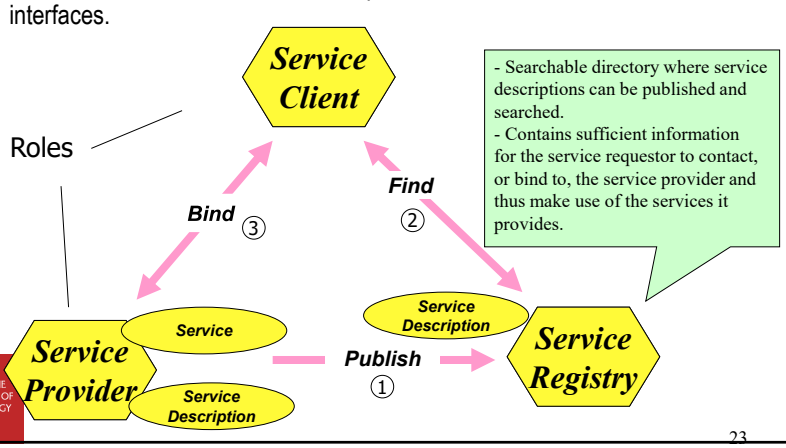
Web Architectural Styles – SOA

Service Oriented Architecture

- SOA is fundamentally of client-server style, and based on
  - the interaction between decoupled services and/or end-user applications
  - associated with messages & governed by policies.
  - services distributed in a network, via published and discoverable interfaces.



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Web Architectural Styles

Web Architectural Styles

Fundamentally, client-server…. Sub-styles:

- Method-oriented RPC (Remote Procedure Call)
  - Interface: Method, parameters
  - Interaction: synchronous request-response, request-acknowledge
- Message-oriented (aka Document style)
  - Interface: Domain specific operation, Message type
  - Interaction: Various synch/asynch, request-response, one way, solicit-notify
- Resource-oriented
  - Interface: generic CRUD, Resource id, Media type
  - Interaction: synchronous request-response, request-acknowledge
- Event-oriented
  - Interface: event type
  - Interaction: Subscribe-notify, publish-subscribe-notify

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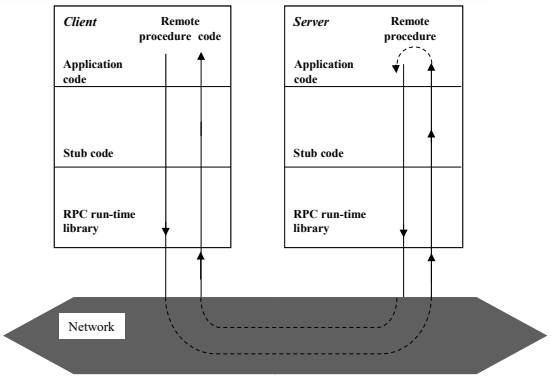
Web Architectural Styles - RPC

Remote Procedure Calls - an oo/component approach

- Object/component-oriented approach to distributed computing e.g. CORBA
- Application elements use a request/wait-for-reply (**synchronous**) model of communication.
- RPC-style programming leads to *tight coupling* of interfaces and applications.



- In an RPC environment each application needs to know the intimate details of the *interface* of every other application – the number of methods it exposes & the details of each method signature it exposes.

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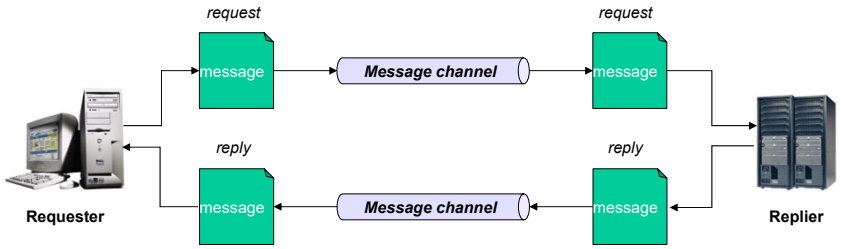
Web Architectural Styles - Messaging

Asynchronous request/reply messaging

- Most asynchronous messaging mechanisms follow the "fire-and-forget" messaging principle where the sending application can conduct its work as usual once a message was asynchronously sent.
  - The sending application assumes that the message will arrive safely at its destination at some point in time.
  - This mode messaging does not preclude the necessity to perform request/reply operations.



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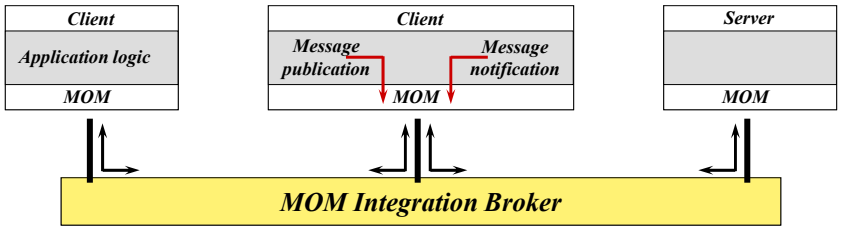
Web Architectural Styles – Message-oriented

Message-oriented Middleware

- MOM is an infrastructure that involves the passing of data between applications using a common communication channel that carries self-contained messages.
- Messages are sent and received asynchronously.
- The messaging system (integration broker) is responsible for managing the connection points between clients & for managing multiple channels of communication between the connection points.



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Web Architectural Styles – Resource-oriented

Resource-oriented Architecture

- Resources exposed on a network
- Resources uniquely identified
- Application is a series of *linked* resource updates between clients and servers
- Resource examples
  - something returned by an SQL query
  - text or media file
  - a transaction
  - a web site
  - a downloadable program
  - ...

CRUD: Create, Read, Update, Delete

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Web Architectural Styles – Event-oriented

EDA – Event Driven Architectures

- Event emitters and consumers
- Promotes further decoupling of business processes
- Same event can be consumed by a number of other (possibly anonymous) processes.
- Event emitter does not care who consumes the event
- Fits well with declarative rules based approach to defining business processes (as distinct from an imperative activity based approach as in BPEL (ie, the WS composition language))

http://www.infoq.com/presentations/SOA-Business-Autonomous-Components

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How does SOA help achieve loose coupling?

Type of Coupling	Problem Description	Reduced by
Functional	One module relies on the internal workings others	Well defined interface/API describing inputs and outputs
Interface	Interfaces reflect the implementation details	Avoid detailed mandatory parameters; Use more general methods and message passing (do not get too fine-grained)
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Web Application (Standard) Approaches

- Web Service Standards – "WS*"
  - SOAP message and WSDL interface descriptions
  - Stack of other WS* Standards (UDDI, WS-Transaction, WS-Security, …)
  - Service composition and orchestration
    - e.g. BPEL – Business Process Execution Language
  - Middleware based - many frameworks and technologies being developed
    - e.g. Web Sphere, JBoss, Apache Axis, WSO2, …
- REST– based (**Re**presentational **S**tate **T**ransfer)
  - Light-weight approach, inter-operability based on HTTP
  - View machine clients like automatic 'browsers'
  - Resource/data centric
  - http://www.infoq.com/presentations/The-Counterintuitive-Web
- Microservices: functions (data) as service …

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Technologies for Web Architectures

Different Web 'protocol patterns' suit various architectural styles

Architectural Style

- RPC
- Message-oriented
- Resource-oriented
- Event-oriented

Standard Protocol patterns

- **WS* (SOAP, WDSL, …)**
- **RESTful / Microservices**

Note: There are many Web applications that do not follow these standard approaches

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????

Which architectural style is the most "decoupled"?

Which architectural style is the hardest to change / evolve? a.k.a "Fragile"

Method-oriented

Message-oriented

Resource-oriented

Event-oriented

Coupling of reference address, interface, implementation, behaviour, …

Fragility - What breaks when something is changed?

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WS* (SOAP) Architectures

- Evolution of the enterprise computing middleware approach
  - CORBA, MoM, ESB
- * = Standards needed, so enterprise system can interoperate
  - Description, Discovery, QoS, Security, Transactions, etc.
- "Big" Web Services – many big vendors developing middleware products to support standards based approach
  - IBM, BEA, Microsoft, JBoss, WSO2, ...
- An application protocol (**SOAP**), views/uses **HTTP** as a ***transport protocol*** to carry SOAP messages
  - Although almost always HTTP, such SOAP services can use other transports i.e. they are not necessarily "Web" services.
- **Calls/Messages** defined and exchanged by machine using **XML Schema**

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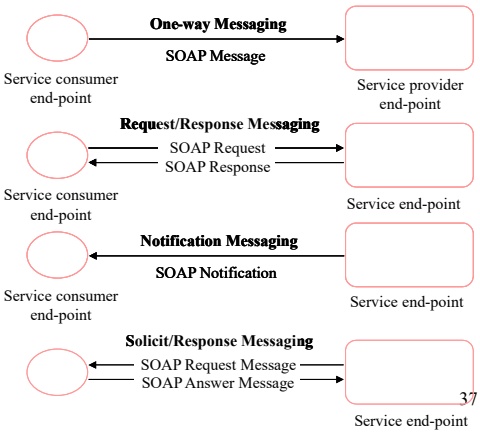
Message Exchange Patterns

- Four common types of operations that represent possible combinations of input and output messages
- Support for both ***push*** and ***pull*** interaction models at the interface level.
- Not just ***client-server request - response***



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Web Services and Messaging

- WS* approach defines a standard messaging format called **SOAP** (originally defined as Simple Object Access Protocol)
- Can use multiple application protocols for transport:
  - HTTP, HTTPS, SMTP, ...
- **WSDL** (service interface description) is designed to work with SOAP

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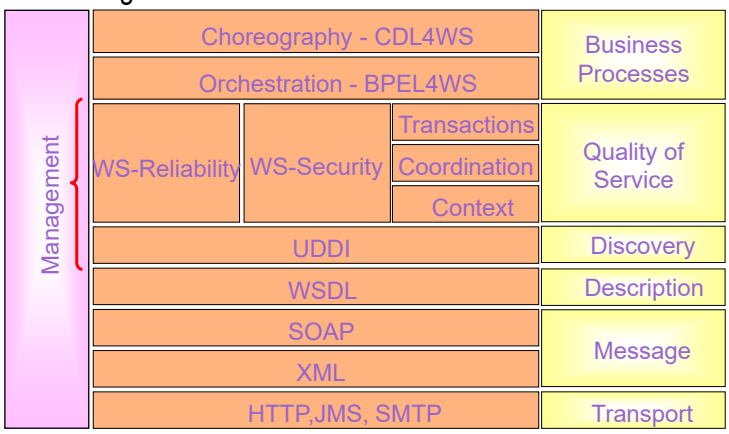
WS Technology Stack implementation of SOA

- Web services are implemented by a collection of several related technologies & standards.



WS* Standards are defined in XML Schema

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WSDL – Web Service (Interface) Description

- Interface descriptions
- Structure of WSDL documents
- Abstract part
- Concrete part

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An example: in programming language style (illustration only)

```
Service StokeQuote {
  //types
  struct TradePriceRequestType {              //RPC
        string tickerSymbol;
  };
  struct TradePriceType{
        float price;
  };

  Interface StokeQuotePortType {
        void GetLastTradePrice
              (in TradePriceRequestType   GetLastTradePriceInput,
               out TradePriceType   GetLastTradePriceOutput);
        … …
  };
};
```

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Web services in context

- For "use of service" to happen, the consumer needs to understand and the provider needs to tell:
  - What the service can do – functionality: (by WSDL …)
  - How good the service can do it – qualities: (partly by other WS standards …)
  - How to use the service – usage: (partly by WSDL …)
- How can we achieve this "understanding":
  - Self-describing Web service interface (in WSDL, and …)
  - Platform independent (in XML)
  - Provider / Registry tells …
  - Consumer understands …

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Web Services Description Language

- The Web Services Description Language (WSDL) is the XML-based service representation language used to describe the details of the complete interfaces exposed by Web services and thus is the means to accessing a Web service.
  - For instance, neither the service requester nor the provider should be aware of each other's technical infrastructure, programming language or distributed object framework (if any).
- WSDL is a platform-independent description meant to be created and read by machines (not hand-written)
  - Generated from code objects *or* ide design tools

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Structure of WSDL documents

- WSDL documents can be separated into distinct sections:
  - The ***service interface definition*** describes the general web service interface structure. This contains all the operations supported by the service, the operation parameters and abstract data types.
  - The ***service implementation part*** binds the abstract interface to a concrete network address, to a specific protocol and to concrete data structures.
- This enables each part to be defined separately and independently, and **reused** by other parts
- The combination of these two parts contains **sufficient information** to describe to the service requester how to invoke and interact with the web service at a provider's site.

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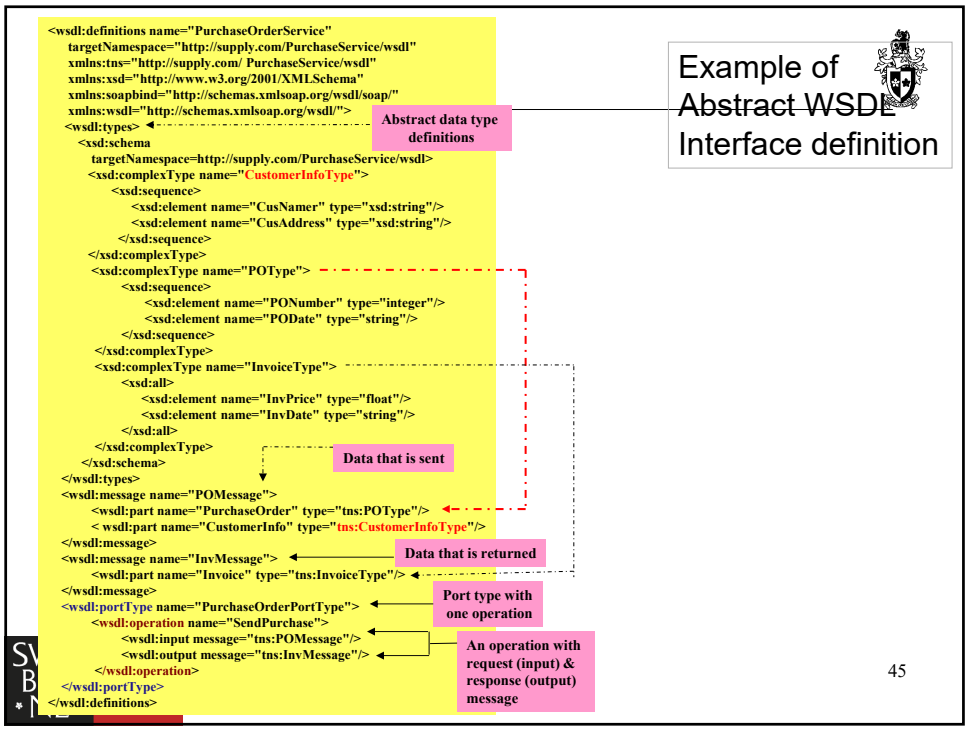
Example of Abstract WSDL Interface definition
Abstract data type definitions
Data that is sent
Data that is returned
Port type with one operation
An operation with request (input) & response (output) message
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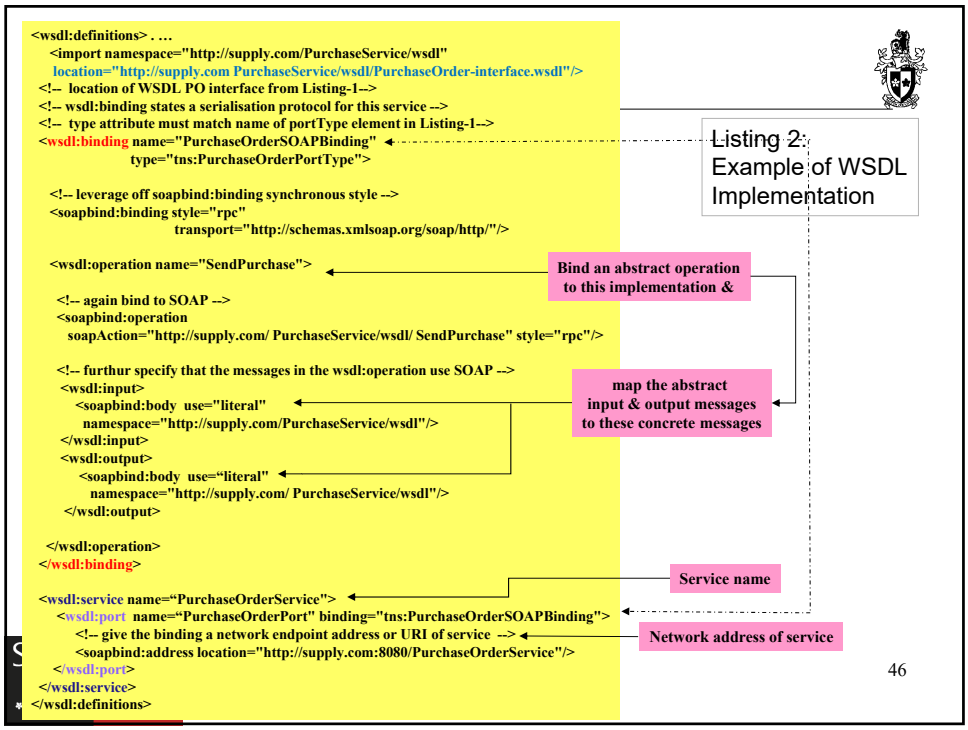
Listing 2: Example of WSDL Implementation
Bind an abstract operation to this implementation &
map the abstract input & output messages to these concrete messages
Service name
Network address of service
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SOAP (Simple Object Access Protocol)

- an XML-based communication protocol for exchanging messages between computers, regardless of their operating systems or programming environments
- Overcomes the problems of conventional distributed object models
  - ☐ Does not require uniform object model across applications
  - ☐ Loose-coupling/strong encapsulation for applications (no internal object ref)
  - ☐ Designed to work with WSDL http://schemas.xmlsoap.org/wsdl/
  - ☐ Use HTTP - work over firewalls or proxy servers, e.g, most firewalls are configured to allow Hypertext Transfer Protocol (HTTP) to pass across

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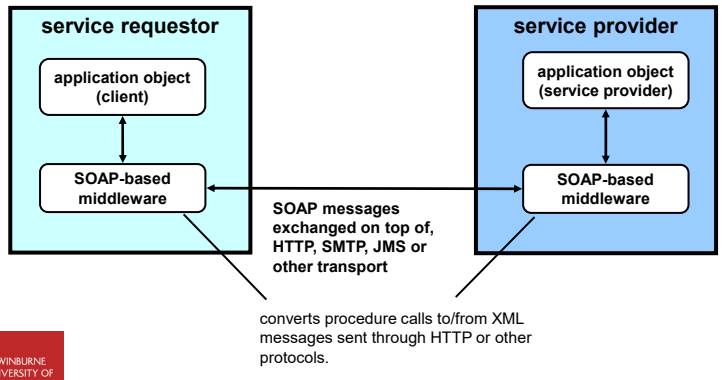
What is SOAP?

- The standard messaging protocol used by Web services
- Primarily for inter-application communication ('server' to 'server')
- Use an XML-based scheme for encoding message (request and response) data
- Typically uses HTTP as a means for transport



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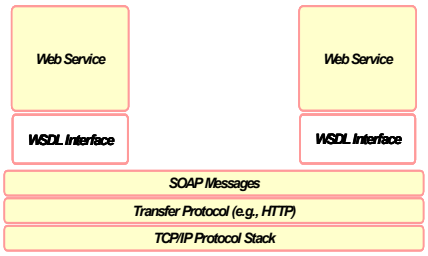
SOAP as a lightweight protocol

- SOAP is a lightweight protocol that allows applications to pass messages and data back and forth between disparate systems in a distributed environment enabling remote method invocation.



- Lightweight: SOAP protocol possesses only two fundamental properties. It can :
  - send and receive HTTP (or other) transport protocol packets, and
  - process XML messages.
- Supports both RPC and message (document) style interaction
- This can be contrasted with the heavyweight protocols such as ORPC protocols. Designed to work with these.

Guiding principle:
"First invent no new technology"
http://msdn.microsoft.com/en-us/magazine/bb985060.aspx

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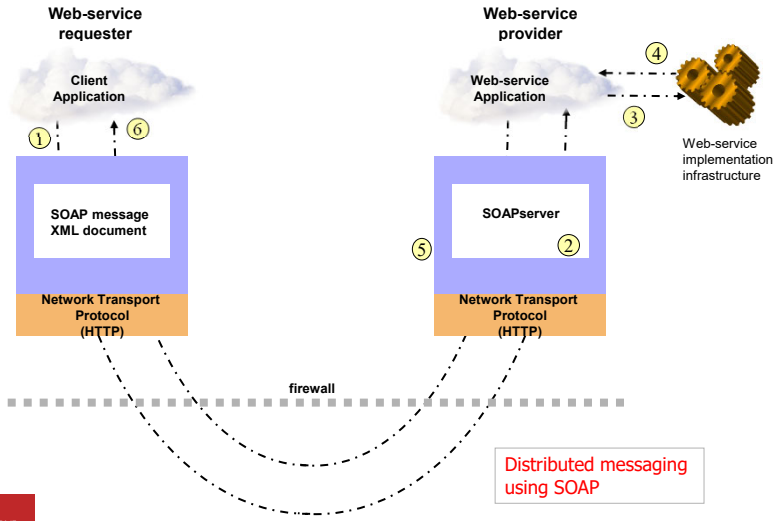
Distributed messaging with SOAP



Distributed messaging using SOAP

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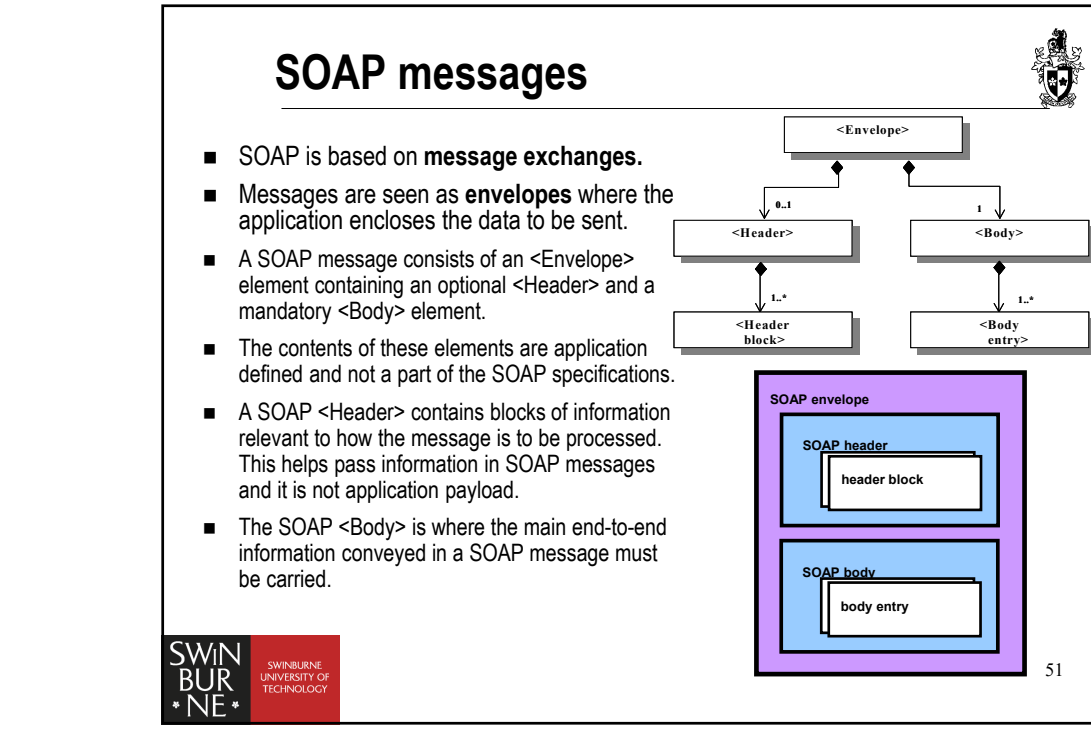
SOAP messages



- SOAP is based on **message exchanges.**
- Messages are seen as **envelopes** where the application encloses the data to be sent.
- A SOAP message consists of an <Envelope> element containing an optional <Header> and a mandatory <Body> element.
- The contents of these elements are application defined and not a part of the SOAP specifications.
- A SOAP <Header> contains blocks of information relevant to how the message is to be processed. This helps pass information in SOAP messages and it is not application payload.
- The SOAP <Body> is where the main end-to-end information conveyed in a SOAP message must be carried.

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Example of RPC-style SOAP body

```
<env:Envelope
 xmlns:SOAP="http://www.w3.org/2003/05/soap-envelope"
 xmlns:m="http://www.plastics_supply.com/product-prices">
    <env:Header>
        <tx:Transaction-id
            xmlns:t="http://www.transaction.com/transactions"
             env:mustUnderstand='1'>
                512
        </tx:Transaction-id>
    </env:Header>
    <env:Body>
        <m:GetProductPrice>
           <m:product-id>  450R6OP  </m:product-id >
        </m:GetProductPrice >
    </env:Body>
</env:Envelope>
```

Corresponding method invocation in programming language style:

GetProductPrice("450R6OP");

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Example of RPC-style SOAP response message

```
<env:Envelope
 xmlns:SOAP="http://www.w3.org/2003/05/soap-envelope"
 xmlns:m="http://www.plastics_supply.com/product-prices">
    <env:Header>
      <--! - Optional context information -->
    </env:Header>
    <env:Body>
      <m:GetProductPriceResponse>
         <m:product-price>   134.32  </m:product-price>
      </m:GetProductPriceResponse>
    </env:Body>
</env:Envelope>
```

Corresponding method invocation in programming language style:

134.32

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Implementing WS* Web Services

- Design and implement an OO software system
- Generate WSDL interface
- Deploy service
- Publish WSDL interface (API)
- Other services/systems use

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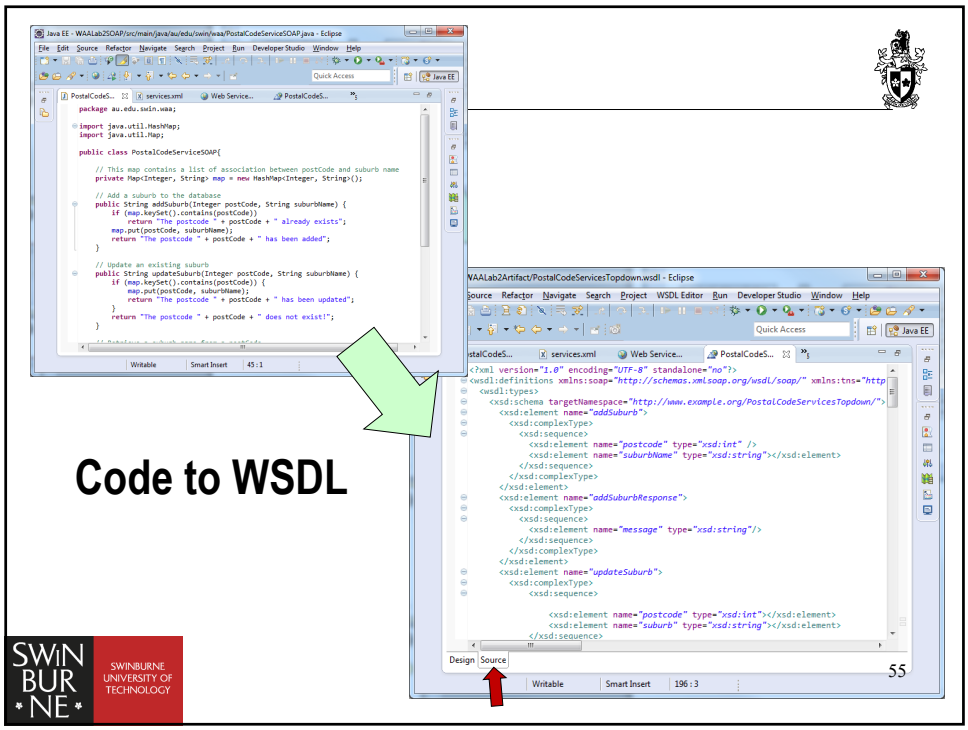
Code to WSDL
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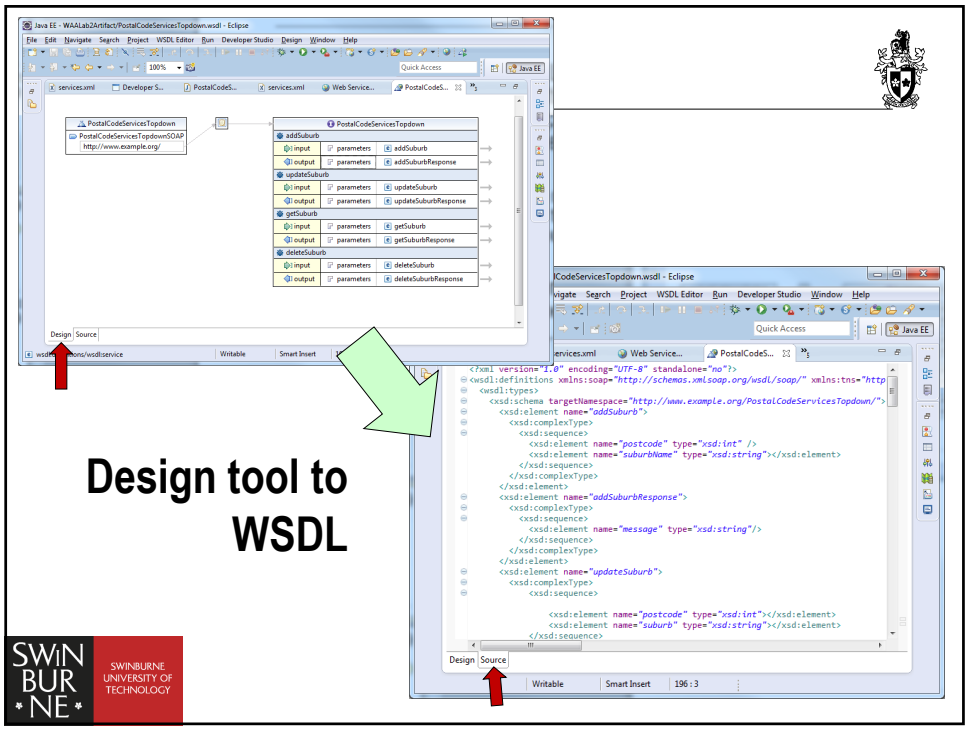
Design tool to WSDL
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Content

- Software services / web services
- Some concepts you need to understand
- Service oriented architecture (SOA)
- Web application architectural styles and middleware
- WS* (SOAP) approach
- **REST approach**
- Microservices

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REST based architectures

- Purist and Hybrid approaches
- RESTful Web Services (purists)
  - HTTP as an *application protocol*
  - 'Resource-oriented' architecture
    - Everything referenced as a URI
  - HTTP 'verbs' have specific meaning → uniform CRUD interface
    - **GET** – retrieve information on a resource
    - **POST** – Create a new resource
    - **PUT** – Modify an existing resource
    - **DELETE** – Delete an existing resource
    - Also use **HEAD** (get meta-data), **OPTIONS** (check which verbs supported)
  - E.g. Most Yahoo's web services, Amazon's S3 (Simple Storage Service)

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REST – a resource-oriented architecture

- **Re**presentational **S**tate **T**ransfer
- Expose resources to clients on a networked system
  - Everything referenced as a URI
- Client-server architecture
- Application state is driven by the client's updating resources across the resource network *using links* provided by the server(s)
  - *"Hypermedia is the engine of state"*
- What is a resource? Not just relational XML infosets
  - something returned by an SQL query, text file, media file, a transaction, a queue, a web site, a downloadable program, ...
- REST is a style or "design guideline" – *not* a standard

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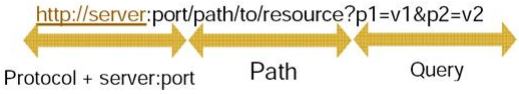
REST – Resource identification

- All resources (services) referenced by a unique URI
  - e.g. GET



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REST Methods – strict HTTP

- RESTful Web Services (purist)
  - HTTP as an *application protocol*
  - HTTP 'verbs' have specific meaning → uniform CRUD interface for keeping resources updated:
    - **GET** – retrieve information on a resource
    - **POST** – Create a new resource
    - **PUT** – Modify an existing resource
    - **DELETE** – Delete an existing resource
    - Also use **HEAD** (get meta-data), **OPTIONS** (check which verbs supported)
  - E.g. Most Yahoo's web services, Amazon's S3 (Simple Storage Service)

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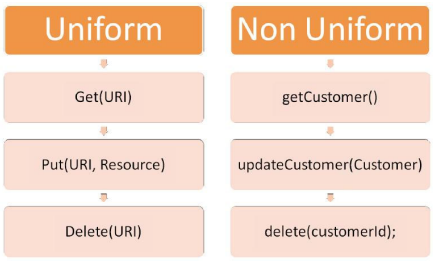
REST presents a uniform interface



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Graphic courtesy of CSE UNSW

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REST Example

- Step 1 : Client asks for a list of parts
  - Getting the list of parts

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Graphic courtesy of CSE UNSW

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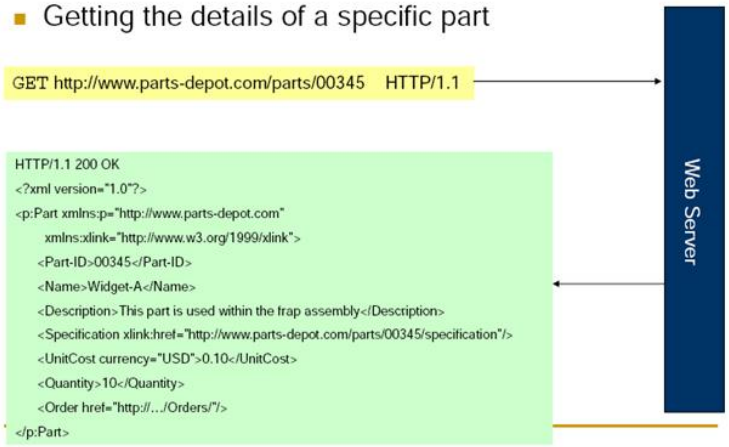
REST Example

- Step 2. Given the part number ….
  - Getting the details of a specific part



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Graphic courtesy of CSE UNSW

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REST example

- Placing an order (i.e. creating a new order resource)
  - Placing an order

Graphic courtesy of CSE UNSW

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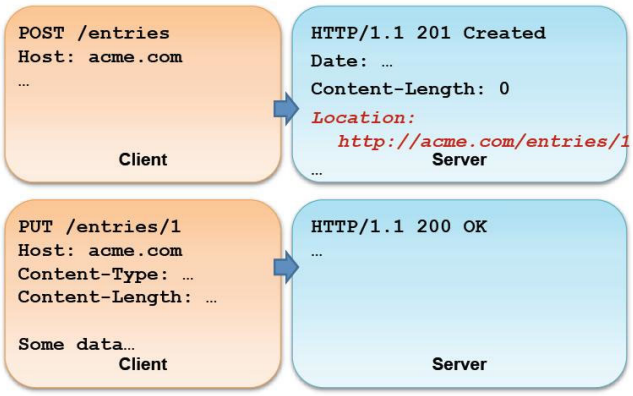
REST example

- Updating a resource



Graphic courtesy of CSE UNSW

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Implementing REST Web Services

- Design and implement an OO software system (main class with CRUD)
- Deploy service (with API)
- Publish API interface
- Other services/systems use

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WS* vs RESTful?

	WS*	RESTful
Easy to understand approach	Complex	Simpler
Easy to implement	Depends...	Depends...
Interface definition	Specific	Generic
Interface Contracts	Yes - WSDL	Not yet (WADL?)
Specific to the Web	No	Yes
Implementation of SOA	Yes	Not really
Scalable	Hmmm....	Yes
Addresses enterprise concerns (e.g. transactions, end-end security)	Yes	Not directly
Orientation	Method	Resource

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Microservices

An architectural approach - Some perspectives

- A type of SOA
- Functional perspective
  - Business functionality/capability oriented partition
- Modular
- Small (capability) & light-weight (technology: REST)
- Self-contained & deployable
- Oriented towards development, delivery & deployment
- Scalable
- Granularity vs Complexity …

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A compromise: (system) performance v (design) modularity 70

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Question to Answer – Week 10

The spec of the "Question to Answer" is under the corresponding assignment setup, which will be released after this lecture.

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Required Reading Week 11

- Len Bass, Paul Clements, and Rick Kazman, *Software Architecture in Practice* (**4th Edition**), Addison-Wesley, 2021, Chapter 22 (Documenting an Architecture).
  OR,
- Len Bass, Paul Clements, and Rick Kazman, *Software Architecture in Practice* (**3rd Edition**), Addison-Wesley, 2013, Chapter 18.

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