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SWE30003 Software Architectures and Design

Lecture 10
Service Oriented Architectures (SOA) and Web Services

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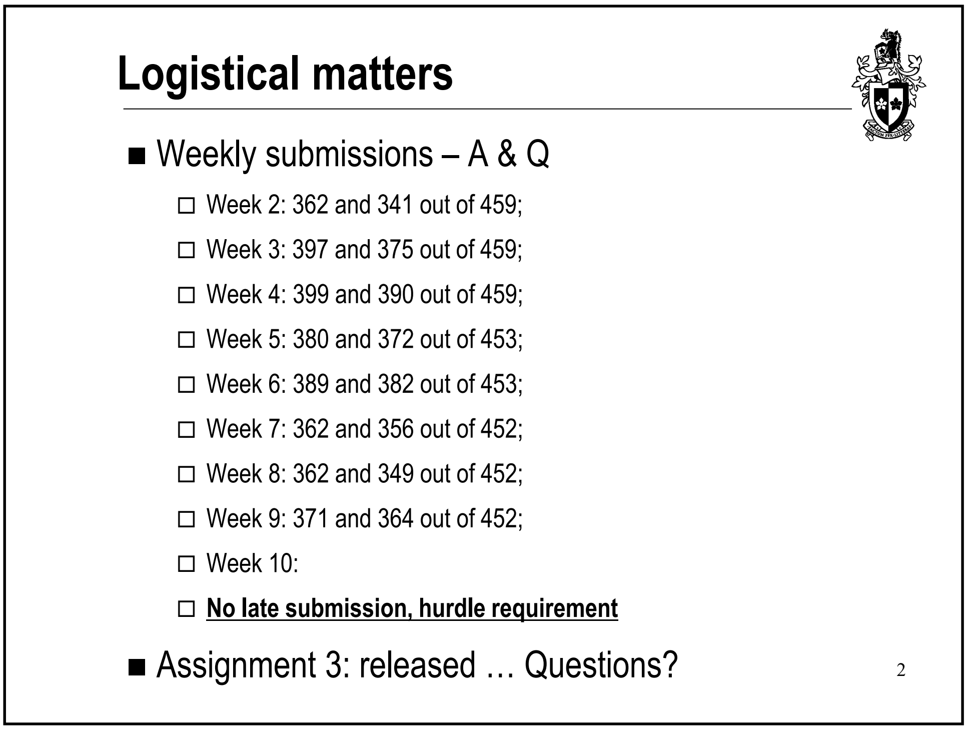

Logistical matters

- Weekly submissions – A & Q
  - □ Week 2: 362 and 341 out of 459;
  - □ Week 3: 397 and 375 out of 459;
  - □ Week 4: 399 and 390 out of 459;
  - □ Week 5: 380 and 372 out of 453;
  - □ Week 6: 389 and 382 out of 453;
  - □ Week 7: 362 and 356 out of 452;
  - □ Week 8: 362 and 349 out of 452;
  - □ Week 9: 371 and 364 out of 452;
  - □ Week 10:
  - □ **No late submission, hurdle requirement**
- Assignment 3: released … Questions?

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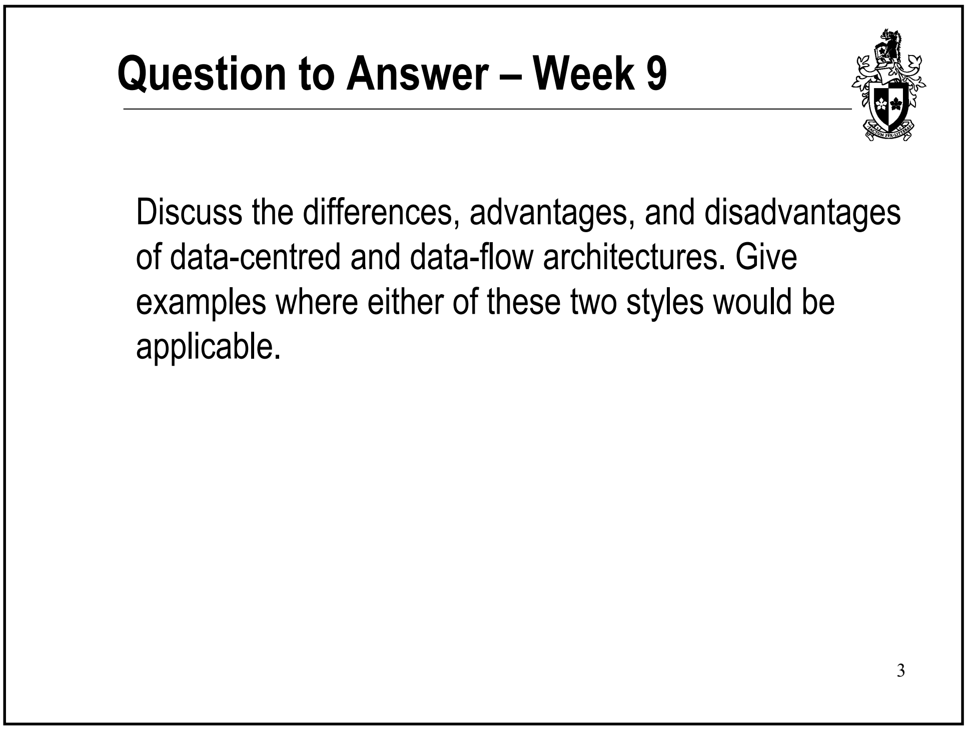

Question to Answer – Week 9

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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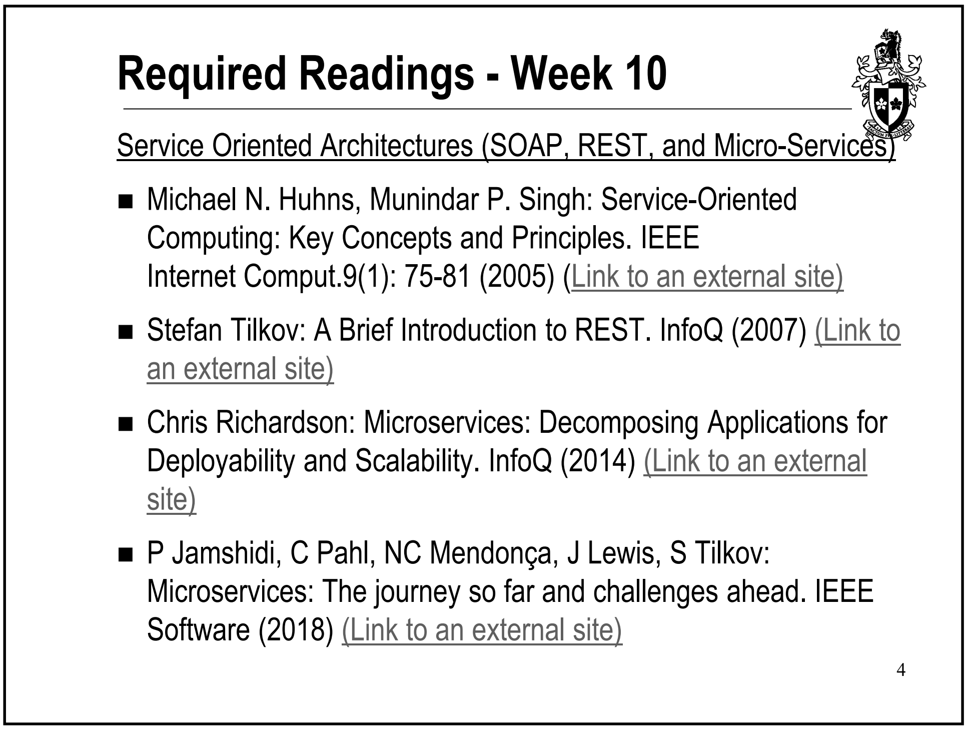

Required Readings - Week 10

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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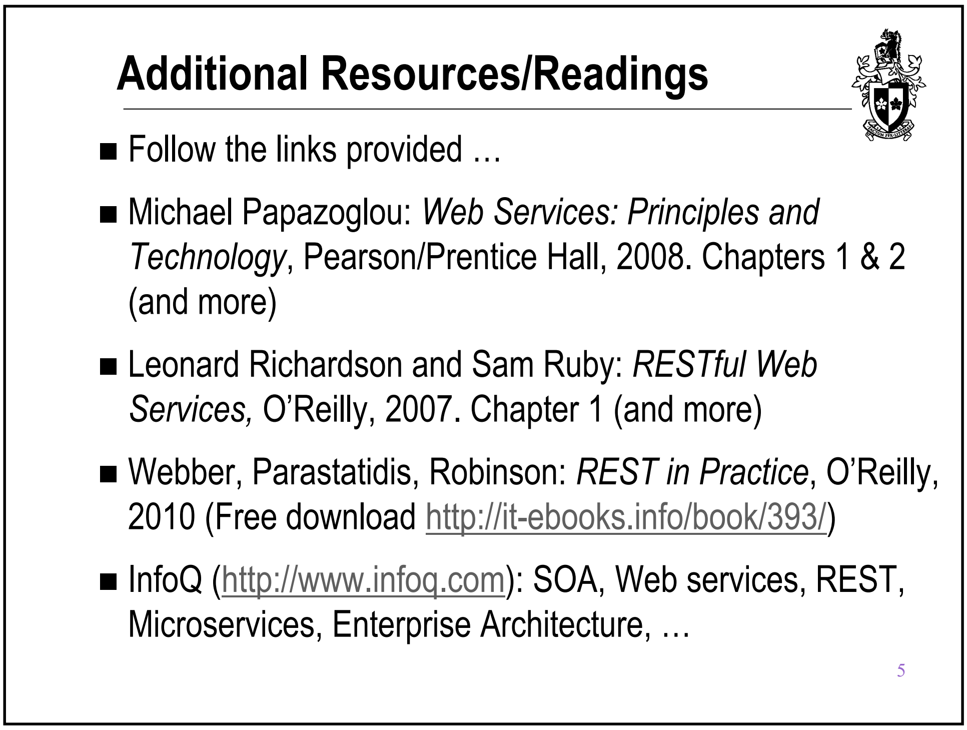

Additional Resources/Readings

- 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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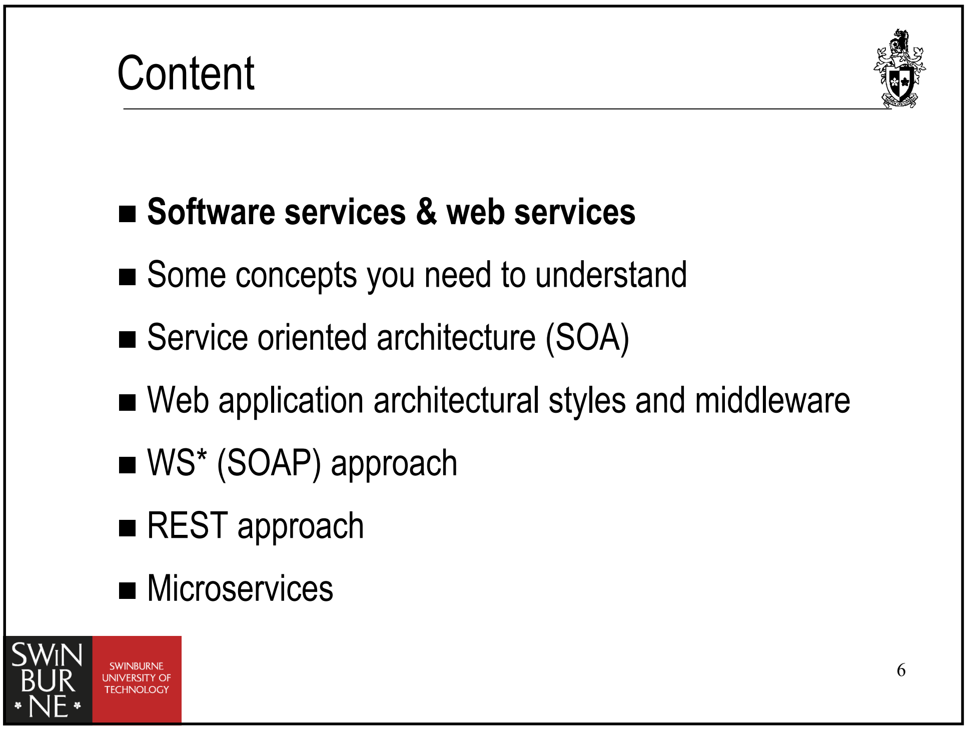
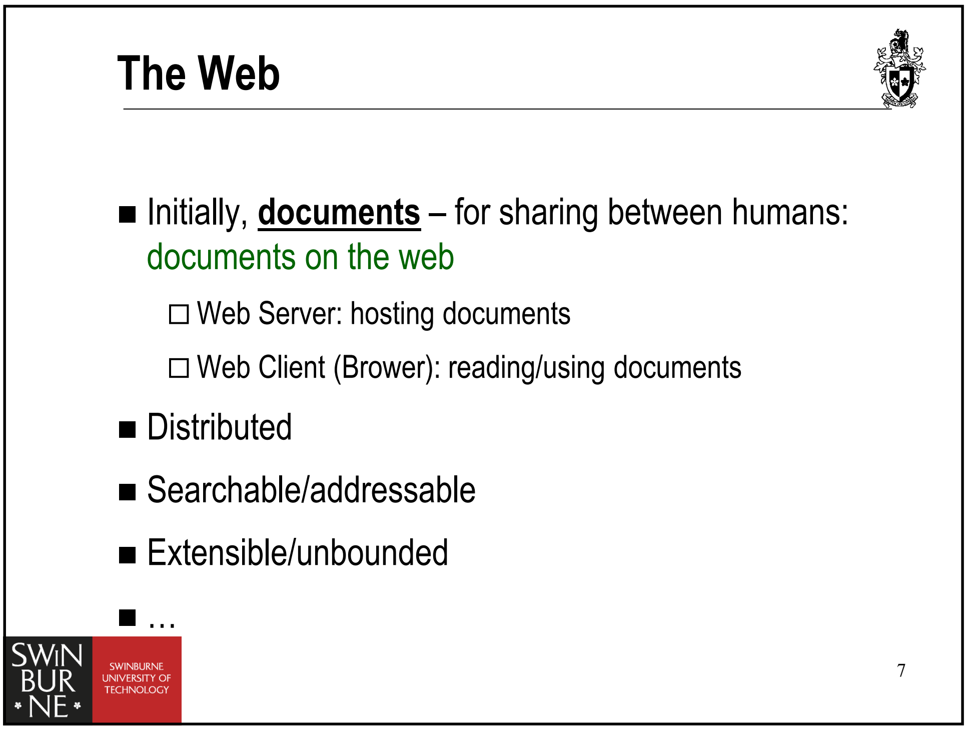


Content

- **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

6

6



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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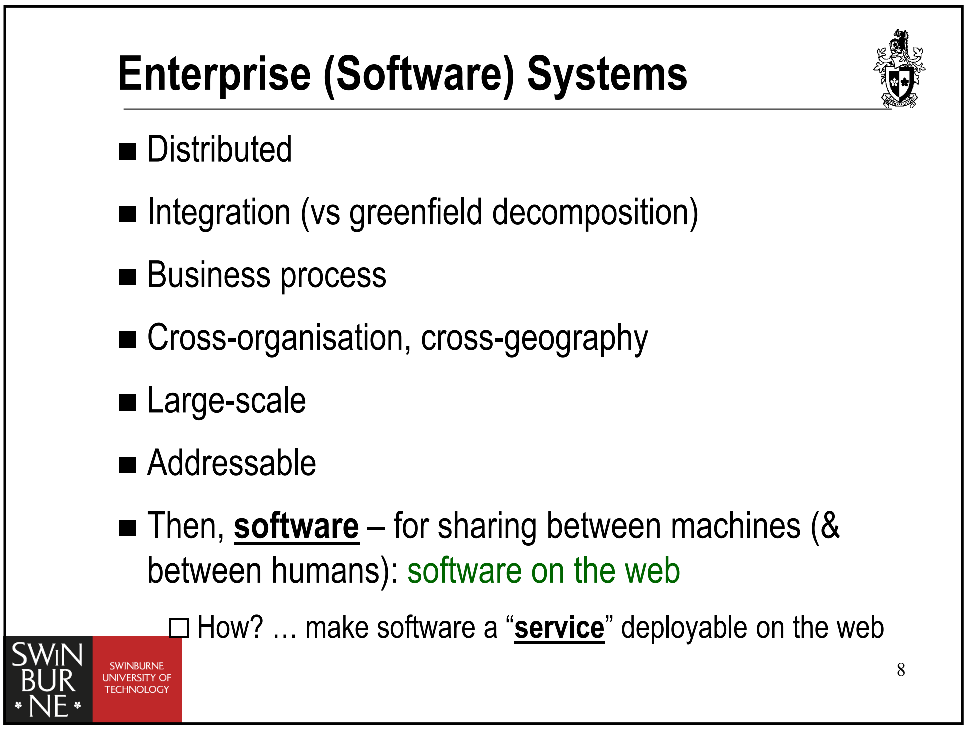

Enterprise (Software) Systems

- 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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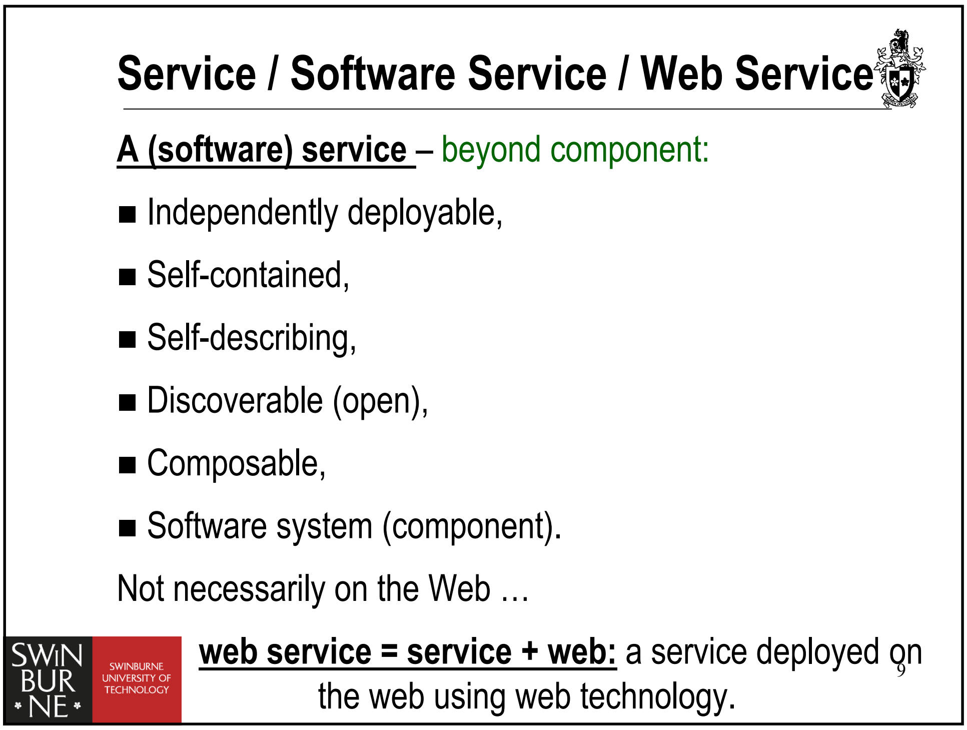

Service / Software Service / Web Service

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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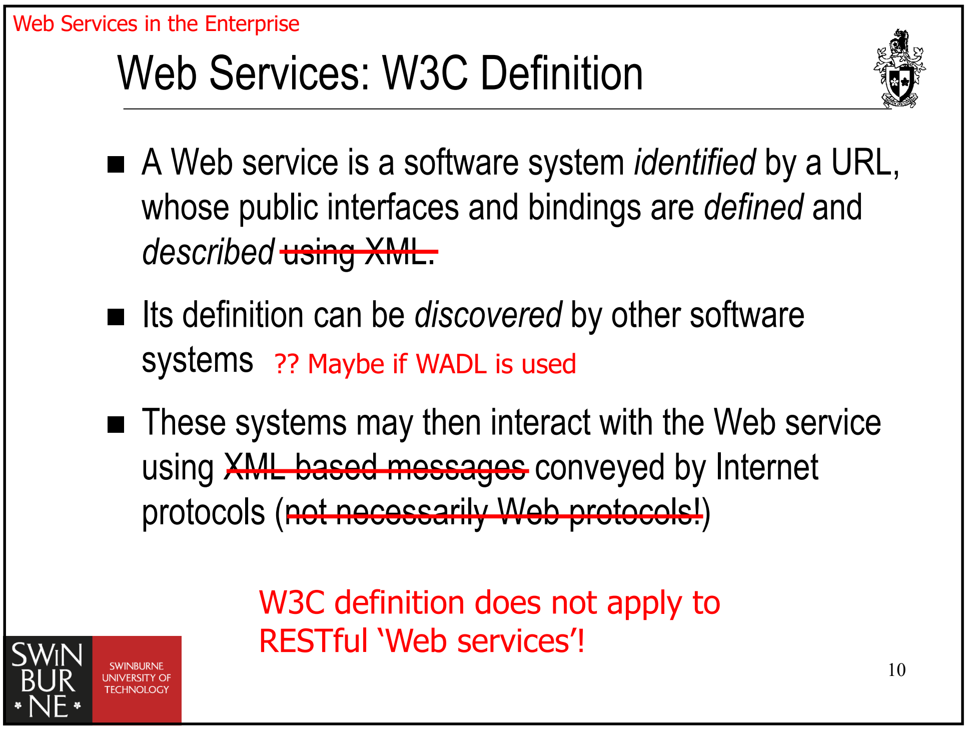

Web Services in the Enterprise

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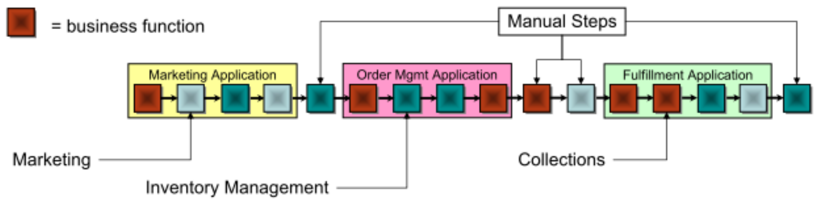
Web Services in the Enterprise – Example (business/sales process management)

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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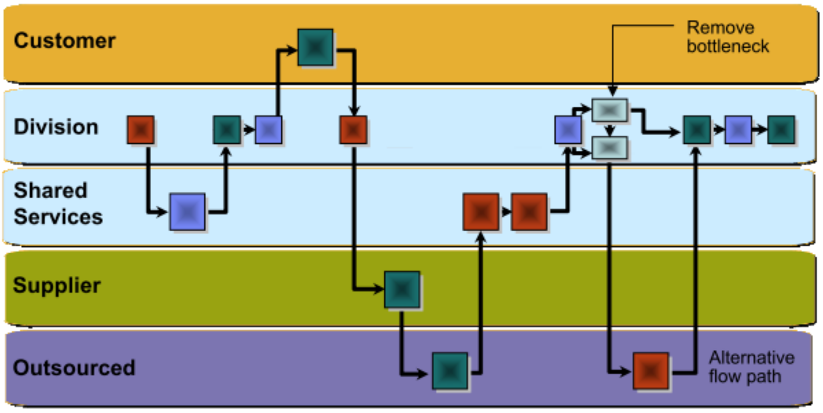
On demand flexibility: Improve the process



- 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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12

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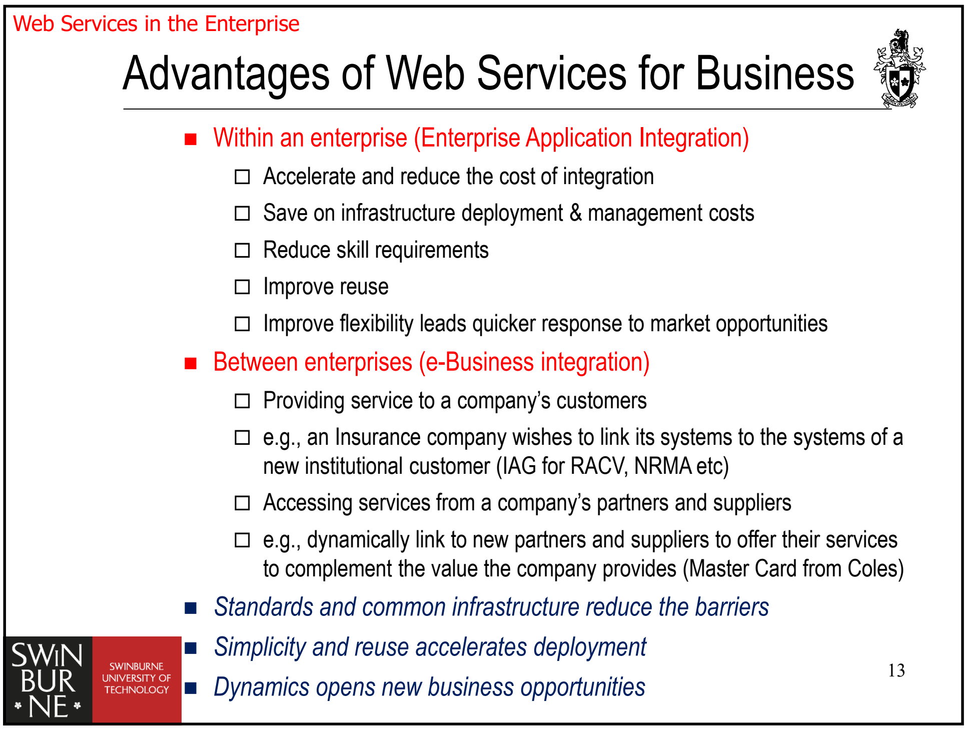

Web Services in the Enterprise

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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13

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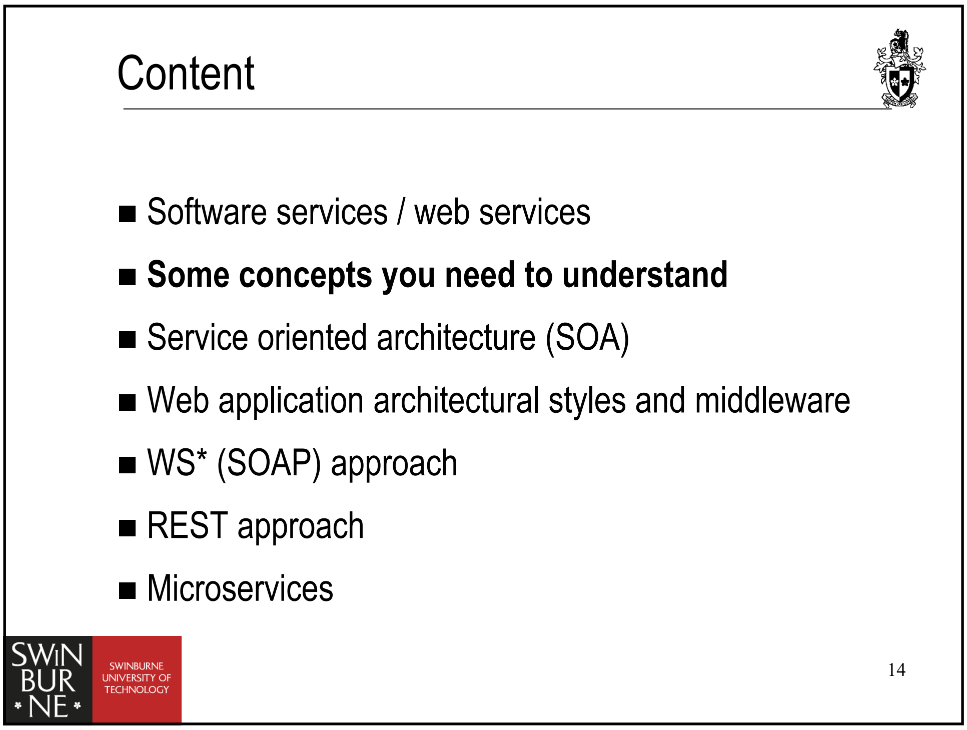

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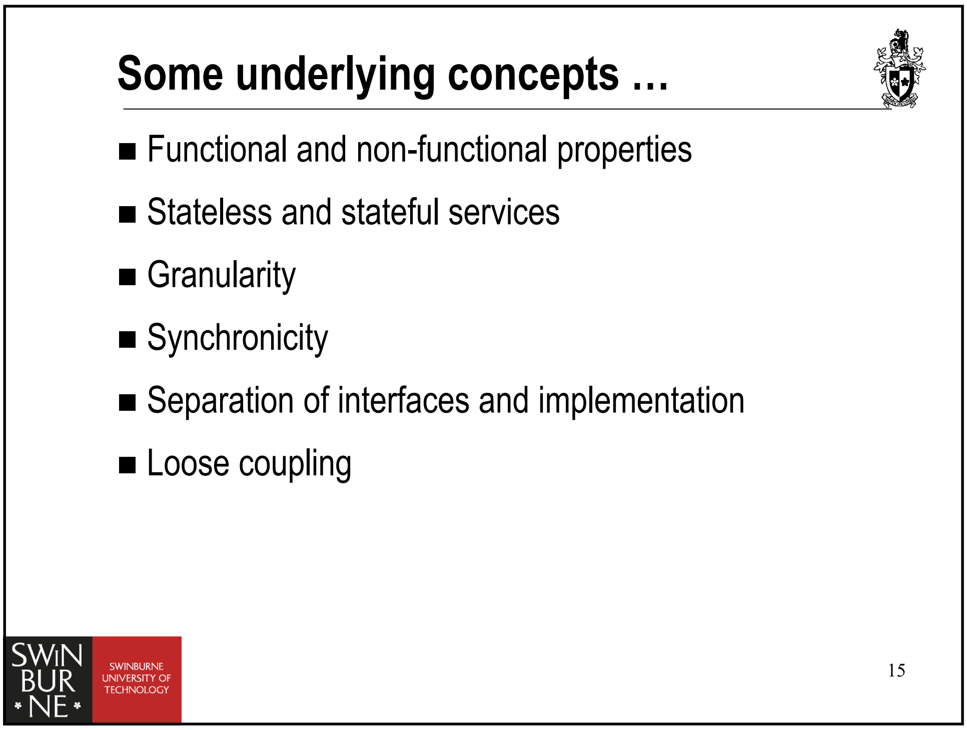
14

14

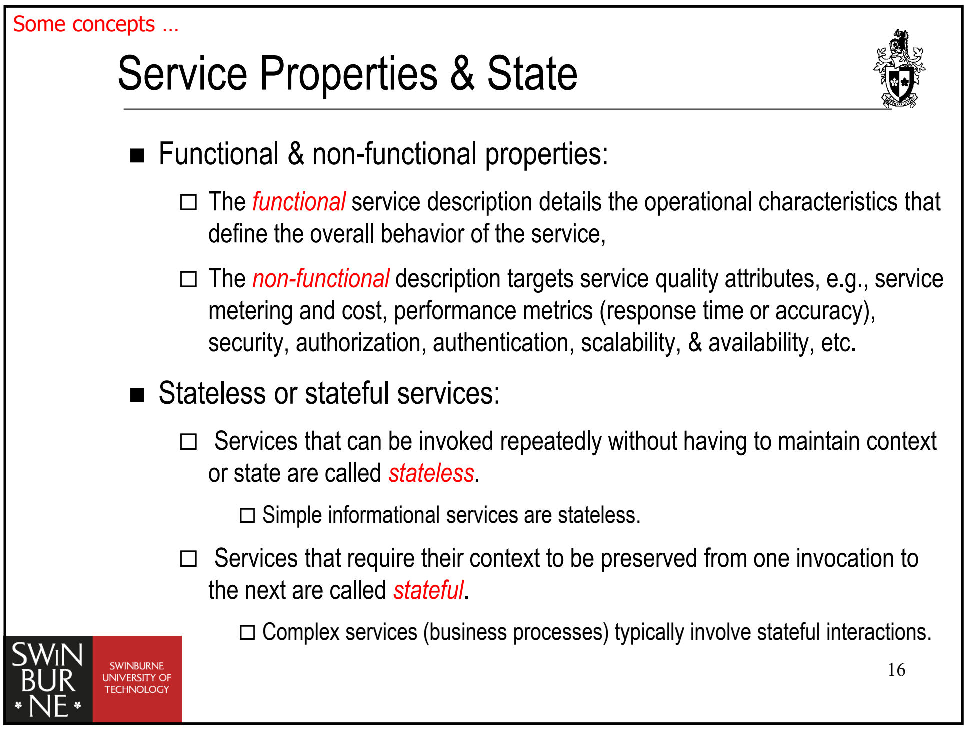


Some underlying concepts …

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

15

15



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.

16

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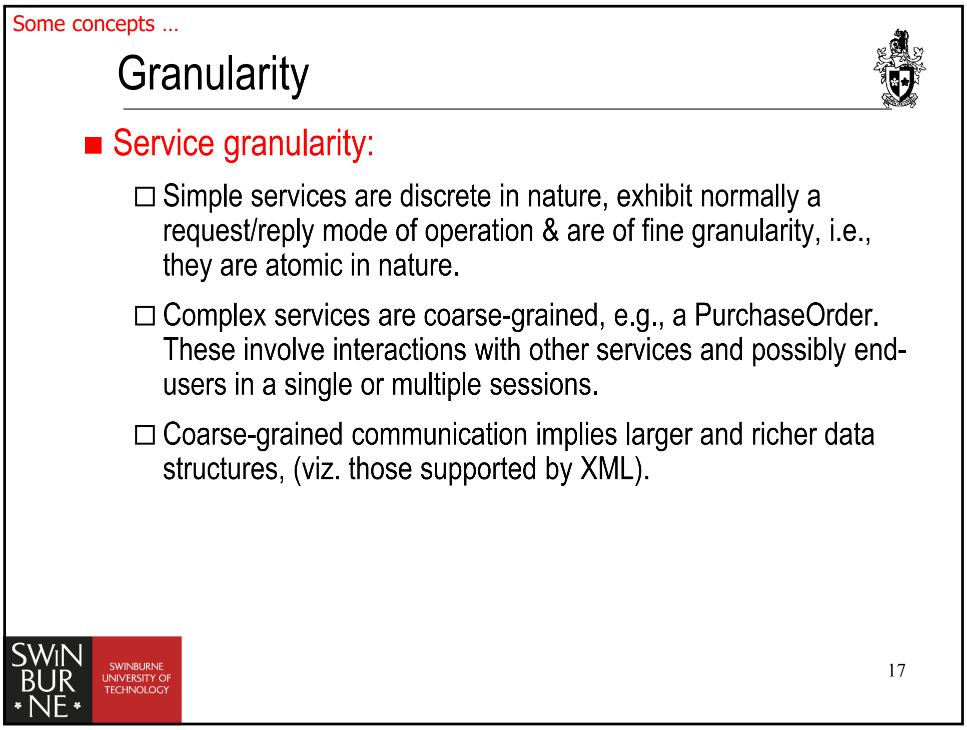
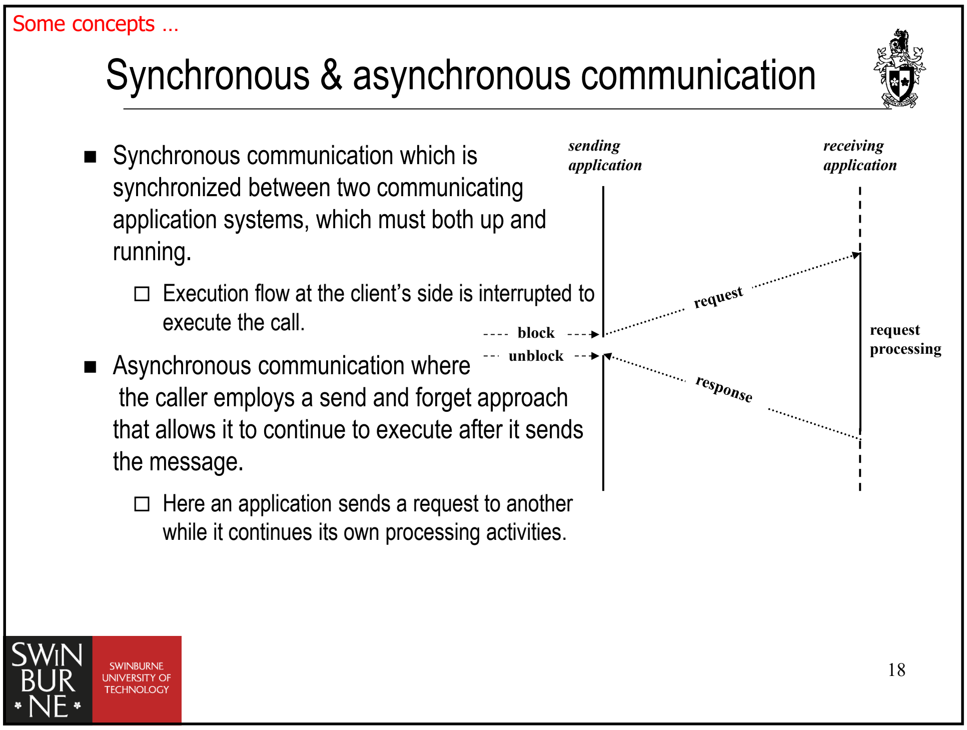


Some concepts …

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).

17

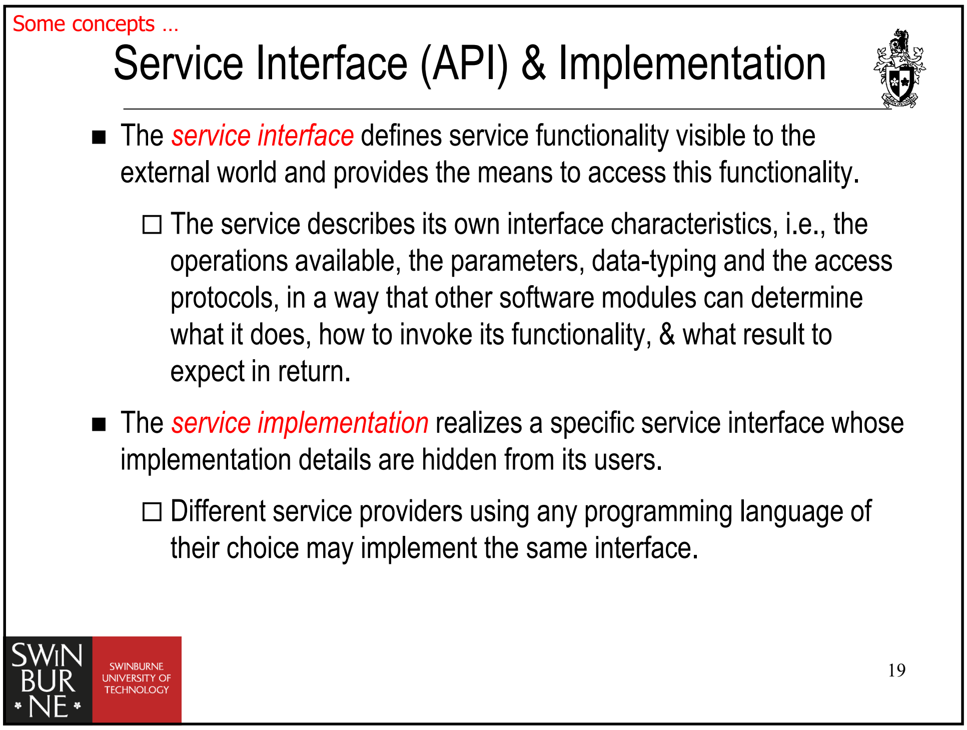


Some concepts …

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.

18



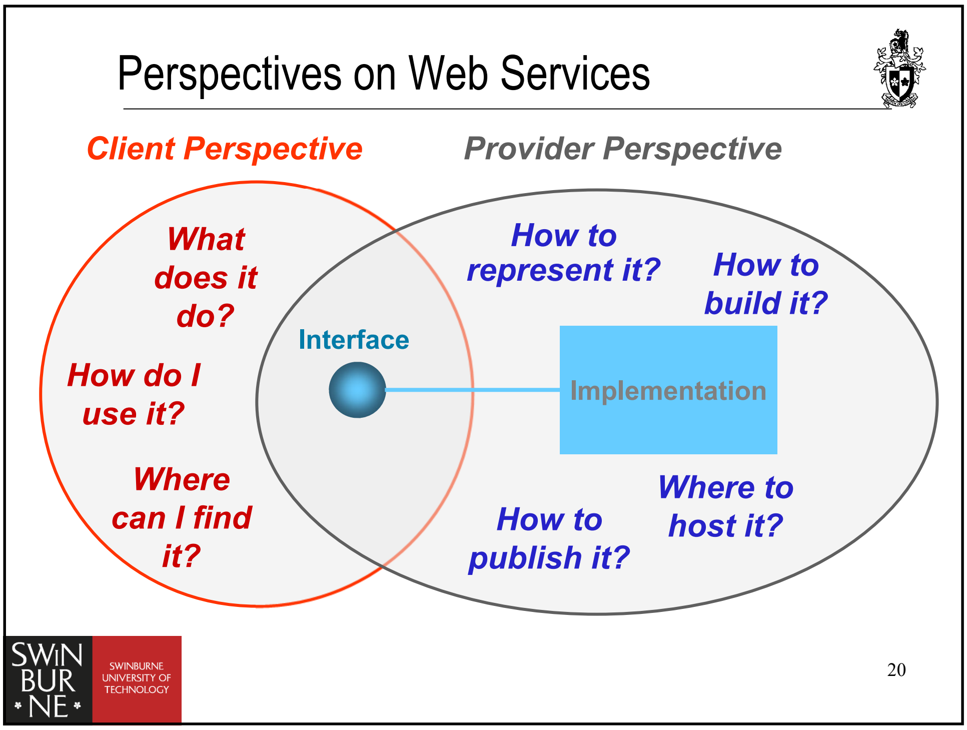
Some concepts …

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.

19

19



Perspectives on Web Services

Client Perspective

Provider Perspective

What does it do?

How do I use it?

Where can I find it?

Interface

Implementation

How to represent it?

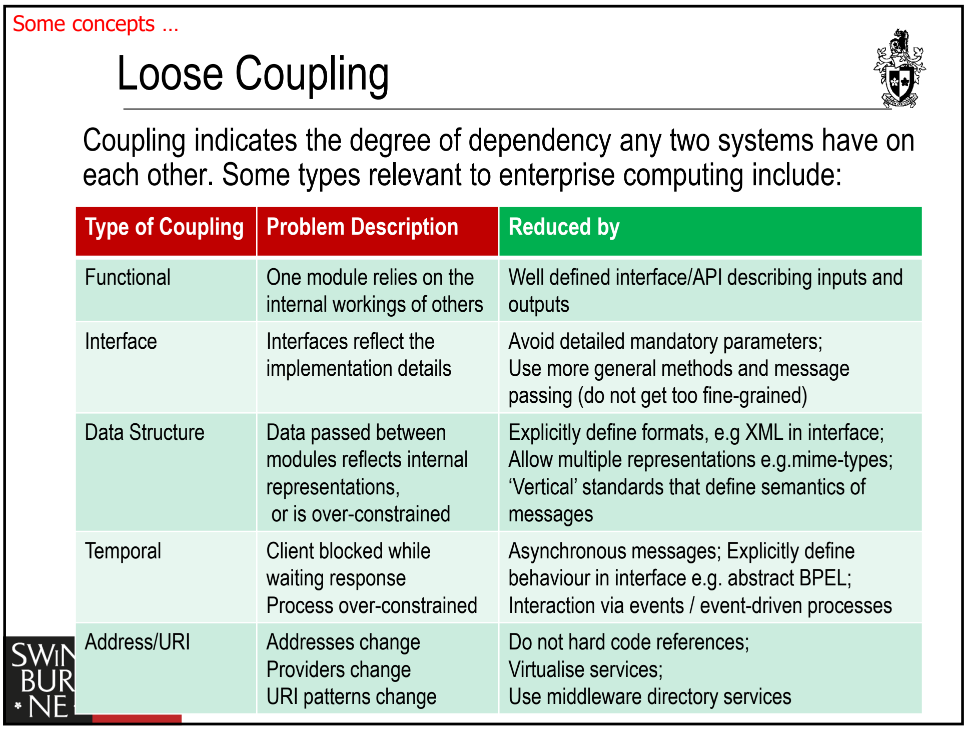
How to build it?

How to publish it?

Where to host it?

20

20



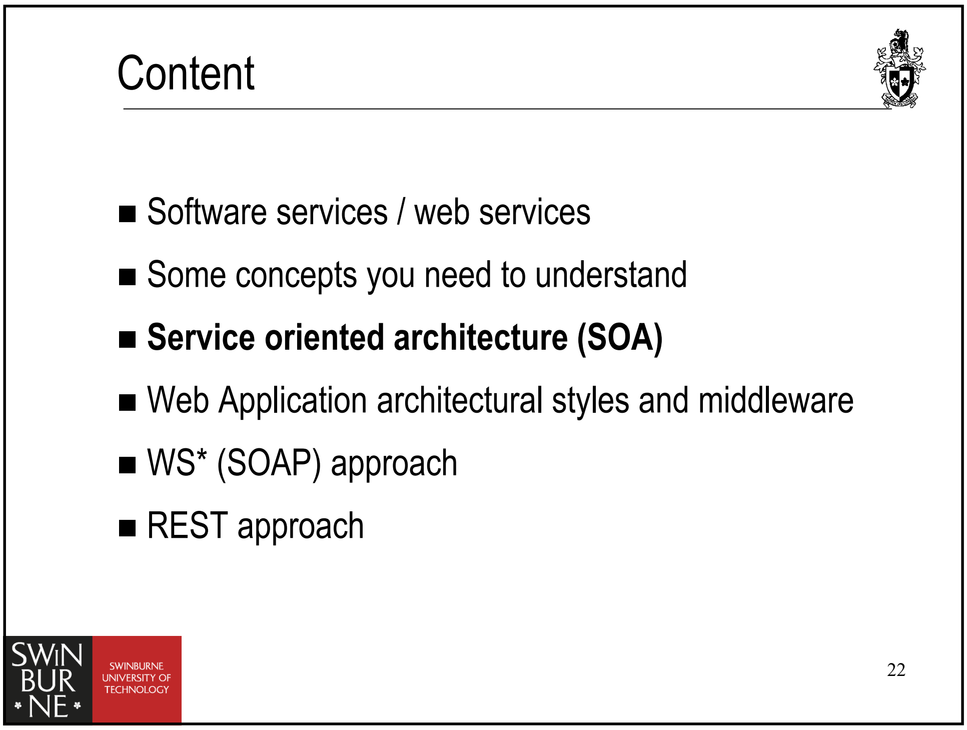
Some concepts …

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

21



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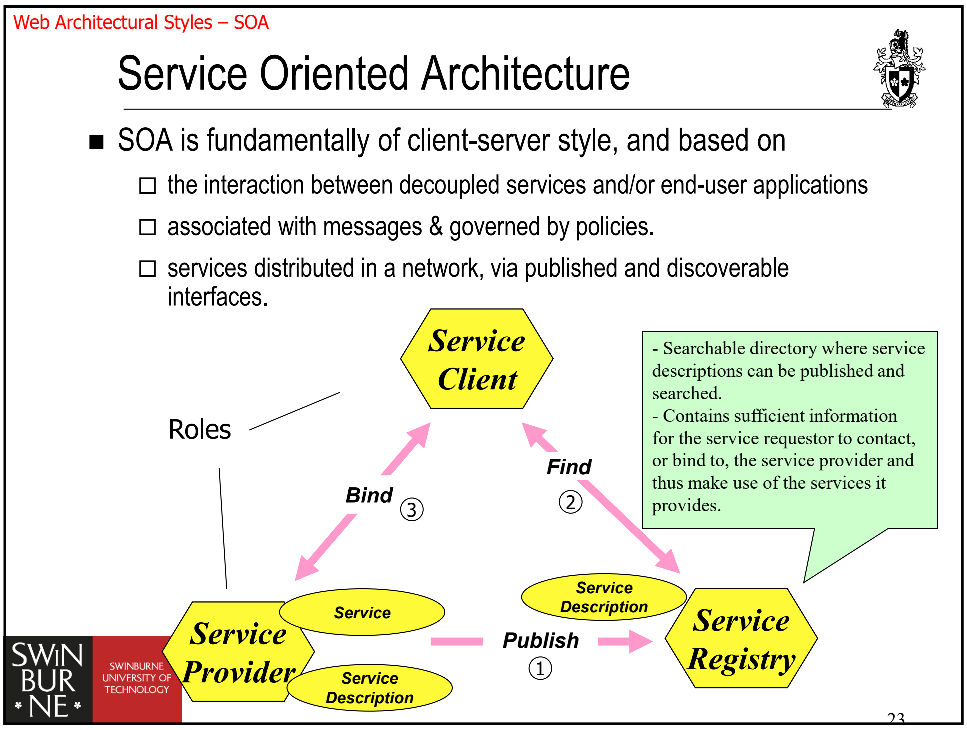
22

22



Web Architectural Styles – SOA

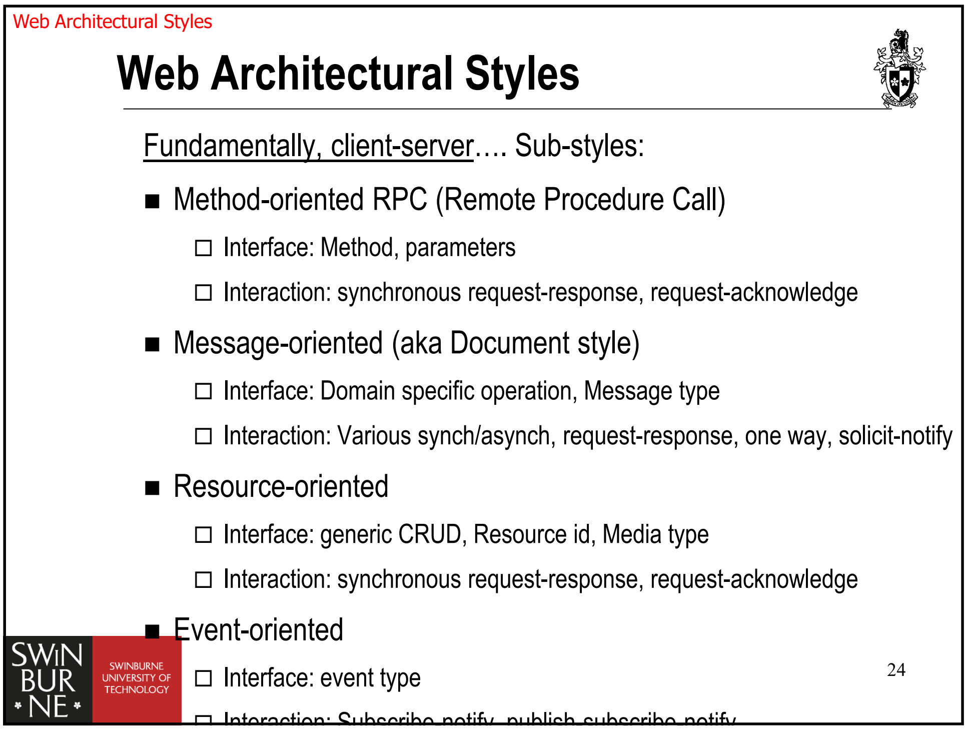
Service Oriented Architecture

- 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.

- Searchable directory where service descriptions can be published and searched.
- Contains sufficient information for the service requestor to contact, or bind to, the service provider and thus make use of the services it provides.

23

23



Web Architectural Styles

Web Architectural Styles

Fundamentally, client-server…. Sub-styles:

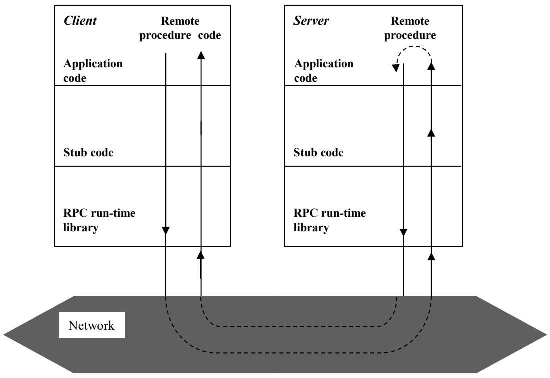
- Method-oriented RPC (Remote Procedure Call)
  - □ Interface: Method, parameters
  - □ Interaction: synchronous request-response, request-acknowledge
- Message-oriented (aka Document style)
  - □ Interface: Domain specific operation, Message type
  - □ Interaction: Various synch/asynch, request-response, 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

24

24

Remote Procedure Calls - an oo/component approach

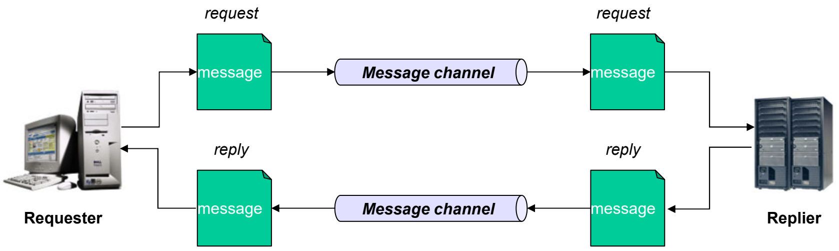
- Object/component-oriented approach to distributed computing e.g. CORBA
- Application elements use a request/wait-for-reply (**synchronous**) model of communication.
- RPC-style programming leads to *tight coupling* of interfaces and applications.

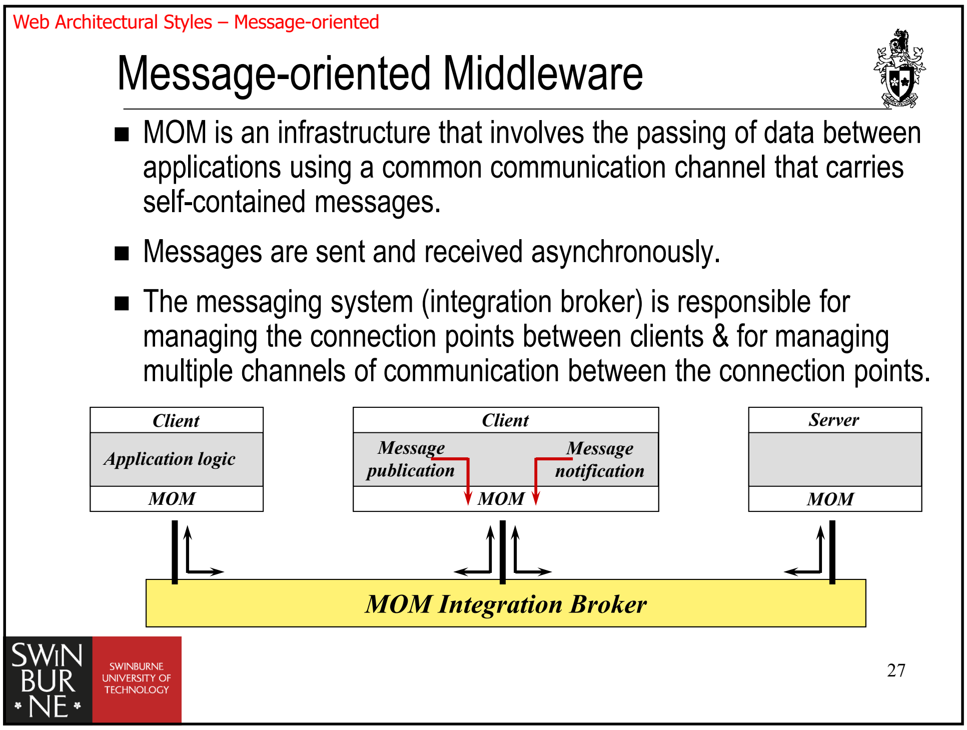


- In an RPC environment each application needs to know the intimate details of the *interface* of every other application – the number of methods it exposes & the details of each method signature it exposes.

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.





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.

27

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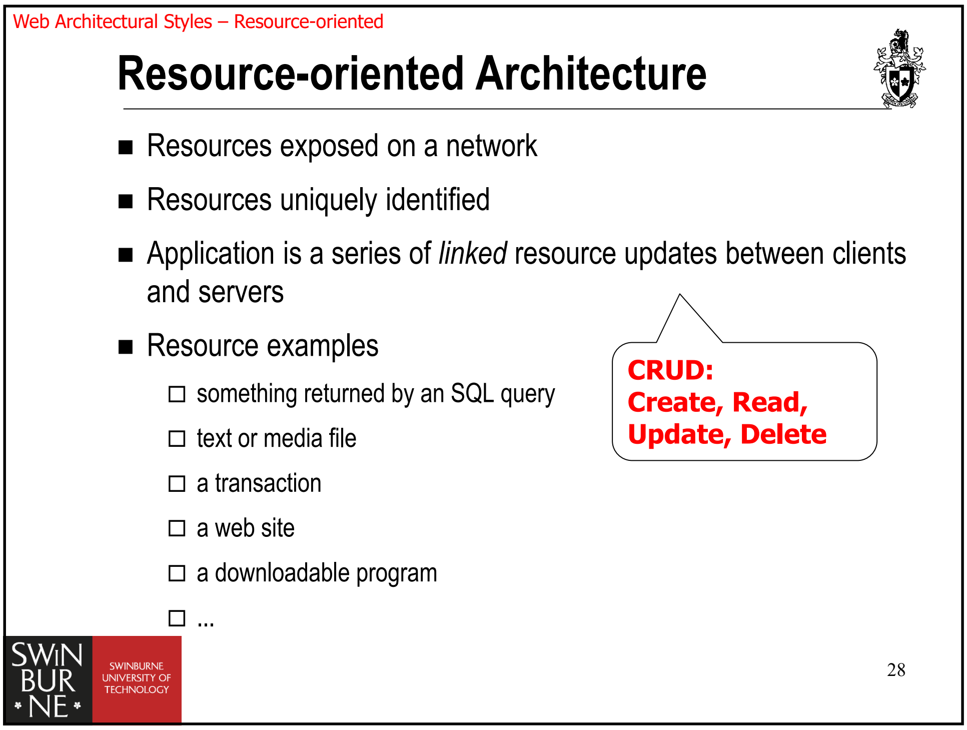


Web Architectural Styles – Resource-oriented

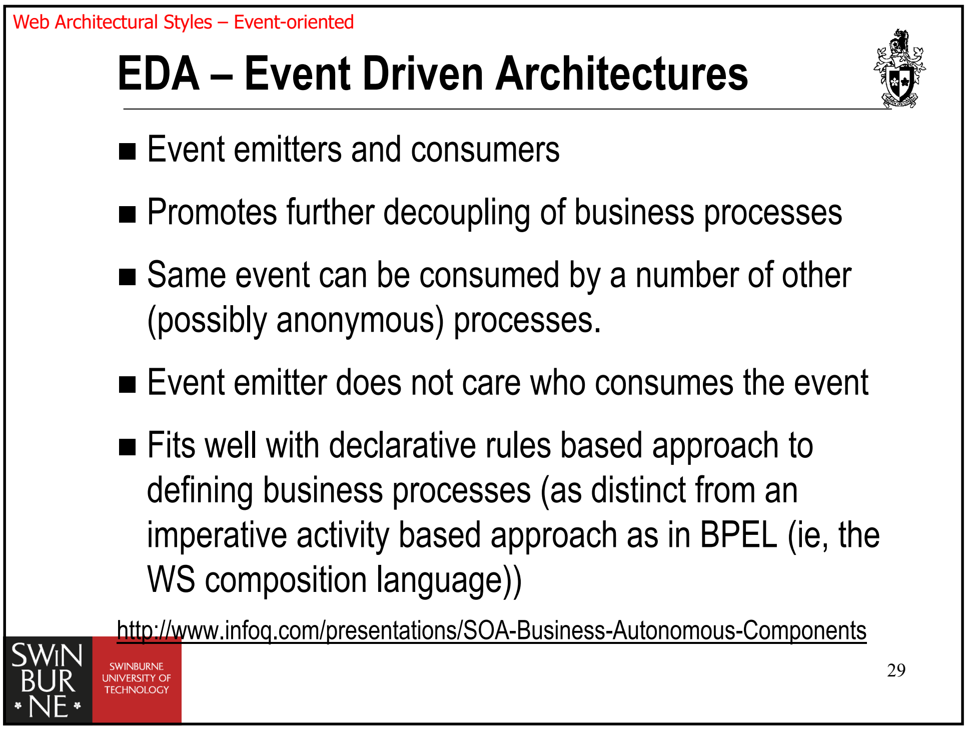
Resource-oriented Architecture

- 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

28

28



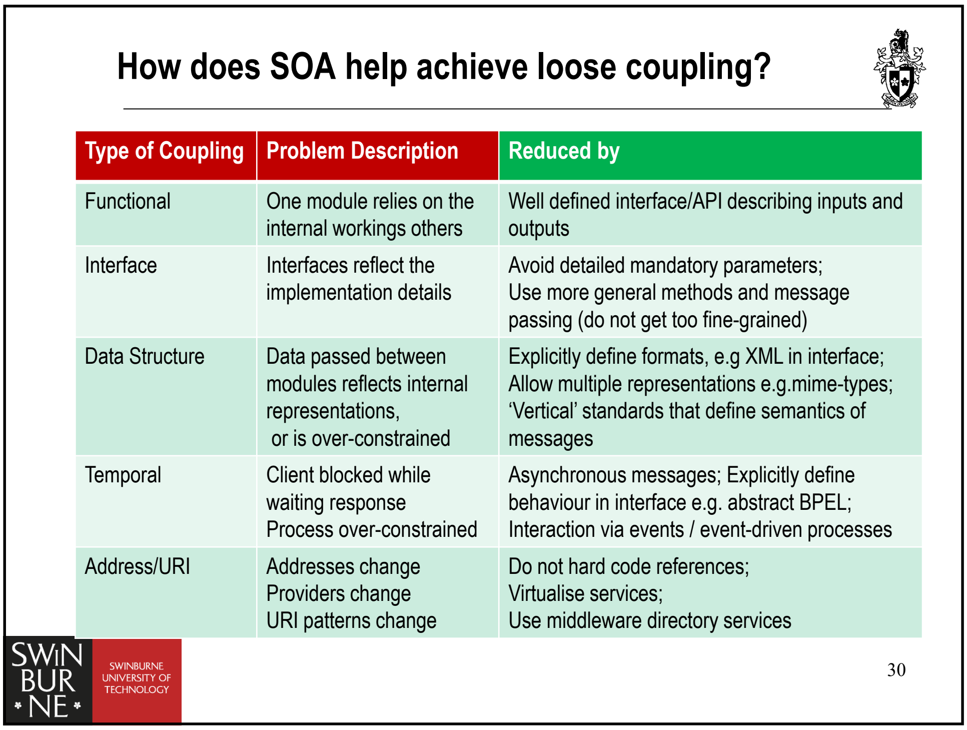
Web Architectural Styles – Event-oriented

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

29



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)
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
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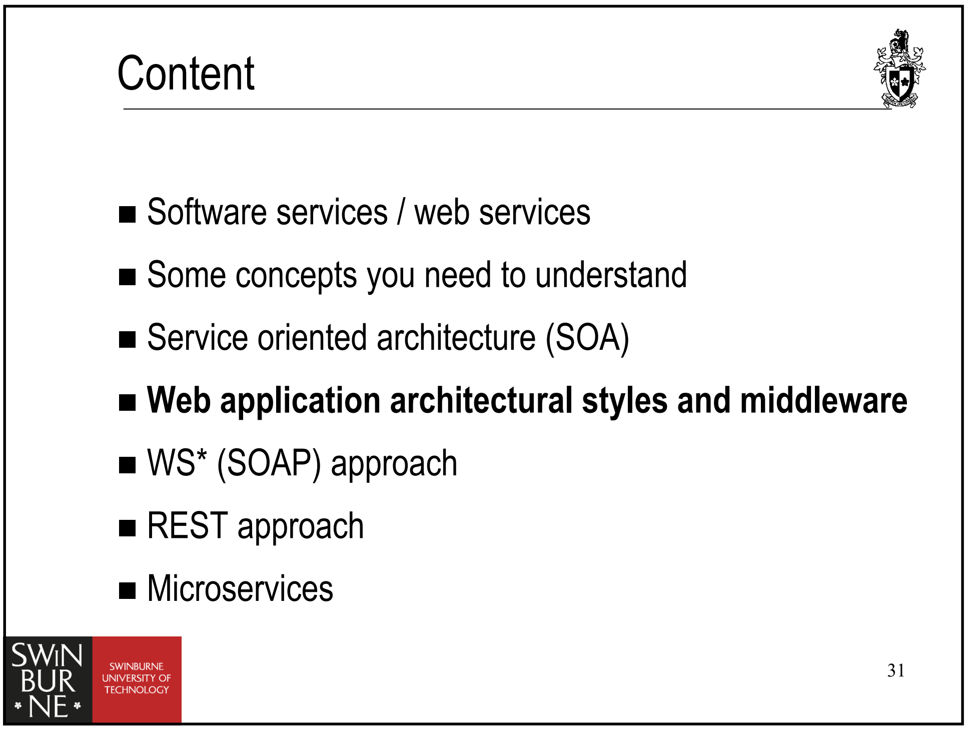
30



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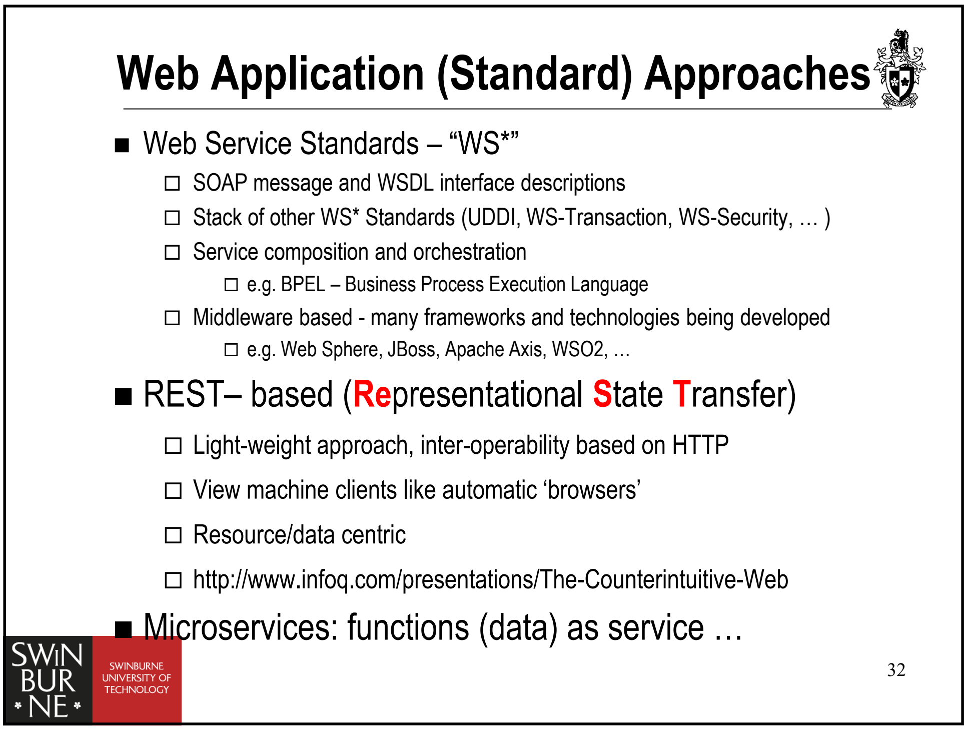
31

31



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 (Representational State Transfer)
  - □ 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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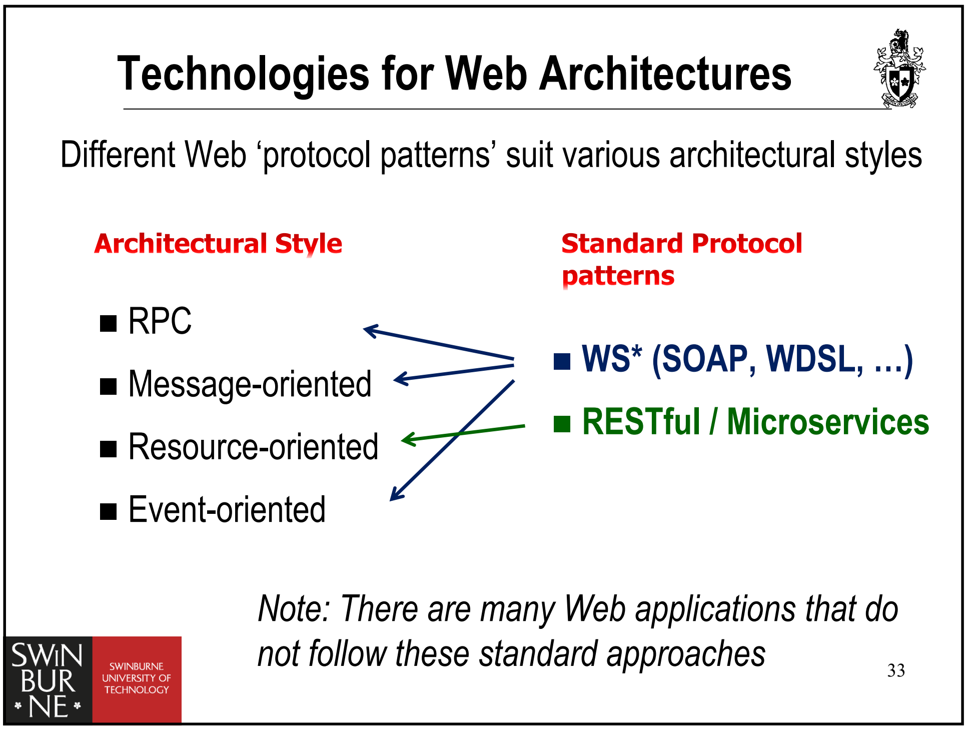
32

32



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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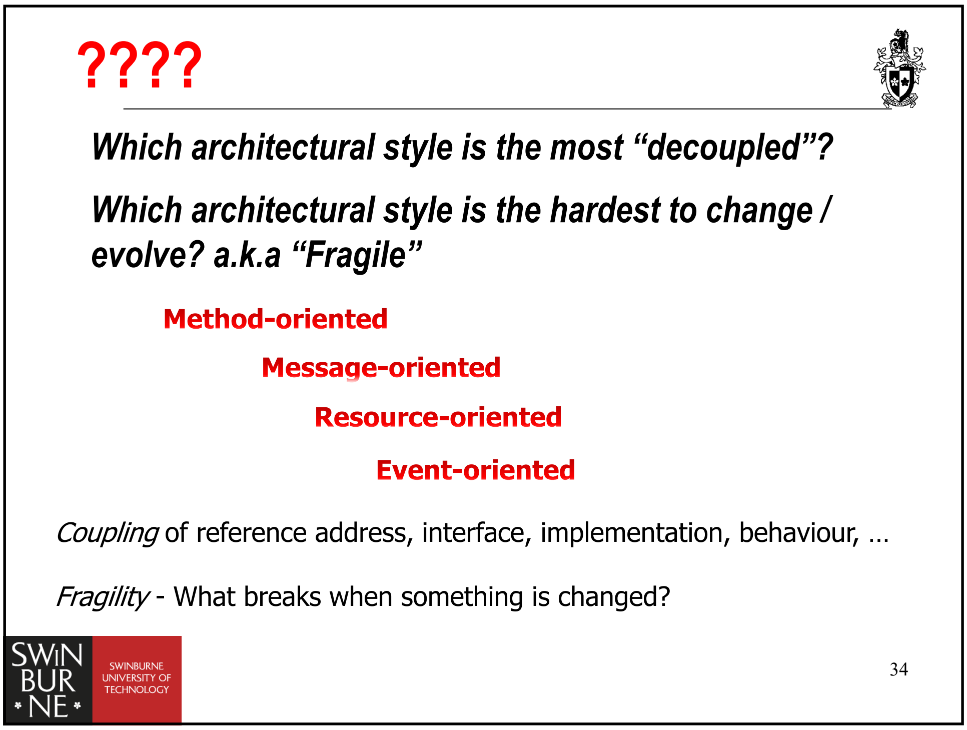

????

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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34

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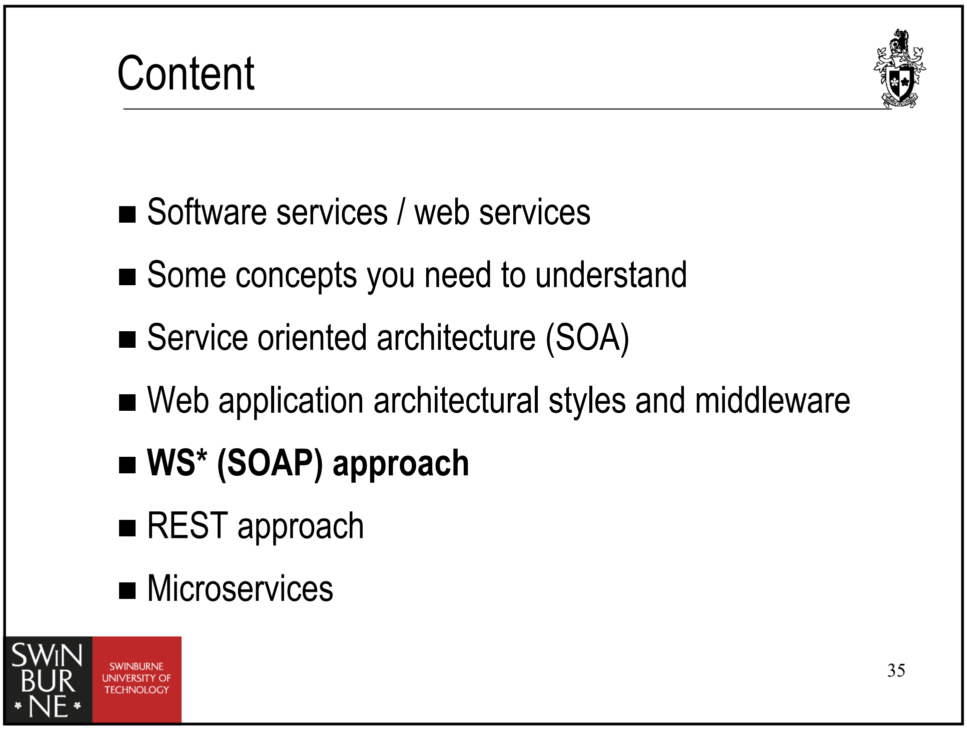

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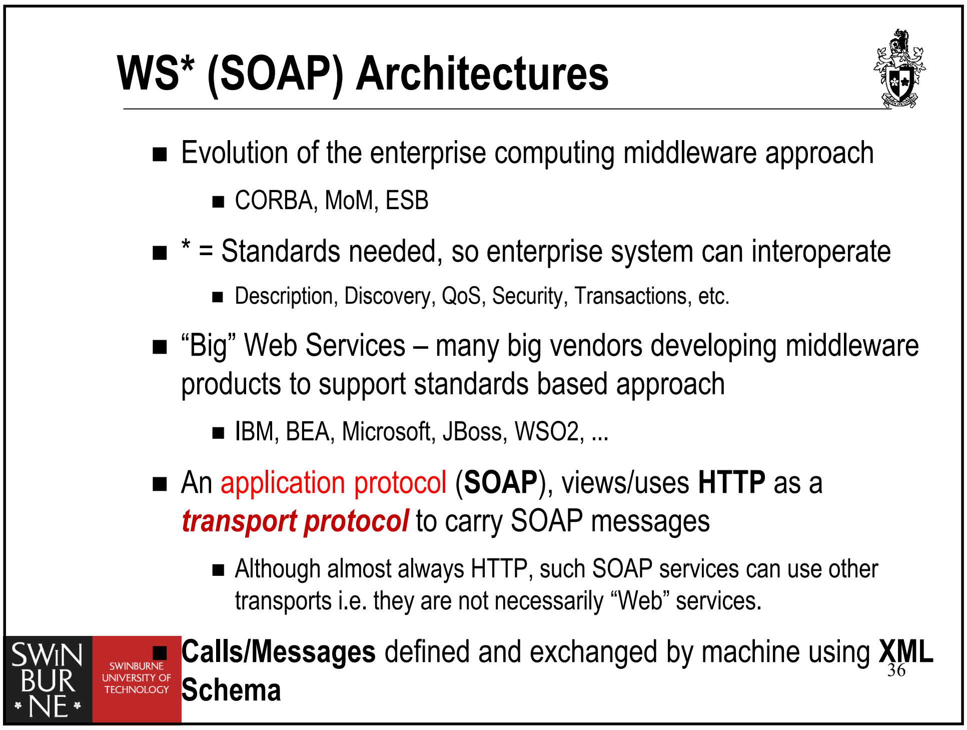
35

35

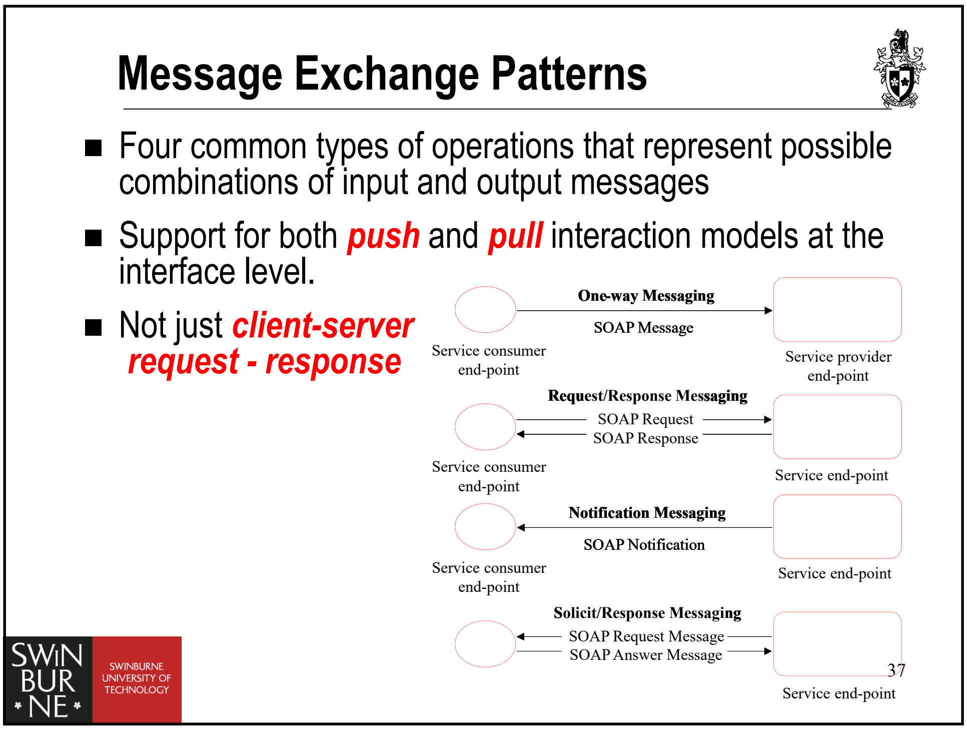


WS* (SOAP) Architectures

- 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**

36

36



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***

One-way Messaging

Service consumer end-point — SOAP Message → Service provider end-point

Request/Response Messaging

Service consumer end-point — SOAP Request → / ← SOAP Response — Service end-point

Notification Messaging

Service consumer end-point ← SOAP Notification — Service end-point

Solicit/Response Messaging

Service consumer end-point ← SOAP Request Message / SOAP Answer Message → Service end-point

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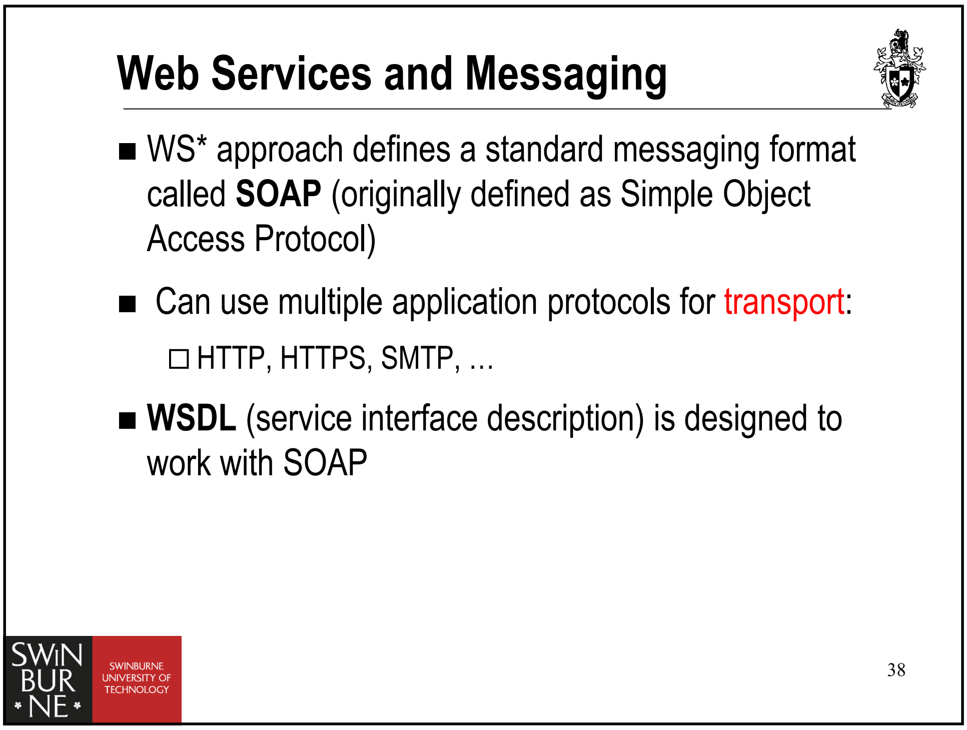
37



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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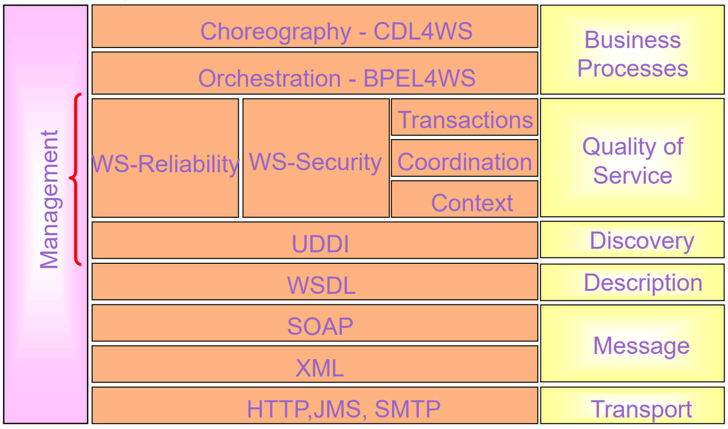
38

WS Technology Stack implementation of SOA

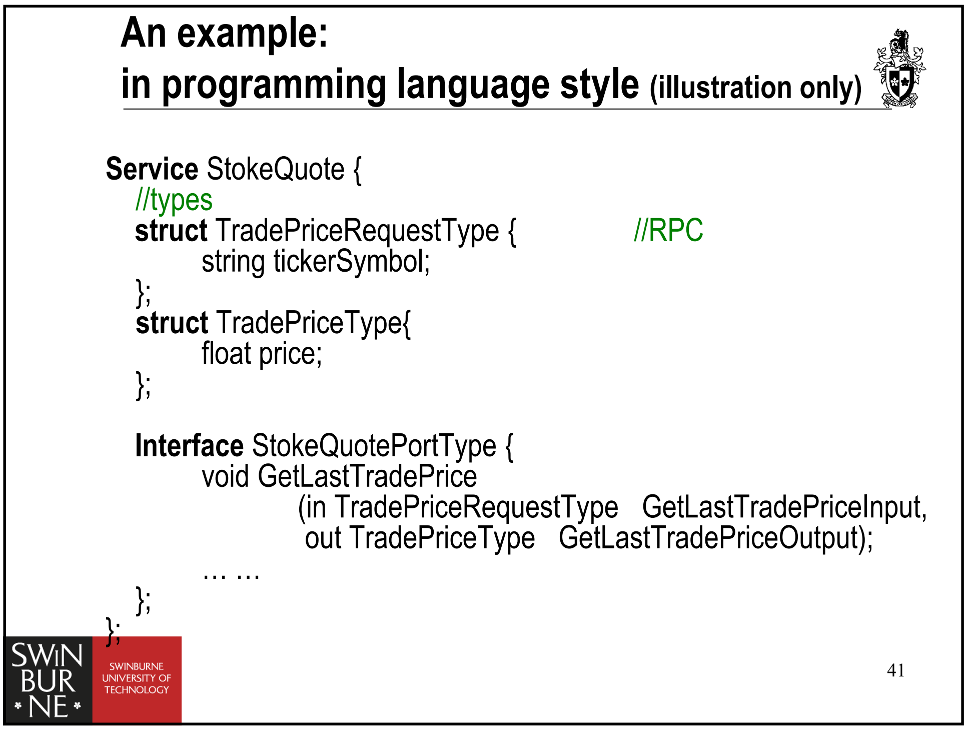
- Web services are implemented by a collection of several related technologies & standards.



WS* Standards are defined in XML Schema

WSDL – Web Service (Interface) Description

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



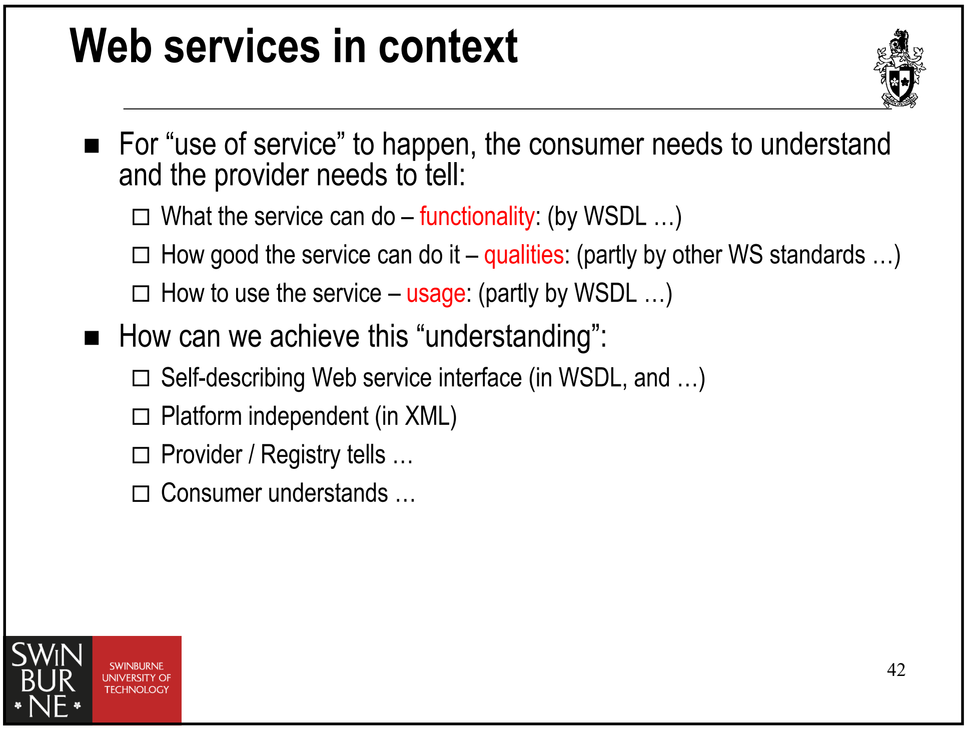
An example: in programming language style (illustration only)

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

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

41

41

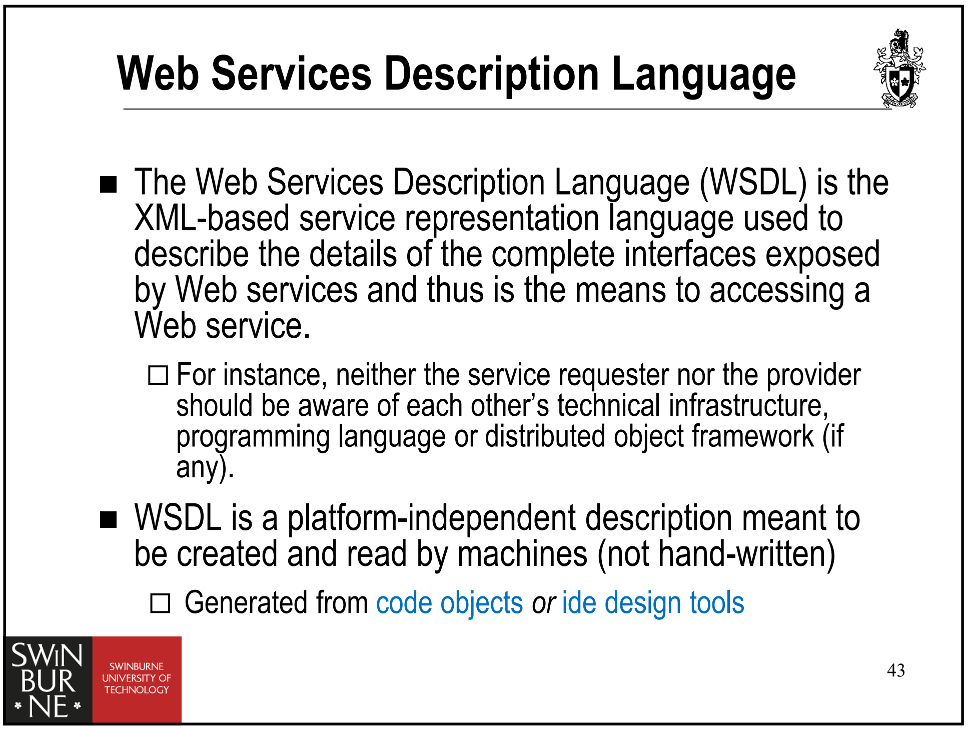


Web services in context

- 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 …

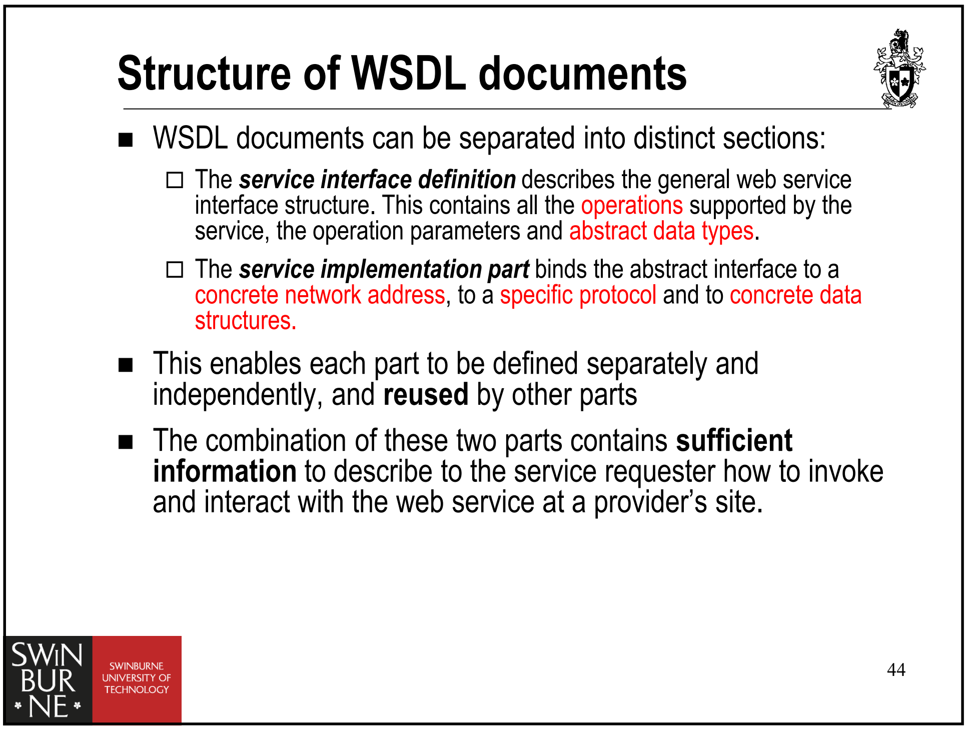
42

42



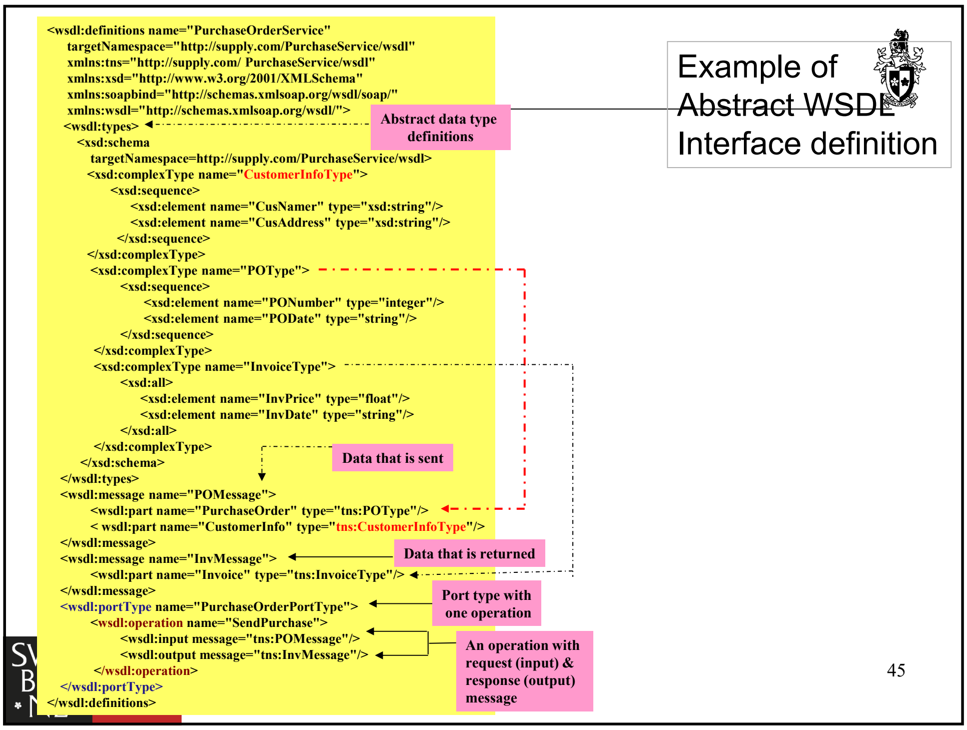
Web Services Description Language

- 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



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.



Example of Abstract WSDL Interface definition

```
<wsdl:definitions name="PurchaseOrderService"
    targetNamespace="http://supply.com/PurchaseService/wsdl"
    xmlns:tns="http://supply.com/ PurchaseService/wsdl"
    xmlns:xsd="http://www.w3.org/2001/XMLSchema"
    xmlns:soapbind="http://schemas.xmlsoap.org/wsdl/soap/"
    xmlns:wsdl="http://schemas.xmlsoap.org/wsdl/">
   <wsdl:types>
     <xsd:schema
        targetNamespace=http://supply.com/PurchaseService/wsdl>
       <xsd:complexType name="CustomerInfoType">
           <xsd:sequence>
              <xsd:element name="CusNamer" type="xsd:string"/>
              <xsd:element name="CusAddress" type="xsd:string"/>
            </xsd:sequence>
       </xsd:complexType>
        <xsd:complexType name="POType">
             <xsd:sequence>
                <xsd:element name="PONumber" type="integer"/>
                <xsd:element name="PODate" type="string"/>
             </xsd:sequence>
        </xsd:complexType>
        <xsd:complexType name="InvoiceType">
             <xsd:all>
                <xsd:element name="InvPrice" type="float"/>
                <xsd:element name="InvDate" type="string"/>
             </xsd:all>
        </xsd:complexType>
      </xsd:schema>
   </wsdl:types>
   <wsdl:message name="POMessage">
        <wsdl:part name="PurchaseOrder" type="tns:POType"/>
        < wsdl:part name="CustomerInfo" type="tns:CustomerInfoType"/>
   </wsdl:message>
   <wsdl:message name="InvMessage">
        <wsdl:part name="Invoice" type="tns:InvoiceType"/>
   </wsdl:message>
   <wsdl:portType name="PurchaseOrderPortType">
        <wsdl:operation name="SendPurchase">
             <wsdl:input message="tns:POMessage"/>
             <wsdl:output message="tns:InvMessage"/>
        </wsdl:operation>
   </wsdl:portType>
</wsdl:definitions>
```

Abstract data type definitions

Data that is sent

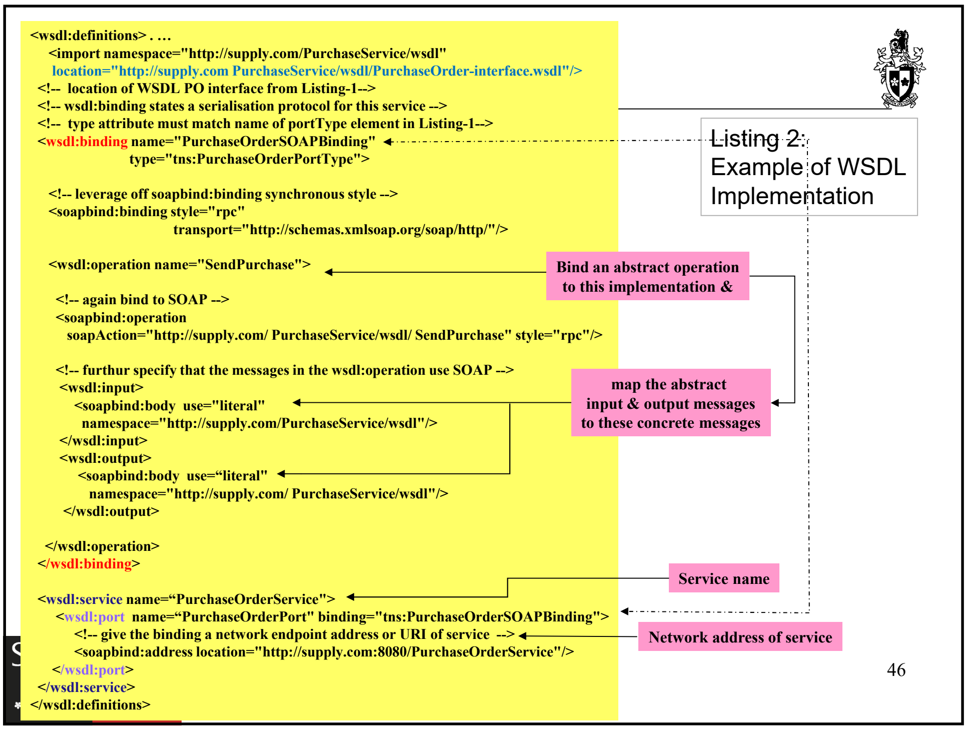
Data that is returned

Port type with one operation

An operation with request (input) & response (output) message

45

45



Listing 2: Example of WSDL Implementation

```
<wsdl:definitions> . …
   <import namespace="http://supply.com/PurchaseService/wsdl"
    location="http://supply.com PurchaseService/wsdl/PurchaseOrder-interface.wsdl"/>
 <!--  location of WSDL PO interface from Listing-1-->
 <!-- wsdl:binding states a serialisation protocol for this service -->
 <!--  type attribute must match name of portType element in Listing-1-->
 <wsdl:binding name="PurchaseOrderSOAPBinding"
                   type="tns:PurchaseOrderPortType">

   <!-- leverage off soapbind:binding synchronous style -->
   <soapbind:binding style="rpc"
                          transport="http://schemas.xmlsoap.org/soap/http/"/>

   <wsdl:operation name="SendPurchase">

    <!-- again bind to SOAP -->
    <soapbind:operation
      soapAction="http://supply.com/ PurchaseService/wsdl/ SendPurchase" style="rpc"/>

    <!-- furthur specify that the messages in the wsdl:operation use SOAP -->
     <wsdl:input>
        <soapbind:body  use="literal"
          namespace="http://supply.com/PurchaseService/wsdl"/>
     </wsdl:input>
     <wsdl:output>
         <soapbind:body  use="literal"
           namespace="http://supply.com/ PurchaseService/wsdl"/>
      </wsdl:output>

  </wsdl:operation>
 </wsdl:binding>

 <wsdl:service name="PurchaseOrderService">
    <wsdl:port  name="PurchaseOrderPort" binding="tns:PurchaseOrderSOAPBinding">
       <!-- give the binding a network endpoint address or URI of service  -->
       <soapbind:address location="http://supply.com:8080/PurchaseOrderService"/>
    </wsdl:port>
 </wsdl:service>
</wsdl:definitions>
```

Bind an abstract operation to this implementation &

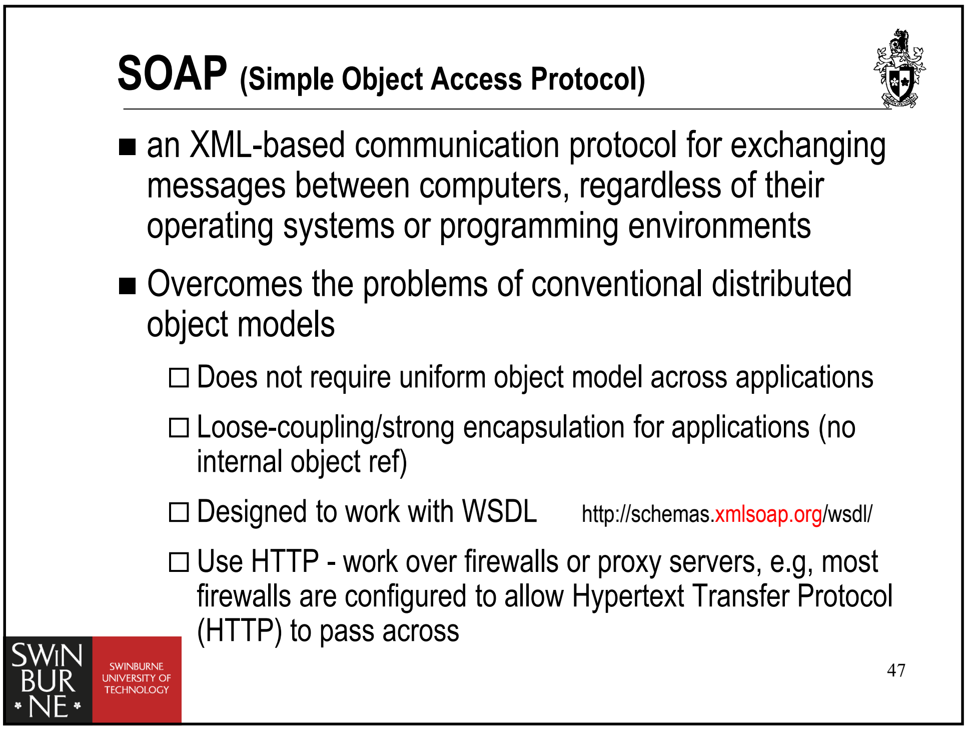
map the abstract input & output messages to these concrete messages

Service name

Network address of service

46

46

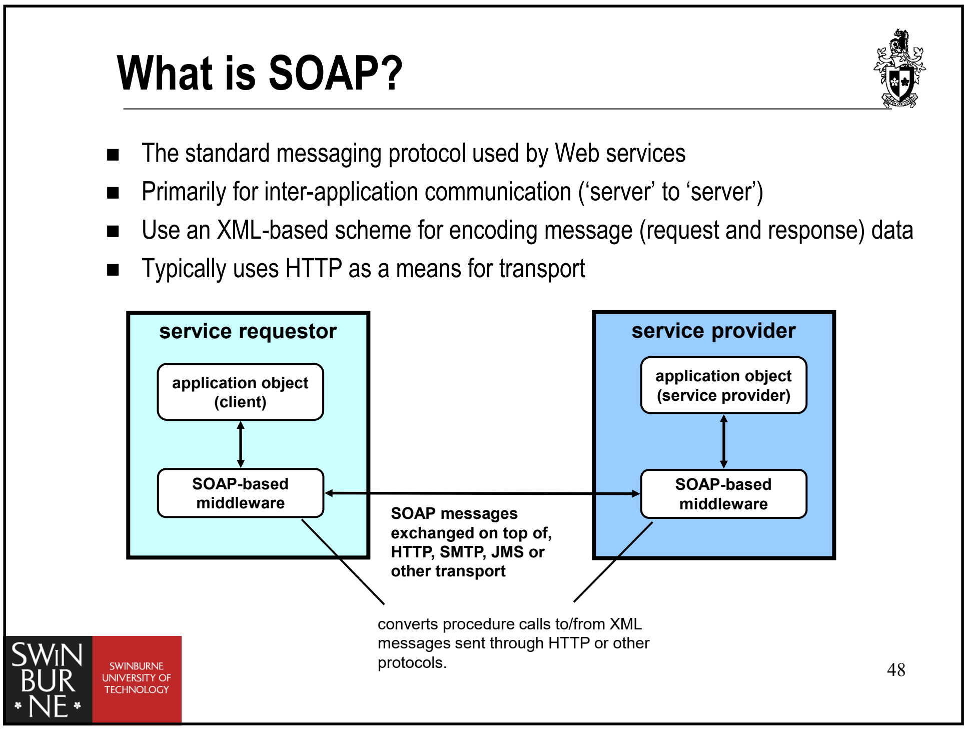


SOAP (Simple Object Access Protocol)

- 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

47

47



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

service requestor
application object (client)
SOAP-based middleware
service provider
application object (service provider)
SOAP-based middleware
SOAP messages exchanged on top of, HTTP, SMTP, JMS or other transport
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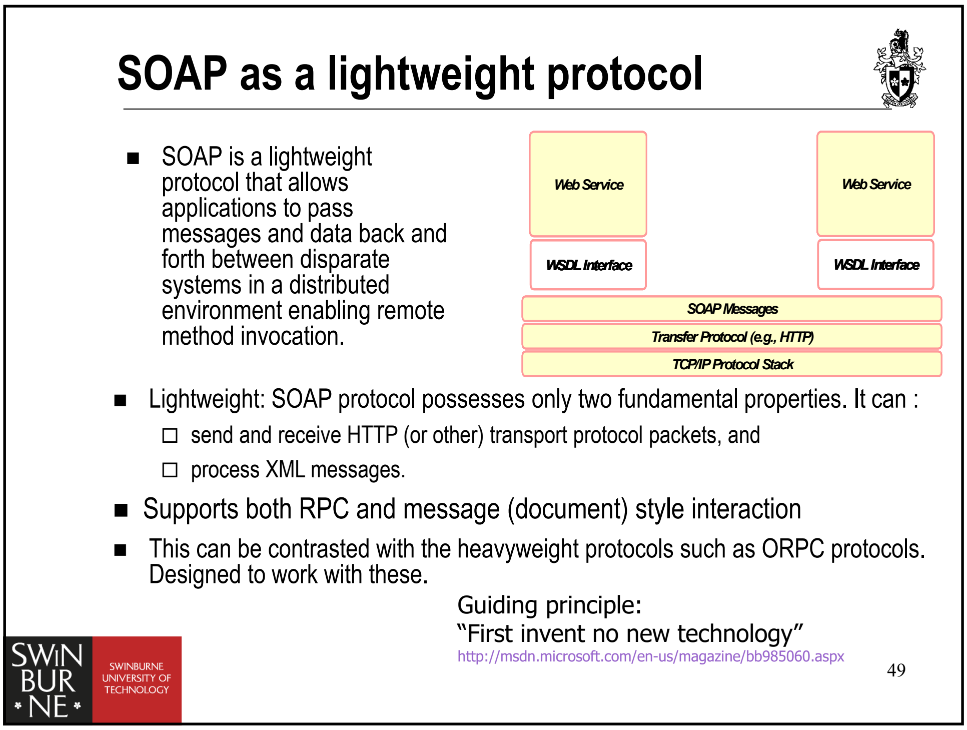
converts procedure calls to/from XML messages sent through HTTP or other protocols.

48

48



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.

Web Service

WSDL Interface

Web Service

WSDL Interface

SOAP Messages

Transfer Protocol (e.g., HTTP)

TCP/IP Protocol Stack

- 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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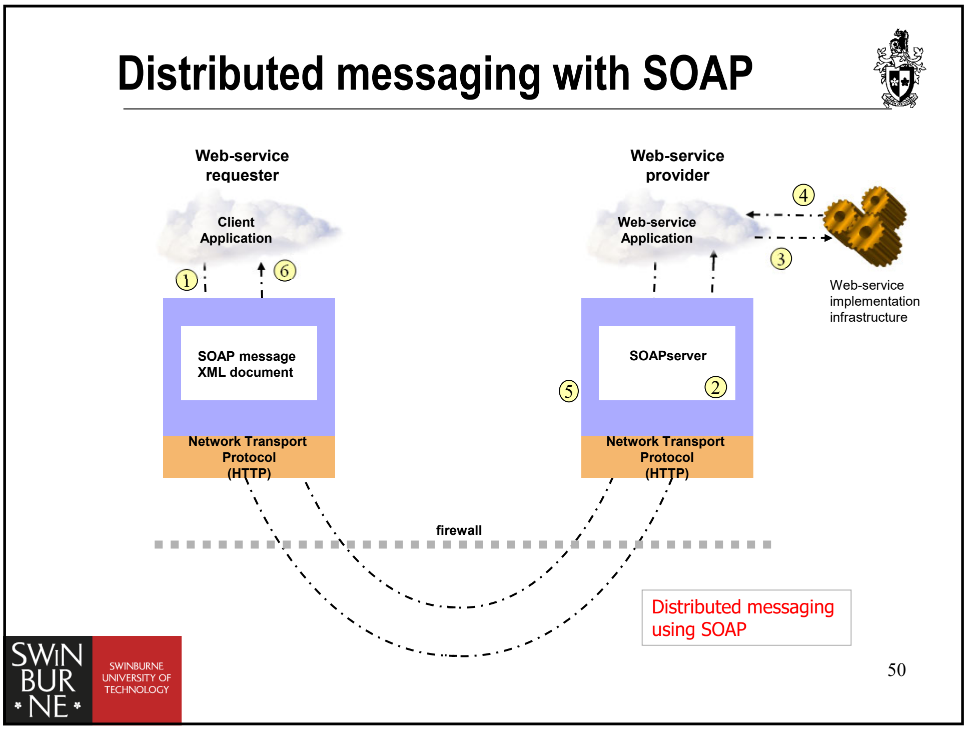

Distributed messaging with SOAP

Web-service requester
Client Application
1
6
SOAP message XML document
Network Transport Protocol (HTTP)
Web-service provider
Web-service Application
4
3
Web-service implementation infrastructure
SOAPserver
5
2
Network Transport Protocol (HTTP)
firewall

Distributed messaging using SOAP

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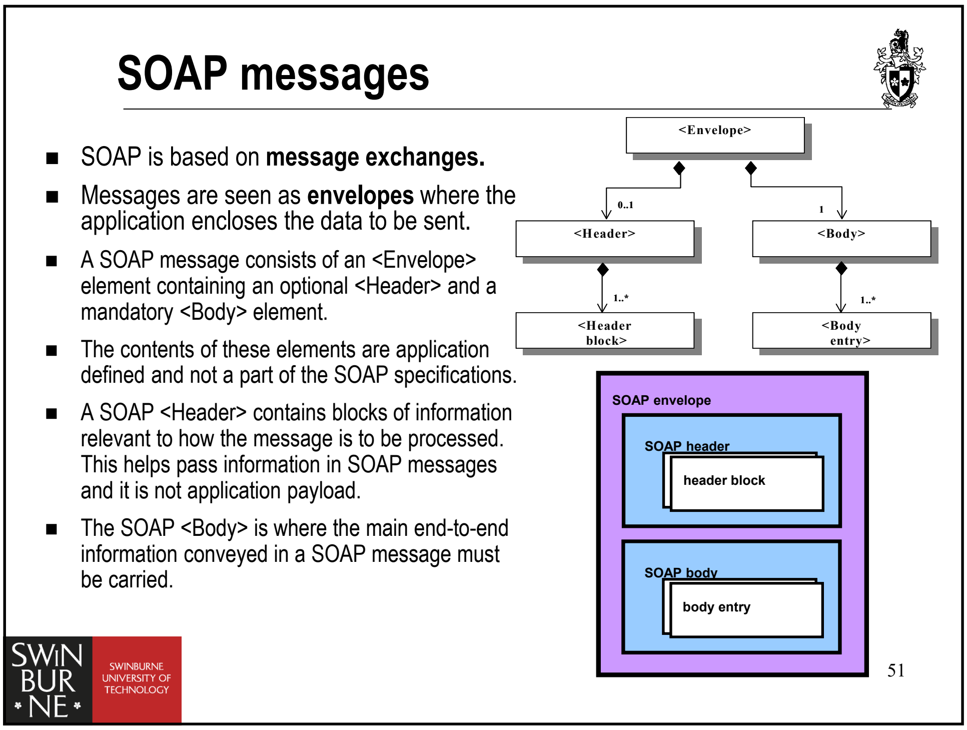
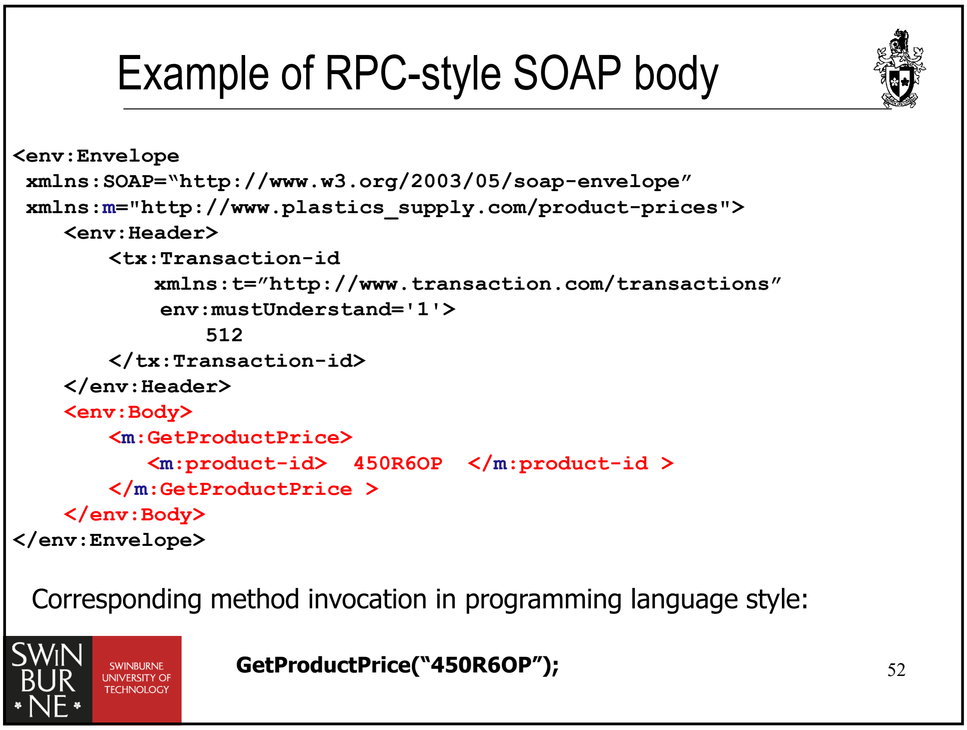


SOAP messages

- 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.

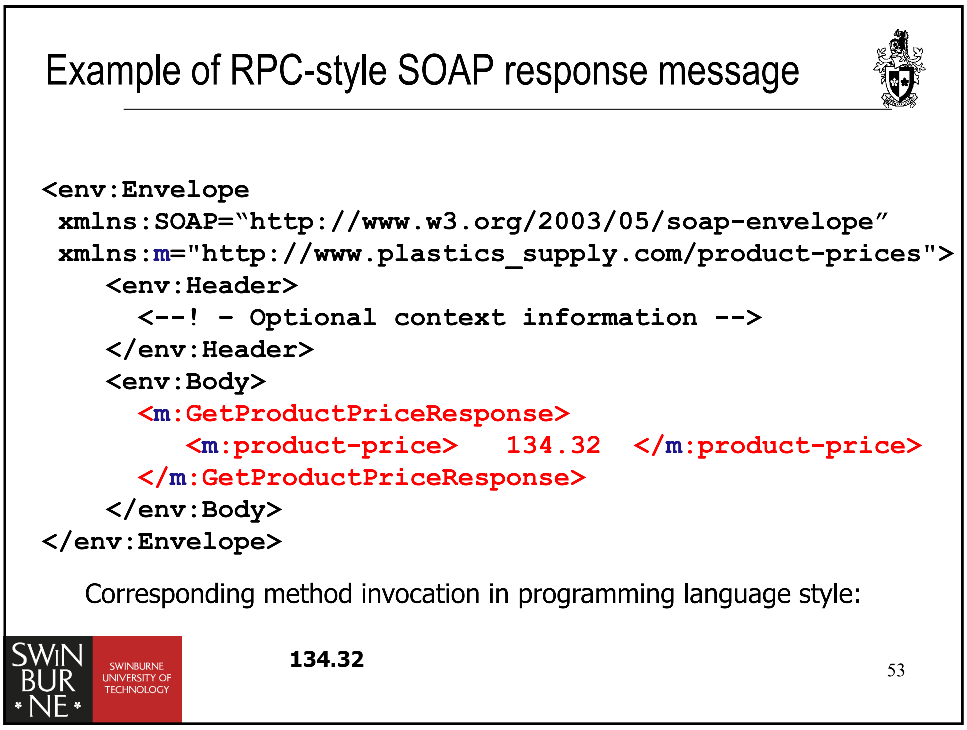


Example of RPC-style SOAP body

```
<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");



Example of RPC-style SOAP response message

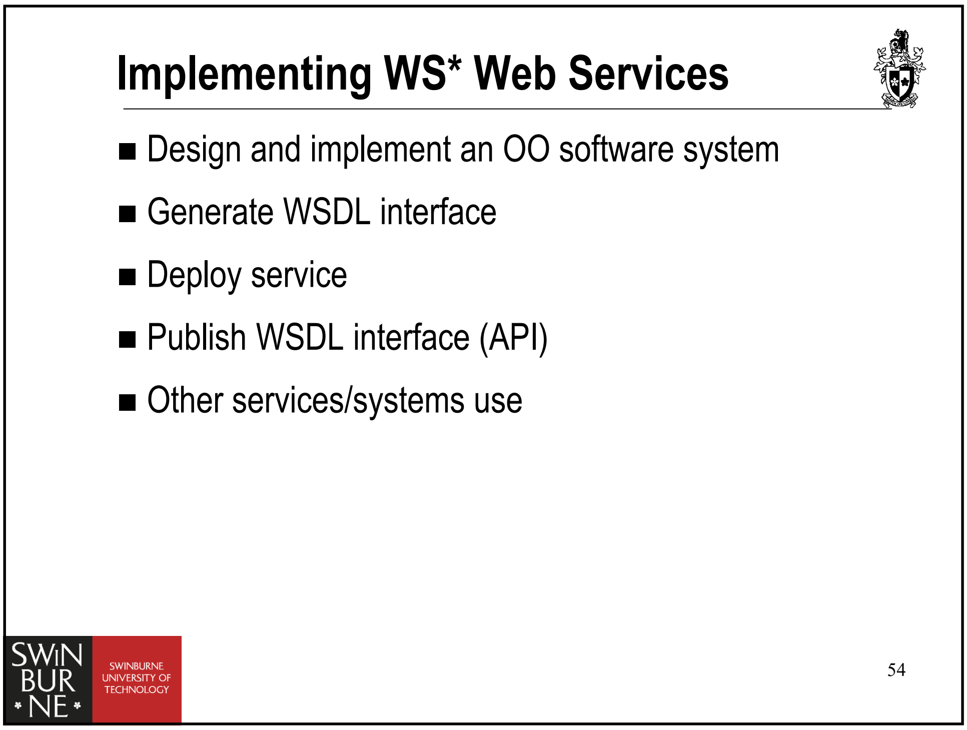
```
<env:Envelope
 xmlns:SOAP=“http://www.w3.org/2003/05/soap-envelope”
 xmlns:m="http://www.plastics_supply.com/product-prices">
    <env:Header>
      <--! – Optional context information -->
    </env:Header>
    <env:Body>
      <m:GetProductPriceResponse>
         <m:product-price>   134.32  </m:product-price>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

Corresponding method invocation in programming language style:

134.32

53

53

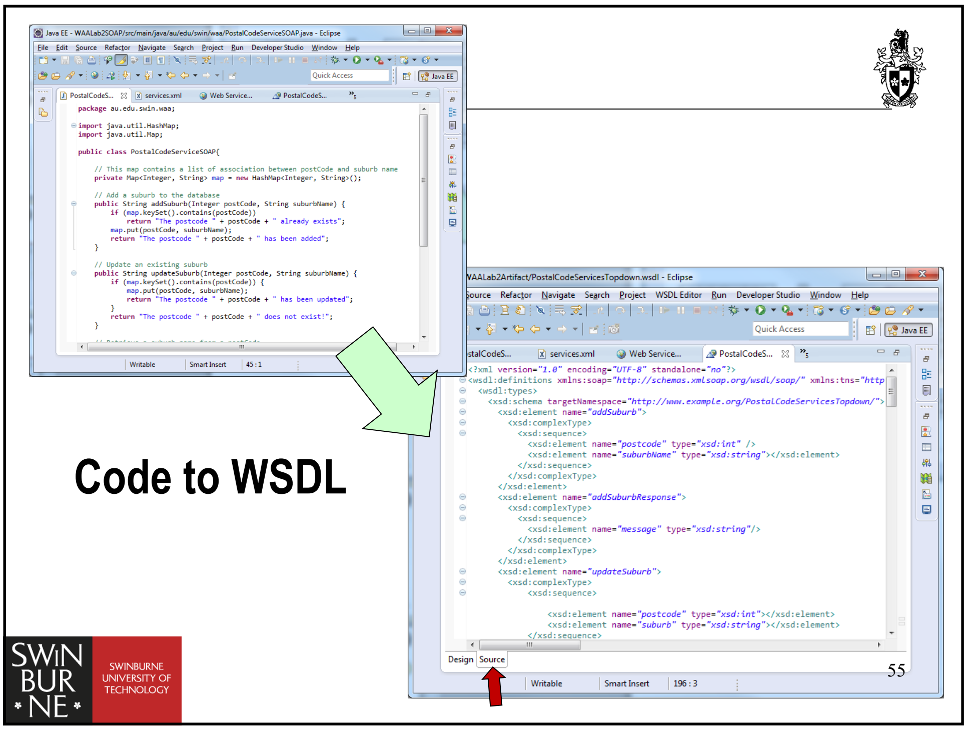


Implementing WS* Web Services

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

54

54



Java EE - WAALab2SOAP/src/main/java/au/edu/swin/waa/PostalCodeServiceSOAP.java - Eclipse

```java
package au.edu.swin.waa;

import java.util.HashMap;
import java.util.Map;

public class PostalCodeServiceSOAP{

    // This map contains a list of association between postCode and suburb name
    private Map<Integer, String> map = new HashMap<Integer, String>();

    // Add a suburb to the database
    public String addSuburb(Integer postCode, String suburbName) {
        if (map.keySet().contains(postCode))
            return "The postcode " + postCode + " already exists";
        map.put(postCode, suburbName);
        return "The postcode " + postCode + " has been added";
    }

    // Update an existing suburb
    public String updateSuburb(Integer postCode, String suburbName) {
        if (map.keySet().contains(postCode)) {
            map.put(postCode, suburbName);
            return "The postcode " + postCode + " has been updated";
        }
        return "The postcode " + postCode + " does not exist!";
    }
```

WAALab2Artifact/PostalCodeServicesTopdown.wsdl - Eclipse

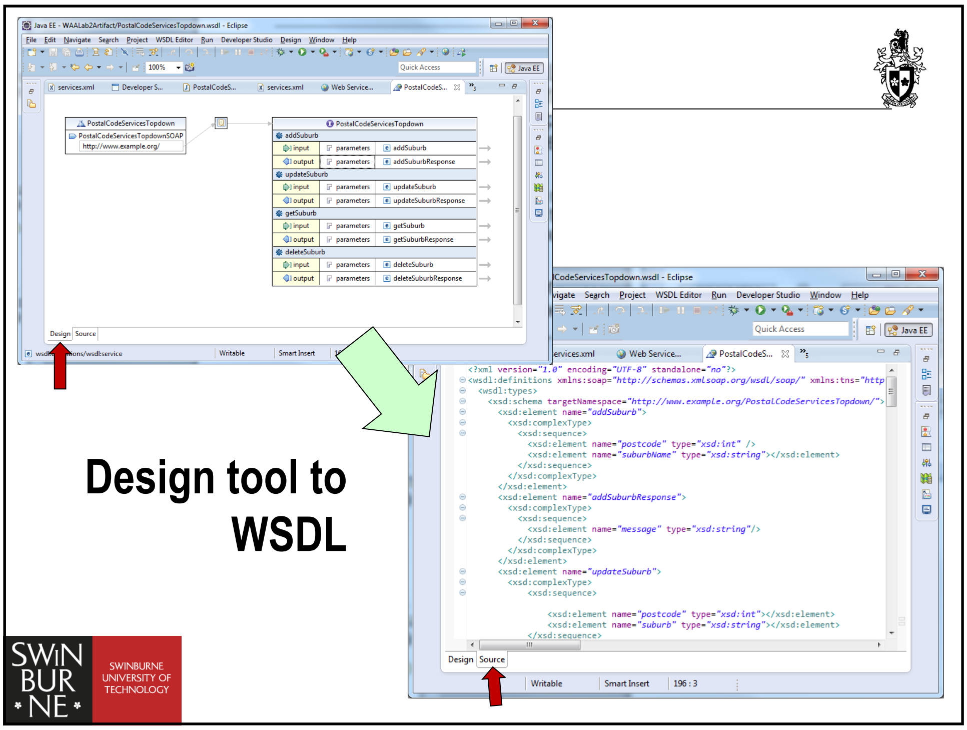
```xml
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<wsdl:definitions xmlns:soap="http://schemas.xmlsoap.org/wsdl/soap/" xmlns:tns="http
  <wsdl:types>
    <xsd:schema targetNamespace="http://www.example.org/PostalCodeServicesTopdown/">
      <xsd:element name="addSuburb">
        <xsd:complexType>
          <xsd:sequence>
            <xsd:element name="postcode" type="xsd:int" />
            <xsd:element name="suburbName" type="xsd:string"></xsd:element>
          </xsd:sequence>
        </xsd:complexType>
      </xsd:element>
      <xsd:element name="addSuburbResponse">
        <xsd:complexType>
          <xsd:sequence>
            <xsd:element name="message" type="xsd:string"/>
          </xsd:sequence>
        </xsd:complexType>
      </xsd:element>
      <xsd:element name="updateSuburb">
        <xsd:complexType>
            <xsd:sequence>

                <xsd:element name="postcode" type="xsd:int"></xsd:element>
                <xsd:element name="suburb" type="xsd:string"></xsd:element>
            </xsd:sequence>
```

Code to WSDL

55

55



Java EE - WAALab2Artifact/PostalCodeServicesTopdown.wsdl - Eclipse

PostalCodeServicesTopdown
PostalCodeServicesTopdownSOAP
http://www.example.org/

PostalCodeServicesTopdown

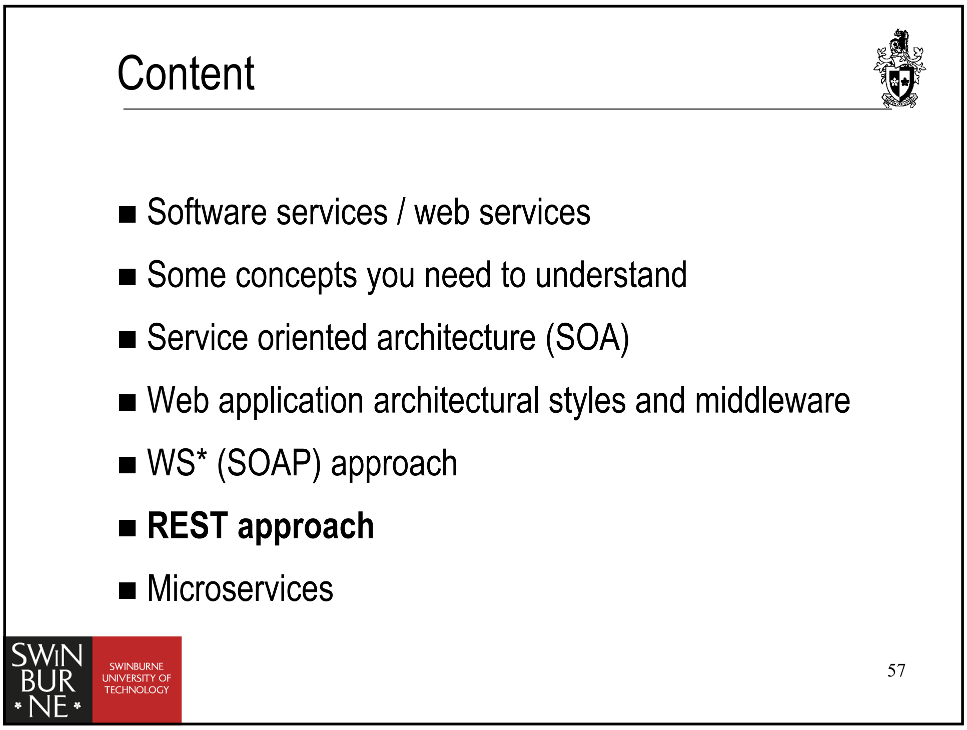
addSuburb		
input	parameters	addSuburb
output	parameters	addSuburbResponse
updateSuburb		
input	parameters	updateSuburb
output	parameters	updateSuburbResponse
getSuburb		
input	parameters	getSuburb
output	parameters	getSuburbResponse
deleteSuburb		
input	parameters	deleteSuburb
output	parameters	deleteSuburbResponse

```xml
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<wsdl:definitions xmlns:soap="http://schemas.xmlsoap.org/wsdl/soap/" xmlns:tns="http
  <wsdl:types>
    <xsd:schema targetNamespace="http://www.example.org/PostalCodeServicesTopdown/">
      <xsd:element name="addSuburb">
        <xsd:complexType>
          <xsd:sequence>
            <xsd:element name="postcode" type="xsd:int" />
            <xsd:element name="suburbName" type="xsd:string"></xsd:element>
          </xsd:sequence>
        </xsd:complexType>
      </xsd:element>
      <xsd:element name="addSuburbResponse">
        <xsd:complexType>
          <xsd:sequence>
            <xsd:element name="message" type="xsd:string"/>
          </xsd:sequence>
        </xsd:complexType>
      </xsd:element>
      <xsd:element name="updateSuburb">
        <xsd:complexType>
            <xsd:sequence>

                <xsd:element name="postcode" type="xsd:int"></xsd:element>
                <xsd:element name="suburb" type="xsd:string"></xsd:element>
            </xsd:sequence>
```

Design tool to WSDL

56



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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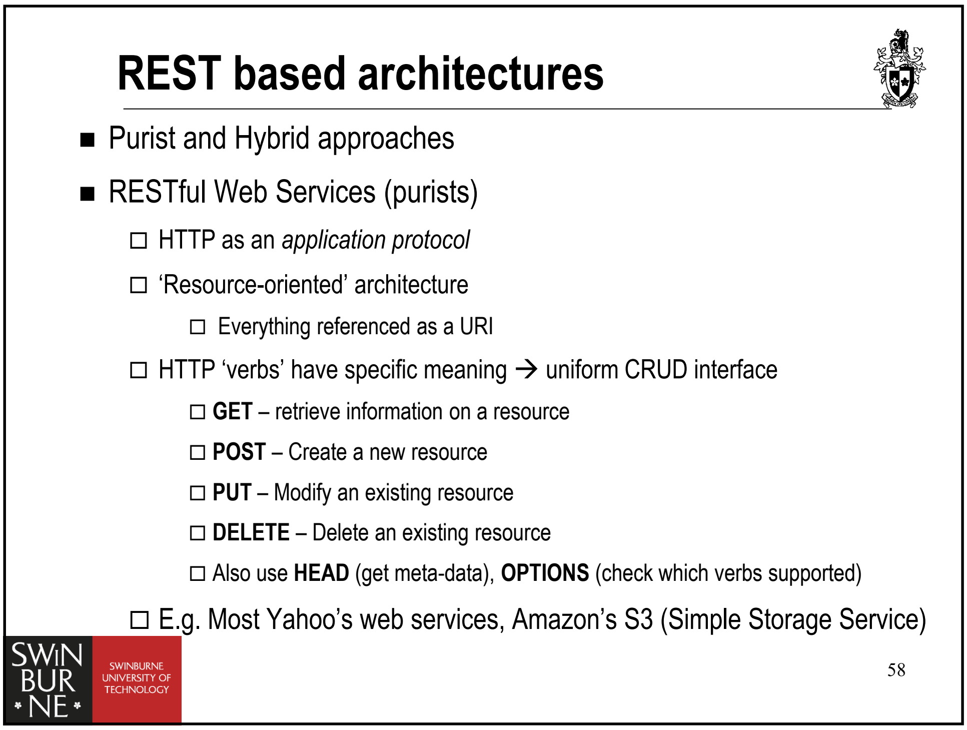
57



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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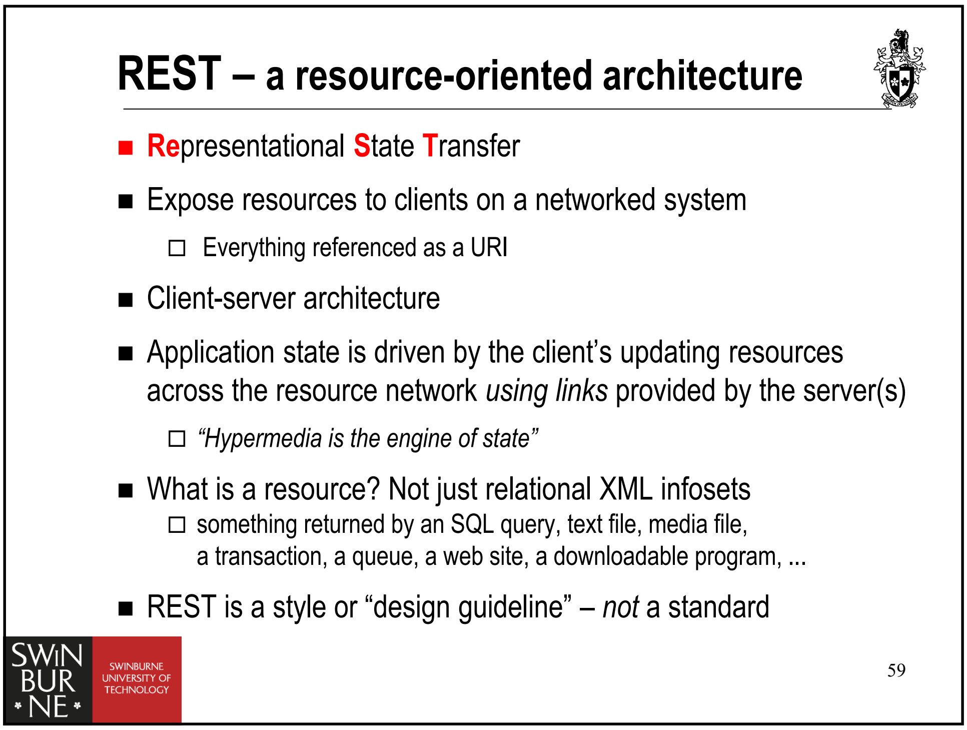
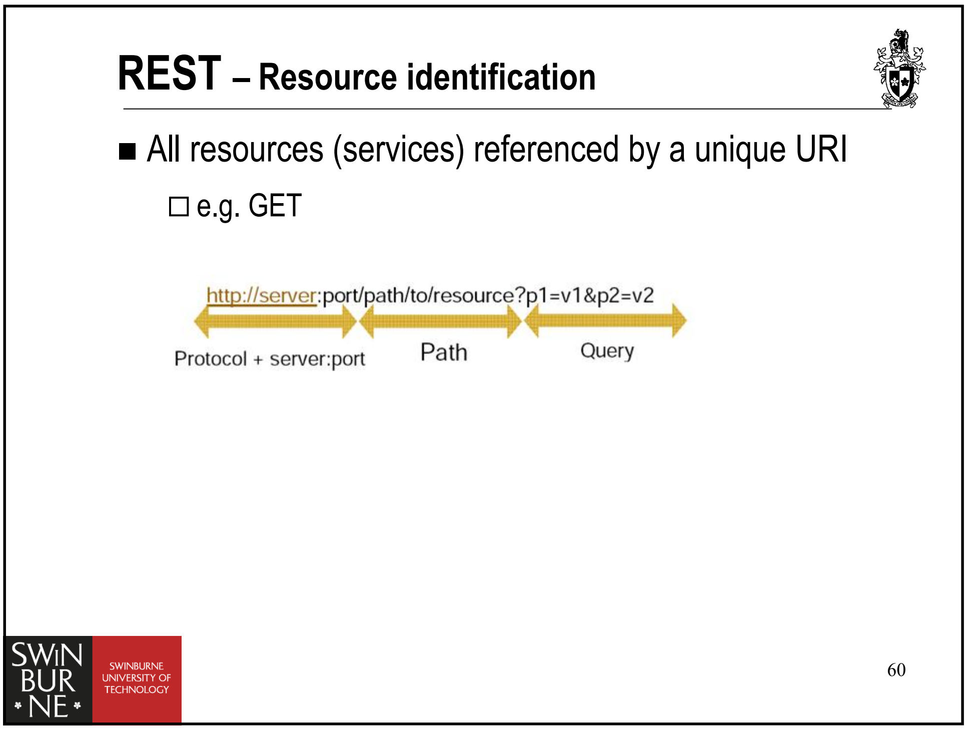
58



REST – a resource-oriented architecture

- Representational State Transfer
- 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

59



REST – Resource identification

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

http://server:port/path/to/resource?p1=v1&p2=v2

Protocol + server:port
Path
Query
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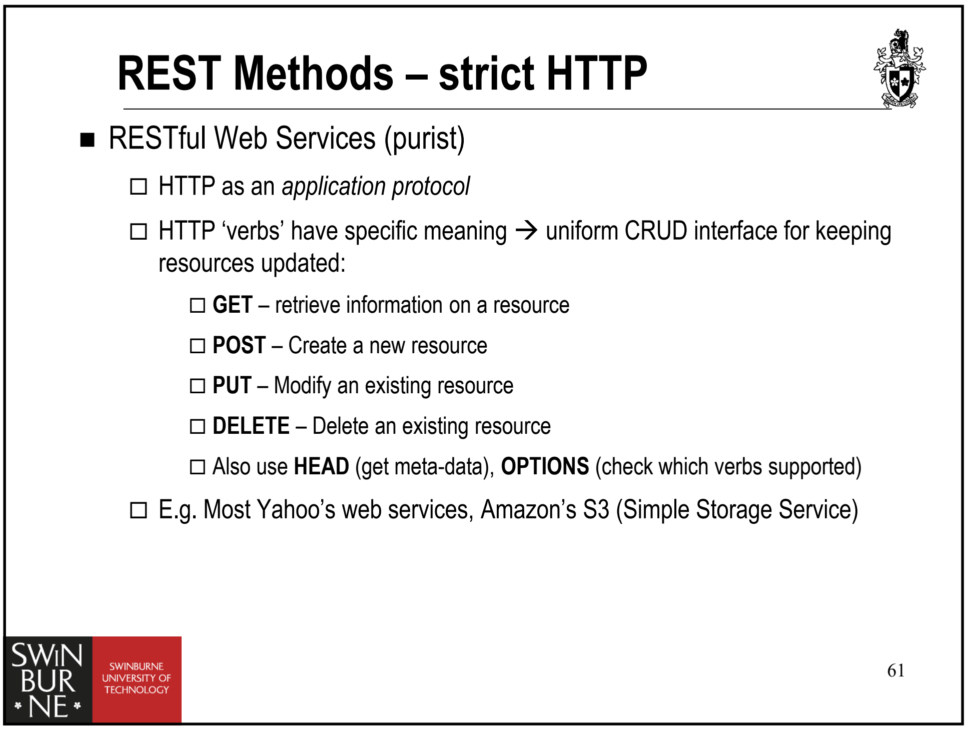
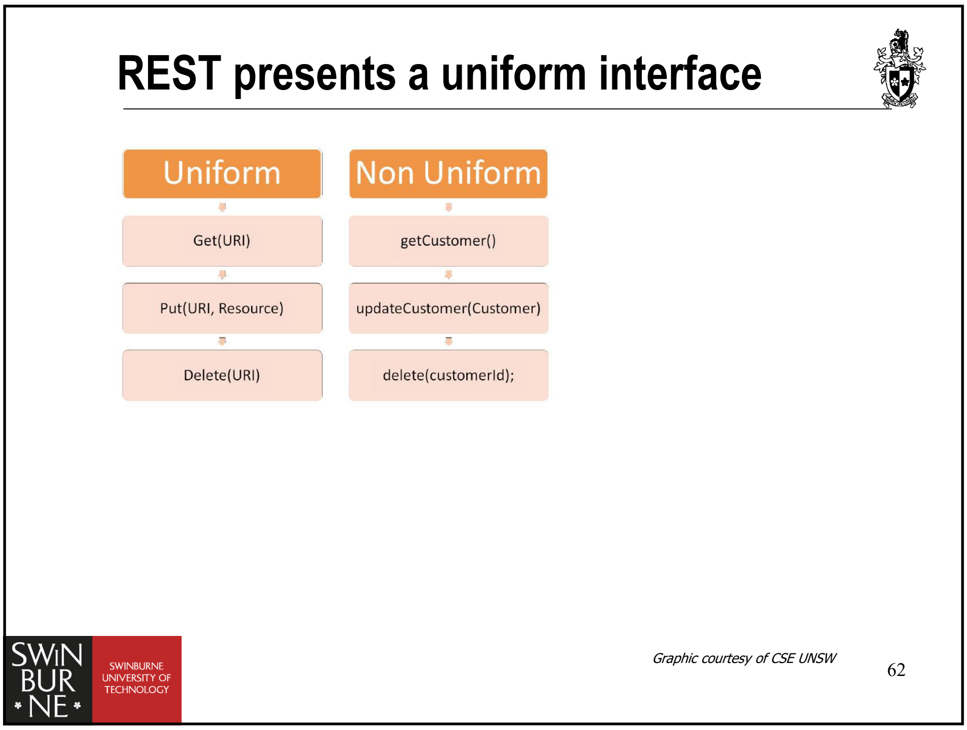


REST Methods – strict HTTP

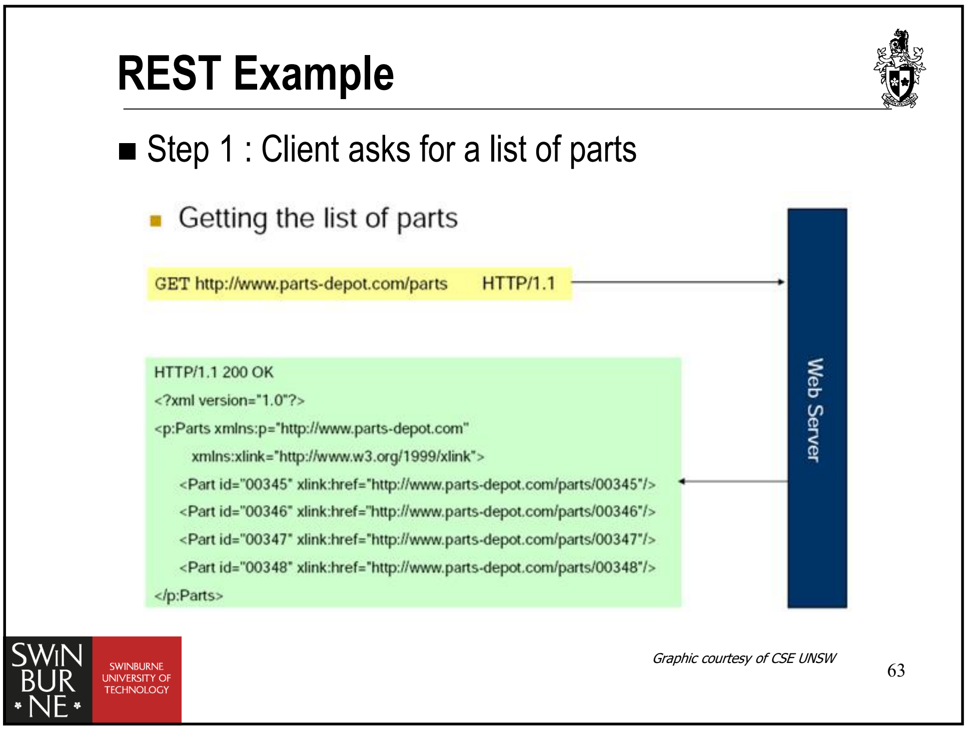
- RESTful Web Services (purist)
  - □ HTTP as an *application protocol*
  - □ HTTP 'verbs' have specific meaning → uniform CRUD interface for keeping resources updated:
    - □ **GET** – retrieve information on a resource
    - □ **POST** – Create a new resource
    - □ **PUT** – Modify an existing resource
    - □ **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)



REST presents a uniform interface

Uniform	Non Uniform
Get(URI)	getCustomer()
Put(URI, Resource)	updateCustomer(Customer)
Delete(URI)	delete(customerId);

Graphic courtesy of CSE UNSW



REST Example

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

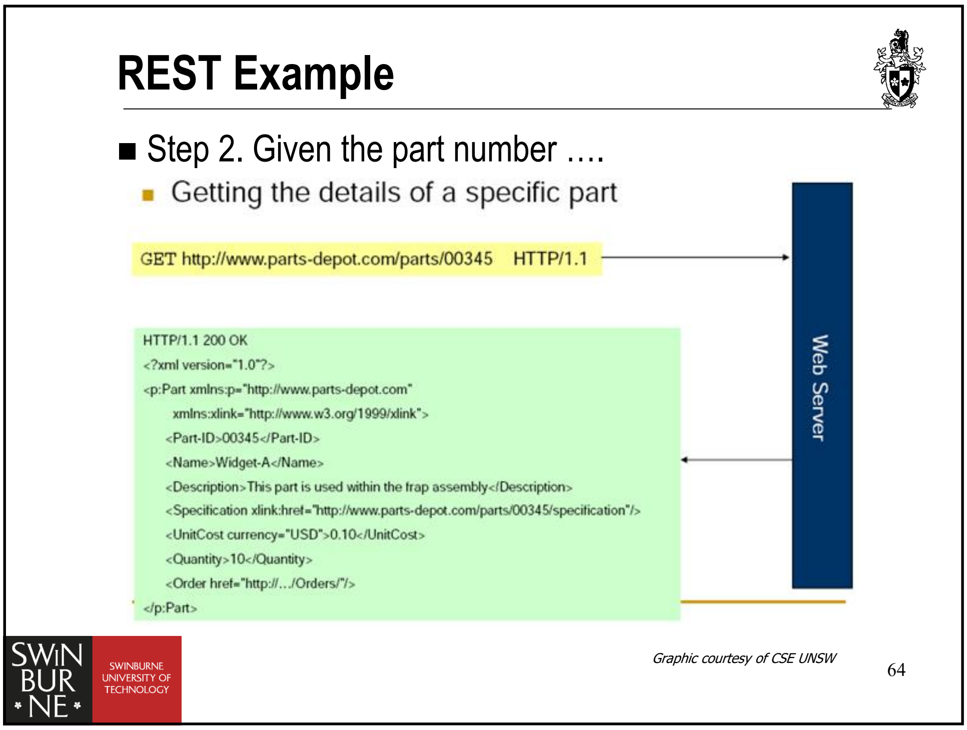
```
GET http://www.parts-depot.com/parts      HTTP/1.1
```

```
HTTP/1.1 200 OK
<?xml version="1.0"?>
<p:Parts xmlns:p="http://www.parts-depot.com"
      xmlns:xlink="http://www.w3.org/1999/xlink">
    <Part id="00345" xlink:href="http://www.parts-depot.com/parts/00345"/>
    <Part id="00346" xlink:href="http://www.parts-depot.com/parts/00346"/>
    <Part id="00347" xlink:href="http://www.parts-depot.com/parts/00347"/>
    <Part id="00348" xlink:href="http://www.parts-depot.com/parts/00348"/>
</p:Parts>
```

Graphic courtesy of CSE UNSW

63

63



REST Example

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

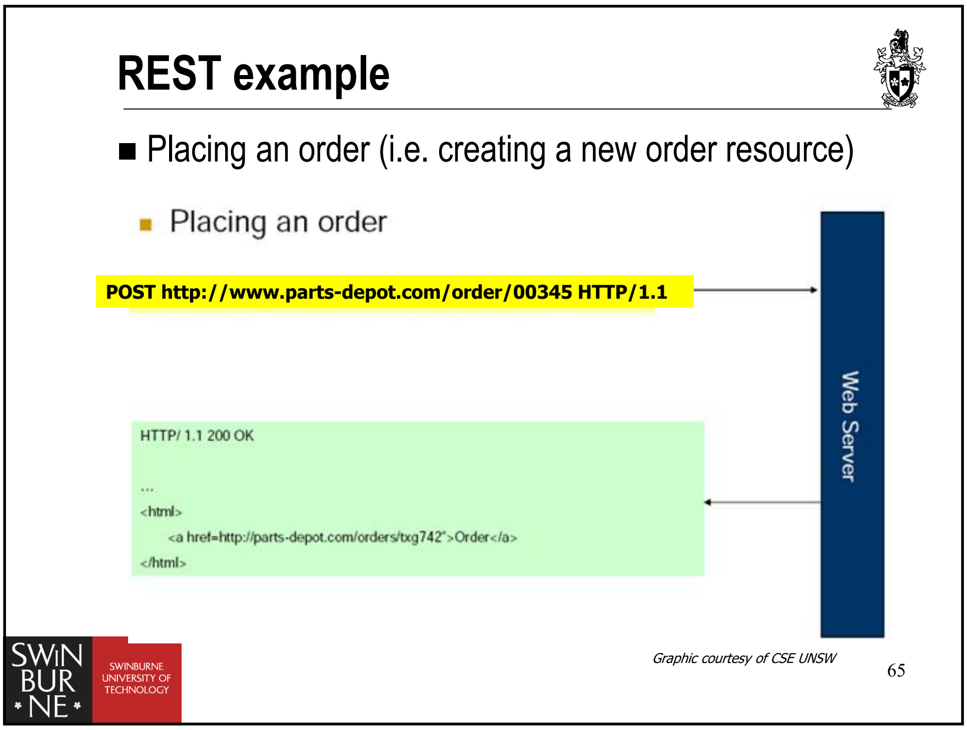
```
GET http://www.parts-depot.com/parts/00345   HTTP/1.1
```

```
HTTP/1.1 200 OK
<?xml version="1.0"?>
<p:Part xmlns:p="http://www.parts-depot.com"
      xmlns:xlink="http://www.w3.org/1999/xlink">
    <Part-ID>00345</Part-ID>
    <Name>Widget-A</Name>
    <Description>This part is used within the frap assembly</Description>
    <Specification xlink:href="http://www.parts-depot.com/parts/00345/specification"/>
    <UnitCost currency="USD">0.10</UnitCost>
    <Quantity>10</Quantity>
    <Order href="http://.../Orders/"/>
</p:Part>
```

Graphic courtesy of CSE UNSW

64

64



REST example

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

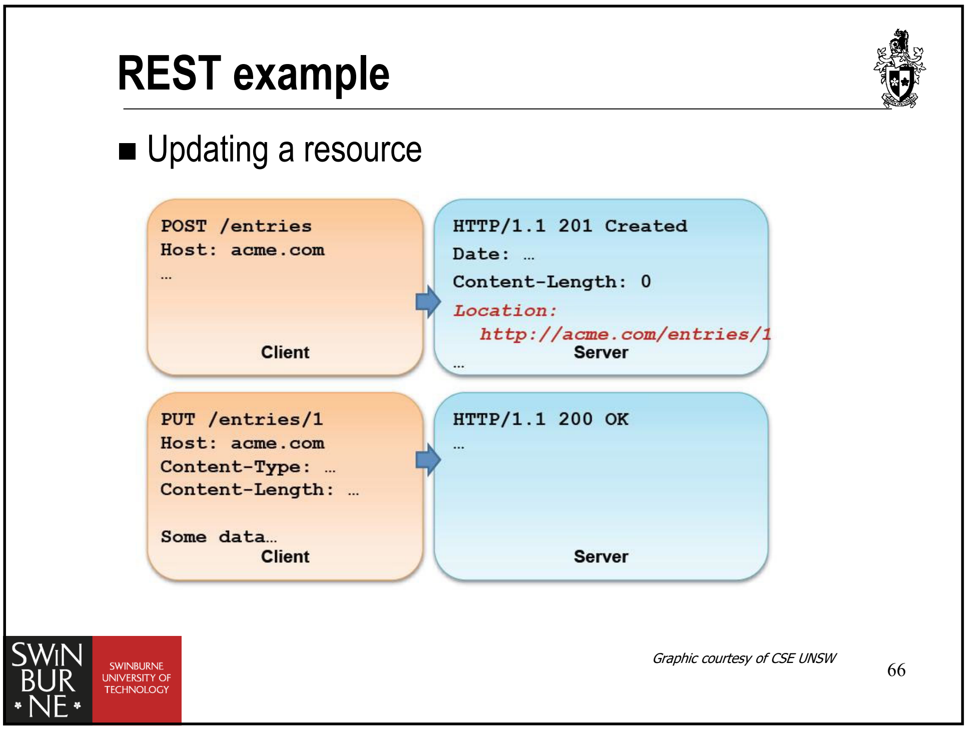
```
POST http://www.parts-depot.com/order/00345 HTTP/1.1
```

```
HTTP/ 1.1 200 OK

…
<html>
    <a href=http://parts-depot.com/orders/txg742">Order</a>
</html>
```

Graphic courtesy of CSE UNSW

65

65



REST example

- Updating a resource

```
POST /entries
Host: acme.com
…
```

```
HTTP/1.1 201 Created
Date: …
Content-Length: 0
Location:
   http://acme.com/entries/1
…
```

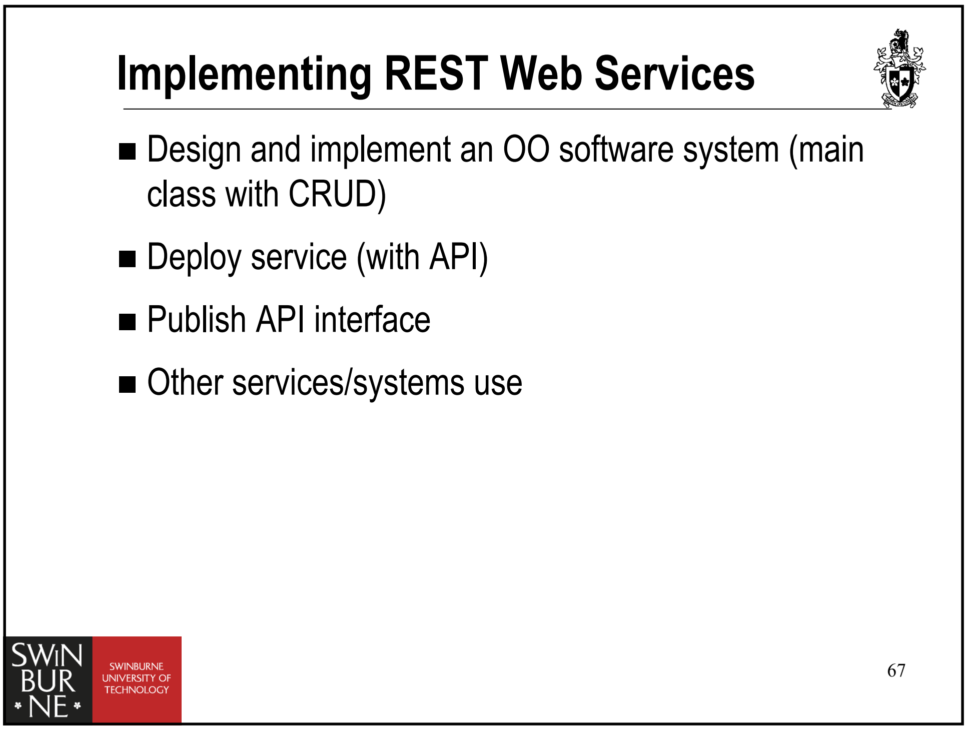
```
PUT /entries/1
Host: acme.com
Content-Type: …
Content-Length: …

Some data…
```

```
HTTP/1.1 200 OK
…
```

Graphic courtesy of CSE UNSW

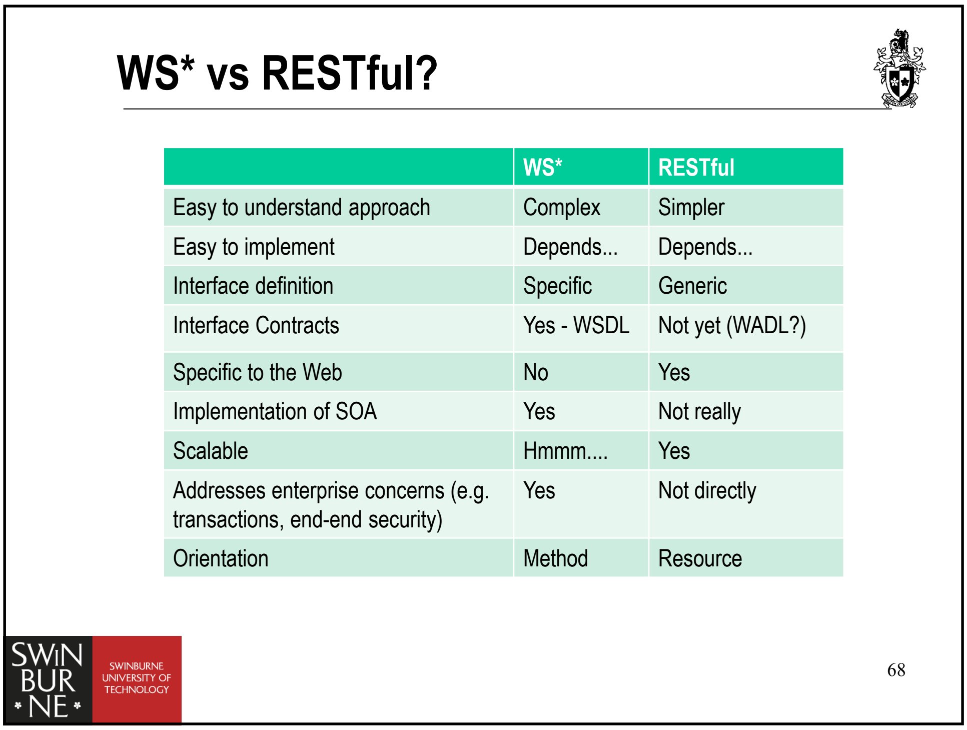
66

66



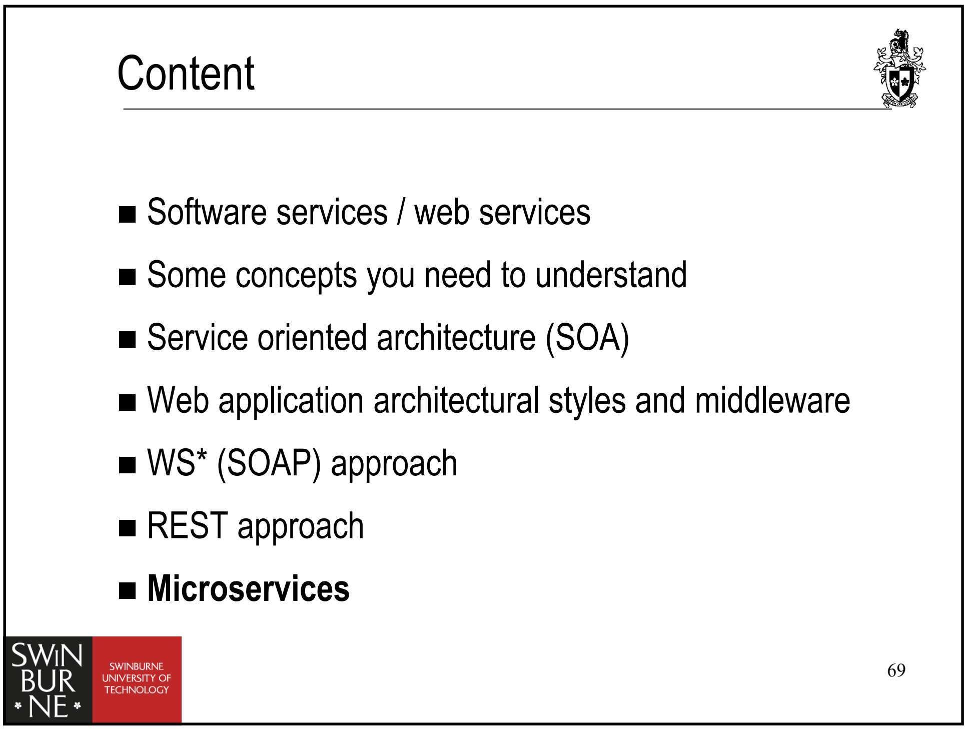
Implementing REST Web Services

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



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



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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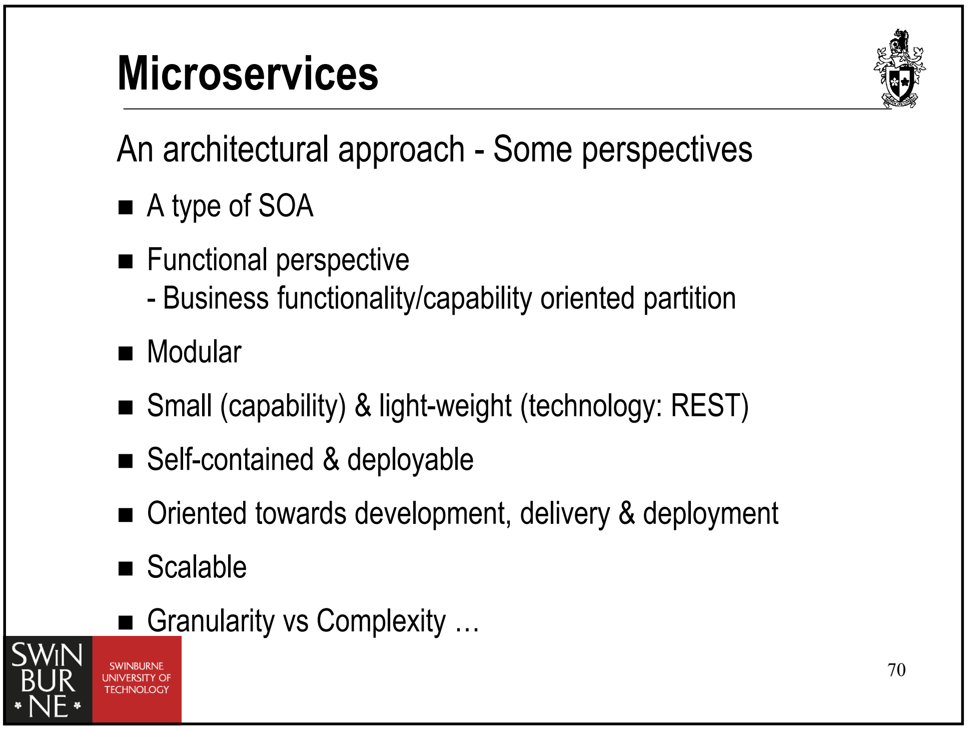

Microservices

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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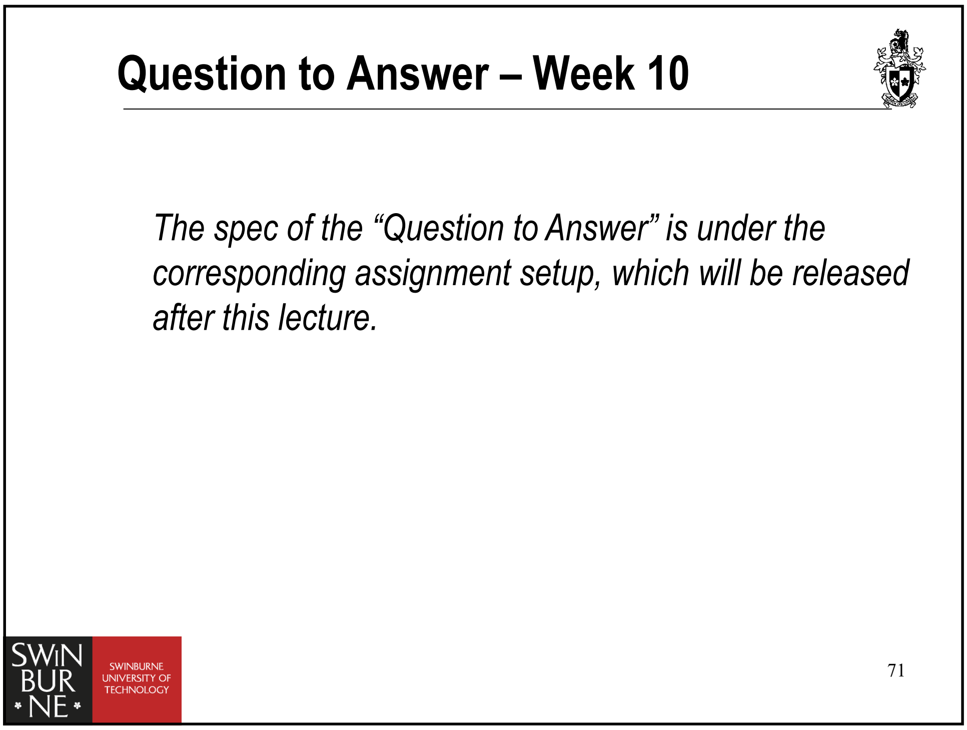
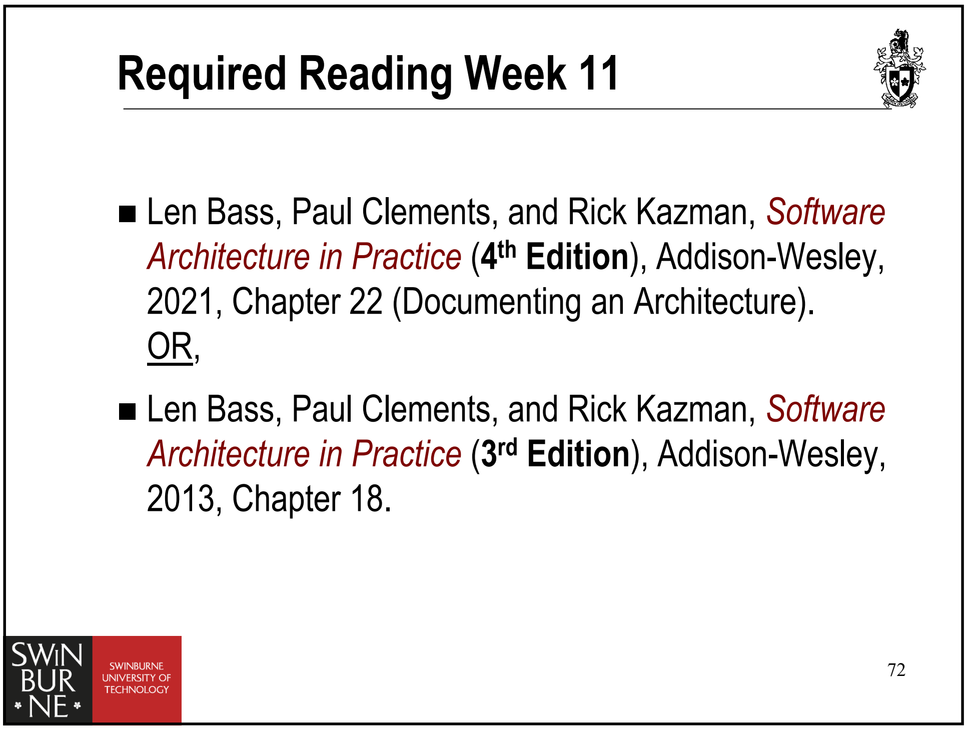


Question to Answer – Week 10

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

71



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.

72