Web services

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Motivation for web services

- Electronic data interchange
- Distributed applications
  - even as simple as client / server
- Interoperability and flexibility
  - need for (high-level and device-independent) standards
- Service Oriented Architecture

Evolution of internet applications

- human ↔ human
  - email
  - WWW sites written manually
- application ↔ human
  - web applications (e.g. an internet shop)
- application ↔ application
  - “electronic data interchange”
    - low-level technologies and ad-hoc solutions
    - pre-XML standards (e.g. EDIFACT)
    - “web services”
    - REST, AJAX, etc.

Electronic data interchange (EDI) – motivation

- How to interchange data between companies / institutions (B2B)?
    - paper
    - electronic data interchange
- How to establish EDI protocol?
    - customer receives (or buys) a tool from provider
    - smaller partner complies to bigger parter
    - ad-hoc created conversion tools
    - **standard**
- Standard deployment levels
    - software developed according to standard from beginning
    - interface added to legacy system

Pre-XML solutions

- ANSI Accredited Standards Committee X12 sub-group
  - USA national standard
  - used mainly in America
- EDIFACT
  - international standard (UN/CEFACT and ISO)
  - used mainly in Europe and Asia

EDIFACT characteristic

- Format
  - text
  - hardly readable
  - tree structure
- Predefined dictionaries
- 193 message types
- 279 segments
- 186 elements

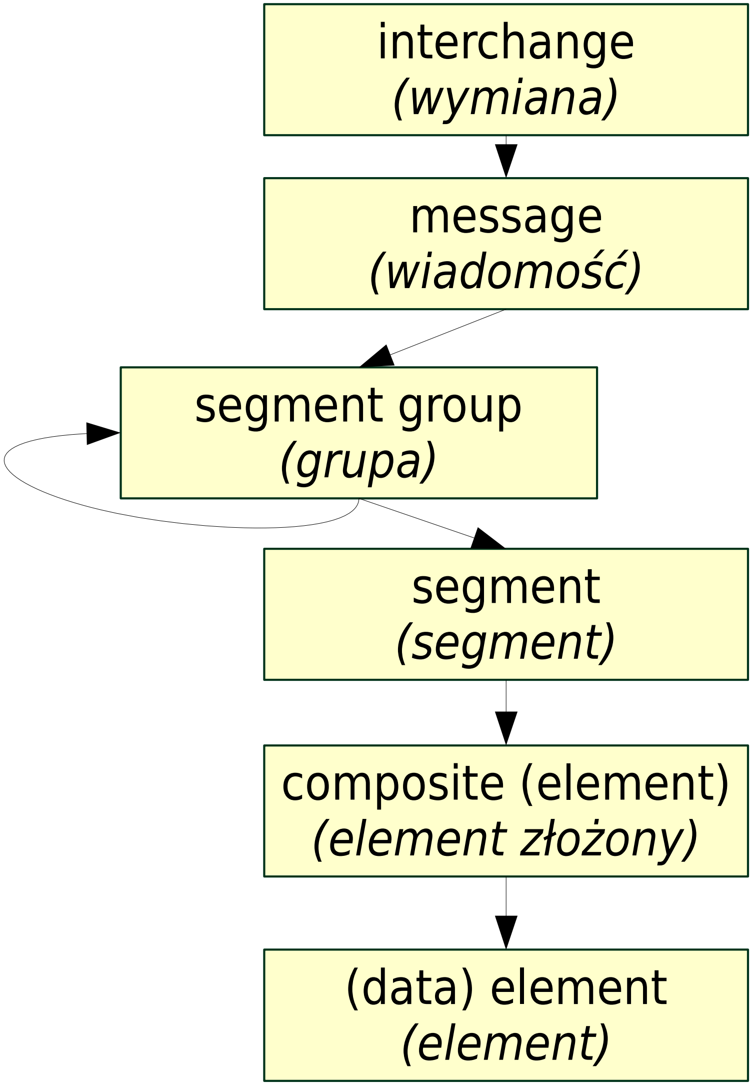
(counted for version 08a, 2008)

EDIFACT

- EDIFACT message example

```
UNB+IATB:1+6XPPC+LHPPC+940101:0950+1'
UNH+1+PAORES:93:1:IA'
MSG+1:45'
IFT+3+XYZCOMPANY AVAILABILITY'
ERC+A7V:1:AMD'
IFT+3+NO MORE FLIGHTS'
ODI'
TVL+240493:1000::1220+FRA+JFK+DL+400+C'
PDI++C:3+Y::3+F::1'
APD+74C:0:::6++++++6X'
TVL+240493:1740::2030+JFK+MIA+DL+081+C'
PDI++C:4'
APD+EM2:0:1630::6+++++++DA'
UNT+13+1'
UNZ+1+1'
```

EDIFACT structure



```
TVL+240493:1000::1220+FRA+JFK+DL+400+C'
PDI++C:3+Y::3+F::1'
APD+74C:0:::6++++++6X'
```

```
TVL+240493:1000::1220+FRA+JFK+DL+400+C'
```

```
+240493:1000::1220+
```

```
:1000:
```

XML EDI

Idea: use XML as data format for EDI

- Traditional EDI
  - Documents unreadable without specification
  - Compact messages
  - Centralised standard maintenance
  - Changes in format requires software change
  - Specialised tools needed
- XML EDI
  - “Self-descriptioning” documents format
  - Verbose messages
  - “Pluggable”, flexible standards
  - Well written software ready to extensions of format
  - XML-format layer handled by general XML libraries

XML EDI flexibility

- Format flexibility
  - Structures: choosing, repeating, nesting, optionality
  - Format extensions and mixing via namespaces
- Applications
  - Data interchange between partners' systems
  - Web interface (with little help from XSLT)
- Web Services integration

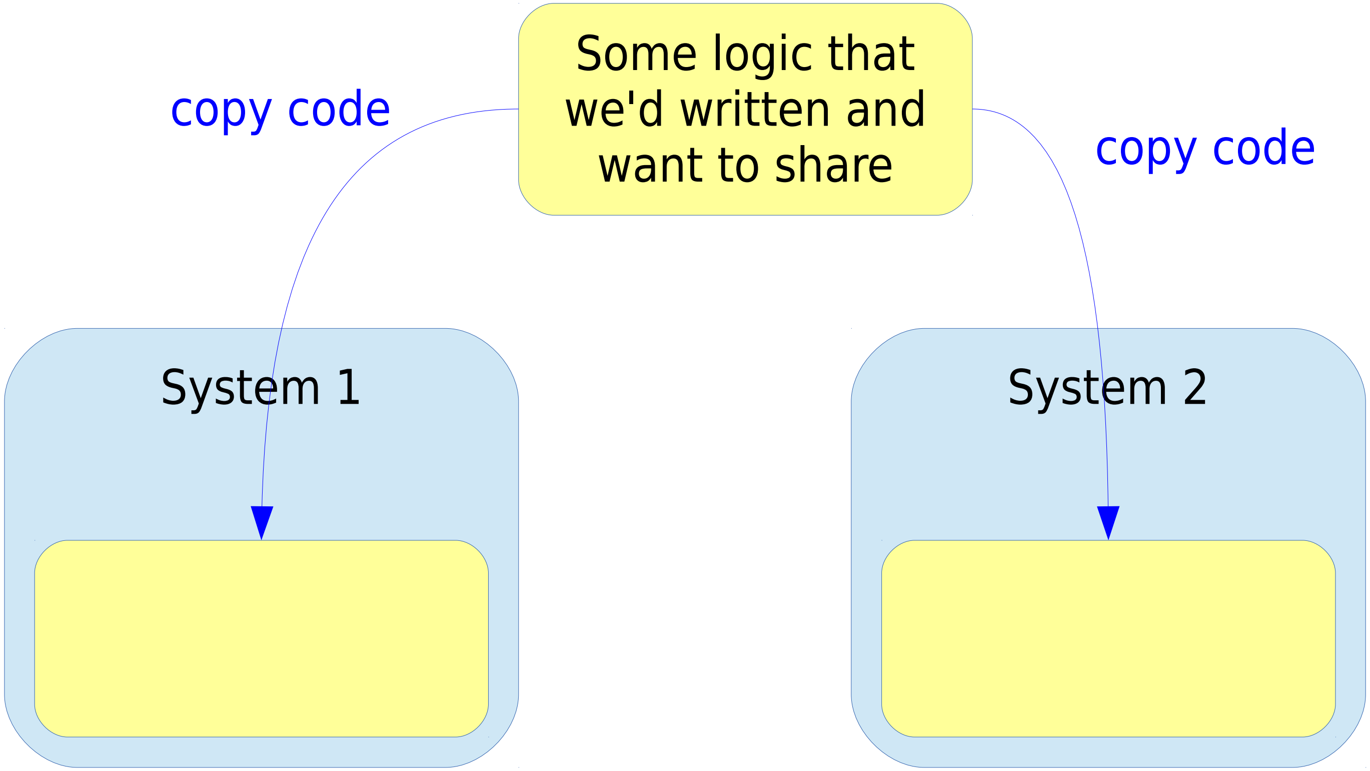
Service Oriented Architecture (SOA)

- Build software modules as services
  - available for other services and programs
  - using other services when necessary
- Share working services, not code

- It is a general characteristic, it does not require to use any particular type of services or standards.
  - However, standardisation helps to prepare *interoperable* services which are independent of hardware and software architecture.

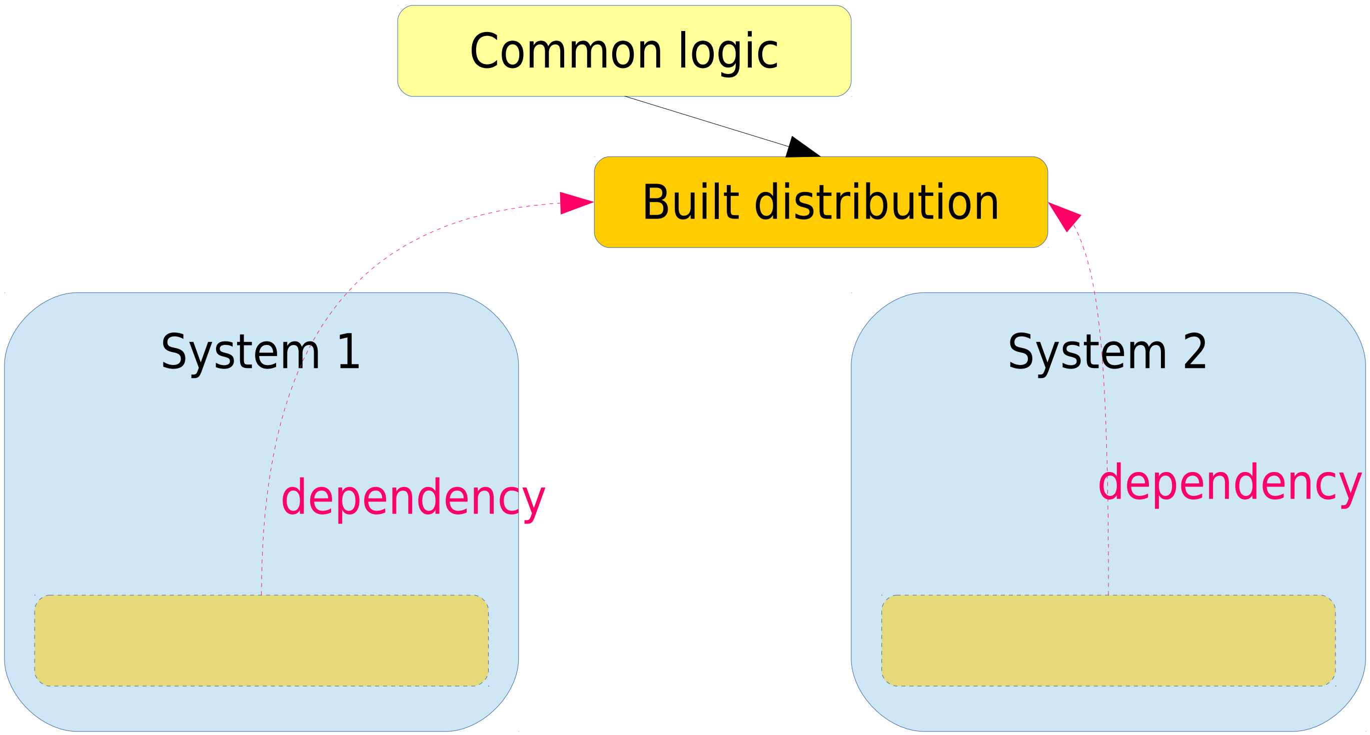
Bad approach to share systems logic

- Write the same thing twice
- Copy & paste source code
  - Different systems include the same source code; at best – synchronised to a common repository



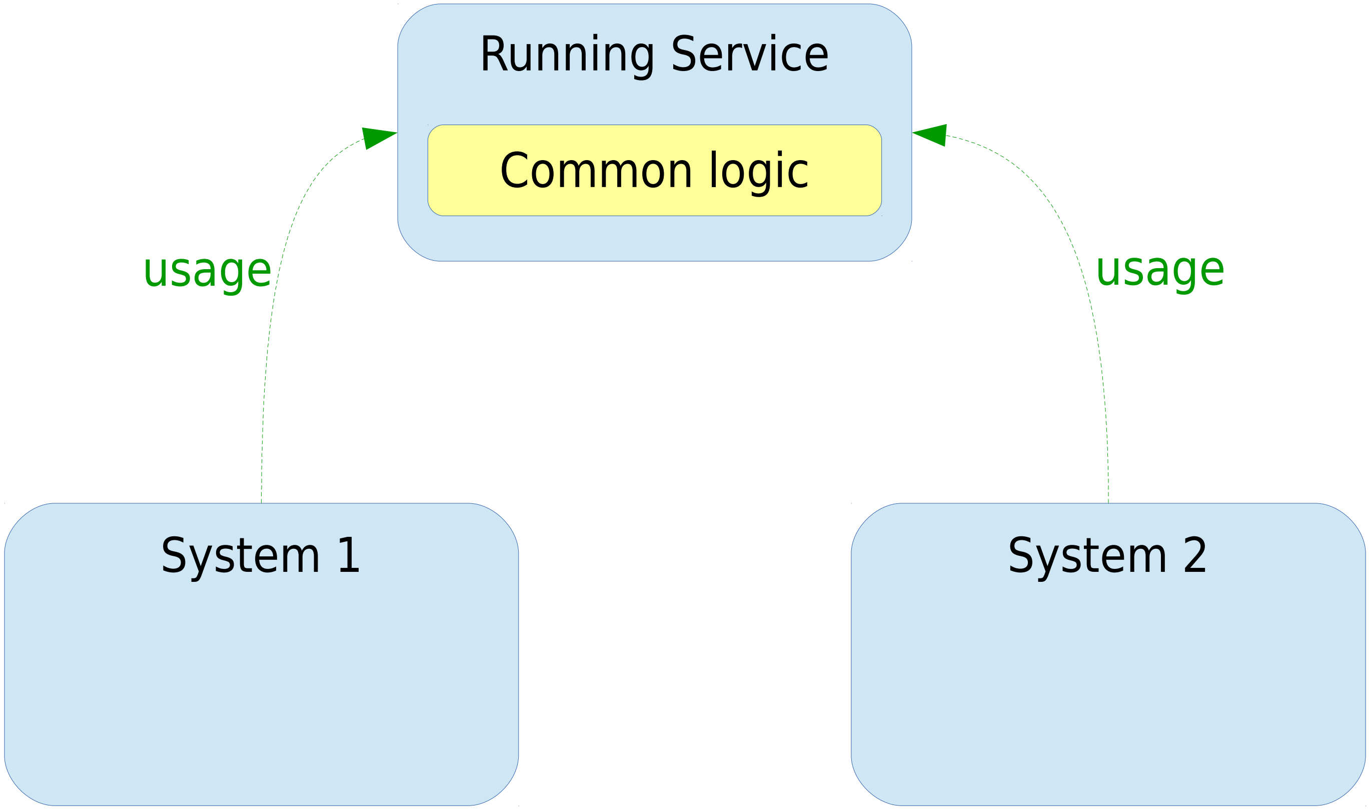
Traditional *component* approach

- Build software components that can be used **within** different software systems via their public API.
  - Usually realised as dependencies (e.g. Maven) and sharing of compiled software libraries



Service approach

- Expose the common logic as a running service and make other systems use it.
  - Only one running instance of the logic, no copying.



Benefits and costs of SOA

- Systems are lighter (at least in theory) as they do not duplicate logic.
- A (well designed) service available for different client platforms (*interoperability*).
- One place of (that "logic") management:
  - bug fixes and enhancements,
  - security, access control.

But...

- In practice, standard-based web services (especially classical web services based on SOAP and WSDL) adds a notable cost

Web Services

- Idea: a website for programs (instead of people)
- General definition
  - communication based on high-level protocols
  - structural messages
  - services described
  - searching services
- Concrete definition: “Classical” Web-Services
  - HTTP or other protocols
  - SOAP
  - WSDL
  - UDDI
  - Web Services Interoperability

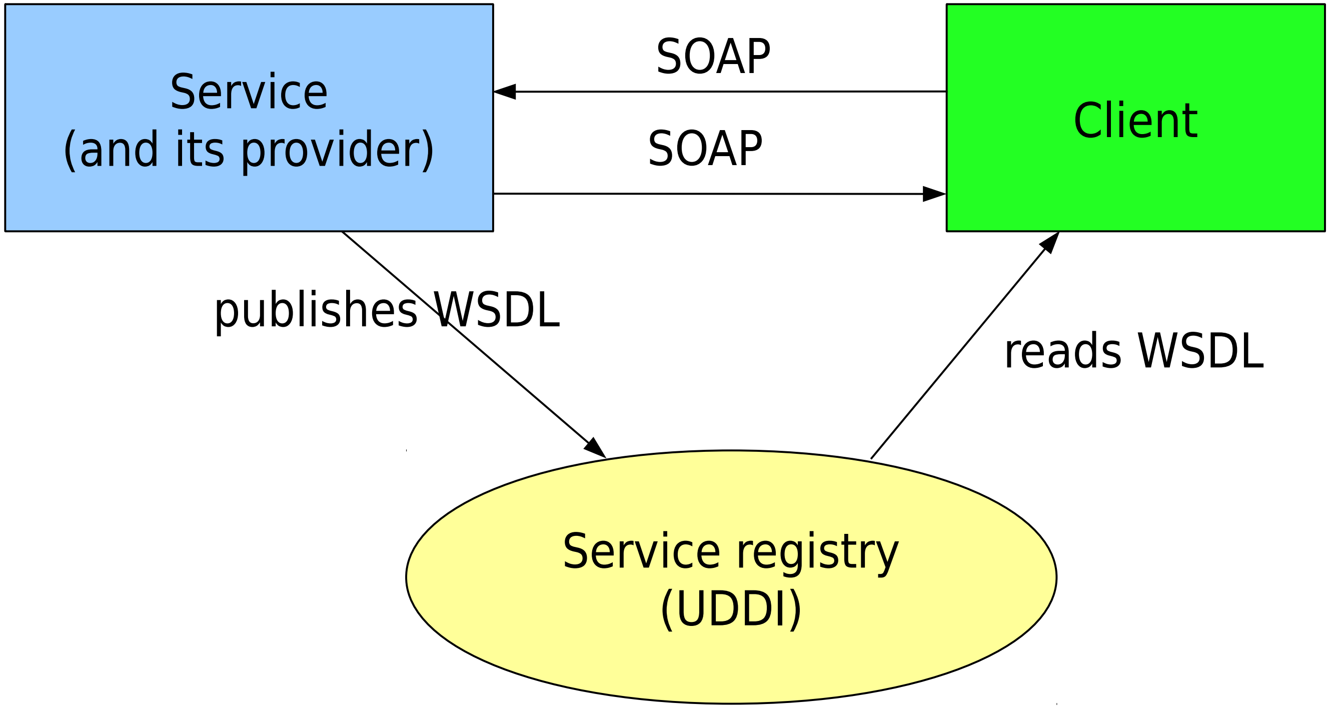
Web Services standardisation

- SOAP (initially Simple Object Access Protocol:
  - beginnings: 1998
  - v1.1: W3C Note, 2001 (still in use)
  - v1.2: W3C Recommendation, June 2003 (also used)
- Web Services Description Language:
  - W3C Note, 2001 (most applications use this version!)
  - v2.0: W3C Recommendation, June 2007
- Universal Description Discovery and Integration:
  - OASIS project

Web Services standardisation (2)

- Web Services Interoperability – levels of WS compliance:
  - WS-I Basic Profile, Simple Soap Binding Profile, ...
- WS-* standards: various standards, usually not W3C:
  - WS-Eventing, WS-Addressing, WS-Routing, WS-Security
- Business Process Execution Language (OASIS) – WS semantics description, programming using WS as building blocks

Classical vision of web services operation

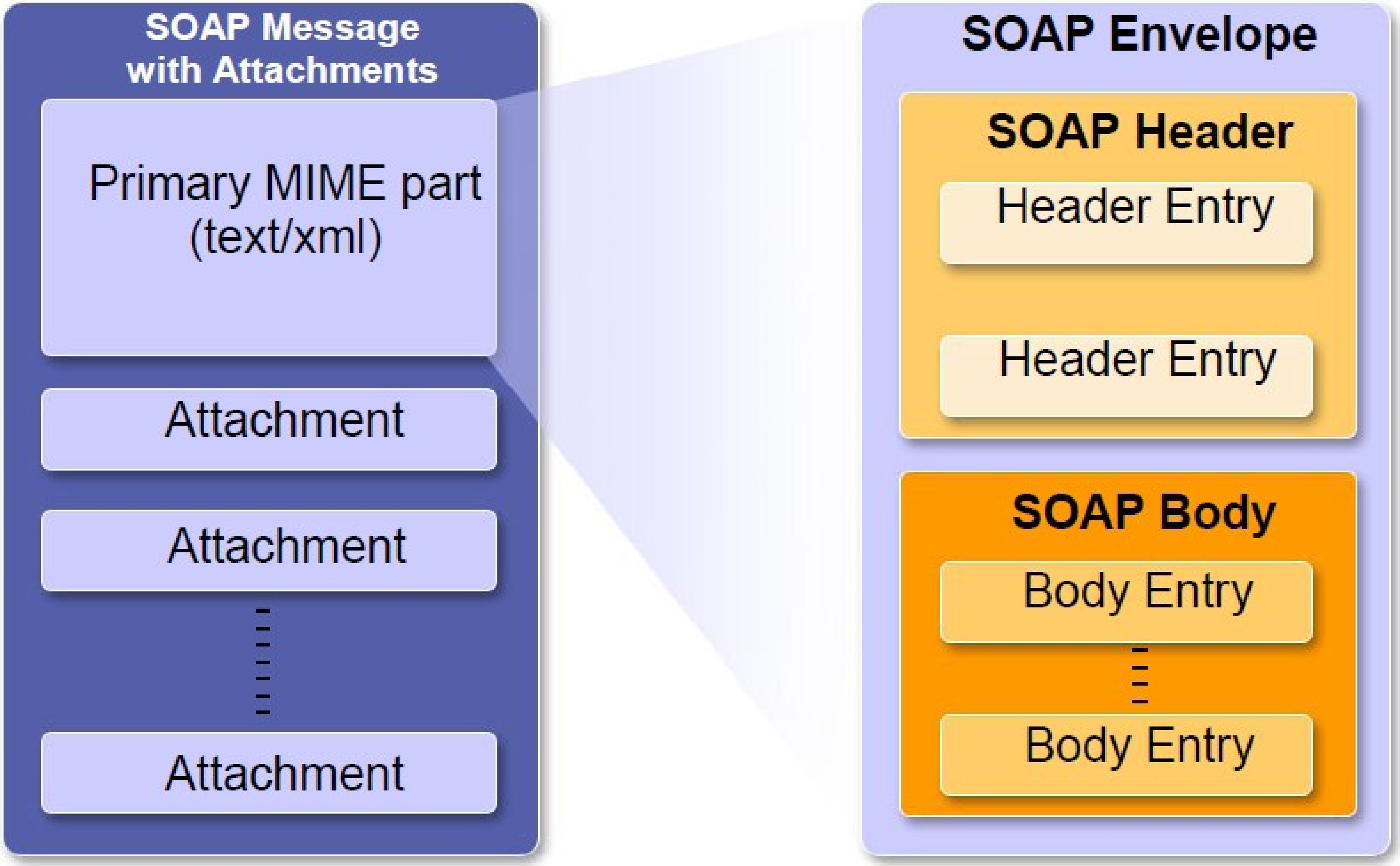


In fact, most of deployed solutions don't use the UDDI layer

SOAP – communication protocol

- Built on top of existing transport protocol (HTTP or other)
- Message format
  - XML message with optional binary attachments
  - headers (optional XML elements) and body content
  - envelope and some special elements defined in standard
  - implementation-dependent content
- Differences to RPC, CORBA, DCOM etc.:
  - data represented in extensible, structural format (XML)
  - data types independent of platform (XML Schema)
  - lower efficiency

SOAP message – general form



SOAP 1.2 message

```
<soap:Envelope
      xmlns:soap="http://www.w3.org/2001/12/soap-envelope"
      soap:encodingStyle="http://www.w3.org/2001/12/literal">

   <soap:Header>
      <t:Trans xmlns:t="http://www.w3schools.com/transaction/"
         soap:mustUnderstand="1">234</m:Trans>
   </soap:Header>

   <soap:Body>
      <m:GetPrice xmlns:m="http://www.w3schools.com/prices">
         <m:Item>Apples</m:Item>
         <m:Currency>PLN</m:Currency>
      </m:GetPrice>
   </soap:Body>
</soap:Envelope>
```

SOAP 1.2 – normal response

```
<soap:Envelope
      xmlns:soap="http://www.w3.org/2001/12/soap-envelope"
      soap:encodingStyle="http://www.w3.org/2001/12/soap-encoding">

   <soap:Body>
      <m:GetPriceResponse xmlns:m="http://www.w3schools.com/prices">
         <m:Price>1.90</m:Price>
         <m:Currency>PLN</m:Currency>
      </m:GetPriceResponse>
   </soap:Body>
</soap:Envelope>
```

SOAP 1.2 – fault response

```
<soap:Envelope xmlns:usos="urn:USOS"
      xmlns:soap="http://www.w3.org/2001/12/soap-envelope"
      soap:encodingStyle="http://www.w3.org/2001/12/soap-encoding">

   <soap:Body>
      <soap:Fault>
         <soap:faultcode>soap:Receiver</soap:faultcode>
         <soap:faultstring>Data missing</soap:faultstring>
         <soap:faultdetail>
            <usos:exception>Found no student identified
               with <usos:ind>123</usos:ind>
            </usos:exception>
         </soap:faultdetail>
      </soap:Fault>
   </soap:Body>
</soap:Envelope>
```

SOAP – more info

- Request and response have the same structure.
  - In fact, we can think of SOAP as a document transport protocol, not necessarily in client-server architecture.
- Header part optional, Body part required.
- Restrictions on XML part:
  - no DTD (and external entity references),
  - no processing instructions.
- Although SOAP allows many body elements (elements within `soap:Body`), WS-I BP requires exactly one.
  - To make applications portable we should follow this restriction.

WSDL – service description

- XML document describing a service
- Interface (“visit card”) of a service (or set of services)
- Specifies (from abstract to concrete things)
  - XML types and elements (using XML Schema)
  - types of messages
  - port types – available operations, their input and output
  - details of binding abstract operations to a concrete protocol (SOAP in case of “classical” services)
  - ports – concrete instances of services, with their URL
- Splitting definitions into several files and using external schema definitions available

WSDL 1.1 structure

```
<?xml version="1.0" encoding="UTF-8"?>
<definitions name='HelloWorldService'
   targetNamespace='http://example.com/hello'
   xmlns='http://schemas.xmlsoap.org/wsdl/'
   xmlns:soap='http://schemas.xmlsoap.org/wsdl/soap/'
   xmlns:tns='http://example.com/hello'
   xmlns:xsd='http://www.w3.org/2001/XMLSchema'>
 <types>
...............
 </types>
 <message name='HelloWorld_sayHello'>
...............
 </message>
 <message name='HelloWorld_sayHelloResponse'>
...............
 </message>
 <portType name='HelloWorld'>
...............
 </portType>
 <binding name='HelloWorldBinding' type='tns:HelloWorld'>
...............
 </binding>
 <service name='HelloWorldService'>
  <port binding='tns:HelloWorldBinding' name='HelloWorldMyPort'>
...............
  </port>
 </service>
</definitions>
```

XML Schema element and type defs.

Message defs.

The interface (set of operations)

Binding with a particular protocol, usually SOAP

Web Service instance (concrete URL given)

WSDL and SOAP interaction

Basically – specified through binding element in WSDL

  - not so simple, because of many possibilities

- **RPC style**
  - SOAP XML structure derived basing on operation name and message parts
- **Document style**
  - theoretically designed to allow sending arbitrary content enclosed in XML documents
  - in practice - also used for RPC realisation, but the author of WSDL has to define the appropriate document structure
    - (some tools may be helpful, e.g. bottom-up service generation in Java JAX-WS)
- Message use: **literal** or **encoded**.
  - We should use literal in modern applications.

Service registration and discovery

- Idea
    - service registries
    - service providers register their services
    - clients search for services and find them in registries
- Universal Description Discovery and Integration (UDDI)
    - available as service (SOAP)
    - business category-based directory (“yellow pages”)
    - searching basing on service name, description (“white pages”)
    - registration and updates for service providers

UDDI – issues

- Main issue – who can register?
  - anybody – chaos and low reliability
  - accepted partners – an institution responsible for access policy needed, no such (widely accepted) institution exists
- Reality
  - UDDI rarely used
  - if ever – for “local” SOA-based solutions (intranets)

Web Services advantages and problems

- Advantages:
  - Standardised, platform-independent technology
  - Interoperability
  - Existing tools and libraries
- Main drawbacks:
  - Inefficiency
    - size of messages → transfer, memory usage
    - data representation translated many times on the road from client to server (and vice versa) → processor usage / time
  - Complex standards, especially when using something more than raw WSDL+SOAP

Are Web Services good or bad?

- SOA and Web Services give an opportunity to build
  - modular, flexible, and scalable solutions
  - (sometimes) by the cost of irrational inefficiency and complexity
- Web Service recommended when
  - Many partners or public service (standardisation)
  - Heterogeneous architecture
  - Text and structural data already present in problem domain
  - Interoperability and flexibility more important than efficiency
- Web Service?... not necessarily
  - Internal, homogeneous solution.
  - Binary and flat data
  - Efficiency more important than interoperability

Web services in Java

Basically – web services and web service clients can be built from scratch in any technology

- but it would be the same mistake as reading XML documents char by char.

- Low-level technologies:
  - HTTP servlets and HTTP clients supported by XML processing APIs (DOM, SAX, StAX, JAXB, Transformers, ...)
  - SOAP with Attachments API for Java (**SAAJ**) – extension of DOM directly supporting SOAP
- High level approach (with low level hooks available):
  - Java API for XML Web Services (**JAX-WS**)

Web services in Java

- WS support (XML APIs, SAAJ, JAX-WS) present in Java SE
  - JAX-WS and some of XML APIs since version 6.0
- Client side:
  - Possible to develop and run WS client in Java SE without any additional libraries!
- Server side:
  - Developing and compiling WS server (without any vendor-specific extensions) available in Java SE
  - Running a service requires an application server and a WS implementation
    - “Big” app servers (Glassfish, JBoss, WebSphere...) have preinstalled WS implementations
    - Lightweight servers (e.g. Tomcat) can be used by applications equipped with appropriate libraries and configuration

SAAJ

- Package javax.xml.soap
- Main class – SOAPMessage
- Tree-like representation of SOAP messages
  - extension of DOM
  - easy access to existing and building fresh SOAP messages
  - support for HTTP headers, binary attachments, ...
- Easy sending of requests from client side
  - see example Client_Weather_SAAJ
- Possible implementation of server side as a servlet
  - see example Server_SAAJ

JAX-WS – introduction

- Annotation-driven
- Uses JAXB to translate Java objects to/from XML
- Central point: Service Endpoint Interface (SEI)
  - Java interface representing a WS port type
    - kalkulator.Kalkulator and pakiet.Service in our examples
- Translation between web services world (WSDL) and Java
  - **top-down**: from WSDL generate Java
    - server side – service interface and implementation skeleton
    - client side – proxy class enabling easy remote invocations
    - both sides – auxiliary classes, usually JAXB counterparts of XML elements appearing in messages
  - **bottom-up**: from Java code generate WSDL
    (and treat the Java code as a WS implementation)
    - usually done automatically during application deployment

Advantages and risks of using JAX-WS

- High level view on web service
  - details of communication and SOAP/XML not (necessarily) visible to a programmer
  - proxy object on client side enables to transparently invoke methods on server-side just like on local objects
- Automatic generation/interpretation of WSDL
  - conformance to WSDL controlled by system
- Bottom-up scenario – easy introduction of WS interface to already existing systems
  - or for programmers not familiar with WSDL/XML details
- Risk of
  - accidental service interface (WSDL)
    (automatically generated, not elaborated enough)
  - inefficiency

JAX-WS – main elements

- Class level annotations:
  - `@WebService`, `@SOAPBinding`
- Method-level annotations:
  - `@WebMethod`, `@OneWay`, `@SOAPBinding`, `@RequestWrapper`, `@ResponseWrapper`
- Parameter-level annotations:
  - `@WebParam`
  - `@WebResult` (syntactically a method annotation, applies to what the method returns)
- Support for specific technologies
  - `@MTOM` – automatically created binary attachments
  - `@Addressing` – adds WS-Addressing headers

JAX-WS – low level hooks

- Providers – low level server side
  - Useful when
    - high efficiency required (e.g. streaming processing)
    - XML technology used in implementation
- Dispatch – low level client side
- One way methods
- Asynchronous client calls
- Handlers and handler chains
  - additional processing of messages between client and server logic
  - one place to perform common logic: logging, authentication, session binding

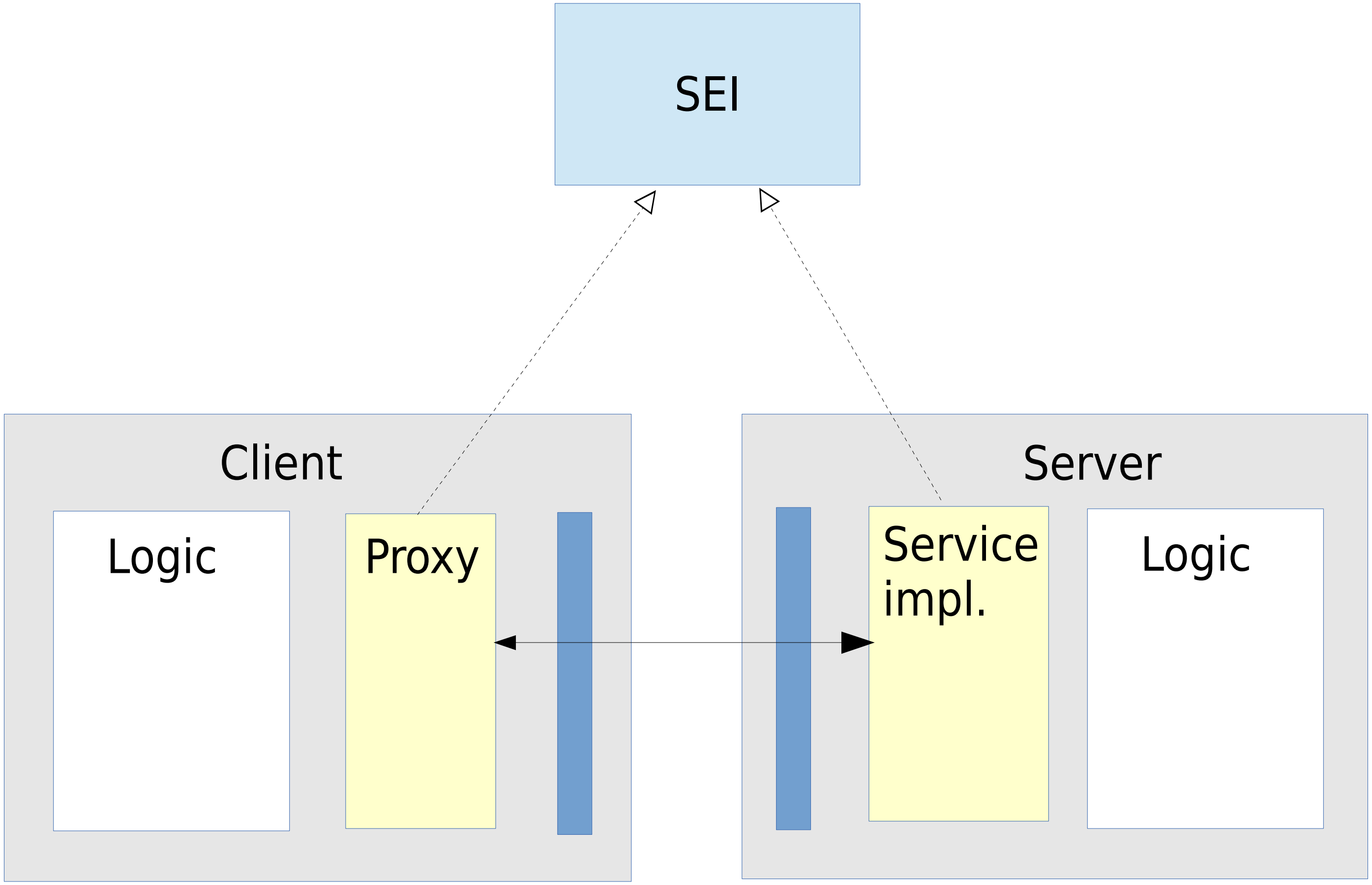
JAX-WS examples

Details to note:

- top-down (Kalkulator):
  - (different) form of WSDL in RPC and Document styles
  - 3 ways WSDL can be translated to Java (and SOAP) (RPC, document-wrapped, document-bare)
  - @WebService annotation in implementation class
- bottom-up (Hello)
  - how annotations affect SOAP messages (and WSDL)
  - how Java objects are represented in SOAP messages (JAXB)
- high level proxy clients (Client_Weather_JAXWS)

JAX-WS architecture

When both sides written in Java...



High level Java clients available also for non-Java servers!

REST – motivation

- Complexity and inefficiency of SOAP-based services led designers/researchers to propose other solutions
  - service-oriented
  - but simpler (and less general) than classical WS
- The most popular alternative these days: Representational State Transfer (**REST**)
  - Idea by Roy Fielding (2002)
  - Very popular solution for integration of JavaScript clients (AJAX) with servers
  - And mobile clients as well...
  - In Java (EE) available through JAX-RS interface

REST – basic ideas

- Service = set of resources
  - resource identified by its URL
  - best practices: URLs unique, resources organised in collections

    http://rest.example.org/service/orders/302312
- Resources
  - are representable
    - e.g. as XML
    - other formats available, a popular one is JSON
  - can be transferred through the net
- HTTP – protocol for remote access to the resources
  - HTTP methods (GET, PUT, etc) used directly

HTTP methods (in REST, but not only)

- GET – read the resource
  - no side effects
- PUT – write the resource
  - request body contains new contents
  - for writing new and overriding existing resources
- DELETE – deletes the resource
- POST – “take this piece of data and do something with it”
  - conceptually incompatible with REST ideas
  - used in practice to call remote logic more complex that reading or writing a resource
- OPTIONS, HEAD – no special meaning in REST
  - well, getting last modification time makes sense in REST...

JAX-RS – REST in Java

- Java API for RESTful Services (JAX-RS)
- Annotation driven API
- Support for different ways of passing arguments
- Content-type negotiation
  - the same resource may be available in different formats
- Easy to write HTTP servers
  - REST-specific logic has to be written manually