Semantic Web Services

John Domingue and David Martin

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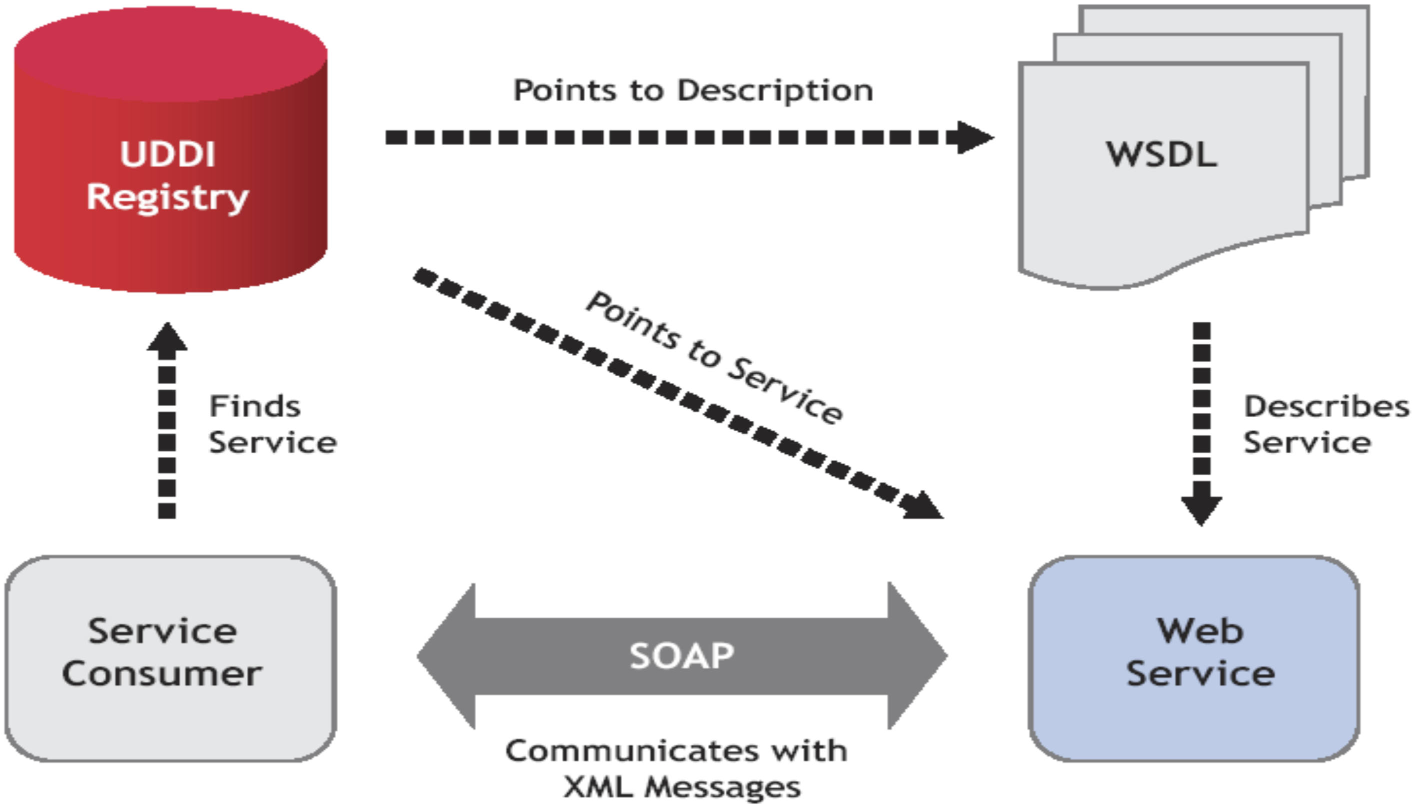
Web Services

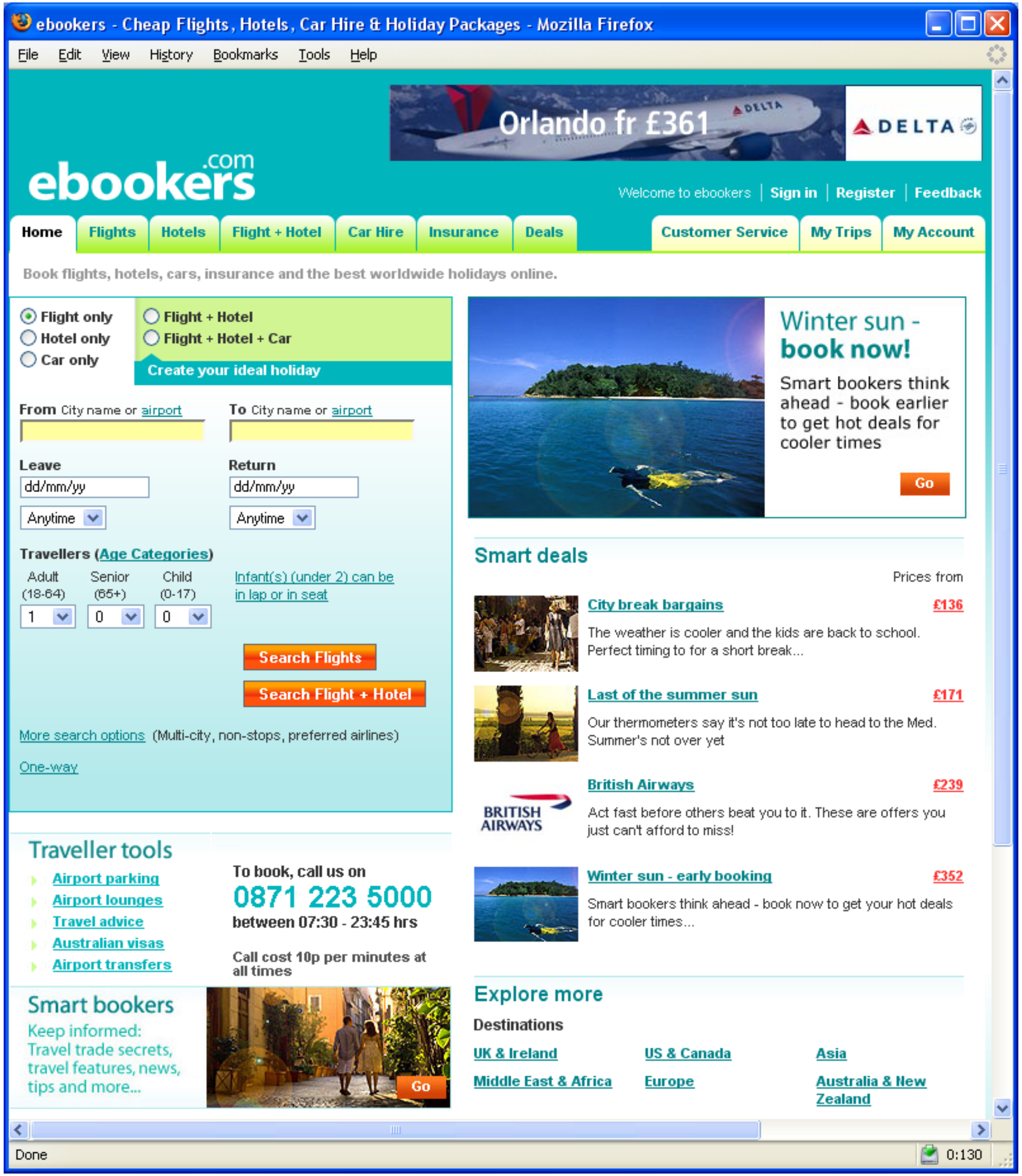
John Domingue

What’s a Web Service?

- A program programmatically accessible over standard internet protocols
- Loosely coupled, reusable components
- Encapsulate discrete functionality
- Distributed
- Add new level of functionality on top of the current web

Web Services Framework





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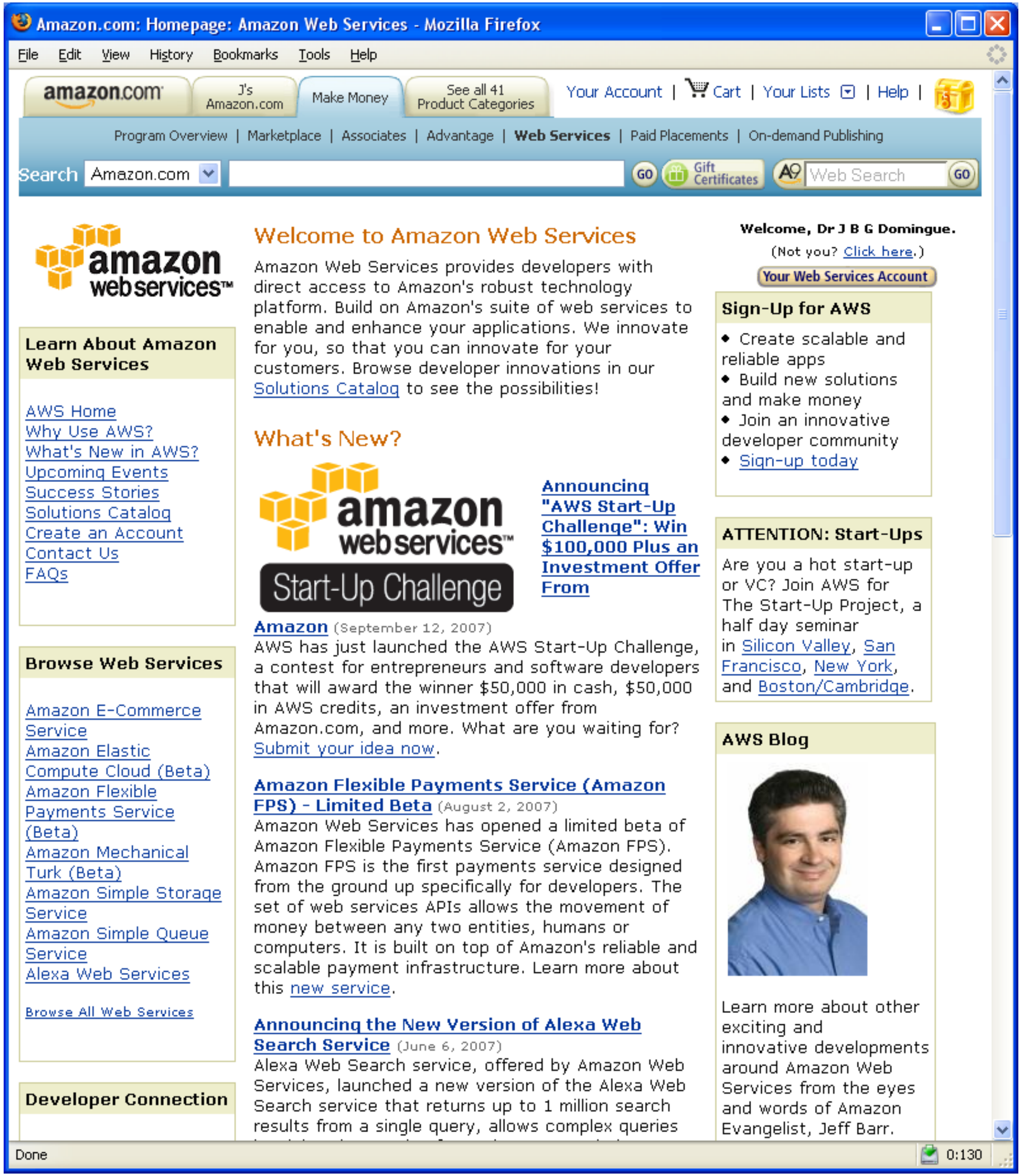
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What's New?

Announcing "AWS Start-Up Challenge": Win $100,000 Plus an Investment Offer From Amazon (September 12, 2007)
AWS has just launched the AWS Start-Up Challenge, a contest for entrepreneurs and software developers that will award the winner $50,000 in cash, $50,000 in AWS credits, an investment offer from Amazon.com, and more. What are you waiting for? Submit your idea now.

Amazon Flexible Payments Service (Amazon FPS) - Limited Beta (August 2, 2007)
Amazon Web Services has opened a limited beta of Amazon Flexible Payments Service (Amazon FPS). Amazon FPS is the first payments service designed from the ground up specifically for developers. The set of web services APIs allows the movement of money between any two entities, humans or computers. It is built on top of Amazon's reliable and scalable payment infrastructure. Learn more about this new service.

Announcing the New Version of Alexa Web Search Service (June 6, 2007)
Alexa Web Search service, offered by Amazon Web Services, launched a new version of the Alexa Web Search service that returns up to 1 million search results from a single query, allows complex queries

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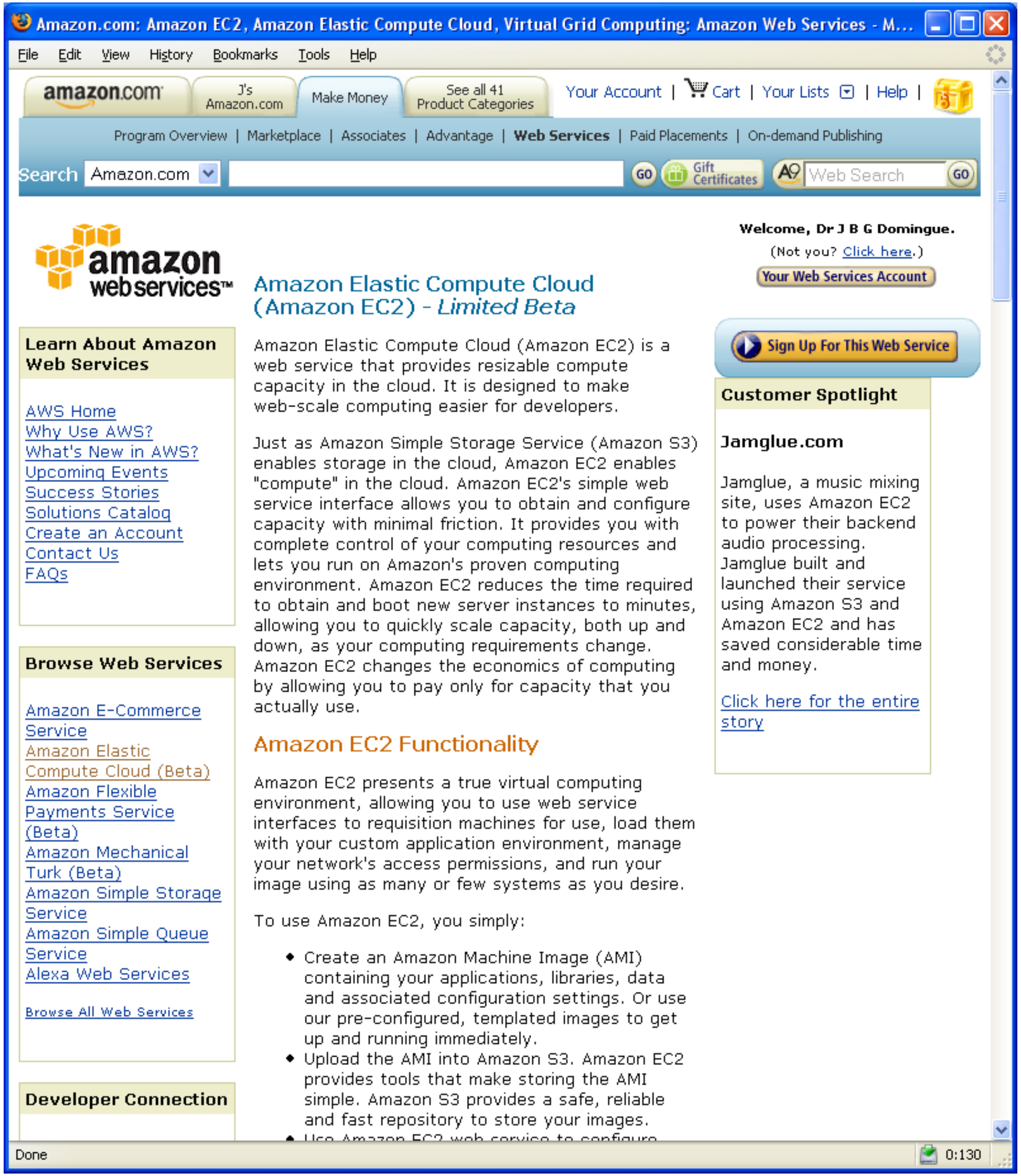
AWS Blog

Learn more about other exciting and innovative developments around Amazon Web Services from the eyes and words of Amazon Evangelist, Jeff Barr.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Amazon Elastic Compute Cloud (Amazon EC2) - *Limited Beta*

Amazon Elastic Compute Cloud (Amazon EC2) is a web service that provides resizable compute capacity in the cloud. It is designed to make web-scale computing easier for developers.

Just as Amazon Simple Storage Service (Amazon S3) enables storage in the cloud, Amazon EC2 enables "compute" in the cloud. Amazon EC2's simple web service interface allows you to obtain and configure capacity with minimal friction. It provides you with complete control of your computing resources and lets you run on Amazon's proven computing environment. Amazon EC2 reduces the time required to obtain and boot new server instances to minutes, allowing you to quickly scale capacity, both up and down, as your computing requirements change. Amazon EC2 changes the economics of computing by allowing you to pay only for capacity that you actually use.

Amazon EC2 Functionality

Amazon EC2 presents a true virtual computing environment, allowing you to use web service interfaces to requisition machines for use, load them with your custom application environment, manage your network's access permissions, and run your image using as many or few systems as you desire.

To use Amazon EC2, you simply:

- Create an Amazon Machine Image (AMI) containing your applications, libraries, data and associated configuration settings. Or use our pre-configured, templated images to get up and running immediately.
- Upload the AMI into Amazon S3. Amazon EC2 provides tools that make storing the AMI simple. Amazon S3 provides a safe, reliable and fast repository to store your images.
- Use Amazon EC2 web service to configure

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Alexa Web Services

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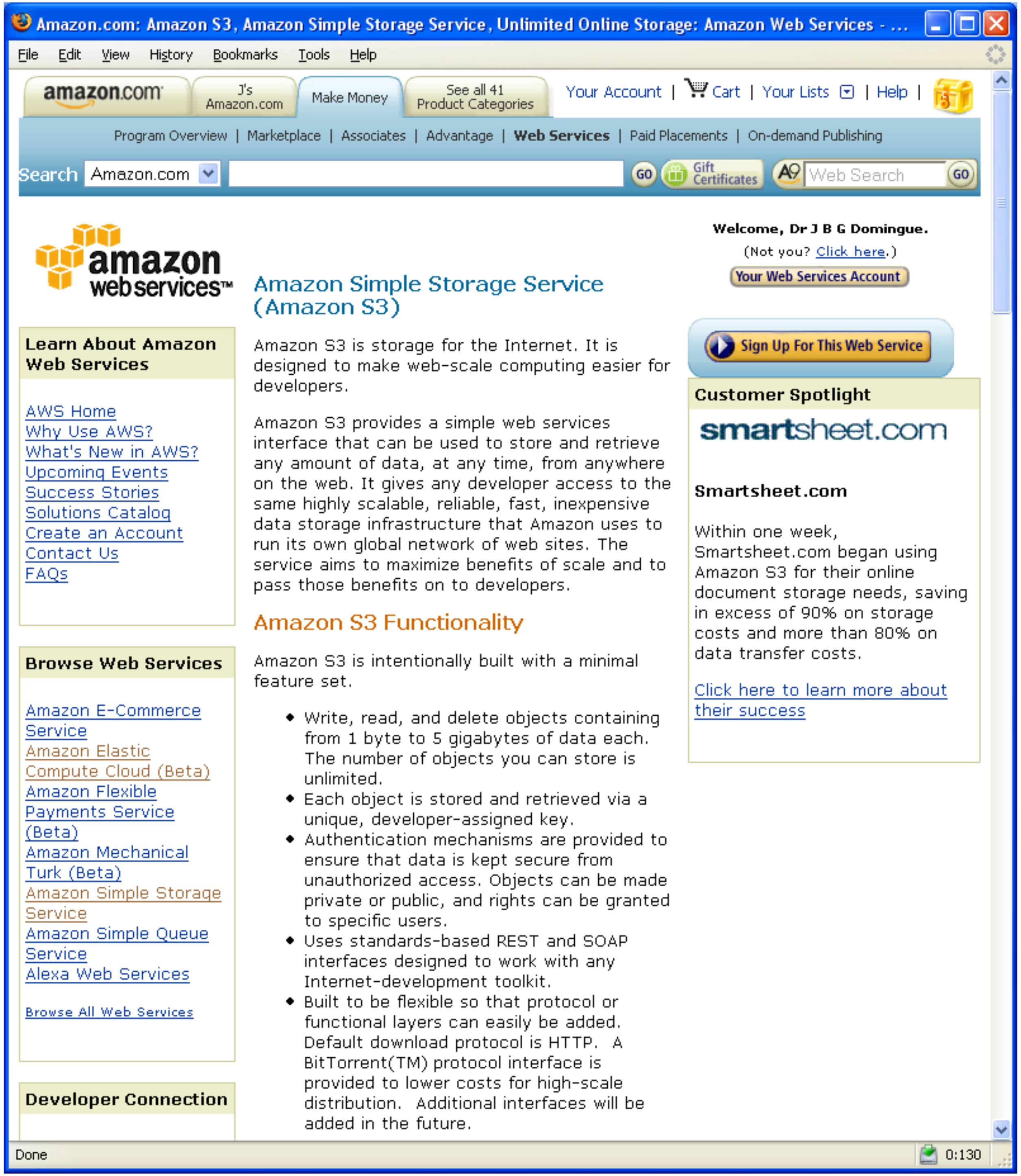
Developer Connection

Customer Spotlight

Jamglue.com

Jamglue, a music mixing site, uses Amazon EC2 to power their backend audio processing. Jamglue built and launched their service using Amazon S3 and Amazon EC2 and has saved considerable time and money.

Click here for the entire story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Amazon Simple Storage Service (Amazon S3)

Amazon S3 is storage for the Internet. It is designed to make web-scale computing easier for developers.

Amazon S3 provides a simple web services interface that can be used to store and retrieve any amount of data, at any time, from anywhere on the web. It gives any developer access to the same highly scalable, reliable, fast, inexpensive data storage infrastructure that Amazon uses to run its own global network of web sites. The service aims to maximize benefits of scale and to pass those benefits on to developers.

Amazon S3 Functionality

Amazon S3 is intentionally built with a minimal feature set.

- Write, read, and delete objects containing from 1 byte to 5 gigabytes of data each. The number of objects you can store is unlimited.
- Each object is stored and retrieved via a unique, developer-assigned key.
- Authentication mechanisms are provided to ensure that data is kept secure from unauthorized access. Objects can be made private or public, and rights can be granted to specific users.
- Uses standards-based REST and SOAP interfaces designed to work with any Internet-development toolkit.
- Built to be flexible so that protocol or functional layers can easily be added. Default download protocol is HTTP. A BitTorrent(TM) protocol interface is provided to lower costs for high-scale distribution. Additional interfaces will be added in the future.

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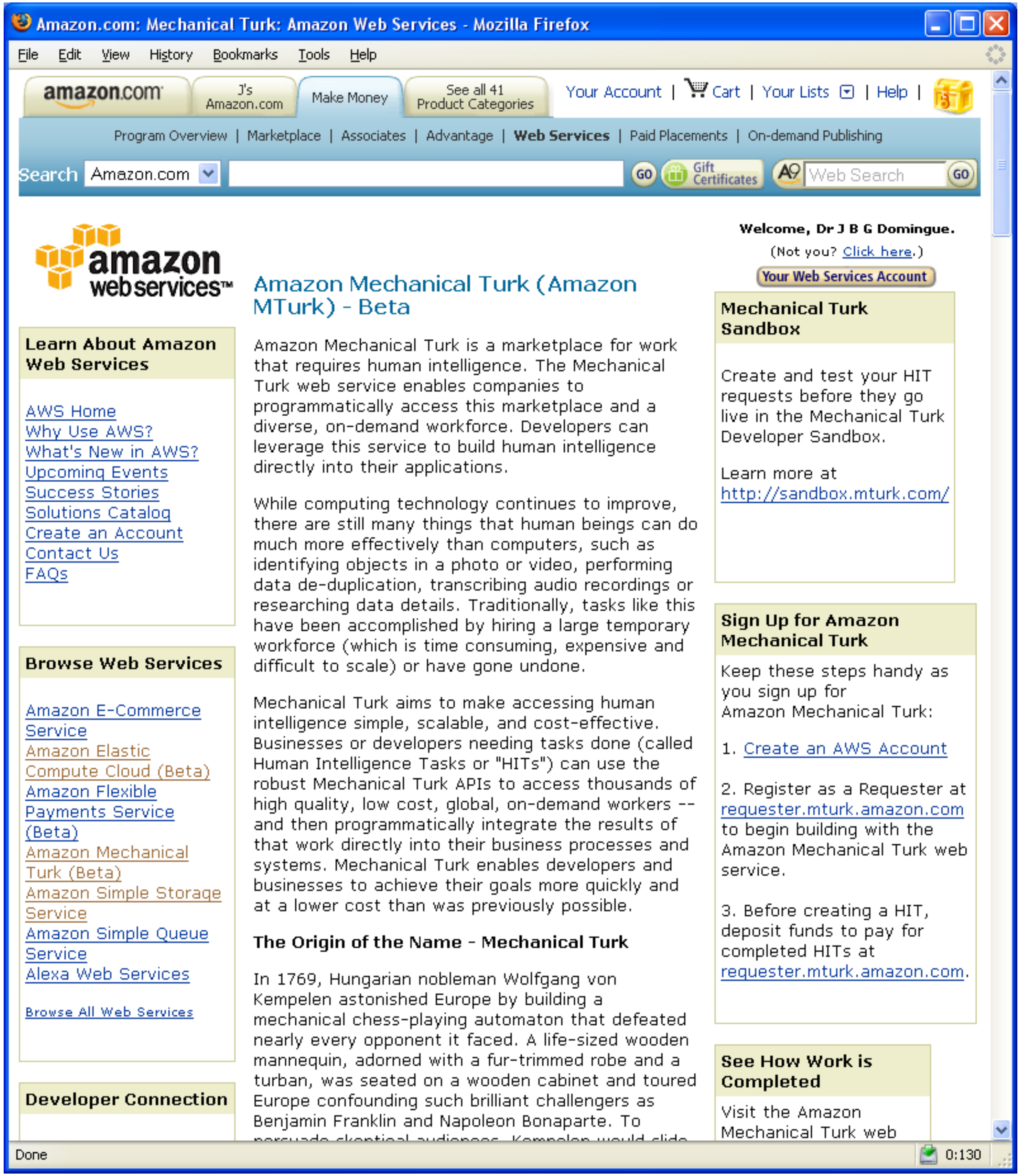
Customer Spotlight

Smartsheet.com

Within one week, Smartsheet.com began using Amazon S3 for their online document storage needs, saving in excess of 90% on storage costs and more than 80% on data transfer costs.

Click here to learn more about their success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Amazon Mechanical Turk (Amazon MTurk) - Beta

Amazon Mechanical Turk is a marketplace for work that requires human intelligence. The Mechanical Turk web service enables companies to programmatically access this marketplace and a diverse, on-demand workforce. Developers can leverage this service to build human intelligence directly into their applications.

While computing technology continues to improve, there are still many things that human beings can do much more effectively than computers, such as identifying objects in a photo or video, performing data de-duplication, transcribing audio recordings or researching data details. Traditionally, tasks like this have been accomplished by hiring a large temporary workforce (which is time consuming, expensive and difficult to scale) or have gone undone.

Mechanical Turk aims to make accessing human intelligence simple, scalable, and cost-effective. Businesses or developers needing tasks done (called Human Intelligence Tasks or "HITs") can use the robust Mechanical Turk APIs to access thousands of high quality, low cost, global, on-demand workers -- and then programmatically integrate the results of that work directly into their business processes and systems. Mechanical Turk enables developers and businesses to achieve their goals more quickly and at a lower cost than was previously possible.

The Origin of the Name - Mechanical Turk

In 1769, Hungarian nobleman Wolfgang von Kempelen astonished Europe by building a mechanical chess-playing automaton that defeated nearly every opponent it faced. A life-sized wooden mannequin, adorned with a fur-trimmed robe and a turban, was seated on a wooden cabinet and toured Europe confounding such brilliant challengers as Benjamin Franklin and Napoleon Bonaparte. To

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Developer Connection

Mechanical Turk Sandbox

Create and test your HIT requests before they go live in the Mechanical Turk Developer Sandbox.

Learn more at http://sandbox.mturk.com/

Sign Up for Amazon Mechanical Turk

Keep these steps handy as you sign up for Amazon Mechanical Turk:

1. Create an AWS Account

2. Register as a Requester at requester.mturk.amazon.com to begin building with the Amazon Mechanical Turk web service.

3. Before creating a HIT, deposit funds to pay for completed HITs at requester.mturk.amazon.com.

See How Work is Completed

Visit the Amazon Mechanical Turk web

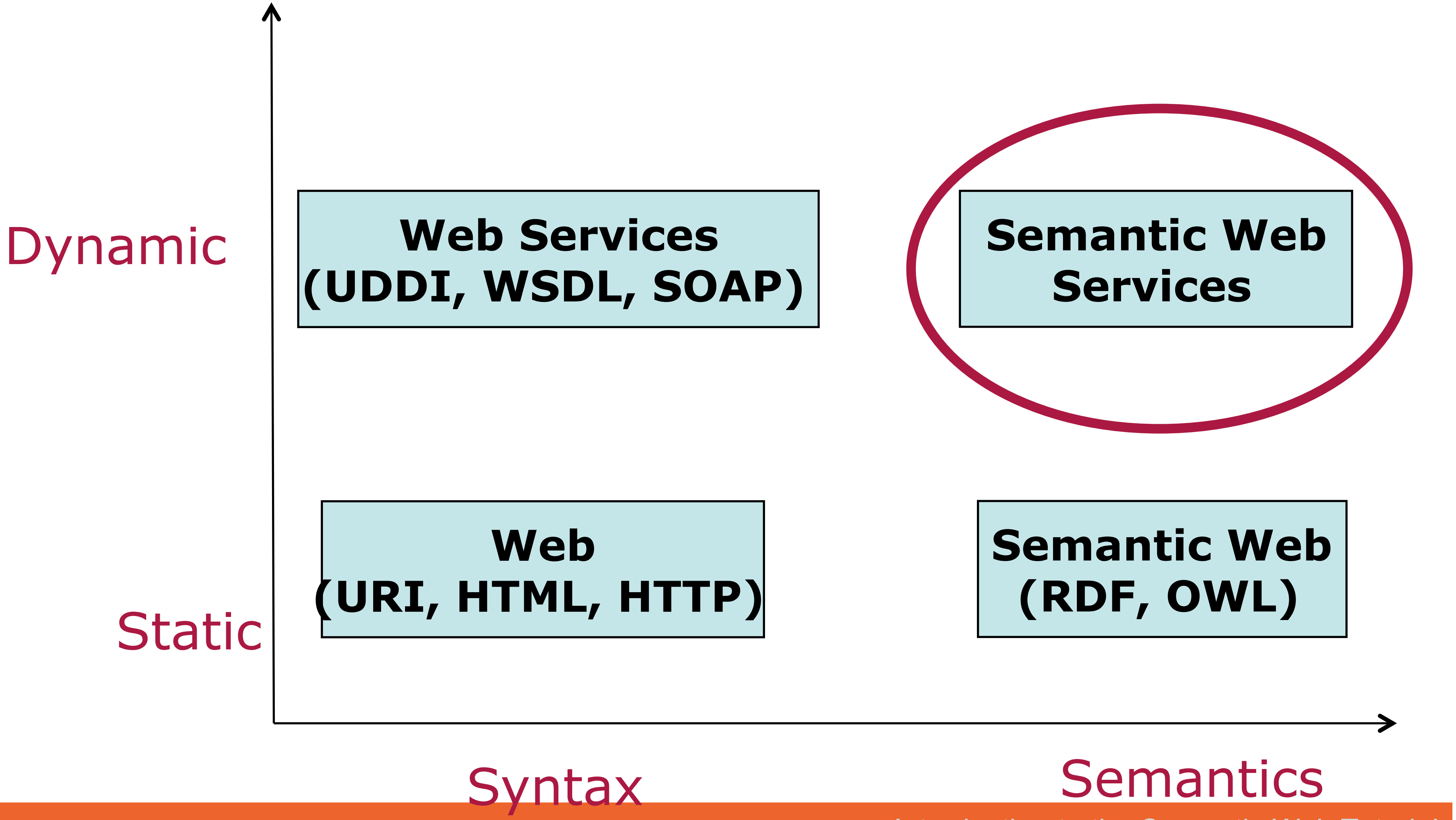
Problems with Web Services Today

- Descriptions are syntactic
- All tasks associated with web services application development have to be carried out by humans:
  - discovery, composition and invocation
- Problems of scalability

Semantic Web Services

John Domingue

SWS Vision



Dynamic
Static
Web Services
(UDDI, WSDL, SOAP)
Semantic Web
Services
Web
(URI, HTML, HTTP)
Semantic Web
(RDF, OWL)
Syntax
Semantics

Semantic Web Services (is)

- Semantic Web Technology
  - Machine readable data
  - Ontological basis

Applied to

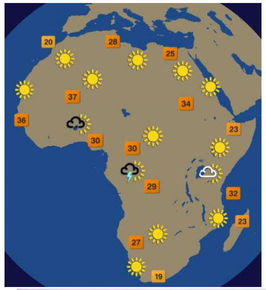
- Web Services Technology
  - Reusable computational resources

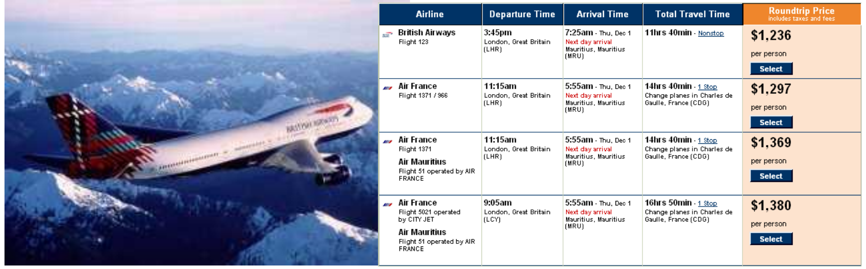
To automate all aspects of application development through reuse

Semantic Web Service Broker

Client

Semantic Execution Environment





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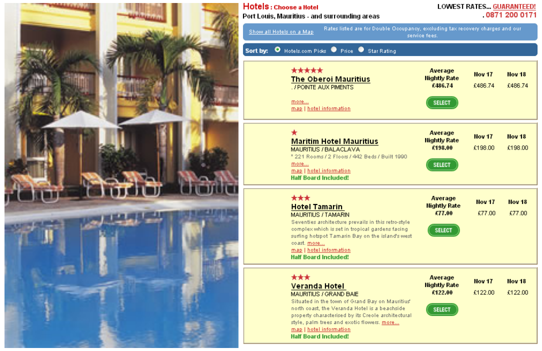
British Airways Flight 123	**3:45pm** London, Great Britain (LHR)	**7:25am** - Thu, Dec 1 Next day arrival Mauritius, Mauritius (MRU)	**11hrs 40min** - Nonstop	**$1,236** per person Select
Air France Flight 1371 / 966	**11:15am** London, Great Britain (LHR)	**5:55am** - Thu, Dec 1 Next day arrival Mauritius, Mauritius (MRU)	**14hrs 40min** - 1 Stop Change planes in Charles de Gaulle, France (CDG)	**$1,297** per person Select
Air France Flight 1371 **Air Mauritius** Flight 51 operated by AIR FRANCE	**11:15am** London, Great Britain (LHR)	**5:55am** - Thu, Dec 1 Next day arrival Mauritius, Mauritius (MRU)	**14hrs 40min** - 1 Stop Change planes in Charles de Gaulle, France (CDG)	**$1,369** per person Select
Air France Flight 5021 operated by CITY JET **Air Mauritius** Flight 51 operated by AIR FRANCE	**9:05am** London, Great Britain (LCY)	**5:55am** - Thu, Dec 1 Next day arrival Mauritius, Mauritius (MRU)	**16hrs 50min** - 1 Stop Change planes in Charles de Gaulle, France (CDG)	**$1,380** per person Select



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★★★★★
The Oberoi Mauritius
. / POINTE AUX PIMENTS
more...
map | hotel information

Average Nightly Rate	Nov 17	Nov 18
£486.74	£486.74	£486.74

SELECT

★
Maritim Hotel Mauritius
MAURITIUS / BALACLAVA
* 221 Rooms / 2 Floors / 442 Beds / Built 1990
more...
map | hotel information
Half Board Included!

Average Nightly Rate	Nov 17	Nov 18
£198.00	£198.00	£198.00

SELECT

★★★
Hotel Tamarin
MAURITIUS / TAMARIN
Seventies architecture prevails in this retro-style complex which is set in tropical gardens facing surfing hotspot Tamarin Bay on the island's west coast. more...
map | hotel information
Half Board Included!

Average Nightly Rate	Nov 17	Nov 18
£77.00	£77.00	£77.00

SELECT

★★★
Veranda Hotel
MAURITIUS / GRAND BAIE
Situated in the town of Grand Bay on Mauritius' north coast, the Veranda Hotel is a beachside property characterised by its Creole architectural style, palm trees and exotic flowers. more...
map | hotel information
Half Board Included!

Average Nightly Rate	Nov 17	Nov 18
£122.00	£122.00	£122.00

SELECT

Services

OWL-S

David Martin

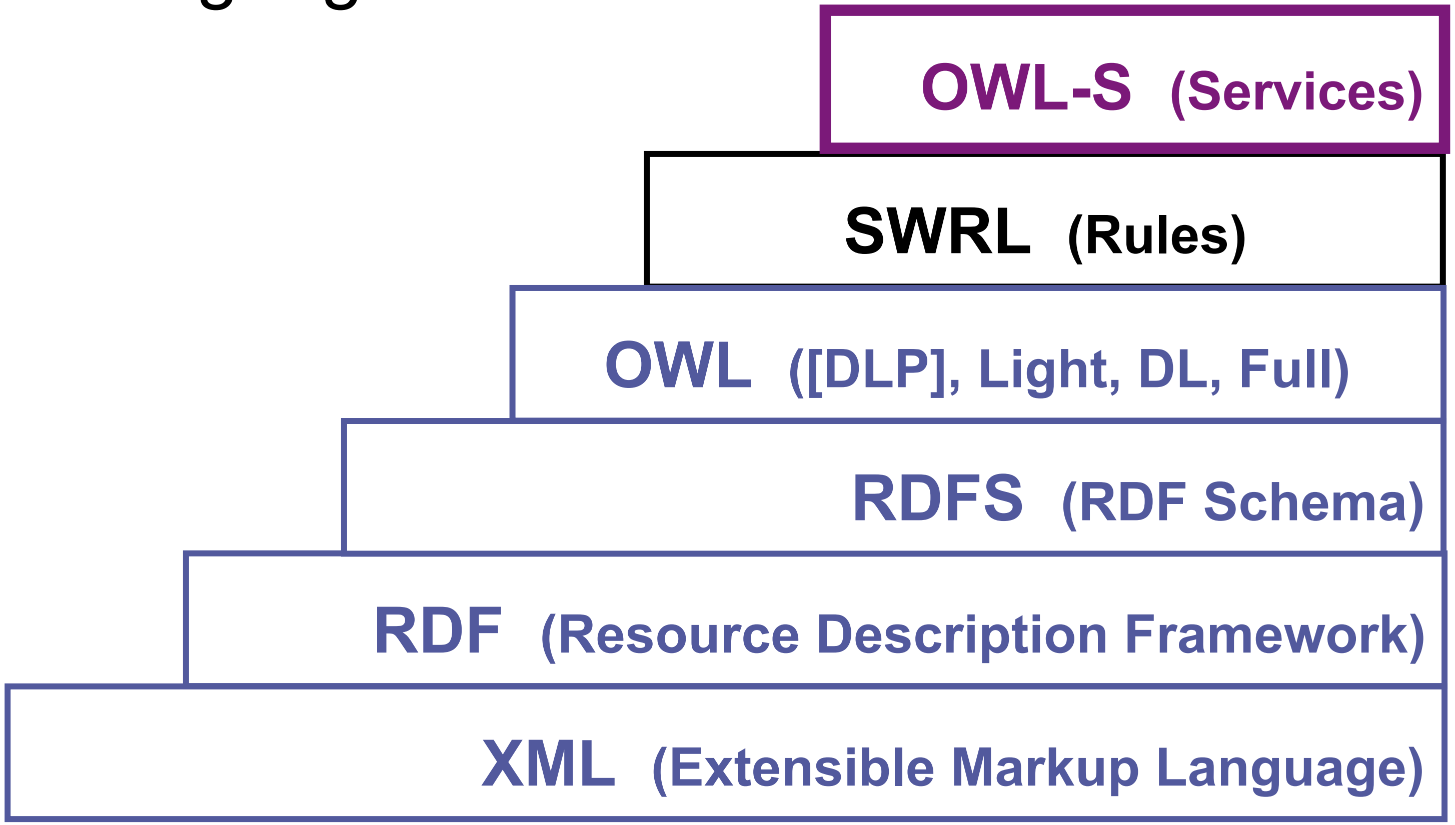
What is OWL-S?

- Ontology Web Language for Services
- An OWL ontology/language for (formally) describing properties and capabilities of Web services
- An approach that draws on many sources
  - Description logic
  - AI planning
  - Workflow
  - Formal process modeling
  - Agents
  - Web services

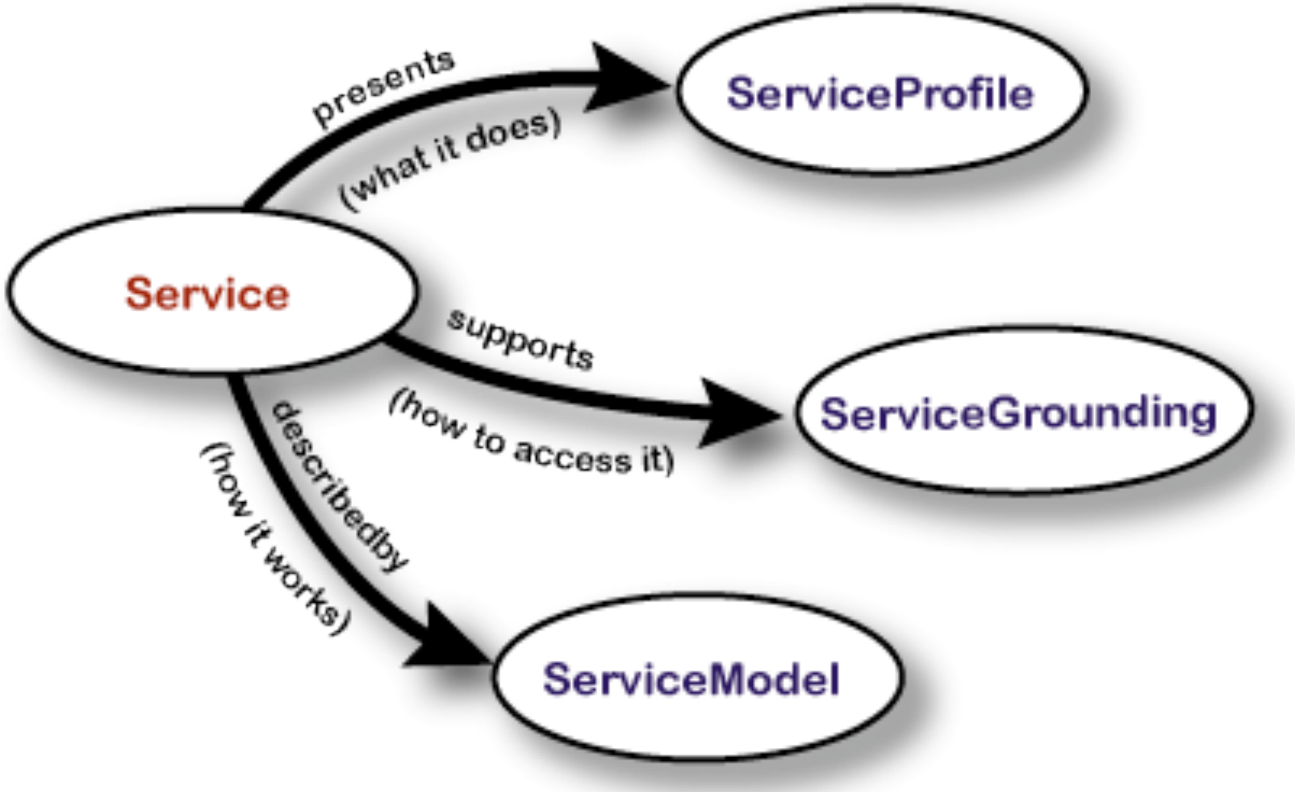
http://www.daml.org/services/owl-s

Layered Approach to Language Development

OWL-S: an ontology expressed in OWL and related languages


OWL-S (Services)
SWRL (Rules)
OWL ([DLP], Light, DL, Full)
RDFS (RDF Schema)
RDF (Resource Description Framework)
XML (Extensible Markup Language)

Upper Ontology of Services



Ontology images compliments of Terry Payne, University of Southampton

Service Profile: “What does it do?”

High-level characterization/summary of a service

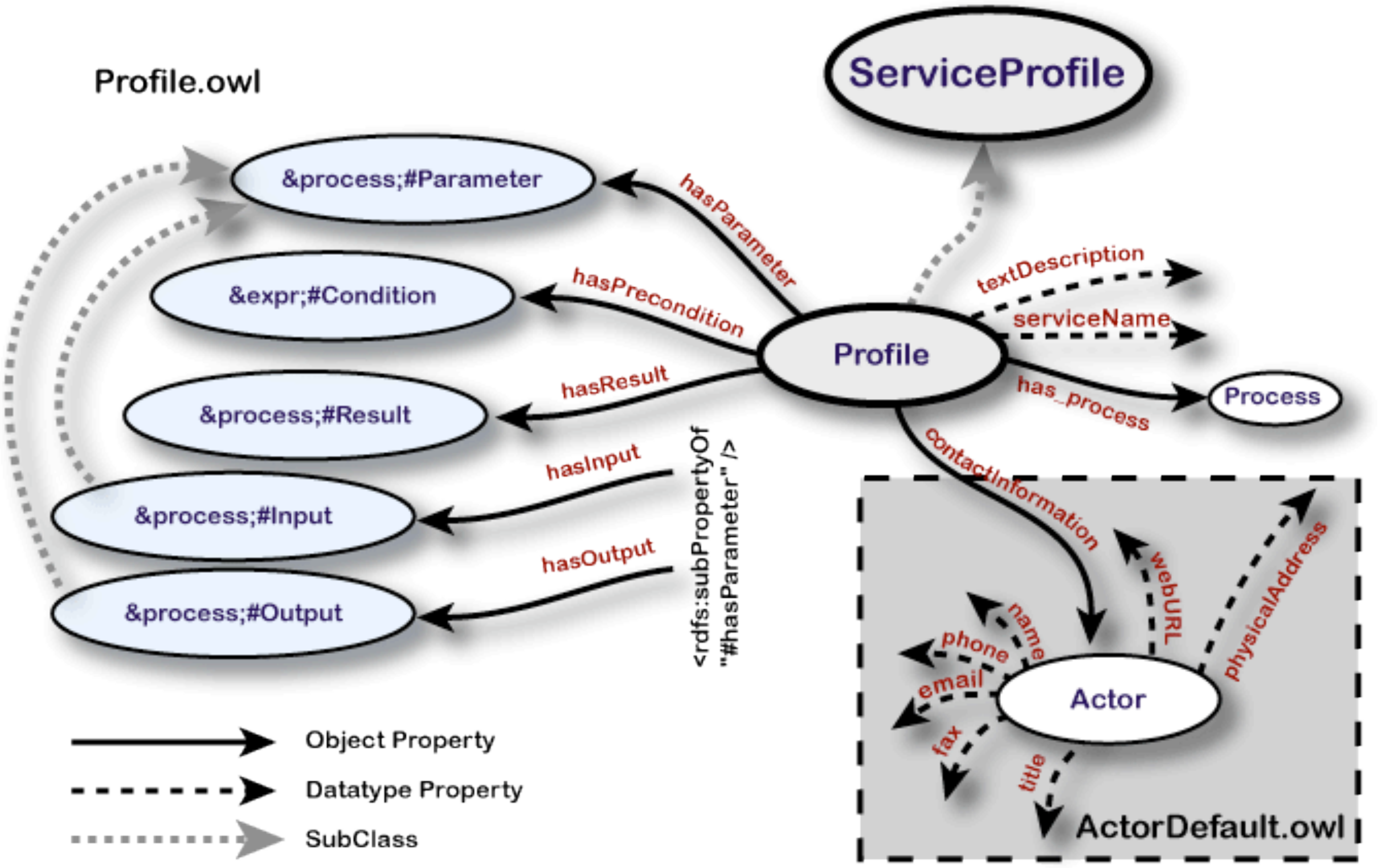
Used for

- Populating service registries
  - A service can have many profiles
- Automated service discovery
- Service selection (matchmaking)

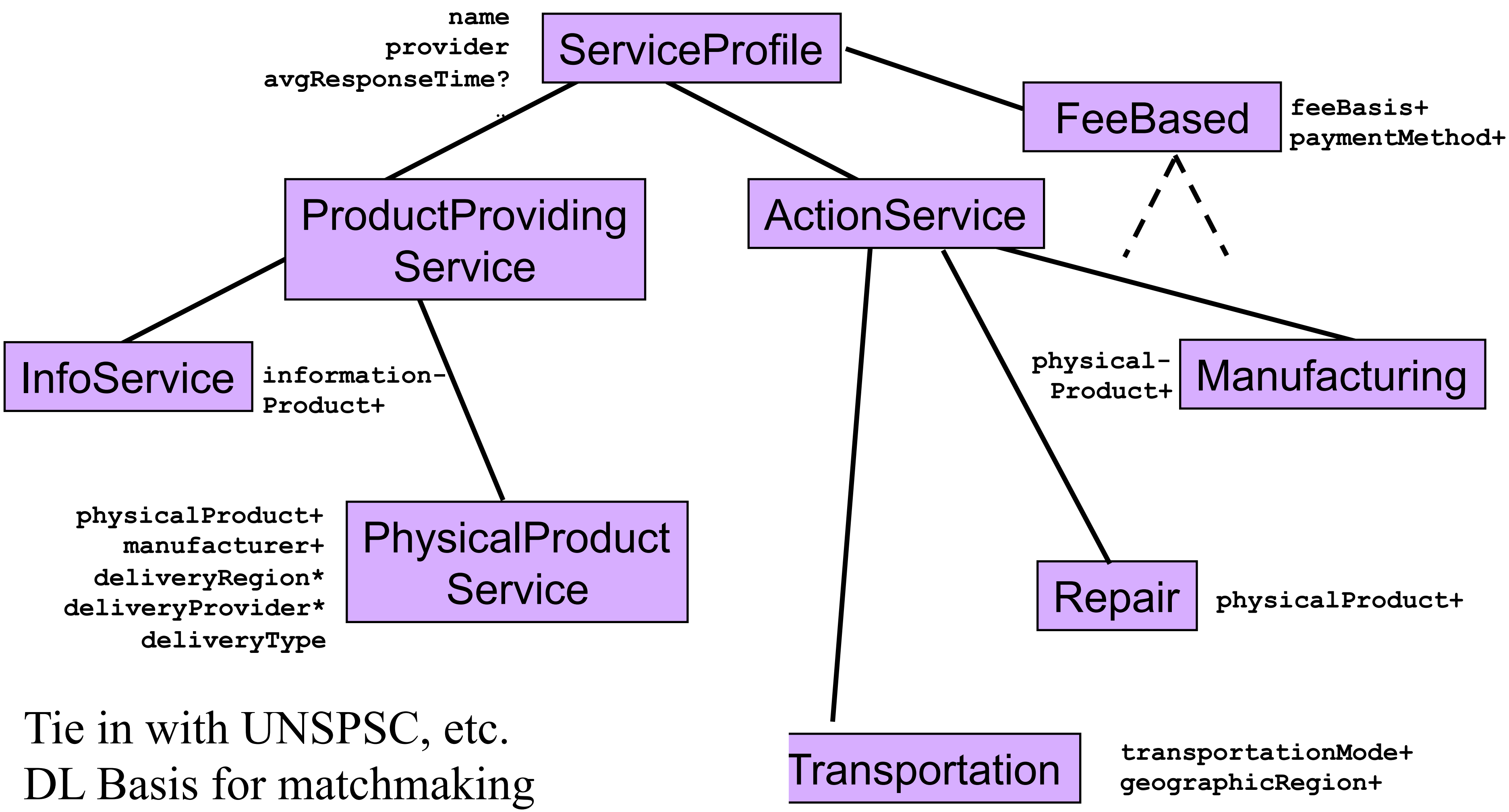
One can derive:

- Service advertisements
- Service requests

Service Profile (partial)



Class Hierarchies of Services



Tie in with UNSPSC, etc.

DL Basis for matchmaking

Multiple profiles; multiple hierarchies

Service Profile: Styles of use

- Class hierarchical yellow pages
  - Implicit capability characterization
  - Arrangement of attributes on class hierarchy
  - Can use multiple inheritance
  - Relies primarily on “non-functional” properties
- Process summaries for planning purposes
  - More explicit
  - Inputs, outputs, preconditions, effects
  - Less reliance on formal hierarchical organization
  - Summarizes process model specs
  - Relies primarily on functional description

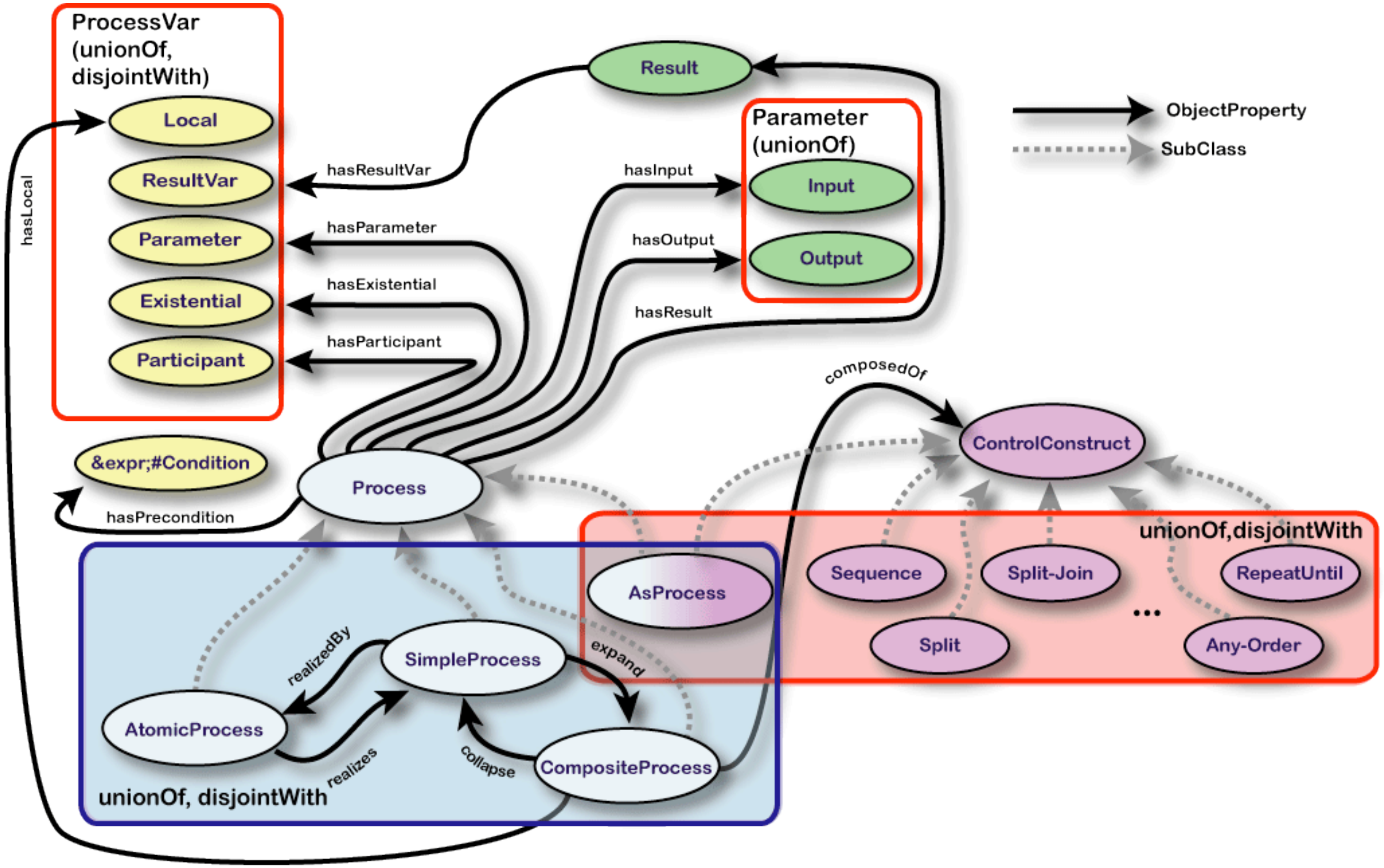
Process Model: “How does it work?”

Process

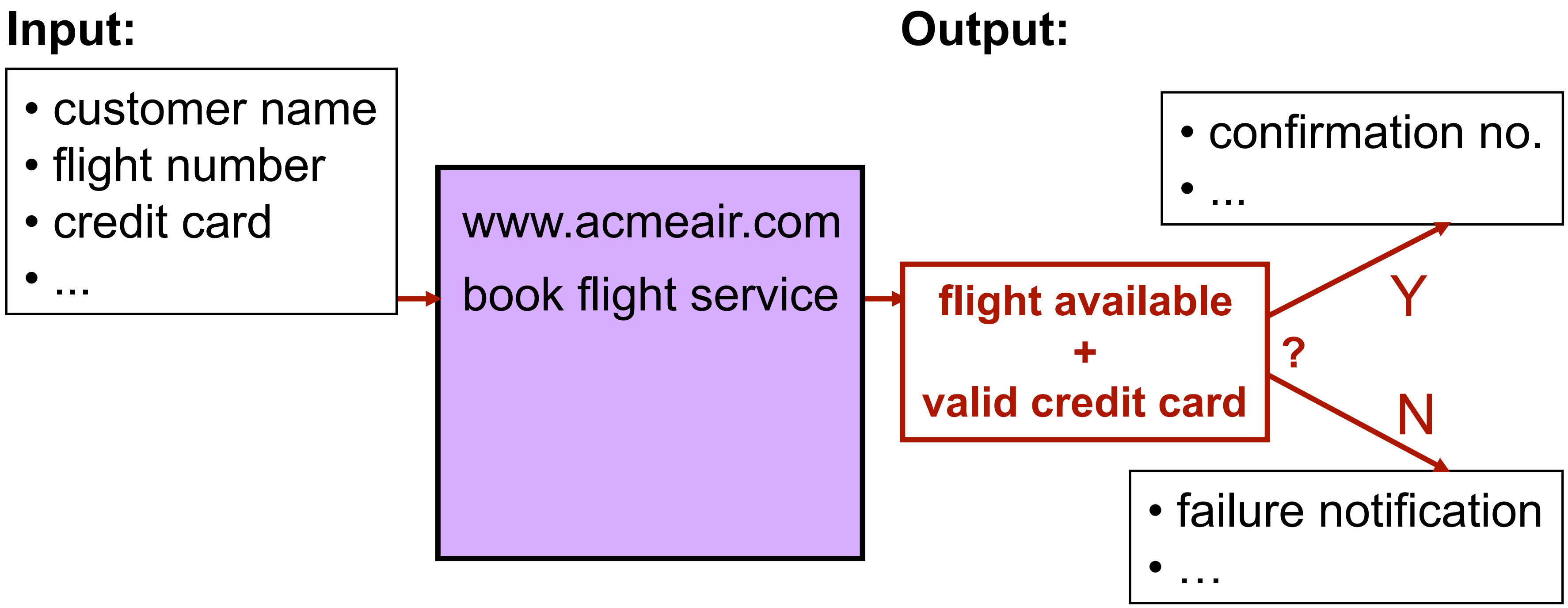
  - Potentially interpretable description of service provider’s behavior
  - Tells service user how and when to interact (read/write messages)

- Used for:
  - Service invocation, planning/composition, interoperation, monitoring
- All processes have
  - Inputs, outputs, preconditions and effects
- Composite processes
  - Control flow
  - Data flow
- OWL standard serializations; presentation syntax

Process Model (partial)



Function/Dataflow Perspective



Input:

- customer name
- flight number
- credit card
- ...

www.acmeair.com

book flight service

Output:

flight available
+
valid credit card

?

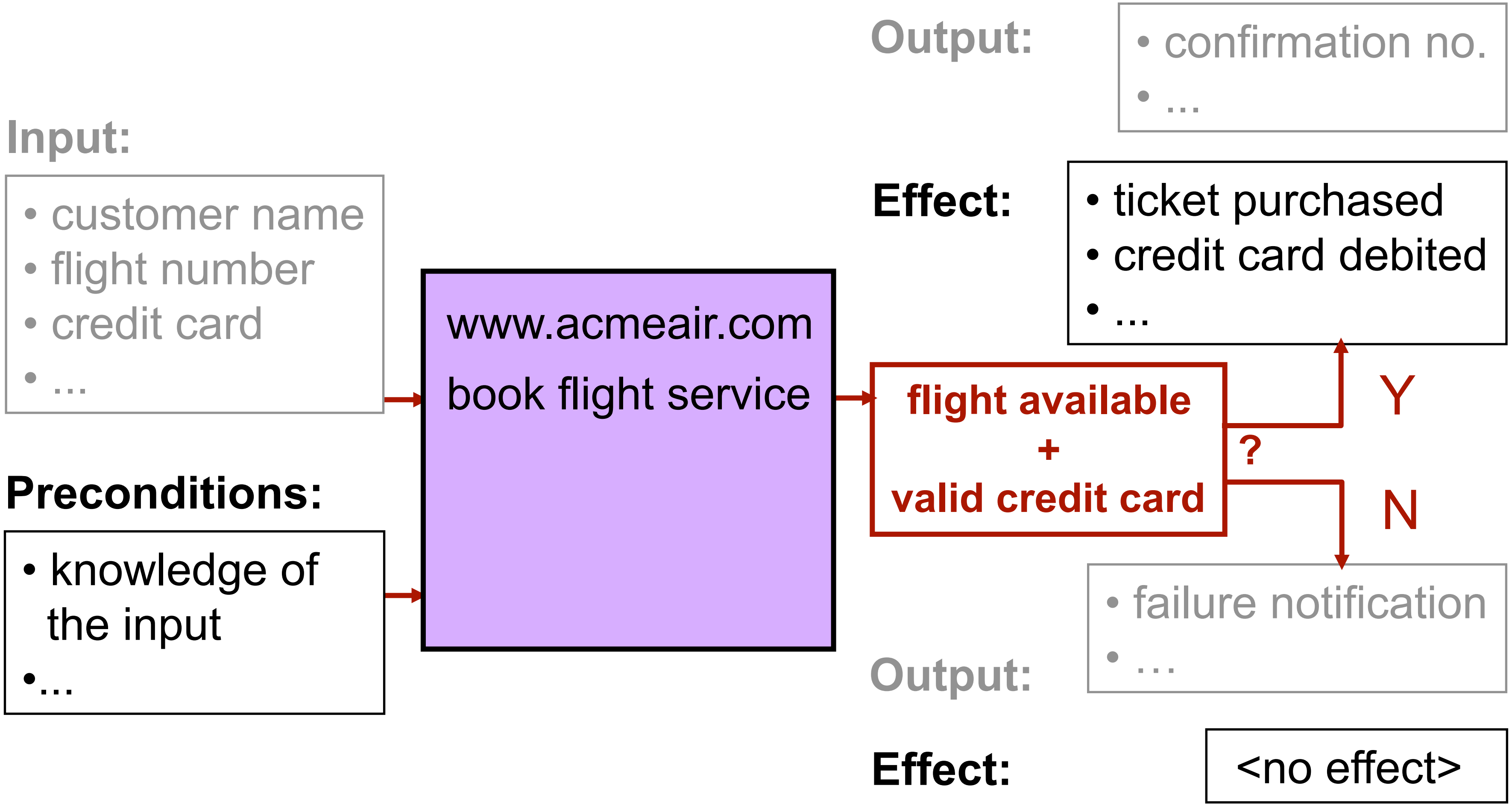
Y

- confirmation no.
- ...

N

- failure notification
- …

Action/Process Perspective



Input:

- customer name
- flight number
- credit card
- ...

Preconditions:

- knowledge of the input
- ...

www.acmeair.com

book flight service

flight available + valid credit card

?

Y

Output:

- confirmation no.
- ...

Effect:

- ticket purchased
- credit card debited
- ...

N

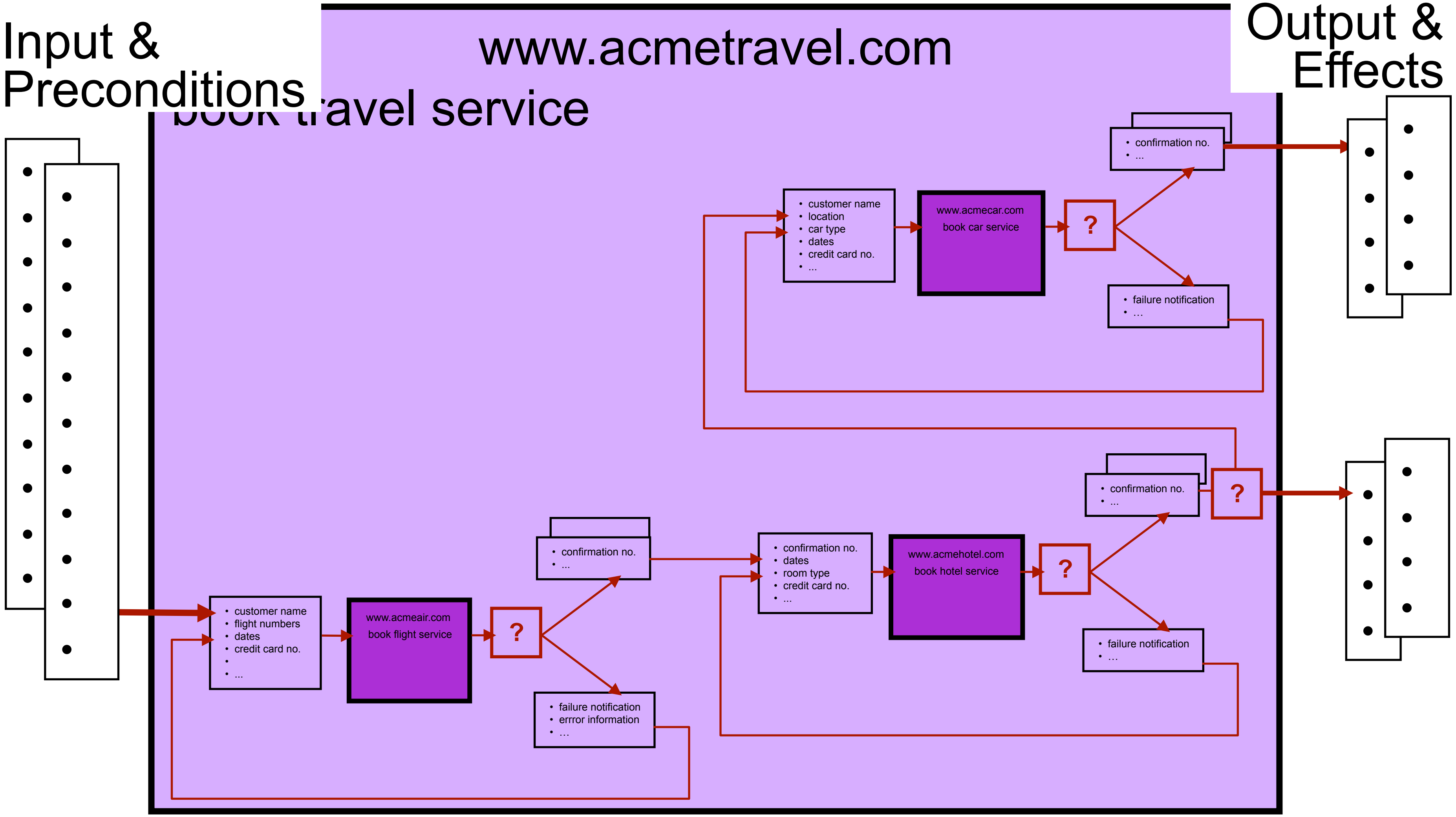
Output:

- failure notification
- …

Effect:

<no effect>

Composite Process



Input & Preconditions

www.acmetravel.com

book travel service

Output & Effects

- customer name
- flight numbers
- dates
- credit card no.
-
- ...

www.acmeair.com
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?

- confirmation no.
- ...

- failure notification
- errror information
- …

- confirmation no.
- dates
- room type
- credit card no.
- ...

www.acmehotel.com
book hotel service

?

- confirmation no.
- ...

- failure notification
- …

?

- customer name
- location
- car type
- dates
- credit card no.
- ...

www.acmecar.com
book car service

?

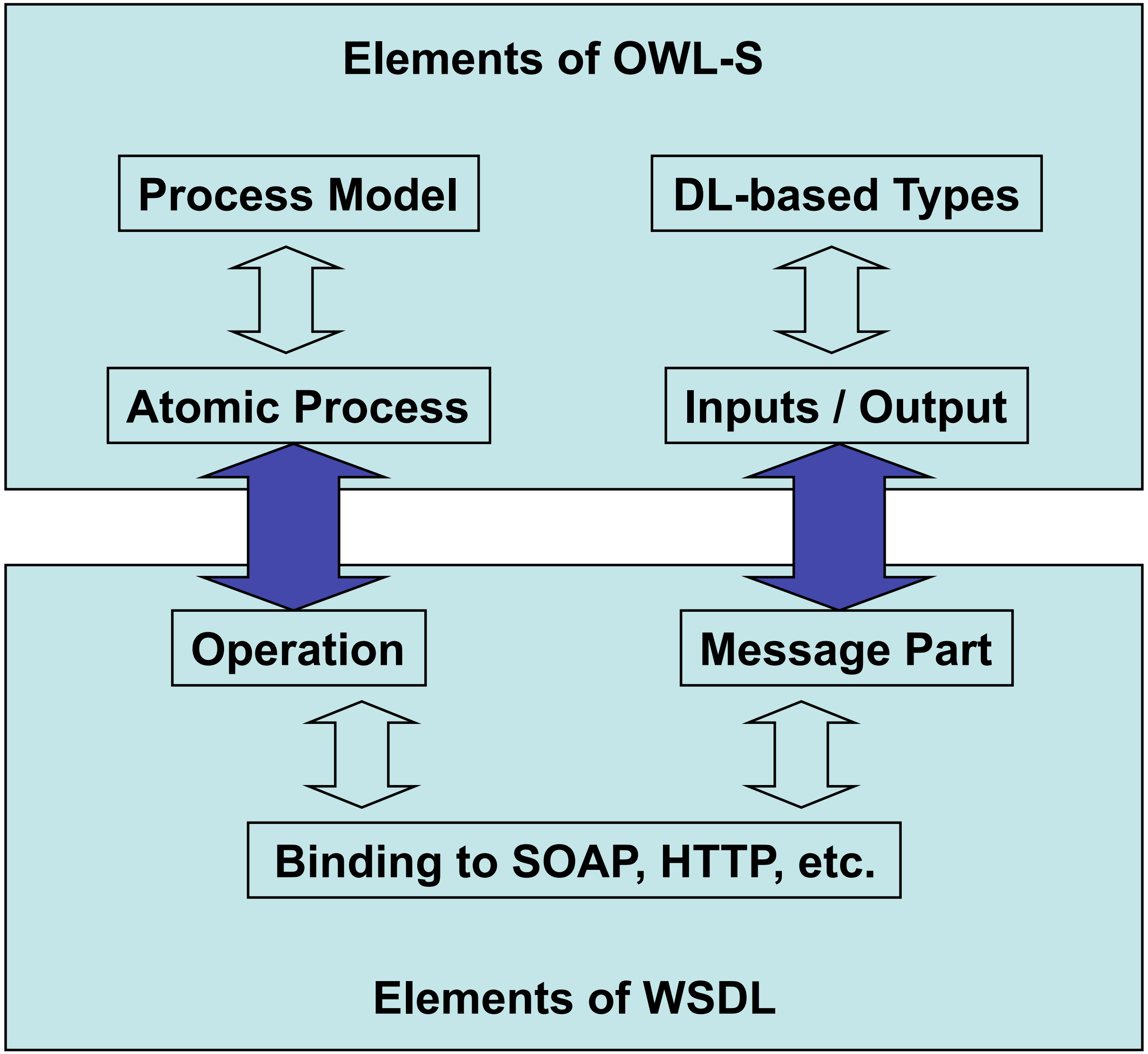
- confirmation no.
- ...

- failure notification
- …

Service Grounding: “How to access it”

- Implementation specific
- Message formatting, transport mechanisms, protocols, serializations of types
- Service Model + Grounding give everything needed for using the service
- Builds upon WSDL

OWL-S / WSDL Grounding
(pre-SAWSDL)



OWL-S: Summary & Status

- Describes “what it does”, “how it works”, “how to access it”
  - Profile, Process, Grounding subontologies
- Ties in naturally with WSDL, UDDI
- Additional semantics supports
  - Automation of various Web service tasks
  - Varied applications (later slides)

- W3C member submission
  - http://www.w3.org/Submission/2004/07/
  - Corresponds to 1.1 release on daml.org
- 1.2 release completed
- Publications, tools, examples
  - See http;//www.daml.org/services/owl-s/
  - See http://www.semwebcentral.org

Applications Using OWL-S

- Many examples, including
  - **Task Computing**
  - Software Interoperability
  - e-Science
  - Geospatial Data / Query Integration
  - Autonomous Vehicles

Application:
Task Computing

Technology to enable easy orchestration
of devices and e-services,
and support users in executing complex tasks

Fujitsu Laboratories of America, Inc.
MINDLab of the University of Maryland

http://www.taskcomputing.org

Thanks to
Ryusuke Masuoka
for use of this material

Goals of Task Computing

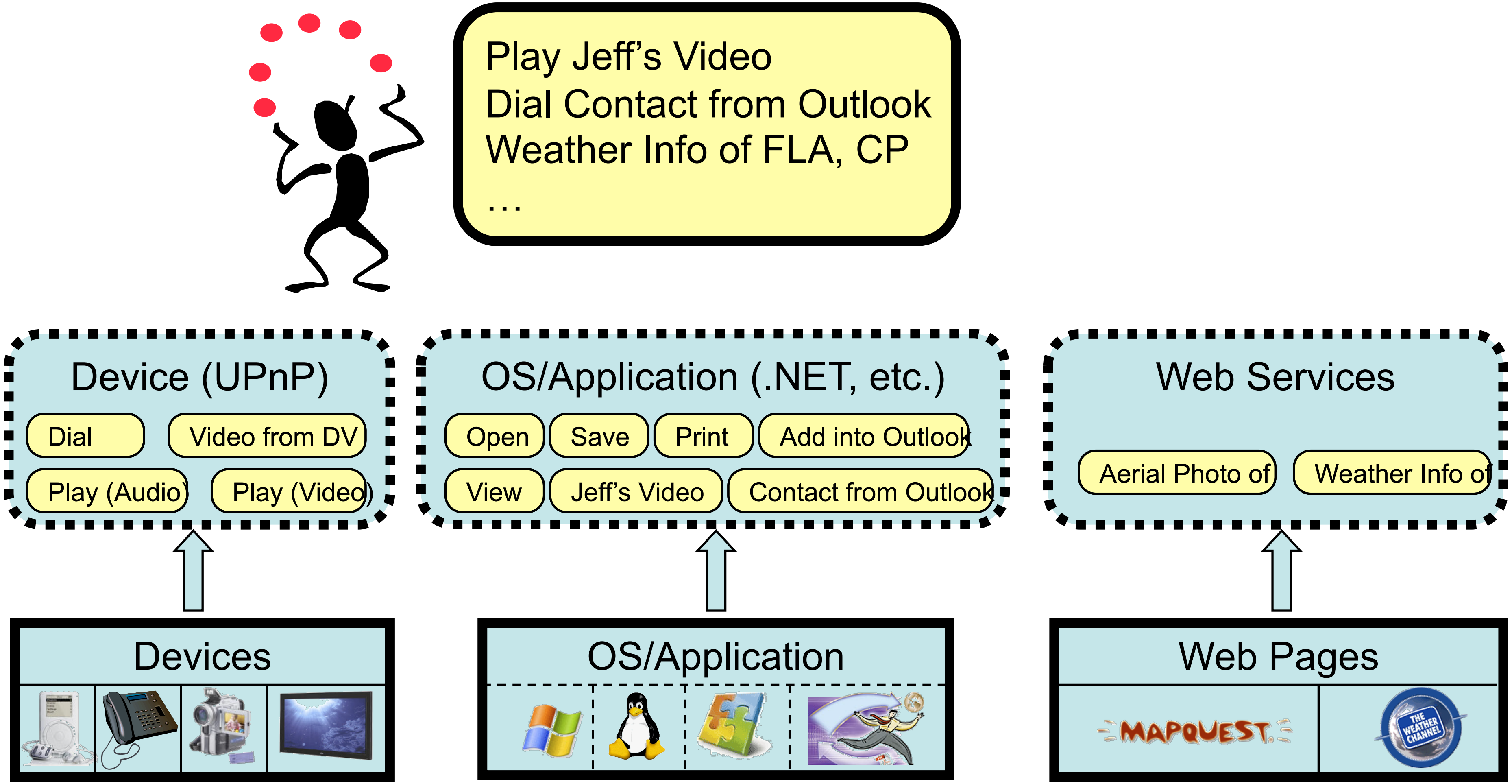
- Minimize/facilitate user interaction
  - User interface: mouse clicks and voice
- Focus on ***What*** (task) instead of ***How*** (means)
- No preprogramming of devices for tasks

User wants to do “Tasks”

Filling the gap

“Services” offered means
Web services, UPnP, etc.

A Giant Leap



Play Jeff's Video
Dial Contact from Outlook
Weather Info of FLA, CP
…

Device (UPnP)

Dial | Video from DV | Play (Audio) | Play (Video)

OS/Application (.NET, etc.)

Open | Save | Print | Add into Outlook | View | Jeff's Video | Contact from Outlook

Web Services

Aerial Photo of | Weather Info of

Devices

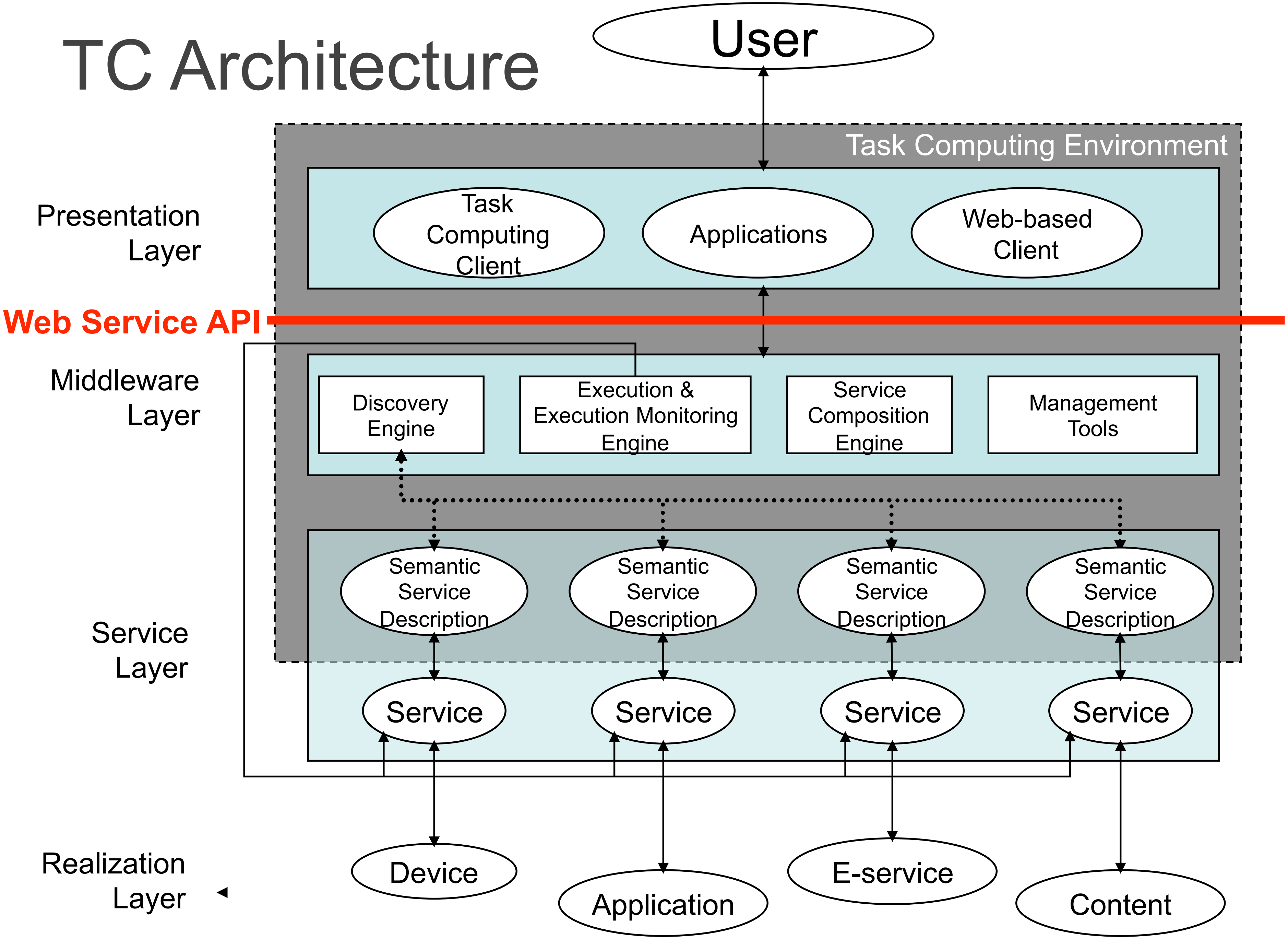
OS/Application

Web Pages

Fujitsu's Task Computing

- Approach:
  - Integration of Semantic Web and Web Service computing
  - Abstraction of functionality as services: Describe functionality of device or services in OWL-S
  - Use of UPnP for Semantic Service Discovery Mechanism (SSDM) and for service invocation
- More application examples:
  - Display presentation file from mobile computer on the projector in a room you visit for the first time, without connecting a VGA cable
  - Display pictures from a mobile phone on a TV in any room and print it on an available foto printer, without moving memory cards around
- Precondition: Devices are network-ready and equipped with lightweight web server

TC Architecture



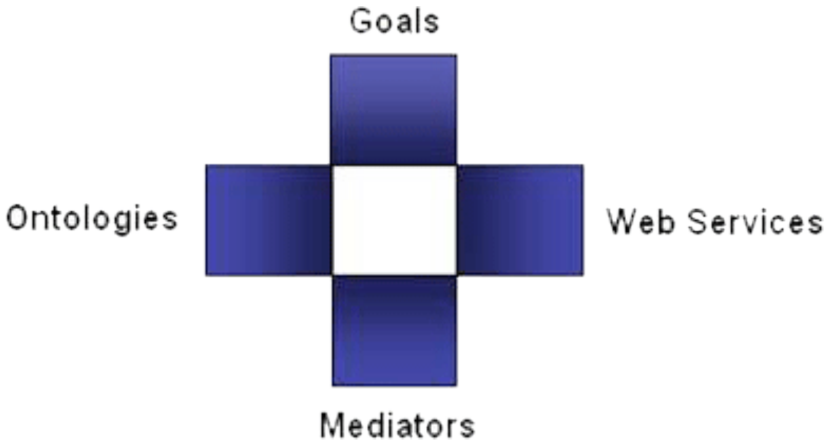
Web Service Modelling Ontology (WSMO)

John Domingue

WSMO Top Level Notions

Objectives that a client wants to achieve by using Web Services

Provide the formally specified terminology of the information used by all other components



Semantic description of Web Services:
- **Capability** *(functional)*
- **Interfaces** *(usage)*

Connectors between components with mediation facilities for handling heterogeneities

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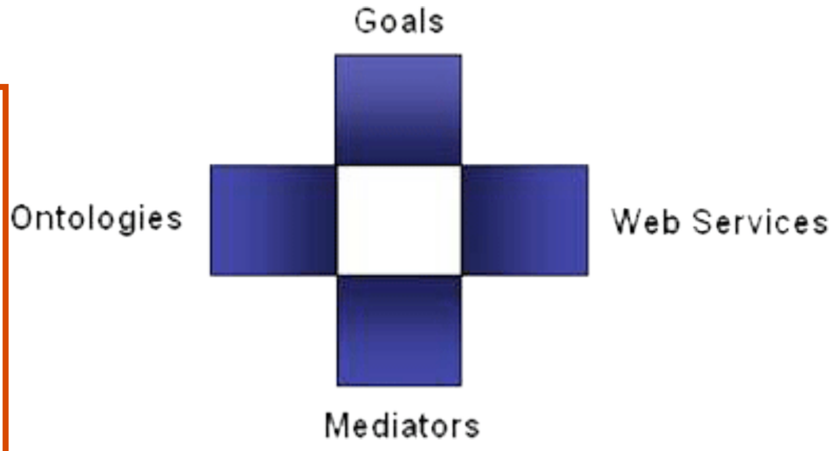

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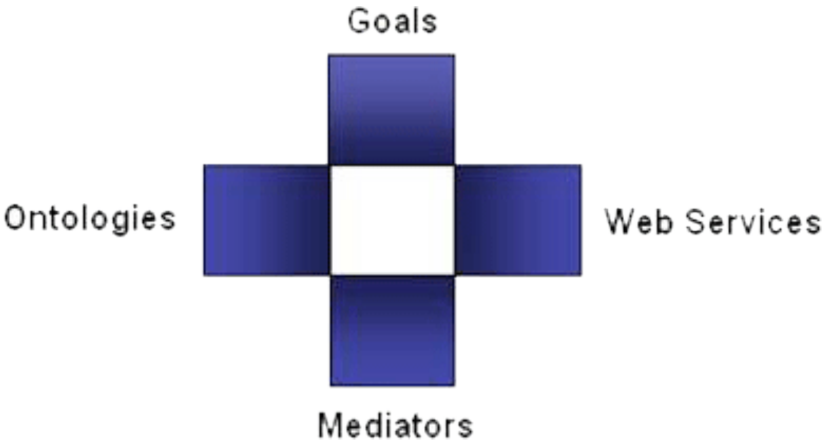

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Goals

- Ontological De-coupling of Requester and Provider
- Derived from task / problem solving methods/domain model
- Structure and reuse of requests
  - Search
  - Diagnose
  - Classify
  - Personalise
  - Book a holiday
- Requests may in principle not be satisfiable
- Ontological relationships & mediators used to link goals to web services

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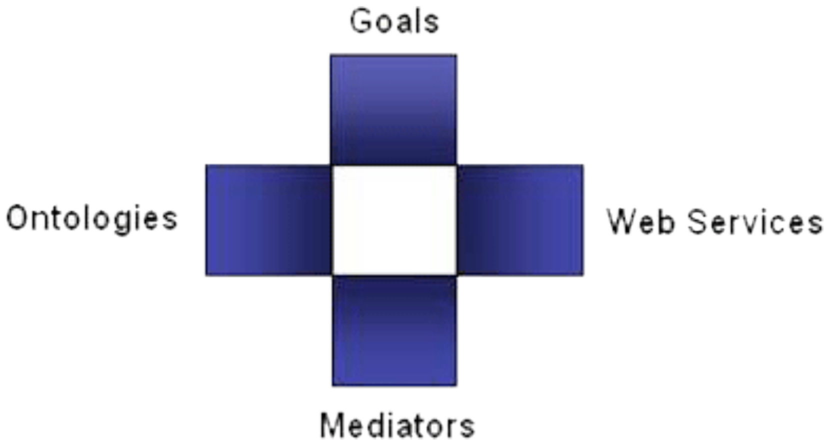

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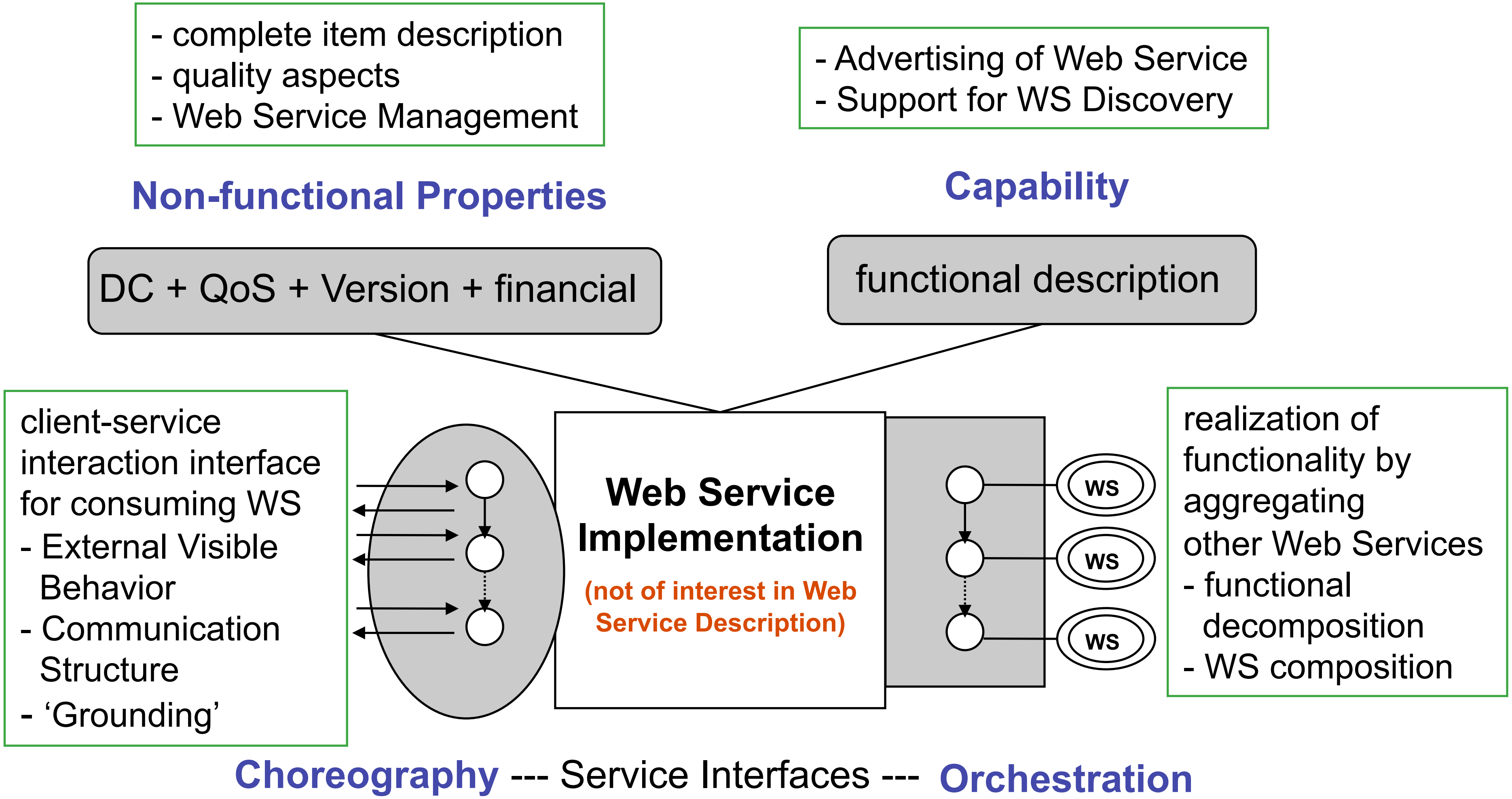


- complete item description
- quality aspects
- Web Service Management

Non-functional Properties

DC + QoS + Version + financial

- Advertising of Web Service
- Support for WS Discovery

Capability

functional description

client-service interaction interface for consuming WS
- External Visible Behavior
- Communication Structure
- ‘Grounding’

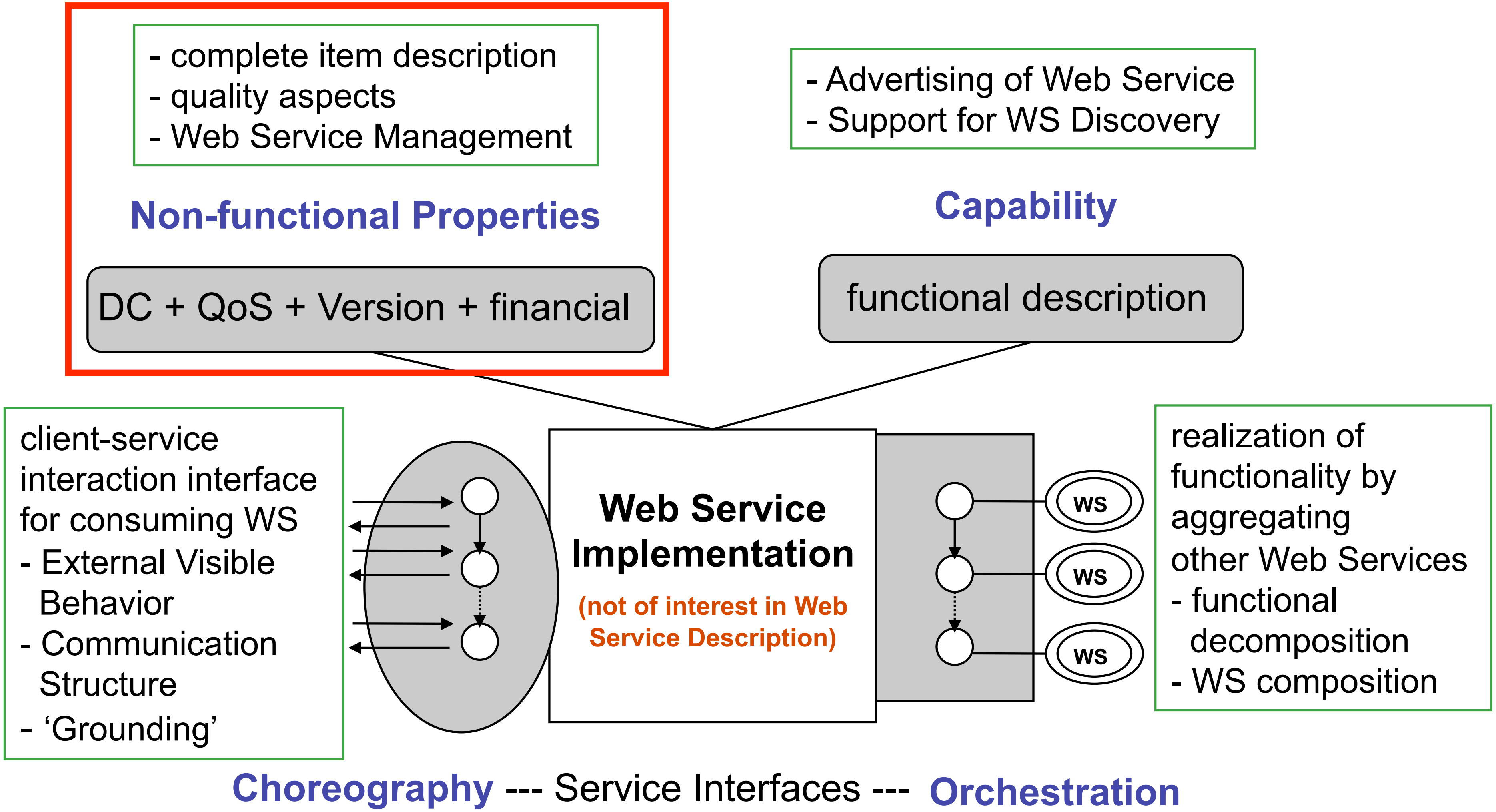
Web Service Implementation

(not of interest in Web Service Description)

realization of functionality by aggregating other Web Services
- functional decomposition
- WS composition

Choreography --- Service Interfaces --- **Orchestration**

WSMO Web Service Description



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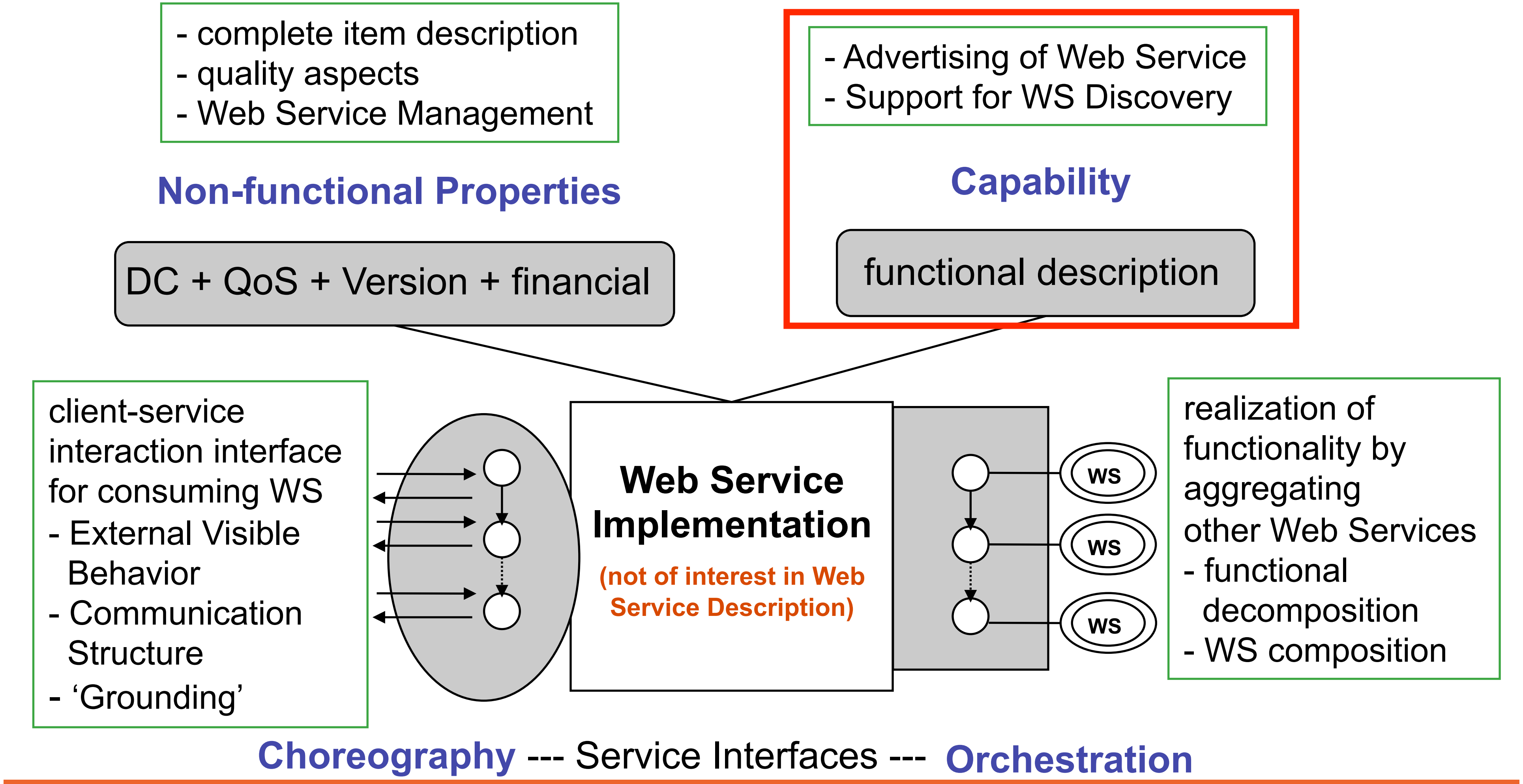

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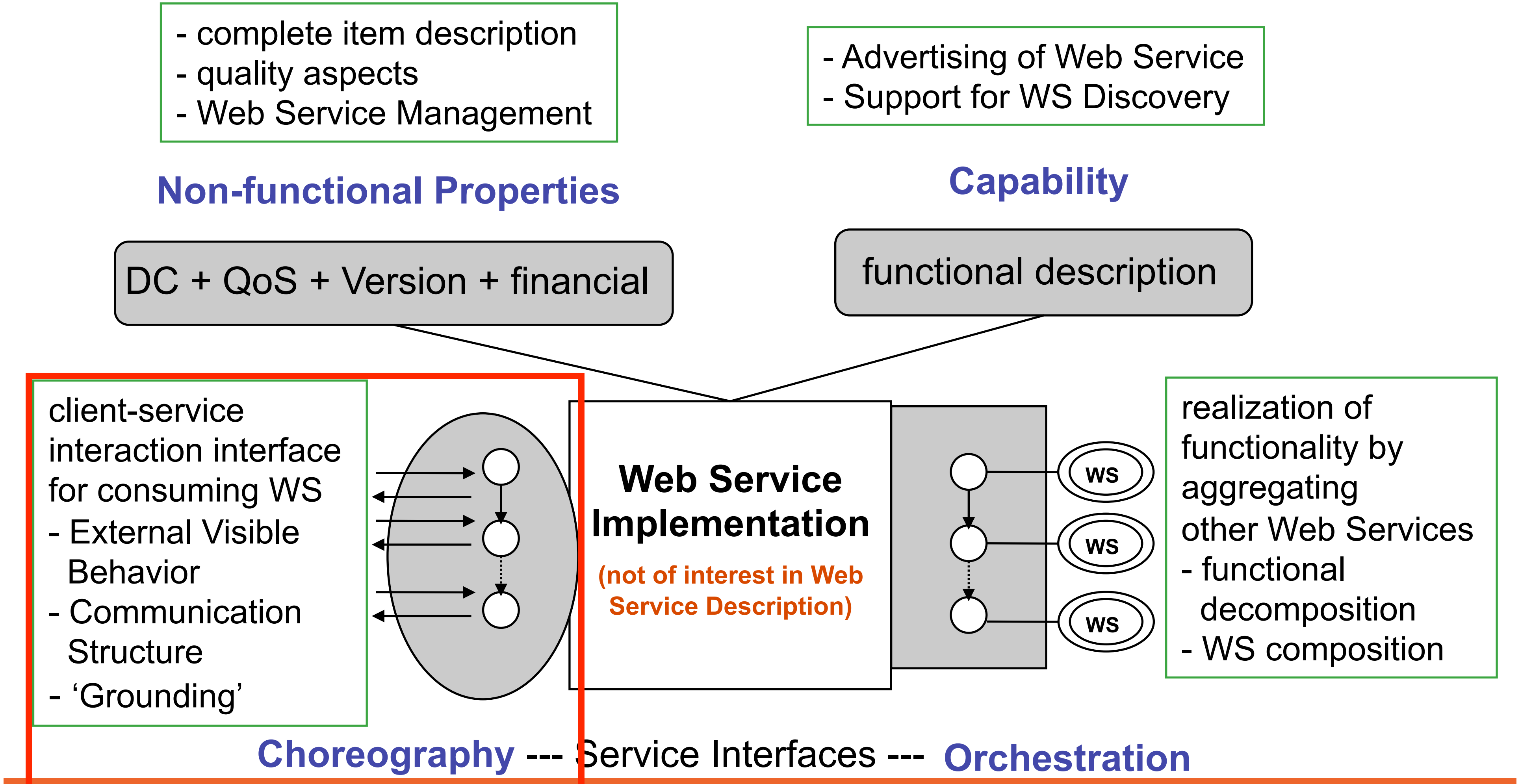

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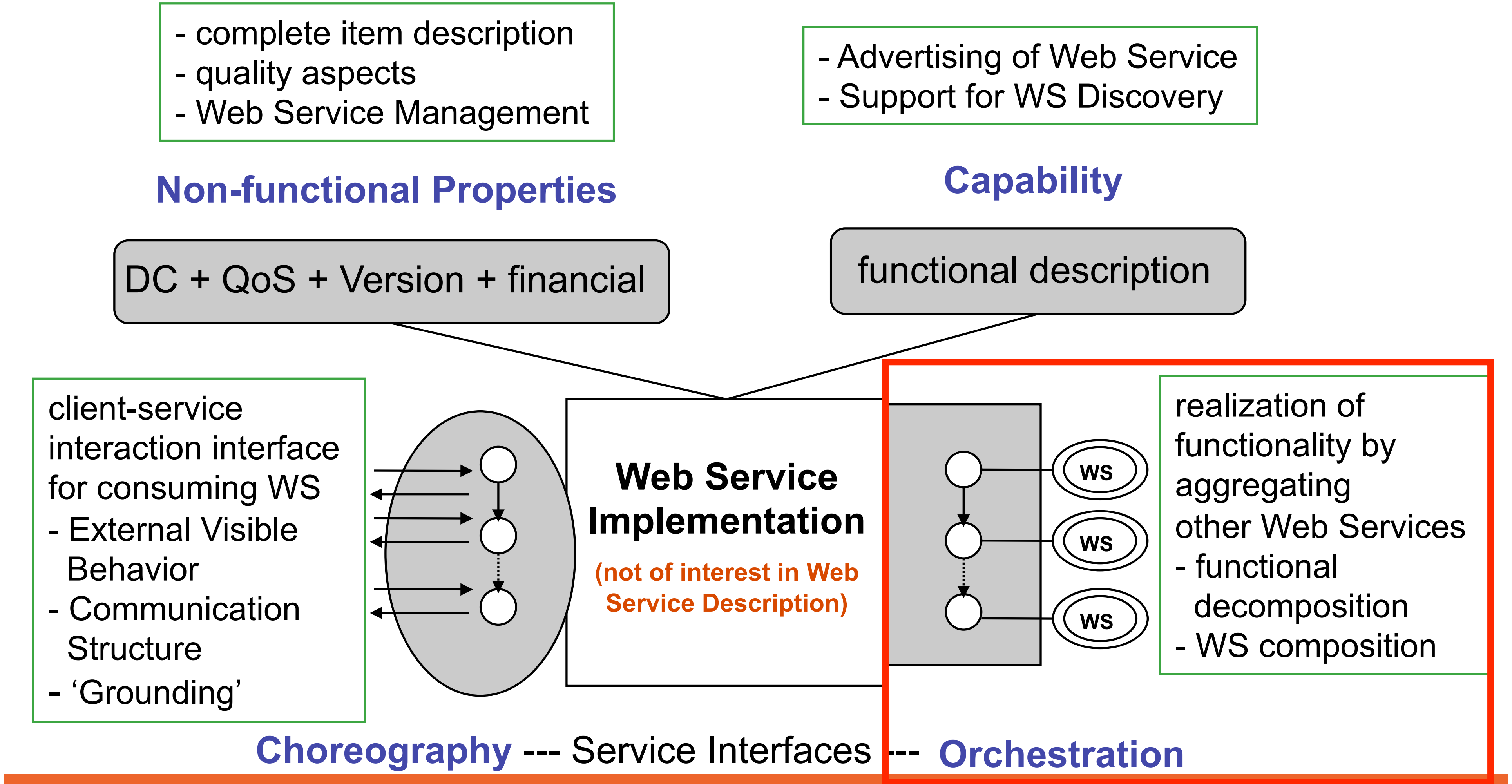

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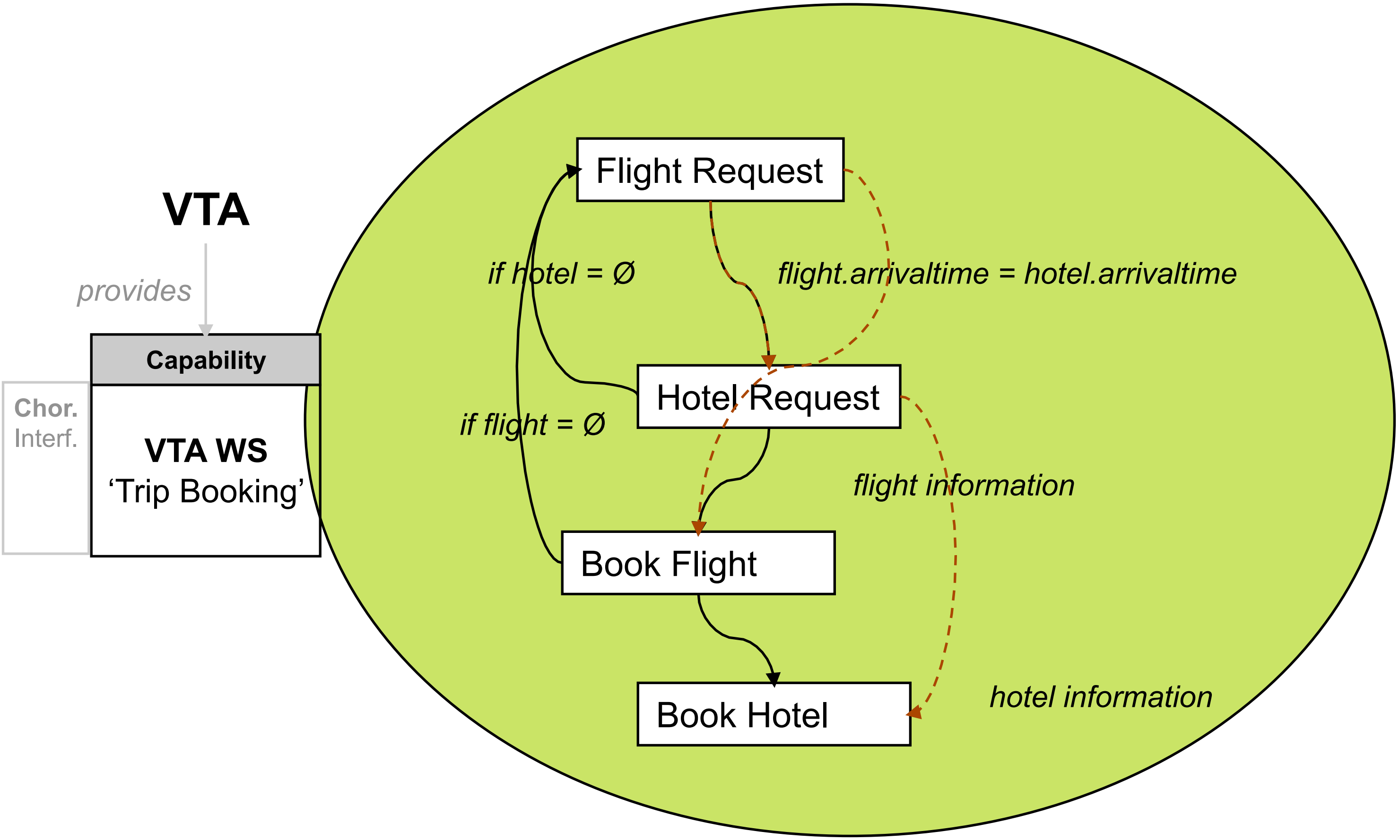
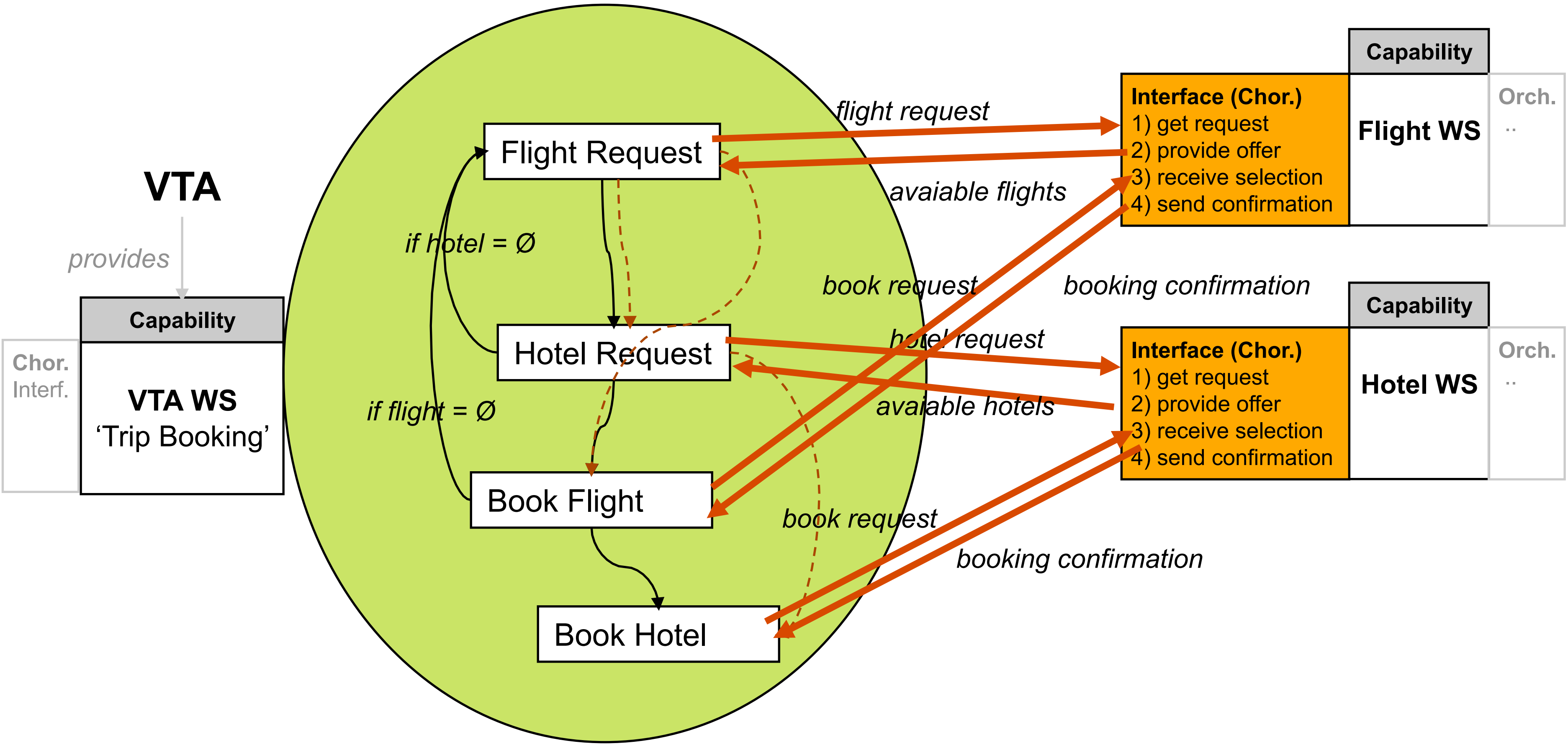
Choreography --- Service Interfaces --- **Orchestration**

Orchestration Definition



process (control + data flow) of goals

Runtime Orchestration



process (control + data flow) between "states"
+ communication behavior of orchestrating Web Service

WSMO Top Level Notions

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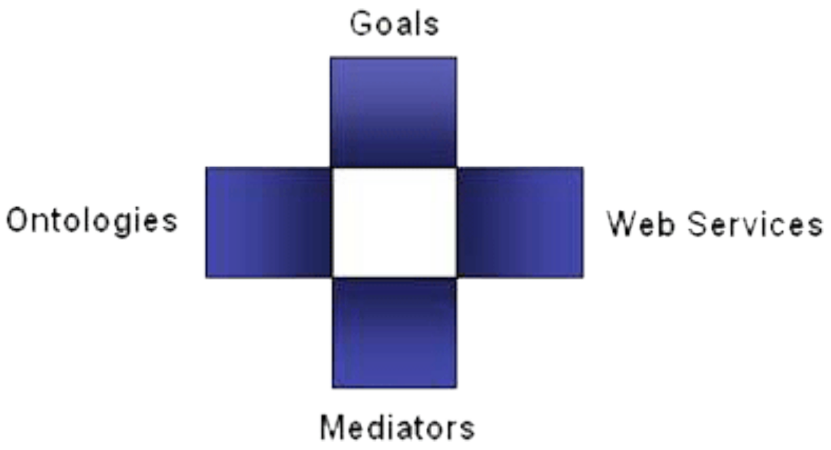

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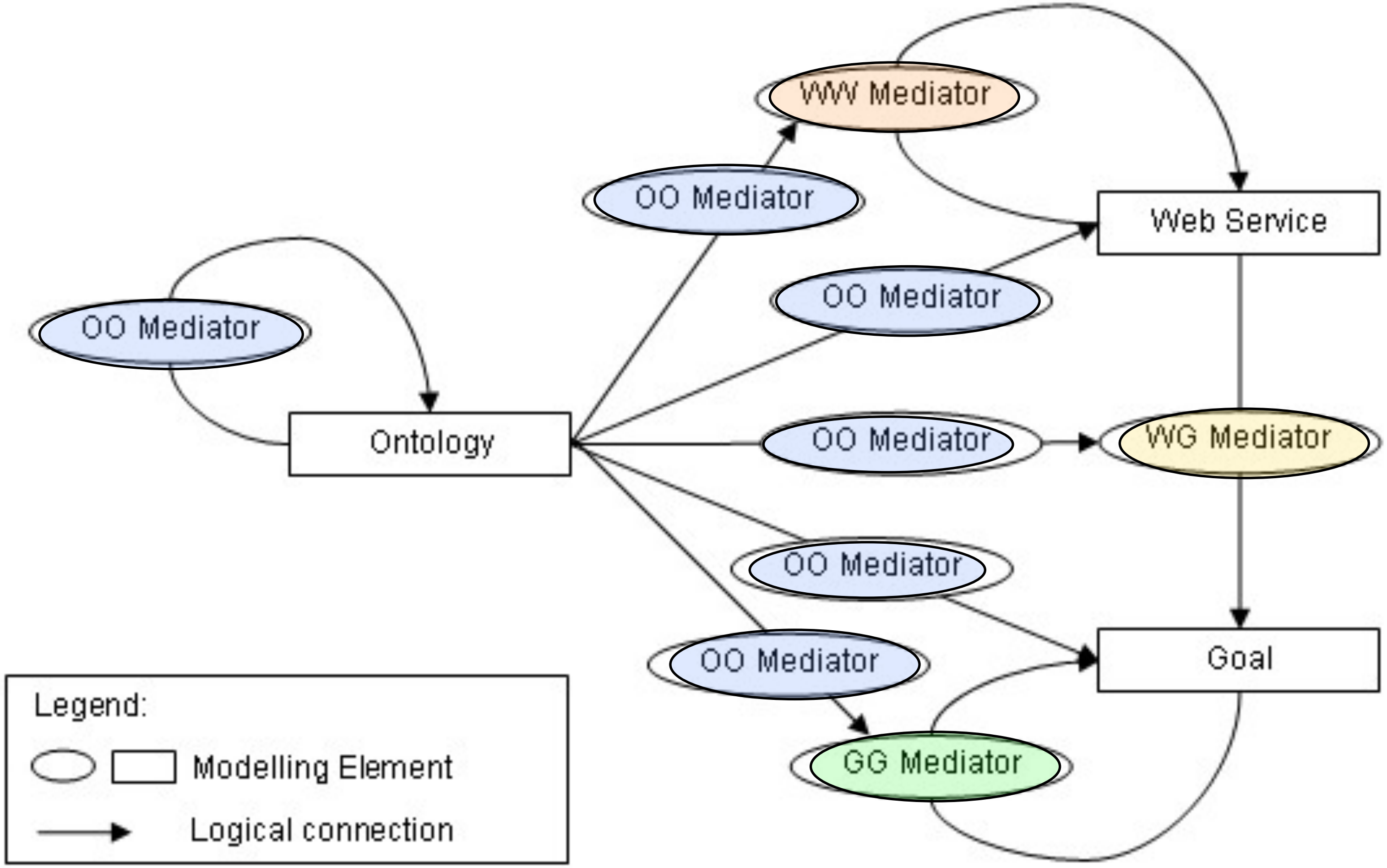
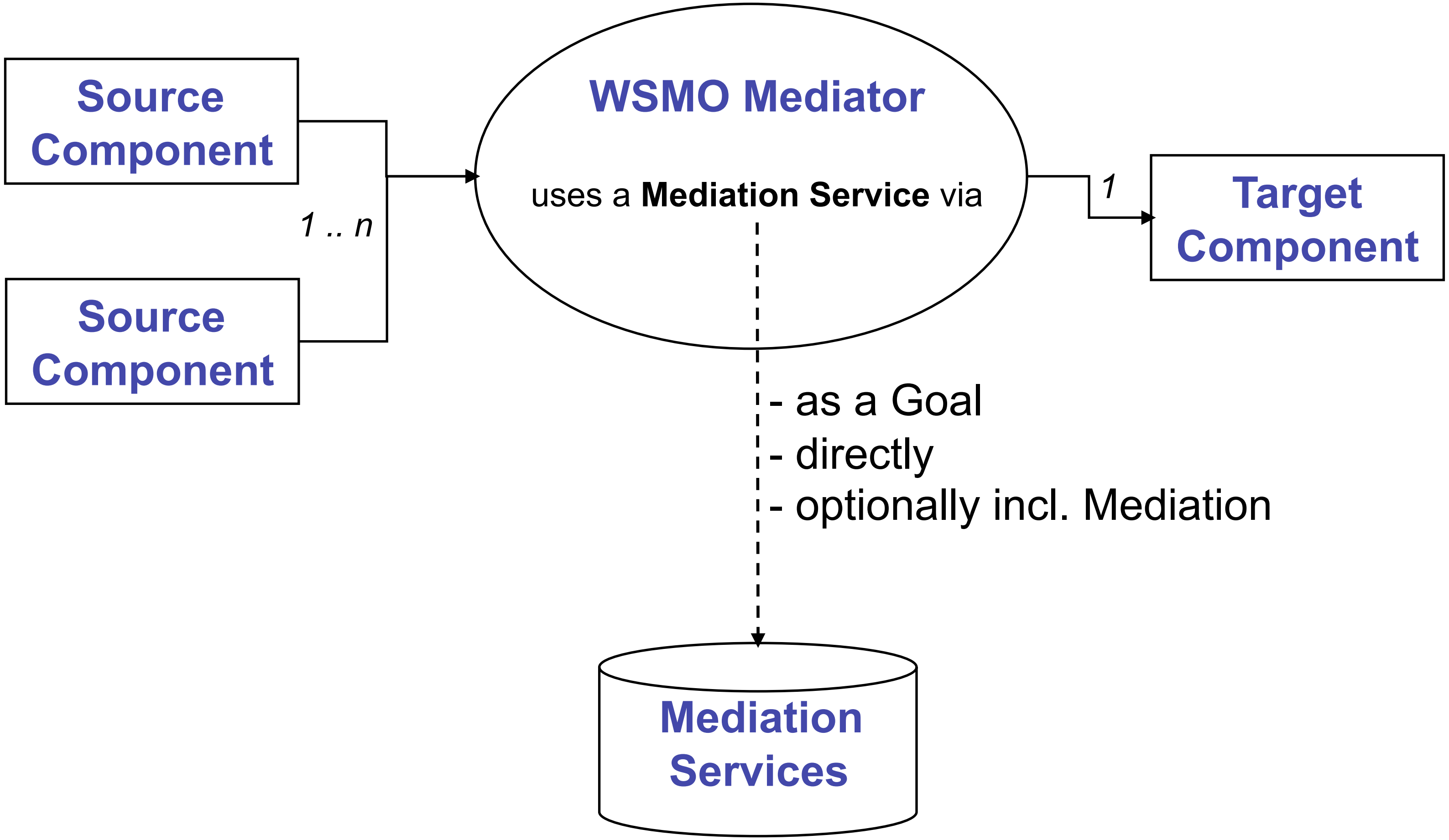
Mediation

- For 1$ on programming, $5 - $9 on integration © IBM, Nelson Mattos
- Mismatches on structural / semantic / conceptual / level
- Assume (nearly) always necessary
- Description of role

WSMO Mediators Overview



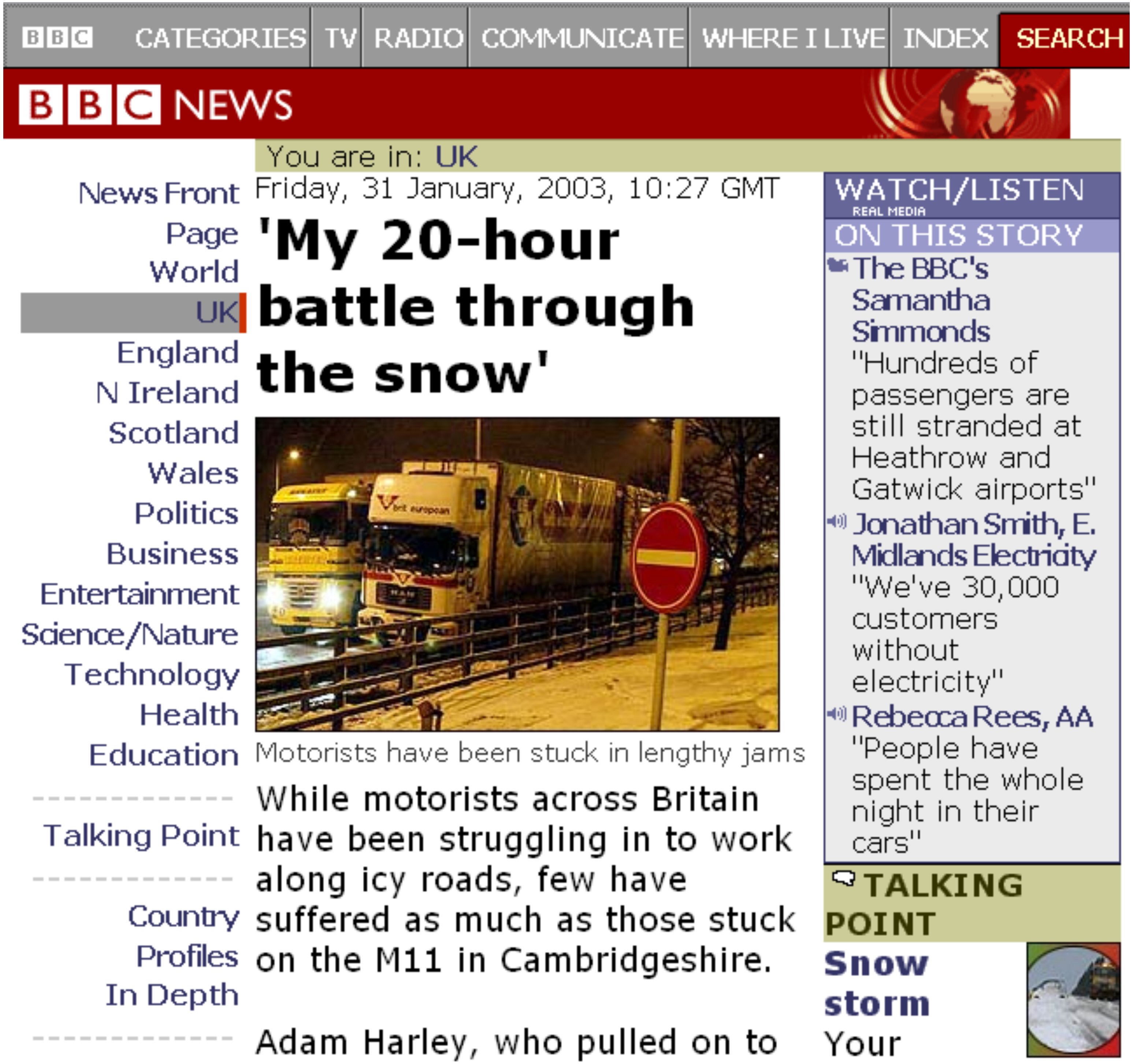
Mediator Structure



WSMO based Application using IRS-III

John Domingue

Data, Information and Process Integration
with Semantic Web Services



BBC NEWS

You are in: UK

News Front Page
World
UK
England
N Ireland
Scotland
Wales
Politics
Business
Entertainment
Science/Nature
Technology
Health
Education

Talking Point

Country Profiles
In Depth

Friday, 31 January, 2003, 10:27 GMT

'My 20-hour battle through the snow'

Motorists have been stuck in lengthy jams

While motorists across Britain have been struggling in to work along icy roads, few have suffered as much as those stuck on the M11 in Cambridgeshire.

Adam Harley, who pulled on to

WATCH/LISTEN
REAL MEDIA
ON THIS STORY

The BBC's Samantha Simmonds
"Hundreds of passengers are still stranded at Heathrow and Gatwick airports"

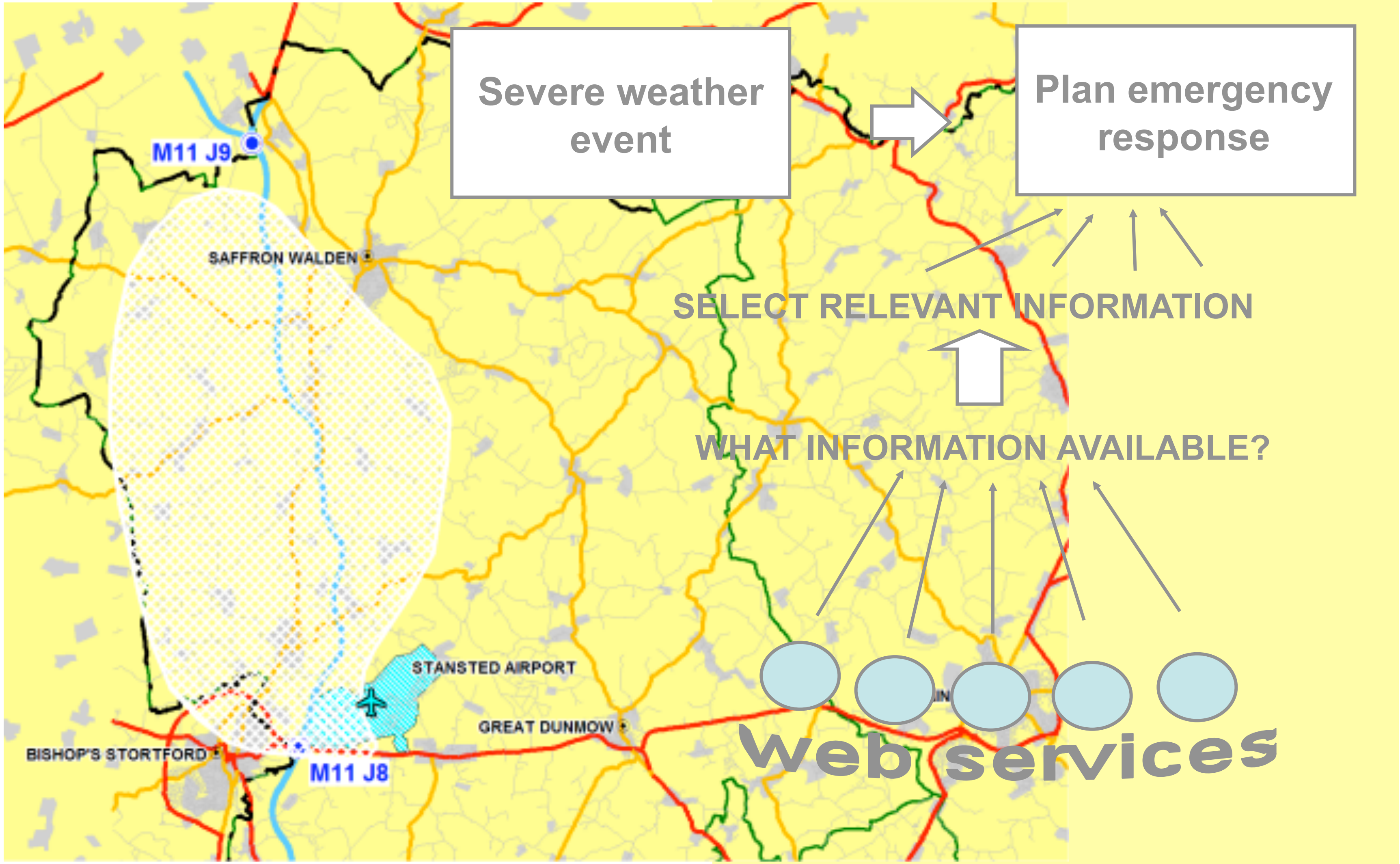
Jonathan Smith, E. Midlands Electricity
"We've 30,000 customers without electricity"

Rebecca Rees, AA
"People have spent the whole night in their cars"

TALKING POINT

Snow storm
Your

Emergency planning scenario



Severe weather event

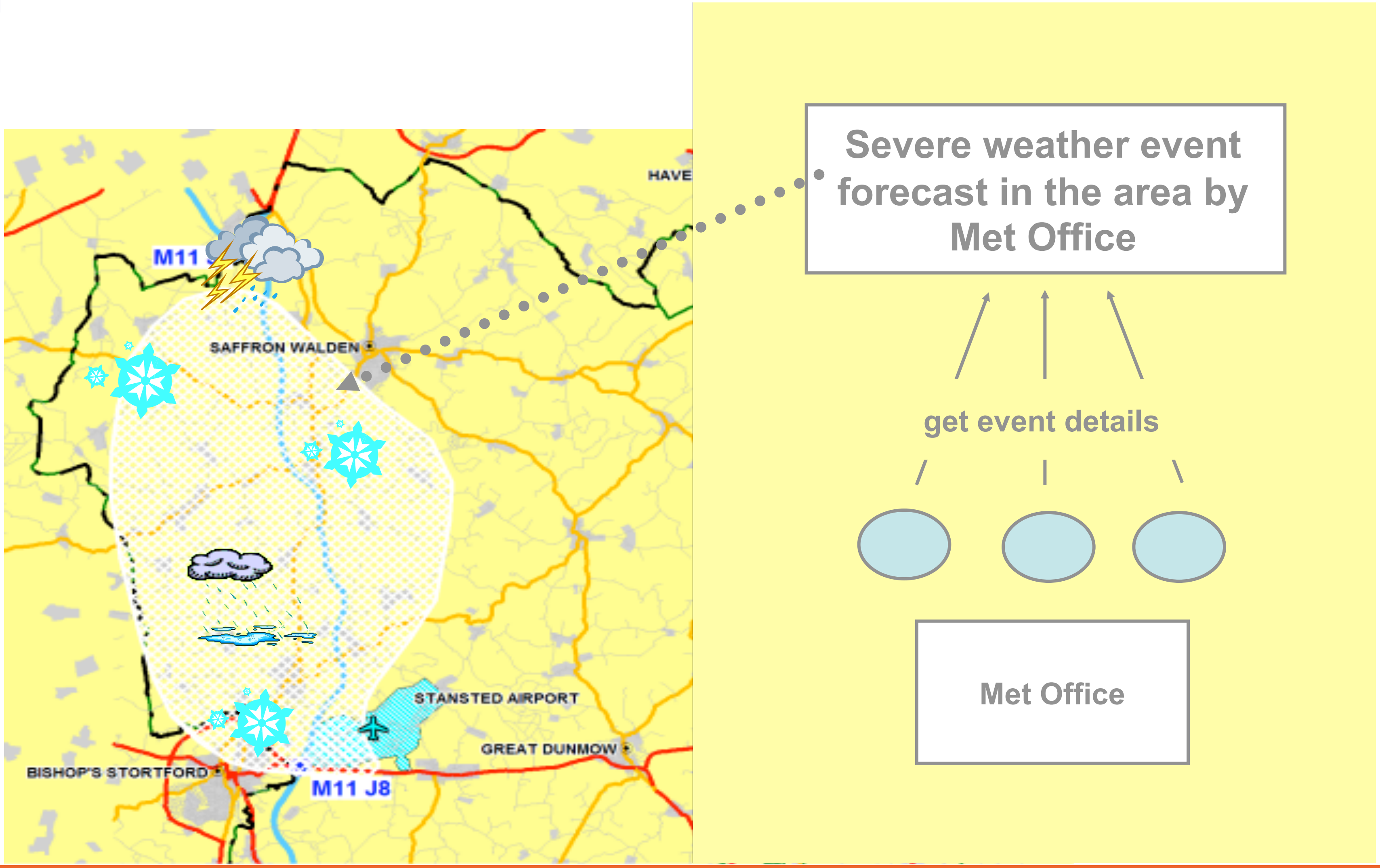
Plan emergency response

SELECT RELEVANT INFORMATION

WHAT INFORMATION AVAILABLE?

Web services

Emergency planning scenario

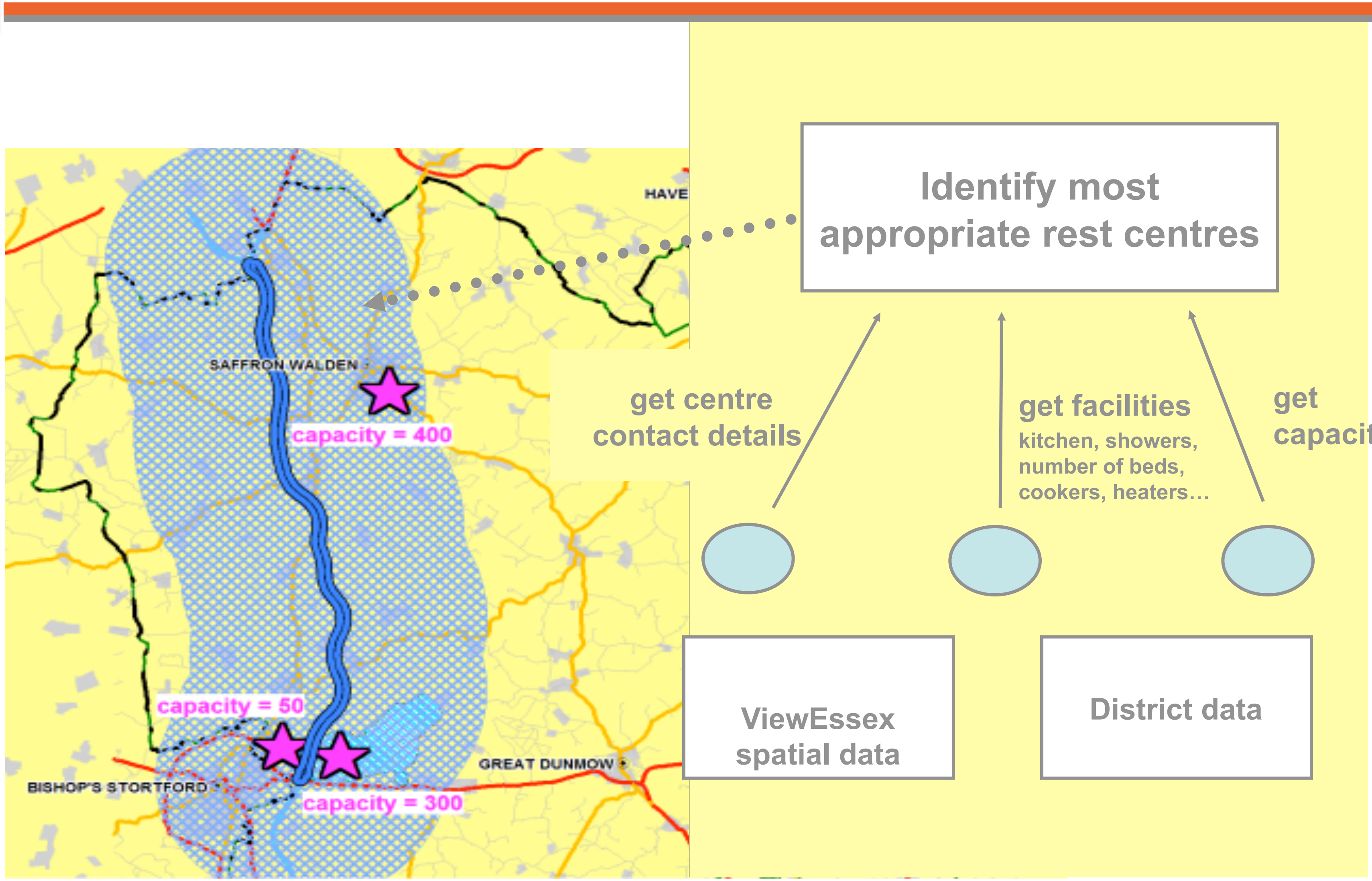


Severe weather event forecast in the area by Met Office

get event details

Met Office

Emergency planning scenario



Identify most appropriate rest centres

get centre contact details

get facilities

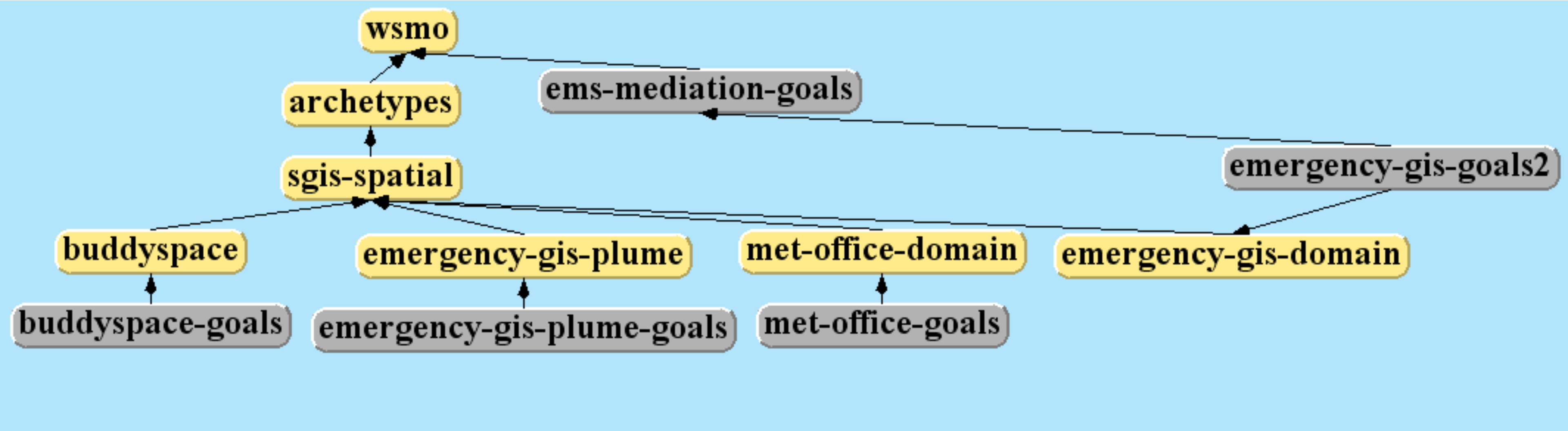
kitchen, showers, number of beds, cookers, heaters…

get capacity

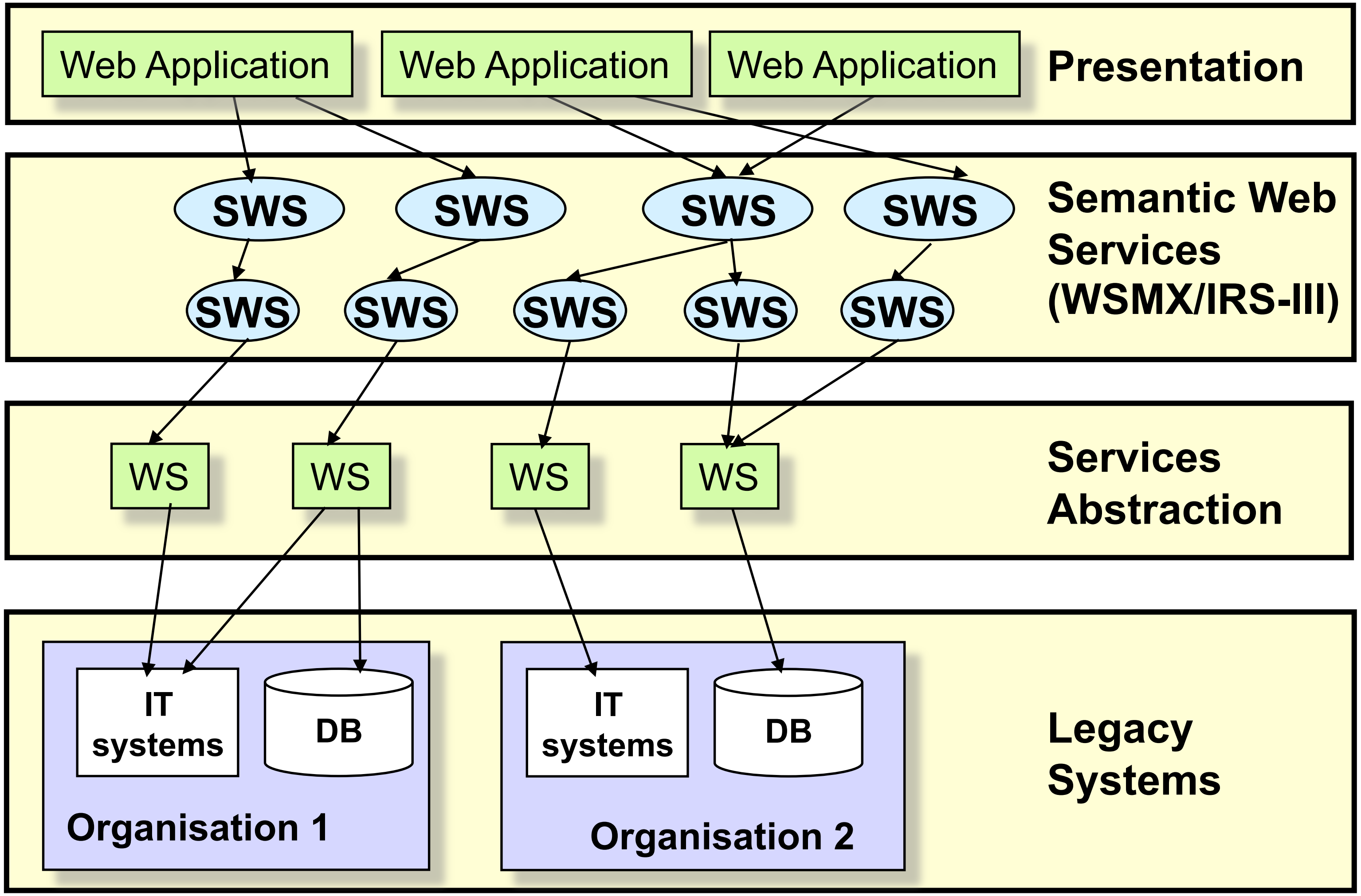
ViewEssex spatial data

District data

eMerges Ontologies



Generic Application Structure



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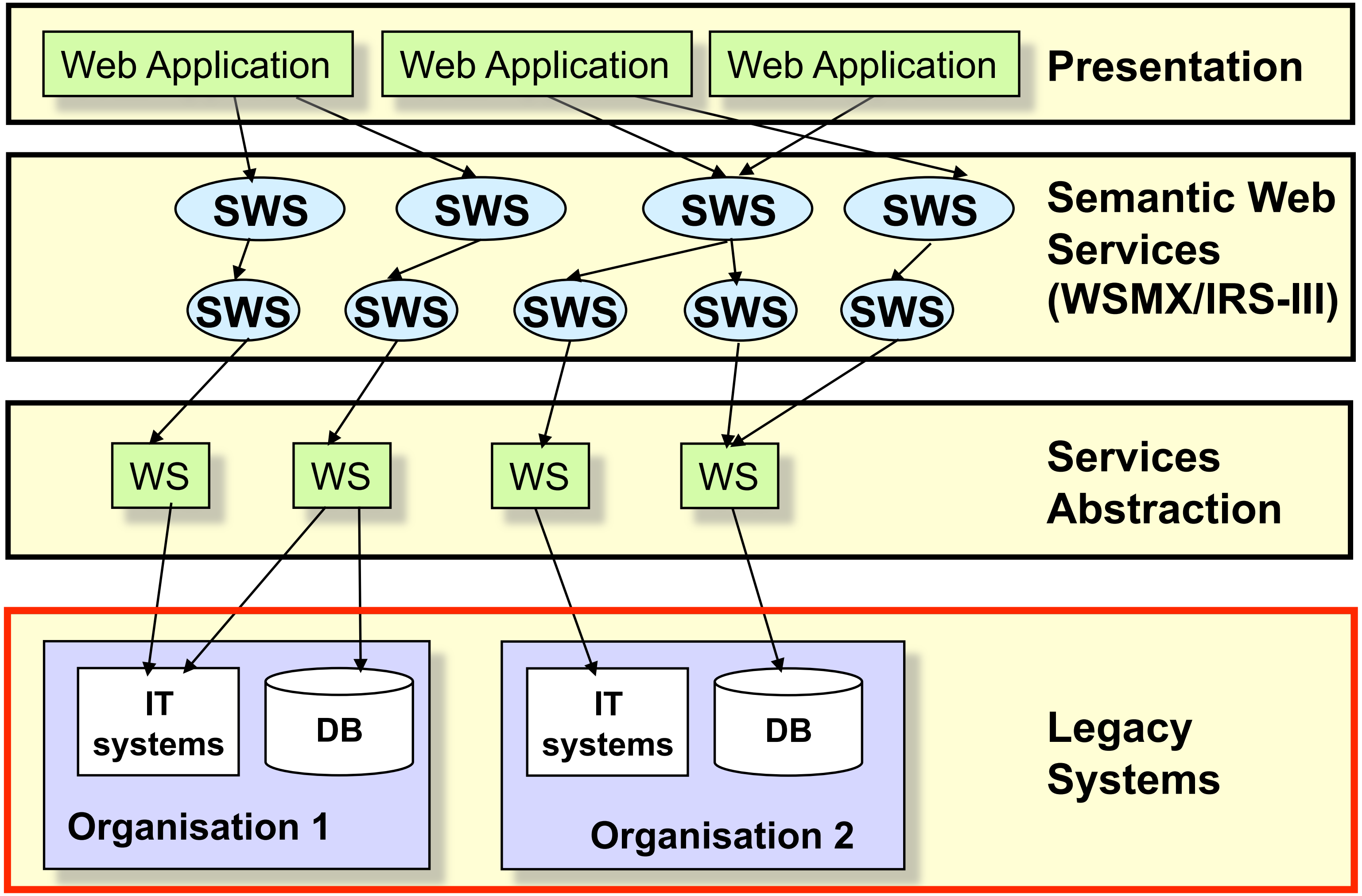

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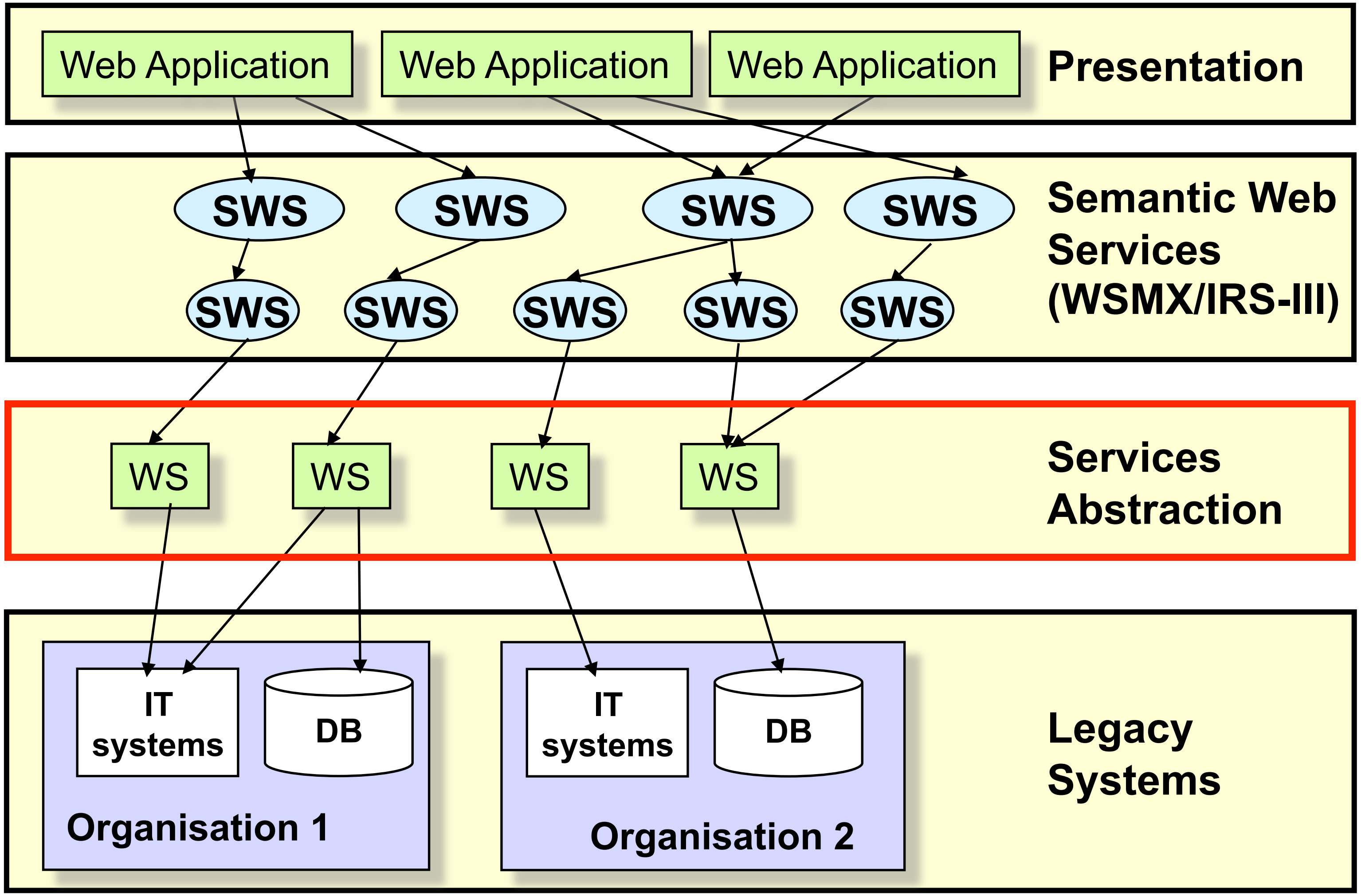

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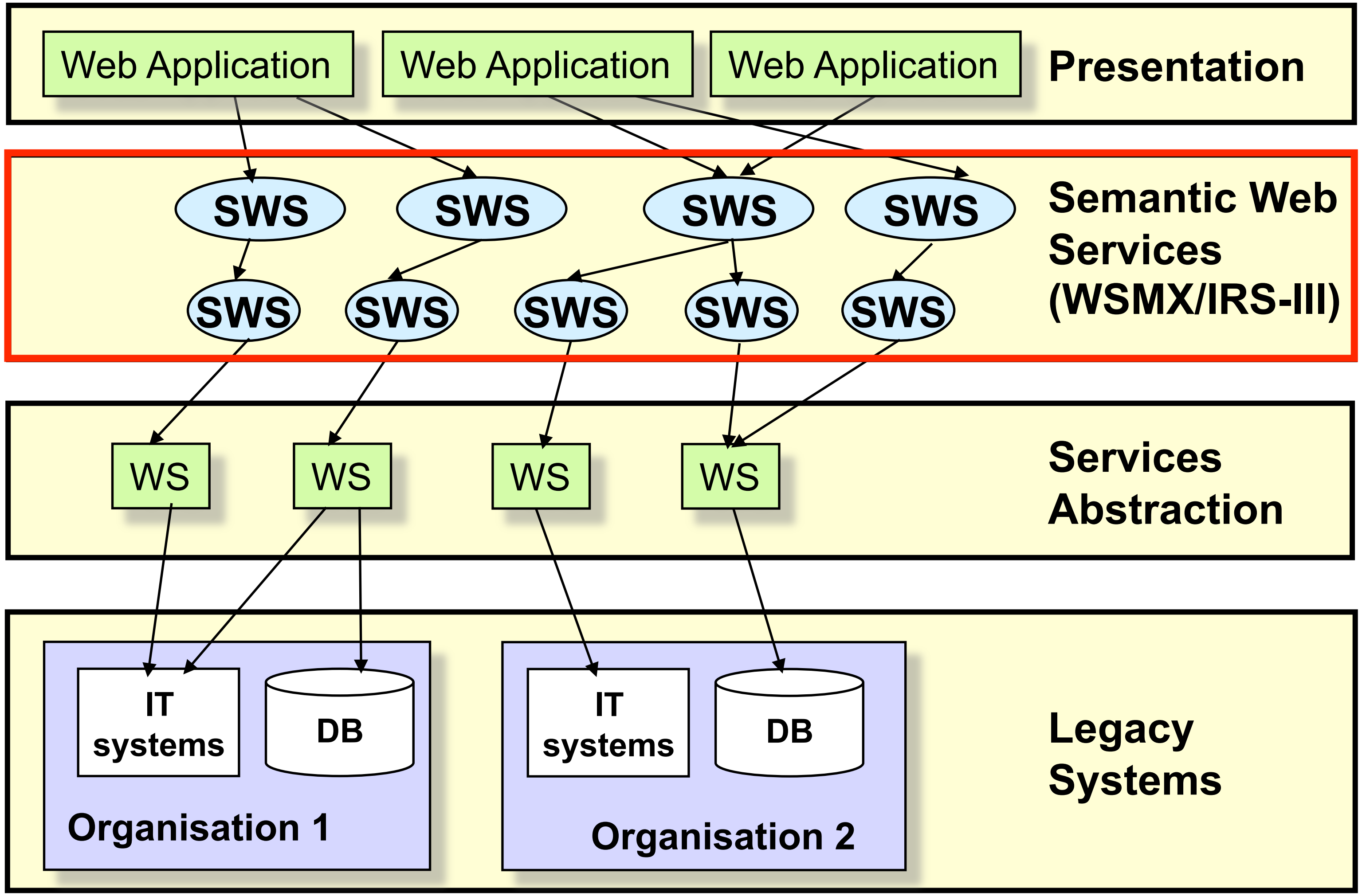

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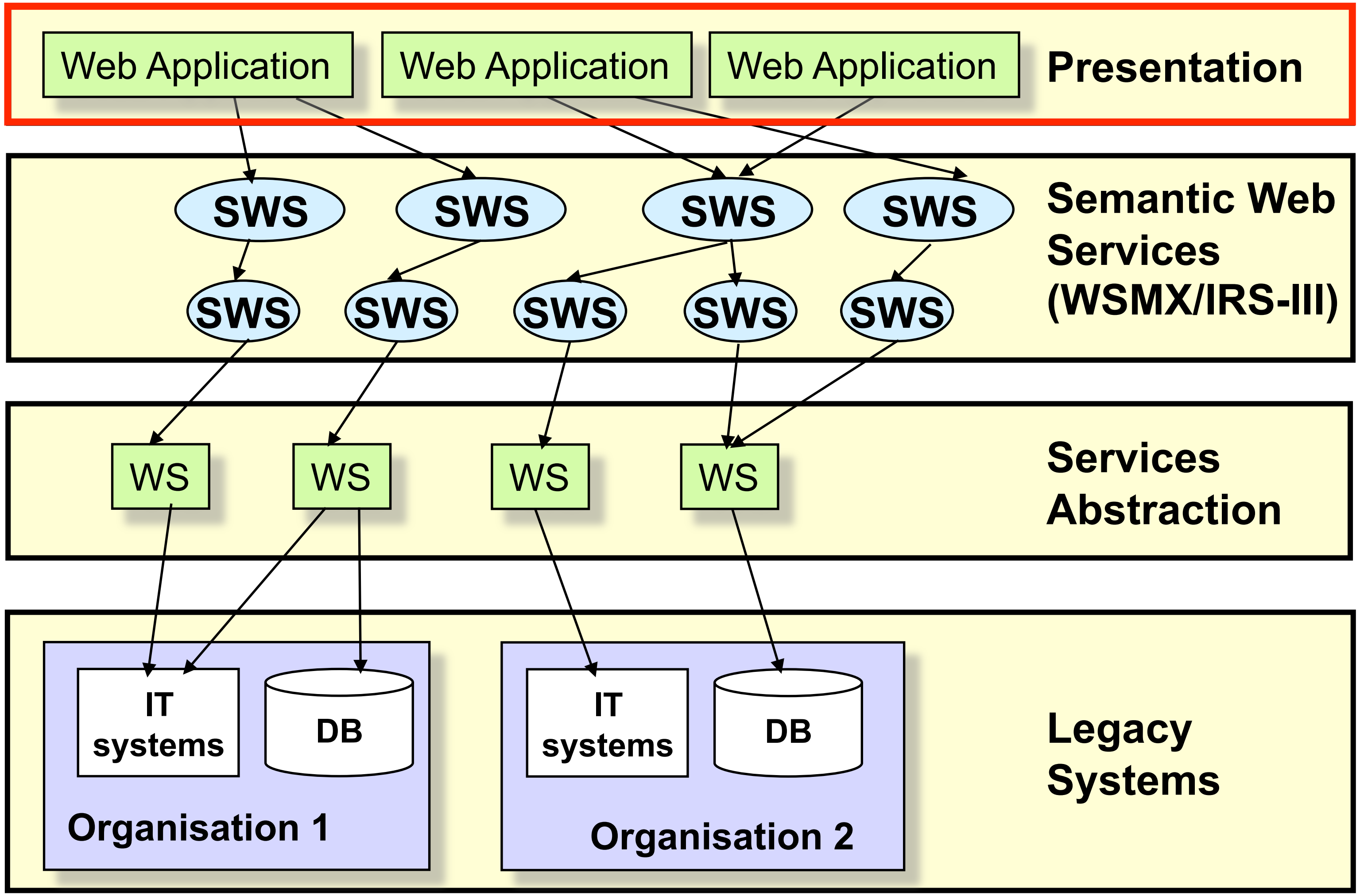
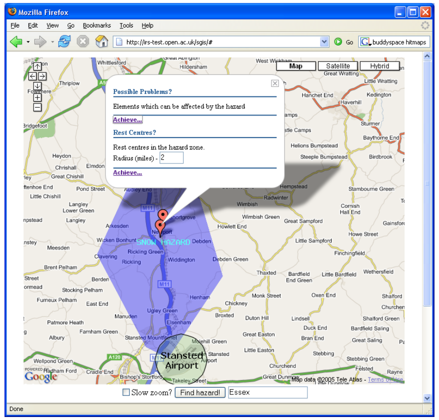


Video of Emergency Planning (GIS) Prototype V1

EMerges Prototype Architecture

Archetypes

SGIS-Spatial



Mozilla Firefox

File Edit View Go Bookmarks Tools Help

http://irs-test.open.ac.uk/sgis/#

Possible Problems?

Elements which can be affected by the hazard

Achieve...

Rest Centres?

Rest centres in the hazard zone.

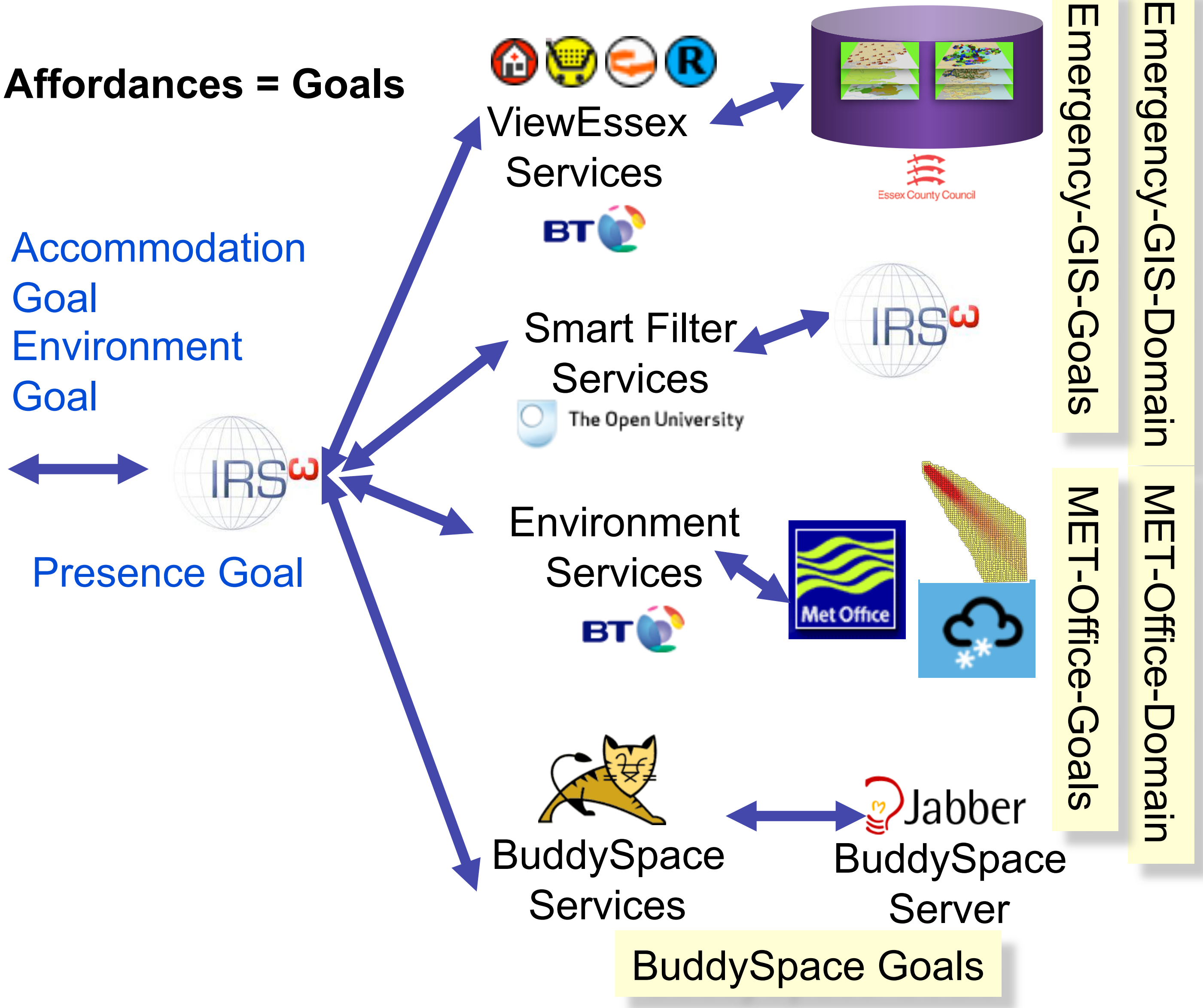
Radius (miles) - 2

Achieve...

□ Slow zoom? Find hazard! Essex

Done

Google Web Toolkit



Affordances = Goals

Accommodation Goal

Environment Goal

Presence Goal

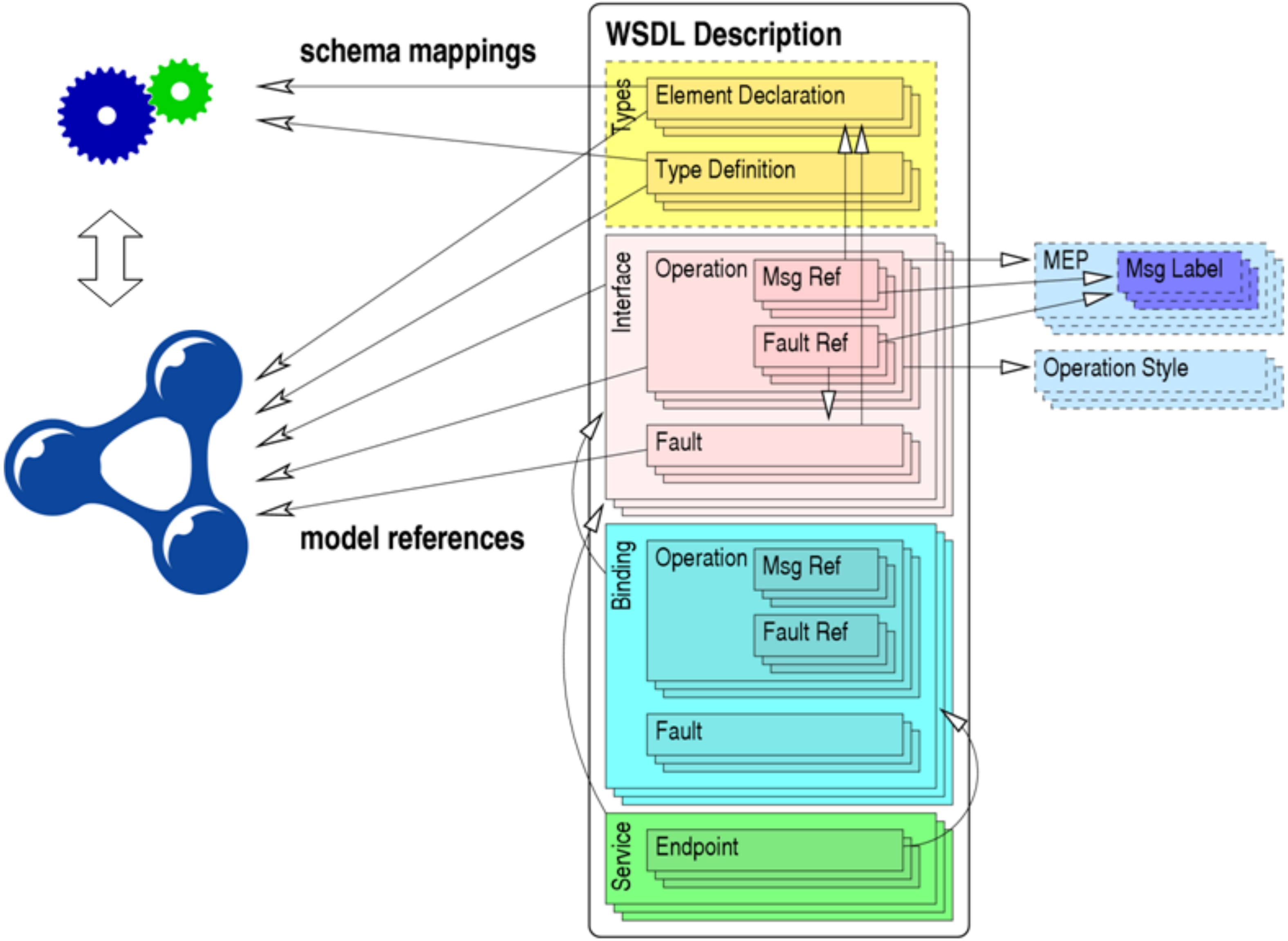
SAWSDL

David Martin

SAWSDL

- **S**emantic **A**nnotations for **WSDL** and XML Schema
- W3C Recommendation, August, 2007
- Largely based on WSDL-S
  - Some SAWSDL ideas also appeared earlier in OWL-S
- A simple, incremental approach
  - Builds naturally on the WSDL-centric view of Web services

Technical Overview of SAWSDL (1)



Technical Overview of SAWSDL (2)

- 3 extensibility elements
  - *modelReference*
  - *liftingSchemaMapping*
  - *loweringSchemaMapping*
- Can be used in both WSDL and XML Schema documents
- Values are lists of URIs
- No Preconditions and Effects

```
<wsdl:description>
 <wsdl:types>
  <xs:schema elementFormDefault="qualified">
   <xs:element name="OrderRequest“
       sawsdl:modelReference=“...”
       sawsdl:liftingSchemaMapping="..."
       sawsdl:loweringSchemaMapping="...">
       ...
   </xs:element>
  </xs:schema>
 </wsdl:types>
 <wsdl:interface name="Order“
      sawsdl:modelReference="...">
  <wsdl:operation name="order“
      pattern="…“
      sawsdl:modelReference="...">
   <wsdl:input element="OrderRequest" />
   <wsdl:output element="OrderResponse" />
  </wsdl:operation>
 </wsdl:interface>
</wsdl:description>
```

modelReference

- May be used with every element within WSDL
- “However, SAWSDL defines its meaning only for
  - wsdl:interface
  - wsdl:operation
  - wsdl:fault
  - xs:element
  - xs:complexType
  - xs:simpleType
  - xs:attribute.”

```
<wsdl:description>
 <wsdl:types>
  <xs:schema elementFormDefault="qualified">
   <xs:element name=“OrderRequest”
       sawsdl:modelReference=
  “http://ontology/po#OrderRequest”>
   </xs:element>
  </xs:schema>
 </wsdl:types>
 <wsdl:interface name="Order“
      sawsdl:modelReference=
  "http://.../products/electronics">
  <wsdl:operation name=“order”
      pattern="…“
      sawsdl:modelReference=
  "http://ontology/po#RequestPurchaseOrder">
   <wsdl:input element="OrderRequest" />
   <wsdl:output element="OrderResponse" />
  </wsdl:operation>
 </wsdl:interface>
</wsdl:description>
```

Schema Mapping Attributes

- *liftingSchemaMapping*
  - *lift* data from XML to a semantic model
- *loweringSchemaMapping*
  - *lower* data from a semantic model to XML
- Can map to XSLT script

```
<wsdl:description>
  <wsdl:types>
    <xs:schema elementFormDefault="qualified">
      <xs:element name="OrderRequest“
          sawsdl:liftingSchemaMapping=
    "http://.../mapping/Response2Ont.xslt"
          sawsdl:loweringSchemaMapping=
    "http://.../mapping/Ont2Request.xml">
      </xs:element>
    </xs:schema>
  </wsdl:types>
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    <wsdl:operation name="order“
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         sawsdl:modelReference="...">
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      <wsdl:output element="OrderResponse" />
    </wsdl:operation>
  </wsdl:interface>
</wsdl:description>
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SAWSDL References

- The Standard
  - http://www.w3.org/TR/sawsdl/
- Implementation Report
  - http://www.w3.org/2002/ws/sawsdl/CR/
- Initial Specs for Use with OWL-S
  - "Bringing Semantic Annotations to Web Services: OWL-S from the SAWSDL Perspective"
    - ISWC 2007
  - "Grounding OWL-S in SAWSDL"
    - ICSOC 2007
- Initial Specs for Use with WSMO
  - WSMO Grounding
    - http://www.wsmo.org/TR/d24/d24.2/v0.1/20070427/
  - WSMO Lite
    - http://wsmo.org/TR/d11/v0.2/20070622/d11v02_20070622.pdf

Conclusion

- The service paradigm is becoming an important and *integral* part of the Web (including *intra*nets)
- SWS aims to provide an expressive, comprehensive framework for handling activities on the Web
  - Enabling greater automation of *discovery, selection, invocation, composition, monitoring,* and other service management tasks
  - Should enable use of agents on the Web
    - Simplicity and widespread adoption of WS building blocks are enablers
- Many tools & applications exist today; mostly prototype
- Many challenges remain
  - SWS is a vigorous research area
- Strong interest and many paths to adoption also exist
  - E.g., the standards path
- Stay tuned – it will be interesting to see how far (and how fast) the service/process/agent-oriented Web will evolve!

Relevant URLs

- DIP
  - http://dip.semanticweb.org/
- IRS-III
  - http://kmi.open.ac.uk/projects/irs/
- OWL-S, SAWSDL
  - See earlier slide
- WSMO Working Group
  - http://www.wsmo.org/
- Conceptual Models of Services WG
  - http://cms-wg.sti2.org
- SOA4All
  - http://www.soa4all.eu/
- Service Web 3.0
  - http://www.serviceweb30.eu