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The Semantic Web promises a Smarter Electricity Grid

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Outline

- Semantics in today's grid
- Objectives for a semantic Smart Grid
- Possible architectures of a distributed information system for Smart Grids
- Conclusion

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What is a „Smart Grid“?

- Smart Grid, SmartGrids: a vision
  - Not a standard, not even an architecture
- “A SmartGrid is an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies.”

European Technology
Platform SmartGrids


IEC/PAS 62559

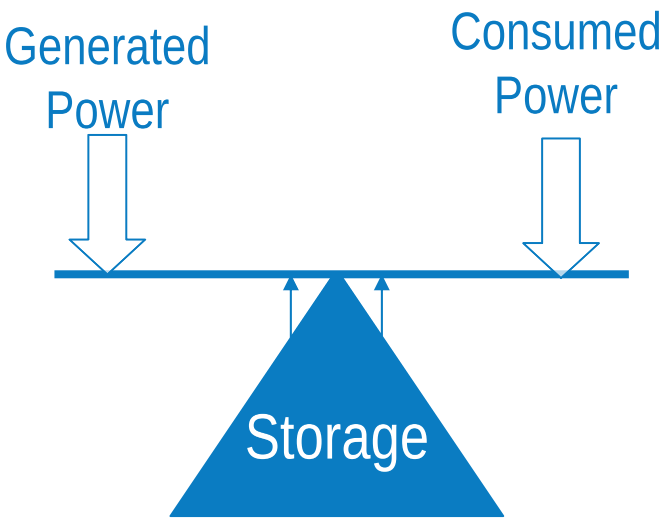
PUBLICLY AVAILABLE SPECIFICATION

PRE-STANDARD

IntelliGrid Methodology for Developing Requirements for Energy Systems

Some Problems with Today's Grid

- Keeping the balance:
  - At any time, matching production, consumption and storage
  - Increasing consumption
    - Energy consumption (still) increases with consumers' buying power
    - Broader usage of energy in the form of electricity
      - Heat pumps, electrical vehicles…
  - Changing production
    - More volatile production
      - Wind turbines, solar panels
    - Society concerns about sustainability
      - Often difficult to build new plants using fossil / nuclear fuel



- Production and consumption have their own (decoupled) logic
- No feedback:
  - Consumers assume infinite production capacity
  - Electricians understand their role as to provide as much power as asked

Some Problems with Today's Grid

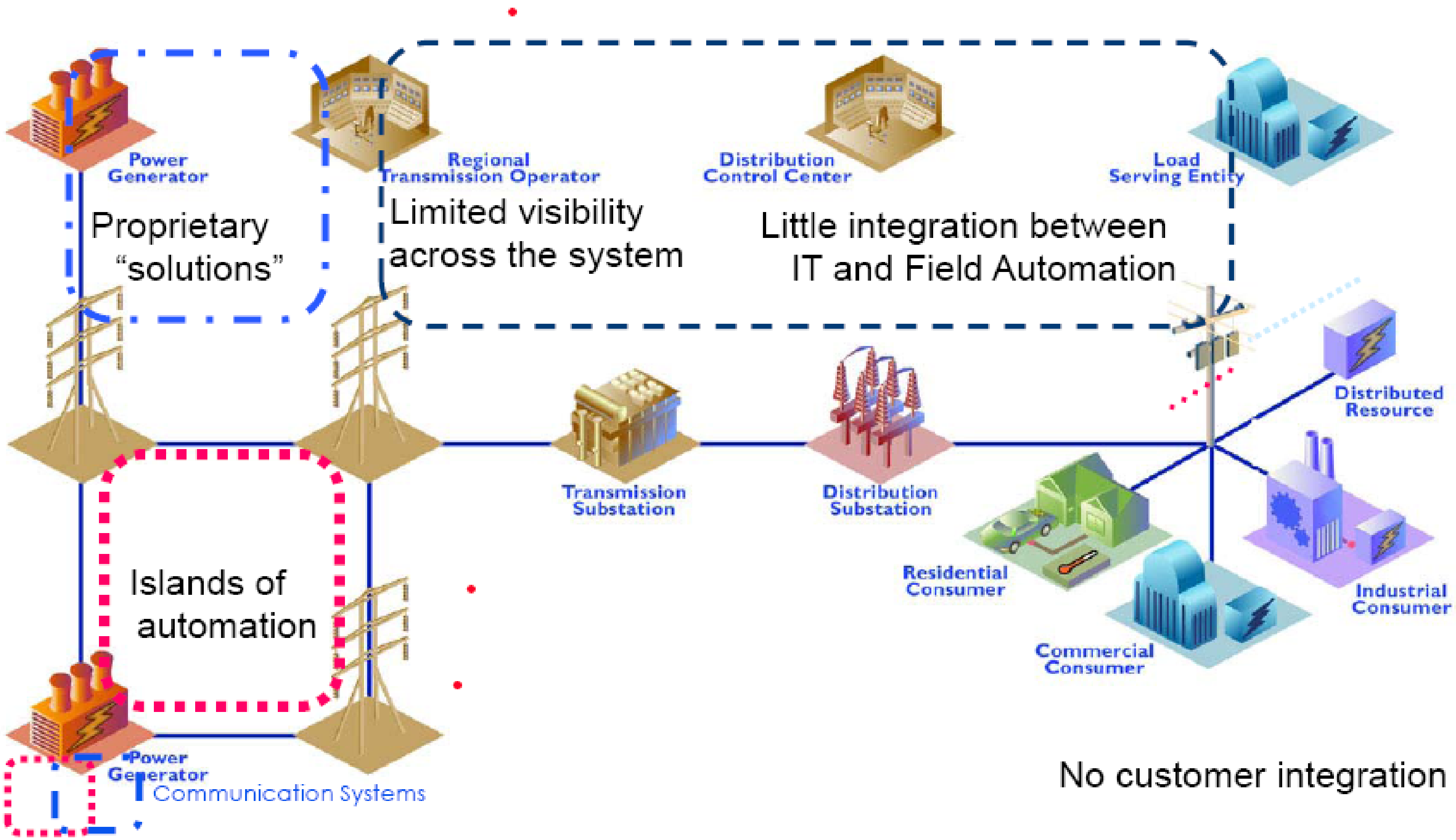
- Managing a more distributed architecture
  - From a limited number of big power plants to a large number of distributed energy resources
  - Consumers become "active"
    - "Grid friendly" consumer behaviour
- Optimising usage of existing energy production, transmission and distribution assets
  - Congestion control *and* operation closer to the infrastructure capacity level
  - Automation of the distribution system to reduce the work force
- Providing self-healing capability
  - Avoiding that a local failure turns into a blackout
    - Domino effect
- Managing the cooperation between independent and sometimes competing companies
  - Energy markets liberalisation increases the number of participating companies and therefore the complexity of the system

Information is Part of the Solution

"A smarter grid makes this transformation possible by bringing the philosophies, concepts and technologies that enabled the internet to the utility and the electric grid."

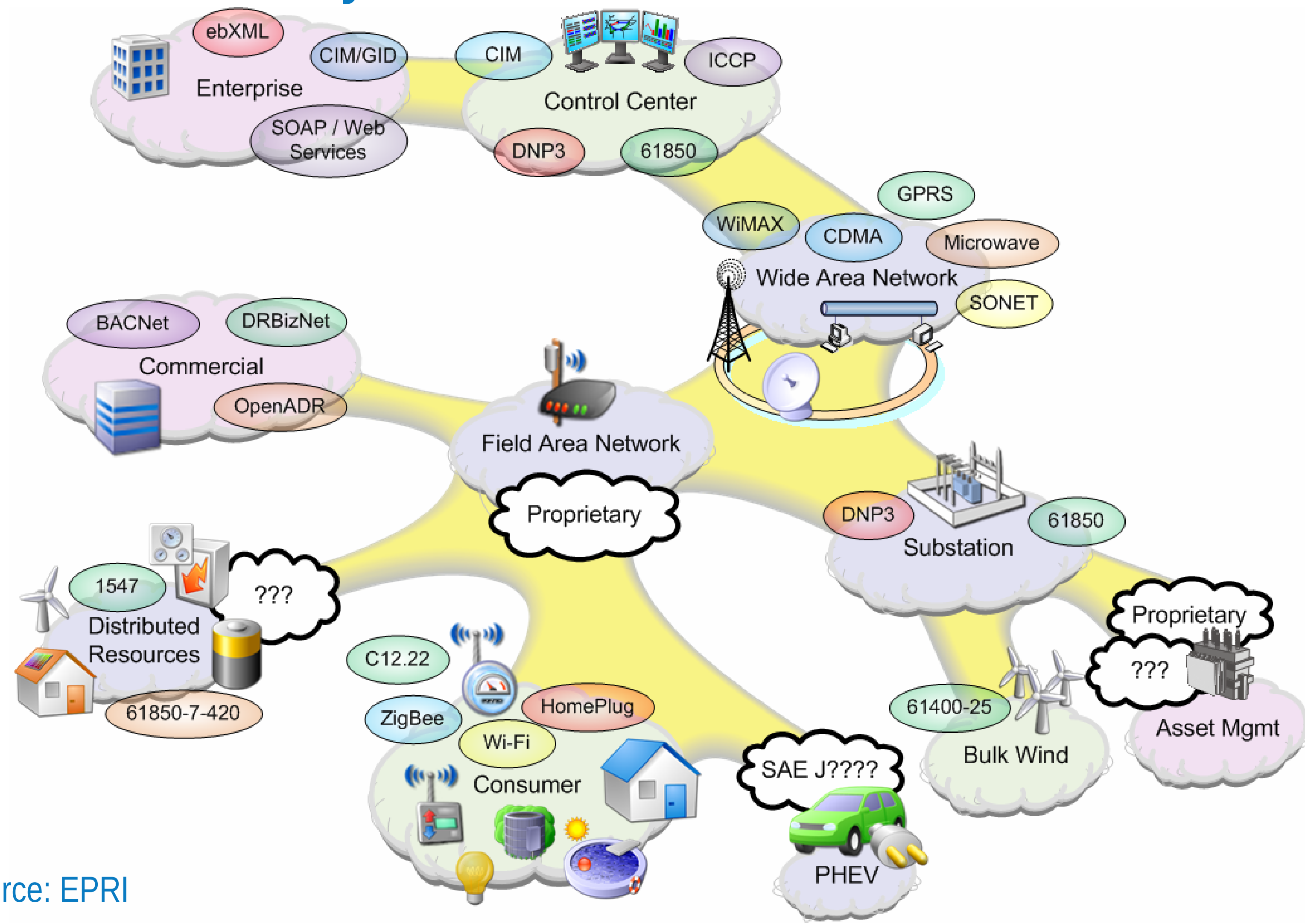
US Department of Energy

The Grid Today



"Standards and Architecture Development for Development for "Smart Grid" Infrastructure"
EPRI

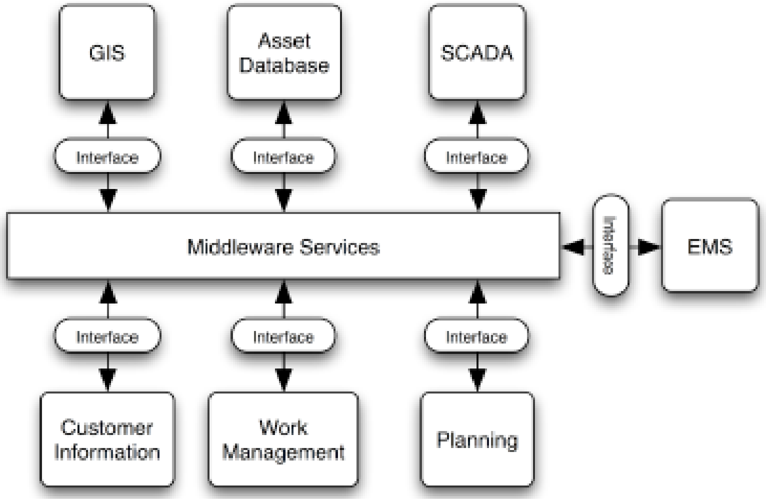
The Grid Today



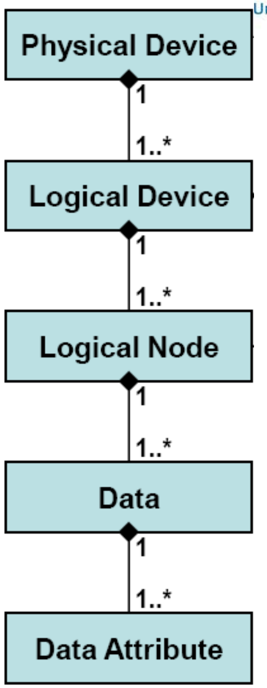
Source: EPRI

Semantics in Today's Grid

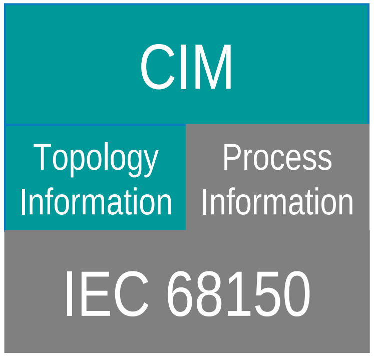
- Common Information Model (CIM)
  - IEC 61970-301 & 61968-11
    - IEC: International Electrotechnical Commission (www.iec.ch)
  - Object-oriented model dealing with semantics
    - UML definition
      - RDF serialisation defined
    - So-called Profiles defined in OWL
  - Enterprise centric view
    - Goal: uniform interface between software applications
  - Pure model
    - no constraints on implementation
    - no communication protocol
  - Primary focus on Generation and Transmission, but recent extensions towards Distribution
    - Smart Grids : Distribution



Semantics in Today's Grid



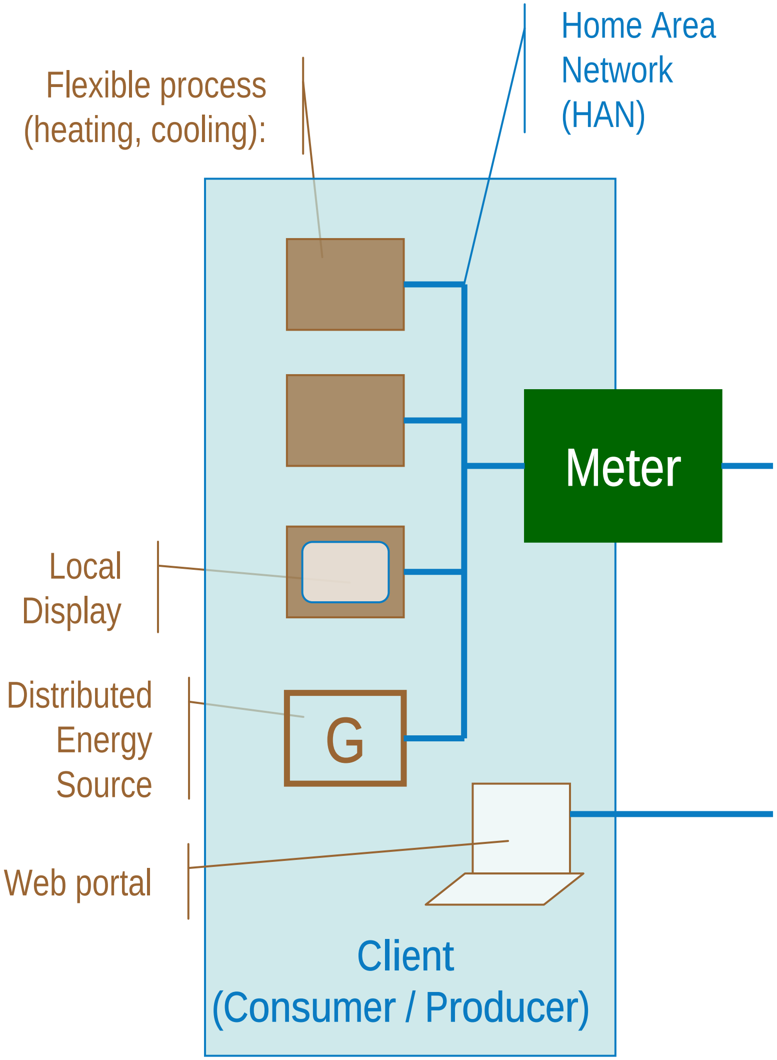
- IEC 68150
  - Substation automation
    - High to low voltage, low to high voltage
  - Standard being extended for the management of other systems
    - e.g. hydro power plant
    - Object-oriented view of Physical Devices
      - called Intelligent Electronic Devices (IEDs)
  - Naming conventions to assign object names
  - Basic set of services to manipulate objects
    - Get, Set, Dir…
  - Based on OSI's MMS
    - Manufacturing Messaging System



Semantics in Today's Grid

- DLMS (IEC 62056)
  - Meter – utility interface
  - Similar to SNMP and MIB used in the telecom world
    - … but implemented completely differently
  - Tree logical view of a meter
    - Get and Set services
- Assessment of IEC Standards
  - Base for interoperability in their (limited) domain
  - No global information model
    - Consumer / meter / distributor / transmission / supplier / transmission operator
  - Long development time
    - Sometimes a decade
  - Many optional features
    - Sometimes weak interoperability
  - In practice, still many proprietary solutions

Smart House, Smart Metering…



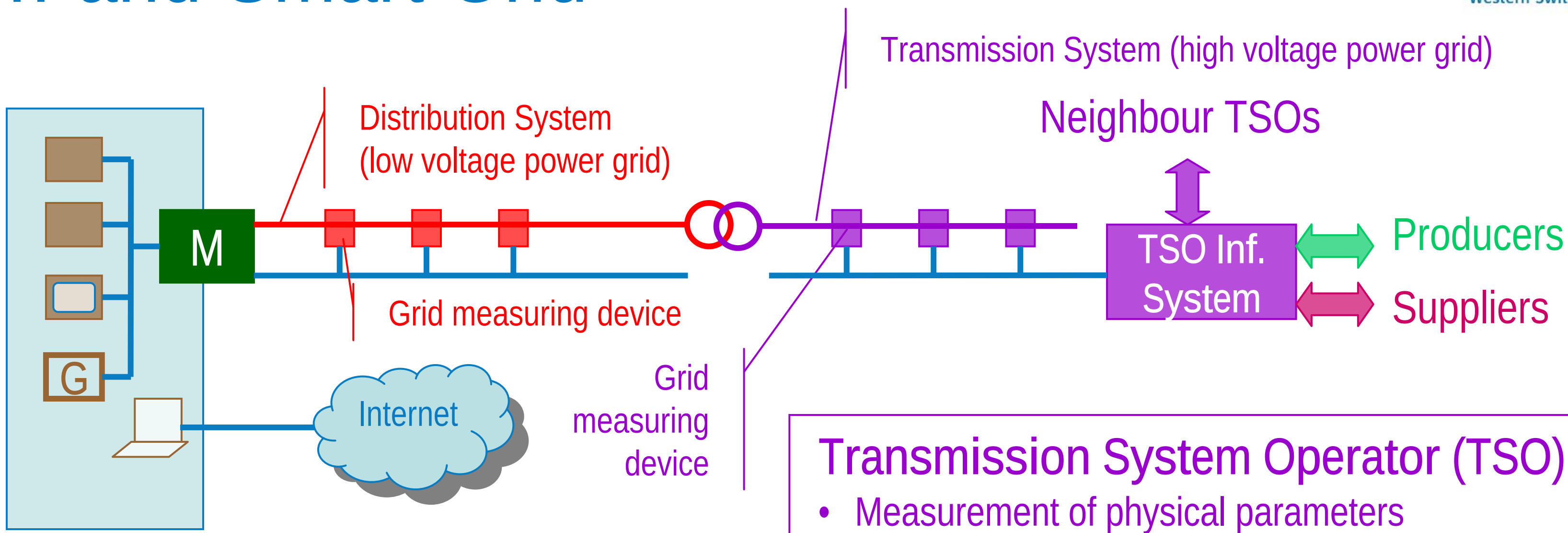
Client:

- Automated Demand Response
  - Control of flexible loads typically through dynamic prices
- Client information
  - Current prices, instantaneous feedback
- Monitoring and control of on-site generation
- Web portal
  - Processed feedback

Metering Company:

- Metering according to supplier's (dynamic) tariffs
- Information channels
  - One for the supplier and one for the DSO
- Automated Demand Response Channel
  - For the supplier
- Power quality measurements
  - For the DSO

… and Smart Grid



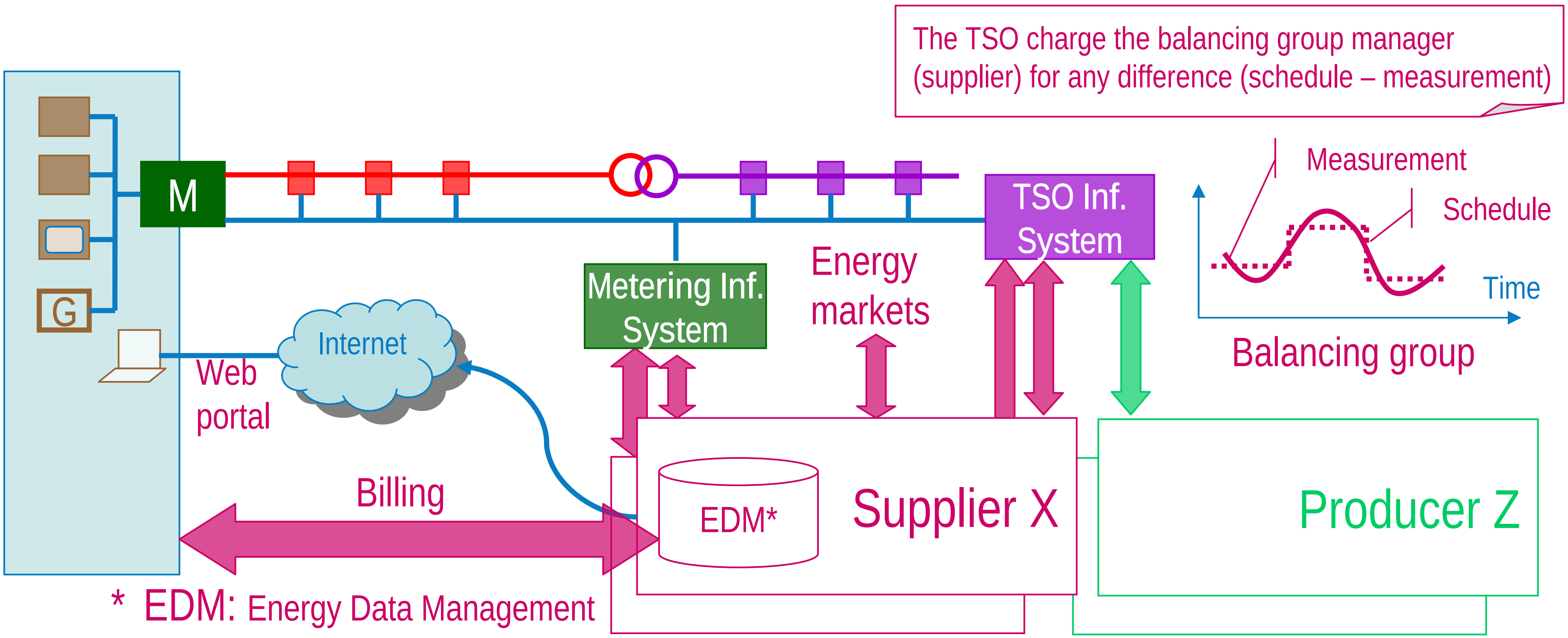
Distribution System Operator (DSO):

- Measurement of physical parameters
  - Voltages, currents, energy flows…

Transmission System Operator (TSO):

- Measurement of physical parameters
  - Voltages, currents, energy flows…
- Remote control of substations
- Management of inter TSO energy exchanges
- Balancing group management
  - Ahead of time schedule
  - Energy Measurement
- Ancillary services
  - Goal: Maintaining the 50 Hz frequency
  - Keeping the exchanges with neighbour TSOs at the planned level
  - Mandate to producers

…Smart Grid

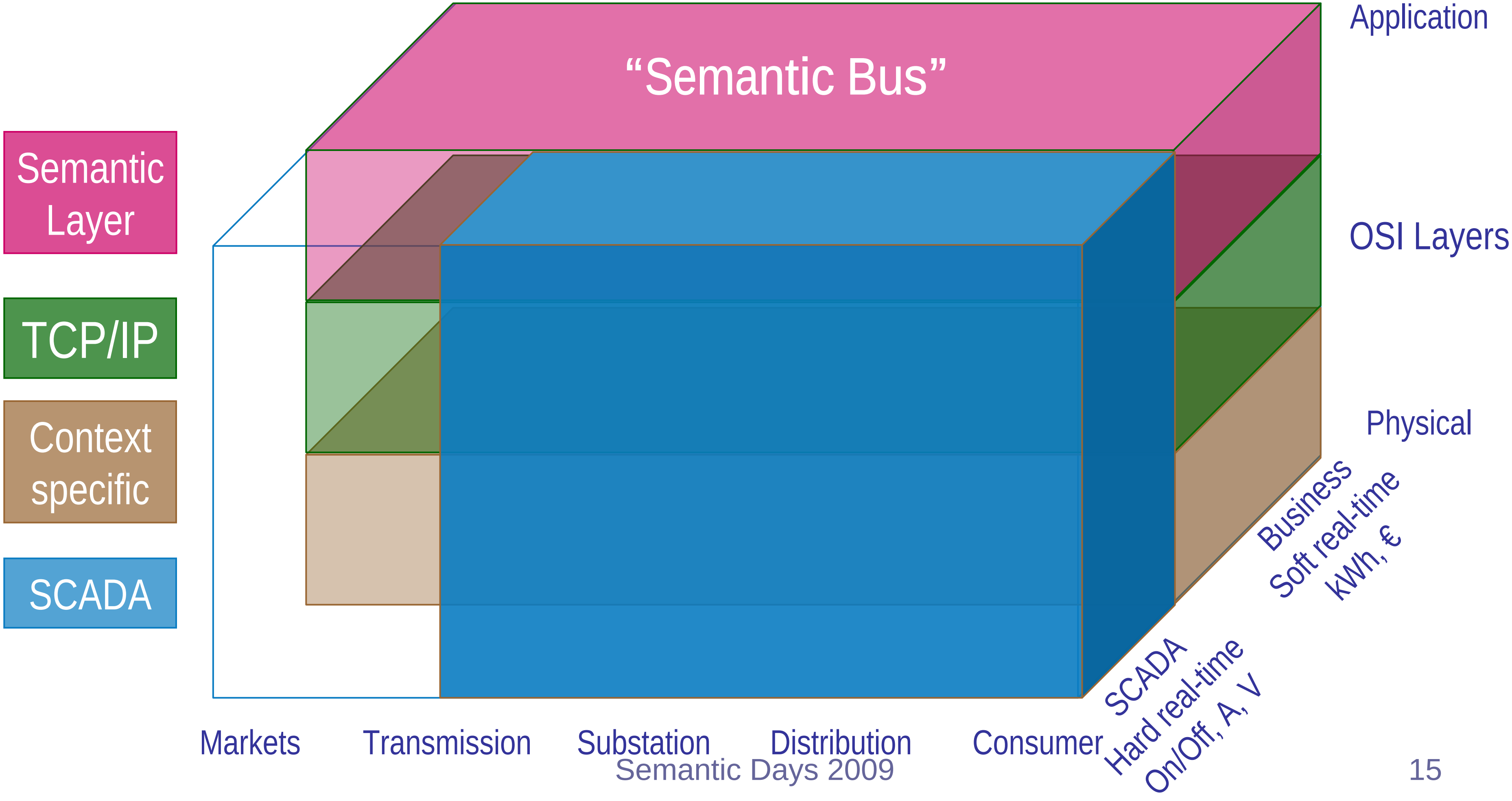


And also:
Geographical Information Systems
Work Management Systems
Asset management
Outage Management
Customer Relationship Management

Supplier :
- Business only role
  - Buy and sell energy
- Schedule calculation
  - and transmission to the TSO

Producer :
- Produces and sells energy
  - either to Suppliers or to the TSO (ancillary services)

Sketch of a Purely Semantic Information System for a Smart Grid



Smart Grids Features

- Smart Grids features
  - Self-healing and adaptive
  - Interactive with consumers and markets
  - Optimized to make best use of resources and equipment
  - Predictive rather than reactive, to prevent emergencies
  - Distributed across geographical and organizational boundaries
  - Integrated: merging monitoring, control, protection, maintenance, energy markets, customer management
  - Secure from attacks

Semantics for the Smart Grid

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- Two main problems to solve:
  - Distributed architecture of the information system
    - Distribution of the information system required to cope with the geographical distribution of the power grid
    - Information security connected to physical safety, grid reliability and data privacy
  - Ontologies
    - Reuse of existing ontologies
    - Development of high quality ontologies
    - Standardisation process for ontologies

Distributed Architecture Design Method

- Top down:
  - Specify
  - Derive architecture and protocols
  - Standardise protocols
  - Develop products and services
  - Deploy
- Cyclic:
  - Design a system with intrinsic extension capability
  - Develop and deploy a simple system
  - Extend
  - Example: Web

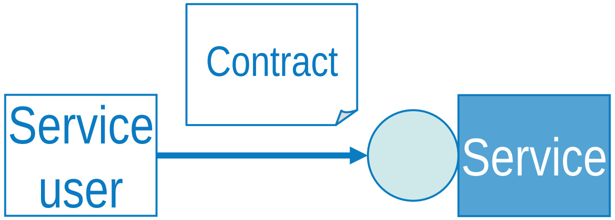
- The top down approach is unrealistic

  "Imagine a standards-making process that's 10 times more complex than ... the computer industry, with a deadline for delivering those game-changing decisions of mere months."

- Two approaches: REST and SOA

About REST and SOA

- SOA: Service Oriented Architecture
  - Usually implemented using SOAP and WSDL and known as "Web Services"
  - Design goals:
    - Splitting interface from implementation
    - Service contract specifying the interface



- REST: Representational State Transfer
  - Particular type of Web Services relying solely on HTTP and URI for communication
  - Basically similar to the classical web
    - GET, PUT, POST, DELETE resources
    - Machines must be able to process transported resources
      - XML or RDF/OWL encoded resources instead of HTML resources
  - 2 versions
    - Pure Rest: **`http://example.com/energy/companyx/2009-04`**
    - "RESTified" Web Service:
      - **`http://example.com/getenergy?who=companyx&when=2009-04`**

SOA vs. REST Architecture

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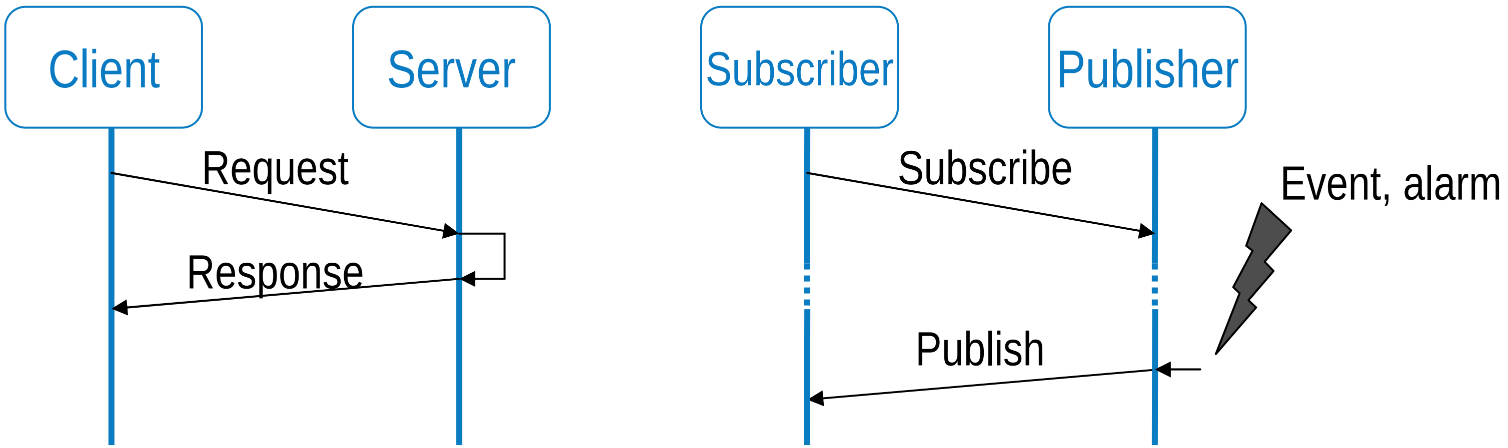
	SOA	REST
Published interface	• Service interface is defined by a contract (WSDL) • Contract defines both services and data – Services: methods – Data: parameters • Client and server must agree on services and data	• Data in documents • Uniform interface: one object class – Web document with 4 methods (GET, PUT, POST, DELETE) • Client and server must agree on the web documents' data
Stateful / stateless modes	• Stateful or stateless communication – Received or sent messages can trigger state change – Operations requiring sequence of messages • Capable to support transactions – set of operations with pass or fail results • Tighter coupling between components	• Stateless communication – Document transfer only – A party is not aware of its partner current state • Party receiving information can decide how to process it • HTTP caching possible • Looser coupling between components
Scalability	• Fixed set of services required – Flexibility to add new data (parameters)	• Uniform interface provides a better capability to access not yet known resources
Frameworks	• Many available	• A method – no framework required

Communication models



- Client – Server model
  - Client downloads data from Server
  - Client uploads data to Server

- Publisher – Subscriber model
  - Subscriber registers itself for a class of events / alarms
  - Upon occurrence of an event / alarm, Publisher calls back the Subscriber

REST and SOA support both model

Semantic Web & REST Architecture

- Context: Client - Server model, download information

- Semantic Web
  - A Semantic Web Object (SWO) is identified by a URI

- Web / REST
  - A Semantic Web Document (SWD) is addressed by a URL
    - Formally a URI, but let's call it URL to differentiate it from a SWO URI

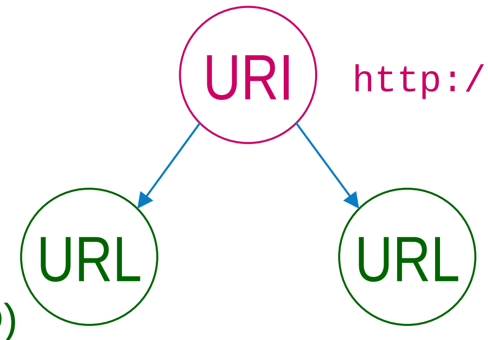
- Relations between URIs and URLs*
  - Provide a SWD (i.e. one URL) for each SWO
    - Possibly same SWD (URL) for several SWOs
  - If useful, provide an HTML document for each SWO
    - URL for the HTML document should be different form the URL for the SWD

*[Cool URIs for the Semantic Web" http://www.w3.org/TR/cooluris]

REST Architecture: URIs and URLs

`http://example.com/xbrk36#xbrk36`

`http://example.com/rdf/xbrk36`



`http://example.com/html/xbrk36`

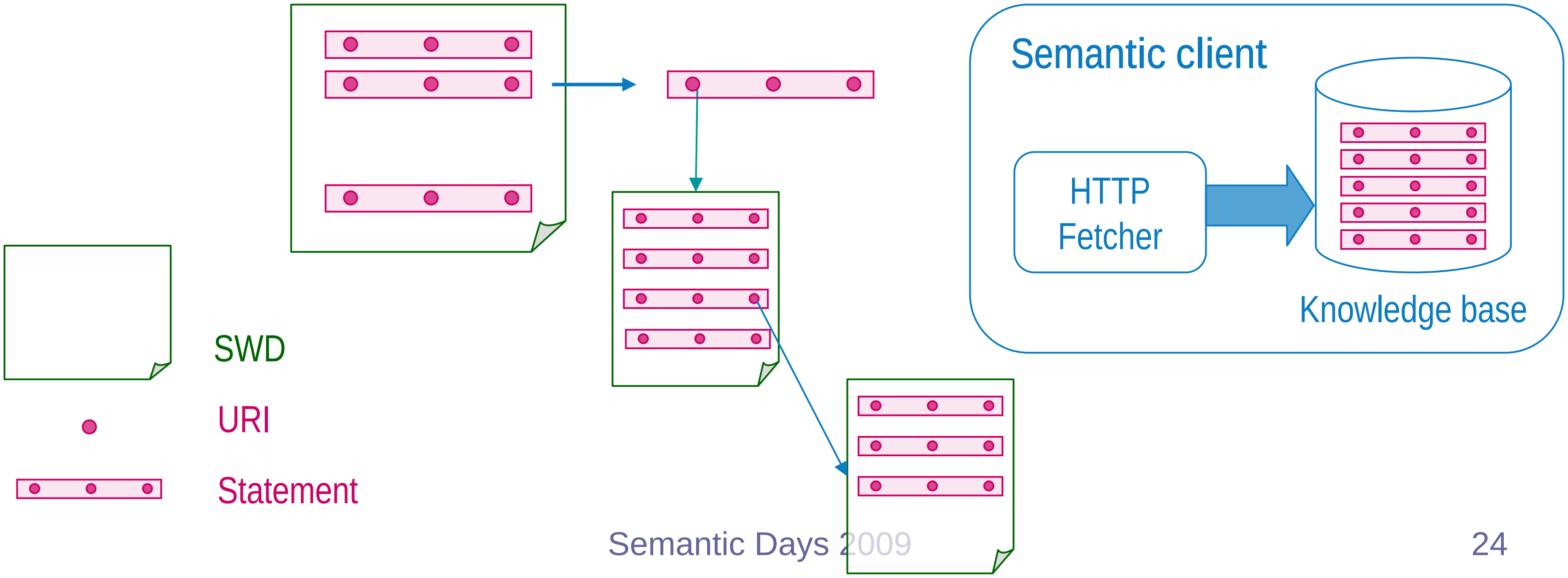
Semantic Web Document (SWD) for machines

HTML Document for humans

- URI - URL translation uses plain HTTP features
  - SWD URLs and HTML URLs may be found out of the URI
  - Involved HTTP mechanisms:
    - “303 Redirect” Status Code
    - Content Negotiation
- Content of the Semantic Web Document SWD
  - Information *about* the resource identified by the URI
  - URIs in the SWD can at their turn be used to find further SWD URLs itself containing URIs…
- HTML and semantic (SWD) representations are cross-referenced

REST architecture: Enriching the Knowledge Base

- Data download: the "browsing experience"
  - The Client's HTTP Fetcher
    - selects relevant URIs
    - downloads corresponding SWDs using their URLs
    - add the statements within the SWD in the local knowledge base
  - Each new SWD enriches the client knowledge base



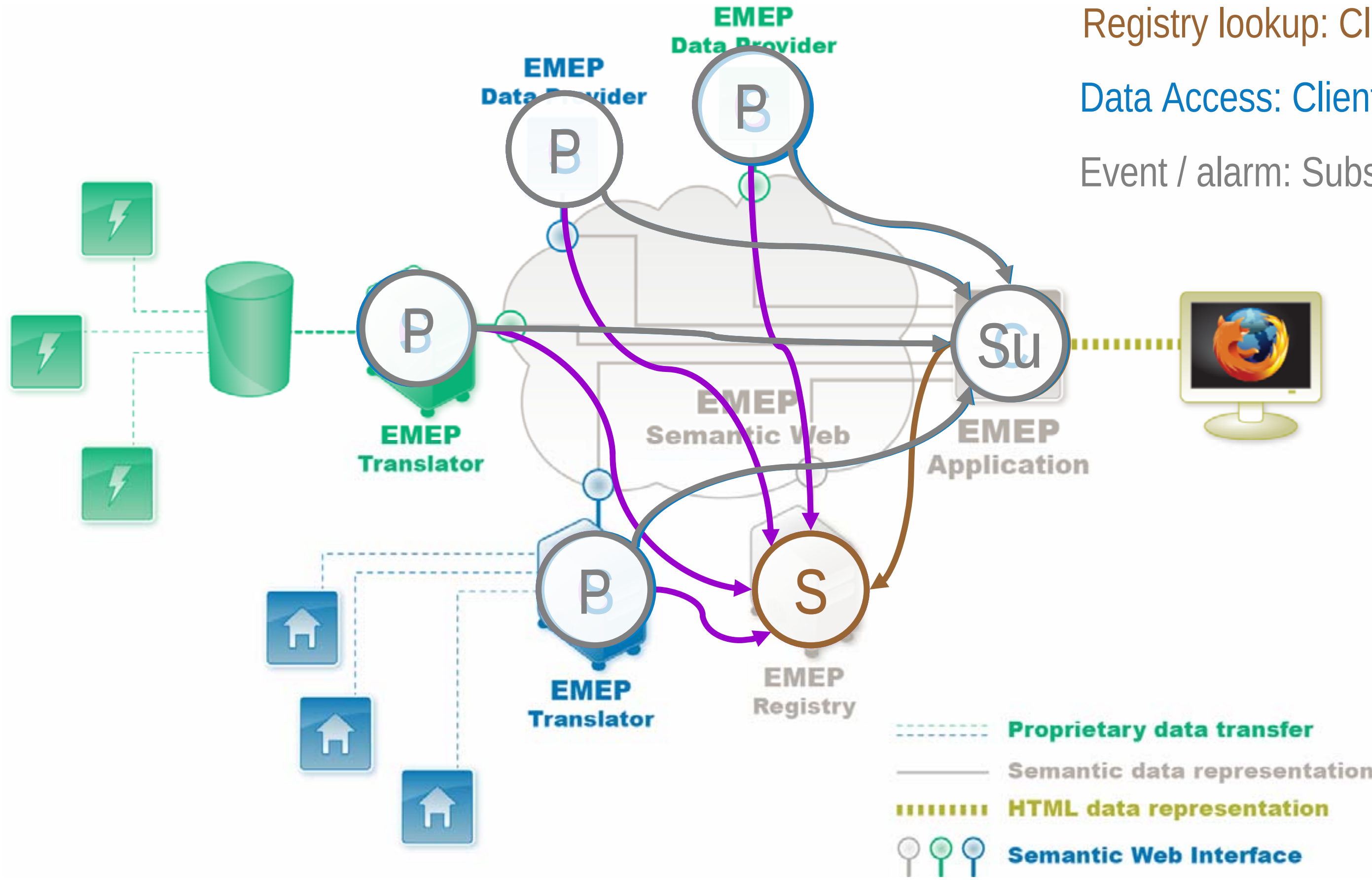
REST Architecture: Upload in the Client – Server Model

- The “POST” HTTP method allows to add information in a Server side SWD
  - Information is about a SWO identified by its URI
    - Same URI – URL mapping
  - The “PUT” HTTP method allows to create a new SWD on Server
    - or replace an existing one
  - “POST” and “PUT” request messages transport data

REST Architecture: Publisher – Subscriber Model

- Can be implemented on the basis of plain HTTP
  - Subscribe operation:
    - Performed through a Client - Server upload operation
      - Subscriber is Client, Publisher is Server
      - “POST” a (semantically expressed) message specifying:
        - » the alarm/event class being subscribed
        - » the call back URI for the publish operation
  - Publish operation:
    - Performed through a Client - Server upload operation
      - Publisher is Server, Subscriber is Client
      - “POST” a (semantically expressed) message defining the occurring alarm/event

REST Architecture: an Example



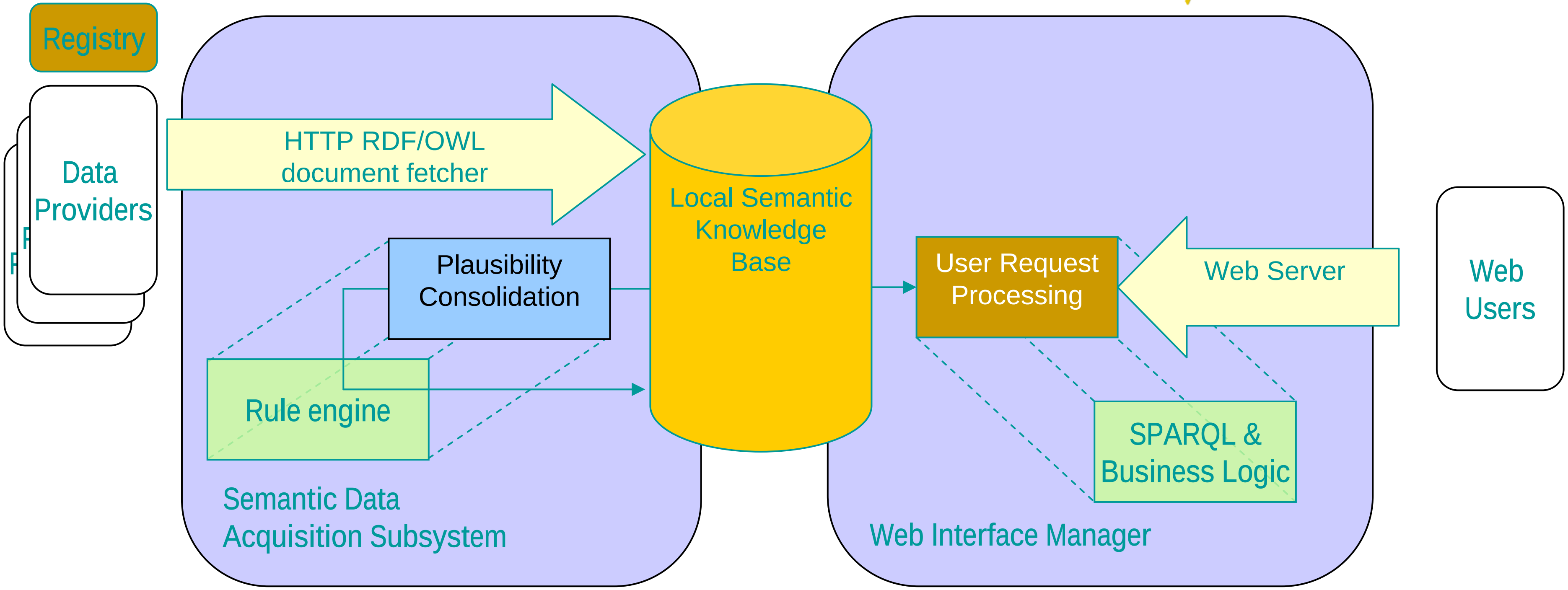
Registration: Client – Server upload

Registry lookup: Client – Server download

Data Access: Client - Server download

Event / alarm: Subscriber - Publisher

REST Architecture: an Example



Workflow

Architecture

Semantic Web & SOA

- 2 approaches:
  - Semantics embedded in web services parameters
    - Web services themselves are not semantic
  - Semantic annotation of the WSDL (contract)
    - Web services are (also) not semantic
    - Annotations in the WSDL bind parameters with their semantic counterparts
      - See W3Cs SAWSDL recommendation
      - Difficult to use these annotations in machines, merely documentation for programmers
        - » (SA)WSDL mainly used at development time

REST vs. SOA

- REST lacks flexibility:
  - Assume a client component wants to find out the energy consumption of `CompanyX` between `2009-02-21T00:00:00` and `2009-02-26T18:00:00`
    - A SOA based system would provide the method:

      `getEnergy(CompanyX,2009-02-21T00:00:00, 2009-03-16T18:00:00)`
    - A REST based system would expose the following URIs:

      `http://companyx.com/energy/2009-02#this` for Feb. 2009 energy values

      `http://companyx.com/energy/2009-03#this` for Mar. 2009 energy values

      Relevant values must then be filtered out
- Stateful mode sometimes required:
  - Information retrieval is intrinsically stateless
  - Some systems feature a stateful behaviour
    - Possible states for a circuit breaker are “open” and “close”
  - REST used to gather context information - decisions taken locally
    - This implies loose coupling between partner entities
- **SOA for (more) tightly coupled systems**
  REST for loosely coupled systems

Safety, Reliability, Privacy and Data Security

- Not a “data only” information system
  - Safety and reliability concerns
    - Basic difference with classical web technologies
  - Redundancy and hard real-time behaviour required for critical systems
    - What role for semantic technologies in the safety/reliability chain?
      - Critical role or “nice to have”?
        - » Is a non-critical role really possible?
- Cross-companies information system
  - A company may access some data but may not pass them further to other companies
    - Access rights may be defined at the semantic level
      - A framework would then be required to apply these access rights
  - Authentication, integrity check, access control and encryption are all required

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REST, SOA and Security

- Security issues not addressed in REST
  - HTTPS secure point-to-point communication channel
    - Required but not sufficient
  - Diffusion range managed per class of information elements
    - Can be defined semantically
  - Stateless mode eases the security management
    - Required tools: XML-Encryption, XML-Signature
- SOA frameworks feature a set of security tools:
  - WS-Security and its companion standards

Conclusion

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- Today
  - Semantics already present in information systems for the grid
  - No global semantic model for the whole chain
  - (Rather) slow adoption of existing standards
- Tomorrow
  - Global semantic information model at the heart of the Smart Grids vision
    - IEC 61970 / CIM provides a good basis
  - Standardise a distributed information system
    - REST and/or SOA
  - Include clients and their premises in information systems
  - Long term vision with step by step approach necessary to convince manufacturers and operators
  - Operators must solve short term problems now
    - Their information system are meanwhile becoming so complex that they won't escape a global semantic approach soon…