
TOWARDS AN INTELLIGENT
INTERNET OF THINGS
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OUTLINE

- Internet of Things
- The Path Towards Intelligence
- IoT Resources, Services and Modelling
- Knowledge Management and Processing
- Summary

INTERNET OF THINGS

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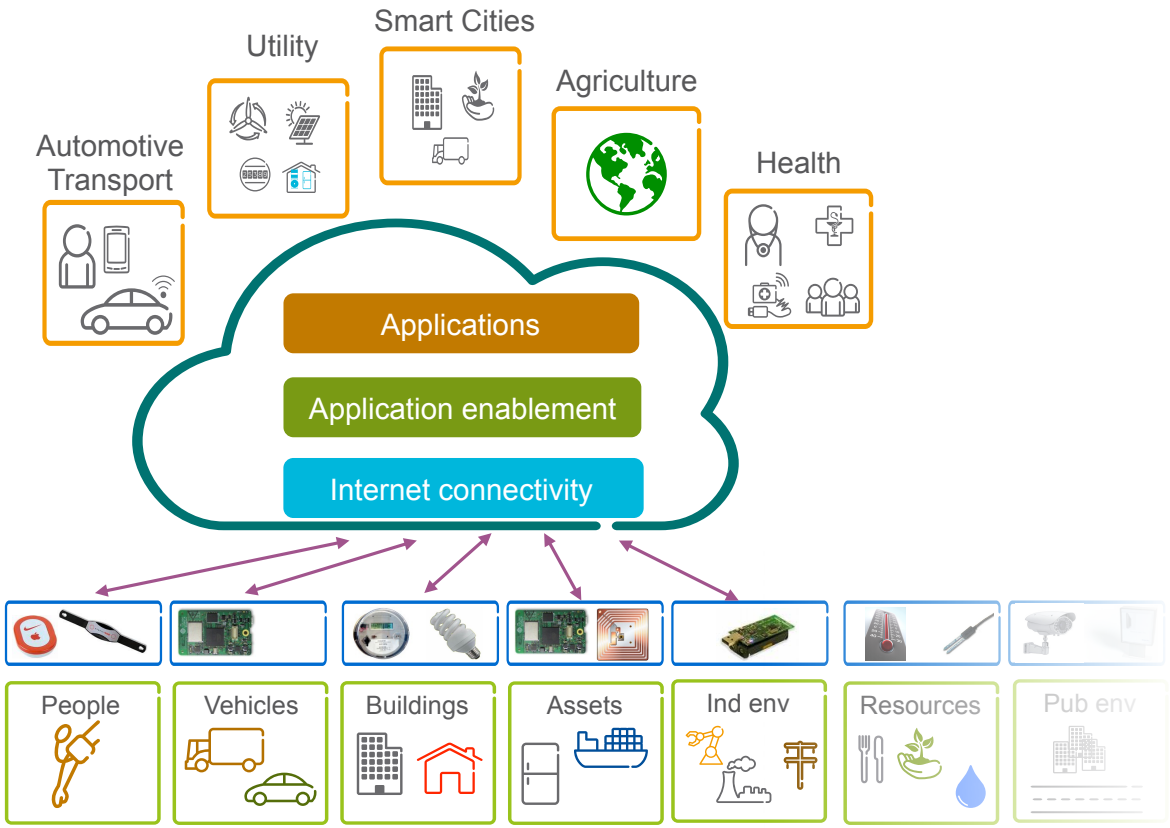
INTERNET OF THINGS



Things and Places shall be First Class Citizens on the Internet

- Monitoring and controlling real world objects – provide smartness
- Meeting the needs of enterprises, people and society
- Application domains are endless
- The underlying technology is embedded networked computing with sensors, actuators and tags

EMERGING APPLICATION DOMAINS

Consumer Electronics

- Connected gadgets
- Wearables
- Robotics
- Participatory sensing
- Social Web of Things

Automotive Transport

- Autonomous vehicles
- Multimodal transport

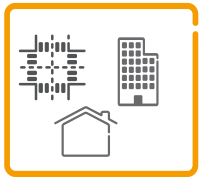
Retail Banking

- Micro payments
- Retail logistics
- Product life-cycle info
- Shopping assistance

Environmental

- Pollution
- Air, water, soil
- Weather, climate
- Noise

Infrastructures



- Buildings and Homes
- Roads, rail

Utilities

- Smart Grid
- Water management
- Gas, oil and renewables
- Waste management
- Heating, Cooling

Health Well-being

- Remote monitoring
- Assisted living
- Behavioral change
- Treatment compliance
- Sports and fitness

Smart Cities

- Integrated environments
- Optimized operations
- Convenience
- Socioeconimics
- Sustainability
- Inclusive living

Process industries

- Robotics
- Manufacturing
- Natural resources
- Remote operations
- Automation
- Heavy machinery

Agriculture

- Forestry
- Crops and farming
- Urban agriculture
- Livestock and fisheries

SMART MACHINES AND EMBEDDED INTELLIGENCE

[ROBOTS]

[DEVICES]

Images removed for copyright reasons

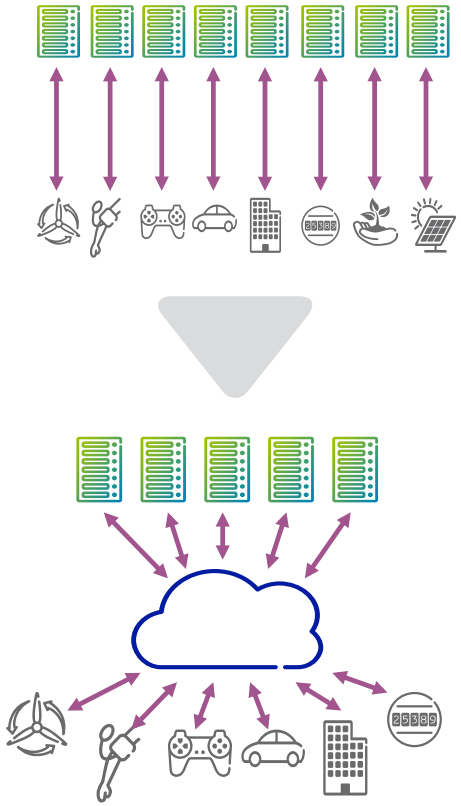
[MACHINES]

[EMBEDDED]

M2M VERSUS IoT

M2M

stove pipes – point problem
one device per app
proprietary solutions
in-house IT
connectivity focus
industry specific technologies
no data sharing



Internet of Things

multi-purpose devices
service enablement
web paradigm
apps migrate to cloud
standardization driven
open environment
data marketplace

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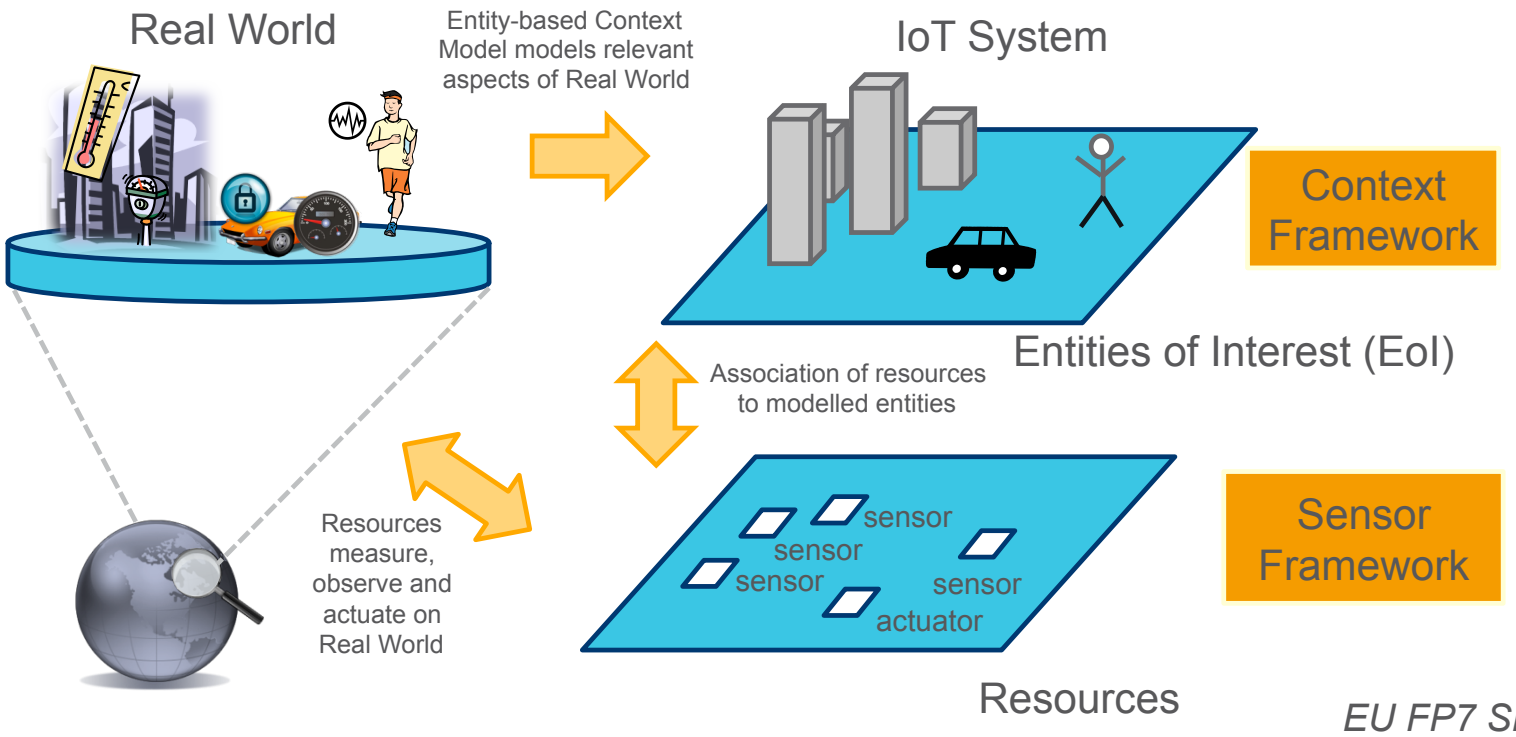
THE PATH TOWARDS INTELLIGENCE

REAL WORLD MODEL



EU FP7 SENSEI, IoT-A

KEY CAPABILITIES AND SCOPE

Technologies and Components

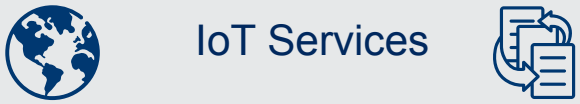
Examples – Enterprise

USE CASE

Business objectives
"Optimize grid utilization"

KNOWLEDGE AND REASON

Expert rules and reasoning
"phase drift is X - increasing price by Y for area Z would reduce consumption 5%, stabilizing grid" alternatively "increase hydro power by 2%"



REAL WORLD MODEL

Semantics and context
Smart meter for user A @ high reactive power outtake
Substation Norra 2 IED @ outage

Data Analytics

ANALYTICS

Processed data feeds
D/M/Y pattern and average of Sensor 5 is: Y (curve)
Anomaly detected in Sensor 8

OBSERVATION AND CONTROL

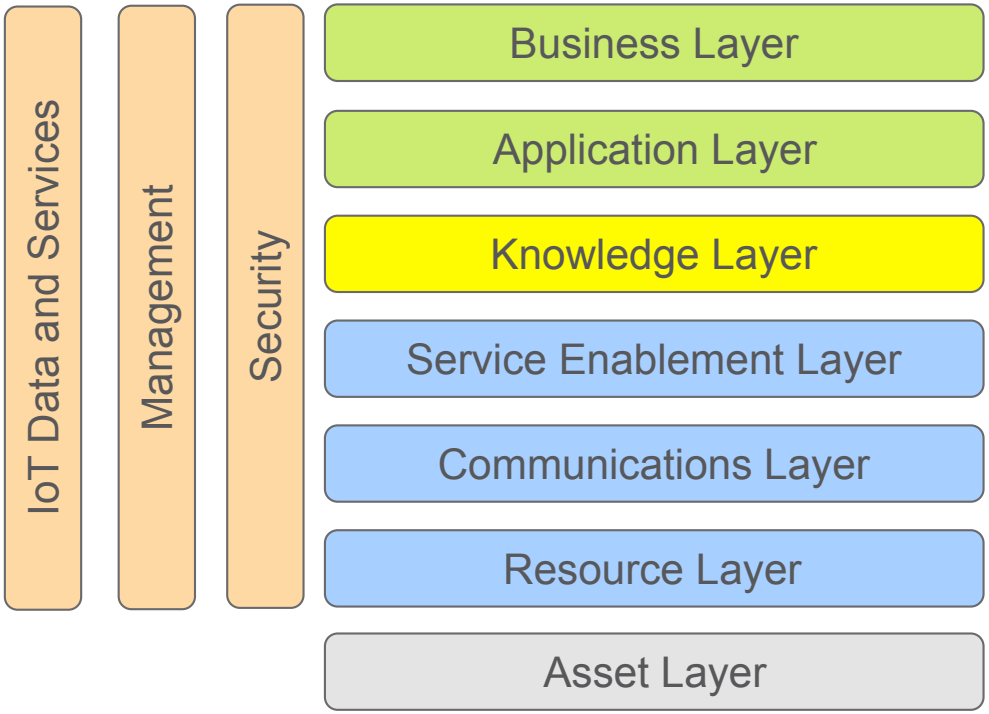
Raw data feeds
Sensor 5 = 3.4 kW
Sensor 8 = 0 kW
Valve 2 = 12°

THINGS AND PLACES

Available assets
Smart meter, 10kV Distribution Substation, Energy Service Interface (ESI), Photovoltaic/Hydro, Electrical vehicle

ABSTRACTION AND SEMANTICS

LAYERED IoT ARCHITECTURE



***Enterprise business support and integration**: CRM, ERP, BSS,...*
***User exposure**: Retail, Portals, Visualizations*

***IoT-specific applications**: Meter Data Management, Food Tracing, Building Automation, Farming Control,...*

***Knowledge Management and Processing**: Metadata, Resource modelling, Analytics, Context Awareness, Entity Modelling, Reasoning, Actionable services, Learning, ...*

***Common enablers:** Device Management, Resource Management, OSS, Data and Event capture, Data Warehousing*

***Communications**: Capillary Networks (HAN, NAN, BAN,...), Mobile, Fixed, Public, Private, Satellite, Managed Connectivity, ...*

***Monitor&Control:** Sensors, Actuators, Devices, Gateways, WSAN, Tags*

***Real World Assets:** Building, Smart Grid, Vehicle, Body,...*

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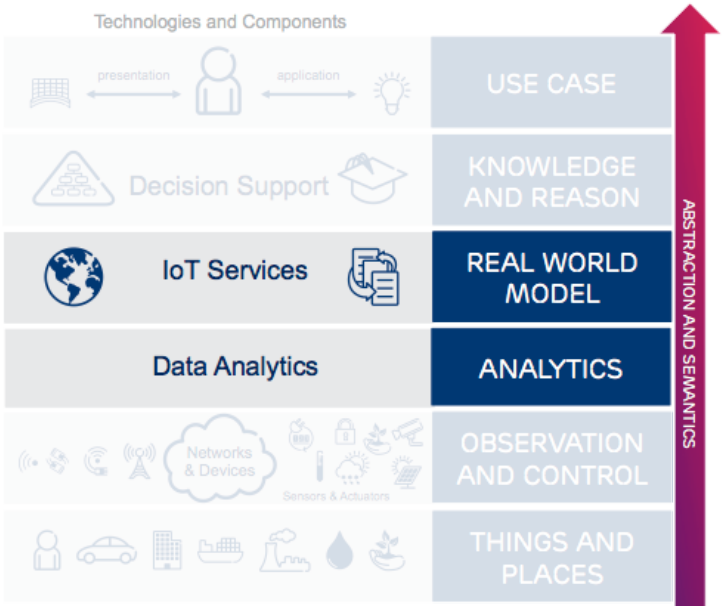
IOT SERVICE MODELLING AND EXECUTION

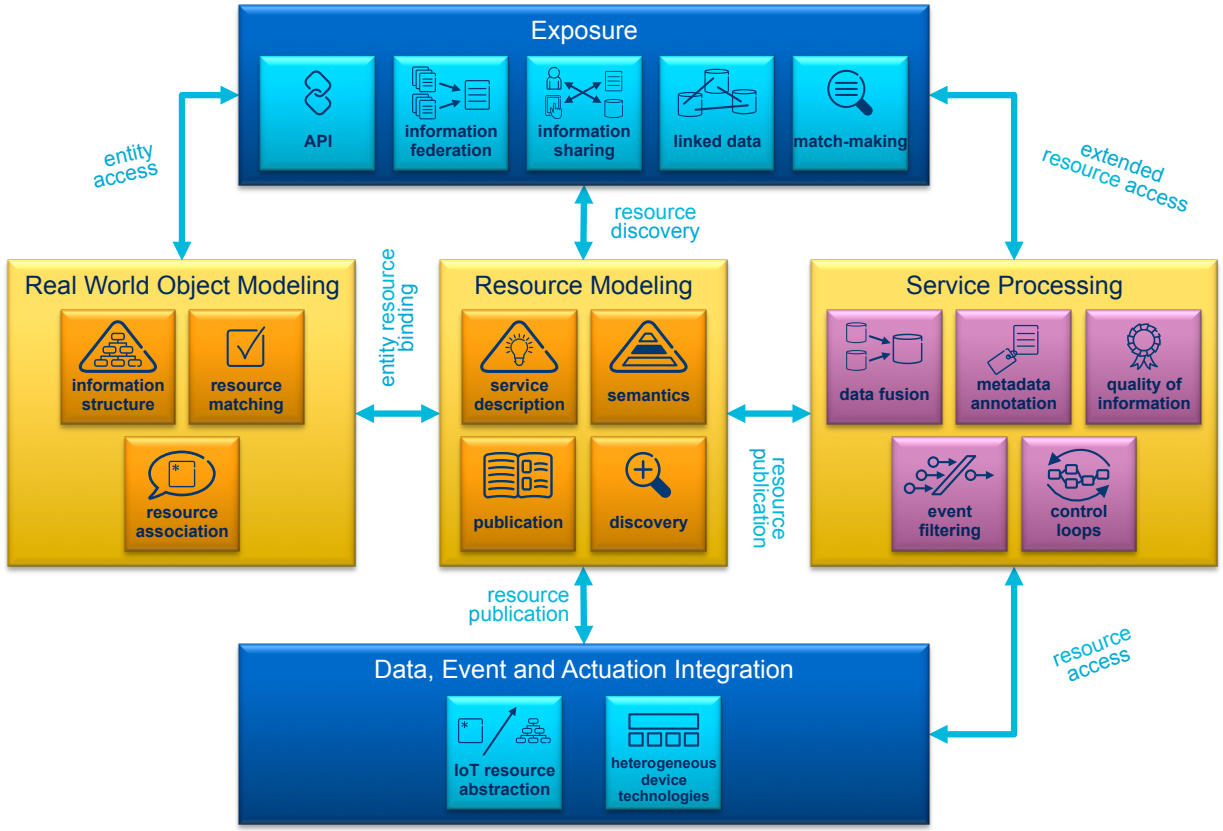


Real World Observations and Models

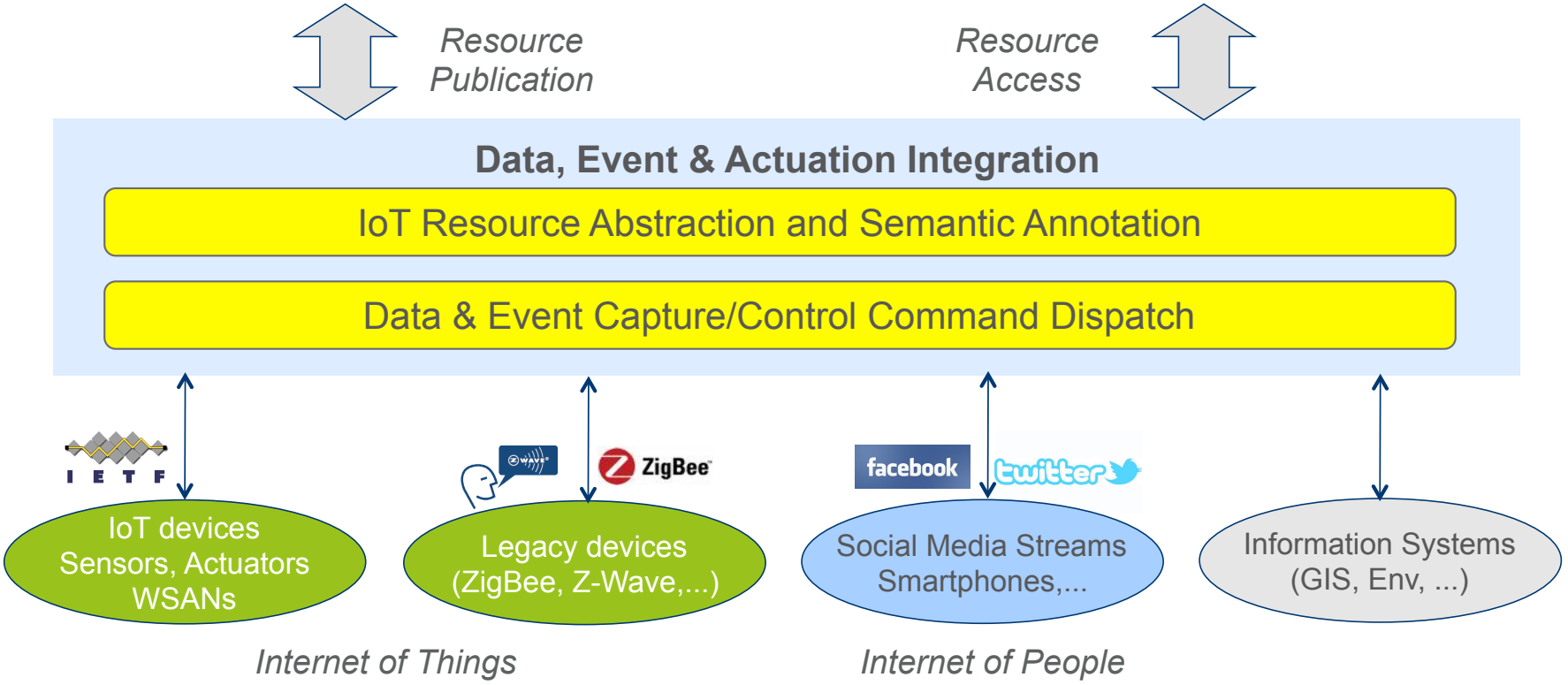
IoT SERVICES MODELLING AND PROCESSING
CONCEPTUAL AND FUNCTIONAL OVERVIEW

Key features

- Data capture and service integration of heterogeneous sources
- Resource virtualization and semantic annotation
- Resource publication and discovery
- Entity of Interest modeling
- Data and service processing
- Capability federation and exposure

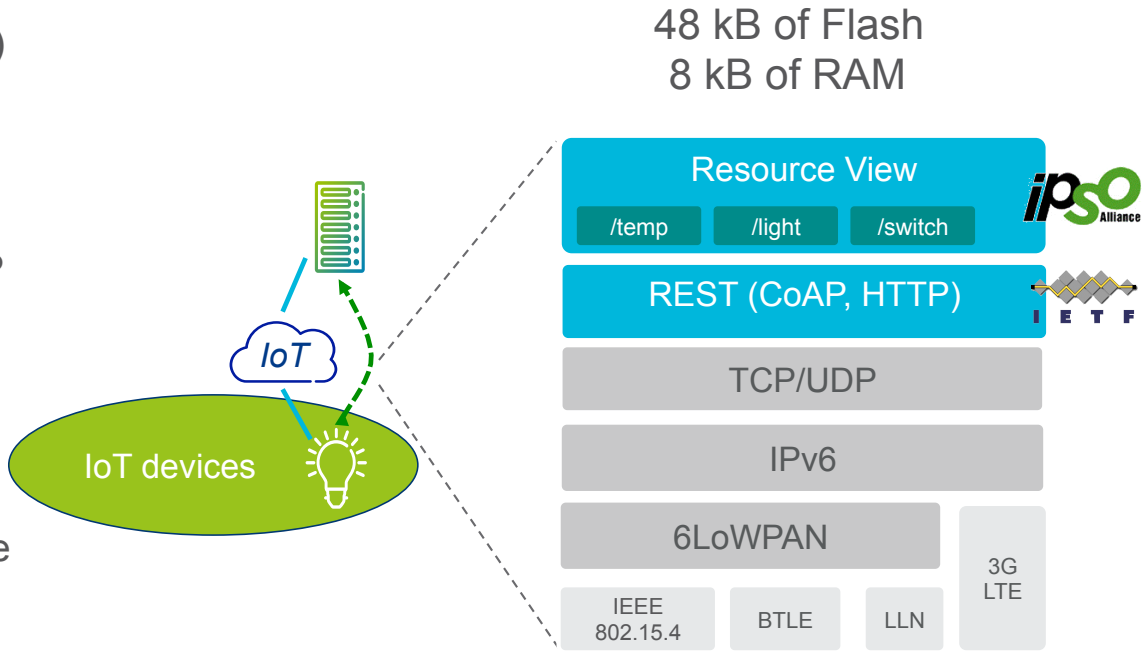


DATA AND SERVICE INTEGRATION



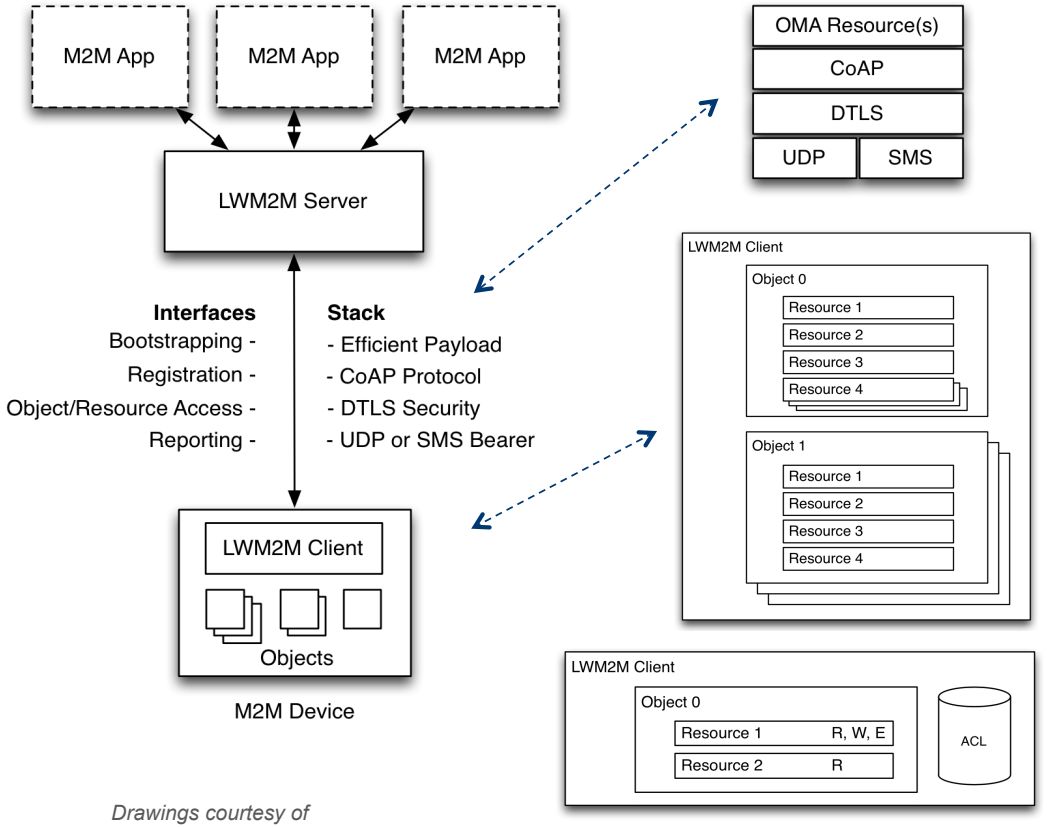
IOT CONSTRAINED DEVICE INTEGRATION - EMBEDDED WEB SERVICES

- Normalization of IoT resources
- Embedded Web Services (IETF CoRE)
  - RESTful approach (REST+URI+MIME)
  - Web linking of IoT resources
- Features
  - Constrained Application Protocol, CoAP
  - HTTP-CoAP proxying
  - Observations
  - Resource publication and discovery
- Simplified resource view
  - Application independent resource profile
  - XML, JSON, EXI formats
- Wrapping of legacy devices



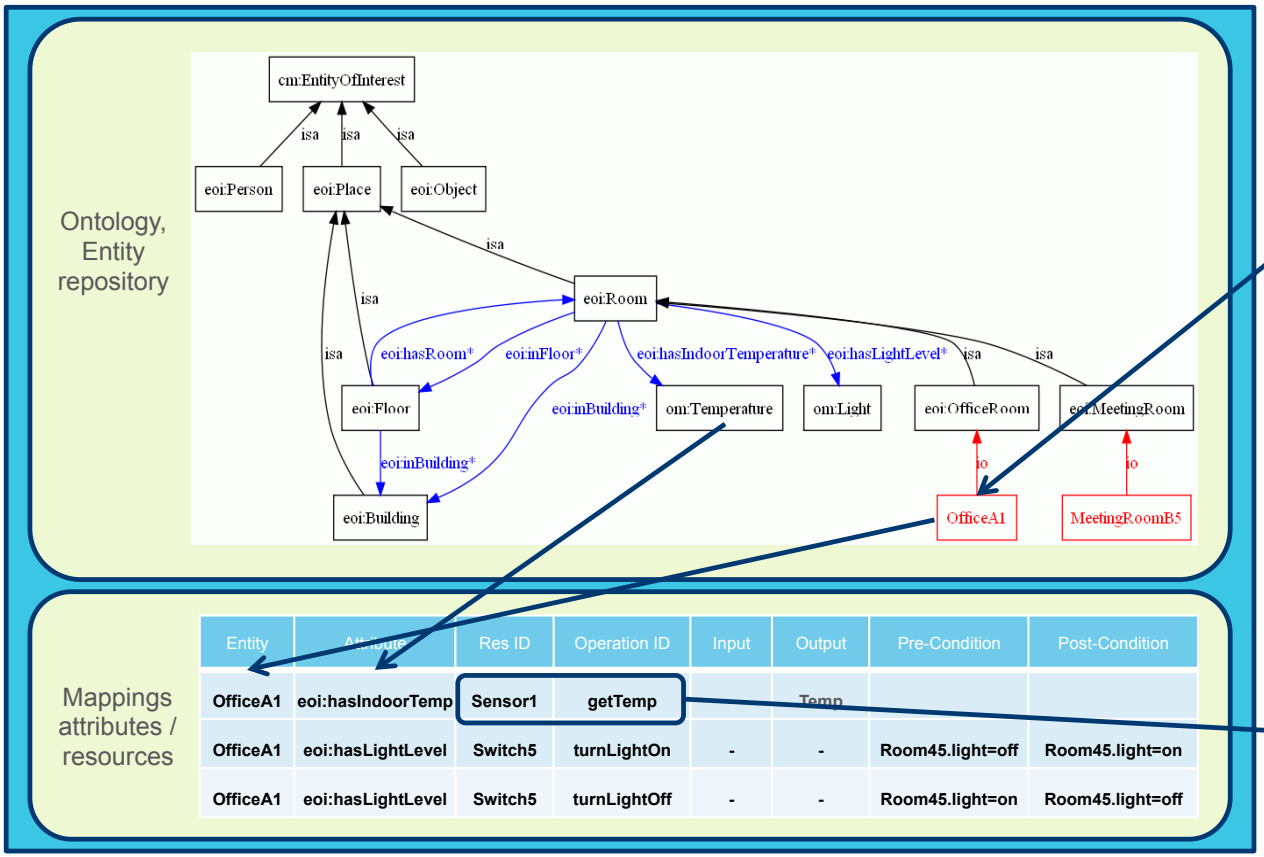
OMA LIGHTWEIGHT M2M DM

- Management and control of constrained devices
  - microcontroller, battery operated
  - device AND application level
- Efficient Device-Server interface based on IETF CoRE
  - Small RESTful stack
  - Lean extensible object and resource model for semantics
- Interfaces
  - Bootstrapping
  - Registration
  - Object/Resource access
  - Reporting



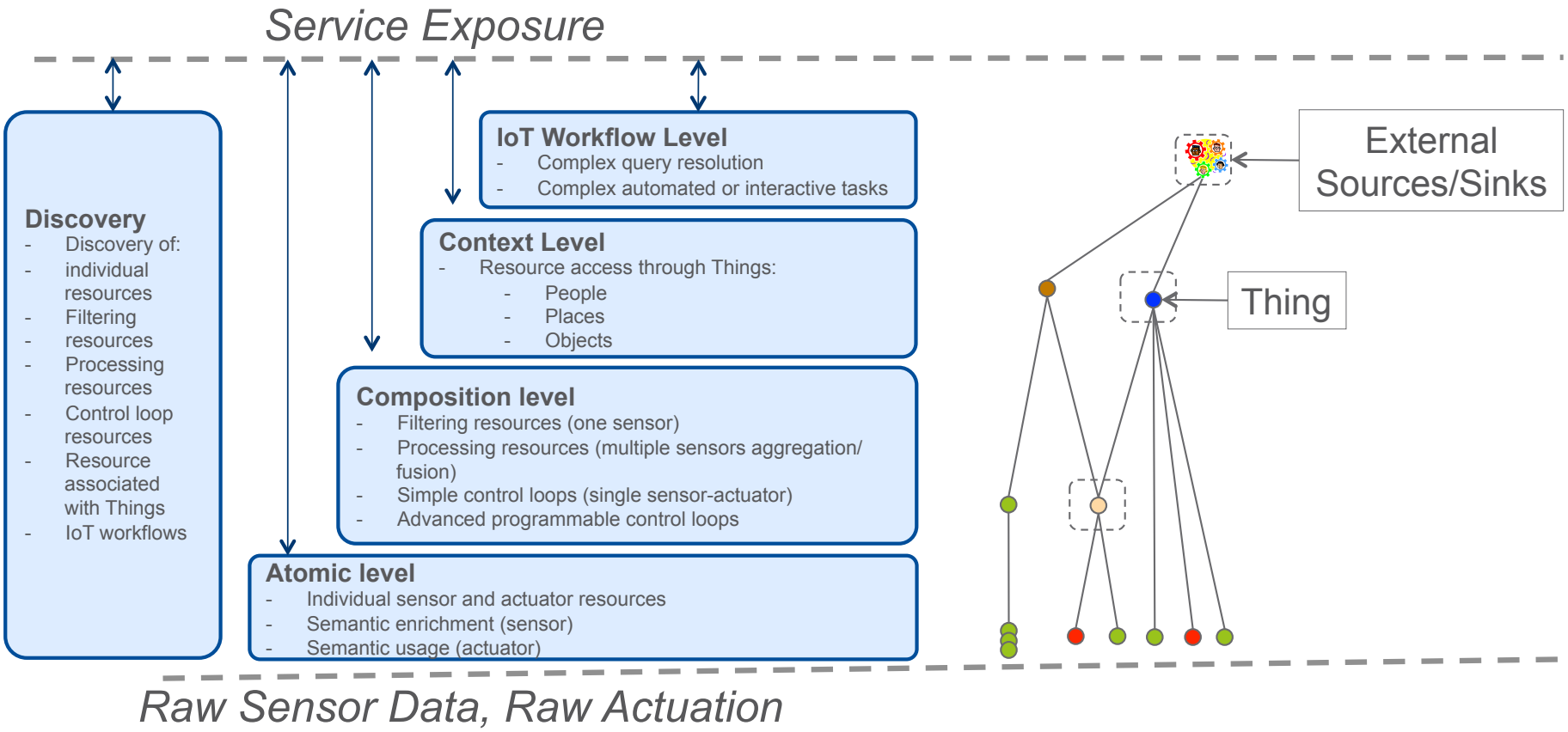
Drawings courtesy of Zach Shelby, Sensinode/ARM

ENTITY OF INTEREST MODELLING



EU FP7 SENSEI

IOT DATA AND SERVICES ABSTRACTIONS - EXPOSURE AT DIFFERENT LEVELS



SOME STATE-OF-THE-ART

- Horizontalization
  - ETSI M2M
  - oneM2M
  - OMA LW M2M DM
  - IETF CoRE
  - IPSO
- Semantics
  - W3C SSN, GSN,
  - IPSO and IETF CoRE
  - OGC SWE,...
- Research
  - European Internet of Things Research Cluster, IERC
    - IoT-A
    - SENSEI
    - CityPulse
    - Butler
    - iCore

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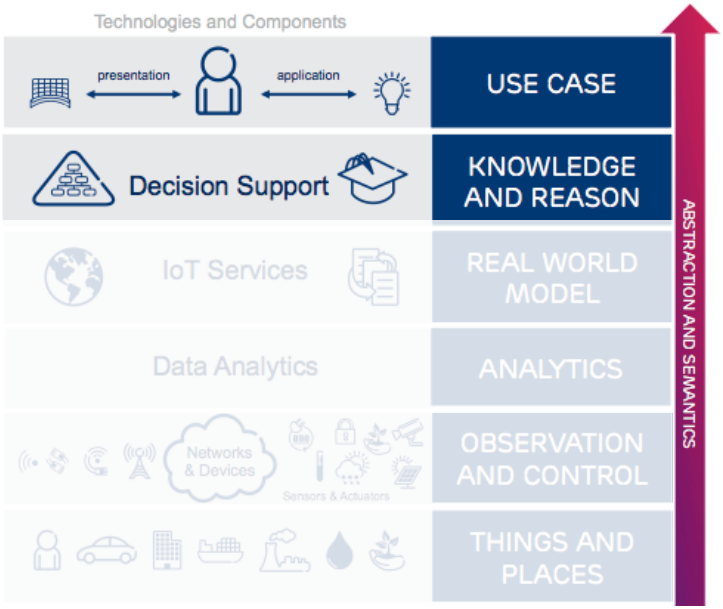
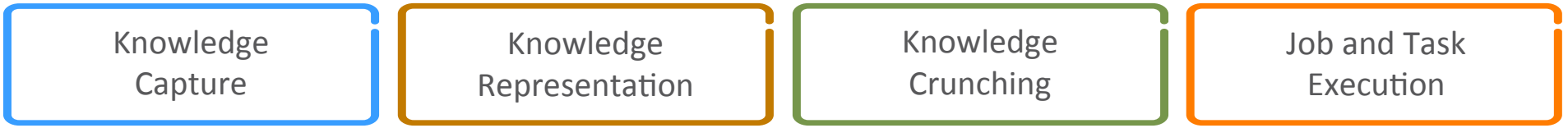
KNOWLEDGE REASONING DECISION



Making Intelligent Decisions

KNOWLEDGE MANAGEMENT AND REASONING

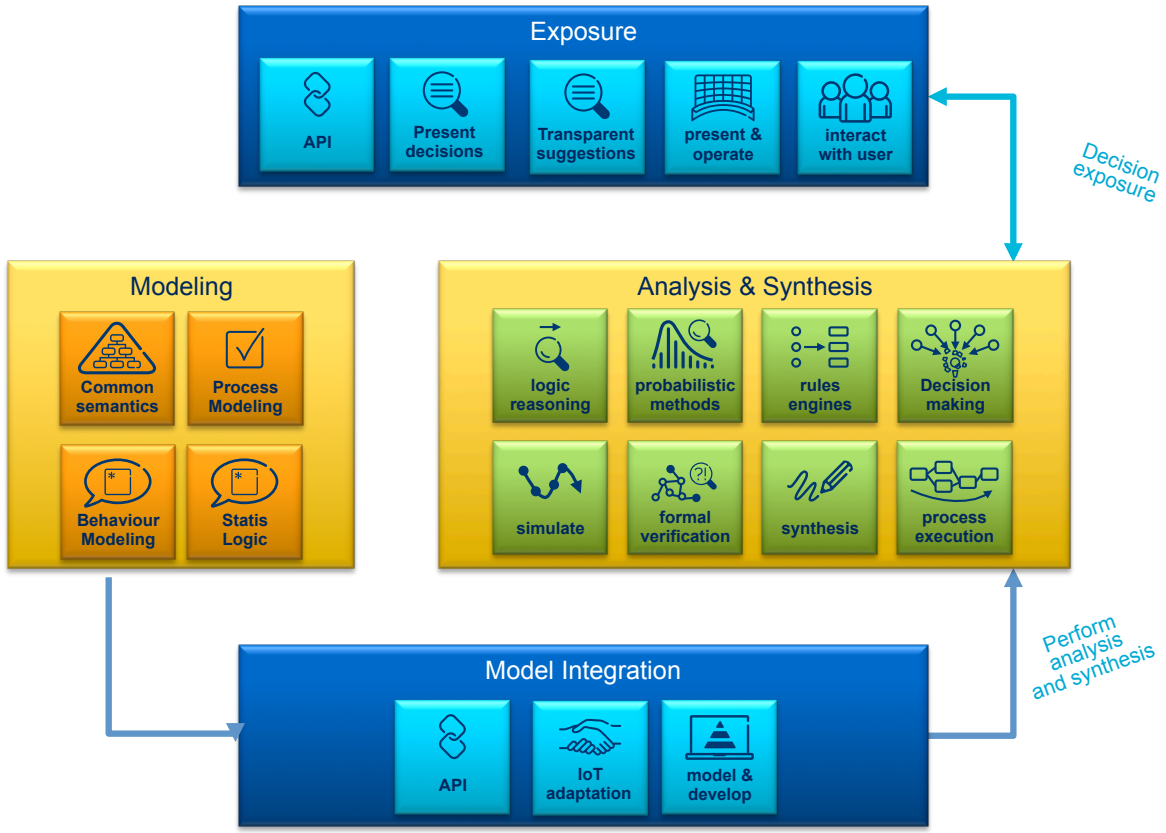
› In the Networked Society, a continuously changing and transforming environment, and in the absence of a *universal* semantically annotated model that would take into account any operating variation identified in practice, it is extremely important to take advantage of prior experts' knowledge and combine it with knowledge extracted from heterogeneous data streams to facilitate decision making and execution and continuous evolvement of knowledge



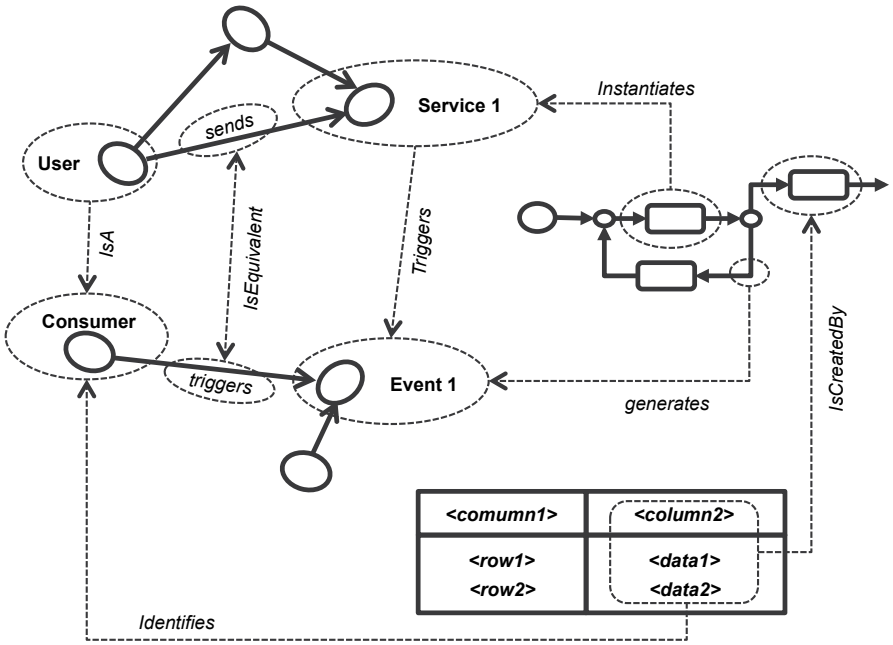
KNOWLEDGE MANAGEMENT
A CONCEPTUAL AND FUNCTIONAL OVERVIEW

Key features

- Common meta-model and semantics
- Consolidation of multiple modeling techniques
- Assistance in decision making through knowledge processing and synthesis techniques
- Consolidation of multiple analysis techniques (formal methods, reasoning, probabilistic methods)
- Distributed execution

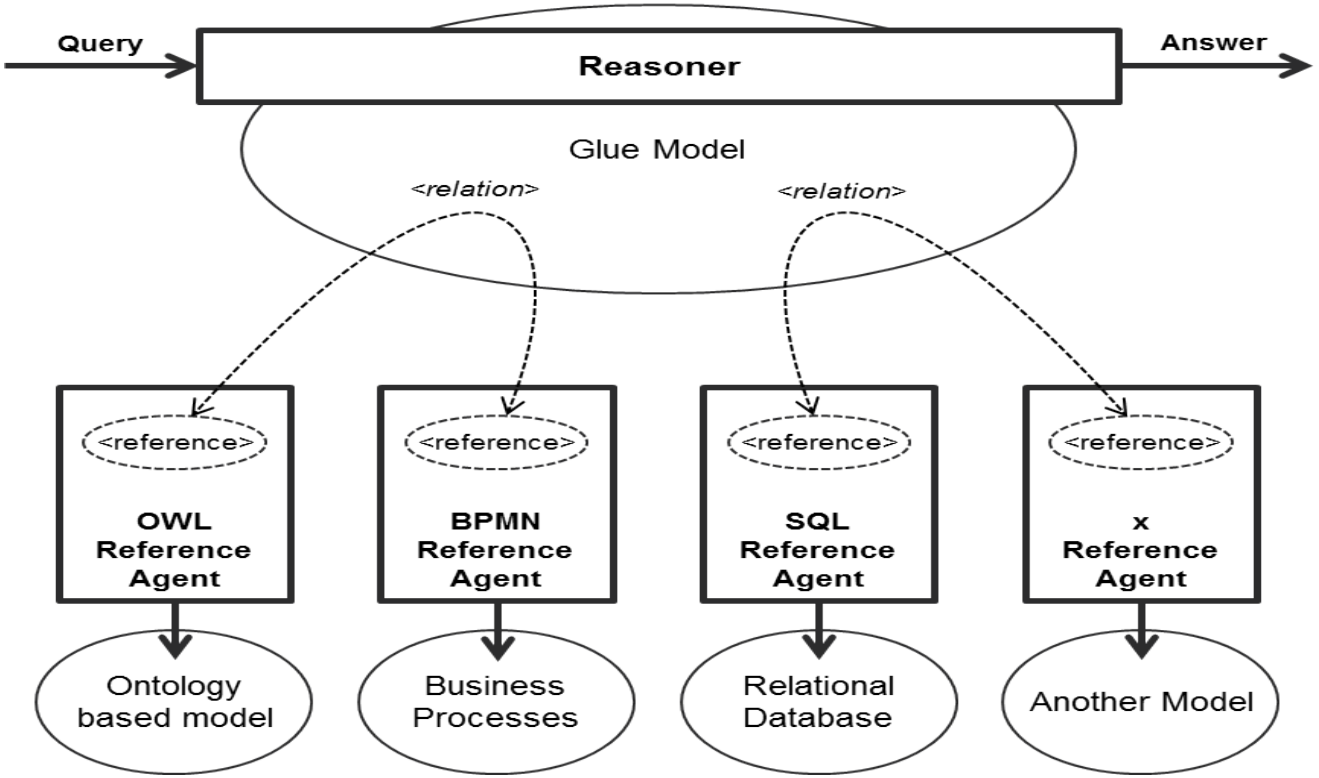


‘GLUE MODEL’
COMBINES DOMAIN SPECIFIC MODELS

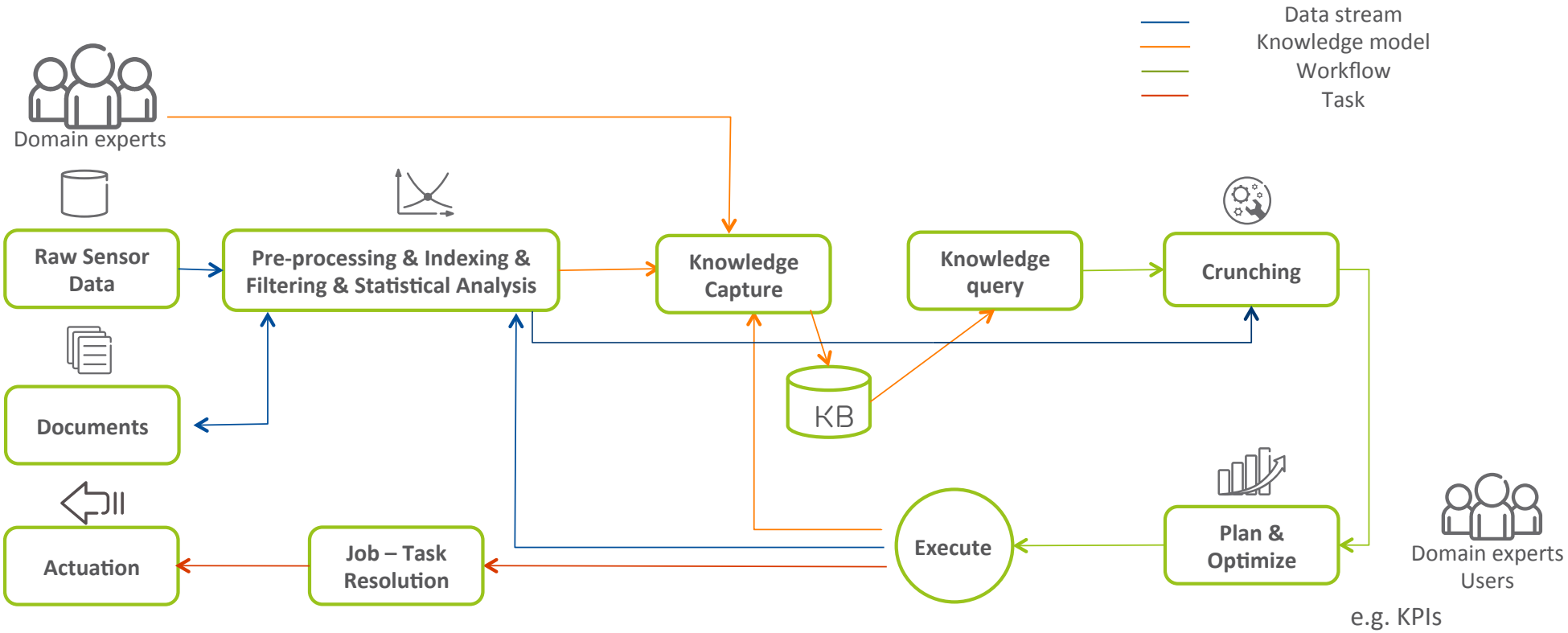


- The facts are expressed as explicit relations between model entities
- Entities may also denote meta concepts
- Additionally rules are used to express pattern relations (e.g. “every user has a name”)

REASONER AS AN INTERFACE AND RUNTIME FOR THE GLUE MODEL



OVERVIEW OF KNOWLEDGE MANAGEMENT PROCESS FLOW



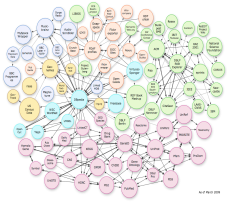
OPENING UP FOR IoT - CAVEATS

Privacy
- useful vs. concern
- legislation

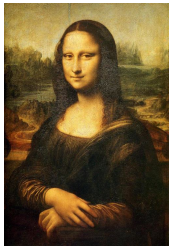
Participation
- incentives
- new models

Security
- authorized access
- actuation

Reliability
- trust the info
- liability

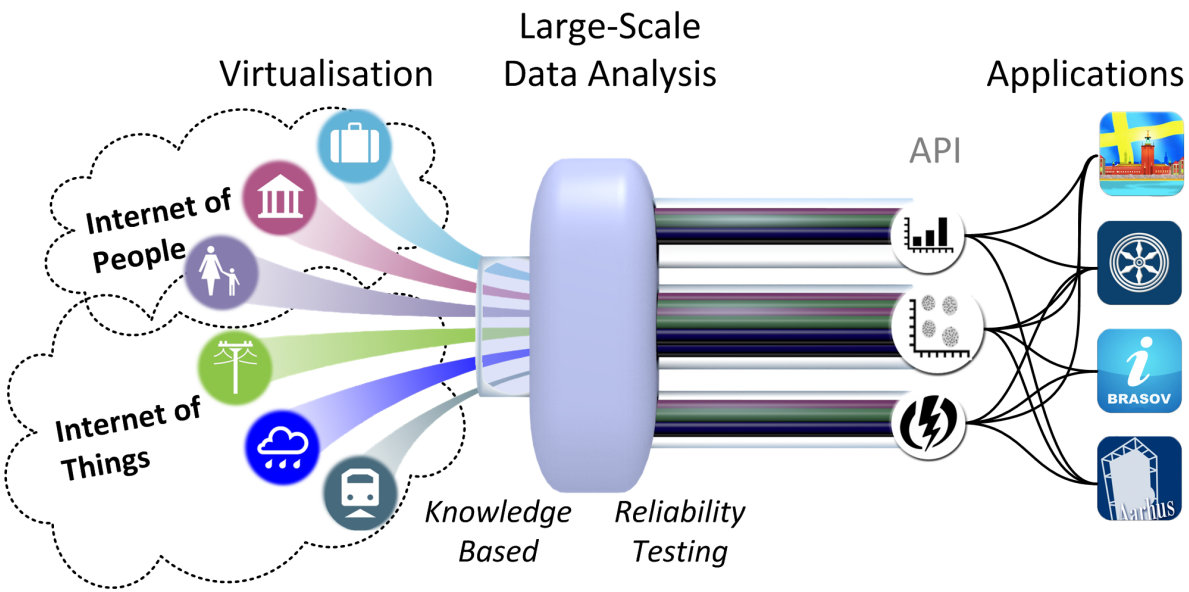


Open data
- PSI Directive
- Enterprises



Provenance
- machine generated

CITYPULSE
- A SMART CITY EXAMPLE



Partners:
Siemens, Ericsson, Alexandra Institute
Uni Surrey, NUI Galway, Wright State
Aarhus, Brasov, (Stockholm, Osnabruck)

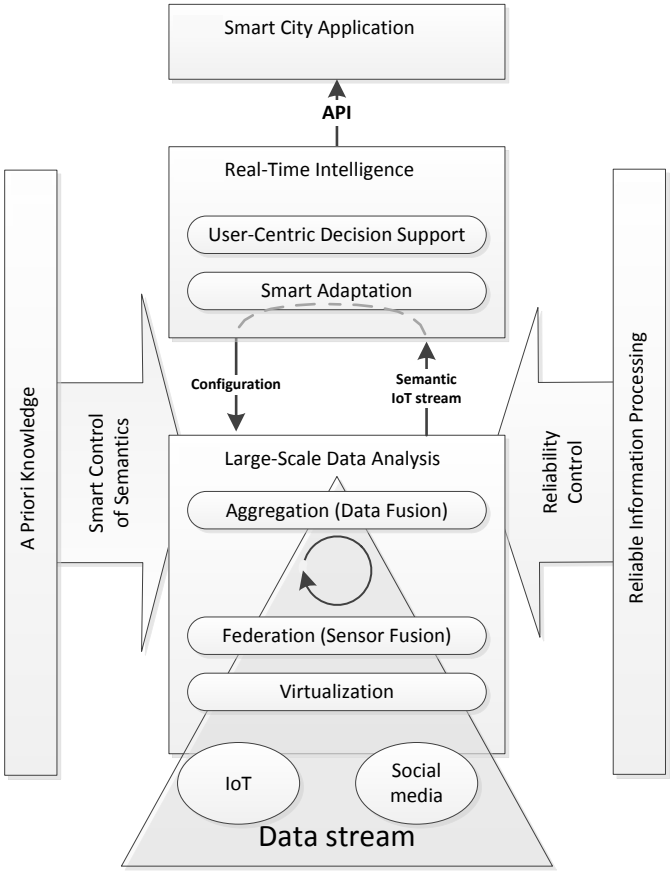
SEVENTH FRAMEWORK PROGRAMME

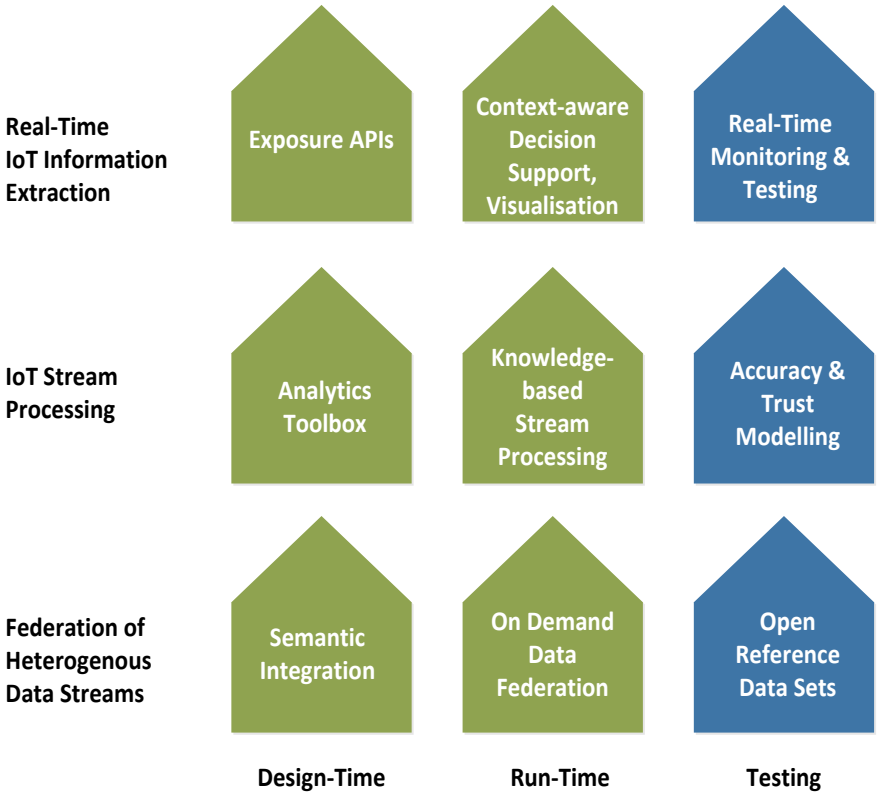
Objectives

› To develop, build and test a distributed framework for the semantic discovery and processing of large-scale real-time IoT and relevant social data streams for knowledge extraction in a city environment.

› It will prototype and demonstrate its major concepts in a city environment and evaluate the results for exploitation towards future smart city delivery and development platform and testing products

CITYPULSE LIFE-CYCLE VIEW



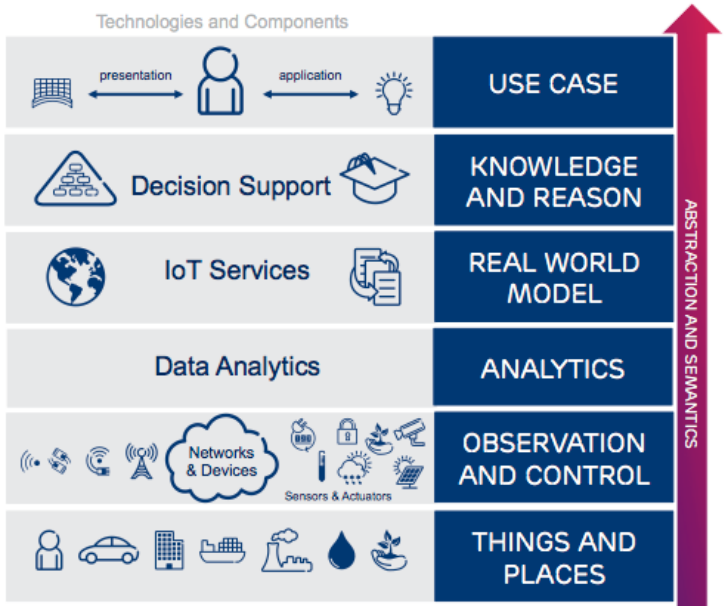


SOME RESEARCH TOPICS

- Distributed processing of real-time streaming data from a vast number of heterogeneous sources
- Semantic interoperability across systems and across representations
- Efficient reasoning and learning tools based on complex knowledge around real world representations
- Job and task planning of complex actuation services
- Quality of Information techniques based on large amounts of heterogenous data from many sources, associated provenance tools
- Privacy ensuring knowledge representations
- Digital Marketplaces

SUMMARY

- Intelligent applications in an Internet of Things require an integration and efficient handling of basic resources, modelling and knowledge tools
- IoT Resource Management is needed to integrate heterogeneous sources of data and actuation, to model real world properties and do relevant basic processing to support application development and execution
- Knowledge complexity requires cognitive methods to provide intelligence and smartness for applications to increase automation and intuitive services



POINTERS AND RESOURCES

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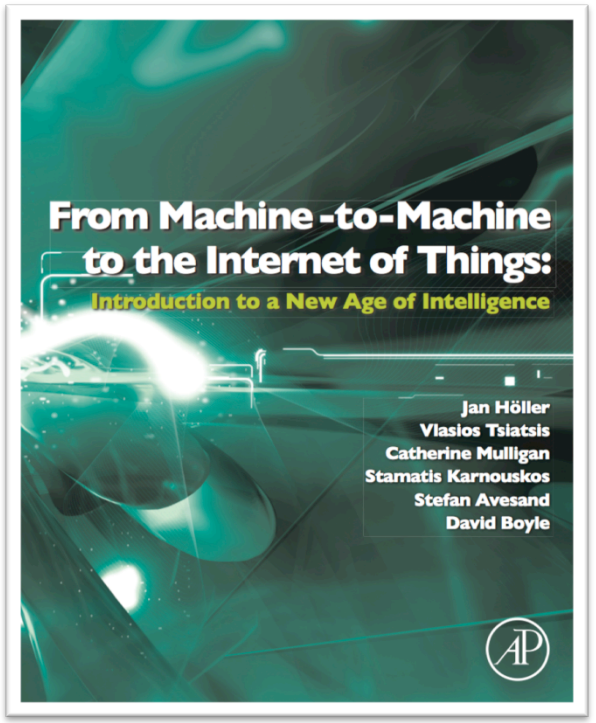

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