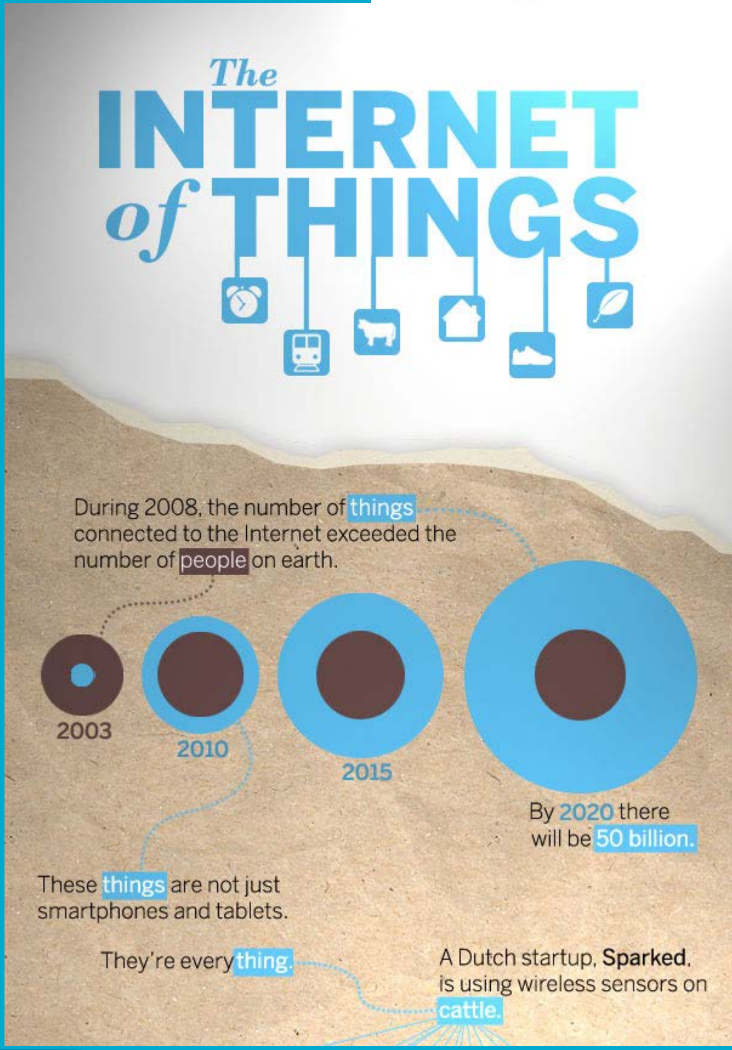
Context-aware Sensor Search, Selection and Ranking Model for Internet of Things Middleware



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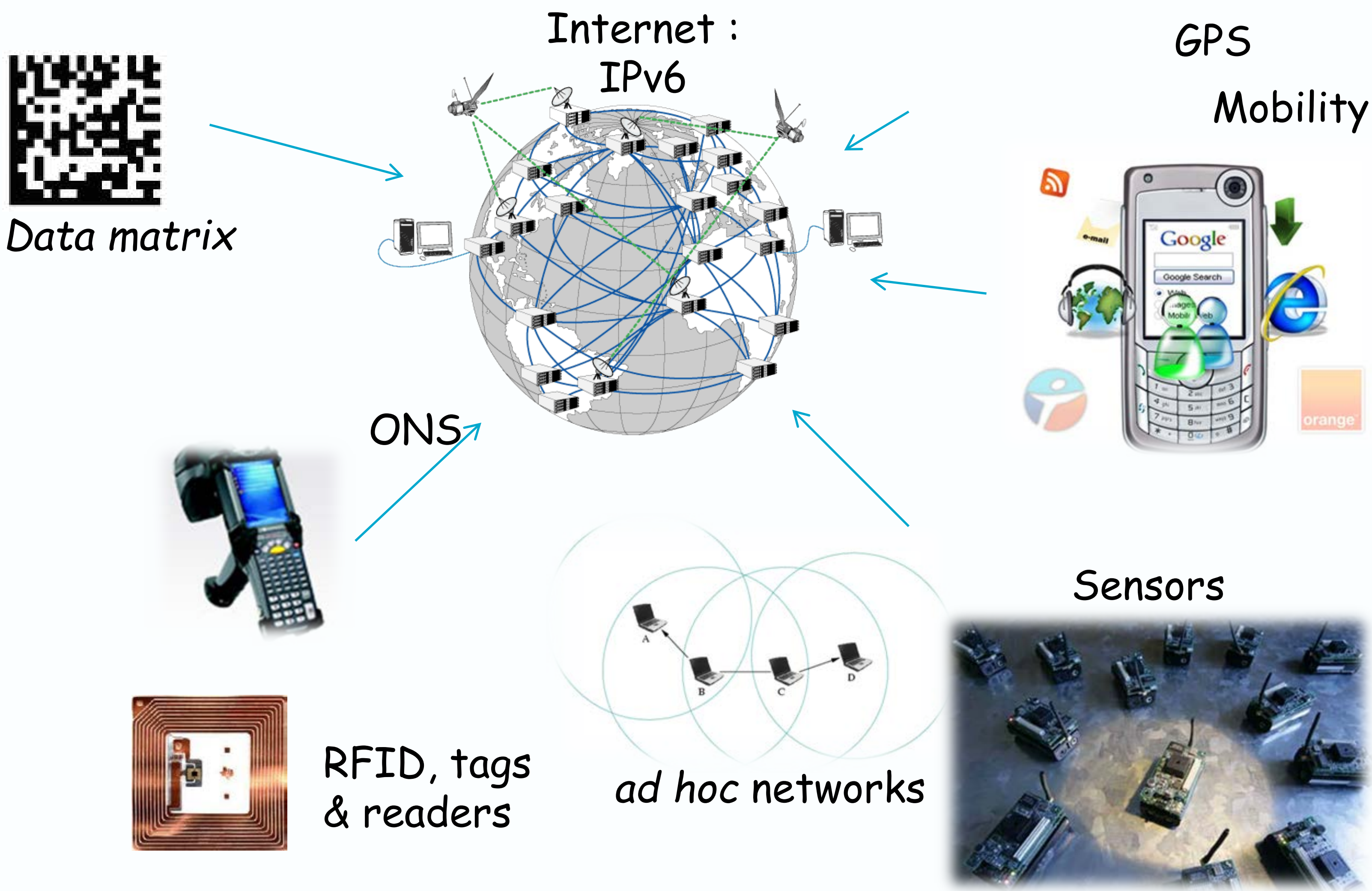
IEL, ICT CENTRE
www.csiro.au

MDM2013, Milan, 6 June, 2013

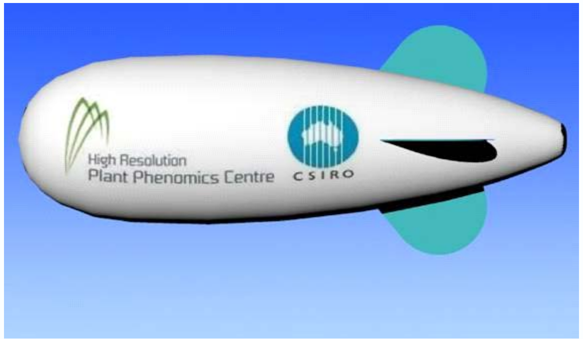
Outline

- Setting the IoT scene
- Motivating scenarios
- CASSARA Model & Tool
- Conclusion

Rather : a network of converging networks



CSIRO Things – Sensors, cameras, nanosensors on the ground, ocean, autonomous vehicles & airships



Other Things – Other Smart Internet Connected Objects

Nike shoe sensor

CSIRO virtual fence

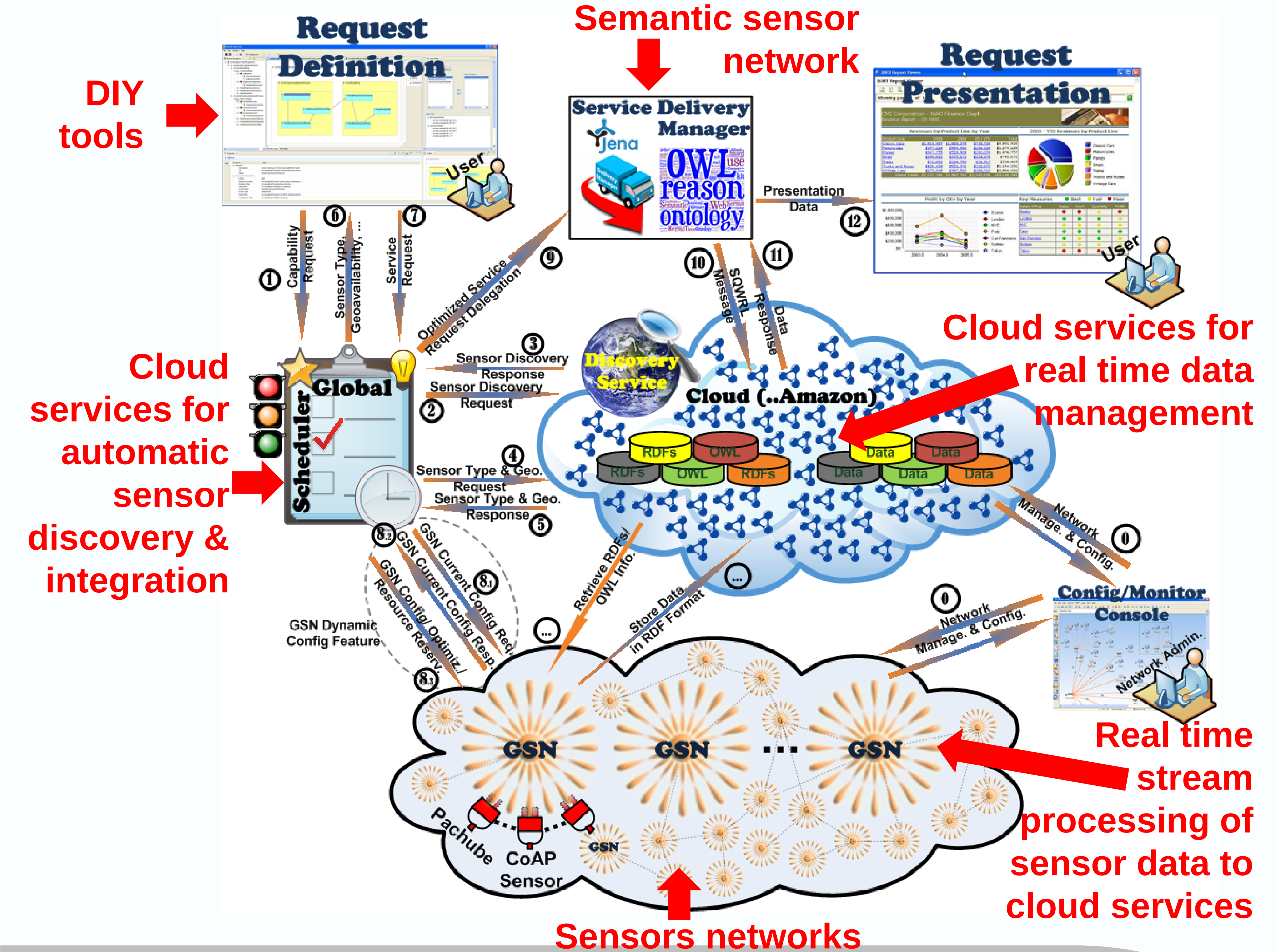
Stick on RFIDs

Olinda radio

Smart meter

Proteus pill

OpenIoT High Level Architecture



Motivating Scenario

- An office building just has been renovated. The owner wants to evaluate dust concentration, places which require careful cleaning and deploys massive amounts of low-cost sensors
- Not much point in collecting and processing values from all 1000s sensors
- From which sensors you would like to collect data ??? ← PROBLEM
- What factors matters ?? (YES location is the most critical, but what else ??)
- Assume: if there 20 sensors within $10m^2$ and user wants only 4 sensors, how to select the BEST 4 sensors
- What is meant by BEST→ BEST means most suitable to user needs
- Examining context information allows to select the BEST sensors

EXAMPLE set of context information related to sensor selection

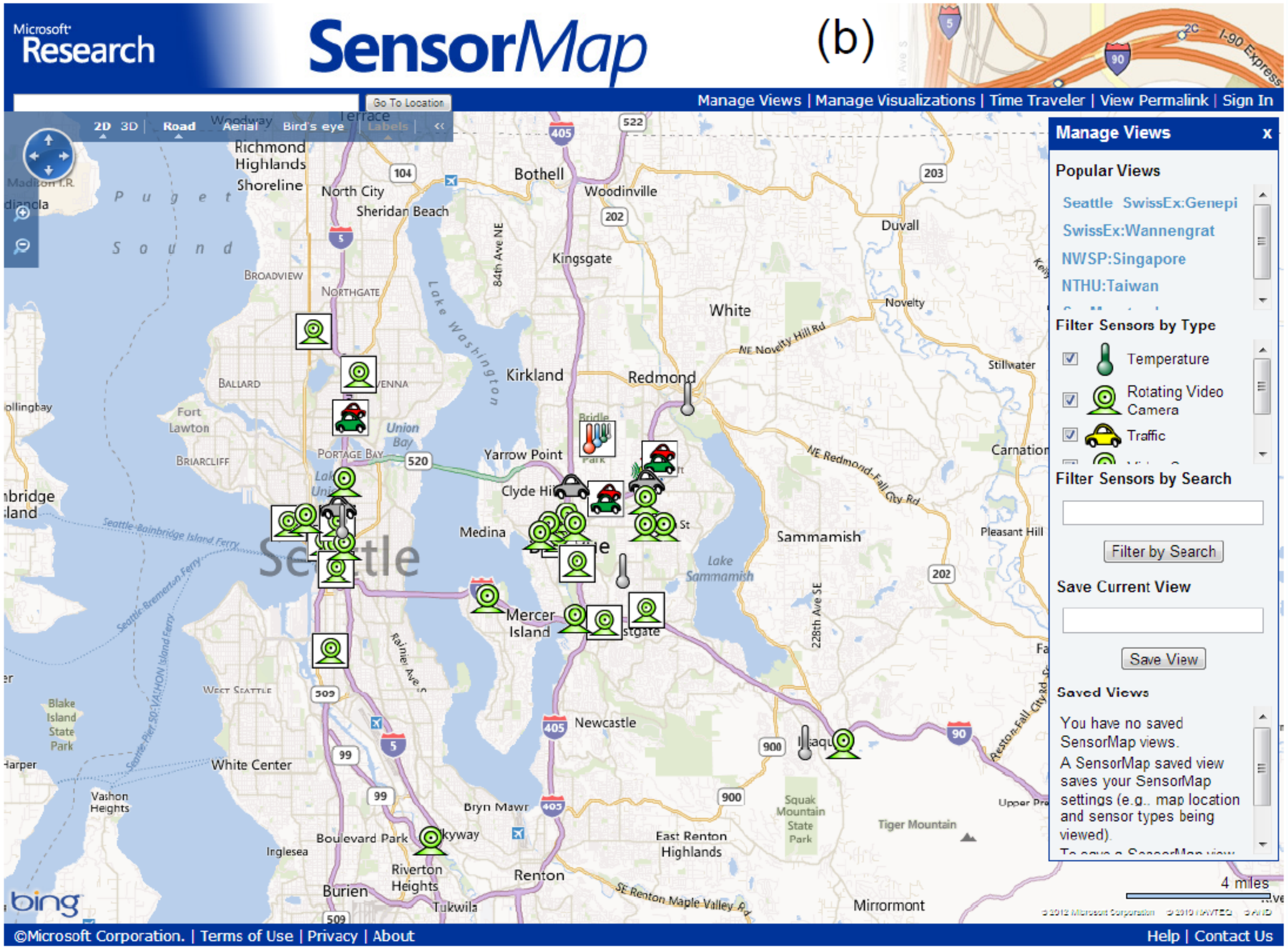
availability, accuracy, reliability, response time, frequency, sensitivity, measurement range, selectivity, precision, latency, drift, resolution, detection limit, operating power range, system (sensor) lifetime, battery life, security, accessibility, robustness, exception handling, interoperability, configurability, user satisfaction rating, capacity, throughput, cost of data transmission, cost of data generation, data ownership cost, bandwidth, and trust.

What MATTERS to you MOST ?

Give more priority to them

Background:

No existing system provide such sensor search functionality ☹



Semantic Sensor Networks (SSN) Goals and Outcomes

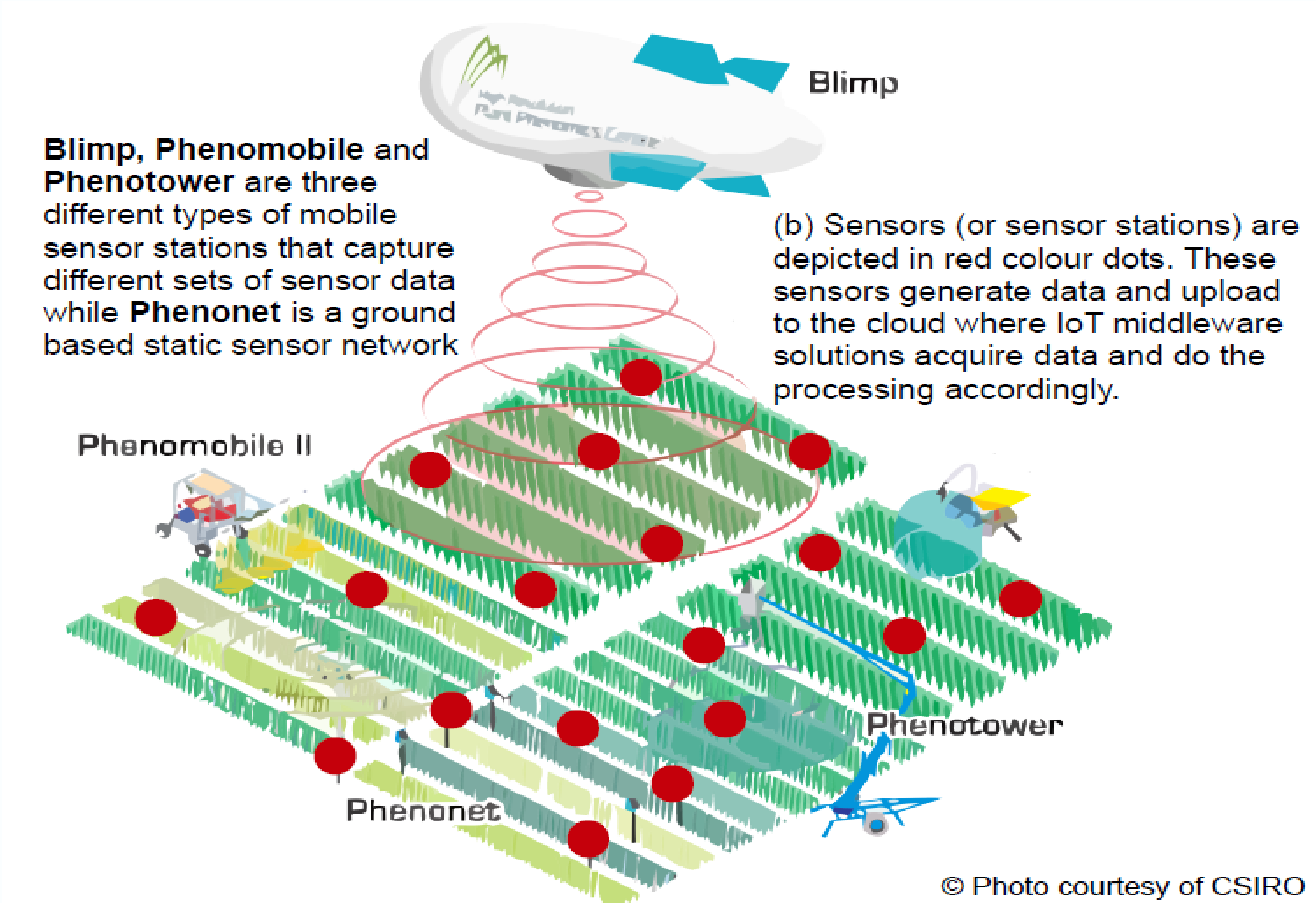
The goal of the W3C Incubator Activity XG was to develop an SSN ontology for sensor discovery and dynamic integration of:

- Heterogeneous sensors and other internet connected objects (ICOs)
- All data produced by such sensors and other ICOs
- Different sensor networks

Results

- SSN ontology for description of sensors and sensor networks
- Extended OGC's Sensor Model Language (SensorML) and four Sensor Web Enablement (SWE) languages, to support such semantic annotations

Sensor-based monitoring in digital agriculture



CASSARAM concepts

Data Models

We extended the Semantic Sensor Network Ontology (SSNO) as follows:

This is how we extended the SSNO (orange colour)

We normalize [0,1] the context information accordingly using min-max ranges.
(e.g. accuracy 74 means 0.74)

We generated 1 millions synthetic sensor data descriptions (individuals). Similar to the one example depicted in green color above

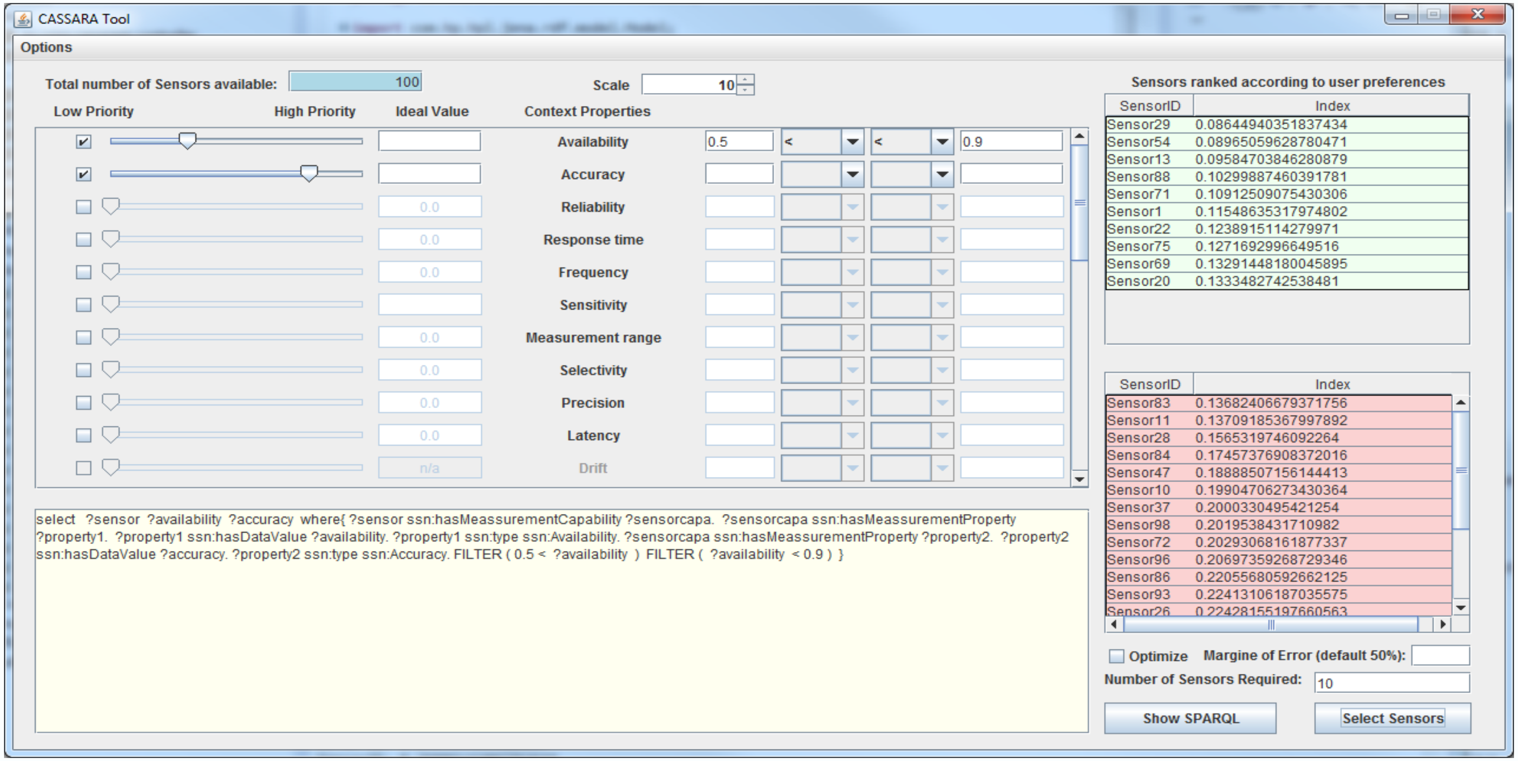
Algorithm 1 Execution Flow of CASSARAM

Require: $(\mathbb{O})$, $(\mathbb{P})$, $(\mathbb{Q})$, $(\mathbb{N})$, $(\mathbb{S}_{Results})$, $(\mathbb{S}_{Indexed})$, $(\mathbb{M})$.

```
Output: S_Results
S_Filtered ← queryOntology(O, Q)
if cardinality(S_Filtered) < N then
    return S_Results ← S_Filtered
else
    P ← captureUserPriorities(UI)
    M ←Plot Sensors in Multidimensional Space (S_Results)
    S_Indexed ← calculateCPWI(S_Results, M)
    S_Results ← rankSensors(S_Indexed)
    S_Results ← selectSensors(S_Results, N)
    return S_Results
end if
```

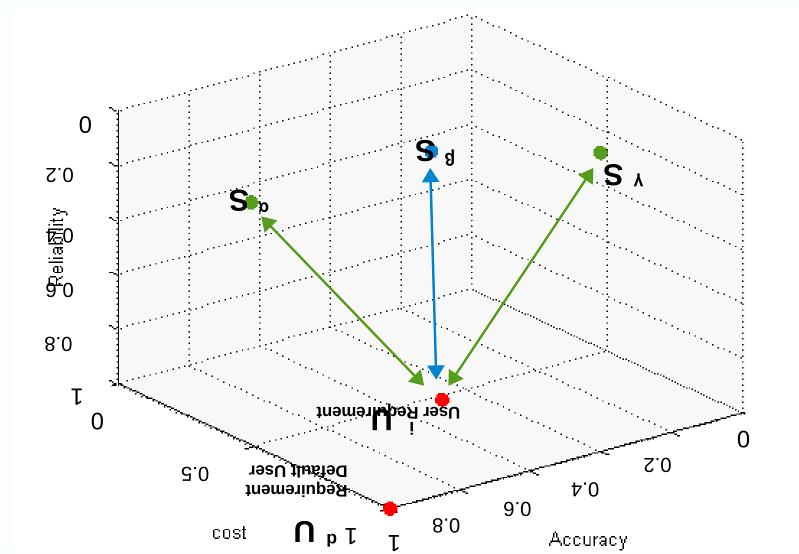
Phase 1: Search

Users express their priories using GUI tool that generates the SPARQL



select ?sensor ?availability ?accuracy ?reliability ?responsetime where{ ?sensor ssn:hasMeassurementCapability ?sensorcapa. ?sensorcapa ssn:hasMeassurementProperty ?property1. ?property1 ssn:hasDataValue ?availability. ?property1 ssn:type ssn:Availability. ?sensorcapa ssn:hasMeassurementProperty ?property2. ?property2 ssn:hasDataValue ?accuracy. ?property2 ssn:type ssn:Accuracy. ?sensorcapa ssn:hasMeassurementProperty ?property3. ?property3 ssn:hasDataValue ?reliability . ?property3 ssn:type ssn:Reliability. ?sensorcapa ssn:hasMeassurementProperty ?property4. ?property4 ssn:hasDataValue ?responsetime . ?property4 ssn:type ssn:ResponseTime.}

Phase 2: Index



Generate similarity index by combining context information and user priorities. (i.e. smaller the index, closer to the user preferred request)

Phase 3: Rank

Sort the sensors using indexes
(i.e. smaller the index, closer to the user preferred request)
OR one can use the inverse (1-x) as illustrated in the GUI: no difference

Phase 4: Select

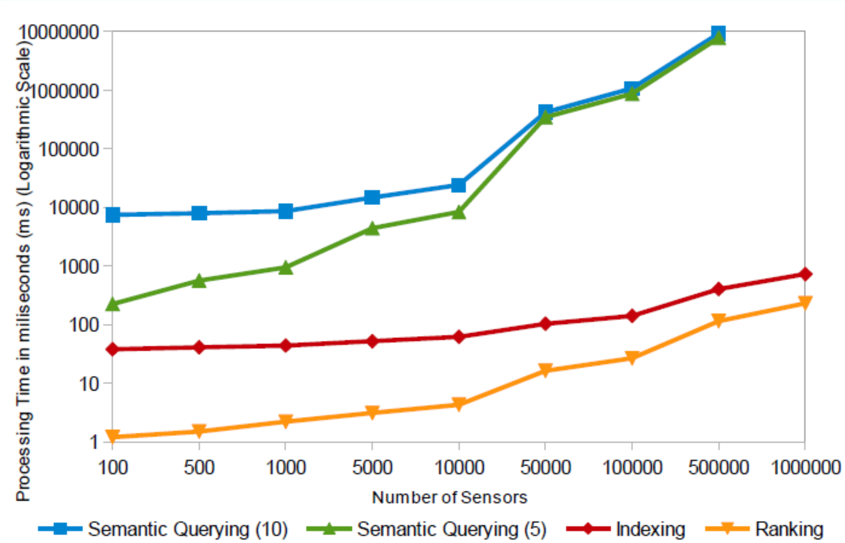
select the top-k sensors from the sorted list

Extended Features I

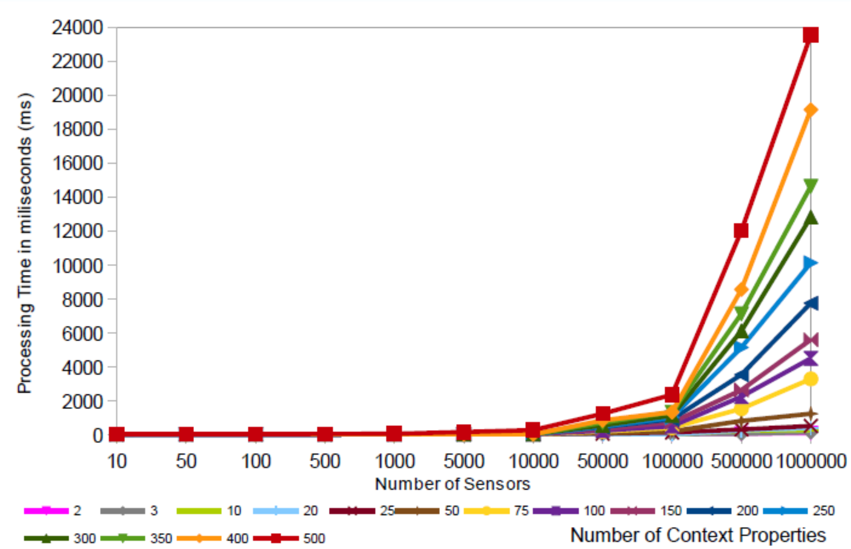
Comparative Priority-based Heuristic Filtering (CPHF)

A user wants to select sensors and has four flexible requirements: accuracy, reliability, battery life, and sec
According to the user defined priorities, weights fo are calculated as follows: accuracy (0.4), reliability (0.3), battery life (0.2), and securit

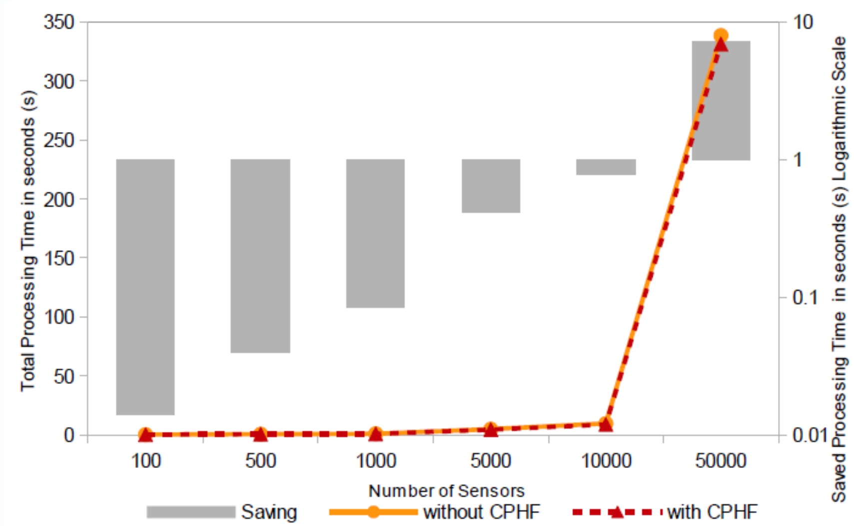
Evaluation



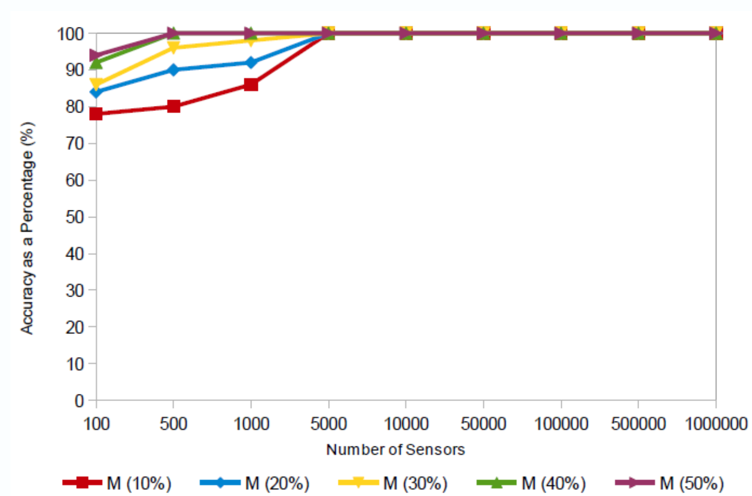
Processing Time in miliseconds (ms) (Logarithmic Scale)
10000000
1000000
100000
10000
1000
100
10
1
100
500
1000
5000
10000
50000
100000
500000
1000000
Number of Sensors
Semantic Querying (10)
Semantic Querying (5)
Indexing
Ranking



Processing Time in miliseconds (ms)
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
10
50
100
500
1000
5000
10000
50000
100000
500000
1000000
Number of Sensors
2
3
10
20
25
50
75
100
150
200
250
300
350
400
500
Number of Context Properties



Total Processing Time in seconds (s)
350
300
250
200
150
100
50
0
10
1
0.1
0.01
Saved Processing Time in seconds (s) Logarithmic Scale
100
500
1000
5000
10000
50000
Number of Sensors
Saving
without CPHF
with CPHF



Accuracy as a Percentage (%)
100
90
80
70
60
50
40
30
20
10
0
100
500
1000
5000
10000
50000
100000
500000
1000000
Number of Sensors
M (10%)
M (20%)
M (30%)
M (40%)
M (50%)

Conclusions

- Context-based framework for IoT sensors
- Extended SSNO
- CASSARAM
- CASSARA tool for prioritising sensor properties
- Comparative Priority-based Heuristic filtering
- Prototype development, performance and efficiency measurement

Thank you !

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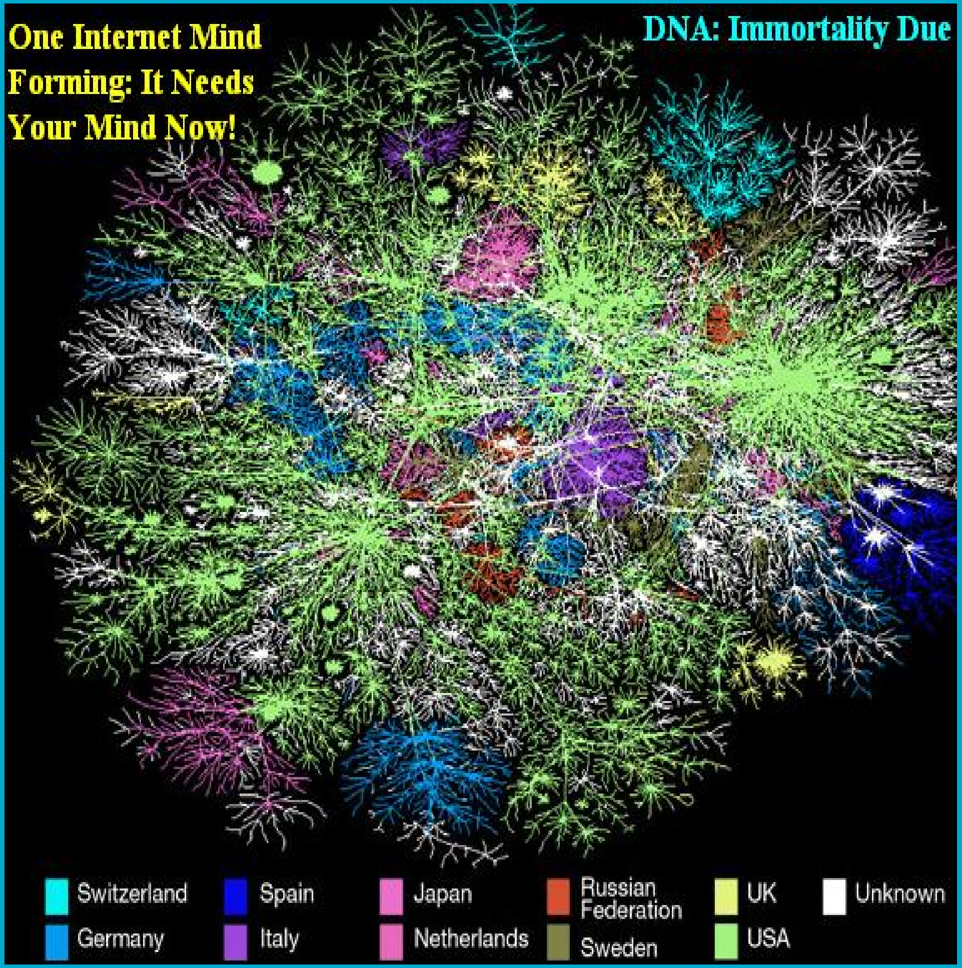
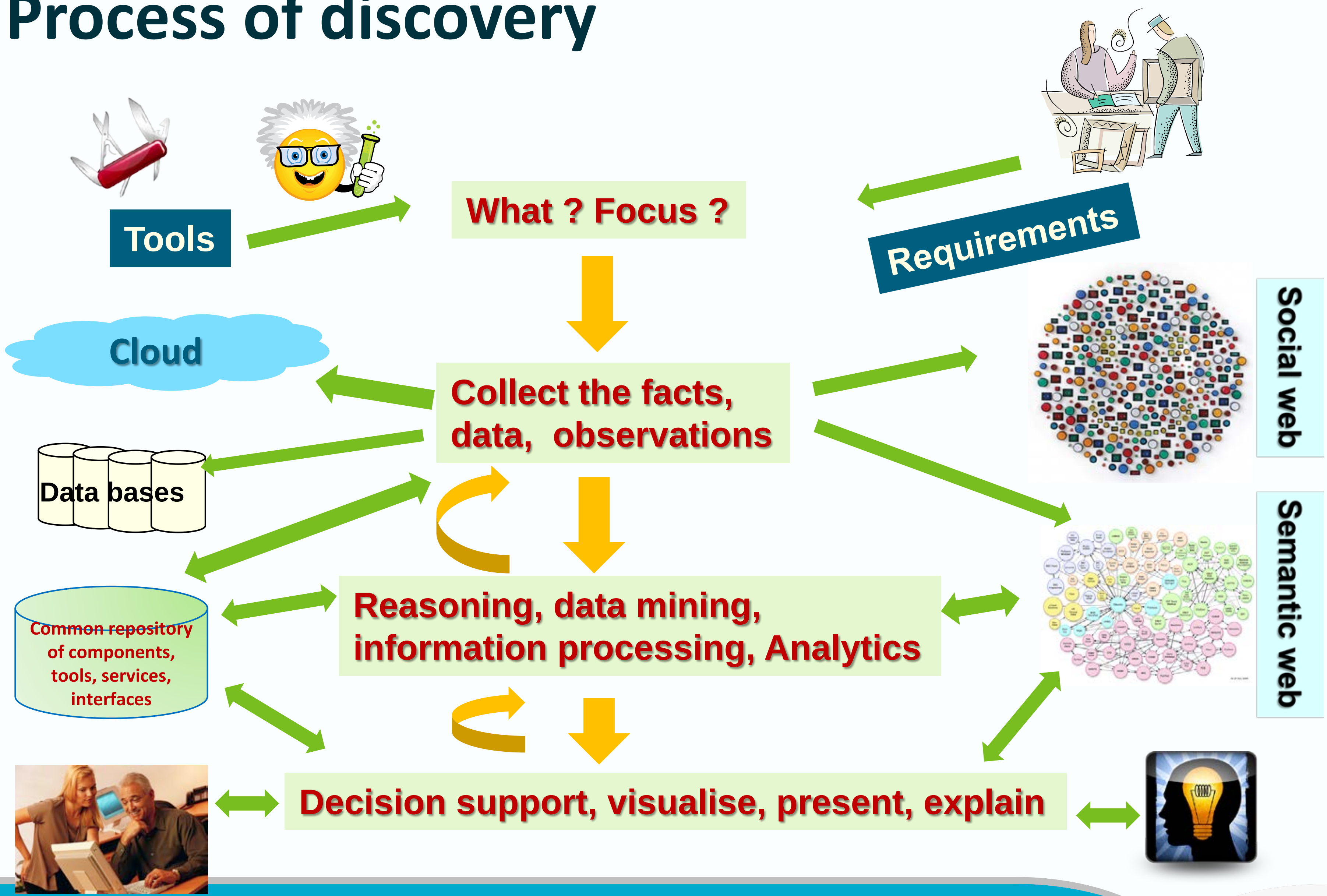


Process of discovery



Semantic Sensor Description
for sensor discovery and integration

Semantic Sensor Networks (SSN)

W3C Incubator Activity XG (2009-11)

http://www.w3.org/2005/Incubator/ssn

Chairs:

- Commonwealth Scientific and Industrial Research Organization, Australia
- Kno.e.sis Lab, Wright State University, USA

Members:

- Ericsson, USA
- Boeing, USA
- Fundacion CTIC, Spain

Members (continued):

- National University of Ireland (NUIG), Digital Enterprise Research Institute (DERI), Ireland
- University of Surrey, UK
- Universidad Politécnica de Madrid, Spain
- Fraunhofer Gesellschaft, Germany
- Pennsylvania State University, USA
- The Open University, UK
- University of Southampton, UK
- Monterey Bay Aquarium Research Institute, USA

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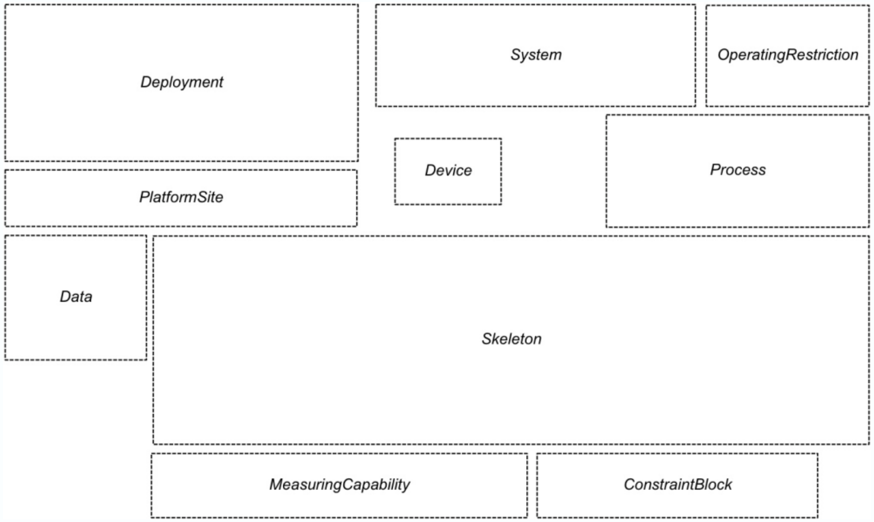
SSN Ontology structure and uses

The SSN ontology consist of several ontology modules



The ontology can be used for a focus on any (or a combination) of a number of perspectives:

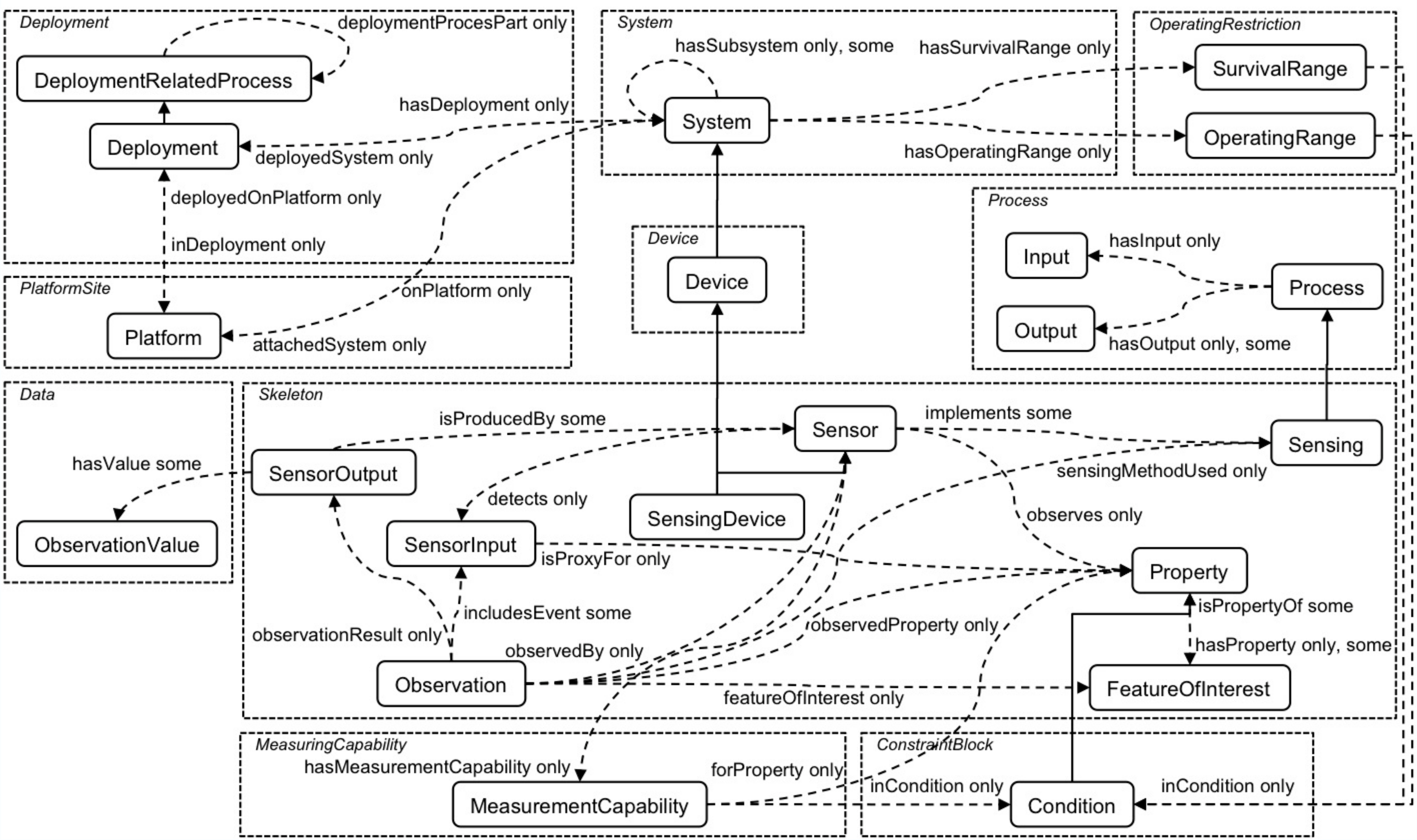
A **sensor perspective**, with a focus on what senses, how it senses, and what is sensed

A **data or observation perspective**, with a focus on observations and related metadata

A **system perspective**, with a focus on systems of sensors, or

A **feature and property perspective**, with a focus on features, properties of them, and what can sense those properties

The SSN Ontology



Adoptions of the SSN Ontology (more recently)

Linked Sensor Data

- http://knoesis.wright.edu/

EU FP6 SPITFIRE

- http://spitfire-project.eu/

EU FP7 Exalted project

- http://www.ict-exalted.eu/

EU FP7 SemSorGrid4Env

- http://www.semsorgrid4env.eu/

EU FP7 OpenIoT

- http://www.openiot.eu/