# Context Awareness for Internet of Things (CA4IOT)

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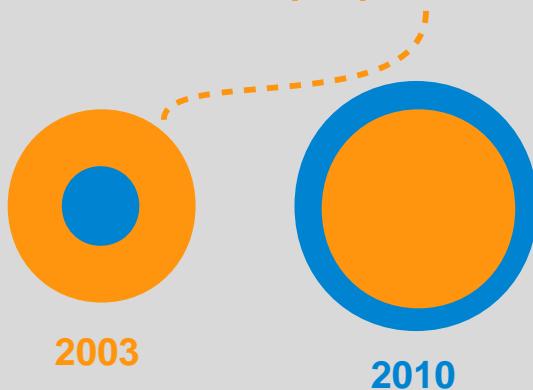
# Agenda

- **Background**

- **Research Challenges and Motivations**

- **Our Objectives and Functional Requirements**

- **Proposed Solution: CA4IOT Architecture**

- **Real world Scenario**

- **Future Work and Research Directions**
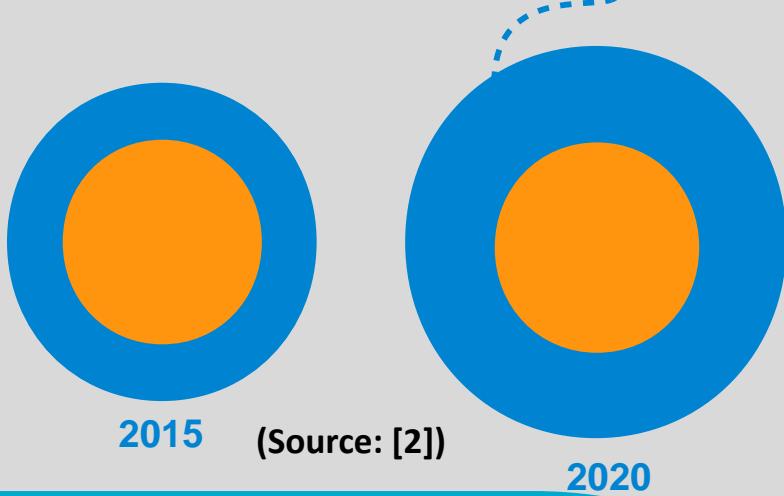
# Statistics and Predictions on Internet of Things

- **1.5 billion Internet-enabled PCs and over 1 billion Internet-enabled mobile phones today.**

- **By 2020, there will be 50 to 100 billion devices (i.e. things, sensors, smart objects) connected to the Internet (Source: [1])**

- **The global market for sensors was around $56.3 billion in 2010, $62.8 billion in 2011, expected to increase to $91.5 billion by 2016, at a compound annual growth rate of 7.8%. (Source:[5])**

**During 2008, the number of things connected to the Internet exceeds the number of people on earth**

**By 2020 there will be 50 billion *things***

**2003**

**2010**

**2015**

**(Source: [2])**

**2020**

# Conclusions based on Statistics and Predictions

- **Massive amount of data will be generated by sensors.**
    - **Big Data = Volume + Velocity + Variety** (Source: [6])

- **It is not be feasible to collect and process all the sensor data generated by the sensors**
    - **Resource limitations: processing, storage, communication**
    - **Cost involvement: related to resources and related data ownership**

- **We should collect data only from selected number of sensors that will help us to achieve our objectives**

# Main Challenges

- **Select appropriate sensors when large number of sensors are available to …**

- **Decide what information to consider when selecting the appropriate sensors; Context matters…**

- **Cannot make assumptions during the development time in IoT paradigm. Dynamic, configurable at runtime is a must…**

# Trends in IoT Middleware and Context Awareness
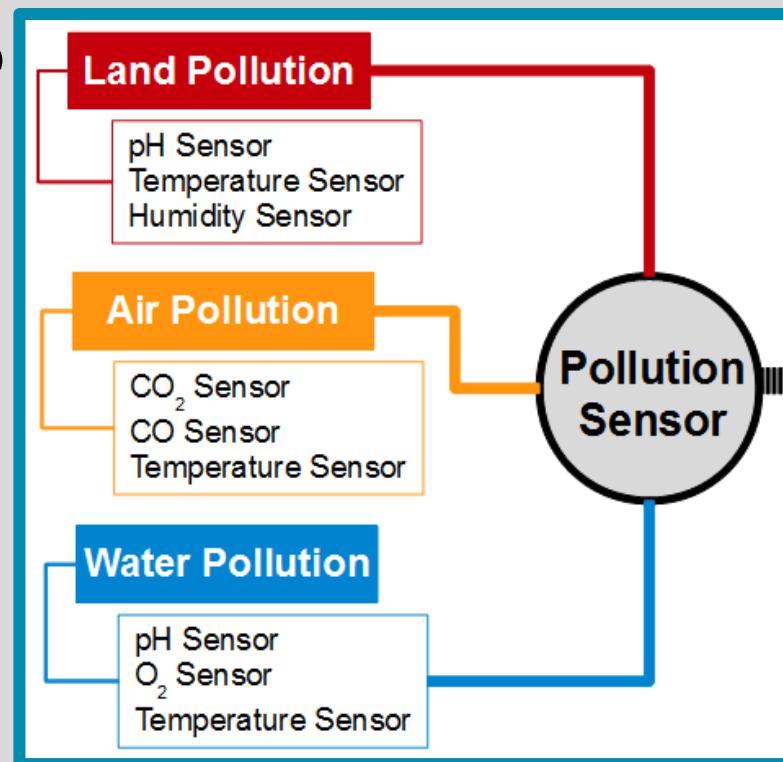
- **More and more sensor network/IoT middleware solutions are available**
  - **OpenIoT (next generation of GSN + Aspire) [http://www.openiot.eu/]**
  - **SenseMA (improved functionalities on top of the OpenIoT and GSN)**
- **Context awareness is lacking in most IoT middleware**

- **Lack of dynamic configuration, semantic Interactions, scalable fusion capabilities**

- **Critical functionalities (EU recommendation):**

- **Adaptation of sensor ontologies**
- **Distributed registries**
- **Sensor searching and discovery**
- **Reasoning and knowledge discovery**
- **Context aware data processing**
- **Automated sensor configuration**

# Conclusions based on Literature Review

- **Two main Categories: Conceptual and Operational**

- **Operational categorization** **schemes allow us to understand the issues and challenges in data acquisition techniques, as well as quality and cost factors related to context.**

- **Conceptual categorization** **allows an understanding of the conceptual relationships between context**

- **We need to capture and model context comprehensively by in cooperating all different aspects mentioned above**
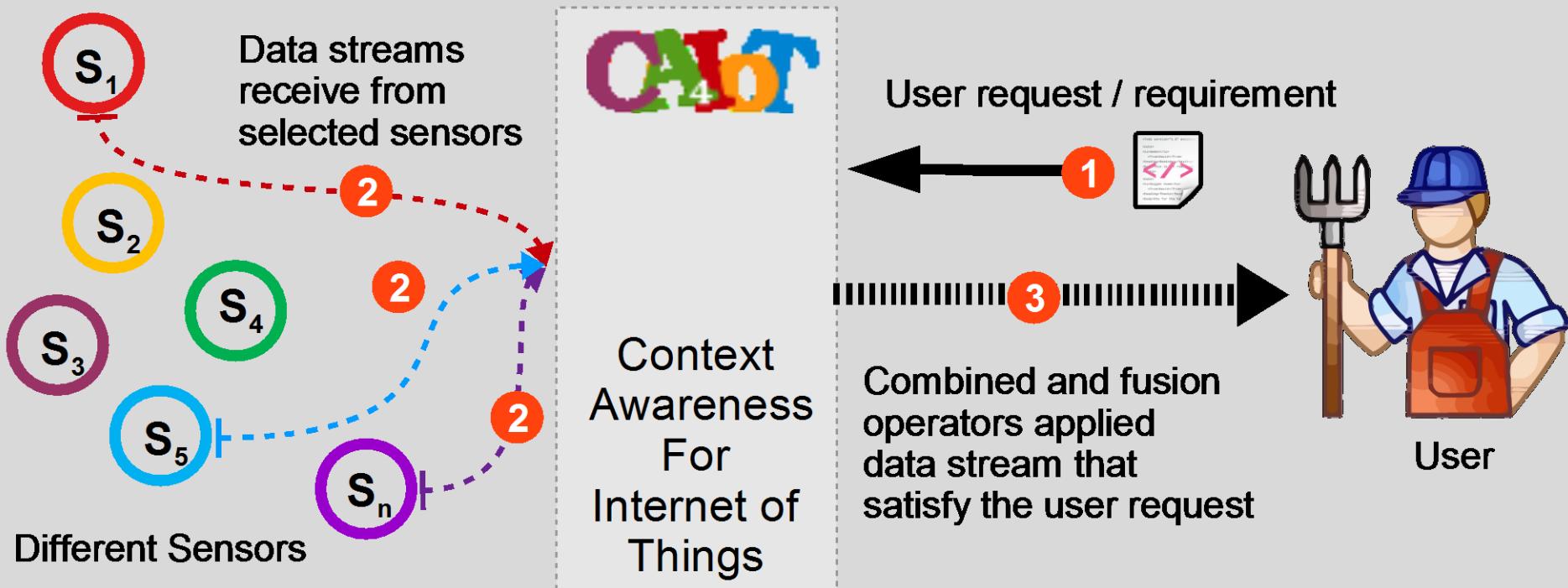
# The Research challenges and Motivations

- **How to help the users to select appropriate sensors when large number of sensors are available to use…?**

- **How to reduce the gap between what user needs and what low level sensors can provide by understanding the user requirements /problems?**

- **How context (information) can help to select the sensors…? Specially when alternative sensors (e.g. multiple sensors produce same kind of data) with different characteristics (e.g. energy consumption, accuracy, quality) are available…**

- **How to connect and configure sensors and programming components dynamically on demand…?**

**Land Pollution**
pH Sensor
Temperature Sensor
Humidity Sensor

**Air Pollution**
$CO_2$ Sensor
CO Sensor
Temperature Sensor

**Water Pollution**
pH Sensor
$O_2$ Sensor
Temperature Sensor

**Pollution Sensor**

# **Our Objective and Functional Requirements**
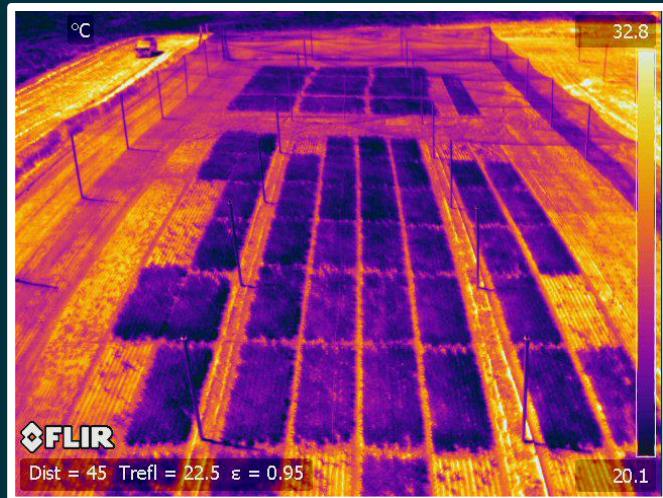
- **Our objective is not to introduce another middleware Our objective is to explore the possibilities of embedding (applying) context-aware functionalities into IoT middleware solutions**
- **Our goal is to design an solution to help users to automating the task of selecting the sensors according to the problems at hand.**
- **We DO NOT answer user queries**



$S_1$

Data streams receive from selected sensors

$S_2$

$S_4$

$S_3$

$S_5$

$S_n$

Different Sensors

CA4IoT

Context Awareness For Internet of Things

User request / requirement

1

3

Combined and fusion operators applied data stream that satisfy the user request

User

# Functional Requirements

- **Connect and configure sensors to an IoT middleware easily, dynamically and on demand.**

- **Capture context and understand the user requirement**

- **Reduce the gap between high-level user requirements and low-level sensors capabilities.**

- **Model and maintain context (information) about sensors**

- **Model and maintain context (information) about processing components**

# Real World Scenario



The Australian Plant Phenomics Facility

# Australian Agriculture

- **Agricultural research obtains $AUS1.2 billion per annum**
- **Fourth largest wheat and barley exporter after US, Canada and EU**
- **BUT has to deal with scarcity of resources:**
  - **Water quality and quantity**
  - **Low soil fertility**

- **Grains Research and Development Corporation (GRDC) trials plant varieties in very many 10m x 10m plots across Australia.**

- **Every year, Australian grain breeders plant up to 1 million plots across the country to find the best high yielding**

- **Information sources about plant variety performance:**
  - **Site visits**
  - **Australian Bureau of Meteorology**

- **Issues in current practices:**
  - **Site visits are expensive and time-consuming (e.g., 400km away)**

- **Lack of accurate information limits the quality of results**

# Why context knowledge matters?
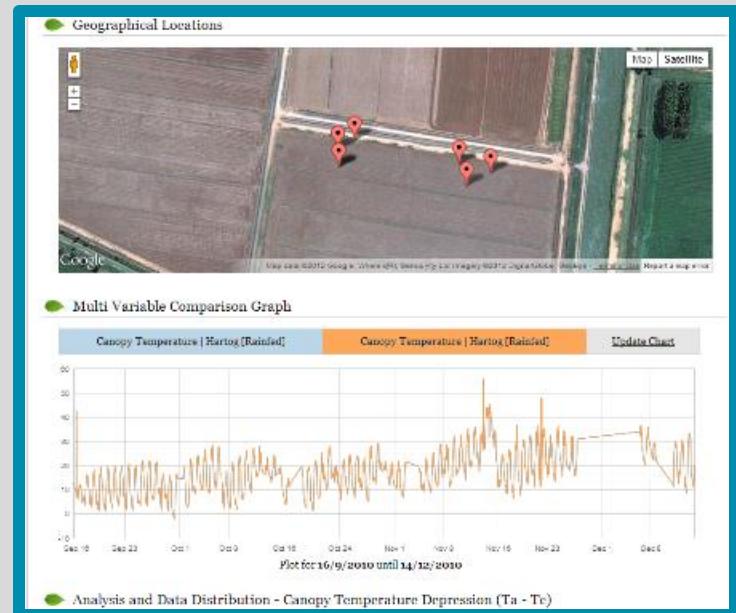
- **Monitoring/Sensing strategies** (data collection frequency, real-time event detection, data archiving for pattern recognition, etc.) **need to be changed depending on the time of the day, time of the year, phase of the growing plant, type of the crop, energy efficiency and availability, sensor data accuracy, etc…**

# Need to be considered in developing a solution:

- **Agricultural/biological scientists and engineers do not know much about computer science.**
- **Users focus on what they want**
- **Learning curve, usability, processing time, dynamicity of sensors…**

# Phenonet:
## A Distributed Sensor Network for Phenomics

- **Aim is to Improve yield by improving crop selection process. How?**
  - **Sensor-based monitoring and Sophisticated data analysis**
- **Combined research effort from CSIRO's ICT Centre and High Resolution Plant Phenomics Centre**
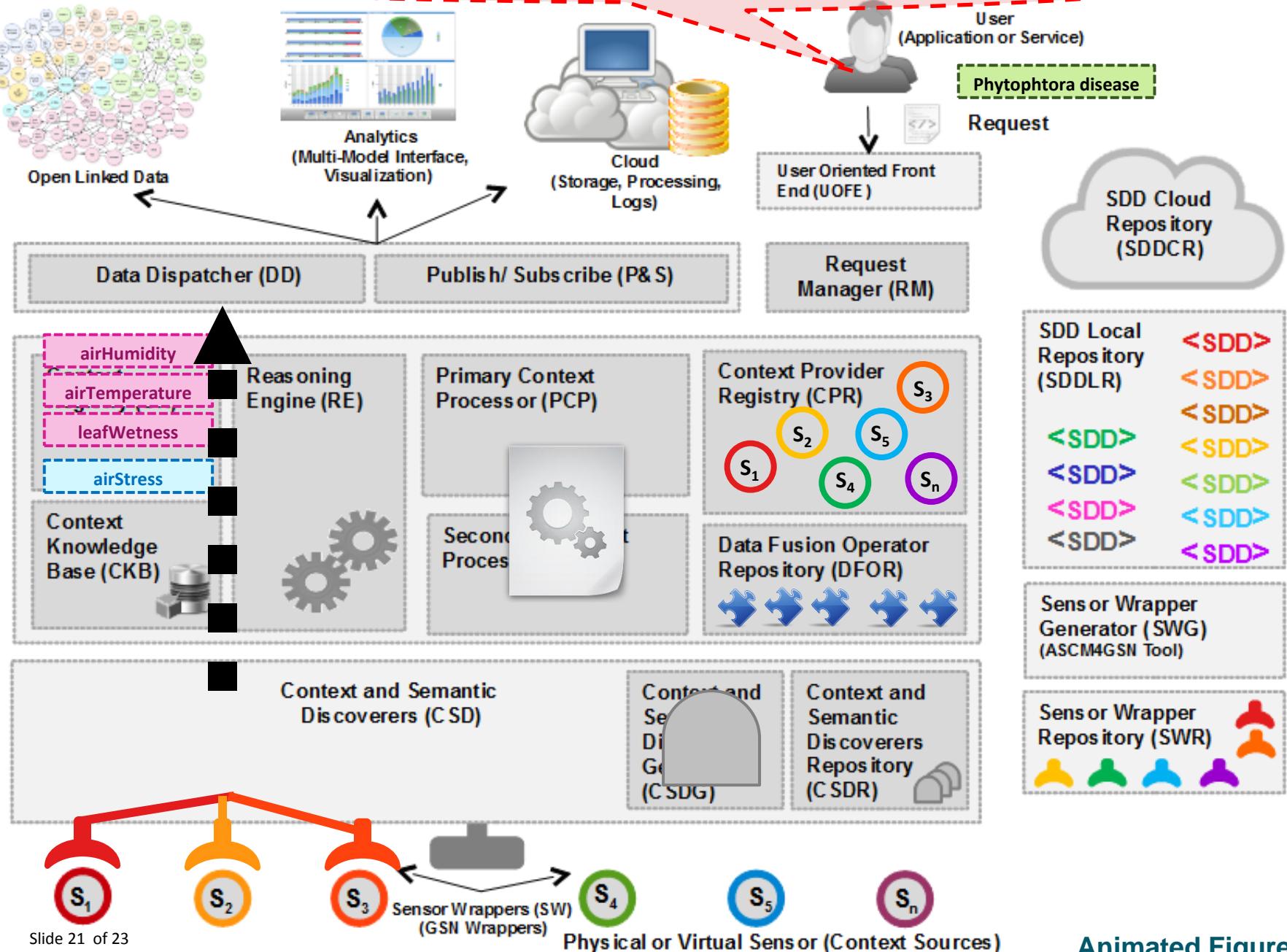
# Use case

- Let's consider a scenario: John, a plant scientist, who is looking after a experimental crops growing facility, wants to know whether the crops are infected by Phytophtora disease.

- Phytophtora [8]  is a fungal disease which can enter a field through a variety of sources. Humidity plays a major role in the development of Phytophtora. Both temperature and whether or not the leaves are wet are also important indicators to monitor Phytophtora.

- IF **airTemperature** $<$ 12 AND **airHumidity** $<$ 25% THEN **airStress** level = low
- IF **airTemperature** $\geq$ 12 AND **airHumidity** $\geq$ 25% THEN **airStress** level = high
- IF **airStress** = high AND **leafWetness** $>$ 50 THEN *Phytophtora disease* = infected ELSE = not-infected

**The values used for demonstration purposes only**

"...I want to know whether experimental plants in Canberra have infected with Phytophtora disease..."

**Animated Figure**

# **Future Work and Research Directions**

- **Understand user requirements**
  - **Extract knowledge from large knowledge bases and build simple context registries that maps sensor measurements into context**
  - **Sensor description modelling, storage and reasoning (e.g. SSNO)**
  - **Efficient and scalable mapping between context and sensor measurements**

- **Context discovery by data fusion**
  - **Developing models that allows to describe programming components**
  - **Plugin architecture to different data fusion operations and context discovery**
  - **Adaptation of OSGi component based model**

- **Sensor selection based on characteristics**
  - **Probabilistic Vs. Semantic**

# Thank You!

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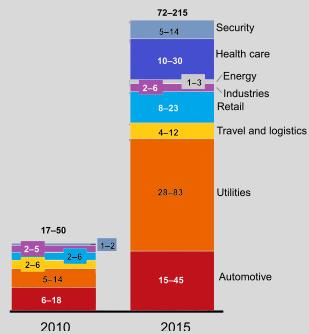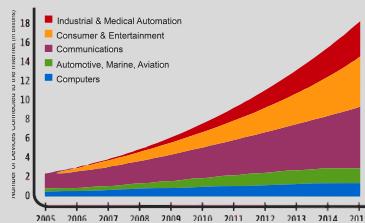
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# Appendix

Industrial & Medical Automation
Consumer & Entertainment
Communications
Automotive, Marine, Aviation
Computers

18
16
14
12
10
8
6
4
2
0

2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015

72–215
5–14 Security
10–30 Health care
2–6 1–3 Energy
Industries
8–23 Retail
4–12 Travel and logistics

28–83 Utilities

17–50
2–5 2–6 1–2
2–6
5–14
6–18 Automotive
15–45 Automotive

2010          2015

**During 2008, the number of things connected to the Internet exceeds the number of people on earth**

**By 2020 there will be 50 billion *things***

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Non Animated Figure