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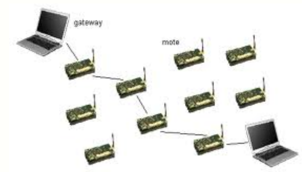

Semantic Web

Domain knowledge Interoperability to build the Semantic Web of Things

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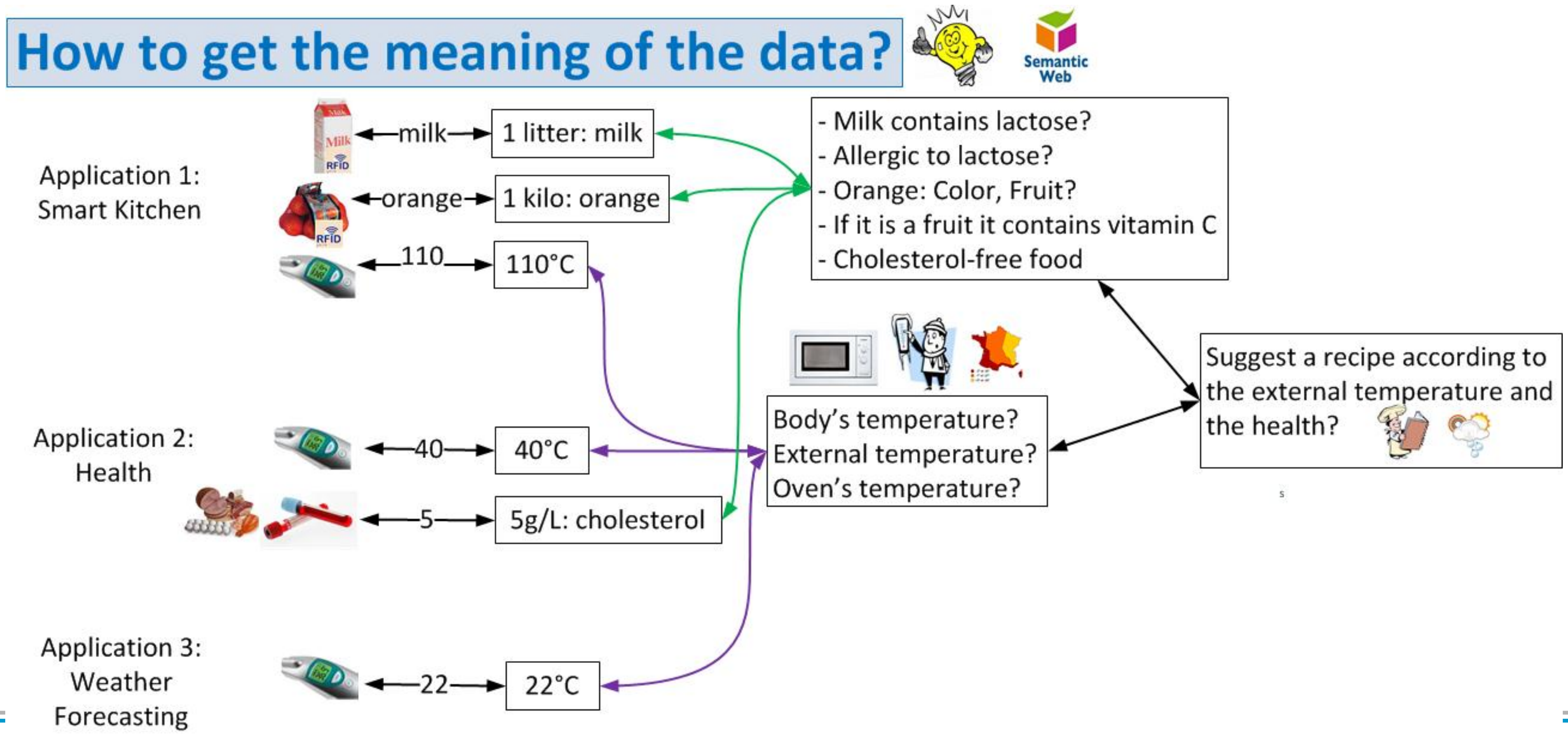
- Christian Bonnet (Eurecom, Mobile Communication)
- Karima Boudaoud (I3S, Security)

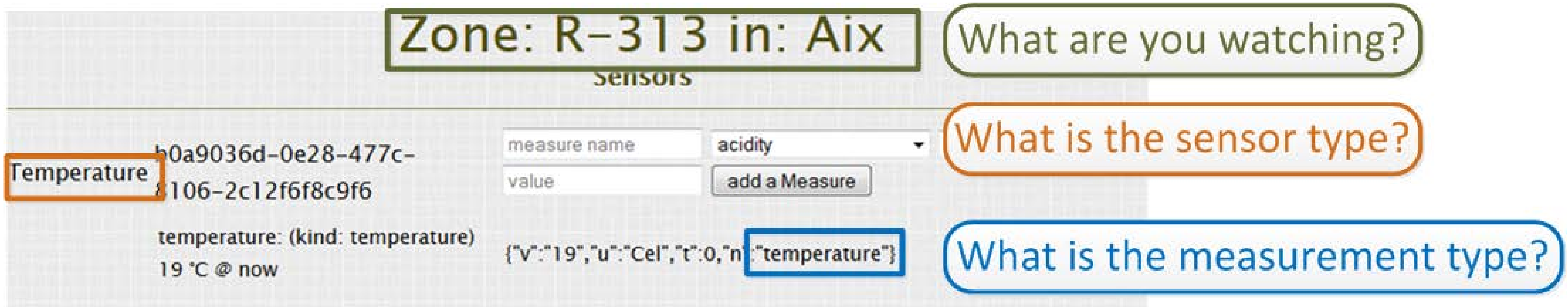
Motivation

- **How to help developers to design IoT applications?**
  - How to combine domains?
  - How to reuse domain knowledge?
  - How to reason on sensor data?



The M3 ontology (Machine to Machine Measurement)

- **SenML protocol [draft-jennings-senml-10]**



- **Extension of the W3C Semantic Sensor Networks (SSN) ontology (Observation Value concept)**
  - Do not provide a basis for reasoning that can ease the development of advanced applications

- **Classify all the concepts in the Machine-to-Machine (M3) ontology**
  - **Domain** (health, smart building, weather, room, city, etc.)
  - **Measurement type** (t = temp = temperature)
  - **Sensor type** (rainfall sensor = precipitation sensor)

- **Standardize sensors, measurements and domain terms?**

How to deduce new knowledge?

- **Rules example:**
  - If **Domain** == Health && **MeasurementType** == Temperature then NewType = **BodyTemperature**
  - If **BodyTemperature** > 39°C then "**Fever**"
  - **BodyTemperature** and **Fever** are already described in domain ontologies or datasets!
- **More than 200 ontology-based IoT applications are referenced:**
  - Difficulties to automate knowledge extraction
    - Lack of semantic web best practices [OneM2M, Gyrard 2014]
    - Heterogeneous terms used (e.g., etymology, synonyms)
  - **Standardize sensor-based domain ontologies?**
    - As it has been done for W3C SSN, W3C Time or Schema.org

OneM2M, Working Group 5 (Management, Abstraction and Semantics)
OneM2M Semantic Web Best practices [Gyrard et al. 2014]

Intelligent Transport Systems

Authors	Year	Paper	Url onto	Technologies	Sensors	Rules
Stocker et al. (in red)	2012	Paper: Making sensor of sensor data using ontology: a discussion for road vehicle classification	Trivial ontology: few concepts (response), uses SSN Concepts: Vehicle, Light, Heavy, Dirving Side, Driving Speed.	Protege, Jena	Vibration, magnetometer, vehicle velocity	
Feld, Muller (in purple)	2011	Paper: The Automotive ontology: Managing knowledge inside the vehicle and sharing it between cars.	Work in progress (Response) Concepts: Road, Parking, Traffic Events, Emotional State, Driving Preferences, Mental State, Abilities, Characteristics, Personality		Speed, voice (microphone), ice sensor, heart beat, blood pressure, arousal, alcohol level	
Hulsen, Zollner, Weiss (in white)	2011	Paper: Traffic intersection situation description ontology for advanced driver assistance.	Concepts: Traffic Sign, Traffic Light, Road, Car, Crossing	RacerPro		
Ruta et al. (in green)	2010	Paper: A mobile knowlege-based system for on-board diagnostics and car driving assistance.	Ontology and Rules URL Concepts: Weather condictions (fog, windy, cloud, rain, snow, clear), road surface (unever, even), road condition (high/low speed), traffic (high/low density), driving style (even pace, imprudent) vehicle speed(low, hight), safety		GPS, accelerometer, speed, wind, esp, abs, fog lamp	fog -> low speed, fog lamp, abs (OWL restrictions)

http://www.sensormeasurement.appspot.com/?p=ontologies

Sensor-based Linked Open rules

LINKINGOPENDATA
W3C SWEO Community Project

Linked Open Vocabularies (LOV)

- **We propose the Linked Open Rules**
  - Heterogeneous formats (ontology editor tool, inference engine, etc.)

Sensors used in your application?

Choose a sensor [Precipitation Sensor, Pluviom▾]

Wind Direction Sensor
Fuel Level Sensor
Gyroscope Sensor
Precipitation Sensor, Pluviometer, Rainfall sensor
HeartBeat Sensor, Heart rate
Oxygen Sensor — A pluviometer is a sensor measuring the amount of precipitation/rainfall.
Car Speed Sensor, speedometer, Velocity
Atmospheric Pressure Sensor, Barometer, Barometric Pressure Sensor
Presence detector, Pyroelectric IR Occupancy Detector, Intrusion Detector/ Trespass
Microphone
Sun Position Direction Sensor
Pressure sensor (e.g., bed)
Cloud Cover Sensor
Body Thermometer
Throttle Position Sensor
Distance Sensor
Light Sensor
Water Flow Sensor
Thermometer
Shake Sensor

Rules using this sensor

- Rule: TropicalStormRain, IF Rain GREATEF
  Project: Paul Staroch, 2013
- Rule: HeavyRain, IF Rain GREATER_THAN
  Project: Paul Staroch, 2013
- Rule: MediumRain, IF Rain GREATER_THA
  Project: Paul Staroch, 2013
- Rule: RainySpeedSafetyDevice, IF Rainy T
  Project: Ruta et al. 2010
- Rule: ModeratePrecipitation, IF Precipitatio
  Project: Kofler et al., ThinkHome, 2011
- Rule: NoPrecipitation, NoRain, IF Precipitat
  Project: Paul Staroch, 2013
- Rule: NoPrecipitation, NoRain, IF Precipitation = 0 mm THEN NoPrecipitation
  Project: Kofler et al., ThinkHome, 2011
- Rule: HeavyPrecipitation, IF precipitation GREATER_THAN 4mm THEN HeavyPrecipitation
  Project: Kofler et al., ThinkHome, 2011

http://www.sensormeasurement.appspot.com/?p=swot_template

Scenario 1: Body Temperature Reason on M2M Data

http://sensormeasurement.appspot.com/

Find food recommended when you are sick

1. SenML API (Simulate M2M measurements): Simulate temperature measurements
2. M2M Aggregation Gateway (Convert Health Measurements into Semantic Data): Convert health measurements
3. We deduce that the temperature corresponds to the body temperature.
4. We deduce that the person is sick.
5. We propose all fruits/vegetables according to this disease.
6. M2M Application: Temperature => Cold => Food: (Wait 10 seconds!) Food if you are sick

<rdf:Description rdf:about="http://sensormeasurement.appspot.com/m3#Measurement5">
<m3:hasUnit rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Cel</m3:hasUnit>
<m3:hasDateTimeValue rdf:datatype="http://www.w3.org/2001/XMLSchema#dateTime">0.0</m3:hasDateTimeValue>
<m3:hasValue rdf:datatype="http://www.w3.org/2001/XMLSchema#decimal">39.0</m3:hasValue>
<m3:hasName rdf:datatype="http://www.w3.org/2001/XMLSchema#string">temperature</m3:hasName>
<rdf:type rdf:resource="http://sensormeasurement.appspot.com/m3#Measurement"/>
<rdf:type rdf:resource="http://sensormeasurement.appspot.com/m3#BodyTemperature"/>
</rdf:Description>

Semantic Web

6. M2M Application: Temperature => Cold => Food: (Wait 10 seconds!) Food if you are sick

- Value = 39.0, Unit = Cel, Type = Body Temperature, Disease = Cold, Food = Kiwi
- Value = 39.0, Unit = Cel, Type = Body Temperature, Disease = Cold, Food = Lemon
- Value = 39.0, Unit = Cel, Type = Body Temperature, Disease = Cold, Food = Honey
- Value = 39.0, Unit = Cel, Type = Body Temperature, Disease = Cold, Food = Ginger

Linked Open Data

Linked Open Vocabularies (LOV)

Linked Open Rules

Paper: Honey as Complementary Medicine - A Review [Singh et al. 2012]

Scenario 2: Weather Temperature & Luminosity

Weather & Activity

1. SenML API (Simulate M2M measurements): Simulate Weather measurements
2. M2M Aggregation Gateway (Convert weather Measurements into Semantic Data): Convert weather measurements
3. We deduce the weather outside.
4. We propose activities according to the weather.
5. M2M Application (Temperature => weather => Activity): Activity & Temperature
6. M2M Application (Luminosity => weather => Activity): Activity & Luminosity
7. M2M Application (Precipitation => weather => Activity): Activity & Precipitation
8. M2M Application (Wind speed => weather => Activity): Activity & Wind Speed

- Value = 39.0, Type = Weather Temperature, Unit = Cel, Weather = Sunny, Activity = BeachSunbathing
- Value = 39.0, Type = Weather Temperature, Unit = Cel, Weather = Sunny, Activity = BeachVolley

Weather & Emotion

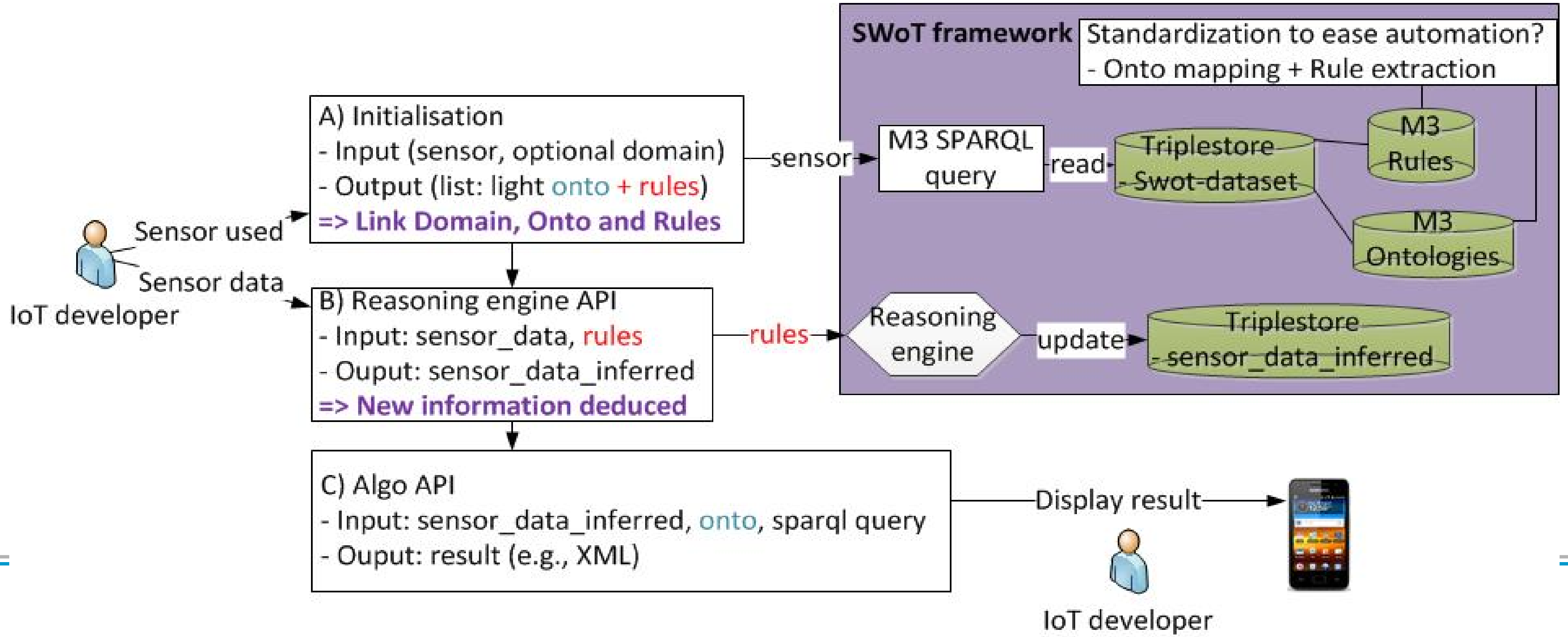
- Value = 50000.0, Type = Weather Luminosity, Unit = lx, Emotion = Joy, Color = Yellow
- Value = 50000.0, Type = Weather Luminosity, Unit = lx, Emotion = Happiness, Color = Yellow
- Value = 50000.0, Type = Weather Luminosity, Unit = lx, Emotion = Fear, Color = Yellow
- Value = 5000.0, Type = Weather Luminosity, Unit = lx, Emotion = Sadness, Color = Gray
- Value = 5000.0, Type = Weather Luminosity, Unit = lx, Emotion = Confusion, Color = Gray
- Value = 5000.0, Type = Weather Luminosity, Unit = lx, Emotion = Boredom, Color = Gray
- Value = 5000.0, Type = Weather Luminosity, Unit = lx, Emotion = Depressed, Color = Gray

Paper: Mapping emotion to color [Nijdam 2009]

“Seasonal affective disorder”

SWoT framework (Semantic Web of Things)

- **To help developers to build IoT applications:**
  - Reason on sensor data
  - Build interoperable IoT applications
  - Easily combine domains
  - Reuse domain knowledge



Conclusion & Future works

- **Standardization suggestions:**
  - OneM2M, ETSI M2M, W3C Web of Things, W3C SSN
  - Semantic web best practices
  - Sensor measurements in a unified way
  - Linked Open Rules
  - Sensor-based domain ontologies

Thank you!

- **We are looking for new real-use case scenarios**
- **gyrard@eurecom.fr**
- **http://sensormeasurement.appspot.com/**