

Combine, enrich, secure and reason about Internet of Things data

Amelie Gyrard

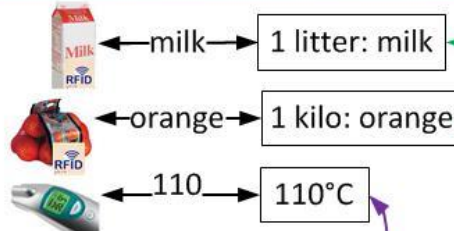
- Christian Bonnet (Eurecom, Mobile Communication)
- Karima Boudaoud (I3S, Security)

Motivation 1/2

How to get the meaning of the data?

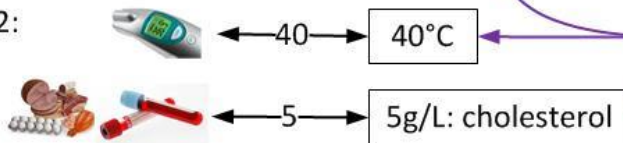


Application 1:
Smart Kitchen



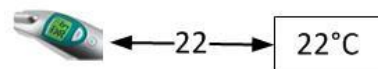
- Milk contains lactose?
- Allergic to lactose?
- Orange: Color, Fruit?
- If it is a fruit it contains vitamin C
- Cholesterol-free food

Application 2:
Health



Body's temperature?
External temperature?
Oven's temperature?

Application 3:
Weather
Forecasting

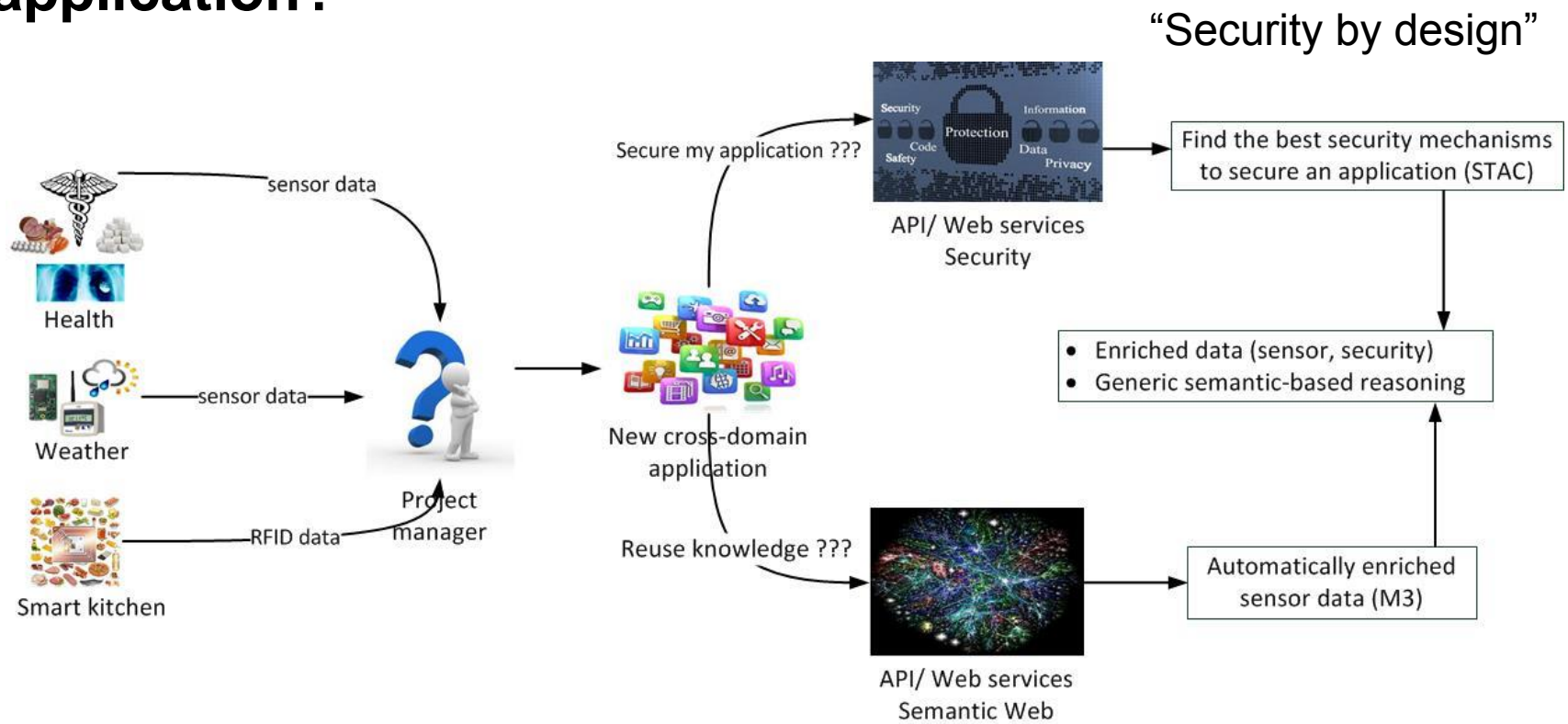


Suggest a recipe according to
the external temperature and
the health?



Motivation 2/2

- How to easily enrich sensor data to reason about them?
- Which security mechanism should I choose to secure my application?



Enrich and reason about IoT data

State of the art

■ Semantic Web of Things: Spitfire [Pfisterer 2011]



- Internet of Things (IoT), a smart world
- Machine-to-Machine (M2M) enables machines to communicate with each other without human intervention.
- Semantic Sensor Networks
 - (SSN) ontology, Sense2Web, SensorGrid4Env



■ Limitations:

- Do not reuse domain knowledge (ontologies, datasets and rules) defined by domain experts
- Different reasoning about data
- Do not combine **disparate** domains.

Contributions

■ The M3 (Machine to Machine Measurement) approach

- Enrich M2M data with semantic web technologies
- The M3 ontology: A hub for cross-domain ontologies and datasets
 - Naturopathy: weather, recipe, health, emotion
 - Smart city: weather, home automation, transport, vacation
- LOR (Linked Open Rules)



■ A semantic-based (Machine-to-Machine) M2M architecture



■ The STAC application

- To secure the M2M architecture
 - M2M data
 - M2M applications
 - Help project managers to secure applications



The M3 ontology (Machine to Machine Measurement)

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

The screenshot shows a web interface for the SenML protocol. It features a header 'Zone: R-313 in: Aix' with a 'Sensors' label below it. A search bar contains the text 'What are you watching?'. Below the header, there is a list of sensors. One sensor is highlighted with an orange box and labeled 'Temperature'. To the right of the sensor list, there is a form with a 'measure name' dropdown set to 'acidity' and a 'value' input field. A button labeled 'add a Measure' is next to the input field. Below the form, there is a JSON-like representation of a measurement: `{ "v": "19", "u": "Cel", "t": "0", "n": "temperature" }`. The word 'temperature' in the JSON is highlighted with a blue box. To the right of the JSON, there is a blue box with the text 'What is the measurement type?'. Another orange box with the text 'What is the sensor type?' is positioned above the JSON. The interface also displays a UUID 'b0a9036d-0e28-477c-8106-2c12f6f8c9f6' and a status 'temperature: (kind: temperature) 19 °C @ now'.

- Extension of the W3C Semantic Sensor Networks (SSN) ontology (Observation Value concept)
- 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)

How to deduce new knowledge?

■ Rules example:

- If **Domain** == Health && **MeasurementType** == Temperature
then NewType = **BodyTemperature**
- If **BodyTemperature** > 38°C then “**Flu**”
- **BodyTemperature** and **Flu** are already described in domain ontologies or datasets!

■ We propose the **Linked Open Rules**

- SPARQL CONSTRUCT
- Semantic Web Rule Language (SWRL) rules



Linked Open Vocabularies (LOV)

How to reuse domain ontologies and datasets?

- **BodyTemperature** and **Flu** are **already described in domain ontologies or datasets!**

- **Reuse the domain ontologies already designed and defined by experts**

- “**flu**” has a meaning in health ontologies
- “**hot**” has a meaning in weather ontologies

- **How to reuse domain ontologies and datasets?**

- How to find domain ontologies or datasets?

- Best practices
- Semantic tools




Linked Open Vocabularies (LOV)



LINKING OPEN DATA
W3C SWEO Community Project

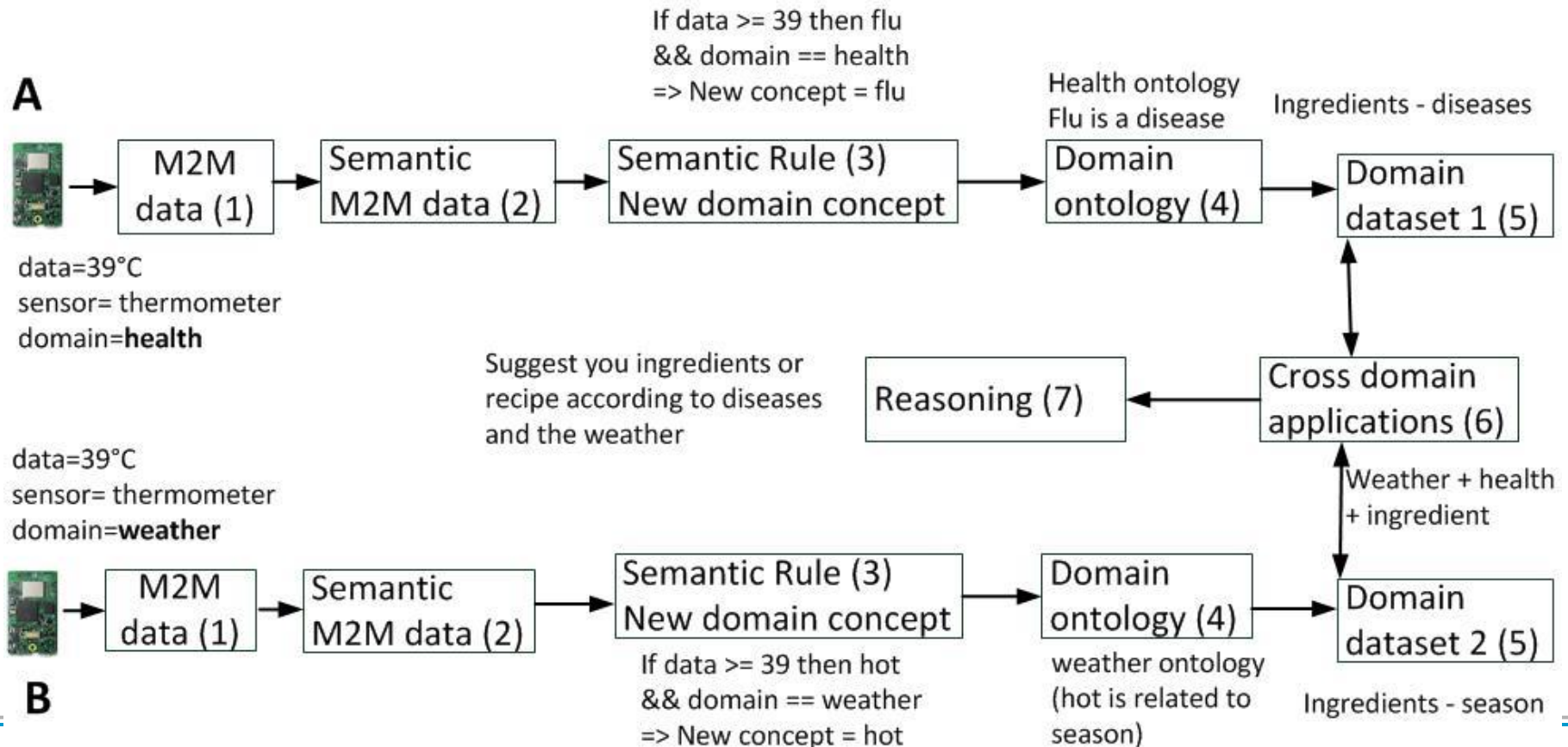
- In a specific domain, which ontology or dataset do we choose?
- How to use the complementarity of existing ontologies and datasets?



```
<Fruit rdf:about="#orange fruit">
  <rdfs:label xml:lang="en">orange</rdfs:label>
  <rdfs:label xml:lang="es">naranjado</rdfs:label>
  <hasUse rdf:resource="#juice"/>
  <hasMineral rdf:resource="#magnesium"/>
  <hasColor rdf:resource="#orange_color"/>
  <hasFlavor rdf:resource="#sweet"/>
  <hasVitamin rdf:resource="#vitaminC"/>
</Fruit>
```


The proposed approach: M3

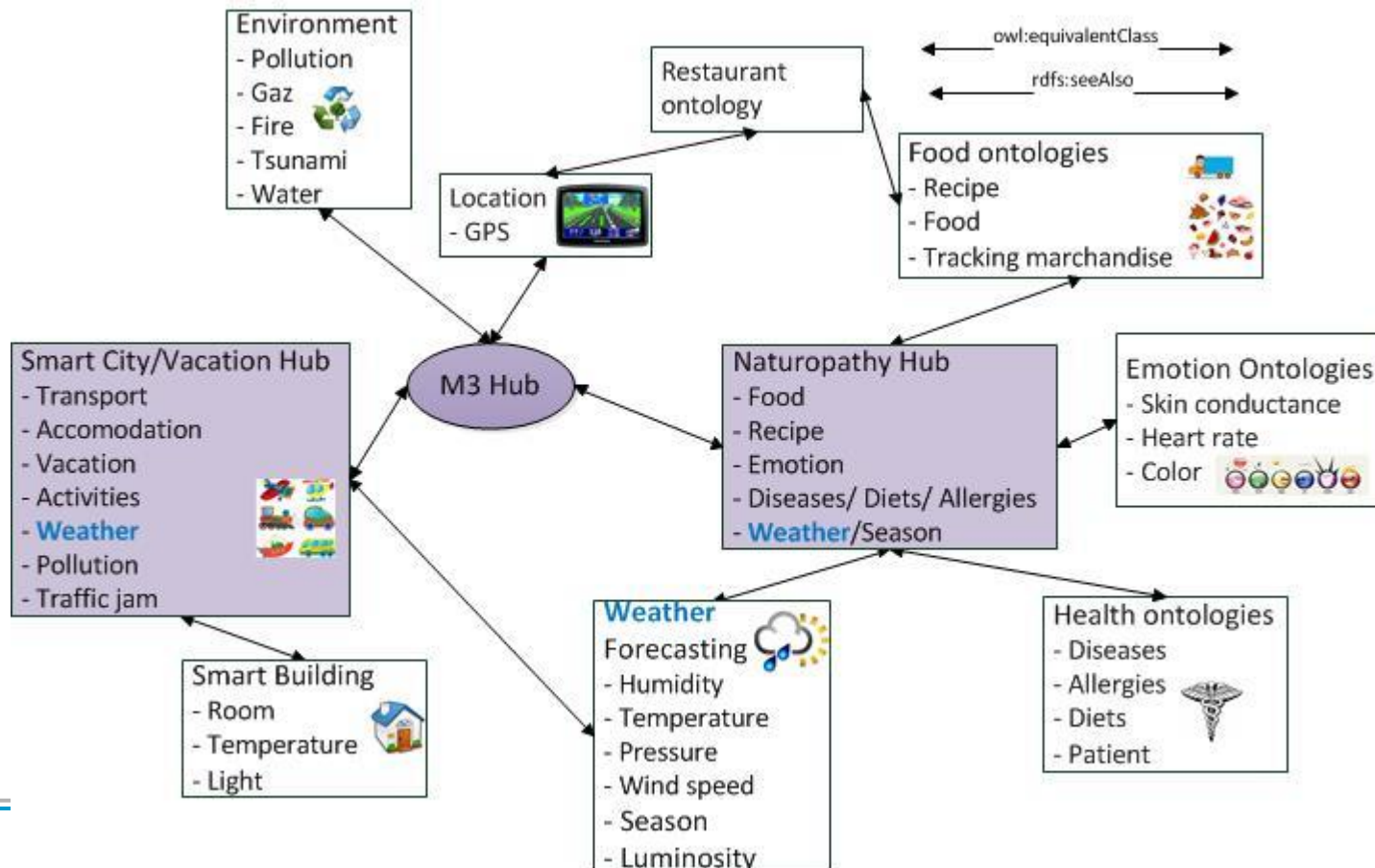
■ How to interconnect the data provided by heterogeneous domains?



M3: a hub for cross-domain ontologies and datasets

■ The M3 approach

- Enrich M2M data
- Reason on semantic M2M data
- A hub for cross-domain ontologies and datasets



Scenario 1: Body Temperature

Enrich 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](#)

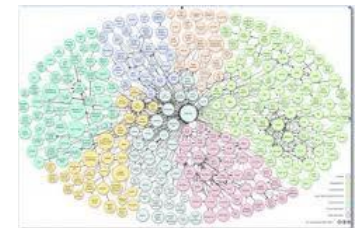
```
<rdf:Description rdf:about="http://sensormeasurement.appspot.com/m3#Measurement5">
  <m3:hasUnit rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Cel</m3:hasUnit>
  <m3:hasDateTimeValue rdf:datatype="http://www.w3.org/2001/XMLSchema#dateTime">0.0</m3:hasDateTimeValue>
  <m3:hasValue rdf:datatype="http://www.w3.org/2001/XMLSchema#decimal">39.0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



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



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

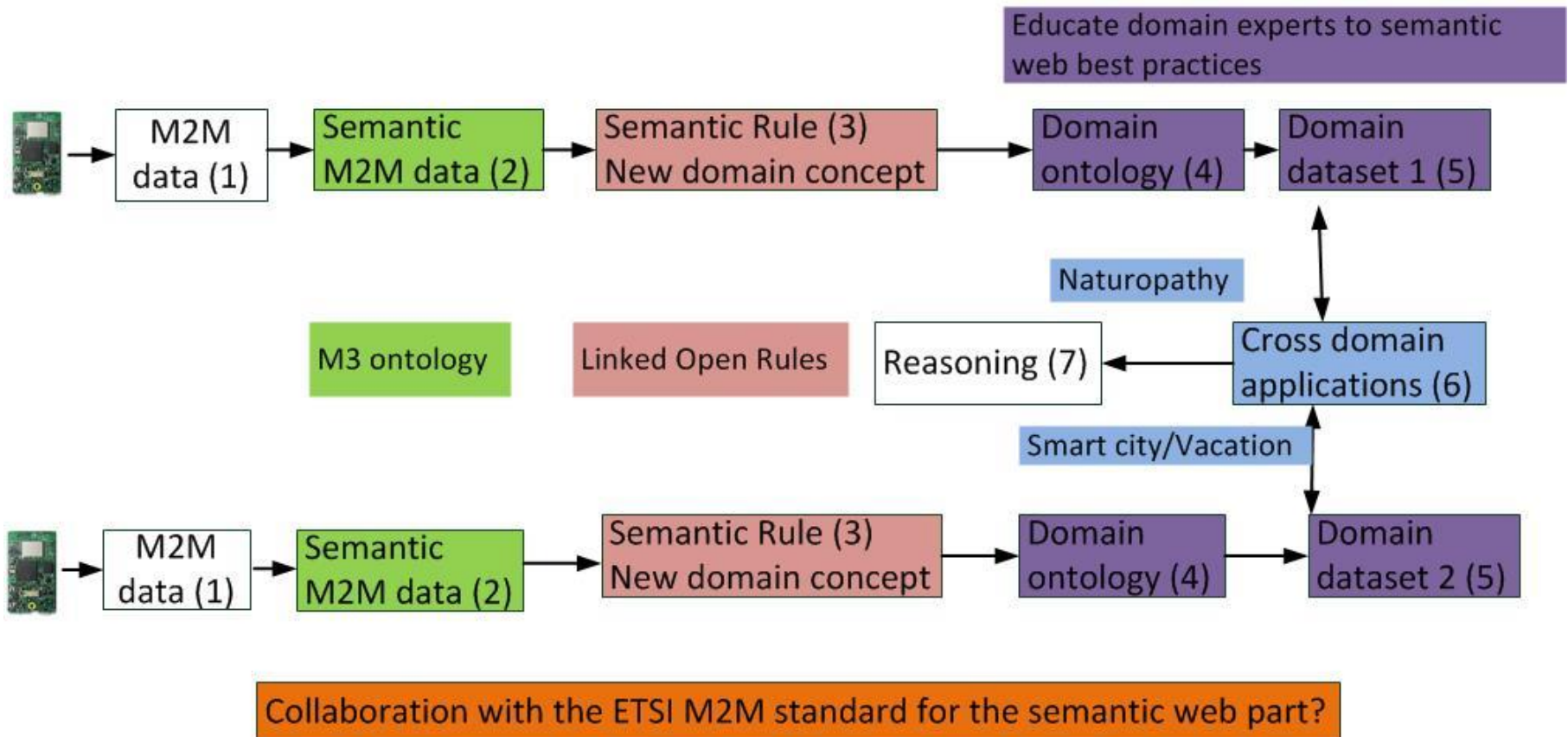
- Value = 39.0, Type = Weather Temperature, Unit = Cel, Weather = Sunny, Activity = BeachSunbathing
- Value = 39.0, Type = Weather Temperature, Unit = Cel, Weather = Sunny, Activity = BeachVolley

Weather & Emotion

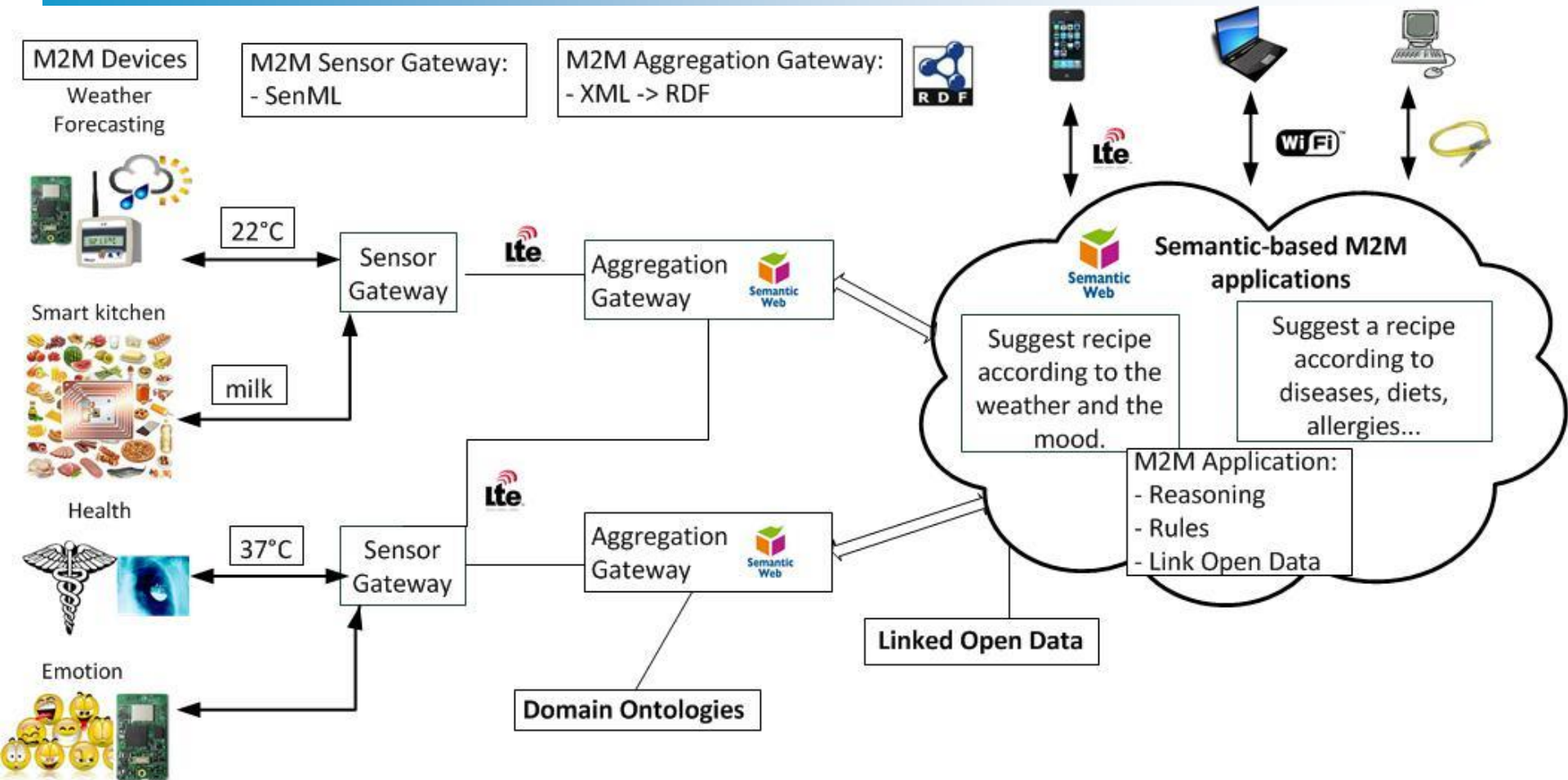
- Value = 50000.0, Type = Weather Luminosity, Unit = lx, Emotion = Joy, Color = Yellow
- Value = 50000.0, Type = Weather Luminosity, Unit = lx, Emotion = Happiness, Color = Yellow
- Value = 50000.0, Type = Weather Luminosity, Unit = lx, Emotion = Fear, Color = Yellow
- Value = 5000.0, Type = Weather 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

Contributions

- The M3 approach to enrich, combine and reason on IoT data



Semantic-based M2M Architecture



- **Paper: A Machine-to-Machine Architecture to Merge Semantic Sensor Measurements [Gyrard et al., WWW 2013]**

How to secure the M2M architecture?

- **How to secure M2M communications?**



- **How to secure M2M data?**

- Ensure privacy and access control



- **How to secure M2M applications?**

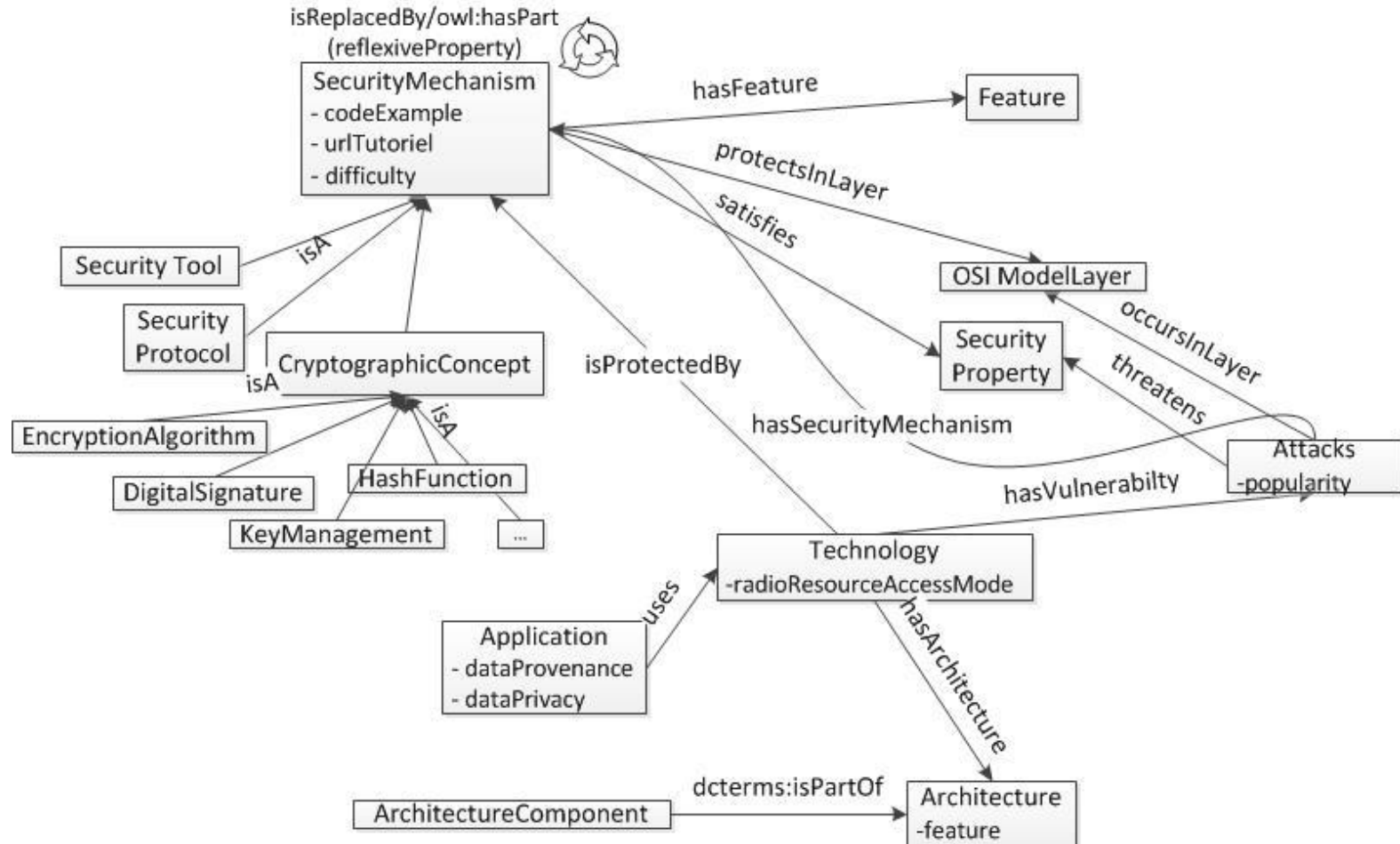
- **The STAC application (Security Toolbox: Attacks & Countermeasures)**

- STAC ontology
- STAC dataset



The STAC ontology

- <http://securitytoolbox.appspot.com/stac#>



STAC ontology & dataset



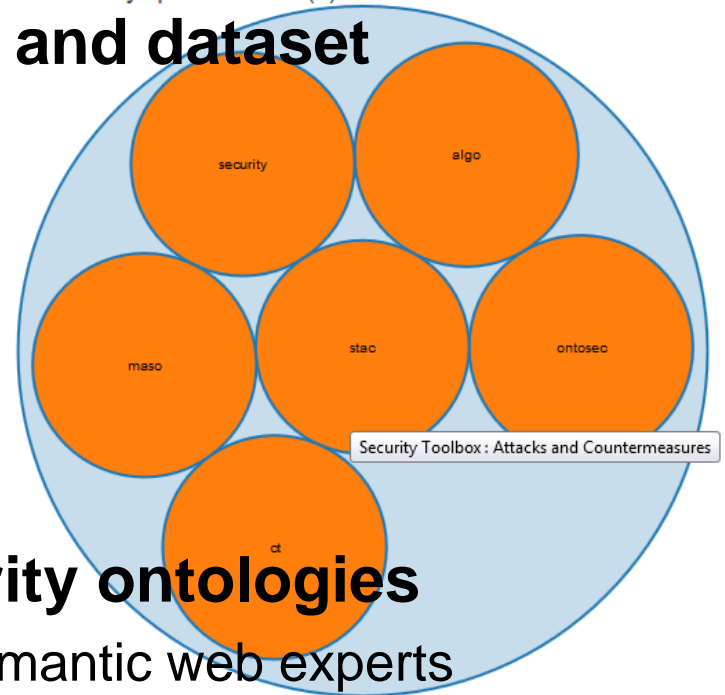
Linked Open Vocabularies (LOV)

Security - Security

Metadata:

Property	Value
is part of vocabulary space	All > Data & Systems
Description	Security Network, attacks and countermeasures

Vocabulary space content (6):



- <http://securitytoolbox.appspot.com/stac-dataset>
- **A cross-domain security ontology and dataset**
 - Security for sensor networks
 - Security for cellular networks
 - Security for web applications
 - Security for network management
- **STAC referenced on LOV**
- **Difficulties to reuse existing security ontologies**
 - Designed by security experts and not semantic web experts

The STAC application

- To help us to secure the M2M architecture
- Could be used by project managers!

The screenshot displays the STAC application interface, which is designed for configuring security measures for M2M architectures. The interface is divided into several sections, each with a title and a list of options.

Sensor Protocols

- SPINS
- Is composed Of: RC6

Sensor Attacks

- Sinkhole
- Countermeasures: Link-Layer Security Protocol (LLSP)

Sensor Key management

- Localized encryption and authentication protocol (LEAP)
- Is composed Of: Pairwise Key

Sensor Countermeasures

- Spread Spectrum Communication

Technologies used in your application?

1. Choose a technology (e.g., WiFi Technology) Wi-Fi technology (Wireless-Fidelity)
2. Attacks related to this technology: Rogue Access Point
3. Wait (1 minute!)
4. A tooltip is displayed for more information about a specific security mechanism Wi-Fi Protected Access (WPA2)
5. Click on a security mechanism (e.g., WPA2):
6. Advantages and weaknesses are displayed (Feature): Secured
7. Security properties satisfied are displayed: Authentication, Confidentiality, Integrity

<http://securitytoolbox.appspot.com/>

Conclusion & Future works

■ The M3 approach

- M3 ontology to enrich M2M data
- Combine heterogeneous M2M data
- Reason about semantic M2M data

■ M3 enables to build cross-domain M2M applications



■ A similar approach is used in the security domain

- STAC application to suggest the best security mechanism to secure M2M applications



Thank you!



- **Amelie Gyrard, Christian Bonnet and Karima Boudaoud**
A machine-to-machine architecture to merge semantic sensor measurements
WWW 2013, 22nd International World Wide Web Conference, Doctoral Consortium, May 13-17, 2013, Rio de Janeiro, Brazil
- **Amelie Gyrard, Christian Bonnet and Karima Boudaoud**
The STAC (Security Toolbox: Attacks & Countermeasures) ontology
WWW 2013, 22nd International World Wide Web Conference, Poster, May 13-17, 2013, Rio de Janeiro, Brazil
- **Amelie Gyrard, Christian Bonnet and Karima Boudaoud**
STAC: Un outil pour vous aider à sécuriser vos applications
SAR-SSI 2013, 8ème Conférence sur la Sécurité des Architectures Réseaux et des Systèmes d'Information, Poster, September 16-19, 2013, Mont De Marsan, France
- **Amelie Gyrard, Christian Bonnet and Karima Boudaoud**
An architecture to aggregate heterogeneous and semantic sensed data
ESWC 2013, 10th Extended Semantic Web Conference, PhD Symposium, May 26-30, 2013, Montpellier, France