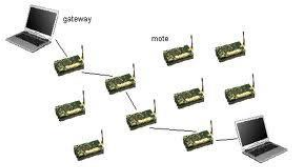
EURECOM
Sophia Antipolis



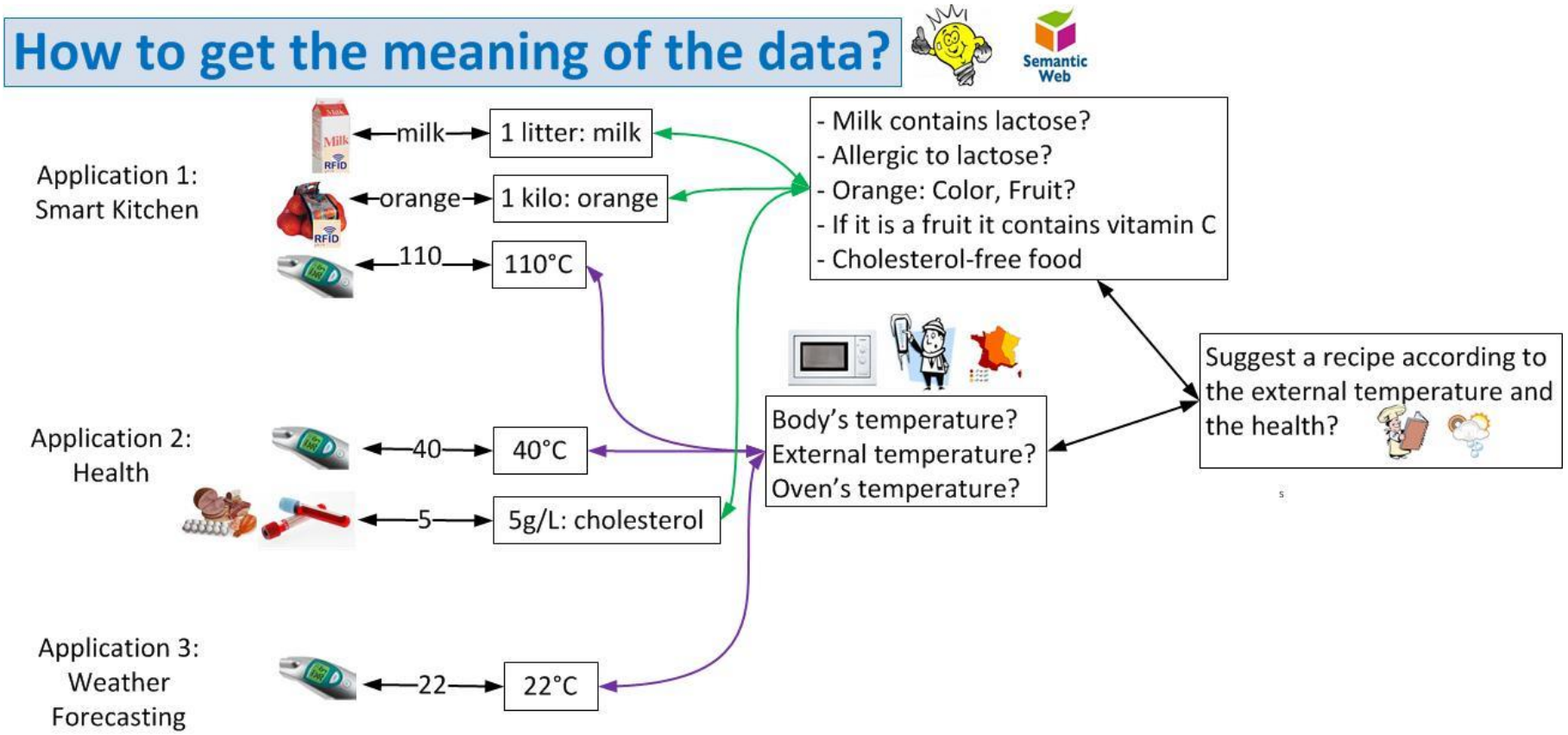
Semantic Web

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

Amelie Gyrard

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

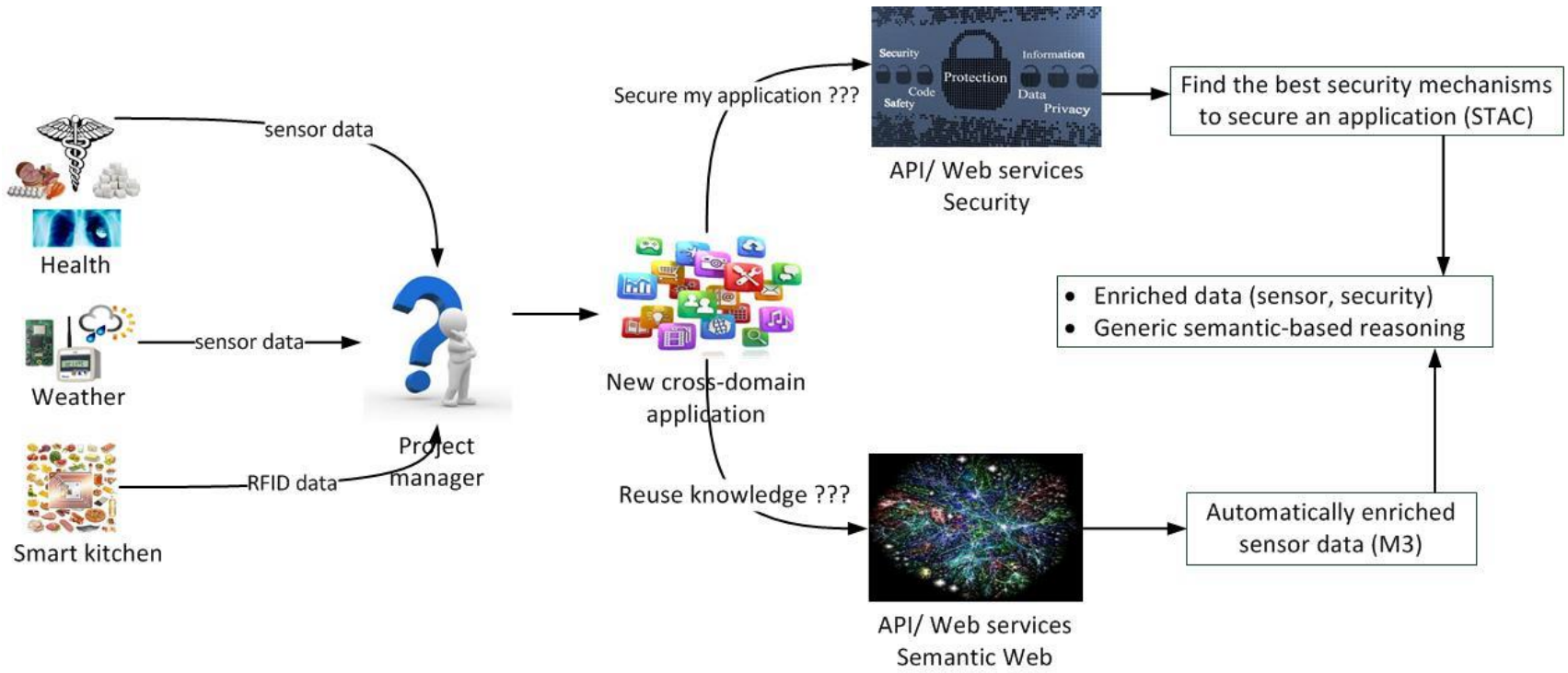
Motivation 1/2



Motivation 2/2

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

"Security by design"



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, SemsorGrid4Env

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

Contributions

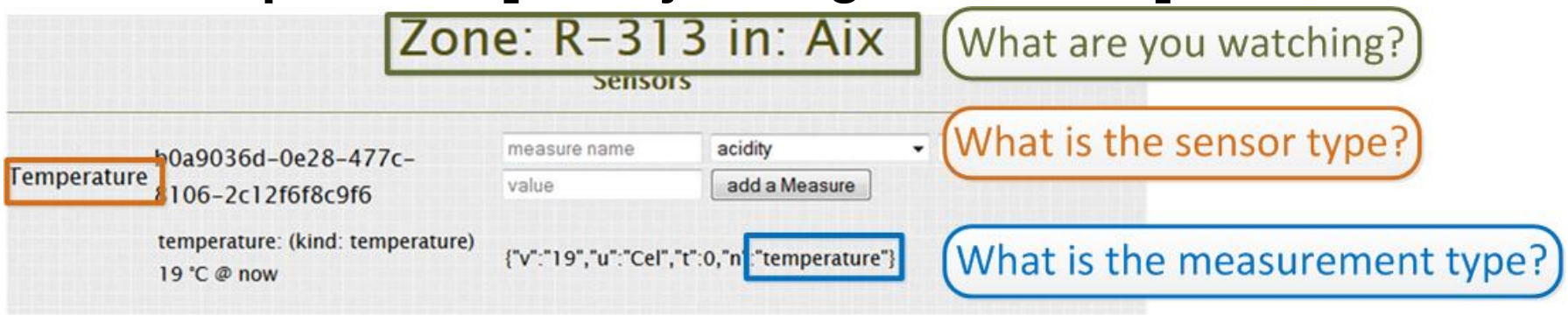
- **The M3 (Machine to Machine Measurement) approach**
  - Enrich M2M data with semantic web technologies
  - The M3 ontology: A hub for cross-domain ontologies and datasets
    - Naturopathy: weather, recipe, health, emotion
    - Smart city: weather, home automation, transport, vacation
  - LOR (Linked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



- **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!

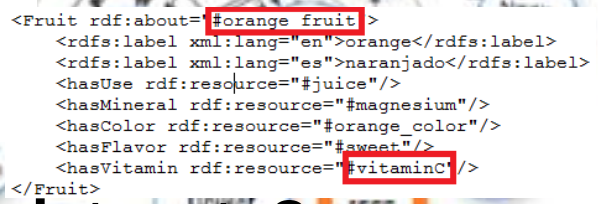
- **We propose the Linked Open Rules**
  - SPARQL CONSTRUCT
  - Semantic Web Rule Language (SWRL) rules

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

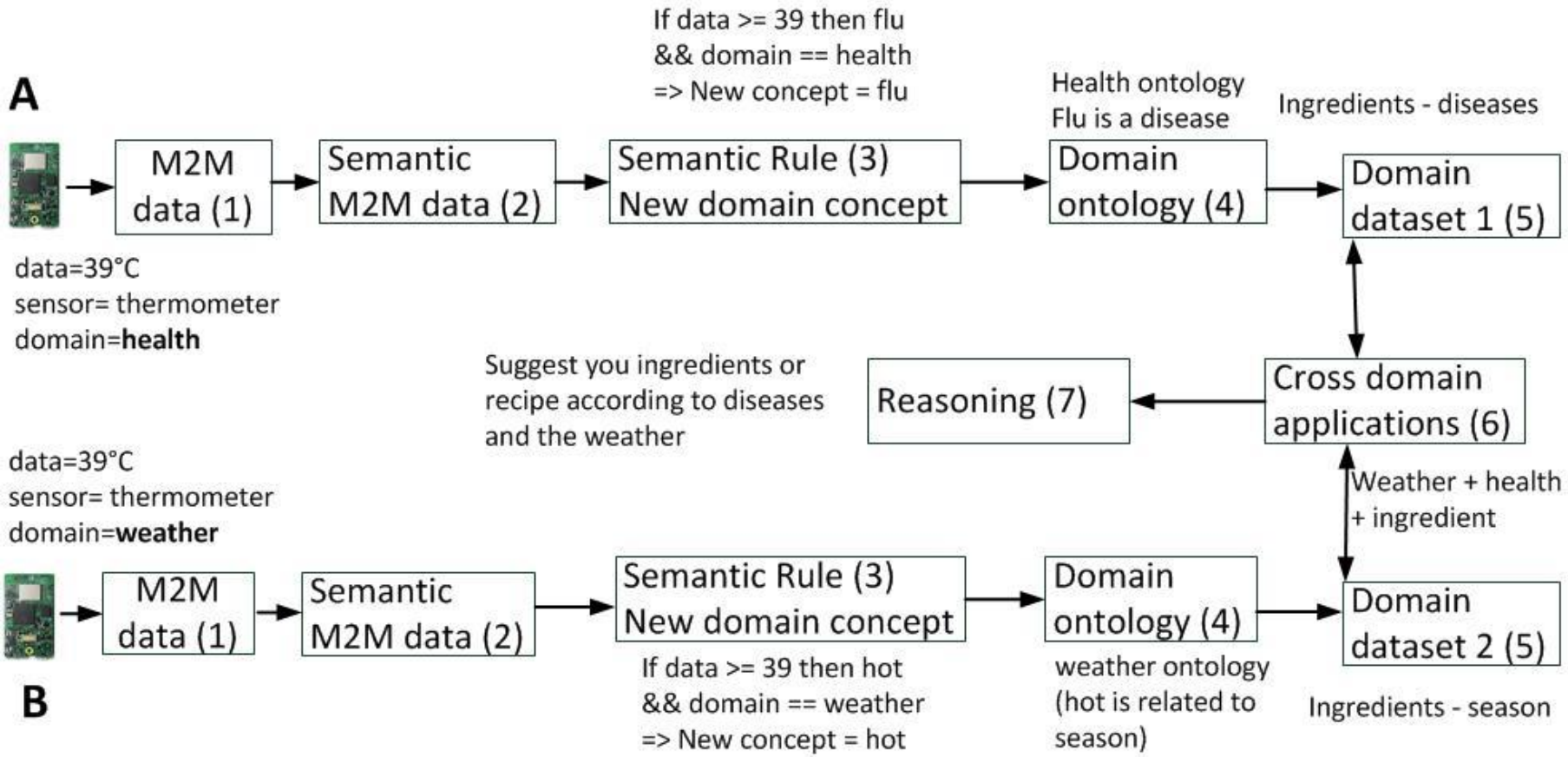
Linked Open Vocabularies (LOV)

LINKINGOPENDATA
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?

The proposed approach: M3

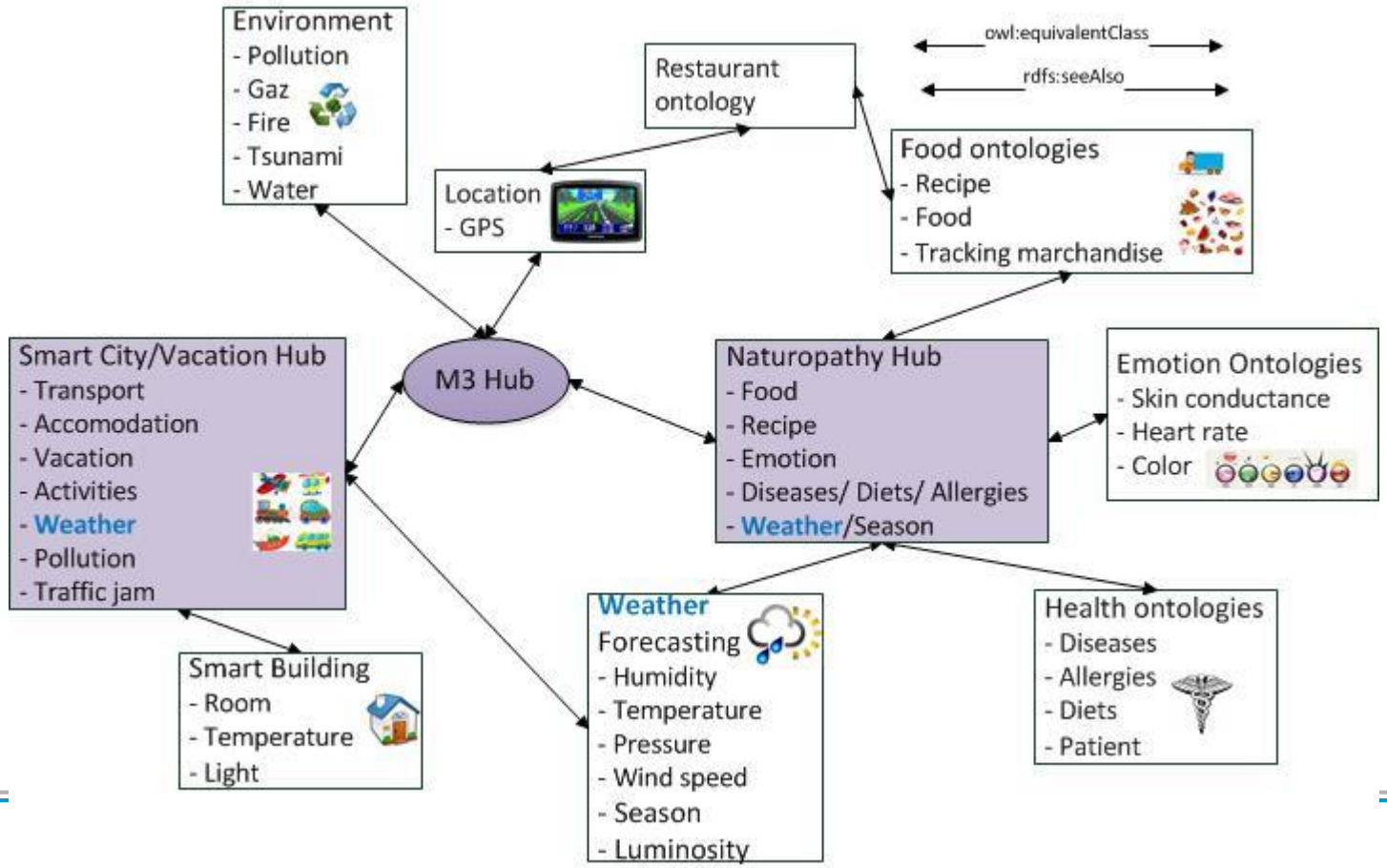
- **How to interconnect the data provided by heterogeneous domains?**



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

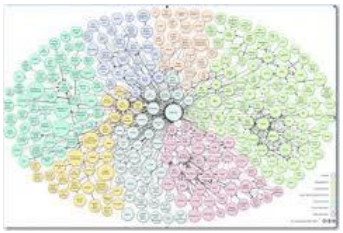
```
<rdf:Description rdf:about="http://sensormeasurement.appspot.com/m3#Measurement5">
 <m3:hasUnit rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Cel</m3:hasUnit>
 <m3:hasDateTimeValue rdf:datatype="http://www.w3.org/2001/XMLSchema#dateTime">0.0</m3:hasDateTimeValue>
 <m3:hasValue rdf:datatype="http://www.w3.org/2001/XMLSchema#decimal">39.0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

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



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

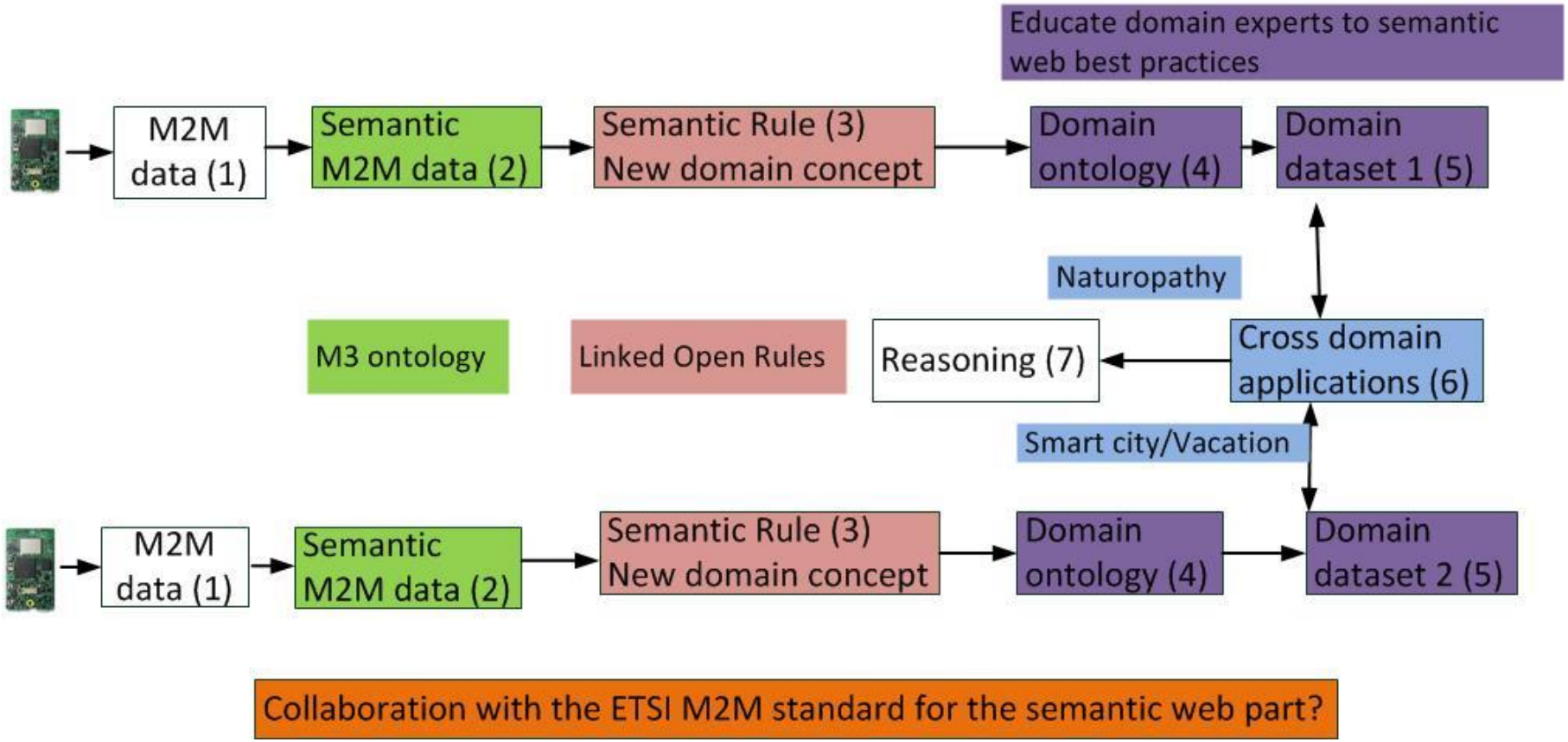
- Value = 50000.0, Type = Weather Luminosity, Unit = lx, Emotion = Joy, Color = Yellow
- Value = 50000.0, Type = Weather Luminosity, Unit = lx, Emotion = Happiness, Color = Yellow
- Value = 50000.0, Type = Weather Luminosity, Unit = lx, Emotion = Fear, Color = Yellow
- Value = 5000.0, Type = Weather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

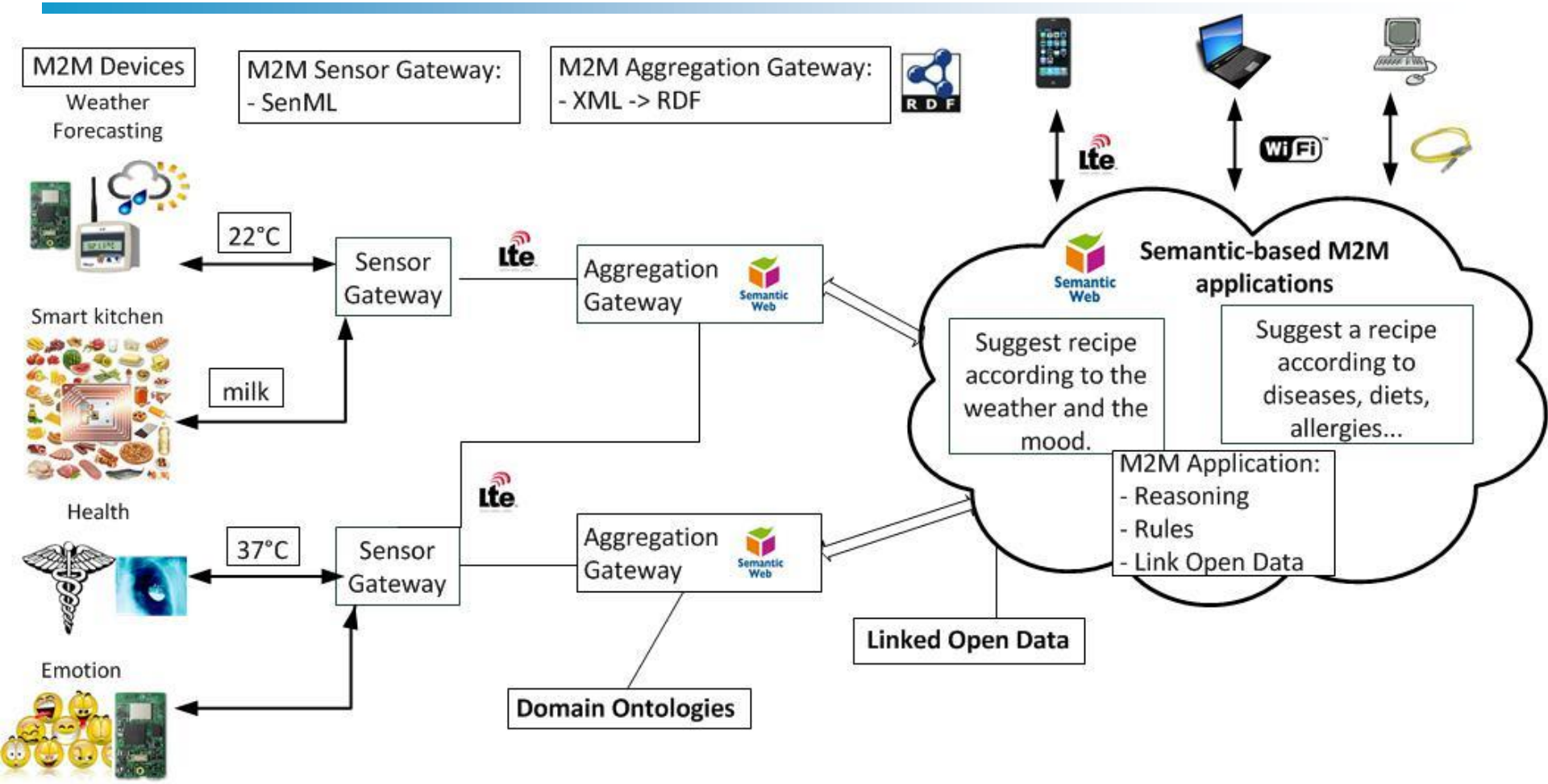
“Seasonal affective disorder”

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

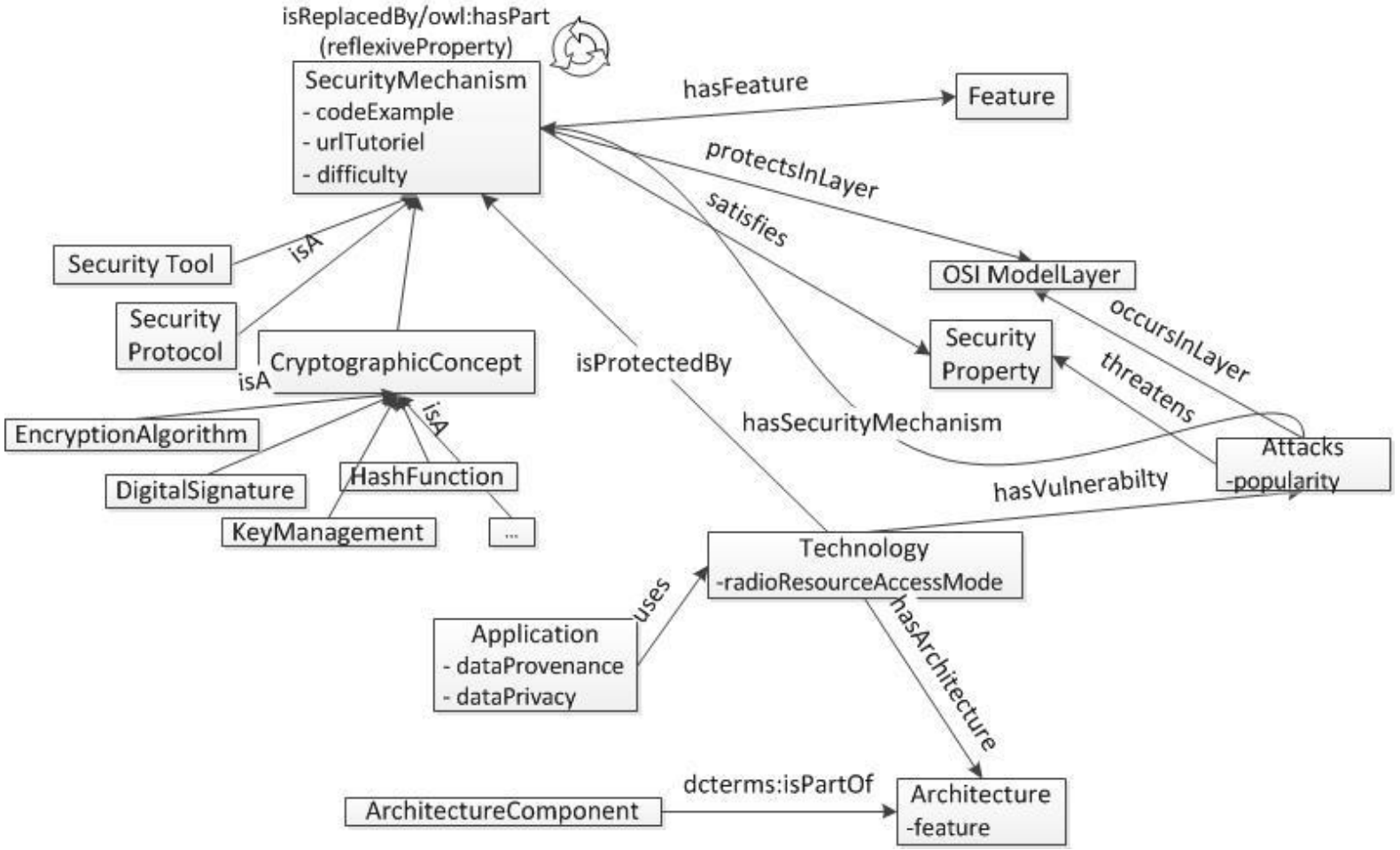
- **How to secure M2M applications?**

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

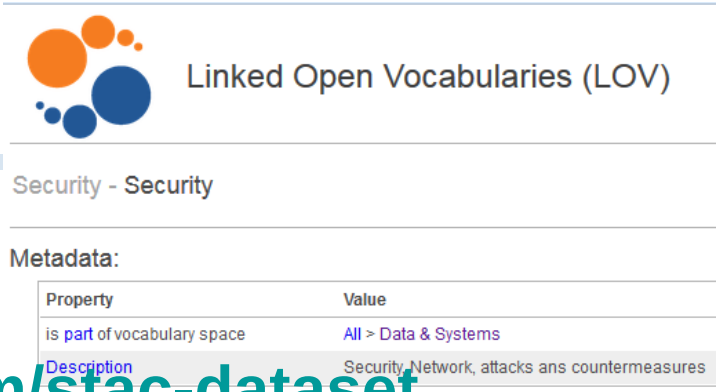
Semantic Web

The STAC ontology

- **http://securitytoolbox.appspot.com/stac#**



STAC ontology & dataset



- 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!

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