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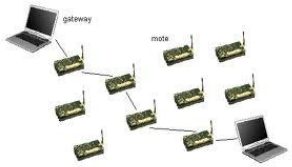


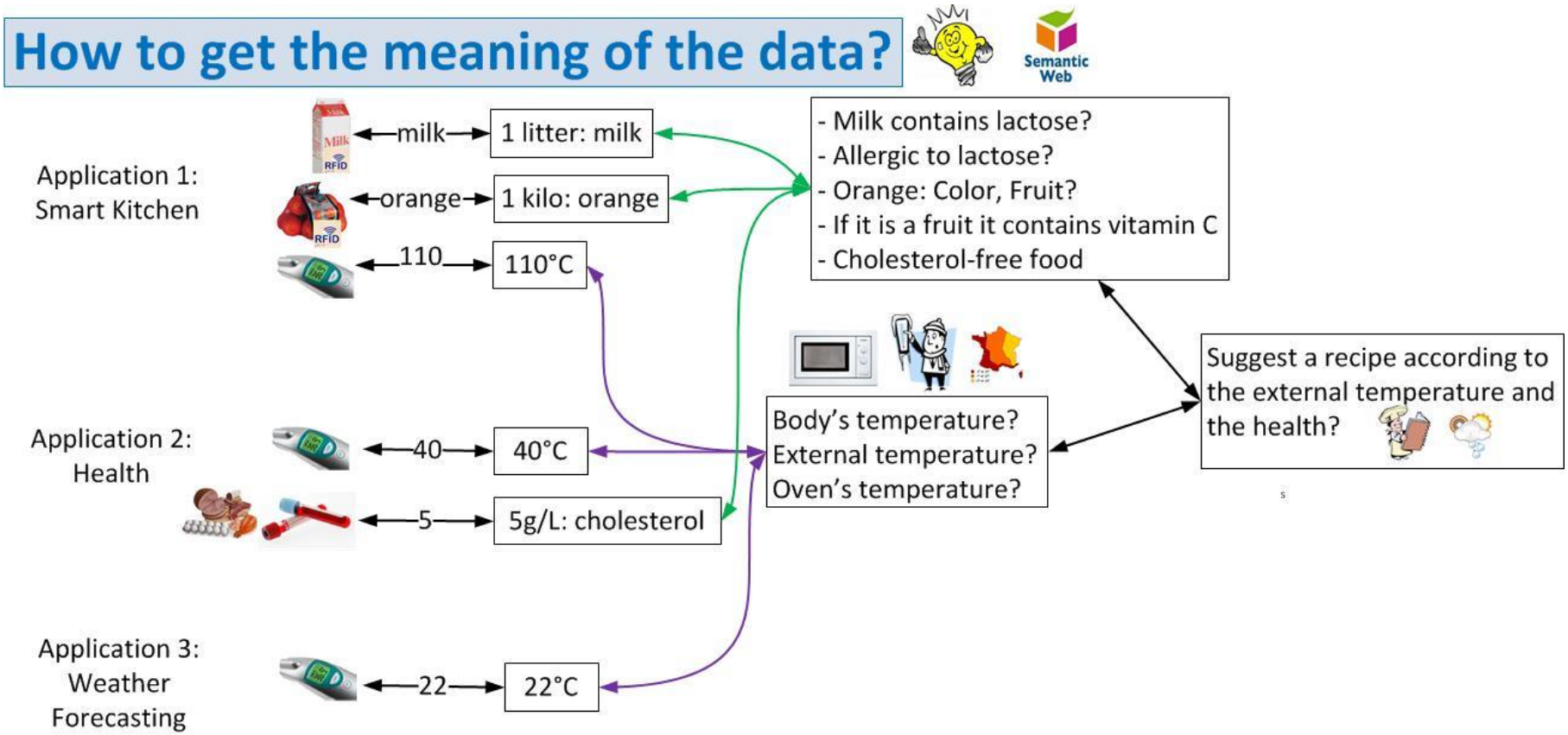
Semantic Web

Domain Knowledge Interoperability to build the Semantic Web of Things

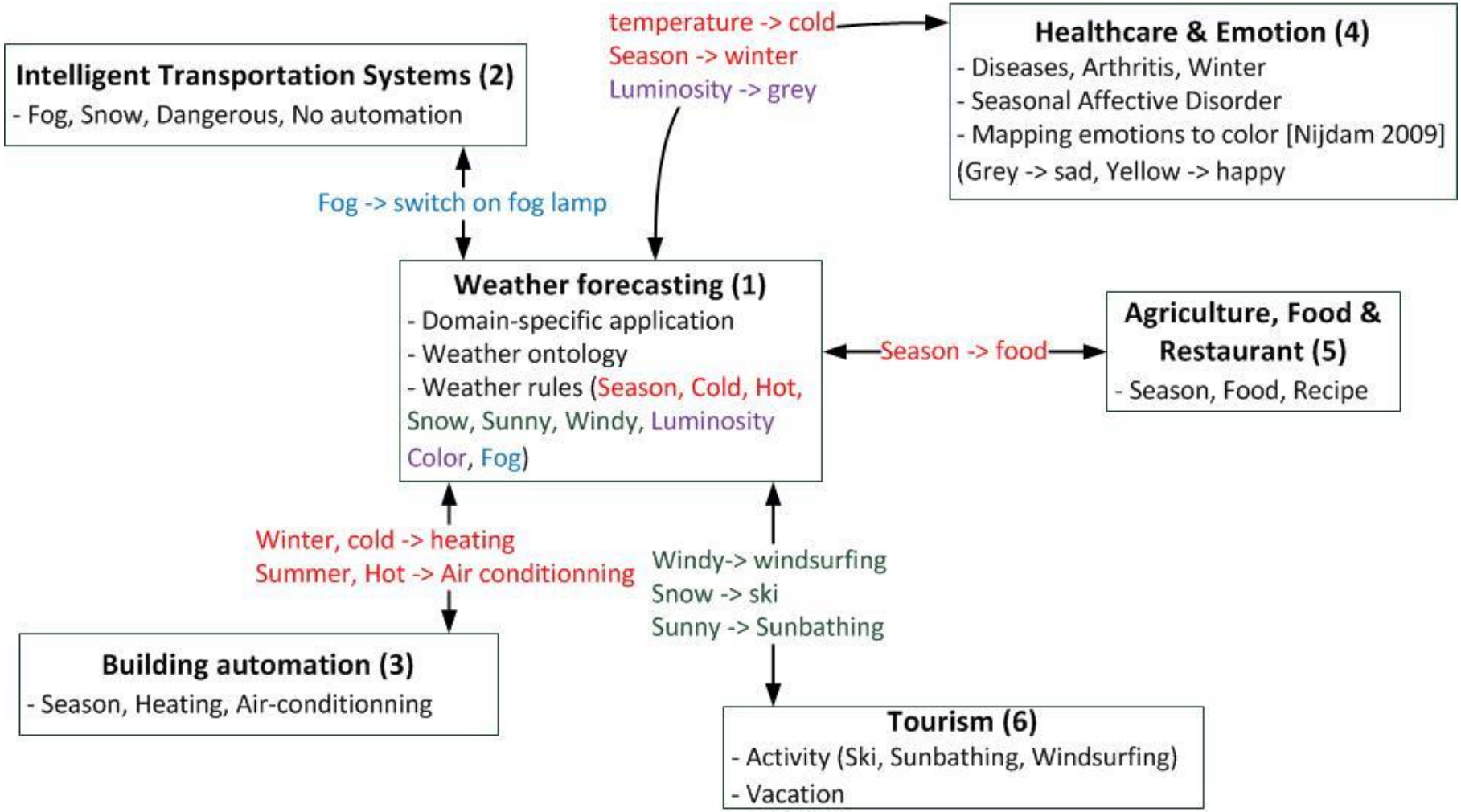
Amelie Gyrard

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

Motivation 1/2



Motivation 2/2



State of the art

- **Semantic Sensor Web [Sheth 2008], Semantic Sensor Networks:**
  - W3C SSN ontology, Sense2Web, SemsorGrid4Env, etc.
- **Semantic Web of Things: Spitfire [Pfisterer 2011]**
- **Machine-to-Machine (M2M) enables machines to communicate with each other without human intervention.**

- **Limitations:**
  - Do not reuse domain knowledge (ontologies, datasets and rules) defined by domain experts
  - Do not introduce the Linked Open Rules
  - Do not combine **disparate** domains.

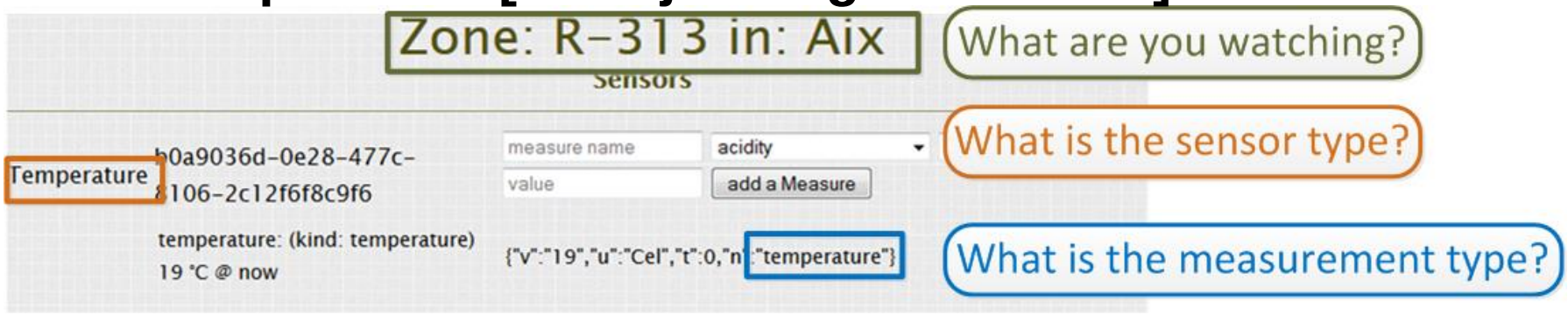
Contributions

- **The M3 (Machine to Machine Measurement) approach**
  - Enrich M2M data with semantic web technologies
  - The M3 ontology: A hub for cross-domain knowledge
    - Naturopathy: smart home (kitchen), weather, health, affective science
    - Smart tourism: weather, transportation, activities
    - STAC (security): sensor, cellular, web, mobile phone
  - LOR (Linked Open Rules): share and reuse domain rules

- **M3 integrated in a semantic-based Machine-to-Machine (M2M) architecture**
- **Prototype: http://sensormeasurement.appspot.com/**

The M3 ontology (Machine to Machine Measurement)

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



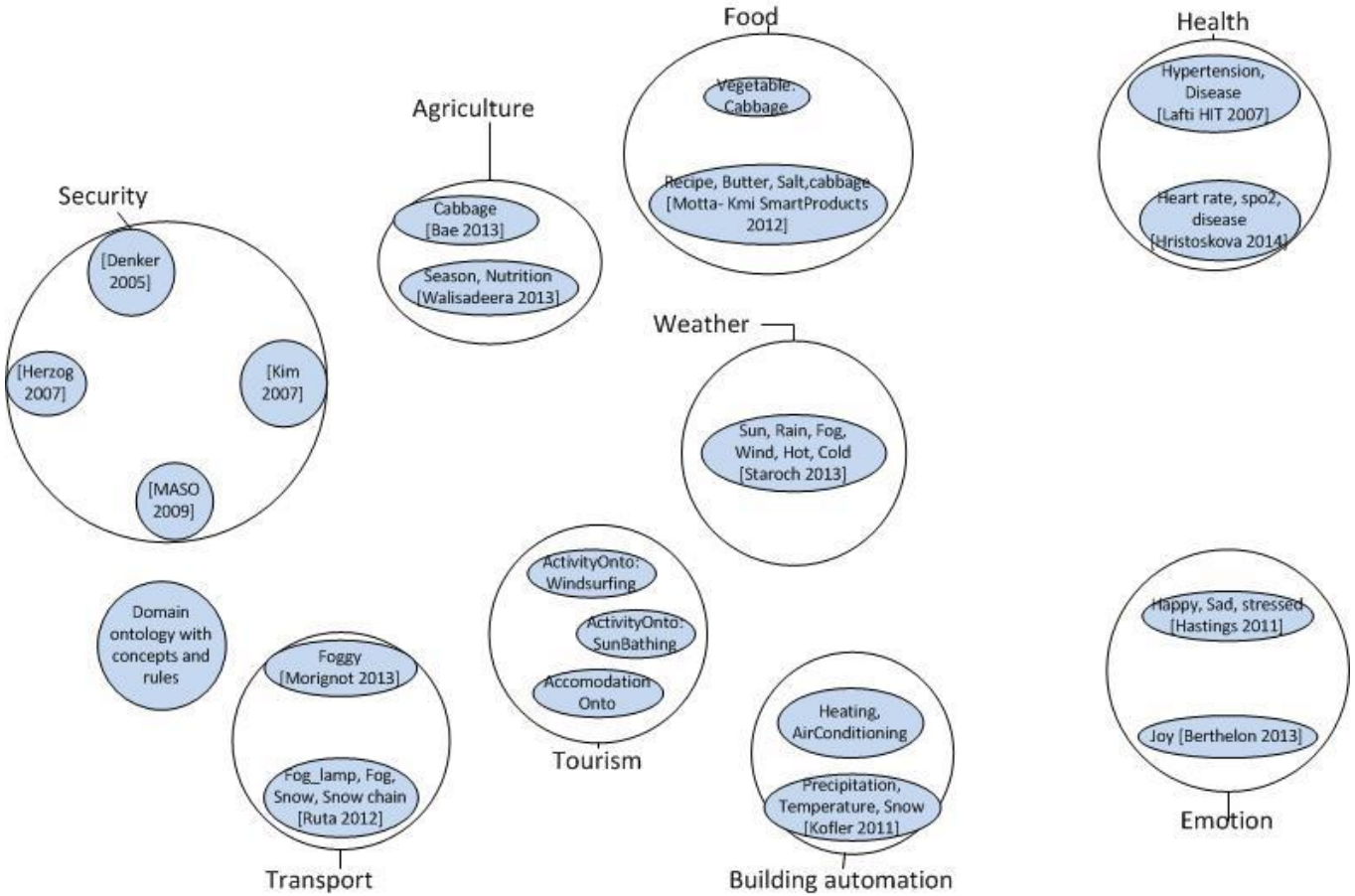
- **Extension of the W3C Semantic Sensor Networks (SSN) ontology (Observation Value concept)**
  - M3 focuses on the interoperability of the sensor data
- **Classify all the concepts in the M3 ontology**
  - **Domain** (health, smart building, weather, room, city, etc.)
  - **Measurement type** (t = temp = temperature)
  - **Sensor type** (rainfall sensor = precipitation sensor)

How to deduce new domain knowledge?

- **Rules example:**
  - If **Domain** == Health && **MeasurementType** == Temperature then NewType = **BodyTemperature**
  - If **BodyTemperature** > 38°C then "**Fever**"
  - **BodyTemperature** and **Fever** are already described in domain ontologies or datasets!
- **Reuse the domain ontologies already designed and defined by experts**
  - "**fever**" has a meaning in health ontologies
  - "**hot**" has a meaning in weather ontologies

How to reuse domain knowledge?

- **More 170 domain ontologies have already been implemented by domain experts in numerous domains**



Reference more than 170 domain ontologies

- **Domain experts are not aware of semantic web best practices! Domain ontologies are:**
  - Not published online
  - Not linked with each other (intra-domain, cross-domain)
  - Not referenced by Linked Open Vocabularies (LOV)
  - Language: English, Chinese, German, etc.
- **Encourage domain experts to publish and share online the domain ontology according to the Semantic Guidelines**
  - http://sensormeasurement.appspot.com/?p=ontologies

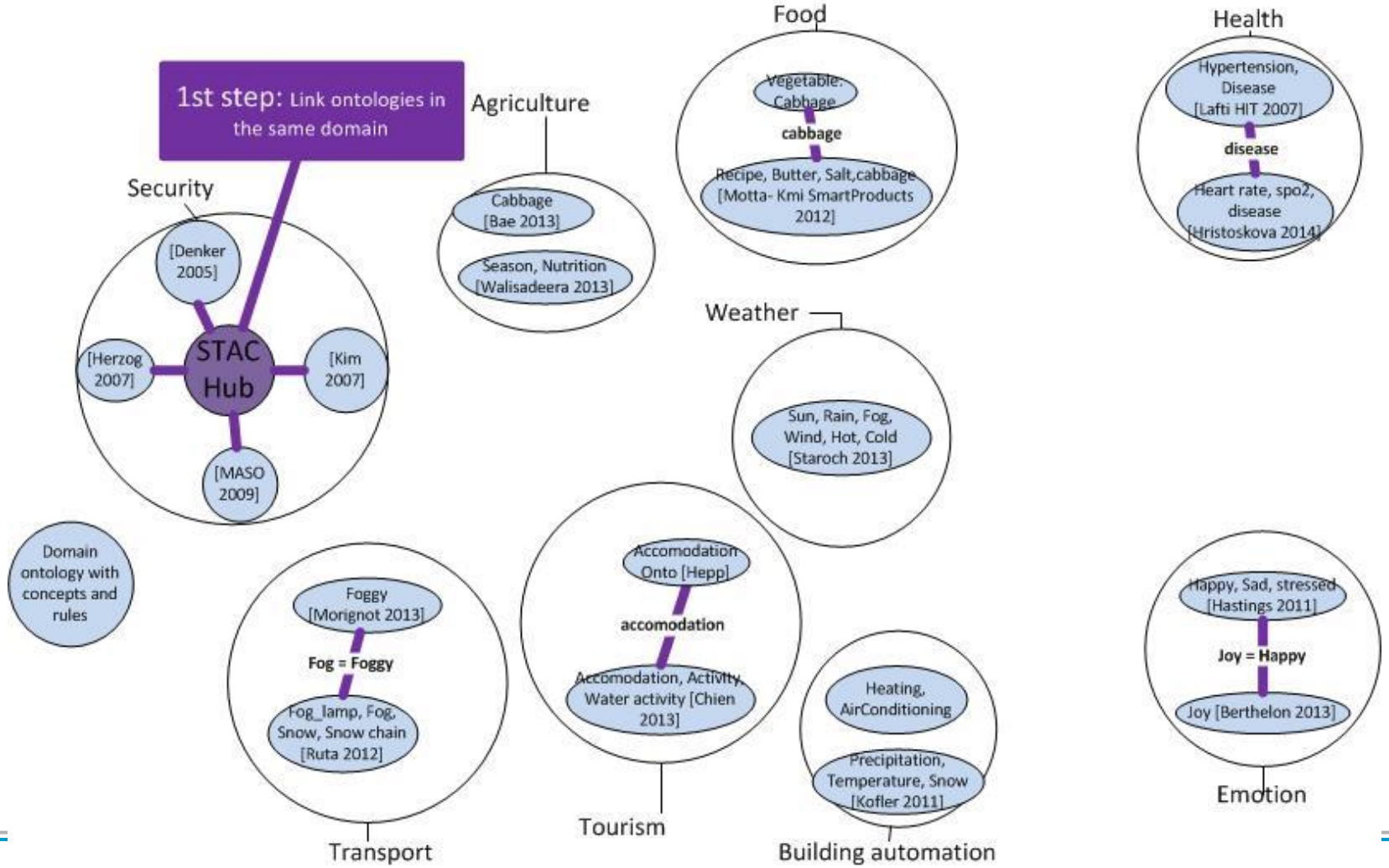
- **Various domains referenced:**
  - Smart home, eHealth, Transportation Systems
  - Weather, Tourism, Affective Science, Food, Agriculture, Security

Smart Home, Building Automation, Activities of Daily Living, Ambient Assited Living ontologies

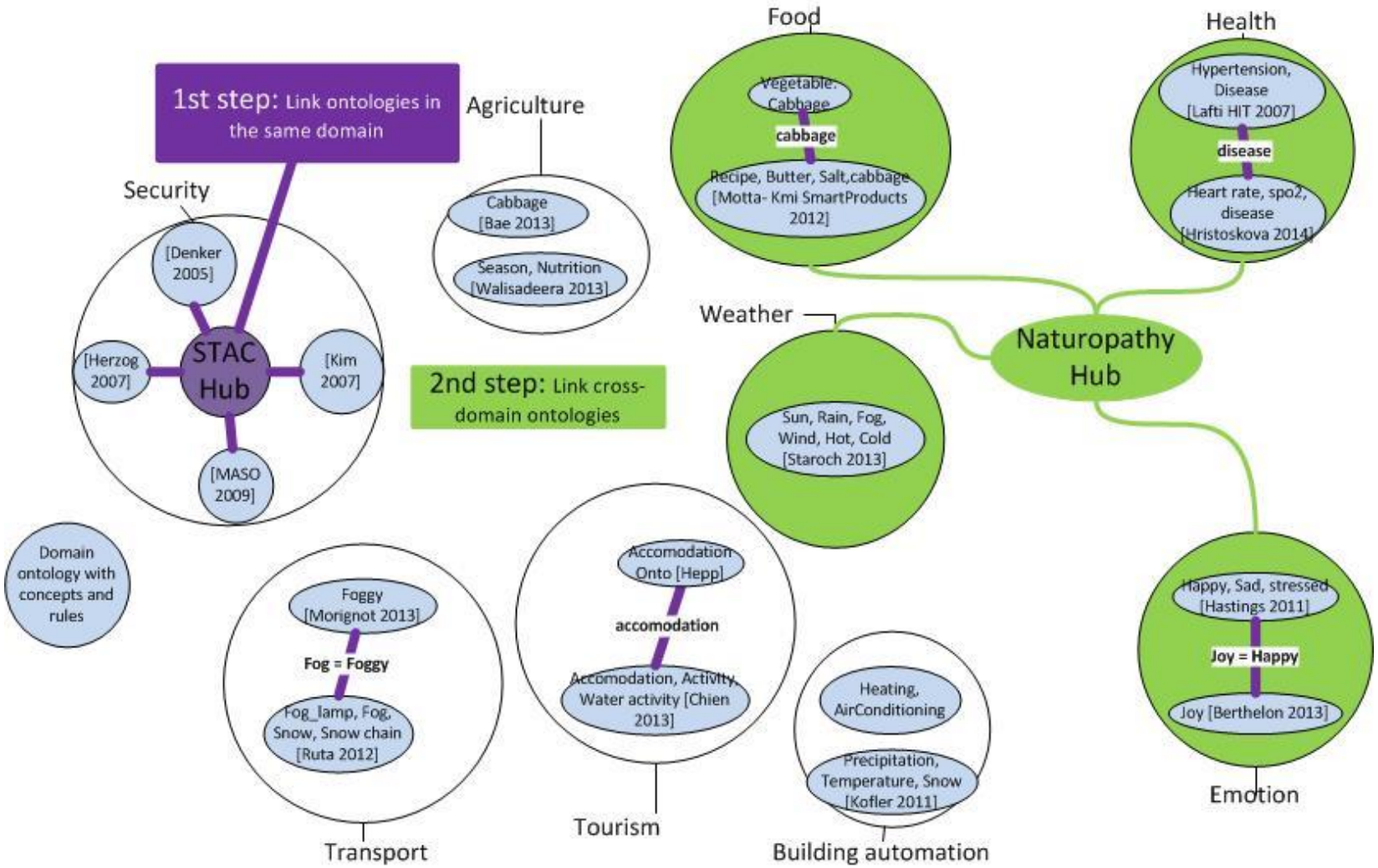
Authors	Year	Paper	Url onto	Technologies	Sensors	Rules
De paola Mail: 05/02/14, 25/02/14	2014	Book Chapter: An ontology-based autonomic system for ambient intelligence scenarios	??? Ontology URL ??? Concepts: Sensor, Actuator, Device, Closed, RoomOccupancy	SWRL, JESS	Light, Sound, pressure, temperature, humidity, door (close/open)	
Park et al Mail: 17/02/14, Response: 20/02/14	2013	Paper: A feedback-based approach to validate swrl rules for developing situation-aware software	Cannot share the code (research regulation). Concepts: fire	SWRL	temperature, humidity, c02	rule (age -> adult, fire, temp too hight, humidity too low)
Nguyen, Raspitzu et al. Mail: 24/02/14, Response: 26/02/14, 26/02/14	2013	Paper: Ontology-based office activity recognition with applications for energy savings.	??? Ontology URL ??? Concepts: working room (PC), meeting room (presentation), coffee corner (having coffee, having lunch)	Protege, Hermit, Java API	Acoustic, pressure, PIR (Passive Infrared)	
Kofler et al. - ThinkHome	2011	Paper: Thinkhome energy efficiency in future smart homes 2011 Paper: A semantic representation of energy-related information in future smart homes	Ontology URL Concepts: Weather(rain, hail, sleet, snow, thunder, sun cloud, fog) Onto + Dataset + rules	Pellet	Occupancy sensor, temperature, humidity, lighting, ventilation, solar panel, wind turbine, actuator (heating, washing machine, dishwasher, window)	Rules owl restrictions ontology

Intra-Domain Interoperability

- **Link ontologies (owl:EquivalentClass, owl:SameAs)**

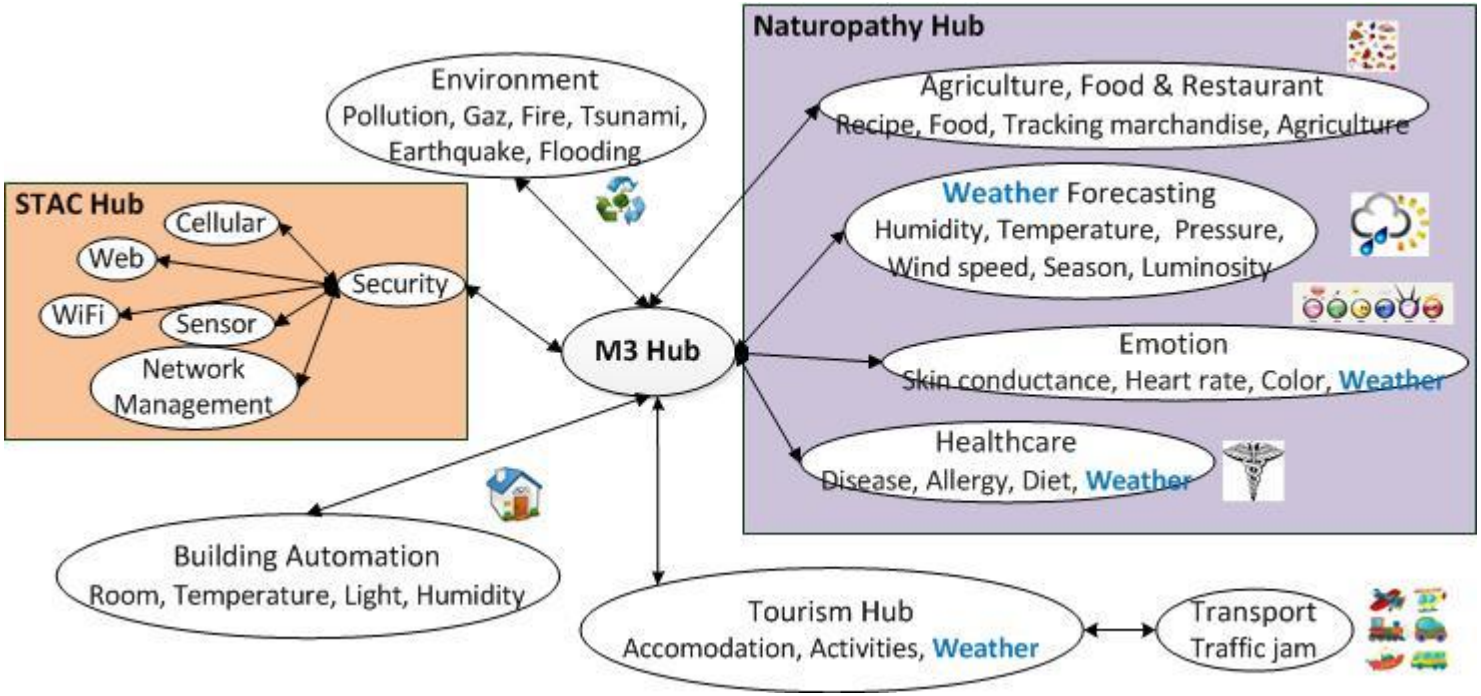


Cross-Domain Interoperability



M3: a hub for cross-domain knowledge

- **The M3 approach**
  - Enrich M2M data
  - Reason about semantic M2M data
  - A hub for cross-domain knowledge

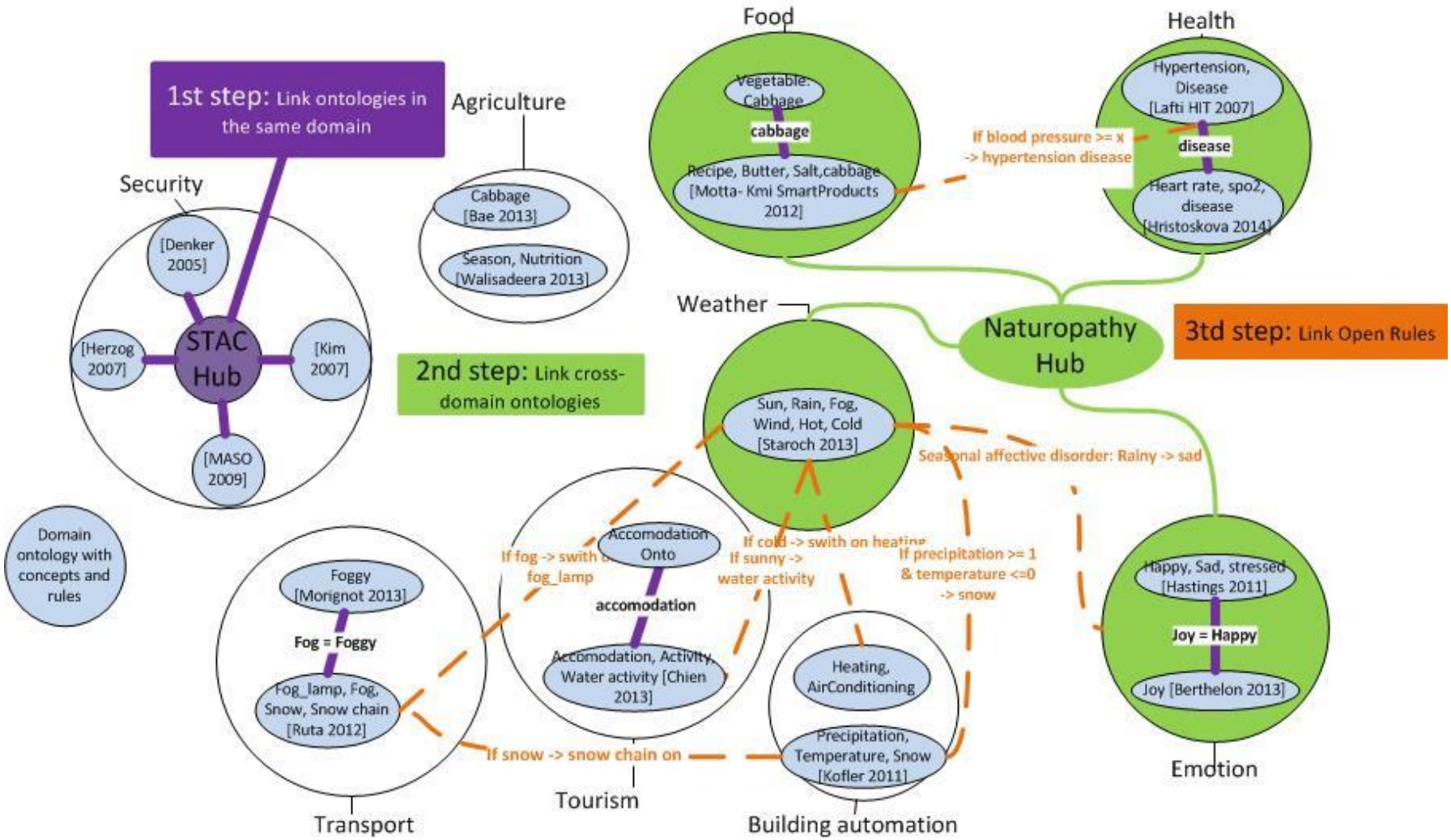


Rule Interoperability (Linked Open Rules)

- **Combine Weather & Smart Home**
  - If external temperature < 15°C then cold (weather)
  - If cold -> switch on heating (smart home)

- **Combine Weather & Transport**
  - If temperature <=0°C && precipitation > 0mm then snowy (weather)
  - If snowy -> switch on the snow chain (transport)
- **Semantic Web experts design the SPARQL Inference Notation (SPIN) W3C Recommendation**
- **Domain experts use Semantic Web Rule Language (SWRL)**
  - Implemented differently according to the software used
    - More than 7 various implementations
  - http://sensormeasurement.appspot.com/index.html?p=rule

Rule Interoperability (Linked Open Rules)



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

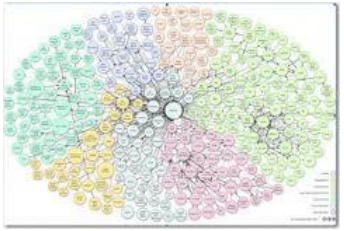
```
<rdf:Description rdf:about="http://sensormeasurement.appspot.com/m3#Measurement5">
 <m3:hasUnit rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Cel</m3:hasUnit>
 <m3:hasDateTimeValue rdf:datatype="http://www.w3.org/2001/XMLSchema#dateTime">0.0</m3:hasDateTimeValue>
 <m3:hasValue rdf:datatype="http://www.w3.org/2001/XMLSchema#decimal">39.0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

Linked Open Data

- 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



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

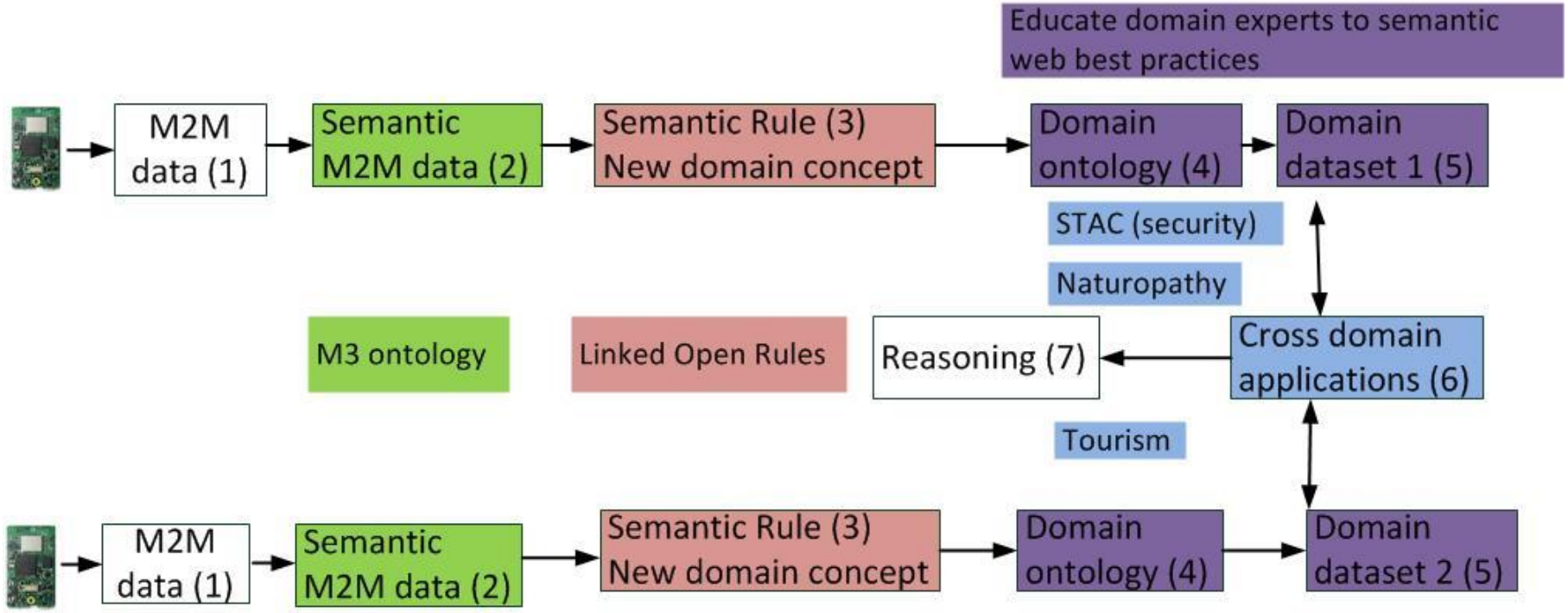
- Value = 50000.0, Type = Weather Luminosity, Unit = lx, Emotion = Joy, Color = Yellow
- Value = 50000.0 Type = Weather Luminosity, Unit = lx, Emotion = Happiness, Color = Yellow
- Value = 50000.0, Type = Weather Luminosity, Unit = lx, Emotion = Fear, Color = Yellow
- Value = 5000.0, Type = Weather Luminosity,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

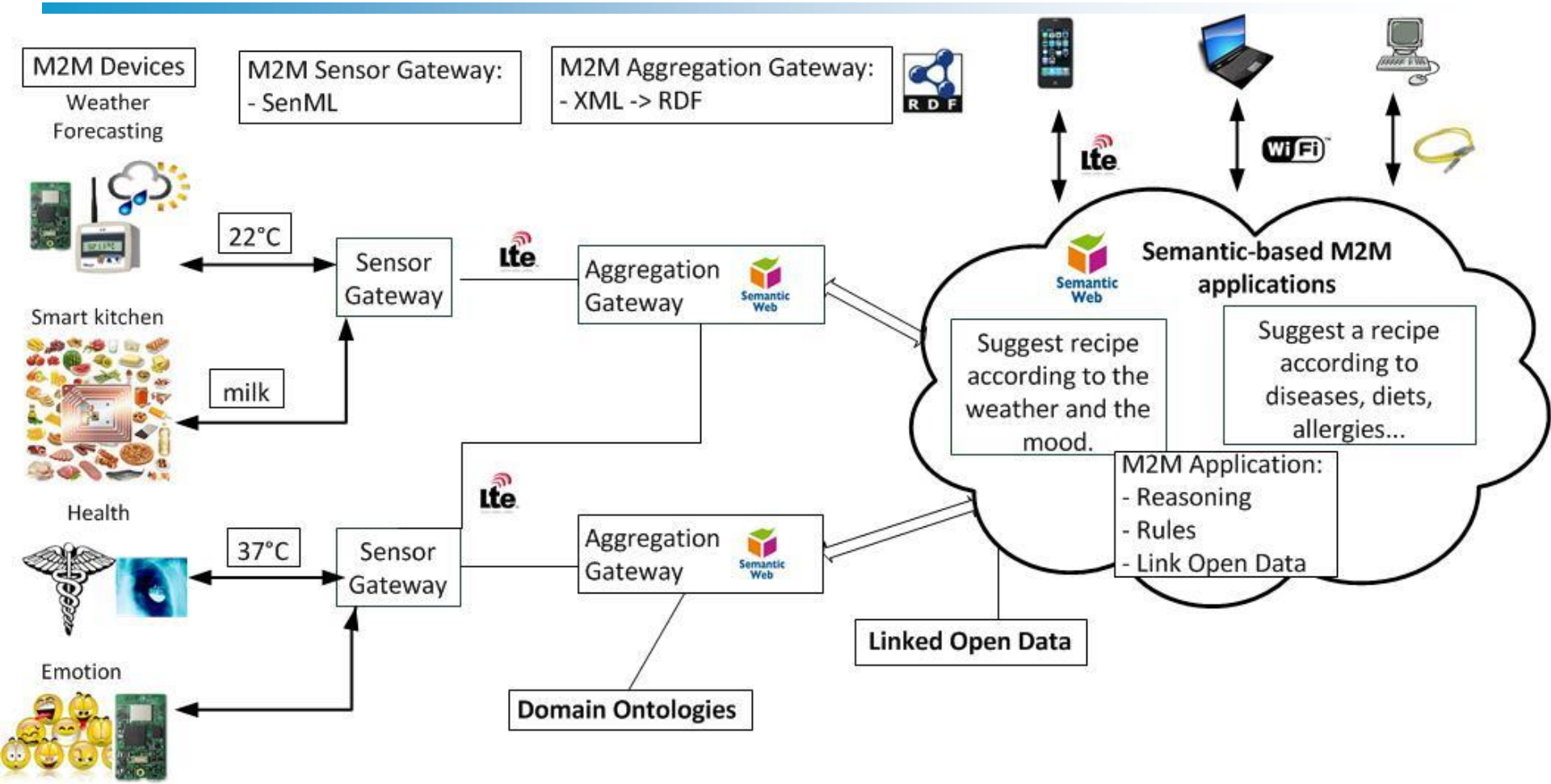
“Seasonal affective disorder”

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]**

Conclusion & Future works

- **The M3 approach**
  - M3 ontology to enrich M2M data
  - Reason about semantic M2M data
  - Combine cross-domain 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!

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- http://sensormeasurement.appspot.com/