An ontology to semantically annotate the M2M data

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Motivation

- Enrich M2M data to build cross-domain M2M applications

How to get the meaning of the data?

Application 1: Smart Kitchen
- Milk → 1 litter: milk
- Orange → 1 kilo: orange
- 110°C

Application 2: Health
- 40°C
- 5 g/L: cholesterol

Application 3: Weather Forecasting
- 22°C

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

Body’s temperature?
External temperature?
Oven’s temperature?

Suggest a recipe according to the external temperature and the health?
How to get M2M data?

- **Get M2M data:**
  - E.g.: temperature, food, blood glucose level
  - Sensor Web Enablement (SWE)
  - SenML protocol [draft-jennings-senml-10]
  - Semantic Sensor Networks ontology (SSN)
The M3 ontology (Machine to Machine Measurement)

- Extension of the W3C SSN ontology to explicitly describe the 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 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!
What is the meaning of the new measurement type?

- 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?
  - In a specific domain, which ontology or dataset do we choose?
  - How to use the complementarity of existing ontologies and datasets?
M3: our proposed approach

How to interconnect the data provided by heterogeneous domains?

- **A**
  - M2M data (1) → Semantic M2M data (2) → Semantic Rule (3) → New domain concept → Health ontology (4) → Domain dataset 1 (5)
  - If data >= 39 then flu & domain == health ⇒ New concept = flu
  - Health ontology: Flu is a disease
  - Ingredients - diseases
  - Reasoning (7)
  - Cross domain applications (6)
  - Suggest you ingredients or recipe according to diseases and the weather

- **B**
  - M2M data (1) → Semantic M2M data (2) → Semantic Rule (3) → New domain concept → Weather ontology (4) → Domain dataset 2 (5)
  - If data >= 39 then hot & domain == weather ⇒ New concept = hot
  - Weather ontology: hot is related to season
  - Ingredients - season
M3: a hub for cross-domain ontologies and datasets

- We propose M3 as a hub for cross-domain ontologies and datasets
Find the dataset corresponding to the domain ontology

- Reuse the knowledge bases already designed and defined by experts
- Link semantic M2M measurements to:
  - Linked Open data
Combine cross-domain datasets?

- Existing domain datasets:
  - Naturopathy (weather & ingredient & recipe & emotion & color)
  - Vacation & Weather

- We propose cross-domain datasets
  - Naturopathy (weather & ingredient & recipe & emotion & color)
  - Vacation & Weather

- New M2M cross-domain applications
  - Suggest you a recipe according to user’s diseases, diets, allergies, the weather, the mood!
  - Suggest activities according to the weather
  - …
Scenario 1: Body Temperature Convert into semantic measurements (M3 ontology)

- A first prototype to validate the M3 approach
  - http://sensormeasurement.appspot.com/
- Infer a new type

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):
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!)

`<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:hasDate_TimeValue rdf:datatype="http://www.w3.org/2001/XMLSchema#dateTime">0.0</m3:hasDate_TimeValue><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#BodyTemperature"/>
</rdf:Description>`
Scenario 1: Body Temperature
Enrich Semantic M2M Data

- Link our semantic M2M measurements to the Linked Open Data
- Naturopathy dataset: a cross-domain dataset

Find food recommended when you are sick

1. SenML API (Simulate M2M measurements): Simulate temperature measurements
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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!)

- 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

Scenario 2: Weather Temperature

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 = Beach Sunbathing
- Value = 39.0, Type = Weather Temperature, Unit = Cel, Weather = Sunny, Activity = Beach Volley
Semantic-based M2M Architecture

- M2M Devices: Weather Forecasting
- M2M Sensor Gateway: SenML
- M2M Aggregation Gateway: XML -> RDF

Smart kitchen
Smart home
Health
Emotion

Sensor Gateway
Aggregation Gateway
Domain Ontologies
Linked Open Data

22°C
milk
37°C

Semantic-based M2M applications
Suggest recipe according to the weather and the mood.
Suggest a recipe according to diseases, diets, allergies...

M2M Application: Reasoning, Rules, Link Open Data

Conclusion & Future works

- The M3 approach to combine heterogeneous M2M data and reason on them
- M3 to build cross-domain applications
- STAC (Security Toolbox: Attacks & Countermeasures)
  - Help developers to design secure M2M applications
  - http://securitytoolbox.appspot.com/
Thank you!