



Semantic Annotator to unify sensor data by designing a nomenclature/dictionnary/language

Creator	Dr. Amelie Gyrard (Bio: http://wiki.aiisc.ai/index.php/AmelieGyrard) Institutes: • Trialog, Paris, France 2020-Onwards • Previously (Kno.e.sis - Ohio Center of Excellence in Knowledge-enabled Computing Wright State University, Ohio, USA) 2018-2019 • Previously (Ecole des Mines de Saint-Etienne, France) 2017 • Previously (Insight - NUIG/DERI, Galway, Ireland) 2015-2016 • Previously (Eurecom, Sophia antipolis, France) 2012-2015 Designed and implemented by Amélie Gyrard, she was a PhD student at Eurecom under the supervision of Prof. Christian Bonnet and Dr. Karima Boudaoud. The M3 language/dictionary/nomenclature and its Semantic Annotator is still maintained (2020-2012). She also was a post-doc researcher at Insight within the IoT unit led by Dr. Martin Serrano. She was highly involved in the FIESTA-IoT (Federated Interoperable Semantic IoT/Cloud Testbeds and Applications) H2020 project.
Contributors	Thanks to Pankesh Patel for fruitful questions and numerous questions ☺
Donation	If you are using this document, please help us: http://sensormeasurement.appspot.com/?p=help_us Donate to use via Paypal: https://www.paypal.com/pools/c/8prmfYbOne
Send Feedback	Do not hesitate to ask for help or give us feedback, advices to improve our tools or documentations, fix bugs and make them more user-friendly and convenient:
& Contact us	https://groups.google.com/d/forum/m3-semantic-web-of-things Follow us on social networks: http://sensormeasurement.appspot.com/?p=socialNetworks
Last updated	2022 Agriculture • Agriculture sensors: nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, boron, iron, manganese, zinc copper, molybdenum, sodium, chlorine, lithium. December-November-October-September 2020 • Table weather refined – linked to SAREF and limitations • Automotive domain table updated – compliance with SAREF • Home domain table updated – compliance with SAREF • Energy domain table updated – compliance with SAREF • Matching with W3C Web of Things – Thing Description (TD) ontology - ONGOING • Matching with iotschema.org – ONGOING

	• Air quality scenario improved • Waste management domain August 2020 • Emotion table July 2020 • Links added to mention IEC 61360 - Common Data Dictionary • Units for energy topics refined June 2020 • Agriculture domain • Air quality • Energy domain • Robotic domain • Manufacturing and industry domain • City domain • Water domain • Activity domain • Emotion domain • The implementation of this documentation is done within the M3 ontology which is frequently updated: http://sensormeasurement.appspot.com/?p=m3 • Download ontology code: http://sensormeasurement.appspot.com/m3# Note: Check this demo which will be more often updated and uses the M3 ontology: http://linkedopenreasoning.appspot.com/?p=slorv2 July 2016 • Why M3 ontology, Why SSN is not sufficient (Pankesh's question) June 2016 • Add semantic annotator • Add M3 ontology March 2016 • Check actuators and RFID with M3 ontology
Created	2015 (Documentation). But the project started in 2012.
Status	 Work in progress
Goal	We propose to use common terms to describe sensors, measurements, actuators and domains. Of course, we should improve it all together. This work synthetizes all concepts found in existing ontologies or projects related to Internet of Things (IoT) and are implemented in the M3 ontology to unify sensor measures/ IoT data. This step is essential to define interoperable/unified rules to interpret sensor measures. The M3 nomenclature defines a unified data model for the Internet of Things and is an extension of the W3C SSN ontology.

	The M3 taxonomy describes sensor names, measurement names, units and IoT applicative domains. This is a kind of dictionary for IoT to easily deal with synonyms, etc. This M3 taxonomy is implemented as an ontology extending W3C SSN ontology. The M3 ontology is a cornerstone component to semantically annotate data and extract meaningful information from IoT/sensor data. This documentation also enables understanding the Semantic Annotator: • A nomenclature/language/dictionary to unify terms to describe sensor data • A semantic annotator to unify databased on semantic web technologies (RDF) • Web services to query the M3 ontology
Caption	Rows in green, compliant with: • M3 ontology • Linked Open Rules • IoT application template Rows in white or red (to finish)
Definitions	• Correctness means that are no incompatibility with other rules. • Completeness means that all sensor values are covered by an high level information.
Links	• M3 Web site: http://www.sensormeasurement.appspot.com/ • NS_M3 = http://sensormeasurement.appspot.com/m3# • SenML language: http://www.ietf.org/archive/id/draft-jennings-senml-10.txt • LOV4IoT: • http://www.sensormeasurement.appspot.com/?p=ontologies
This work has been extended for FIESTA-IoT EU project	This M3 taxonomy has been reused and refactor for the FIESTA-IoT EU project • Refactored • Aligned with other ontologies such as IoT-lite, QU-rec-20, etc. • Extended with more Quantity Kinds, units to cover the one required by different testbeds (e.g., KETI, University of Surrey, Smart Santander, Com4Innov) • M3-lite taxonomy: http://purl.org/iot/vocab/m3-lite#

Table of contents

I.	Citations	8
II.	M3 Nomenclature / Language / Sensor Dictionary	8
1.	Weather Sensor Dictionary (Last Updated: November 2020)	9
a)	Compliant with SAREF-Core, SAREF4ENER, SAREF4BLDG (Ongoing).....	10
2.	Agriculture Sensor Dictionary (Last Updated: 2022)	10
3.	Air quality Sensor Dictionary (Last Updated: December 2020)	14
b)	Memento Air Quality Threshold Europe (NEW: October 2020)	15

c)	Memento Air Quality Threshold USA:.....	15
a)	Memento Air Quality Threshold – More Sensors (CO, SO2) – USA	16
b)	Memento Air Quality Threshold - Health Advices – Australia	16
4.	Energy/Grid Sensor Dictionary (Last Updated: October 2020).....	17
c)	Compliance with SAREF4ener, SAREF core, and saref4bldg	20
d)	Units compliant with OM ontology.....	20
5.	Smart Home/Smart Building Sensor Dictionary (Last Updated: November 2020)	24
e)	Compliance with SAREF4bldg	27
6.	Transportation/Automotive Sensor Dictionary (Last Updated: November 2020)	27
f)	Matching with SAREF4AUTO.....	29
a)	Matching with auto.schema.org (TO DO)	29
7.	Manufacturing/Industry/Logistics Sensor Dictionary (Ongoing - Last Updated: June 2020)	29
8.	City Sensor Dictionary (Ongoing - Last Updated: November 2020).....	30
9.	Water Sensor Dictionary (Ongoing - Last Updated: December 2020)	30
10.	Activity Sensor Dictionary (Ongoing - Last Updated: November 2020).....	31
11.	Emotion Sensor Dictionary (Ongoing - Last Updated: November 2020)	31
12.	Robotics Sensor Dictionary (Ongoing - Last Updated: November 2020).....	35
13.	Healthcare Sensor Dictionary (Last Updated: November 2020).....	36
14.	Environment Sensor Dictionary (Ongoing)	39
15.	Waste Management Sensor Dictionary (Ongoing - Last Updated: November 2020).....	39
16.	Cyber Physical System (CPS) Sensor Dictionary (TO DO)	40
17.	Other or Generic Sensor Dictionary	40
18.	IoT Applicative Domain Sensor Dictionary.....	40
19.	Actuator Sensor Dictionary	41
20.	Others Measurement Name Sensor Dictionary	42
III.	Matching with Standards Ontologies or well-Known Ontologies.....	43
1.	Compliant with SAREF and its extensions see dedicated tables per domains (ONGOING).....	43
2.	Sensor Dictionary Compliant with IEC 61360 - Common Data Dictionary (ONGOING)	43
3.	Sensor Dictionary Compliant with IEC 62720 Units (ONGOING)	44
4.	Matching with iot.schema.org (ONGOING – September 2020).....	44
IV.	M3 Language: a Unified sensor Dictionary	50
1.	Why W3C SSN ontology is not enough?	50

2.	Why do we need the M3 ontology?	50
3.	M3-lite taxonomy (M3 ontology V2)	51
4.	M3 interoperable domain knowledge	51
5.	M3 hub to combine cross-domain ontologies	51
V.	Semantic Annotator: M3 Converter	55
1.	M3 converter user interface	55
2.	Code example to semantically annotate IoT data with M3	56
3.	Enrich the M3 converter and adapt it to your data	56
VI.	Simulating SenML sensor measurements	59
VII.	Converting senML sensor data	62
VIII.	Querying the M3 nomenclature/ontology	65
1.	Web service: querying sensors	65
2.	Web service: querying actuators	65
3.	Web service: querying domains	66
4.	Web service: querying health devices	66
5.	Web service: querying transport devices	66
6.	Web service: querying home devices	66
IX.	Code	67
1.	eurecom.data.converter	67
X.	Semantic annotator: Tutorial	68
1.	Use case: M3 framework	68
2.	Use Case: M3 embedded in Android-powered devices	68
3.	Use Case: FIESTA-IoT project	68
4.	Use Case: Insight testbed	68
XI.	References	68

Table of Figures

FIGURE 1. M3 ONTOLOGY: EXTENSION OF W3C SSN.....	51
FIGURE 2. M3 TO BUILD CROSS-DOMAIN KNOWLEDGE.....	52
FIGURE 3. M3 TO BUILD CROSS-DOMAIN KNOWLEDGE: NATUROPATHY AND SECURITY EXAMPLE	52
FIGURE 4. WITHOUT M3, THE KNOWLEDGE IS NOT CONNECTED	53
FIGURE 5. M3 USED TO BUILD CROSS-DOMAIN KNOWLEDGE: ONTOLOGIES, DATASETS AND REASONING.....	54
FIGURE 6. SEMANTICALLY ANNOTATING IoT DATA WITH THE M3 CONVERTER USER INTERFACE.....	55
FIGURE 7. SEMANTICALLY ANNOTATING IoT DATA WITH THE M3 CONVERTER WEB SERVICE.....	56
FIGURE 8. RULES PROVIDED IN THE TEMPLATE TO SEMANTICALLY ANNOTATE SENSOR DATA	57
FIGURE 9. ADD NEW RULES TO SEMANTICALLY ANNOTATE SENSOR DATA ACCORDING TO THE M3 ONTOLOGY.....	57
FIGURE 10. EXPLICIT M3 MEASUREMENT TYPE IS REUSED IN THE REASONING PROCESS.....	58
FIGURE 11. SIMULATE M2M AREA NETWORKS	59
FIGURE 12. SIMULATING SENSOR MEASUREMENTS	61
FIGURE 13. SEMANTICALLY ANNOTATING IoT DATA WITH THE M3 CONVERTER USER INTERFACE	62
FIGURE 14. SEMANTICALLY ANNOTATING SENSOR DATA	63
FIGURE 15. THE CONVERTER PACKAGE	67

Table of Tables

TABLE 1. AGRICULTURE DOMAIN: SENSORS, MEASUREMENTS AND UNITS.....	13
TABLE 2. AIR QUALITY DOMAIN: SENSORS, MEASUREMENTS AND UNITS.....	15
TABLE 3. ENERGY DOMAIN: SENSORS, MEASUREMENTS AND UNITS	20
TABLE 4. TRANSPORTATION DOMAIN: SENSORS, MEASUREMENTS AND UNITS	ERROR! BOOKMARK NOT DEFINED.
TABLE 5. MANUFACTURING OR INDUSTRY DOMAIN: SENSORS, MEASUREMENTS AND UNITS	30
TABLE 6. CITY DOMAIN: SENSORS, MEASUREMENTS AND UNITS.	30
TABLE 7. CITY DOMAIN: SENSORS, MEASUREMENTS AND UNITS.	31
TABLE 8. ACTIVITY DOMAIN: SENSORS, MEASUREMENTS AND UNITS.....	31
TABLE 9. EMOTION DOMAIN: SENSORS, MEASUREMENTS AND UNITS.	33
TABLE 10. ROBOTICS DOMAIN: SENSORS, MEASUREMENTS AND UNITS	36
TABLE 11. HEALTHCARE DOMAIN: SENSORS, MEASUREMENTS AND UNITS	37
TABLE 12. WEATHER DOMAIN: SENSORS, MEASUREMENTS AND UNITS.....	10
TABLE 13. SMART HOME DOMAIN: SENSORS, MEASUREMENTS AND UNITS.....	27
TABLE 14. ENVIRONMENT DOMAIN: SENSORS, MEASUREMENTS AND UNITS	39
TABLE 15. GENERIC DOMAIN: SENSORS, MEASUREMENTS AND UNITS	40
TABLE 16. DOMAIN NAMES	41
TABLE 17. ACTUATOR NAMES.....	42
TABLE 18. RFID TAGS COMMON TERMS.....	42
TABLE 19. MEASUREMENT NAMES	43

Terms and acronyms

IoT	Internet of Things (IoT)
M3 framework	Machine-to-Machine Measurement (M3) framework

I. Citations

Please remember to cite our work:

- [Energy] SAREF-Compliant Knowledge Discovery for Semantic Energy and Grid Interoperability. Amelie Gyrard, Antonio Kung, Olivier Genest, Alain Moreau. IEEE World Forum on Internet of Things (WF-IoT 2021).
- <http://linkedopenreasoning.appspot.com/?p=publication>
- <http://sensormeasurement.appspot.com/?p=publication>
- Enrich Machine-to-Machine Data with Semantic Web Technologies for Cross-Domain Applications. IEEE World Forum on Internet of Things (WF-IoT), Seoul, Korea, March 6-8, 2014. Amelie Gyrard, Christian Bonnet and Karima Boudaoud
- Standardizing Generic Cross-Domain Applications in Internet of Things. Third Workshop on Telecommunications Standards, Part of IEEE Globecom 2014, Austin, TX, USA, 8-12 December 2014. Amelie Gyrard, Soumya Kanti Datta, Christian Bonnet and Karima Boudaoud
- A unified language to describe M2M/IoT data. OneM2M, MAS Working Group 5, 22-27 March 2015, Sophia Antipolis, France. Amelie Gyrard, Christian Bonnet
- An Ontology to Semantically Annotate the Machine-to-Machine (M2M) Device Measurements. ETSI M2M Workshop 2013, 5-7 November 2013, Mandelieu, France. Amelie Gyrard, Christian Bonnet and Karima Boudaoud

II. M3 Nomenclature / Language / Sensor Dictionary

Sensor and measurement interpretation:

E.g., precipitation and rainfall sensor have the same meaning and represents the same sensor, we should explicitly describe this information in machine to machine communications to ensure interoperability in each layer of the OneM2M architecture.

1. Weather Sensor Dictionary (Last Updated: November 2020)

Weather domain: sensors, measurements and units

m3:FeatureOfInterest (e.g., SenML domain)/ m3:M2MDevice	M3 or SenML sensor/ measurement name, and unit	Description, other names (synonyms)	M3 rules
m3:Weather/ m3:WeatherM2MDevice	HumiditySensor/ Humidity m3:Percent	Hygrometer, humidity sensor, moisture sensor, soil moisture probes	Correctness OK (Conflict resolved with [Kofler 2011] and [Rodriguez 2014]) + Completeness OK (5 rules [Staroch 2013])
m3:Weather/ m3:WeatherM2MDevice	WindDirectionSensor/ WindDirection DegreeAngle	Wind direction	Completeness OK (5 rules [Staroch 2013]) + Correctness OK
m3:Weather/ m3:WeatherM2MDevice	SunPositionDirectionSensor/ SunPosition DegreeAngle	sun position direction to detect east, west, south, north	Completeness OK (5 rules [Staroch 2013]) + Correctness OK
m3:Weather/ m3:WeatherM2MDevice	AtmosphericPressureSensor/ AtmosphericPressure Pascal	Atmospheric pressure sensor, Barometer, barometric pressure sensor	Completeness OK (5 rules [Staroch 2013]) + Correctness OK (even with [Kofler 2011])
m3:Weather/ m3:WeatherM2MDevice	CloudCoverSensor/ CloudCover Okta	Cloud cover sensor	Completeness OK (5 rules [Staroch 2013]) + Correctness OK (even with [Kofler 2011])
m3:Weather/ m3:WeatherM2MDevice	SunPositionElevationSensor/ SunElevation DegreeAngle	sun position elevation to detect (twilight, day, night, etc.)	8 rules [Staroch 2013] Completeness NO + Correctness NO
m3:Weather/ m3:WeatherM2MDevice	SolarRadiationSensor/ SolarRadiation WattPerMeterSquare	Solar radiation sensor, par (photo synthetically active radiation) sensor, sun light, solar sensors, sun's radiation intensity, solar irradiance	Completeness OK (5 rules [Staroch 2013]) + Correctness OK (even with [Kofler 2011])
m3:Weather/ m3:WeatherM2MDevice	VisibilitySensor/ Visibility Miles, Meter	Visibility sensor to detect fog	
m3:Weather/ m3:WeatherM2MDevice	Thermometer, AirThermometer/ Temperature DegreeCelsius	Thermometer, temperature sensor, thermistor	Integrate [Kofler 2011] 15 rules See LOV4IoT [Staroch 2013] (6 home temperature rules)
m3:Weather/ m3:WeatherM2MDevice	LightSensor/ Luminosity Lux	Light, luminosity, illuminance, lighting	

m3:Weather/ m3:WeatherM2MDevice	PrecipitationSensor/ Precipitation MilimeterPerHour	Precipitation sensor, rainfall sensor, rain fall, pluviometer, rain, rainfall gauge	
m3:Weather/ m3:WeatherM2MDevice	WindSpeedSensor/ WindSpeed MeterPerSecond	Wind speed sensor, wind velocity sensor, anemometer	[Kofler 2011] 16 rules See LOV4IoT [Staroch 2013] 5 overlapping
m3:Weather/ m3:WeatherM2MDevice	WindChillSensor/ WindChill	Wind chill	

Table 1. Weather domain: sensors, measurements and units

a) Compliant with SAREF-Core, SAREF4ENER, SAREF4BLDG (Ongoing)

Sensor, Measurement Name and Unit	M3 Scenarios	SAREF-Core, SAREF4ENER, SAREF4BLDG	Other Names and Standards E.g., IEC 61360 Common Data Dictionary
m3:Thermometer m3:Temperature m3:DegreeCelsius	✓ M3- Energy	✓ saref-core:TemperatureSensor saref-core:Temperature saref-core:TemperatureUnit	IEC 61360 AAA110 - temperature sensor Thermostat
m3:LightSensor (Sensor) m3:Illuminance m3:Lux	✓ M3- Weather	✓ saref-core:LightSwitch	Illuminance Sensor, Lighting, IEC 61360 AAA105 - light sensor Light switch, Luminosity Sensor, Lamp
m3:HumiditySensor m3:Humidity m3:Percent	✓ M3- Weather	✓ saref-core Humidity (property) no HumiditySensor, no HumidityUnit no percent	AAA104 - humidity sensor Hygrometer, Humidifier
m3:PrecipitationSensor m3:Precipitation m3:MilimeterPerHour	✓ M3- Weather	Not found	Rain, Pluviometer
m3:AtmosphericPressureSensor m3:AtmosphericPressure m3:Pascal	✓ M3- Weather	✓ saref-core:Pressure (property) but not as a sensor saref4bldg:workingPressure?	AAA108 - pressure sensor Atmospheric Pressure Sensor, Barometer, Barometric Pressure Sensor
m3:SolarRadiationSensor m3:SolarRadiation m3:WattPerMeterSquare	✓ M3- Weather	✓ saref4bldg:SolarDevice, saref4bldg:solarReflectance, saref4bldg:solarTransmittance	- PAR (Photosynthetically Active Radiation) Sun Light, Solar Panel, Photovoltaic, solar irradiance
m3:WindSpeedSensor m3:WindSpeed m3:KiloMeterPerHour	✓ M3- Weather	Not found	-
m3:WindDirectionSensor m3:WindDirection m3:DegreeAngle	✓ M3- Weather	Not found	-
m3:CloudCoverSensor m3:CloudCover m3:Okta	✓ M3- Weather	Not found	-
m3:SunPositionElevationSensor m3:SunPosition m3:DegreeAngle	✓ M3- Weather	Not found	-
m3:SunPositionDirectionSensor m3:SunPositionDirection m3:DegreeAngle	✓ M3- Weather	Not found	-

TABLE II: Sensor Dictionary: M3 ontology relevant for Interconnect and compliant with SAREF applied to weather.

2. Agriculture Sensor Dictionary (Last Updated: 2022)

Note: Check this demo which will be more often updated and uses the M3 ontology:

<http://linkedopenreasoning.appspot.com/?p=slorv2>

m3:FeatureOfInterest (e.g., SenML domain)/ m3:M2MDevice	M3 or SenML sensor/ measurement name/ Unit	Description, other names (synonyms)	Knowledge referenced (LOV4IoT & SLOR)
---	---	--	--

m3:Agriculture/ m3:AgricultureM2MDevice	m3:PrecipitationSensor m3:Precipitation m3:Inch m3:Meter m3: MilimeterPerHour	Pluviometer saref4agri:Pluviometer saref4agri:Precipitation	LOV4IoT project and SLOR rules YES
m3:Agriculture/ m3:AgricultureM2MDevice	m3:Thermometer m3:Temperature m3:AirThermometer m3:AirTemperature m3:SoilThermometer m3:SoilTemperature m3: DegreeCelsius m3: DegreeFahrenheit m3: DegreeKelvin °C, K, F	Thermometer, temperature sensor, thermistor saref4agri:Thermometer saref4agri:Thermometer saref4agri:SoilTemperature saref4agri:AirTemperature	LOV4IoT project YES and SLOR rules YES
m3:Agriculture/ m3:AgricultureM2MDevice	m3:SolarRadiationSensor m3:SolarRadiation m3:WattPerMeterSquare	Solar radiation	LOV4IoT project and SLOR rules YES
m3:Agriculture/ m3:AgricultureM2MDevice	m3:WindSpeedSensor m3:WindSpeed m3:MeterPerSecond	Wind speed	LOV4IoT project YES and SLOR rules YES
m3:Agriculture/ m3:AgricultureM2MDevice	m3:AtmosphericPressureSensor or m3: AtmosphericPressure m3:Pascal	-	LOV4IoT project YES and SLOR rules YES
m3:Agriculture/ m3:AgricultureM2MDevice	M3:LightSensor m3:Luminosity m3:Lux	Light/Illuminance Sensor, Lighting, Light switch LightIntensity	Note: LOV4IoT project YES and SLOR rules YES
m3:Agriculture/ m3:AgricultureM2MDevice	m3:CO2_Sensor m3:CO2 m3:PPM	CO2	LOV4IoT project YES and SLOR rules YES (1 rule)
m3:Agriculture/ m3:AgricultureM2MDevice	m3:LeafWetnessSensor m3:LeafWetness m3:Percent	Leaf wetness Note: LOV4IoT project YES and SLOR rules NO	
m3:Agriculture/ m3:AgricultureM2MDevice	m3:HumiditySensor m3:Humidity m3:Percent m3:SoilHumiditySensor m3:SoilHumidity m3:Percent	Humidity sensor, Hygrometer saref4agri:SoilMoisture saref4agri:AmbientHumidity Note: soil moisture in millibar?	LOV4IoT project YES and SLOR rules NO

m3:Agriculture/ m3:AgricultureM2MDevice	m3:LeafWetnessSensor m3:LeafWetness m3:Percent	Humidity sensor, Hygrometer	LOV4IoT project YES and SLOR rules NO
m3:Agriculture/ m3:AgricultureM2MDevice	m3:PHSensor m3:PH -	-	LOV4IoT project YES and SLOR rules NO
m3:Agriculture/ m3:AgricultureM2MDevice	m3:Accelerometer m3:Motion -	saref4agri:MovementActivity Sensor	LOV4IoT project YES and SLOR rules NO
m3:Agriculture/ m3:AgricultureM2MDevice	m3:WeightSensor m3:Weight -	saref4agri:MovementActivity Sensor	LOV4IoT project YES and SLOR rules NO
m3:Agriculture/ m3:AgricultureM2MDevice	m3:SaltMeter m3:Salinity -	=? m3:ConductivitySensor/	LOV4IoT project YES and SLOR rules YES (1 rule)
m3:Agriculture/ m3:AgricultureM2MDevice	m3:SoilTensiometer - -	saref4agri:SoilTensiometer Note:	LOV4IoT project NO and SLOR rules NO
m3:Agriculture/ m3:AgricultureM2MDevice	m3:SmartForkSensor -	saref4agri:EatingActivitySens or	LOV4IoT project NO and SLOR rules NO
m3:Agriculture/ m3:AgricultureM2MDevice	m3:MilkSensor -	saref4agri:MilkingSensor	LOV4IoT project NO and SLOR rules NO
m3:Agriculture/ m3:AgricultureM2MDevice	m3:IrrigationActuator -	saref4agri:IrrigationWater	LOV4IoT project NO and SLOR rules NO
m3:Agriculture/ m3:AgricultureM2MDevice	-	saref4agri:PlantGrowthStage	LOV4IoT project NO and SLOR rules NO
m3:Agriculture/ m3:AgricultureM2MDevice	-	saref4agri:Intake	
m3:Agriculture/ m3:AgricultureM2MDevice	-	saref4agri:Yield:	LOV4IoT project NO and SLOR rules NO
m3:Agriculture/ m3:AgricultureM2MDevice	m3:NitrogenSensor m3:Nitrogen m3:Kilogram	TODO	TODO
m3:Agriculture/ m3:AgricultureM2MDevice	m3:PhosphorusSensor m3:Phosphorus m3:Kilogram	TODO	TODO
m3:Agriculture/ m3:AgricultureM2MDevice	m3:PotassiumSensor m3:Potassium m3:Kilogram	TODO	TODO

m3:Agriculture/ m3:AgricultureM2MDevice	m3:CalciumSensor m3:Calcium m3:Kilogram	TODO	TODO
m3:Agriculture/ m3:AgricultureM2MDevice	m3:MagnesiumSensor m3:Magnesium m3:Kilogram	TODO	TODO
m3:Agriculture/ m3:AgricultureM2MDevice	m3:SulfurSensor m3:Sulfur m3:Kilogram	TODO	TODO
m3:Agriculture/ m3:AgricultureM2MDevice	m3:BoronSensor m3:Boron m3:Kilogram	TODO	TODO
m3:Agriculture/ m3:AgricultureM2MDevice	m3:IronSensor m3:Iron m3:Kilogram	TODO	TODO
m3:Agriculture/ m3:AgricultureM2MDevice	m3:ManganeseSensor m3:Manganese m3:Kilogram	TODO	TODO
m3:Agriculture/ m3:AgricultureM2MDevice	m3:ZincSensor m3:Zinc m3:Kilogram	TODO	TODO
m3:Agriculture/ m3:AgricultureM2MDevice	m3:CopperSensor m3:Copper m3:Kilogram	TODO	TODO
m3:Agriculture/ m3:AgricultureM2MDevice	m3:CopperSensor m3:Copper m3:Kilogram	TODO	TODO
m3:Agriculture/ m3:AgricultureM2MDevice	m3:MolybdenumSensor m3:Molybdenum m3:Kilogram	TODO	TODO
m3:Agriculture/ m3:AgricultureM2MDevice	m3:ChlorineSensor m3:Chlorine m3:Kilogram	TODO	TODO
m3:Agriculture/ m3:AgricultureM2MDevice	m3:LithiumSensor m3:Lithium m3:Kilogram	TODO	TODO

Table 2. Agriculture domain: sensors, measurements and units.

Agriculture domain: sensors, measurements and units.

Legend: LOV4IoT project and SLOR rules (YES means that knowledge is available on this demo (<http://linkedopenreasoning.appspot.com/?p=slorv2>, NO otherwise)

Memento SAREF4AGRI (June 2020)

<https://saref.etsi.org/saref4agri/>

saref4agri:Sensor:

- **saref4agri:Pluviometer**
- **saref4agri:SoilTensiometer**
- **saref4agri:Thermometer**

- saref4agri:EatingActivitySensor
- saref4agri:MovementActivitySensor
- saref4agri:WeightSensor
- saref4agri:MilkingSensor

saref4agri:Property:

- saref4agri:SoilMoisture
- saref4agri:IrrigationWater
- saref4agri:SoilTemperature
- saref4agri:AirTemperature
- saref4agri:AmbientHumidity
- saref4agri:Precipitation
- saref4agri:PlantGrowthStage
- saref4agri:Intake
- saref4agri:Yield

3. Air quality Sensor Dictionary (Last Updated: December 2020)

Note: Check this demo which will be more often updated and uses the M3 ontology:

<http://linkedopenreasoning.appspot.com/?p=slorv2>

m3:FeatureOfInterest (e.g., SenML domain)/ m3:M2MDevice	M3 or SenML Sensor Name, Measurement Name, and Unit	Description, other names (synonyms)	Knowledge referenced (LOV4IoT & SLOR)
m3:AirQuality/ m3:AirQualityM2MDevice	m3:AirPollutantSensor m3:AirQualityIndex m3:EAQI	Air pollutant sensor, air quality	LOV4IoT projects referenced YES & SLOR YES
m3:AirQuality/ m3:AirQualityM2MDevice	m3:Ozone_Sensor m3:Ozone m3:MilligramPerMeterCube	Ozone O3	LOV4IoT projects referenced & SLOR rules YES
m3:AirQuality/ m3:AirQualityM2MDevice	m3:CarbonMonoxide_Sensor m3:CarbonMonoxide m3:PPM	Carbon monoxide CO sensor	LOV4IoT projects referenced & SLOR YES
m3:AirQuality/ m3:AirQualityM2MDevice	m3:NitrogenDioxide_Sensor m3:NitrogenDioxide m3:MilligramPerMeterCube	Nitrogen dioxide sensor NO2	LOV4IoT projects referenced & SLOR YES
m3:AirQuality/ m3:AirQualityM2MDevice	m3:SulfurDioxide_Sensor m3:SulfurDioxide m3PPB	Sulfure dioxide sensor SO2	LOV4IoT projects referenced & SLOR YES
m3:AirQuality/ m3:AirQualityM2MDevice	m3:PM10_Sensor m3:PM10 m3:MilligramPerMeterCube	PM10	LOV4IoT projects referenced & SLOR YES
m3:AirQuality/ m3:AirQualityM2MDevice	m3:PM25_Sensor m3:PM25	PM25	LOV4IoT projects referenced & SLOR YES

	m3:MilligramPerMeterCube		
m3:AirQuality/ m3:AirQualityM2MDevice	m3:CarbonDioxide_Sensor m3:CarbonDioxide m3:PPM	Carbon Dioxide Sensor Ppm (parts per million)	LOV4IoT projects referenced & SLOR (1 rule)
m3:AirQuality/ m3:AirQualityM2MDevice	m3:Oxygen_Sensor m3:Oxygen -	oxygen sensor	LOV4IoT projects referenced & SLOR NO
m3:AirQuality/ m3:AirQualityM2MDevice	m3:NitrogenOxide_Sensor m3:NitrogenOxide -	Nitrogen oxide sensor NO	LOV4IoT projects referenced & SLOR NO
m3:AirQuality/ m3:AirQualityM2MDevice	m3:Methane_Sensor m3:Methane -	Methane CH4	LOV4IoT projects referenced & SLOR NO
m3:AirQuality/ m3:AirQualityM2MDevice	m3:Ammonia_Sensor m3:Ammonia -	NH3, ammonia	LOV4IoT projects NO & SLOR NO
m3:AirQuality/ m3:AirQualityM2MDevice	m3:HydrogenSulfide_Sensor m3:HydrogenSulfide -	Hydrogen sulfide H2S	LOV4IoT projects referenced & SLOR NO
m3:AirQuality/ m3:AirQualityM2MDevice	m3:GaseousPollutantSensor -	Gaseous Pollutant Sensor	LOV4IoT projects NO & SLOR NO

Table 3. Air quality domain: sensors, measurements and units

b) Memento Air Quality Threshold Europe (NEW: October 2020)

Source: https://en.wikipedia.org/wiki/Air_quality_index#Europe

Qualitative name	Index or sub-index	Pollutant (hourly) concentration in $\mu\text{g}/\text{m}^3$			
		NO ₂	PM ₁₀	O ₃	PM _{2.5} (optional)
Very low	0–25	0–50	0–25	0–60	0–15
Low	25–50	50–100	25–50	60–120	15–30
Medium	50–75	100–200	50–90	120–180	30–55
High	75–100	200–400	90–180	180–240	55–110
Very high	>100	>400	>180	>240	>110

c) Memento Air Quality Threshold USA:

Wikipedia Air Quality Index (AQI): https://en.wikipedia.org/wiki/Air_quality_index

Air Quality Index (AQI) Basics <https://airnow.gov/index.cfm?action=aqibasics.aqi>

Daily AQI Color	Levels of Concern	Values of Index	Description of Air Quality
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone.
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

Figure. AQI Basics for Ozone and Particle Pollution
(Source: <https://www.airnow.gov/aqi/aqi-basics/>)

a) Memento Air Quality Threshold – More Sensors (CO, SO₂) – USA

Source: https://en.wikipedia.org/wiki/Air_quality_index

O ₃ (ppb)	O ₃ (ppb)	PM _{2.5} (µg/m ³)	PM ₁₀ (µg/m ³)	CO (ppm)	SO ₂ (ppb)	NO ₂ (ppb)	AQI	AQI
$C_{low} - C_{high}$ (avg)	$C_{low} - C_{high}$ (avg)	$C_{low} - C_{high}$ (avg)	$C_{low} - C_{high}$ (avg)	$C_{low} - C_{high}$ (avg)	$C_{low} - C_{high}$ (avg)	$C_{low} - C_{high}$ (avg)	$I_{low} - I_{high}$	Category
0-54 (8-hr)	-	0.0-12.0 (24-hr)	0-54 (24-hr)	0.0-4.4 (8-hr)	0-35 (1-hr)	0-53 (1-hr)	0-50	Good
55-70 (8-hr)	-	12.1-35.4 (24-hr)	55-154 (24-hr)	4.5-9.4 (8-hr)	36-75 (1-hr)	54-100 (1-hr)	51-100	Moderate
71-85 (8-hr)	125-164 (1-hr)	35.5-55.4 (24-hr)	155-254 (24-hr)	9.5-12.4 (8-hr)	76-185 (1-hr)	101-360 (1-hr)	101-150	Unhealthy for Sensitive Groups
86-105 (8-hr)	165-204 (1-hr)	55.5-150.4 (24-hr)	255-354 (24-hr)	12.5-15.4 (8-hr)	186-304 (1-hr)	361-649 (1-hr)	151-200	Unhealthy
106-200 (8-hr)	205-404 (1-hr)	150.5-250.4 (24-hr)	355-424 (24-hr)	15.5-30.4 (8-hr)	305-604 (24-hr)	650-1249 (1-hr)	201-300	Very Unhealthy
-	405-504 (1-hr)	250.5-350.4 (24-hr)	425-504 (24-hr)	30.5-40.4 (8-hr)	605-804 (24-hr)	1250-1649 (1-hr)	301-400	Hazardous
-	505-604 (1-hr)	350.5-500.4 (24-hr)	505-604 (24-hr)	40.5-50.4 (8-hr)	805-1004 (24-hr)	1650-2049 (1-hr)	401-500	

b) Memento Air Quality Threshold - Health Advices – Australia

Source: https://en.wikipedia.org/wiki/Air_quality_index

AQI	Description	Health advice	[hide]
0-33	Very Good	Enjoy activities	
34-66	Good	Enjoy activities	
67-99	Fair	People unusually sensitive to air pollution: Plan strenuous outdoor activities when air quality is better	
100-149	Poor	Sensitive Groups: Cut back or reschedule strenuous outdoor activities	
150-200	Very Poor	Sensitive groups: Avoid strenuous outdoor activities. Everyone: Cut back or reschedule strenuous outdoor activities	
200+	Hazardous	Sensitive groups: Avoid all outdoor physical activities. Everyone: Significantly cut back on outdoor physical activities	

4. Energy/Grid Sensor Dictionary (Last Updated: October 2020)

- Note: EnergyFOI (FOI = Feature of Interest) to distinguish with energy measurement and energy sensor.
- Question: Energy meter != electricity meter?
- Note: need domain experts to check and complete this table.
- Thermometer sensor found in numerous domains.
- Useful for the Interconnect H2020 project

m3:FeatureOfInterest (e.g., SenML domain)/ m3:M2MDevice	M3 or SenML sensor name, measurement name, and Unit	Description, other names (synonyms)	Knowledge referenced (LOV4IoT & SLOR)
m3:EnergyFOI/ m3:EnergyM2MDevice	m3:Thermometer m3:Temperature m3:DegreeCelsius m3:DegreeFahrenheit m3:DegreeKelvin	Thermometer, temperature saref-core:TemperatureSensor saref-core:Temperature om:degree_Celsius om:degree_Fahrenheit NO om:degree_Kelvin	LOV4IoT YES & SLOR YES
m3:EnergyFOI/ m3:EnergyM2MDevice	m3:GasDetector m3:Gas -	Gas detector, gas metering, gas, meter seeAlso saref-core:Gas	LOV4IoT YES SLOR NO
m3:EnergyFOI/ m3:EnergyM2MDevice	m3:VibrationSensor m3:Vibration -	Vibration sensor, Accelerometer?, Motion? saref4bldg:vibrationTransmissibility saref4bldg:VibrationIsolator	LOV4IoT YES SLOR NO
m3:EnergyFOI/ m3:EnergyM2MDevice	m3:ConductivitySensor m3:Conductivity m3:SiemendPerHour	Salt Meter?, Salinity? Conductance? ElectricalConductance? m2 Kelvin/Watt?	LOV4IoT YES SLOR NO
m3:EnergyFOI/ m3:EnergyM2MDevice	m3:ThermalConductivitySensor m3:ThermalConductivity m3:WattPerMeterKelvin	saref4bldg:thermalConductivity (owl:ObjectProperty)? No OM WattPerMeterKelvin	LOV4IoT YES SLOR NO
m3:EnergyFOI/ m3:EnergyM2MDevice	m3:ElectricalCurrentSensor m3:ElectricCurrent m3:Ampere	- saref4ener not found saref4bldg:ElectricGeneratorEfficiency? saref4bldg:ElectricMotorEfficiency? saref4bldg:ElectricGenerator? saref4bldg:ElectricMotor?	LOV4IoT YES SLOR NO

		om:ampere	
m3:EnergyFOI/ m3:EnergyM2MDevice	m3: EnergyMeter m3:EnergyConsumption m3:KiloWattHour m3:Joule	Electricity meter, electric meter, energy meter, power?, energy, work, heat saref4ener:Energy? saref4ener:EnergyMax? saref4ener:EnergyStandardDeviation? saref4ener:EnergyExpected? saref4ener:ResumeEnergyEstimated? saref4ener:ResumeSkewness? saref4ener:energyMin? om:kilowatt_hour om:joule	LOV4IoT YES SLOR NO
m3:EnergyFOI/ m3:EnergyM2MDevice	m3:ElectricityMeter m3:Electricity	Electricity meter saref-core:Electricity?	LOV4IoT NO SLOR NO
m3:EnergyFOI/ m3:EnergyM2MDevice	m3:ElectricalResistanceSensor ElectricalResistance m3:Ohm	Resistance/ impedence/ reactance saref4bldg:initialResistance? saref4bldg:finalResistance? saref4bldg:flowResistanceMin? saref4bldg:flowResistanceMax? om:Ohm	LOV4IoT NO SLOR NO
m3:EnergyFOI/ m3:EnergyM2MDevice	m3:CapitanceSensor m3:Capitance m3:Farad	- saref-core, saref4bldg, saref4ener not found om:farad	LOV4IoT NO SLOR NO
m3:EnergyFOI/ m3:EnergyM2MDevice	m3:ElectricChargeSensor, m3:ElectricCharge m3:Coulomb	- saref-core, saref4bldg, saref4ener not found om:coulomb	LOV4IoT NO SLOR NO
m3:EnergyFOI/ m3:EnergyM2MDevice	m3:ElectricalPotentialSensor m3:ElectricalPotential m3:Volt	Voltage sensor saref4bldg:secondaryVoltage? saref4bldg:primaryVoltage? saref4bldg:nominalSupplyVoltage? saref4bldg:nominalSupplyVoltageMin? saref4bldg:nominalSupplyVoltageMax? NO OM volt	LOV4IoT NO SLOR NO
m3:EnergyFOI/ m3:EnergyM2MDevice	m3:FrequencySensor m3:Frequency	- saref4bldg:primaryFrequency	LOV4IoT NO

	m3:Hertz	saref4bldg:secondaryFrequency om:hertz or cycle? saref4envi:FrequencyUnit	SLOR NO
m3:EnergyFOI/ m3:EnergyM2MDevice	m3:PressureSensor m3:Pressure m3:Bar m3:Pascal	- saref-core:Pressure saref4bldg:nominalTotalPressure? saref4bldg:workingPressureMin? saref4bldg:workingPressureMax? saref4bldg:nominalStaticPressure? saref4bldg:pressureRating? saref4bldg:testPressure? om:bar om:pascal Pascals (Pa, N/m2) saref-core:PressureUnit	LOV4IoT NO SLOR NO
m3:EnergyFOI/ m3:EnergyM2MDevice	m3:PowerSensor m3:Power m3:Watt	- saref-core:Power NO saref-core:PowerMeter NO watt unit in OM saref-core:PowerUnit	LOV4IoT NO SLOR NO
m3:EnergyFOI/ m3:EnergyM2MDevice	m3:LightSensor m3:Illuminance m3:Lux	Light/Illuminance Sensor, Lighting, Light switch Illuminance/Luminosity saref-core:LightSwitch saref-core:Light NO lux unit in OM	LOV4IoT NO SLOR NO
m3:EnergyFOI/ m3:EnergyM2MDevice	m3:RadioactivitySensor m3:Radioactivity m3:Becquerel	- saref-core, saref4bldg, saref4ener not found om:becquerel	LOV4IoT NO SLOR NO
m3:EnergyFOI/ m3:EnergyM2MDevice	m3:LuminousFluxSensor m3:LuminousFlux m3:Lumen	- saref4bldg:contributedLuminousFlux om:lumen	LOV4IoT NO SLOR NO
m3:EnergyFOI/ m3:EnergyM2MDevice	m3:ElectricalConductanceSensor m3:ElectricalConductance m3:Siemens	WARNING != conductivity saref-core, saref4bldg, saref4ener not found om:siemens	LOV4IoT NO SLOR NO
m3:EnergyFOI/	m3:MagneticFluxSensor	-	LOV4IoT

m3:EnergyM2MDevice	m3:MagneticFlux m3:Weber	saref-core, saref4bldg, saref4ener not found om:weber	NO SLOR NO
m3:EnergyFOI/ m3:EnergyM2MDevice	m3:InductanceSensor m3:Inductance m3:Henry	- saref-core, saref4bldg, saref4ener not found om:henry	LOV4IoT NO SLOR NO

Table 4. Energy domain: sensors, measurements and units

c) Compliance with SAREF4ener, SAREF core, and saref4bldg

saref4ener "https://saref.etsi.org/saref4ener/"

Note:

- Temperature and TemperatureSensor can be found in <https://saref.etsi.org/core/>
- Gas type of commodity
 - `<owl:Class rdf:about="https://saref.etsi.org/core/Gas">`
 - `<rdfs:label xml:lang="en">Gas</rdfs:label>`
 - `<rdfs:comment xml:lang="en">A type of commodity</rdfs:comment>`
 - `<rdfs:subClassOf>`
 - `<owl:Class rdf:about="https://saref.etsi.org/core/Commodity"/>`
 - `</rdfs:subClassOf>`
 - `</owl:Class>`

`<rdfs:seeAlso rdf:resource="&saref-core;Gas"/>`

`<owl:ObjectProperty rdf:about="https://saref.etsi.org/saref4bldg/thermalConductivity">`

`<rdfs:label xml:lang="en">thermal conductivity</rdfs:label>`

`<rdfs:comment xml:lang="en">Fouling factor of the tubes in the tube bundle. Usually measured in m2 Kelvin/Watt.</rdfs:comment>`

`</owl:ObjectProperty>`

d) Units compliant with OM ontology

Note: om ontology namespace: <http://www.foodvoc.org/vocabularies/om-1.8/>

SI unit of energy is in Joule

https://en.wikipedia.org/wiki/Units_of_energy

unit of power Watt

watt-hour represents the amount of energy [...] produced or consumed by a one-**watt** device in one hour.

Power is the amount of **energy** transferred or converted per unit time

In the **International System of Units**, the unit of power is the **watt**, equal to one **joule** per second.

According to the International System of Units:

https://en.wikipedia.org/wiki/International_System_of_Units

Name	Symbol	Quantity	In SI base units	In other SI units
radian ^[N 1]	rad	plane angle	m/m	1
steradian ^[N 1]	sr	solid angle	m ² /m ²	1
hertz	Hz	frequency	s ⁻¹	
newton	N	force, weight	kg·m·s ⁻²	
pascal	Pa	pressure, stress	kg·m ⁻¹ ·s ⁻²	N/m ²
joule	J	energy, work, heat	kg·m ² ·s ⁻²	N·m = Pa·m ³
watt	W	power, radiant flux	kg·m ² ·s ⁻³	J/s
coulomb	C	electric charge	s·A	
volt	V	electrical potential difference (voltage), emf	kg·m ² ·s ⁻³ ·A ⁻¹	W/A = J/C
farad	F	capacitance	kg ⁻¹ ·m ⁻² ·s ⁴ ·A ²	C/V
ohm	Ω	resistance, impedance, reactance	kg·m ² ·s ⁻³ ·A ⁻²	V/A
siemens	S	electrical conductance	kg ⁻¹ ·m ⁻² ·s ³ ·A ²	Ω ⁻¹
weber	Wb	magnetic flux	kg·m ² ·s ⁻² ·A ⁻¹	V·s
tesla	T	magnetic flux density	kg·s ⁻² ·A ⁻¹	Wb/m ²
henry	H	inductance	kg·m ² ·s ⁻² ·A ⁻²	Wb/A
degree Celsius	°C	temperature relative to 273.15 K	K	
lumen	lm	luminous flux	cd·sr	cd·sr
lux	lx	illuminance	m ⁻² ·cd	lm/m ²
becquerel	Bq	radioactivity (decays per unit time)	s ⁻¹	
gray	Gy	absorbed dose (of ionising radiation)	m ² ·s ⁻²	J/kg
sievert	Sv	equivalent dose (of ionising radiation)	m ² ·s ⁻²	J/kg
katal	kat	catalytic activity	mol·s ⁻¹	

- Frequency in Hertz OK
- Pressure/stress in Pascal OK
- Energy/Work/Heat in Joule OK

- Power in watt OK
- Electric charge in Coulomb OK
- Capacitance in Farad OK
- radioactivity in becquerel OK
- illuminance in lux OK
- Luminous flux in lumen OK
- Electric potential difference (Voltage) in Volt OK
- temperature degree celsius OK
- Resistance/impedance/reactance in Ohm OK
- Electrical conductance in Siemens OK
- Magnetic flux in weber OK
- Inductance in Henry OK

Note: Watt is not mentioned within the Units of Measure (OM)
<http://www.foodvoc.org/vocabularies/om-1.8/joule>

Note: lux is not within the Units of Measure (OM)
 Note: volt is not within the Units of Measure (OM)
 Note: siemens per meter is not within the Units of Measure (OM)
 Note OM does not have an uppercase for each unit concept.

Note:

Conductance is a property of the component but **conductivity** is a property of the material. **Conductance** depends on the dimensions of the conductor, but **conductivity** does not depend on the dimensions. **Conductance** is measured in Siemens while **conductivity** is measured in Siemens per meter.

<https://www.differencebetween.com/difference-between-conductivity-and-vs-conductance/#:~:text=Conductance%20is%20a%20property%20of%20the%20component%20but,a%20property%20of%20the%20material.&text=Conductance%20depends%20on%20the%20dimensions,not%20depend%20on%20the%20dimensions.&text=Conductance%20is%20measured%20in%20Siemens%20while,measured%20in%20Siemens%20per%20meter.>

Some units cannot be found in OM ontology:

volt	lux
abvolt	electric flux
ampere per volt	electric flux density
attovolt	heat flux density
centivolt	luminous flux
coulomb per volt	magnetic flux
decavolt	magnetic flux density
decivolt	radiant flux
electronvolt	radiant flux density
exavolt	sound energy flux
femtovolt	attolux
gigaelectronvolt	centilux
gigavolt	decalux
hectovolt	decilux
kiloelectronvolt	electric flux density dimension
kilovolt	exalux
megaelectronvolt	femtolux
megavolt	gigalux
microvolt	hectolux
millivolt	kilolux
nanovolt	<u>luminous flux dimension</u>

Home

language ▾ en

watt

ampere per watt

attowatt

centiwatt

decawatt

deciwatt

exawatt

femtowatt

gigawatt

hectowatt

kilowatt

kilowatt hour

luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540e12 hertz and that has a radiant intensity in that direction of 1/683 watt per steradian

megawatt per megawatt

megawatt

microwatt

milliwatt

OM 1.8: Units of Measure

application area

dimension

measure

measurement scale

phenomenon

point

prefix

quantity

system of units

unit of measure

vectorial or tensorial character

FOOD & BIODEBASED RESEARCH

WAGENINGEN

© 2013-2015 Wageningen UR Food & Biobased Research

Other relations

Related concept

Property

zettajoule

singular unit

zeptojoule

singular unit

yottajoule

singular unit

yoctojoule

singular unit

work

unit of measure

terajoule

singular unit

superconductor energy gap

unit of measure

reaction energy

unit of measure

Properties

Property

Value

om:dimension

energy dimension

om:definition

newton metre

5. Smart Home/Smart Building Sensor Dictionary (Last Updated: November 2020)

Smart home domain: sensors, measurements and units

m3:FeatureOfInterest (e.g., SenML domain)/ m3:M2MDevice	M3 or SenML sensor name, measurement name, and unit	Description, other names (synonyms)	Knowledge referenced (LOV4IoT & SLOR) & Rules
m3:BuildingAutomation/ m3:HomeM2MDevice	m3:SoundSensor m3:Sound m3:Decibel	Noise, sound, microphone, audio sensor saref4bldg audioVolume?	LOV4IoT OK SLOR oK Correctness OK (3 rules [Rodriguez 2014]) + Completeness NO (Between 30 and 110, overlapping with Vasileios]
m3:BuildingAutomation/ m3:HomeM2MDevice	m3:Thermometer m3:Temperature m3:DegreeCelsius	Thermometer, temperature sensor, thermistor saref-core:TemperatureSensor saref-core:Temperature saref-core:TemperatureUnit	LOV4IoT OK SLOR oK [Kofler 2011] 15 rules (only 9 implemented) See LOV4IoT [Staroch 2013] (6 home temperature rules) Rodriguez 3 rules Overlapping overlapping with Vasileios Yus
m3:BuildingAutomation/ m3:HomeM2MDevice	m3:LightSensor m3:Luminosity m3:Lux	Light, luminosity, illuminance, lighting, illumination saref-core:LightSwitch saref-core:Light saref-core:IlluminanceUnit	LOV4IoT OK SLOR OK Pb with Vasileios
m3:BuildingAutomation/ m3:HomeM2MDevice	m3:Presence -	Presence sensor, motion sensor, occupancy detector, pyroelectric IR occupancy, intrusion detector/ trespassing, infrared sensor, motion sensor, motion detector, motion sensor, proximity, passive infrared (PIR) saref-core:Motion? No saref-core:MotionSensor?	LOV4IoT OK SLOR OK 2 rules combined with light See LOV4IoT [Jacquet 2013]

		saref-core, saref4bld, sare4ener not found No saref-core:MotionUnit	
m3:BuildingAutomation/ m3:HomeM2MDevice	m3:PowerConsumption m3:Watt	saref-core:Power no saref-core:PowerMeter no saref-core:PowerSensor saref-core:PowerUnit	LOV4IoT OK SLOR OK
m3:BuildingAutomation/ m3:HomeM2MDevice	m3:HumiditySensor m3:Humidity m3:Percent	Hygrometer, humidity sensor, moisture sensor, soil moisture probes saref-core:Humidity no saref-core:Humiditysensor no saref-core: Hygrometer No saref-core:HumidityUnit	LOV4IoT OK SLOR OK 5 rules See LOV4IoT [Staroch 2013] Completeness ok Correctness : Overlapping with kofler, Rodriguez More rules staroch
m3:BuildingAutomation/ m3:HomeM2MDevice	m3:gyroscope rad/s	Gyroscope attached to objects (e.g., mop) to detect if they are used saref-core, saref4bld, sare4ener not found	LOV4IoT OK SLOR OK No too complicated need machine learning to detect activities
m3:BuildingAutomation/ m3:HomeM2MDevice	m3:pressure m3:Pascal m3:Bar	Pressure for beds, sofa, couch to detect (lying, sitting), bed occupancy saref-core:Pressure no saref-core:PressureSensor om:bar om:pascal saref-core:PressureUnit	LOV4IoT OK SLOR OK
m3:BuildingAutomation/ m3:HomeM2MDevice	m3:Accelerometer/ m3:Motion m/s ²	Accelerometer saref-core:Motion? No saref-core:MotionSensor? No saref-core:MotionUnit	LOV4IoT OK SLOR OK

m3:BuildingAutomation/ m3:HomeM2MDevice	m3:magnetic field	Magnetometer, magnetic sensor attached to cupboards to detect if they are opened or closed saref-core, saref4bld, sare4ener not found	LOV4IoT OK SLOR OK
m3:BuildingAutomation/ m3:HomeM2MDevice	m3:Camera	Video sensor saref-core, saref4bld, sare4ener not found (check for video and camera)	LOV4IoT OK SLOR OK
m3:BuildingAutomation/ m3:HomeM2MDevice	m3:SmokeDetector	Smoke Detector, Fire Alarm, Smoke Sensor saref-core:SmokeSensor saref-core:Smoke No saref-core:Smoke	LOV4IoT OK SLOR NO
m3:BuildingAutomation/ m3:HomeM2MDevice	m3:GasDetector	saref-core:Gas No saref-core:GasSensor of GasDetector No saref-core:GasUnit	LOV4IoT OK SLOR NO
	m3:Lamp actuator		
	m3:ElectricityMeter m3:Check Energy Table		
	m3:HVAC		
	m3:Ventilation		
	m3:Air conditionner		
	m3:Parking space		
	m3:Electric vehicle charging		
	m3:Alarm system		
	m3:Fall detector		
	m3:CO2		
	m3:Dish washer		
	m3:Water meter m3:Check water table		
	m3:Water flow m3:Check water table		
	m3:Door		
	m3:Tensiometer Check health table		
	m3:Coagulometer Check health table		
	m3:Luminous flux sensor check energy table		
	m3:Emergency push button		
	m3:battery		

	m3:CO sensor Check air quality table		
	m3:Air pollutant sensor Check air quality table		
	m3:GaitSensor		
	m3:Wheelchair		
	m3:WasteManagementSensor check waste table		
	m3:Elevator		
	m3:UltrasonicSensor		
	m3:RFID Check numerous objects with embedded RFID		

Table 5. Smart home domain: sensors, measurements and units

e) Compliance with SAREF4bldg

**6. Transportation/Automotive Sensor
Dictionary (Last Updated: November
2020)**

m3:FeatureOfInterest (e.g., SenML domain)/ m3:M2MDevice	M3 or SenML Sensor Name/ Measurement Name, and Unit	Description, other names (synonyms)	Knowledge referenced (LOV4IoT & SLOR)
m3:Transportation/ m3: TransportM2MDevice	m3:Accelerometer m3:Motion m3:MeterPerSecondSquare	Saref4auto:Acceleration	LOV4IoT YES SLOR YES
m3:Transportation/ m3: TransportM2MDevice	m3:SpeedSensor m3:Speed m3:MeterPerSecond	saref4auto:Speed Speed sensor, speedometer, velocity sensor (car)	LOV4IoT YES SLOR YES
m3:Transportation/ m3: TransportM2MDevice	m3:GPSSensor m3:Location m3: Latitude m3: Longitude m3: Altitude	saref4auto:Position	LOV4IoT YES SLOR YES
m3:Transportation/ m3: TransportM2MDevice	m3:OccupancyDetector m3:Presence -	saref4auto:Movement	LOV4IoT YES SLOR YES

m3:Transportation/ m3: TransportM2MDevice	m3:WeightSensor m3:Weight m3:Kilo m3:Pound	saref4auto:Weight	LOV4IoT YES SLOR NO
m3:Transportation/ m3: TransportM2MDevice	m3:BrakeActuator m3:Brake	saref4auto:BrakeCapacity	-
m3:Transportation/ m3: TransportM2MDevice	m3:Length	saref4auto: Length	
m3:Transportation/ m3: TransportM2MDevice	m3:Height	saref4auto:Height	
m3:Transportation/ m3: TransportM2MDevice	m3:Size	saref4auto:Size	
m3:Transportation/ m3: TransportM2MDevice	m3:Shape	saref4auto:Shape	
m3:Transportation/ m3: TransportM2MDevice	m3:Heading	saref4auto:Heading	
m3:Transportation/ m3:TransportM2MDevice	battery	Battery charge level	
m3:Transportation/ m3: TransportM2MDevice	motorTemperature		
m3:Transportation/ m3: TransportM2MDevice	RoadSurfaceThermometer RoadTemperature		
m3:Transportation/ m3: TransportM2MDevice	NumberVehicleSensor NumberVehicle		
m3:Transportation/ m3: TransportM2MDevice	tire pressure		
m3:Transportation/ m3: TransportM2MDevice	fuel	Fuel level	
m3:Transportation/ m3: TransportM2MDevice	DistanceSensor Distance	Distance sensor, safety distance	
m3:Transportation/ m3: TransportM2MDevice	rpm	Position and/or rotational speed	
m3:Transportation/ m3: TransportM2MDevice	Maf	mass air flow sensor	
m3:Transportation/ m3:	SoundSensor Sound		

TransportM2MDevice	dB		
m3:Transportation/ m3: TransportM2MDevice	AlcoholLevelSensor AlcoholLevel		

Table 6. Transportation domain: sensors, measurements and units

f) Matching with SAREF4AUTO

Source: ETSI TS 103 410-7 V1.1.1 (2020-07). SmartM2M; Extension to SAREF; Part 7: Automotive Domain

SAREF4Auto (<https://saref.etsi.org/saref4auto/>):

- s4auto: Acceleration - OK
- s4auto: Speed – OK
- s4auto: Position – OK
- s4auto: Weight – OK
- s4auto: Movement ? OccupancyDetector? OK
- s4auto: BrakeCapacity OK
- s4auto: Height OK
- s4auto: Length OK
- s4auto: Width OK
- s4auto: Size OK
- s4auto: Shape OK
- s4auto: Heading OK

a) Matching with auto.schema.org (TO DO)

7. Manufacturing/Industry/Logistics Sensor Dictionary (Ongoing - Last Updated: June 2020)

m3:FeatureOfInterest (e.g., SenML domain)/ m3:M2MDevice	M3 or SenML sensor name/measurement name	Description, other names (synonyms)	M3 or SenML Unit	Knowledge referenced (LOV4IoT & SLOR)
m3:Manufacturing/ m3:ManufacturingM2MDevice	m3:Gripper / -	-	-	LOV4IoT YES SLOR NO
m3:Manufacturing/ m3:ManufacturingM2MDevice	m3:Mover/ -	-	-	LOV4IoT YES SLOR NO

m3:Manufacturing/ m3:ManufacturingM2MDevice	m3:Shaver/ -	-	-	LOV4IoT YES SLOR NO
--	-----------------	---	---	------------------------

Table 7. Manufacturing or industry domain: sensors, measurements and units

8. City Sensor Dictionary (Ongoing - Last Updated: November 2020)

Note: Check this demo which will be more often updated and uses the M3 ontology:

<http://linkedopenreasoning.appspot.com/?p=slorv2>

City domain: sensors, measurements and units.

Legend: LOV4IoT project and SLOR rules (YES means that knowledge is available on this demo (<http://linkedopenreasoning.appspot.com/?p=slorv2>, NO otherwise)

m3:FeatureOfInterest (e.g., SenML domain)/ m3:M2MDevice	M3 or SenML Sensor Name/ Measurement Name, and Unit	Description, other names (synonyms)	Knowledge referenced (LOV4IoT & SLOR)
m3:City/ m3:CityM2MDevice	M3:Photometer	Photometer saref4envi :Photometer	LOV4IoT project and SLOR rules NO
m3:City/ m3:CityM2MDevice	m3:TESS	tess	
m3:City/ m3:CityM2MDevice	m3:Lamppost	lamppost	

Table 8. City domain: sensors, measurements and units.

9. Water Sensor Dictionary (Ongoing - Last Updated: December 2020)

Note: Check this demo which will be more often updated and uses the M3 ontology:

<http://linkedopenreasoning.appspot.com/?p=slor-water>

Water domain: sensors, measurements and units.

Legend: LOV4IoT project and SLOR rules (YES means that knowledge is available on this demo (<http://linkedopenreasoning.appspot.com/?p=slorv-water>, NO otherwise)

m3:FeatureOfInterest (e.g., SenML domain)/ m3:M2MDevice	M3 or SenML Sensor Name/ Measurement Name, and Unit	Description, other names (synonyms)	Knowledge referenced (LOV4IoT & SLOR)
m3:Water/ m3:WaterM2MDevice	m3:WaterMeter/ m3:WaterQuantity xsd:double	Water meter	LOV4IoT project NO and SLOR rules NO

m3:Water/ m3:WaterM2MDevice	m3:WaterFlow -	-	LOV4IoT project NO and SLOR rules NO
m3:Water/ m3:WaterM2MDevice	m3:Hydrophone -	-	LOV4IoT project NO and SLOR rules NO
m3:Water/ m3:WaterM2MDevice	m3:ConductivitySensor	-	LOV4IoT project NO and SLOR rules NO
m3:Water/ m3:WaterM2MDevice	m3:WaterTank	-	LOV4IoT project NO and SLOR rules NO
Water/ m3:WaterM2MDevice	m3:AmmoniaSensor m3:Ammonia	-	LOV4IoT project YES and SLOR rules YES

Table 9. Water domain: sensors, measurements and units.

Note: saref4bldg:waterPressureMin

10. Activity Sensor Dictionary (Ongoing - Last Updated: November 2020)

Note: Check this demo which will be more often updated and uses the M3 ontology:

<http://linkedopenreasoning.appspot.com/?p=slorv2>

Activity domain: sensors, measurements and units.

Legend: LOV4IoT project and SLOR rules (YES means that knowledge is available on this demo (<http://linkedopenreasoning.appspot.com/?p=slorv2>, NO otherwise)

m3:FeatureOfInterest (e.g., SenML domain)/ m3:M2MDevice	M3 or SenML Sensor Name/ Measurement Name, and Unit	Description, other names (synonyms)	Knowledge referenced (LOV4IoT & SLOR)
m3:Activity/ m3:ActivityM2MDevice	m3:Accelerometer/ m3:Motion m3: MeterPerSecondSquare	accelerometer	LOV4IoT project YES and SLOR rules NO

Table 10. Activity domain: sensors, measurements and units

11. Emotion Sensor Dictionary (Ongoing - Last Updated: November 2020)

Note: Check this demo which will be more often updated and uses the M3 ontology:

Dedicated web page: <http://linkedopenreasoning.appspot.com/?p=slor-emotion>

Generic: <http://linkedopenreasoning.appspot.com/?p=slorv2>

Emotion domain: sensors, measurements and units.

Legend: LOV4IoT project and SLOR rules (YES means that knowledge is available on this demo (<http://linkedopenreasoning.appspot.com/?p=slorv2>, NO otherwise)

m3:FeatureOfInterest (e.g., SenML domain)/ m3:M2MDevice	M3 or SenML Sensor Name/ Measurement Name, and Unit	Description, other names (synonyms)	Knowledge referenced (LOV4IoT & SLOR)
m3:Emotion/ m3:EmotionM2MDevice	m3:SnoringLevelSensor/ m3:Snoring	Snoring	LOV4IoT project YES and SLOR rules YES
m3:Emotion/ m3:EmotionM2MDevice	m3:SmartWatch	Smart watch	LOV4IoT project YES (no onto) and SLOR rules YES (random forest)
m3:Emotion/ m3:EmotionM2MDevice	m3:SkinConductanceSensor m3:SkinConductance m3:Siemens om:siemens	skin conductance, galvanic skin response sensor, GSR, sweating	LOV4IoT project YES and SLOR rules NO
m3:Emotion/ m3:EmotionM2MDevice	m3:GPSSensor m3:Location	Gps	LOV4IoT project YES (no onto) and SLOR rules YES (random forest)
m3:Emotion/ m3:EmotionM2MDevice	m3:StressLevelSensor m3:StressLevel	Stress level sensor	LOV4IoT project YES (No onto) and SLOR rules YES (Naïve Bayes, decision tree)
m3:Emotion/ m3:EmotionM2MDevice	m3:ECG	Ecg ekg	LOV4IoT project YES and SLOR rules NO
m3:Emotion/ m3:EmotionM2MDevice	m3:Accelerometer m3:Motion	-	LOV4IoT project YES (no onto) and SLOR rules YES (naïve bayes)
m3:Emotion/ m3:EmotionM2MDevice	m3:MobilePhone	Mobile phone	LOV4IoT project YES (no onto) and SLOR rules YES (SVM, GMM)
m3:Emotion/ m3:EmotionM2MDevice	m3:BloodPressureSensor m3:BloodPressure m3:mmGg	Blood volume pressure	LOV4IoT project YES (no onto) and SLOR rules YES (KNN)
m3:Emotion/ m3:EmotionM2MDevice	m3:HeartBeatSensor m3:HeartBeat m3:BeatPerMinute	-	LOV4IoT project YES (no onto) and SLOR rules YES (KNN)
m3:Emotion/ m3:EmotionM2MDevice	m3: Electroencephalogram	EEG	LOV4IoT project NO and SLOR rules NO
m3:Emotion/ m3:EmotionM2MDevice	m3:Electromyogram	Electromyogram EMG	LOV4IoT project NO and SLOR rules NO
m3:Emotion/ m3:EmotionM2MDevice	m3:Electrooculography	EOG	LOV4IoT project NO and SLOR rules NO
m3:Emotion/ m3:EmotionM2MDevice	m3:SoundSensor m3:Sound m3:Decibel	Microphone	LOV4IoT project YES and SLOR rules YES (rule, GMM, SVM)

Table 11. Emotion domain: sensors, measurements and units.

Note:

- See the IAMHAPPY paper:

<https://www.sciencedirect.com/science/article/pii/S2352648319300479>

How is it used?

Within the SLOR demo: <http://linkedopenreasoning.appspot.com/?p=slorv2>

See the other images for the source of knowledge.

Select a domain and we provide you rules and projects for various sensors.

Choose a domain

Domain:

Sensor	Projects
Stress Level Sensor Stress Level Sensor	Get project Get rule [Ko et al. 2006]. See LOV4IoT for more details. - Paper: Ontology-based context-aware service engine for U-Healthcare
ECG or EKG (Electrocardiogram) ECG or EKG (Electrocardiogram)	Get project Get rule [CodeBlue 2004]. See LOV4IoT for more details. - Paper: An ad-hoc sensor network infrastructure for emergency medical care, 2004 [Ko et al. 2006]. See LOV4IoT for more details. - Paper: Ontology-based context-aware service engine for U-Healthcare
SkinConductanceSensor, GSR (Galvanic Shin Response)	Get project Get rule [Ko et al. 2006]. See LOV4IoT for more details. - Paper: Ontology-based context-aware service engine for U-Healthcare

Authors	Year	Research Problem Addressed & Project	Sensor or Measurement Type	Reasoning
Nouh et al. [33]	2019	Smart RS of Hybrid Learning (SRHL), Well-being RS	No	✓ Hybrid RS, KNN Unsupervised ML
Budner et al. [34]	2017	Detect happiness from watch Correlation weather and mood Correlation friends having Positive or negative mood	✓ Pebble smart watch (to track activity), GPS heart rate, light, activity, VMC temperature, humidity, pressure, wind, cloud	✓ Random Forest ML Weka
Ahmed et al. [35]	2017	Heart attack prediction	✓ Heart rate, blood pressure cholesterol, blood sugar	✓ KNN ML
Lim [36]	2013	I-Wellness: Personalized wellness therapy RS	✓ Health status, personal lifestyle, wellness concern	✓ RS, Hybrid Case-Based Reasoning (CBR)
Likamwa et al. [37]	2013	User's: mood mobile app Correlates mood and phone usage	✓ Phone	✓ Clustering classifier Multi-linear regression
Lin et al. [38]	2011	Motivate: Personalized context-aware RS	✓ Location, weather, agenda	✓ RS, Rule-based (If-then rules)
Lane et al. [39]	2011	BeWell: Well-being mobile app	✓ Sleep, activity, social	No
Rabbi et al. [40]	2011	Well-being mobile application	✓ Voice, accelerometer, depressive symptoms	✓ HMM
Church et al. [41]	2010	MobiMood: Mobile mood awareness and communication	✓ Location, calls, SMS, mood intensity	No
Afzal et al. [42]	2018	Personalized well-being health	✓ Location, activity, weather, emotion	✓ RS, Rule-based
Garcia-Ceja et al. [43]	2018	Mental Health Monitoring Systems (NHMS) Survey	✓ Heart rate, GSR, body or skin temperature	Survey paper ✓ ML algorithm
Kim et al. [44]	2017	Depression Severity Elderly People, AAL	✓ Infrared motion sensor	✓ Bayesian Network Decision Tree, SVM, ANN
Zhou et al. [45]	2015	Monitoring mental health states	✓ Heart rate, pupil variation, head movement, eye blink facial expression	✓ ML (Logistic regression, SVM)
Garcia-Ceja et al. [46]	2016	Stress	✓ Accelerometer data (from smartphone)	✓ Naive Bayes, Decision Tree
Yoon et al. [47]	2016	New stress monitoring patch	✓ Skin conductance, pulse wave, skin temperature	No
Lu et al. [48]	2012	StressSense	✓ Voice data (smartphone)	✓ GMMs
Chang et al. [49]	2011	AMMON: Stress detector	✓ Voice data	✓ SVM
Yacchirema et al. [50]	2018	Obtrusive Sleep Apnea (OSA)	Heart rate, snoring, activity, BMI, weight, step counts temperature, humidity air pollutant	✓ Rule-based ANN-MLP RELU
Angelidou [51]	2015	Sleep apnea diagnosis, snoring	✓ Bio-signal and sound data	✓ Decision tree (Weka)
Laxminarayan [52]	2004	Exploratory sleep analysis	✓ Heart rate, oxygen potential, body position	✓ Association rule mining Logistic regression, Weka

TABLE II: Well-being and IoT-based emotion applications (positive and negative). Sensor measurement and reasoning taxonomy to later process sensor data with reasoning mechanisms within applications. Set of keywords relevant for automatic analysis. Legend: Machine Learning (ML), Support Vector Machine (SVM), Recommender System (RS), Ambient Assisted Living (AAL), Gaussian Mixture Models (GMMs), Artificial Neural Network (ANN), Multilayer Perceptron (MLP), Galvanic Skin Response (GSR), Hidden Markov Model (HMM), K-Nearest Neighbors (KNN)

Authors	Year	Project	OA	Reasoning
Berthelon et al. [53]	2013	Emotion Ontology for Context Awareness	✓	No
Sanchez-Rada et al. [54]	2013	Onyx: Describing emotions on the web of data	✓	No SPIN mentioned but not used
Hastings et al. [55]	2012 2011	MFOEM: Mental health and disease ontologies	✓	No
Lopez et al. [56]	2008	Describing emotions	✓	No
Arguedas et al. [57]	2015	Emotion Awareness	No	No
Tapia et al. [58]	2014	Semantic Human Emotion Ontology (SHEO) DetectionEmotion: Facial complex emotions	No	✓ SWRL rules for complex emotions
Sykora et al. [59]	2013	Emotive ontology	No	No
Fang et al. [60]	2010	Relationships between colors and main meridians	No	No
Grassi et al. [61]	2009	Human Emotions Ontology (HEO)	No	No
Radulovic et al. [62]	2009	Smiley Ontology	No	No
Benta et al. [63]	2007	Context Aware Museum Guide by considering users' affective state	No	✓ Fuzzy Logic (logical inference)
Obrenovic et al. [64]	2005	Emotional Cues	No	No
Mathieu et al. [65]	2005	Ontology of Emotions and Feelings	No	No

TABLE III: Ontology-based IoT emotion projects and reasoning mechanisms employed. Legend: Ontology Availability (OA)

12. Robotics Sensor Dictionary (Ongoing - Last Updated: November 2020)

Robotics domain: sensors, measurements and units

Note: Warning mix between M3 domain (m3:Robotic) and classification of devices (m3:RoboticM2MDevice)

m3:FeatureOfInterest (e.g., SenML domain)/ m3:M2MDevice	M3 or SenML Sensor Name, Measurement Name, and Unit	Description, other names (synonyms)	Knowledge referenced (LOV4IoT & SLOR)
m3:Robotic/ m3:RoboticM2MDevice	m3:Thermometer m3:Temperature m3: DegreeCelsius m3: DegreeFahrenheit m3: DegreeKelvin °C, K, F See other domains - Duplication	Thermometer	LOV4IoT YES & SLOR YES
m3:Robotic/ m3:RoboticM2MDevice	See other domains - Duplication	humidity	LOV4IoT YES & SLOR YES
m3:Robotic/ m3:RoboticM2MDevice	See other domains - Duplication	light	LOV4IoT YES & SLOR YES
m3:Robotic/ m3:RoboticM2MDevice	See other domains - Duplication	presence	LOV4IoT YES & SLOR YES
m3:Robotic/ m3:RoboticM2MDevice		pressure	LOV4IoT YES & SLOR YES
m3:Robotic/ m3:RoboticM2MDevice		gyroscope	LOV4IoT YES & SLOR YES
m3:Robotic/ m3:RoboticM2MDevice		sound	LOV4IoT YES & SLOR YES
m3:Robotic/ m3:RoboticM2MDevice	m3: / -	Gas detector	LOV4IoT YES SLOR NO
m3:Robotic/ m3:RoboticM2MDevice	m3: / -	Smoke detector	LOV4IoT YES SLOR NO
m3:Robotic/ m3:RoboticM2MDevice		accelerometer	LOV4IoT YES SLOR NO
m3:Robotic/ m3:RoboticM2MDevice		camera	LOV4IoT YES SLOR NO
m3:Robotic/ m3:RoboticM2MDevice		gps	LOV4IoT YES SLOR NO
m3:Robotic/ m3:RoboticM2MDevice		Rfid tag	LOV4IoT YES SLOR NO
m3:Robotic/ m3:RoboticM2MDevice		Chemical sensor	LOV4IoT NO SLOR NO
m3:Robotic/ m3:RoboticM2MDevice		gyrometer	LOV4IoT NO SLOR NO

m3:RoboticM2MDevice			
---------------------	--	--	--

Table 12. Robotics domain: sensors, measurements and units

13. Healthcare Sensor Dictionary (Last Updated: November 2020)

Demo dedicated web page (more often updated rather this documentation):

<http://linkedopenreasoning.appspot.com/?p=slor-health>

Healthcare domain: sensors, measurements and units

m3:FeatureOfInterest (e.g., SenML domain)/ m3:M2MDevice	M3 or SenML Sensor Name, Measurement Name, and Unit	Description, other names (synonyms)	M3 rules
m3:Health/ m3:HealthM2MDevice	BodyThermometer/ BodyTemperature DegreeCelcius	Body thermometer	Completeness OK (3 rules [Obaid 2013] + 3 rules [Jara 2009]), Correctness OK
m3:Health/ m3:HealthM2MDevice	HeartBeatSensor/ HeartBeat BeatPerMinute	Pulse sensor, pulse oxymeter, pulse-ox, heart beat, heart rate, pulse rate, cardiac frequency, breath rate	Correctness ok (2 rules [5 rules Tanatong 2011] & [Hristoskova 2014]) + Completeness No (>300 nothing)
m3:Health/ m3:HealthM2MDevice	PulseOxymeter/ SPO2 Percent	Pulse oxymeter, spO2, blood oxygen saturation sensor, pulse and oxygen in blood sensor	Correctness OK (1 rule [Hristoskova 2014]) + Completeness NO
m3:Health/ m3:HealthM2MDevice	CholesterolSensor/ Cholesterol MmolPerLiter	cholesterol	Correctness OK (1 rule [Bravo 2009-2013]) + Completeness NO
m3:Health/ m3:HealthM2MDevice	Glucometer/ BloodGlucose GramPerLiter	Glucometer, glucose sensor, blood glucose meter, blood sugar level	Completeness OK (3 rules [Guermah 2014]), Correctness OK
m3:Health/ m3:HealthM2MDevice	BloodPressureSensor/ BloodPressure mmHg	blood pressure meter, sphygmomamometer, MAP (Mean arterial pressure), CVP (central venous pressure)	0 rule
m3:Health/ m3:HealthM2MDevice	SkinConductanceSensor/ SkinConductance -	skin conductance, galvanic skin response sensor, GSR, sweating	0 rule
m3:Health/	WeightSensor	Weight sensor, body	0 rule

m3:HealthM2MDevice	Weight Kilo, Pound	weight, weight scale	
m3:Health/ m3:HealthM2MDevice	Pedometer NumberStep		

Table 13. Healthcare domain: sensors, measurements and units

14. Environment Sensor Dictionary (Ongoing)

Environment domain: sensors, measurements and units

m3:FeatureOfInterest (e.g., SenML domain)/ m3:M2MDevice	M3 or SenML Sensor Name/ Measurement Name, and Unit	Description, other names (synonyms)	M3 rules
m3:Environment/ m3:EnvironmentM2MDevice	AirPollutantSensor/ AirPollution EAQI	Air pollutant sensor	5 rules Completeness + Correctness Kofler + See LOV4IoT [Staroch 2013]
m3:Environment/ m3:EnvironmentM2MDevice	SaltMeter / Salinity ppt		
m3:Environment/ m3:EnvironmentM2MDevice	oxygen	oxygen sensor	
m3:Environment/ m3:EnvironmentM2MDevice	NO	Nitrogen oxide sensor	
m3:Environment/ m3:EnvironmentM2MDevice	CO	Carbon monoxide CO sensor	
m3:Environment/ m3:EnvironmentM2MDevice	SO2	Sulfure dioxide sensor	
m3:Environment/ m3:EnvironmentM2MDevice	CO2 PPM	Carbon Dioxyde Sensor Ppm (parts per million)	
m3:Environment/ m3:EnvironmentM2MDevice	pH	pH	

Table 14. Environment domain: sensors, measurements and units

15. Waste Management Sensor Dictionary (Ongoing - Last Updated: November 2020)

Note: Check this demo which will be more often updated and uses the M3 ontology:

<http://linkedopenreasoning.appspot.com/?p=slorv2>

Water domain: sensors, measurements and units.

Legend: LOV4IoT project and SLOR rules (YES means that knowledge is available on this demo

(<http://linkedopenreasoning.appspot.com/?p=slorv2>, NO otherwise)

m3:FeatureOfInterest	M3 or SenML Sensor	Description, other names	Knowledge
----------------------	--------------------	--------------------------	-----------

(e.g., SenML domain)/ m3:M2MDevice	Name, Measurement Name, and Unit	(synonyms)	referenced (LOV4IoT & SLOR)
m3:WasteManagement/ m3:WasteM2MDevice	m3:GasDetector m3:Gas -		LOV4IoT project YES and SLOR rules NO
m3:WasteManagement/ m3:WasteM2MDevice	m3:WasteManagementSensor -	-	LOV4IoT project YES and SLOR rules NO
m3:WasteManagement/ m3:WasteM2MDevice	m3:Methane_Sensor, m3:Methane -	-	LOV4IoT project YES and SLOR rules NO

16. Cyber Physical System (CPS) Sensor Dictionary (TO DO)

17. Other or Generic Sensor Dictionary

Generic domain: sensors, measurements and units

m3:FeatureOfInterest (e.g., SenML domain)/ m3:M2MDevice	M3 or SenML Sensor Name, Measurement Name, and Unit	M3 or SenML measurement name	Description, other names (synonyms)
Generic	HumiditySensor Percent	Humidity	Hygrometer, humidity sensor, moisture sensor, soil moisture probes
Generic	Thermometer °C	Temperature	Thermometer, temperature sensor, thermistor
Generic	LightSensor lux	Luminosity	Light, luminosity, illuminance, lighting
Generic	lon, lat, alt	gps	Global positioning system, gps, location sensor
Generic	Hz	frequency	
Generic		shake	Shake sensor, vibration

Table 15. Generic domain: sensors, measurements and units

18. IoT Applicative Domain Sensor Dictionary

E.g., Aix means Air en Provence which is a city.

E.g., you use the temperature in the health domain enable the computer to understand that the measurement corresponds to a body temperature.

For instance, Fire is a subclass of Environment.

FOI when duplication with measurement type,
FOI for feature of Interest

M3 or SenML Domain name	Description, other names (synonyms)
BuildingAutomation (subclass: Activity)	Smart home, building automation, or building or room (kitchen, bathroom, living room, dining room)
Health	healthcare
Weather	Weather forecasting, meteorology
Agriculture	Agriculture, smart farm, garden
Environment (subclass: Fire)	Environment (earthquake, flooding, forest fire, air pollution)
Emotion	Affective science, emotion, mood, emotional state; brain wave
Transport	Intelligent transportation systems (ITS), smart car/vehicle, transportation
EnergyFOI	Smart grid, smart energy
Tourism	Tourism
Location	Location, place, GPS coordinates
City	Smart city, city automation, public lighting
TrackingGood (subclasses: TrackingFood, TrackingCD)	Tracking RIFD goods
Generic	Others

Table 16. Domain names

19. Actuator Sensor Dictionary

If SenML value = 0 it means the actuator is not used

If SenML value = 1 it means the actuator is used

M3 or SenML domain	M3 or SenML Actuator name	Description, other names (synonyms)
Transport	FogLamp	Fog lamp
Transport	Brake	
Transport	ABS	Abs, anti-lock braking system
Transport	ESP	Electronic stability program
Transport	SeatBeltTensionSensor	Seat belt tension sensor
BuildingAutomation	WaterFlow	water flow attached to sinks, showers, flushing
BuildingAutomation, Transportation	AirConditioner	Air conditioner, ac
BuildingAutomation, Transportation	AlarmSystem	
BuildingAutomation	Heating	
BuildingAutomation	Blind	
BuildingAutomation	Ventilation	
BuildingAutomation	Curtain	
BuildingAutomation	Window	
BuildingAutomation	Cupboard	
BuildingAutomation	DishWasher	
BuildingAutomation	WashingMachine	

BuildingAutomation	Drawer	
BuildingAutomation	Door	
BuildingAutomation	Boiler	
BuildingAutomation	CoffeeMachine	Coffee machine, coffee maker
BuildingAutomation	Computer	Computer, pc
BuildingAutomation	Shower	Water actuator
BuildingAutomation	TV	tv, television
BuildingAutomation	Lavatory	
BuildingAutomation	Fridge	Refrigerator, fridge
BuildingAutomation	Freezer	Chiller
BuildingAutomation	Microwave	
BuildingAutomation	Lamp	Dimmable light, lamp

Table 17. Actuator names

RFID tags name	Description, other names (synonyms)
RFID_Food	food
RFID_Book	book (isbn)
RFID_CD	cd, music
RFID_DVD	dvd, movie
RFID_Garment	clothes, garments
RFID_BrushTeeth	
RFID_Broom	
RFID_TeaBag	
RFID_Cup	
RFID_Mop	
RFID_Bed	
RFID_Sofa	
RFID_Pan	
pill box	
passport	
luggage	
parking space	
toll	
animal	
payment card	
transit pass	

Table 18. RFID tags common terms

20. Others Measurement Name Sensor Dictionary

E.g., t temp and temperature have the same meaning and represents the temperature measurement.
The same as the one referenced for sensors

M3 or SenML measurement name	Description, other names (synonyms)
lon	longitude
lat	latitude
Others measurements are the same than those referenced for sensors	

Table 19. Measurement names

III. Matching with Standards Ontologies or well-Known Ontologies

1. Compliant with SAREF and its extensions see dedicated tables per domains (ONGOING)

Numerous links have been added within the M3 ontology code, such as:

- rdfs:subclassOf
- rdfs:seeAlso
- owl:equivalentClass
- Etc.

See also tables above when we explicitly remind SAREF concepts used.

2. Sensor Dictionary Compliant with IEC 61360 - Common Data Dictionary (ONGOING)

IEC 61360 - Common Data Dictionary (CDD - V2.0014.0016)

<https://cdd.iec.ch/cdd/iec61360/iec61360.nsf/TreeFrameset?OpenFrameSet>

AAA103 - sensor
AAA104 - humidity sensor
AAA105 - light sensor
AAA107 - nuclear sensor
AAA108 - pressure sensor
AAA109 - proximity sensor
AAA110 - temperature sensor
AAA159 - microphone
AAA075 - lamp
AAA017 - battery

3. Sensor Dictionary Compliant with IEC 62720 Units (ONGOING)

Compliant with IEC 62720 units ontology of IEC SC3D
<https://webstore.iec.ch/publication/7395>

4. Matching with [iot.schema.org](http://iotschema.org) (ONGOING - September 2020)

<http://iotschema.org/>

<http://iotschema.org/Property>

<http://iotschema.org/docs/full.html>

More specific Types	PropertyValue
• DONE – ElectricCurrentA • DONE – ElectricCurrentB • ExpectedPressure • LineFrequency • Discharging • ActiveEnergyExported • AveragePhaseToNeutralVoltage • DONE – Temperature • DemandControlledVentilation • PhaseToPhaseVoltageBC • ExpectedFloatImmersionDepth • DONE – CarbonDioxideConcentration • SoundPressureLevel • DONE – Humidity warning also TargetHumidity • MaxDischargeCurrent • TotalActivePower • Charging • DONE – ElectricCurrentC • DONE – CarbonDioxideConcentrationLimit • DONE – OxygenConcentration • ReactivePowerC • AverageElectricCurrent • ApparentEnergy • CurrentColour • OperationStatus • MotionType • ArgonConcentration • TotalPowerFactor • SwitchStatus • RampTime • DONE – Illuminance http://iotschema.org/Illuminance • CurrentDimmer • DONE – TargetHumidity • ApparentPowerC • PowerFactorC • PhaseToNeutralVoltageA • ActivePowerB • NitrogenConcentration • ReactiveEnergyExported • ReactivePowerB • MaxDischargePower • TargetTemperature	• CarbonDioxideConcentrationData • CarbonDioxideConcentrationLimitData • StateOfChargeData • ElectricChargeData • LowBatteryData • TimeData • SoundPressureData • PowerFactorData • DimmerData • ReactiveEnergyData • LevelData • PressureData • TemperatureData • RampTimeData • DemandControlledVentilationData • DensityData • WindData • ReactivePowerData • ArgonConcentrationData • HumidityData • MotionTypeData • VoltageData • ImmersionDepthData • IlluminanceData • LineFrequencyData • ApparentPowerData • AudioVideoData • RColourData • ActiveEnergyData • FlowRateData • RunModeData • BColourData • ChargingStatusData • ApparentEnergyData • CRateData • ActivePowerData • OxygenConcentrationData • ElectricCurrentData • ERateData • GColourData • NitrogenConcentrationData

- ReactivePowerA - StateOfCharge - ActiveEnergyImported - RunMode - TotalApparentPower - PhaseToPhaseVoltageCA - PowerFactorA - MaxChargeCurrent - ActivePowerA - PhaseToNeutralVoltageB - TotalReactivePower - ExpectedDensity - ApparentPowerA - ActivePowerC - PccPower - CountDown - WindStrength - ReactiveEnergyImported - OverflowStatus - Capacity - AveragePhaseToPhaseVoltage - PowerFactorB - PhaseToPhaseVoltageAB - ExpectedFlowRate - ApparentPowerB - PhaseToNeutralVoltageC - TransitionTime - ExpectedUpstreamPressure - MaxChargePower - LowBattery CurrentLevel	
--	--

<u>Thing</u>	<u>Enumeration</u>
<u>Capability</u> <u>MotionControl</u> <u>VoltageMonitoring</u> <u>ElectricBattery</u> <u>Pump</u> <u>AirConditioner</u> <u>Camera</u> <u>ElectricPowerSystem</u> <u>TemperatureSensing</u> <u>BinarySwitchControl</u> <u>LevelSwitch</u>	<u>PressureUnit</u> <u>Domain</u> <u>ReactiveEnergyUnit</u> <u>ElectricCurrentUnit</u> <u>LineFrequencyUnit</u> <u>ReactivePowerUnit</u> <u>LevelUnit</u> <u>ActiveEnergyUnit</u> <u>TemperatureUnit</u> <u>VoltageUnit</u> <u>GasInAirConcentrationUnit</u>

▪ <u>FloatSwitch</u> ○ <u>Microphone</u> ○ <u>UltrasonicSensing</u> ○ <u>HumiditySensing</u> ○ <u>SoundPressure</u> ○ <u>PowerMonitoring</u> ○ <u>EnergyMonitoring</u> ○ <u>Thermostat</u> ○ <u>ColourControl</u> ○ <u>AmbientAir</u> ○ <u>Valve</u> ○ <u>ElectricCurrentMonitoring</u> ○ <u>IlluminanceSensing</u> ○ <u>ProximitySensing</u> ○ <u>DimmerControl</u> • <u>Device</u> ○ <u>Actuator</u> ○ <u>Sensor</u>	• <u>ActivePowerUnit</u> • <u>MotionSensorType</u> • <u>ApparentPowerUnit</u> • <u>DensityUnit</u> • <u>ApparentEnergyUnit</u> • <u>RunModeType</u> • <u>AudioVideoDataMode</u> • <u>TimeUnit</u> • <u>FlowRateUnit</u>
---	---

<u>InteractionPattern</u> • <u>Property</u> ○ <u>ElectricCurrentA</u> ○ <u>ElectricCurrentB</u> ○ <u>ExpectedPressure</u> ○ <u>LineFrequency</u> ○ <u>Discharging</u> ○ <u>ActiveEnergyExported</u> ○ <u>AveragePhaseToNeutralVoltage</u> ○ <u>Temperature</u> ▪ <u>AirTemperature</u> ▪ <u>ExpectedAmbientTemperature</u> ○ <u>DemandControlledVentilation</u> ○ <u>PhaseToPhaseVoltageBC</u> ○ <u>ExpectedFloatImmersionDepth</u> ○ <u>CarbonDioxideConcentration</u> ○ <u>SoundPressureLevel</u> ○ <u>Humidity</u> ○ <u>MaxDischargeCurrent</u> ○ <u>TotalActivePower</u>	<u>Event</u> • <u>PropertyChangedEvent</u> • <u>UnderVoltageAlarm</u> • <u>TemperatureAlarm</u> • <u>UnderTemperatureAlarm</u> • <u>OverTemperatureAlarm</u> • <u>BatteryLowVoltageAlarm</u> • <u>OverVoltageAlarm</u> • <u>OverElectricCurrentAlarm</u> • <u>MotionDetected</u> • <u>OverPressureAlarm</u> • <u>HighCarbonDioxideConcentrationAlarm</u>
--	--

- | | |
|---|--|
| <ul style="list-style-type: none">○ <u>Charging</u>○ <u>ElectricCurrentC</u>○ <u>CarbonDioxideConcentrationLimit</u>○ <u>OxygenConcentration</u>○ <u>ReactivePowerC</u>○ <u>AverageElectricCurrent</u>○ <u>ApparentEnergy</u>○ <u>CurrentColour</u>○ <u>OperationStatus</u>○ <u>MotionType</u>○ <u>ArgonConcentration</u>○ <u>TotalPowerFactor</u>○ <u>SwitchStatus</u>○ <u>RampTime</u>○ <u>Illuminance</u>○ <u>CurrentDimmer</u>○ <u>TargetHumidity</u>○ <u>ApparentPowerC</u>○ <u>PowerFactorC</u>○ <u>PhaseToNeutralVoltageA</u>○ <u>ActivePowerB</u>○ <u>NitrogenConcentration</u>○ <u>ReactiveEnergyExported</u>○ <u>ReactivePowerB</u>○ <u>MaxDischargePower</u>○ <u>TargetTemperature</u>○ <u>ReactivePowerA</u>○ <u>StateOfCharge</u>○ <u>ActiveEnergyImported</u>○ <u>RunMode</u>○ <u>TotalApparentPower</u>○ <u>PhaseToPhaseVoltageCA</u>○ <u>PowerFactorA</u>○ <u>MaxChargeCurrent</u>○ <u>ActivePowerA</u>○ <u>PhaseToNeutralVoltageB</u>○ <u>TotalReactivePower</u>○ <u>ExpectedDensity</u>○ <u>ApparentPowerA</u>○ <u>ActivePowerC</u>○ <u>PccPower</u>○ <u>CountDown</u>○ <u>WindStrength</u>○ <u>ReactiveEnergyImported</u>○ <u>OverflowStatus</u>○ <u>Capacity</u> | |
|---|--|

○ <u>AveragePhaseToPhaseVoltage</u> ○ <u>PowerFactorB</u> ○ <u>PhaseToPhaseVoltageAB</u> ○ <u>ExpectedFlowRate</u> ○ <u>ApparentPowerB</u> ○ <u>PhaseToNeutralVoltageC</u> ○ <u>TransitionTime</u> ○ <u>ExpectedUpstreamPressure</u> ○ <u>MaxChargePower</u> ○ <u>LowBattery</u> ○ <u>CurrentLevel</u>	
--	--

<u>Action</u> • <u>TurnOn</u> ○ <u>StartRecording</u> • <u>TurnOff</u> ○ <u>StopRecording</u> • <u>PauseRecording</u> • <u>SetLevel</u> • <u>ResumeRecording</u> • <u>SetPointBattery</u> • <u>DischargeBattery</u> • <u>SetDimmer</u> • <u>SetColour</u> • <u>ChargeBattery</u> • <u>StartRecording</u> • <u>ToggleAction</u> • <u>ChangePropertyAction</u> • <u>MakeImage</u> • <u>StopRecording</u>	
---	--

IV. M3 Language: a Unified sensor Dictionary

1. Why W3C SSN ontology is not enough?

As explained by [W3C SSN](#) (final report):

- The W3C SSN ontology does not describe domain concepts, time, locations, etc. these are intended to be included from other ontologies via OWL imports.
- Future work: Standardise the SSN ontology to bridge the Internet of Things
- Future work: Standardise the SSN ontology to use it in a Linked Sensor Data context

To sum up, W3C SSN is insufficient to unify sensor metadata such as describing units, sensor measurement types, applicative domains, and sensor types.

They suggest to reuse domain ontologies, but a deep analysis from the Linked Open Vocabularies for Internet of Things (LOV4IoT)¹ dataset [1] [2] shows that we can find several ontologies describing units, or the same sensor types.

2. Why do we need the M3 ontology?

To add reasoning on sensor data, we identified the need to design a common taxonomy to unify sensor metadata.

For this reason, we build this taxonomy that we called M3 nomenclature/language [3] as presented in the previous section.

The M3 nomenclature has been implemented in our [M3 ontology](#). The M3 Ontology references more than 30 sensors, measurements, units and about 10 domains. The M3 ontology is focused on the `ssn:ObservationValue` concept from the [W3C SSN ontology](#) which describes sensors and observations, and related concepts.

¹ <http://sensormeasurement.appspot.com/?p=ontologies>

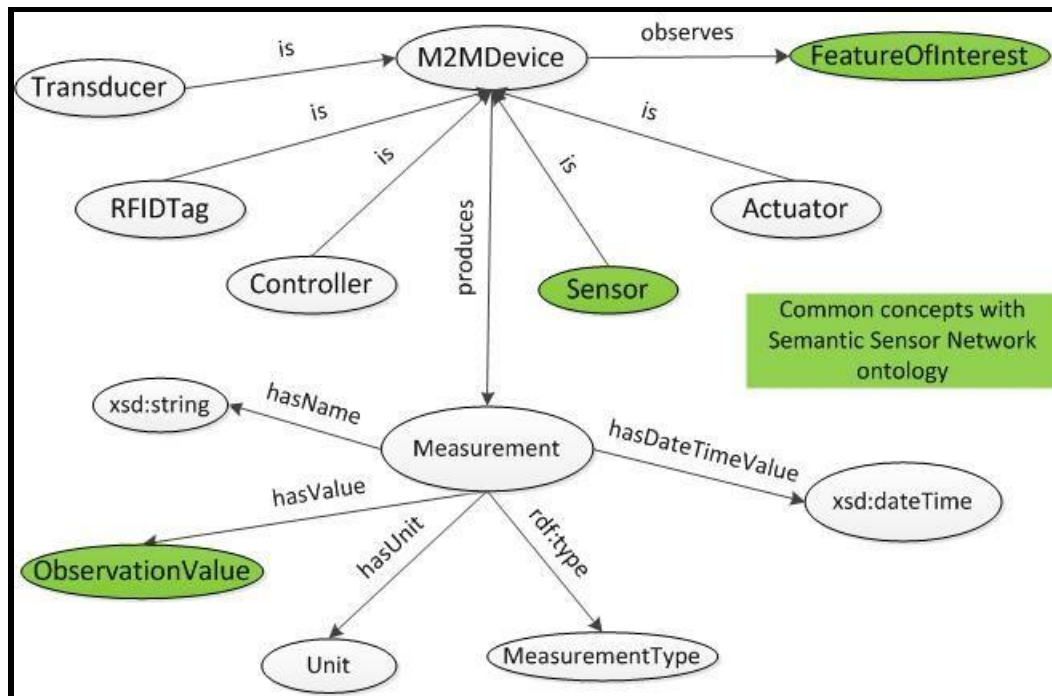


Figure 1. M3 ontology: extension of W3C SSN

3. M3-lite taxonomy (M3 ontology V2)

M3-lite taxonomy is a refinement of the M3 ontology (refactored, cleaned and aligned with the vision of the EU H2020 **FIESTA-IoT** project).

4. M3 interoperable domain knowledge

The key aspect of the M3 ontology is enabling linking domain ontologies and rules to deduce meaningful knowledge from sensor data.

5. M3 hub to combine cross-domain ontologies

The Machine-to-Machine Measurement (M3) hub interlinked cross-domain knowledge (ontologies, datasets and rules) as follows:

- Link ontologies in the same domain
- Link cross-domain ontologies

- Link rules thanks to the **Sensor-based Linked Open Rules (S-LOR)** to interpret IoT data.

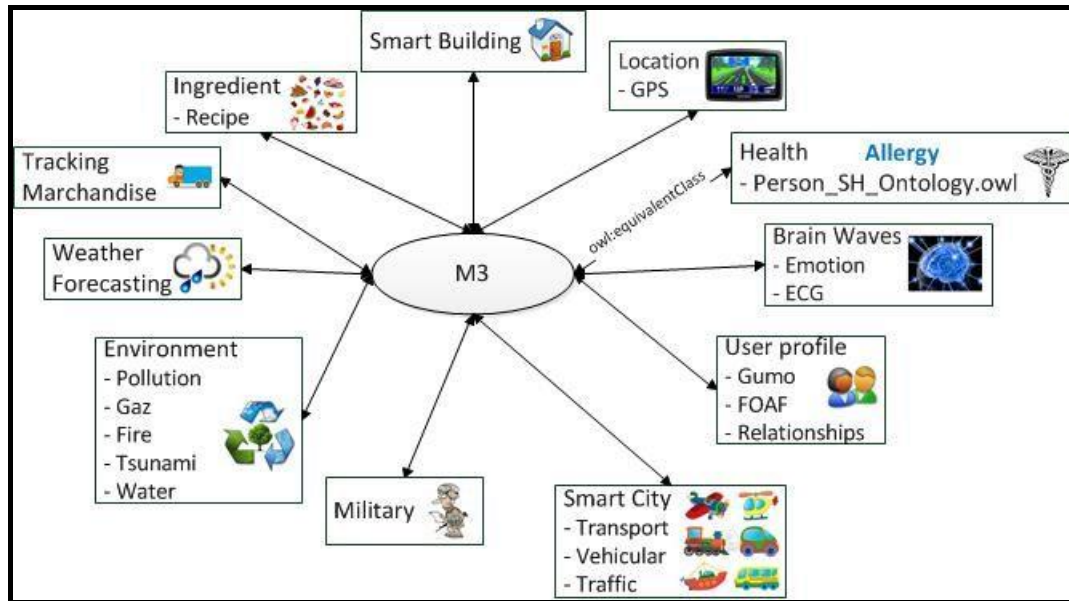


Figure 2. M3 to build cross-domain knowledge

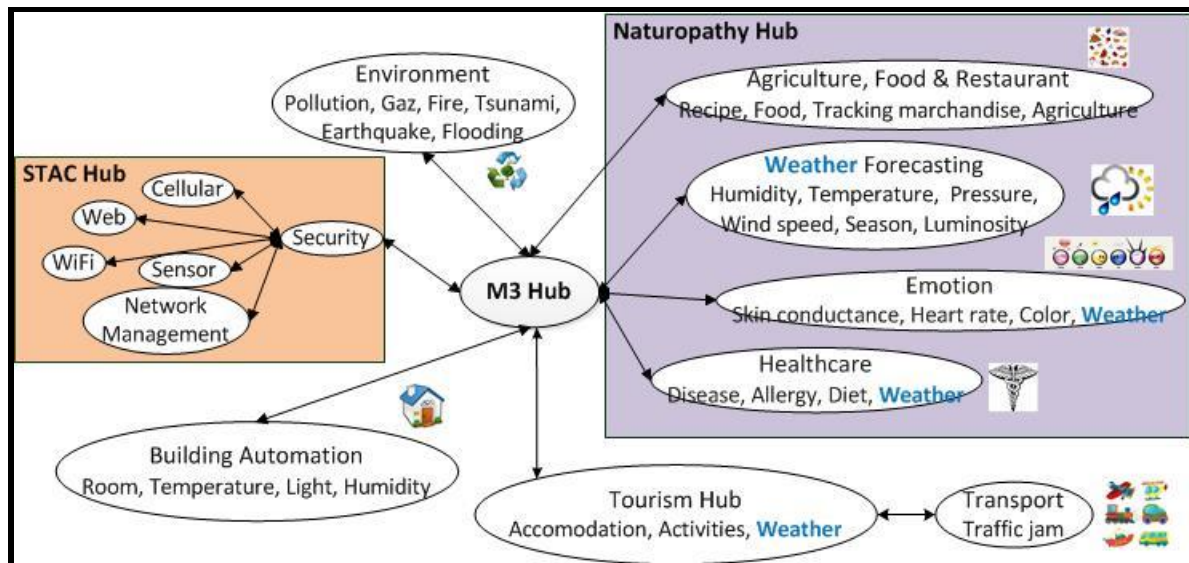


Figure 3. M3 to build cross-domain knowledge: Naturopathy and security example

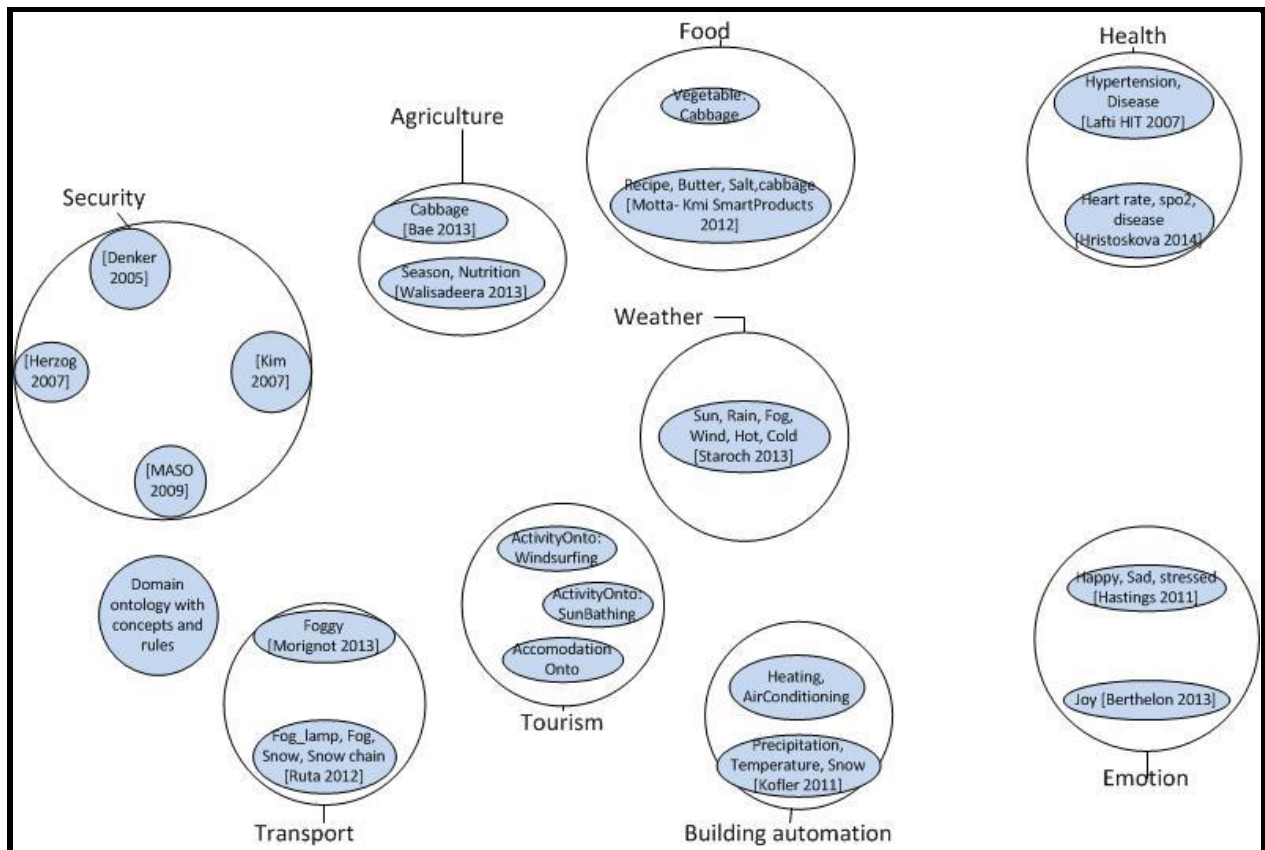


Figure 4. Without M3, the knowledge is not connected

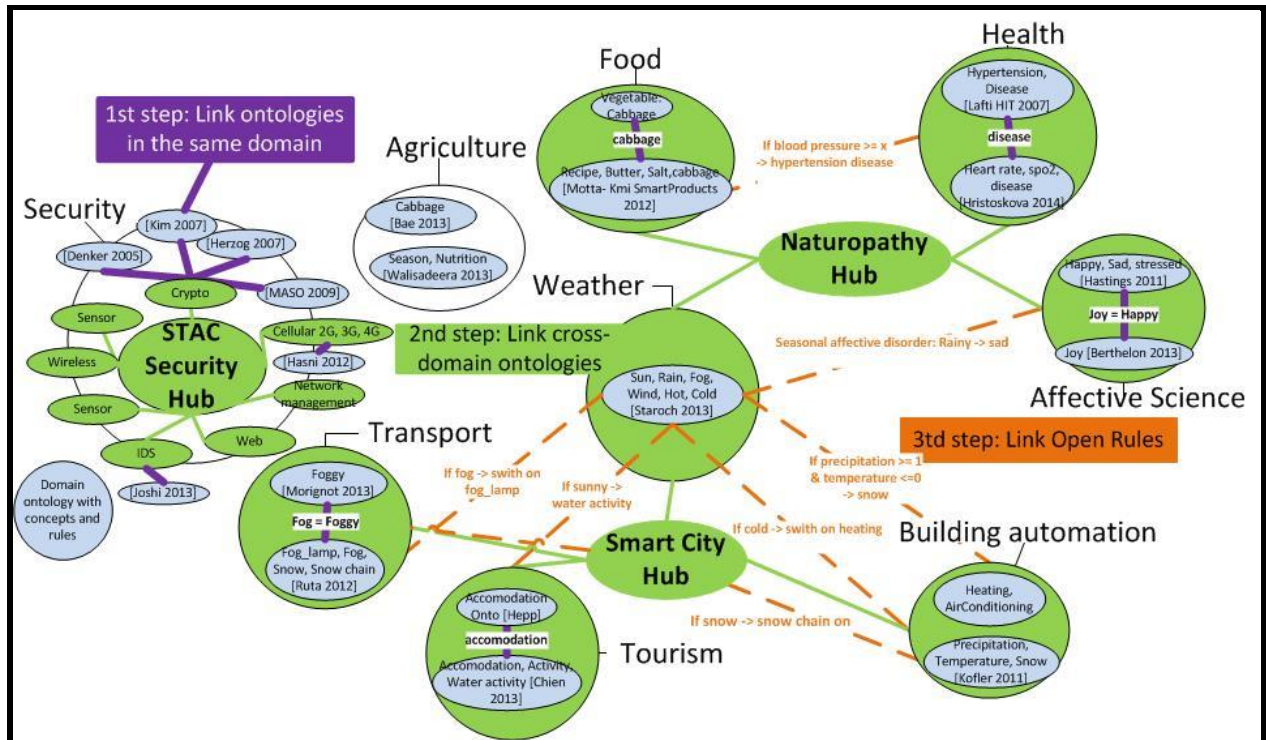


Figure 5. M3 used to build cross-domain knowledge: ontologies, datasets and reasoning

V. Semantic Annotator: M3 Converter

1. M3 converter user interface

The developer can use the M3 converter user interface:

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

See user guide: www.sensormeasurement.appspot.com/documentation/UserGuide.pdf



Use Chrome to get the data in a text format, with Firefox you only have the JavaScript alert popup.

SenML to RDF Converter

Copy/paste your SenML/XML sensor data here :

-09eb-4303-ae3c-d5d23149ee96">
<e n="blood pressure" t="0"
u="Pa" v="56">
<e n="heartbeat" t="0"
u="beet/m" v="155"></e>
<e n="temperature"
t="1374069830362" u="Cel"
v="40"></e>
</senml>

SenML/XML to RDF Converter

M3 interoperable IoT data

```
<rdf:Description rdf:about="http://sensormeasurement.appspot.com/m3#Measurement4">  
<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">1.374069830362E12</m3:hasDateTimeValue>  
<m3:hasValue rdf:datatype="http://www.w3.org/2001/XMLSchema#decimal">40.0</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>  
</rdf:RDF>
```

M3 inferType

Figure 6. Semantically annotating IoT data with the M3 converter user interface

2. Code example to semantically annotate IoT data with M3

```
1 // Converting your IoT data using SenML to RDF converter
2
3 // String URL_M3_CONVERTER = "http://www.sensormeasurement.appspot.com/swot/";
4 String format = "xml"; // or json
5 String iot_data = getSenMLData();
6
7 String m3_data = queryWebService(URL_M3_CONVERTER + "convert_senml_to_rdf/?data=" + iot_data +
8                               "&format="+ format);
9
10 store(m3_data);
```

Figure 7. Semantically annotating IoT data with the M3 converter web service

3. Enrich the M3 converter and adapt it to your data

When you download a template with the SWoT generator² you also get the rules to semantically annotate data, the file is called 'ruleM3Converter.txt'.



We did not have time to implement all the M3 nomenclature. Further, we frequently update the M3 nomenclature³.



But you can still improve and add more rules to semantically annotate your sensor data.

² <http://www.sensormeasurement.appspot.com/?p=m3api>

³ <http://www.sensormeasurement.appspot.com/documentation/NomenclatureSensorData.pdf>

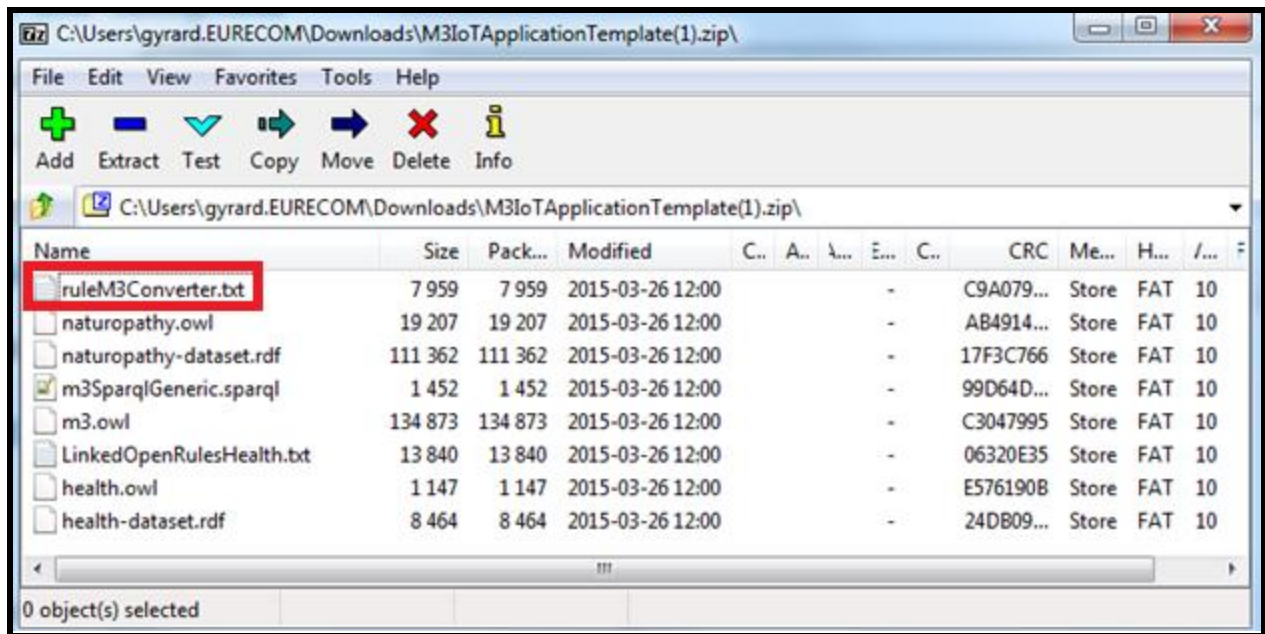


Figure 8. Rules provided in the template to semantically annotate sensor data

The following rule means that we explicitly add the context:

If you get a temperature from health domain (subclassOf m3:FeatureOfInterest), we will explicitly add that it corresponds to a body temperature.

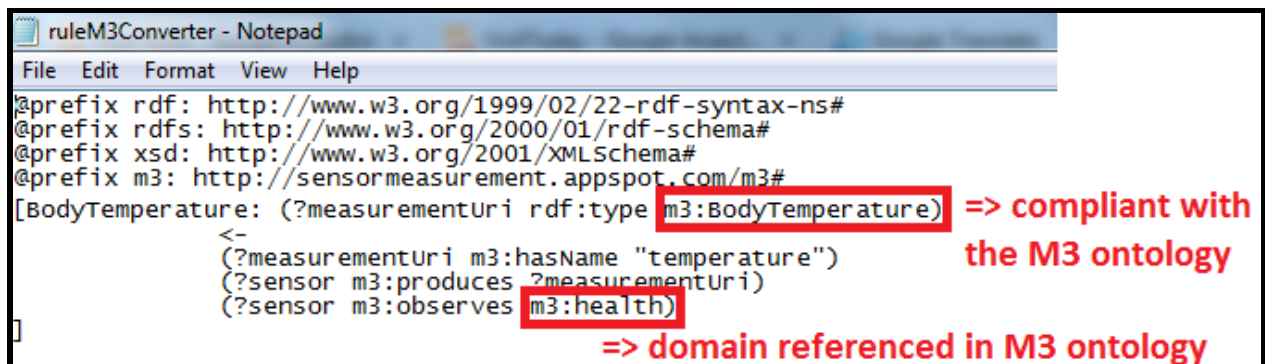


Figure 9. Add new rules to semantically annotate sensor data according to the M3 ontology.

This is important because after, you have the rules adapted to this kind of measurement.

```
LinkedOpenRulesHealth - Notepad
File Edit Format View Help
@prefix rdf: http://www.w3.org/1999/02/22-rdf-syntax-ns#
@prefix rdfs: http://www.w3.org/2000/01/rdf-schema#
@prefix xsd: http://www.w3.org/2001/XMLSchema#
@prefix m3: http://sensormeasurement.appspot.com/m3#
@prefix naturopathy: http://sensormeasurement.appspot.com/naturopathy#
@prefix nat: http://sensormeasurement.appspot.com/naturopathy-dataset/
@prefix emotion-dataset: http://sensormeasurement.appspot.com/dataset/emotion-dataset/
@prefix health-dataset: http://sensormeasurement.appspot.com/dataset/health-dataset/
@prefix transport: http://sensormeasurement.appspot.com/ont/m3/transport#

##### LINKED OPEN RULES - HEALTH #####

##### BODY TEMPERATURE RULES #####
#Paper: An ontology based system for social networking for health application support [Obaid et al. 2013]
#IF m3:BodyTemperature GREATER_THAN 39 m3:DegreeCelsius THEN CriticallyHighFever
#tested
# completeness + correctness OK
[CriticallyHighFever:
  (?measurement rdf:type m3:BodyTemperature)
  (?measurement m3:hasValue ?v)
  greaterThan(?v,39.0)
  ->
  (?measurement rdf:type health-dataset:CriticallyHighFever)
]
```

Figure 10. Explicit M3 measurement type is reused in the reasoning process

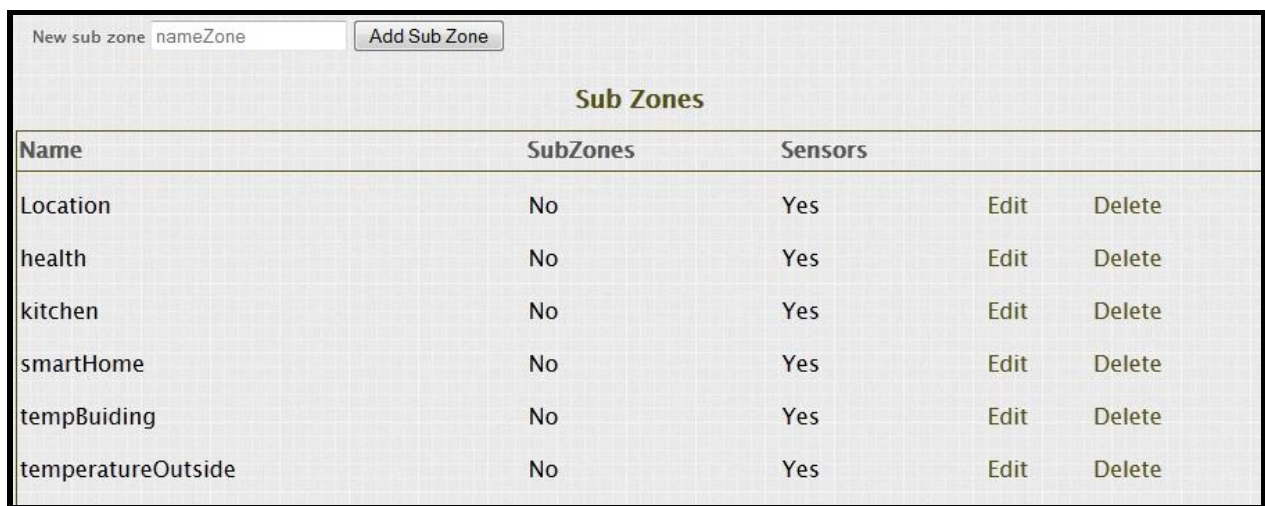
VI. Simulating SenML sensor measurements

The following interface enables to simulate sensor data:

<http://emulator-box-services.appspot.com/senmladmin/zones>

These data are compliant with the SenML⁴ format.

You can simulate heterogeneous domains (healthcare, smart kitchen, smart home, etc.), as you can see in **Error! Reference source not found.** You can create a new domain (Add sub zone button).



The screenshot displays a web interface for managing sub zones. At the top, there is a form with a text input labeled 'New sub zone' containing the placeholder text 'nameZone', and a button labeled 'Add Sub Zone'. Below this is a table titled 'Sub Zones'.

Name	SubZones	Sensors		
Location	No	Yes	Edit	Delete
health	No	Yes	Edit	Delete
kitchen	No	Yes	Edit	Delete
smartHome	No	Yes	Edit	Delete
tempBuiding	No	Yes	Edit	Delete
temperatureOutside	No	Yes	Edit	Delete

Figure 11. Simulate M2M area networks

Click on the button “Edit” associated to the kitchen zone.

You go to the following URL:

<http://emulator-box-services.appspot.com/senmladmin/ahdzfmVtdWxhdG9yLWJveC1zZXJ2aWNlc3IWCxIJWm9uZUFkbWlulgdraXRjaGVuDA/edit>.

You can simulate smart devices (sensors, actuators, transducer, controllers and RFID tags).

⁴ <http://www.ietf.org/archive/id/draft-jennings-senml-10.txt>

In this use case, we simulate RFID tags embedded on ingredients.

We simulate SenML measurements (in XML or JSON).

A measurement has a name, a value, a unit, and the date.

Example 1: Measure name: Temperature, Unit: Degree Celsius, Value: 35

Example 2: Measure name: banana, Unit: Gram, Value: 1000



Use the M3 nomenclature⁵ to describe sensor measurements.

To be sure that the M3 converter will semantically annotate correctly the sensor measurements.

It will ease the process to build the application with the Semantic Web of Things template.

⁵ www.sensormeasurement.appspot.com/documentation/NomenclatureSensorData.pdf

New Sensor

Sensors

Title	UUID	Measures				
fridge	695eb2c6-befc-43a5-b2d8-a7025063de32	measure name	acidity	float	now	Delete
		value	add a Measure			
	banana: (kind: mass) 1000 g @ now		{ "v": "1000", "u": "g", "t": 0, "n": "banana" }		Delete	
	chocolate: (kind: mass) 1000 g @ now		{ "v": "1000", "u": "g", "t": 0, "n": "chocolate" }		Delete	
	milk-expires: (kind: time) 5 d @ 2013.02.01 AD at 10:12:10 UTC		{ "v": "5", "u": "d", "t": 1359713530376, "n": "milk-expires" }		Delete	
	milk: (kind: volume) 2 l @ now		{ "v": "2", "u": "l", "t": 0, "n": "milk" }		Delete	
	peach: (kind: mass) 1000 g @ now		{ "v": "1000", "u": "g", "t": 0, "n": "peach" }		Delete	

Figure 12. Simulating sensor measurements

VII. Converting senML sensor data

Go to the M3 converter to semantically annotate SenML data with RDF according to the M3 ontology.

Web page: http://www.sensormeasurement.appspot.com/?p=senml_converter



Use Chrome to get the data in a text format, with Firefox you only have the JavaScript alert popup.

SenML to RDF Converter

Copy/paste your SenML/XML sensor data here :

```
-09eb-4303-  
ae3c-d5d23149ee96">  
<e n="blood pressure" t="0"  
u="Pa" v="56">  
<e n="heartbeat" t="0"  
u="beet/m" v="155"></e>  
<e n="temperature"  
t="1374069830362" u="Cel"  
v="40"></e>  
</senml>
```

SenML/XML to RDF Converter

M3 interoperable IoT data

```
<rdf:Description rdf:about="http://sensormeasurement.appspot.com/m3#Measurement4">  
<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">1.374069830362E12</m3:hasDateTimeValue>  
<m3:hasValue rdf:datatype="http://www.w3.org/2001/XMLSchema#decimal">40.0</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>  
</rdf:RDF>
```

M3 inferType

Figure 13. Semantically annotating IoT data with the M3 converter user interface

SenML to RDF Converter

SenML to RDF Converter (Use chrome)

1. [Simulate your data](#)
2. [Get SenML/XML data](#)
3. Enter an url (see previous link):

<http://emulator-box-services.appspot.com/senml/zones/ahdzfmVtdWxhdG9yLWJveC1zZXJ2aWNlc3lVCxIJWm9uZUFkbWlulgZoZWFSdGgM>

SenML to RDF Converter

Wait 1 minute!

Figure 14. Semantically annotating sensor data

VIII. Querying the M3 nomenclature/ontology

1. Web service: querying sensors

Search for all M3 sensors:

<http://www.sensormeasurement.appspot.com/m3/subclassOf/?nameClass=Sensor&format=json>

Results:



```
{
  head: {
    vars: [
      "subject",
      "object",
      "label",
      "comment",
      "imgUrl"
    ]
  },
  results: {
    bindings: [
      {
        subject: {
          type: "uri",
          value: http://sensormeasurement.appspot.com/m3#WindDirectionSensor
        },
        object: {
          type: "uri",
          value: http://sensormeasurement.appspot.com/m3#Sensor
        },
        label: {
          type: "literal",
          "xml:lang": "en",
          value: "Wind Direction Sensor"
        },
        comment: {
          type: "literal",
          "xml:lang": "en",
          value: "WindDirectionSensor, unit in Degree"
        },
        imgUrl: {
          type: "uri",
          value: http://sensormeasurement.appspot.com/images/sensor/windDirection.png
        }
      }
    ]
  }
}
```

2. Web service: querying actuators

Search for all M3 actuators:

<http://www.sensormeasurement.appspot.com/m3/subclassOf/?nameClass=Actuator&format=json>

3. Web service: querying domains

Search for all M3 domains (=FeatureOfInterest):

<http://www.sensormeasurement.appspot.com/m3/subclassOf/?nameClass=FeatureOfInterest&format=json>

4. Web service: querying health devices

Search for all M3 health devices:

<http://www.sensormeasurement.appspot.com/m3/subclassOf/?nameClass=HealthM2MDevice&format=json>

5. Web service: querying transport devices

Search for all M3 transport devices:

<http://www.sensormeasurement.appspot.com/m3/subclassOf/?nameClass=TransportM2MDevice&format=json>

6. Web service: querying home devices

Search for all M3 home devices:

<http://www.sensormeasurement.appspot.com/m3/subclassOf/?nameClass=HomeM2MDevice&format=json>

IX. Code

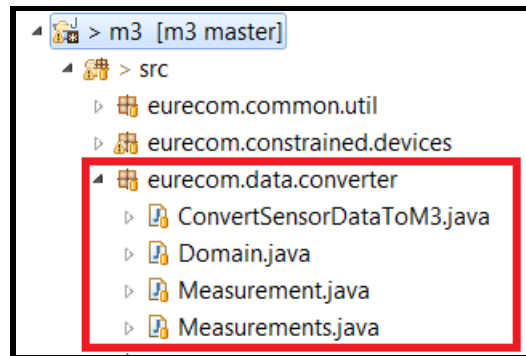


Figure 15. The converter package

1. *eurecom.data.converter*

- Domain.java: Class which transforms XML data to RDF data. Have a public ArrayList containing the measurements, getter and setter of the nameZone.
- ConvertSensorDataToM3.java: Behaviour of the conversion of java object (Measurements) into RDF data and of the other way. Can create also some instance object into RDF (type of object: Measurement, FeatureOfInterest, and Sensor).
- Measurement.java && Measurements.java: Objects measurements, describe the object that is used to transform Xml data into RDF data. Mostly composed by variables and their getter/setter.
- *Note:* A Domain has an ArrayList of Measurements (with an S) and Measurements has an ArrayList of Measurement. Where Measurement is just a data (30 °C for instance), Measurements is a bunch of data (all the data from one sensors) and FeatureOfInterest could be the domain (Temperature).

X. Semantic annotator: Tutorial

TO DO

1. Use case: M3 framework

TO DO

Semantically annotate XML data following the SenML format.

It employs the M3 ontology.

2. Use Case: M3 embedded in Android-powered devices

TO DO

Semantically annotate JSON data following the SenML format provided by Raspberry Pi.

It employs the M3 ontology.

3. Use Case: FIESTA-IoT project

TO DO

It employs the M3-lite taxonomy.

4. Use Case: Insight testbed

TO DO

Data sent by netatmo devices.

It employs the M3-lite taxonomy.

XI. References

- [1] A. Gyrard, G. Atemezing, C. Bonnet, K. Boudaoud, and M. Serrano. Reusing and unifying background knowledge for internet of things with lov4iot. In *Future Internet of Things and Cloud (FiCloud)*, 2016 4th International Conference on, Aug 2016.

[2] A. Gyrard, C. Bonnet, K. Boudaoud, and M. Serrano. Lov4iot: A second life for ontology-based domain knowledge to build semantic web of things applications. In *Future Internet of Things and Cloud (FiCloud), 2016 4th International Conference on*, Aug 2016.

[3] Amélie Gyrard, Soumya Kanti Datta, Christian Bonnet, and Karima Boudaoud. Standardizing generic cross-domain applications in Internet of Things. In *GLOBECOM 2014, 3rd IEEE Workshop on Telecommunication Standards: From Research to Standards, December 8, 2014, Austin, Texas, USA, Austin, UNITED STATES*, 12 2014.