Open Mobile Alliance Lightweight Machine-2-Machine (LwM2M)

and related open standards for managing sensor/actuator devices in IoT application scenarios

Francesco Doddo

IoT System Development Manager

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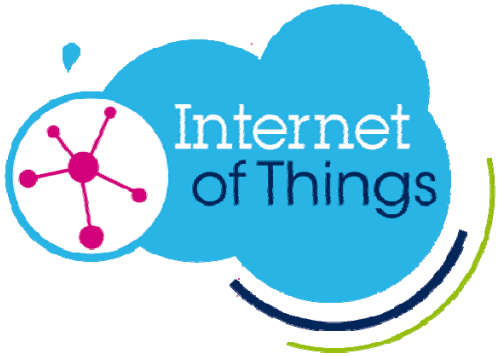
Technology Tour 2017

Application Scenarios



Smart Home & City

Smart Industry

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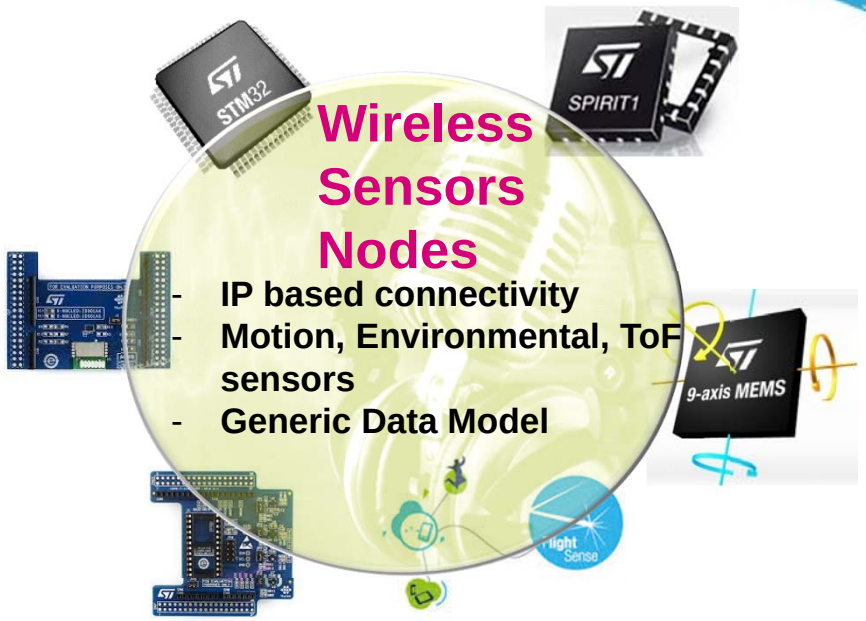
End-to-End View

Terminal



Wireless Sensors Nodes

- IP based connectivity
- Motion, Environmental, ToF sensors
- Generic Data Model

Cloud

- Application Services
- IoT Devices Management (bootstrapping, Firmware Update, Change settings)
- Sensors Data Access
- Actuators Control

Manage Home/City Devices

Sensors Data Collection

Actuators Management

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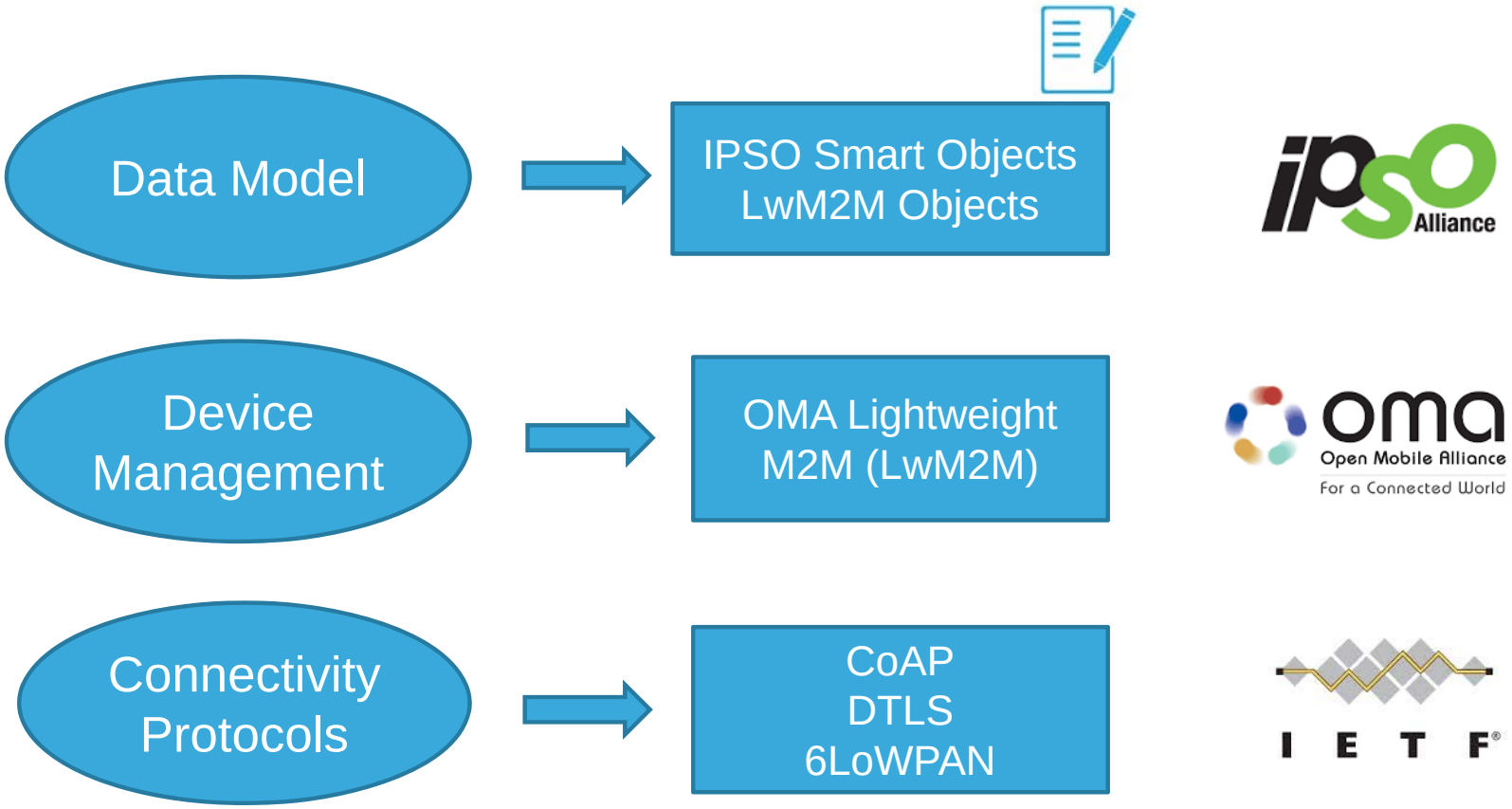
Data Access and Management of IoT Devices: Emerging Open Standards



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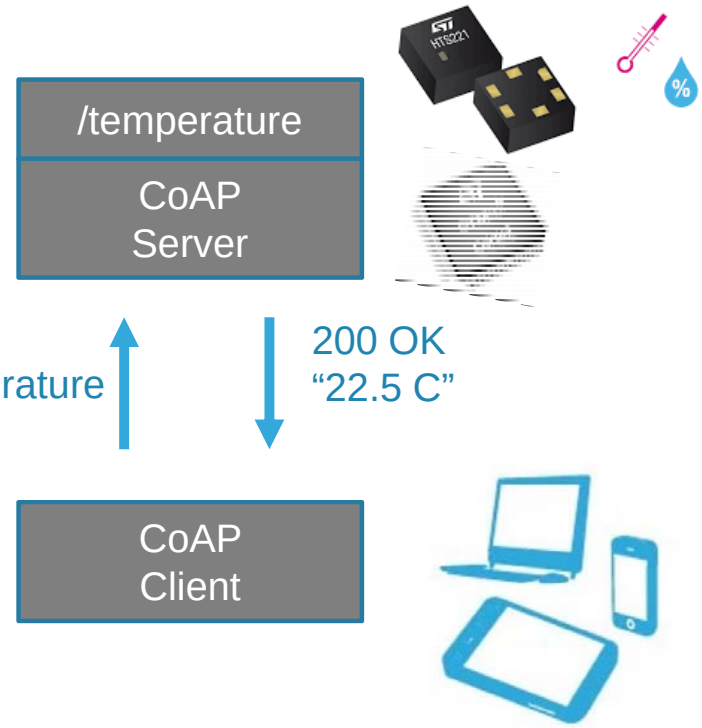
Connectivity IETF Standards

CoAP:
- Makes each IoT device a lightweight server that exposes a REST API
- Similar to HTTP, but designed for low power devices
- Publish/Subscribe support
- Specified in RFC 7252

DTLS:
- Provides communication security by providing confidentiality, integrity and authentication
- Specified in RFC 6347 and builds on TLS 1.2

6LoWPAN:
- Adaptation layer to transport IPv6 over low-power RF links
- Specified by RFC 6282 for 802.15.4



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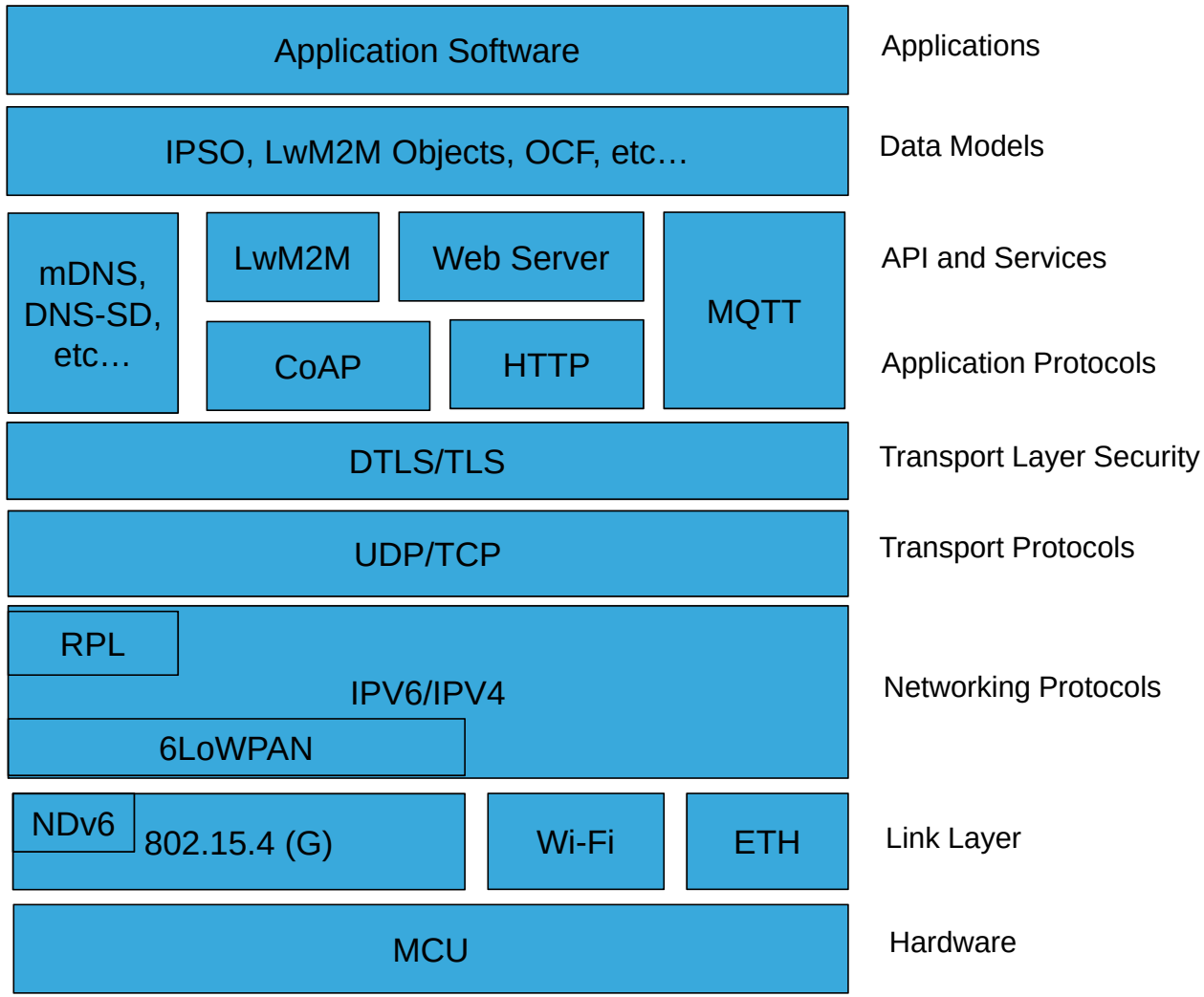
Protocol Stack of an IP Based IoT Device



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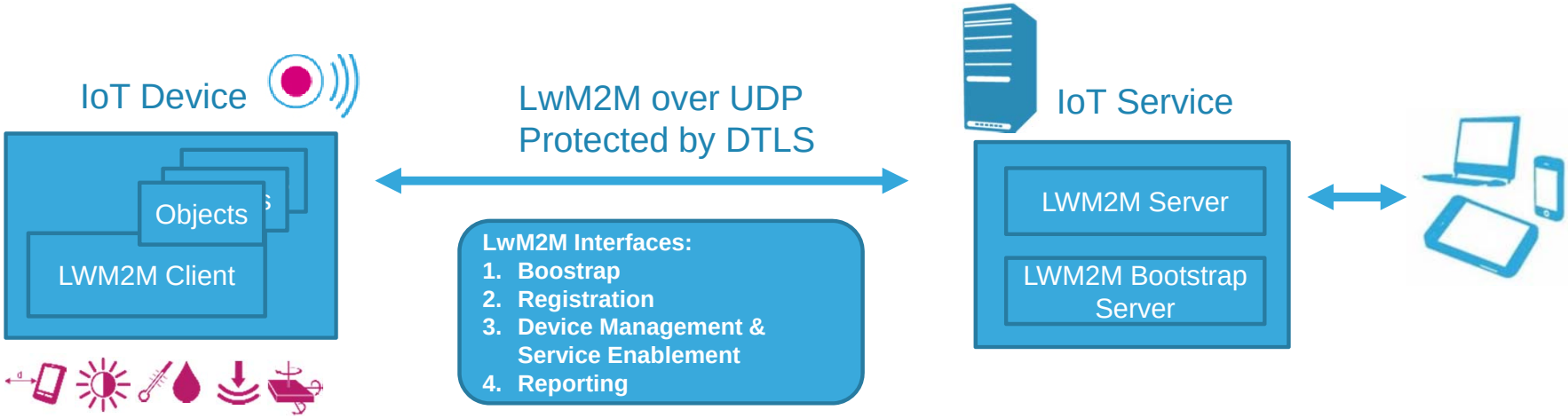
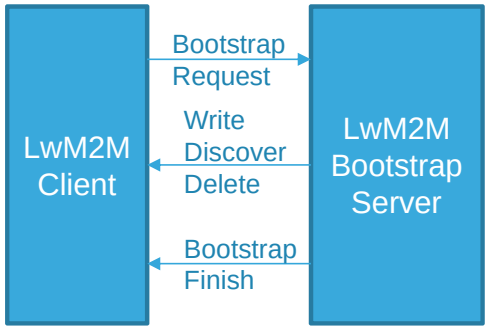
IoT Device Management LwM2M Protocol

OMA Lightweight M2M (LwM2M):

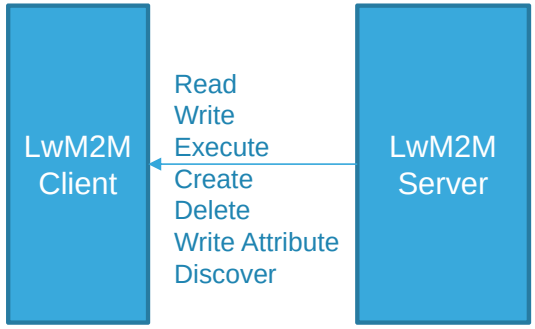
- **Management protocol for resource constrained devices** (e.g. Sensor hub)
- **Features: device bootstrapping** (service provisioning, key management), **firmware update**, **remote management** (change settings, trigger actuators), **fault management**, **information reporting** (notification of sensors values)
- Simple and extensible **Data Model**
- Version 1.0 ratified in Feb. 2017



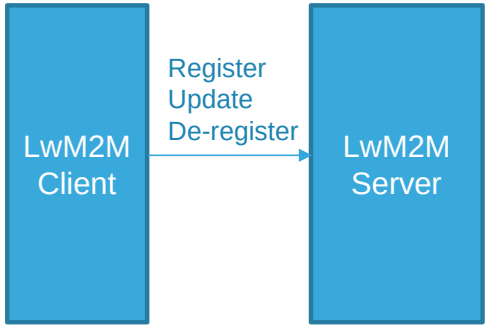
LwM2M Interfaces



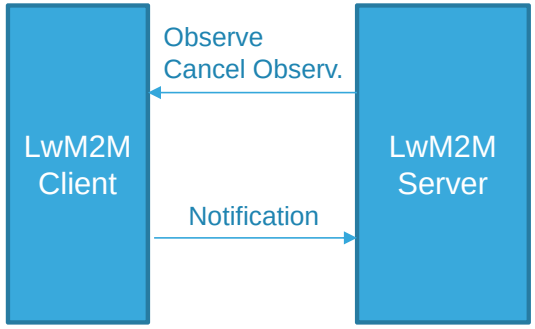
Bootstrap



Device Management
And Service Enablement



Client Registration



Information Reporting

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LwM2M Object Model

LwM2M Object Model:
Objects/Resources are accessed with simple URIs:
/{Object ID}/{Object Instance}/{Resource ID}

- Defines the object type
- Instance Number (one or more)
- Defines the Resource type

Reusable resource and object IDs
- Common definitions
- Map to semantic terms (e.g. temperature)
- **IDs uniquely defined since they are registered by the Open Mobile Naming Authority (OMNA)**

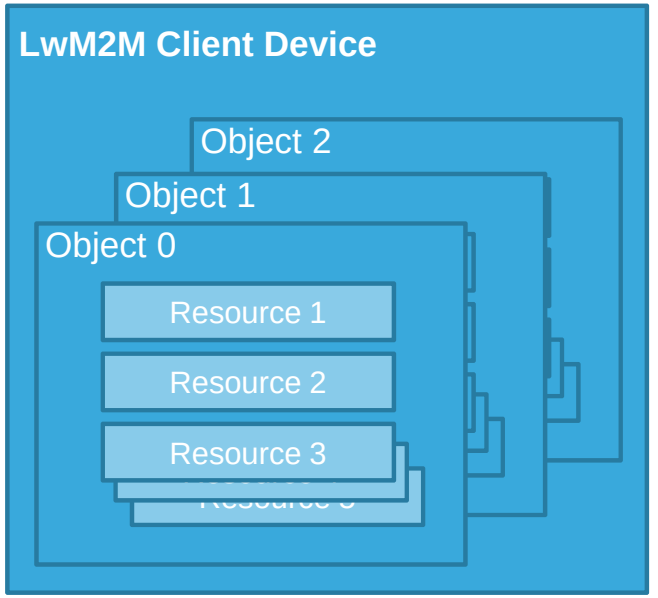
For example, take the case of a weather station device in your home: the access on this device/object/resource can be made at:

/home/weather/3303/0/5700

→ a reply from the device will provide a reading of the value from a **Temperature Sensor** (Object ID: 3303), **Instance #0**, **Sensor Value** (Resource ID: 5700)

/home/weather/3304/0/5602

→ a reply from the device will provide a reading of the value from a **Humidity Sensor** (Object ID: 3304), **Instance #0**, **Max Measured Value** (Resource ID: 5602)



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LwM2M Objects (defined by OMA)

- **The LwM2M v1.0 standard defines 8 objects**
- **Other organizations (for ex. IPSO Alliance) and vendors can define some objects**
- **A public repository managed by the OMA contains all the registered objects**

OMA Defined Object	Object ID	Description
LwM2M Security	0	Keying material of a LwM2M client to access a specified LwM2M server
LwM2M Server	1	Data related to a LwM2M server
Access Control	2	Used to check whether the LwM2M server has access right for performing an operation
Device	3	Device related information which can be queried by the server, include device reboot and factory reset functions
Connectivity Monitoring	4	Monitoring of parameters related to network connectivity
Firmware	5	Management of firmware to be updated (FOTA)
Location	6	Information related to device location
Connectivity Statistics	7	Statistics about connectivity collected by the client

LwM2M Objects (defined by IPSO Alliance)

«IPSO Smart Objects»:

- Simple Data Model for semantic interoperability across IoT Devices
- Compliant with the LwM2M specification
- **54 standards sensors and actuator Objects already specified and inserted in the OMA public registry**

LwM2M Client Device Example
(with Temperature, Humidity sensors and LED actuator)

IPSO Temperature Sensor Object (Instance: 0)	**IPSO Humidity Sensor Object** (Instance: 0)	**IPSO Light Control Object** (Instance: 0)
Object ID: 3303	Object ID: 3304	Object ID: 3311
Resource: Sensor Value (ID: 5700)	Resource: Sensor Value (ID: 5700)	Resource: On/Off (ID: 5850)
Resource: Min Measured Value (ID: 5601)	Resource: Min Measured Value (ID: 5601)	Resource: Dimmer (ID: 5851)
Resource: Max Measured Value (ID: 5602)	Resource: Max Measured Value (ID: 5602)	

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IPSO Smart Object Specification Examples

Object Info:

Object	Object ID	Object URN	Multiple Instances?	Description
IPSO Temperature	3303	urn:oma:lwm2m:ext:3303	Yes	Temperature sensor, example units = Cel

Object ID

Resources:

Resource Name	Resource ID	Access Type	Multiple Instances?	Mandatory	Type	Range or Enumeration	Units	Descriptions
Sensor Value	5700	R	No	Mandatory	Float			Last or Current Measured Value from the Sensor
Units	5701	R	No	Optional	String			Measurement Units

Definition of an IPSO Object and associated Resources

Resource ID

Allowed Access Type from Server e.g. Read (R), Execute (E)…

Resources are reusable (the same can be used in multiple object definitions)

Object Info:

Object	Object ID	Object URN	Multiple Instances?	Description
IPSO Light Control	3311	urn:oma:lwm2m:ext:3311	Yes	Light control object with on/off and optional dimming and energy monitor

Resources:

Resource Name	Resource ID	Access Type	Multiple Instances?	Mandatory	Type	Range or Enumeration	Units	Descriptions
On/Off	5850	R, W	No	Mandatory	Boolean			On/off control, 0=OFF, 1=ON
Dimmer	5851	R, W	No	Optional	Integer	0-100	%	Proportional control,

Description

The resource implementation Is Mandatory or Optional

Source: IPSO Alliance

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IPSO Smart Object XML Version in the OMA registry

URN / Version	ObjectID / xml	LwM2M Editor	Vorto	Object Name / Specification	Owner	Description
urn:oma:lwm2m:ext:3303	3303	3303	-	Temperature Sensor	IPSO Alliance	This IPSO object should be used over a temperature sensor to report a remote temperature measurement. It also provides resources for minimum/maximum measured values and the ---more---

```
▼<LWM2M xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:noNamespaceSchemaLocation="http://openmobilealliance.org/tech/profiles/LWM2M.xsd">
  ▼<Object ObjectType="MODefinition">
    <Name>Temperature</Name>
    ▼<Description1>
      Description: This IPSO object should be used with a temperature sensor to report a temperature measurement. It also provides resources for minimum/maximum measured
      values and the minimum/maximum range that can be measured by the temperature sensor. An example measurement unit is degrees Celsius (ucum:Cel).
    </Description1>
    <ObjectID>3303</ObjectID>
    <ObjectURN>urn:oma:lwm2m:ext:3303</ObjectURN>
    <MultipleInstances>Multiple</MultipleInstances>
    <Mandatory>Optional</Mandatory>
    ▼<Resources>
      ▼<Item ID="5700">
        <Name>Sensor Value</Name>
        <Operations>R</Operations>
        <MultipleInstances>Single</MultipleInstances>
        <Mandatory>Mandatory</Mandatory>
        <Type>Float</Type>
        <RangeEnumeration/>
        <Units>Defined by "Units" resource.</Units>
        <Description>Last or Current Measured Value from the Sensor</Description>
      </Item>
      ▼<Item ID="5601">
        <Name>Min Measured Value</Name>
        <Operations>R</Operations>
        <MultipleInstances>Single</MultipleInstances>
        <Mandatory>Optional</Mandatory>
        <Type>Float</Type>
```

XML Definition of the an Object Stored in the OMA Registry

Example here with Object 3303: Temperature Sensor
http://www.openmobilealliance.org/tech/profiles/lwm2m/3303.xml

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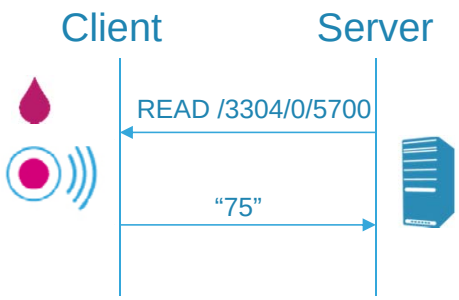
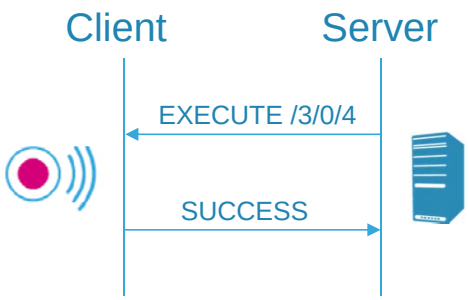
Source: http://www.openmobilealliance.org/wp/OMNA/LwM2M/LwM2MRegistry.html

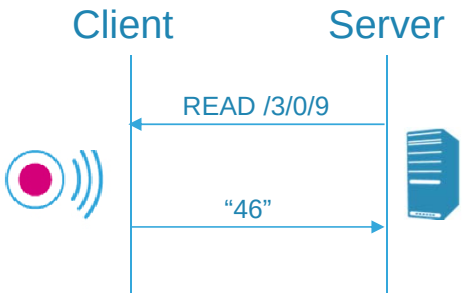
Interaction Scenarios Examples



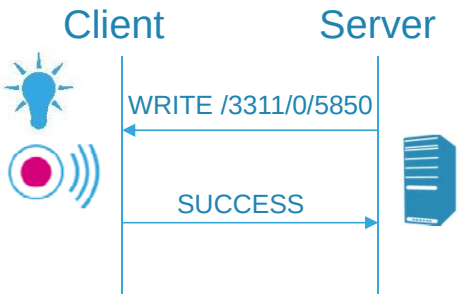
Reading a Humidity Sensor Value



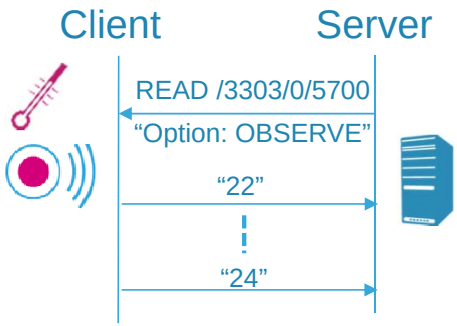
Rebooting the Device



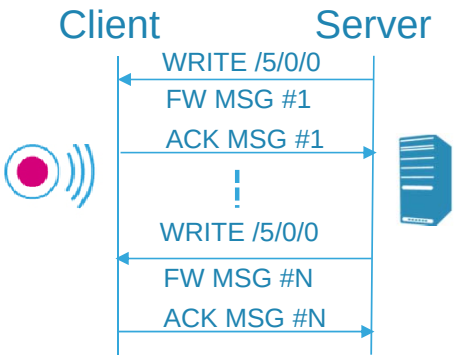
Retrieving the Device Battery Level



Switch a Light On



Receiving Notifications of Temperature Sensor Value Changes



Firmware Update

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Benefits for the IoT Scenarios

LwM2M and related standards cover the IoT needs

- Horizontal and extensible open standard
- Proven Web paradigm (“REST”) applied to the IoT
- Single protocol for device and application management
- Based on efficient communication protocols, designed for low power resource constrained devices (e.g. CoAP)
- State of the art security (DTLS)
- Open source implementations for both server and client are available

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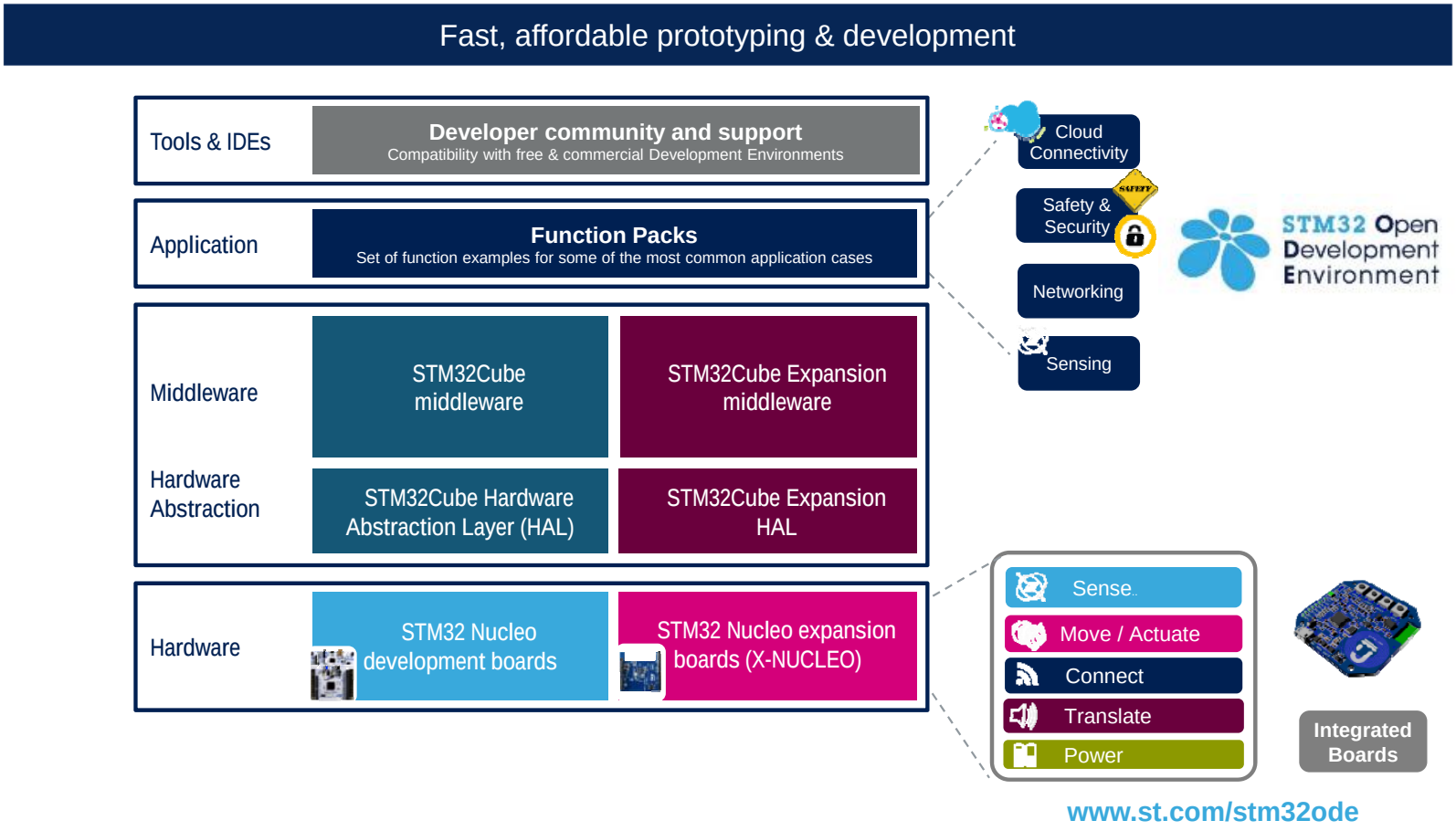
STM32 ODE



www.st.com/stm32ode

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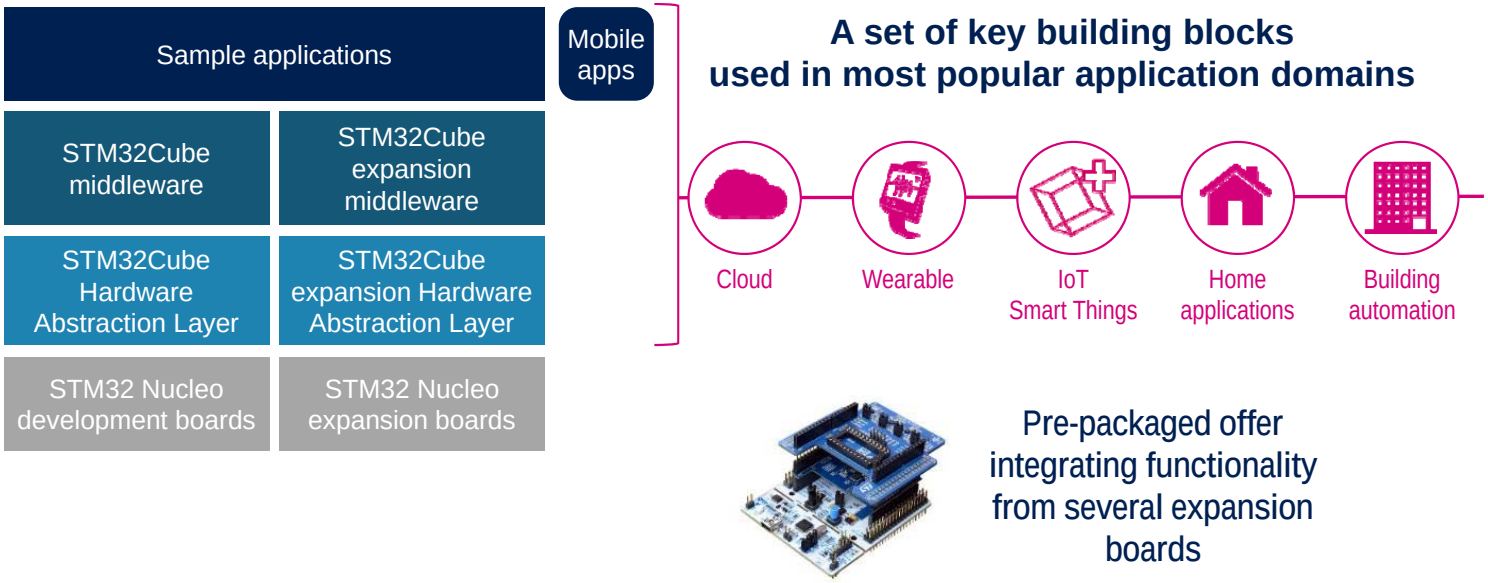
STM32 ODE Function Packs



Pre-packaged offer integrating functionality from several expansion boards

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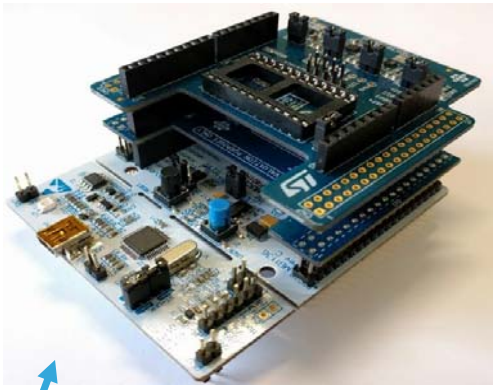
STM32 ODE Function Pack
FP-SNS-6LPNODE1: 6LoWPAN Node



IoT node - STM32 ODE solution		
Hardware	NUCLEO-L152RE (*)	
	X-NUCLEO-IDS01A4 or X-NUCLEO-IDS01A5	
	X-NUCLEO-6180XA1	
	X-NUCLEO-IKS01A2 (**)	
Software	FP-SNS-6LPNODE1	

(*) or NUCLEO-F401RE - (**) or X-NUCLEO-IKS01A1

FP-SNS-6LPNODE1 Function Pack

- This firmware package allows connecting an IoT node with sensors and actuators to a 6LoWPAN network, using sub-1GHz RF communication technology
- Middleware library with Contiki OS and Contiki 6LoWPAN protocol stack 3.x
- Support for mesh networking technology through the standard RPL protocol
- Environmental, Motion MEMS and Time of Flight sensors supported
- Embedded LwM2M Client with IPSO Smart Objects representation of sensors

Latest info available at www.st.com
FP-SNS-6LPNODE1

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STM32 ODE Function Pack
FP-SNS-6LPNODE1: LwM2M/IPSO Objects

Object	ID	Instances	Notes
Server	1	1	
Device	3	1	
IPSO Digital Input	3200	1	The instance maps the NUCLEO board User button
IPSO Light Control	3311	2	The instances map the NUCLEO and X-NUCLEO-IDS01A4/5 boards LEDs

LwM2M/IPSO Objects for
STM32 Nucleo Board

Object	ID	Instances	Notes
Server	1	1	
Device	3	1	
IPSO Digital Input	3200	1	The instance maps the NUCLEO board User button
IPSO Presence Sensor	3302	1	
IPSO Light Control	3311	1	The instance maps the NUCLEO board LED

LwM2M/IPSO Objects for Proximity and
ambient light Sensors
(X-NUCLEO-6180XA1 board)

Object	ID	Instances	Notes
Server	1	1	
Device	3	1	
IPSO Digital Input	3200	1	The instance maps the NUCLEO board User button
IPSO Temperature	3303	1	
IPSO Humitidy	3304	1	
IPSO Light Control	3311	1	The instance maps the NUCLEO board LED
IPSO Accelerometer	3313	1	
IPSO Magnetometer	3314	1	
IPSO Barometer	3315	1	

LwM2M/IPSO Objects for
Motion & Environmental Sensors
(X-NUCLEO-IKS01A2 board)

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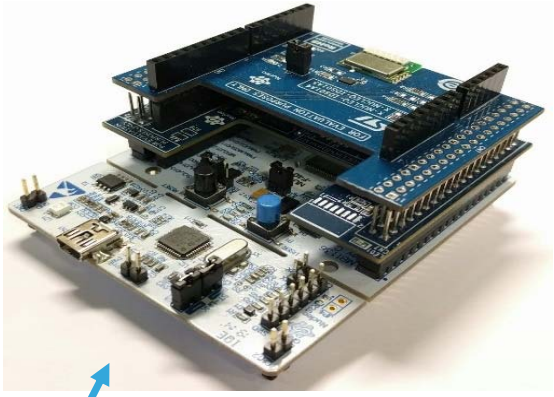
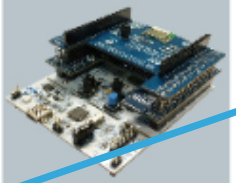
STM32 ODE Function Pack
FP-NET-6LPWIFI1: 6LoWPAN-Wi-Fi Bridge



Gateway - STM32 ODE solution		
Hardware	NUCLEO-F401RE	
	X-NUCLEO-IDS01A4 or X-NUCLEO-IDS01A5	
	X-NUCLEO-IDW01M1	
Software	FP-NET-6LPWIFI1	

FP-NET-6LPWIFI1 Function Pack

- This firmware package provides application-level functions to bridge 6LoWPAN and Wi-Fi networks
- Middleware library with Contiki OS and Contiki 6LoWPAN protocol stack 3.x
- Support for mesh networking technology by the means of the standard RPL protocol
- Middleware library for Wi-Fi connectivity using the SPWF01SA module

Latest info available at www.st.com
FP-NET-6LPWIFI1

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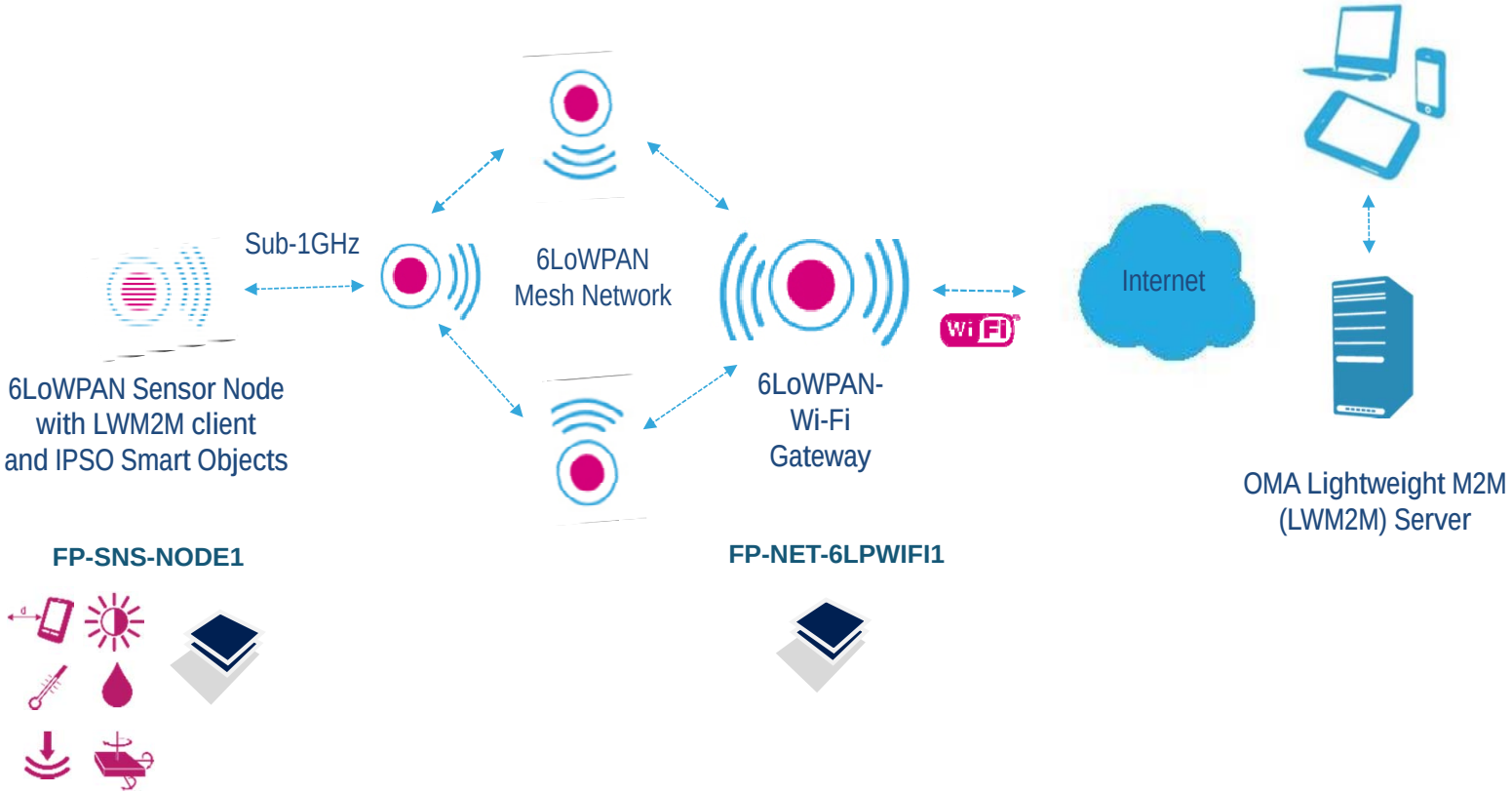
STM32 ODE Solutions
End-to-End Deployment Example

FP-SNS-6LPNODE1 ←→ FP-NET-6LPWIFI1 ←→ LwM2M SERVER



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LwM2M Server

STM32 ODE solutions are interoperable with a public LwM2M Server

- For evaluation purpose, the sensors nodes FP-SNS-6LPNODE1 can be managed by an OMA Lightweight M2M server called "**Leshan**"
- This public server is available at: http://leshan.eclipse.org
- The server can also be installed on a local machine by the user

WHAT IS ECLIPSE LESHAN?

- Leshan provides libraries that help people develop their own Lightweight M2M server and client
- Eclipse project since 2014
- Modular Java libraries
- Based on Californium CoAP implementation
- Based on Scandium DTLS implementation
- IPSO objects support
- http://www.eclipse.org/leshan/

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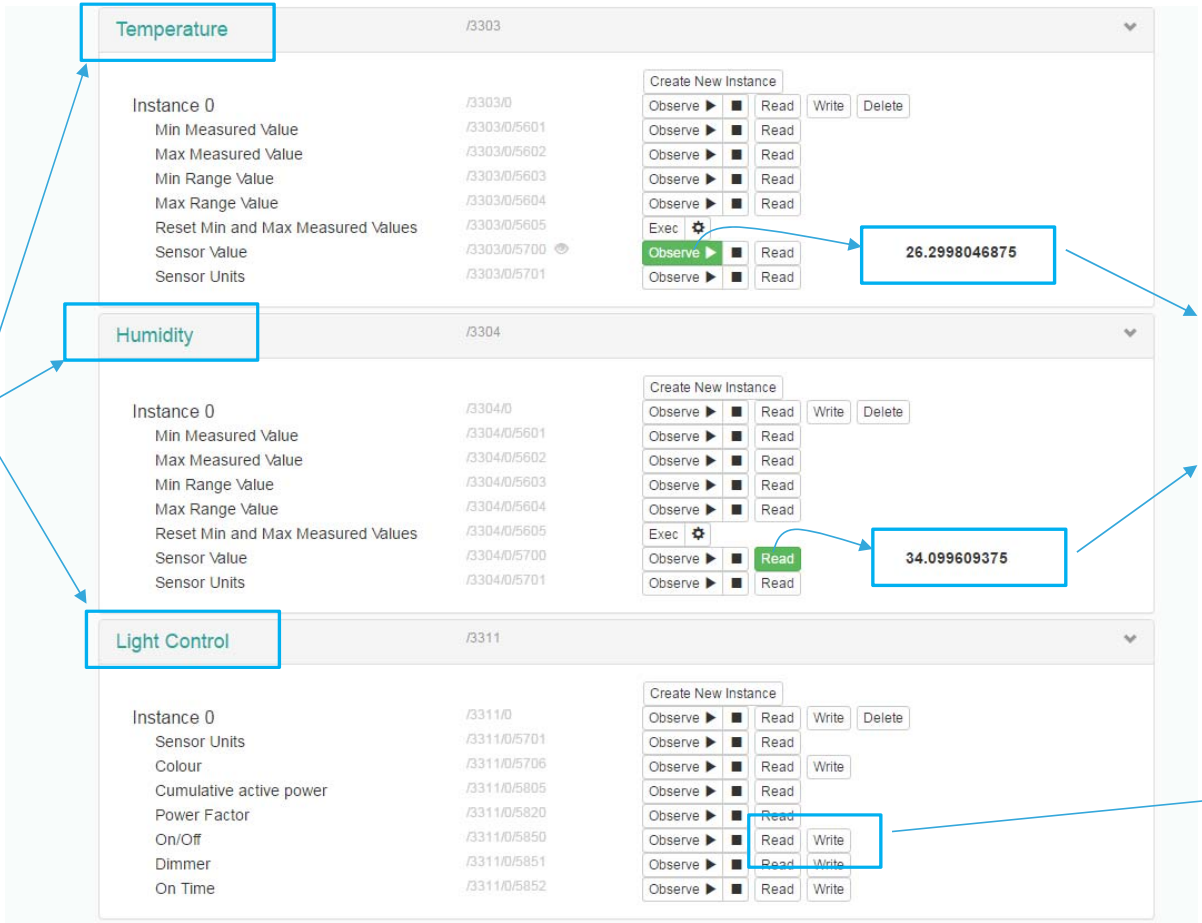
LwM2M Server Access

LwM2M Server Dashboard (http://leshan.eclipse.org)

Standard Objects implemented on the 6LoWPAN node (running the LwM2M client) accessed by the Leshan LwM2M Server on the Internet



Current temperature and humidity sensor values on the IoT node that are read by the server

LED light control (e.g. ON/OFF) on the node

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Available STM32 ODE Function Packs (1/2)

Function	Application case	STM32 Nucleo Develop. board	X-NUCLEO Expansion board	STM32 ODE Function Pack	
				Software	Apps iOS/ Android
Local and cloud connectivity	An IoT node with Wi-Fi and sensors, securely connected to Microsoft Azure cloud	NUCLEO-F401RE	X-NUCLEO-IDW01M1 X-NUCLEO-IKS01A2 X-NUCLEO-NFC01A1	**FP-CLD-AZURE1**	-
	An IoT node with Wi-Fi, NFC and sensors, securely connected to IBM Bluemix cloud	NUCLEO-F401RE	X-NUCLEO-IDW01M1 X-NUCLEO-IKS01A2 X-NUCLEO-NFC01A1	**FP-CLD-WATSON1**	-
	An IoT node with Wi-Fi and sensors, securely connected to Amazon AWS IoT	NUCLEO-F401RE	X-NUCLEO-IDW01M1 X-NUCLEO-IKS01A2	**FP-CLD-AWS1**	-
Sensing	An IoT node with BLE Connectivity, sensors and NFC for simple and secure Bluetooth BLE pairing	NUCLEO-F401RE NUCLEO-L476RG	X-NUCLEO-IDB05A1 X-NUCLEO-IKS01A2 X-NUCLEO-NFC01A1 X-NUCLEO-6180XA1	**FP-SNS-FLIGHT1**	ST BlueMS
	An IoT node with BLE connectivity and with sensors for temperature, humidity, pressure, motion, and digital microphone	NUCLEO-F401RE NUCLEO-L476RG	X-NUCLEO-IDB05A1 X-NUCLEO-IKS01A2 X-NUCLEO-CCA02M1	**FP-SNS-ALLMEMS1**	ST BlueMS
	An IoT node with BLE Connectivity and with and 4 sensors sensors for temperature, humidity, pressure and motion	NUCLEO-F401RE NUCLEO-L476RG NUCLEO-L053R8	X-NUCLEO-IDB05A1 X-NUCLEO-IKS01A2	**FP-SNS-MOTENV1**	ST BlueMS
Safe and security	An IoT node with secure BLE network pairing through NFC	NUCLEO-F401RE NUCLEO-L053R8	X-NUCLEO-IDB05A1 X-NUCLEO-NFC01A1	**FP-SEC-BLENFC1**	ST BlueMS
	An IoT node with secure Wi-Fi network pairing through NFC	NUCLEO-F401RE	X-NUCLEO-IDW01M1 X-NUCLEO-NFC01A1	**FP-SEC-WIFINFC1**	ST M24SR

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Available STM32 ODE Function Packs (2/2)

Function	Application case	STM32 Nucleo Develop. board	X-NUCLEO Expansion board	STM32 ODE Function Pack	
				Software	Apps iOS/ Android
Network infrastructure	A BLE star network connected via Wi-Fi bridge to IBM Bluemix cloud	NUCLEO-F401RE NUCLEO-L476RG NUCLEO-L053R8	X-NUCLEO-IDW01M1 X-NUCLEO-IDB05A1 (X-NUCLEO-IKS01A2)	**FP-NET-BLESTAR1**	ST SensNet
	A bridge to connect 6LoWPAN IoT nodes connected to smartphones via BLE interface	NUCLEO-F401RE	X-NUCLEO-IDS01A4 (X-NUCLEO-IDS01A5) X-NUCLEO-IDB05A1	**FP-NET-6LPBLE1**	-
	6LowPAN SPIRIT connectivity and bridge to Wi-Fi connectivity	NUCLEO-F401RE	X-NUCLEO-IDS01A4 (X-NUCLEO-IDS01A5) (X-NUCLEO-6180XA1) (X-NUCLEO-IKS01A2)	**FP-NET-6LPWIFI1**	-
	6LowPAN SPIRIT nodes based on the LwM2M standard	NUCLEO-F401RE	X-NUCLEO-IDS01A4 (X-NUCLEO-IDS01A5) (X-NUCLEO-6180XA1) (X-NUCLEO-IKS01A2)	**FP-SNS-6LPNODE1**	-

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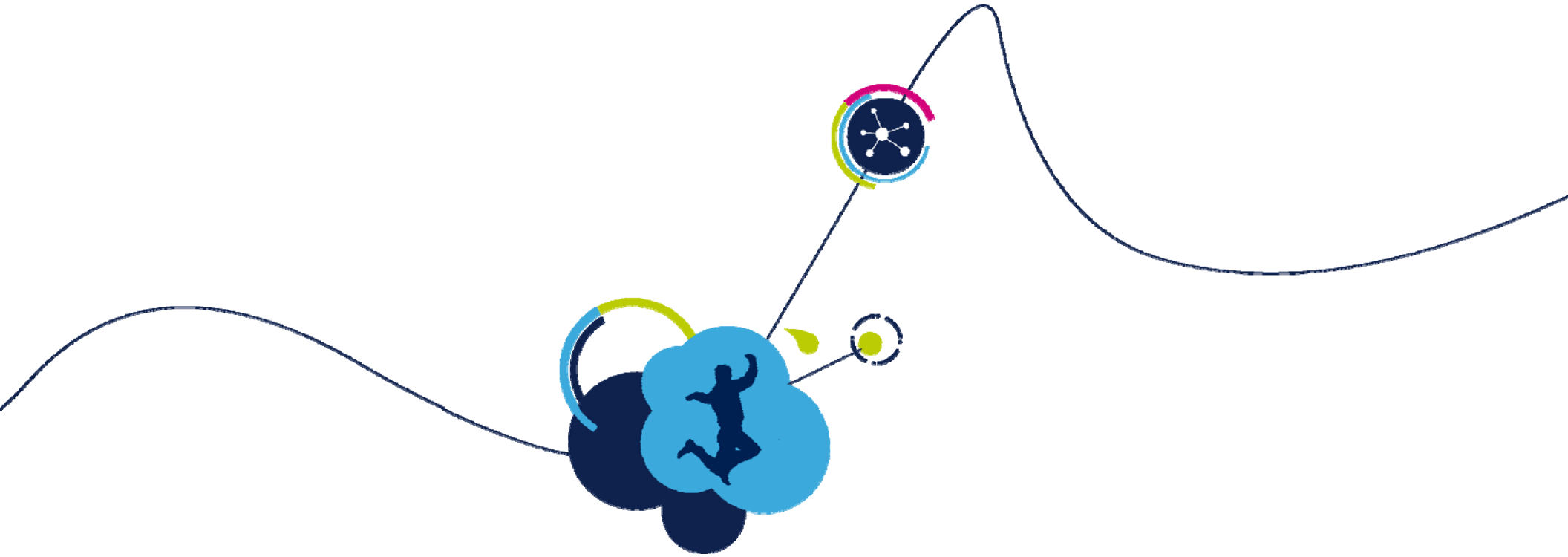

Questions?

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