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NANJING 2017
Challenges for a data-driven society

How to make the interoperability of IoT data

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Challenge of IoT data interoperability due to IoT standards Jungle

Source: AIOTI WG03, 2015

- IoT standards are no doubt the key enablers for IoT industries.
- But the growth looks a bit “wild” and still extending

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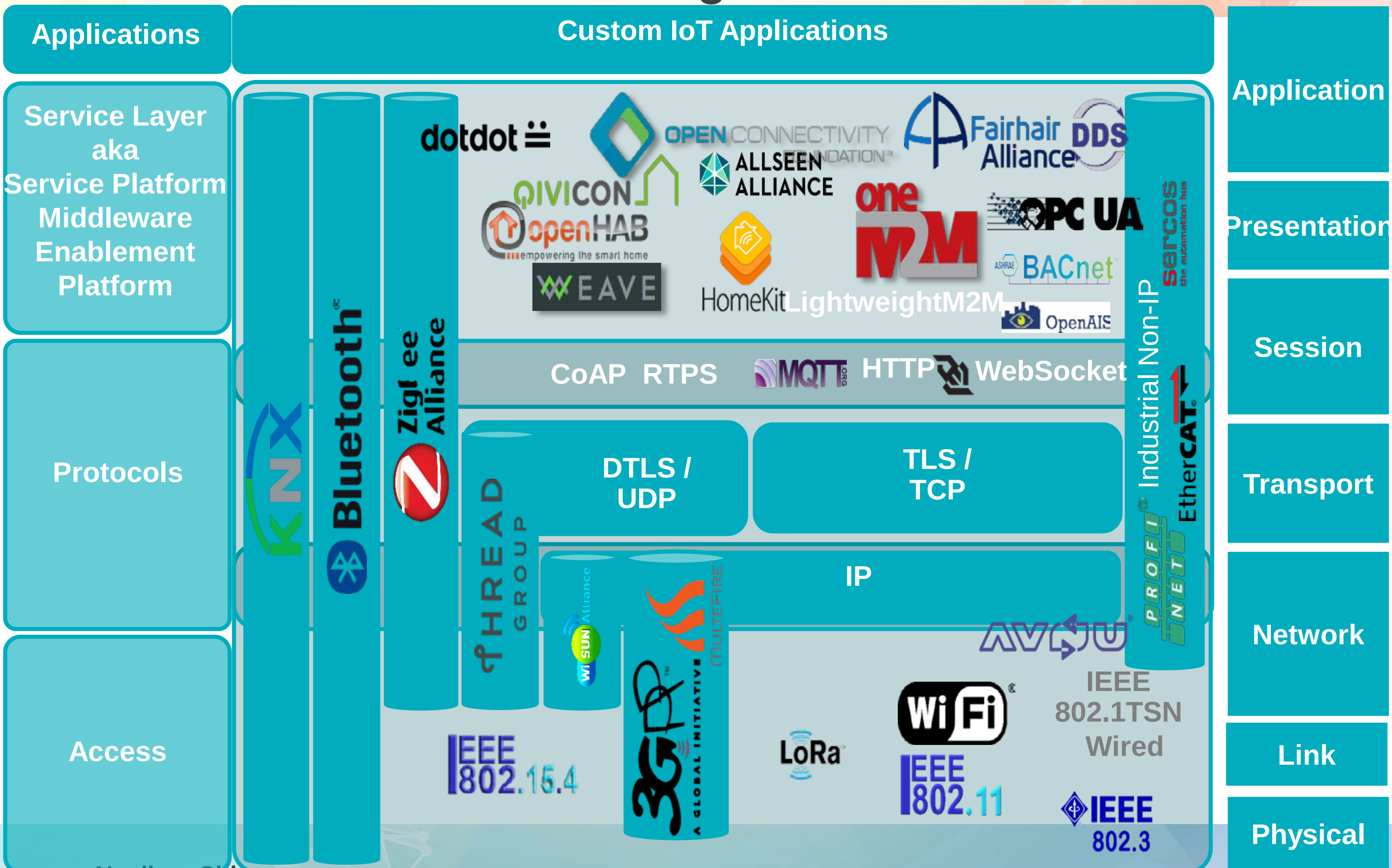
Technologies in IoT Stack



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Source: 3rd oneM2M Industry Day, How oneM2M fits into the landscape of IoT technologies, 2017

ETSI White Paper: Achieving Technical Interoperability

Technical Interoperability is usually associated with hardware/software components, systems and platforms that enable machine-to-machine communication to take place. This kind of interoperability is often centred on (communication) protocols and the infrastructure needed for those protocols to operate.

Semantic Interoperability is usually associated with the meaning of content and concerns the human rather than machine interpretation of the content.

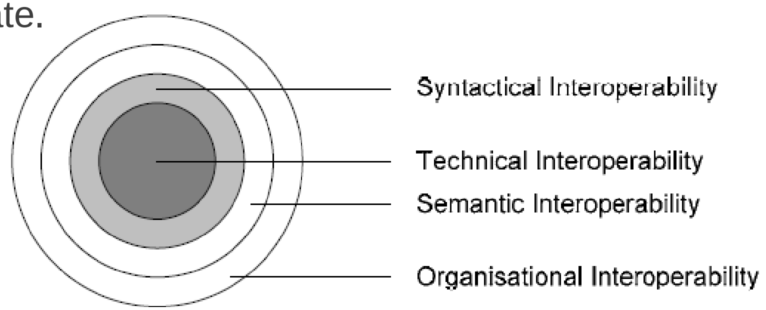


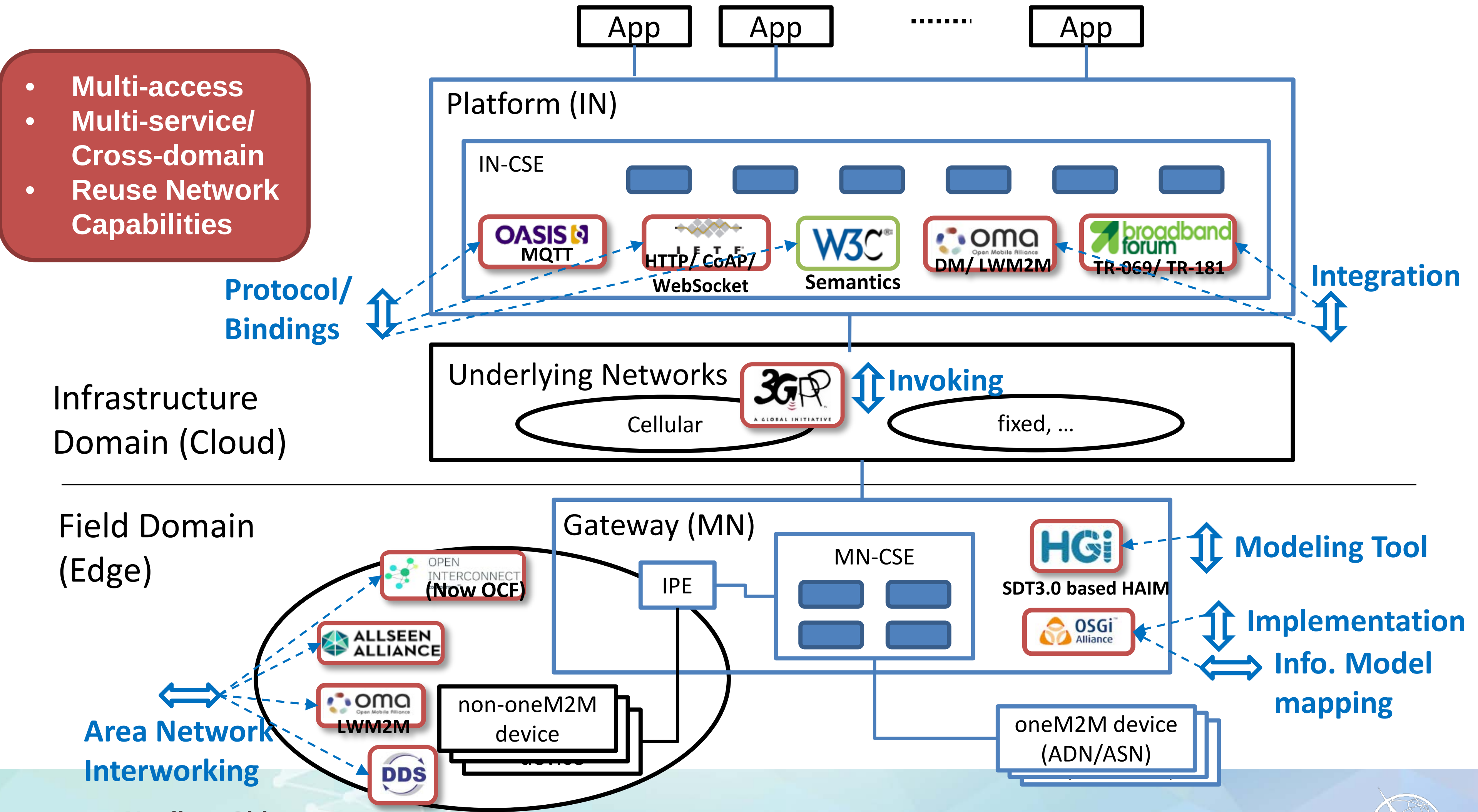
Figure 1: Different levels of interoperability

Syntactical Interoperability is usually associated with data formats. Certainly, the messages transferred by communication protocols need to have a well-defined syntax and encoding, even if it is only in the form of bit-tables. However, many protocols carry data or content, and this can be represented using high-level transfer syntaxes such as HTML, XML or ASN.1.

Organizational Interoperability is the ability of organizations to effectively communicate and transfer (meaningful) data (information) even though they may be using a variety of different information systems over widely different infrastructures, possibly across different geographic regions and cultures. Organizational interoperability depends on successful technical, syntactical and semantic interoperability.

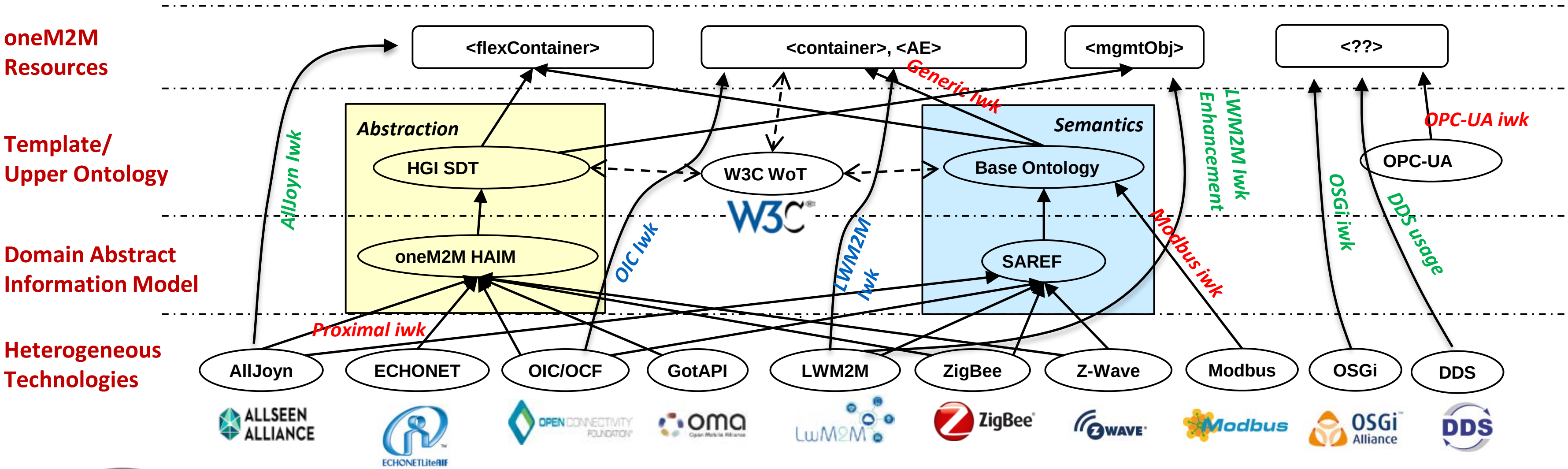
oneM2M Technical View on Interworking

- Multi-access
- Multi-service/ Cross-domain
- Reuse Network Capabilities



oneM2M flexible framework of interworking from transparent, translucent to semantic

IoT Applications independent of accessing/device technologies



To make different technologies working smoothly together and build a converged ecosystem

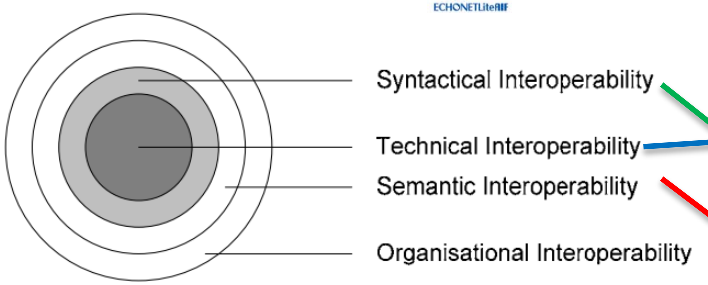
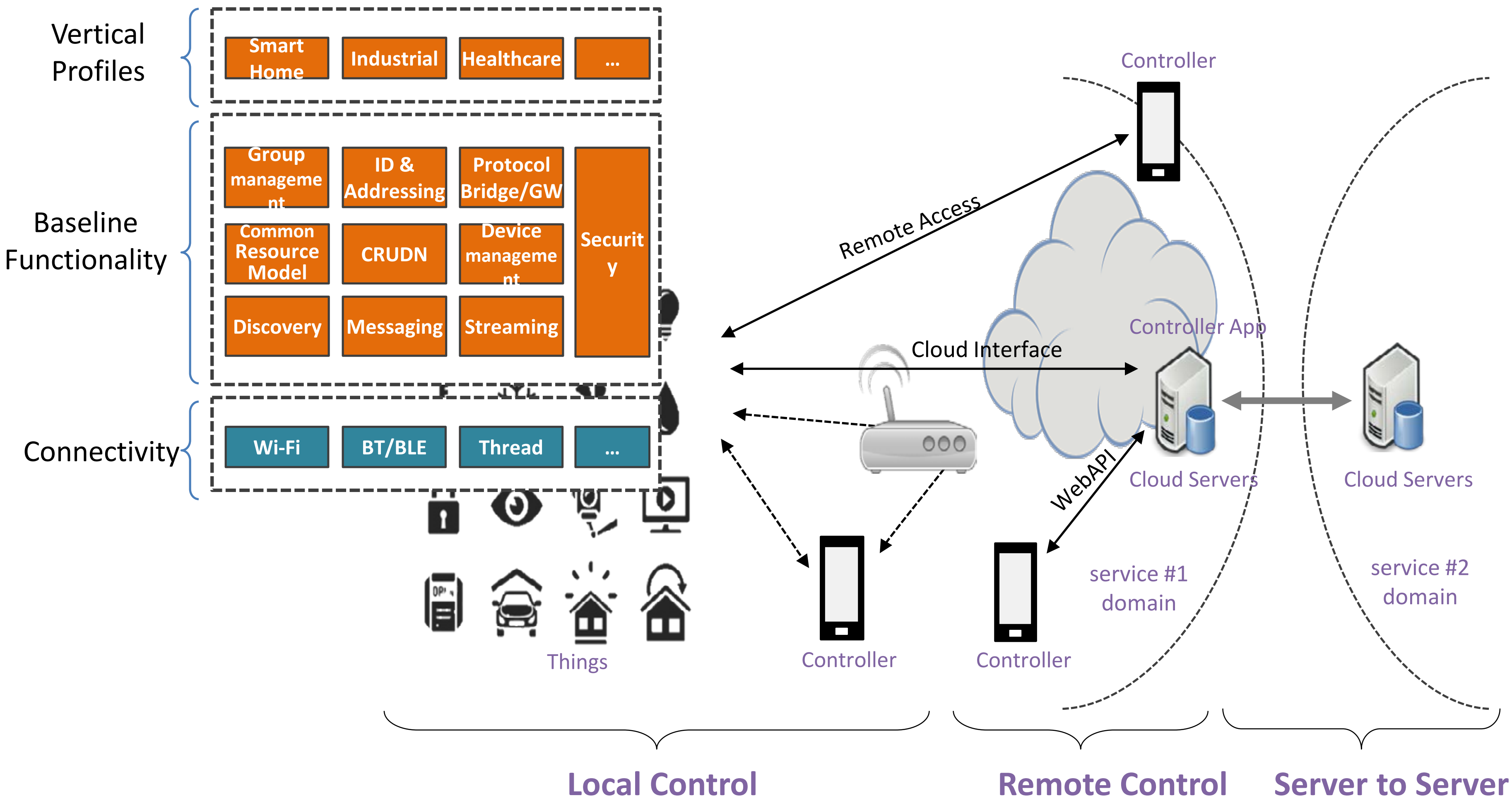


Figure 1: Different levels of interoperability

Source: ETSI IOP Whitepaper 3rd Edition, 2008

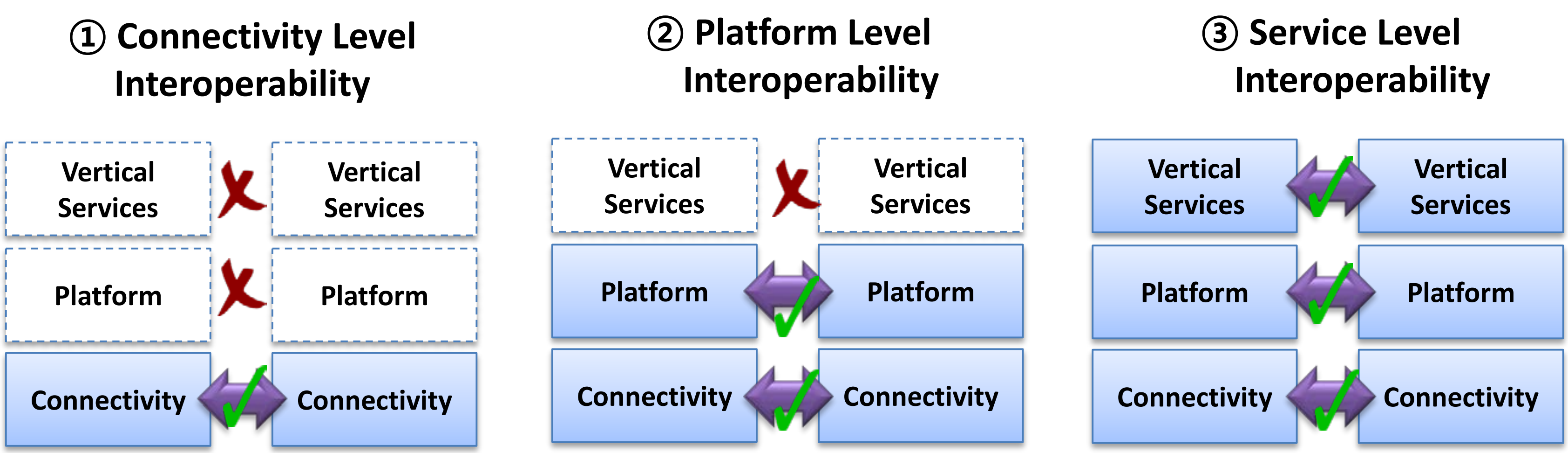
- **Transparent Interworking**: encapsulate the data model of one technology into another (as a pipe)
- **Translucent Interworking:** data model structures are mapped, while semantics/data types are not
- **Semantic Interworking:** mapping not only protocols, but also full data models and semantics

OCF IoT Scope

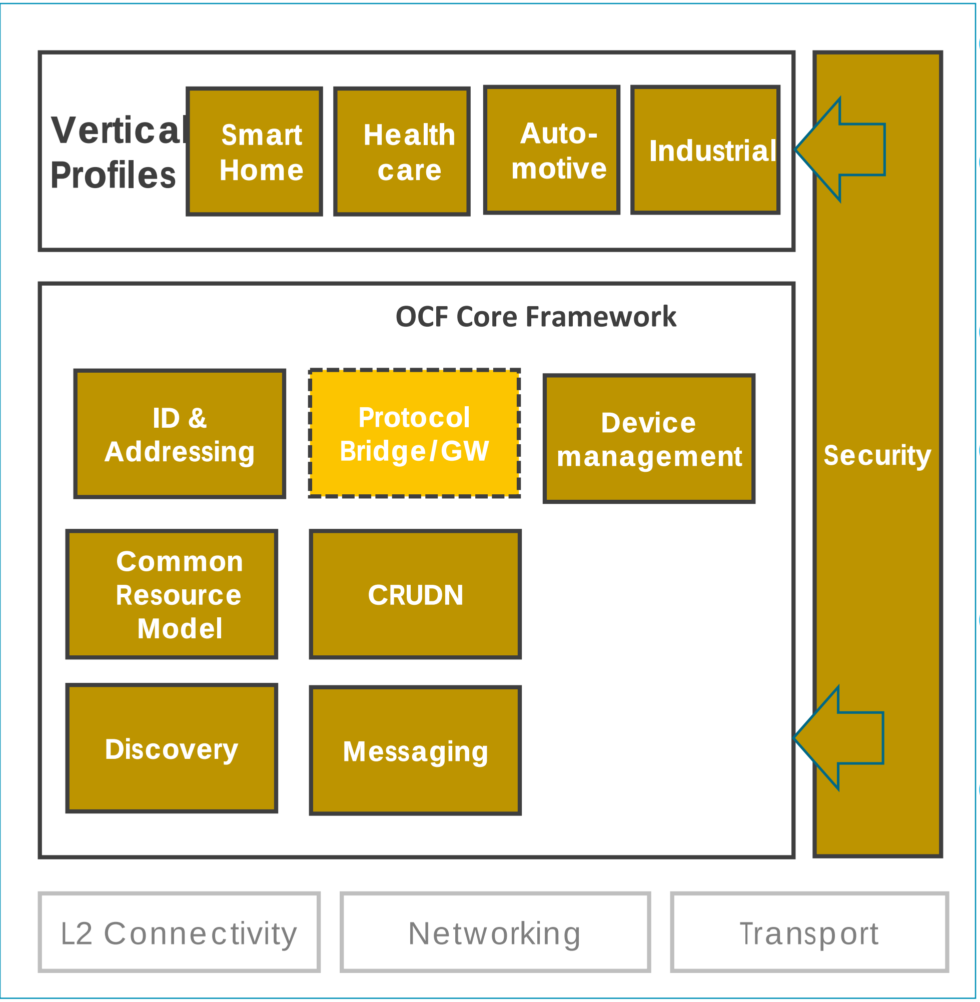


OCF consider for Interoperability

- **Full interoperability** from the connectivity layer up to the service layer is the only way to truly guarantee a satisfactory UX
- Interoperability at the Connectivity and/or Platform layer only provides partial interoperability which can ultimately lead to fragmentation



OCF Core Framework Spec

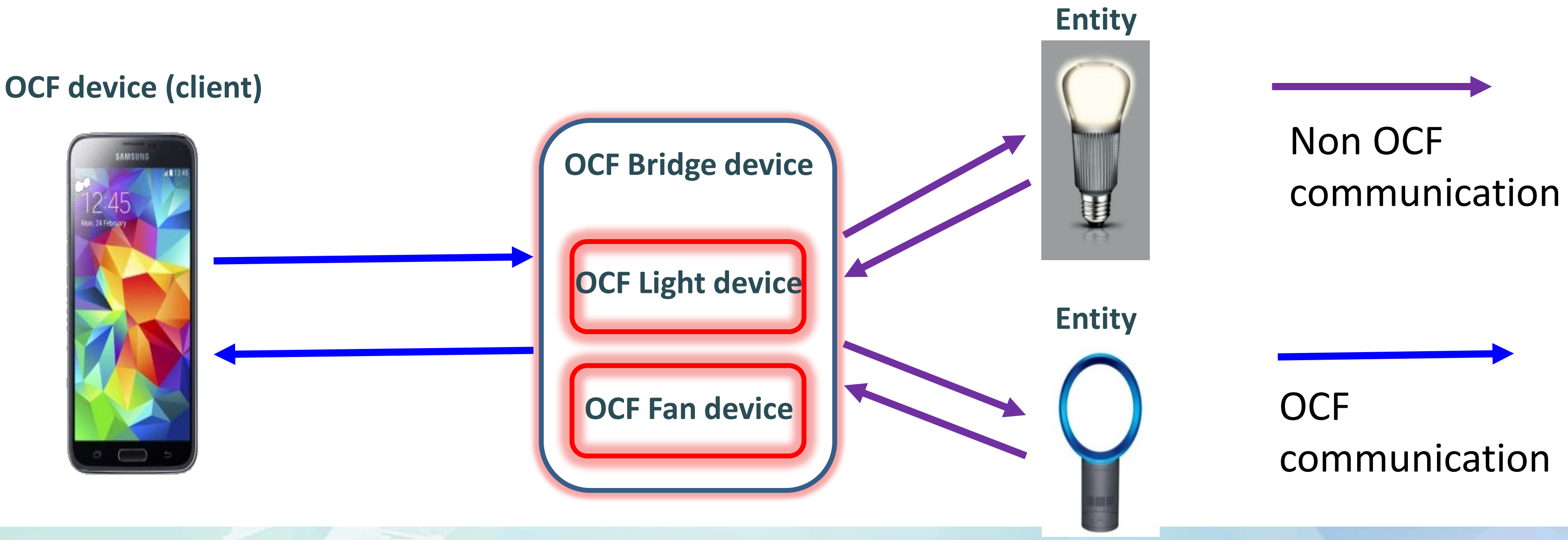


1. **Discovery:** Common method for device discovery (IETF CoRE)
2. **Messaging:** Constrained device support as default (IETF CoAP) as well as protocol translation via bridges
3. **Common Resource Model:** Real world entities defined as data models (resources)
4. **CRUDN:** Simple Request/Response mechanism with Create, Retrieve, Update, Delete and Notify commands
5. **ID & Addressing:** OCF IDs and addressing for OCF entities (Devices, Clients, Servers, Resources)
6. **Protocol Bridge/GW**: Handled by the Bridging Spec with some implications on the Core

Security is fundamental to the OCF ecosystem and applies to all elements

OCF Bridge Specification

- ◆Specifies a framework for bi-directional translation between devices in OCF and non-OCF ecosystems.
- ◆Specifies general requirements for translation between OCF and non-OCF ecosystems
  - ◆Requirements for resource discovery, message translation, security, and handling of multiple bridges.
- ◆Specifies specific requirements for translation between OCF and AllJoyn ecosystems
  - ◆Requirements for mapping core resources, propagating errors, and algorithmically translating custom resource types.
  - ◆Refers to OCF to AllJoyn Mapping specification for translating well-known resource types.



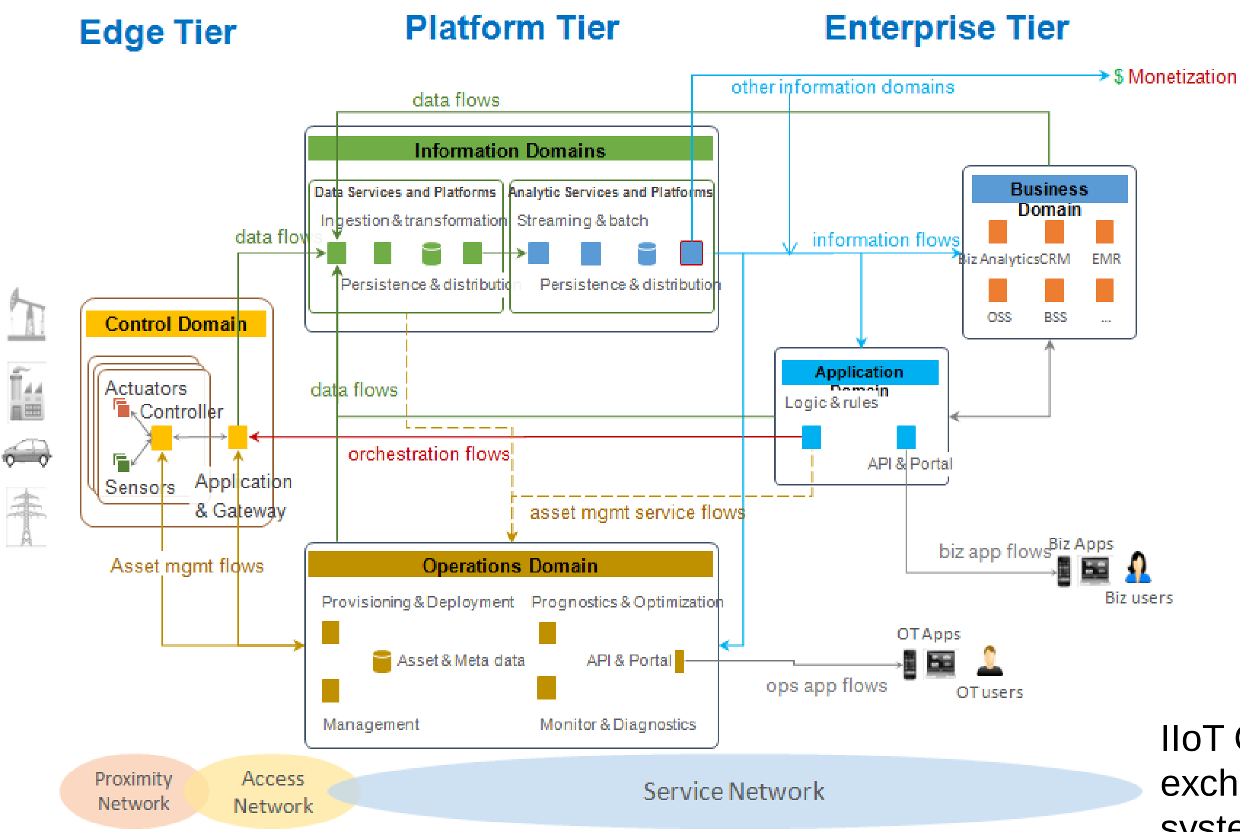
OCF to AllJoyn Mapping

- Models the interworking between OCF and AllJoyn
- Makes use of derived model syntax
- Defines the mapping in terms of:
  - Device Type equivalency
  - Resource <-> Interface equivalency
  - Detailed Property by Property mapping on a per Interface Basis (Derived Models)

Classification	ASA Device Type	OCF Device Type	OCF Device Type ID
Air Care	Air Conditioner	Air Conditioner	oic.d.airconditioner
	AirPurifier	Air Purifier	oic.d.airpurifier
	AirQualityMonitor	Air Quality Monitor	oic.d.aqm
	Dehumidifier	Dehumidifier	oic.d.dehumidifier
	Humidifier	Humidifier	oic.d.humidifier
	ElectricFan	Fan	oic.d.fan
	Thermostat	Thermostat	oic.d.thermostat
Fabric Care	Clothes Washer	Washer	oic.d.washer
	Clothes Dryer	Dryer	oic.d.dryer
	Clothes Washer-Dryer	Washer-Dryer	oic.d.washerdryer
Food Preservation	Refrigerator	Refrigerator	oic.d.refrigerator
	Ice Maker	Ice Maker (Resource)	oic.r.icemaker
	Freezer	Freezer	oic.d.freezer
Food Preparation	Oven	Oven	oic.d.oven
	Cooktop	Cooktop	oic.d.cooktop
	Cookerhood	Cooker Hood	oic.d.cookerhood
	Foodprobe	Food Probe	oic.d.foodprobe
Dish Care	Dishwasher	Dishwasher	oic.d.dishwasher
Floor Care	Robot Cleaner	Robot Cleaner	oic.d.robotcleaner
Entertainment	TV	Television	oic.d.tv
	Set Top box (STB)	Set Top Box	oic.d.stb

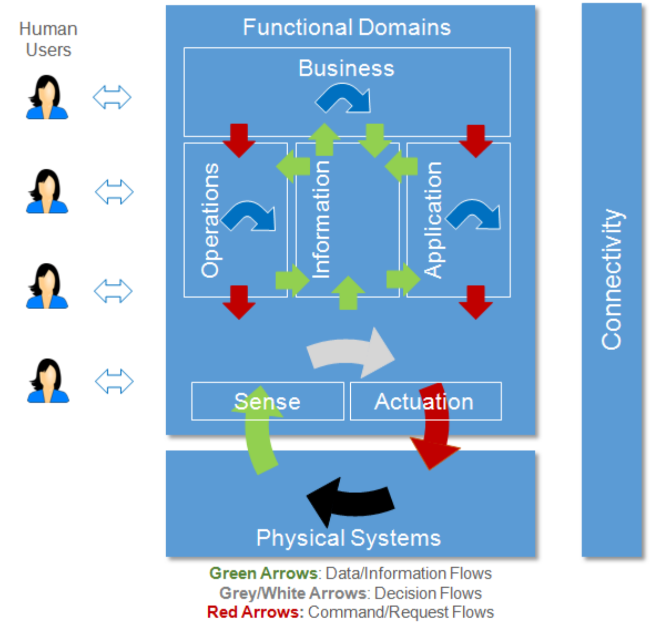
AllJoyn Interface	OCF Resource Type Name	OCF Resource Type ID	OCF Interface(s)
Environment.CurrentAirQuality	Air Quality Collection	oic.r.airqualitycollection	oic.if.s
Environment.CurrentAirQualityLevel	Air Quality Collection	oic.r.airqualitycollection	oic.if.s
Environment.CurrentHumidity	Humidity	oic.r.humidity	oic.if.s
Environment.CurrentTemperature	Temperature	oic.r.temperature	oic.if.s
Environment.TargetHumidity	Humidity	oic.r.humidity, oic.r.selectablelevels	oic.if.a
Environment.TargetTemperature	Temperature	oic.r.temperature	oic.if.a
Operation.AudioVolume	Audio Controls	oic.r.audio	oic.if.a
Operation.Channel	Not mapped		
Operation.ClimateControlMode	Mode	oic.r.mode	oic.if.a
	Operational State	oic.r.operational.state	oic.if.s
Operation.ClosedStatus	Door	oic.r.door	oic.if.s
Operation.CycleControl	Operational State	oic.r.operational.state	oic.if.s
Operation.FanSpeedLevel	Air Flow	oic.r.airflow	oic.if.a
Operation.HeatingZone	Heating Zone Collection	oic.r.heatingzonecollection	oic.if.s
Operation.HvacFanMode	Mode	oic.r.mode	oic.if.a
Operation.OnOffStatus	Binary Switch	oic.r.switch.binary	oic.if.s
Operation.OvenCyclePhase	Operational State	oic.r.operationalstate	oic.if.s

IIC Industrial Internet Reference Architecture (IIRA)



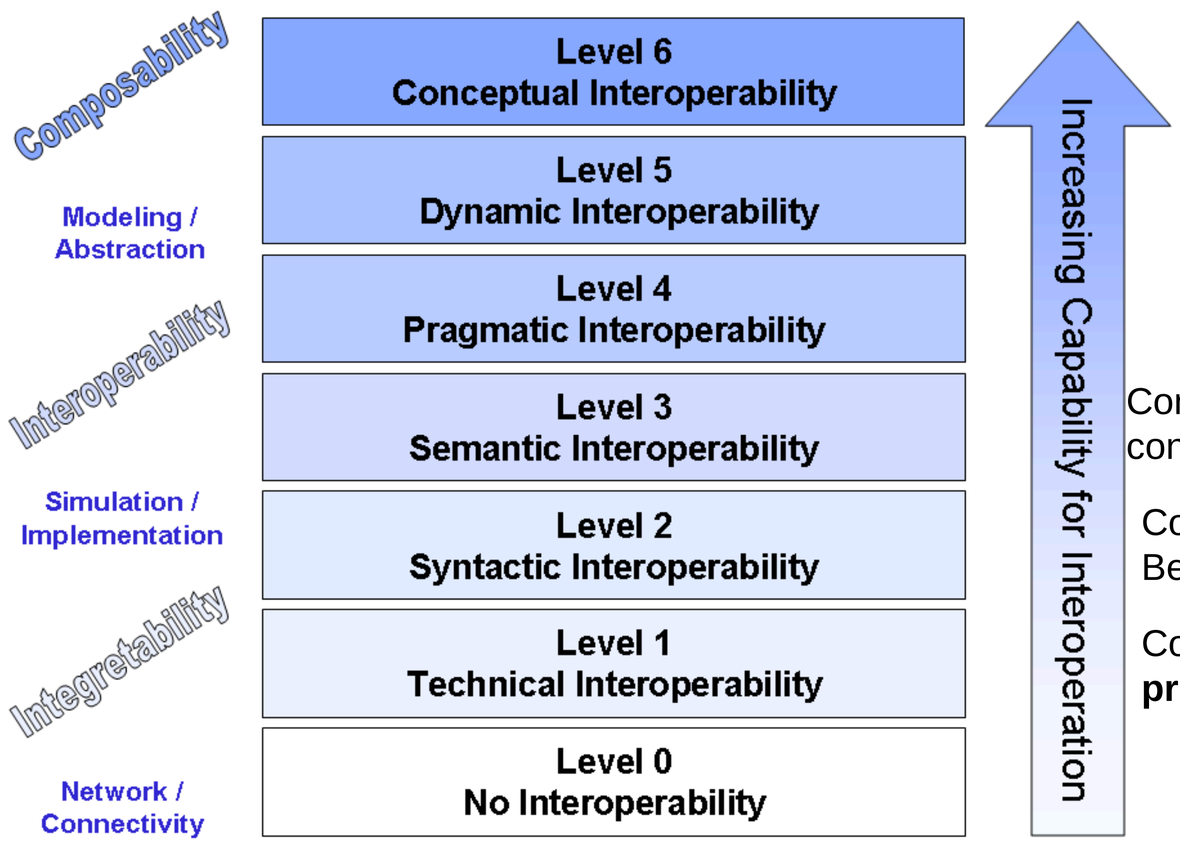
IIRA Implementation Viewpoint

IIRA Functional Viewpoint



IIoT Connectivity Function: Ability to exchange information among endpoints in a system of interest, include: sensor updates, commands, alarms, events, status changes , configuration updates

IIoT Connectivity enables Interoperability



Interoperability is about sharing Data governed by Quality of Service (QoS)

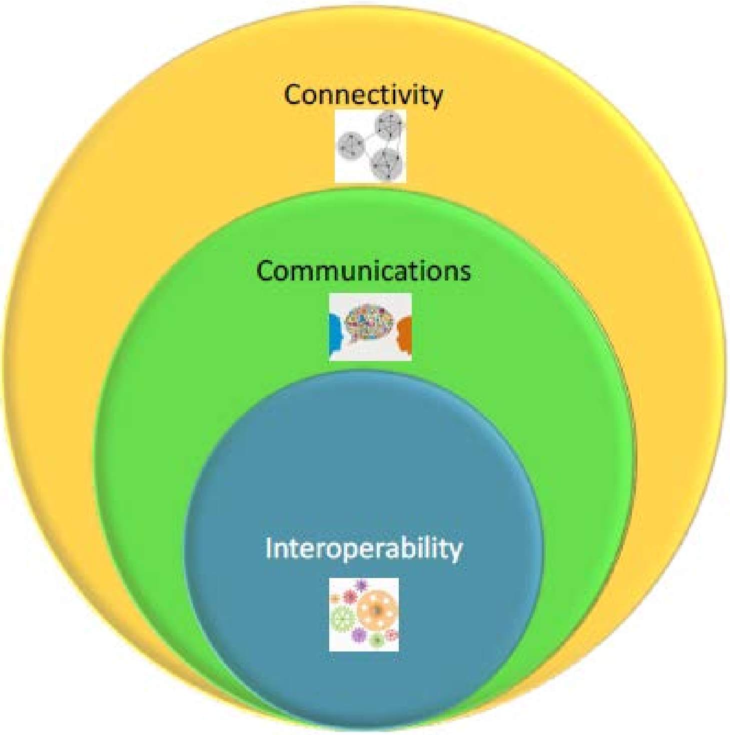
Compatible meaning of **data models** in the context of the vertical application domain.

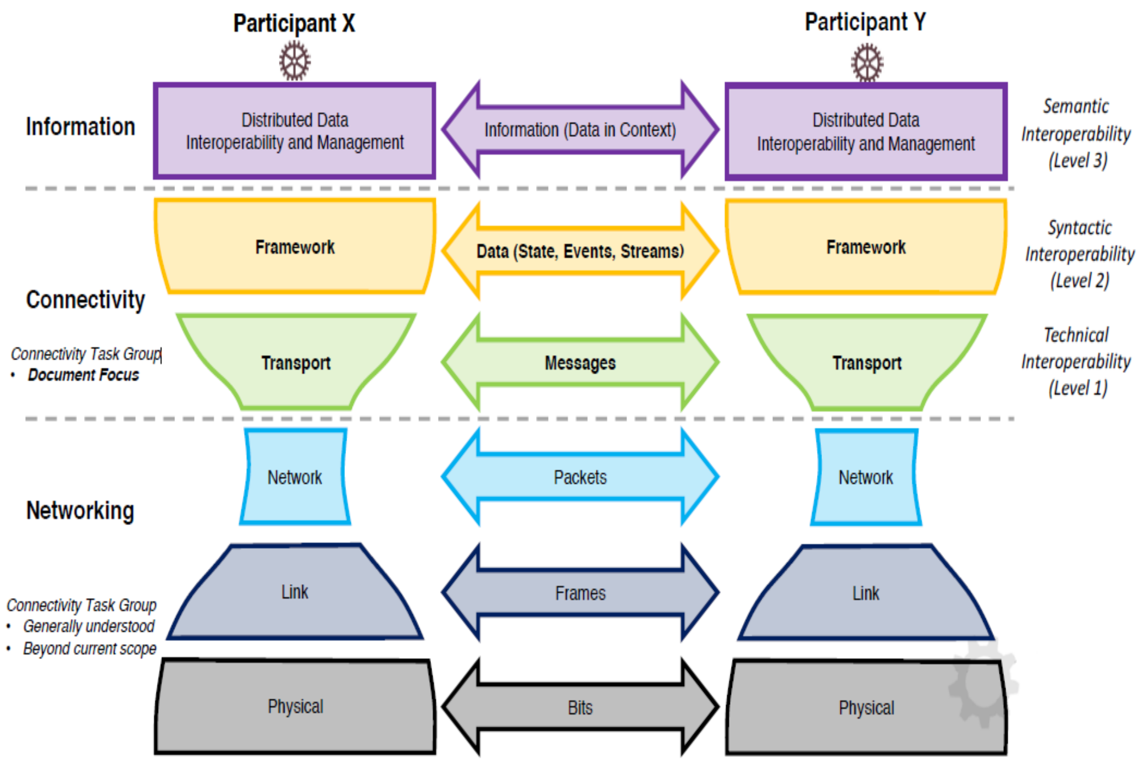
Compatible means of sharing **datatypes**. Be able to evolve those datatypes.

Compatible means of **signaling and protocols**

http://en.wikipedia.org/wiki/Conceptual_interoperability

IIC Connectivity Framework





Interoperability requires a Suitable Connectivity Infrastructure for Meaningful Communications between…

IIoT Connectivity Stack Model

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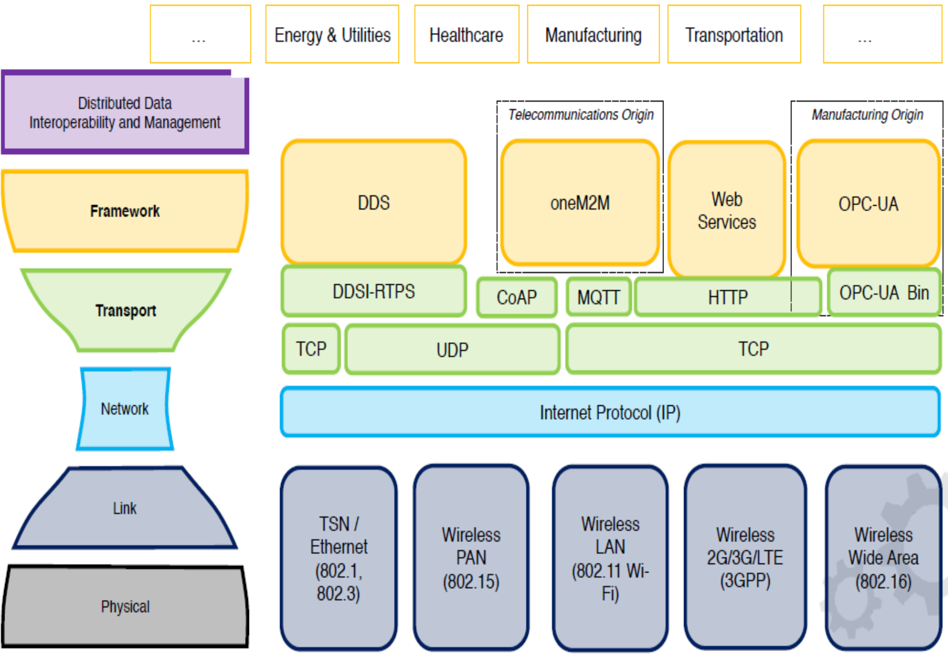
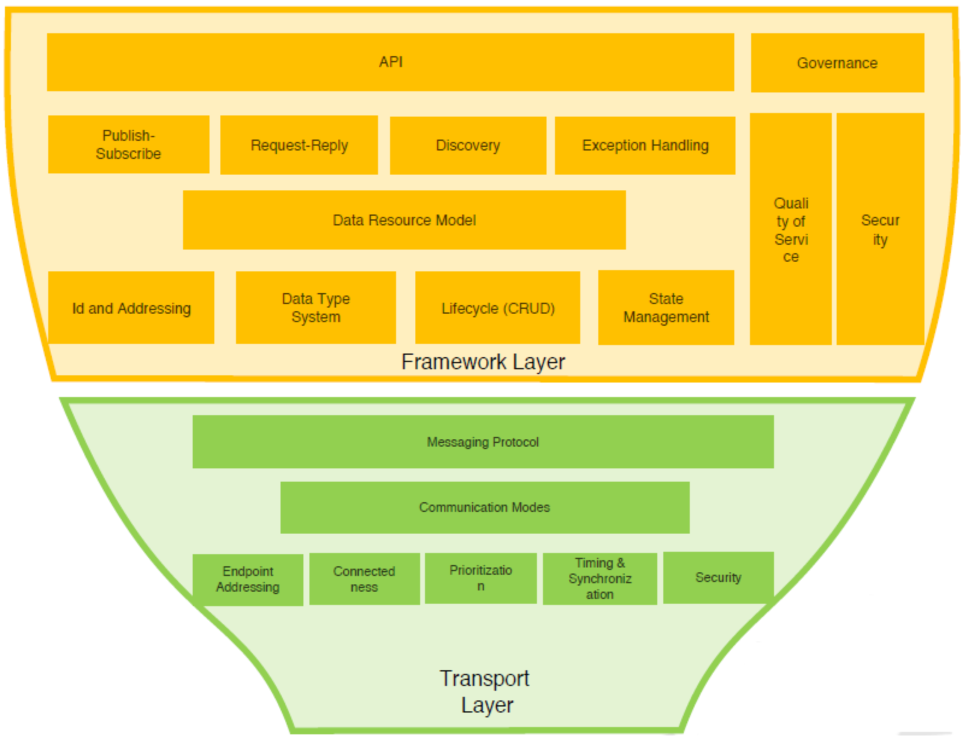
IIoT Horizontal Interoperability



Relevant Connectivity Standards



IIoT Connectivity Stack

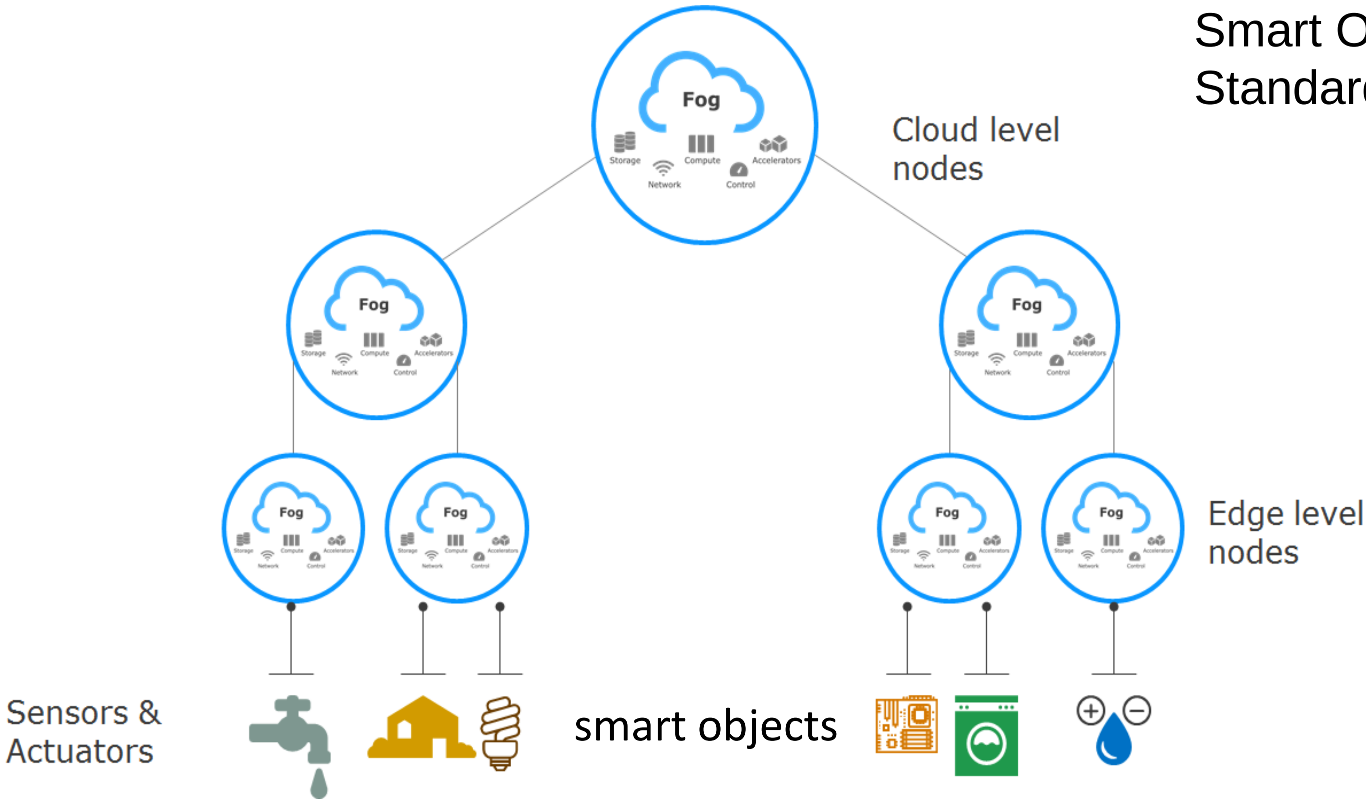
Connectivity Core Standards Criteria Applied

	Core Standard Criterion	DDS	Web Services	OPC-UA	oneM2M
1	Provide **syntactic interoperability**	√	Need XML or JSON	√	√
2	Open standard with strong **independent, international governance**	√	√	√	√
3	**Horizontal and neutral in its applicability across industries**	√	√	√	√
4	**Stable and deployed across multiple vertical industries**	Software Integration & Autonomy	√	Manufacturing	Home Automation
5	Have **standards-defined *Core Gateways to all other core connectivity standards***	Web Services, OPC-UA*, oneM2M*	DDS, OPC-UA, oneM2M	Web Services, DDS*, oneM2M*	Web Services, OPC-UA*, DDS*
6	Meet the connectivity framework **functional requirements**	√	**X**	Pub-Sub in development	√
7	Meet **non-functional requirements of performance, scalability, reliability, resilience**	√	**X**	Real-time in development	Reports not yet documented or public
8	Meet **security and safety requirements**	√	√	√	√
9	Not require any single component from any single vendor	√	√	√	√
10	Have readily-available SDKs both **commercial and open source**	√	√	√	√

GREEN = Gating Criteria

*** = work in progress √= supported, X = not supported**

OpenFog Smart Object prefer to reuse existing standards



Smart Object Landscape of Standards bodies and alliances

W3C Semantic Web
UPnP
OPEN CONNECTIVITY FOUNDATION
ALLSEEN ALLIANCE
WEB OF THINGS
industrial internet CONSORTIUM
IPSO Alliance
Haystack Connect
IETF
RDA RESEARCH DATA ALLIANCE
OPC Unified Architecture
NIST National Institute of Standards and Technology U.S. Department of Commerce

The Fog/Cloud can be (dynamically) configured to process/analyze, route, cache and archive data in multiple tiers of the Fog. Data, devices, and code are all smart objects in a registry which can be mapped onto physical locations.

OpenFog Interoperability, Interconnectivity, Interchangeability

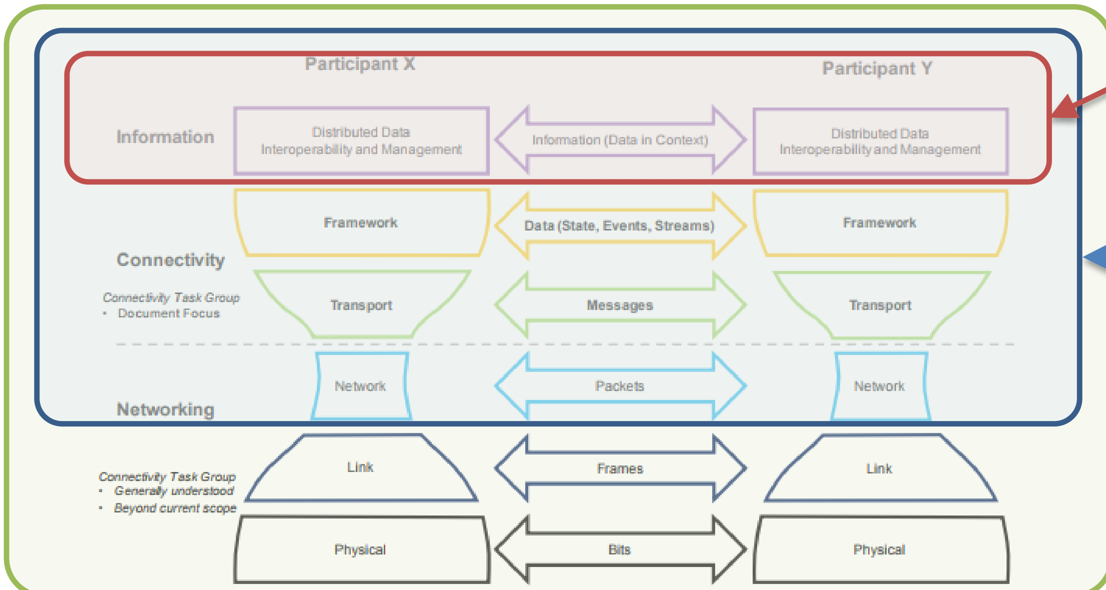


Figure 2-2: The focus of this document is on connectivity layers above the network layer, namely the connectivity transport and the connectivity framework layers.

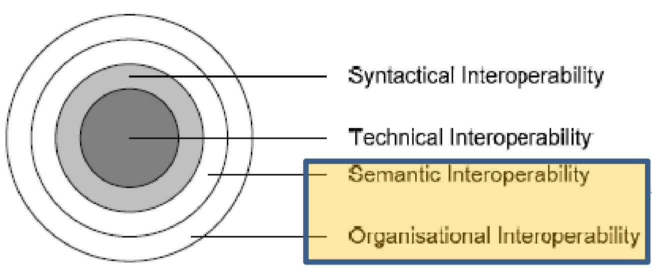


Figure 1: Different levels of interoperability

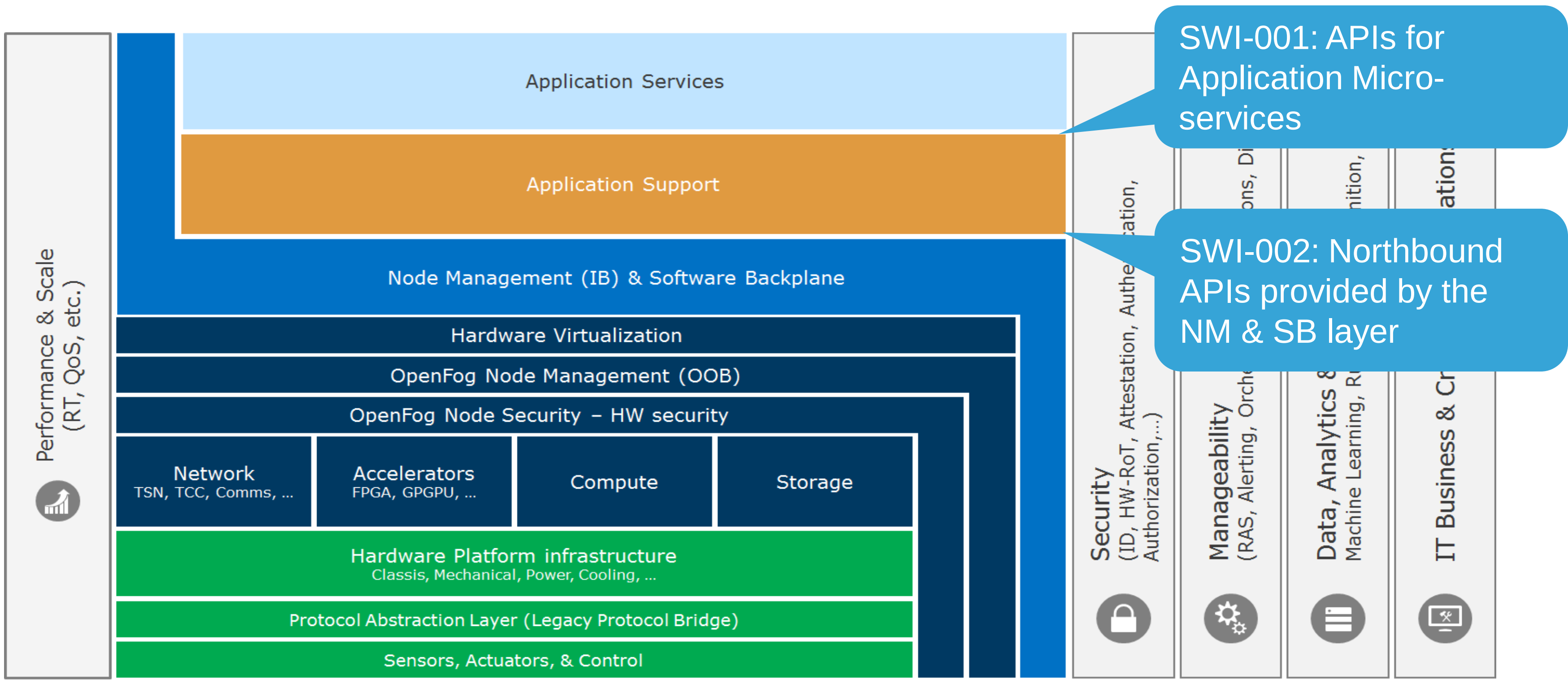
OpenFog Interoperability Focus

OpenFog Interoperability Focus
- Application/Service Compatibility
- API Based
- Built from Service Bus / SW Backplane

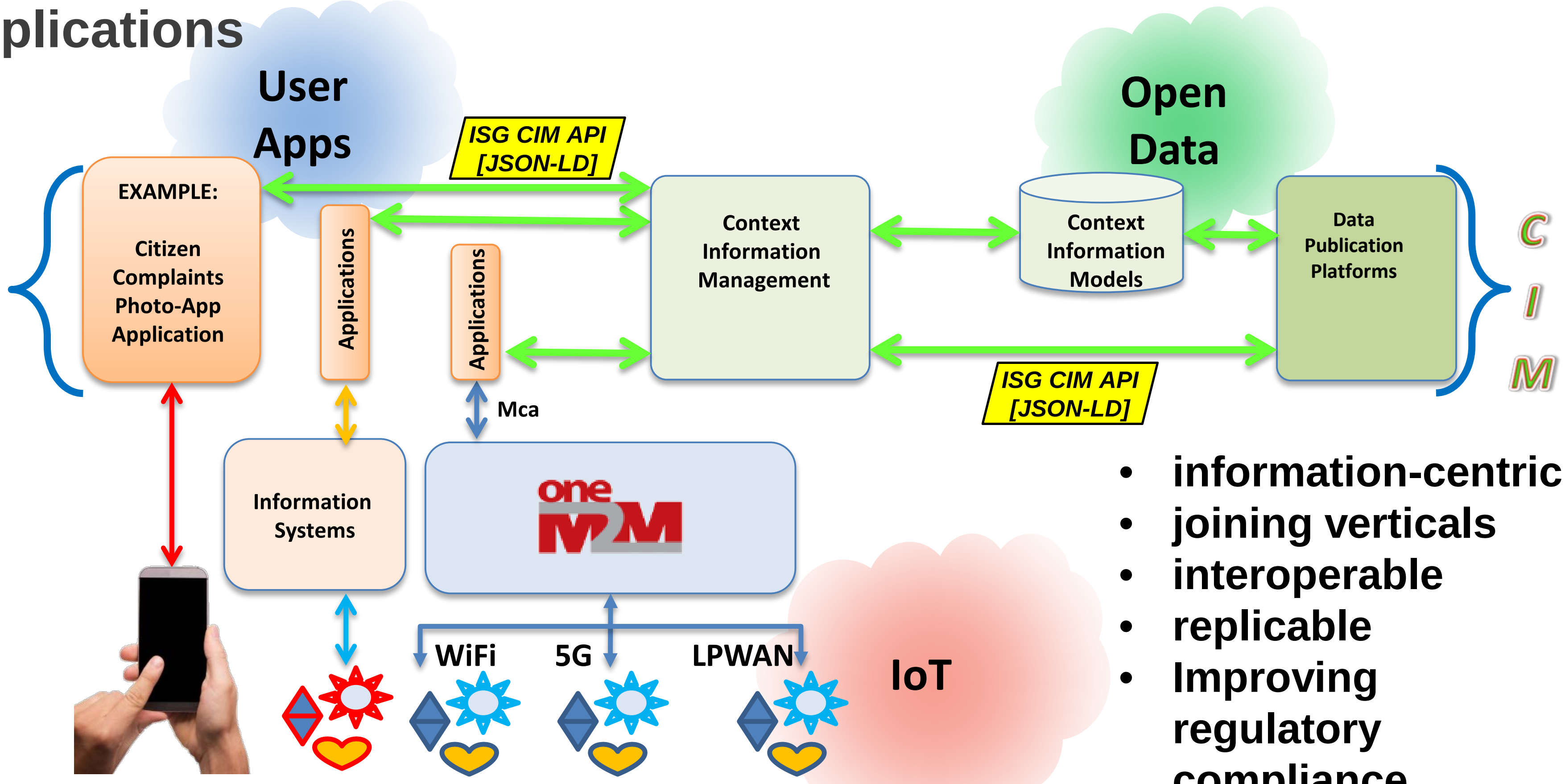
OpenFog Interconnectivity Focus
- Information Interchange Capability
- Protocol Based
- Built from Network Layer (IP)
- Communications consider IIC Connectivity Framework

OpenFog Interchangeability Focus
- Device Function Compatibility
- Spec Based
- Built from Physical / Logical Device

OpenFog Architecture to build a multi-vendor interoperable fog computing ecosystem



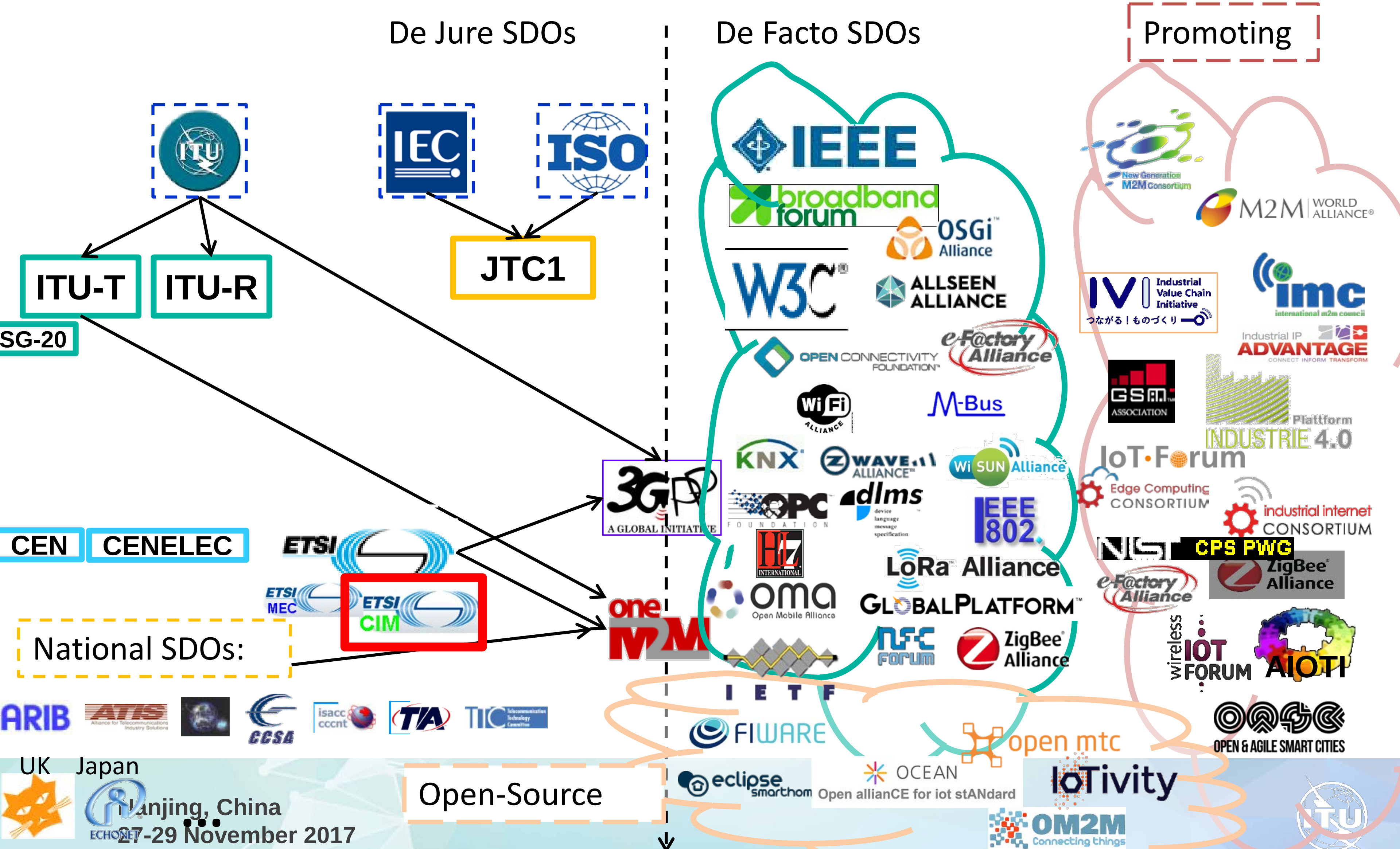
ETSI ISG CIM: establish an info-exchange layer on top of IoT platforms like oneM2M, especially targeting Smart City applications



- information-centric
- joining verticals
- interoperable
- replicable
- Improving regulatory compliance

Goal = interoperable exchange of data & metadata between systems

ETSI ISG CIM overview IoT-related SDOs & Fora



ETSI ISG CIM Features

- ◆ Flexible exchange of information between domains
  - ➢ Graph-based
  - ➢ Core concepts include Entities and Relationships
  - ➢ Entities can have Properties and Relationships
  - ➢ *Relationships/Properties can also have Properties and Relationships*
- ◆ Aim to be developer-friendly
  - ➢ Using familiar technologies (e.g. HTTP, JSON-LD)
  - ➢ Simple query interface
    - • Based on entity type or identifier
    - • Scoping of query (e.g. by time/geography)
    - • Filtering of results

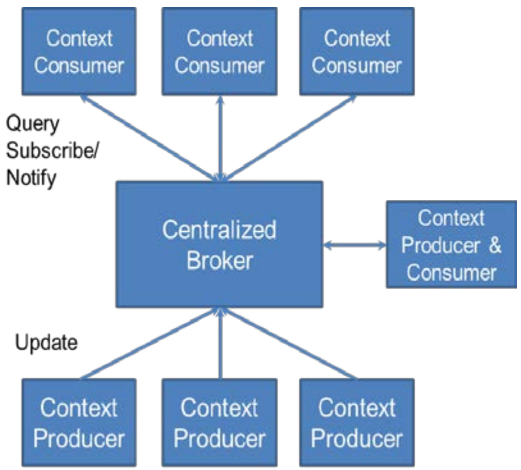
◆API is agnostic to the deployed architecture
◆Applications need only know the URL where the API is exposed
◆Actual choice of architecture depends on (changeable) trade-offs

- ➢ Centralised Architecture is simplest
- ➢ Distributed architecture may be chosen to improve scalability
- ➢ Federated architecture enables different organizational units to transparently integrate their information sources

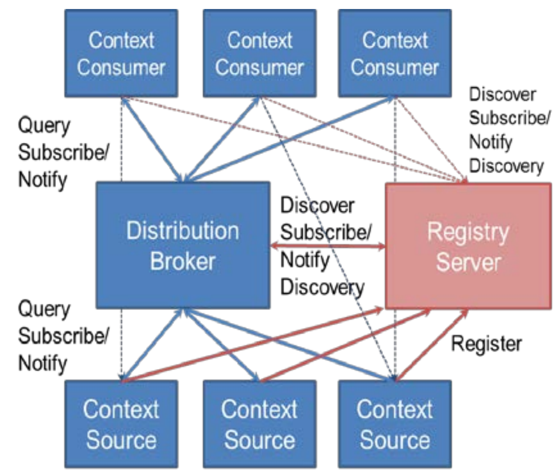
◆NOT yet another IoT/M2M standard
◆NOT for low-layer protocol or network-centric connectivity
◆NOT just a semantic annotation vocabulary
◆NOT specific to one particular environment
◆NOT restricted to one type of information source
◆NOT dedicated to one particular type of application

◆ETSI ISC CIM entities are represented by URIs
◆Entities are "first class citizens" in the Information Model and API
◆All entities must reference some ontology (to define their type)

Various Architectures possible using ETSI ISG CIM

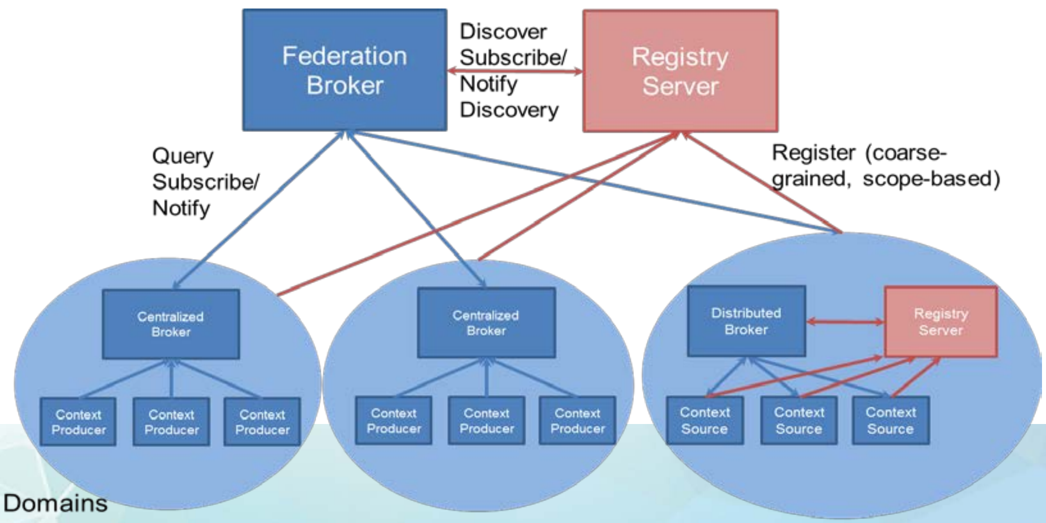


Centralised

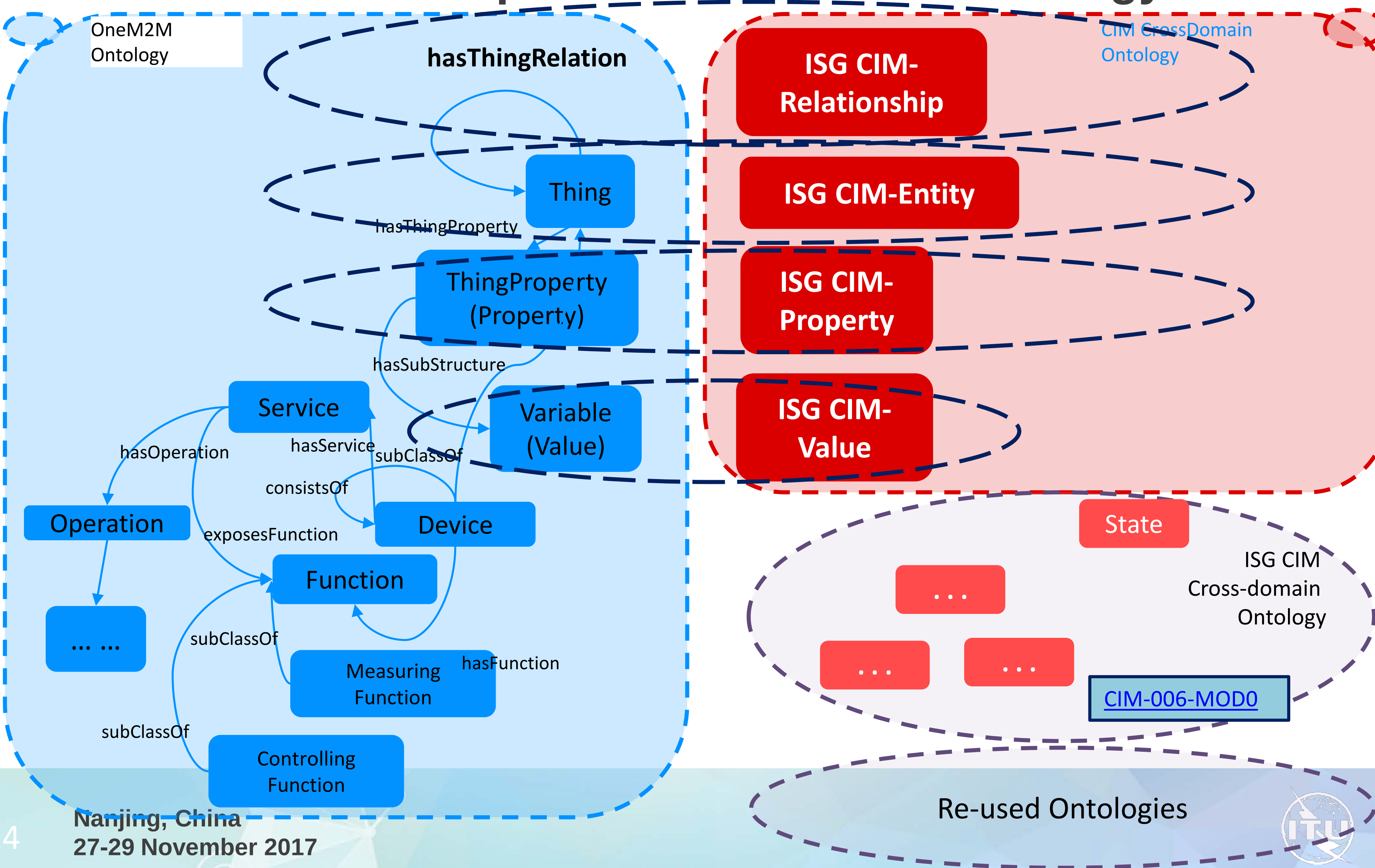


Distributed

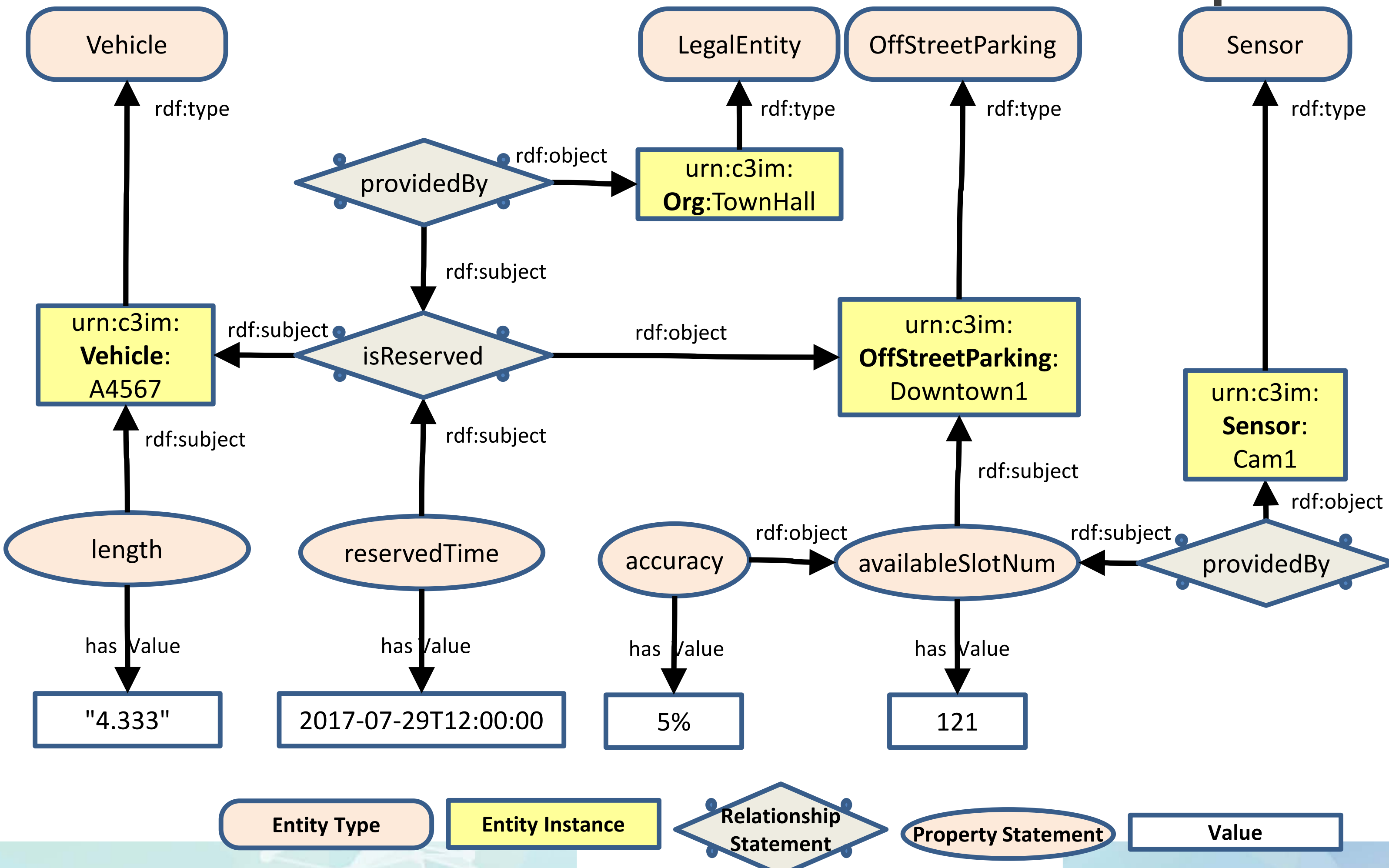
Federated



ETSI ISG CIM maps to oneM2M Base Ontology



ETSI ISG CIM Data Model instantiation example: - what information do CIM need to express?



Conclusion

IoT SDO	IoT focus area	Technical Interoperability	Syntactic interoperability	Semantic Interoperability	Pragmatic Interoperability	Dynamic Interoperability	Conceptual Interoperability
					Organizational Interoperability		
oneM2M	Telecom platform	√	√	√ (OIC, Alljoyn, LWM2M, DDS, OPC-UA, OSGI, Modbus, etc)			
OCF	Smart home	√	√	√(Alljoyn)			
IIC	Industry, Manufacturing	√	√(Web service)	√(oneM2M,DDS, OPC-UA)			
openfog	Fog/edge computing	√	√ starting	√ starting		ideal	
ETSI ISG CIM		√			√		
Better solution?							